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IAEA-INDEN (Post-CIELO) ^{56}Fe Evaluation and Benchmarking

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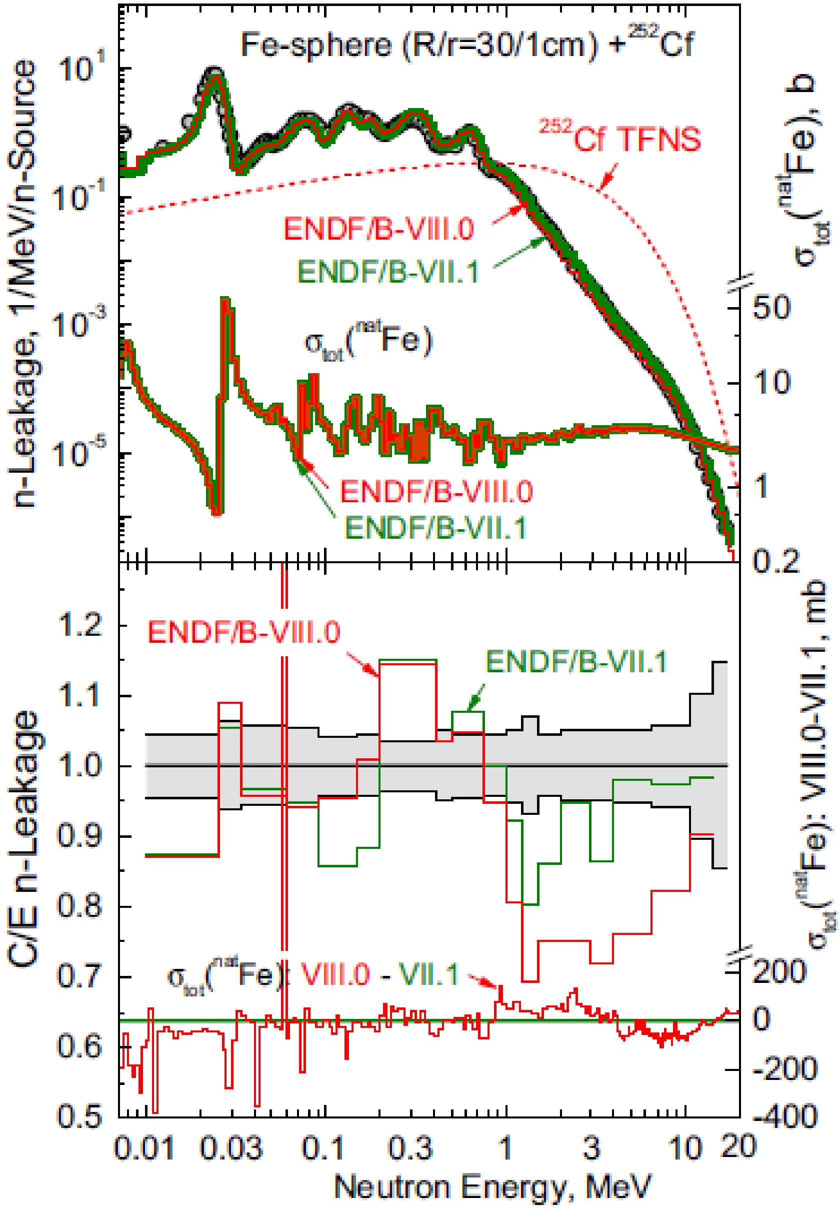
Background

- The ENDF/B-VIII.0 adopted the CIELO evaluation for ^{56}Fe.
- Deficiencies were revealed in the ^{56}Fe CIELO evaluation just before the release of the ENDF/B-VIII.0 library
- Work is in progress to remove the deficiencies.

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).
- The problem was traced to the non-elastic cross section that could be too high in some energy regions.
- There were also minor fixes to the elastic cross sections in the resonance region.



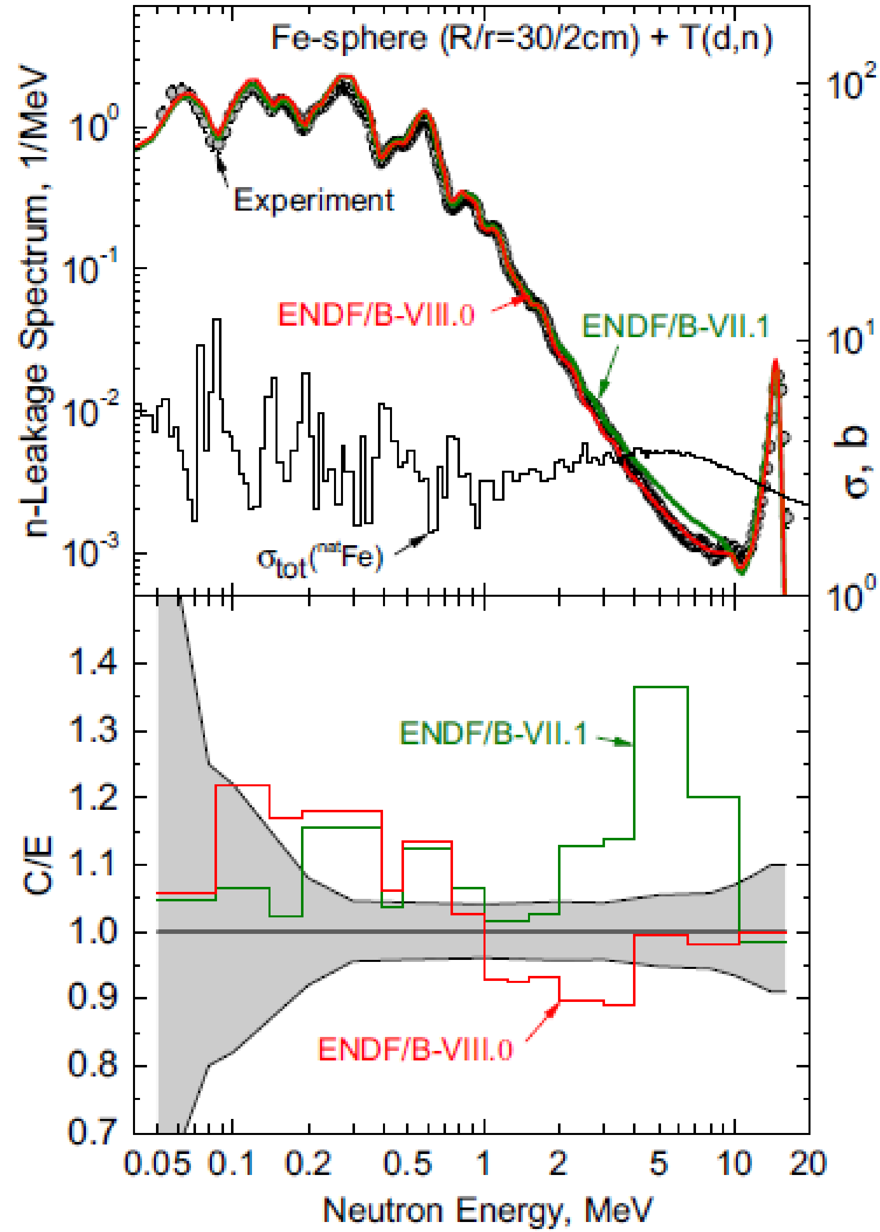


Fig. 32, 35, Nuclear Data Sheets,148 (2018) 214-253

Improvements to ^{56}Fe evaluation

- Total cross sections above 2 MeV are trusted.
- New measurements by E. Pirovano at JRC Geel support a higher elastic cross section.
- Capture is too small to play a role.

  →Hypothesis: inelastic is too high at least above 2 MeV where measurements of the elastic x.s. are available.
- Inelastic cross section was scaled down to the lowest bound of uncertainty, assigning the difference to elastic (exact comparison of cross sections is difficult due to strong fluctuations).
- Small changes to the total cross section below 2 MeV.
- Small corrections to the elastic cross section in the resonance interference minima (e.g., near 300 keV)
- Thermal capture reduced by 10%

  (Firestone et al, PRC **95**(2017) 014328)

Experimental data used below 4 MeV:

Differential experiments:

- ✓ High resolution σ_{tot}, σ_{inl}
- ✓ Lower resolution σ_{inl}
- ✓ 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

Differential experiments: σ_{inl}

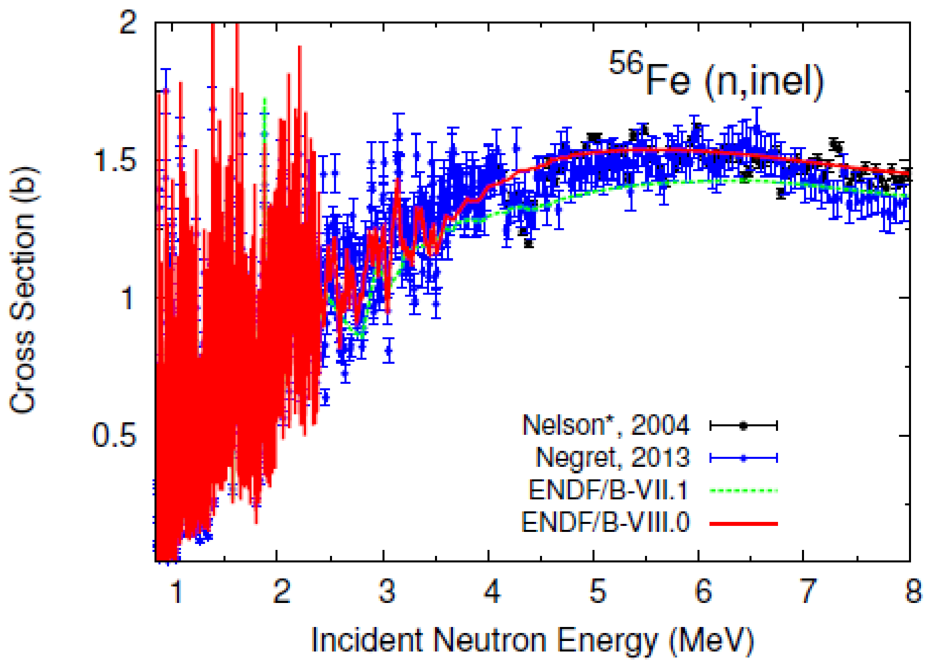


FIG. 34. (Color online) Evaluated ^{56}Fe(n, n') neutron inelastic cross section compared with data retrieved from EXFOR and with the previous evaluation. The asterisk on the Nelson data indicates that they are renormalized as described in Ref. [19].

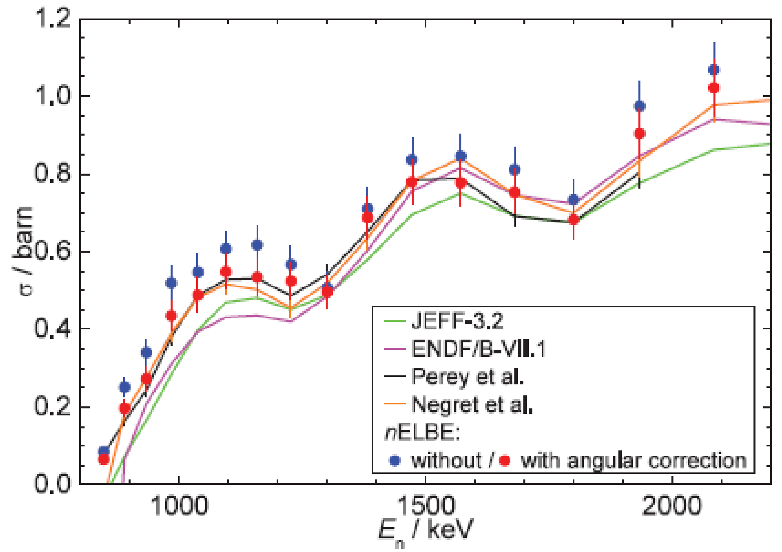
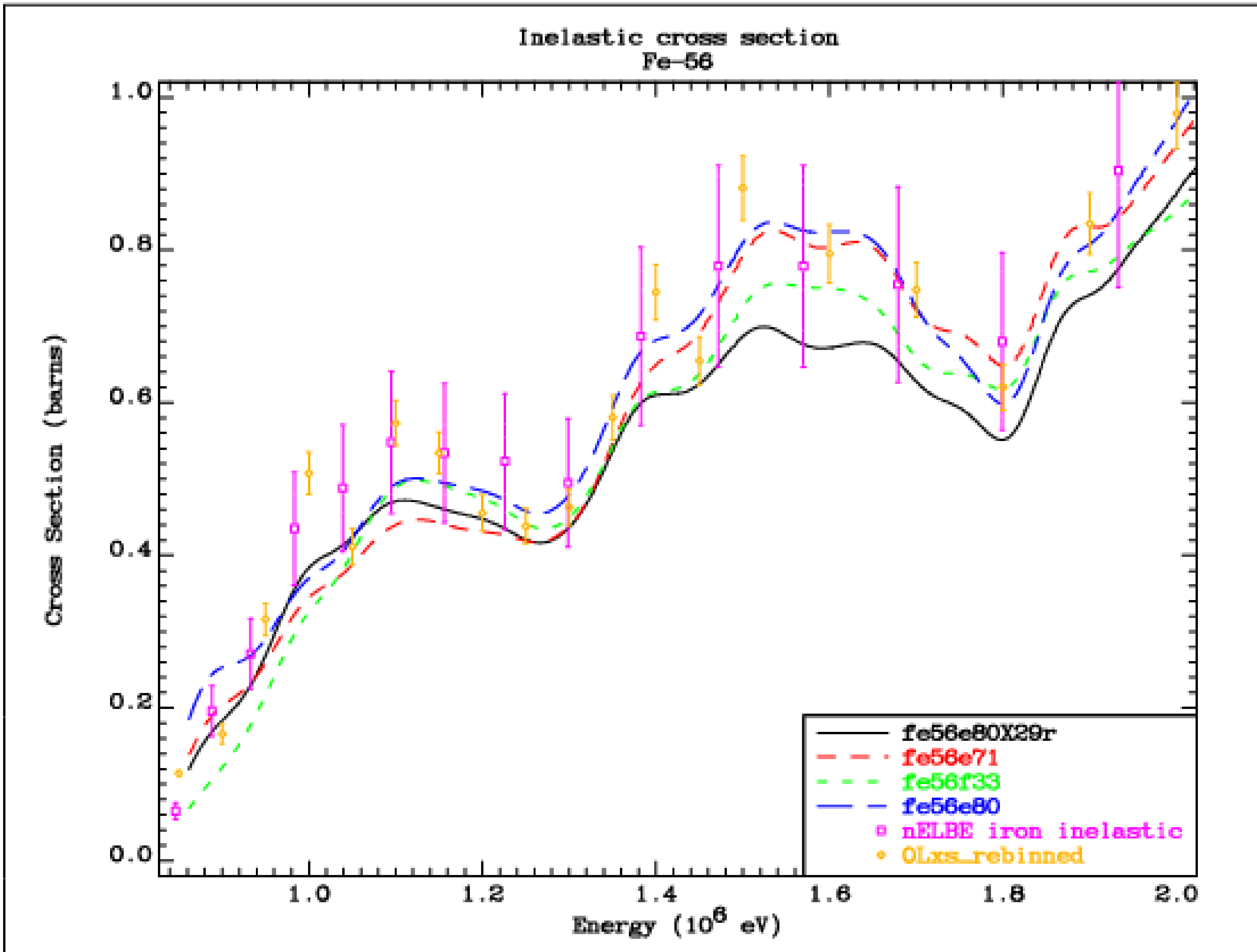
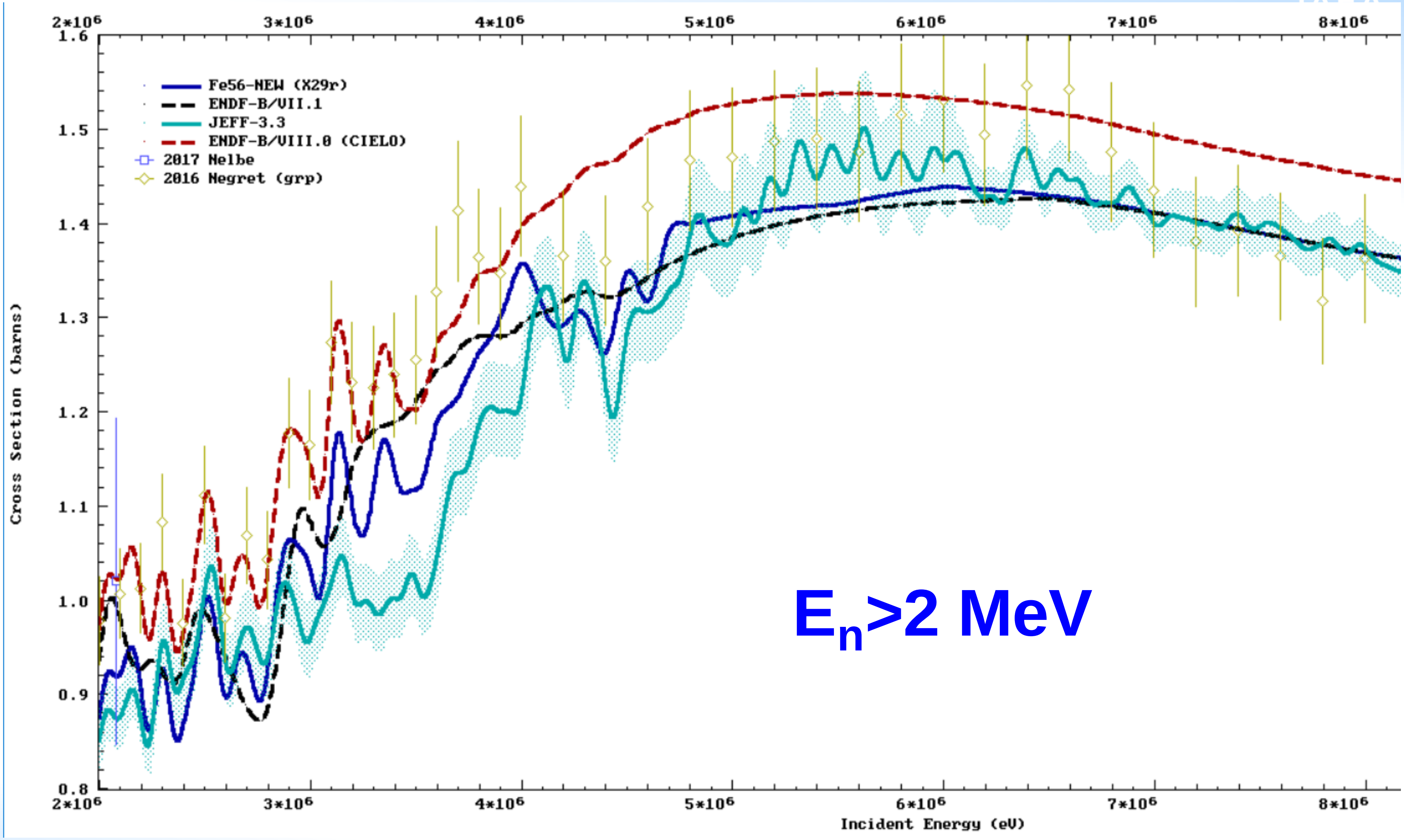


Figure 9. Inelastic neutron scattering cross section under excitation of the first excited state of ^{56}Fe determined in the γ-ray production measurement before and after correction for the γ-ray angular distribution. (Note: The reference data are averaged to the binsize of the *n*ELBE measurement.)

Beyer et al, EPJ WoC 146 (2017) 02017

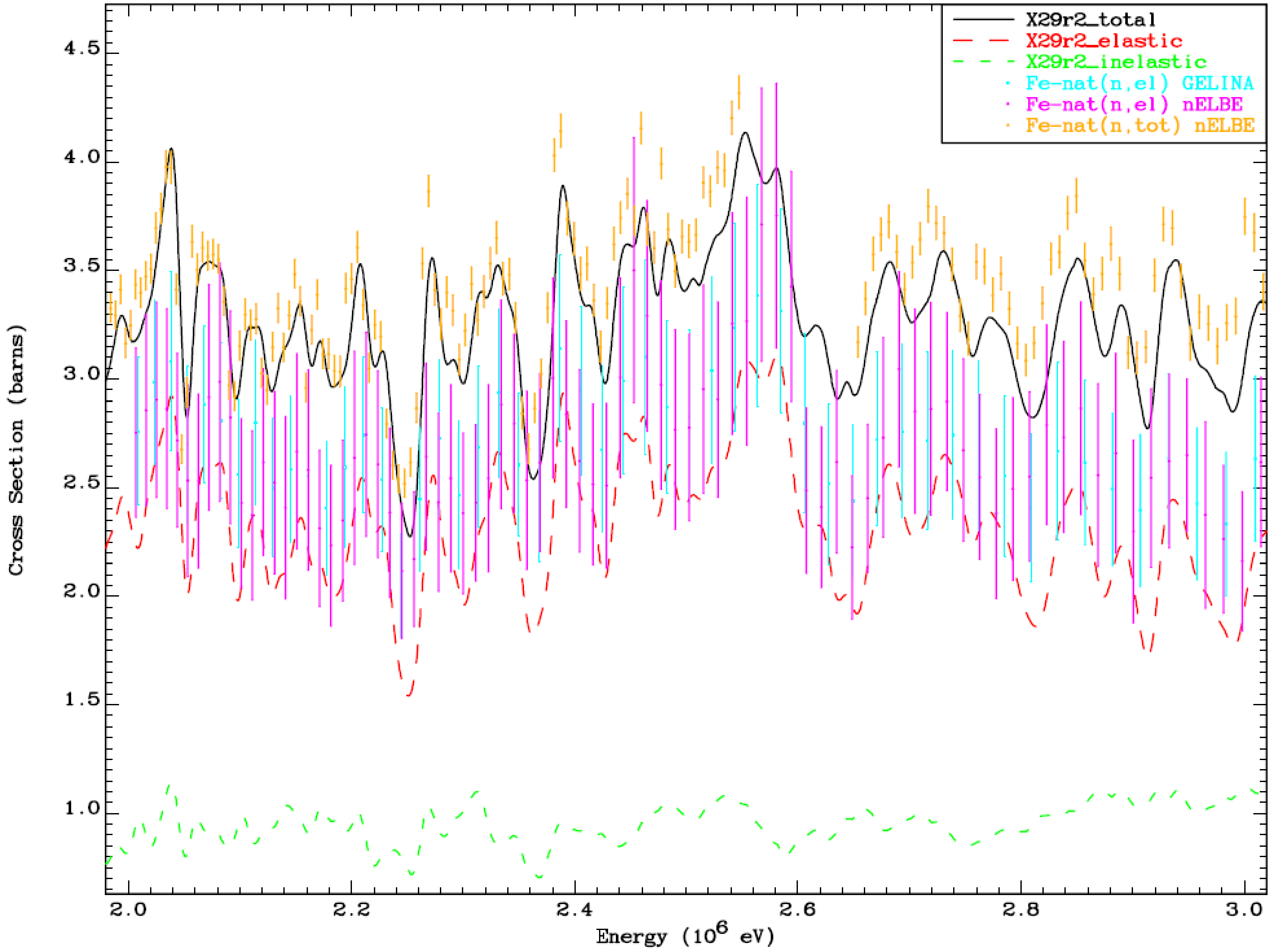

Inelastic cross section
Fe-56
Cross Section (barns)
Energy (10^6 eV)
fe56e80X29r
fe56e71
fe56f33
fe56e80
nELBE iron inelastic
OLxs_rebinned

Differential experiments: σ_{inl}

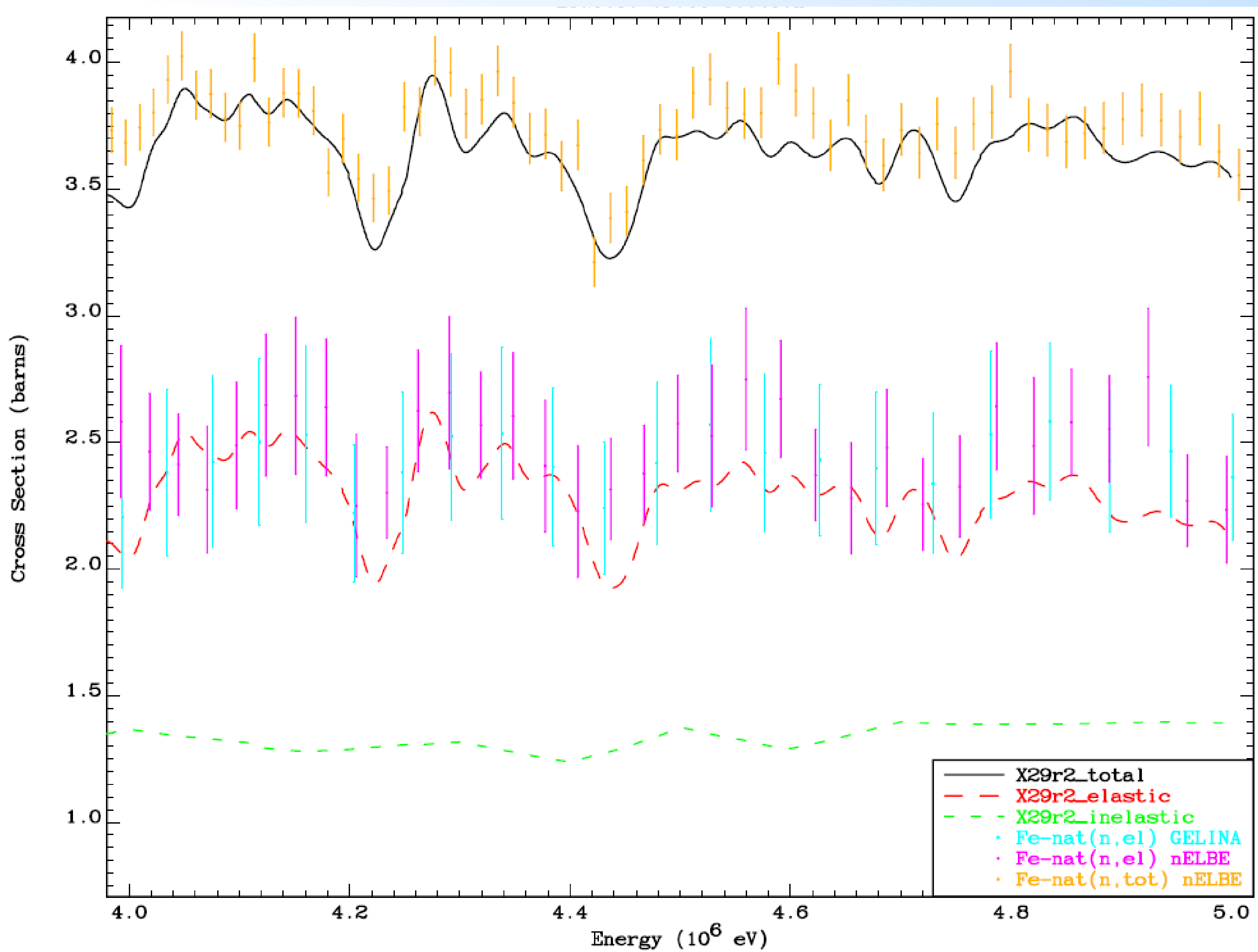


E_n>2 MeV

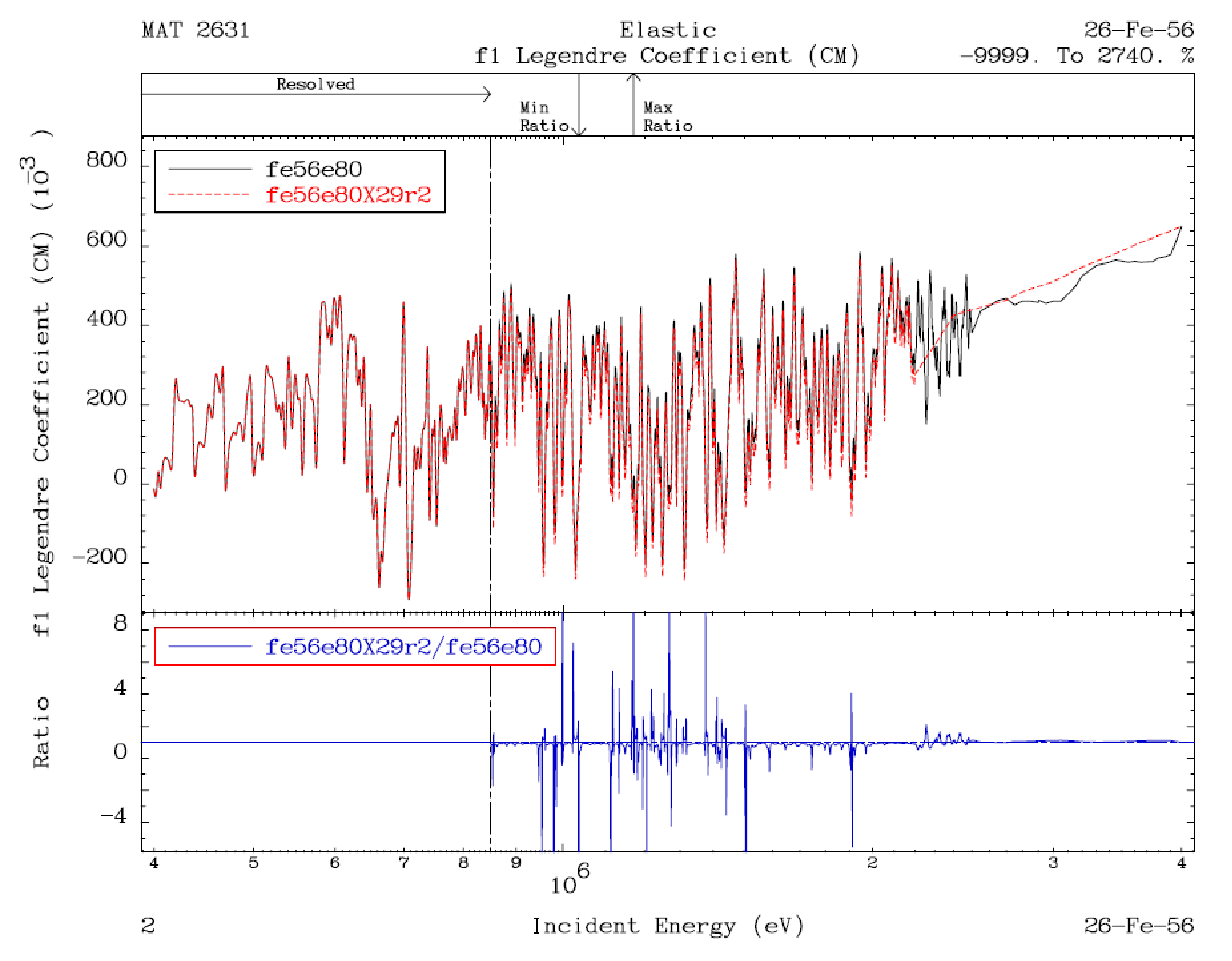
Differential experiments: σ_{tot}, σ_{el}, σ_{inl}



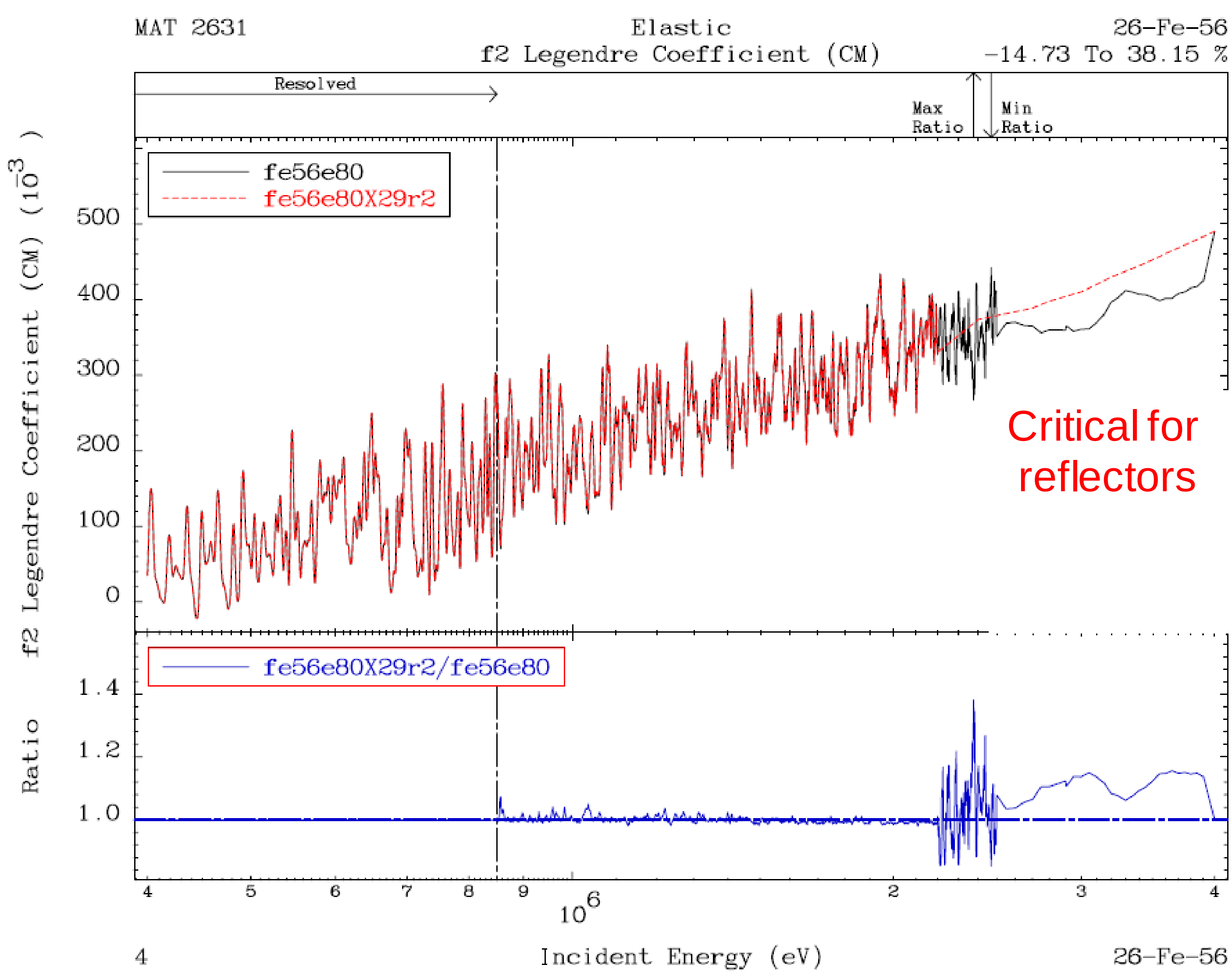
Differential experiments: σ_{tot}, σ_{el}, σ_{inl}



Fitted Kinney/Perey DA data



Fitted Kinney/Perey DA data



Performance of new ^{56}Fe file

- Independent analysis of IPPE benchmarks with a ^{252}Cf source from ICSBEP was made:
  - Problem with 60 cm diameter sphere with ^{252}Cf source is resolved.
  - Overestimation of the spectrum near 300 keV is significantly reduced.
- ICSBEP – IPPE broomstick experiments:
  - Flux attenuation in some energy regions in RRR in better agreement with measurements.

Useful benchmarks for ^{56}Fe file validation

1. IPPE leakage spectra from thick iron shells with a ^{252}Cf source (ICSBEP:ALARM-CF-FE-SHIELD-001)
2. ASPIS-Fe88 deep penetration case with a ^{235}U fast fission source (SINBAD)
3. IPPE leakage spectra from thick iron shells with a D-T source (SINBAD)
4. LLNL leakage spectra from thick iron shells with a D-T source
5. Oktavian leakage spectra from thick iron shells with a D-T source (SINBAD)

Useful benchmarks for ^{56}Fe file validation (cont.)

6. FNS-Fe thick slab ToF transmission spectra from a D-T source at different angles (SINBAD)
7. TIARA-Fe 40 MeV and 65 MeV transmission measurement (SINBAD)
8. IPPE iron broomstick experiments with quasi-monoenergetic p-T source (ICSBEP:FUND-IPPE-VDG-MULT-TRANS-001)

Less-useful benchmarks for ^{56}Fe file validation

- NIST-Fe leakage spectra from thick iron shells with a ^{252}Cf source (Stanka et al. NSE 134, 68-76 (2000)); coarser binning, but on average the results from IPPE iron spheres are confirmed
- Illinois-Fe leakage spectra from thick iron shells with a ^{252}Cf source (SINBAD); coarse
- EURACOS-Fe deep penetration case with a ^{235}U fast fission source (SINBAD); poor source definition
- LSD-RPI lead-slowing-down low-resolution cross section measurement (poor statistics)

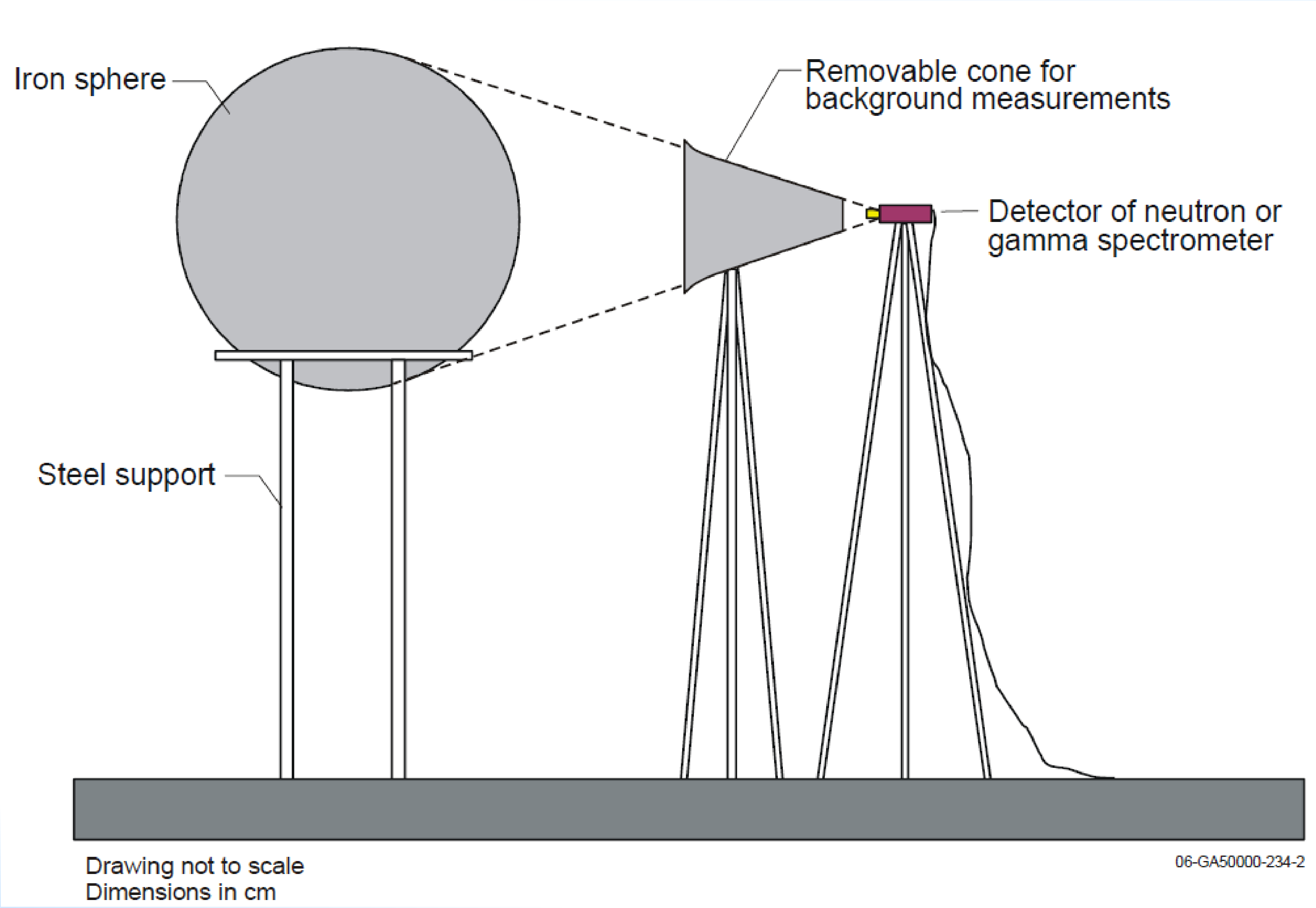
Potentially-useful benchmarks for ^{56}Fe file validation

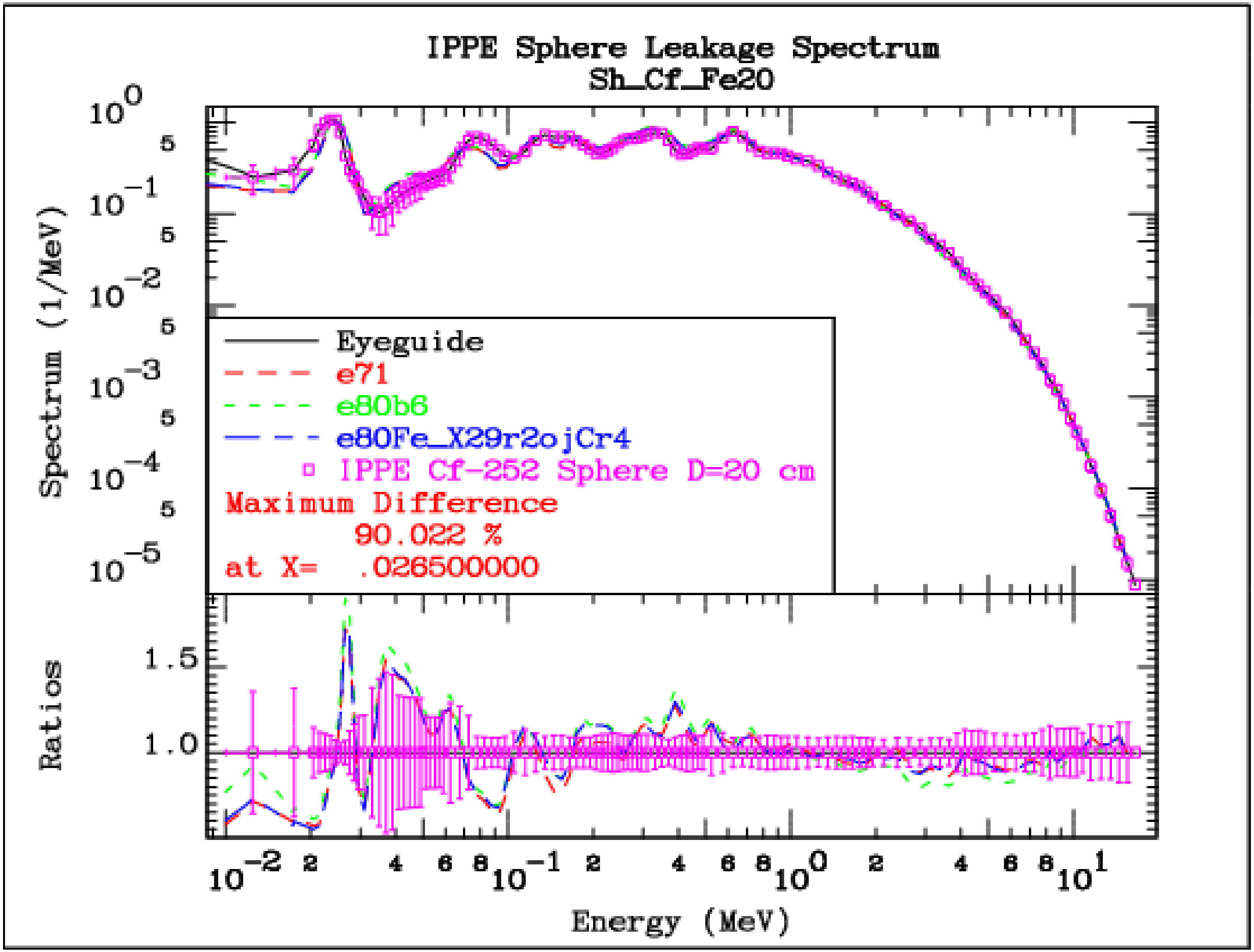
- KfK-Fe leakage spectra from thick iron shells with a ^{252}Cf source (SINBAD); (analysis by Simakov shows some contradiction with IPPE benchmark, MCNP input not available)
- NRI & Skoda leakage spectra from thick iron shells with a ^{252}Cf source, ANE 20,9, (1993), Sajo et al.; (new measurements from Rez also exist, but neither the measured data nor the MCNP model are available)
- ORNL Broomstick experiments (SINBAD) (not analysed)
- Ohio University – several benchmarks – e.g. Wenner et al. NSE 170 207 (2012); (details not available)
- RPI-Fe quasi-differential cross section measurement (waiting for data to be released)

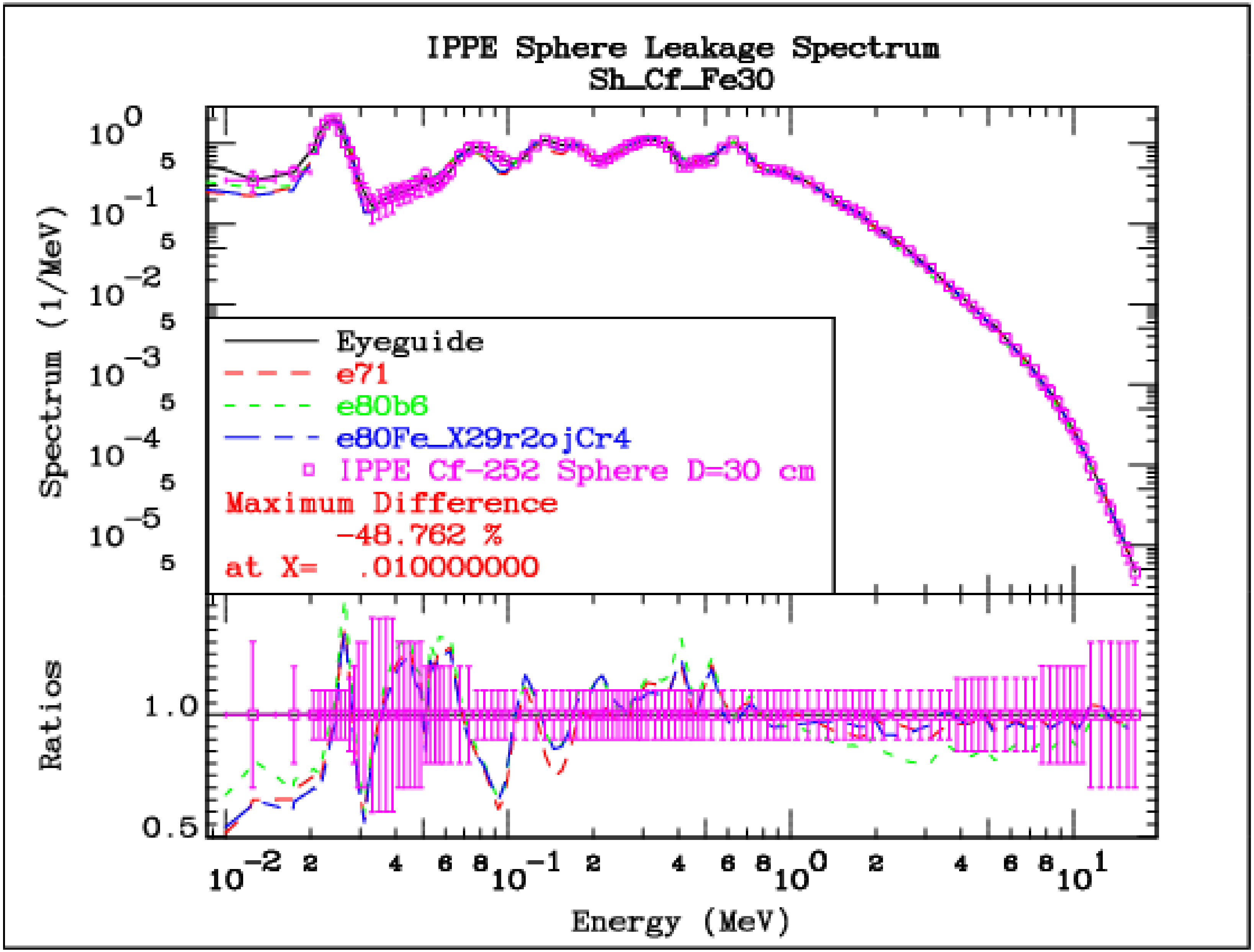
1. IPPE spheres with ^{252}Cf source

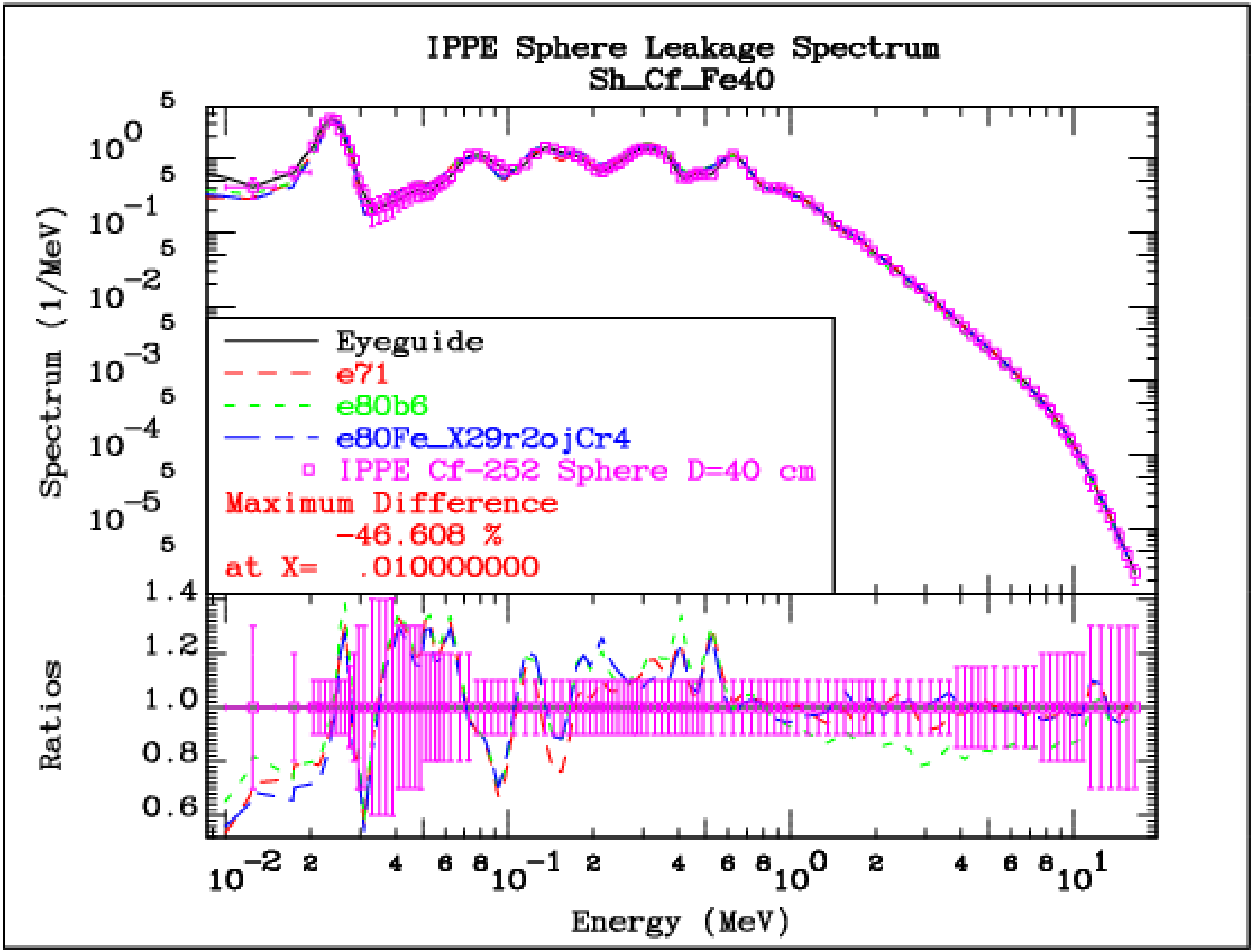
- Benchmarks are available in ICSBEP for six spheres of diameters 20, 30, 40, 50, 60, 70cm

