56th Winter Nuclear & Particle Physics Conference

WNPPC 2019

Banff, Alberta Canada

February
14-17 2019

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Book of Abstracts

University of Regina
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WNPPC 2019

56th Winter Nuclear and Particle Physics Conference

February 14th – 17th, 2019

Banff, Alberta, Canada

Hosted by the University of Regina and TRIUMF

Organizing Committee

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Thomas Brunner	McGill University
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Isabel Trigger	TRIUMF

Welcome to WNPPC 2019!

On behalf of the organizing committee, I would like to welcome you to the 56th Winter Nuclear and Particle Physics Conference (WNPPC). As always, this year's conference brings together the entire Canadian subatomic physics community and serves as an important venue for our junior scientists and researchers from across the country. The program has 6 invited talks as well as 41 contributed talks that span a wide range of topics. So enjoy the presentations, take in the beautiful scenery that Banff has to offer, meet with your colleagues and make new ones! I wish you a fruitful and pleasant conference!

Gwen Grinyer, *University of Regina*

Invited Speakers

Dr. Andrea Capra (TRIUMF)
ALPHA: Precision Measurements of Antihydrogen

Dr. Deborah Harris (Fermilab, York University)
Neutrino Interferometry at DUNE

Dr. Jesse Heilman (Carleton University)
Progressively Sharper Rocks

Dr. David McKeen (TRIUMF)
Dark Matter

Dr. Pascal M. Reiter (TRIUMF)
Time-of-Flight mass spectrometry for investigation of the N=32 shell closure

Dr. Simon Viel (Carleton University)
Dark Matter Search with DEAP-3600 at SNOLAB

Registration Information

Registration will be on Thursday February 14, from 16:00 to 17:30 in the PDC Central Foyer and from 18:00 to 19:00, just outside the meeting room (KC 103).

Reception and Banquet

A welcome reception will take place on Thursday February 14 at 20:30, immediately after the last talk of the evening session in KC 105. Tickets for the welcome reception will be provided when you register and these are *included* in your conference registration fee.

The conference banquet will be held on Saturday evening at 17:30 in the Vistas Dining Room. The cost of the banquet is *included* in your conference registration fee.

Meals and Coffee Breaks

Coffee breaks (am/pm) will be held just outside the meeting room. Coffee and snacks are *included* in your conference registration fee. Attendees that are staying at the Banff Centre have breakfast, lunch and dinner included in their room rate. All meals are at the reserved tables in the Vistas Dining Room. Attendees who have not purchased a meal package can purchase their meals at the Vistas Dining Room, the Three Ravens Restaurant, the MacLab Bistro or Le Café in the Sally Borden building.

Sponsors

The organizing committee and attendees of WNPPC 2019 gratefully acknowledge all of our sponsors for their support.

Main Sponsors

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http://www.cap.ca/divisions/ppd

SNOLAB
http://www.snolab.ca

Registered Participants

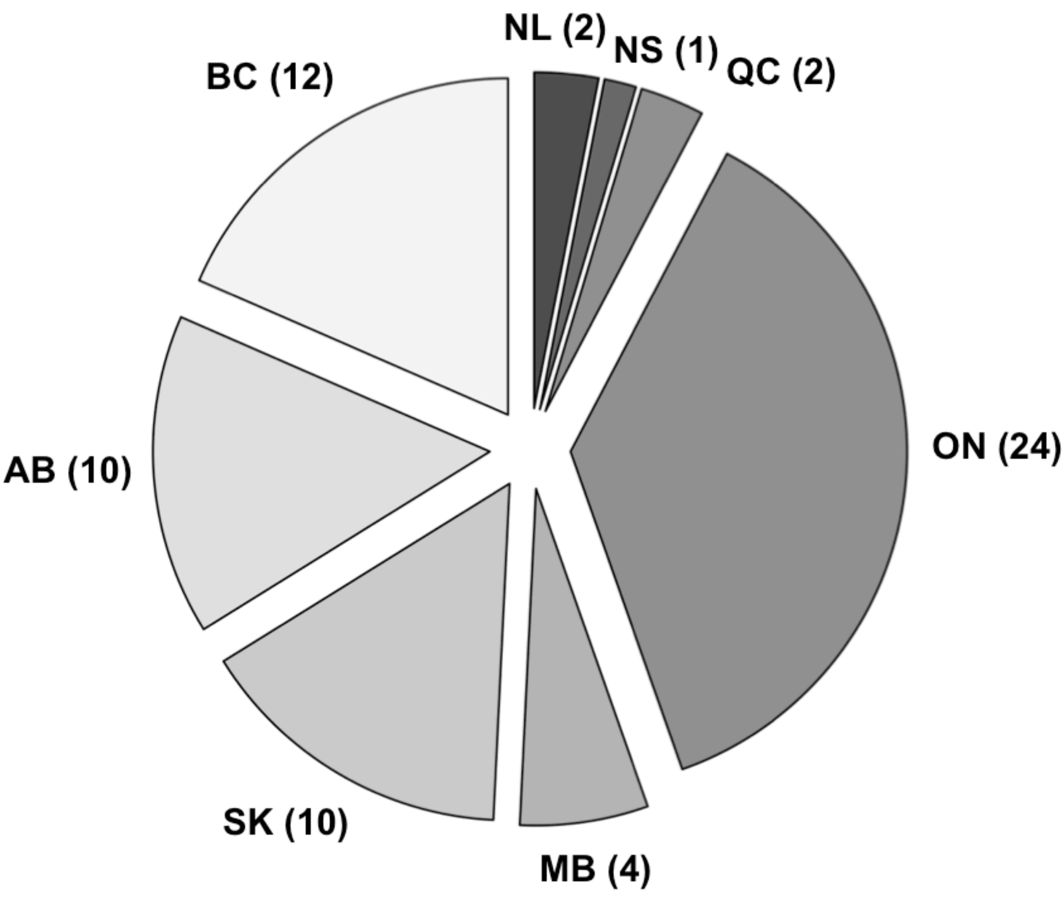
A warm welcome to all of our 65 registered participants from across the country!

Mark Anderson	Queen's University
Christopher Anelli	University of Victoria
Alexander Bachiu	Carleton University
Gordon Ball	TRIUMF
Tegan Beattie	University of Regina
Alain Bellerive	Carleton University
Harris Bidaman	University of Guelph
Andrea Capra	TRIUMF
Evan Carlson	University of Victoria/TRIUMF
Simon Chen	Université de Montréal
Robin Coleman	University of Guelph
Jens Dilling	TRIUMF
Andrew Evans	University of Calgary
Liz Fletcher	Queen's University
Jake Flowerdew	University of Calgary
Ahmed Foda	University of Regina
Beatrice Franke	TRIUMF
Michael Gericke	University of Manitoba
Beau Greaves	University of Guelph
Gwen Grinyer	University of Regina
Chris Gubbels	UBC/TRIUMF
Deborah Harris	Fermilab/York University
Jesse Heilman	Carlton University
Garth Huber	University of Regina
Andrew Jacobs	University of British Columbia
Blair Jamieson	University of Winnipeg
Preetinder Jassal	Saint Mary's University
Eva Kasanda	University of Guelph
Stephen Kay	University of Regina
Wolfgang Klassen	University of Manitoba
Bryn Knight	University of Guelph
Nikolay Kolev	University of Regina
Nico Koning	University of Calgary
Vijay Kumar	University of Regina
Alex Laffoley	University of Guelph
Alexandre Laurier	Carleton University
Marilena Lykiardopoulou	University of British Columbia
Andrew MacLean	University of Guelph
Nick Macsai	University of Manitoba
Erin McGee	University of Guelph
Carlton-James Osakwe	University of Calgary
Pierre-Philippe Ouimet	University of Regina
Rachid Ouyed	University of Calgary
Ahmed Ouyed Hernandez	University of Calgary
Zisis Papandreou	University of Regina
Dylan Pizzi	Carleton University
Adam Powell	University of Calgary
Allison Radich	University of Guelph
Reefat	Memorial University
Pascal Reiter	TRIUMF/JLU
Sina Safarabadi Farahani	University of Alberta
Ingrida Semenec	Queen's University
Michael Staelens	University of Alberta

Registered Participants *(continued)*

Matthew Stukel	Queen's University
Karthik Suresh	University of Regina
Benjamin Tam	Queen's University
Tsvetelin Totev	McGill University
Dominique Trischuk	University of British Columbia
Ryan Underwood	Queen's University
Pourya Vakilipourtakalou	University of Alberta
Sally Valbuena	University of Guelph
Simon Viel	Carleton University
Stephen Weber	Carleton University
Shihao Wu	Memorial University
Daniel Yates	UBC/TRIUMF

Participant Breakdown by Province



Program Overview
All presentations will be held in KC 103.

Thursday February 14, 2019

16:00 – 17:30	Registration (PDC Central Foyer)
18:00 – 19:00	Registration (PDC Central Foyer)
19:00 – 20:30	Session 1
20:30 – 23:00	Welcome Reception (KC 105)

Friday February 15, 2019

08:30 – 10:00	Session 2a
10:00 – 10:30	Coffee Break
10:30 – 12:00	Session 2b
12:00 – 14:00	Lunch

Afternoon free for other activities

19:00 – 20:30	Session 3a
20:30 – 20:45	Coffee Break
20:45 – 21:30	Session 3b

Saturday February 16, 2019

09:00 – 10:00	Session 4a
10:00 – 10:30	Coffee Break
10:30 – 12:00	Session 4b
12:00 – 14:00	Lunch

Afternoon free for other activities

17:30 – 19:00	Conference Banquet (Vistas Dining Room)
19:00 – 20:30	Session 5a
20:30 – 20:45	Coffee Break
20:45 – 21:30	Session 5b

Sunday February 17, 2019

09:00 – 10:00	Session 6a
10:00 – 10:30	Coffee Break
10:30 – 12:00	Session 6b
12:00 – 14:00	Lunch

End of the Meeting

Detailed Program

Names in bold are the invited speakers and non-student talks. All invited talks are 30 minutes (25 + 5 questions) and all contributed talks are 15 minutes (12 + 3 questions) in duration. For formatting purposes, the titles of the presentations in the program below have, in some cases, been abbreviated. Full titles are available in the abstract section.

