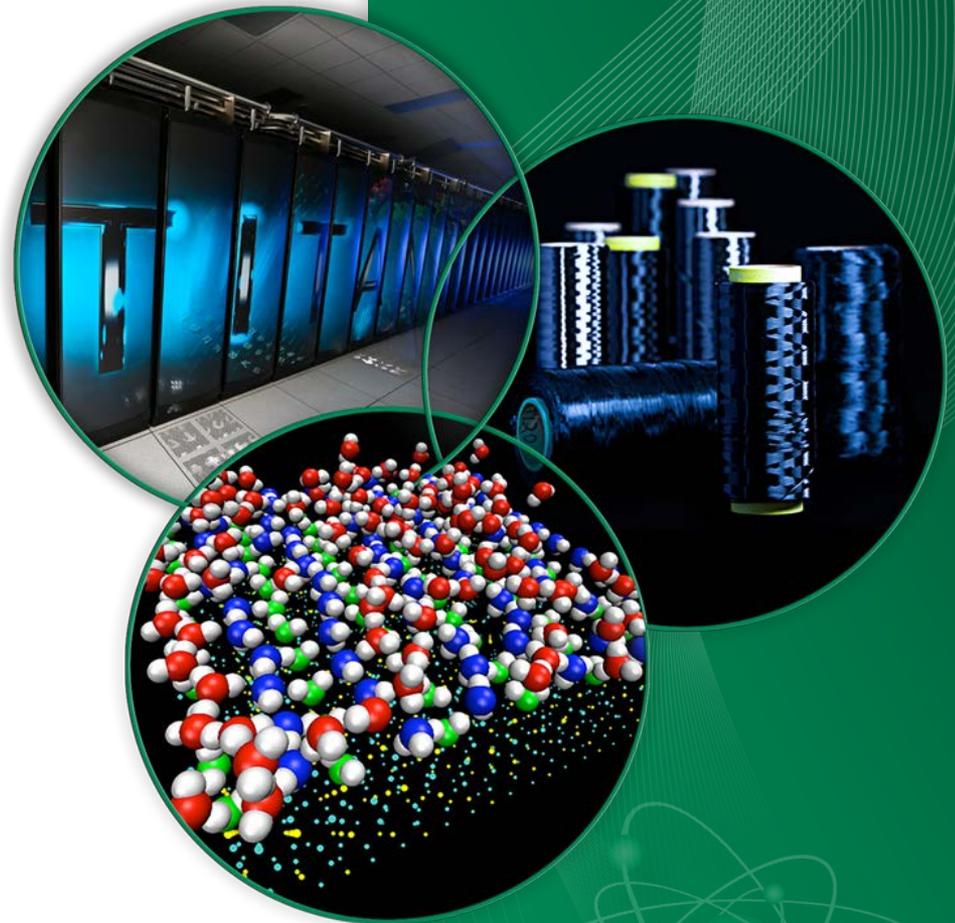


ORNL Nuclear Data Evaluation Accomplishments for FY2013

Luiz Leal, Marco Pigni, Vladimir Sobes,
Doro Wiarda, Klaus Guber, Goran Arbanas,
and Mike Dunn

Nuclear Data & Criticality Safety Group

NCSP Technical Program Review
Los Alamos National Laboratory
March 26-27, 2014



Outline

- ORNL nuclear data evaluation work to address NCS nuclear data needs
- Data analysis and evaluation effort with SAMMY
- ORNL collaboration efforts with IRSN and CEA/Cadarache
- Collaborative International Evaluated Library Organization (CIELO) Project
- Summary of Evaluation Accomplishments



ORNL Resonance Evaluations and deliverables

	Energy Range	Resonance Covariance Evaluation	Target date to deliver the evaluation
$^{63,65}\text{Cu}$	Thermal to 300 keV	Yes	Completed
^{182}W	Thermal to 10 keV	Yes	FY2014
^{183}W	Thermal to 5 keV	Yes	FY2014
^{184}W	Thermal to 10 keV	Yes	FY2014
^{186}W	Thermal to 10 keV	Yes	FY2014
^{56}Fe	Thermal to 2 MeV	Yes	FY2014—new angular data & testing may delay to FY15 CIELO
^{239}Pu	Thermal to 2.5 keV	Use ENDF/B-VII.1 (FILE33)	Completed
^{235}U	Thermal to 2.25 keV	Use ENDF/B-VII.1 (FILE33)	FY2014 CIELO

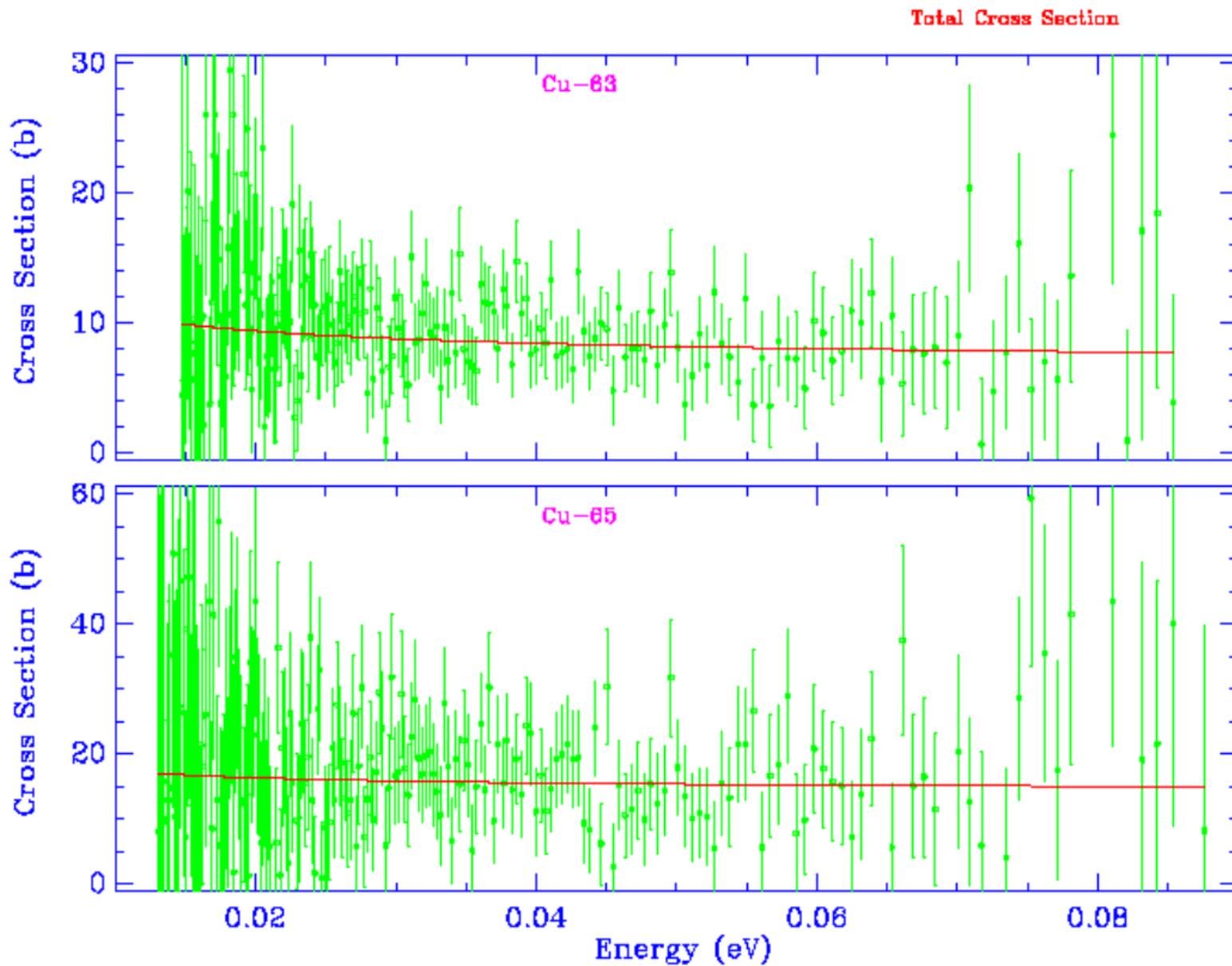
ORNL Planned Evaluations

	Energy Range	Resonance Covariance Evaluation	Target date for delivery the evaluation
Ca	⁴⁰ Ca (96.95 %) ⁴⁴ Ca (2.086 %)	Yes	FY2015
Ce	¹⁴⁰ Ce (88.450 %) ¹⁴² Ce (11.114 %)	Yes	FY2015
Dy	¹⁶¹ Dy (18.889 %) ¹⁶² Dy (25.475 %) ¹⁶³ Dy (24.896 %) ¹⁶⁴ Dy (28.260 %)	Yes	FY2015
Gd	¹⁵⁵ Gd (14.80 %) ¹⁵⁶ Gd (20.47 %) ¹⁵⁷ Gd (15.65 %) ¹⁵⁸ Gd (24.84 %) ¹⁶⁰ Gd (21.86 %)	Yes	FY2015
CH₂	Thermal Scattering S(α,β)	-	FY2015

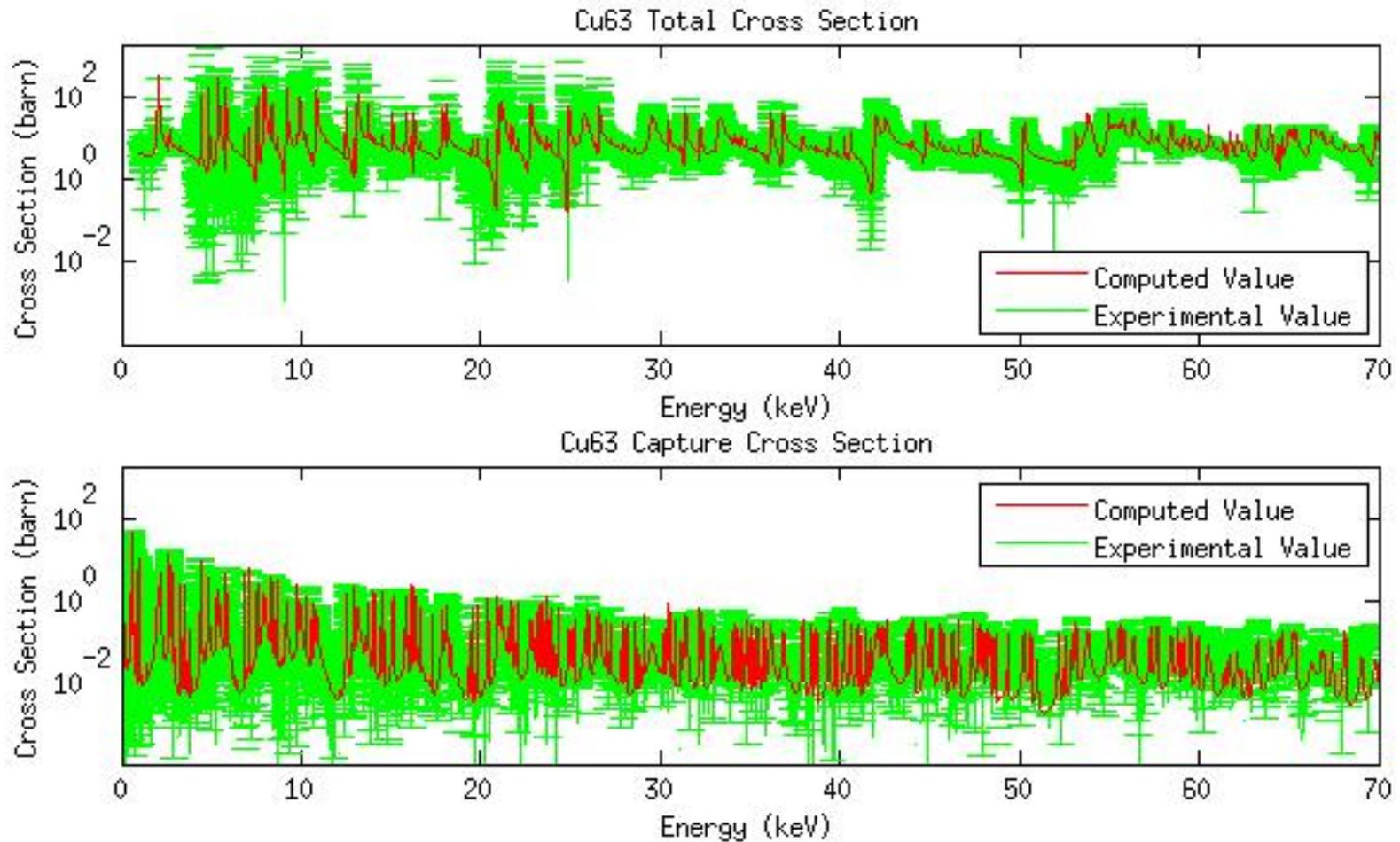
Copper Evaluation (Vladimir Sobes Ph.D. Thesis – completed September 2013)

