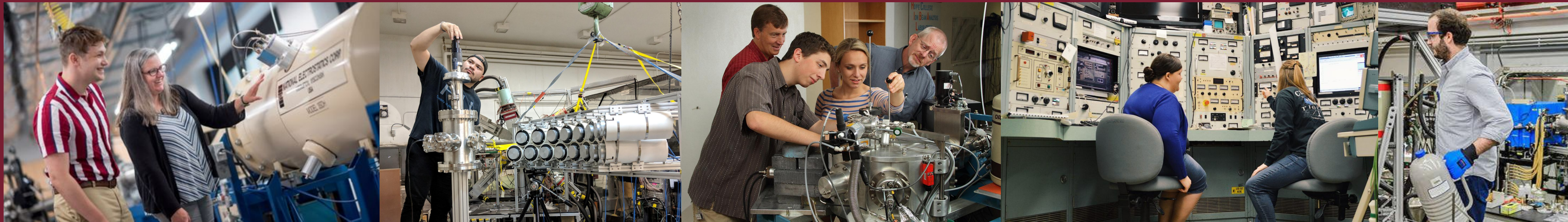
Association for Research at University Nuclear Accelerators

Interconnected collective of 11 institutions
Around 200 registered users
https://aruna.physics.fsu.edu/



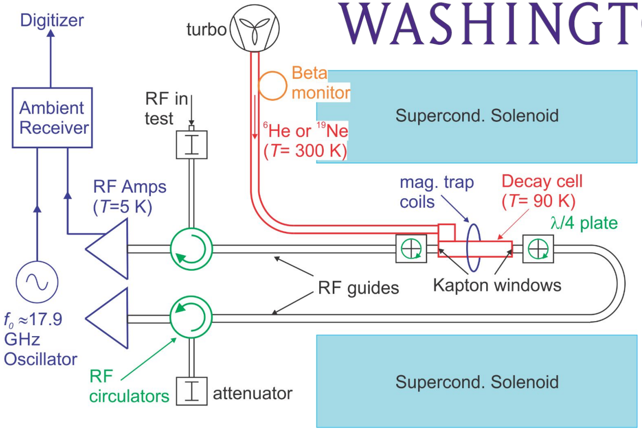
Cyclotron Radiation Emission Spectroscopy (CRES)

Measure beta energy by frequency of cyclotron radiation:

$$E = \frac{qB\,c^2}{2\pi\, f}$$

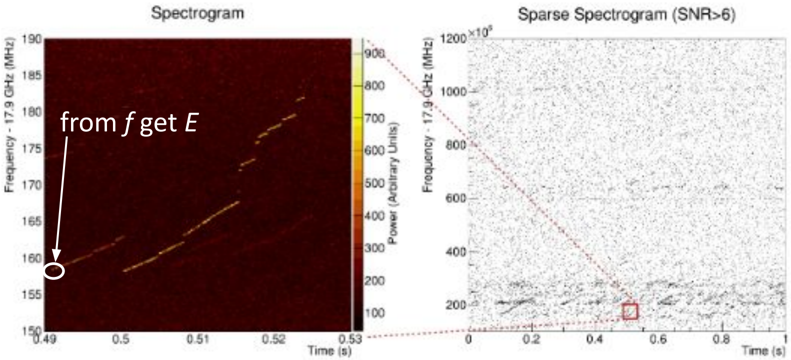
with $E \approx 1$ MeV, $B \approx 1$ T → $f \approx 15$ GHz

Recently observed CRES events from ^{6}He and ^{19}Ne



Collaboration with:
Argonne, Mainz, NCSU, PNNL, Texas A&M, Tulane

Below: example of frequency extraction for electron



Recent highlights

PHYSICAL REVIEW LETTERS

Highlights Recent Accepted Collections Authors Referees Search Press About Staff

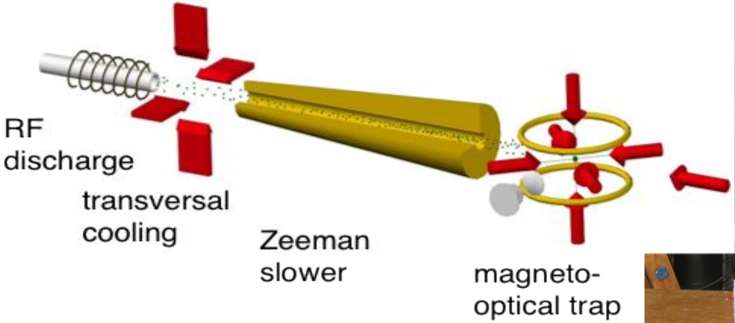
Accepted Paper

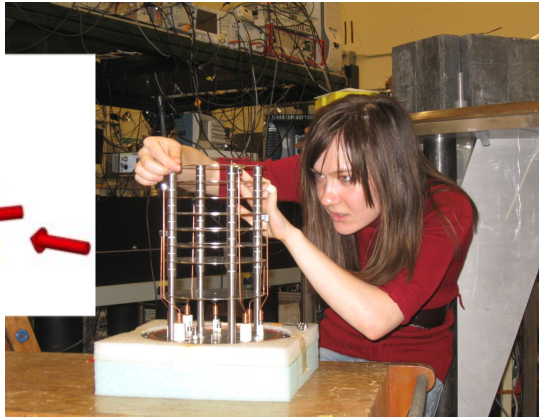
β-nuclear-recoil correlation from ^{6}He decay in a laser trap

Phys. Rev. Lett.

P. Müller, Y. Bagdasarova, R. Hong, A. Leredde, K. G. Bailey, X. Fléchard, A. García, B. Graner, A. Knecht, O. Naviliat-Cuncic, T. P. O'Connor, M. G. Sternberg, D. W. Storm, H. E. Swanson, F. Wauters, and D. W. Zumwalt

Accepted 1 June 2022





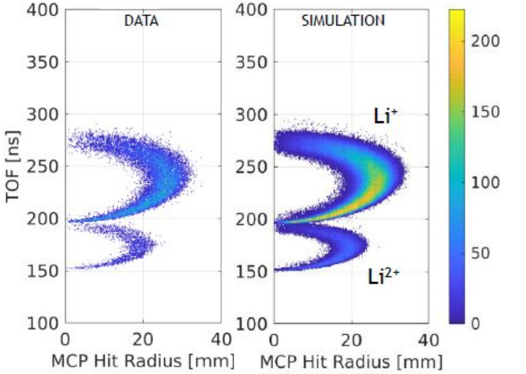
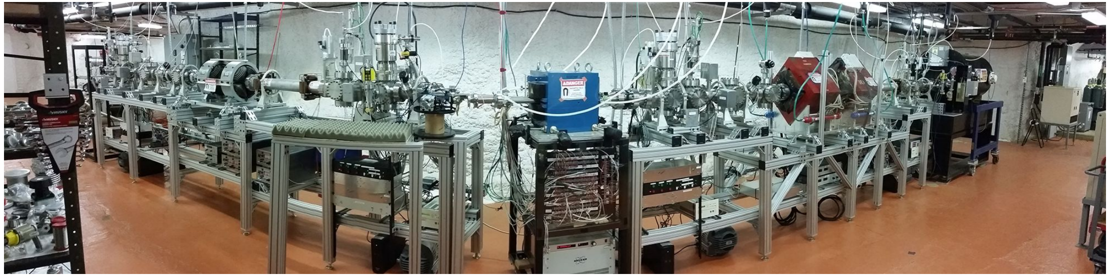
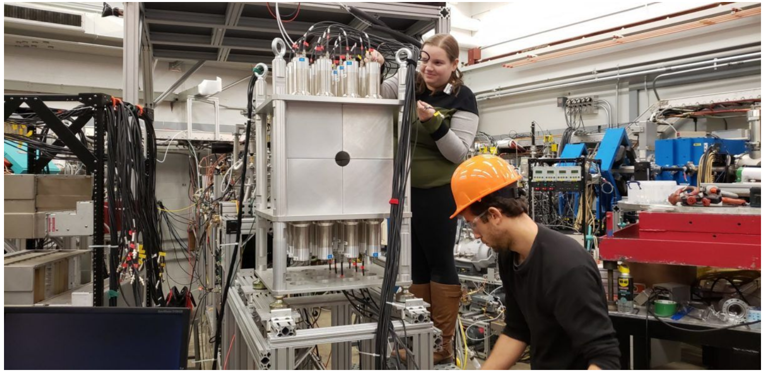


