Cross sections and covariance data through international collaboration

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Objective

- Describe evaluation methodology
- Describe methodology for producing covariances up to 150 MeV
- Apply methods on:
  - Th-232
  - Pa-231,233
  - W isotopes (including ^{180}W)
  - Mn-55

Evaluation procedure

- Select EMPIRE calculation options
- Define model parameters (iteratively)

- Generate covariance prior by MC with EMPIRE
- Adjust cross sections and covariances by GLSQ with GANDR
- Perform verification and validation

^{232}Th – Current status

- MF1/MT451: Corrections & clarification
- MF1/MT458: added
- MF3/all reactions: small differences due to refinements in GANDR
- MF32/MT151: setting ISR=0
- MF33/MT2: fully correlated uncertainty added to account for ignored contributions (e.g. scattering radius uncertainty)

^{232}Th - Validation

- Broad-group average cross sections
- Integral benchmarks

3-group average cross sections

- E-breakpoints: 1e-4, 0.55, 2e6, 20e6 eV
- Spectrum 293.6K thermal up to 0.25 eV, 1/E up to 2 MeV, fission spectrum tail (kT=1.4 MeV)

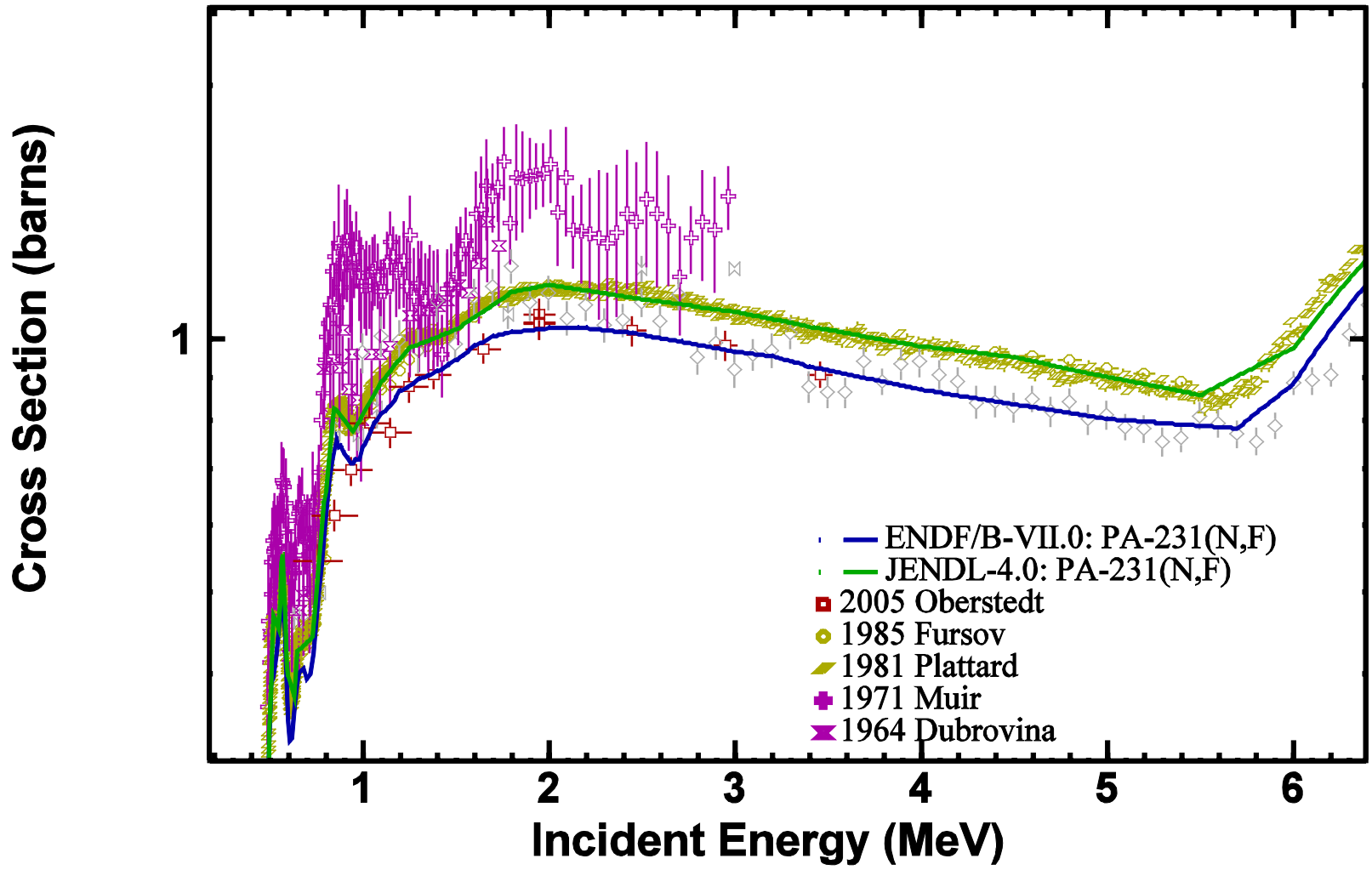
MT	Sig_th [b]	Sig_e [b]	Sig_f [b]
1	18.4 1.6%	24.8 2.0%	8.73 1.7%
2	13.0 2.2%	17.9 2.7%	6.59 2.4%
18			.0434 2.1%
102	5.17 1.5%	6.91 1.9%	0.125 11%
16+24+41			.0122 20%

