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Estimation of Anisotropy from Total Cross Section and Optical Model

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Objectives

Approximation Method for Anisotropy in the Fast Energy Region

- Considering these situmations
  - high resolution total cross section data $\sigma_T(E)$ available
  - but resonance parameters are not
- Is it possible to extract (or esimate) P_1 from $\sigma_T(E)$?

Here we assume:

- s and p-waves are mostly contributing
- capture cross section is small
- p-waves have narrow resonances, and their scattering matrix elements fluctuate
- gross structure seen in σ_T is due to large s-wave resonances
- we want to know some averaged properties in $P_1 = B_1/B_0$

$$\frac{d\sigma}{d\Omega} = \sum_L \frac{2L+1}{4\pi} B_L P_L(\cos\theta)$$

Elastic Scattering Angular Distribution

Blatt-Biedenharn Formula

The Legendre coefficient is given by

$$B_L = \frac{\pi}{k^2} \frac{1}{(2i+1)(2I+1)(2L+1)} \sum Z^2 \mathrm{Re}\left\{(1 - S_{l_1 j_1})(1 - S_{l_2 j_2})^*\right\}$$

Blatt-Biedenharn Z-coefficient

$$Z(l_1 j_1 l_2 j_2; sL) = \hat{l}_1 \hat{l}_2 \hat{j}_1 \hat{j}_2 \langle l_1 l_2 00; sL \rangle W(l_1 j_1 l_2 j_2; sL)$$

In many cases $Z = 0$, so that a few terms remain in the summation.

$L = 0$

l_1	j_1	l_2	j_2	Z^2
0	1/2	0	1/2	2
1	1/2	1	1/2	2
1	3/2	1	3/2	4

$L = 1$

l_1	j_1	l_2	j_2	Z^2
0	1/2	1	1/2	2
0	1/2	1	3/2	4
1	1/2	0	1/2	2
1	3/2	0	3/2	4

Approximation to L=0 Term

Since $S_0 \gg S_1$,

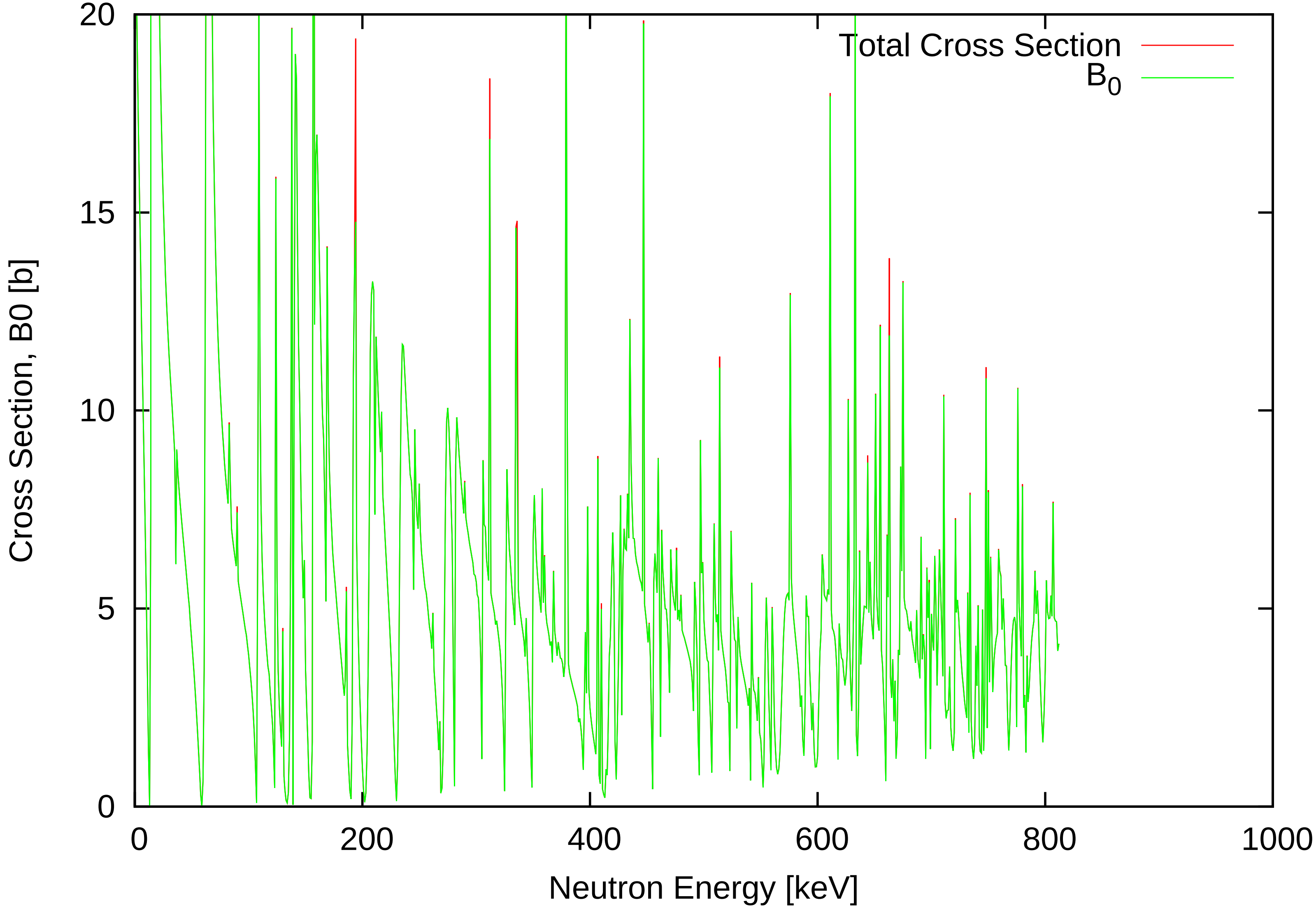
$$\begin{aligned}
B_0 &\simeq 2\Re\left\{(1-S_0^{(1/2)})^*(1-S_0^{(1/2)})\right\} \\
&+ 2\Re\left\{(1-S_1^{(1/2)})^*(1-S_1^{(1/2)})\right\} \\
&+ 4\Re\left\{(1-S_1^{(3/2)})^*(1-S_1^{(3/2)})\right\} \\
&+ \ldots \\
&\approx 2\Re\left\{(1-S_0^{(1/2)})^*(1-S_0^{(1/2)})\right\} \\
&= 2(1-\Re S_0^{(1/2)})
\end{aligned}$$

