Angular distributions in ENDF/B-VIII.0

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Sodium void reactivity effect (SVRE)

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:

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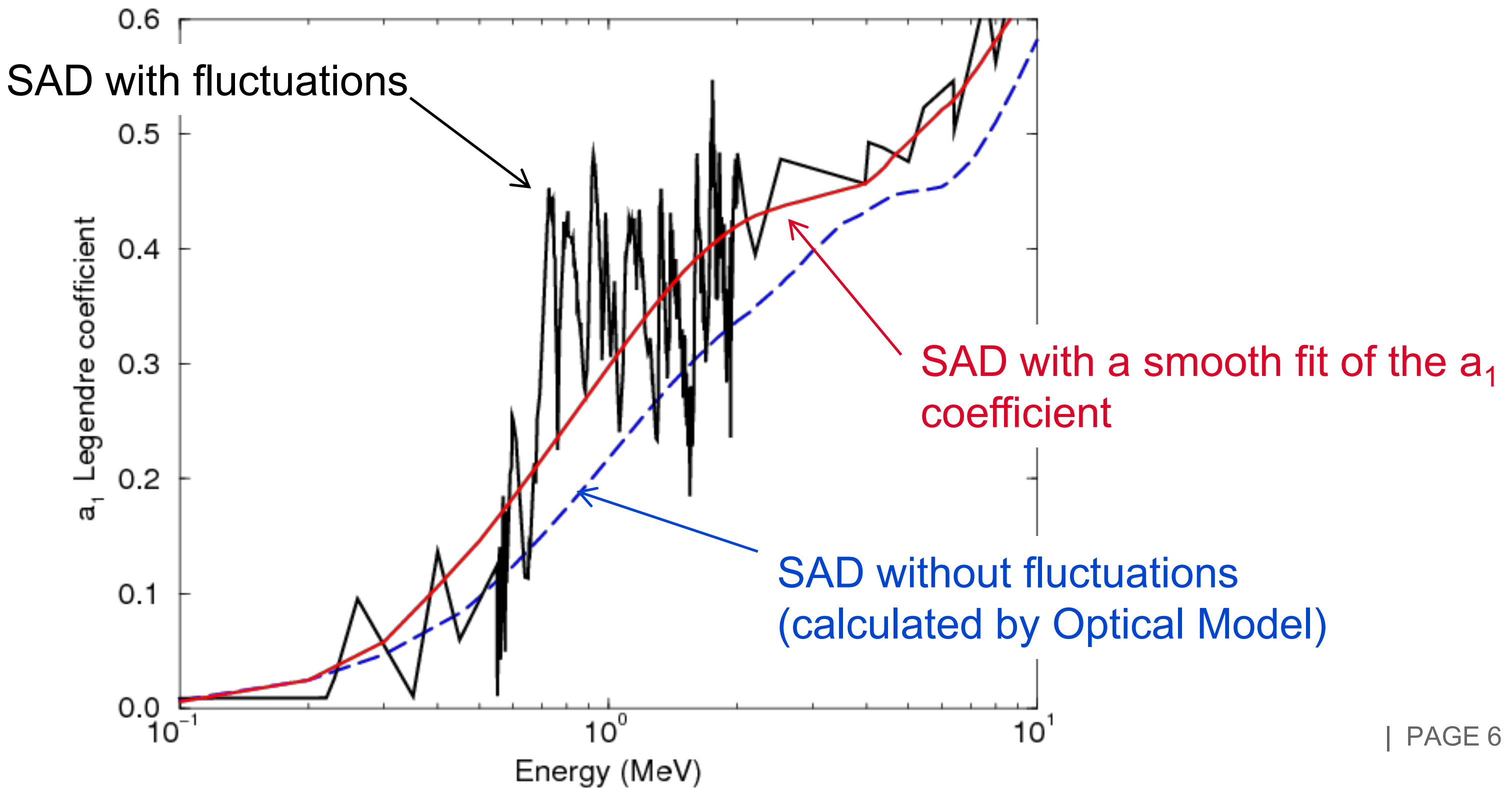

