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Hope College
Hope College Ion Beam Analysis Laboratory
Ohio University
John E. Edwards Accelerator Laboratory
Texas A&M University
Cyclotron Institute
TUNL
Triangle Universities Nuclear Laboratory
Union College
Union College Ion Beam Analysis Laboratory
University of Massachusetts-Lowell
Radiation Laboratory
University of Kentucky
Accelerator Laboratory
University of Notre Dame, ISNAP, Institute for Structure and Nuclear Astrophysics
University of Washington CENPA Center for Experimental Nuclear Physics and Astrophysics

Research directions

- Nuclear Astrophysics
- Nuclear Structure Physics
- Nuclear Reactions
- Fundamental Symmetries
- QCD
- Nuclear Physics Applications
- Surface Science

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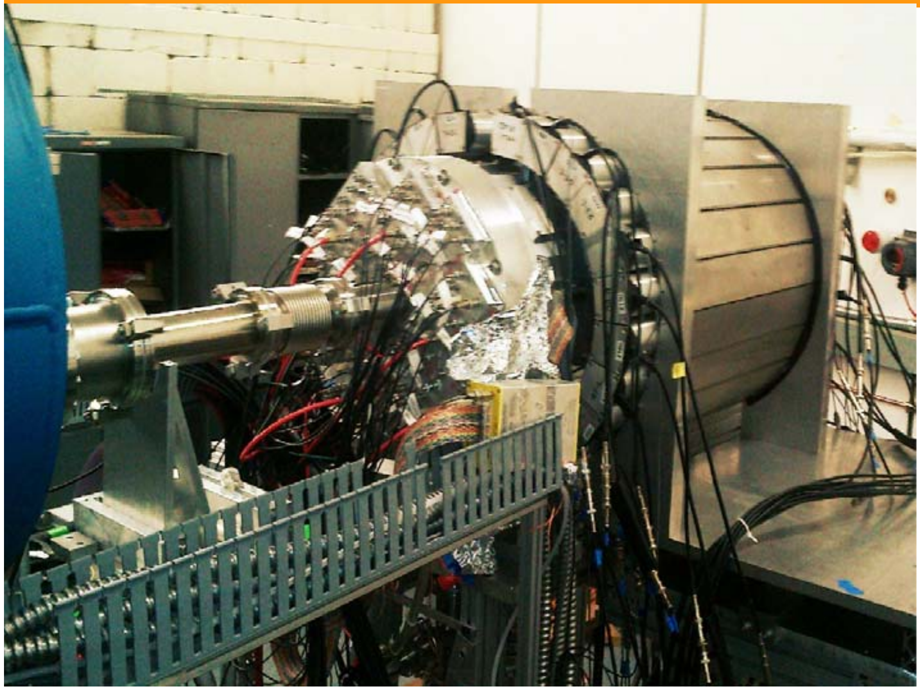
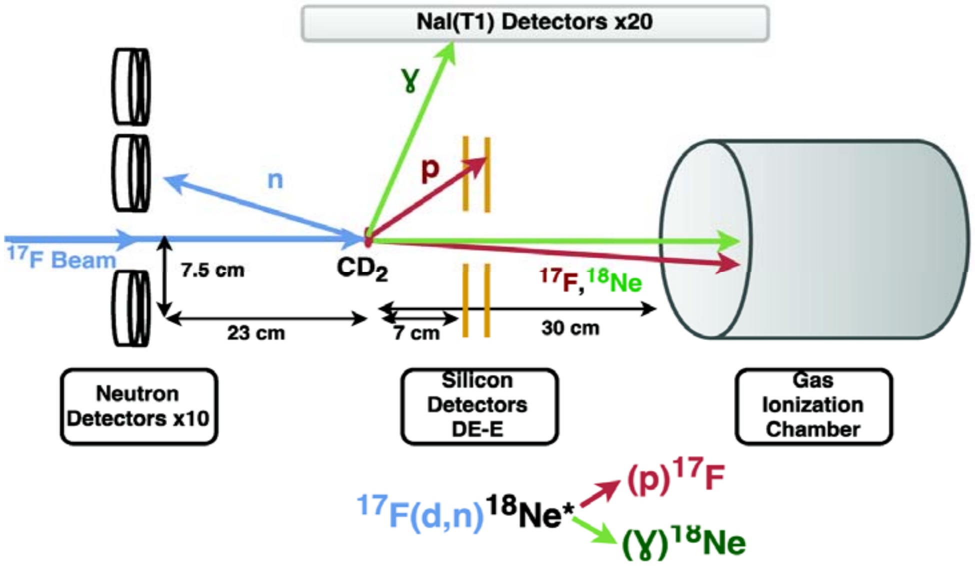
Resonance spectroscopy with RIB for Nuclear Astro





- RIB ~5 MeV/u from RESOLUT facility
  e.g. ^{17}F, ^{19}F, ^{25}Al
- resonances decay by p-emission
- New: coincident neutron and γ-detection
- Narrow HI recoil cone, detected in IC in coinc.

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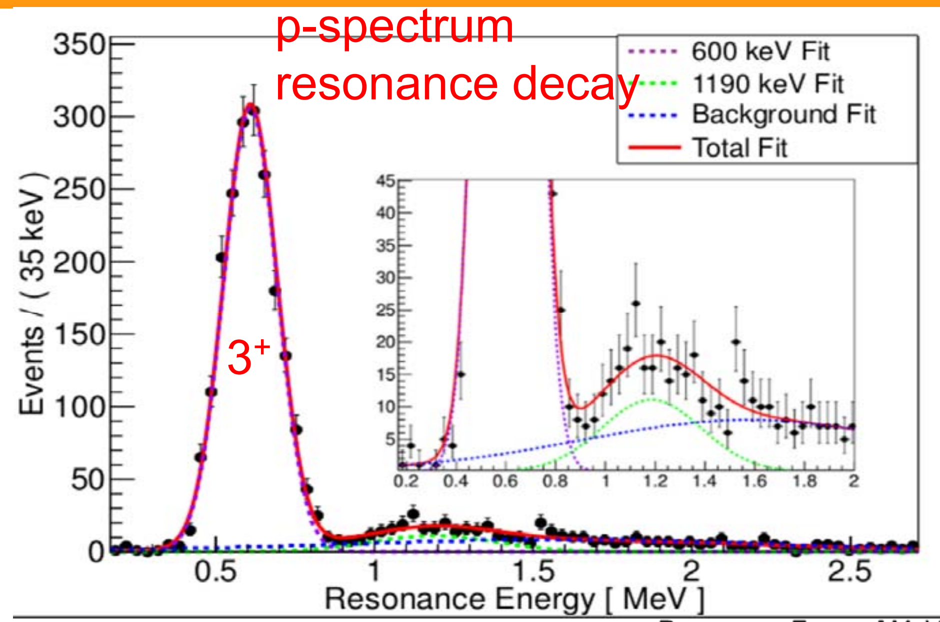
Radioactive ^{17}F beam from RESOLUT at 5.6 MeV/u

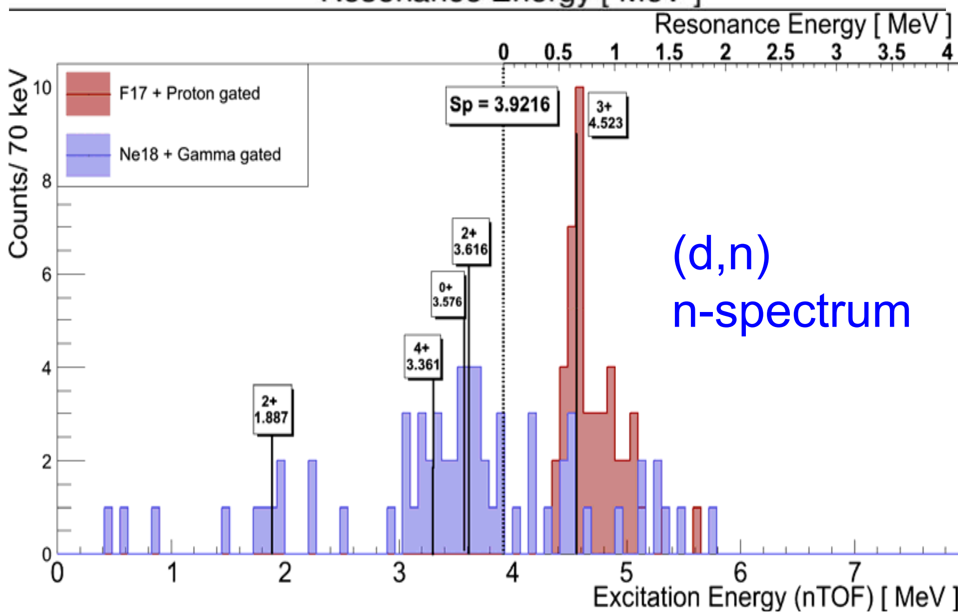
Neutron time-of-flight spectrum from $^{17}F(d,n)$ in inverse kinematics

^{18}Ne 3^+ resonance parameters consistent with HRIBF $^{17}F(p,\gamma)^{18}Ne$ (Chipps et al.)

Measure l=0 transfer to highest ^{18}Ne bound states: 0^+, 2^+

Determine "direct capture" rate $^{17}F(p,\gamma)^{18}Ne$ from asympt. norm. coeff.





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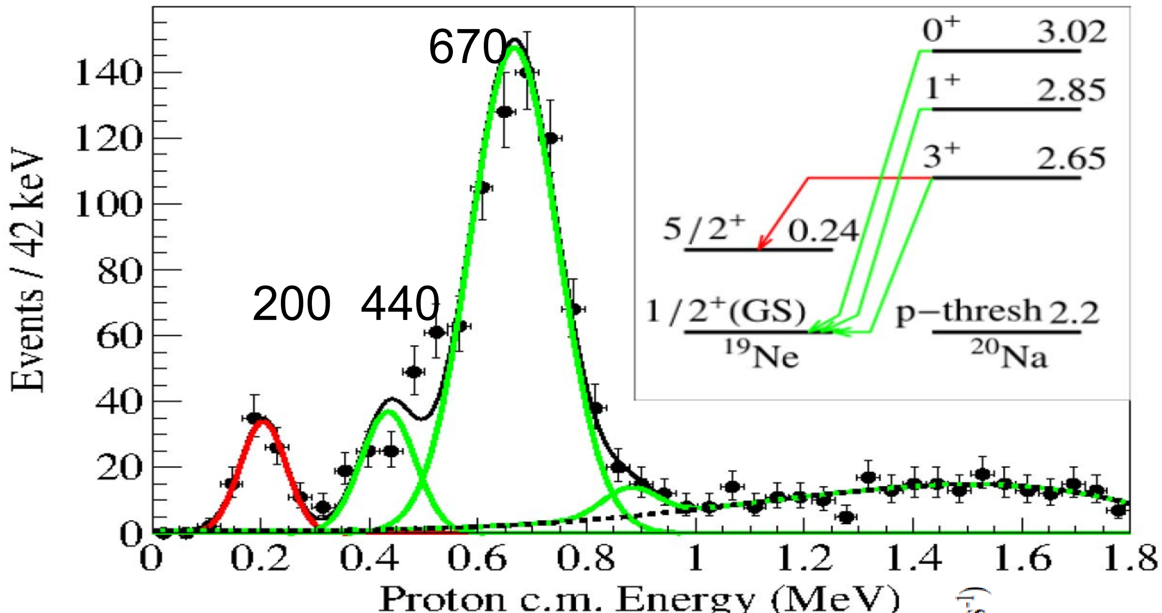
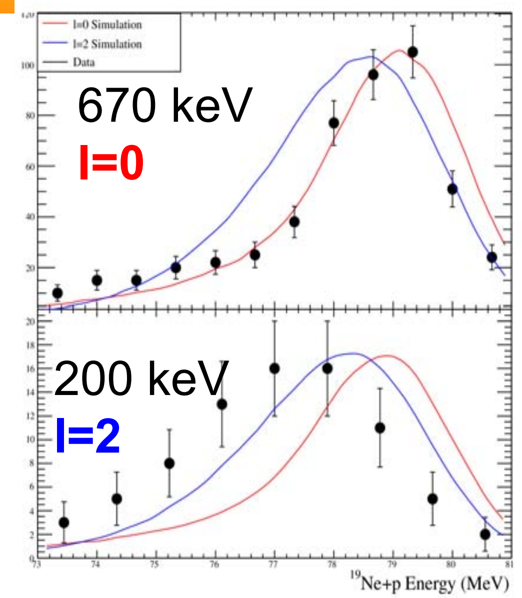
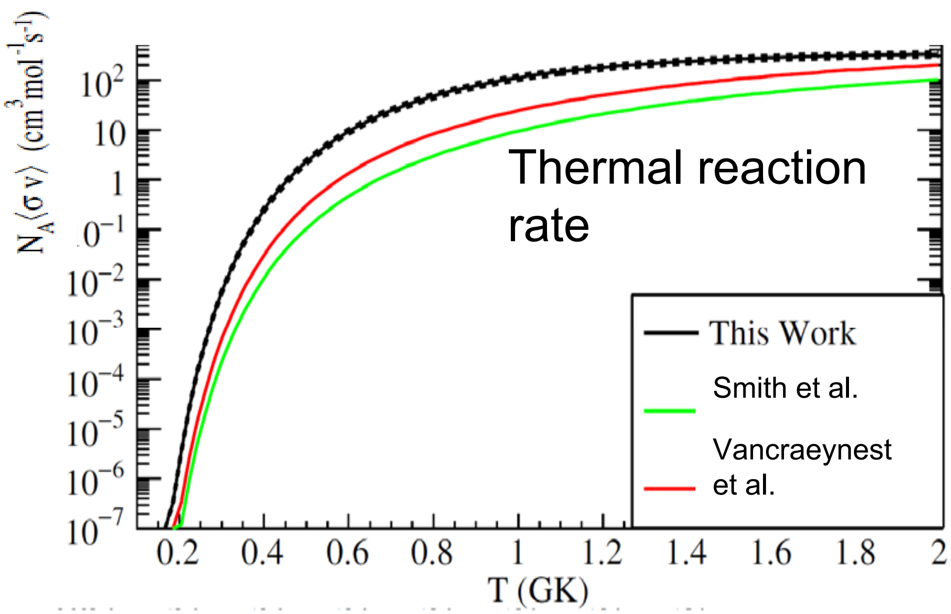
J. Belarge *et al.*: ^{19}Ne(d,n)^{20}Na (p) ^{19}Ne





