WNPPC 2017

54th Winter Nuclear & Particle Physics Conference

Banff, Alberta, 16-19 February 2017

Organised by the University of Victoria & TRIUMF

Organising Committee

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Welcome!

On behalf of the Organizing Committee, I welcome you to the 54th Winter Nuclear & Particle Physics Conference. This year we have a record attendance! The program includes 9 plenary talks and 47 contributed talks, spanning a wide range of topics. Enjoy the talks, enjoy the venue, meet new and old colleagues. I wish you a fruitful and pleasant conference.

Invited Speakers

- **Thomas Brunner** (McGill), *Barium-Ion Tagging for* ^{136}*Xe Double-Beta Decay Studies with nEXO*
- **Benoit Côté** (University of Victoria), *Connecting Nuclear Astrophysics to Cosmological Structure Formation*
- **Beatrice Franke** (TRIUMF), *Introduction to the Ultracold Neutron Facility at TRIUMF*
- **Dag Gillberg** (Carleton University), *Exploring the Higgs Boson with ATLAS Data*
- **Pierre Gorel** (SNOLAB), *Dark Matter Searches at SNOLAB: looking for WIMPs, either heavy or light*
- **Nigel Hessey** (TRIUMF), *Inner Tracker Detector Advances*
- **Rituparna Kanungo** (Saint Mary's University), *Reaction Spectroscopy unveils new Features of Rare Isotopes*
- **Oliver Kester** (TRIUMF), *Accelerator Physics Developments for Rare Isotope Facilities*
- **Anna Kwiatkowski** (TRIUMF), *Ion Trapping at Rare-Isotope-Beam Facilities*

Registration

Thursday 16 February, from 16:00 to 17:30 in the PDC Central Foyer and from 18:00 to 19:00 just outside the meeting room (KC203).

Reception

The Welcome Reception will take place after the last talk on Thursday 16 February, starting at approximately 21:00, in KC105.

Banquet

The conference Banquet will take place Saturday evening, starting at approximately 17:30, in KC105.

Others Meals & Breaks

Coffee breaks (am/pm) will be outside the meeting room. Attendees staying at the Banff Centre have included in their room stay, breakfast, lunch and dinner. All meals (except the banquet) are at the reserved tables in the Vistas Dining room. Attendees who pre-ordered a bagged lunch are requested to pick up their bagged lunch at lunchtime in the Vistas Dining lounge. All other attendees who have not purchased a meal package may purchase their meal at Vistas Dining Lounge, Three Ravens Restaurant, the MacLab Bistro or Le Cafe in the Sally Borden Building.

Talks

All presentations will be in KC203. Presenters are required to put the PDF file of their talk on a memory stick and transfer it to the presentation laptop no later than 15 minutes prior to the start of the relevant session. Prizes will be awarded for the best student talks, funded by our sponsors.

Sponsors

The support from our sponsors is gratefully acknowledged.

Main Sponsors

- TRIUMF
- University of Victoria, Office of the Vice President, Research
- University of Victoria, Office of the Dean of Science

Student Prizes Sponsors:

- CAP Division of Nuclear Physics (DNP)
- CAP Particle Physics Division (PPD)
- CAP Division of Theoretical Physics (DTP)
- Canadian Institute of Nuclear Physics (CINP)
- Institute of Particle Physics (IPP)
- SNOLAB

Schedule Overview

Thursday 16 February

16:00 – 17:30	Registration (PDC Central Foyer)
17:30 – 19:00	Dinner
18:00 – 19:00	Registration (Outside KC303)
19:00 – 21:00	Session 1
21:00 – 23:00	Reception

Friday 17 February

07:00 – 08:30	Breakfast
08:30 – 10:00	Session 2a
10:00 – 10:15	Coffee break
10:15 – 12:00	Session 2b
12:00 – 13:30	Lunch

Afternoon is free for other activities

17:30 – 19:00	Dinner
19:00 – 20:30	Session 3a
20:30 – 20:45	Coffee break
20:45 – 22:00	Session 3b

Saturday 18 February

07:00 – 08:30	Breakfast
08:30 – 10:00	Session 4a
10:00 – 10:15	Coffee break
10:15 – 12:00	Session 4b
12:00 – 13:30	Lunch

Afternoon is free for other activities

17:30 – 19:00	Banquet
19:00 – 20:30	Session 5a
20:30 – 20:45	Coffee break
20:45 – 22:00	Session 5b

Sunday 19 February

07:00 – 08:30	Breakfast
08:30 – 10:00	Session 6a
10:00 – 10:30	Coffee break
10:30 – 11:30	Session 6b
11:30 - 12:00	Awards: Student prizes
12:00 – 13:30	Lunch

Detailed Schedule

Legend:

- **bold names** are the invited speakers
- ★ after the name are non-student talks
- all the others are student talks

Thursday 16 February, evening

17:30 – 19:00	Dinner

Session 1

19:00 – 19:15	Opening remarks
19:15 – 19:45	**Nigel P. Hessey**, *Inner Tracker Detector Advances*
19:45 – 20:00	Robin Newhouse, *Proposed CMOS-based Sensors for the ATLAS Detector: CHESS-2*
20:00 – 20:15	Graeme Niedermayer, *Investigations of Calorimeter Clustering in ATLAS Using Machine Learning*
20:15 – 20:30	Savino Longo, *Neutral Hadron Particle Identification using CsI(Tl) Scintillation Pulse Shape Analysis*
20:30 – 20:45	Andrea Fodor, *Design and Simulation of Beam-Background Monitors in the Vicinity of the Electromagnetic Calorimeter for the Belle II Experiment*
20:45 – 21:00	Alexandre Beaulieu, *BEAST-II: Measurement of Machine-Induced Backgrounds during Commissioning of SuperKEKB*

21:00 – 23:00	Reception

Friday 17 February, morning

07:00 – 08:30	Breakfast

Session 2a

08:30 – 09:00	**Oliver Kester**, *Accelerator Physics Developments for Rare Isotope Facilities*
09:00 – 09:15	Dennis Muecher★, *A Silicon Tracker for ISAC-II and the Future ARIEL Facility*
09:15 – 09:30	Fatima H. Garcia, *Calculation of Isotope Rates for Radioactive Beam Production*
09:30 – 09:45	Julien Refour Tannenbaum, *Simulation of Optical Pumping in TRIUMF's Collinear Laser Spectroscopy Experiment*
09:45 – 10:00	Joseph Turko, *Simulating the DESCANT Neutron Detection Array with the Geant4 Toolkit*

10:00 – 10:15	Coffee break

Session 2b

10:15 – 10:45	**Anna A. Kwiatkowski**, *Ion Trapping at Rare-Isotope-Beam Facilities*
10:45 – 11:00	Andrew Finlay, *Integration of a Multi Reflection Time of Flight Isobar Separator into the TITAN Experiment at TRIUMF*
11:00 – 11:15	Erich Leistenschneider, *Towards $N = 82$ r-Process Waiting Point: Precision Atomic Mass Measurements of $^{125-127}$Cd*
11:15 – 11:30	Jonathan Williams, *Study of ^{22}Ne and ^{28}Mg Excited States using Fusion-Evaporation and Doppler Shift Measurements*
11:30 – 11:45	Steffen Cruz, *Single Particle Structure of Exotic Strontium Isotopes*
11:45 – 12:00	Thomas Domingo, *Neutron Activation Analysis via Nuclear Decay Kinetics using Gamma-Ray Spectroscopy at SFU*

12:00 – 13:30	Lunch

Friday 17 February, evening

17:30 – 19:00	Dinner

Session 3a

19:00 – 19:30	**Pierre Gorel**, *Dark Matter Searches at SNOLAB: looking for WIMPs, either heavy or light*
19:30 – 19:45	Francisco Vazquez de Sola Fernandez, *Dark Matter Direct Detection with NEWS-G: Analysis and Results*
19:45 – 20:00	Alison Elliot, *Search for Dark Matter with leptonically-decaying Z Bosons and Missing Transverse Energy in the ATLAS Detector at the LHC*
20:00 – 20:15	Courtney Mielnichuk, *A likelihood Ratio Algorithm to remove localized Alpha Particle Backgrounds in the DEAP-3600 Detector*
20:15 – 20:30	Thomas McElroy, *Photo-Electron Pulse Finding and Pile-up Detection for the DEAP Experiment*

20:30 – 20:45	Coffee break

Session 3b

20:45 – 21:15	**Thomas Brunner**, *Barium-Ion Tagging for ^{136}Xe Double-Beta Decay Studies with nEXO*
21:15 – 21:30	Jie Hu★, *The ^{16}N Source for the Calibration of the SNO+ Experiment*
21:30 – 21:45	Pawel Mekarski, *Detection of Antineutrinos Using the SNO+ Detector*
21:45 – 22:00	Adam J. Mayer, *Geochemical Measurement of the Half-Life of the Double-Beta Decay of ^{96}Zr*

Saturday 18 February, morning

07:00 – 08:30	Breakfast

Session 4a

08:30 – 09:00	**Beatrice Franke**, *Introduction to the Ultracold Neutron Facility at TRIUMF*
09:00 – 09:15	Sanmeet Chahal, *EDM Monte Carlo Simulations for the UCN Experiment at TRIUMF*
09:15 – 09:30	Shomi Ahmed, *Compensation of Magnetic Fields in the TRIUMF nEDM Experiment*
09:30 – 09:45	Andrew Evans, *Observation of Atomic Transition in Antihydrogen*
09:45 – 10:00	Connor Stephens, *The Application of the Variational Principle to the Calculation of a Tetraquark Bound State*

10:00 – 10:15	Coffee break

Session 4b

10:15 – 10:45	**Benoit Côté**, *Connecting Nuclear Astrophysics to Cosmological Structure Formation*
10:45 – 11:00	Annika Lennarz★, *The ^{22}Ne(p,γ)^{23}Na Reaction and the Origin of ^{23}Na*
11:00 – 11:15	Roger Caballero-Folch★, *Experimental Results of β-delayed Neutron Branching Ratios for heavy Species*
11:15 – 11:30	Harris Bidaman, *A Study on Low Spin States in ^{154}Gd using (p,p') Reaction*
11:30 – 11:45	Christina Burbadge, *Investigation of excited 0^+ States populated via the Er-162 two-Neutron Transfer Reaction*
11:45 – 12:00	Anish Verma, *The Nuclear Delta Force and The Two-Particle-Rotor Model*

