Future CIELO Activities

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BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

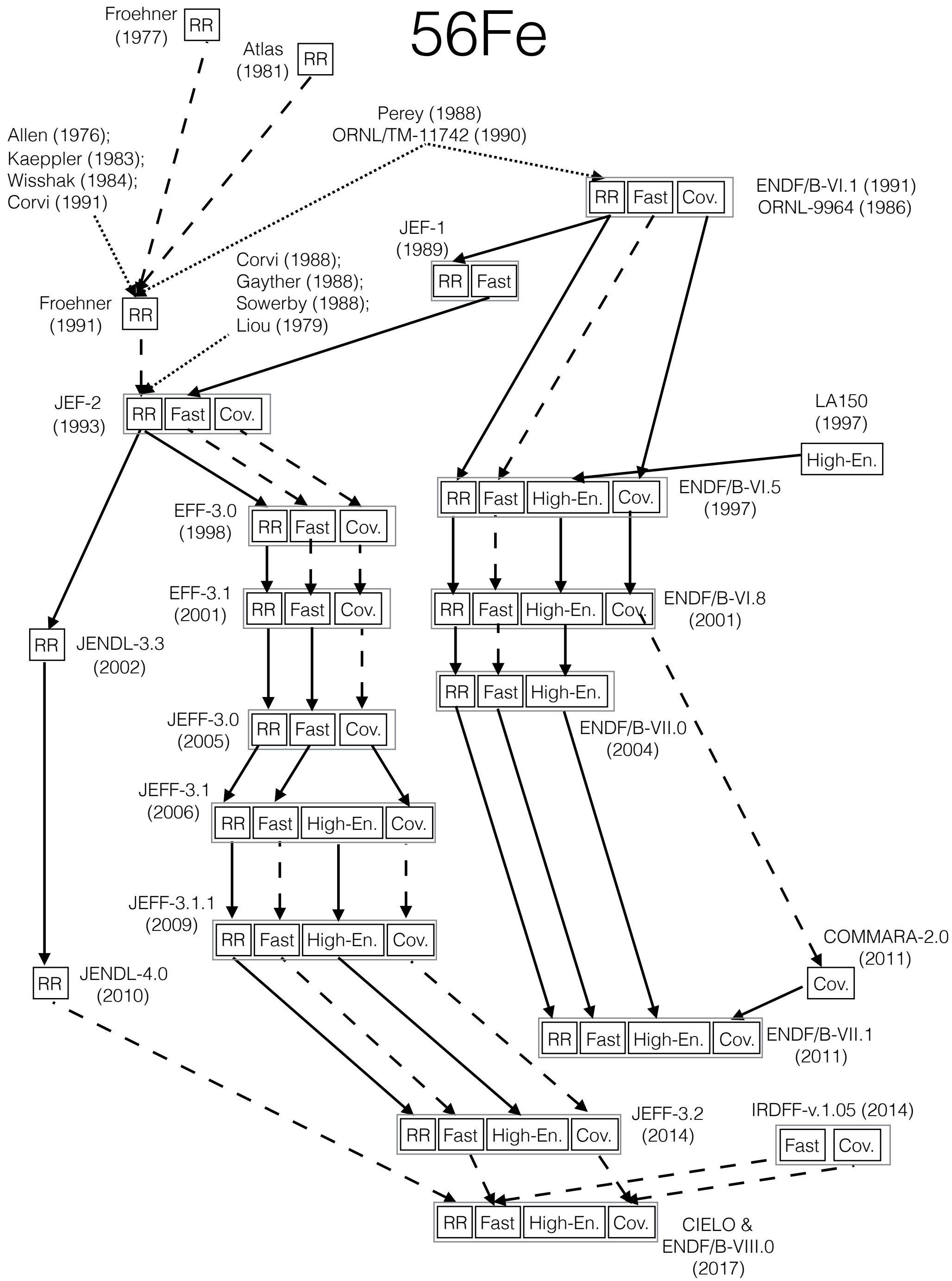
U.S. DEPARTMENT OF ENERGY | Office of Science

We are interested in **fluctuations** (esp. near closed shell nuclei like Fe) and **improved direct reaction modeling** (esp. for (in)elastic cross sections)

Unfinished business: CIELO Fe

Our CIELO Fe evaluation was very much driven by data, and respected previous excellent evaluations

56Fe



Thousands of datasets, we could not get through it all. Used history to guide us.

Unfinished business: CIELO Fe

- **Better Resonances**
  - LRF=7 option for ^{56}Fe
  - The low energy background (from 10 to 100 keV) in ^{56}Fe capture
  - EGAF thermal capture cross section for ^{56}Fe
  - Elastic angular distribution on ^{56}Fe
- **Fusion cross section between elastic and inelastic in the energy range from 4 to 8 MeV**
- **Minor Fe covariances, esp. in RRR**
- **Other steel constituents (Cr, Ni)**

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LRF=7 resonances needed

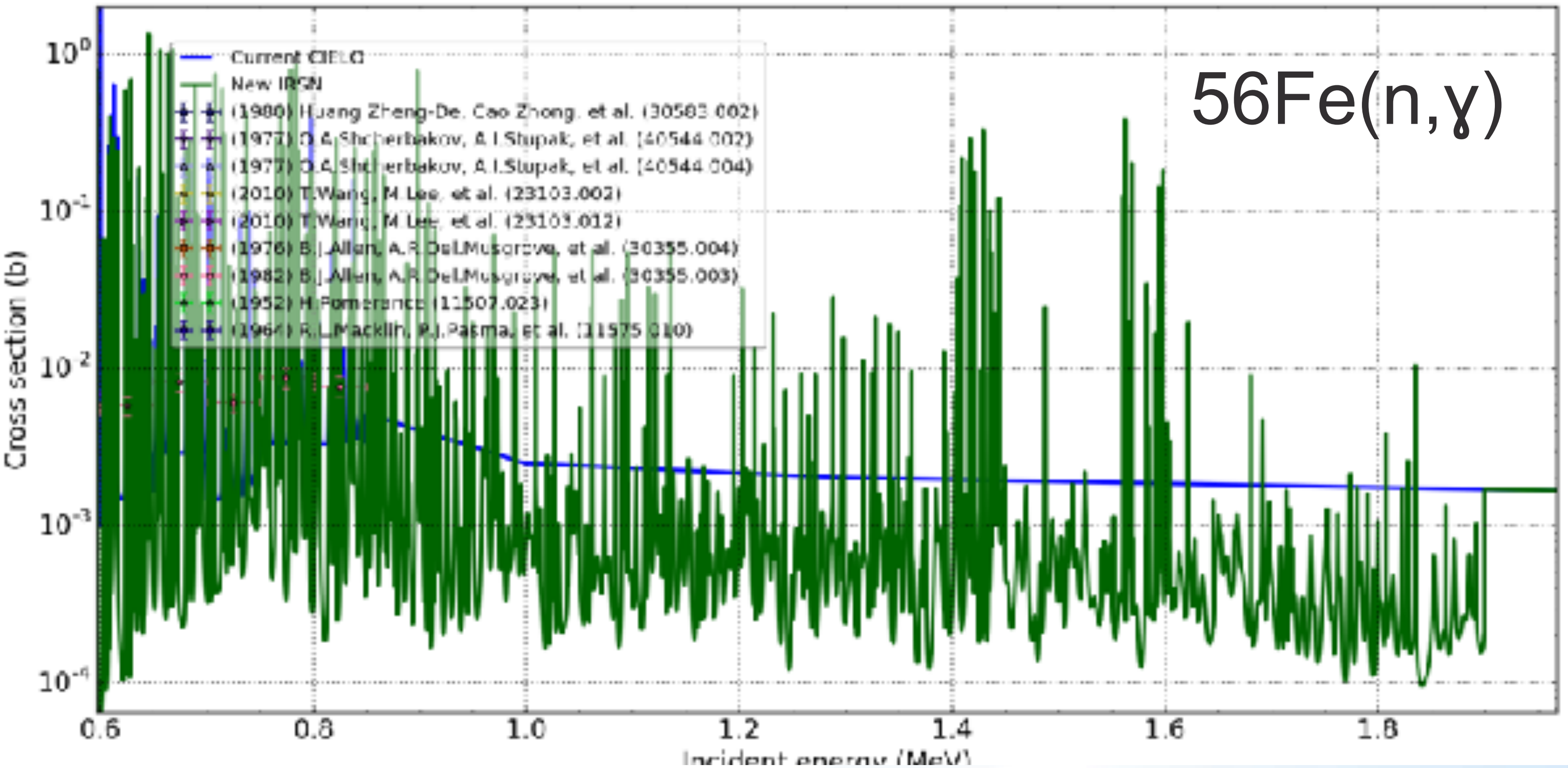
Legacy RRR evaluations (Froehner's and hence JENDL-4.0, Atlas and ours) use LRF=3 format.

