PHYSICS DIVISION
FY 2004 PERFORMANCE EVALUATION REPORT
December 9, 2004

EXECUTIVE SUMMARY

The Holifield Radioactive Ion Beam Facility (HRIBF) operated with beam a total of 4484 hours, with 1667 hours for radioactive ion beams (RIBs), 281 hours for RIB development, 1088 hours for stable ion beam (SIB) for RIB experiments, 560 hours for SIB experiments, 362 hours for equipment development and testing with beam, and 526 hours of machine development. There were 5264 total operating hours for research, startup, and setup. Beam availability was 61.8% and predictability was 89.4%. DOE funded the first phase of a three-phase plan for improving the HRIBF. This plan provides us with a stand-alone research facility, the High Power Target Laboratory (HPTL). A proposal for a second major upgrade, the Injector for Radioactive Ion Species #2 (IRIS2), has been submitted. An upgrade of the Multicharged Ion Research Facility (MIRF) was continued. Critical Decisions 1, 2 and 3a were received for a new Spallation Neutron Source (SNS) beamline for experiments on fundamental properties of the neutron. R&D was begun for laser-purified RIBs for HRIBF and for the proposed national Rare Isotope Accelerator (RIA) facility. The Pioneering High Energy Nuclear Interaction Experiment (PHENIX) at the Relativistic Heavy Ion Collider (RHIC) collected record amounts of data with the heaviest colliding system (gold+gold). Analysis of this and earlier datasets yielded results which suggest that at high enough density, nuclear matter goes through a phase transition. There were 154 publications and 122 talks produced by Division staff, for a total of 276 publications and presentations. Laboratory Directed Research and Development (LDRD), Seed Money, and program development efforts were performed in the areas of fundamental neutron physics, neutron detector development, PHENIX Silicon Vertex upgrade electronics, fast laser design, nuclear structure theory, HRIBF upgrade design, gamma-tracking-detector electronics, neutron star merger calculations, electro-fission produced RIBs, and experimental nuclear astrophysics.

ACRONYMS AND ABBREVIATIONS

AIP: Accelerator Improvement Project
ALICE: A Large Ion Collider Experiment at CERN LHC
ANL: Argonne National Laboratory
APS: American Physical Society
ASIC: Application Specific Integrated Circuit
ATS: Assessment Tracking System
BNL: Brookhaven National Laboratory
CD: Critical Decision
CEBAF: Continuous Electron Beam Accelerator Facility at JLab
CERN: Centre Europeanne pour la Researche Nucleaire, Geneva, Switzerland
CLARION: CLover Array for Radioactive ION beams at HRIBF

CLEO: a detector that captures the collision events at the Cornell Electron Storage Ring
CPU: Central Processing Unit
DNP: Defense Nuclear Programs or Division of Nuclear Physics
DOE: Department of Energy
DP: (DOE) Defense Programs
DRS: Daresbury Recoil Separator at HRIBF
EDM: electric dipole moment (of the neutron)
EM: electromagnetic
ENAM: Exotic Nuclei and Atomic Masses
EOS: equation of state
ESH: environment, safety, and health
F&O: Facilities and Operations (Directorate)
FNPB: Fundamental Neutron Physics Beam-line at the SNS
FY: fiscal year
GenASiS: General Astrophysical Simulation System
GlueX: A project to better understand gluons and QCD at CEBAF
GRETINA: the Gamma Ray Energy Tracking In-beam Nuclear Array
GSI: Gesellschaft fur Schwerionenforschung, Darmstadt, Germany
HEPA: High Efficiency Particulate Absolute (filter)
HFIR: High Flux Isotope Reactor at ORNL
HPTL: High Power Target Laboratory at HRIBF
HRIBF: Holifield Radioactive Ion Beam Facility at ORNL
HVAC: heating, ventilating, and air-conditioning
INT: Institute for Nuclear Theory
IOP: Institute of Physics
IRIS2: Injector for Radioactive Ion Species #2 at HRIBF
ISIS: ISIS Facility, Rutherford Appleton Laboratory, UK
ISM: Integrated Safety Management
ISO: International Organization for Standardization
ITER: International Tokomak Experimental Reactor
JICS: Joint Institute for Computational Sciences
KEK: High Energy Accelerator Research Organization in Tsukuba City, Japan
LANL: Los Alamos National Laboratory
LBNL: Lawrence Berkeley National Laboratory
LDRD: Laboratory Directed Research and Development
LHC: Large Hadron Collider at CERN
MHD: magnetohydrodynamics
MIRF: Multicharged Ion Research Facility at ORNL
MSU: Michigan State University
NASA: National Aeronautic and Space Administration
NCSU: North Carolina State University
NERSC: National Energy Research Scientific Computing (Center)
NIST: National Institute of Standards and Technology
NLCF: National Leadership Computing Facility
NP: Nuclear Physics
NRC: National Research Council

NSAC: Nuclear Science Advisory Committee
NSC: Neutron Sciences Consortium
NSCL: National Superconducting Cyclotron Laboratory (at MSU)
NSTD: Nuclear Science and Technology Division
NSTX: National Spherical Torus Experiment at PPPL
NTS: Noncompliance Tracking System
OA: Office of Independent Oversight and Performance Assurance
OBES: Office of Basic Energy Sciences
OFES: Office of Fusion Energy Sciences
OIP: Operations Improvement Program
ONP: DOE Office of Nuclear Physics
ORELA: Oak Ridge Electron Linear Accelerator at ORNL
ORIC: Oak Ridge Isochronous Cyclotron at HRIBF
ORNL: Oak Ridge National Laboratory
ORO: (DOE) Oak Ridge Operations
OSHA: Occupational Safety and Health Administration
P-AAA: Price-Anderson Amendments Act
PAC: Program Advisory Committee
PCBs: Polychlorinated Biphenyls
PHENIX: Pioneering High Energy Nuclear Interaction Experiment at RHIC
PPE: Personal Protective Equipment
ppm: parts per million
PPPL: Princeton Physics Plasma Laboratory
PSD: Physical Science Directorate
QCD: Quantum Chromodynamics
QGP: Quark Gluon Plasma
QM: Quark Matter
R&D: research and development
RCRA: Resource Conservation and Recovery Act
RCT: Radiological Control Technician
RER: Radiological Event Report
RHIC: Relativistic Heavy Ion Collider at BNL
RIA: Rare Isotope Accelerator
RIB: Radioactive Ion Beam
RIKEN: Rikagaku Kenkyusho, the Institute of Physical and Chemical Research of Japan.
RMS: Recoil Mass Spectrometer at HRIBF
RSS: Research Safety Summary
RWP: Radiological Work Permit
SASI: stationary accretion shock instability
SBMS: Standards Based Management System
SC: (DOE) Office of Science
SciDAC: Scientific Discovery through Advanced Computing
SESAPS: Southeastern Section of the American Physical Society
SIAM: Society for Industrial and Applied Mathematics
SIB: Stable Ion Beam
SLAC: Stanford Linear Accelerator

SNS: Spallation Neutron Source at ORNL
SPC: Scientific Policy Committee
TAMU: Texas A&M University
TM: Technical Manual
TRIUMF: TRI University Meson Facility, Canada
TRU: transuranic
TSI: TeraScale Supernova Initiative
TUNL: Triangle Universities Nuclear Laboratory
UT: University of Tennessee
UTK: University of Tennessee Knoxville

INTRODUCTION

This document provides an analysis and evaluation of progress towards achieving the performance objectives outlined in the Physics Division FY04 Performance Assessment Plan. The evaluation period for this report is October 1, 2003, through September 30, 2004. Strengths and opportunities for improvement are identified. This information will be useful for Division managers as a basis for decisions throughout the year and as input into next year's business planning process.

The Physics Division has developed performance objectives and indicators based on relative risk and Division-specific needs. These objectives and indicators support the Oak Ridge National Laboratory (ORNL) Institutional Plan, the Lab Agenda, the critical outcomes in the UT-Battelle Performance Evaluation Plan, and the Division's own business plan.

PART 1: RESULTS OF THE CRITICAL OUTCOMES AND PERFORMANCE INDICATORS

The Physics Division carries out basic research, both experimental and theoretical, in low-energy and high-energy nuclear physics, nuclear astrophysics, fundamental neutron physics, and atomic physics.

HRIBF R&D

Coulomb Excitation and Transfer Reactions

Two important Coulomb excitation experiments that were performed this year were RIB-124 and RIB-114. RIB-124 was a pilot study of Coulomb excitation of odd-mass beams close to doubly-magic ^{124}Sn. A rare-isotope beam of mass 129, comprising mostly ^{129}Sb and ^{129}Te, was excited by scattering from a ^{50}Ti target. New levels were discovered, and the B(E2; 7/2+ -> 11/2+) value in ^{129}Sb was measured to very small. This technique looks very promising for future studies of odd-mass rare isotopes. RIB-114 was a study of excited states in ^{136}Te, in addition to the known first 2+ state.

A major breakthrough in transfer-reaction studies with rare beams was achieved in RIB-116, when we were able to identify the previously unknown single-neutron i-13/2 state in ^{135}Te. The state was populated by transfer of a neutron from a ^{13}C target onto a ^{134}Te beam, at a beam energy just above the Coulomb barrier (4.3 MeV per nucleon). It was identified through its decay to the known 11/2- state at 1180 keV, as seen in gamma-gamma coincidence data from the CLover Array for Radioactive ION beams (CLARION) array. We were also able to confirm the spin of the new level by means of particle-gamma angular correlations.

