NSF Nuclear Physics Overview for NSAC

Allena K Opper

- NSF Support for Nuclear Physics in FY16
- Highlights
- Announcements
  - Solicitations
  - Other funding opportunities
- Physics Division Personnel

Budget Trends – NSF Nuclear Physics

Includes co-funding and other leveraged funds

~ 25% = Research
~ 75% = Operations

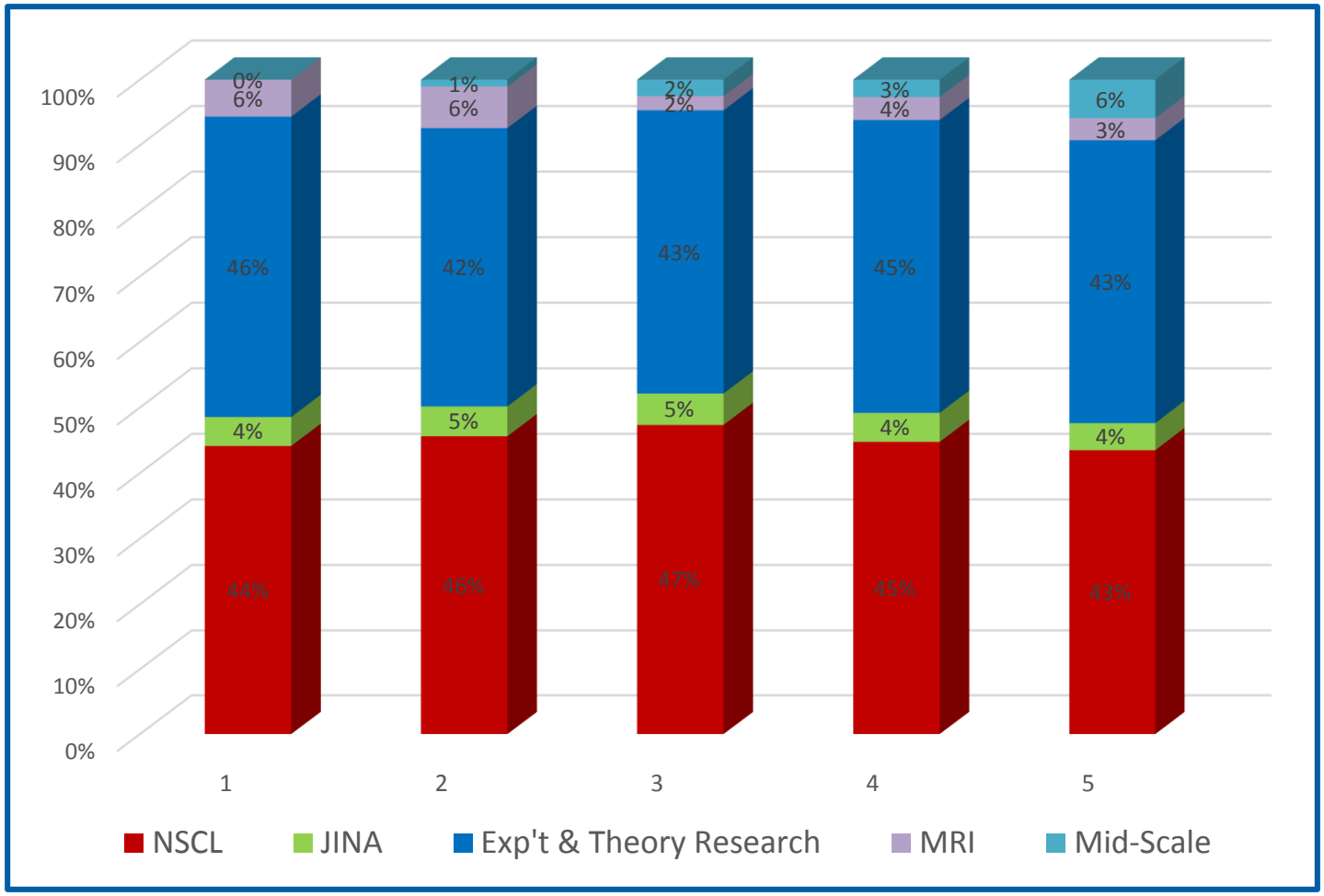
FY	Nucleon & Hadron QCD (k$)	Nuclear Astroph, Reactions, Structure (k$)	Nuclear Prec Meas'ts & Fund. Symm. (k$)	Total Exp't Nuclear Physics (k$)	Nuclear Theory (k$)	Nuclear Program Total (k$)	NSCL (k$)	JINA & JINA -CEE (k$)	MRI (K$)	Mid-Scale (K$)	Total Nuclear Physics (k$)
2010				19,939	3,855	23,794	21,000	2,150	1,134		48,033
2011				19,164	3,719	22,883	21,500	2,150	729		47,262
2012	7,969	4,185	6,343	18,497	3,829	22,326	21,500	2,150	2,744		48,720
2013	6,183	4,693	5,653	16,509	3,474	20,008	21,500	2,150	2,996	490	47,144
2014	5,826	5,189	5,999	17,014	3,514	20,528	22,500	2,280	1,038	1,188	47,533
2015	6,769	4,702	7,304	18,774	4,183	22,957	23,000	2,280	1,801	1,367	51,406
2016	7,141	5,046	7,391	19,579	4,223	23,802	24,000	2,280	1,869	3,238	55,189

FY15 Fundamental Symmetries: + $1.32M for $0\nu\beta\beta$

MRI: competes each year; one-time acquisition/development funds

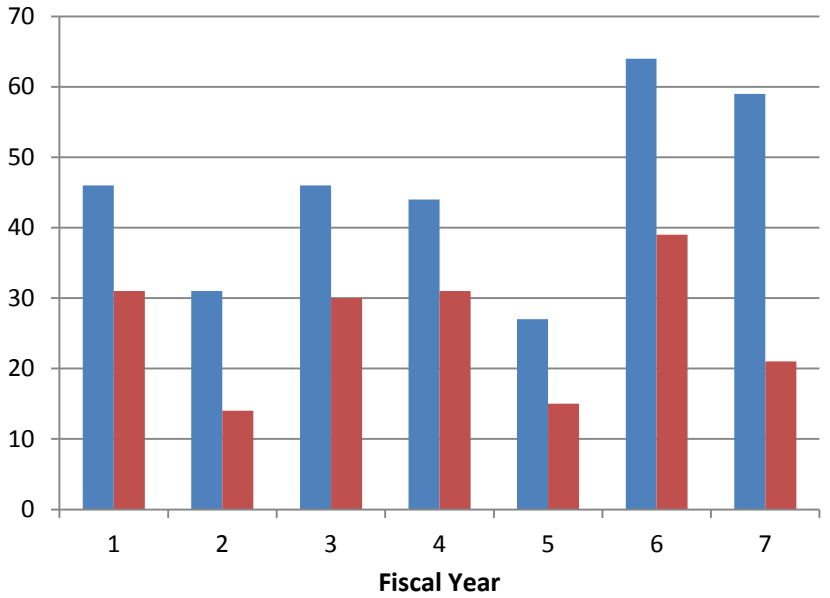
Mid-scale: ad hoc competition; design and construction funds; FY16 = nEDM & MUSE