Thursday February 14, 2019

Session 1: Chair (Gwen Grinyer)

19:00 – 19:15	Welcome Introduction from Gwen Grinyer
19:15 – 19:45	**Andrea Capra**, *ALPHA: Precision measurements of antihydrogen*
19:45 – 20:00	Adam Powell, *Commissioning the ALPHA-g experiment at CERN*
20:00 – 20:15	Andrew Evans, *Lamb shift in antihydrogen*
20:15 – 20:30	Michael Staelens, *Expanding the LHC's discovery frontier*
20:30 – 22:30	Welcome Reception (KC 105)

Friday February 15, 2019

Session 2: Chair (Beatrice Franke)

08:45 – 09:15	**Pascal Reiter**, *Time-of-flight mass spectrometry*
09:15 – 09:30	Andrew Jacobs, *Approaching the* $N = 20$ *island of inversion*
09:30 – 09:45	Marliena Lykiardopoulou, *Mass measurements of neutron deficient Yb*
09:45 – 10:00	Jake Flowerdew, *Improving ion transport using Monte-Carlo optimization*
10:00 – 10:30	Coffee Break
10:30 – 10:45	**Alex Laffoley**, *High-precision branching ratio for* ^{22}Mg *superallowed decay*
10:45 – 11:00	Nicholas Macsai, *Precision measurements of correlations in neutron* β *decay*
11:00 – 11:15	Wolfgang Klassen, *Magnetic field decomposition for TUCAN nEDM*
11:15 – 11:30	Matthew Stukel, *Update on the KDK (potassium decay) experiment*
11:30 – 11:45	Shihao Wu, *Next to leading order dilepton production calculations*
11:45 – 12:00	Reefat, *Running of fine structure constant up to two loop level*
12:00 – 14:00	Lunch

Session 3: Chair (Blair Jamieson)

19:00 – 19:30	**Jesse Heilman**, *Progressively Sharper Rocks*
19:30 – 19:45	**Christopher Anelli**, *Future of the ATLAS liquid argon calorimeter*
19:45 – 20:00	Evan Carlson, *Results of the 2018 ATLAS sTGC beam tests*
20:00 – 20:15	Alexandre Laurier, *Current state of the ATLAS new small wheel simulation*
20:15 – 20:30	Dylan Pizzi, *Simulation of gas detectors using Ramo's theorem*
20:30 – 20:45	Coffee Break
20:45 – 21:00	**Stephen Kay**, *Photoproduction of the d*(2380) dibaryon*
21:00 – 21:15	Ahmed Foda, *Photoproduction of the* $b_1(1235)$ *meson at* $E = 6 – 12$ *GeV*
21:15 – 21:30	Tegan Beattie, *Decay channels of the eta(548) and eta(958) at GlueX*
21:30 – 21:45	Karthik Suresh, *Gain calibrations of SiPMs using* π^0 *events for GlueX*
21:45 – 22:00	Vijay Kumar, *Kaon L–T experiment at Jefferson Lab*

Saturday February 16, 2019

Session 4: Chair (Alain Bellerive)

09:00 – 09:30	**Deborah Harris**, *Neutrino interferometry at DUNE*
09:30 – 09:45	Tsvetelin Totev, *Measurement of Cherenkov radiation in liquid xenon*
09:45 – 10:00	Amir Ouyed, *Detecting the birth of a proto-quark star*
10:00 – 10:30	Coffee Break
10:30 – 10:45	Dominique Trischuk, *ATLAS strip detector upgrade for the inner tracker*
10:45 – 11:00	Chris Gubbels, *Automated visual inspection of ITk sensors*
11:00 – 11:15	Stephen Weber, *Production of Z bosons in association with jets at 13 TeV*
11:15 – 11:30	Alexander Bachiu, *Prediction of Drell-Yan angular coefficients with ATLAS*
11:30 – 11:45	Pourya Vakilipourtakalou, *Low-scale string resonances at the LHC*
11:45 – 12:00	Sina Safarabadi Farahani, *Quantum black hole production at the LHC*
12:00 – 14:00	Lunch

Session 5: Chair (Gordon Ball)

19:00 – 19:30	**David McKeen**, *Dark Matter – WIMPS and beyond*
19:30 – 19:45	Preetinder Jassal, *Measurement of the* $^{19}F(p,\alpha)^{16}O$ *astrophysical reaction*
19:45 – 20:00	Bryn Knight, *Degenerate neutron capture within neutron star crusts in TALYS*
20:00 – 20:15	Carlton-James Osakwe, *Sensitivity metrics in r-process simulations*
20:15 – 20:30	Coffee Break
20:30 – 20:45	Andrew MacLean, *Spectroscopy of* ^{188}Tl *decay* β^+*/EC decay with GRIFFIN*
20:45 – 21:00	Daniel Yates, *Decay spectroscopy of* ^{160}Eu *using the GRIFFIN spectrometer*
21:00 – 21:15	Robin Coleman, *Investigating the shell closure N=32 in neutron-rich* ^{52}Ca
21:15 – 21:30	Sally Valbuena, *Nuclear structure of* ^{98}Ru *using* β *decay*
21:30 – 21:45	Erin McGee, *Searching for shape coexistence in* ^{124}Te

Sunday February 17, 2019

Session 6: Chair (Pierre-Philippe Ouimet)

09:00 – 09:30	**Simon Viel**, *Dark matter search with DEAP-3600 at SNOLAB*
09:30 – 09:45	Ryan Underwood, *The CUTE facility*
09:45 – 10:00	Mark Anderson, *Machine learning to improve analysis of data from SNO+*
10:00 – 10:30	Coffee Break
10:30 – 10:45	Beau Greaves, *Opportunities for future experiments at ISAC-II, TRIUMF*
10:45 – 11:00	Eva Kasanada, *Gamma spectroscopy for range verification in proton therapy*
11:00 – 12:00	Best Student Prizes Awards
12:00 – 14:00	Lunch

WNPPC 2019 Abstracts

ALPHA: Precision Measurements of Antihydrogen
(Invited)

Andrea Capra[1] *

[1] TRIUMF, Vancouver BC

On behalf of the ALPHA collaboration

The fundamental theories in physics predict that matter and antimatter have the same mass and the same lifetime, an invariance law that goes under the name of “CPT theorem”. Moreover, the Weak Equivalence Principle, one of the cornerstones of General Relativity, implies that matter and antimatter have the same gravitational acceleration in the Earth’s field. In the last decade, the simplest form of antimatter, the antihydrogen atom, became available in the ALPHA trapping apparatus at the CERN Antiproton Decelerator. This allowed ALPHA to perform precise determinations of some antihydrogen spectral lines and compare them to the hydrogen’s ones. The first of such measurement was the ground state hyperfine splitting at a level of 4 parts in 10^4. The most precise to date is the measurement of the transition frequency between the ground state and the first excited state, the so-called 1S-2S transition, at a level of 2 parts per trillion. The most recent one is the measurement of the 1S-2P transition at the level of $5x10^{-8}$, opening the possibility of laser cooling of antihydrogen. I will present the so-called ALPHA-2 apparatus and the antihydrogen trapping scheme. I will explain the aforementioned spectroscopic measurements and discuss the physics implications of said measurements in relation to the CPT invariance. Finally, I will overview the project to measure the antihydrogen gravitational acceleration with the so-called ALPHA-g apparatus and present the initial commissioning of this experiment. Throughout the talk, particular attention will be devoted to the particle detectors and the analysis techniques used in ALPHA.

* acapra@triumf.ca (A.Capra)

Commissioning the ALPHA-g Experiment at CERN

Adam Powell *

Department of Physics and Astronomy, University of Calgary, Calgary, AB

On behalf of the ALPHA collaboration

The baryonic asymmetry has long been a problem for standard model physics. The ALPHA experiment at CERN studies trapped antihydrogen in an attempt to test CPT and Einstein's equivalence principle, perhaps finding a solution. Most recently, the collaboration has expanded, from laser and microwave spectroscopy, to test gravitational interactions between matter and antimatter through the ALPHA-g experiment. While gravitational experiments involving antimatter have been attempted in the past, it has always been with charged particles where electromagnetic forces dominate [1]. In ALPHA-g, antihydrogen will be produced in a vertical Penning-Malmberg trap and held in a magnetic well. Once released, the free fall of antihydrogen in the Earth's gravitational field can be measured. The method was originally described and demonstrated in 2013 using a horizontal Penning-Malmberg trap [2]. Construction of several key components of ALPHA-g began in early 2018 with the assembly of the first stage of ALPHA-g taking place in the second half of the year. I will briefly lay out the key elements that make up ALPHA-g and their function within the apparatus. Following this, I will provide a more in-depth description of the Penning trap and hardware required for microwave experiments and spectroscopy. Finally, I will show some initial data collected in ALPHA-g before the start of the CERN long shut down in November 2018.

[1] Fred C. Witteborn & William M. Fairback, Nature 220, 436-440 (1968)
[2] The ALPHA Collaboration & A. E. Charman, Nature communications 4, 1785 (2013)

* adam.powell1@ucalgary.ca (A.Powell)

Lamb shift in Antihydrogen

Andrew Evans[1] *

[1] Department of Physics and Astronomy, University of Calgary, Calgary, AB

On behalf of the ALPHA collaboration

Antihydrogen and hydrogen are simple atomic systems which provide an ideal platform to study differences between antimatter and matter. Current theories predict that the universe should be composed of equal quantities of matter and antimatter but cosmological observations calculate the ratio of have an upper limit of 10^{-4}[1]. The ALPHA (Antihydrogen Laser PHysics Apparatus) collaboration at CERN studies the atomic structure of antihydrogen through photon interactions and have recently succeeded in observing three 1S-2P and 1S-2S transitions in trapped antihydrogen. This was in part due to an improvement to the experimental procedure as well as increases in laser power.

Experiments that attempt to find and quantify difference between particles and their antiparticle partners are at the forefront of explaining the discrepancy between theory and experiment. The CPT (charge conjugation, parity reversal, time reversal) theory requires that the spectrum of hydrogen and antihydrogen to be identical; any deviation between the two spectra would indicate a CPT violation. The Lamb shift, the energy difference between the 2S and 2P1/2 energy levels in hydrogen, is a cornerstone in modern quantum electrodynamics. It was measured for the first time in 2018 by ALPHA.

I present a summary of: the experimental procedure used in the 2018, an overview of the Lyman alpha laser system, the Lamb shift result, and the prospects of laser cooling in the ALPHA apparatus.