Total Cross Section

$$\sigma_T = \frac{\pi}{k^2}\sum_{lj}\frac{2j+1}{(2s+1)(2I+1)}(2j+1)2(1-\Re S_l^{(j)})$$

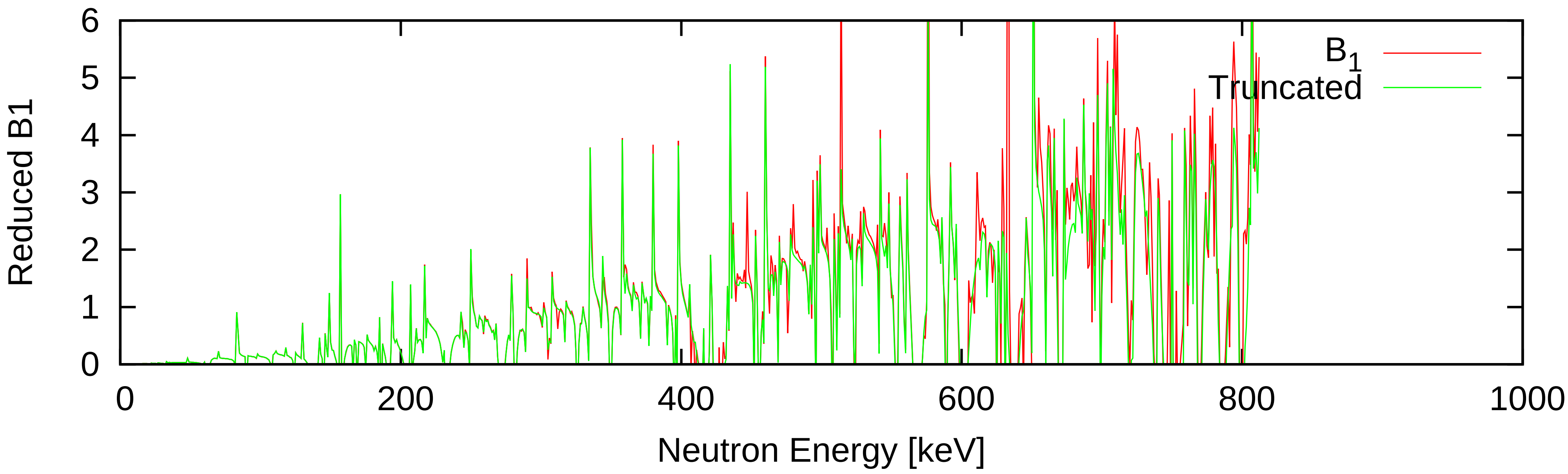
Total Cross Section and B(L=0) Term

Cross Section From Ni58 Resonance Parameters



Approximation to L=1 Term

$$B_1 \simeq \frac{4}{3}\Re\left\{(1 - S_0^{(1/2)})^*(1 - S_1^{(1/2)})\right\} + \frac{8}{3}\Re\left\{(1 - S_0^{(1/2)})^*(1 - S_1^{(3/2)})\right\} + \dots$$



