IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

^{235}U Resonance Evaluation

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IRSN
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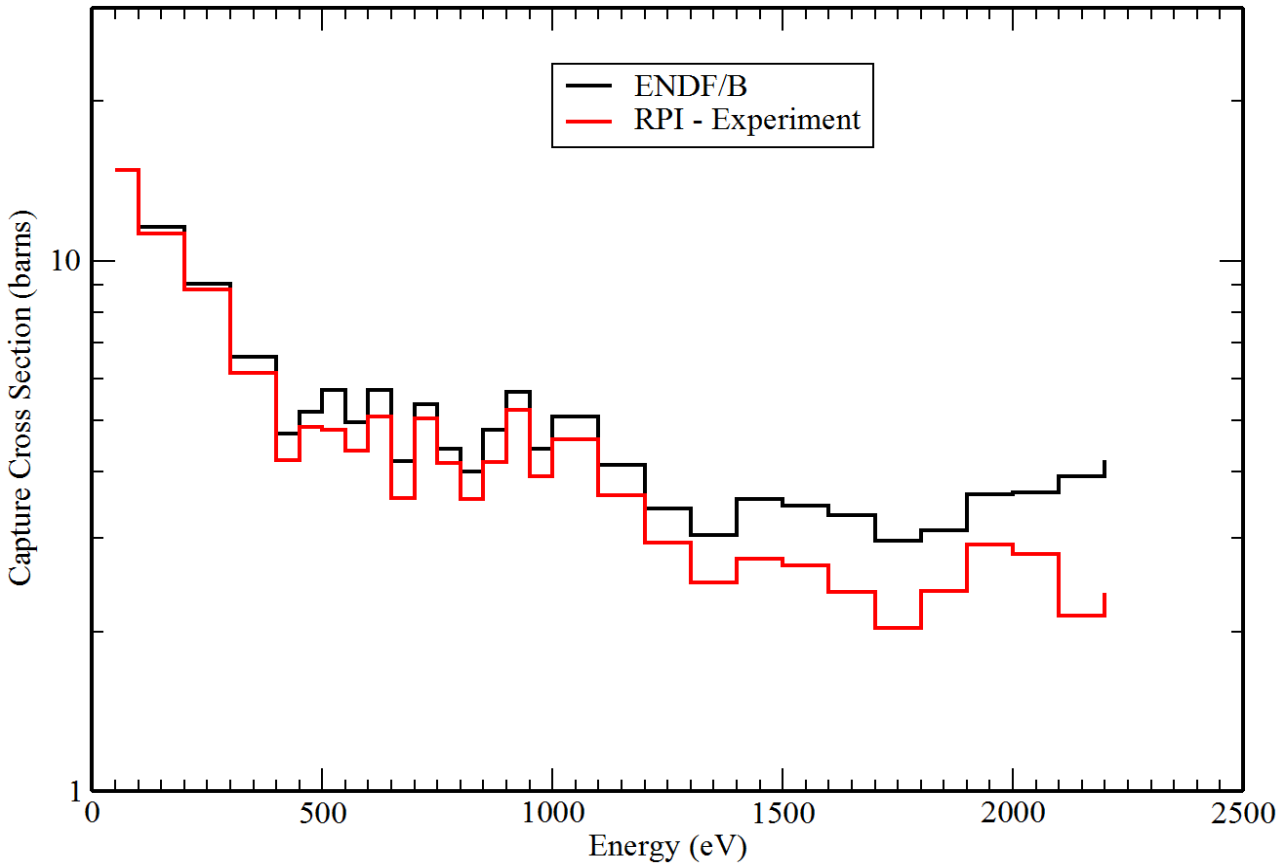
New evaluations Features:

- ✓ Much cleaner and physically acceptable set of resonance parameters (few bound levels - negative resonances);

