UK Nuclear Physics Early Career Research Forum 2021

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Book of Abstracts

Contents

Contributions / 1

Using a charge plunger method for lifetime measurements in the heavy elements

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The Recoil Distance Doppler-Shift (RDDS) method for measuring the lifetime of excited nuclear states relies on the detection of γ rays. In cases where the internal conversion coefficient (ICC) becomes large, e.g. for low energy transitions in heavy nuclei, the intensity of γ-ray emissions may be small and the RDDS method becomes impractical. To overcome this difficulty, a charge plunger technique has been previously employed by G. Ulfert et al. [1]. The charge plunger technique relies on two effects that change the charge state of an ion. Firstly, the large increase of an ionic charge state due to a cascade of Auger electrons that follow the internal conversion of a transition depopulating an excited nuclear state [2]. Secondly, when an ion passes through a thin foil it will pick up electrons causing the charge state to reset to a lower value [3]. In a plunger setting this results in high and low charge components in the ionic charge state distribution (CSD) with intensities that depend on the flight time of the ions between the target and charge reset foil, the ICC of the transition and the lifetime of the excited state. Therefore, an analysis of high and low charge components can be used for lifetime measurements.

The charge plunger method has recently been used at the University of Jyvaskyla Accelerator Laboratory, Finland, to perform lifetime measurements of yrast states in ^{178,180}Pt [4,5]. The Differential Plunger for Unbound Nuclear States (DPUNS) was employed together with the vacuum separator MARA to observe the intensities of different charge states. The Jurogam 3 array was used to detect prompt γ-ray emission. The results for ^{178}Pt are presented here, along with two planned experiments on ^{222}Th and ^{254}No which have been approved to run at the University of Jyvaskyla.

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Contributions / 2

The hunt for exotic particles at Jefferson Lab and EIC

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Quantum Chromo Dynamics (QCD), the theory describing the strong force, predicts how quarks and gluons form into hadrons. Although all established meson and baryon states are either quark-anti

quark pairs or three (anti)quark states, QCD also allows for combinations of four or more quarks. In addition, states in which gluons are excited and contribute to the quantum numbers of the hadrons are also possible. Jefferson Lab, with its GlueX experiment, is one of the prime facilities to hunt for these exotic particles.
In this talk I will introduce the open questions around exotic hadrons and present some of the ongoing efforts at Jefferson Lab. In addition, I will present how a future Electron-Ion Collider, currently in its planning stage, will provide us with opportunities to study these states in unprecedented detail.

Contributions / 3

E0 Transitions Present and Future

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Interpretations of the collective behaviour of nuclei have long been dependent on our understanding of E2 nuclear matrix elements. Owing to mastery of the electromagnetic force and it's spherical tensor we claim confident in quadrupole properties of the nucleus. Despite this confidence there are frequent discrepancy in assignments often owing to interpretations made with incomplete information.
As we look more frequently at the interpretation of shape coexistence across a broader swathe of the nuclear chart, E0 matrix elements have become a key observable in our experiments.
However in contrast to E2 matrix elements, our interpretations of E0 transitions are often flawed and inconsistent, and theoretical models frequently fail to reproduce E0 strength. A greater wealth of knowledge and detailed study is clearly required.
In this talk I will highlight the current state on E0 knowledge in the field, discuss some recent interesting E0 measurement and present some early concept ideas for a future electron spectrometer.

Contributions / 4

Electrons for Neutrinos: Old and New Experiments at Jefferson Lab and Beyond

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The Electrons for Neutrinos project (e4nu) at the Thomas Jefferson National Accelerator Facility (JLab) uses wide phase space exclusive electron scattering data from past and future experiments on nuclear targets with the CLAS and CLAS12 detector systems to obtain a comprehensive understanding of the interaction of leptons with matter. Data from JLab provides us with the means to constrain the available theoretical tools that are crucial in modelling the neutrino-nucleus interaction, and thus play a key role in the precise determination of the physics observables from neutrino-nucleus interactions measured at current and future neutrino experimental facilities, including MicroBooNE, MINERvA, DUNE and T2K.

The interdisciplinary nature of the e4nu project has brought new insights to older data, establishing the value of data mining efforts at JLab, and motivating new experiments, including a dedicated e4nu run period with the CLAS12 detector. Starting this autumn, we will take data with 1, 2, 4, and 6 GeV beams, on Deuterium, Oxygen, Carbon and Argon targets, greatly expanding the available data. Coupled with neutrino event generator descriptions of various reaction topologies, and a common analysis framework, e4nu can serve as a prime example of how to motivate future experiments and build new collaborations.

Contributions / **5**

MARA Low-Energy Branch: A new facility for the study of exotic proton-rich nuclei

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The MARA low-energy branch (MARA-LEB) [1] is a novel facility currently under development at the University of Jyväskylä. The primary aim of MARA-LEB will be to study ground and isomeric-state properties of exotic proton-rich nuclei employing in-gas-cell and in-gas-jet resonance ionisation spectroscopy and mass measurements. Initially these studies will focus on nuclei close to the N=Z line and in the region of 100Sn which are of particular interest to the astrophysical rp process [2] and the study of the proton-neutron interaction [3], before expanding to other regions of the nuclear chart.
For the study of exotic nuclei, special experimental conditions are required to isolate the ions of interest from the overwhelming amount of unwanted nuclei produced during nuclear reactions. In MARA-LEB these conditions will be achieved by combining the MARA vacuum-mode mass separator [4,5] with a buffer gas cell, an ion guide system [6] and a dipole mass separator for stopping, thermalising and transporting reaction products to the experimental stations.
Resonance laser ionisation spectroscopy will be possible either in a separate region inside the gas cell or inside a hypersonic gas jet at the exit of the cell, which will allow for more accurate measurements [7]. A dedicated state-of-the-art Ti:Sapphire laser system will be used to provide reliable experimental data on the ground and isomeric-state properties of exotic isotopes.
Mass measurements will be achieved using a radiofrequency quadrupole cooler and buncher coupled to a multi-reflection time-of-flight mass spectrometer [8]. These devices will allow for fast and accurate mass measurements of several isotopes with high impact on the rp process or isotopes which can be used as test grounds for state-of-the-art nuclear models.
A dedicated high-efficiency decay station, in combination with the low-background ion signals available after laser ionisation or mass purification, will provide ideal conditions for detailed decay studies of the nuclei of interest.
In this presentation I will give an overview of the MARA-LEB facility and some of the key science cases, and present the outcome of preliminary tests.

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Contributions / **6**

Nuclear physics activities at Sheffield Hallam University

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After joining Sheffield Hallam University (SHU) in 2017, Robin Smith has grown a small nuclear physics group, which now includes three PhD students, who are working on a variety of topics, spanning nuclear structure, astrophysics, nuclear data, and fusion.

This talk will give a brief overview of some of the research that is happening in nuclear physics at SHU, with a focus on searches for unambiguous signatures of alpha particle clustering, and developing new techniques for nuclear astrophysics. It will also cover the facilities used, funding, and will give an outlook for the next few years.

Career development / 7

STFC NP overview

Career development / 8

Panel introductions

Welcome session / 9

Welcome

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Welcome session / 10

Low-energy nuclear physics in the UK

Welcome session / 11

Medium/high-energy nuclear physics in the UK

Contributions / 12

An industry perspective

Contributions / 13

Fellows' perspectives

Contributions / 14

Summary, Questionnaire and Close

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