The Notre Dame Nuclear Science Laboratory

Dan Bardayan
The NSL Laboratory

St. GEORGE Recoil Separator

5U Pelletron

AMS spectrometer

TwinSol

10 MV FN Tandem

250 kV Implanter

3MV Tandem Pelletron
Besides new experimental hall for TwinSol and new 3MV accelerator spacelab is expanded by about 25% in research space for nuclear physics and applications.

Chemistry for AMS and applications
Detector development
Experiment Preparations
General research group space
Possibly new experimental hall for FN
Three accelerators for basic research, one accelerator for applied research, TwinSol as radioactive beam facility

- **10MV FN Tandem**
- **3 MV Pelletron Tandem**
- **1 MV JN VdG**
- **5MV Pelletron**
- **TwinSol**

Producing:

- $^1$H, $^4$He, $^{14}$N, $^{16}$O, $^{20}$Ne, $^{40}$Ar
- $^7$Be, $^{10}$Be, $^{12}$B, $^{10}$C, $^{11}$C, $^{12}$N, $^{14}$O, $^{15}$O, $^{17}$F,$^{19}$Ne, $^{23}$Mg, $^{25}$Al, $^{26}$Al: $10^3$-$10^7$ pps
Accelerator Operation

On average: 40% user operation; 40% local groups, 20% maintenance

Voltage on Terminal

<table>
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<tr>
<th>Year</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>Avg</th>
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<td>FN</td>
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FN shut-down for ion source

5U operation

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Acc. Operational Hours

- FN
- 5U

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Upgrade to FN Injection System

The AMS System

MRI proposal for up-grading the ion source arrangement for improved AMS resolution was successful!
The NSL User Community

In 2014-2015:

**FN accelerator:** 40% users  
36% NSL programs  
24% Maintenance

In 2015-2016:

**FN accelerator:** 40% users  
40% NSL programs  
20% Maintenance


**5U accelerator:** 30% users  
50% NSL programs  
20% Maintenance

The NSL Science Program

➢ Nuclear astrophysics
  • Low energy reactions, fusion reactions, late stellar evolution, explosive hydrogen burning, s-process nucleosynthesis, r-process nucleosynthesis, p-process nucleosynthesis

➢ Nuclear structure physics
  • Vibrational modes in nuclei, nuclear incompressibility, E0 transitions, alpha cluster structure in light nuclei, γ-strength functions, nuclear life times, reaction theory (R-matrix, HF method)

➢ Radioactive ion beam physics
  • Elastic scattering, transfer reaction measurements with radioactive beams

➢ Accelerator mass spectrometry
  • Nuclear reaction studies, analysis of geological, astrophysical, cultural samples

➢ Fundamental symmetries
  • Super-allowed mirror transitions with light nuclei in ion traps

➢ Applied nuclear physics
  • AMS, PIXE, PIGE, reaction analysis
TWINSOL has been in operation for ~20 years. 100s of scientists from 10s of countries have participated in TWINSOL experiments.

Precise $t_{1/2}$ need to extract $V_{ud}$ from $\beta$ decay.

$T_{1/2} = 64.402 \pm 0.041$ s
Brodeur et al. (2016)

$T_{1/2} = 7.1656 \pm 0.0024$ s
Long et al. (2017)
5U cross section measurements

High beam currents from 5U allow for precise and complete data sets to be taken.

$^{20}\text{Ne}(p,\gamma)^{21}\text{Na}$ – S. Lyons, Ph. D. Thesis

St. George Recoil Separator

Coupling of 5U to St. George in unique in the world.
AMS Dating of materials  
(U. Vienna, Hebrew U.) (P. Collon, D. Robertson)

PIXE/XRF on historical artifacts  

PIGE water pollution and aerosol analysis  
(Hope College) (G. Peaslee, D. Robertson, E. Stech)

Nanomaterial modification & explosion under beam  
(ND Engineering, John Hopkins U., MIT, I. Moscow) (K. Manukyan)

Radiation chemistry for long term storage, nuclear reactor material, and nuclear medicine  
(ND RadLab, U. Manchester, UK) (J. LaVerne, D. Robertson)

