October 2018 Issue 64

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Newsletter archive: http://npg.dl.ac.uk/OutreachNewsletter/index.html

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1. Nuclear Physics Publications for October

If you are publishing a paper that you think would be of media value please contact Wendy Ellison, STFC Press Officer. She can help with press releases and publicity. If you get in touch with her before publication she can also get material ready in advance for the day of publication.

Nature Physics https://www.nature.com/articles/s41567-018-0292-8
Characterization of the shape-staggering effect in mercury nuclei
B. A. Marsh, T. Day Goodacre, S. Sels, Y. Tsunoda, B. Andel, A. N. Andreyev, N. A. Althubiti, D. Atanasov, A. E. Barzakh, J. Billowes, K. Blaum, T. E. Cocolios, J. G. Cubiss, J. Dobaczewski, G. J. Farooq-Smith, D. V. Fedorov, V. N. Fedosseev, K. T. Flanagan, L. P. Gaffney, L. Ghys, M. Huyse, S. Kreim, D. Lunney, K. M. Lynch, V. Manea, Y. Martinez Palenzuela, P. L. Molkanov, T. Otsuka, A. Pastore, M. Rosenbusch, R. E. Rossel, S. Rothe, L. Schweikhard, M. D. Seliverstov, P. Spagnoletti, C. Van Beveren, P. Van Duppen, M. Veinhard, E. Verstraelen, A. Welker, K. Wendt, F. Wienholtz, R. N. Wolf, A. Zadvornaya & K. Zuber
Published 1 October 2018

Phys. Rev. Lett. 121, 142701 (2018) https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.121.142701
First Accurate Normalization of the β-delayed α Decay of ^{16}N and Implications for the ^{12}C(α,γ)^{16}O Astrophysical Reaction Rate
O. S. Kirsebom[1,*], O. Tengblad[2], R. Lica[3,4], M. Munch[1], K. Riisager[1], H. O. U. Fynbo[1], M. J. G. Borge[2,3], M. Madurga[3], I. Marroquin[2], A. N. Andreyev[5,18], T. A. Berry[6], E. R. Christensen[1], P. Díaz Fernández[7], D. T. Doherty[5], P. Van Duppen[8], L. M. Fraile[9], M. C. Gallardo[9], P. T. Greenlees[10,11], L. J. Harkness-Brennan[12], N. Hubbard[1,5], M. Huyse[8], J. H. Jensen[1], H. Johansson[7], B. Jonson[7], D. S. Judson[12], J. Konki[3,10,11], I. Lazarus[13], M. V. Lund[1], N. Marginean[4], R. Marginean[4], A. Perea[2], C. Mihai[4], A. Negret[4], R. D. Page[12], V. Pucknell[13], P. Rahkila[10,11], O. Sorlin[3,14], C. Sotty[4], J. A. Swartz[1], H. B. Sørensen[1], H. Törnqvist[15,16], V. Vedia[9], N. Warr[17], and H. De Witte[8]
Published 3 October 2018

Phys. Lett. B 785, 441 (2018) https://www.sciencedirect.com/science/article/pii/S0370269318306427
Shape coexistence and isospin symmetry in A = 70 nuclei: Spectroscopy of the $T_z = -1$ nucleus ^{70}Kr
K.Wimmer[ab], W.Korten[c], T.Arici[de], P.Doornenbal[b], P.Aguilera[f], A.Algora[gh], T.Ando[a], H.Baba[b], B.Blank[i], A.Boso[j], S.Chen[b], A.Corsi[c], P.Davies[k], G.de Angelis[l], G.de France[m], D.T.Doherty[c], J.Gerl[d], R.Gernhäuser[n], D.Jenkins[k], S.Koyama[a], T.Motobayashi[b], S.Nagamine[a], M.Niikura[a], A.Obertelli[cb], D.Lubos[n], B.Rubio[g], E.Sahin[o], T.Y.Saito[a], H.Sakurai[ab], L.Sinclair[k], D.Steppenbeck[b], R.Taniuchi[a], R.Wadsworth[k], M.Zielinska[c]
Published 10 October 2018

