INEL5— Single-Crystal Chopper Spectrometer —Reference Instrument WBS 1.7.12
Technical Note ANL/SNS/98-10
 R. K. Crawford – 12/11/98

1 Instrument Description

1.1 Overview

INEL5 is designed for the study of relatively high energy cooperative excitations in single crystals. Figure 1 provides a schematic representation of INEL5, and Table 1 gives the parameters for this instrument. The use of linear position sensitive detectors provides good vector Q resolution, and the coverage of a large solid angle at low scattering angles permits sampling of the necessary regions of reciprocal space to follow the dispersion of these excitations. The instrument is optimized for studies with relatively high incident energies (tens to hundreds of meV), but can also be used with incident energies as low as 10 meV. Provision is made to allow addition at a later date of a detector bank at higher scattering angles in order to enhance the capabilities for the lower energy transfer studies.

Fig. 1. Schematic plan view of the single-crystal chopper spectrometer INEL5.

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The front cover shows images of Maria Goeppert Mayer who shared the Nobel Prize for her work on the nuclear shell model which she performed while at the Argonne Physics Division, and Enrico Fermi, Nobel Prize winner whose ideas and early work at Argonne stimulated many of the research programs in the Physics Division.

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PHYSICS DIVISION
ARGONNE NATIONAL LABORATORY

DESCRIPTION
OF
THE PROGRAMS AND
FACILITIES

April 1999

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Edited by Karen J. Thayer

INTRODUCTION

The ANL Physics Division traces its roots to nuclear physics research at the University of Chicago around the time of the second world war. Following the move from the University of Chicago out to the present Argonne site and the formation of Argonne National Laboratory, the Physics Division has had a tradition of research into fundamental aspects of nuclear and atomic physics. Initially, the emphasis was on areas such as neutron physics, mass spectrometry, and theoretical studies of the nuclear shell model. Maria Goeppert Maier was an employee in the Physics Division during the time she did her Nobel-Prize-winning work on the nuclear shell model. These interests diversified and at the present time the research addresses a wide range of current problems in nuclear and atomic physics.

The major emphasis of the current experimental nuclear physics research is in heavy-ion physics, centered around the ATLAS facility (Argonne Tandem-Linac Accelerator System) with its new injector providing intense, energetic ion beams over the full mass range up to uranium. ATLAS is a designated National User Facility and is based on superconducting radio-frequency technology developed in the Physics Division. A small program continues in accelerator development.

In addition, the Division has a strong program in medium-energy nuclear physics carried out at a variety of major national and international facilities. The nuclear theory research in the Division spans a wide range of interests including nuclear dynamics with subnucleonic degrees of freedom, dynamics of many-nucleon systems, nuclear structure, and heavy-ion interactions. This research makes contact with experimental research programs in intermediate-energy and heavy-ion physics, both within the Division and on the national and international scale.

The Physics Division traditionally has strong connections with the nation's universities. We have many visiting faculty members and we encourage students to participate in our programs for performing thesis research.

The Division in early 1999 has 105 full-time members [36 regular scientific (Ph.D. level) staff, 19 postdoctoral appointees and visitors, and 50 technical, administrative, and secretarial personnel] and an annual operating budget of about \$17 million. On average, the Division annually supports 50 graduate and undergraduate students.

HEAVY-ION PHYSICS

One of the major programs in the Argonne Physics Division is research at the Division's superconducting linear accelerator, ATLAS. At this facility, nuclear collisions between complex nuclei are studied using the full range of stable isotopes, both as a target nucleus and as a projectile. Over the last few years a program of studies with beams of short-lived isotopes (e.g. radioactive beams) took place as well. The research addresses key questions about the structure and dynamics of the nuclear many-body system. The major thrusts of this program are three-fold: a) the understanding of the nucleus as a many-body system built of protons and neutrons and governed by the strong force, b) the exploration of the origin of the chemical elements and their role in shaping the reactions that occur in the cataclysmic events of the cosmos, and c) tests of the limits of validity of the Standard Model, the fundamental theory that currently best represents our understanding of the laws and fundamental symmetries of nature.

The specific current research topics include the development and acceleration of short-lived nuclei and their use in measurements of cross-sections of astrophysics interests as well as in nuclear structure and reaction dynamics studies; the production and study of nuclei at the very limits of stability, in particular the discovery of new proton emitters near the drip line and the study of the level structure of very heavy elements ($Z > 100$) at the limits of Coulomb stability; the study

of exotic nuclear shapes, including superdeformation; the delineation of the physics governing dynamics of reactions between heavy nuclei such as fusion, fission, transfer and deep inelastic reactions; tests of current descriptions of the weak force.