LRF=3 format uses Reich-Moore approximation, but channels limited to capture, elastic and fission

First and second excited states show fluctuations: we need resonance treatment

Angular distributions can be computed from RRR data, if they are trustworthy

IRSN ^{56}Fe RRR evaluation appeared like attractive option



- Higher energy, up to 2nd excited state threshold
- Many more resonances

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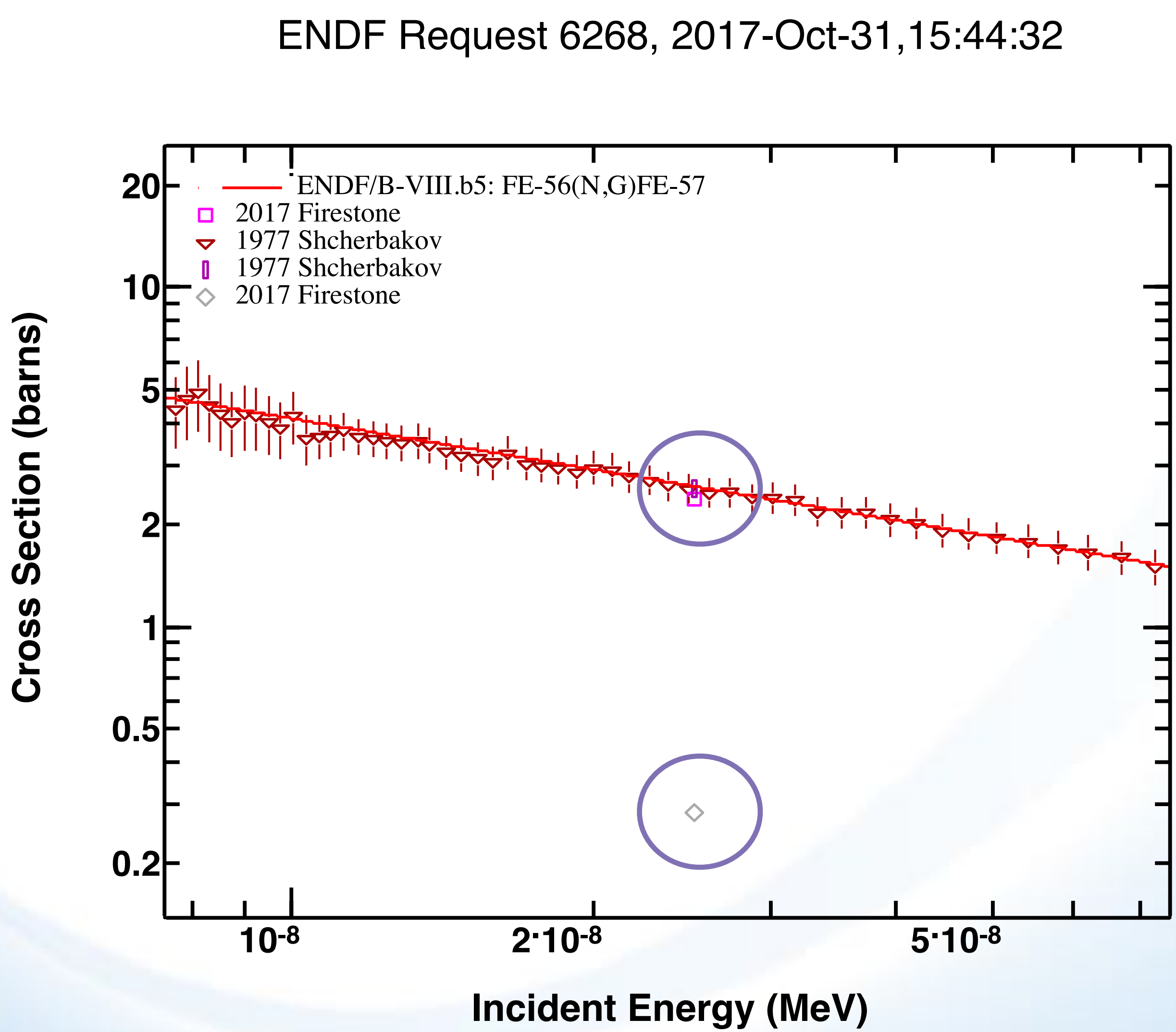
IRSN ^{56}Fe RRR evaluation appeared like attractive option

Gripes about IRSN evaluation:

- Resonances shifted from Atlas, ours, & J4.0 (aggressive use of ToF correction)
- Not using all available data, focusing only on ORNL measurements
- Poor reproduction of MT51 (resonance J^{Π} assignments?)
- Poor reproduction of angular distributions (resonance J^{Π} assignments?)
- Missing capture resonances
- PI focused on other things, not very responsive

- Many more resonances

Firestone's thermal capture (EGAF)



Which is it? Why? is it a 15% correction, or something worse?

Cross Section (barns)

PHYSICAL REVIEW C **95**, 014328 (2017)

Thermal neutron capture cross section for ^{56}Fe(n,γ)

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[2]*Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA*

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[4]*Charles University in Prague, Faculty of Mathematics and Physics, V. Holešovičkách 2, CZ-180 00 Prague 8, Czech Republic*

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The ^{56}Fe(n,γ) thermal neutron capture cross section and the ^{57}Fe level scheme populated by this reaction have been investigated in this work. Singles γ-ray spectra were measured with an isotopically enriched ^{56}Fe target using the guided cold neutron beam at the Budapest Reactor, and $\gamma\gamma$-coincidence data were measured with a natural Fe target at the LWR-15 research reactor in Řež, Czech Republic. A detailed level scheme consisting of 448 γ rays populating/depopulating 97 levels and the capture state in ^{57}Fe has been constructed, and ≈99% of the total transition intensity has been placed. The transition probability of the 352-keV γ ray was determined to be $P_\gamma(352) = 11.90 \pm 0.07$ per 100 neutron captures. The ^{57}Fe level scheme is substantially revised from earlier work and ≈33 previously assigned levels could not be confirmed while a comparable number of new levels were added. The ^{57}Fe γ-ray cross sections were internally calibrated with respect to ^{1}H and ^{32}S γ-ray cross section standards using iron(III) acetylacetonate ($C_{15}H_{21}FeO_6$) and iron pyrite (FeS_2) targets. The thermal neutron cross section for production of the 352-keV γ-ray cross section was determined to be $\sigma_\gamma(352) = 0.2849 \pm 0.015$ b. The total ^{56}Fe(n,γ) thermal radiative neutron cross section is derived from the 352-keV γ-ray cross section and transition probability as $\sigma_0 = 2.394 \pm 0.019$ b. A least-squares fit of the γ rays to the level scheme gives the ^{57}Fe neutron separation energy $S_n = 7646.183 \pm 0.018$ keV.