Comparison with measured values

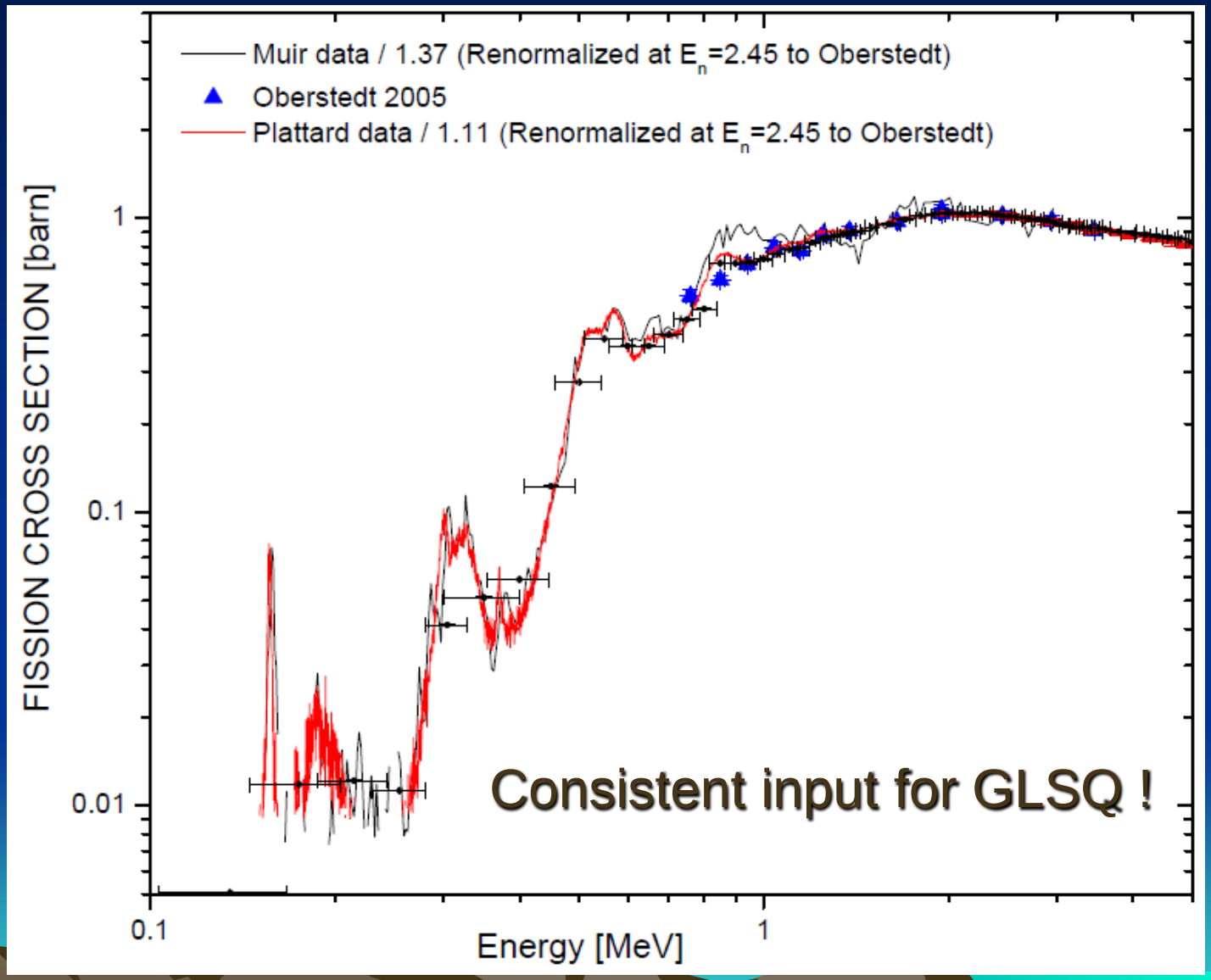
- Ref. Kayzero database: Sig_0, Q_0=RI/Sig_0
- EXFOR: Sig_Cf

Reaction	Measured	C/E-1
Sig_0(n,g) [b]	7.37 0.34 %	-0.4 1.5%
Q0(n,g)	11.53 3.6 %	-0.5 2.4%
Sig_Cf(n,g) [b]	0.0891 2.4 % (?)	+2.4 12 %
Sig_Cf(n,f) [b]	0.0829 9.1 % (?)	-4.5 2.1 %

^{231,233}Pa – Current status



^{231}Pa – Renormalized EXFOR



W-isotopes - Status

- Cross-sections essentially unchanged
- Work on covariances to include elemental cross section measurements
- Validation results – big improvement compared to ENDF/B-VI.8, but criticality is overpredicted; some problems with ^{55}Mn activation in FNG-W benchmark
- LLNL EGAF levels to be used …
- New resonance measurements at Geel …

^{55}Mn - Status of existing files

- Limited to 20 MeV
- All recent evaluations adopt the same cross section data
- No covariances except an ad-hoc evaluation in IRDF-2002, and model-based covariances in TENDL
- RI inconsistent with Kayzero
- Problem with FNG-W benchmark Mn foil activation measurement

^{55}Mn - Empire-3 options

- Direct interaction cross sections - coupled channel formalism (CC)
- Emerging channels – spherical OM
- Non-coupled levels by DWBA
- Pre-equilibrium emission by exciton model
- Width fluctuation by HRTW (Hofmann, Richert, Tepel, Weidenmueller)
- Radiative strength function - Modified Lorenzian
- Level densities - Enhanced Generalized Superfluid Model (RIPL-3 EGSM)