Budget Trends – NSF Nuclear Physics



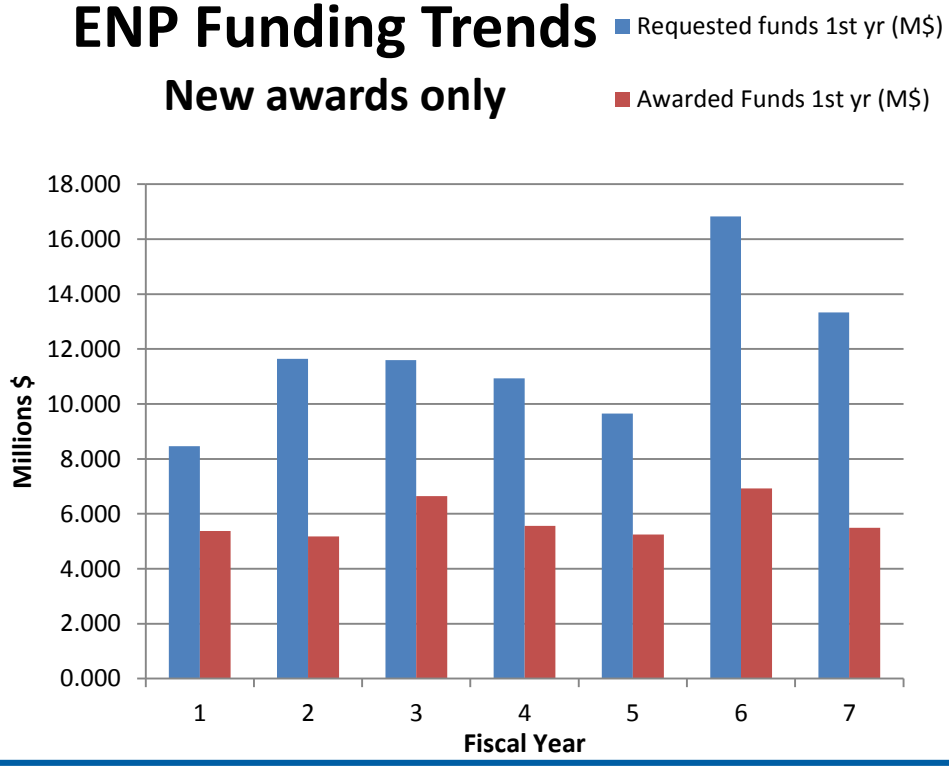
ENP Proposal Trends

*** 2015 includes 8 0vBB proposals**
2016 includes 7 0vBB proposals



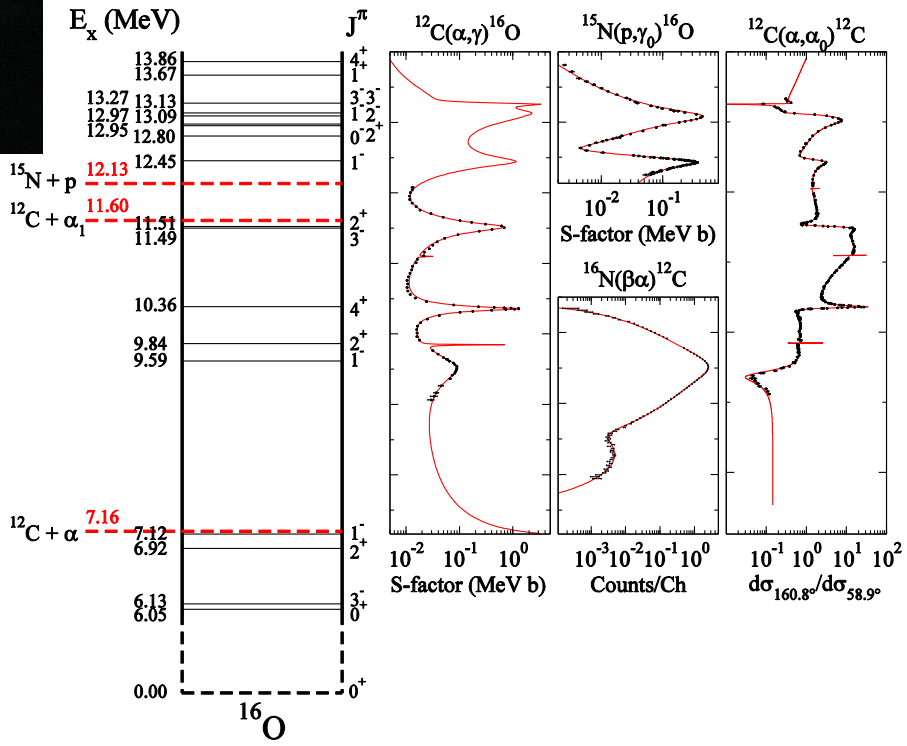
ENP Funding Trends

New awards only

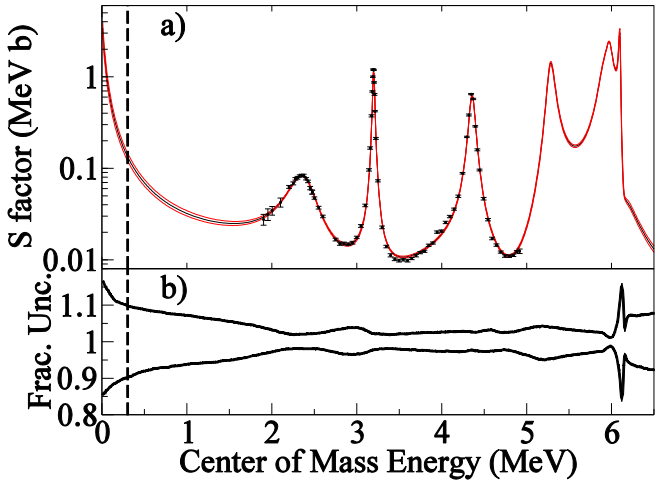


$^{12}C(\alpha, \gamma)^{16}O$ & Stellar Helium Burning

- $^{12}C(\alpha, \gamma)^{16}O$ determines ^{12}C:^{16}O in the universe
  - building blocks of organic life & fuel for stars in later stages
- Comprehensive *R*-matrix analysis to fit unprecedented amount of experimental nuclear physics data →
  - constrain the $^{12}C(\alpha, \gamma)^{16}O$ cross section
  - investigate uncertainties stemming from data and model



Monte Carlo Uncertainty analysis

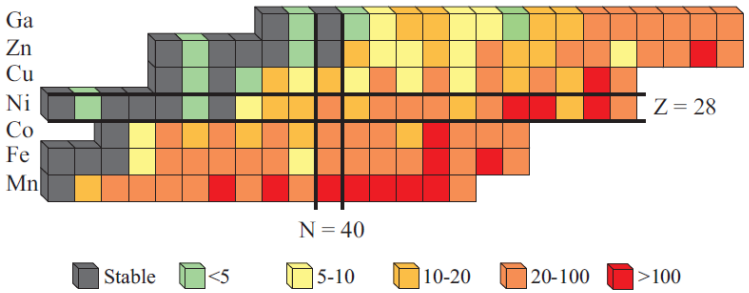


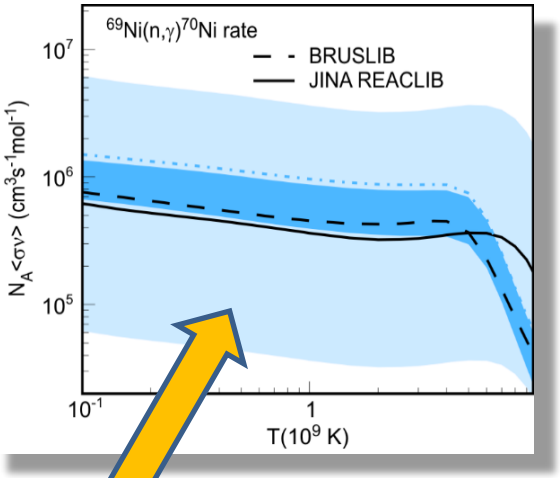
R.J. deBoer *et al.*, RMP (submitted to journal)