DOI: 10.1103/PhysRevC.95.014328

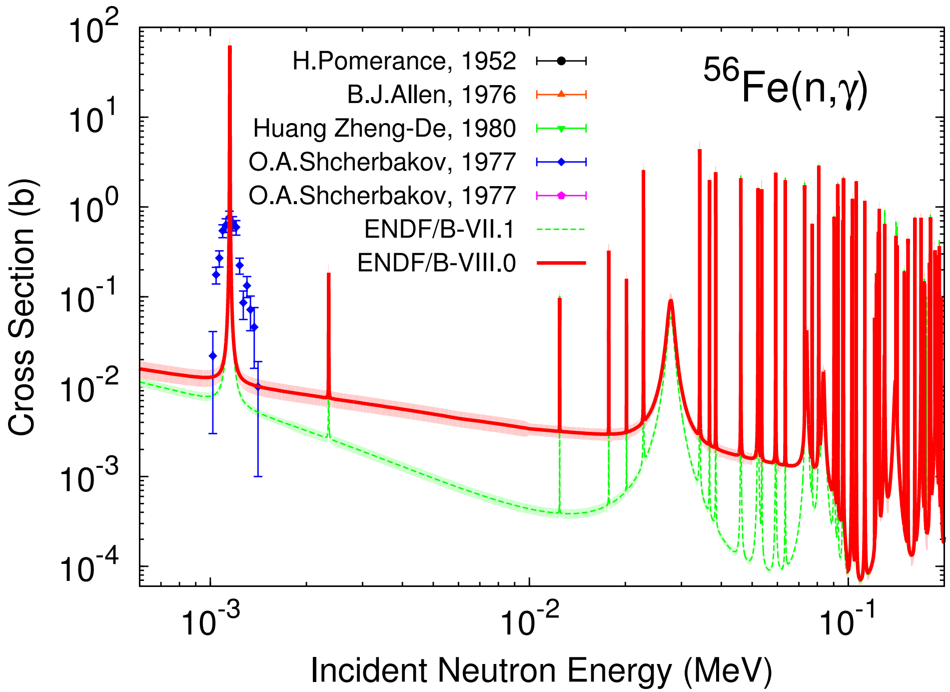
I. INTRODUCTION

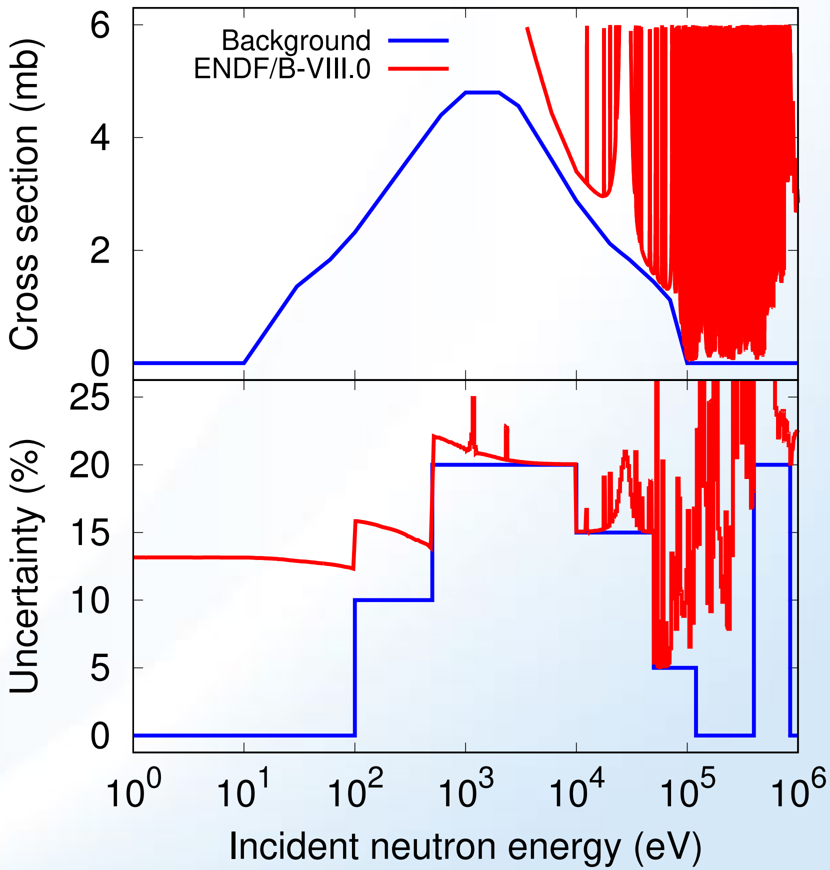
Precise thermal neutron capture γ-ray spectra were measured for all elements with $Z = 1$–83, 90, and 92, except for He and Pm, using neutron beams at the Budapest Reactor [1,2]. The γ-ray energies and cross sections were determined and combined, together with additional information from the literature, to generate the Evaluated Gamma-ray Activation File (EGAF) [3] and they were also published in the *Handbook of Prompt Gamma Activation Analysis with Neutron Beams*

of the total radiative thermal neutron cross section accurate to ≈0.8%.

The ^{56}Fe(n,γ) reaction was previously studied by Vennink *et al.* [6], who placed 191 γ rays that populated/depopulated 62 levels in ^{57}Fe. Levels and γ rays were assigned by Vennink *et al.* on the basis of γ-ray energy sums but without the aid of $\gamma\gamma$ coincidence data. That procedure can be unreliable due to a high probability of chance energy sums matching known level energies resulting from the complexity of the (n,γ) spectrum.

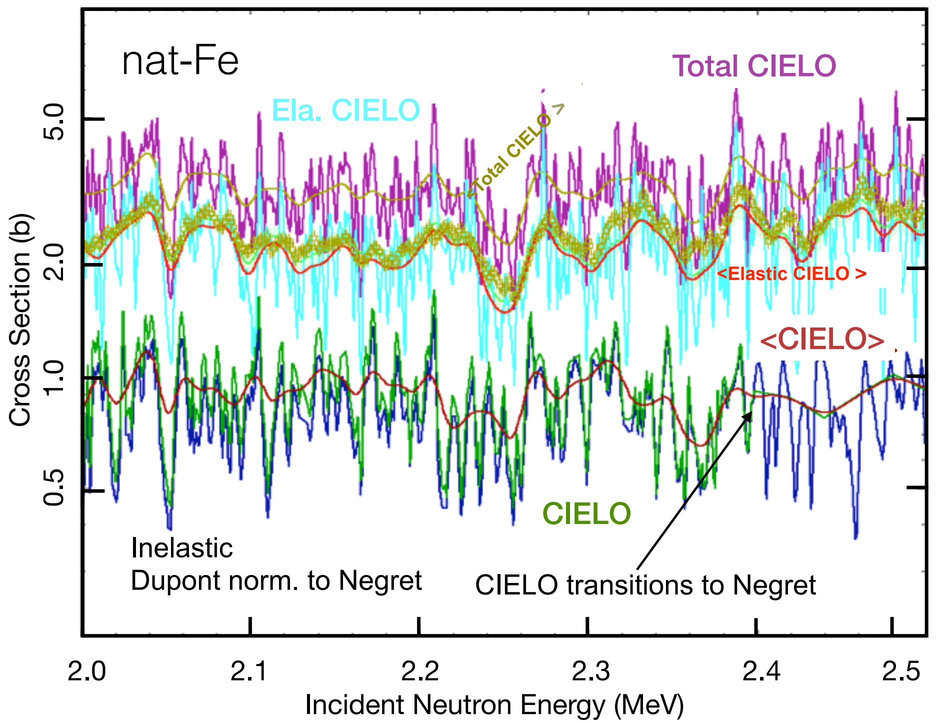
A background was added to ^{56}Fe capture, we want to get rid of it

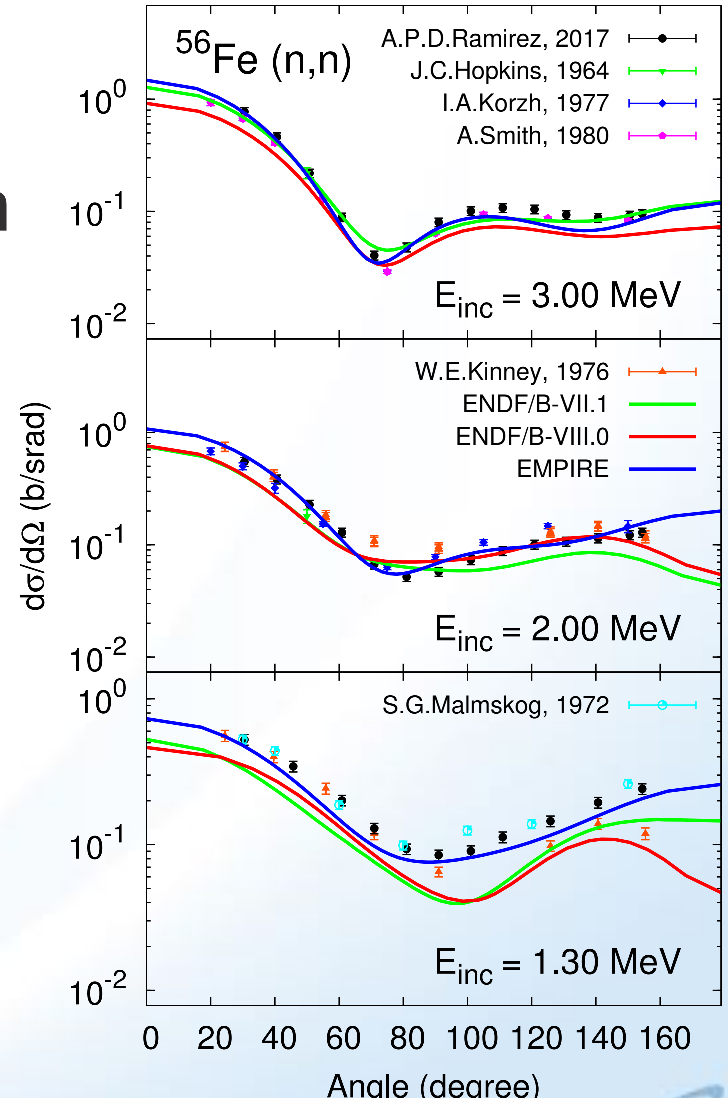




Must improve angular distributions

High resolution Cierjacks data not used, data from Ramirez et al. came out after evaluation finished