^{55}Mn - Model parameters

- New dispersive CC OMP (RIPL 1484)
- Selection of No. of discrete levels for residuals

^{55}Mn - Covariance prior

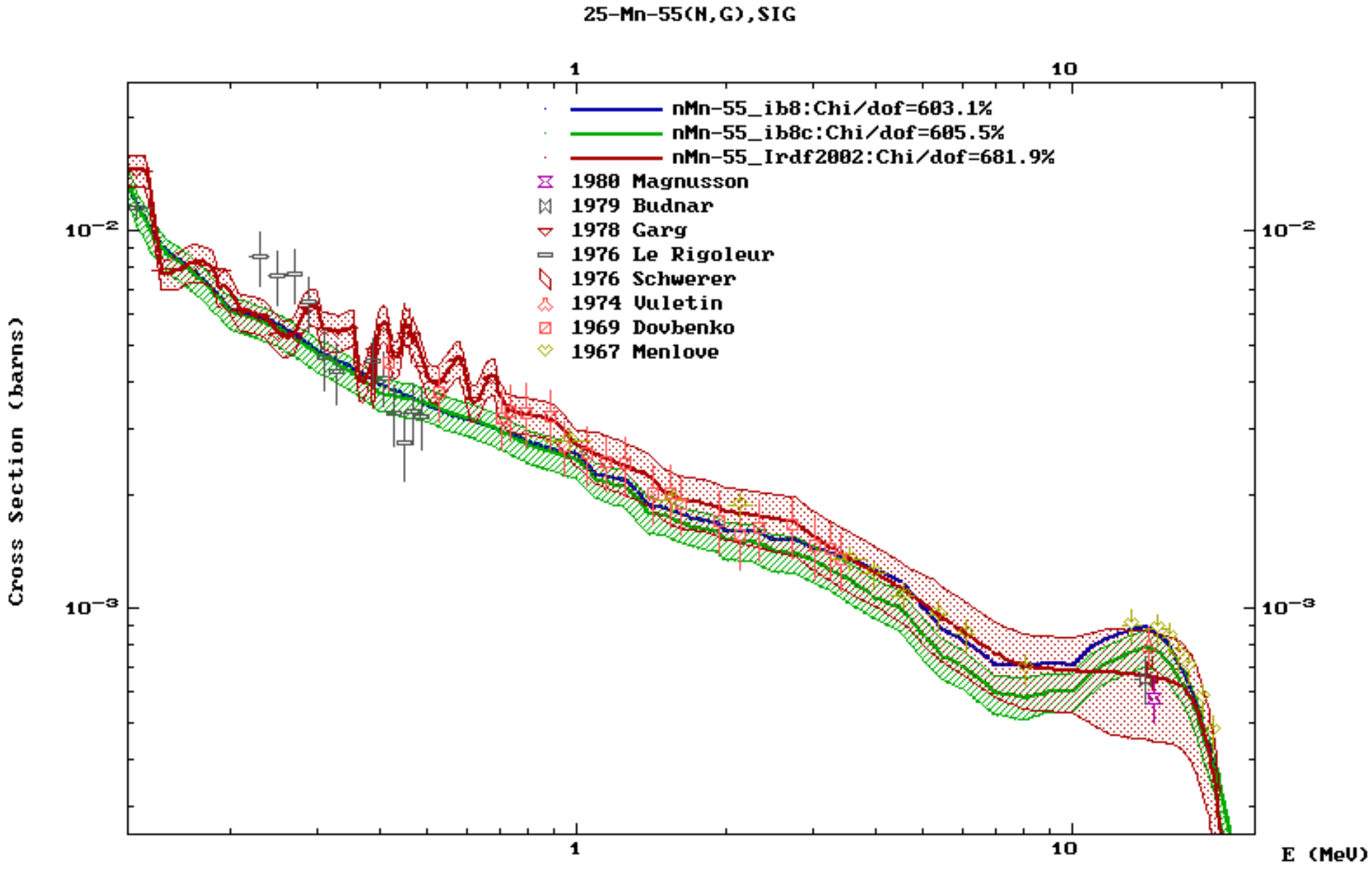
- Random sampling of parameters (500-1000 samples)
- Equal number of ENDF files
- Covariance matrix of GANDR reactions on fixed energy grid (up to 700 parameters)
- P1-P3 scattering for elastic and P1 for first discrete inelastic
- Emission spectra can be included (not used at present, except for fission)

^{55}Mn - GLSQ adjustment

Selected capture data from EXFOR included

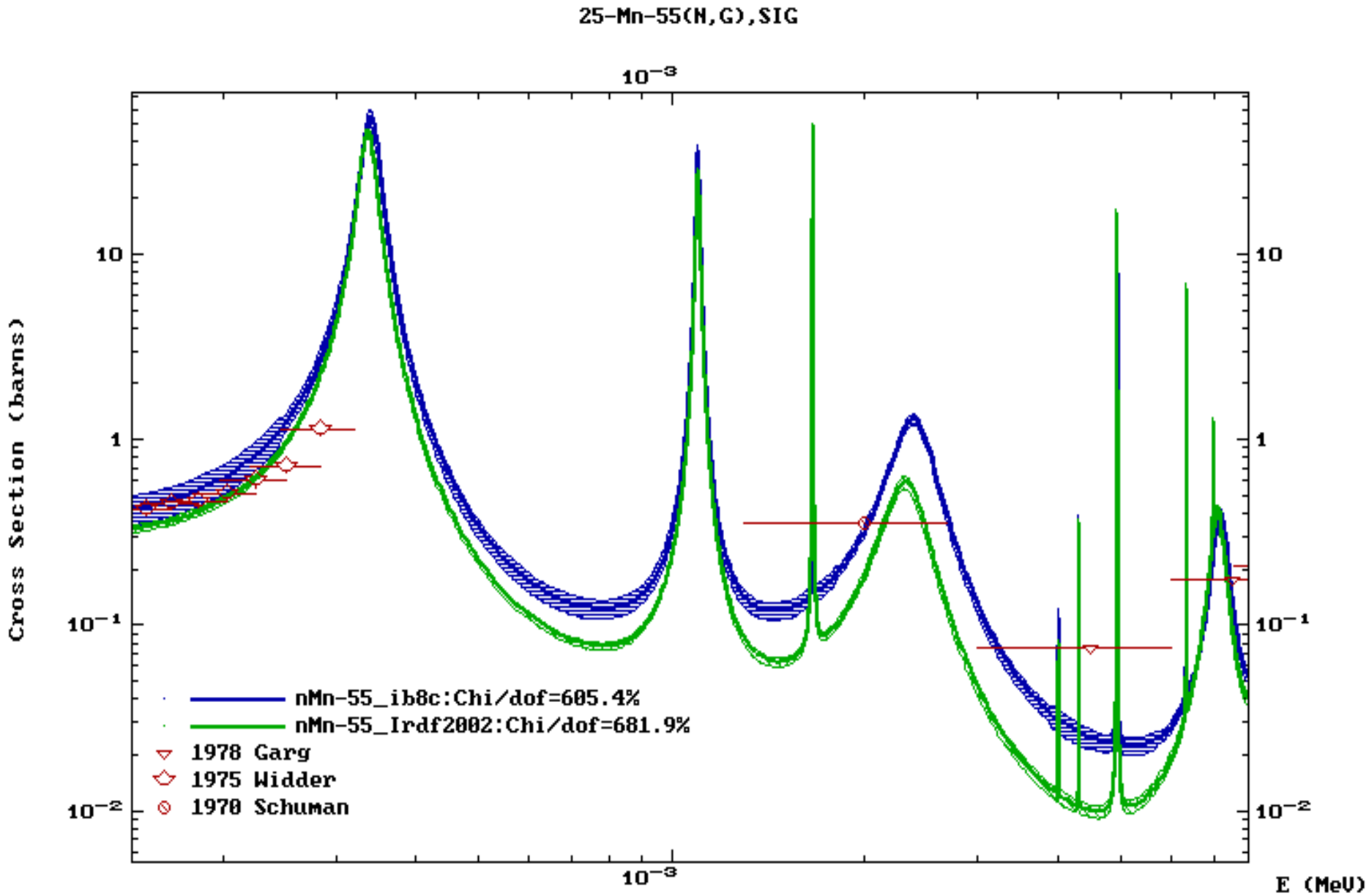
```
A.G.DOVBENKO,ET.AL. (69) 40001  2  (22)
H.O.MENLOVE,ET.AL.  (67) 11420  3  (17)
M.Budnar,ET.AL.     (79) 30532 20  E=14.1 MeV
J.Vuletin,ET.AL.    (74) 30314  5  E=14.4 MeV
O.SCHWERER,ET.AL.   (76) 20670  6  E=14.6 MeV
G.MAGNUSSON,ET.AL.  (80) 21004  2  E=14.7 MeV
J.B.GARG,ET.AL.     (78) 10752  4  E>100 keV
C.LE RIGOLEUR,ET.AL.(76) 20572  5  E>100 keV
```

Reasons for rejecting other data given in the comments
(Decision might be reversed in future work)


25-Mn-55(N,G),SIG
nMn-55_ib8:Chi/dof=603.1%
nMn-55_ib8c:Chi/dof=605.5%
nMn-55_Irdf2002:Chi/dof=681.9%
1980 Magnusson
1979 Budnar
1978 Garg
1976 Le Rigoleur
1976 Schwerer
1974 Vuletin
1969 Dovbenko
1967 Menlove
Cross Section (barns)
E (MeV)
1
10
10^{-2}
10^{-3}

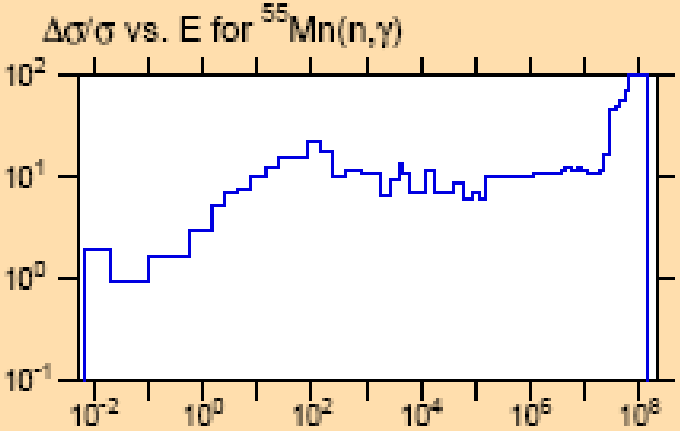
Resonance data

- H. Derrien et al., PHYSOR 2008


25-Mn-55(N,G),SIG
Cross Section (barns)
E (MeV)
nMn-55_ib8c:Chi/dof=605.4%
nMn-55_Irdf2002:Chi/dof=681.9%
1978 Garg
1975 Widder
1970 Schuman

Final covariance matrix

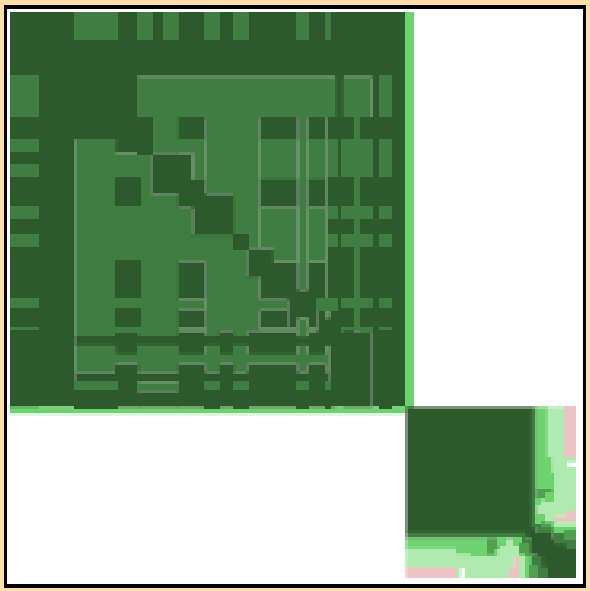
- Prior by MC sampling of model parameters with EMPIRE-3
- GANDR adjustment of cross sections and covariances by GLSQ



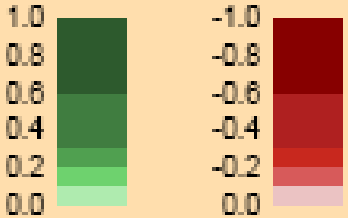
Ordinate scales are % relative standard deviation and barns.

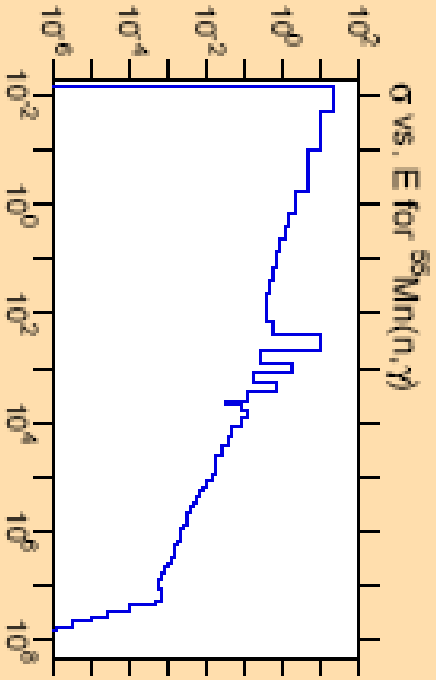
Abscissa scales are energy (eV).

Warning: some uncertainty data were suppressed.



Correlation Matrix





Verification and validation

- Formal correctness
  - CHECKR, FIZCON, PSYCHE, Pre-Pro
- Thermal capture and resonance integral
- Cf-252 spectrum averaged cross section
- FNG-W Mn-55 foil activation
- Oktavian Mn sphere leakage spectrum