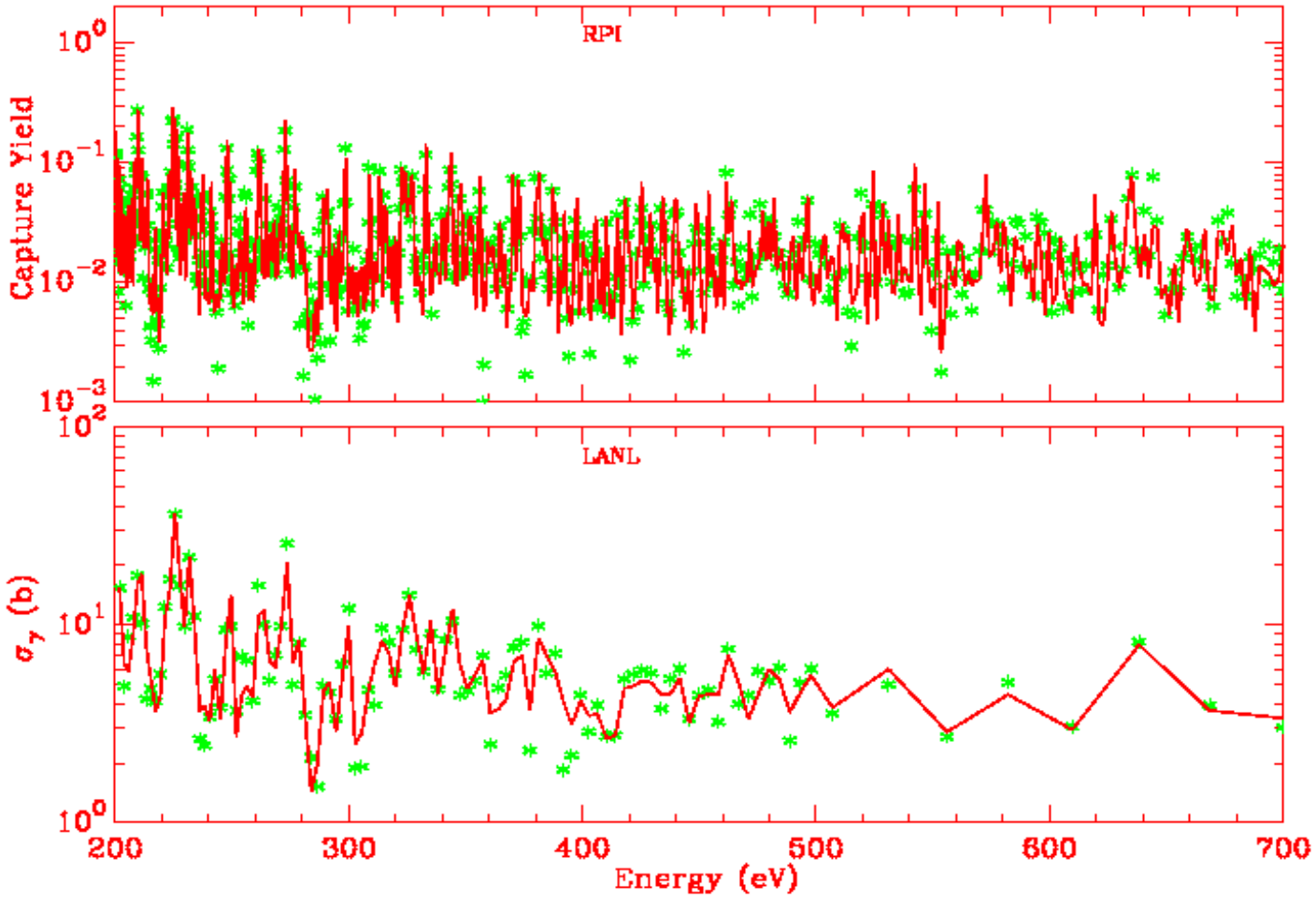
  3180 resonances with 3170 in the energy range analyzed and 10 external energies (5 bound levels and 5 levels above 2250 eV)

- ✓ Fit new capture measurements from RPI (capture and fission yields) (kind of alpha measurements);
- ✓ Fit new capture data from LANL;
- ✓ Fit new fission data from nTOF;
- ✓ Use SAMMY code for fitting the new data;
- ✓ Improve benchmark calculations for the ZEUS benchmarks;
- ✓ Address issues in connection with standards;

RPI capture data and ENDF evaluation



RPI and LANL Capture Data



Selected Data

- Four transmission measurements, eight fission cross section measurements and four capture cross section measurements were used in the evaluation;
- Evaluation performed up 2250 eV with 3180 resonances with 3170 in the energy range analyzed and 10 external resonances;
- Evaluation done using SAMMY with the Reich-Moore formalism;
- Fitted also integral data such as K1, Westcott factor, capture resonance integral;