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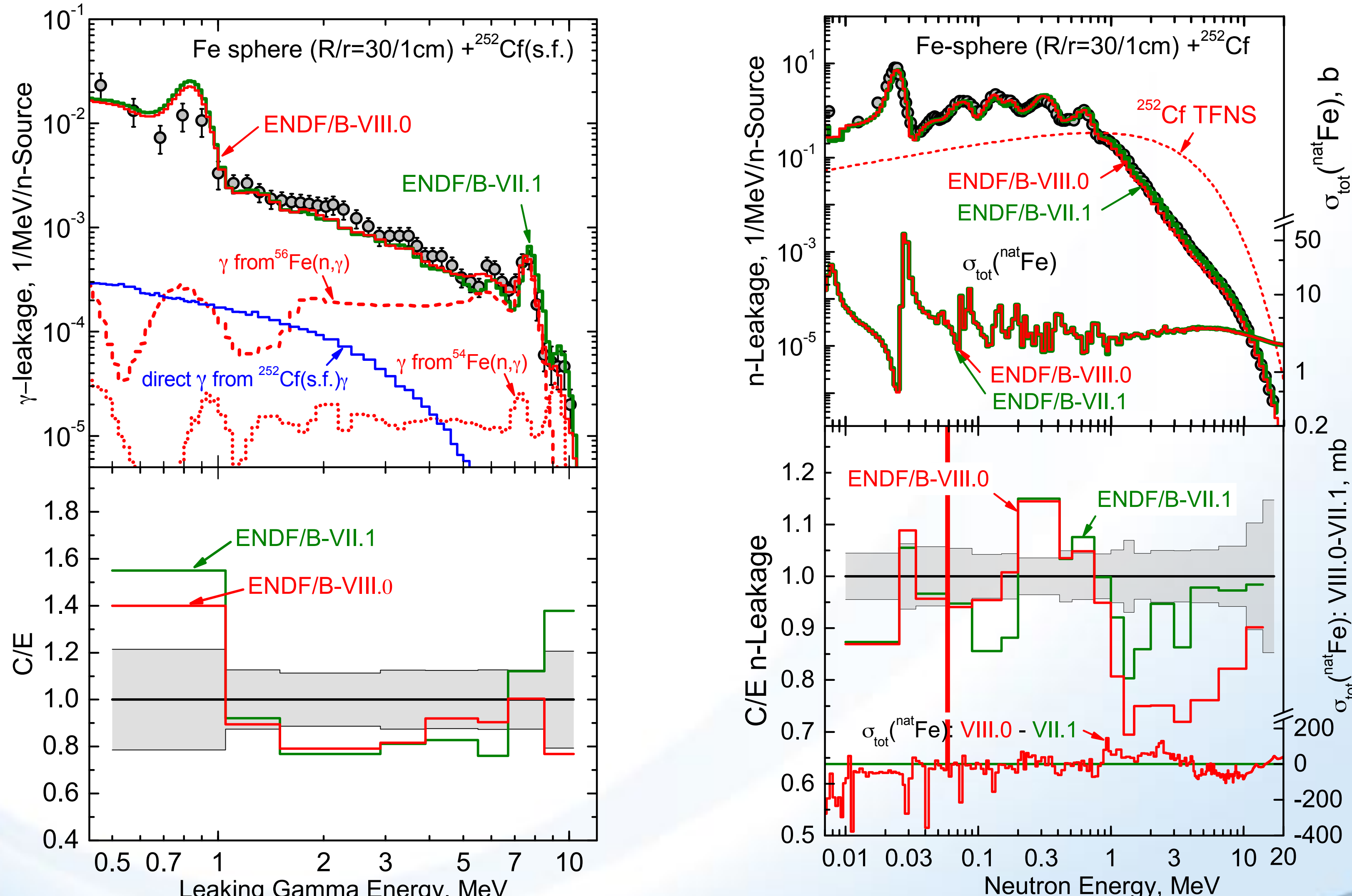
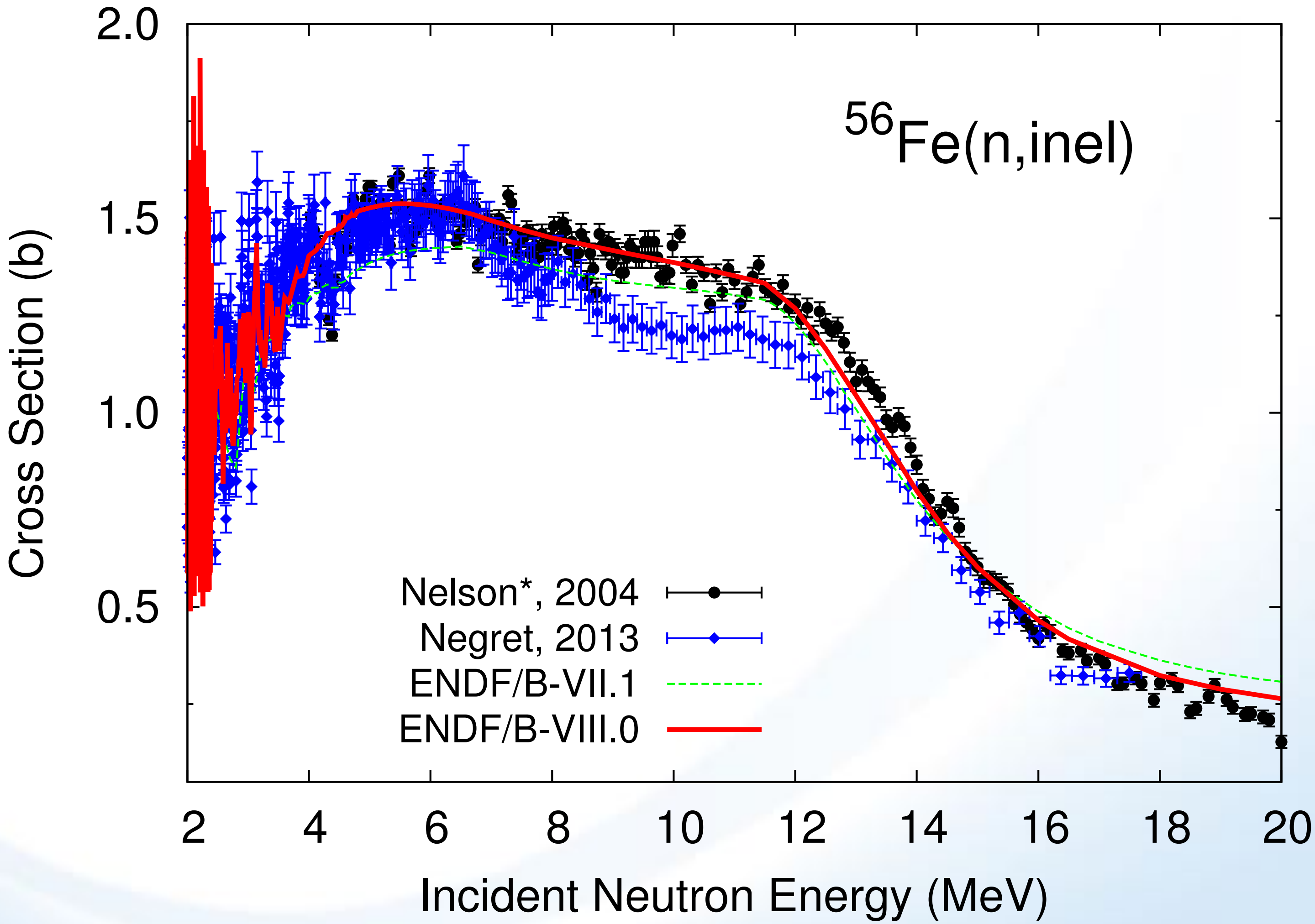
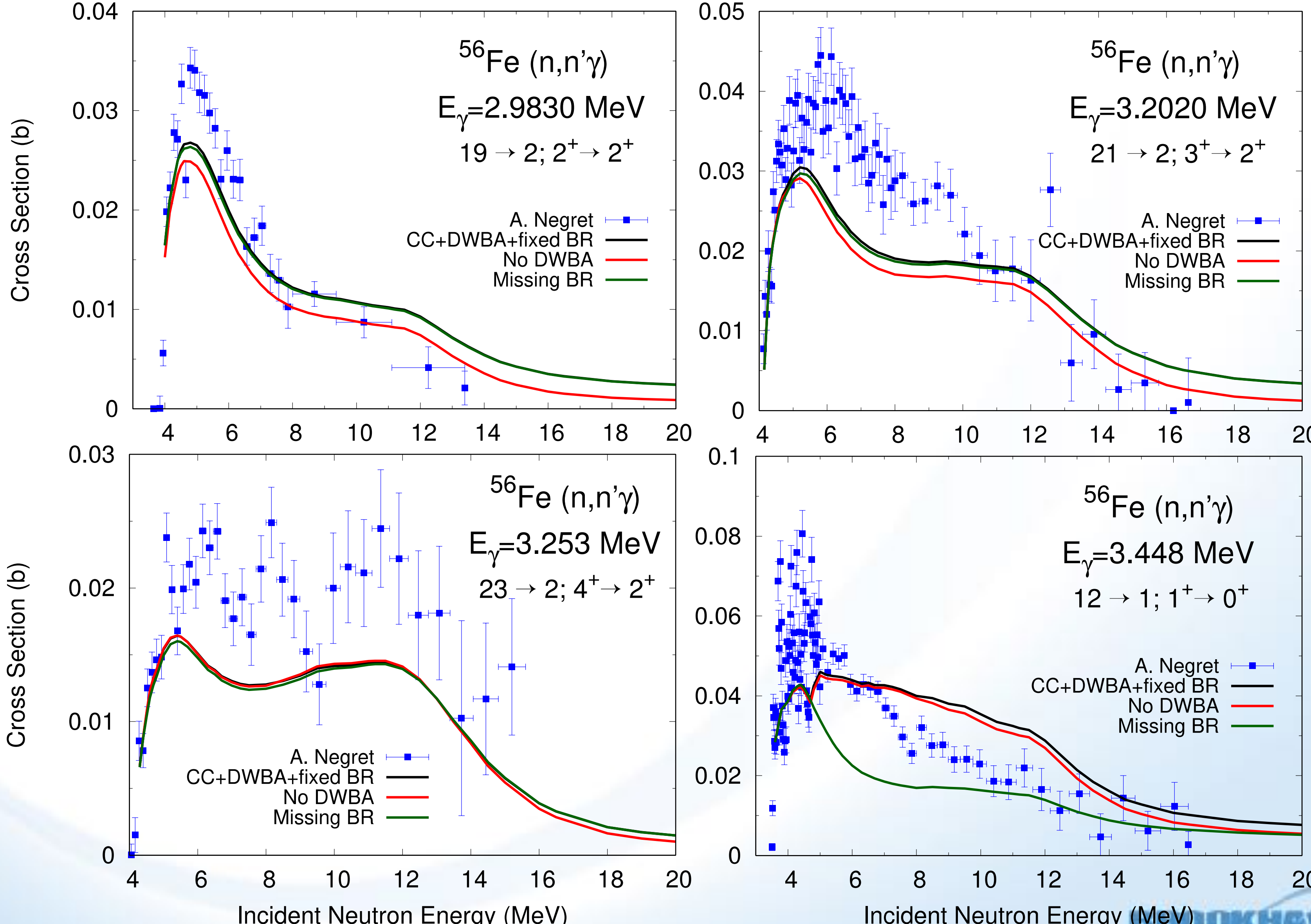
^{252}Cf(sf) source in Fe sphere



