Angular distributions in ENDF/B-VIII.0

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a passion for discovery



Impact on the SVRE:

The impact of the elastic SAD on the SVRE was investigated with MASURCA and ZPPR integral experiments. The calculations were performed with the deterministic code **ERANOS**

Those calculations were carried out using 3 different Na23 elastic scattering angular distributions:



compared to results from Hauser-Feshbach calculations alread ENDF/B files. Because the resonance parameters in the files we experiment, the experimental smoothed distributions should H Hauser-Feshbach smoothed distribution. We aimed to test this provide other isotope-based checks on ENDF/B angular distribution



Legend



Figure 1 Scattering neutrons in a critical assembly (lowpower nuclear system) represented as arrows originating from the PU-MET-FAST-040 core [5]

Reconstructed angul distribution i

Impact on the SVRE (ZPPR-10A benchmark):

Significant improvement of the C-E results by using SAD calculated by optical model + fit of a₁



Two-body angular distributions are calculable, analytically, using Blatt-Beidenharn formalism

$$\frac{d\overline{\sigma}_{a\to b}}{d\Omega_b} = \left(\frac{2\pi}{\hbar}\right)^4 \mu_a \mu_b \frac{k_b}{k_a} \frac{1}{2I_x + 1} \frac{1}{2I_A + 1} \sum_{L=0}^{\infty} B_L(\underline{b}, \underline{a}; E_a) P_L(\mu) \tag{15}$$

$$B_{L}(\underline{b},\underline{a};E_{a}) = \sum_{S_{a},S_{b}} \frac{(-)^{S_{b}-S_{a}}}{4} \sum_{J\ell_{a}\ell_{b}} \sum_{J'\ell'_{a}\ell'_{b}} \bar{Z}(\ell_{a}J\ell'_{a}J';S_{a}L)\bar{Z}(\ell_{b}J\ell'_{b}J';S_{b}L)\Re\left[T^{J*}_{\{\underline{a};\ell_{a}S_{a}\}\to\{\underline{b};\ell_{b}S_{b}\}}T^{J'}_{\{\underline{a};\ell'_{a}S_{a}\}\to\{\underline{b};\ell'_{b}S_{b}\}}\right].$$
(16)

 $\bar{Z}(\ell_a J \ell'_a J'; S_a L) = \sqrt{(2\ell_a + 1)(2\ell'_a + 1)(2J + 1)(2J' + 1)} (\ell_a 0 \ell'_a 0 | L0) \mathcal{W}(\ell_a J \ell'_a J'; S_a L)$

$$\mathcal{W}\left(\ell_a J \ell'_a J'; S_a L\right) = (-1)^{-(\ell_a + \ell'_a + J + J')} \left\{ \begin{array}{ccc} \ell_a & J & S_a \\ J' & \ell'_a & L \end{array} \right\}$$

It's ugly, but well understood.

Implemented in FUDGE, EMPIRE, CoH, SAMMY, AMPX, NJOY,
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⁶³Cu (⁶⁵Cu is similar)

Legendre Moment for Cu63(n,el)



 Smoothed distribution in excellent agreement with reconstructed distribution. – is actually no surprise: FUDGE & SAMMY used these data to validate against each other



Justin Vega's project

- BNL's High School Research Program
- Final report is huge, available upon request.
 Report number BNL-114446-2017-IR

• The project:

- Test that energy average SAD approaches HF SAD
- Check all SAD in ENDF/B-VIII.0 beta3



Demonstration that RRR angular distributions and HF angular distributions are consistent



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a function of the incident energy of th d compare Legendre moments, I also between isotopes of the same element veloped Python scripts to automate th ons and their plots onto an HTML we is of each element and evaluated isoto d the generated plots and decided ⁹⁰Z erence test between smoothed and Ha reconstr**icted DigBlat/dl**strib**usiong** for applied the Legendre transformation x-y coordinate pairs to plot. I computed summations evels of shoetingsphericed their values.



L=1 moments for ENDF/B Zirconium isotopes



experimental angular distributio

r, David Brown, for giving me an in-depth experience into the world of nuclear physics and for taking the time to nks to the Office of Educational Programs and the Department of Energy for allowing me this tremendous cience & Technology Building and all the interns I have connected with over the course of my time at BNL. A ondrage, and my physics teacher, Mr. Plana, for recommending me into this program. Last but not least, I have other, Maria Vega, for dealing with the commute every single day.

HF SAU as expected



RATORY

Brookhaven Science

Issues encountered in full library scan (I will be adding trackers for each of these)



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Anomaly in Si isotopes



Legendre Moment for Si28(n,el)



- All isotopes have same distribution, taken from ENDF/B-V ^{nat}Si
- Natural SAD built from isotopic SADs
- If SAD is smooth, is OK to replace isotopic with natural SADs
- THIS IS NOT THE CASE



³¹P looks odd, and it is our fault



- Data given as pointwise & my Legendre fitter failed
- Need to investigate further



Anomaly in Cr isotopes

Legendre Moment for Cr50(n,el)

Legendre Moment for Cr52(n,el)



- Same issue as Si
- May be part of problem with steel assemblies



¹⁰¹Ru, ¹⁰⁵Pd, ¹⁰⁹Ag, ^{108,110,116}Cd, 131Xe, ¹³³Cs, ¹⁴¹Pr

Legendre Moment for Ru101(n,el)



- Symmetry requires that, as $E \rightarrow 0$, $P_{L=0}(\mu) \rightarrow 0$
- Several isotopes violate this requirement





- Here agreement is poor
- Near closed shell, fluctuations large, extend to high energy
- May indicate problem with OMP's involved
- Requires further investigation



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Scattering Angular Distributions in the ENDF/B Nuclear Data Library

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Nuclear reactors function by controlling the chain reaction of fission events in a fissile material. Understanding the gain and loss of neutrons is crucial for controlling this chain reaction. The role of fission in liberating neutrons from nuclei is well known. The fact that neutrons can scatter out of a reactor and therefore be lost is less well appreciated. Scattering can happen within fissile fuel or off of any number of the non-fissile structural components holding a reactor together. The scattering angular distributions for reactor material are the quantity that give the probability for a particle (usually a neutron) to scatter off a nucleus into a given angle. The Evaluated Nuclear Data File/B (ENDF/B) nuclear data library is the most complete and authoritative reference for neutron scattering data, containing reaction cross sections and outgoing particle distributions (including scattering angular distributions). In this project, we will compare the scattering angular distributions given in these ENDF/B data sets with those that can be derived using the Blatt-Biedenharn formalism and the resolved resonance data also in the ENDF/B files. More comparisons between the scattering angular distributions of relevant isotopes will help identify and correct any errors in the ENDF/B files. The results of this study will be an important component of the next major release of the ENDF/B library.

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