TRIUMF Science Week

Monday, 16 July 2018 - Thursday, 19 July 2018

TRIUMF and UBC

Book of Abstracts

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Introduction

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Neutron Stars and Mergers

We discuss observations of neutron stars and neutron star mergers and how these depend on the equation of state and other properties of dense neutron rich matter. We also discuss some related laboratory experiments with neutron rich nuclei.

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Daddy, Where Did I Come From?

I will outline how nearly all of the elements essential to you are produced in the evolution of low-mass and high-mass stars and in white-dwarf binaries. All the essential elements except for iodine, that is. The story of where did iodine come from along more common materials like platinum (yes, platinum is more common in the Universe) was a mystery for 60 years between when B2FH first posed the question and the discovery of the production of lanthanides in the merging of neutron stars in 2017. What are neutron stars, why did astronomers argue that they could be the source for the r-process elements, and what may we learn in the future?

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The R-Processes and their Astrophysical Sites

The r-process occurs in neutron star mergers. This has been confirmed by the observation of the decay of neutron rich radioactive nuclei as a kilonova light curve after the neutron star merger detected with gravitational waves GW170817. We study the nucleosynthesis and kilonova light curves from different ejecta of neutron star mergers discussing the astrophysical and nuclear physics uncertainties. Moreover, core-collapse supernovae driven by neutrinos can produce elements up to silver. The astrophysical and nuclear physics uncertainties of this weak r-process will be discussed. In order to have a successful r-process and to produce the heaviest elements in core-collapse supernovae, magnetic fields are necessary. We will report about the impact of rotation and magnetic fields based on recent simulations including detailed neutrino transport

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Fission in the R-Process

Last August marked the first observation of gravitational waves and electromagnetic signals from the merging of two neutron stars sending ripples through the astrophysics, atomic physics, nuclear physics and gravitational wave communities. In some components of neutron star merger ejecta fission is thought to re-cycle the material and impact the abundances. I will focus the talk on the sensitivity of the r-process to theoretical calculations of fission, in particular, the treatment of neutron-induced fission, beta-delayed fission and fission yields. The production of the heavy actinide Californium-254 will be discussed along with its impact on observational signatures of kilonovae.

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Onward and Upward: Prospects for applying ab initio methods to the structure of medium-heavy nuclei

The past decade or so has seen great progress in applying effective field theory ideas and non-perturbative many-body methods towards the quantitative prediction of the structure of light nuclei. I will give a brief overview of this program and discuss work in progress to extend this success up the nuclear chart beyond A=100, with a focus on binding energies, beta decay, and the limits of stability.

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R-Process Sensitivities and Measurements

The origins of the heavy elements have continued to be one of the grand challenges for all of science in the 21st century. The recent observation of gravitational waves from two neutron star mergers simultaneously with the spectroscopy showed that rare earth elements are in fact being made in neutron star mergers. While questions remain about sufficient numbers of mergers to account for the observed abundances of the heavy elements in the universe and whether mergers are the only sources of the heavy elements, measurements of the most exotic nuclei that we can make in our laboratories are the most powerful tools for understanding the astrophysical conditions in which the r-process operates. I will present results of our sensitivity studies and quantifications of nuclear uncertainties to point out the most impactful nuclei to measure and the precision with which they should be measured.

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Capabilities of ARIEL

Corresponding Author: garns@triumf.ca

The new beam delivery capabilities of the ARIEL facility offer many exciting science opportunities. Among these new possibilities is access to isotopes of particular importance to characterizing the rapid-neutron capture process. Understanding the mechanisms responsible for creating the elements in our universe is one of the most compelling open questions in contemporary science. I will give an overview of the capabilities of the ARIEL facility which will help answer these questions.

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Opportunities for Nucleosynthesis Studies with TI-STAR and TIGRESS at ARIEL

The goal of the TI-STAR (TIGRESS Silicon Tracker Array) project is to build a new tracking silicon detector, combined with an extended gas target that will fit in the TIGRESS gamma detection array at ISAC-II. Different from (active) gas detectors, TI-STAR will use a silicon tracker with an ultra-thin first silicon layer to track the emitted recoiling nuclei.

