Challenges in nuclear data evaluation of actinide nuclei

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  - A. Trkov (IAEA)
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  - Y. Danon and A. Daskalakis (RPI)
  - M.W. Herman (BNL)
  - B.V.Carlson (ITA)

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OUTLOOK

- Introduction and motivation
- Experimental challenges *(from an evaluator point of view)*
- Modelling challenges
- Evaluation methodology challenges
- Challenges in use of integral data

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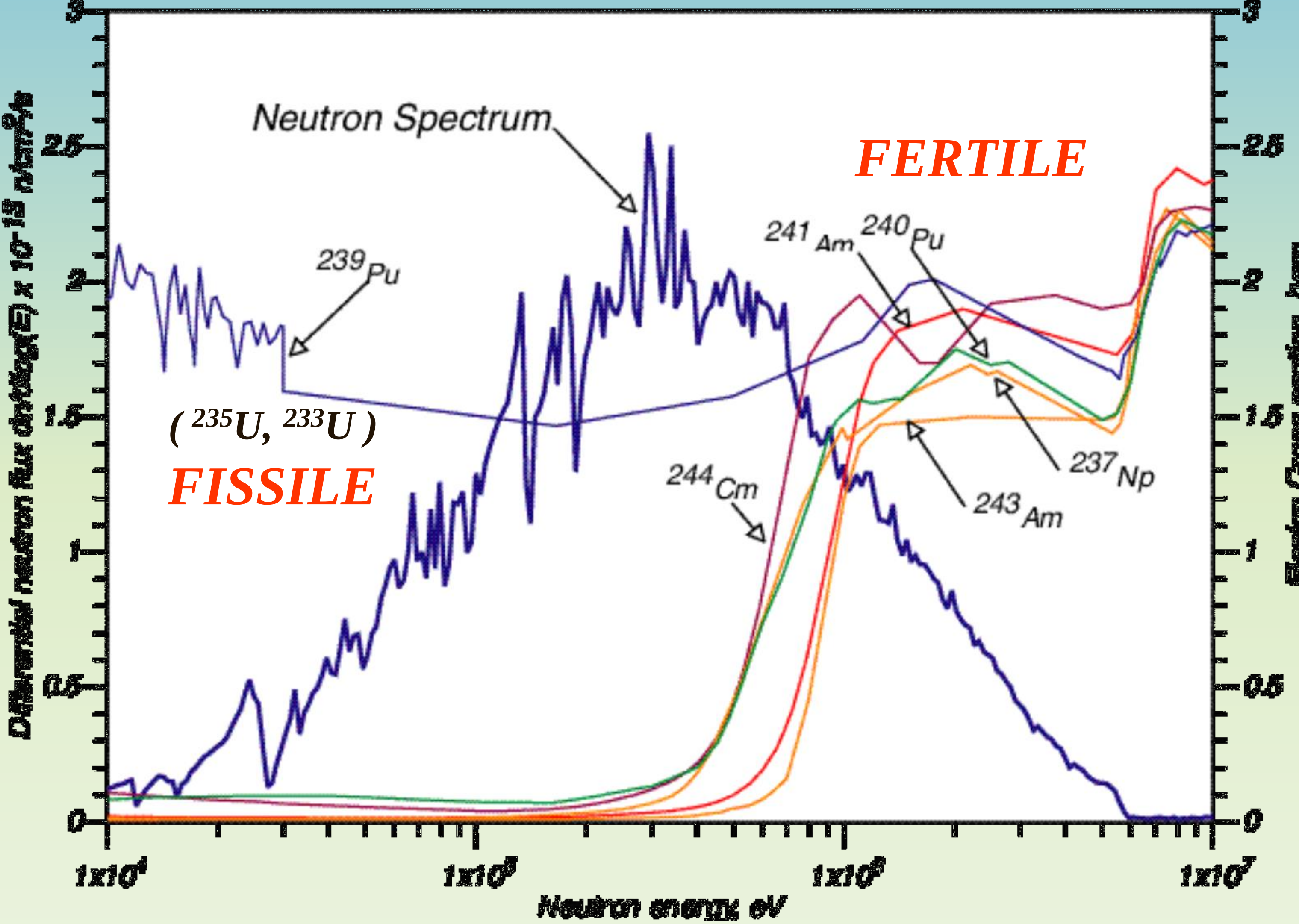
Why we need ADS/fast reactors?



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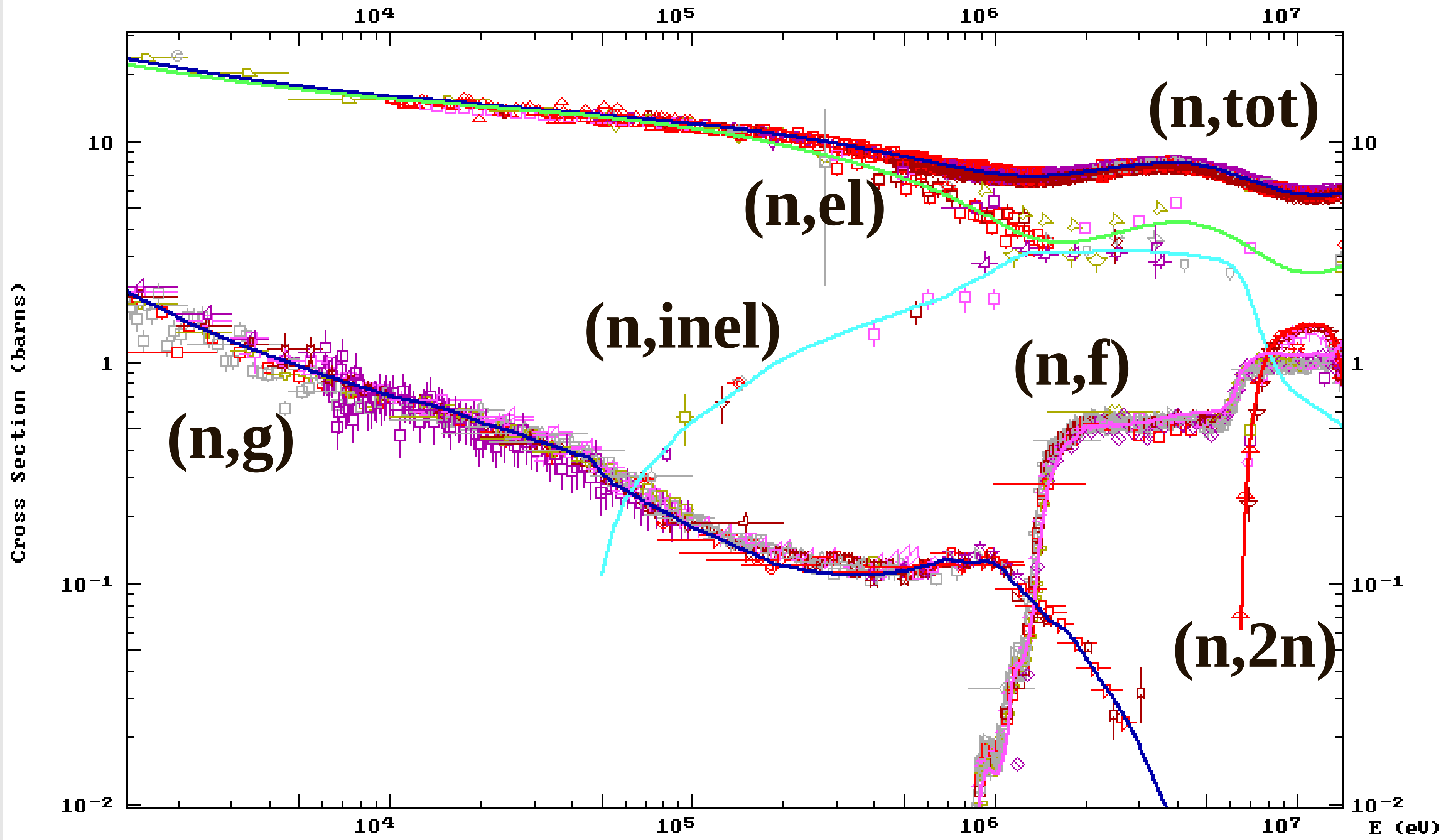
Neutron induced reactions on U-238