Phys Lett B 785, 615 (2018) https://www.sciencedirect.com/science/article/pii/S0370269318306087
Neutron-hole states in ^{131}Sn and spin-orbit splitting in neutron-rich nuclei
R.Orlandi[abcd], S.D.Pain[e], S.Ahn[f], A.Jungclaus[b], K.T.Schmitt[f], D.W.Bardayan[e], W.N.Catford[g], R.Chapman[cd], K.A.Chipps[he], J.A.Cizewski[i], C.G.Gross[e], M.E.Howard[i], K.L.Jones[f], R.L.Kozub[j], B.Manning[i], M.Matos[k], K.Nishio[a], P.D.O' Malley[i], W.A.Peters[l], S.T.Pittman[e], A.Ratkiewicz[i], C.Shand[gi], J.F.Smith[cd], M.S.Smith[e], T.Fukui[mn], J.A.Tostevin[go], Y.Utsuno[a]
Published 10 October 2018

Eur. Phys. J. A 54: 142 (2018) https://link.springer.com/article/10.1140%2Fepja%2Fi2018-12609-0
On the self-calibration capabilities of γ-ray energy tracking arrays
S. Heil, S. Paschalis, M. Petri
Published 12 October 2018

Phys. Rev. Lett. 121, 172701 (2018) https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.121.172701
Direct Capture Cross Section and the Ep=71 and 105 keV Resonances in the 22Ne(p,γ)23Na Reaction
F. Ferraro[1,2], M. P. Takács[3,4,§], D. Piatti[5,6], F. Cavanna[2], R. Depalo[5,6], M. Aliotta[7], D. Bemmerer[3,*], A. Best[8,9], A. Boeltzig[10], C. Broggini[6], C. G. Bruno[7], A. Caciolli[5,6,†], T. Chillery[7], G. F. Ciani[10,11], P. Corvisiero[1,2], T. Davinson[7], G. D'Erasmo[12,13], A. Di Leva[8,9], Z. Elekes[14], E. M. Fiore[12,13], A. Formicola[11], Zs. Fülöp[14], G. Gervino[15,16], A. Guglielmetti[17,18], C. Gustavino[19], Gy. Gyürky[14], G. Imbriani[8,9], M. Junker[11], A. Karakas[20], I. Kochanek[11], M. Lugaro[21], P. Marigo[5,6], R. Menegazzo[6], V. Mossa[12,13], F. R. Pantaleo[12,13], V. Paticchio[13], R. Perrino[13,‡], P. Prati[1,2], L. Schiavulli[12,13], K. Stöckel[3,4], O. Straniero[22,9], T. Szücs[3,14], D. Trezzi[17,18], and S. Zavatarelli[2] (LUNA Collaboration)
Published 23 October 2018

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2. News to Report

a. 2018 IOP Business Award winner

University of Glasgow spin-off company Lynkeos Technology Ltd. has been announced as one of the winners of the 2018 IOP Business Awards. At a Parliamentary Reception at Westminster yesterday they received a Business Start-Up Award as a young company with a great business idea based on a physics invention.

"We are proud and honoured to receive this prestigious IOP Award, which rewards the efforts of the Lynkeos team to turn basic science into a game-changing product", said Prof Ralf Kaiser, the Founder and Managing Director of Lynkeos Technology Ltd.

Lynkeos Technology Ltd. is the first company in Europe to commercialise cosmic muon tomography. It was founded in 2016, following an intense 7-year research project carried out by the University of Glasgow and the National Nuclear Laboratory.

Muons are elementary particles, similar to electrons but heavier, that are produced in particle showers in the atmosphere by high-energy cosmic rays. There are about 100 muons per second per square metre at sea level and the typical muon energy is about 10,000 times the typical energy of an X-ray. This means that muons are highly penetrating, ubiquitous, natural and cost-free.

The Lynkeos Muon Imaging System uses cosmic-ray muons to provide a 3D image of the object inside the system. Detectors above and below the object track the path travelled by the muons and sophisticated software algorithms analyse the collected data. This is similar to an X-ray CAT scan, except that no artificial radiation is used.

The result is an image of the contents of shielded containers, e.g. for nuclear waste, that cannot be imaged by conventional X-ray or gamma-based imaging techniques. It not only allows for a visualisation in 3D, but also to distinguish between different materials.

