To TUNL… *and beyond*!
Robert's contributions to studying the cosmos at TUNL

TUNL
TRIANGLE UNIVERSITIES NUCLEAR LABORATORY

Argonne NATIONAL LABORATORY

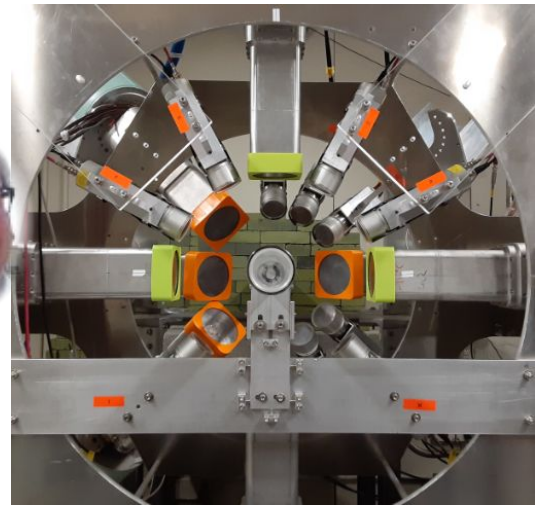
Richard Longland
North Carolina State University (NCSU)
Triangle Universities Nuclear Laboratory (TUNL)