Sub-Barrier Fusion Work

We are interested in studying the reaction mechanisms in fusion induced by short-lived neutron-rich nuclei. The first experiment used radioactive ^{132}Sn beams incident on a ^{64}Ni target. A large enhancement of fusion yields was observed at reaction energies near and below the Coulomb barrier. We have extended the measurement to higher energies to study fusion-fission in the same reaction and used other neutron-rich radioactive beams, ^{134}Sn and ^{134}Te, to measure fusion excitation functions.

Low-Energy Resonances ^{17,18}F

New results from HRIBF experiments with unique radioactive fluorine beams are leading to a better understanding of what happens when stars explode. The latest measurements involved scattering ^{18}F off hydrogen in a thick target and transferring a neutron from a deuterium target onto an ^{18}F beam particle. The results of the measurements lead to a factor of two to three decrease in the extracted rates of certain nuclear reactions in nova outbursts. The rates affected are those that destroy ^{18}F that is freshly synthesized in the stellar explosion. When this laboratory information is processed and inserted into an ORNL computer model of the outburst, it was found that three times more radioactive ^{18}F than calculated previously should survive the explosion and be ejected into space. The decay of this ^{18}F should be visible to multi-million dollar orbital satellites and provides an important window into the workings of novae.

G-Factor Experiments

In another first-of-a-kind measurement, we have successfully determined a nuclear magnetic moment using the recoil-into-vacuum technique together with radioactive beams. A beam of ^{132}Te was Coulomb-excited in a carbon target and allowed to recoil into vacuum. Gamma rays were detected in the CLARION array, in coincidence with carbon recoils in the HyBall detector. Gamma-carbon angular correlations show a strong deorientation of the nuclear spin due to its precession in the intense hyperfine field of the highly-charged ^{132}Te recoil. The effect was calibrated using a series of stable Te beams and the same experimental setup. This has allowed us to determine the g-factor of the first 2+ state in ^{132}Te to be 0.35(5).

Decay Spectroscopy Studies

Studies of nuclei very far from beta stability, performed within a large collaboration of the HRIBF users at the Recoil Mass Spectrometer (RMS), were concentrated on the decays of odd-odd proton emitters allowing us to deduce the properties of proton and neutron states around proton drip line. New microsecond radioactivity of ^{144}Tm was discovered and the properties of fine structure in proton emission from N=77 isotone ^{146}Tm were revised. The related measurements involving conversion electron counting helped to understand the evolution of $\pi h_{11/2}\nu h_{11/2}$ and $\pi h_{11/2}\nu s_{1/2}$ microsecond isomeric states in lighter N=77 isotones ^{140}Eu, ^{142}Tb and ^{144}Ho.

A novel technique of ranging-out (separation) of the most exotic neutron-rich component from an isobaric cocktail of post-accelerated beam was developed and tested using stable and radioactive beams. The test measurements of the electron-electron timing for the neutron beta decay project were performed with two high-resolution electron detectors and 40MHz digitizers, while the commissioning of novel digital spectrometers (100 MHz, 12-bit, PCI-standard) has started. The analysis of fragmentation experiments with an ^{86}Kr beam performed at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) allowed us to approach the structure of nuclei near doubly-magic ^{78}Ni. The levels of ^{74}Ni and ^{76}Ni were unambiguously identified and a beta-delayed neutron emission was observed for ^{71}Co, ^{72}Co, ^{73}Co and ^{74}Co decay.

Nuclear Astrophysics

A ^{7}Be beam of intensity greater than 10 million particles per second has been developed for a measurement of the ^{7}Be - proton capture reaction that is crucial to understanding the flux of neutrinos emitted by our Sun. The beam was successfully used for a proton scattering measurement in FY04, and capture reaction data will be taken in FY05. The Daresbury Recoil Separator (DRS) was commissioned with a windowless hydrogen gas target system in preparation for this experiment, as well as others involving capture reactions on radioactive heavy ion beams. Sixteen short commissioning experiments were done utilizing 100 eight-hour shifts of beam to characterize the transmission of the recoils through the separator to 8% and the total gas target thickness to 3%.

A very successful proof of principle neutron transfer experiment was carried out with a beam of stable Sn nuclei in preparation for upcoming similar measurements with beams of radioactive ^{130}Sn and ^{132}Sn nuclei. Our work with N=50 neutron transfer has also been advanced by a very successful measurement with a radioactive ^{84}Se beam. The results of these transfer studies will give insight into the structure of nuclei important in the rapid neutron capture process in supernovae, and demonstrate the viability of a technique touted for years as a cornerstone of astrophysics studies to be done at the future RIA facility. Planning is underway for a test of another technique, this one looking for gamma decays in coincidence with the signature of the neutron transfer, which promises to give significantly higher energy resolution (and thus a more precise experiment) than previous measurements.

A major advancement was made this past year in the Nuclear Data Project with the release of an online suite of computer programs (available at http://nucastrodata.org) that enable the rapid incorporation of new nuclear physics results into astrophysical models.

Users can import their own nuclear data, modify this data, convert it into thermonuclear reaction rates, modify and plot these rates, combine the rates into rate libraries, merge libraries, document the contents of the libraries, share libraries with others in the community, and run and visualize element synthesis calculations with these libraries. This suite is part of our uniquely integrated astrophysics program in which (1) frontier measurements are made with intense, high-purity, high quality radioactive beams, (2) the results are analyzed and then evaluated to determine the best values for measured quantities, (3) these results are processed with our online computational infrastructure and inserted into an astrophysical model, and (4) the model is run and the results visualized with our online tools.

Low-Energy Nuclear Theory

We calculated the ground- and excited-state properties of ^{4}He and ^{16}O using the coupled-cluster technique including triples-corrections. We formulated a method that accurately approximates the shell-model ground state by products of suitable many-body basis states. The optimal factors are determined by a variational principle and result from the solution of rather low-dimensional eigenvalue problems. We calculated rates for electron capture on nuclei with mass numbers A=65-112 for the temperatures and densities appropriate for core collapse supernovae. We find that these rates are large enough that electron capture on nuclei dominates over capture on free protons. This leads to significant changes in core collapse simulations. We also calculated neutral-current neutrino-nucleus cross sections relevant to supernova simulations. Using self-consistent mean-field theory with pairing and exact particle-number projection, we calculated nuclear mass tables. We included, for the first time, proton-neutron correlations in the Gamow continuum shell model. All these techniques are important in developing the theory for unstable nuclei being studied at HRIBF, and later, RIA.

Astrophysics Theory

Significant effort was invested this year to make two critical hires to the Theoretical Astrophysics Group: the hiring of Christian Cardall through the Joint Institute for Computational Sciences (JICS), and the hiring of Raph Hix at the Laboratory. The former is among the first JICS hires. The latter is the first hire, and the first major concerted effort, of the Division's new Astrophysics Program. These two hires now provide the essential kernel of expertise on which the Theoretical Astrophysics Group will be based and from which it can grow. Expertise in modeling stellar explosions; their nucleosynthesis; the expertise needed to bridge the theoretical astrophysics, experimental nuclear astrophysics, and theoretical nuclear physics efforts; and the expertise to help foster the development of a neutrino physics program (from the astrophysics perspective) in the Division are now "in-house." Overall, this was a significant growth year for the Group and Program.

We have added a visiting faculty member, Jirina Stone, of Oxford University, two new postdocs (Eric Lentz and Eirik Endeve), four new students [Mark Baird (UTK), Will Goddard (UTK), Clark Downum (Oxford University), and Will Newton (Oxford University)] to the Theoretical Astrophysics Group, and we have continued assignments for two postdocs (Alex Razoumov and Gergana Stoitcheva) and three students [Suzanne Parete-Koon (UTK), Ted Lee (UTK), and Rueben Budiardja (UTK)] in the Group.

The ORNL-centered Scientific Discovery through Advanced Computing (SciDAC) TeraScale Supernova Initiative (TSI) has sustained its performance as a highly successful large-scale computing initiative. It continues to meet project goals and to deliver on breakthrough science. In addition, it continues to serve as a centerpiece tested for the development of computational science infrastructure for many applications teams in the Office of Science (SC).

One of the scientific breakthroughs this year has been recognized by the Laboratory in the UT-Battelle Awards Night competition. Members of the ORNL SciDAC team are finalists in the Scientific Research category. The work being recognized is the first simulations of stellar core collapse to integrate state of the art neutrino transport and astrophysics with state of the art nuclear structure theory. This work merges efforts of two programs in the Division (Nuclear Theory and Astrophysics Theory), and represents two communities: nuclear physics and astrophysics. It is a highly international effort, involving five nations (U.S., Canada, Spain, Germany, and Denmark). The inclusion of far more sophisticated models of electron capture on nuclei in the ORNL models altered our understanding of the dynamics of stellar core collapse in a significant way, with ramifications for the explosion mechanism and supernova nucleosynthesis. This work led to the publication of two Physical Review Letters, one focused on the nuclear structure physics and one focused on the astrophysics.

