



Improvement of the CIELO evaluations of neutron induced reactions on natural iron

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WONDER 2018 : 5th International
Workshop On Nuclear Data Evaluation
for Reactor applications

OUTLOOK

- Introduction
- Overview of CIELO evaluation of iron
- Identified deficiencies
- Suggested improvements
- Conclusions



Optical model defects below 4 MeV

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Cross-section measurements for the $^{57}\text{Fe}(n,ny)^{57}\text{Fe}$ and $^{57}\text{Fe}(n,2ny)^{56}\text{Fe}$ reactions

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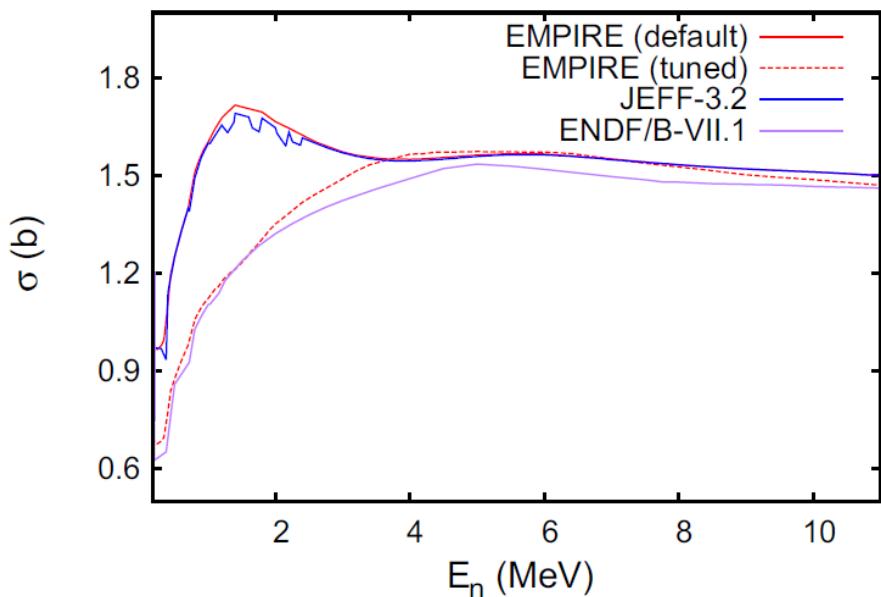


FIG. 6. Neutron nonelastic cross section on ^{57}Fe calculated with EMPIRE, compared to the values from the evaluated libraries JEFF-3.2 and ENDF/B-VII.1.

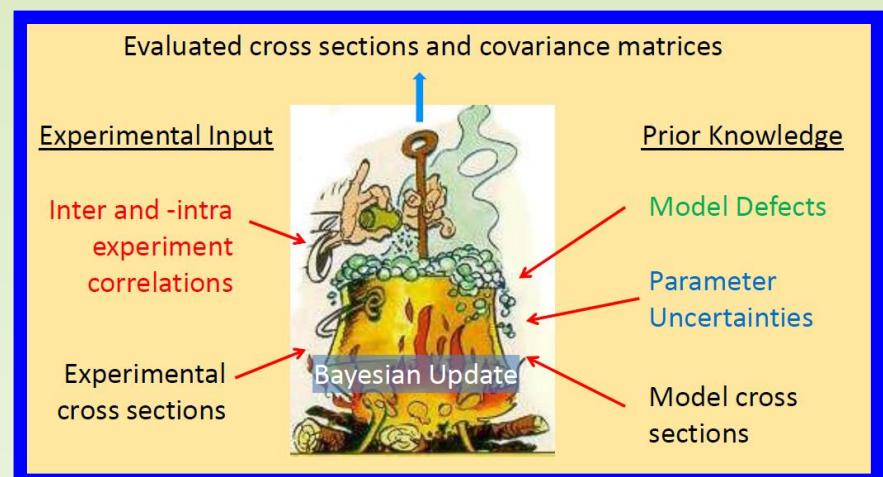
Optical models in RIPL do not describe neutron scattering cross sections on iron isotopes below 4 MeV

- Koning Delaroche (SPH)
- Soukhovitskii et al. (CC)

General problems in evaluation of structural materials: Fe, Cr, Ni

- ✓ Major isotopes show σ_{tot} fluctuations up to 5-6 MeV
- ✓ Common OMPs fail below ~ 4 MeV
- ✓ RRR usually goes up to the first inelastic level (~ 1 MeV)
- ✓ Missing resonances above ~ 0.4 MeV (bad capture & AD)
- ✓ Most important region: ~ 1 -4 MeV (PFNS maximum)

Therefore, evaluation
from 0.5-4 MeV
= cooking with
experimental data



From D. Neudecker, S. Gundacker, H. Leeb *et al.*,
ND2010, Jeju Island, Korea



Experimental data below 4 MeV

Differential experiments:

- ✓ High resolution σ_{tot}
- ✓ Lower resolution σ_{inel}
- ✓ Elastic cross sections (AD)
- ✓ High resolution AD (Kinney et al, Perey et al.)

Integral experiments:

- ✓ Criticality assemblies
- ✓ Cf-252(sf) shielding benchmarks
- ✓ DT shielding benchmarks
- ✓ SACS in well defined neutron spectra



CIELO ^{56}Fe evaluation adopted for ENDF-/B-VIII.0 (+ $^{54,57,58}\text{Fe}$)



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Evaluation of Neutron Reactions on Iron Isotopes for CIELO and ENDF/B-VIII.0

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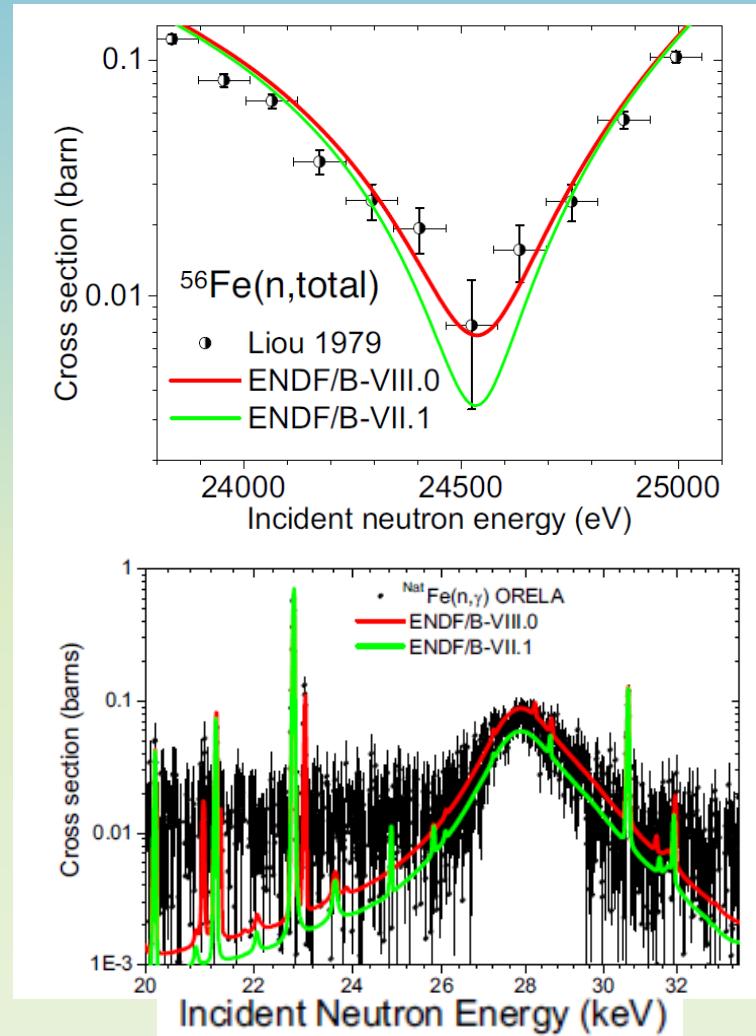
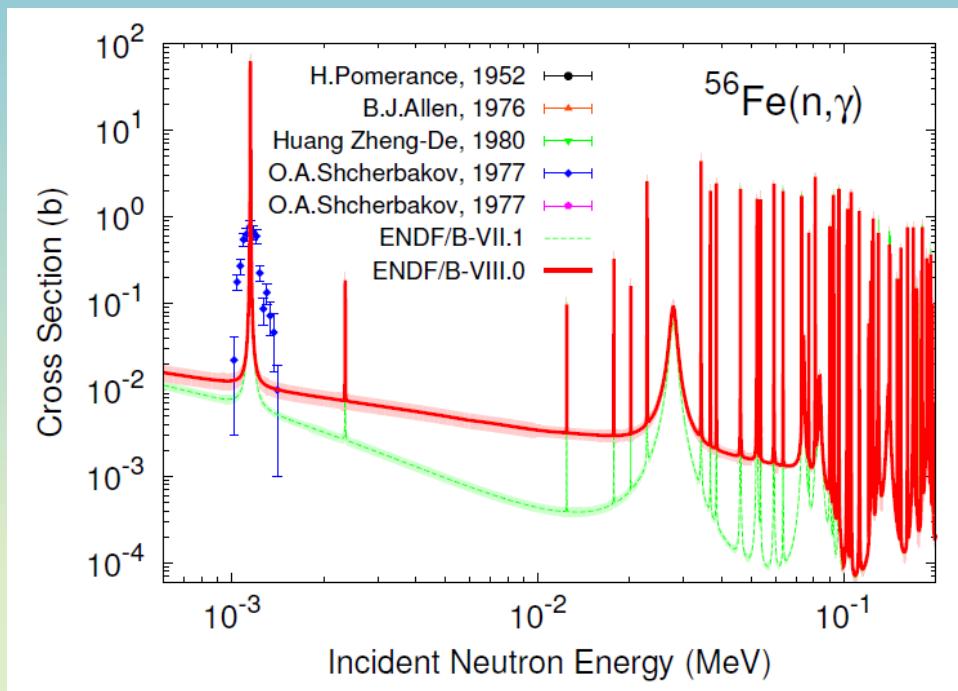
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Deficiencies in ^{56}Fe RPs => background



1/v background
added ~ direct (n, γ) ?

