

Nuclear Data Evaluation Work at IRSN

IRSN-ND1 / ORNL-ND1

Luiz Leal - Isabelle Duhamel

**NCSP/TPR Meeting
Amarillo, TX**

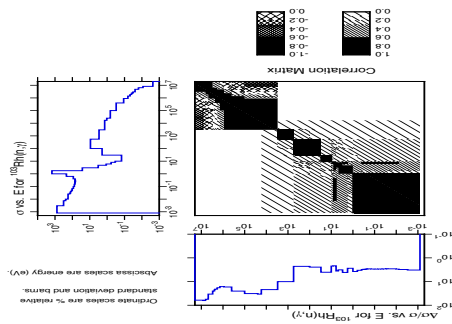
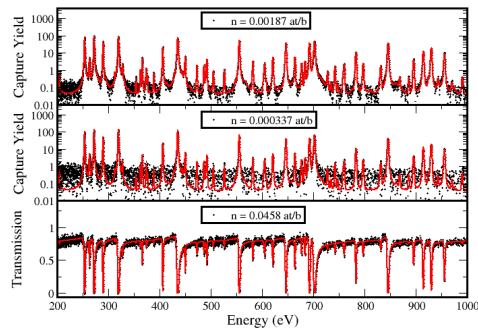
**IRSN / PSN-EXP/SNC
March 26-27, 2019**

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OUTLINE

1. Evaluations Performed at IRSN
2. Measurements Efforts
3. Concluding remarks

Already presented at the last TPR



Appendix B Nuclear Data

Priority Needs +/- Additional Needs	Thermal scattering (Paraffinic Oil, HF, Silicone Oil, UO ₂ F ₂ , PuH ₂ , UH ₃ , Paraffin, U ₃ O ₈ , U ₃ Si ₂ , UC, PuO ₂ , etc.), ²³⁵ Pu, Fe, Cr, ²³⁷ Np, Pb, ²³⁵ Mn, Ti, ²⁴⁰ Pu, ²³³ U, Th, Be, ²³ V, Zr, F, K, Ca, Mo, Na, La							
Completed Evaluations (FY)	Minor Actinides (13), SiC(17), SiO ₂ (17), C ₂ O ₃ H ₂ (16), CH ₂ (17), Be (17), BeO (17), Graphite (17), UO ₂ (17), UN (17), ⁵⁵ Mn (12), ^{58,60} Ni (14), ^{160,128,183,184,186} W (14), Ca (16), ⁵⁹ Co (17), ^{63,65} Cu(17)							
	Materials	Pre FY2018	FY2018	FY2019	FY2020	FY2021	FY2022	Post-FY2022
Measurements	Calcium (Ca)							
	Cerium (Ce)							
	Iron (Fe)							
	Molybdenum (Mo)							
	Tantalum (Ta)							
	Vanadium (V)							
	Zirconium (Zr)							
	Polyethylene (CH ₂)	NO / CH						
Lucite (C ₅ O ₈ H ₈)								
Evaluations	Calcium (Ca)							
	Cerium (Ce)							
	Cobalt (Co)							
	Copper (Cu)							
	Dysprosium (Dy)							
	Gadolinium (Gd)							
	Iron (Fe)							
	Lead (Pb)							
	Oxygen (O)							
	Rhodium (Rh)							
	Plutonium-239							
	Tantalum (Ta)							
	Uranium-234							
	Uranium-235							
	Uranium-236							
	Uranium-238							
	Vanadium (V)							
Zirconium (Zr)								
Lucite (C ₅ O ₈ H ₈)								
Polyethylene (CH ₂)								
Beryllium (metal)								
Beryllium Oxide (BeO)								
Crystal Graphite								
Reactor Graphite								
Silicon Carbide (SiC)								
Silicon Dioxide (SiO ₂)								
Uranium Dioxide (UO ₂)								

Extract from five year plan 2018-2022

Evaluation Work

Isotope	Energy Range	Resonance Covariance Evaluation	Target date for delivery the evaluation
Gd isotopes (152, 154, 155, 156, 157, 158, 160)	Varies according to the isotopes Common task IRSN-ORNL	RP + CV	Ongoing
^{56}Fe	Thermal to 2 MeV	RP + CV	Ongoing
^{54}Fe	Thermal to 1.2 MeV	RP	Standby
Pb isotopes (204, 206, 207, 208)	Varies according to the isotopes Common task IRSN-ORNL	RP + CV	Ongoing
Mo isotopes (95, 96)	Varies according to the isotopes	RP + CV	Ongoing

