IAEA 60 Years
Atoms for Peace and Development

Current status of ^{235}U and ^{238}U evaluated nuclear data files (IAEA CIELO)

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Department for Nuclear Sciences and Applications

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Thanks to all collaborators:

M. Sin (University of Bucarest, Romania) M.W. Herman (BNL, USA), V.G. Pronyaev (PI Atomstandard, Russia), P. Talou (LANL, USA), D. Bernard (CEA Cadarache, France), G. Noguere (CEA Cadarache, France), A. Daskalakis (RPI, USA) , Y. Danon (RPI, USA)

U238 RRR: P. Schillebeeckx, I. Sirakov, S. Kopecky (EC JRC Geel)
U235 RRR: M. Pigni, L. Leal (ORNL, USA)
PFNS: D. Neudecker, D.L. Smith, P. Talou, M. Rising
and IAEA CRP participants

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E. Soukhovitskii (JINER, Belarus), J. M. Quesada (Univ. Sevilla, Spain), S. Chiba (TIT, Japan), D. Martyanov (JINER, Belarus)

IAEA CIELO evaluations & B/VIII.0

^{235}U

- ENDF/B-VIII.β3 = ENDF/B-VIII.β2 (IAEA u238-b18)
- ENDF/B-VIII.β4 = IAEA u238-b25 … (STD 2016)

^{238}U

- ENDF/B-VIII.β3 = ENDF/B-VIII.β2 (IAEA u238-b46)
- ENDF/B-VIII.β4 = IAEA u238-b51 … (STD 2016)

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Evaluation of n + ^{235}U reaction

RRR (*n*,γ) : Pigni et al., E_n<100 eV
Leal et al., 100 eV <E_n<2.25 keV
Fast (E_n>2.25 keV): this work

- (*n*,f) from 2006/2016 Standards (b18/b25)
- PFNS: GMA thermal + Rising/Neudecker above (b18/b25)
- Dispersive optical model RIPL 2408 (with 8 CC from gsb)
- (n,γ) 1-60keV based on Jandel (b18/b25)
- (n,γ) 60-500keV based on Jandel & Wallner (b25)
- (n,γ) E_n>1MeV based on Allmond (b25)
- (n,f): triple-humped barrier with absorption
- Elastic, inelastic and (n,xn) from modelling with scarce data constrains (except unitarity)

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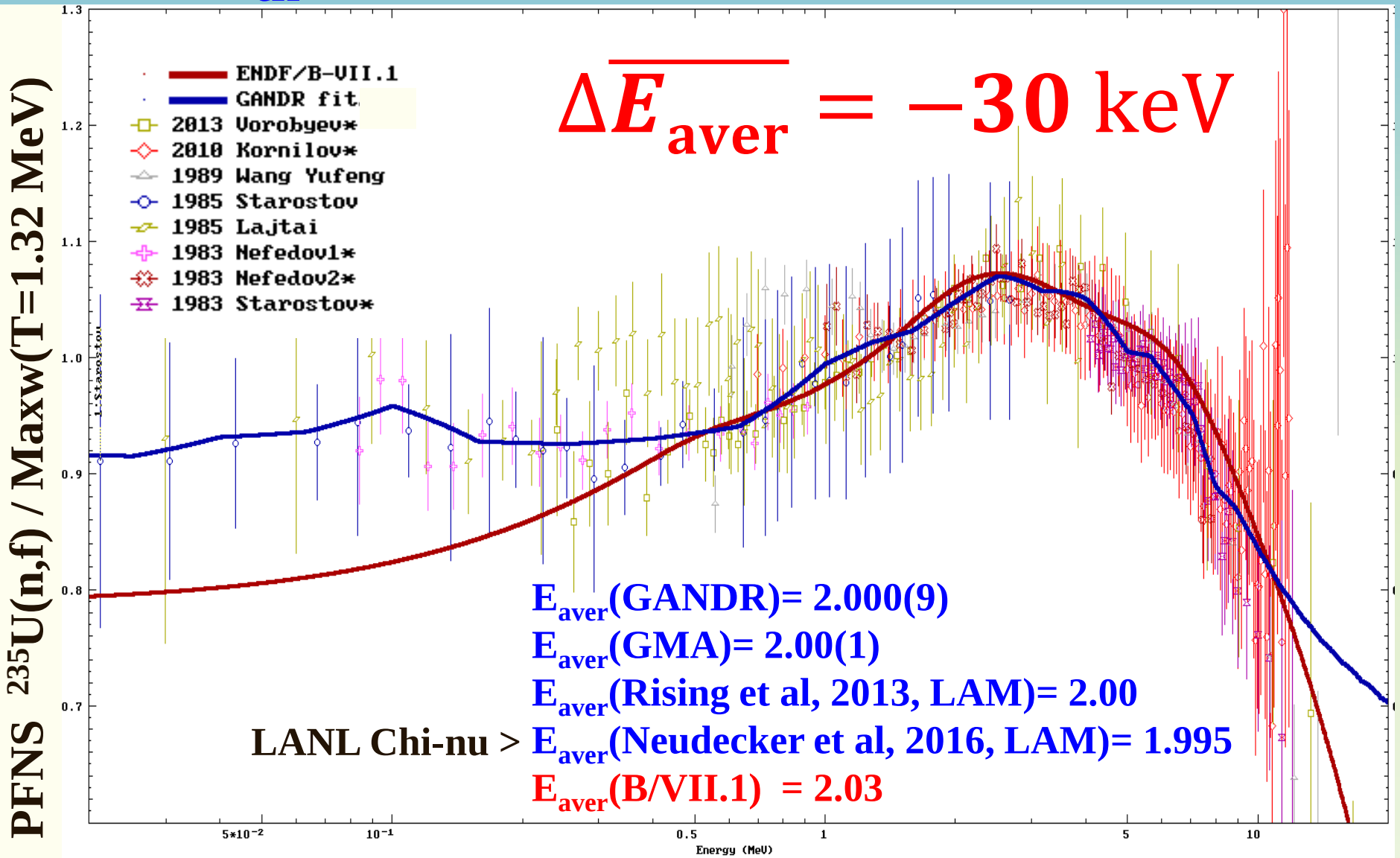
$^{235}U(n_{th},f)$ PFNS non-model evaluation



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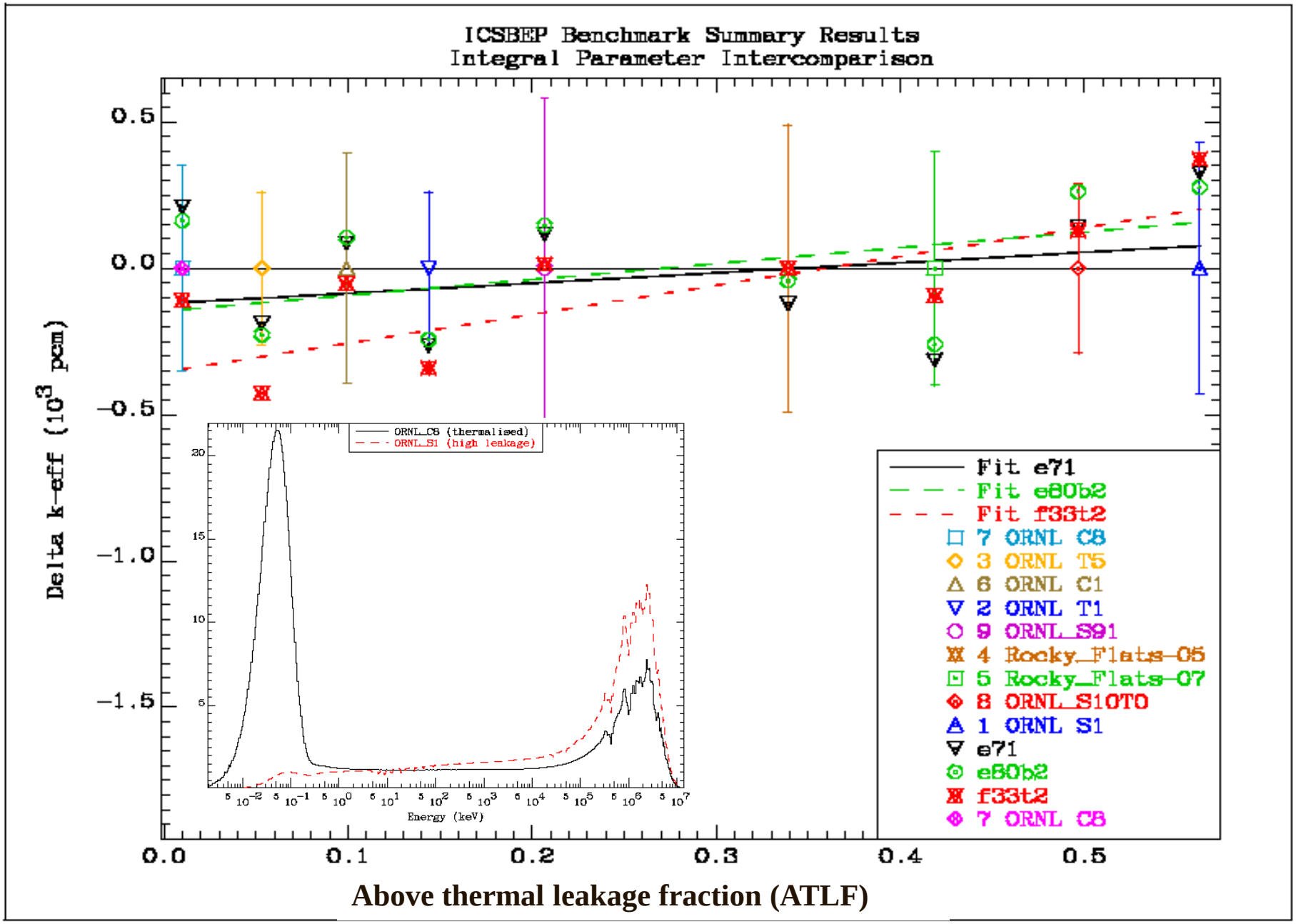

Above thermal leakage fraction (ATLF)

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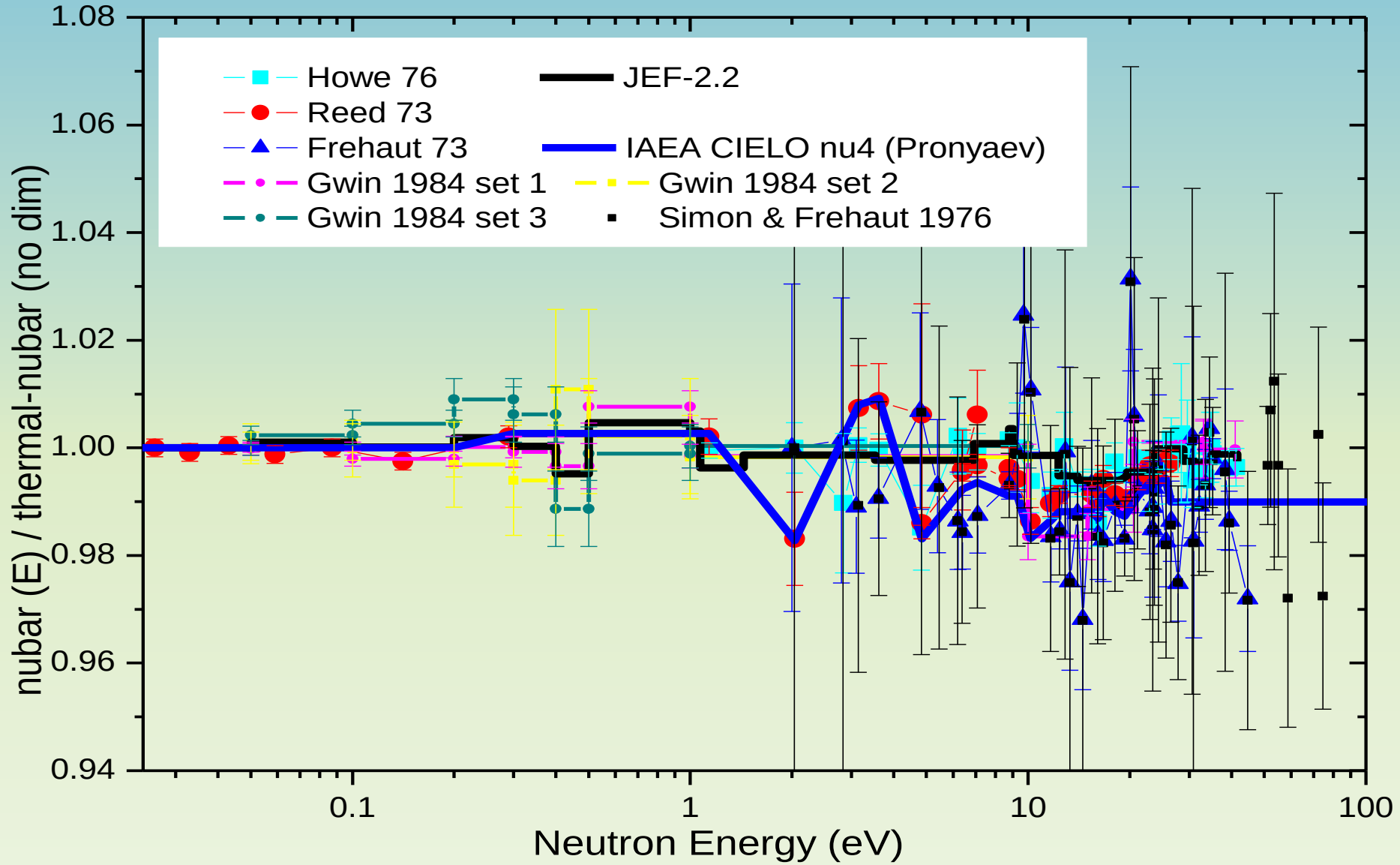
$^{235}U(n_{th},f)$ nubar fluctuations



