The 58th Winter Nuclear & Particle Physics Conference 2021

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Virtual Meeting

Book of Abstracts

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Welcome

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Searching for Neutrinoless Double Beta Decay at SNOLAB

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The nature of the neutrino has been a question puzzling physicists since its discovery. Many experiments are trying to solve this problem by searching for neutrino-less double beta decay. Two such projects that I work on are SNO+ and nEXO; using different technologies and different target isotopes to achieve similar scientific goals. I will compare and contrast these experiments, their sensitivities, and discuss the role that SNOLAB plays in their future success.

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Experiment

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Using Machine Learning to Identify Neutron Captures in Gd Loaded Water Cherenkov Detectors

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Hyper-Kamiokande is the proposed next generation Water Cherenkov neutrino detector in Kamioka, Japan that began construction in 2020. Hyper-K will have an order of magnitude larger fiducial mass than the existing Super-Kamiokande detector, enabling the survey of topics in neutrino physics with improved sensitivity. One handle on detecting neutrino versus anti-neutrino interactions is to detect the neutron in the inverse beta decay of anti-neutrinos on proton. When an anti-neutrino collides with a proton in the atomic nucleus, it yields an anti-lepton and a free neutron. The Cherenkov light from the lepton is promptly detected, while the neutron captures on Gd about one hundred microseconds later. The low-energy signal from the neutron capture (totalling about 8 MeV of gamma rays) is recorded by only tens of PMTs, making neutron captures difficult to distinguish from dark noise and radioactive backgrounds. This talk presents various machine learning approaches to optimize the neutron capture detection capability in the new Intermediate distance Water Cherenkov (IWCD) detector for Hyper-K. The methods benchmarked are graph neural network models (Graph Convolutional Networks, attention-based networks), Multi-Layered Perceptron, XGBoost on engineered features, and a likelihood-based classifier.

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Experiment

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Feature Recognition for Photogrammetry Calibration of the Super-Kamiokande Detector

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The Super-Kamiokande detector is a 40m tall cylindrical tank with a 40m diameter, filled with ultra-pure water. It makes detailed measurements of solar, atmospheric, and accelerator neutrinos. About 11,000 PMTs (photomultiplier tubes) facing inwards are set up on the detector wall to record neutrino interaction events. The use of the accurate location of photomultiplier tubes (PMTs) on the detector wall will increase the accuracy of the events that the PMTs record. Over 15000 images (57GB) of SuperK were taken in with an underwater drone to reconstruct the locations of the PMTs using photogrammetry. In this study, we used the bolts surrounding each PMT as features. The location of bolts surrounding each PMT is determined using image processing techniques. Further processing was done on bolts to eliminate false bolts. In this talk, I will present the methods used in our study to detect features and various geometrical techniques we used to obtain the final set of bolts.

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Super-Kamiokande PMTs Characterizations Using Artificial Magnetic Field and Robotic Laser-Equipped Arms

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Super-Kamiokande is a neutrino detector in Japan containing 11,000 photomultiplier tubes (PMTs) surrounding a massive tank filled with 50 ktonne of ultra-pure water. The single-photon sensitive PMTs detect Cherenkov radiation produced by charged particles travelling faster than the speed of light in water. A detailed understanding of the PMTs, as well as their response to environmental effects, is necessary for a precise understanding of the detector and even more importantly for the future Hyper-Kamiokande detector made of 40,000 PMTs.

One of the effects we need to understand is the response to the varying Earth geomagnetic field in the detector. The photon detection efficiency and timing of the PMT are affected by magnetic fields due to the resultant trajectory of the photo-electrons induced by Cherenkov light. A photosensor test facility (PTF) at TRIUMF consisting of laser-equipped robotic gantry arms is used to characterize PMTs.

I will discuss the procedure to control the magnetic field, environmental systematics, and the motion and monitoring of the gantries. Moreover, I will show the effect of the magnetic field on 3 parameters of the PMT: the gain, transit time and detection efficiency.

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Instrumentation

6

Light Dark Photon Detection with Atomic Transitions

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We propose to improve light-shining-through-wall setup by employing macro coherent super radiance on the detection side. Parahydrogen molecules are pumped to their first excited states by counter-propagating laser beams. The background dark photon field will interact with the parahydrogen and trigger the collective deexcitation of the atomic system, resulting in a nonlinear amplification of the two-photon emission process called superradiance. With the superradiant amplification the current bound on sub-meV mass dark photon can be advanced by orders of magnitude.

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Theory

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Search for Dark Matter Produced in Association with a Dark Sector Higgs Boson in Proton-Proton Collisions with the ATLAS Detector

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Longstanding evidence from observational astronomy indicates that non-luminous "dark matter" constitutes the majority of all matter in the universe, yet this mysterious form of matter continues to elude experimental detection. The study presented in this talk is part of an ongoing programme to search for dark matter production in high-energy proton-proton collisions at the Large Hadron Collider (LHC) at CERN. This search targets a model in which dark matter is produced in association with the emission of a hypothesized heavy Higgs boson in the dark sector, which then decays to a pair of W bosons. The final-state signature of this model would be an excess of missing transverse energy in the detector due to undetected dark matter production, along with two reconstructed W bosons. A search was recently performed targeting this final state in the 'hadronic' decay channel, wherein both W bosons decay to a pair of quarks. The semi-leptonic WW decay channel, in which one of the bosons instead decays to a lepton and neutrino, is expected to complement and extend the reach of the existing search in the hadronic channel. Ongoing work towards developing a dark matter search in this semi-leptonic WW decay channel is presented.

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Experiment

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Search for String Resonances in ATLAS

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Some string theories predict that the extra dimensions of space must be large. In this scenario the energy scale of strings is on the order of TeV and string resonances can be produced in proton-proton collisions. This makes the theory a good candidate for investigation at the Large Hadron Collider. Using the cross sections of string resonances we can simulate particle interactions and compare results to data collected by the ATLAS detector. We generate events at several string scales and study the significance of signals over QCD background in the dijet invariant mass distribution. We search resonant for deviations from smooth background and set lower limits on string scale.

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Experiment

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Numerical Loop-Integration Methods for Finite Temperature Effects in QCD Sum Rules

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Thermal field theory is the extension of quantum field theory to a non-zero temperature environment and is achieved by modifying the propagators in loop integrations represented by Feynman diagrams. The program package pySecDec is designed to numerically calculate dimensionally-regularized loop integrals in quantum field theory using the sector decomposition approach. It is shown how pySecDec can be applied to thermal field theory numerical calculation using modifications within the Matsubara formalism. Using the formulated algorithm, a 2-point correlation function (such as those occurring in QCD correlation functions) at finite temperature can be numerically calculated for a variety of spacetime dimensions. The topologies of the Feynman diagrams that the algorithm is targeting would occur in QCD sum rules.