- Radioactive ^{19}Ne beam from RESOLUT
- Reconstruct p-resonance spectrum,
  - (d,n) angular distribution
- 440, 670 keV resonances known,
  - additional 200 keV peak is "inelastic" l=0 proton-emission from 440 keV resonance to excited state populated through **l=2**
- Effective capture in ^{19}Ne(p,γ)^{20}Na,
  - no bottleneck in hot-CNO breakout



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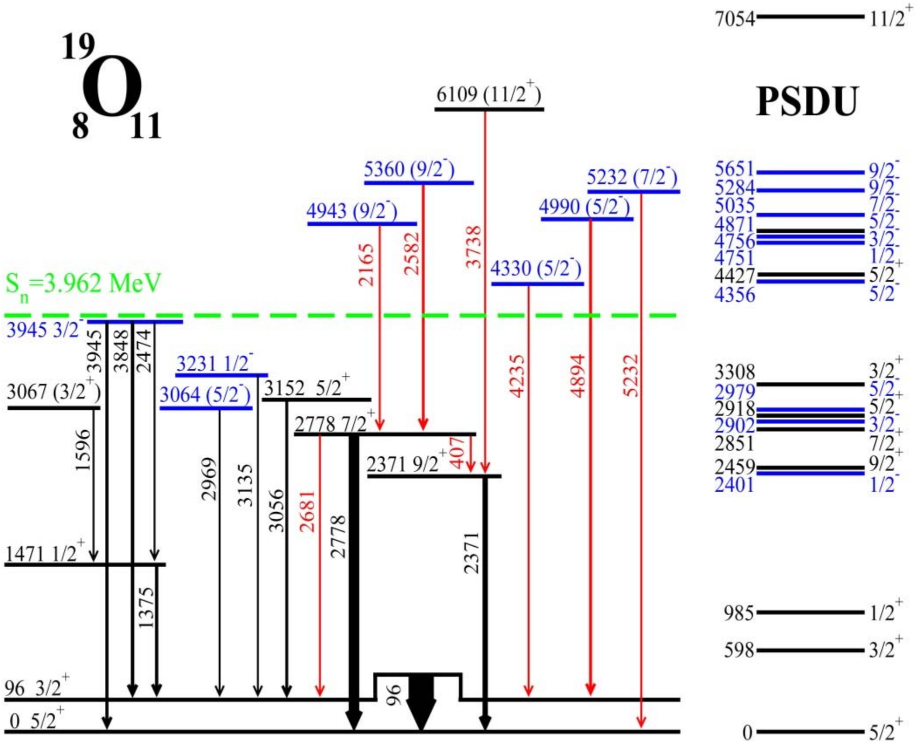
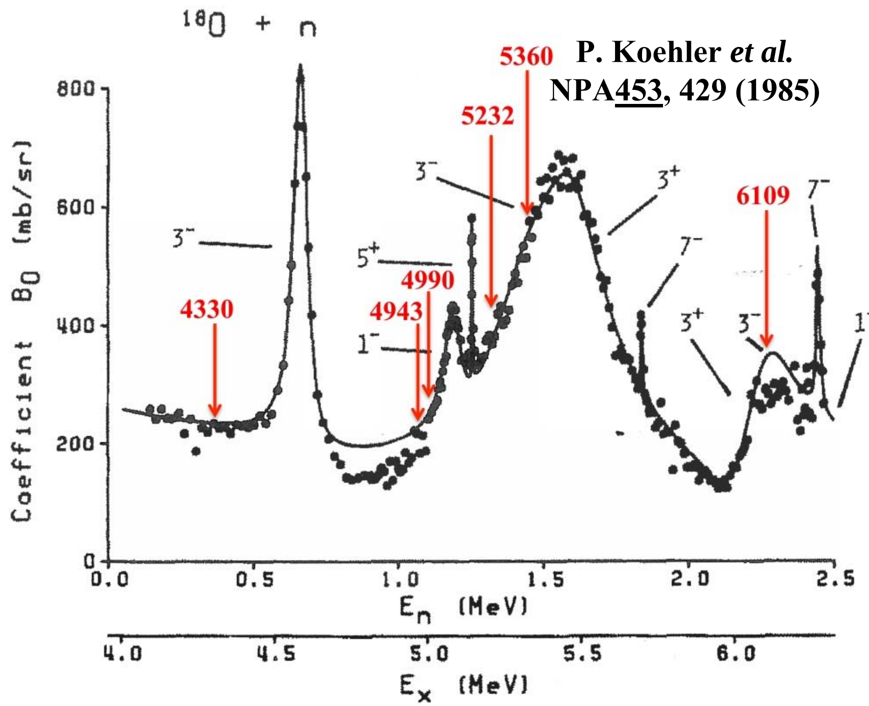


These states are interspersed among *n* decaying states as shown by the red arrows in the n resonance curve shown below. Lower *n* penetrability from the somewhat higher spins of the γ-decaying states is not enough to explain how eV E-M widths can compete with normally keV *n*-decay widths. The former have more complex intruder configurations leading to very small overlap with $^{18}O + n$.

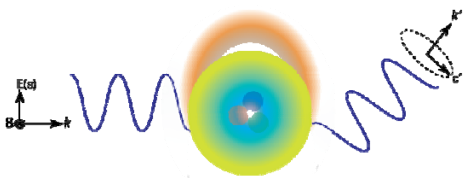
FSU grad student Rutger Dungan discovered 6 γ-decaying states which are unbound to neutron decay in ^{19}O from the $^{9}Be(^{14}C,\alpha n)$ reaction.

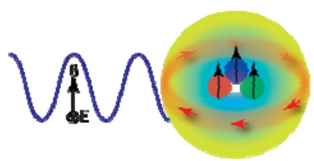


Triangle University National Laboratory

Compton Scattering: A Low-Energy QCD Program at the High Intensity Gamma-Ray Source (HIGS)

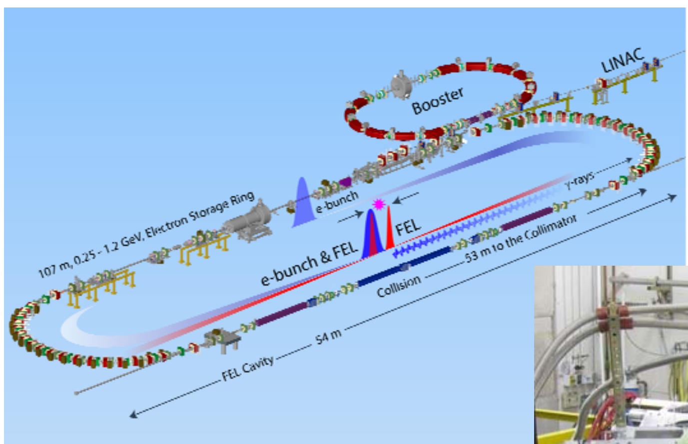
Measurement of polarizabilities via Compton Scattering provides stringent test of calculations that link the effective low-energy description of nucleons to QCD, and Lattice QCD predictions. At HIGS, we are measuring proton and neutron polarizabilities at unprecedented accuracies.



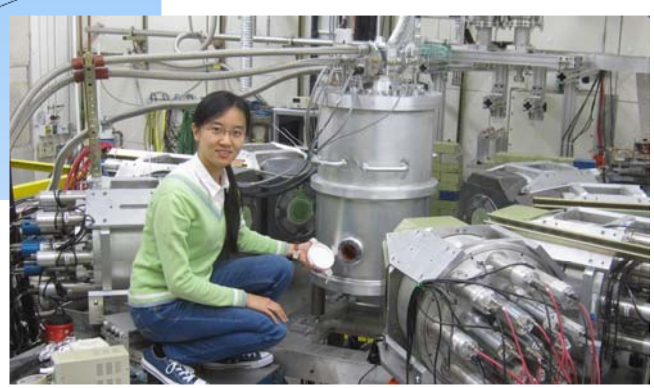


$$\vec{m} = 4\pi\beta_{M1}(\omega)\vec{B}(\omega)$$

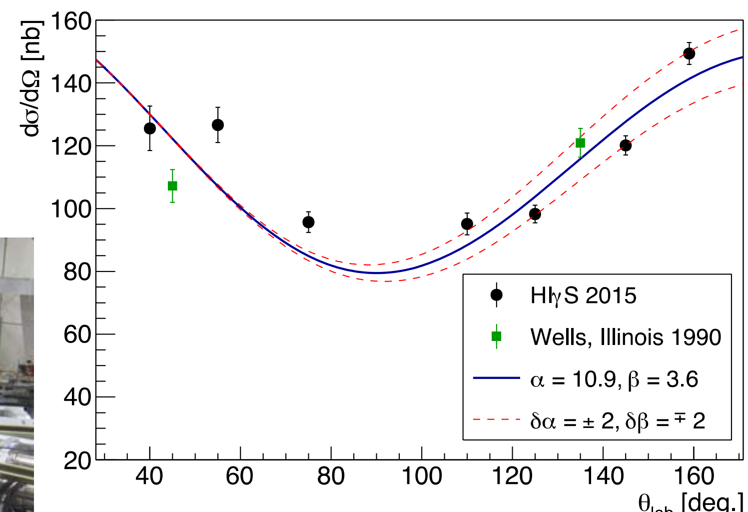
The EM self-energy of the nucleon can be related to the measured elastic/inelastic cross sections; Largest source of uncertainty is from $\beta_p - \beta_n$ (where uncertainty from neutron dominates)



