The applications program at ATLAS and CARIBU

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Presenters at the ATLAS user meeting:

Extreme Materials, Development of fast-release solid catchers for rare-isotopes, The development of a new production capability for 211At – **J. Nolen**
Improving Superconductors with Heavy-ion Irradiation – **U. Welp**
CARIBU for Applications – **J. Clark**
Beta-decay spectroscopy for applications – **N. Scielzo**
Applications Nuclear Data Needs – **A.A. Sonzogni**
AMS at ATLAS – **R. Pardo**

Introduction:

A wide variety of applications can be addressed at ATLAS using both the accelerator as well as the low-energy beams of fission fragments provided by CARIBU. Many research programs involving ATLAS are already well-established and could expand if a multi-user capability was added to ATLAS. The applications requiring CARIBU beams are still in their infancy, however, the fission fragment beams coupled to the existing experimental equipment opens up many possibilities for addressing topics related to reactor-based applications.

Applications using ATLAS:

Several material science applications can be addressed at ATLAS. To understand the irradiation damage to fuel and structural materials in a reactor, these components are irradiated by heavy-ions from ATLAS. This approach allows one to achieve dose rates experienced in a reactor over many years in a matter of days. Samples irradiated at ATLAS are then analyzed at the APS, providing a nice synergy between Argonne's two major user facilities. Another successful material science line of research already in existence at ATLAS involves high-energy, heavy-ion irradiation of superconductors. The columnar tracts created by the heavy ions enhance the pinning of vortices, resulting in superior performance of the superconducting material. The variety of ion species, tunable energies, and orientation of sample, allow one to investigate the effects of different size, length, and patterns of tracts through the sample. These material science applications have some flexibility in the beam energy and species and thus, would benefit greatly from a multiuser capability at ATLAS.

An Accelerator Mass Spectrometry (AMS) program has been well established at ATLAS for over 20 years. It has focused on questions related to nuclear astrophysics (^{44}Ti, ^{60}Ni, ^{146}Sm,…) Environmental science (^{39}Ar) as well as basic questions in nuclear physics. Currently ongoing are projects to measure neutron capture cross-sections on samarium isotopes and the MANTRA project (Measurement of Actinide Neutronic TRAnsmutation) which has a very important AMS component based on the development of a laser actinide ablation system using a multisample changer for ECRII as well as an automated beam switching capability for ATLAS. This project is a clear example of the complementarity of the applied program and the basic nuclear physics mission of the lab. The stringent requirements of AMS measurements as related to the transmission and tune reproducibility of ATLAS have actually let to the development of a new sample changer for the source as well as new tuning techniques that ultimately will be very advantageous to the rest of the basic science program.

A final use of ATLAS for applications would be the possibility of medical isotope production. One example is the production of ^{211}Rn, via the ^{209}Bi(^{7}Li,5n) reaction, which is a precursor for the α emitting radionuclide ^{211}At, considered to be a promising isotope for targeted cancer therapy. This effort would benefit tremendously from a multiuser capability, and also not place considerable strain on the available beam time, as just one 8 hour shift every month could provide the US required supply of ^{211}At. Such a program would require a radiochemistry setup to perform separation and handling of the radioisotope, which could pave the way for additional isotope production scenarios.

Applications using CARIBU:

The low-energy beams of fission fragments provided by the CARIBU facility offer a natural opportunity to study many topics related to reactor applications. The currently available equipment, the X-array and Beta-Paul trap, allow for discrete gamma-ray spectroscopy, complete beta-spectra, and beta-delayed neutron measurements. Such information would provide important components to addressing many key issues. Additional devices, such as a total absorption gamma-ray spectrometer (TAGS) or neutron detection systems, would augment and complement these studies. The main requirement for this line of research is a pure CARIBU beam.

The study of nuclei relevant to decay heat and delayed nu-bar of a reactor are the obvious applications which could be addressed by CARIBU. Decay heat is heat in the form of electromagnetic and light-particle radiation emitted by a reactor as the fission fragments beta decay back to stability. The need for precise knowledge of decay heat was recently highlighted by the incident of Fukushima, also becomes essential for planning reactor scenarios with new, innovative fuels. Here, the relevant quantities are the average electromagnetic energy release (gamma-rays and x-rays) and the average light particle energy release (beta’s and electrons). The X-Array with SATURN can provide some of the required information, however, the ideal device would be a TAGS. Delayed nu-bar is the number of neutrons emitted following beta-decay of the fission fragments. This is a crucial quantity which keeps the reactor running at a sub-critical level. Equally important quantities would be the percentage of the beta-decay that proceeds through beta-delayed neutron emission as well as the neutron spectrum. These can be measured directly with the Beta-Paul trap or neutron TOF detectors, while the %beta-delayed neutron branch can be inferred from gamma-rays measured with the X-Array.

A topic which has gained significant interest recently, is trying to understand the flux of antineutrinos from a reactor based on the underlying properties of the beta-decay of all the fission fragments. This has consequences in extracting the theta_13 mixing angle for neutrino oscillation studies as well as understanding of the so-called “reactor antineutrino anomaly”. To calculate the antineutrino flux properly requires accurate knowledge of the beta-decay feeding intensities, in particular the feeding to the ground state or low-lying states. This can be accomplished using SATURN with the X-Array. Also relevant is the shape of the beta-spectrum, as new calculations have indicated that the different shapes produces by allowed versus forbidden transitions could have a measurable effect on the calculation of the overall flux. CARIBU coupled with the Beta-Paul trap provides a unique experimental capability to make precise beta-spectrum measurements and test these new theories.

Conclusions:

In addition to providing some very unique beams and facilities for a number of diverse applications, one very important component of the applications program at ATLAS is the fostering and development of collaborations between the applied community and those making measurements for basic science purposes. Often, the results of basic science experiments will overlap the information required by the applications community and providing an avenue for the needs and results to be easily communicated between the two groups would benefit both communities greatly. Also as seen with the AMS case, the specific requirements of certain measurements have led to the development of new and improved beam tuning capabilities for ATLAS as well as new developments on the ion source side.