# IOP Joint APP and HEPP Annual Conference

**3–5 April 2023**

King's College London, London, UK

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IOP Institute of Physics

# Timetable

**Monday 3 April 2023**

| | |
|---|---|
| 8:30am to 9:30am | **Registration and Refreshments** (including breakfast)<br>Rooms: Registration – entrance foyer (South East/Bush House Arcade Entrance). Refreshments – South and North Side (floor 8) |
| 9:30am to 10am | **Welcome and a presentation from Kirsty Hall, Hamamatsu**<br>Room: Auditorium (ground level) |
| 10am to 10:30am | **Plenary Session: Sophie Renner**, University of Glasgow<br>Room: Auditorium |
| 10:30am to 11am | **Morning break**<br>Rooms: South and North Side (floor 8) |
| 11am to 11:30am | **Plenary Session: Tessa Baker**, Queen Mary University of London<br>Room: Auditorium |
| 11:30am to 12pm | **Plenary Session: Sarah Williams**, University of Cambridge<br>Room: Auditorium |
| 12pm to 12:30pm | **Plenary Session: XinRan Liu**, The University of Edinburgh and UNDO<br>Room: Auditorium |
| 12:30pm to 1:30pm | **Lunch**<br>Room: King's Kitchen (lower ground level) |
| 1pm to 1:30pm | **APP AGM**<br>Room: S2.06 (Floor 2) |
| 1:30pm to 2pm | **Plenary Session: Jeff Grube**, King's College London<br>Room: Auditorium |
| 2pm to 2:30pm | **Plenary Session: Elena Gramellini**, The University of Manchester<br>Room: Auditorium |
| 2:30pm to 3pm | **Afternoon break**<br>Rooms: South and North Side (floor 8) |
| 3pm to 4:30pm | **Parallel Sessions**<br>Rooms: Auditorium, Lecture Theatre (floor 1), Seminar Rooms S2.01/2.02 and S2.03 (floor 2) |
| 4:30pm to 5pm | **Late afternoon break**<br>Rooms: South and North Side (floor 8) |
| 5pm to 6:30pm | **Parallel Sessions**<br>Rooms: Auditorium, Lecture Theatre, Seminar Rooms S2.01/2.02 and S2.03 |
| 6:30pm to 8:30pm | **Drinks reception and poster session**<br>Rooms: South and North Side (floor 8) |

**Tuesday 4 April 2023**

| | |
|---|---|
| 8am to 9am | **Registration and Refreshments** (including breakfast)<br>Rooms: Registration – entrance foyer (South East/Bush House Arcade Entrance). Refreshments – South and North Side (floor 8) |
| 9am to 9:30am | **Plenary Session: Jeanne Wilson**, King's College London<br>Room: Auditorium |
| 9:30am to 10am | **Plenary Session: Davide Costanzo**, University of Sheffield<br>Room: Auditorium |
| 10am to 10:30am | **Plenary Session: Joost Vossebeld**, University of Liverpool<br>Room: Auditorium |
| 10:30am to 11am | **Morning break**<br>Rooms: South and North Side (floor 8) |
| 11am to 11:30am | **Plenary Session: Sally Shaw**, The University of Edinburgh<br>Room: Auditorium |
| 11:30am to 12pm | **Plenary Session: Jay Howarth**, University of Glasgow<br>Room: Auditorium |
| 12pm to 12:30pm | **Plenary Session: Jessica Turner**, University of Durham<br>Room: Auditorium |
| 12:30pm to 1:30pm | **Lunch**<br>Room: King's Kitchen (lower ground level) |
| 1pm to 1:30pm | **HEPP AGM**<br>Room: S2.06 (Floor 2) |
| 1:30pm to 2pm | **Plenary Session: Hannah Newton**, STFC<br>Room: Auditorium |
| 2pm to 2:30pm | **Plenary Session: Rachael Windsor**<br>Room: Auditorium |
| 2:30pm to 3pm | **Afternoon break**<br>Rooms: South and North Side (floor 8) |
| 3pm to 4:15pm | **Town Meeting: Executive Chair Report – Mark Thomson, STFC**<br>Rooms: Auditorium |
| 4:15pm to 4:45pm | **Late afternoon break**<br>Rooms: South and North Side (floor 8) |
| 4:45pm to 5pm | **Town Meeting: Science Board Update – Tara Shears, University of Liverpool**<br>**Reports from advisory panels**<br>Rooms: Auditorium |
| 5pm to 5:15pm | **Town Meeting: Particle Astrophysics Advisory Panel (PAAP) – Sergey Burdin, University of Liverpool**<br>Rooms: Auditorium |
| 5:15pm to 5:30pm | **Town Meeting: Particle Physics Advisory Panel (PPAP) – Matthew Needham, The University of Edinburgh**<br>Rooms: Auditorium |
| 5:30pm to 6:30pm | **Drinks reception and poster session**<br>Rooms: South and North Side (floor 8) |
| 7pm to 10pm | **Drinks reception and conference dinner**<br>Venue: De Vere Grand Connaught Rooms, 61-65 Great Queen Street, London, WC2B 5DA |

**Wednesday 5 April 2023**

| | |
|---|---|
| 8:30am to 9:30am | **Registration and Refreshments** (including breakfast)<br>Rooms: Registration – entrance foyer (South East/Bush House Arcade Entrance). Refreshments – South and North Side (floor 8) |
| 9:30am to 10am | **Plenary Session: John Ellis**, King's College London<br>Room: Auditorium |
| 10am to 10:30am | **Plenary Session: Cristina Lazzeroni**, University of Birmingham<br>Room: Auditorium |
| 10:30 to 11am | **Plenary Session: Connor FitzPatrick**, University of Manchester<br>Room: Auditorium |
| 11am to 11:30am | **Morning break**<br>Rooms: South and North Side (floor 8) |
| 11:30am to 12:30pm | **Parallel Sessions**<br>Rooms: Auditorium, Lecture Theatre, Seminar Rooms S2.01/2.02 and S2.03 |
| 12:30pm to 1:30pm | **Lunch**<br>Room: King's Kitchen (lower ground level) |
| 1:30pm to 3pm | **Parallel Sessions**<br>Rooms: Auditorium, Lecture Theatre, Seminar Rooms S2.01/2.02 and S2.03 |
| 3pm to 3:30pm | **Afternoon break**<br>Rooms: South and North Side (floor 8) |
| 3:30pm to 4pm | **Plenary Session: Nicola McConkey**, University College London<br>Room: Auditorium |
| 4pm to 4:30pm | **Plenary Session: Mike Holynski**, University of Birmingham<br>Room: Auditorium |
| 4:30pm to 5pm | **Plenary Session: Laurie Nevay**, Royal Holloway, University of London<br>Room: Auditorium |
| 5pm to 5:30pm | **Finale** |
| 5:30pm to 5:45pm | **Depart** |

# Supporters of the Conference

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# Plenary Speakers

Please note: not all the speakers are listed.

## Developments in Astroparticle Theory

Dr Jessica Turner

Plenary Session 12, April 4, 2023, 12:00 – 12:30

In this talk, I will review recent theoretical developments in astroparticle physics ranging from neutrinos to dark matter. I will discuss how the detection of the diffuse supernovae neutrino background and measurements of solar neutrinos can place novel constraints on new physics scenarios such as lifetimes and oscillations if neutrinos are neutrinos are pseudo-Dirac. I will also discuss how dark matter detectors can be used to constrain non-standard neutrino interactions as well as how neutrino detectors can be used to understand theories of dark matte

# Neutrino-less double beta-decay - experimental status and UK involvement

Jeanne Wilson

Plenary Session 07, April 4, 2023, 09:00 – 09:30

In this talk I will give a brief explanation of the process of neutrino-less double beta decay and motivate why we need to search for it. I'll discuss the pros and cons of different experimental strategies and review the existing limits of neutrino less double beta decay rates and hence neutrino mass. I'll discuss the achievements of current experiments and the R&D for future experiments with a strong focus on experiments with UK involvement and the UK strategy in this field.

# High Intensity Kaon Experiments (HIKE) at the CERN SPS

Cristina Lazzeroni

Plenary Session 16, April 5, 2023, 10:00 – 10:30

The availability of high-intensity kaon beams at the CERN SPS North Area gives rise to unique possibilities for sensitive tests of the Standard Model in the quark flavor sector. Precise measurements of the branching ratios for the flavor-changing neutral current decays K to pion and 2 neutrinos can provide unique constraints on CKM unitarity and, potentially, evidence for new physics. Building on the success of the NA62 experiment, the HIKE comprehensive program includes the measurement of the branching ratio for charged Kaon to charged pion neutrino antineutrino to 5% precision and precision measurements of several other kaon rare decays; lepton flavor universality tests, lepton number and flavor conservation tests; as well as searches for exotic particles in kaon decays. The talk will give an overview of the physics goals, detector requirements, and project status for the next generation of kaon physics experiments at CERN.

# Gravitational Waves: what you need to know now

Tessa Baker

Plenary Session 02, April 3, 2023, 11:00 – 23:30

The first three observing runs of the LIGO-Virgo-KAGRA gravitational wave detectors have had a profound impact on the landscape of cosmology, astrophysics and fundamental physics. Ninety-one confirmed gravitational wave events are currently in hand, and the next observing run is due to start very soon, in May 2023. In this talk I'll summarise some of the key discoveries so far and things to look out for in future, for the broader physics community, with a bias towards testing the nature of gravity and fundamental physics.

# Dark Matter in HEP

Sally Shaw

Plenary Session 10, April 4, 2023, 11:00 – 11:30

The fundamental nature of our universe is still mostly unknown: 85% of the matter in the universe is dark and qualitatively different to everything we understand via the Standard Model. Experiments devoted to detecting interactions, production or decay products of dark matter particles have not yet seen a convincing signal, but we may be on the cusp of discovery. I will give an overview of state of the field, covering current and future searches for particle dark matter.

# The Cherenkov Telescope Array

Jeff Grube

Plenary Session 05, April 3, 2023, 13:30 – 14:00

The Cherenkov Telescope Array (CTA) is the next-generation observatory for ground-based gamma-ray astrophysics. CTA will achieve unprecedented sensitivity and angular resolution at energies from 20 GeV to 300 TeV across both the northern and southern hemisphere skies. Construction and early operations are underway at the two sites of La Palma in the Canary islands, and in the Paranal desert in Chile.
The main UK contributions to CTA instrumentation are the cameras for the Small-Sized Telescopes.
For the thousands of gamma-ray sources CTA will study, synergies will be key and CTA will be a major contributor to multi-messenger astrophysics.

# Don’t Panic Dark Matter to the Rescue

XinRan Liu

Plenary Session 04, April 3, 2023, 12:00 – 12:30

The latest and final part of the report by the Intergovernmental Panel on Climate Change (IPCC), made up of the world’s leading climate scientists is out and it delivered a “final warning” on the climate crisis, as rising greenhouse gas emissions continue to push the world towards irrevocable damage which requires swift and drastic action to avert. To meet the ambitious and necessary target set at the Paris Agreement, to limit the rise in mean global temperature to 1.5 °C above pre-industrial levels, drastic reductions on emissions is critical. However innovation and new technology will be needed to achieve carbon dioxide removal (CDR) from the atmosphere in order to achieve net zero global emissions.
In my talk I will present an overview of the current CDR space and the pros and cons of each approach, in particular focusing on enhance rock weathering as a high permanence, cost effective and rapidly scalable solution.

# Recent Results from the World of Neutrinos

Elena Gramellini

Plenary Session 06, April 3, 2023, 14:00 – 14:30

The increasingly stringent limits on new physics posed by modern neutrino oscillation experiments are pushing the field of neutrino physics into the precision era. Exciting times are ahead for neutrinos which build upon current results. For future neutrino experiments to succeed in making breakthrough discoveries, such as CP-violation in the lepton sector and the neutrino mass ordering, a total systematic uncertainty budget at the level of a few percent must be achieved. Currently, one of the main sources of systematic uncertainty is the lack of detailed understanding of neutrino interactions.

In this talk, I will review the most recent results from the world of neutrinos, both in terms of neutrino-nucleus interactions and oscillation measurements.

# Software and computing in particle physics

Costanzo Davide

Plenary Session 08, April 4, 2023, 09:30 – 10:00

Modern particle physics detectors produce phenomenal amounts of data at an ever increasing rate. The developments in detector technology that allow these data to be collected has to be matched by developments in the software and computing infrastructure needed to select, process and analyse these data. More precise measurements also require high fidelity simulations of both the underlying physics processes and of particle interactions with the detectors. This talk will give an overview of the current software and computing infrastructure in use and the methods used to simulate the physics and the experiments. A few examples will be given to show how artificial intelligence and machine learning methods are used in particle physics, and how these are now common tools in our research.

# Harassment as a Selection Bias in Science

Rachael Windsor

Plenary Session 14, April 4, 2023, 14:00 – 14:30

Recent high-profile cases have drawn attention to bullying and harassment in physics, but are merely the tip of an enormous iceberg of behaviour that has a negative effect on the culture of science. I will discuss the ways in which this culture disproportionately impacts members of marginalised groups and thus acts as a selection bias in the field, how survivorship bias works to conceal this effect, and what practical steps you can take to prevent your department ending up in the press for the wrong reasons.

# Nu opportunities: Neutrino Experiments of the future

Nicola McConkey

Plenary Session 18, April 5, 2023, 15:30 – 16:00

There remain many unanswered questions in the field of neutrino physics – their mixing, mass and nature, even the number of types of neutrino is open to question. In this talk I will review the next generation of neutrino experiments, touching on some of the key challenges and exciting opportunities as we move towards the era of precision measurements in neutrino physics.

# Expanding the UK's Underground Laboratories: Boulby Development Programme

Hannah Newton

Plenary Session 13, April 4, 2023, 13:30 – 14:00

STFC are forming ambitious plans for the future of Boulby Underground Laboratory. We want to expand our national laboratory to become a truly world leading facility, hosting a major international physics experiment and enabling an expanse of science in the 'quiet frontier'. The Boulby Development Programme has been established to build this business case to take to government.

The current laboratory at Boulby operates 1.1 km deep underground in a working polyhalite and salt mine in the northeast of England. This depth and geology offers an exceptional environment for a wide range of scientific studies, including pure and applied ultralow background particle physics. Conceptual designs for an entirely new excavation and outfitted laboratories at 1.1 km (salt layer) and 1.4 km (polyhalite layer) have already been generated and options analysis are now underway to develop a design to be proposed in the business case. In this talk we will outline our current plans, vision and ways for you to engage with the Boulby Development Programme.

# The energy frontier at the LHC: Results so far

Sarah Williams

Plenary Session 03, April 3, 2023, 11:30 – 12:00

After more than a decade of running the Large Hadron Collider (at CERN) is now into its third data-taking run and the LHC experiments are continuing to new and exciting results based on the first two runs. This talk will summarise some of the physics highlights from the last year across direct searches for Beyond-the-Standard Model (BSM) physics and precision tests of the Standard Model, as well as some of the new results released for the winter conferences. The aim is to highlight how innovative new analysis techniques and new reconstruction methods are enabling the LHC experiments to push our understanding of physics at the energy frontier further, which bodes well for the path ahead to the High-Luminosity LHC.

# Parallel Speakers

**51** Remote Reactor Ranging using Neutrino Oscillations

Stephen Wilson[1]
[1]*University Of Sheffield, United Kingdom*

**83** Unbinned amplitude analysis of the decay $B^0 \rightarrow K^{*0} \mu^+ \mu^-$ using a q2 ansatz

Rui Wang[1], Mr Matthew Birch[2]
[1]*University of Bristol, Bristol, United Kingdom,* [2]*Imperial College London, London, United Kingdom*

**48** Probing the Nature of Heavy Neutral Leptons in Direct Searches and Neutrinoless Double Beta Decay

Zhong Zhang[1]
[1]*UCL, LONDON, United Kingdom*

**106** Neutron-Gamma Detection in Novel Borehole Detectors

Mr James Greer[1], Prof Lee Thompson, Dr Patrick Stowell
[1]*University Of Sheffield, United Kingdom*

**11** Differential cross-section measurement of the production of a top and anti-top quark pair in association with a Z boson with the ATLAS detector

Ms Harriet Watson[1]
[1]*University Of Glasgow, Glasgow, United Kingdom*

**6** How and why to simulate ALPs and cosmologies.

Dimitrios Karamitros[1]
[1]*University Of Manchester, United Kingdom*

**127** Modelling Cosmic Ray Muon Spallation in Super-Kamiokande VI+

Jack Fannon[1]
[1]*University Of Sheffield, United Kingdom*

**133** Measuring the flavour ratio of >1 TeV astrophysical neutrinos using differences in interaction morphologies at the IceCube Neutrino Observatory

Rogan Clark[1], Teppei Katori[1]
[1]*King's College London, London, United Kingdom*

**46** Timing Resolution of the Data Acquisition in the Short Baseline Near Detector

Vu Chi Lan Nguyen[1]
[1]*University Of Sheffield, Sheffield, United Kingdom*

**73** Searching for dark tridents with the MicroBooNE detector

Luis Mora[1]
*[1]The University Of Manchester, Manchester, United Kingdom*

**8** Model independent angular analysis of B -> D* mu nu decays at LHCb

Rizwaan Mohammed[1]
*[1]University Of Oxford, Oxford, United Kingdom*

**9** Latest results from the NA62 experiment at CERN

Artur Shaikhiev[1]
*[1]University Of Birmingham, United Kingdom*

**12** Search for Prompt Pentaquarks in the LHCb Experiment

Mr. Gary Robertson[1]
*[1]University Of Edinburgh, Edinburgh, United Kingdom*

**10** New model independent measurement of the CKM angle gamma with B->D(->KKpipi)h at LHCb and BESIII

Martin Tat[1]
*[1]University Of Oxford, Oxford, United Kingdom*

**94** The complexity of cosmic large-scale structure encoded in a single wavefunction

M. Alex Gough[1]
*[1]Newcastle University, United Kingdom*

**136** The next-generation gravitational-wave observatory

Stephen Fairhurst[1]
*[1]Cardiff University, United Kingdom*

**116** Measuring neautrino magnetic moment in the NOvA near detector

Robert Kralik[1]
*[1]University Of Sussex, Brighton, United Kingdom*

**25** FPGA readout commissioning at ProtoDUNE

Shyam Bhuller[1]
*[1]University of Bristol, Bristol, United Kingdom*

**13** A search for decays of the Higgs boson to invisible particles in ttH and VH final states at the CMS experiment and Run1+2 Higgs to invisible combination

Robert White[1]
*[1]University Of Bristol, Bristol, United Kingdom*

**14** Search for the Lepton Flavour Violating Decay Lb2Lemu

Paul Swallow[1]
[1]*University Of Birmingham, United Kingdom*

**43** New triggers for long-lived particles which decay in the Inner Detector for the ATLAS detector in Run 3

Benjamin Kerridge[1]
[1]*University Of Warwick, United Kingdom*

**15** Flavour symmetries and CP asymmetries- testing the Standard Model in B->DD decays

Jonathan Davies[1]
[1]*University Of Manchester, United Kingdrom*

**31** The CMS Upgrade High Granularity Calorimeter Electronics Test Systems

Miloš Vojinović[1]
[1]*Imperial College London, London, United Kingdom*

**18** Exploring the Potential of Machine Learning for Neutrino Identification in the DUNE Trigger System

Raul Stein[1]
[1]*University Of Bristol, United Kingdom*

**19** Novel Quantum Levitated Sensors For Directional Dark Matter Detection

Fiona Alder[1], Chamkaur Ghag[1], Peter Barker[1], Jonathan Gosling[1], Robert James[1]
[1]*University College London, United Kingdom*

**21** Higgs boson pair production searches in ATLAS

Dr Panagiotis Bellos[1]
[1]*University of Birmingham, Birmingham, United Kingdom*

**23** Using Machine Learning to improve the sensitivity of Stau Searches with the ATLAS Detector at the Large Hadron Collider

Dominic Jones[1]
[1]*University Of Cambridge, Cambridge, United Kingdom*

**29** Towards a measurement of charm mixing and CPV using D^0 to K pi pi pi decays at LHCb

Jenny Smallwood[1]
[1]*University Of Oxford, United Kingdom*

**24** Making measurements reusable: a case study with missing energy at ATLAS

Mr. Yoran Yeh[1]
[1]*University College London, London, United Kingdom*

**26** Bayesian Neutrino Oscillation Analysis for DUNE using the MaCh3

Markov Chain Monte Carlo Fitter

Liban Warsame[1]
*[1]Imperial College London, London, United Kingdom*

**27** Investigating the Preservation and Revival of Raw Bubble Chamber Data

Dr Andrew Chisholm
*[1]University Of Birmingham, Birmingham, United Kingdom*

**41** Developing an array of particle detectors to be used for cosmic ray coincidence detection

Mustafa Ozkaynak[1]
*[1]UCL, , United Kingdom*

**28** Model-independent high-mass Drell-Yan ditau measurement

Luzhan Yue[1]
*[1]University College London, London, United Kingdom*

**88** Non-Parametric Data-Driven Background Modelling using Conditional Probabilities

Júlia Silva[1], Konstantinos Nikolopoulos[1]
*[1]University Of Birmingham, Birmingham, United Kingdom*

**38** Measurement of the branching fraction and CP asymmetry of the decay B->pimumu

Rebecca Murta[1]
*[1]Imperial College London, United Kingdom*

**74** QUantum Enhanced Superfluid Technologies for Dark Matter and Cosmology

Mr Rob Smith[1]
*[1]Royal Holloway, University Of London, Egham, United Kingdom, [2]QUEST-DMC Collaboration*

**30** Measurement of differential cross sections for W boson production and W+/W- production cross-section ratios in association with jets at \sqrt{s} = 13 TeV with the ATLAS detector at the LHC

Eimear Conroy[1]
*[1]University Of Oxford, United Kingdom*

**53** Lepton universality test in VBF topology with tau(had) tau(lep) final states.
Mr Diego Baron[1], Prof. Terry Wyatt[1]
*[1]University Of Manchester, United Kingdom*

**45** MicroBooNE's tests of the MiniBooNE anomalous low-energy excess

Pawel Guzowski[1]
*[1]The University Of Manchester, United Kingdom*

**33** The NEXT tonne-scale programme

Helena Almazan[1]
*[1]University Of Manchester, United Kingdom*

**34** From NEXT-White to NEXT100: Results and expectations.

Brais Palmeiro Pazos[1]
*[1]University Of Manchester, Manchester, United Kingdom*

**35** Search for QCD Instantons at the LHC

Ynyr Harris[1]
*[1]University Of Oxford, United Kingdom*

**64** The Super Fine-Grained Detector: Assembly and Gain Calibration

Chien Lin[1]
*[1]Imperial College London, United Kingdom*

**39** Search for heavy Majorana neutrino production via vector boson scattering with the ATLAS detector

Benjamin Wilson[1]
*[1]University Of Manchester, Manchester, United Kingdom*

**129** Particle Identification and Position Reconstruction with a Machine Learning Technique in the Hyper-Kamiokande Detector

Joanna Gao[1], Dr Teppei Katori[1], Dr Nicholas Prouse[2], Professor Patrick de Perio[3]
*[1]King's College London, United Kingdom, [2]Imperial College London, United Kingdom, [3]Kavli IPMU, University of Tokyo, Japan*

**69** Neutron Activation Background in the LUX-ZEPLIN Experiment

Tom Rushton[1]
*[1]University Of Sheffield, United Kingdom*

**40** Large Area Picosecond Photodetector for the Upgrade II of the LHCb RICH

Federica Oliva[1]
*[1]University of Edinburgh, Edinburgh, United Kingdom*

**42** Calibration using a YBe source in the LUX-ZEPLIN experiment

Amardeep Chawla[1]
*[1]Royal Holloway, London, United Kingdom*

**47** Not all hopes die immediately: Searching for new particles beyond the standard model if they are long-lived, using displaced vertex signatures in ATLAS

David Rousso[1]
*[1]University Of Cambridge, United Kingdom*

**68** Low energy electron recoil searches in LUX-ZEPLIN

Anh Nguyen[1]
[1]*LUX-ZEPLIN , United States*

**60** The SoLAr Concept: LArTPCs for solar neutrino physics

Anyssa Navrer-Agasson[1]
[1]*The University of Manchester, Manchester, United Kingdom*

**54** Photon Propagation in the LUX-ZEPLIN Experiment

Anna David[1]
[1]*University College London, London, United Kingdom*

**57** A new hydrogen-filled Cherenkov detector for Kaon tagging at NA62

Dr Angela Romano[1]
[1]*University Of Birmingham, United Kingdom*

**59** Measurement of the CKM angle γ in $B^\pm \rightarrow DK^{*\pm}$ decays at LHCb

Fidan Suljik[1]
[1]*University of Oxford, United Kingdom*

**71** Improving systematic uncertainties in the oscillation analysis with the new $NC1\pi^0$ samples for the T2K experiment

Tailin Zhu[1]
[1]*Imperial College London, London, United Kingdom*

**63** BUTTON: a technology testbed for the future of (anti)neutrino detection

Liz Kneale[1]
[1]*University of Sheffield, United Kingdom*

**103** Measuring Solar Neutrino Oscillations in the SNO+ Detector
Daniel Cookman[1]
[1]*University Of Oxford, Oxford, United Kingdom*

**65** The Cold Radon Emanation Facility

Emily Perry[1]
[1]*UCL, London, United Kingdom*

**66** High-Statistics Measurement of Nuclear Dependence in Inclusive Antineutrino Scattering in 1D and 2D with MINERvA

Anežka Klustová[1]
[1]*Imperial College London, United Kingdom*

**67** First measurement of a joint CC0Pi/CC1Pi cross-section with the T2K near detector ND280

Yassine Alj Hakim[1]
*[1]Imperial College London, United Kingdom*

**92** DarkSide50 low mass analysis with non standard operators and Earth shielding effects

Elizabeth Leason[1]
*[1]Royal Holloway University of London, Egham, United Kingdom*