12:00 – 13:30	Lunch

Saturday 18 February, evening

17:30 – 19:00 Banquet

Session 5a

19:00 – 19:30 **Dag Gillberg**, *Exploring the Higgs Boson with ATLAS Data*

19:30 – 19:45 Christopher Anelli★, *Quartic Gauge Boson Coupling Results from the LHC*

19:45 – 20:00 Stephen Weber, *Measurement of Z Bosons produced in association with Jets via Vector Boson Fusion at 13 TeV with the ATLAS Detector*

20:00 – 20:15 Elham E. Khoda, *Hunting for "Bumps" in the Dilepton Invariant Mass Spectrum using* BUMPHUNTER *at the ATLAS Detector*

20:15 – 20:30 Etienne Dreyer, *The Hunt for the Z′ Boson in ATLAS: a Statistical Perspective*

20:30 – 20:45 Coffee break

Session 5b

20:45 – 21:00 Sakib Rahman, *Spectrometer and Detector Simulations for the MOLLER Experiment*

21:00 – 21:15 Ryan Spies, *Electron Detection for the Jefferson Lab Hall A Compton Polarimeter*

21:15 – 21:30 Tegan Beattie, *Analysis of the* $\eta(548) \rightarrow \pi^+\pi^-\pi^0$ *and* $\eta'(958) \rightarrow \pi^+\pi^-\eta$ *Channels using a 8-9 GeV tagged Photon Beam for the GlueX Experiment*

21:30 – 21:45 Ahmed M. Foda, *Preliminary Survey of the Photoproduction of* $\pi^+ + \pi^- + 4\gamma$ *Final State in GlueX Experiment*

21:45 – 22:00 Dilli R. Paudyal, *Spin Polarizability of a Proton via Measurement of Nuclear Structure Observable with Polarized Target and Polarized Beam at MAMI*

Sunday 19 February, morning

07:00 – 08:30	Breakfast

Session 6a

08:30 – 08:45	Kenneth Whitmore★, *Detailed Spectroscopy of* ^{132}*Sn with GRIFFIN*
08:45 – 09:00	Andrew D. MacLean, *Angular Correlation Measurements With GRIFFIN*
09:00 – 09:15	Mukut R. Kalita★, *Progress towards measuring Parity Non Conservation in Francium*
09:15 – 09:30	Nikita Bernier, *Decay Spectroscopy of Neutron-Rich Cd Around the N = 82 Shell Closure*
09:30 – 09:45	Joochun Park, *Ground State Spin of* ^{101}*Sn and the Role of the Tensor Force in exotic Nuclei*
09:45 – 10:00	Ahmed Rayyan, *Coulomb Artifacts and Bottomonium Hyperfine Splitting in Lattice NRQCD*

10:00 – 10:30	Coffee break

Session 6b

10:30 – 11:00	**Rituparna Kanungo**, *Reaction Spectroscopy unveils new Features of Rare Isotopes*
11:00 – 11:15	Fuad A. Ali★, *Identification of the* 2^+_{ms} *mixed-symmetry State in* ^{52}*Ti using Alpha Transfer Reaction*
11:15 – 11:30	Kim Maltman★, *A new Determination of* V_{us}

11:30 - 12:00	**Awards: Student prizes**

12:00 – 13:30	Lunch

BARIUM-ION TAGGING FOR ^{136}Xe DOUBLE-BETA DECAY STUDIES WITH nEXO

Thomas Brunner*

for the nEXO collaboration

McGill University

The nature of the neutrino, i.e. whether it is a Dirac or Majorana particle, remains a mystery. Decay experiments that search for the lepton-number violating neutrino-less double decay ($0\nu\beta\beta$) are an experimental approach to answer this question and search for physics beyond the Standard Model. EXO-200 is one such experiment, searching for a $0\nu\beta\beta$ signal in the $\beta\beta$ decay of ^{136}Xe to its daughter isotope ^{136}Ba. This detector, located at the WIPP site in New Mexico, USA, contains $\approx$ 200 kg liquid Xe enriched to $\approx 80\%$.

In order to further push sensitivity, it is necessary to suppress the background (currently dominated by gamma rays) and increase the mass of the parent isotope. A unique advantage of a Xe time-projection chamber (TPC) is the possibility to extract into vacuum and identify (to tag) Ba-daughter ions. This tagging possibility, combined with enough energy resolution to separate $0\nu\beta\beta$ from $2\nu\beta\beta$ decays, allows one to dramatically reduce the background of the measurement to virtually zero.

EXO has started development on nEXO, a multi-ton scale TPC. In addition, Ba-tagging techniques, in both liquid and gas phase TPCs, are under development. In a liquid Xe TPC, the Ba ion will be extracted mechanically by a probe or sucked out through a capillary. In the latter case, the Ba ion will be extracted into vacuum through a supersonic nozzle combined with an extraction RF-funnel. The current status of these Ba-tagging techniques will be presented and possible future developments will be discussed with a strong focus on the Canadian Ba-tagging developments.

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CONNECTING NUCLEAR ASTROPHYSICS TO COSMOLOGICAL STRUCTURE FORMATION*

Benoit Côté†

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Galactic chemical evolution is a multidisciplinary topic that involves nuclear physics, stellar evolution, galaxy evolution, and cosmology. Observations, experiments, and theories need to work together in order to build a comprehensive understanding of how the chemical elements synthesized in astronomical events are ejected and spread inside galaxies and recycled into new generations of stars. Nuclear physics provides nuclear reaction rates, stellar models provide the composition of stellar ejecta, galaxy models follow the evolution of chemical species driven by multiple stellar populations, cosmological simulations dictate how galaxies form and evolve in general, and observations provide constraints to test and improve numerical recipes driven by theories. During this talk, I will introduce the topic of galactic chemical evolution and present our efforts to create permanent connections between different fields of research (including nucleosynthesis and gravitational wave physics). Our ultimate goal is to better understand the origin of the elements in the universe and to explain the diverse chemical evolution patterns observed in nearby galaxies.

*Work supported by JINA-CEE (USA) and FRQNT (Quebec)

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INTRODUCTION TO THE ULTRACOLD NEUTRON FACILITY AT TRIUMF

Beatrice Franke*

TRIUMF

A permanent non-zero electric dipole moment (nEDM) violates CP-symmetry. Beyond Standard Model theories predict nEDMs very close to the current upper limit of 3×10^{-26} e·cm. Those predictions result from CP-violating processes, which in turn can be related to the matter-antimatter asymmetry observed in our universe. Thus the search for an nEDM contributes to understanding the Baryon asymmetry, as well as it has a high discovery potential for Beyond Standard Model physics. The tool of choice to investigate the nEDM are ultracold neutrons (UCN), since they have such low energies that they can be stored in traps and allow observation times of hundreds of seconds.

The distinct feature of TRIUMFs UCN facility is the combination of a neutron spallation source with a superfluid helium UCN converter - unique among all existing and planned UCN sources worldwide. The goal of the UCN project at TRIUMF is to provide a density of several hundreds of UCN per cubic cm to experiments at up to two ports, whereas one will be dedicated to determine the nEDM to the 10^{-27} e·cm level of precision.

This presentation shall give an introduction and motivation to UCN physics, and further update the audience on the current status of the UCN facility at TRIUMF.

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EXPLORING THE HIGGS BOSON WITH ATLAS DATA

Dag Gillberg*
Carleton University

After the discovery of the Higgs boson in July 2012, the attention of the LHC experiments has shifted to measure its properties. The spin and charge parity quantum numbers, as well as the coupling strength to other particles have been probed in many Higgs decay channels using global fits and found to be in good agreement with the expectations. I will present an overview of some of these results, but primarily focus on measurements of kinematic distributions of the Higgs boson such as distribution of its momentum, rapidity (production angle) and features of other particles produced in association with the Higgs boson. These measurements are corrected for detector effects (unfolded) and are compared both with predictions from the Standard Model as well as with various BSM models.

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DARK MATTER SEARCHES AT SNOLAB: LOOKING FOR WIMPS, EITHER HEAVY OR LIGHT

Pierre Gorel*

SNOLAB

In the heart of the Canadian Shield, deep underground, lies SNOLAB, a world-class underground laboratory. With one of the best overburden against cosmic rays in the world, it is an ideal place for ultra-low background experiments. With 7 distinct detectors (either running or planned), a large effort is made to look for the elusive dark matter, thought to account for more than 84% of the mass of the Universe. The favored candidate is the Weakly Interacting Massive Particle (WIMP), for a mass range between 0.2 GeV and 1 TeV. DEAP-3600 is a single-phase dark matter detector. With almost 3500 kg of liquid argon in a vessel made of transparent acrylic, it is one of the biggest worldwide. Using carefully selected low background materials and the pulse shape discrimination technique, the aim is to gather 3000 kg-year of background-free data in the region of interest and reach a maximum sensitivity of 10-46 cm2 for a WIMP mass of 100 GeV. The detector has been taking data for a few months, allowing us to present some exciting insights.
On the opposite side of the spectrum, the NEWS-G project aims at sampling the WIMP mass down to 0.2 GeV. It is the successor to the SEDINE detector, a 60 cm diameter spherical gaseous detector, operated at the Laboratoire Souterrain de Modane. The one designed for SNOLAB will have a 140 cm diameter and will use light target elements such as hydrogen, helium and neon to maximize the energy transfer during the WIMP-nuclei scattering. The construction is starting and the deployment is planned for the second half of the year.

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INNER TRACKER DETECTOR ADVANCES

Nigel P. Hessey*

TRIUMF

After a brief summary of the expected future needs for tracking detectors, I will discuss current advances in silicon particle detectors and their associated electronics. I will cover n-in-p strip detectors that are sufficiently rad-hard for use at the future High Luminosity LHC, and modern and future pixel devices, including monolithic CMOS devices currently under development. The emphasis will be on detectors for use in the ATLAS upgrade aimed for deployment in 2025, but if time permits, I will also touch on recent advances in gaseous pixel detectors.