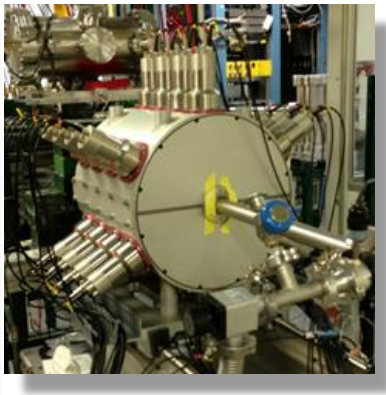
UNIVERSITY OF NOTRE DAME

Constraints on Neutron Capture Rates – Key to Modeling Stellar Explosions

- Nuclear physics & structure → element abundances from stellar events
- Need reaction rates(esp. those far from stability) to test r-process models
- Color = uncertainty of neutron-capture rates.

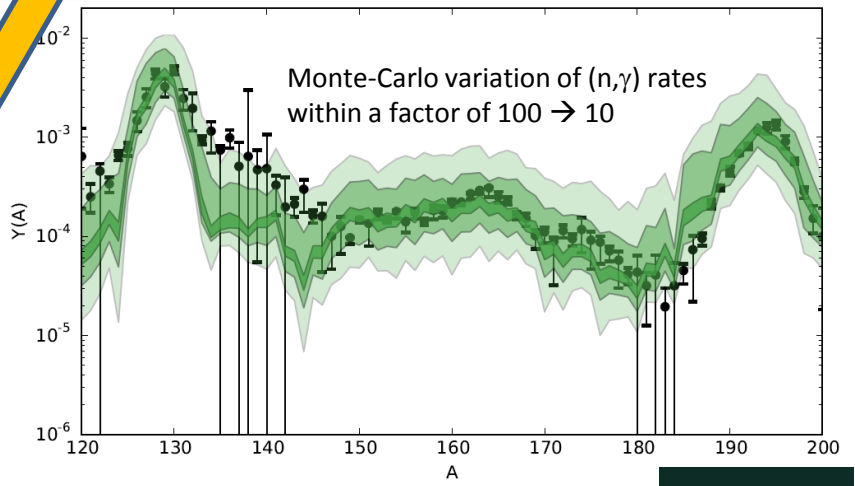






SuN detector at NSCL

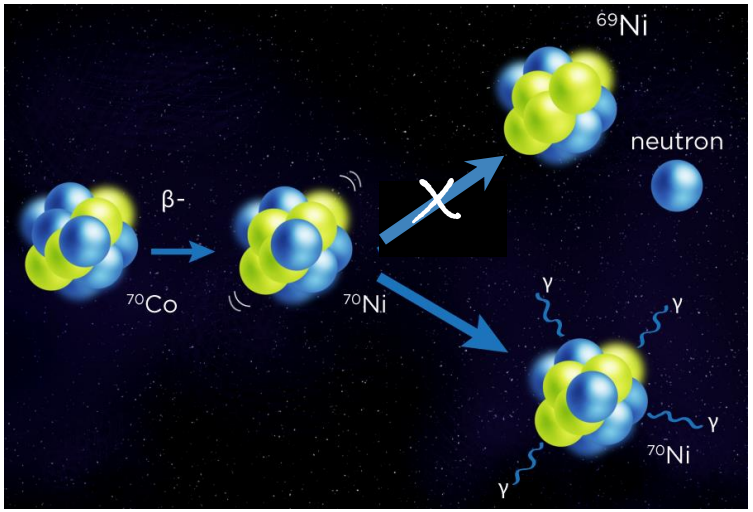
- New technique: γ-ray calorimetry developed by MSU and Univ of Oslo with SuN detector at NSCL used to extract ^{69}Ni(n,γ)^{70}Ni.
- Uncertainty now ~ 2-3 (dark blue band) – achievable for rare isotopes far from stable
- Accurate rates allow model comparisons. With error of 2-3 dark green band is possible



S.N. Liddick, A. Spyrou et al., Phys. Rev. Lett 116, 242502 (2016)
http://physics.aps.org/synopsis-for/10.1103/PhysRevLett.116.242502

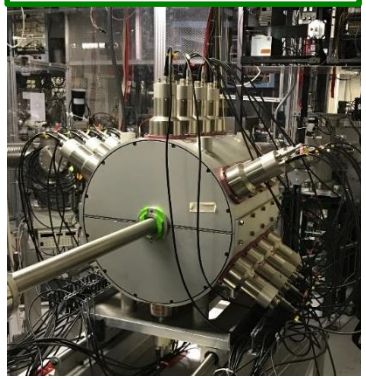
New Results Indicate Past Assumptions Key for Astrophysical Models Incorrect

- β-delayed neutron emission is important for r-process nucleosynthesis.

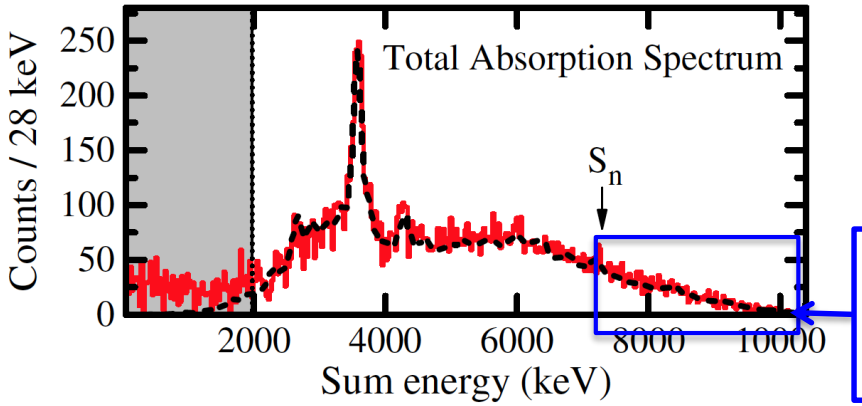


- *Neutron emission weaker than previously thought*
- This particular case can only be explained using shell model calculations & mismatch between populated states in ^{70}Ni and the neutron daughter ^{69}Ni.
- ***Hindered*** neutron emission is likely to divert the reaction flow from the projected path and → shift the final abundance distribution.

Experiment used the SuN detector at NSCL



- β-decay intensity of ^{70}Co studied using Total Absorption Spectroscopy
- Strong γ-ray emission was observed above the neutron threshold.