The Lynkeos Muon Imaging System is the first system of its kind that has been CE-marked as a commercial product. Worldwide, it is also the first system that has been deployed on a nuclear site, at Sellafield, where it will image different nuclear waste containers over the coming months.

Contribution by Ralf Kaiser
ralf.kaiser@lynkeos.co.uk (Lynkeos Technology Ltd)

b. Tastes of Nuclear Physics 2018 and MANDELA
David Jenkins (York) and Dan Doherty (Surrey) attended the Tastes of Nuclear Physics 2018 organised by Nico Orce at the University of Western Cape (UWC), South Africa in early October. Dan presented on Nuclear Astrophysics while David presented lectures on Nuclear Applications. Visiting UWC allowed David to visit the Modern African Nuclear DEtector LAboratory (MANDELA) as it has been named by the students there.

This laboratory contains equipment funded by the STFC GCRF project called NuTRAIN led by David. The laboratory will be used by students to develop their own detectors for experimental nuclear physics as well as societal applications in medical imaging and environmental monitoring. A parallel laboratory has been established at the University of Zululand (UZ), also with GCRF funding. During 2018, the GCRF project has supported the visit of 6 students (3 from UWC and 3 from UZ) to York, each for a period of three weeks. During their visit, they received hands-on training and lectures in nuclear applications and detector development.

We are eagerly anticipating a second phase for this project where York will collaborate with UWC and UZ to develop plastic-scintillator based PET detectors which can be of benefit to people across the developing world. A two-year project was submitted to the recent GCRF call.
For more information see: York Physics Department News.
Contribution by David Jenkins
david.jenkins@york.ac.uk (York)

c. Mercurial nuclei get back in shape
Experiment and theory go hand-in-hand to understand variable shapes of exotic isotopes of mercury:
Mercury got its name from being “mercurial”, that is, "pertaining to the Roman god Mercury”, meaning sprightly, volatile, quick, changeable, or indecisive. Indeed, at room temperature mercury is a liquid quicksilver metal that assumes the shape of its container. As it turns out, the term mercurial fits like a glove when describing the properties of mercury nuclei, which assume different shapes depending on the number of neutrons they contain.
In a recent work published in Nature Physics [https://www.nature.com/articles/s41567-018-0292-8], an international team of scientists, including 13 UK researchers from Manchester, Paisley, and York, has carried out ground-breaking experimental and theoretical studies of nuclear shapes in mercury.
Mercury isotopes are unique among all atomic nuclei: in a long chain of almost spherical isotopes with neutron numbers between 97 and 128, those containing 101, 103, and 105 neutrons suddenly turn out to be strongly elongated. The phenomenon is spectacular, especially considering that the adjacent isotopes with 100, 102, 104, and 106 neutrons stay near spherical. This is the famous odd-even shape staggering studied in the Nature Physics publication.
The initial measurements, first performed at ISOLDE more than 40 years ago, remained a highlight of the facility and sparked great interest in this field. The observed variation in shape is amongst the strongest evidence for a phenomenon known as shape coexistence. A large spectrum of subsequent experimental campaigns followed over the years.
It was not until recently that experimenters could push these measurements to the extremes of the nuclear chart, and therefore conclude the work by fully examining this shape-staggering region by laser spectroscopy.
This was a part of long-term collaboration within a multi-national/multi-institutional program on laser spectroscopy in the lead region. The success was possible by combining new developments of the Resonance Ionisation Laser Ion Source with the suite of radio-isotope detection techniques of several different experimental teams at ISOLDE. In doing so, we were able to examine the

nuclear structure of extremely exotic mercury isotopes, at a production rate of only a few ions per minute!

We were also able to explain the microscopic origins of the shape staggering effect theoretically. We did this by enlisting the help of colleagues in Japan, who had one of the world's most powerful computers, the K supercomputer in Kobe, at their disposal to perform the largest and most ambitious nuclear shell model calculation to date. This was accompanied by theoretical analyses performed at York, where we used state-of-the-art nuclear DFT techniques.