All these programs are carried out with the use of experimental equipment located in several target areas. For example, the Fragment Mass Analyzer (FMA), a combination of electric and magnetic dipoles, separates the exotic nuclei produced in fusion reactions between two heavy nuclei from the intense primary beam and disperses the reaction products at the focal plane of the instrument according to their charge to mass ratio. Thus, the instrument provides mass identification. The instrument is being used, among other things, to study the properties of nuclei at the very limits of stability.

Fig. 1. The Gammasphere array in front of the FMA in the experimental area at ATLAS.

At the present time, the Gammasphere array is located at the target position of the FMA (Fig. 1). Gammasphere is the national gamma-ray facility. A consortium of scientists from the national laboratories (Argonne, Berkeley and Oak Ridge) and many universities designed and built Gammasphere. The project was coordinated by scientists at Lawrence Berkeley National Laboratory, and the device was first assembled there. It consists of 110 large volume, high purity germanium detectors, each in a bismuth germanate (BGO) Compton suppression shield. The device is especially powerful for collecting gamma-ray data following the fusion of heavy-ions. It has high granularity, which allows many gamma rays to be measured simultaneously, and permits precise correction for Doppler shifts. As such, Gammasphere is the world's most powerful spectrometer for nuclear structure research. One of the main motivations for the move of Gammasphere to ATLAS is in the unique opportunity to study the properties of nuclei located far from the valley of stability by coupling the power of Gammasphere with the channel selection/identification of the FMA.

Another major instrument installed at ATLAS is the Canadian Penning Trap (CPT) built by a collaboration between Argonne National Laboratory, the Chalk River Laboratories, the University of Manitoba, McGill University and Texas A&M University. The CPT is a powerful tool designed for the precise determination of the atomic masses of short-lived isotopes produced with ATLAS. The CPT is designed to perform mass measurements with an accuracy in the 0.01 to 0.001 ppm range.

A multi-purpose scattering facility is used for reaction studies with a wide variety of particle detectors, including time-of-flight systems that make use of the picosecond pulse width of the sharply-pulsed beams from ATLAS. Two magnetic split-pole spectrographs are also available for high-resolution studies in energy and in mass of a multitude of reaction products from collisions between complex nuclei. Provisions also exist to accommodate gas targets and to surround the target location with other charged-particle and/or gamma-ray detectors. Several general-purpose beam lines are available for use with experimental equipment to be brought in by users of the facility.

One of the many research programs at the FMA aims at testing the very limits of nuclear stability. For example, proton radioactivities from neutron-deficient nuclei can be measured at the focal plane of the instrument. A number of proton emitters, including the heaviest known one, ^{185}Bi , were discovered at ATLAS and, recently, first evidence for deformed proton emitters was found in ^{131}Eu and ^{141}Ho . With Gammasphere used in conjunction with the FMA it was even possible to correlate gamma rays emitted at the target with the nuclei detected subsequently at the FMA focal plane. In this way it was possible to show that a sequence of rotational levels exist in ^{141}Ho on top of the proton emitting state. In another experiment, the high-spin states in the transfermium nucleus ^{254}No were identified for the first time by using the Gammasphere-FMA combination. This becomes the element with the highest Z for which the level structure was identified. The ground-state band and the derived deformation show that this nucleus is deformed, supporting theories that calculate the shell-correction energy responsible for the stability of superheavy elements.

Another topic of research in nuclear structure is the study of collective excitations in nuclei. These investigations range from studies of the properties of very elongated nuclei (so-called superdeformed nuclei) to the identification of the various vibration modes that nuclei can experience. First evidence for the existence of an "island" of superdeformed nuclei around ^{192}Hg was obtained at ATLAS some years ago following calculations by an Argonne theorist. Since then, properties such as (1) the quantum numbers and energies, (2) the stability of the nucleus under the stress of rotation, (3) the role of the pairing force at large deformations, (4) the nature of collective excitations in the superdeformed nuclear potential, and (5) the mechanism responsible for the decay out of the superdeformed states toward the nuclear ground state were performed. Most of these experiments were performed with Gammasphere. Recently, first evidence was also found for the evolution with spin and rotational frequency of an octupole vibration into a deformed octupole rotation in a series of Coulomb excitation measurements performed with Gammasphere on $^{238-244}\text{Pu}$ nuclei using $^{207,208}\text{Pb}$ beams from ATLAS.