Significant progress has been made on the development of GenASiS (General Astrophysical Simulation System), our 2D/3D Boltzmann neutrino transport code. GenASiS is running and has successfully performed some hydrodynamics and radiation transport test problems. Work is underway to use GenASiS to study the neutrino energy deposition in collapsar/hypernova/gamma ray burst models. It has been proposed that neutrino-antineutrino annihilation of neutrino pairs emerging from the inner hot disk around the central black hole will provide sufficient energy to power the supernova and relativistic outflows associated with hypernovae/gamma ray bursts. This mechanism is extremely sensitive to the neutrino transport in and around the disk, and past collapsar models have simply imposed, rather than computed, the energy deposition rate. In fact, hypernovae may be magnetohydrodynamically (MHD) driven and not neutrino driven. The studies mentioned above will compute the energy deposition rate from a first principles solution of the 2D neutrino Boltzmann equations for the 2D neutrino radiation field in a collapsar-like environment. Such a study will go a long way to determine whether the neutrino deposition mechanism is a viable mechanism for collapsars/hypernovae/gamma ray bursts. The next application target for GenASiS will be to use it in the context of fully dynamic 2D core collapse supernova simulations. These simulations are planned for FY05.

We have made significant progress on the development of 2D/3D radiation magnetohydrodynamics simulations of core collapse supernovae. These will deploy sophisticated "ray-by-ray" neutrino transport coupled to 2D/3D magnetohydrodynamics.

This is a stepping-stone to fully 2D/3D simulations that will deploy 2D/3D transport. Nonetheless, the inclusion of sophisticated ray-by-ray neutrino transport will mark a significant advance in realism in 2D/3D models. No contemporary, realistic models of core collapse supernovae that include magnetic fields exist. Therefore, the precise role of magnetic fields in the core collapse supernova mechanism remains unknown. This is one of the last major frontiers in modeling core collapse supernovae, where a solution to the supernova problem might be expected. The simulations mentioned here will be the first contemporary simulations to include magnetic fields and will shed much light on how stellar core magnetic fields evolve and are potentially amplified during collapse and through various instabilities after stellar core bounce, and how they then help drive the supernova dynamics and potentially power the explosion. Perhaps the most fundamental question now in core collapse supernova theory is whether such supernovae are neutrino driven, MHD driven, or both.

We have initiated a new study under TSI during this past FY focused on the high-density equation of state in core collapse supernovae. A central goal of this study is to replace phenomenological models based on the Skyrme parameterizations of the nucleon-nucleon interaction potential with more microphysically motivated models based on quark interactions. Aside from improving the high-density equation of state (EOS) microphysical foundations, this work will also reduce the number of parameters in the models dramatically, from dozens to two. When a new EOS based on the quark models of the nucleon interactions is available, studies that can for the first time investigate the sensitivity of our supernova models to this high-density stellar core physics will be performed.

We have continued studies, now in three spatial dimensions, of the stationary accretion shock instability (SASI) in core collapse supernovae, a new supernova instability we discovered. Recent studies are confirming the possibility that the SASI may in fact be the underlying mechanism, as suggested by us and our colleagues, for producing the observables in core collapse supernovae associated with the most gross asymmetries: the polarization of supernova light and neutron star kicks.

TSI continues to serve as a test-bed for the development of algorithms, methodologies, and technologies for computational science. This past year, TSI played a role in the development of the ORNL Science Exploratorium (PowerWall amphitheater). 3D simulations of the SASI were used to test the visualization hardware and software deployed in the Exploratorium. Remote and collaborative visualization using the state of the art visualization software, EnSight, the Exploratorium, and visualization resources at North Carolina State University (NCSU) were successfully deployed. TSI continued to serve as a test-bed for the development of new networking protocols for remote and collaborative visualization and for the development of an NSF-funded networking test-bed, Cheetah, and for the continued development of new networking paradigms/technologies offered by Logistical Networking.

ORNL TSI members played an important role in the successful National Leadership Computing Facility (NLCF) proposal. They defined one of six computational End

Stations that were proposed and were the heart of the NLCF proposal.

This year saw the publication of our recent nucleosynthesis calculations which revealed the impact of recent HRIBF determinations of the rates of $^{17}F(p,\gamma)^{18}Ne$ and $^{18}F(p,\alpha)^{15}O$ on the elemental production that occurs in nova outbursts. These calculations, which were selected for a press release at the American Astronomical Society's Meeting in January 2003, were the subject of UTK graduate student Suzanne Parete-Koon's M.S. thesis. This year also saw further progress on our Monte Carlo reaction sensitivity studies on novae. This work, which allows us to determine the global impact of all nuclear uncertainties and prioritize reaction measurements, was the subject of several conference presentations and proceedings articles by members of the Theoretical Astrophysics and Experimental Astrophysics Groups. Together with collaborators [at Arizona State, Los Alamos National Laboratory (LANL), and Villanova], we investigated the growth of white dwarf stars toward the Chandrasekhar mass limit. Our simulations are the first to show that accretion onto a massive white dwarf over a wide range of rates can lead to the growth of the white dwarf and ultimately to its demise as a thermonuclear (or Type Ia) supernova. Furthermore, our simulations have observational signatures quite similar to Supersoft X-ray sources, confirming the prior supposition that these objects are the progenitors of Type Ia supernovae. We believe that identifying and studying the progenitors of these supernovae will allow improvements in their use as cosmological distance indicators and therefore further refine our understanding of our accelerating universe. This work was selected for a press release and press conference at the American Astronomical Society's Meeting in January 2004.

Hadron Physics Theory

Since the ORNL Physics Division has a large PHENIX experimental group, topics in the physics of hadrons that are important to the search for a Quark Gluon Plasma (QGP) are of special interest to our group. The specific area we have been investigating in this regard is the problem of the interaction of charmonium with light hadrons. This topic arose from the suggestion by Matsui and Satz that a sudden drop in charmonium production rates might signal the presence of a QGP, since this medium would screen the usual c-cbar confining potential. A problem with this idea is that competing processes in heavy ion collisions, such as charmonium dissociation through collisions with light hadrons, might cause similar reductions in the observed charmonium production rate. Unfortunately, little was known about low-energy inelastic charmonium cross sections; a high-energy diffractive method suggested very small cross sections near threshold to a Brookhaven National Laboratory (BNL) group, but this method was not justified at low energies. Since 1999, we have undertaken the task of calculating these charmonium dissociation cross sections near threshold in a quark model formalism developed by Barnes and Swanson, which uses explicit quark model meson wavefunctions in a constituent interchange model. This model has been tested on many light hadron scattering processes, and is known to give results that compare well with experiment. To date we have evaluated ca. 50 charmonium-light meson dissociation reactions in this model, and we find that the early expectations of negligible cross sections are unjustified; is a typical low energy scale, and many channels, such as J/psi + rho, actually diverge at threshold (for the obvious reason that they are exothermic). Other theory groups using meson exchange models and Quantum Chromodynamics (QCD) sum rules have found results which are numerically rather similar to ours. This 1 mb charmonium dissociation scale has now become a standard in Monte Carlo simulations of RHIC events. In the future, we plan to extend this work to J/psi - nucleon cross sections, as these are also expected to be important in RHIC collisions.

The many recent discoveries in charmonium and open-charm mesons (for example at CLEO, KEK, SLAC, Fermilab and BES), as well as plans for future facilities to study charmonium and light meson exotics (CLEO, BES, Fermilab) have motivated studies by our group of some novel aspects of meson spectroscopy. We have also contributed to these efforts by assisting in writing the physics cases for new facilities (most recently CLEO-c, GSI, GlueX, and Fermilab). Our specific studies have been reasonably complete predictions of the spectrum, and numerical evaluation of all strong decay modes and strong amplitudes, in the $^3P_0$ decay model (for strange mesons, as a recent example, our study considered 43 resonances, all 525 allowed open flavor modes, and evaluated all 891 allowed strong decay amplitudes). Our current study of charmonium, motivated by CLEO-c, BaBar, Fermilab and BES, is evaluating the masses and all strong and electromagnetic (EM) decay amplitudes of all c-cbar states expected to 4.3 GeV (40 states). Next we plan to investigate the very important question of the effects of virtual meson decay loops on the spectrum and composition of hadronic states, first in the relatively well established charmonium spectrum, and then in open charm mesons. These mass shifts are quite large and may explain the surprising light masses of the new D_{sJ}(2317) and 2463 states. They are also a systematic error for Lattice Gauge Theory, since they are neglected in the quenched approximation.

Although neutron sciences is primarily a UT-based activity, and is not directly related to QCD, it is of considerable relevance to ORNL and for this reason, we include a short summary here. Much of the work done at the High Flux Isotope Reactor (HFIR) (and in future work at the SNS) is concerned with studies of magnetic materials, such as hgh-Tc superconductors and nanomagnets. We have been contributing to this work through calculations of neutron scattering intensities from various magnetic systems for several years, and have collaborated on several neutron scattering experiments, at HFIR, ISIS and NIST. We are also contributing to the future ORNL neutron science program by collaborating on two UT neutron science research programs, the Chemical Physics program and the Neutron Sciences Consortium (NSC) (both are joint UT Chemistry and Physics Department projects). The NSC has been involved in training graduate students in neutron science applications, and we have developed a graduate course in Neutron Science for this purpose, which will be offered in Spring term 2005.

Astrophysics at the Oak Ridge Electron Linear Accelerator (ORELA)

In collaboration with scientists from the Japan Nuclear Cycle Development Institute and the Tokyo Institute of Technology, we have developed a new apparatus for neutron capture measurements at ORELA and made the first test measurements with this apparatus. As part of the n_TOF collaboration, we measured neutron capture cross sections in the energy range between 100 eV and 500 keV for ^{135}Cs, ^{151}Sm, and isotopes of Mg, Os, and Zr at the n_TOF facility at the Centre Europeanne Researche pour la Nucleaire (CERN) and at the Forschungszentrum Karlsruhe. We are doing a resonance analysis of the Mg data using the R-matrix code SAMMY.