- Vladimir Ph.D. thesis work for the NCSP
 - Performed thermal $^{63,65}\text{Cu}$ cross-section measurements at MITR
 - Completed $^{63,65}\text{Cu}$ resonance evaluations (with covariance data) through analysis of measured data from ORELA, GELINA (IRMM) and MITR
 - Development of analysis capability that couples TSUNAMI sensitivity/uncertainty tool with SAMMY resonance analysis tool – couples integral with differential data analysis
- Transmission and capture data:
 - ORELA: 32 eV – 185 keV
 - ORELA: 1 keV – 1.4 MeV
 - MITR: 0.01 eV – 0.1 eV
 - GELINA: Capture Cross-section 1 keV – 200 keV

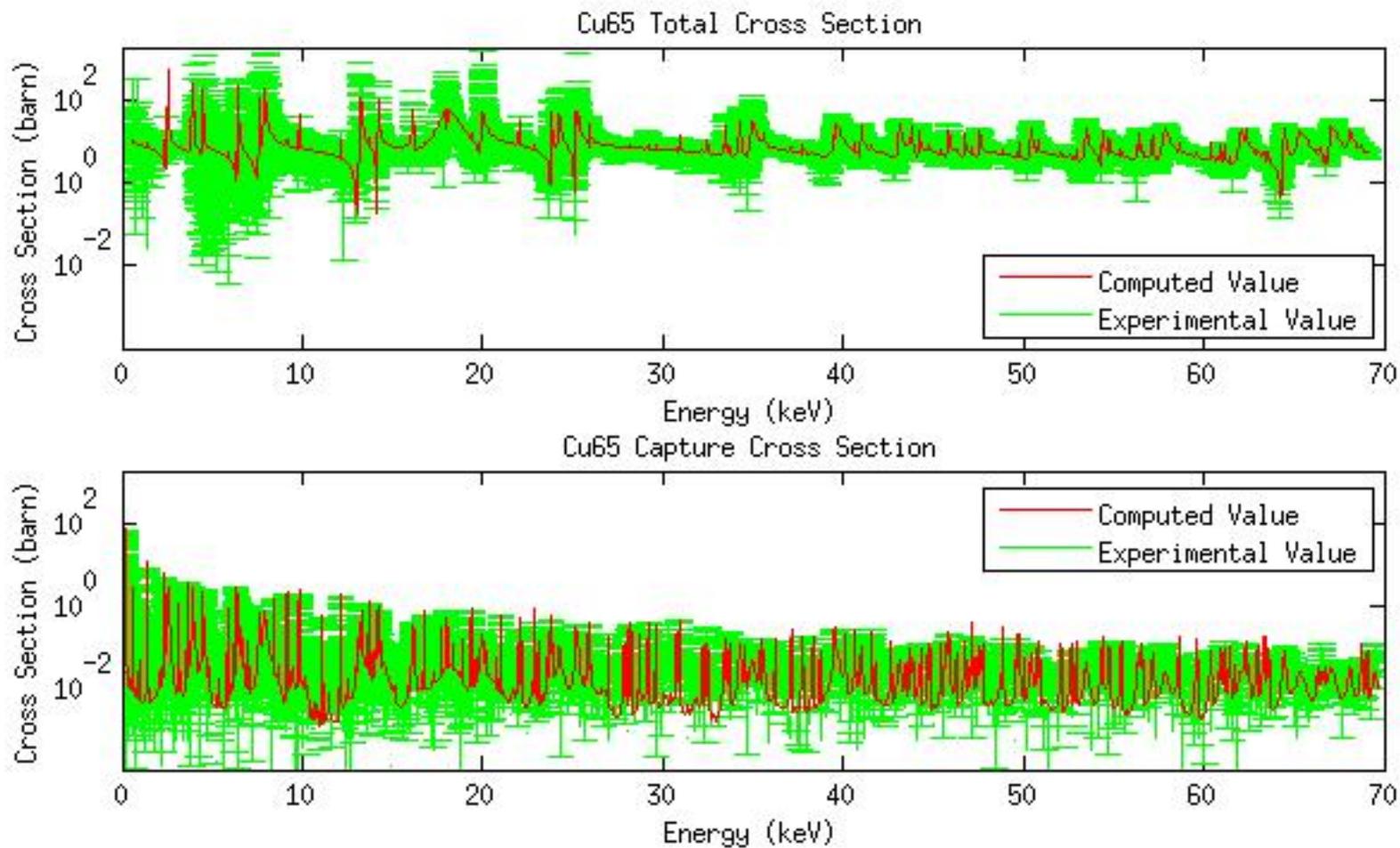
SAMMY fit at low energy (MIT data)