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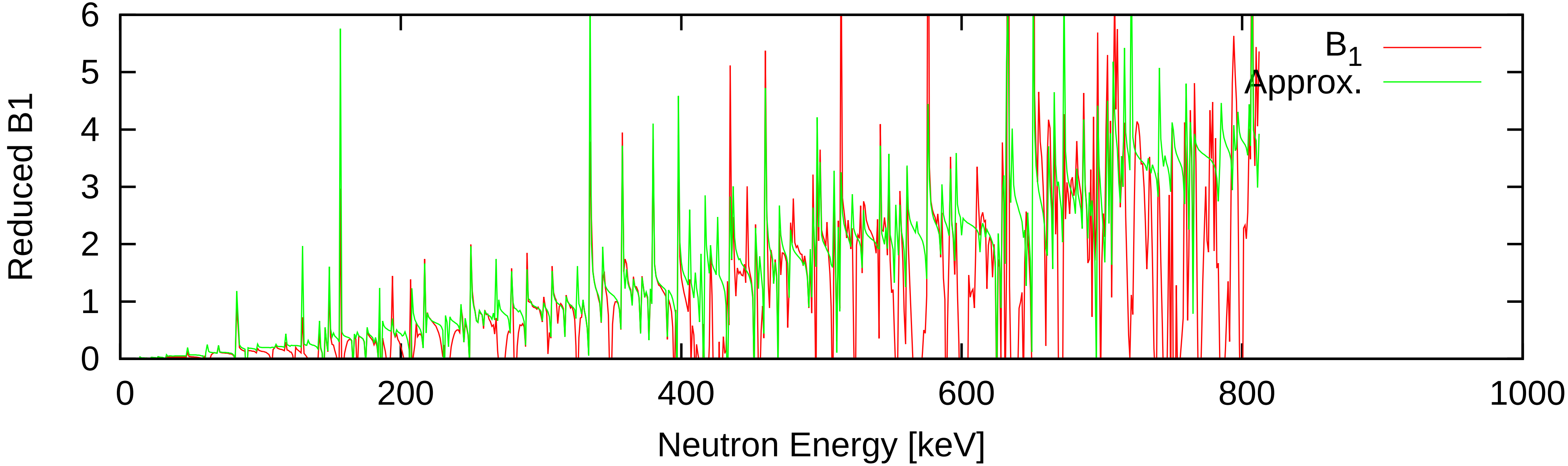
Approximation to L=1 Term, Cont'd

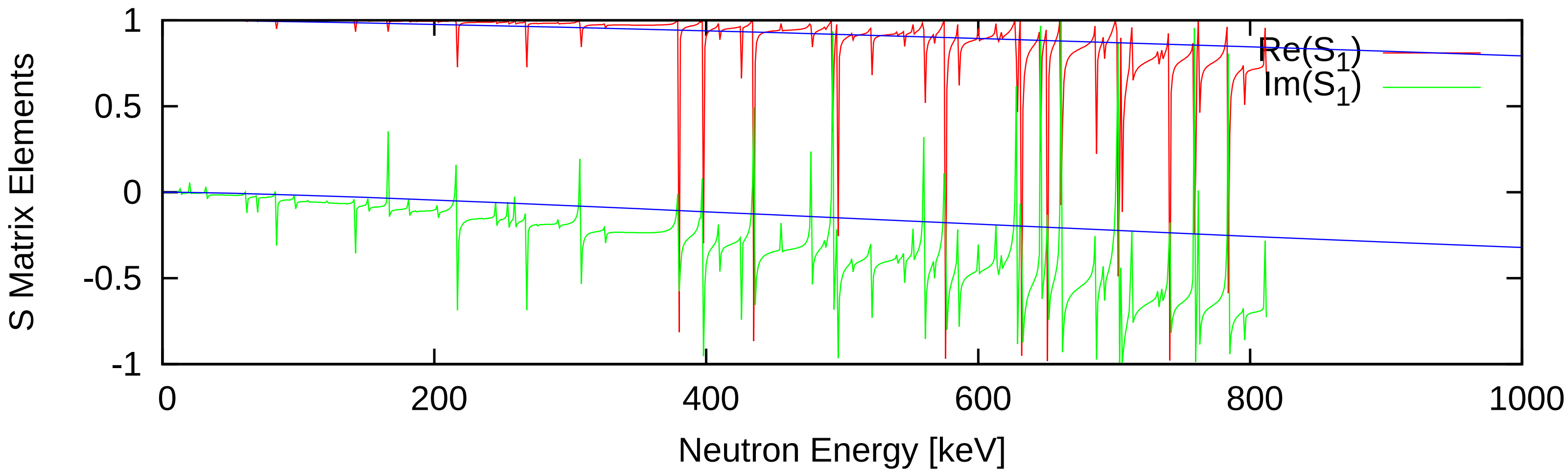
Because $\Re S_0$ fluctuates a lot, and $\langle \Im S_0 \rangle \simeq -1$,