Fundamental Neutron Physics

The SNS and the HFIR are, or will soon be, the world's most powerful pulsed and continuous neutron sources, respectively. They allow for ORNL to be home to a world-class science program in fundamental neutron physics. Towards this end, the $9.2M project to construct a beamline at the SNS dedicated to fundamental neutron physics made important progress in the last year. Based on favorable results from a series of reviews, DOE granted the project Critical Decisions 1, 2 and 3a, resulting in project funding of $1M last year and allowing detailed design to progress and allowing the purchase of long lead-time components (the innermost portions of the shielding and neutron guides).

In a pair of Lab-funded efforts (described in Part 2) we made progress on developing a novel neutron beamline monitor and on developing an experiment to simultaneously measure four of the neutron beta-decay angular parameters (a, A, b, B), an experiment that is anticipated to run both at HFIR and at the SNS. These projects increased ORNL visibility and expertise in the field of fundamental neutron physics.

We also took the first steps to develop a local fundamental neutron science program. With initial funding from DOE we hired a UT Research Assistant Professor who will pursue optimization and implementation of a fundamental neutron physics beamline at HFIR; will help develop the first experiment at that beamline; and will participate on experiments to measure the electric dipole moment of the neutron (EDM) and to measure the gamma-ray asymmetry in neutron capture on a hydrogen target (npdgamma) – two of the highest priority experiments expected to run on the SNS beamline.

High-Energy Nuclear Physics

This year the operation of the PHENIX experiment at RHIC was led by Physics Division staff member Terry Awes, who served as Run Coordinator. Massive datasets were collected for both proton-proton and gold-gold collisions and Terry received a Significant Event Award for his efforts. Both muon spectrometers (which received major contributions in design, implementation and physics analysis from ORNL staff) were operational. This completes both the baseline and the original upgrade program for PHENIX. Simulation work was performed to optimize shielding against machine backgrounds and significant efforts were made to optimize the Muon Identifier detector performance. As a result of these efforts, the Muon Identifier was able to operate during the highest luminosity portions of nearly all RHIC stores and was better than 93% efficient across nearly its entire area. Communication with the first level trigger, necessary for the upcoming high luminosity proton-proton run, was also commissioned. Analysis of this dataset is underway. Physics Division staff serve on the Executive

Council, on the Speaker's Bureau, on Paper Preparation Groups, on Internal Review Committees, and as Physics Working Group chairs.

ORNL Physics Division staff members developed and published results on the centrality dependent production of direct photons, charged hadrons, charm quarks, J/Psi particles and jet correlations. These results, plus others produced by PHENIX and the other RHIC experiments, have led to a growing consensus that the matter created in the highest density regions of these collisions has undergone a phase transition to a new state of matter in which quarks and gluons, not protons and neutrons, are the natural degrees of freedom. Each of the four RHIC experiments has attempted to synthesize the available data and theory in order to clarify what can be rigorously concluded. PHENIX produced an impressive document, with one ORNL staff member (Paul Stankus) a key member of the writing team.

Further progress towards characterization of the nuclear matter created at RHIC will eventually require new instruments to extend the experimental precision. Key areas of desired improvement include higher-momentum particle identification, precision vertex reconstruction and increased trigger selectivity. After successful completion of a Seed Money project to develop a concept for the electronic readout of a proposed Silicon Vertex detector upgrade to the PHENIX central tracking system, we received R&D funds from BNL to develop prototypes of the various system components. Fabrication of all components is nearly complete, as is development of the on-board firmware and data acquisition system. Full system tests will begin shortly. PHENIX is also considering an upgrade of the forward muon arm detectors. Until now, this upgrade has been primarily focused on increasing level-1 trigger selectivity in proton+proton collisions. However, ORNL staff members recognized that one of the proposed implementations of this upgrade would also help substantially with reconstruction in head-on gold+gold collisions, both in terms of efficiency and computation speed. Due to ORNL expertise with the readout electronics of the majority of PHENIX detector systems, we were able to recognize and suggest an electronics readout chain for this favored implementation that re-uses previously engineered components, thus reducing cost and complexity.

We have implemented a computer farm at ORNL to allow local analyses of PHENIX data. This farm consists of 13 compute nodes, each with dual Intel Xeon 3.06 GHz CPUs and 12 (raw) terabytes of RAID5 storage and has been configured nearly identically to the PHENIX computing farm (the same operating system, database, batch queue, etc.). PHENIX can send different datasets to different local computing farms, where they can remain disk-resident while algorithms and cuts are optimized, thus reducing bottlenecks associated with retrieving files from long-term storage. Our first large-scale project will be analysis of charm production in Run-4 proton+proton collisions via semi-leptonic decay into muons and J/Psi production in Run-5 copper+copper collisions.

On the theory front, new signatures of a first-order phase transition to a Quark-Gluon Plasma state, based on the technique of intensity interferometry were proposed. Mechanisms of J/psi dissociation in the medium created in a heavy-ion collision were quantitatively evaluated. A program to extend these calculations to study centrality dependence and lighter collision species was started.

Upgrade of the HRIBF

The HRIBF is presently the only dedicated radioactive ion beam facility in the U.S. It is a highly visible National User Facility and a facility that will continue to play a crucial role over the next decade as a bridge to the RIA era. RIA (the Rare Isotope Accelerator), is a $1B next-generation radioactive ion beam facility and is proposed as the next major construction project in nuclear physics.

In order to successfully accomplish the mission of HRIBF, we have begun to implement a series of aggressive facility upgrade projects. These upgrades target the enhancement of capabilities such as new beam species, higher intensities, and higher purities. They also target improved operational efficiency and higher reliability. In FY03, the DOE Office of Nuclear Physics (ONP) funded the first major upgrade, a three-year project known as the High Power Target Laboratory (HPTL). This $4.75M project will be completed by the end of FY05 and will address many of the capability enhancement issues by providing a dedicated facility for developing and testing new radioactive ion beam production targets, ion sources, and beam preparation techniques. An annual review of the HPTL Project was conducted by DOE-ONP in late September. Indications were that the review panel was satisfied that the project is on schedule and on budget, although a final report has not been received.

We are presently submitting a proposal for a second major upgrade, a second radioactive ion beam production system. This system, the Injector for Radioactive Ion Species #2 (IRIS2), has a total project cost of $4.7M and will address both operational efficiency and reliability issues by providing much needed redundancy in the RIB production environment. If approved, the project would begin in FY06 and span 3 years. In conjunction with the HPTL mid-year project review in September 2004, the IRIS2 proposal was reviewed for scientific and technical merit, and DOE directed us to proceed with preparations for a cost and schedule review.

The Atomic Physics Program

Supported jointly by the Office of Basic Energy Sciences (OBES) and the Office of Fusion Energy Sciences (OFES), the Atomic Physics Program continues to carry out a combination of fundamental atomic, molecular, optical, and nanoscale science and work immediately applicable in plasma science. Owing to the ready synergy, work is also performed that is supported by the National Aeronautic and Space Administration (NASA) of relevance to astrophysical and space environments. The Group had three active NASA grants continuing in FY04 and five new proposals were submitted.

The Program consists of experimental work centered about the Physics Division's Multicharged Ion Research Facility (MIRF), which is undergoing a major upgrade, described elsewhere in this document, and a theoretical/computational program. The

Group continued to perform a range of work studying the interaction of ions with surfaces and solids, electrons with ions, and ions with atoms, all of which are of basic interest in atomic physics and of practical importance in the development of plasma science. These applications include diagnostic and modeling inputs for existing national fusion experiments such as the National Spherical Torus Experiment (NSTX) at the Princeton Physics Plasma Laboratory (PPPL) and the DIII-D tokomak at General Atomics, as well as for next-step devices such as the ITER fusion reactor. The experimental work was carried out using the MIRF and other facilities such as the heavy ion storage ring in Stockholm, CRYRING. In addition, new facilities are being developed that will soon reach operation such as the new electron-molecular ion laboratory in Building 6010 and full complement of upgraded end-stations for the MIRF that have been designed to more completely take advantage of the capabilities of the laboratory upgrade.

The Atomic Physics Group maintained a vigorous record of publishing, invited talks during the past year, and successfully completed on-site program reviews by both OBES and OFES with very positive responses from the peer review committees and the DOE program officers. The Group also continued a strong performance in development of new work and applications of its expertise and experience. For example, in partnership with the Nuclear Physics and Ion Source Development Groups in the Division and the University of Mainz, the Atomic Physics Group successfully won RIA R&D development funds and carried out initial demonstration work towards a resonance laser ionization source.

Upgrade of the Multicharged Ion Research Facility (MIRF)

The MIRF upgrade, funded to a total of $840K, continued in FY04 with design completion, major procurement, and start of assembly. Upgrading of the user end stations was initiated in FY04 to best utilize the ion beams to be available through the ion source upgrades. These are funded through new capital and operating funds. The upgrade will result in a doubling of the user beam time available, an increase in the number of user ports for end stations, and a tremendous expansion of the collision energy range accessible. This will result in a significant enhancement of the mission driven work for OBES and OFES and will open avenues for new work. Execution of the upgrade is on track for completion in FY05.

Hours RIB on Target

The HRIBF provided 1667 hours RIB on experimenters' targets during FY04. The goal was 1200 hours. The facility produced beam for a total of 4484 hours, which was broken down as follows: RIB experiments 1667 hours, RIB development 281 hours, SIB for RIB experiments 1088 hours, SIB experiments 560 hours, equipment development and testing with beam 362 hours, and machine development 526 hours.

The HRIBF operated a total of 5264 hours for research, including startup and setup. Beam availability was 61.8% for FY04 (outstanding is >50%). Physics Division has added another measure of beam availability, referred to as predictability, which reflects the status of the tandem with facility unscheduled maintenance. This number more accurately reflects the facility availability as it removes the setup and startup/shutdown numbers of the ORIC and RIB platform, which can occur simultaneously with tandem operations. HRIBF predictability in FY04 was 89.4% (outstanding is >85%). The goal was 90%.

During FY04, the HRIBF logged 3.68 billion events to tape. The goal for the year was 5.3 billion events. We have gathered only 69.4% of the anticipated events. This does not reflect any lack of productivity in use of the beam by experimenters. It is merely a result of the nature of experiments approved by the HRIBF Program Advisory Committee (PAC) and the evolution of the experiment mix to an ever-stronger emphasis on experiments with more difficult to produce RIBs.

During FY04, the HRIBF provided 21 stable beam species and 14 RIB species for experiments. Of the 14 RIBs, 7 had not previously been accelerated. Approximately 100 additional radioactive beams have been demonstrated to be feasible (extracted from an ion source) but not yet post-accelerated for use by experimenters.

Publications and Presentations

- Refereed journal articles: 85
- Conference proceedings published in refereed journals: 33
- Total journal articles: 118

- Conference proceedings: 31
- Other: Theses (2), Technical Manual (TM) Report (1), Book chapter (2): 5
- Total Publications: 154

- Oral presentations: Contributed talks (65), Invited talks (57)
- Total presentations: 122

Occurrences

The Physics Division had five reportable occurrences in FY04, as follows:

- Ammonia cylinder leak in Building 6000
- Contaminated printer found during cleanup in Building 6010
- Inadequate receipt inspection hydrogen sulfide lecture bottles in Building 6000
- Contaminated pipe found during cleanup in Building 6000
- Contaminated plastic bag found during cleanup in Building 6010

Three of these occurrences resulted from legacy contamination discovered on materials and equipment during cleanup activities.

Radiological Event Reports (RERs)

The Physics Division had ten RERs in FY04. Seven of the RERs occurred in Building 6000 and three occurred in Building 6010. Seven of the RERs resulted from legacy contamination discovered on materials and equipment during cleanup activities.

Price-Anderson Amendments Act (P-AAA)

Sixteen incidents were screened for P-AAA applicability in FY04; none of these incidents resulted in a Noncompliance Tracking System (NTS) report. The ORNL Assessment Tracking System (ATS) is now used for P-AAA reporting. Quarterly summary reports of all conditions screened were submitted to the ORNL P-AAA Program Office as required by the ORNL Standards Based Management Systems (SBMS) subject area. DOE still has not closed the P-AAA NTS report that was filed in response to the unplanned X-ray exposure incident that occurred in 2001. All corrective actions from this incident were completed in 2002.

Recordable Injuries, Lost Work Day Cases, and First Aid Cases

The Physics Division had no recordable injuries, lost workday cases, or first aid cases in FY04. Physics has worked 4,957,329 hours since the last lost workday case with days away, which occurred in 1975. Physics has also worked 265,024 hours since the last recordable injury, which occurred in July 2002.

Training Deficiencies

The Physics Division had eight training deficiencies in FY04. All of these resulted from retraining completed after renewal deadlines; all training was completed.

Assessment Tracking System (ATS) Actions

One hundred and seven actions have been entered in ATS for FY04; fifty-six are now closed (52%). Twenty-seven actions resulted from occurrence reports, with only one action remaining open. Eight actions are assessment activities; three of these remain open. The remaining seventy-two actions were identified during four quarterly performance assessment inspections; fifty-one of these actions remain open (48%).

PART 2: SUMMARY OF RESULTS FROM LABORATORY DIRECTED RESEARCH AND DEVELOPMENT (LDRD), PROGRAM DEVELOPMENT, AND TECHNOLOGY TRANSFER

Fundamental Neutron Physics

Significant progress was made on the design of an experiment to simultaneously measure four of the neutron beta-decay angular parameters (a, A, b, B). Such an over-constrained set of measurements will be key to reducing systematic errors on the parameters and will make this one of the most sensitive experiments trying to identify physics beyond the standard model of particle physics. This experiment is envisioned to first run at HFIR, where a very sensitive measurement of those parameters not requiring neutron polarization (a,b) can be made as soon as the apparatus is ready. When the fundamental neutron physics beamline (FNPB) at the SNS is operational, the experiment will move there to measure all parameters. Significant progress was made in the development of a thick pixilated silicon detector with a very thin dead layer; a single-pixel version with all required properties is being fabricated. Significant progress was also made on the data acquisition for this experiment. Timing and energy resolution requirements are very stringent and require an extension of digital signal processing techniques pioneered at ORNL; a readout system meeting our specifications has been designed and built. System tests are underway.

<u>Neutron Rich Radioactive Ion Beam Production with High-Power Electron Beams</u>

The science that has been done over the last several years at HRIBF has been truly outstanding. However, in its current form HRIBF cannot meet the level of performance that will be required of it over the next decade. Consequently, we have developed a strategic plan for upgrading our facility that fits well with our understanding of possible funding profiles that are acceptable to the DOE Office of Nuclear Physics. As one possible part of this plan, we have identified an entirely new direction for RIB production using photofission induced by a high-power electron beam, which, according to calculations, might improve the intensities of critical neutron-rich species at HRIBF by two orders of magnitude or more. A project intended to provide with a firm experimental basis for this concept has been supported by LDRD funds since the fourth quarter of FY02 with a total budget of $276,000. With these funds we have conceived, designed, and constructed an experiment to be run at ORELA, which allows us to directly measure the production rate of a variety of particularly interesting neutron-rich radionuclides produced by electron-induced fission. The experiment, which has been carefully optimized by extensive Monte-Carlo simulation and empirical testing of subsystems, involves the transport of radionuclides out of the production region by a jet of aerosol–laden helium gas for subsequent identification and study. The LDRD funds have been highly leveraged since we were able to incorporate into the experiment critical equipment worth in excess of $1M obtained from colleagues at LANL and Chalk River Nuclear Laboratory (Canada). Because of problems at ORELA and the need to complete long delayed experiments there, it has not yet been possible to install and run the experiment. We expect this to be done within six months.

<u>Laser-Produced RIBs</u>

Initial experiments were performed, beginning in FY02, to demonstrate a capability to produce radioactive species through laser-driven heavy-ion bombardment. Potential applications include medical isotope production for diagnostics or therapy, or fundamental unstable ion research. That early work has led to an LDRD proposal, submitted in FY04, to demonstrate production of RIBs through electron acceleration (leading to bremsstrahlung induced photofragmentation) by ultrafast, ultraintense laser pulses. If funded in FY05, the ultimate goal is follow-on funding for a laser-driven RIB source suitable to address future needs of HRIBF.

Other laser-ion source work, resonance laser ionization purification of ion source beams, is also being pursued. An initial grant was made from the DOE R&D program for the proposed RIA project; first experiments were carried out during August and September of 2004. A proposal to follow-up on this successful demonstration of laser-ion production will be submitted during October of 2004. If funded and fully developed, a resonance ionization laser source would significantly add to the capabilities of a future RIA, and to the present HRIBF, to produce desired beams for research.

PHENIX Silicon Vertex Upgrade Readout Electronics

Significant progress has been made in the development of a PHENIX-compatible readout of a novel silicon detector (two-dimensional readout with a single-sided process) using the SVX4 chip, a pre-existing Application Specific Integrated Circuit (ASIC). System tests with an ORNL-developed test-board and control program were promising and as a result, we received R&D funds from BNL to develop a complete functional prototype of the readout electronics.

Neutron Beam Monitor Development

The goal of this Joint Seed Money project (with NCSU) is to develop a neutron detector with nearly 100% efficiency, $1cm^2$ position resolution and modest energy resolution capable of handling the high rates ($100\ MHz/cm^2$) expected at the HFIR and at the SNS. The proposed detector concept is a merger of a segmented ionization chamber design that was successfully used in a preliminary measurement of the neutron spin rotation in a liquid helium target at NIST and the neutromegas technology currently being developed at ORNL as a low-efficiency transmission beam monitor for the SNS. We will use ^3He as both fill gas and neutron converter and will optimize gas mixture, pressure, and drift length to obtain the desired performance.

NCSU has designed and is constructing the pressure vessel that will hold the detector, and has designed and is constructing a gas handling system. ORNL is fabricating micromegas detector plates, copies of the plates used in the prototype neutromegas detector. ORNL has built printed circuit boards (modified versions of boards developed for general use at the SNS) that will readout the detector signals and has written modified firmware to control electronics operation.

Program Development: Proposal for a Topical Center for RIB Theory

We developed and wrote a proposal for a Topical Center for RIB Theory which was submitted to the Nuclear Theory Program at DOE in March 2004. The proposal aims to prepare nuclear theory for the advent of RIA. The proposal involves thirteen senior researchers at eight institutions with ORNL as the lead institution. If funded, the Center will be administered through the ORNL Physics Division and the Joint Institute for Heavy Ion Research.

Program Development for IRIS2 Proposal

Program development support was used to do preliminary engineering and cost schedule development for the IRIS2 new ion source for HRIBF.