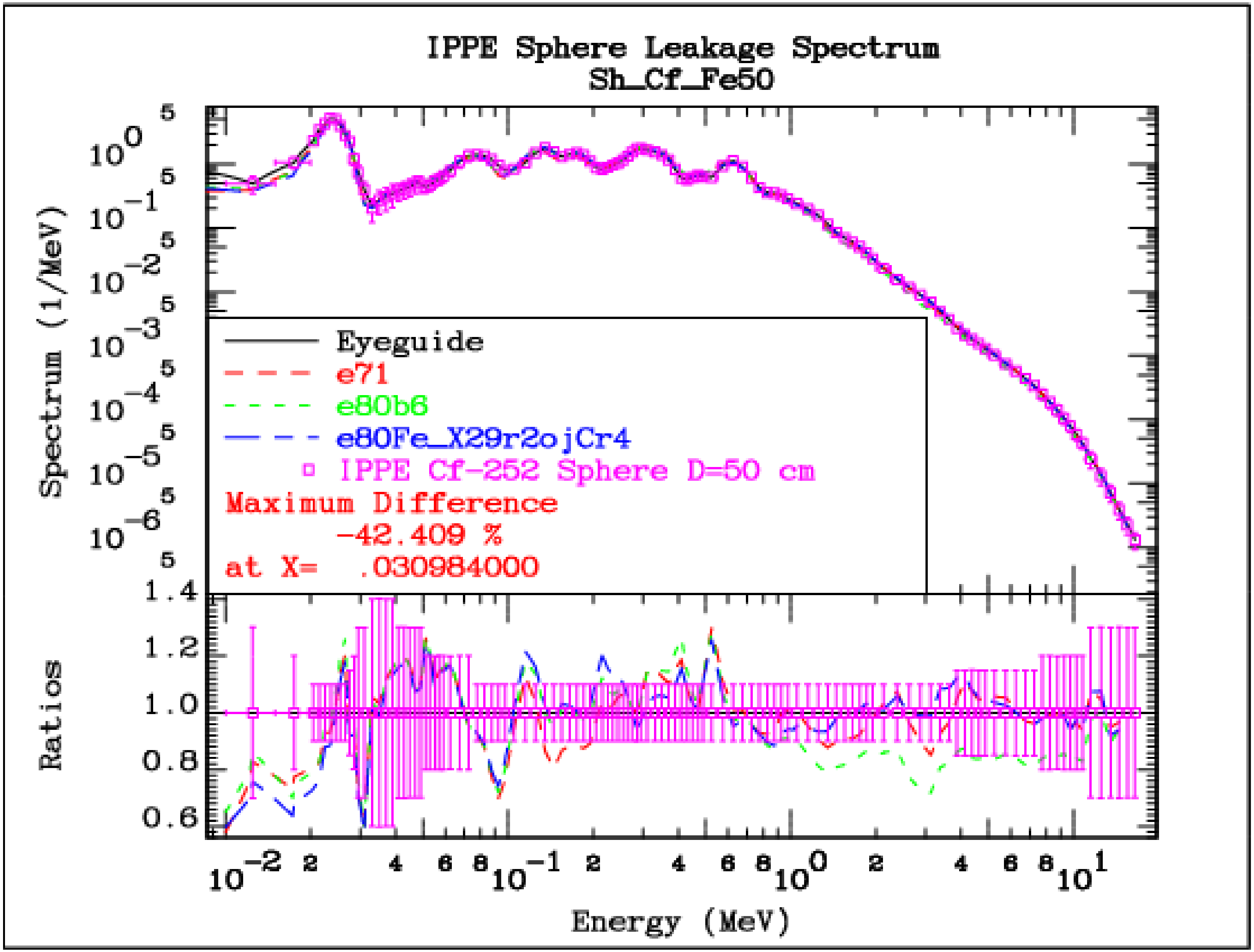
IPPE spheres with ^{252}Cf source



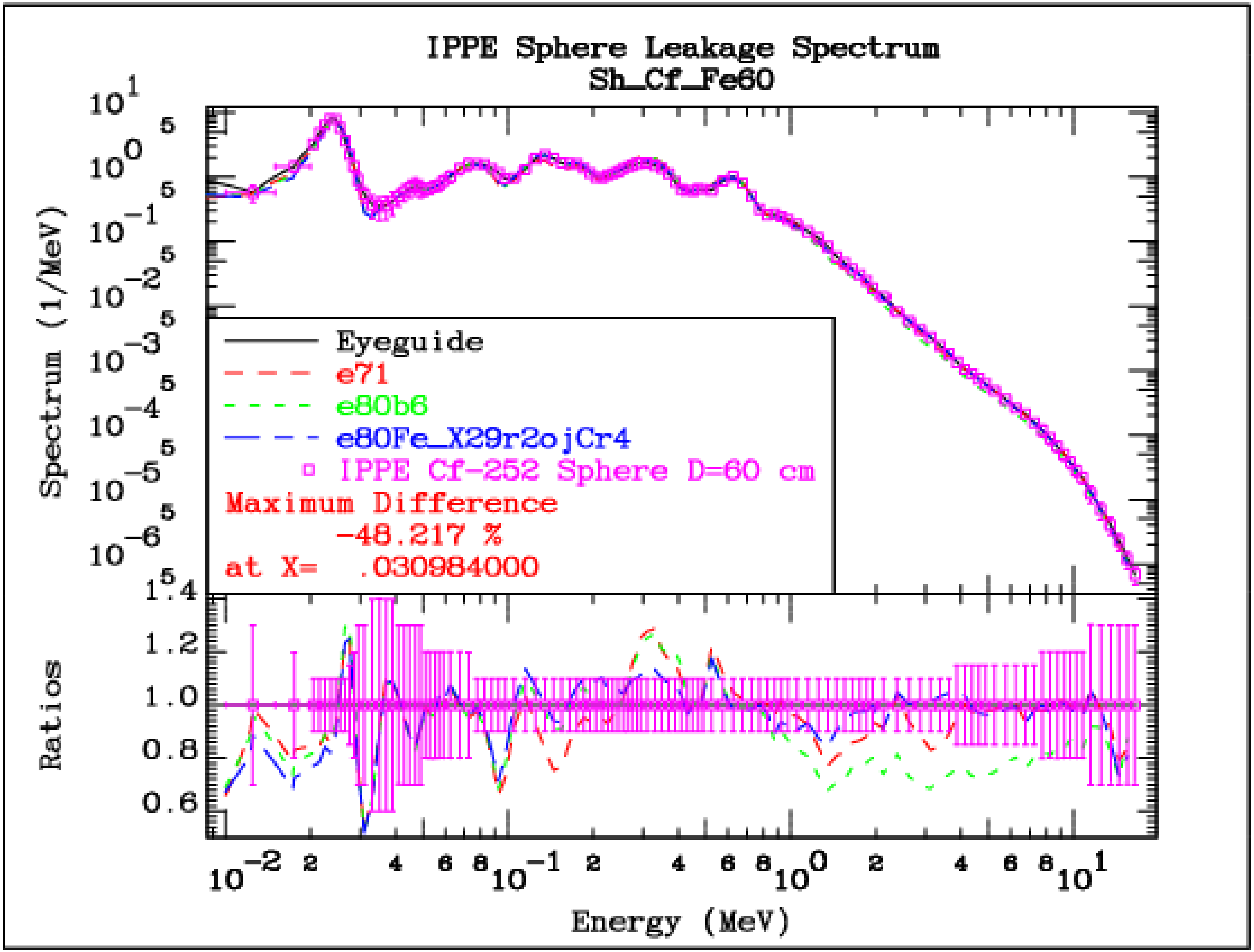

IPPE Sphere Leakage Spectrum
Sh_Cf_Fe20
Spectrum (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
IPPE Cf-252 Sphere D=20 cm
Maximum Difference
90.022 %
at X= .026500000

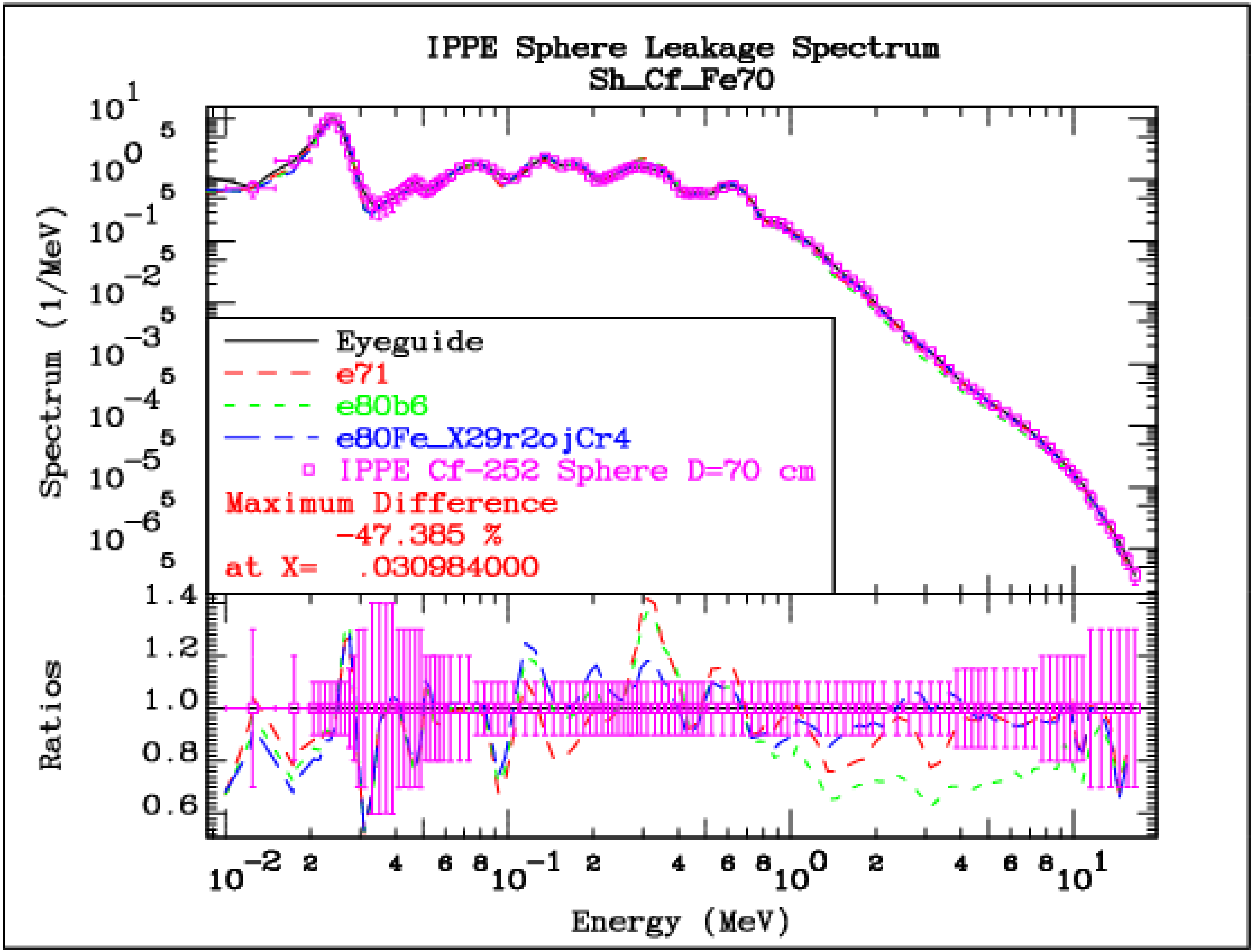

IPPE Sphere Leakage Spectrum
Sh_Cf_Fe30
Spectrum (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
IPPE Cf-252 Sphere D=30 cm
Maximum Difference
-48.762 %
at X= .010000000


IPPE Sphere Leakage Spectrum
Sh_Cf_Fe40
Spectrum (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
IPPE Cf-252 Sphere D=40 cm
Maximum Difference
-46.608 %
at X= .010000000



IPPE Sphere Leakage Spectrum
Sh_Cf_Fe50
Spectrum (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
IPPE Cf-252 Sphere D=50 cm
Maximum Difference
-42.409 %
at X= .030984000


IPPE Sphere Leakage Spectrum
Sh_Cf_Fe60
Spectrum (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
IPPE Cf-252 Sphere D=60 cm
Maximum Difference
-48.217 %
at X= .030984000


IPPE Sphere Leakage Spectrum
Sh_Cf_Fe70
Spectrum (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
IPPE Cf-252 Sphere D=70 cm
Maximum Difference
-47.385 %
at X= .030984000

Rez neutron leakage of ^{252}Cf(sf) source, ∅=100cm using Fe-56 evaluations

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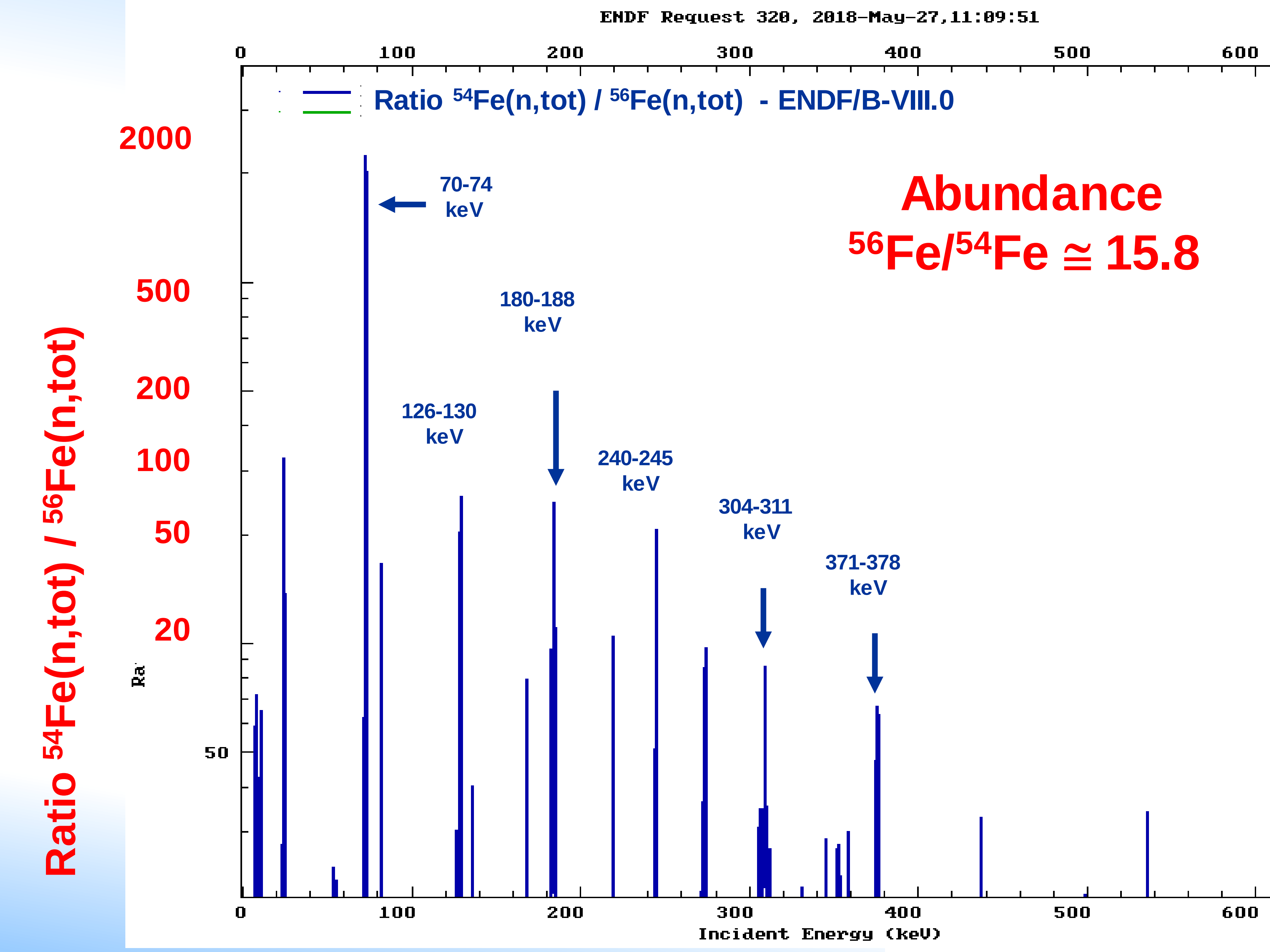
Tab.1 Assembly FE DIA100, R53; 200gpd, integral values, C/E
(Jansky, ND 2013, New York, [1])

	En.range[MeV]		main peak [keV]	Library used for MCNP Calculation					
No.	from	to	in measurement	ENDF/B-VII.1	BROND-3	JENDL-4.0	JEFF-3.2T2	TENDL-2012	CENDL-3.1
0	**0.013**	**1.290**	**total range**	**1.031**	**1.036**	**1.049**	**1.053**	**1.031**	**1.040**
1	0.013	0.030	24.4	0.918	0.836	1.029	0.989	1.221	0.891
2	0.030	0.075		0.909	0.835	0.903	0.967	0.858	1.146
3	0.075	0.090	82	1.008	0.912	0.999	1.017	1.119	1.402
4	0.090	0.150	137	0.845	0.828	0.920	1.004	0.970	0.732
5	0.150	0.200	167+183	0.907	0.898	0.974	1.015	1.012	0.909
6	0.200	0.250		1.012	1.051	1.024	1.018	0.872	1.196
7	0.250	0.289	272	1.075	1.097	1.011	1.015	0.948	1.115
8	0.289	0.333	309	1.423	1.366	1.338	1.245	1.317	1.129
9	0.333	0.410	350	1.269	1.256	1.278	1.235	1.335	1.474
10	0.410	0.520		1.044	1.177	1.046	1.085	0.779	1.036
11	0.520	0.780	610+650+703	1.147	1.366	1.122	1.064	0.835	1.152
12	0.780	1.060		0.946	1.017	0.863	1.050	0.730	0.681
13	1.060	1.290		0.910	0.710	0.834	0.866	0.826	0.777

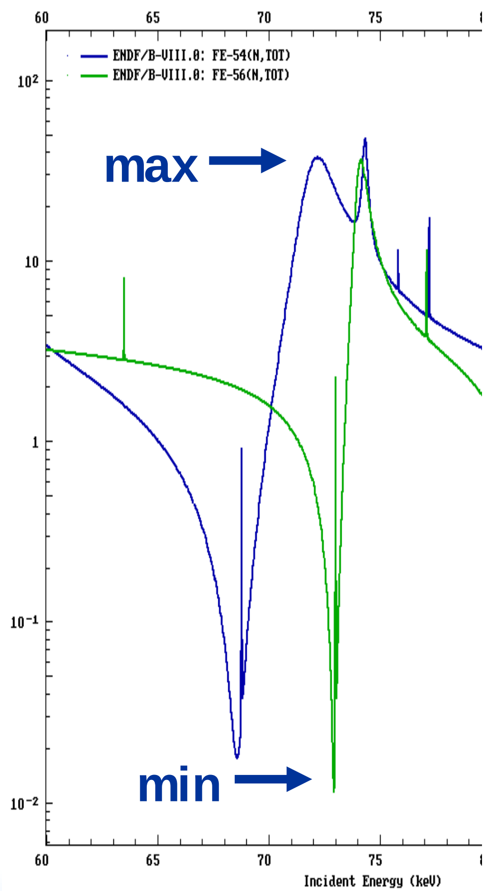
See next slide to compare energies
^{54}Fe(n,tot) / ^{56}Fe(n,tot)

Jansky et al, JEFDOC 1218 (2018)
Presented at JEFF meeting held in Madrid, Spain

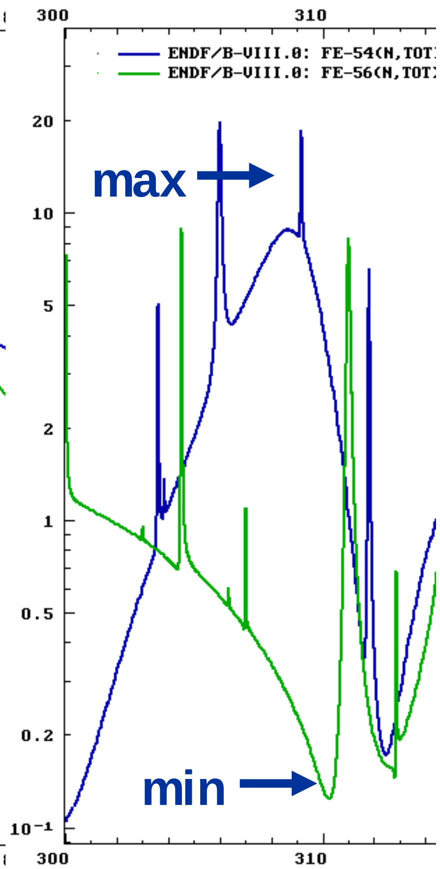


ENDF Request 320, 2018-May-27,11:09:51
Ratio ^{54}Fe(n,tot) / ^{56}Fe(n,tot) - ENDF/B-VIII.0
Ratio ^{54}Fe(n,tot) / ^{56}Fe(n,tot)
2000
500
200
100
50
20
70-74 keV
180-188 keV
126-130 keV
240-245 keV
304-311 keV
371-378 keV
Abundance
^{56}Fe/^{54}Fe ≅ 15.8
0
100
200
300
400
500
600
Incident Energy (keV)

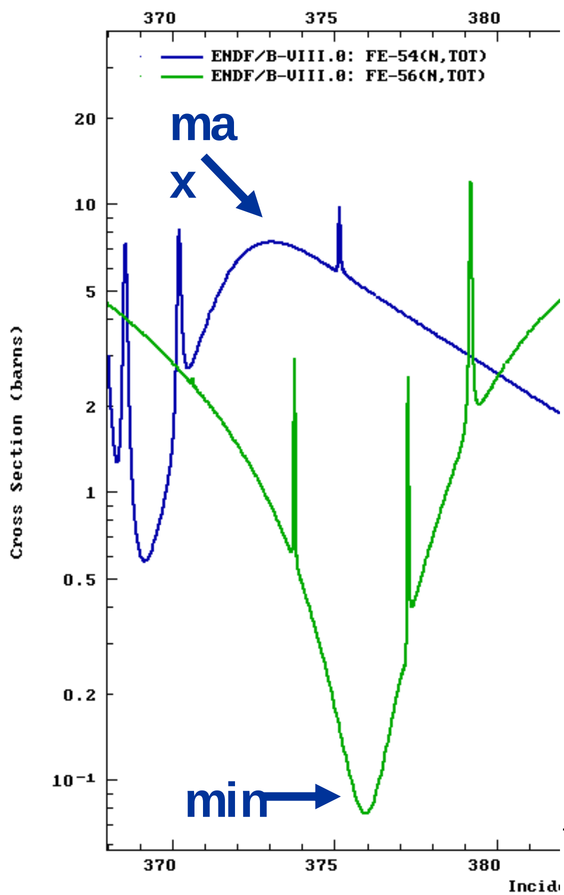
Importance of $^{56}Fe(n,tot)$ minima: max(^{54}Fe (n,tot)) coincident with min($^{56}Fe(n,tot)$)



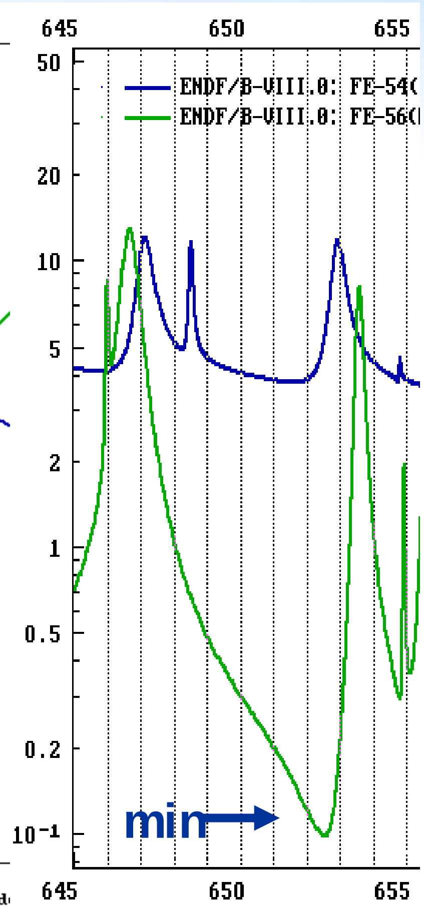
E_n≈70-74 keV



E_n≈304-311 keV



E_n≈371-378 keV



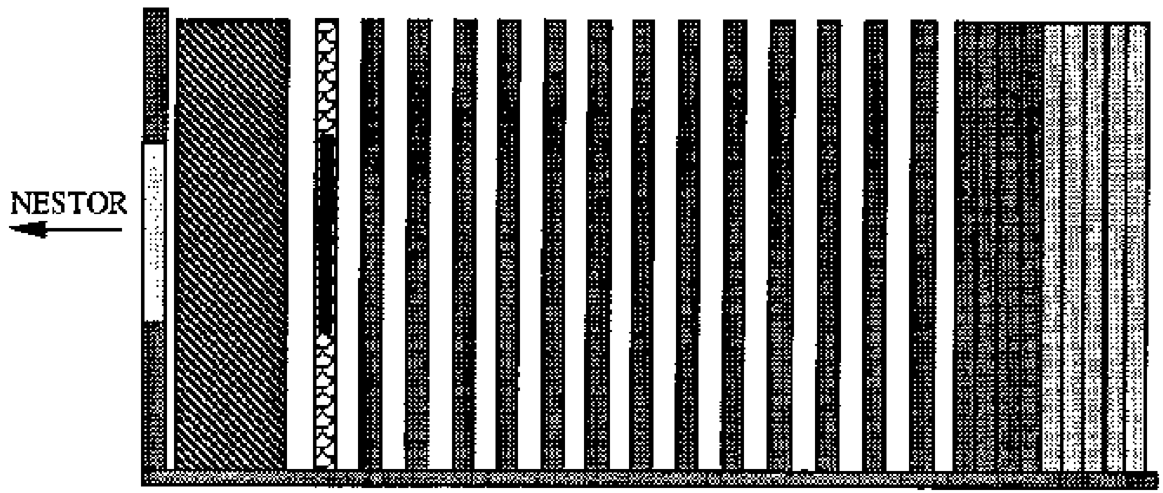
E_n≈648-654 keV

2. ASPIS-Fe-88 benchmark

- Available in SINBAD, no MCNP model
- Contract from IAEA with B. Kos, JSI (working with I. Kodeli)
- Input models with variance reduction delivered
- Agreement with measured activities are generally good, except for Al(n,a) systematic over-prediction – possible Na impurity?

ASPIS-Fe-88 benchmark

Figure 1 Schematic side elevation of the shield in the iron 88 single material benchmark experiment

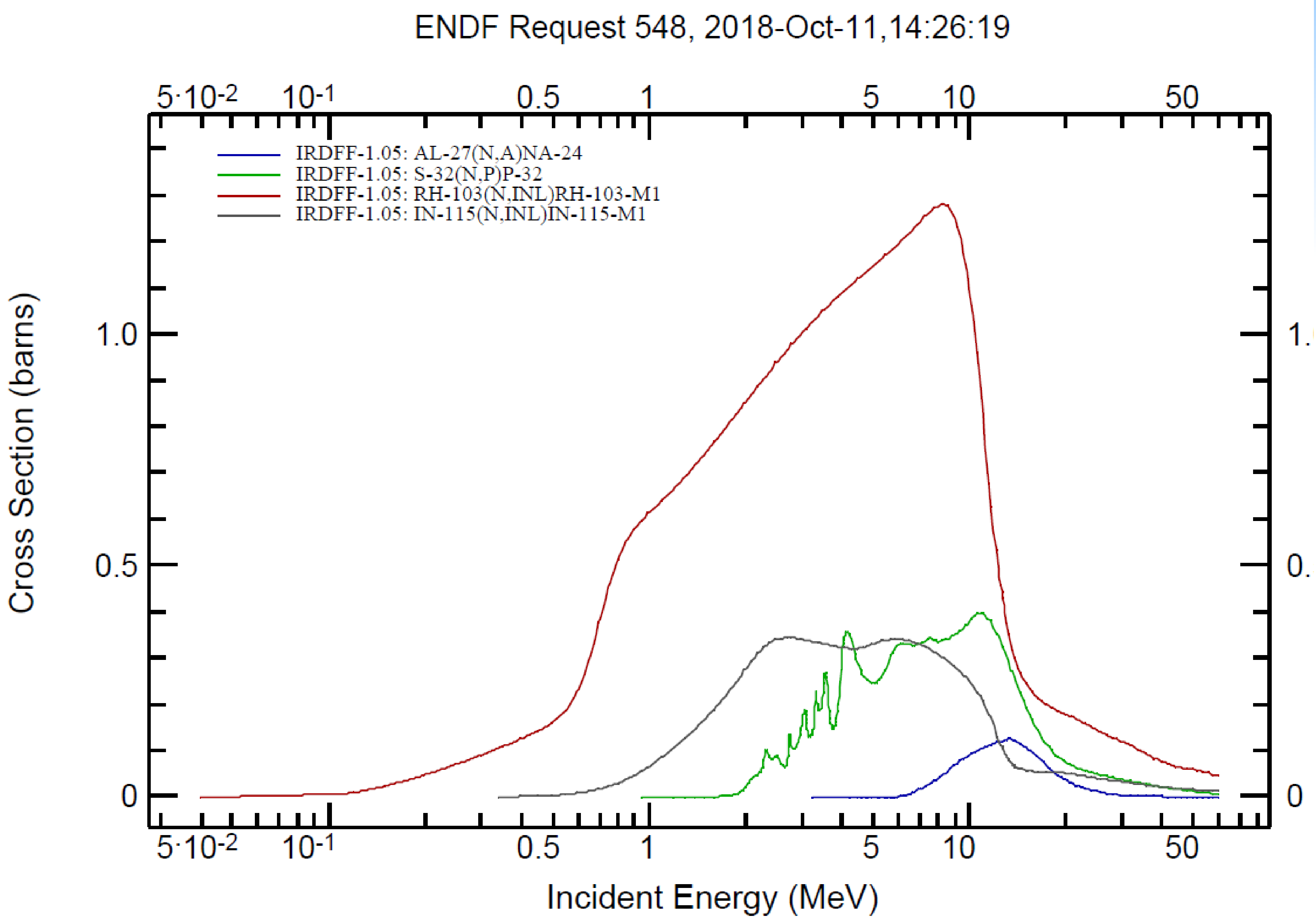


KEY

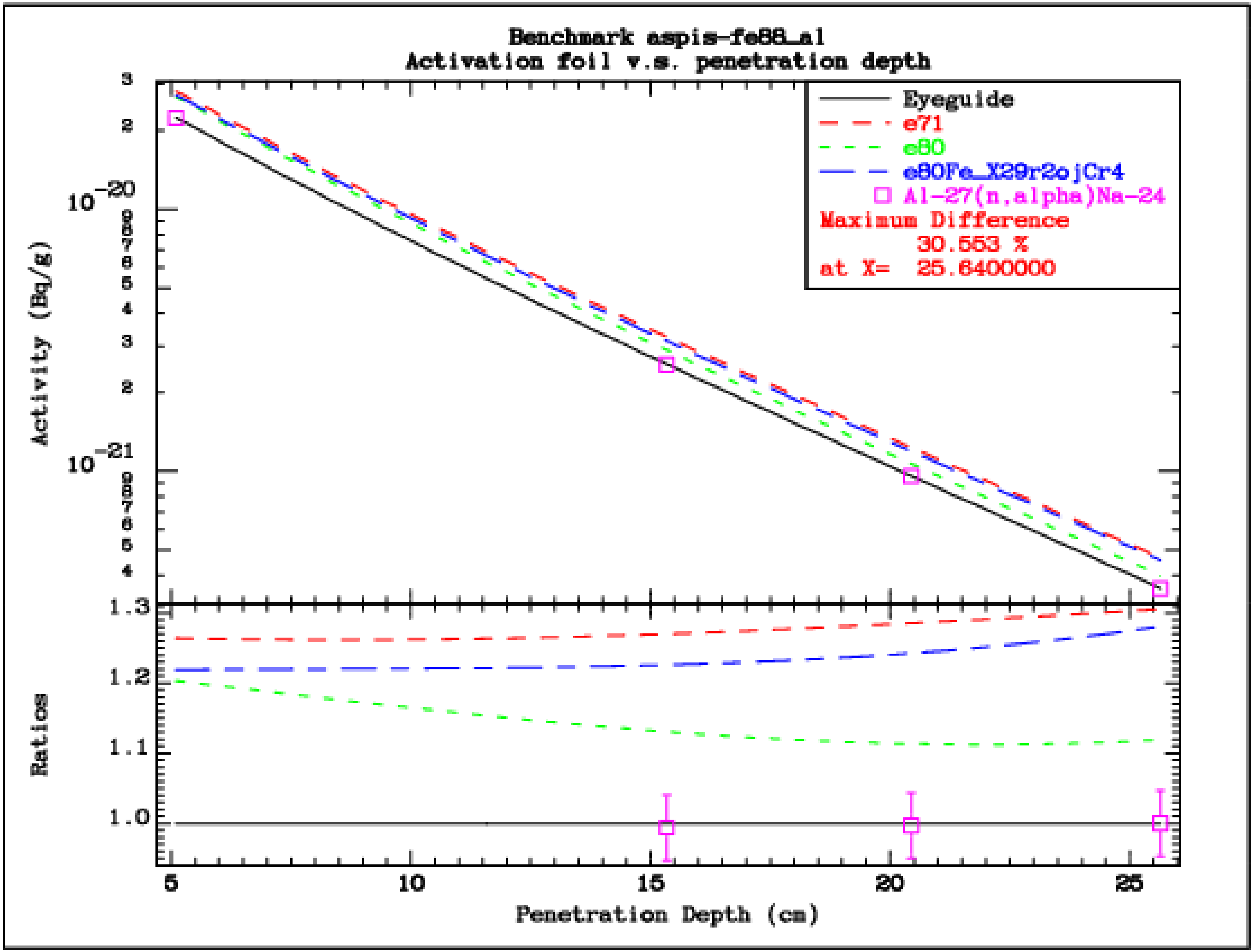
- Fuel
- Mild Steel
- Stainless Steel
- Fission Plate
- Graphite
- Aluminium

All components are 182.9cm wide by 191.0cm high

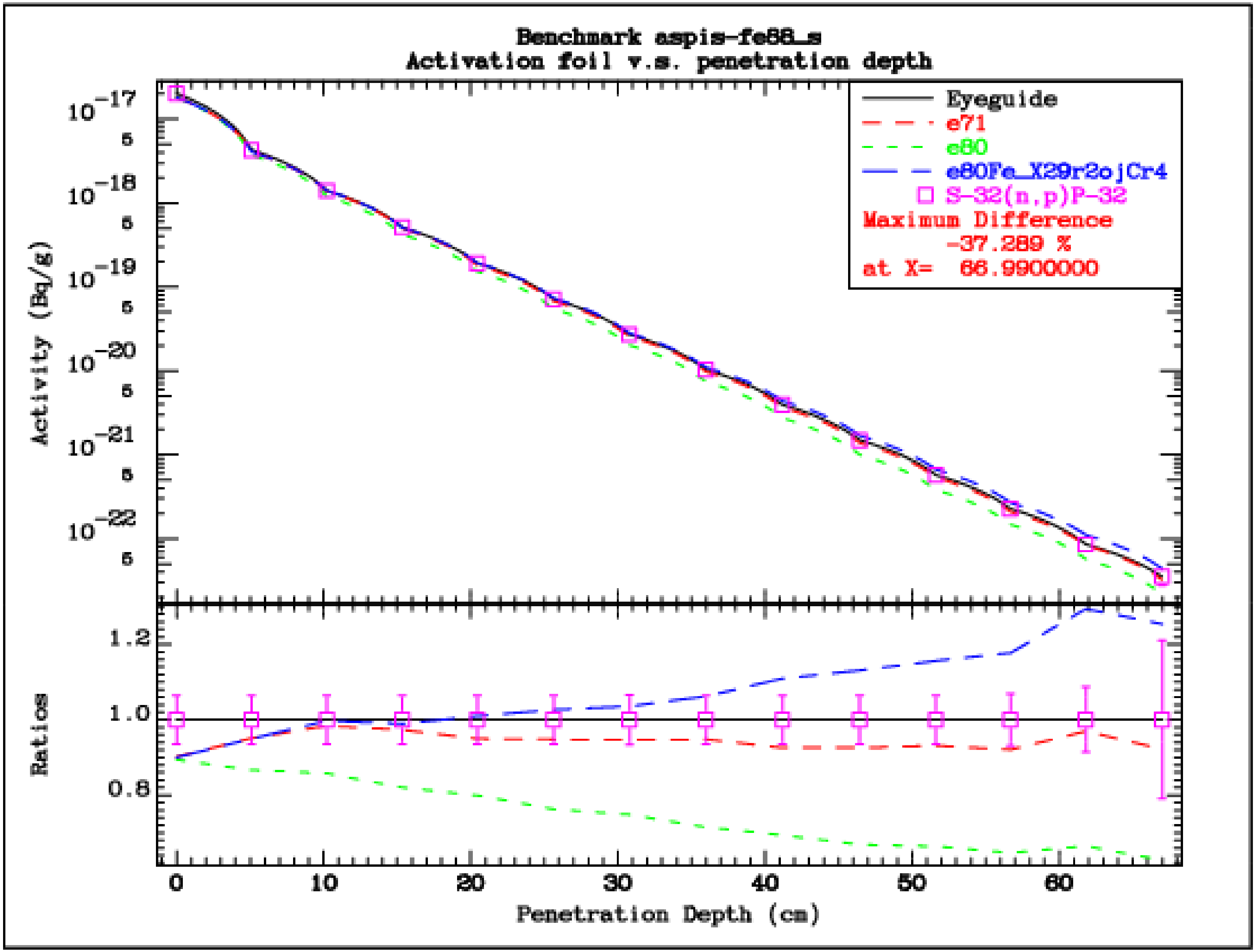
Not To Scale



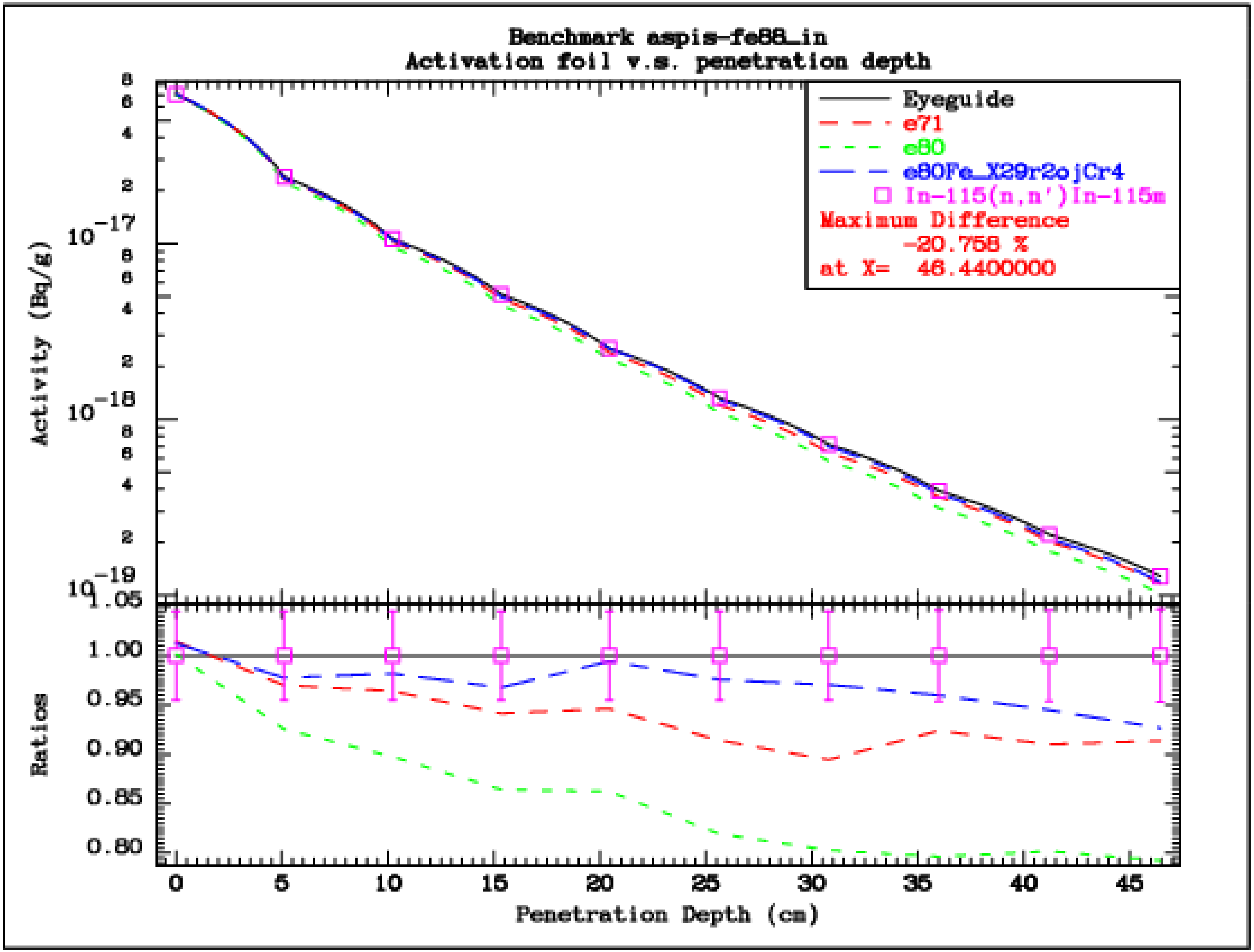
ENDF Request 548, 2018-Oct-11,14:26:19
IRDFF-1.05: AL-27(N,A)NA-24
IRDFF-1.05: S-32(N,P)P-32
IRDFF-1.05: RH-103(N,INL)RH-103-M1
IRDFF-1.05: IN-115(N,INL)IN-115-M1
Cross Section (barns)
Incident Energy (MeV)
5·10-2
10-1
0.5
1
5
10
50
0
0.5
1.0

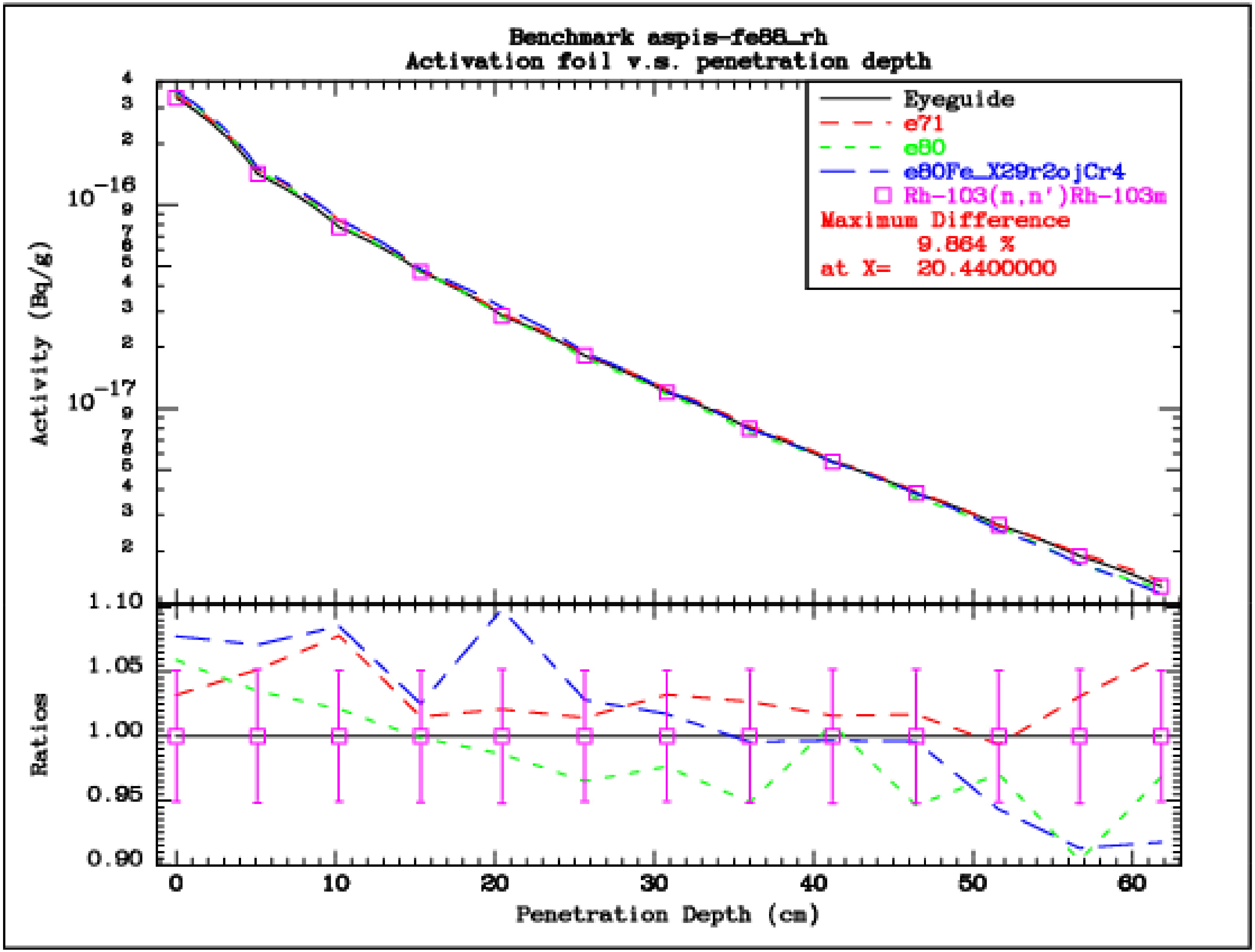


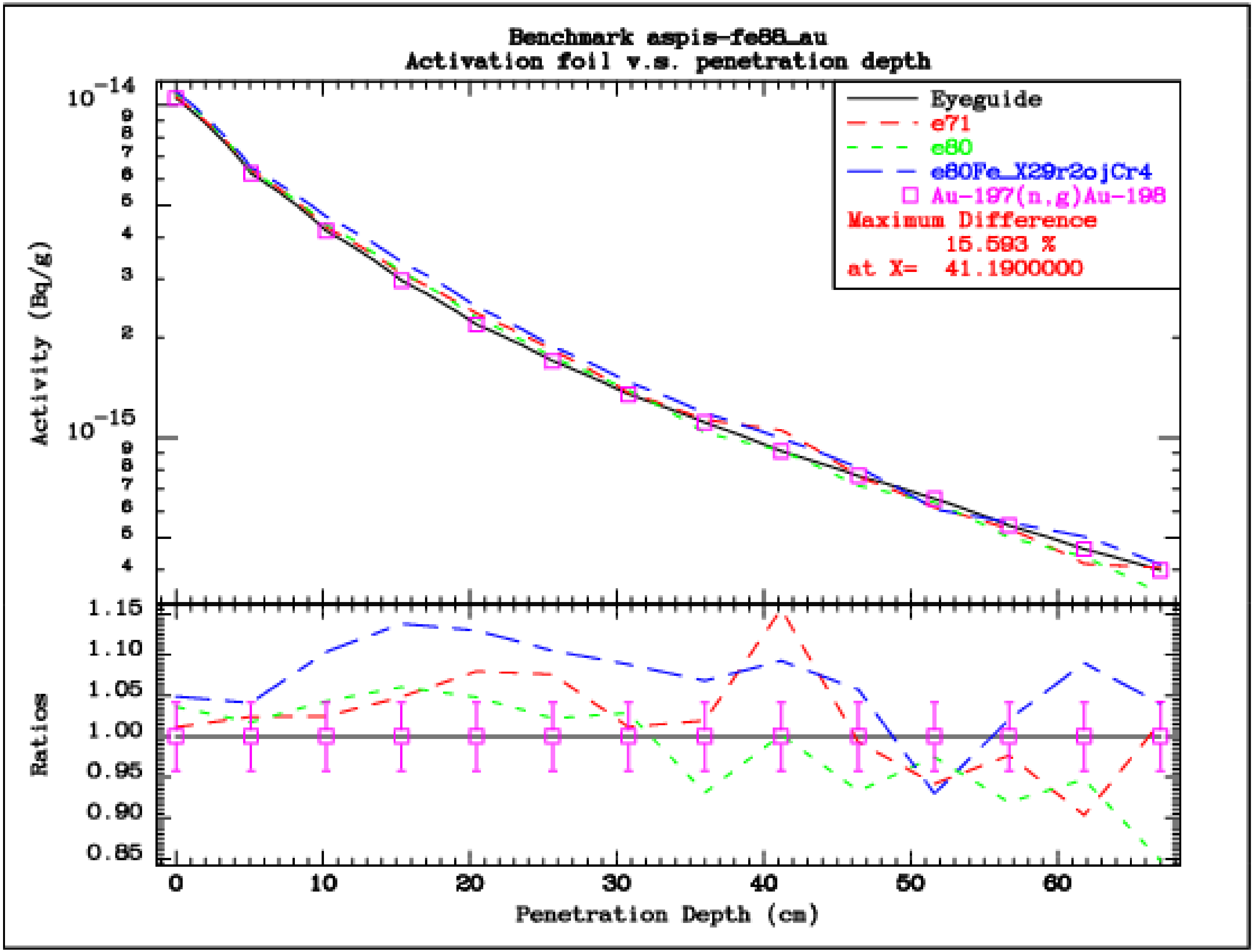
Benchmark aspis-fe88_al
Activation foil v.s. penetration depth
Activity (Bq/g)
Ratios
Penetration Depth (cm)
Eyeguide
e71
e80
e80Fe_X29r2ojCr4
Al-27(n,alpha)Na-24
Maximum Difference
30.553 %
at X= 25.6400000



Benchmark aspis-fe88_s
Activation foil v.s. penetration depth
Eyeguide
e71
e80
e80Fe_X29r2ojCr4
S-32(n,p)P-32
Maximum Difference
-37.289 %
at X= 66.9900000
Activity (Bq/g)
Ratios
Penetration Depth (cm)


Benchmark aspis-fe88_in
Activation foil v.s. penetration depth
Eyeguide
e71
e80
e80Fe_X29r2ojCr4
In-115(n,n')In-115m
Maximum Difference
-20.758 %
at X= 46.4400000
Activity (Bq/g)
Ratios
Penetration Depth (cm)


Benchmark aspis-fe88_rh
Activation foil v.s. penetration depth
Eyeguide
e71
e80
e80Fe_X29r2ojCr4
Rh-103(n,n')Rh-103m
Maximum Difference
9.864 %
at X= 20.4400000
Activity (Bq/g)
Ratios
Penetration Depth (cm)


Benchmark aspis-fe88_au
Activation foil v.s. penetration depth
Eyeguide
e71
e80
e80Fe_X29r2ojCr4
Au-197(n,g)Au-198
Maximum Difference
15.593 %
at X= 41.1900000
Activity (Bq/g)
Ratios
Penetration Depth (cm)

3. IPPE spheres with D-T source

- Benchmarks are available in SINBAD but without adequate MCNP inputs
- Analysed previously by A. Milocco at JSI (working with A. Trkov and I. Kodeli), computational model in the time domain, converted to energy

