Nuclear Physics Conference 2025

23–25 April 2025

University of Manchester, UK

iop.org

IOP Institute of Physics

Welcome

On behalf of the organising committee, we are pleased to welcome you to the **IOP Nuclear Physics Conference 2025**. This meeting will feature invited talks from national and international speakers, as well as extensive opportunities for contributed talks. A poster session will take place to showcase work and discoveries, and updates and discussions with senior members of the Science and Technology Facilities Council will be provided at a town meeting. The conference is particularly welcoming to PhD students and all are offered the opportunity to present their research.

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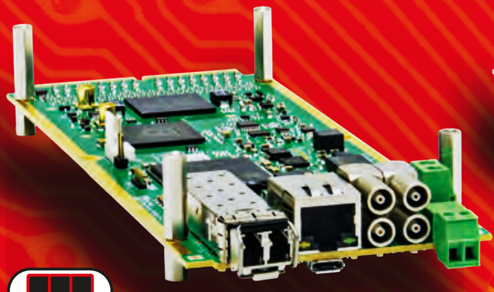

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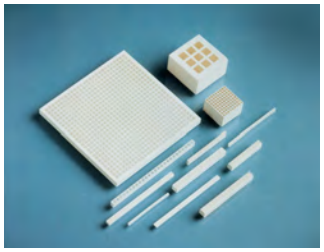

Hilger Crystals

State-of-the-art scintillation and detection solutions for security, defence, and medical industries

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MATERIALS INDEX: SCINTILLATION CRYSTALS

- Bismuth Germanate – BGO - $Bi_4Ge_3O_{12}$
- Cadmium Tungstate - $CdWO_4$
- Caesium Iodide - CsI
- CLYC - Cs_2LiYCl_6(Ce)
- Europium doped Calcium Fluoride - CaF_2 (Eu)
- GLuGAG - $(Gd,Lu)_{3},(GaAl)_{5},O_{12}$ (Ce)
- Lutetium Yttrium Silicate - LYSO(Ce)
- Sodium doped Caesium Iodide - CsI(Na)
- Sodium Iodide - NaI
- Thallium doped Caesium Iodide - CsI(Tl)
- Thallium doped Sodium Iodide - NaI(Tl)
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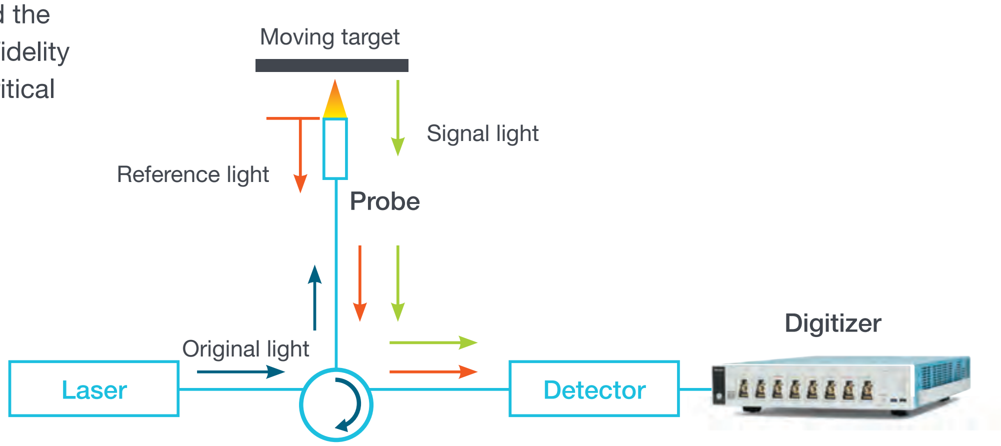

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Invited Speakers

Plenary Speakers

- Dr Lee Barnby (University of Derby, UK)
- Dr Iain Darby (UKNNL, UK)

Invited Speakers

- Sonia Bacca (Johannes Gutenberg-Universität Mainz, Germany)
- Alison Bruce (University of Brighton, UK)
- Andreas Ekström (Chalmers University of Technology, Sweden)
- Jacklyn Gates (Lawrence Berkeley National Laboratory, USA)
- David Jenkins (University of York, UK)
- Ben Kay (Argonne National Laboratory, USA)
- Louis Lalanne (IPHC, CNRS, Strasbourg, France)
- Claudia Lederer-Woods (University of Edinburgh, UK)
- Silvia Leoni (INFN, Milan, Italy)
- Giuseppe Lorusso (National Physical Laboratory, UK)
- Kei Minamisono (Michigan State University, USA)
- Rachel Montgomery (University of Glasgow, UK)
- Refilwe Setso (University of York, UK)
- Jagjit Singh (University of Manchester, UK)
- Alex Smith (University of York, UK)
- Heather Williams (The Christie NHS Foundation Trust, UK)
- Matt Williams (University of Surrey, UK)

Oral Presentations

24Mg (n,n’) measurement at n TOF, CERN

Matthew Birch[1], Tobias Wright[1], Giuseppe Lorusso[2]
[1]University of Manchester, [2]National Physical Laboratory
24Mg (n,n’) measurement at n TOF, CERN

M. Birch1,2, C. Petrone3, M. Bacak1,4, T. Wright1, G. Lorusso2, N. Colonna5, M. Boromiza3, N. Patronis6, A. Negret3, N. Kalantar-Nayestanaki7, M. Kavatsyuk7, D. Jenkins8, P. Finocchiaro9, S. Amaducci9, L. Cosentino9, D. Cano-Ott10 and the n TOF collaboration11
.
November 4, 2024
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2National Physical Laboratory, Teddington, UK
3Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, Romania
4European Organization for Nuclear Research (CERN), Switzerland
5INFN, sezione di Bari, Bari, Italy
6University of Ioannina, Greece
7ESRIG, University of Groningen, Groningen, Netherlands
8University of York, York, UK
9INFN Laboratori Nazionali del Sud, Catania, Italy
10Centro de Investigaciones Energ´eticas, Medioambientales y Tecnol´ogicas, Spain
11www.cern.ch/ntof

Abstract
The design and construction of next generation nuclear reactors, both fission and fusion, is critically reliant upon precise knowledge of a broad range of nuclear data. Specifically, cross sections for fast-neutron induced reactions are of particular interest, yet often lack adequate precision and accuracy. Many advanced nuclear technologies in both fusion and fission applications are highly sensitive to the inelastic scattering cross section in the epithermal and fast neutron energy range. Efforts are ongoing to optimise the measurement capabilities for these reactions at the CERN’s “neutron time-of-flight” facility, which provides a white neutron beam up to 100s of MeV neutron energy. To this end, 24Mg(n,n’) has been measured as it represents a good benchmark for facility performance whilst also being important for a number of applications within the nuclear industry. For example, magnesium (as MgF2) has been proposed as one of the main moderator components of beam shaping assemblies for neutron beams in boron neutron capture therapy, whilst also being considered as a major component of the fuels proposed for use in the European Facility for Industrial Transmutation. Five Lanthanum-Bromide (LaBr3(Ce)) scintillators have been used due to their excellent temporal resolution and good energy resolution (3.5% at 661.7 keV). The measurement was conducted using an enriched (98.5%) 422 mg 24Mg sample during five days of beam-time. The inelastic cross section can be resolved up to 25 MeV neutron energy, whilst signals from 24Mg(n,2n)23Mg reactions are still well identified up to 100 MeV. The detectors performed well, without major gain shift or baseline ringing, demonstrating their capacity to provide high-precision data up to 100 MeV.

A feasibility study using an array of LaBr3(Ce) scintillation detectors as a Compton camera for prompt gamma imaging during BNCT

Kiran Nutter[1], Dr Tony Price[1], Prof. Tzany Kokalova[1], Prof. Stuart Green[1,2], Dr Ben Phoenix[1]
[1]University of Birmingham, [2]Queen Elizabeth Hospital Birmingham

Boron Neutron Capture Therapy (BNCT) is a binary cancer therapy where a low energy neutron beam is incident upon a patient who has been administered a tumour-seeking 10B loaded compound. The neutron capture reaction on 10B results in the production of two short range particles, 7Li and 4He, that deposit all of their energies within the targeted cell. However, accurate, online dosimetry during BNCT is challenging as it requires knowledge of both the neutron fluence and 10B concentration in cells. An additional product in the neutron capture reaction on 10B is a 478 keV prompt gamma ray, and if the production vertices of these gamma rays could be imaged by an external camera, the density of the vertices could be used to infer the dose delivered to the patient. In this study, the feasibility of using an array of LaBr3 scintillators as a modified Compton camera for prompt gamma imaging during BNCT was investigated. The initial investigation was performed using Geant4 simulations, and the results from this simulation study were published in Frontiers in Physics. The simulations demonstrated that a phantom containing a 3 cm diameter region of 400 ppm 10B could be reconstructed using clinically relevant neutron fluences. Experimental work to validate, and compare against, the simulations is currently being carried out. The results from both the simulation and experimental work will be presented, along with the methodology associated with the novel Compton camera, details of the reconstruction algorithm and future plans for assessing the dose delivered during BNCT treatment and the impact for patients.

A Modelling Approach to Defining Radiochemical Separation Requirements for Radiometric Assay

Mr Tom Stokes[1,2], Dr Matthew Goodwin[1], Mr Mark Jackson[1], Prof Andrew Boston[2]
[1]AWE, [2]The University of Liverpool

Whilst the equations for calculating detection limits in gamma spectrometry have been established for several decades [1,2], predicting detection limits for a given sample composition is a non-trivial task. This complexity is largely due to the multiple variables impacting gamma spectrometry measurements including detector geometry, sample geometry, sample composition and measurement duration.

For complex multi-radionuclide samples, it may be the case that less-detectable analytes are not measurable via gamma spectrometry alone and, instead, radiochemical separations and purifications are required. By doing so, the Compton continuum created by partial energy deposition of gamma photons from impurity radionuclides can be removed, reducing the measurement background at lower gamma energies and aiding identification and quantification. The success of radiochemical separations therefore affects the detection limit achievable by the subsequent gamma spectrometry measurement. This success can be assessed through three key metrics: radiochemical yield, impurity removal and separation time.

In this work, a high-purity germanium (HPGe) gamma detector has been modelled using the GEANT4 toolkit [3] and validated against empirical measurements. The full energy peak efficiency response of this model was found to be within 4% of measured values across a 10-2500 keV energy range. Automated analysis tools utilising the universal software development kit (U-SDK), developed by Mirion Technologies, have also been developed to analyse the spectra produced during the simulations for detection limits. Analysis of a range of analytes in a variety of sample compositions has been simulated, and the effect on detection limit with differing radiochemical separation outcomes is investigated. The result of this work presents a method to effectively define separation requirements to measure low-level analytes in complex samples.

[1] Currie, L.A., 1968. Limits for qualitative detection and quantitative determination. Application to radiochemistry. Analytical chemistry, 40(3), pp.586-593.

[2] Kanisch, G., 2017. Detection limit calculations for peak evaluation methods in HPGe gamma-ray spectrometry according to ISO 11929. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 855, pp.118-132.

[3] Agostinelli, S., Allison, J., Amako, K.A., Apostolakis, J., Araujo, H., Arce, P., Asai, M., Axen, D., Banerjee, S., Barrand, G.J.N.I. and Behner, F., 2003. GEANT4—a simulation toolkit. Nuclear instruments and methods in physics research section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 506(3), pp.250-303.

A new charge-reset method for determining Auger-electron emission multiplicities

Jacob Heery[1], The ATLAS 2123 Collaboration
[1]University Of Surrey

Targeted internal radiotherapy and patient-specific treatment is of great importance for treating advanced staged cancers, allowing for personalised radiotherapeutics to be deployed to treat otherwise unresponsive cancers. Within the radiotherapeutic armoury, Auger-electron therapy is of particular interest since the low-energy electrons deposit their energy over short distances (on the scale of nm-μm), resulting in a high linear energy transfer (LET), and allowing for precise targeting of cancerous cells. Auger electrons are emitted during atomic relaxation following the creation of a vacancy in an inner-atomic shell, for example, following electron capture decay or internal conversion. During the entire relaxation process multiple Auger electrons can be emitted into the surrounding environment. For determining the impact of Auger electron emission, precise nuclear data measurements are required, not just for the energy of the emitted electrons, but also the multiplicity, i.e. the average number of electrons emitted.

A new charge-reset method (CRM) has been developed for determining emission multiplicities of Auger electrons following the creation of a vacancy in an inner-atomic orbital. Excited states are populated through below-barrier Coulomb-excitation reactions. The de-excitation of states by internal conversion will then trigger a series of Auger cascades, increasing the charge state of the ion. The distribution of charge states can be measured by passing the ions through an electromagnetic spectrometer. The addition of a charge reset foil, placed between the target and the spectrometer, resets the atomic charge state of scattered ions to a nominal value. An internal conversion that occurs after the reset foil then induces an Auger cascade and so affects the distribution of charge states measured by the electromagnetic spectrometer. Here, I will present initial results, using the FMA+GRETINA setup at Argonne National Laboratory, to determining Auger-electron emission multiplicities in ^{197}Au, daughter of ^{197}Hg, a candidate for targeted Auger-electron therapy.

A Platform for Cross-section Measurements on the National Ignition Facility

Dr Daniel Pitman-weymouth[1]
[1]AWE Nuclear Security Technologies

Understanding neutron induced reaction cross–sections is of great importance to a variety of fields from nuclear astrophysics, to criticality safety and defence. Unfortunately, the study of these reactions has been broadly restricted to stable isotopes, due to both technological development and radiation safety issues. In a collaboration between the radiochemistry team at Lawrence Livermore National Laboratory and physicists at AWE, a new platform for the measurement of neutron induced reaction cross–sections on the National Ignition Facility (NIF) has been developed.

The new platform exploits the intense neutron yield of NIF combined with chemical capsule–doping techniques to achieve cross–section measurements on targets of only 1012 atoms. The nanograms of target material required for such measurements negates radiation safety issues, enabling the study of a broader number of off–stability isotopes. Further, the intense pulse of up to 10^18 neutrons facilitates the measurement of reactions on shorter lived species which are not possible with traditional irradiation methods and opens the door to studying multi–order reactions, and reactions which proceed through isomeric states.

In this talk the methodology of neutron induced cross–section measurements on NIF will be presented, including the recent results of an 89Y(n,2n)88Y experiment. In addition, progress towards the upcoming measurement of s–process branching point reaction 171Tm(n,γ)172Tm will also be discussed, along with plans to pursue isomeric reaction pathways.

Alpha-particle condensation in diluted 16O at finite temperatures

Miriam Davies[1], Esra Yüksel[1], Ebran J-P[2,3], Elias Khan[4,5], Paul Stevenson[1]
[1]School of Mathematics and Physics, University of Surrey, [2]CEA,DAM,DIF, [3]Université Paris-Saclay, CEA, Laboratoire Matière en Conditions Extrêmes, [4]IJCLab, Université Paris-Saclay, CNRS/IN2P3, [5]Insitut Universitaire de France (IUF)

Cluster phenomena pose an exciting opportunity to investigate the various superfluid behaviours of atomic nuclei. Predictions regarding the occurrence of cluster states in light nuclei date back to 1937, when various possible arrangements of neutrons and protons into distinct groups, such as alpha particles and dineutrons, were proposed [1][2], and studies regarding the clustering in nuclei remains an active field of research [3][4].

This talk outlines the effect of temperature on α-particle clustering in the diluted 16O nucleus, using the multi-constrained finite-temperature relativistic Hartree-Bogoliubov model with the DD-ME2 interaction [5]. It has been known that under the dilution of 16O, the nucleus undergoes a Mott-like transition at a critical density from a homogeneous to a localised configuration characterised by α-particle clustering. This transition is accompanied by the development of a finite non-axial octupole deformation. We studied the interplay between the onset of localisation under nuclear dilution and the suppression of deformation and α-particle clustering due to increasing temperature. By investigating the density-temperature quantum phase diagram, our findings indicate that temperature delays the formation of non-axial octupole deformation and α-particle clustering in dilute environments. Furthermore, there is a maximum temperature beyond which clustering no longer emerges.

[1] J.A. Wheeler, Phys. Rev. 52, 1107 (1937)
[2] W. Wefelmeier, Z. Phys. 107, 332 (1937)
[3] B. Zhou, Y. Funaki, H. Horiuchi, et al. Nat Commun 14, 8206 (2023)
[4] J-P. Ebran, M. Girod, E. Khan, R.D. Lasseri, P. Schuck, Phys. Rev. C 102, 014305 (2020)
[5] M. Davies, E. Yüksel, J-P. Ebran, E. Khan, and P. Stevenson, in preparation.