[1] Ballmoos, P. (June 2013). Antimatter in the Universe: constraints from gamma-ray astronomy. Proceedings of the 11th International Conference on Low Energy Antiproton Physics (LEAP 2013)

* andrew.evans2@ucalgary.ca (A. Evans)

MoEDAL – Expanding the LHC's Discovery Frontier

Michael Staelens[1] *

[1] Department of Physics, University of Alberta, Edmonton, AB

On behalf of the MoEDAL collaboration

MoEDAL (Monopole and Exotics Detector at the LHC) is the 7th experiment, specifically dedicated to investigating beyond the Standard Model scenarios by searching for highly ionizing particles, such as magnetic monopoles or massive pseudo-stable charged particles and multiply electrically charged particles as messengers of new physics. Sharing the same interaction point as the LHCb experiment, MoEDAL is complementary to the larger ATLAS and CMS experiments, thereby expanding the discovery reach of the LHC. This largely passive detector is comprised of the following subdetectors: A large array of NTD (Nuclear Track Detector) stacks, a magnetic trapping detector (designed to trap both electrically and magnetically charged highly ionizing particles), and a TimePix chip array that monitors particle backgrounds. MAPP (MoEDAL Apparatus for Penetrating Particles), a new MoEDAL subdetector, is currently being prototyped. The aim of MAPP is to enable MoEDAL to search for fractionally charged particles as well as long-lived neutrals. The goal of this talk is to summarize the physics programme of MoEDAL, introduce the physics and detection methods used, and present MoEDAL's latest results.

* staelens@ualberta.ca

Time-of-flight mass spectrometry for investigation of the N=32 neutron shell closure
(Invited)

Moritz Pascal Reiter[1,2,*], Samuel Ayet san Andres[3], Carla Babcock[1], Soenke Beck[2,3], Julian Bergmann[2], Timo Dickel[2,3], Jens Dilling[1], Eleanor Dunling[1], Christine Hornung[2], Chris Izzo[1], Andrew Jacobs[1,4], Renee Klawitter[1], Brian Kootte[1], Ania Kwiatkowski[1], Yang Lan[1], Erich Leistenschneider[1], Marilena Likiardopoulou[1,4], Ish Mukul[1], Stefan Paul[1], Wolfgang R. Plass[2,3], Christoph Scheidenberger[2,3],

[1] TRIUMF National Laboratory, Vancouver, BC
[2] Justus-Liebig-Universität Gießen, II. Physikalisches Institut, Gießen, Germany
[3] GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany
[4] University of British Columbia, Vancouver, BC

On behalf of the TITAN collaboration

TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN), located at the ISAC facility at TRIUMF, Vancouver, is a multiple ion trap system capable of performing high-precision mass measurements and in-trap decay spectroscopy. TITAN has specialized in fast Penning trap mass spectrometry of singly-charged, short-lived exotic nuclei using its Measurement Penning Trap (MPET). Although ISAC can deliver high yields for some of the most exotic species, many measurements suffer from strong isobaric background. In order to overcome this limitation an isobar separator based on the Multiple-Reflection Time-Of-Flight Mass Spectrometry (MR-TOF-MS) technique has been developed and installed at TITAN.

After a first commissioning, the MR-TOF-MS was employed in a measurement campaign aiming to investigate the evolution of the N = 32 neutron shell closure. This shell closure forms several neutrons away from stability and had been established in neutron-rich K, Ca and Sc isotopes, where as in V and Cr, no shell effects are found; leaving the intermediate Ti isotopes as the ideal test case for state-of-the-art ab-initio shell model calculations. High-precision mass measurements with TITAN's MPET and for the first time with the new MR-TOF-MS were able to prove the existence of a weak shell closure in Ti and quenching of the shell in V. These findings challenge modern ab-initio theories, which over predicted the strength and extent of this weak N=32 shell closure.

We will discuss our recent nuclear structure investigations making use of MPET and the new MR-TOF-MS of the N = 32 neutron shell closure as well as the concepts and tricks of operation of the new MR-TOF-MS technique.

* mreiter@triumf.ca (M.P. Reiter)

Approaching the N = 20 Island of Inversion

Andrew Jacobs[1,2] *, M.P. Reiter[2,3], J.Dilling[1,2], A.A. Kwiatkowski[2,4]

[1] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC
[2] TRIUMF, Vancouver, BC
[3] II. Physikalisches Institut Justus-Liebig-Universität, 35392 Gießen, Germany
[4] Department of Physics and Astronomy, University of Victoria, Victoria, BC

On behalf of the TITAN collaboration

To better understand nuclear structure, precision mass spectrometry of radioactive beams is required. Nuclides of interest become short lived and production rates drop further from stability. Additionally, these beams are frequently contaminated which can shift mass values or obscure the species of interest altogether. To help overcome these challenges, the Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS) was commissioned at TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN). This device is capable of both beam purification and fast, precise, high-sensitivity mass measurements. Furthermore, these two different modes of operation can be used sequentially. This capability was demonstrated during the mass measurements of neutron rich $^{24-26}$Ne in which precisions on the order of 10^{-7} were achieved. This approach towards the "island of inversion" motivates further measurements in this region and serves as a starting point for the chain of Ne isotopes crossing the N = 20 isotone.

* ajacobs@triumf.ca (A.Jacobs)

Mass Measurements of Neutron-Deficient Ytterbium

<u>Marilena Lykiardopoulou[1,2]</u> *, M.P. Reiter[2,7], A. Jacobs[1,2], I. Mukul[2], E.Leistenschneider[1,2], B. Kootte[2,3], S.F. Paul[2,9], V. Monier[6], M. Vansteenkiste[5], S.Beck[7], L. Graham[2], E. Dunling[2,6], J.L. Tracy, Jr.[2], Y. Lan[1,2], R. Klawitter[2,8], C. Will[7], J. Flowerdew[4], T. Brunner[11], C. Andreoiu[10], G. Gwinner[3], R. Thompson[4], M.Wieser[4], J. Dilling[1,2], A.A. Kwiatkowski[2]

[1] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC
[2] TRIUMF 4004, Wesbrook Mall, Vancouver, BC
[3] Department of Physics and Astronomy, University of Manitoba, Winnipeg, MB
[4] Department of Physics and Astronomy, University of Calgary, Calgary, AB
[5] Department of Physics and Astronomy, University of Waterloo, Waterloo, ON
[6] Department of Physics, University of York, York, UK
[7] II. Physikalisches Institut, Justus-Liebig_Universitat, Giessen, Germany
[8] Max-Planck-Institut fur Kernphysik, Heidelberg, Germany
[9] Ruprecht-Karls_universitat at Heidelberg, Heidelberg, Germany
[10]Department of Chemistry, Simon Fraser University, Vancouver, BC
[11] Department of Physics, McGill University, Montreal, Quebec

On behalf of the TITAN collaboration

Neutron-deficient lanthanides are a subject of interest from many perspectives. Not only can they provide information about the neutron shell closure at N=82, but they can also indicate where the proton drip-line lies in this region. In addition, since some lanthanides are anchors of alpha decay chains, they can give valuable information about the progenitors and intermediate nuclei. To this end, the masses of neutron-deficient lanthanides were measured with TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN). TITAN's Multi-Reflection Time of Flight mass spectrometer (MR-ToF) was used to trap and measure the masses of the ytterbium isotopes with atomic numbers 150-157. From the nuclides measured, the masses of ^{150}Yb and ^{153}Yb were measured for the first time, while the mass of ^{151}Yb was measured for the first time directly. The first results of this mass measurement campaign will be presented.

* marilena@triumf.ca (M.Lykiardopoulou)

Improving Ion Transport Using Monte Carlo Optimization Methods

Jake Flowerdew[1] *, Ish Mukul[2], Anna A. Kwiatkowski[2,3], Jens Dilling[2,4], Michael E. Wieser[1] and Robert I. Thompson[1,2]

[1] Department of Physics and Astronomy, University of Calgary, Calgary, AB
[2] TRIUMF, Vancouver, BC
[3] Department of Physics and Astronomy, University of Victoria, Victoria, BC
[4] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC

On behalf of the TITAN collaboration

The controlled collimation of ion beams is of paramount importance in particle accelerators as it determines the sensitivity and resolution of the instrument. This is especially the case when dealing with radioactive ion beams, where high transportation yields are crucial due to the short lifetimes of certain nuclei. The ion source of a thermal ionization mass spectrometer (TIMS), comprised of a heated filament followed by a series of ion optical lenses, was modelled and Monte Carlo simulations were run using SIMION. The voltages on three of the electrostatic lenses were optimized, in order to maximize the illuminated area of the exit slit. The optimization method employed achieved up to a 40% increase in signal intensity when compared to the existing manufacture provided lens tuning algorithm. 3D plots were effective in visualizing whether this new voltage configuration leads to a solution which lies in a local or global optimum, showing that the previous tuning technique was rarely successful in achieving the global optimum.

A similar modelling and optimization approach is being used in the commissioning of a plasma ion source at the TITAN experiment at TRIUMF. This would provide a versatile ion source capable of delivering stable isotopes from gas and solid samples. We have been successful in navigating the beam through the Einzel lens to a Faraday cup, as well as steering ions through 90° by a quad-bender on to an MCP in the laboratory. The results show that these models have been successful in collimating ion beams and the applications of these models has improved resolution and sensitivity of the experiments. This provides confidence when moving forward to simulating and optimizing more complex ion optics.

* jake.flowerdew@ucalgary.ca (J.Flowerdew)

High-Precision Branching Ratio Measurement for the Superallowed Fermi Beta Emitter ^{22}Mg†

Alex Laffoley[1] *, C. Andreoiu[2], G. C. Ball[3], N. Bernier[3,4], H. Bidaman[1], V. Bildstein[1], M. Bowry[3], C. Burbadge[1], R. Caballero-Folch[3], A. Diaz Varela[1], M. R. Dunlop[1] , R. Dunlop[1] , A. B. Garnsworthy[3], P. E. Garrett[1] , G. Hackman[3], B. Jigmeddorj[1], K. G. Leach[5], J. R. Leslie[6], A. D. MacLean[1], J. Measures[3,7], C. Natzke[4], B. Olaizola[3], Y. Saito[3,4], J. K. Smith[8], C. E. Svensson[1], J. Turko[1], T. Zidar[1]

[1] Department of Physics, University of Guelph, Guelph, ON
[2] Department of Chemistry, Simon Fraser University, Burnaby, BC
[3] Physical Sciences Division, TRIUMF, Vancouver, BC
[4] Department of Physics, University of British Columbia, Vancouver, BC
[5] Department of Physics, Colorado School of Mines, Golden, CO, USA
[6] Department of Physics, Queen's University, Kingston, ON
[7] Department of Physics, University of Surrey, Guildford, Surrey, UK
[8] Department of Physics, Reed College, Portland, OR, USA

On behalf of the GRIFFIN collaboration

High-precision measurements of the ft values for superallowed Fermi β decays between 0^+ isobaric analogue states have provided invaluable probes of the Standard Model (SM) description of the electroweak interaction. To provide these stringent tests, theoretical corrections must be applied to the experimentally determined ft values obtained from precise measurements of the half-lives, branching ratios, and Q values of the decays.