**99** Joint Fit Between Atmospheric Neutrinos and Accelerator Neutrinos

Zhenxiong Xie[1]
*[1]King's College London, United Kingdom*

**72** Searching for heavy neutral leptons with the MicroBooNE experiment

Mr David Marsden[1]
*[1]The University Of Manchester, Manchester, United Kingdom*

**85** Gas Gains in SF6 on the Order of 10^4 with a Novel Multi-Mesh Thick Gaseous Electron Multiplier for use in a Directional Dark Matter Search

Alasdair McLean[1], Neil Spooner[1], Robert Renz Marcelo Greggorio[1], Anthony Ezeribe[1], Callum Eldridge[1], Andrew Scarf[1]
*[1]University of Sheffield, Sheffield, United Kingdom*

**86** Early Run-3 W±/Z cross-section measurements at the ATLAS experiment

Mihaela Marinescu[1], Kostas Nikolopoulos[1]
*[1]University Of Birmingham, United Kingdom*

**77** DarkSPHERE: Extending light dark matter searches to the neutrino floor with spherical proportional counters in the UK

Patrick Knights[1]
*[1]University Of Birmingham, United Kingdom*

**81** On the development of the Mu2e Stopping Target Monitor software

Pawel Plesniak[1]
*[1]UCL, London, United Kingdom*

**82** Searching for dark neutrinos using the SBND Cosmic Ray Tagger

Jiaoyang Li[1]
*[1]The University Of Edinburgh, Edinburgh, United Kingdom*

**84** Duplicate Track Removal in the CMS L1 Track-Finder

Katie Walkingshaw Pass[1]
*[1]University Of Bristol, United Kingdom*

**107** Neutron spectroscopy with a high-pressure nitrogen-filled spherical proportional counter

Thomas Neep[1], Patrick Knights[1], Ioannis Manthos[1], Kostas Nikolopoulos[1], Robert Ward[1], Ioannis Katsioulas[1]
*[1]University Of Birmingham, United Kingdom*

**102** Searches for exclusive Higgs and Z boson decays to a meson and a photon at ATLAS

Robert Ward[1]
*[1]University Of Birmingham, Birmingham, United Kingdom*

**100** Search for the resonant production of two Higgs bosons in a final state with two photons and two tau leptons

Matthew Knight[1]
*[1]Imperial College London, United Kingdom*

**109** Development of a Phase Shear Detection System for the MAGIS-100 and AION Experiments

Dr Gedminas Elertas[1]
*[1]University of Liverpool, Liverpool, United Kingdom*

**95** Terrestrial Limits on Ultra-light Dark Matter Detection With Atom Interferometers; MAGIS-100 and AION

Dr. Jeremiah Mitchell[1]
*[1]University Of Cambridge, Cambridge, United Kingdom*

**111** LEGEND-200 first operational results

George Marshall[1]
*[1]University College London, United Kingdom*

**114** Individual anode readout for position reconstruction and tracking with the Spherical Proportional Counter

Dr. Ioannis Manthos[1], Mr. Dominic Herd[1], Dr. Patrick Knights[1], Ms. Jack Matthews[1], Mr. Lex Millins[1], Dr. Tom Neep[1], Prof. Konstantinos Nikolopoulos[1], Dr. Rob Ward[1]
*[1]University of Birmingham, Birmingham, United Kingdom*

**98** MightyPix: An HV-CMOS Pixel Chip for LHCb's Mighty Tracker

Sigrid Scherl[1,2], Nicolas Striebig[2], Ivan Peric[2], Richard Leys[2]
*[1]University of Liverpool, Liverpool, United Kingdom, [2]Karlsruhe Institute of Technology, Karlsruhe, Germany*

**101** Electronic feedback system for the MAGIS-100 and AION retro reflection chamber

Henry Throssell[1]
*[1]University of Liverpool, Liverpool, United Kingdom*

**105** Photon-induced WW production as a test of the electroweak boson self-interactions

Joshua Puddefoot[1]
*[1]University Of Sheffield, United Kingdom*

**112** Calibration and Noise Suppression of ATLAS Run3 Electron Trigger

Chonghao Wu[1]
*[1]University Of Birmingham, Birmingham, United Kingdom*

**120** Use of Gd-WCDs for Extreme Space Weather Monitoring

Patrick Stowell[1]
*[1]Durham University, United Kingdom*

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Dr Sukanya Sinha[1]
*[1]University Of Manchester, Manchester, United Kingdom*

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*[1]University of Oxford, Oxford, United Kingdom*

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Dr Tobias Fitschen[1]
*[1]University Of Manchester, United Kingdom*

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Dr Seb Jones[1]
[1]*University College London, London, United Kingdom*

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Pratik Jawahar[1], Thea Aarrestad[1], Nadezda Chernyavskaya[1], Maurizio Pierini[1], Kinga A. Wozniak[2], Jennifer Ngadiuba[3], Javier Duarte[4], Steven Tsan[4]
[1]*CERN, Geneva, Switzerland,* [2]*University of Vienna, Vienna, Austria,* [3]*Fermi National Accelerator Laboratory (FNAL), Batavia, USA,* [4]*University of California, San Diego, San Diego, USA*

**142** The Future of Supernova Neutrinos

Jost Migenda[1]
[1]*King's College London, London, United Kingdom*

**147** CKM angle gamma measurement at LHCb using partially reconstructed B → D*h with D* → Dpi0 and D* → Dgamma

Seophine Stanislaus

**150** QSHS collaboration

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**145** Probing jet quenching through hadron+jet measurements with the ALICE experiment

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**7** Status of the FASER Experiment at the LHC and first run-3 results

Carl Gwilliam[1], Monica D'Onofrio[1], Josh McFayden[2], Michaela Queitsch-Maitland[3]
[1]*University Of Liverpool, United Kingdom,* [2]*University of Sussex, United Kingdom,* [3]*University of Manchester, United Kingdom*

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# Remote Reactor Ranging using Neutrino Oscillations

Stephen Wilson[1]
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Nuclear reactors can be observed via their antineutrino emission as the flux is dependent on their thermal power output. Neutrinos and antineutrinos are unique amongst the known particles, in that they carry information about the distance they have travelled. This information is contained in the spectral distortions caused by the quantum mechanical effect known as neutrino oscillation. This allows the distance of an observed reactor to be determined via a spectral analysis.

This talk presents two analyses that have been developed for a proposed kiloton scale, gadolinium-doped water-based liquid scintillator detector at STFC's Boulby Underground Laboratory, and tested on real reactor signals. A minimum chi-squared analysis shows promise in ranging reactors that produce a dominant signal, such as the EDF Hartlepool complex 26 km from the detector. A Fourier transform method is able to handle more complex scenarios with much more distant reactors, up to 200 km.

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# Unbinned amplitude analysis of the decay $B^0 \rightarrow K^{*0} \mu^+ \mu^-$ using a q2 ansatz

Rui Wang[1], Mr Matthew Birch[2]
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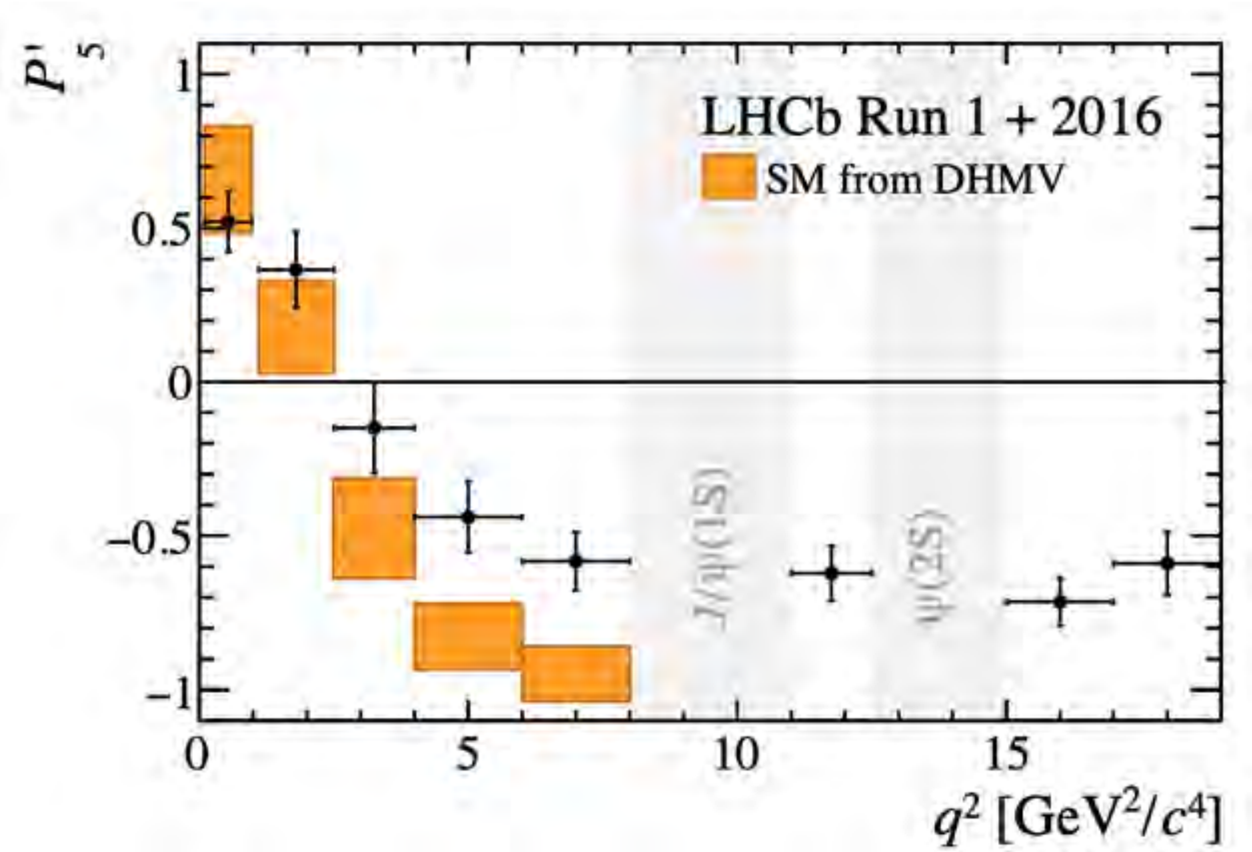
The anomalies in the b→sll process have been one of the most promising candidate signals beyond the Standard Model (SM). These processes involve quark flavour-changing neutral current transitions. These are forbidden at tree level in the SM and can only occur through electroweak penguin and box processes. Therefore, such a process is very sensitive to new physics.

The analysis of the decay B → K*μμ and similar decays have revealed tensions in the branching fractions and angular distributions of these transitions. Further study is therefore well motivated. Current measurements of these decays are performed in bins of the dimuon mass squared ($q^2$) There have been suggestions to perform the measurements unbinned in $q^2$ using heavily model-dependent approaches.

In this analysis, we will present progress towards an analysis of B → K*μμ decays using a less model-dependent unbinned analysis of the decay B → K*μμ, where the eight helicity amplitudes extracted as continuous functions of $q^2$ using a $q^2$ dependent ansatz. The amplitudes are modelled with a $q^2$-dependent Legendre polynomial ansatz. The analysis is constructed in a TensorFlow framework to make use of the fast-fitting feature with GPUs.



48

# Probing the Nature of Heavy Neutral Leptons in Direct Searches and Neutrinoless Double Beta Decay

Zhong Zhang[1]
*[1]UCL, London, United Kingdom*

Heavy Neutral Leptons (HNLs) are a popular extension of the Standard Model to explain the lightness of neutrino masses and the matter-antimatter asymmetry through leptogenesis. Future direct searches, such as fixed target setups like DUNE, and neutrinoless double beta decay are both expected to probe the regime of active-sterile neutrino mixing in a standard Seesaw scenario of neutrino mass generation for HNL masses around mN $\lesssim$ 1 GeV. Motivated by this, we analyse the complementarity between future direct searches and neutrinoless double beta decay to probe the nature of HNLs, i.e., whether they are Majorana or quasi-Dirac states, and CP-violating phases in the sterile neutrino sector. Following an analytic discussion of the complementarity, we implement a generic fixed target experiment modelling DUNE. We perform a statistical study in how a combined search for HNLs in direct searches and neutrinoless double beta decay, using DUNE and LEGEND-1000 as representative examples, can probe the nature of sterile neutrinos.

106

# Neutron-Gamma Detection in Novel Borehole Detectors

Mr James Greer[1], Prof Lee Thompson, Dr Patrick Stowell
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Radioisotope sources are highly prevalent in the oil and gas well-logging industry. Downhole detectors are reliant upon the interactions of neutron and gamma radiation within the surrounding rocks and pore-occupying fluids. Sources used often have activities of the order $10^{10}$ Bq. These high activity sources have in many cases became lodged downhole [1], at great financial cost to operators, and posing significant environmental risk. In addition, sources have been lost in transit to and from work sites, such as the recent disappearance of a 19 GBq Cs-137 source in Western Australia. In this work, a novel detector design is proposed that will instead leverage a D-T pulsed neutron generator. Deuterium-Tritium neutron sources can be switched off when not in use, provide higher energy neutrons, and their pulsed nature allows exploitation of timing characteristics in the detector response. Though the industry has begun to adopt pulsed sources, offering further advantages in D-T source-detector systems is likely to accelerate wider adoption of this safer alternative to radioisotope sources. This work will investigate the use of low-cost, segmented detectors, made from a combination of in-house manufactured plastic scintillator and BN:ZnS(Ag) thermal neutron capture foils. GEANT4 simulation data has been combined with machine learning techniques to make predictions of key petrophysical parameters.

[1] Notice of Source Abandonment, US NRC / Halliburton (2012) –
https://www.nrc.gov/docs/ML1229/ML12291A746.pdf

11

# Differential cross-section measurement of the production of a top and anti-top quark pair in association with a Z boson with the ATLAS detector

Ms Harriet Watson[1]
*[1]University Of Glasgow, Glasgow, United Kingdom*

Precision measurements in top-quark physics are required to stringently test the consistency of the Standard Model (SM). The production of a top and anti-top quark pair in association with a Z boson (ttZ) is a rare SM process that is sensitive to the top-Z coupling, the value of which is not yet well constrained experimentally and varies theoretically depending on the chosen model. A precision measurement of the ttZ differential cross section is underway that aims to improve upon the previous ATLAS cross section measurement. The differential cross section measurement is performed in the trilepton and tetralepton channels using profile likelihood unfolding and in signal regions defined by dense neural networks.

6

# How and why to simulate ALPs and cosmologies.

Dimitrios Karamitros[1]
[1]*University Of Manchester, United Kingdom*

I will talk about MiMeS and NSC++, two libraries that can simulate axions/ALPs and the energy density of fluids, respectively, in the Universe. I will argue for their necessity, I will explain how they work, and I will share my vision for their future.

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# Modelling Cosmic Ray Muon Spallation in Super-Kamiokande VI+

Jack Fannon[1]
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Super-Kamiokande (SK) is a 50 000 tonne water Cherenkov detector located underneath Mount Ikeno in the Gifu Prefecture of Japan. The primary research topic of SK is the neutrino, a neutral particle that rarely interacts with matter. As such, neutrinos from specific sources are challenging to detect in the presence of overwhelming backgrounds. One background of specific interest are events caused by cosmic ray muon spallation, particularly the decay of radioactive isotopes caused by the spallation of oxygen nuclei in the SK water.

High-energy muons are produced in the upper atmosphere when pions, created by interactions between the atmosphere and cosmic rays, decay to a muon and its corresponding neutrino.
Even though Mount Ikeno reduces the flux of cosmic ray muons by a factor of 100 000, SK observes 2.5 muons per second with approximately 1 spallation interaction per muon. Many daughter isotopes of the spallation process are stable or decay in ways that do not produce Cherenkov radiation. Though, 16 nuclei can be created that cause a significant background in analyses focused in the 0-20 MeV range.

Though most background rejection cuts utilise Monte-Carlo (MC) simulation to model the backgrounds, a solely data-based reduction is currently used to identify spallation events at SK. Presented here is the development of an MC simulation, combining output from multiple particle physics simulations, to model the spallation background at SK and verify it against data. Current results show a good agreement between simulation and data, and preliminary results from training a machine learning classification display good reduction power of a gradient-boosted algorithm.

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# Measuring the flavour ratio of >1 TeV astrophysical neutrinos using differences in interaction morphologies at the IceCube Neutrino Observatory

Rogan Clark[1], Teppei Katori[1]
[1]*King's College London, London, United Kingdom*

The IceCube Neutrino Observatory is a cubic-kilometre neutrino detector that uses the Antarctic ice cap as a Cherenkov medium for high energy (> 100 GeV) neutrino interactions. These interactions include those of the diffuse astrophysical neutrino flux, which comprises of all three neutrino flavours. We aim to perform a measurement of the flavour ratio of this flux, with events of energy > 1 TeV, focusing on the NuMu/NuTau charged current interaction to muon. We aim to perform flavour separation on these two channels by looking at the distribution of energy in the ice relative to the event's starting point, and calculating flavour ratio by fitting to three reconstruction variables - neutrino energy, neutrino zenith angle, and effective interaction inelasticity.

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Timing Resolution of the Data Acquisition in the Short Baseline Near Detector

Vu Chi Lan Nguyen[1]
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The Short-Baseline Neutrino (SBN) program at Fermilab aims to carry out precision searches for new neutrino physics [1]. Being the closest detector of the program to the Booster Neutrino Beam (BNB), Short Baseline Near Detector (SBND) is expected to measure an extremely high neutrino flux, allowing for world leading neutrino-nucleus interaction measurements as well as searches for physics Beyond Standard Model (BSM).

SBND aims to achieve high timing resolution within the order of a few nanoseconds, allowing for the reconstruction of the BNB substructure. The precise timing enables identification of an interaction inside the detector whether it is in-time with the neutrino spill. This opens up possibilities not only to reject out-of-time cosmics muons background, but also to select delayed interactions from the BNB which can be signatures of BSM physics.

In order to achieve the targeted resolution, it is crucial to implement the Data Acquisition (DAQ) system of SBND to ensure the precise timing at the hardware level. This talk will outline the utilisation of the White Rabbit SPEC TDC in the DAQ, which functions as a high precision clock in addition to the intrinsic clock of each DAQ subsystem. The immediate goal of the SPEC TDC is to characterise the timing resolution contributions from each DAQ subsystem as well as to provide an alternative method for event timing reconstruction.

[1] P. Machdao, O Palamara and D. Schmitz, arxiv 1903.04608 (2019)

73

## Searching for dark tridents with the MicroBooNE detector

Luis Mora[1]
[1]*The University Of Manchester, Manchester, United Kingdom*

In this talk, I will present an ongoing search for dark matter using the MicroBooNE experiment and the NuMI neutrino beam. The MicroBooNE detector is a liquid argon time projection chamber located 680 m from the NuMI beam target on the Fermilab campus. It has great calorimetric and spatial reconstruction capabilities that make it an ideal experiment to explore beyond the Standard Model physics, such as the dark trident interaction. Dark tridents are a barely explored interaction channel that arises in dark matter models composed of a sub-GeV dark matter fermion and a massive bosonic mediator. This dark matter candidate can be produced in the decay of neutral mesons themselves as the result of interactions of the proton beam with the NuMI target. The resulting dark matter particles can travel to the MicroBooNE detector where they might interact with an argon nucleus producing charged leptons. I will introduce the strategy designed to search for this dark matter signature along with the tools used, possible backgrounds, systematic uncertainties and present status of the analysis. In addition, I will discuss a novel event selection method using deep learning techniques.

8

## Model independent angular analysis of B -> D* mu nu decays at LHCb

Rizwaan Mohammed[1]
*[1]University Of Oxford, Oxford, United Kingdom*

The differential decay rate of B → D*μν decays is fully described by a sum of 12 terms. Each term is a function of the three decay angles, which can be calculated from the kinematics of the final state particles, multiplied by a coefficient – herein referred to as an angular observable. Theoretical predictions of these angular observables depend on choices of form factor scheme, Wilson Coefficients and the momentum transfer ($q^2$). A model-independent approach to measure the 12 angular observables has been developed using a 4 dimensional, probability density templates, derived from simulation, to describe the data. Angular analysis is well established in fully-reconstructed decays but its use in partially-reconstructed modes is novel. The model independence of the novel method will be demonstrated. Finally, the sensitivity to these 12 observables using data from the LHCb experiment will be estimated and presented in the context of the current global understanding of the angular structure of B -> D*μν decays

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# Latest results from the NA62 experiment at CERN

Artur Shaikhiev[1]
[1]*University Of Birmingham, United Kingdom*

An overview of the latest NA62 results is presented. The NA62 experiment at CERN collected the world's largest dataset of charged kaon decays in 2016-2018.

The radiative kaon decay K+ -> π0 e+ ν γ (Ke3g) is studied with a data sample of O(100k) Ke3g candidates with sub-percent background contaminations. The most precise measurements of the branching ratio and T-asymmetry are achieved.

Results from the study of the flavour-changing neutral current decay K+ -> π+ μ+ μ- decay is presented. The decay is induced at the one-loop level in the Standard Model, and is well suited to explore its structure and, possibly, its extensions. The sample comprises about 27k signal events with negligible background contamination, and the presented analysis results include the most precise determination of the the branching ratio and the form factor.

New preliminary results are obtained from an analysis of the K+ —> π+ γ γ decay. The decay sample is about 15 times larger than the previous largest one, which along with the improved di-photon mass resolution, leads to an unprecedented sensitivity. The measurement represents an important test of the theories describing low-energy dynamics. The analysis can be naturally extended to search for the K+ -> π+ a, a -> γ γ process, where a is a short-lived axion-like particle.

Dedicated trigger lines were employed to collect di-lepton final states, which allowed establishing new stringent upper limits on the rates of lepton flavour and lepton number violating kaon decays.

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# Search for Prompt Pentaquarks in the LHCb Experiment

Mr. Gary Robertson[1]
*[1]University Of Edinburgh, Edinburgh, United Kingdom*

A search for pentaquark states decaying into a range of $\Sigma c$ baryons and D mesons (as well as a smaller range of $\Lambda c$ baryons and D mesons) was conducted using Run 2 data corresponding to 5.7 inverse fb. Since no obvious signal was found, upper limits were set on the yield relative to the control mode.
In this talk I will discuss the details of this analysis from the signal selection to the scan of the mass range in each mode, as well as the procedure to find the p-values and set the upper limits.

10

# New model independent measurement of the CKM angle gamma with B->D(->KKpipi)h at LHCb and BESIII

Martin Tat[1]
[1]*University Of Oxford, Oxford, United Kingdom*

The CKM angle gamma, an important Standard Model parameter, is the only CKM angle accessible at tree level. By comparing direct measurements of gamma with indirect determinations, any discrepancies may give us hints as to where New Physics may arise at loop level. In this talk, I will present a new model independent measurement of gamma, using the channel B->D(->KKpipi)h. This charm decay has a five-dimensional phase space, where the charm strong phase difference has a non-trivial variation. With a state of the art amplitude model, a binning scheme in phase space is optimised for maximum sensitivity to gamma. In addition, I will also discuss the ongoing effort at BESIII to directly measure the strong phase difference in each bin, using quantum correlated DD pairs. Together, LHCb and BESIII will perform the first model independent measurement of gamma in this decay mode.

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# The complexity of cosmic large-scale structure encoded in a single wavefunction

M. Alex Gough[1]
[1]*Newcastle University, United Kingdom*

On large scales, the dark matter distribution can be treated as a perfect fluid. On small scales, gravitationally bound structures form through nonlinear clustering. Capturing the resulting cascade of multiple fluid streams in 6d phase space is challenging. We approximate the time evolution of this complex phase-space dynamics using a wavefunction, in the spirit of the quantum-classical correspondence. This method is a tool both for modelling the phase-space dynamics of cold dark matter in position-space, and is the fundamental description of ultralight dark matter candidates such as axions. In a simple dynamical model for the evolution of this dark matter wavefunction, I will demonstrate how the rapid oscillations from wave interference automatically encode information beyond perfect fluid models and how the classical streams are recovered from "unweaving" the interference. This description, together with connections to optical caustics and diffraction integrals, presents rich universal features that can unlock new ways of modelling and probing both wavelike and cold dark matter on the scales of the cosmic web.

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# The next-generation gravitational-wave observatory

Stephen Fairhurst[1]
*[1]Cardiff University, United Kingdom*

Gravitational Waves (GWs) emitted by colliding black holes were detected for the first time by LIGO in 2015. The subsequent observation of merging neutron stars in 2017, and its electromagnetic counterpart signal, attracted the attention of the astronomy community worldwide. Almost 100 gravitational wave signals have been observed to date, providing a glimpse of the binary black hole population in the nearby universe.

The next-generation global GW observatory will be transformative in its reach, capable of observing spacetime vibrations caused by colliding neutron stars and black holes out to the edge of the Universe. The network, consisting of US 'Cosmic Explorer' (CE) and European 'Einstein Telescope' (ET) nodes, will provide guaranteed discoveries in astrophysics, cosmology and fundamental physics, generating a rich scientific return. It will provide a detailed understanding of black-hole and neutron-star mass and population statistics, their formation channels and demographics; enable tests to the extreme the limits of General Relativity; and provide a wealth of unforeseen astrophysical information through GW and electromagnetic multi-messenger astronomy. Observations will provide tight constraints on the nature of matter at the extreme densities represented by neutron stars, including aspects of the QCD phase diagram that cannot be probed in large-scale colliders like the LHC; a much improved understanding of the central engine for short gamma-ray bursts and the formation of heavy elements from rapid nuclear reactions in matter outflows following binary mergers.

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# Measuring neautrino magnetic moment in the NOvA near detector

Robert Kralik[1]
[1]*University Of Sussex, Brighton, United Kingdom*

In theory, neutrinos already have a very small magnetic moment after including neutrino masses into the standard model. Measuring an enhanced neutrino magnetic moment would therefore be a direct evidence of physics beyond the standard model and could also point to the Dirac/Majorana nature of neutrinos.

