Life at a National Laboratory

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Junior Seminar, Fall 2009
University Of Notre Dame
October 14, 2009
Argonne: Direct descendent of Enrico Fermi’s Metallurgical Laboratory
Argonne’s History

Argonne began with Chicago Pile 1 in a squash court under Stagg Field at the University of Chicago.
Argonne’s History

- The world’s first usable amount of electricity from nuclear energy was produced by Experimental Breeder Reactor 1 in Southeastern Idaho and used to light these four light bulbs on December 21, 1951.
Argonne TODAY

Argonne National Laboratory is located on 1,500 acres, 25 miles southwest of downtown Chicago along I-55 South, Exit → Darien
National Laboratories and Technology Centers

Multi-purpose Labs

Single-mission Labs

Technology Centers

Some Labs shared with other agencies (NASA, Homeland Security, NIH,..)
About Argonne
**About Argonne**

- $630M operating budget
- 2,800 employees
- 1,000 scientists and engineers
- 750 Ph.D.s
- Operated by U. Chicago for DOE
Argonne National Laboratory

Mission:
(1) Basic scientific research in the physical, life and environmental sciences
(2) Operate National Users Facilities
(3) Develop new Energy technologies
(4) Environmental stewardship
(5) National Security
(6) Education
User Facilities

Advanced Photon Source

Argonne Tandem Linac Accelerator System

Leadership Computing Facility

Center for Nanoscale Materials

Electron Microscopy Center

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User Facilities: Advanced Photon Source (APS)

- Nation’s brightest source of X-rays for research
- Nation’s largest scientific user facility
- 56 beam lines in simultaneous operation
- The APS hosts about 3,500 users per year and has 5,000 total users.
- Operates year-round, 5,000 hours/year
- Hard X-rays: i.e., 12.4 keV to 1.24 MeV.
- Wavelengths range from 10 to 100 picometers
Leading companies and universities at APS
Notable research at the Advanced Photon Source

Structural studies of a portion of the HIV virus helped Abbott Labs develop *Kaletra*, a world-leading drug to fight AIDS.

Analysis of Beethoven’s hair and bone fragments proved the composer suffered from severe lead poisoning.

X-rays of living insects show lung-like tracheal movements that assist insects’ breathing.
Impact of the Advanced Photon Source

ANL Press Release:

Argonne's Advanced Photon Source Lit the Way to Chemistry Nobel

ARGONNE, Ill. (Oct. 7, 2009) – All three recipients of the 2009 Nobel Prize in Chemistry published papers on their award-winning work based on data collected at the U.S. Department of Energy's (DOE) Argonne National Laboratory. Between them, biochemists Thomas Steitz of Yale University, Ada Yonath of Israel's Weizmann Institute, and Venkatraman Ramakrishnan of Cambridge, England's Medical Research Center have published more than 60 papers that describe research performed at Argonne's Advanced Photon Source (APS). The three shared the award for their study of the structure and function of the ribosome.
On Sept. 2 you had a presentation on **Nano-Science & Technology** by Gregory Crawford
Argonne spin-off: Nanophase Technologies Corp.
Electron Microscopy Center

Research includes microscopy-based studies of high-Tc superconducting materials, irradiation effects in metals and semiconductors, phase transformations in solids, and processing related structure and chemistry of interfaces in thin films.
<table>
<thead>
<tr>
<th>Understand the molecular basis of Parkinson’s disease</th>
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<td>Assess the impact of climate change on forest ecology</td>
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<td>Model supernovas</td>
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<td>Design the next generation of reduced-emissions jet engines</td>
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<td>Gain insight into dangerous heart rhythm disorders</td>
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<td>Understand cell membrane processes in bio fuels and toxic organic waste clean up</td>
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<td>Study how water interacts with the surfaces of various materials</td>
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**User Facilities**

- Superconducting resonators are the heart of the Argonne Tandem Linac-Accelerator System. ATLAS was the world's first accelerator to use superconducting elements for beam focusing and acceleration.

  - ATLAS is located within the Physics Division → will discuss further.
ESE Directorate

- Basic Sciences & Applied Research under the same umbrella organization, sometimes within the SAME Division.

- The historical role of reactor engineering is still present but not nearly as prominent as in the past.

- Role of DOD and Homeland Security related activities.

→ Fundamental Research
Interlinked programs in nuclear research: a strength of the Physics Division

Medium Energy Nuclear Physics
Exploring hadron and nuclear structure at the QCD level and physics beyond the standard model

Operation of ATLAS as a National User Facility

Accelerator R&D
Developing the capabilities for the next generation of exotic beam facilities

Low Energy Nuclear Physics
The structure of the nuclei How the elements are formed in stars The search for physics beyond the standard model

Nuclear Theory
From quarks to neutron stars

Significant applications
• Atom Trap Trace Analysis
• Accelerator Mass Spectrometry
• Gamma-ray tracking
• New acceleration and isotope production concepts

The Division’s program is more than the sum of its parts
The ATLAS Facility – The world’s first superconducting ion accelerator

✓ Unique and powerful accelerator
✓ Unique experimental equipment
✓ Great user community

8.5-MV Tandem Injector
  Important for:
  Beams of A<58
  Long-lived RIB’s

2 ECR Ion Sources on HV platform

12-MV Positive Ion Injector (PII)
  Required for:
  Beams with A>58
  Noble gases
  High current