Of particular interest is the isospin symmetry-breaking correction (δ_C), which is model-dependent; several theoretical approaches can and have been used to calculate these corrections. In the most recent survey of the superallowed Fermi β emitters [1], the selection of the particular δ_C model used depended, to a significant degree, on four of the least precisely determined corrected-ft values ^{22}Mg, ^{38}Ca, ^{62}Ga, and ^{74}Rb for the well-measured cases.

In light of this, we have performed a branching ratio measurement for ^{22}Mg at TRIUMF's ISAC facility using the GRIFFIN spectrometer to measure the ^{22}Mg superallowed branching ratio to ±0.15% and improve the precision of the ft value by a factor of 2. Taking advantage of GRIFFIN's high γ-ray detection efficiency allows us to measure the branching ratio using a novel technique based on γ-γ coincidences that eliminates the need for high-precision absolute efficiency calibrations that plagued previous measurements. This presentation will discuss preliminary branching ratio results for ^{22}Mg as well as comparing these results to previous measurements. These results, culminating in an updated ft value for ^{22}Mg, will play a major role in discriminating between different theoretical approaches to the δ_C corrections in superallowed decays. [1] J.C. Hardy and I.S. Towner, Phys. Rev. C 91, 025501 (2015).

† GRIFFIN infrastructure has been funded jointly by the Canada Foundation for Innovation, TRIUMF, the British Columbia Knowledge Development Fund (BCKDF), the Ontario Ministry of Research and Innovation (ON-MRI) and the University of Guelph. TRIUMF receives federal funding via a contribution agreement through the National Research Council Canada (NRC). C.E.S. acknowledges support from the Canada Research Chairs program. This work was supported in part by the Natural Sciences and Engineering Research Council of Canada (NSERC) and funded in part by the U.S. Department of Energy, Office of Science under grant DE-SC0017649.

* alaffole@uoguelph.ca (A.Laffoley)

The Nab Experiment: Precision Measurements of Correlation Parameters in Neutron Beta Decay

Nicholas Macsai[1] *

[1] Department of Physics and Astronomy, University of Manitoba, Winnipeg, MB

Neutron beta decay is a fundamental nuclear process that provides a means to perform precision measurements that test the limits of our present understanding of the weak interaction described by the Standard Model of particle physics. Precision measurements of decay parameters in neutron beta decay put constraints on physics beyond the Standard Model. The Nab experiment with measure 'a', the electron-neutrino angular correlation parameter and b, the Fierz interference term. 'a' is a function of λ, the ratio of the axial vector and vectorcoupling constants in neutron beta decay. A precise value of λ is required for accurate calculations of cross sections in nuclear-astrophysical processes and for precision tests of fundamental properties such the unitarity of the CKM Matrix. A non-zero measurement of b could indicate the presence of additional scalar and tensor interactions which are not part of the Standard Model. The Nab experiment implements time of flight proton spectroscopy, an asymmetric spectrometer design and large area segmented silicon detectors to determine 'a' to a precision of $\delta\, a/a \sim 10^{-3}$. In this talk I will describe the motivations for precision tests of the weak interaction and the experimental configuration of the Nab experiment.

* ummacsai@myumanitoba.ca (N.Macsai)

Magnetometry and Magnetic-Field Decomposition for the TUCAN nEDM Experiment

Wolfgang Klassen[1] *, J.W. Martin[1,2], R. Mammei[1,2]

[1] Department of Physics and Astronomy, University of Manitoba, Winnipeg, MB
[2] Department of Physics, The University of Winnipeg, Winnipeg, MB

On behalf of the TUCAN collaboration

The TUCAN collaboration aims to provide a factor of 30 improvement on the current upper bound for the neutron electric dipole moment, resulting in a planned sensitivity of 10^{-27} e cm. EDM experiments of this kind require measuring changes in the precession frequency of ultracold neutrons as we subject them to parallel and anti-parallel electric and magnetic fields. In order to reach the planned sensitivity, precise control of these magnetic fields and their gradients is required. To this end, I am developing an array of optical magnetometers and analysis software sensitive enough to measure the strength of the 1 μT holding field to a precision of 10 fT, and determine field gradients up to third order.

* klasse77@myumanitoba.ca (W.Klassen)

Update on the KDK (Potassium Decay) Experiment

Matthew Stukel[1] *, N. Brewer[2], P.C.F Di Stefano[1], A. Fijalkowska[2,6,8], Z. Gai[9], K.C.Goetz[3], R. Grzywacz[2,3,7], D. Hamm[3], P. Lechner[5], Y. Liu[2], E. Lukosi[3], M.Mancuso[4], C. Melcher[3], J. Ninkovic[5], F. Petricca[4], B.C. Rasco[2], C. Rouleau[9], K.P.Rykaczewski[2], P. Squillari[1], L. Stand[3], D. Stracener[2], M. Wolinska-Cichocka[2,6,7] and I. Yavin

[1] Department of Physics, Engineering Physics and Astronomy, Queen's University, Kingston, ON
[2] Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA
[3]Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee, USA
[4]Max-Planck-Institut Für Physik, Föhringer Ring 6, Müchen, Germany
[5]MPG Semiconductor Laboratory, Munich, Germany
[6]Heavy Ion Laboratory, University of Warsaw, Warsaw, Poland
[7]Joint Institute for Nuclear Physics and Application, Oak Ridge, Tennessee, USA
[8]Department of Physics and Astronomy, Rutgers University, New Brunswick, New Jersey, USA
[9] Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

On behalf of the KDK collaboration

Potassium-40 (^{40}K) is a background in many rare-event searches, especially those involving Sodium-Iodide detectors, (ex. DAMA, SABRE and COSINE-100). The electron-capture of ^{40}K to the ground state of ^{40}Ar is a unique-third forbidden transition, whose branching ratio has never been experimentally measured. KDK (pun for potassium decay) is an international collaboration dedicated to this measurement. The experiment is performed using an enriched ^{40}K source, a silicon drift x-ray detector (SDD) and the Modular Total Absorption Spectrometer at Oak Ridge National Laboratory. We report on the performance of the SDD/MTAS combination on multiple radioactive sources (^{54}Mn, ^{65}Zn, ^{88}Y) leading up to the December 2017 ^{40}K experimental run.

* 15mjs5@queensu.ca (M.Stukel)

Next-to-Leading Order Dilepton Production Calculations

Shihao Wu[1] *, A. Aleksejevs[1], S. Barkanova[1], M. Heller[2], O. Tomalak[2], M.Vanderhaeghen[2]

[1] Department of Physics, Memorial University, Corner Brook, NL
[2] Institut fur Kernphysik and PRISMA Cluster of Excellence, Johannes Gutenberg Universität, Mainz, Germany

We present the leading QED corrections for γ p $\rightarrow$ $l^+ l^-$ p* process. It is for a developing experiment at MAMI to test lepton universality, by comparing cross sections between muon and electron pair productions. It is a high precision driven experiment, and loop level corrections are required. For the kinematics at MAMI experiment, we find corrections of the percent level for muons, and of order 10% for electrons.

* swu@grenfell.mun.ca (S.Wu)

Running of Fine Structure Constant up to Two-Loop Level

Reefat[1,2] *

[1] Department of Physics and Physical Oceanography, Memorial University of Newfoundland, St. John's, NL
[2] Grenfell Campus, School of Science and Environment, Memorial University of Newfoundland, Corner Brook, NL

In this presentation, we will show how we can use the dispersive approach to calculate running of the fine structure constant. In this calculation, a truncated self-energy photon diagram up to Next-to-Next to Leading Order (NNLO) is considered. We have used dispersive approach to evaluate NNLO (two loop) contributions and as a result obtained is rather compact expressions using only two loop Passarino-Veltman function basis. Finally, the numerical result was obtained using LoopTools package in Mathematica.

* reefat@mun.ca (Reefat)

Progressively Sharper Rocks†
(Invited)

Jesse Heilman[1] *

[1] Department of Physics, Carleton University, Ottawa, ON

On behalf of the ATLAS collaboration

The history of the human species is inexorably linked with the construction of better and better tools. Our desire to understand the basic principles of our universe has culminated in the creation of one of the most powerful tools of discovery ever conceived: The Large Hadron Collider (LHC). Located under the Swiss-French border near Geneva, collisions inside the LHC provide us with the deepest look at the most basic structure of matter. Collecting and interpreting these data requires the use of other advanced tools such as the ATLAS and CMS detectors. These machines are continually refined to meet the demands on their operation through projects such as the ATLAS New Small Wheel (NSW) upgrade. Composed of two complimentary detector technologies, the NSW will enhance the ability of the ATLAS Muon spectrometer to collect the immense volume of data that the LHC produces. Once completed, the NSW will help to reduce fake signals in the high rapidity regions of the ATLAS detector allowing the ATLAS trigger system to reliably collect the most relevant data. Additionally, the NSW will allow for enhanced reconstruction of high rapidity muons for use in physics measurements. Carleton University plays a large part in the construction of one of these detectors: The small-strip Thin Gap Chambers (sTGC).

† This research was partially supported by the Canadian Foundation for Innovation under Project No. 33338.

* Jesse.Heilman@carleton.ca (J.Heilman)

Future of the ATLAS Liquid Argon Calorimeter

Christopher Anelli [1,*]

[1] Department of Physics and Astronomy, University of Victoria, Victoria, BC

On behalf of the ATLAS collaboration

Improvements to the ATLAS liquid argon calorimeter (LAr) as part of the Phase-I upgrades (2019-2020) are currently underway. A new baseplane will be installed to split the calorimeter signal between the new LAr Trigger Digitizer Boards and legacy Tower Builder Boards. Further improvements for the Phase-II upgrades (2024-2026) are planned to prepare for the High-Luminosity LHC (HL-LHC). The HL-LHC will operate at luminosities 5-7 times the LHC's original design. New readout electronics are necessary to cope with the increased radiation damage and for compatibility with the new trigger system. The 182,500 LAr calorimeter cells will be readout at 40 MHz with a 16 bit dynamic range. For the first time, full LAr calorimeter granularity will be sent to the lowest level trigger processors. Prototypes of the new front-end electronics have been tested, and design studies of the off-detectors digital filtering algorithms and bandwidth requirements performed. An overview of the Phase-II LAr readout electronic design is presented.