We can measure neutrino magnetic moment by searching for an excess of neutrino-on-electron elastic scattering events at low electron energies. This way we measure an effective neutrino magnetic moment, which is a combination of neutrino magnetic and electric dipole moment and neutrino oscillation parameters. This means that the effective neutrino magnetic moment measured for electron antineutrinos, or solar neutrinos, is not the same as the one measured for muon neutrinos and antineutrinos.

NOvA is an accelerator-based neutrino experiment with its near detector located underground, right by a very intense and about 95% pure source of muon neutrinos and antineutrinos. This allows us to make a potentially world-leading measurement of muon neutrino and antineutrino effective magnetic moment.

25

## FPGA readout commissioning at ProtoDUNE

Shyam Bhuller[1]
[1]*University of Bristol, Bristol, United Kingdom*

The Deep Underground Neutrino Experiment (DUNE) is a next-generation long baseline neutrino experiment with a 70-kt liquid argon detector at the Sanford Underground Research Facility (SURF) 1300 km from Fermilab. This programme includes studies of neutrino oscillations with a high-intensity muon-neutrino beam from Fermilab; as well as, proton decay and supernova neutrino burst searches. The DAQ system is in development as part of the ProtoDUNE programme at CERN, which included the development of readout using the Front-End LInk eXchange (FELIX) readout board designed at ALTAS. The FELIX features an FPGA (field programmable gate array) which was used to process the incoming data to produce trigger primitives which could then be used to trigger on physics events. This presentation documents the commissioning of both hardware, firmware and software throughout 2022 discussing the successes and lessons learned when trying to develop FPGA readout and how this knowledge can be used in the future development of trigger primitive generation for DUNE.

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# A search for decays of the Higgs boson to invisible particles in ttH and VH final states at the CMS experiment and Run1+2 Higgs to invisible combination

Robert White[1]
*[1]University Of Bristol, Bristol, United Kingdom*

A search for decays to invisible particles of Higgs bosons produced in association with a top-antitop quark pair or a vector boson, which both decay to a fully hadronic final state, has been performed using proton-proton collision data collected at $\sqrt{s}$ = 13 TeV by the CMS experiment at the LHC, corresponding to an integrated luminosity of 138 /fb. The 95% confidence level upper limit set on the branching fraction of the 125 GeV Higgs boson to invisible particles, B(H->inv), is 0.47 observed (0.40 expected), assuming standard model production cross sections. The results of this analysis are combined with previous B(H->inv) searches carried out at $\sqrt{s}$ = 7, 8, and 13 TeV in complementary production modes. The combined upper limit at 95% confidence level on B(H->inv) is 0.15 observed (0.08 expected).

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# Search for the Lepton Flavour Violating Decay Lb2Lemu

Paul Swallow[1]
[1]*University Of Birmingham, United Kingdom*

Although the Standard Model includes lepton flavour violation (LFV) in the neutrino sector, charged lepton flavour violation (cLFV) is forbidden at tree-level. Precise searches for cLFV therefore have direct sensitivity to potential sources of new physics (NP) that could enhance the production of such modes, where any observation then provides very clear evidence of NP. The Λb->Λeμ mode provides a complementary and independent search for cLFV within LHCb where previous searches for cLFV have examined meson decays. This analysis epresents the first search for this mode at LHCb, and will either report an observation or set the first upper limit. This talk will review the current status and strategy of the analysis.

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# New triggers for long-lived particles which decay in the Inner Detector for the ATLAS detector in Run 3

Benjamin Kerridge[1]
*[1]University Of Warwick, United Kingdom*

Massive long-lived particles (LLPs), which are absent in the Standard Model, can occur in many well-motivated theories of physics BSM. The large lifetimes of LLPs result in unusual experimental signatures within the detector, which required custom techniques to identify.

During the upgrades of the ATLAS detector for Run 3 many developments in the trigger have taken place. Major improvements in the tracking for non prompt particle in the trigger (Large Radius Tracking) are discussed.

New triggers have been developed which make use of the tracking upgrades, to improve the trigger efficiency for long-lived particles, one such example, is the Displaced Jet trigger.

For some signatures such as H-> aa -> 4b where the a is long lived, with gluon-gluon fusion production of the Higgs boson, only a high pT threshold jet trigger was available in Run 2, with the new Displaced Jet trigger, the tracks from the displaced tracks are identified and used to select the event for retention. The expected performance of this new trigger will be presented.

15

# Flavour symmetries and CP asymmetries- testing the Standard Model in B->DD decays

Jonathan Davies[1]
[1]*University Of Manchester, United Kingdrom*

The discrepancy between the Baryon Asymmetry of the Universe and its Standard Model (SM) prediction implies the existence of physics beyond the SM, which must include further sources of CP violation. Generically, physics beyond the SM comes with O(1) weak phases. LHCb has recently made several CP asymmetry measurements for B->DD decays. For such non-leptonic modes, a lack of knowledge of long-distance strong interaction contributions means these are challenging to predict. We use QCD's approximate SU(3)-flavor symmetry, systematically including breaking effects, to assess the consistency of current data with the SM and to predict yet unmeasured CP asymmetries.

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# The CMS Upgrade High Granularity Calorimeter Electronics Test Systems

Miloš Vojinović[1]
*[1]Imperial College London, London, United Kingdom*

In preparation for the High-Luminosity era of the LHC, the CMS experiment will replace the existing calorimeter endcaps with a novel device - the High Granularity Calorimeter. The device will have around six million readout channels. Given the scale of the endcap upgrade project, the electronics system is highly specialised and has significant complexity involving multiple layers of data transfer, so testing must be carefully planned. The strategy has been to split the efforts between vertical (start-to-end) and horizontal (parallelisation) test systems wherever possible. An important milestone for the former has been the development and operation of test systems to prototype one vertical slice of the future endcap electronics system.

As for the final detector, the test systems consist of front-end (on-detector) electronics hardware with prototype custom ASICs and a back-end (off-detector) ATCA board running custom firmware and software. In addition, in both its front-end and back-end segments, the test system readout is split into two parts for the readout of coarse granularity data (for the trigger system) and high granularity data (for full event readout). The trigger back-end is responsible for using the coarse data to decide if the corresponding event should be read out in high definition. The DAQ back-end is also responsible for distributing a precise timing reference to both the front-end systems and also for their control and configuration.

The main goals of the tests have been to verify various kinds of data exchange between the front-end and the back-end electronics, specifically the timing distribution, slow and fast control, acquisition of coarse and high-definition data, etc., across all the relevant interfaces. The success in all these activities will allow the project to move towards horizontal system scaling. Everything listed, except readout of the high-definition data (where the relevant prototype ASIC is not yet fabricated), has already been achieved.

Specifically, the clock reference brought from the back-end can be reliably recovered in the front-end ASICs such that the two parts are fully synchronised. Regarding slow control, it is possible to read from and write to any register of any ASIC existing in the front-end. Considering fast control, the back-end can send a variety of fast commands with evidence of them being properly received by the front-end ASICs. The front-end readout ASICs can be configured to send user-defined trigger data.  These data can then be transmitted through a sequence of several additional front-end ASICs, complete their journey via the fibre-optic channel to the back-end and be unpacked by the back-end firmware where they precisely match what the readout ASICs were configured to originally send out.

This presentation will illustrate the architecture of the electronics systems, explain how the prototypes are related to a vertical slice of the future endcap electronics system, and summarise the central objectives that have been achieved to date. In addition, it will give an outlook into future test system activities.

# HGCAL Electronics Test Systems

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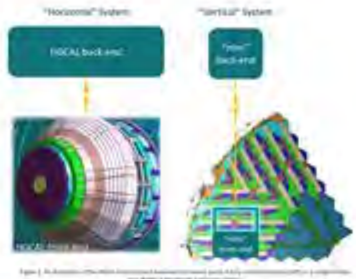
Imperial College London

Miloš Vojinović
On behalf of the CMS Collaboration

## Abstract

In preparation for the High-Luminosity era of the LHC, CMS will replace the existing calorimeter endcaps with a novel device - the High Granularity Calorimeter (HGCAL), which will have around **six million readout channels**. Given the scale and complexity of the endcap upgrade project, **the electronics testing must be carefully planned**. The strategy has been **to split the efforts between vertical (start-to-end) and horizontal (parallelisation) test systems** wherever possible (Figure 1). An important milestone is the operation and development of test systems to **prototype one vertical slice** of the future endcap electronics system.




## Motivation

The test system at CERN consists of front-end hardware with **real ASICs and a back-end board** running custom firmware and software. In addition, it is split into its respective **trigger and DAQ** paths in both cases. The main goals are to test various kinds of data exchange between the front-end and the back-end, specifically the **timing distribution, slow and fast control, and acquisition of trigger and DAQ data**, across all the relevant interfaces. All have been achieved except DAQ data acquisition. Success in these activities allows the project to move towards horizontal system scaling.

## The System Setup and Achievements

DAQ back-end (Zynq)

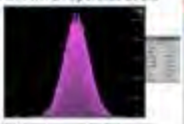

TPG back-end (Serenity)

External Clock Generator

Trigger data

### Timing Distribution

- The DAQ back-end distributes the 40 MHz clock reference embedded in the fibre-optical link which operates at 2.5 Gb/s to the front-end.
- There are custom front-end chips that recover the clock and distribute it to the read-out chips.
- **Able to reliably lock the front-end and the back-end to work on the same 40 MHz clock.**
- Measurements (Figure 2) show that the **jitter** in the system **meets** the **specification requirements** (i.e. TIE ~ 8.5 ps < 15 ps) [*].



### Slow Control

- The DAQ back-end performs slow control (i.e. configuration, monitoring, resets) of the front-end (Figure 3).
- **Able to read from and write to any register of any ASIC existing in the front-end.**

### Fast Control

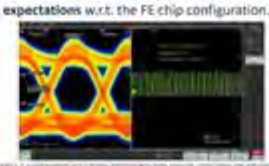
- The DAQ back-end generates and distributes various fast commands (i.e. Level-1 Accept, OrbitSync, Idle, etc.) to the front-end chips (Figure 4).

- **Able to send a variety of fast commands with evidence of them being received by the front-end ASICs.**

front-end

### Data production and acquisition

- **Able to** configure the readout chips **in the front-end** to **produce** user-programmable **trigger data** patterns (Figure 5).
- **Able to transmit trigger data through** the **entire sequence of front-end chips** that filter, format and error-protect them.
- **Able to transmit trigger data to** the **TPG back-end**, **where** it is **captured and unpacked - precisely meeting** the **expectations** w.r.t. the FE chip configuration.



## Conclusion and Future Work

**The components** (i.e. PCBs and ASICs) of this system are usually products that **came from completely different parts of the world** and have **only** been **tested** in their home institutes **standalone**. Moreover, the **experience of** assembling one such setup and **getting all these devices to work together was very limited**. Nevertheless, over the past couple of years, **most** of the **interfaces** have been **tested** and the **full chain of Timing, Slow Control, Fast Control and trigger data acquisition was shown to work**. **The future goals** are to **integrate the missing DAQ data concentrator ASIC** (design to be submitted) to the setup (which will allow testing DAQ data acquisition), expand to **service several copies of the front-end** test systems in parallel, have **all control and readout of the TPG and the DAQ back-end in the Serenity** board, **prepare the system for production cassette testing**, etc.

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# Exploring the Potential of Machine Learning for Neutrino Identification in the DUNE Trigger System

Raul Stein[1]
[1]University Of Bristol, United Kingdom

The Deep Underground Neutrino Experiment (DUNE) is a long baseline neutrino experiment with several ambitious physics goals that include measurements of the neutrino mass hierarchy with unprecedented precision, leptonic CP-violation in neutrino oscillations, proton decay, and real time observation of a supernova and possibly the formation of a black hole. For the latter it is imperative to detect, capture, and study the neutrino burst expelled from any core-collapse supernovae that could occur within our or a nearby galaxy as this would be the first signal we get of the event. While neutrinos are abundant, supernovae are (un)fortunately not and the sheer amount of data generated by DUNE present significant challenges for data storage and analysis requiring high precision when triggering and storing events for analysis. By leveraging the rapidly advancing machine learning (ML) technology it may be possible to also improve the DUNE triggering system to overcome these challenges and ultimately expand our understanding of the universe.

The presentation will cover an extensive study on merging neural networks, traditionally used for detecting common objects such as cars, with neutrinos arriving from light-years away and interacting inside a liquid-argon time projection chamber located 1500m deep inside a cave in South Dakota. Forming images and annotations from this that are suitable for modern object detection algorithms is not straightforward and it is also necessary to maintain high accuracy for neutrino identification from background while pushing the ML inference very close to real-time speed in order to keep up with the required data rate of DUNE. We introduce an object detection approach based on You Only Look Once (YOLO) networks that might be able to address all these requirements for forming trigger decisions on low energy neutrinos and present results from training and evaluating a YOLOv3 network.

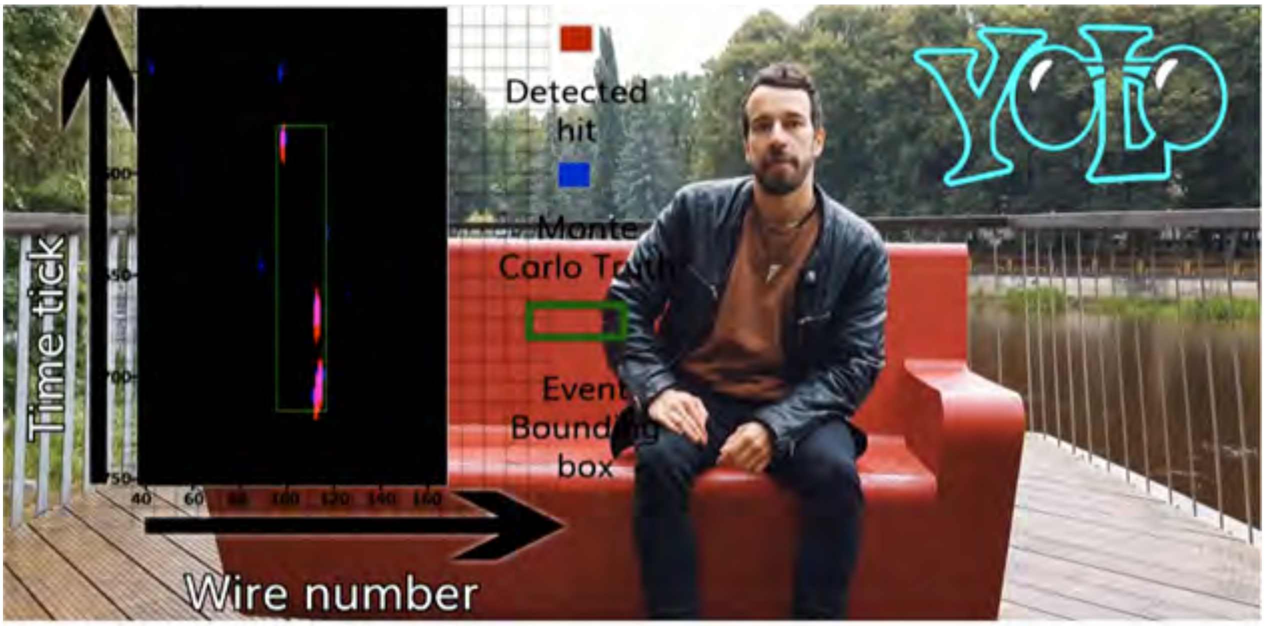


Figure 1: Trying to train a YOLO network to identify neutrino interactions in DUNE. Might need a GPU for this...

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# Novel Quantum Levitated Sensors For Directional Dark Matter Detection

Fiona Alder[1], Chamkaur Ghag[1], Peter Barker[1], Jonathan Gosling[1], Robert James[1]
[1]*University College London, United Kingdom*

With much of the dark matter candidate parameter space still unexplored, novel detection technologies can enable searches for previously inaccessible, yet viable candidates. In particular, due to the movement of our solar system through our galaxy's dark matter halo, methods which exploit directional discrimination will allow for unambiguous confirmation of a galactic signal.

Nano- and micro-particles, cooled to approximately 100 µK and isolated from the environment through optical levitation within ultra high vacuum, enable detection of collisions with extremely light and/or weakly interacting particles. Furthermore, the remarkable acceleration sensitivity achieved by levitated quantum optomechanical systems makes them ideal platforms to search for physics beyond the Standard Model including dark energy, quantum gravity effects, and new forces.

Results will be presented from our levitated optomechanical direct dark matter experiment, which is capable of resolving collisions in all three dimensions. It utilises a nanoparticle test mass (10-18 kg), levitated using the trapping potential of a focused laser, to search for composite dark matter candidates in the 10 MeV/c2 – 10 GeV/c2 mass range. I will describe the current experimental apparatus, data analysis framework and profile likelihood ratio based statistical techniques used in our search, and present sensitivity projections which are competitive with world-leading dark matter constraints. I will also outline planned improvements and alternative experimental setups which will further enhance our search into unexplored dark matter parameter space.

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# Higgs boson pair production searches in ATLAS

Dr Panagiotis Bellos[1]
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One of the primary goals of the LHC physics programme is the measurement of the Higgs boson trilinear self-coupling (λHHH), which is essential for probing the mechanism of electroweak symmetry breaking. This coupling is accessible through pair Higgs boson production. The cross-section for this process is also sensitive to enhancements from new physics, while several beyond the SM theories predict new heavy scalars psrticles decaying to a pair of Higgs bosons. Recent ATLAS results on Higgs boson pair production searches are presented, focusing on the bbtautau final state.

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# Using Machine Learning to improve the sensitivity of Stau Searches with the ATLAS Detector at the Large Hadron Collider

Dominic Jones[1]
*[1]University Of Cambridge, Cambridge, United Kingdom*

Supersymmetry is a proposed extension to the Standard Model of particle physics that predicts the existence of a new ‘super’ particle for each standard model particle that differs in spin by one half. Such super-particles (sparticles) might be able to be produced at the Large Hadron Collider (LHC) at CERN, Switzerland but there is yet to be any evidence for their existence in the data collected by the ATLAS and CMS experiments.

Despite this there are still strong theoretical motivations for the existence of Supersymmetry. Additionally, in certain Beyond the Standard Model theories that invoke Supersymmetry the lightest sparticle is stable and a promising dark-matter candidate. In particular, theoretical models in which the mass of the Stau (the super-particle of the Standard Model Tau particle) is of order 100 GeV can give a dark-matter relic density which is consistent with cosmological observations. Such models are yet to have been fully excluded by previous analyses of LHC data due to their challenging experimental signature.

This talk explores the use of machine learning to better separate events in which Staus could be produced from the Standard Model background and hence develop an improved analysis of ATLAS data with enhanced sensitivity to these models. Sensitivity is especially improved at low and compressed masses as well as obtaining the first sensitivity to the right-handed Stau interpretation.

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# Towards a measurement of charm mixing and CPV using D^0 to K pi pi pi decays at LHCb

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[1]*University Of Oxford, United Kingdom*

Neutral meson mixing and CP-violation are phenomena of the Standard Model that have been well studied for kaons and B mesons, but have only recently been observed in the charm sector. Large charm datasets from pp-collisions collected by LHCb during 2015-2018, corresponding to an integrated luminosity of 5.9 fb^-1, are used to make precision measurements of the mixing and CPV parameters using a variety of charm meson decays. This talk will present work done towards a charm-mixing measurement using D^0 to K pi pi pi decays, and will additionally state how this measurement will contribute in future measurements of the CKM angle gamma.

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# Making measurements reusable: a case study with missing energy at ATLAS

Mr. Yoran Yeh[1]

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The ATLAS experiment at the Large Hadron Collider (LHC) has a broad physics programme, ranging from precise Standard Model (SM) measurements to exotic new physics searches. With a proton bunch crossing rate of up to 40MHz in the interaction point, a huge amount of data is recorded. It is a multi-step process to extract differential cross-sections, particle masses or exclusion limits from the raw signals in the inner trackers, calorimeters and the muon spectrometer.

Historically, when an analysis finishes and the data is published in a paper, the life cycle of the analysis comes to an end. However, when progress in the theory community leads to a higher-order matrix-element calculation, this new prediction can change the interpretation of the analysis. Or when a new theory, beyond the SM, is proposed, it could impact the region of phase-space that was already measured by this particular analysis. In both cases, would it not be desirable to reuse the published, public data without having to redo the entire analysis with only a few minor changes? The general answer from both the experimental and theory community is "yes", but without sufficient information about the analysis this is not possible. Phenomenologists and experimentalists started working together to decide what extra information the experiments should provide with their analysis to accommodate this. Examples are the publication on HEPData of the analysis' full statistical frameworks, machine learning models or efficiency maps.

This discussion played a more central role in the design of LHC analyses in the last decade and will be the focus of this talk: the past, present and future of the reinterpretability of LHC data.

First, I will highlight the development of preservation and reinterpretation tools such as Rivet, Contur and SimpleAnalysis, followed by an overview of the current methods and challenges in a typical analysis. Today's design choices tie in with the following question: what is the legacy we want to leave behind after the LHC has stopped operating?

In line with this philosophy, the missing transverse energy plus jets analysis at ATLAS is a SM measurement that has been designed with reinterpretability in mind. The motivation behind this analysis is explained, preliminary results are presented and the reusability is demonstrated by setting exclusion-limits on a dark matter model with Contur.

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# Bayesian Neutrino Oscillation Analysis for DUNE using the MaCh3 Markov Chain Monte Carlo Fitter

Liban Warsame[1]
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The Deep Underground Neutrino Experiment (DUNE) is a next-generation long-baseline neutrino oscillation experiment, currently in its late-design phase, in which muon neutrinos from Fermilab in the USA will propagate to the Sanford Underground Research Facility. The primary objective of DUNE is to investigate charge-parity (CP) violation in the lepton sector. This is of high interest to the scientific community since if enough CP violation is found, it could help explain the matter dominance in the universe. The calculation of expected neutrino event rates at DUNE requires complex models of the neutrino flux, cross-section and detector behaviour. In reality, these models are degenerate with each other and any analysis must be able to replicate these degeneracies to prevent biased results. MaCh3 is a Bayesian oscillation analysis framework software which uses a Markov Chain Monte Carlo (MCMC) fitter to make estimates of the oscillation parameters from experimental data. MaCh3 keeps all event information in during a fit, allowing detector systematic uncertainties to change the reconstructed variables and hence affect which bins and samples events are in. These techniques will give us a more accurate treatment of systematics and help produce more realistic predictions on DUNE's sensitivity to the oscillation parameters.

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# Investigating the Preservation and Revival of Raw Bubble Chamber Data


<u>Dr Andrew Chisholm</u>

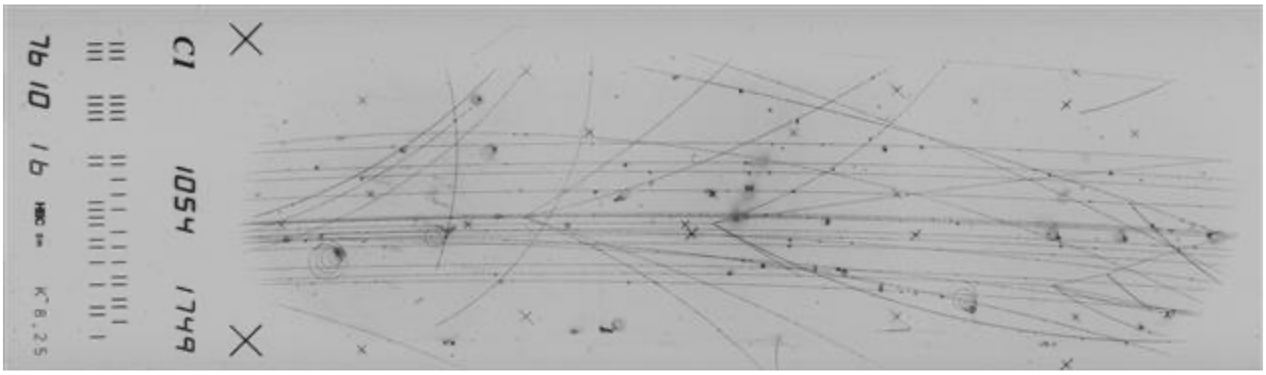
[1]*University Of Birmingham, Birmingham, United Kingdom*



Many of the defining advances in particle physics during the mid twentieth century were made at bubble chamber experiments. The particle physics group of the University of Birmingham have a rich history of involvement in bubble chamber experiments dating back to the 1950s. As part of this legacy, the group hold an extensive collection of photographic film recorded by experiments at the CERN 2m Hydrogen Bubble Chamber (HBC), which operated between 1965 and 1976. These photographic |records of particle interactions in the chamber volume represented the primary raw data format of such experiments, from which particle trajectories and momenta were then reconstructed from careful measurements of the film. Remarkably, nearly 60 years since the chamber was commissioned, the basic technical information required to reconstruct particle interactions from measurements of 2m HBC film has been comprehensively preserved by CERN and is publicly available.

The bulk of the Birmingham collection represents film from the T209 experiment, which involved an exposure of the 2m HBC to an 8.25 GeV K- beam. The collection comprises around 10,000 beam exposures, a dataset large enough to open a wide variety of educational and scientific opportunities, were the data to be digitised and sufficiently understood.

This talk will describe an effort to investigate the feasibility of digitally reviving this dataset towards reopening its scientific exploitation. In particular, an initial study to characterise the performance of consumer-grade film scanning equipment in digitising film samples as the basis for computer-based image analysis will be discussed. Additionally, the experience of developing a basic software framework to reconstruct particle interactions recorded on digitised 2m HBC film images will be described.
The performance of this approach will be summarised in view of potential educational and scientific applications of the dataset.