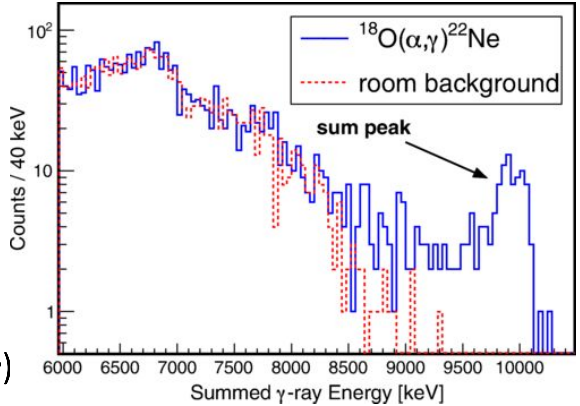
FIG. 3. Comparing TOF distribution versus hit radius between experiment (left) and GEANT4-based simulations (right) for beta-particle kinetic energy of $1.2 \leq K_\beta \leq 1.5$ MeV. The two arches in each graph correspond to the two charge states of the Li ions. No Li^{3+} ions are observed above background [21].

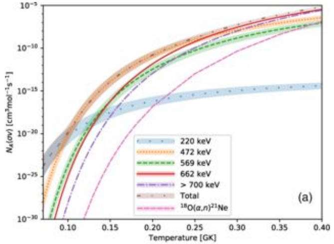
Notre Dame experiments @ CASPAR

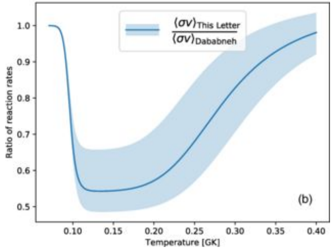


- Underground lab in (under?) South Dakota
- HECTOR, a summing array, has now been commissioned using the $^{27}Al(p,\gamma)$ reaction - EPJA 58 57 (2022)
- Recent highlights include a direct measurement of the $^{18}O(\alpha,\gamma)$ reaction with HECTOR which produces ^{22}Ne, a source of neutrons for the s-process Dombos++ Phys Rev Lett 128 162701 (2022)

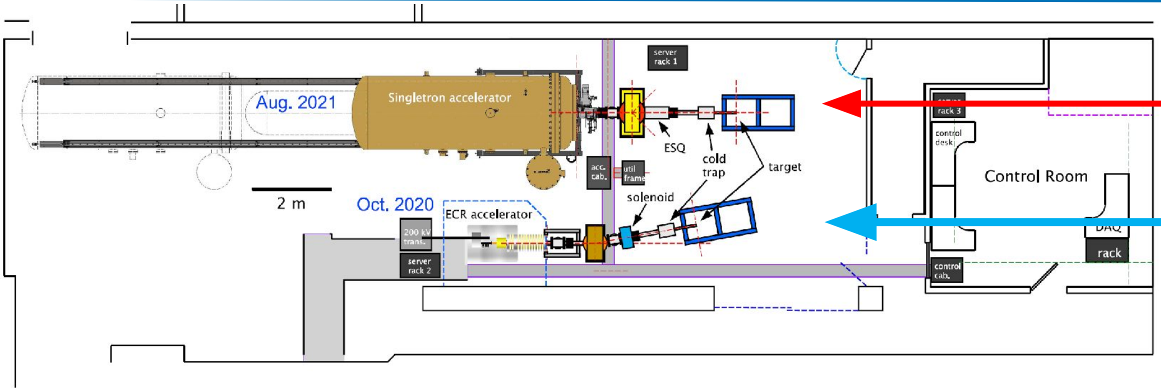








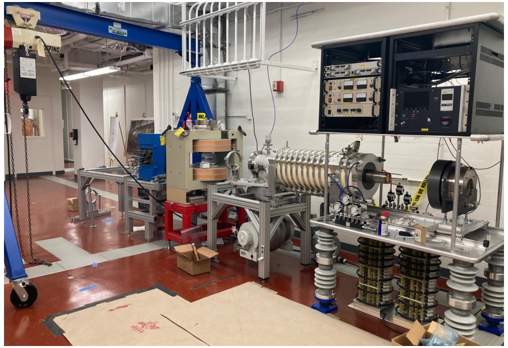
LENA Upgrade: LENA-II



2-MV Singletron accelerator with new 2.45 GHz ECR ion source

Refurbished ECR on HV platform with pulsing capabilities

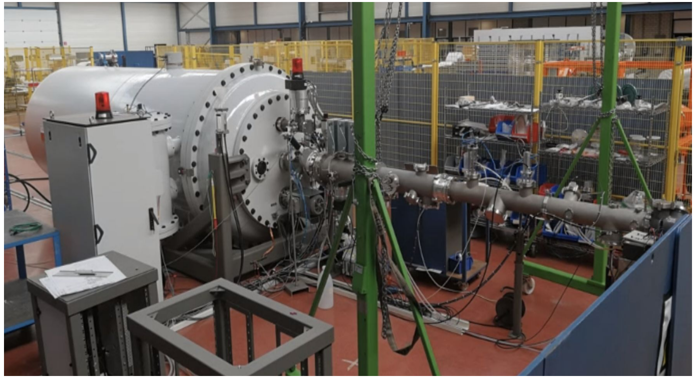
Installation of ECR accelerator in renovated laboratory space