One of the main research programs at the CPT concentrates on mass measurements of nuclei with mass > 60 having the same number of protons and neutrons (so-called super-allowed beta emitters). These mass determinations have a direct impact on the determination of the fundamental weak vector coupling constant. High-accuracy mass measurements on selected stable isotopes of great current interest, such as the ^{76}Ge and ^{100}Mo (these two nuclei are candidates for double beta decay), are planned.

The acceleration of unstable beams is rapidly becoming one of the highest priorities in low-energy nuclear physics. First measurements at ATLAS began with the successful acceleration of beams of ^{17}F ($t_{1/2}=65$ s), ^{18}F ($t_{1/2}=1.8$ h), ^{21}Na ($t_{1/2}=22.5$ s), ^{25}Al ($t_{1/2}=7.2$ s), ^{56}Ni ($t_{1/2}=5.9$ d) and ^{56}Co ($t_{1/2}=77$ d). A large fraction of the research program focuses on measurements of cross sections of interest in astrophysics. For example, the competition between the reactions

$^{18}\text{F}(p,\alpha)^{15}\text{O}$ and $^{18}\text{F}(p,\gamma)^{19}\text{Ne}$ was studied at energies encountered in stars because these reactions are of importance for the so-called break-out of the hot CNO cycle. Other experiments with beams of short-lived nuclei addressed issues of importance in nuclear structure --such as the measure of spectroscopic factors in nuclei around ^{56}Ni -- and in reaction dynamics.

Finally, a research program also uses the Relativistic Heavy-Ion Collider at Brookhaven National Laboratory to study the behavior of nuclear matter at high density by exploring collisions between relativistic heavy ions. Studies focus on particle production, phenomena associated with collective flow and in-medium modification of meson masses.

MEDIUM-ENERGY PHYSICS

Medium-energy physics research at Argonne explores the structure of nucleons, nuclei and the fundamental interactions between the constituents of nuclei. The Argonne program emphasizes studies in which the quark-gluon structure of nucleons can be revealed. It is usually simplest to do this using the precise spatial resolution of high-energy probes with complementary studies of the impact of this substructure on low-energy properties of nuclei. Staff members lead and collaborate in research projects at a variety of national and international research facilities. They design, develop and construct innovative detector systems and targets for this research.

In recent years, the medium-energy group was involved in studies of muon scattering by nuclei at Fermilab in Batavia, IL (FNAL); and in electron scattering at both the NPAS facility of SLAC at Stanford, CA, and the VEPP-3 storage ring in Novosibirsk, Siberia. Currently, the program focuses on leading a comprehensive set of experiments at the nation's newest nuclear physics facility, the Thomas Jefferson National Accelerator Facility (Jefferson Lab) and on measurements of how the spin of the neutron and proton is carried by the quarks in the HERMES experiment at DESY in Hamburg, Germany. At FNAL, research now focuses on the measurement of the properties of the sea of light quark-antiquark pairs in the proton in the production of high-mass virtual photons in high-energy proton-nucleon collisions.

Jefferson Lab is the culmination of two decades of focus in nuclear physics for a facility with continuous (100% duty factor) multi-GeV beams of electrons. Electromagnetic probes can penetrate deep into the nucleus with excellent resolution and the high duty factor is essential to measure accurately the properties of the particles which are knocked out by these interactions. Argonne helped define the configuration of the first experimental area to be operational at Jefferson Lab, Hall C, and constructed the Short-Orbit Spectrometer (SOS), one of the two spectrometers that comprise the primary instrumentation of Hall C (see Fig. 2). The SOS is a broad-acceptance spectrometer (momentum range 0.2-2.0 GeV, 40% momentum acceptance, solid angle ~ 9 msr) that was designed to have a relatively short (7.4 m) flight path, a crucial feature for the detection of unstable particles such as pions and kaons. The rigid structural design of the spectrometer permits measurements out of the scattering plane.

