Nuclear data for γ's and $\bar{\nu}_e$'s

MTV Consortium Webinar

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BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

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Two very powerful probes

γ

Unique to an isotope

$\bar{\nu}_e$

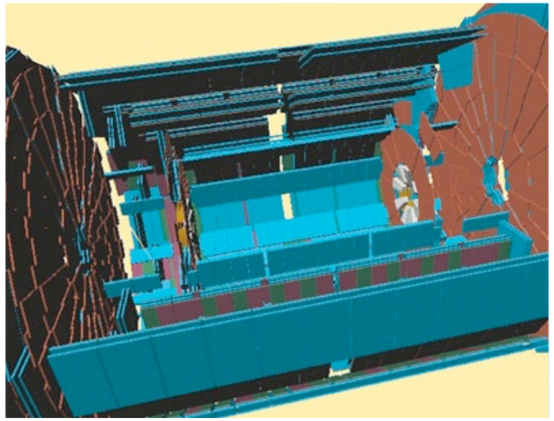
Can’t shield

Accompanies β-decays
… like from fission products

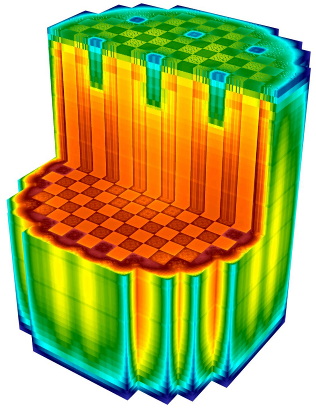
Taking full advantage of these probes in nonproliferation applications requires nuclear data

The role of nuclear data is often hidden behind the codes we use

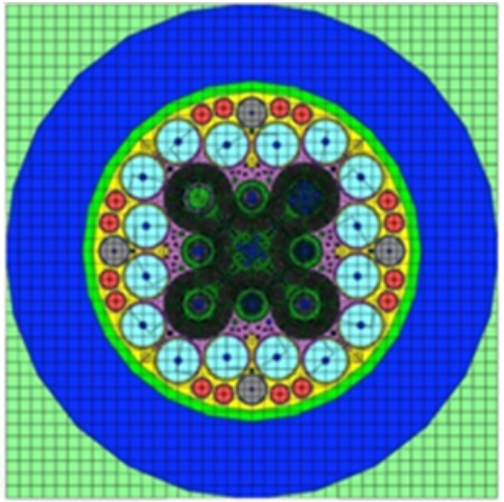
- **MCNP6, SCALE, & GEANT4 particle transport codes**
  - used for simulating nuclear energy generation
  - shielding and health physics calculations
- **ORIGEN & CINDER for isotope burn-up**
  - nuclear waste management
  - radiochemical applications
- **All have modules that use ENDF/ENSDF data**
- **Codes switch between models and data tables based on:**
  - speed
  - fidelity to physics
- **Other code systems also use covariance data in uncertainty quantification (e.g. SCALE's TSUNAMI)**



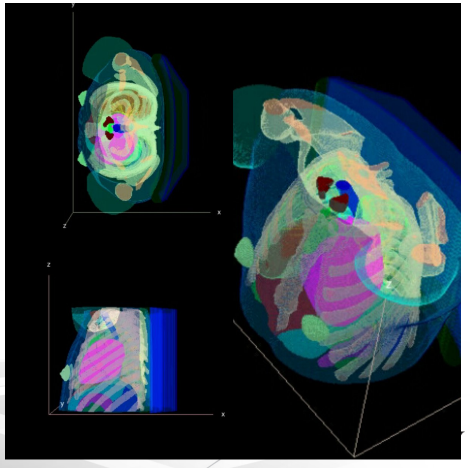
ATLAS detector muon system, simulated in GEANT4



A visualization showing the distribution of the fission product Xenon-135, an important marker for predicting reactor behavior, in the WB2 reactor core during startup. VERA enables the detailed tracking of Xenon-135 with greater fidelity than any modern reactor simulation tool available today. From ORNL



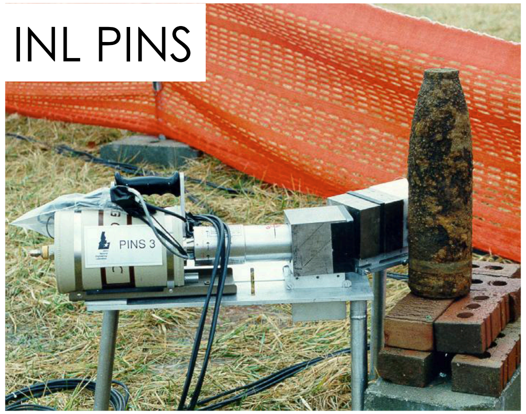
SCALE model of INL Advanced Test Reactor



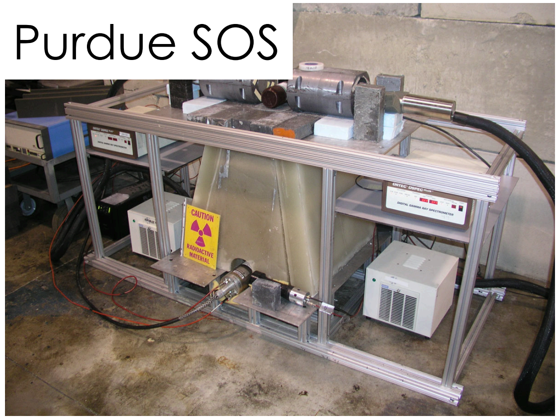
Monte Carlo simulations of #AAPM 195 report's case 5 with #EGSnrc code. From Lucus Paixao

Material Identification with Neutron-induced Gamma Spectrometry

INL PINS



Purdue SOS



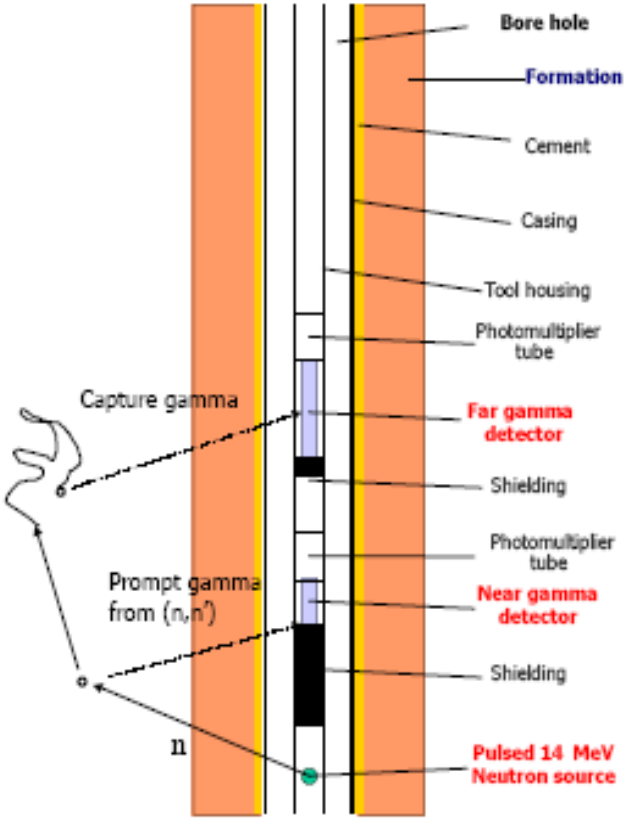
EURITRACK

WKU PELAN

A.C.T.d.o.o. Surveyor

CSIRO NITA

Oil well tool from schematic



- Developers of these technologies are **User Group #1** in this study
- These users need the number of absorption or scattering reactions and the number and energies of emitted gammas to be correct on average over many source neutrons