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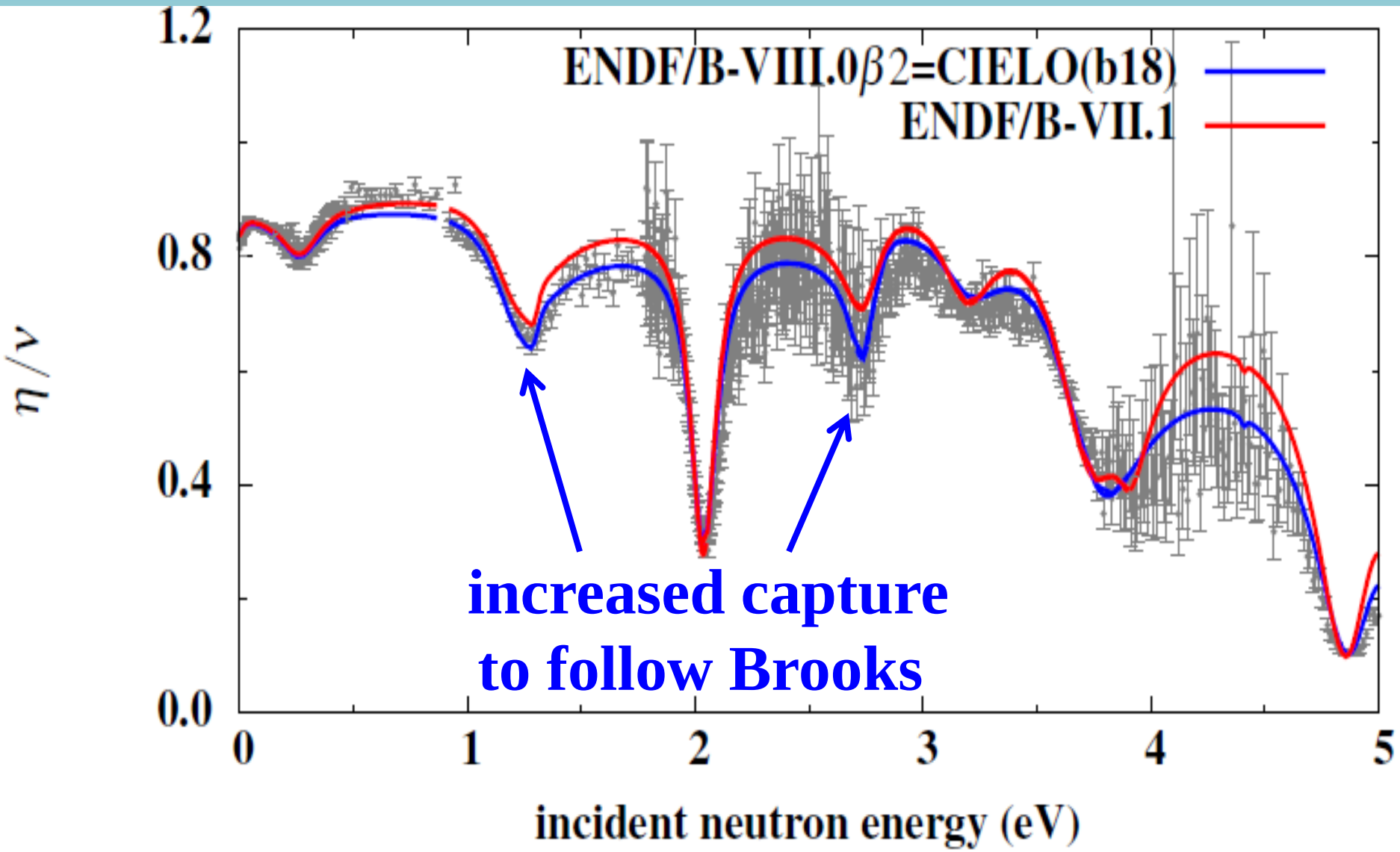
$^{235}U(n_{th},f)$ new RP (Pigni et al)



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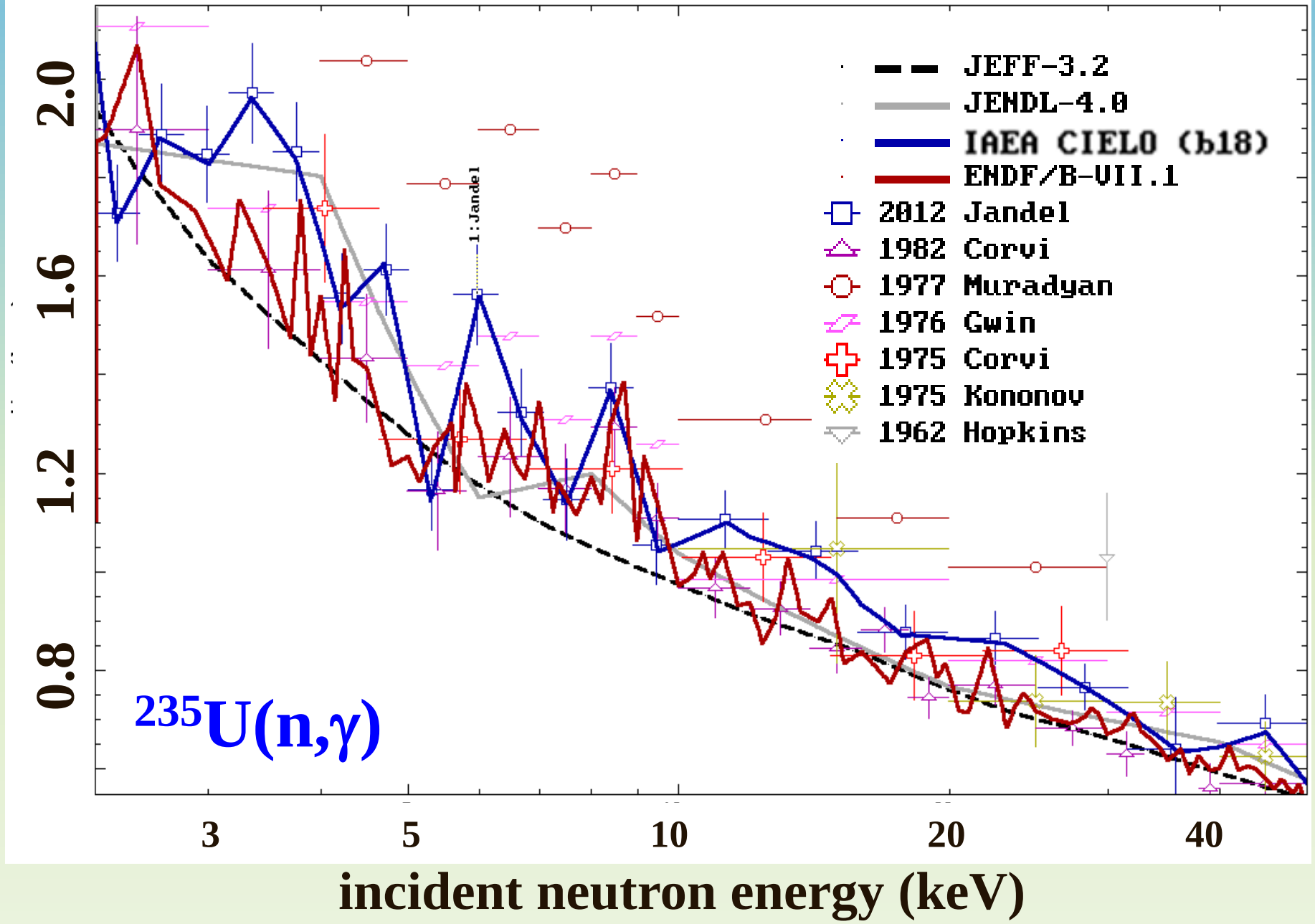

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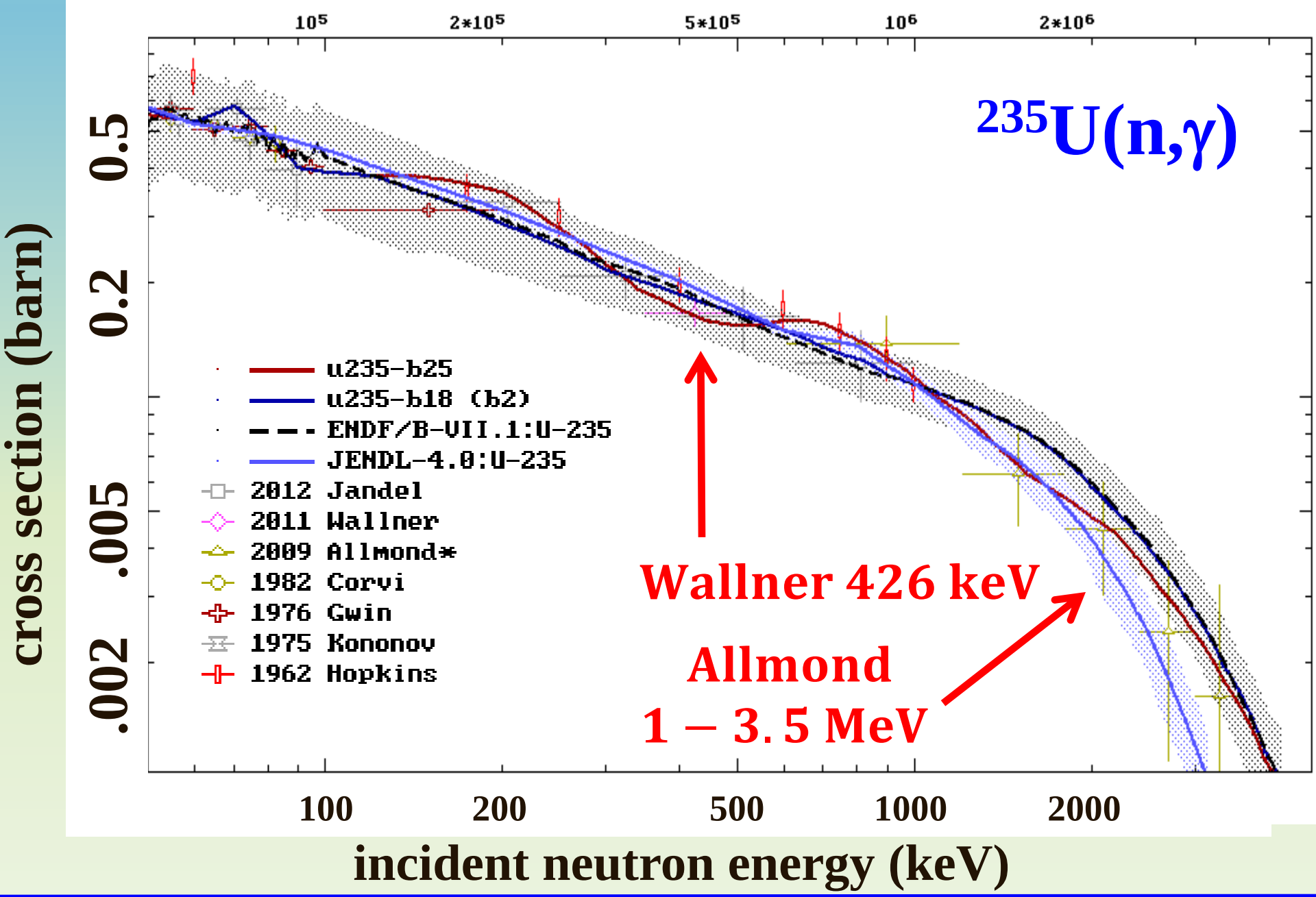

