Nuclear data for $\gamma$’s and $\bar{\nu}_e$’s

MTV Consortium Webinar
David Brown
National Nuclear Data Center (Nuclear Science & Tech. Dept.)
Two very powerful probes

\[ \gamma \]

Unique to an isotope

\[ \bar{\nu}_e \]

Can’t shield

Accompanies \( \beta \)-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)**

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.
Material Identification with Neutron-induced Gamma Spectrometry

• 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

Oil well tool from schematic

Slide from S. McConchie (ORNL)
Active interrogation with neutrons is a 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

Using activation, can also determine thermal cross section
The role of nuclear data may be hidden, but it has impacts.

Let’s examine the $\bar{\nu}_e$ case in some more detail.
THE LITTLE NEUTRINO

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

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

Diverted $^{239}\text{Pu}$ shows up as unexpected change in spectrum vs. burn-up
IBD Antineutrino yield vs. $^{239}$Pu fission fraction

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


$\sigma$ values (10$^{-43}$ cm$^2$/fission)

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>Daya Bay 17 fit</th>
<th>Huber/Mueller</th>
<th>Summation E8D+J31FY</th>
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<tbody>
<tr>
<td>$^{235}$U</td>
<td>6.17±0.17</td>
<td>6.69±0.15</td>
<td>6.46</td>
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<tr>
<td>$^{239}$Pu</td>
<td>4.27±0.26</td>
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<td>$^{238}$U</td>
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<tr>
<td>$^{241}$Pu</td>
<td>6.04±0.19</td>
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<td>6.21</td>
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</table>
USNDP Work on data for Antineutrinos

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

Need to revise FPY & decay data

A. A. Sonzogni et al., PRL 116, 132502 (2016)

235U Thermal

(a)

Antineutrino Energy (MeV)

S_f/S_{tot}

(b)

Fine structure due to 4 fission products.

FPY re-evaluation project funded by NA-22
Takeaway: nuclear data are crosscutting & often hidden