EUROfusion

Evaluation of the spectrum-unfolding methodology for neutron activation systems of fusion devices

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* *See the Appendix of F. Romanelli et al., Proceedings of the 25th IAEA Fusion Energy Conference 2014, Saint Petersburg, Russia*

Aim – To develop and evaluate an improved, fast and robust methodology for processing of neutron activation data from fusion reactors

Spectral Adjustment Toolkits –

MAXED from UMG-3.3

- Unfolding using MAXED & GRAVEL (UMG) from PTB (DE)
- Maximum entropy algorithm for adjusting default spectrum
- Frequently implemented and used in fusion applications
- χ2 parameter often difficult to decide & only total errors given

← EVALUATE →

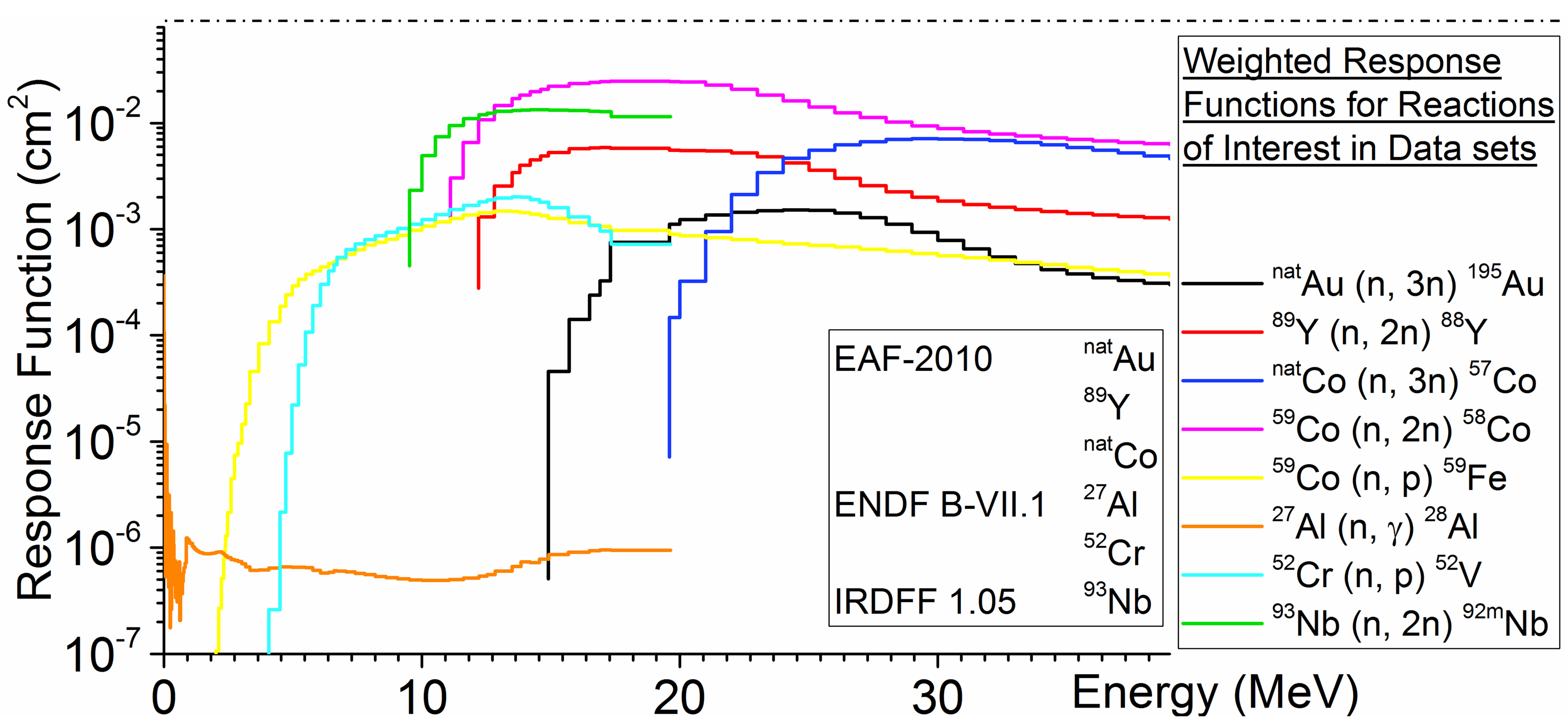
← COMPARE →

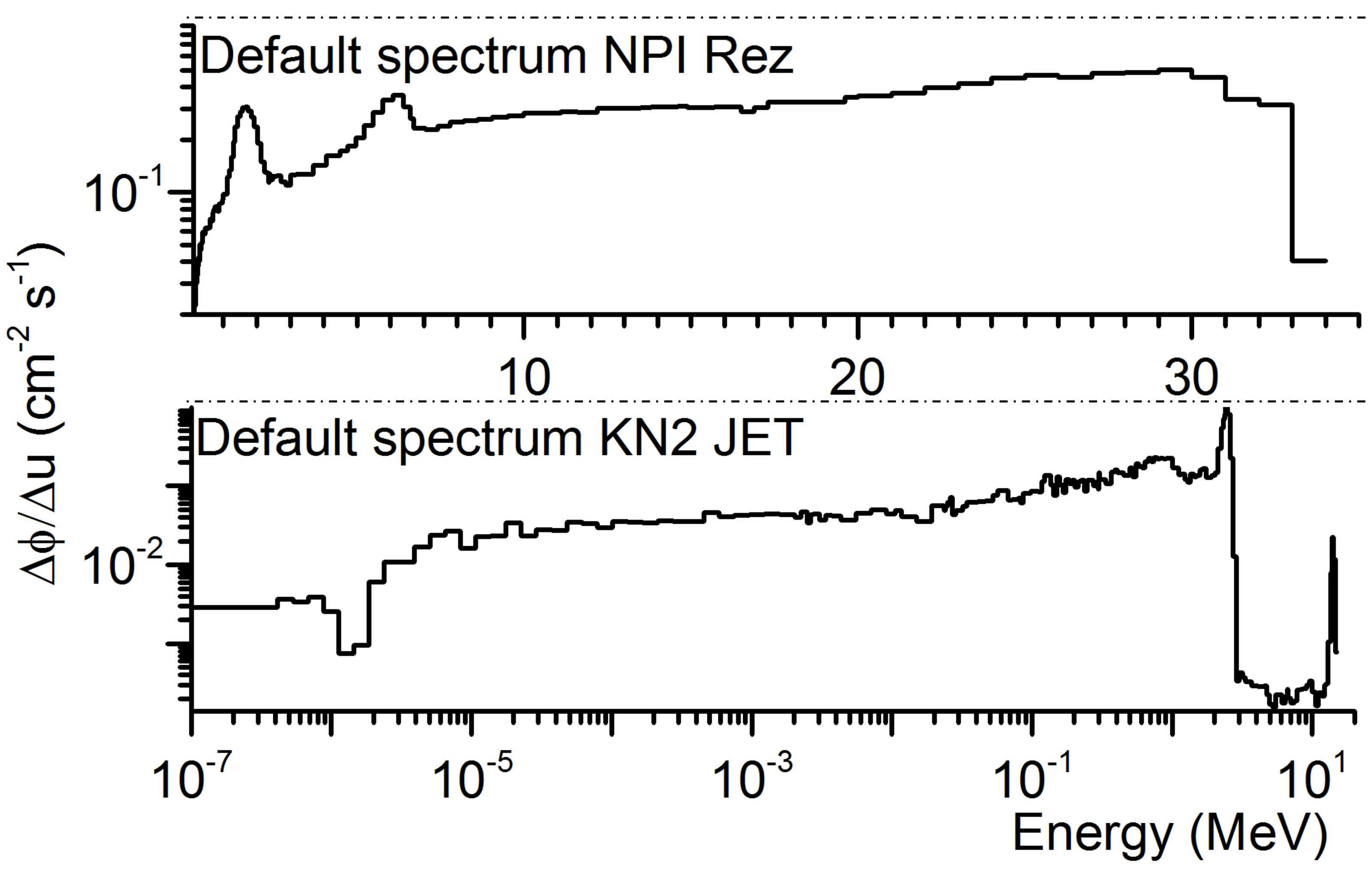
STAYSL from STAYSL-PNNL

- Adapted from Perey's least squares unfolding code STAYSL
- Pre-calculation & formatting tools for input data & files
  - SigPhi Calculator, BCF, SHIELD, NJpp etc.
- A potential alternative to common codes used in fusion
- Propagates all sources of error to errors in group-wise fluxes