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IAEA CIELO evaluations vs Wallner AMS
^{238}U(n,g)-b46/b51, ^{235}U(n,g)-b18/b25

^{238}U(n,g)

kT=25 keV
Wallner: 0.391±0.017 b (4.3%)
- ✓ **IAEA CIELO (β2): 0.391**
- ✓ **IAEA CIELO (β4): 0.394**

kT=426 keV
Wallner: 0.108±0.004 b (3.7%)
- ✓ **IAEA CIELO (β2): 0.109**
- ✓ **IAEA CIELO (β4): 0.108**

^{238}U(n,g)/^{235}U(n,g)

kT=25 keV
Wallner: 0.60±0.03 (4.7%)
- ❖ **IAEA CIELO (β2): 0.55 (-8.4%)**
- ✓ **IAEA CIELO (β4): 0.57**

kT=426 keV
Wallner: 0.64±0.03 (3.9%)
- ❖ **IAEA CIELO (β2): 0.60 (-6.3%)**
- ✓ **IAEA CIELO (β4): 0.63**

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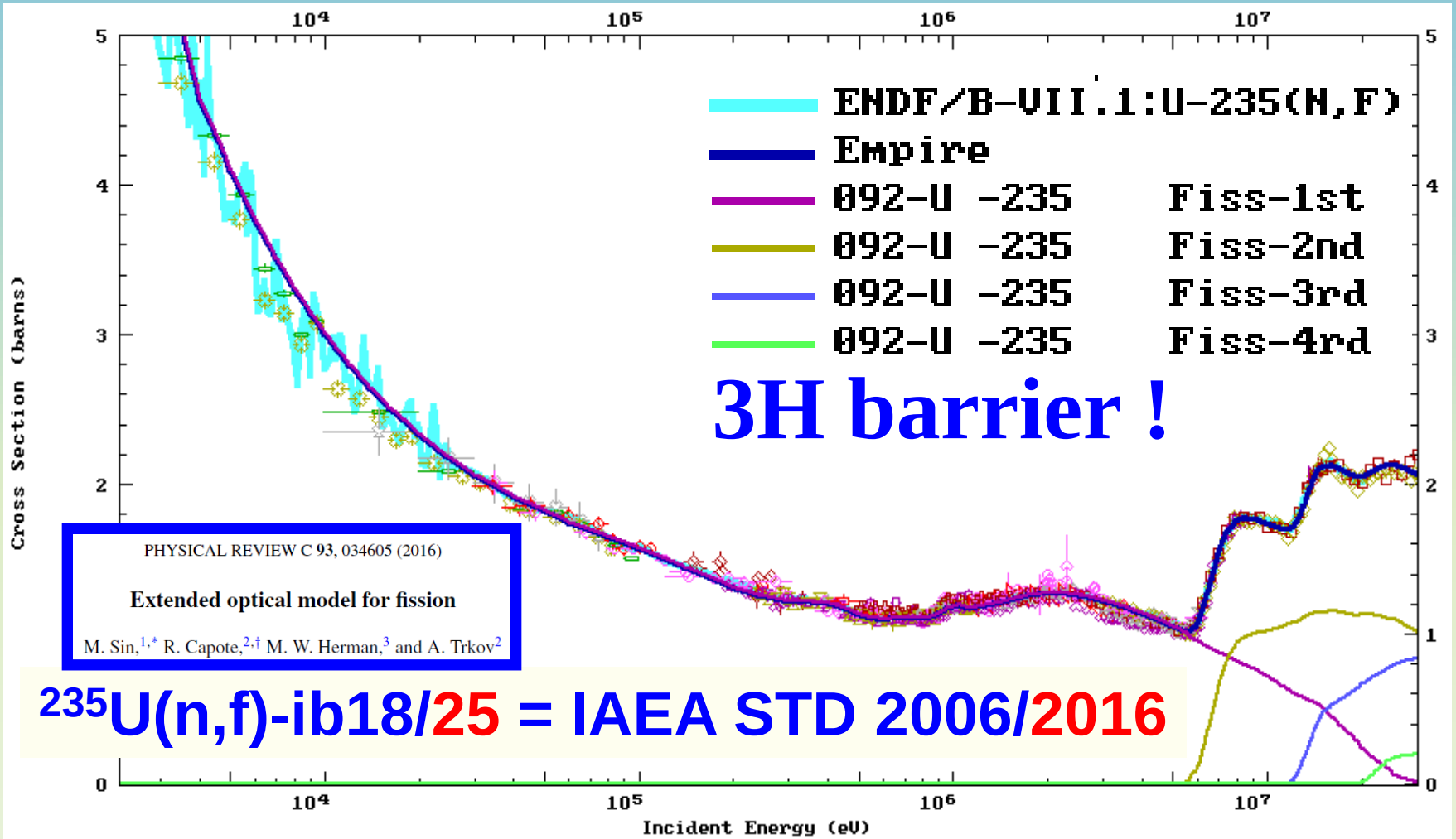
Empire ^{235}U(n,f) vs IAEA standards



EMPIRE calc. agrees within 3% with IAEA standards

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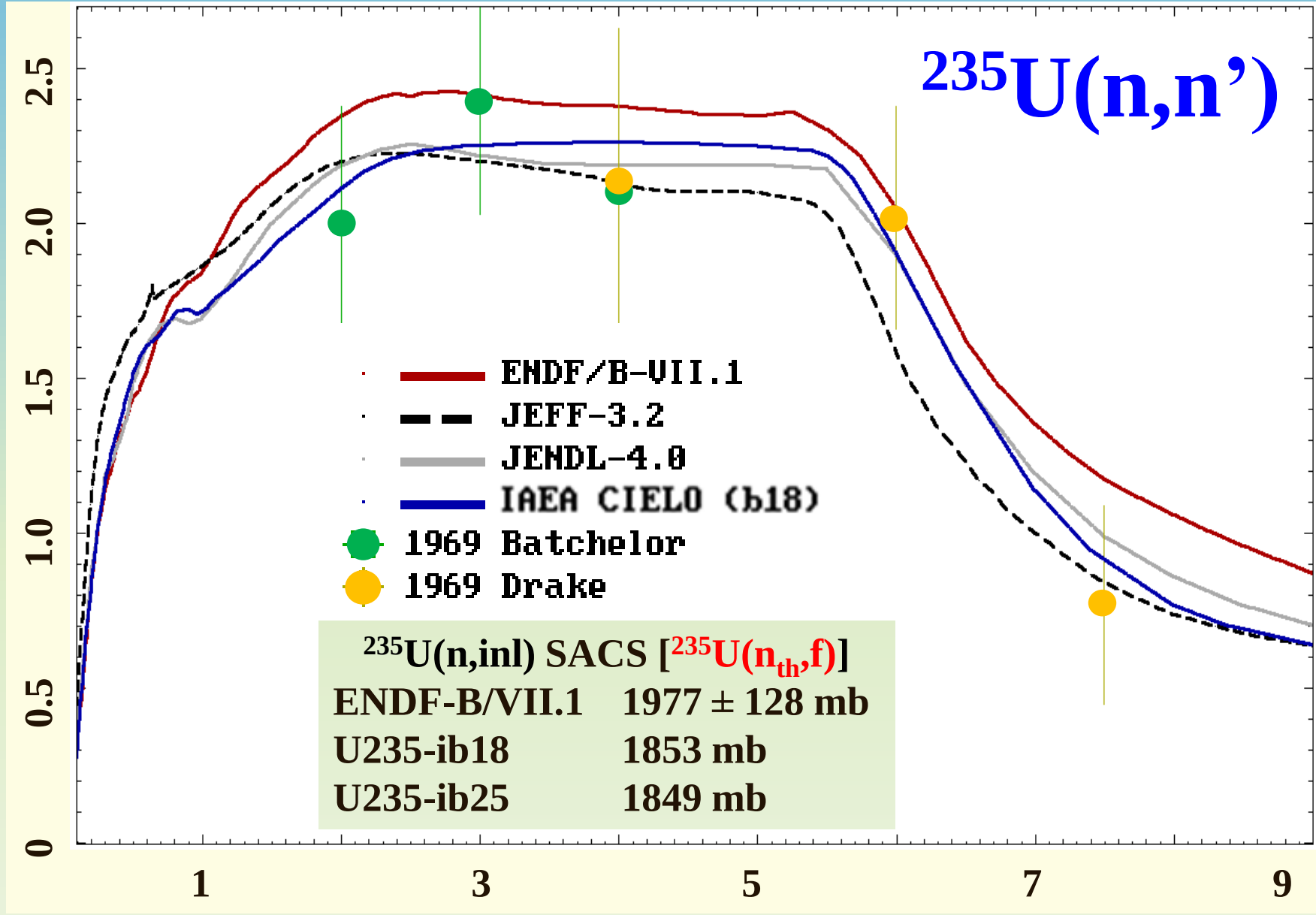

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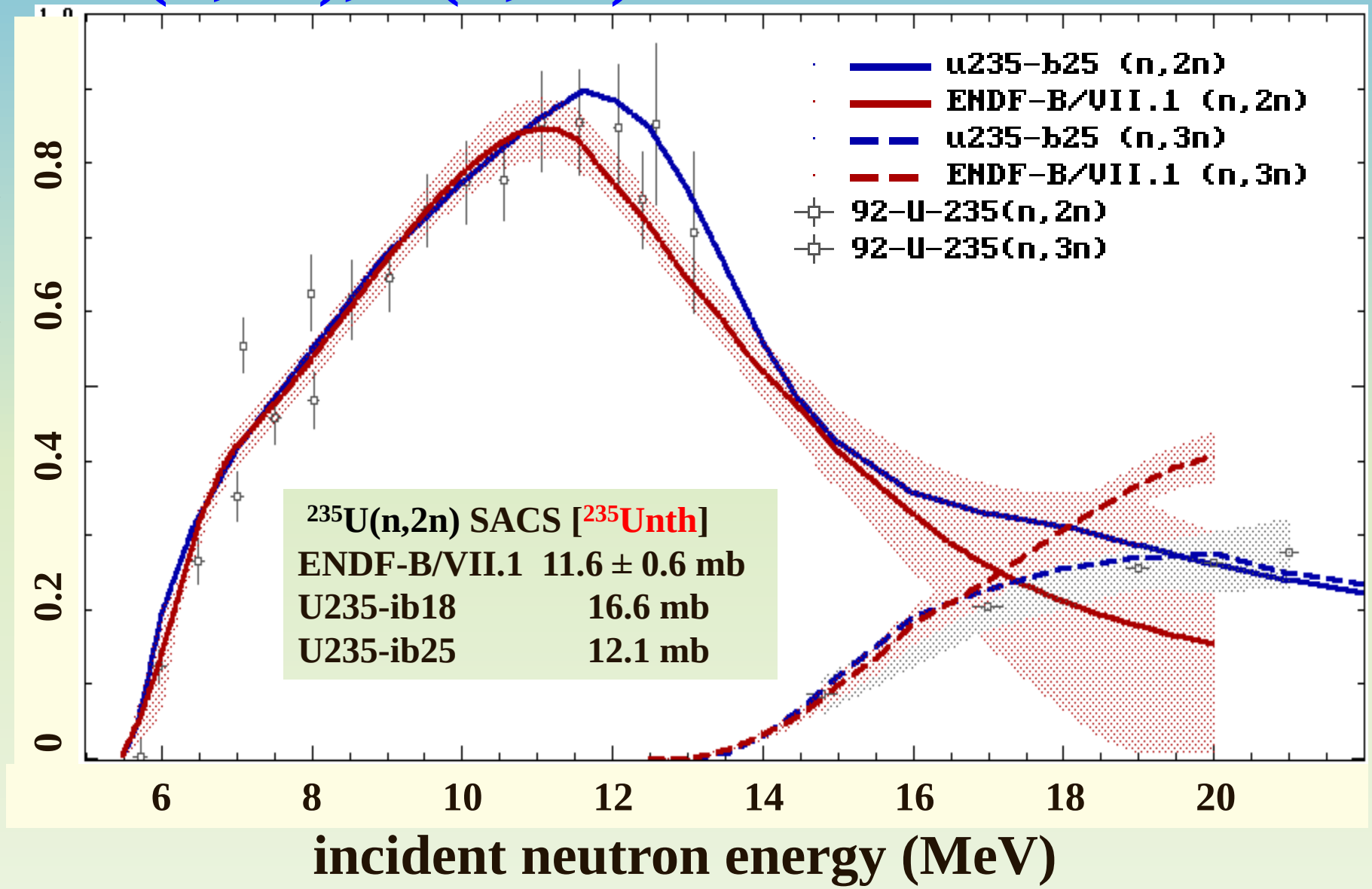
σ(n,2n), σ(n,3n) vs ENDF/B-VII.1