ZPR 9/34 (hmi001) criticality reduced by ~1%

Deficiencies in ^{56}Fe RPs => background

RPI exp.

Can not be used
for RP analysis !

background
added
400-850 keV

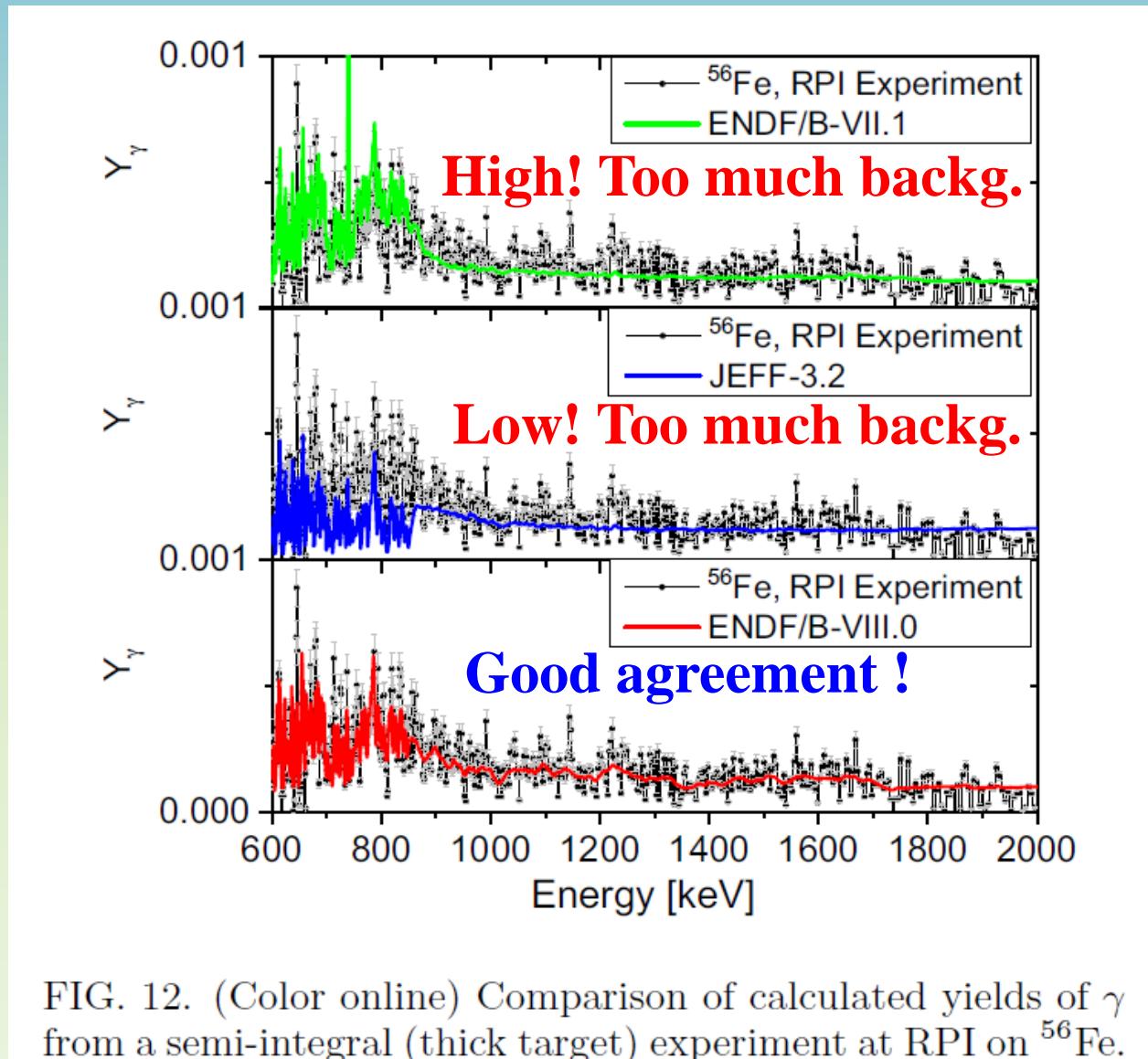
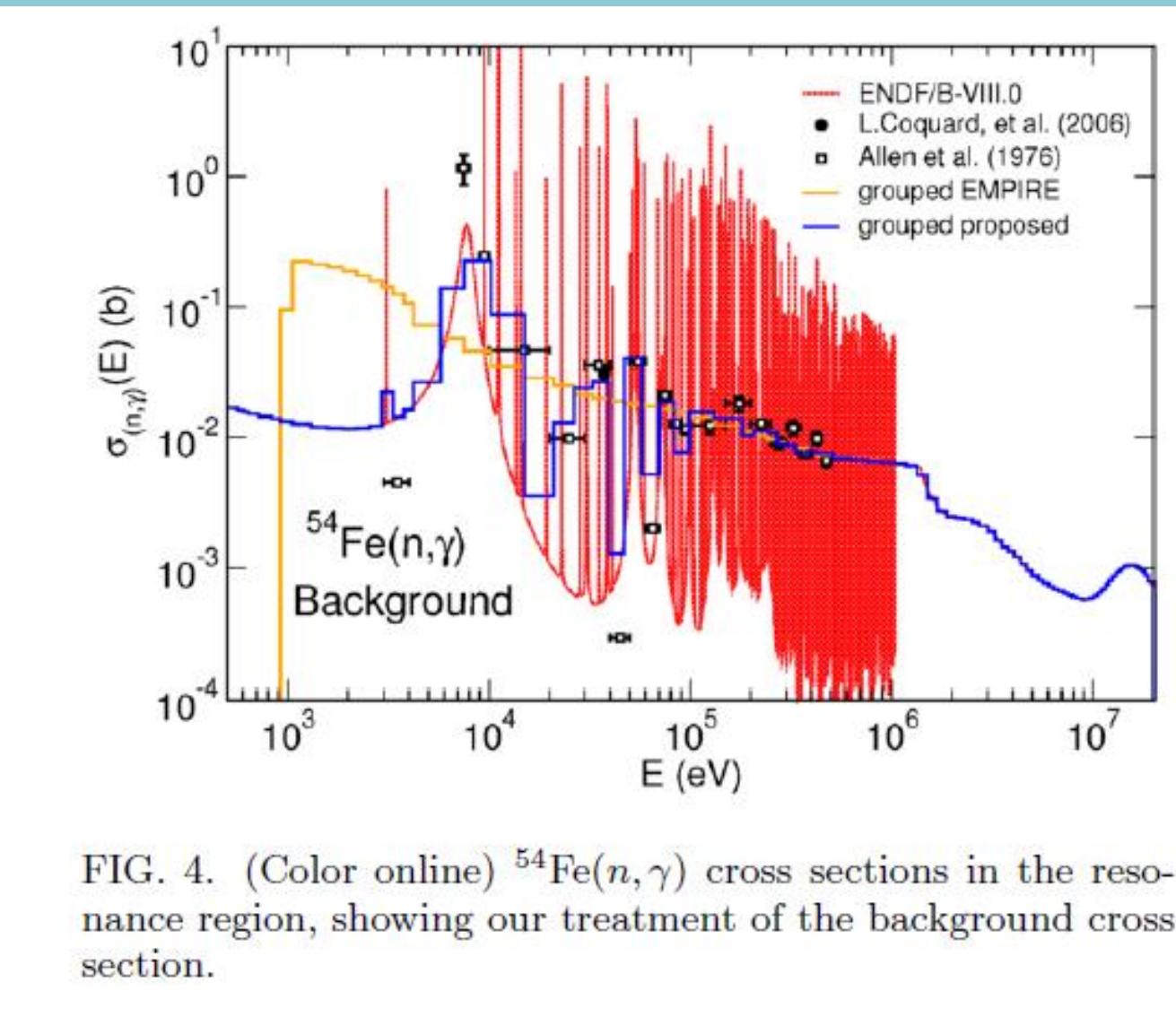


FIG. 12. (Color online) Comparison of calculated yields of γ from a semi-integral (thick target) experiment at RPI on ^{56}Fe .