Resolved Resonance Region for ^{63}Cu



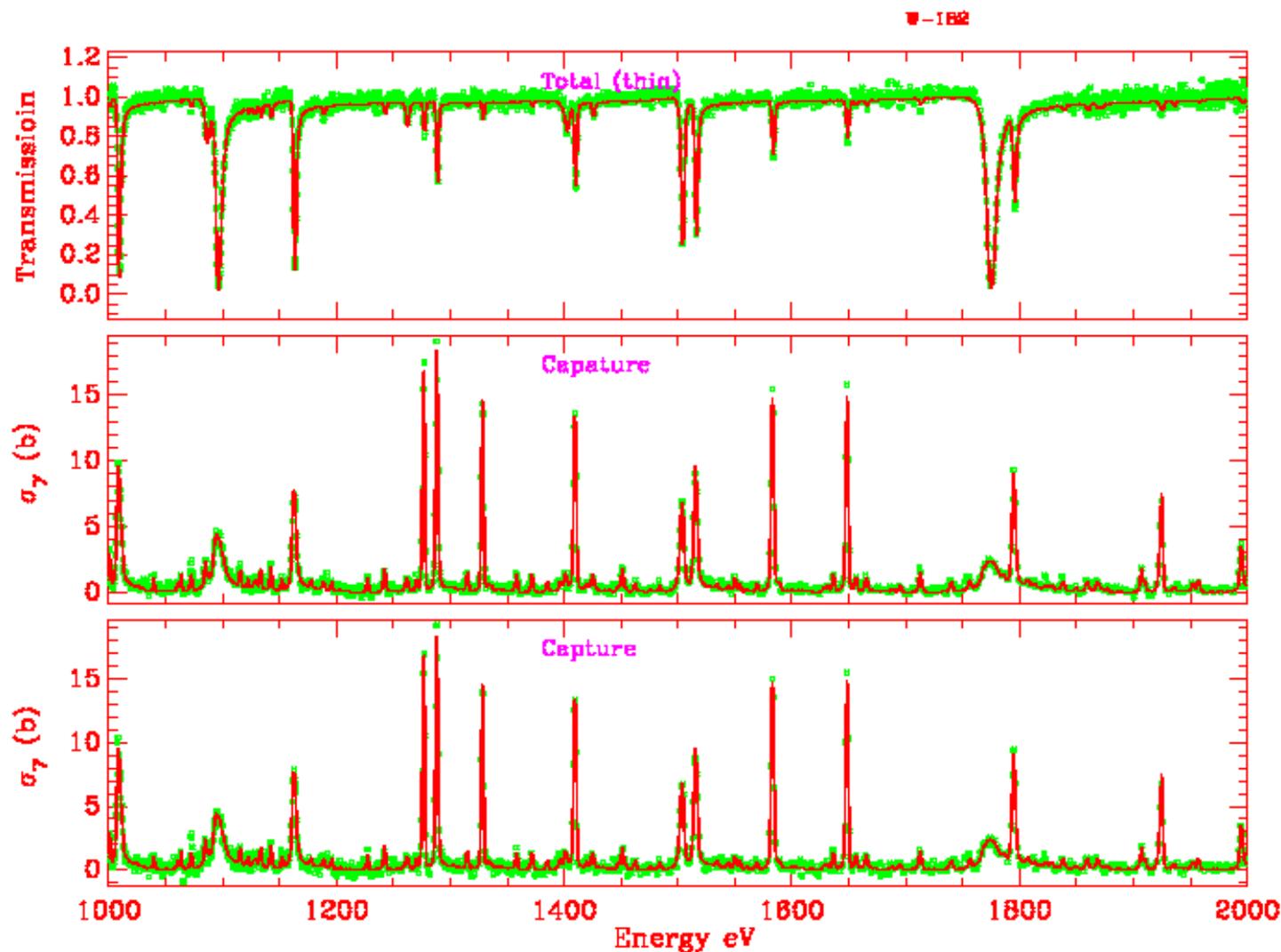
Resolved Resonance Region for ^{65}Cu



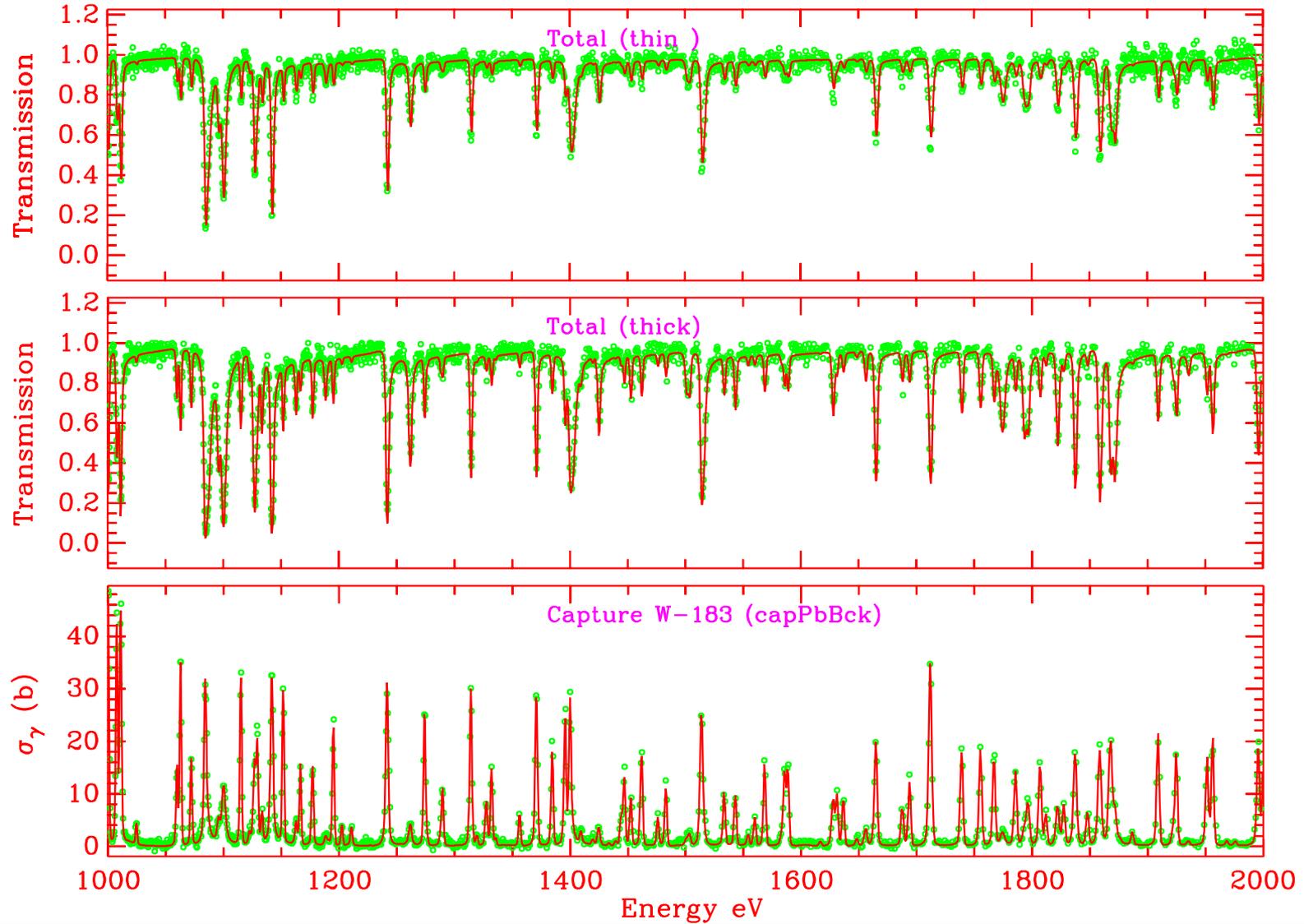
Tungsten Resolved Resonance

Isotope	Energy Range (old)	Energy Range (new)
^{182}W	10^{-5} eV – 5 keV	10^{-5} eV – 10 keV
^{183}W	10^{-5} eV – 2.2 keV	10^{-5} eV – 5 keV
^{184}W	10^{-5} eV – 4 keV	10^{-5} eV – 10 keV
^{186}W	10^{-5} eV – 8 keV	10^{-5} eV – 10 keV

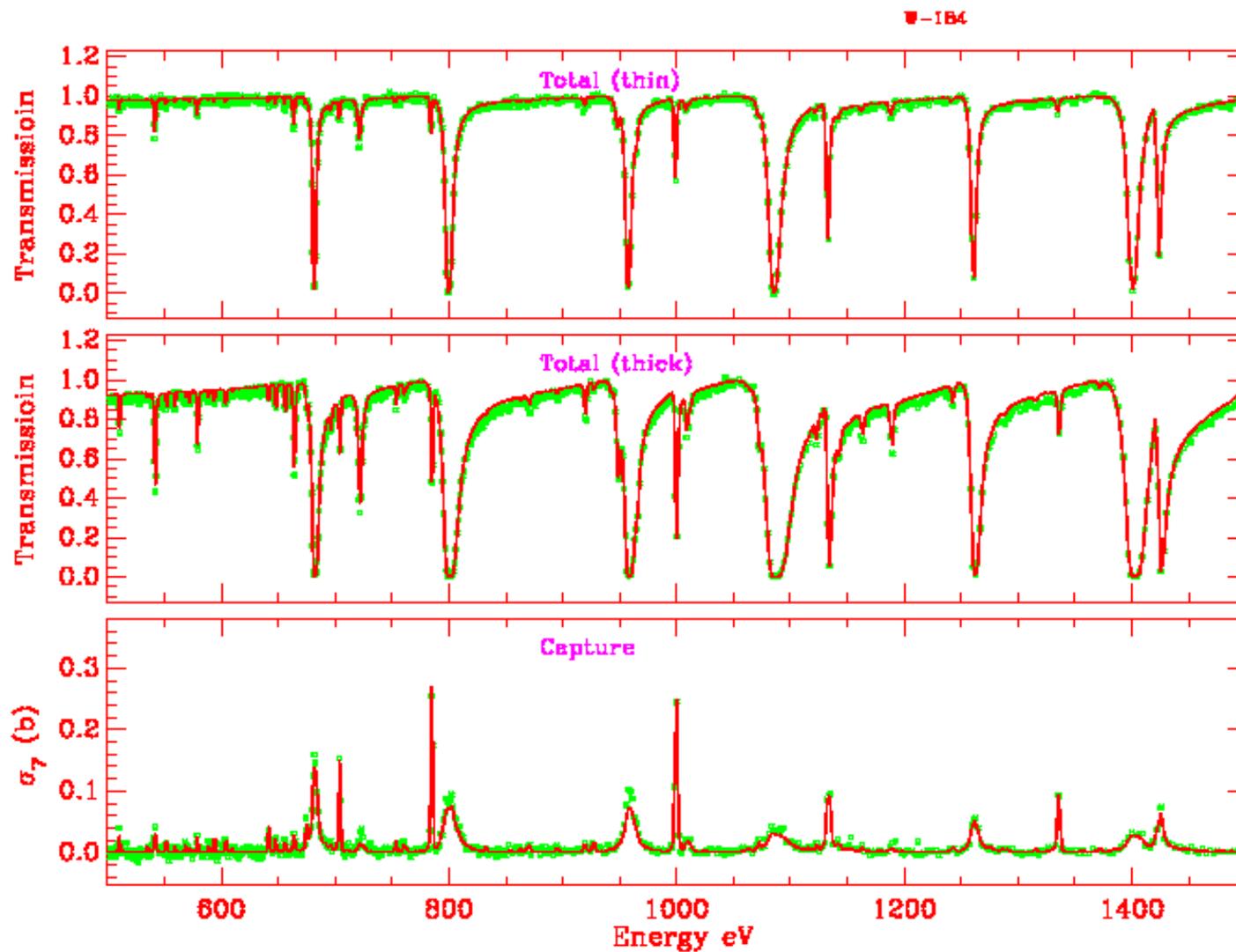
SAMMY fit of W-182 transmission and capture (GELINA)



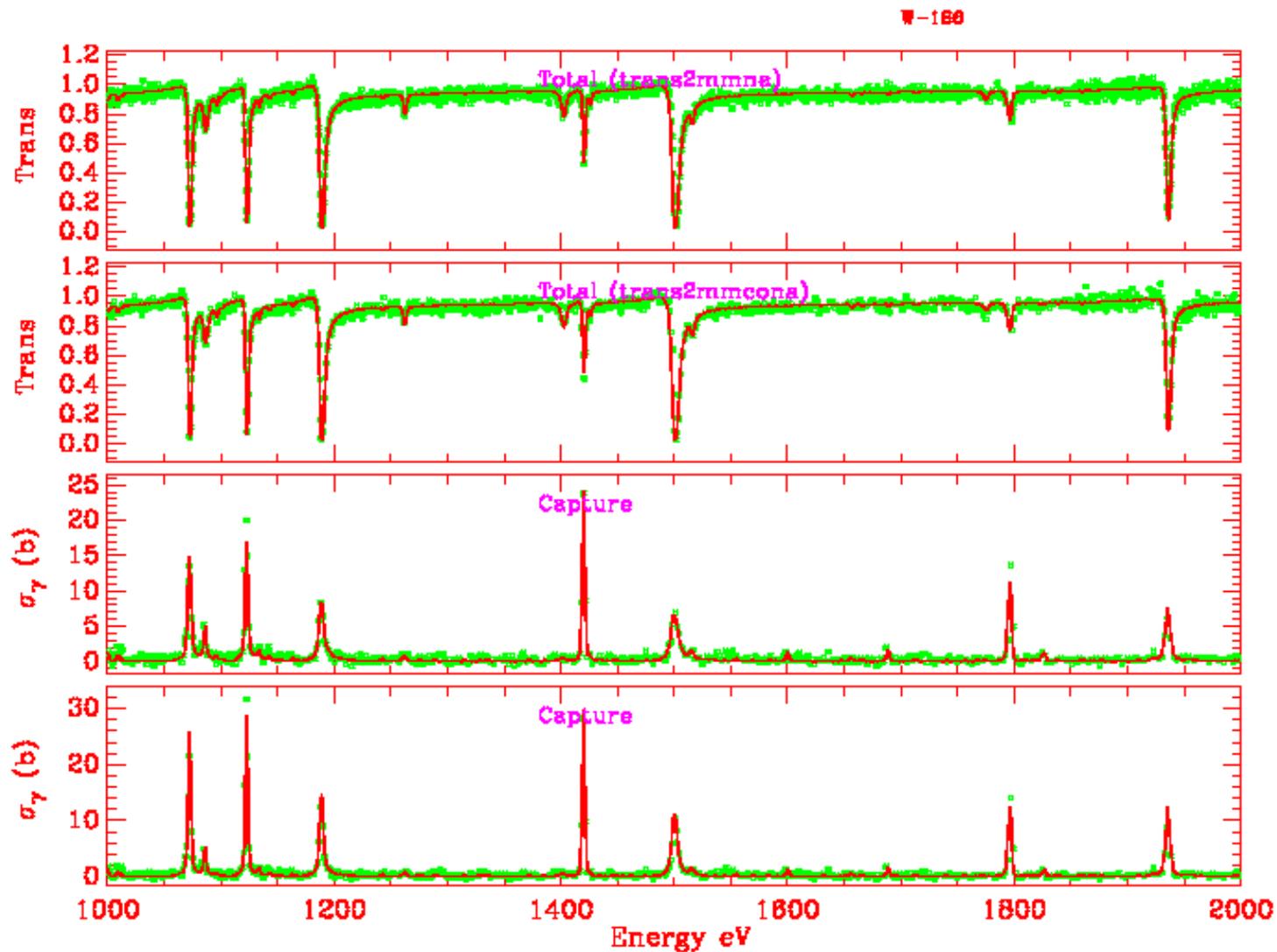
SAMMY fit of W-183 transmission and capture (GELINA)



SAMMY fit of W-184 transmission and capture (GELINA)



SAMMY fit of W-186 transmission and capture (GELINA)



^{56}Fe Resonance Evaluation up to 2.0 MeV

- Motivation for evaluating ^{56}Fe in the resolved resonance Region
- Evaluation description
- Use RML option of the SAMMY code (R-matrix Limited Format)
- Experimental Data
- Preliminary results