We followed Nelson, maybe we should have followed Negret or split difference



$^{56}Fe(n,n'\gamma)$ powerful test of many things



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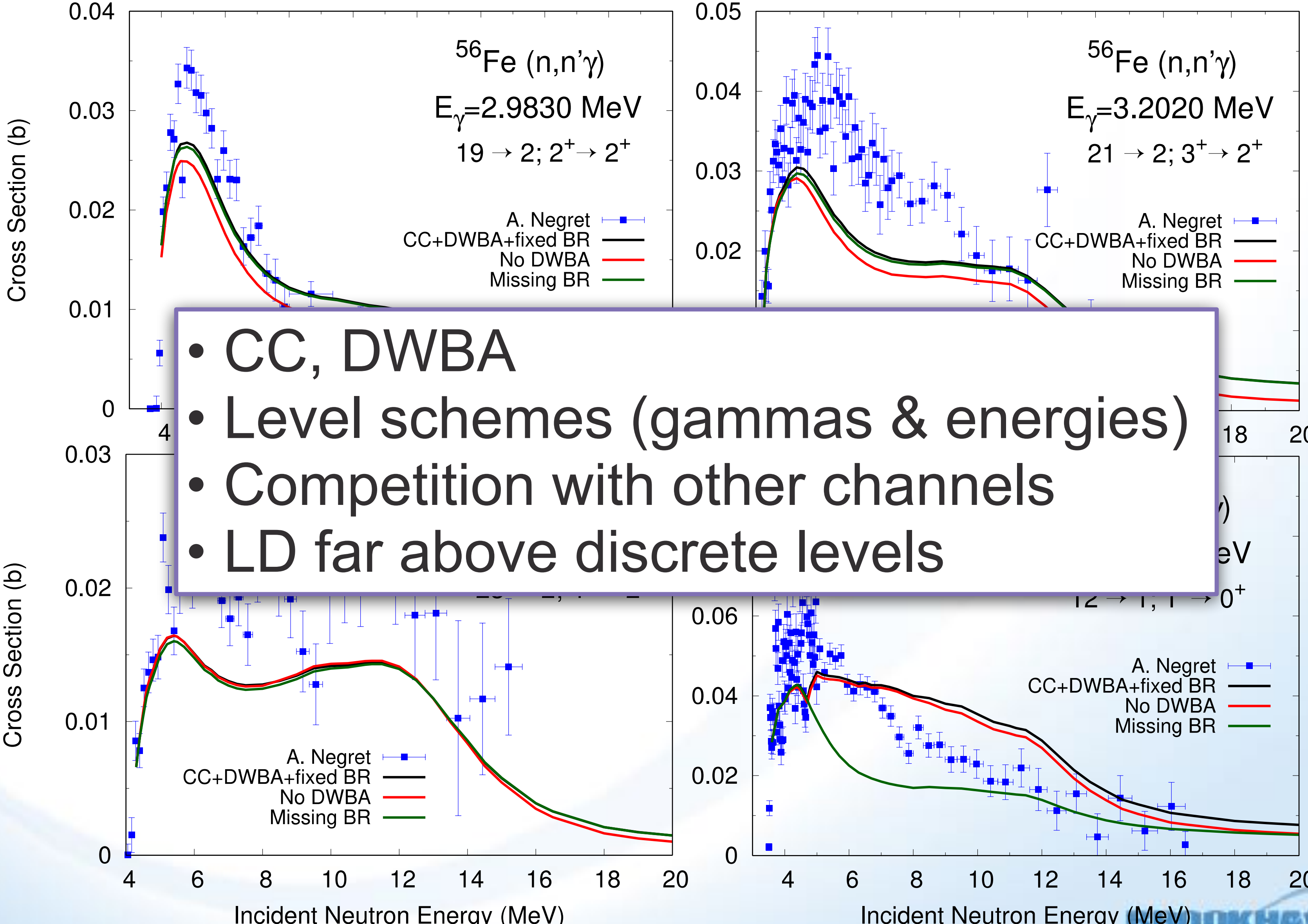

- CC, DWBA
- Level schemes (gammas & energies)
- Competition with other channels
- LD far above discrete levels

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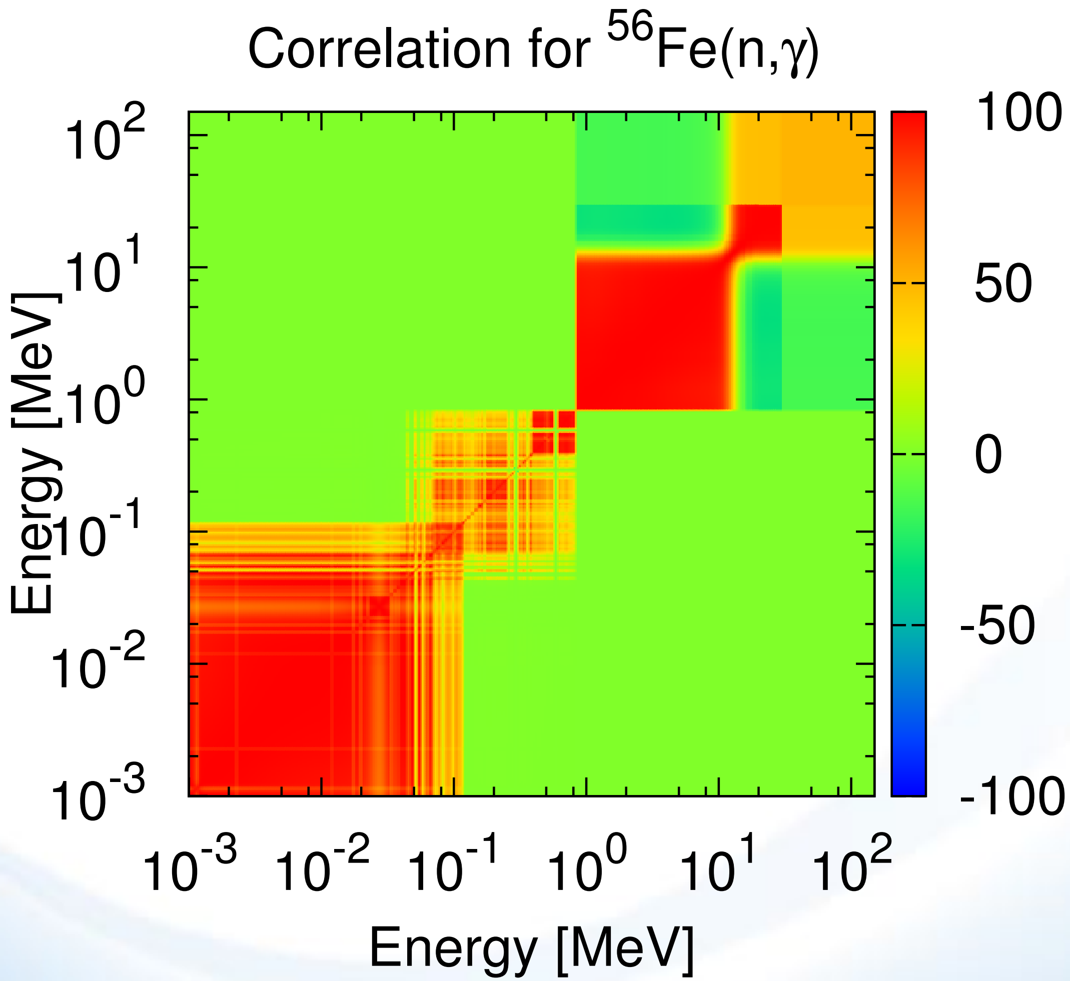
Must adapt RRR covariance code for Reich-Moore approximation