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# Developing an array of particle detectors to be used for cosmic ray coincidence detection

Mustafa Ozkaynak[1]
*[1]UCL, United Kingdom*

Starting from technology developed for CHIPS project, an array of PMT-based detectors was developed. With past application in water Cherenkov detectors, CHIPS PMT arrays are designed to readily identify coincident gamma events. The timing synchronisation is achieved through the White Rabbit technology developed by CERN and the data acquisition is controlled by a distributed system. The system is modular in nature and is currently placed in various locations across the World intend to investigate coincident events happening around the same time in the locations to detect increased cosmic ray activity. There are currently setups in London, Prague, and Quy Nhon. One of the main advantages of this setup is that it is both relatively cheap and universal; one of these setups can be installed anywhere with an internet connection and GPS signal and be able to start taking data with PMTs connected to it over any ethernet cable, and the high voltage of the PMTs are produced in situ using a Cockroft-Walton base. The data from these setups are streamed through a Kafka data pipeline to the central system located at UCL, where it goes through a quality control checks, and upon passing, all location data are merged and compared to look for coincidental events indicating increased cosmic ray activity. The project is currently developing a web interface that allows researchers from around the world to access and analyse the data in real-time alongside automating the whole data collection and analysis process. Proving the concept and capabilities of this project can be useful to other experiments, as it could be used as cheap supplementary detectors for larger experiments. For instance the NOvA experiment could benefit from installing these at various locations off axis in order to investigate their kaon background better, or to look for long lived particles in collider experiments. Having a mobile detector setup that can be placed in many locations could also provide an easy prototyping opportunity before the deployment of larger experiments.

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# Model-independent high-mass Drell-Yan ditau measurement

Luzhan Yue[1]
*[1]University College London, London, United Kingdom*

The LHC gives ATLAS and CMS access to the energy frontier, where new processes can be measured in previously inaccessible kinematic regions, challenging Standard Model predictions. Physics beyond the Standard Model could also be present and the high-mass region is an obvious place to look for deviations from the Standard Model. Yet we have almost no particle-level measurements in the di-tau channels from ATLAS and CMS experiments, though multiple lighter lepton measurements exist. Therefore, to address this gap in coverage, ATLAS is working on detector-corrected (particle-level) measurements in the di-tau channel using the full Run-2 dataset, designed to be as model-independent as possible so that they can be easily compared to any theoretical predictions to test the limit of the Standard Model and, potentially, help reveal the possible regions for physics beyond it.

The talk will be a work-in-progress update for this precision measurement, illustrating the concept, the approach with intermediate results and further plans.

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# Non-Parametric Data-Driven Background Modelling using Conditional Probabilities

Júlia Silva[1], Konstantinos Nikolopoulos[1]
[1]*University Of Birmingham, Birmingham, United Kingdom*

Background modelling is one of the main challenges of particle physics analyses at hadron colliders. Commonly employed strategies are the use of simulations based on Monte Carlo event generators or the use of parametric methods. However, sufficiently accurate simulations are not always available or may be computationally costly to produce in high statistics, leading to uncertainties that can limit the sensitivity of searches. On the other hand, parametric methods rely on the use of a functional form with free parameters to fit the observed data, which may bias the extraction of a potential signal.

A novel approach for non-parametric data-driven background modelling is presented, which addresses these issues for a broad class of searches and measurements [1]. This approach relies on a relaxed version of the event selection to estimate conditional probability density functions. Two different methods are provided for its implementation. The first is based on ancestral sampling and uses the data from the relaxed selection to obtain a graph of probability density functions of the relevant variables, accounting for the most significant correlations. A background model is generated by sampling events from this graph, before the full event selection is applied. This provides a robust implementation for cut-and-count based analyses. The strategy is further expanded in the second implementation, in which a generative adversarial network is trained to estimate the joint probability density function of the variables used in the analysis, conditioned on the variable used to blind the signal region. This training proceeds in the sidebands, and the conditional probability density function is interpolated into the signal region to estimate the background. The application of each implementation of the method on a case study is presented, and their performance is discussed.

[1] A. Chisholm, T. Neep, K. Nikolopoulos, R. Owen, E. Reynolds, J. Silva, Non-Parametric Data-Driven Background Modelling using Conditional Probabilities, Journal of High Energy Physics, 2022, https://doi.org/10.1007/JHEP10(2022)001

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# Measurement of the branching fraction and CP asymmetry of the decay B->pimumu

Rebecca Murta[1]
[1]*Imperial College London, United Kingdom*

Several measurements of b->sll processes made with the LHCb detector have shown deviations from the Standard Model predictions. The B->πμμ decay involves a b->dll transition, which is suppressed in the Standard Model by a factor |Vtd/Vts| relative to b->sll processes. In b->dll processes, new physics contributions may have an even more pronounced effect on observables such as the branching fraction. Measurements of these processes can also provide insight into the flavour structure of new physics. The branching fraction and CP asymmetry have been measured using the Run I dataset. This analysis will produce updated measurements of the branching fraction and CP asymmetry in bins of q2 using the full Run I and Run II datasets.

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# QUantum Enhanced Superfluid Technologies for Dark Matter and Cosmology

Mr Rob Smith[1]
*[1]Royal Holloway, University Of London, Egham, United Kingdom, [2]QUEST-DMC Collaboration*

QUEST-DMC (QUantum Enhanced Superfluid Technologies for Dark Matter and Cosmology) is an experiment searching for dark matter particle interactions in a superfluid $^3He$ target. QUEST-DMC aims to be sensitive to dark matter particle interactions in the GeV to sub-GeV mass range with recoil energies in the eV to keV range. Extremely low energy threshold is required to probe this parameter space, pushing the need for innovation in detector and readout technologies. QUEST-DMC employs bolometers consisting of vibrating nanowire resonators submerged in $^3He$, coupled with a quantum sensor readout, to achieve resolution at the eV scale. This talk will describe the quantum sensor readout commissioning and energy measurement in the first QUEST-DMC data, background simulations, and sensitivity to dark matter interactions.

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# Measurement of differential cross sections for W boson production and W+/W- production cross-section ratios in association with jets at \sqrt{s} = 13 TeV with the ATLAS detector at the LHC

Eimear Conroy[1]
[1]*University Of Oxford, United Kingdom*

Measurement of the production of W bosons in association with jets (W+jets) is a crucial Standard Model measurement for testing our understanding of QCD. This talk describes the first √s = 13 TeV ATLAS analysis to measure W+jets production cross-sections, for variables sensitive to the QCD aspects of MC modelling, using the ATLAS experiment at the LHC. An overview of the analysis, which is in an advanced stage, will be presented, with particular focus on the W-->μν channel.

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# Lepton universality test in VBF topology with tau(had) tau(lep) final states.

Mr Diego Baron[1], Prof. Terry Wyatt[1]
[1]*University Of Manchester, United Kingdom*

The Standard Model (SM) incorporates the Lepton Universality (LU) hypothesis. LU is an accidental symmetry of the SM in the sense that the SM was not designed to include it. Several experiments have tested LU in different scenarios. At low energies in b hadron decays and at higher $q^2$ processes as Z and W boson decays. LU hypothesis is better established between the lighter two generations of leptons. However, some measurements of LU involving the third family of leptons are in tension with the SM. Although yet, the evidence for LU violation is not conclusive.

Motivated by these results, I will present a measurement that can be interpreted as a high $q^2$ LU test. In my talk, I will describe the status of an analysis targeting the Z production, via the Vector Fusion Mode. With the Z boson sub-sequentially decaying into a pair of charged leptons, including the τ(had)τ(let) final state. Comparisons between different MC predictions for the Z-QCDjj background and the cross-section measurement for the Z-EWjj process will be discussed.

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# MicroBooNE's tests of the MiniBooNE anomalous low-energy excess

Pawel Guzowski[1]

[1]*The University Of Manchester, United Kingdom*

MicroBooNE is an 85 tonne active mass liquid argon time projection chamber that sits in the same mainly-muon-neutrino beamline as the MiniBooNE experiment. One of the main motivations when the experiment was proposed was to investigate the nature of the MiniBooNE excess of electron-neutrino-like interactions at lower energies, which could not be explained by standard three-flavour neutrino oscillation models. MicroBooNE has recently released the first results of this measurement, searching for an excess of either electrons or photons (which MiniBooNE could not distinguish). In this talk I will present these initial results, and also the interpretation of these results in the context of neutrino oscillation models with an additional sterile state which induce both appearance and disappearance of electron neutrinos, comparing to other sterile neutrino oscillation hints from LSND, Neutrino-4 and gallium experiments, and show estimated sensitivities for the full MicroBooNE dataset. I will finish the talk with an overview other BSM explanations of the MiniBooNE anomaly, including new exotic scalar or vector portal models that produce electron-positron pairs in the final state, and how MicroBooNE is well-suited to observe or rule out these explanations.

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## The NEXT tonne-scale programme

Helena Almazan[1]
*[1]University Of Manchester, United Kingdom*

The NEXT collaboration is searching for neutrinoless double beta decays (0nubb) of Xe-136 using high pressure xenon gas time projection chambers (HPXeTPC). The power of electroluminescent HPXeTPCs for 0nubb derives from their excellent energy resolution (FWHM < 1% at Qbb), their topological classification of two electron events, and good scalability. NEXT-HD, with 1 tonne of enriched xenon will represent the first phase of the NEXT tonne program, and is expected to reach a sensitivity better than 1e27 years with less than 5 years of operation. A second phase that would include barium daughter tagging, allowing a near background-free experiment, could unlock sensitivities that extend beyond the inverted neutrino mass ordering. This talk will cover in detail the advances in R&D towards the large scale future phases of the NEXT programe and the development of single ion barium tagging.

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## From NEXT-White to NEXT100: Results and expectations.

Brais Palmeiro Pazos[1]
*[1]University Of Manchester, Manchester, United Kingdom*

The Neutrino Experiment with a Xenon TPC (NEXT) searches for the neutrinoless double beta decay of 136Xe using a high-pressure-gas xenon time projection chamber. This detector technology has several essential advantages, including excellent energy resolution thanks to the EL approach to amplify the signal, robust event classification based on track topology and favourable mass scalability. The most recent stage of the experiment, NEXT-White, took data at the Laboratorio Subterráneo de Canfranc in Spain from late 2016 until mid-2021. NEXT-100 is the detector currently under construction and scheduled to start taking data in the next year and will demonstrate the scalability of the technology. In this talk, we will review both the main results of NEXT-White and the efforts towards the challenges of NEXT-100. On the one hand, NEXT-White, holding 5kg, has been a successful step in the program, showing the validation of the concept in a large-scale dimension detector, assessing the background model, proving the tracking and resolution capabilities, and measuring the two-neutrino double beta decay half-life, using a novel subtraction method. On the other hand, NEXT-100, with 100kg, has a projected sensitivity of 6e25 yr after 3 effective years of data taking. The combined good resolution, topological rejection abilities, and low-radioactive budget yield an expected background index of, at most, 4e-4 count/ keV·kg·yr.

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# Search for QCD Instantons at the LHC

Ynyr Harris[1]
*[1]University Of Oxford, United Kingdom*

QCD instantons are a basic prediction of the Standard Model of particle physics. They are non-perturbative solutions of the equations of motion arising in any Yang-Mills theory and correspond to tunnelling between topologically-distinct vacuum sectors.  Although recent calculations suggest that the production of QCD instantons at the LHC may be experimentally accessible, these objects remain to be seen.  This talk will present the status of a search that is currently underway in the ATLAS Collaboration, which hopes to discover or severely constrain the production cross-section of this curious topological effect.

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# The Super Fine-Grained Detector: Assembly and Gain Calibration

Chien Lin[1]
[1]*Imperial College London, United Kingdom*

The upgrade of the T2K near detector ND280 is predicted to increase the acceptance and the coverage of phase space considerably. As part of the Upgrade, the Super Fine-Grained Detector (SuperFGD) utilises a novel design that consists of roughly two million one centimetre fully-active scintillating plastic cubes. The scintillation lights produced by the products of neutrino interactions inside the detector are collected by the 56K wavelength-shifting fibres along three orthogonal directions, which allows 3D event images to be reconstructed.

The high spatial and energy resolutions of the SuperFGD provide a great opportunity to observe events that previously could not be measured precisely. As a result, systematic uncertainties related to neutrino interaction cross-section and neutrino flux are expected to be significantly reduced, paving the road for the measurement of CP phase.

In the talk, I describe the SuperFGD assembly work in Tokai, Japan, and its electronic calibration.
An on-going study of low momentum proton tracks inside SuperFGD is also given as an example.

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# Search for heavy Majorana neutrino production via vector boson scattering with the ATLAS detector

Benjamin Wilson[1]
*[1]University Of Manchester, Manchester, United Kingdom*

I will present a new search for heavy Majorana neutrinos at the ATLAS detector at the LHC using the full Run-2 ATLAS datasets of 139 fb-1 of proton–proton collisions at a centre of mass energy of 13 TeV. Specifically, this new search studies the scenario where a heavy Majorana neutrino is produced through vector boson scattering, resulting in the production of a pair of same-sign muons plus two jets. This process is the high energy equivalent of neutrinoless double beta decay and is sensitive to similar beyond-the-Standard-Model production mechanisms. The analysis is optimised to search for heavy neutrinos, and in lieu of a discovery, places limits on the muon-heavy neutrino mixing parameter vN2 and the heavy neutrino mass mN in the context of the type-I see-saw mechanism. Additionally, we also complement the search by also considering the Weinberg operator, an effective field theory which adds a contact interaction between the Standard Model neutrinos.

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# Particle Identification and Position Reconstruction with a Machine Learning Technique in the Hyper-Kamiokande Detector

Joanna Gao[1], Dr Teppei Katori[1], Dr Nicholas Prouse[2], Professor Patrick de Perio[3]
*[1]King's College London, United Kingdom, [2]Imperial College London, United Kingdom, [3]Kavli IPMU, University of Tokyo, Japan*

Hyper-Kamiokande (Hyper-K) is a next-generation water-Cherenkov neutrino detector based in Kamioka, Japan. Designed to have approximately eight times the fiducial volume of its predecessor Super-Kamiokande (Super-K), it is hoped to have enormous physics potential. The inner detector (ID) region is planned to house around 20,000 20-inch PMTs and additional multi-PMTs (mPMTs) to provide photo-coverage for signal detections, whereas the outer detector (OD) region is set to have up to 10,000 3-inch PMTs. The PMT arrays are designed to detect the Cherenkov photons radiated from charged particles, which are the products of neutrinos interacting with atoms and sub-atomic structures in the water tank. The ring like signals produced from charged particles with energy below 10 GeV is the subject of this study.

This machine learning (ML) study utilises an innovative convolutional neural network (CNN) model, PointNet [2]. In contrast to the conventional CNN models such as ResNet [3], which requires flattening 3D data into 2D images as inputs, PointNet processes directly from 3D point cloud [2]; therefore, its application to the Hyper-K simulated data ensures that the relative locations of the hit PMTs are preserved, compared to the traditional unfolding methods of the Hyper-K cylindrical tank for 2D CNN. Furthermore, the employment of PointNet for particle identification and reconstruction aims at replacing the traditional likelihood-based method, fiTQun, which could take much longer time to process the data compared to the ML methods.

The preliminary results from this study have shown that the PointNet is performing on par with fiTQun on electron and muon classification, and it performs slightly better on the electron and pi0 front. On the contrary, both PointNet and fiTQun have very underwhelming performance for electron/gamma separation. Currently, more studies are underway to improve the performance of electron and gamma separations and kinematic reconstructions for all particles using PointNet.

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[3] He K, Zhang X, Ren S, Sun J. Deep Residual Learning for Image Recognition. arXiv:1512.03385 [cs]. 2015; http://arxiv.org/abs/1512.03385

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# Neutron Activation Background in the LUX-ZEPLIN Experiment

Tom Rushton[1]
*[1]University Of Sheffield, United Kingdom*

Dark matter is one of the most prominent mysteries in physics, with Weakly Interacting Massive Particles (WIMPs) a particularly strong candidate for its solution. The LUX-ZEPLIN (LZ) experiment is a dual-phase liquid-gas xenon time projection chamber (TPC) seeking to discover these particles or set limits on their properties. The detector has been built at the SURF underground laboratory in South Dakota, USA, and first data set world leading limits on WIMP-nucleon interaction cross sections. To have this sensitivity, the backgrounds in the detector have to be measured and understood.
The background from radioactive isotopes of xenon created through neutron activation from either cosmic rays or calibration sources is of particular concern over the first science run. These rates were tracked through the LZ's first run to provide an understanding of their impact on the detector performance. I will present an analysis of these neutron activation event rates over the first science run of LZ.

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# Large Area Picosecond Photodetector for the Upgrade II of the LHCb RICH

Federica Oliva[1]
*[1]University of Edinburgh, Edinburgh, United Kingdom*

The Large Area Picosecond Photodetector (LAPPD) is a new generation microchannel plate (MCP) based photodetector that is currently an attractive technology thanks to its excellent timing resolution, high gain and low dark rate. It is produced and commercialised by INCOM (US) and consists of a photocathode that responds to a single photon of light by producing a photoelectron that enters a pair of microchannel plates, which is then multiplied to a million electrons in a fast-rising pulse that is easily detected by electronics.

The speed of this process provides the time resolution essential for high intensity environments such as the high luminosity Large Hadron Collider (LHC) at the CERN laboratory. The LAPPD also has a large sensitive area 200x200 mm2, which reduces the number of sensors that are needed.

The increased particle collision rate in the future LHC High Luminosity phase represents a great challenge for the photodetectors of the Ring Imaging Cherenkov (RICH) of the LHCb experiment at the LHC. The LHCb collaboration is already working for the Upgrade II that will take place during the Long Shutdown 4 of the LHC (>2032) and the LAPPD represents one of the main candidates considered for the next generation RICH photodetectors.

The LHCb Edinburgh group is involved in the Upgrade II R&D programme, testing and characterising a Gen II LAPPD in the laboratory of the University.

The LAPPD technology, the current Edinburgh setup and the first performance of the detector will be presented.

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# Calibration using a YBe source in the LUX-ZEPLIN experiment

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This talk covers the design, deployment, and analysis of monoenergetic neutron calibrations for the xenon dark matter experiment LUX-ZEPLIN (LZ) based on the photonuclear process of neutron production from a YBe source. Photoneutron production is typically achieved using a beryllium target, inducing the reaction: γ + Be9 -> n + Be8. YBe is particularly interesting for LZ because the 4.6 keV Xe recoil endpoint is at a similar energy scale as that of coherent B-8 solar neutrino scattering in xenon. This coherent scattering signal is expected to limit sensitivity to GeV-scale WIMPs in LZ, but it is also a rare Standard Model process never previously observed from astrophysical sources. Calibrating the detector and analysing the efficiency at these energies is a critical step in extending LZ's sensitivity to low energy nuclear recoils from WIMPs and coherent neutrino scatters.

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# Not all hopes die immediately: Searching for new particles beyond the standard model if they are long-lived, using displaced vertex signatures in ATLAS

David Rousso[1]
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Until fairly recently, the ATLAS experiment has been relatively blind to the possibility that the particles we are trying to discover beyond the standard model (BSM) do not decay promptly, due to assumptions built into the tracking algorithms. However with the development of large-radius tracking we are now able to explore more signatures of long-lived particles. The recently-submitted ATLAS DV+Jets search is one of such efforts, searching for displaced vertex (DV) signatures caused by when these long-lived BSM particles finally decay into charged standard model tracks in the inner detector. Additionally, a DV+MET search (searching for displaced vertices in the presence of missing transverse energy) is currently underway. This unique signature allows these analyses to be fairly general, as well as sensitive to supersymmetry, Higgs portal, and other exotic model interpretations.

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## Low energy electron recoil searches in LUX-ZEPLIN

Anh Nguyen[1]
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The LUX-ZEPLIN (LZ) instrument is optimised for the direct detection of weakly interacting massive particles (WIMPs), a leading candidate for dark matter. LZ's scale and extremely low background rates mean it also has excellent sensitivity to a wide range of other astrophysical particle signatures, including galactically-bound axion-like particles, U(1)'-type gauge boson hidden photons, and pp-chain solar neutrinos exhibiting an effective neutrino magnetic moment or millicharge. While WIMPs are expected to generate nuclear recoils, these signals will produce low energy electron recoils, and sensitivity is constrained by a variety of non-negligible backgrounds. The signals, expected backgrounds and sensitivities will be discussed.

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## The SoLAr Concept: LArTPCs for solar neutrino physics

Anyssa Navrer-Agasson[1]
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SoLAr is a new concept for a liquid argon neutrino detector technology which aims to extend the sensitivities of these devices to the MeV energy range, thus including solar neutrinos into the physics reach of these future detectors. The SoLAr technology will be based on an integrated light-charge readout plane using pixels and SiPMs, which addresses the main requirements for such a detector: a low energy threshold with excellent energy resolution and background rejection through pulse-shape discrimination. SoLAr will be installed in the Boulby Underground Laboratory to achieve flavour-tagging of solar neutrinos in liquid argon for the first time. The SoLAr concept is also a possible technology choice for the DUNE "Module of Opportunity" which could serve as a next-generation multi-purpose observatory for neutrinos in the MeV to GeV range. SoLAr will pave the way for a precise measurement of the 8B flux, an improved precision on solar neutrino mixing parameters, and ultimately lead to the first observation of hep neutrinos in the DUNE Module of Opportunity.

This talk will present the status and plans for SoLAr.

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# Photon Propagation in the LUX-ZEPLIN Experiment

Anna David[1]
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From an initial 60 live-day dataset, the LUX-ZEPLIN (LZ) dark matter direct detection experiment has produced world-leading limits in the search for Weakly Interacting Massive Particles (WIMPs). This talk will present studies of photon propagation within the detector's liquid xenon target, both in simulations and in the first LZ data. Simulations with full photon tracking play an important role in the validation of results by providing well-understood digitised waveforms required for modelling complex event topologies. This talk will demonstrate how, by constraining optical parameters, these Geant4-based simulations can be tuned to match the position-dependent light collection efficiency observed in the data. Finally, the talk will present a use case showing how waveforms allow for rejection of background signals based on arrival times of prompt scintillation photons.

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# A new hydrogen-filled Cherenkov detector for Kaon tagging at NA62

Dr Angela Romano[1]
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To ensure the necessary precision for the $K+\rightarrow\pi+\nu\nu$ analysis, the NA62 kaon identification detector is required to have a time resolution better than 100 ps, at least 95% kaon tagging efficiency, and a pion mis-identification probability of less than $10^{-4}$.

For the data collected so far, the positive identification of kaons in the NA62 beam has been performed with a Cherenkov detector filled with nitrogen gas as radiator. A new detector using hydrogen gas (CEDAR-H) as the Cherenkov radiator has been built for the kaon identification in NA62. The CEDAR-H leads to a reduction of beam particle scattering in the gas and background from pile-up events in the detector.

The CEDAR-H was commissioned in a two-weeks test beam at CERN at the end of 2022, and approved by the NA62 collaboration to be used in the data taking from 2023. The test beam results and installation on the NA62 beam line are presented in this talk.

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# Measurement of the CKM angle γ in B±→DK*± decays at LHCb

Fidan Suljik[1]
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Within the Standard Model, the amount of CP-violation allowed is not sufficient to account for the matter-antimatter asymmetry of our universe. One of the primary goals in particle physics is to observe New Physics, or to constrain its flavour structure, for which the weak interaction and the quarks interaction is a key place for this purpose. The CKM matrix describes the quark mixing and its unitarity can be represented by a triangle in the complex plane. The internal angle γ=arg(-Vud Vub*/Vcd Vcb*) is the only angle easily accessible at tree level and for which direct measurements are expected to be benchmarks of the Standard Model. These can be compared to indirect measurements where New Physics could contribute through loop processes and which are currently more precise. Therefore, the precision of the direct measurement of γ needs to be improved in order to look for any discrepancy which would be a clear sign of New Physics.

In the era of high precision measurement, the overall strategy is to perform measurements in many decay modes and combine them to improve the sensitivity to γ. I will present the ongoing analysis which consists of the measurement of γ in B±→DK*± decays, using the full LHCb dataset (Run 1 and Run 2). While the most precise measurement from a single experiment was obtained from the recent LHCb combination, it is important to include sub-dominant channels which provide further constraints and understanding due to the different backgrounds and systematic uncertainties present in these decays. This comprehensive study of the B±→DK*± channel uses many D decay modes to measure CP observables and is expected to lead to a valuable addition to the determination of γ.

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# Improving systematic uncertainties in the oscillation analysis with the new NC1$\pi^0$ samples for the T2K experiment


Tailin Zhu[1]

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T2K is a long-baseline neutrino experiment in Japan that has been operated for over 10 years and is currently being upgraded for neutrino beam production and detection techniques. Neutrino oscillation parameters are measured through the event rates of the neutrino spectra at the near and far detectors. The major signal at the far detector comes from charged-current quasi-elastic (CCQE) interactions and produces electron-like or muon-like Cherenkov rings in water. However, the event identification can be affected if the rings are produced by the photons decayed from $\pi^0$ or charged mesons produced at neutrino-nucleus interactions, rather than the primary CC interaction leptons, which will make the reconstruction of CC events difficult.

The 1-ring neutral current (NC) 1$\pi^0$ events can contribute as a background in the oscillated electron neutrino sample. The current selection shows a fraction of the CCQE electron-like events are mis-identified as NC1$\pi^0$ interactions in the oscillation analysis, in which adding the 1-ring NC1$\pi^0$ sample can thus provide a >5% (>10%) increase in the oscillated electron neutrino event rate over all the statistics available for the (anti-)neutrino beam modes. A high purity (76%) and efficiency (72%) 2-ring NC1$\pi^0$ selection is available to help understand pi0 interaction cross sections and kinematics, and better constrain the $\pi^0$ backgrounds in the 1-ring NC1$\pi^0$ event sample. At the current stage, the kinematic properties of both samples are being studied by breaking the kinematic spectra into topological modes to identify interactions that produce 1-ring or 2-ring samples. Together with the T2K upgrade, adding these new samples will aim for improvements in the precision of the oscillation parameter measurements for a future oscillation analysis.

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# BUTTON: a technology testbed for the future of (anti)neutrino detection

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A gadolinium-doped, water-based Cherenkov detector could detect reactor antineutrinos for remote nonproliferation monitoring. Aggregate detection of reactor antineutrinos has been achieved for the first time in pure water in SNO+, and the sensitivity of a water-based detector to real reactor signals has been explored. There is now a need to develop and test cutting-edge technology for antineutrino detection which could be applied to real-world nonproliferation treaty safeguards verification.