Bridging Scales, Connecting Fields: An Introduction to the IPPP for the Nuclear Physics Community

Michael Spannowsky

The Institute for Particle Physics Phenomenology (IPPP) is the UK's national centre for theoretical particle physics, with a broad research scope that spans precision Standard Model studies, collider and neutrino phenomenology, and the search for new physics. In this talk, I will introduce the IPPP, including a brief historical overview, and outline its current role within the international theory community. I will then explore a number of areas where nuclear and particle physics naturally intersect, and where closer collaboration is becoming increasingly important. These include both longstanding questions and emerging directions, often unified by the need for precision, control of nuclear theory input, and modern computational methods. The goal is to highlight opportunities for dialogue and collaboration at the interface of our communities.

Calorimeter Construction for Luminosity Monitoring at the Electron Ion Collider.

Alex Smith[1]
[1]University Of York

The electron ion collider is a new accelerator facility planned to be built at Brookhaven National Laboratory, colliding electrons with ion species from protons to gold. Both beams will have the ability to be polarised, and the accelerator will operate at very high luminosities. To achieve the scientific aims of the project, which include probing the distribution of spin and momentum within nuclei as well as studying quark confinement, the luminosity must be measured to one percent absolute uncertainty.

The luminosity monitoring system is designed to measure the energy and rate of bremsstrahlung photons produced at the interaction point, via both a direct measurement and a pair spectrometer, and from this determine the luminosity. This will require three calorimeters, planned to be constructed using a novel technique to meet the requirements placed on the system.

The University of York is leading the effort on developing the pair spectrometer system, and this talk will detail the current progress on its design and construction. Of particular focus will be the calorimeters, and on the efforts to produce and test detector prototypes.

Characterization of an ASIC-based readout system for the SAND experiment

Camilla Maggio[1], Andrea Abba[2], Vincenzo Bottiglieri[1], Antonio Di Domenico[3,4], Paolo Gauzzi[3,4], Annalisa Mati[1], Daniele Ninci[1], Andrea Picchi[1], Carlo Tintori[1], Yuri Venturini[1]

[1]CAEN SpA, [2]Nuclear Instruments srl, [3]Dipartimento di Fisica, Sapienza Università di Roma , [4]INFN Sezione di Roma

The System for on-Axis Neutrino Detection (SAND), part of the Deep Underground Neutrino Experiment (DUNE), is designed to monitor the long-term stability of the neutrino beam at Fermilab. SAND reuses the lead scintillating-fiber electromagnetic calorimeter (ECAL) of the KLOE experiment with excellent time and energy resolutions. The calorimeter is read-out by approximately 5000 PMTs requiring a cost-effective, high-channel-density readout system capable of matching the stringent ECAL performance.
Traditional analog electronics impose excessive dead time, while fully digital solutions present significant cost constraints. An ASIC-based approach provides a viable alternative, balancing performance and scalability.
This study evaluates the Radioroc front-end ASIC for energy measurements, complemented by timing measurements performed with the FERS A5203 picoTDC unit. The tests were carried out using a signal generator producing pulses that mimic PMT signals, with a programmable attenuator enabling an amplitude sweep over a 60 dB range before reaching the Radioroc. In the final detector configuration, the Radioroc front-end, originally designed for SiPM readout, will interface with ECAL PMTs through a fast-inverting amplifier integrated into the PMT housing.
Energy resolution was assessed by comparing the Radioroc ADC chain with the ToT-based estimation from FERS A5203. Results indicate that for large signals (>100 mV), the ADC provides superior resolution, whereas for smaller signals, the ToT method proves to be more effective. The complementarity of these approaches extends the dynamic range of acquired energies, enhancing measurement capabilities.
These results appear very promising in satisfying both energy and time resolutions requirements for the SAND calorimeter, confirming the suitability of this ASIC-based solution for high-density readout in neutrino physics experiments.

Chiral forces and uncertainty quantification in ab initio nuclear structure predictions

Andreas Ekström[1]
[1]Chalmers University of Technology

The ab initio method is a systematically improvable approach for quantitatively describing nuclei using the finest resolution scale possible while maximizing its predictive capabilities. In this talk, I will highlight recent advances in ab initio nuclear structure calculations, focusing on developments in chiral nuclear forces and methods for estimating uncertainties in theoretical predictions.

Collinear resonance ionization spectroscopy of neutron-deficient antimony

Abigail McGlone[1]
[1]University Of Manchester

Recently, significant effort has been invested into laser spectroscopy in the region surrounding the doubly magic 100Sn at various ISOL facilities [1-4]. Antimony (Z=51) has a single proton above the magic tin (Z=50) core and as such is an ideal candidate to test the single-particle shell model. Investigations into the neutron-deficient antimony study the evolution of nuclear structure between the neutron shell closures (50<N<82). Neutron-deficient isotopes of antimony have been measured at the CRIS experiment at ISOLDE, CERN. This talk will present an overview of the CRIS technique as a method for performing high precision, sensitive laser spectroscopy measurements of radioactive isotopes.

Building on previous investigations at ISOLDE [5,6], CRIS has performed measurements of 111-123 Sb, including the first laser spectroscopy measurement of 111 Sb. Initial data analysis will be presented, in comparison to this previous campaign. Measurements of the hyperfine structure, nuclear spins, electromagnetic moments and changes in mean square charge radii will be presented, studying the evolution of these nuclear observables across the isotopic chain, in comparison to single-particle values.

[1] N. Frömmgen et al., Eur. Phys. J. D 69, 164 (2015)
[2] M. Reponen et al. Nat. Commun 12, 4596 (2021)
[3] A. R. Vernon et al., Nature 607, 260-265 (2022)
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Comprehensive Characterisation of the A601 AGATA Detector: Insights from Analogue, and Advanced Scanning Measurements

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This research presents a comprehensive experimental investigation of the A601 AGATA detector, focusing on its performance through analogue and characterisation measurements. Analogue measurements assessed energy resolution, efficiency, and the effects of bias voltage on the detector's performance, with results compared to the manufacturer-provided Mirion values. These comparisons revealed critical insights, including energy resolution variations across all segments and the core, as well as differences in relative and absolute efficiency. Bias voltage scans further established the depletion voltage, confirming operational thresholds necessary for optimal detector performance.
Front face singles scans were conducted to map the detector's response uniformity and sensitivity across its surface. The accompanying figure illustrates the total number of Fold-1 photopeak events at each detector position, where all energy was entirely contained within a single segment and met the energy threshold of 662 ± 4 keV.

This intensity map highlights the spatial distribution of gamma-ray interactions, revealing higher count rates near segment centres and reduced sensitivity at segment boundaries. These scans provided valuable insights into charge collection efficiency and positional dependence of detector performance.
Coincidence measurements employed AGATA and BGO detectors in a 90-degree scattering geometry, enabling high-resolution three-dimensional mapping of gamma-ray interactions. AGATA detected 374 keV while BGO captured 288 keV from scattered photons, offering detailed insights into depth sensitivity and the effects of interaction positions on charge collection and segment boundaries.
Key findings include confirmation of the detector's full depletion voltage, systematic evaluation of energy resolution and efficiency, and enhanced understanding of its spatial and depth response. This work establishes methodologies for optimizing segmented germanium detectors in high-resolution gamma-ray spectroscopy applications.

Creating a beta-gamma detection system for fuel condition monitoring of spent nuclear fuel rods and operational nuclear reactors

Miss Sifa Poulton[1,2], Prof Patrick Regan[1,2], Dr Steven Bell[2], Dr Robert Shearman[2], Dr Matthew Ryan[4], Dr Matthew Goodwin[3]

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The detection of radioxenon isotopes can be used to monitor the condition of nuclear fuel rods throughout their lifecycle. The detection of any xenon reveals the presence of cracked cladding while the isotopic ratio detected can be used to monitor the criticality of the fuel using principles adapted from the International Monitoring System [1]. Some gas-cooled reactors use gamma detectors to monitor the reactor [2], but using a beta-gamma coincidence system improves sensitivity to weak signals and has shown to be effective with radioactive noble gases [3]. This talk presents preliminary results for a detector system comprising a PIPSBox [4] and HPGe detector [5].

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Cyclotron production of manganese isotopes via alpha-beam irradiation of nickel in the energy range of 0–24 MeV nuclear reactions

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Manganese isotopes have recently found increasing potential applications in various fields, including nuclear medicine. In the present work, the excitation functions for some manganese isotopes have been measured from deuteron-induced nuclear reactions on natural nickel metals from 24 MeV energy down to threshold using the well-established stacked-foil activation procedure. The activation products were measured for emitted characteristic gamma lines using HPGe γ-ray spectrometry. The data was used for the calculation of cross sections of the radionuclides of interests, the 52,54,56Mn. The measured cross sections have also been compared with the all accessed literature data and also the theoretical prediction of Talys code via its latest library, the TENDL-2021. Present work shows reasonable agreement with the literature data for the isotopes of interest. Our work shows that, on the other hand, the theoretical data extracted from the TENDL-2021 library could not reproduce the experimental data of this study. The present measured data could have potential applications in improving the predicting capability of the Talys nuclear reactions model code as well as serve as additional data for nuclear reactions cross sections database.

Development of a gamma radiation detector system for localisation and mapping of distributed sources.

Miss Refilwe Setso[1,2], Dr Oscar Chamunorwa Kureba[2], Professor David Jenkins[1]
[1]University Of York, Department of Physics, [2]Botswana International University of Science and Technology, Department of Physics and Astronomy

Identifying contaminated hotspots requires mapping and localisation of radioactive sources by detecting ionizing gamma-ray emissions. Such techniques show potential applications in nuclear decommissioning and environmental monitoring. There are, however, some challenges in localising distributed sources as there is often a ‘blurring’ effect. This overestimates the edges of the radiation source. A scanning system is proposed in this study, which features a commercial robotic arm, the Eva arm, fitted with a compact Bismuth Germanate (BGO) detector to scan the region of interest in a raster pattern. This point grid scanning method will allow for more accurate source localisation and mapping. A mock-up of a radiation-contaminated environment was simulated to test the system’s detection capabilities. All potassium-rich materials consist of approximately 0.012% of the naturally occurring radioisotope K-40, which emits 1460 keV gamma rays about 11% of the time during its decay. The directional detection of these 1460 keV gamma rays will give a picture of the radiation intensity across the wall. By overlaying the positional data from the robot arm with the radiation intensity data from the gamma radiation sensor, we can generate 2D radiation maps. The maps will highlight the distribution of the gamma source within the wall, guiding the extraction of the contamination. The presentation will shed more light on the technical details of the proposed development of a gamma detector system.

Direct measurements of astrophysical reactions with radioactive beams

Dr Matthew Williams[1]
[1]University Of Surrey

Many nuclear processes that produced elements we observe today involve short-lived radioactive nuclei, which can only be formed in extreme astrophysical environments such as supernovae and neutron star mergers (NSMs). The properties of exotic nuclei and their reactions are key to understanding nucleosynthesis in these violent events, feeding back into long-standing problems on the origin of elements heavier than iron. While experimentally challenging, direct measurements of key reaction cross-sections using radioactive beams are becoming more feasible than ever before, due to the advent of new facilities and equipment. In this talk, I will present recent efforts to measure such reactions at TRIUMF and discuss plans to exploit new facilities, such as FRIB and ARIEL, for similar measurements in the future.

ELECTROWEAK REACTIONS WITH LIGHT (AND NOT SO LIGHT) NUCLEI

Sonia Bacca[1]
[1]Johannes Gutenberg University

Atomic nuclei are central to electroweak processes driving the synthesis of chemical elements, serving as laboratories for testing fundamental interactions, and offering critical insights into the Standard Model of particle physics. Advances in nuclear theory and high-performance computing now enable unified calculations of nuclear structure and reactions for increasingly complex systems, along with robust estimates of theoretical uncertainties. In this talk, I will highlight recent breakthroughs in ab initio approaches for light (and not so light) nuclei, showcasing their role in addressing contemporary challenges such as few-body reactions, giant dipole resonances, and lepton-nucleus cross sections.

Elucidating Strangeness with Electromagnetic Probes

Asli Acar[1]
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Theory models predict a total of 44 cascade baryons below 2.5 GeV. Currently, there are only six cascade states that have at least a three-star rating in the PDG, with the production mechanism of these states still remaining mostly elusive. The study of cascades is appealing from a theoretical perspective due to the symmetry from two medium-mass s-quarks. Additionally, cascade studies are promising as a tool to differentiate genuine quark states from hadronic molecules, since we have the ability to measure the line shape in various decay branches with unprecedented precision. This work focuses on the analysis of CLAS12 data collected at Jefferson Lab to study the production mechanisms and decays of excited cascade baryon states that are not well established or missing, with the aim of determining their branching ratios and quantum numbers.

Experimental Investigation of Isomeric Decays in Neutron-Rich 183,184Hf isotopes Using the KISS Facility

Mr Siddharth Doshi[1], Dr S. Pascu[2], Prof. Zs. Podolyak[2], Prof. P.M Walker[2], Prof. A.M. Bruce[1], Y. Hirayama[3], Y.X. Watanabe[3], P. Schury[3], S. Kimura[3], M. Wada[3], A. Takamine[4], J. Yap[4], H. Watanabe[5], J. Chen[5], G. Bartman[2], G. Hudson-Chang[2,4], V. Chandrakumar[2,4], S. Dutt[6], S. Guo[6], G. Li[6], J. Gada[6], Z. Liu[6], P. Ma[6], Y. Litvinov[7], F.G. Kondev[8], G.J. Lane[9], J.G. Cubiss[10]

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The neutron-rich region of the nuclear chart, around mass numbers A∼180−190, is a region of interest for studying nuclear properties like high-spin isomeric states and shape transitions. These nuclei are predicted to undergo a prolate-to-oblate shape/phase transition, which is expected to result in prolate high-K isomers decaying to oblate low-K states1,2). Exploring this region is difficult due to the low production rates of neutron-rich isotopes and the refractory nature of elements, especially in the hafnium (Z=72) to platinum (Z=78) range, constraining possibilities for comprehensive studies.

A recent experiment at the KEK Isotope Separation System (KISS), at RIKEN, has investigated the decay properties of neutron-rich hafnium isotopes produced through multi-nucleon transfer (MNT) reactions. A 136Xe beam at 7.2 MeV/nucleon was directed onto a tungsten target, yielding neutron-rich isotopes that were slowed, neutralized, and captured in a gas cell. Laser resonance ionization was used to selectively ionize hafnium isotopes, followed by mass separation using Isotope Separation On-Line (ISOL) techniques. The isotopes were implanted onto Mylar tape surrounded by a detector system consisting of a multi-segmented proportional gas counter (MSPGC) for beta spectroscopy and high-purity-germanium clover detectors for gamma-ray spectroscopy, with measurements taken under precise timing conditions to separate isomeric and prompt events.

The current results indicate the successful production of neutron-rich 183,184Hf+ ions. Further analysis is underway and has begun to provide valuable insights into the isomers, their lifetimes as well as their nuclear properties. The oral presentation will give a progress report on the state of the analysis, highlighting the potential capabilities of the KISS facility.

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Exploring the structure and reactions of two-neutron halos at the low-Z coast of the island of inversion

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The advent of cutting-edge Rare Isotope Beam (RIB) facilities has revolutionized our exploration of the nuclear landscape, providing us access to the neutron-rich shores of the nuclear chart. This exciting era has triggered intense theoretical and experimental investigations into exotic nuclear structures, particularly two-neutron halos at the low-Z coast of the Island of Inversion with and around the neutron magic numbers N=20 and N=28 [1-9].

In this talk, I will discuss the few-body insights into the structure and reactions of two-neutron halos with and around N=20 and N=28. I will explore key structure observables of two-neutron halos within a three-body (core+n+n) framework based on the hyperspherical-harmonics formalism by using an analytical-transformed harmonic-oscillator basis. This includes configuration mixing, matter radius, neutron-neutron correlations, and the electric dipole (E1) response. For the reaction aspect, I will discuss the total reaction cross-section estimates within the conventional Glauber reaction theory. The discussion will cover results for the heaviest observed 2n-halo nucleus, 29F [2-4], as well as potential two-neutron halo candidates in fluorine (31F) [7], sodium (39Na) [9], and magnesium (40Mg) [9] isotopes.

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Exploring The Use of the Trojan Horse Method for Radiative Neutron Capture Reactions

Dominik Stajkowski[1], Prof. Carl Wheldon[1], Prof. Tzany Kokalova[1], Dr Jack Bishop[1], Dr Neil Curtis[1], Dr Stuart Pirrie[1]
[1]University Of Birmingham

Cross section data for (n,γ) reactions are needed for nuclear physics applications, such as fusion, and fundamental research. These data are challenging to obtain via direct neutron irradiation, as it requires specialised facilities and techniques, such as having neutron time-of-flight capability. The Trojan Horse Method (THM) is proposed as a more accessible alternative for obtaining these data.

The THM uses the clustered nature of nuclei and a quasi-free mechanism to investigate reactions at low (often sub-Coulomb) energies. So far, the method has been successfully applied to nuclear reactions of astrophysical relevance (e.g. Ref. [1] and references within). The THM has also been used to study neutron-induced reactions in light isotopes, such as 3He(n,p)3H via the 2H(3He,pp)3H reaction [2] and investigations of neutron-induced reactions on heavier (A~28) species [3]. This technique can also be used to obtain radiative capture cross-sections, as was theoretically presented by A. M. Mukhamedzanov et al. [4], although this has not yet been attempted experimentally.