Slide from S. McConchie (ORNL)

Active interrogation with neutrons is common technique in many applications

- Inelastic (14 MeV) gammas are an obvious need
- Less obvious needs:
  - Capture gammas — neutrons moderate in surrounding material
  - Decay gammas — these are often background (but could be signal too)

The gamma data in ENDF is woefully deficient

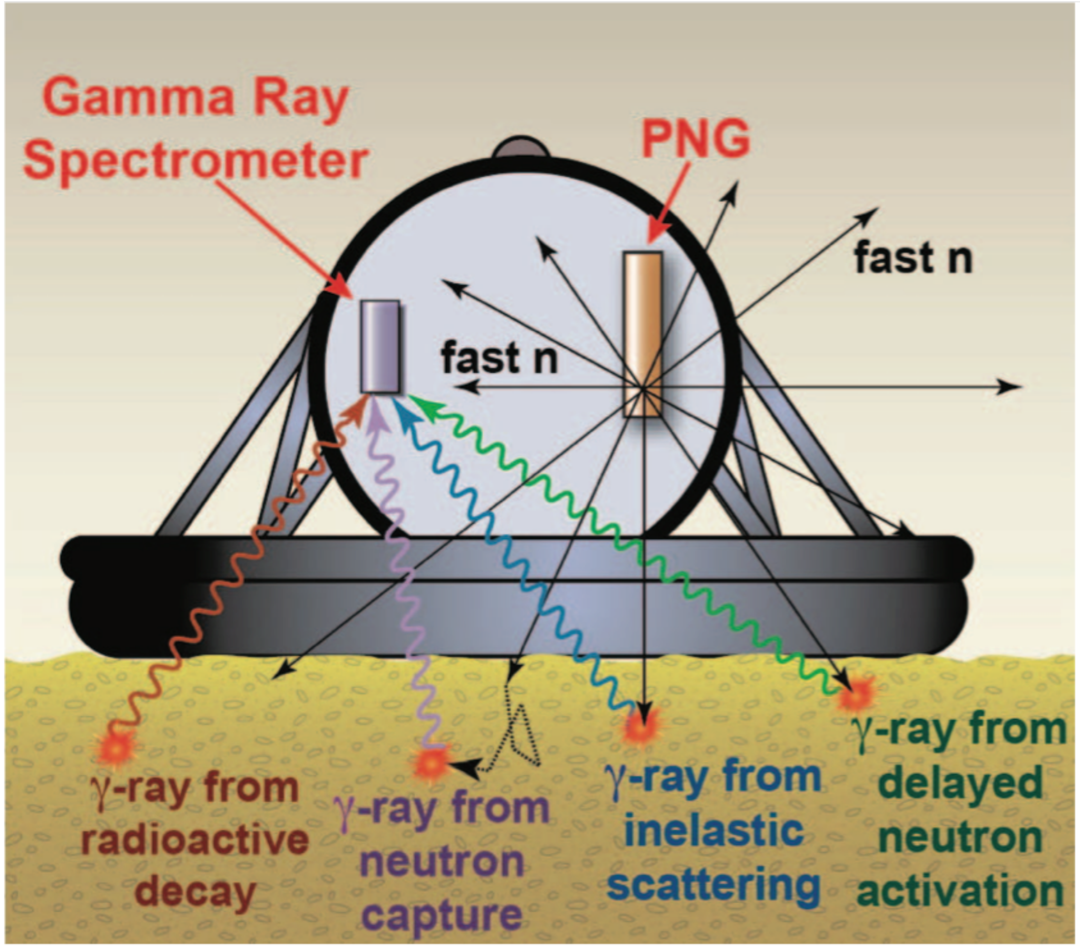
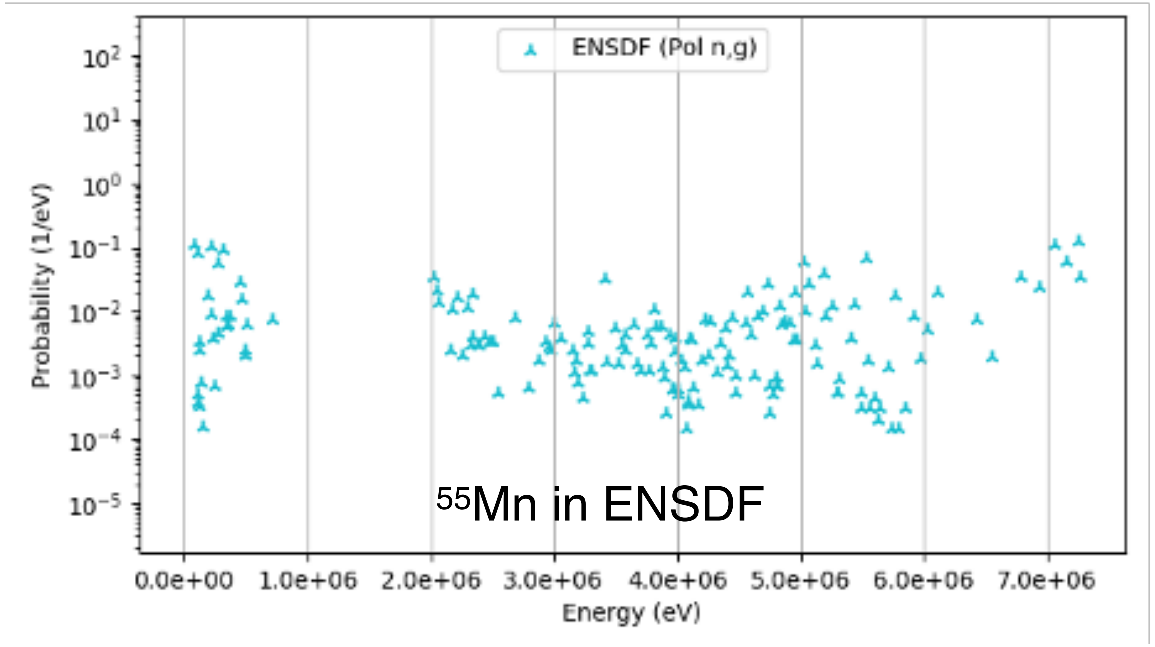
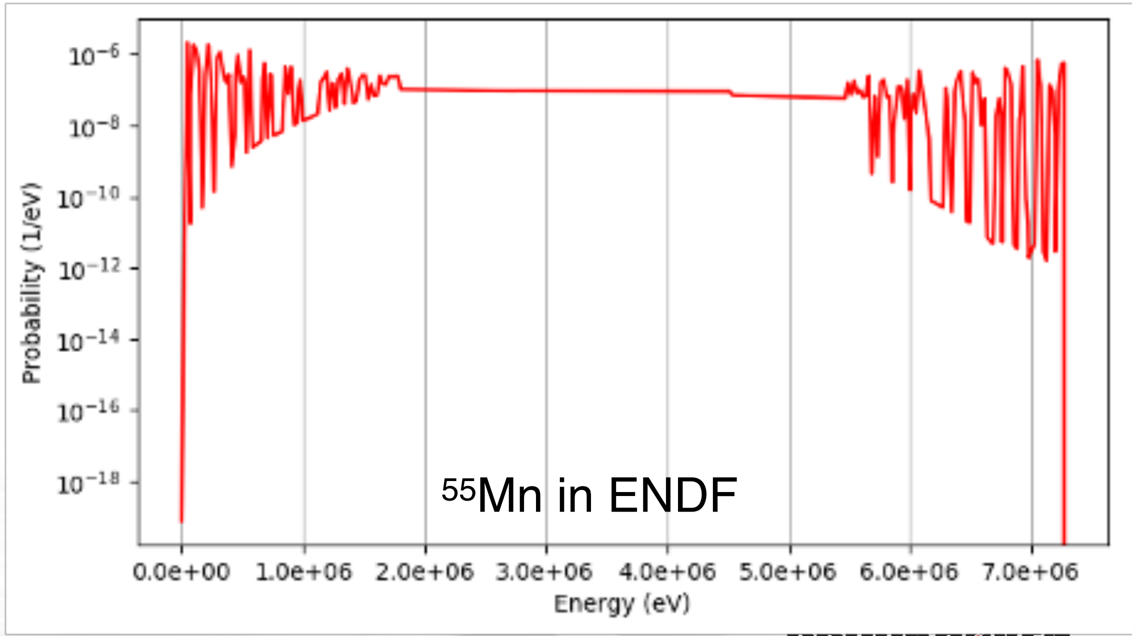