In November 1995, Argonne scientists led the first Jefferson Lab experiment, a study of the propagation of protons from 300 to 1800 MeV through the nuclear medium by knocking the protons out of a nucleus with the electron beam. This experiment builds on previous ANL work at MIT and SLAC to provide significant tests of the single-particle model of the reaction. This work was quickly followed by another extension of ANL measurements at SLAC to observe the breakup of the deuteron into a proton and a neutron by 0.8- to 4.0-GeV photons. At large scattering angles, the energy dependence of this reaction appears to count the number of constituent quarks which participate in the reaction. While this behavior is well established for the proton and pion, deuteron photodisintegration is the only nuclear reaction which has been found, thus far, to have this property. Experiments on the electroproduction of kaons, short-lived particles that contain strange quarks, capitalize on the unique design features of the SOS. The

Fig. 2. Hall C at TJNAF was the first hall available for research at this new facility. The SOS spectrometer, constructed by ANL, is on the left of the scattering chamber. It is optimized to detect the hadrons in $(e, e'X)$ coincidence reactions. The 6-GeV/c HMS spectrometer forms the other component of this spectrometer pair which will be used by the entire nuclear physics community for many experiments.

experiments will determine the kaon production characteristics on the proton and neutron, and the electromagnetic form factor of the kaon.

Experiments on the helium isotopes will begin the study of hypernuclei, nuclear systems containing strange quarks, at Jefferson Lab, including the intriguing possibility of narrow Σ hypernuclear states. Low-energy theories of the nucleus describe the nucleon-nucleon interaction by the exchange of meson, primarily pions. Measurements of the production of pions on few-nucleon systems by longitudinally-polarized virtual photons directly probe this description of the nuclear dynamics.

At higher energies, the HERMES experiment (Fig. 3) directly probes how the spin of the proton is divided between the quarks and gluons by measuring the deep inelastic scattering of polarized electrons from polarized targets of hydrogen, deuterium and ^3He . A major advantage of the HERMES experiment is that its large-acceptance geometry makes possible the detection of the coincident hadrons in the reaction, giving sensitivity to the flavors of the quarks which carry the spin. Argonne constructed a Cerenkov counter for particle identification of these hadrons. In 1997-98 Argonne led a project to significantly upgrade the hadron identification capabilities of HERMES with the installation of a Ring Imaging Cerenkov counter (RICH). This dual-radiator detector now provides complete hadron identification from 2-20 GeV and a powerful flavor tag for the struck quark.

Recent ANL measurements of di-muon production in 800-GeV proton-induced reactions on hydrogen and deuteron clearly demonstrate that, contrary to a long-held assumption, the distribution of up antiquarks in the proton is quite different than the distribution of down antiquarks. This result provides new insight into the structure of the proton and its surrounding meson cloud. A new experiment at FNAL will extend these measurements to very high antiquark fractional momenta by making use of the intense 120 GeV proton beams of the new Main Injector. Subsequent experiments with secondary meson beams will address the quark and gluon distributions of mesons.

Fig. 3. The HERMES detector for internal target spin physics in the HERA ring at DESY. This experiment began measuring deep inelastic scattering data in 1995 on the spin structure of hydrogen, deuterium and ^3He . The beam enters from the left.

At the opposite end of the energy scale, Argonne scientists are exploring the new opportunities made possible by the technology of laser atom traps. Laser atom traps provide a very unique, selective environment for many studies. A demonstration project is set to push the limits of trace element analysis for noble gas atoms such as krypton isotopes. ^{81}Kr isotope abundance measurements can be applied to date old groundwater on the time scale of 10^5 - 10^6 years. ^{85}Kr provides a sensitive monitor for fission fragments. Cold atoms also appear to be a promising new area to improve tests of time-reversal symmetry in electric dipole moment experiments on radon atoms. Atomic techniques are also being used to study isotope shifts of radioactive atoms produced in the Division's ISOL test stand.

THEORETICAL PHYSICS

The theoretical physics group consists of six staff members, four postdocs, and a number of students, visitors and retired staff. The principal areas of investigation are non-perturbative quantum chromodynamics (QCD), intermediate-energy nuclear physics, nuclear many-body problems, and heavy-ion reactions. The group has many collaborators at other research institutions in the United States and around the world.

The QCD work is based on the Dyson-Schwinger equation and models the effective gluon and quark propagators that provide confinement and asymptotic freedom. It has been successful in describing a variety of hadronic properties, most recently the electromagnetic pion form factor and $\pi\pi$ scattering. The approach is complementary to lattice QCD simulations but requires far smaller computer resources.

