IAEA CRP on PROMPT FISSION SPECTRA OF ACTINIDES

CRP Participants

- Vladimir Maslov
- Nengchuan Shu
- Franz-Josef Hambsch
- Stephan Oberstedt
- Benjamin Morillon
- Thierry Granier
- Olivier Serot
- K.-H.Schmidt
- Srinivasan Ganesan
- Aloks Saxena
- Takaaki Ohsawa
- Anabella C. Tudora
- Gennady Manturov
- Alexander S. Vorobyev
- Ivan Kodeli
- Patrick Talou
- Denise Neudecker
- Ramona Vogt
- Nikolay Kornilov

Roberto Capote, IAEA Nuclear Data Section, Austria

IAEA
International Atomic Energy Agency

INDC(NDS)-0541
Distr. AI+MN+NM

INDC International Nuclear Data Committee

Summary Report

Consultants' Meeting on

Prompt Fission Neutron Spectra of Major Actinides

R. Capote Noy, IAEA Nuclear Data Section, Austria
V. Maslov, Joint Institute for Power and Nuclear Research – Sosny, Belarus
E. Bauge, Commissariat à l'énergie atomique, France
T. Ohsawa, Kinki University, Japan
A. Vorobyev, Petersburg Nuclear Physics Institute, Russia
M.B. Chadwick, Los Alamos National Laboratory, USA
S. Oberstedt, Institute for Reference Materials and Measurements, Belgium

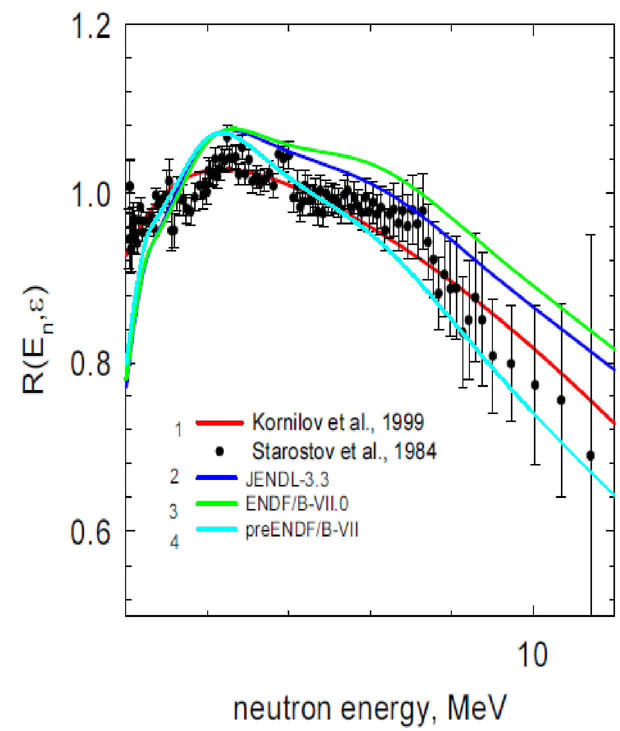

FIG.1b $^{235}U + n(th)$: Ratio of PFNS to the Maxwellian distribution at fixed temperature in linear energy scale.

RC et al, Technical report INDC(NDS)-0541 (2008)
http://www-nds.iaea.org/publications/indc/indc-nds-0541.pdf

#	CRP Meeting Dates	Place	Project Officer	Title
1	21-24 October 2013	Vienna, Austria	R. Capote Noy	3rd RCM of the CRP on Prompt Fission Neutron Spectra of Actinides
2	13-16 December 2011	Vienna, Austria	R. Capote Noy	2nd RCM of the CRP on Prompt Fission Neutron Spectra of Major Actinides
3	6-9 April 2010	Vienna, Austria	R. Capote Noy	1st RCM of the CRP on Prompt Fission Neutron Spectra of Major Actinides
4	24-27 November 2008	Vienna, Austria	R. Capote Noy et al	CM on Prompt Fission Neutron Spectra of Major Actinides
5	------------------------	-------------------	----------------------	---
6	1-5 July 2013	Vienna, Austria	S. Simakov	1st RCM of the CRP on International Reactor Dosimetry Library for Fission and Fusion (IRDFF) Testing and Validation
7	8-12 July 2013	Vienna, Austria	R. Capote Noy	TM on Toward a New Evaluation of Neutron Standards
8	13-15 October 2010	Vienna, Austria	R. Capote Noy	CM on International Cross Section Standards: Extending and Updating

Deadline for new evaluations: 06/2014

Technical Document : 12/2014

Expected publication: Summer 2015-January 2016

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EXPERIMENTAL DATA

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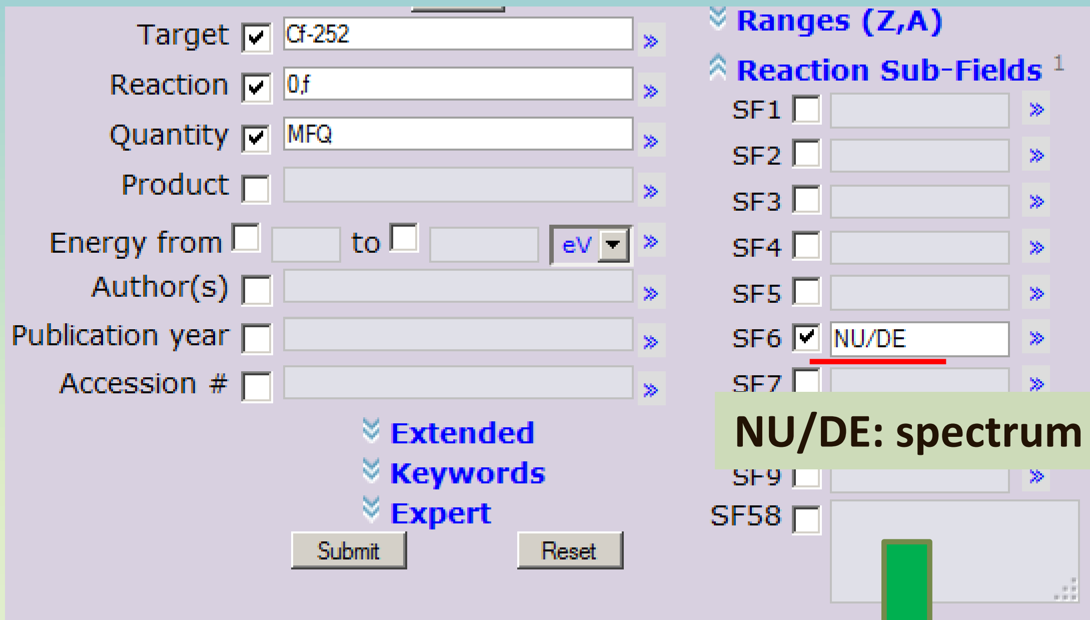
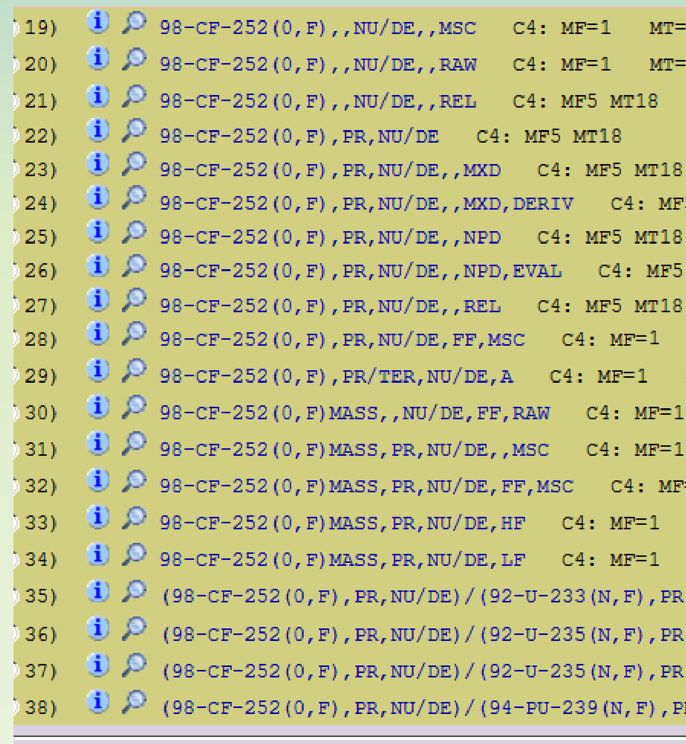
Better Access to PFNS Data Sets in EXFOR

Use of “Reaction Sub-Fields” is useful for narrowing.



NU/DE: spectrum

rather short list



Revised EXP + unc/corr

https://www-nds.iaea.org/pfns/expdata/Pronyaev/

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Recent Addition of PFNS data to EXFOR (I)

NRDC has put a high priority to add PFNS to EXFOR for the CRP.

New entries from new experiments (data from authors)

X4#	Author	Lab.	Reference	Nuclide	En
14290	S. Noda	LANL	PRC 83(2011)034604	U235, Pu239	1 – 8 MeV
14350	A. Enqvist	LANL	PRC 86(2012)064605	U235	0.5-600 MeV
31692	N. Kornilov	KFKI	NSE 165(2010)117 NSE 168(2011)73	U235	100 K

(Nikolay Kornilov kindly answered to various questions from NDS during compilation.)