Construction of the BUTTON (Boulby Underground Technology Testbed Observing Neutrinos) 30-tonne detector is due to begin this year, with data-taking to commence next year (2024). BUTTON-30 will test advanced photosensors and detection media, including Large-Area Picosecond Photodetectors (LAPPDs) and water-based liquid scintillators (WbLS) with an emphasis on gadolinium doping.

In this talk, I will detail the planned BUTTON-30 detector as the first in a series of testbeds at the Boulby Underground Laboratory. I will discuss the uniquely flexible design of the detector and the significance of the project for nonproliferation, underground science in the UK, and wider physics research.

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# Measuring Solar Neutrino Oscillations in the SNO+ Detector

Daniel Cookman[1]
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The SNO+ experiment is a large multi-purpose neutrino detector, currently filled with liquid scintillator. For the first time in a single experiment, SNO+ has the opportunity to measure the neutrino oscillation parameters, $\theta_{12}$ and $\Delta m^2_{12}$, simultaneously through both terrestrial nuclear reactor anti-neutrinos and Boron-8 solar neutrinos. In this talk, a full methodology for this latter analysis is demonstrated. A Bayesian statistical approach via Markov Chain Monte Carlo is used, which allows for the simultaneous fitting of the oscillation parameters alongside the Boron-8 neutrino flux and all background components with constraints and floating systematics. With this approach, credibilty contours for the oscillation parameters can be produced for a given dataset, as well as credibility intervals for all the other parameters within the fit, which allow us to understand the impact of systematics on the result. This analysis is applied to a small scintillator-phase dataset, demonstrating its capabilities with real data.

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## The Cold Radon Emanation Facility

Emily Perry[1]
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Radon emanation from construction materials has emerged as a dominant background to current and next generation dark matter searches, particularly those deploying noble liquid targets where radon progeny is expected to decay uniformly across fiducial volumes. Sensitivity studies show that radon activities of ~0.1uBq/kg must be achieved in order to probe the remaining parameter space accessible to standard intermediate mass WIMPs. Some fraction of radon may be removed from targets through purification and there is also potential to identify radon events in xenon target analysis, the latter of which will be discussed in this talk. However, the most direct mitigation at present is to screen potential construction materials for radon emanation directly.

Radon emanation assays of materials are typically performed at room temperature, resulting in large uncertainties when translating screening results to expected rates in noble liquid targets due to the cold suppression of radon diffusion within and subsequent emanation out of materials. Accurately predicting radon emanation from materials in experiments therefore requires assays at final operating temperatures.

The Cold Radon Emanation Facility (CREF), which is in its last stages of commissioning at RAL, is designed to perform radon emanation studies of materials with sufficient sensitivity and at temperatures of relevance for the construction phases of next generation rare-event searches. It inherits heavily from existing radon emanation assay systems, such as those deployed for the LZ and SuperNEMO projects, to deliver a world-leading sensitivity below 0.1 uBq/kg to 222Rn emanated from materials at room temperature into dedicated emanation chambers. Additionally, CREF is designed to be operated with the emanation chambers cooled to LAr or LN2 temperatures for low-temperature assays. Finally, CREF incorporates a large 200 L litre chamber, operating within a 500 L cryogenic vessel, that can be cooled and stabilised at temperatures down to ~77 K. This allows measurement of ‘as built’ detector components and to establish their rate of emanation as a function of temperature.

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# High-Statistics Measurement of Nuclear Dependence in Inclusive Antineutrino Scattering in 1D and 2D with MINERvA

Anežka Klustová[1]
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The MINERvA experiment performs precision studies of neutrino-nucleus scattering in the GeV regime on various nuclear targets using the high-intensity NuMI beam at Fermilab. We present MINERvA's first inclusive 1D charged-current analysis of antineutrino interactions on iron and lead using antineutrino energy and Bjorken x. We also report the interactions on carbon and hydrocarbon. Additionally, we outline the current progress on the inclusive charged-current double differential cross-sections in muon transverse and longitudinal momentum in the passive targets and the hydrocarbon tracker region. The data recorded corresponds to $9.74\times10^{20}$ POT produced in the NuMI beamline with a peak antineutrino energy of approximately 6 GeV. Individual steps of the analysis are reviewed with focus on the complex structure of the target region. The importance of the Bjorken x variable to investigate nuclear modifications is discussed. The analysis will provide high-statistics, self-contained studies of nuclear effects and nuclear dependence, and comparisons to the current neutrino interaction generators such as GENIE.

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# First measurement of a joint CC0Pi/CC1Pi cross-section with the T2K near detector ND280

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Long baseline neutrino experiments are entering the precision measurement era. With future upgrades, the next-generation experiments will be able to acquire enough data to reduce their statistical uncertainty below their systematic uncertainties. In water Cherenkov detectors, one of the main sources of uncertainties comes from pion interactions, especially final state interactions from pions produced via neutrino-nucleus interactions. Pions can end up being below Cherenkov threshold due to re-scattering in the nucleus, they could also be absorbed before producing a ring. This can affect the kinematics, multiplicity, and charge of the hadrons in the final state which has a direct impact on neutrino energy reconstruction for the oscillation analysis.

This analysis will focus on a measurement of CC0Pi and CC1Pi events using the T2K near detector, ND280. CC0Pi events are those where the neutrino interacts and produces a lepton and no pions in the final state while CC1pi events are those with a lepton and one charged pion in the final state. The focus of the analysis will be to perform a joint cross-section measurement of these two processes. There is an intrinsic large correlation between these two channels, in a way that usually CC1Pi events are the main background source in a selected CC0Pi sample and vice versa. Performing a joint analysis will allow us to treat both processes as signals and to extract simultaneously the two corresponding cross sections while providing a useful correlation between the two measurements.

This talk will present the selection process of these two samples as well as the selection efficiency and purity. It will then discuss the next steps of the analysis, in particular, a study of detector systematics, the development of the cross-section systematic model and the cross-section extraction.

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# DarkSide50 low mass analysis with non standard operators and Earth shielding effects

Elizabeth Leason[1]
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Searches for low mass dark matter are challenging in liquid noble time projection chambers, due to the small recoil energies that may fall below detector thresholds. The Migdal effect adds electromagnetic energy to dark matter nucleus scattering, improving the possibility for sub-GeV dark matter to be detected. Analysis using the Migdal effect can be extended beyond the momentum and velocity independent interactions using a non-relativistic effective field theory (NREFT). Here, analysis of 12 tonne days of DarkSide-50 ionisation-only data will be presented using the Migdal effect to constrain dark matter masses down to 40 MeV/c2 for NREFT operators, and for the first time including Earth shielding effects. When considering sub-GeV dark matter masses and higher cross sections, it is important to consider interactions of the incoming dark matter with atoms in the Earth's atmosphere, crust or interior. The resulting modification of the dark matter flux and velocity at the detector will be discussed, along with the effect on the NREFT interaction limits in dark matter cross section vs mass parameter space, for both low and high cross sections.

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# Joint Fit Between Atmospheric Neutrinos and Accelerator Neutrinos

Zhenxiong Xie[1]
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T2K is a long baseline neurtino experiment which used the J-PARC neutrino beam and near detectors to constrain the flux and cross section systematic uncertainties. However, the baseline of T2K is 295 km which causes T2K not sensitive to Mass Ordering (MO). Atmospheric neutrinos which travel through the earth are sensitive to the MO, which in combination with accelerator neutrinos will improve the possibility of oscillation sensitivity.

Hyper-Kamiokande (HK) is a next-generation water Cherenkov neutrino experiment, which aims to start taking data in 2027. It will use the J-PARC neutrino beam, which will be upgraded to 1.3 MW. The upgraded near detector ND280 and new Intermediate Water Cherenkov Detector (IWCD) will improve the constraint of the systematic uncertainties. Atmospheric neutrinos in combination with accelerator neutrinos will allow for the possibility of a 5-$\sigma$ sensitivity to CP-violation regardless of the true MO. Moreover, HK also aims to make precision measurements of the neutrino oscillation parameters, which require a precise understanding of the systematic uncertainties in HK.

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# Searching for heavy neutral leptons with the MicroBooNE experiment

Mr David Marsden[1]
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Heavy neutral leptons are hypothesised beyond the Standard Model particles which, if discovered, could solve fundamental problems in particle physics. These right-handed singlet states would be produced in neutrino beams via mass-mixing with the three active neutrinos. MicroBooNE is a liquid argon time projection chamber neutrino experiment, based at Fermilab. The detector technology and the flux from two different neutrino beams allow for dedicated heavy neutral lepton searches to be performed with MicroBooNE, in addition to several other beyond the Standard Model searches. MicroBooNE has published searches for heavy neutral leptons decaying to muon-pion pairs. This talk will outline ongoing work on a new search for heavy neutral leptons decaying via a different channel, to a neutrino and an electron-positron pair.

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# Gas Gains in SF6 on the Order of 10^4 with a Novel Multi-Mesh Thick Gaseous Electron Multiplier for use in a Directional Dark Matter Search

Alasdair McLean[1], Neil Spooner[1], Robert Renz Marcelo Greggorio[1], Anthony Ezeribe[1], Callum Eldridge[1], Andrew Scarf[1]
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Conventional Dark Matter (DM) detectors are approaching the limitations of the neutrino fog, however DM searches with directional sensitivity offer the potential for probing beneath this neutrino background. For this purpose, the CYGNUS collaboration proposes a network of large scale Time Projection Chambers (TPCs) filled with a gas mixture which will likely include the Negative Ion (NI) gas $SF_6$. NI gases like $SF_6$ offer advantages here because they improve the ability to reconstruct Nuclear Recoil (NR) tracks due to their small diffusion coefficient. However, the electronegative nature of the gas makes it challenging to achieve significant charge amplification which ultimately limits the sensitivity to low energy recoil events. In this talk, the design and operating principles of a novel Multi-Mesh Thick Gaseous Electron Multiplier (MMThGEM) gain stage device are presented. By building on previous results with the device, gas gains peaking around $4\times10^4$ were measured. Following this, a further optimisation procedure was conducted and a final maximum gas gain of ~$6\times10^4$ was achieved before sparking occurred. These results are noteworthy because they are an order of magnitude larger than typical gas gains previously attained with other Micro Patterned Gaseous Detectors (MPGDs) in NI gases.

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# Early Run-3 W±/Z cross-section measurements at the ATLAS experiment

Mihaela Marinescu[1], Kostas Nikolopoulos[1]
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Measuring the vector boson production cross-section at the LHC provides important tests of the Standard Model (SM), offering insight into the underlying dynamics of strongly interacting particles by testing theoretical predictions and imposing constraints on SM parameters such as the parton distribution functions (PDF) [1].

With Run-3 underway at the LHC and data being collected at a new centre-of-mass energy of 13.6 TeV, it is important to measure the cross-section of W± and Z-bosons at this new energy as well as provide early validation of detector performance and software for the upgraded ATLAS detector.

The major background for the W± boson measurement is the multijet (MJ) background, which cannot be reliably estimated from simulation as it involves processes which give rise to fake lepton signatures, which are typically not accurately modelled. Data-driven methods are used instead, where control regions defined by inverting the isolation requirement on the lepton and relaxing kinematic requirements are used to estimate the MJ templates. The lepton isolation variable is scanned in order to obtain results from several templates, which are then extrapolated back to the signal region to correct for the isolation-related bias on the MJ yield.

In this talk, preliminary results for the cross-section measurement of W± and Z-bosons will be presented, together with the detailed overview of the MJ background estimation method used in this analysis.

[1] ATLAS Collaboration, Measurement of W± and Z-boson production cross sections in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, Phys. Lett. B, https://doi.org/10.1016/j.physletb.2016.06.023 (2016)

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# DarkSPHERE: Extending light dark matter searches to the neutrino floor with spherical proportional counters in the UK

Patrick Knights[1]
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The particle nature of dark matter (DM), which makes up around 80% of the matter content of the universe, remains elusive. The NEWS-G experiment uses spherical proportional counters in its search for light DM candidates. While current and past NEWS-G detectors have placed world-leading constraints in both spin-independent and spin-dependent DM-nucleon cross sections, the collaboration is planning the next-generation detectors. DarkSPHERE is a proposed 3 m in diameter detector which could be installed in the UK's deep underground science facility. DarkSPHERE will be fully-electroformed, using cutting-edge ultra-pure copper electroforming techniques, directly in the underground laboratory where it will be operated. This, combined with a water-based shielding and the use of light-nuclei gaseous targets, afford DarkSPHERE world-leading sensitivity potential across a wide range of interaction types, including spin-independent and spin-dependent DM-nucleon and DM-electron interactions. The conceptual design of DarkSPHERE and its shielding will be presented, along with background simulations that informed the experimental background calculations, as well as recent instrumentation developments.
A deep-underground electroforming facility is being established in Boulby, which is a prerequisite for DarkSPHERE, and this will be presented. Furthermore, with the current electroforming facility, there is the possibility to make a 30 cm in diameter DarkSPHERE prototype that also has world-leading physics potential, which will be presented.

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## On the development of the Mu2e Stopping Target Monitor software

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The Mu2e experiment seeks to probe BSM physics through improving upon the limit for neutrinoless muon to electron conversion in a nuclear potential by four orders of magnitude. The current experimental limit of R_{\mu e}<7E-13 (90% C.L.) was set by SINDRUM II in 1992. This aim can be achieved due to the repurposed accelerators for the muon campus at Fermilab, combined with the experimental design. In this talk I will give an overview of the experiment with a focus on the Stopping Target Monitor (STM) which is being provided for the experiment by the UK.

The STM provides the normalisation of the ratio by measuring the rate of muon capture on Mu2e's aluminium target determined by counting the number of X-rays emitted using both high-purity germanium (HPGe) and lanthanum bromide (LaBr) detectors. The UK contribution to the STM is providing the HPGe detectors and developing a data acquisition (DAQ) infrastructure. This talk will specifically focus on the physics of the measurements made by the STM detectors and the developments in the DAQ including the infrastructure, data quality monitoring, testbeam results, resolution analysis, and the proposed next stages leading towards the start of data taking.

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## Searching for dark neutrinos using the SBND Cosmic Ray Tagger

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The Short Baseline Neutrino (SBN) programme is being constructed to explain the so-called MiniBooNE low-energy excess, which could be interpreted as oscillations into a yet undiscovered sterile neutrino. The three liquid argon time projection chamber (LArTPC) detectors will search for electron neutrinos appearing in the Booster Neutrino Beam. The Short-Baseline Near Detector (SBND) is a 100-ton scale Liquid Argon Time Projection Chamber neutrino detector positioned in the Booster Neutrino Beam at Fermilab, as one of three LArTPC detectors. Several alternative models have been proposed to explain MiniBooNE's results without involving oscillations. One such model involves dark neutrinos which can be produced via neutrino-nucleus up-scattering, and subsequently decaying into a lepton pair. The SBND will finish construction this year, however it has taken data using the bottom layer of the Cosmic Ray Tagger (CRT) system was installed in the detector hall from 2017 to 2019. This data was used to test the CRT performance, but it might be possible to use this data to perform a search for dark neutrinos decaying in the dirt upstream of the detector hall. This talk will outline ongoing work on the dark neutrino searches decaying via two different channels, to an electron-positron pair or a muon-antimuon pair.

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# Duplicate Track Removal in the CMS L1 Track-Finder

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The upgrade of the Large Hadron Collider (LHC) to the High-Luminosity LHC (HL-LHC) will provide a larger number of simultaneous proton-proton collisions, providing more data for physics analysis, but will challenge the level-1 trigger selections. Tracking information will be provided to the level-1 hardware trigger to counter this. It will reconstruct the tracks of charged particles with pT > 2 GeV, within 4 µs. Due to parallel sector processing and seeding tracks in multiple outer tracker layers simultaneously, duplicate tracks may arise track-finding chain. The poster will detail how this problem is mitigated and how a solution is written in firmware.

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# Neutron spectroscopy with a high-pressure nitrogen-filled spherical proportional counter

Thomas Neep[1], Patrick Knights[1], Ioannis Manthos[1], Kostas Nikolopoulos[1], Robert Ward[1], Ioannis Katsioulas[1]
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Fast-neutron spectroscopic measurements are an invaluable tool for many scientific and industrial applications. In underground dark matter (DM) experiments, neutron induced background produced by cosmic ray muons and radioactivity in rocks can mimic the expected DM signal. However, measuring neutrons is currently very challenging.

The most widely used neutron detectors to date use 3He as a gaseous target. 3He is scarce and extremely expensive, while its low atomic mass requires large target masses (high pressures or large volumes).

A promising alternative for fast-neutron spectroscopy is the use of a Nitrogen filled Spherical Proportional Counter (SPC). The neutron energy is estimated by measuring the products of the 14N(n, a)11B and 14N(n, p)14C reactions, which have comparable cross sections for fast neutrons to the 3He(n,p)3H reaction. Furthermore, the use of a light element such as N2 keeps γ-ray efficiency low and enhances the signal to background ratio in mixed radiation environments. This constitutes a safe, inexpensive, effective, and reliable alternative. A partial proof of principle of this idea [1] suffered from issues such as the wall effect, where the alpha particles and protons hit the wall of the detector before depositing all their energy, electron attachment, and low charge collection efficiency.

We tackle these challenges by incorporating the latest SPC instrumentation developments such as resistive multi-anode sensors [2], which allow for high-gain operation with high-charge collection efficiency. This allows us to operate with larger target masses than have previously been used, leading to a reduced wall effect and increased sensitivity.

We demonstrate spectroscopic measurements of fast and thermalised neutrons from an Am-Be source [3] and from the MC40 cyclotron facility at the University of Birmingham (UoB). The response of the detector to neutrons is simulated using a framework developed at UoB, based on GEANT4 and Garfield++ for high energy physics applications [4]. The simulation provides the expected efficiency, the pulse shape characteristics, and the means to discriminate the events according to their interaction, providing a good agreement with the measurements.

[1] E. Bougamont et al, Nucl. Instrum. Meth. A 847 (2017), 10-14,
[2] I. Giomataris et al, JINST 15 (2020) 11, 11
[3] I. Giomataris et al, Nucl. Instrum. Meth. A 1049 (2023), 168124
[4] I. Katsioulas et al, JINST 15 (2020) 06, C06013

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# Searches for exclusive Higgs and Z boson decays to a meson and a photon at ATLAS

Robert Ward[1]
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In the Standard Model (SM), the mass generation of fermions is implemented through Yukawa couplings to the Higgs boson. Experimental evidence exists for the Higgs boson couplings to second- and third-generation leptons through its decay to muon and tau pairs. For quarks, direct evidence exists only for the third-generation couplings, and searches for inclusive decays of the Higgs boson to pairs of lighter-generation quarks are challenging due to large QCD backgrounds at the LHC. With their distinct experimental signatures, radiative decays of the Higgs boson to a meson and a photon, complemented by searches for analogous decays of the Z boson, offer an alternative probe of quark Yukawa couplings. Moreover, these decays provide an opportunity to investigate physics beyond-the-SM, as many such theories predict branching fractions significantly modified from the SM expectations, or the existence of potential quark-flavour-violating couplings of the Higgs and Z bosons. This talk will summarise the searches by the ATLAS experiment for Higgs and Z boson decays to a vector quarkonium state and a photon, lighter vector meson states such as an omega meson and a photon, and the flavour-violating decay of a Higgs boson to a K* meson and a photon. These searches use the $\sqrt{s}$ = 13 TeV dataset with dedicated triggers that were in operation throughout Run 2 of the LHC, as well as novel non-parametric data-driven techniques to model the backgrounds.

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# Search for the resonant production of two Higgs bosons in a final state with two photons and two tau leptons

Matthew Knight[1]
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In this talk, we present a search for new resonances in the final state of two photons and two tau leptons. Events are selected from proton-proton collision data collected by the CMS experiment at √s = 13 TeV from 2016 to 2018, corresponding to an integrated luminosity of 138 fb^-1. We explore the production of a new scalar boson, X, with a mass range of 260-1000 GeV, which decays to two Standard Model Higgs bosons, HH, or a single H and another new scalar boson, Y, with a mass range of 50-800 GeV. The scenarios where Y decays to two photons and where Y decays to two tau leptons are both considered. The results are expected to exclude currently-allowed regions of phase in the Next-to-Minimal Supersymmetric Standard Model and will shed light on recent excesses seen in similar final states.

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# Development of a Phase Shear Detection System for the MAGIS-100 and AION Experiments

Dr Gedminas Elertas[1]
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Gedminas Elertas, on behalf of the MAGIS and AION collaborations, University of Liverpool, UK. MAGIS-100 is a next-generation quantum sensor under construction at Fermilab that aims to explore fundamental physics with atom interferometry over a 100-meter baseline. AION is a UK initiative to develop the technology further. AION project has established five strontium atom interferometry laboratories nationwide, and a 10 m prototype at the University of Oxford is planned. Both projects will search for the ultralight dark matter fields and lead the technology for a future kilometre-scale detector that would be sensitive to gravitational waves from known sources [1-3].

Several technological challenges must be overcome to reach the sensitivity required to probe the ultralight dark matter range from $10^{-22}$ eV – $10^{-15}$ eV [1,4]. To achieve this, MAGIS 100 and AION will have to demonstrate the shot-noise limited detection, the ability to launch atoms for tens of meters, maintain the record-breaking spatial separation of the wave packets, and account for multiple systematic uncertainties.

As part of UK input to MAGIS-100 and a future AION experiment, the University of Liverpool is developing a phase-shear detection platform.

The phase-shear detection method is a novel technique which imprints the interference fringes across the atom cloud allowing single-shot measurements of the phase and contrast [5]. This increases the repetition rate, significantly improving the experiment's sensitivity to dark matter, and allows for better control of the systematics, such as Coriolis force. Atoms are free-falling under gravity for up to 100 m vertically. The Earth's rotation causes the stationary main interferometry beam to be no longer perpendicular to the motion of atoms. The platform precisely controls the angle of the interferometry beam following Earth rotation and compensating for the Coriolis effect.

The phase-shear platform design, specifications, current status and integration into the experiment's detection system are presented. The platform is an ultra-high vacuum chamber housing the primary ultra-flat mirror of the interferometer beam. The mirror is controlled with amplified piezoelectric actuators to achieve the phase-shear and Coriolis corrections. The experiment's sensitivity is directly related to the precision control of this mirror, which will initially be achieved by an electronic feedback system employing strain gauge sensors attached to the actuators. Ultimately, the optical feedback loop can enhance the precision further using a laser reflected from the back of the mirror and a position-sensing detector.

[1] Matter-wave Atomic Gradiometer Interferometric Sensor (MAGIS-100). M. Abe, et al., Quantum Sci. Technol. 6 044003 (2021)
[2] AION: An Atom Interferometer Observatory and Network. L. Badurina et al., JCAP 05 011 (2020)
[3] AEDGE: Atomic Experiment for Dark Matter and Gravity Exploration in Space. Y. A. El-Neaj, et al., EPJ Quantum Technology (2019)
[4] Search for light scalar dark matter with atomic gravitational wave detectors. A. Arvanitaki, et al., Phys. Rev. D 97, 075020 (2018)
[5] Enhanced Atom Interferometer Readout through the Application of Phase Shear. A. Sugarbaker, et al., Phys. Rev. Lett. 111, 113002 (2013)

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# Terrestrial Limits on Ultra-light Dark Matter Detection With Atom Interferometers; MAGIS-100 and AION

Dr. Jeremiah Mitchell[1]
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Long-baseline atom interferometers have potential to probe an unexplored parameter space of ultra-light dark matter (ULDM). With the future landscape of very-long-baseline atom interferometers increasing, we present studies on statistically quantifying ULDM signal detection in the presence of atom shot-noise and a seismically generated gravity gradient noise (GGN) background, which will be a fundamental terrestrial limit [1]. Adopted from particle physics experiments searching for axion-like particles we formulate a statistical framework for signal detection in a multi-gradiometry atom interferometer. Such a detector utilizes multiple atom interferometers run simultaneously with a common laser beam along a vertical or horizontal baseline. MAGIS-100 and AION will utilize a minimum of three atom interferometers for their 100 m vertical designs. With this formalism in hand we then investigate the impact of correlating many measurements down a baseline while folding in the fundamental limit of incoherent atom shot-noise and the terrestrial low-frequency limit of seismic density perturbations i.e. GGN. We find that for the longest baseline configurations planned (~ 1 km) some of the loss in the detector sensitivity attributed to GGN can be reclaimed via the use of multi-gradiometry.

[1] L. Badurina, V. Gibson, C. McCabe, and J. Mitchell, “Ultralight dark matter searches at the sub-Hz frontier with atom multi-gradiometry.” arXiv, Nov. 03, 2022. doi: 10.48550/arXiv.2211.01854.

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## LEGEND-200 first operational results

George Marshall[1]
[1]*University College London, United Kingdom*

The discovery of neutrinoless double beta decay would definitively prove both that lepton number is not a fundamental symmetry in nature and that neutrinos are their own antiparticles. LEGEND is a ton scale program using the isotope 76Ge to search for this decay. The first phase of which, LEGEND-200, utilising up to 200kg of Germanium detectors and based at the Gran Sasso underground laboratory in Italy, has now started its first period of data taking. In this talk the initial results will be presented with the focus on the performance of the Germanium detectors.

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# Individual anode readout for position reconstruction and tracking with the Spherical Proportional Counter

Dr. Ioannis Manthos[1], Mr. Dominic Herd[1], Dr. Patrick Knights[1], Ms. Jack Matthews[1], Mr. Lex Millins[1], Dr. Tom Neep[1], Prof. Konstantinos Nikolopoulos[1], Dr. Rob Ward[1]
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The Spherical Proportional Counter (SPC) [1] is a novel gaseous detector with several applications, spanning from probing uncharted light Dark Matter phase space regions to neutron spectroscopy. The use of the multi-anode ACHINOS sensor enables the operation of large-size high-pressure SPCs, opening new frontiers to the detector potential.