The work just published in Nature Physics is a nice example of a close theory-experiment collaboration within the York nuclear physics group. The group was some time ago extended by hiring Andreyev, who was instrumental in conceiving the project, and more recently by creating new theory positions initially funded by a dedicated STFC grant. The collaboration now continues by enlisting the help of theoretical groups in Brussels and Lyon, which will very soon lead to an in-depth common publication giving all details of the performed studies of mercury isotopes.

Contribution by Jacek Dobaczewski
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d. ISOLDE Solenoidal Spectrometer Successes!

A milestone in the ISOLDE Solenoidal Spectrometer (ISS) project has been reached with the successful completion of the first two physics measurements with radioactive beams. The ISS project is part of the £4M UK ISOL-SRS project funded by STFC. The nuclear physics groups of the Universities of Liverpool and Manchester and STFC Daresbury Laboratory have led the ISS work. An ex-MRI 4T super-conducting solenoid (Figure 1) has been recommissioned and given a new lease of life as a magnetic spectrometer for the study of direct reactions.

Figure 1. The ISS 4T superconducting solenoid.

This device is based upon the HELIOS concept that has been successfully deployed at Argonne National Laboratory (ANL) in the USA. In these devices, ejectiles from reactions are detected by an on-axis position-sensitive silicon array after completing an orbit in the solenoidal field. For the early exploitation of the device at ISOLDE, CERN the HELIOS array was loaned from ANL but in the future the project will benefit from a new silicon array currently under construction at the University of Liverpool, which will provide better Q-value resolution and wider angular coverage.

The first physics measurement was the $d(^{28}Mg,p)^{29}Mg$ reaction, measured with an incident beam energy of 9.47 MeV/u – a record energy for HIE-ISOLDE. This measurement was led by The University of Manchester with an aim to better understand the evolution of single-particle behaviour in this region of the nuclear chart where significant changes in shell structure have been observed. The characteristic kinematic lines from this reaction, when plotting the ejected proton energy vs position along the beam axis from the target, are shown in Figure 2 with a projected excitation energy plot for states plotted in ^{29}Mg shown in Figure 3. The resolution observed online was ~100keV.

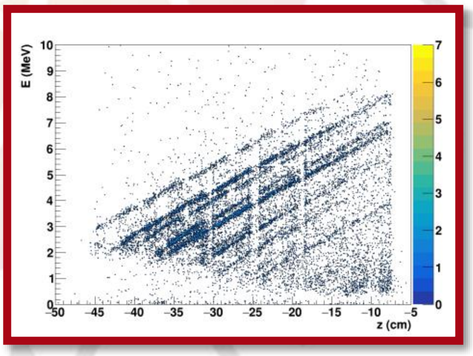

Figure 2. Proton energy plotted against distance from target for d(28Mg,p)29Mg reaction.

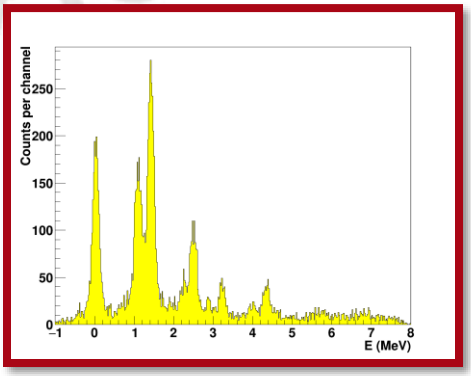

Figure 3. Projected excitation energy plot for states populated in 29Mg - summing all detectors on the array.