New entries from old experiments (data digitized from figures)

X4#	Author	Lab.	Reference	Nuclide	En
14278	V.P. Poenitz	ANL	82ANTWERP p465	Cf252	Spon
23175	C. Budtz-Jørgensen	IRMM	NPA 490(1988)307	Cf252	Spon

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Recent Addition of PFNS data to EXFOR (II)

New entries from old experiments (data from authors)

X4#	Author	Lab.	Reference	Nuclide	En
41582	Uy.I. Kolevatov	IPPE	FEI-913 (1979)	Cf252	Spon
41589	L.V. Drapchinsky	KRI	ISTC-1828-01	Am241	3 – 15 MeV
				Am243	3 – 15 MeV
				Cm243	Thermal

Updated entries with data newly received from authors

X4#	Author	Lab.	Reference	Nuclide	En
13982	P. Staples	LANL	NPA 591(1995)41	U235, Pu239	0.5-3.5 MeV
41340	G.S. Boykov	KRI	97Trieste p1310	Cm244, Cm246	Spon
41421	B. Gerasimenko	KRI	2002Tsukuba p362	Pu240, Pu242	Spon
				Am242m, Cm245	Thermal

Red nuclide: Only one experimental work for PFNS is in EXFOR.

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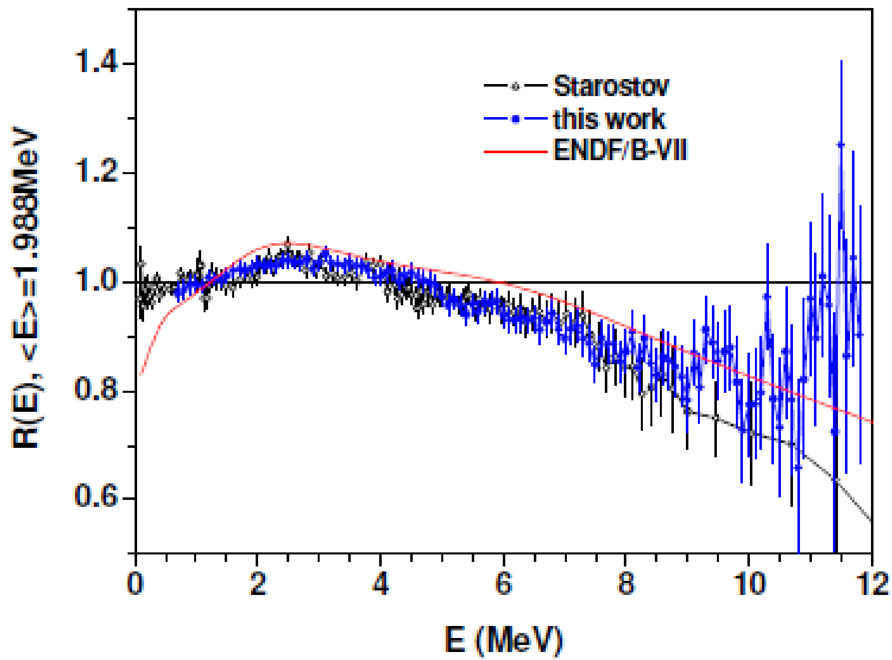
Comparison to Literature Data

Ratio to Maxwellian



Our Data

Starostov et al. 1984 (EXFOR)

ENDF/B-VII

- Starostov et al.: Gas-scintillation-ionization detector + ^{235}U, IC, Reactor, relative to ^{252}Cf
- **Excellent agreement** with Starostov et al. over full energy range

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Individual detector results

Average parameters of the PFNS for the reaction 235U(nth,f)			
Detector No.	Angle, degree	<E>, MeV	ν-prompt (Neutrons / fission)
1	72	1.987	2.491
2	102	1.990	2.548
3	132	1.987	2.378

$< \nu > = 2.47 \pm 0.08$ ENDF/B-VII: $< \nu > = 2.421$

$< E > = 1.988 \pm 0.010$ MeV ENDF/B-VII: $< E > = 2.03$ MeV

- Detectors agree well with each other
- < E> agrees with nearly all literature data
- Mean Energy in ENDF/B-VII is higher than all measurements

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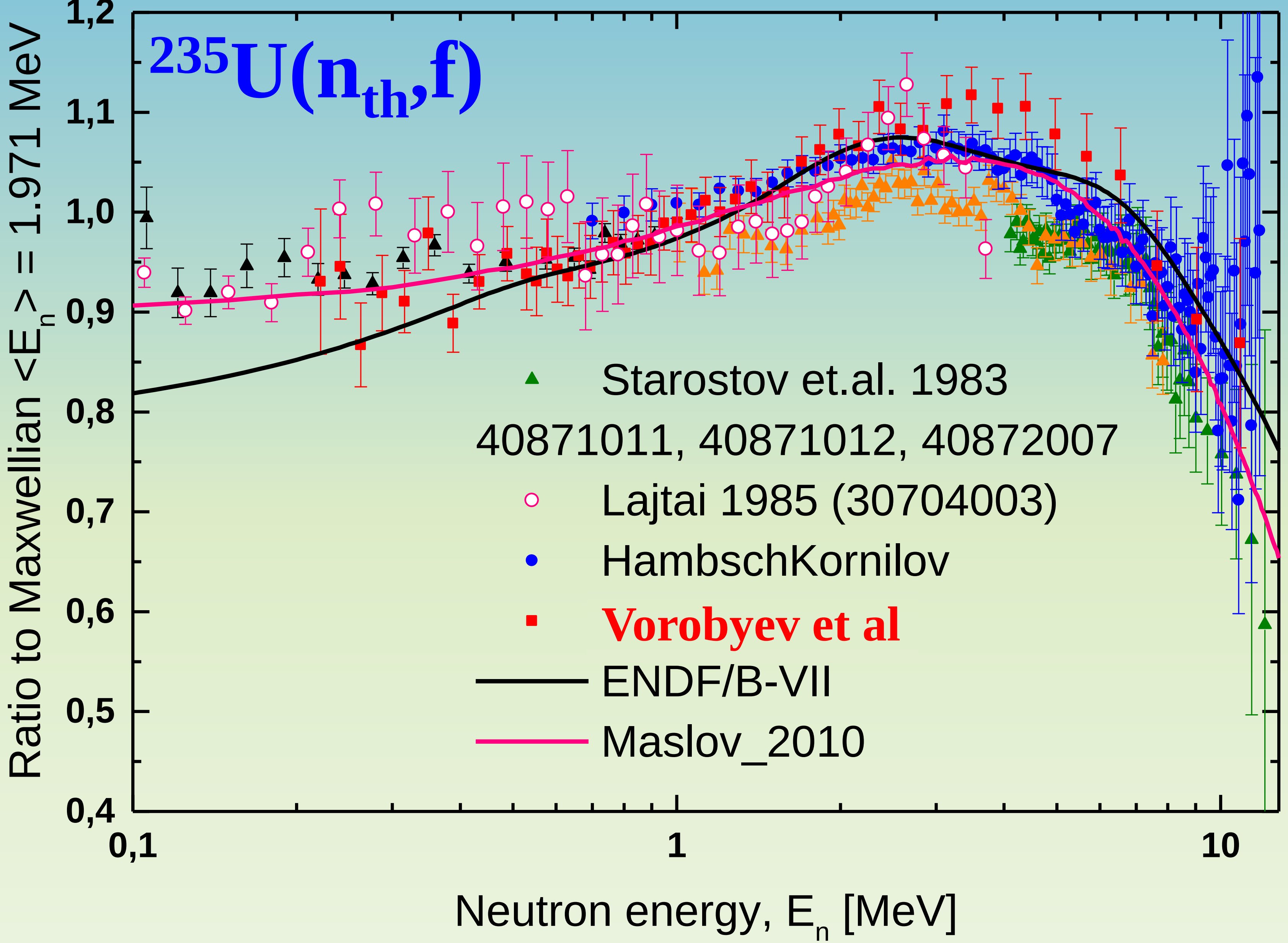