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REACTION SPECTROSCOPY UNVEILS NEW FEATURES OF RARE ISOTOPES*

Rituparna Kanungo†

Saint Mary's University, Halifax, Canada

Rare isotopes with highly asymmetric ratios of protons and neutrons offer us the scope of exploring new features that surface prominently at large isospin. They are the pathways for understanding processes and characteristics of extreme matter in the universe such as neutron stars. Direct reactions have laid the foundations of unraveling unexpected phenomena through the discovery of the nuclear halo. This has triggered a new era in nuclear science breaking the boundaries of conventional concepts. The new features in exotic nuclei challenge our understanding of the nuclear strong interaction which remains a major task to understand from the fundamentals of quantum chromodynamics. Nuclei at the edges of nuclear binding hold promise to be sensitive probes for constraining the nuclear interaction.

In this presentation I will describe how reaction spectroscopy using low-energy re-accelerated beams at TRIUMF in Canada and relativistic energy beams at GSI in Germany, provide us different avenues to uncover the hidden secrets in the structure of rare isotopes. Recent explorations with the reaction spectroscopy facility IRIS at TRIUMF on the structure and excitation of neutron halo and investigations on proton drip-line nuclei for defining the nuclear force will be presented. Characterizing the nuclear halos and hence relating the nuclear interactions to such properties requires the fundamental knowledge of nuclear radii. These investigations, possible with the high-energy beams of rare isotopes at GSI, will be discussed.

*Work supported by NSERC, CFI, NSRIT

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ACCELERATOR PHYSICS DEVELOPMENTS FOR RARE ISOTOPE FACILITIES

Oliver Kester*

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Rare isotope beam (RIB) facilities drive the understanding in nuclear physics research and many other disciplines. Rare-isotope accelerators play a significant role for the research at modern RIB facilities and become more sophisticated to provide the impetus for cutting edge research. Such particle accelerators are required to provide either unprecedented intensities of driver beams to produce significant intensities of short lived isotopes or high transmission and beam quality in case of post acceleration. Premiere facilities with cutting edge accelerator technology are the advanced rare isotope laboratory - ARIEL at TRIUMF, Canada and the Facility for Antiproton and Ion Research – FAIR at GSI, Germany. Both facilities are under development. In these facilities, beam manipulation, beam transport and acceleration, beam instrumentation and target technology must be highly optimized. The beam intensities and quality of the driver beams as well as of the secondary beams are far beyond existing facilities. Some new accelerator physics developments in the field that are required to realize these facilities will be presented and discussed.

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ION TRAPPING AT RARE-ISOTOPE-BEAM FACILITIES*

Anna A. Kwiatkowski†

TRIUMF

Ion traps first entered experimental nuclear physics by the demonstration of Penning trap mass spectrometry of radioactive beams at ISOLDE-CERN. Since then, ion traps have grown in popularity at rare-isotope-beam (RIB) facilities as they allow beams to be tailored to the desired experiment and can offer textbook-like conditions. Their versatility ranges from beam preparation to high-precision experiments and from intense beams to a single charged particle. For example, the most accurate and precise mass measurements are performed in a Penning trap, providing insight into nuclear astrophysics and fundamental symmetries. Nuclear-structure investigations are conducted on isomerically purified beams via trap-assisted or in-trap decay spectroscopy; indeed, ion traps allow such studies of highly charged ions which would be impossible with traditional techniques. Beam bunching reduces the background for laser spectroscopy, allowing for a better understanding of the nuclear charge distribution.

A brief introduction to ion trapping will be presented. Thereafter, the versatility and utility of the technique will be illustrated through measurements performed at TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN) facility. These measurements will be related to the synthesis of the heavier elements in the universe, the evolution of nuclear shell structure, and neutrino studies.

*Work supported by the the Natural Sciences and Engineering Research Council (NSERC) of Canada and the National Research Council (NRC) of Canada through TRIUMF.

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COMPENSATION OF MAGNETIC FIELDS IN THE TRIUMF nEDM EXPERIMENT

Shomi Ahmed*

University of Manitoba

The existence of a non-zero neutron electric dipole moment (nEDM) would violate parity and time-reversal symmetry. Extensions to the Standard Model predict the nEDM to be 10^{-26} – 10^{-28} e-cm. The current best upper limit set by Sussex/RAL/ILL nEDM experiment is 3.0×10^{-26} e-cm. The nEDM experiment at TRIUMF is aiming at the 10^{-27} e-cm level in Phase 2 operations. We are developing the world's highest density source of UCN. The experiment requires a very stable ($<$ pT) and homogeneous ($<$ nT/m) magnetic field (B0) within the measurement cell. My involvement in the nEDM experiment is the development of active magnetic shielding to stabilize the external magnetic field by compensation coils. A prototype active magnetic shield has been tested at The University of Winnipeg. I will report on experimental results from this prototype and simulations conducted to understand the results. The magnetic environment at TRIUMF is more challenging than in our lab in Winnipeg, because of the closeness of the experiment to the TRIUMF cyclotron (B $\sim 350 - 400$ μT). Studies of the implementation at TRIUMF will also be reported.

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IDENTIFICATION OF THE 2^+_{ms} MIXED-SYMMETRY STATE IN ^{52}Ti USING ALPHA TRANSFER REACTION *

Fuad A. Ali★ †,
D. Muecher
University of Guelph

The residual nucleon-nucleon interaction is a central theme in nuclear structure physics. In spherical even-even nuclei the quadrupole interaction leads to so called proton-neutron mixed symmetry states, which are sensitive to the underlying subshell structure. We present new data using the MINIBALL germanium array on the ^{48}Ca + ^{4}He = ^{52}Ti nucleus. States in ^{52}Ti were populated via the alpha transfer reaction ^{48}Ca(^{12}C,^{8}Be)^{52}Ti using a ^{48}Ca beam from the Maier-Leibnitz-Laboratory in Munich. The relative population of the 2^+_{ms} mixed-symmetry state to the 2^+_1 state was measured and found to be surprisingly strong and characteristic for the mixed-symmetry state. We will present the status of the ongoing data analysis.

*Work supported by NSERC grant SAPIN-2016-00030
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QUARTIC GAUGE BOSON COUPLING RESULTS FROM THE LHC

Christopher Anelli★*
University of Victoria

We present recent measurements from the ATLAS and CMS experiments of triboson production and diboson production through vector boson scattering (VBS). These rare multiboson final states are just becoming accessible at the LHC and are a probe of the electroweak vector boson self-interactions. The non-Abelian structure of the Standard Model (SM) requires the presence of quartic gauge couplings the strengths of which are precisely predicted by the SM. Deviations of these coupling strengths are a clear signal of new physics and manifest as an excess of events at high partonic center of mass energies. Anomalous quartic gauge couplings are modeled using dimension-8 effective field theories and confidence limits on these theories are placed. Triboson and diboson VBS measurements are also a validation of the SM in a region where higher order electroweak and QCD corrections can be taken into account, and they are backgrounds to Higgs measurements and searches for beyond the SM physics. Current results are consistent with the SM predictions, and significant improvement in sensitivity is expected with the increased integrated luminosity of the 2016 data.

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ANALYSIS OF THE $\eta(548) \rightarrow \pi^+ \pi^- \pi^0$ AND $\eta'(958) \rightarrow \pi^+ \pi^- \eta$ CHANNELS USING A 8-9 GEV TAGGED PHOTON BEAM FOR THE GLUEX EXPERIMENT *

Tegan Beattie †,

Z. Papandreou
University of Regina

J. Stevens
College of William and Mary

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, is now entering the physics data taking phase. 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 η 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 η/η' samples and analyse their decays is of utmost importance to understand future work on more complicated decay structures. Preliminary analysis results from commissioning data for particular decay channels of the η and η' 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

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BEAST-II: MEASUREMENT OF MACHINE-INDUCED BACKGROUNDS DURING COMMISSIONING OF SuperKEKB

Alexandre Beaulieu*

on behalf of the BEAST-II group

University of Victoria

SuperKEKB is a new electron-positron accelerator designed and built for the Belle-II experiment. The aim is to provide a 40-fold increase of delivered luminosity compared to its predecessor, the KEKB machine. Such increase in luminosity however also means increased machine-induced backgrounds.

Right now, prediction of the impact of such backgrounds, both on overall Belle-II physics performance and on detector components lifetimes, is achieved solely using simulation. This may be problematic since some processes are notoriously difficult to calculate, and so far the accuracy of the simulated background levels has never been assessed experimentally in the context of SuperKEKB.

To address this issue, the BEAST-II experiment's goal is to measure the machine-induced backgrounds during SuperKEKB commissioning, and check how the various contributions scale with beam parameters.

The detector consists of eight independent sub-systems assembled for this dedicated study. Each system accomplishes a specific measurement in the experiment, such as the thermal neutron flux, the electromagnetic radiation dose, the x-ray dose and the injection background time-structure. All these measurements were carried out while changing beam parameters in a controlled manner in order to disentangle the different background sources.

The current report focuses on data recorded during the first phase of SuperKEKB commissioning, spanning from early February 2016 to the end of June 2016. The first comparisons of measured and simulation backgrounds are presented, together with first measurements of the injection background and an empirical description of the vacuum scrubbing process.

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DECAY SPECTROSCOPY OF NEUTRON-RICH Cd AROUND THE *N* = 82 SHELL CLOSURE*

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The neutron-rich region around A = 132 is of special interest for nuclear structure and astrophysics. From an astrophysics perspective, this region is connected to the second r-process abundance peak at A≈130 and the corresponding waiting-point nuclei around N = 82. Together, the shell structure and half-lives far off stability provide critical information on the position and the shape of the abundance peaks for the r-process. This can also be understood from nuclear structure studies, where the neighbours of the doubly-magic ^{132}Sn (Z = 50, N = 82) are an ideal test ground for shell model predictions. The beta-decay of the N = 82 isotope ^{130}Cd into ^{130}In was first studied a decade ago, but the information for states of the lighter indium isotopes (^{128,129}In) is still limited.

In the present experiment, detailed gamma-spectroscopy of the beta-decay of $^{128-132}$Cd was achieved with the newly commissioned GRIFFIN (Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei) germanium array, which is capable of measuring down to rates of 0.1 pps. The low-energy cadmium isotopes from the ISAC-I facility at TRIUMF were implanted into a movable tape at the center of the spectrometer, where the auxiliary beta-particle detector SCEPTAR performs beta-tagging. The high statistics beta-gamma(-gamma) coincidence data required to expand the beta-decay level scheme and investigate spin assignments were acquired. Previously published discrepancies in half-lives can be resolved with the timing information collected. The ongoing analysis of the ^{128}Cd dataset will be presented.