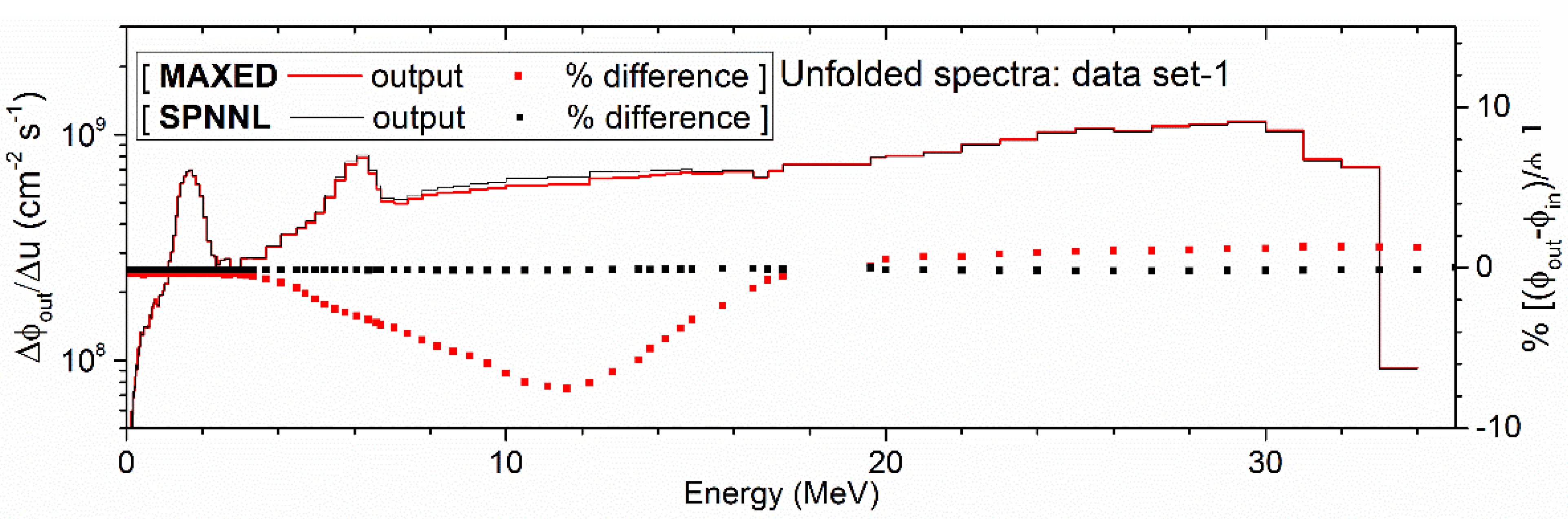
Input Experimental Data, Response Functions & Default Spectra –