Deficiencies in ^{54}Fe RPs => background



Deficiencies in ^{57}Fe RPs => background

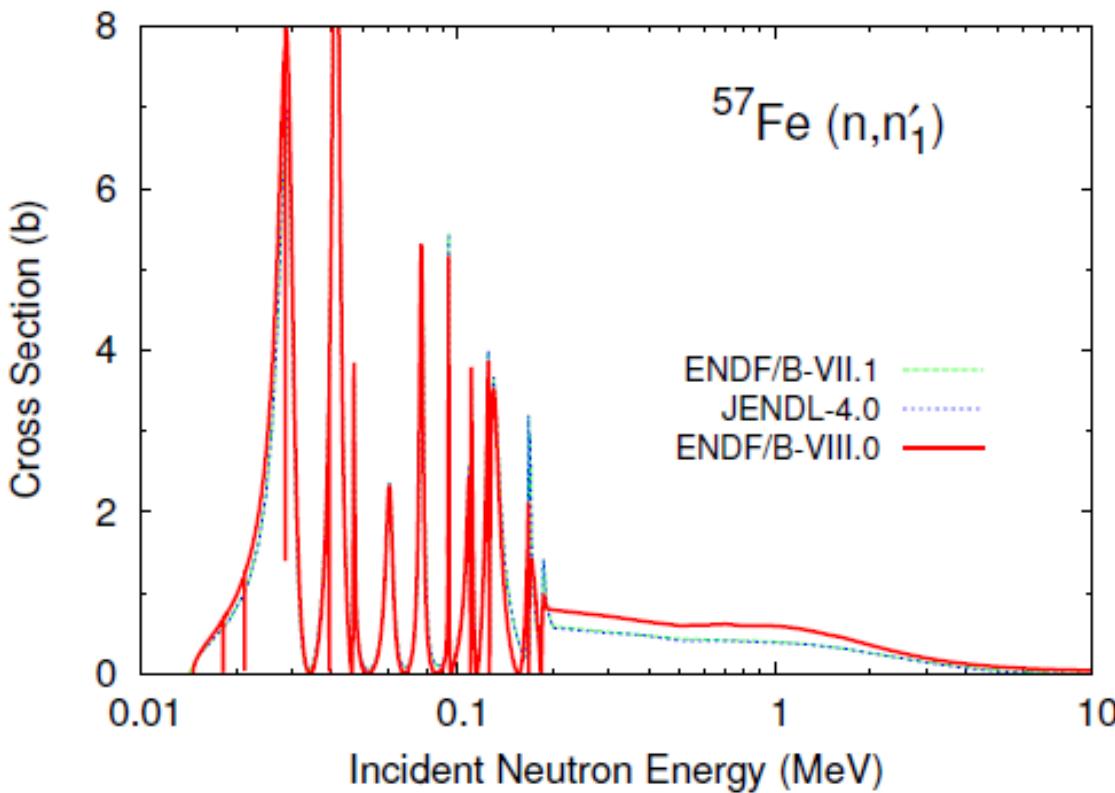


FIG. 5. (Color online) Evaluated $^{57}\text{Fe}(n, n')$ cross section compared with JENDL-4.0 and with the previous ENDF evaluation. The fluctuating structure below 200 keV is the inelastic cross section reconstructed from the resonance parameters stored in the evaluated file using LRF=7 option.

Inelastic cross section from experiment

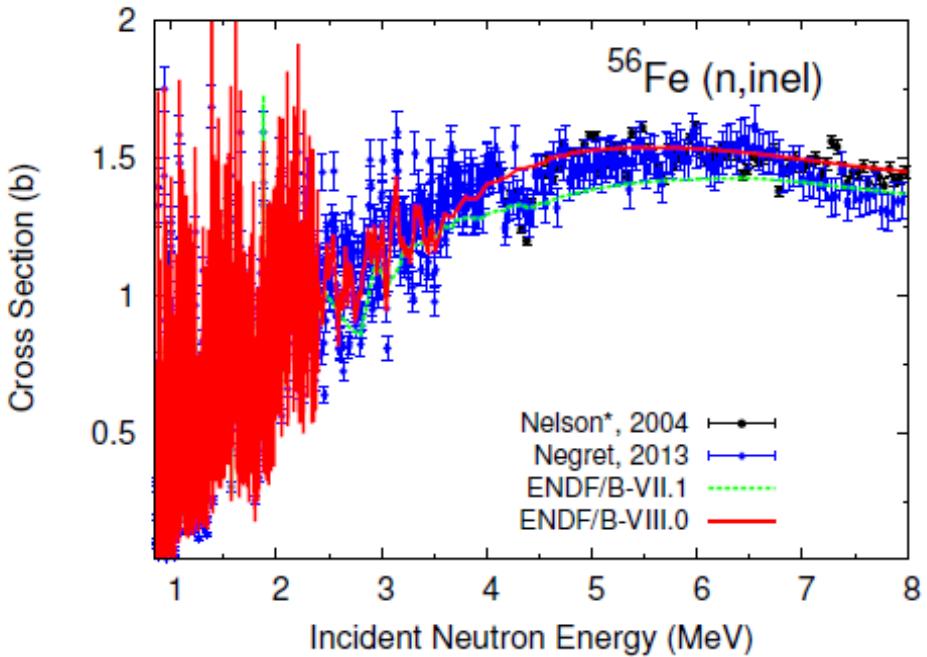


FIG. 34. (Color online) Evaluated $^{56}\text{Fe}(n, n')$ neutron inelastic cross section compared with data retrieved from EXFOR and with the previous evaluation. The asterisk on the Nelson data indicates that they are renormalized as described in Ref. [19].

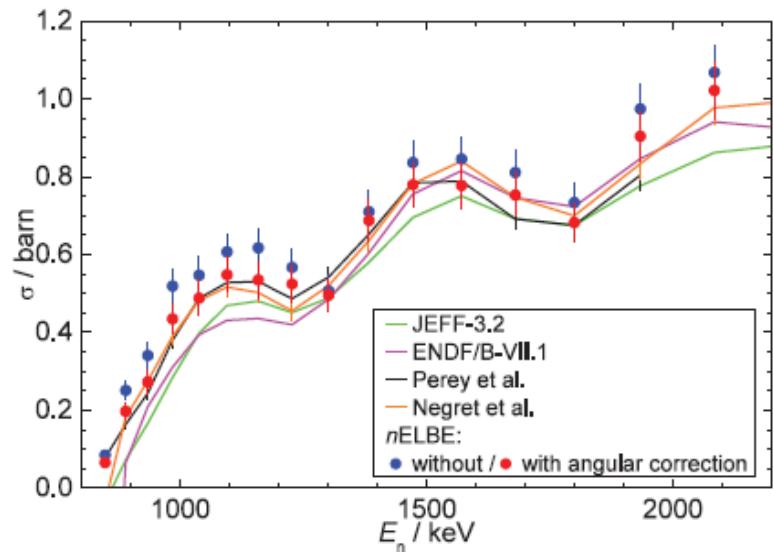
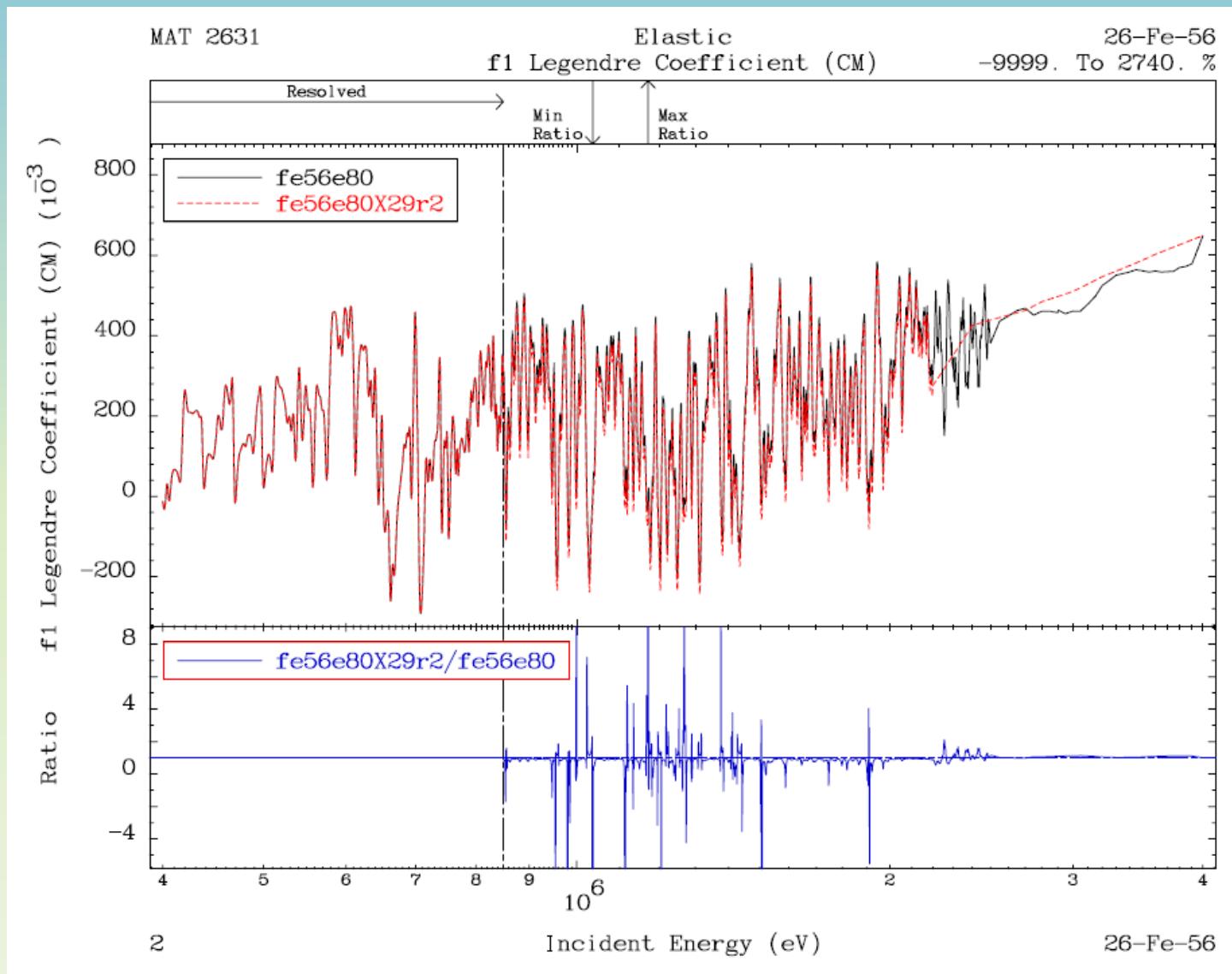