HIGS schematic



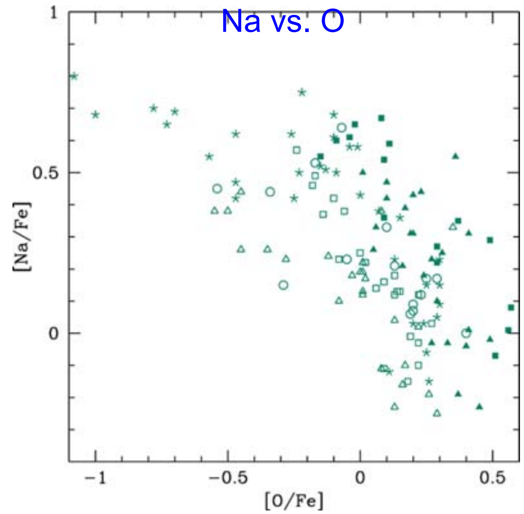
TUNL grad student Xiaqing Li with the HIGS NaI array and cryogenic target



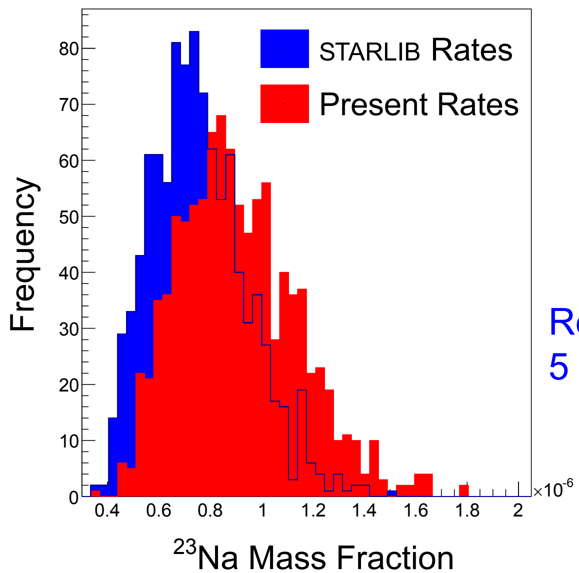
^{4}He Compton scattering cross section at 65 MeV. Data have been collected on Deuterium as well

Triangle University National Laboratory

$^{22}Ne(p,\gamma)^{23}Na$ and Abundance Anomalies in Globular Clusters



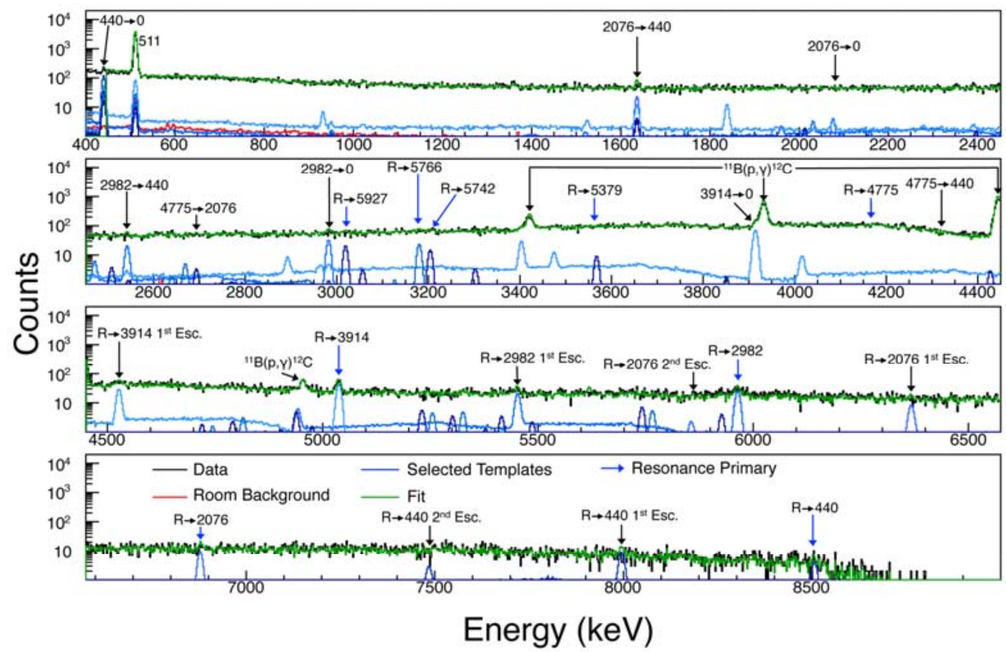
various clusters; see: P. Ventura and F. D'Antona, A&A 457, 995 (2006)



Revised ^{23}Na abundance for 5 M_{sun} AGB model

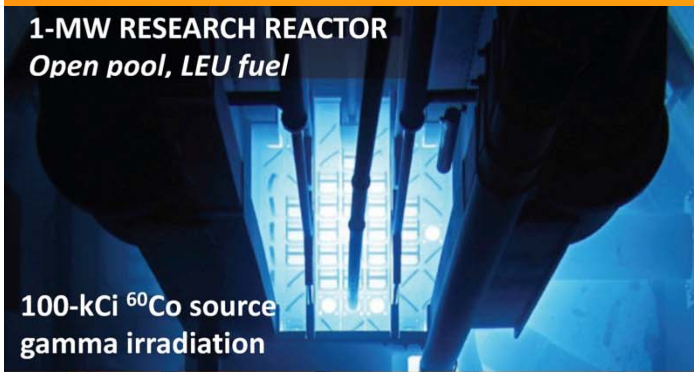
LENA measurements:

E_{cm} = 151 keV resonance; $\omega\gamma$ = 0.203(40) μeV



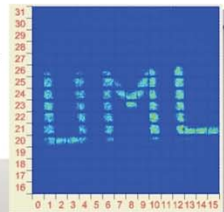
[K.J. Kelly, PhD thesis]

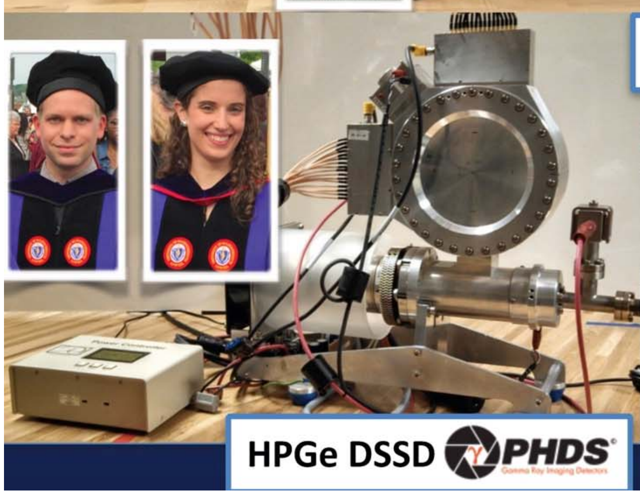
University of Massachusetts-Lowell

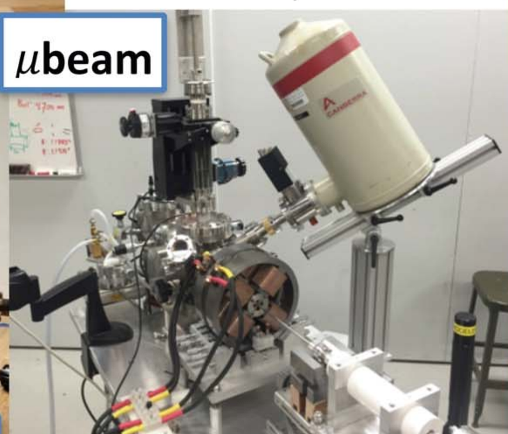


Current local science highlights

- Development of enriched **C^7LYC array** for neutron spectroscopy with experiments at Lowell, ANL, LANSCE, and other facilities.
- Neutron damage tests, charge collection studies, and continued research for advanced designs of **HPGe DSSDs**.
- Characterization of large 3"x3" C^7LYC.
- Measurements using a newly constructed Compton-suppressed HPGe array for assays of BLIP/BNL **medical isotopes** and nuclear science. (LARA)
- Assays of fuel plate burn-up.
- Commissioning of μ**beam** for interdisciplinary and applied science.
- Advanced XIA Pixie-4e DAQ.
- Improvements in accelerator operations.

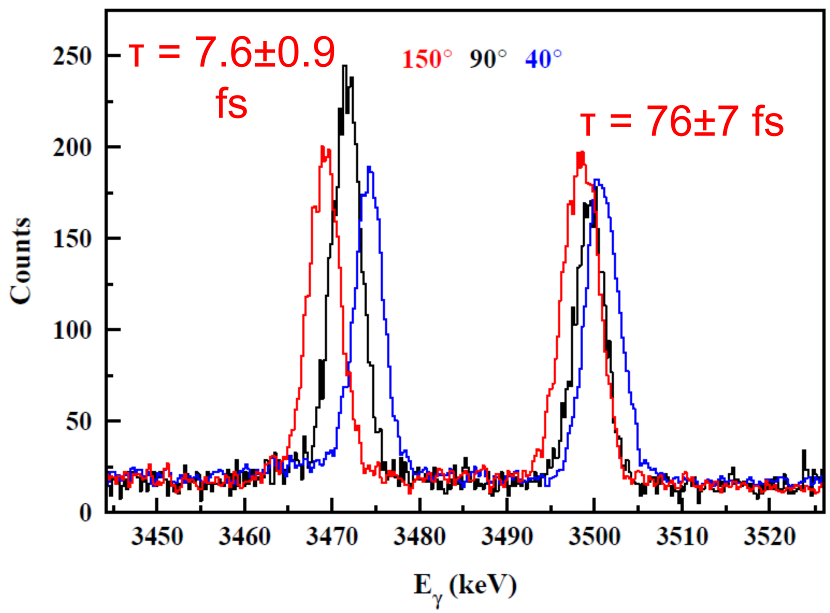


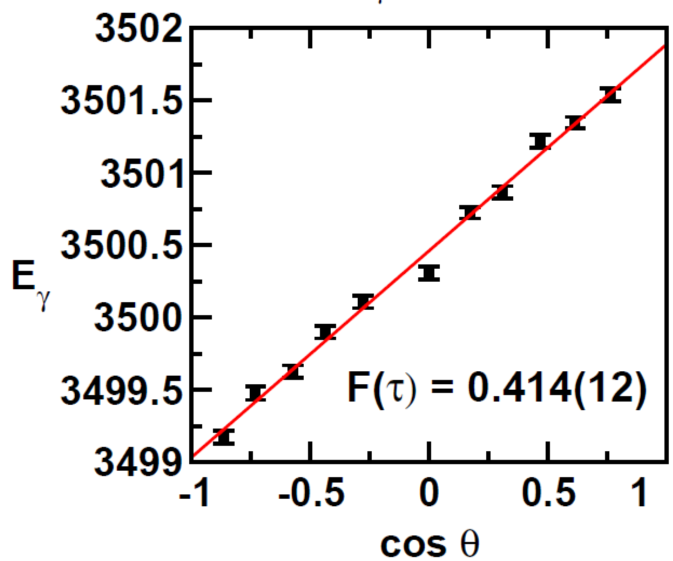




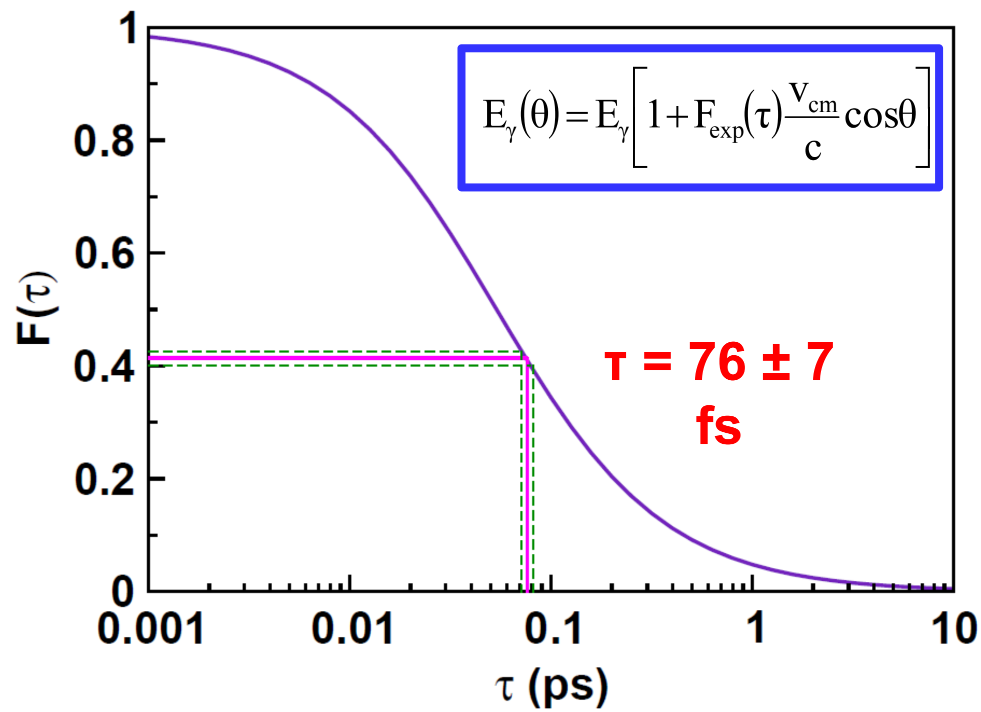
University of Kentucky

Nuclear Level Lifetimes by Doppler-Shift Attenuation following Inelastic Neutron Scattering