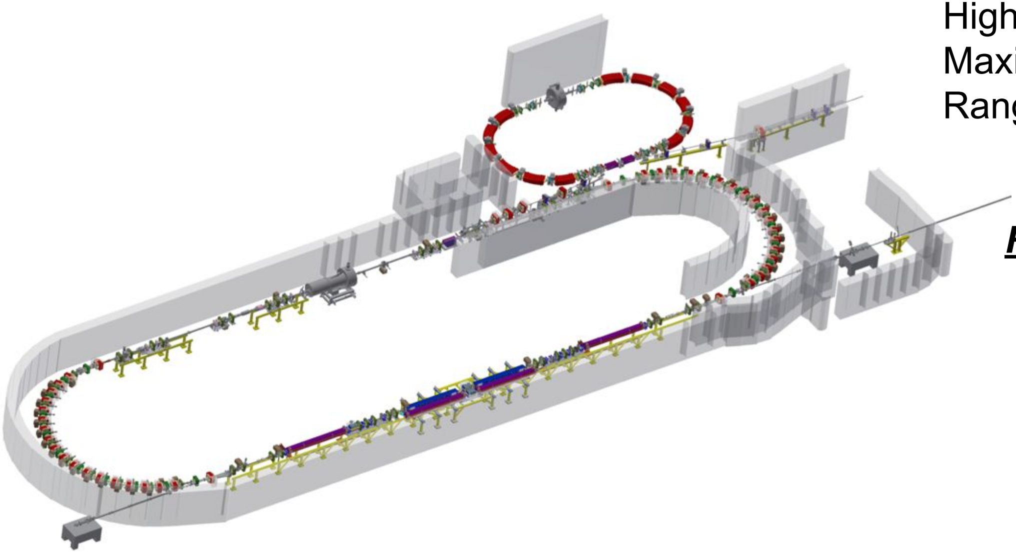
Singletron accelerator properties

Terminal voltage	0.1 – 2 MV 2.2 MV actual
Terminal stability	200 V
DC beam current at 250 kV	0.4 mA (H), 0.3 mA (He) 0.54 mA (H), 0.41 mA (He)
DC beam current at 1 - 2 MV	2 mA (H and He) 2 mA
Pulse frequency	0.125, 0.25, 0.5, 1, 2, 4 MHz
Pulse width	2 – 20 ns 2 ns (H), 2.5 ns (He)

Singletron accelerator on factory floor prior to shipping



HIGS: Toward PION Threshold



High Intensity Linearly and Circularly polarized Photons
Maximum flux (~ 3 x10^{10} γ/s);
Range 2.5 – 100 MeV

Recent developments:

- Optical cavity mirror R&D for 175-nm VUV FEL operation at HIγS was successful.
- This accomplishment enables HIγS operation up to 120 MeV γ-ray beam energy and enables Compton-scattering measurements with increased sensitivity to nucleon polarizabilities
- Tests of Low-Energy QCD (LEQCD)

New Initiatives:

- R&D for 155 nm mirror in order to reach 150 MeV γ-ray energy
- Maximum sensitivity for Compton Scattering program on p, d, ^{3,4}He
- LEQCD approach the energy threshold of pion-photoproduction.

New Information on ^{74}Ge from combining 3 techniques

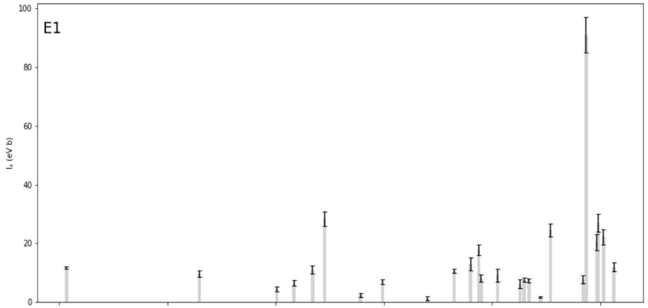
TUNL

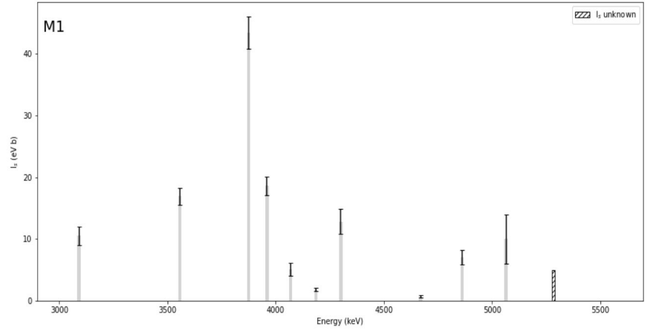
Motivation

Advances in computational techniques indicate that a better understanding of neutrinoless double beta decay (0νββ) can be achieved by expressing the nuclear matrix elements governing the decay in terms of a summation over states in the (A – 2) nucleus. Thus, in the case of $^{76}\text{Ge} \xrightarrow{0\nu\beta\beta} {}^{76}\text{Se}$, an extensive ^{74}Ge study provides constrains for 0νββ calculations.

New structure information on ^{74}Ge was obtained by combining results from Coulomb Excitation, NRF and (n,n'γ) carried out at three U.S. laboratories (HIGS at TUNL, ATLAS at ANL and the 7-MV neutron scattering facility at U. Kentucky).

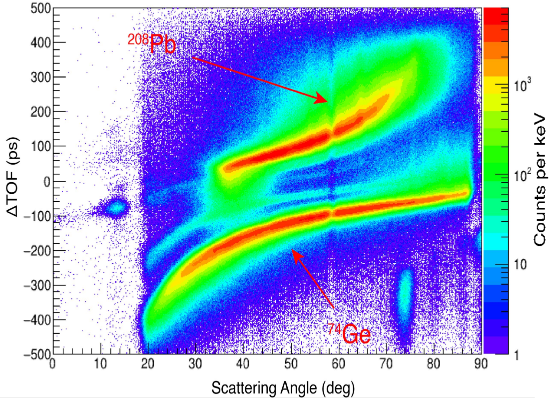
NRF study of ^{74}Ge at HIγS

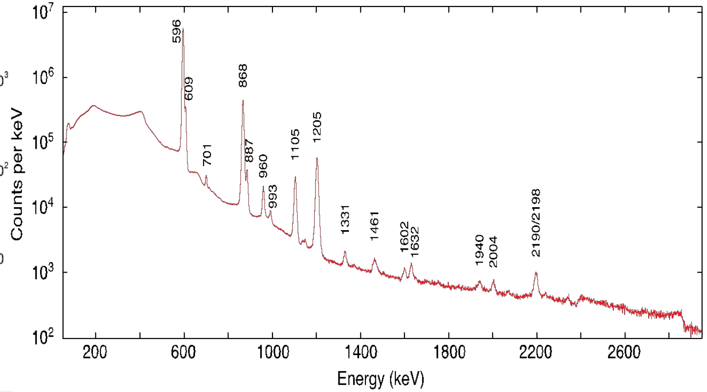




Experimentally determined integrated scattering cross section and energy of $J^\pi = 1^-$ (top) and $J^\pi = 1^+$ (bottom) states in ^{74}Ge.