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Experimental challenges *(biased)*

1. **Quasi-differential experiments (~RPI) for ^{235}U, ^{239}Pu, ^{232}Th, ^{237}Np**
   Goal: better elastic an inelastic scattering from 0.5 to 10 MeV

2. **SPA cross sections measurements in ^{235}U and ^{239}Pu PFNS fields (inelastic and n,2n reactions)**
   Goal: better PFNS below 700 keV and above 8 MeV, PFNS validation

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RPI quasi-differential data measured on Zr (published) and ^{238}U

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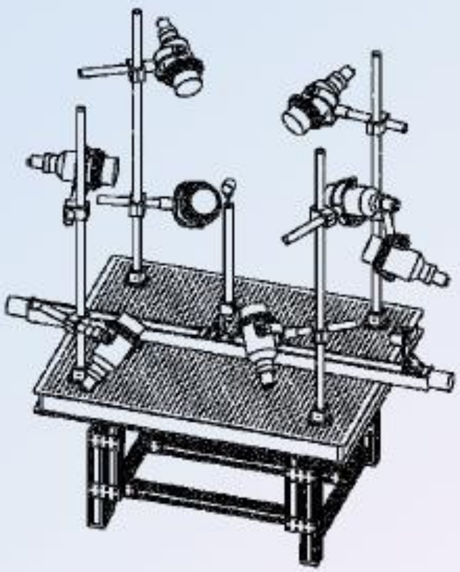
Measurement of Neutron Scattering as Benchmark for Nuclear Data Evaluations

Y. Danon
Gaerttner LINAC Center
Rensselaer Polytechnic Institute, Troy, NY, 12180



International Workshop in Inelastic and Elastic Scattering (WINS 2012), September 17-19, 2012

Rensselaer
Mechanical, Aerospace and Nuclear Engineering

linac The Gaerttner LINAC Center 1

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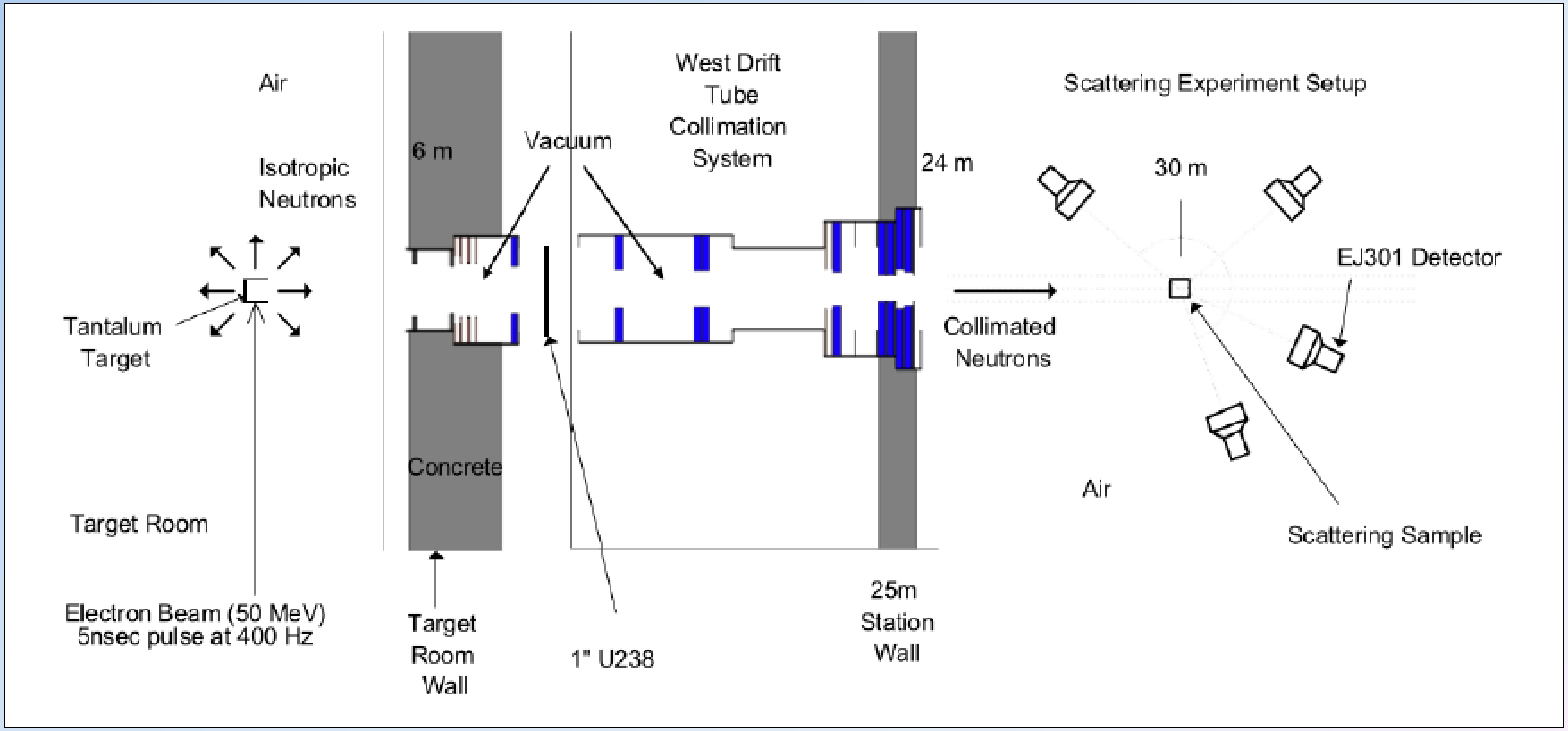
RPI experimental setup