Electronics for Gamma-Ray Tracking

A Seed Money project was continued to develop a novel preamplifier for very low noise and low power readout of silicon strip detectors to be used for gamma-ray tracking. The preamplifier has been assembled this year and is prepared for testing. This could be used for tracking gammas emitted from galactic sources, a topic of great interest in astrophysics.

Towards Neutron Star Merger Simulations

The project advanced the development of a code to be used to simulate astrophysical systems involving hot and dense nuclear matter, such as neutron star mergers and supernovae, which are believed to be the engines of gamma-ray bursts. This code, named GenASiS (General Astrophysical Simulation System), will solve the equations of self-gravity, fluid dynamics, and energy- and angle-dependent neutrino radiative transfer, all with adaptive refinement of the spatial mesh. The developments in FY04 were: design and implementation of the distributed gravity solver for the adaptive spatial mesh; addition of a realistic nuclear equation of state to the fluid dynamics; addition of a second order upwind flux scheme and a Riemann solver flux scheme to the fluid dynamics; tests of self-gravitating fluid dynamics problems, which led to ongoing refinements in the method of mutual solution of fluid dynamics and gravity on the adaptive mesh; design and implementation of a distributed table of realistic neutrino interaction kernels; inclusion of realistic neutrino emission and absorption interactions in the neutrino transport solver; and basic visualization of fluid dynamics variables on the adaptive mesh.

PART 3: SUMMARY OF RESULTS FROM INFRASTRUCTURE IMPROVEMENT, OPERATIONS IMPROVEMENT PROGRAM (OIP), AND LAB RESERVES-FUNDED INITIATIVES

Office Moves

In 2003, Physics Division began preparations for relocating personnel from Buildings 6000 and 6011 to Buildings 6010 and 6025. Space in Buildings 6010 and 6025 was cleared and prepared. Two conference rooms in Building 6025 were upgraded, including the addition of a new HVAC system, new audio/video systems, and new bookcases and furniture. Doors were moved, a suspended ceiling was installed, walls were painted, bulletin boards were installed, and telephone and computer lines were installed. Additionally, furniture from Building 4500N was disassembled and moved to Buildings 6010 and 6025 for the new occupants. The facility renovations took about a year to complete.

Lab Space Cleanup Initiative

In support of the Laboratory's newly implemented Lab Space Management Program, Physics Division conducted a comprehensive cleanup campaign in FY04, targeting excess hazardous materials and surplus equipment. Two Contamination Monitors surveyed materials for almost five months, at a cost of approximately $150k to the Physics Division. Of particular note is the work completed in Building 6010, which freed a significant amount of space for research. Much work remains do be done though. One Contamination Monitor will return to Building 6010 in FY05 for a short time to finish surveys of excess materials suitable for Property Sales.

Legacy Waste Cleanup Initiative

The Physics Division is hopeful that the Laboratory legacy waste cleanup initiative will continue to help us. At 2.9% in FY05, our share of the legacy tax will be around $500k. We have taken advantage of the following legacy cleanup initiatives:

- Gas cylinders
- ~500 old vacuum pumps, compressors, and motors (PCBs, mercury, rad)
- 223 legacy chemicals from Building 6000, room 107 in FY03
- 104 legacy chemicals from Building 6000, room 107 in FY04
- 4 unserviceable explosive squibs from Building 6010

Asbestos in Physics Division Facilities

Floor tiles and pipe insulation are the primary sources of legacy asbestos in Physics Division facilities. PCB-detectable (<50 ppm) and PCB (>500 ppm) insulated electrical cable, some with asbestos insulation, is used in some applications in Division facilities.

Beryllium Contamination in Physics Division Facilities

The ORNL beryllium baseline inventory and sampling activity identified a few areas in Physics Division facilities where beryllium surface contamination levels exceed DOE limits. Cleanup has been completed in the following areas:

- A hazardous material storage cabinet where beryllium is stored, located in Building 6000, room T201
- Overhead light fixtures in Building 6000, room C112 where beryllium was once used
- Two gloveboxes and associated ductwork in Building 6000, room C112

Overhead light fixtures in the F&O shop also have beryllium contamination. The light fixtures are not in a breathing zone and airborne contamination is not a concern, therefore, warning signs are the only controls that have been implemented by F&O.

PCB Contamination in Physics Division Facilities

- PCB-detectable (<50 ppm) and PCB (>500 ppm) insulated electrical cable, some with asbestos insulation, is used in Physics Division facilities
- Two milling machines from Building 5500, now stored in Building 6005, have PCB concentrations <50 ppm (one also has known radioactive contamination, the other is suspect) and are on the Laboratory's Legacy Materials list
- Used oily filters from the ORELA vacuum pump exhaust baghouse have PCBs in concentrations >50 ppm, but <500 ppm
- Purple paint on the elevator doors in Building 6000 and on a pressure vessel in Building 6005 have PCBs in concentrations >500 ppm

Legacy (Radiological) Contamination in Physics Division Facilities

The inactive 14MeV neutron generator in the Shield Test Station at ORELA has internal tritium contamination (5 tritium targets, 5 curies each, were used) and has been identified as a potential candidate for the FY05 Laboratory legacy waste initiative.

PART 4: SUMMARY OF RESULTS FROM SELF-ASSESSING ACTIVITIES

Self-Discovered Events

- FY03 radioactive sources over hazard category 3 limit for nuclear facilities
- FY04 hydrogen sulfide lecture bottles, receipt inspection error
- Legacy contamination events

The first two events are similar in that they relate to safety limits, specifically, failure to recognize and enforce all elements of the safety limits, resulting in less than adequate hazard controls.

In the case of the radioactive sources that were discovered to be over the hazard category 3 limit for nuclear facilities, the limit was recognized, but because exclusions to the rule were misinterpreted, the limits were unintentionally exceeded. Some sources did not have the necessary written pedigrees and had to be re-encapsulated. This deficiency was discovered during an annual inventory verification exercise.

In the case of the hydrogen sulfide lecture bottles ordered as "short-fills" but received fully charged, limits were recognized and procurement paperwork was inspected, but the tags on the cylinders themselves were not inspected. The tags indicated the true weight of the fill, much more than the requested weight. The lecture bottles needed to be short-filled to ensure that a release would not result in exposures above permissible limits.

Corrective actions included enhancing our procurement form to ensure that requests with special inspection requirements are identified and can be tracked. This discrepancy was discovered after an ammonia cylinder leak (see self-disclosing events) prompted a revalidation of all gas cylinder use and storage practices in the Division. We also now check total and tare weights on receipt of short-fill lecture bottles.

Legacy contamination discovered during cleanup activities resulted in seven (out of ten) RERs and three (out of five) occurrences reported in FY04. The Physics Division hired two Contamination Monitors for a period of approximately five months to survey surplus materials and equipment for release. The fact that legacy contamination continues to be found validates the need for radiological surveys for future cleanup activities.

Physics Division Performance Assessment Inspections

The Physics Division Performance Assessment Program continues to strengthen and support our mission. Quarterly walk-through inspections have proven beneficial for heading off potential problems. The new Assessment Tracking System (ATS) is used to track actions from quarterly walk-through inspections. One hundred and seven actions have been entered in ATS for FY04; fifty-six are now closed (52%). Twenty-seven actions resulted from occurrence reports, with only one action remaining open. Eight actions are assessment activities; three of these remain open. The remaining seventy-two actions were identified during four quarterly performance assessment inspections; fifty-one of these actions remain open (48%).

Safety observations made during quarterly walk-through inspections typically include housekeeping, waste disposal, facility maintenance, and OSHA-related safety requirements. Radiological protection concerns are few, and when identified, are resolved expeditiously. As in past years, most of the safety observations in FY04 were either electrical safety or OSHA-related issues.

Top Ten Priority Actions

- Lithium hydride in sprinklered room under stairwell Building 6010 (water reactive)
- Backup power for exhaust fan in battery room Building 6000 (hydrogen accumulation)
- Ventilated cabinets for toxic or pyrophoric gases (not an immediate need)
- Move cooling tower switches (or wear respirators)
- Eyewash upgrades at ORELA (drench hoses not hands-free)
- Upgrade smoke detectors, alarms over beds in 6000 (per fire protection engineering)
- Electrical transformer Building 6003 (water accumulation during rain storms)
- Radioactive waste backlog
- Teach staff to use the Hazardous Material Inventory System (from hydrogen sulfide lecture bottle occurrence)
- Update and consolidate Physics Division training

New and Revised Standards Based Management System (SBMS) Requirements

New requirements resulting from the issuance of SBMS subject areas or procedures are to be fully implemented 60 days after issuance unless otherwise addressed with an implementation plan or an agreement with the management system owner. Changes in the following SBMS subject areas will have an impact on Physics Division operations.

- Conducting Critiques (approved facilitators)
- Cyber Security (sanitization utilizing degaussing)
- Excavation/Penetration Permits (surveys for utilities)
- HEPA Filters (differential pressure gauges and inspections)
- Hoisting and Rigging (lift plans)
- Pressure Vessels (implementation plan for legacy pressure vessels)
- Respiratory Protection (PPE for cooling towers)
- Spill Response (use of HEPA vacuums requires RWP)
- Work Control for Operations, Maintenance, Services (work plans)
- Work Control Lab Space Management Program (certify space, control access)

Lab Space Management

In January of 2004, the Laboratory implemented a Lab Space Management Program. Lab Space Managers were identified for every workspace covered by a Research Safety Summary (RSS). By the end of January, all Lab Spaces in the Physics Division had been inspected against a safety checklist provided by ORNL and were certified to be safe or placed in inactive status. In support of the new Lab Space Management Program, an extensive cleanup campaign was also conducted, lasting six months. Of particular note is the work completed in Building 6010, which freed a significant amount of space for research. As much work remains, cleanup will continue in FY05.