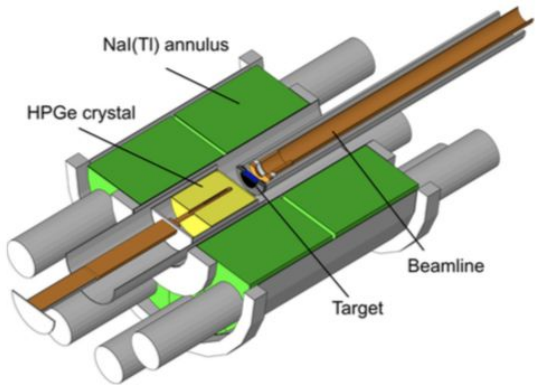
Nuclear Astrophysics at TUNL

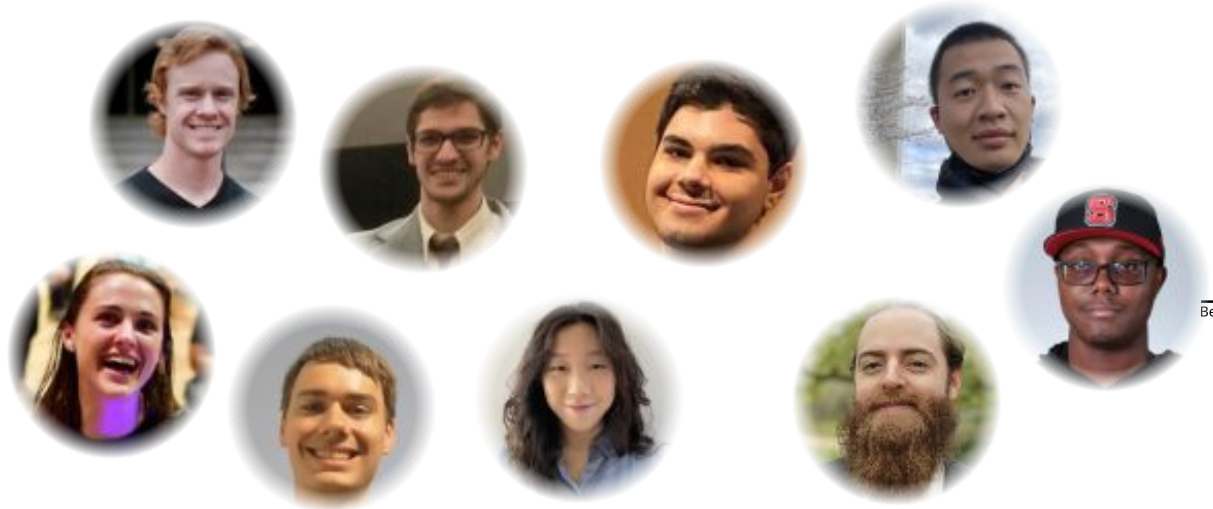
TUNL

LENA-II

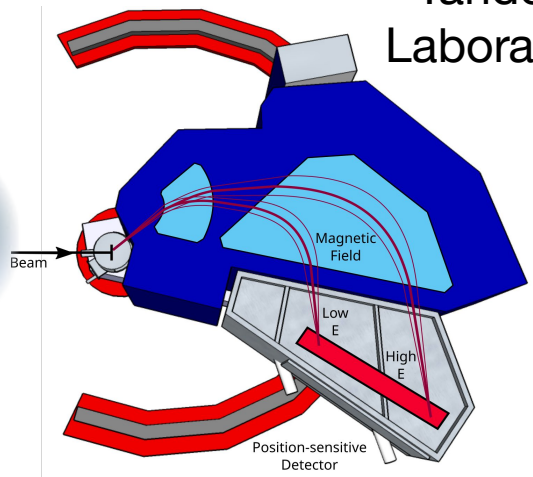
HIγS



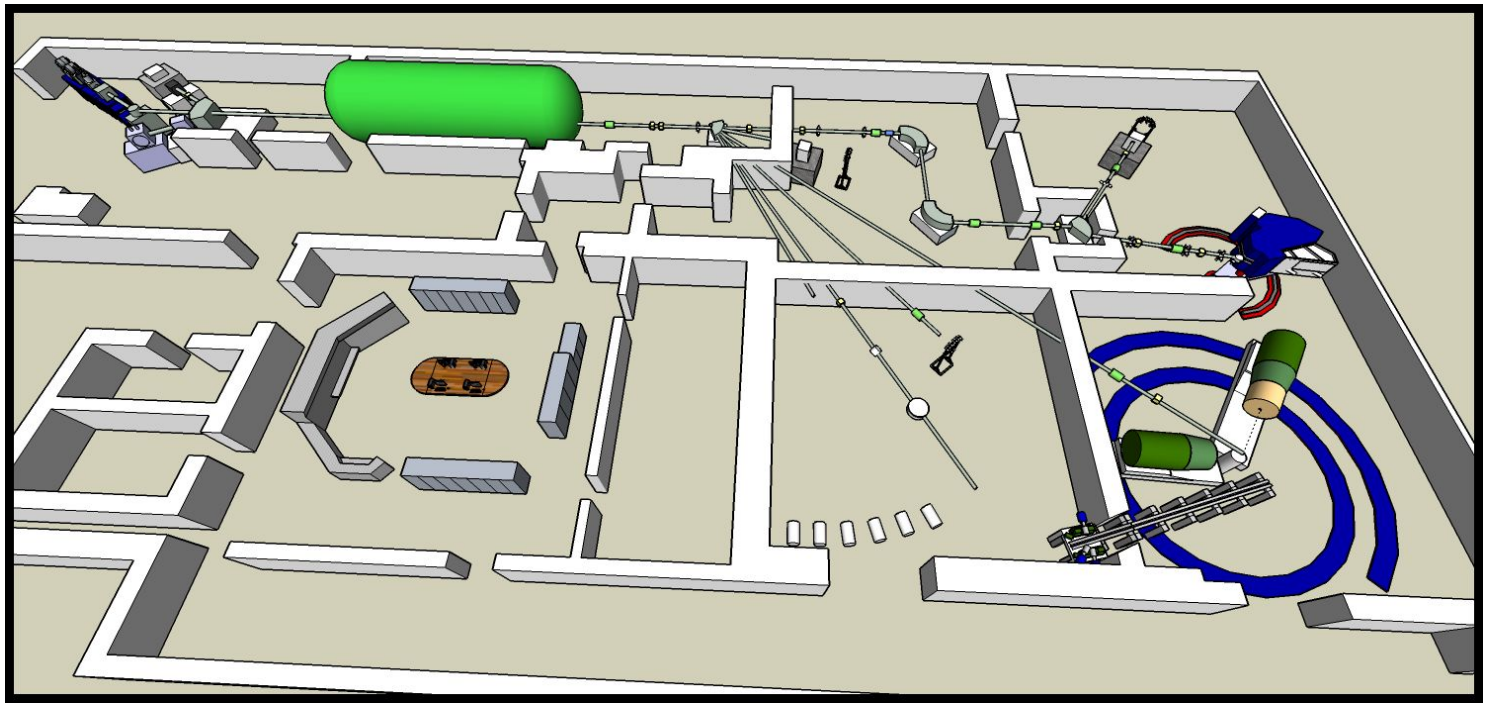




Tandem Laboratory



TUNL Tandem Laboratory: main research topics



Advanced Neutron Calibration Facility

P.S. Barbeau, D. Markoff

Detector development for neutrinos, dark matter, nuclear security

Neutron-induced and Neutron-emitting Reactions

C. R. Howell, W. Tornow

Measurements of neutron induced cross sections
RABBITS system for short-lifetime activation studies

Nuclear Astrophysics

R. Longland

Particle transfer measurements for astrophysics using the Enge split-pole spectrograph

$0\nu\beta\beta$ Matrix Elements

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Experimentally constrain matrix elements for $0\nu\beta\beta$ theory calculations

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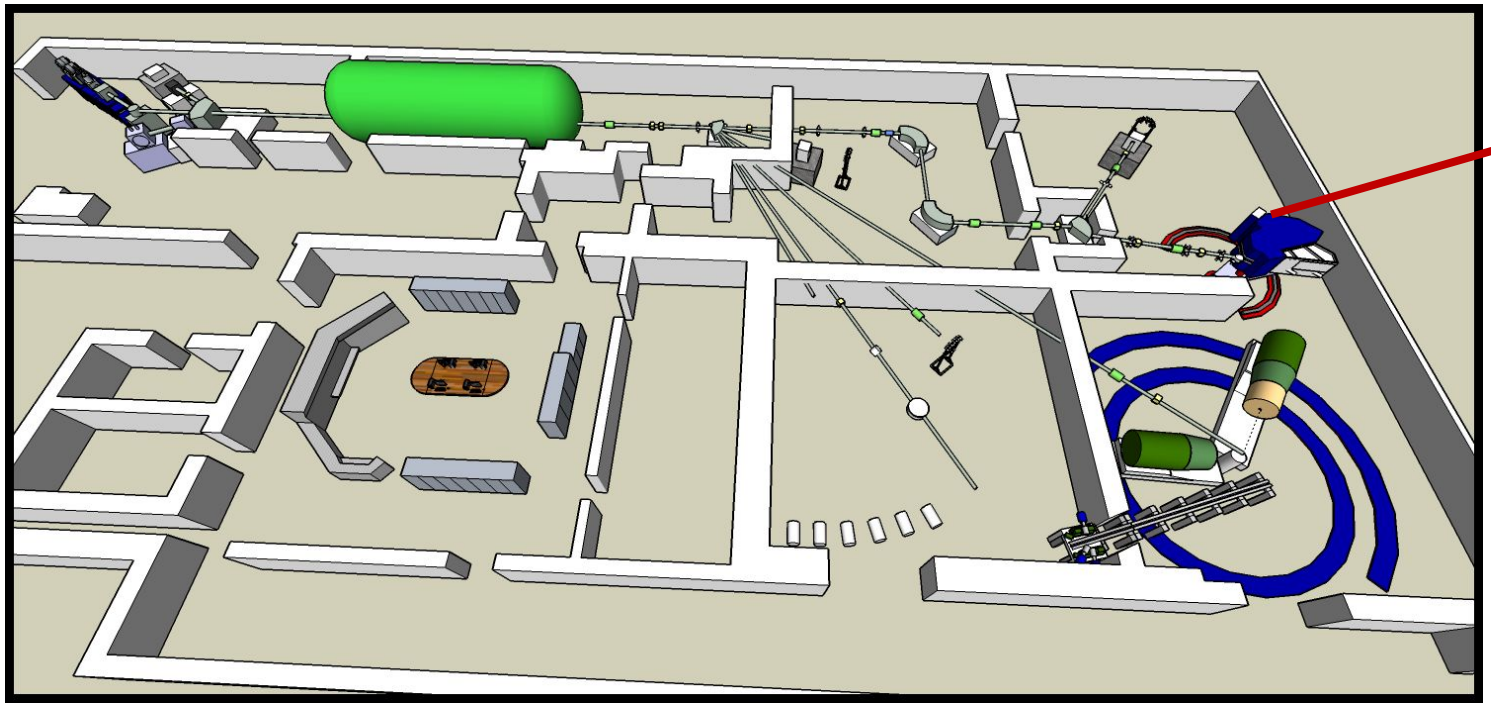