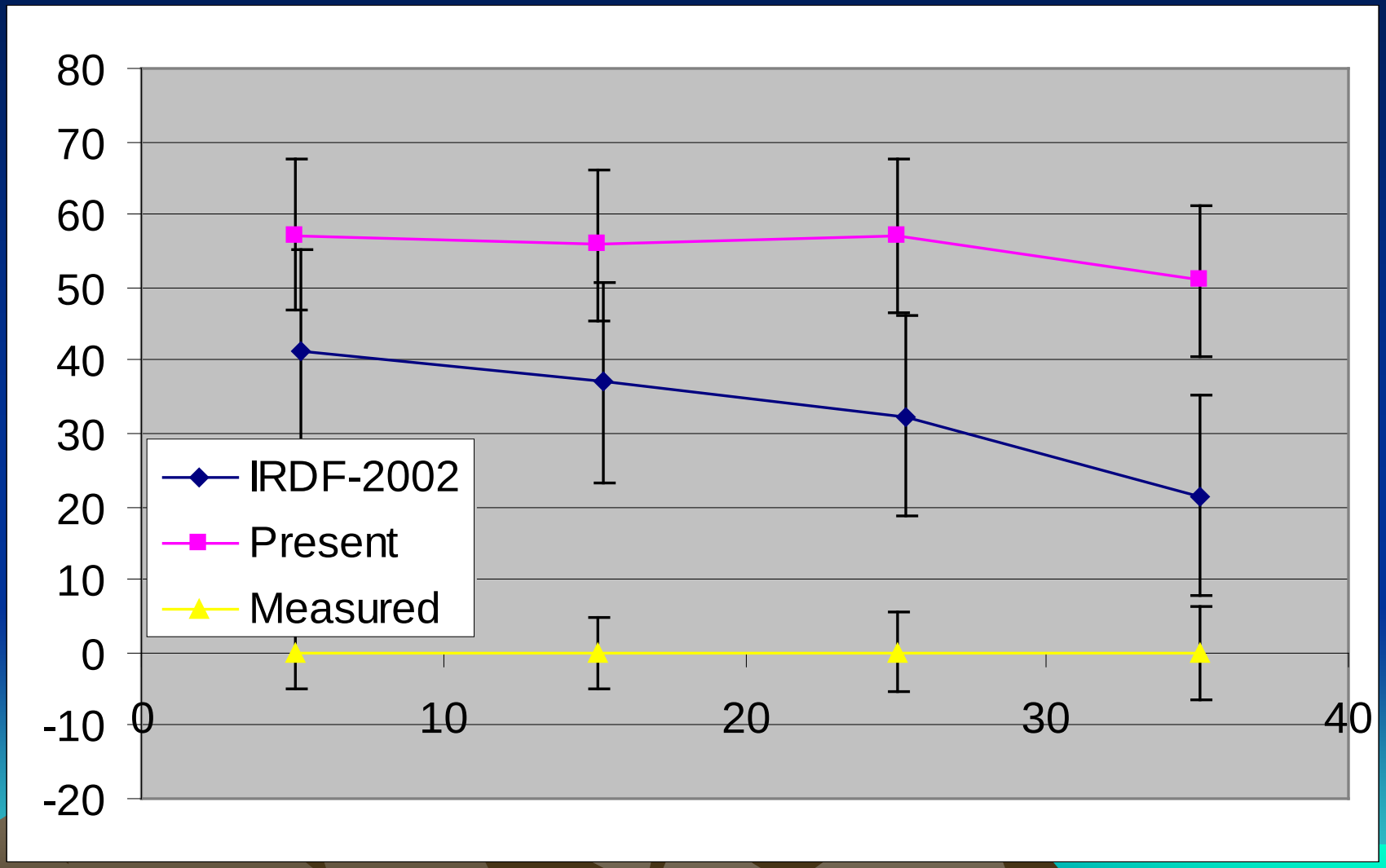
Sig0 and RI

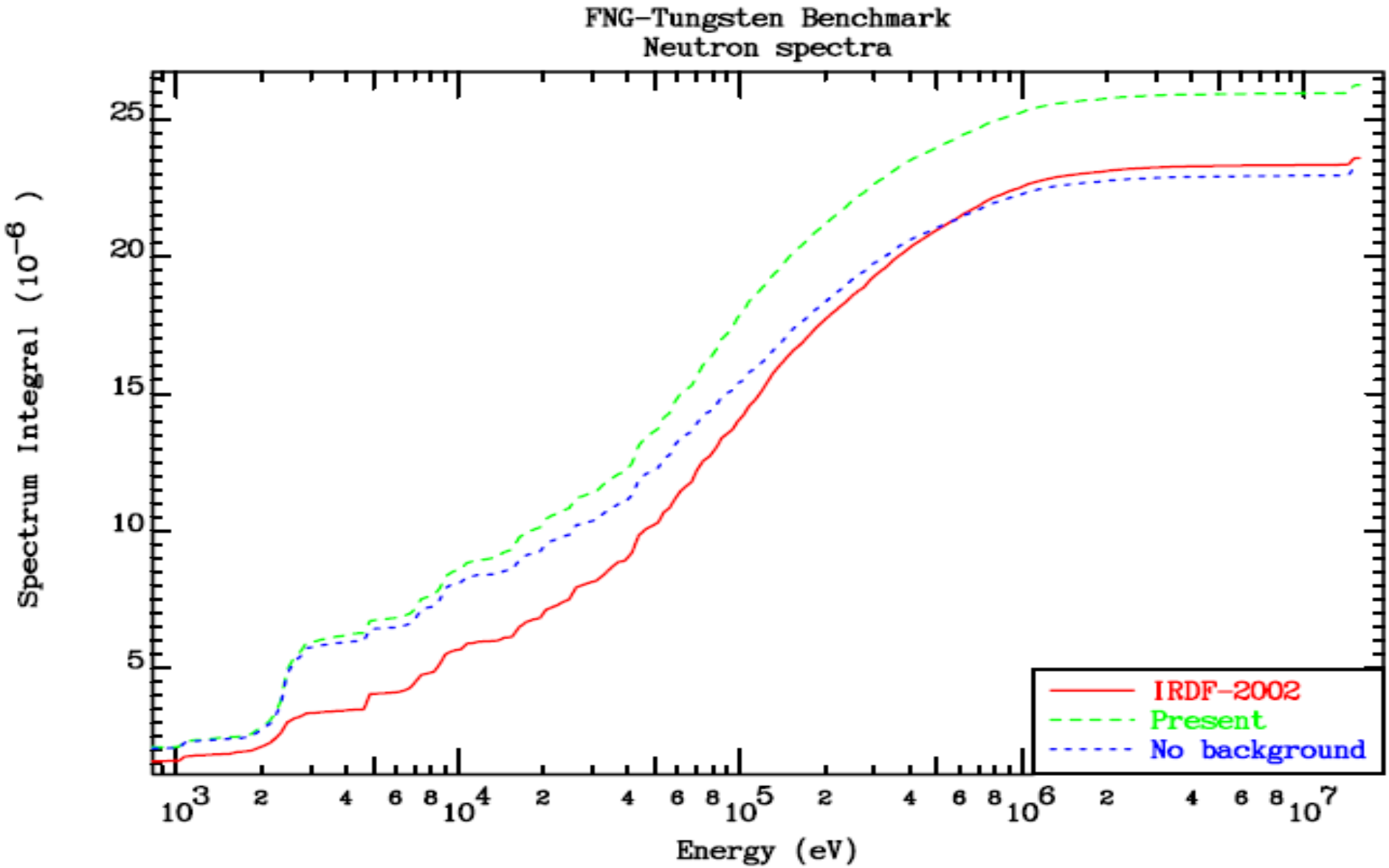
	σ_0 [b]	d σ_0 [%]	Diff. [%]	RI [b]	dRI [%]	Diff. [%]
Kayzero	13.18	0.92	Ref	13.88	2.8	Ref
Mughabghab	13.36	0.37	1.34	13.4	3.73	-3.47
IRDF-2002	13.18	0.92	0	11.31	7.56	-18.53
Present	**13.28**	**1.53**	**0.74**	**13.22**	**6.51**	**-4.73**

Cf-252 sp.aver. x.s.

