**2014 ATLAS User's Meeting - Fundamental Interaction Working Group Report**

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The Standard Model description of the electroweak interaction and fundamental neutrino properties can be investigated in detail by performing low-energy beta-decay measurements at ATLAS and CARIBU. For these efforts, experiments take advantage of specific decay properties of certain radioactive nuclei that can be produced with sufficient yield either by in-flight techniques or by the new CARIBU facility and that can subsequently be isolated and delivered as pure low-energy beams – predominantly through the gas-stopping technique – to the experimental setup. The following four experimental efforts were presented at the workshop:

- Beta-decay correlations in ion traps (Ralph Segel, Northwestern University)
- Beta-decay correlations in atom traps (Peter Mueller, Argonne National Laboratory)
- Fission-product studies and the reactor antineutrino anomaly (Libby McCutchan, Brookhaven National Laboratory)
- EXO and CARIBU (Liang Yang, University of Illinois at Urbana-Champaign)

The first two efforts aim to search for evidence of exotic tensor couplings in the Gamow-Teller beta decay of light isotopes that would indicate physics beyond the Standard Model. These experiments employ novel techniques to trap the isotopes of interest in vacuum and detect the decay products with high precision to extract beta-decay angular correlations:

- The Beta-decay Paul Trap is installed at ATLAS to study the decay of $^{8}$Li and $^{8}$B. High statistics runs have been conducted for $^{8}$Li and the data analysis is nearly complete. The result is expected to provide the best limit on tensor couplings from nuclear beta decay. The first trapping of $^{8}$B has been demonstrated and high statistics data runs are expected shortly. Both isotopes are produced in-flight and are transferred to the ion trap via a gas-stopper. This experiment takes advantage of the unique decay of these isotopes into two alpha particles, which allows angular correlations to be extracted with high sensitivity by measuring the alpha energy difference. This ion-trap system has also been used to develop a novel approach to measure beta-delayed neutron emission by detecting the recoil ion time-of-flight spectrum.
- An atom trap based setup to measure the beta-neutrino angular correlation in the $^{6}$He decay is currently being developed using the tandem accelerator at the University of Washington to produce an intense source of $^{6}$He atoms. First coincidence data from laser-trapped $^{6}$He has been observed and higher statistics data is expected soon. Atom traps provide highly accurate control over the initial condition of the decaying isotope, a precondition for precision decay measurements. The laser-trapping technique can also be applied to other noble gas atoms ($^{19}$Ne, $^{35}$Ar) and alkali and alkaline earth atoms that can be produced in abundance with the higher intensity (up to 10 p$\mu$A) beams now available at ATLAS. Laser polarization of these samples opens up the study of several additional decay correlations in the future.

Experiments for neutrino physics can benefit from specific low-energy beams available at the ATLAS facility – especially with the new CARIBU fission-product source. These isotopes provide the opportunity for development of critical techniques and the measurement of basic decay properties. Examples of these were represented by the two latter presentations:

- The precision measurement of beta-decay energy spectra and branching ratios of specific fission products can help resolve an apparent discrepancy in the measured flux of anti-neutrinos from reactors: fewer antineutrinos are detected near the reactors than theoretically predicted. This reactor antineutrino anomaly may be a tantalizing indication of new physics such as the existence of sterile neutrinos or it may merely reflect insufficient knowledge of the underlying nuclear data. CARIBU can provide the fission-product beams at low energy with the desired intensity and purity (especially after the installation of an MR-TOF isobar separator) that are required for precision decay measurements to resolve this puzzle. The ion trap used to study beta decay and gamma-ray arrays such as the X-Array are well suited for these measurements.
- Neutrinoless double beta decay experiments will be key to determine the Majorana or Dirac nature of the neutrino and possibly to set the overall neutrino mass scale. The EXO experiment uses a time-projection chamber filled with enriched liquid $^{136}$Xe to search for the neutrinoless double beta decay of $^{136}$Xe. Detection of the $^{136}$Ba ion resulting from the decay would eliminate all backgrounds and greatly increase the sensitivity of the experiment. An effort is currently underway to develop an approach that achieves this difficult feat. Radioactive barium ions from CARIBU can be easily monitored by decay counting (unlike stable $^{136}$Ba ions) and have been successfully used to study the ion dynamics of barium in solid xenon. Further studies of the adsorption and desorption behavior of barium ions on various surfaces are planned.

While not represented by a talk, stringent tests of the unitarity of the CKM matrix and limits on the Fierz interference term can be performed by further improving the uncertainty on Ft values for allowed nuclear decays. These efforts involve making very precise measurements of beta-decay Q values, half-lives, and branching ratios for a variety of nuclei. Together with improvements in the nuclear data, improved theoretical calculations of nuclear corrections needed to determine the Ft values are in progress.

The techniques developed for studies of fundamental interactions also have an impact in other fields of fundamental and applied nuclear science. The recoil-ion spectroscopy approach developed to study beta-decay angular correlations is used for study beta-delayed neutron emission which has an impact on nuclear structure, astrophysics, and applications of nuclear science. The laser trapping and laser spectroscopy techniques are also powerful tools for studying nuclear structure and trace isotope analysis.

In conclusion, weak-interaction studies benefit from the development of novel trapping techniques in combination with access to high-intensity pure beams of specific isotopes. The now-completed intensity upgrade of ATLAS is an essential basis for these experiments. Respective shielding requirements around the production targets will have to be taken into account. In addition, the planned multi-user upgrade of ATLAS would be very beneficial for this program as extensive beam time is often needed for detailed studies of systematic effects. Efforts that play an important role for neutrino-related experiments will benefit from the availability of low-energy, high-purity, high-intensity beams from CARIBU in combination with the X-Array and the novel linear Paul trap to study beta-delayed neutron decays. Space limitations at the low-energy beam area at CARIBU are a concern, but the extension of the low-energy area to the former tandem hall will alleviate the situation. It will also ease the installation of specialized experimental equipment such as needed for the R&D work to improve the sensitivity of an experiment such as EXO.