The role of mesons, nucleon resonances, and relativity in nuclear dynamics is the focus of efforts in intermediate-energy nuclear physics. These include the study of nucleon-nucleon scattering up to 2 GeV and a variety of few-nucleon reaction problems where non-nucleonic degrees of freedom are important. A major recent success is the explanation of threshold pion-production in the reaction $pp \rightarrow pp\pi^0$, which depends on the accurate knowledge of short-range meson-exchange currents. Work is also performed on relativistic quantum mechanics and a light-front formulation for electromagnetic interactions relevant to a variety of electron-scattering experiments, such as those performed at CEBAF.

The research in many-body problems is aimed at developing a consistent picture of nuclear structure, stability, and reactions starting from realistic two- and three-nucleon potentials. Recently a new nucleon-nucleon potential was constructed which incorporates charge-dependent and charge-symmetry-breaking terms and gives an excellent fit to both pp and np elastic scattering data. This model is being used in calculations of few-body nuclei like ^3H , ^4He , ^6Li , ^7Li , and ^8Be , larger near-closed-shell nuclei like ^{15}N , ^{16}O and ^{40}Ca , nuclear matter and neutron stars. These calculations provide the first microscopic demonstration of the relative stability of these nuclei and are being used to study nuclear response to electron and (p,n) probes and low-energy electroweak reactions of astrophysical interest.

The focus of our heavy-ion research is the collision dynamics accessible to the ATLAS accelerator. This includes a unified coupled-channel approach which can describe simultaneously elastic and inelastic scattering, particle transfer and fusion processes. This formulation is being used to study an extensive array of data on heavy-ion collisions at a few MeV/nucleon. Theoretical calculations are also carried out on rapidly rotating nuclei, the rotation initiated by peripheral heavy-ion collisions, which can lead to superdeformed nuclear states. This work successfully predicted regions in the periodic table where superdeformed states were subsequently discovered at ATLAS. Extensive theoretical work is also going into the study of the structure and reactions of halo nuclei, like ^8B and ^{11}Li , which have become experimentally accessible in the last few years.

A large part of the theoretical effort is based on computer modeling of nuclear systems. Extensive use is made of the massively parallel IBM and SGI supercomputers at Argonne.

THE ATLAS FACILITY

The ATLAS facility is a heavy-ion accelerator system designed for precision studies in nuclear physics and other areas of science. As shown in Fig. 5, the accelerator consists of several major components: two injectors, a positive-ion injector (PII) and an alternate tandem electrostatic accelerator, which serve as sources of low-energy ions, followed by two stages of superconducting heavy-ion linear accelerator (linac), the BOOSTER section, and the ATLAS addition. A small part of the linac was first operated in 1978, the world's first ion accelerator based on the phenomenon of superconductivity. Since then the linac has been used steadily for research and has been gradually increased in size, capability, and reliability to its present status as a major facility capable of accelerating nuclei throughout the entire periodic table to energies above the Coulomb barrier for nuclear reactions.

A recent addition to the ATLAS facility is the positive-ion injector, completed in early 1992. It consists of an electron-cyclotron resonance (ECR) ion source and a superconducting injector linac (Fig. 5) optimized for low-velocity ions. Highly-charged ions produced in an ECR source are analyzed, bunched and then fed into the superconducting linac for further acceleration.

The ECR source and low-velocity linac provide an injection accelerating voltage of 12 Megavolts. PII increases beam intensities by 100 fold over those achieved with the tandem injector and, in addition, allows the acceleration of ions of all elements up to and including uranium to energies sufficient to overcome the Coulomb barrier between the heaviest nuclei. Also shown at the left side of Fig. 5 is a new ECR ion source, which was commissioned during 1998. This new source is of an advanced design, which further upgrades beam intensities for ions of any mass, and especially extends ATLAS's capabilities for the heaviest masses.

ATLAS is a National User Research Facility and is used by scientists from many institutions in the United States and some from abroad. Running time for proposed experiments is allocated by a Program Advisory Committee. The experimental areas of ATLAS contain many state-of-the-art instruments which include two scattering chambers, two magnetic spectrographs, and beam lines for atomic physics experiments and for general-purpose use. Two large experimental facilities, a Fragment Mass Analyzer (FMA) and the Argonne Positron Experiment (APEX) are shown at the upper right side of Fig. 5. In the Fall of 1997 a large array of gamma detectors, called Gammasphere, was moved from Berkeley to ATLAS and installed at the FMA. It has been used at ATLAS for a wide variety of experiments beginning in January of 1998. Another new program at ATLAS is based on the Canadian Penning Trap which was moved to ATLAS from Chalk River, Canada in 1997.

Fig. 5. The ATLAS facility.

There is currently a strong interest in nuclear physics experiments which are made possible through the use of high-quality secondary beams of short-lived isotopes, which do not occur in nature. Several such beams have been developed and used for research at ATLAS during the past couple of years. Plans are also being developed for a major upgrade of ATLAS to greatly extend its capability in this frontier area of nuclear physics.

COMPUTING FACILITIES

The Physics Division operates several clusters of computers (Fig. 6). These clusters reflect the natural division of tasks found within the Division. General computing, support of secretarial and support staff computing needs are provided by the Vax/VMS General Computing Cluster. Its primary task is to allow the various PCs and Macintoshes access to shared resources such as disks and printers.

Operation of the ATLAS accelerator facility is handled by the ATLAS Operations Cluster. Data acquisition for ATLAS-based experiments is done on a pair of DEC 3000/300's which serve as backend hosts for a pair of the Michigan State University DAQ systems. Data are analyzed on both the Alpha/VMS Cluster and the Unix Cluster. The Unix Cluster was expanded with the procurement of additional Linux work stations and upgrading previous Pentium 90 models to Pentium 200's. In addition, there are 2 single-purpose computer clusters--a 4-processor SGI Origin 200 which is dedicated to numerically-intensive computations, and a pair of 500-MHz VMS Alphas which is part of the Brookhaven E917 collaboration in which Argonne participates.

Fig. 6. Physics Division Computer Network

The Medium Energy Physics Group operates its own VMS and Unix Clusters which are used for data analysis and CAD, while the Theory Group operates a pair of IBM RS6000s which is used to program development and numerical computation. Large numerical computations are done on the ANL IBM SP2, the ANL Origin 2000, the Cornell IBM SP2, and the NERSC Crays.

The Division network consists of a CISCO Router/Gateway, which connects it to the Laboratory-wide networks and allows access to the Internet.

TARGET DEVELOPMENT LABORATORY

The Physics Division operates a target development laboratory that produces targets and foils of various thicknesses and substrates, depending on the requirements, for experiments performed at the ATLAS and Dynamitron accelerators. The targets are prepared from both naturally occurring materials and stable isotopes which are supplied either in pure, elemental form or as stable compounds. Targets are made not only for the Physics Division but also for other divisions at the Laboratory and occasionally for other laboratories and universities.

As part of ATLAS support, carbon stripper foils of $2 \mu\text{g}/\text{cm}^2$ for use in the Tandem, as well as other thickness for additional stripping are being routinely produced by the target lab. Also prepared are various forms of isotopic source material used for the production of enriched beams at ATLAS. This includes reducing separated isotope into a form and shape suitable for introduction into PIIECR and SNICS sources. Procurement of stable and enriched material for ATLAS consumption continues to be provided by the target laboratory staff.

The target development laboratory includes state-of-the-art equipment used for thin-film fabrication. The available techniques consist of multiple resistive heating, focussed ion beam sputtering, glow-discharge plasma deposition, electron beam and electron bombardment evaporation, electrodeposition and mechanical rolling. The evaporators are maintained under high vacuum and each vessel contains a quartz-crystal film-thickness monitor with deposition rate indicators. Also included are movable shutters, quartz-lamp substrate heaters and thermocouple temperature sensors, allowing for complete process monitoring during target deposition.

Other auxiliary equipment used for target development includes a small rolling mill, an alpha particle counting chamber, inert atmosphere glove box, laminar flow clean bench, pellet press, equipment for electrodeposition, a reduction furnace, and a variety of precision balances. A turbo-pumped target storage facility is in operation for maintaining, under high vacuum, those targets which readily oxidize in air. This system utilizes computer-controlled circuitry to prevent targets from exposure to atmosphere during power interruptions. A second storage system employs a bank of vacuum desiccators connected to a mechanically-pumped manifold for use by individual experimenters. An additional system consisting of two large glass desiccators and small turbo-pump system has been constructed for material storage. This allows a separation of this material storage from the target storage desiccators, hence eliminating their exposure when transferring and retrieving targets.

A low-level radioactive source and target preparation laboratory has been established at a separate location within the Division that is dedicated to the production of these sources and targets. Available preparation techniques include multiple resistive heating, electrodeposition and mechanical rolling. An evaporator is presently installed with plans for the addition of an electron beam evaporator system in the near future. A second much smaller evaporator system was constructed for close-proximity evaporations of higher activity materials, to be used not only as targets, but for radioactive source development as well. The size of this system allows for minimal contamination and is presently installed within a hood. Also produced in this laboratory are natural uranium and thorium foil targets prepared by mechanical rolling. A HEPA filtered balance table and pellet preparation hood has recently been added.