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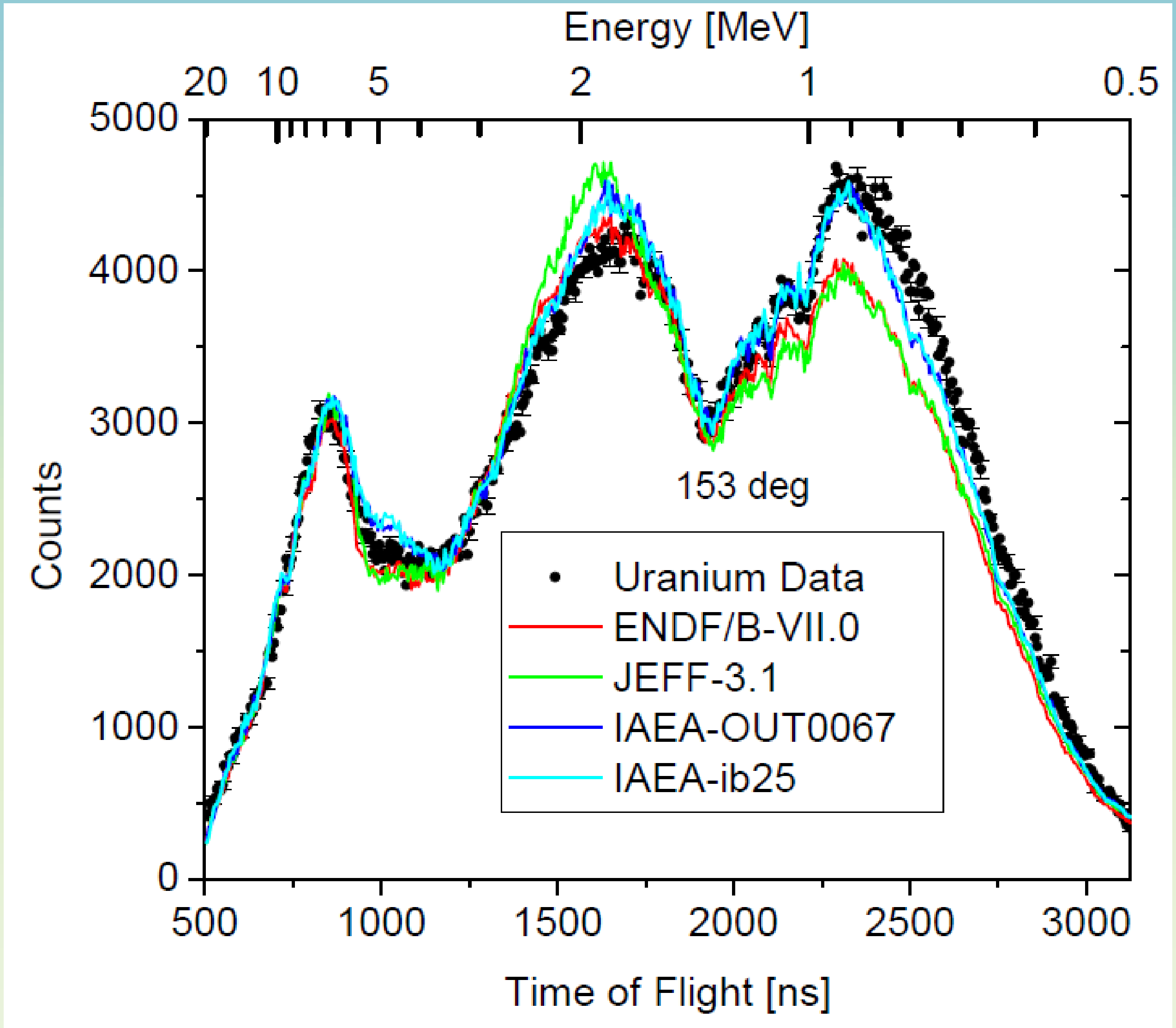
RPI benchmark: 153^0



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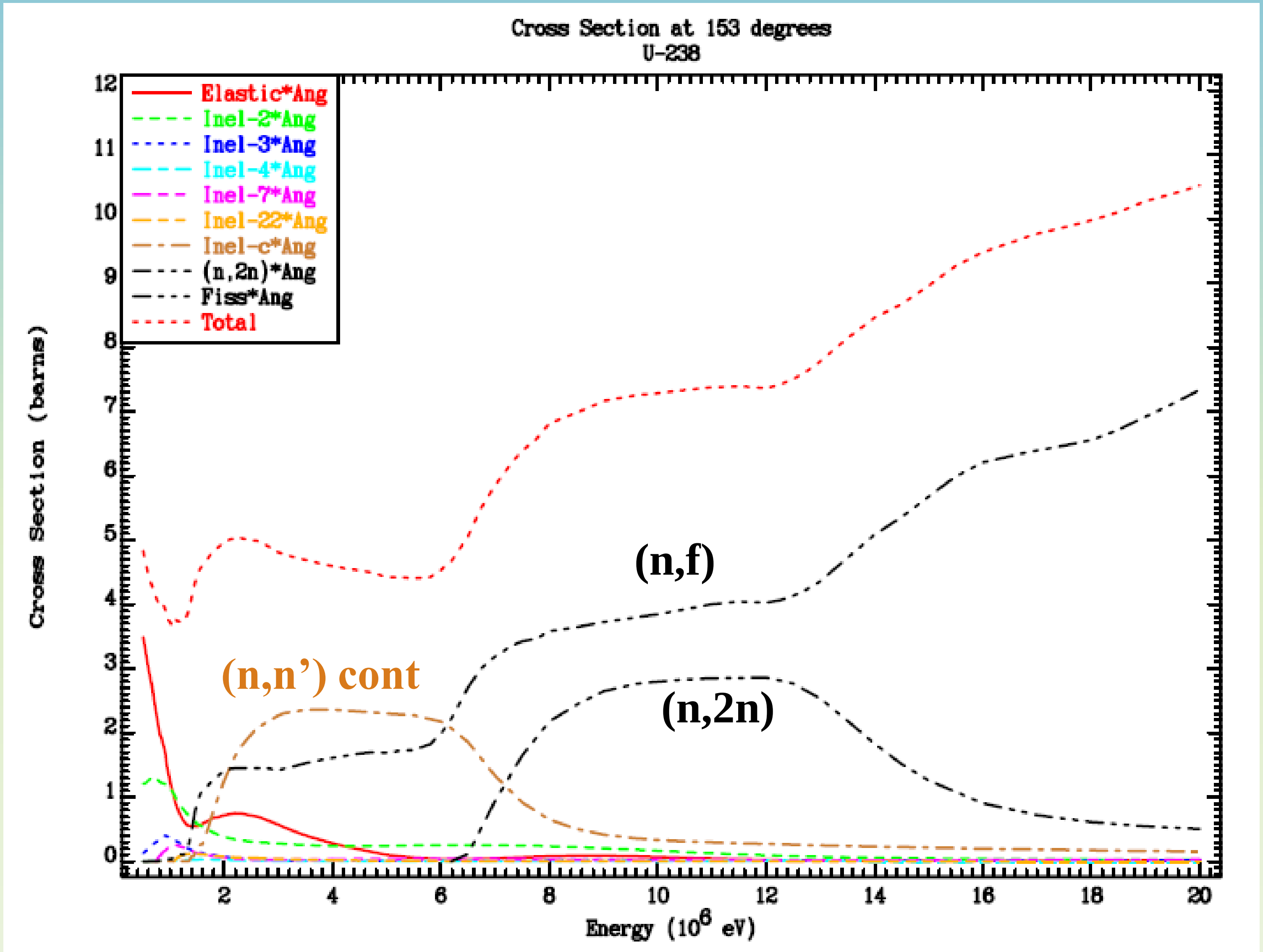
Angle dependent cross sections



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SPA cross sections measurements in ^{235}U and ^{239}Pu PFNS thermal fields