NEMEA7/CIELO workshop, JRC-IRMM
Geel, Belgium, 5-8 November 2013

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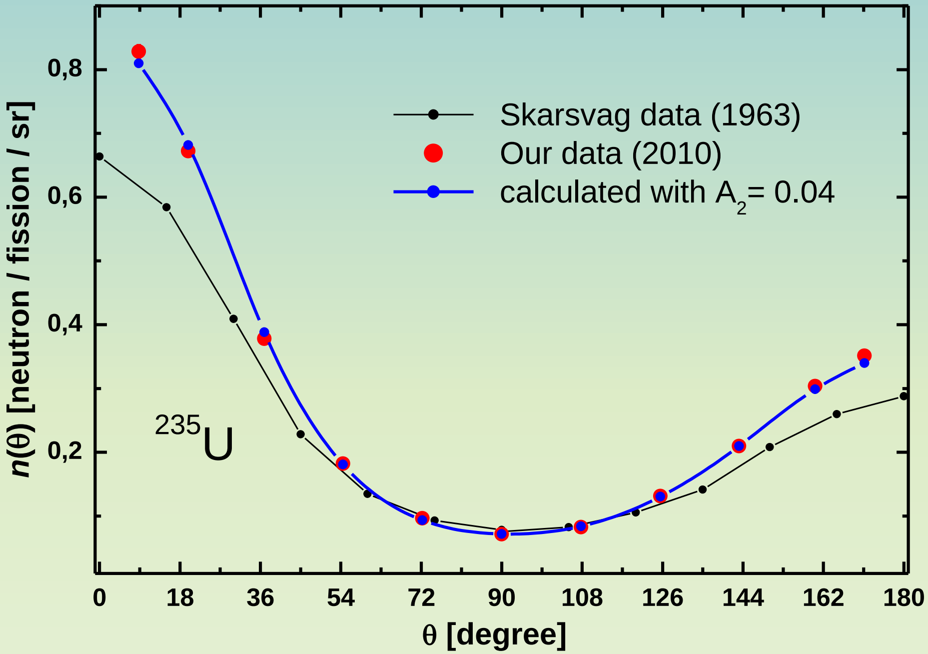
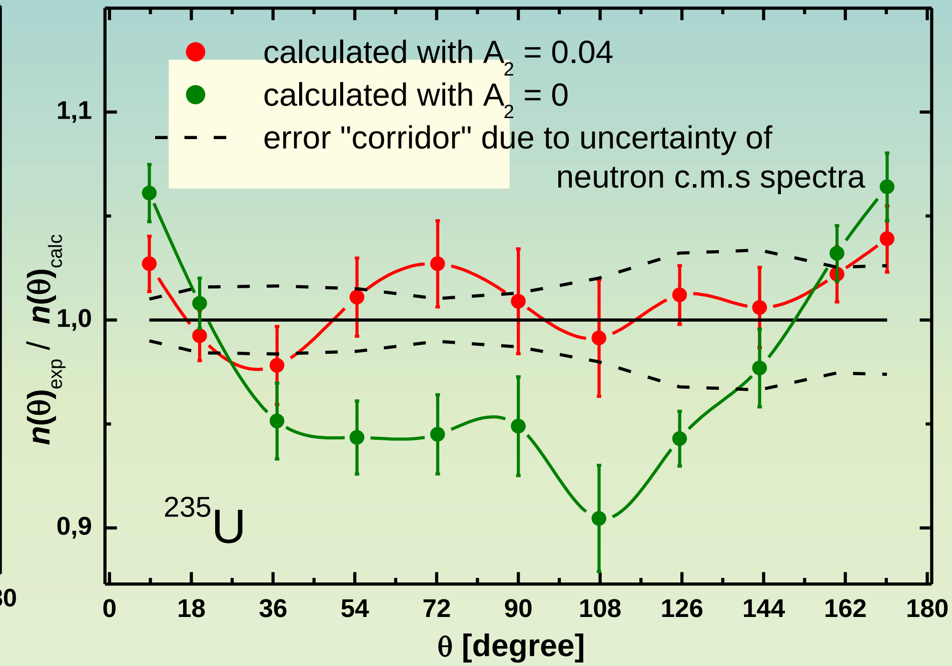
Results:

yield of prompt neutrons as a function of angle relative to the direction of light fission fragment in the lab. system





- **Introduction of anisotropy with A_2 = 0.04 into the calculation improves agreement with obtained experimental data. At that, there is some surplus of measured yield over calculated at angles near 90^0.**

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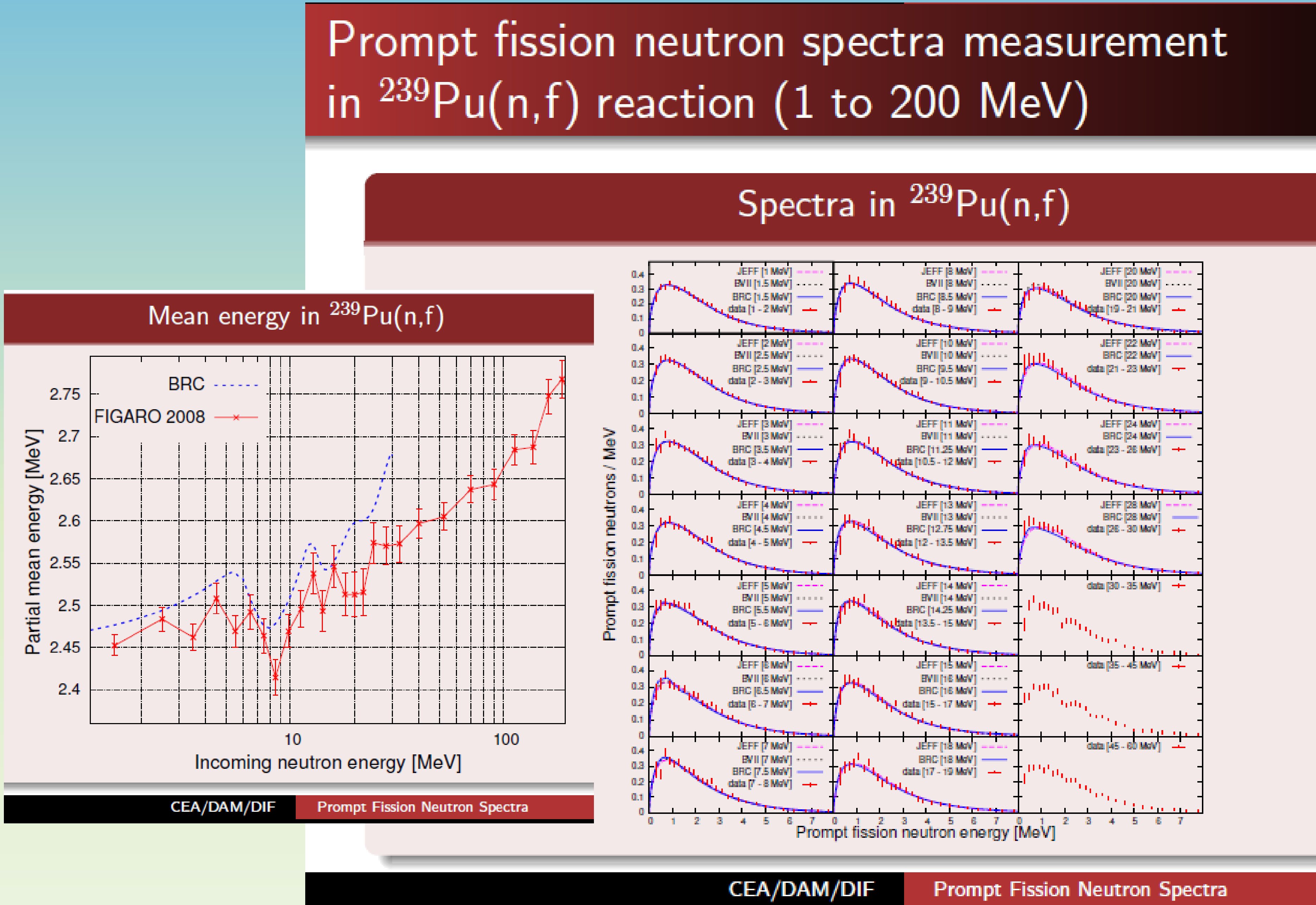

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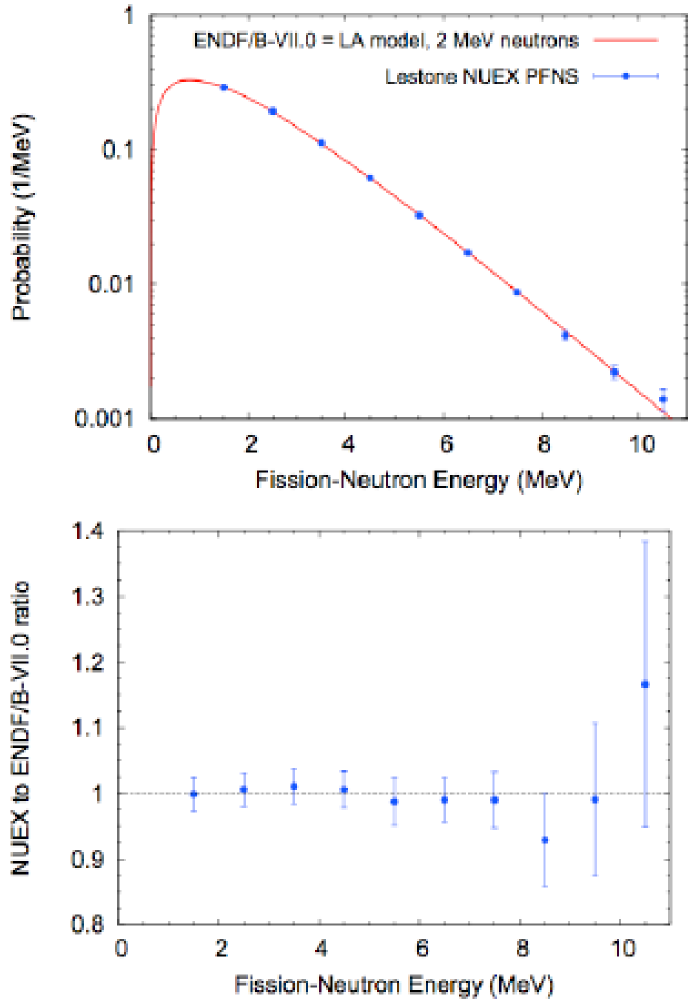
NUEX Data
Underground Explosion

- J.P. Lestone, LA-UR-03167 (2011)
- Very high neutron fluence → very good statistics
- Shape measurement
- 8% systematic uncertainty on absolute magnitude
- 2 MeV n+^{239}Pu PFNS
- **Remarkable agreement between LA model and NUEX data!**
- Outgoing energy range limited
  - E_{min}=1.5 MeV; no data.
  - E_{max}=11 MeV; difficulties above due to down scatter of 14 MeV neutrons.