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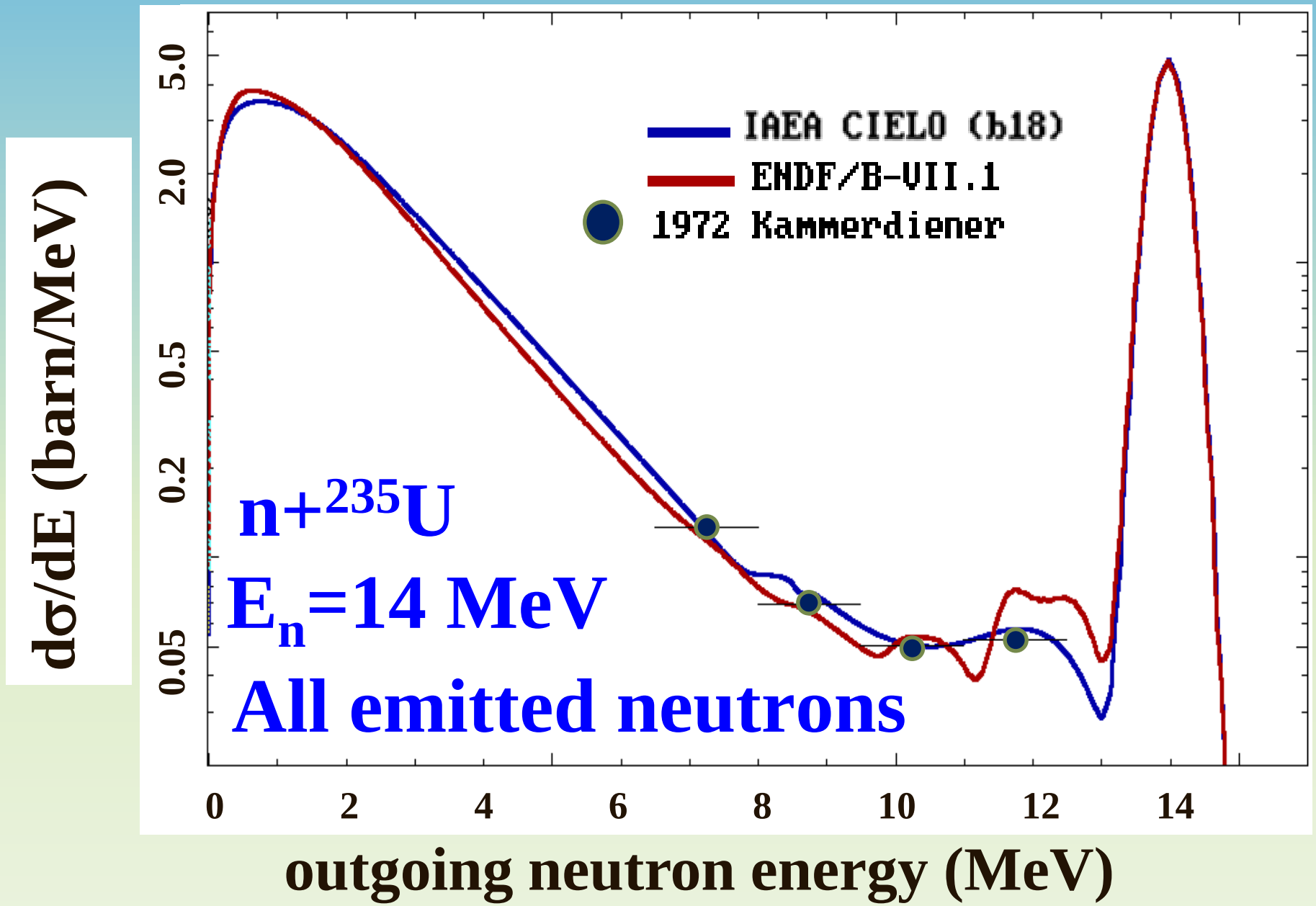

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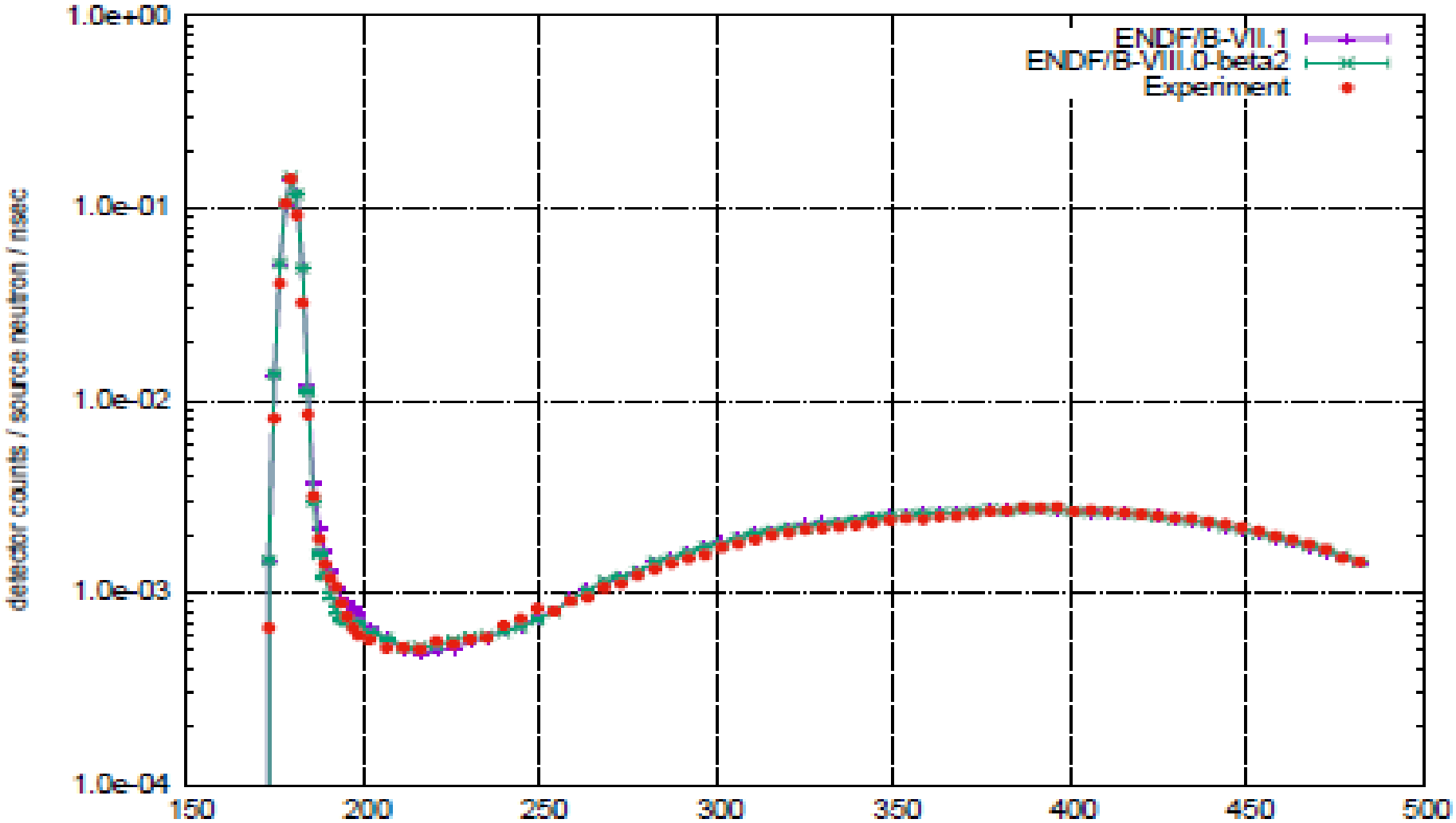
LLNL Pulsed Sphere (14MeV n + ^{235}U)



LLNL Pulsed Spheres calculations by B. Kiedrowski using MCNP

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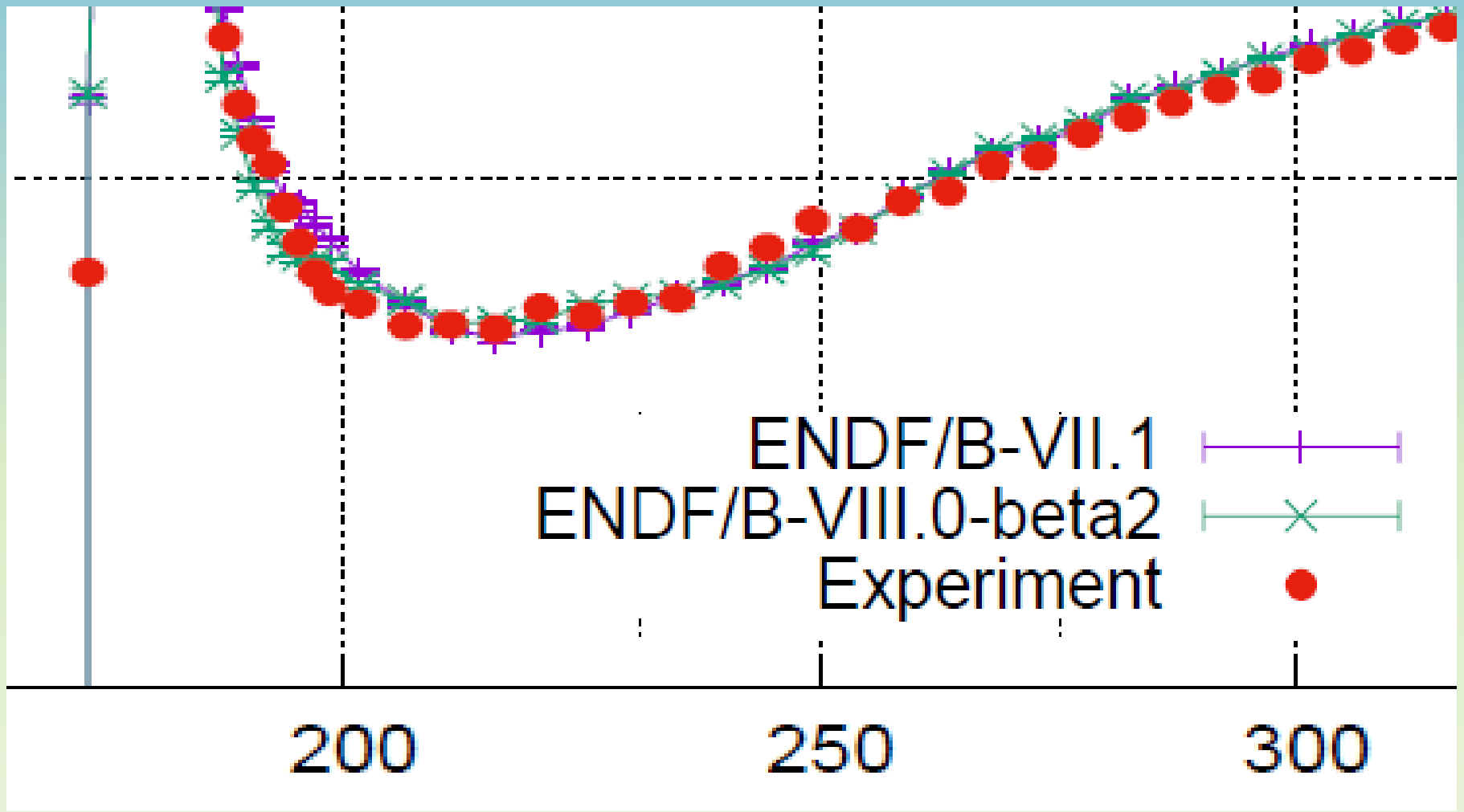

LLNL Pulsed Spheres calculations by B. Kiedrowski using MCNP

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Summary: ^{235}U fast region

- Fission in fast region from **Neutron Standards 2006/2016 (a non-model Bayesian evaluation based on EXP. DATA)**
- New fast evaluation with **fission cross sections (3H) consistent with IAEA Standard** leading to elastic/inelastic and (n,xn) **consistent** changes (b18/b25)
- Collective cont. levels to describe Kammerdiener (& LPS)
- PFNS thermal from IAEA (E_{av}=2.00±0.01 MeV)
- PFNS fast from Neudecker et al. evaluation + Chi-nu (2016)
- Capture in fast region updated based on Jandel, Wallner and Allmond experimental data

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Evaluation of n + ^{238}U reaction

RRR (*n*,γ) : Schillebeeckx et al., E_n<20 keV
URR (*n*,γ) : Schillebeeckx et al., E_n:20-149 keV