To investigate THM's capability for neutron radiative capture, the 2H(27Al,pγ)28Al THM reaction will be used to measure the n(27Al,γ)28Al cross section at The University of Birmingham MC40 Cyclotron Facility using a deuteron beam. The results of the THM experiment will be validated using the new High Flux Accelerator-Driven Neutron Facility at The University of Birmingham, commissioned in December 2023.

The relevant theory and considerations for designing a THM experiment will be discussed using the above-mentioned reaction as an example. The simulation results will be presented.

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Exploring unphysical quadrupole triaxiality in 200,202Hg with Coulomb excitation

Mr Greg Willmott[1]
[1]University of Surrey

Nuclear deformation is often probed via the technique of Coulomb excitation and interpreted with the rigid-rotor model. Using the results of Spear et al, 1980, both 200 and 202Hg end up with unphysical results as the observed 2+ quadrupole moment exceeds the prediction of an axial rotor. The understanding of the quadrupole deformation in this mass region is key to interpreting EDM measurements using 199Hg. This discrepancy motivated an experiment carried out at Argonne National Laboratory in December 2023 to remeasure the quadrupole moments and reduced transition probabilities (B(E2)) of the low-lying excited states of these nuclei. The experiment was carried out in inverse kinematics using the Gammasphere HPGe array and an S3 type DSSD. Targets of Ti and 120Sn were used, and the beam energies were 'safe'. The analysis is ongoing and has included two Geant4 simulations. I will present the results of simulations, as well as preliminary analysis of the experimental data, laying out the future steps and challenges.

Gaussian Processes: Machine Learning for Observable Interpolation and Data Analysis

Ryan Ferguson[1]
[1]University Of Glasgow

Current studies of the hadron spectrum are limited by the accuracy and consistency of datasets. Information derived from theory models often requires fits to points at specific values of kinematic variables, which needs interpolation between measured points. In sparse data sets the quantification of uncertainties is problematic.

Machine Learning is a powerful tool that can be used to build an interpolated dataset, with quantification of uncertainties. The primary focus here is one type of machine learning called a Gaussian Process (GP). By using Bayesian inference and calculating the covariance between known datapoints, the GP can predict the mean and standard deviation of other, unknown, datapoints, with no theoretical model dependence. The GP model presented here uses a bespoke method to find the optimal hyperparameters. The GP model built here is checked and tested using Legendre polynomials to ensure it is unbiased and gives accurate predictions. The GP can also be used to give a prediction between conflicting and potentially inconsistent datasets of the same physics observable.

GEn-RP: Neutron Electric Form Factor Measurement at $Q^2 = 4.4\ (GeV/c)^2$ via Charge Exchange Recoil Polarimetry at Jefferson Lab

Andrew Cheyne[1]
[1]University Of Glasgow, [2]Jefferson Lab

The electromagnetic form factors of nucleons are fundamental observables that provide crucial constraints for theoretical predictions of hadron structure. The Super BigBite Spectrometer (SBS) program at Jefferson Lab (JLab) comprises a suite of experiments measuring nucleon electromagnetic form factors at high momentum transfer.

This presentation focuses on GEn-RP, which aims to measure the neutron electric form factor (GEn) at the highest Q^2 to date using recoil polarimetry (RP).

The experiment makes use of CEBAF's high-luminosity, highly polarised electron beam scattered from an unpolarised liquid deuterium target. By measuring the polarisation transfer to recoiling neutrons, GEn can be extracted from the ratio of transverse to longitudinal polarisation components (Pt/Pl).

At high momentum transfer, traditional neutron polarimetry via np→np scattering becomes challenging due to decreasing analysing power. GEn-RP aims to validate the charge exchange (np→pn) polarimetry technique that maintains analysing power at higher Q^2, enabling future form factor measurements at unprecedented energies. The experiment also incorporates a secondary channel using a side plane hodoscope to measure wide-angle np→np scattering.

Data collection was completed in Hall A at Jefferson Lab between April 16 and May 14, 2024, using typical beam current of 10-12 µA on LD2 at $Q^2 = 4.4\ (GeV/c)^2$. Preliminary analysis reveals expected azimuthal asymmetry, with ongoing calibration work to refine these results.

This presentation will detail the experimental setup, analysis procedures, and preliminary findings from the collaboration.

Identification of excited states in Ba-114 using recoil-decay tagging

Ben Hogg[1]
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Octupole collectivity is present in atomic nuclei which adopt a reflection-asymmetric shape, said to resemble that of a pear. Theoretical and experimental studies of reflection-asymmetry in nuclei have been reviewed in Refs. [1, 2]. There are several regions of enhanced octupole correlations on the nuclear chart, most notably in the light actinides, close to Ra-224, and in the neutron-rich lanthanides, around Ba-146. Enhanced octupole correlations are also expected to occur in the neutron-deficient N=Z=56 region, close to Ba-112 [3]. In these nuclei, negative-parity states and enhanced E1 transitions characteristic of octupole deformation have been observed in Xe-112 [4], Xe-114 [5, 6, 7] and Ba-118 [8]. Theoretical predictions suggest that octupole correlations are larger for Z = 56 than for Z = 54. The present experimental knowledge of nuclei around Ba-112 is limited due to low production cross sections using stable beams and targets. Presently, there is no spectroscopic information known amongst the even-even neutron-deficient barium nuclei with A < 118. Although the N=Z nucleus Ba-112 remains out of reach in gamma-ray spectroscopy experiments, new techniques suggest that the identification of excited states in N=Z+2 Ba-114 is possible. Accordingly, an experiment has been carried out at the Accelerator Laboratory at the University of Jyväskylä. The experiment used a beam of Ni-58 with an intensity up to 10 pnA on Ni-58 targets. The Jurogam-3 spectrometer detected prompt gamma rays around the reaction site. Recoiling evaporation residues were transported by the vacuum-mode recoil-separator MARA and were implanted into a double-sided silicon-strip detector behind the MARA focal plane. A silicon-diode box and three BEGe detectors were positioned around the DSSD. Identification of Ba-114 will be achieved by using the alpha-decays of implanted nuclei in the recoil-decay tagging method. Recoil-decay tagging will also be attempted using the beta-delayed proton decay of Ba-114. It is expected that the data will allow excited states in Ba-114 to be identified along with the potential assignment of interleaving negative-parity states and E1 gamma-ray transitions, indicative of octupole-deformation in even-A nuclei. The analysis is in progress and the preliminary results will be presented.

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Identification of parity-doublet bands in odd-Z 223Pa

Dr James Keatings[1]
[1]University Of The West Of Scotland

The presence of low-lying negative-parity states which interleave with positive-parity states has become a spectroscopic signature of reflection-asymmetric octupole deformation. This type of deformation has been identified in a number of nuclei in several regions of the nuclear chart, with the largest octupole deformations observed near ^{224}Th (Z=90, N=134). The majority of experimental information in this region is for even-even nuclei with Z<90, due to the relative ease of producing these nuclei, but recent theoretical predictions have shown that the region of octupole deformation in the light actinides may extend further north-west than previously thought. In order to probe the extent of octupole correlations above Z=90, the Z=91 ^{223}Pa nucleus has been studied. The Jurogam3 gamma-ray spectrometer has been used with the RITU gas-filled recoil spectrometer, and an array of detectors including double-sided silicon strip detectors are the focal place of RITU. The ^{223}Pa nuclei were produced in a ^{208}Pb(^{19}F,4n) reaction and identified using the recoil-decay tagging method. Gamma-ray spectroscopy is being used to study the excitation energies and B(E1)/B(E2) ratios within the parity-doublet bands, which will give information about the octupole correlations in this nucleus. The current state of the analysis will be presented.

Impact of the meson-exchange currents on the magnetic dipole moments in odd near doubly magic nuclei analyzed within nuclear DFT framework

Herlik Wibowo[1], Dr. Rui Han[2], Ms. Betania Camille Backes[1], Prof. Jacek Dobaczewski[1], Prof. Markus Kortelainen[2]
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The study of nuclear electromagnetic moments plays a crucial role in understanding the structure of atomic nuclei [1]. While the electric quadrupole moments in atomic nuclei indicate nuclear deformation and collectivity, the magnetic dipole moments are sensitive to the single-particle properties of valence nucleons. In our nuclear DFT methodology, the intrinsic electric quadrupole and magnetic dipole moments in odd nuclei are generated by the self-consistent shape and spin core polarization effects induced by the unpaired nucleon. The spectroscopic moments of angular-momentum-projected wave functions are determined and compared with the available experimental data without introducing effective charges and g-factors. We have applied our methodology to calculate the spectroscopic moments in heavy deformed open-shell odd nuclei in several regions of the nuclear chart [2, 3, 4].

In contrast to the predicted quadrupole moments that generally reproduce the data very well, the calculated magnetic dipole moments may deviate from the data sometimes by a significant amount. To improve the agreement with the data, following Refs. [5, 6], we extended the one-body magnetic dipole moment operator used in the nuclear DFT by two-body terms derived from the meson-exchange currents. We have incorporated these terms into our recent calculations for the odd-nuclei around eight doubly magic nuclei (O-16, Ca-40, Ca-48, Ni-56, Ni-78, Sn-100, Sn-132, and Pb-208). In this talk, the impact of the inclusion of the meson-exchange currents on the spectroscopic magnetic dipole moments will be discussed.

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Introducing thermal effects into neutron capture cross sections for the (n,188Os) reaction

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The neutron capture process plays a vital role in the creation of the heavy nuclei in the universe. The environments involved in these processes are in general high in temperature and are split into two different reaction mechanisms, the slow and rapid neutron capture regimes. Each of these is dependent on the temperature of the environment and the neutron density, where the slow neutron capture process takes place in the nucleosynthesis of stars and the rapid neutron capture process takes place in explosive astrophysical events. The temperature range of these environments is as low as 5 keV for the slow capture regime, and as high as 10 MeV for the fast capture regime. Here, the Time-Dependent Coupled Channels Wave-Packet (TDCCWP) method utilizes a quantum dynamical model with a many-body nuclear potential while also including these thermal effects in the initial state of the model. Static methods, such as CCFULL (Hagino, 2014), have previously been used for similar coupled channels calculations by solving the coupled channels equations of motion. However, the inclusion of these thermal effects in the calculation of neutron capture cross sections has not been explored. The differences in cross sections are compared to first check the validity of TDCCWP, a dynamic model, with CCFULL, a static model, excluding any thermal effects. The importance of the temperature of the environment, particularly at thermal energies larger than 0.1 MeV, is highlighted by the increase in reaction rates when thermal effects are included in TDCWWP, as shown in the attached figure.

Investigating strange baryons and charm production with the upgraded ALICE Inner Tracker

Dr Lee Barnby[1], ALICE Collaboration[2]
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The ALICE experiment at the LHC investigates the properties of the quark-gluon plasma (QGP), a high-temperature phase of matter where quarks are no longer confined to hadrons. It forms in high-energy heavy-ion collisions before expanding, cooling, and hadronizing. Characterising the relative production of different hadron species, their momentum spectra, and correlations helps understand the QGP and its evolution.

The ALICE inner tracker, upgraded during the LHC's long shutdown, began operating in 2022. It is a 7-layer silicon pixel detector with Monolithic Active Pixel Sensor (MAPS) technology, substantially improving tracking resolution near the collision vertex. This enables the identification of charmed hadron decays, with typical cτ values of order 100 µm into stable charged daughters, distinguishable from charged tracks direct from the primary collision.

Since the original design report, it was realised that the detector can also directly track short-lived charged particles crossing several silicon layers, opening up new physics opportunities.

Tracking strange baryons with a cτ of order cm leads to several interesting applications. Multi-strange baryons can be produced in the decay of charmed baryons, such as $\Omega^{0}c \rightarrow \Omega^{-} \pi$ followed by $\Omega^{-} \rightarrow \Lambda K^{-}$. The new precision information about the Ω allows this population to be distinguished, providing insights into the distribution of charm quarks among various charmed hadrons at hadronization.

Charged Σ baryons decaying to a charged plus neutral particle can also now be identified. This provides an opportunity to investigate their interactions, using pairs with low relative momentum, with other baryons using correlation techniques. This can have astrophysical implications, as these strange baryons should be included in the equation of state of 'neutron' stars.

Investigating the Internal Decay Characteristics of Gold Nuclei Beyond the N=104 Midshell

Anthony Mcfarlane[1]
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The shape of an atomic nucleus is a fundamental property that governs its excitation spectrum and available decay modes. In the region surrounding the Z = 82 shell closure and the N = 104 midshell, the interplay between spherical and deformed configurations leads to shape coexistence, driven by a delicate balance of shell effects and collective interactions. Understanding these structural phenomena requires precise experimental data, particularly in the neutron-deficient gold isotopes. In this work, we investigate the low-energy structure of ^{180}Au, populated through the β-decay of ^{180}Hg, produced at ISOLDE, CERN. The isotope was selectively purified using laser ionization, a new quartz-line system, and high-resolution mass separation. The resulting γ-rays were detected with the upgraded ISOLDE Decay Station (IDS), providing improved sensitivity to nuclear transitions. While some isotopes in this mass region have been widely studied, available experimental data for others remain scarce and lacking precision. By reanalyzing historical α-decay data alongside our new β-decay results, we construct a more refined decay scheme, offering fresh insights into the nuclear structure evolution near the midshell and beyond.

Investigation of Secondary Particle Generation in Carbon Ion Beams for Cancer Radiotherapy

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Precise radiotherapy through carbon ion therapy necessitates accurate monitoring of radiation dose distribution within the patient to target tumors effectively while protecting healthy tissues. This study utilized Monte Carlo (MC) simulations to investigate secondary radiation doses produced by a 4.48 GeV carbon ion beam. Using GEANT4 simulations, we identified secondary particles (protons, gamma rays, alpha particles, neutrons, and tritons) formed during carbon ion interactions with water and analyzed their relationship with the carbon ion beam. Interaction Vertex Imaging (IVI) was pivotal in monitoring dose distribution, particularly with protons, as it identified the locations and abundances of secondary particles. IVI reconstructs particle trajectories using charged particles from ion fragmentation, revealing range information from their origin, or vertex. Our simulations demonstrated a strong correlation between certain secondary particles and the carbon ion range. We observed an increase in proton production as the target depth increased due to the growing inelastic cross section at lower energy levels. However, multiple Coulomb scattering induced significant discrepancies between the reconstructed proton path and the primary beam, especially at lower energies. To address this, we developed a beam back-projection algorithm, using pixel hit data from Silicon detectors, to reconstruct vertices by approximating trajectories as straight lines. Additionally, the Timepix3 ASIC detector was employed to measure Time over Threshold (ToT) for different cluster sizes, focusing on how particles interact with the detector. Calibration of the detector revealed a relationship between cluster size and energy deposition, with Fe-55 X-rays producing smaller clusters due to their lower energy, while Sr-90 beta radiation and Am-241 alpha particles produced larger clusters. These measurements established a reliable method for distinguishing radiation types and accurately measuring energy deposition, enabling the Minipix detector to monitor carbon ion ranges effectively for enhanced radiotherapy precision.

Investigations of the unbound 2+ state in 20C

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The carbon isotopes, with Z=6 being the first spin-orbit shell gap originating from the splitting of the 1p1/2–1p3/2 orbitals, provide an excellent ground to study changes in proton spin-orbit splitting from stability to the dripline. Neutron-rich carbon isotopes have been intensively investigated over the last decade. Transition probabilities, B(E2;2+→0+), have been measured up to 20C [1,2], revealing an increase from 16C to 20C. These B(E2) values have been interpreted in terms of the mixing of unperturbed neutron and proton 2+ excitations, with the observed increase in collectivity explained by an enhanced contribution of proton excitations. This enhancement is likely due to a reduction of the proton 1p1/2–1p3/2 spin-orbit splitting toward the dripline [3].

In a more recent experiment [4], neutron-rich carbon isotopes 16,18,20C were studied via proton removal reactions from nitrogen isotopes. Cross sections populating the ground and 2+1 states were measured in each case. The results showed an increase in the proton component of the 2+1 state, supporting a moderate reduction of the proton 1p1/2–1p3/2 splitting towards the neutron dripline [4]. This study, as well as [3], further suggested that a mixed-symmetry 2+ state with an excitation energy around 7 MeV should be strongly populated in proton removal reactions from nitrogen isotopes. This state, lying above the neutron separation energy and therefore unbound, likely decays via neutron emission. Investigating this unbound 2+ state in carbon isotopes will provide critical experimental data to shed light on the evolution of the Z=6 spin-orbit splitting and benchmark theoretical models.