* Christopher.Anelli@gmail.com (C.Anelli)

Results of the 2018 ATLAS sTGC Beam Tests†

Evan Carlson[1,2] *

[1] Department of Physics and Astronomy, University of Victoria, Victoria, BC
[2] TRIUMF, Vancouver, BC

Including results from the ATLAS sTGC group

After a successful three-year run at 13 TeV, the Large Hadron Collider has paused operation, and will not circulate beams again until 2021. During this shutdown period, extensive repairs and upgrades will be made to the LHC and its experiments. For the ATLAS experiment, the major upgrade will be to the muon spectrometer in the form of the New Small Wheels (NSW). The NSW will serve in the Level 1 Trigger and will also provide precision tracking of muons. The NSW will consist of two types of gas detectors: Micromegas and Small-strip Thin Gap Chambers (sTGC). The sTGC quadruplets consist of four layers, with each layer composed of pad and strip cathode boards, with high voltage wires in between. In August and October 2018, beam tests of a production sTGC quadruplet were performed in the H8 beamline of the Super Proton Synchrotron at CERN as well as in the Gamma Irradiation Facility (GIF++) on the H4 beamline to characterize detector response and efficiency while operating under different background conditions. This talk will detail the results of multiple aspects of the beam test.

† This research was partially supported by the Natural Sciences and Engineering Research Council of Canada (NSERC).

* evancarlson@uvic.ca (E. Carlson)

Current State of the ATLAS New Small Wheel Simulation System

Alexandre Laurier[1] *, A.Bellerive[1]

[1] Department of Physics, Carleton University, Ottawa, ON

CERN's Large Hadron Collider (LHC) is undergoing an extensive upgrade program, which will last over a decade, resulting in a seven-fold increase in instantaneous luminosity. In order to benefit from the increased performance of the LHC, the ATLAS experiment requires a series of upgrades including the replacement of the Small Wheel, a major component of the Muon Spectrometer, by the New Small Wheel (NSW). The NSW will operate in a high background radiation environment, while reconstructing muon tracks with high precision as well as serving as a Level-1 Trigger system. The simulation of the complete NSW system integrated in the ATLAS simulation and reconstruction chain is a necessary part of the Monte Carlo (MC) studies required for physics analysis. In order to simulate the NSW, a detailed response model was developed using MC studies and test beam results in conjunction with a faithful description of the detector's geometry. This contribution will summarize the current state of the NSW simulation model.

* alaurier@physics.carleton.ca (A.Laurier)

Simulation of Gas Detectors Using Ramo's Theorem

Dylan Pizzi[1] *

[1] Department of Physics, Carleton University, Ottawa, ON

Gas detectors, such as multiwire proportional chambers, have long been used in particle physics to reconstruct the tracks of particles passing through them. As high energy particles traverse the detection region they produce ionization clusters in the gas. These ionized electrons drift towards the anodes causing an induction of charge on the detector cathodes. In this discussion, we will highlight how Ramo's theorem can be used to determine the charge induced on electrodes. A brief overview of detector technique will be introduced, leading into an explanation of how it is simulated. The effects of detector components on signal formation will be presented, followed by how we account for them in our simulations. After, we will showcase how the simulations compare to experimental test beam data.

* dpizzi@physics.carleton.ca (D.Pizzi)

Photoproduction of the d*(2380) Dibaryon†

Stephen Kay[1,2] *, D.P. Watts[3], M. Bashkanov[3]

[1] Department of Physics, University of Regina, Regina, SK
[2] SUPA School of Physics and Astronomy, University of Edinburgh, EH9 3FD, UK
[3] Department of Physics, University of York, Heslington, York, YO10 5DD, UK

On behalf of the A2 collaboration

The field of multiquark states (beyond the known meson $q\bar{q}$ and baryon qqq states) has had renewed interest in recent years with findings of potential four, five and six quark states. Recent experiments by the WASA-at-COSY and HADES collaborations have observed a dibaryon (6q) resonant state, the d*(2380). Numerous measurements of this state across a range of different hadronic production channels indicate properties of M =2380 MeV, Γ= 70 MeV and $I(J^p) = 0(3^+)$. So far no photoproduction channels have been examined. A new measurement by the A2 collaboration at MAMI aims to observe the d*(2380) from a photoproduction reaction for the first time. A new large acceptance recoil polarimeter measures the final state spin polarisation of nucleons from the $D(\vec{\gamma}, \vec{n}p)$ deuteron photodisintegration reaction. Establishing that the d*(2380) has an electromagnetic coupling opens up opportunities to constrain its size and internal structure. Results from the analysis of the data will be presented.

† This research was supported: The UK Science and Technologies Funding Council (STFC), Studentship 1526286, Grants ST/L00478X/1 and ST/L005824/1 and the Natural Sciences and Engineering Research Council of Canada (NSERC), FRN: SAPIN-2016-00031.

* Stephen.Kay@uregina.ca

Photoproduction of the $b_1(1235)$ meson on the proton at E_γ = 6-12 GeV†

Ahmed M. Foda[1] *, Zisis Papandreou[1]

[1] Department of Physics, University of Regina, Regina, SK

On behalf of the GlueX collaboration

The GlueX experiment in Hall D, Jefferson Lab aims to map the meson spectrum, with a focus on exotic mesons and hybrids which are not allowed in a simple quark-antiquark model. In this talk, we will present our results on the photoproduction of the $b_1(1235)$ meson as a gateway to a few exotic mesons, especially as a prominent decay mode for the $\pi_1(1600)$, one of the lightest exotics. Acceptance-corrected helicity frame angular distribution, Mandelstam-t dependence and preliminary total cross-section are presented.

† Work supported by Natural Sciences and Engineering Research Council of Canada.

* amfoda@uregina.ca (A.M.Foda)

Analysis of Major Decay Channels of the Eta(548) and Eta'(958) Mesons for the GlueX Experiment†

Tegan Beattie[1 *], Z. Papandreou[1], J. Stevens[2]

[1] Department of Physics, University of Regina, Regina, SK
[2] Jefferson Lab, Newport News, Virginia, USA

On behalf of the GlueX collaboration

The primary goal of the GlueX experiment is to conduct a definitive mapping of states in the light meson sector with an emphasis on searching for exotic hybrid mesons as evidence of gluonic excitations. The experiment, housed in the Hall D facility at Jefferson Lab following its accelerator upgrade to 12~GeV, has been taking physics data for two years, with many more to come. The eta(548) and eta'(958) mesons are two of the richest unflavoured light mesons readily available at GlueX energies for studying resonances. Many other light mesons have decay channels involving the eta mesons with significant branching ratios, and (pi eta) / (pi eta') resonances are among the top contenders for possibly-accessible exotic and hybrid resonances which GlueX aims to study. As such, the ability to reconstruct pure eta / eta' samples and analyze their decays is of utmost importance for understanding future work on more complicated decay structures. Near-final analysis results for particular decay channels of the eta and eta' will be presented.

† This work was supported by NSERC grant SAPJ-326516 and Jefferson Science Associates, LLC, who operates Jefferson Lab under U.S. DOE Contract No. DE-AC05-06OR23177

* beattite@uregina.ca (T. Beattie)

Gain Calibration of SiPMs using Exclusive π^0 Events for the GlueX Experiment†

Karthik Suresh[1] *, Zisis Papandreou[1]

[1] Department of Physics, University of Regina, Regina, SK

The principle aim of the GlueX Experiment is to study hybrid mesons produced by impinging a 12GeV linearly polarized photon beam on to a liquid hydrogen target. The Experiment uses solenoid-based hermetic detector to collect data on meson production and its decays. The Barrel Calorimeter (BCAL) is a salient detector which is responsible for detection, identification and total energy measurements of both neutral and charged particles. Silicon PhotoMultipliers (SiPM) are used as readouts in the BCAL. Gain calibrations are carried out for every run period which also serves as a quality check on the SiPM's performance. Exclusive π^0 events are used in an iterative manner to achieve the correct π^0 mass while minimizing its width. A detailed summary on the calibration and recent updates such as SiPM saturation corrections to the BCAL gains will be presented in the talk.

† Work supported by NSERC

* ksv656@uregina.ca (K.Suresh)

Kaon L-T experiment at Jefferson Lab†

Vijay Kumar[1] *, G.M. Huber[1], S. Kay[1], G.R. Ambrose[1], T. Horn[2], R.L. Trotta[2]

[1] Department of Physics, University of Regina, Regina, SK
[2]Department of Physics, Catholic University of America, Washington DC, USA

On behalf of the Jlab Hall- C Collaboration

It is well understood that hadrons are composed of smaller, more fundamental particles, quarks and gluons. But the central problem for hadron physicists is to understand how the interaction of these fundamental particles gives rise to the properties of hadrons. To better understand this complex issue, the Kaon L-T experiment is being carried out at the Thomas Jefferson National Accelerator Facility (JLab) in Newport News, Virginia, USA. JLab has recently undergone a major upgrade to its capabilities. The $p(e, e'K^+)\Lambda$ and $p(e, e'K^+)\Sigma^0$ reactions are being measured in this experiment. To perform an L-T separation of the Kaon electroproduction cross-section, data at two different values of virtual photon polarization, ε, are required. Data taking for $Q^2 = 0.5$ GeV^2 for both low and high ε have been finished.

Data taking for Q^2 values of 2.1, 3.0 and 4.4 GeV^2 have been completed at high values of ε so far. We will continue low ε data taking in March 2019. In this talk, I will outline the upgraded experimental facility and our experiment. Preliminary analysis of the data will also be presented.

† This research supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) FRN: SAPIN-2016-00031.

*vkb135@uregina.ca (V.Kumar)

Neutrino Interferometry at DUNE
(Invited)

Deborah A. Harris[1,2] *

[1] Fermi National Accelerator Laboratory, Batavia, Illinois, USA
[2] Department of Physics and Astronomy, York University, Toronto, ON

On behalf of the DUNE collaboration

The fact that neutrinos have mass and change flavors means that we can learn a great deal about them by studying what are effectively interference patterns that arise after neutrinos propagate over hundreds of kilometers. The DUNE experiment will measure these interference patterns over a broad neutrino energy range after neutrinos have propagated 1300km. In addition, DUNE will use a detector technology that provides exquisite detail about the interactions that make up the interference pattern. This talk will present the current state of neutrino interference measurements and the various ways the field is preparing to jump to a new level of understanding.

* dharris@fnal.gov (D.A.Harris)

Measurement of Cherenkov Radiation in Liquid Xenon†

Tsvetelin Totev[1] *, T. Brunner[1,2], T. McElroy[1], F. Retiere[2]

[1] Department of Physics, McGill University, Montreal, QC
[2] TRIUMF, Vancouver, BC

For the LoLX collaboration

The Light-only Liquid Xenon (LoLX) experiment aims to study and characterize the emission of Cherenkov radiation in liquid xenon. The experiment will detect both Cherenkov and scintillation photons and focus on sub-10ns times scales. The experimental setup consists of a small 3D printed cylindrical chamber of few cm^3 whose inner walls are covered with silicon photo-multipliers (SiPMs). The chamber will be submerged in liquid xenon and we will initially detect scintillation and Cherenkov light using a beta source. Goals for LoLX include reconstructing the deposited energy using scintillation light thus measuring energy resolution, performing topological measurements to determine the recoil directions of the emitted electrons and assessing the background rejecting capabilities of Cherenkov photons in light-only LXe experiments. These measurements will provide crucial input into the operation of future large-scale liquid xenon experiments. The presented technique aims to support the developments of the planned neutrinoless double-beta decay experiment nEXO.