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A STUDY ON LOW SPIN STATES IN ^{154}Gd USING (p, p') REACTION*

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The investigation of N = 90 nuclei has been the subject of many experimental studies. These isotones, such as ^{154}Gd and ^{152}Sm, lie at the center of a region of rapid shape change between vibrational and rotational characteristics, and demonstrate striking similarities. The low lying spin states of the ^{154}Gd nucleus were investigated at the University of Jyväskylä accelerator laboratory in Finland, using the ^{154}Gd$(p, p'\gamma)$ reaction. A proton beam of 12 MeV was used to excite the ^{154}Gd target, with the gamma-rays from the reaction detected with the JUROGAM II array, while the LISA charged-particle spectrometer was used for detection of the inelastically scattered protons. This experiment marked one of the first uses of the LISA spectrometer at Jyväskylä, which enabled the efficient tagging of the proton-emitting reactions, thus helping to distinguish between the (p, p') and the much more copious (p, xn) channels. By analysing the peaks obtained from the gamma-gamma, and gamma-gamma-proton coincidence matrices, a decay scheme has been built using the RadWare software Escl8r. Experimental methods, new transitions, gamma branching ratios, and future steps will be discussed.

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INVESTIGATION OF EXCITED 0^+ STATES POPULATED VIA THE Er-162 TWO-NEUTRON TRANSFER REACTION

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Interpreting the nature of excited states in well-deformed nuclei has been an ongoing challenge in our understanding of nuclear structure. Some of the approaches that have been implemented to interpret the occurence of low-lying excited 0^+ states include vibrational excitations in β-phonons and γ-phonons, as well as pairing excitations. A further complication is the presence of shape coexistence which can increase the number of low-lying states, and if the shapes undergo mixing that spectroscopic signatures can become ambiguous. The $N = 90$ region is just such a case with a well known rapid change in the ground state shape from $N = 88$ to $N = 92$. However, one of the difficulties in resolving the nature of these states is that there is an absence of data, particularly for excited 0^+ states, in the rare earth region.

Two-neutron transfer reactions are ideal for probing $0^+ \rightarrow 0^+$ transitions in deformed nuclei. One of the intriguing features of the rare-earth region is the strongly-populated 0_2^+ states that emerge in both (p, t) and (t, p) two-neutron transfer reactions into $N = 90$ nuclei ^{154}Gd and ^{152}Sm [1]. Excited 0^+ states in ^{160}Er have been studied via the ^{162}Er (p, t) reaction at the Maier-Leibnitz Laboratory in Garching, Germany using 22 MeV and 24 MeV proton beams supplied by a Tandem Van de Graaff accelerator. Reaction products were momentum-analyzed with a Quadrupole-3-Dipole magnetic spectrograph.

The variance in the cross section of these low-lying excited 0^+ states, with the 0_2^+ state population around 18% of the ground state strength, suggests a special character for this state which is not consistent with a β-vibration. In fact, evidence points towards the nature of this state being more consistent with a shape co-existence picture. Final results of the relative population of the excited 0^+ states in ^{160}Er will be presented, and placed into context with similar experiments in the $N = 90$ region.

[1] W. D. Kulp *et al.*, Phys. Rev. C **71**, 041303(R) (2005).

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EXPERIMENTAL RESULTS OF β-DELAYED NEUTRON BRANCHING RATIOS FOR HEAVY SPECIES*

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A key to a better knowledge of the nuclear structure of neutron-rich isotopes above the neutron separation energy and to improve the input data for theoretical models that try to explain the astrophysical phenomena of the rapid neutron capture process (r-process), is the study of the iβ-delayed neutron emission probability.

A recent experiment performed at the RIB facility of GSI Darmstadt (Germany) has allowed us to extend the knowledge in heavier regions than previously measured, and to provide for the first time several one-neutron emission ratios beyond the magic number N=126 at A$<$200, specifically for isotopes of Hg and Tl. So far only isotopes up to A$\sim$150 and a single measurement for ^{210}Tl had been experimentally measured. In addition, another experiment at the IGISOL facility in Jyväskylä (Finland) has provided the first reliable information about a multiple neutron emitter above A=100, specifically the β2n emitter ^{136}Sb. In both measurements a 4pi neutron detector based on ^{3}He counters was used (BELEN).

In this contribution I will report information and the results of the aforementioned measurements and give a brief summary of the main near future goals in this field that will be carried out through the BRIKEN campaign at RIKEN (Japan). The BRIKEN project has already 4 experiments approved in several regions of the chart of nuclides involving many β1n, β2n and some β3n, that will be also presented in this contribution. This campaign will represent the first measurement for lots of them and the most exotic neutron emitters measured so far.

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EDM MONTE CARLO SIMULATIONS FOR THE UCN EXPERIMENT AT TRIUMF

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The value of the neutron electric dipole moment (nEDM), d_n, is an important parameter for many theories of particle physics such as the Standard Model and super symmetry (SUSY). The nEDM is also a source of CP symmetry violation which is a requirement by Sakharov's criteria to explain the asymmetry between the amount of matter and anti-matter in the Universe. The measurement of the nEDM requires the use of Ultracold Neutrons (UCN) which are storable low energy neutrons that can be easily handled in experiments. As part of an international collaboration, the UCN group at TRIUMF in Canada is undertaking an experiment to decrease the upper bound on the current nEDM measurement by at least one order of magnitude. Such a measurement could disprove particle physics theories which predict high nEDM values and helping humanity understand the processes that shaped the early universe.

PENTrack is a Monte Carlo simulation software capable of simulating proton, electron and neutron trajectories in arbitrary electric, magnetic fields and experimental geometry. In the past, PENTrack was used to facilitate the decision of the UCN guide layout by obtaining neutron transport efficiencies of several proposed layouts. In this work, we discuss progress in developing PENTrack into a fully capable nEDM simulator. The new features were validated by conducting several benchmark simulations studying the dependencies of the false EDM signal due to the geometrical phase effect (GPE) and comparing it to analytic expressions derived in [1]. A key decision for the UCN experiment will be the orientation of the EDM cells with respect to the stationary magnetic field (B_0). Results from a study which compared the false EDM signal arising in the case of both EDM cell orientations (horizontal and vertical) are presented and demonstrate PENTrack's broad range of capabilities to assess the systematic errors for the nEDM experiment.

[1] Pendelbury J M, Heil W, Sobolev Y, et al. Geometric phase-induced false electric dipole moment signals for particles in traps, Phys. Rev. A 70 (2004) 3.

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SINGLE PARTICLE STRUCTURE OF EXOTIC STRONTIUM ISOTOPES

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Nuclei near the so called magic numbers of protons and neutrons are observed to have a spherical shape in their low lying states. Nuclei between magic numbers, where the binding energy tends to be less, are often observed to show deformation in low lying states. These deformations are perceived to have either a prolate or oblate nature. States within a nucleus that have different shapes that are close in energy are colloquially referred to as shape coexisting. A dramatic occurrence of shape coexisting states is observed in nuclei in the vicinity of Z=40, N=60, which is the subject of substantial current experimental and theoretical effort.
An important aspect in this context is the evolution of single particle structure for $N < 60$ leading up to the shape transition region, which can be calculated with modern large scale shell model calculations using a ^{78}Ni core or Beyond Mean Field Models. One-neutron transfer reactions are a proven tool to study single-particle energies as well as occupation numbers. Here we report on the study of the single-particle structure in ^{95,96,97}Sr via (d,p) one-neutron transfer reactions in inverse kinematics. The experiments presented were performed in the ISAC facility using the TIGRESS gamma-ray spectrometer in conjunction with the SHARC charged-particle detector. Highly charged beams of ^{94,95,96}Sr, produced in the ISAC UCx target and charge-bred by an ECR source were accelerated to 5.5 MeV/u in the superconducting ISAC-II linac before delivery to the experimental station. Other than their clear scientific value, these measurements were the first high mass ($A > 30$) post-accelerated radioactive beam experiments performed at TRIUMF. A thorough analysis of single particle states will improve our understanding of the onset of these unique structures, encouraging the ongoing theoretical discussions.

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NEUTRON ACTIVATION ANALYSIS VIA NUCLEAR DECAY KINETICS USING GAMMA-RAY SPECTROSCOPY AT SFU

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Gamma-ray spectroscopy is a powerful tool used in a variety of fields including nuclear and analytical chemistry, environmental science, and health risk management. At SFU, the Germanium detector for Elemental Analysis and Radiation Studies (GEARS), a low-background shielded high-purity germanium gamma-ray detector, has been used recently in all of the above fields. The current project aims to expand upon the number of applications for which GEARS can be used while enhancing its current functionality. A recent addition to the SFU Nuclear Science laboratory is the Thermo Scientific P 385 neutron generator. This device provides a nominal yield of 3×10^8 neutrons/s providing the capacity for neutron activation analysis, opening a major avenue of research at SFU which was previously unavailable. The isotopes created via neutron activation have a wide range of half-lives. To measure and study isotopes with short half-lives above a second, a new analog data acquisition system has been installed on GEARS allowing accurate measurements of decay kinetics. This new functionality enables identification and quantification of the products of neutron activation. Results from the neutron activation analysis of pure metals will be presented.

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THE HUNT FOR THE Z′ BOSON IN ATLAS: A STATISTICAL PERSPECTIVE

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Despite its many successes, the Standard Model leaves physicists unsatisfied about several phenomena such as non-zero neutrino masses, the nature of dark matter, and the hierarchy of fundamental forces. A host of theories aim at a unified description of nature beyond the Standard Model but in doing so often require the existence of a new particle generically called the Z′ boson. If this exotic boson exists, it should produce a clear signal in the ATLAS detector, namely, a localized excess in the number of events with dilepton final states. This presentation will summarize the latest results garnered from the search for a Z′ boson with an emphasis on the statistical framework used to hunt for a signal. Intended for a new graduate student audience, the content will review key concepts of discovery statistics including signal significance, the look-elsewhere effect, data-driven methodology, and limit-setting.

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SEARCH FOR DARK MATTER WITH LEPTONICALLY-DECAYING Z BOSONS AND MISSING TRANSVERSE ENERGY IN THE ATLAS DETECTOR AT THE LHC

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A search is presented for pairs of dark matter particles recoiling against a leptonically-decaying Z boson in the ATLAS detector at the Large Hadron Collider. Events with large missing transverse momentum and two oppositely-charged electrons or muons consistent with the decay of a Z boson are analyzed. A set of dark matter models with different masses are compared to the Standard Model background prediction with this signature. These Monte Carlo simulations are compared with the 2015 + partial 2016 data set (13.3 fb^{-1} total) produced at a centre of mass energy of 13 TeV, and are used to search for an excess of events above the expected background.