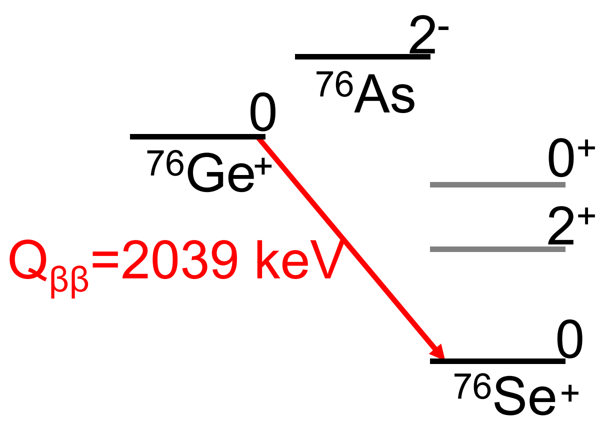
- Following neutron scattering, the nucleus recoils.
- The emitted γ rays experience a small Doppler shift.
- Level lifetimes in the femtosecond regime can be determined.

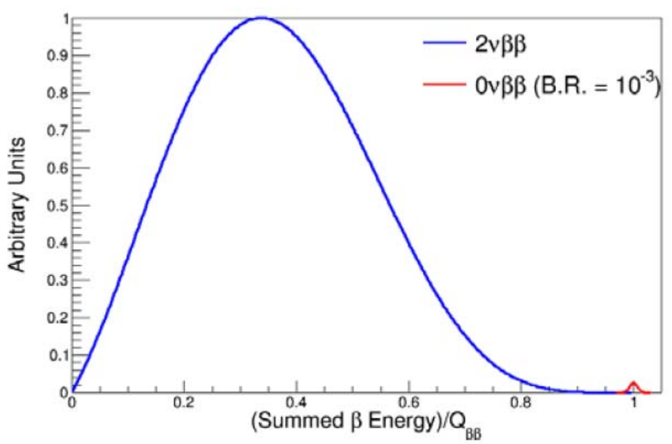


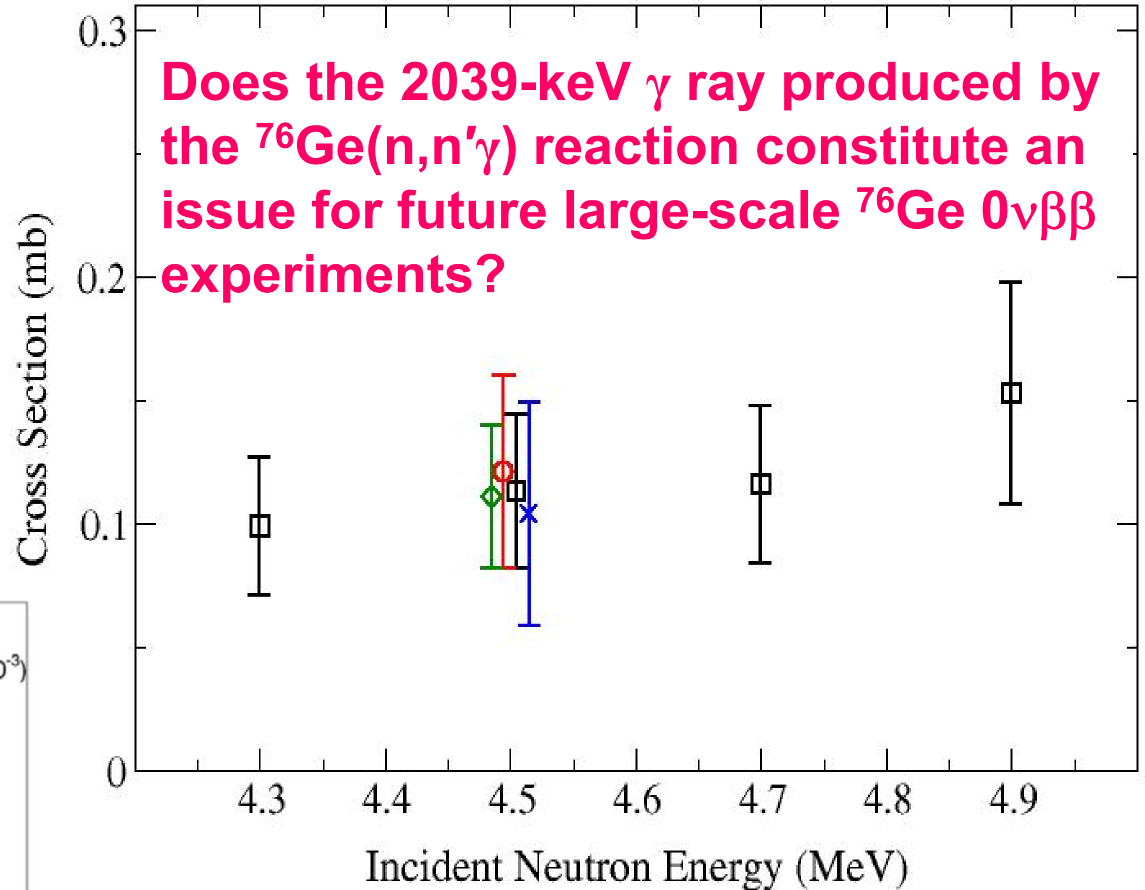
University of Kentucky

Fast-neutron-induced Background Near the *Q* value for 0νββ

A detailed study of the nuclear structure of ^{76}Ge via the ^{76}Ge(n,n′γ) reaction



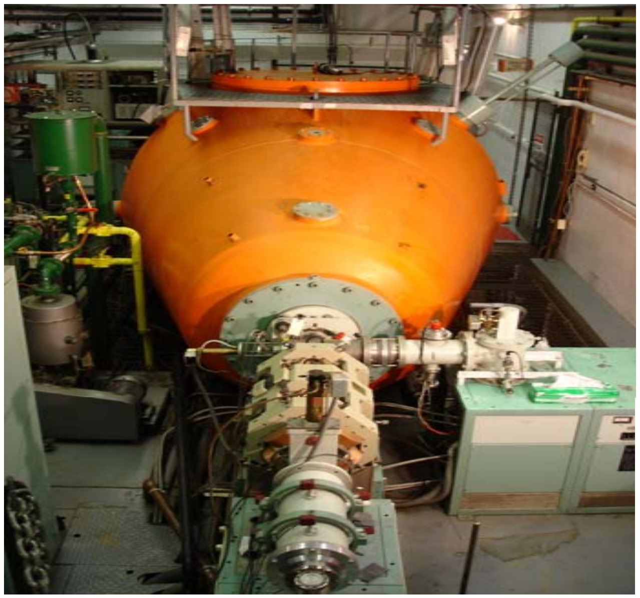




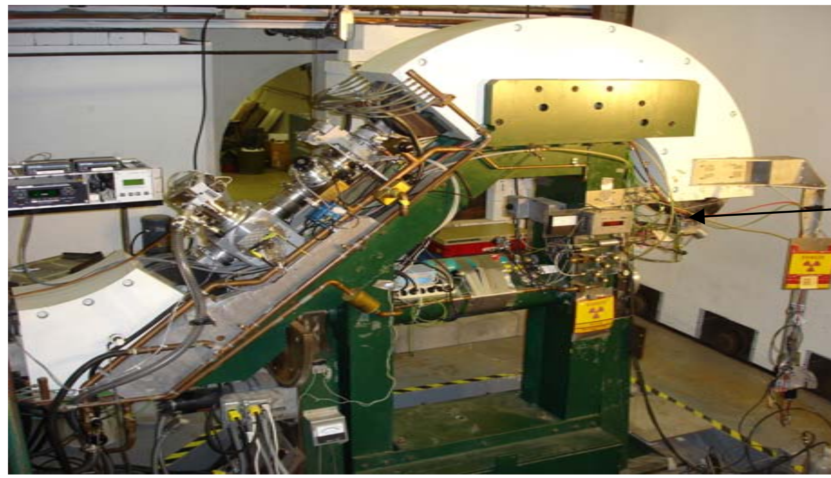
Does the 2039-keV γ ray produced by the ^{76}Ge(n,n′γ) reaction constitute an issue for future large-scale ^{76}Ge 0νββ experiments?

B.P. Crider *et al*., Phys. Rev. C 92, 034310 (2015).

Edwards Accelerator Laboratory at Ohio University

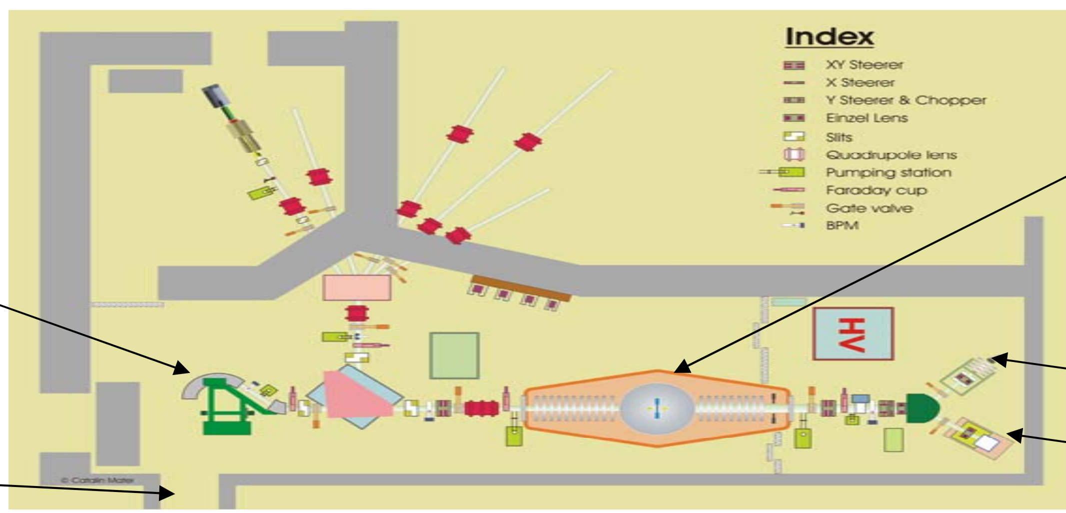


Beam Swinger Facility



Target chamber

4.5-MV T-type tandem



Swinger Magnet ($-4° \leq \theta_{lab} \leq 158°$)