IPPE spheres with D-T source

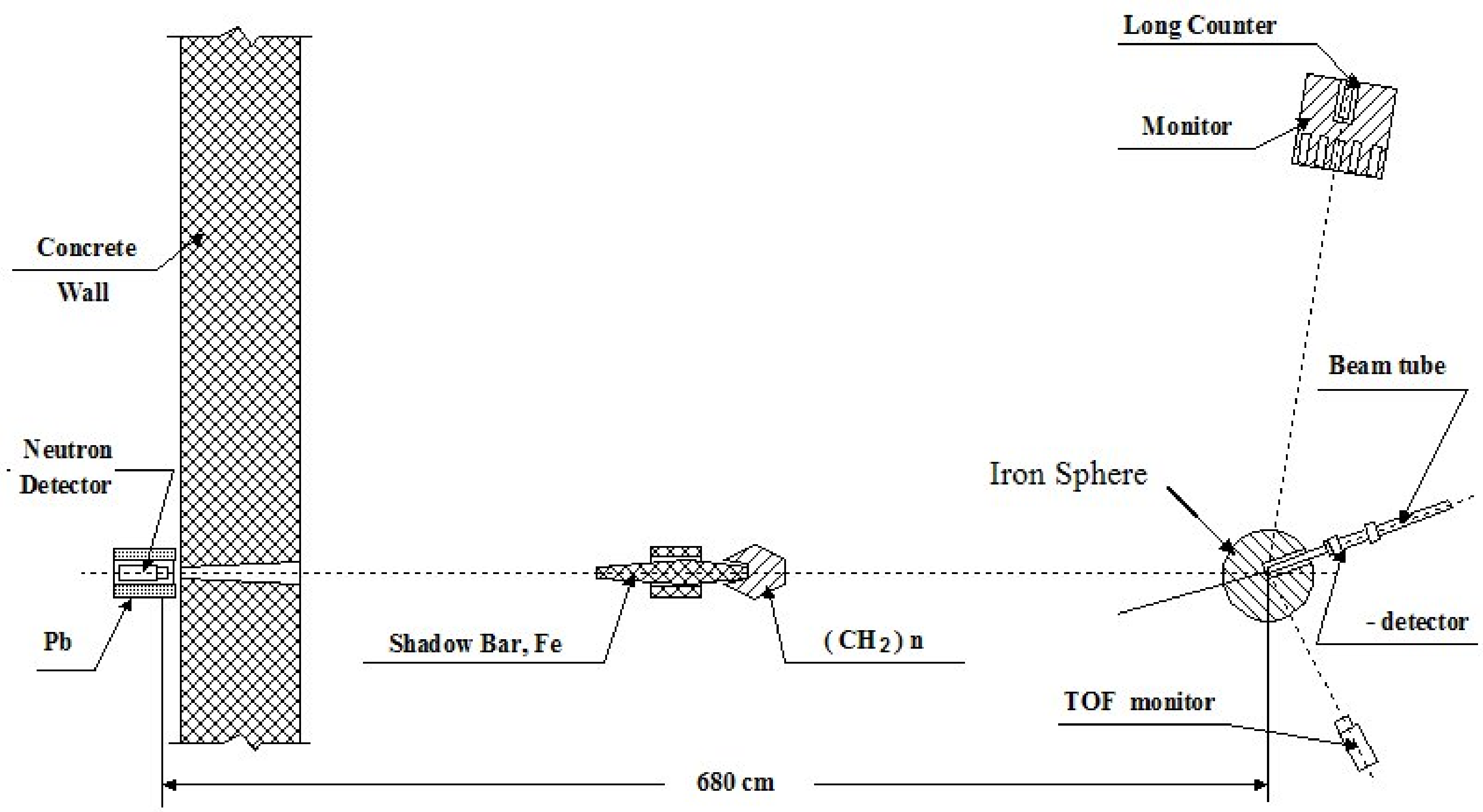
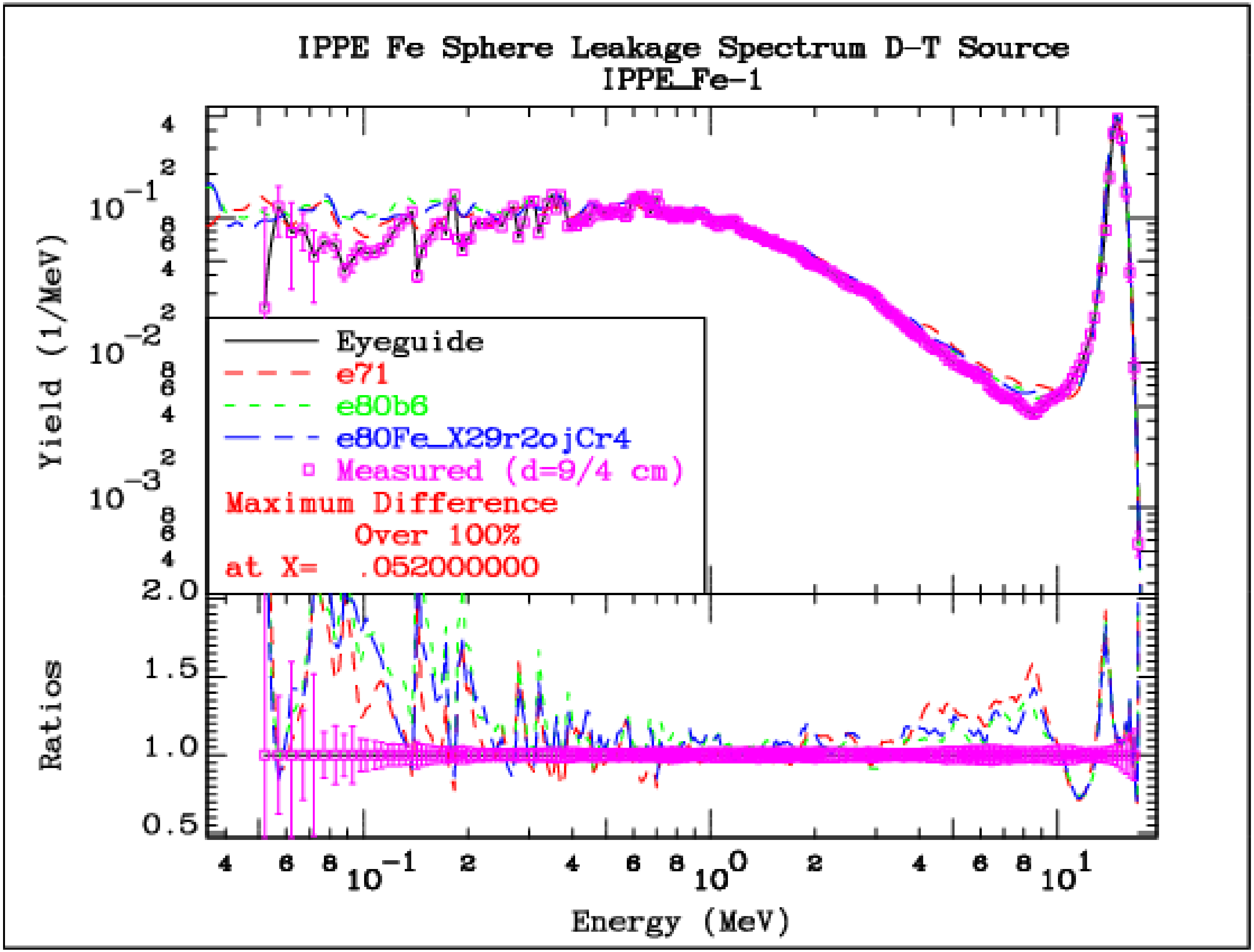
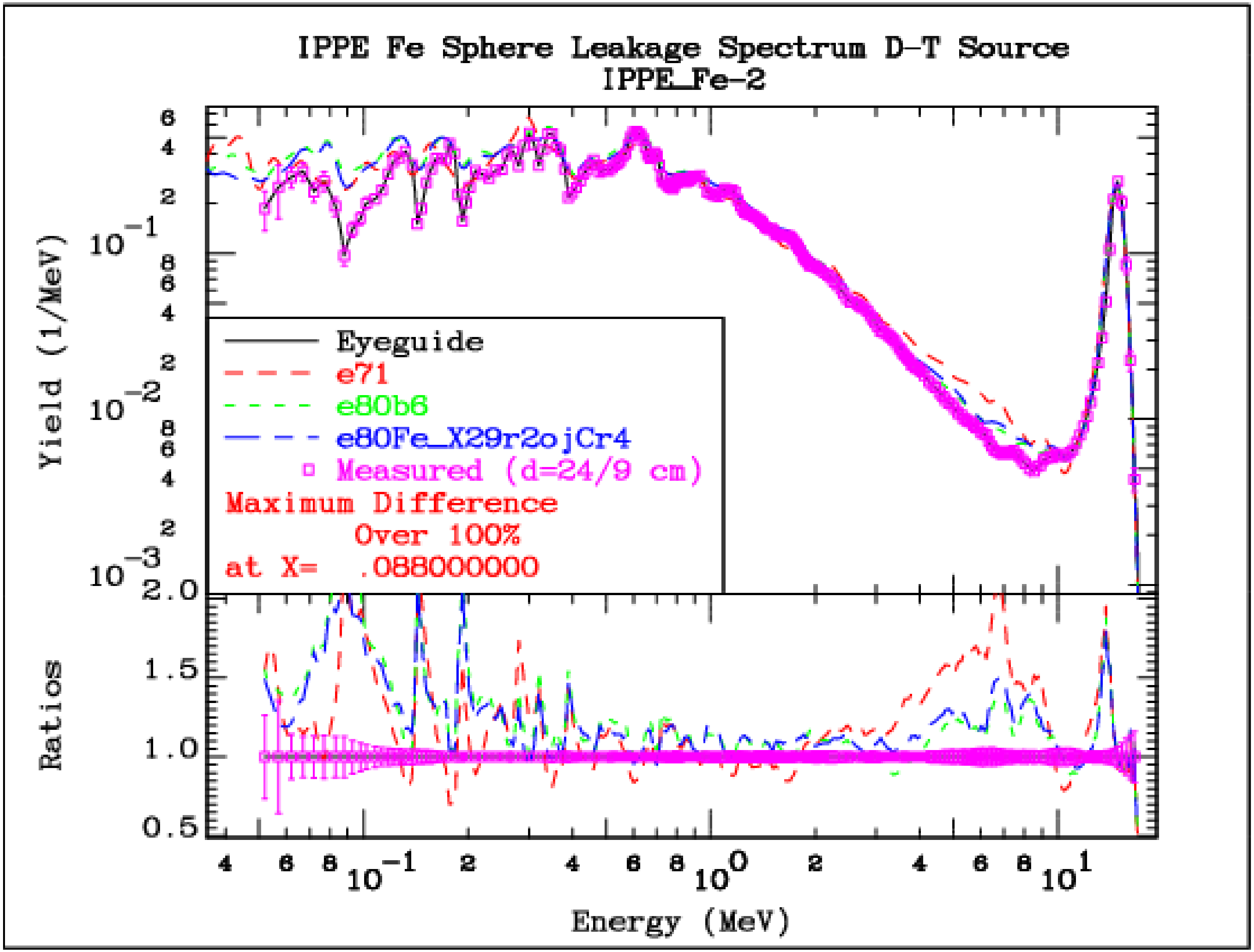
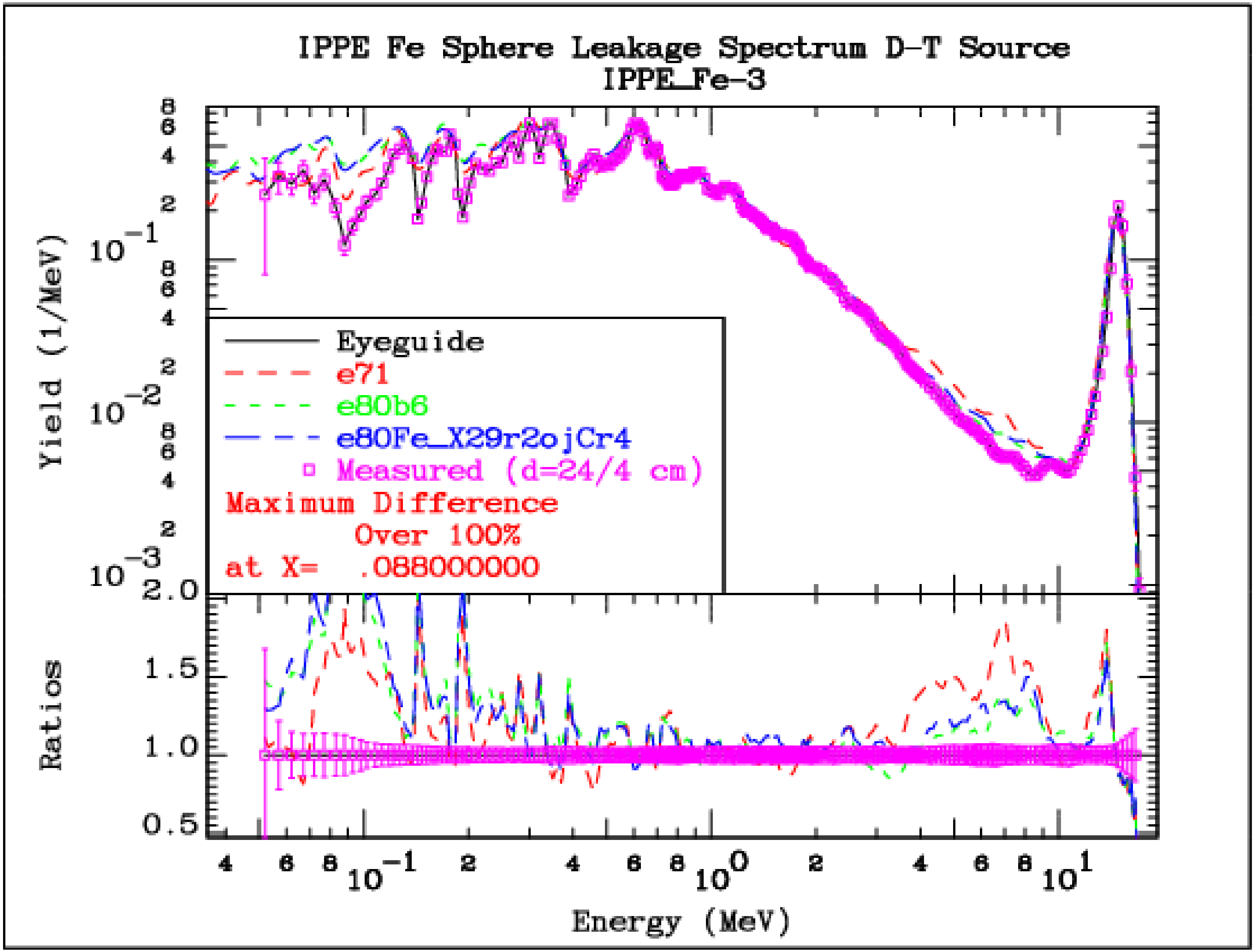
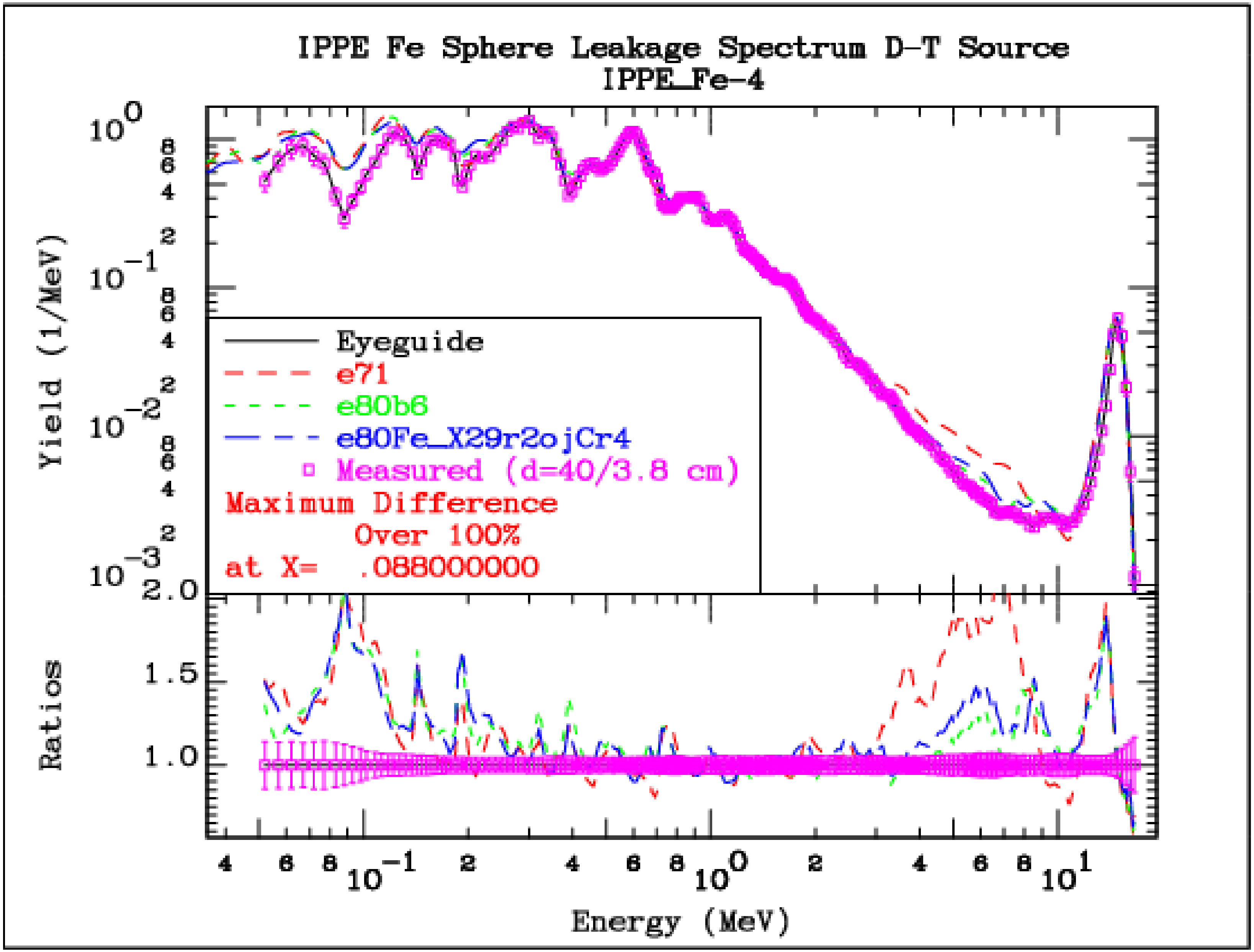


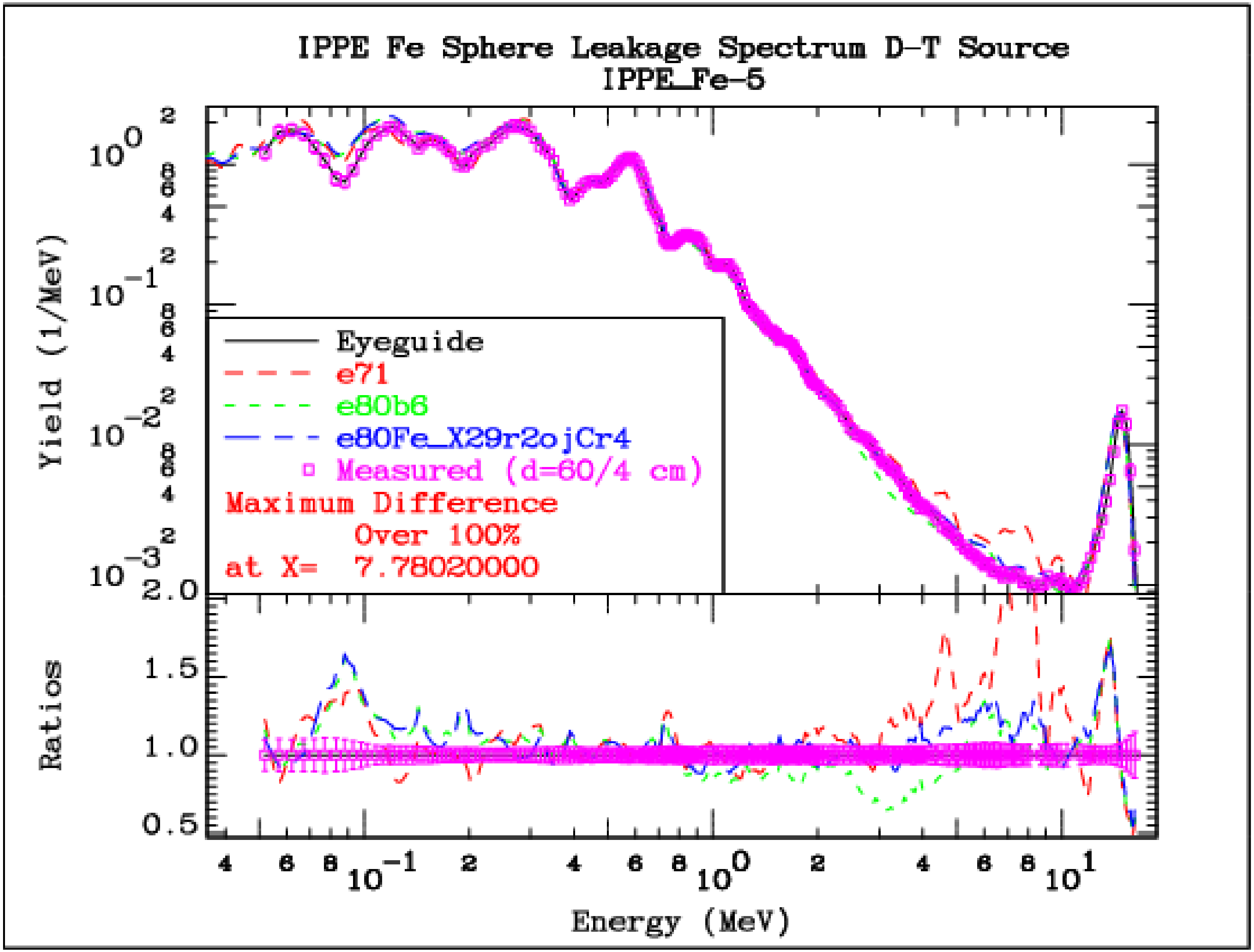
Fig. 1. Lay-out of experiment for measuring the neutron leakage spectra from iron spheres.


IPPE Fe Sphere Leakage Spectrum D-T Source
IPPE_Fe-1
Yield (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
Measured (d=9/4 cm)
Maximum Difference
Over 100%
at X= .052000000


IPPE Fe Sphere Leakage Spectrum D-T Source
IPPE_Fe-2
Yield (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
Measured (d=24/9 cm)
Maximum Difference
Over 100%
at X= .088000000


IPPE Fe Sphere Leakage Spectrum D-T Source
IPPE_Fe-3
Yield (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
Measured (d=24/4 cm)
Maximum Difference
Over 100%
at X= .088000000

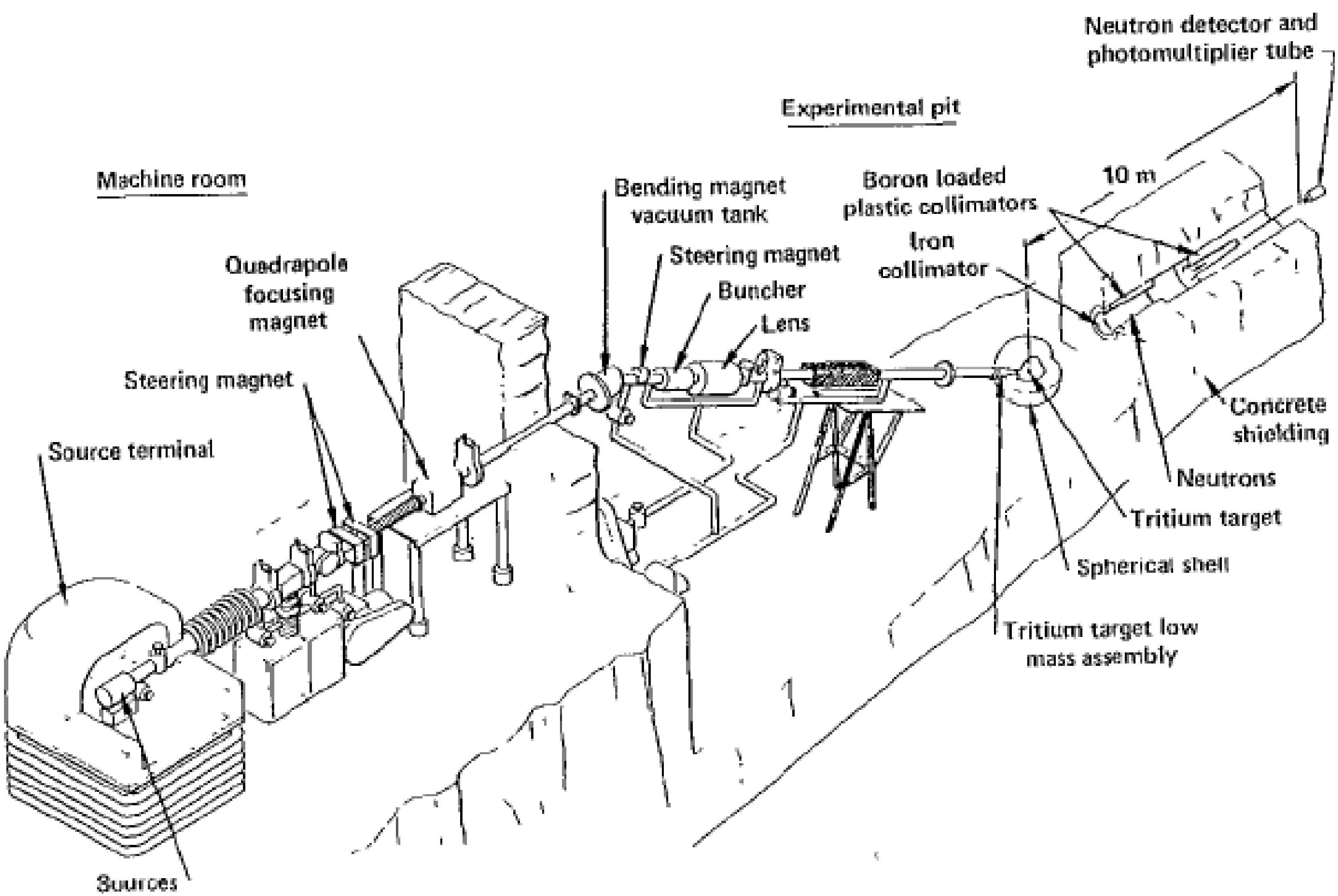

IPPE Fe Sphere Leakage Spectrum D-T Source
IPPE_Fe-4
Yield (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
Measured (d=40/3.8 cm)
Maximum Difference
Over 100%
at X= .088000000

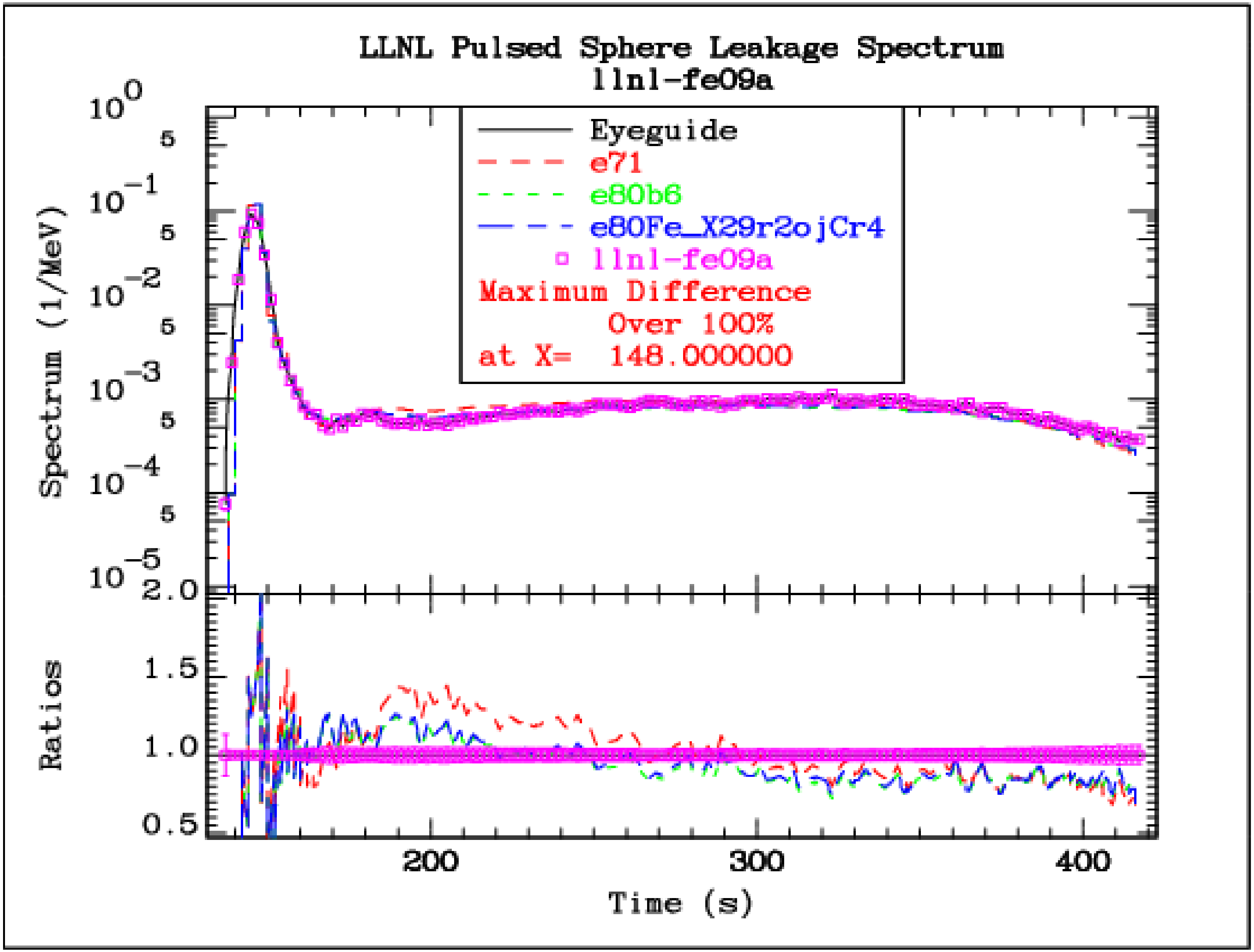

IPPE Fe Sphere Leakage Spectrum D-T Source
IPPE_Fe-5
Yield (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
Measured (d=60/4 cm)
Maximum Difference
Over 100%
at X= 7.78020000

4. LLNL spheres with D-T source

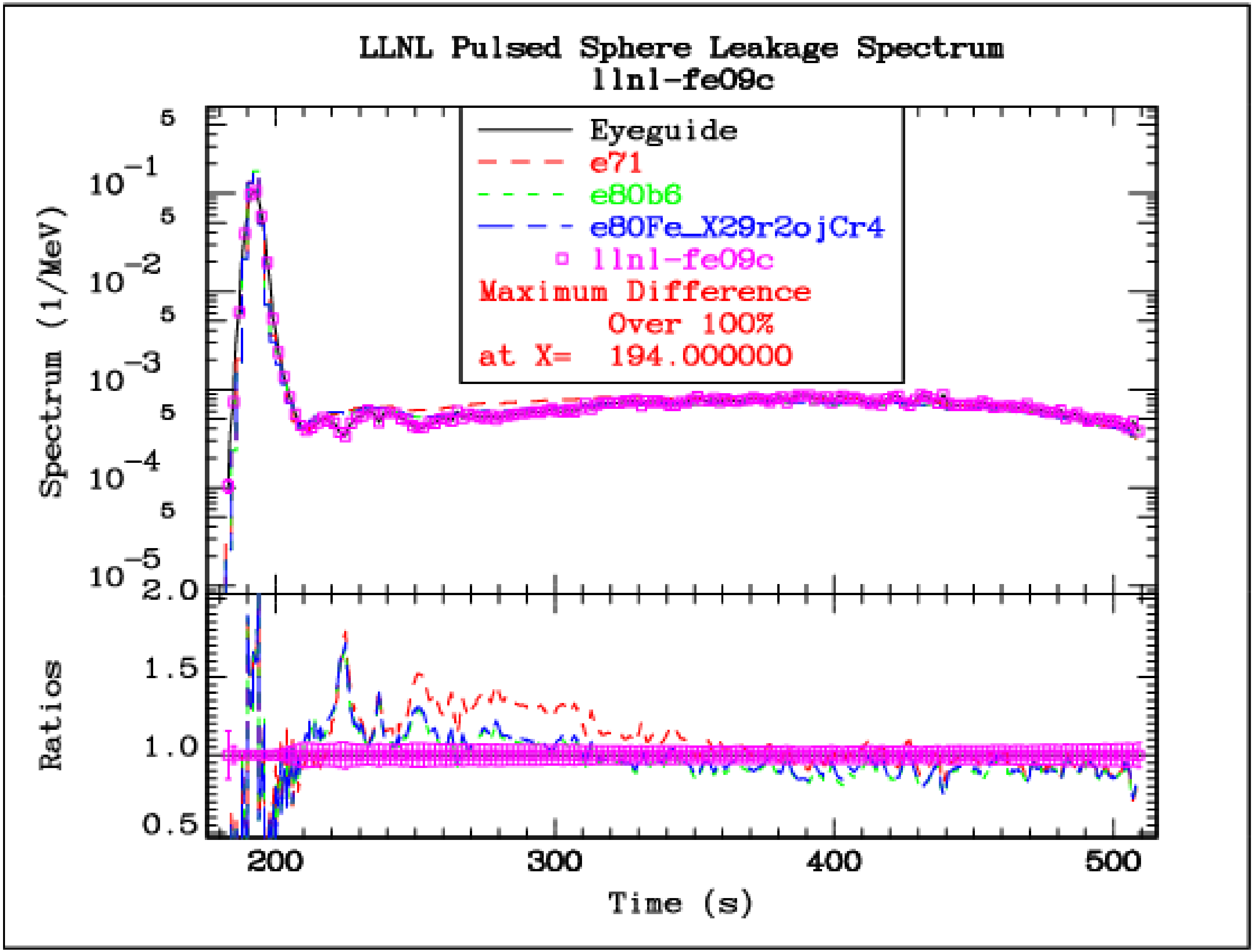
- Experiments from Lawrence Livermore National Laboratory
- Two spheres 8.92 cm diam. (0.9 m.f.p.) and 44.6 cm diam. (4.8 m.f.p.) and two detectors
- Computational models by S. Frankle (obtained from LANL); computational model in the time domain, converted to energy.
- Similar to IPPE benchmark with D-T source, but over a shorter energy range – supports the observation of a difference in gradient (difference is smaller with the new file)

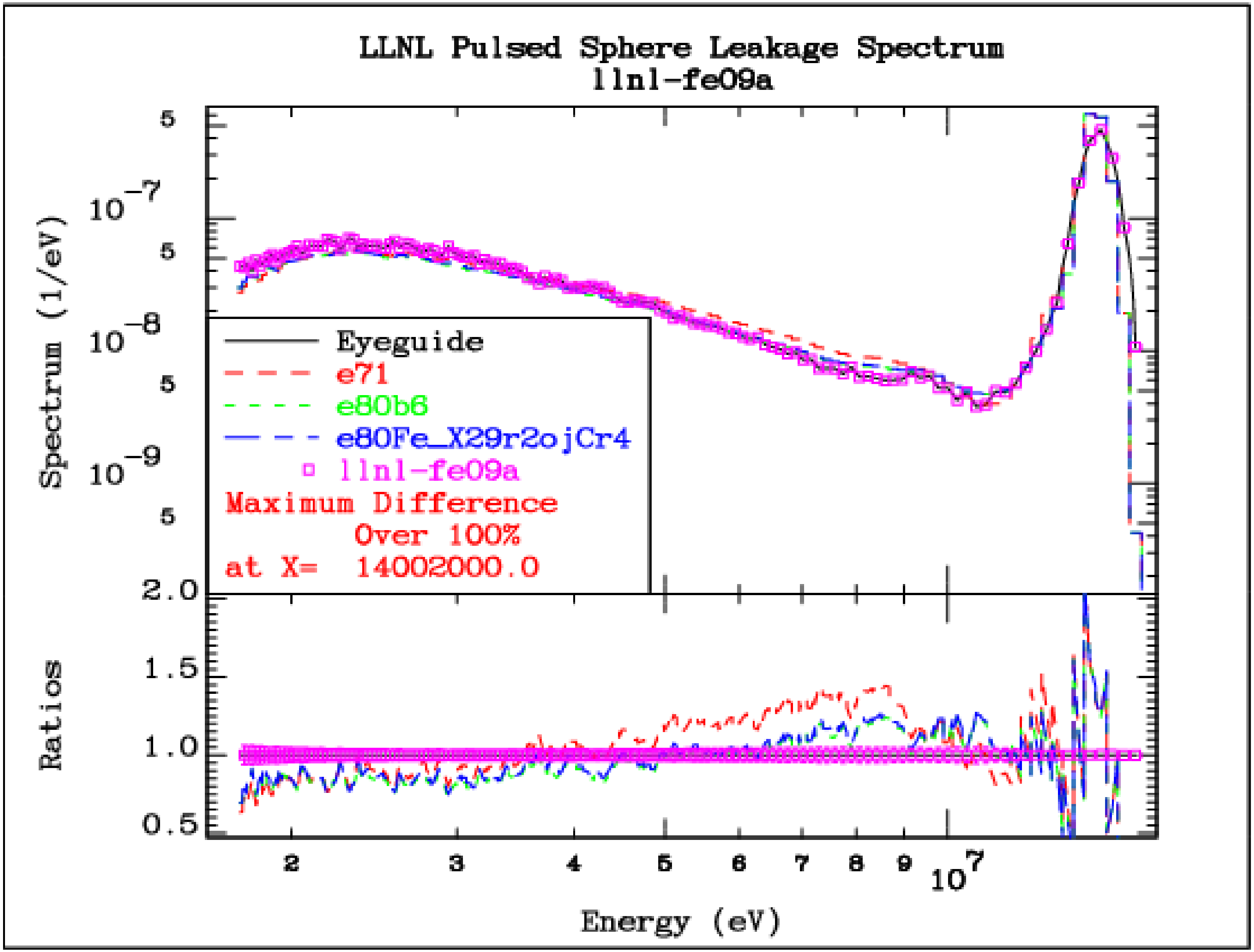
LLNL spheres with D-T source



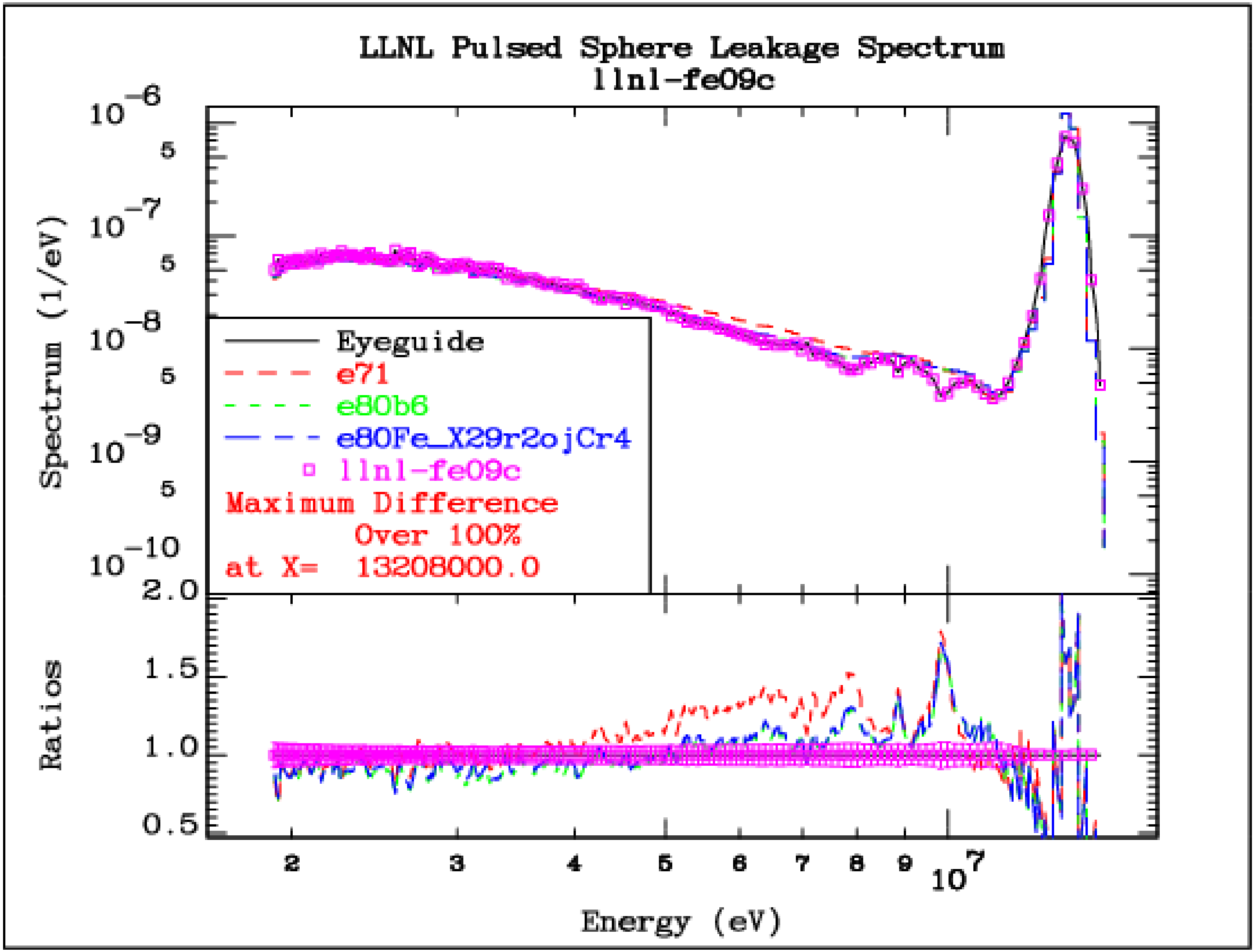


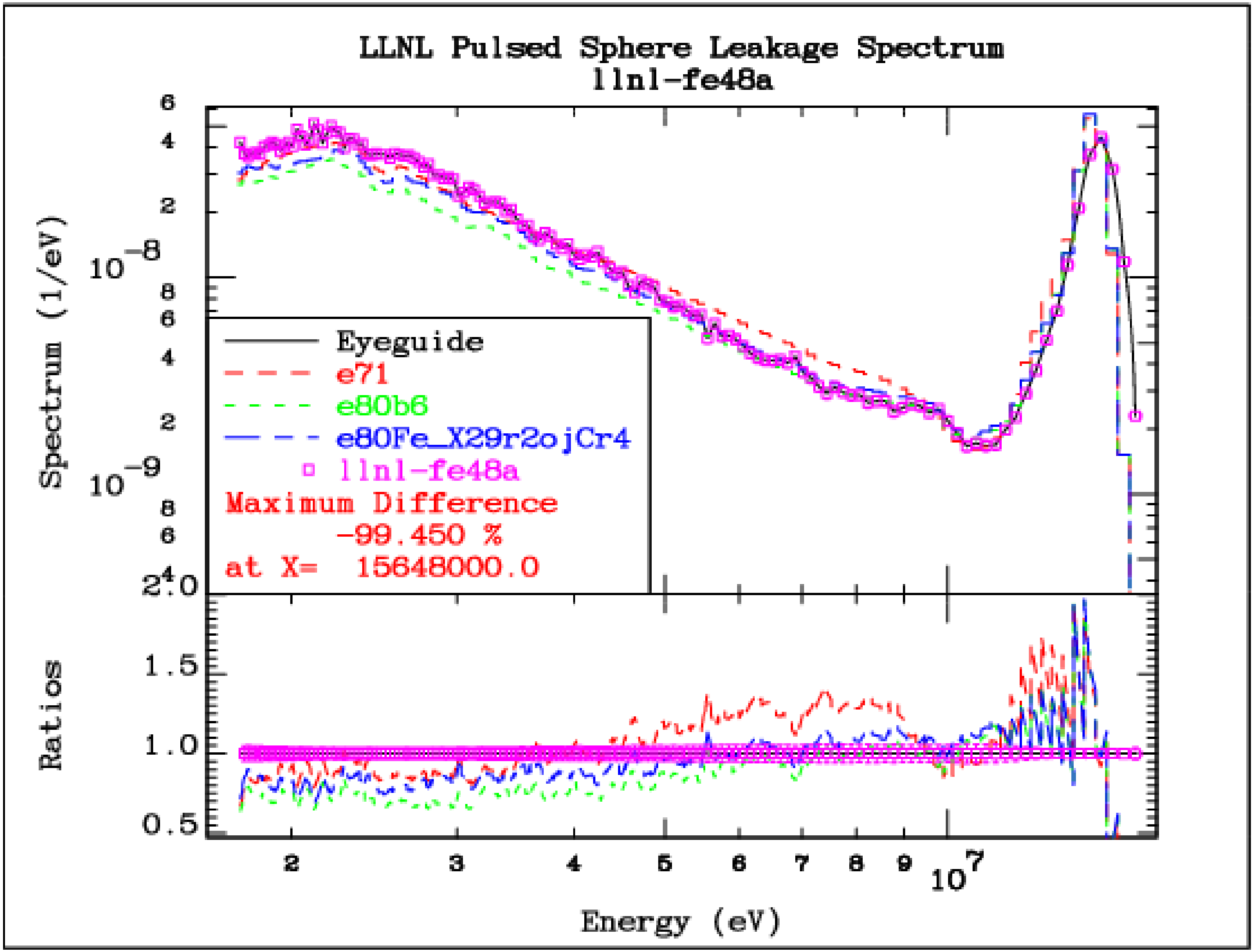
LLNL Pulsed Sphere Leakage Spectrum
llnl-fe09a
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
llnl-fe09a
Maximum Difference
Over 100%
at X= 148.000000
Spectrum (1/MeV)
Ratios
Time (s)
200
300
400


LLNL Pulsed Sphere Leakage Spectrum
llnl-fe09c
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
llnl-fe09c
Maximum Difference
Over 100%
at X= 194.000000
Spectrum (1/MeV)
Ratios
Time (s)
200
300
400
500
2.0
1.5
1.0
0.5

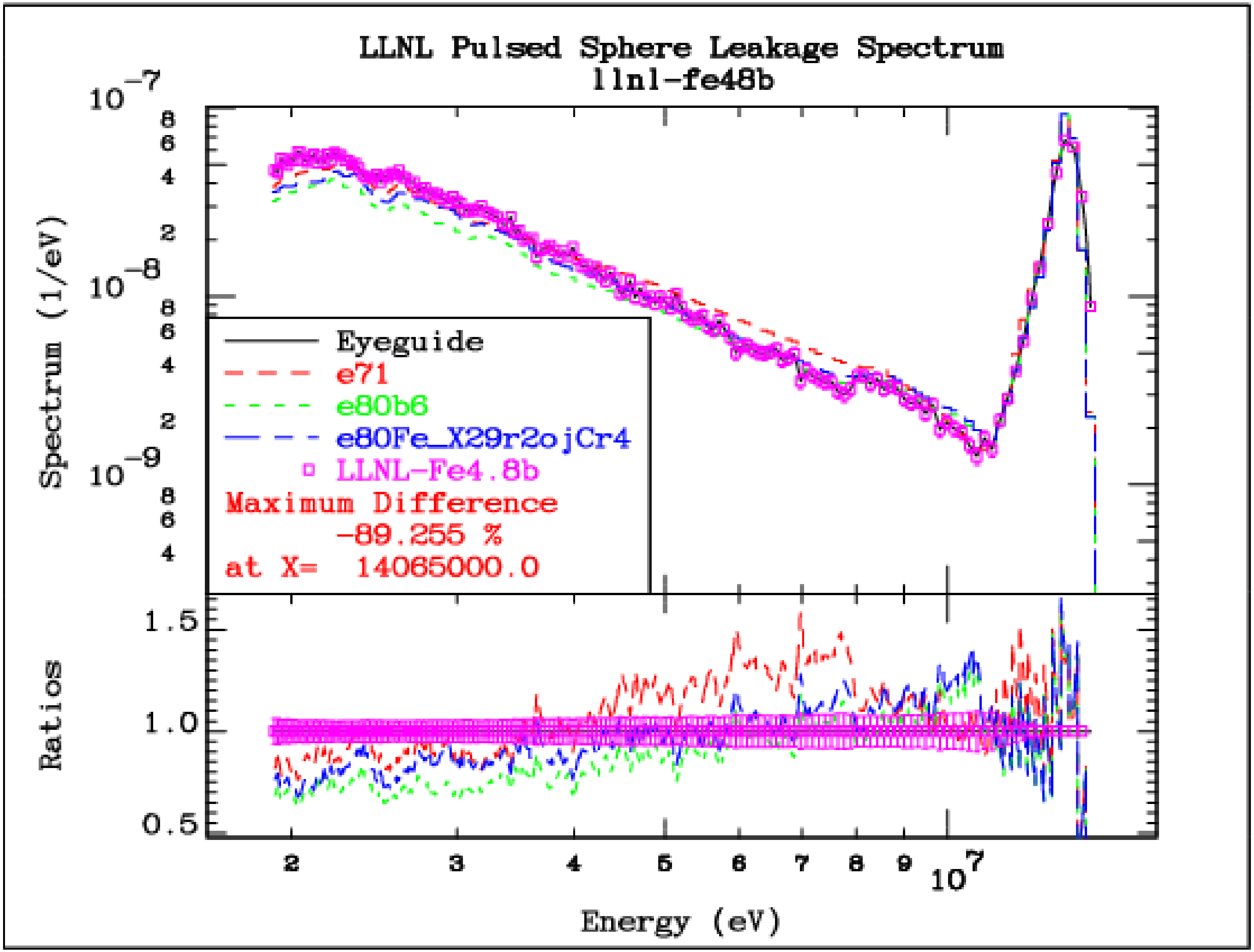


LLNL Pulsed Sphere Leakage Spectrum
llnl-fe09a
Spectrum (1/eV)
Ratios
Energy (eV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
llnl-fe09a
Maximum Difference
Over 100%
at X= 14002000.0

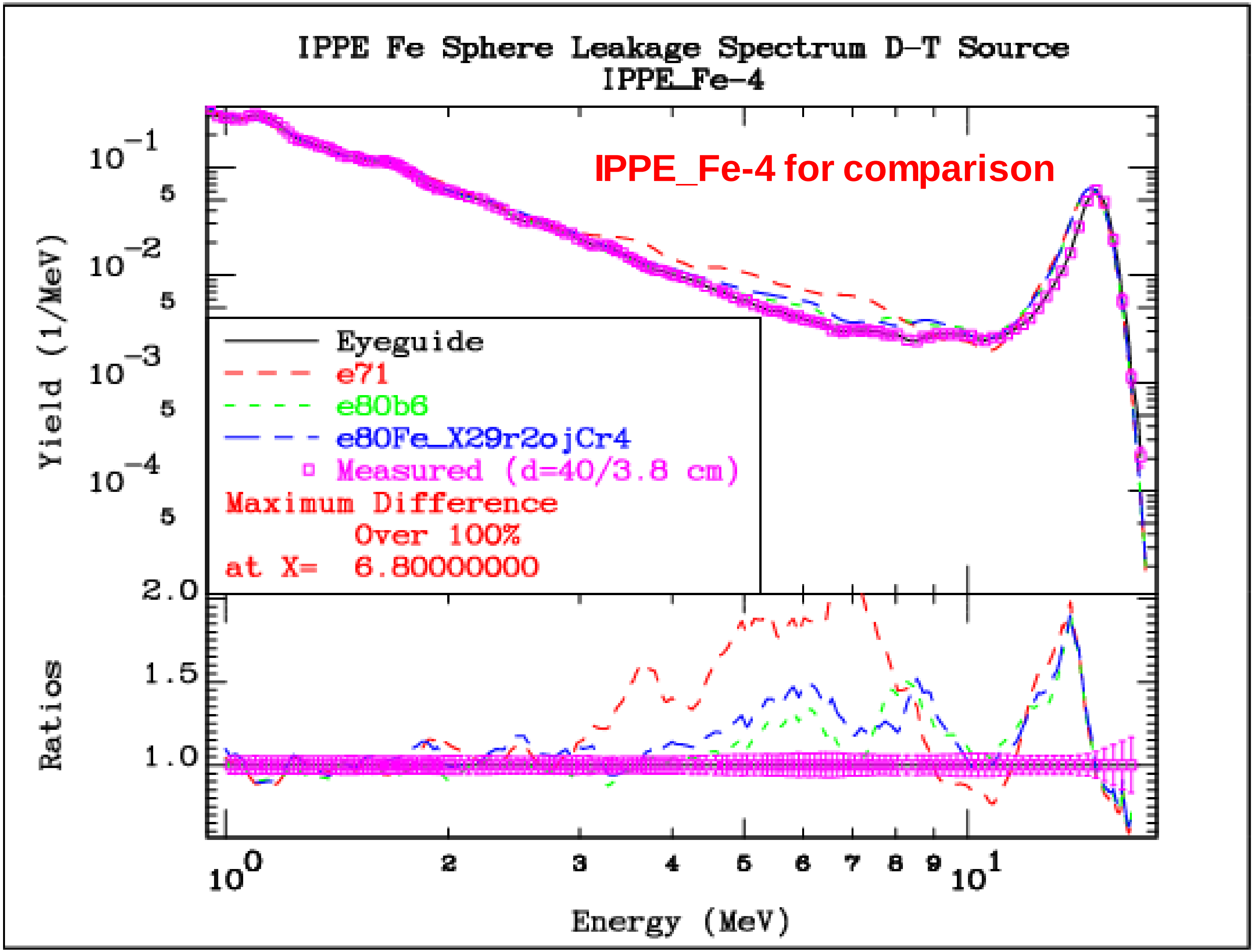

LLNL Pulsed Sphere Leakage Spectrum
llnl-fe09c
Spectrum (1/eV)
Ratios
Energy (eV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
llnl-fe09c
Maximum Difference
Over 100%
at X= 13208000.0



LLNL Pulsed Sphere Leakage Spectrum
llnl-fe48a
Spectrum (1/eV)
Ratios
Energy (eV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
llnl-fe48a
Maximum Difference
-99.450 %
at X= 15648000.0

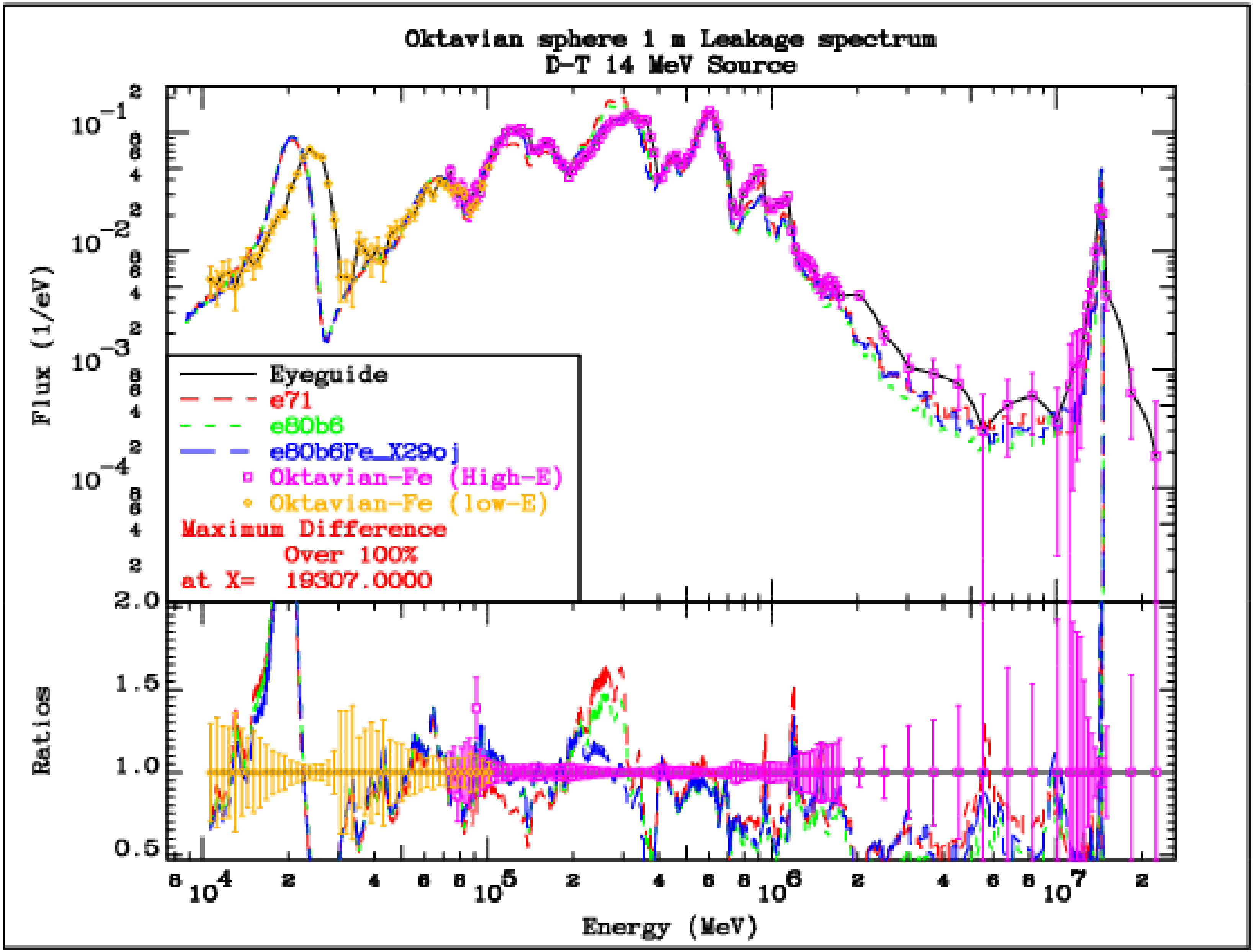


LLNL Pulsed Sphere Leakage Spectrum
llnl-fe48b
Spectrum (1/eV)
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
LLNL-Fe4.8b
Maximum Difference
-89.255 %
at X= 14065000.0
Ratios
Energy (eV)

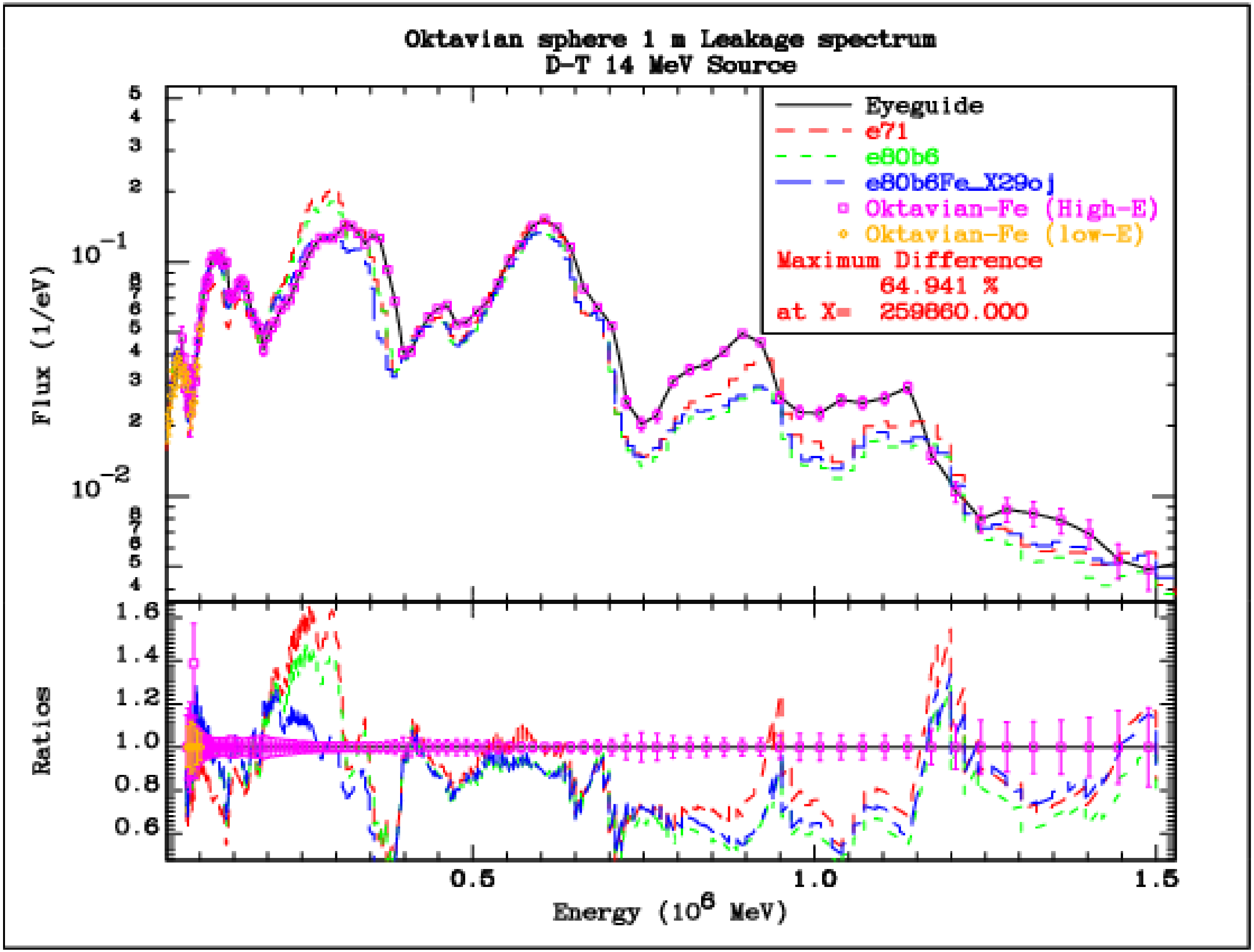

IPPE Fe Sphere Leakage Spectrum D-T Source
IPPE_Fe-4
IPPE_Fe-4 for comparison
Eyeguide
e71
e80b6
e80Fe_X29r2ojCr4
Measured (d=40/3.8 cm)
Maximum Difference
Over 100%
at X= 6.80000000
Yield (1/MeV)
Ratios
Energy (MeV)

5. Oktavian-Fe sphere with D-T source

- Experiments from Osaka University documented in SINBAD
- Fe sphere of 100.64 cm diameter
- At energies above 0.7 MeV significant deviations from measured values are observed
- Above 2 MeV the measurements are not reliable
- Low-energy measurement seems to be shifted in energy



Oktavian sphere 1 m Leakage spectrum
D-T 14 MeV Source
Flux (1/eV)
Ratios
Energy (MeV)
Eyeguide
e71
e80b6
e80b6Fe_X29oj
Oktavian-Fe (High-E)
Oktavian-Fe (low-E)
Maximum Difference
Over 100%
at X= 19307.0000

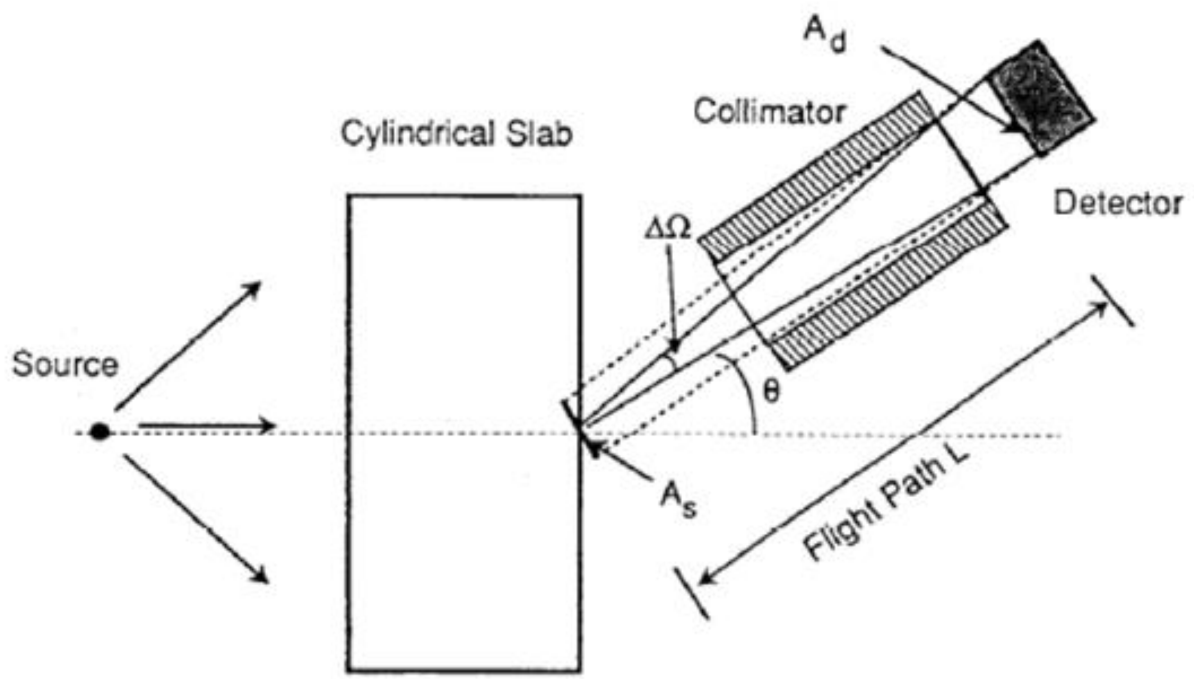


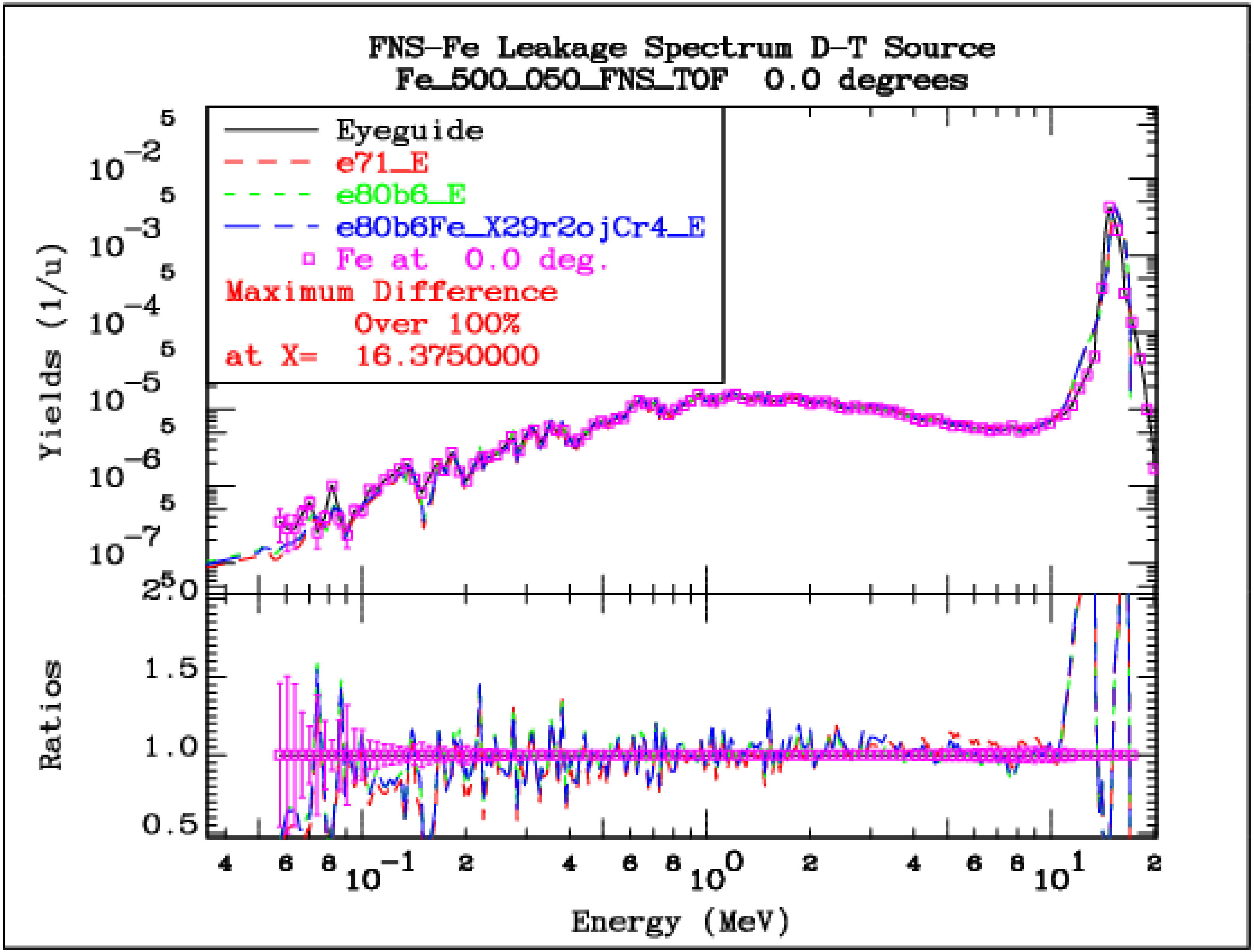
Oktavian sphere 1 m Leakage spectrum
D-T 14 MeV Source
Eyeguide
e71
e80b6
e80b6Fe_X29oj
Oktavian-Fe (High-E)
Oktavian-Fe (low-E)
Maximum Difference
64.941 %
at X= 259860.000
Flux (1/eV)
Ratios
Energy (10^6 MeV)

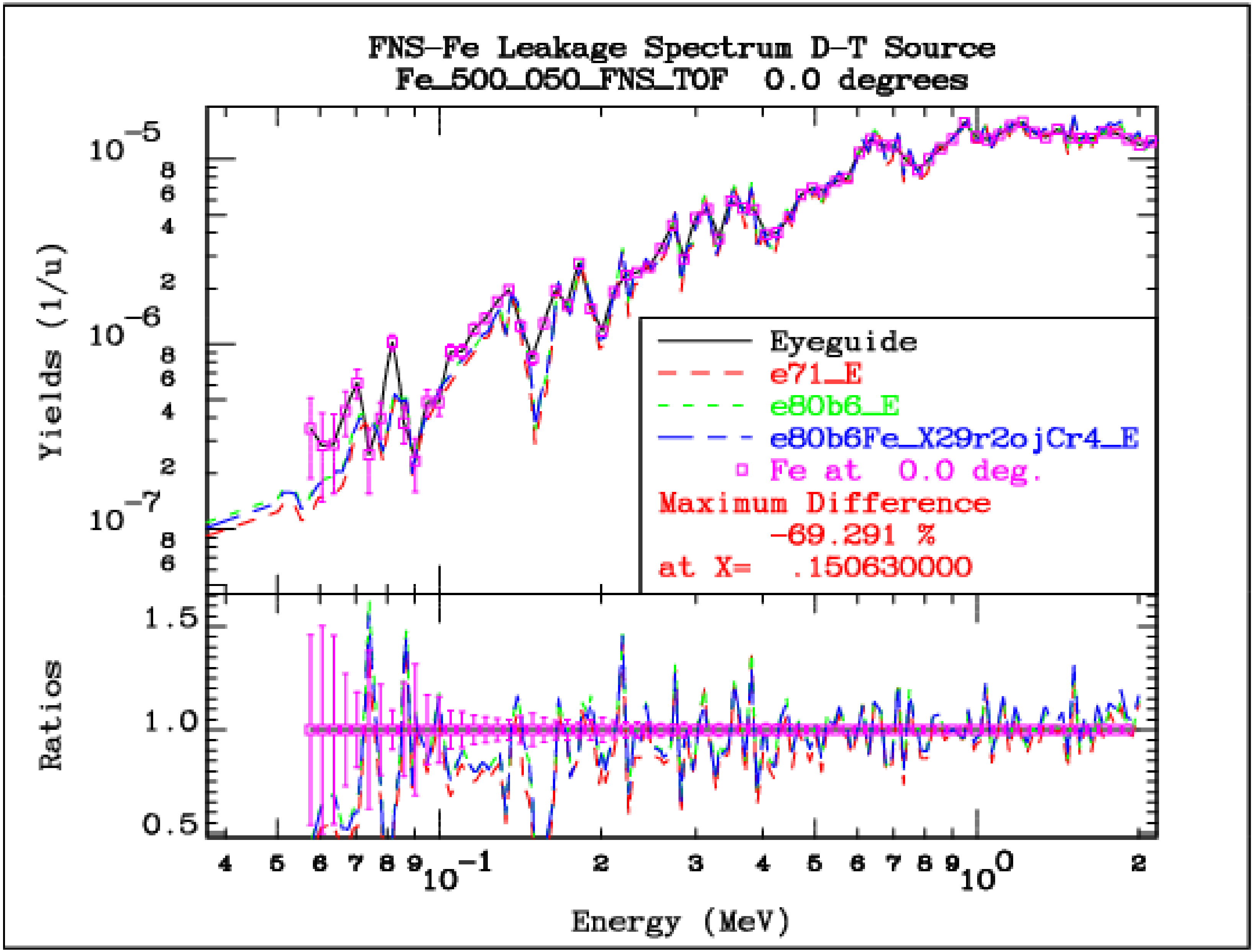
6. FNS-Fe thick slab transmission spectra at different angles

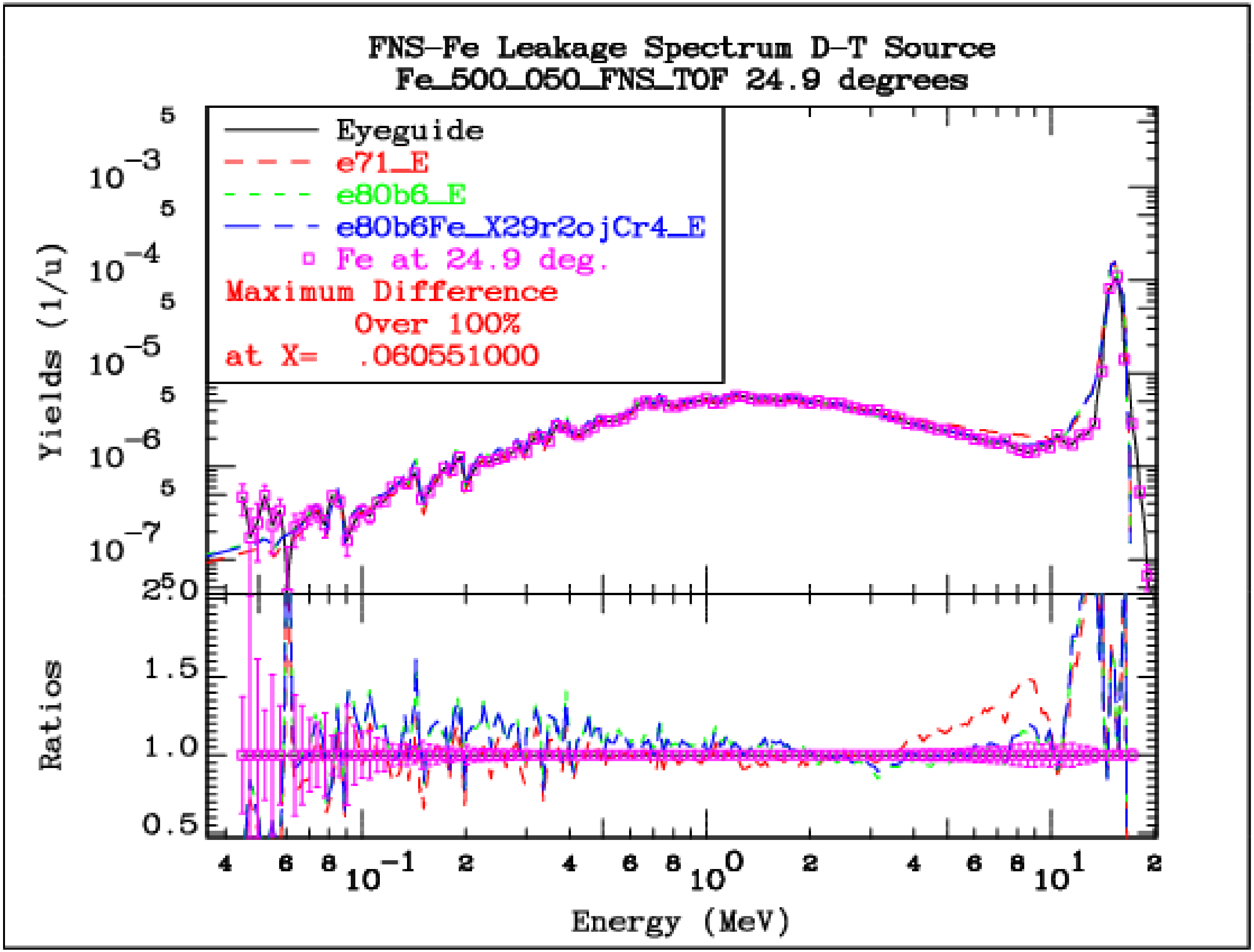
- Recent re-analysis by B. Kos from JSI with weight-windows variance reduction

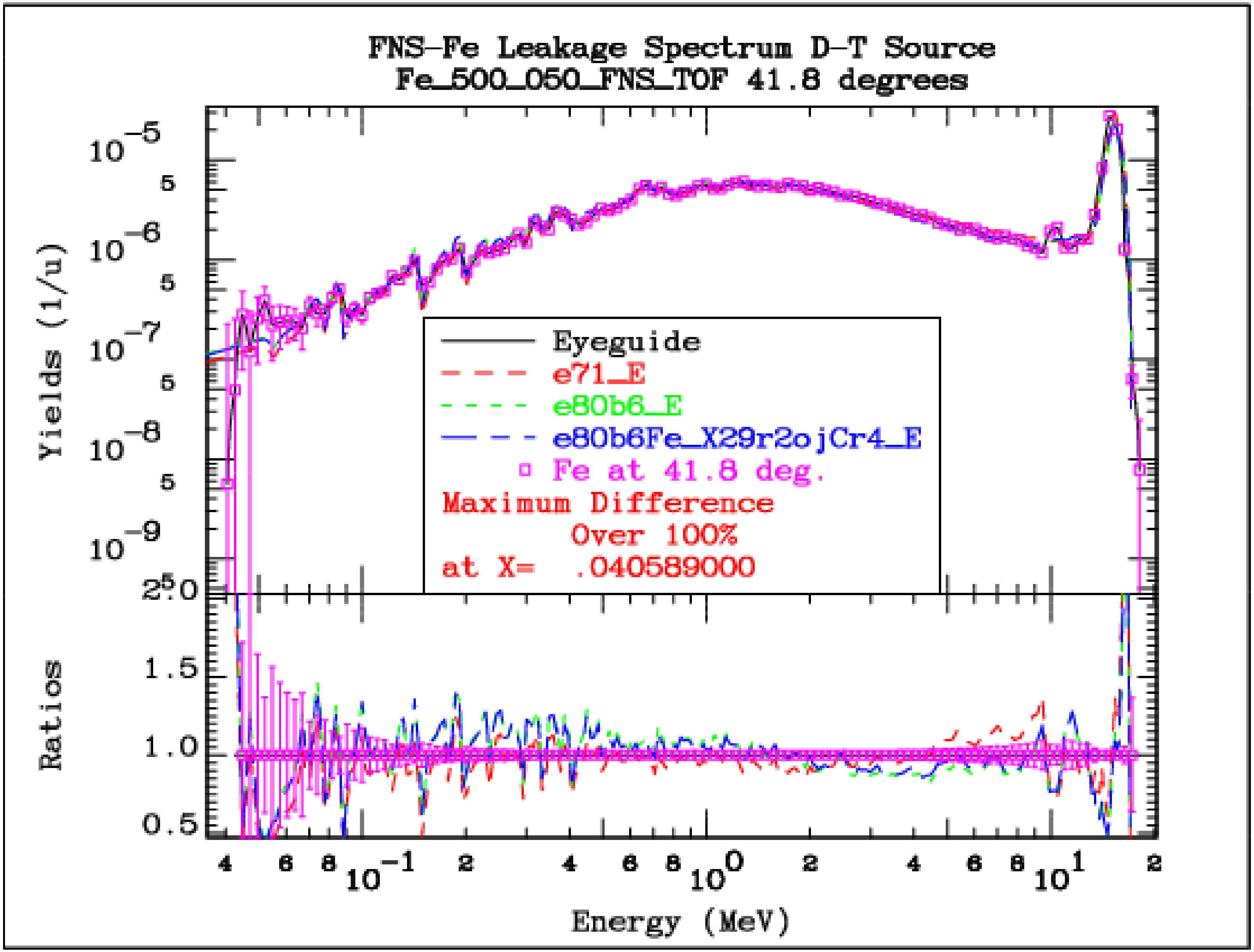
1. TOF

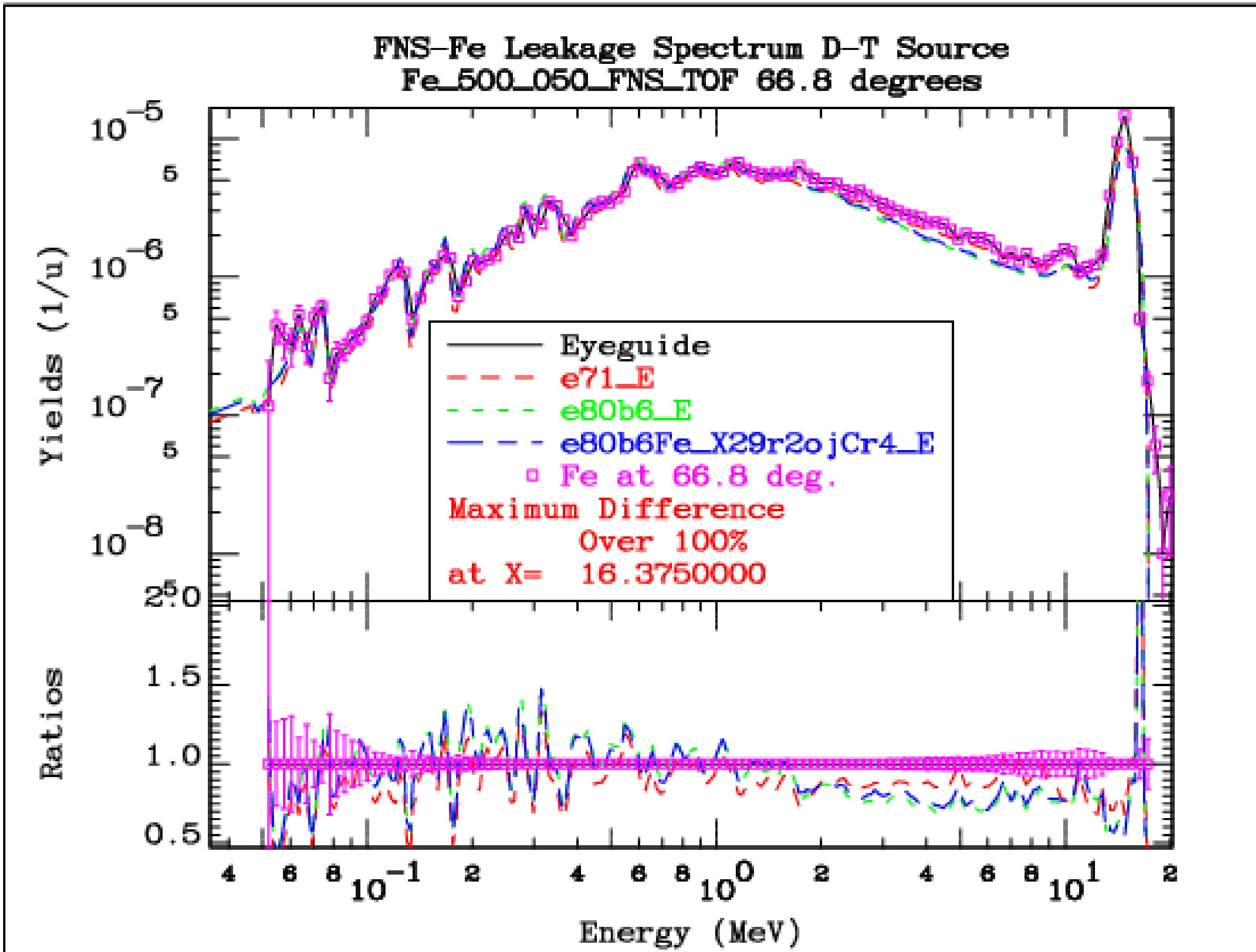


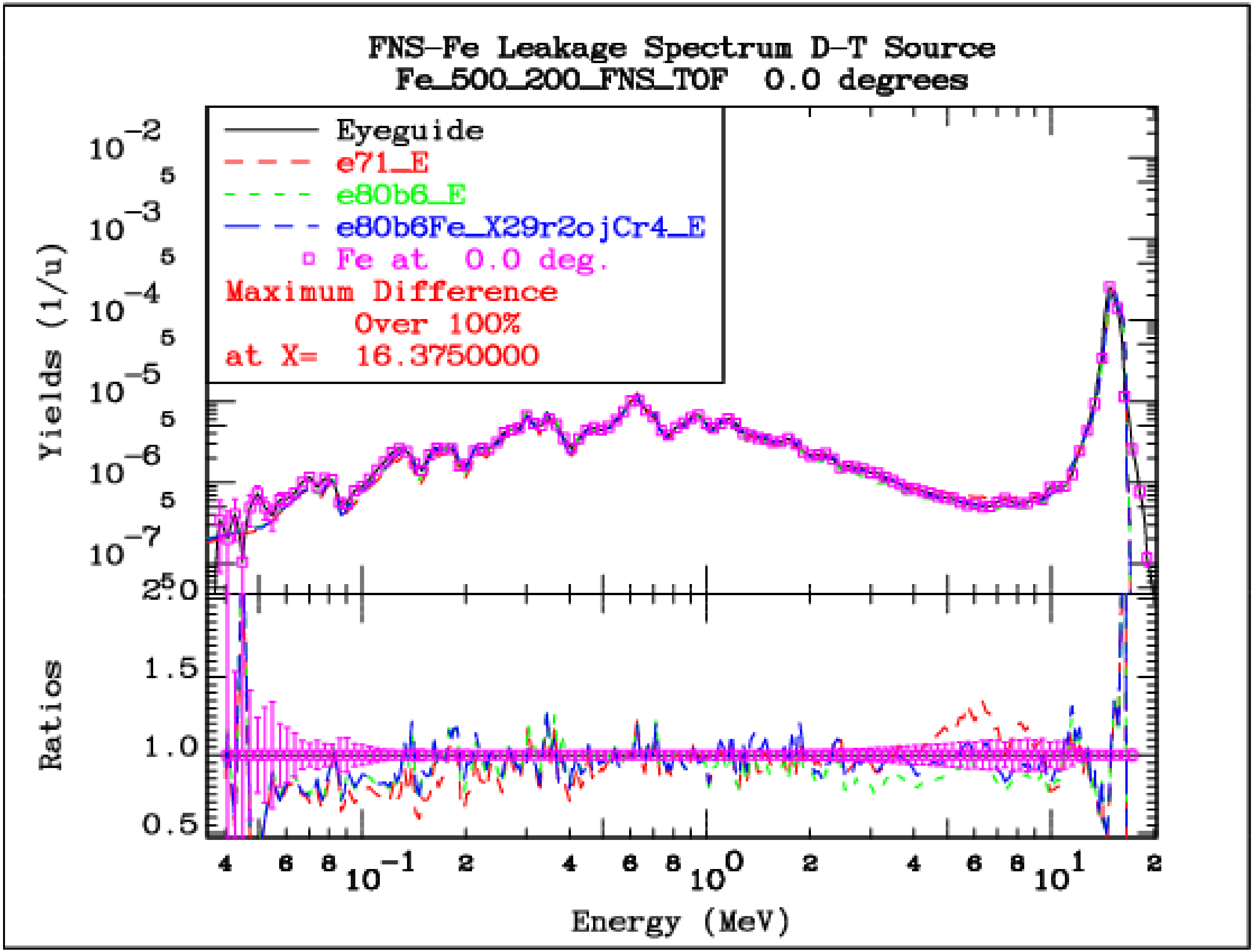

FNS-Fe Leakage Spectrum D-T Source
Fe_500_050_FNS_TOF 0.0 degrees
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 0.0 deg.
Maximum Difference
Over 100%
at X= 16.3750000
Yields (1/u)
Ratios
Energy (MeV)

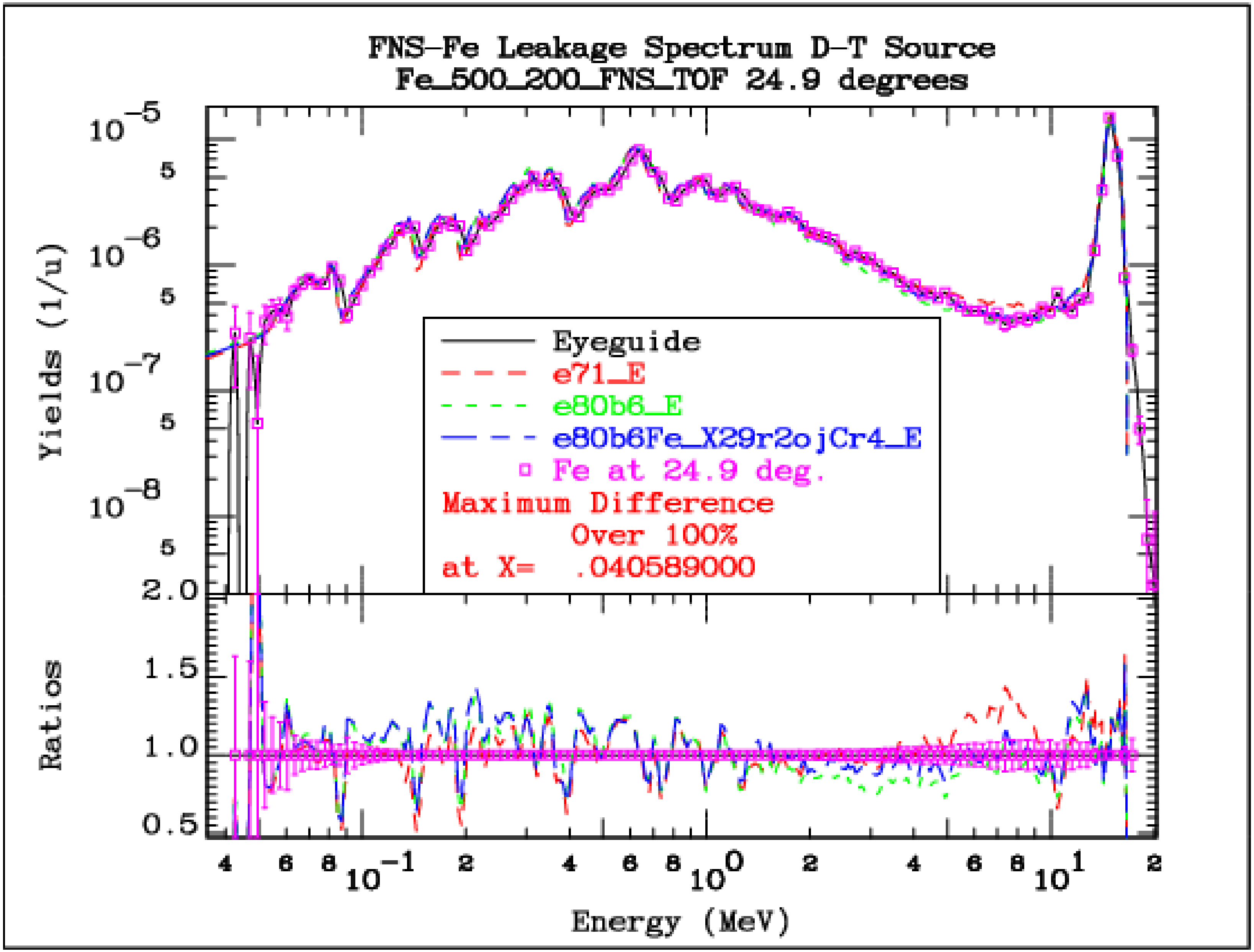

FNS-Fe Leakage Spectrum D-T Source
Fe_500_050_FNS_TOF 0.0 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 0.0 deg.
Maximum Difference
-69.291 %
at X= .150630000

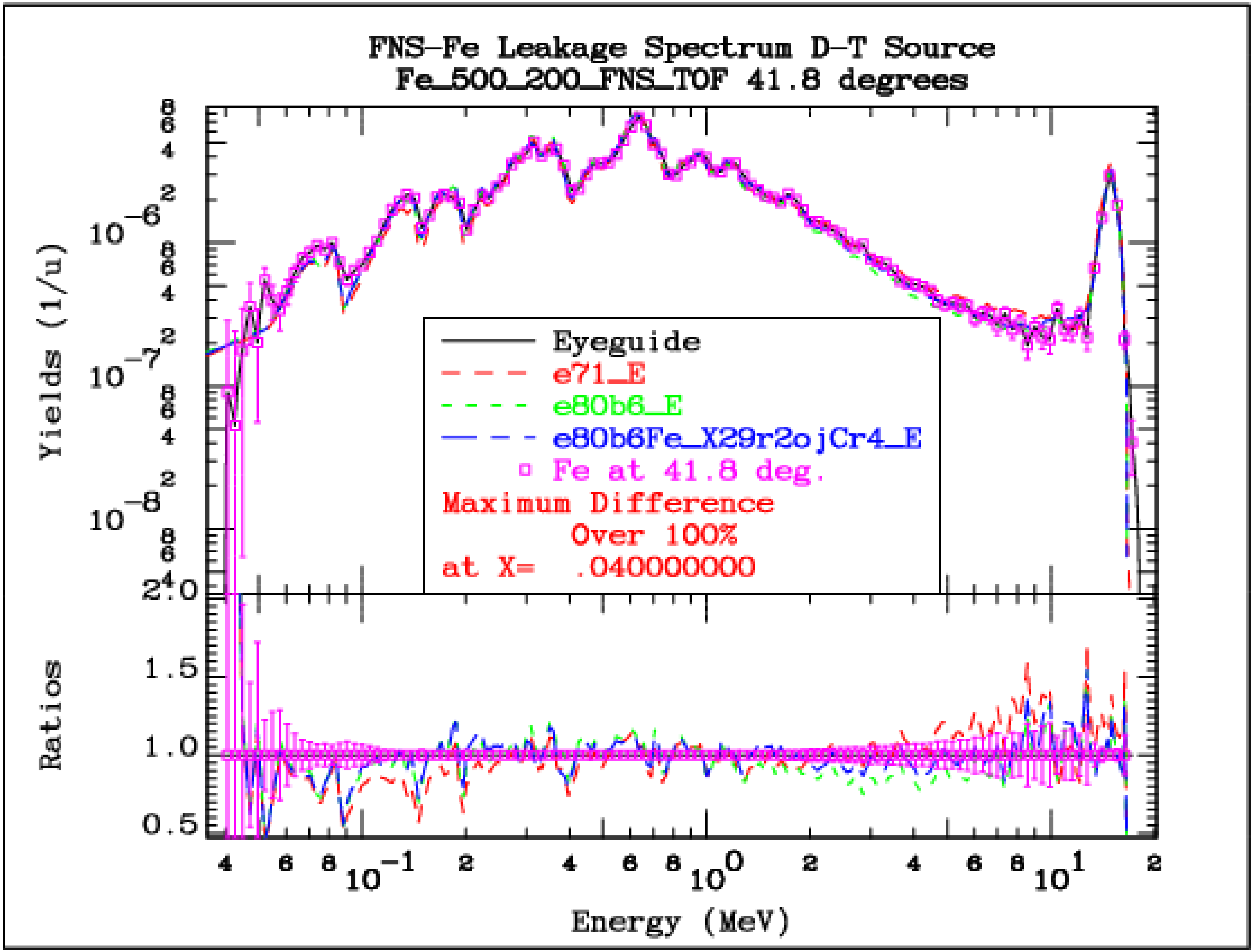

FNS-Fe Leakage Spectrum D-T Source
Fe_500_050_FNS_TOF 24.9 degrees
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 24.9 deg.
Maximum Difference
Over 100%
at X= .060551000
Yields (1/u)
Ratios
Energy (MeV)


FNS-Fe Leakage Spectrum D-T Source
Fe_500_050_FNS_TOF 41.8 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 41.8 deg.
Maximum Difference
Over 100%
at X= .040589000

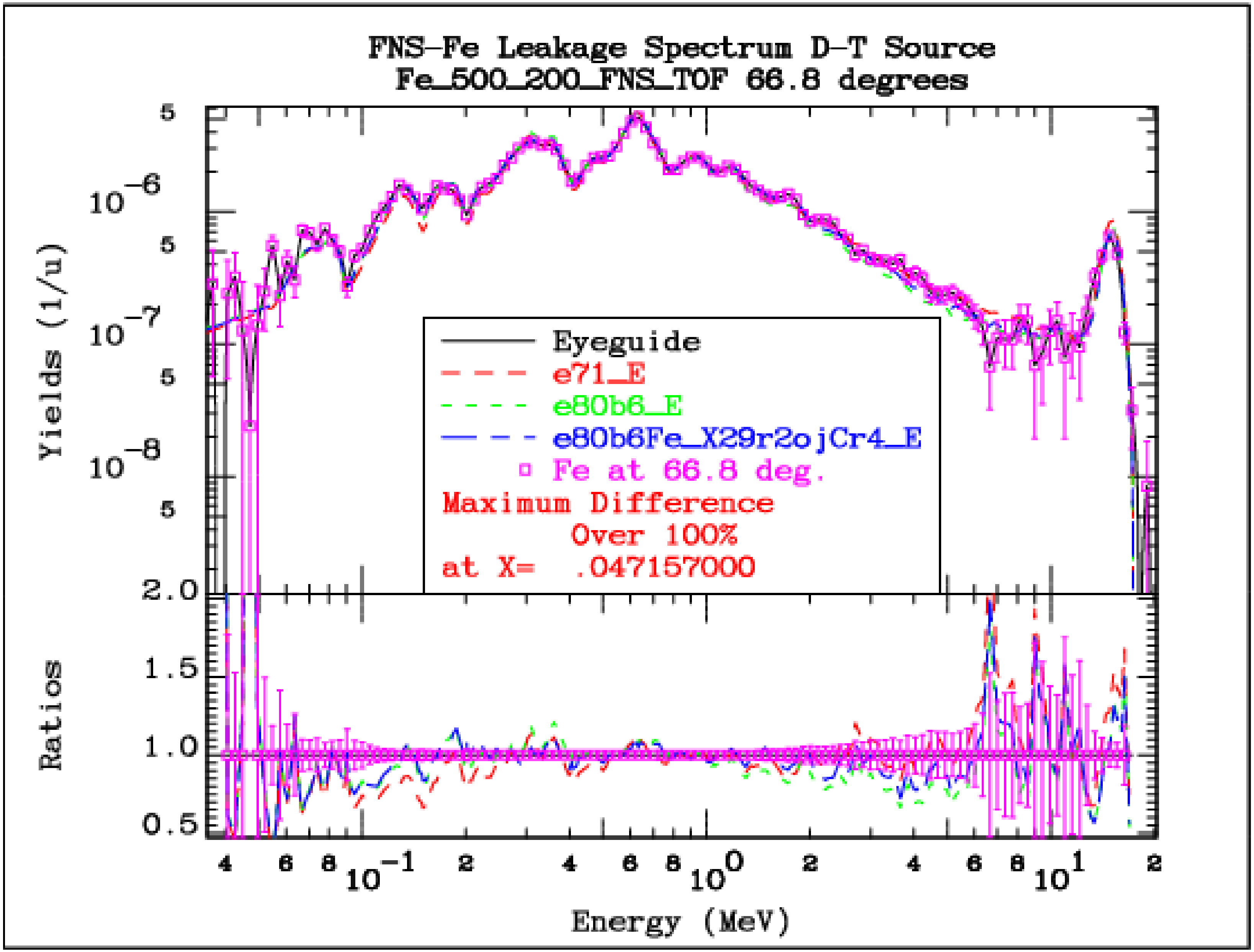

FNS-Fe Leakage Spectrum D-T Source
Fe_500_050_FNS_TOF 66.8 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 66.8 deg.
Maximum Difference
Over 100%
at X= 16.3750000


FNS-Fe Leakage Spectrum D-T Source
Fe_500_200_FNS_TOF 0.0 degrees
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 0.0 deg.
Maximum Difference
Over 100%
at X= 16.3750000
Yields (1/u)
Ratios
Energy (MeV)

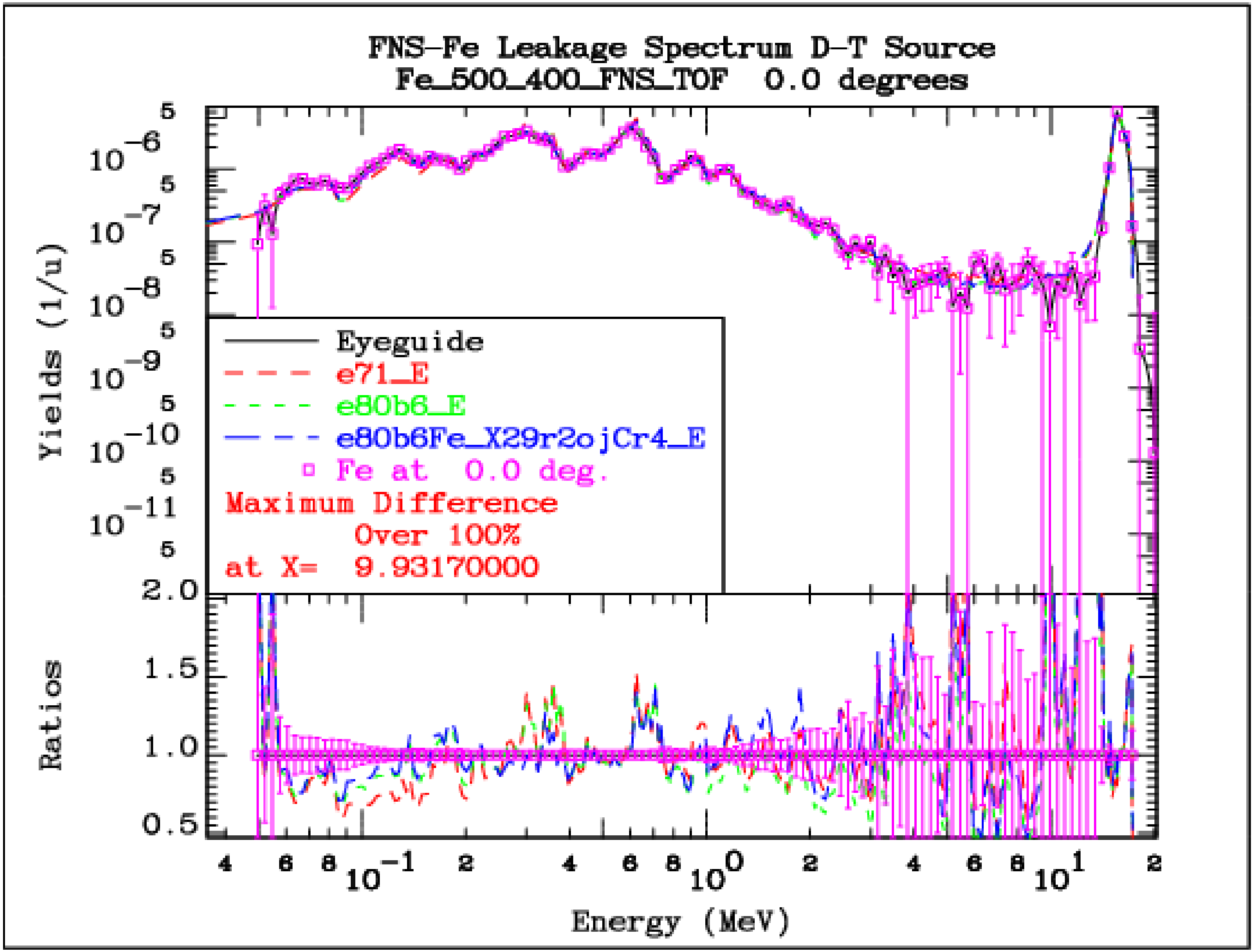

FNS-Fe Leakage Spectrum D-T Source
Fe_500_200_FNS_TOF 24.9 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 24.9 deg.
Maximum Difference
Over 100%
at X= .040589000



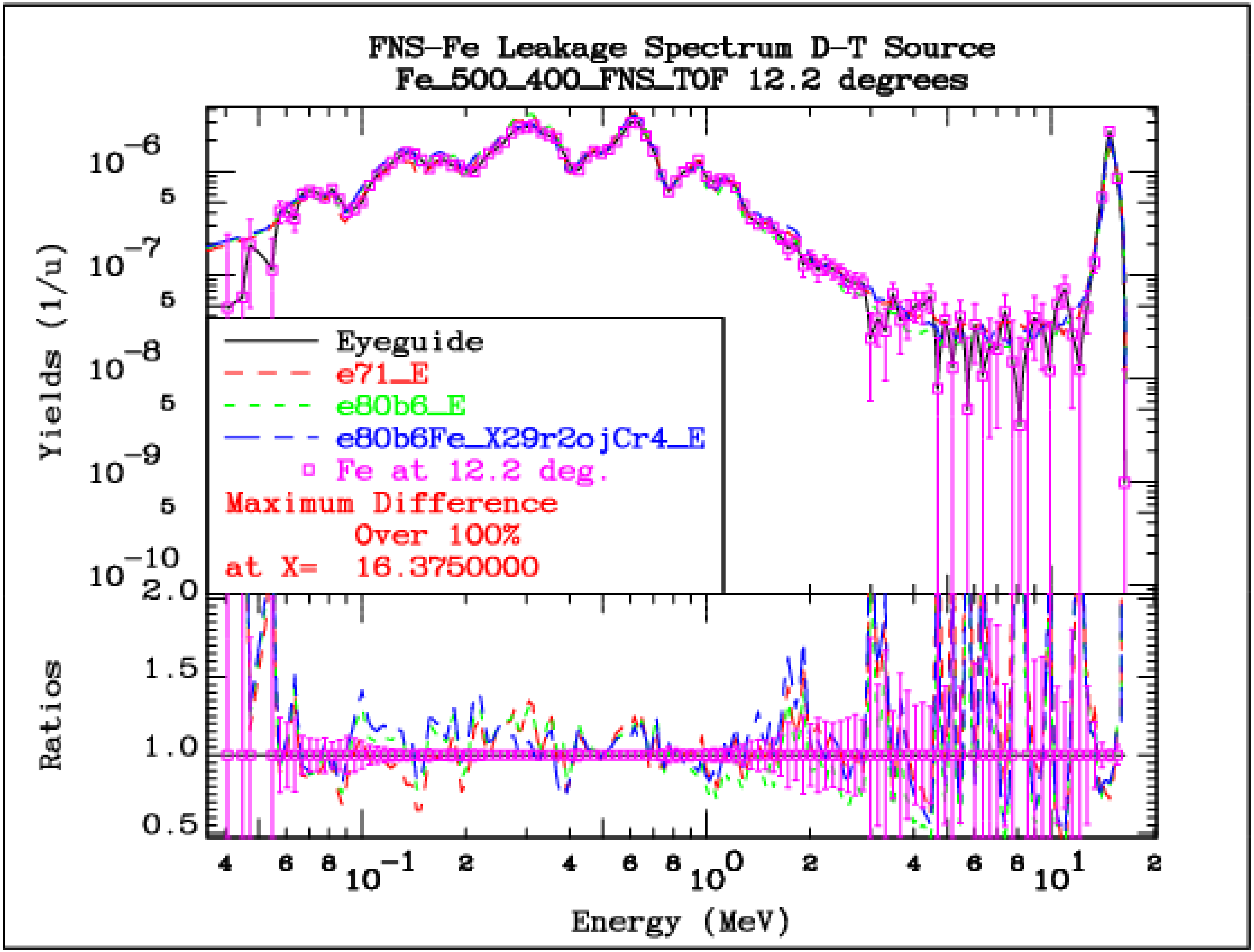
FNS-Fe Leakage Spectrum D-T Source
Fe_500_200_FNS_TOF 41.8 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 41.8 deg.
Maximum Difference
Over 100%
at X= .040000000

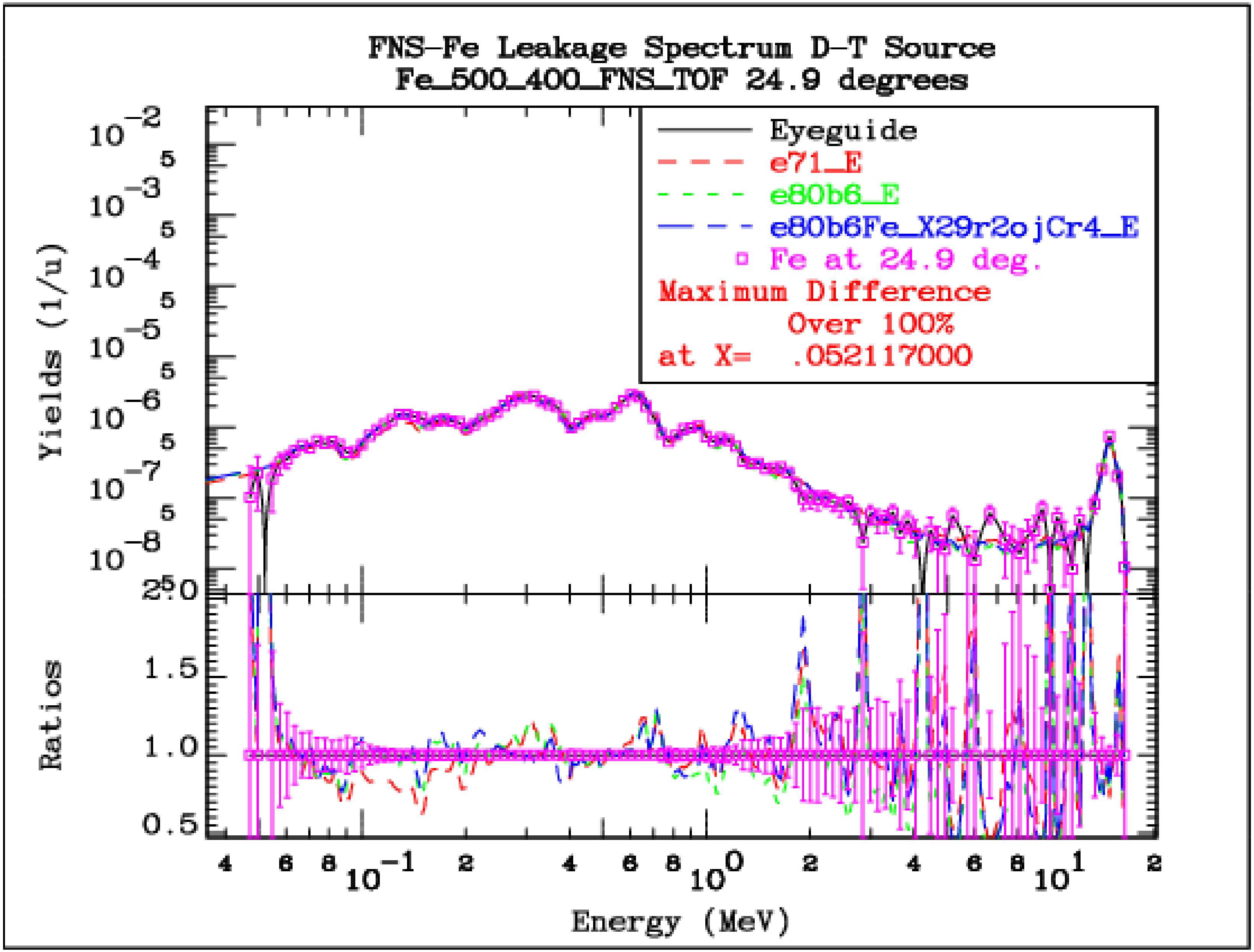


FNS-Fe Leakage Spectrum D-T Source
Fe_500_200_FNS_TOF 66.8 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 66.8 deg.
Maximum Difference
Over 100%
at X= .047157000

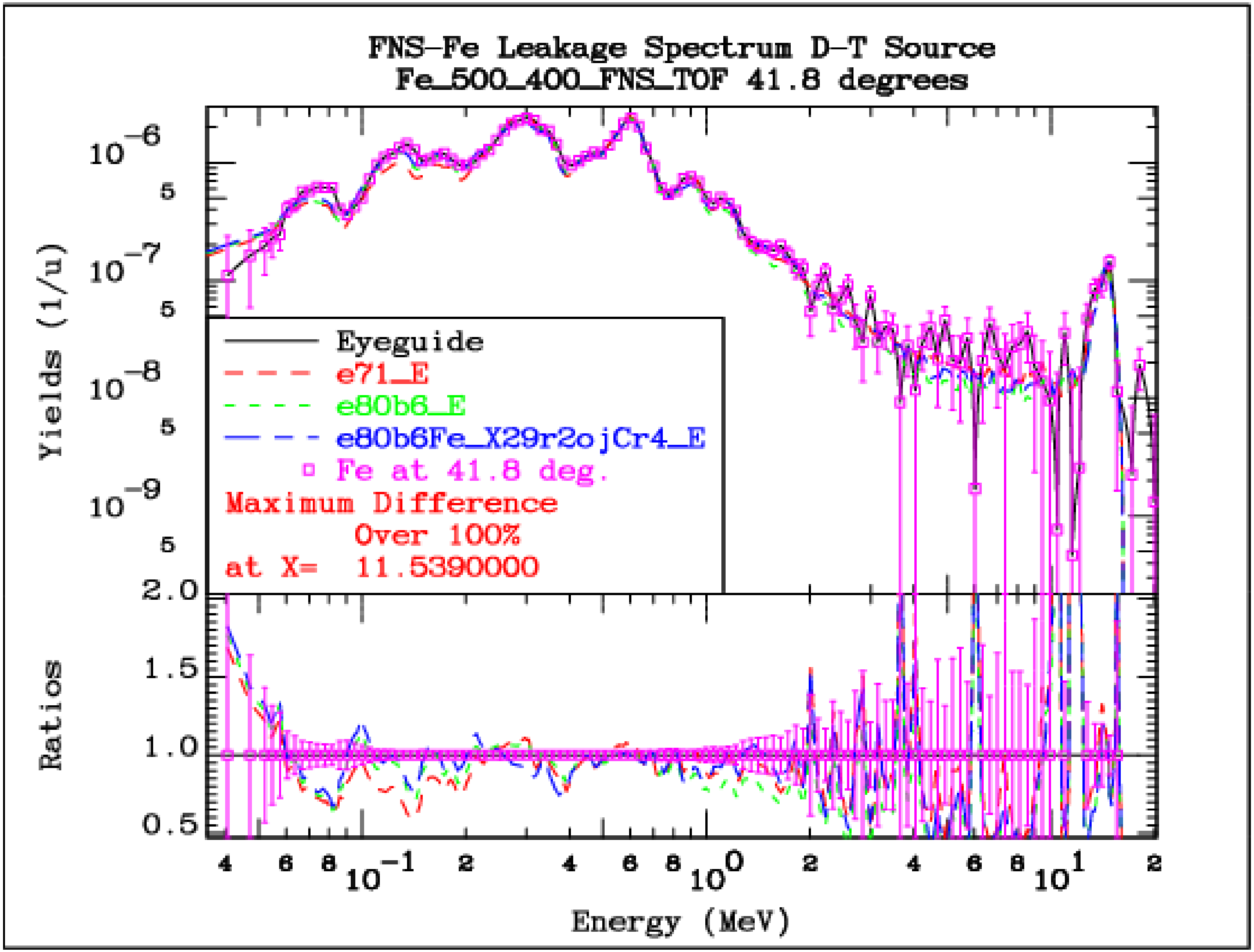


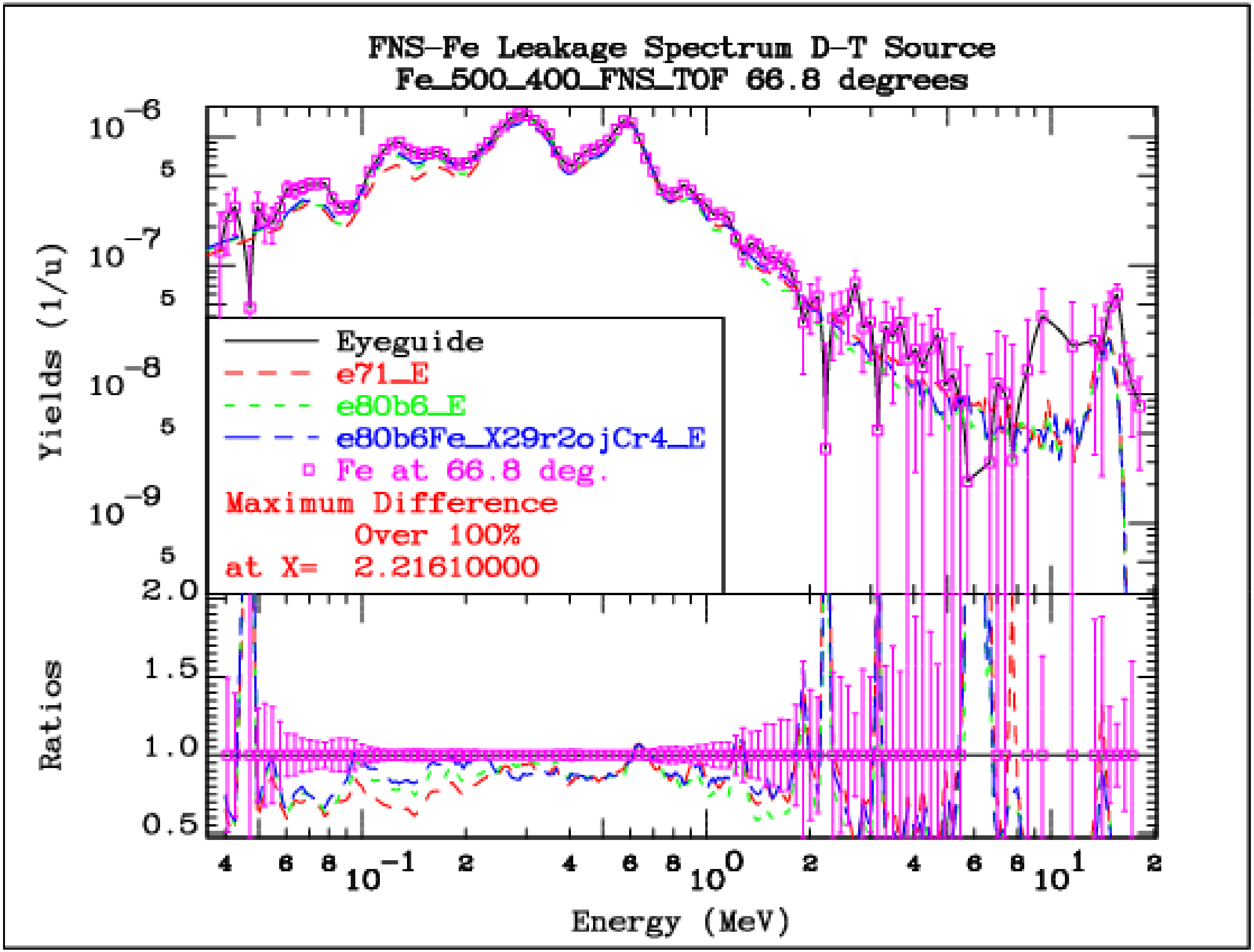
FNS-Fe Leakage Spectrum D-T Source
Fe_500_400_FNS_TOF 0.0 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 0.0 deg.
Maximum Difference
Over 100%
at X= 9.93170000

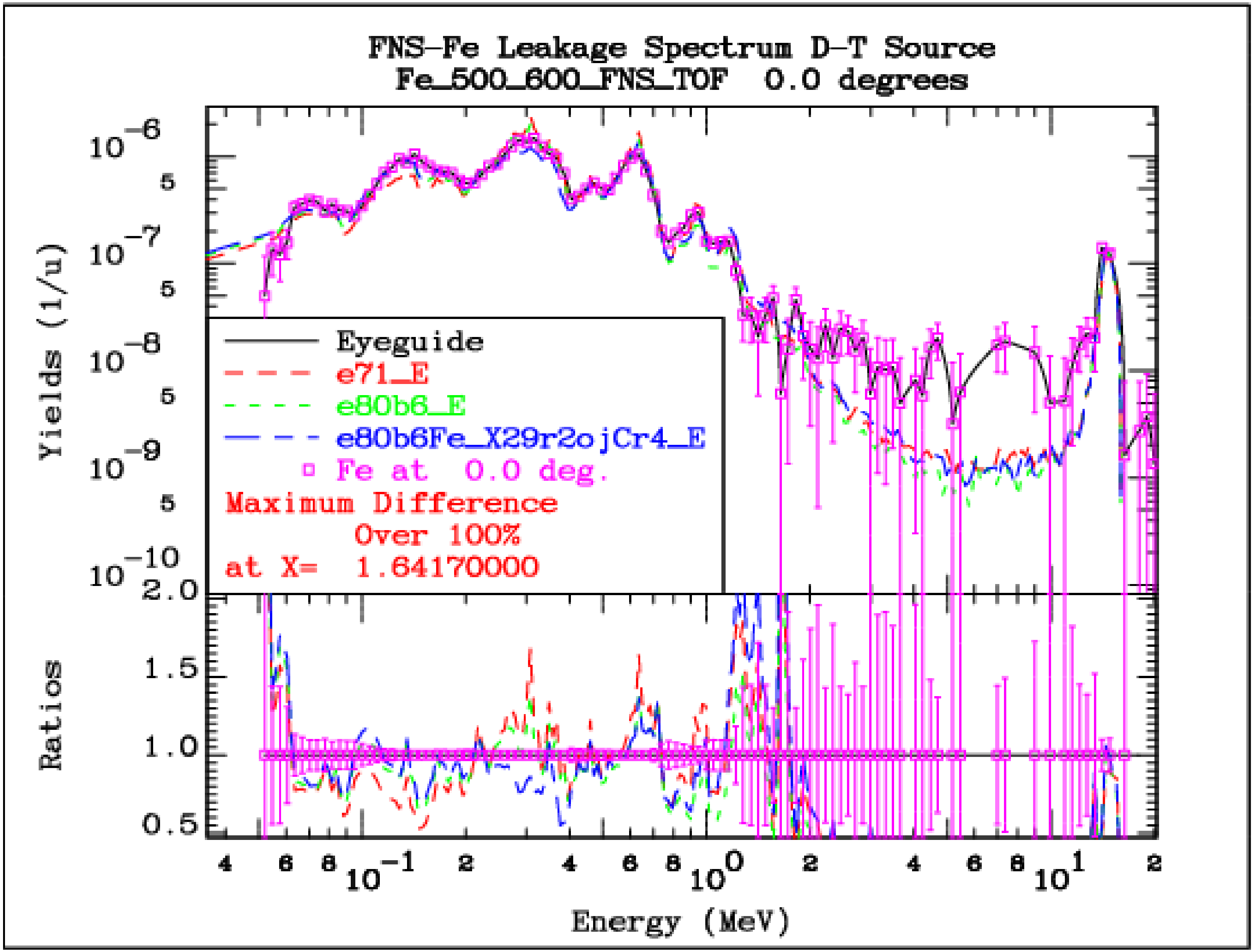

FNS-Fe Leakage Spectrum D-T Source
Fe_500_400_FNS_TOF 12.2 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 12.2 deg.
Maximum Difference
Over 100%
at X= 16.3750000

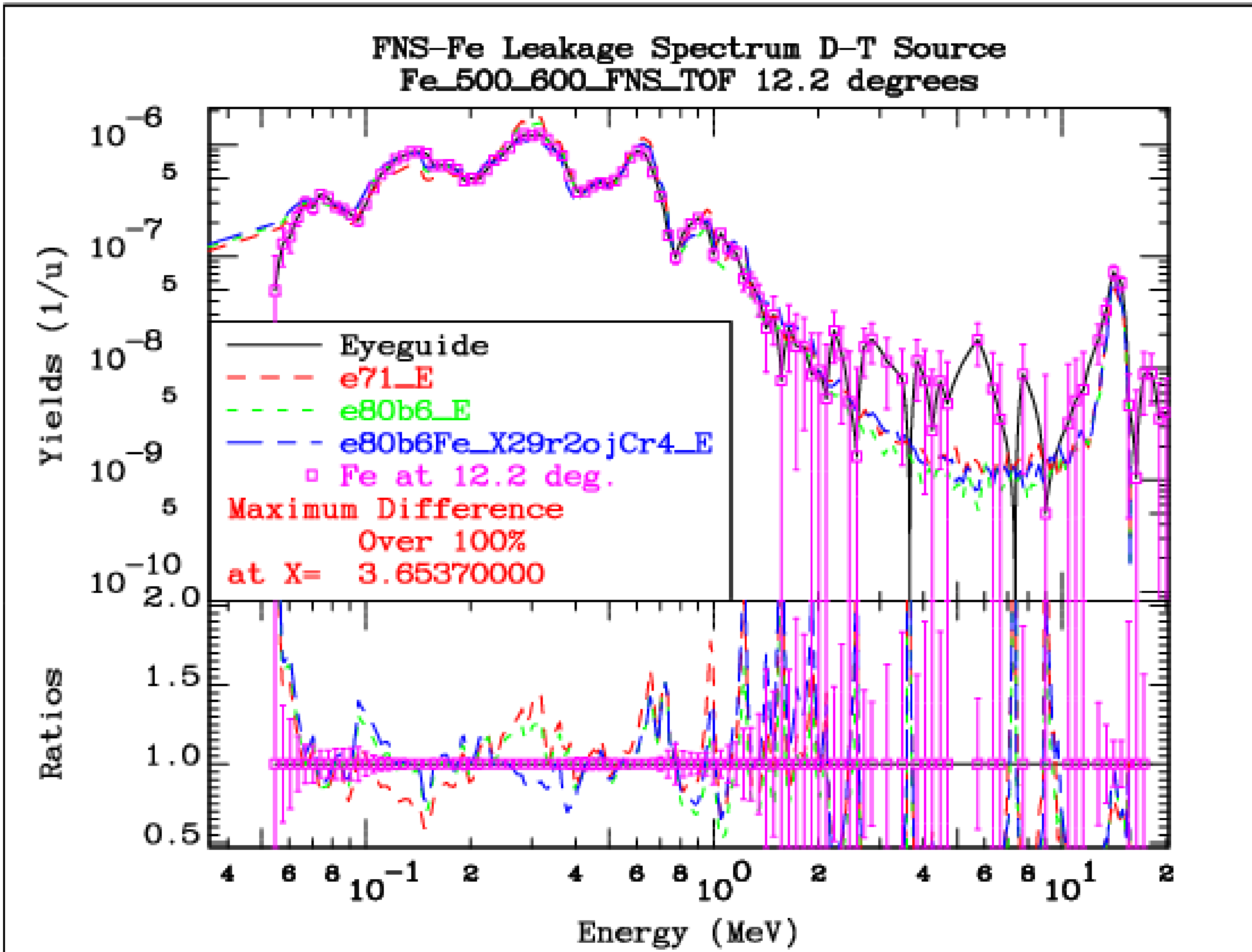


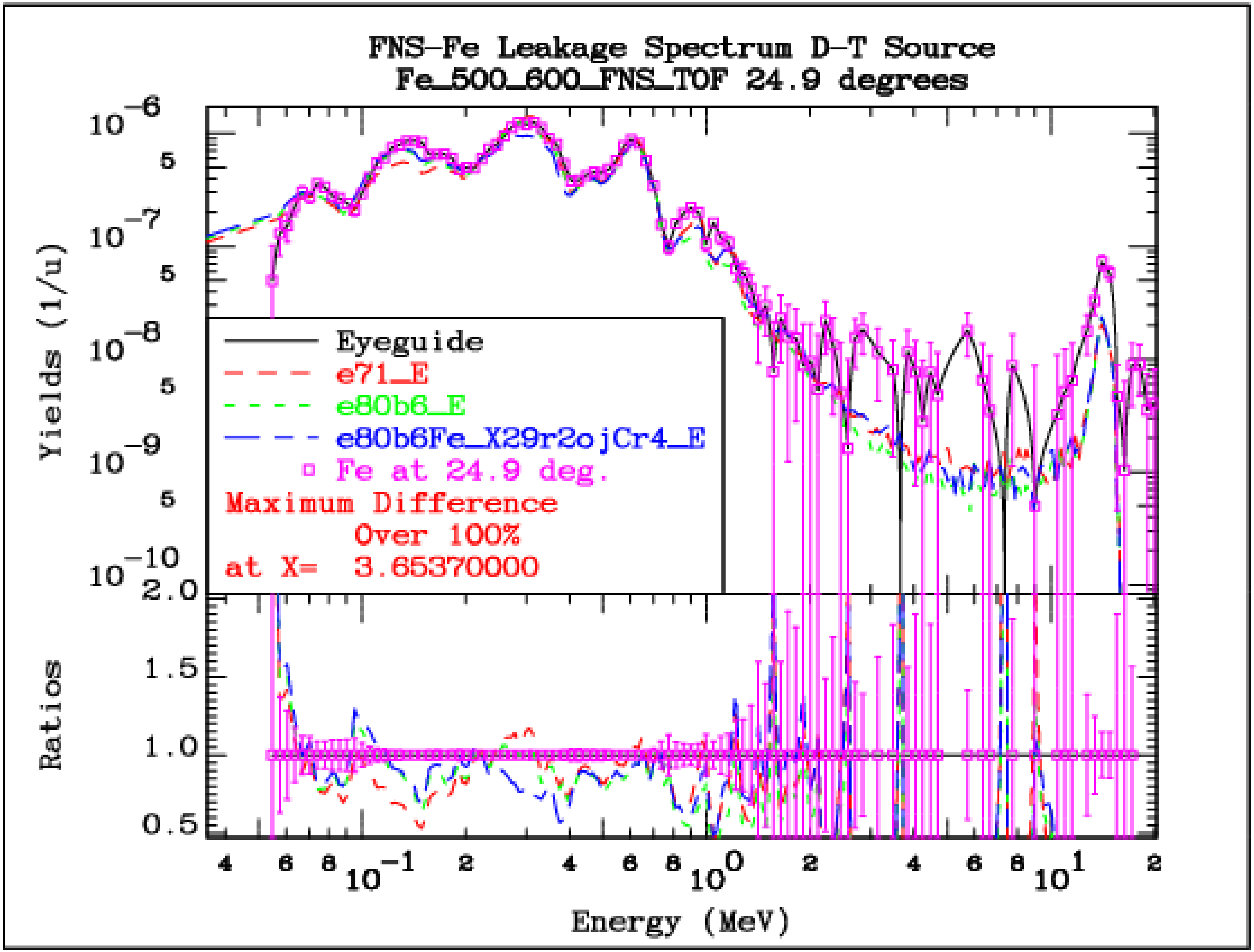
FNS-Fe Leakage Spectrum D-T Source
Fe_500_400_FNS_TOF 24.9 degrees
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 24.9 deg.
Maximum Difference
Over 100%
at X= .052117000
Yields (1/u)
Ratios
Energy (MeV)

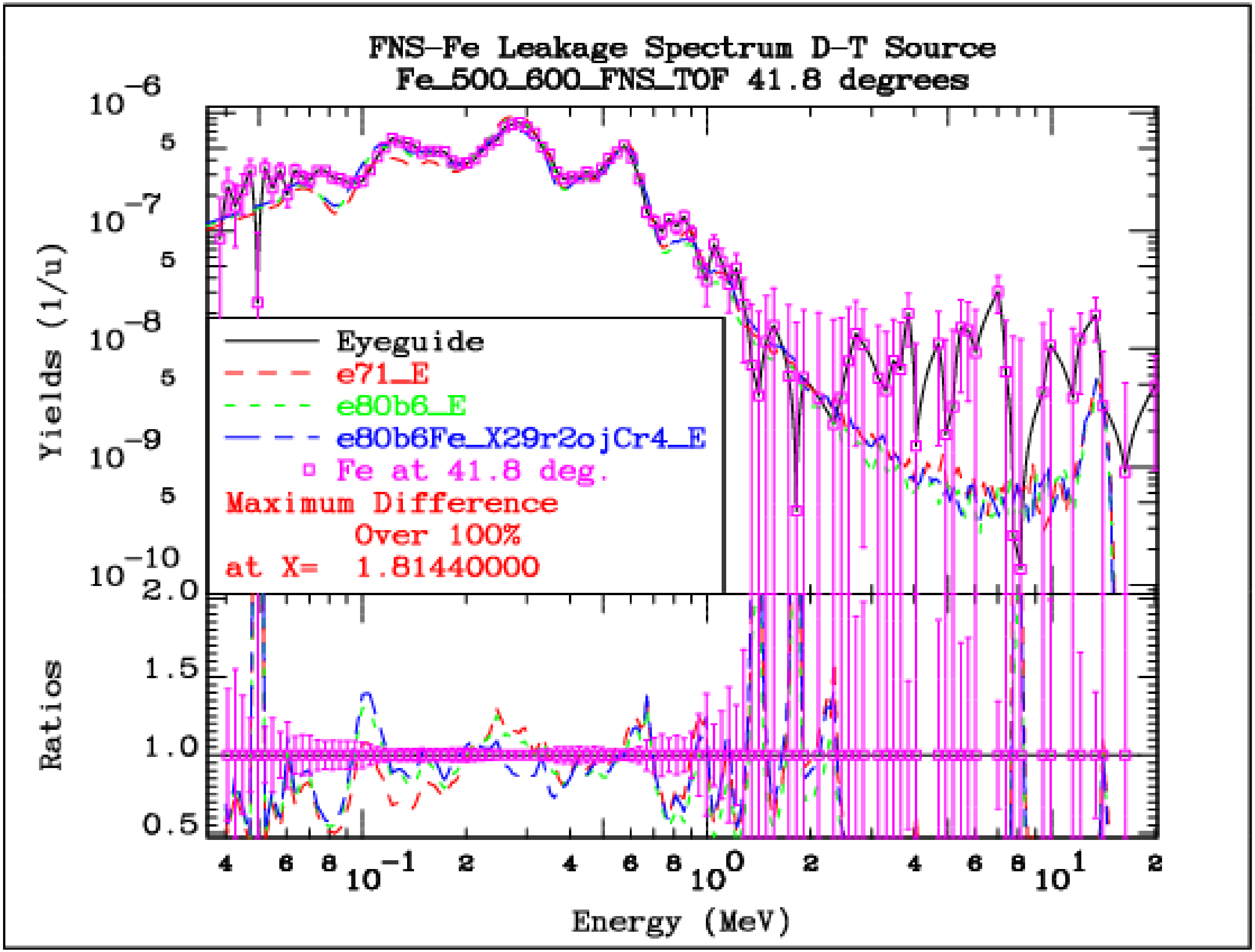

FNS-Fe Leakage Spectrum D-T Source
Fe_500_400_FNS_TOF 41.8 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 41.8 deg.
Maximum Difference
Over 100%
at X= 11.5390000


FNS-Fe Leakage Spectrum D-T Source
Fe_500_400_FNS_TOF 66.8 degrees
Yields (1/u)
Ratios
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 66.8 deg.
Maximum Difference
Over 100%
at X= 2.21610000
Energy (MeV)


FNS-Fe Leakage Spectrum D-T Source
Fe_500_600_FNS_TOF 0.0 degrees
Yields (1/u)
Ratios
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 0.0 deg.
Maximum Difference
Over 100%
at X= 1.64170000
Energy (MeV)


FNS-Fe Leakage Spectrum D-T Source
Fe_500_600_FNS_TOF 12.2 degrees
Yields (1/u)
Ratios
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 12.2 deg.
Maximum Difference
Over 100%
at X= 3.65370000
Energy (MeV)


FNS-Fe Leakage Spectrum D-T Source
Fe_500_600_FNS_TOF 24.9 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 24.9 deg.
Maximum Difference
Over 100%
at X= 3.65370000

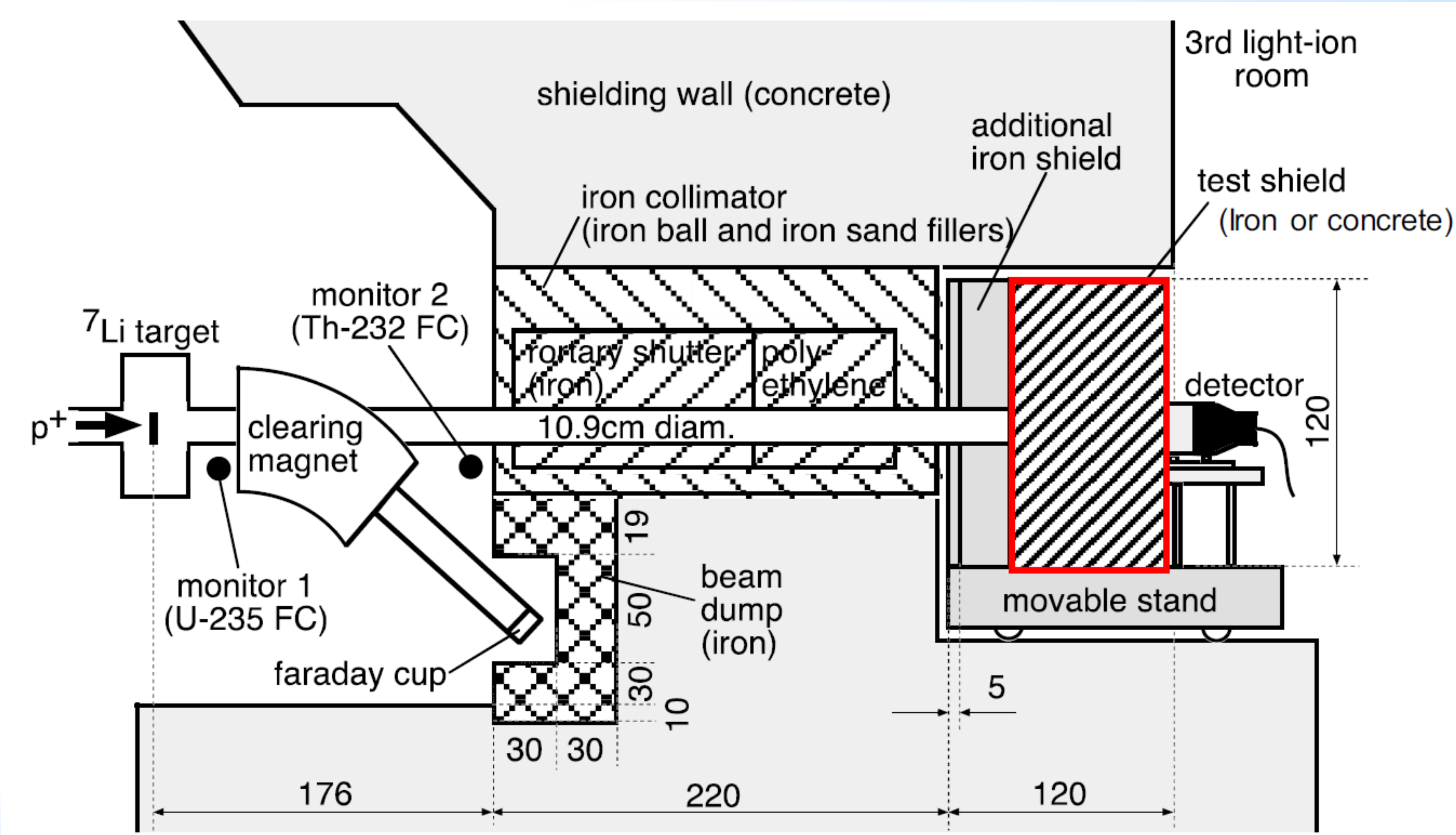


FNS-Fe Leakage Spectrum D-T Source
Fe_500_600_FNS_TOF 41.8 degrees
Yields (1/u)
Ratios
Energy (MeV)
Eyeguide
e71_E
e80b6_E
e80b6Fe_X29r2ojCr4_E
Fe at 41.8 deg.
Maximum Difference
Over 100%
at X= 1.81440000

7. TIARA benchmark

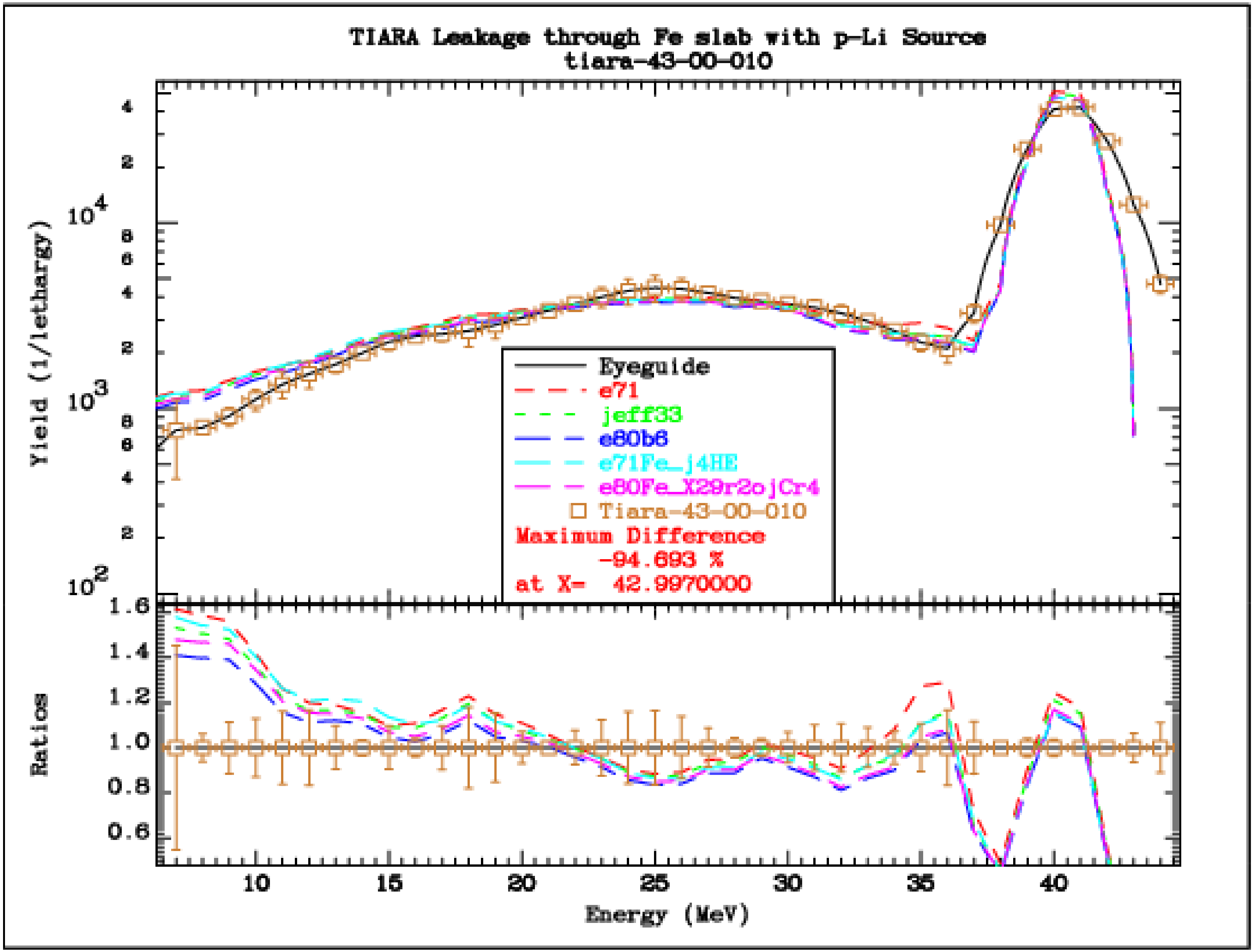
- The 40 MeV and 65 MeV benchmarks are described in SINBAD, but no adequate MCNP models are available.
- Under contract with the IAEA, B. Kos (JSI, working with I. Kodeli) performed the analysis and delivered computational models for MCNP with weight-windows variance reduction
- The 40 MeV, 70 cm case has suspicious structure that is not observed with other spheres
- Agreement is less good for the 65 MeV case
- (Analysis of additional measured data is pending)

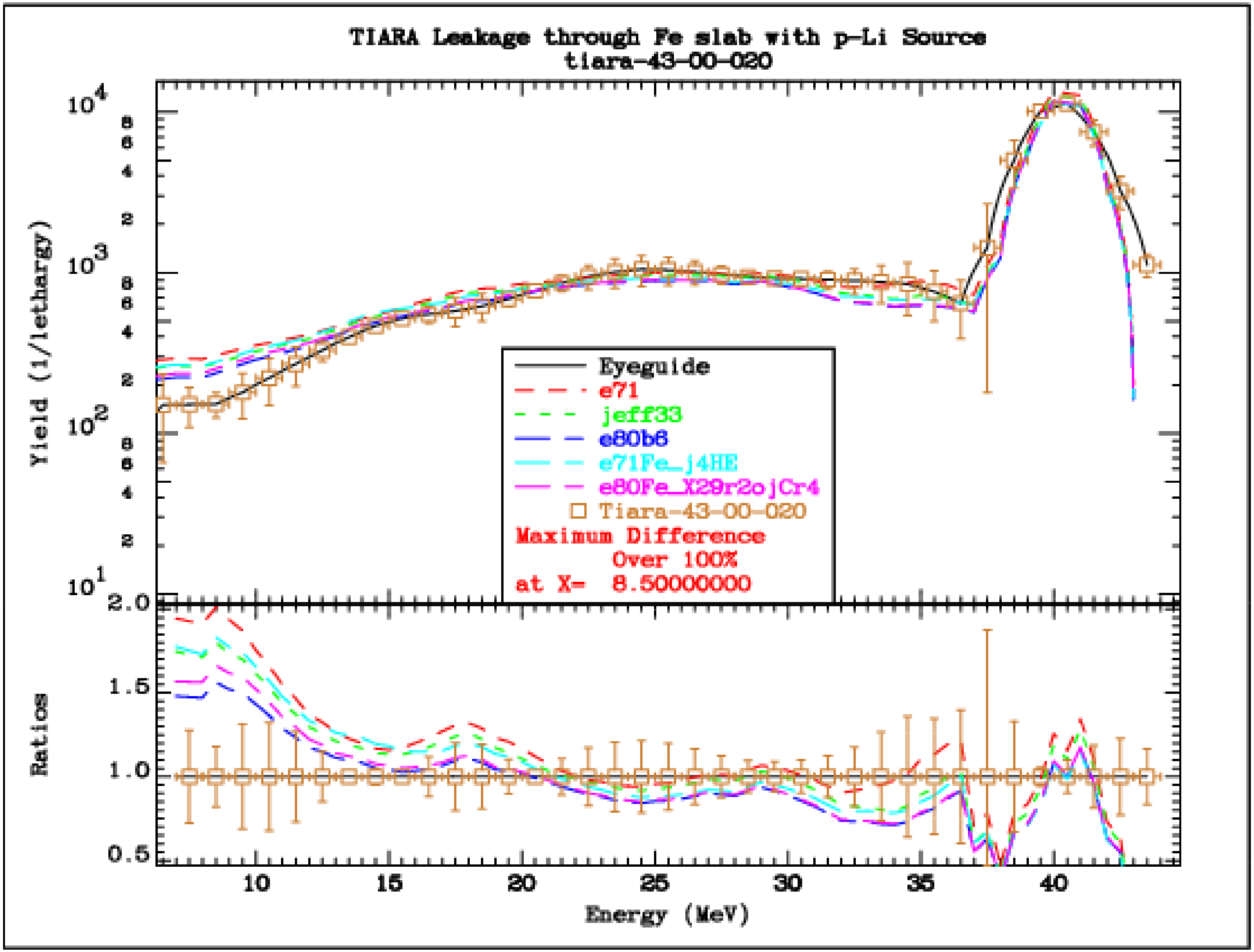
TIARA benchmark



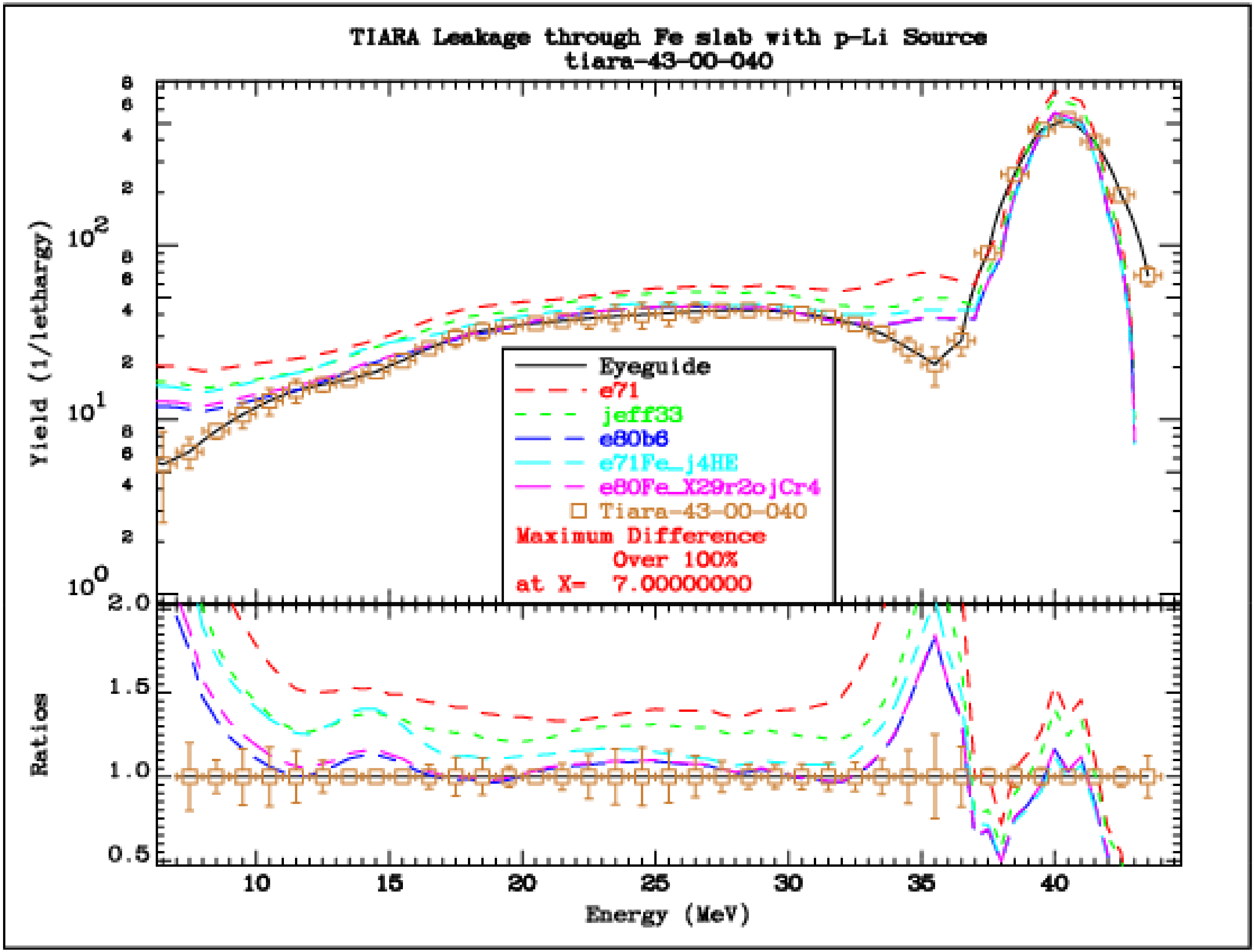
Fusion Engineering and Design. 10.1016/j.fusengdes.2017.11.021

(Units in cm)

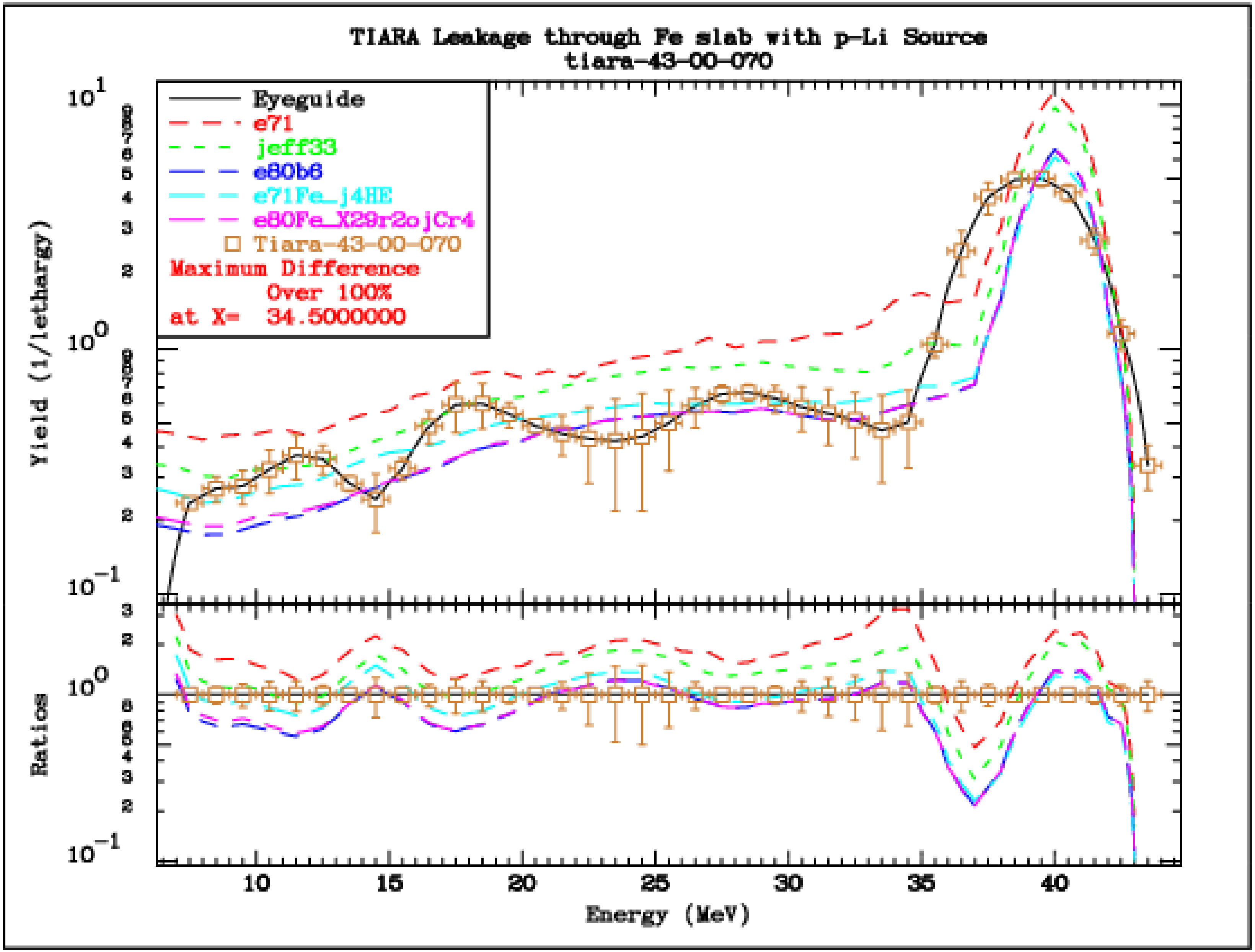

TIARA Leakage through Fe slab with p-Li Source
tiara-43-00-010
Yield (1/lethargy)
Ratios
Energy (MeV)
Eyeguide
e71
jeff33
e80b6
e71Fe_j4HE
e80Fe_X29r2ojCr4
Tiara-43-00-010
Maximum Difference
-94.693 %
at X= 42.9970000



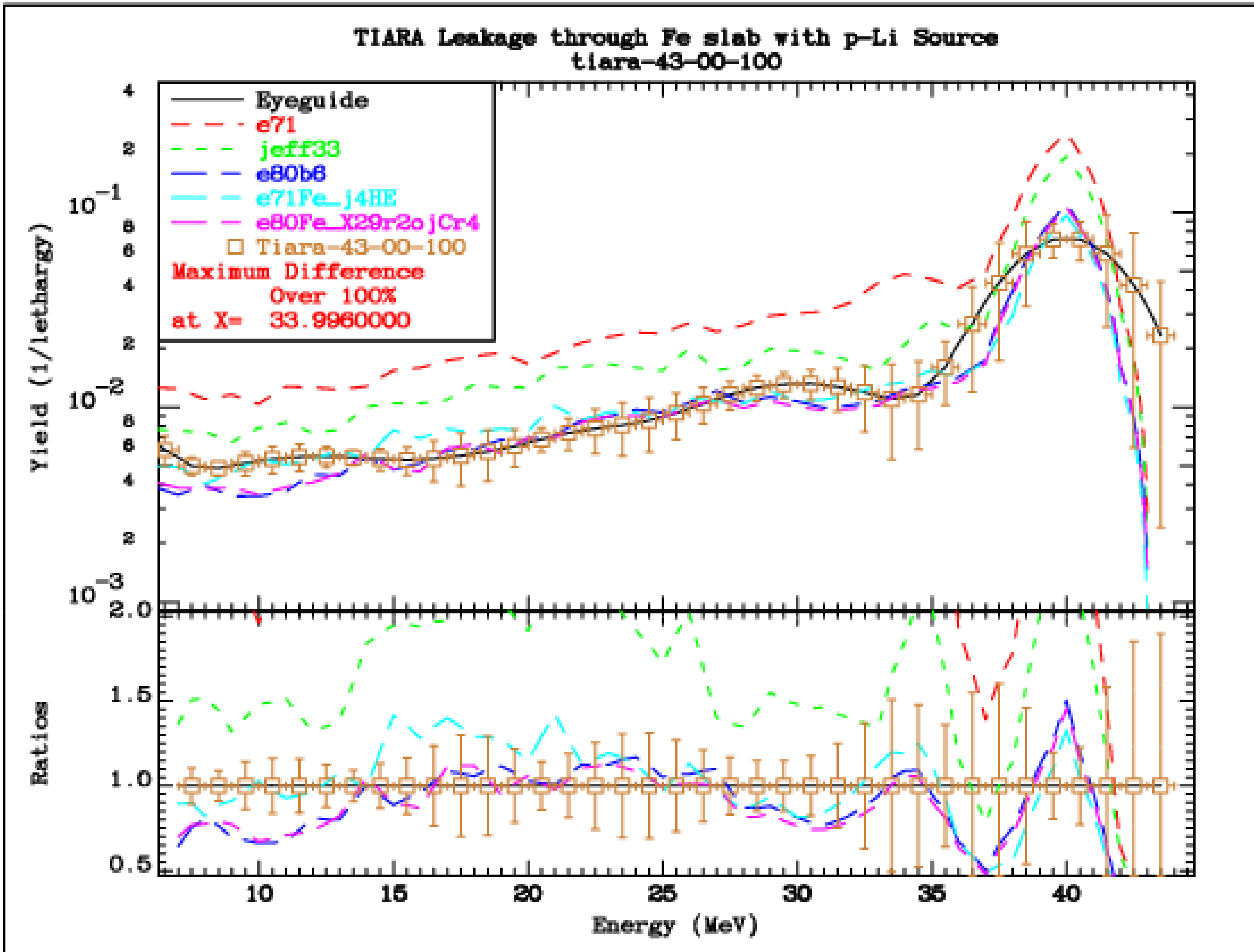
TIARA Leakage through Fe slab with p-Li Source
tiara-43-00-020
Yield (1/lethargy)
Ratios
Energy (MeV)
Eyeguide
e71
jeff33
e80b6
e71Fe_j4HE
e80Fe_X29r2ojCr4
Tiara-43-00-020
Maximum Difference
Over 100%
at X= 8.50000000



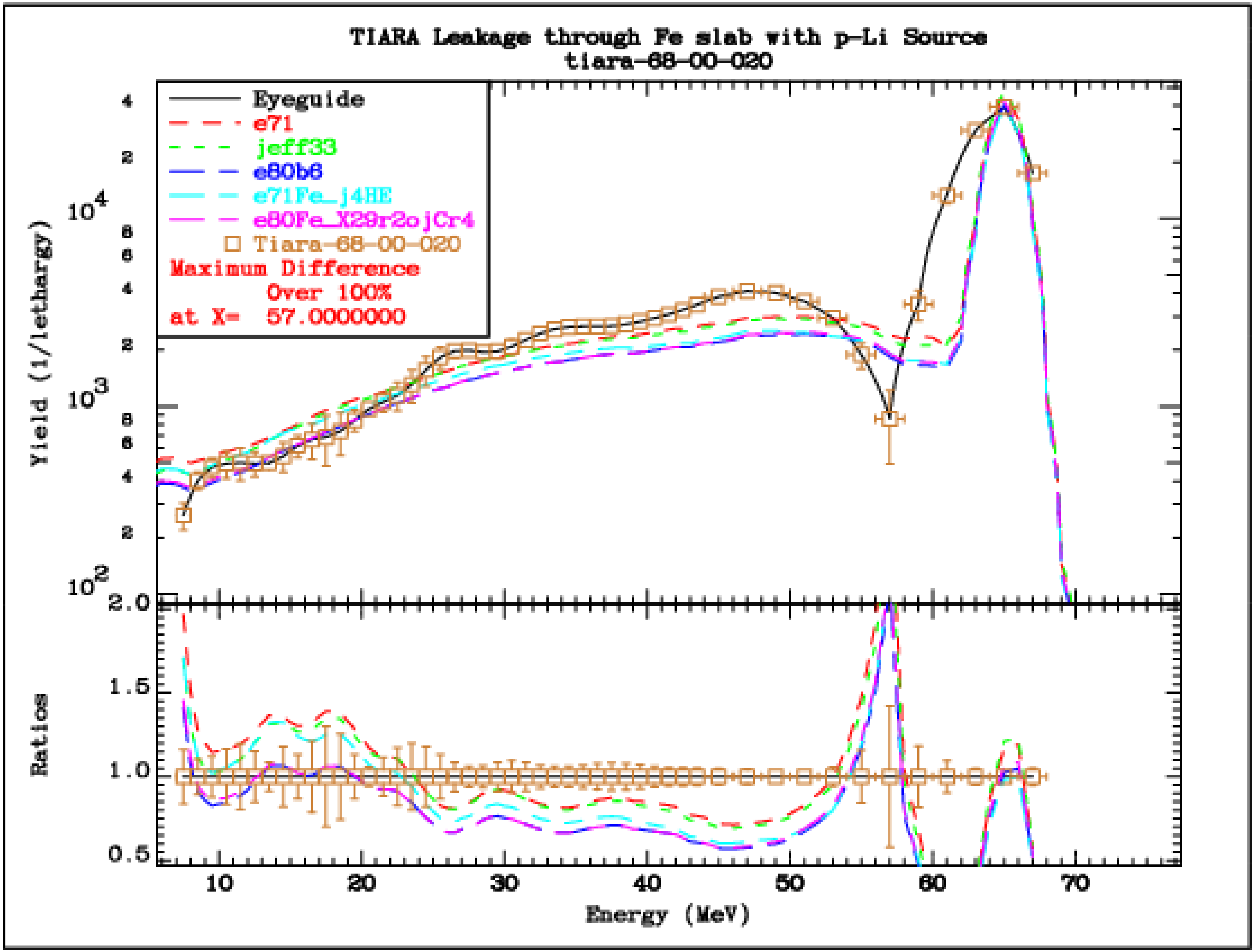
TIARA Leakage through Fe slab with p-Li Source
tiara-43-00-040
Yield (1/lethargy)
Ratios
Energy (MeV)
Eyeguide
e71
jeff33
e80b8
e71Fe_j4HE
e80Fe_X29r2ojCr4
Tiara-43-00-040
Maximum Difference
Over 100%
at X= 7.00000000

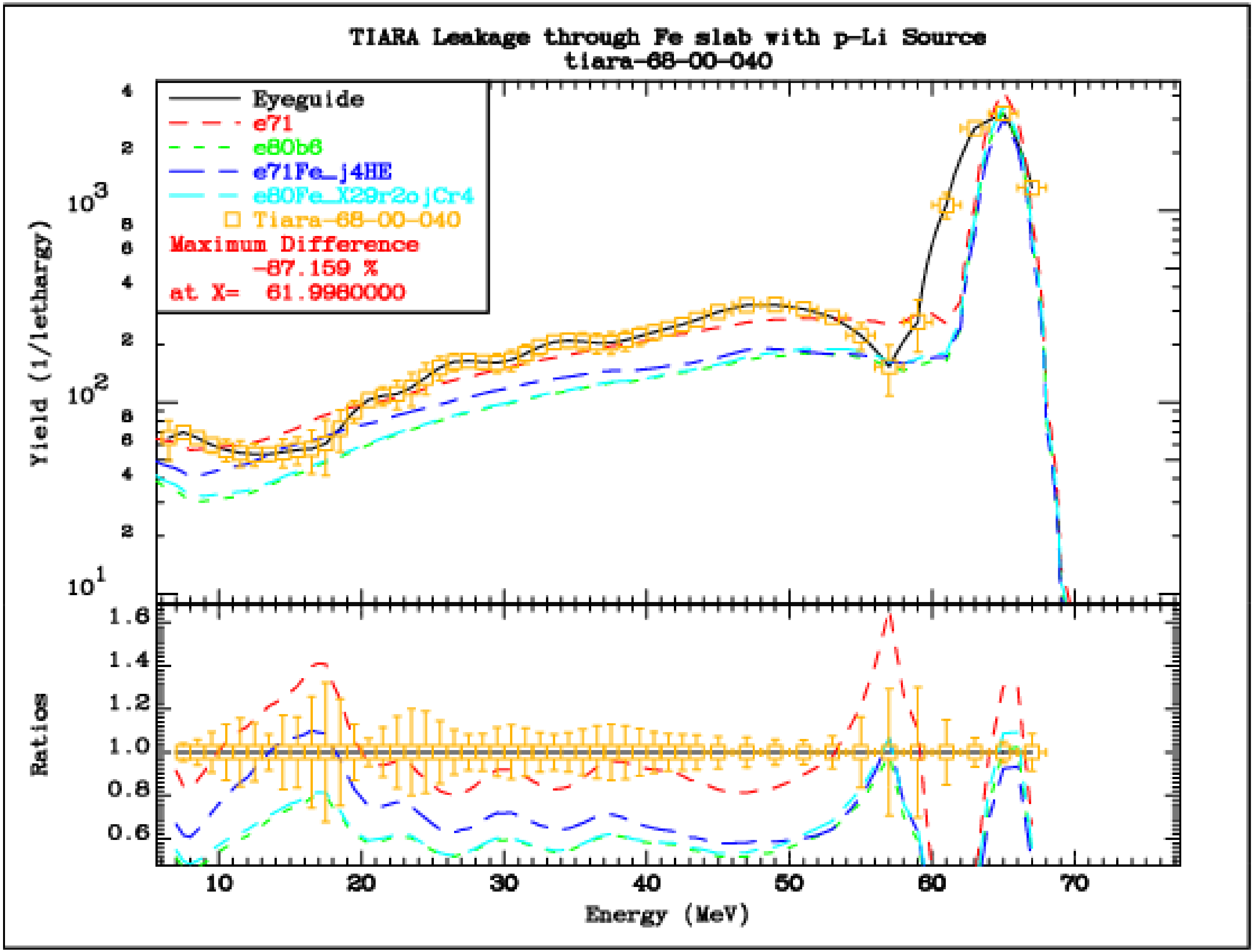


TIARA Leakage through Fe slab with p-Li Source
tiara-43-00-070
Eyeguide
e71
jeff33
e80b6
e71Fe_j4HE
e80Fe_X29r2ojCr4
Tiara-43-00-070
Maximum Difference
Over 100%
at X= 34.5000000
Yield (1/lethargy)
Ratios
Energy (MeV)

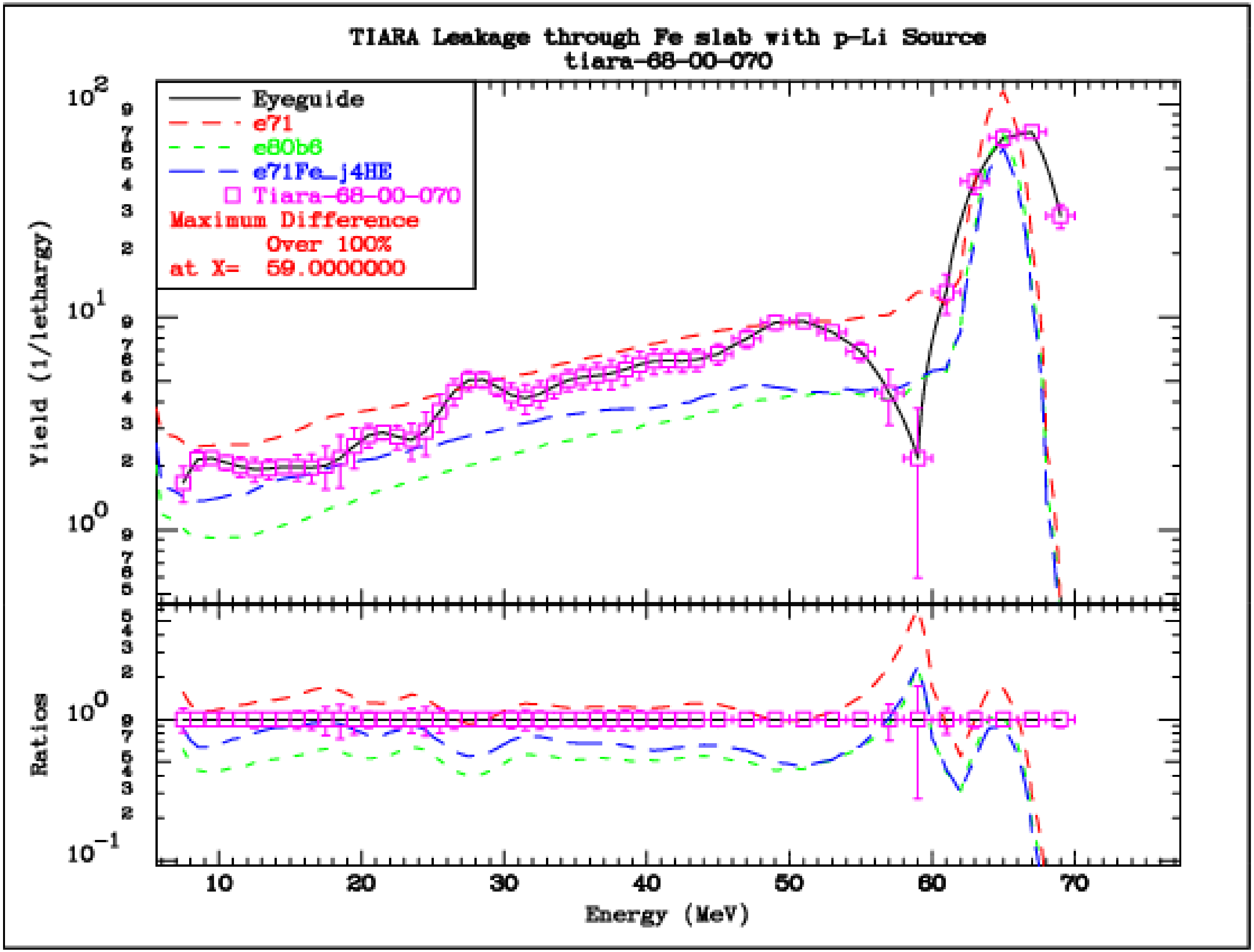


TIARA Leakage through Fe slab with p-Li Source
tiara-43-00-100
Eyeguide
e71
jeff33
e80b6
e71Fe_j4HE
e80Fe_X29r2ojCr4
Tiara-43-00-100
Maximum Difference
Over 100%
at X= 33.9960000
Yield (1/lethargy)
Ratios
Energy (MeV)