Nevertheless, the readout of the ACHINOS sensor was restricted to two channels, partitioning the detector into 2 hemispheres. This channel summing scheme did not benefit from the full power of the multi-anode sensor [2,3].

In this contribution, we present results from the individual readout of an 11-anode ACHINOS sensor. We report on the signal readout configuration and calibration, as well as energy resolution results from runs using α-particles from a $^{210}$Po source. Also, first results in detector fiducialisation and track reconstruction are presented. Furthermore, an investigation of the construction tolerances for future ACHINOS sensors is presented. Results of this work will have a direct positive impact the detector's applications in searches for light dark matter and neutron spectroscopy.

[1] I. Giomataris et al. "A Novel large-volume Spherical Detector with Proportional Amplification read-out" JINST 3 (2008) P09007, 10.1088/1748-0221/3/09/P09007
[2] I. Giomataris et al. "Neutron spectroscopy with a high-pressure nitrogen-filled spherical proportional counter" (2023) Nucl. Instrum. Methods A 1049 168124, 10.1016/j.nima.2023.168124
[3] I. Giomataris et al. "A resistive ACHINOS multi-anode structure with DLC coating for spherical proportional counters" (2020) JINST 15 P11023, 10.1088/1748-0221/15/11/P11023

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# MightyPix: An HV-CMOS Pixel Chip for LHCb's Mighty Tracker

Sigrid Scherl[1,2], Nicolas Striebig[2], Ivan Peric[2], Richard Leys[2]
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In the coming years the Large Hadron Collider (LHC) at CERN will be upgraded to work at higher luminosities, leading to the High-Luminosity LHC. The HL-LHC will reach luminosities up to 5 × 10^34 cm^-2 s^-1 collecting at least 3000 fb^-1 of data in its lifetime. To handle the increased luminosity and data rate, the experiments at the LHC will be upgraded as well. One of the proposed changes is the installation of the Mighty Tracker, a new hybrid tracking system for the LHCb detector. It would consist of scintillating fibres in the outer regions and silicon sensors in the inner regions, where the hit density is the highest. The proposed baseline technology for the silicon sensors are High-Voltage CMOS detectors, which meet the requirements for radiation hardness and granularity. These pixel chips combine the sensing element and readout logic in a single device, and other HV-CMOS chips for the ATLAS and Mu3e experiments have already proven successful.

The HV-CMOS pixel chip currently being developed for the Mighty Tracker is called MightyPix [3]. The first prototype, MightyPix1, has been submitted for fabrication in June 2022 and received back in December 2022. It has a full column height of 2 cm and is 0.5 cm wide, one fourth of the final width. It can already handle the Timing and Fast Control signals coming from LHCb and has an I2C interface, needed for the lpGBT readout chips used by LHCb. The chip's efficiency within the LHCb environment has been simulated extensively to ensure its optimal performance within the Mighty Tracker. These studies provide input for decisions on Mighty Tracker electronics and investigate different possibilities of improvement for the next iteration, MightyPix2. MightyPix2 will be the first full-sized prototype with a reticle size of 2 cm x 2 cm and will follow this year. Eventually, over 46000 MightyPix sensors would be installed in the Mighty Tracker to cover an area of 18 m^2.

This contribution will give an overview of MightyPix1, explaining the requirements and the working principle of the chip. Additional focus will lie on the results of the efficiency studies, which show that MightyPix is able to handle the expected occupancy at the Mighty Tracker.

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# Electronic feedback system for the MAGIS-100 and AION retro reflection chamber

Henry Throssell[1]
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The Matter-wave Atomic Gradiometer Interferometric Sensor (MAGIS-100) is a 100 m vertical baseline detector under construction at Fermilab. It works closely with the Atom Interferometry Observatory Network (AION), a UK based program also investigating vertical baseline atom interferometers, with an initial goal of constructing a 10 m detector. Both programs will investigate the feasibility of constructing future kilometre baseline detectors for the detection of mid-band (0.01 – 3 Hz) gravitational waves, have sensitivity to ultra-light dark matter candidates (10-22 – 10-15 eV), and conduct tests of quantum mechanics on a uniquely macroscopic scale.

The University of Liverpool will deliver the retro reflection chamber for both experiments; a UHV chamber housing a tip-tilt mirror. The mirror reflects the laser beams required for interferometry, and must be rotated to corrects for the Coriolis force. Further rotation allows for phase shear readout, a technique for single shot detection of an interferometry sequence. The mirror is rotated by amplified piezoelectric actuators, whose motion is precisely measured by strain gauges. The strain gauge signal is amplified and sent to the piezo controller, this completes the servo loop, allowing for the precise movement of the mirror. The testing of this system is presented, as well as the future plans to implement on MAGIS.

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# Photon-induced WW production as a test of the electroweak boson self-interactions

Joshua Puddefoot[1]
[1]*University Of Sheffield, United Kingdom*

The pair production of W-bosons from interacting photons (yy->WW) in proton-proton collisions is predicted by the Standard Model (SM) to solely involve trilinear and quartic gauge-boson interactions. At leading order, only the electroweak gauge-bosons are involved in the process. As such, study of this process is a direct test of the electroweak sector of the SM. This process is also particularly sensitive to anomalous gauge-boson interactions, which can be described in effective field theory (EFT) using additional dimension-6 and dimension-8 operators.

The ongoing analysis aims to improve on the previous observation of this process in several ways. The reconstruction of tracks with pT<500 MeV allows for improved background rejection.

Additionally, differential distributions of the cross-section will be extracted. An EFT interpretation of the results, which can be used in global EFT fits, will be provided. This talk will briefly outline the strategy and summarize the current progress of the analysis.

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# Calibration and Noise Suppression of ATLAS Run3 Electron Trigger

Chonghao Wu[1]
*[1]University Of Birmingham, Birmingham, United Kingdom*

The trigger system of the ATLAS experiment is designed to select processes of interest for physics analysis with high efficiency and reduce high-rate processes that are not relevant.

During Phase-I Upgrade of the trigger system, new feature identification systems eFEX (electron Feature Extractor), jet Feature Extractor (jFEX) and global Feature Extractor (gFEX) were installed, supplied by new finer granularity LAr digital signals, so called Supercells (SC).

The noise analysis of eFEX is an important step in understanding the efficiency of trigger system in Run 3. To understand the input of eFEX and its noise, energies of SCs in Run3 data were studied.
This talk will discuss the performance of upgraded ATLAS trigger system in Run 3, focusing on the eFEX.
The noise levels of supercells in different regions and the comparison with legacy system (trigger towers) will be presented.

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## Use of Gd-WCDs for Extreme Space Weather Monitoring

Patrick Stowell[1]
[1]*Durham University, United Kingdom*

Due to the unpredictable nature of space weather, continuous observation of variations in the Galactic Cosmic Ray (GCR) rate is necessary to both monitor equivalent radiation dose at ground level and at high altitudes, and to understand background measurement uncertainties in applied cosmic ray studies. One class of solar events, emission of Solar Energetic Particles (SEP), can be so intense that they lead to significant increases in cosmic ray radiation at ground level, termed Ground Level Enhancements (GLE). These intense bursts of particles can directly affect critical infrastructure, causing so-called single event upsets in electronic systems, and significantly increasing radiation dose rate in manned aviation. Currently a network of neutron monitoring stations based on the traditional NM64/IGY neutron detector designs monitor variations in the incoming cosmic ray spectrum and provide a warning system for GLEs.

In this talk I'll discuss how technology from the high energy neutrino experiment community (gadolinium-doped water Cherenkov tanks) could be used to construct a next generation of space weather monitoring stations at a lower cost than the traditional NM64/IGY designs. Using simulation results of possible water Cherenkov tank configurations I'll discuss the key parameters that affect the sensitivity of these systems to cosmic-ray induced high energy spallation events, and their potential to directly probe the incoming cosmic ray energy distribution using neutron counting techniques.

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# A search for semi-visible jets in non-resonant production mode in ATLAS

Dr Sukanya Sinha[1]
[1]*University Of Manchester, Manchester, United Kingdom*

Collider searches for dark matter (DM) so far have mostly focussed on scenarios, where DM particles are produced in association with heavy standard model (SM) particles or jets. However, no deviations from SM predictions have been observed so far. Several recent phenomenology papers have proposed models that explore the possibility of accessing the strongly coupled dark sector, giving rise to unusual and unexplored collider topologies. One such signature is termed as semi-visible jet (svj), where parton evolution includes dark sector emissions, resulting in jets interspersed with DM particles. Owing to the unusual MET-along-the-jet event topology this is still a largely unexplored domain within LHC.
This talk presents the first results from a search for svj in t-channel production mode in pp collisions for an integrated luminosity of 139 fb^{-1} at centre-of-mass energy corresponding to 13 TeV at the LHC, based on data collected by the ATLAS detector during 2015-2018.

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# Development of the MAGIS-100 primary science imager

Daniel Wood[1], Daniel Weatherill[1], Ian Shipsey[1]
[1]*University of Oxford, Oxford, United Kingdom*

The Matter-wave Atomic Gradiometer Interferometric Sensor (MAGIS) program is leading the development of long-baseline atom interferometry with the goal of exploration of fundamental physics. MAGIS-100 is a novel 100-metre baseline interferometer under construction at Fermilab which will utilise techniques developed in state-of-the-art 10-metre baseline interferometers and technological advances in the world's leading atomic clocks, in order to search for ultralight dark matter candidates, probe quantum mechanics in new regimes, and serve as development for a future, kilometre-baseline interferometer which will be sensitive to gravitational waves from known sources in the previously unexplored 0.1Hz to 3Hz range.

Such a complex and powerful instrument as MAGIS-100 requires a leading imaging system, to precisely capture the interference patterns that compose the science signal. In order to capture these interference patterns, the atom cloud will be fluoresced with light at 461nm, presenting a novel and challenging imaging problem. Here we present the development of the primary science imaging system for MAGIS-100, which will constitute six CMOS camera and optical assemblies. The imaging environment is described in detail, and simulations of the photon distributions are presented which include realistic intensity, diffraction and depth-of-field effects. Results of camera characterisation tests are described including linearity, quantum efficiency, and sensor MTF measured both through a conventional 'knife-edge' method and the use of laser speckle. Optical assembly simulations using Zemax are shown, and a method of optical testing is outlined which uses lateral-shear interferometry to measure the lens pupil function. All of this simulation and experimental work is combined to lead the selection of the proposed baseline MAGIS-100 science imaging system.

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# Tau leptons-enriched semi-visible jets at the LHC

Dr Tobias Fitschen[1]
*[1]University Of Manchester, United Kingdom*

https://arxiv.org/abs/2212.11523

This Letter proposes a new signature for confining dark sectors at the Large Hadron Collider. Under the assumption of a QCD-like hidden sector, hadronic jets containing stable dark bound states could manifest in proton-proton collisions. We present a simplified model with a Z′ boson yielding the production of jets made up of dark bound states and subsequently leading to the decays of those that are unstable to τ leptons and Standard Model quarks. The resulting signature is characterised by non-isolated τ lepton pairs inside semi-visible jets. We estimate the constraints on our model from existing CMS and ATLAS analyses. We propose a set of variables that leverage the leptonic content of the jet and exploit them in a supervised jet tagger to enhance the signal-to-background separation. Furthermore, we discuss the performance and limitations of current triggers for accessing sub-TeV Z′ masses, as well as possible strategies that can be adopted by experiments to access such low mass regions. We estimate that with the currently available triggers, a high mass search can claim a 5σ discovery (exclusion) of the Z′ boson with a mass up to 4.5TeV (5.5TeV) with the full Run2 data of the LHC when the fraction of unstable dark hadrons decaying to τ lepton pairs is around 50%, and with a coupling of the Z′ to right-handed up-type quarks of 0.25. Furthermore, we show that, with new trigger strategies for Run3, it may be possible to access Z′ masses down to 700 GeV, for which the event topology is still composed of two resolved semi-visible jets.

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# Quantum Technologies for Neutrino Mass

Dr Seb Jones[1]
*[1]University College London, London, United Kingdom*

The observation of neutrino oscillations provides proof of non-zero neutrino masses. However, these same neutrino oscillation experiments do not provide information on the absolute scale of the neutrino masses, which remain unknown. The neutrino masses are most directly accessed through those experiments which measure the shape of the beta-decay energy spectrum. In particular, a technique known as Cyclotron Radiation Emission Spectroscopy (CRES) offers the opportunity to measure neutrino masses lower than the final projected sensitivity of the KATRIN experiment (0.2 $eV/c^2$). The Quantum Technologies for Neutrino Mass (QTNM) collaboration aims to utilise CRES, along with recent breakthroughs in quantum technologies, to build a demonstrator apparatus for measuring the neutrino mass.

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# Improving Variational Autoencoders for New Physics Detection at the LHC With Normalizing Flows

Pratik Jawahar[1], Thea Aarrestad[1], Nadezda Chernyavskaya[1], Maurizio Pierini[1], Kinga A. Wozniak[2], Jennifer Ngadiuba[3], Javier Duarte[4], Steven Tsan[4]
*[1]CERN, Geneva, Switzerland, [2]University of Vienna, Vienna, Austria, [3]Fermi National Accelerator Laboratory (FNAL), Batavia, USA, [4]University of California, San Diego, San Diego, USA*

We investigate how to improve new physics detection strategies exploiting variational autoencoders and normalizing flows for anomaly detection at the Large Hadron Collider. As a working example, we consider the DarkMachines challenge dataset. We show how different design choices (e.g., event representations, anomaly score definitions, network architectures) affect the result on specific benchmark new physics models. Once a baseline is established, we discuss how to improve the anomaly detection accuracy by exploiting normalizing flow layers in the latent space of the variational autoencoder.

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# The Future of Supernova Neutrinos

Jost Migenda[1]
*[1]King's College London, London, United Kingdom*

This talk will present two new developments in the field of supernova neutrinos. First, I will introduce the next-generation Supernova Early Warning System, SNEWS 2.0, and explain how it brings the field of supernova neutrinos into the multi-messenger era. Next, I will present SNEWPY, a new software package for supernova neutrino studies, and show how it can be used all the way from simple event rate estimates to the most advanced analyses requiring experiment-specific tools.

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# CKM angle gamma measurement at LHCb using partially reconstructed B → D*h with D* → Dpi0 and D* → Dgamma

Seophine Stanislaus

The measurement of CKM angle gamma is an important test of the Standard Model. It is also one of the key goals of the LHCb experiment. In this talk I will present an overview of LHCb and how measurements of gamma are extracted. In addition, work towards a measurement of gamma using partially reconstructed B → D*h with D* → Dpi0 and D* → Dgamma decays followed by D → Ks pipi and and D → KsKK, will be presented. This is the first measurement of its kind for this combination of decays at LHCb.

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## QSHS collaboration

Paul Smith

Device physicists have made significant progress towards developing new classes of detectors and coherent quantum amplifiers that can detect individual quanta or other more exotic electrodynamic states. Such sensors in the right instrument may be able to reveal new unexplored structures close to the ground state, the vacuum, of physics. In 2021 the Quantum Sensors for the Hidden Sector (QSHS) collaboration was founded in the UK and received funding to develop and test a range of quantum devices in a facility utilising a haloscope configuration with the potential to demonstrate the detection of hidden sector particles in the microeV to 100microeV mass window. A dilution fridge is due to be installed at Sheffield imminently. Here, we will introduce the QSHS collaboration's aims and describe its progress.

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# Probing jet quenching through hadron+jet measurements with the ALICE experiment

Jaime Norman

The quenching (energy loss) of jets in heavy-ion collisions is one of the clearest signatures of the formation of a deconfined state of quarks and gluons, known as the Quark Gluon Plasma (QGP). The measurement of jets recoiling from a trigger hadron provides unique probes of medium-induced modification of jet production. Jet deflection via multiple soft scatterings with the medium constituents may broaden the correlation between the trigger hadron and the recoiling jet. In addition, the tail of this correlation may be sensitive to single-hard `Rutherford-like' scatterings off quasi-particles in the medium.

In this talk we present measurements of the distribution of charged jets recoiling from a trigger hadron in pp and Pb-Pb collisions by ALICE - the LHC experiment dedicated to studying heavy-ion collisions. We employ precise, data-driven subtraction of the large uncorrelated background contaminating the measurement in Pb-Pb collisions, enabling the exploration of medium-induced modification of jet production and acoplanarity over a wide phase space. It is observed that the jet yield at low transverse momentum and at large angles between the trigger hadron and jet is significantly enhanced in Pb--Pb collisions with respect to pp collisions. Comparison to theoretical calculations incorporating jet quenching will also be discussed.

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## Status of the FASER Experiment at the LHC and first run-3 results

Carl Gwilliam[1], Monica D'Onofrio[1], Josh McFayden[2], Michaela Queitsch-Maitland[3]
*[1]University Of Liverpool, United Kingdom, [2]University of Sussex, United Kingdom, [3]University of Manchester, United Kingdom*

FASER, the ForwArd Search ExpeRiment, is a new LHC experiment located 480 m downstream of the ATLAS interaction point, along the beam collision axis. FASER and, its sub-detector FASERnu have, two physics goals: (1) search for new light and very weakly-interacting particles and (2) to detect and study TeV-energy neutrinos, the most energetic neutrinos ever detected from a human-made source. FASER was designed, constructed, installed, and commissioned during 2019-2022 and has been taking physics data since the start of LHC Run 3 in July 2022. This talk will present the status of the experiment, including detector design and performance, along with first results from Run 3 data.

# Poster Presentations

**17** ARIADNE+: Large Scale Demonstration of Fast Optical Readout for Dual Phase LArTPCs at the CERN Neutrino Platform

Mr Adam Lowe[1], Mr Pablo Amedo[2], Dr Diego Gonzalez-Diaz[2], Dr Alexander Deisting[4], Dr Krishanu Majumdar[1], Dr Konstantinos Mavrokoridis[1], Dr Marzio Nessi[3], Dr Barney Philippou[1], Dr Francesco Pietropaolo[3], Mr Sudikshan Ravinthiran[1], Dr Filippo Resnati[3], Dr Adam Roberts[1], Dr Angela Saa Hermandez[2], Prof Christos Touramanis[1], Dr Jared Vann[1]
*[1]University Of Liverpool, Liverpool, United Kingdom, [2]Instituto Galego de Fisica de Altas Enerxias (IGFAE), Universidade de Santiago de Compostela , Spain, [3]European Organization for Particle Physics (CERN), Switzerland, [4]Royal Holloway University of London, United Kingdom*

**20** Characterisation and Calibration of Photosensors for Water Cherenkov Neutrino Detectors

Stephen Wilson[1]
*[1]University Of Sheffield, United Kingdom*

**4** Development of the data acquisition system for the Mu2e STM detector

Claudia Alvarez Garcia[1]
*[1]University of Manchester, Manchester, United Kingdom*

**97** Studying penguins in the jungle

Anja Beck[1]
*[1]University Of Warwick, United Kingdom*

**49** Development of Water based Liquid Scintillator (WbLS) for Future Neutrino Experiments

Adam Tarrant[1]
*[1]University Of Liverpool, Liverpool, United Kingdom*

**36** Using the 4-momentum subtraction algorithm to

model medium response in JEWEL

Daniel Jones[1]
*[1]University Of Liverpool, Liverpool, United Kingdom*

**37** Development of an Ion-Acoustic Dose-Deposition Mapping System for LhARA

Maria Maxouti[1,2,3], Lau HT[1], McGarrigle J[1,4], Anthea MacIntosh-LaRocque[1], Emma Harris[5], Ben Smart[2], Colin Whyte[6], John Matheson[2], Jeff Bamber[5], Ben Cox[7], Long K[1,2,3]
*[1]Department of Physics, Imperial College London, London, United Kingdom, [2]John Adams Institute for Accelerator Science, Imperial College London, London, United Kingdom, [3]Particle Physics Department, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot, United Kingdom, [4]Institut Curie-Orsay Research Center, Bat a Campus d'Orsay, 91400 Orsay,, France, [5]The Joint Department of Physics, Institute of Cancer Research and Royal Marsden NHS Foundation Trust, London, United Kingdom, [6]Department of Physics, University of Strathclyde, Glasgow, United Kingdom, [7]Dept of Medical Physics and Biomedical Engineering, University College London, London, United Kingdom*

**22** Cosmogenic Neutron Multiplicty in SNO+

Katharine Dixon[1]
*[1]King's College London, London, United Kingdom*

**32** Translating Near to Far Detector for DUNE-PRISM Analysis

Alex Wilkinson[1]
*[1]University College London, United Kingdom*

**78** An overview of the LZ Outer Detector: Calibration, Monitoring and Performance, and its Contribution to the First Science Run

Sam Woodford[1]
*[1]University of Liverpool, Liverpool, United Kingdom*

**80** Neutrino Oscillation Global Fit with GAMBIT

Chien Lin[1]
*[1]Imperial College London, United Kingdom*

**56** Searching for Dark Matter in the Sun using DUNE

Francisco Martinez Lopez[1,2,3]
*[1]Queen Mary University Of London, London, United Kingdom, [2]Rutherford Appleton Laboratory, Didcot, United Kingdom, [3]University of Southampton, Southampton, United Kingdom*

**62** Solar axion searches in LUX-ZEPLIN

Anh Nguyen[1], Harkirat Riyat[1]
*[1]Universtiy Of Edinburgh, Edinburgh, United Kingdom*

**52** Q-Pix concept: Kiloton-scale pixelated liquid noble TPCs

Shion Kubota[1]
*[1]Harvard University, Cambridge, United States*

**55** The Water Cherenkov Test Experiment and its calibration

Alie Craplet[1]
*[1]Imperial College London, United Kingdom*

**58** Reactor Antineutrinos at SNO+: Predicting Survival

Mr James Page[1]
*[1]University Of Sussex, BRIGHTON, United Kingdom*

**61** Measuring the CKM angle $\gamma$ using $B^0 \to D K^+ \pi^-$ decays at LHCb

Aidan Wiederhold[1], Matthew Kenzie[1], Timothy Gershon[1], Luis Miguel Garcia Martin[3], Yuya Shimizu[2], Frederic Machefert[2]
*[1]University Of Warwick, Coventry, United Kingdom, [2]Universite Paris-Saclay, Orsay, France, [3]EPFL, Lausanne, Switzerland*

**76** Developing Numerical Simulations of Atom Interferometers for Direct Searches of Ultra-light Dark Matter with the AION project

Noam Mouelle[1]
*[1]University of Cambridge, Cambridge, United Kingdom*

**119** Love, Glue and Robots: on the loading of ATLAS ITk Pixel Models on Outer Endcap Half-rings

Simon Florian Koch[1], Daniel Hynds[1], Daniela Bortoletto[1]
*[1]University Of Oxford, Oxford, United Kingdom*

**79** Using Bayesian Inference to Study Gravitational Wave Signals in Atom Interferometers and Formulate a Network of the MAGIS-100 and AION Experiments

Yu Zhi[1]
*[1]Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*

**113** Commissioning and characterisation of the MIGDAL detector

Mr Lex Millins
*[1]University of Birmingham, United Kingdom, [2]Rutherford Appleton Laboratory, Oxford, United Kingdom*

**75** Quantum Technologies for Neutrino Mass – Investigating Trigger Design

Mr Daniel Swinnock[1]
*[1]University Of Warwick, Coventry, United Kingdom*

**128** Kaon Cross Section Measurement with NuMI beam at MicroBooNE

Natsumi Taniuchi[1]
*[1]University Of Cambridge, Cambridge, United Kingdom*

**87** Assembly and characterisation of new 20 cm x 20 cm silicon photosensor arrays for direct dark matter searches with the DarkSide-20k detector

Conner Roberts[1]
*[1]The University Of Manchester, United Kingdom*

**115** Assembly and QA/QC of the readout electronics for the DarkSide-20k veto photodetector modules

Dr Ioannis Manthos[1], Professor Konstantinos Nikolopoulos[1], Giovanni Rogers[1]
*[1]University Of Birmingham (UK), Birmingham, Edgebaston, United Kingdom*

**117** One lepton channel measurement of ttZ with Z decaying to neutrinos

Zoë Earnshaw[1]
*[1]University of Sussex, Brighton, United Kingdom*

**118** COSMIC-SWAMP : Smart Water Management using Cosmic Ray Neutrons

Patrick Stowell[1]
*[1]Durham University, United Kingdom*

**121** Development of a proton beam delivery system to treat tumours via laser-driven acceleration

Josie McGarrigle[1]
*[1]Imperial College London, London, United Kingdom, [2]Institut Curie, Paris, France*

**126** QUEST-DMC: Superfluid Helium-3 Bolometers for a Direct Dark Matter Search

Miss Tineke Salmon[1]
*[1]Lancaster University, Lancaster, United Kingdom*

**123** Development of Simulations for the BUTTON Testbed

Alexander Morgan[1]
*[1]University Of Liverpool, Liverpool, United Kingdom*

**124** Investigating the use of the z expansion in the axial form factors for nuclear neutrino scattering

Miss Abigail Peake[1]
*[1]Royal Holloway, London, United Kingdom*

**125** An Automated Bandwidth Division for the LHCb Upgrade Trigger

Mr Joshua Horswill[1], Mr Conor Fitzpatrick, Mr Timothy Evans
*[1]University Of Manchester, Manchester, United Kingdom*

**132** Finding what you didn't know you were looking for: Machine learning for the detection of anomalies with LUX-ZEPLIN

Leah Wolf[1]
*[1]Royal Holloway University of London, United Kingdom*

**135** The ATLAS jet trigger and Trigger-Level Analysis applications in Run 3 of the LHC

Max Amerl[1], Caterina Doglioni[1], Tobias Fitschen[1]
*[1]University Of Manchester, Manchester, United Kingdom*

**140** The KM3NeT Project

Matthew Malek[1], Brad Gibson
*[1]University of Sheffield, Sheffield, United Kingdom*

**141** AION & MAGIS – Long baseline Atom Interferometry for Dark Matter and Gravitational Waves searches

Mr Kamran Hussain[1]
*[1]University Of Liverpool, Liverpool, United Kingdom*

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George Burton
*King’s College London, United Kingdom*

**148** Reparameterisations of the PMNS matrix in long-baseline neutrino experiments

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**149** High Energy Neutron-Water Cross Section Measurements at ISIS

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**146** Overview of the near detector analysis strategy with MaCh3

Ewan Miller
*King's College London, United Kingdom*

**151** Developing Pilot Tuneable Microwave Receiver for Axion Detection

Ian Bailey[2], Saul Baker[2], Ed Daw[3], John Gallop[1], Ling Hao[1], Mitchell Perry[3], Paul Smith[3]
*[1]National Physical Laboratory, King's College London, United Kingdom, [2]Lancaster University, United Kingdom*
*[3]Sheffield University, United Kingdom*

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# ARIADNE+: Large Scale Demonstration of Fast Optical Readout for Dual Phase LArTPCs at the CERN Neutrino Platform

Mr Adam Lowe[1], Mr Pablo Amedo[2], Dr Diego Gonzalez-Diaz[2], Dr Alexander Deisting[4], Dr Krishanu Majumdar[1], Dr Konstantinos Mavrokoridis[1], Dr Marzio Nessi[3], Dr Barney Philippou[1], Dr Francesco Pietropaolo[3], Mr Sudikshan Ravinthiran[1], Dr Filippo Resnati[3], Dr Adam Roberts[1], Dr Angela Saa Hermandez[2], Prof Christos Touramanis[1], Dr Jared Vann[1]

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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Optical readout of large scale dual-phase liquid Argon TPCs is an attractive and cost effective alternative to charge readout. Following the successful demonstration of 3D optical readout with the ARIADNE 1-ton detector, the ARIADNE+ experiment was recently deployed using the protoDUNE “cold box” at the CERN neutrino platform imaging a much larger active region of 2mx2m. ARIADNE+ uses 4 Timepix3 cameras imaging the S2 light produced by 16 novel, patent pending, glass THGEMs. ARIADNE+ takes advantage of the raw Timepix3 data coming natively 3D and zero suppressed with a 1.6 ns timing resolution. Three of the four THGEM quadrants were visible readout with the fourth featuring a VUV light image intensifier, thus removing the need for wavelength shifting altogether. Cosmic muon events were recorded successfully at stable conditions providing the first demonstration for its use in kton scale experiments such as DUNE.