Coulomb excitation of ^{74}Ge at ATLAS





Samantha Johnson, PhD thesis UNC

University of Kentucky Accelerator Laboratory (UKAL)

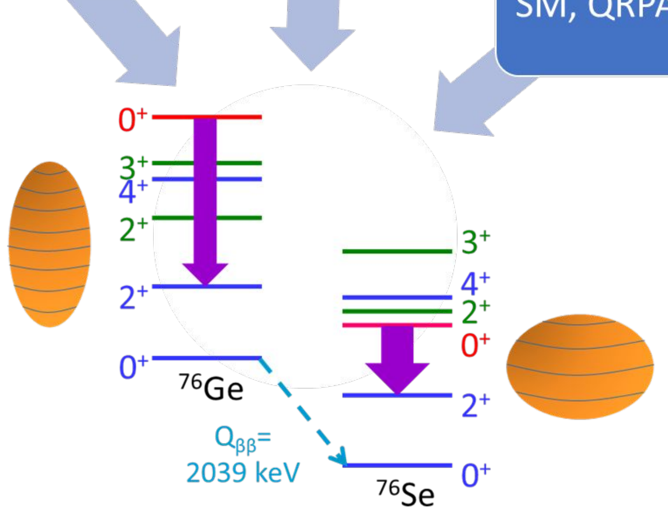
www.pa.uky.edu/accelerator

- **Using neutrons:**
  - **to probe nuclear structure relevant to 0νββ.**
  - **to study shape coexistence in nuclei.**
  - **to understand nuclear shape evolution.**

Identify and characterize all low-lying states with (n,n'γ)

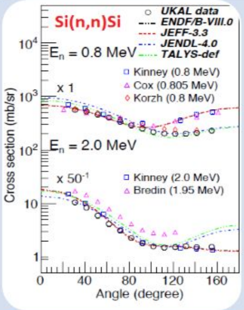
DSAM lifetimes: B(M1), B(E1) & B(E2) values

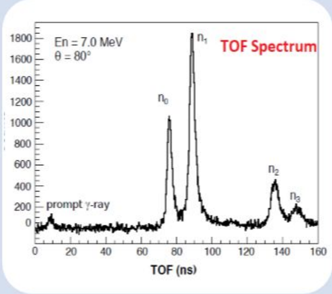
Collaborate with theorists: SM, QRPA, IBM

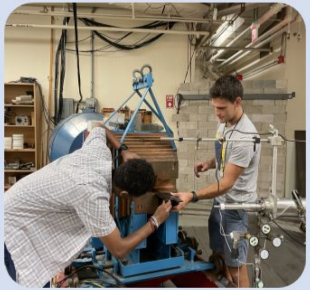


University of Kentucky Accelerator Laboratory (UKAL)

Probing nuclei with fast neutrons: Nuclear data for pure and applied science







$^{13}C(n,n)$, Si(n,n)

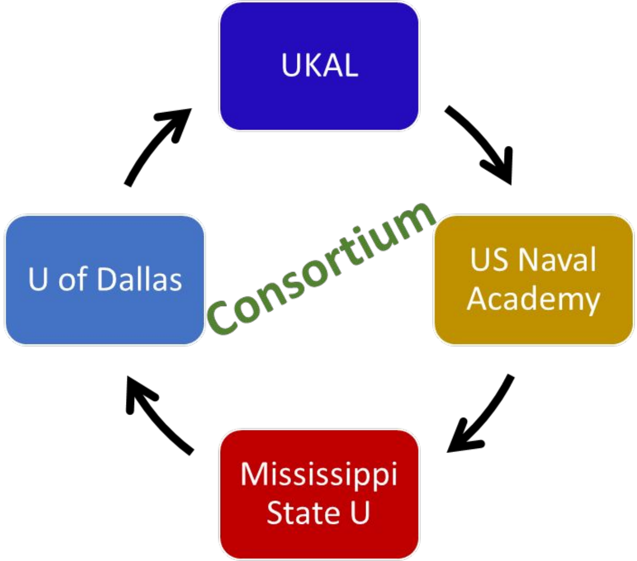
Cross sections for reactor applications, global models, and standards

$^7Li(n,n)^7Li$

Cross sections to answer discrepancies in existing data for global models

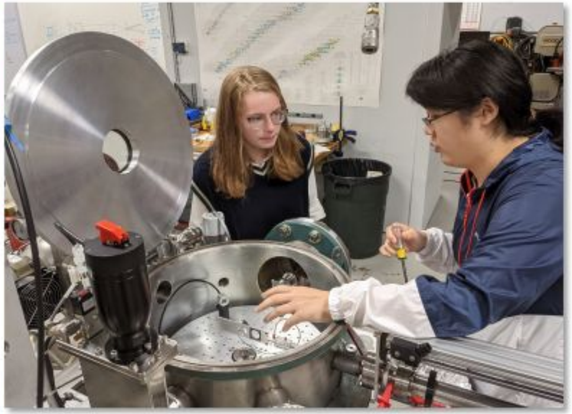
Workforce Development

A hands-on student-run facility to prepare the next generation of nuclear scientists

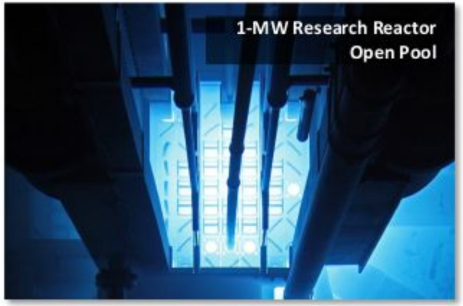


U.S. DEPARTMENT OF ENERGY | Office of Science

Research Highlights Radiation Lab

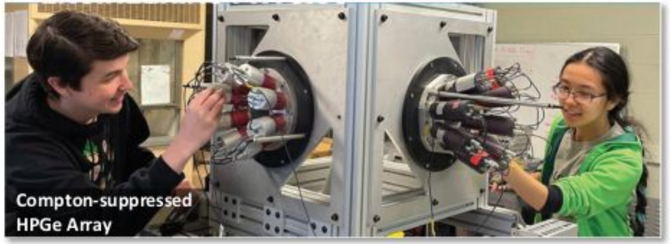


Main Facilities: 5.5-MV Van de Graaff
1-MW Research Reactor
6 graduate students, ~6-8 undergrads, 1-2 postdocs



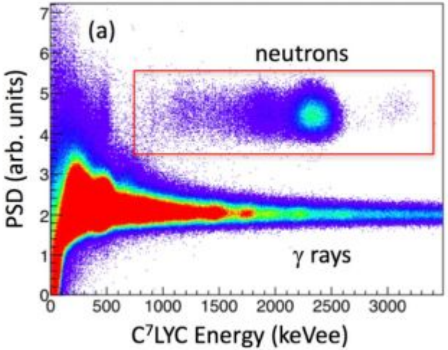
Implanted targets and characterization

- Well characterized H and He implanted targets are important in both nuclear structure (precision DSAM) and astrophysical (reaction rate) measurements.
- High current (> 1 μA) Deuteron and Alpha beams are implanted within the first μm of a heavy target foil using energy-degraded and low-voltage plasma sources.
- Implantation depth and number of implanted ions is determined via Elastic Recoil Detection Analysis (ERDA).



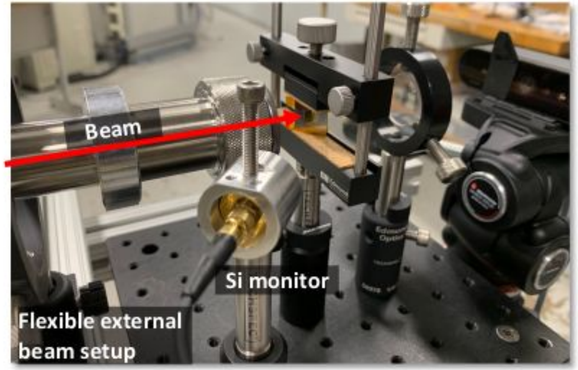
C^7LYC development

- Characterization of several new detectors.
- Exploring new geometries.