Selected Data

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

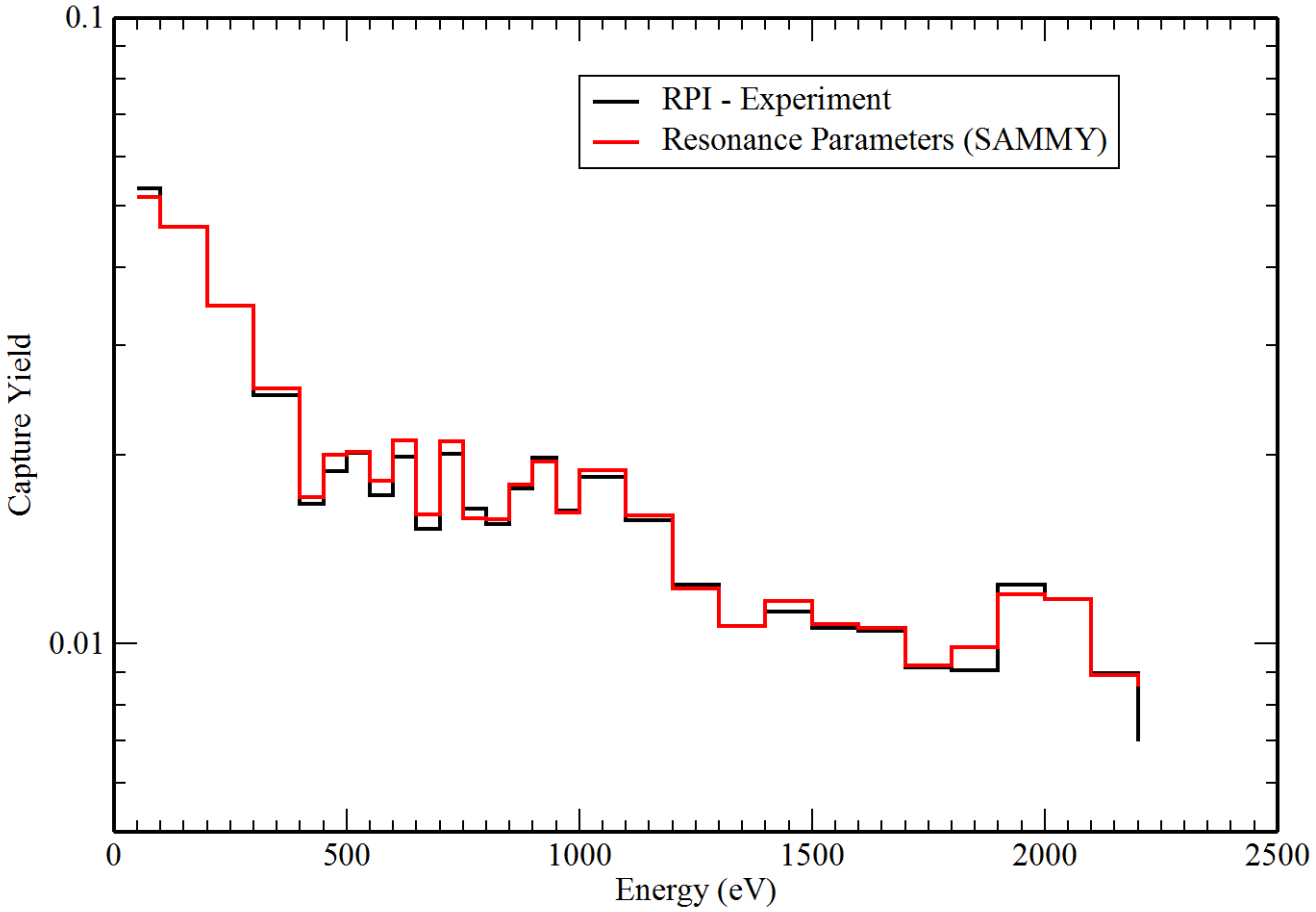
Selected Data

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)