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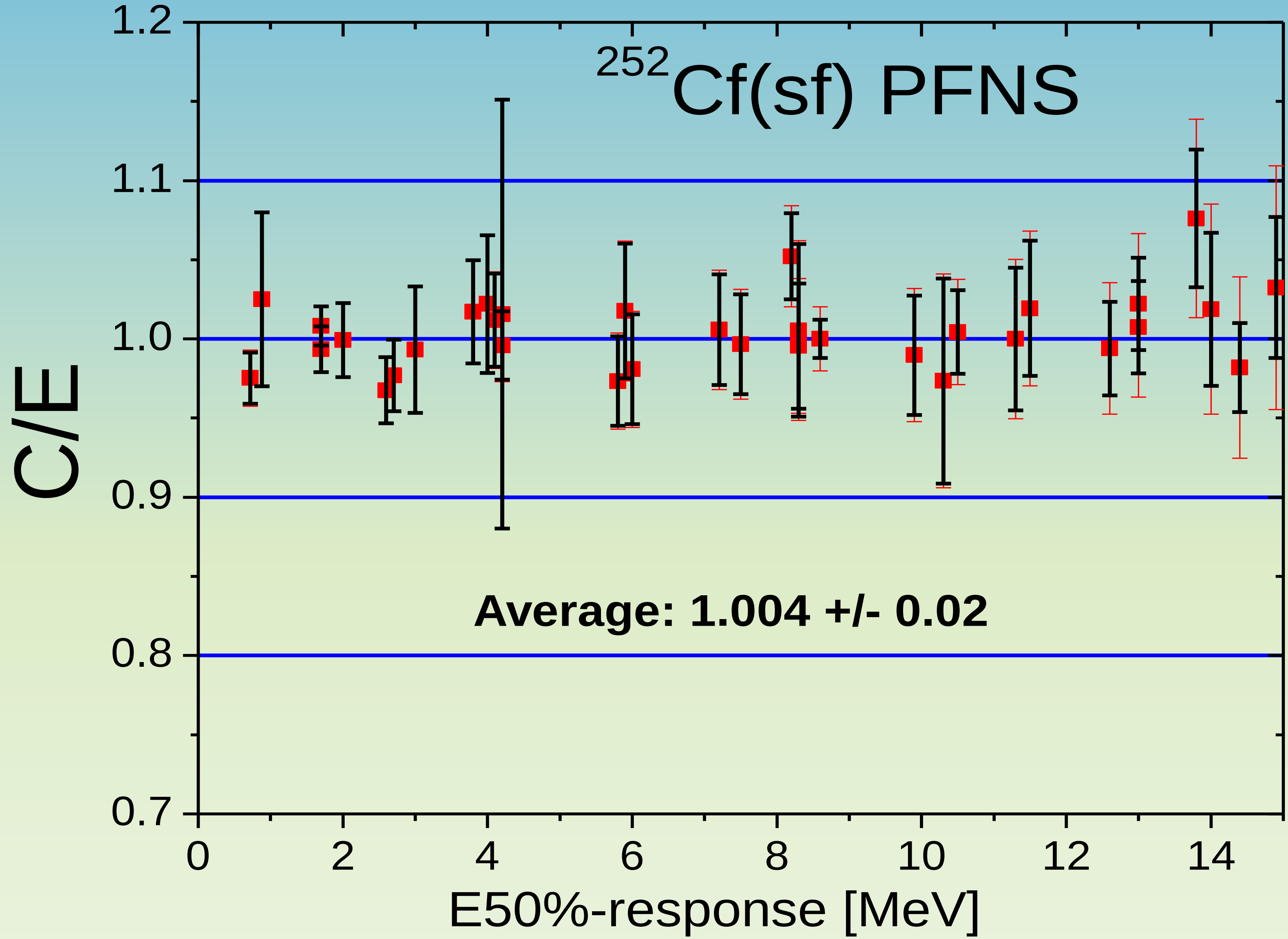

Experimental and theoretical problems around actinides for future reactors, 17-19 March 2014, CEA ESNT workshop

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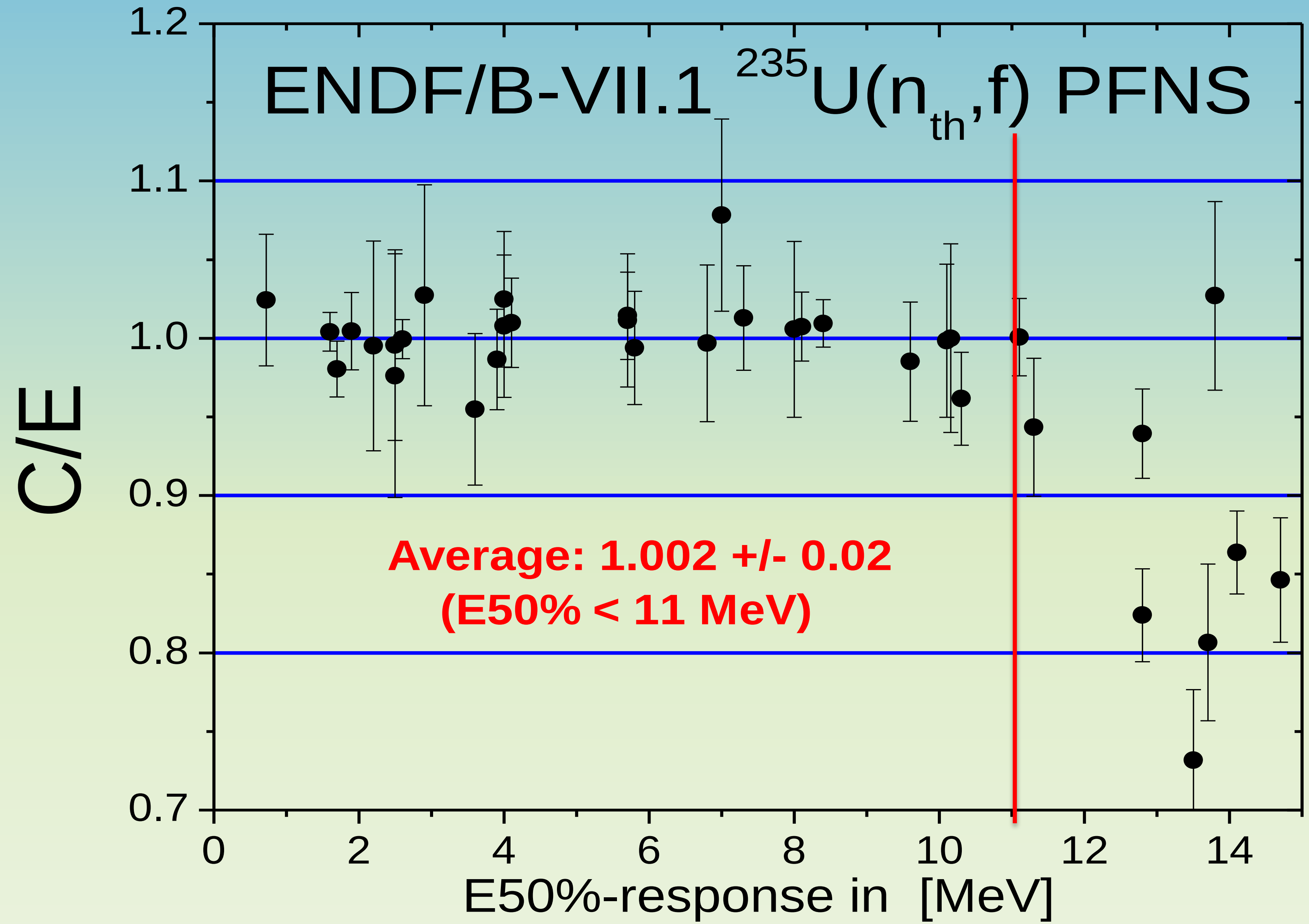
ENDF/B-VII.1 235U(nth,f) PFNS
C/E
Average: 1.002 +/- 0.02
(E50% < 11 MeV)
E50%-response in [MeV]
1.2
1.1
1.0
0.9
0.8
0.7
0
2
4
6
8
10
12
14