We present the investigation of the unbound 2+ state in 20C, populated via proton removal from 21N. The radioactive 21N beam was produced by the BigRIPS separator at RIBF and induced a proton removal reaction on a carbon target. The unbound 2+ state in 20C was analyzed using the SAMURAI spectrometer via invariant mass spectroscopy. In this report, the experimental setup, the data analysis as well as the preliminary results will be presented.

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Isomer Spectroscopy in the Transfermium Region

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The search for the island of stability among superheavy nuclei is a longstanding challenge in nuclear physics [1]. Theoretical models predict a region of enhanced stability between Z=114-126 [2], however information on such nuclei is limited due to their significantly low production cross-sections. Instead it becomes necessary to study lighter, more deformed systems in which single particle orbitals relating to the stabilisation of the heaviest known elements are populated at higher rates. K-isomers in the transfermium region provide valuable insight into these Nilsson orbitals.

This work is centered on 250Fm, where bands built on the known K-isomer [3] have now been studied through the simultaneous measurement of gamma rays and internal conversion electrons using the SAGE spectrometer (Jyväskylä, Finland) [4]. These methods, applicable to other nuclei in the region, facilitate the assignment of quasiparticle configurations, offering broader insights into Nilsson orbitals and their role in nuclear stability.

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Laser spectroscopy for nuclear structure studies: future plans at the GANIL and DESIR facility

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Understanding how nuclear structure emerges from the nucleon-nucleon interaction and how it evolves going far from the valley of stability has become one of the main quests of contemporary nuclear physic. High-resolution laser spectroscopy has long been established as a very powerful tool to study ground-state nuclear properties, providing a nuclear model-independent access to the nuclear ground-state spin, changes in mean square charge radii, magnetic dipole, and electric quadrupole moments. It is used at several radioactive beam facilities all over the world and gives insight into many aspects of nuclear structure and provide crucial input for the development of nuclear theories.

In the past decade, the GANIL facility has undergone a major upgrade with the development of a new radioactive ion beam facility SPIRAL2-S3 and a new low-energy experimental hall DESIR. The SPIRAL2 facility, coupled to the S3 recoil separator, will enhance the study of exotic nuclei by producing intense beams of rare radioactive isotopes. The S3-LEB setup will allow high-efficiency laser ionization studies to be performed on those isotopes. The DESIR facility, now under construction, will host several experimental setups, among which a versatile high-resolution laser spectroscopy setup: LASAGN.

In this talk, laser spectroscopy as a tool for nuclear structure studies will be introduced. An overview of the different laser spectroscopy technics will be presented together with a detailed example: the study of neutron rich chromium isotopes, recently performed at the CRIS experiment at ISOLDE/CERN. Finally ongoing laser spectroscopy projects and future plans at the GANIL facility will be presented.

Laser spectroscopy of Fe isotopes using an electrostatic ion trap at IGISOL

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Substantial effort in the field of nuclear laser spectroscopy is presently directed towards the (future) measurement of nuclear charge radii in proton-emitting nuclear systems. The behaviour of this bulk property in such exotic nuclei is an open theoretical challenge but severe experimental challenges are encountered in attempting the spectroscopy (and measurements of such radii remain elusive). At JYFL, Jyväskylä, the laser-IGISOL collaboration, has developed spectroscopy with which we intend to make three key measurements (critical for an accurate interpretation of the radial trend in such systems). Measurement of three systems, 53mFe, 53mCo and 52mFe, provides a unique opportunity to resolve the effect of being proton-unbound.
Technical upgrades to the laser spectroscopy station at the IGISOL have enabled our collaboration to perform spectroscopy in the deep UV and make new measurements on radioactive species in Fe and Co ions. Successful spectroscopy of the three cases cited above (53mFe, 53mCo and 52mFe) however demands a further increase in experimental sensitivity, by at least one order of magnitude.
At the IGISOL, collinear laser spectroscopy coupled with optical pumping has proved a highly successful technique [1-3]. We intend to couple this technique with a new electrostatic ion trap (the ConeTrap) and exploit the enhanced sensitivity to make the desired measurements.
The Manchester developed ConeTrap, pioneered by Schmidt et al. [4], is an electrostatic device that is especially suitable for deployment at IGISOL [5]. The devices have been shown to successfully contain close to 10^5 ions for time periods exceeding 100 ms (many times the atomic excitation and de-excitation lifetimes) and their injection is well matched to the ion plumes released from the IGISOL cooler-buncher. While successfully demonstrating the device was operational, tests showed that only a physically larger trap with matched injection and extraction ion optics would provide the desired spectroscopic performance. Such a trap, developed on a bespoke Manchester testbed, has now been installed at IGISOL. The forthcoming commissioning of the device, as well as future spectroscopic opportunities will be presented.

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Level-lifetime measurements as a probe of shapes and symmetries in nuclei

Alison Bruce

The measurement of lifetimes of excited nuclear levels is an important technique for probing the details of internal nuclear structure. The electromagnetic transition rates extracted can be linked to the composition of the wavefunctions of the initial and final states involved, and also to nuclear shape (via β2 deformation), thereby allowing stringent tests of nuclear models. In recent years, arrays of LaBr3(Ce) detectors with sub-nanosecond timing capabilities have enabled precision electromagnetic transition rate determinations in some of the most exotic radionuclides. This talk will describe some recent measurements in A~100 nuclei and discuss the physics insights that have been obtained from interpreting the results.

Lifetime measurements in ^{102}Mo interpreted in the interacting boson model and the X(5) symmetry

Dr Calum Jones[1]
[1]University Of Surrey

Lifetimes of low-lying excited states in ^{102}Mo populated in the two-neutron transfer reaction ^{100}Mo(^{18}O,^{16}O)^{102}Mo were measured using the recoil distance Doppler shift method at the IFIN-HH Tandem accelerator. Lifetimes of the 2^+_1, 0^+_2, 4^+_1, 2^+_2, 2^+_3, 3^+_1, 6^+_1, (0^+_3), 4^+_2, (3^-_1) and (5^-_1) states were obtained. The deduced electromagnetic transition strengths have been compared to calculations performed in the interacting boson model framework including models representing the U(5) and X(5) symmetries. It is found that ^{102}Mo lies between the U(5) limit and the X(5) critical point symmetry.

Lifetime measurements in neutron-rich barium and cerium isotopes using the fast-timing technique

Faye Rowntree[1], Liam Gaffney[1], Pietro Spagnoletti[1,7], Magda Satrazani[1], Alejandra Diaz Varela[3], Allison Radich[3], Robin Coleman[3], Fuad Ali[3], James Smallcombe[2], John Smith[7], Adam Garnsworthy[2], Mustafa Rajabali[4], Ben Luna[4], Corina Andreoiu[5], Costel Petrache[6], James Keatings[7], Konstantin Mashtakov[7], Nikita Bernier[2,8], Mike Bowry[2], Bruno Olaizola Mampaso[2], Roger Cabellero-Folch[2], Lewis Sexton[2,9], Paulina Sluryte[2,9], S. Bhattacharjee[2], Yukiya Saito[2,8], Elena Timakova[2], Kenneth Whitemore[5], Daniel Yates[2,8], Carl Svensson[3], Ryan Lefleur[3], Fatima Garcia[5], Gwen Grinyer[10], M. Hladun[10], J. Mitchell[10]

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The neutron-rich lanthanides are expected to exhibit octupole collectivity, which can lead to asymmetric nuclear shapes. The study of low-lying negative-parity states in the even-even nuclei in this region is key to understanding the magnitude of collectivity and whether the nucleus adopts a static or dynamic asymmetric shape. Lifetimes of these states are particularly sensitive to electric-dipole transition strengths, where an enhancement can signify octupole deformation.

The fast-timing technique can be used to measure lifetimes of short-lived states in radioactive nuclei by analysing γ-γ and β-γ coincidences following β-decay. In this work, the lifetimes of low-lying states in barium and cerium isotopes with A = 144, 146, and 148 have been measured using the GRIFFIN spectrometer based at the ISAC-I facility at TRIUMF, Vancouver. Primary beams of cesium were delivered on to a moving tape collector at the centre of the GRIFFIN spectrometer, which consists of an array of 16 HPGe clover detectors, supplemented with an array of 8 $LaBr_3$ scintillator detectors for fast timing, and a zero-degree scintillator for the detection of electrons emitted during β-decay.

This talk will present preliminary results of these measurements obtained using both the convoluted decay-curve method and the generalised centroid-shift method. Additionally, this work supplements the recent Coulomb excitation study of ^{144}Ba using the Miniball array based at the ISOLDE facility at CERN.

Lifetime measurements of low-energy octupole states in radium-224

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For certain nuclei long-range octupole-octupole residual interactions can cause a reflection-asymmetric (pear) shape to occur. This octupole deformation, combined with quadrupole deformation, causes a separation between the centre of mass and centre of charge in the nucleus, resulting in a significant electric dipole (E1) moment. This effect enhances the strength of the E1 and electric octupole (E3) transitions, characteristic features of such nuclei.

The presence of these low lying J^(π)= 1^(-) and 3^(-) is indicative of octupole deformation. An example of one of these nuclei is radium-224 which is octupole deformed in the ground state as evidenced by the observation of enhanced E3 transitions[1]. Their work measured a large E3 strength but could only give an upper limit on the reduced transition probability of the E1 transition (B(E1)).

The aim of this experiment was to measure the lifetimes of the low-lying J^(π)= 1^(-)and 3^(-) states in radium-224 and, therefore, measure the E1 strength. This was done by observing the beta decay of francium-224 ions which were produced at the ISAC facility in TRIUMF. The lifetime of these states was measured by using the LaBr$_3$(Ce) detectors of the GRIFFIN array and the generalised centroid difference method. Measuring the lifetime of these states makes it possible to perform a direct measurement of the low-energy dipole response in radium-224 for the first time.

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Mass and Half-life Measurements in the Neutron-rich N~116 Hf Region

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N=116 is the critical point for a prolate to oblate shape/phase transition in neutron rich nuclei. Certain isomers in the region are predicted to decay from prolate high-K states to oblate low-K states. Mass and lifetime measurements of isomers in the surrounding area will help improve structure and nucleosynthesis models, especially as it is near to the r-process path. Many isomers are known, and many more are predicted [1].

Combined Schottky + Isochronous Mass Spectrometry (S+IMS) was established in a recent experiment at the GSI experimental storage ring (ESR) allowing for the revolution frequency of every stored ion to be determined within a few ms [2]. In another experiment, nuclei with half-lives as short as 3 ms could be measured. These properties, along with the ESR's ability to store nuclei with a broad range of A/Q ratios simultaneously, make the ESR ideal for examining the Yb-Os 208Pb projectile fragments for known and unknown isomers, as well as finally giving access to an isomer in 188Hf which is predicted to be prolate with Kπ = 18+, and may have an especially long lifetime.

The experiment is scheduled for the 208Pb beam time block in early April 2025 at the ESR and will use a 9Be target. Every particle stored in the ESR will be measured. Assuming a shot as often as every 2 seconds, each shift adds 14400 chances to produce a rare species, therefore the allocated 3 days of beam time will allow for studying isomers produced with cross-sections approaching tens of pb. Preliminary results will be presented.

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Measurement of the 68Zn(n,γ) Cross Sections at n TOF, CERN, and their Astrophysical Implications

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The slow neutron capture process (s-process) is responsible for the production of about half of the elemental abundances heavier than iron in the universe. The weak component of the s-process takes place in massive stars during He core and C shell burning phases, and dominantly contributes to abundances between iron and strontium.

A recent study by Nishimura et al. [1] investigated the impact of nuclear reaction uncertainties on the uncertainties of the s-process abundances predicted by stellar models. This study was completed for two different types of massive stars: those with solar metallicity and very metal poor stars. Among other results, this study showed that the stellar 68Zn(n,γ)69Zn reaction cross section represents one of the main nuclear physics uncertainties affecting abundance uncertainties of the isotopes 68Zn and 78Se. More precise knowledge of the 68Zn(n,γ) reaction cross section would therefore provide an improved understanding of the origins of those isotopes.

A measurement of the 68Zn(n,γ) cross section was performed at the neutron time- of-flight facility, n TOF, at CERN, using low neutron sensitivity liquid scintillation detectors. The neutron capture yield was determined for neutron energies between thermal and several hundred keV, covering the energy range of stellar interest. This presentation will include the measurement, data analysis and preliminary results, as well as possible implications on nucleosynthesis processes in massive stars.

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Measurements of Fission Fragment Masses and Proton Numbers at ILL and n TOF, CERN

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The Fission Fragment Identification (FiFI) spectrometer is a 1-energy 1-velocity (1E1v) device developed at the University of Manchester for accurate measurements of fission fragment (FF) mass distributions and investigation of the possibility of extracting the FF nuclear charge signature from pulse-shape analysis of the collected detector signals. The device consists of a vacuum time-of-flight (TOF) section equipped with two microchannel-plate timing detectors and an isobutane-filled Bragg detector, which provide velocity and kinetic energy information used for calculating the FF mass. FiFI has been used at the Lohengrin separator at Institut Laue-Langevin, France, to investigate atomic number signatures of the pulse shapes from FFs produced in thermal neutron-induced fission of 239Pu.

An energy resolution of 850 keV and a timing resolution of 700 ps were attained during the test, yielding a mass resolution of approximately 1.2%. Following the tests at ILL, a test with a 235U target has been conducted at the neutron Time-of-Flight (n_TOF) Facility at CERN, aimed at examining detector response as a function of neutron energy. Successful extraction of mass yields in the 1-10 MeV region with uranium target would enable a planned investigation of the 243Am FF mass distribution in fast-neutron regime to supplement a prior 243Am(n,f) cross-section measurement at n_TOF. 243Am measurement is motivated by nuclear waste transmutation data needs. The details of both detector tests at the two facilities will be discussed in this presentation.

Measurements of octupole collectivity in 144Ba via Coulomb-excitation

Ben Jones[1], Liam Gaffney[1], Marcus Scheck[3], Patrick MacGregor[2], Faye Rowntree[1], James Keatings[3], Thorsten Kröll[4], Andreas Heinz[5], Stina Persson[5], Philipp Klenze[13], Andrea Jedele[4], Alice Svärdström[5], Kristian Haverson[6], Robin Smith[6], Anna-Lena Hartig[4], Josh Curry[1], Björn Johansson[5], Pietro Spagnoletti[1], Frank Browne[7], Carlotta Porzio[2], Andy Briscoe[1], Maria Vittoria Managlia[5], Greg Willmott[8], Nigel Warr[1], Sean J Freeman[2,7], Steffen Meyer[4], Kasia Wrzosek Lipska[9], Iwona Pietka[9], Han-Bum Rhee[4], Janne Pakarinen[11], Antonio Lopez[10], Manfred Jaftha[12]

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Identifying nuclei with stable octupole deformation is crucial in the search for odd-mass isotopes with atomic electric dipole moments, which would signal CP violation due to physics beyond the Standard Model. Mean-field calculations predict enhanced octupole correlations in certain nuclei within the actinide and lanthanide regions. These correlations are inferred from nuclear energy levels, E1 transition strengths, and E3 moments—the most unambiguous measure of octupole collectivity due to their insensitivity to single-particle effects. Direct measurements of the E3 moments in 222,224,226Ra confirm stable octupole deformation, while 228Ra exhibits octupole vibrational behaviour [1]. However, B(E3) data in the lanthanides is scarce, with measurements for 144,146Ba [2,3] being significantly enhanced over theory and consistent with octupole deformation, but suffering from very large uncertainties.

To address this, a Coulomb-excitation experiment on 144Ba was conducted at HIE-ISOLDE in November 2024 to re-measure the B(E3). A 144Ba beam, re-accelerated to 4.52 MeV/u, was focused onto a 208Pb target, with excitation occurring solely via electromagnetic interaction by insuring Cline's safe energy criterion. Scattered particles were detected with a downstream DSSSD, while de-excitation γ-rays were measured using the Miniball spectrometer, comprising seven HPGe clusters. Despite isobaric beam contaminants, the experiment was successful and greatly benefited from ISOLDE's intense beams.

Data analysis using GOSIA (a multistep Coulomb-excitation) code is underway to extract E2 and E3 moments. Higher statistics for the 144Ba (3− → 2+) transition compared to prior measurements [2] are expected to improve the precision of the extracted B(E3) value. Current results will be presented.

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Meson Spectroscopy at CLAS12

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Quantum chromodynamics (QCD) is the theory of the strong interactions in the standard model and describes how quarks bind together via the gluonic field to form mesons and baryons. At Jefferson Laboratory, located in Newport News, Virginia, photo- and electro-production experiments are conducted to produce mesons from nucleon targets. These mesons are detected by the large acceptance spectrometer known as CLAS12. Whilst the lightest mesons are well-established, the heavier mesons are more challenging to identify in experimental data. Furthermore, QCD predicts mesons not expected by the naive constituent quark model known as exotic mesons. The observation of exotic mesons is an important test of QCD and determining how exotic mesons are produced experimentally will help us understand how the fundamental quarks and gluons interact to form a spectrum of allowed bound states.