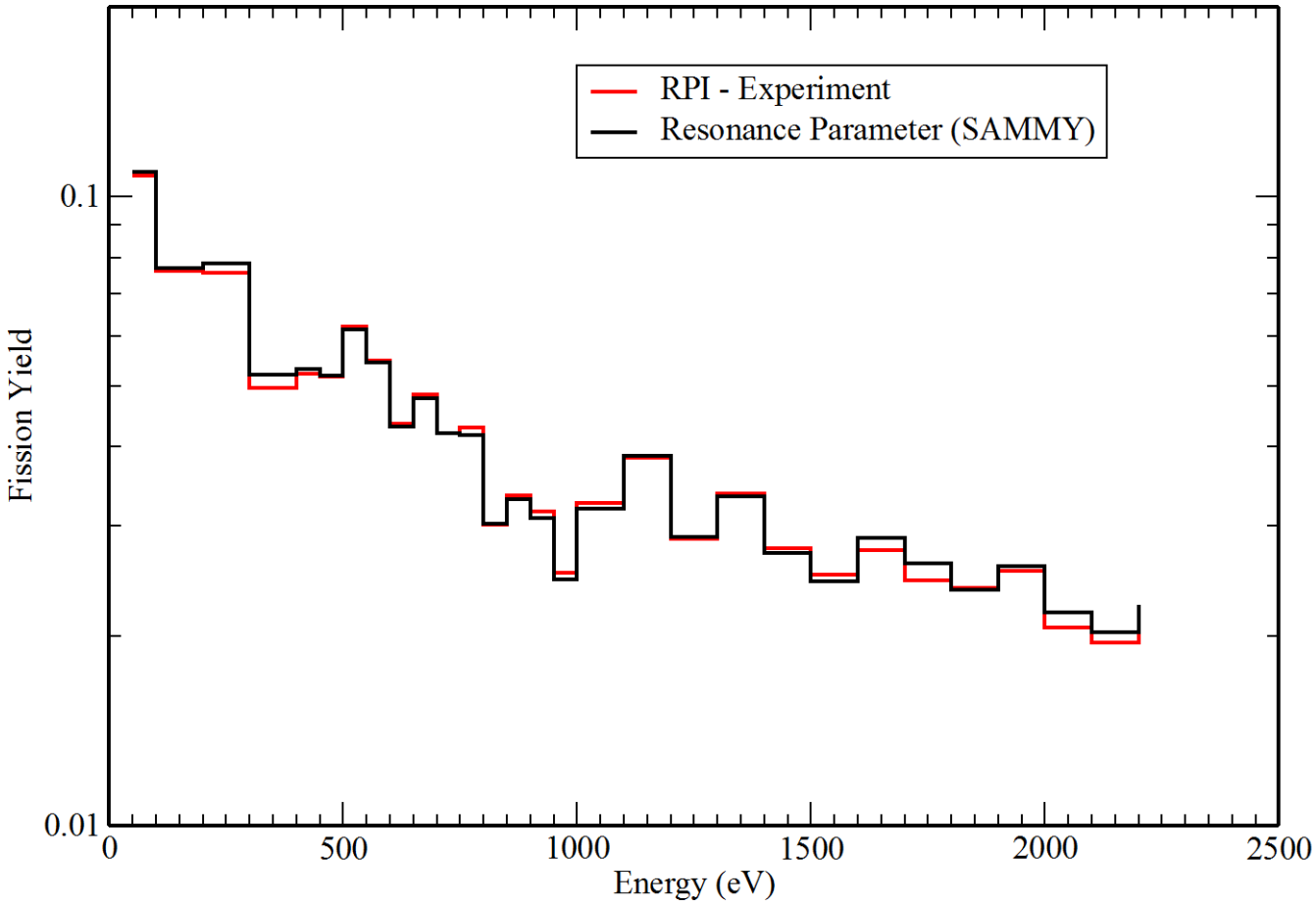
Selected Data

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)
nTOF	2.0 - 1000	Fission

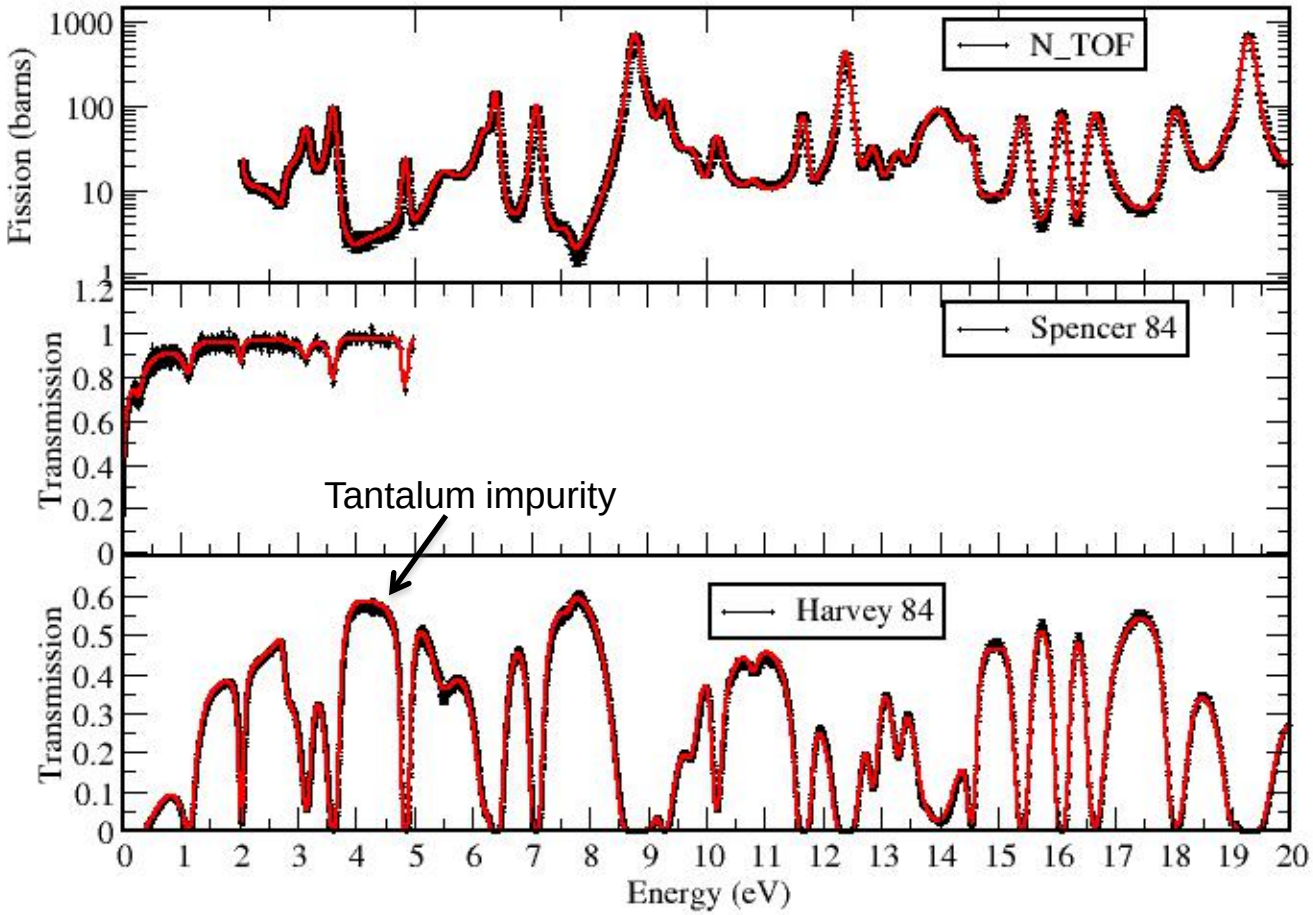
Fit of the RPI Capture Data



Fit of the RPI Fission data



SAMMY Fit of the Data



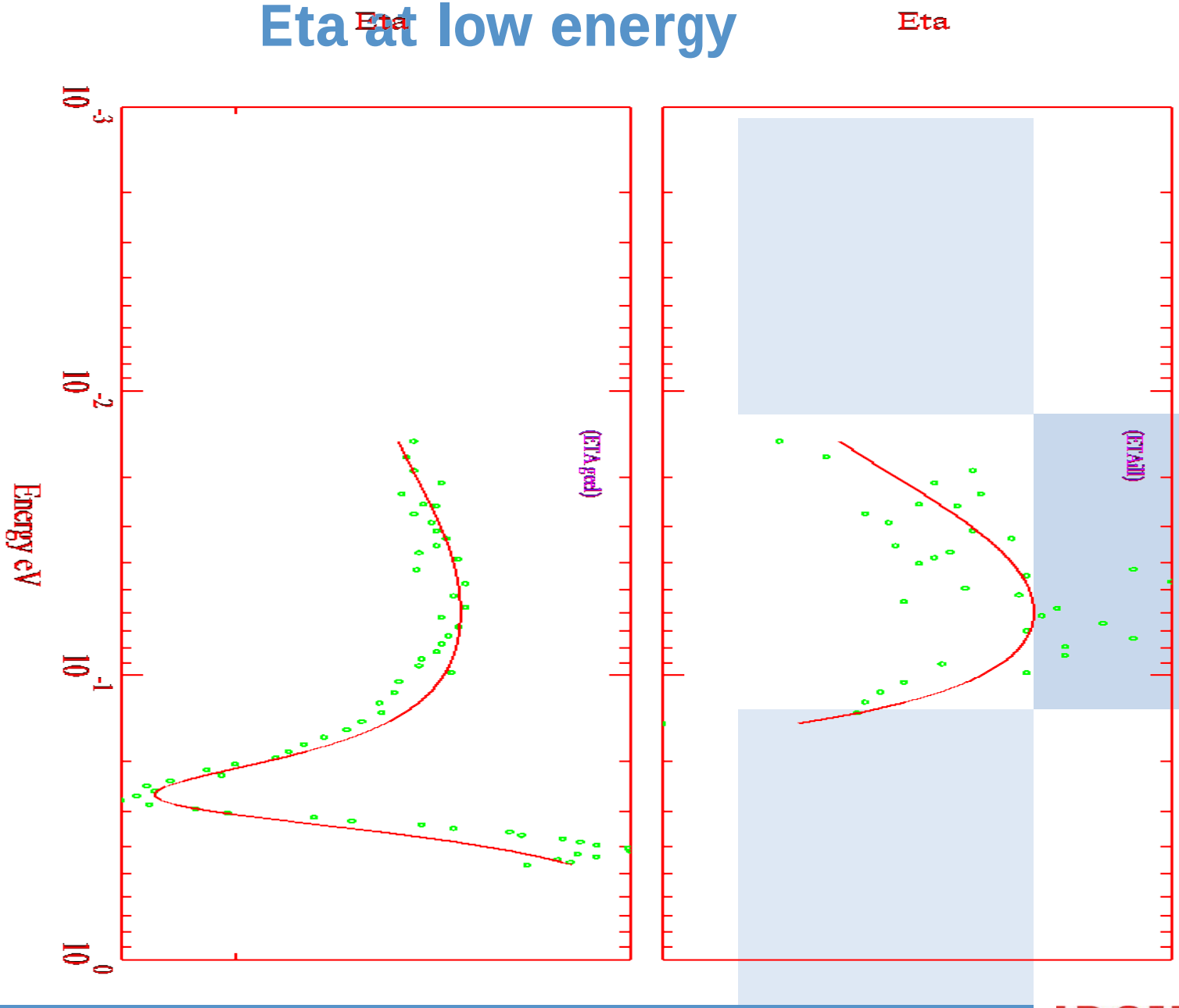
Resonance Parameter (previous evaluation)

-2038.30000 33.7920000 19.7030000-46.6520000-100.880000 0 0 0 0 0 1
-1812.10000 37.4450000 .857400000 736.170000-741.870000 0 0 0 0 0 1