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

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

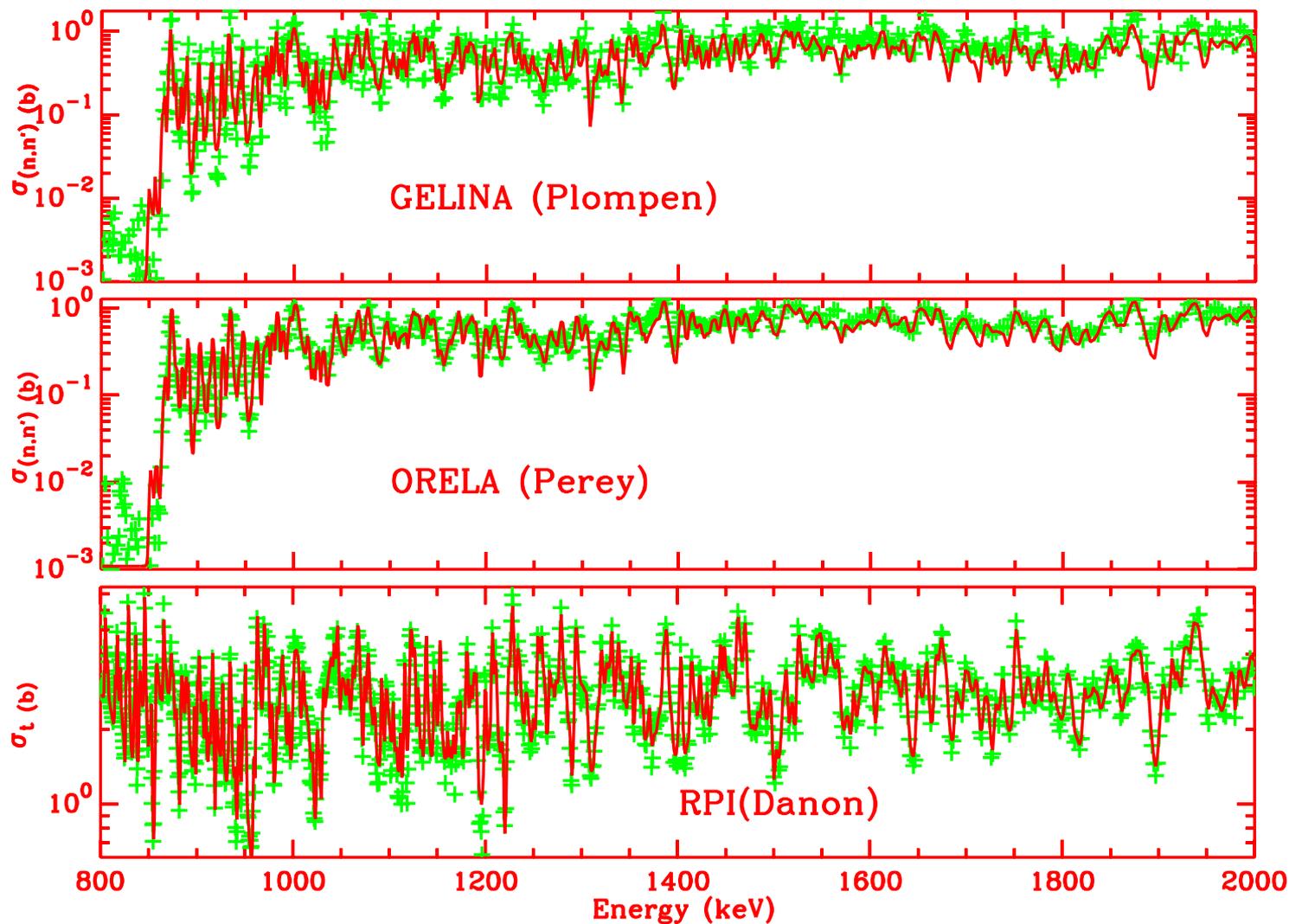
Evaluation Features

- Extend the resolved resonance region from 850 keV to 2.0 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
- Compare the cross section processed with SAMMY, NJOY, AMPX and PREPRO using the evaluated iron resonance parameters

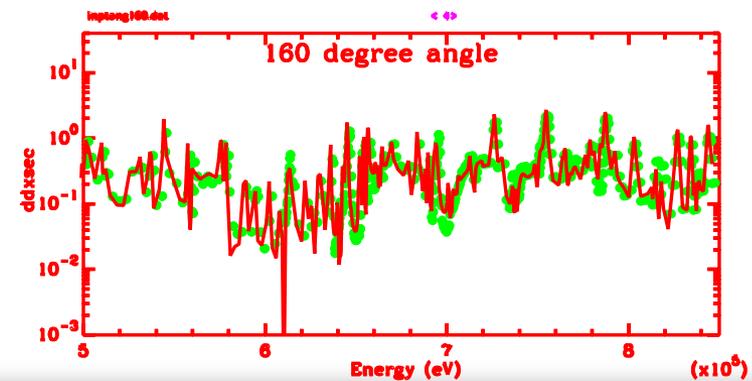
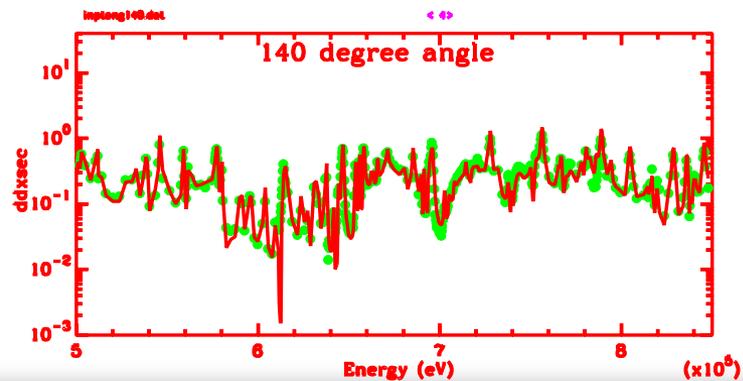
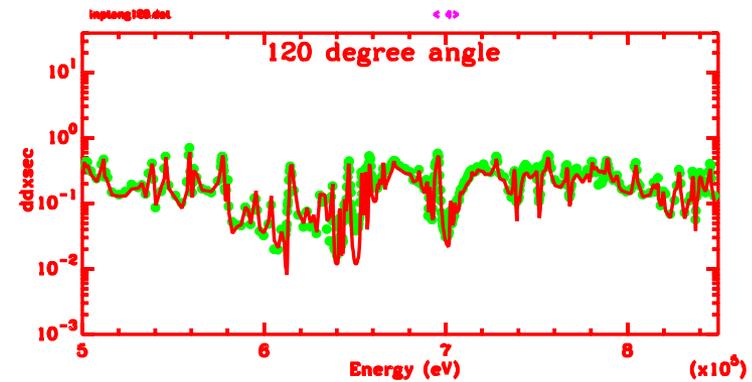
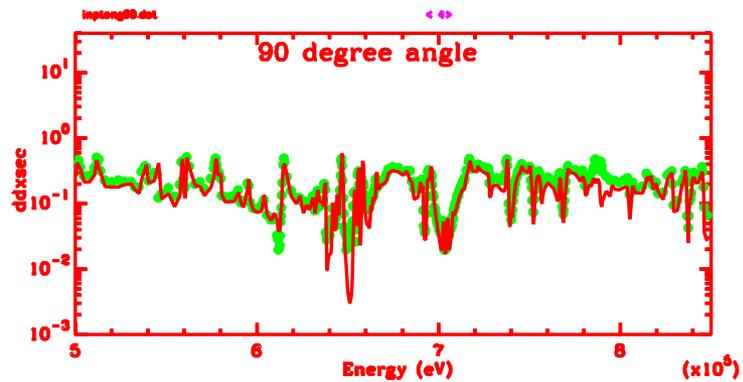
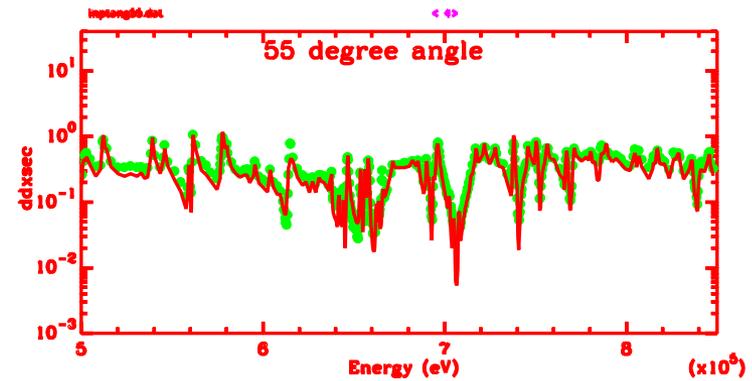
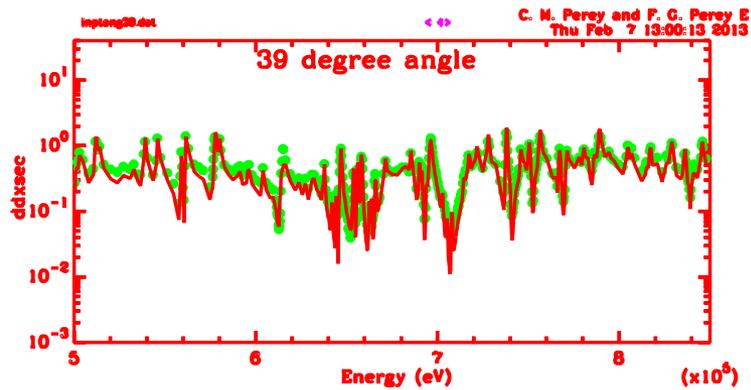
Experimental Data for the $n+^{56}\text{Fe}$ Interaction

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
Perey (1990)	850 keV – 1.5 MeV	ORELA	201.575	Inelastic
Plompen (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