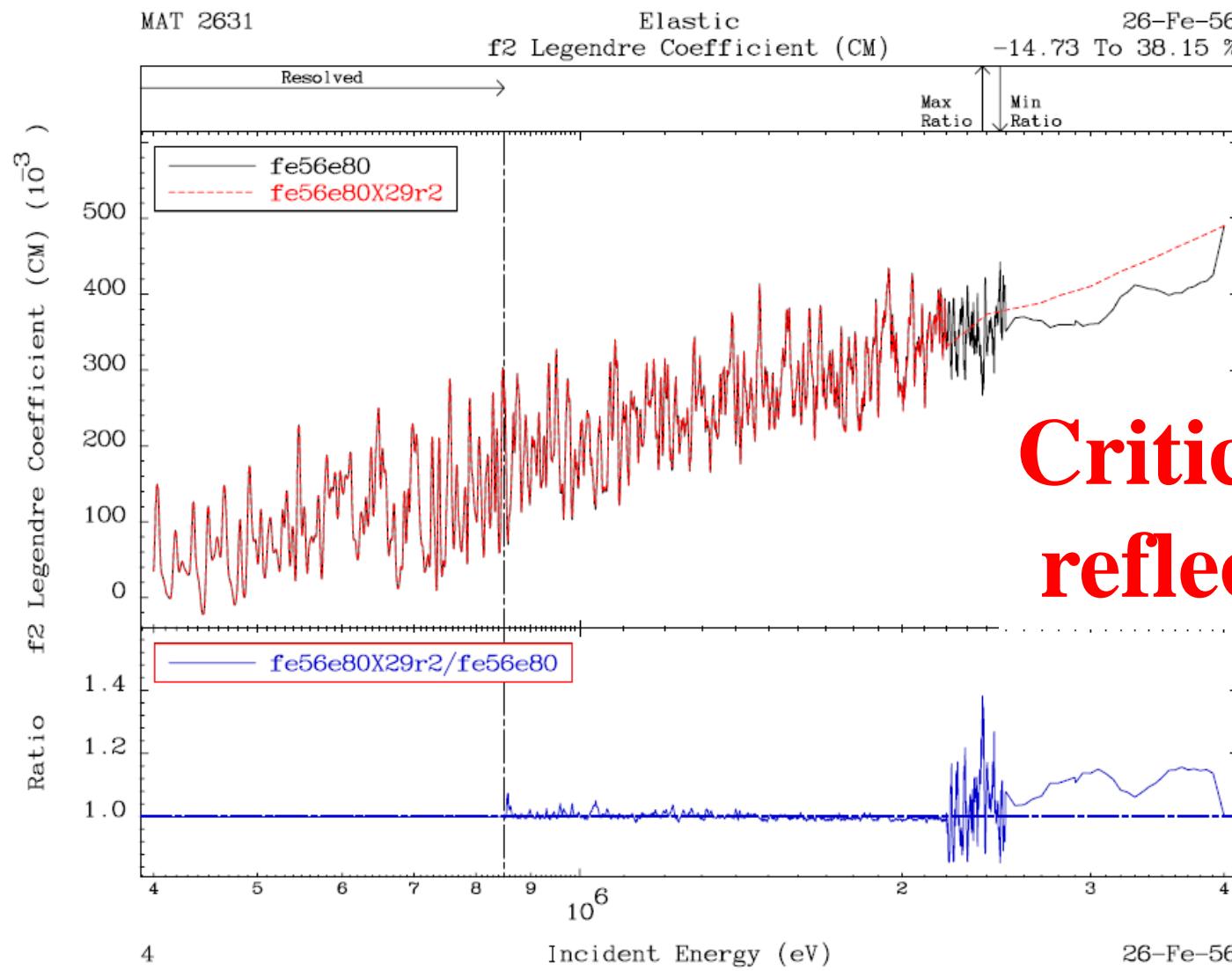
Figure 9. Inelastic neutron scattering cross section under excitation of the first excited state of ^{56}Fe determined in the γ -ray production measurement before and after correction for the γ -ray angular distribution. (Note: The reference data are averaged to the binsize of the *n*ELBE measurement.)

Beyer et al, EPJ WoC 146 (2017) 02017

Fitted Kinney/Perey DA data



Fitted Kinney/Perey DA data



Critical for reflectors



AD from fits to HRes Kinney/Perey

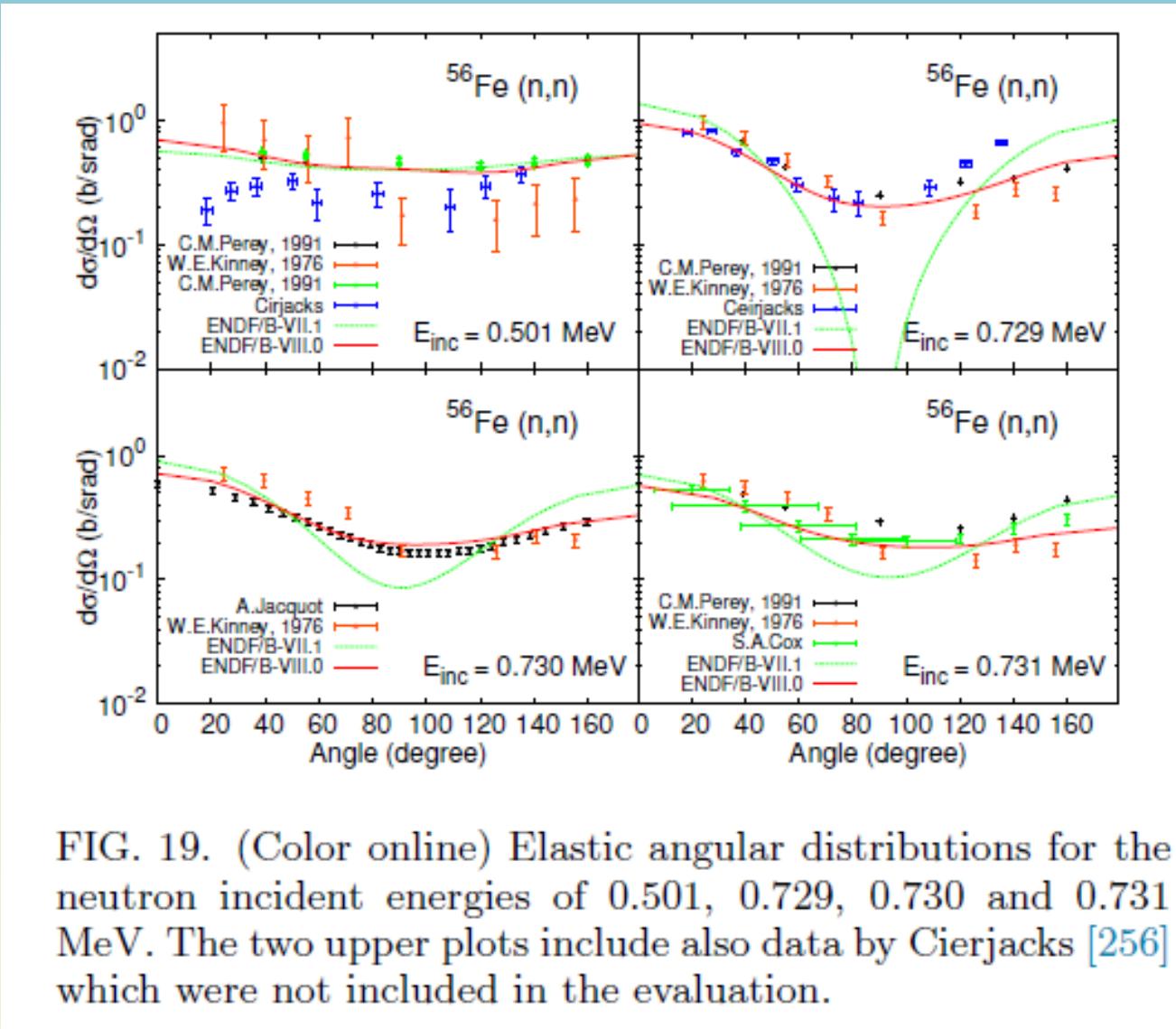


FIG. 19. (Color online) Elastic angular distributions for the neutron incident energies of 0.501, 0.729, 0.730 and 0.731 MeV. The two upper plots include also data by Cierjacks [256] which were not included in the evaluation.