Our workaround for ^{56}Fe only worked because Atlas==JENDL-4.0

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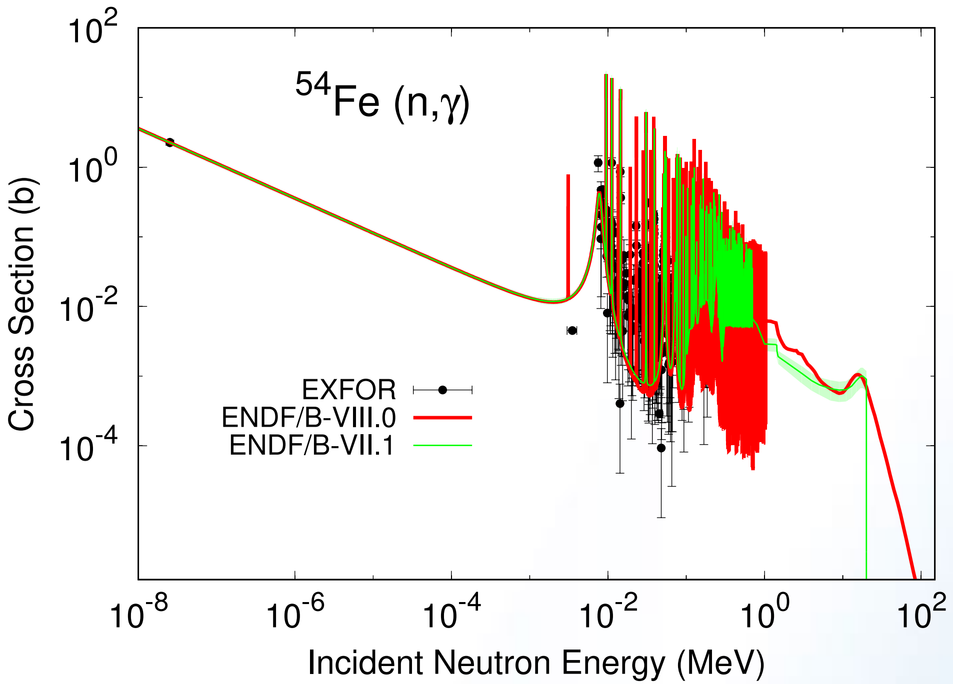
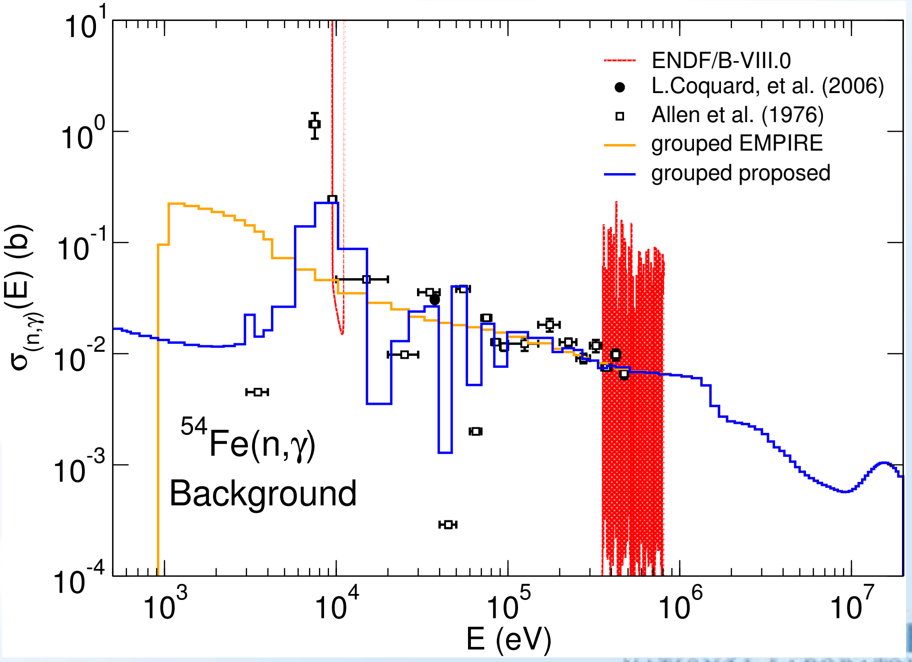
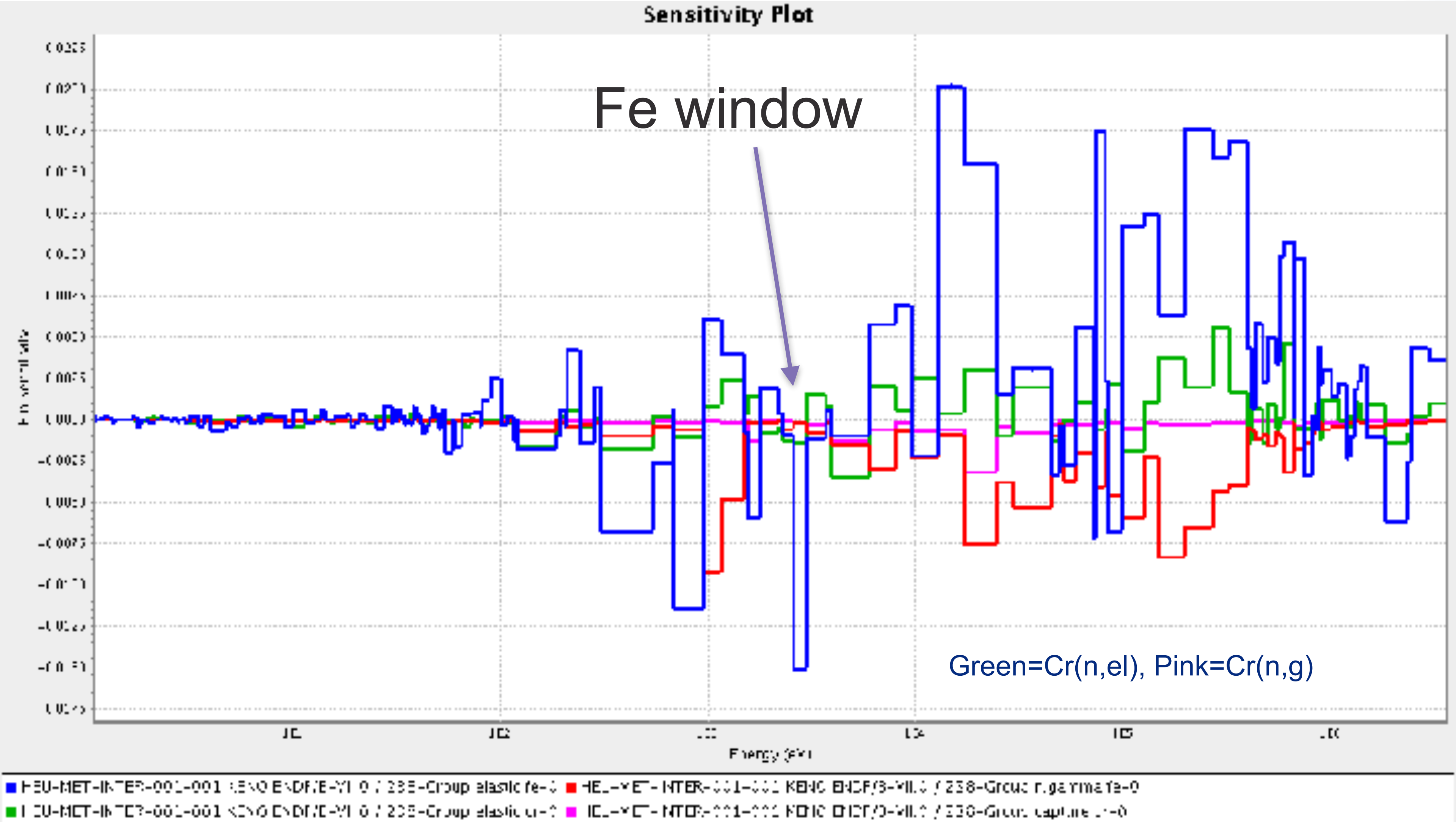
Questions about ^{54}Fe capture background determination