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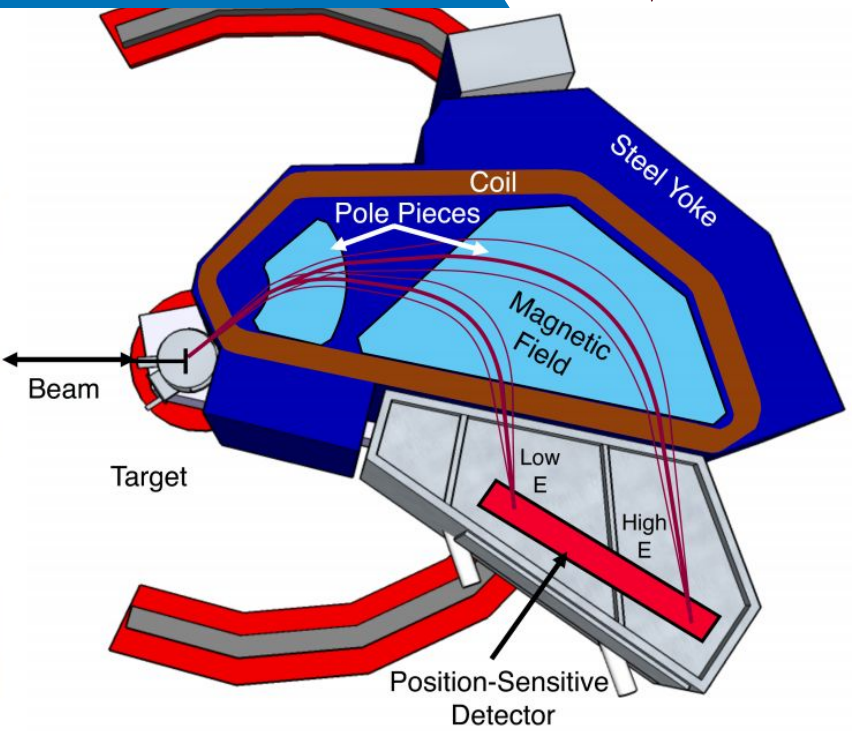
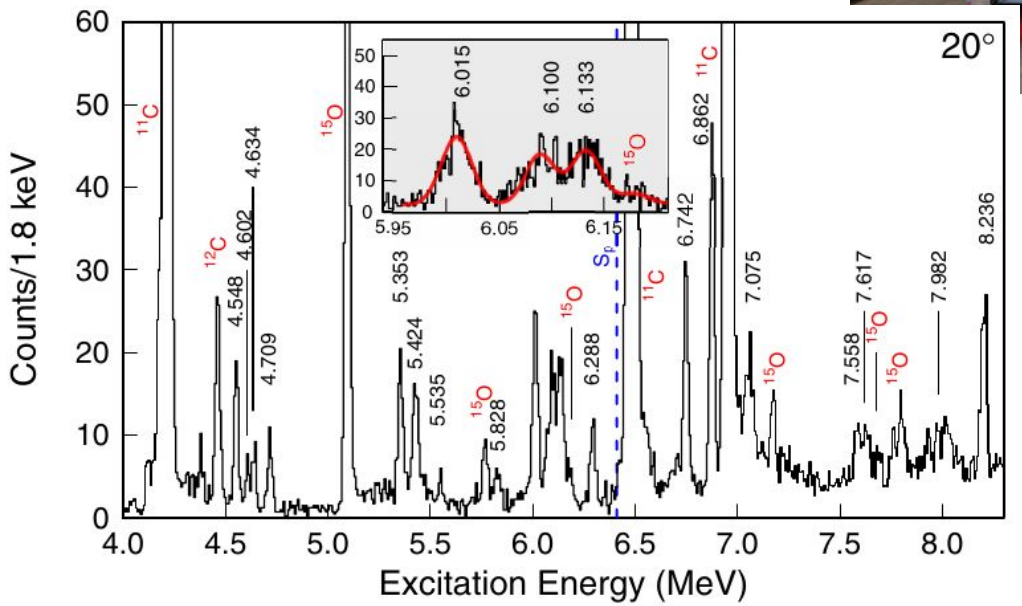
Nuclear Astrophysics at the Tandem Laboratory

- Particle transfer reactions to study nuclear structure for nucleosynthesis.
- High-resolution beams, precise target manufacture, and high-resolution detectors.
- Sophisticated analysis techniques to modernize particle transfer measurements





Spectrograph highlights since 2017:

- Fox et al., PR L 132, 062701 (2024) [^{39}K(^{3}He,d)^{40}Ca]
- Portillo-Chaves et al., PR C 107, 035809 (2023) [^{20}Ne(^{3}He,α)^{19}Ne]
- Frost-Schenk et al., MNRAS 514 (2022) 2650 [^{20}Ne(d,p)^{21}Ne]
- Marshall et al., PR C 104, L032801 (2021) [^{23}Na(^{3}He,d)^{24}Mg]
- Hamill et al., EPJ A 56, 36 (2020) [^{25}Mg(d,p)^{26}Mg]
- Setoodehnia et al., PR C 99, 055812 (2019) [^{32}S(α,p)^{35}Cl]
- Setoodehnia et al., PR C 98, 055804 (2018) [^{40}Ca(^{3}He,α)^{39}Ca]