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Theory

72

Towards Atomic Parity Violation in Francium

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Low-energy precision tests of electro-weak physics keep playing an essential role in the search for new physics beyond the Standard Model. Atomic parity violation (APV) measures the strength of highly forbidden atomic transitions induced by the parity violating (PV) exchange of Z bosons between electrons and quarks in heavy atoms. APV is sensitive to additional interactions such as leptoquarks, and is complementary to other approaches such as PV electron scattering. Our group is working towards the measurement in francium (Z=87), the heaviest alkali, at TRIUMF where we capture Fr atoms in a magneto-optical trap (MOT) online to ISAC. The APV signal in Fr is ≈18 x larger than in Cs. Working on the atomic 7S-8S transition, the PV observable will be the interference between a parity-conserving amplitude, a "Stark induced" E1 amplitude created by applying a dc electric field to mix S and P states, and the vastly weaker PV amplitude. In preparation, we now explore the Stark amplitude, in particular the ratio of its scalar to vector components. After a review of recent progress, I will discuss our plans for a precision determination of this ratio, including the challenge of producing spin-polarized Fr in a MOT environment.

Supported by NSERC, NRC, TRIUMF, U Manitoba, U Maryland.

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Experiment

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Measurements of the TUCAN Vertical UCN Source Heat Load Response

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The TUCAN collaboration is developing a dense source of Ultracold neutrons (UCN) that will be used in a neutron Electric Dipole Moment (nEDM) experiment, with a goal sensitivity of $10^{(-27)}$ e*cm which is 10 times more precise than the best measurement to date. UCNs are neutrons with energies below 300 neV, that are travelling with speeds less than 30 km/h. In order to carry out a world-leading nEDM experiment higher densities of UCN need to be produced. The TUCAN UCN are produced by cooling spallation neutrons to cold temperatures in successive layers of increasingly cold moderator, where the UCN production layer is a liquid He-II vessel, where cold neutrons (~1 meV) down scatter to UCN energies (~100 neV) by interactions with phonons and rotons in the fluid. The UCN production becomes more efficient when the He-II is kept at temperatures below 1~K, which is difficult because of the heat flux from the spallation target. Critical to the performance of the superfluid helium UCN source is the temperature of the superfluid and its response to heat input. The TUCAN collaboration aims to achieve their goal by developing a next generation UCN source based on superfluid helium. To benchmark the design of the new He-II source, heater tests were performed, and a model of the heating of the source was developed. In this talk, I will present the simple heating model that was developed, and how well the heater test measurements matched this model.

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Experiment

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Hunting for the Extreme Accelerators in Our Universe with Multi-Messenger Observations

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The Earth has been bombarded by high-energy particles for millions of years. Known as cosmic rays, these particles can have higher energies than particles accelerated by the best human-made accelerators. We have studied these energetic particles for over a hundred years. However, the sources of these particles remain a mystery because of the deflection of their trajectories by magnetic fields and their interactions with particles and radiation in interstellar and intergalactic space. Observations of the neutral particles, such as gamma rays and neutrinos, produced during the interactions experienced by cosmic rays have been studied in order to search for their elusive source sites. Observations of neutrinos provide an essential element in these studies as the neutrinos are only generated by hadronic interactions, and they can travel much longer distances than gamma rays. The best way to study the extreme accelerators in our Universe is to combine all of the information from different messengers - cosmic rays, gamma rays, and neutrinos. Recent multi-messenger observations triggered by the IceCube neutrino observatory in the direction of the blazar TXS 0506+056 showed the potential of this approach. I will highlight the role that these high-energy neutrino observations play in the emerging discipline of multi-messenger astrophysics and this will allow us to explore fundamental physics, including searches for decaying dark matter throughout the Universe.

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Theory

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Warming Nuclear Pasta with Dark Matter: Kinetic and Annihilation Heating of Neutron Star Crusts

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Neutron stars serve as excellent next-generation thermal detectors of dark matter, heated by the scattering and annihilation of dark matter falling into them. However, the composition and dynamics of neutron star cores are uncertain, making it difficult at present to unequivocally compute dark matter scattering in this region. On the other hand, the crust of a neutron star is more robustly understood. Dark matter scattering solely with the low-density crust can still kinetically heat neutron stars to infrared temperatures detectable by forthcoming telescopes, providing low cross-section sensitivities in a wide dark matter mass range, with the best sensitivity arising from dark matter scattering with a crust constituent called nuclear pasta. I discuss how these detection prospects are obtained for both spin-independent and spin-dependent scattering with the crust constituents, as well as the effects of dark matter annihilation in the case the dark matter particles are captured and thermalized by the crust alone.

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Theory

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Sub-GeV Dark Vector Bosons and their Impacts on Cosmology

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The purpose of this presentation is to recognize the effects of electromagnetic energy injection into the early Universe from decaying sub-GeV dark vectors. Decay widths and energy spectra for the most prominent channels in the sub-GeV region are calculated for various dark vector models. The models include the kinetic mixing of the dark photon with the Standard Model photon, $U(1)_{A'}$, a dark vector boson which couples to the baryon minus the lepton current, $U(1)_{B-L}$, and the last three are dark vector bosons which couple one lepton's current minus a different lepton's current, $U(1)_{L_i-L_j}$ where $i, j = e, \mu, \tau$. Measurements from Big Bang Nucleosynthesis and the Cosmic Microwave Background are used to constrain the lifetime, mass and coupling constant of the dark vectors.

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Theory

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Astrophysical tau Neutrinos in the Pacific Ocean

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The Pacific Ocean Neutrino Explorer (P-ONE) is a planned large-scale Cherenkov neutrino detector to be deployed in Cascadia Basin, close to Vancouver Island. This detector will join a worldwide network of neutrino telescopes and holds exciting possibilities of bringing us a step closer to true neutrino astronomy as well as unravelling new physics. High energy tau neutrinos, above energies of 50 TeV, is one exciting channel that P-ONE could access. These neutrinos must have an astrophysical origin and could be used to independently confirm the flux previously observed by IceCube, the largest neutrino telescope in operation, as well as verify neutrino mixing over cosmic distances. This study is a first attempt at developing a method to detect tau neutrinos in P-ONE.

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Experiment

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Searching for Low-Energy Shape Coexistence in ^{80}Ge

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Study of nuclear structure around the magic numbers is key to understanding the chart of nuclei. The region around ^{78}Ni is of interest, not only because it is one of the heavier doubly magic nuclei, but also because it has been proposed as a portal to the fifth island of inversion [Nowacki, F. *et al.* Phys. Rev. Lett. 117, 272501]. Evidence for low-lying shape coexistence near N=40 has been observed, but, until recently, no evidence of low-lying 0_2^+ states in the Ge isotopes near N=50 had be reported. An experiment at the ALTO facility identified a 0_2^+ state at 639 keV above the 0^+ ground state in ^{80}Ge [Gottardo, A. *et al.* Phys. Rev. Lett. 116, 182501]. However, β-decay studies using the GRIFFIN facility at TRIUMF, show no evidence for this state. Furthermore, the decay of a proposed (2^+) 2403-keV state to the 0_2^+ 639-keV state was not observed, nor was there other evidence for this state. Large-scale shell model calculations were performed, using two different valence spaces and interactions, for ^{78,80,82}Ge. These calculations were able to reproduce the energies of known 0_2^+, $2_{1,2}^+$ and 4_1^+ levels in these Ge isotopes. The 0_2^+ state in ^{80}Ge is predicted to be near 2 MeV and arises from the recoupling of valence particles. The search for this state, will be described, and the recently published findings [Garcia, F.H. *et al.* Phys. Rev. Lett. 125, 172501] will be presented.