-1586.20000 34.4390000 8.28450000 153.650000-99.1860000 0 0 0 0 0 1
-1357.50000 38.5060000 50.7870000-169.140000-386.220000 0 0 0 0 0 1
-1132.10000 39.7940000 1714.40000 477.010000-469.370000 0 0 0 0 0 2
-722.390000 36.1220000 2503.60000 774.940000-830.090000 0 0 0 0 0 2
-515.880000 38.0300000 2988.40000-812.850000-818.050000 0 0 0 0 0 1
-324.360000 38.9340000 151.960000 760.830000-775.110000 0 0 0 0 0 2
-74.7660000 52.0850000 383.750000-864.400000-786.520000 0 0 0 0 0 1
-3.49280000 37.7910000 8.539000-5-6.88440000 12.9770000 0 0 0 0 0 1
-3.36040000 26.2400000 5.42770000 178.410000-74.8620000 0 0 0 0 0 2
-1.50430000 37.8280000 8.533300-5-7.03970000 11.6860000 0 0 0 0 0 1
-.560980000 20.8550000 .299740000 95.6440000-11.8390000 0 0 0 0 0 1
-.181820000 20.5775100 .003707878 183.800100-19.6895500 0 0 0 0 0 2
3.657500-5 40.0000000 6.460800-8-.509120000 .935360000 0 0 0 0 0 2
.273793300 46.2030000 .004248600 117.710000 .348480000 0 0 0 0 0 1