Problems with ^{56}Fe

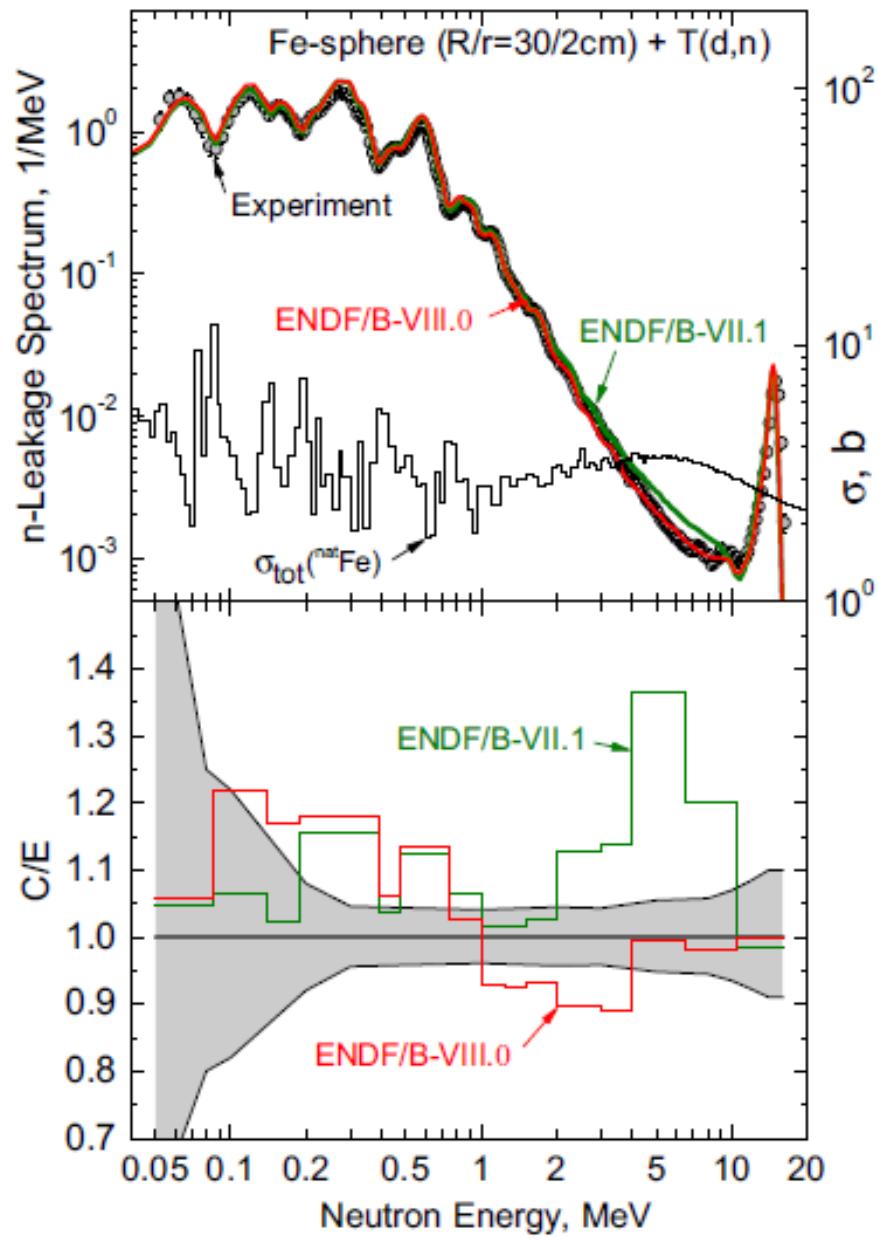
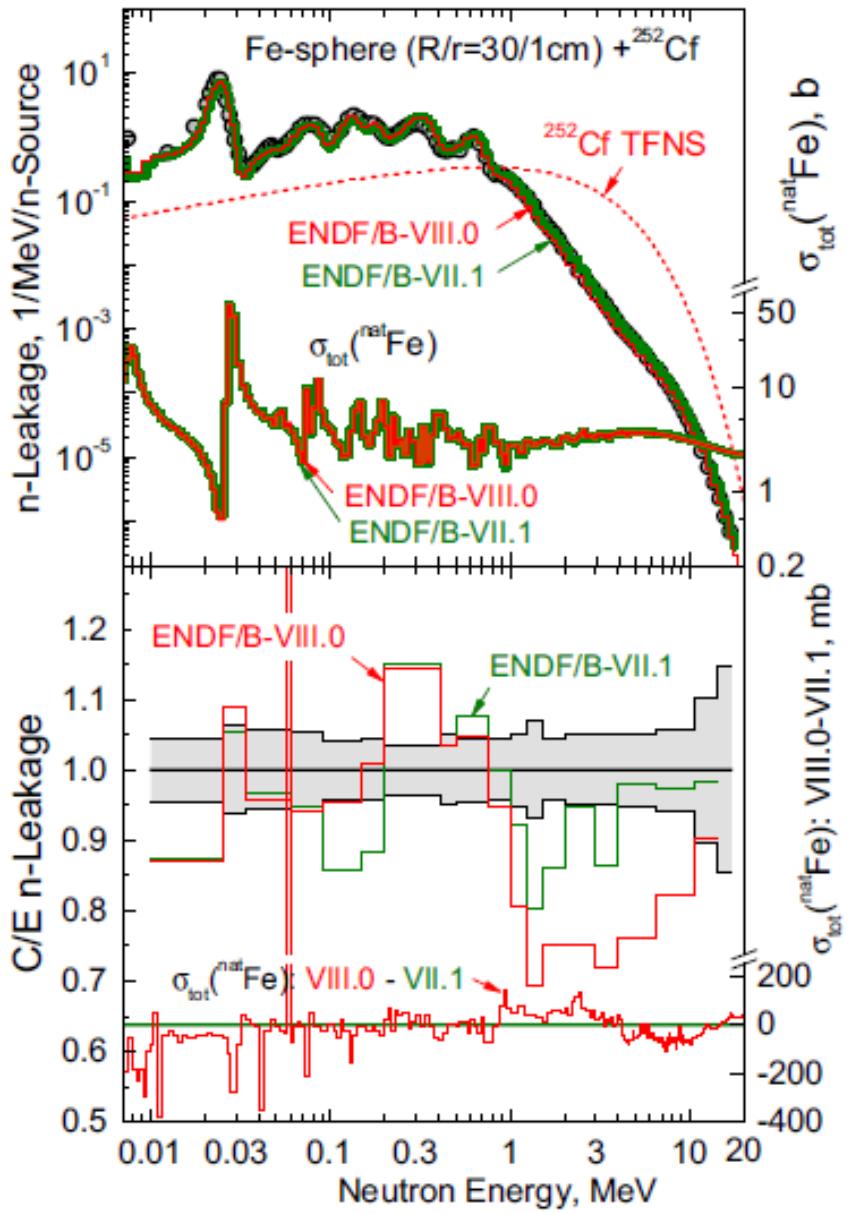
- It was noted during benchmarking of the ENDF/B-VIII.0 library that leakage spectra from thick iron shells with ^{252}Cf source and with D-T source were poorly reproduced (reported by S. Simakov).

Problems with ^{57}Fe

- Inconsistency between evaluated cross section in the RRR and “measured” data using $(n,n'\gamma)$ by Negret et al.

(PRC96 (2017) 02420)



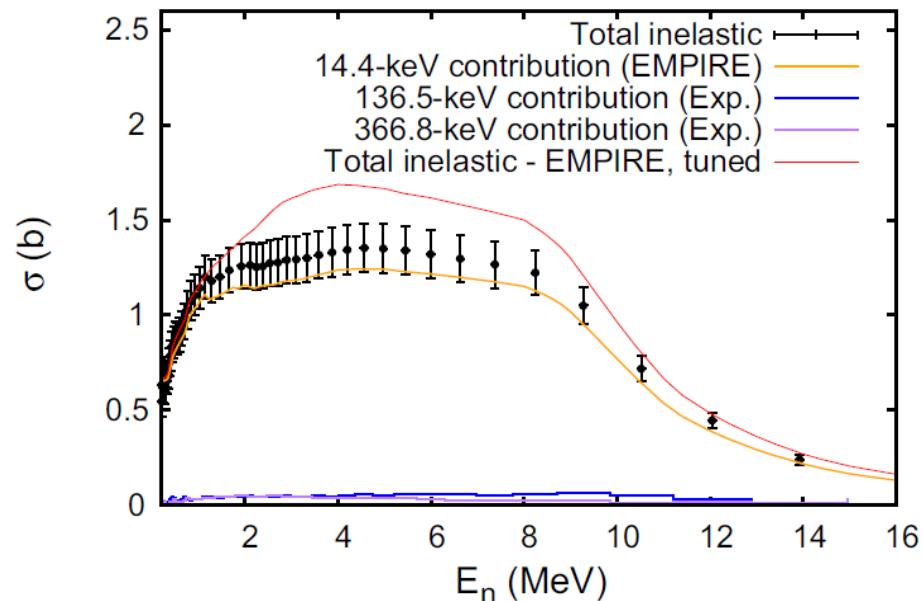
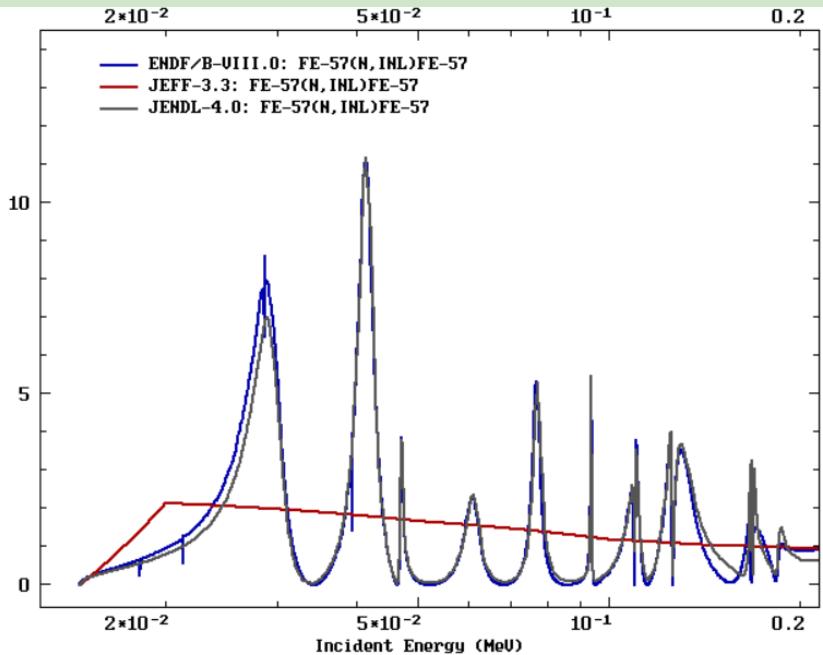