30-meter TOF Tunnel

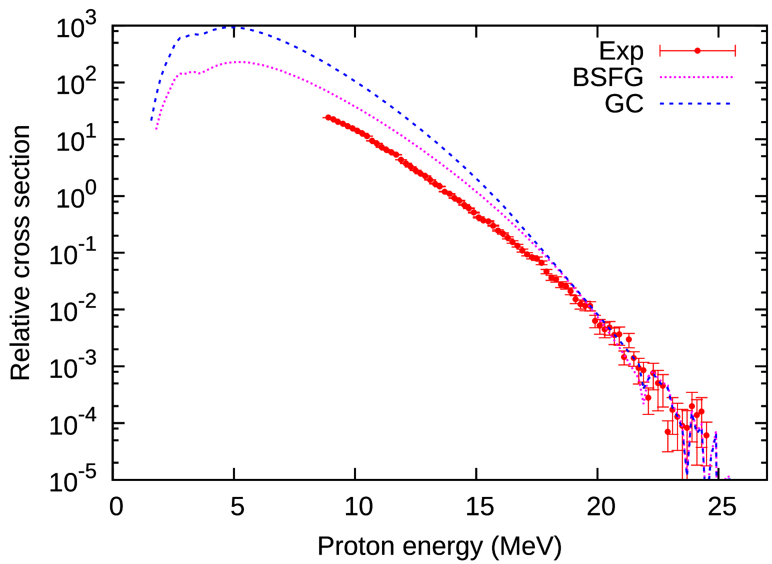
Cs Sputter Source

Duoplasmatron He Source

Edwards Accelerator Laboratory at Ohio University

Research Areas: Nuclear Astrophysics, Nuclear Structure, Surface Science, Applied Nuclear Science

Research Highlight: Fusion evaporation from Li-induced reactions



Led by Alexander Voinov (Ohio) and Oslo. Collaboration also includes LLNL, Michigan State University, and Central Michigan University. Experiment performed in January 2016.

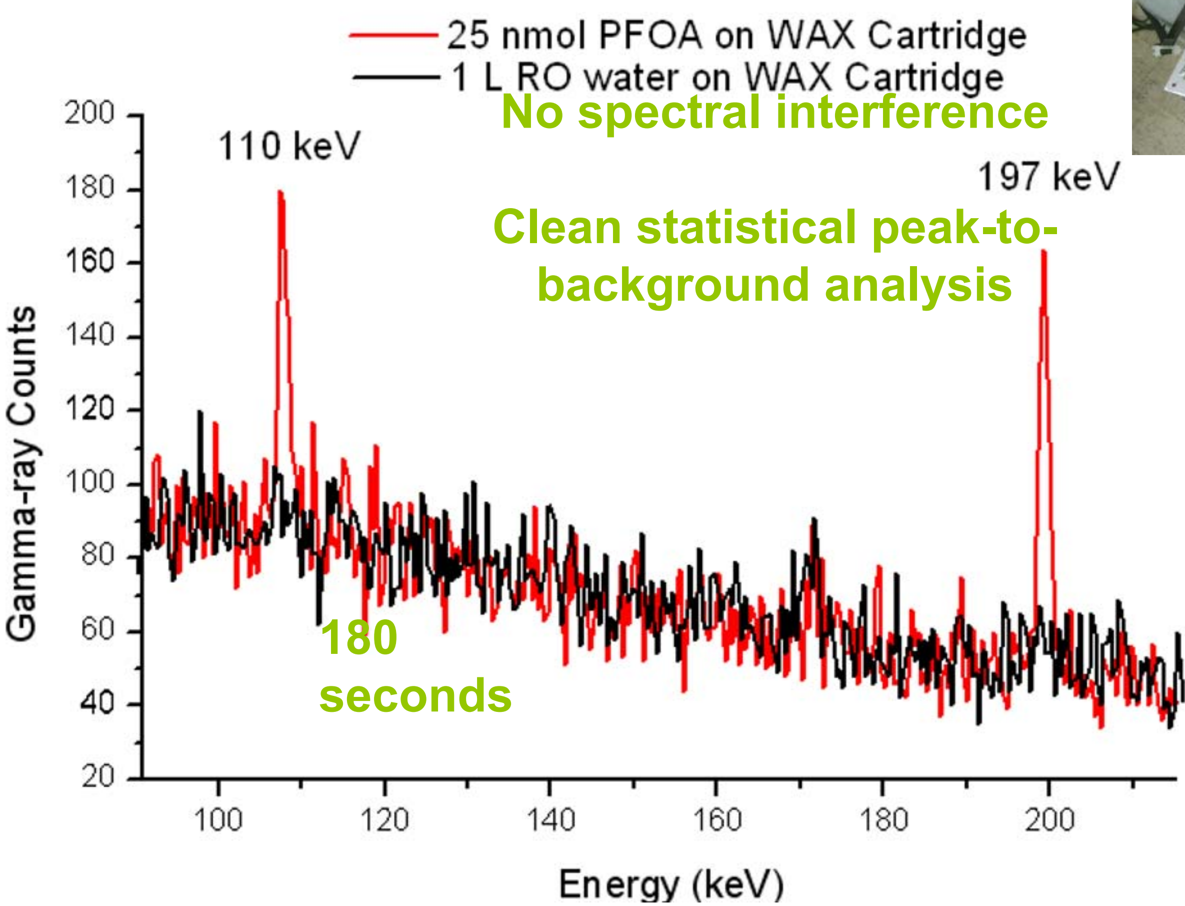
$^{7}Li + ^{70}Zn \rightarrow ^{76}Ge + p$ results courtesy of T. Renstrom (Oslo student)

Proton spectrum does not agree with level density models!

Hope College

PIGE Spectroscopy for Total Fluorine in Groundwater

1.7 MV Pelletron tandem accelerator with a nuclear microprobe



Hope College
Spinning off a company:

UMP ANALYTICAL

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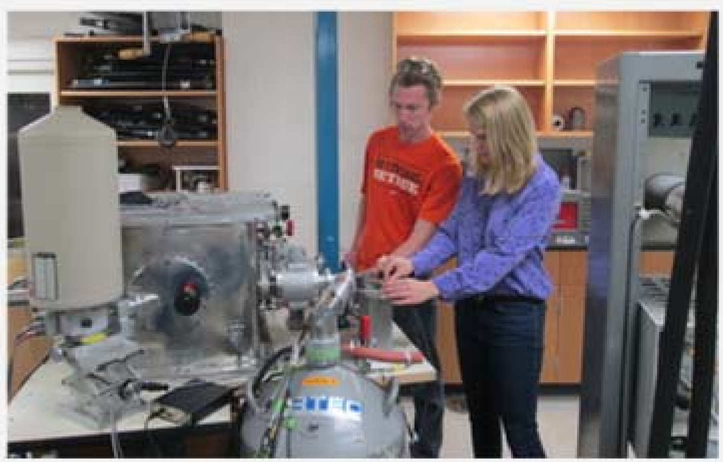
Discovery
Nuclear physics technique helps companies detect dangerous compound

Scientist develops new approach to rapidly identify toxic compounds in everyday materials such as clothing



Students are using nuclear physics to detect dangerous chemicals in everyday products.
Credit and Larger Version

Peaslee's method helps manufacturers detect a type of dangerous chemical in their raw materials.
Credit and Larger Version

University of Washington

^{6}He β-ν angular correlation

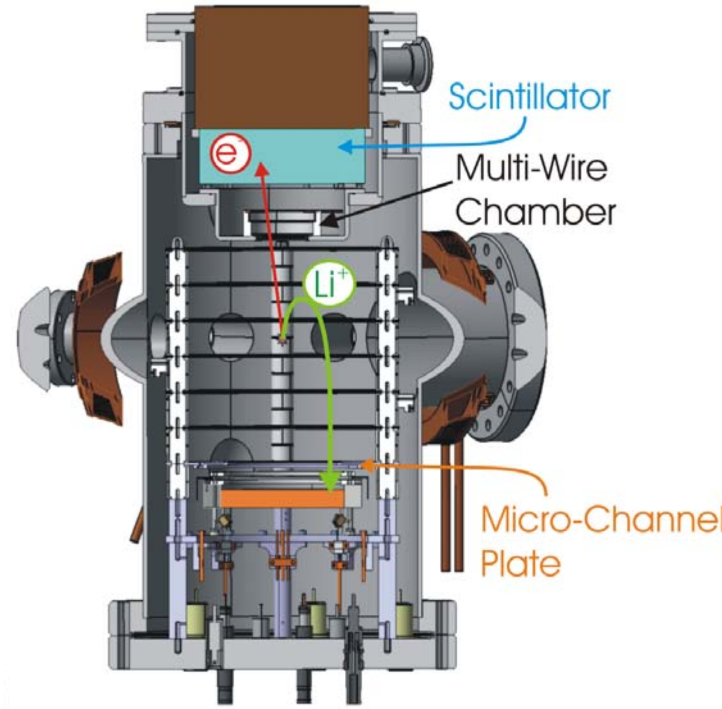
Y. Bagdasarova[1], K. Bailey[2], X. Fléchard[3], A. Garcia[1,*], R. Hong[1], A. Knecht[4], A. Leredde[2], E. Liennard[3], P. Mueller[2,*], O. Naviliat-Cuncic[5], T. O'Connor[2], M. Sternberg[1], H.E. Swanson[1], F. Wauters[1]

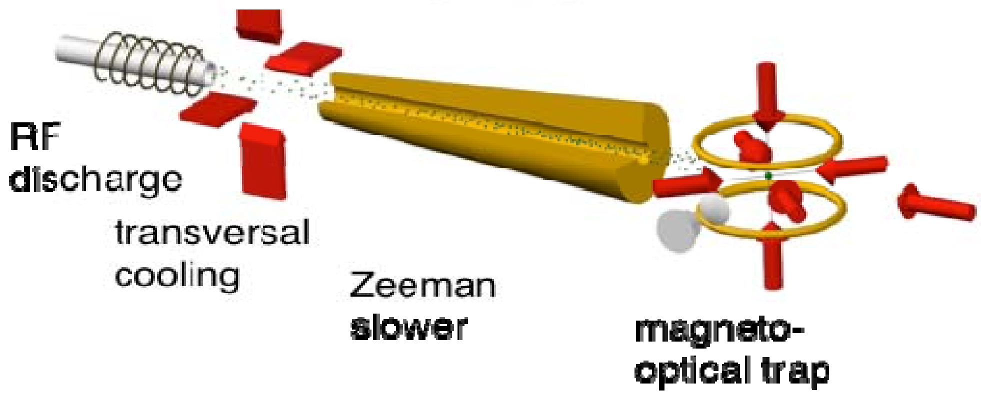
[1]*University of Washington*, [2]*Argonne National Lab*, [3]*LPC, CAEN, France*
[4]*PSI*, [5]*NSCL, Michigan State University*

[*]Spokepersons

- Goal: measure "little a" to 0.1% in ^{6}He
  - pure Gamow-Teller decay
  - sensitive to tensor couplings
  - simple nuclear and atomic structure
- Laser cooling and trapping to prepare ^{6}He source
- Detect electron and ^{6}Li in coincidence
- ΔE-E scintillator system for electron detection (energy, start of time-of-flight)
- Micro-channel plate detector for ^{6}Li detection (position, time-of-flight)