Resonance Parameter (present evaluation)

-75.4054194 47.7816381 507.274815-487.090282-443.345624 0 0 0 0 0 1
-5.25305749 36.7971443 12.1702723 195.680634-160.038731 0 0 0 0 0 2
-.480833205 39.2285205 .088766263 129.661719-80.5350655 0 0 0 0 0 1
-.432058744 38.0239552 .033255031 167.072576-8.28323254 0 0 0 0 0 2
-3.657500-5 39.9884562 6.460800-8-.509120000 .935360000 0 0 0 0 0 2
.2638505352 45.7354656 .004252450 123.218845 .061140628 0 0 0 0 0 1
1.136136387 38.5500000 .015265599 .066738201 119.250588 0 0 0 0 0 2
1.298683329 38.6000000 .000381621-.167112518 17.3541004 0 0 0 0 0 2
2.035044979 38.4665748 .009236482-11.8873383 .396497809 0 0 0 0 0 1

Eta at low energy



^{235}U Thermal Values

Quantity	Standard	B7 (barns)	JEFF3.2 (barns)	JENDL4 (barns)	IRSN (barns)
σ_f (barns)	584.380 ± 1.030	584.897	584.897	584.897	584.417
σ_γ (barns)	99.304 ± 0.725	98.665	98.665	98.665	99.231
σ_s (barns)	14.087 ± 0.219	15.115	15.115	15.115	14.086

^{235}U Fission Integral in the Energy Range 7.8 eV to 11 eV

$$\int_{7.8\ eV}^{11\,eV} \sigma_f(E)\, dE$$

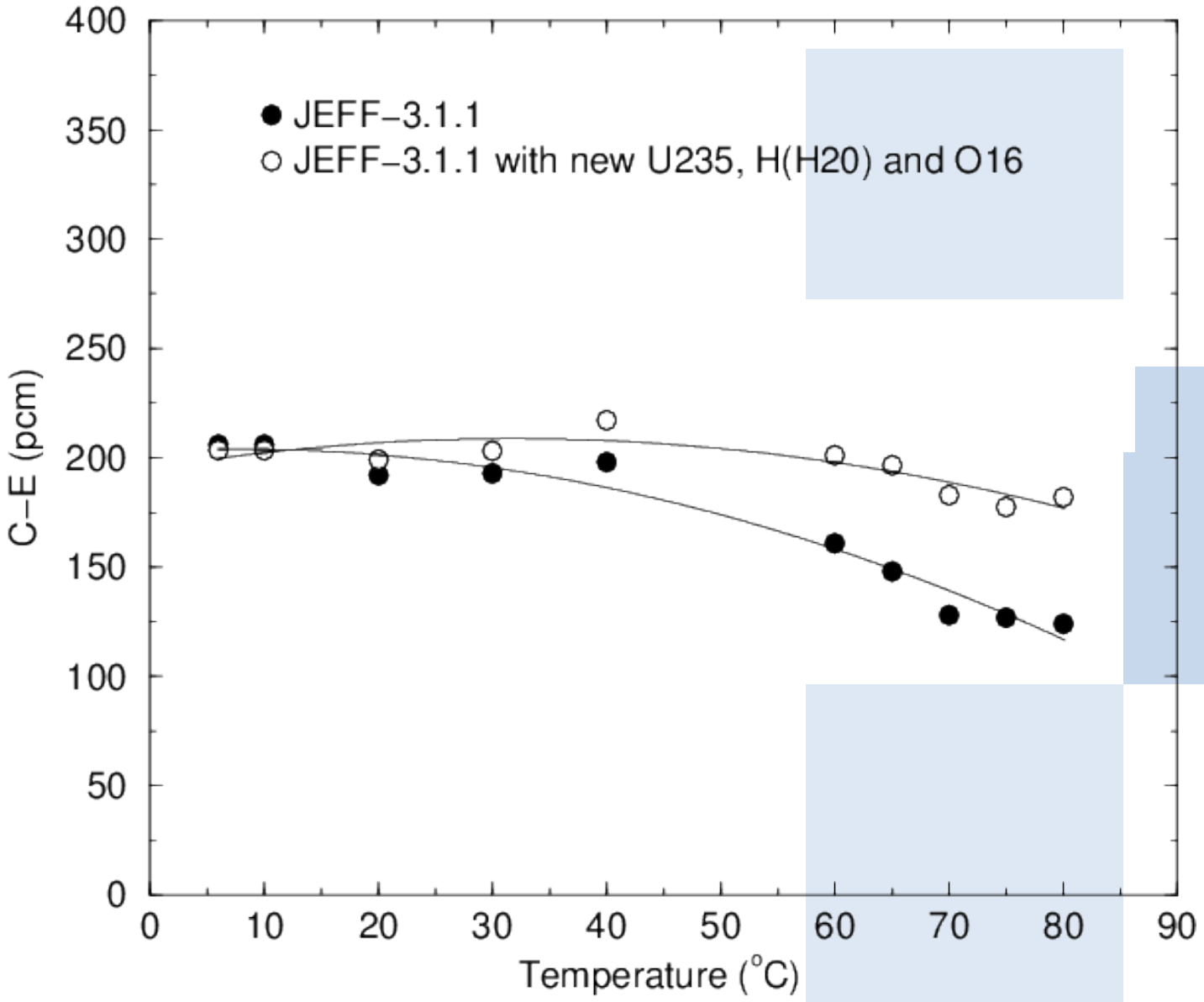
ΔE (eV)	Standard (b.eV)	B7 (b.eV)	JEFF3.2 (b.eV)	JENDL4 (b.eV)	IRSN (b.eV)
7.8 eV – 11 eV	246.40 ± 1.24	241.90	241.90	241.90	246.31