Inconsistencies between RP and average cross sections: $^{57}\text{Fe}(n,\text{inl})$

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Cross-section measurements for the $^{57}\text{Fe}(n,n\gamma)^{57}\text{Fe}$ and $^{57}\text{Fe}(n,2n\gamma)^{56}\text{Fe}$ reactions

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Improvements to ^{56}Fe evaluation

- Total cross sections are trusted
 - New measurements by E. Pirovano at Geel support a higher elastic cross section
 - Inelastic constrained by Perey, Negret and Beyer et al below 2 MeV
 - Capture is too small to play a role
- Conclusion: measured inelastic is too high or total is not so well known (total~elastic, inelastic is small)

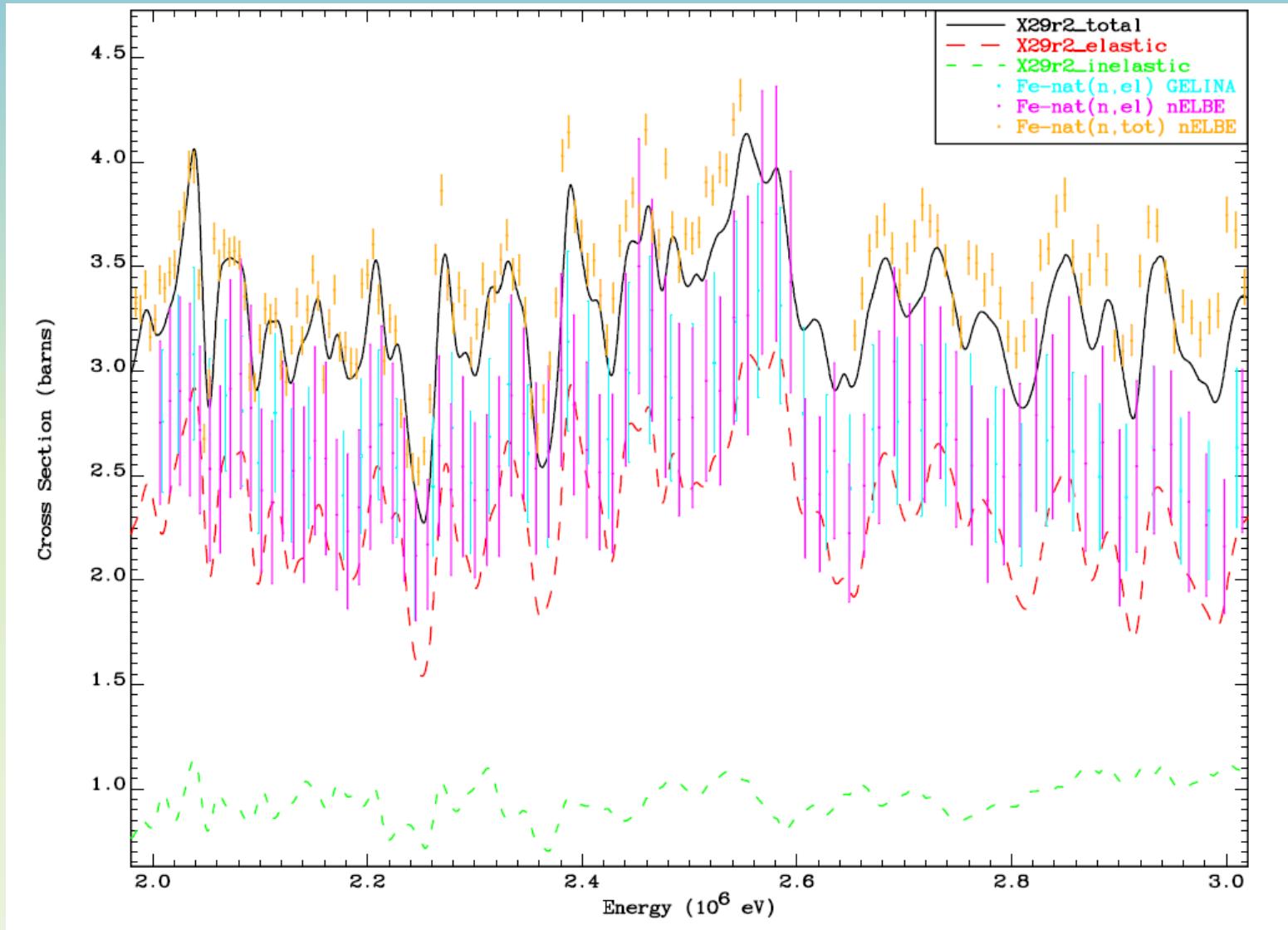
Total minima are very important for transmission !!!

Elastic may be increased in the minima

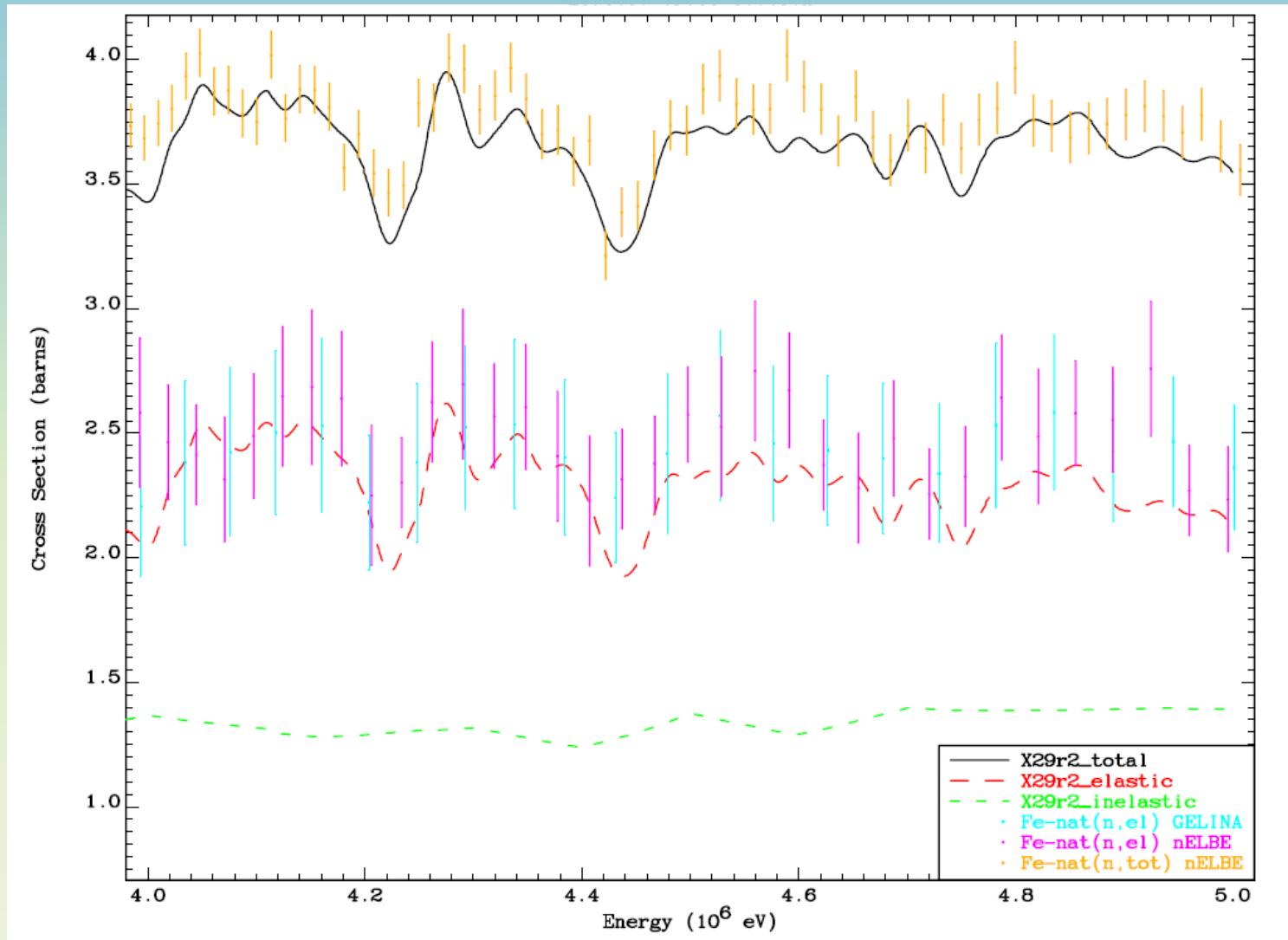
(as suggested by B. Jansky, Rez, JEFF-DOC 1918, 2016)