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OBSERVATION OF ATOMIC TRANSITION IN ANTIHYDROGEN

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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 place the ratio of the two near 10^{-4}. The ALPHA (Antihydrogen Laser PHysics Apparatus) collaboration at CERN studies the atomic structure of antihydrogen through photon interactions and has recently succeeded in observing 1S-2S transitions in trapped antihydrogen. This was in part due to a large increase in the production in antihydrogen and a highly trained machine learning algorithm.

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 be identical; any deviation between the two spectra would indicate a CPT violation. The 1S-2S transition in hydrogen has been determined to a very high accuracy, a few parts in 10^{15}, making it an ideal measurement to attempt to reproduce with antihydrogen.

I present a summary of: the ALPHA experiment and changes made in the 2016 run leading to the increased antihydrogen production, an overview of the detector hardware and software including the machine learning classifier, and the 1S-2S transition result.

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INTEGRATION OF A MULTI REFLECTION TIME OF FLIGHT ISOBAR SEPARATOR INTO THE TITAN EXPERIMENT AT TRIUMF

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The TITAN experiment at TRIUMF specializes in high precision penning trap mass spectrometry; to expand the range of nuclides available for study a new Multi-Reflection Time of Flight isobar separator (MR-ToF) has been commissioned and is soon to be installed into the TITAN system. This MR-ToF has demonstrated the isobar separation with 40Ar from 40K as well as perform mass measurements with a resolving power up to 190,000. To prepare for the integration of this MR-ToF, simulations of the TITAN beamline are being performed to characterize the beam entering and leaving the MR-ToF, the impact on the existing beamline of integrating the MR-ToF, and determine optimal optics parameters to maximize transport efficiency. Another part of this integration process has been to perform emittance measurements at the location of the MR-ToF's input, the implications of this will also be discussed.

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PRELIMINARY SURVEY OF THE PHOTOPRODUCTION OF $\pi^+ + \pi^- + 4\gamma$ FINAL STATE IN GLUEX EXPERIMENT*

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The GlueX experiment aims to study the spectrum of light mesons with special focus on exotic hybrid meson states. The hermetic design of GlueX detector makes it capable of reconstructing all particles in the final state. The exclusive reconstruction becomes a powerful tool for particle identification via kinematic fitting. The focus in this talk is a preliminary survey of the final state of $\pi^+ + \pi^- + 4\gamma$ from commissioning data, which offers access to scalar (f_0), pseudoscalar (η and η'), vector (ω and ϕ) and pseudovector (b_1) states. The short-term goals include extraction of the yield and Sigma asymmetry versus Mandelstam variable (t) for the b_1 meson, which will prime the analysis for the exotic b_2 meson in the future. Eventually, reconstructing all isospin-related final states available provides an isospin consistency check of our PWA and of our understanding of the detector acceptance.

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DESIGN AND SIMULATION OF BEAM-BACKGROUND MONITORS IN THE VICINITY OF THE ELECTROMAGNETIC CALORIMETER FOR THE BELLE II EXPERIMENT

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The Belle II experiment at the SuperKEKB accelerator is scheduled to start data taking by the end of 2018. The design instantaneous luminosity of SuperKEKB is $8{\cdot}10^{35}$ cm^{-2}s^{-1}, forty times higher than that at KEKB. To adapt to the new high-luminosity environment of SuperKEKB, the Belle detector was upgraded to the Belle II detector. The goal of the Belle II experiment is to search for evidence of new physics beyond the Standard Model. It will perform high-precision measurements that include rare and forbidden decays in the Standard Model, and charge-parity violation in heavy quarks and leptons.

Due to the 40-fold increase in luminosity, the beam backgrounds are expected to increase by forty times compared to those encountered by the Belle experiment. The Belle II collaboration has implemented various countermeasures to combat the increase in beam background and enable a safe operation of the Belle II detector. Prior to the run of the Belle II detector, two commissioning phases are being performed to examine the background environment that will be present. Touschek, beam-gas and beam-beam interactions are the most important sources of beam background.

A beam background monitoring system was needed for measuring the background levels in the vicinity of the electromagnetic calorimeter endcaps. The system will need to be sensitive to both the fast changing injection background and the more slowly changing DC-like background during regular collider operation. The existing background simulation for the calorimeter was analyzed in preparation for the beam background monitors' design. Based upon the simulation results, the optimal position and technologies for the monitors were selected. The detectors will consist of a scintillating crystal read out by a photomultiplier tube (PMT). Crystal with short decay time and high light yield was chosen. The selected PMT has a spectral response range that well matches the wavelength of scintillation of the crystal, and can operate in the high magnetic field environment. The final design of the background monitors was included in the background simulation, which was used to estimate the energy deposition they will be receiving.

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CALCULATION OF ISOTOPE RATES FOR RADIOACTIVE BEAM PRODUCTION

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Radioactive ion beam (RIB) facilities around the world such as TRIUMF† work to develop target materials to generate new and rare isotope beams to be used in nuclear medicine, astrophysics and fundamental physics studies. At Simon Fraser University, we have built the first generation of a GEANT4‡ computer simulation of the RIB targets at TRIUMF, in order to augment the existing working knowledge and to support new target developments. This simulation will also be used to gauge the efficacy of using new target materials and varying driver beam intensities to generate another range of isotopes than those currently in use. The simulation consists of a target of 5 depleted uranium disks, which are bombarded by a 480 MeV proton beam. The simulation records the isotopes generated and other related properties. These results are then compared to data gathered at the TRIUMF yield station§, a nuclear spectroscopy experiment dedicated to RIB characterization. The simulation prototype is presented, along with benchmarking and comparison to the yield station data, experimentally measured cross sections and other nuclear transport codes. The results from the simulation are also used to gain insight into product release times, to motivate new target development and other isotope studies.

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‡ Geant4 - A Simulation Toolkit, S. Agostinelli et al., Nuclear Instruments and Methods A 506 (2003) 250-303

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THE ^{16}N SOURCE FOR THE CALIBRATION OF THE SNO+ EXPERIMENT

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SNO+ is a multi-purpose neutrino experiment aiming to explore the unknown properties of neutrinos. The main physics goal of SNO+ is to explore whether the neutrinos are Majorana-type particles by searching for neutrinoless double-beta decay of ^{130}Te. The whole experiment can be divided into three stages: first the water phase, then the scintillator phase and finally the tellurium-loaded scintillator phase searching for the neutrinoless double-beta decay.

The SNO+ detector is currently filled with water and has been turned on recently for the water phase operation. In order to calibrate the detector, an ^{16}N calibration source inherited from the SNO experiment will be deployed. This presentation focuses on studies of the ^{16}N source to estimate the reconstruction resolution of the event position and direction and the energy response of the detector.

We apply the current SNO+ reconstruction methods to old SNO ^{16}N calibration data and the corresponding Monte Carlo simulations to check the position and direction resolutions of the SNO+ algorithms. The results are comparable to those from SNO. A SNO+ energy response processor is also tested by using the old SNO data and the simulations.

By comparing the simulation results with the SNO data, we can estimate the systematic uncertainties given by the current SNO+ algorithms.

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PROGRESS TOWARDS MEASURING PARITY NON CONSERVATION IN FRANCIUM *

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Measurements of parity non-consevation (PNC) effects in atomic systems test the Standard Model at low energies. We are developing an experiment to probe PNC effects in neutral francium atoms. Francium ions produced at the ISAC radioactive beam facility at TRIUMF are neutralized using a zirconium foil located at the end of the beamline. The foil is momentarily heated, and the released atoms are first trapped in a capture magneto optical trap (MOT). Then, the atoms are transferred to another MOT in a science chamber. We are preparing for two PNC experiments in this chamber: in one experiment the 7S to 8S atomic transition will be probed using a laser beam, and in another experiment transition between the 7S hyperfine levels will be probed using a microwave beam. Recently, we have observed for the first time the 7S to 8S atomic transition in several francium isotopes using two photon spectroscopy. The data allows us to investigate the isotope shift of the 8S state, which is much more sensitive to the charge density of the nucleus than the P states. In this talk, I will report on our recent developments towards the measurements.

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HUNTING FOR "BUMPS" IN THE DILEPTON INVARIANT MASS SPECTRUM USING BUMPHUNTER AT THE ATLAS DETECTOR*

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Due to the limitations of the Standard Model of particle physics several extensions like Grand Unification Theories, supersymmetric and extra dimensional models have been proposed. A number of such models with extended gauge groups often feature additional $U(1)$ symmetries with corresponding heavy spin 1 Z' bosons. The decay of these heavy particles would manifest itself as a narrow resonance in the dilepton mass spectrum. Other models like compositeness models, motivated by the repeated pattern of quark and lepton generations, predict new interactions involving their constituents. These interactions may be represented as a contact interaction between initial-state quarks and final-state leptons and could be seen as wide excesses in the mass spectrum.

The ATLAS collaboration searches for proton-proton collisions where two high energy, same-flavour leptons are produced and analyses their invariant mass spectrum. Due to the large number of possible models that could give such an excess, BUMPHUNTER was developed as a model independent statistic test to search for deviations in the data from the expected background. The BUMPHUNTER tool has been used to search for narrow resonances as well as broad excesses in the dilepton mass spectrum; this now includes full treatment of the systematic uncertainties. This presentation will describe the analysis of the dilepton mass spectrum and details of the search method using BUMPHUNTER.

*Work supported by ATLAS Canada

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TOWARDS $N = 82$ r-PROCESS WAITING POINT: PRECISION ATOMIC MASS MEASUREMENTS OF $^{125-127}$Cd

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State-of-the-art r-process calculations can provide great insight into the inner workings of the nucleosynthesis of species heavier than Fe. They require, however, input of the nuclear properties of the participating nuclei, most of which lie very far from the line of stability and are generally hard to study experimentally. For instance, r-process relative elemental abundances vary exponentially with one neutron separation energies, and thus atomic masses need to be known with high precision (< 10 keV/c^2).

Of particular interest are regions around neutron shell closures. The sharp drop in neutron separation energy leads to a high density of waiting points, which are believed to generate the abundance peaks around A = 130 and 195, and bring the r-process path closer to the beta-stability line, making these regions potentially easier to study with current experimental techniques.