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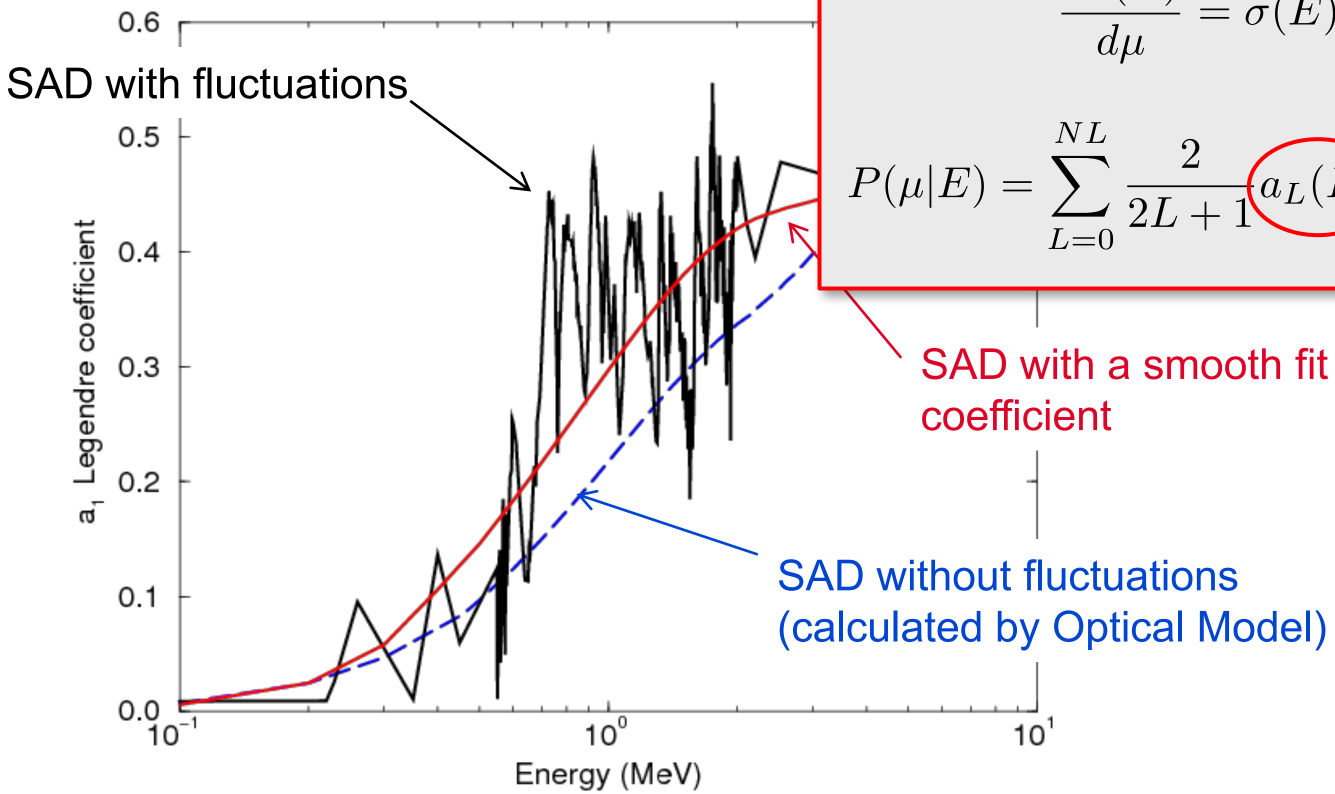
$$\frac{d\sigma(E)}{d\mu} = \sigma(E)P(\mu|E)$$

$$P(\mu|E) = \sum_{L=0}^{NL} \frac{2}{2L+1} a_L(E) P_L(\mu)$$



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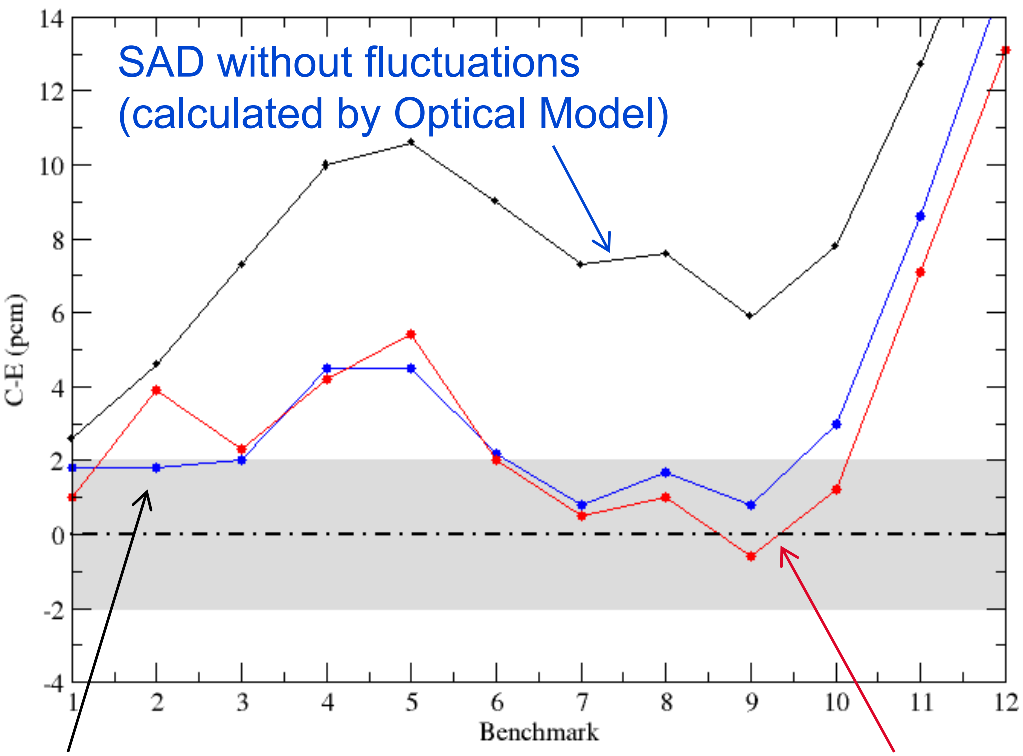
Sodium void reactivity effect (SVRE)

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

Significant improvement of the C-E results by using SAD calculated by optical model + fit of a_1



SAD with « fluctuations »