Gd Evaluation (collaboration with ORNL - V. Sobes)

RPI experimental data measured at the 25.59725 meters flight-path

Data	Energy range (eV)	Nature
Transmission	0.2 - 300.0	natural
Transmission	0.3 - 500.0	natural
Transmission	0.3 - 1000.0	natural
Capture	0.2 - 1000.0	91.74 % Gd155 enriched
Capture	0.2 - 1000.0	90.96 % Gd157 enriched
Capture	0.2 - 1000.0	natural

Gd Evaluation (new capture measurements)

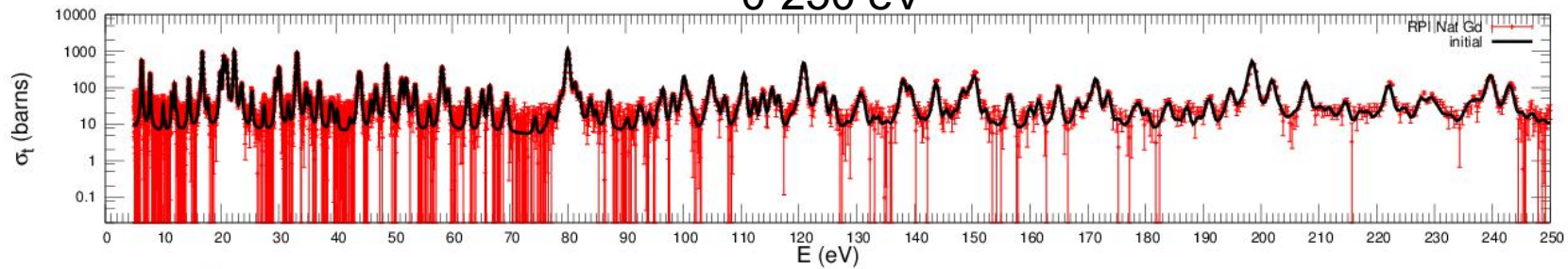
n-TOF experimental data measured at the 183.90 meters flight-path

Data	Energy range (eV)	Nature
Capture	1.0 - 1000.0	91.74 % Gd155 enriched
Capture	1.0 - 1000.0	88.32 % Gd157 enriched

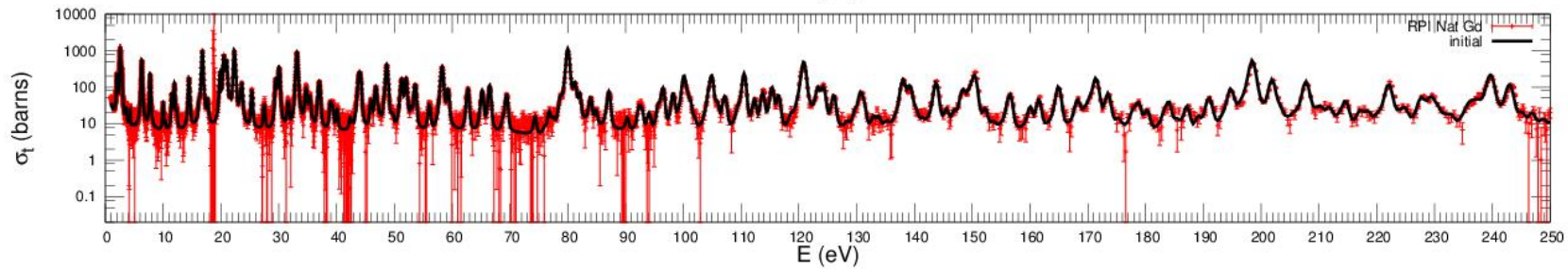
Gd RPI data (SAMMY Fitting) resonance range extended to 500 eV for $^{155,157}\text{Gd}$