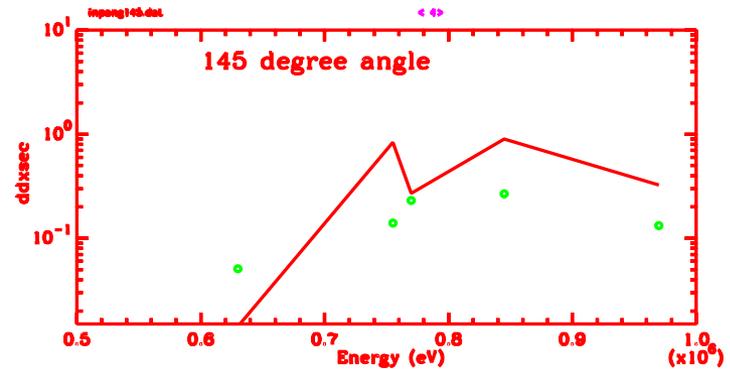
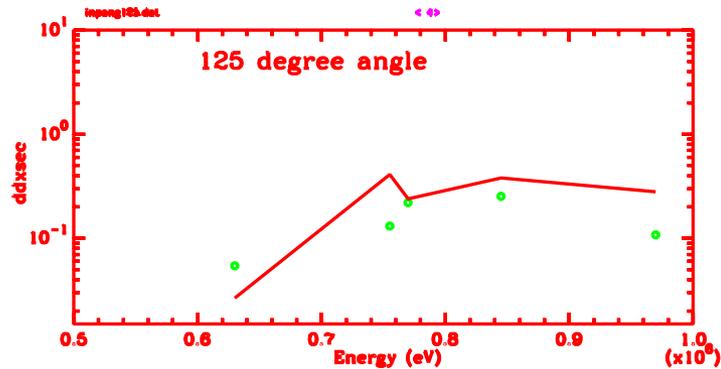
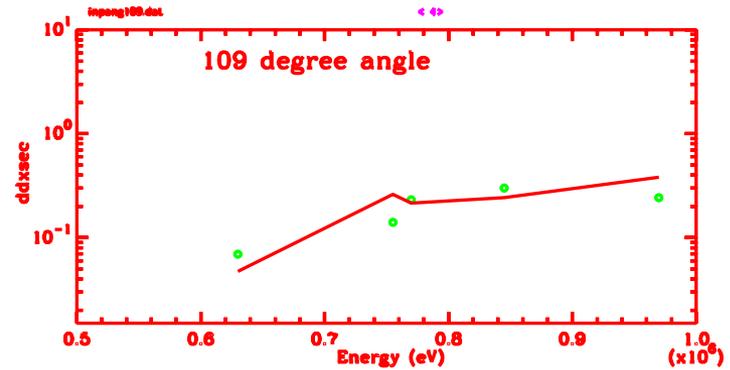
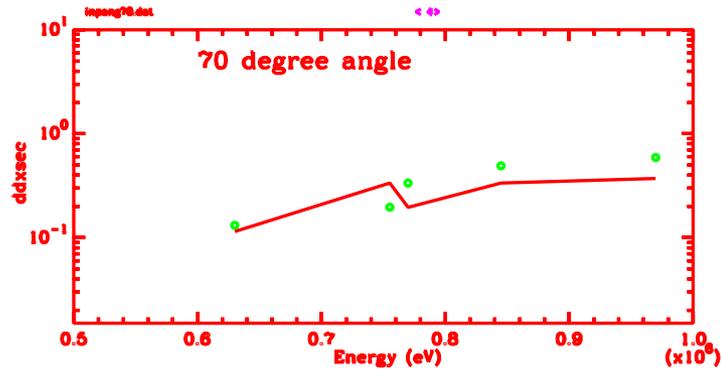
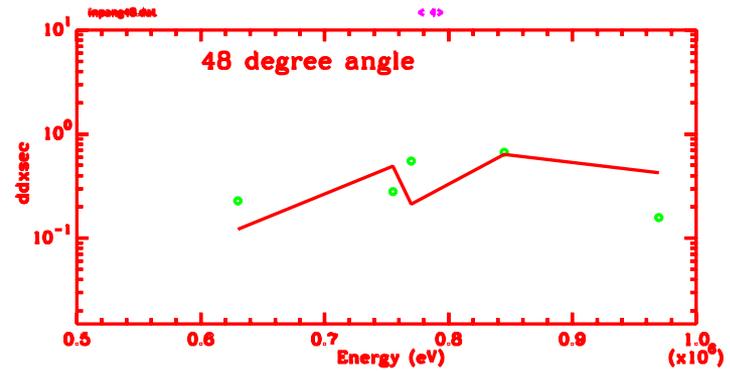
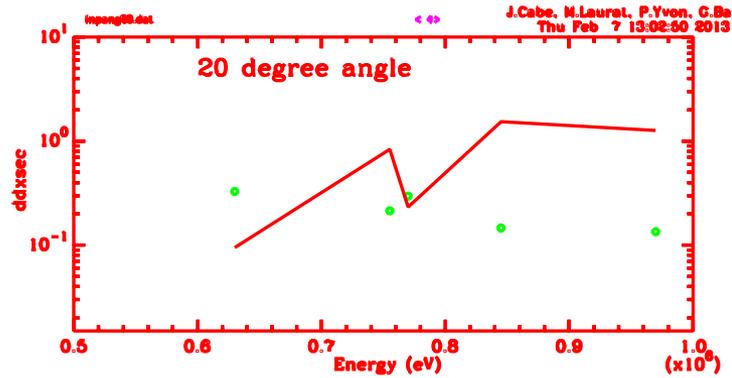
Comparison of SAMMY Fits for Total and Inelastic ^{56}Fe data.



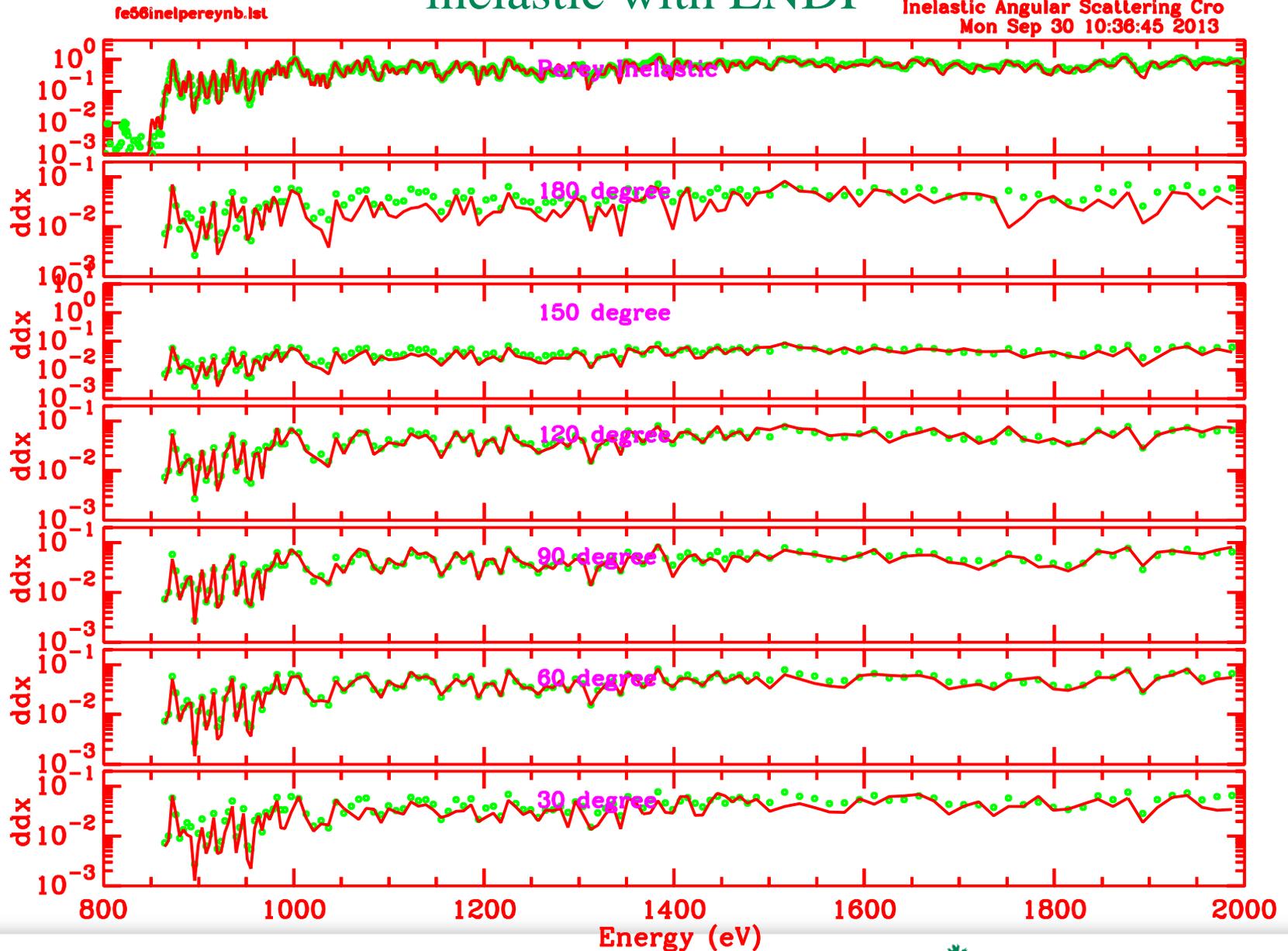
Comparison of SAMMY Fits to Perey Differential Elastic ^{56}Fe data



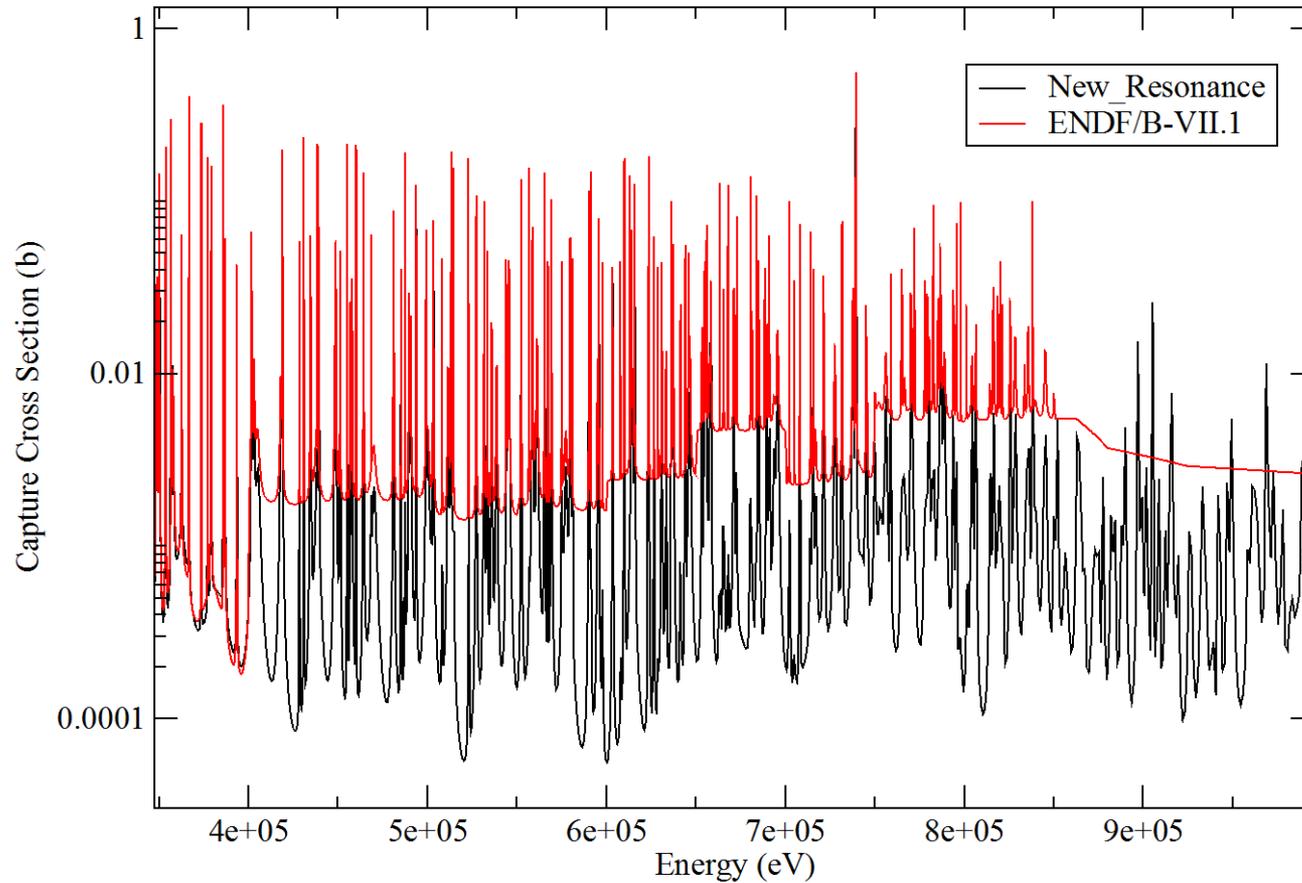
Comparison of SAMMY Fit of ^{56}Fe differential elastic data of Cabé .