SAD with a smooth fit of the a_1 coefficient

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

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

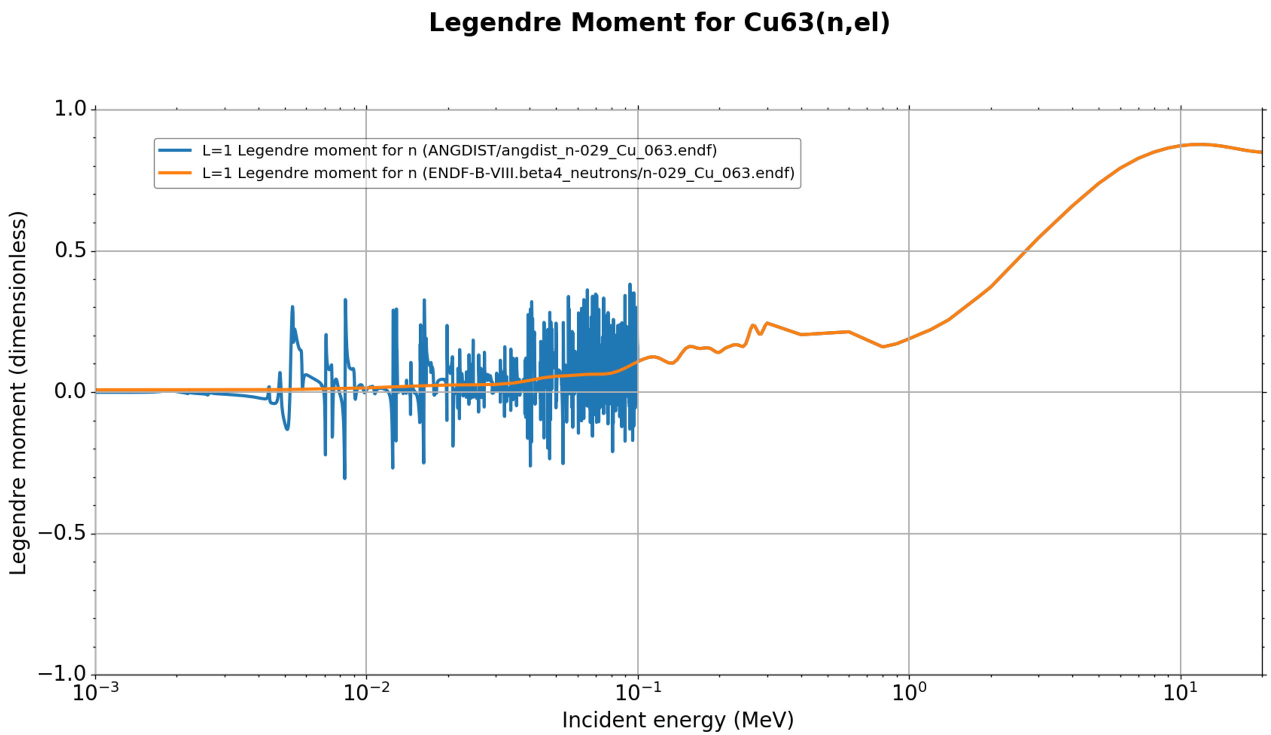
$$B_L(\underline{b}, \underline{a}; E_a) = \sum_{S_a, S_b} \frac{(-)^{S_b - S_a}}{4} \sum_{J\ell_a\ell_b} \sum_{J'\ell'_a\ell'_b} \bar{Z}(\ell_a J \ell'_a J'; S_a L) \bar{Z}(\ell_b J \ell'_b J'; S_b L) \Re \left[T^{J*}_{\{\underline{a};\ell_a S_a\}\to\{\underline{b};\ell_b S_b\}} T^{J'}_{\{\underline{a};\ell'_a S_a\}\to\{\underline{b};\ell'_b S_b\}} \right]. \tag{16}$$

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

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

- It's ugly, but well understood.
- Implemented in FUDGE, EMPIRE, CoH, SAMMY, AMPX, NJOY, ...

^{63}Cu (^{65}Cu is similar)



- 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

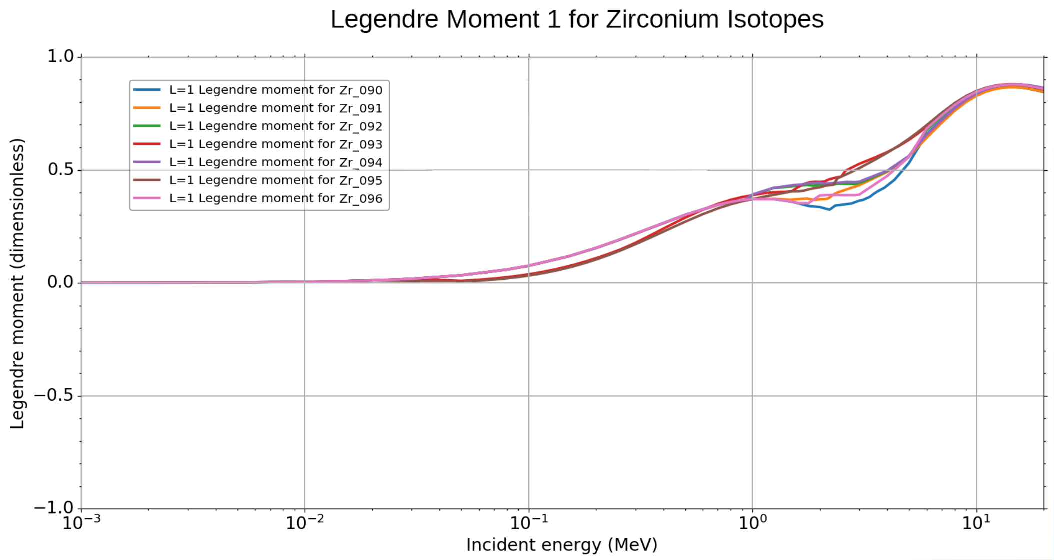
- BNL's High School Research Program
- Final report is huge, available upon request. Report number BNL-114446-2017-IR