(Nuclear reaction) modelling challenges

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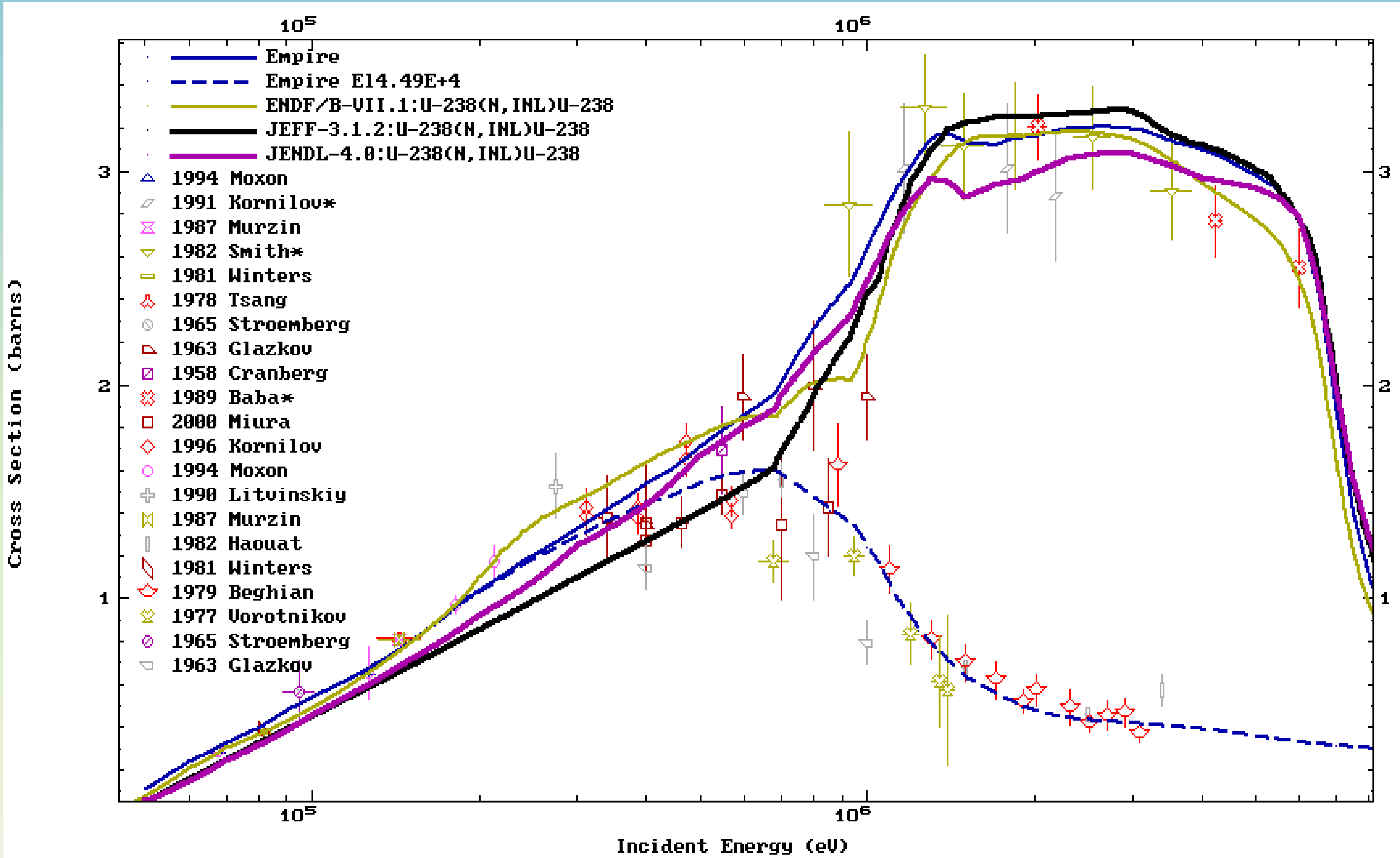
total (and 1st lev) inelastic cross sections



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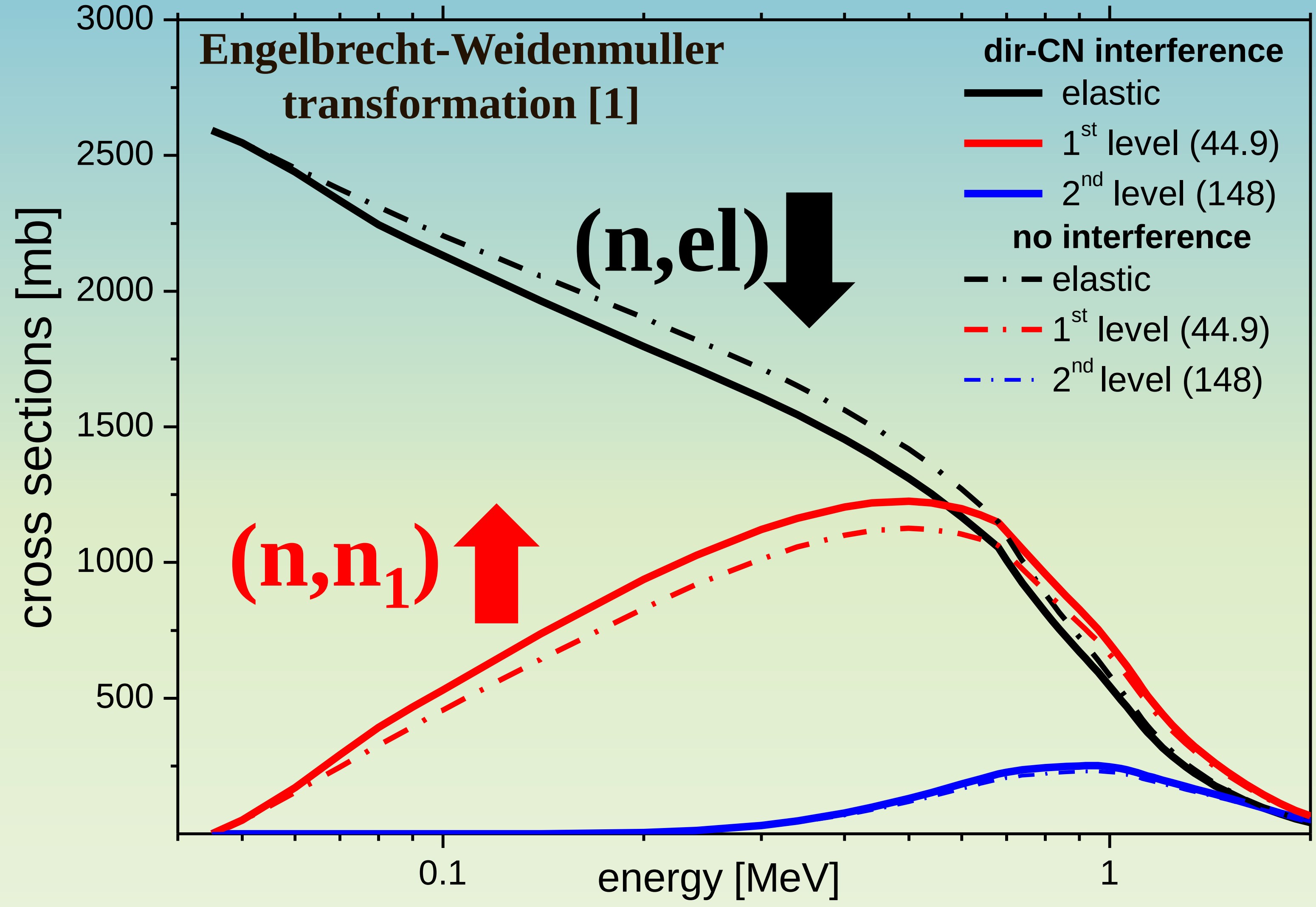
new physics: DIR-CN interference



[1] C.A. Engelbrecht, H.A. Weidenmuller, “Hauser--Feshbach theory and Ericson fluctuations in the presence of direct reactions”, Phys.Rev. **C8** (1974) 859-862