Comparison of SAMMY Predictions of ^{56}Fe differential inelastic with ENDF

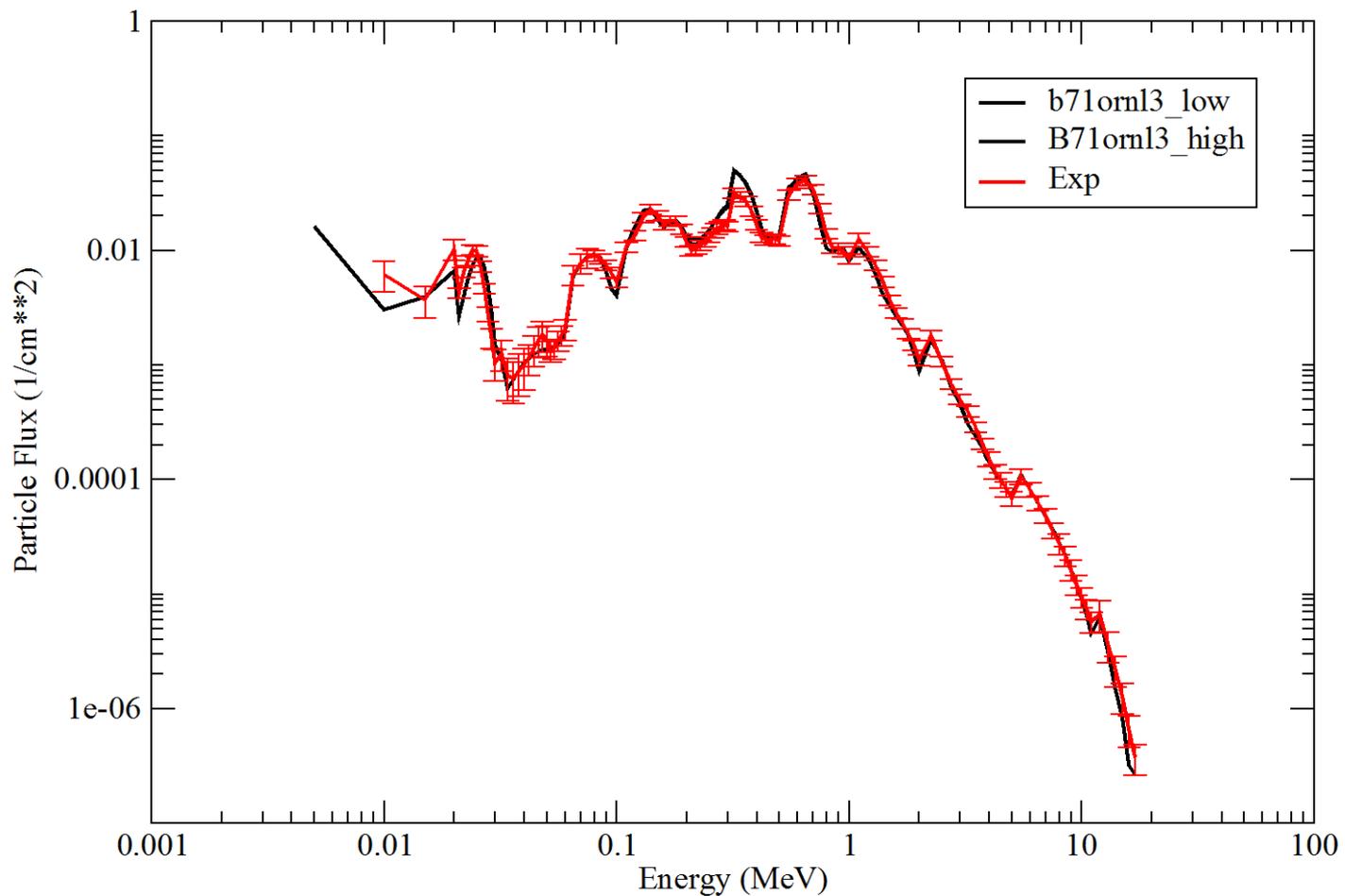


Issues with Fe-56 capture cross-section data identified through collaboration working visit at IRSN



Fe-56 Benchmark Calculations Performed at IRSN

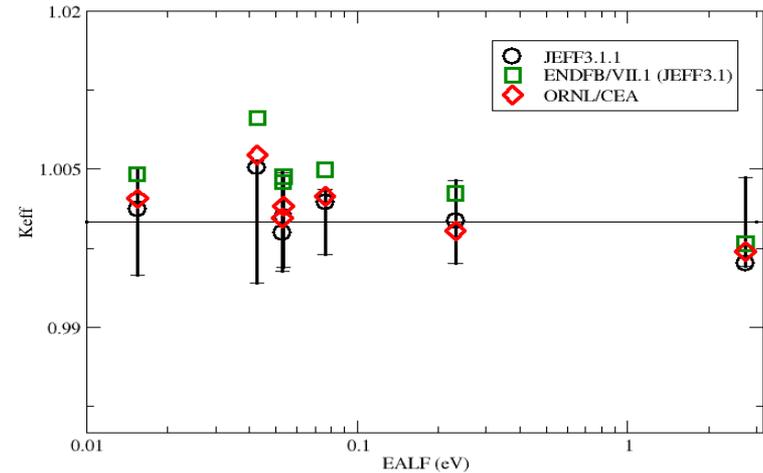
Case: 70 cm



^{239}Pu Resonance Evaluation—Task Completed

- ^{239}Pu evaluation details presented at previous NCSP TPR
- Resonance parameters evaluation done with SAMMY
- Work performed in collaboration with CEA/Cadarache and as part of WPEC Subgroup 34
- Evaluation testing collaboration with Skip Kahler (LANL)
- Final data library submitted to BNL
- Library being tested for further improvements—will likely require updates to fission spectrum and ^{240}Pu to improve results further for thermal solution systems

ICSBEP Pu benchmarks



^{235}U Evaluation

- Working Party on International Nuclear Data Evaluation Co-operation (WPEC) subgroup 29 (SG 29)
- Problem Description: ^{235}U data issue in the energy range 0.1 to 2.25 keV
- Issues and Resolutions
- Method of Evaluation: SAMMY code
- ZEUS Benchmark Results
- Conclusions

WPEC subgroup 29:

“Uranium-235 Capture Cross-section in the keV to MeV Energy Region”

Mission:

- Investigate C/E discrepancies in uranium-core integral parameters observed with all major evaluated libraries (ENDF, JENDL, JEFF)
- Perform sensitivity analyses of integral parameters with respect to differential data
- Review the ^{235}U capture cross-section to determine recommended values in the energy region from 100 eV to 1 MeV
- Perform Benchmark calculations for the FCA-IX-1, -2 and -3 cores and the ZEUS-1, -2, -3, and -4

^{235}U Issues and Resolutions:

Issues:

Overestimation of ^{235}U capture cross-section in the resonance region range (0.1 to 2.5 keV).

Recommend:

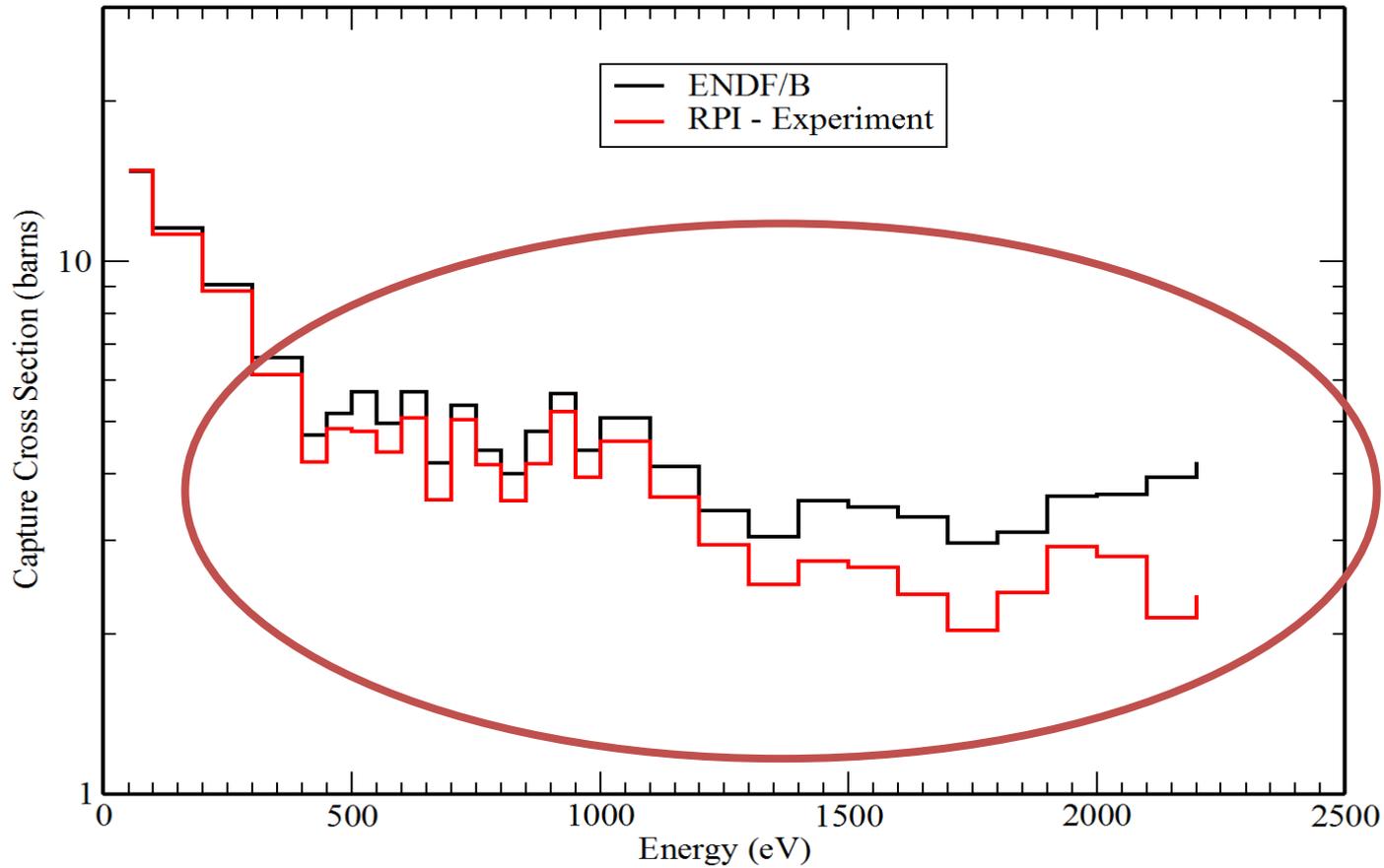
1. New measurements of capture and fission cross-section in the keV region
2. Perform new resonance analysis in the 0.1 to 2.5 keV region
3. Investigate the reason for the overestimation of criticalities for some benchmarks

²³⁵U Issues and Resolutions:

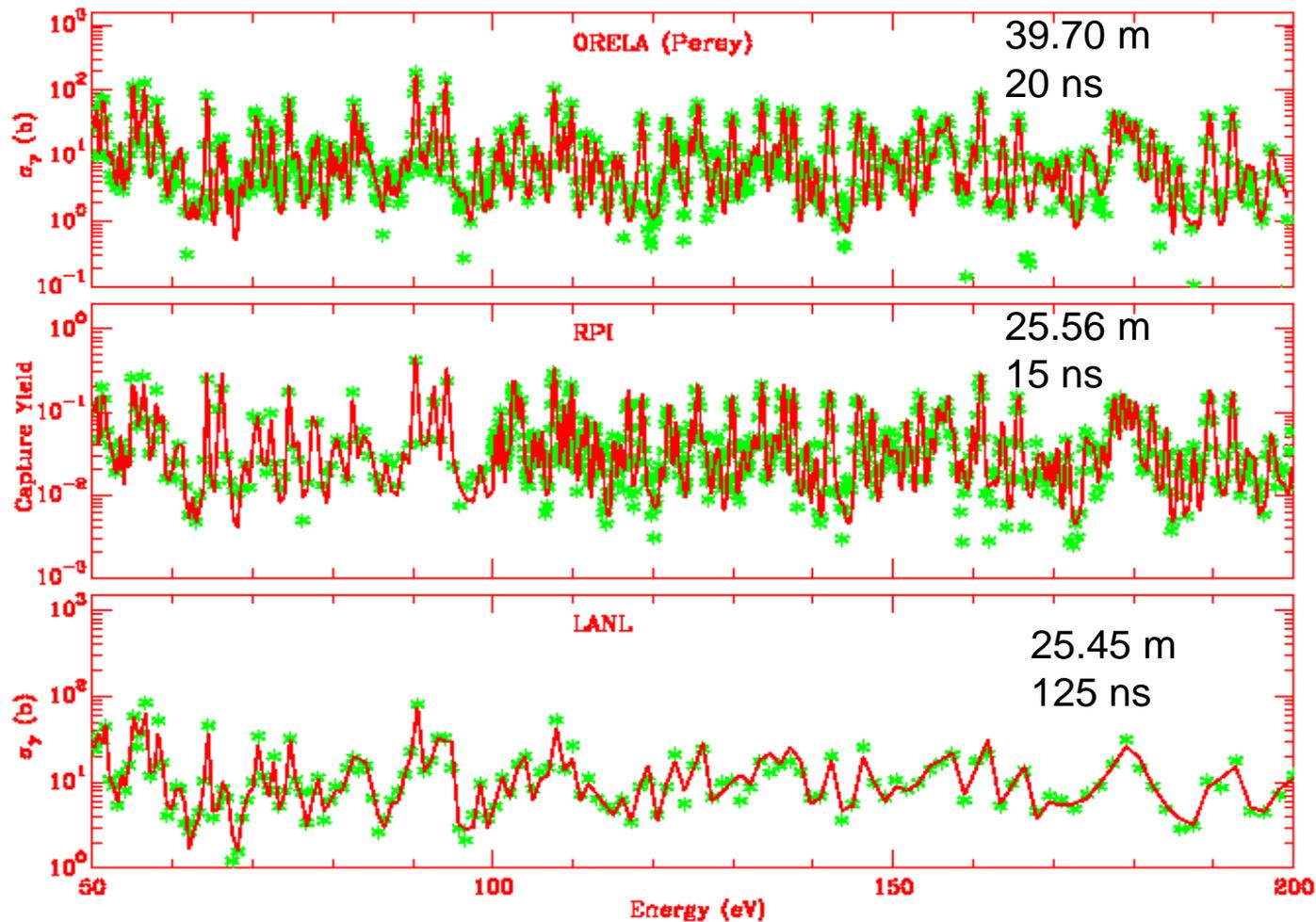
Resolution:

- ✓ New data measurements from RPI (capture and fission yields) (kind of alpha measurements)
- ✓ New capture data from LANL
- ✓ Use SAMMY code for fitting the new data
- ✓ Test the new evaluation in benchmark calculations:
 - ZEUS benchmarks (FCA not available)
- ✓ Use JENDL4 as the template
- ✓ Benchmark Calculations done with MCNP with everything else from ENDF/B-VII.0

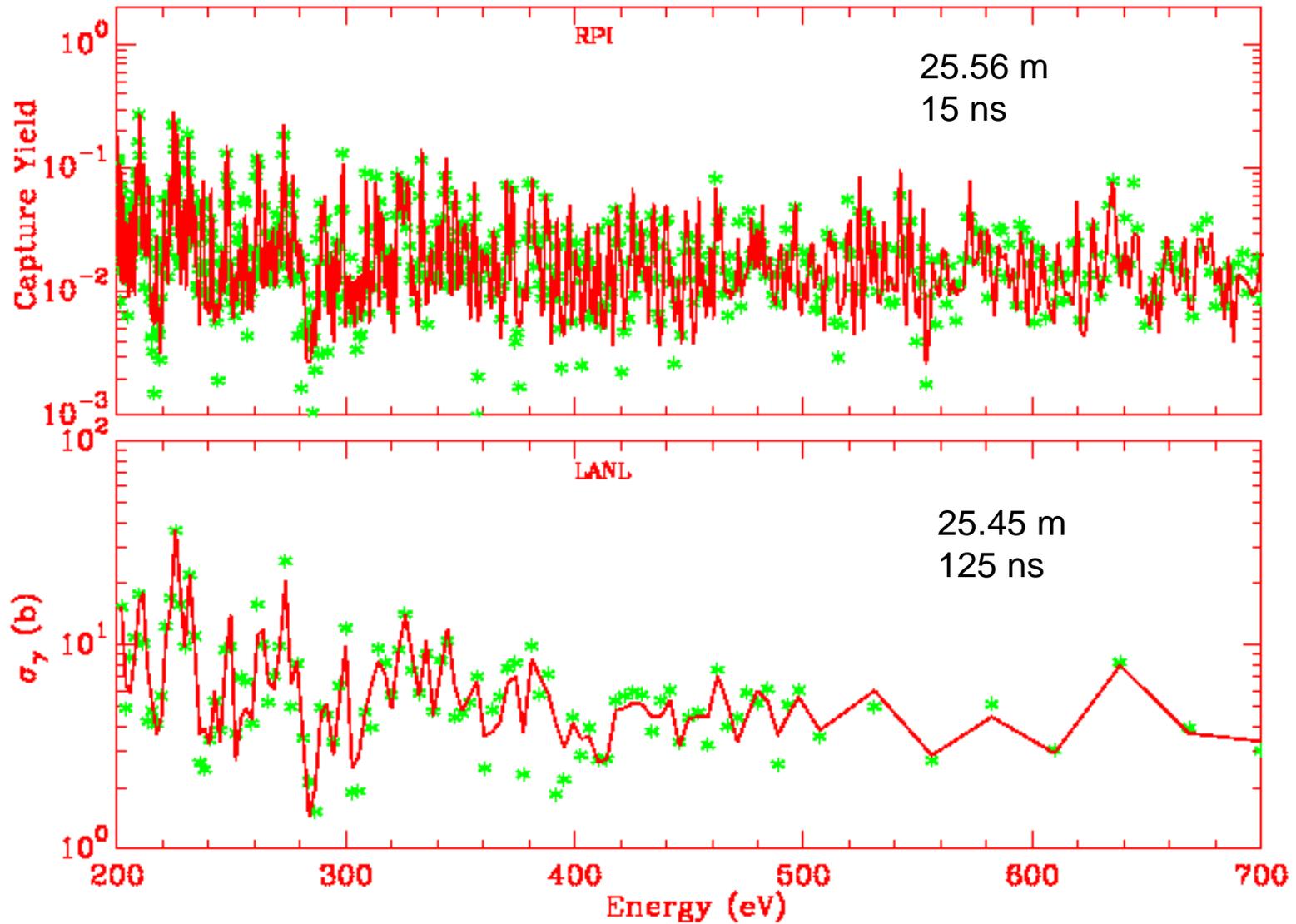
RPI capture data and ENDF evaluation (SG29 prediction confirmed)



ORNL, RPI and LANL Capture Data



RPI and LANL Capture Data



Selected Measurements

Author	Energy (eV)	Data
De Saussure (RPI/1967)	0.01 - 2250.0	Fission and Capture at 25.2 meters
Perez (ORNL/1972)	0.01 - 200.0	Fission and Capture at 39.7 meters
Weston (ORNL/1984)	14.0 - 2250.0	Fission at 18.9 meters
Gwin (ORNL/1984)	0.01 - 20.0	Fission at 25.6 meters
Spencer (ORNL/1984)	0.01 - 1.0	Transmission at 18 meters and sample thickness of 0.001468 atom/barn
Harvey (ORNL/1986)	0.4 - 68.0	Transmission at 18 meters and sample thickness of 0.03269 atom/barn

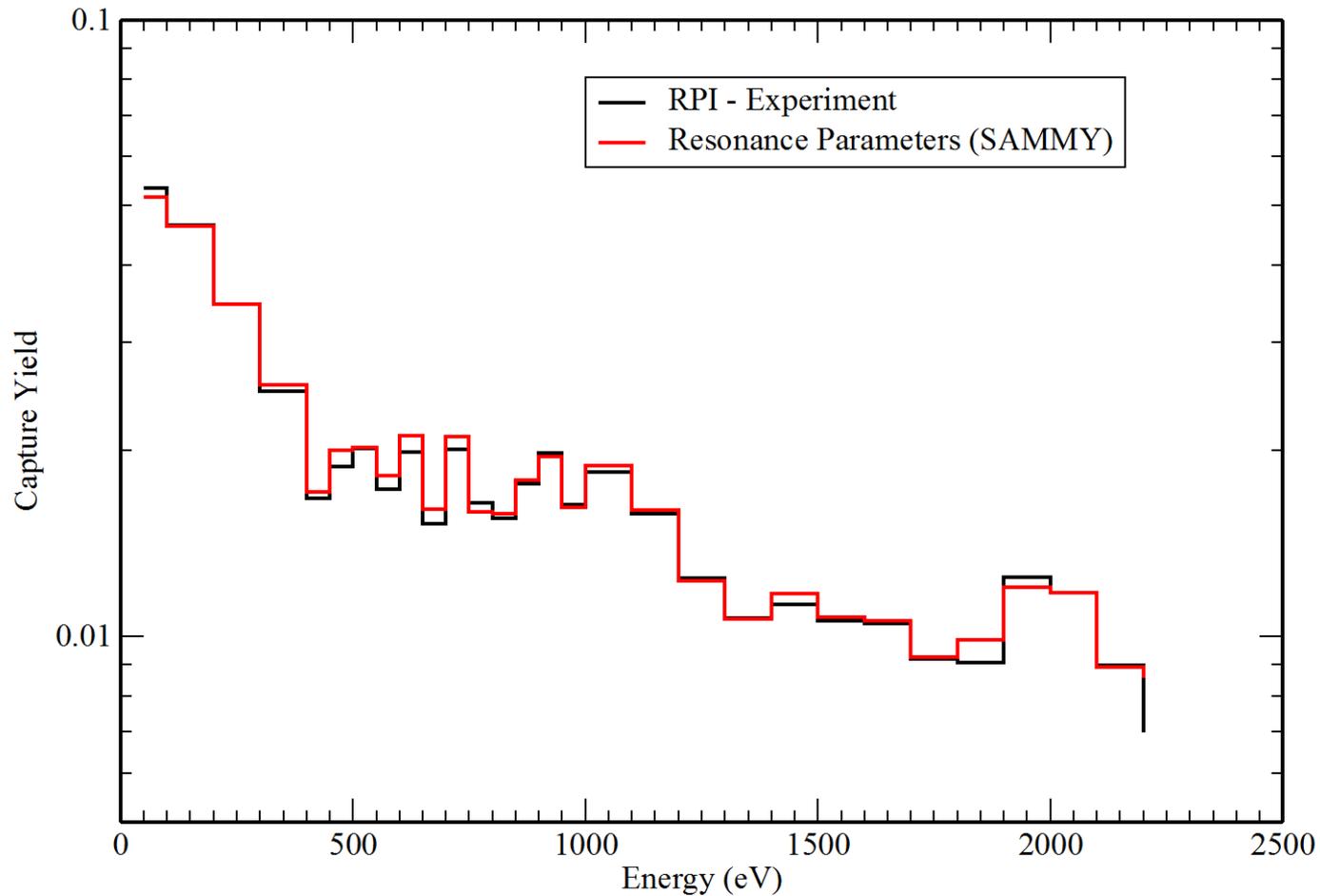
Selected Measurements

Author	Energy (eV)	Data
Harvey (ORNL/1986)	4.0 - 2250.0	Transmission at 80 meters and sample thickness of 0.00233 atom/barn cooled to 77 K
Harvey (ORNL/1986)	4.0 - 2250.0	Transmission at 80 meters and sample thickness of 0.03269 atom/barn cooled to 77 K
Wartena (Geel/1987)	0.0018 - 1.0	Eta at 8 meters
Wagemans (Geel/1988)	0.001 – 0.4	Fission at 18 meters
Schrack (RPI/1988)	0.02 - 20.0	Fission at 8.4 meters
Weigman (ILL/1990)	0.0015 – 0.15	Eta (Chopper)