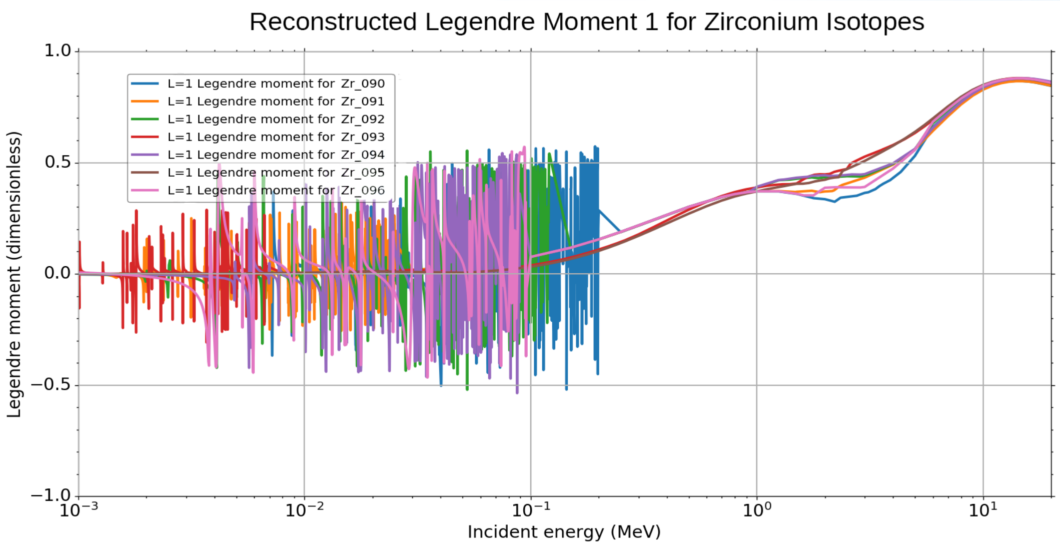
- ***The project:***
  - Test that energy average SAD approaches HF SAD
  - Check all SAD in ENDF/B-VIII.0 beta3

Demonstration that RRR angular distributions and HF angular distributions are consistent

