Series Preface

The National Institute for Nuclear Theory Series

The national Institute for Nuclear Theory (INT) was established by the US Department of Energy in March, 1990. The goals of the INT include:

(1) Creating a productive research environment where visiting scientists can focus their energies and exchange ideas on key issues facing the field of nuclear physics, including those crucial to the success of existing and future experimental facilities;
(2) Encouraging interdisciplinary research at the intersections of nuclear physics with related subfields, including particle physics, astrophysics, atomic physics, and condensed matter;
(3) Furthering the development and advancement of physicists with recent Ph.D.s;
(4) Contributing to scientific education through graduate student research, INT summer schools, undergraduate summer research programs, and graduate student participation in INT workshops and programs; and
(5) Strengthening international cooperation in physics research through exchanges and other interactions.

While the INT strives to achieve these goals in a variety of ways, its most important efforts are the three-month programs, workshops, and schools it sponsors. These typically attract 300-400 visitors to the INT each year. In order to make selected INT workshops and summer schools available to a wider audience, the INT and World Scientific established the series of books to which this volume belongs.

In January 2004 the INT and three partners, Argonne National Laboratory, Michigan State University, and the Joint Institute for Nuclear Astrophysics, began a new workshop series to explore scientific questions that might be answered by the proposed U.S. Facility for Rare-Isotope Beams (FRIB). This volume summarizes the proceedings of the fourth workshop in this series, which was hosted by the INT in September 2007 and organized by Alex Brown, Jonathan Engel, Wick Haxton, Michael Ramsey-Musolf,

Michael Romalis, and Guy Savard. The organizers designed a scientific program to provide a broad overview of the potential role rare isotopes could play in tests of fundamental symmetries, such as time reversal and parity. For example, certain short-lived isotopes exhibit enhanced electric dipole polarizabilities, a phenomenon that can be exploited by experimentalists to place tighter constraints on time reversal violation. The workshop proceedings are being published so that this overview will be available to the broader nuclear, atomic, and particle physics communities, as the planning for FRIB progresses. As series editors, we would like to thank the organizers for the considerable effort they invested in designing the scientific program and in editing this volume.

This volume is the 16th in the INT series. Earlier series volumes include the proceedings of the 1991 and 1993 Uehling summer schools on Nucleon Resonances and Nucleon Structure and on Phenomenology and Lattice QCD; the 1994 INT workshop on Solar Modeling; the tutorials of the spring 1997 INT program on Tunneling in Complex Systems; the 1998 and 1999 Caltech/INT workshops on Nuclear Physics with Effective Field Theory; the proceedings of the 1998 RHIC Winter Workshop on Quarkonium Production in Relativistic Nuclear Collisions; the proceeding of Nucleon Resonance Physics (1997), Confinement III (1998), Exclusive and Semi-exclusive Reactions at High Momentum (1999), Chiral Dynamics 2000, and the Phenomenology of Large-N QCD (2002), all collaborative efforts with Jefferson Laboratory; the 2004 workshop on the Astrophysical Origin of the Heavy Elements and the 2006 workshop on Opportunities with Exotic Beams, two earlier volumes from the FRIB series; and the 2004 workshop on Open Issues in Core Collapse Supernova Theory. We intend to continue publishing those proceedings of INT workshops and schools that we judge to be of broad interest to the physics community.

Wick C. Haxton and Ernest Henley
Seattle, Washington, April, 2008

VOLUME PREFACE

The Fourth Argonne/INT/MSU/JINA FRIB Theory Workshop
On Rare Isotopes and Fundamental Symmetries

This workshop on Rare Isotopes and Fundamental Symmetries was held September 19-22, 2007, at the INT. The fourth in a series dedicated to exploring the science important to FRIB, the proposed Facility for Rare Isotope Beams, this workshop focused on the use of radioactive ions in various symmetry tests. It is envisioned that symmetry tests would form a third leg of the FRIB experimental program, in addition to nuclear structure studies and nuclear astrophysics. At existing facilities radioactive beams in combination with atom traps and other instrumentation have opened new opportunities for such measurements. FRIBs expected intensities could help move this field further forward.

The topics discussed at the workshop included:

- Fermi beta decay: Nuclear systems have provided our most accurate determination of the CKM matrix element Vud that is central to tests of quark unitarity.
- Electron-neutrino correlations in nuclear beta decay: Rather precise constraints on new interactions, such as scalar interactions, have already been set with trapped isotopes at facilities such as TRIUMF.
- Precision mass measurements: Mass ratio measurements based on cyclotron frequency measurements in stable trap magnetic fields have enormous potential for constraining Q-values important to neutrino mass measurements (e.g., tritium beta decay), Fermi beta decay, and double beta decay.
- Atomic parity violation: Atomic PNC provides our best low-energy measurement of Qweak. Atomic and nuclear (neutron skin) theoretical uncertainties are a significant issue in the associated analysis. Measurements in isotopic chains have been discussed as a possible strategy for reducing such uncertainties.
- Electric dipole moments: Certain nuclei have enhanced polariz-

abilities due to parity near-degeneracies associated with nuclear structure phenomena such as octupole deformation. In principle enhancements of 3-4 orders of magnitude in electric dipole moments could result. Theoretical issues include the calculation of the "Schiff moment", the residual interaction at the nucleus after atomic screening is evaluated.

- Hadronic parity violation and anapole moments: The parity-violating but T-even anapole moment has been measured in a single atomic nucleus, ^{133}Cs. As in the case of the edm, large enhancements are expected in certain nuclei due to ground-state parity doublets. In other cases, the anapole moment arises from polarization associated with giant dipole collectivity in the nucleus.

The workshop extended over 3.5 days and included presentations from 25 speakers with a mix of theory and experiment. Approximately half of the talks focused on experiments currently under development, some of which would benefit from FRIB beams. Theory talks focused on the progress in nuclear and electronic structure required to extract fundamental properties from the observations. The format allowed for considerable discussion, and included a designated end-of-the day discussion period (though this proved unnecessary, as questions were asked frequently during presentations). The participants included several locals from the atomic physics group and from CENPA. A workshop dinner was held at Ivars Salmon House.

The earlier workshops in this series covered the topics of *The r-Process: the Astrophysical Origin of the Heavy Elements and Related Rare Isotope Accelerator Physics*; (INT, University of Washington, January 8-10, 2004); *Reaction Mechanisms for Rare Isotope Beams* (Michigan State University, March 9-12, 2005); and *Opportunities with Exotic Beams* (Argonne National Laboratory, April 4-7, 2006).