- **(*n*,f), (*n*,γ) from 2006/2016 Neutron Standards**
- **PFNS** adopted from Rising et al, analysis
- **Elastic and inelastic** cross sections based on modelling guided by RPI "quasi-integral" data and integral benchmarks (BIG-10,JEMIMA,Flaptops)
- **(n,n')** integral feedback from EXCALIBUR (CEA,2016)
- **(n,2n)** integral benchmark feedback from PROFIL-2(B81) (CEA Cadarache)
- **(n,2n)** TUNL new data (Krishichayan et al)

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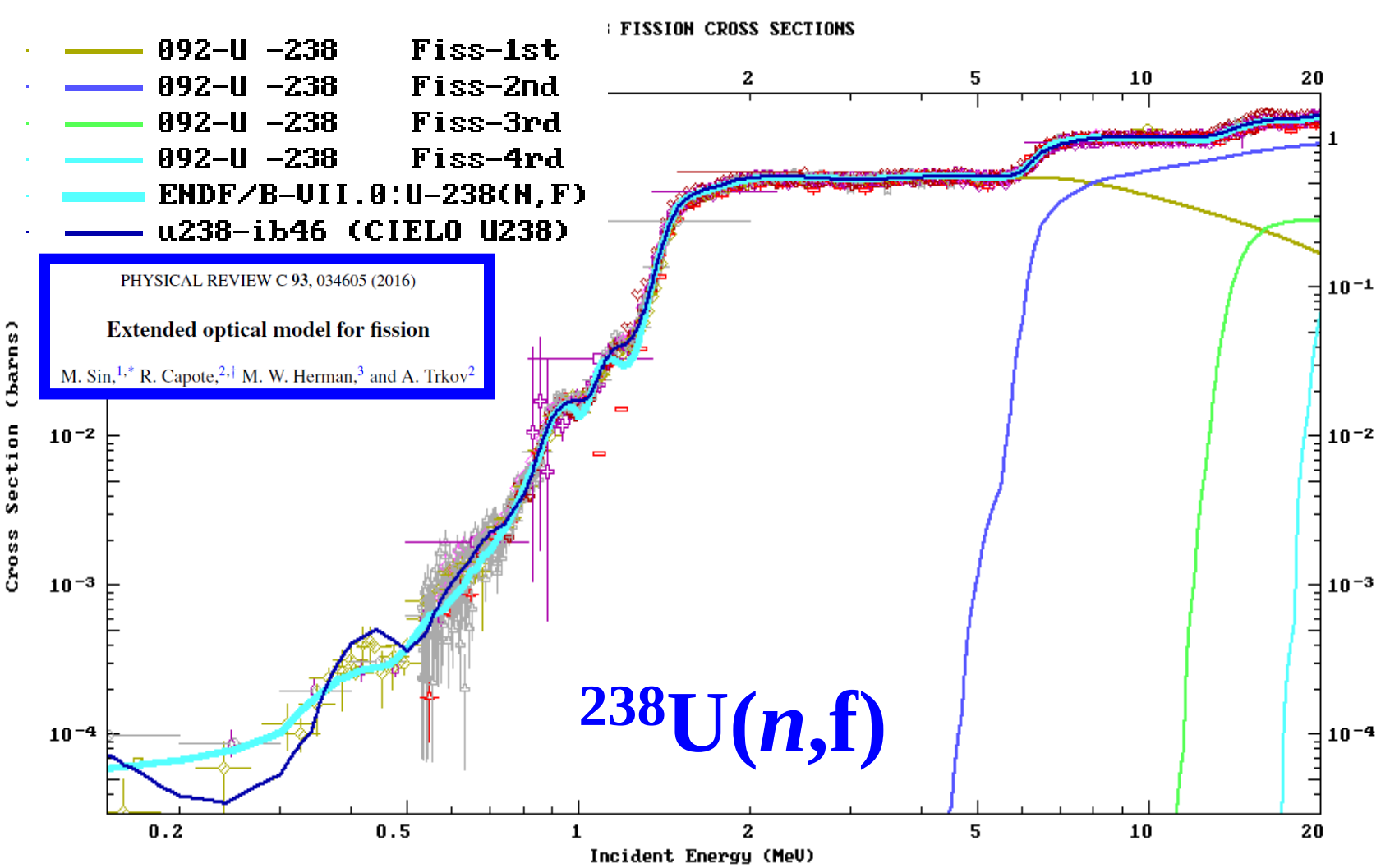
^{238}U(n,f) ib46 (β2) vs ENDF/B-VII.1



^{238}U(n,f)-b46/b51 agree within 3% with STD2006/2016

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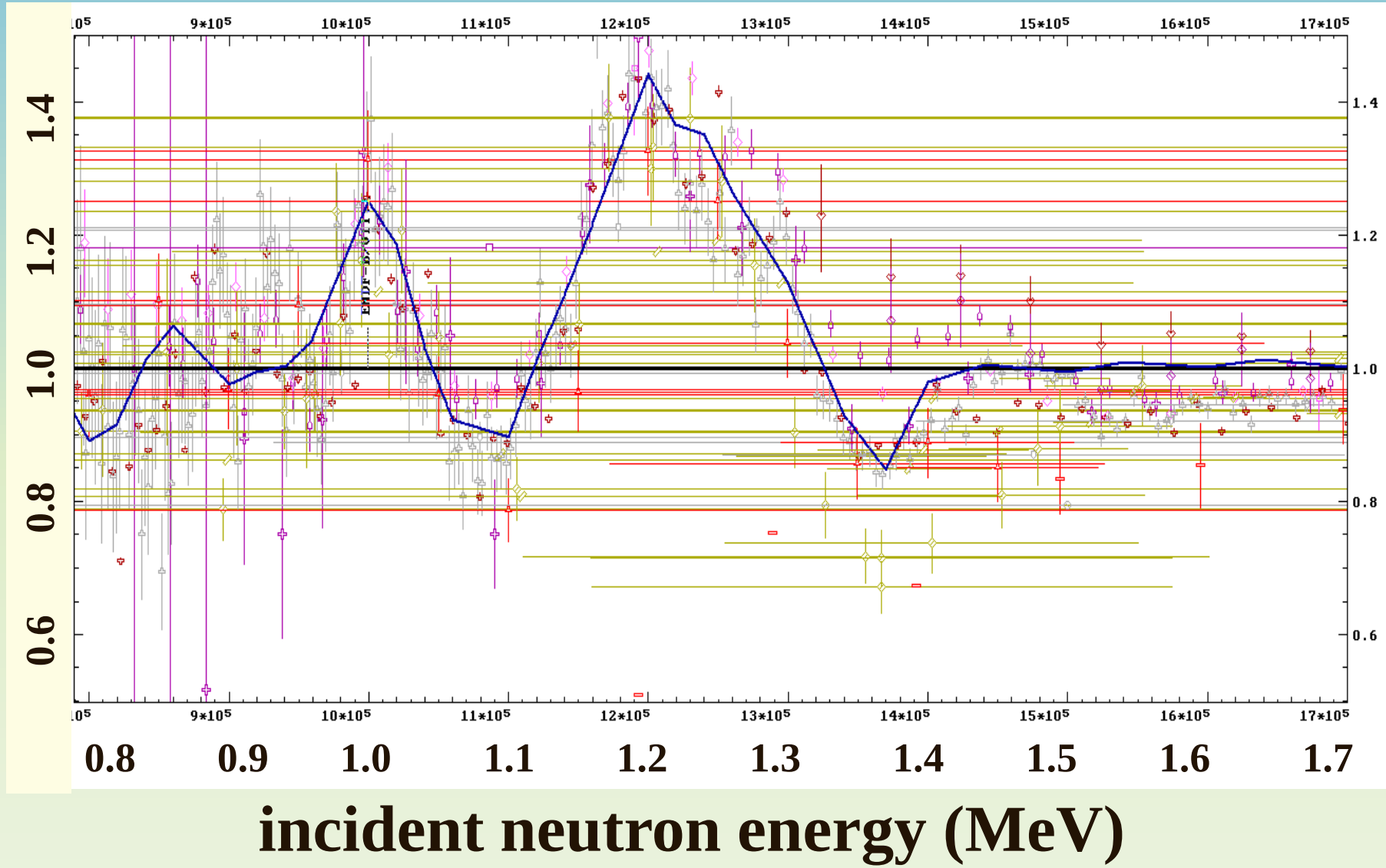
^{238}U(n,f) below the STD range



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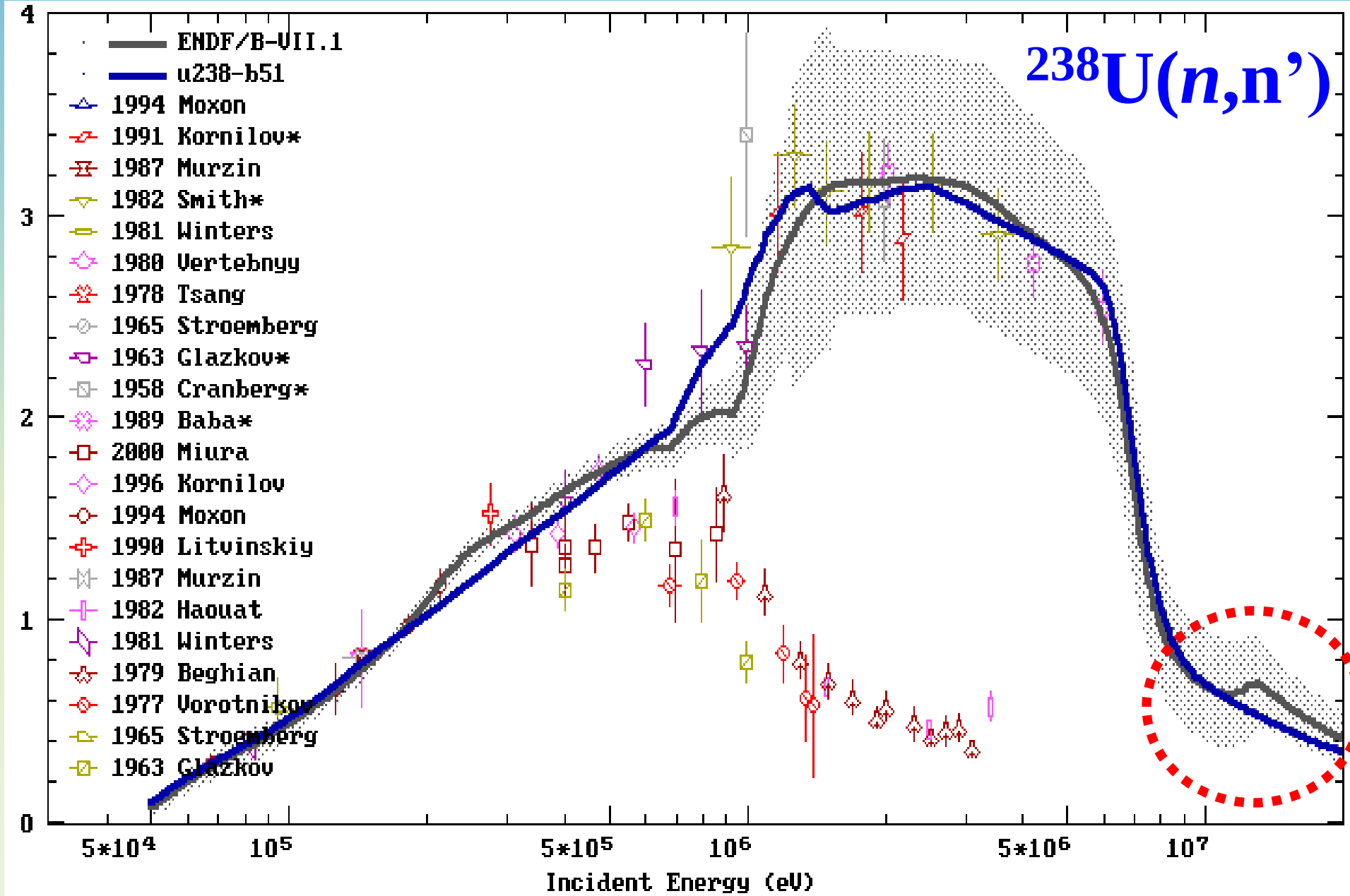