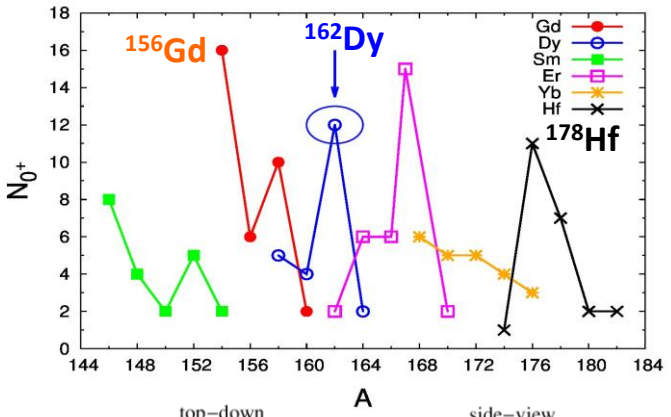


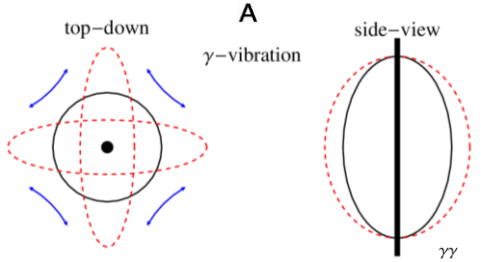
Unexpected γ-emission above neutron threshold

A. Spyrou, S.N. Liddick, et al.,
Phys. Rev. Lett 117, 142701 (2016)

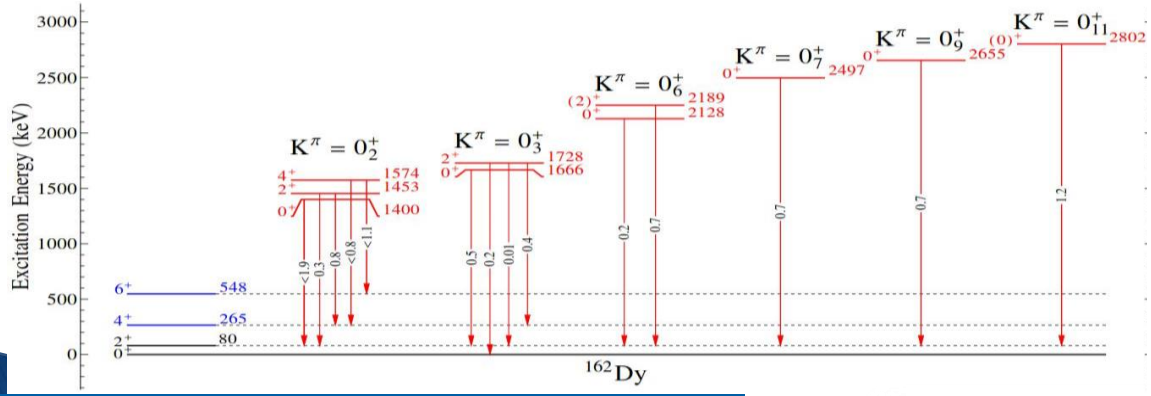
Nature of 0^+ States in Deformed Nuclei

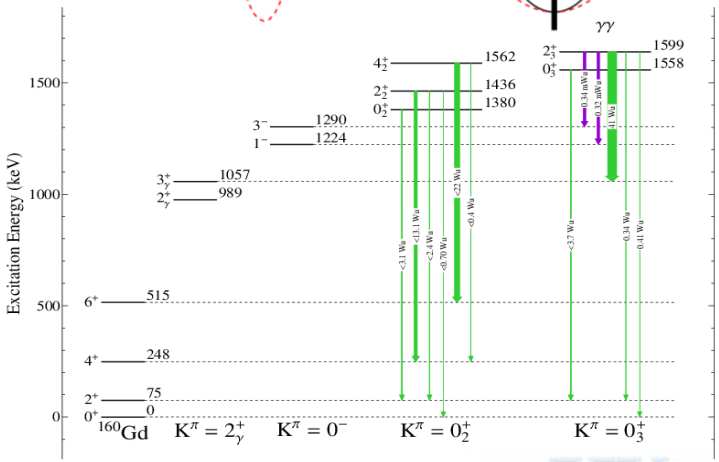
- The 0^+ states in deformed nuclei = fundamental excitations but have remained an enigma for several decades
- Full understanding of this nature requires measurement of nuclear lifetimes
- Campaign using Doppler Shift Attenuation following (n, n'γ) @ Univ. of Kentucky measured lifetimes:
  - 58 levels in ^{162}Dy
  - Several crucial 0^+ states in ^{160}Gd → identified 2-phonon $\gamma\gamma$ vibration in the 3rd 0+ band





Measured lifetimes of 0^+ states

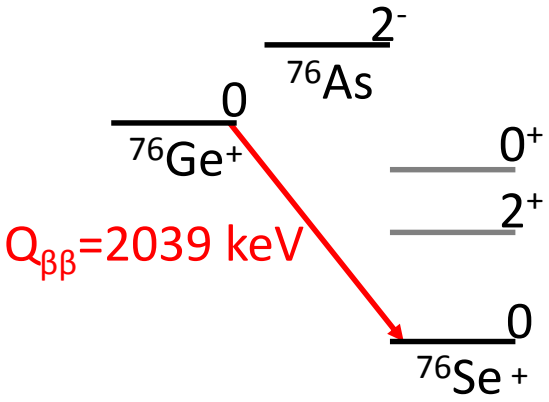


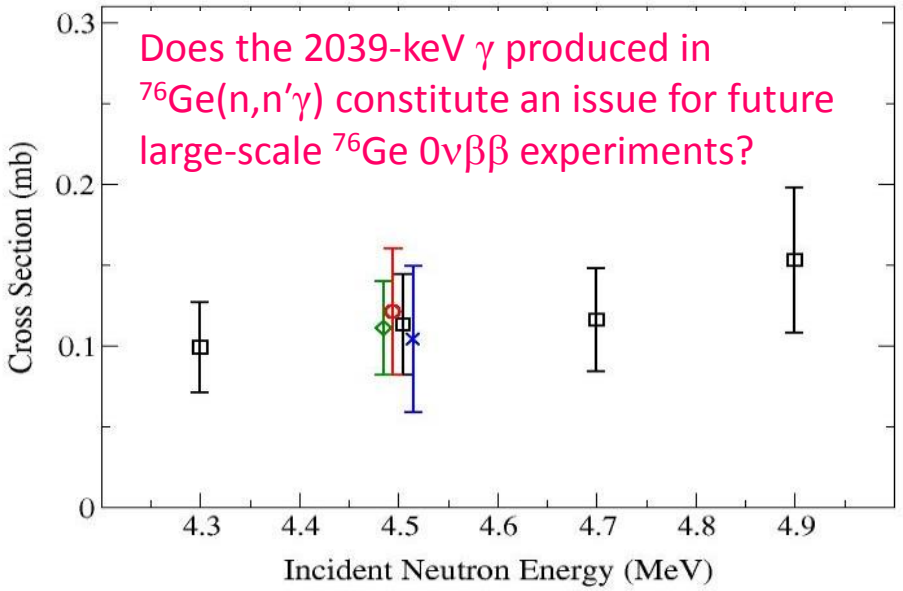


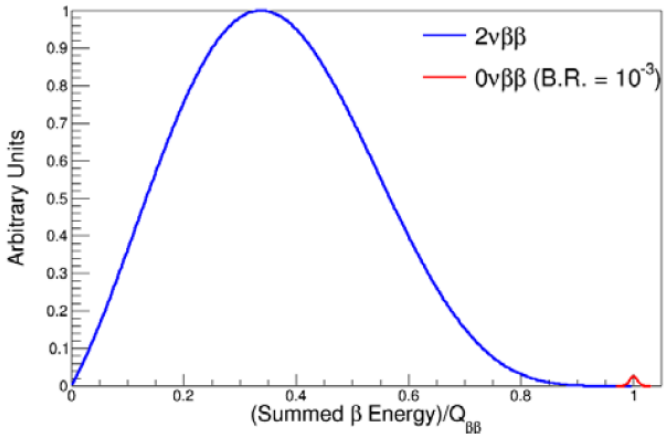
C. Casarella, S.R. Lesher, A. Aprahamian et al.