The Lab Space Management Program has had a considerable impact on the Physics Division. First, significant improvements in housekeeping and utilization of space are evident. Second, more rigorous safety reviews are resulting in increased attention to detail and Lab Space Managers are taking a more active role in addressing safety-related matters.

Physics Division Lab Space Managers have expressed concern with SBMS requirements for controlling access to Lab Spaces. Physical access controls (badge/prox cards or keypad codes) have been used successfully for many years at the HRIBF and ORELA facility, but access controls for individual Lab Spaces has never been considered. Several improvements are planned in this regard.

- A Physics Division Lab Space Management procedure will be developed to communicate expectations and guidance will be developed to assist Lab Space Managers in implementing requirements.

- The control for passive access (passing through without conducting work) to Lab Spaces will be facility access training, unless access to the space is otherwise controlled by locks, signs, postings, etc.
- Building 6000 access training will be reviewed and updated and Building 6010 access training will be developed to ensure passive access controls exist for all Lab Spaces.
- The control for active access (conducting experimental work or operations in support of experimental work) to Lab Spaces will be site-specific HazCom training and/or required reading of applicable Research Safety Summaries.
- A variety of methods are currently used to provide hazard information to F&O personnel who conduct maintenance in Lab Spaces; including but not limited to, F&O work plans, pre-job briefings, and facility specific training.

Other Assessments

- ORNL ISM Maturity Assessment
- ORNL Independent Oversight Review of PSD Performance Assessment Program
- PSD Maturity Assessment ISM in R&D (verification of RSS controls)
- PSD Verification No Unknown Chemicals (during OA-40 audit)
- Extent of Condition Review Glovebox Fire (during OA-40 audit)
- SBMS Maturity Assessment of Training Management
- SBMS Maturity Assessment of Radiological Protection
- SBMS Gas Cylinder Safety Assessment
- Physics Division Laser Safety Assessment

Waste Minimization

ORNL has established a goal to reduce routine regulated solid waste generation by 25% for FY04 and 50% for FY05 (compared to the FY04 waste generation forecast). Note that the FY04 waste generation forecast was prepared by the Waste Management organization, not by Physics Division.

	FY04 Forecast	FY04 Actual
Hazardous Waste	325 kg	0 kg
Mixed Waste	110 kg	49 kg
Low Level Waste	19 m3	0
TRU Waste	0	0

Hazardous waste generation in FY04 included 26 kg of excess, out-of-spec explosive squibs from ORELA and 601 kg of PCB wastes (capacitors, hydraulic door closures, and ballasts). These wastes are classified as legacy, rather than routine, and are not included in the ORNL waste reduction efforts.

Mixed wastes in FY04 included 49 kg of PCB contaminated oily filters from the ORELA baghouse and 81 kg of PCB ballasts and capacitors removed from the ORELA accelerator room. While the contaminated oily filters are routinely generated in support of on-going operations, the ballasts and capacitors removed from the ORELA accelerator room are classified as legacy wastes and are not included in the ORNL waste reduction efforts.

PART 5: SUMMARY OF RESULTS FROM EXTERNAL ASSESSMENTS AND SELF-DISCLOSING EVENTS AND CONDITIONS

DOE Reviews

An annual review of the HPTL Project was conducted by DOE-ONP in late September at the midpoint of the project. Indications were that the review panel was satisfied that the project is on schedule and on budget, although a final report has not been received. Minor suggestions for improvement were offered, but no significant concerns were noted.

A proposal was submitted to DOE for a second major upgrade to the HRIBF for an additional radioactive ion beam production system, the Injector for Radioactive Ion Species #2 (IRIS2). This system has a total project cost of $4.7M and will address both operational efficiency and reliability issues by providing much needed redundancy in the RIB production environment. If approved, the project would begin in FY06 and span 3 years. Coincident with the HPTL annual review, the IRIS2 proposal was reviewed for scientific and technical merit. The panel responded favorably and we anticipate that, following receipt of a final report, we will be asked to proceed with preparations for a cost and schedule review in the spring.

We have set up external review/advice mechanism for HRIBF via the Scientific Policy Committee (SPC) for HRIBF. We have standing inputs via the HRIBF and RHIC PACs. Reports from both the SPC and PAC are discussed regularly with the relevant DOE sponsors.

In February and March, three-year program reviews of the entire Atomic Physics Program were held by OBES (February) and OFES (March). The reports are highly complimentary of the Group’s research, management, and MIRF upgrade work. Increased base program funding, in excess of 14% of the existing program base, has already been received, together with targeted capital funds for the MIRF upgrade and its endstations.

The proposed fundamental neutron physics beamline at the SNS underwent numerous project reviews this year. These reviews were very favorable and resulted in receipt of Critical Decisions 1, 2 and 3a.

The Heavy Ion Physics Program was the first of the four DOE-ONP subprograms to undergo a four-year programmatic review. This review occurred in January and was focused on the four-year plan of each of the national lab programs in heavy ion physics. The report supported the Group’s physics focus for PHENIX, its participation in the PHENIX upgrades, and the proposed move to LHC.

In June NSAC was charged with reviewing the entire U.S. heavy ion physics effort. This review was not aimed at performance of individual groups, but rather on prioritizing RHIC operations, RHIC detector upgrades and establishment of a U.S. program at the LHC in the context of a constant-effort budget. The final report presented to NSAC recommended reducing RHIC running time, if necessary, to fund the RHIC upgrade and LHC programs, thus endorsing the commitment to ensure a long-term program at RHIC. Among the highest priority recommendations from this review committee were the PHENIX Silicon Vertex Detector Upgrade and participation in the LHC; both efforts have strong participation by ORNL.

External Assessments of Physics Division

Office of Independent Oversight and Performance Assurance (OA-40) ESH Management Assessment

- Physics Division received an overall rating of "effective performance" on ISM core functions 1-4
- Finding #5 (assigned to DOE): ORO and SC have not performed functions, including developing guidance and approving safety basis revisions, consistent with the expectations of DOE Order 420.2A and have not provided sufficient guidance and oversight to ensure that the Work Smart Standards process provided a set of standards and requirements that establish adequate and appropriate ESH protection for all aspects of accelerator operations.
- Finding #6 (assigned to Physics): The ORNL Physics Division's implementation of requirements for approved written procedures does not ensure that all operations and activities are conducted in accordance with approved procedures.

Physics Division anticipates adopting the new DOE Order 420.2B on Accelerator Safety. A corrective action plan to address OA-40's concerns with use of approved written procedures has been developed. The following improvements are planned, including:

- Establishment of a Division Document Control Program and clarification of requirements for procedures, guidelines, and operational aids
- Review of HRIBF operations documents to ensure DOE Order 420.2B requirements for approved written procedures are addressed
- Assessment of new procedures

ISO-14001 Environmental Management System Audit

- ORNL successfully obtained ISO-14001 registration
- Physics Division was praised for having positive attributes related to staff training and qualification.
- Physics Division's purchasing program was praised for reviews of hazardous material procurements

- The use of links in Research Safety Summaries was praised, a practice that Physics Division has implemented

Self-Disclosing Events

- FY04 ammonia cylinder leak, failure to control hazard

The ammonia gas supply system for the HRIBF stable injector was installed around 1990 and preventative maintenance had not been performed in many years. The pressure regulator failed, allowing 115 psi in the nylon tubing. Two small holes were discovered in the nylon tubing that connected the cylinder regulator to the supply valve. The ammonia cylinder was not listed on the facility hazardous material inventory, so the potential for a total release had not been recognized or evaluated. A thorough evaluation of all gas cylinder storage/use in the Division was conducted in response to this incident. Changes in gas cylinder storage, inventory kept on site or in a lab, and construction of gas delivery systems were made as analysis of specific cases indicated.

PART 6: ORGANIZATION STRENGTHS AND AREAS FOR IMPROVEMENT

Strengths

HRIBF staff have created the only facility in the U.S. for post-accelerated RIBs and provide the only beams of neutron rich RIBs. Unique research opportunities are thus presented to the national and international nuclear physics community.

The Division is the anchor institution for one of the leading, and the largest, computational efforts in the world to study core collapse supernovae: the DOE SciDAC TeraScale Supernova Initiative. It also houses a unique Astrophysics Program based on extensive collaborations between astrophysics theory, nuclear theory, nuclear data, and laboratory nuclear astrophysics experiments with unique radioactive beams.

Physics Division contributes to the national and international conference organization, including: the RIA summer school at Argonne National Laboratory (ANL) in July 2004, the SESAPS meeting in November 2004, the Exotic Nuclei and Atomic Masses (ENAM) conference in September 2004, the Quark Matter (QM) 2004 and 2005 conferences, and the Institute for Nuclear Theory (INT) Program on Supernovae and Gamma Ray Bursts (INT-04-2), June 21 - August 27, 2004.

As first noted in the FY02 Physics Division Performance Evaluation Report, there existed a need to improve the design process and scheduling for the MIRF upgrade. These needs were addressed in frequent meetings of the Atomic Physics Group, increased communication on a day-to-day basis among the Group regarding the upgrade, accelerated consideration of the upgrading of the experimental end stations to take advantage of the upgraded ion beams to be delivered, and increased diligence regarding project management and reporting to the Division Director. With the nearing of completion of the MIRF upgrade, it is clear that this increased diligence is paying off in improved progress. Continued diligence should see the project to completion in FY05.