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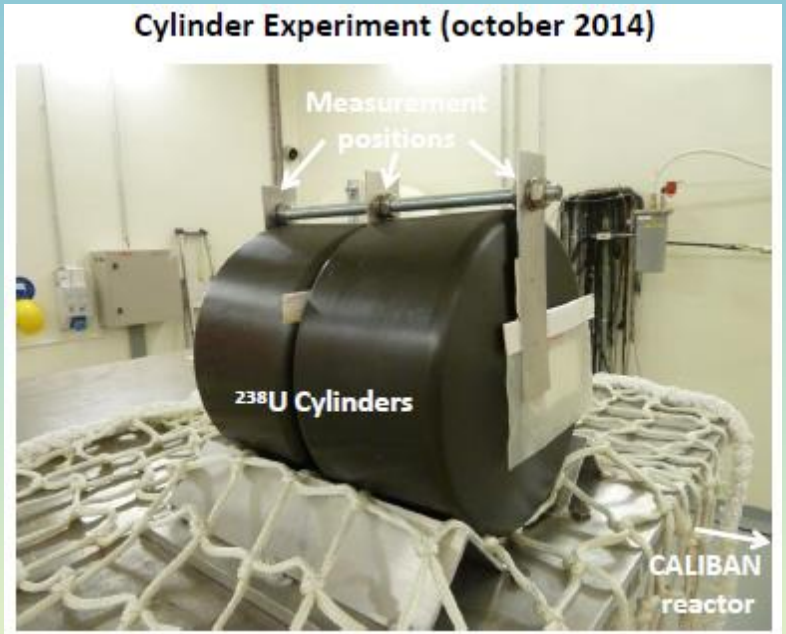
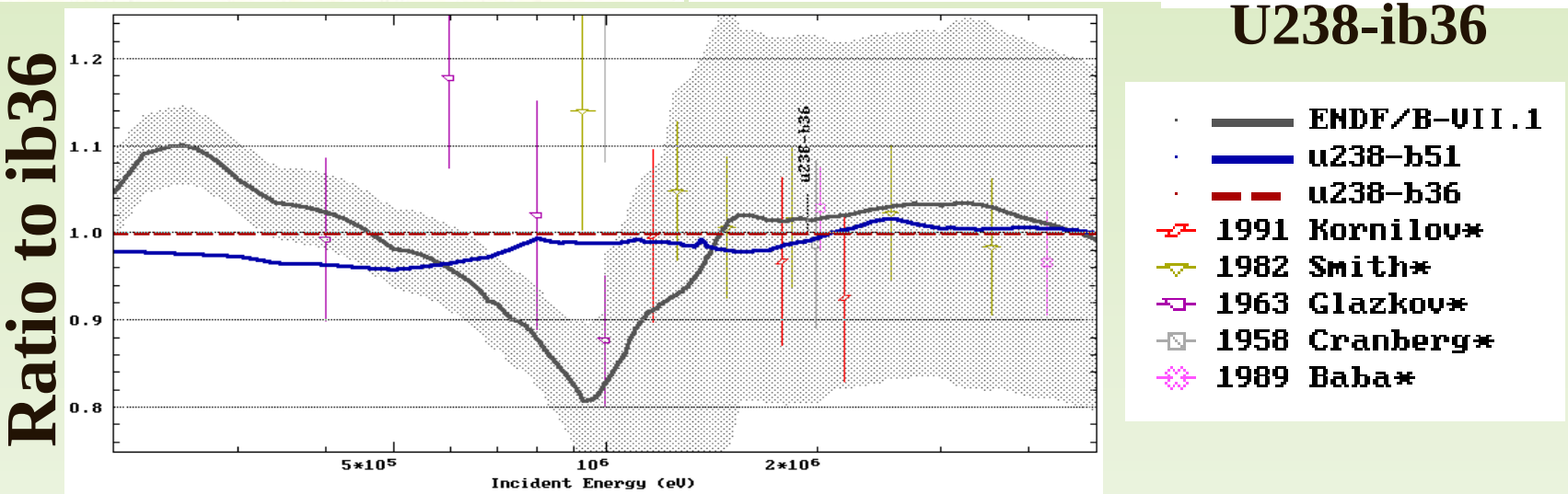
EXCALIBUR, CEA, Leconte & Bernard



Reaction	E50% 252Cf SF[MeV]	Cylinder Experiment	
		Δx ≈ 9cm	Δx ≈ 18cm
^{103}Rh(n,n'γ)^{103m}Rh	2.38	-5.6% ± 0.6%	-6.4% ± 1.1%
^{115}In(n,n'γ)^{115m}In	2.67	-5.5% ± 0.6%	-4.9% ± 1.5%
^{238}U(n,f)PF	2.78	-9.7% ± 0.9%	-5.8% ± 2.3%
^{47}Ti(n,p)^{47}Sc	3.82	-3.8% ± 0.8%	2.2% ± 2.1%
^{58}Ni(n,p)$^{58(g+m)}$Co	4.20	-0.2% ± 0.3%	-0.4% ± 0.5%
^{54}Fe(n,p)^{54}Mn	4.28	-0.7% ± 0.6%	-1.9% ± 0.7%
^{48}Ti(n,p)^{48}Sc	6.08	-2.7% ± 0.7%	-3.2% ± 1.1%
^{56}Fe(n,p)^{56}Mn	7.58	-1.0% ± 1.6%	-2.3% ± 1.8%
^{24}Mg(n,p)^{24}Na	8.26	-0.3% ± 1.7%	-2.7% ± 1.6%
^{48}Ti(n,p)^{48}Sc	8.35	2.8% ± 2.5%	2.7% ± 4.5%

U238-ib36



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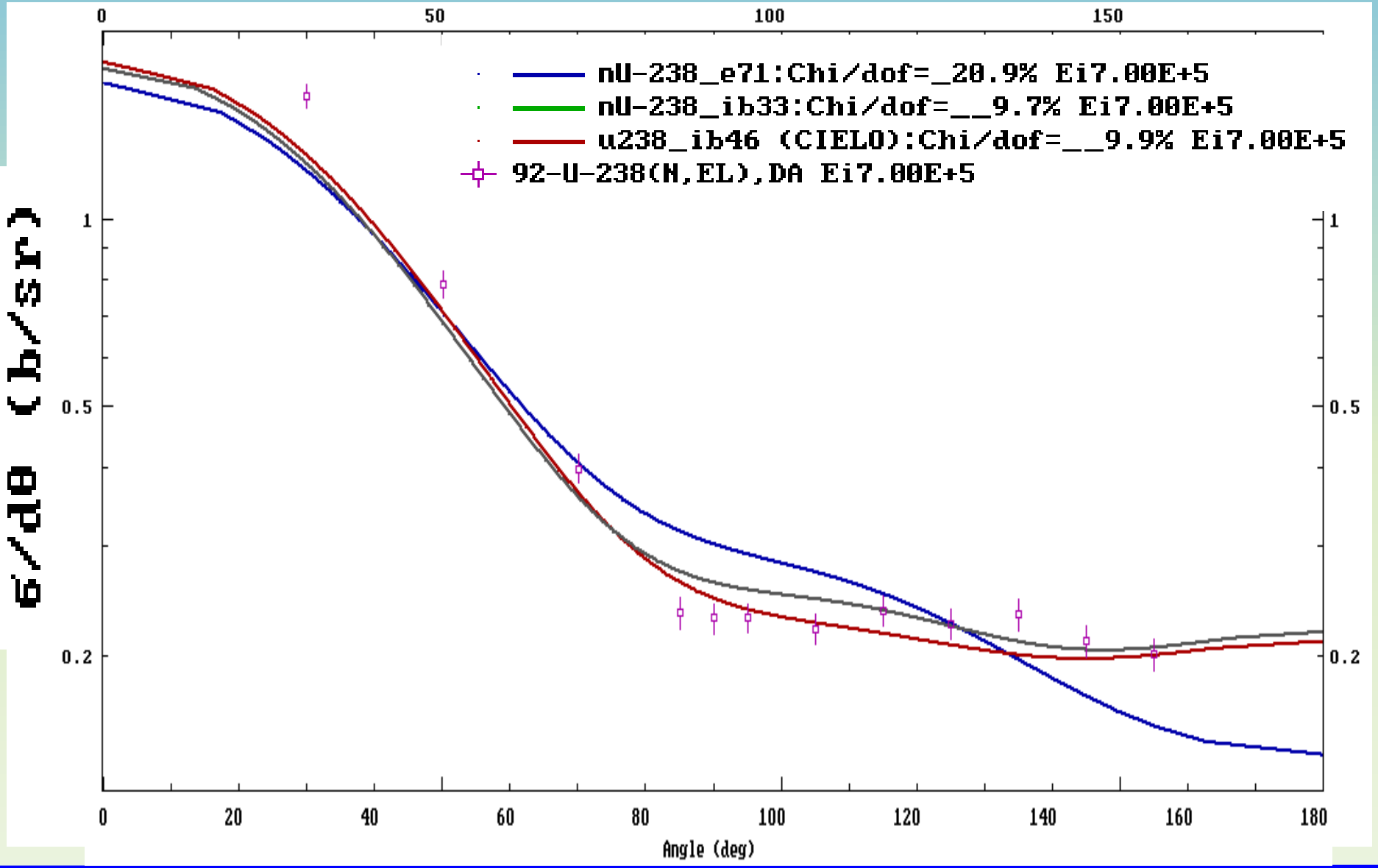
^{238}U(n,el), E_n=700 keV, ang. distributions



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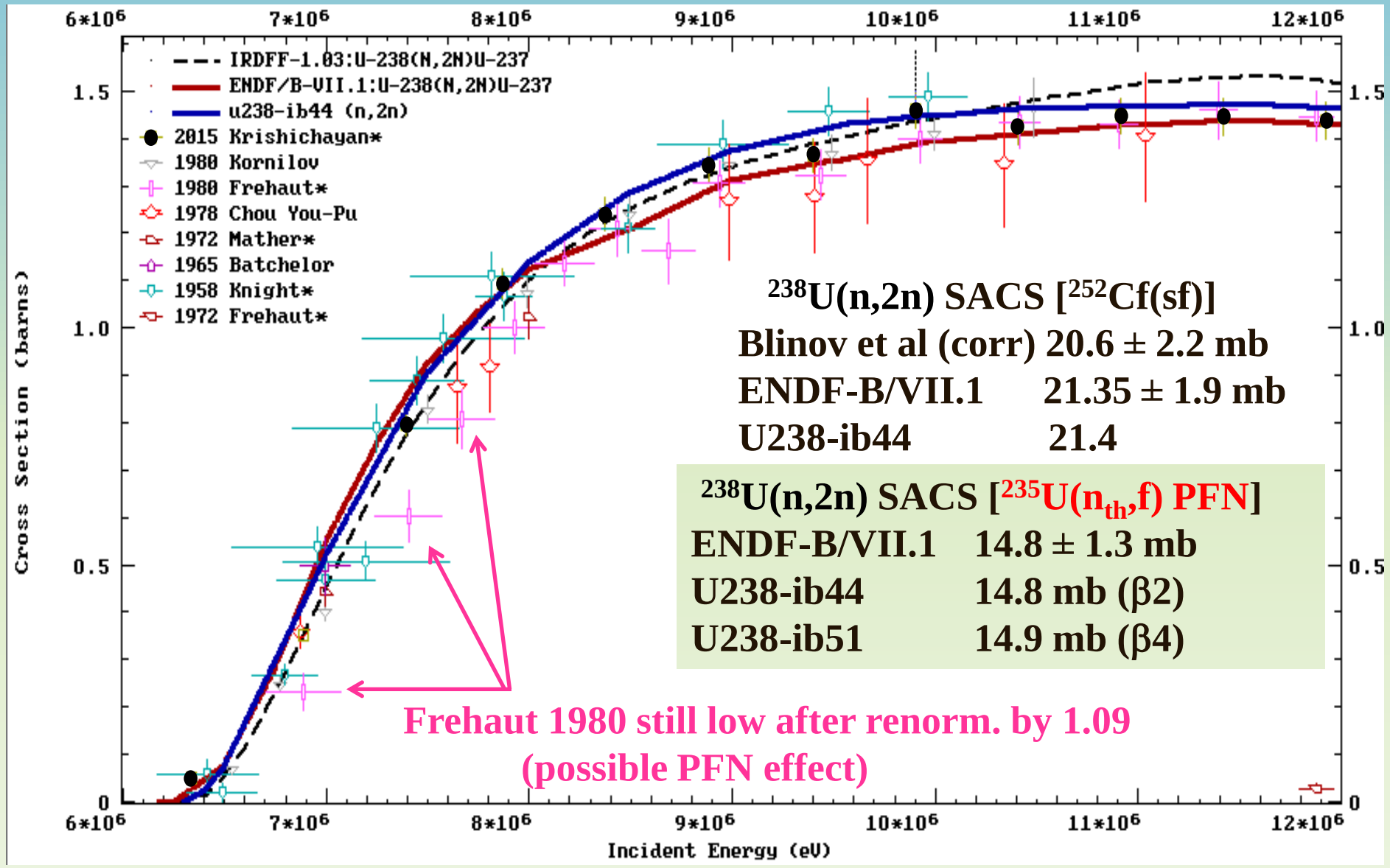
IAEA 60 Years Atoms for Peace and Development