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Experiment

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Coulomb Excitation of Rn Isotopes in the Region of Large Octupole Collectivity

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Reflection-asymmetric nuclei are of considerable interest for the understanding of nuclear structure. Reflection asymmetry arises as a consequence of strong octupole correlations which occur when states with Δj=Δl=3$\hbar$ lie close to the Fermi surface for both neutrons and protons. Octupole correlations are largest in the region with octupole magic numbers Z=88 and N=134. The Z=86 radon isotopes lie close to the centre of the octupole-deformed region but have been very difficult to study experimentally. Excited states have previously been identified in the N=136 isotope 222Rn[1], forming a characteristic alternating-parity octupole band, while the first observation of excited states in the more neutron-rich 224,226Rn isotopes was recently presented [2] using data from our experiment. An experiment has been performed using the Miniball spectrometer at ISOLDE, CERN to investigate the E3 moments of some Ra and Rn nuclei. The radioactive Rn isotopes were post-accelerated using the HIE-ISOLDE beam line to approximately 5 MeV/A and were incident upon stable Sn and Ni targets in separate measurements. Excited states in these nuclei were populated via Coulomb excitation. Analysis of the intensities of transitions using the multiple Coulomb-excitation code GOSIA will provide a direct measurement of both electric quadrupole (E2) and octupole (E3) moments.

[1] J.F.C.Cocks, Nucl. Phys. A645, 61 (1999).
[2] P. A. Butler, Nature Comm. 10, 2473 (2019)

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Experiment

81

Prototypes of an Ion Trap for the Barium Tagging of nEXO

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The next Enriched Xenon Observatory (nEXO) is a planned ton-scale experiment to search for neutrinoless double beta decay ($0\nu\beta\beta$) in xenon-136. The sensitivity of nEXO is limited by the natural occurrence of radioactive background events which produce signals indistinguishable from $0\nu\beta\beta$ in nEXO's detector. Barium tagging is a planned future upgrade of nEXO to reject backgrounds by identification of a barium ion extracted from the same vicinity as the detected decay. An ion trap has been developed as a part of a barium tagging approach. Prototypes of the ion trap have been built and tested. Experiments with the prototypes demonstrate successful ion transmission, trapping, cooling and ejection to meet the requirements for barium tagging.

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Experiment

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Ab-Initio Calculations of Electric Dipole Moments in Light Nuclei

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In any finite system, the presence of a non-zero permanent electric dipole moment (EDM) would require both parity (P) and time-reversal (T) violation. The standard model predicts a very small CP violation and consequently any observation of the EDM would imply physics beyond the standard model. Thus, EDMs have long been proposed as a way to test these fundamental symmetries. Experimental studies have placed upper bounds on neutron, nuclear and atomic EDMs, while theoretical studies have calculated their magnitudes using a variety of methods. In particular, it has been found that nuclear structure in certain nuclei can enhance the EDM. Here, we use an ab-initio no-core shell model (NCSM) framework to theoretically investigate the magnitude of the nuclear EDM. We calculate the EDMs of several light nuclei using chiral two- and three-body interactions and a PT-violating Hamiltonian based on a one-meson-exchange model. We will present a successful benchmark calculation for 3He, as well as results for the more complex nuclei ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B, ^{13}C, ^{14}N, ^{15}N, and ^{19}F. Our results suggest that different nuclei can be used to probe different terms of the parity violating interaction. These calculations will allow us to better understand which nuclei may have enhanced EDMs, and thus allow us to suggest which ones may be good candidates in the search for a measurable permanent dipole moment.

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Theory

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Ab Initio Neutrinoless Double-Beta Decay Matrix Elements

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As experiments searching for neutrinoless double beta decay ($0\nu\beta\beta$) are about to a reach ton-scale era, an effective way of calculating the nuclear matrix elements (NMEs), which govern the rate of the decay, is imperative. Observation of this decay would show the Majorana nature of neutrinos as well as potentially giving the absolute mass of the neutrino, as long as the NMEs are known accurately. The "In-Medium Similarity Renormalization Group" (IMSRG) method allows for an *Ab initio*, or first principles, prediction of the NMEs by approximately solving the nuclear many-body Schrodinger equation. This work uses the valence space formulation of the IM-SRG (VS-IMSRG) to compute the NMEs of candidate isotopes from A=48 to A=136. These results provide the first *Ab initio* NMEs for all isotopes of high interest for next generation experiments, including ongoing and future Canadian experiments.

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Theory

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Adapting the Ab-Initio IMSRG for Open-Shell Atomic Systems

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The nuclear charge distribution and nuclear magnetic moment modify the Coulomb potential in atoms, resulting in shifts in the electronic levels. Thus, atomic spectroscopy provides a way to probe nuclear structure. These measurements, however, require precise calculations of isotope shift factors and hyperfine constants. The IMSRG is an ab-initio technique, successfully used in nuclei, that evolves a many-body Hamiltonian using continuous unitary transformations. I will present a new application of the IMSRG to atomic systems for calculating spectra and isotope shift factors. I will discuss first results and the current status of these calculations as well as what we hope to achieve moving forward.

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Theory

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New Experimental Approaches for Constraining Neutron Capture Cross Sections in Exotic Nuclei

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The synthesis of heavy elements via the r-process involves extremely neutron-rich nuclei. Compared to light nuclei, our understanding of the properties of heavy, neutron-rich nuclei is sparse. The next-generation radioactive ion beam facilities, like ARIEL (TRIUMF), FAIR (GSI), CARIBU(ANL) and FRIB will offer unique possibilities to probe such nuclei.

I will give an overview about our current and future nuclear astrophysics program with reaccelerated beams at TRIUMF. The new TI-STAR silicon tracker detector, under development at the University of Guelph and TRIUMF, is designed for experiments with heavy, exotic beams at the future ARIEL facility. TI-STAR coupled to the TIGRESS array of HPGe detectors and the new EMMA recoil separator will offer constraining neutron-capture rates in the A=130 key region of r-process nucleosynthesis.

The extraction of neutron capture rates relies on a more model-independent determination of the nuclear level density in heavy nuclei. I present the newly developed "Shape Method" and present new data from an experiment at Argonne National Laboratory using the SuN Total Absorption Spectrometer. I show that we are able to extract a model-independent absolute partial nuclear level density for the short-lived unstable nucleus Kr-88, for the first time. This is an important step towards more reliable neutron capture rate data in exotic nuclei.
This work has been done in collaboration with TRIUMF, MSU, ANL and the "Oslo" group.

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Experiment

93

Bound-State Beta-Decay Rate of 205Tl

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Bound-state beta-decay (β_b-decay) is an exotic β^--decay mode where the electron is emitted directly into a bound orbital (often K/L) of the daughter nuclei. Hence, the decay mode is only accessible to highly charged ions with no electrons (HCIs). Thallium-205 is an interesting stable neutral ion, whilst being unstable to β_b-decay as a bare ion. This instability at high charge states could cause a branching point just before the termination of the slow neutron capture process. In addition, the capture of solar-neutrinos onto 205Tl to produce 205Pb is the lowest energy threshold neutrino-induced reaction known. The geochemical activation experiment LOREX (LORandite EXperiment) aims to calculate the integrated solar neutrino flux from this reaction in thallium bearing Lorandite. The nuclear matrix element of this reaction is currently unknown but identical to the β_b-decay matrix element.