Figure 1: The Bulk Elemental Compositional Analyzer (BECA) instrument proposed for a future NASA mission to Venus. From Fig 1. of [Parsons 2016].

ENDF structure data must be synced to ENSDF

- Level schemes (energies & BR's) needed for inelastic data often used as "knob" by evaluators, not always synced with ENSDF
- Capture gammas
  - In ENDF often just modeled
  - Sometimes forgotten entirely
  - Rarely in sync with ENSDF
- 19 ENDF trackers are directly or indirectly related to deficient gamma data;
  - 3 trackers are just lists of deficient isotopes
  - One list is the 137 isotopes with no capture data at all!

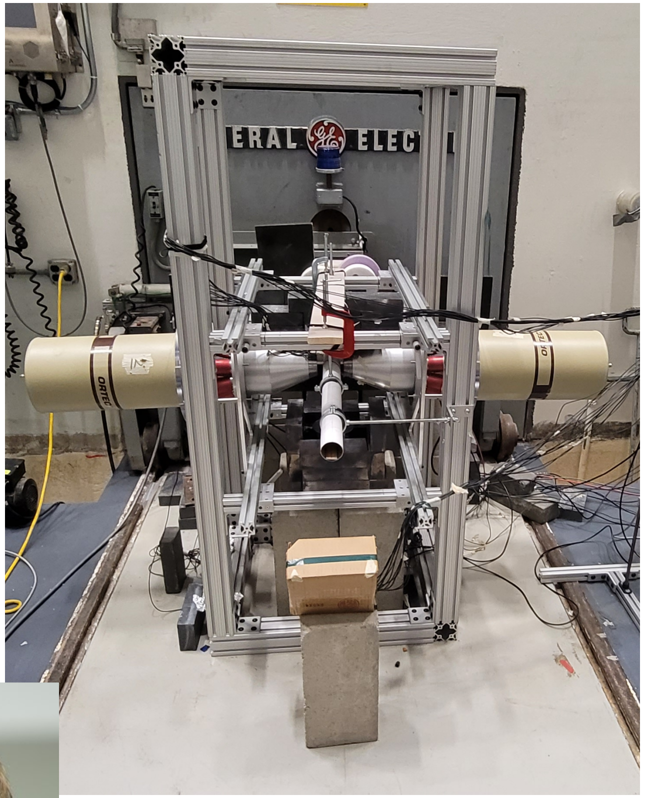


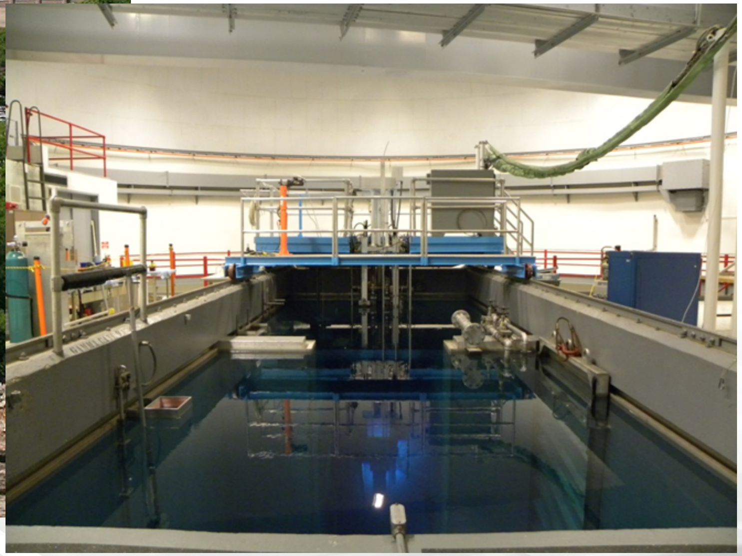


Seeking NA-22 funds to fix ENDF & get into codes

New Experimental Capabilities

- UMass Lowell 1MW Research Reactor
  - Collimated thermal neutron beam
- High-resolution coincidence gamma-ray spectroscopy
  - MIXED ARRAY OF DETECTORS (MAD) with HPGe/BGO assemblies