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IAEA CRP on PFNS of Actinides, 2nd Meeting, Vienna, Dec. 12-16, 2011

NNSA

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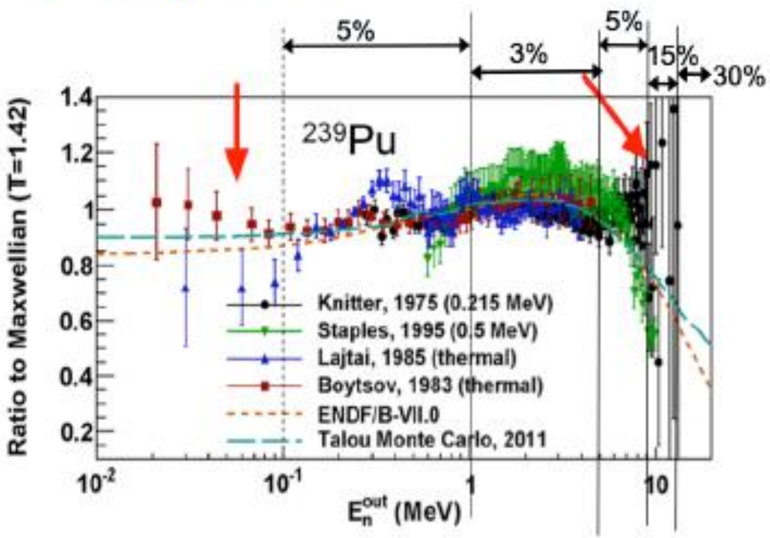
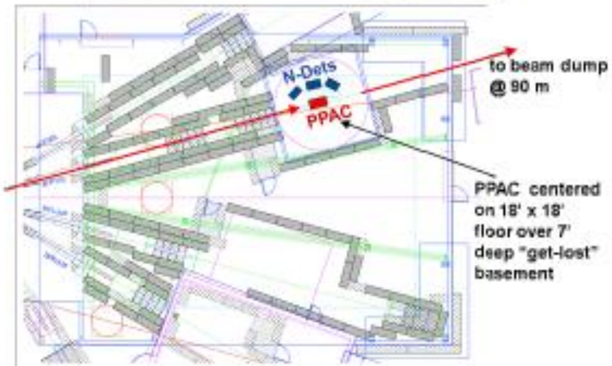
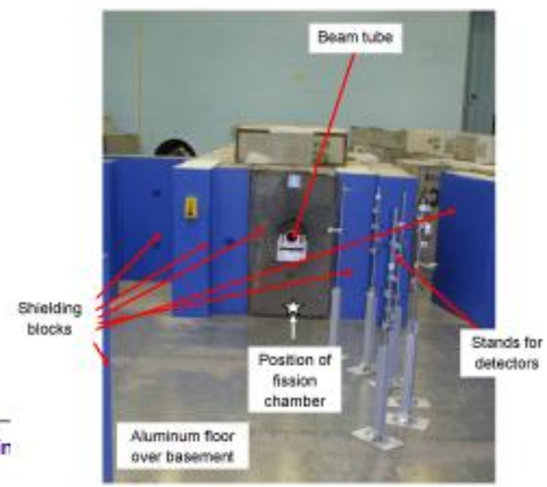
Status of Chi-Nu Experimental Efforts

Courtesy of Robert C. Haight & Chi-Nu Team

- ^{239}Pu PFNS:
  - Significant discrepancies observed at both ends of the spectrum
  - Measurements at WNR, LANSCE
  - Target accuracies:







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IAEA CRP on PFNS of Actinides, Third Meetin

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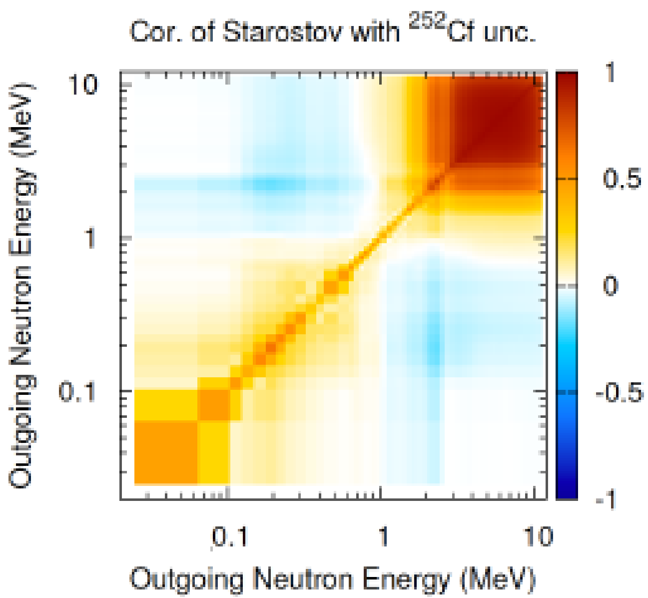
Estimation of Experimental Covariance Matrices

- "Compilation of ^{239}Pu PFNS Experimental Covariance Matrices," D.Neudecker, T.Taddeucci *et al.*, **LA-UR-13-24743** (2013).
- **Thorough review of experimental data & uncertainties by:**
  - Knitter, 1975, E_{inc}=0.215 MeV
  - Staples, 1995, E_{inc}=0.5, 1.5, 2.5 and 3.5 MeV
  - Lajtai, 1985, thermal
  - Starostov, 1985, thermal
  - Belov, 1968, thermal *(discarded)*
  - Batenkov, 2004, thermal *(discarded)*
- **Sources of experimental uncertainty:**
  - Statistics; Background; Detector efficiency; Time resolution; Energy calibration; Multiple scattering; Angular distortion; …



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EVALUATIONS

List of new PFNS evaluations

#	Main author (Lab)	Nuclei	Comments	Link
1	P. Talou (LANL, USA)	U232-240; Pu239-240	incl. covariances	LANL_NSE_PFNS_Evals
2	R. Vogt (LLNL, USA)	U235, Pu239	incl. covariances	Files
3	N. Kornilov (Ohio Univ., USA)	U235 thermal	Scale method	U235th-SCALE
4	N. Shu (CIAE, China)	U235 th-5 MeV	Semi-empirical	PFNS-235U
5	A. Tudora (Romania)	U233, Th232, U234	PbP Los Alamos	Files
6	V.M. Maslov (JIENR, Belorussia)	U235, U238, etc	Maslov method	Files

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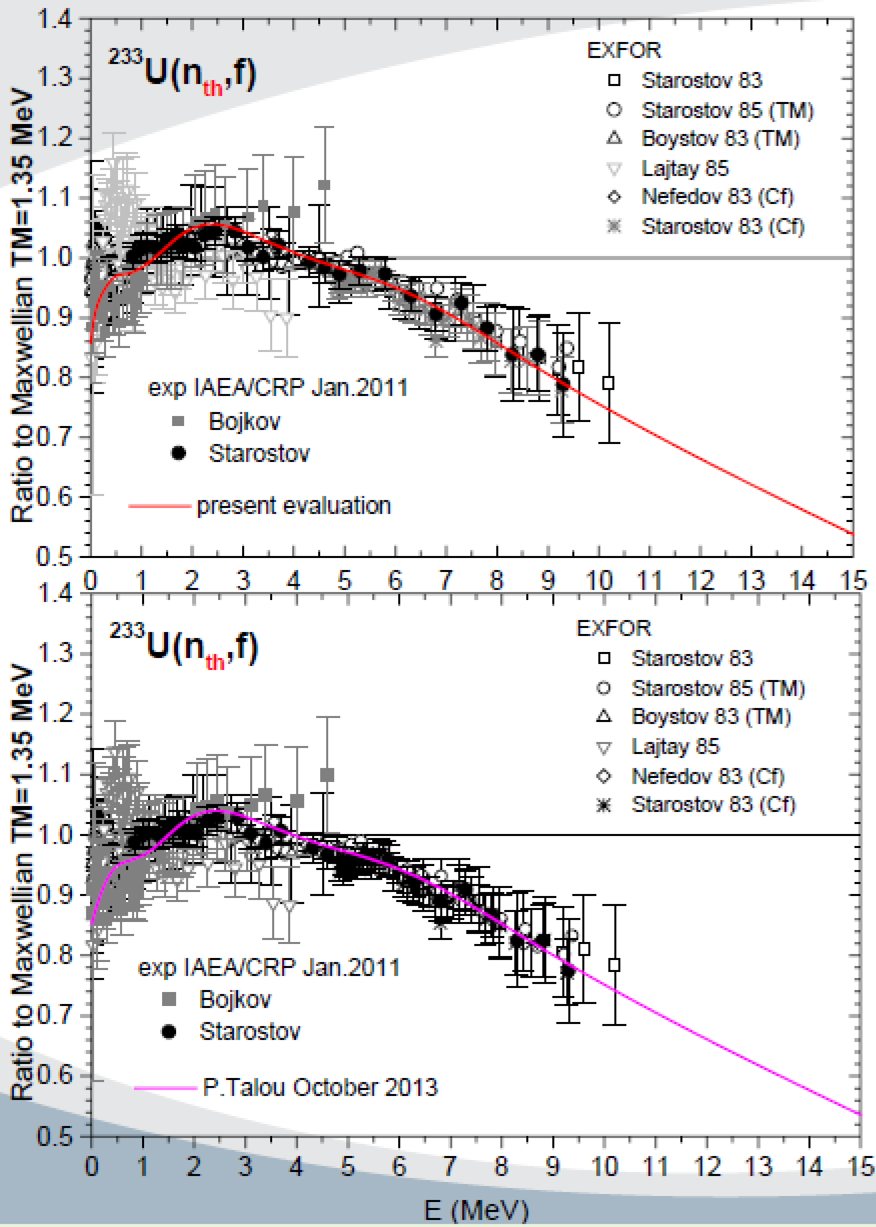
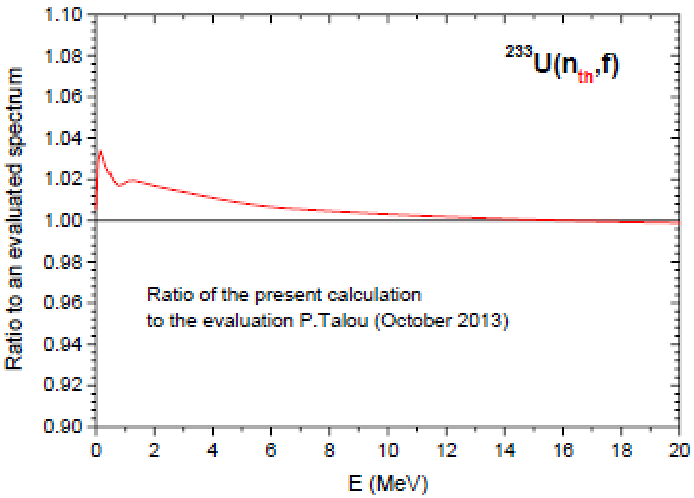
^{233}U(n,f) – PbP calculation