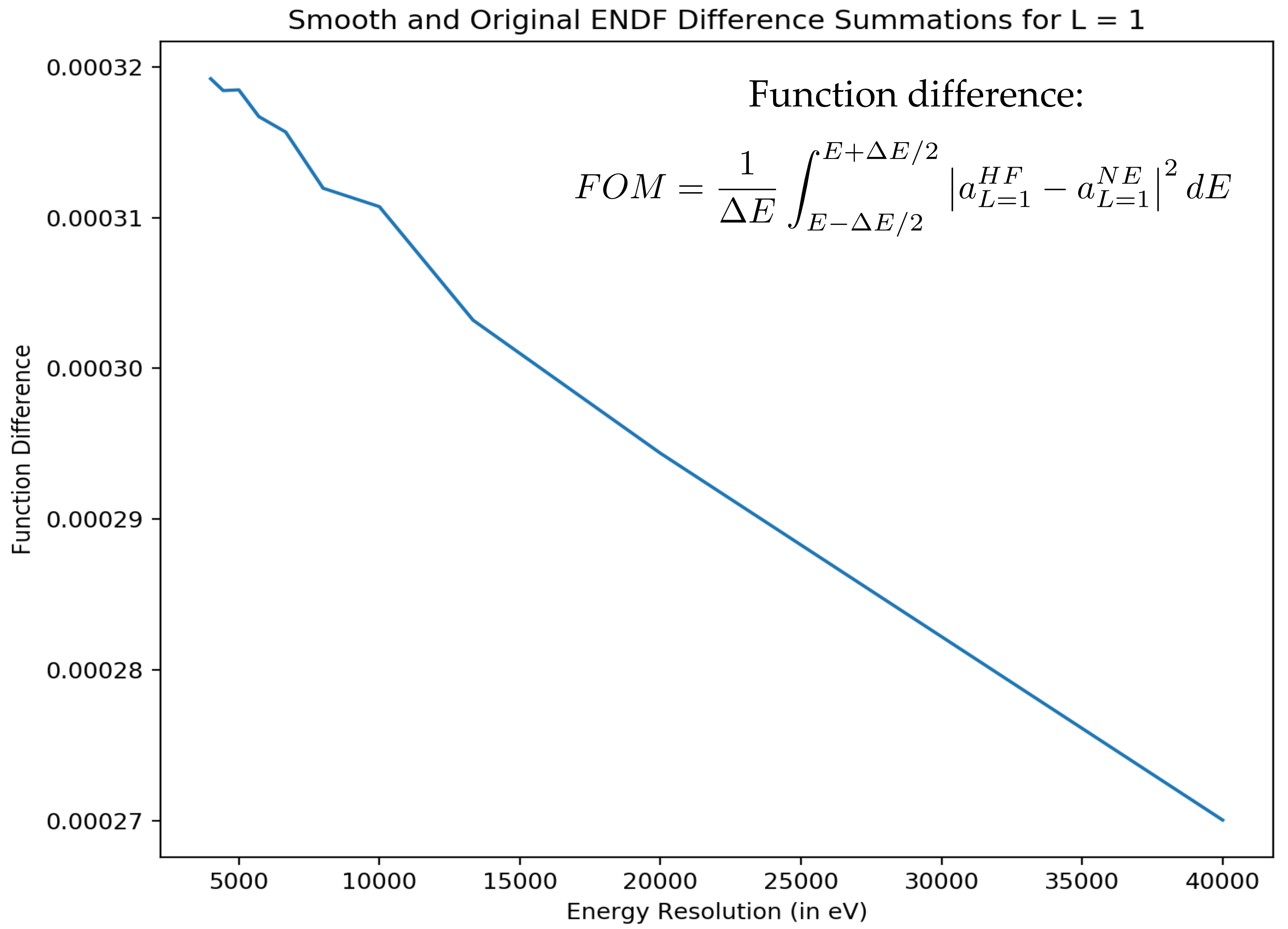
Zr isotopes are our testbed

- Evaluated for ENDF/B-VII.1 using EMPIRE
- Nearly spherical
- Fluctuations extend to high energy, but resonances well resolved
- Resonances given as MLBW



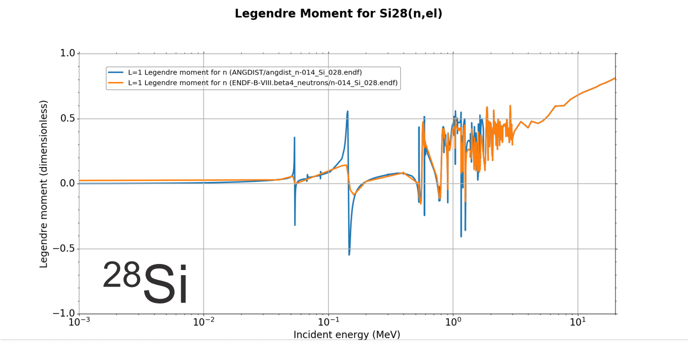


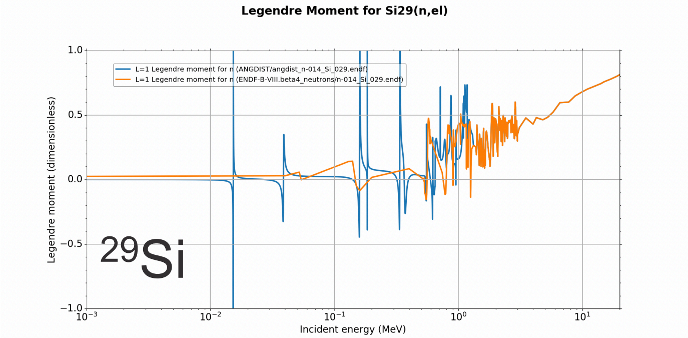
As smooth RRR SAD, it approaches HF SAD as expected

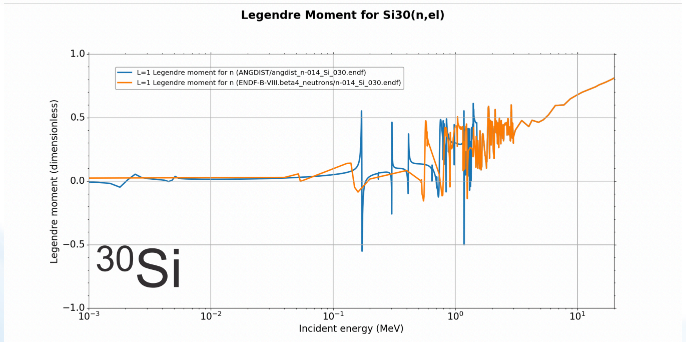


Issues encountered in full library scan (I will be adding trackers for each of these)