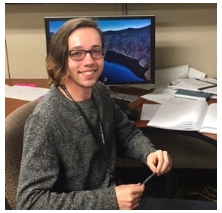


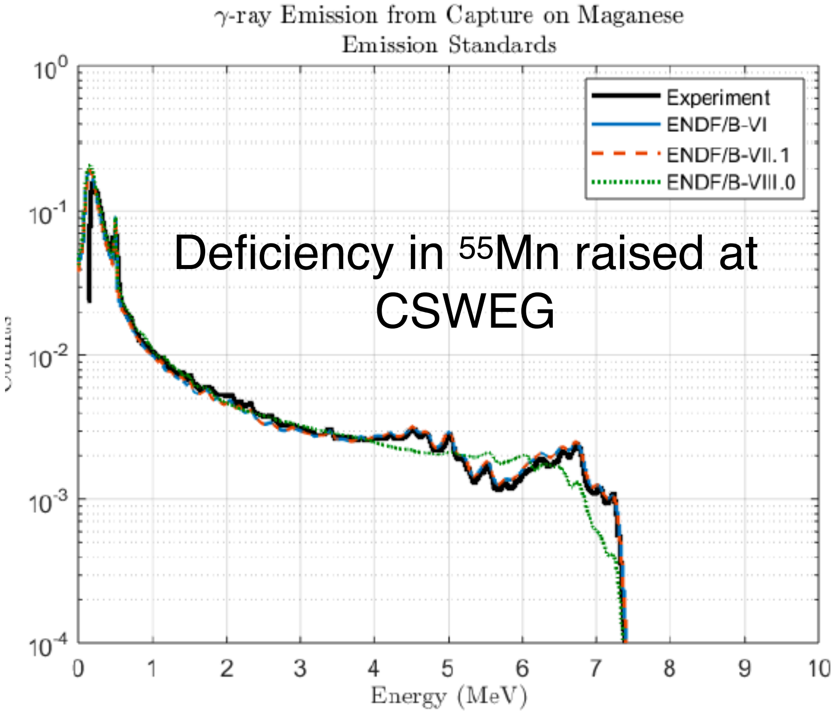


Marian Jandel

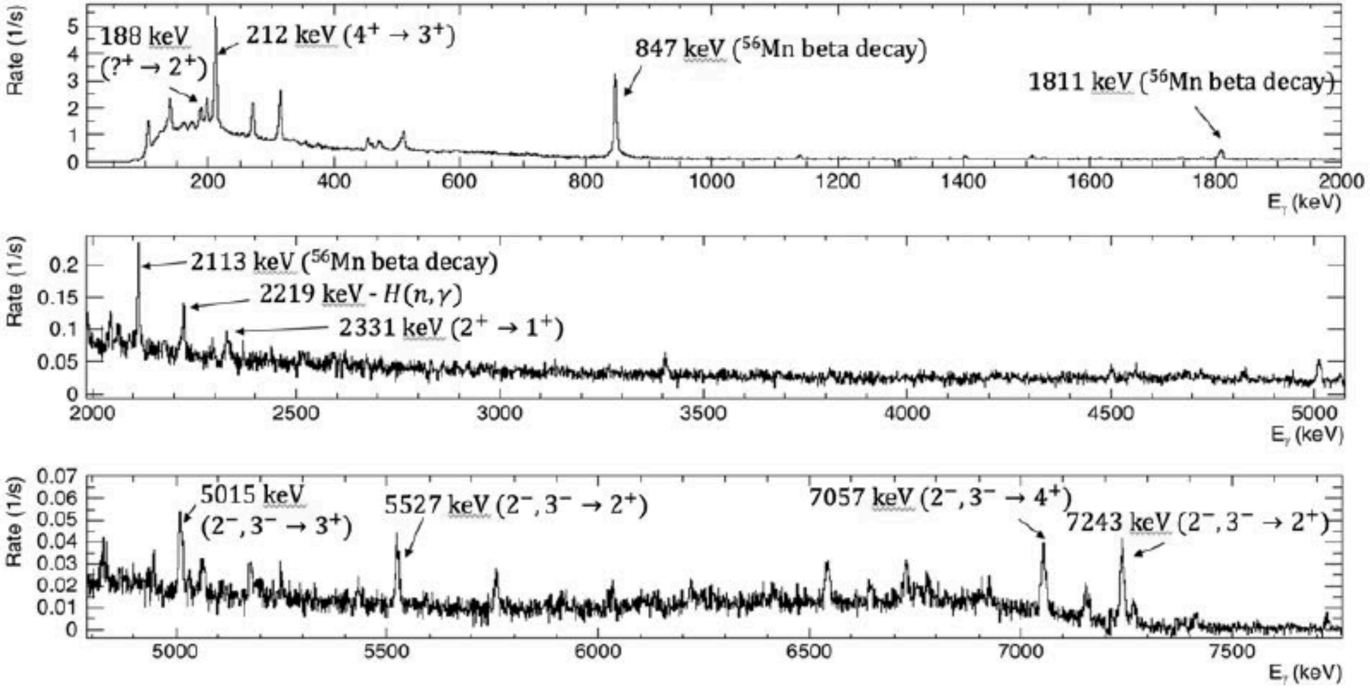
- Formerly Los Alamos
- Recipient of DOE Early Career Award in Nuclear Data

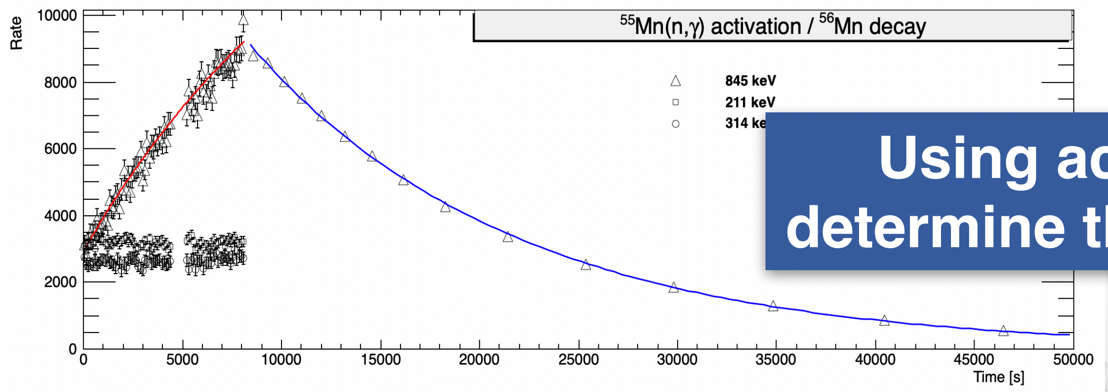
Rapidly addressing user needs





Deficiency in ^{55}Mn raised at CSWEG



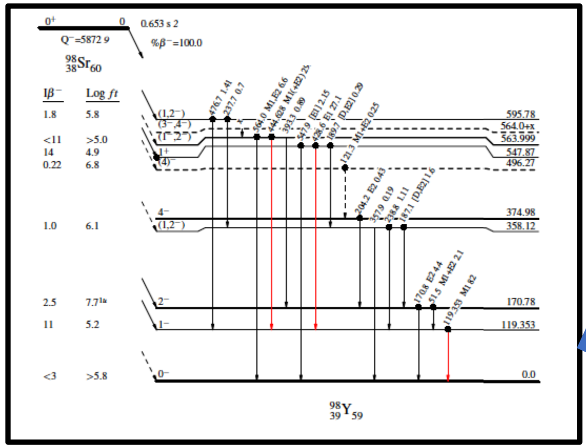


Using activation, can also determine thermal cross section

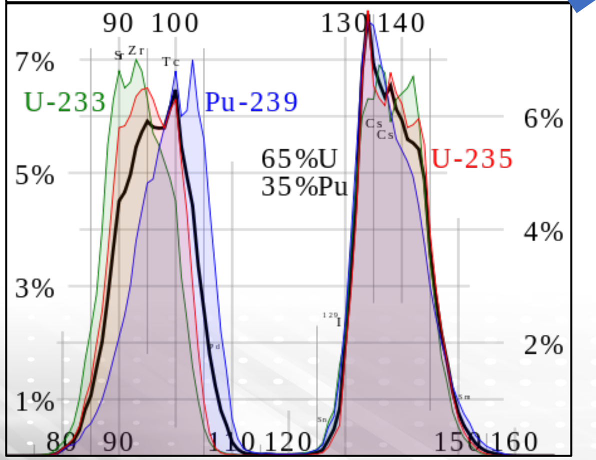
E [keV]	I [%] EGAF	I [%] ENSDF	I [%] UML
212	15.9	10.6	**11.9**
271.2	7.04	5.7	**5.9**
314.4	10.9	9.4	**8.5**
1401	3.5*	0.88	**3.4**
1705	1.39	1.39	**<0.5**
1747	3.31	3.31	**1.77**
1915	2.0	2.5	**1.35**