The experiment was conducted at the GSI Helmholtz Centre, Darmstadt, Germany during March 2020. A 400 MeV/u 205Tl beam was produced by the Fragment Separator (FRS) and stored in the

Experimental Storage Ring (ESR). During storage, the beam is electron cooled and monitored by resonant Schottky detectors that identify ion species by their revolution frequency in the ring. Growth of the 205Pb^{82+} signal in the ring over time is directly attributable to β_b-decay. The authors aim to present the motivation, storage ring methods, and some preliminary results.

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Experiment

73

Precision Branching-Ratio Measurement for the Superallowed Fermi β Emitter 18Ne

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The precise studies of nuclear β decays between I$^{\pi}$ = 0^{+} isobaric analogue states provide stringent tests of electroweak interactions. Precision measurements of the ft values for superallowed β Fermi emitters between isospin T = 1 states has provided by far, the most precise value of V$_{ud}$, the up-down element of the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix. Recent survey on superallowed decay, recommended value of V$_{ud}$ is one standard deviation smaller than its previous value and is due to a new theoretical evaluation of a nucleus independent radiative correction that is universally applied to the ft values. As a result, the top row test of CKM unitarity now violates unity at the 3.3σ level, which has motivated a renewed search for any and all possible trivial sources that may explain this apparent discrepancy.
In this work, we focus on a new measurement of the superallowed branching ratio of ^{18}Ne decay that was deduced from an experiment performed at the GANIL facility in France. To date, the ft value for this decay has not yet been determined precisely enough to be included in the evaluation of V$_{ud}$ and it is perhaps the most interesting case for constraining model dependencies that arise in a second set of theoretical corrections accounting for isospin symmetry breaking effects. A detailed description of the experiment, analysis and preliminary results will be presented.

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Experiment

82

Mass Measurements around the $N = 32$ and $N = 34$ Shell Closures and Upgrades for TITAN's Measurement Penning Trap

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Mass measurement facilities are extremely important in furthering our understanding of nuclear structure away from the valley of stability. TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN) is among the world's premier precision trapping facilities, with the newly added Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-ToF-MS) expanding its reach. The TITAN MR-ToF-MS was used in the measurement of neutron-rich scandium, vanadium and titanium isotopes in the $A = 54 - 57$ mass region. In total, the masses of $^{54-55}$Sc, $^{54-57}$V and $^{54-56}$Ti were measured, resulting in significant improvements over current literature uncertainties. These masses are critical to the evolution of the $N = 32$ and $N = 34$ shell closures, and our new measurements allow for better understanding of trends along these isotones. Morever, the Measurement Penning Trap (MPET) at TITAN has undergone a series of upgrades to allow for the measurement of radioactive, highly-charged ions. Along with a new cryogenic cooling system, the implementation of the Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) technique will increase the resolution and precision capabilities of MPET. These upgrades, along with the aforementioned mass measurements, will be discussed.

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Experiment

78

Simulating DAEMON: A New Complementary Neutron Detector for GRIFFIN

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The study of neutron rich nuclei far from the valley of stability has become an increasingly important field of research within nuclear physics. One of the decay mechanisms that opens when the decay Q value becomes sufficiently large is that of beta-delayed neutron emission. This decay mode is important when studying the astrophysical r-process as it can have a direct effect on theoretical solar abundance calculations. The utilization of large-scale neutron detector arrays in future experiments is therefore imperative in order to study these beta-delayed neutron emitters and better understand these processes.
The deuterated scintillator array, DESCANT, was designed to be coupled with the large-scale gamma-spectrometer arrays GRIFFIN and TIGRESS at the TRIUMF ISAC facilities. However, DESCANT was originally intended to be a neutron-tagging array and extracting the neutron energy was not considered a priority over optimized neutron detection efficiency. This limitation could be overcome through the use of thin plastic scintillators positioned in front of the DESCANT detectors. The energy of the neutrons can then be determined via the TOF technique, improving the precision of the neutron energy with the existing setup significantly and allow for a more in-depth analysis of beta-delayed neutron emitters at the GRIFFIN decay station. To investigate this augmentation, GEANT4 will be used to simulate and optimize the experimental design, the progress of which will be discussed.

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Instrumentation

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Professional Development provided by the McDonald Institute

WNPPC PROFESSIONAL DEVELOPMENT WORKSHOP – EXPANDING DISSEMINATION IMPACT
Have you ever struggled to prepare your presentation before a conference? Have you felt underwhelmed by the response you got after presenting your research? Sharing the results of your work is a fundamental part of every scientific career, but it is also a key skill for career building and networking. Research "dissemination" can take many forms and has a massive range of desired outcomes; from helping colleagues follow your work, to convincing funders to support you, to landing a fellowship in a laboratory, or just helping family members appreciate what you've been doing for the last few years.
Whether you are presenting your work in journal papers, classroom lectures, job applications, conference posters, public education events, grant proposals, media interviews, or the dinner table, we invite you to join Dr. Adrian Kelly and a guest panel for a one-hour workshop to discuss ways you can present your research to maximize the outcomes you want to achieve. The session will start off with a short presentation from Dr. Kelly on how to discuss your research as a narrative and will move to a panel question and answer with opportunities for participants to engage directly. Topics covered will include:
Helping readers/audience members situate your work in the context of the discipline
Creating an impression that highlights who you are and your main research interests
Highlighting your capabilities and skills with the needs of a prospective employer or funder
AGENDA:
20-minute presentation from Dr. Adrian Kelly
40-Panel Discussion with Q&A (Edward Thomas - moderator)
Panelists: Dr. Adrian Kelly, Dr. Brigitte Vachon (McGill University), Dr. Jens Dilling (TRIUMF/UBC), Dr. Alexandra Pedersen (McDonald Institute)

95

Advancing Dark Matter Theory with Black Holes, Exploding Compact Stars, Supercool Gas, and Underground Detectors

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Recent theoretical investigation continues to suggest that dark matter could be either a supermassive or superlight particle. Discovering dark matter at these mass extremes requires radical new approaches. I will survey some fascinating developments, including dark matter that forms black holes in the sun and Earth, dark matter that would make old white dwarfs explode, supermassive dark matter detected through its fusion of nuclei in Antarctic ice, and ultralight photon-mixed dark matter heating supercold gas clouds near the center of the Milky Way.

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Theory

19

Superfluid Neutron Matter with a Twist

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Superfluid neutron matter is a key ingredient in the composition of neutron stars. The physics of the inner crust is largely dependent on that of its S-wave neutron superfluid which has an effect on pulsar glitches and the neutron star cooling. Moreover, with recent gravitational-wave observations of neutron star mergers, the need for an equation of state for the matter of these compact stars is further accentuated and a model-independent treatment of neutron superfluidity is important. Ab initio techniques developed for finite systems can be guided to perform extrapolations to the thermodynamic limit and attain this model-independent extraction of various quantities of infinite superfluid neutron matter. To inform such an extrapolation scheme, we performed calculations of the neutron $^1S_0$ pairing gap using the model-independent odd-even staggering in the context of the particle-conserving, projected BCS theory under twisted boundary conditions. While the practice of twisted boundary conditions is standard in solid state physics and has been used repeatedly in the past to reduce finite-size effects, this is the first time it is employed in the context of pairing. We find that a twist-averaging approach results in a substantial reduction of the finite-size effects, bringing systems with $N > 50$ within a 2% error margin from the infinite system. This can significantly reduce extrapolation-related errors in the extraction of superfluid neutron matter quantities.