Nuclear diagnostics for forensic analysis  
(LLNL) (M. Couder, G. Peaslee, M. Wiescher)
Applied Nuclear Physics
Accelerator – New 2016

Sept 2016

Oct 2016
Perfluorinated Compounds

Fluorinated Compounds in U.S. Fast Food Packaging
Laurel A. Schaidner, Simona A. Balan, Arlene Blum, David Q. Andrews, Mark J. Strynar, Margaret E. Dickinson, David M. Lunderberg, Johnie R. Lang, and Graham F. Peaslee

215 major news stories in 7 days in print, television, radio and internet format. The research paper was downloaded 4,000 times in a single week from the ACS Environmental Science & Technology Letters site, a result of the collaboration between co-authors and their institutions to distribute coordinated releases.
DIANA project on hold; DIANA demonstrator project being initiated with NSF, ND, CSM, SDSM&T & SURF funding

**CASPAR** (Compact Accelerator System for Performing Astrophysical Research)

- D. Robertson
- M. Couder
- M. Wiescher

First beam accelerated July 2017. Data taking begins Fall 2017. $^{13}\text{C}(\alpha,n)$ and $^{22}\text{Ne}(\alpha,n)$ are key experiments.
The AOV program doubled the number of faculty.
The Notre Dame Nuclear Theory Group

Close collaboration with the experimental group on nuclear structure and astrophysics!
The NSL research faculty

- JINA support
  - James DeBoer
    - R-matrix development
  - Micha Kilburn
    - NSL Outreach

- NSF support
  - Ed Stech
    - NSL Operation
  - Daniel Robertson
    - CASPAR Development

- Project based DOE support
  - George Berg
    - SECAR
  - Jay Laverne
    - Rad. Chemistry
  - Joachim Görres
    - Research Support

- University support
  - Khachatur Manukyan
    - Materials & Applications
  - Wanpeng Tan
    - User Support
New Equipment developments

- Solenoid-Spectrometer for Nuclear Astrophysics
- Enge Split-Pole Separator
- Multi-Reflection-Time-of-Flight mass spectrometer at ANL; Paul trap for TwinSol
- Gamma Summing Detector Array: HECTOR (High EffiCiency TOtal absorption spectrometer)
- Prototype Active Target Time-Projection Chamber
- St. Andre for Nuclear Applications
- Solenoid-Spectrometer for Nuclear Astrophysics
## NSL students

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<thead>
<tr>
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**NSF Site Visit - February 16, 2017**

**NSF grant, TA support (University), Other grants (DOE NSF) & fellowships (NSF&NNSA)**
Presently 30+ graduate students at Notre Dame do their research project in Nuclear Physics, five have graduated in 2016. Since 2001, 52 students have received their PhD at Notre Dame on average 3.3/year.

PhD topics from 2001 to 2016

- Nuclear Astrophysics: 50%
- Nuclear Structure Physics: 34%
- Nuclear Applications: 6%
- Nuclear Theory: 10%
# NSL postdocs

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<tr>
<th>Name</th>
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<tr>
<td>Axel Boeltzig</td>
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<td>Kevin Macon</td>
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<td>Farheen Naqvi</td>
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<td>Simon/NSF</td>
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<tr>
<td>Patrick O’Malley</td>
<td>Nuclear Astrophysics</td>
<td>Bardayanan/ND</td>
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*Typically 1-2 postdocs paid by NSF grant, with rotating assignments to research groups*
The NSL Long Range Plan

Maintain an innovative and competitive research program in nuclear structure and nuclear astrophysics.

- Focus on reactions and structure near particle thresholds.
- Expand on light radioactive beams and trapping light isotopes.
- Capitalize on new instruments/people working at the intensity frontier.

Broaden the scientific program by using new low energy probes.

Grow nuclear application program using different probes.

- ARUNA university facilities are crucial for the development of the field due to their unique versatility and flexibility.
- They provide innovative ideas and developments for large scale facilities.
- They are not only cheap test benches but important national resources serving important scientific and national needs.
- Last not least they are an important training ground for future generations of nuclear scientists.
Thank you