18 Quarter-wave SC resonators

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One of four DOE-ONP National User Facilities
RHIC
CEBAF
HRIBF
ATLAS

Argonne National Laboratory
ATLAS: a User Facility for Physics at the Coulomb Barrier

World’s First Superconducting Accelerator for Ions

**Capabilities:**

- beams of all masses \( (H \text{ to } ^{238}U, \text{ and exotic beams}) \)
- energies comparable to internal energies of the nucleus
  
  (16 MeV/A for light ions, 7 MeV/A for heaviest ions, upgrade to 10 MeV/A on-going)
- high beam intensities (particle micro-amps)
- exceptional beam quality (spot sizes of 1mm diameter or less)
  
  (emmitances: transverse \( \sim 0.2 \pi mm \text{ mrad} \))
  
  longitudinal \( \sim 20 \text{ keV - ns} \))
  
  (resolutions: energy \( \sim 10^{-3} \) or better,
  
  time as low as 100 ps, 200 – 400 ps typical)
- great flexibility and reliability (energy changes in minutes, > 95%reliability)
- and more (duty cycle, micro-pulsing…)
**The User Program at ATLAS**

FY08 – 387 Users (71 Students / 9 Theses) 63 pubs in refereed journals (13 letters)
FY07 – 330 Users (62 Students / 10 Theses) 57 pubs in refereed journals (15 letters)
FY06 – 411 Users (75 Students / 12 Theses) 68 pubs in refereed journals (19 letters)

*: Users at the facility plus Users on approved proposals. The distribution of the Users at the facility between institutions is given below.
ATLAS: Major Thrusts of Research

(1) Nature of Nucleonic Matter:

understanding the nucleus as a many-body system built of protons and neutrons governed by the strong force with a major focus on exploring the limits that a nucleus can sustain in mass, neutron-to-proton ratio, spin and excitation energy

New Shapes & Excitation Modes
Structure of neutron-rich nuclei
Phonon Condensates
Abnormal structure near the island of inversion above $^{48}\text{Ca}$, towards $^{78}\text{Ni}$
Structure of neutron-rich nuclei
Shell structure near $^{100}\text{Sn}$
Impact of the proton drip line

Chiral excitations
Beyond band termination
Hot nuclei

Structure of the lightest nuclei
Tests of ab-initio calculations beyond spins and parities, i.e.
Charge radii, transition rates
Validity of interactions for neutron-rich nuclei

Structure of the heaviest nuclei
New symmetries (mixed symmetry states)
Kuo shell structure near $^{132}\text{Sn}$
Interactions for neutron-rich nuclei

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ATLAS: Major Thrusts of Research

(2) Origin of the Elements:

understanding the origin of chemical elements and their role in shaping the reactions that occur in the cataclysmic events of the cosmos

rp-process

rp-process end & vp process

rp-process yields

$^{12}\text{C}$ & $^{12}\text{C}(\alpha,\gamma)$ & $^{12}\text{C} + ^{12}\text{C}$ etc.
ATLAS: Major Thrusts of Research

(3) Tests of Fundamental Symmetries:

high-precision tests of the limits of the Standard Model

emphasis changed from - Unitarity of the CKM matrix to - Search for possible scalar, tensor and right-handed components to electro-weak interactions

(\textsuperscript{6}He, \textsuperscript{8}Li, \textsuperscript{14}O)

- Masses relevant to double beta-decay

(\textsuperscript{130}Te, \textsuperscript{128}Te, \textsuperscript{120}Te)

(4) Applications:

exploit the unique features of ATLAS for challenging applied projects

emphasis on: - Accelerator Mass Spectrometry, Materials Research, ..

\rightarrow \textsuperscript{39}Ar for dark matter detectors,

\rightarrow \textsuperscript{146}Sm a tracer for SNe (p-process nucleus)
Canadian Penning Trap

\[ \omega_c = \frac{qB}{m} \]

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Fragment Mass Analyzer

Fragment Mass Analyzer

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Gammasphere
Improved resolution for $^{11,12}\text{B}(d,p)^{12,13}\text{B}$

"Conventional"

$^{11}\text{B}(d,p)^{12}\text{B}$

$^{12}\text{B}(d,p)^{13}\text{B}$

$\sim 300 \text{ keV}$

$\sim 100 \text{ keV}$

HELIOS Preliminary

HELIOS Preliminary

$\theta_{CM} = 6^\circ - 29^\circ$

$\theta_{CM} = 16^\circ - 29^\circ$

$3.48 \text{ MeV}$

$3.68 \text{ MeV}$
Example of an Experiment at ATLAS Charge radius of He isotopes

Quantum Monte Carlo Calculations of Light Nuclei

Example of an Experiment at ATLAS

Experimental Setup - Schematic

$^6$He production: $1 \times 10^6 \text{ s}^{-1}$
Transport time $\sim 1 \text{ sec}$

He energy level diagram

Strong Links between Experimental Programs (Low & Medium Energy) & Theory
Charge Radius $^6$He and $^8$He & Ab-initio Calculations

This work

[3] [15] \{ Nucl. scatter

[16] [17] NCSM

[18] GFMC

Nuclear Radii, fm

1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8

$^6$He

$^8$He

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Scientific Careers at National Laboratories

- Postdoctoral Fellow: - 2-3 years duration (possibilities of prestigious fellowships)

- Assistant Scientist: - 5 years & tenure track

- Scientist: - tenured ...but only as long as there is a DOE contract

- Senior Scientist:

- Distinguished Fellow: