IAEA 60 Years Atoms for Peace and Development

INDEN evaluation of Fe isotopes and the ^{55}Mn update

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On behalf of the INDEN collaboration
@ https://www-nds.iaea.org/INDEN

Nuclear Data Week - CSWEG 2020 (virtual)
30 November –December 4, 2020, BNL, US NNDC

Problems identified in inelastic/capture gammas of many ENDF/B-VIII.0 evaluations

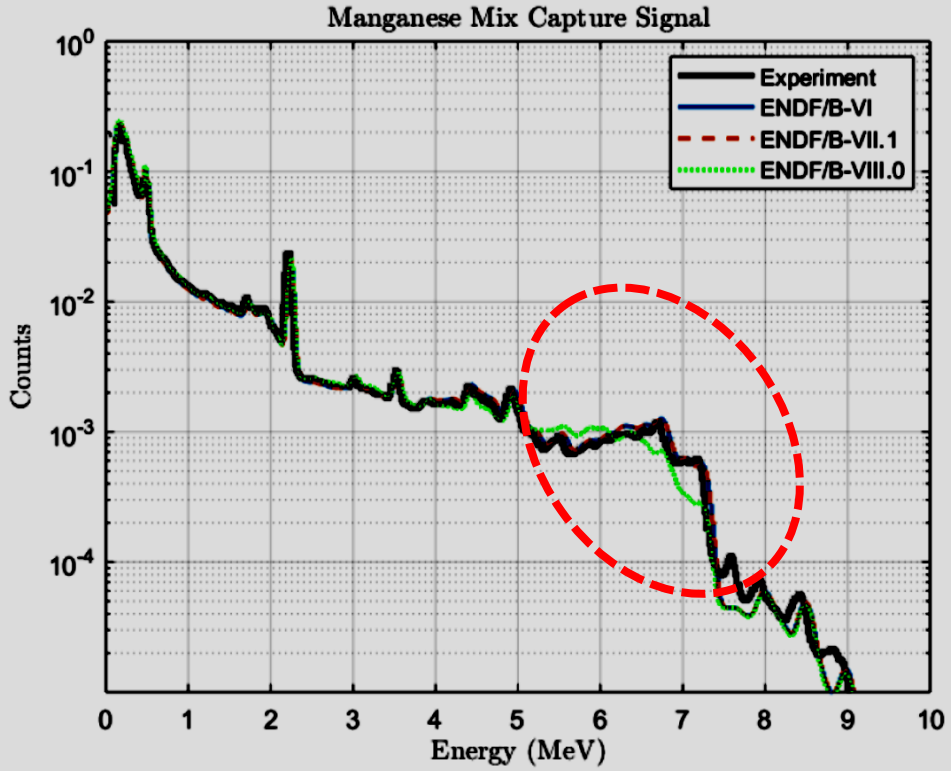

Fig. 9: Comparison of capture γ-ray spectra from the manganese mix from experiment and modeled with various libraries

Similar problems:
Si(n,n'γ),
Fe(n,γ), Fe(n,n'γ),
Mg(n,γ), Mg(n,n'γ),
Ti(n,γ), Ti(n,n'γ)

Hint:
ENDF/B-VI.8
was better for gammas

Marie-Laure Mauborgne et al, CSWEG 2019 & EPJ WoC **239** (2020) 20007 (ND2019)

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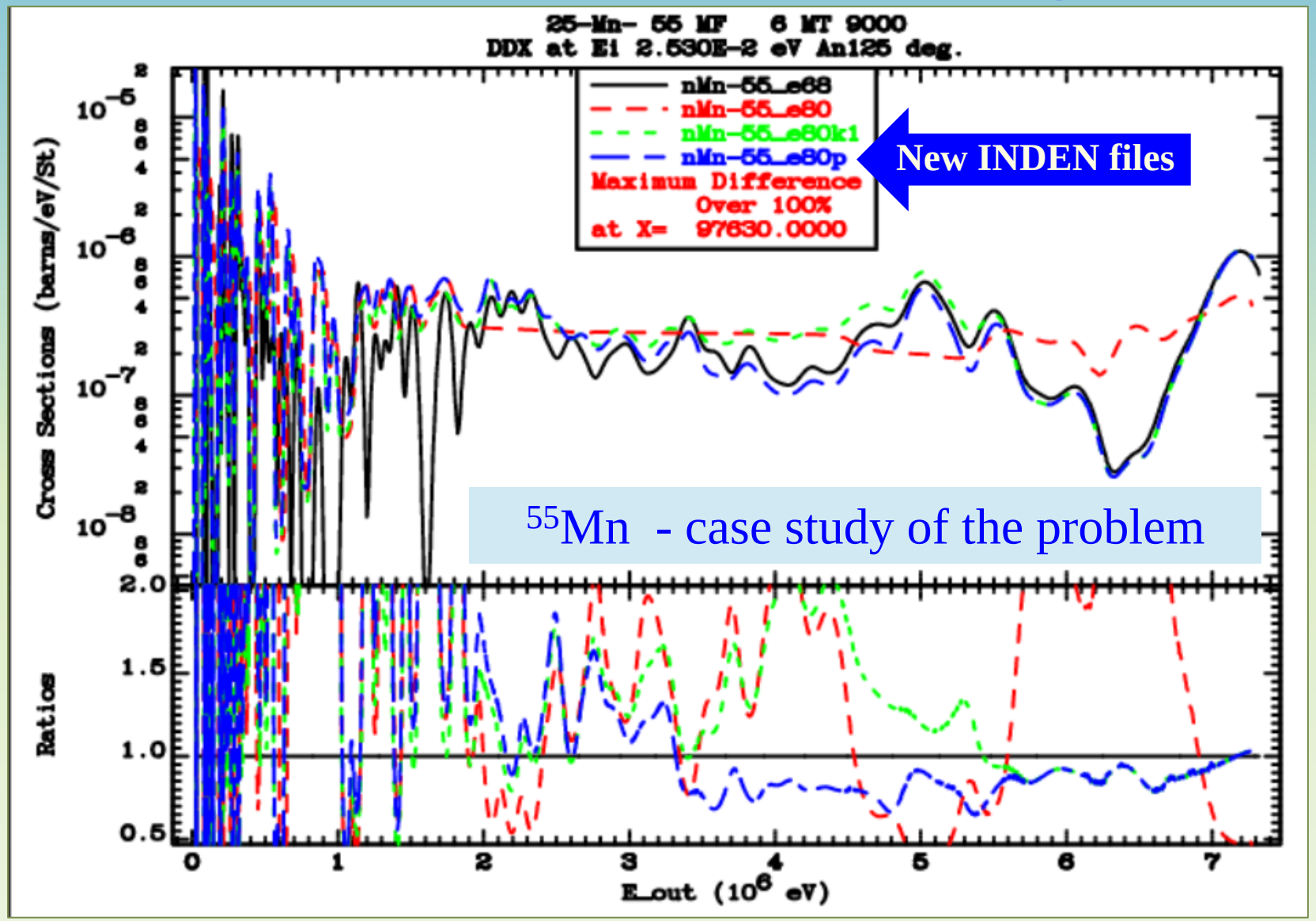
^{55}Mn update of thermal (n,γ) gammas



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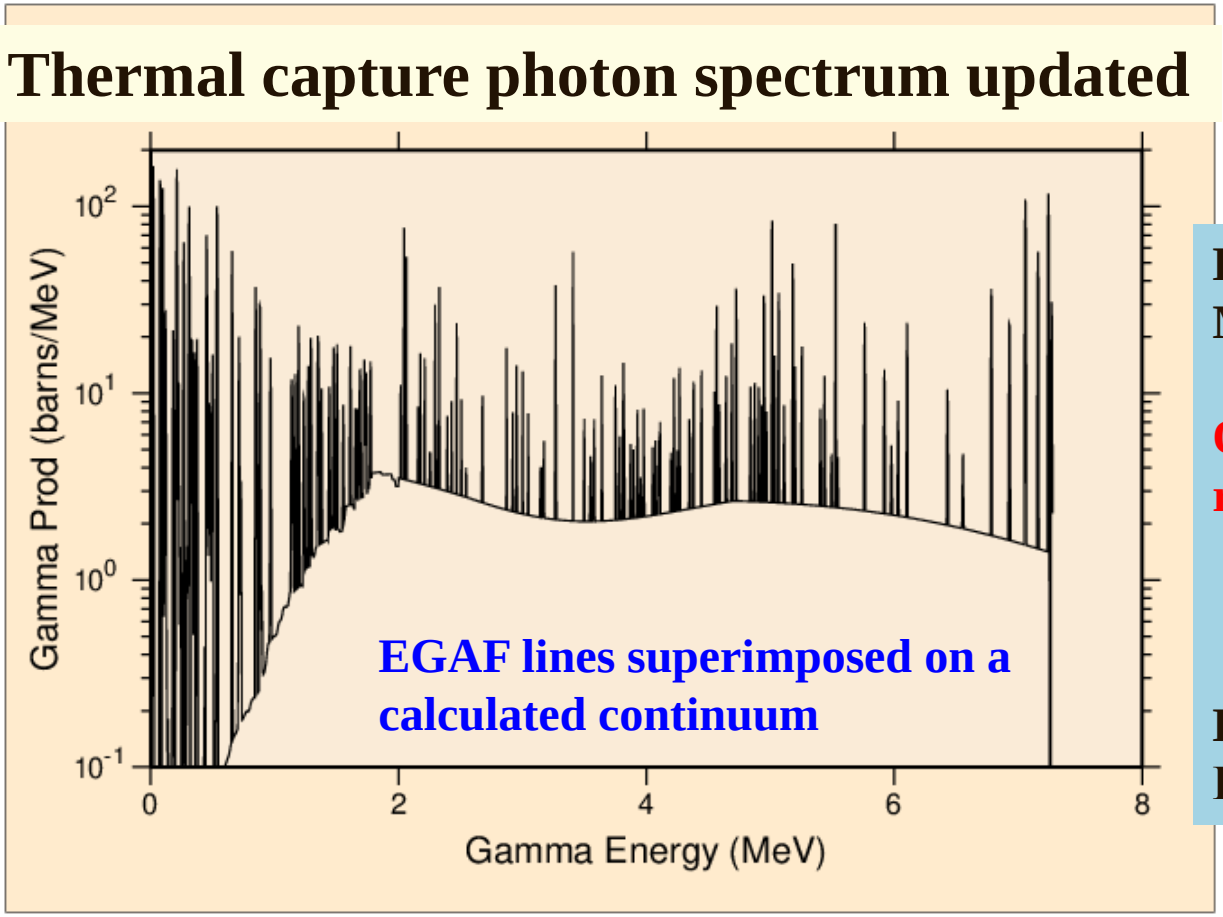
^{55}Mn update of thermal (n,γ) gammas

Thermal capture photon spectrum updated



EGAF IAEA database: Measured thermal capture γ

Quite challenging to reproduce via modelling

But very well measured ☺, Let's use it.

See description in INDC(NDS)-0810, performance restored

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^{55}Mn update of thermal (n,g) gammas

- Mn-55 evaluation in ENDF/B-VIII.0 was criticized for poor prediction of capture gamma spectra (Marie-Laure Mauborgne, CSEWG-2019, EPJ WoC **239**, 20007 (2020).
- The data are important for oil-well exploration.
- Using the information in the EGAF library and EMPIRE nuclear model calculations the gamma production data were improved. High resolution energy bins (~5 keV/bin)
- Good performance of updated file **mn55e80p** on proprietary benchmark was confirmed by Marie-Laure Mauborgne
- Documented in INDC(NDS)-0810 on "Evaluation of thermal capture gamma spectra"

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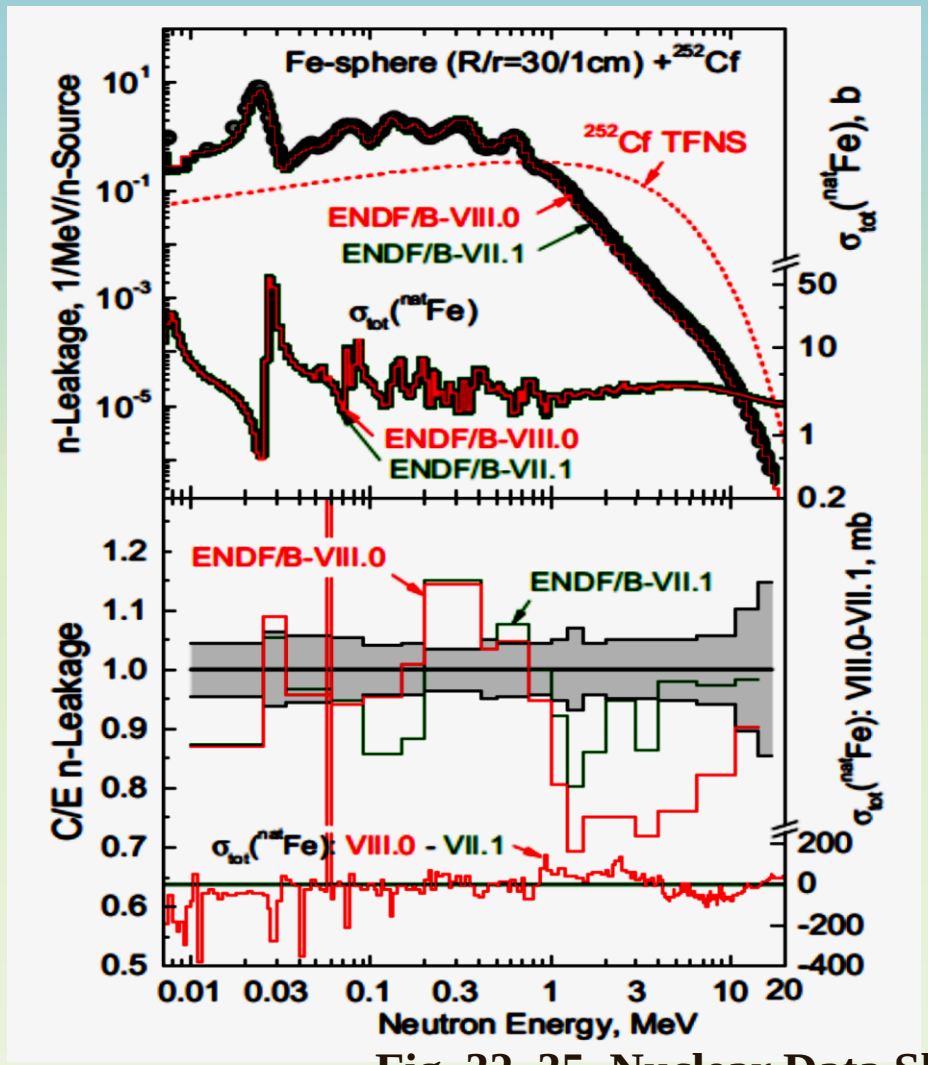
Problems with ENDF/B-VIII.0 (CIELO) ^{56}Fe

Up to 30% underestimation of neutron leakage for En=1-4 MeV



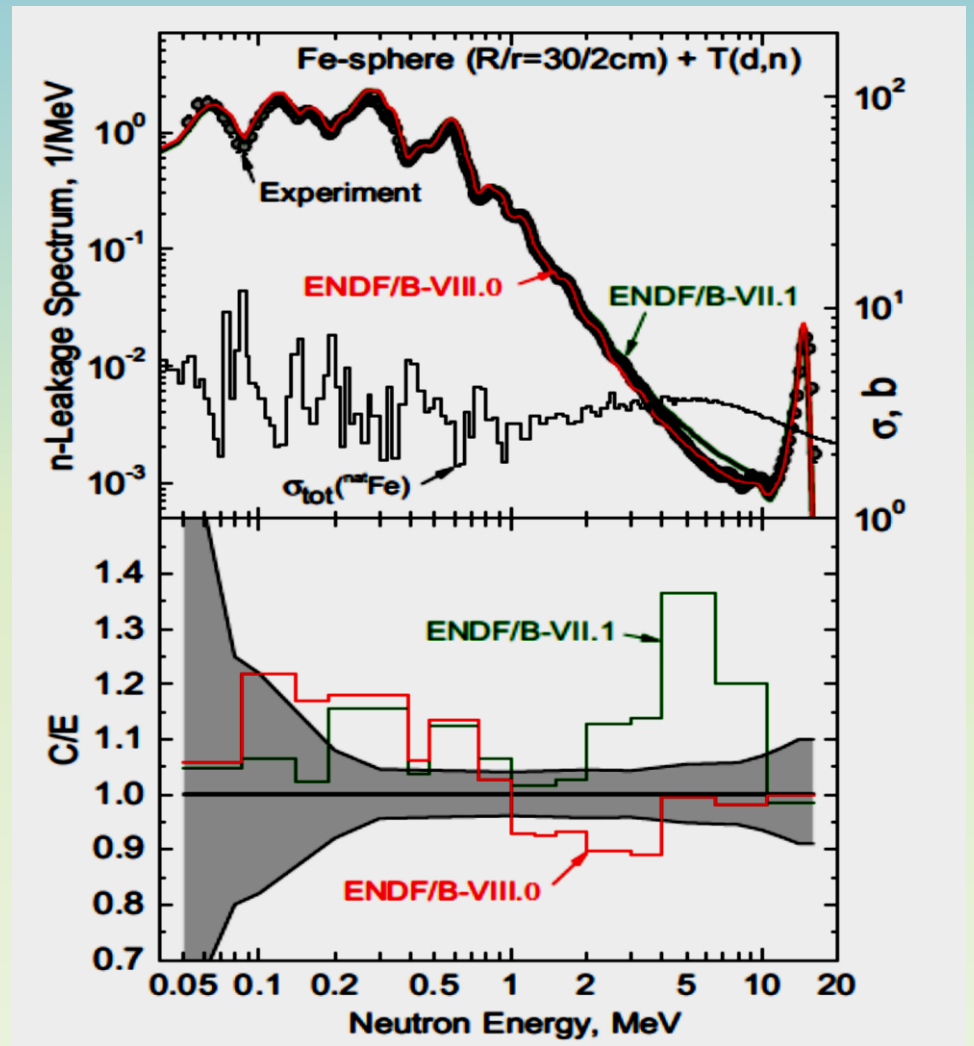


Fig. 32, 35, Nuclear Data Sheets,148 (2018) 214-253

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Fe 14 MeV – problem

Indep. confirmation

Polyethylene $(C_2H_4)_n$

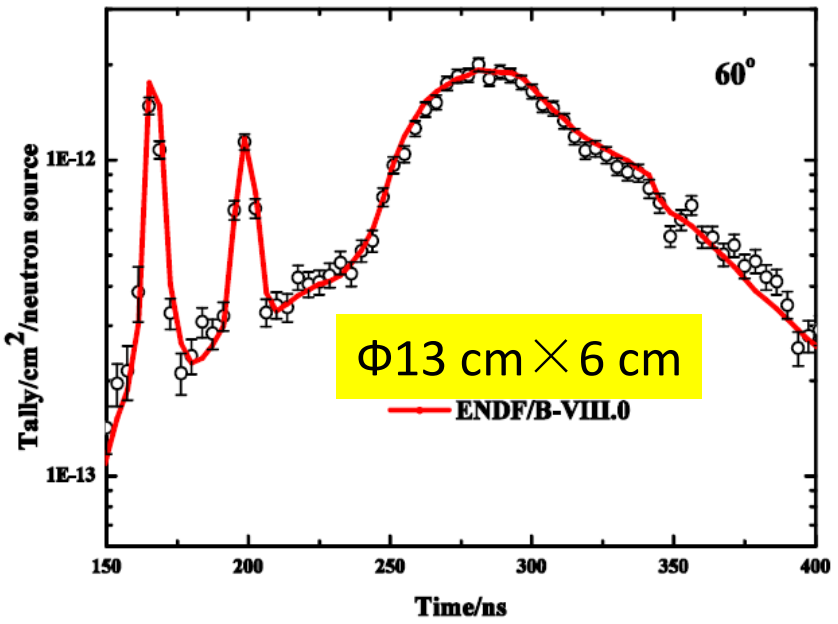
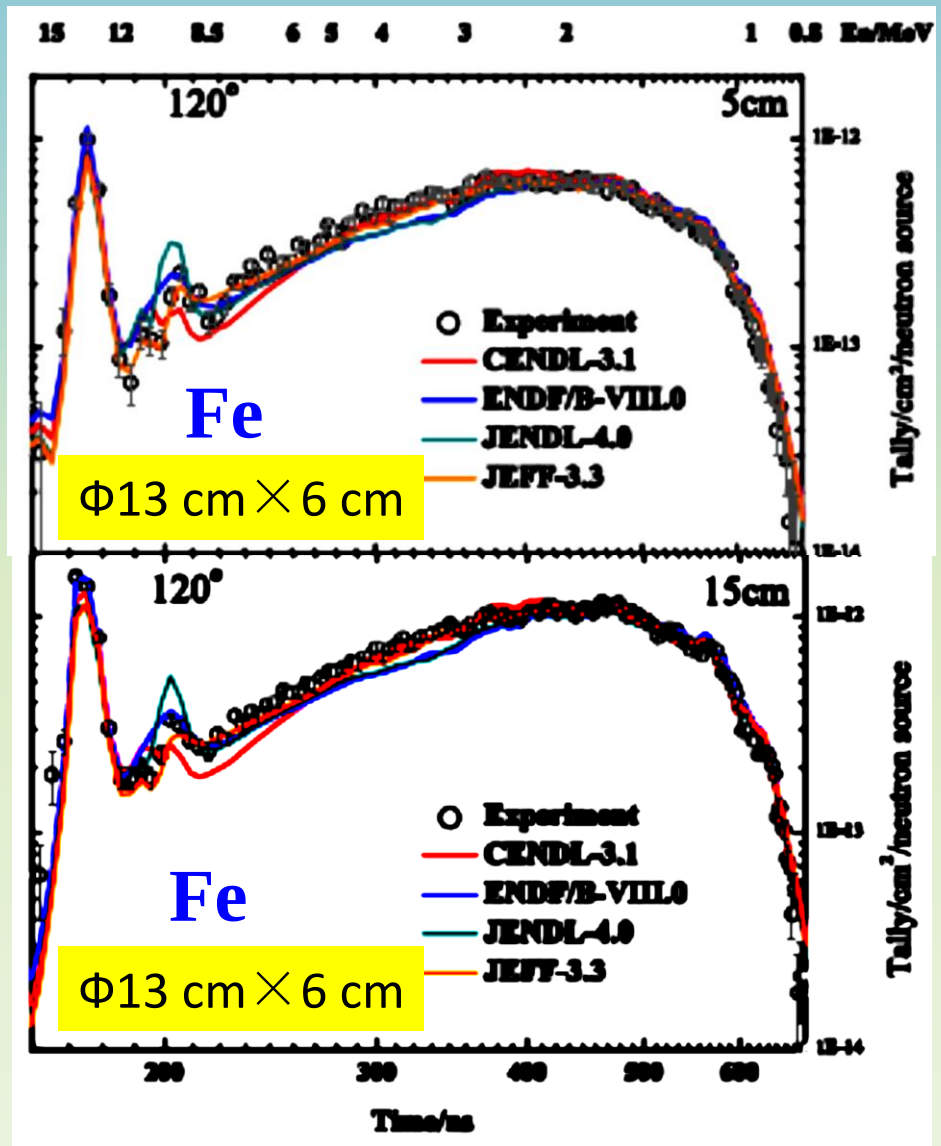


Fig.3 Leakage neutron spectrum from polyethylene sample at 60° (Φ13 cm×6 cm)



Y. Ding et al. EPJ WoC **239** (2020) 18010 (ND2019)

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^{252}Cf(sf) neutron leakage: 100 cm sphere

Up to 30% overestimation of neutron leakage for En~300 keV

B. Jansky et al., CVR, Rez, Czechia,EPJ WoC **239** (2020) 18005 (ND2019)

En [MeV]		C/E ratio	
From	To	CIELO	JEFF-3.2T2
0.013	**1.290**	**1.0450**	**1.0520**
0.013	0.033	0.9138	0.9958
0.033	0.060	0.9005	1.0190
0.060	0.090	0.9702	0.9894
0.090	0.150	0.9934	1.0070
0.150	0.200	1.0370	1.0070
0.200	0.250	1.0280	1.0130
0.250	0.289	1.0360	1.0050
0.289	0.333	1.3330	1.2290
0.333	0.367	1.3050	1.2680
0.367	0.410	1.1910	1.1710
0.410	0.520	1.0330	1.0810
0.520	0.780	1.0890	1.0620
0.780	1.060	0.7834	1.0490
1.060	1.290	0.7584	0.8654

D abs<5% D=5-10% D<-10%

H-proportional detector (HPD)

Figure 4. Comparison of calculated and measured spectra - assembly FE100R53,“ HPD region”, E: HPD, C: CIELO, JEFF, IND-R22 and IND-R34.

En [MeV]		C/E ratio	
From	To	CIELO	JEFF-3.2T2
1.0	**10.0**	**0.859**	**0.992**
0.8	0.9	0.921	1.120
0.9	1.0	0.957	1.080
1.0	1.2	0.874	0.941
1.2	1.4	0.868	0.971
1.4	1.6	0.773	0.901
1.6	1.8	0.893	1.032
1.8	2.0	0.913	1.095
2.0	3.0	0.852	1.114
3.0	4.0	0.817	1.193
4.0	5.0	0.843	1.120
5.0	6.0	0.857	1.022
6.0	7.0	0.874	1.029
7.0	8.0	0.878	1.040
8.0	9.0	0.940	1.110
9.0	10.0	0.912	1.058
10.0	12.0	0.895	0.975
12.0	14.0	0.799	0.803
14.0	16.0	0.672	0.638

D abs<5% D=5-10% D<-10%

stilbene detector

Figure 6. Comparison of calculated and measured spectra - assembly FE50R100,“stilbene region”, E: averaged from 4 measurement, C: CIELO, JEFF-3.2T2, IND-R22, IND-R34.

Note that ENDF/B-VIII.0 Fe = CIELO

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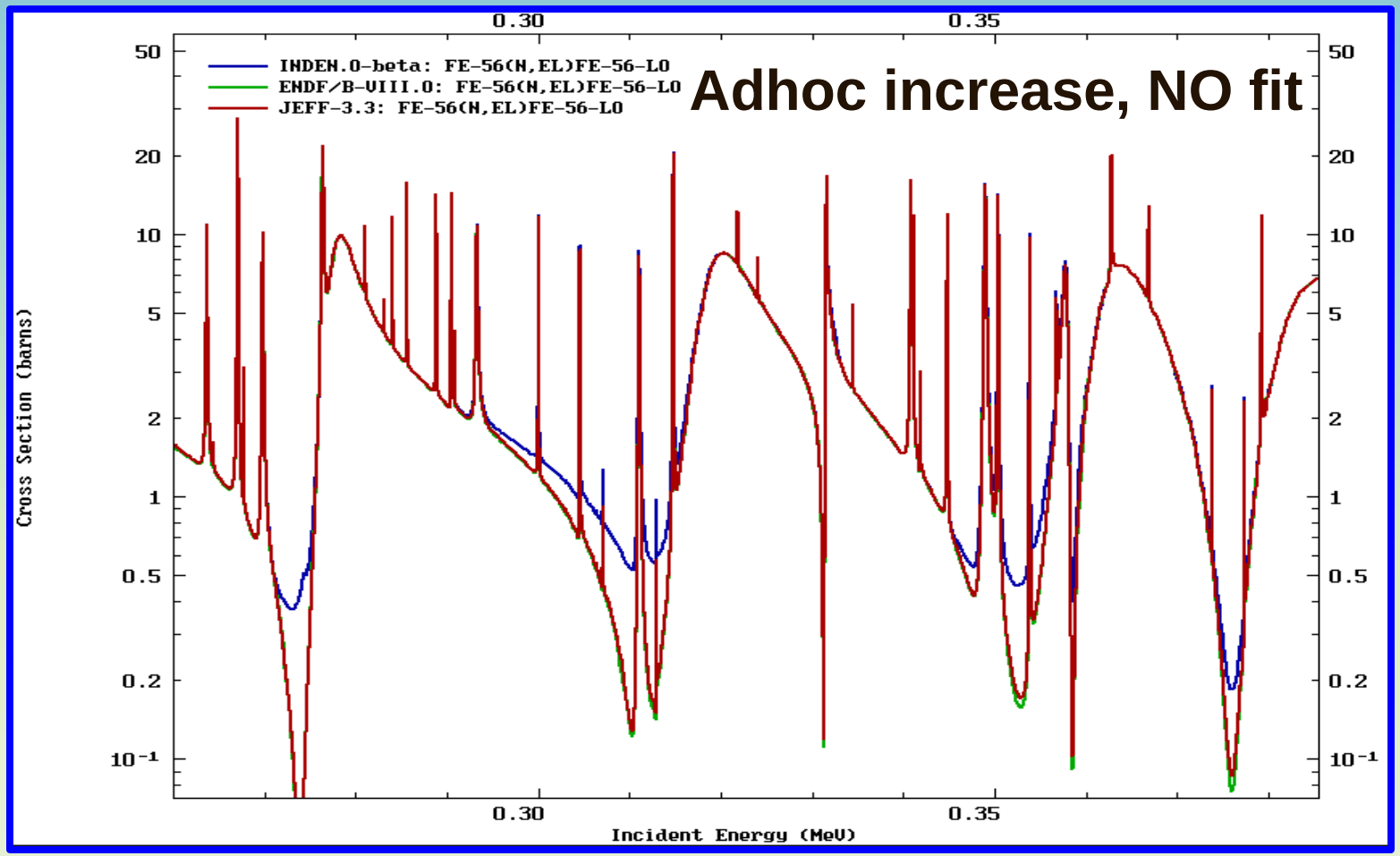
Patching the Fe-56 evaluation: EL (1)



(n,el) minima poorly described (27 keV,~300keV, ...)

Sensitive to transmission through thick samples (>5 cm)

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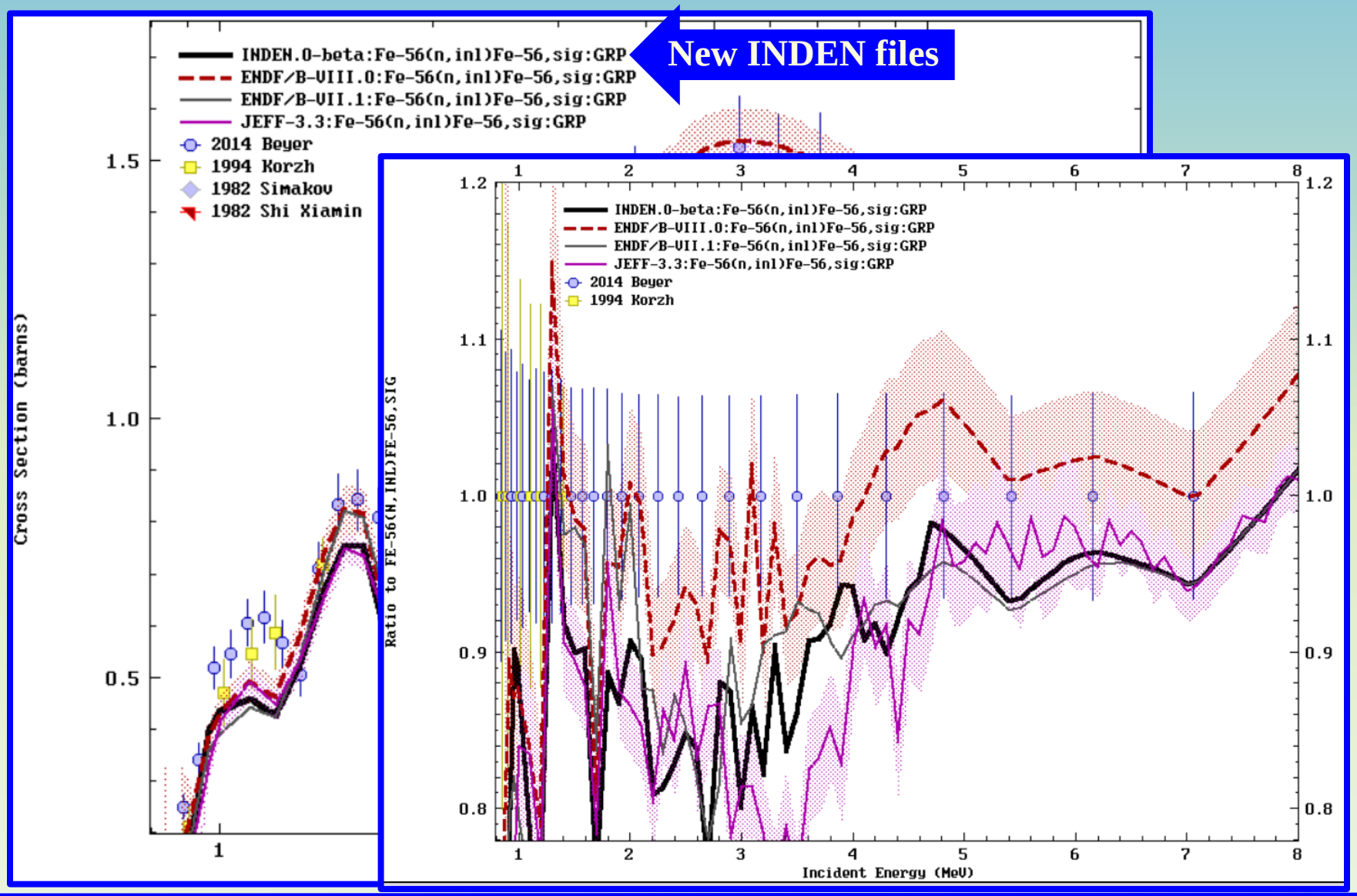
Patching the Fe-56 evaluation: INEL (2)



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Improvements to ^{56}Fe evaluation

- Total cross sections are trusted
- New measurements by E. Pirovano at IRMM support a higher elastic cross section
- Capture is too small to play a role

  →Conclusion: measured inelastic likely too high
- Inelastic cross section was scaled down by 10-15%, assigning the difference to elastic (exact comparison of cross sections is difficult due to strong fluctuations)
- Elastic minima were filled to reproduce observed transmission. A proper R-matrix fit will be appreciated.

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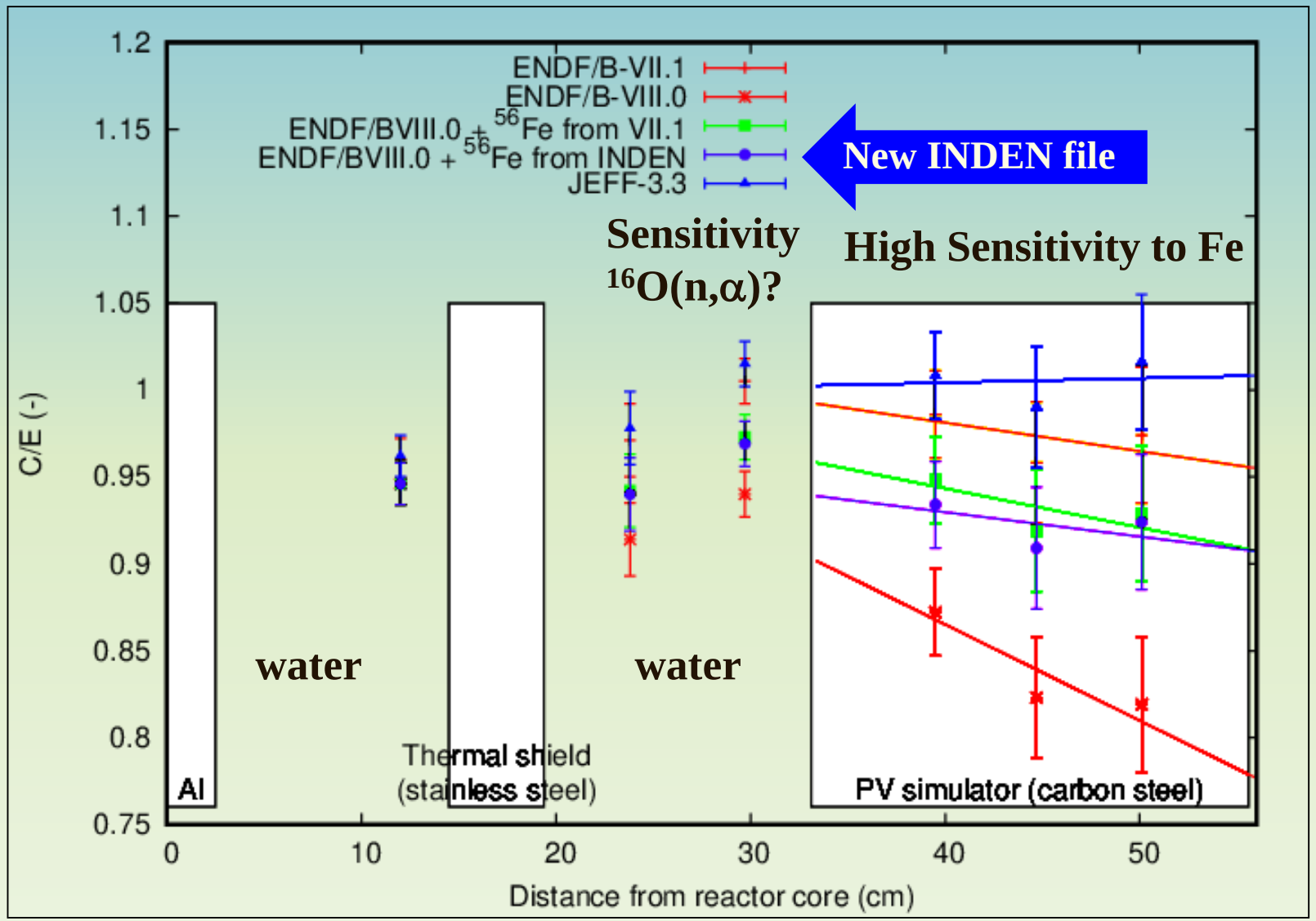
PCA reactor benchmark

Courtesy of Steven van der Marck (priv. comm.)



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Conclusions

- INDEN interactions strongly helped to find deficiencies in existing evaluations and highlight potential solutions to existing challenges: https://www-nds.iaea.org/INDEN/

- Updated evaluations for Mn-55, Fe-56, and Fe-57 (inelastic) are available for testing.
- Reduced inelastic in Fe-56 deserves further experimental and/or theoretical investigations
- New R-matrix fit that reproduces fitted minima of the elastic cross-section of Fe-56 desirable.
- Mn-55 updated evaluation was tested on a relevant proprietary benchmark. Significant improvement was demonstrated.
- See Trkov/Capote presentation tomorrow for additional validation

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Back-up

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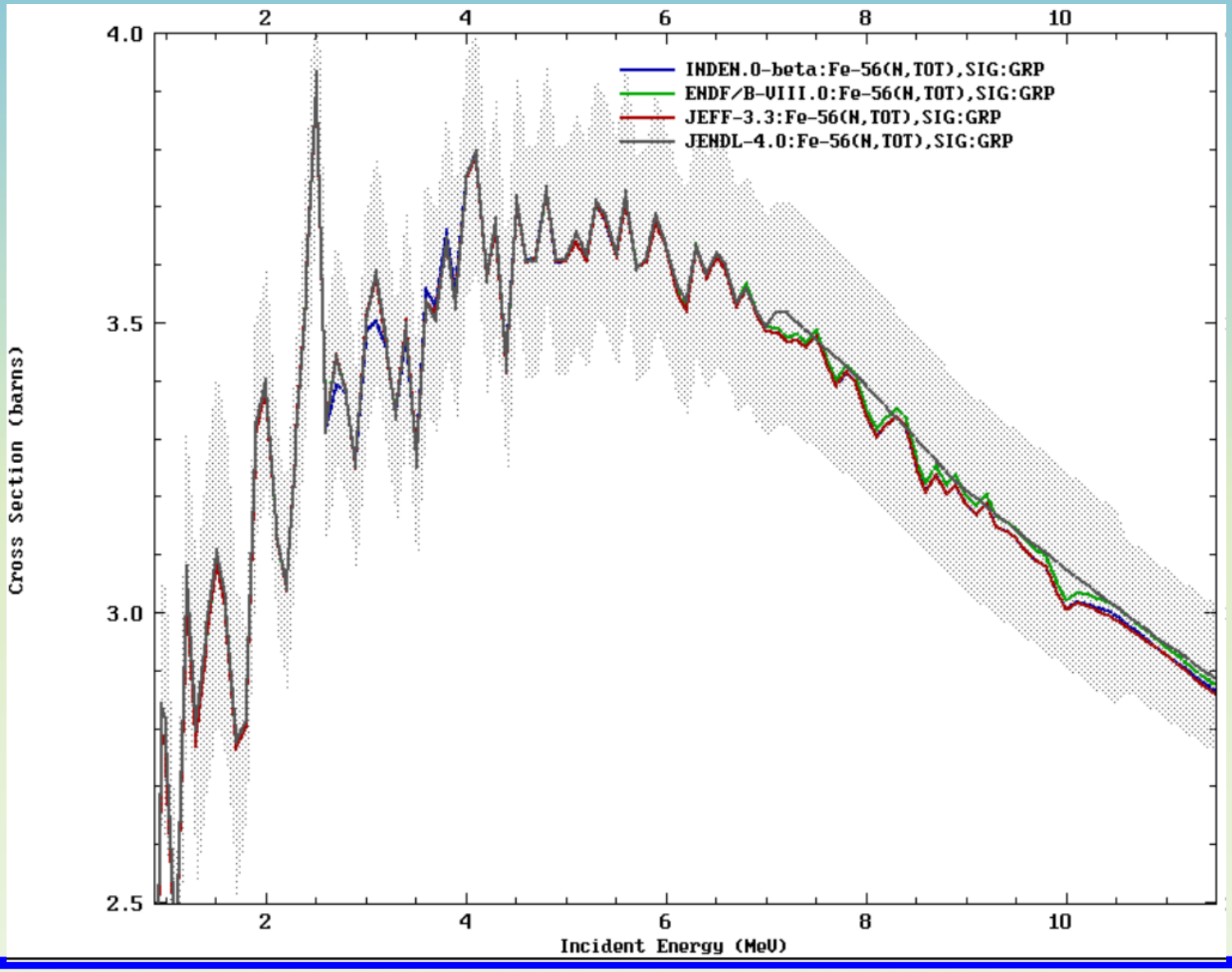

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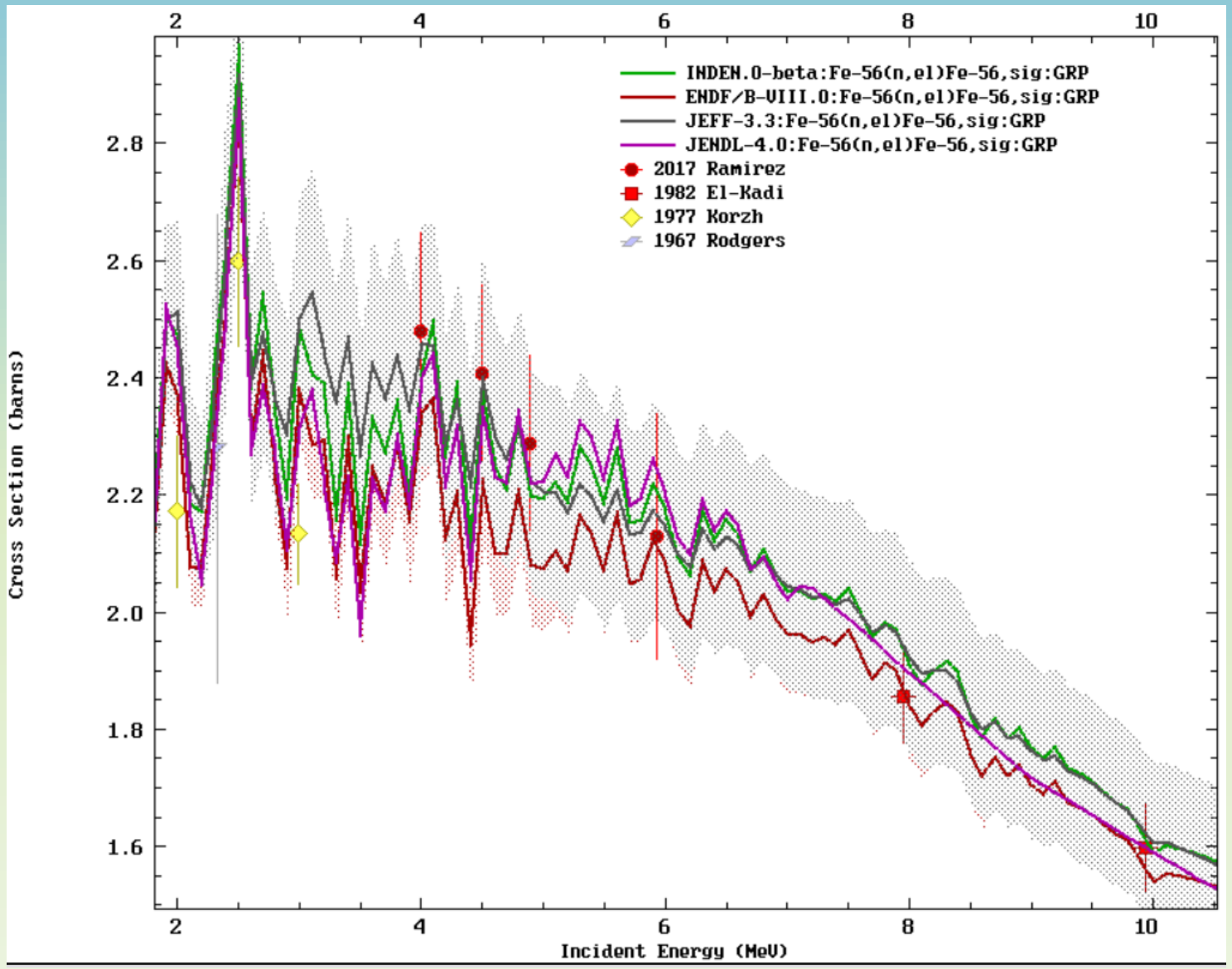

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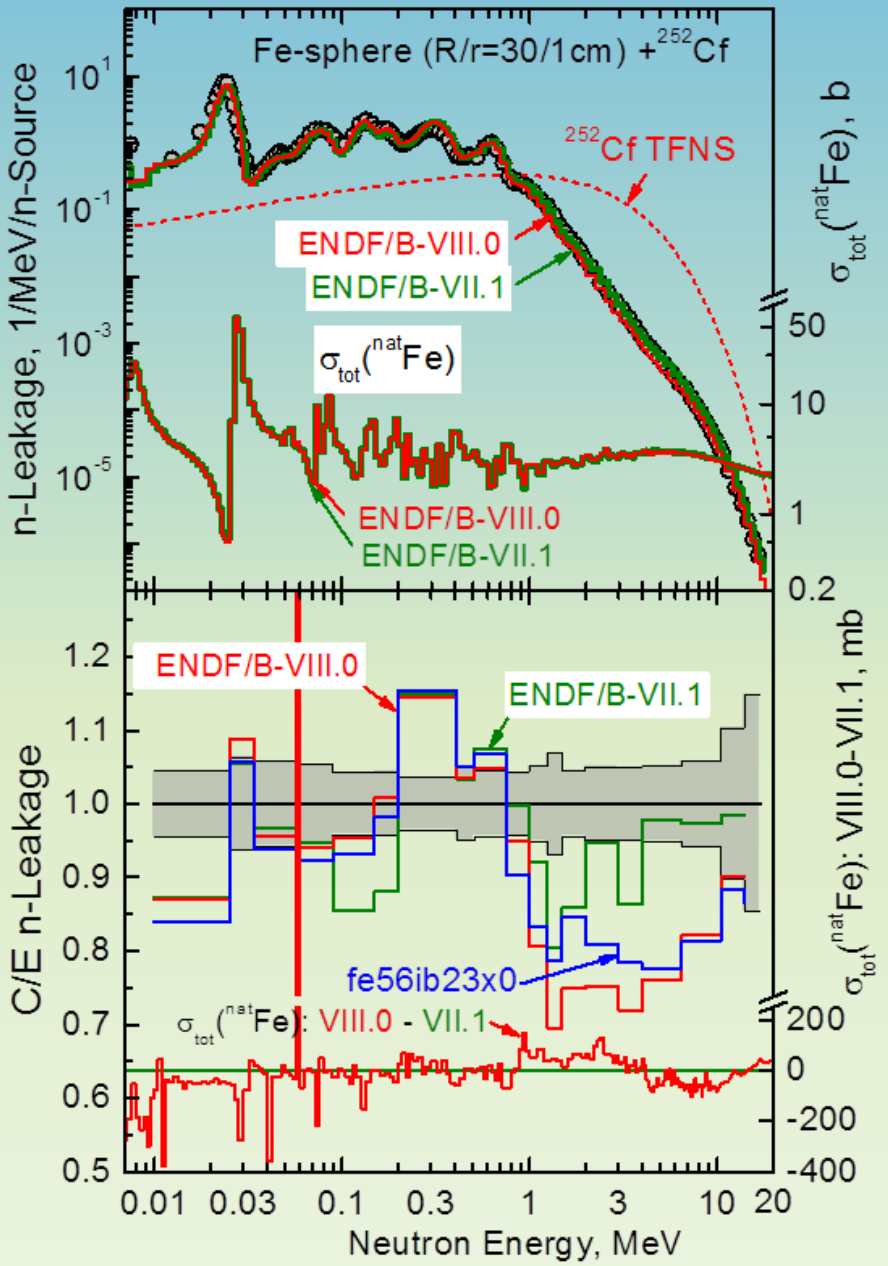
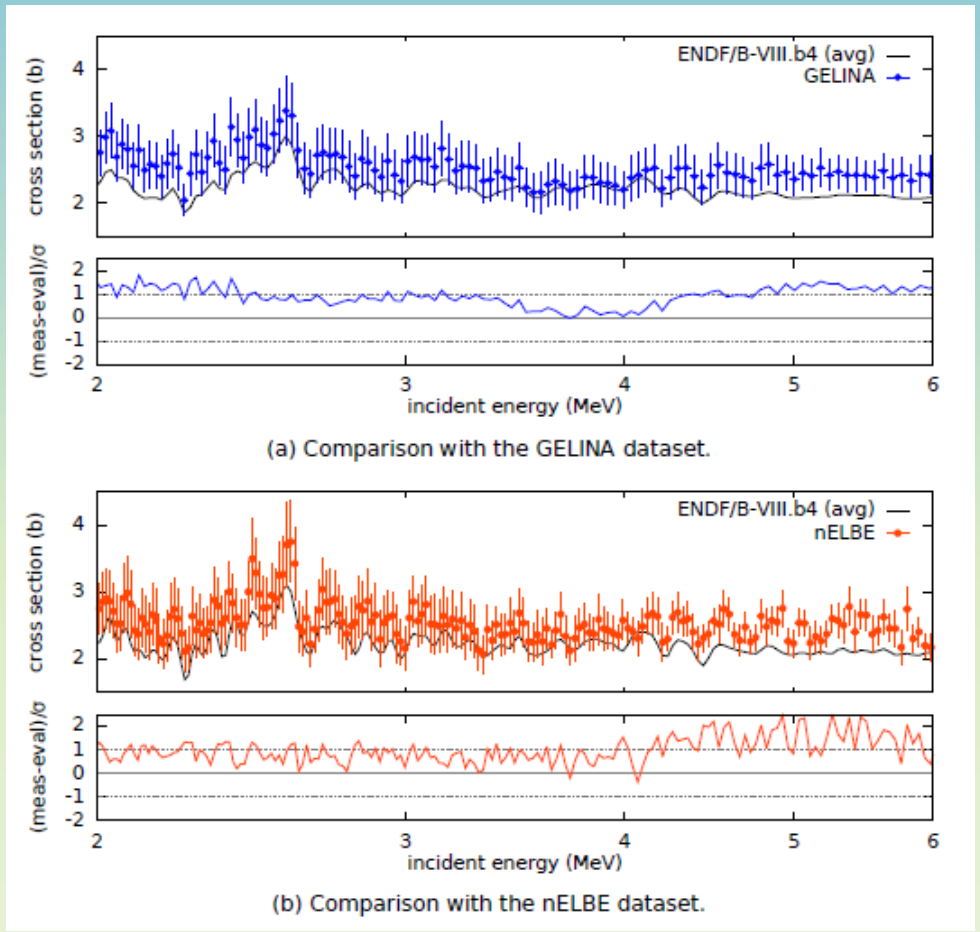
^{56}Fe evaluation





New measurements ^{56}Fe(n,el)
E. Pirovano et al, JRC Geel

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