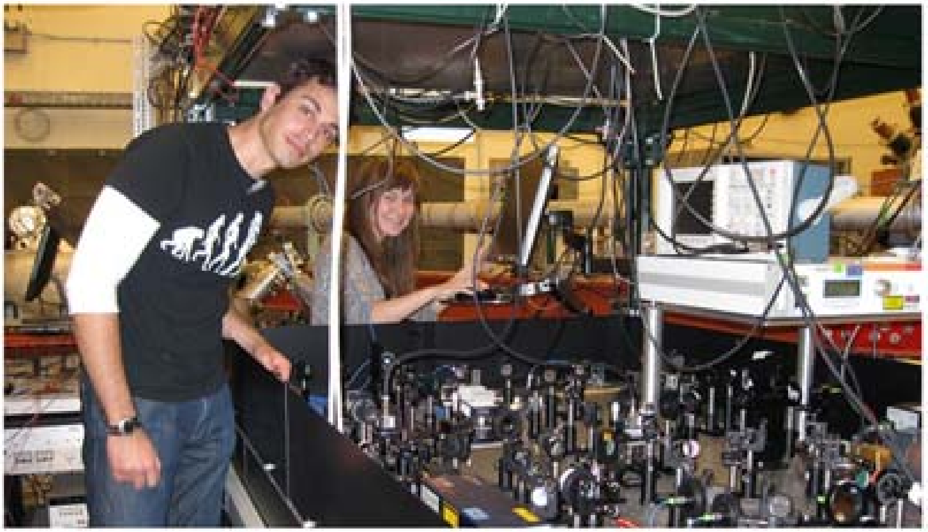
^{6}He Trap/Detector Chamber





University of Washington

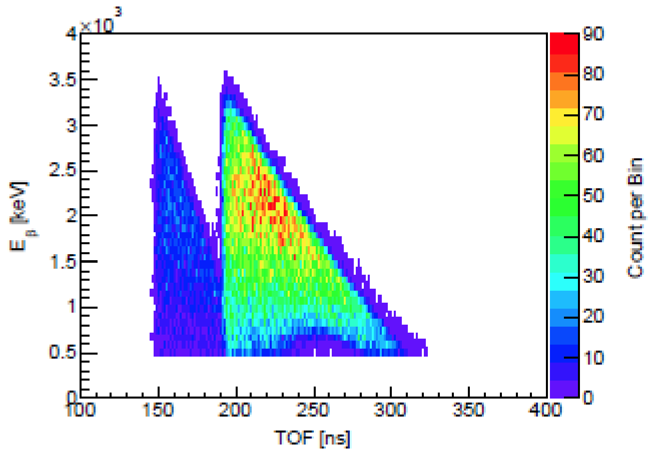
^{6}He β-ν angular correlation at UW



6He Source:
Reliable source of ~10^{10} ^{6}He's/s in low-background environment
A High-Intensity Source of 6He Atoms for Fundamental Research
A. Knecht et al. NIM A. **660**, 43 (2011)

Laser trapping:
All systems working and efficiencies enough for a determination of little-a at the 1% within 3 days (including calibrations)!

Example of data taken recently:
E_β versus TOF which yields $\Delta a/a$ =1%.



(a) Experiment

Status:
Presently working on systematic uncertainties.
Aiming for $\Delta a/a$ <1% in near future.
Ultimate goal: 0.1% uncertainty.

University of Washington

^{6}He little-b measurement UW

M. Fertl[1], A. Garcia[1], M. Guigue[4], P. Kammel[1], A. Leredde[2], P. Mueller[2], R.G.H. Robertson[1], G. Rybka[1], G. Savard[2], D. Stancil[3], M. Sternberg[1], H.E. Swanson[1], B.A. Vandeevender[4], A. Young[3]

[1]*University of Washington,* [2]*Argonne National Lab,* [3]*North Carolina State University,* [4]*Pacific Northwest National Laboratory*

- Goal: measure "little b" to 10^{-3} or better in ^{6}He
  - Highest sensitivity to tensor couplings
- Determine shape of beta spectrum in search for tensor couplings.
- Use Cyclotron Emission Spectroscopy. Similar to Project 8 setup for tritium decay but need to extend the technique to higher energy betas and to a precision determination of a continuum spectrum. Non trivial: under development.
- In 1 day of running would determine *b* one order of magnitude better than any previous experiment.

Decay rate: C_T and C_T' represent the new physics. C_A is the usual axial coupling constant for Weak Int.

$$dw = dw_0 \left[1 + a \frac{\overrightarrow{p_e}}{E_e} \cdot \frac{\overrightarrow{p_\nu}}{E_\nu} + b \frac{\Gamma m_e}{E_e} \right]$$

$$a \approx -\frac{1}{3} \frac{2|C_A|^2 - |C_T|^2 + |C_T'|^2}{2|C_A|^2 + |C_T|^2 + |C_T'|^2}$$

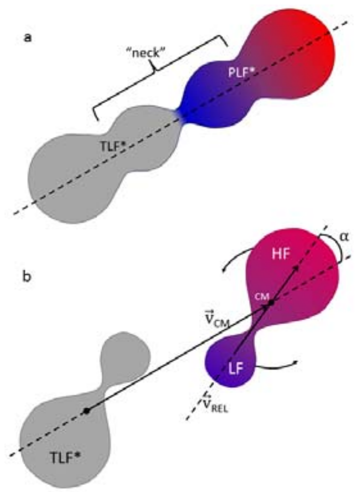
$$b \approx \frac{\mathrm{Re}\left[2C_A\left(C_T + C_T'\right)\right]}{2|C_A|^2 + |C_T|^2 + |C_T'|^2}$$

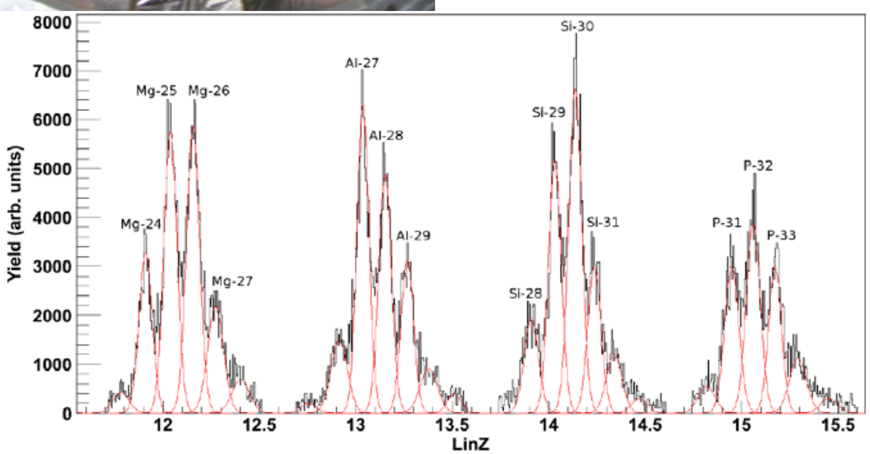
Little-*b* is called "Fierz interference" and depends linearly on the new couplings. This makes it a more sensitive probe of the new physics.

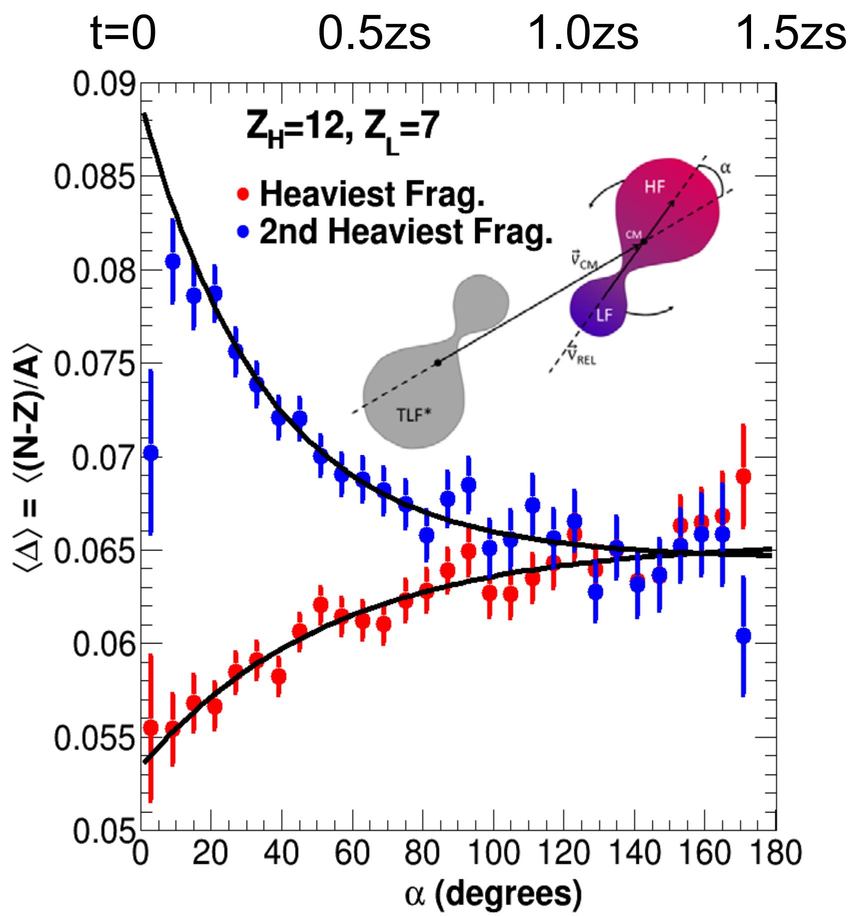
Texas A&M University

Equilibration Chronometry Offers a New View on the Nuclear Equation of State

NIMROD 4π Array $^{70}Zn + ^{70}Zn$ **@ 35A MeV**







A. Jedele, submitted PRL

Test of Astrophysical Equations of State Equilibrium Constant, K_α

- Many tests of EOS are done using mass fractions. Various calculations include various different competing species., if all relevant species are not included, mass fractions are not accurate.

- Equilibrium constants, e.g.,

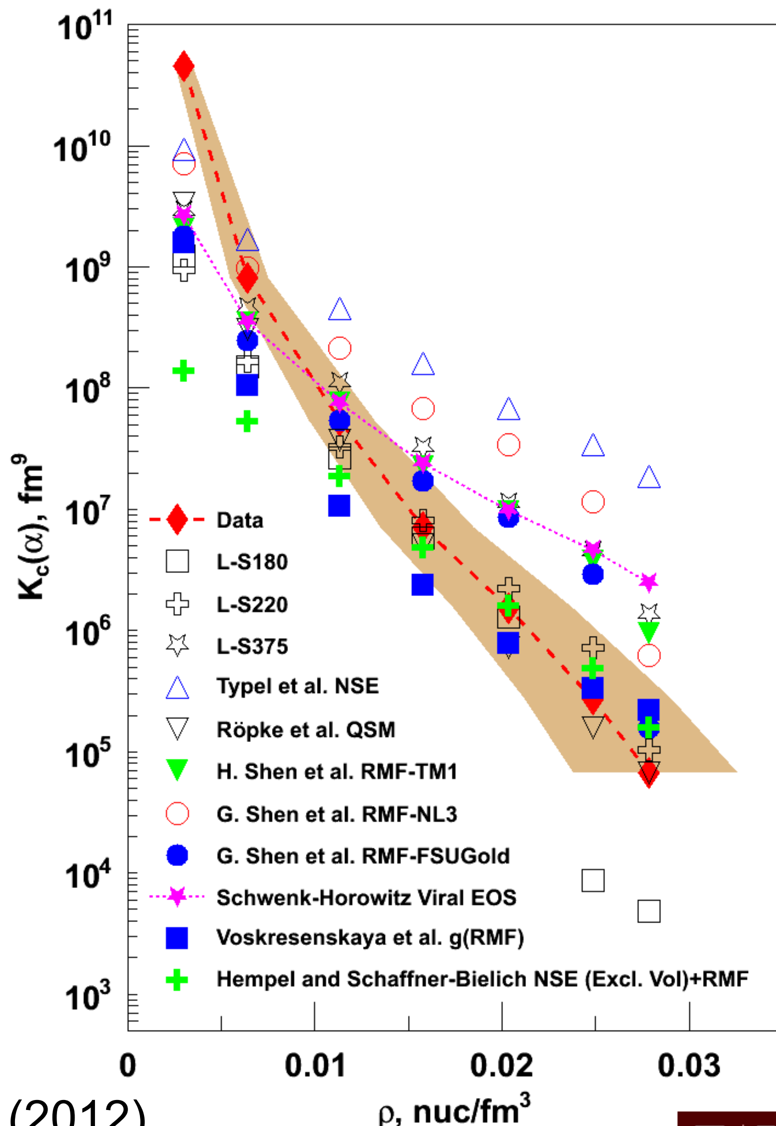
$$K_c = \frac{\rho(A,Z)}{\rho_p^Z \rho_n^{(A-Z)}}$$

should be independent of proton fraction and choice of competing species.