This talk will show the first analysis of CLAS12 data using novel analysis methods to isolate a specific meson decay channel. The channel of interest is the electro-production of charged kaon pairs (K+K-) off the proton which is predicted to have numerous mesonic resonances. Due to the kaon pairs, this channel has tight constraints on the allowed quantum numbers of the resonances; therefore, glueballs, a type of exotic meson, are expected to be produced alongside conventional mesons. My main objective is to obtain model-independent quantities known as the moments of the angular distribution, which contain the contributions of different mesons produced in electron-proton interactions. Furthermore, obtaining the exact partial wave decomposition for the mesons in the range of interest will be considered. A comprehensive study can be conducted in collaboration with theorists to obtain the quantum numbers, such as spin and angular momentum, of the mesons corresponding to the different partial waves, allowing for full identification of the mesons.

Multiparameter study of fission with STEFF at n_TOF

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Nuclear physics data accuracy is necessary for the development of the new generation of nuclear reactors for clean energy production that can be considered safer: both in the operating conditions and the nuclear waste production. In the particular case of 239Pu fission, the accurate prediction on the γ-heating in the reactor dictates small uncertainties in Prompt Fission Gammas (PFG) energy and multiplicity distributions. Moreover, further measurements on fission fragments mass and energy distributions would increase the reliability of the neutronics calculations. The SpecTrometer for Exotic Fission Fragments (STEFF) has been used in the Experimental Area-2 at n_TOF (CERN) to study the 239Pu(n,f) and 235U(n,f) reactions and it has been designed for the simultaneous extraction of multiple parameters that characterize the fission reaction. The n_TOF facility allows the analysis of fission induced by neutrons with a wide range of energies (from meV to GeV). The investigation of the PFG properties is made possible by the presence of an array of 16 scintillators (NaI and LaBr3). Furthermore, mass and energy distributions of the fission fragments can be extracted from the setup consisting of a 2E2v arm perpendicular to the neutron beam axis. The current state of the 239Pu(n,f) analysis will be discussed in this context, as well as the main results of the previous 235U(n,f) campaign.

Muographic Image Upsampling with Machine Learning for Built Infrastructure Applications

Mr William O'Donnell[1,2], Dr David Mahon[1,2], Dr Guangliang Yang[1,2], Dr Simon Gardner[1]
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The civil engineering industry faces a critical need for innovative non-destructive evaluation methods, particularly for ageing critical infrastructure such as bridges, where current techniques fall short. Muography, a non-invasive imaging technique, constructs three-dimensional density maps by detecting the interactions of naturally occurring cosmic-ray muons within the scanned volume. Cosmic-ray muons offer both deep penetration capabilities due to their high momenta and inherent safety due to their natural source. However, the technology's reliance on a natural source imposes a constraint on the muon flux, resulting in prolonged acquisition times, noisy reconstructions and challenges in image interpretation. To address these limitations, we developed a two-model deep learning approach. First, we employed a conditional Wasserstein generative adversarial network with gradient penalty (cWGAN-GP) to perform predictive upsampling of undersampled muography images. The structural similarity index measure (SSIM) demonstrates that one-day sampled images can be enhanced to match the quality of 21-day baseline acquisitions, while the peak signal-to-noise ratio (PSNR) metric indicates an improvement of one-day to a 31-day baseline. A second cWGAN-GP model, trained for semantic segmentation, was developed to quantitatively assess the upsampling model's impact on feature interpretability. This segmentation model was able to to achieve segmentation of rebar grids and tendon ducts within the test dataset with Dice-Sørensen accuracy coefficients of 0.8174 and 0.8663, respectively. This model also revealed an unexpected capability to mitigate -- and in some cases entirely remove -- z-plane smearing artifacts caused by the muography's inherent inverse imaging problem. Both models were trained on a comprehensive dataset generated through Geant4 Monte-Carlo simulations, designed to reflect realistic civil infrastructure scenarios. Our results demonstrate significant improvements in both acquisition speed and image quality, marking a substantial step toward making muography more practical for reinforced concrete infrastructure monitoring applications.

Neutron Reactions in Astrophysics

Claudia Lederer-Woods[1]
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Neutron induced reactions play a key role in stellar nucleosynthesis. Neutron capture cross sections on stable and long lived nuclei represent the main nuclear inputs to predict isotopic abundances produced by the slow neutron capture process, which is resposible for about half of the abundances of elements heavier than iron. In addition, neutron induced reactions followed by charged particle emission can significantly affect abundances of some light nuclei, such as the cosmic gamma-ray emitter Al-26 and the naturally occuring radioisotope K-40. I will present recent advances in the measurement of neutron induced reactions, focussing on the CERN n_TOF facility, and future perspectives.

Nuclear breathing mode analyzed in the multi-reference density functional theory

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Nuclear incompressibility remains one of the most intriguing topics in nuclear physics and astrophysics, as it is a key parameter to the nuclear equation of state. Determining the nuclear incompressibility from extrapolations of the compression modulus of finite nuclei [1, 2, 3] relies on a thorough understanding of how the nuclear structure affects the breathing mode. In particular, the role of shape mixing is paramount [4].

This study presents a self-consistent description of the shape mixing and analyzes its impact on the nuclear breathing mode within the framework of the symmetry-restored multi-reference density functional theory (MR-DFT). The coupling between nuclear shapes with different radii and deformations (as presented in the figure for Sn-116) and the small-amplitude vibrations around the ground state and shape isomer are investigated to reveal the possible anharmonic effects in nuclear breathing mode.

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Nuclear Data and medical radioisotope production activities at UKNNL

Luigi Capponi

Nuclear data are the foundation of every simulation and modelling in nuclear physics. Whenever a calculation is performed, whether it is deterministic or probabilistic, the computer code will need a collection of libraries containing the interaction probabilities at the various energies of all the elements involved in the calculation, the radioactive decay information, or the physical properties of the nucleus. These libraries are compiled by international collaborations based on nuclear experiments and on a continuous work of checking, analysis, and validation. It is apparent that using reliable libraries and testing the nuclear data available with well-designed experiments is the condition for producing good quality modelling.

The United Kingdom National Nuclear Laboratory (UKNNL) is active in nuclear data sourcing and researching in both industrial and academic settings. Simulation of irradiated fuel composition, shielding calculations, criticality studies, medical radioisotope production, are just few examples of the fields where nuclear data play a key role. In this talk some of the UKNNL activities will be presented together with some examples of practical application.

In particular, one of the applications of nuclear data to real life is the calculations for the production of medical radioisotopes. Good nuclear data allow us to explore novel production routes and optimisation techniques. UKNNL have recently conducted some experimental work in the production of some key medical radioisotopes by neutron irradiation, and some preliminary results will be presented.

Nuclear Science Opportunities at HF-ADNeF

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The High-Flux Accelerator Driven Neutron Facility (HF-ADNeF) [1] at the University of Birmingham was commissioned in December 2023. Providing a fast neutron flux up to 3×10^{11} n/s/cm^2 from a 2.6 MeV 30 mA proton beam impinging a rotating lithium target, opportunities for many new avenues of nuclear science are possible.

This talk will highlight some of the current science cases including nuclear astrophysics, medical physics, cultural heritage work, and fusion research. The tools being developed to facilitate access for future projects will also be discussed.

[1] https://www.birmingham.ac.uk/research/activity/nuclear/about-us/facilities/high-flux-neutron-facility

Nuclear Science to Benefit Society

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Nuclear Science to Benefit Society is at the heart of the work the United Kingdom National Nuclear Laboratory undertakes as the UK's lead civil national laboratory for nuclear fission.

Nuclear science, and nuclear physicists, are a critical part of the skills and capabilities the UK needs to power progress while achieving net zero by 2050, and protecting the nation.

In this talk I will present several case studies, highlighting the work of UKNNL scientists in our four strategic focus areas: Clean Energy, Health and nuclear medicine, Environmental restoration, and Security & non-proliferation.

Octupole deformation in neutron-deficient plutonium isotopes.

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Recent calculations have suggested that the region of strong octupole correlations in the light actinides extends to higher Z values than previously thought, with neutron-deficient plutonium (Z =94) and curium (Z = 96) nuclei predicted to have large β3 values in their ground states [1, 2]. In order to test the predictions, an experiment has been performed to study the structure of neutron-deficient plutonium (Z = 94) isotopes. The experiment was carried out at the Legnaro National Laboratory
using the AGATA γ-ray spectrometer [3, 4] together with the PRISMA [5] magnetic spectrometer and the DANTE channel-plate array [6]. The main aim of the experiment was to identify excited states in the isotopes 232Pu and 234Pu. The nuclei of interest were populated using multi-nucleon transfer reactions induced with a beam of 112Sn incident on a thin 238U target. Reaction channels were selected by identifying the beam-like reaction products behind the focal plane of PRISMA and, where possible, detecting target-like products in the DANTE detectors to reduce fission backgrounds in the coincident γ-ray spectra. Analysis of the data is ongoing, and the preliminary results will be presented. This work is supported by Science and Technology Facilities Council, UK, under grants numbered ST/P005101/1 and ST/V001124/1.

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Position Reconstruction of Multiple Interactions Gamma Events in SIGMA Detector Using Two-step Search Algorithm

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High Purity Germanium (HPGe) detectors are an essential tool for performing gamma-ray spectroscopy in nuclear structure experiments due to their excellent energy resolution and efficiency. However, effects such as Doppler broadening and partial gamma-ray absorption present challenges for precise energy measurements. These challenges highlight the need to determine the position of gamma interactions within the detector through the application of gamma-tracking algorithms. Segmented HPGe detectors enable accurate position localisation of gamma interactions by utilising Pulse Shape Analysis (PSA) techniques. The Segmented Inverted-coaxial Germanium Array (SIGMA) detector, featuring 19 segments, is designed for this purpose. In PSA, signals from each segment's preamplifier are analysed and compared against a verified simulated database produced by Agata Detector Library (ADL). The database contains expected output signals for all potential interaction locations within the detector. Comparison of the experimentally observed signals against simulated signals allows the interaction position of the gamma ray to be inferred. Reconstruction of a single gamma interaction can be straightforward, whereas the reconstruction of multiple interactions (multi-fold) events, when a gamma-ray undergoes multiple interactions before being absorbed, are complicated. Thus, a two-step search algorithm using the simulated ADL database has been developed to reconstruct positions for multi-fold events. The algorithm includes a coarse grid search to determine the approximate interaction region, followed by a fine search to achieve higher precision within the identified area. Testing the algorithm with GEANT4 simulated data demonstrates accurate reconstruction in cylindrical coordinates. By calculating the difference between true and reconstructed position, the algorithm's reconstruction achieves a standard deviation of 24° in azimuthal angle variation, 1 mm in radial and 1 mm in depth (z). This work highlights the potential of SIGMA detector and advanced reconstruction algorithms for improving gamma-ray tracking in nuclear structure studies.

Probing Short-Range Correlations via (p,pd) Quasi-Free Scattering reactions

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The experimental evidence points to the existence, at short distances, of strongly correlated neutron-proton pairs much like they are in the deuteron or in free scattering processes. As it moves through the nuclear medium, a “bare” nucleon in the presence of the nucleon-nucleon short-range correlations becomes “dressed” in a quasi-deuteron cloud [1], about 20% of the time. A phenomenological analysis of the quenching of spectroscopic factors [2] and recent data from Jefferson Lab [3] point to an isospin dependence of the independent-particle model content in a dressed nucleon. It is expected that this dependence should also be reflected in the dressed amplitude and thus, in the virtual quasi-deuteron content in the ground state.
Following from the qualitative arguments above, quasi-free scattering (QFS) of deuterons could offer a sensitive probe to examine these concepts. We have performed a pioneering experiment at the R3B setup at GSI-FAIR to measure the (p,pd) QFS cross section for knocking out a deuteron in 10,14,16C relative to 12C as a tool to probe short-range correlations and their isospin dependency. In this contribution we will present the motivation for this experiment and the experimental setup used, together with preliminary analysis and results.

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Quantum entanglement of positron annihilation gamma – new insights and future plans

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The intrinsic quantum entanglement (QE) of linear polarisation between the two-gamma arising from positron annihilation was initially highlighted at the dawn of the quantum information age by Bohm and Aharanov. In recent years our MeVQE group at York has led developments in detection of the QE information using segmented gamma-calorimeter apparatus, developed the first simulation (based on Geant4) which accounts for the QE in the (correlated) propagation of the entangled gamma in matter and recently developed the first quantum theory for QE loss to the environment in their propagation. The two-gamma MeV scale QE system offers many opportunities for fundamental tests of QE in new regimes and applications (e.g. PET imaging and industrial imaging, quantum sensors).

Recent results from the MeVQE group at York will be presented along with future plans and prospects for this emerging field of photonic QE at the MeV scale. Particular focus will be given to the design of experimental measurements of large scattering angles >130° for the triple Compton scattering and three-gamma decays.

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Quasi-Free Scattering Studies in and Around the Ca Mass Region

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The R³B collaboration at GSI-FAIR has conducted Quasi-Free Scattering (QFS) studies in the calcium mass region using inverse kinematics. These experiments aim to investigate the nuclear structure of both stable and exotic nuclei, with a particular focus on single-particle strength in this region. This objective is achieved through precise cross-section measurements, providing valuable insights into the underlying nuclear dynamics. Cross sections for QFS reactions for Ca isotopes, including (p,2p) and (p,pn), have been calculated. Both results have been compared with theoretical cross sections calculated using single-particle cross sections deduced from a QFS reaction theory based on the Eikonal model. The values are quenched and are consistent with (e,e'p) data for stable nuclei [1], showing a weak correlation with nuclear asymmetry. These findings are consistent with recent studies [2] reported on the evolution of the proton single-particle strength as a function of isospin asymmetry using (p,2p) QFS reactions along the Oxygen isotopic chain and found a weak or no dependence. The reduction of the single-particle strength has been attributed to nucleon-nucleon correlations and a recent phenomenological study [3] has quantified the long and short-range part of these correlations and their dependency with isospin.

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Reactor physics and the Pygmy Dipole Resonance.

A detailed study of the beta decay of 92Rb with GRIFFIN.

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Reactor antineutrino experiments provided the first experimental observation of antineutrinos and have played a pivotal role in our understanding of neutrino physics for several decades. These antineutrinos are produced via β decay of fission fragments and on average a single fission event is followed by six β decays. Advances in theoretical predictions of the antineutrino flux led to the Reactor Antineutrino Anomaly (RAA) and has prompted a flurry of activity across multiple disciplines. The RAA denotes an ~6% deficit of the measured antineutrino flux compared to predictions of the Huber-Mueller model and a ~10% excess of antineutrinos situated at ~6 MeV. This antineutrino flux is dependent on the β decay of fission products, and a robust understanding of these decays is essential. However, much existing β-decay data suffer from the “Pandemonium” effect questioning their reliability.

The β decay of 92Rb is one three main contributors to the high-energy antineutrino spectrum at this ‘shoulder’ and consequently a prime candidate for Total Absorption Spectroscopy (TAS). These new results present significant discrepancies with High-Resolution Spectroscopy studies performed in the seventies which can be attributed directly to Pandemonium effect. While TAS measurements are free from Pandemonium, it’s poor energy resolution limits the sensitivity of this probe, and the fine structure is lost.

We have thus revisited the β-decay of with the GRIFFIN spectrometer at TRIUMF, utilising 15 Compton-supressed HPGe clover detectors. The excellent capabilities of GRIFFIN combined with intense beams of rubidium isotopes, we have obtained an unparalleled picture of 92Sr with over 180 levels many in the region of the Pygmy Dipole Resonance and 850 γ-ray transitions up to and beyond the neutron separation energy of ~7.3 MeV. The results of this study are also compared to recent TAS experiments and theoretical calculations and show a great agreement despite of the large density of levels and fragmented decay in 92Sr.

Shape coexistence in 196Po: An in-beam γ-e spectroscopic study

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Investigating nuclei that exhibit different coexisting shapes is important for gaining insight into the underlying mechanisms that influence nuclear structure. Having just two valence protons above the shell closure at Z = 82, the neutron-deficient Po isotopes are ideal for studying the deformed intruder structures that compete with spherical ground states when approaching the neutron mid-shell.

Initial studies of 196Po identified second-excited 2+ and 4+ states at low energy, suggestive of an intruding deformed band structure [1]. A later study confirmed this, but provided an alternative explanation within the vibrational-phonon model [2]. Subsequent α-decay fine structure coincidence measurements revealed the existence of excited intruding 0+ states in 196,198,200,202Po [3], similar to those now observed in numerous Z≈82 nuclei [4]. This calls for a complementary study to extend experimental sensitivity to the structures above the excited 0+ state in 196Po.

The experiment was performed at the Accelerator Laboratory of the University of Jyväskylä within a campaign to study coexisting shapes in the neutron deficient Hg-Pb-Po region. Nuclei were produced in the 165Ho(35Cl, 4n)196Po fusion-evaporation reaction at 165 MeV. By exploiting the SAGE spectrometer [5] coupled to the MARA [6] separator a concurrent measurement of conversion electrons and γ rays emitted from excited states in 196Po was performed. Ongoing analysis and the interpretation of these data will be presented.