Target	Csikai [mb]	Unc. [%]	IRDF-2002 [mb]	Unc. [%]	C/E-1 [%]	Unc [%]	New [mb]	Unc. [%]	C/E-1 [%]	Unc. [%]
Mn-55	2.96	7.09	2.84	15.6	-4.0	17.1	2.49	8.41	-15.9	11.0

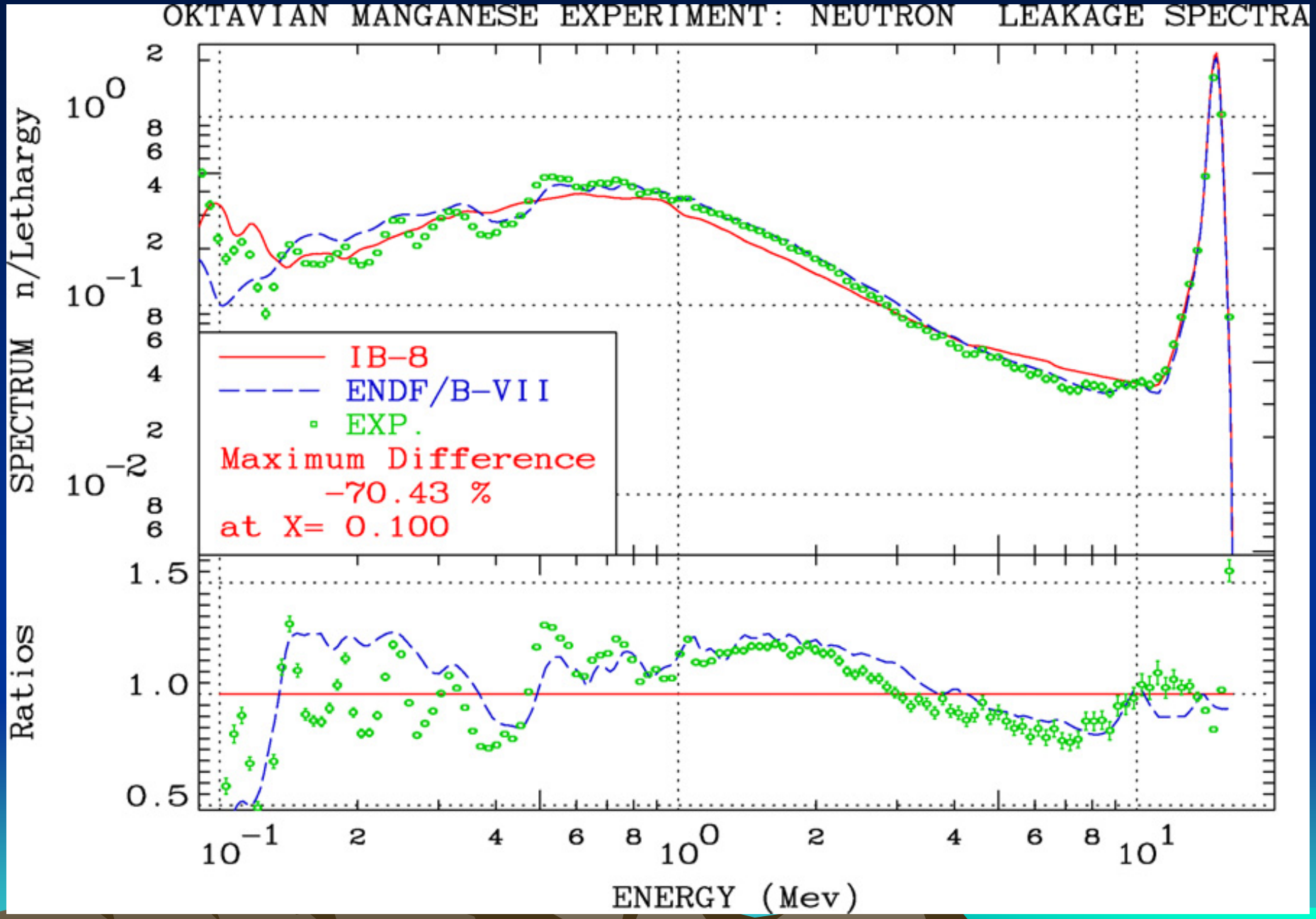
FNG-W Mn foil activation

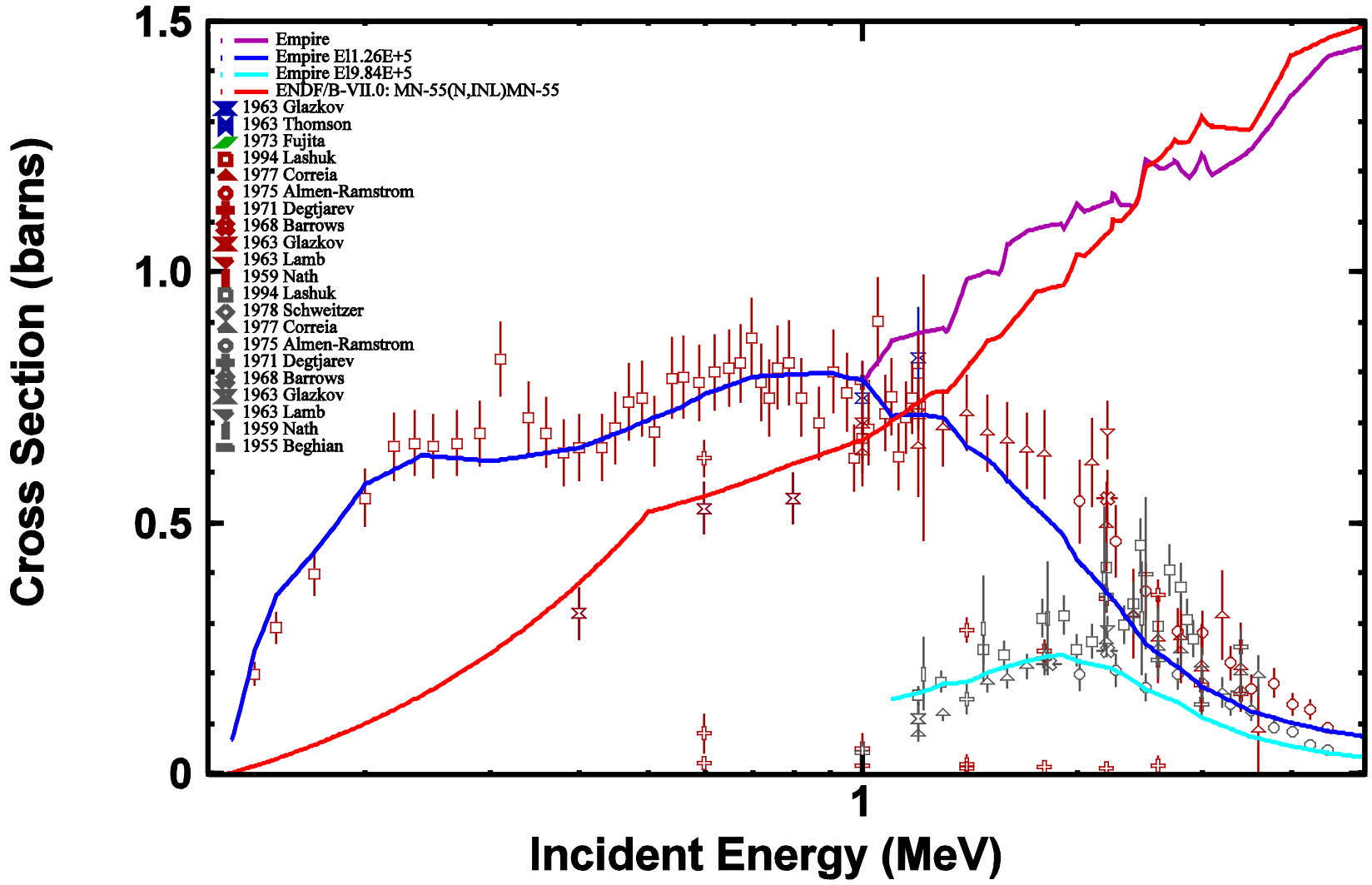



FNG-Tungsten Benchmark
Neutron spectra
Spectrum Integral (10^{-6})
25
20
15
10
5
10^3
2
4
6
8
10^4
2
4
6
8
10^5
2
4
6
8
10^6
2
4
6
8
10^7
Energy (eV)
IRDF-2002
Present
No background

Oktavian Mn sphere

- Measured leakage spectrum
- Good results with ENDF/B-VII
- Highly sensitive to (n,n’)
- ENDF/B-VII inelastic unsupported by differential cross section data
- Good performance due to cancellation of errors?


OKTAVIAN MANGANESE EXPERIMENT: NEUTRON LEAKAGE SPECTRA
SPECTRUM n/Lethargy
IB-8
ENDF/B-VII
EXP.
Maximum Difference
-70.43 %
at X= 0.100
Ratios
ENERGY (Mev)


Empire
Empire El1.26E+5
Empire El9.84E+5
ENDF/B-VII.0: MN-55(N,INL)MN-55
1963 Glazkov
1963 Thomson
1973 Fujita
1994 Lashuk
1977 Correia