The TITAN system at TRIUMF is an ideal setup to explore such cases. It employs fast Penning Trap Mass Spectrometry techniques suitable to study short-lived radioactive nuclides produced and delivered by the ISAC facility, with the possibility of boosting precision and resolving power by charge state breeding.

This work focuses on masses of neutron-rich Cd isotopes close to the $N = 82$ shell closure, recently measured at TITAN with highly-charged ion beams. We report the precision mass measurements of $^{125-127}$Cd and of long lived isomeric states in ^{125}Cd and ^{127}Cd, whose excitation energies are hard to access through typical spectroscopic techniques.

Of particular note is the realization that previous mass measurements of the ^{127}Cd isomeric state misidentified it as the ground state. We explore the implications of the new data on r-process nucleosynthesis and nuclear structure, and discuss the state of knowledge of this region based on nuclear shell-model calculations. We also cover our plans to approach the neutron-magic ^{130}Cd and beyond.

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THE ^{22}Ne(p,γ)^{23}Na REACTION AND THE ORIGIN OF ^{23}Na*

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The astrophysical ^{22}Ne(p,γ)^{23}Na reaction largely impacts the abundance of ^{23}Na in various stellar environments, among them low and high mass AGB stars, massive stars and novae. For the latter, the uncertainty in the ^{22}Ne(p,γ)^{23}Na reaction rate further affects the abundances of elements between ^{20}Ne and ^{27}Al. Constraining the relevant reaction rates experimentally will reduce the uncertainties in the stellar models used to predict stellar yields, which in turn can be compared to observational data. The thermonuclear reaction rate for the ^{22}Ne(p,γ)^{23}Na proton capture reaction is dominated by a number of narrow resonances within the Gamow window. Most recently, a study with the objective to measure the strengths of the most relevant resonances for the ^{22}Ne(p,γ)^{23}Na reaction (within an energy range of $E_{c.m.}$=178 keV to $E_{c.m.}$=632 keV) in inverse kinematics was carried out using the DRAGON (Detector of Recoils and Gammas Of Nuclear Reactions) recoil separator at TRIUMF. In this presentation the astrophysical motivation behind this measurement as well as preliminary results will be outlined.

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NEUTRAL HADRON PARTICLE IDENTIFICATION USING CsI(Tl) SCINTILLATION PULSE SHAPE ANALYSIS

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The Belle II detector will be operating at the SuperKEKB e^+e^- collider and plans to begin collecting collision data in late 2017 with the goals of performing precision measurements in the flavour sector of the Standard Model and to search for new physical processes. This analysis demonstrates the potential to use pulse shape analysis of the Belle II calorimeter CsI(Tl) scintillation crystals to improve the identification of neutral hadrons such as kaons and neutrons at Belle II. By analysing data collected from $e^{\pm}, \mu^{\pm}$ and $\pi^{\pm}$ particle beams at TRIUMF with momentums of 100, 120, 140 and 300 MeV/c, we demonstrate that CsI(Tl) pulse shape analysis can be used to identify events containing electromagnetic verses hadronic material interactions. GEANT4 simulations incorporating particle dependent scintillation response will also be presented and used to validate electromagnetic and hadronic simulation physics independently. In addition, the scintillation response of high energy neutrons generated by the TRIUMF cyclotron will be shown for CsI(Tl) crystals using PMT and PIN diode readout.

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ANGULAR CORRELATION MEASUREMENTS WITH GRIFFIN*

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The assignment of spins and parities to excited nuclear states plays an important role in determining nuclear structure. In a $\gamma - \gamma$ cascade from an excited nuclear state an anisotropy is found in the spatial distribution of the second γ-ray, γ_2, with respect to the first γ-ray, γ_1. By defining the direction of γ_1 to be the z-axis (setting θ = 0), the intermediate level in general will have an uneven distribution of m-states. The anisotropy depends on the sequence of spin values for the nuclear states involved, the multipolarities, and mixing ratios of the emitted γ-rays.

These γ-ray angular correlations are used for the assignment of spins and parities to the nuclear states, and thus provide a powerful means to elucidate the structure of nuclei away from stability. The goal of this work was to explore the sensitivity of the new Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei (GRIFFIN) 16 clover-detector γ-ray spectrometer, at TRIUMF-ISAC, to such γ - γ angular correlations. The methodology was established using the well-known $4^+ \rightarrow 2^+ \rightarrow 0^+$ γ - γ cascade from ^{60}Co decay, and optimized through both experimental measurements and Geant4 simulations. Simulations allow the creation of angular correlation templates using the GRIFFIN geometry, to provide comparisons with experimental data sets.

A first in-beam test of the γ - γ angular correlation measurements with GRIFFIN was performed with a radioactive beam of ^{66}Ga ($T_{1/2}$ = 9.49(3) hours) from the ISAC facility at TRIUMF. In the daughter nucleus, mixing ratios were measured for the $2^+ \rightarrow 2^+ \rightarrow 0^+$ 833-1039 keV and $1^+ \rightarrow 2^+ \rightarrow 0^+$ 2752-1039 keV cascades. The results are in excellent agreement and the mixing ratio for the 833-1039 keV cascade is more precise. Also, the sensitivity to the 1333-1039 keV cascade, which is a pronounced $0^+ \rightarrow 2^+ \rightarrow 0^+$ angular correlation, was measured.

The ability to assign spins for a $0^+ \rightarrow 2^+ \rightarrow 0^+$ cascade is important for the case of ^{62}Ga superallowed Fermi β decay. Another measurement was taken in an attempt to clarify the two conflicting measurements for the spin assignment of the 2.34 MeV excited state in the daughter nucleus. This spin assignment has implications that affect the isospin-symmetry-breaking correction, δ_{C1}, applied to $\mathcal{F}$t values. Results from the decay of ^{60}Co, ^{66}Ga as well as ^{62}Ga will be presented.

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A NEW DETERMINATION OF V_{us}*

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Recent evidence for the breaking of lepton flavor universality in semi-leptonic B decays, which suggests the possibility of BSM physics coupling differentially to the third generation, makes a determination of V_{us} from analyses of the hadronic decays of the third generation lepton (the τ), of heightened interest. I describe here a new approach to determining V_{us} from τ decay data. The approach employs a dispersive analysis of the inclusive strange hadronic τ decay distribution employing weights constructed in such a way as to allow the theoretical side of the dispersion relation to be evaluated using high-precision lattice results for the relevant combination of scalar polarizations of the vector and axial-vector two-point functions. It is shown that the method (i) is superior to the conventional alternate τ-decay-based determination involving flavor-breaking finite energy sum rule analyses of inclusive strange *and* non-strange decay data, and (ii) promises to be competitive with determinations from $K_{\ell 3}$ and $\Gamma[K_{\mu 2}]/\Gamma[\pi_{\mu 2}]$. Preliminary results will be presented, which show good agreement with determinations from these other approaches and compatibility with the expectations of 3-family unitarity.

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GEOCHEMICAL MEASUREMENT OF THE HALF-LIFE OF THE DOUBLE-BETA DECAY OF ^{96}Zr

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Double-beta ($\beta\beta$) decay measurements are a class of nuclear studies with the objective of detecting the neutrinoless (0ν) decay variants. ^{96}Zr is of particular interest as a $\beta\beta$ decay candidate as it has one of the shortest $\beta\beta$ decay half-lives and largest Q-values. A geochemical measurement of its $\beta\beta$ decay half-life was previously performed by measuring an isotopic anomaly of the ^{96}Mo daughter in ancient zircons. This measurement yielded a value of 0.94(32)x10^{19} a [1]. More recently, the NEMO collaboration measured the half-life by a direct count rate measurement to be 2.4(3)x10^{19} a [2], twice as long as the geochemical measurement.

We aim to study this discrepancy through a series of experiments combining nuclear physics and geochemical techniques. We are measuring the amount of daughter product of the $\beta\beta$ decay of ^{96}Zr$\rightarrow^{96}$Mo in ancient zircons with distinct ages from 500 Ma to 2.5 Ga. The zirconium silicates, which have remained a closed system over their lifetimes, are especially suitable for this investigation due to their high zirconium content and the low natural molybdenum abundance. This makes it possible to detect the small amount of accumulated decay product.

In order to measure the ^{96}Mo excess, the molybdenum must be fully separated from zirconium as the stable isotope mass spectrometer cannot resolve ^{96}Mo from ^{96}Zr. I will present advancements in the chemical purification of molybdenum ([Mo]$\sim$1 ppm) from the zirconium silicate matrix using Eichrom TEVA ion exchange resin. Further, I will present significant improvements to how the isotopic composition of Mo is measured using the Thermo Scientific Neptune inductively coupled plasma mass spectrometer (MC-ICP-MS). These advancements have enabled us to produce the first measurements of Mo isotopes from 1 Ga zircons using MC-ICP-MS.

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PHOTO-ELECTRON PULSE FINDING AND PILE-UP DETECTION FOR THE DEAP EXPERIMENT

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Dark Matter continues to be one of the largest mysteries that affects not only our understanding of large scale formation in our universe but also holds the key to unlocking physics beyond the standard model of particle physics. DEAP-3600, comprised of a 1 tonne fiducial mass of ultra-pure liquid argon, is designed to achieve world-leading sensitivity for spin-independent dark matter interactions. DEAP-3600 measures the time distribution of scintillation light from the de-excitation of argon dimers to select events. This measurement allows background events from Ar39 decays to be rejected at a high level. The construction and commissioning of the detector have been completed and physics data has started to be collected.
Several aspects of the data analysis will be discussed. First the precision measurement of singlet photo-electron pulses in the waveforms of the photo-multilier tubes (PMTs) will be shown. Furthermore, the ability for DEAP to identity pile-up events will be discussed.

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DETECTION OF ANTINEUTRINOS USING THE SNO+ DETECTOR

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The SNO+ (Sudbury Neutrino Observatory) detector, currently being commissioned, consists of a 12 metre diameter acrylic sphere filled with 780 tonnes of liquid scintillator. Its primary goal is to look for a neutrinoless double beta decay signal in the search of a Majorana neutrino. This large-scale liquid scintillator will, however, also be used for a number of other measurements — one such measurement includes the detection of antineutrinos.