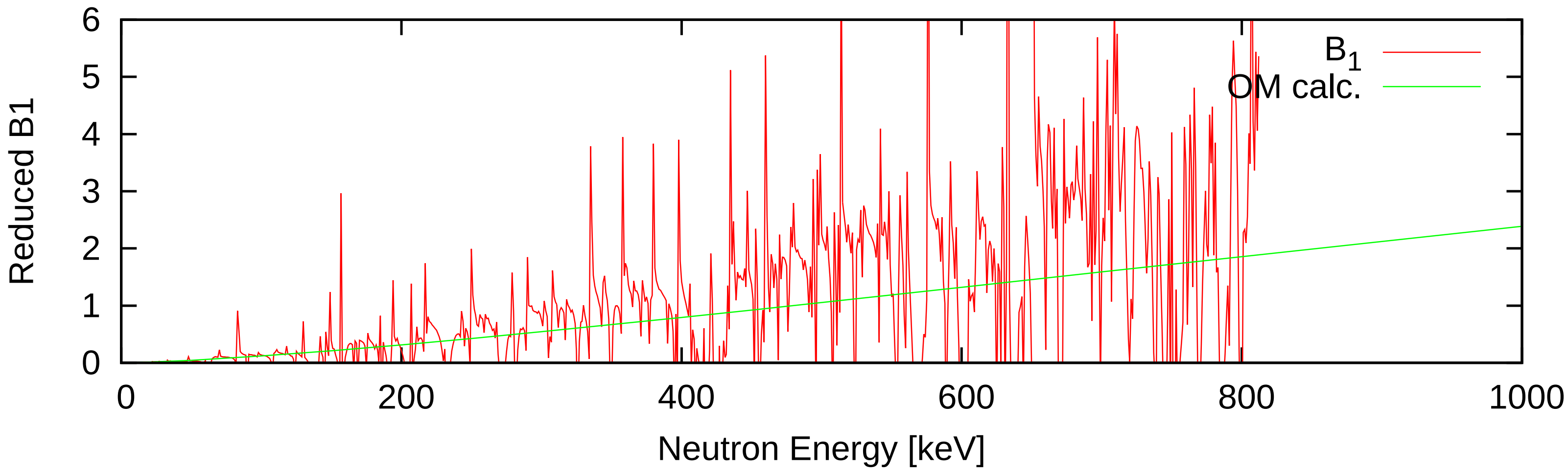
$$B_1 \approx \frac{4}{3}\left\{1 - \Re S_1^{(1/2)} - \Im S_1^{(1/2)}\right\} + \frac{8}{3}\left\{1 - \Re S_1^{(3/2)} - \Im S_1^{(3/2)}\right\}$$



Energy Average and Replace by Optical Model

$$\langle B_1 \rangle \approx \frac{4}{3}\left\{1 - \left\langle \Re S_1^{(1/2)} \right\rangle - \left\langle \Im S_1^{(1/2)} \right\rangle \right\} + \frac{8}{3}\left\{1 - \left\langle \Re S_1^{(3/2)} \right\rangle - \left\langle \Im S_1^{(3/2)} \right\rangle \right\}$$