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Simulation of a ^{241}Am-^{9}Be neutron source using Geant4 Monte Carlo

Filippo Falezza[1], Jack Bishop[1], Tzany Kokalova[1], Stuart Pirrie[1], Carl Wheldon[1], Neil Curtis[1]
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Among commercially available neutron sources, the ^{241}Am-^{9}Be proves to be useful in both industrial, education and research environments because of its constant neutron flux and longer working life compared to other alternatives. An accurate simulation tool of this source would allow a better understanding of the neutron energy spectrum and flux.

The $^{9}Be(\alpha,n)^{12}C$ reaction of interest is not isotropic. However, Geant4 nuclear libraries can only handle isotropic reactions, and for this reason a new source term has been developed. This talk will focus on accurately reproducing the emerging neutron and γ spectra.

The simulation will be experimentally verified against experimental results; it is then employed in a cylindrical water bath to analyse neutron moderation and flux in water and eventually dose from emerging particles is investigated.

Solving the 9B(1/2+) mystery using the R-matrix formalism

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A historical difficulty associated with the identification of the first excited state of Boron-9 has resulted in previous experimental measurements attempting to measure the excitation energy of this state producing two conflicting solutions where only one is expected. These results, and thus the apparent observation of a charge asymmetry in the nuclear force, present a problem to our current understanding of nuclear structure. A conclusive resolution to this long-standing dilemma is now presented whereby the proposed 0.8 MeV candidate is attributed to the ground-state ghost peak as highlighted through R-matrix calculations. With this clarification, a re-evaluation of previous experimental data is performed providing further evidence of historical misidentification of the ghost peak, thus allowing for further delineation of the nuclear properties of Boron-9 and the behaviour of the strong nuclear force in mirror nuclei systems.

The analysis of π− mesons produced in Pb-Pb collisions at 30A GeV/c from NA61/SHINE

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NA61/SHINE is a multipurpose, fixed-target experiment located at the CERN Super Proton Synchrotron designed to investigate the phase diagram of strongly interacting matter. It is achieved through a two-dimensional scan of the diagram by varying the beam momentum (13A-150(8)A GeV/c) and the system size (p+p, p+Pb, Be+Be, Ar+Sc, Xe+La, Pb+Pb). These measurements are intended to understand the onset of deconfinement and to locate the critical point of strongly interacting matter.

The main aim of the analysis is to obtain kinematic spectra and yields of π− mesons in Pb-Pb collision at beam momentum of 30A GeV/c measured by the NA61/SHINE experiment. The spectra of transverse momentum and rapidity, as well as yields of π− mesons, will be presented for different centrality regimes. They will be compared with the results of the analysis, which uses energy losses for particle identification, and the data from the NA49 experiment.

The Development of the Compact Cherenkov Detector HEPI - the High Energy Proton Instrument for Satellite Missions

Dr Joseph O'Neill[1], Dr Fan Lei[1], Dr Fraser Baird[1], Dr Benjamin Clewer[1], Prof. Clive Dyer[1], Mr Paul Morris[1], Prof Keith Ryden[1], Prof Paul Sellin[1], Dr Melanie Heil[2], Dr Piers Jiggens[3], Dr Giovanni Santin[3]
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The monitoring of the near-Earth space radiation environment has been a key component of space agencies' strategies since their inception. This space weather originates from radiation from various sources, including high-energy protons emitted in solar energetic particle events. These protons, with energies greater than 300 MeV, are a source of damage to satellites, space station infrastructure and personnel, and also have effects that are observed in aircraft and at ground level. Increasing the number of instruments monitoring the flux of these high-energy protons is vital for the future of humanity in space. We present the development and characterisation of a miniaturised Cherenkov detector system for use on CubeSat missions: the high-energy proton instrument, HEPI. This detector displays particle species discrimination and has an inherent energy threshold via the Cherenkov radiation emission mechanism. The response of HEPI to electron sources, galactic cosmic ray muons and proton beams produced at a beam facility are presented, alongside the design of the detector as an instrument to be implemented in a multitude of small-volume satellite missions.

The KLong Facility in Hall D at Jefferson Lab

Stuart Fegan[1], Mikhail Bashkanov[1], Daniel Watts[1], Nick Zachariou[1]
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The KLong Experiment in Jefferson Lab Hall D will use a secondary beam of neutral kaons and the GlueX experimental setup to perform strange hadron spectroscopy. By achieving a flux on the order of 1×10^4 KL/sec, KLF will allow a broad range of measurements that improve the statistics of previous world data by several orders of magnitude.

The experiment will measure both differential cross sections and self-analysed polarisations of the produced Λ, Σ, Ξ and Ω hyperons spanning the mass range W = 1490 MeV to 2500 MeV. KLF data will significantly constrain partial wave analyses and reduce model-dependent uncertainties in the extraction of the properties and pole positions of the strange hyperon resonances, as well as establish the orbitally excited multiplets in the spectra of the Ξ and Ω hyperons. The proposed facility will also explore the strange meson sector through measurements of the final state Kπ system up to 2 GeV invariant mass, and with the addition of nuclear emulsion detectors for high-resolution tracking, contribute to studies of hypernuclei.

This talk will give an overview of the KLong Facility design, current status, and prospects for its impact in strangeness spectroscopy.

The Resonance Ionization Laser Ion Source RILIS at CERN-ISOLDE: Expanding limits of selectivity, intensity, and nuclear structure laser spectroscopy

Reinhard Heinke[1], for the ISOLDE-RILIS collaboration
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The Resonance Ionization Laser Ion Source RILIS, employing laser radiation in a hot cavity ion source directly coupled to an isotope production target, has become a principal method for provision of radioactive ion beams at facilities world-wide, such as at CERN-ISOLDE. Stepwise resonant excitation and subsequent detachment of an electron via element-unique atomic shell transitions allows for highly efficient and chemically selective provision of the desired nuclide in a mass-separated ion beam.

Alongside a summary of its utilization in standard operation, I will present developments regarding key aspects for specific applications:
The specialized high selectivity RILIS variant LIST, employing spatial separation of the hot cavity from a dedicated laser ionization volume in a directly adjacent RF quadrupole unit, has been augmented with perpendicular laser beam access. It allows for reduction of the effective Doppler broadening in interaction with the hot atom vapor, thus enhancing spectral resolution from experimental linewidths in the GHz regime down to a few 100 MHz. This novel unit was employed to perform nuclear structure investigations on neutron-rich actinium isotopes in a region of potential octupole deformation. The presented results outline its potential for further high-resolution applications, and greatly enhanced capabilities for isomer-selective ionization of nuclides for experiments demanding highest ion beam purity. Ongoing in-source spectroscopy campaigns at ISOLDE entail programmes in the heavy-element region around lead, and new endeavours investigate the lanthanide region and neutron-rich nickel.

Toward Pursuing New Superheavy Elements

Jacklyn Gates[1]
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In the past two decades, significant progress has been made with the discovery of elements Z=114-118 through reactions between 48Ca beams and actinide targets, achieving production rates of atoms-per-day or more. Unfortunately, the pursuit of elements beyond Oganesson (Z=118) faces substantial challenges. The synthesis of elements with Z=119 or 120 using 48Ca would necessitate targets of Es (Z=99) or Fm (Z=100), but these elements cannot be produced in sufficient quantities. This limitation necessitates exploring new reaction pathways.

Numerous theoretical studies have aimed at predicting production rates for new elements using actinide targets and heavier ion beams. While these models reliably reproduce excitation functions for SHE production with 48Ca beams, predictions diverge significantly for reactions involving heavier beams. For instance, the predicted cross section for reactions to produce Z=120 vary by more than three orders of magnitude and tens of MeV. These discrepancies hinder experimental efforts, as the low expected cross sections suggest the detection of only one event every few weeks or months under ideal conditions.

Berkeley Lab has been proactively addressing these challenges to push beyond E118. By testing theoretical predictions, we have begun the 50Ti+244Pu experiment to understand the impact of using 50Ti instead of 48Ca beams on cross sections. This presentation will highlight significant upgrades to our experimental facilities, including ion sources, target setups, detectors, and electronics, aimed at enhancing our capability to produce and detect elements beyond E118. We will also present the initial results from the 50Ti+244Pu experiment, showcasing our progress in this ambitious endeavor.

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Towards Complete Decay Spectroscopy of 152Tb

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Terbium-152, decaying by electron capture and β+ emission to 152Gd with QEC = 3990(40) keV and T1/2 = 17.8784(95) h [1], shows promise in nuclear medicine [2]. First-in-human trials have demonstrated its suitability for positron emission tomography (PET) imaging, with potential applications in personalised cancer treatments through its membership of the terbium theragnostic quartet [3]. Routine use of this radionuclide requires improved nuclear data for patient dosimetry [4], involving precision measurements of gamma-ray emission probabilities and the calculation of beta feeding strengths. Preliminary results of a decay spectroscopy study of 152Tb are presented, using sources prepared using spallation of a 1.4 GeV proton beam on a tantalum target, and mass-separated using the ISOL method at CERN-ISOLDE. Gamma-ray coincidences were measured using the Fission Product Prompt γ-ray Spectrometer (FIPPS) [5] at the Institut Laue-Langevin, Grenoble, supported by measurements taken using the PN1 Si(Li)-HPGe conversion electron spectroscopy setup using sources created in the same ISOLDE production run. Preliminary analysis has resulted in the identification of multiple previously unreported excited states in 152Gd up to excitation energies of 3.7 MeV [6]. Angular correlation and electron-gamma coincidence analysis aid in the construction of the final level scheme, providing information on the multipolarities and mixing ratios of discrete transitions [7]. The result of the completed spectroscopy will be a revised gamma-ray and β+ dose to patients compared to the current expected values.

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Unfolding Jet Substructure Observables with Machine Learning.

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Unfolding refers to the process of correcting measurements from detector effects in experimental physics and is an essential step of any analysis, not only because measurements become more precise but also, in some occasions, results might be misleading if not unfolded properly. Unfolding belongs to the category of inverse problems since one aims to estimate the true value of an event that has already happened and measured, through the exploitation of available information of measurements, experimental apparatus, theory and simulations.

Jets are collimated clusters of hadrons produced in hard scattering processes during particle collisions and serve as an important probe for understanding the properties of quark-gluon plasma (QGP). This research focuses on jet substructure observables and more specifically observables within the Lund plane which describes a reclustering of jet constituents, in particular, the angular and momentum phase space of partonic emissions of the leading prong.

Traditional unfolding methods rely on discretizing distributions through binning that is often predetermined hence are restricted to low-dimensional unfolding. Machine learning methods provide unbinned and dimensionless solutions to this problem that can become more efficient in determining detectors response due to their multidimensional functionality. In this talk, I will present two of such methods, Omnifold and Moment Unfolding. The unfolded data are from proton-proton (pp) collisions at 13 TeV collected from the A Large Ion Collider Experiment (ALICE) at the LHC. Omnifold is an iterative reweighting method that utilizes maximum likelihood classifiers to update weights via a neural network. The weights are obtained through a weighting function that aims to match simulated Monte Carlo data to the distributions of experimental measurements. On the other hand, Moment Unfolding utilizes the concept of a Generative Adversarial Network (GAN) to match statistical moments of distributions through a weighting function inspired by the Maxwell-Boltzmann distribution from Statistical Mechanics.

Posters

Applications of scintillators in radiation detection.

Dr Jan Jongman[1]
[1]Scintacor

Scintillating materials are widely used to visualize ionizing radiation. In this talk we give an overview of the different scintillating materials used in commercial applications and their key performance parameters. Examples will be given for low and medium energy X-ray detection in medical and homeland security applications. Phosphors are widely used for beam visualization, charge particles, IR and UV laser and in SEM or TEM applications. Combining phosphors and CMOS sensors enables low cost radiation and charge particle detection with excellent positional information.
Neutron detection capabilities of large area 6LiF coated screens will be discussed. Large area neutron detection screens are a cost effective solution to reveal weak neutron sources hidden in cargo. Lithium-6 and Lithium-7 glasses are ideal when high neutron detection cross section is required. The advantages of glass neutron detectors include: robustness; a wide useable temperature range and the glass can be manufactured into different geometries.

Bayesian Analyses of Key Quark-Gluon Plasma Parameters Using JETSCAPE

Matthew Ockleton[1], Dr. Jaime Norman
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This poster focuses on constraining parameters associated with the Quark-Gluon Plasma (QGP); the state produced by strongly interacting matter at high energy densities in heavy-ion collisions.

JETSCAPE [1] is a multidisciplinary collaboration that connects Quantum Chromodynamics theory to experimental data through a modular framework of Monte Carlo simulations. These simulations represent the evolution of a heavy-ion collision, allowing comparisons to experimental data to test the theory. Key parameters of the QGP, such as the jet transport coefficient, are estimated using Bayesian inference. Investigations using the JETSCAPE framework [2] [3] have shown promising results.

Previous Bayesian analyses did not fully account for all factors in jet-medium interaction and the hydrodynamic medium. The new approach will simulate both plasma evolution and jet propagation simultaneously, allowing the variation of parameters such as initial temperature and jet-medium coupling. These changes will be studied through observables like the jet nuclear modification factor RAA and elliptic flow v2. This work represents initial steps towards advancing Bayesian analyses within JETSCAPE.

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Beta-decay spectroscopy of proton-rich N=82 isotones.

Norah Alwadie[1,2], Robert Page[1], David Joss[1], Andrew Briscoe[1], Betool Alayed[1,3], Adam McCarter[1,4], Muneerah Al'Aqeel[1,5], David O'Donnell[6], Emmanuel Rey-herme[7], Paul Greenlees[4], Matti Leino[4], Rauno Julin[4], Juha Uusitalo[4], Tuomas Grahn[4], Janne Pakarinen[4], Panu Rahkila[4], 1 Panu Ruotsalainen[4], Jan Sarén[4], Kalle Auranen[4], Andres Illana[4], Minna Luoma[4], Hena Joukainen[4], Henri Jutila[4], Jussi Louko[4], George Zimba[4], Ville Bogdanoff[4], Eetu Uusikylä[4], Holly Tann[1], Lorna Waring[1], Conor Sullivan[1], James Deary[4], Marc Labiche[8], Martin Venhart[9], James Cubis[10], Chris Page[11], Philippos Papadakis[6], Monika Birova[9], George Beeton[10], James Keetings[6], Hamid Ayatollahzadeh[5], John Smith[12], Shiyamjith Nathanial[1], Alvaro Tolosa-Delgado[4]

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The beta decay of the heaviest known N=82 nuclide 156W was recently reported and found to exhibit a different decay pattern to152Yb and their lighter isotones [1]. This work investigates the beta decays of the intermediate isotone 154Hf to learn about the evolution with increasing atomic number of the beta decays of even-even N=82 isotones. Although a microsecond isomer in 154Hf has been identified [2,3] and its half-life has been indirectly determined as 2(1)s from the time differences between the alpha decays of 158W and 154Yb [4], the beta decay of the ground state remains unknown. The ground state of 154Hf nuclei was populated via the alpha decay of the ground and isomeric states of 158W. The 158W nuclei were produced at the Jyväskylä Accelerator Laboratory in fusion-evaporation reaction by bombarding a 106Cd target with 58Ni ion beam. The 158W nuclei were separated in-flight using the Mass Analysing Recoil Apparatus (MARA) and implanted into a double-sided silicon strip detector (DSSD) at its focal plane. The DSSD was surrounded by an array of germanium detectors, which were used to measure gamma rays in coincidence with beta particles emitted in the decay of 154Hf . These measurements enabled the determination of a more precise half-life and a preliminary level scheme for 154Hf to be constructed. The latest of results from the analysis will be presented along with prospects for future studies.

Constraining Abundance Anomalies in Globular Clusters: γ-ray Spectroscopy of 39K

Claire Jameson[1]
[1]University Of Surrey

Globular clusters (GCs) are densely populated groups of stars that orbit galaxies and they are predominantly found in the galactic halo. They contain anywhere from tens of thousands to millions of stars, placing them somewhere between open clusters and galaxies. Observations of GCs have shown abundance anomalies that indicate multiple periods of star formation within each cluster. The current understanding is that there was a "first generation" of stars and that later stars formed from the ejecta of these stars. However, knowledge of the nature of the polluting site(s) and how the cluster inter-stellar medium was enriched with their processed matter is still limited. Solving this puzzle will allow us to gain critical insight into both galaxy formation and stellar evolution. A new Mg-K anti-correlation has been observationally identified in a number of GCs, and computational models have shown super-Asymptotic Giant Branch (AGB) stars and classical novae to be potential sites for the source of this anti-correlation. They have also identified the 38Ar(p, γ)39K reaction as crucial for understanding how this anti-correlation develops. Under super-AGB and classical novae conditions the 38Ar(p, γ)39K reaction is governed by resonant capture into excited states over the proton-emission threshold energy in 39K. Specifically, there are three resonances that are key to this reaction that are predicted to have the most significant impact on the reaction rate at super-AGB and classical novae temperatures. However, we know very little about the strengths of these resonances, as the spin-parity assignments of the corresponding excited states in the 39K nucleus are unknown. We recently performed a detailed γ-ray spectroscopy study of the 39K nucleus using the GRETINA γ-ray tracking array and Fragment Mass Analyzer at the Argonne National Laboratory to attempt to determine the spin-parity assignments of the critical excited states and will present our findings to date.

