I. HEAVY-ION NUCLEAR PHYSICS RESEARCH

OVERVIEW

This research involves investigating the structure, stability, reactions and decays of nuclei. This information is crucial for understanding the evolution of the universe, the workings of stars and the abundances of the elements that form the world around us. A forefront area of research is investigating the properties of nuclei which lie very far from stability, and which are critical in understanding nucleosynthesis. Most of our research is based at the Argonne Tandem-Linac Accelerator (ATLAS), a national heavy-ion user facility. Programs are also mounted at the Relativistic Heavy Ion Collider (RHIC), at the 88" cyclotron at Berkeley and at other forefront facilities. The major thrusts of the program are: a) deepening and generalizing our understanding of nuclear structure to allow a reliable description of all bound nuclear systems, b) studying the reactions which are important in the cataclysmic events in the cosmos which lead to the synthesis of the chemical elements, c) testing the limits of the Standard Model, the fundamental theory that currently best represents our understanding of the laws and fundamental symmetries of nature.

The specific research topics we are pursuing include the studies of transfermium nuclei ($Z > 100$) with a goal of studying the very heaviest nuclei, the study of the shapes, and stability of nuclei along the proton dripline, the effects of deformation on proton radioactivity, the production and acceleration of short-lived nuclei and their use in measurements of reactions which are important in astrophysics, and the high-precision measurement of nuclear masses. In addition, there are complimentary efforts in the use of Accelerator Mass Spectrometry (AMS) for environmental research; in the investigation of nuclear matter at relativistic energies; and in the dynamics of cooled ions confined in storage rings or traps. The ATLAS-based research exploits the unique capabilities of the accelerator, both in the stable beam program, and in production of accelerated beams of short-lived isotopes. The experiments employ state-of-the-art research equipment, including the Fragment Mass Analyzer (FMA), a large solid angle silicon array, "Ludwig", and the Canadian Penning Trap, (CPT) which is operating at ATLAS. Several new detector initiatives are being pursued including upgrading the FMA, refining the "In-Flight" radioactive beam facility, constructing the Advanced Penning Trap (APT) and developing next generation gamma ray detectors with "tracking" capability. Full participation in the Gammasphere program continues, in publication of results from the Argonne cycle of operation, in performing experiments at Berkeley, and in preparing the scientific case and planning a return of Gammasphere to ATLAS in 2003. Intensive participation in the PHOBOS experiment at Brookhaven has continued, and has lead to the first published results from this project.

Some of the specific goals of the program can be summarized as follows:

- Develop and utilize beams of short-lived nuclei, $^{17,18}F$, ^{21}Na, ^{25}Al, ^{44}Ti, ^{56}Ni, ^{8}B, ^{14}O and others, to improve the understanding of reactions of astrophysical importance. Particular emphasis has recently been focused on "in-flight" production of short-lived ion-species using kinematically inverse reactions on gaseous targets.

- Study the structure, stability, and modes of excitation and decay of the heaviest elements and study of the reaction mechanisms through which they can be synthesized. This research has many facets, including exploring the opportunities for producing the very heaviest nuclei ($Z > 106$), studies of isomeric decays, studies of "fine-structure" in the alpha decay of heavy elements, and "inbeam" spectroscopy and calorimetry.

- Study the shapes, stability and decay modes of nuclei along the proton dripline in order to improve understanding of partially bound nuclei. Studying proton tunneling through deformed barriers, in order to increase the spectroscopic information obtained through proton radioactive decay rates.

- Make high-precision measurements of nuclear masses with the CPT, particularly the masses of $N = Z$ nuclei which are of astrophysical interest and are important for testing CVC theory. Improve the efficiency for production, separation, cooling, transportation, and trap loading of ions to increase sensitivity.

- Developing position sensitive germanium detectors, for "tracking" gamma rays in order to allow the imaging of the source of radiation. The ANL focus has been on developing planar germanium wafer technologies, in parallel with involvement in national plans to construct a 4-π germanium shell, following the GRETA concept.

- Investigate the collisions and deconfinement of nucleons in nuclear matter at very high temperatures and densities that are achieved in relativistic heavy-ion collisions of gold nuclei at 200 GeV/u. Our participation is using the PHOBOS detector at the RHIC accelerator at Brookhaven National Laboratory.

- Perform detailed R&D studies for the Rare Isotope Accelerator (RIA) and participate in all efforts to refine the designs for the accelerators, target stations, post accelerator, and experimental equipment. Intense effort is being directed to development of the "gas catcher" technology for cooling primary beams.