University of Notre Dame
University of Wisconsin La Crosse
University of Kentucky

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







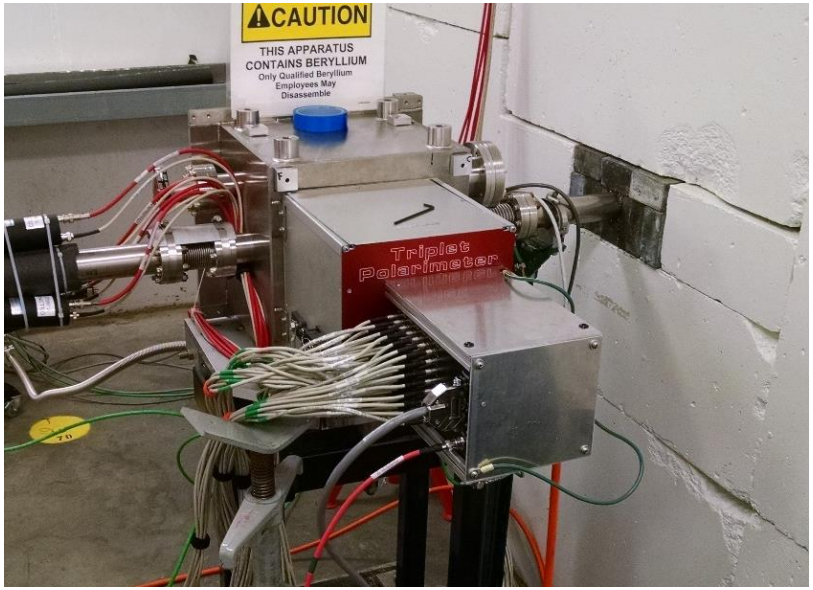
- Completed nuclear structure studies of ^{76}Ge and ^{76}Se → constrain theoretical calculations of 0νββ matrix element
- <u>If 0νββ is observed</u>, this matrix element is required to determine the neutrino mass.
- Also performed similar measurements on ^{136}Xe (for the EXO experiment) and ^{130}Te (for CUORE).

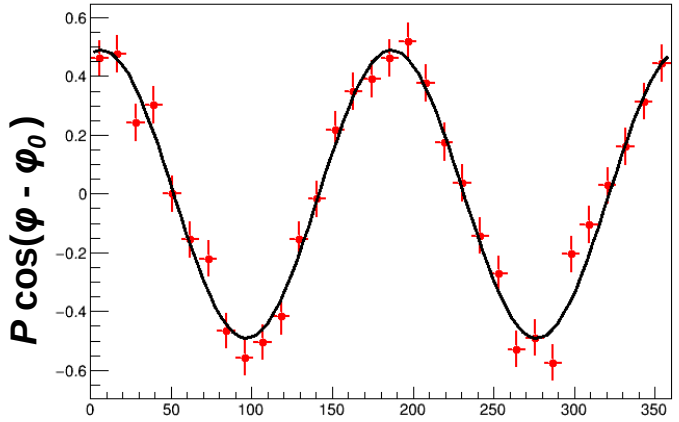
B.P. Crider *et al*., Phys. Rev. C 92, 034310 (2015)
S. Mukhopadhyay *et al*. Phys. Rev. C, submitted

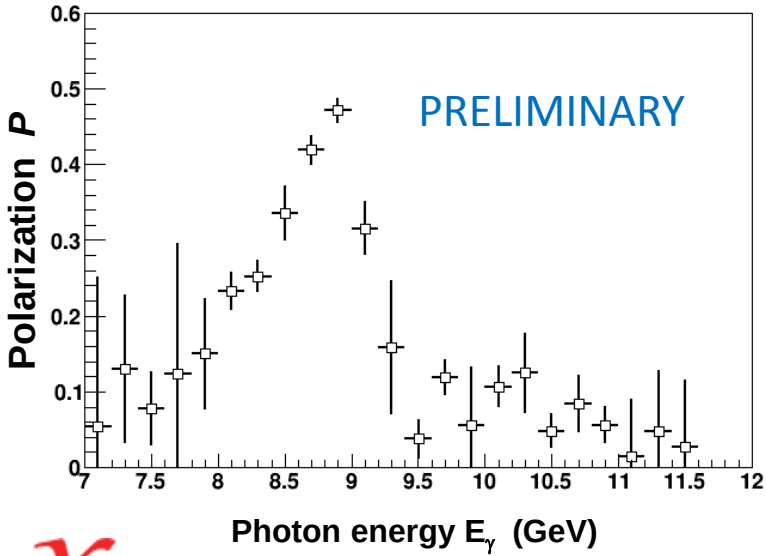
UNIVERSITY OF KENTUCKY

Hall D Triplet Polarimeter

- Uses triplet photoproduction process to measure photon beam polarization
  - Triplet production: pair production on an atomic electron
  - Polarization in photon beam yields asymmetry in recoil atomic electron distribution
- Double-sided silicon strip detector, vacuum housing, beryllium target, and custom electronics