† This research was partially supported by NSERC, FQRNT, and McDonald Institute (CFREF).

* tsvetelin.totev@mail.mcgill.ca (T.Totev)

Detecting the birth of a proto-quark star from its formative neutrino and electromagnetic signal†

Amir Ouyed[1] *, R. Ouyed[1], P. Jaikumar[2]

[1] Department of Physics and Astronomy, University of Calgary, Calgary, AB
[2] Department of Physics & Astronomy, California State University Long Beach, Long Beach, California, USA

The rapid and complete burning of a neutron star to a proto quark-star (PQS) implies that neutrinos from weak decays in hot quark matter are trapped and later released in a burst. We use a microscopic non-equilibrium framework of reaction-advection-diffusion for combustion to strange quark matter and macroscopic neutrino transport equations to estimate the neutrino count rate in Super Kamiokande-II and Halo-2, finding the total counts to be one order of magnitude higher than expected from the formation of a proto-neutron star in a Type II Supernova. The large neutrino luminosity triggers relativistic mass ejection, where in in the case of surrounding circumstellar material (e.g. supernova remnant or common envelope), the ejecta shocks the surrounding material, powering a superluminous, double-humped supernova-like light curve. Therefore, the detection of black body neutrinos of neutrinospheric temperature $T > 20$ MeV coupled with superluminous supernova, would act as strong evidence for the existence of absolutely stable quark matter.

† R.O. is funded by the Natural Sciences and Engineering Research Council of Canada. P.J. is supported by the U.S. National Science Foundation under Grant No. PHY 1608959

* ahouyedh@ucalgary.ca (A.Ouyed)

ATLAS Strip Detector Upgrade for the Inner Tracker

Dominique Trischuk[1] *, Colin Gay[1]

[1] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC

On behalf of the ATLAS collaboration

Starting in 2024 the Large Hadron Collider (LHC) will be upgraded in order to produce ten times the amount of data that the ATLAS experiment can use to perform precision measurements of Standard Model particles and search for rare new signals. In order to meet the requirements of this challenging new environment, an all-silicon tracking system, called the ATLAS Inner Tracker (ITk), will be installed in the innermost layer of the detector. This tracker will consist of a pixel detector near the beam line surrounded by a larger strip tracking detector. The focus for this talk will be on the ITk-Strip detector, which has a large Canadian contribution. This talk will describe the design and requirements of the ITk-Strip detector, as well as highlight some of the Canadian contributions. The ITk Strip detector will have 60 million channels that need to be readout at a frequency of 1 MHz. This provides a challenging readout requirement on the order of 10^{13} channels per second. This talk will also discuss firmware emulation as a method of tackling such a complex electronic readout system.

* dtrischuk@physics.ubc.ca (D.Trischuk)

Automated Visual Inspection of ITk Sensors

Chris Gubbels[1,2] *, F.Guescini[2] and O.Stelzer-Chilton[1,2]

[1] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC
[2] TRIUMF, Vancouver, BC

On behalf of the ATLAS collaboration

The Large Hadron Collider is currently undergoing upgrades to substantially increase the instantaneous luminosity. This increase in luminosity will provide researchers the increased statistics necessary to perform higher precision measurements; however, it will also require corresponding improvements in current detectors. The ATLAS collaboration is currently developing several upgraded detectors for the ATLAS experiment, including an upgrade to the central tracking system. The new Inner Tracker (ITk), set to replace the current central tracking system, is an all-silicon tracking system composed of many small silicon modules. It is critical to the success of this upgraded system that these modules meet rigorous quality control standards. As part of this quality control process, the modules must undergo visual inspection to ensure that there are no evident defects (e.g. cracks, scratches, broken corners, etc.) on the sensors. At present, this visual inspection relies on a person scanning over the sensor surface using a microscope to search for defects. This process is time consuming, tedious, and potentially inconsistent. In order to improve the speed and consistency of this visual inspection process, our research aims to automate this process using machine learning and other image processing techniques. Having now tested out several different approaches, our preliminary results suggest that it should be possible to at least partially automate this process by flagging potential defects and displaying them to a user to make the final judgment. Future work shall be focused on maintaining sufficiently low false negative rates while decreasing the rate of false positive flags to further reduce the effort and input required from the user.

* gubbels@phas.ubc.ca (C.Gubbels)

Electroweak production of Z bosons in association with jets at 13 TeV with the ATLAS detector

Stephen Weber[1] *, Will Buttinger[2], J. Crane[3], C. Chhiv Chau[1], Monica Dobre[4], Dag Gillberg[1], Alexandre Laurier[1], Andrew Pilkington[3], Marina Rotaru[4]

[1] Department of Physics, Carleton University, Ottawa, ON
[2] Cavendish Laboratory, University of Cambridge, Cambridge, UK
[3] School of Physics and Astronomy, University of Manchester, Manchester, UK
[4] IFIN-HH, Bucharest, Romania

On behalf of the ATLAS collaboration

Z bosons are readily produced in collisions at the Large Hadron Collider via the strong process through a qqZ vertex. However, occasionally Z boson are produced by rarer electroweak processes such as Vector Boson Fusion (VBF). These electroweak processes are of interest for new physics, in particular the WWZ vertex of the VBF Z production channel is a probe of the triple gauge coupling. An anomaly in this coupling strength could indicate the presence of new physics occurring in higher order interactions in the WWZ vertex. The full Run II dataset of 140 fb^{-1} will be used to measure the electroweak Z production cross section both inclusively and differentially as a function of characteristic variables. Analysis technique will be outlined, focusing on the challenge of handling monte carlo miss modelling of the strong Z production background as well as systematic uncertainty estimation of the electroweak signal extraction procedure.

* sweber@physics.carleton.ca (S.Weber)

Prediction of Drell-Yan Angular Coefficients with the ATLAS Detector

Alexander Bachiu[1] *, M. Vincter[1]

[1] Department of Physics, Carleton University, Ottawa, ON

In proton-proton collisions at the Large Hadron Collider at CERN, one area of interest that can be measured using the ATLAS detector is the production of Z bosons. These can have easily observable decays of two leptons, such as electron-positron pairs and allow the probing of the parton distribution functions that describes the protons. With the Z bosons we can also measure $\sin^2\theta_W$, the weak mixing angle, which allows us to constrain the Standard Model. This process involves two spin 1/2 particles going to a spin 1 back to two spin 1/2 particles. Due to the spin dependence of the colliding protons and resulting leptons, the Z boson differential cross section can be split into 9 helicity dependent cross section ratios denoted by A_i. My work has been using different Monte Carlos to predict values for these A_i's for a special data set that was taken in 2017 and 2018 at $\sqrt{s}$ = 13 TeV. This involved testing the statistical sensitivity of the A_i's with Monte Carlo to see if we are able to make measurements with this specific data set. It has now expanded into using this data set to measure these A_i values.

* alexanderbachiu@carleton.ca (A. Bachiu)

Low-Scale String Resonances at the Large Hadron Collider

Pourya Vakilipourtakalou[1] *, Douglas Gingrich[1,2]

[1] Department of Physics, University of Alberta, Edmonton, AB
[2] TRIUMF, Vancouver, BC

Using an intersecting D-branes model in large extra dimensions could lead to low-scale string theories, in which the string scale Ms is of the order of a few TeV. In the D-brane formulation of low-scale string theory, string resonances (Regge excitations) can be produced in proton-proton collisions through 2-parton scatterings, and furthermore, in the limit Ms → ∞ these scattering amplitudes match the ones derived in QCD. Using the cross-sections and decay widths of the string resonances, we write a Monte Carlo event generator, STRINGS 1.00, for the production and decay of the first and second string resonances, and also for QCD tree-level scatterings, in proton-proton collisions, such that colour, quark flavour and electric charge are conserved. We will study the discovery potential of the first string resonance by using STRINGS to generate events for different string scales and studying the significance of the signals over the backgrounds in the dijet invariant mass distributions.

* vakilipo@ualberta.ca (P.Vakilipourtakalou)

Quantum Black Hole Production and Decay to the Di-top Final State at the LHC

Sina Safarabadi Farahani[1] *, Douglas M. Gingrich[1,2]

[1] Department of Physics, University of Alberta, Edmonton, AB
[2] TRIUMF, Vancouver, BC

Quantum Black Holes (QBHs) are predicted to be produced near the Planck scale (10^{18} GeV). This energy is not accessible on Earth. In models with large extra dimensions, ADD model, the Planck scale can be reduced to orders of a few TeV which may be accessible at the LHC. QBHs produced with a mass near the Planck scale are modeled to decay to a few particle final state with a probability depending on the number of extra dimensions in the model where the two-particle final state is always the dominant one.

In our study, we have simulated QBH production from proton-proton collisions at a centre of mass energy of 13 TeV and their decay to the di-top final state using the QBH generator. Our goal is to reconstruct the QBH state from the stable particles detected by the ATLAS detector and determine the predicted significance of this signal above the background.

* safaraba@ualberta.ca (Sina Safarabadi Farahani)

Dark Matter - WIMPS and Beyond
(Invited)

David McKeen[1] *

[1] TRIUMF, Vancouver, BC

The most popular candidate for particle dark matter is the so-call WIMP, a Weakly Interacting Massive Particle. A tremendous worldwide effort to detect WIMPs has taken place over the past few decades, so far without discovery. In recent years, this has motivated the community to consider other potential dark matter candidates which could require very different techniques to discover. I will describe the current state of the field and highlight new, novel probes of non-WIMP dark matter.