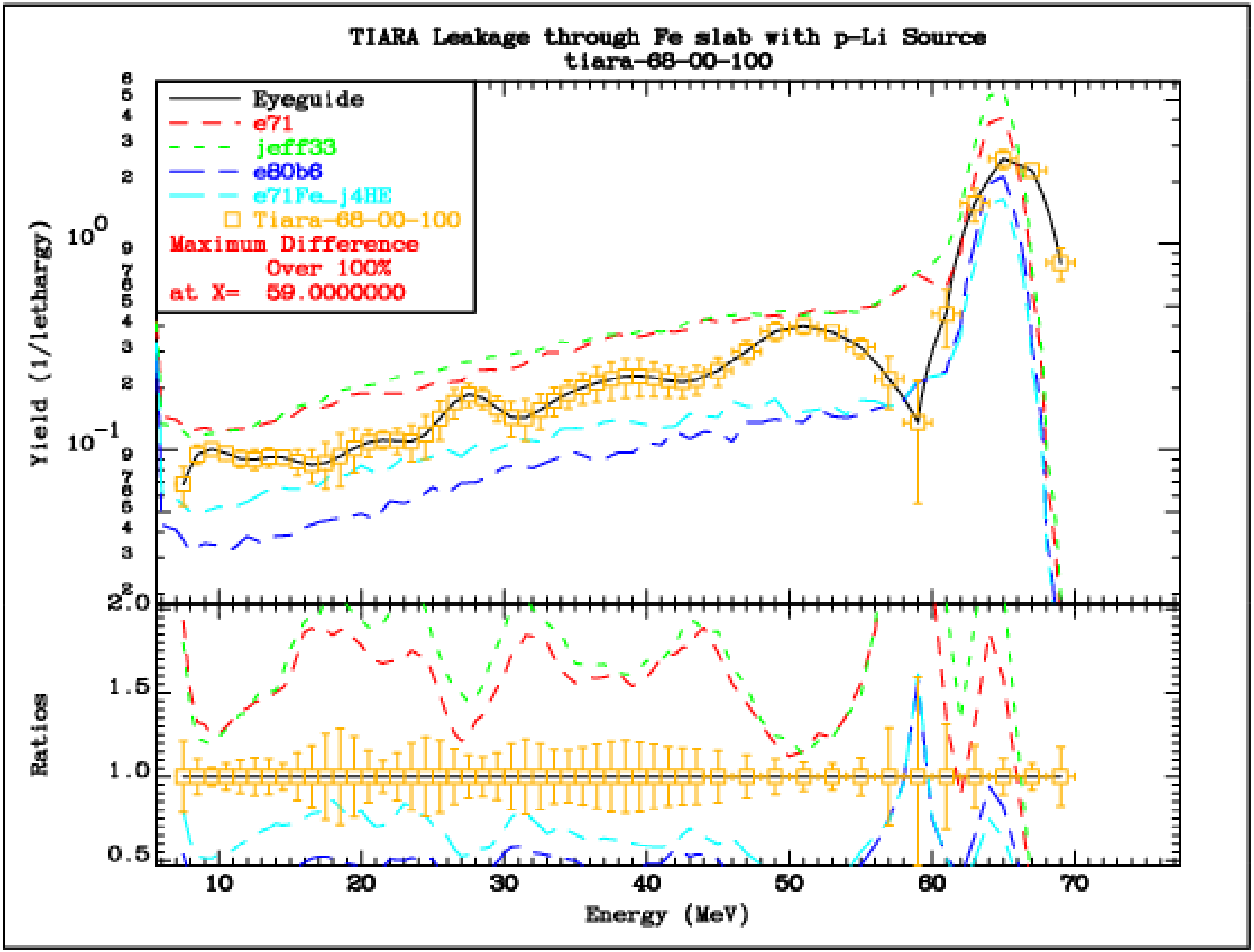

TIARA Leakage through Fe slab with p-Li Source
tiara-68-00-020
Eyeguide
e71
jeff33
e80b6
e71Fe_j4HE
e80Fe_X29r2ojCr4
Tiara-68-00-020
Maximum Difference
Over 100%
at X= 57.0000000
Yield (1/lethargy)
Ratios
Energy (MeV)
10
20
30
40
50
60
70
2.0
1.5
1.0
0.5



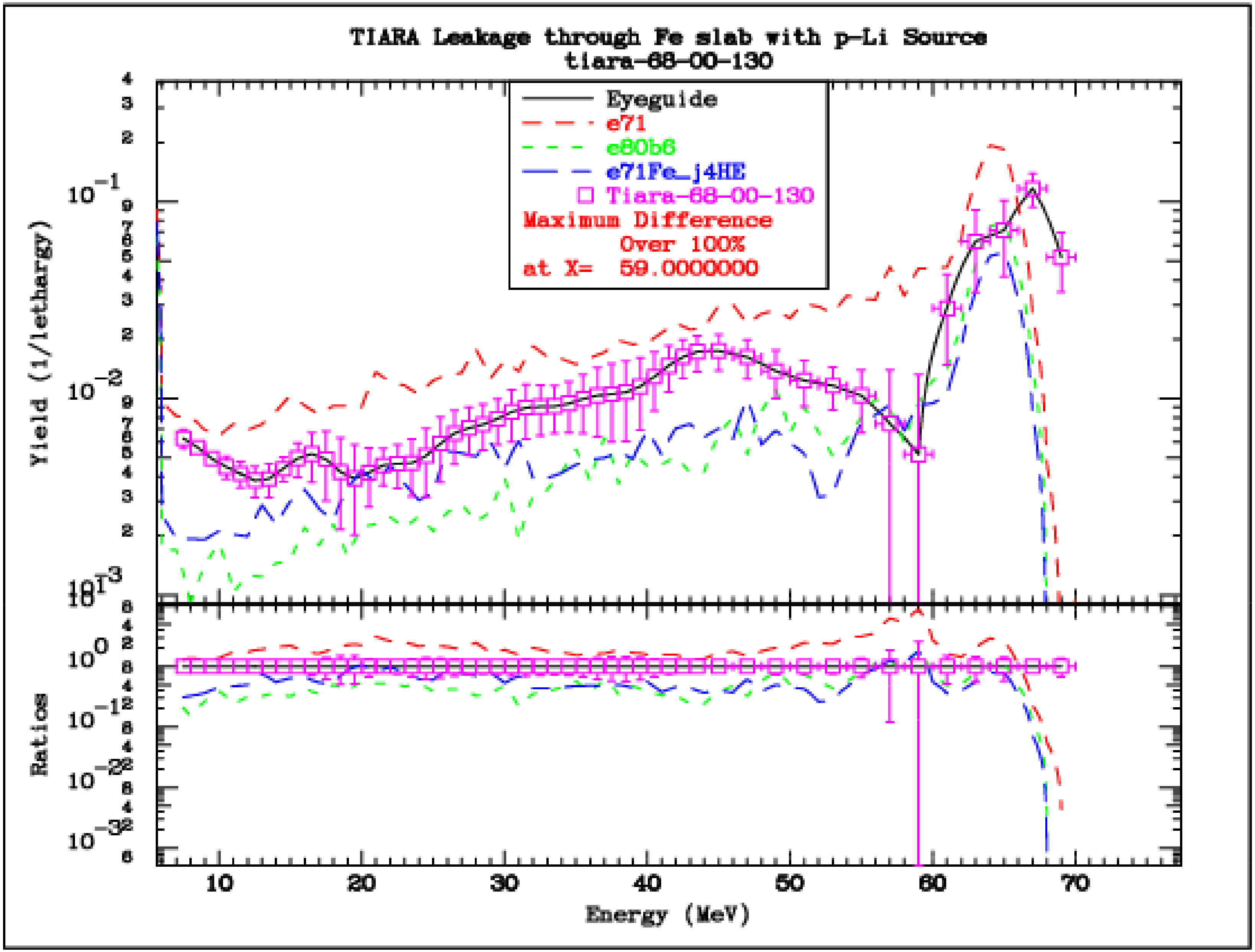
TIARA Leakage through Fe slab with p-Li Source
tiara-68-00-040
Eyeguide
e71
e80b6
e71Fe_j4HE
e80Fe_X29r2ojCr4
Tiara-68-00-040
Maximum Difference
-87.159 %
at X= 61.9980000
Yield (1/lethargy)
Ratios
Energy (MeV)



TIARA Leakage through Fe slab with p-Li Source
tiara-68-00-070
Eyeguide
e71
e80b6
e71Fe_j4HE
Tiara-68-00-070
Maximum Difference
Over 100%
at X= 59.0000000
Yield (1/lethargy)
Ratios
Energy (MeV)



TIARA Leakage through Fe slab with p-Li Source
tiara-68-00-100
Eyeguide
e71
jeff33
e80b6
e71Fe_j4HE
Tiara-68-00-100
Maximum Difference
Over 100%
at X= 59.0000000
Yield (1/lethargy)
Ratios
Energy (MeV)

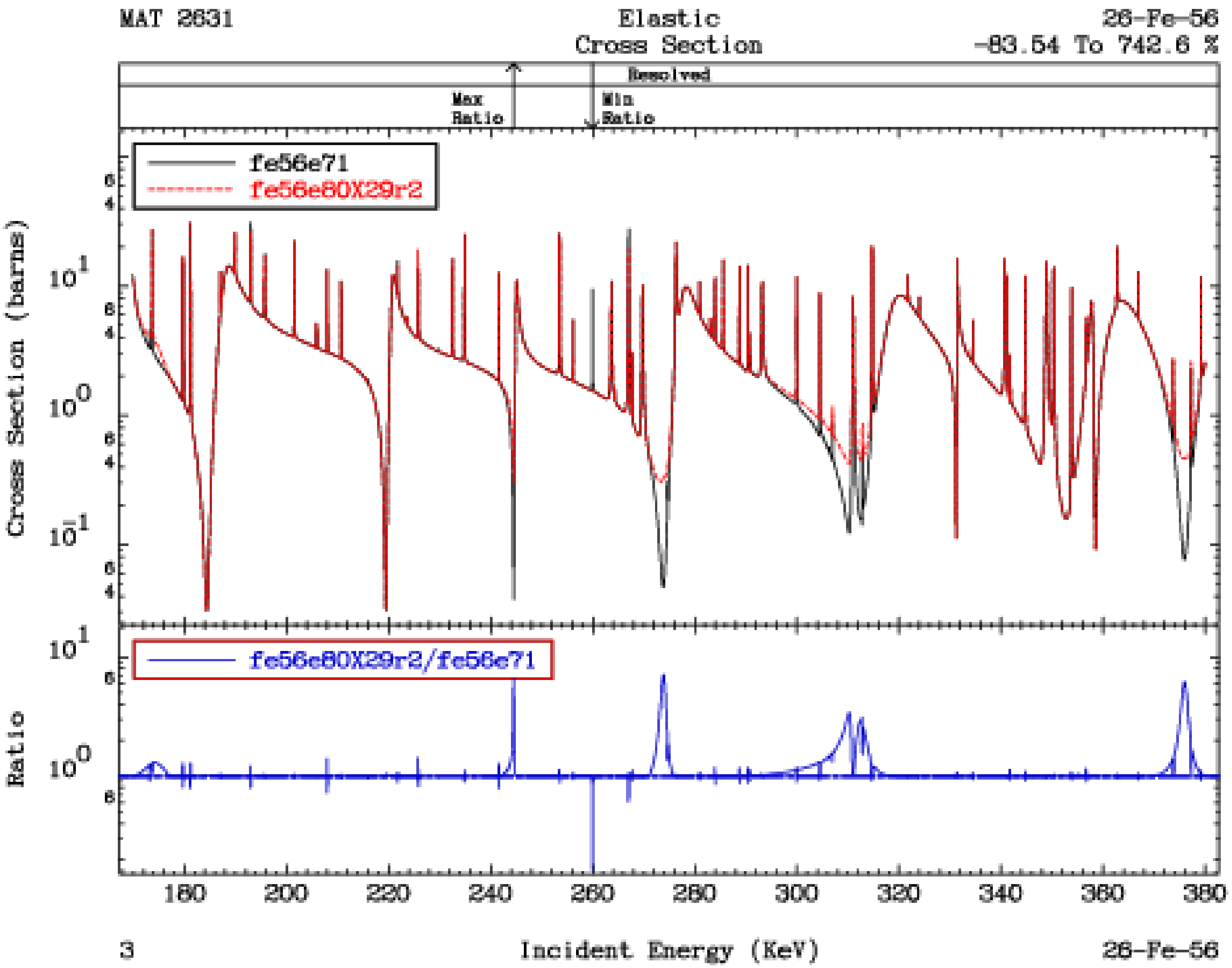

TIARA Leakage through Fe slab with p-Li Source
tiara-68-00-130
Eyeguide
e71
e80b6
e71Fe_j4HE
Tiara-68-00-130
Maximum Difference
Over 100%
at X= 59.0000000
Yield (1/lethargy)
Ratios
Energy (MeV)

8. IPPE Fe broomstick experiments with p-T source

IAEA

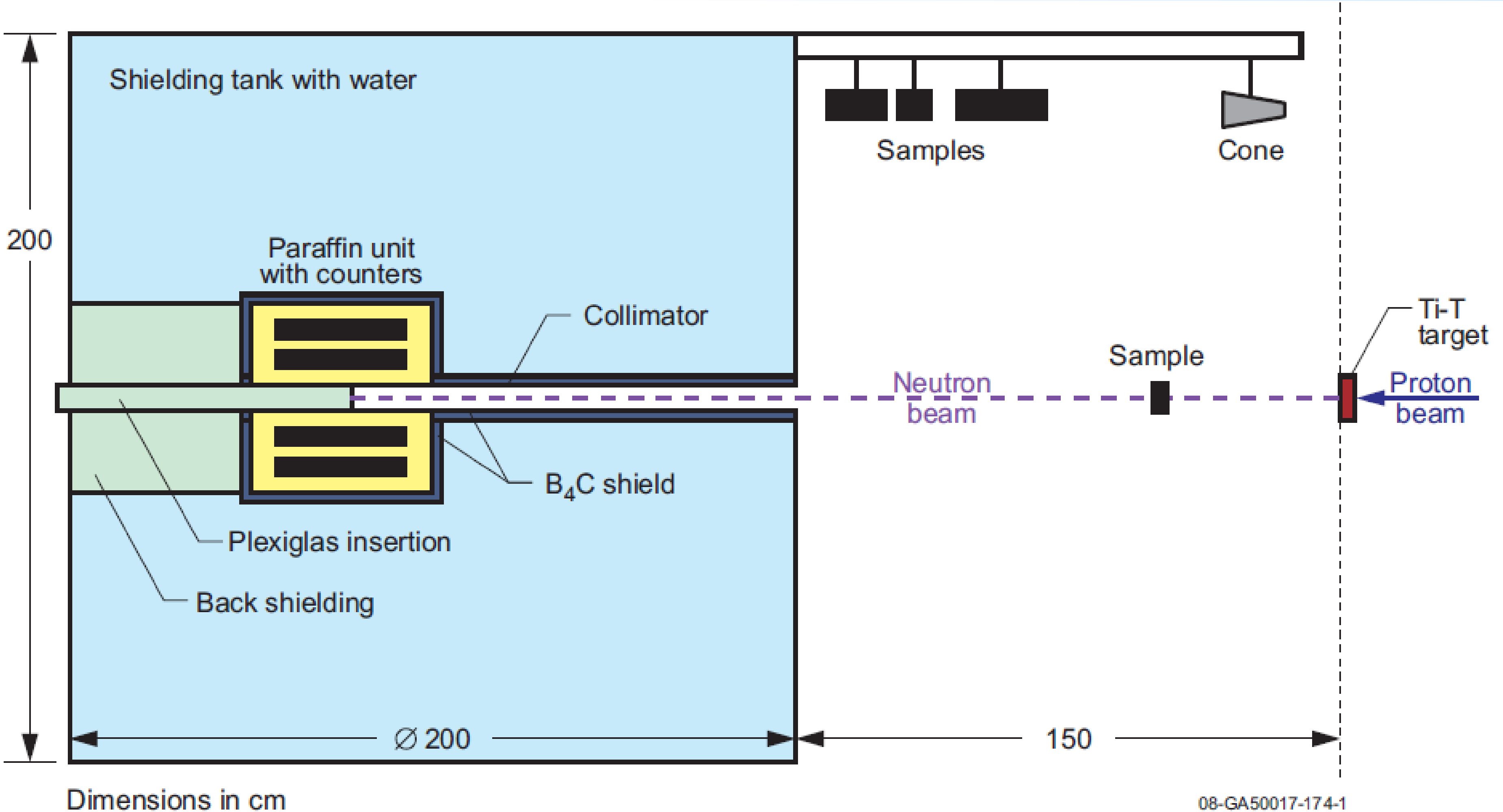
- Transmission of quasi-monoenergetic neutrons from a p-T source through iron cylinders of different thicknesses
- “Detailed” results pointed to elastic x.s. deficiencies in the resonance minima at:

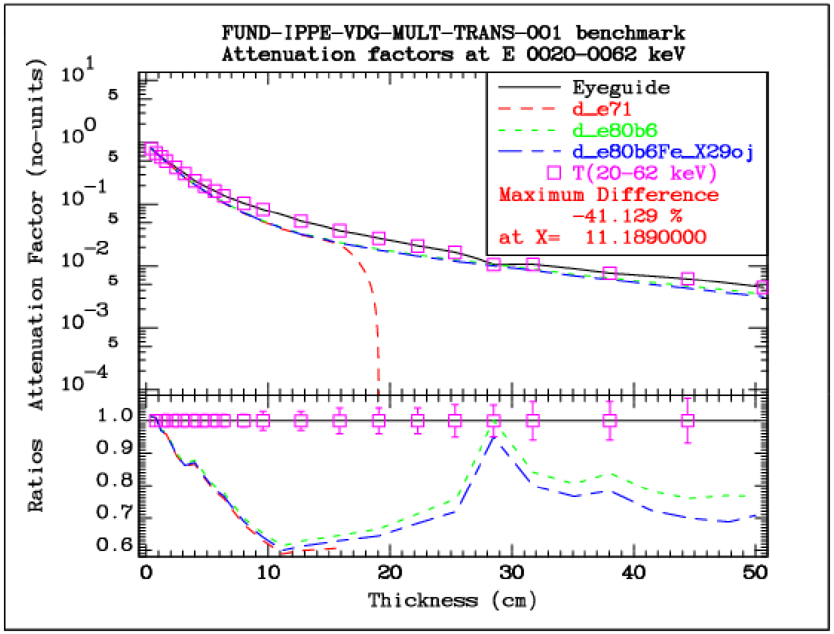
174 keV	1.0 b	(0 at 170, 177 keV)
244 keV	0.3 b	(0 at 242, 245 keV)
267 keV	-10 b	(0 at 266.95, 267.1 keV)
274 keV	0.3 b	(0 at 271, 276 keV)
310-313 keV	0.3 b	(0 at 290, 320 keV)
376 keV	0.3 b	(0 at 370, 380 keV)
1.02 MeV	0.1 b	(from 0 at 0.85 MeV)
1.40 MeV	-0.15 b	
1.60 MeV	0.10 b	
1.90 MeV	-0.20 b	(to 0 at 2.0 MeV)

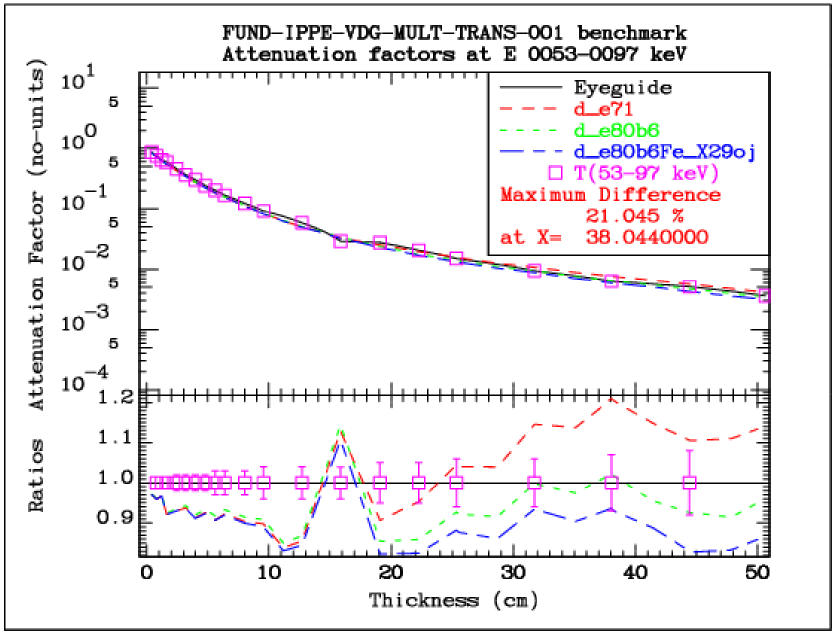


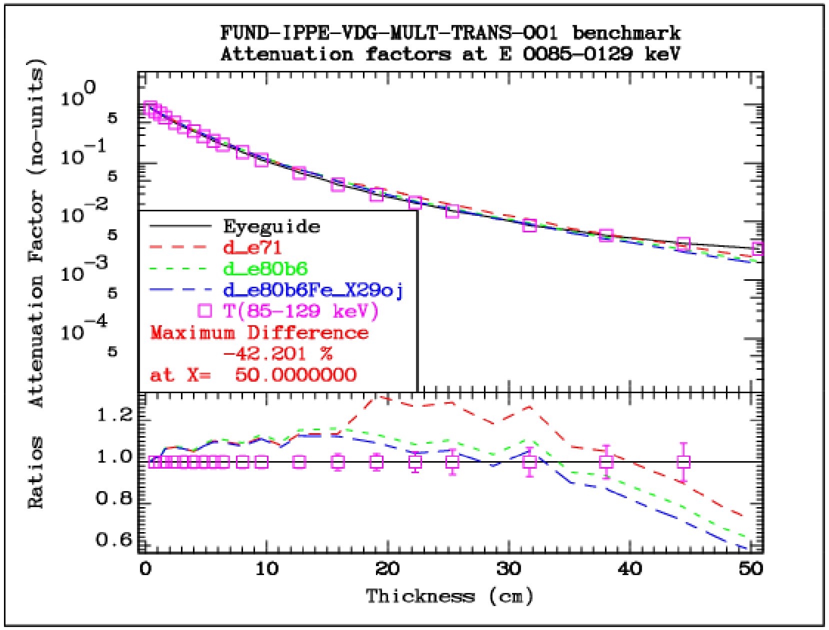
MAT 2631
Elastic
Cross Section
26-Fe-56
-83.54 To 742.6 %
Resolved
Max
Ratio
Min
Ratio
fe56e71
fe56e80X29r2
Cross Section (barns)
fe56e80X29r2/fe56e71
Ratio
160
200
220
240
260
280
300
320
340
360
380
3
Incident Energy (KeV)
26-Fe-56

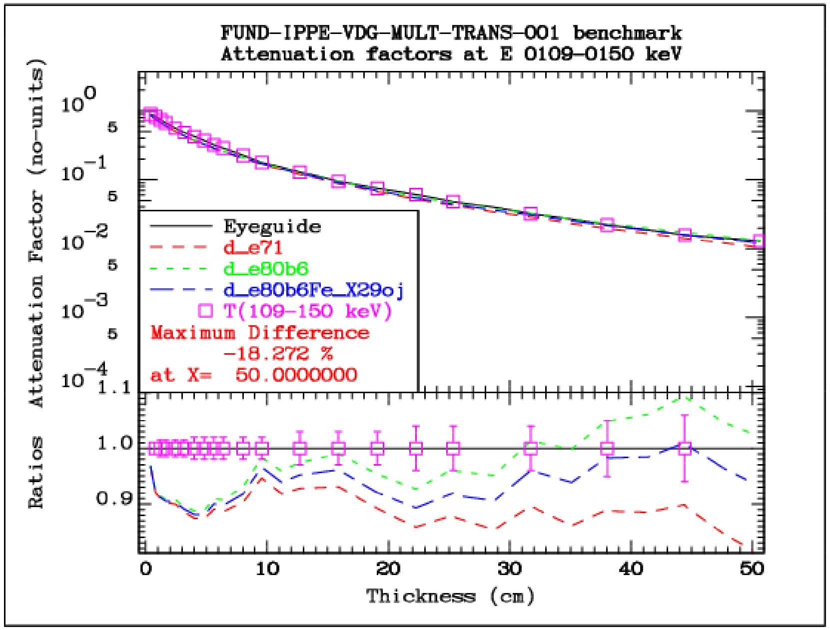
IPPE Fe broomstick experiments with p-T source

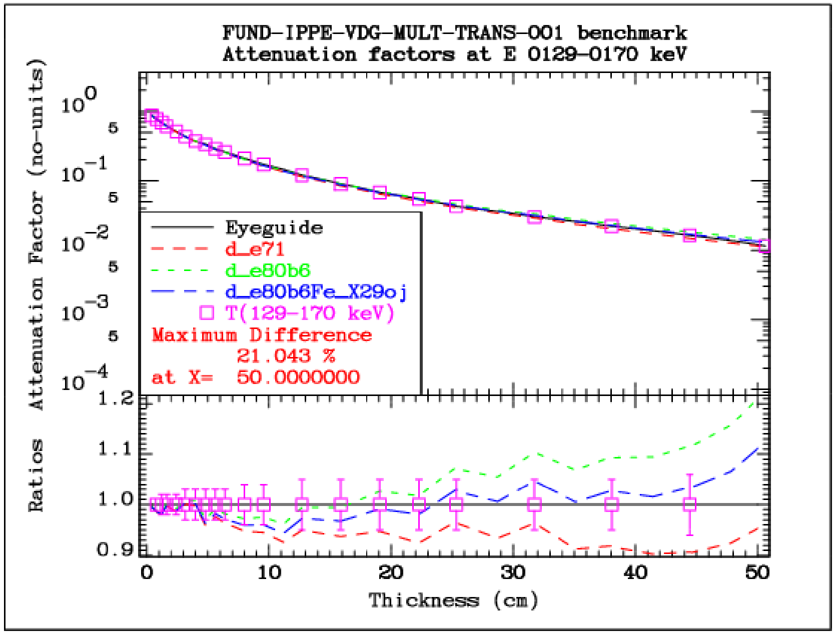


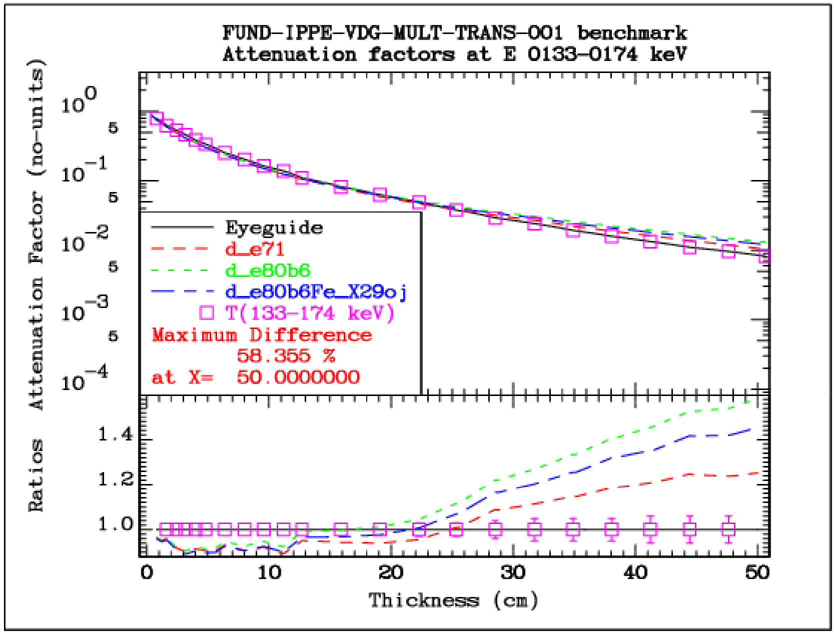

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0020-0062 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(20-62 keV)
Maximum Difference
-41.129 %
at X= 11.1890000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

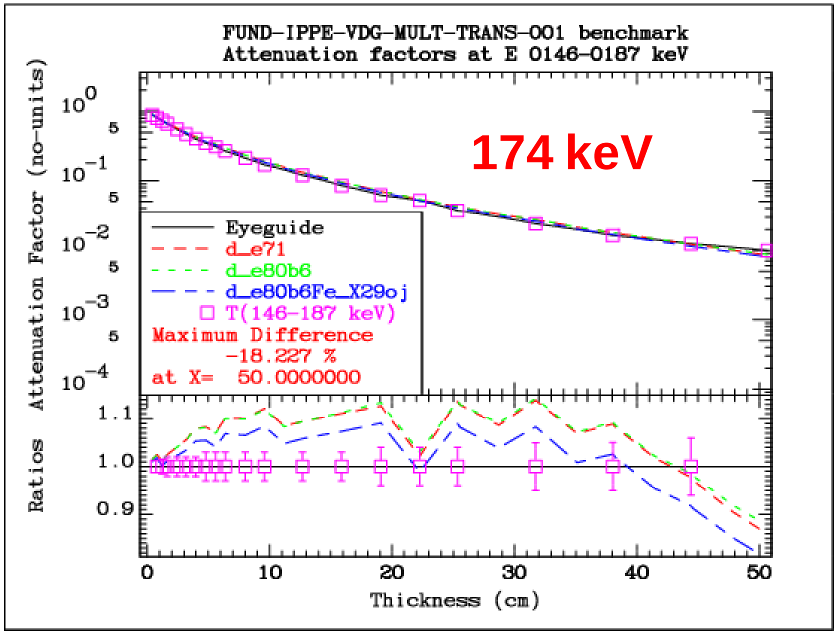

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0053-0097 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(53-97 keV)
Maximum Difference
21.045 %
at X= 38.0440000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

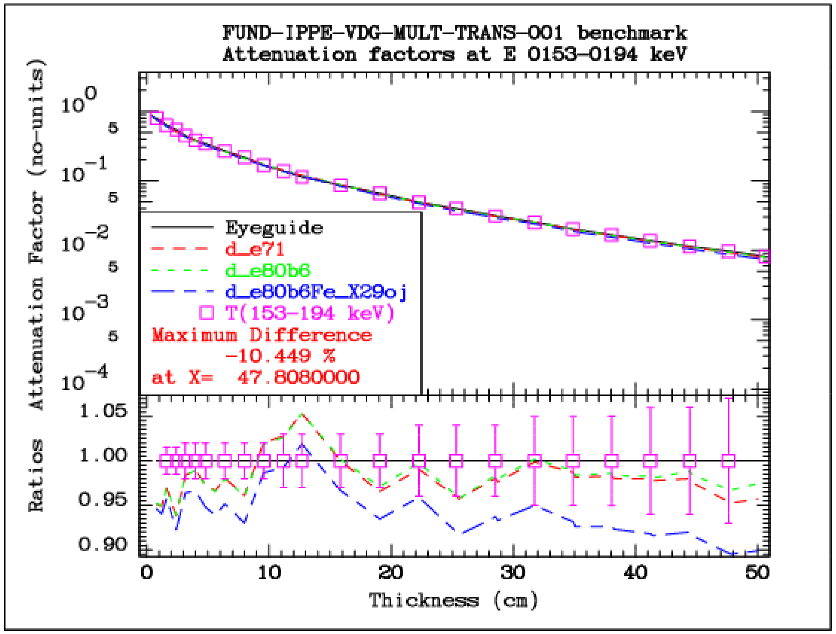

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0085-0129 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(85-129 keV)
Maximum Difference
-42.201 %
at X= 50.0000000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

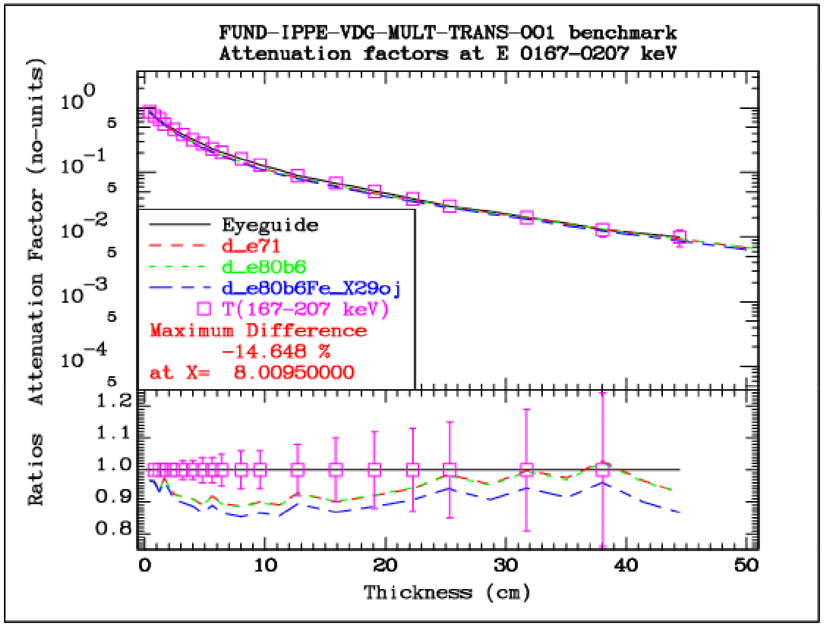

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0109-0150 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(109-150 keV)
Maximum Difference
-18.272 %
at X= 50.0000000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

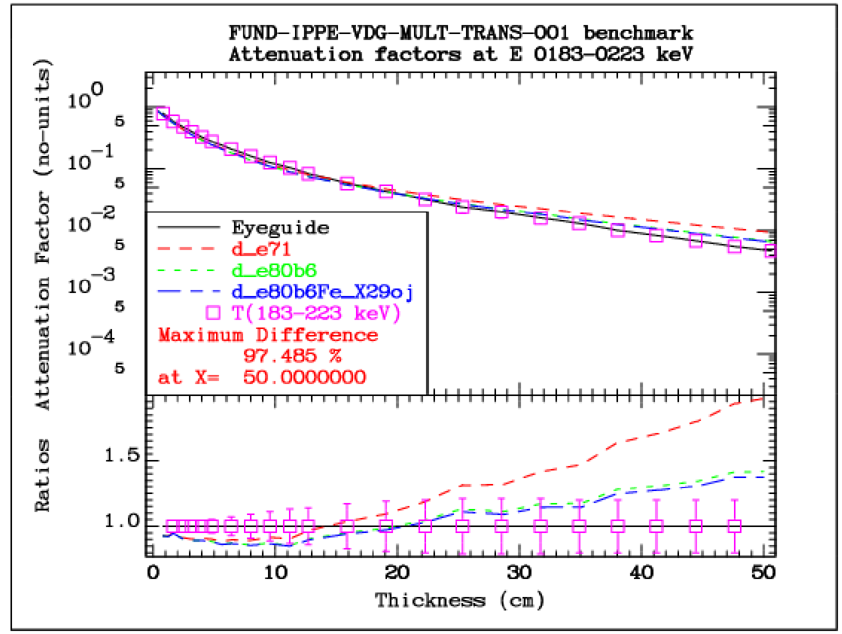

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0129-0170 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(129-170 keV)
Maximum Difference
21.043 %
at X= 50.0000000
Thickness (cm)

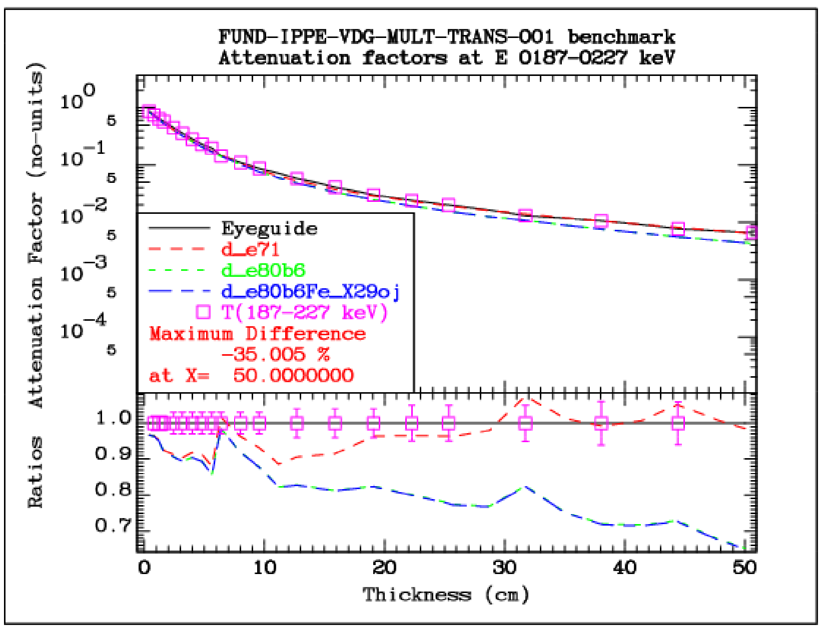

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0133-0174 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(133-174 keV)
Maximum Difference
58.355 %
at X= 50.0000000
Thickness (cm)

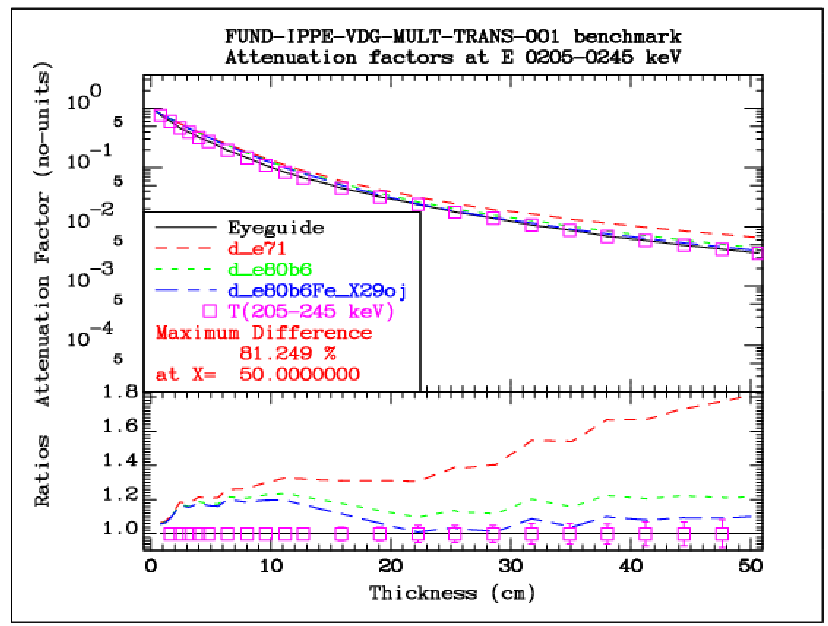

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0146-0187 keV
174 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(146-187 keV)
Maximum Difference
-18.227 %
at X= 50.0000000
Thickness (cm)

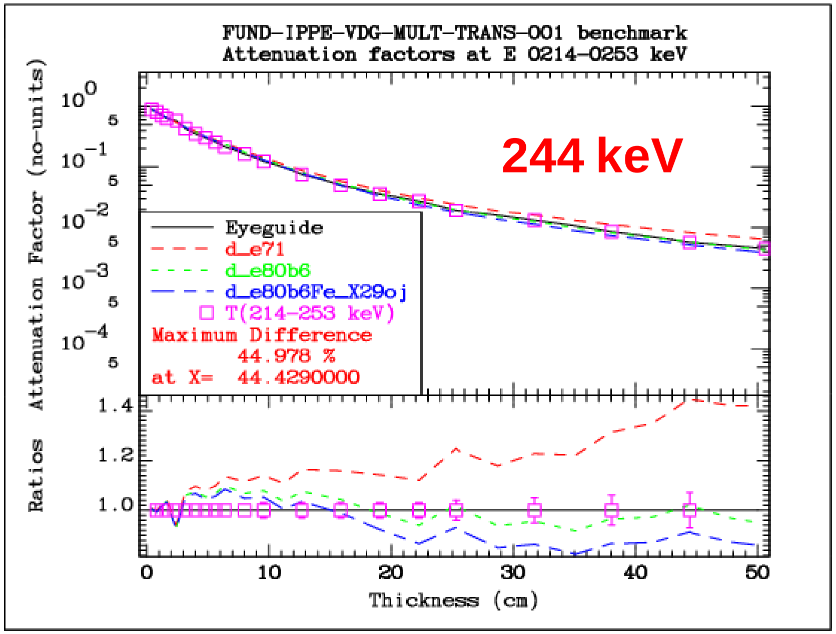

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0153-0194 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(153-194 keV)
Maximum Difference
-10.449 %
at X= 47.8080000
Thickness (cm)

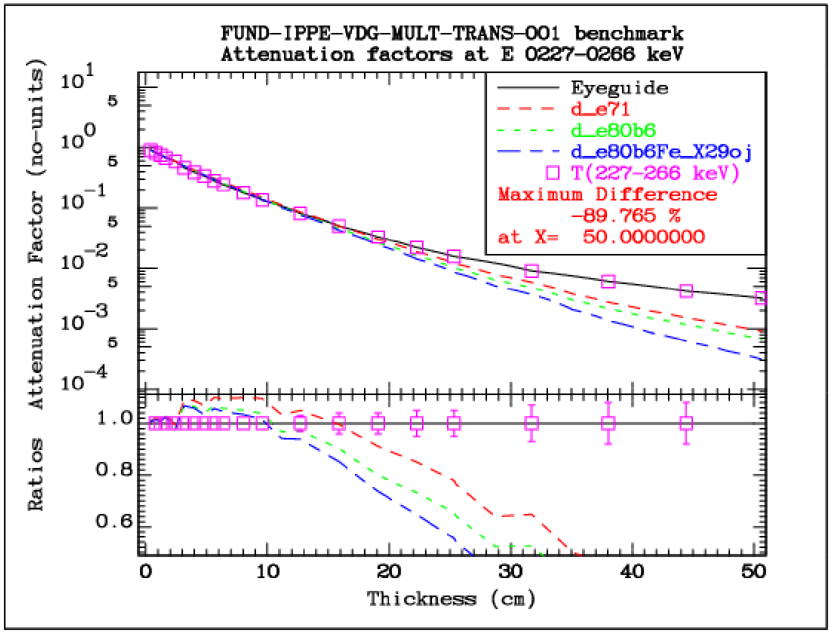

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0167-0207 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(167-207 keV)
Maximum Difference
-14.648 %
at X= 8.00950000
Thickness (cm)

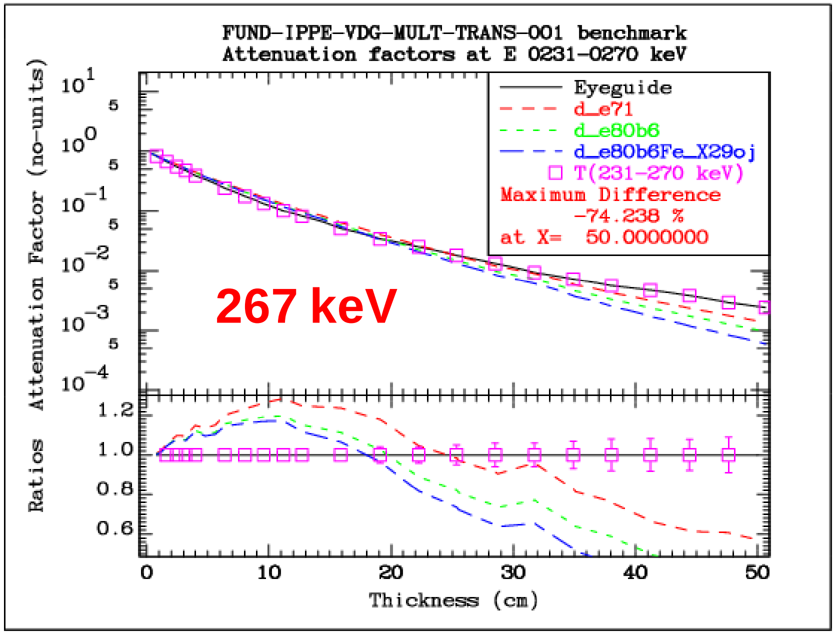

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0183-0223 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(183-223 keV)
Maximum Difference
97.485 %
at X= 50.0000000
Thickness (cm)

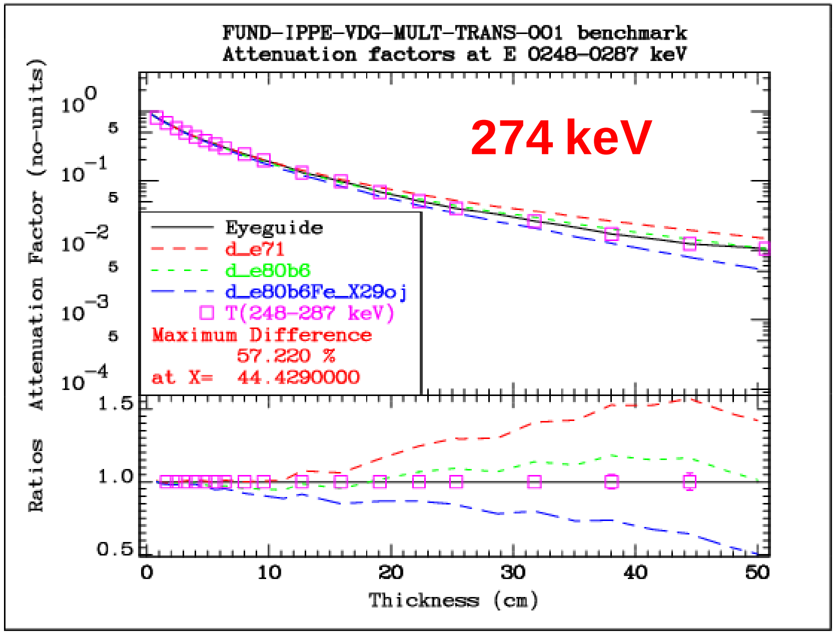

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0187-0227 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(187-227 keV)
Maximum Difference
-35.005 %
at X= 50.0000000
Thickness (cm)

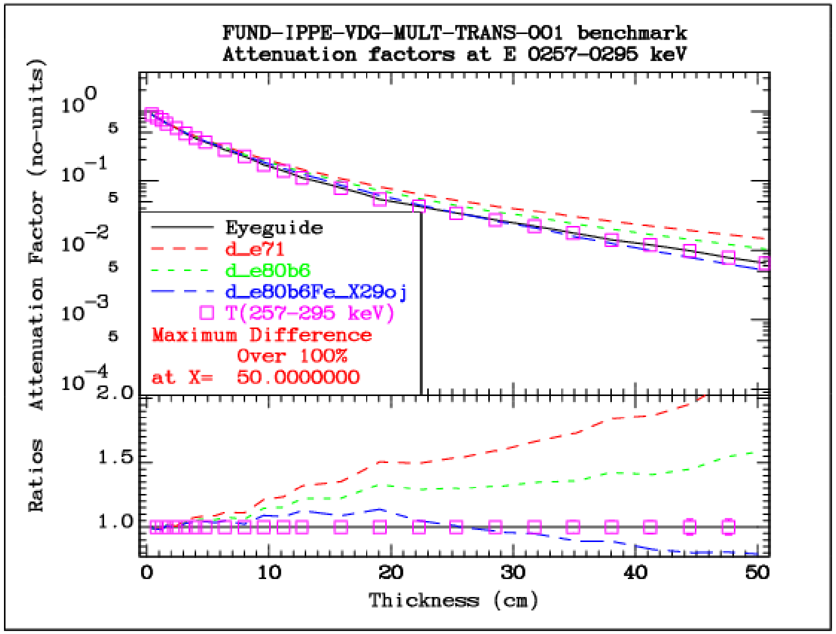

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0205-0245 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(205-245 keV)
Maximum Difference
81.249 %
at X= 50.0000000
Thickness (cm)

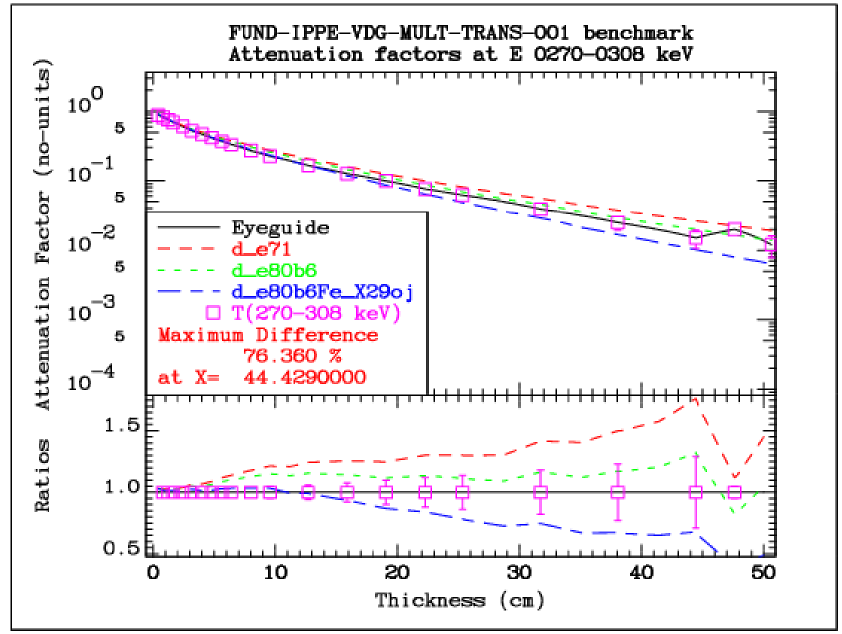

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0214-0253 keV
244 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(214-253 keV)
Maximum Difference
44.978 %
at X= 44.4290000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

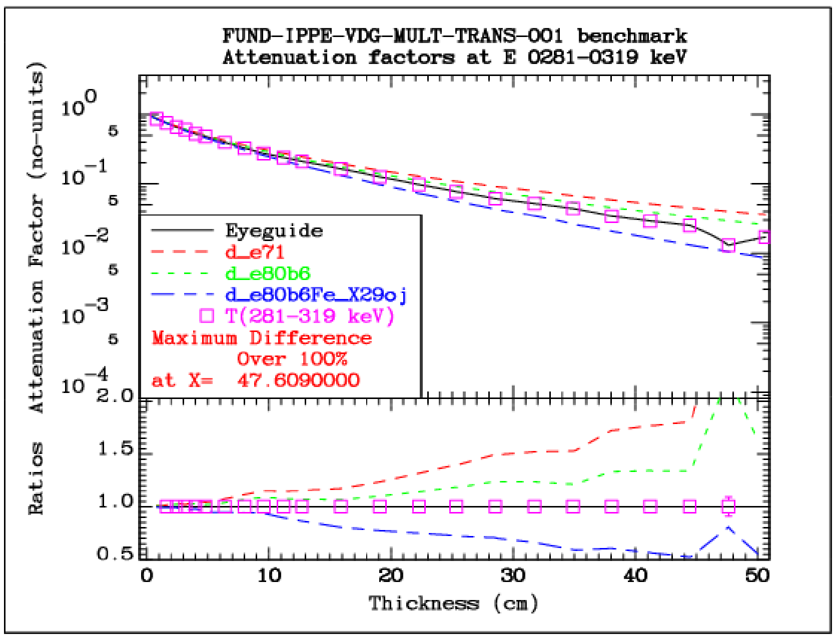

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0227-0266 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(227-266 keV)
Maximum Difference
-89.765 %
at X= 50.0000000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

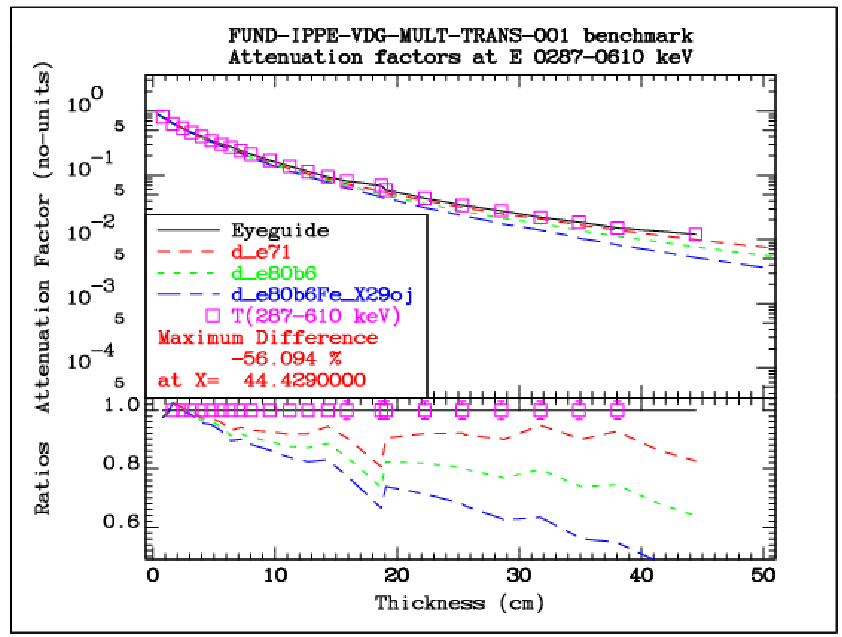

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0231-0270 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(231-270 keV)
Maximum Difference
-74.238 %
at X= 50.0000000
267 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)