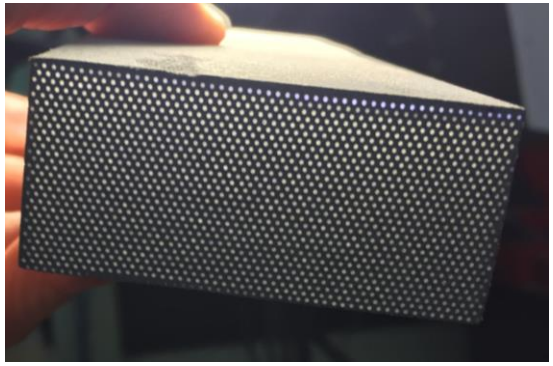


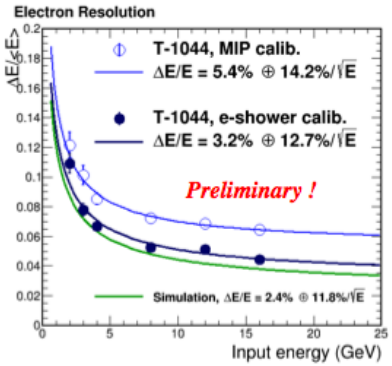


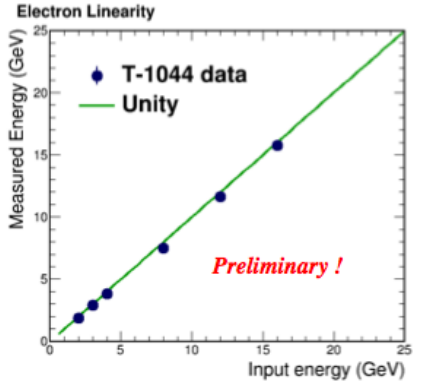


sPHENIX EMCal

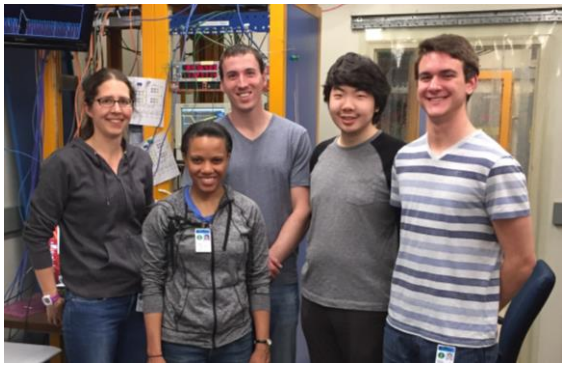
- Tungsten powder-scintillating fiber calorimeter
- April 2016 test beam with 1D projective modules: preliminary energy resolution better than required 15%/ √E
  - Paper in final preparation
- First 2D projective modules built at IUIC
  - Test at FNAL in Jan 2017



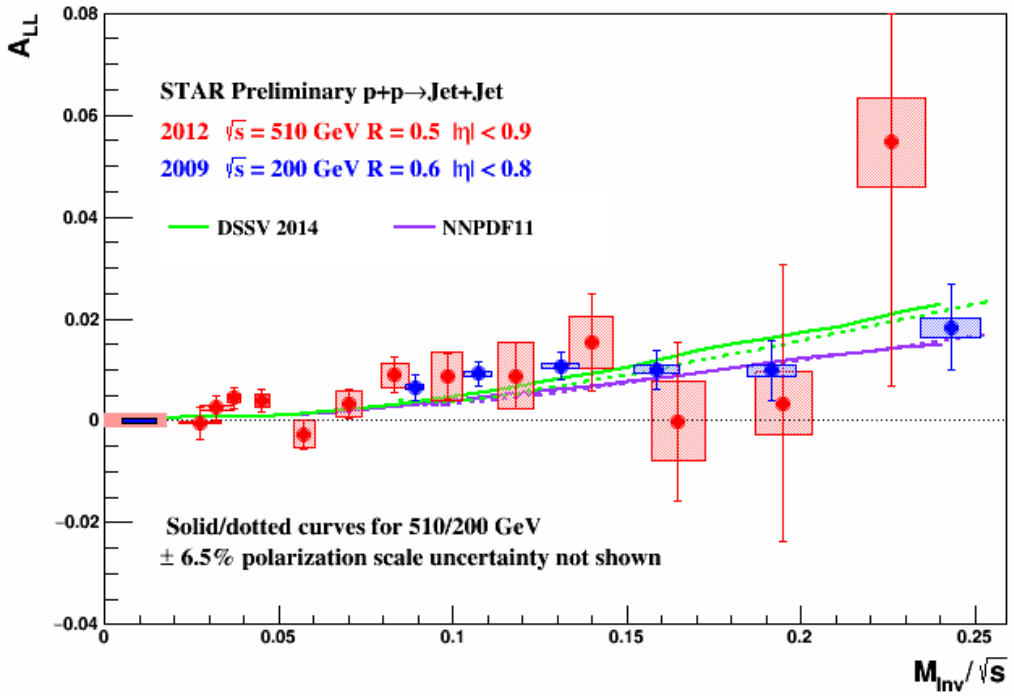




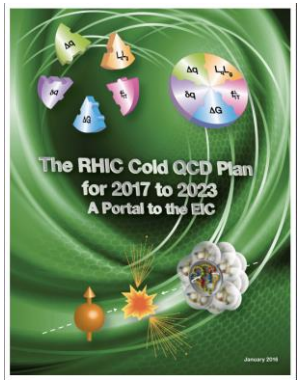
Illinois sPHENIX Group at Fermilab



Constraining the Low x Gluon Helicity Distribution with Dijets in $\sqrt{s}$ = 500 GeV p+p Collisions



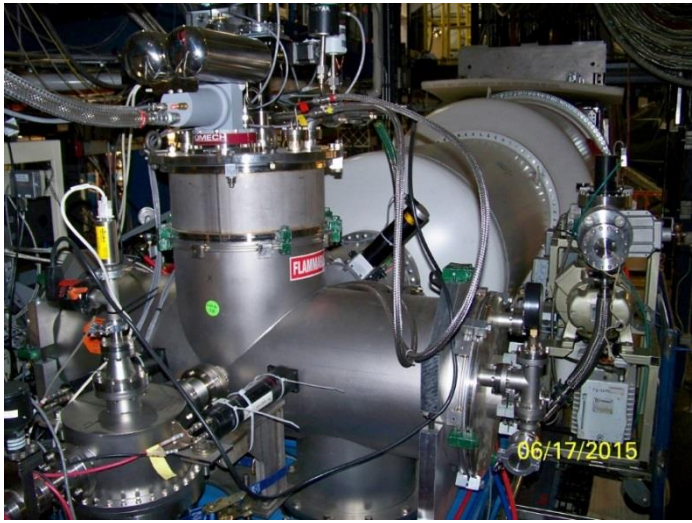
- Di-jet A_{LL} plotted vs $M_{inv}/\sqrt{s}$, which is ~$\sqrt{x_1 x_2}$ at L.O., for data taken at $\sqrt{s}$ = **200** and **510** GeV
- **510** GeV data extend to lower x where Δg(x) is not as well constrained, while **200** GeV data give better precision at mid to high x.
- The **510** data were released this year & highlighted in the RHIC Cold QCD plan.

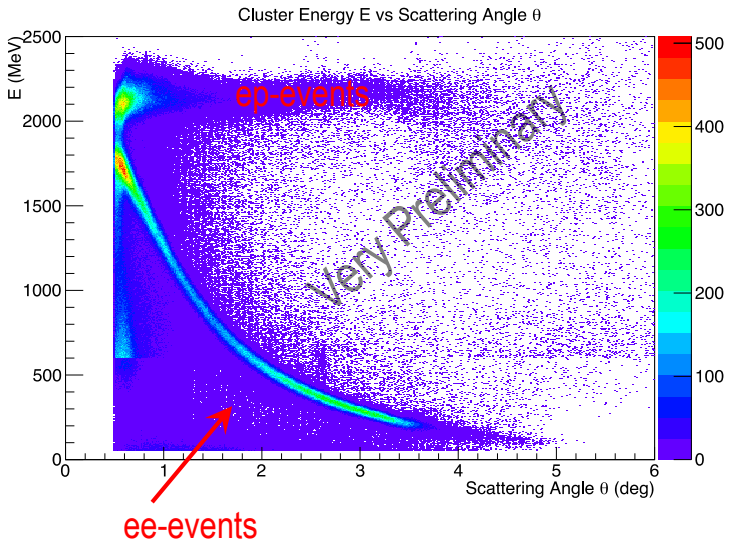


Additional data from 2013 and 2015 → reduce uncertainty by ~ ½

Prad Experiment (JLab Hall B)

- PRad to address the *"Proton Radius Puzzle"*
  - ✓ novel hydrogen gas flow windowless target (**funded by NSF MRI award: PHY-1229153**);
  - ✓ HyCal calorimeter refurbished and tested;
  - ✓ GEM large-size detectors constructed and tested
  - ✓ integrated high-speed DAQ system developed and tested;
- PRad acquired data from May 13 to June 21, 2016.
  - ✓ data taking at 1.1 GeV and 2.2 GeV
- Major accomplishments so far:
  - ✓ $2x10^{+18}$ (H atoms/cm^2) areal density in hydrogen gas flow target achieved;
  - ✓ lowest Q^2 data set (~10^{-4} GeV/C^2) have been collected for the first time in ep-scattering experiments;
  - ✓ separation of Moller and ep-events at very low scattering angles demonstrated
- Data analysis is in progress, first physics results are expected in 2017.