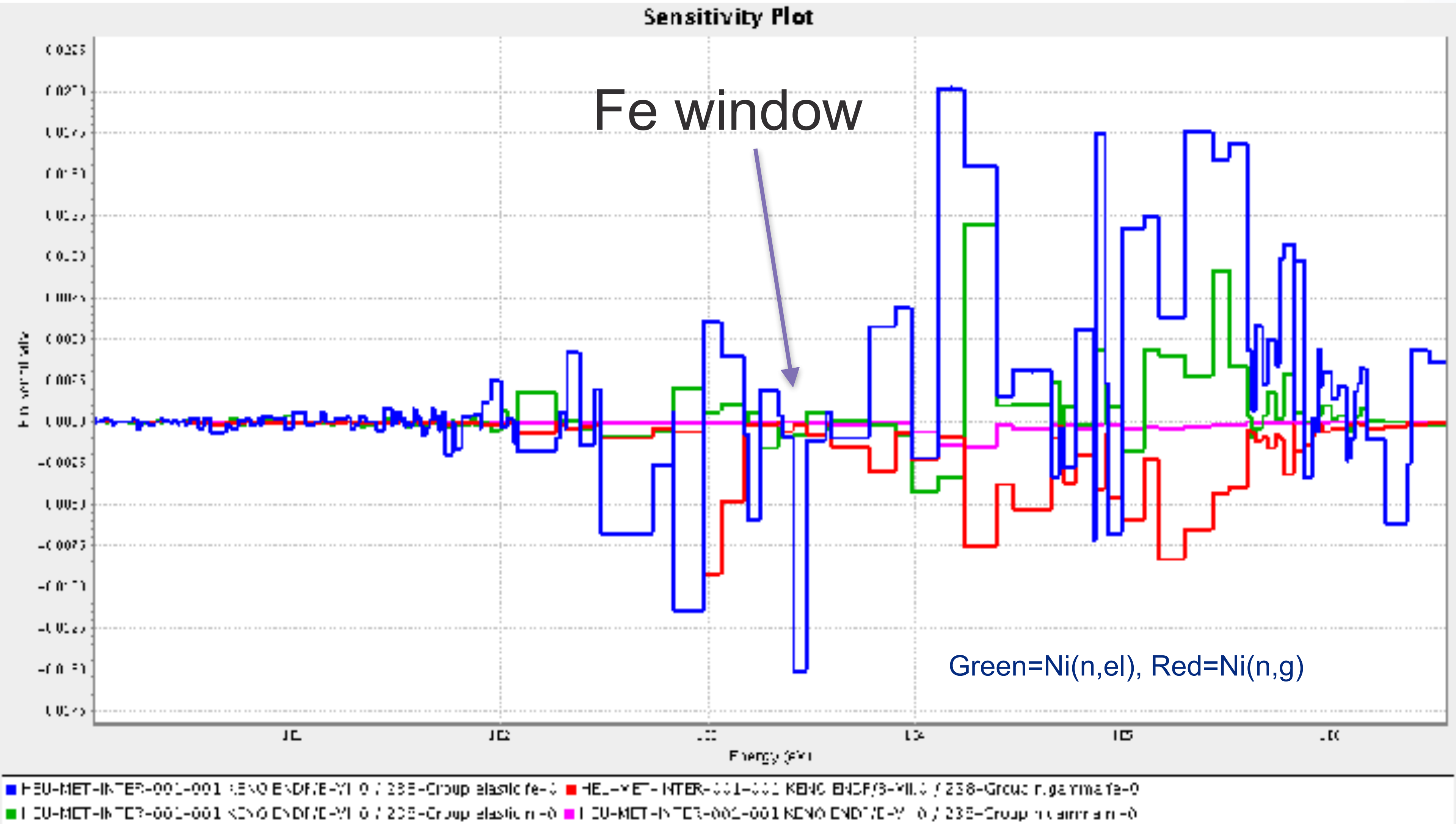
Need more capture data above 500 keV



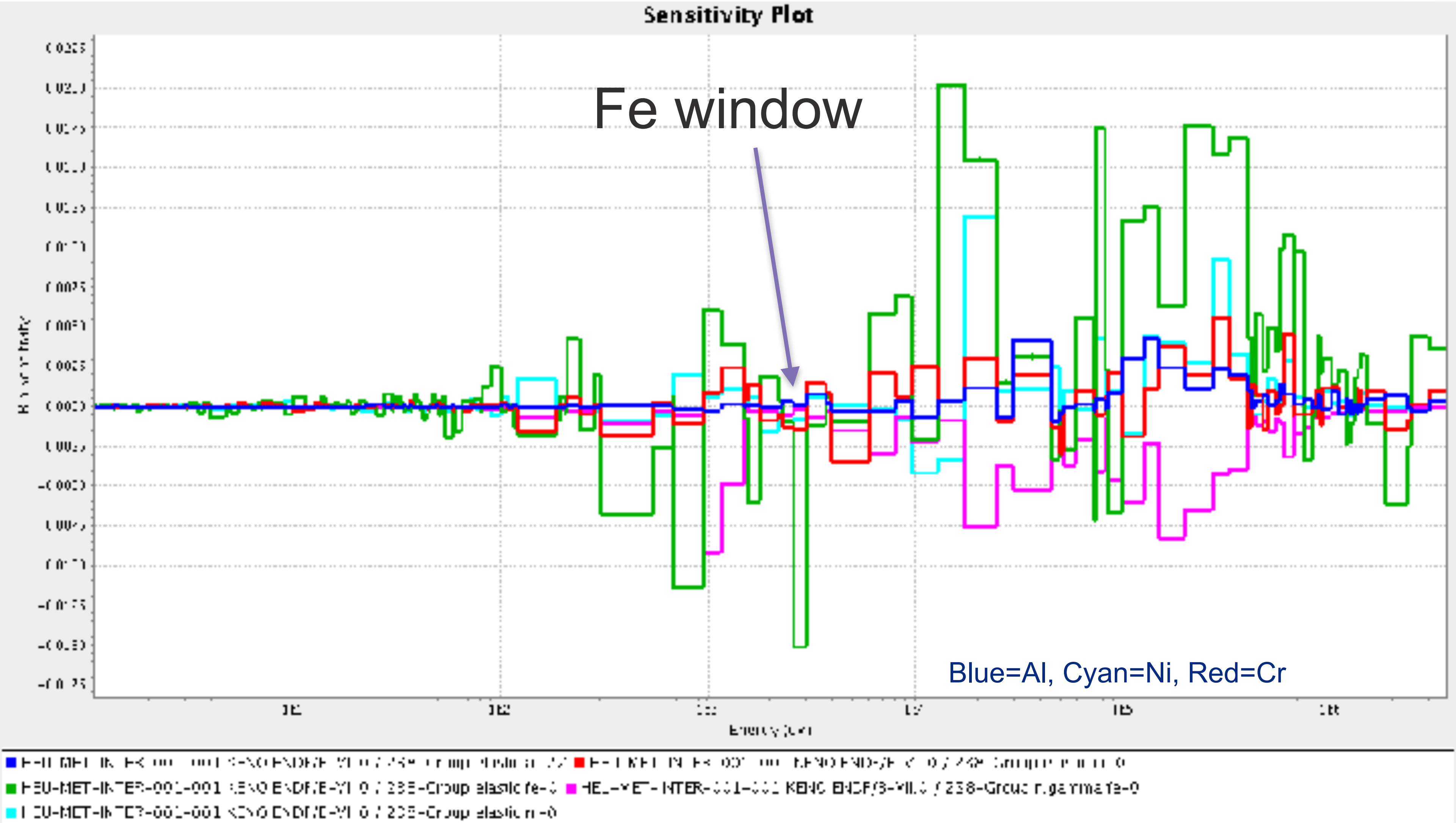
Cr, Fe Sensitivities for HMI-001



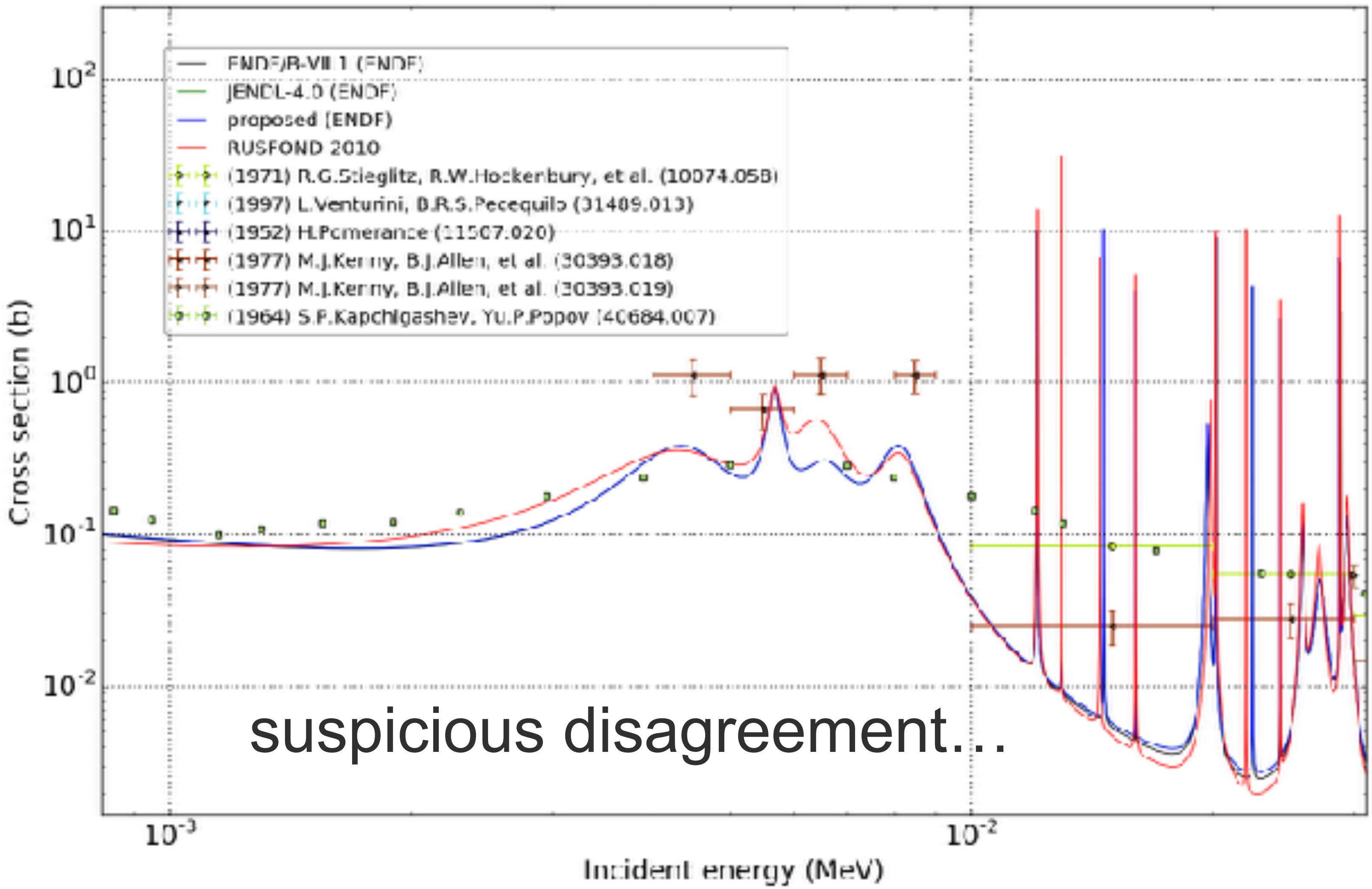
Ni, Fe Sensitivities for HMI-001



Elastic Sensitivities for HMI-001

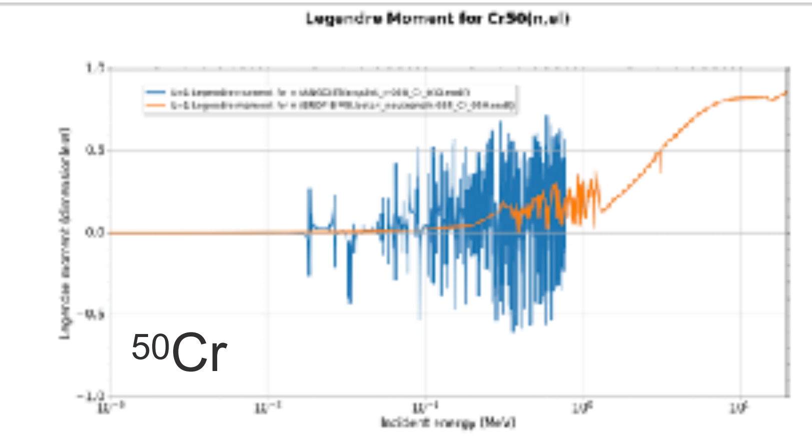


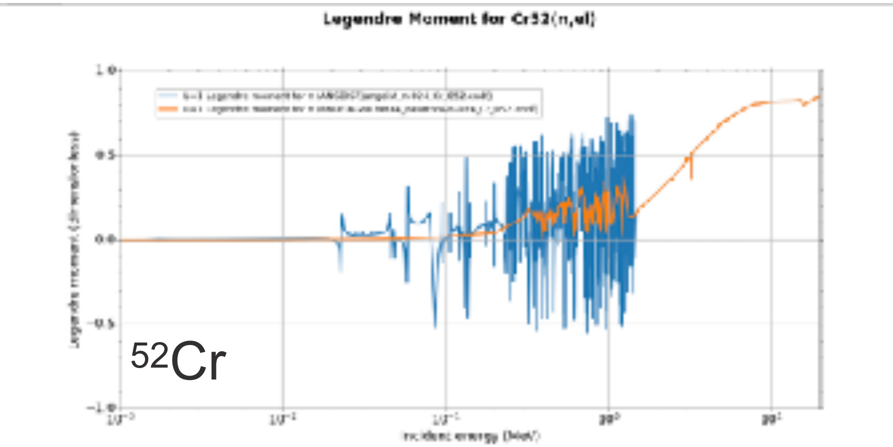
$^{53}Cr(n,\gamma)$

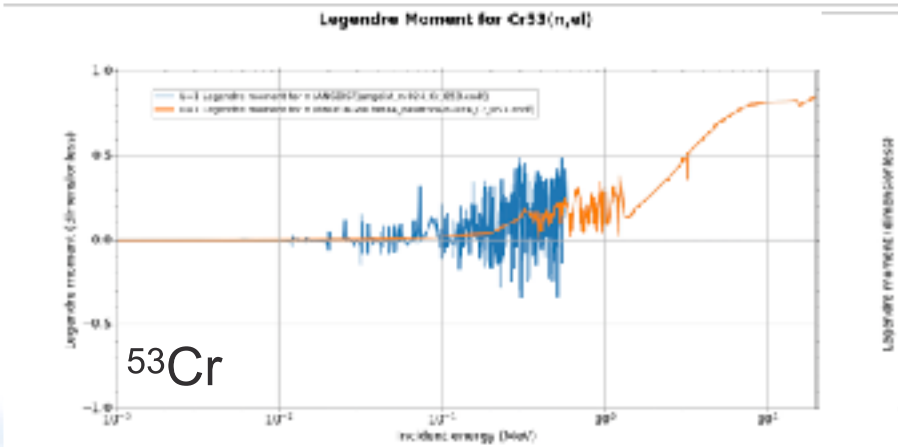


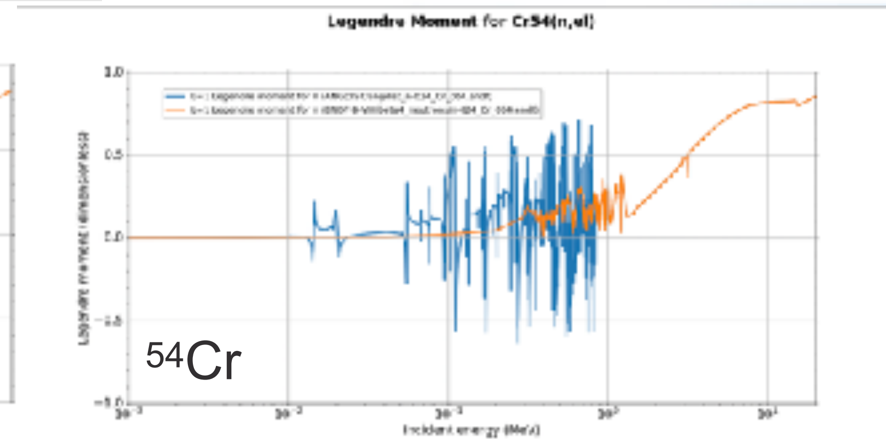