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Theory

20

Novel Method for the Detection of Axions by Daily and Annual Modulations

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Axions which were originally proposed as a solution to the Strong CP problem have gained interest as a potential Dark Matter candidate. Axion Quark Nuggets (AQNs) are a new model for Dark Matter consisting of quark or anti-quark matter contained within an axion domain wall. AQNs can produce axions when they encounter time dependent perturbations (such as passing through the interior of the Earth) which enable their potential detection. In this talk, we will review the basics of the AQN model and give a review of contemporary Axion cavity search focusing on the CAST-CAPP experiment. Next we will show how the CAST-CAPP experiment and search procedure can be modified to search for AQNs by looking for daily and annual modulations in the CAST data. We will present preliminary results for this new search procedure and provide comments on future directions for AQN searches.

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Experiment

10

Using Underground Nuclear Accelerators in the Quest for Dark Matter

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The existence of dark matter is ubiquitous in cosmological data and its distribution has been mapped across many galaxies. From these observations, it must be some type of particle beyond the Standard Model. Yet, numerous underground particle detectors on Earth have been thoroughly looking for dark matter without any success. The null results call for bigger and more sensitive detectors, but this comes at an expensive price. Instead, I attempt at leveraging the finest tools present in these underground laboratories to hopefully achieve a successful detection. Here I will discuss how nuclear accelerators, such as LUNA in Gran Sasso, could provide just what we need to detect dark matter.

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Theory

33

Optimization of Drift Time Measurement in P-Type Point-Contact HPGe Detectors

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P-type point contact (PPC) high-purity germanium detectors have gained substantial interests in the search for neutrinoless double beta decay ($0\nu\beta\beta$) due to their background-rejection capabilities and excellent energy resolution. The drift time of charge carriers in the detector can be used in determining the position of an energy deposition and identifying sources of the background. One can also use drift time to look for evidence of charge trapping by impurities in the germanium crystal and correct the degraded energy resolution. In this presentation, we discuss an optimized method for measuring the drift time. The results will be demonstrated using both experimental and simulated data.

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Experiment

55

LoLX Experiment

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The Light only Liquid Xenon (LoLX) experiment aims to investigate the emission of scintillation and Cherenkov light in liquid xenon for its applications in rare event searches in particle physics. LoLX consists of 24 quadruple Hamamatsu VUV4 Silicon Photomultipliers (SiPM) arranged in an octagonal prism. SiPMs are covered with two different kinds of optical filters used to separate scintillation and Cherenkov light. Out of 24 SiPMs, 22 are covered with 225nm long-pass filters to see Cherenkov light from liquid xenon, one is covered with a band-pass filter centred at 175nm to detect the scintillation light of liquid xenon and one is left bare. A strontium-90 beta source placed at centre of the structure is used for light production in LoLX. The beta electrons will deposit energy in liquid xenon and produce scintillation and Cherenkov light to be detected by SiPMs. First LoLX data have been taken in cold nitrogen gas to measure the external crosstalk events where photons emitted from surface of one SiPM are detected in another. The first data set of LoLX with liquid xenon is planned to be taken at McGill University by the time of this conference. This talk will give an overview of the LoLX experiment, its current status and upcoming plans.

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Experiment

40

The Data Acquisition System for the DarkSide-20k Detector

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The DarkSide Collaboration intends to build a new direct WIMP search detector DarkSide-20k (DS-20k), a dual-phase Liquid Argon Time Projection Chamber (LAr TPC) with an active mass of 23 t. Located at the Gran Sasso Laboratory in Italy, the DS-20k LAr TPC will be enclosed inside a liquid scintillator neutron veto and submerged inside an external liquid scintillator bath which will act as a cosmogenic veto. The experiment is designed to be "background-free", achieved with the use of low-radioactivity underground argon, Pulse-Shape Discrimination (PSD) and the veto systems. The DS-20k experimental designs boasts a projected sensitivity to the spin-independent WIMP-nucleon cross section of 1.2 × 10−47 cm2 for a 1 TeV/c2 WIMP mass, assuming a 100 tonne-year exposure (5-year run) in the absence of any backgrounds inside the WIMP search region.

Scintillation photons generated inside the TPC and veto will be measured with the use of Silicon Photomultipliers (SiPMs). DarkSide-20k will use 50 x 50 mm2 Photodetector Modules (PDMs), comprised of a large tile of SiPMs that will act as a single photodetector. There are approximately 5000/3500 PDMs envisioned for the TPC/veto systems. To readout such a vast number of PDMs poses various logistical challenges for the data acquisition (DAQ) system. This talk will outline the proposed DAQ system/readout strategy for the DS-20k detector and discuss the challenges associated with such a system, with a particular focus on the neutron veto.

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Experiment

66

Towards Validating Misalignment Measurements of Small-Strip Thin Gap Chamber Quadruplets for the ATLAS New Small Wheel

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The small wheels of the end-caps of the ATLAS muon spectrometer must be replaced to improve the angular resolution of tracks for precision muon momentum reconstruction during Run-3. The New Small Wheel (NSW) will be covered with two detector technologies, one of which is small-strip thin gap chambers (sTGCs). Canada is responsible for one quarter of the required sTGCs: the electrode boards are prepared at TRIUMF; sTGCs are constructed at Carleton University and four sTGCs are glued into a quadruplet; the quadruplets are tested at McGill University using a cosmic ray hodoscope; and finally the quadruplets are sent to CERN for integration into the NSW. The strip electrode layers of each sTGC in a quadruplet have 3.2 mm pitch, chosen so that they can achieve 1 mrad angular resolution on tracks. However, misalignments between a quadruplet's strip layers introduced during construction must be corrected for. The charge profile left by an x-ray gun on quadruplets and coordinate measuring machine (CMM) measurements of individual strip layers are being used to define these parameters. Work on using cosmic ray data to validate misalignment parameters derived using the above-mentioned methods will be presented.

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Instrumentation

32

Charged Meson Form Factors at Jefferson Lab Hall C

Author(s): Nathan Heinrich[1]

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Quantum Chromodynamics (QCD) is the accepted theory of the strong force between quarks and gluons and in recent years many successful predictions have come out of perturbative QCD (pQCD). However, pQCD is restricted by the running coupling constant α_s, so at lower energies a problem arises where the predictions of pQCD no longer apply. While QCD-based models attempt to understand this region, they must be guided by experiment. Thus, many open questions remain: How does QCD transition between the perturbative (weak) and non-perturbative (strong) regimes? What predictions does QCD make for hadronic structure? How do other properties of hadrons, such as mass and spin, arise from QCD? In order to help answer these questions, the form factors of charged mesons, specifically the π^+ and K^+, are ideal candidates as they are relatively simple systems for theory to predict and are accessible experimentally. As the Goldstone bosons of the strong interaction, they are also seen as key to understanding some properties of QCD, such as Dynamic Chiral Symmetry Breaking (DCSB), which is the mechanism believed to generate >98% of the visible mass in the universe. This talk will give an overview of the effort to study the π^+ and K^+ form factors at Jefferson Lab, as well as a quick overview of the facilities at Jefferson Lab and Hall C.