Physics Division staff are very involved and proactive with respect to ESH. The staff participate in work reviews and inspections; they develop and present training, write procedures, and implement corrective actions. The Lab Space Management Program imposed many new requirements that had to be completed in a very short time, but the staff rose to the challenge.

A unique challenge for the Physics Division is providing quality training in a timely manner to the literally hundreds of visiting scientists who come to the Division accelerator facilities each year to participate in experiments. Physics has developed a system that assures that all experimenters have the correct training before engaging in any experimental work, even if they come to ORNL in the middle of the night or the middle of an experiment. Web-based training has been developed to address most aspects of experimental work in the Division. HRIBF research staff supplement the web-based training with comprehensive site-specific HazCom training developed specifically for the major HRIBF user end stations, including the Recoil Mass Spectrometer (RMS), Daresbury Recoil Separator (DRS), and the Enge split-pole spectrograph (a magnetic device originally designed by Harold Enge for Scanditronix Corporation). With the exception of Rad Worker Practical Factors training provided by the HRIBF Radiological Control Technicians (RCTs), and the site-specific HazCom briefing, visiting scientists can take all of their required training before arriving at Physics Division facilities. Physics Division's comprehensive training program was praised by both the OA-40 and ISO-14001 assessment teams.

Physics Division has been working at reducing the legacy footprint since 1994. Hundreds of obsolete power supplies, controllers, and other electronic apparatus have already been salvaged or disposed of, including a fair amount of oil-containing power supplies that were managed as PCB waste. Chemical inventories have been purged of unwanted reactive metals (we still have and use reactive metals), poisons, unknown gas cylinders, out-of-spec explosive squibs, and other hazardous materials. Physics has a backlog of radioactive waste. A new gamma counting system was obtained and several of the operations and research staff were trained on its use.

Physics invests time annually in proposals for new work. Successful ones are mentioned here and those needing work are noted in the next subsection. A proposal for upgrading the HRIBF via addition of a High Power Target Laboratory was funded and a follow-on proposal to add a new ion source, IRIS2, has been told to proceed to cost schedule preparation following a review of the scientific and technical merit. A proposal for adding a physics beamline to the SNS was awarded CD's 1, 2 and 3a. Several external proposals for NASA funding in areas of nuclear and atomic astrophysics were successful. The SciDAC program on the Terascale Supernova Initiative received continued funding. The proposal for an upgrade to PHENIX by adding a silicon micro-vertex detector is steadily being developed in collaboration with BNL, and ORNL has been assigned a role in the version submitted by BNL management to DOE, and initial R&D funding has been received. A specific proposal for capital funding for apparatus to use with the MIRF was funded. Proposals will be submitted in FY05 and FY06 in response to expected solicitations on reaction theory and continuance of the TSI SciDAC effort, respectively.

A strength of the division is service by many division staff on national and international committees and editorial boards. This assures contact with colleagues in many areas of importance to us, allows division staff input to policy-making bodies, and improves our own research and operations via exchange of ideas. A partial list of such service is given here. One or more division staff serve on each of the following national and international committees and in the following professional positions:

- 68th Annual Meteoritical Society Meeting
- Advisory Committee for TRIUMF, NRC Canada
- APS/DNP Nuclear Physics Summer School Steering Committee
- APS Neutrino Study working group
- APS Bethe Prize Committee
- Atomic and Nuclear Data Sheets editor
- DOE Computational Science Graduate Fellowship Howes Scholar Committee
- DOE review committee for the HIGS project at TUNL
- DOE review committee for TAMU RIB upgrade
- DOE/NSF Nuclear Science Advisory Committee
- Editorial Board of Reports on Progress in Physics, IOP, United Kingdom
- GRETINA Management and Executive Committees
- Institute for Nuclear Theory Program on Supernovae and Gamma Ray Bursts
- IOP's Journal of Physics G editorial board
- LBNL Director's review committee for the Nuclear Science Division
- NSAC subcommittee for RIA-GSI comparison
- PHENIX executive committee
- Program Advisory Committee, Center for Gyrokinetic Simulation of Turbulent Transport of Burning Plasmas, PPPL
- RIA Steering Committee, Chair
- RIA Steering Committee
- RIA Theory Working Group Executive Committee, Chair
- RIA Theory Working Group Steering Committee
- RIA Summer School Directorate
- RIKEN Facility (Japan) International Advisory Committee
- Michigan State University NSCL Users Exec Committee
- NERSC Users Group Executive Committee (NUGeX, 1999-2005)
- SESAPS
- SIAM Conference on Computational Science and Engineering
- University of Chicago review committee for ANL Physics Division

<u>Opportunities for Improvement</u>

Facility maintenance/upkeep needs continued attention. The ORIC part of HRIBF is 40 years old, the Tandem part is 20 years old, and both areas need continued rejuvenation. Annual site visits by DOE Office of Nuclear Physics staff have been used for each year since HRIBF became operational to make the case for continued AIP funds and capital allocations, as well as for support for ongoing engineering and crafts staffs dedicated to HRIBF to maintain our knowledge base. We must add a mechanical engineer for HRIBF.

We need a significant capital upgrade for ORELA. ORELA has not had a major capital improvement program in 20 years, and the difficulties caused by this lack of rejuvenation are now evident. Extensive repairs to ORELA were performed during FY04. This required borrowing staff from other divisions to help with manpower as well as respond to staff absence due to illness. Capital investment funds were obtained from DOE ONP and partial operational support funds were obtained from DOE DP. Return of an NSTD staff member from overseas assignment allowed work on refurbishing the injector gun for ORELA to be completed. By late summer 2004, ORELA was turned on again and brought to 5 kW beam power, and initial neutron scattering experiments were performed. Reliability remains an issue, with electron gun lifetime and vacuum issues remaining chief problem areas. Securing increased and more stable funding is also needed. One research staff member was lost (illness). A new technician was hired to replace him. Funds have been found for a second technician, who must be hired soon to help with repeated problems with the electron gun that prevent regular operation.

An engineering study is being conducted to determine if settling problems in Building 6025 can be fixed or if the rear of the building needs to be demolished and rebuilt. One corner of the building is on bedrock, the rest of the building is not and is settling, causing significant structural damage. Additionally, tree roots have damaged drainpipes under Building 6025 resulting in kitchen and bathroom drains that are no longer functional. There are also roof drains running through the interior of some offices in Building 6025 that get clogged with leaves, causing the drain lines to fill up with water, which then slowly leaks out inside the offices. Carpet and floor tiles have developed mold and mildew, which smells terrible. Even after cutting back tree branches overhanging the roof, these leaks are still occurring.

The Division’s plans for a neutrino facility at the SNS have been resurrected due to recent exciting developments in neutrino physics and heightened expectations that neutrinos play a key role in generating supernova explosions. Simulation of these explosions is a major computational effort in the Division and this facility would provide key input data. This effort was embraced by Lab management at the Spring 2003 Leadership Retreat and by the SNS (which has worked with us to identify a suitable location and calculate neutron-induced backgrounds). Significant progress has been made towards completing a proposal suitable for submission to DOE. Submission has been delayed while awaiting an NSAC review of the entire field of neutrino physics. The experimental program was highlighted in the recently released APS report on neutrino physics, which greatly increases its chances for favorable review and inclusion in DOE’s program plans. Timely completion of this process will allow facility commissioning when SNS first reaches full power.

A proposal to extend the PHENIX jet measurement by joining a large heavy-ion experiment, ALICE, now under construction for the CERN Large Hadron Collider (LHC), has been updated extensively and reviewed by NSAC. NSAC strongly advocated U.S. participation in the LHC heavy ion program, but did not select from among competing proposals. We are in communication with DOE in order to decide how to proceed.

Other proposal areas need further development. A concept for an electrostatic storage ring for atomic and molecular physics as applied to plasma physics applications has been sketched out. This proposal is still being developed and must identify interested scientists and sponsors (NASA being identified as the principal targeted sponsor), but is making progress on the relevant fronts. The Atomic Physics Group needs continued improvement in its established funding base to be able to focus away from financial issues. Development here has focused on the above-noted electrostatic ring, ultrafast lasers, and a focused computational effort in support of the International Tokomak Experimental Reactor (ITER). The work on gamma-astronomy has begun electronics front-end development but is on a rather slow track and would benefit with more discussions with the Naval Research Lab. The Majorana experiment on neutrinoless double beta decay received the highest marks in the APS neutrino study noted above; the Division needs a formal plan to participate in this, building on the present rather informal one. The Rare Isotope Accelerator (RIA) remains the top construction priority for the Office of Nuclear Physics. The Division is developing plans for an experimental program at RIA and the apparatus to support it, and has some work on laser-purified ion sources approved as a part of the national RIA R&D plan, but needs to develop a larger overall plan for participating in the construction of the accelerator. The Low-Energy Group runs the risk of becoming stretched thin between existing commitments and the exciting new ones presenting themselves, not only at FNPB and in neutrinos, but also in other areas under discussion. The Division thus needs a plan for expanding this Group’s personnel base. The Division sees opportunities in Homeland Security matters but as yet has not found an area for concentration that could take advantage of the Division’s strengths in X-ray, gamma-ray and nuclear particle detection and detector development. This year’s LDRD proposals for advanced computing were not funded despite the Division’s strong existing computational programs, suggesting better alignment with either Lab and/or DOE focus areas may be needed for further progress in building up this area.