suspicious disagreement…

Anomaly in Cr(n,el) SAD









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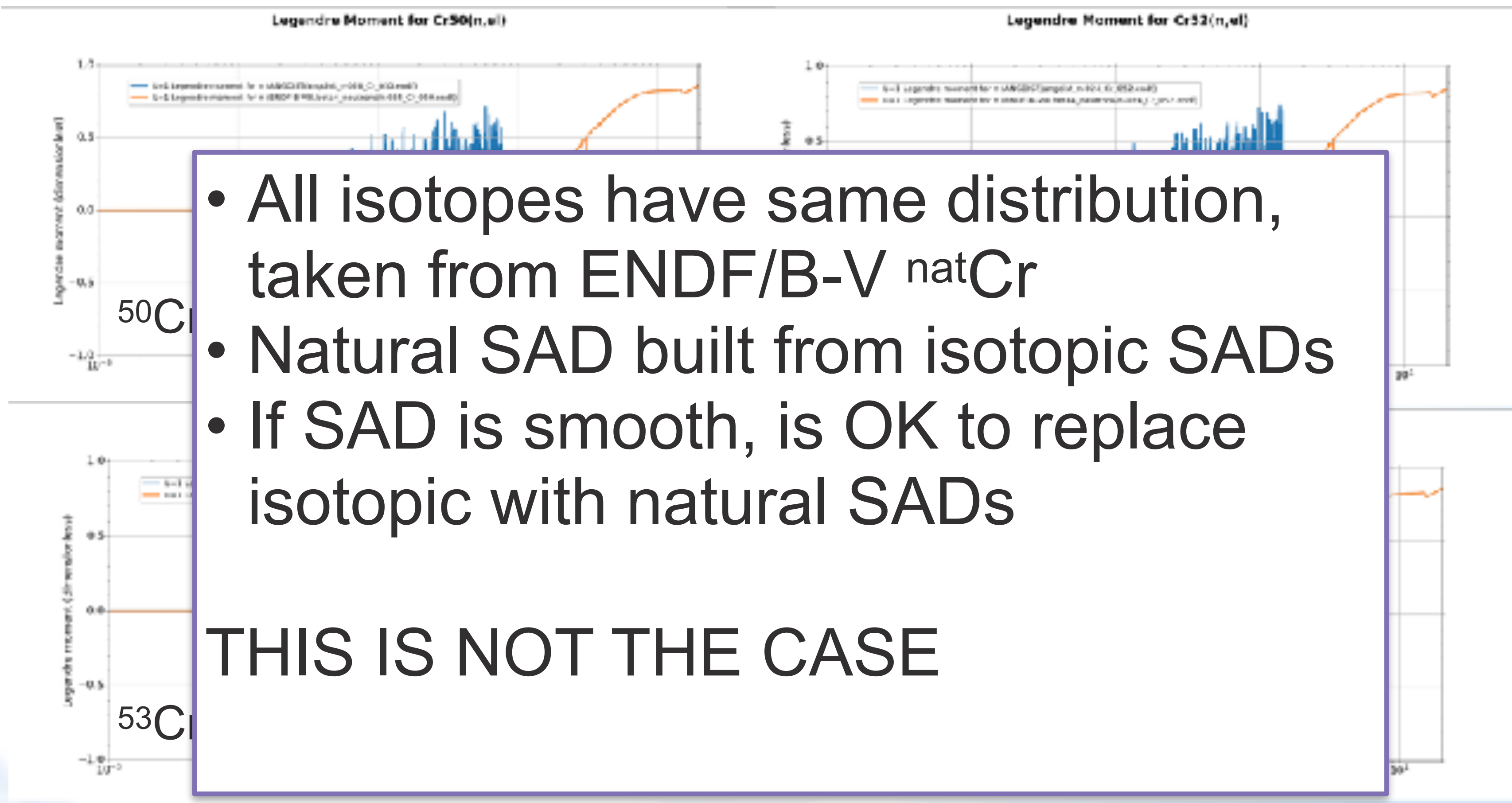

- All isotopes have same distribution, taken from ENDF/B-V ^{nat}Cr
- Natural SAD built from isotopic SADs
- If SAD is smooth, is OK to replace isotopic with natural SADs

THIS IS NOT THE CASE

Potential $^{238}U(n,n')$ project

Potential $^{238}U(n,n')$ project

… if our proposal funded