Comparison with the evaluation of P.Talou (October 3, 2013)

the two spectrum evaluations at thermal En are very close to each other



Ratio of the calculated PFNS to the Evaluation of Talou

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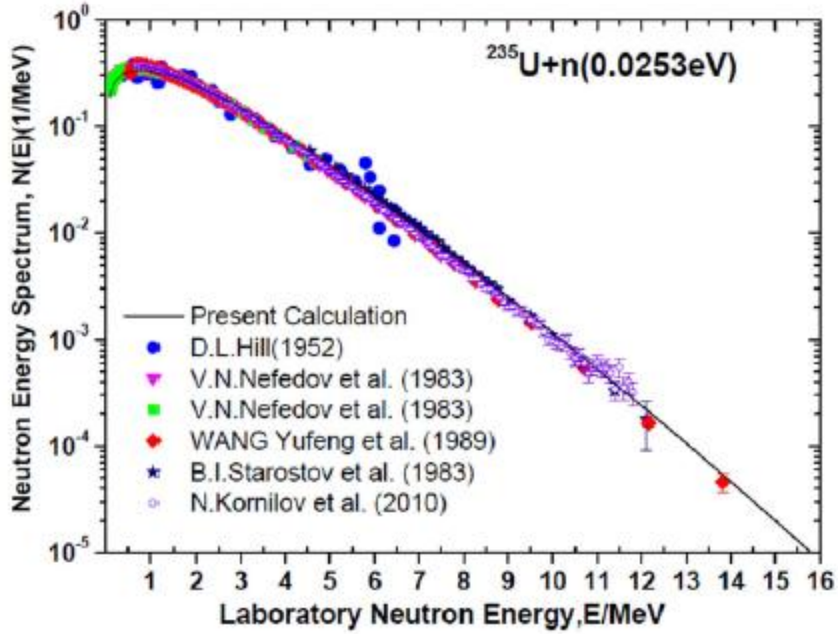
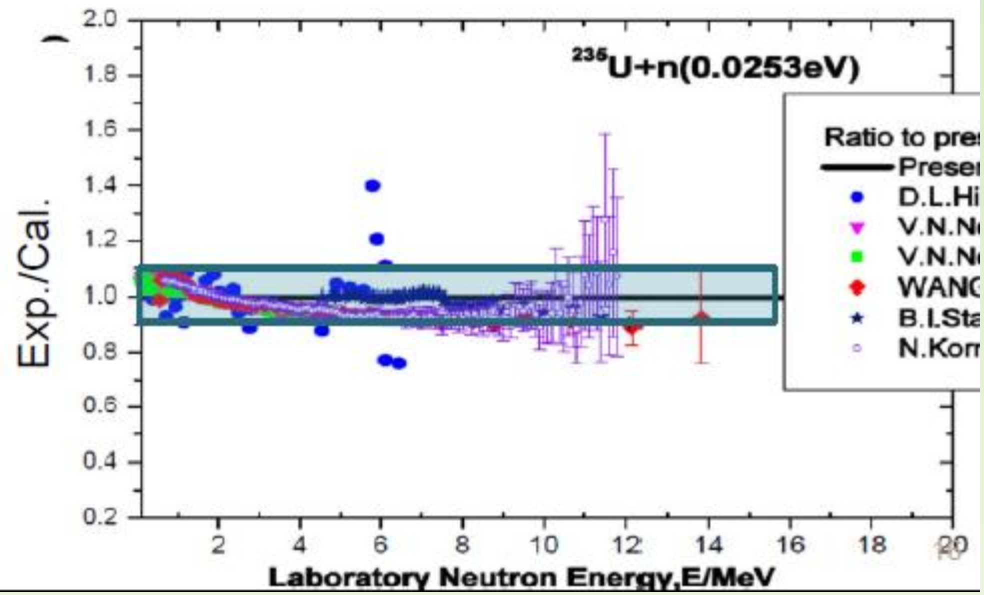
3. Results

n+^{235}U
thermal

Up: the PFNS
lower: ratio E/C.

It shows that most residuals are less than 10% compare to exp data.





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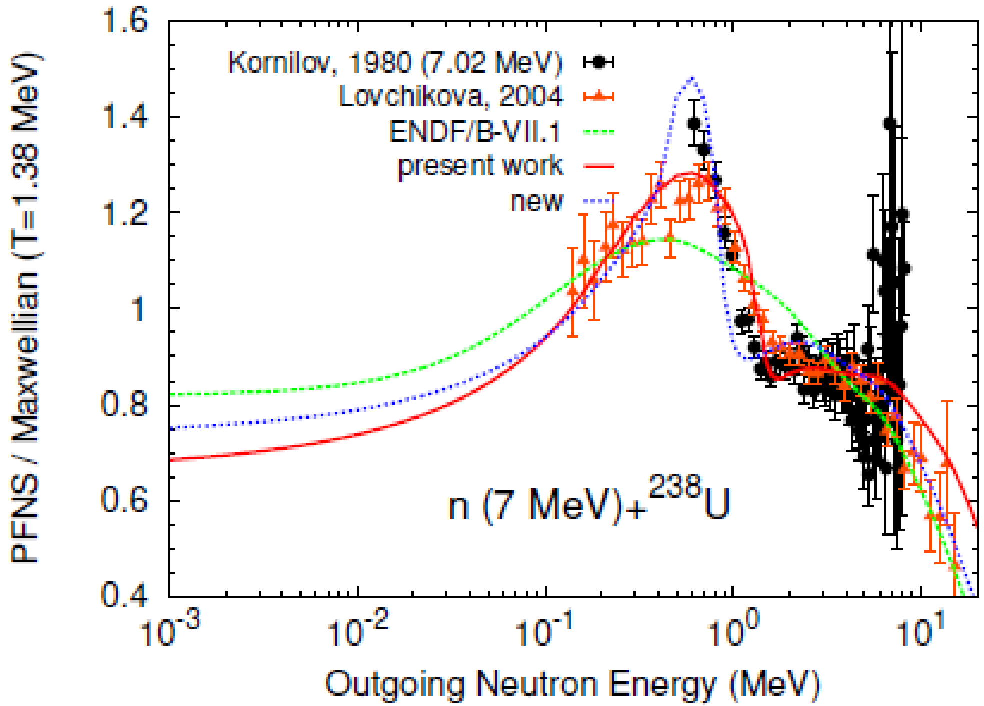
LAM calculations at higher energies

n+^{238}U

- **Exact agreement with ENDF/B-VII at low energies**
- **Big changes near multi-chance thresholds**



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IAEA CRP on PFNS of Actinides, Third Meeting, Vienna, Oct. 22-24, 2013