Development of ICP-MS-CRIS

Alexandra Roberts

Measuring trace isotopes is a necessity in the management of UK nuclear wastes. Current instruments struggle to detect minor actinides at concentrations representing the boundary between low and very low level waste, i.e. 4 MBq/tonne total activity [1]. Inductively Coupled Plasma Mass Spectrometers (ICP-MS) have been widely used in the nuclear industry but have been shown to fail to detect an equivalent level of radiostrontium (the stable isotope 88Sr was used for testing) in a potential waste sample. Better classification around this boundary will reduce the cost of nuclear disposal while maintaining the industry's high safety standards.

ICP-MS is a well understood technology, however, it is limited by isobaric interferences from neighbouring isotopes and molecules, some of which are formed within the device. Several techniques of improving the limit of quantitation have been attempted and failed. Joining ICP-MS with more sensitive technology has the potential to solve this issue of waste classification and open the door to some interesting fundamental physics. Collinear Resonance Ionisation Spectroscopy (CRIS) is a laser spectroscopy technique that is widely used, with experiments at CERN, JYFL, FRIB and PKU. It has a high sensitivity to individual isotopes and can shed insight into the structure and hyperfine structure of nuclei. The joining of these technologies will create an instrument, ICP-MS-CRIS, able to detect almost any element across the periodic table [2]. This has wide ranging applications including very low level waste classifications and further expanding the study of nuclear structure.

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Development of Silicon Carbide-based Neutron Detectors using Geant4 Simulations

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This work investigates Silicon Carbide (SiC) as a thermal neutron detectors using the Geant4 Monte Carlo simulation toolkit. 4H-SiC has excellent radiation hardness, wide bandgap, good thermal conductivity, and capability to function at high temperatures [1]. This makes the 4H-SiC an ideal candidate for wide range of applications, including nuclear radiation detection, high-temperature environments, neutron detection, and dosimetry[2, 3], with potential of surpassing detectors based on conventional materials, e.g. silicon (Si), for neutron detection in challenging conditions.
Various configurations, including planar and trench-type of SiC based detectors were investigated. The modelled configurations employed different neutron conversion materials, including Boron (^{10}B), Boron Carbide ($^{10}B_4C$), Boron Nitride (BN), Boric Acid (H_3BO_3), and lithium fluoride (^{6}LiF). From the simulations, it was found that the intrinsic detection efficiency can be optimised by adjusting geometrical parameters such as converter layer thickness, trench spacing, and trench depth. Comparisons between planar and trench-type designs indicate that single and double trench configurations have significantly better detection efficiency.
We have also found that a single-trench SiC neutron detector filled with one of the boron-based compounds was more effective than the double-trench configuration containing different neutron conversion materials. The highest detection efficiency of 41.8% was achieved using a trench filled with ^{10}B with a trench depth of 25 µm. This detector design also offers better performance in certain critical energy deposition scenarios.

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Electromagnetic moments of yttrium and zirconium isomeric states

Alejandro Restrepo Giraldo[1], Jacek Dobaczewski[1], Lee Morgan[2], Aaron Stott[2]
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Isomeric states provide crucial information on the internal structure, decay mechanisms, and fundamental interactions in the atomic nucleus [1]. In medium-mass nuclei such as yttrium and zirconium, a rapid shape transition from spherical to deformed shapes occurs around $A \approx 100$ making them excellent candidates for testing nuclear theories. Using the density functional theory implemented in the code HFODD [2], we determined the spectroscopic magnetic dipole and electric quadrupole moments for ground and excited states of the odd-mass yttrium and zirconium isotopes in the range of A=79-121. The methodology implemented [3] aligns the results with available experimental data, achieving a good representation of the internal structure of the studied nuclei without the use of phenomenological effective charges or g-factors. As a next step, we are going to extend the calculations to determine the electromagnetic transition rates and compare them with the measured isomeric lifetimes.

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Energy Losses in Low-Energy Electron Interactions for Auger Electron Radiotherapy Development

Mr. Alfredo Vigny Mercado Quintero[1], Dr Christian Aaen Diget Diget[1], Dr Christopher Walker[1], Dr Julien Joseph Felix Bordes[1], Dr Andrew Pratt[1], Mr Yousef Alharbi[1], Dr Steve Tear[1], Dr Christian Aaen Diget[2]
[1]University Of York, [2]TRIUMF

We present mechanisms of energy loss in backscattered electrons on copper using a 900 eV electron beam, focusing on surface and volume plasmon excitation, phonon losses, valence electron excitations, and inner-shell electron excitations. Energy distribution histograms from Geant4 simulations are compared with experimental spectra obtained using a Bessel Box Electron Energy Analyser. The study specifically evaluates the angular dependence of the incident electron beam with regards to its energy loss and scattering, providing insights into the dynamics of both elastic and inelastic low-energy electron interactions.

Furthermore, simulations for Highly Oriented Pyrolytic Graphite (HOPG) will be compared with experimental data as a next step towards assessing the interaction of Auger electrons in bioequivalent materials. The results aim to enhance our understanding of the cellular response to radiation and have potential applications in radiation therapy. This work will contribute to the development of microdosimetric models for energy deposition in cellular regions, particularly the cell nucleus, using isotopes such as Iodine-125, Indium-111, Platinum-195m, and Thallium-201. Comparisons of microdosimetric simulations with simplified models assuming average electron energy will help assess variations in energy deposition, ultimately refining predictions of efficacy for new cancer treatments.

Enhancing Particle Identification and Simulation in the ALICE Experiment with Machine Learning and ONNX Integration

Robert Forynski[2]
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The ALICE experiment at CERN focuses on studying the quark-gluon plasma, a state of matter present in the early universe, by analysing data from ultrarelativistic heavy-ion and proton-proton collisions. As the Large Hadron Collider (LHC) transitions to Runs 3 and 4, higher collision rates create significant computational challenges for data analysis and particle identification (PID). This study addresses these challenges by implementing advanced machine learning (ML) methods within the ALICE O^2 Physics framework.

The research centres on enhancing PID by utilising deep neural networks (DNNs) and transformer-based models to analyse signals from key detectors, primarily the Time Projection Chamber (TPC) and Time-of-Flight (TOF). These ML models exploit inter-detector correlations, providing improved classification precision and recall compared to traditional approaches. Additionally, generative adversarial networks (GANs) are employed to augment simulation workflows, offering an alternative to computationally intensive Monte Carlo simulations. The outcome is faster and more scalable data generation, which is critical for meeting the demands of the high-luminosity collision environment.

A key innovation of this work is the integration of ML models into ALICE's C++ infrastructure using the Open Neural Network Exchange (ONNX) runtime library, enabling seamless deployment of Python-trained models within distributed workflows. By utilising the hipe4ml package, this approach ensures scalability while maintaining compatibility with the O^2 framework. Optimising computational workflows enhances particle identification and simulation efficiency, meeting the high-throughput demands of Runs 3 and 4 while supporting real-time data analysis in ALICE.

This research establishes a framework that integrates advanced ML techniques with scalable deployment strategies, ensuring efficient processing of high-energy physics data. By improving real-time analysis and simulation, these developments contribute to the broader evolution of data-driven methodologies in modern physics.

Investigating Nuclear Excitation by Electron Capture

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Experimental evidence of the inverse of internal conversion, nuclear excitation by electron capture (NEEC), continues to elude nuclear physicists. Following the reported observation of NEEC in Nature, 2018, using 93mMo, and its subsequent theoretical disagreement, there has been heightened interest in the nuclear excitation mechanism.

Induction and isolation of NEEC versus other competing mechanisms such as CoulEx and NEET remains the most significant challenge when it comes to authenticating NEEC measurements. The 93mMo used was produced in a fusion-evaporation reaction, then recoiled through a carbon foil, resulting in a considerable spread in the energy and charge state entering the carbon foil where NEEC was suggested to occur. The goal of the present study is to observe NEEC using an accelerated beam of 84mRb. Just 3 keV above the isomer exists a short-lived 5- state, enabling an excellent signature for this de-excitation route. The accelerated beam allows for a defined charge state and a constrained energy and energy spread. Therefore, the conditions of the present study become favourable for the NEEC process.

Investigation of the role of Multi-Neutron Transfer on sub-barrier fusion enhancement

Ms Anjali Merin[1], Dr E. Prasad[1], Dr S. Nath[2], Dr J. Gehlot[2], Ms Gonika[2], Ms B. Ashna[1], Ms Varsha K.V[1], Ms Panchami P.P[1], Mr Shivaprasad[1], Dr A. M Vinodkumar[3], Ms Jinu K.V[3], Ms K. Prameela[4], Mr S. Ramakrishna Reddy[4], Dr S. Appannababu[4], Mr Chandra Kumar[2], Mr Alankar Singh[2], Dr Rishabh Kumar[2], Dr P. Manju[1], Mr Rayees Ahmad Yatoo[5]

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The investigation of heavy-ion collision dynamics at sub-barrier energies has been the focus of significant experimental and theoretical research for several decades. An intriguing phenomenon in this energy regime is the enhancement of fusion cross sections, which is attributed primarily to quantum tunneling through the Coulomb barrier. Empirical studies consistently report a substantial increase in sub-barrier fusion cross sections, surpassing the theoretical predictions of the One Dimensional Barrier Penetration Model (1D-BPM) [1]. Such enhancement provides a path to explore various degrees of freedom between the interacting nuclei such as the static deformation, the dynamical effects, coupling of inelastic excitations and nucleon transfer channels. The effect of positive Q value Neutron Transfer (PQNT) channels on the sub-barrier fusion enhancement is still elusive in most of the cases. Therefore, in order to ascertain the aforementioned aspects, fusion excitation function measurements from ~15 % below and above the Coulomb barrier have been performed for 28Si + 142,150Nd systems using the Heavy Ion Reaction Analyzer (HIRA) at Inter University Accelerator Centre (IUAC), New Delhi. The experimentally measured fusion cross sections for the both Nd isotopes around the Coulomb barrier have been found to be enhanced as compared to uncoupled calculations. Coupled-Channels (CC) formalism has been employed to probe the underlying reaction mechanism [2]. The effect of Multi-Neutron Transfer (MNT) channels on sub-barrier fusion enhancement has been highlighted. Further, fusion barrier distribution have also been derived from the experimental data to understand the dynamics of the various channels coupled in the reaction. Detailed analysis and results will be presented during the conference.

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Laser spectroscopy of neutron deficient lutetium (Z=71)

David Mcelroy[1], Kara Lynch[1]
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Laser spectroscopy of neutron-deficient lutetium isotopes (Z=71) can provide insights into the evolution of nuclear structure towards the proton drip line, independent of any nuclear models. Probing the hyperfine structure with laser spectroscopy allows the measurement of nuclear spins, magnetic moments, quadrupole moments and isotope shifts of these exotic nuclei. The isotope shift can then be used to determine the charge radii across the isotopic chain, which in turn reveals how the nucleus deforms with varying neutron number [1].

Previous experiments in 1998 at the ISOLDE – CERN facility used collinear laser spectroscopy to probe the nuclear structure of lutetium isotopes [2], however, there have since been many improvements to laser spectroscopy techniques. The Laser Ion Source and Trap (LIST) and its newly-developed variant, the Perpendicularly Illuminated Laser Ion Source and Trap (PI-LIST), are useful methods for achieving high selectivity in resonance ionization spectroscopy. In LIST, resonance ionization occurs within a radiofrequency (RF) quadrupole, allowing only laser-ionized species to pass through while suppressing background ions. PI-LIST extends the capability of the LIST configuration by reducing doppler broadening effects, resulting in a higher resolution with spectral linewidths in the range of 200-300 MHz [3].

Recent tests (LOI278) on lutetium isotopes conducted at ISOLDE utilised these techniques to investigate the sensitivity of a new resonance ionization scheme to the isotope shift, in preparation for future in-source laser spectroscopy of neutron-deficient lutetium with the PI-LIST setup.

Additionally, this project involves the development of an RF transducer device to enhance the efficiency of the LIST setup. This device will incorporate phase-locking within a resonant LCL circuit to optimise signal stability and RFQ efficiency for improved performance.

This contribution presents an overview of the motivation for investigating neutron-deficient lutetium isotopes, a summary of the PI-LIST technique, recent results from Lu LOI278 and upgrades to the RF transducer box that is soon to be installed at ISOLDE.

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Low cost, high speed VME data acquisition for Nuclear physics heterogeneous, multi-detector experimental setups

Ms Mamta Jain[1,2], Mr Subramaniam E.T.[1], Prof. Shouri Chatterjee[2]
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The new VME based data acquisition system have been designed and developed to fullfil the need of the Nuclear physics experimental setups at IUAC using in-house developed VME crate controller module ROSE and the commercial 32 bit VME data converter modules, analog to digital converters (ADC), time to digital converter (TDC), Scalar and charge to digital converter (QDC). Readout Ordained Sequencer Engine(ROSE): A single FPGA chip is used to integrate the hardware & software features inside the firmware to reduce the number of context switching in the computer. it results in higher throughput and lower dead time for acquisition of voluminous data. It includes a sequencer for event mode data collection, two ping-pong buffers for simultaneous acquire and transmission and a busy logic for event validation along with time stamping for synchronization at 10ns. The USB interface section facilitates the super speed 5Gbps USB 3.0 link or 1Gbps ethernet. Apart from all this it supports VME interface with 32bit VME standards ANSI/IEEE 1014-1987. it provides 40 Megabytes/s VME back plane throughput.

As the demand for high resolution and the data handling of large number of signals along with maximizing the throughput are the key requirements in the nuclear physics experiments. This raises the need for high density, complex and compact modules for charge, time and energy measurements. A 21 slot VME crate may handle around 500/1000 parameters in a data acquisition setup. The VME based DAQ provides high throughput, high speed readout (110ns read) thereby achieving very less dead time as compared to the CAMAC based data acquisition systems. The VME based DAQ have been installed in HIRA, HYRA, NAND, GPSC, INGA, GDA nuclear physics facilities along with, Atomic physics and LEIBF facilities. To serve the need of wide application areas, where high reliability, accuracy and high speed are desired, different types of slave modules are used. Like for gamma spectroscopy, high resolution 13 bit MADC32 are used in high resolution mode with the conversion period of 12.8us to achieve the max hi-resolution, where as in HIRA / HYRA the same MADCs are used in 13 bit low resolution mode with conversion time of 6.4us, to reduce the dead time. To acquire a meaningful event from a master trigger of the experimental setup, the acquisition should provide apt time for conversion and readout. This requires a robust busy logic that works seamlessly even at very high input rates. In our case the busy logic is implemented inside the VME crate controller to take care of the dead time requirements of the DAQ modules like ADC, TDC, QDC and scaler etc., along with readout time delay and provides the second level trigger of the accepted events, as per dead time requirements for all the slave modules. Finally, the zero suppressed data is collected in ROOT format, to maintain the international standards and improve the adaptability of the users.

Machine-Learning Optical Model Parameters

Samuel Sullivan[1], Paul Stevenson[1,2], James Benstead[1,2], Lee Morgan[1,2]
[1]University Of Surrey, [2]AWE

Optical model potentials (OMPs) are key for the description of mid-to-high energy nuclear scattering. OMPs are complex potentials which reduce the many-body nuclear interaction to a single-body interaction involving an incident particle interacting with an average potential. The optical model provides a relatively straightforward schema for calculating scattering cross sections, as well as transition amplitudes which are necessary for the prediction of direct and compound-nucleus reaction channels. The most effective optical potentials are phenomenological, determined by fitting numerical parameters to nuclear data. An example of these is the Koning-Delaroche (KD) optical potential. Accurate OMPs are crucial for the prediction of cross sections in many domains, from nuclear astrophysics to nuclear reactor physics.

This presentation describes a novel approach to generating locally optimised KD optical potentials using machine learning (ML). An initial stochastic sampling of KD parameterisations are generated using the nuclear reaction code TALYS, and these are used to train a neural network which emulates TALYS. This ML model is then used to sample the parameter space more rigorously, ultimately generating data which is used to train a parameter-estimating neural network. This latter network takes evaluated nuclear data as input, and aims to predict the KD parameters which will ultimately best reproduce the input data.