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Experiment

16

The Electron Ion Collider – A Canadian Perspective

Author(s): Stephen Kay[1]

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A major future initiative of the international nuclear physics community is the construction of the world's first electron-nucleus collider in the coming decade, with the flexibility to change the nuclear ion species as well as the beam energies. For electron-proton collisions, the Electron-Ion Collider (EIC) would be the world's first collider where both beams are polarised. Recently, the EIC has been approved for construction by the U.S. Department of Energy (US-DOE), at Brookhaven National Laboratory (Long Island, NY). In this talk, I will briefly outline the design specifications and main scientific goals of this brand-new facility. In particular, I will examine the planned and ongoing contributions of the Canadian subatomic physics community to this exciting new facility.

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Experiment

53

Analysis and Identification of Alpha Events for NEWS-G

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The NEWS-G experiment uses a spherical proportional counter filled with gas in order to detect potential dark matter particles that can ionize the gas after a nuclear recoil. The detector works by attracting the free electrons towards the centre of the sphere where there is a high voltage anode inducing a radial electric field. Near the anode, the accelerated electrons then cause a Townsend avalanche that produces many drifting ions, which creates an identifiable electrical signal. Since this method has been most efficient at energies below 1 GeV, that is where keeping the background contamination at minimum is of utmost importance. However, there is approximately 20 mBq of alpha particles coming from impurities in the copper surface of the sphere that create a sudden influx of events close to the region of interest for up to five seconds. These alphas also lead to fluctuations in the electric field, which in turn alters the time taken for electrons to reach the anode at the centre. This presentation aims to show how the consequences of alpha particles in the detector can be characterized, as well as how those consequences can be used to better identify alpha events in order to remove the correlated influx of low energy events.
*On behalf of the NEWS-G collaboration

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Experiment

9

Neutrons for Characterizing Dark Matter Detectors

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At the Queen's University Reactor Materials Testing Laboratory (RMTL) we are developing a quasi-monoenergetic beam of intermediate-energy neutrons. These neutrons will be used to do scattering experiments on the nuclei of gas atoms in the NEWS-G dark matter detector to measure the so-called quenching factor. The quenching factor relates the energy measured from nuclear recoils (such as from a neutron or dark matter detector) to electronic recoils (from normal calibration sources). The quenching factor depends on the nuclear recoil energy, so a specific and tunable neutron energy is important to get the best possible calibration for NEWS-G. I will describe progress made in 2020, with a new detector, shielding, nuclear targets, and improved positioning and alignment in the experimental room.

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Instrumentation

37

A Measurement of Zinc-65 Using Data from the KDK Experiment

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Zinc-65 (Zn-65) is a radionuclide of interest in the fields of medicine and gamma-ray spectroscopy, within which its continued use as a tracer and common calibration source necessitates increasingly-precise nuclear decay data. A Zn-65 dataset was obtained as part of the KDK ("potassium decay") experiment, whose apparatus consists of an inner X-ray detector and an efficient outer detector, the Modular Total Absorption Spectrometer (MTAS), to tag gamma rays. This setup allows for the discrimination of the electron capture decays of Zn-65 to the ground (EC) and excited (EC*) states of Copper-65 (Cu-65) using an emerging technique for such a measurement, exploiting the high efficiency ($\sim$98%) of MTAS. Techniques used to obtain the ratio of EC to EC* decays are applicable to the main KDK analysis, which is making the first such measurement for Potassium-40, a common background in rare-event searches such as those for dark matter. We present our current methodology and analysis procedures developed to obtain a novel measurement of the electron-capture decays of Zinc-65.

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Experiment

46

Light Collection in the Scintillation Bubble Chamber

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The ongoing search for dark matter continues to evolve, and the quest to reach lower cross-sections is leading to new technologies. One of the newer proposals involves the use of a bubble chamber which employs noble elements (such as argon and xenon) as the active mass. Combining recent developments of bubble chambers with liquid noble gases allows additional scintillation and ionization data to be collected. These channels further suppress backgrounds allowing the exploration of lower dark matter mass parameter space with a lower energy threshold. This talk/poster focuses on the current development of SBC (scintillating bubble chamber), and the SiPMs (silicon photomultipliers) used in the detector.

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Experiment

68

Characterizing and Removing ER Background Events in the DEAP-3600 Experiment

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DEAP-3600 searches for dark matter via the coherent scattering of argon nuclei by dark matter particles as they traverse the detector. The detector is located at SNOLAB, and uses 255 photomultiplier tubes (PMTs) viewing ~3300 kg of liquid atmospheric argon (AAr) in a spherical acrylic vessel. The use of liquid argon as a target allows the powerful discrimination of nuclear recoils (NR) (produced in DM collisions or from background interactions) from beta and gamma electronic recoil (ER) backgrounds. Due to the fraction of Argon-39 naturally present within the AAr, with activity ~0.95 Bq per kg of AAr, ER events form the dominant component of the backgrounds. The discrimination is only possible due to the large difference in the scintillation live times between the triplet (predominantly produced in ER interactions) and singlet (predominantly produced in NR interactions) states of Ar.

As the scintillation spectrum of Argon peaks at 128 nm, it needs to be shifted to a wavelength where the PMTs are sensitive, this is achieved by coating the inner surface of the acrylic vessel with TPB wavelength shifter. The fluorescence time profile of the TPB, and other detector effects need to be taken into account when developing a model for the detector response. This presentation will cover the development and components of a model for the response of the detector to Argon-39 decays and the application of the Argon-39 ER band to develop a region of interest for the dark matter search.

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Experiment

70

A Novel Algorithm for Alpha Discrimination in PICO Bubble Chambers

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A new comprehensive algorithm is presented for acoustic analysis of the complete exposure of the PICO-60 dark matter detector. The PICO-60 detector is a bubble chamber filled with 52 kg of C_3F_8 operated at the SNOLAB underground laboratory. The bubble chamber experiments run by PICO have been some of the leading experiments in direct detection of spin-dependent WIMP-proton interactions; the complete exposure of the PICO-60 detector sets an upper bound on the cross-section of these interactions at 2.5×10^{-41} cm^2 for a 25 GeV WIMP (Amole et. al, 2019). One advantage the PICO bubble chambers have is the Acoustic Parameter (AP) used for rejection of alpha decays of ^{222}Rn. Using the AP for alpha discrimination of the WIMP search produced 3 events which could not be classified as either alphas or nuclear recoils, called "mid-AP" events. Using this new algorithm to find optimal frequency bands in the acoustic power spectra, the "Signal to Noise Ratio" (SNR) was able to be calculated to replace the AP, and Machine Learning Algorithms were used to supplement the SNR. Using the SNR, all 3 "mid-AP" events from PICO-60 were able to be classified as alphas or nuclear recoils. Furthermore, this algorithm can be applied to any other PICO bubble chamber, or any other bubble chamber with acoustic alpha discrimination.

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Experiment

98

Particle Physics with Neutrino Telescopes in Canada

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Every time researchers have pushed the energy boundary in particle physics we have found something new about our Universe. Recently, IceCube has demonstrated that Neutrino Telescopes can use neutrinos from the cosmos as excellent tools to continue this exploration. In this talk I will cover the latest searches for new physics using IceCube, as well as plans to deploy a new Neutrino Telescope in the Pacific, off the coast of Vancouver Island: P-ONE.