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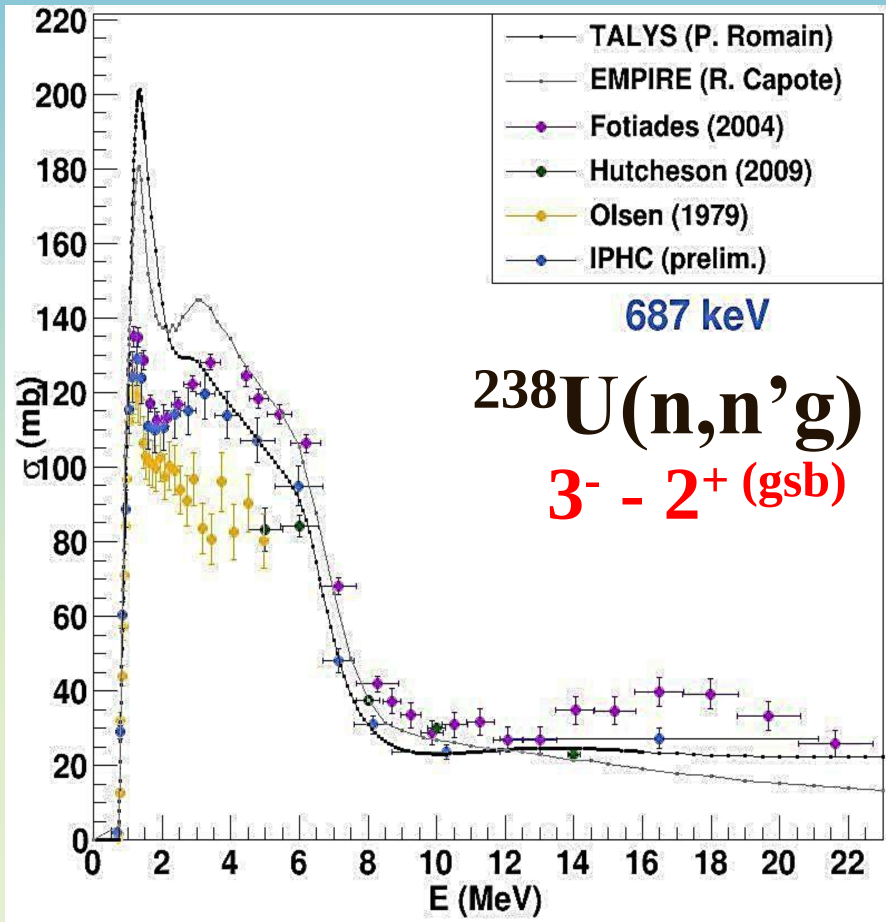
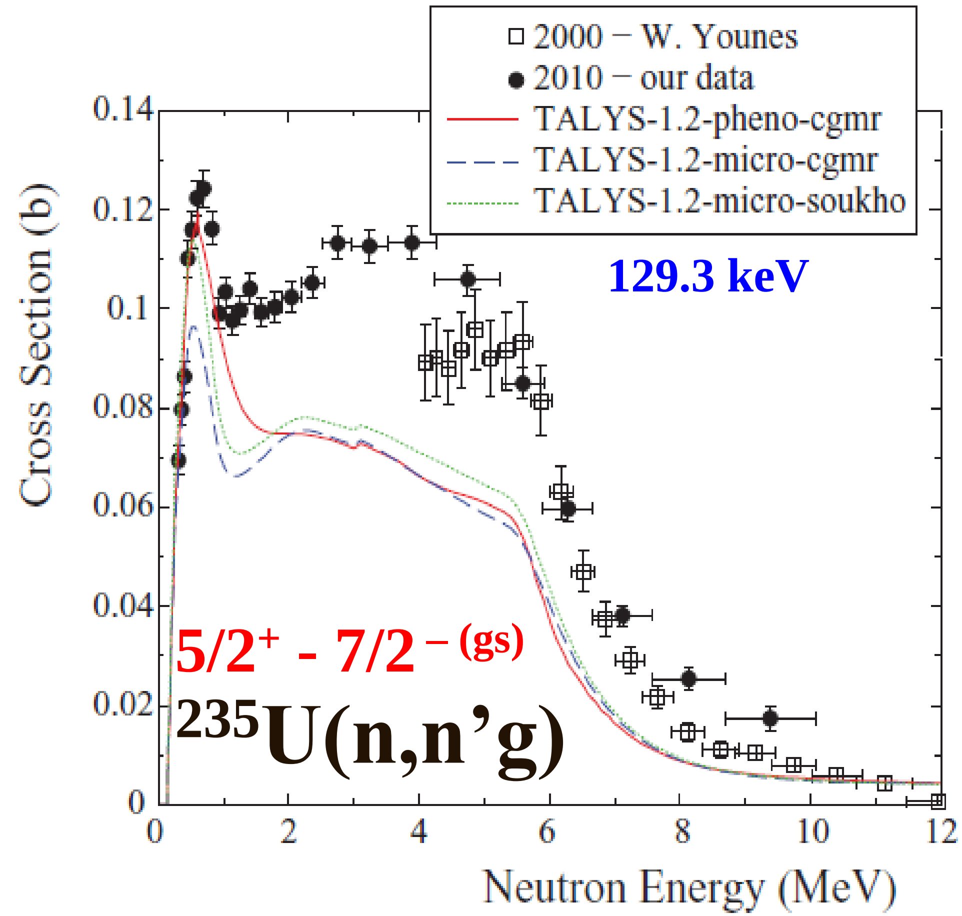
MODELLING CHALLENGES





Bacquias/Kerveno *et al (prelim., unpublished)*

Kerveno *et al*, PRC87(2013) 024609

Better structure models => CC OMP

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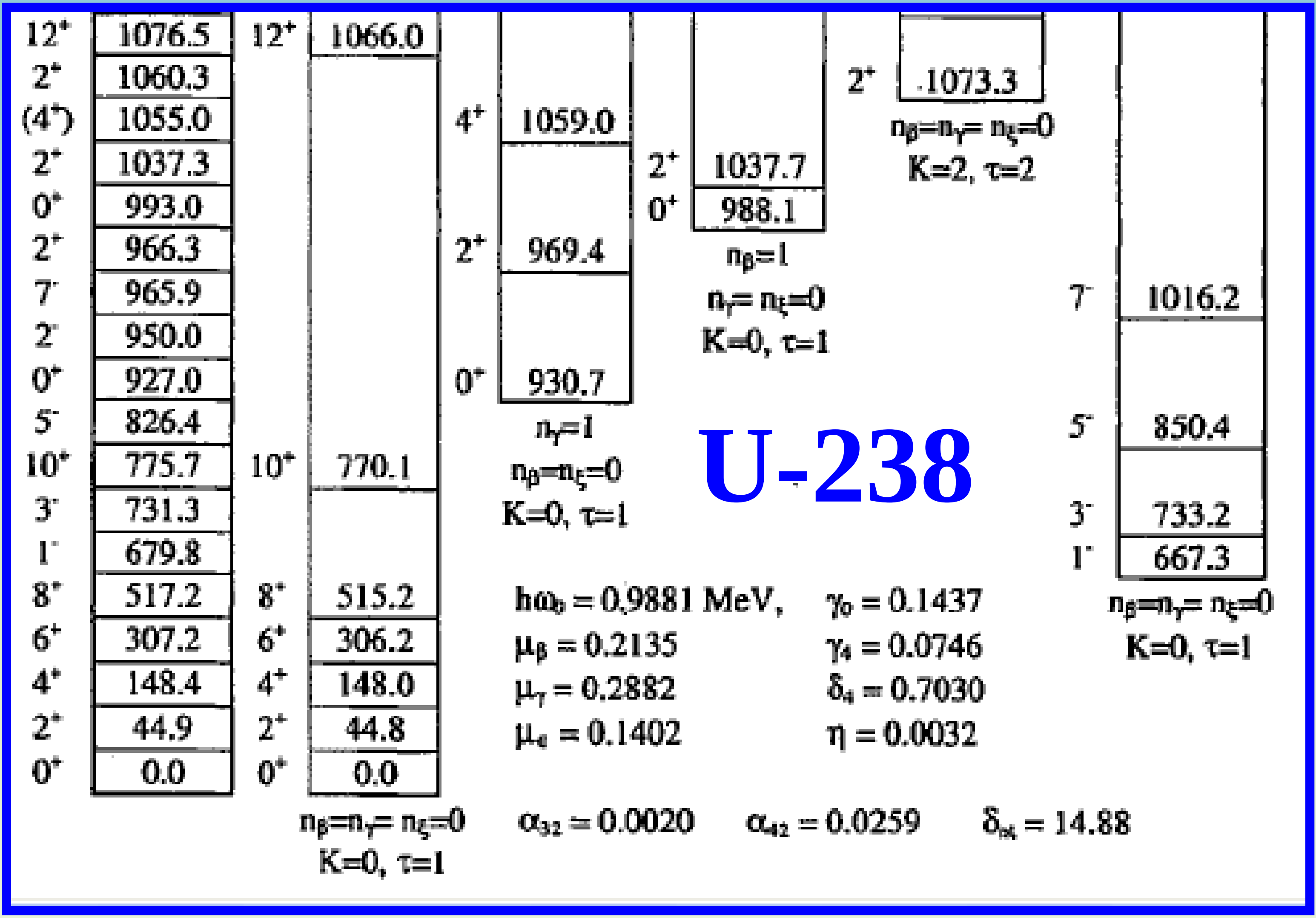
Rigid rotor with soft-rotor corrections