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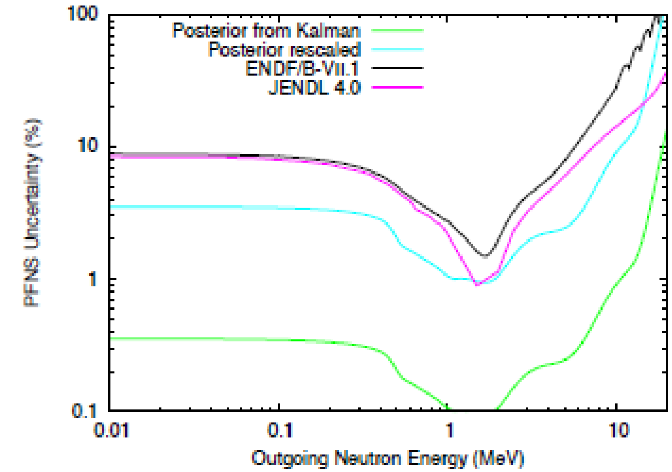
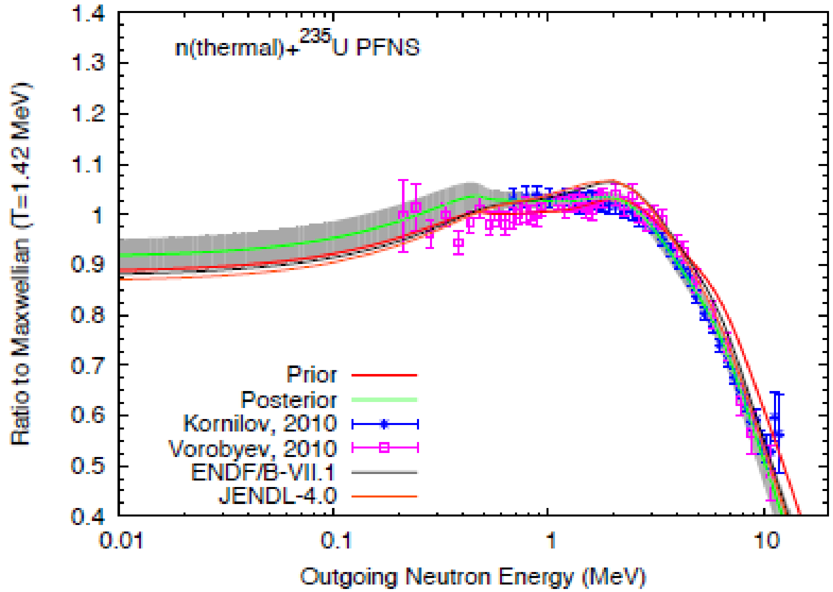
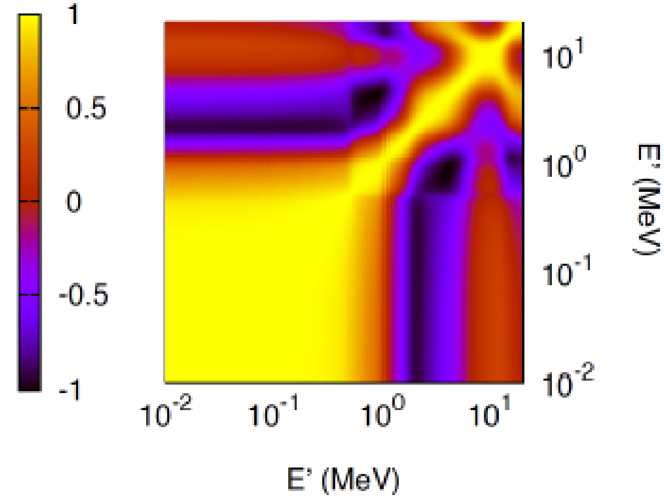
$n_{th}+^{235}U$







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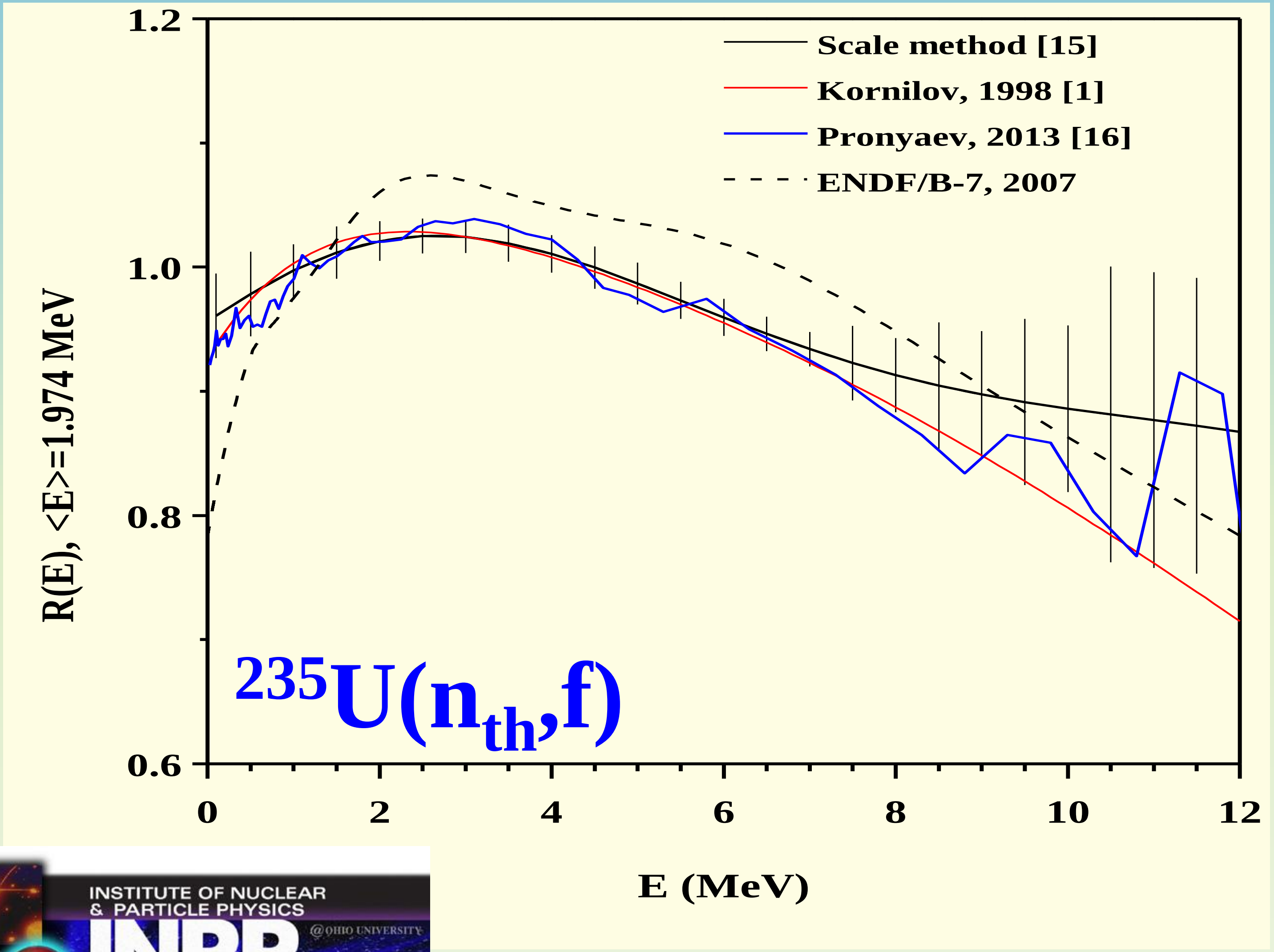
Contradiction between evaluations



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MONTE CARLO MODELS

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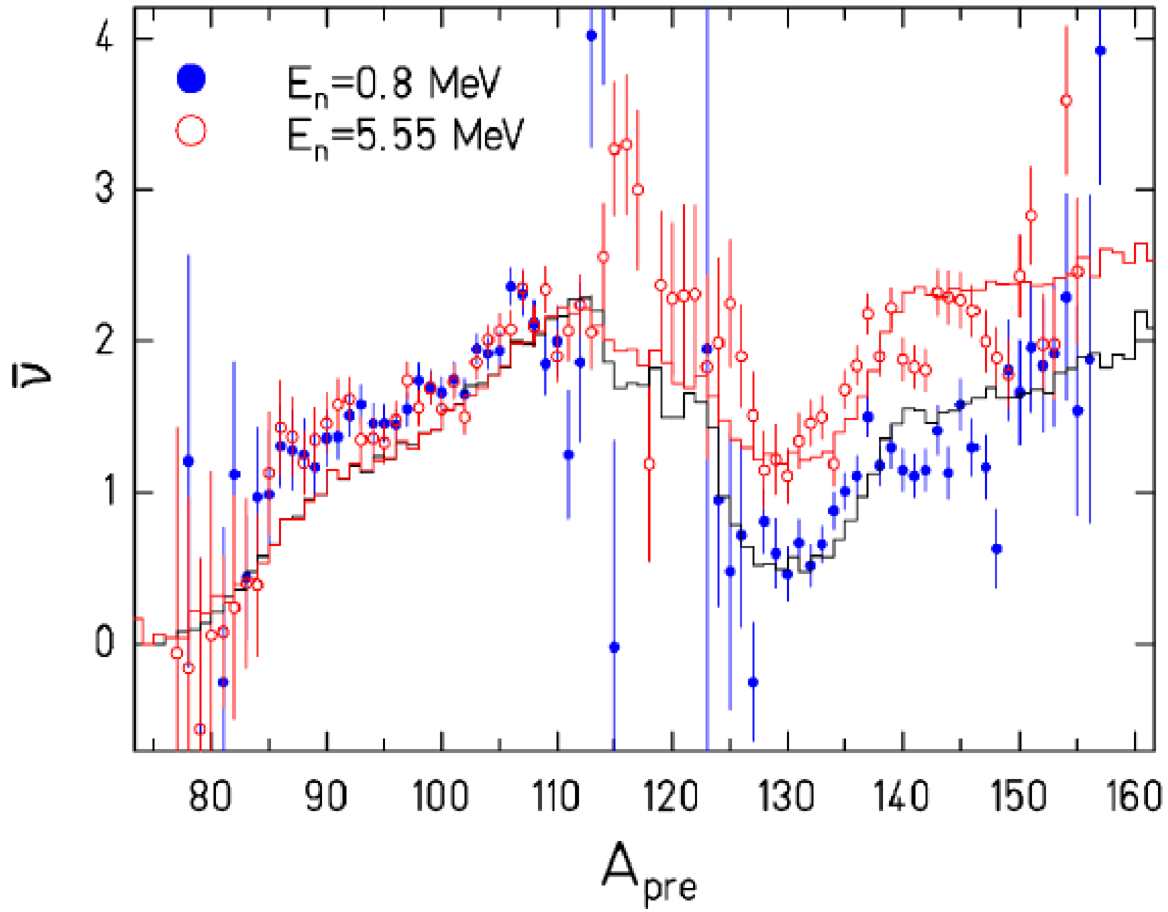