1975 Almen-Ramstrom
1971 Degtjarev
1968 Barrows
1963 Glazkov
1963 Lamb
1959 Nath
1994 Lashuk
1978 Schweitzer
1977 Correia
1975 Almen-Ramstrom
1971 Degtjarev
1968 Barrows
1963 Glazkov
1963 Lamb
1959 Nath
1955 Beghian
1.5
1.0
0.5
0
1
Cross Section (barns)
Incident Energy (MeV)

^{55}Mn Conclusions

- Mn-55 evaluation – work in progress
- Marked improvement of RI
- “low” tendency in Cf-252 spectrum averaged cross section
- FNG-W Mn-55 activation 60% high → problem with measurement?
- Inelastic cross section to be resolved

Zr Data Testing

- ENDF/B-VII overpredicts reactivity of ICSBEP TRIGA reactor benchmark
- Substitution of Zr with JEFF-3.1
- Substitution of Zr with JENDL-4

	Δk_{eff} [pcm]//132	Δk_{eff} [pcm]//133
Benchmark k_{eff}	**1.0006 0.0056**	**1.0046 0.0056**
ENDF/B-VII.0	550	536
^{90}Zr (J4) – rest ENDF/B-VII	758	763
^{91}Zr (J4) – "-"	34	28
^{92}Zr (J4) – "-"	583	574
^{94}Zr (J4) – "-"	504	505
^{96}Zr (J4) – "-"	582	576
All Zr JENDL-4	290	290
All Zr JEFF-3.1	129	129