External-beam development

- Cell death studies in collaboration with UML Biomedical Engineering using proton irradiation for space physics applications.
- PIGE for identifying and quantifying total ^{19}F found in PFAS samples.



Edwards Accelerator Laboratory at Ohio University

Research Areas:

Nuclear Astrophysics, Applications, & Structure, Thin Films & Surface Science

Senior Researchers:

Carl Brune, Steve Grimes, David Ingram, Tom Massey, Zach Meisel, Alexander Voinov

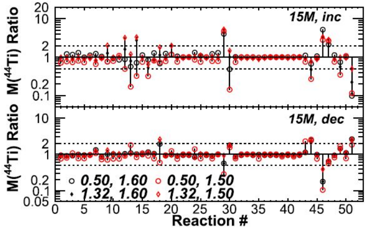
Technical Staff:

Don Carter, Greg Leblanc

PhDs since last LECM:

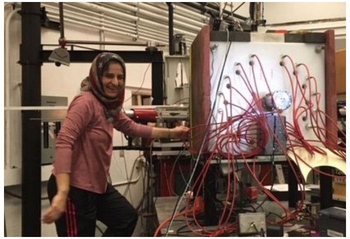
Shiv Subedi

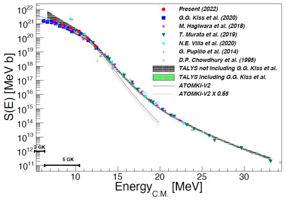
Measurements for CCSN ^{44}Ti production

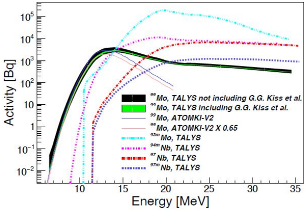


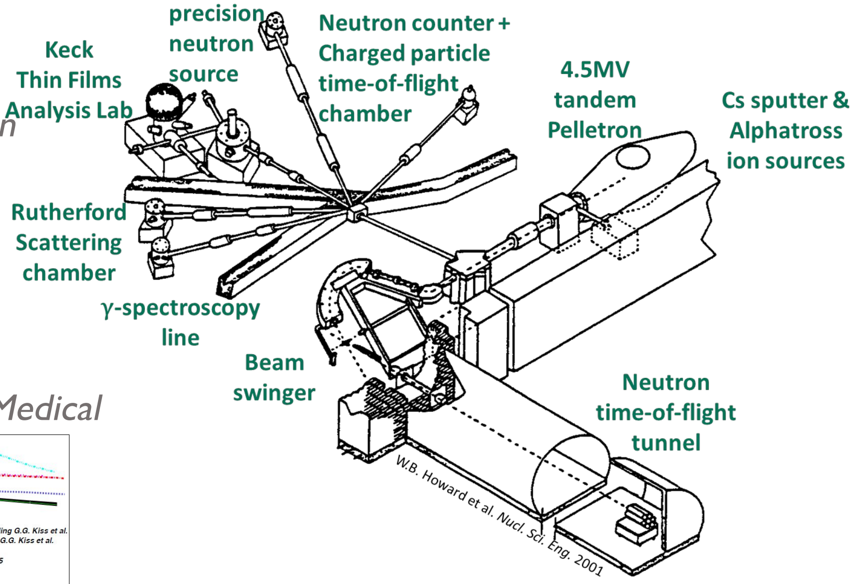
Gula Hamad

^{96}Zr(α,n) Measurements for CCSN & Medical









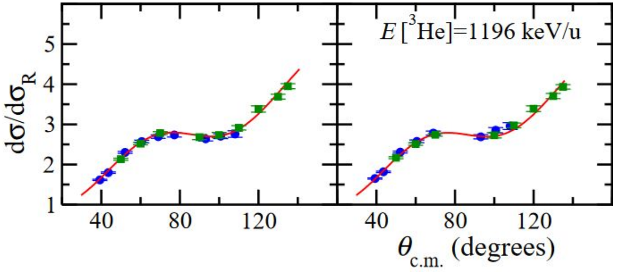
Edwards Accelerator Laboratory at Ohio University

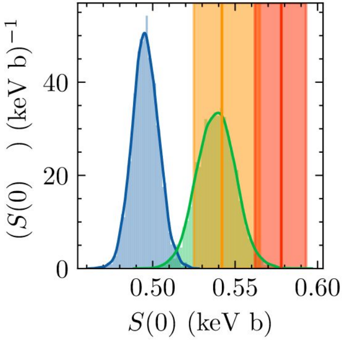
Recent Science Highlights in Astrophysics & Applications

Bayesian R-Matrix Analyses & Scattering Measurements for $^3He(\alpha,\gamma)$ for BBN & Solar Fusion

Daniel Odell (PD)

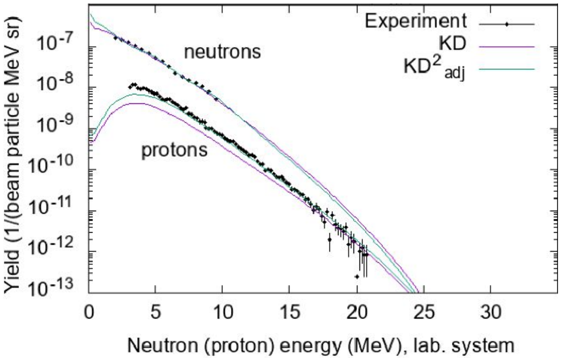
S. Paneru *PhD Dissertation* 2020





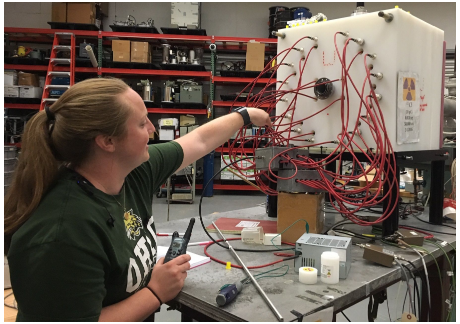
Odell+ *Front.Phys.* 2022

Reduction in Imaginary Neutron Optical Potential Off-stability for i & r-Processes

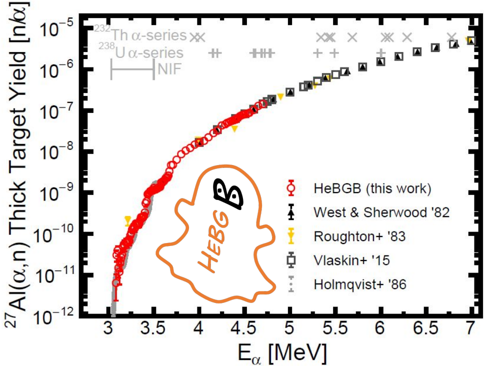


Voinov+ *PRC* 2021

(α,n) Cross Section Measurements & Detector Development for Astrophysics & Applications