A complete description of the capabilities of the Physics Division Accelerator Target Facility can be found on the World Wide Web.

The URL is: <http://www.phy.anl.gov/targetlab/homepage.htm>

TECHNICAL SUPPORT GROUP

The Physics Division Technical Support Group is a group of technicians, designers, and engineers dedicated to the technical support of the experimental program in the Division. The disciplines are basically electrical and mechanical, with recent emphasis on the new possibilities of interating the two, by making use of the hardware and software capabilities of computers. Its functions range from novel and unique design and engineering, to construction, start-up, operation, and future expansion of equipment.

The electronics section of the Technical Support Group consists of two engineers and a technician whose responsibilities cover two areas. One area is electronic design and construction. Interfacing micro-computers to experimental equipment and designing chassis for data taking is typical of the work done in this area. The group also designs, constructs, and tests dedicated electronics modules specific to some experiments. Larger, more time-consuming projects may require the construction phase to be completed by the Electronics Division. The electronics section maintains a wealth of information on circuits, vendors, techniques, and industry trends.

The second of these areas covers electronic service and maintenance. Any on-line data-taking computers not under maintenance contracts require highest-priority attention when hardware failures occur. Peripherals to the computers, such as terminals and magnetic tape units, are also repaired and maintained.

Proper execution of experiments on all levels requires efficient and reliable equipment, much of which does not exist in the normal market place. It is the purpose of the mechanical section of this group to find appropriate equipment if it exists, or to design it if it does not. The mechanical section of the Technical Support Group consists of one design engineer and two technicians. Once designed, members of the group are responsible for the fabrication, installation, start-up, and operation throughout the equipment's life cycle.

Typical responsibilities include such diverse assignments as accelerator beam-transport-system design, commercial component testing and evaluation, high-vacuum chamber and pumping-system design, detector development, experimental area utility interfacing, structural support and mechanical mechanism design, and plant layout.

EDUCATIONAL PROGRAMS AND STUDENT APPOINTMENTS

The Physics Division offers college/university faculty and students opportunities to participate in ongoing research projects. The various research participation programs are administered by Argonne's Division of Educational Programs.

There are two research programs available for faculty. The Faculty Research Participation (FRP) Program is typically for 10-12 week periods normally during the summer, but may be at any time. Participation in this program usually takes the form of individual collaborations with an ANL staff member on an ongoing ANL project of interest to the faculty participant. Faculty Research Leave Appointments (FRLA) are normally for nine to twelve month periods whereby faculty members spend their sabbatical leave at Argonne.

Student research programs are designed to provide the opportunity to study and participate in research. The Physics Division typically supports about 50 graduate and undergraduate students annually. Participation takes the form of individual collaboration with a staff member in some part of an ongoing project of interest to the student participant. There are a variety of programs for both graduate students and undergraduate students. The Laboratory-Graduate Participant Appointments support graduate students from U. S. universities carrying out their Ph.D. thesis or Master thesis research at Argonne, under the joint sponsorship of an Argonne staff member and a professor at the student's university. Resident Graduate Student research

opportunities are available in each of the Physics Division's programmatic areas. Thesis Parts Appointments support graduate students from U. S. universities making brief visits to Argonne to make use of special Argonne facilities or to confer with Argonne staff members in the course of their thesis research.

There are several programs available for students who have completed their sophomore year of college and not as yet completed their first year of graduate school. These programs offer challenging opportunities for students selected nationally for participation in energy-related research during the academic year or the summer.

In addition to research participation opportunities, the Physics Division offers temporary employment appointments to college/university students. These appointments, made primarily during the summer months, are designed to provide Physics Division scientific and engineering staff with technical assistance. On a longer term basis, there is the Cooperative Education Program. There are two types of Co-op programs: alternating (full-time work followed by full-time school) and parallel (part-time work concurrent with full-time school). Students employed in the Co-op program are expected to work a minimum of one year as a parallel Co-op or three semesters as an alternating Co-op.

Specific information on individual programs should be obtained from the Division of Educational Programs and is available online at www.dep.anl.gov. Call or write the Physics Division for information on research done here and how it may relate to specific programs.