0-250 eV

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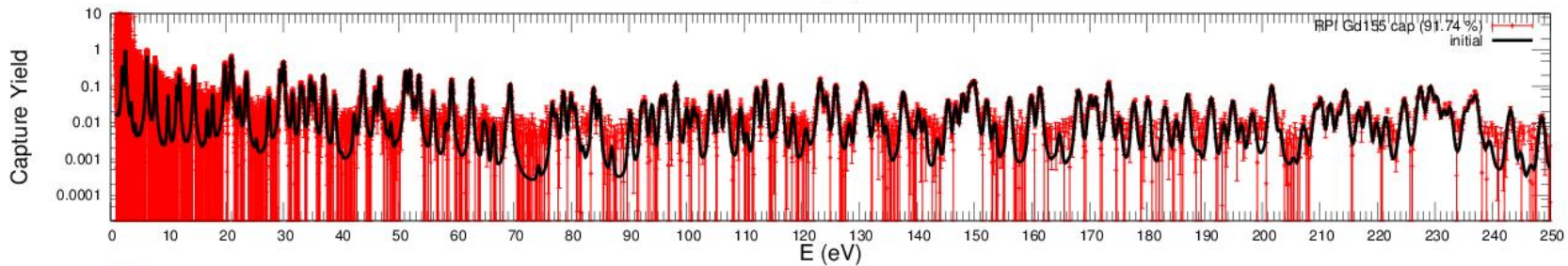


Gd
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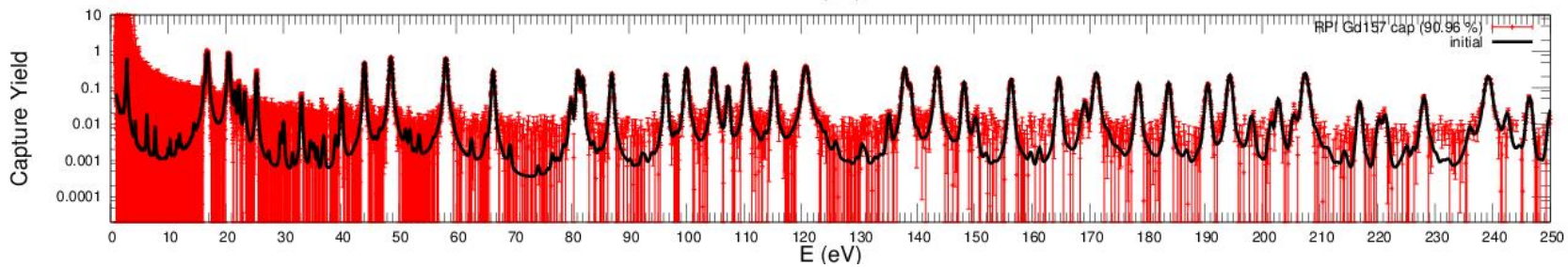


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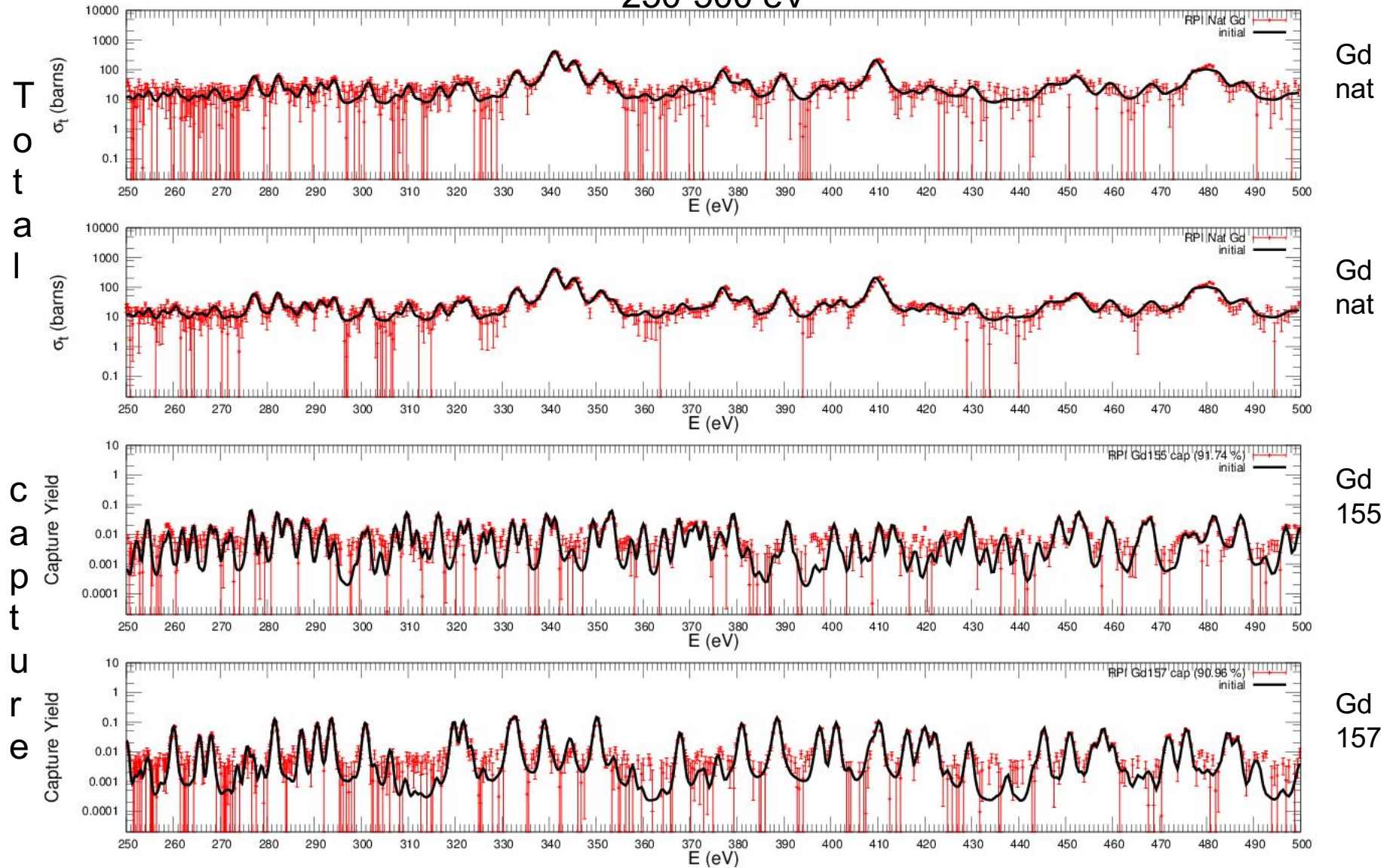
Gd
155