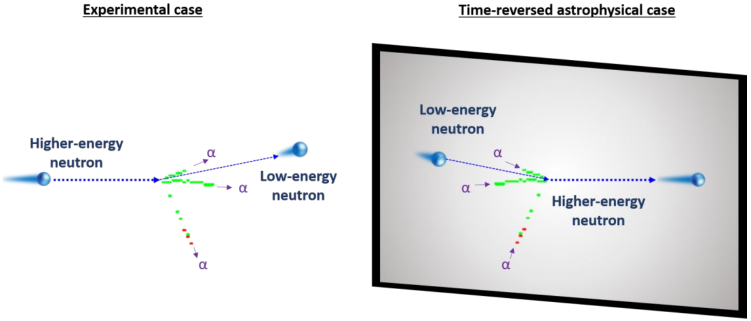


Kristyn Brandenburg+ *J. Inst.* 2022



Brandenburg+ *Submitted*

Enhancement of triple-alpha reaction rate via upscattering

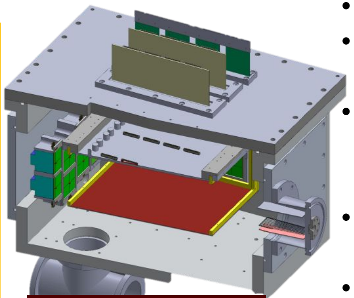


Measurement of $^{12}C(n,n_2)3\alpha$ XS with TexAT at Edwards Accelerator Lab, OU in astrophysically-relevant region (E_n = 8.3-10 MeV)
First neutron-induced reactions with an active target TPC!

Time-reversal mirror comparing experimentally-measured reaction and the neutron upscattering reaction in stars – enhancing Hoyle radiative width!

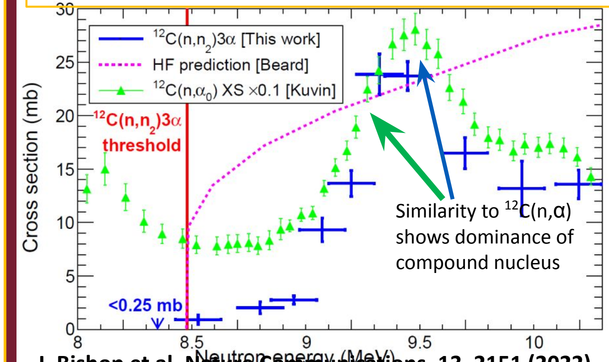
TAMU, WashU, OU collaboration

TexAT TPC

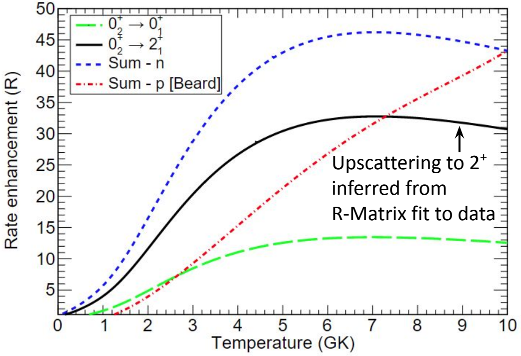


- Versatile TPC
- Micromegas readout
- Single GEM avalanche stage
- GET system used
- Nuclear structure/astrophysics studies

E. Koshchiy et al. NIMA 957, 163398 (2020)



$^{12}C(n,n_2)3\alpha$ XS smaller than expected (particularly near threshold) □ neutron upscattering enhancement **smaller** than expected (particularly at low T) – no suitable astro sites?? Settles longstanding question of importance of neutron upscattering



J. Bishop et al. Nature Communications, 13, 2151 (2022),
Carbon Conundrum: Experiment Aims to Re-create Synthesis of Key Element – Scientific American article (2020)

Methods:

- Thick target Inverse kinematics technique **TTIK**
- **Active target**, TexAT
- **^{14}O** radioactive **beam** at MARS (TAMU)
- **R-matrix** analysis

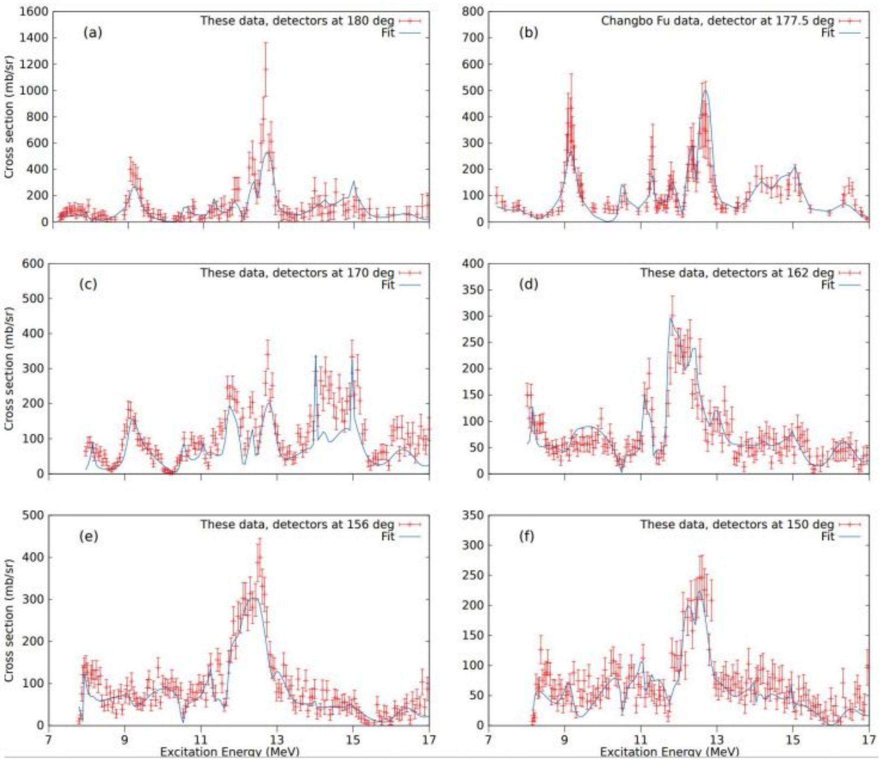
Data Analysis:

- **Excitation function** of **^{18}Ne** in the excitation energy range **8-17 MeV**.
- R-matrix analysis **starting form the parameters** listed in [PRC 90, 024327 (2014)] for the mirror nucleus **^{18}O**.
- **Comparison** of the α-cluster states in **^{18}O and ^{18}Ne**
- **Comparison** with a **shell-model** calculation [PRC 100, 034321 (2019)]

Conclusions:

- **α-clustering is strong** in ^{18}O and ^{18}Ne, with good correspondence of the mirror levels.
- At high excitation energy the observed **states are more clustered than predicted**. This can be due to the limitations of the model. However, the fact that, in the experiment, on each J^{π} group, one or two levels for each configuration absorb all the alpha strength going in that reaction channel suggests that these could be **superradiant states**.
- More experimental and theoretical studies are required to understand the role of superradiance in α-cluster states