The role of nuclear data may be hidden, but it has impacts

Decay Data



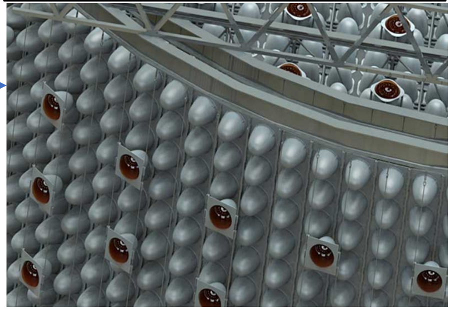
Fission Product Yield Distribution Data



scale
Nuclear Systems Modeling & Simulation
MCNP6

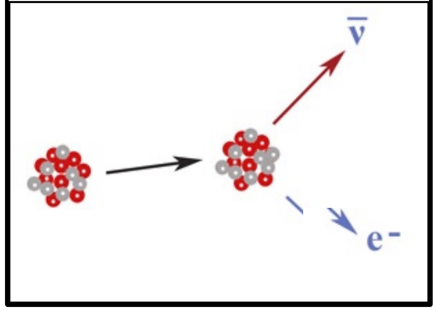
Models

Non-proliferation using $\bar{\nu}_e$ monitors

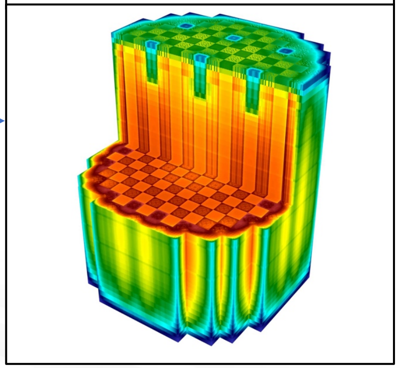


National Nuclear Security Administration

Physics beyond the standard model



Decay Heat calculations



Let's examine the $\bar{\nu}_e$ case in some more detail

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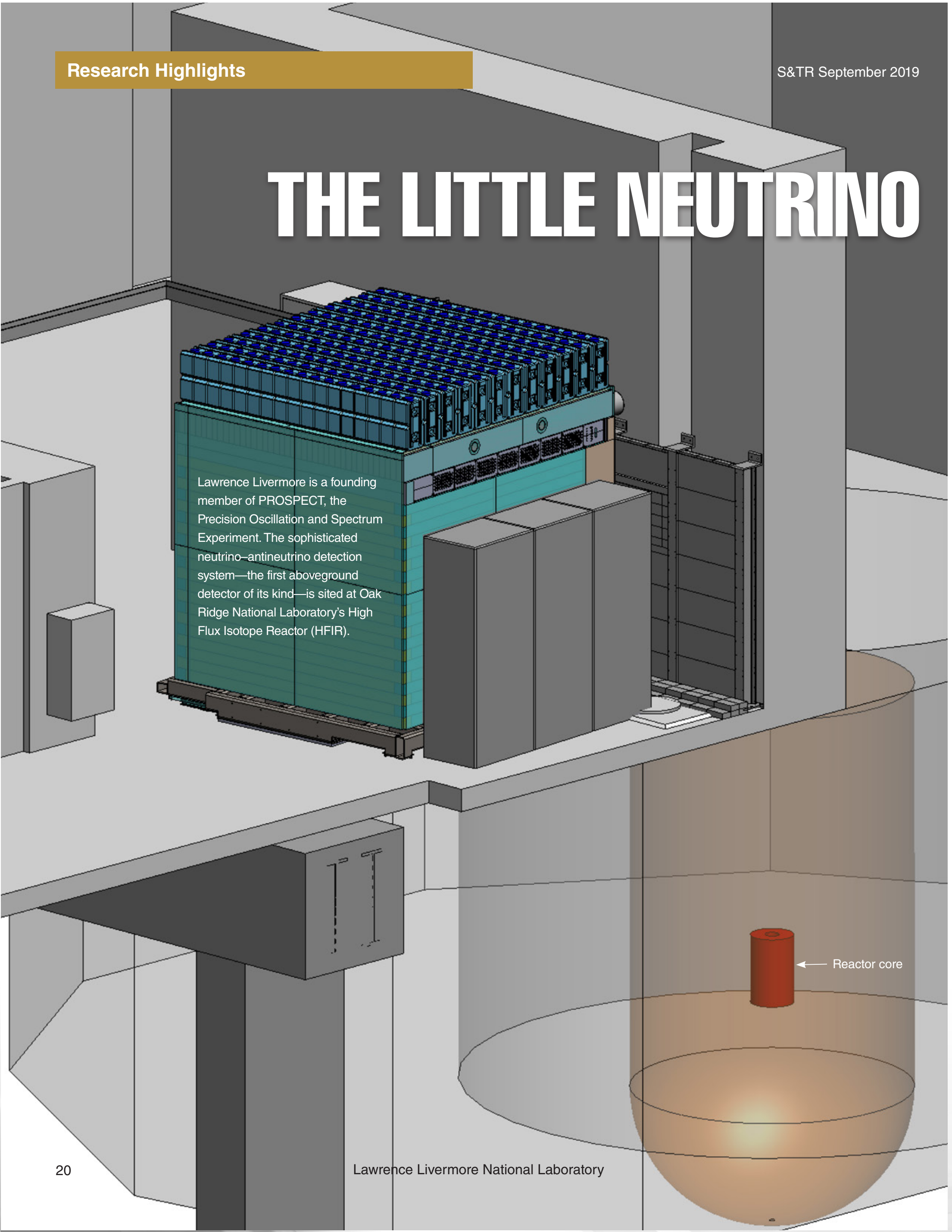
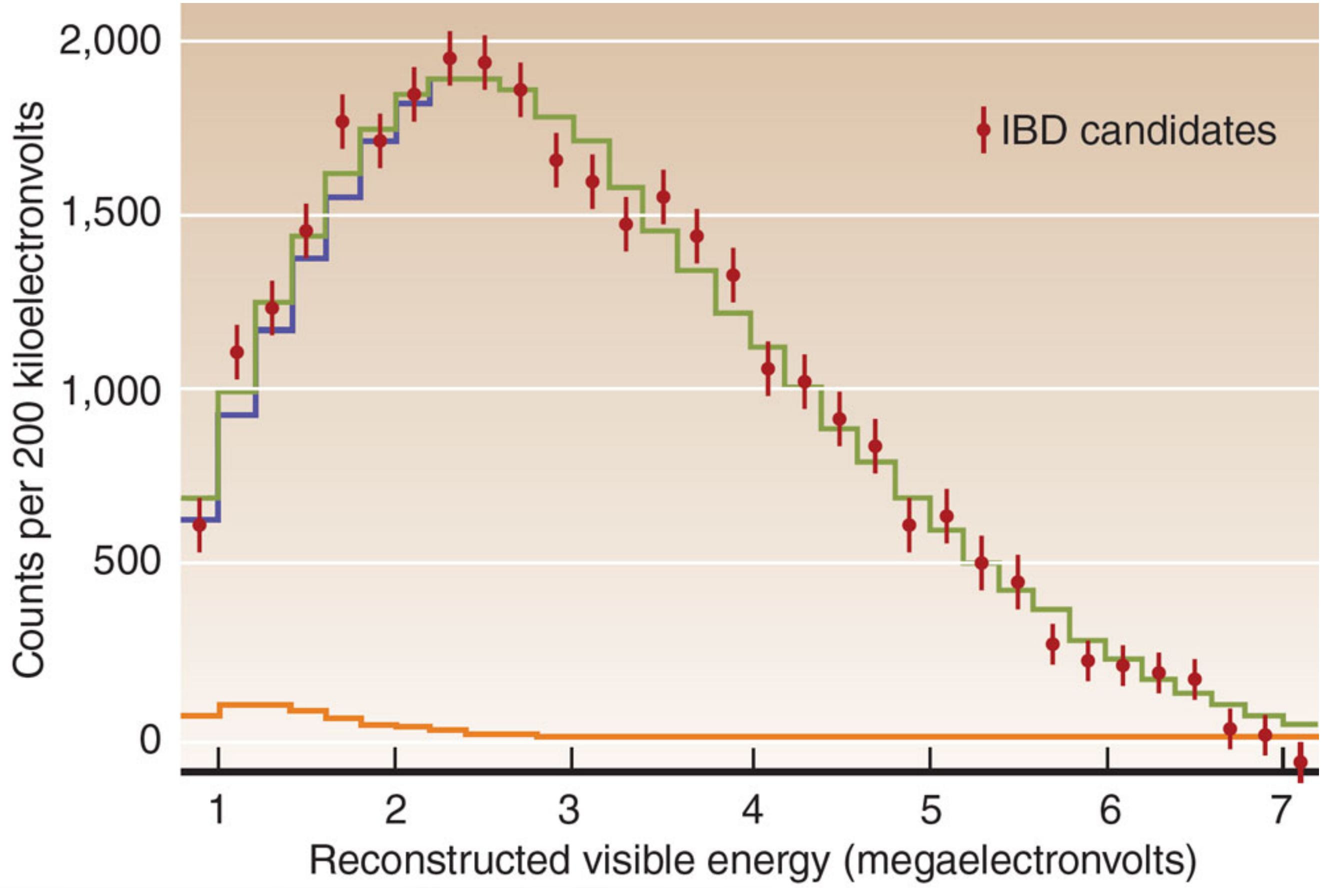
Office of NUCLEAR ENERGY