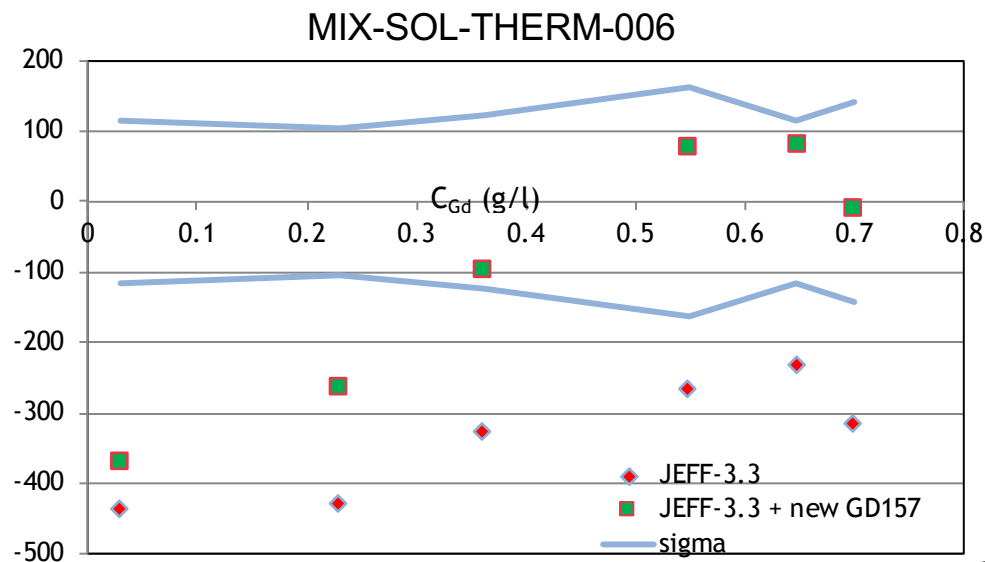
Gd
157

Gd RPI data (SAMMY Fitting) resonance range extended to 500 eV for $^{155,157}\text{Gd}$