- Models converge at lowest densities, but many are significantly above data at higher density

- Lattimer & Swesty with K=180, 220 show reasonable agreement with data

- QSM with in-medium binding energy shifts works well



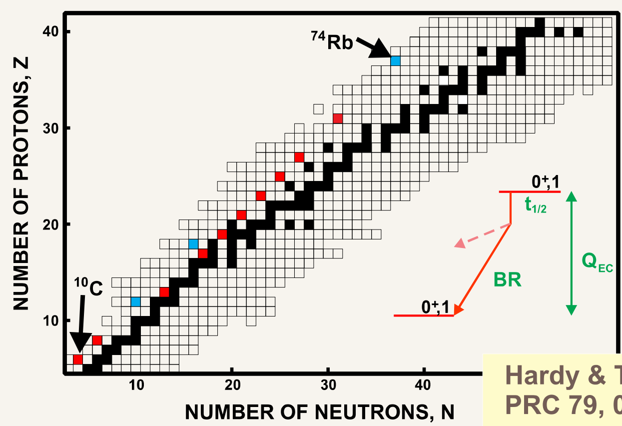
L. Qin et al.PRL **108** 172701 (2012).

ARUNA

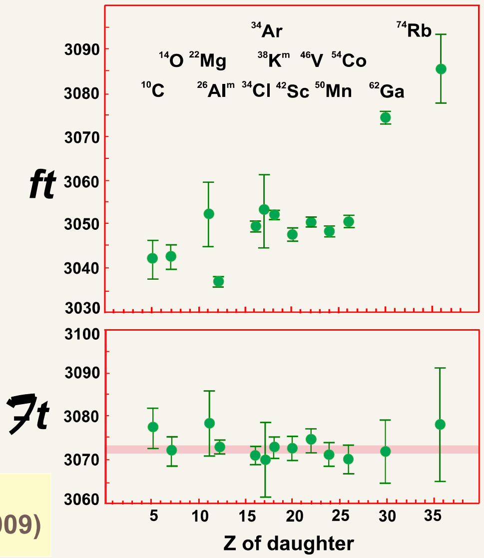
Texas A&M University

SUPERALLOWED $0^+ \rightarrow 0^+$ BETA DECAY

$$\mathcal{F}t = ft\,(1 + \delta_R')[1 - (\delta_C - \delta_{NS})] = \frac{K}{2G_V^2\,(1 + \Delta_R)}$$



Hardy & Towner
PRC 79, 055502 (2009)



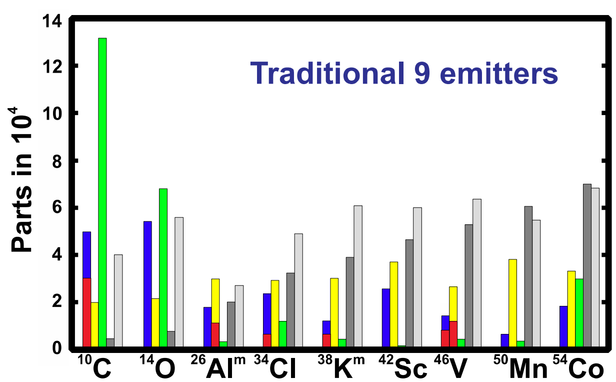
- CVC verified
- $V_{ud} = 0.97425(22)$

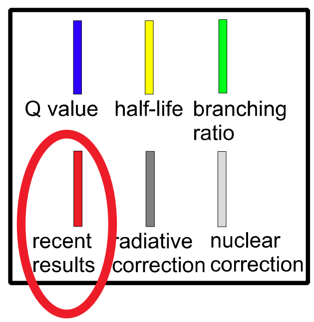
CKM unitarity test:

$$V_{ud}^2 + V_{us}^2 + V_{ub}^2 = 0.9999(6)$$

Improvements since 2009

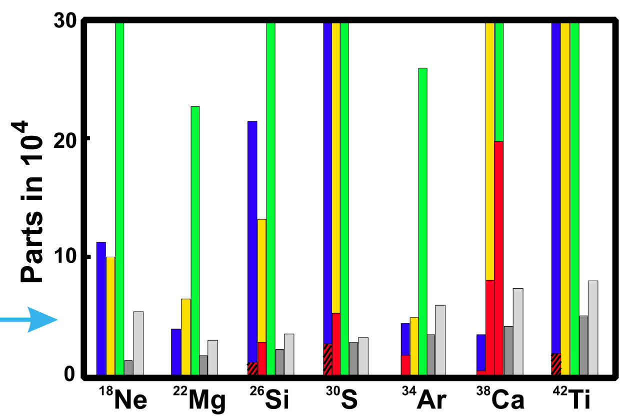
(Most done at, or in collaboration with TAMU)





Uncertainty budgets

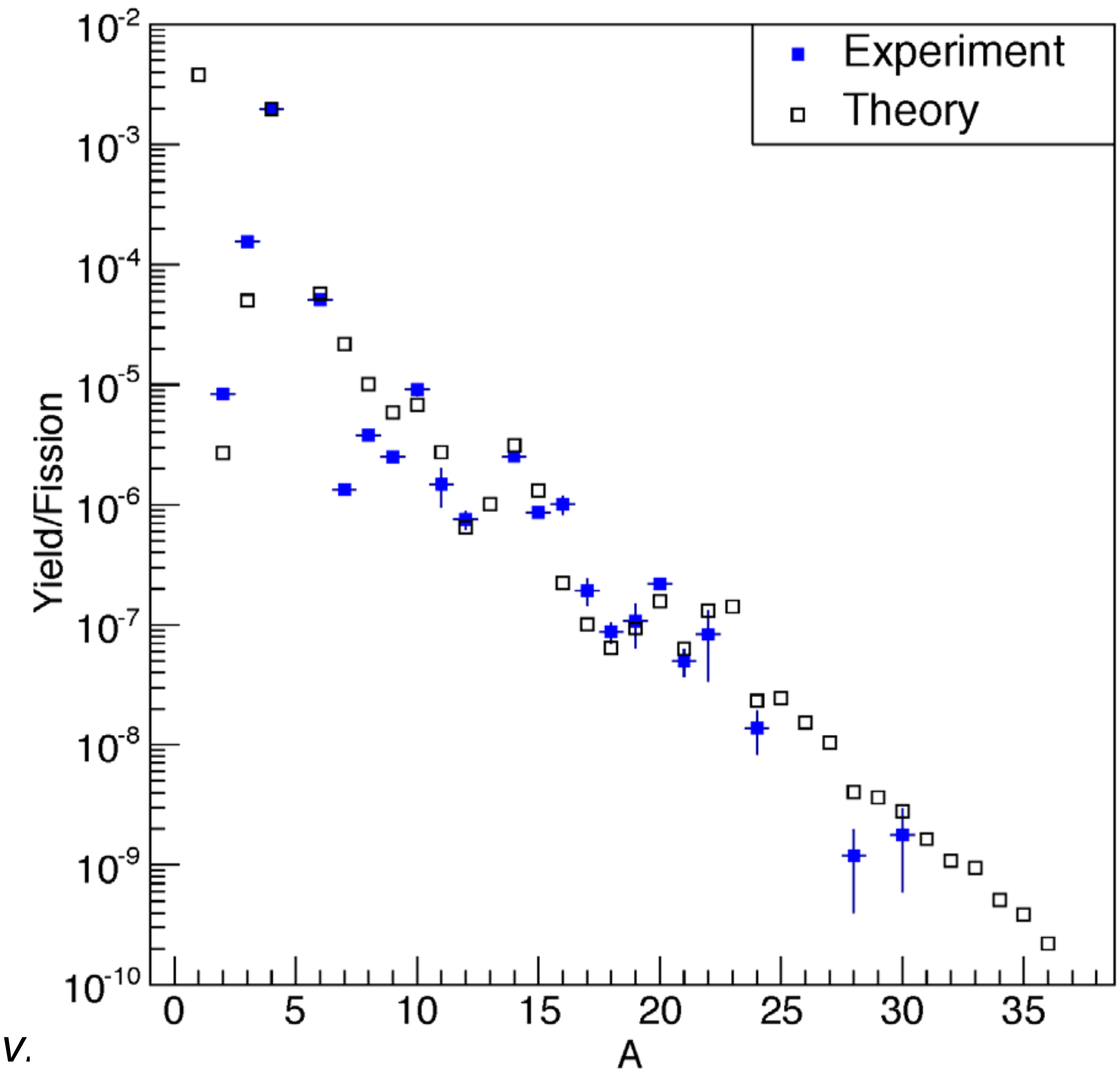
New $T_z = -1$ emitters



Texas A&M University

Nucleation and cluster formation as a mechanism for ternary fission fragment production

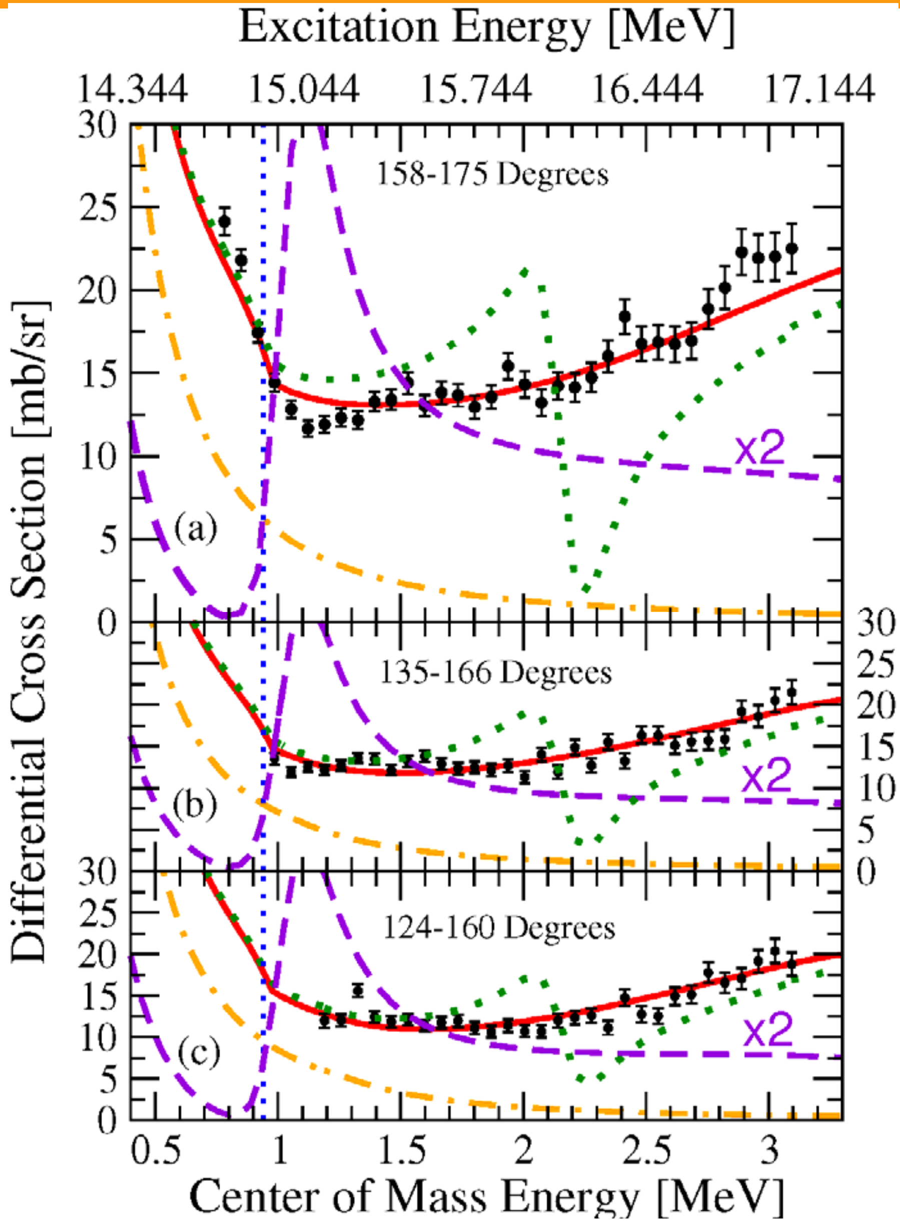
Yield per fission event as a function of ternary fragment mass number (A). Solid points represent $^{241}Pu(n_{th},f)$ experimental yields. Open data points are the product of nucleation moderated nuclear statistical equilibrium (NSE) model