Preliminary work has been encouraging. In particular, the TALYS-emulating network performs well against a test dataset of cross sections, with root-mean-square error of less than 12 mb. The parameter-estimator model currently predicts the value of KD parameters with a mean absolute % error of less than 10% compared to test set values in the majority of cases. This model also produced a parameter set which was used to calculate cross sections that agreed well with the EXFOR cross section data used as input, but did not demonstrate an improvement on TALYS global or local parameterisations. Future work will involve improving the parameter-estimator model, and incorporating further reaction channels during model training. Bayesian methods will be used to quantify uncertainties introduced at all stages of the framework.

Integration of machine learning into nuclear data evaluation

Mr William Hopkins[1]
[1]University Of Glasgow

My work investigates the integration of machine learning into nuclear data evaluation, with a focus on neutron-induced reaction cross-sections. Traditional approaches often struggle with data gaps and human biases, limiting their predictive accuracy. By applying supervised learning models—Decision Trees, K-Nearest Neighbors, Random Forests, and Gradient Boosting Regressors—we aim to enhance cross-section predictions.

I have compiled a dataset incorporating experimental data from EXFOR, evaluated data from ENDF, and nuclear properties from the AME2016 dataset. My findings demonstrate that ML models can effectively predict neutron cross-sections, often surpassing traditional nuclear data libraries in accuracy.

Notably, the Gradient Boosting Regressor and Decision Tree models successfully predicted the $^{35}Cl(n,p)^{35}S$ reaction cross-sections, closely matching new experimental data not included in training. Feature importance analysis identified incident neutron energy and nuclear properties, such as separation energies, as key predictive factors.

This study highlights the potential of ML to improve nuclear data evaluation by increasing accuracy and reducing bias. The findings have implications for applications requiring high-precision nuclear data. Future work will focus on improving model interpretability and integrating ML with physics-based methods.

Nuclear Astrophysics Studies with the High-Flux Accelerator-Driven Neutron Facility (HF-ADNeF)

Patrick Galvin[1], Dr Jack Bishop[1]
[1]University Of Birmingham

Experimental cross section measurements are an essential component of understanding the nucleosynthesis of elements in stars and refining astrophysical models, especially in understanding the contribution of the intermediate (i-) neutron capture process, characterised by neutron fluxes between the slow (s-) and rapid (r-) processes, to the formation of elements heavier than iron[1].

This project employed the uniquely high neutron fluxes available at the University of Birmingham's High Flux Accelerator-Driven Neutron Facility (HF-ADNeF) to measure the well-studied 59Co(n,γ)60^(m+g)Co cross section, the novel partial 59Co(n,γ)60^(m)Co cross section, and ultimately test the feasibility of measuring i-process reaction cross sections at the facility with the 60Co(n,γ)61Co double activation serving as a pilot. Preliminary results and conclusions will be presented here.

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Optical Segmentation of Cadmium Tungstate Scintillators via Sub-Surface Laser Etching

Mr Alexander Kippax[1]
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Scintillation detectors enable the detection and measurement of high energy photons. They have applications in a number of fields including gamma-ray and particle spectroscopy in fundamental nuclear physics, PET scans in medical imaging, and x-ray imaging in the security sector. The performance of detectors in these applications depends on their position resolution. This either requires detectors which are position sensitive, which can be achieved through the use of many optically isolated scintillation crystals, through pulse shape analysis of signals collected via segmented silicon photomultipliers (SiPMs), or through the use of collimation, which can both be costly, and therefore prohibit approaches in industry, or reduce the efficiency of the system, which is important in terms of the delivered dose in applications.

This project explores the use of sub-surface laser etching (where a laser is focussed beneath the surface of a transparent medium to produce micro-fissures within the bulk of the material) to optically segment a single crystal of cadmium tungstate (CdWO_4). The optically segmented crystal is then coupled to SiPMs. Through signal comparison, position information can be determined along with low levels of energy discrimination. This will effectively improve the position resolution and energy discrimination of the scintillator crystal, improving the capabilities of any scintillator array, whilst costing less than traditional methods.

This project is supported by EPSRC and Rapiscan Systems Ltd

Pixel-based Target Recoil Tracker (TRT) for R3B at FAIR

Ms Beatriz Amorim[1], Luke Rose[1], Stefanos Paschalis[1], Marina Petri[1], for the R3B TRT working group
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The upgraded setup for the R³B experiments at FAIR introduces a pixel-based Target Recoil Tracker (TRT) detector, designed to enhance the detection capabilities of light-charged particles, such as protons, emitted in nuclear reactions. The TRT surrounds the reaction target and is further enclosed within a highly segmented calorimeter constructed from CsI crystals, named CALIFA, focusing on precise angle measurements of these particles. This innovative detector utilizes the fully developed ALPIDE Monolithic Active Pixel Sensor (ALPIDE MAPS) technology, originally designed for ALICE/CERN experiments [1].

The project progresses through three key stages. Stage 1 is an ongoing R&D effort, delivering two detector arms equipped with ALPIDE sensors with limited acceptance, suitable for Phase 0 experiments and beam tracking. Stage 2 involves a barrel-shaped detector array with large angular coverage and an optimized material budget. The final stage envisions integrating next-generation sensors using large, ultra-thin silicon wafers bent and arranged in perfectly cylindrical layers [2].
In this contribution, we present the results from in-beam evaluation using ALPIDE, demonstrating the excellent performance of the TRT detector. In addition, we present and discuss recent studies on efficiency and resolution performance of Stage 2 using R3BRoot (Geant4) simulations.

[1] B. Abelev et al. and the ALICE Collaboration. “Technical Design Report for the Upgrade of the ALICE Inner Tracking System”. In: Journal of Instrumentation 41 (2014). DOI: 10.1088/0954-3899/41/8/087002.
[2] R³B Collaboration et al. “Technical Report for the Design, Construction and Commissioning of the Pixel-based Target Recoil Tracker (TRT) for R³B”. In: (2023), pp. 0-72.

Progress towards a multi-detector system for quantification and identification of low-activity CTBT-relevant radionuclides

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The International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) performs continuous radionuclide monitoring, supported by a network of 16 radionuclide laboratories which undertake verification and reanalysis of samples. The current analysis technique employed across the IMS uses high-resolution gamma-ray spectroscopy to identify and quantify radionuclides present on high-volume air filters. Ongoing efforts to increase the sensitivity of measurements and reduce detection limits have seen the development of more advanced techniques. Multi-detector systems can be utilised to vastly reduce the signal-to-noise ratio of measurements by gating on coincident events in the detectors. This poster presents work being conducted at the UK's CTBT radionuclide laboratory, GBL15, on a multi-detector system for the application of identifying low-activity CTBT-relevant radionuclides. The system consists of two High Purity Germanium (HPGe) detectors and two Sodium Iodide (NaI) detectors. So far, an experimental testbed has been established to determine if the additional scintillator detectors can improve the detection limit for radionuclides of interest. Initial results will be presented.

R-matrix fitting with probabilistic transformer neural networks

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The transformer model has recently become one of the most powerful machine-learning architectures, serving as the foundation for large language models (LLMs) due to its ability to learn long-range context in input sequences. This model has since been adapted for purposes in nuclear physics including the identification of resonances in compound nuclei from differential cross-section data [1]. Typically, resonance parameters are identified through chi-squared minimisation with R-matrix phenomenology; however, the uncertainties produced with this method can be unreliable and the process requires a lot of manual effort.

A probabilistic neural network based on the transformer model has been used to identify the resonance parameters of the first three excited states of 13N with their associated uncertainties, from differential cross-section data of 12C(p,p)12C elastic scattering at three angles. The competence of this model when applied to more complex cross-section data will be investigated, as well as the implementation of more sophisticated transformer models. This poster overviews the architecture of the transformer model, the method for uncertainty quantification and potential investigations into how the model can be improved.

[1]: Kim, C. H., et al. "Probabilistic neural networks for improved analyses with phenomenological R-matrix." Phys. Rev. C 110.arXiv: 2305.02623 (2024).

Simulations for development of RF cooler-buncher for beam prep into MR-ToF

Charlie Agg

The Multi-reflection Time-of-Flight mass spectrometer has in recent decades become a powerful technique for high-precision mass measurement and isobaric separation. The path length traversed by an ion bunch is increased by reflection between electrostatic mirrors, traversing the analyzer up to 1000s of times. With a measurement time of a few milliseconds, high precision mass measurements of exotic nuclei can be obtained, with mass resolving powers $R = m / \Delta m = t / 2\Delta t$ beyond 106 achieved in an instrument of tabletop size.

Preceding construction of an MR-ToF at the Photon Science Institute at UoM, simulations have been performed to investigate the beam conditioning requirements for an integrated ICP-MS-MR-ToF experiment. Simulations of an Ar beam through a Linear Paul trap have been completed within SIMION to optimize time focusing of an ion bunch for beam energies of 3 - 10 keV. A bunch width of 500 ns in time was achieved for injection into MR-ToF, allowing R of 104 to be achieved, with the aim of improving this in further optimizations of MR-ToF potentials.

Simulations for the development of a new Ion Source Test Stand

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Infrastructure for a new Manchester-based Ion Source Optimisation and Testing Apparatus (IOTA) is currently being developed. This system will be employed for ion source development with a focus on long lived medically relevant isotopes. The target and ion source will be biased at 2 kV with a grounded extraction electrode, greatly simplifying the system. A realistic field gradient at extraction will be maintained by proportionally reducing the distance between the ion source and extraction optics. The front-end of this system will be compatible with both CERN-ISOLDE and TRIUMF-ARIEL ion source geometries. IOTA will be coupled to a dedicated laser system composed of tuneable Ti:Sa and dye lasers, enabling selective laser resonance ionisation. In combination, these systems will enable ion source optimisation, laser spectroscopy, and ionisation scheme development for exotic isotopes with medical applications.

Preliminary ion beam transport simulations, which will enable the construction of IOTA, are presented. The locations and geometries of the ion-beam optics have been optimised. Simulated beam-line components include extraction optics, a double focusing electrostatic deflector, beam diagnostics, einzel lenses, and deceleration optics. Beam quality has been evaluated using the following metrics: normalised and non-normalised transverse emittance, longitudinal energy spread, and beam profile. Estimated ion beam transport efficiencies for surface ion sources will also be presented.

Spectroscopy of 225Ra following Beta Decay of 225Fr

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The onset of permanent octuple-deformed nuclear shapes like nuclei located between radon (Z=86) and uranium (Z=92) with N ≈ 138 have generated intense interest. Odd-mass actinides in particular, offer a promising ground for the revealing of new physics through the search for an atomic electric dipole moment (EDM), where the presence of nuclear octuple-deformation has an enhanced effect on it. The even-odd ^{225}Ra nucleus is a good candidate for measuring electric dipole moment (EDM). Therefore, this experiment was conducted in 2022 at TRIUMF, using the GRIFFIN spectrometer located at ISAC-I. The aim for this experiment is to measure the excited states of ^{225}Ra populated by β decay of ^{225}Fr. Precise measurements of the intensities of γ-rays and conversion-electrons will aid ongoing Coulomb excitation studies. In addition branching ratios, multipolarities and D_0 values will be extracted.

Preliminary analysis of this experiment will be presented including calibrations of the detectors and an initial work to extract branching ratios which are compared with the literature listed in an NNDC.

Strange Hadron Spectroscopy in Hall D Jefferson Lab

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The identification of exotic mesons is fundamental to further our understanding of confinement within the framework of Quantum Chromodynamics. Strange hybrid mesons are notably difficult to identify owing to them being crypto exotics, meaning they don't have quantum numbers inaccessible to normal quark anti-quark mesons. As a result of this, the establishment of a strange hybrid meson necessitates a complete mapping out of the strange meson spectrum to allow for explicit comparison between the number of predicted and found states.

Excited strange mesons decay to lighter longer lived particles. The examination of these longer lived particles, through techniques such as partial wave analysis, allows for establishment of the excited state quantum numbers. This required an experimental setup able to measure many different reaction products.

The GlueX experiment located in Hall D at Jefferson Lab, Virginia, is ideally suited for this task. The setup consists of a 9GeV linearly polarized photon beam and a liquid hydrogen target. Data gathered from a variety of different detectors surrounding the target makes the required reconstruction possible. This poster will motivate the analysis of specific decay channels using data provided by GlueX, and give brief descriptions of the techniques used to do so.

Studying the scintillation and photon transport characteristics of CeBr3

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$CeBr_3$ is a novel scintillator material that has recently gained interest as an improvement over more conventional scintillator materials such as NaI. $CeBr_3$ possesses excellent performance characteristics for gamma-ray spectroscopy including superior energy and timing resolutions along with a high detection efficiency and low intrinsic background . This poster seeks to demonstrate the capabilities of $CeBr_3$ as a scintillator material by presenting experimental and simulated data obtained at the University of York for the HYPATIA (HYbrid Photon detector Array To Investigate Atomic nuclei) project. $CeBr_3$ is extremely hydroscopic which requires testing to be conducted in an ultra low humidity environment. The University of York has the specialist capability to assemble and test these crystals on-site, providing a unique opportunity for studying the properties of $CeBr_3$. In particular we focus on the characterization and potential application of the positional sensitivity of $CeBr_3$. The experimental data was obtained from $8x3x3cm^3$ $CeBr_3$ crystals using a highly collimated 662 keV gamma-ray from a ^{137}Cs source and the simulated data was obtained from Monte Carlo GEANT4 photon transport simulations developed at the University of York.

The evolution of nuclear structure near the N = 20 Island of Inversion - a measurement of 30Mg(d,p)31Mg reaction

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The region of the nuclear chart centred around 32Mg, known as the Island of Inversion (IOI), is characterised by the onset of deformed configurations in the ground states due to particle excitations across a weakening N=20 shell gap. The IOI has been described using numerous observables, but information regarding the single-particle structure of nuclei in this region is limited. The aim of this work is to portray the evolution of the single-particle properties across the boundary of the IOI, through comparison with previous measurements of nuclei located outside of it. This offers valuable insights into the mechanisms of cross-shell interactions and acts as a robust test of modern shell model calculations that have struggled to describe the transition to this region in the past.

The 30Mg(d,p)31Mg reaction was performed in inverse kinematics at the incident beam energy of 8 MeV/u. Using the ISOLDE Solenoidal Spectrometer at CERN to analyse the outgoing protons, the experiment probed the single-particle structure of both the bound and unbound states of 31Mg up to the excitation energy of 3 MeV. Combining the results with previously obtained data on 29Mg, allowed for a characterisation of the evolution of single-particle properties across the boundary of the IOI. This work was supported by the U.K. Science and Technology Facilities Council [Grants No. ST/P004598/1, No. ST/N002563/1, No. ST/M00161X/1 (Liverpool), No. ST/P004423/1 (Manchester), No. ST/P005314/1 (Surrey), the ISOL-SRS Grant (Daresbury), No. ST/R004056/1 (Ernest Rutherford Fellowship - Gaffney), No. ST/T004797/1 (Ernest Rutherford Fellowship - Sharp)], the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contracts No. DE-AC02-06CH11357 (ANL), the Research Foundation Flanders (FWO, Belgium), and the European Research Council under the European Union’s Seventh Framework Programme (FP7/2007-2013)/ERC Grant Agreement No. 617156.

The optimisation of neutron-producing targets for the d-7Li reaction.

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The d-7Li reaction can produce high-energy neutrons covering the D-T spectrum peak at 14 MeV. The University of Birmingham's High-Flux Accelerator-Driven Neutron Facility (HF-ADNeF), the most intense neutron source of its kind in the world, currently utilises the p-7Li reaction. However, the accelerator could feasibly accelerate deuterons onto the lithium target instead. The aim of this project is to realise the d-7Li capability of the facility, producing high-energy, quasi-mono-energetic neutrons at high flux for a range of exciting applications. The pathway to producing neutrons in this way will be covered in this poster.

Towards fast calculations of nucleon-nucleus scattering from microscopic optical potentials

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The optical potential (OP) is a fundamental ingredient that is widely used in nuclear reactions. Broadly speaking, there are two types of approaches to determine OPs, phenomenological and microscopic. Phenomenological OPs are based on some free parameters that are fixed to reproduce the existing experimental data, while microscopic OPs are obtained from fundamental theory. Although phenomenological OPs can give a better description of the data, they lack predictive power due to their dependence on the free parameters. In contrast, microscopic OPs have predictive power to perform calculations in situations where no experimental data is available.

A successful approach used to calculate a microscopic OP, which is valid in the energy range of 100-300 MeV, is based on the folding integral of the nucleon-nucleon t matrix and the ab initio target density. However, the numerical calculation of this integral is computationally expensive and makes the OP difficult to use in complicated scattering processes.

To solve this problem, our aim is to develop a new algorithm that allows us to compute the OP faster than the standard method. With this goal in mind, we present preliminary results for elastic nucleon-nucleus scattering calculated using a microscopic OP derived from multiple-scattering theory, which we have expanded in the harmonic oscillator basis. We demonstrate that, at least for the central term, expanding the reaction and structure inputs that go into the microscopic OP in such a basis leads to an appreciable speed-up in the calculation of differential cross sections compared to the standard approach of numerically computing the folding integral.

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