^{235}U Average Fission integral

ΔE (eV)	Standard (barns)	B7 (barns)	JEFF3.2 (barns)	JENDL4 (barns	IRSN (barns)
100 – 200	21.17 (11)	20.33	20.33	20.29	21.01
200 – 300	20.69 (11)	20.62	20.62	20.66	20.78
300 – 400	13.13 (7)	12.81	12.81	12.81	13.22
400 – 500	13.78 (8)	13.33	13.33	13.31	13.51
500 – 600	15.17 (9)	14.89	14.89	14.73	15.21
600 - 700	11.51 (7)	11.26	11.26	11.13	11.52
700 – 800	11.10 (6)	10.89	10.89	11.06	11.11
800 – 900	8.21 (48)	7.98	7.98	7.93	8.12
900 – 1000	7.50 (44)	7.25	7.25	7.46	7.39
1000 - 2000	7.30 (40)	7.14	7.14	7.10	7.29

$$< \sigma_f > = \frac{1}{E_f - E_i} \int_{E_i}^{E_f} \sigma_f (E)\, \mathrm{d}\, E$$

Doppler Reactivity Coefficient



Conclusions

✓ Present evaluation addresses issues regarding fission integral in the energy range 7.8 – 11 eV with the help of the nTOF data

✓nTOF fission data well represented;

✓ Thermal values are reproduced as indicated by the standard

✓Average fission standard values well reproduced;

✓ New capture data well fitted above 100 eV;

✓ Benchmark results favors the new resonance parameters;

✓ Impact of lower thermal scattering compensated with new ^{16}O resonance evaluation;

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^{239}Pu evaluation work

- Extension of the resolved resonance region from 2.5 keV to 4 keV.
  - Purpose: eliminate issues with the unresolved resonance representation by using resolved resonance parameters;

- High-resolution transmission data of Harvey and fission of Weston were used in the SAMMY fitting;

- Fission cross section of Weston (1984) normalized according to the NEA-WPEC-5 subgroup on the fission of ^{239}Pu. Recommendation that the fission cross section integral in 100 eV – 1000 eV is 9275 b.eV

What is new:

- Fitting of the capture cross section above 2 keV using data measured at LANL recently;
- Fitting of thermal values to the standards;
- Fitting of average fission values to the standards;
- The evaluation indicates the fitted standard values a more consistent with benchmark results !!

SAMMY fit to the experimental data