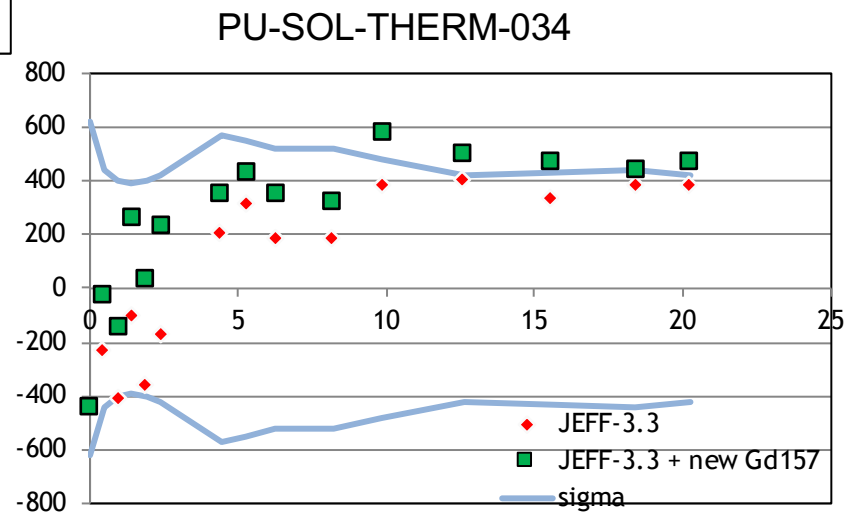
250-500 eV



^{157}Gd preliminary test



New ^{157}Gd : effect up to 400 pcm



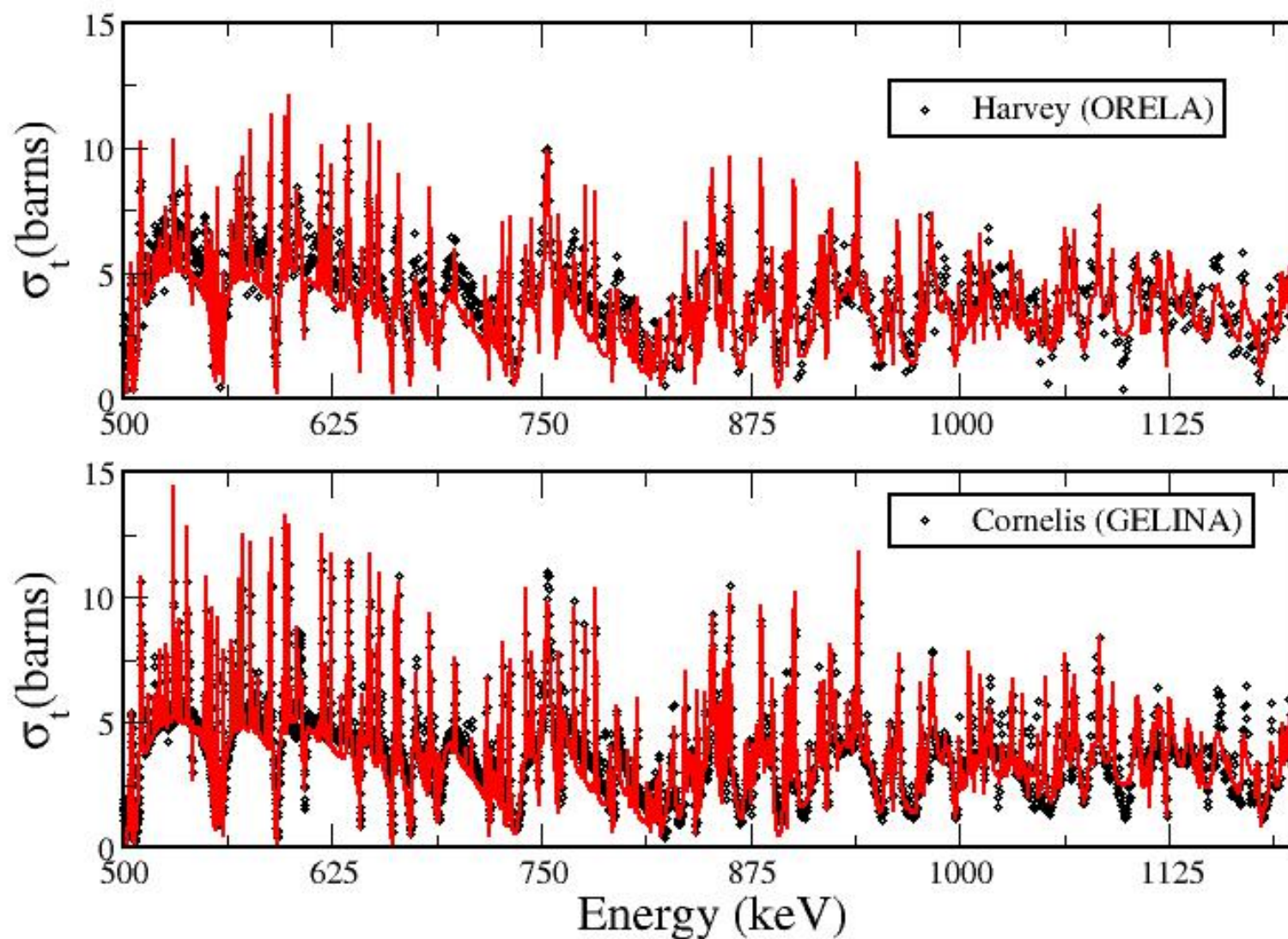
^{54}Fe Evaluation in the Resolved Resonance*