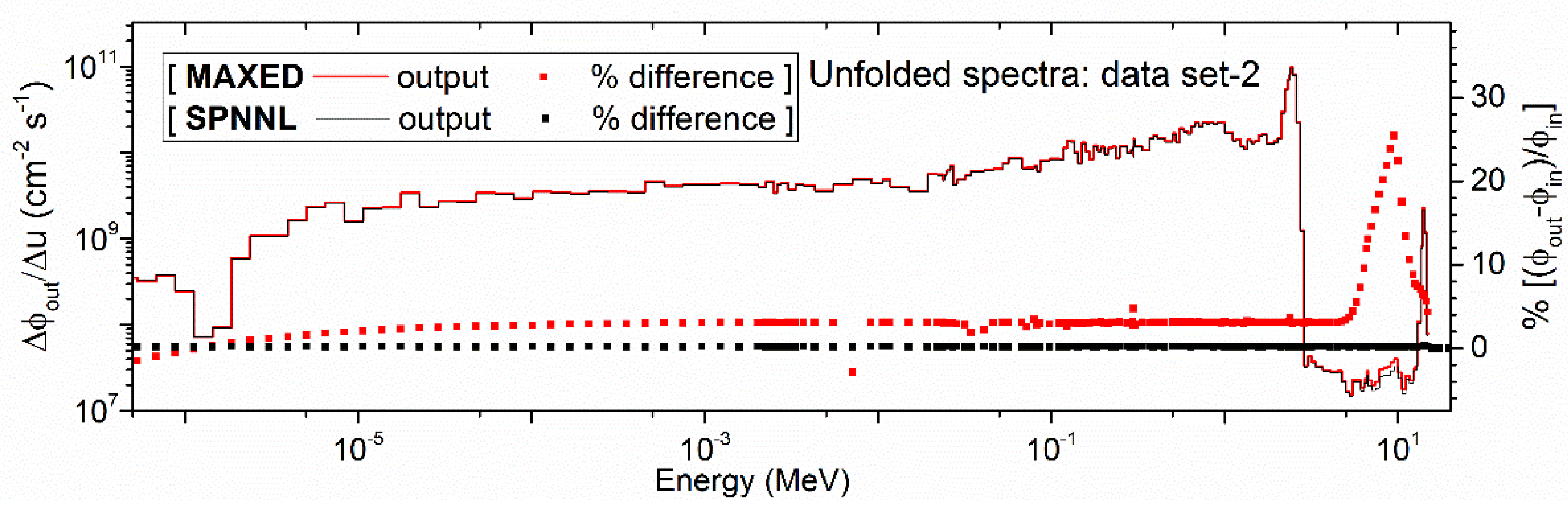
Foil	Mass (g)	Reaction	$T_{1/2}$ (s)	E_γ (keV)	Rate (s^{-1})
Data set — 1: Early Neutron Source (ENS)					
Test at Cyclotron Fast Neutron Source, Nuclear Physics Institute (NPI) Řež					
$\Phi_{estimated} = 2.3 \times 10^9$ cm^{-2} s^{-1}		$T_{irradiation} = 9.5$ h	$T_{cooling} = 3$ mon		
AU	0.3047	^{nat}Au (n, x) ^{195}Au	1.6×10^7	98.9	6.3×10^5
Y	0.7000	^{89}Y (n, 2n) ^{88}Y	9.2×10^6	1836.1	3.7×10^6
CO	2.7911	^{59}Co (n, 3n) ^{57}Co	2.3×10^7	122.1	2.7×10^6
		^{nat}Co (n, x) ^{58}Co	6.1×10^6	810.8	1.5×10^7
		^{59}Co (n, p) ^{59}Fe	3.8×10^6	1099.2	1.0×10^6
Data set — 2: Test Blanket Modules (TBM) of ITER					
Test at KN2 Laboratory, Joint European Torus (JET) Reactor, Culham					
$\Phi_{estimated} = 9.7 \times 10^{10}$ cm^{-2} s^{-1}		$T_{irradiation} = 3$ s	$T_{cooling} = 28$ s		
AL	0.0699	^{27}Al (n, γ) ^{28}Al	1.3×10^2	1778.7	5.2×10^5
CR	2.1211	^{52}Cr (n, p) ^{52}V	2.2×10^2	1434.1	2.5×10^5
NB	4.4726	^{93}Nb (n, 2n) ^{92m}Nb	8.7×10^5	934.5	1.6×10^6





Adjusted Spectra & Differences w.r.t. Default Inputs –





Conclusions of this Evaluation –

- MAXED & STAYSL successfully evaluated for use in fusion
- Net neutron fluxes predicted very well by both of the codes
- STAYSL-PNNL established as a good addition to the tools
- MAXED: up to 28% deviation from best guess spectrum
- STAYSL: less than 1% difference in any energy-group
- STAYSL shows strong dependence on input uncertainty data

Future Developments for Unfolding Methodology –

- Optimally utilize the in-built methods in STAYSL-PNNL for defining covariance matrices for input fluxes, activities etc.
- Compare available nuclear data libraries for production of cross-section files and covariance matrices for unfolding
- Produce high-confidence covariance matrix for input spectrum

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