S. Wuenschel, et al, *Phys. Rev.* 011601R (2014).

Texas A&M University

Structure of very exotic helium isotope - ^{9}He

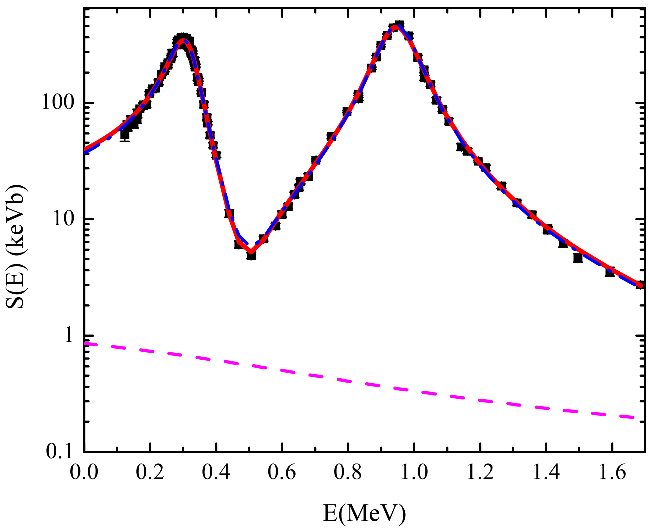


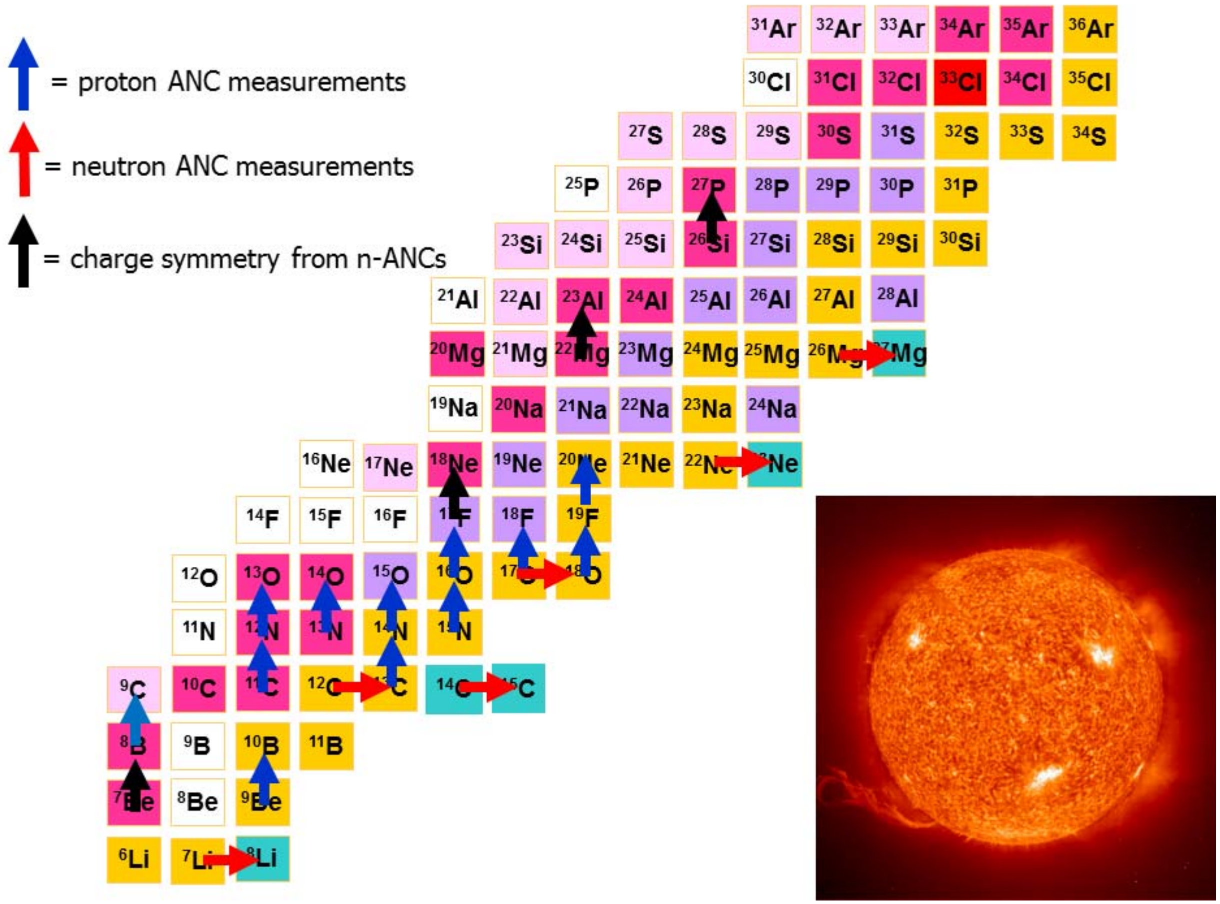
^{8}He+p elastic scattering excitation function measured at three different lab. angles. No narrow structures are observed in the proton spectrum. The sensitivity of these data to the hypothetical narrow T=5/2 isobaric analog resonances in ^{9}Li is demonstrated by purple dashed and green dotted lines.

E. Uberseder et al,
Physics Letters B **754** 323 (2016)

Texas A&M University

Looking in the Lab to Better Understand the Stars : Determining reaction rates at stellar energies





R.E. Tribble et al, Rep. Prog. Phys. 77 106901 (2014)

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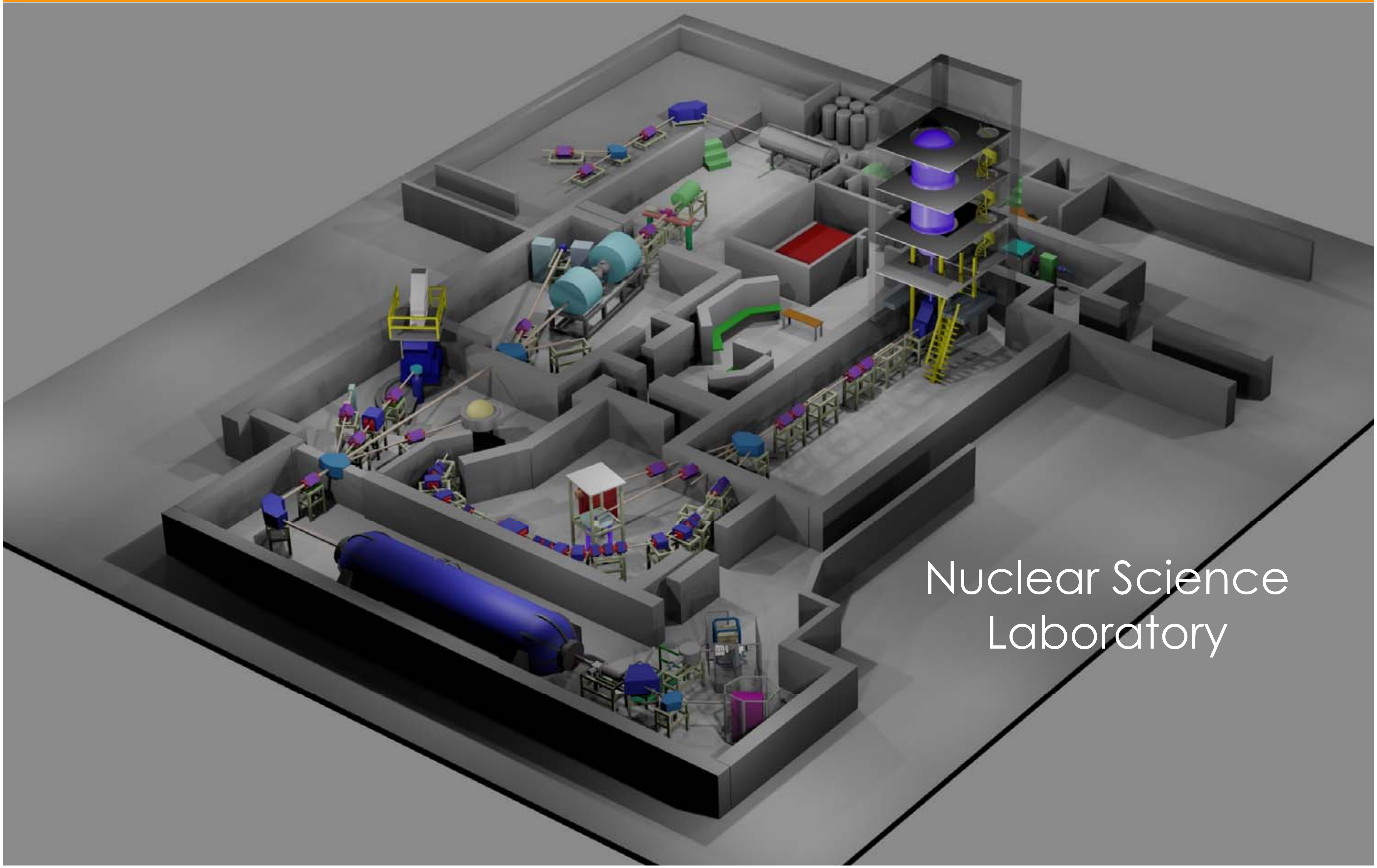

Scientific Workforce at NSL

- 10 T&R Faculty members
- 7 R Faculty
- 6 Postdocs
- 38 grad. students

Research directions at NSL

- Nuclear Astrophysics
- Nuclear Structure Physics
- Fundamental Symmetries
- Nuclear Physics Applications

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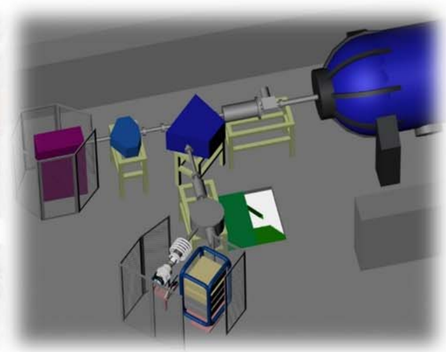
New technical developments


- 3MV tandem pelletron for applications
- TwinSOL upgrade with new target room for radioactive beam experiments
- St. George recoil separator for 5U single ended pelletron
- New gamma detection systems (GEORGINA array, HECTOR summing detector)
- New low energy injection magnet and beamline for FN Tandem (AMS system)
- CASPAR underground accelerator at SURF

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Future Directions

- Low energy nuclear astrophysics (NSL, CASPAR): fusion, capture reactions for stellar burning environments
- Nuclear astrophysics with radioactive beams (NSL, FRIB): reactions, nuclear masses and decay patterns in explosive stellar environments
- Nuclear Structure (NSL): Conversion electron spectroscopy, cluster structure, statistical physics
- Fundamental symmetries (NSL, CARIBU)
- Nuclear physics applications (NSL, NIF, ELI): PIXE, PIGE, XRF for material analysis, reactions for plasma characteristics, radiation damage studies