* mckeen@triumf.ca (D.McKeen)

New Attempt on Measurement of $^{19}F(p,\alpha)^{16}O$ Reaction at Relevant Astrophysical Energy†

Preetinder Jassal[1,2] *, R.Kanungo[1,2], M.Holl[1,2], M.Alcorta[2], S.Beceiro[3], S. Bhattacharjee[2], A.A.Chen[4], B.Davids[2], S.Roy-Garand[1], S. Gillespie[2], G.Hackman[2], R.Kruecken[2], J.Laroche[1], J.Liang[4], A.Psaltis[4], J.S.Randhawa[3]

[1] Department of Astronomy and Physics, Saint Mary's University, Halifax, NS
[2] TRIUMF, Vancouver, BC
[3] Department of Physics and Astronomy, Michigan State University, USA
[4] Department of Physics and Astronomy, McMaster University, Hamilton, ON

Galactic fluorine abundance is strongly dependent on the conditions in the astrophysical sites. This feature makes it useful to probe different nucleosynthesis scenarios, mainly in the AGB stars. It is also important in understanding s-process elements production and mixing processes in AGB stars. The observed upper limit of fluorine abundance is much lower than the one predicted with most recent AGB models, hinting at some catalytic material activating fluorine destruction via reactions involving fluorine, in particular $^{19}F(p,\alpha)^{16}O$. Therefore, it is of vital importance to get an insight into this destruction channel. Despite of its importance, the S-factor of this reaction is poorly known from previous studies..

In this presentation, I will discuss my observations and data analysis on $^{19}F(p,\alpha)^{16}O$. This reaction was measured in inverse kinematics at the ISAC rare isotope beam facility at TRIUMF. The ^{19}F beam, at mid-target E_{cm} = 2.35 MeV, was impinged on a solid hydrogen target at IRIS spectroscopy station. This energy was chosen keeping in mind the energy range of astrophysical interest. In an attempt to identify the ground state in ^{16}O, missing mass spectrum technique is used in the analysis.

† This research was partially supported by NSERC

* Preetinder.Jassal@smu.ca

Degenerate neutron capture within neutron star crusts with TALYS

Bryn Knight[1] *, and L.Caballero[1].

[1] Department of Physics, University of Guelph, Guelph, ON

Within the extremely dense neutron star crust, a degeneracy correction to neutron capture rates is required. To determine such rates, the capture cross sections of neutrons incident on very neutron rich nuclei are needed. However, experimental data is often unavailable, and rates must be modeled theoretically. On top of this, using Fermi-Dirac statistics to properly describe these neutrons can prove computationally difficult; compounded by the vast range of thermodynamic conditions leads to the need for more efficient, but still accurate, calculations. In this work, cross sections, the key component in capture rates, are calculated using a variety of theoretical models to find the most influential factor when accounting for captures in degenerate neutron matter. We find that the level density, and gamma strength function create little change, while the mass model has dramatic effects on neutron capture.

* Knightb@uoguelph.ca (B. Knight)

Assessment of Sensitivity Metrics in *r*-process Simulations

Carlton-James Osakwe[1] *, Z.Shand[1], N.Koning[1], R.Ouyed[1], I.Dillmann[2,3], R.Kruecken[2,4] and P.Jaikumar[5]

[1] Department of Physics and Astronomy, University of Calgary, Calgary, AB
[2] TRIUMF, Vancouver, BC
[3] Department of Physics and Astronomy, University of Victoria, Victoria, BC
[4] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC
[5] Department of Physics & Astronomy, California State University Long Beach, Long Beach, California, USA

About half of the stable elements that are heavier than iron in our universe were created by the process of rapid neutron capture, also known as the *r*-process. Building accurate simulations of the *r*-process is critical to understanding the origin of heavy elements, as this process cannot be observed directly. Many of the isotopes involved have never been observed, therefore their properties can only be predicted with theoretical models. Here I will analyze a series of metrics that are used to measure the "sensitivity" of the distribution of heavy elements to small variations in input parameters (namely mass) for specific isotopes in *r*-process simulations. These sensitivity studies help determine which isotopes have the greatest effect on the *r*-process, and whose properties therefore need to be known to high precision. Some of these metrics have never been used, and I will assess their usefulness in describing sensitivity.

* cuosakwe@ucalgary.ca (C. Osakwe)

High-Statistic Spectroscopy of ^{188}Tl ß$^+$/EC Decay with GRIFFIN†

Andrew MacLean[1] *, F.A. Ali[1], C. Andreoiu[4], G.C. Ball[2], N. Bernier[2,6], H. Bidaman[1], V. Bildstein[1], M. Bowry[2], R. Caballero-Folch[2], A. Diaz Varela[1], I. Dillmann[2,7], M.R.Dunlop[1], R. Dunlop[1], A. B. Garnsworthy[2], P. E. Garrett[1], G.Hackman[2], B.Jigmeddorj[1], A. I. Kilic[1], A. T. Laffoley[1], H.P. Patel[2], B. Olaizola[2], Y. Saito[2,6], J.Smallcombe[2], J.K. Smith[5], C.E. Svensson[1], J. Turko[1], K. Whitmore[4] and T. Zidar[1]

[1] University of Guelph, Guelph, ON
[2]TRIUMF, Vancouver, BC
[3]Colorado School of Mines, Golden, CO, USA
[4]Simon Fraser University, Burnaby, BC
[5]Reed College, Portland, Oregon, USA
[6]University of British Columbia, Vancouver, BC
[7]University of Victoria, Victoria, BC

Shape coexistence is associated with nuclear states of different deformations coexisting at low excitation energies and has been a topic of extensive research in nuclear physics over the past 60 years. Shape coexistence is driven by two opposing forces. The stabilizing effect of closed shells causes the nucleus to assume a spherical shape, while the residual quadrupole-quadrupole interaction between protons and neutrons leads to deformation. Across the nuclear chart the most extensive manifestation of shape coexistence is around the neutron deficient Z ~ 82 nuclei where spherical, prolate, and oblate nuclear states are all found to co-exist at low excitation energy. A region of particular interest is the neutron deficient Hg isotopes. Using the high efficiency GRIFFIN spectrometer, a detailed study of the excited states populated in ^{188}Hg following the ß$^+$/EC decay of ^{188}Tl was performed as part of an experimental campaign to help further a comprehensive understanding of nuclear structure evolution in this region. Preliminary results from the analysis of these data will be presented.

† Work supported by the Canada Foundation for Innovation, the Natural Sciences and Engineering Research Council of Canada and the National Research Council of Canada.

* amacle02@uoguelph.ca (A. MacLean)

Decay Spectroscopy of ^{160}Eu using the GRIFFIN Spectrometer

Daniel Yates[1,2] *, R. Krücken[1,2], I. Dillmann[2,3]

[1] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC
[2] TRIUMF, Vancouver, BC
[3] Department of Physics and Astronomy, University of Victoria, Victoria, BC

On behalf of the GRIFFIN Collaboration

Although the nuclear shell model—used to describe structure and increased stability at certain nucleon numbers within the nucleus—does well to predict the structure of spherical nuclei, its ability to describe deformed nuclei far from these shell closure numbers is lacking. Models attempting to describe the structure of deformed nuclei, both from the microscopic and macroscopic perspective, require information on the excited energy levels of these nuclei in order to improve their predicting power. Incomplete and disagreeing information on the decay scheme of ^{160}Eu to ^{160}Gd has been previously published [1,2], so a comprehensive picture of this decay is not yet available. Recently published data [3] improves the decay scheme, though there are still many unplaced levels and gamma-ray transitions, and information on beta-feeding intensities is lacking. At TRIUMF-ISAC, ^{160}Eu decay data was collected using the GRIFFIN (Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei) array of high-purity germanium detectors coupled with $LaBr_3$ fast-timing detectors and a conversion electron spectrometer. Over 10 million decays were recorded, allowing a comprehensive analysis of the beta-decay of ^{160}Eu. New results from the ongoing analysis of this decay, including the identification and placement of 15+ new excited states and 45+ new transitions in the ^{160}Gd daughter, will be presented.

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* dyates@triumf.ca (D.Yates)

Investigating the Nuclear Shell Closure at N=32 in Neutron-Rich ^{52}Ca

Robin Coleman[1]*, C.E.Svensson[1], F.A.Ali[1,2] C.Andreoiu[3], G.C.Ball[4], N.Bernier[4,5], S.S.Bhattacharjee[4], V.Bildstein[1], M.Bowry[4], C.Burbadge[1], R.Caballero-Folch[4], I.Dillmann[4,6], R.Dunlop[1], F.H.Garcia[3], A.B.Garnsworthy[4], P.E.Garret[1], F.Ghazi Moradi[1], G.F.Grinyer[7], G.Hackman[4], M.P.Hladun[7], A.T.Laffoley[1], R.Lafleur[4], J.L.Mitchell[7], A.D.MacLean[1], C.R.Natzke[8], B.Olaizola[4], C.J.Pearson[4], A.Radich[1], Y.Saito[4,5], L.Sexton[4,9], E.Timakova[4], K.Whitmore[3], D.Yates[4,5], and T.Zidar[1]

[1] Department of Physics, University of Guelph, Guelph, ON
[2] Department of Physics, College of Education, University of Sulaimani, Kurdistan Region, Iraq
[3] Department of Chemistry, Simon Fraser University, Burnaby, BC
[4] TRIUMF, Vancouver, BC
[5] Department of Physics and Astronomy, University of British Columbia, Vancouver, BC
[6] Department of Physics and Astronomy, University of Victoria, Victoria BC
[7] Department of Physics, University of Regina, Regina, SK
[8] Department of Physics, Colorado School of Mines, Golden, CO, USA
[9] Department of Physics, University of Surrey, Guildford, Surrey, UK

Nuclei away from the line of beta stability have been found to demonstrate behavior that is inconsistent with the traditional magic numbers of the spherical shell model that was developed for nuclei close to stability. This has led to the concept of the evolution of nuclear shell structure in exotic nuclei and the neutron-rich Ca isotopes are a key testing ground of these theories. However, there have been conflicting results from various experiments as to the true nature of a sub-shell closure for neutron-rich nuclei around ^{52}Ca. In June of 2018, an experiment was performed at the ISAC facility of TRIUMF; ^{52}K was delivered to the GRIFFIN gamma-ray spectrometer which was paired with the beta-tagger SCEPTAR and the Zero Degree Scintillator auxiliary detectors, along with 8 DESCANT neutron detectors for precise beta-neutron-gamma-gamma coincidences. Using this powerful combination of detectors, the level scheme of ^{52}Ca populated following the beta decay of ^{52}K has been constructed. Preliminary results from the analysis will be presented and discussed in the context of an N=32 shell closure in neutron-rich nuclei.