PROSPECT (Precision Oscillation & Spectrum Experiment) show can monitor reactors with antineutrinos



From "The Little Neutrino Experiment That Could", Science and Technology Review, LLNL, Sept (2019), pp. 20-23

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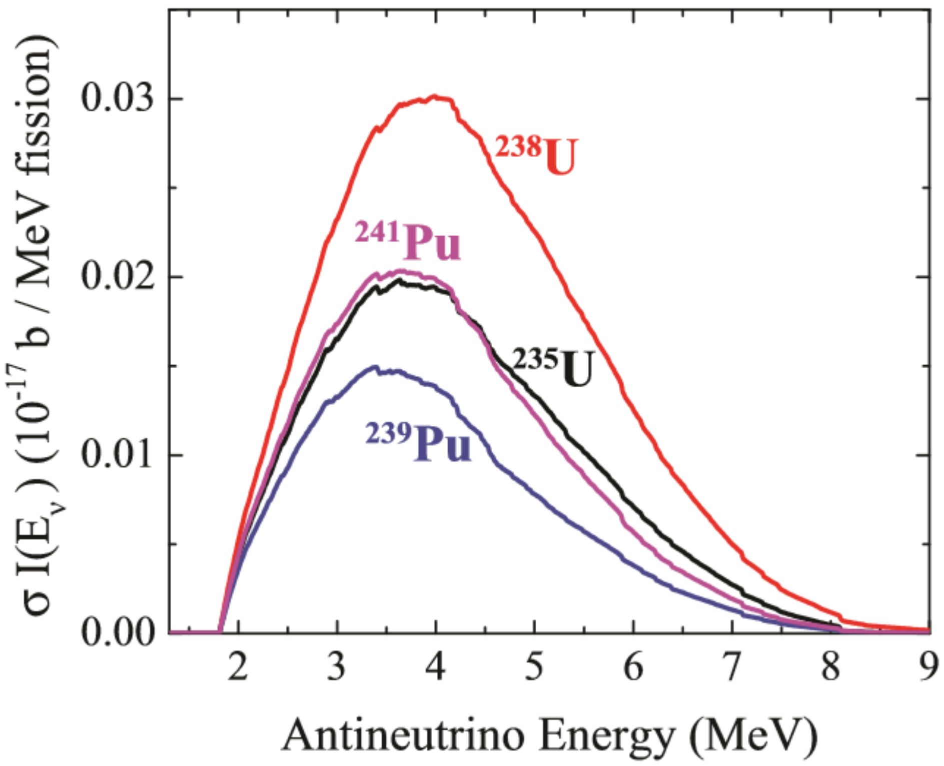
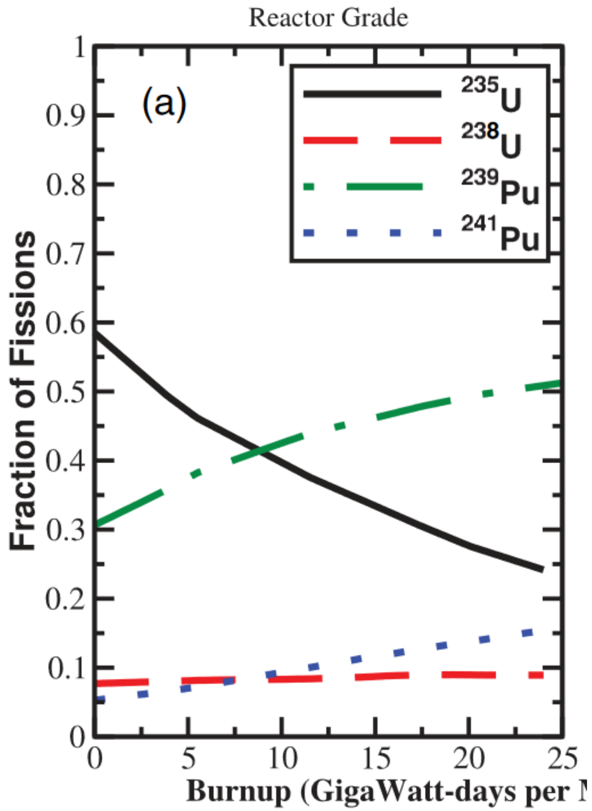
The antineutrino spectra changes with different ^{239}Pu fission fraction