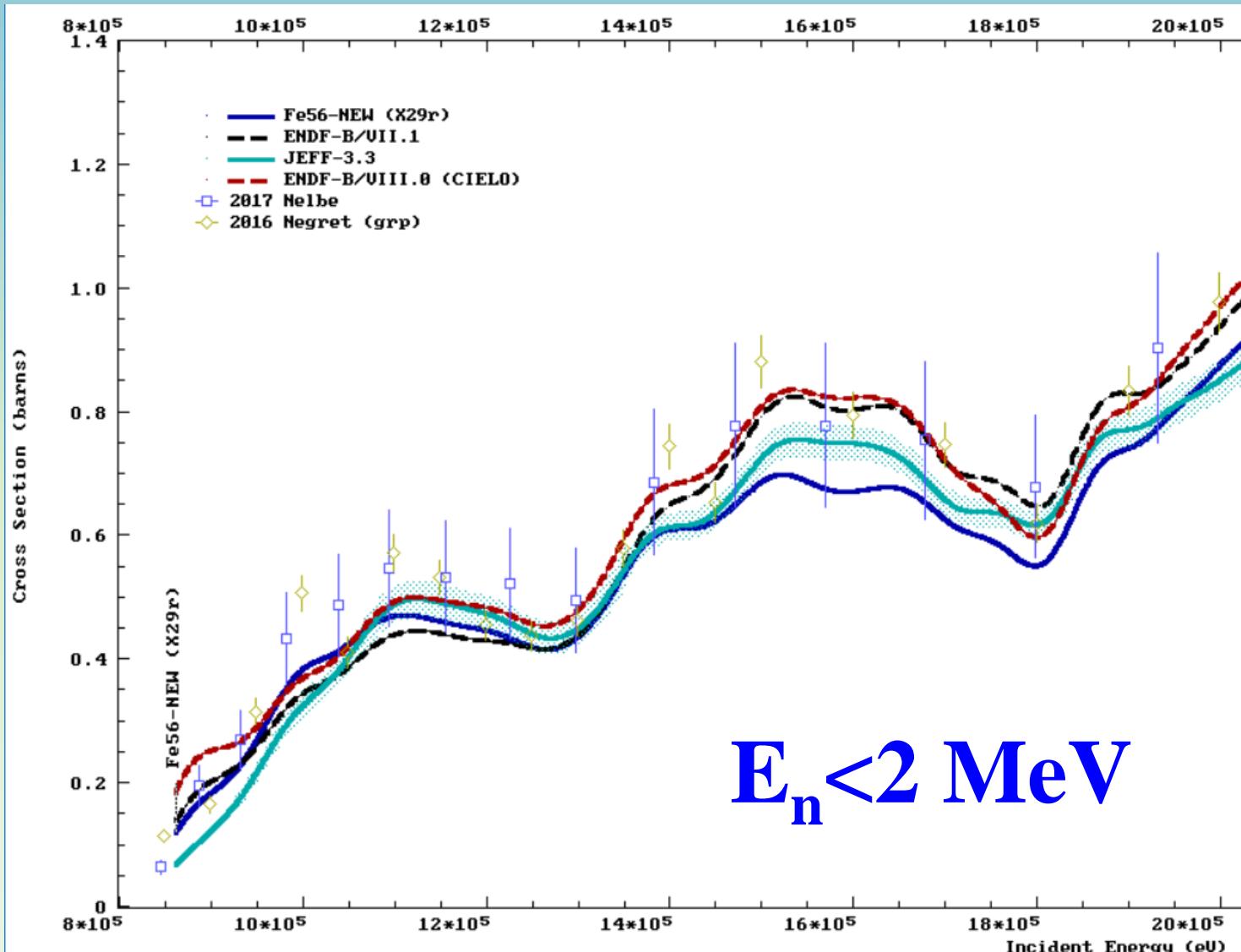
Differential experiments: σ_{tot} , σ_{el} , σ_{inel}



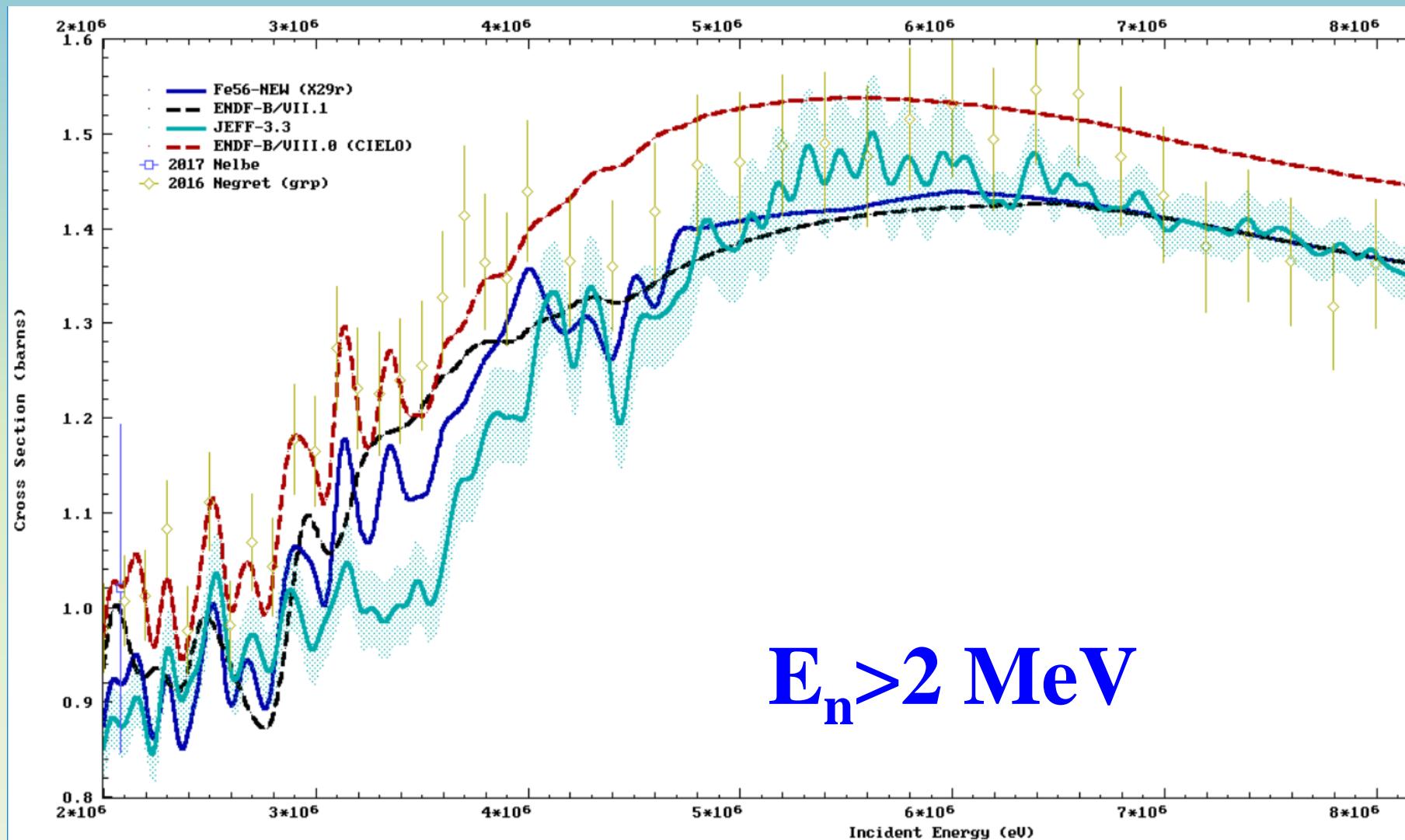
Differential experiments: σ_{tot} , σ_{el} , σ_{inel}