In my talk I will be discussing in detail the innovative ideas that make ARIADNE+ unique and the benefits that come with these technologies. These include, but is not limited too, TPX3Cams, the PEN wavelength shifting, a chemically etched stainless steel extraction grid, Invar support structure and a new way to manufacture glass THGEMs. I will also be presenting a gallery of cosmic muon events along with a breakdown of our mechanisms for analysis allowing us to arrive at an energy calibration and resolution.

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# Characterisation and Calibration of Photosensors for Water Cherenkov Neutrino Detectors

Stephen Wilson[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Dark noise is a dominant background in photomultiplier tubes (PMTs), which are used for the detection of the products of neutrino interactions in liquid filled detectors. Thermionic emission, where an electron is liberated from the photocathode by thermal energy, is one of the major mechanisms that produces dark noise. The pulses produced by thermionic emission are single-electron pulses and cannot be discriminated from single-photoelectron (SPE) pulses produced by photons, causing them to mask interesting light pulses from target physics events. As such, the characterisation of thermionic dark noise is required.

PMTs are, in most cases within neutrino detection, run completely submerged in the detector fill medium. However, they are typically characterised in air, normally at a single ambient temperature, before installation. It is therefore important to characterise PMTs in a realistic dielectric and magnetic environment, and with varying temperature to understand the performance and thermionic dark noise contribution that can be expected in a detector.

Presented here is the characterisation of the temperature-dependent dark noise of 10" Hamamatsu R7081-100 PMTs when submerged in pure water. The results suggest thermionic emission dominates the SPE dark noise between 15 C and 25 C, but below 15 C other effects become increasingly important.

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# Development of the data acquisition system for the Mu2e STM detector

Claudia Alvarez Garcia[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The observation of a significant deviation in the muon g-2 relative to the Standard Model (SM) e+e- prediction is perhaps a harbinger of new muon interactions beyond the SM and in many models of physics beyond the SM (BSM) a significant rate of charged lepton flavour violating (CLFV) muon interactions is predicted. The Mu2e experiment at Fermilab will extend the sensitivity to BSM CLFV interactions by 4 orders of magnitude by seeking to observe the coherent neutrinoless transition of a muon to an electron when captured by an aluminium target. Critical to this measurement is the determination of the number of muons captured by the aluminium target. This cannot be estimated very reliably from simulation since the rate of the parent pions is model dependent and there are uncertainties in the collection and transmission efficiencies of the solenoids. However, muons captured are accompanied by distinctive X-rays which can be used to determine the muon flux. X-rays of 347 keV, 844 keV and 1809 keV will be measured by the Stopping Target Monitor (STM), a High Purity Germanium detector (HPGe), to determine the muon rate. The X-rays create transient pulses in the detector, the height of which is related to the incident energy of the X-rays. To determine the rates of the three X-rays I have implemented a Moving Window Deconvolution (MWD) algorithm. The input parameters of this algorithm have been tested on real X-ray data from 137-Cs and 152-Eu radioactive sources and beam data from the HZDR gELBE bremsstrahlung facility and optimised using simulated data. Testing this algorithm on a simulation based on the physical processes taking place in the detector has allowed the MWD resolution and efficiency to be determined as a function of rate. Furthermore, the pulse shapes expected in the HPGe STM detector have a long decay tail and the amount of data generated is bigger than the available storage capacity. I have developed a Zero-Suppression (ZS) algorithm to reduce the amount of raw data being stored and analysed. This algorithm has also been tested on real data and simulation. I will present performance results from the ZS and MWD algorithms and how these will be used to accurately determine the muon flux at Mu2e.

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## Studying penguins in the jungle

Anja Beck[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Flavour-changing neutral-current processes, such as electroweak penguin decays of a b-quark into an s-quark and either a photon or two leptons, are a powerful probe of physics beyond the Standard Model (SM). Studies of b->s transitions have mainly focused on B meson decays, where global analyses suggest the need for non-SM couplings. It is important that these discrepancies are confirmed in other systems, for example in b-baryon decays. The decay of a Λb baryon to a proton, a kaon and either a photon or two leptons results in a rich pK spectrum consisting of several Λ resonances. The composition of the spectrum is not yet fully understood and the different states cannot easily be separated. This is an experimental and phenomenological challenge but the large interference between states can provide interesting new observables. The LHCb experiment is the first experiment to be able to perform precise measurements of rare electroweak penguin decays of Λb baryons. This talk explains how recent and future measurements of Λb->Λγ and Λ->Λll transitions can improve our understanding of the anomalies in b->s transitions.

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# Development of Water based Liquid Scintillator (WbLS) for Future Neutrino Experiments

Adam Tarrant[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Water based Liquid Scintillator (WbLS) is a novel fill material being developed for future water-based Cherenkov detectors. A limiting factor of current Cherenkov detectors is a relatively high energy threshold, due to the Cherenkov threshold of 0.8 MeV for electrons. In practice, this is even higher because of backgrounds and detection efficiency. The addition of liquid scintillator amplifies low energy events by shifting the wavelength of light and increasing the number of scintillated photons while maintaining high optical transparency. Before this technology can be deployed in a neutrino experiment, a suitable purification system must be created, and the optical properties of WbLS must be measured. Light attenuation is an important property to understand due to its impact on detection efficiency.
The neutrino group at the University of California at Davis has developed the Scattering and Attenuation Measuring Device (SAMD) for the purpose of measuring the attenuation of WbLS. With further evolution, SAMD could be used in working detectors to monitor the attenuation coefficient. In this talk, I will present the work that I conducted with the UC-Davis group to make repeatable attenuation measurements in water, and I will show some of the first attenuation lengths measured for WbLS. Compared to pure water, it was found that WbLS reduced the attenuation length by up to 87% at 410 nm while only slightly reducing the attenuation length by 33% at longer wavelengths (520 nm). The impact of these results on the design and performance of future detectors, such as Boulby Underground Technology Testbed Observing Neutrinos (BUTTON), will also be discussed.

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# Using the 4-momentum subtraction algorithm to model medium response in JEWEL

Daniel Jones[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

When nuclear matter experiences extreme temperatures and pressures, it exists in a new phase known as the Quark-Gluon Plasma (QGP), where partons (quarks and gluons) are free to propagate in a near perfect fluid. The QGP is investigated at experiments such as ALICE at the CERN LHC, where heavy ions such as lead are collided at high energies to create a QGP for a small fraction of time. As a result of the recent upgrades of the ALICE experiment and the LHC we are entering a new era of data collection, which makes this an exciting time to be working with ALICE.

Produced in both heavy-ion collisions and proton-proton collisions are jets - collimated streams of high energy hadrons originating from a high-energy parton created in a hard scattering process. As heavy ion collisions also result in the generation of a QGP, it is expected that the properties of jets will be modified when they are produced in it. The modifications can include an increase or decrease in the jet energy, a change in the jet shape or substructure or a deflection from its propagation axis when produced in a vacuum. Phenomena which demonstrate such modifications include “jet quenching” in which even the jet topology is lost. Thus, measurements of jet production can be expected to yield critical information which relates to the collective behaviour of the QGP which is manifest as a perfect fluid.

In this poster we present phenomenological studies of jets that recoil off a high transverse momentum hadron (hadron+jet production), which is one of the main ways that ALICE studies how jets interact with the medium. We use a Monte Carlo event generator, JEWEL [1], which simulates both proton-proton and heavy ion collisions and models phenonema such as jet energy loss, parton showers and hadronization. We study hadron+jet production as a function of the jet transverse momentum and the azimuthal angle between the hadron and jet, utilising an observable which subtracts the uncorrelated background present in heavy-ion collisions. Finally, we present different approaches to the modelling of the ‘medium response’ - thermal partons which have interacted and recoiled from the expanding QGP medium. This thermal momentum can be subtracted from the reconstructed jet, and many jet structure observables are sensitive to this response. This poster demonstrates the use of a background subtraction algorithm, known as “four momentum subtraction”.

[1] Zapp K. JEWEL 2.0. 0: directions for use. The European Physical Journal C. 2014 Feb;74:1-4.

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# Development of an Ion-Acoustic Dose-Deposition Mapping System for LhARA

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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

LhARA, the Laser-hybrid Accelerator for Radiobiological Applications [1], is a proposed facility dedicated to the study of radiation biology. The accelerator has been designed to deliver a variety of ion species over a wide range of spatial and temporal profiles at ultra-high dose rates.

The powerful pulse lasers that will be used will generate a short burst of protons and light ions. The automation of sample handling in LhARA requires the measurement of the deposited dose distribution in real-time at a repetition rate of 10 Hz. Due to the nanosecond-scale pulses delivered by LhARA, the thermal expansion generated by the almost instantaneous energy deposition satisfies the stress confinement criterion necessary for the efficient generation of acoustic waves. Due to the satisfaction of this criterion, an ion-acoustic dose mapping system, that is based on ultrasound (pressure) waves induced by the passage of the ions, has been developed that has the potential to allow real-time monitoring and Bragg peak localisation during ion-beam therapy [2]. An experiment to demonstrate the feasibility of the system to provide the 3D energy-deposition profile, within the required timeframe, has been developed and its performance is evaluated using Geant4 [3] and k-Wave [4].

A water phantom has been modelled in Geant4, which takes beams with energies up to 80 MeV and calculates the energy deposited as a function of position and time. The time-dependent 3D energy distribution is then used as the source in k-Wave to simulate the generation of pressure waves and their propagation in the three-dimensional space. A hemispherical sensor array has also been designed in k-Wave and its pressure distribution reconstruction performance has been evaluated. Different reconstruction algorithms have also been investigated and analysis of the reconstructed images led to an initial optimisation of the detector size, position, and the number of elements to be used in the acoustic array.

The results show that the 3D deposited-energy distribution can be reconstructed with sub-millimetre accuracy. This suggests that further development can lead to a real-time, non-invasive system that can provide dose deposition profile feedback during LhARA beam irradiation.

[1] Aymar G. et al. Front Phys. 2020;0:432.
[2] Haffa D. et al. Sci Rep. 2019;9(1):6714.
[3] Allison J. et al. Nucl. Instrum. Meth. A. 2016;835:186-225.
[4] Treeby BE, Cox BT. J. Biomed. Opt. 2010;15(2):021314.

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## Cosmogenic Neutron Multiplicty in SNO+

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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The neutrons produced by high energy cosmic muons are a background to the physics searches of many underground experiments. The SNO+ detector is located 2000m underground where it experiences cosmogenically induced neutrons. The water and scintillator phases of SNO+ present the opportunity to measure the cosmogenic neutron multiplicity in different media, using the same muon flux. Here, the progress on the work for measuring the neutron multiplicity for the water phase of SNO+ is presented.

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## Translating Near to Far Detector for DUNE-PRISM Analysis

Alex Wilkinson[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The Deep Underground Neutrino Experiment (DUNE) is a next-generation long-baseline neutrino oscillation experiment that aims to measure CP-violation in the neutrino sector as part of a wider physics programme. DUNE consists two detectors in a high power neutrino beam originating at Fermilab. A near detector measures the unoscillated flux near to the neutrino source and a far detector situated 1300km downstream and 1.5km underground measures the oscillated flux. Oscillation parameters are typically extracted by comparing data and model predictions at the far detector, with model parameters tuned using near detector data. Due to limited understanding of neutrino-nucleus interactions, the reliance of this method on any particular model makes it susceptible to bias in oscillation measurements. The DUNE-PRISM (Precision Reaction Independent Spectrum Measurement) analysis offers a complementary approach with significantly less reliance on interaction models. Measurements of different fluxes at the near detector, obtained by moving the detector into off-axis beam positions, are combined to produce a prediction of the oscillated spectrum at the far detector under a given oscillation hypothesis. The resulting cancellation between detectors significantly reduces dependency on neutrino interaction models over an analysis using only on-axis samples.
Due to different detector designs, near detector observables need to be converted to far detector observables to predict an oscillated spectrum. This work demonstrates the possibility of using machine learning to accomplish this by translating detector response between the detectors for each event. Such a method avoids the introduction of model dependence associated with using Monte Carlo to construct a smearing matrix.

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# An overview of the LZ Outer Detector: Calibration, Monitoring and Performance, and its Contribution to the First Science Run

Sam Woodford[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The LUX-ZEPLIN dark matter experiment recently completed its first science run, revealing world-leading sensitivities. The centrepiece of the experiment is a dual-phase liquid xenon time projection chamber sensitive to low energy nuclear recoils, with rejection of backgrounds enhanced by a Xe skin veto detector and by a liquid scintillator Outer Detector (OD), loaded with gadolinium for efficient neutron capture and tagging. This talk will cover three main facets of the OD: calibration, monitoring of performance and data quality, and overall contribution to first science results. The calibration section will discuss the role of the optical calibration system (OCS), alongside on-site PMT calibrations using radioactive sources. OD calibrations include PMT response to single photoelectrons and ionic after-pulsing. A brief description of LZ's Physics Readiness Monitor (PREM) will be provided, with a specific focus on its function in tracking overall trends in the OD, from the initial quality assurance, up to now. Finally, a summary of OD data analysis will be covered, with an emphasis on how these studies contributed to an effective background veto in the first science run.

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# Neutrino Oscillation Global Fit with GAMBIT

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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The Global And Modular Beyond-the-Standard-Model Inference Tool (GAMBIT) is a software framework for performing global fitting of particle and astroparticle models. Due to its highly modular and flexible design, GAMBIT is ideal for tackling and analysing problems that involve vast parameter spaces. The software suite allows one to easily implement an alternate model and subject it to the constraint of a user-defined subset of observational results. Experiment information and observation data used by GAMBIT are collected from publicly available sources, including papers, technical notes, theses, and presentation slides, in line with the open-source policy.

It is well understood that global fitting is an effective method for studying the phenomenon of neutrino oscillation. By combining results from different neutrino experiments that are sensitive to different parts of the neutrino oscillation parameter space, stronger constraints that cannot be achieved by the experiments individually may be set. NeutrinoBit, a GAMBIT module, which includes a variety of neutrino experiments across a wide range of experimental techniques, is coming close to its final phase of development before release. Inside the module, each experiment is represented by a set of likelihood functions. These likelihood functions compare the predictions produced by GAMBIT to their experimental counterparts and calculate the likelihoods, on which the software can perform statistical inference and construct confidence intervals.

The poster focuses on the development of the NeutrinoBit module, including the descriptions of the scanning algorithm and the statistical methods. Examples of the included neutrino experiments are also given.

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# Searching for Dark Matter in the Sun using DUNE

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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The Deep Underground Neutrino Experiment (DUNE) is a next-generation neutrino experiment that will consist of two detectors. A near detector (ND) complex will be placed in Fermilab, whereas a larger far detector (FD) will be build in the Sandford Underground Research Facility (SURF), approximately 1300 km away. It will address several questions in neutrino oscillation physics, study neutrinos from supernovae explosions and search for proton decay. The experiment will record neutrino interactions from an accelerator-produced beam (the LBNF multi-megawatt wide-band neutrino beam planned for Fermilab) arriving at predictable times, but will also aim at recording rare events such as supernova neutrinos or potential nucleon decays. This broad physics program requires a superb performance of the detectors, which can be used to look for other BSM phenomena such as Dark Matter (DM). One possible way to probe DM interactions is detecting neutrino signals coming from DM self annihilations in the core of the Sun, as only neutrinos produced in such annihilations can escape the dense interior of the star. In this work, we demonstrate the capability of DUNE to constrain different DM scenarios. We use the neutrino fluxes arising from DM annihilations in the Sun to compute the projected limits that DUNE would be able to set on the the DM scattering cross sections, accounting for the detector resolution effects and the topologies of the different signatures. Specifically, we focus on the cross section sensitivities for the $\tau^{+}\tau^{-}$ and $\bar{b}b$ channels looking at two different kinematic regimes, the high energy neutrinos where DIS interactions with argon dominate and the low energy part of the spectrum where neutrinos mainly undergo QEL interactions. We find that the expected sensitivity of DUNE for DM masses $\lesssim 25 \ \mathrm{GeV}$ surpasses the stronger current indirect limits. Additionally, we explore one specific realisation of the DM interactions, leptophilic fermionic DM, which DUNE could use as a proxy for the electron-DM elastic scattering cross section in the $200-500 \ \mathrm{MeV}$ mass range.

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# Solar axion searches in LUX-ZEPLIN

Anh Nguyen[1], Harkirat Riyat[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The LUX-ZEPLIN (LZ) experiment is a direct dark matter detection experiment that is the successor of the LUX and ZEPLIN experiments, searching primarily for WIMP candidates that produce nuclear recoils (NR) off xenon nuclei. LZ recently completed 60 live days for its science run one (SR1), producing new world-leading limits for the upper bound of the spin-independent and neutron spin-dependent WIMP-nucleon cross-section.

In this poster, we will present searches for signals that result from exotic particles interacting with xenon atomic electrons, specifically solar axions. Axions are a well-motivated Nambu-Goldstone boson that naturally arises in solutions to the CP-problem. (Solar) Axions may be being thermally produced in the Sun, or from the decay of solar 57Fe. Their interaction with electrons in LZ would then generate few-keV scale electron recoil (ER) events with particular spectral shapes. This work will present the status of a search for solar axions in LZ's first science run.

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## Q-Pix concept: Kiloton-scale pixelated liquid noble TPCs

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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Q-Pix is a novel pixel-based readout technology for liquid argon time projection chambers (LArTPCs) that is an alternative to the traditional wire-based readout. The Q-Pix readout scheme provides a path to fully pixelated, kiloton-scale LArTPCs with low-energy detection to maximize future neutrino physics potential by preserving the 3D track information with low data rates. This transformative technology has the potential to enable the study of neutrinos at lower energies, such as supernova and solar neutrinos. An overview of the physics potential from a Q-Pix-enabled readout will be presented in this talk.

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## The Water Cherenkov Test Experiment and its calibration

Alie Craplet[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The next generation of neutrino long baseline experiments will be systematics dominated. The Water Cherenkov Test Experiment (WCTE) is a 4m by 4m cylindrical water Cherenkov detector that will constrain these uncertainties. It will be installed in the CERN low momentum particle beam and will receive a beam of protons, electrons, muons and pions of momenta ranging from 200MeV/c to 1GeV/c. This experiment will serve as a testbed for new technologies, as it is equipped with 106 multi-PMT detectors that are being developed for the Hyper-Kamiokande (HK) experiment. The experiment will also provide a test of the calibration and reconstruction algorithms that will be employed by HK.

WCTE will be essential in helping reduce HK's systematic uncertainty in various domains including energy resolution, particle identification and lepton scattering both in ultra-pure and Gadolinium doped water. Due to the small detector size, new methods will have to be developed in order to calibrate WCTE accurately. This poster presents WCTE, its physics goals and describes a new calibration procedure.

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## Reactor Antineutrinos at SNO+: Predicting Survival

Mr James Page[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The SNO+ experiment's main goal is the detection of neutrinoless double beta decay, but being 200-300km away from the nearest nuclear reactors, it is also a long baseline reactor antineutrino detector with very low backgrounds. We hope to make a competitive measurement of Δm_21^2 within a few years, by measuring the IBD flux. In this talk I will explain how these measurements are made and classified, with particular attention to reducing the alpha-n background. I will then discuss how the expected flux over time is computed: from isotope fission fractions and loading factors, to neutrino oscillations through the crust and the IBD cross-section.

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# Measuring the CKM angle $\gamma$ using $B^0 \to D K^+ \pi^-$ decays at LHCb

Aidan Wiederhold[1], Matthew Kenzie[1], Timothy Gershon[1], Luis Miguel Garcia Martin[3], Yuya Shimizu[2], Frederic Machefert[2]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

One of the key goals of modern flavour physics and the LHCb experiment is to over-constrain the CKM unitarity triangle. The LHCb experiment has a rich portfolio of measurements of the CKM angle $\gamma$ resulting in world leading sensitivity to this benchmark parameter of the Standard Model. Here we present a new measurement using $B^0 \to D K^+ \pi^-$, $D \to (K_S^0 h^+ h^-, h^+ h^-, h^+ h^- h^+ h^-)$ decays with $h=K, \pi$. A simultaneous binned fit is performed on all decays in both the B and D-decay phase space to optimise sensitivity to $\gamma$. Binned population distribution and strong-phase parameters are measured for the first time in the B-decay phase space. Current progress is described alongside preliminary background-inclusive pseudo-experiment study results to estimate the expected statistical sensitivity to $\gamma$.

Exploiting the full Run 1 and Run 2 LHCb dataset of about $9 \text{fb}^{-1}$ we expect a statistical sensitivity of $\mathcal{O}(4^\circ)$, this may result in the most sensitive single measurement of $\gamma$ to date and will result in a significant improvement to the LHCb Beauty and Charm combination.

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# Developing Numerical Simulations of Atom Interferometers for Direct Searches of Ultra-light Dark Matter with the AION project

Noam Mouelle[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The AION project is a groundbreaking initiative that seeks to perform direct searches of ultra-light dark matter using atom interferometers. Accurately identifying and characterizing experimental backgrounds is critical for performing precise measurements and ensuring the success of the experiment. To achieve this, we have begun developing a numerical simulation of AION. Our simulation involves modeling an atom interferometer evolving in a time-dependent Hamiltonian using established theoretical frameworks from the early 2000s. This simulation will enable us to gain a better understanding of the behaviour of the experiment and the effects of various backgrounds, ultimately allowing us to optimize the experiment's sensitivity to ultra-light dark matter. This presentation will provide an overview of the AION project and detail the progress we have made in developing our simulation.

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# Love, Glue and Robots: on the loading of ATLAS ITk Pixel Models on Outer Endcap Half-rings

Simon Florian Koch[1], Daniel Hynds[1], Daniela Bortoletto[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The ATLAS Phase 2 Inner Tracker (ITk) upgrade will construct and install an all-silicon inner detector. OPMD at Oxford will produce half-rings comprising one third of one outer endcap for the upgrade, using a largely automated method involving placement by robotic gantry. Optimisation of both human and robotic procedures is required, and verification that loading is performed to the strict tolerances specified by ATLAS is key to ensuring a functioning inner detector for Run 4 and beyond. This presentation will discuss work done to optimise the thermal interface ("glue") layer between modules and half-rings, and results from initial loading attempts at OPMD, Oxford. Results confirming reproducibility of the adhesive layer height and spread will be presented, and the placement accuracy of modules with respect to their nominal position will be discussed.

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# Using Bayesian Inference to Study Gravitational Wave Signals in Atom Interferometers and Formulate a Network of the MAGIS-100 and AION Experiments

Yu Zhi[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Bayesian inference is becoming a language of gravitational wave (GW) physics. It is useful in estimating the sources' astrophysical properties by extracting modeled parameters from GW data. While Bayesian inference has already been well applied in data analysis with laser interferometers, it is crucial to study the application of this method to GW signals in atom interferometers. Bayesian inference can be used to show that atom interferometers in the mid-frequency band, roughly 0.03 to 10 Hz, have a great potential for angular sky-localization and serves as a platform for understanding the efficacy of extracting parameters from other astrophysical sources of GWs. We also use Bayesian inference to formulate and study a network of multiple atomic detectors, with respect to the MAGIS-100 and AION experiments.

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## Commissioning and characterisation of the MIGDAL detector

Mr Lex Millins
*[1]University of Birmingham, United Kingdom, [2]Rutherford Appleton Laboratory, Oxford, United Kingdom*

Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Many underground dark matter direct detection experiments exploit the Migdal effect, a rare atomic process, to improve their sensitivity to low mass WIMP-like candidates. However, this process is yet to be observed in nuclear scattering. The Migdal in Galactic Dark mAtter expLoration (MIGDAL) experiment aspires to make the first unambiguous observation of the Migdal effect in nuclear scattering.