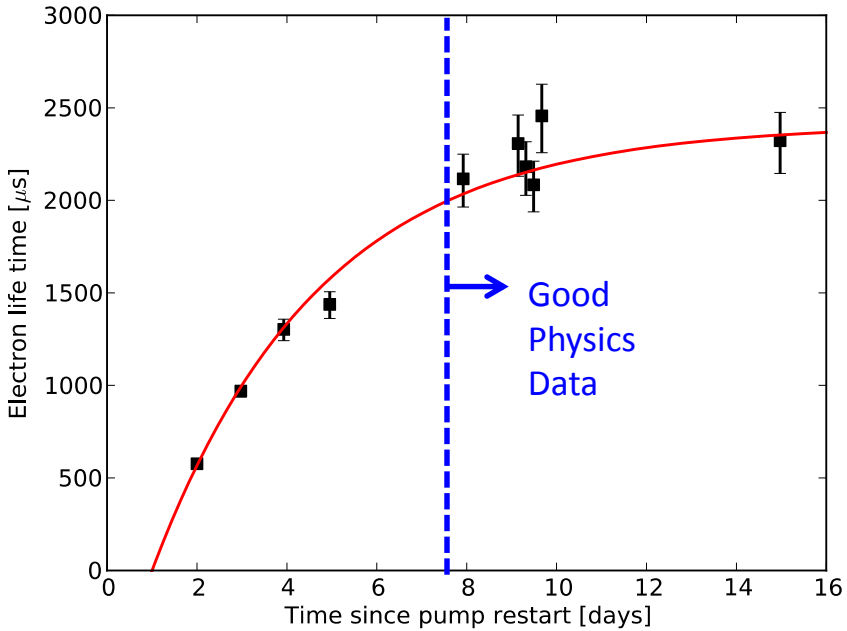




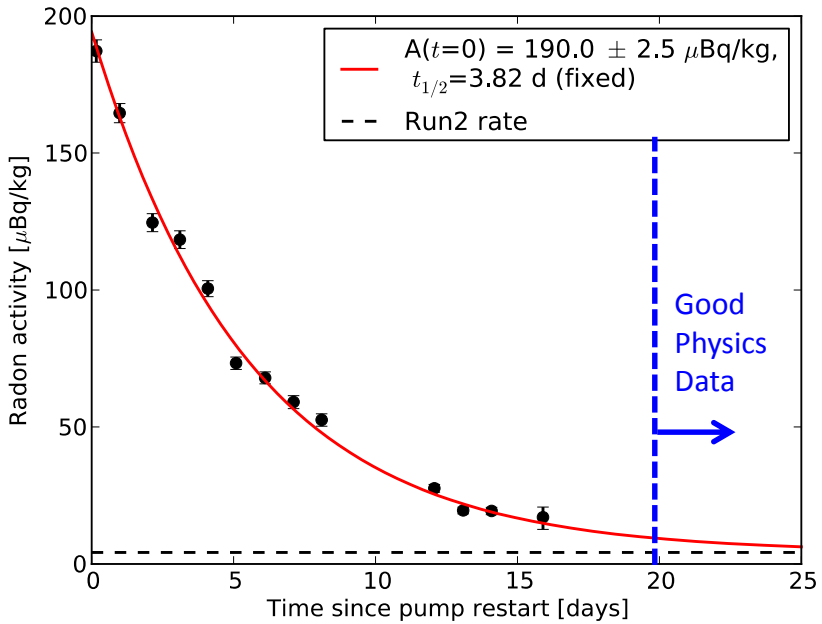
EXO-200 Phase-II Operation

After a two year hiatus due to February 2014 fire and radiation leak at the WIPP site, EXO-200 successfully re-commissioned its major systems and started its Phase-II Operation.

- Enriched liquid xenon fill completed on 1/31/2016.
- Initial data shows that the detector reached excellent xenon purity and ultra-low internal Rn level shortly after restart.



Xenon purity since Jan. 31, 2016



Rn level in TPC since Jan. 31, 2016

Progress in Ba tagging for nEXO

Neutrinoless Double Beta Decay (0νββ) of Xe^{136}:

$^{136}Xe \rightarrow {}^{136}Ba^{++} + 2e^{-}$

Barium Tagging: identify barium daughter at 0νββ decay site for **complete** background elimination

Recent Progress

PRELIMINARY

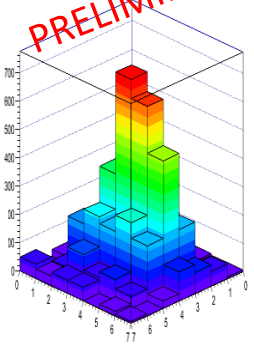
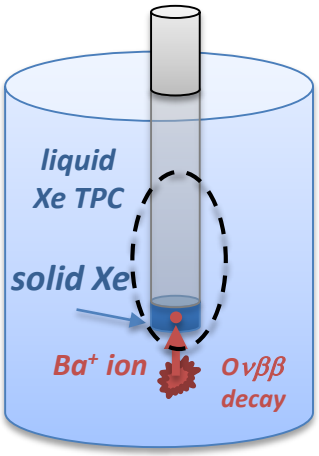
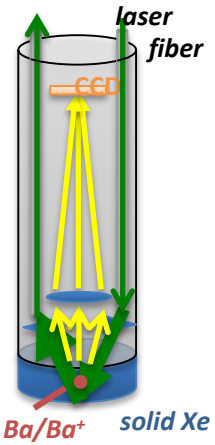


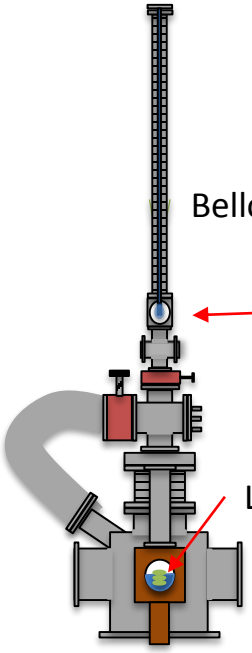
Image of ≤ 1 Ba atom in SXe in a laser beam:

Grab Ba in SXe on cold probe

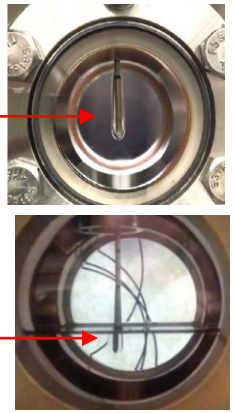


Extract probe and count Ba in SXe on end of probe (0 or 1)





Extraction of SXe ice on probe from LXe under nEXO conditions (169K):



Solicitation for NSF Physics Division Investigator-Initiated Research Projects 16-566

All proposals submitted to the Division of Physics programs must go through this solicitation.