Anomaly in Si isotopes

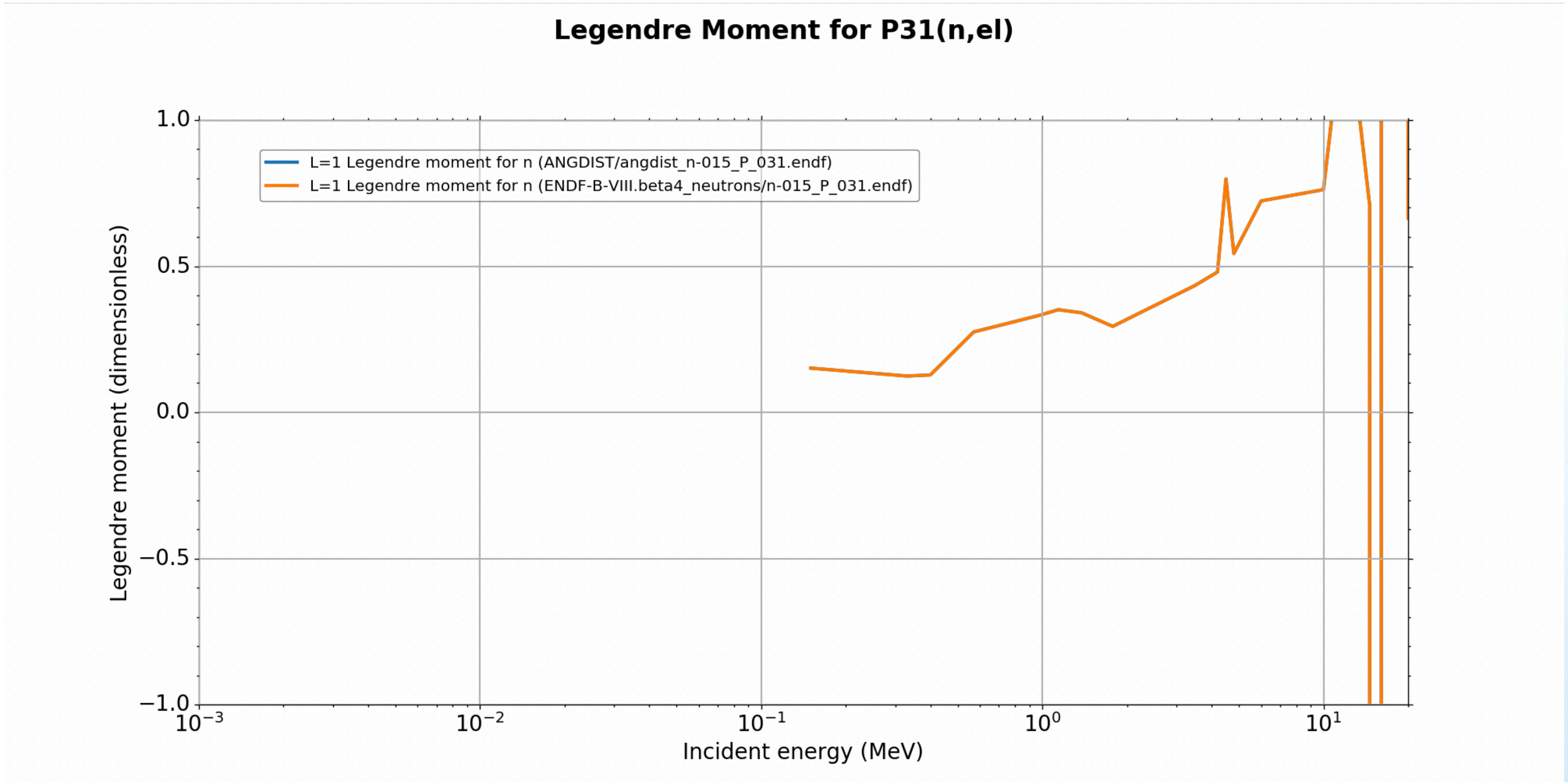






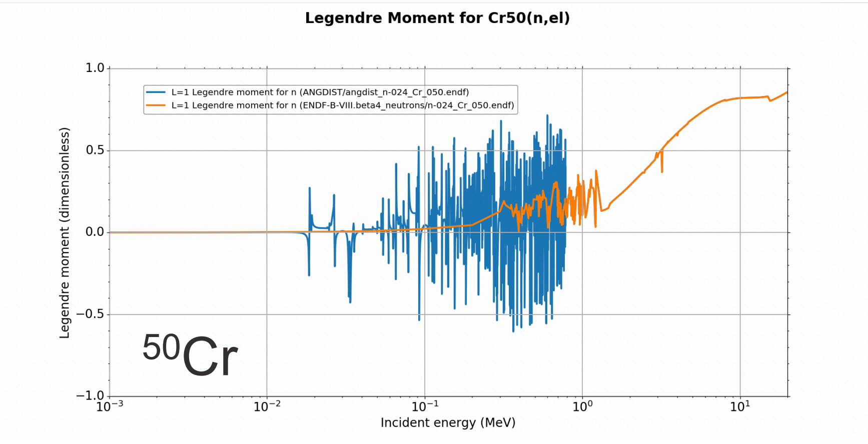
- All isotopes have same distribution, taken from ENDF/B-V ^{nat}Si
- Natural SAD built from isotopic SADs
- If SAD is smooth, is OK to replace isotopic with natural SADs
- THIS IS NOT THE CASE