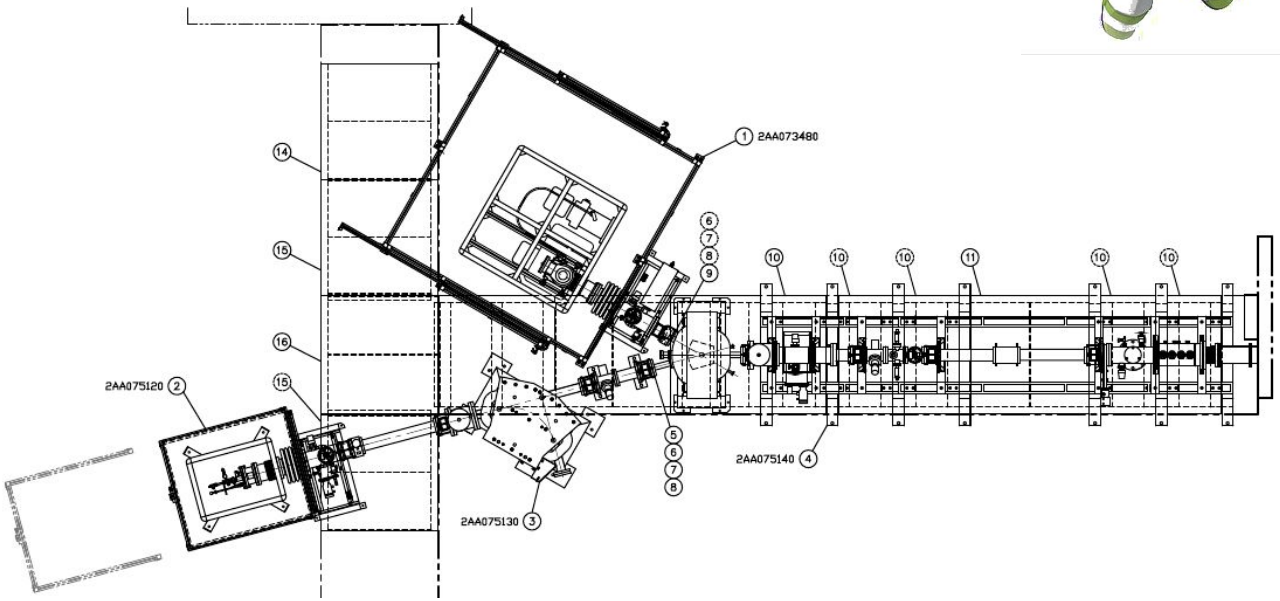
Previous Injector

DENIS-II (H and D beams)

Helium Source

- Helium sources suffered from low intensity and instability
- Entire injection system runs on ancient, dirty diffusion pumps

Both sources acquired as surplus in the 1970s and needed replacing



New Injector

National Electrostatics Corp.

Specifications

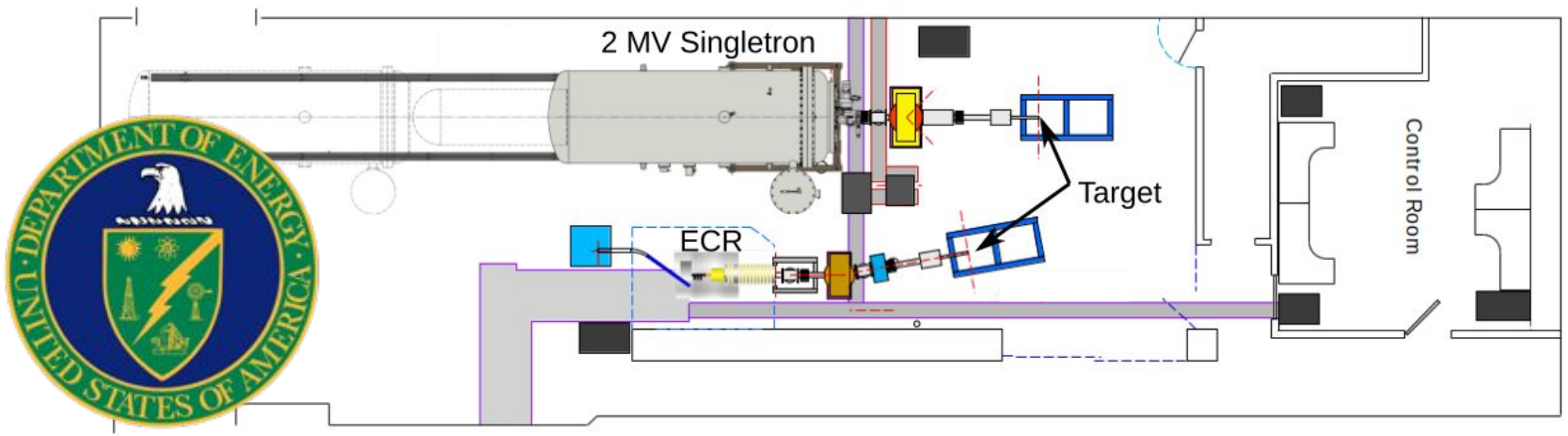
- TORVIS H/He ion source
  - 75 kV source deck
  - 100 μA H^- (factor of 5 improvement)
  - 20 μA He^- (factor of 10 improvement)
- SNICS-II ion source
  - Heavy ion beams from solid targets
  - 90-degree magnet for implantation