σ(n,2n) vs TUNL and SACS



^{238}U(n,2n) SACS [^{252}Cf(sf)]

Blinov et al (corr) 20.6 ± 2.2 mb

ENDF-B/VII.1 21.35 ± 1.9 mb

U238-ib44 21.4

^{238}U(n,2n) SACS [^{235}U(n_{th},f) PFN]

ENDF-B/VII.1 14.8 ± 1.3 mb

U238-ib44 14.8 mb (β2)

U238-ib51 14.9 mb (β4)

Frehaut 1980 still low after renorm. by 1.09 (possible PFN effect)

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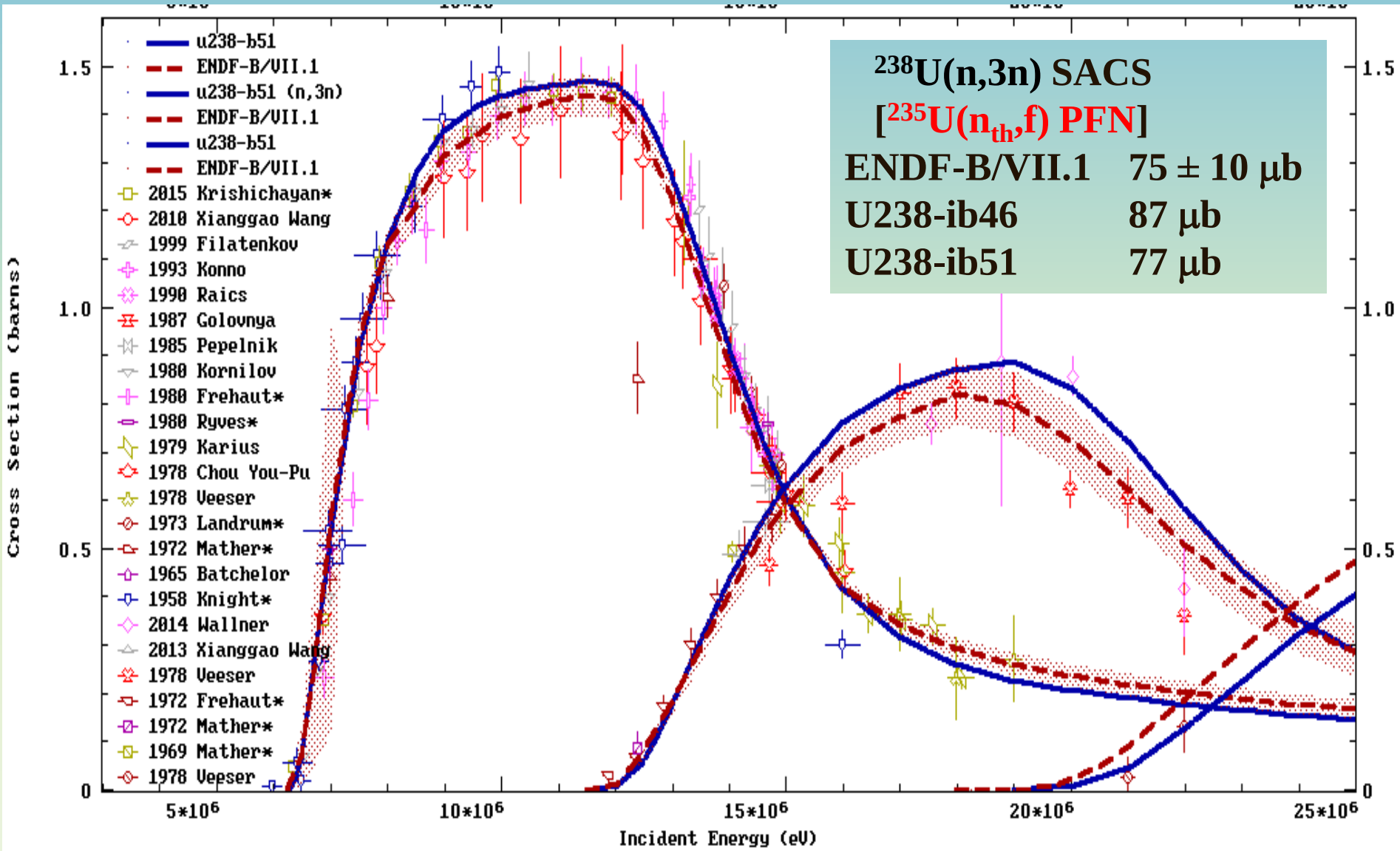
σ(n,2n), σ(n,3n), σ(n,4n)



^{238}U(n,3n) SACS
[^{235}U(n_{th},f) PFN]

ENDF-B/VII.1	75 ± 10 μb
U238-ib46	87 μb
U238-ib51	77 μb

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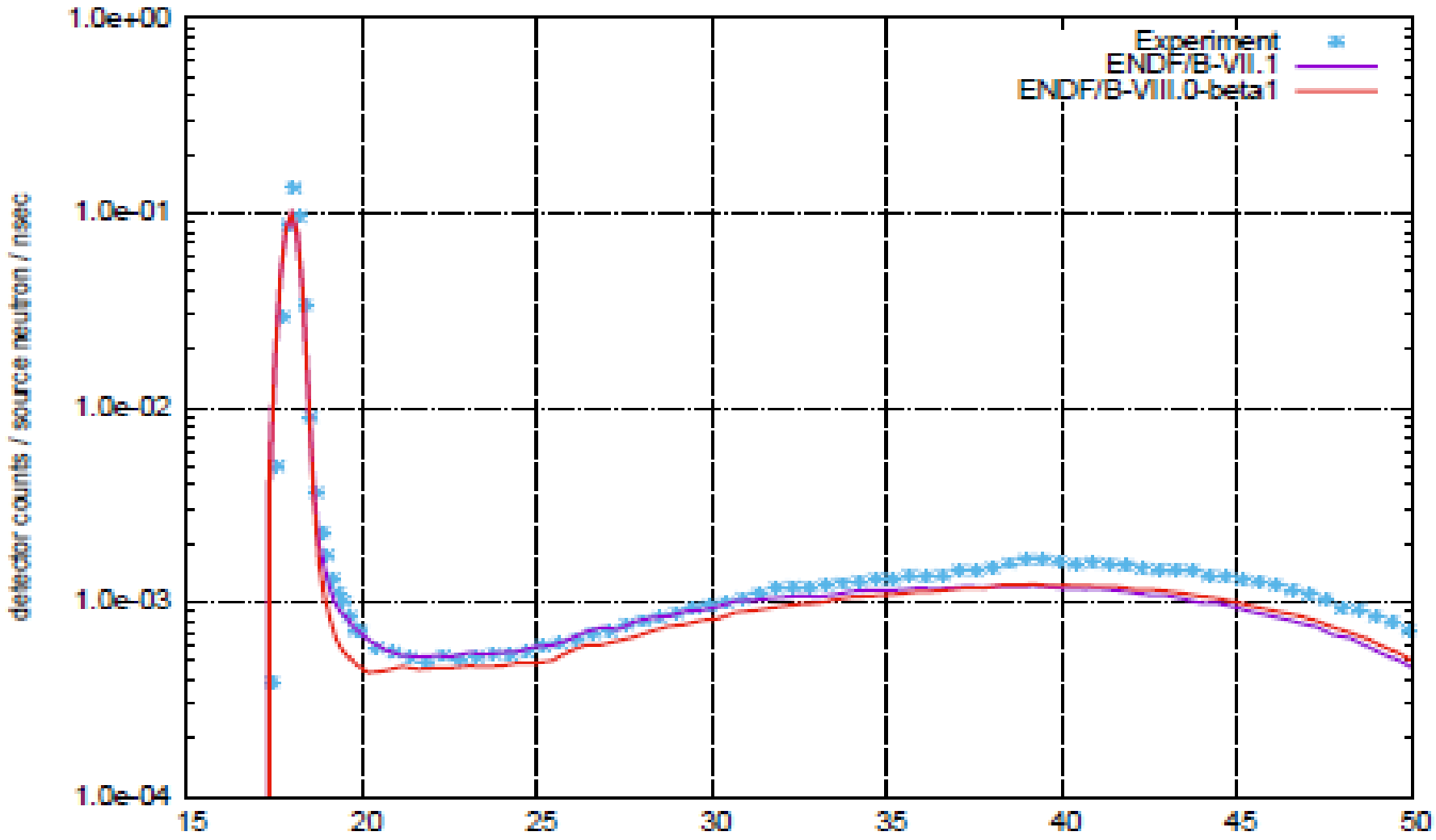
LLNL Pulsed Sphere (14MeV n + ^{238}U)



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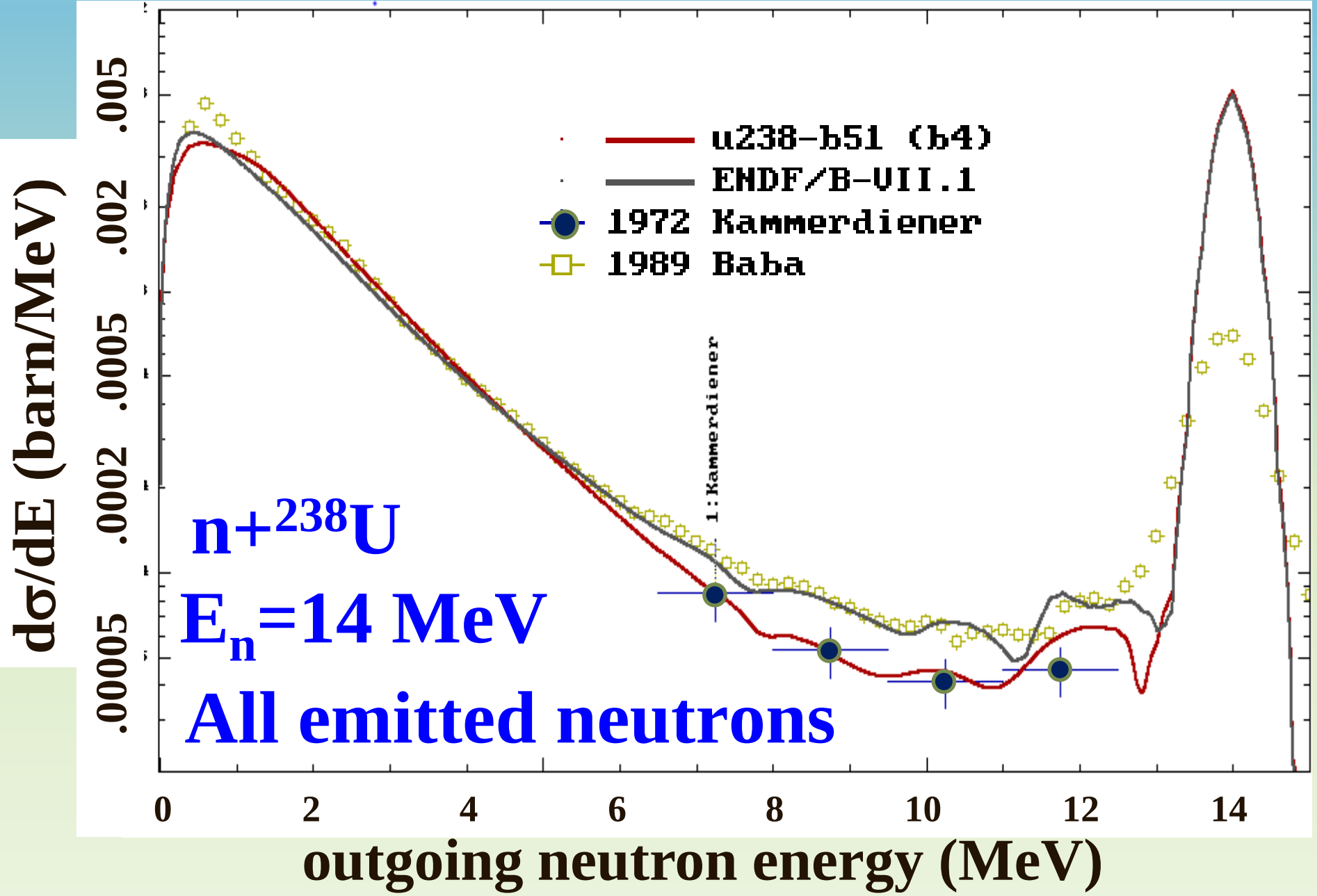