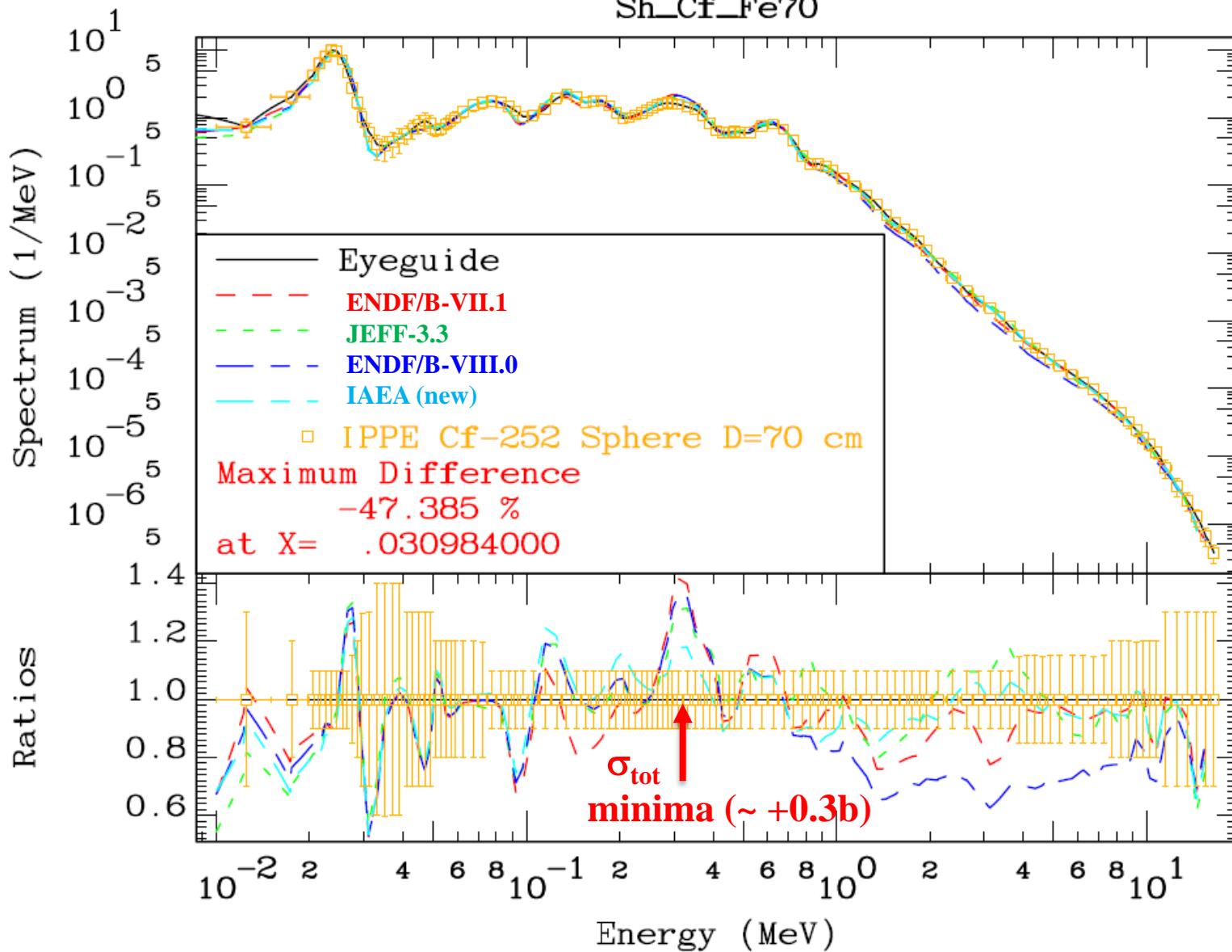
Differential experiments: σ_{inl}



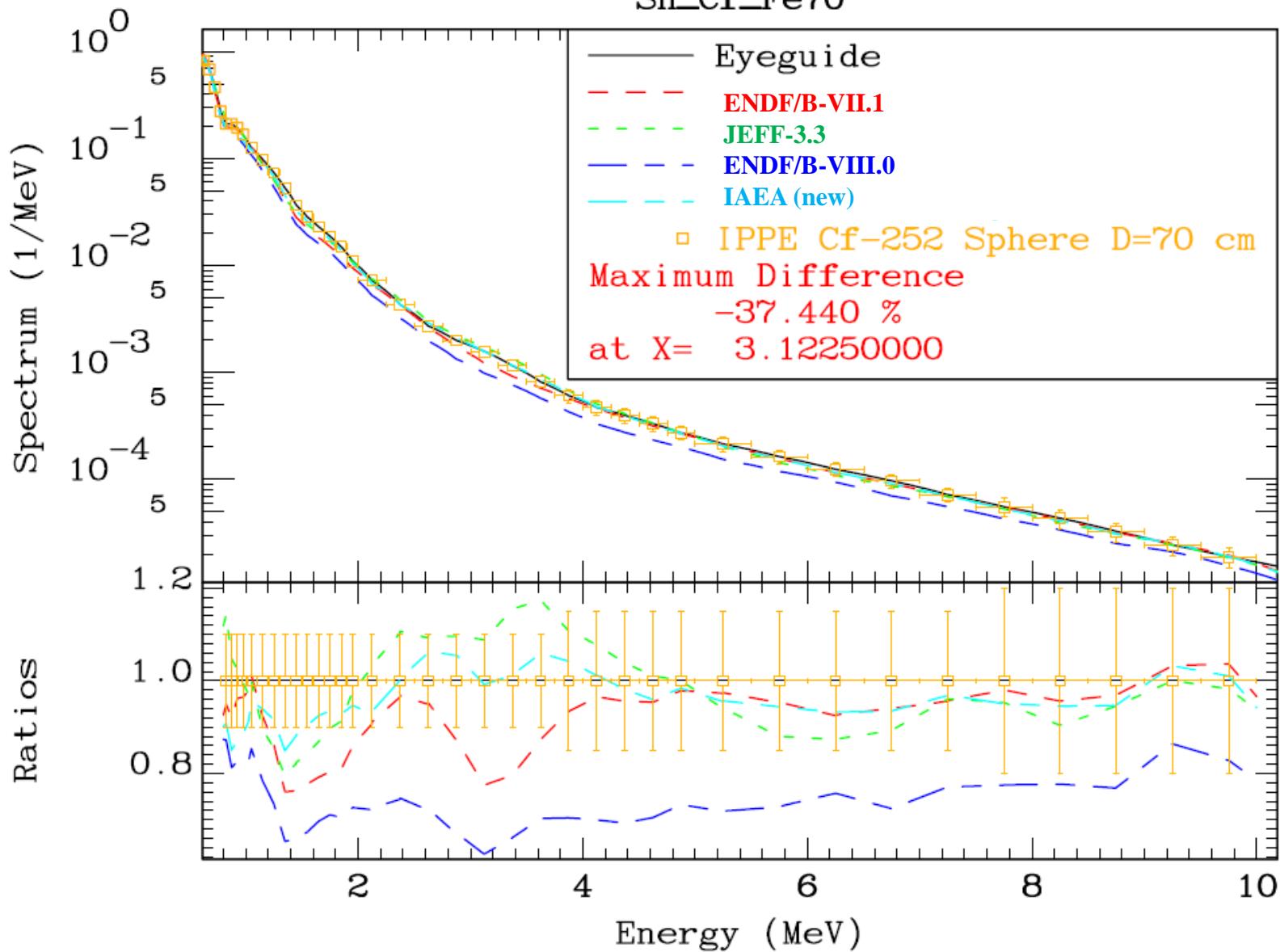
Differential experiments: σ_{inl}



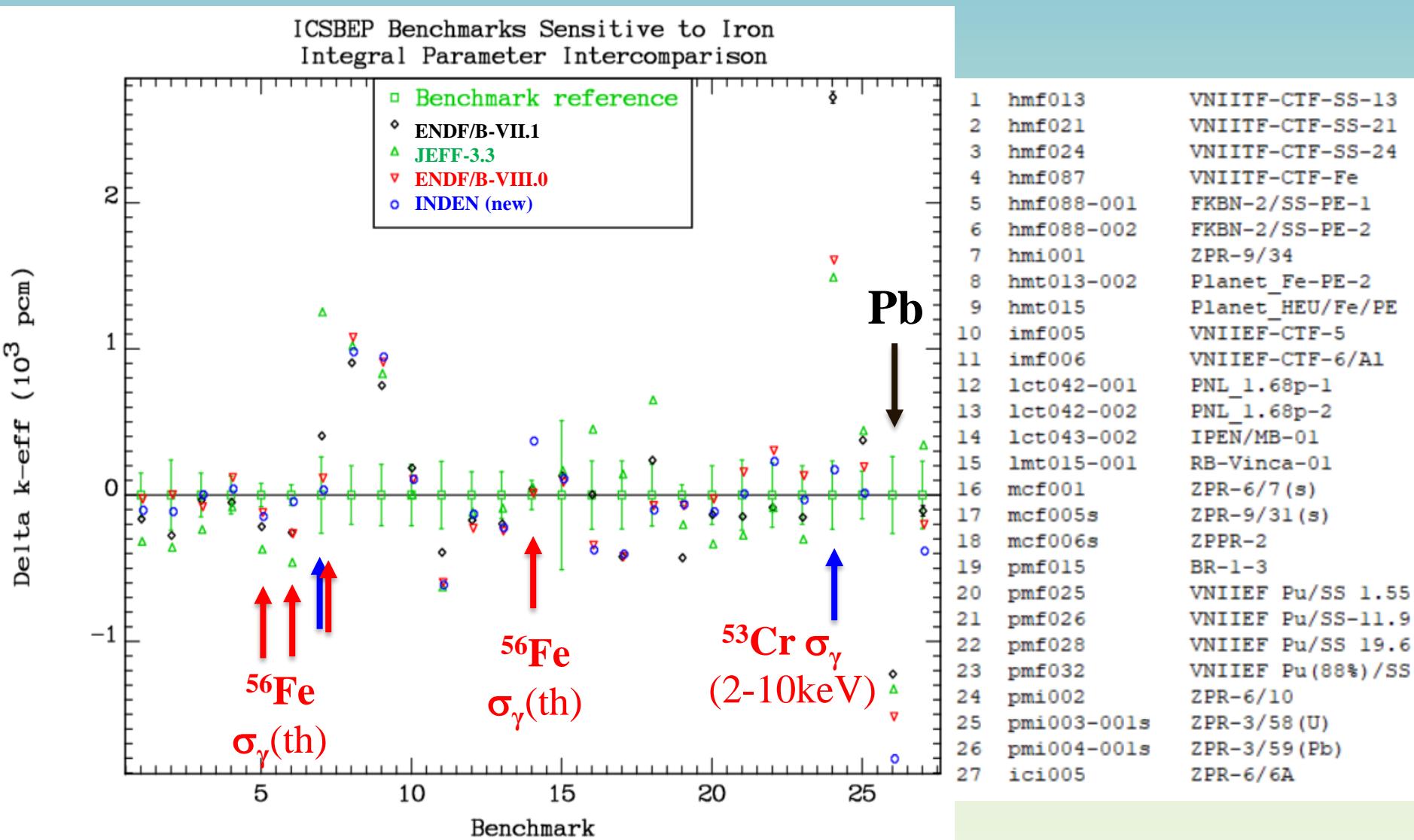
IPPE Sphere Leakage Spectrum Sh_Cf_Fe70



IPPE Sphere Leakage Spectrum Sh_Cf_Fe70



Criticality validation of IAEA $^{56}\text{Fe}/^{53}\text{Cr}$



Criticality validation of IAEA $^{56}\text{Fe}/^{53}\text{Cr}$

ENDF/B-VII.1
ENDF/B-VIII.0
IAEA new ^{53}Cr
exp. benchm. unc.

Δk_{eff}
KBR09

+4.6%

+3.0%

0

800 pcm

Δk_{eff}
KBR15

+11.0%

+11.9%

+2.5%

1600 pcm

SS

Cr



Conclusions

- ✓ New IAEA iron/ ^{53}Cr evaluations show improved performance both in criticality and shielding benchmarks
- ✓ Improvements in RRR evaluation methodology needed to address identified data problems without artificial backgrounds
- ✓ Work continues within the IAEA INDEN project

A new “INDEN” P3 position @ IAEA/NDS is available
THANKS !