- **Deadlines:**
  - October 26, 2016 for Particle Astrophysics
  - ***November 11, 2016 for Experimental Nuclear Physics & Theoretical Nuclear Physics***
  - February 1, 2017 for Accelerator Science
- Contains text on Midscale Instrumentation
- Follow Grant Proposal Guide (GPG) http://www.nsf.gov/pubs/policydocs/pappguide/nsf15001/gpg_index.jsp
- Follow the GPG checklist
- Follow instructions that are specific to this solicitation …

NSF Physics Division:
Investigator-Initiated Research Projects (16-566)

- Proposals to the Nuclear Physics Program for schools, workshops and conferences, must be submitted through this solicitation.
  - Priority will be given to schools.
  - Broad scope that serves a wide nuclear physics community
  - Involvement of under-represented groups
  - Contact me!

- However: Research at Undergraduate Institutions (RUI) proposals should be submitted through the RUI solicitation (14-579) by the deadlines in this PHY solicitation according to the closest disciplinary match.

Career Awards

- Solicitation: 15-555
- Must include excellent research proposal as well as excellent educational plan
- There are eligibility requirements: e.g., must be assistant professor, untenured
- 5 year awards, $400,000 minimum
- Proposal deadline: **July 23, 2015**
- PECASE nominees are chosen from CAREER winners
- Contact program officer for information/advice ahead of time (budget, scope)

Under Review!

Major Research Instrumentation (MRI) NSF 15-504

FY16

- *Physics received 34 proposals, NP received 10 proposals, 2 funded*
- *Development of a Separator for Capture Reactions (SECAR) Phase 2*, MSU, PI = H Schatz, $1,500k
- *Development of the Fast Interaction Trigger Detector for the ALICE Experiment at the LHC*, California Polytechnic State and Chicago State University, PIs = J Klay and A Harton, $369k

FY17

- New solicitation pending!

AGEP GR *Supplements*

- Available to PIs at AGEP or AGEP Legacy Institutions
  https://www.nsf.gov/mps/broadening_participation/index.jsp
- Graduate Student Eligibility
  - Emphasis placed on under-represented groups
  - Not currently supported by federal government (NSF, DOE, NIH, …)
  - US Citizen, US National, or US Permanent Resident
- Stipend, tuition, benefits, and IDC (~$60k)
- Renewable up to two times

See me and DCL 16-125 for more information

NSF/MPS/Physics Personnel

- France Cordova – Director
- Fleming Crim – Associate Director for MPS
- Denise Caldwell – Physics Division Director
- Brad Keister – Deputy Division Director
- Bogdan Mihaila – Nuclear Theory Program Director
- Allena Opper – Expt'l Nuclear Physics Program Director

- Ken Hicks – has returned to his home institution
  - new rotator will start in January

http://www.nsf.gov/pubs/2015/phy15001/phy15001.jsp?org=PHY

http://www.nsf.gov/careers/rotator/index.jsp

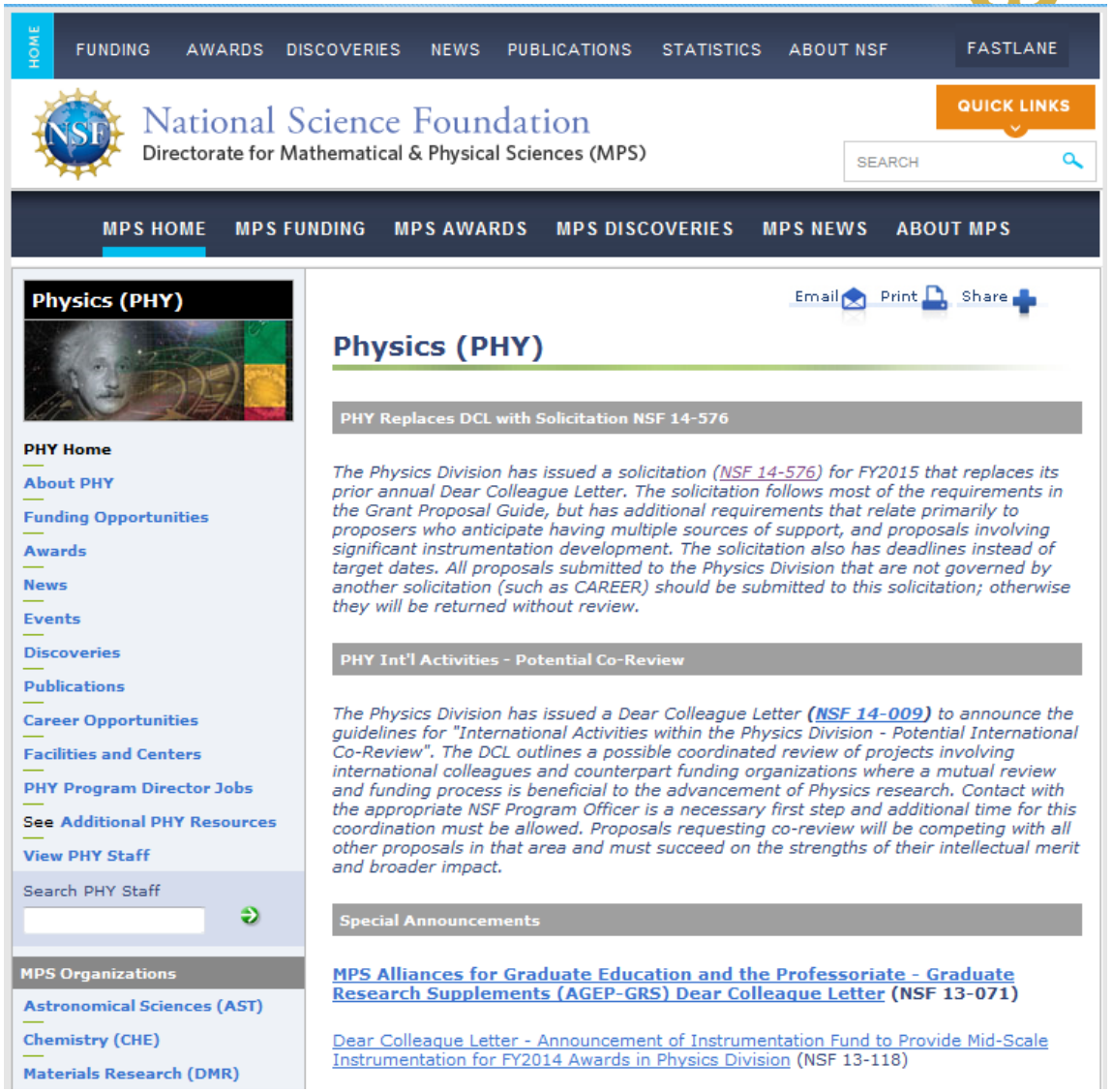
For the latest updates, check out

http://www.nsf.gov/div/index.jsp?div=PHY

Contact us:

- bmihaila@nsf.gov
  or call (703)292-8235

- aopper@nsf.gov
  or call (703)292-8958



Backup Slides