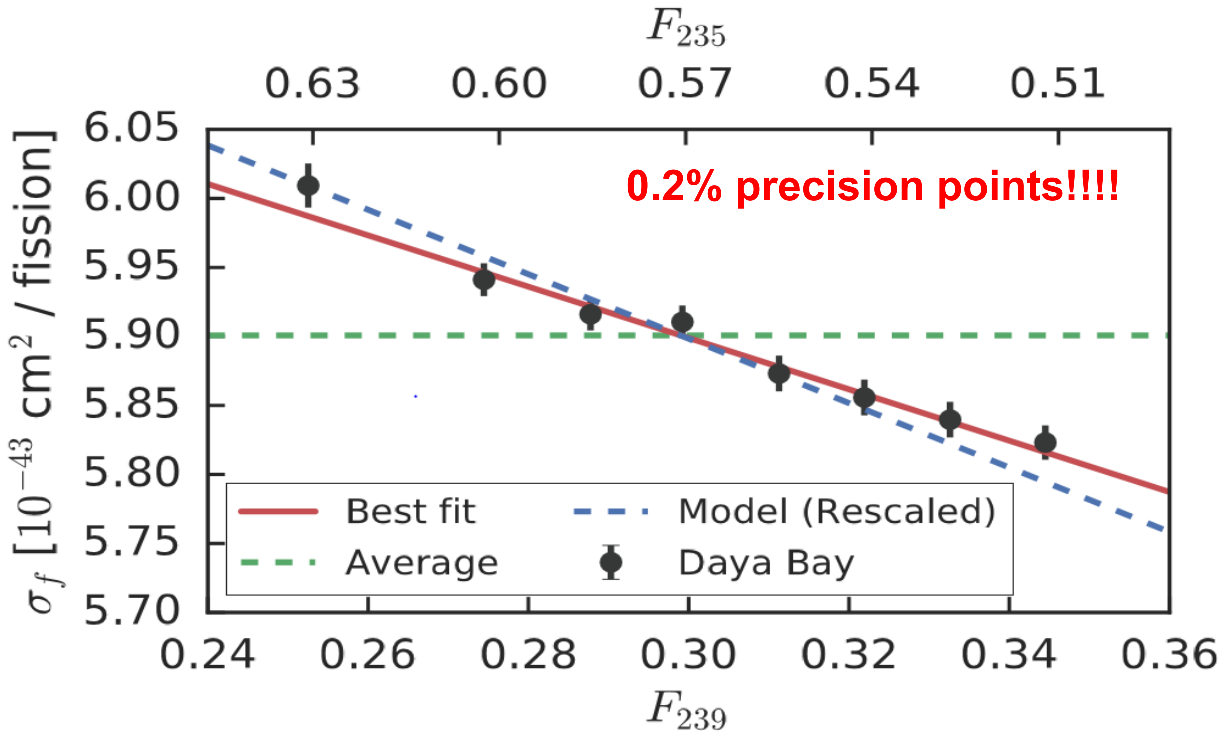




Diverted ^{239}Pu shows up as unexpected change in spectrum vs. burn-up

IBD Antineutrino yield vs. ^{239}Pu fission fraction

F.P. An et al,
PRL **118**, 251801 (2017).

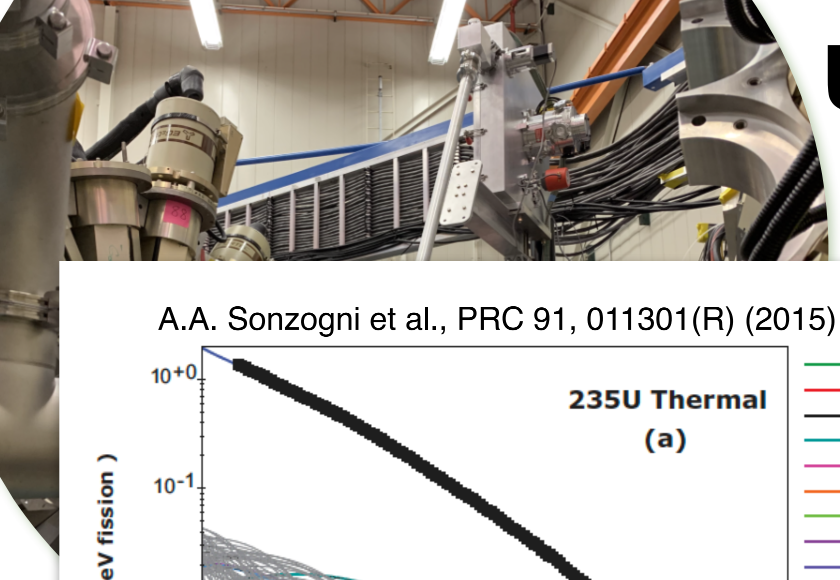


σ values (10^{-43} cm^2/fission)

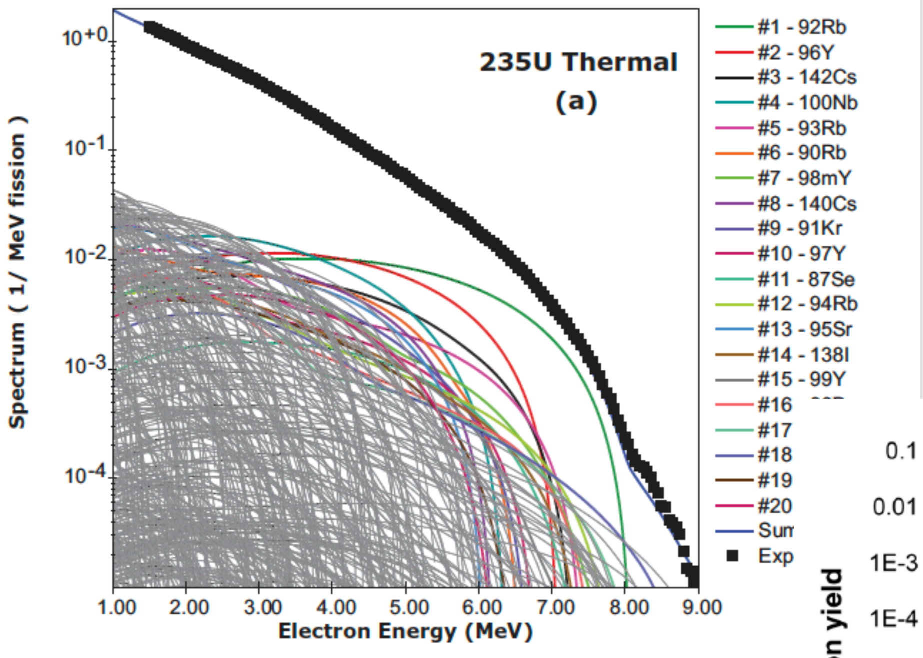
Nucleus	Daya Bay 17 fit	Huber/Mueller	Summation E8D+J31FY
235U	6.17+-0.17	6.69+-0.15	6.46
239Pu	4.27+-0.26	4.36+-0.19	4.41
238U		10.1+-1.17	10.11
241Pu		6.04+-0.19	6.21