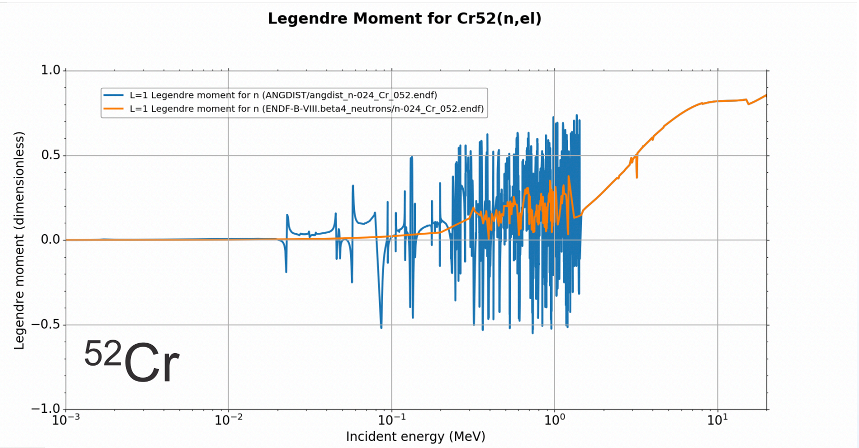
^{31}P looks odd, and it is our fault

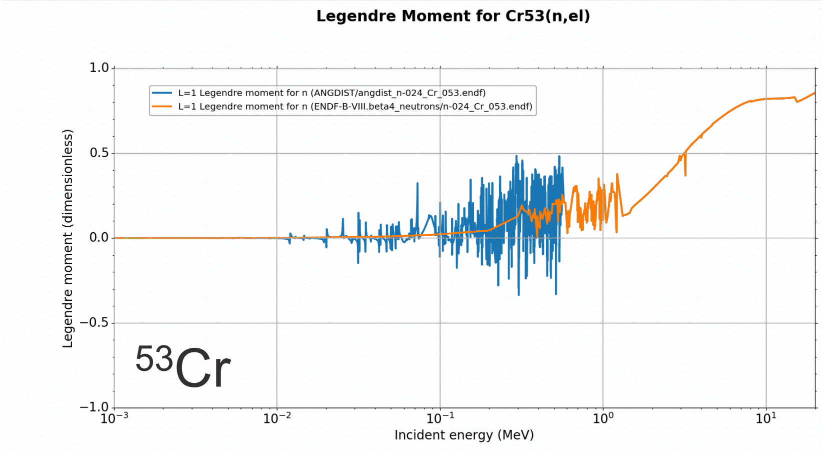


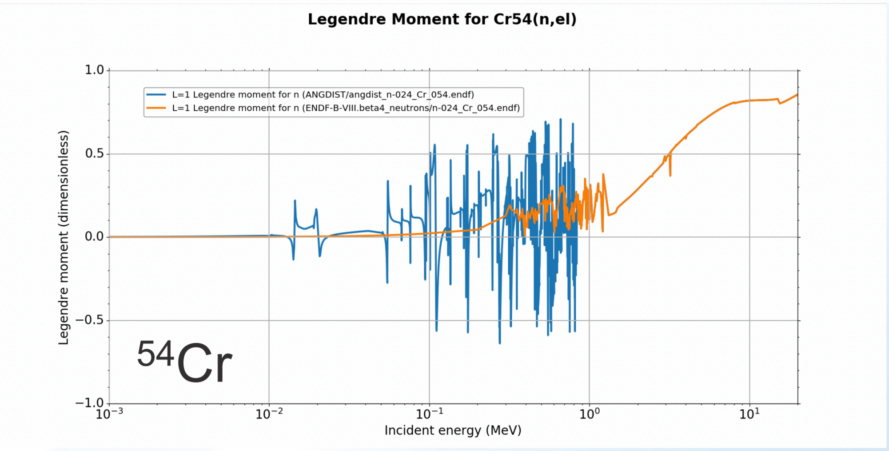
- Data given as pointwise & my Legendre fitter failed
- Need to investigate further