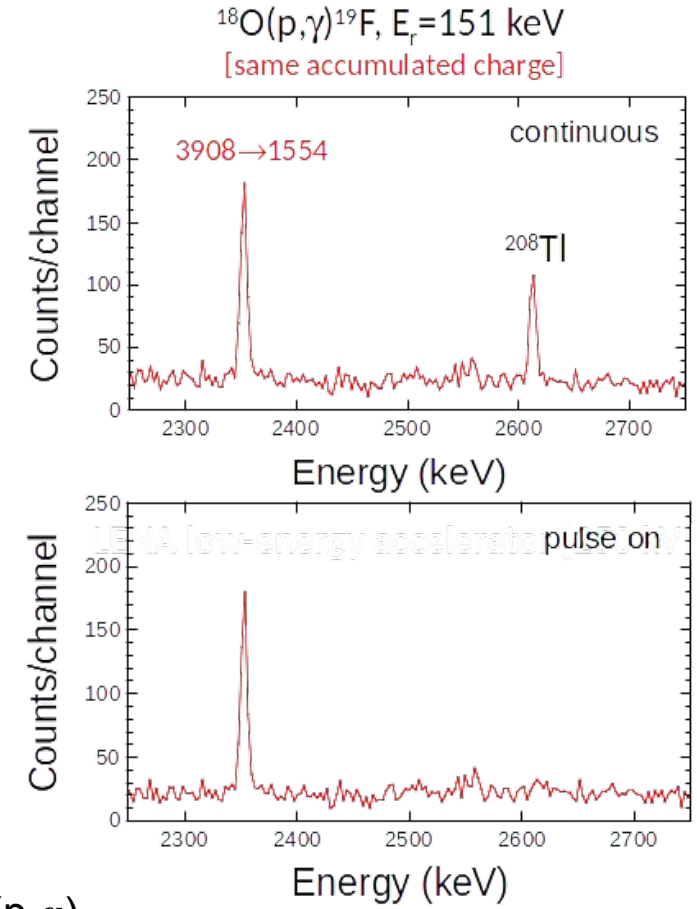
Additional upgrades

- Complete replacement of low-energy beamline
- Optics designed to couple both sources to Tandem
- New 4-species punching system to provide ~ 1 ns timing resolution on target

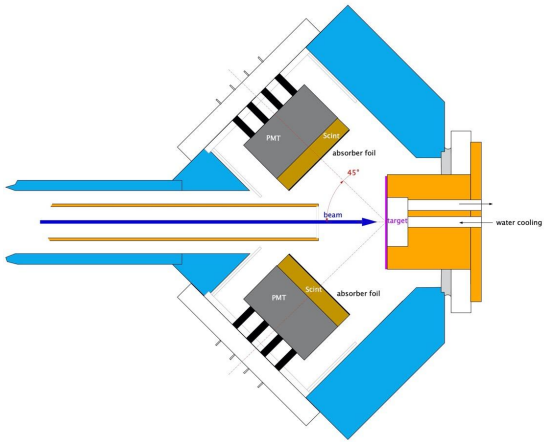
Injector upgrade will allow new scientific opportunities in all aspects of the Tandem research program

Nuclear Astrophysics at LENA-II



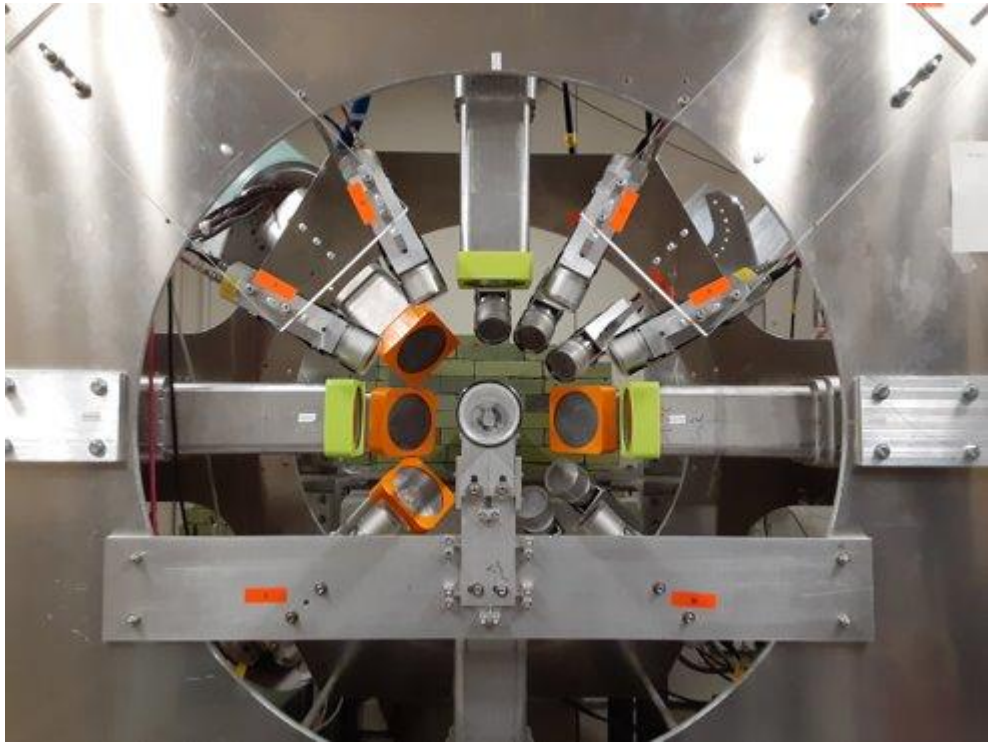


- ECR: < 230 kV 20 mA DC + slow pulsing
- Singletron: 0.1 - 2 MV up to 2 mA DC + fast pulsing