K.-H. Schmidt
Energy sorting
GEF code

Figure 5. Measured prompt-neutron yield in ^{237}Np(n,f) as a function of pre-neutron mass at two different incident-neutron energies [32] (data points) in comparison with the result of the GEF code [8] (histograms).

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COMMON BENCHMARK LIST

Pu-239:

- Jezebel (PU-MET-FAST-001): bare sphere of 95 at.% Pu-239 metal, 4.5 at.% Pu-240, 6.385-cm radius
- Flattop-Pu (PU-MET-FAST-006): about 20-cm natural U reflected 94 wt.% Pu-239 sphere, 4.533-cm radius;

U-233:

- Jezebel-23 (U233-MET-FAST-001): bare about 98.1 % U-233 sphere, 5.983-cm radius;
- Flat-top 23 (U233-MET-FAST-006): about 20-cm natural U reflected 98 at.% U-233 sphere, 4.2-cm radius;

U-235:

- Flattop-25 (HEU-MET-FAST-028): about 20-cm natural U reflected 93 wt.% U-235 sphere, 6.116-cm radius;
- Godiva (HEU-MET-FAST-001)

U-238:

- Bigten (IEU-MET-FAST-007): cylinder of 10% enriched U with depleted U-reflector, radius 41.91-cm, height 96.428-cm.

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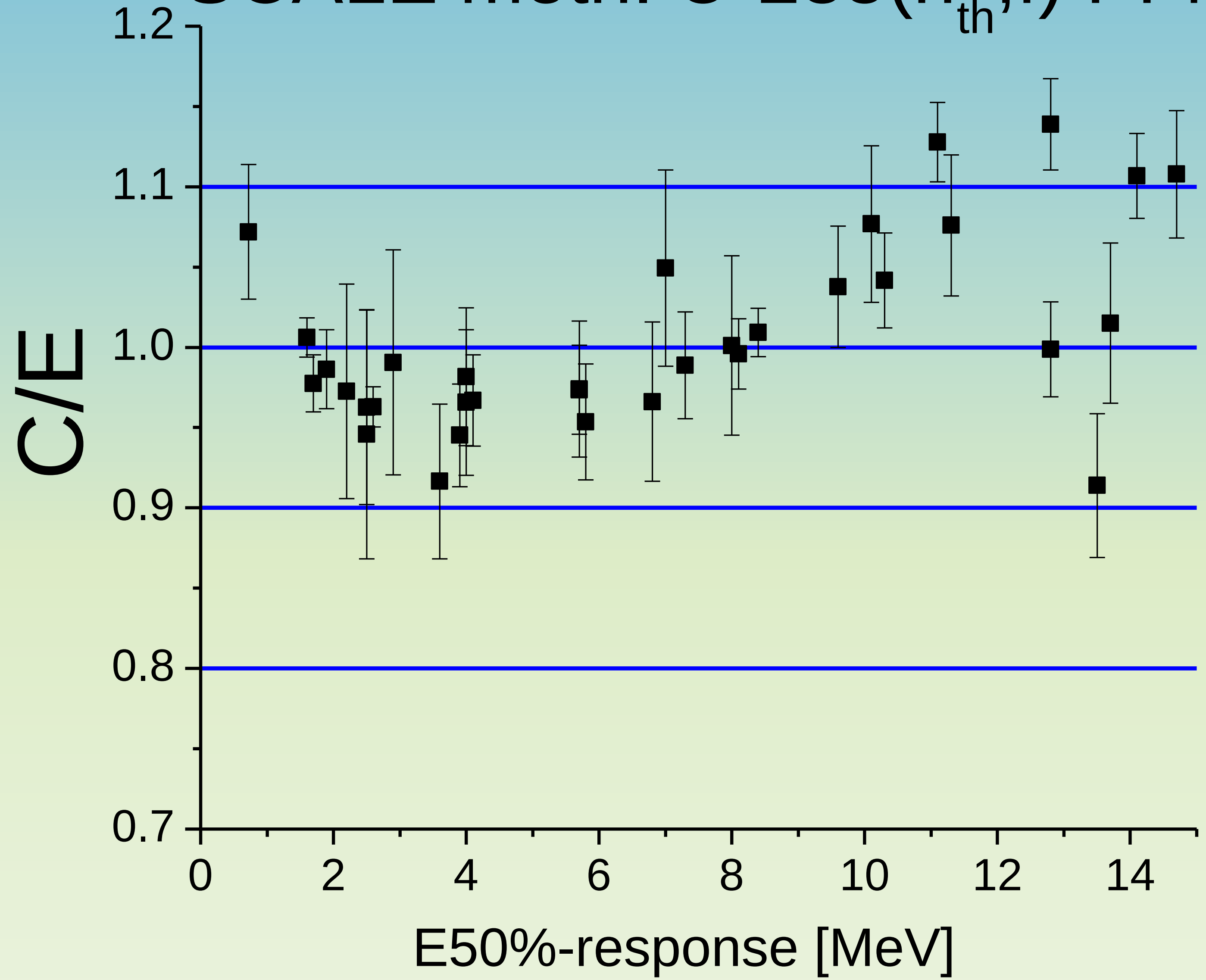
SCALE meth. U-235(n_{th},f) PFNS



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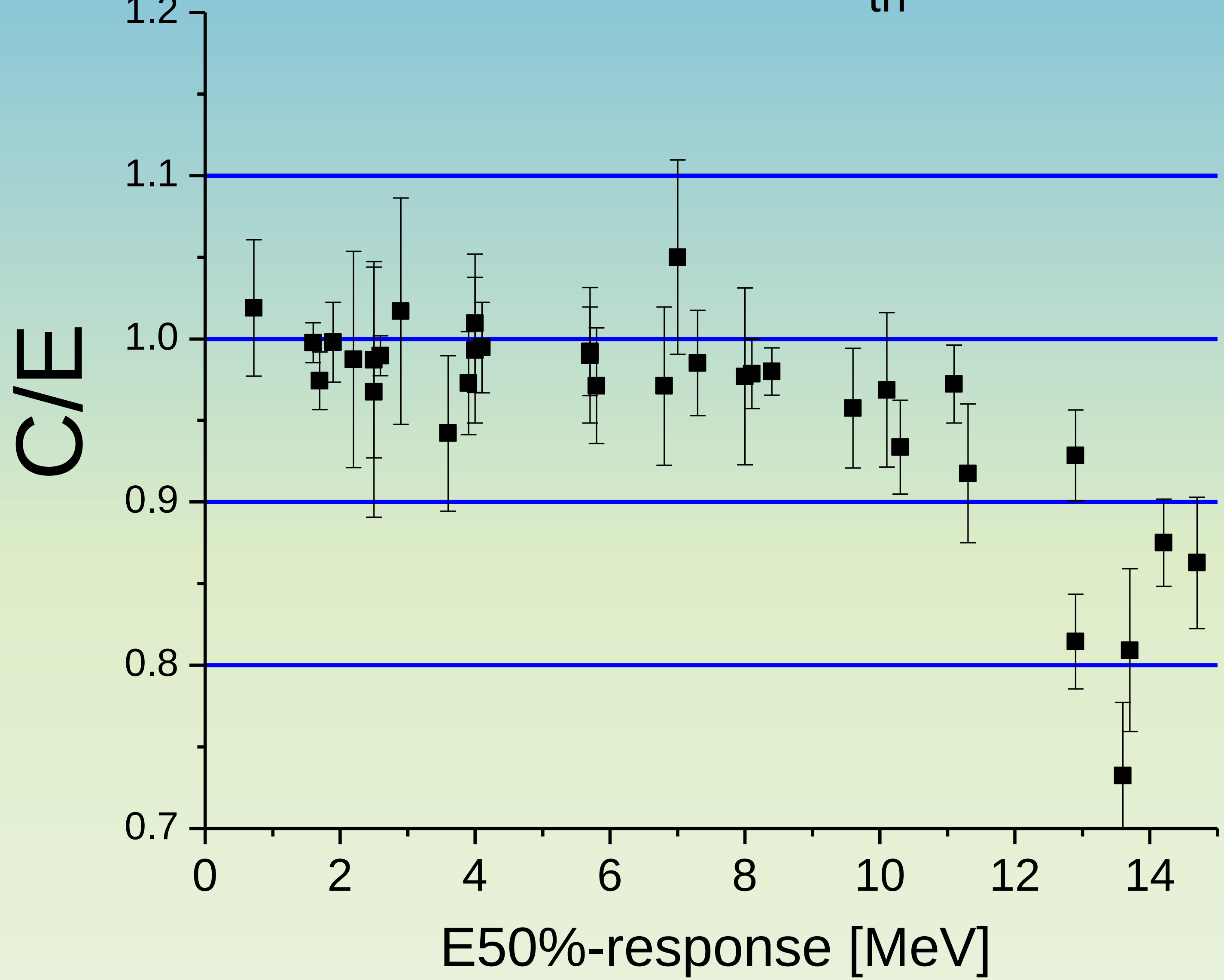
JENDL-4 U-235(n_{th},f) PFNS