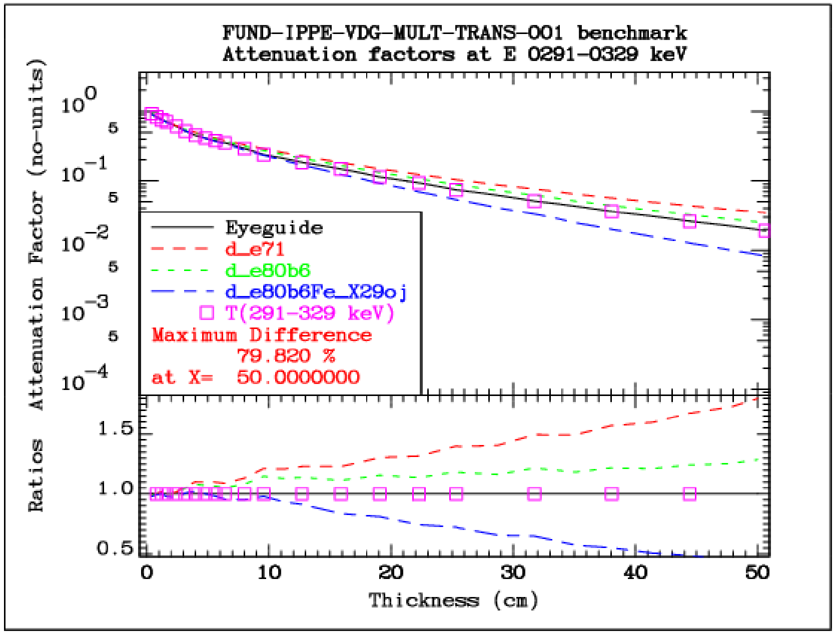

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0248-0287 keV
274 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(248-287 keV)
Maximum Difference
57.220 %
at X= 44.4290000
Attenuation Factor (no-units)
Ratios
Thickness (cm)


FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0257-0295 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(257-295 keV)
Maximum Difference
Over 100%
at X= 50.0000000

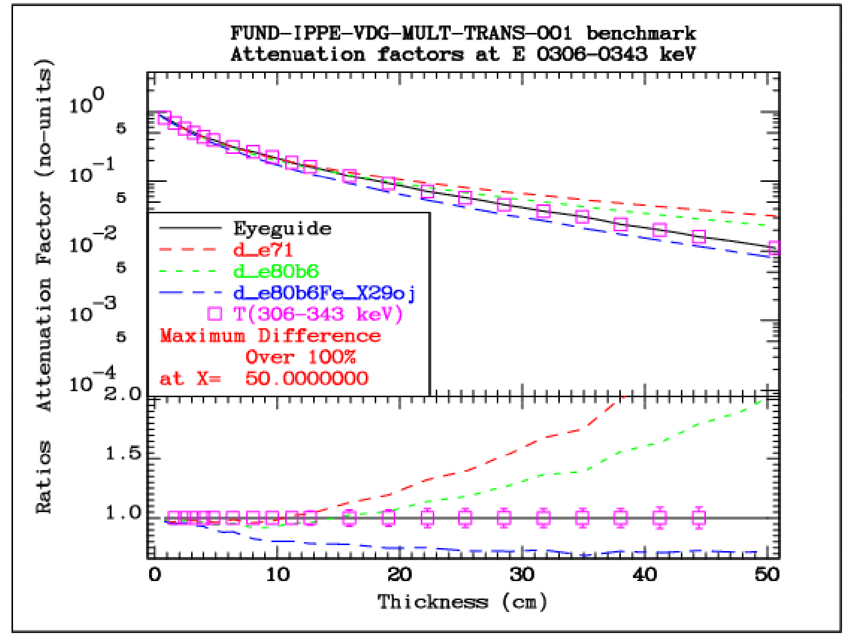

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0270-0308 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(270-308 keV)
Maximum Difference
76.360 %
at X= 44.4290000


FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0281-0319 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(281-319 keV)
Maximum Difference
Over 100%
at X= 47.6090000

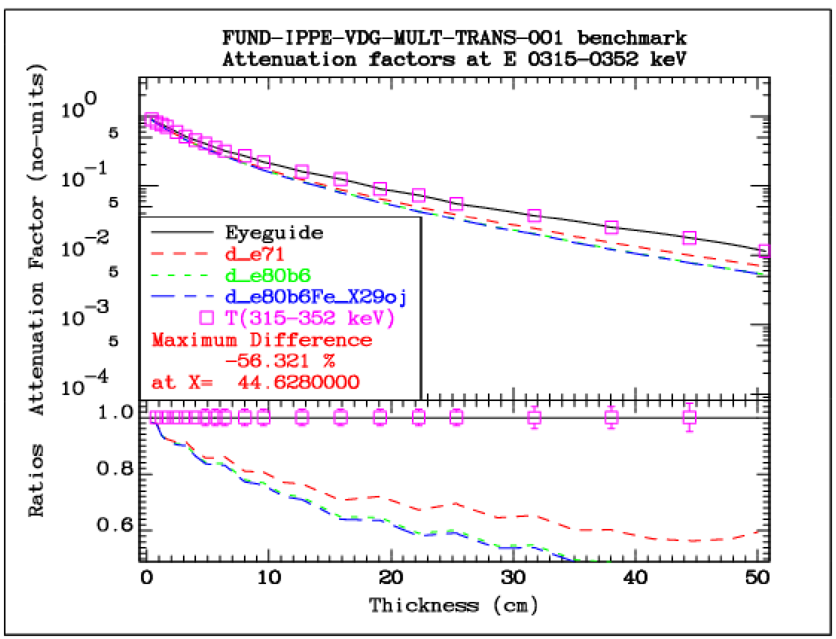

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0287-0610 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(287-610 keV)
Maximum Difference
-56.094 %
at X= 44.4290000



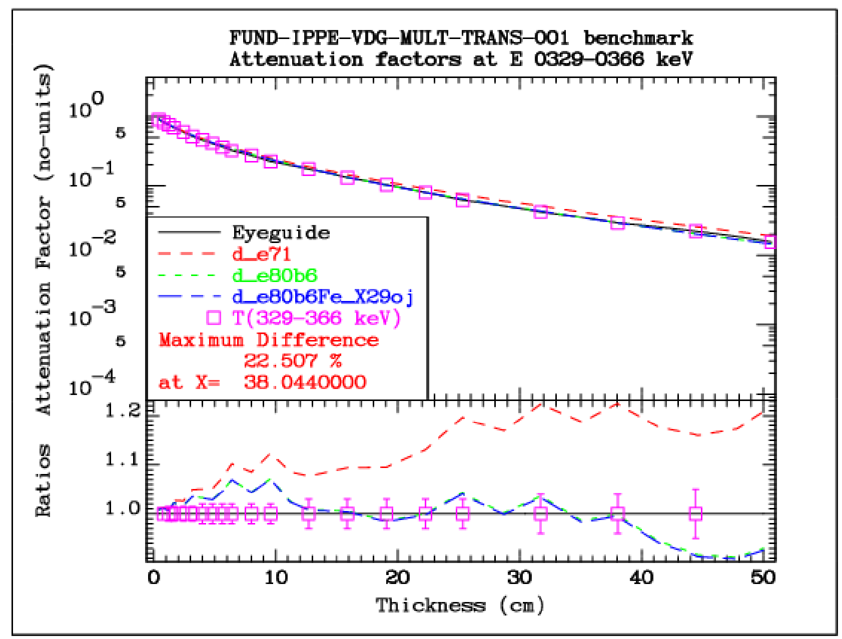
FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0291-0329 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(291-329 keV)
Maximum Difference
79.820 %
at X= 50.0000000
Thickness (cm)



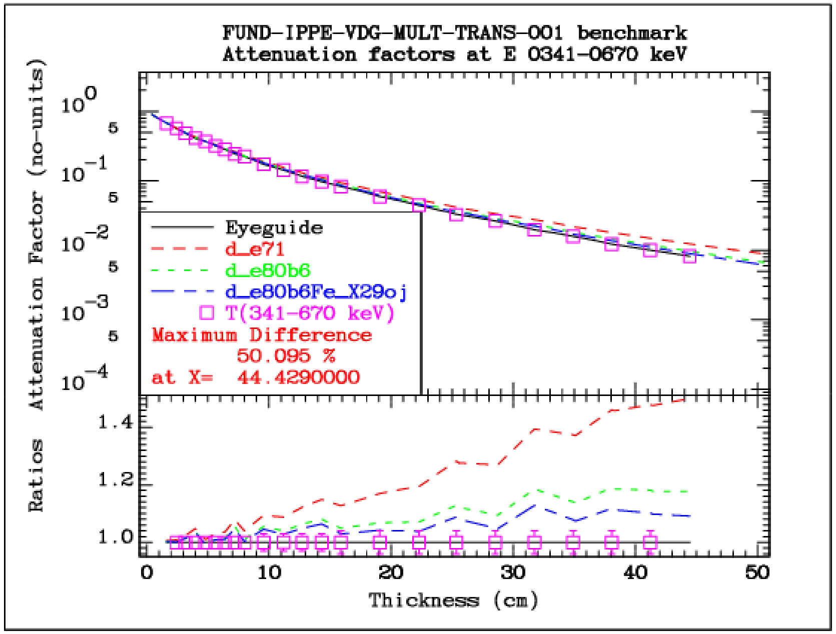
FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0306-0343 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(306-343 keV)
Maximum Difference
Over 100%
at X= 50.0000000
Thickness (cm)

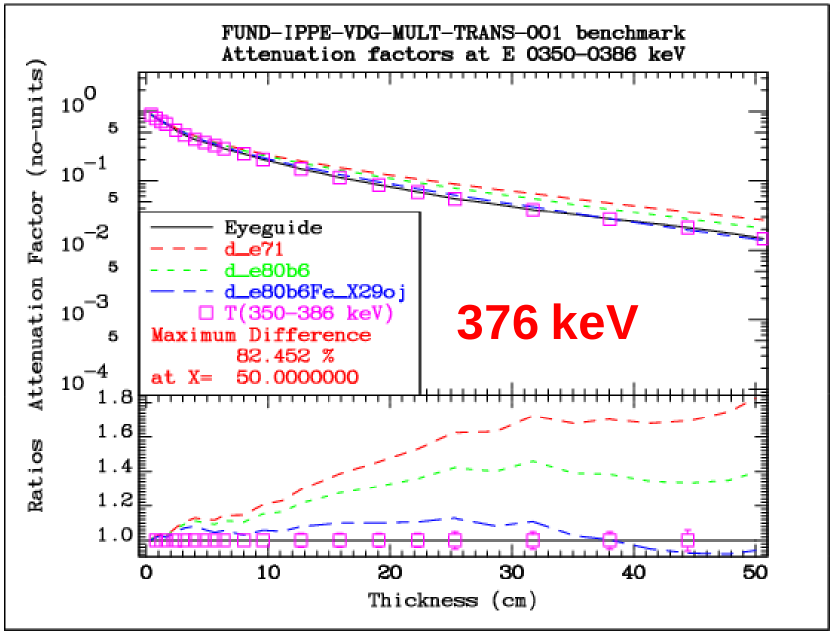


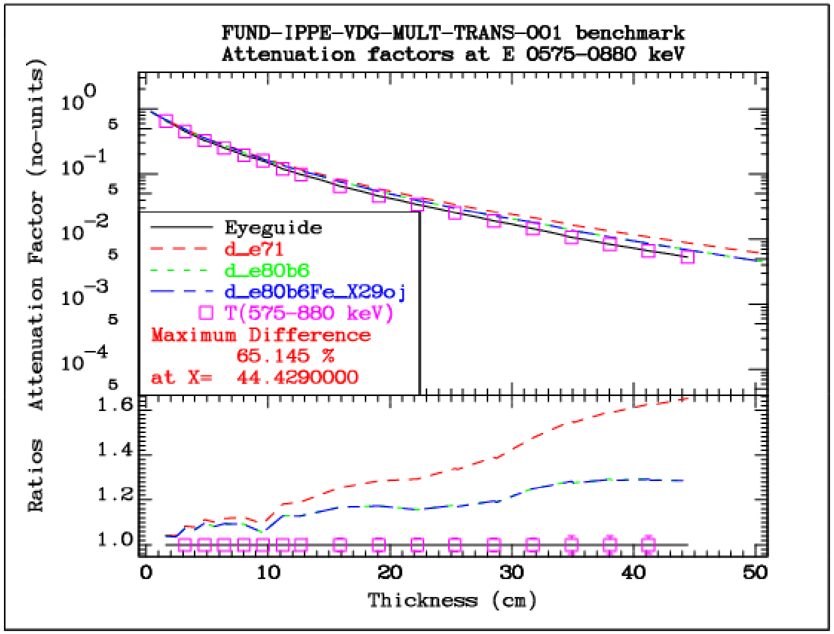
FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0315-0352 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(315-352 keV)
Maximum Difference
-56.321 %
at X= 44.6280000
Thickness (cm)

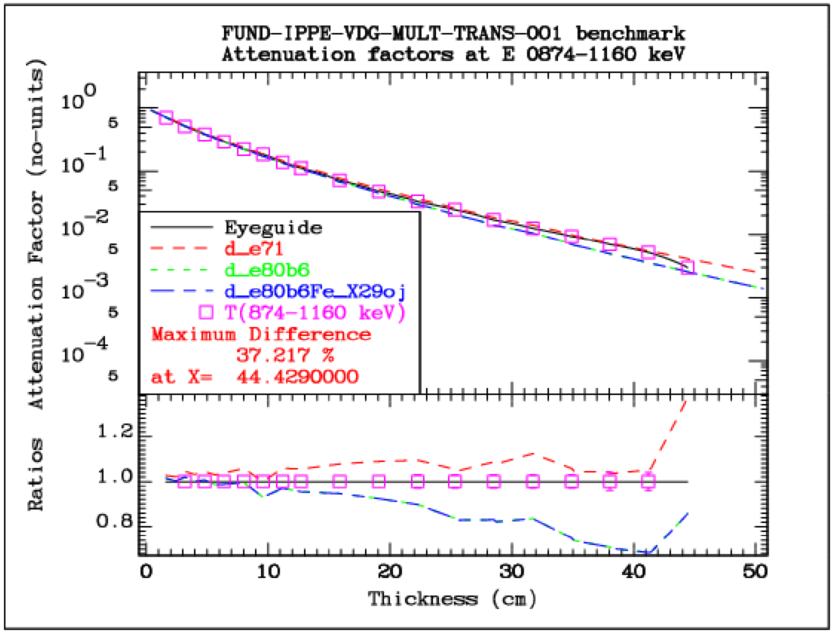


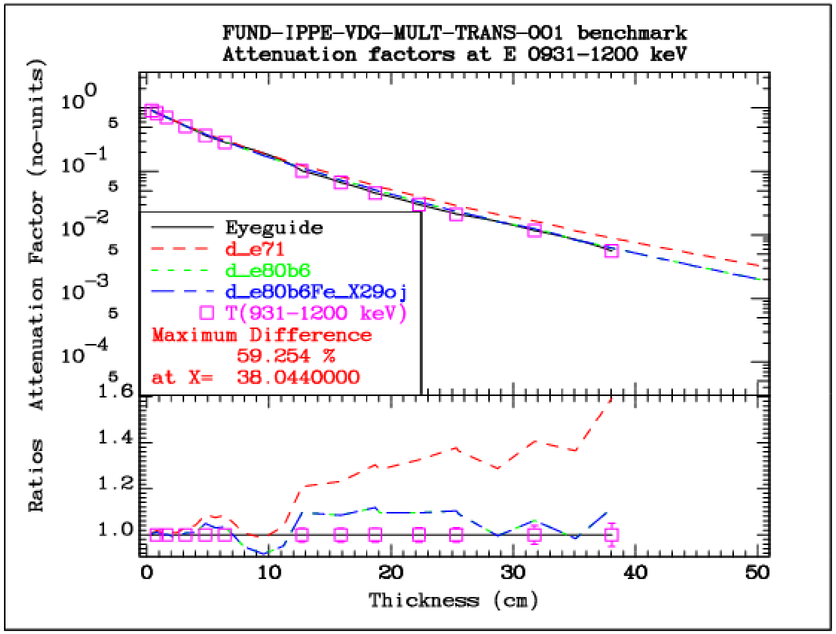
FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0329-0366 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(329-366 keV)
Maximum Difference
22.507 %
at X= 38.0440000
Thickness (cm)

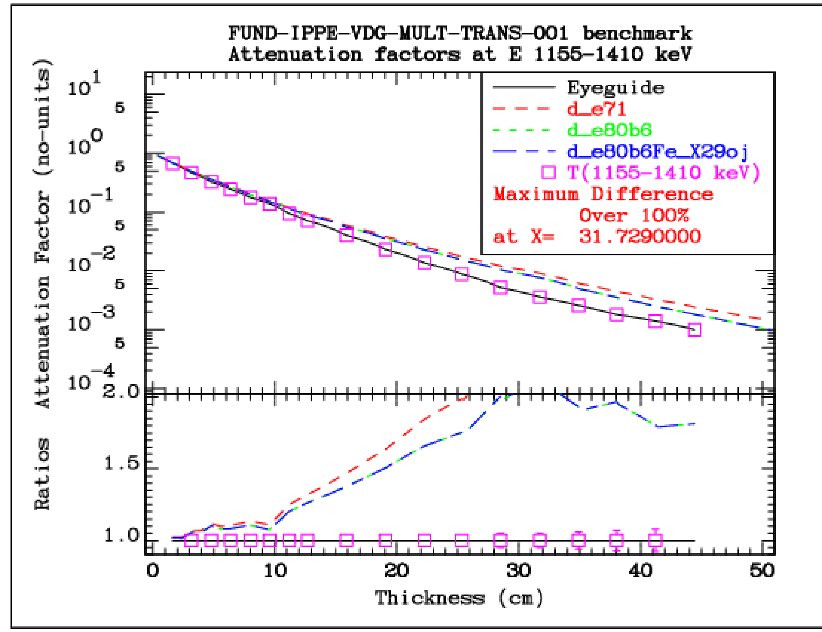

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0341-0670 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(341-670 keV)
Maximum Difference
50.095 %
at X= 44.4290000
Thickness (cm)

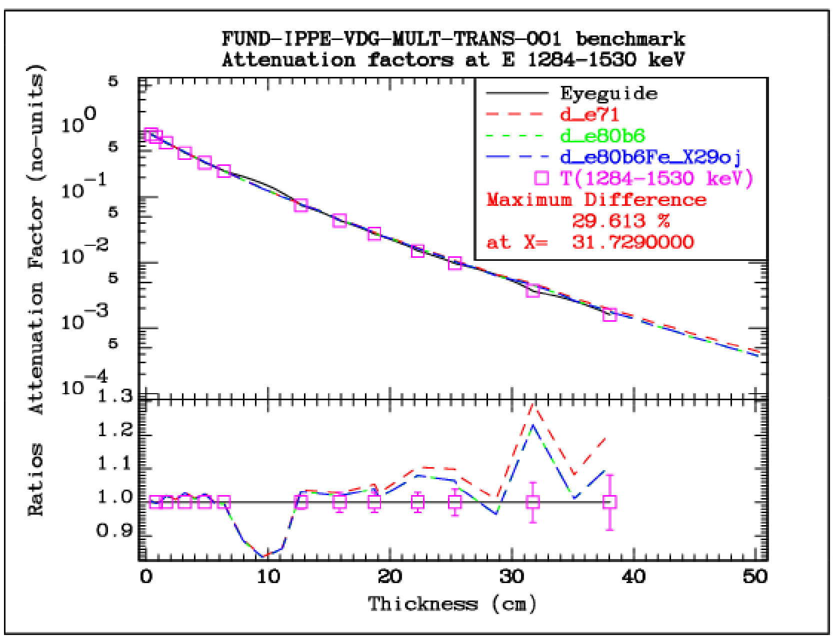

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0350-0386 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(350-386 keV)
Maximum Difference
82.452 %
at X= 50.0000000
376 keV
Thickness (cm)

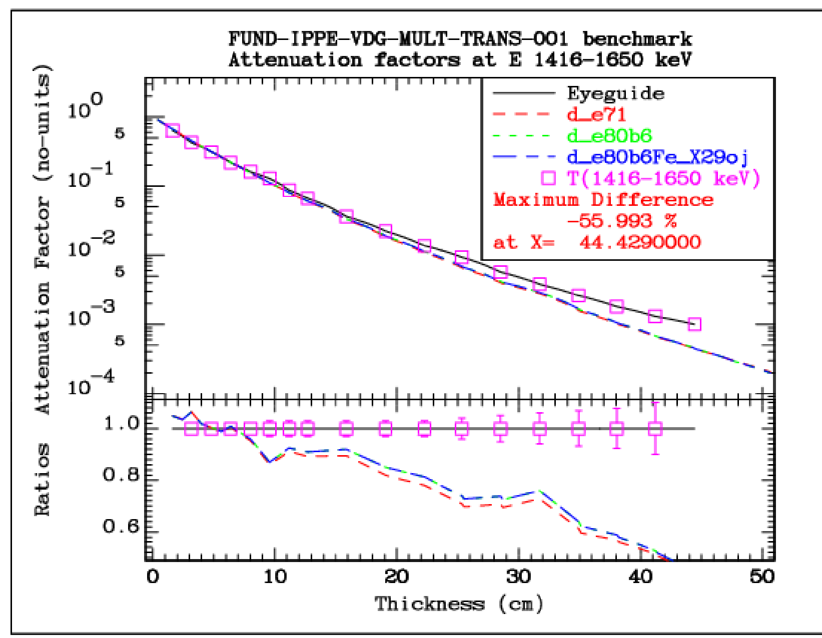

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0575-0880 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(575-880 keV)
Maximum Difference
65.145 %
at X= 44.4290000
Thickness (cm)

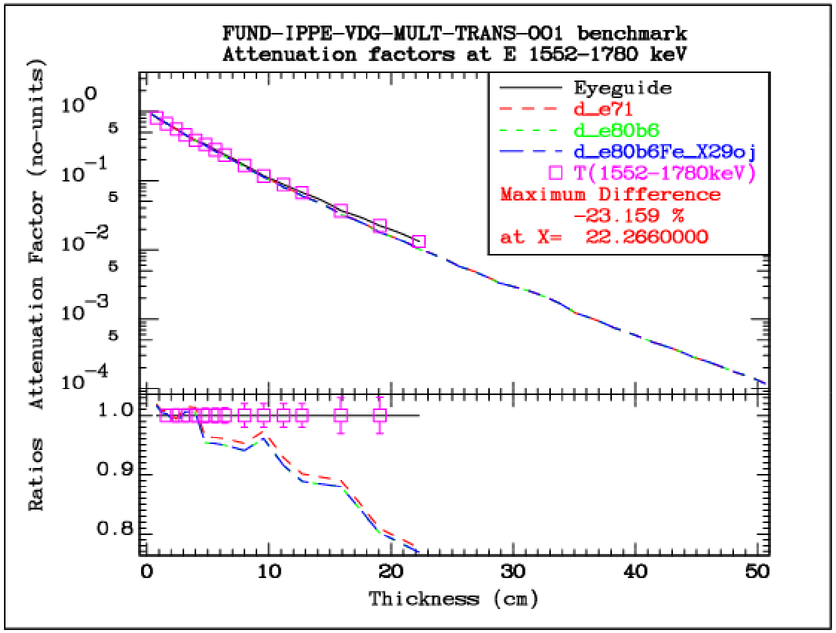

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0874-1160 keV
Attenuation Factor (no-units)
Ratios
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(874-1160 keV)
Maximum Difference
37.217 %
at X= 44.4290000
Thickness (cm)

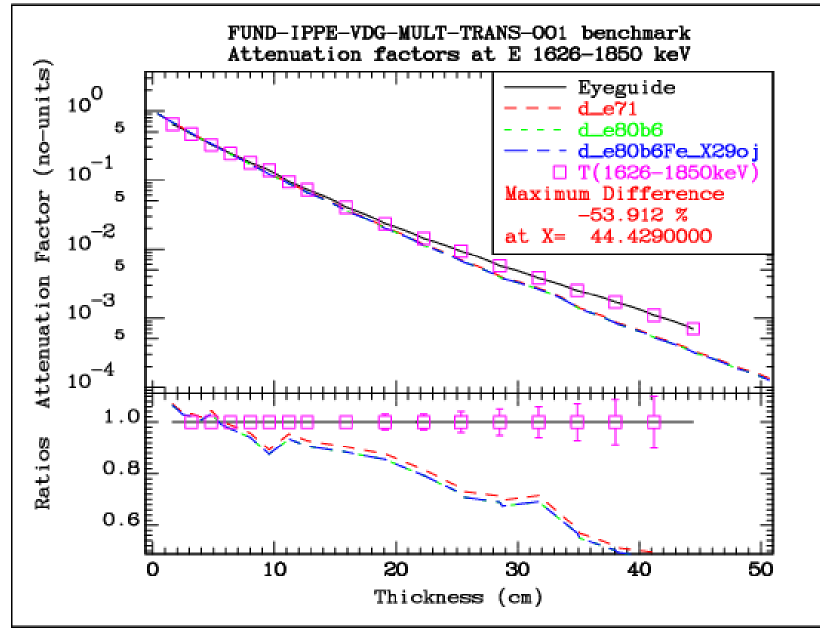

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0931-1200 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(931-1200 keV)
Maximum Difference
59.254 %
at X= 38.0440000

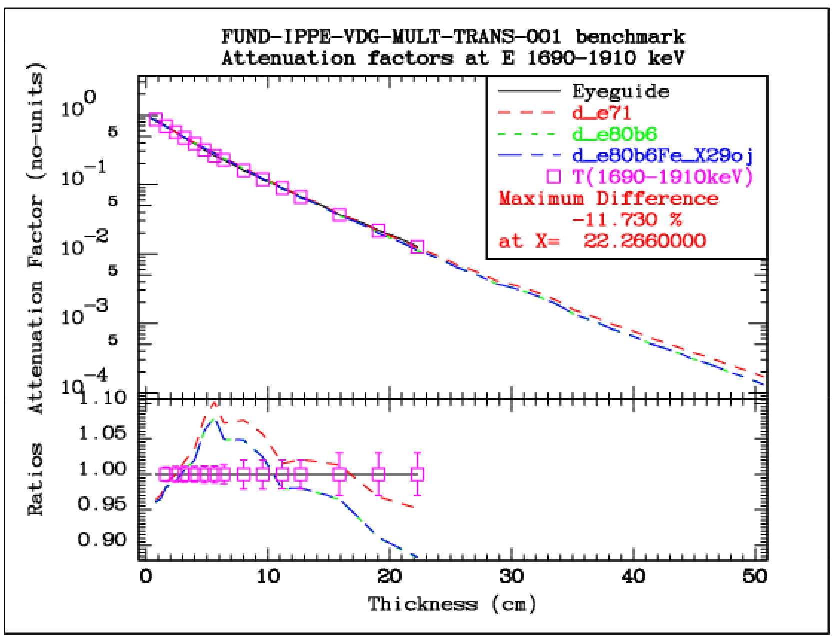

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1155-1410 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1155-1410 keV)
Maximum Difference
Over 100%
at X= 31.7290000

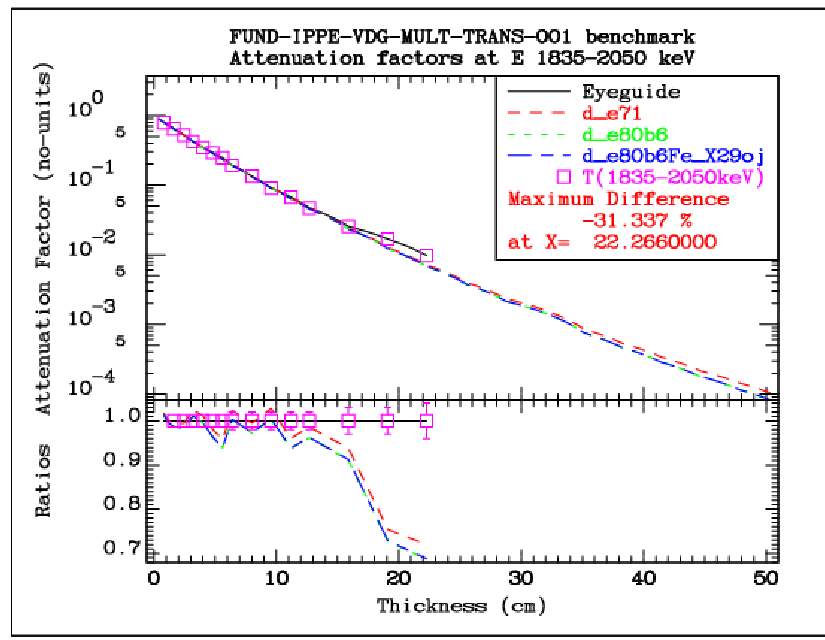

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1284-1530 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1284-1530 keV)
Maximum Difference
29.613 %
at X= 31.7290000

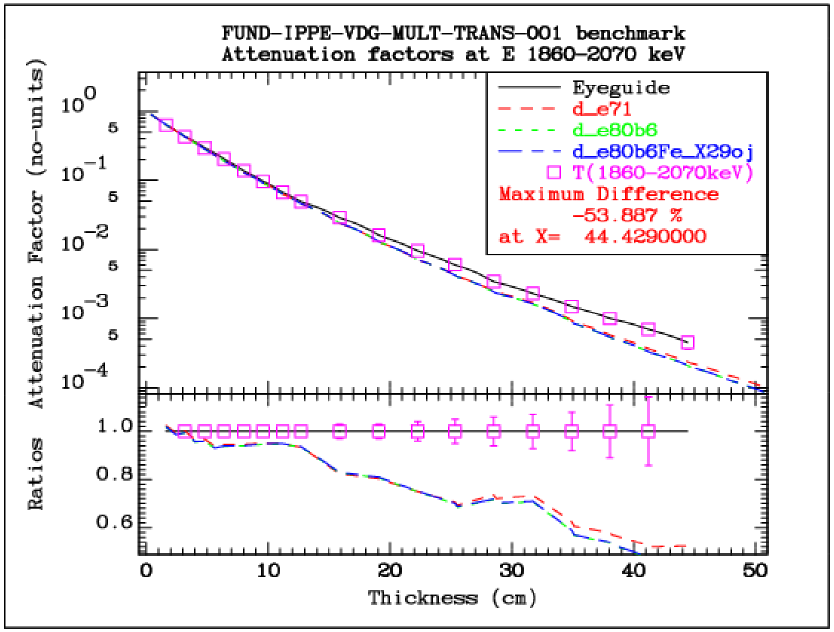

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1416-1650 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1416-1650 keV)
Maximum Difference
-55.993 %
at X= 44.4290000

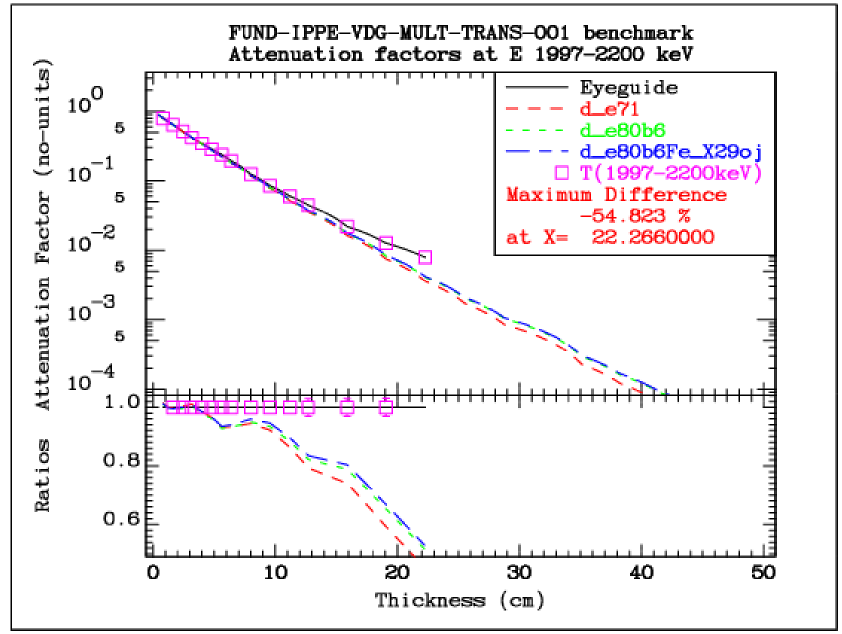

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1552-1780 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1552-1780keV)
Maximum Difference
-23.159 %
at X= 22.2660000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

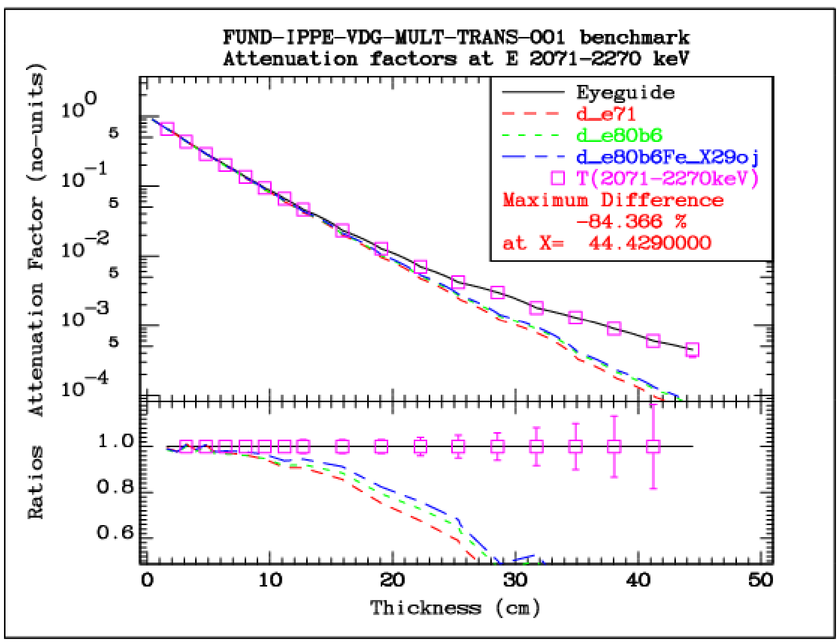

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1626-1850 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1626-1850keV)
Maximum Difference
-53.912 %
at X= 44.4290000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

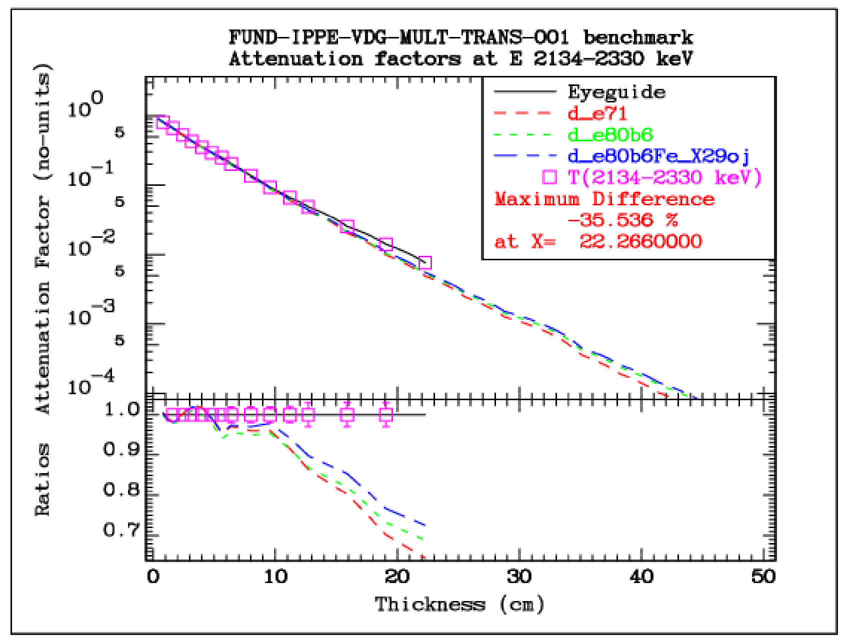

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1690-1910 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1690-1910keV)
Maximum Difference
-11.730 %
at X= 22.2660000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

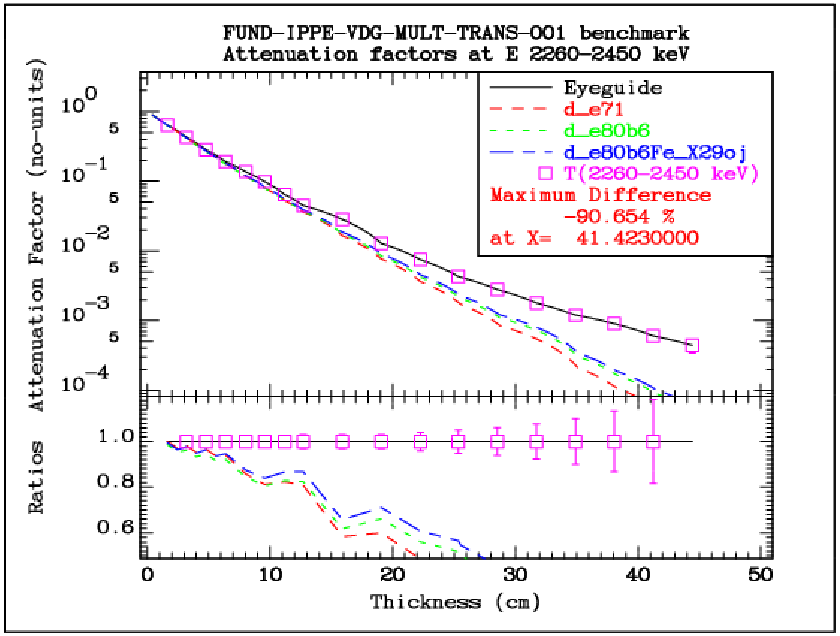

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1835-2050 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1835-2050keV)
Maximum Difference
-31.337 %
at X= 22.2660000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

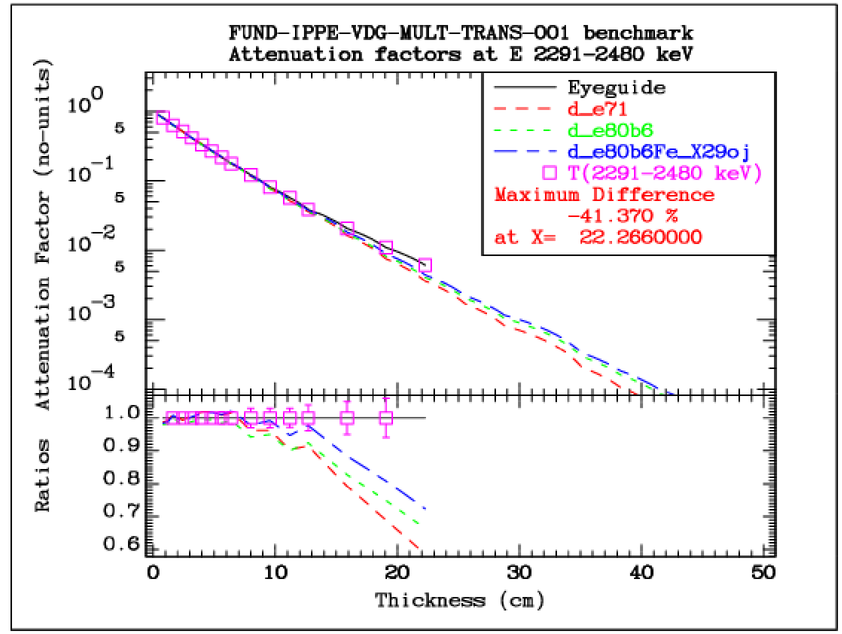

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1860-2070 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1860-2070keV)
Maximum Difference
-53.887 %
at X= 44.4290000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

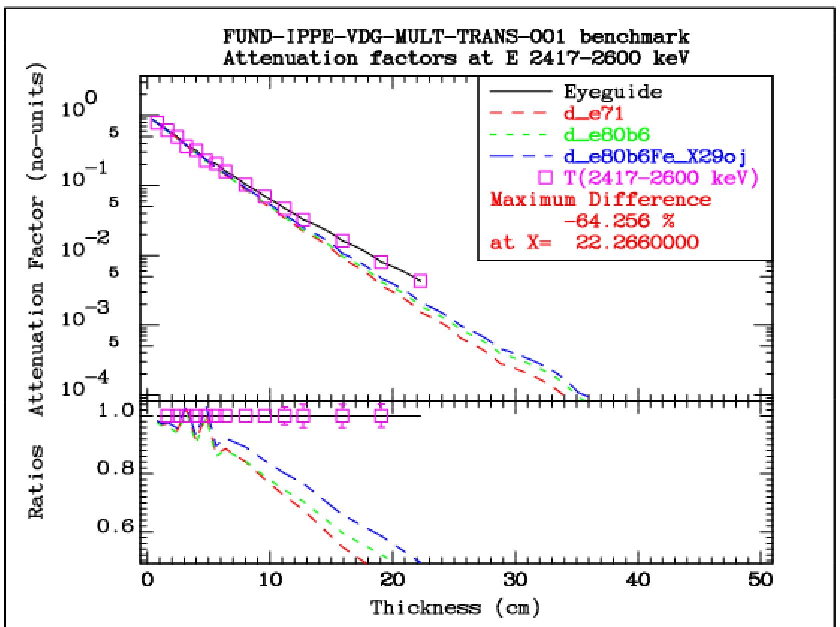

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1997-2200 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1997-2200keV)
Maximum Difference
-54.823 %
at X= 22.2660000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

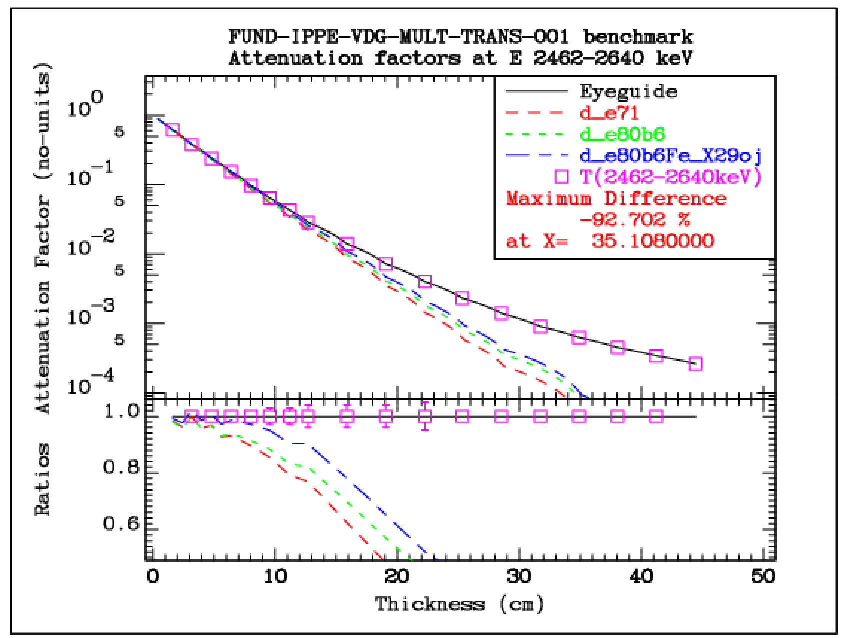

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2071-2270 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2071-2270keV)
Maximum Difference
-84.366 %
at X= 44.4290000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

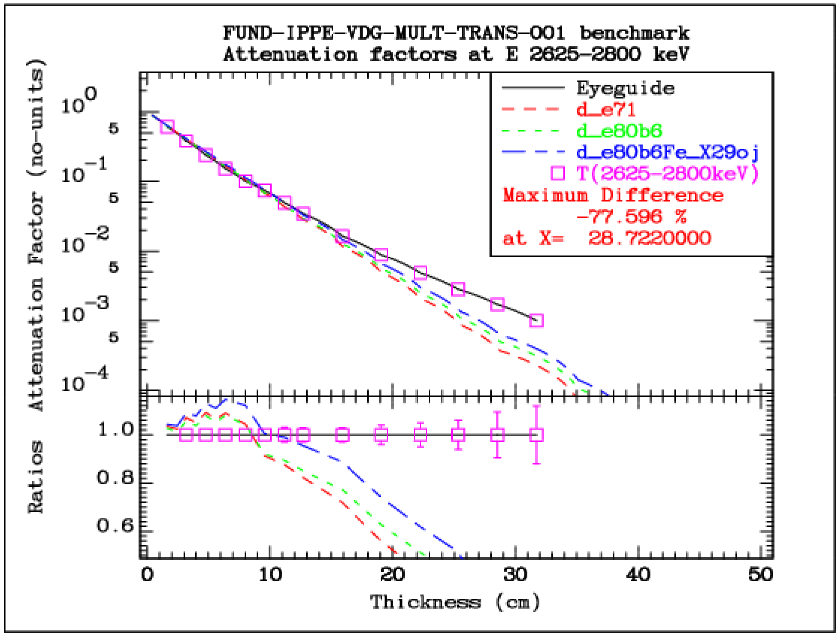

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2134-2330 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2134-2330 keV)
Maximum Difference
-35.536 %
at X= 22.2660000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

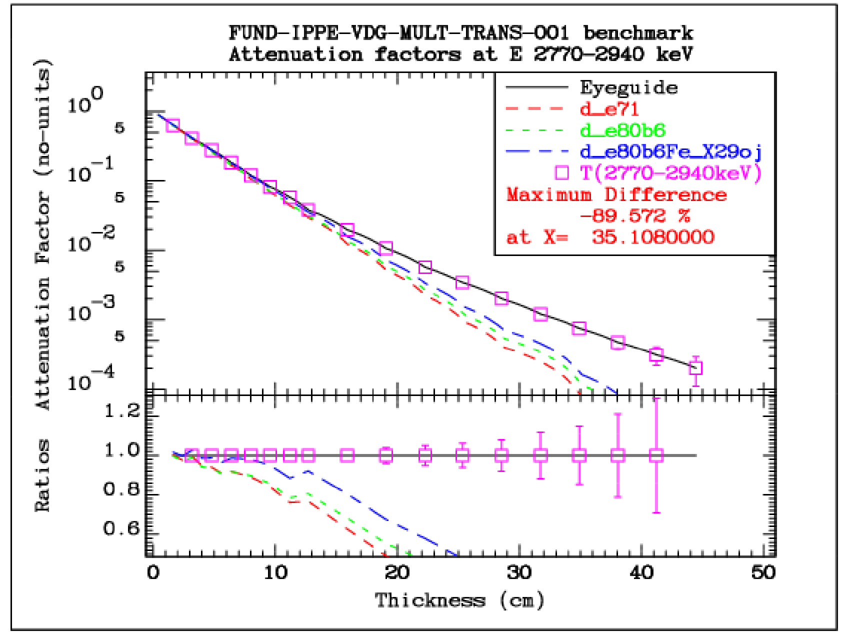

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2260-2450 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2260-2450 keV)
Maximum Difference
-90.654 %
at X= 41.4230000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

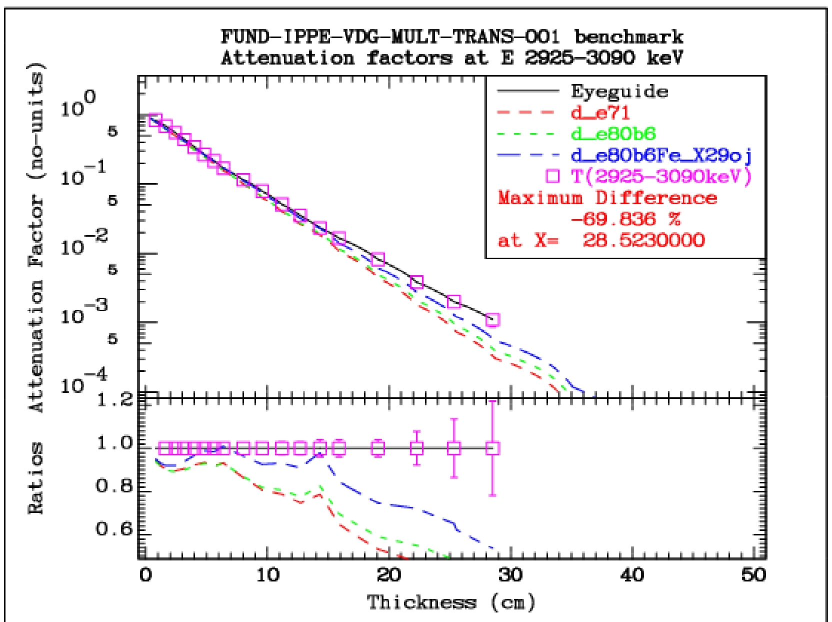

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2291-2480 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2291-2480 keV)
Maximum Difference
-41.370 %
at X= 22.2660000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

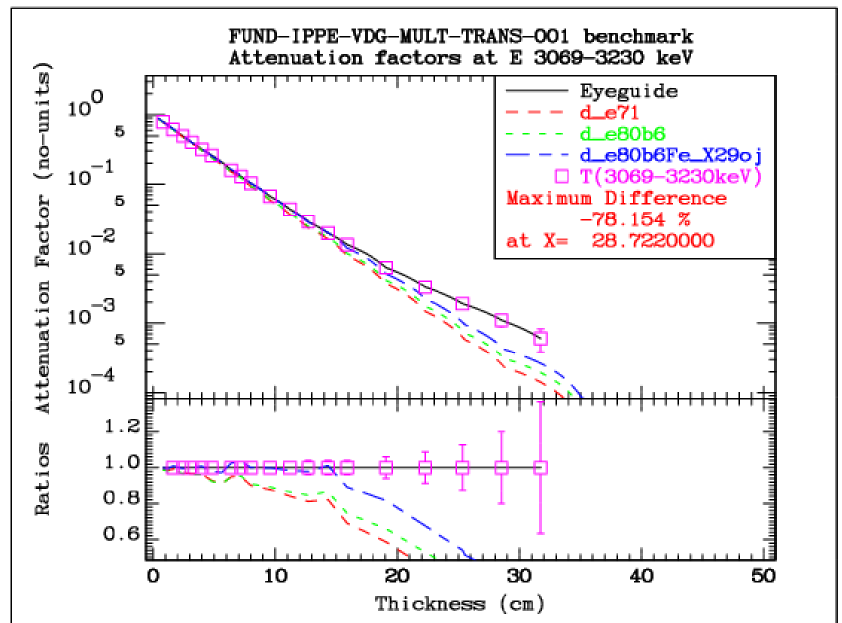

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2417-2600 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2417-2600 keV)
Maximum Difference
-64.256 %
at X= 22.2660000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

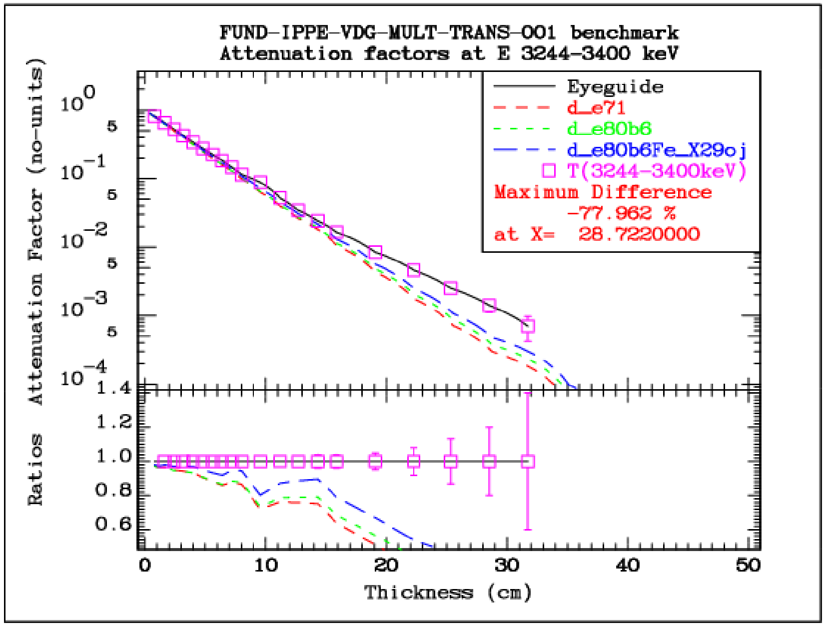

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2462-2640 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2462-2640keV)
Maximum Difference
-92.702 %
at X= 35.1080000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

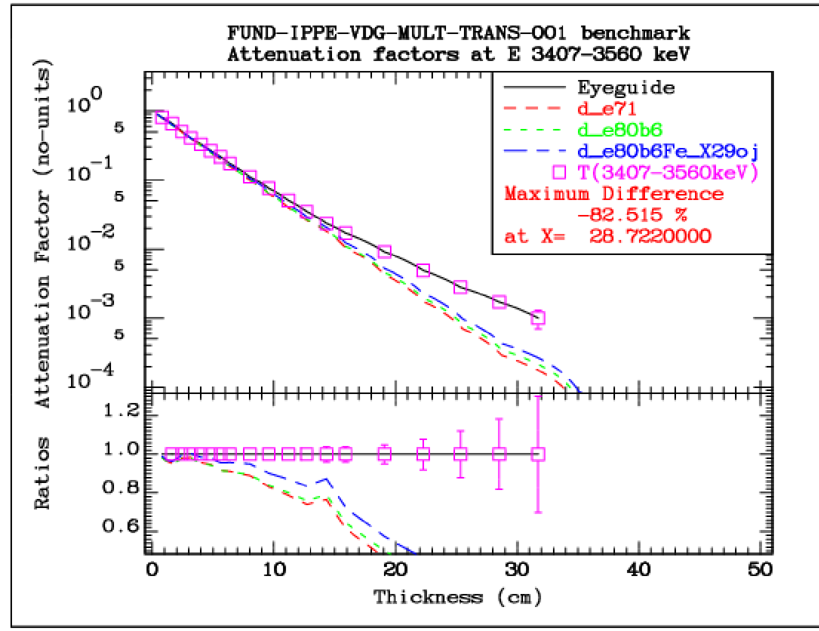

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2625-2800 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2625-2800keV)
Maximum Difference
-77.596 %
at X= 28.7220000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

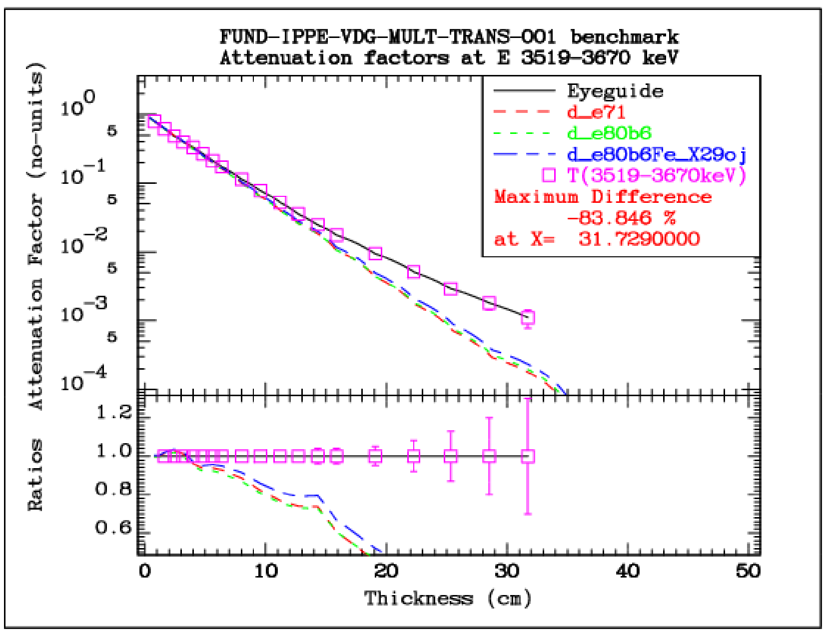

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2770-2940 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2770-2940keV)
Maximum Difference
-89.572 %
at X= 35.1080000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

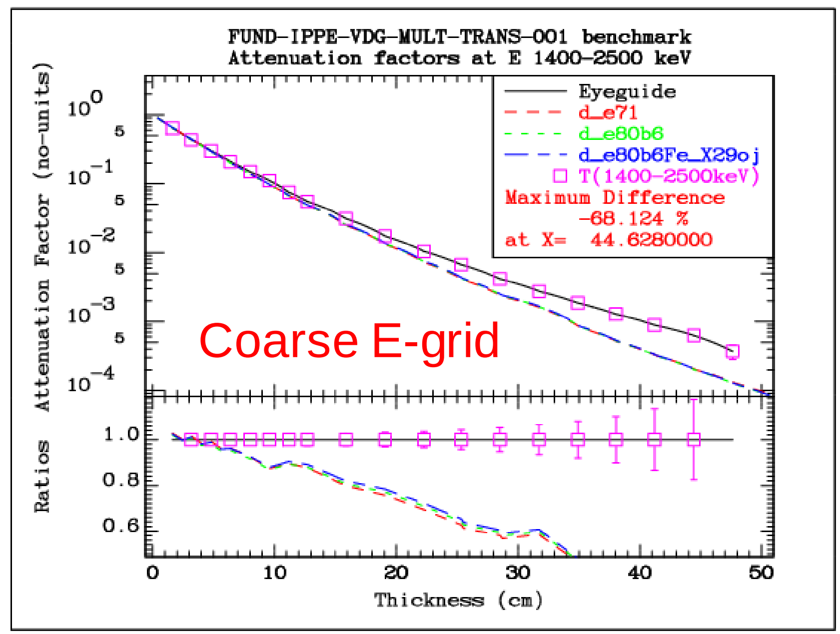

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 2925-3090 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(2925-3090keV)
Maximum Difference
-69.836 %
at X= 28.5230000
Attenuation Factor (no-units)
Ratios
Thickness (cm)


FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 3069-3230 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(3069-3230keV)
Maximum Difference
-78.154 %
at X= 28.7220000
Attenuation Factor (no-units)
Ratios
Thickness (cm)


FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 3244-3400 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(3244-3400keV)
Maximum Difference
-77.962 %
at X= 28.7220000
Attenuation Factor (no-units)
Ratios
Thickness (cm)


FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 3407-3560 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(3407-3560keV)
Maximum Difference
-82.515 %
at X= 28.7220000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

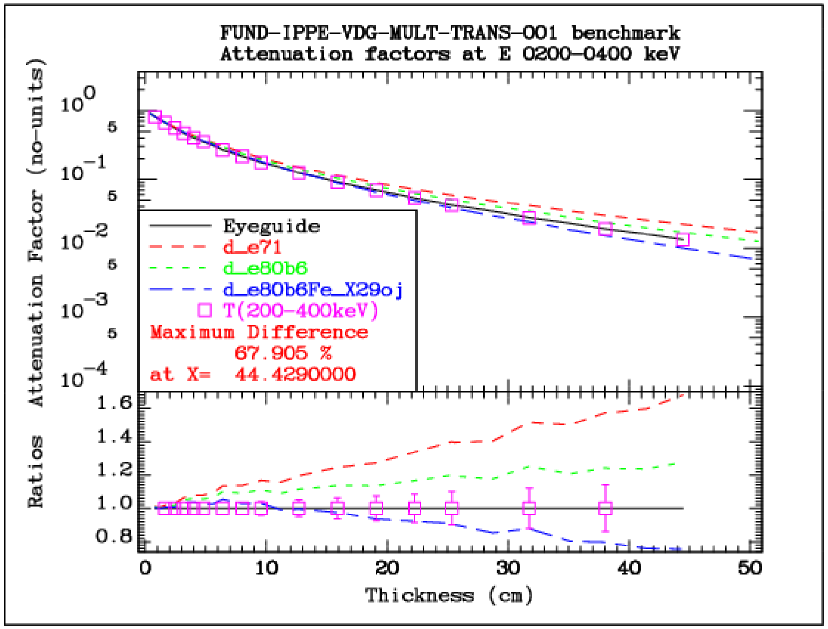

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 3519-3670 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(3519-3670keV)
Maximum Difference
-83.846 %
at X= 31.7290000
Attenuation Factor (no-units)
Ratios
Thickness (cm)

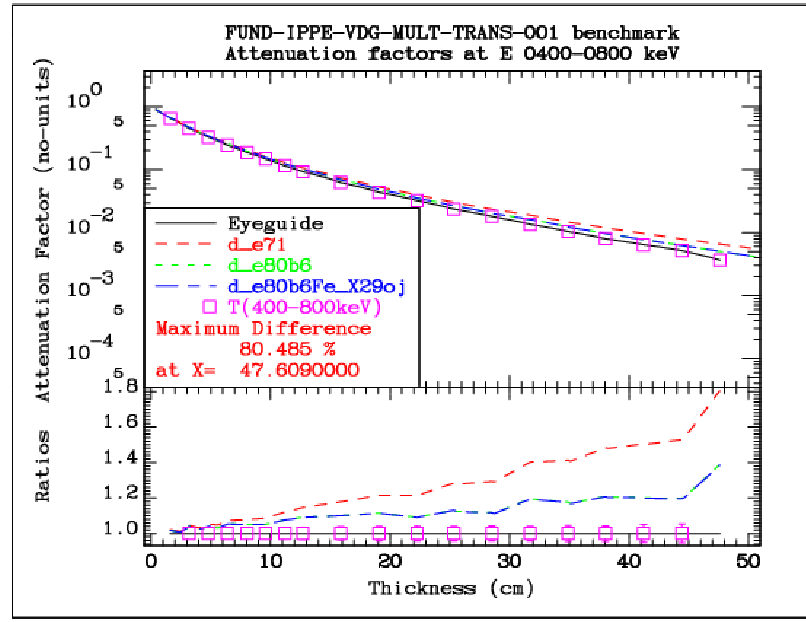

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1400-2500 keV
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1400-2500keV)
Maximum Difference
-68.124 %
at X= 44.6280000
Coarse E-grid
Attenuation Factor (no-units)
Ratios
Thickness (cm)

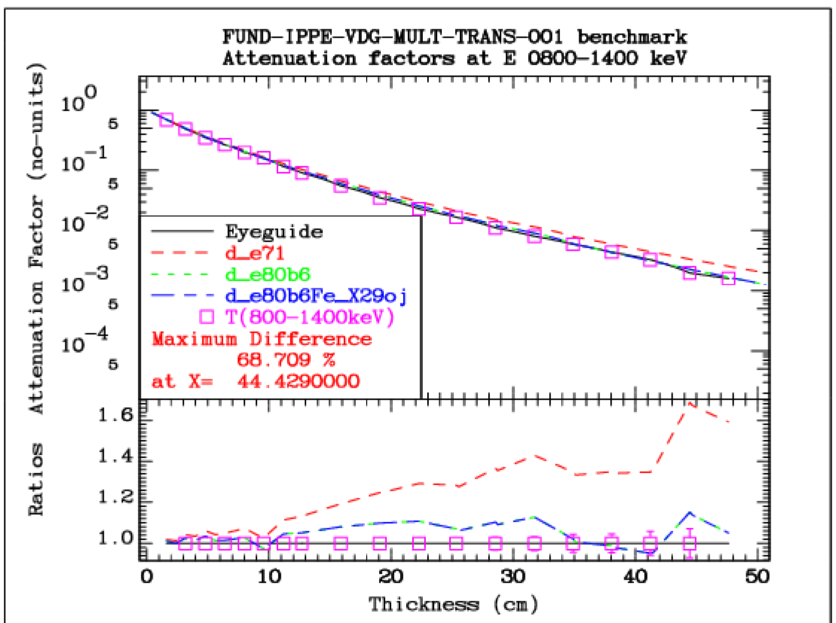
IPPE Fe broomstick experiments with p-T source (cont.)