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Please select: Experiment or Theory:

Experiment

26

Measuring the Absorption Length of the Deep Pacific Ocean: Results from STRAW, a Pathfinder Mission for the Proposed P-ONE Neutrino Telescope

Andreas Gaertner[1] ; Christian Fruck[2]

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In the search for astrophysical neutrinos, neutrino telescopes instrument large volumes of clear natural water. Photomultiplier tubes placed along mooring lines detect the Cherenkov light of secondary particles produced in neutrino interactions, and allow us to search for possible neutrino sources in the sky. The P-ONE experiment proposes a new neutrino telescope off the shore of British Columbia.

To overcome the challenges of a deep-sea installation, we have developed prototype mooring lines in collaboration with Ocean Networks Canada, an initiative of the University of Victoria, which provides the infrastructure for many Oceanographic instruments. The STRAW and STRAW-b mooring lines, deployed in 2018 and 2020, provide continuous monitoring of optical water properties at a new possible detector site in the Pacific.

We present the measurements of the attenuation length, one of the defining properties of the site, based on data taken by the STRAW experiment.

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Experiment

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Muon Track Reconstruction for the Upcoming P-ONE Telescope

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The neutrino, a fundemental particle, offers the potential to image parts of the universe never before seen and can provide an early warning for cosmic events. With their ability to carry information across the universe unperturbed, neutrinos offer a clear image of the cosmos and can provide insight into its nature with relative ease. Learning from successful neutrino telescopes such as IceCube, the Pacific Ocean Neutrino Explorer (P-ONE) will be built in the Cascadia Basin in the Pacific Ocean, supported by an international collaboration. Located 2660 meters below sea level, P-ONE will consist of 70 strings each armed with at least 20 sensitive photodetectors and 2 calibrators in an infrastructure provided by Ocean Networks Canada. A key step in the data analysis pipeline is the reconstruction of the path of particles as they pass through the detector. Using simulated data, I will present my work in reconstructing muon tracks in this proposed detector through a likelihood framework.

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Experiment

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Potassium Decay Noise Modeling for the Pacific Ocean Neutrino Explorer (P-ONE)

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Recent observations by neutrino observatories such as IceCube have thoroughly cemented the research potential of neutrino astronomy. The Pacific Ocean Neutrino Explorer (P-ONE) is a proposed initiative to construct one of the largest neutrino telescopes deep in the northern Pacific Ocean off the coast of British Columbia. The detector itself will consist of an array of strings lined with digital optical modules (DOMs) for detecting Cherenkov light induced by neutrino interactions. Two Pathfinder missions have been deployed in order to study the optical properties of the seawater including scattering and absorption lengths as well as noise. As part of this analysis, the ambient background activity produced by Cherenkov light from the decay of natural ^{40}K in saltwater needs to be characterized. This presentation will detail the modeling process of the undersea environment and detector DOMs using Geant4 while also verifying simulation data against in situ measurements to obtain a full understanding of the ^{40}K background. Not only is this an important step of the site characterization that will serve to improve future event trigger development, but accurate modeling of ambient ^{40}K will also prove to be useful for detector efficiency measurement and recalibration.

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Instrumentation

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ResNet Convolutional Neural Networks for Particle Identification in Water Cherenkov Detectors

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Current and next generation water Cherenkov detectors require precise event reconstruction to maximise detectors' capabilities. Machine learning is being explored in numerous areas related to these detectors for its potential to provide this precision, potentially aiding projects like Super-Kamiokande, and its successor Hyper-Kamiokande. Event reconstruction has been a particular area of focus of these machine learning efforts, including tasks such as particle type identification. This task is complicated by challenges such as the presence of gamma events, which produce multiple highly proximal Cherenkov rings, resulting in a signal that is very difficult to discriminate from single electron events. This talk will provide a discussion of the progress and challenges of ongoing efforts towards event classification in water Cherenkov detectors, with a focus on results achieved with the ResNet architecture. This will include an outline of the approach, an examination of its ability to resolve the e/γ discrimination problem, and a comparison of performance with existing reconstruction algorithms. Future developments and applications related to ResNet classifiers will also be explored, such as the characterization of systematic uncertainties.

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Experiment

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Search for New Physics Inside Jets at the ATLAS Detector Using Machine Learning

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Since the discovery of the Higgs Boson at the LHC in 2012, no sign of new physics beyond the Standard Model has been found. The SUSY and exotic particles searches have not uncovered signs of new physics, as the model-dependent searches. In recent years, multiple unsupervised machine learning methods have been proposed to search for new physics at the LHC. This talk will explore the use of a variational auto-encoder (VAE) to perform a general search in proton-proton collisions at the LHC using large radius jets in ATLAS simulation data. The algorithm was trained on TopoClusters to differentiate between the dominant QCD background and a chosen test signal corresponding to top quark jets. The most anomalous jets predicted by the VAE were selected to plot the invariant mass spectrum to find the top quark mass peak. Our study found an important correlation between the jet invariant mass and the loss function of the VAE, resulting in QCD background sculpting and preventing the apparition of the top peak. We successfully used a mass-decorrelation method based on Outlier Exposure to prevent this sculpting.

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Experiment

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Machine Learning for Energy Reconstruction in ATLAS Calorimeters

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A crucial task of the ATLAS calorimeter is energy measurement of detected particles. In the liquid argon (LAr) calorimeter subdetector of ATLAS, electromagnetically and hadronically interacting particles are detected through LAr ionization. Special electronics convert drifting electrons into a measurable current. The analytical technique presently used to extract energy from the measured current is known as optimal filtering. While this technique is sufficient for contemporary pile-up conditions in the LHC, it has been shown to suffer some degradation of performance with the increased luminosity expected at the High Luminosity LHC. This presentation will explore machine learning techniques as a substitute for optimal filtering, examining the strengths, weaknesses, and limitations of both energy reconstruction methods.

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Experiment

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Light Tetraquarks Mass Estimates Using QCD Sum Rules

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Multiquark states have been of great interest among hadronic physicists, and despite the big breakthrough that came in 2003 with the discovery of the charmonium-like tetraquark candidate X(3872), their internal quark structure (e.g., molecular versus diquark clusters) is not well-understood yet. QCD sum-rule mass estimates for multiquark states can provide insights on possible internal quark structures. Previous research suggests that the next-to-leading order (NLO) corrections to QCD sum-rule mass determinations are quite different in heavy and light multiquark states. The study of these multiquark systems can give us another approach to understanding strong interactions at the elementary level and at different energy scales. The goal of this research is a detailed examination of the NLO corrections to mass estimates of the light scalar tetraquarks using QCD sum-rules.