Antineutrinos, produced in large quantities from nearby nuclear reactors, will interact in the detector through the inverse beta decay (IBD) reaction. Along the way to the detector, some of these antineutrinos will oscillate, therefore escaping detection. Due to its geographical proximity to these reactors, SNO+ is very well suited to measure the parameters that govern this neutrino oscillation.

We have used Monte Carlo simulations to show what the IBD signal from antineutrinos will look like in the SNO+ detector. We have also developed techniques that will distinguish this signal from naturally occurring radioactive backgrounds. The next step is to implement this antineutrino search while the detector is filled with water (an intermediate phase before the scintillator is added).

By performing the search in the water phase of the experiment, we will further develop the efficacy of the tools necessary to sift through the detector data for this rare signal. This also enables us to identify/evaluate possible backgrounds that could mask the IBD interactions. Following this, we will be well positioned to measure antineutrino signals once the experiment is fully commissioned.

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A LIKELIHOOD RATIO ALGORITHM TO REMOVE LOCALIZED ALPHA PARTICLE BACKGROUNDS IN THE DEAP-3600 DETECTOR

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DEAP-3600 is a single phase dark matter experiment using a tonne-scale mass of liquid argon as a target to observe interactions with Weakly Interacting Massive Particles (WIMPs).
Alpha particle decays from radioactive nuclei on the surface of detector materials are a background concern for the experiment. Specifically, alpha particle decays occurring in the neck region of the detector produce signals with characteristics similar to what is expected for WIMP interactions.
To estimate the potential background from alpha particle decays in the detector's neck, projected material radioactivity levels have been incorporated into Monte Carlo simulations. I will present the results of these simulations and a likelihood ratio algorithm designed to discriminate between WIMP signals and alpha particle decays occurring in the detector neck.

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A SILICON TRACKER FOR ISAC-II AND THE FUTURE ARIEL FACILITY*

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We plan a major new development of an optimized silicon tracker detector to study nuclear reactions of highly exotic, heavy ions on light gas targets (mostly ^1H, ^{2}D and ^{3,4}He) near atmospheric pressure using the TIGRESS array at ISAC-II, TRIUMF. There are a variety of advantages of using gas targets and a tracking device in comparison to setups using solid targets. Firstly, straggling of the protons is small, allowing unprecedented Q-value resolutions thanks to the sub-millimetre pitch size of the silicon detectors. At the same time, the effective target density can be more than one order of magnitude larger compared to solid targets. Also, the important scattering angles around 90 degrees in the lab are fully covered. In addition, pure gases can be used, strongly reducing background. An additional advantage is that the energy of the beam can be reconstructed so that excitation functions are measured simultaneously.
To achieve the desired tracking precision of light particles in a wide dynamic range below 1 MeV and good total energy measurement as well as particle discrimination, a silicon array is the chosen solution. Our design contains a first layer of ultra-thin single-sided silicon strip detectors, which are now available at 15μm. Combined with a second layer of double-sided silicon strip detectors (140μm), sufficient tracking is achieved whenever a signal is detected above threshold in the second layer. A third layer of thick silicon detectors allows the total energy measurement for the highest proton energies. ASIC chips will be used for preamplification and multiplexing inside the chamber. This results in low detector noise, important for studies at low reaction Q-values far outside stability. ASICs are also necessary to achieve a most compact design, maximizing the TIGRESS efficiency, and are cost efficient in view of the large number of channels (6000) of this device.
We will present the perspectives of nuclear structure and nuclear astrophysics studies towards CANREB and ARIEL beams at TRIUMF using the silicon tracker and will show the status of our detailed Geant4 simulations and design studies.

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PROPOSED CMOS-BASED SENSORS FOR THE ATLAS DETECTOR: CHESS-2*

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During the long shutdown between 2024 and 2026 the ATLAS detector at the LHC will undergo a full replacement of its tracking detectors including installation of a fully silicon-based inner tracker (ITk). Planar silicon sensors are the leading option for ITk; they are a mature technology that provides higher-resolution tracking, and are designed to operate in high-radiation environments.

Although the planar silicon sensors in the ITk would lead to excellent performance, an alternative technology that makes use of CMOS detectors is being evaluated for potential use in the inner tracker by the "CMOS HV/HR Evaluation for Strip Sensors" (CHESS) program. CMOS sensors, which contain both the detecting array and the readout electronics in a single unit, could drastically decrease cost, reduce the material budget, improve spatial resolution, and simplify assembly. The program is currently in its second phase (CHESS-2) with the primary focus being the evaluation of the operation of CMOS strips in arrays with digital outputs.

A CHESS-2 prototype sensor has been built by the ATLAS collaboration and a full hardware/software test suite is being developed for proof-of-concept testing. The UBC group has developed a readout firmware model for the front-end ASIC and will be conducting preliminary tests on the full prototypes. This presentation will discuss the advantages of CMOS detectors over the current technology and the current progress in the development and testing of the prototype.

*Work supported by ATLAS Canada

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INVESTIGATIONS OF CALORIMETER CLUSTERING IN ATLAS USING MACHINE LEARNING

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In order to improve sensitivity to new physics at the LHC, luminosity increases are planned for 2018 and beyond. With this greater luminosity comes an increase in the number of simultaneous proton-proton collisions per bunch crossing (pile-up). This extra pile-up has adverse effects on algorithms for clustering the ATLAS detectors calorimeter cells. These adverse effects stem from overlapping energy deposits originating from distinct particles and could lead to difficulties in accurately reconstructing events. Machine learning algorithms provide a new tool that may improve clustering performance. Recent developments in computer science have given rise to a new set of machine learning algorithms that, in many circumstances, out-perform more conventional algorithms. One of these algorithms, convolutional neural networks has been shown to have impressive performance when identifying objects in 2d or 3d arrays. This presentation will outline some basics of convolutional neural nets as well as some of the problems that arise when applying them to the clustering of ATLAS calorimeter cells. Tentative solutions to these problems and current performance of the algorithm will be discussed.

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GROUND STATE SPIN OF ^{101}Sn AND THE ROLE OF THE TENSOR FORCE IN EXOTIC NUCLEI*

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The ground state spin of ^{101}Sn has been a controversial topic due to the expected degeneracy between the neutron $d_{5/2}$ and the $g_{7/2}$ orbitals above the doubly-magic ^{100}Sn core. Various experimental approaches have been taken: superallowed α decay of ^{105}Te into ^{101}Sn [1-3], β-delayed proton emission and β^+ decay of ^{101}Sn [4-5]. The conclusions have been mixed or ambiguous.

^{101}Sn and other $N \sim Z \sim 50$ isotopes including the doubly-magic ^{100}Sn have been produced at RIKEN, via fragmentation of an intense ^{124}Xe beam on a thin ^{9}Be target. The radioactive isotopes were implanted on WAS3ABi, a set of position-sensitive silicon detectors for β^+ particles and protons emitted from decay events. High-purity germanium detectors surrounded WAS3ABi and performed measurements on γ rays emitted from the excited states of nuclei.

The γ rays observed after the β^+ decay of ^{101}Sn into ^{101}In are compared to the literature and shell model predictions of ^{101}In's level scheme. An excess intensity of the 511-keV e^+/e^- annihilation γ ray suggests a direct β-decay branch to the $(9/2^+)$ ground state of ^{101}In, which is feasible only if the ground state of ^{101}Sn is $(7/2^+)$. This result will be discussed in the context of ground-state spin systematics of odd-A proton-rich Sn isotopes and the role of the two-body tensor force [6] which has predicted the $(7/2^+)$ ground-state spin of ^{101}Sn.

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SPIN POLARIZABILITY OF A PROTON VIA MEASUREMENT OF NUCLEAR STRUCTURE OBSERVABLE WITH POLARIZED TARGET AND POLARIZED BEAM AT MAMI*

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The nucleon polarizabilities provide a measure of the global resistance of the nucleon's internal degrees of freedom against displacement in an external electric or magnetic field which makes them an excellent tool to study the structure of the nucleon. While the spin independent electric α_{E1} and magnetic β_{M1} polarizabilities of the nucleon have been measured, little effort has been made to extract the spin dependent polarizabilities. These four spin dependent polarizabilities, $\gamma_{E1E1}, \gamma_{M1M1}, \gamma_{M1E2}, \gamma_{E1M2}$ describe the spin response of a proton to an electric and magnetic dipole and quadrupole interactions. Several beam and beam-target asymmetry measurement experiments were approved for the extraction of these spin polarizabilities of the proton using real Compton scattering off the proton at the MAMI tagged photon facility in Mainz, Germany. The $\sum_{2z}$ beam -target asymmetry experiment is the final experiment in that series which is measured via a circularly polarized photon beam on a longitudinally polarized butanol target in the resonance region ($E_\gamma = 250 - 310$ MeV). Our major plan focuses on the precise measurement of $\sum_{2z}$ asymmetry at different energies and angles. Together with constraints from the spin independent polarizabilities α_{E1} and β_{M1}, the forward spin polarizability (γ_0), and QCD based models, should allow us to extract all four spin polarizabilities independently with small statistical, systematic and model-dependent uncertainties from the experimental data. This presentation will be focused on the preliminary results of these four spin polarizabilities via experimental measurement of $\sum_{2z}$ at different energies and angles.

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SPECTROMETER AND DETECTOR SIMULATIONS FOR THE MOLLER EXPERIMENT*

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The MOLLER experiment proposes to measure the parity-violating asymmetry $A_{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$ in electron-electron (Møller) scattering where σ_+ and σ_- are the cross-sections for scattered electrons with positive and negative helicity respectively. The yields in each helicity state from a longitudinally polarized beam of electrons being incident on a liquid hydrogen target are measured by an array of integrating quartz detectors 28 m downstream from the target position. A spectrometer consisting of two resistive toroidal magnets and a system of collimators provides kinematic separation and shielding from backgrounds. To make highly precise measurements of the asymmetry, the spectrometer and the detector systems need to be optimized with regards to sensitivity to coil offsets and background contributions. This presentation discusses Geant 4 simulations performed for this purpose.