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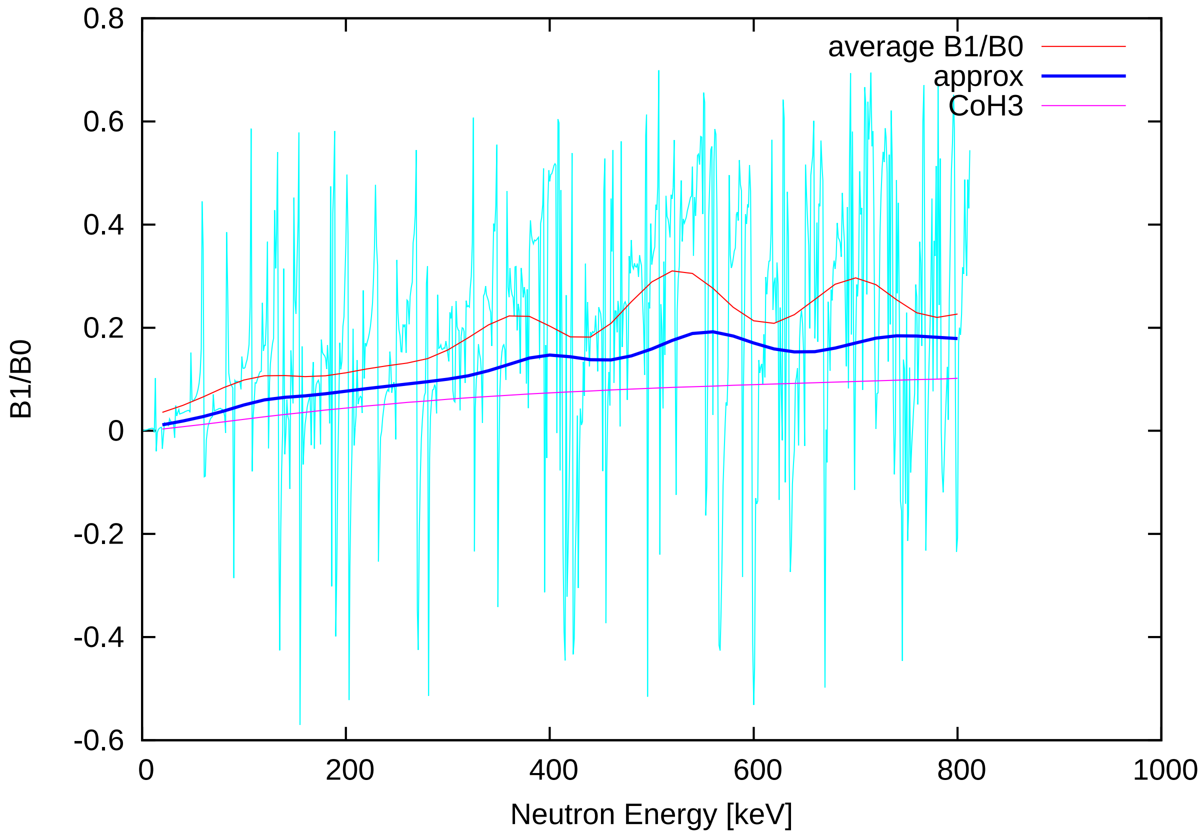
Result and Comparison with Optical Model

$$P_1 \approx \frac{2\pi}{k^2 3(2I+1)\sigma_T} \frac{4}{3} \left\{ 3 - (\Re S_1^{(1/2)} + \Im S_1^{(1/2)}) - 2(\Re S_1^{(3/2)} + \Im S_1^{(3/2)}) \right\}$$

where S's are evaluated by the optical model.



Related Activities

Theory / Evaluation

- IAEA report: “Inelastic Scattering and Capture Cross-Section Data of Major Actiides in the Fast Neutron Region,” A. Plompen, T. Kawano, and R. Capote Noy, IAEA report INDC(NDS)-0597 (2012)
- some model calculations for ^{238}U by R. Capote at ND2013
- new width fluctuation model by T. Kawano at ND2013
- criticality benchmark calculation for new nickel data
  - energy-smoothed $P_1 \sim P_4$ generated from resonance parameters

Experiments

- new scattering data for ^{23}Na from U. Kentucky, data available?

SG Report Plan

Any Definite Conclusions?

- We understand importance of scattering angular distribution
- Relatively large sensitivities to k_{eff}
- Evaluations for structural materials
  - reduce P_l from resonance parameters recommended
  - probably fine structure is not so crucial
  - use NJOY2012 as a future option
- New experimental data and analysis available for better evaluations

Structure

- Overview - Kawano
- Evaluation - Na: Plompen, Fe: Leal, Ni: Kawano, Zr: Brown, Capote ?
- Experiments - Plompen, Danon, Hill ?
- Integral benchmarks - Noguere, Ishikawa, Chiba, Trkov?
- Conclusion - Kawano