The second measurement was $d(^{206}Hg,p)^{207}Hg$, led by collaborators from ANL. This is the heaviest beam accelerated to the maximum HIE-ISOLDE Phase 2A energy so is another feather in the cap for the facility. This measurement probes a region of *terra incognita* to the south-east of ^{208}Pb. For these heavy mass beams HIE-ISOLDE was limited to 7.39 MeV/u limiting the spin of the states that could be studied. This limitation will be resolved during CERN's long shutdown (LS2; 2019-2020) and will open the door to the study of shape coexistence in the neutron-deficient Pb region, for example, which has so far not been probed with direct reactions.
With the success of these two measurements it is frustrating that LS2 is now upon us. However, development during this period will continue with construction and commissioning of the new silicon detector array at Liverpool. In Leuven an active target time projection chamber (SpecMAT) is being developed that will sit inside the ISS magnet for the spectroscopy of reactions involving weak beams. In Manchester, a high-rate ionisation chamber for detecting recoils is being constructed. Further developments underway involving fission-fragment detectors will allow the study of transfer-induced fission, whilst colleagues at INFN are studying the performance of HPGe detectors in the solenoidal field.
Studies with this device are not limited to the (*d,p*) reaction with additional single-nucleon transfer reaction channels possible which can be used to probe both single-neutron and –proton properties as well as pair transfer to investigate pairing properties of nuclei. The feasibility of measuring (*d,d'*) reactions to study octupole nuclei is also under investigation. There are many exciting possibilities with the wide variety of exotic beams produced at HIE-ISOLDE and so the ISS project will provide a powerful tool for the whole Nuclear Physics Community. An ISS Physics Workshop is planned for 2019 with location and date to be confirmed.
Contribution by David Sharp david.sharp@manchester.ac.uk (Manchester) on behalf of the ISS collaboration.

e. TALENT@York

A three-week TALENT (Training in Advanced Low-Energy Nuclear Theory) course on Bayesian inference and Machine Learning, focused on its applications in nuclear physics, will take place at the University of York on 10-28 June 2019.
In recent years, there has been an explosion of interest in the use of Bayesian methods in nuclear physics. Meanwhile machine learning is gaining increased currency as a method for identifying interesting signals in both experiments and simulations.
While most nuclear-physics Ph.D. students are taught some standard (frequentist) statistics as part of their course work, very few encounter Bayesian methods until they are engaged in research. But Bayesian methods provide a coherent and compelling framework to think about inference, and so can be applied to many important questions in nuclear physics. The overall learning goal of this course is to take students who have had no previous exposure to Bayes' theorem and show them how it can be applied to problems of parameter estimation, model selection, and machine learning.
The course will be partly funded by the STFC initiative Nuclear.Theory.Vision@UK [http://personal.ph.surrey.ac.uk/~cb0023/uktheory/Nuclear_Theory_Vision_%40_UK], which is part of the grant financing the new theory positions at York.
Lecturers:

- Christian Forssén (Chalmers University, Sweden)
- Dick Furnstahl (Ohio State University, USA)
- Daniel Phillips (Ohio University, USA)
- Ian Vernon (Durham University, UK)

Alessandro Pastore (University of York, UK) will act as the local liaison and work with the lecturers to help students complete the exercises.
Audience:
Advanced graduate students and early postdocs in all subfields of low-energy nuclear physics (broadly construed), including both theorists and experimentalists. Students will be selected by a competitive process, based on CVs and letters from their advisor.
Format:
The course material will be delivered over three weeks. Each begins with lectures and "in-class" exercises in the mornings, and then students work in groups on more extended analytical and computational exercises in the afternoons. Solutions, implications, and extensions of these exercises will be discussed by everyone at special wrap-up sessions at the end of each day. We will use Python/Jupyter

notebooks to supplement lecture material and provide computational exercises. Total lecture and exercise hours will be comparable to previous TALENT courses (see nucleartalent.org), with a total of 45 hours of lectures and directed exercises, and about 75 hours devoted to out-of-class analytical and computational exercises (out of this 60 hours will be supervised). York University will provide individual certificates to attest to students' participation in the course.

Contribution by Jacek Dobaczewski jacek.dobaczewski@york.ac.uk (York)

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3. Outreach Activity

STFC Public Engagement Funding opportunities: Reaction Awards

The STFC Reaction Award https://stfc.ukri.org/public-engagement/public-engagement-grants/pe-funding-opportunities/pe-reaction-awards/ scheme is still open. The Reaction Awards scheme will allow the funding of public engagement programmes that are a fast response to new and/or unexpected significant developments related to STFC's science and technology remit.

Applicants to The Reaction Awards Scheme are advised contact the Public Engagement Team to discuss their Reaction Award application. Proposed engagement programmes for Reaction Awards must clearly focus around the remit of the STFC science programme (astronomy, solar and planetary science, particle physics, particle astrophysics, cosmology, nuclear physics and accelerator science) or clearly and demonstrably align to the science and technology work of STFC's national and international laboratories and facilities.

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4. Media Interactions

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