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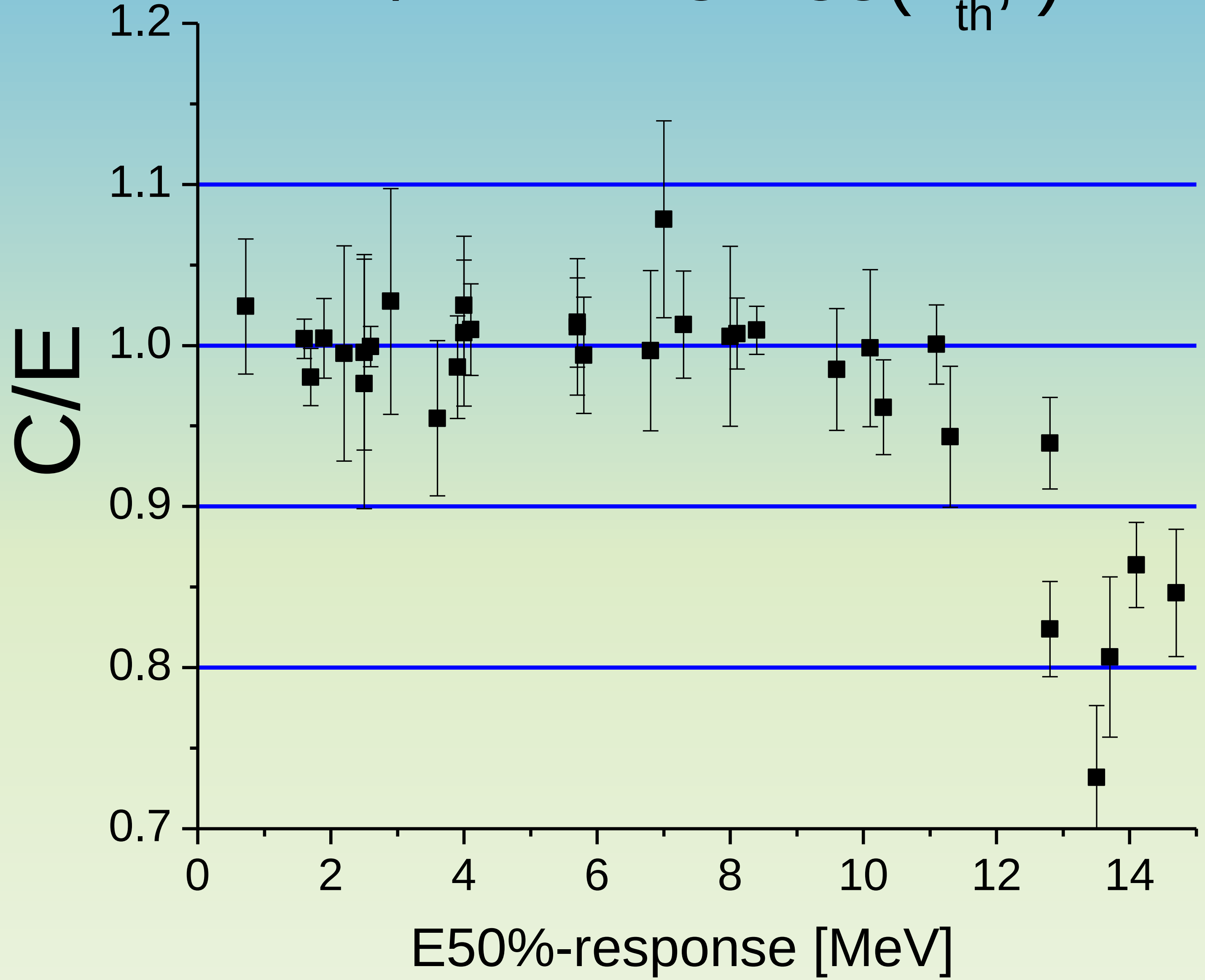
ENDF/B-VII.1 U-235(n_{th},f) PFNS



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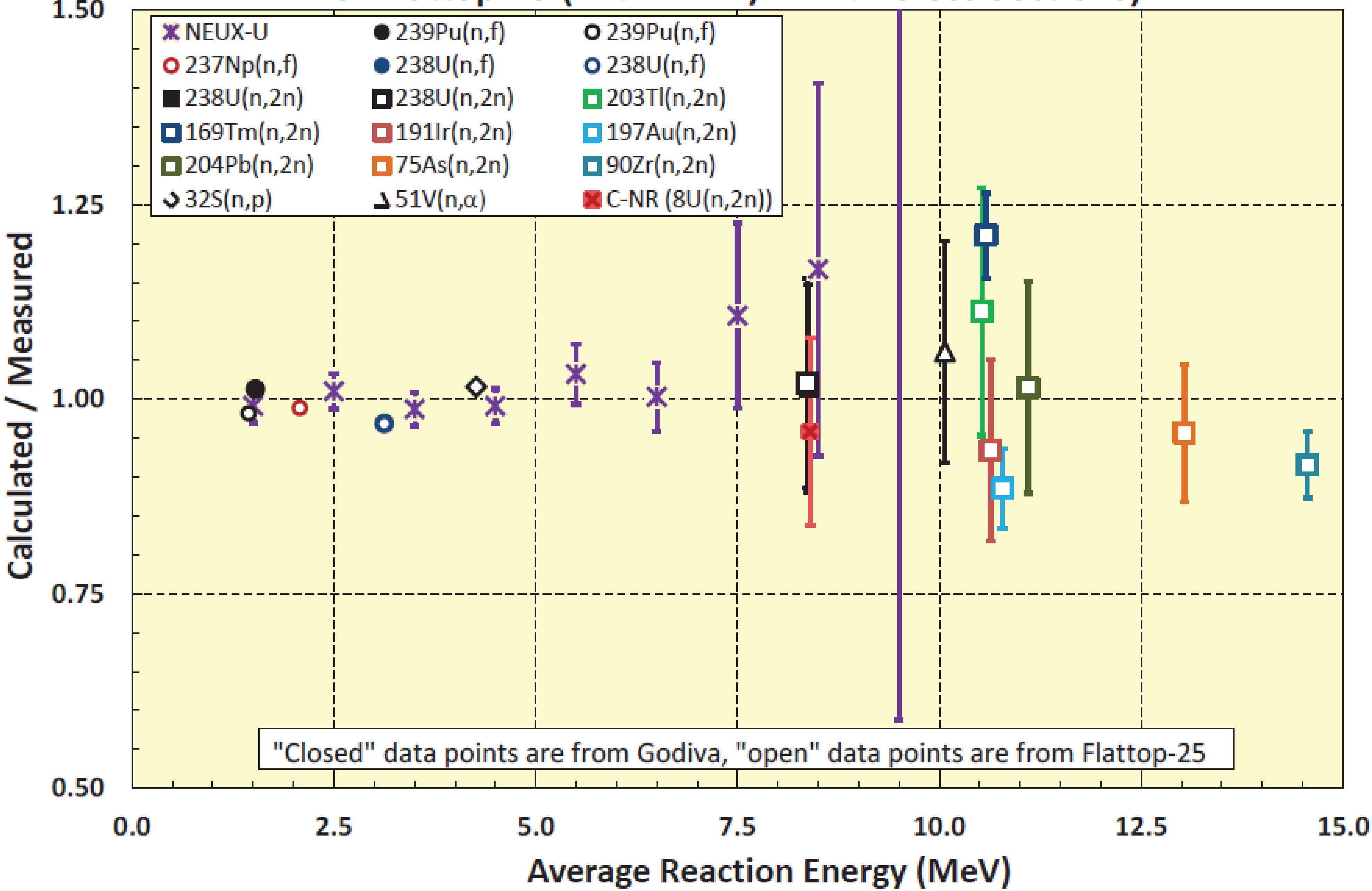
Selected Spectral Index Data for the Central Region of Godiva or Flattop-25 (with ENDF/B-VII.1 Cross Sections)



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CHALLENGES

- Develop evaluation methodology that combines rigid models (highly correlated) with shape experimental data
- Derive evaluations that reproduce the differential data and give reasonable RR and dosimetry performance
- Impact of new evaluations on benchmarks

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