POSTDOCTORAL AND VISITING SCIENTIST APPOINTMENTS

Postdoctoral appointments are available in all research programs of the Physics Division. The appointments are for a one-year period but may be extended up to three years. Visiting Scientist Appointments are available to individuals on leave from their parent institutions who will return on completion of their Argonne assignment. Interested applicants may inquire themselves or be recommended by Division staff. These appointments are available for up to one year.

PRESENT REGULAR SCIENTIFIC STAFF

Irshad Ahmad
Birger B. Back
Paul Benioff*
R. Russell Betts
Arnold Bodmer*
Lowell M. Bollinger*
Michael P. Carpenter
Richard R. Chasman
William J. Childs*
Fritz Coester*
Cary N. Davids
Henning Esbensen
Donald F. Geesaman
Donald S. Gemmell
Walter F. Henning, Division Director
David Hofman
Mitio Inokuti*
Harold E. Jackson, Jr. Assoc. Division Director
Robert V. F. Janssens
Cheng-lie Jiang
Teng Lek Khoo
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Christopher J. Lister
Zheng-Tian Lu
Jerry A. Nolen
Thomas P. O'Neill
Richard C. Pardo
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Karl Ernst Rehm
G. Roy Ringo*
Craig T. Roberts
Guy Savard
John P. Schiffer, Assoc. Division Director
Dariusz Seweryniak
Kenneth W. Shepard
Zeev Vager
Robert B. Wiringa
Alan Wuosmaa
Benjamin Zeidman*

*Post-retirement appointments.

Buildings

- 4 Property Management/Records/Materials; Program
- 5 Shipping/Receiving/Central Mail Room
- 46 Transportation and Grounds
- 91 Guard Post
- 108 Central Boiler House
- 145 High Voltage/Maintenance Facility
- 146 Linemen/High Voltage Facility
- 200 Chemistry
- 201 DOE/CH; ANL Administration; University of Chicago
- 202 Center for Mechanistic and Biotechnology
- 203 Physics and Environmental Research; Technical Information Services
- 205 Chemical Technology
- 206 Engineering Development Laboratory
- 207 Technology Development Division
- 208 Engineering Research
- 211 Low Energy Accelerator Facility
- 212 Energy Technology; Materials Science Division
- 213 Cafeteria
- 214 Plant Facilities and Services
- 221 Electronics and Computing Technologies Division; Mathematics and Computer Science; Information and Publishing Division
- 222 Electronics Technologies; Media Services
- 223 Materials Science; Educational Programs
- 224 Visitor Reception/Science & Technology Information Center
- 233 Credit Union
- 291 Guard Post
- 301 Laboratory; Storage; Office
- 302 Security
- 306 Waste Management Operations
- 308 & 309 Energy Technology Division
- 310 Experimental Breeder Reactor II
- 314 Custodial Operations
- 315 Technology Development Division; Special Projects Office & Reactor Engineering
- 316 Security Division
- 330 Advanced Photon Source Construction Management
- 331 Reactor Engineering
- 333 Central Fire Station
- 335 Energy Technology Division
- 340 Waste Management Operations
- 350 New Brunswick Laboratory
- 360 & 361 Intense Pulsed Neutron Source
- 362 Auditorium; Energy Systems; High Energy Physics; Environmental Management Operations; XFD-ID Group
- 363 Central Shops
- 370 Energy Systems/Technology Development
- 375 Intense Pulsed Neutron Source
- 400 APS Experiment Hall
- 401 APS Central Lab/Office Building
- 402 APS Conference Center
- 411 Linac Building
- 412 Injection Building
- 415 Synchrotron Enclosure
- 420 RF Building
- 431-435, 438 User Laboratory and Office Buildings
- 450 APS Utility Building
- 460 Argonne Guest House
- 600 Lodging Facility Office
- 603 Swimming Pool

ARGONNE NATIONAL LABORATORY

A map of the Argonne National Laboratory area. The map shows several major roads: 75th St. at the top, 91st St. to the right, and International Parkway running diagonally from the bottom left. Other roads include Boughton Rd., Plainfield Ave., Cass Ave., and Archer Rd. Highway shields for 355, 55, 83, and 171 are present. A central area is labeled 'ARGONNE NATIONAL LABORATORY'. A 'MAIN GATE' is marked with a gate icon. A north arrow is in the top left corner. A legend box in the bottom left corner shows a gate icon with the text 'GATE' below it.