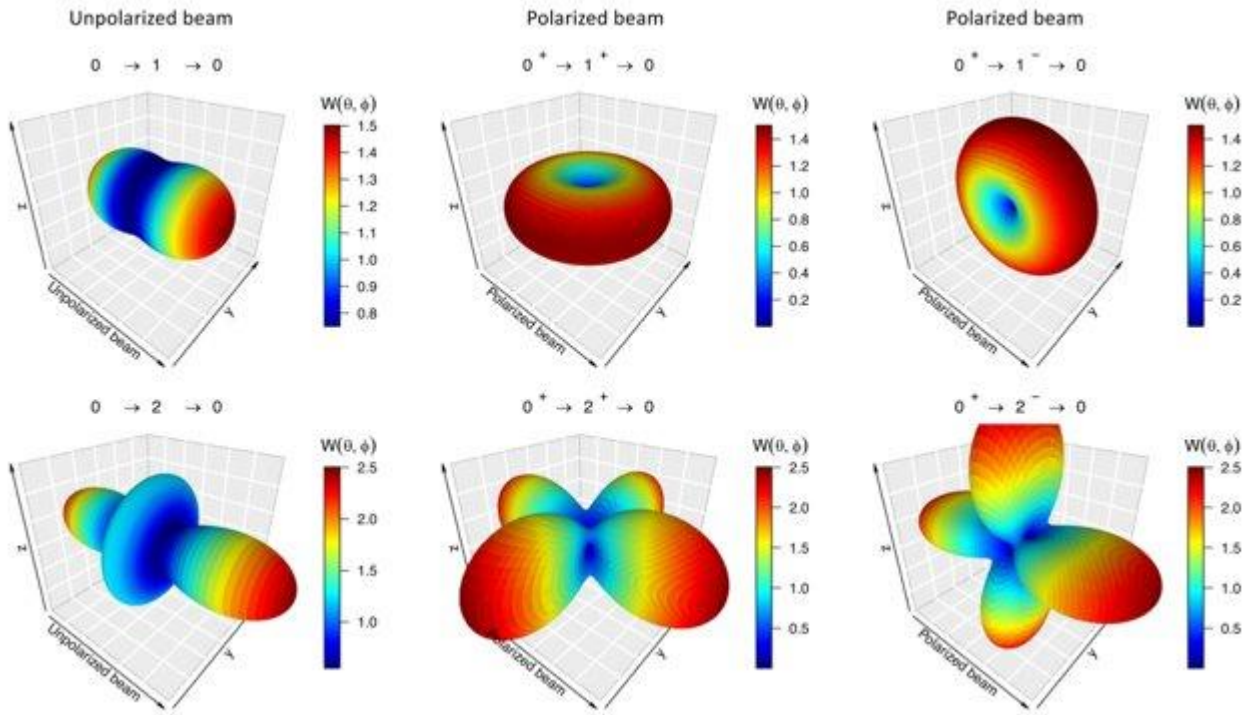
- Previous Highlights:
  - Downen et al., 928, 128 (2022) [$^{29}Si(p,\gamma)^{30}P$]
  - Dermigny et al., PRC 102, 014609 (2020) [$^{30}Si(p,\gamma)^{31}P$]
- New detector development enables high-efficiency (p,α) measurements
- Accelerator upgrade opens opportunities using high-intensity pulsed beams

Nuclear Astrophysics at HIgS



- Anisotropy of the distribution (beam direction, polarization).
- Unequal population of magnetic substates.
- Spin- and parity dependent angular distribution of decay gamma rays.

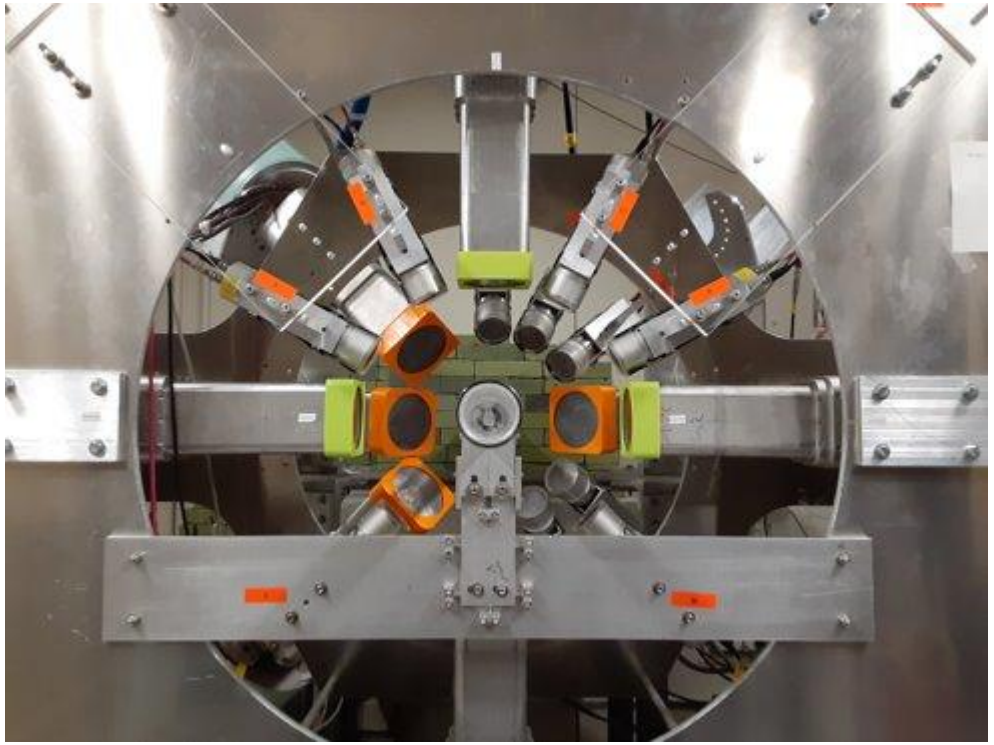
Iliadis & Friman-Gayer Eur. Phys. J. A 57,190 (2021) (**Invited Review**)



- **The Clover Array**: 10 (16) clover-type HPGe and 12 (2″ × 2″) CeBr detectors.
- Higher HPGe rates due to segmentation.
- Higher granularity.
- Solid angle coverage: 14%