In this talk we will focus on the future opportunities of TI-STAR and TIGRESS related to explosive nucleosynthesis studies at ARIEL. One main goal of TI-STAR is to use the intense and clean ARIEL beams to study neutron-capture rates in A=130 and A=200 r-process nuclei. The simultaneous measurement of excitation energy (TI-STAR) and gamma ray response (TIGRESS) will allow to deduce the neutron-capture rates for key nuclei along the r-process via the "Oslo" method. Also, precise spectroscopy of exotic, proton-rich nuclei along N=Z will dramatically improve our understanding of the rp-process. Another topic are indirect studies of low-lying resonance properties in unstable nuclei, relevant to characterize capture rates in the late stages of helium burning in AGB and Wolf-Rayet stars.

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Theory of dark photons and dark sectors

I will review dark sectors—a generic name for new, light particles that couple weakly to the standard model—with a focus on dark photons. Dark sectors have received a large amount of attention in recent years as explanations of a number of experimental anomalies and as the source of the Universe's dark matter, required by astronomical and cosmological observations. I will discuss future prospects to discover dark photons and dark sectors, highlighting new experimental probes.

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Opportunities for Dark Sector Searches with ARIEL

The availability of a high-current electron accelerator at TRIUMF opens novel avenues for dark sector experiments. In particular, fixed-target experiments represent an excellent opportunity for testing dark sector scenarios with high sensitivity. After reviewing some existing experimental proposals, sensitivity calculations for an experiment at TRIUMF taking advantage of the ARIEL beam will be presented.

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TRIUMF e-linac production of weakly-coupled MeV-mass particles

Corresponding Author: behr@triumf.ca

I will discuss backgrounds and possible scenarios using TRIUMF's existing e-linac to produce and detect MeV-mass particles, assuming the previous talks and somewhat dated PPAC submission (daqshare.triumf.ca/~trinat/darkPPAC.pdf).
The recent improved measurement of the fine-structure constant predicts a different electron g-2 compared to experiment, motivating experimentally accessible MeV-mass bosons.
Assuming zero background– essential for sensitivity to increase linearly with counting time– the highest-energy electron beam will always win, as production scales like bremsstrahlung. Yet e-linac experiment backgrounds have two natural plateaus: pion threshold and (gamma,neutron) threshold. Thermal neutrons can produce 10 MeV single-gamma events distinguishable from exotic particles only by direction, so experiments at our low e-linac energies must face this issue both from the cyclotron (the BGO array at DRAGON sees those) and the e-linac .
Neutron damage of electronics in the ISAC mass separator room may prove problematic for that location.

This motivates a scenario that disturbs neither cyclotron beamtime nor e-linac production of neutron rich nuclei:
two pulsed lasers on a photocathode to independently fill the half of the buckets left unused by ARIEL;
Doug Storey's resonant chopper after either the 10 MeV injector (below (gamma,n) threshold on many materials) or the full 35 MeV;
a high-Z detector technology with 10's of psec timing resolution to utilize the 10 psec/1.5 nsec duty cycle for Mev-mass TOF and suppress backgrounds;
a detector after 1.5 meters of tungsten-steel shielding, either in the air in the e-hall to avoid scattered neutrons from the floor or burrowed west to suppress cosmic rays one order. The 10 MeV version appears compatabile with a THz radiation source (see workshop July 5)

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From Nano Materials to Giant Resonances - ARIEL Target Ion Source Opportunities

Corresponding Author: gottberg@triumf.ca

ARIEL will dramatically increase the availability of radioactive ion beams by harvesting isotopes from three target stations simultaneously - a worldwide unprecedented technology - enhancing the scientific output of the laboratory. For the first time, high-power electrons (up to 500 kW) will be converted into gamma rays inducing photonuclear reactions in one target, while two others are being bombarded with protons from TRIUMF's 500 MeV cyclotron. The intrinsic properties of 35-50 MeV electrons are fundamentally different than of MeV neutrons or 0.1 to 2 GeV protons, commonly used for ISOL, calling for a wide range of target ion source development. ARIEL will open new avenues towards functionalized materials, advanced target concepts, and improved ion sources, tailored for meeting tomorrow's demand of exotic and pure radioisotope beams.

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Discussion and Closeout

Corresponding Author: hackman@triumf.ca

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Welcome

Corresponding Author: bagger@triumf.ca