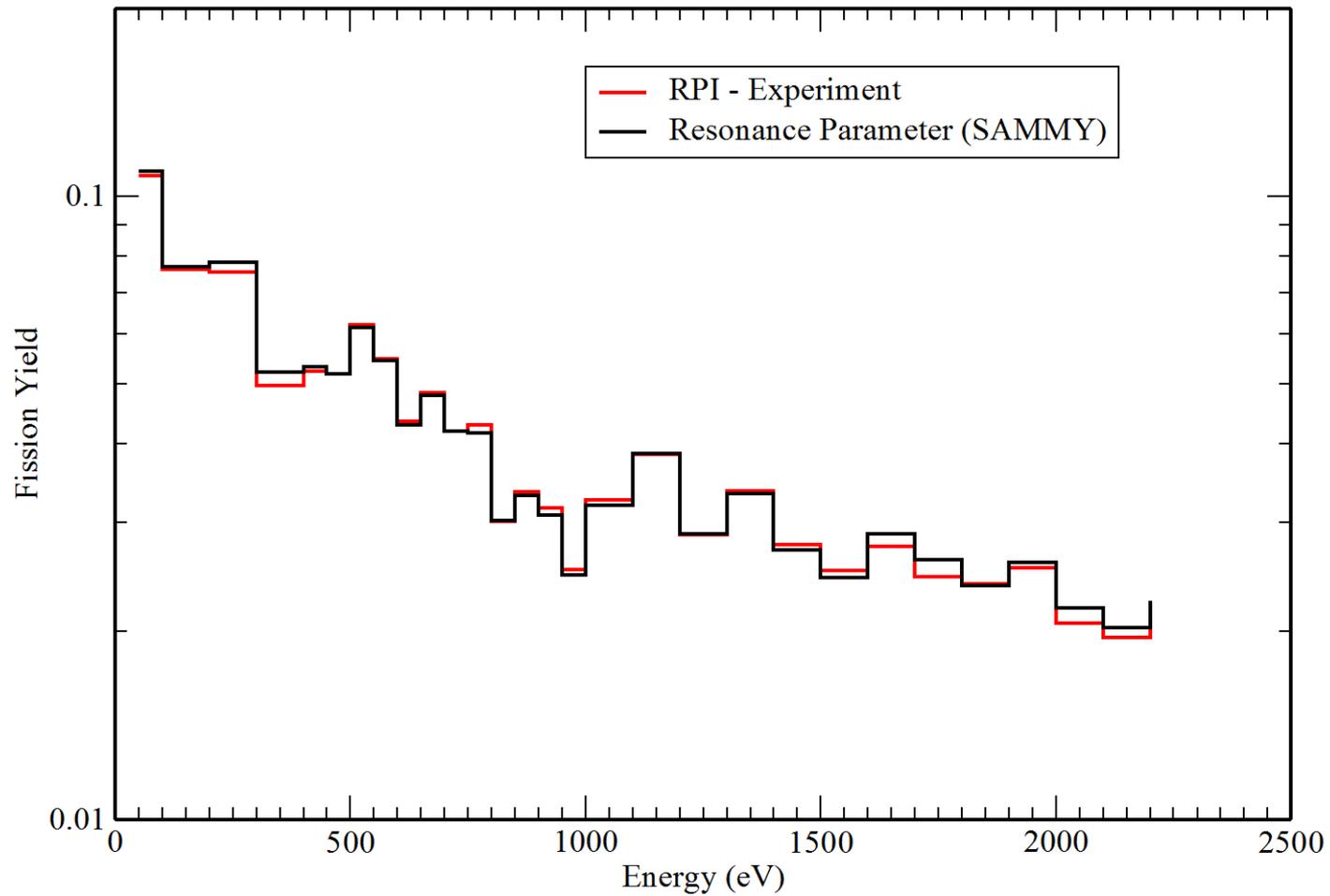
Selected Measurements

Author	Energy (eV)	Data
Weston (ORNL/1992)	100.0 - 2000.0	Fission at 86.5 meters
Moxon (ORNL/1992)	0.01 - 50.0	Fission Yield
Gwin (ORNL/1996)	0.01 - 4.0	Absorption and fission at 21.68 meters
Danon (RPI/2012)	100.0 – 5000	Fission and capture yield at 25.56 meters (burst 15 ns)
Jandel (LANL/2012)	100.0 - 5000	Capture at 25.45 meters (burst 125 ns)

Fit of the RPI Capture Data



Fit of the RPI Fission data



ICSBEP Benchmark Calculations

The HEU-MET-INTER-006 cases (ZEUS)

Intermediate Energy Benchmark:

Designed to test the ^{235}U cross sections in the intermediate energy range.

ISCEB description:

- ✓ heu-met-inter-006-1 (ZEUS1)
- ✓ heu-met-inter-006-2 (ZEUS2)
- ✓ heu-met-inter-006-3 (ZEUS3)
- ✓ heu-met-inter-006-4 (ZEUS4)

The HEU-MET-INTER-006 cases (ZEUS)

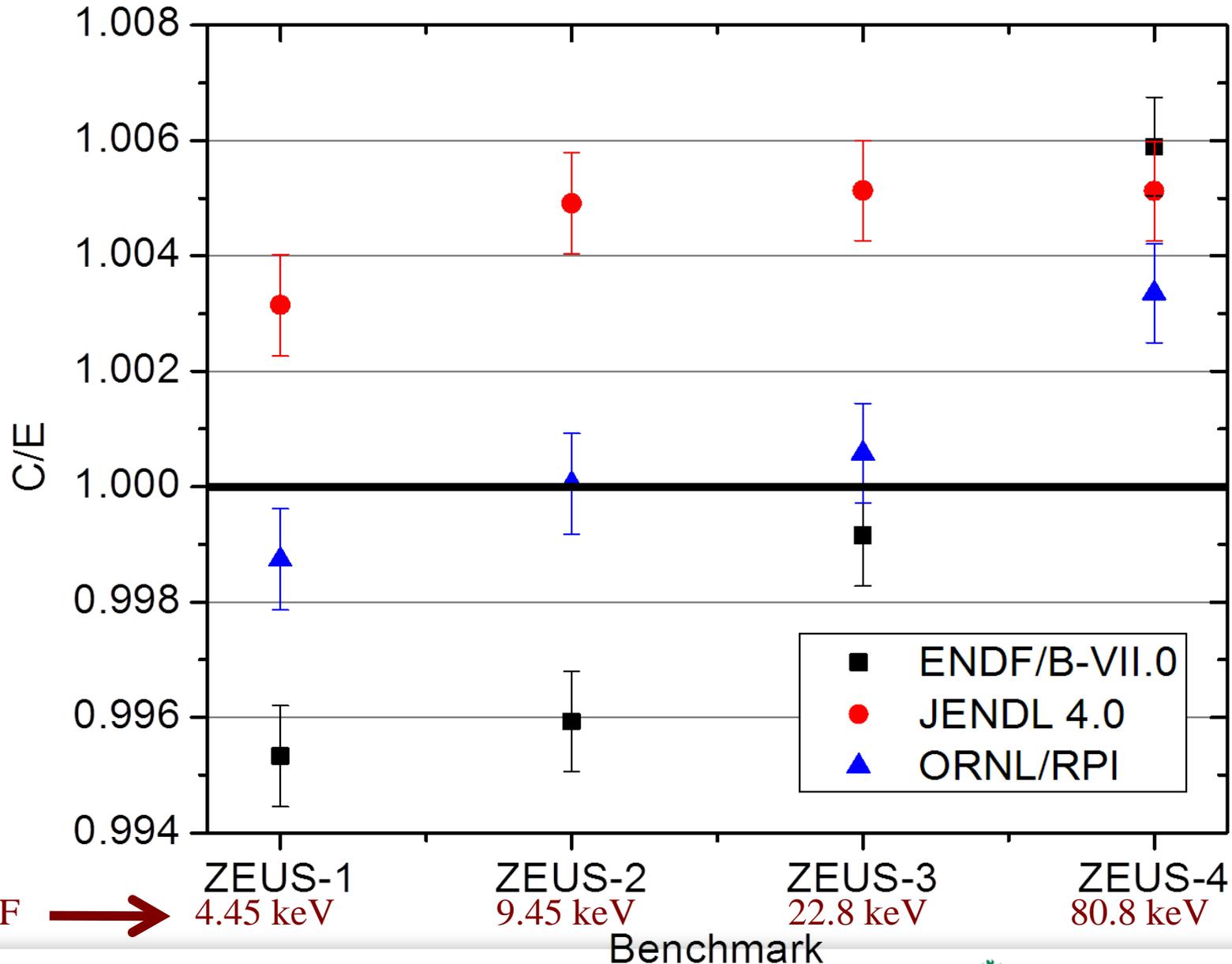
Case Number	k_{eff}	EALF (keV)	Intermediate-Energy Fission Fraction
1 (ZEUS1)	0.9977 ± 0.0008	4.44	0.730
2 (ZEUS2)	1.0001 ± 0.0008	9.45	0.698
3 (ZEUS3)	1.0015 ± 0.0008	22.80	0.636
4 (ZEUS4)	1.0016 ± 0.0008	80.80	0.503

EALF: Energy Average Lethargy Causing Fission

The HEU-MET-INTER-006 cases (ZEUS)

Case Number	Benchmark k_{eff}	Calculated k_{eff}		
		ENDF/B-VII.0	JENDL4	ORNL
1 (ZEUS1)	0.9977 ± 0.0008	0.99304 ± 0.00035	1.00084 ± 0.00036	0.99644 ± 0.00035
2 (ZEUS2)	1.0001 ± 0.0008	0.99603 ± 0.00035	1.00501 ± 0.00036	1.00015 ± 0.00035
3 (ZEUS3)	1.0015 ± 0.0008	1.00065 ± 0.00035	1.00664 ± 0.00034	1.00208 ± 0.00033
4 (ZEUS4)	1.0016 ± 0.0008	1.00750 ± 0.00031	1.00673 ± 0.00034	1.00496 ± 0.00031

The HEU-MET-INTER-006 cases (ZEUS)



Summary of Evaluation Accomplishments

- ORNL resonance evaluations on schedule per the NCSP Five Year Plan
- $^{63,65}\text{Cu}$ evaluations completed and delivered to NNDC—Vladimir Sobes completed Ph.D. dissertation
- Completed measurement and resonance analysis work for 4 tungsten isotopes ($^{182,183,184,186}\text{W}$)—finalization of evaluations in progress and on schedule to submit to NNDC in FY14
- Completed novel work on ^{56}Fe resonance evaluation to produce angular distributions from resonance parameters
 - Initiated work with processing code developers to add new processing capabilities to provide detailed angular distributions
 - Benchmark testing with LANL and IRSN in progress—providing much needed feedback to finalize and improve the evaluation
- ^{239}Pu resonance evaluation completed and submitted to NNDC
- Completed preliminary ^{235}U evaluation
 - Includes new measured data from RPI and LANSCE in the low keV region
 - Testing in progress to finalize the evaluation for submittal in FY14