Yu.V.Porodzinkij and E. Soukhovitdkii, Phys. At. Nuclei **59** (1996) 228-237

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Evaluation methodology challenges

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Evaluation Methodology Challenges

- Use nuclear reaction modelling code (e.g EMPIRE)
- Choose adequate model options (HF+fluct., direct, PE)
- Determine needed input parameters (starting from RIPL)
- Calculate cross sections and other quantities
- Compare calculated values to selected measured data (after correcting for new stds, discarding discrepant, etc)
- Fine-tune the input model parameters

Loop-1

- From model parameter uncertainties and model uncertainties generate covariance matrix prior
- Do the GLSQ fit to combine the EXP and model data

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Evaluation Methodology Challenges

1) MC modeling (EMPIRE, TALYS, CCONE, CoH,…) $\{\boldsymbol{\sigma}_\mathbf{i}\}$

2) For each random set $\{\boldsymbol{\sigma}_\mathbf{i}\}$ we calculate $w^{\exp}(\vec{\sigma}_i) = \mathscr{L}(\mathbf{y_E}, \mathbf{V_E} \mid \boldsymbol{\sigma}_\mathbf{i})$

$$\mathscr{L}(\mathbf{y_E}, V_E \mid \boldsymbol{\sigma}_\mathbf{i}) = \exp\{-(½)[(f(\boldsymbol{\sigma}_\mathbf{i}) - \mathbf{y_E})^T \bullet (V_E)^{-1} \bullet (f(\boldsymbol{\sigma}_\mathbf{i}) - \mathbf{y_E})]\}$$

$$\langle \vec{\sigma} \rangle = \frac{\sum_{i=1}^{N} w^{\exp}(\vec{\sigma}_i) \quad \vec{\sigma}_i}{\sum_{i=1}^{N} w^{\exp}(\vec{\sigma}_i)}, \qquad \mathrm{cov}(\vec{\sigma}_i, \vec{\sigma}_j) = \langle \vec{\sigma}_i \vec{\sigma}_j \rangle$$

UMC-B

Unified Monte Carlo

OUTPUT: 1) $\langle \vec{\sigma} \rangle, \quad \mathrm{cov}(\vec{\sigma}_i, \vec{\sigma}_j) = \langle \vec{\sigma}_i \vec{\sigma}_j \rangle$

2) Stochastic set $\{\boldsymbol{\sigma}_\mathbf{i}\}$ (e.g. to be used in TMC)

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Evaluation Methodology Challenges

ALTERNATIVES to GLSQ:

- **MC methods: No covariance generation**

UMC-B :
Solution is obtained as a linear combination of model results

However:

The solution may not be reproducible by model calculations (more information is derived from experimental data => overcome model defects)

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Challenges in use of integral data

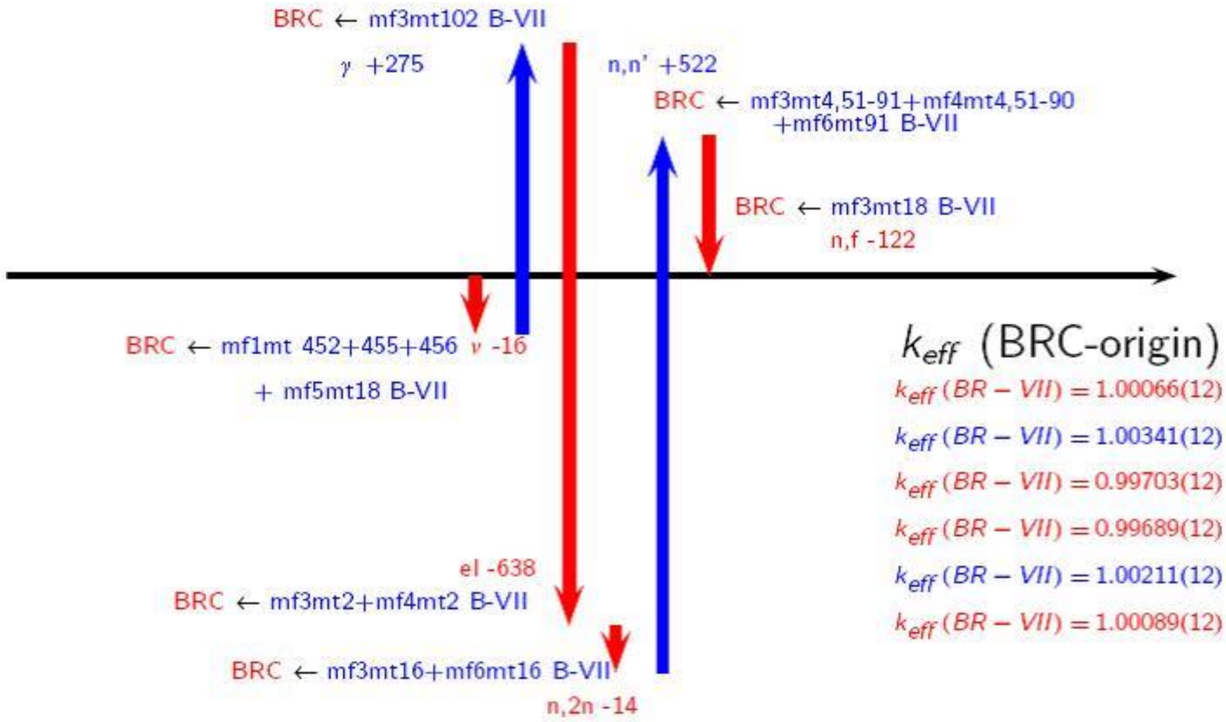
Fresnel Representation - ^{239}Pu (BRC)

But as known from B. Morillon study (calculations MCNP5)
JEZEBEL $k_{eff}(BRC) = 1.00082(11)$ $k_{eff}(B\text{-}VII) = 1.00060(12)$

Compensating errors !!