α-cluster structure of ^{18}Ne

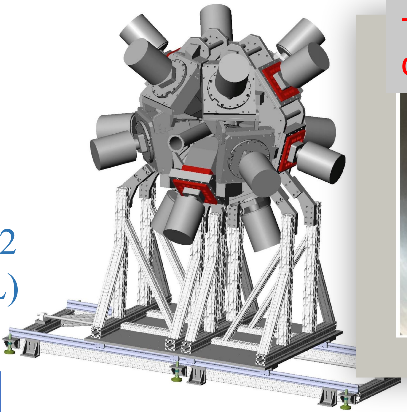


M. Barbui et al. Submitted to PRC: arXiv:2206.10659

CLARION2@FSU

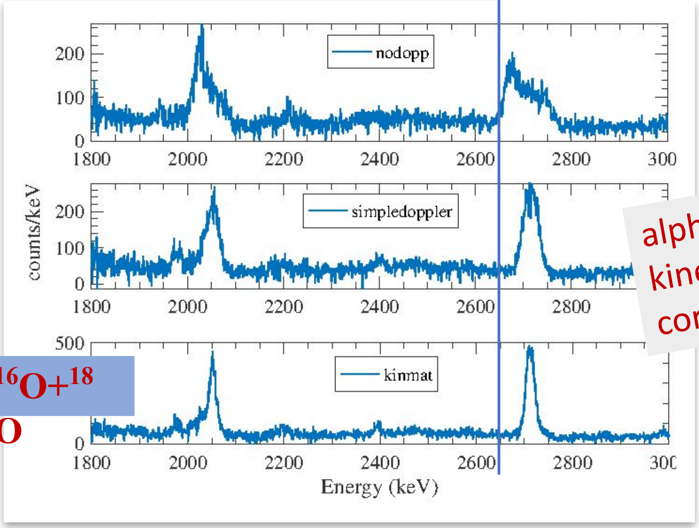
& OAK RIDGE National Laboratory

- γ-ray detection with up to 16 Compton suppressed CLOVERs
- Charged particle detection
  TRINITY: 5 rings of GAGG+ Si
- Commissioned in Dec 2021
- First experiments: Jan-March 22
- Safe Coulex of ^{48,49,50}Ti (ORNL)
- ^{16}O+^{18}O, ^{7}Li + ^{64}Ni (FSU)



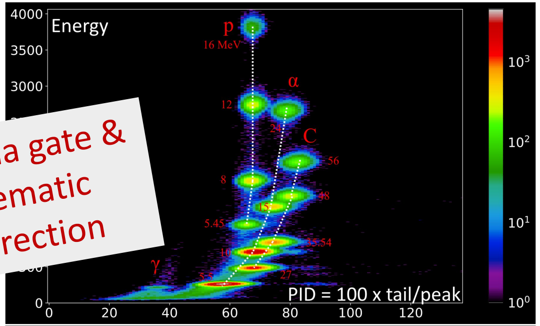
+ TRINITY GAGG det.

Sept 2021

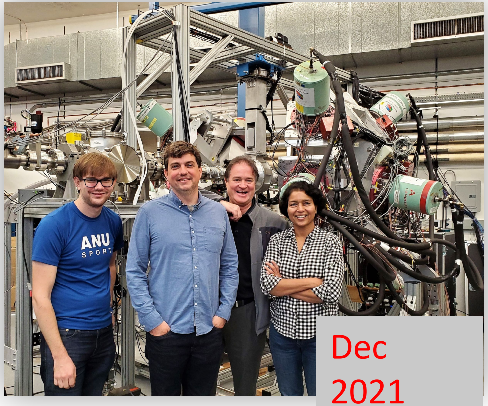


^{16}O+^{18}O

alpha gate & kinematic correction



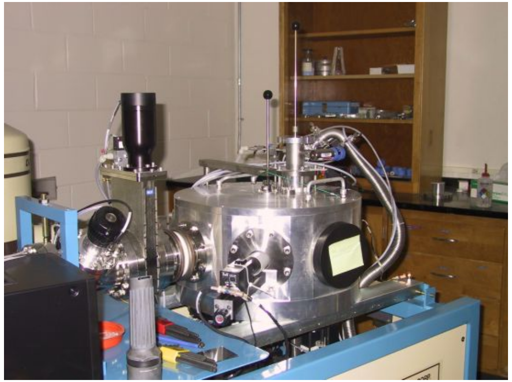
PID capability of TRINITY



Dec 2021

Hope College

- NEC 1.7 MV Tandem
- Protons or alpha beams
- Microfocusing ability
- Instrumented for PIXE, RBS, PIGE, IBL, NRA
- In-air PIXE and PIGE



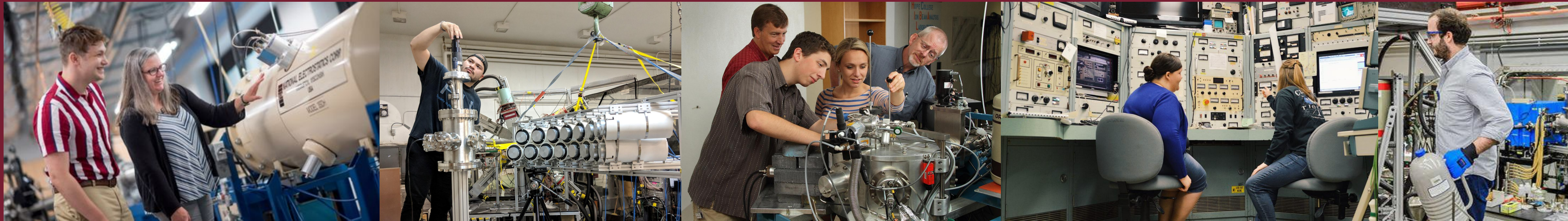
Hope COLLEGE

Recent Work

- Lowering the level of detection for aqueous PIGE measurements
  - Quantifying PFAS in water from PIGE (fluorine)
  - Inexpensive fast-plastic Compton suppressor and sample concentration to lower level of detection; initial results of ~10ppb
- Sample irradiation (interdisciplinary work)
  - Irradiate mice with protons or neutrons (implications for Mars astronauts)
  - Irradiate novel photovoltaics (radiation resistance in space) and new superconductors (changes with lattice damage); at ~150 keV
- Thin target characterization with RBS
- Most recently, Si targets for Indiana University
- Outreach to K-12 about nuclear physics, Boy Scout nuclear science badge

Association for Research at University Nuclear Accelerators

Interconnected collective of 11 institutions



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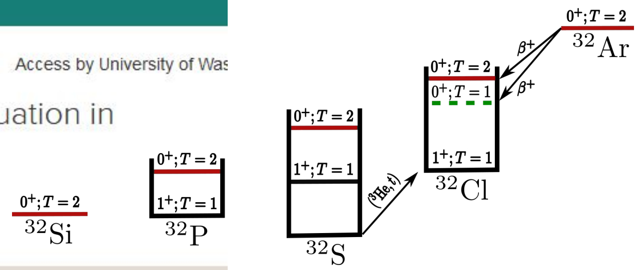
Isospin mixing and the cubic isobaric multiplet mass equation in the lowest $T = 2$, $A = 32$ quintet

M. Kamil *et al.*
Phys. Rev. C **104**, L061303 – Published 15 December 2021

Article | References | Citing Articles (1) | PDF | HTML | Export Citation



The isobaric multiplet mass equation (IMME) relates the masses of an isospin multiplet quadratically, and it plays an important role in studies of nuclear structure, nuclear astrophysics, and fundamental symmetries. This work uses shell-model calculations, together with data from ^{32}Ar β decay and ^{32}S(^{3}He,t) experiments to provide an important step in explaining an observed IMME violation in the *A=32*, *T=2* quintet. It is shown that a small but finite cubic term is required for this case due to *T=1* isospin mixing. The analysis also provides a means to obtain isospin non-conserving corrections for *T=2* ^{32}Ar→^{32}Cl super-allowed decay, which belongs to a category of decays that are used to extract the *Vud* element of the CKM quark-mixing matrix.