* rcolem01@uoguelph.ca (R.Coleman)

Nuclear Structure of ^{98}Ru Using β Decay

**S. Valbuena[1] ***, P.E. Garrett[1], L. Makhathini[2], R.A. Bark[2], V. Bildstein[1], T.R.Rodriguez[3], S. Triambak[4]

[1] Department of Physics, University of Guelph, Guelph, ON
[2] iThemba Labs, Old Faure Road, Faure, South Africa
[3] Departamento de Física Teórica, Universidad Autónoma de Madrid, Madrid, Spain
[4] Department of Physics and Astronomy, University of the Western Cape, Bellville, South Africa

A recent survey [1] of potential candidates for spherical vibrational motion [2] concluded that very few passed the criteria; of those that did, ^{98,100}Ru were the most promising. However, in part this may have been due to the lack of detailed spectroscopic data for 98,100Ru. In order to remedy this, we have performed a high-statistics measurement of the β decay of ^{98}Rh and ^{100}Rh using the newly commissioned β decay Tape Station at iThemba labs located near Cape Town, South Africa. Activities of ^{98,100}Rh were produced using fusion evaporation reactions of ^{14}N and ^{16}O beams on an ^{89}Y target, which was then transported from the irradiation station to a counting station. The counting station consisted of 4 clover-type high-purity germanium detectors, augmented by a TIGRESS detector, a plastic scintillator for the β particles, and an in-vacuum Si(Li) detector for conversion electrons. The decay of ^{98}Rh and ^{100}Rh to ^{98}Ru and ^{100}Ru was the first measurement to be completed on this new facility. Very high-statistics data sets were collected for ^{98,100}Ru, resulting in considerable expansions of their decay schemes. In this talk, we concentrate on results for ^{98}Ru from the analysis of the γ-γ coincidence matrix.

A main focus of this work has been on possible states associated with the first excited 0^+ state, the 0_2^+ level. Several weak E2 transitions: the 495 keV ($2_3^+ \rightarrow 0_2^+$), 402-keV ($2_3^+ \rightarrow 2_2^+$) and 419-keV ($2_3^+ \rightarrow 4_1^+$), were newly observed. The E2 transition to the 0_2^+ state possesses the largest relative B(E2) value, strongly suggesting that the 2_3^+ state is a band member of the excited 0_2^+ band. We have also observed a candidate level for the 4+ rotational band member, suggesting that ^{98}Ru possesses a more-deformed excited 0^+ band coexisting with a less-deformed ground state. Details of the analysis of the ^{98}Rh decay to date will be given.

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* valbuens@uoguelph.ca (S.Valbuena)

Searching for Shape Coexistence in ^{124}Te

**Erin McGee[1] ***, P.E.Garrett[1], V.Bildstein[1], M.R.Dunlop[1], R.Dunlop[1], C.Michelagnoli[2], C.Petrache[3]

[1] Department of Physics, University of Guelph, Guelph, ON
[2] Institut Laue-Langevin, Grenoble, France
[3] CSNSM Orsay, Orsay, France

FIPPS, the Fission Product Prompt gamma-ray Spectrometer, located at the Institut Laue-Langevin (ILL) in Grenoble, is an array of eight clovers of high-purity germanium (HPGe) scintillators. In the first collaboration between the University of Guelph and the ILL, FIPPS was used to conduct the ^{123}Te(n,gamma) reaction with the intent of populating the low-lying 0^+ states necessary to look for evidence of shape coexistence. Tellurium-124 is considered to be a good candidate for the observation of shape coexistence due to both its location in the Z=50 region of the chart of nuclides and the fact that it is mid-neutron-shell (N=72). Our experiment resulted in the collection of extremely high statistics data, with a major 2^+ to 0^+ ground state transition peak containing on the order of 10^8 events. Further results from preliminary analysis of this data, including investigations into the bands above the first three excited 0^+ states, are also discussed.

* mcgeee@uoguelph.ca (E.McGee)

Dark Matter Search With DEAP-3600 at SNOLAB†
(Invited)

Simon Viel[1] *

[1] Department of Physics, Carleton University, Ottawa, ON

On behalf of the DEAP collaboration

DEAP-3600 is an experiment searching for dark matter interactions with a target of liquid argon, located more than 2 km underground at SNOLAB in Sudbury, Canada. The spherical detector consists of 3.3 tonnes of liquid argon contained in a large ultralow-background acrylic cryostat, instrumented with 255 photomultiplier tubes. Direct detection experiments like DEAP-3600 aim to observe the interaction of dark matter with atomic nuclei, resulting in nuclear recoils, which in liquid argon cause the emission of ultraviolet scintillation light. After propagating to the inner surface of the acrylic vessel, this light is wavelength-shifted to visible using a layer of TPB, and the resulting blue light propagates into acrylic light guides to the photomultiplier tubes. Here the latest results from DEAP-3600 will be presented, including performance metrics for pulse-shape discrimination of nuclear recoils against electron recoils, event position and energy reconstruction, background rejection and sensitivity to dark matter.

† This research was undertaken thanks in part to funding from NSERC, CFI, CFREF support of the Arthur B. McDonald Canadian Astroparticle Physics Research Institute, the Ontario MRI, the Alberta ASRIP, Queen's University, University of Alberta, Carleton University, DGAPA-UNAM and CONACyT (Mexico), the European Research Council, the UK STFC, and the Leverhulme Trust. Studentship support by the Rutherford Appleton Laboratory Particle Physics Division, the UK STFC and SEPNet PhD is acknowledged. SNOLAB operations are supported by CFI and the Ontario MRI, with underground access provided by Vale at the Creighton mine site. Computing resources required to undertake this work were provided by Compute Canada, Calcul Québec, the Centre for Advanced Computing at Queen's University, the Carleton University Physics Research Computing Centre, and the Computational Centre for Particle and Astrophysics at the Leibniz Supercomputer Centre.

* simon.viel@carleton.ca (S.Viel)

The CUTE Facility

Ryan Underwood[1,2] *

[1] Department of Physics, Engineering Physics & Astronomy, Queen's University, Kingston, ON
[2]Physical Science Division, TRIUMF, Vancouver, BC

On behalf of SuperCDMS and CUTE

Astronomical observations have led to a preponderance of evidence for dark matter; a kind of matter which does not interact via the electromagnetic or strong forces. The SuperCDMS experiment searches for dark matter particle candidates using cryogenic germanium and silicon semiconductor detectors. Before the next generation of SuperCDMS starts operating at SNOLAB, the Cryogenic Underground TEst Facility (CUTE) will come online, and provide a low-background, low cosmogenic-activation environment to test SuperCDMS detectors underground at SNOLAB. The facility will have the capacity to hold up to six SuperCDMS detectors (one "tower"), and allow for measurements of detector properties well before the main experiment is ready. Given the low background of the facility as well as the expected threshold of the new detectors, it is conceivable that the CUTE facility may be able to acquire some early dark matter search data. This talk will present the CUTE facility and discuss some possibilities for early measurements when it comes online in early 2019.

* 14reu@queensu.ca (R.Underwood)

Applications of machine learning to improve the analysis of data from SNO+

Mark Anderson[1] *

[1] Department of Physics, Engineering Physics & Astronomy, Queen's University, Kingston, ON

On behalf of the SNO+ collaboration

SNO+ is a neutrino physics experiment located 2km underground. The experiment has several physics goals, although the primary focus is on the search for neutrinoless double-beta decay in ^{130}Te. In the detector, background processes and instrumental noise dominate over signals of interest, leading to a large influx of data. This presents a challenge in processing and analyzing data efficiently. For example, event reconstruction algorithms and detector simulations are time consuming because they account for many complex physics processes. Background identification is also a difficult task, and current methods often remove a substantial portion of signal events.

In recent years, machine learning has seen an explosion in use due to proven successes in many fields that deal with large amounts of data. Despite this, it is still relatively underutilized in particle astrophysics. I present several applications of machine learning to assist in the analysis of data from the SNO+ experiment. In particular, I show how machine learning can provide accurate reconstruction of detector events at a rate thousands of times faster than current physics-based models. I also show a novel neutron capture event-by-event identification method that uses machine learning to improve upon existing statistical analyses.

* anderson.mark@queensu.ca (M. Anderson)

Multimessenger area: Opportunities for future experiments at ISAC-II, TRIUMF

Beau Greaves[1] *, Dennis Muecher[1,2]

[1] Department of Physics, University of Guelph, Guelph, ON
[2] TRIUMF, Vancouver, BC

On behalf of the TI-STAR collaboration

Detailed information about the heavy, neutron-rich nuclei involved in the r-process are needed in order to pin down the origin of heavy elements in the universe.

We have designed an innovative new silicon detector, surrounding an extended gas target, optimized for studies of r-process nuclei. The new $750k TI-STAR silicon tracker detector, under development in an international collaboration at the University of Guelph and TRIUMF, will allow measurements of neutron capture rates in the key A=130 mass region around Sn-132, of pivotal importance for our understanding of r-process nucleosynthesis. TI-STAR also will allow unique insight into fission properties of neutron-rich nuclei, important for our understanding of fission re-cycling in the r-process. We present results from S1855 at TRIUMF, targeting resonances with importance for the determination of the neutron flux in explosive nucleosynthesis, to demonstrate the potential of such studies. We also discuss the possibility to couple TI-STAR to GRETINA at FRIB.

* bgreaves@uoguelph.ca (B. Greaves)

Delayed Gamma Spectroscopy of Markers for Range Verification in Proton Therapy

Eva Kasanda[1] *, D.Muecher[1,2], C,Burbadge[1], V.Bildstein[1], C.Hoehr[2], B.Olaizola[2], D.Hymers[1], J.Turko[1]

[1] Department of Physics, University of Guelph, Guelph, ON
[2] TRIUMF, Vancouver, BC

In proton beam radiotherapy (RT), protons are used to irradiate tumor cells for various malignant diseases. Protons differ from X-rays used in conventional RT in that they deposit most of their energy at the end of their track, in a narrow region called the Bragg peak. The localization of the dose profile is particularly useful for the treatment of breast cancers, due to their proximity to the heart and lungs. However, uncertainties in tissue stopping-powers and patient movement can contribute uncertainties in the range of the protons on the order of millimeters. If a metal marker is administered to the breast tumor region, one could use gamma spectroscopy to monitor the range of the beam relative to the marker during delivery. Direct nuclear and fusion-evaporation reactions between the proton beam and metal-marker nuclei result in the emission of prompt and beta-delayed characteristic gamma rays. These signals can be measured off-beam for a more precise measurement on a greatly reduced background compared to on-beam. This can be achieved by periodically switching the beam on and off during delivery. In the treatment of breast cancers, the timing of the fraction delivery is already limited by the patient's breathing cycle, so this toggling would have low impact on treatment time. We propose to take advantage of the energy resolution of HPGe detectors to measure beam range in proton RT of breast tumors. Our Geant4 simulation results show that this technique would allow for accurate measurement of beam range relative to the position of the marker. This technique allows for dose monitoring during the treatment as opposed to afterwards, and is sensitive to the position of the tumor marker.

* ekasanda@uoguelph.ca (E.Kasanda)