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Theory

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The Search for Evidence of Vector Boson Scattering Between a Photon and a W Boson with the ATLAS Detector

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It is known that the unique shape of the Higgs potential assumed in the Standard Model results in spontaneous symmetry breaking in physics at low energies, but the exact role of the Higgs in electroweak symmetry breaking (EWSB) has yet to be experimentally established. This gap in understanding also leaves the possibility that new physics phenomena could contribute to EWSB. One particularly powerful approach to search for new physics phenomena is in the study of the self-couplings of electroweak gauge bosons. In the Standard Model, the interactions between gauge bosons are completely specified by the non-Abelian SU(2) x U(1) structure of the theory. Any deviations from this expectation would indicate the presence of new physics phenomena at unprobed energy scales. The large data samples collected by the ATLAS experiment at the LHC make it possible to now explore extremely rare processes involving the interaction between four gauge bosons.
In this talk I will discuss the search for evidence of one of these rare processes, namely, the vector boson scattering between a W boson and a photon, whose production cross-section has never before been measured by the ATLAS collaboration. This measurement comes with exciting challenges related to the proper modelling of the detector response to jets and adequate modelling of the large QCD background at high dijet mass. I will discuss data-driven and machine learning approaches to overcoming these challenges.

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Experiment

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Beam Asymmetry in γp $\rightarrow \eta\ \Delta^+$ at GlueX

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The photo-production mechanism used in the GlueX experiment by impinging an 8.2-8.8 GeV linearly polarized photon beam on a liquid hydrogen target allows the mapping of light mesons in unprecedented detail with particular interest in exotic meson candidates. Polarization observables such as beam asymmetry Σ, extracted from azimuthal (ϕ) angular distributions between the meson production plane and the polarized photon beam, help in understanding production mechanisms via t-channel quasi-particle exchange processes using Regge theory. We report preliminary results on the beam asymmetry measurements for η in γp $\rightarrow \eta\ \Delta^+$. The reaction γp $\rightarrow \eta\ \Delta^+$ provides an opportunity for validation of previous η asymmetry measurements and theoretical calculations. Ensuring that exchange mechanisms are understood is a crucial ingredient to the establishing of new photoproduced light meson states.

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Experiment

100

Long-Lived Particles - Searching for New Physics at the Energy Frontier

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For the last few decades, High Energy Physics has been a victim of its own early success. Despite numerous theoretical arguments why it cannot be the final explanation for the interactions of fundamental particles, the Standard Model of particle physics continues to withstand intense scrutiny of the most determined experimental physicists. One promising way to search for signs of new physics is at the energy frontier at the LHC, probing energies comparable to those present very shortly after the Big Bang.
In this talk, I will review some recent experimental results for searches for signs of long-lived new particle signatures using data from the ATLAS experiment. Searching for these particles is highly challenging as they have the tendency to avoid interactions, making them elusive to detection. I will discuss details about the detector performance, which are crucial for such searches.

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Measurement of W Boson Drell-Yan Angular Coefficients

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The Large Hadron Collider located at CERN outside of Geneva, Switzerland uses proton-proton collisions to produce a wide range of particles. W and Z bosons, the mediators of the fundamental weak force, are some of the particles that can be produced in proton-proton collisions and can be used to give a more complete understanding of the Standard Model. One of the ways they can decay is into detectable lepton particles, such as electrons, which can be measured with the ATLAS (A Toroidal LHC ApparatuS) detector. The Drell-Yan process is the production of W/Z bosons in proton-proton interactions with leptonic final states. Its differential cross-section expresses the probability for this process to occur depending on the W/Z bosons' and decay products' kinematic variables. It can be separated into eight spin-related ratios, known as the Drell-Yan angular coefficients. The coefficients are coupled to trigonometric polynomials which contain information about the detected leptons. Using the property that the polynomials are orthogonal to each other, it is possible to isolate each coefficient. This talk will cover my research of measuring these coefficients for the W bosons with special data sets. This measurement gives both a unique result for many of the coefficients as well as it helps reduce the uncertainty for other measurements like the mass of the W bosons.

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Experiment

45

Precision Measurement of the Z Boson Transverse Momentum with the ATLAS Detector

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The ATLAS Experiment at CERN is a general-purpose particle physics detector that measures properties of particles created in high-energy proton-proton collisions fueled by CERN's Large Hadron Collider (LHC). Searching for undiscovered particles is exciting, but there is still much to be learned about the particles that we know to exist in the Standard Model by making precision measurements of these particles. One area where increased precision is needed is the electroweak sector, where potential tension exists between theoretical predictions and the current best measurements on important properties such as the mass of the W-boson. In this talk, I will discuss our precision measurement of the transverse momentum of the Z boson, a vital stepping stone to improving our W-boson mass measurement. I will explain how this difficult measurement has been made possible thanks to a unique reduced-background ATLAS dataset.

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Experiment

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Production Cross-Section and Charge Asymmetry of the W Boson with Jets

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W +jets is a curious playground of hard objects like jets, and electroweak interactions from the leptonic decay of the W boson. In this region of phase space, very interesting measurements are made to stringently test the Standard Model production mechanisms, as well as provide inputs to state-of-the-art parton distribution functions determination, for example with the W+/W− asymmetry measurement. Additionally W +jets is a dominant background for many Beyond-the-Standard-Model searches and Higgs measurements, thus improving this measurement and reducing systematics will have a large impact to improve many such analyses and our understanding of fundamental high energy physics.

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Experiment

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W$\gamma\gamma$ Production in Proton-Proton Collisions at the Large Hadron Collider with the ATLAS Detector

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The Large Hadron Collider (LHC) at CERN has been colliding protons at an unprecedented centre of mass energy of 13 TeV since 2015. ATLAS, a general-purpose particle detector located at one of the LHC's interaction points, has collected nearly $140\ \mathrm{fb}^{-1}$ of the resulting data, allowing scientists to perform some of the most stringent tests of the Standard Model (SM) of particle physics to date. This data set offers a newfound sensitivity to rare and yet unobserved processes such as the SM production of a W boson and two photons. This process represents an important test of the electroweak sector since any deviation from the predicted self couplings of the gauge bosons would indicate the presence of new physics phenomena at yet unprobed energy scales. The measurement of this process does not come without its challenges however. Multiple background sources are expected to contribute to this process's signature in the detector. Though some can be modeled through simulation, events where a hadronic jet is reconstructed as either a lepton or photon must be estimated using data-driven techniques. This is due to the numerous sources of jets and the complex nature of their interaction with the detector which are poorly modeled. The estimation of these backgrounds will be crucial to achieving the first observation of $W\gamma\gamma$ production in proton-proton collisions and the precise measurement of its production cross section to test its agreement with SM predictions.

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Experiment

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Award Ceremony and Closing of Conference

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New experimental approaches for constraining neutron capture cross sections in exotic nuclei

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Talk by Dennis Muncher

101

Prizes and end of conference

79

Moller Scattering and Running of Weak Mixing Angle Using MS-Bar Renormalization Scheme

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Moller experiment was designed to obtain ultra-precise measurement of weak mixing angle through Moller scattering. Moller Parity Violating Asymmetry (A_{PV}) measures the electroweak charge which at one loop level is modified and it becomes scale dependent at which the measurement is carried out. We calculated the tree level and one loop level Moller Parity Violating Asymmetry (A_{PV}) by considering left and right polarized electron striking the unpolarized electron target. We used MSBar renormalization scheme to perform the complete one-loop level calculations for Moller A_{PV}. By determining the running of electroweak charge as a function of energy scale at z-pole, we try to get a precise value of weak mixing angle and compare it with the most updated experimentally measured value. The consistency of these results could enable to search for the signals of physics beyond the Standard Model.

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Theory