Uses Clovershare detectors

Nuclear Astrophysics at HIgS



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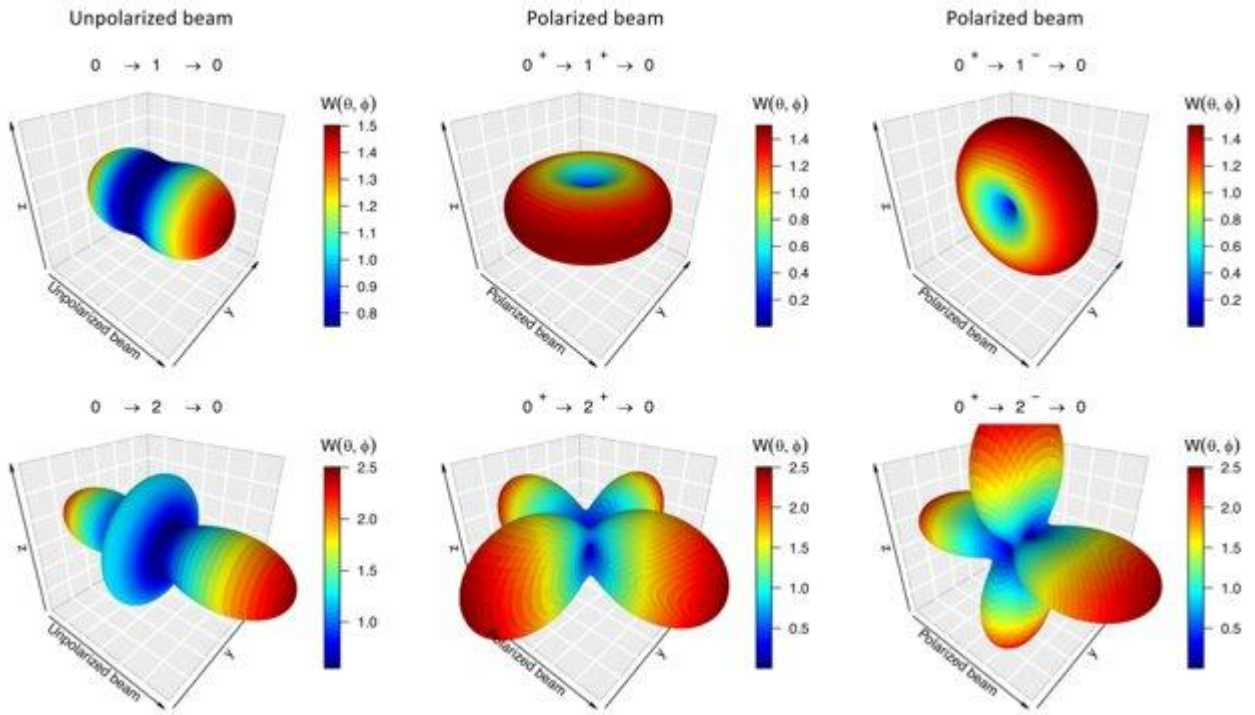

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Nuclear Astrophysics at HIγS - Nuclear Resonance Fluorescence

PHYSICAL REVIEW C **106**, 014308 (2022)

Investigation of ^{11}B and ^{40}Ca levels at 8–9 MeV by nuclear resonance fluorescence

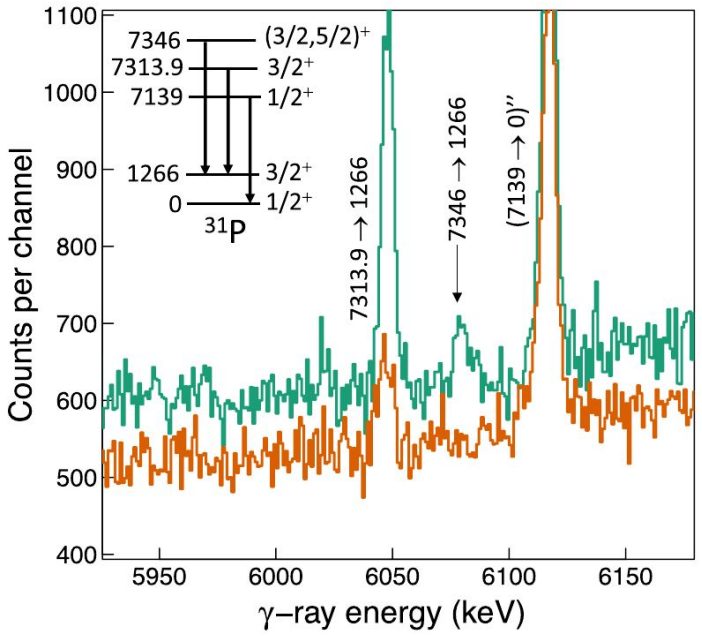
D. Gribble,[1,2] C. Iliadis,[1,2] R. V. F. Janssens,[1,2] U. Friman-Gayer,[2,3] Krishichayan,[2,3] and S. Finch[2]

PHYSICAL REVIEW C **112**, 025804 (2025)

Editors' Suggestion

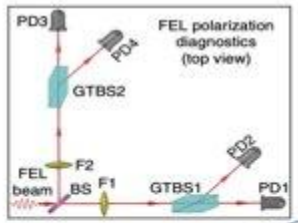
Investigation of ^{31}P levels near the proton threshold with nuclear resonance fluorescence and the impact on the ^{30}Si$(p,\gamma)^{31}$P thermonuclear rate

David Gribble,[1,2] Christian Iliadis,[1,2] Robert V. F. Janssens,[1,2] Udo Friman-Gayer,[3,2] Akaa D. Ayangeakaa,[1,2] Art Champagne,[1,2] Emily Churchman,[1,2] William Fox,[4,2] Steven Frye,[1,2] Xavier K.-H. James,[1,2] Samantha R. Johnson,[1,2] Richard Longland,[4,2] Antonella Saracino,[1,2] Nirupama Sensharma,[1,2] Kaixin Song,[4,2] and Clay Wegner[1,2]