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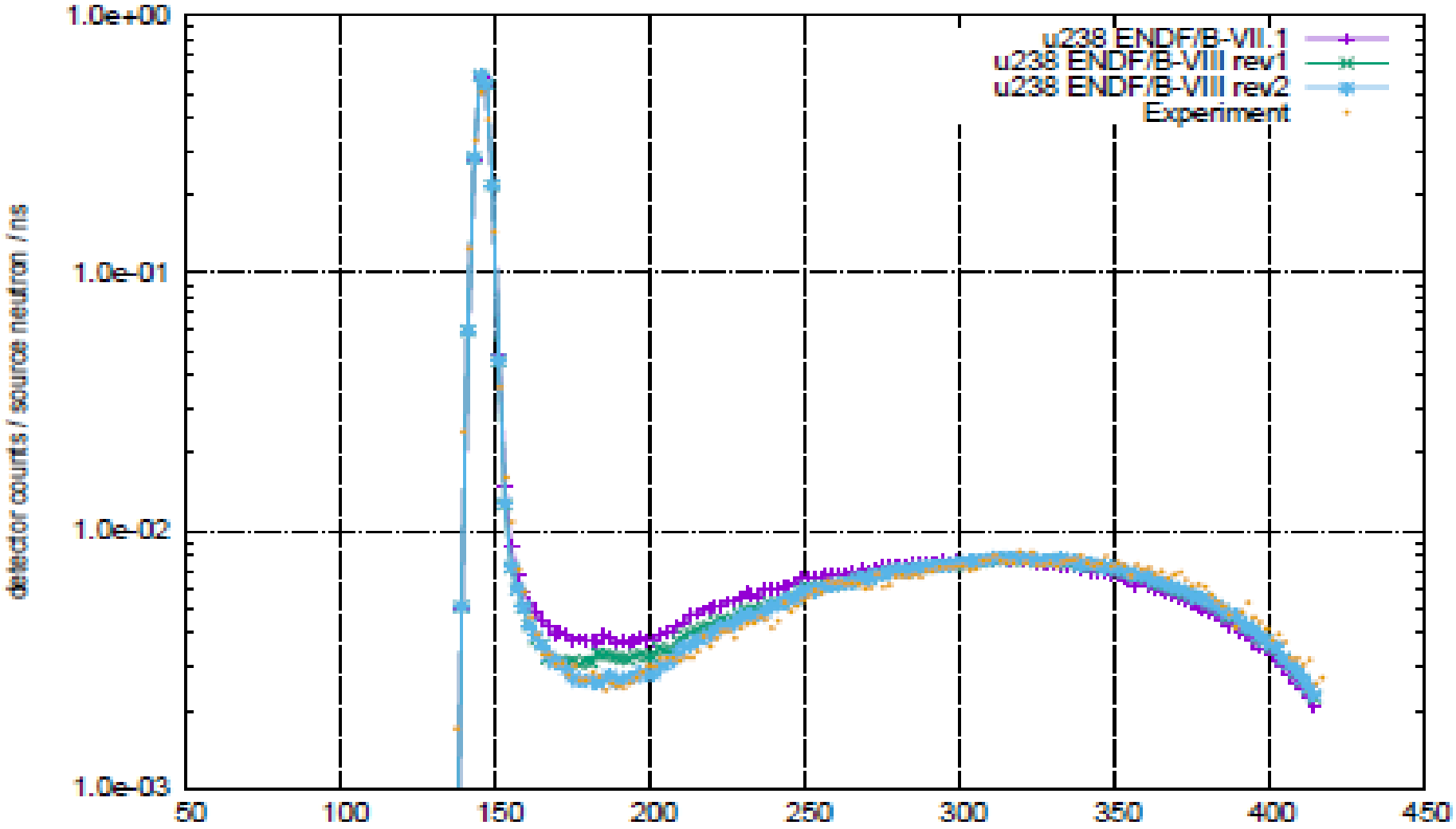

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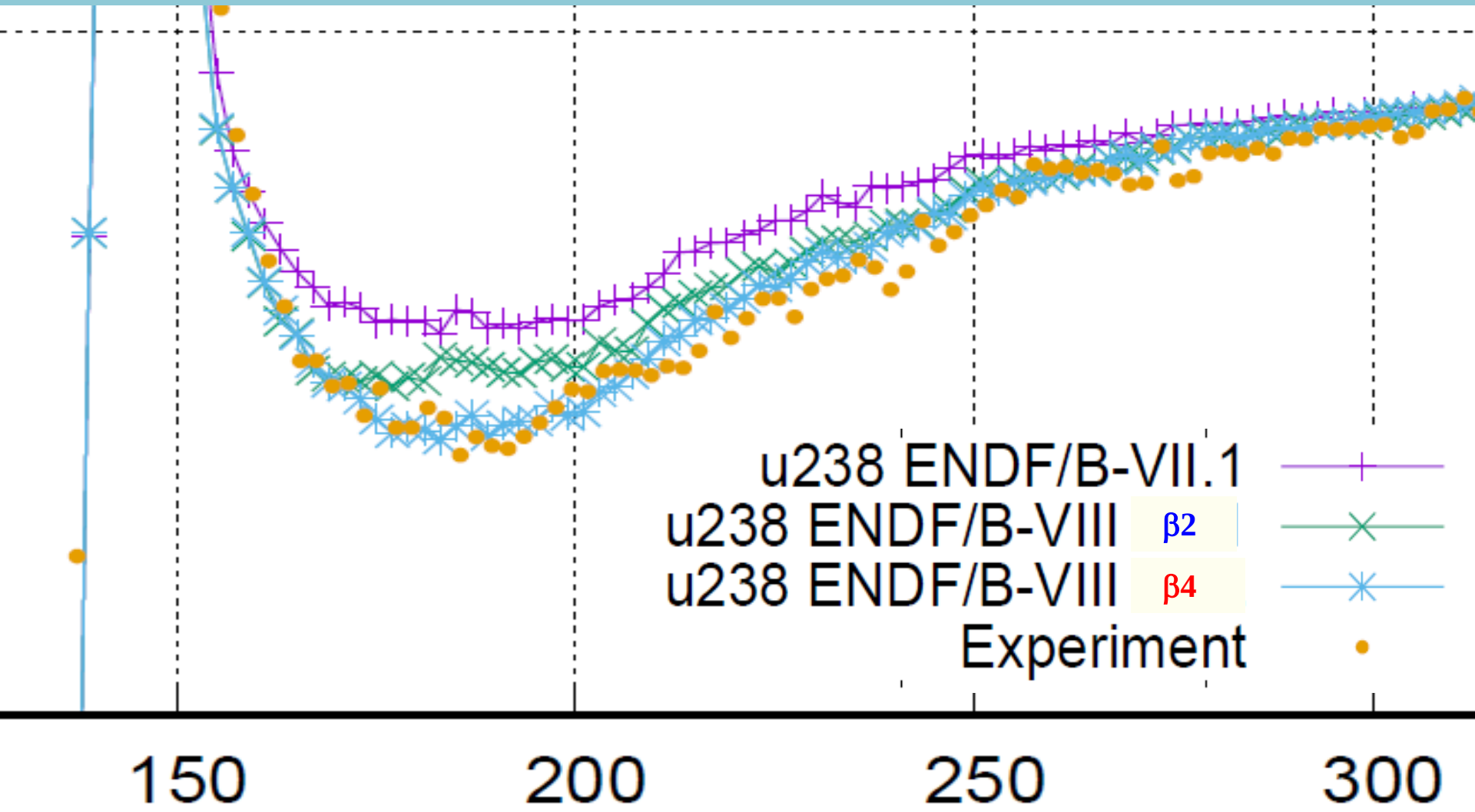

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Summary: ^{238}U IAEA CIELO

- RRR & URR: New Geel measurements and REFIT analysis
- Fission and capture from **Neutron Standards 2006/2016**
  (a non-model Bayesian evaluation based on EXP. DATA)
- PFNS adopted from Rising et al, 2013 (LAM)
- New fast evaluation with elastic/inelastic improvements
- RPI quasi-diff. data - a big help for fast region scattering
- CEA/EXCALIBUR feedback on (n,n')
- Better multiple neutron emission (CEA Cadarache feedback, LANL feedback, inelastic + diff. TUNL data)
- Collective cont. levels to describe Kammerdiener (& LPS)

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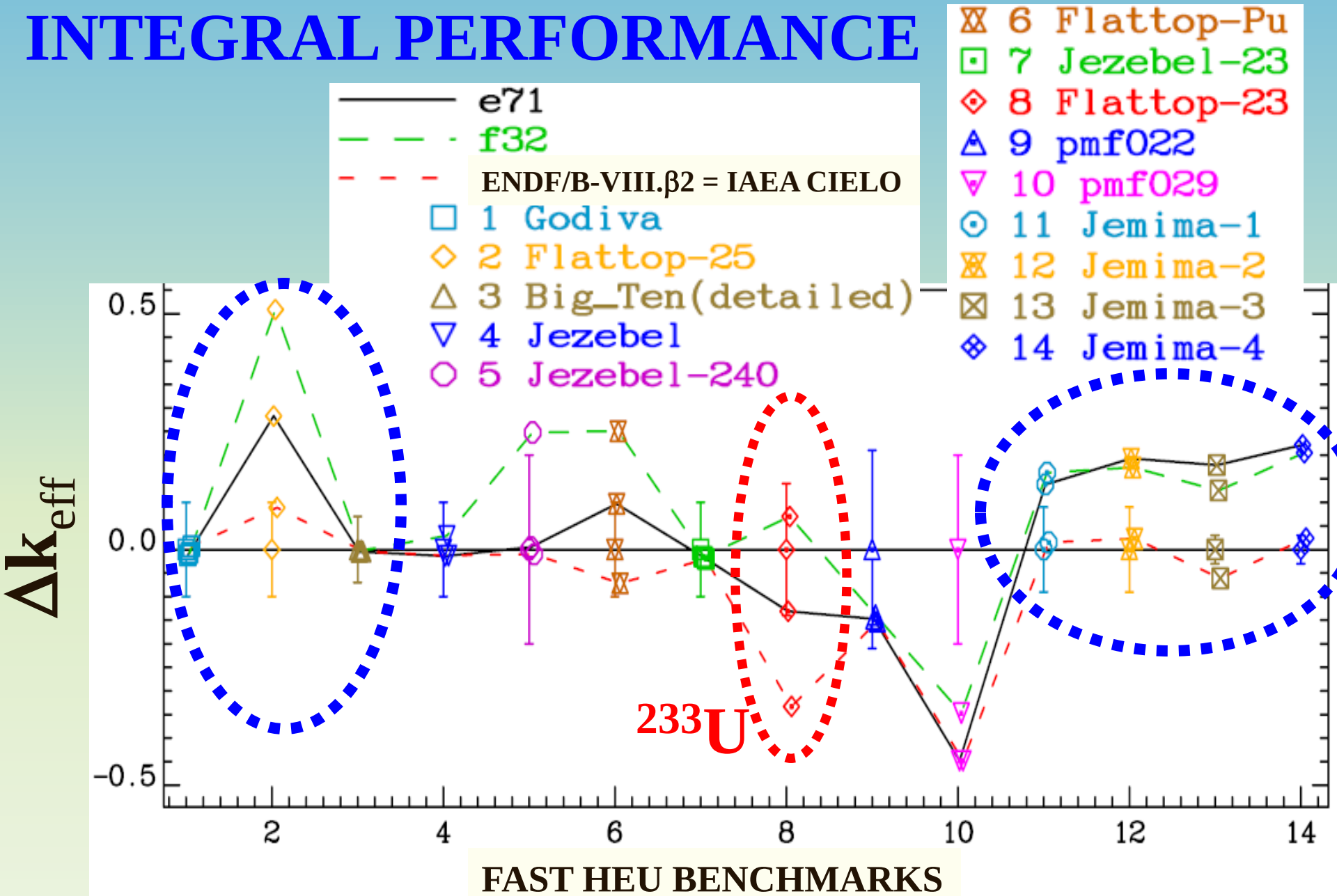
INTEGRAL PERFORMANCE



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Toward β4 (differences from β3=β2)

^{235}U target

- Updated resonance region considering NEW capture data from RPI and n_TOF (E_n<200eV) (and RR nubar ??)
- Fission from IAEA Standards + Weston fluct. (07-11-2016)
- Capture above 100 keV updated (Jandel, Wallner, Allmond)
- PFNS fast adopted from Neudecker et al. evaluation (2016)

^{238}U target

- Fission and capture from IAEA Standards (07-11-2016)
- Collective cont. levels to describe Kammerdiener (& LPS)

Nuclear Data Week, CSWEG 2016
14-16 November 2016, BNL, Upton, NY
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IAEA 60 Years Atoms for Peace and Development