The experiment utilises an Optical Time Projection Chamber (OTPC) to image in three dimensions the characteristic signature of a Migdal event: an electron and a nuclear recoil ionisation track originating from a common vertex. The OTPC features two glass GEMs enabling high gas gain operation at 50 Torr of CF4. Optical read-out is performed using a low noise CMOS camera and a photomultiplier tube for light collection. Charge read-out is performed with an ITO anode segmented in 120 strips.

Commissioning and calibration of the MIGDAL detector is underway using an 55Fe X-ray source and a 252Cf alpha source in pure CF4 and Argon-CF4 mixtures. Results from the characterisation of the detector will be presented with an emphasis on the charge read-out.

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# Quantum Technologies for Neutrino Mass – Investigating Trigger Design

Mr Daniel Swinnock[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Quantum Technologies for Neutrino Mass (QTNM) is a project that aims to investigate methods and techniques for measuring electron energies using Cyclotron Radiation Emission Spectroscopy (CRES), a technique developed by Project 8. The aim is that this technology could be applied to the beta decay of Tritium atoms in a future, larger experiment which can be used to place limits on the neutrino mass as low as 40 meV, which could allow the determination of the absolute neutrino mass for the first time, and whether neutrinos exist in the inverted or normal mass hierarchy.

CRES works by measuring the frequency of radiation emitted by an electron undergoing cyclotron motion induced by a magnetic field. This frequency can be linked to its kinetic energy, allowing for precise frequency measurements to be translated into precise energy measurements. This technique can be used to make a measurement of the electron energy spectrum of Tritium beta decay, for which the shape near the end point is sensitive to the neutrino mass.

The power emitted by a single electron with these energies is very small – around 1 fW total. This means that very low noise conditions and sophisticated analysis techniques are required to make measurements of individual electron radiation frequencies. Along with this, electrons at the end of the Tritium beta spectrum are very rare, so to obtain sufficient statistics requires long observation times. Storing all this data and then processing it with potentially computationally intensive analysis would be very difficult, so it will be important to develop a trigger that can remove unwanted data containing no electrons of interest.

However, the conditions that already make analysis difficult, such as the high noise compared to the electron power, also apply to the trigger, so the trigger itself must be carefully designed in order to detect the presence of a signal electron. One approach that is being investigated is to use a lock-in amplifier implemented on a field-programmable gate array (FPGA) to act as a trigger. Lock-in amplifiers have been used for signal measurements in extremely high noise, making them a possibility for use as a trigger for QTNM. The lock-in amplifier works by mixing a reference signal with the incoming signal and filtering the result to reduce noise. Typically, the reference is a sine wave at a fixed frequency close to the frequency of interest. For QTNM and CRES, the signal is a chirping sine wave, caused by the electron's loss of energy as it radiates. As a result, better performance can potentially be obtained by replacing the static reference frequency with a chirping signal. This has been implemented on the FPGA and is being tested for improved performance against the static frequency case.

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## Kaon Cross Section Measurement with NuMI beam at MicroBooNE

Natsumi Taniuchi[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The existence of Grand Unified Theories describing the unification of the electromagnetic, weak, and strong forces is still an open question. One of the notable features of these theories is the prediction of protons decaying into lighter particles with long lifetimes in the order of $30^30$-$30^40$ years. Although many studies have been conducted assuming various decay channels so far, such decays have yet to be observed. In particular, searches of decay modes involving Kaons have shown a drawback in previous analyses with Cherenkov detectors due to their heavy mass.

The Deep Underground Neutrino Experiment (DUNE) is a state-of-the-art international experiment aiming to reveal the nature of neutrinos and proton decay amongst other BSM topics. DUNE's far detector will utilise a liquid argon time projection chamber (LArTPC) with an active volume of 40 kilotons. While DUNE's LArTPC is still under construction, another LArTPC has been operating in two neutrino beams, namely the MicroBooNE experiment. By analysing the Kaons produced by neutrino interactions in the MicroBooNE LArTPC, we can understand useful information on the behaviour of kaons in the DUNE LArTPC. In this presentation, the event selection method using machine learning techniques for neutrino-induced charge current $K^+$ production at MicroBooNE LArTPC will be described.

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Assembly and characterisation of new 20 cm x 20 cm silicon photosensor arrays for direct dark matter searches with the DarkSide-20k detector.

Conner Roberts[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

A new generation of photosensors are being produced in the UK to instrument the DarkSide-20k detector. DarkSide-20k searches for interactions of the dark matter that makes up 85% of the matter in the universe, yet has not been observed in particle detectors to date. Darkside-20k is designed to observe light signals from Weakly Interacting Massive Particles (WIMPs) scattering on nuclei of a Liquid Argon (LAr) target. The detector is designed to operate with <0.1 instrumental background interactions in a 200 t-yr exposure. Key to this stringent background target is the Neutron Veto that will surround the 51.1 t Time Projection Chamber (TPC). The Veto is designed to tag neutrons that mimic WIMP scattering events and will be instrumented with this new generation of silicon sensors produced at institutes around the UK; assembly and test is done at Manchester. This talk will outline the strict performance specifications of the Veto silicon photosensors set by the experiment's goal of a zero-instrumental-background dark matter search, the procedures and results of the first assembly and testing of such sensors in the UK, and future prospects.

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# Assembly and QA/QC of the readout electronics for the DarkSide-20k veto photodetector modules

Dr Ioannis Manthos[1], Professor Konstantinos Nikolopoulos[1], Giovanni Rogers[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Darkside-20k is a new-generation dual-phase Liquid Argon Time Projection Chamber (LAr TPC) with a 51t active mass, designed to probe WIMP interactions down to the neutrino fog. DarkSide-20k is designed to be an "instrumental background-free" experiment, and to do this the TPC and the inner and outer veto regions are instrumented with novel cryogenic Silicon PhotoMultiplier (SiPM) structures. The structural Photo Detector Module (PDM) consists of a 24 SiPM array integrated onto a readout PCB with a custom ASIC amplifier. PDMs are arranged in a 4x4 array forming a Photo Detector Unit (PDU). The DarkSide-UK groups are building, testing and characterising the 144 PDUs that will instrument the veto detector systems. The University of Birmingham is responsible for the population and QA/QC of veto-PDM PCBs, all under the strict radiopurity requirements of the experiment.

This contribution will describe the production process at the University of Birmingham, focusing on the population of Arlon PCBs using industry standard pick-and-place, reflow oven and stencil machines. The key considerations towards radiopurity will be reported, including material assay screening using the Boulby BUGS facility, dust deposition studies and the ISO-7 low Rn cleanroom chosen for production. Results from the QA/QC procedure, involving charge injection testing of custom ASICs and PCBs, with pulse analysis and DarkSide production database integration will be presented.

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## One lepton channel measurement of ttZ with Z decaying to neutrinos

Zoë Earnshaw[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The ttZ process has been studied by ATLAS throughout Run 2, and while this has included research on events where the Z boson decays to charged leptons, the case where the Z boson decays to neutrinos has so far not been measured. This process has a considerably higher branching ratio than for charged leptons, leading to a greater number of events in the tails of distributions, and potential to probe effective field theory operators such as that modify the interaction of the top quark and Z boson. This process also acts as a background to certain BSM searches, so a measurement will be beneficial to these.

This analysis consists of three parts: the one lepton channel, in which the W boson from one top quark decays to a charged lepton and a neutrino, and the second to light quarks, the zero lepton channel, in which both decay to quarks, and the two lepton channel, in which both decay to charged leptons and neutrinos. In this talk I present the progress of the one lepton branch.

This measurement suffers from a higher background than ttZ with Z decaying to charged leptons, which is difficult to reduce in part due to the three final state neutrinos. To manage this, after an initial cut-based preselection I have applied a multiclass neural network to identify my signal and its two most significant backgrounds (ttbar2L, and single top). The output values of this network provide a classification score for each event giving a 'probability' that it is one of these three processes, and cuts on these scores are used to construct a signal region and two control regions, to be used in a log likelihood fit.

The significance for the measurement of ttZ with Z decaying to neutrinos in the one lepton channel alone is around three. The zero- and two-lepton channels are each under development, and a final combined result is expected to have a significance greater than five.

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# COSMIC-SWAMP: Smart Water Management using Cosmic Ray Neutrons

Patrick Stowell[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Over 75% of freshwater consumption globally is within farming. Optimising agricultural water usage in arid regions is a major challenge that must be overcome when trying to build climate resilience within the global supply chain. Cosmic-Ray Neutron Sensing (CRNS) is a relatively new technique that provides a way to monitor soil moisture over large areas in an efficient, non-invasive way. Whilst the technique is well matched to typical field scales, the high cost and difficulty in using the CRNS technique has limited its adoption within the industrial sector.

COSMIC-SWAMP aims to provide an open-source water monitoring platform that integrates novel low cost cosmic ray sensors with FiWare Smart Application analysis routines. Extending the existing Smart Water Management Platform (swamp-project.org), COSMIC-SWAMP supports the deployment of arrays of cosmic ray sensor streams in a plug and play fashion, allowing automated and continuous crop growth forecasting through the adoption of WOFOST crop simulation models. In this talk I'll give an overview of the status of COSMIC-SWAMP project and the hardware development ongoing at Durham university to make CRNS a viable solution for crop monitoring within agriculture in the long term.

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# Development of a proton beam delivery system to treat tumours via laser-driven acceleration

Josie McGarrigle[1]
*[1]Imperial College London, London, United Kingdom, [2]Institut Curie, Paris, France*

Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Cancer is a collection of uncontrollably reproducing malignant cells created by genetic changes in the body. Although tumours can be reduced or eradicated using radiotherapy, radiation-induced toxicities in normal tissue can cause phenomena such as apoptosis and compromised mitosis cycles. These processes can lead to the creation of secondary tumours via metastasis. The `Laser-hybrid Accelerator for Radiobiological Applications', LhARA, is conceived as a uniquely flexible international facility dedicated to the study of a completely new regime of radiobiology. Three end stations, two dedicated to in-vitro exposures and one for in-vivo studies, are included in the design. These end stations will be optimised by pre-clinical studies to enable LhARA to provide FLASH, mini and microbeams over the full range of energies and dose rates. Radiotherapy delivered using these three modalities have been shown to provide enhanced dose localisation and reduce normal-tissue complications in comparison to conventional methods. A study of pre-clinical data was conducted to evaluate the critical parameters that must be considered when optimising the design of the LhARA end stations. The study combines the results of a multitude of experiments in a searchable database to allow the beam parameters that maximise the therapeutic benefit to be identified. The FLASH analysis presented mean and pulse dose rate as two most influential FLASH variables, but only with a weak correlation. Examining the trends in available data, it was concluded that FLASH radiotherapy transcends conventional radiotherapy in the preservation of both the health and function of normal tissue but proves less effective at treating the tumour. The mini/microbeam analysis produced more promising results, demonstrating both effective antitumour control and radioprotection. A strong correlation with peak valley dose rate (PDVR) was found too. This study suggests a focus on mini/microbeams, and the PVDR parameter, while optimising the design of the LhARA end stations.

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# QUEST-DMC: Superfluid Helium-3 Bolometers for a Direct Dark Matter Search

Miss Tineke Salmon[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The QUEST-DMC (Quantum Enhanced Superfluid Technologies for Dark Matter and Cosmology) collaboration, between Lancaster, Oxford, Royal Holloway University of London, and Sussex universities, is using superfluid helium-3 as a target for a direct dark matter search. The search is focussed on the sub-GeV mass range, motivated from models that link dark matter dynamics to the generation of matter-antimatter symmetry.

Helium-3 can be cooled to very low temperatures using a dilution refrigerator and adiabatic nuclear demagnetisation, with a lowest possible temperature of around 100 µK. At zero pressure, helium-3 becomes a superfluid at temperatures below 1 mK, a fluid that exhibits quantum properties at a macroscopic scale and can flow without resistance.

The fermionic superfluid is composed of pairs of quasiparticles (Cooper pairs) and has a low heat capacity which makes it a sensitive thermometer able to detect extremely small deposited energies. Its light nucleus allows for a higher sensitivity to dark matter candidates in the sub-GeV mass range than targets with heavier nuclei.

Helium-3 provides an environment for ultrasensitive bolometers, acting as both a target and detector. The bolometers consist of micron-sized superconducting vibrating wires encased in centimetre-sized box filled with helium-3. These wires have been well established as thermometers in the field of low temperature physics. Also, nanowires with diameters down to 180 nm are installed in the cryostat. These are showing encouraging preliminary results in the steps towards detecting even smaller energy deposits.

The bolometers are operated in the following manner. A dark matter candidate collides with a Cooper pair and produces heat (quasiparticles). The vibrating wire then experiences a change in damping force which is interpreted from a change in the width of its resonance. This allows a direct detection search for dark matter to be undertaken.

By exploring cutting edge technologies, the collaboration is striving towards very high sensitivities for a dark matter search. The precision is limited by the readout noise therefore, by using a SQUID a threshold energy of the order of eV can be achieved. The radioactivity of the materials of the cryostat and surroundings have been measured with the aspiration to use radiopure materials, where feasible.

In this poster, some promising preliminary results including the calibration of the bolometers and preliminary measurements of events within the superfluid helium-3 will be discussed.

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# Development of Simulations for the BUTTON Testbed

Alexander Morgan[1]
*[1]University Of Liverpool, Liverpool, United Kingdom*

Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

BUTTON (Boulby Underground Technology Testbed for Observing Neutrinos) is a 30-tonne anti-neutrino Cherenkov testbed, due to begin operation in 2024. BUTTON aims to demonstrate the feasibility of various prospective detection technologies, including a Gadolinium doped water based liquid scintillator (WbLS) fill medium, for the detection of reactor anti-neutrinos.

Simulations are required to benchmark the expected results for this novel detection technology. Such simulations for BUTTON are in development within the “Reactor Analysis Tool Plus Additional Code” (RATPAC) software package. The focus of this poster is on the ongoing efforts to build this simulation, along with preliminary expectations for the detector response of BUTTON when filled with different media per these simulations.

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# Investigating the use of the z expansion in the axial form factors for nuclear neutrino scattering

Miss Abigail Peake[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

Understanding neutrino\textendash nucleon Charged-current Quasi-Elastic scattering (CCQE) is of great importance to long-baseline neutrino oscillation experiments operating at $\mathcal{O}\left(1~\textrm{GeV}\right)$ energy scales. In some previous oscillation analyses (such as No$\nu$A and T2K), the axial component of the nucleon weak-charge distribution has been parameterised using a 1-parameter dipole form. This simple model has been shown to poorly predict bubble chamber CCQE data across a range of four momentum transfer, and crucially, the single parameter form of the dipole mischaracterises the uncertainty as a function of four momentum transfer. Using the z expansion formalism (which has 4 free parameters) to model the axial form factor has been shown gives an improved fit to bubble chamber data. However, the multi-parameter form of z expansion may have drawbacks when applied in long-baseline oscillation analyses (such as on T2K and the upcoming DUNE), particularly if the free parameters are not factorisable from the cross-section. One way around this concern is to use an alternative set of parameters in the z-Expansion formalism. This poster describes an investigation into the practical application of an alternate parameterisation. It will also demonstrate that they exhibit a higher degree of stability, together with the option to reduce the dimensionality of the parameterisation which further motivates its usage in current and future oscillation studies.

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# An Automated Bandwidth Division for the LHCb Upgrade Trigger

Mr Joshua Horswill[1], Mr Conor Fitzpatrick, Mr Timothy Evans
[1]*University Of Manchester, Manchester, United Kingdom*

Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The upgraded LHCb detector is the first detector based at a hadron collider able to readout at the full bunch crossing rate prior to reconstruction and selection in a fully software-based trigger.

The first trigger stage, HLT1, reduces the event rate from 30MHz to around 1MHz based on reconstruction criteria from the tracking system and consists of O(100) trigger selections implemented on GPUs. These selections are further refined following the full offline-quality reconstruction at HLT2 prior to saving for analysis. In order to equitably distribute this 1MHz across the trigger selections at HLT1 an automated bandwidth division is proposed.

This is achieved by creating a set of trigger selections that maximise efficiency for signals of interest to LHCb whilst also keeping the total HLT1 readout capped to its maximum. In previous data-taking periods, the bandwidth was divided using a genetic algorithm, designed to optimise the selections for five hardware L0 trigger lines across 23 physics channels.

We propose an evolution of the L0 division, to be applied to the far more complex HLT1, and will take advantage of modern gradient-based methods. The algorithm will determine the optimal selection for around 40 trigger lines over around 100 characteristic physics channels.

This poster presents the current status and preparations for the optimised trigger selections to be used for data taking this year.

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# Finding what you didn't know you were looking for: Machine learning for the detection of anomalies with LUX-ZEPLIN

Leah Wolf[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

LUX-ZEPLIN seeks to detect WIMP dark matter through direct interactions with a liquid xenon target in a time projection chamber. The detector is primarily composed of three constituents: the TPC, the skin, and the outer detector, each of which employs a series of PMTs. The skin is an additional layer of liquid xenon surrounded by PMTs, and serves to act as a veto for non-WIMP interactions. In order to function effectively as a veto, the skin must be monitored closely for anomalous events. A potential method for anomaly detection is the application of autoencoders: machine learning algorithms which are trained to recognise what is expected in the data such that they can identify unexpected or anomalous events.

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## The ATLAS jet trigger and Trigger-Level Analysis applications in Run 3 of the LHC

Max Amerl[1], Caterina Doglioni[1], Tobias Fitschen[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The ATLAS jet trigger is instrumental in selecting events both for Standard Model measurements and Beyond the Standard Model physics searches. Non-standard triggering strategies, such as saving only a small fraction of trigger objects for each event, avoids bandwidth limitations and increases sensitivity to low-mass and low-momentum objects. These events are used by Trigger Level Analyses, which can reach regions of parameter space that would otherwise be inaccessible. To this end, the calibration of trigger-level jets is imperative both to ensure good trigger performance across the ATLAS physics programme and to provide well-measured jets for Trigger Level Analysis. This contribution presents an introduction to the ATLAS jet trigger for Run-3 of the LHC and discusses the performance of the trigger jet calibration. These studies will allow us to commission a Run-3 trigger jet calibration that provides excellent performance across a broad jet transverse momentum range as low as 25 GeV.

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## The KM3NeT Project

Matthew Malek[1], Brad Gibson
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The KM3NeT project is in the process of building a pair of next-generation Cherenkov neutrino telescopes in the Mediterranean Sea. ARCA (Astroparticle Research with Cosmics in the Abyss) is located near Sicily, Italy. Its primary goal is the detection of high energy cosmic neutrinos, in the range from tens of GeV to PeV, originating from distant astrophysical sources. When complete, ARCA will observe 1 gigatonne of seawater. ARCA is complemented by ORCA (Oscillation Research with Cosmics in the Abyss), which is located near Toulon, France. ORCA is more densely instrumented, and observes a few megatonnes of seawater, with the object of detecting atmospheric neutrinos up to energies of about 100 GeV to measure oscillation parameters.

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# AION & MAGIS – Long baseline Atom Interferometry for Dark Matter and Gravitational Waves searches

Mr Kamran Hussain[1]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

AION (Atom Interferometer Observatory and Network) and MAGIS (Matter-wave Atomic Gradiometer Interferometric Sensor) are a consortium of strontium atom interferometry experiments. The goal is to search for ultra-light dark matter. MAGIS is currently constructing the 100 m vertical baseline using the access shaft of the MINOS experiment at Fermilab. AION plans to build the 10 m detector at the University of Oxford, with prospects of setting up the 100 m baseline in Boulby Mine or CERN. Developing these experiments is a stepping stone for deploying a space mission like AEDGE (Atomic Experiment for Dark Matter and Gravity Exploration in Space). This complements other probes of gravitational waves as AEDGE is optimised for mid-band detection region between (0.1 – 10) Hz, between LISA and LIGO.

The University of Liverpool is part of MAGIS and AION and is responsible for developing the phase-shear detection platform. This employs a piezo-driven retro reflection mirror inside the ultra-high vacuum chamber. Two types of position feedback are being developed to track the top-tilt mirror; electronic and optical feedback via a strain gauge and optical lever respectively.

Rutherford Appleton Laboratory hosts one of five strontium labs in the AION consortium currently working on the 2D and 3D strontium magneto-optical traps and a 1064 nm dipole trap. The ultimate goal is to achieve strontium interferometry with the potential to test the out-of-vacuum phase-shear imaging platform in collaboration with the University of Liverpool.

The collaboration between The University of Liverpool and RAL makes it well-situated to investigate the prospects and develop technology for future atom interferometry experiments in space for earth observation and fundamental science.

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# The effect of wavelength shifting plates on PMT dark rate in the Hyper-Kamiokande Outer Detector

George Burton
*King's College London, United Kingdom*

Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The Hyper-Kamiokande experiment aims to build upon the world changing successes of the Super-Kamiokande water Cherenkov detector, by having more sophisticated equipment, better analysis techniques and by having a fiducial volume which is approximately 8 times that of Super-Kamiokande. Among other goals, it aims to take more data, and improve the accuracy with which key neutrino oscillation parameters are measured, such as the mysterious neutrino mass ordering. To do this, it must be shielded from unwanted particle noise as much as possible. Cosmic rays from the upper atmosphere are a large source of uncertainty, and so they must be vetoed by the Outer Detector (OD). The OD will contain approximately 7,200, 3 inch Photomultiplier Tubes (PMTs) which is far less than the Inner Detector (ID). Therefore other techniques will be required to maximise the light collection efficiency. One such technique is the use of square Wavelength Shifting (WLS) plates. WLS plates are made up of a polymer base which is doped with an organic fluorescent compound (fluor) and contain a machined hole in the centre, so that the bulb of the PMT can be inserted and the contact area between the PMT and plate is maximised. The WLS plate enhances the light seen by the PMT by recovering the would-be lost UV part of the Cherenkov light spectrum. The fluor absorbs the UV light, which is then isotropically re-emitted in the visible (blue-green) range to match the region in which the Quantum Efficiency (QE) of the PMT is maximised. One of the fluors (the PPO fluor) in the candidate WLS plate samples could be scintillating, so radioactivity from other sources, for example, could become visible. Also, incoming muons could produce scintillation light, which may or may not be bad, but we need to know. In order to determine whether the plates containing this particular fluor is a viable option to be used in the OD, how each sample affects the dark rate of the candidate PMT must be quantified.

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## Reparameterisations of the PMNS matrix in long-baseline neutrino experiments

Andres Lopez Moreno
*King’s College London, United Kingdom*

Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

We explore the bias introduced in oscillation analyses when choosing a parametrisation of the leptonic mixing matrix and how to take it into account when reporting parametrisation-independent measures of mixing such as the Jarlskog invariant. We discuss how these biases make their way into both Bayesian and frequentist analysis in the context of 3-flavour oscillation physics. We show that, for toy T2K results, the constraints are stronger than the induced bias and reported measurements of the amount of CP violation in the neutrino sector are not significantly changed by a new choice of parametrisation.

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## High Energy Neutron-Water Cross Section Measurements at ISIS

Nahid Bhuiyan
*King's College London, United Kingdom*

Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The multiplicity and distribution of neutrons in neutrino experiments is powerful information for antineutrino identification as well as tau decay searches. Super-K is capable of recording neutrons from their captures, however, due to the complexity of neutrino-nucleus interaction and lack of neutron cross-section data above 20 MeV, simulations unreliably predict the data observed. Neutron-water cross sections are therefore now being studied through activation techniques and Bayesian statistics using ChipIr, the highest energy neutron beam in Europe.

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## Overview of the near detector analysis strategy with MaCh3

Ewan Miller
*King's College London, United Kingdom*

Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The Tokai to Kamioka experiment (T2K) is a long-baseline neutrino oscillation experiment in Japan. A beam of mostly muon neutrinos or anti-neutrinos are produced at the J-PARC accelerator complex in Tokai and the unoscillated beam is characterised by a suite of near detectors. After travelling 295km across Japan, the neutrino beam has undergone oscillation and the oscillated beams contents are measured by the Super-Kamiokande detector. Analyses of these measurements then allow us to extract the parameters governing the oscillations.

The focus of this talk will be on the ND280 detector, the main purpose of which in the oscillation analysis is to measure the initial neutrino fluxes and neutrino interaction cross sections. Both of these greatly impact the uncertainties on the final oscillation parameters.

This talk will give an overview of the near detector analysis strategy with a focus on MaCh3, a bayesian Marcov chain Monte Carlo fitter used by several experiments, and preliminary results from the on-going analysis will be shown.

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## Developing Pilot Tuneable Microwave Receiver for Axion Detection

Ian Bailey[2], Saul Baker[2], Ed Daw[3], John Gallop[1], Ling Hao[1], Mitchell Perry[3], Paul Smith[3]
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Drinks Reception and Poster Session, April 3, 2023, 18:30 – 20:30

The UKRI funded project Quantum Science for the Hidden Sector (QSHS) is searching for axion dark matter in the mass range from 20ueV and 40ueV. We report development of a pilot tuneable microwave receiver to detect predicted microwave photons arising from axion decay. The experiment will use a high quality factor (Q) normal metal cavity resonator situated in a large stable magnetic field. Ultimately the first stage of the receiver will have a first stage amplification stage based on a quantum-limited superconducting amplifier operating at mK temperature. This poster describes the development of the following amplification and detection schemes, employing a cryogenic (3K) high electron mobility transistor (HEMT) microwave amplifier. Further amplification at room temperature, followed by a double heterodyne down-conversion process leads to signal capture, digitisation and processing, aimed at detecting the expected narrow band low level microwave signal expected from the axion decay.
The critical coupling of a high Q copper cavity to the HEMT amplifier is implemented, together with the measurement of the system noise temperature of the HEMT amplifier using a variable temperature microwave noise source. This allows estimation of the overall sensitivity of the base-line receiver. Combined with the signal capture and software processing the receiver sensitivity allows estimation of the measurement time required to reach the predicted theoretical levels of axion decay. We speculate on the expected final system noise temperature and the issue of efficient and reliable tuning of the high Q cavity.

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