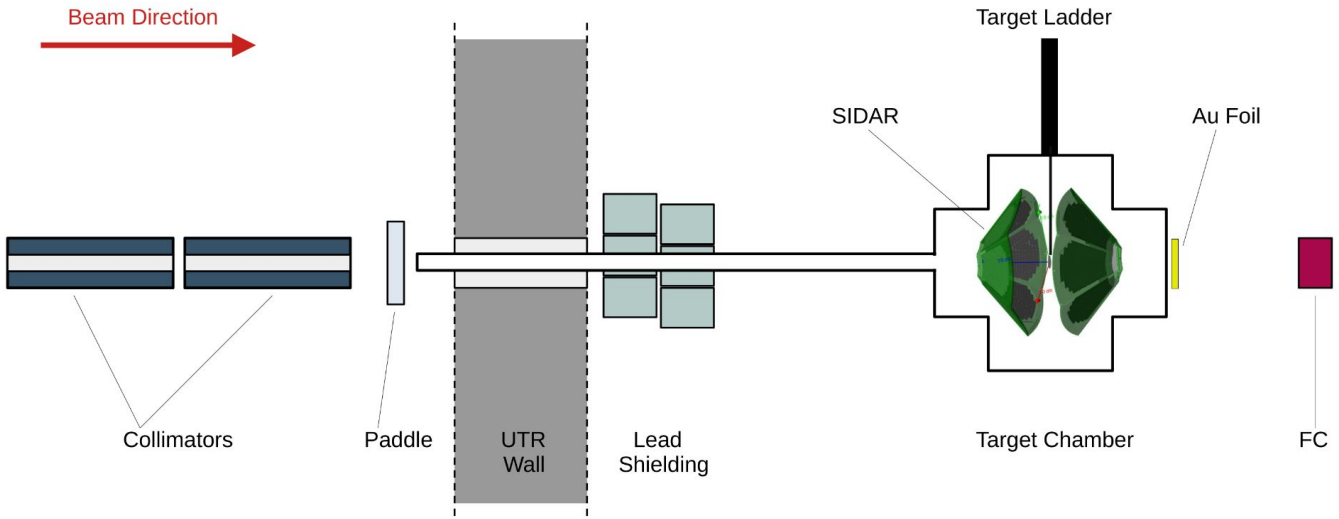
$$\langle \sigma v \rangle \sim (2J+1)\frac{\Gamma_a \Gamma_b}{\Gamma} e^{-E_r/kT}$$

- Linearly polarized photon beams
- Populate astrophysically-relevant excited states
- High-precision E_x
- Largely unambiguous J^π



Nuclear Astrophysics at HIγS - Cross Section Measurements

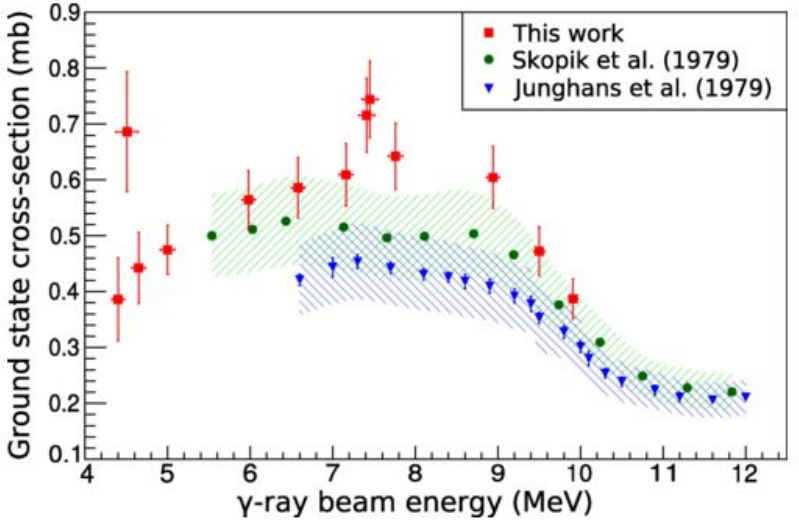
Need *quasi-monoenergetic gamma beams* from ~few to ~10s of MeV



Big bang nucleosynthesis

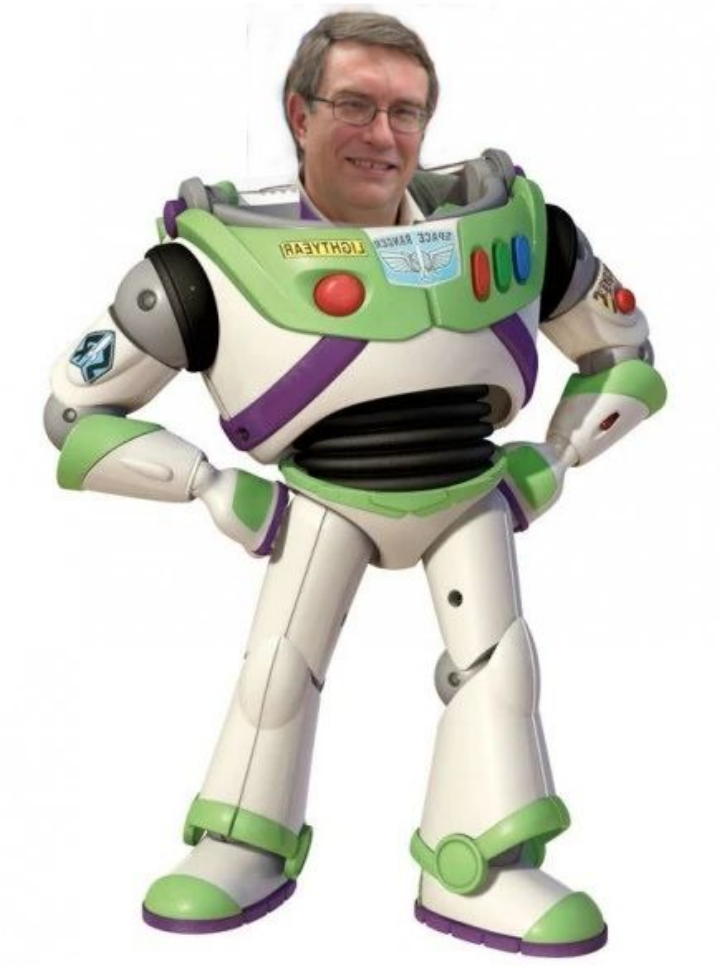
- $^{3}H(\alpha,\gamma)^{7}Li$ and $^{3}He(\alpha,\gamma)^{7}Be$
- Perform inverse reactions at HIgS using monoenergetic photon beam

M. Munch et al., Phys. Rev. C 101 (2020) 055801



p-process

- α optical model assumptions strongly affect photodisintegration reaction rates
- Previous measurements only performed with Bremsstrahlung
- Collaboration between TUNL, ELI-NP, ORNL, and others:
  - March-April 2023
  - (γ,p) and (γ,α)
  - ^{102}Pd and ^{112}Sn
- *HIγS upgrades provided x10 requested beam intensity*



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