- Natural Iron: ^{56}Fe (91.75 %), ^{54}Fe (5.85 %) and ^{57}Fe (2.12 %);
- Resonance region extended from 700 keV to 2 MeV;
- High resolution transmission data of Cornelis (GELINA) and Harvey (ORELA);
- Calculated direct capture with the CUPIDO code from G. Arbanas (ORNL) included;
- Capture and DDX Scattering cross section needed;
- First inelastic channel opens 1.434 MeV;

*Task on hold due to:

- a) Lack of good transmission data above 1 MeV !!
- b) No capture data with good resolution available !!

^{54}Fe Resolved Resonance



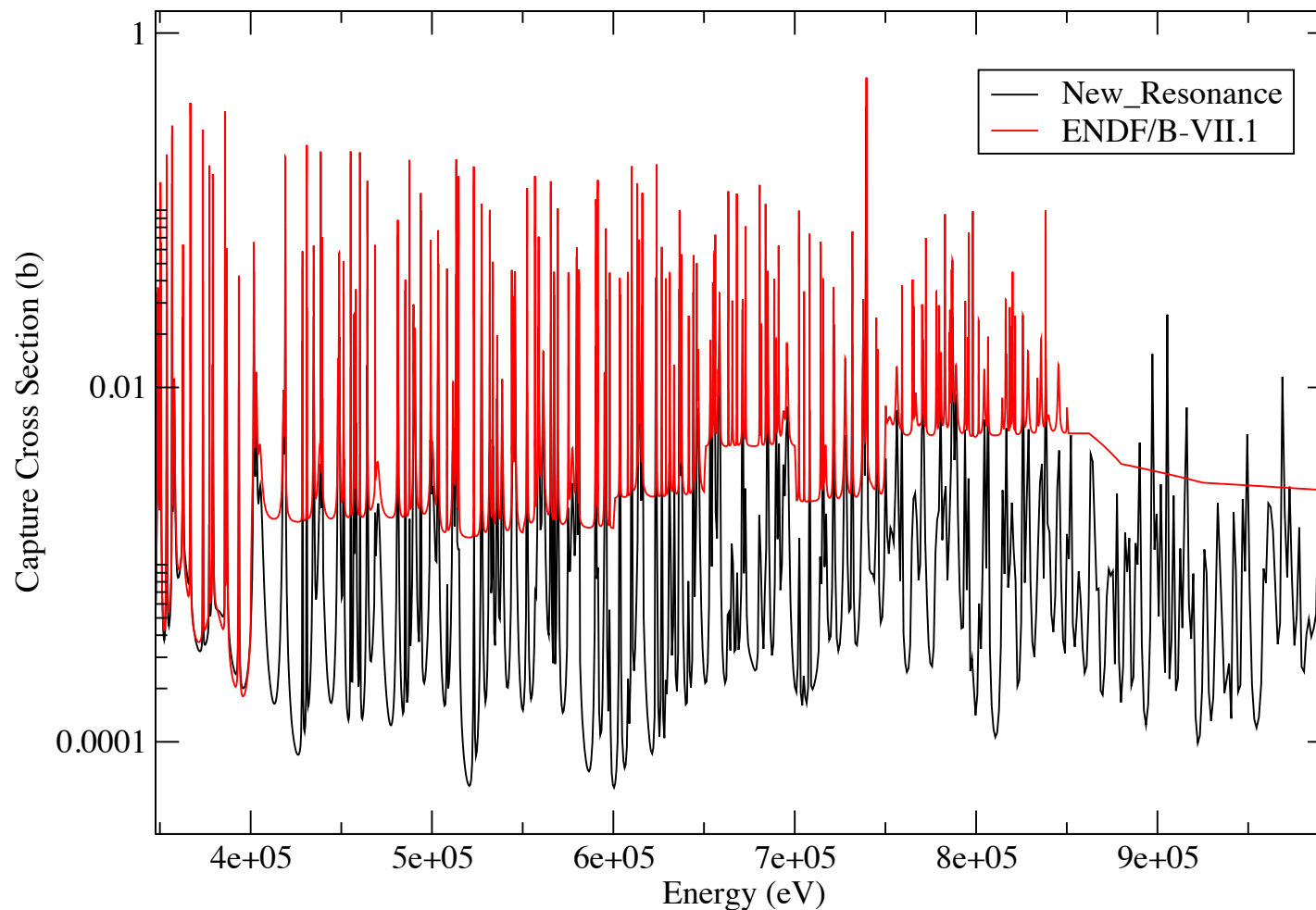
Motivation for evaluating ^{56}Fe in the Resolved Resonance Region up 2 MeV