Anomaly in Cr isotopes



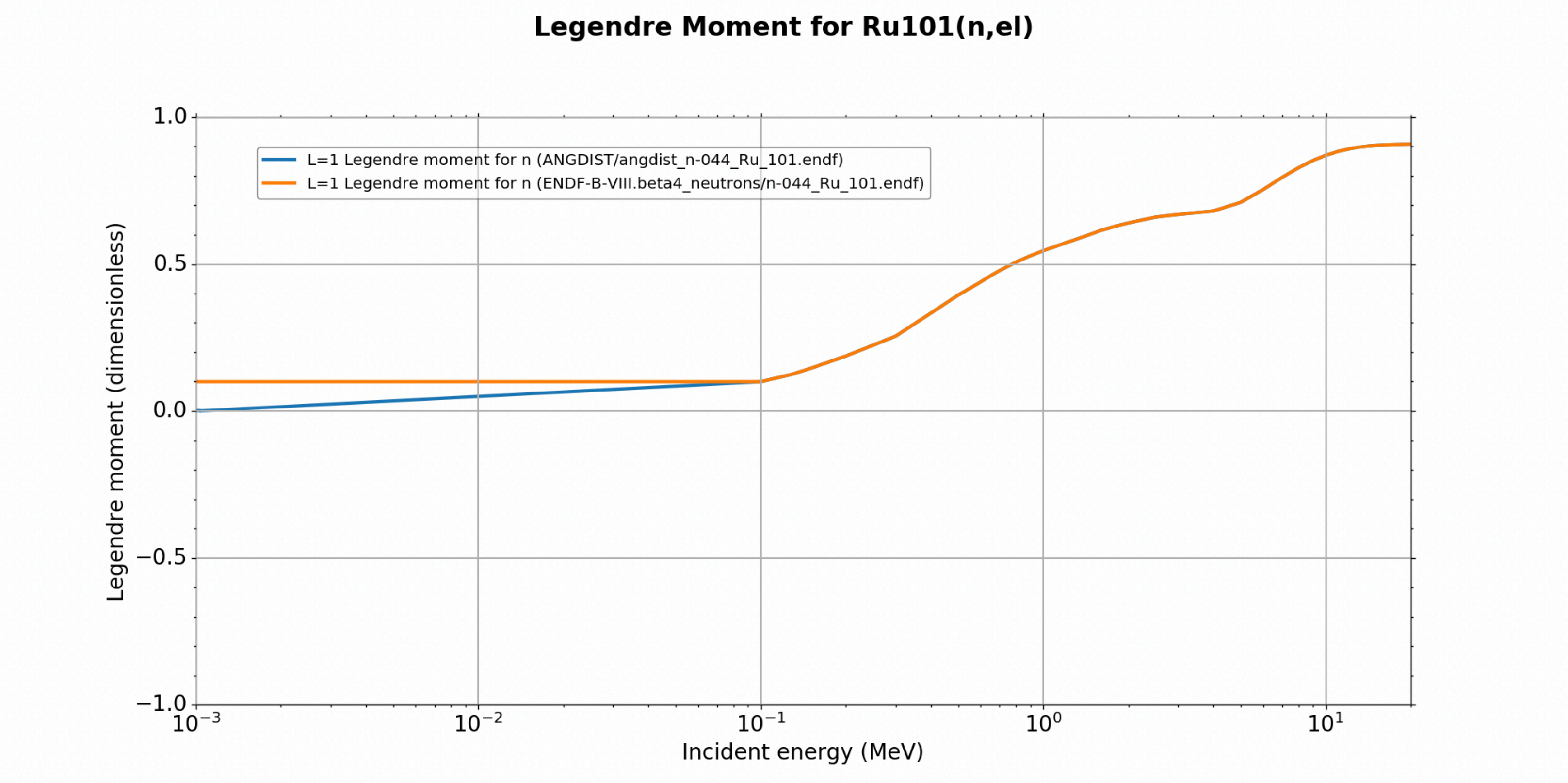






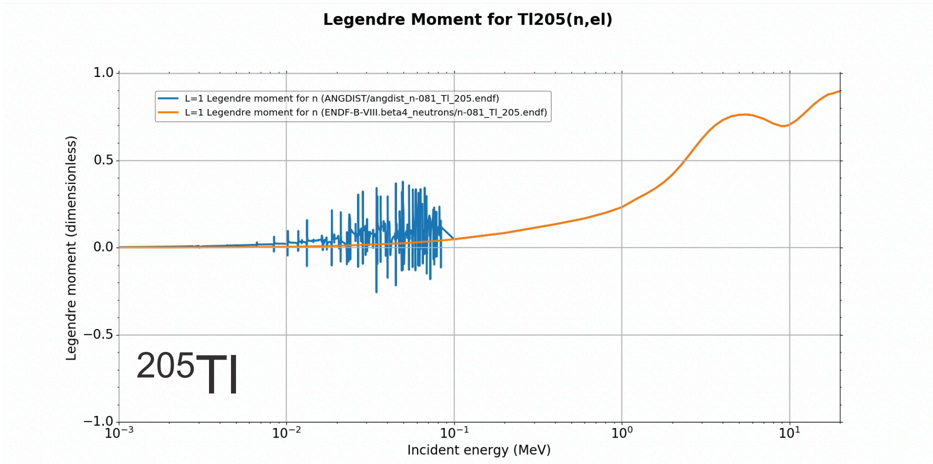
- Same issue as Si
- May be part of problem with steel assemblies

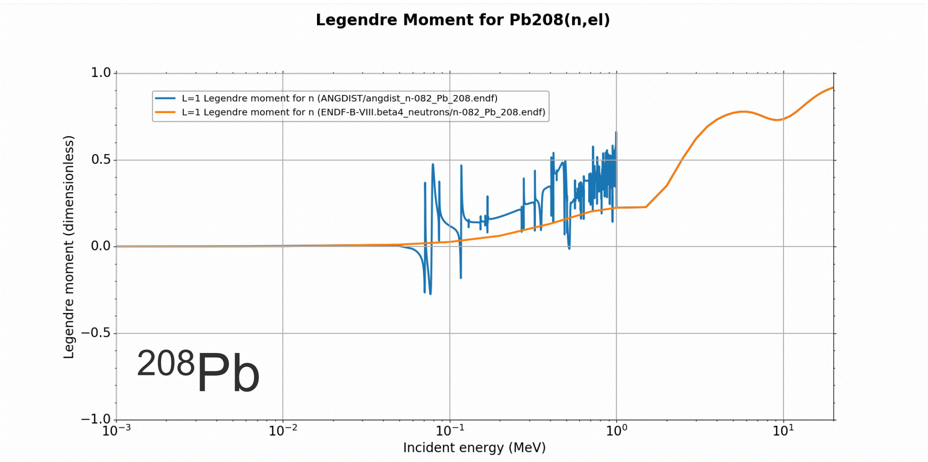
^{101}Ru, ^{105}Pd, ^{109}Ag, ^{108,110,116}Cd, 131Xe, ^{133}Cs, ^{141}Pr

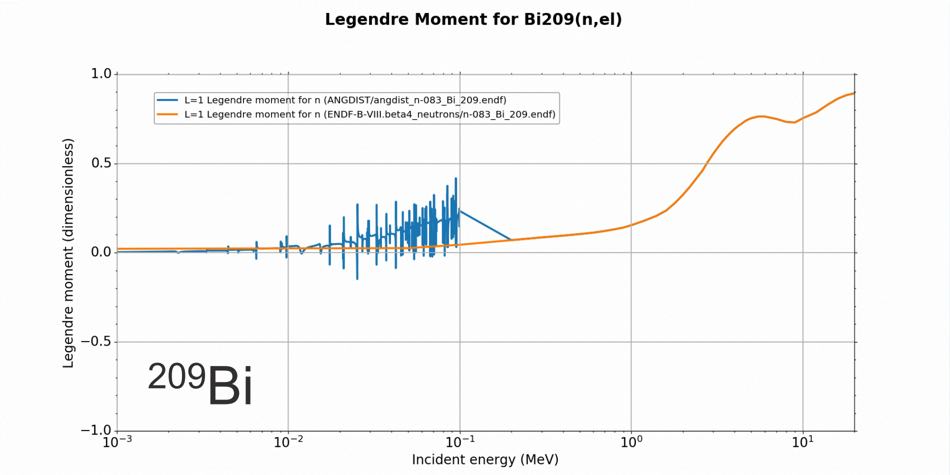


- Symmetry requires that, as $E \rightarrow 0$, $P_{L=0}(\mu) \rightarrow 0$
- Several isotopes violate this requirement

^{x}Tl, ^{x}Pb, ^{209}Bi







- 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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