JEZEBEL

LANL, USA



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INDC(NDS)-0597
A.J. Plompen et al

http://www-nds.iaea.org/publications/indc/indc-nds-0597.pdf

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Challenges in use of integral data

Compensating errors:

Elastic vs Inelastic

Cross-correlations among isotopes:

e.g. Flattop-25 critical assembly

^{235}U (PFNS) and

^{238}U (elastic and inelastic) RELATED

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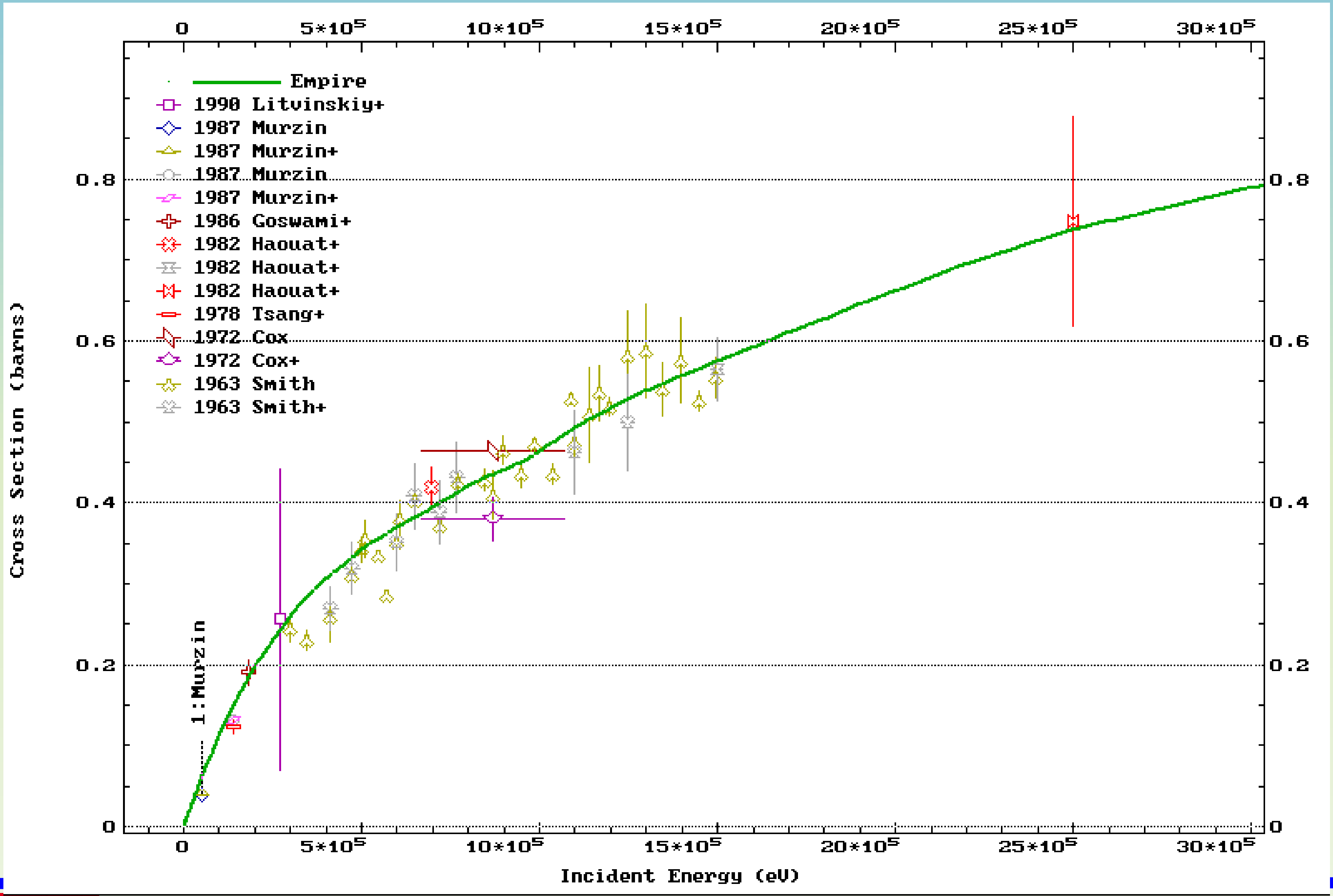
elastic μ-bar (P1 component)



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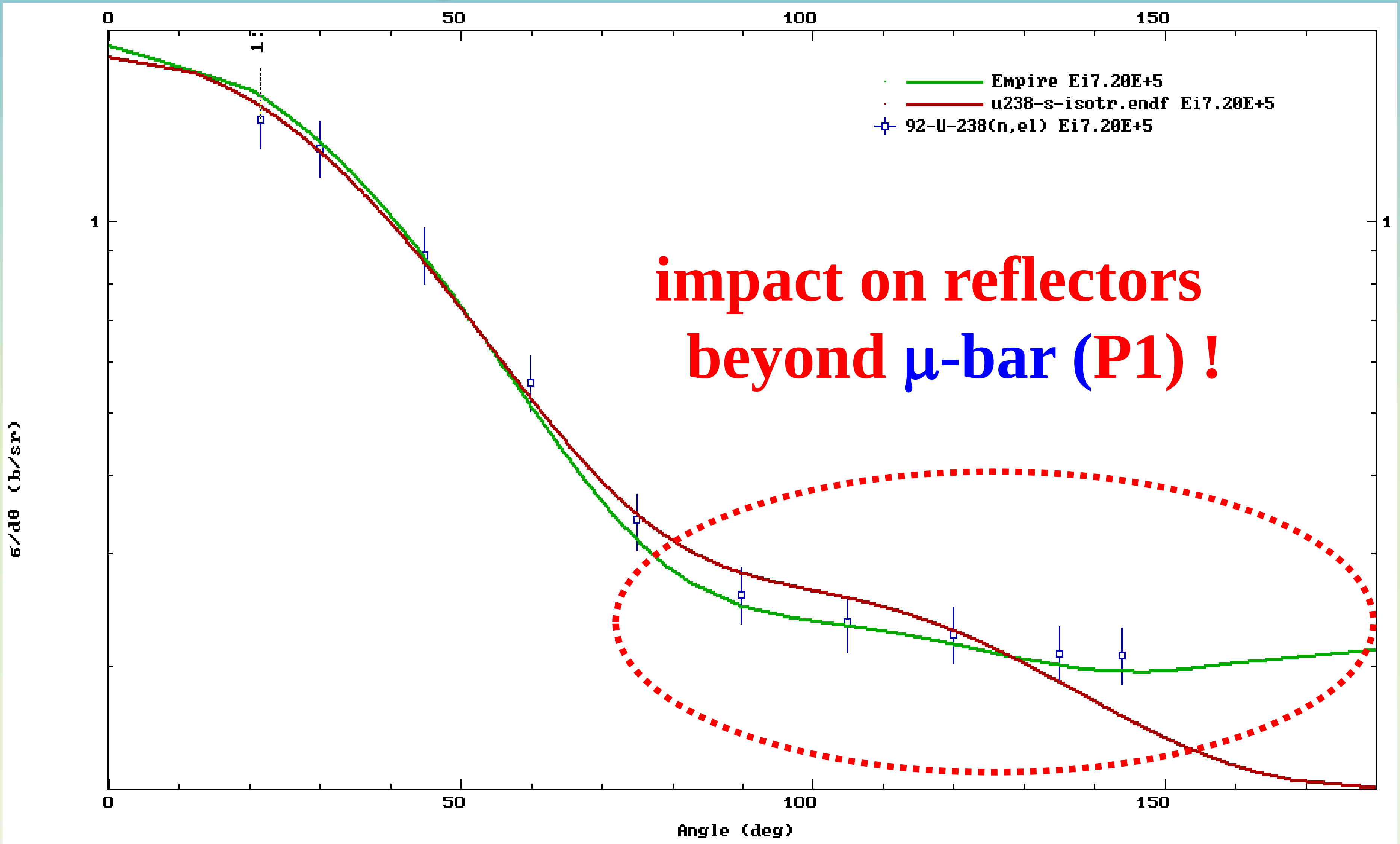
Elastic angular distribution 720 keV



impact on reflectors beyond μ-bar (P1) !

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CONCLUSIONS

- Experimental challenges

New quasi-diff. and SPA cross-section meas.

- Modelling challenges

Better structure in reaction calcs (CC OMPs)

- Evaluation methodology challenges

Going beyond model calcs (e.g. UMC-B)

- Challenges in use of integral data

Cross-isotope correlations

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