Diverted ^{239}Pu shows up as unexpected change in spectrum vs. burn-up

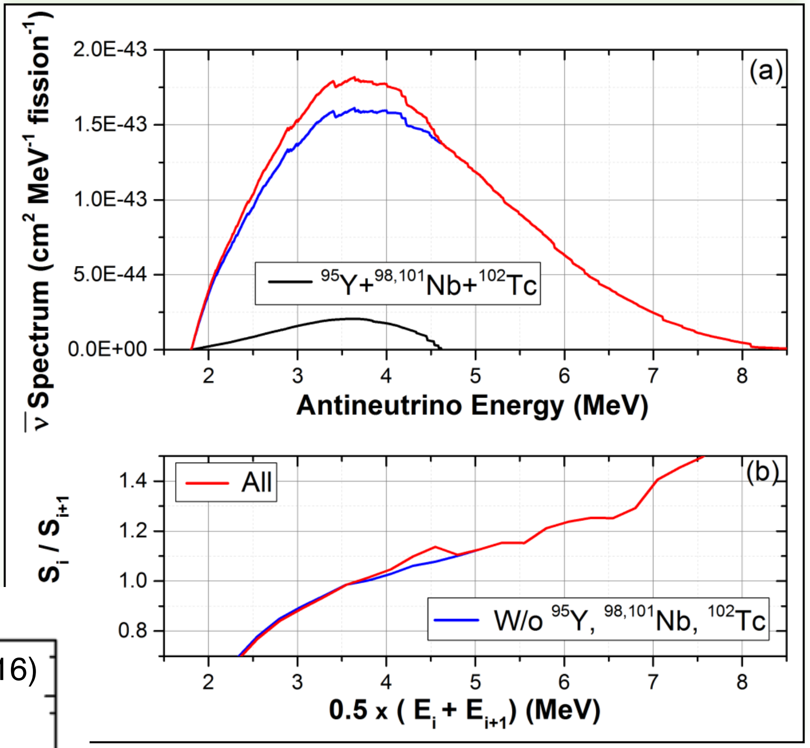
USNDP Work on data for Antineutrinos



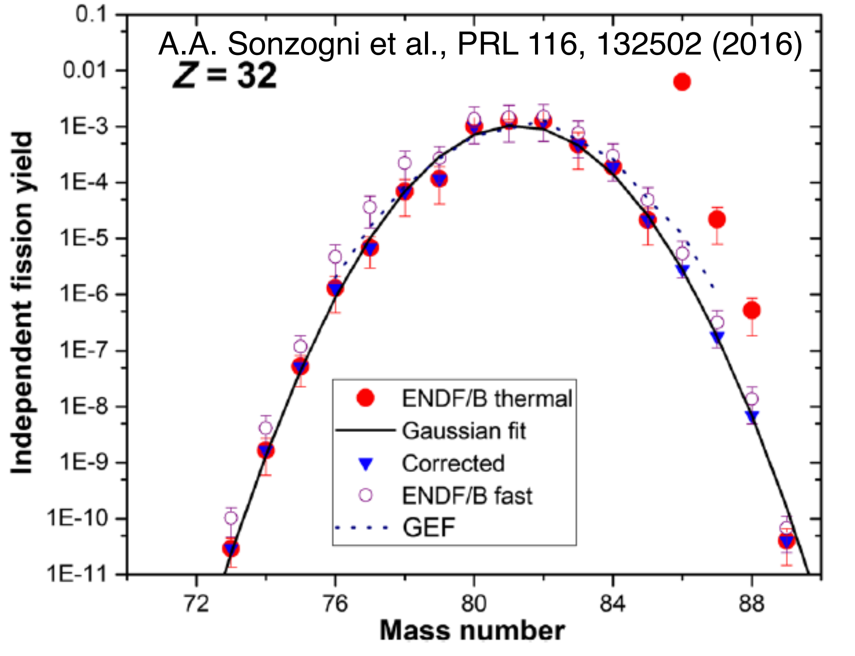
A.A. Sonzogni et al., PRC 91, 011301(R) (2015)

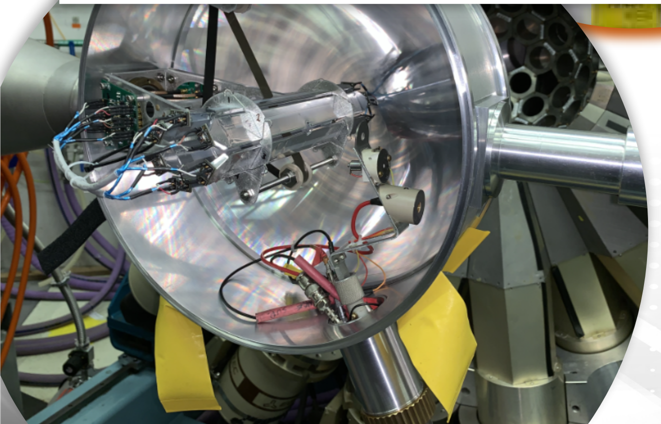


Need to revise FPY & decay data



Fine structure due to 4 fission products.
A.A. Sonzogni, M. Nino et al., Phys. Rev. C 98, 014323 (2018)





FPY re-evaluation project funded by NA-22

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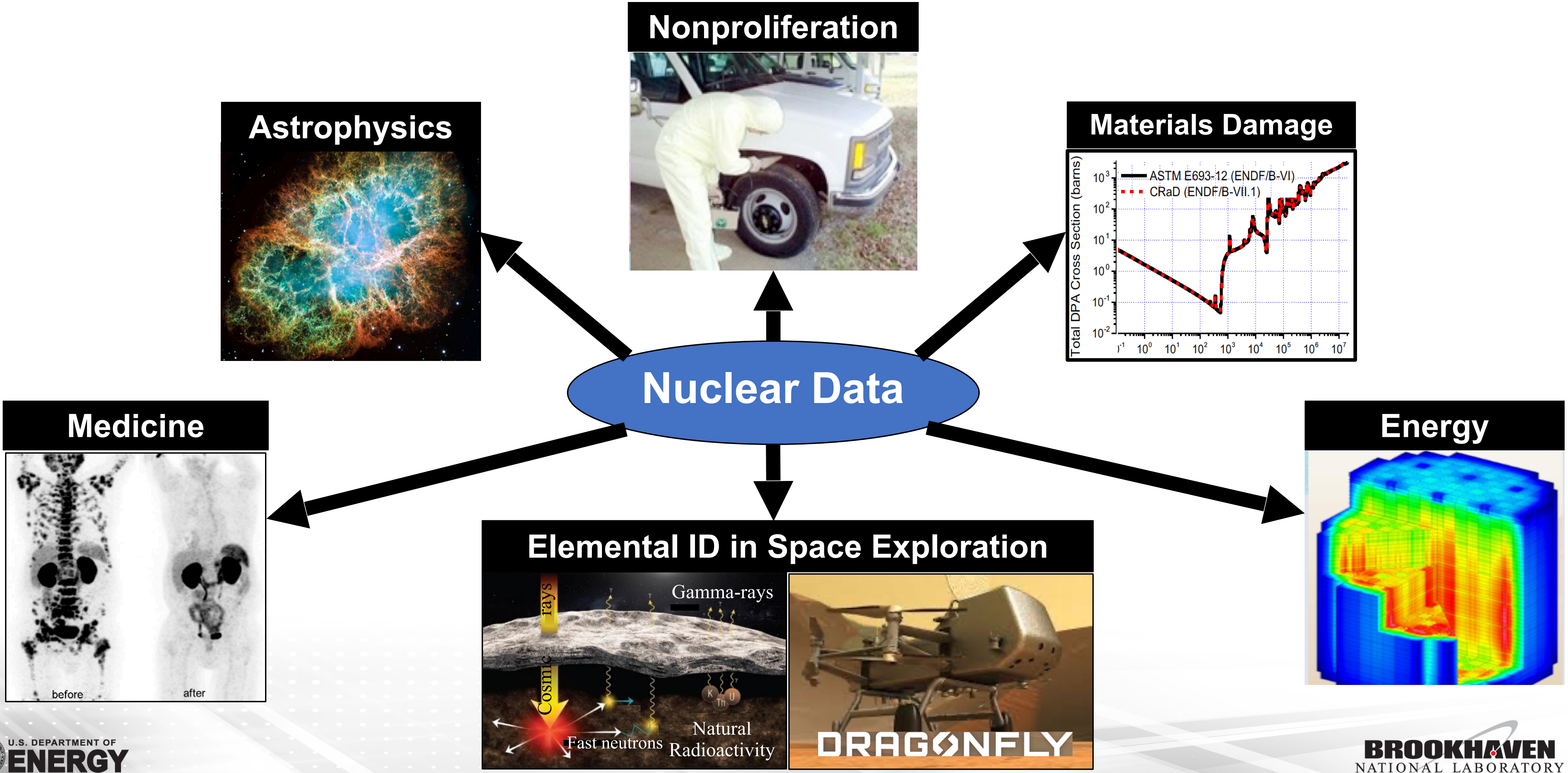
Takeaway: nuclear data are crosscutting & often hidden



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