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COULOMB ARTIFACTS AND BOTTOMONIUM HYPERFINE SPLITTING IN LATTICE NRQCD

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We discuss the role of Coulomb binding effects in the analysis of the heavy quarkonium spectrum within the effective theory of lattice non-relativistic QCD (NRQCD). We find that a naive perturbative matching onto continuum QCD generates spurious linear lattice artifacts, which result in a large systematic error in the lattice predictions for the heavy quarkonium spectrum. This effect is responsible, in particular, for the discrepancy between recent semi-analytic and lattice determinations of the bottomonium hyperfine splitting in the radiatively improved lattice NRQCD. We show that the revised matching procedure, which now provides full control over discretization errors, gives a hyperfine splitting of 52.9 ± 5.5 MeV, which reconciles the lattice and semi-analytic results as well as the most accurate experimental measurement, given by the Belle collaboration. Further applications of the revised matching procedure to the spin-independent sector of the heavy quarkonium spectrum will also be discussed.

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SIMULATION OF OPTICAL PUMPING IN TRIUMF'S COLLINEAR LASER SPECTROSCOPY EXPERIMENT

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The Collinear Laser Spectroscopy experiment at TRIUMF investigates the nuclear structure of rare isotopes through the excitation of atomic transitions with a laser. Provided they are resolvable, the relative positions (in frequency) of these transitions allows for the measurement of hyperfine splitting coefficients, while the position of a central transition can describe the isotope shift with respect to other isotopes.

A key assumption in these experiments is the complete knowledge of the state of the electron as it enters the interaction region. For a ground state with angular momentum J, projection J_z and a nucleus with spin I, the likelihood of finding an electron in a particular J_z is directly proportional to $2F + 1$ ($F = J_z + I$). It is assumed that this is the only factor in the distribution of the electrons as the atoms enter the interaction region. This would hold if the atoms only interacted with the laser as they entered the interaction region. However, at TRIUMF this is not the case and the effects of optical pumping, through which certain ground states are selected over others as the atoms interact with the laser, must be accounted for.

This work concerns itself with a full Monte-Carlo type simulation of spectra produced by the experiment present at TRIUMF. Two principal effects of optical pumping are examined. The first is the reduction in the amount of excitable atoms through the pumping of electrons to another accessible and stable ground state that is off resonance. The second effect is to alter the distribution of the ground states of the atoms. Due to selection rules, certain ground states are more frequently populated by de-exciting electrons. This in turn can change the relative intensities of the transitions, leading to a change in the measured hyperfine splitting coefficients.

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ELECTRON DETECTION FOR THE JEFFERSON LAB HALL A COMPTON POLARIMETER

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In experiments where spin-dependent parity violation is observed and measured such as the lead(Pb) Radius EXperiment (PREX) at Thomas Jefferson National Accelerator Facility, otherwise known as Jefferson Lab or JLab, knowing the overall polarization of the particle beam is key to understanding the scattering processes in these experiments. In JLab Experimental Hall A one of the polarimetry techniques used to determine the polarization of the electron beam entering the experimental hall is Compton polarimetry. In this talk, tests of the electron detector for the Compton polarimeter, a silicon strip detector, is discussed along with tests of the QWEAK amplifer-discriminator board.

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THE APPLICATION OF THE VARIATIONAL PRINCIPLE TO THE CALCULATION OF A TETRAQUARK BOUND STATE

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The tetraquark, a bound state of two quarks and two antiquarks, has recently become a topic of interest in particle physics, with projects such as the LHCb identifying candidates for this theoretical exotic meson. As it is a four-body problem, the ground state of the tetraquark has no analytical solution, and therefore approximation methods must be employed in order to capture the correlation between all particles. The discussed program seeks to improve upon previous attempts to calculate the ground state of one such system, applying the variational principle to converge on the wavefunction of the $bb\bar{b}\bar{b}$ bound state. Analysis of this wavefunction may aid in the discovery of a four-quark meson.

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SIMULATING THE DESCANT NEUTRON DETECTION ARRAY WITH THE GEANT4 TOOLKIT*

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The DEuterated SCintillator Array for Neutron Tagging (DESCANT) is a newly developed high-efficiency neutron detection array composed of 70 hexagonal deuterated scintillators. Due to the anisotropic nature of elastic neutron-deuteron (n,d) scattering, the pulse-height spectra of a deuterated scintillator contains a forward-peaked structure that can be used to determine the energy of the incident neutron without using traditional time-of-flight methods. Simulations of the array are crucial in order to interpret the DESCANT pulse heights, determine the efficiencies of the array, and examine its capabilities for conducting various nuclear decay experiments. To acheive this, we plan: (i) a verification of the low-energy hadronic physics packages in Geant4, (ii) a comparison of simulated spectra with data from a simple cylindrical "test can" detector geometry, (iii) expanding the simulated light response to a prototype DESCANT detector, and (iv) simulating the entire DESCANT array.

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DARK MATTER DIRECT DETECTION WITH NEWS-G: ANALYSIS AND RESULTS

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More than eighty years after its existence was originally postulated, the search for Dark Matter is still ongoing. NEWS-G is a direct detection experiment that aims to detect low mass WIMPs with a metallic spherical detector with a high voltage electrode in its centre, with gas as its target mass.

A particle interacting with the gas inside the detector will produce an ionization, and the resulting electrons will drift towards the central electrode, where the high field will produce an avalanche, effectively multiplying the collected charge. As such, some of the main advantages of this kind of detector are its sensitivity to energy depositions as low as 100 eV or less, all the way down to single electron ionizations, and background rejection based on pulse shape discrimination. The most recent exclusion limits obtained from SEDINE, the 60 cm detector in the Laboratoire Souterrain de Modane, show very competitive results for WIMP masses in the 0.7 to 1.5 GeV range. These should improve even further with the new 140 cm detector with optimized shielding that will be installed at SNOLab in 2017.

This talk will cover the principle of operation of the NEWS-G detectors, and then focus on the extraction of our exclusion limits from the data taken with SEDINE with Neon as our target mass.

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THE NUCLEAR DELTA FORCE AND THE TWO-PARTICLE-ROTOR MODEL

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When modelling excited states of deformed nuclei, the nucleons can be taken collectively as a rotor, significantly simplifying the system. However, in order to take into account single-particle effects it is important to properly model the valence nucleons, especially those occupying large angular momenta orbitals near the Fermi level. For that purpose a model has been developed in which two valence nucleons of the same kind are coupled to an axially symmetric quadrupole deformed rotor of the D_2 symmetry. These identical valence nucleons form a pair, with the pair-coupling strength controlled by the nuclear delta force, a pairing contact force. In this two-particle-rotor model a Coriolis force emerges resulting in the breaking of the pair formed by the valence nucleons. With this, both single particle and collective degrees of freedom are encapsulated in the model and compared to the yrast line of ^{178}Hf and ^{162}Er.

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MEASUREMENT OF Z BOSONS PRODUCED IN ASSOCIATION WITH JETS VIA VECTOR BOSON FUSION AT 13 TeV WITH THE ATLAS DETECTOR

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At the large hadron collider, most Z bosons are produced in a qqZ vertex, sometimes in association with jets produced via the strong interaction. A more rare production mode for Z bosons is through a triple gauge coupling via a process called vector boson fusion (VBF). This VBF Z process is similar in nature to VBF Higgs production, which is of great interest and is being studied by large groups of physicists on the ATLAS and CMS experiments. VBF Z production is interesting in its own right as a probe for new physics via the triple gauge coupling. Measurements of the cross section and kinematic distributions of VBF Z production can also be used to constrain new physics scenarios, such as fits to an effective field theory extension of the Standard Model Lagrangian. The plans for an ongoing analysis that measures cross section and kinematic distributions of this process with Run-2 ATLAS data will be presented.

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DETAILED SPECTROSCOPY OF ^{132}Sn WITH GRIFFIN*

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The region of neutron-rich tin isotopes near $A = 130$ is of great interest to nuclear structure. In particular, $^{132}\mathrm{Sn}$, with 50 protons and 82 neutrons, represents a doubly magic nucleus, and studying this and neighbouring isotopes gives insight into the single-particle nature of excited states. With no excited states below 4 MeV, $^{132}\mathrm{Sn}$ can be considered to be the most magic among heavy nuclei. Several particle-hole multiplets have been identified, as well as a collective 3^- level characteristic of doubly magic nuclei. In addition to nuclear structure considerations, the region around $^{132}\mathrm{Sn}$ is also useful in astrophysics, as studying the properties of these nuclei is key to understanding the r-process and its role in creating the $A = 130$ abundance peak.

The nucleus $^{132}\mathrm{Sn}$ has recently been studied as part of a campaign to investigate the structure of neutron-rich tin isotopes. The present experiment represents the most sensitive study of $^{132}\mathrm{Sn}$ to date, allowing for the identification of very weakly fed levels as well as firm spin and parity assignments of several low-lying excited states. The experiment was performed at the TRIUMF-ISAC facility. Excited states in $^{132}\mathrm{Sn}$ were produced from the β-decay of $^{132}\mathrm{In}$. A low-energy beam of $^{132}\mathrm{In}$ was delivered to the GRIFFIN experimental station, where the 16 high-purity germanium clovers of GRIFFIN were used to detect γ-rays. In addition, SCEPTAR, an array of 20 plastic scintillators, was used to detect β-particles in coincidence. In this talk, preliminary results from the experiment will be presented.

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STUDY OF ^{22}Ne AND ^{28}Mg EXCITED STATES USING FUSION-EVAPORATION AND DOPPLER SHIFT MEASUREMENTS

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Electromagnetic transition rate measurements serve as a fundamental probe of nuclear structure and provide a stringent test for theoretical models. Doppler shift lifetime measurements offer an opportunity to directly access information about electromagnetic transition rates and discriminate between model calculations. The TIGRESS Integrated Plunger device (TIP), constructed at SFU, supports Doppler shift lifetime measurements via gamma-ray spectroscopy with the TIGRESS segmented HPGe clover array as part of the experimental program at the ISAC-II facility of TRIUMF.

A recent study using TIP employs the fusion-evaporation reaction of an ^{18}O beam on a ^{12}C target using a beam energy of 48 MeV, with reaction channel selection provided via coincident charged particle detection using ancillary CsI(Tl) detectors. Transitions were identified belonging to the 2 alpha and 2 proton evaporation channels from the compound system ^{30}Si, corresponding to population of excited states in ^{22}Ne and ^{28}Mg respectively. The stable nucleus ^{22}Ne has been studied extensively and it was therefore chosen as a benchmark for our analysis method. Simulations of the fusion-evaporation process were developed using the GEANT4 toolkit to extract lifetimes from Doppler shifted lineshapes observed in the experimental data. The experimental approach, analysis procedure, and resulting lifetime measurements of excited states of ^{22}Ne will be discussed.

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