- New high resolution transmission measurements done at the RPI extending the resonance region up to 5 MeV;
- Inelastic cross-section measurements done at IRMM;
- Use the SAMMY/RML feature to include inelastic channel in the R-matrix analysis
- Improve results of benchmark systems calculations

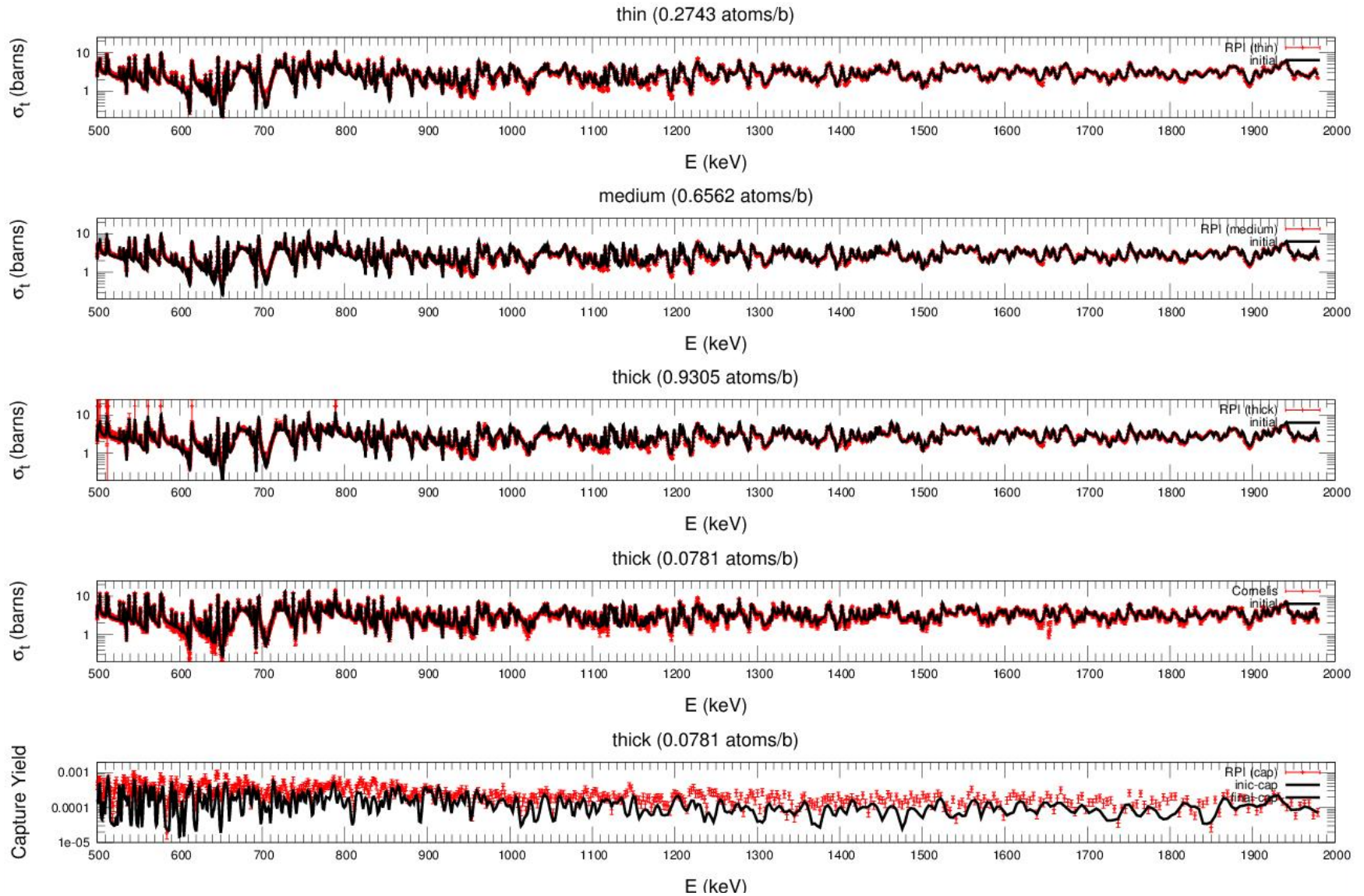
Evaluation Features

- Extend the resolved resonance region from 850 keV to 2 MeV
- Include new transmission measurements and inelastic cross section data
- Use the extended R-matrix formalism in the SAMMY code for fitting the experimental data
- Fit RPI capture data (new addition)