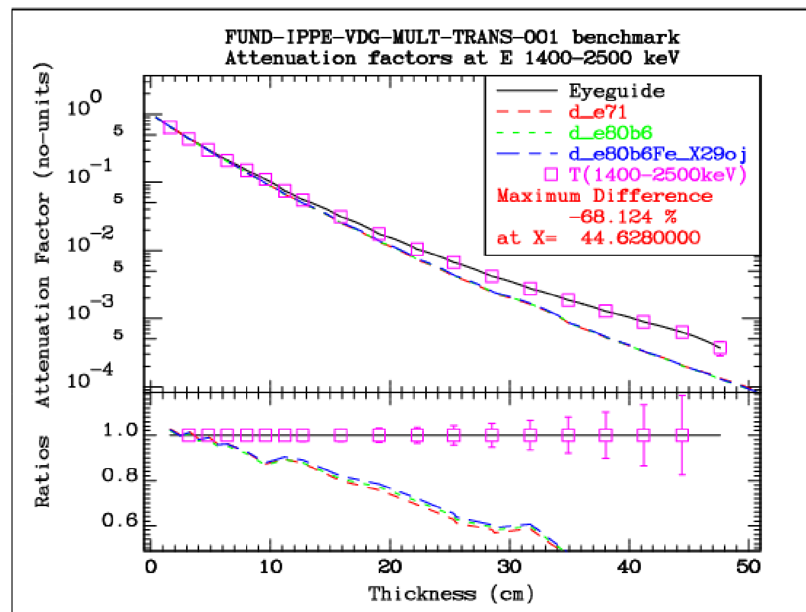
Coarse energy grid:

- Based on this benchmark better agreement with measured data was achieved with the new data in cases, where the dips in the elastic were responsible for the mismatch at energies below ~1.2 MeV
- At higher energies the calculated attenuation is larger with all libraries
- Due to high anisotropy at these energies the attenuation is governed by the non-elastic cross section
- The required decrease in the non-elastic cross section can not be supported by differential data. Possible effects:
  - Downscattering?
  - Room return?
  - Source modelling?


FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0200-0400 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(200-400keV)
Maximum Difference
67.905 %
at X= 44.4290000

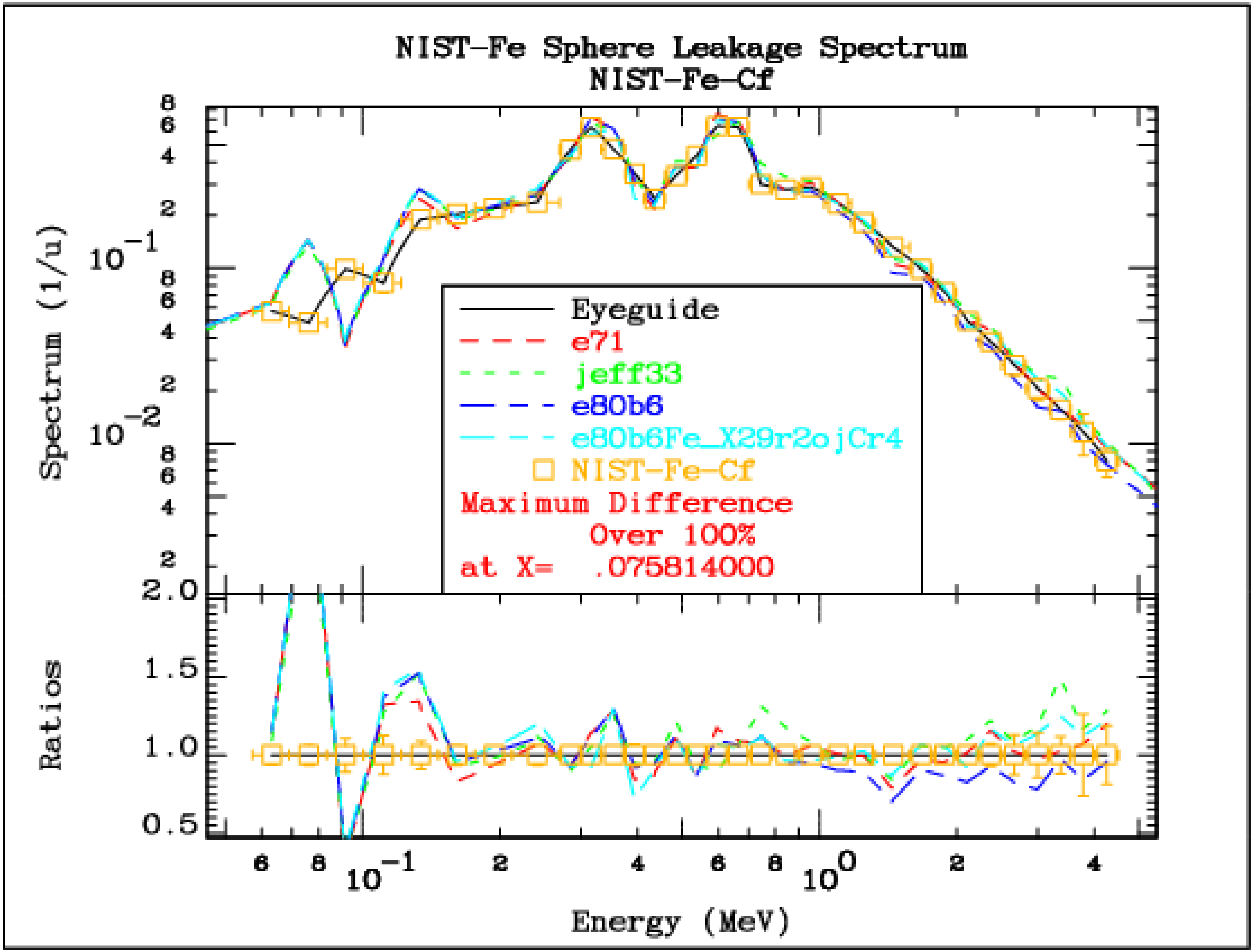

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0400-0800 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(400-800keV)
Maximum Difference
80.485 %
at X= 47.6090000

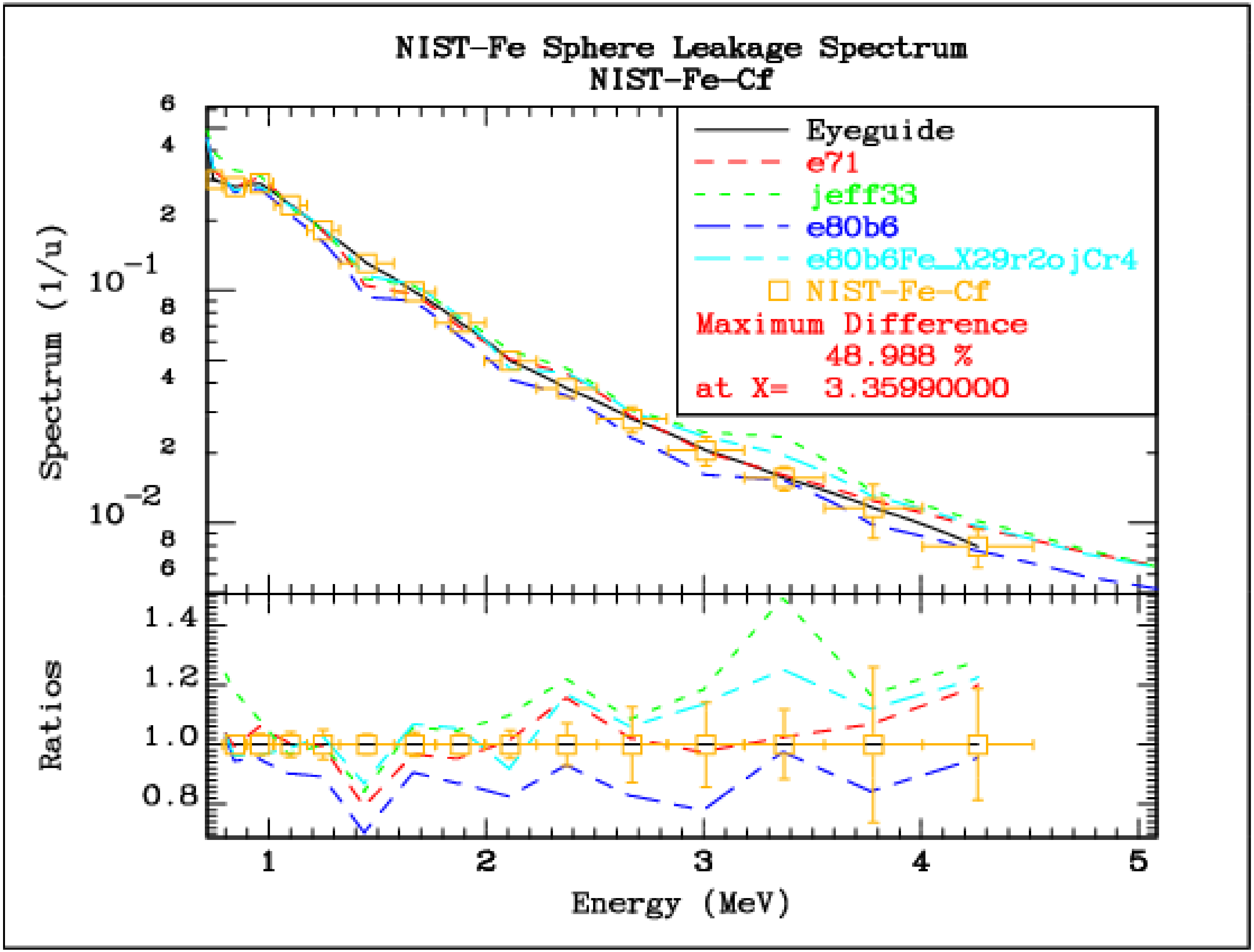

FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 0800-1400 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(800-1400keV)
Maximum Difference
68.709 %
at X= 44.4290000


FUND-IPPE-VDG-MULT-TRANS-001 benchmark
Attenuation factors at E 1400-2500 keV
Attenuation Factor (no-units)
Ratios
Thickness (cm)
Eyeguide
d_e71
d_e80b6
d_e80b6Fe_X29oj
T(1400-2500keV)
Maximum Difference
-68.124 %
at X= 44.6280000

NIST Fe sphere with Cf source

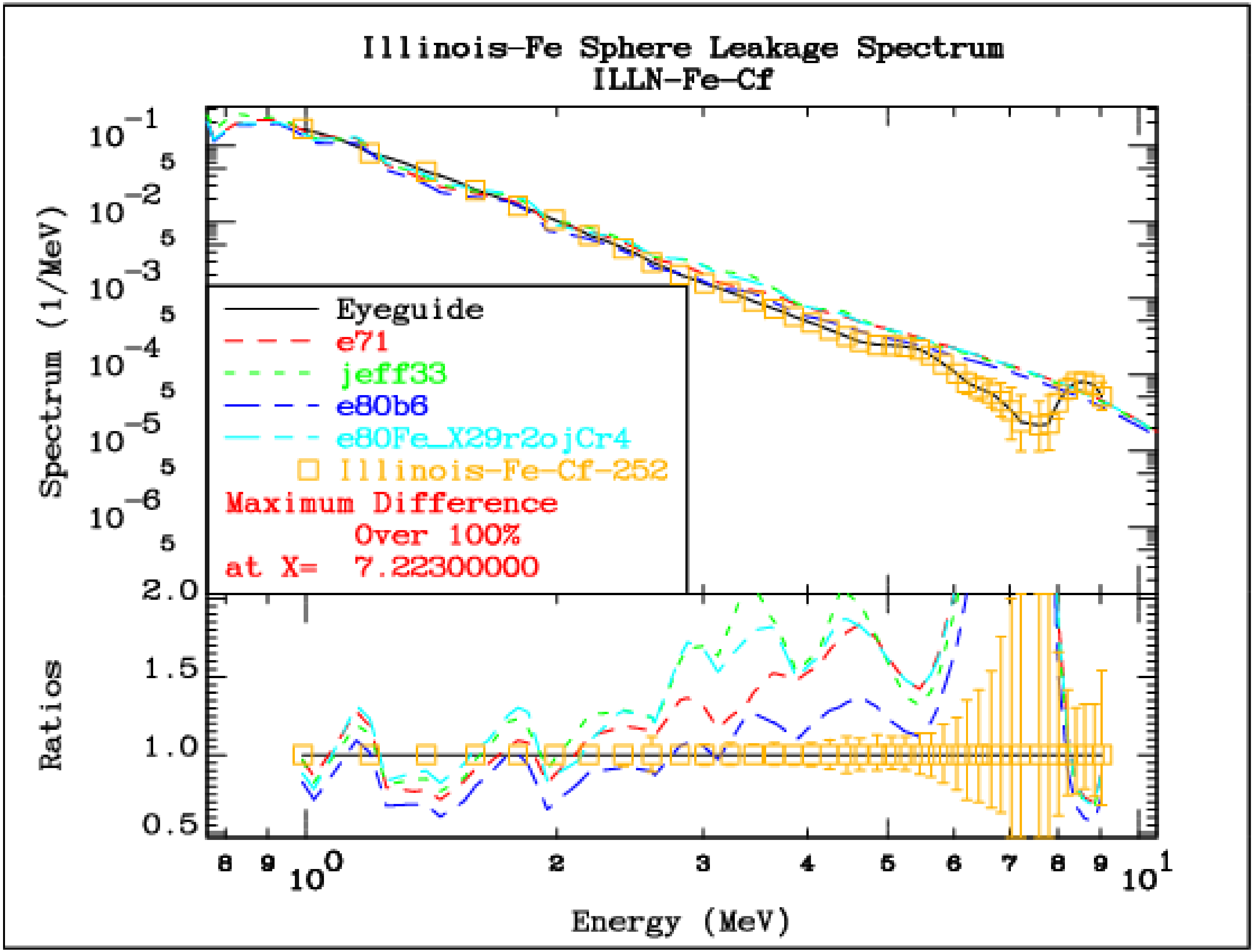
- The benchmark is similar to the IPPE benchmark
- The measured data are consistent with IPPE but too coarse to add to the information


NIST-Fe Sphere Leakage Spectrum
NIST-Fe-Cf
Spectrum (1/u)
Ratios
Energy (MeV)
Eyeguide
e71
jeff33
e80b6
e80b6Fe_X29r2ojCr4
NIST-Fe-Cf
Maximum Difference
Over 100%
at X= .075814000


NIST-Fe Sphere Leakage Spectrum
NIST-Fe-Cf
Eyeguide
e71
jeff33
e80b6
e80b6Fe_X29r2ojCr4
NIST-Fe-Cf
Maximum Difference
48.988 %
at X= 3.35990000
Spectrum (1/u)
Ratios
Energy (MeV)

Illinois Fe sphere with Cf source

- The benchmark is similar to the IPPE benchmark; Fe sphere diameter is 38.1 cm
- The structure in the measured spectrum above 6 MeV seems unphysical
- At lower energies the measured data are consistent with IPPE but too coarse to add to the information

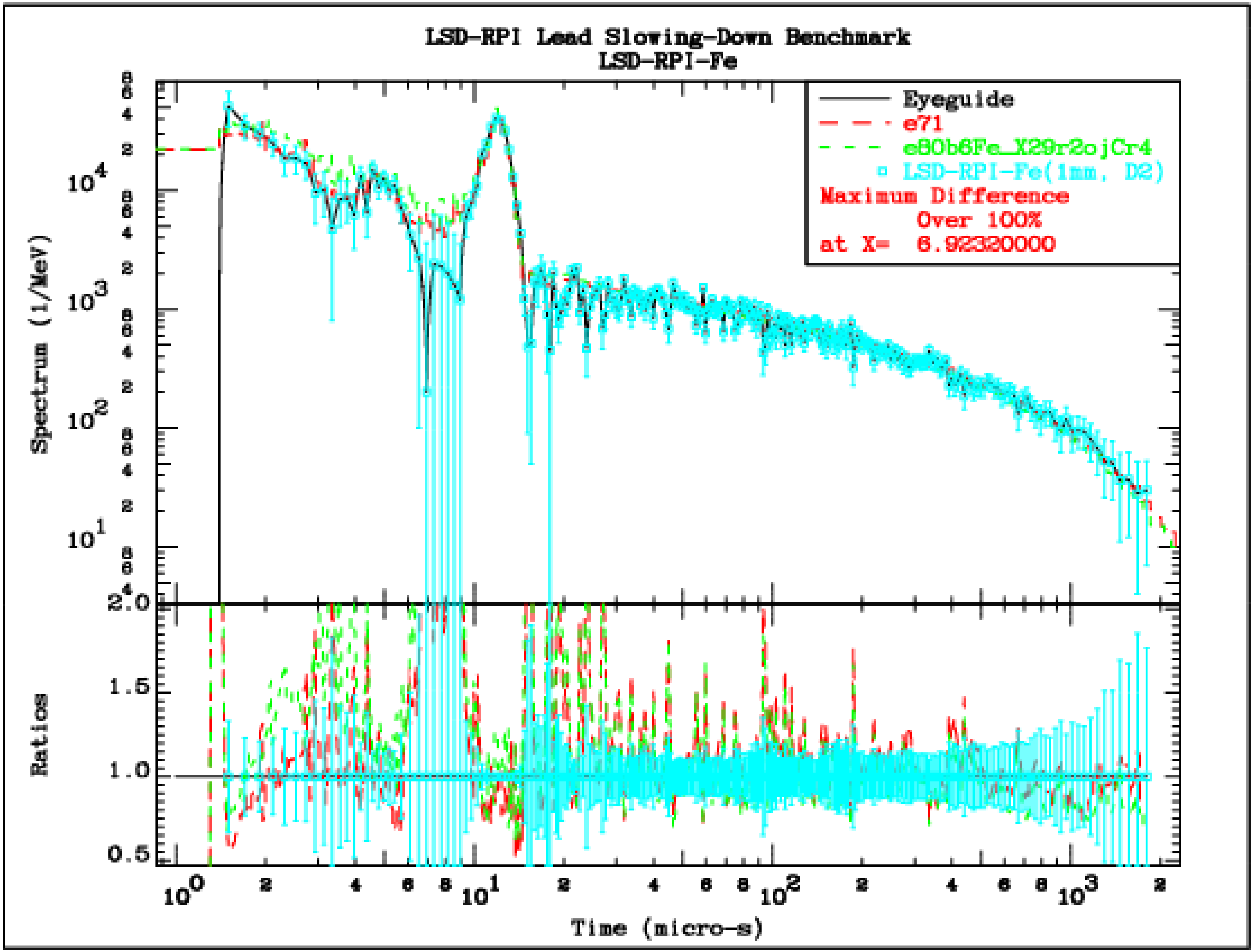

Illinois-Fe Sphere Leakage Spectrum
ILLN-Fe-Cf
Spectrum (1/MeV)
Ratios
Energy (MeV)
Eyeguide
e71
jeff33
e80b6
e80Fe_X29r2ojCr4
Illinois-Fe-Cf-252
Maximum Difference
Over 100%
at X= 7.22300000

EURACOS deep penetration benchmark

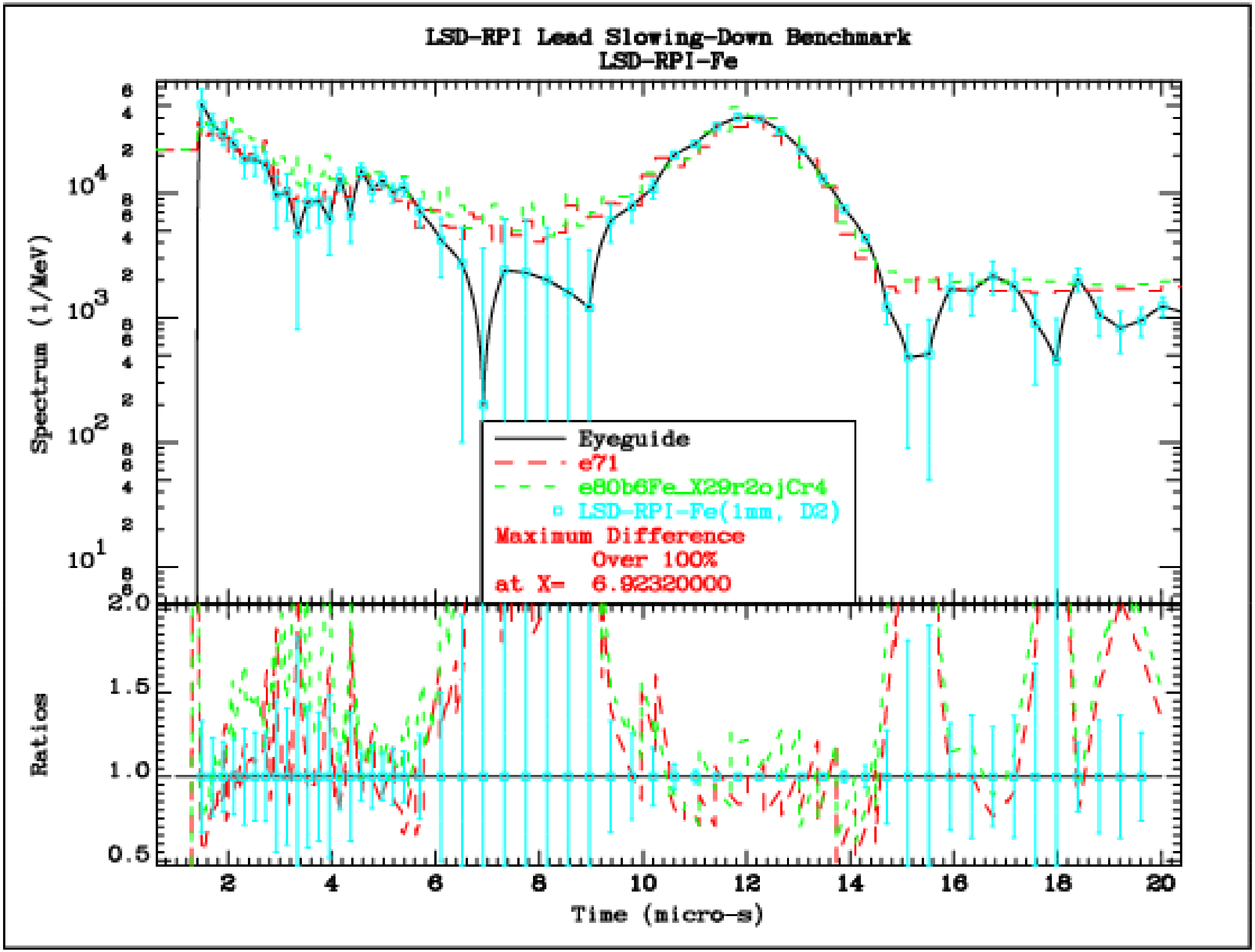
- The benchmark is similar to the ASPIS-Fe88 benchmark
- The source configuration is not well defined, making the results less reliable
- (Calculations were not repeated with the latest data file)

RPI lead-slowing-down benchmark

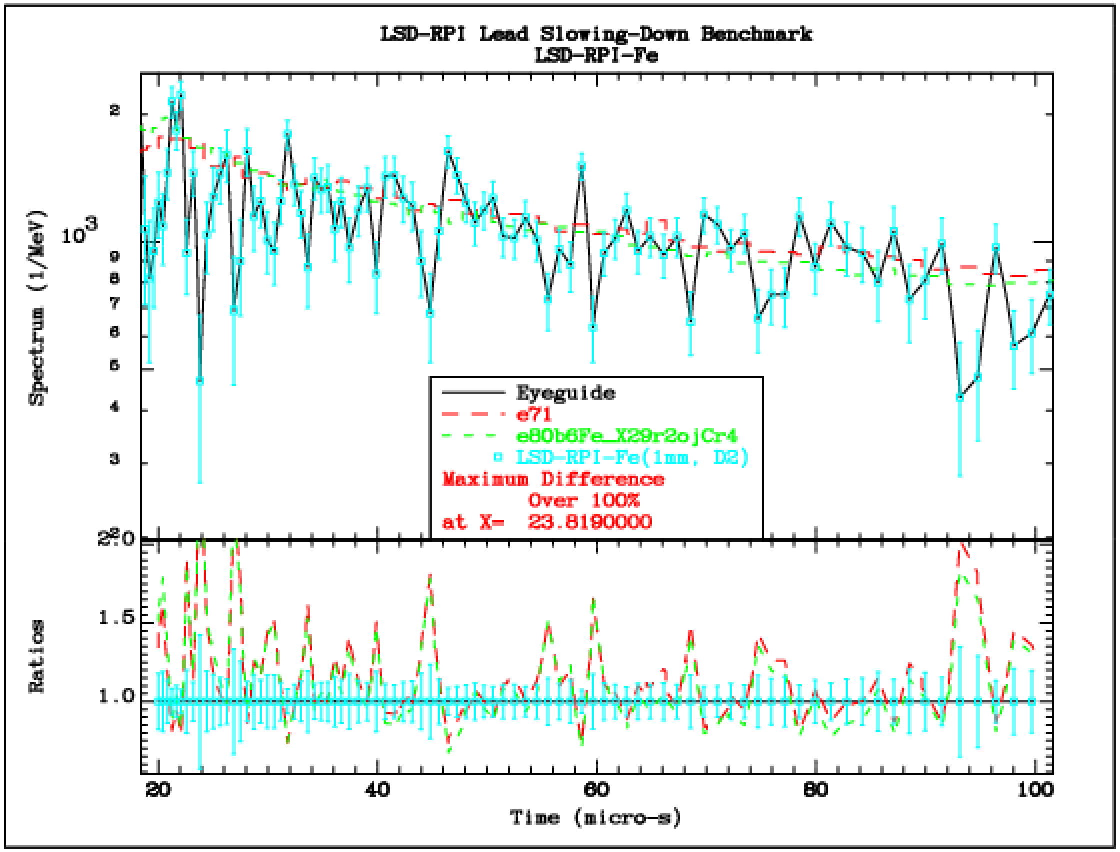
- The benchmark could be valuable for low-resolution cross section validation
- Unfortunately, the statistical scattering of measured data is too large to be of any use

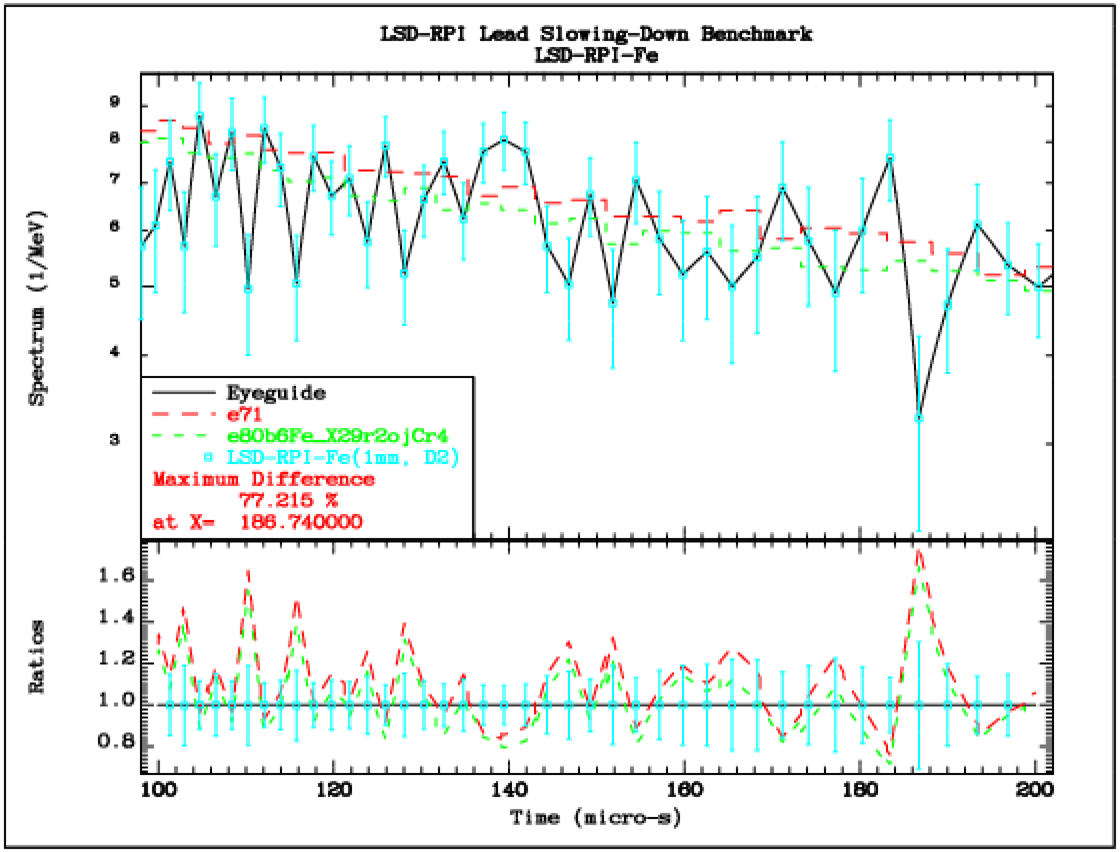


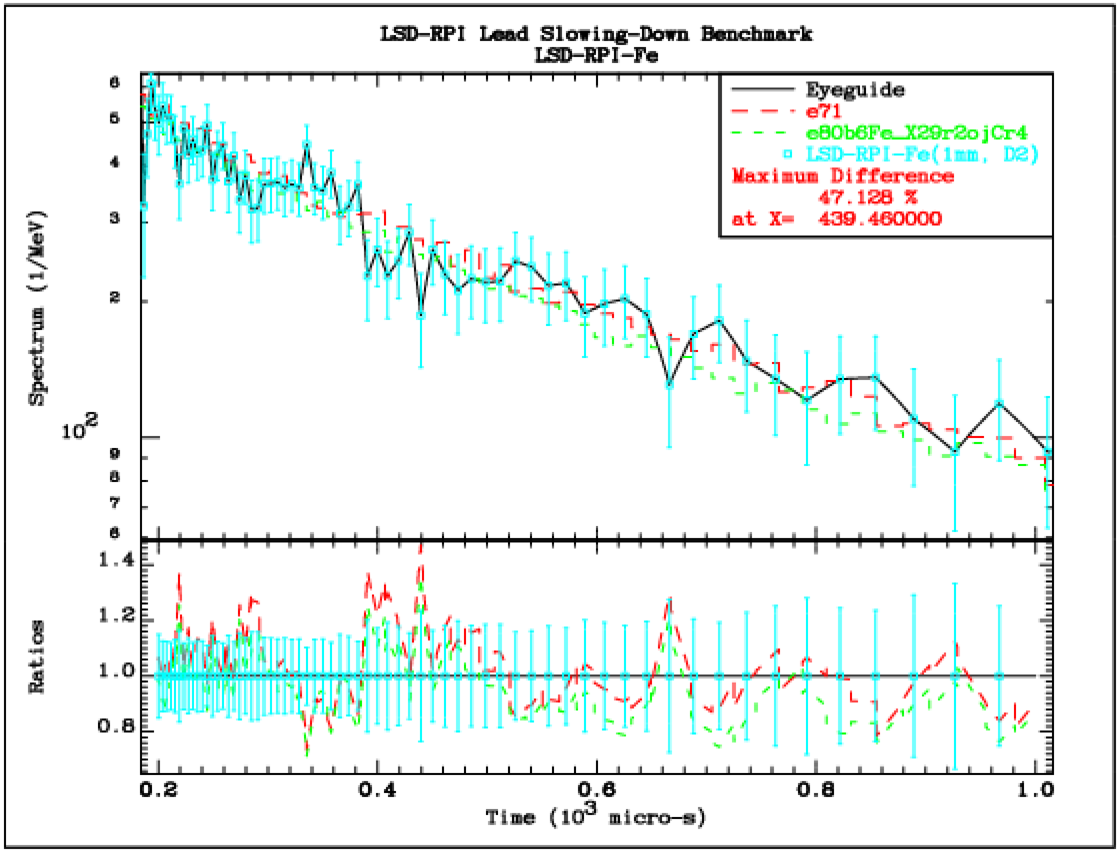
LSD-RPI Lead Slowing-Down Benchmark
LSD-RPI-Fe
Eyeguide
e71
e80b6Fe_X29r2ojCr4
LSD-RPI-Fe(1mm, D2)
Maximum Difference
Over 100%
at X= 6.92320000
Spectrum (1/MeV)
Ratios
Time (micro-s)



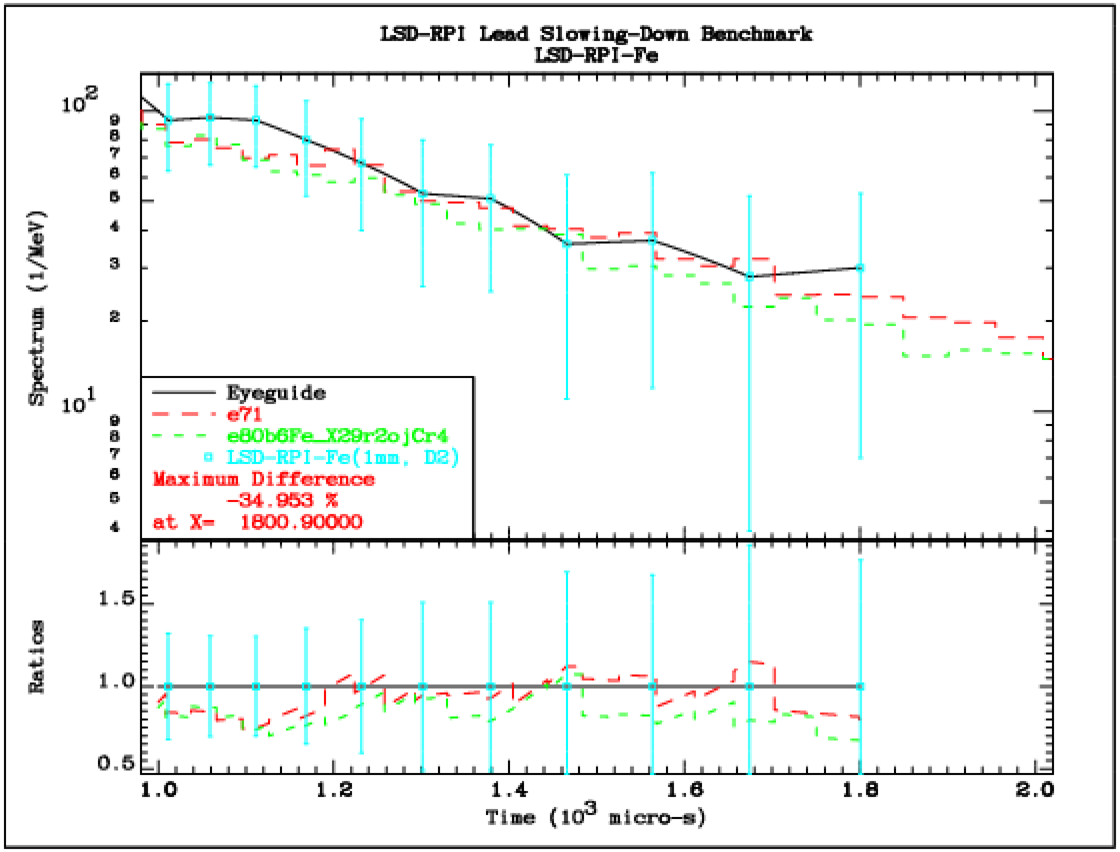
LSD-RPI Lead Slowing-Down Benchmark
LSD-RPI-Fe
Spectrum (1/MeV)
Ratios
Time (micro-s)
Eyeguide
e71
e80b6Fe_X29r2ojCr4
LSD-RPI-Fe(1mm, D2)
Maximum Difference
Over 100%
at X= 6.92320000


LSD-RPI Lead Slowing-Down Benchmark
LSD-RPI-Fe
Spectrum (1/MeV)
Ratios
Time (micro-s)
Eyeguide
e71
e80b6Fe_X29r2ojCr4
LSD-RPI-Fe(1mm, D2)
Maximum Difference
Over 100%
at X= 23.8190000


LSD-RPI Lead Slowing-Down Benchmark
LSD-RPI-Fe
Spectrum (1/MeV)
Eyeguide
e71
e80b6Fe_X29r2ojCr4
LSD-RPI-Fe(1mm, D2)
Maximum Difference
77.215 %
at X= 186.740000
Ratios
Time (micro-s)



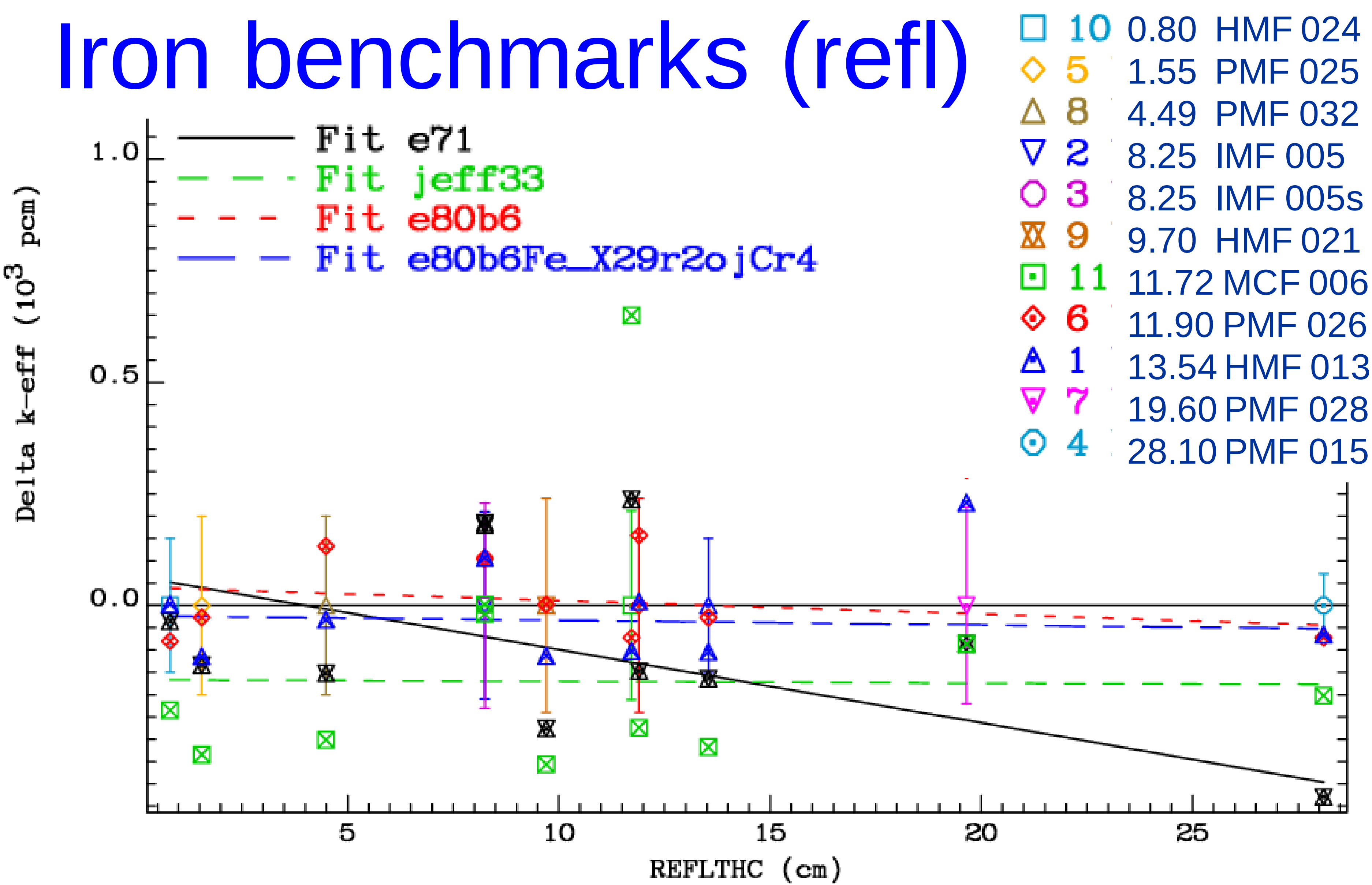
LSD-RPI Lead Slowing-Down Benchmark
LSD-RPI-Fe
Eyeguide
e71
e80b6Fe_X29r2ojCr4
LSD-RPI-Fe(1mm, D2)
Maximum Difference
47.128 %
at X= 439.460000
Spectrum (1/MeV)
Ratios
Time (10^3 micro-s)


LSD-RPI Lead Slowing-Down Benchmark
LSD-RPI-Fe
Spectrum (1/MeV)
Ratios
Eyeguide
e71
e80b6Fe_X29r2ojCr4
LSD-RPI-Fe(1mm, D2)
Maximum Difference
-34.953 %
at X= 1800.90000
Time (10^3 micro-s)

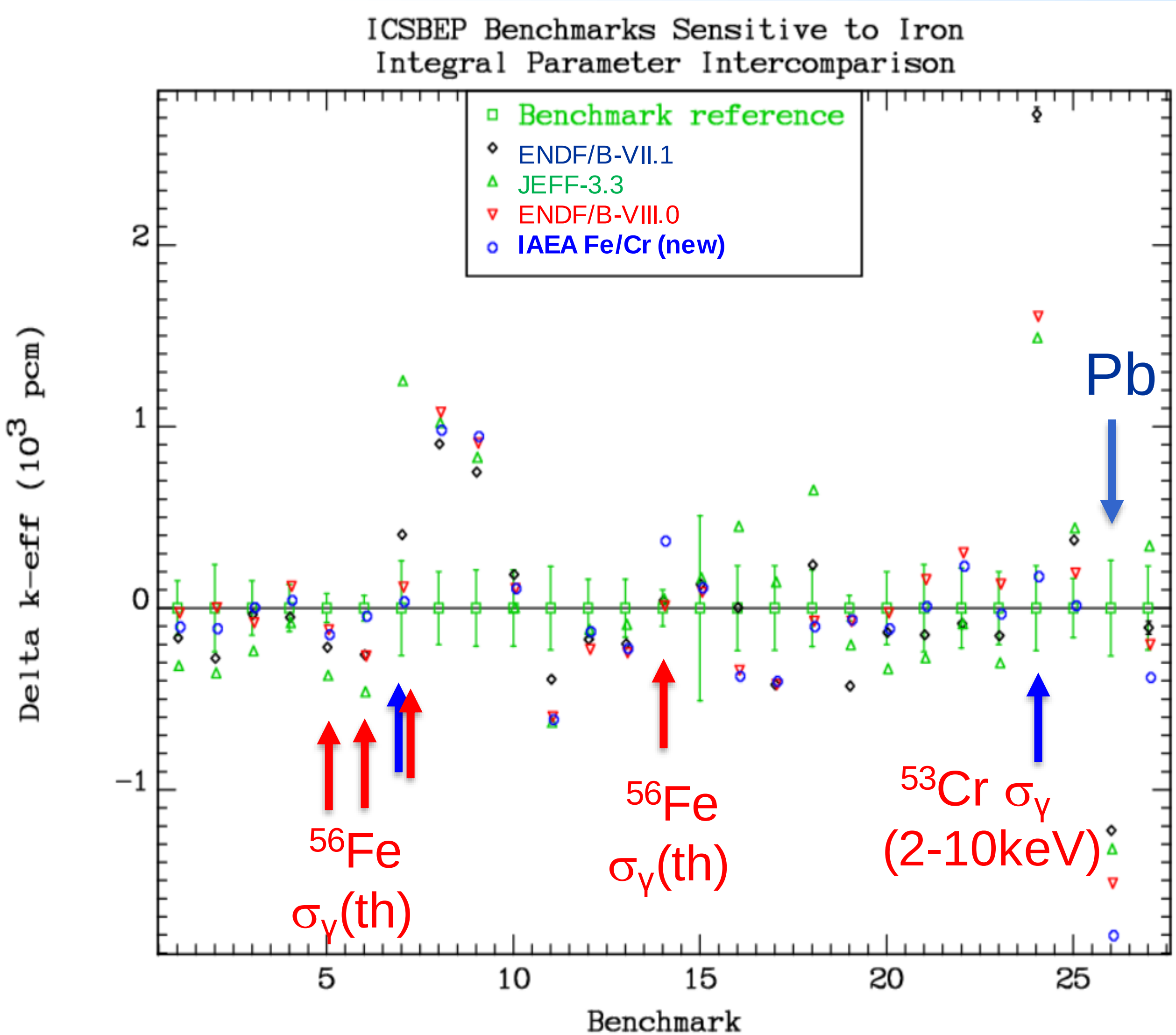
Criticality benchmarks

- Good performance in criticality benchmarks was retained
- Lower thermal capture in ^{56}Fe improves Russian FKBN-2 benchmarks (hmf088), but makes IPEN/MB-01 slightly worse
- Planet-Fe/PE benchmarks are Fe/PE like FKBN-2, but most Planet benchmarks with PE are systematically predicted high
- The ZPR-4/59 (pmi004) is lead-reflected; there seem to be problems with many benchmarks involving Pb
- The big improvement in ZPR-6/10 is mainly due to a trial change to the ^{53}Cr capture data in the triplet of strong resonances near 5 keV

Iron benchmarks (refl)



Criticality impact of ^{56}Fe/ ^{53}Cr



1	hmf013	VNIITF-CTF-SS-13
2	hmf021	VNIITF-CTF-SS-21
3	hmf024	VNIITF-CTF-SS-24
4	hmf087	VNIITF-CTF-Fe
5	hmf088-001	FKBN-2/SS-PE-1
6	hmf088-002	FKBN-2/SS-PE-2
7	hmi001	ZPR-9/34
8	hmt013-002	Planet_Fe-PE-2
9	hmt015	Planet_HEU/Fe/PE
10	imf005	VNIIEF-CTF-5
11	imf006	VNIIEF-CTF-6/Al
12	lct042-001	PNL_1.68p-1
13	lct042-002	PNL_1.68p-2
14	lct043-002	IPEN/MB-01
15	lmt015-001	RB-Vinca-01
16	mcf001	ZPR-6/7(s)
17	mcf005s	ZPR-9/31(s)
18	mcf006s	ZPPR-2
19	pmf015	BR-1-3
20	pmf025	VNIIEF Pu/SS 1.55
21	pmf026	VNIIEF Pu/SS-11.9
22	pmf028	VNIIEF Pu/SS 19.6
23	pmf032	VNIIEF Pu(88%)/SS
24	pmi002	ZPR-6/10
25	pmi003-001s	ZPR-3/58(U)
26	pmi004-001s	ZPR-3/59(Pb)
27	ici005	ZPR-6/6A

Conclusions regarding ^{56}Fe

- Problems identified in the CIELO evaluation were largely removed, while retaining good performance in criticality calculations.
- IAEA INDEN ^{56}Fe evaluation is a significant improvement over CIELO and ENDF/B-VII.1 evaluations.
- The new evaluation is available and could be a candidate for updating current libraries.
- However, this is patching. Consistent solution of the problems is needed.

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Thank you!