CENPA at U. of Washington

Tandem Van de Graaff for production of ^{6}He and ^{19}Ne for Fundamental Symmetries studies

Developing precision beta spectroscopy via Cyclotron Radiation Emission Spectroscopy (CRES)

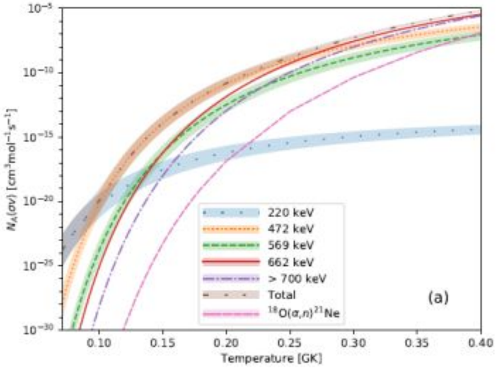
- **Searching for chirality-flipping interactions in ^{6}He and ^{19}Ne**
- **Technique could be used at FRIB with ion trap for beta spectroscopy from many nuclei**

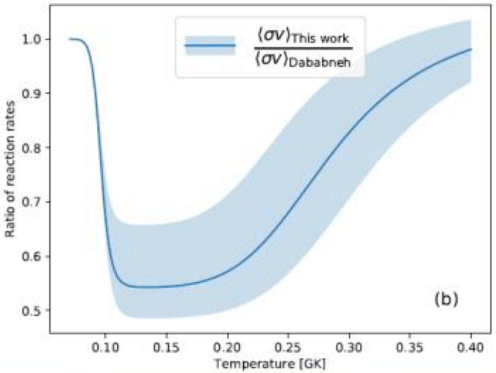
Measurement of Low-Energy Resonance Strengths in the $^{18}O(\alpha,\gamma)^{22}Ne$ Reaction

The $^{18}O(\alpha,\gamma)^{22}Ne$ reaction is an essential part of a reaction chain that produces the $^{22}Ne(\alpha,n)^{25}Mg$ neutron source for both the weak and main components of the slow neutron-capture process. At temperatures of stellar helium burning, the astrophysically relevant resonances in the $^{18}O(\alpha,\gamma)^{22}Ne$ reaction that dominate the reaction rate occur at α particle energies E_{lab} of 472 and 569 keV. However, previous experiments have shown the strengths of these two resonances to be very weak, and only upper limits or partial resonance strengths could be obtained.

This work reports the first direct measurement of the total resonance strength for the 472- and 569-keV resonances, 0.26±0.05 and 0.63±0.30 μeV, respectively. New resonance strengths for the resonances at α particle energies of 662.1, 749.9, and 767.6 keV are also provided.

These results were achieved in an experiment optimized for background suppression and detection efficiency. The experiment was performed at the Sanford Underground Research Facility, in the 4850-foot underground cavity dedicated to the Compact Accelerator System for Performing Astrophysical Research. The experimental end station used the γ-summing High EffiCiency TOtal absorption spectrometeR. Compared to previous works, the results decrease the stellar reaction rate by as much as ≈46+6−11% in the relevant temperature range of stellar helium burning.





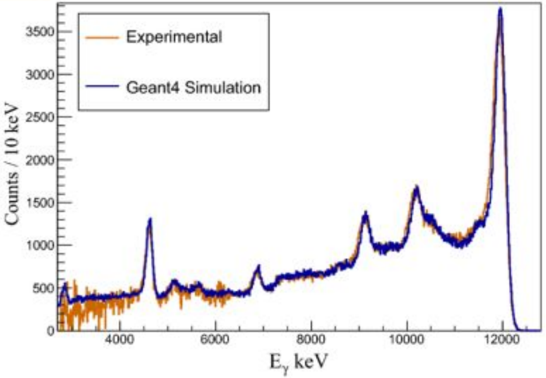
A. Dombos et al., Phys. Rev. Lett. 128 (2022) 162701

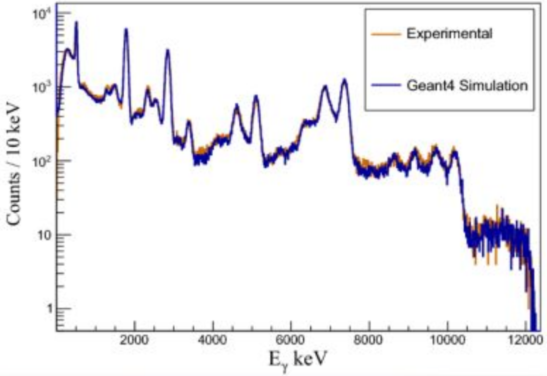
UNIVERSITY OF NOTRE DAME

Commissioning of the 4π γ-summing array HECTOR at CASPAR: measurements of 27Al(p,γ) 28Si resonances 4850 feet underground

The High EffiCiency TOtal absorption spectrometeR (HECTOR) is a 4π γ-summing detector designed to measure capture cross sections. Here, we present the commissioning of HECTOR at the Compact Accelerator System for Performing Astrophysical Research (CASPAR) laboratory, which is located at the Sandford Underground Research Facility 4850 feet underground. With the underground environment drastically improving the signal-to-noise ratio of the detector, it is estimated HECTOR will be able to push cross-section measurements below a nanobarn. Details of the experimental setup are discussed along with the analysis of several resonance strengths measured for the ^{27}Al(p,γ)^{28}Si reaction between the lab energies 0.2–1.0 MeV. The measurements are in excellent agreement with those found in the literature.

E_p keV	This Work ($l.s.$)	This Work ($stat$)	NACRE [22]
	$\omega\gamma$ eV		
292.6	$2.65(17) \times 10^{-4}$	$2.73\,^{0.29}_{0.22} \times 10^{-4}$	$3.8(7) \times 10^{-4}$
405.3	$9.76(51) \times 10^{-3}$	$10.3\,^{0.7}_{0.6} \times 10^{-3}$	$9.0(10) \times 10^{-3}$
632.2	0.266(13)	0.269(14)	0.266(14)
887.8	$1.22(7) \times 10^{-2}$	$1.24\,^{0.19}_{0.15} \times 10^{-2}$	$1.5(2) \times 10^{-2}$
991.9	1.94(10)	1.93(10)	1.9(1)





O. Olivas-Gomez *The Eur. Phys. J. A* **58** (2022) 57