Issues with ^{56}Fe capture cross-section data



^{56}Fe RPI total and capture cross-section data



Experimental Data for the $n+^{56}\text{Fe}$ Interaction

Reference	Energy Range	Facility	TOF (meters)	Measurement
Harvey (1987)	20 keV – 2 MeV	ORELA	201.575	Transmission
Perey (1990)	120 keV – 850 keV	ORELA	201.575	Transmission
Cornelis (1982)	500 keV – 2 MeV	GELINA	387.713	Transmission
Danon (2012) (three thicknesses)	500 keV – 2 MeV	RPI	249.740	Transmission
Danon (2015)	500 keV – 2 MeV	RPI	45.277	Capture
Perey (1990)	850 keV – 1.5 MeV	ORELA	201.575	Inelastic
JRC/GEEL (2011)	850 keV – 2 MeV	GELINA	198.686	Inelastic
Spencer (1994)) (two thicknesses)	10 eV – 650 KeV	ORELA	40.0	Capture
Perey (1990)	850 keV – 1.5 MeV	ORELA	200.191	elastic
Cabé (1967)	500 keV – 1.2 MeV	Université de Louvain (Van de Graaff)	~ 1	elastic
O.A.Shcherbakov (1977)	0.001 eV – 10 eV	TOF/Russia	9.5	Total
O.A.Shcherbakov (1977)	0.001 eV – 10 eV	TOF/Russia	9.5	Capture

Pb Resonance Evaluation (204, 206, 207, 208) (collaboration with ORNL - Vladimir Sobes)

Motivation :

- Transport casks
- Shielding in fuel cycle nuclear facilities and laboratories

Isotope	Abundance	Thermal Capture (mbarns)
Pb-204	1.4%	703± 35
Pb-206	24.1%	26.6± 1.2
Pb-207	22.1%	622 ± 14
Pb-208	52.4%	0.23± 0.02

Assessment of existing evaluations (ENDF, JEFF, JENDL) is being conducted.

Transmission and capture data for enriched samples are needed!

Mo Resonance Evaluation ($^{95}, ^{96}\text{Mo}$)

Motivation :

- Research and naval reactors fuel
- Burn-up credit (one of the major absorbers)
- UPuMoZr residues in reprocessing plants

Isotope	Composition (%)	Thermal Cross Section (barns)	Resonance Integral (barns)
^{92}Mo	14.84	0.08 ± 0.02	0.83
^{94}Mo	9.25	0.34 ± 0.02	1.12
^{95}Mo	15.92	13.4 ± 0.3	118 ± 7
^{96}Mo	16.68	0.5 ± 0.3	17 ± 3
^{97}Mo	9.55	2.2 ± 0.2	14.4 ± 3.0
^{98}Mo	24.13	0.130 ± 0.006	6.7 ± 0.3
^{100}Mo	9.63	0.199 ± 0.002	3.76 ± 0.15

Transmission data and Capture cross section measurements have been carried out recently at J-PARC by IRSN and JAEA

Assessment of existing evaluations (ENDF, JEFF, JENDL) is being conducted.

RPI transmission data for enriched $^{95,96}\text{Mo}$ are needed;

Transmission and capture measurements for ^{95}Mo done by Paul Koehler not available. **NCSP may help on releasing the data!**



Concluding Remarks

- IRSN continues to work close to the NCSP agenda on differential data evaluation;
- Final evaluation includes resonance parameters and resonance parameter covariance;

IRSN priority list *(to be completed)*

Pu-239 (***see TEX preliminary results***),

Pu-240, Pu-241, Am-241,

U-235, U-238, U-234

Gd isotopes, Mo isotopes, Fe-54, Fe56, Pb-204, Pb-206, Pb-207, Pb-208

Cl-35, Cl-37, F-19, Nickel isotopes, Sm-149, Sm-152, Cs-133, Si isotopes,

Ca isotopes, Mn-55, Nd-143