Status of evaluated data for neutron induced reactions on ^{238}U in the resonance region

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EC – JRC – IRMM

Standards for Nuclear Safety, Security and Safeguards (SN3S)

Evaluations in the RRR

- **Sowerby and Moxon (1994) JEF 2, ENDF/B-VI , JENDL 3 (NEANDC Task force)**

  - **Transmission**
    - ORELA 42 m, 2.00 10^{-4} to 0.175 at/b, Olsen et al., NSE 62 (1977) 479
    - ORELA 150 m, 3.80 10^{-3} to 0.175 at/b, Olsen et al., NSE 69 (1979) 202

  - **Capture**
    - ORELA 40 m, ORELAST (OLS), φ (^{6}Li) de Saussure et al., NSE 51 (1973) 385
      Correction for bias on normalization (x 0.845 $e^{0.3842/E^{1/2}}$)
    - ORELA, 150 m, ORELAST (OLS), φ (^{6}Li) Macklin et al., ANE 18 (1991) 576
      Correction for bias on normalization

Evaluations in the RRR

- **Sowerby and Moxon (1994)** **JEF 2, ENDF/B-VI , JENDL 3** **(NEANDC Task force)**
- **Derrien et al. (2005)** **ENDF/B-VII.1, JEFF 3.1.2 , JENDL 4.0** (RRR < 20 keV)
  - **Transmission**
    - ORELA 42 m, 2.00 10^{-4} to 0.175 at/b, Olsen et al., NSE 62 (1977) 479
    - ORELA 150 m, 3.80 10^{-3} to 0.175 at/b, Olsen et al., NSE 69 (1979) 202
    - ORELA 200 m, 1.24 10^{-2} to 0.175 at/b, Harvey et al., NDST, Mito (1988)
    - GELINA 26 m, Doppler studies, Meister et al., NDST, Trieste (1998)
  - **Capture**
    - ORELA 40 m, ORELAST (OLS), φ (^{6}Li) de Saussure et al., NSE 51 (1973) 385
      Correction for bias on normalization (x 0.85)
    - ORELA, 150 m, ORELAST (OLS), φ (^{6}Li) Macklin et al., ANE 18 (1991) 576
      Correction for bias on normalization (x 1.15)
    - GELINA 8.7 m, BGO (coincidence) Corvi et al., NDST, MITO (1988)
      Only shape < 0.1 eV
    - Activation thermal and URR Poenitz et al., NSE 78 (1981) 239

Evaluations in the URR

- **Evaluation reports**
  - Poenitz et al. (1983) Exp. (LSQ) ENDF/B-VI ANL-83-4 (1983) 288
  - Carlson et al. (2012) Exp. (LSQ) partly in ENDF/B-VII.1 NDS 110 (2009) 3215
  - Fröhner (1989) HF JEFF 3.1.2 NSE 103 (1989) 119
  - Maslov et al. (2002) HF MINSK ANE 29 (2002) 1707
  - Courcelle et al. (2007) HF ? NSE 156 (2007) 391

- **Experimental data base**
  - See Carlson et al. NDS 110 (2009) 3215
  - Limited number of TOF + prompt γ -rays, only 1 C_6D_6 measurement
    - Moxon (1969) Moxon-Rae
    - *de Saussure et al. (1973) OLS bias on normalization NSE 51 (1973) 385*
    - *Yamamuro et al. (1980) C_6D_6 $\delta N/N = 7\%$ JNST 17 (1980) 582*
    - Kazakov et al. (1986) OLS ANE 18 (1991) 567
    - *Macklin et al. (1991) OLS bias on normalization ANE 18 (1991) 567*

$\Rightarrow$ **New measurements at GELINA and n_TOF as part of the ANDES project sponsored by the European Commission.**

Additional data

- **n_TOF** (see presentations F. Mingrone and T. Wright)
  - Capture 185 m $\Delta L \sim 10$ cm Total energy (C_6D_6 + WF) n = 9.56 10^{-4} at/b
  - Capture 185 m $\Delta L \sim 10$ cm Total absorption (BaF_2) n = 9.56 10^{-4} at/b

    Normalization : saturated resonance at 6.67 eV with $\Gamma_n << \Gamma_\gamma$

    Neutron flux : combined $^6Li(n,\alpha)$, $^{235}U(n,f)$

- **GELINA**
  - Transmission 50 m $\Delta L \sim 2.0$ cm ^{6}Li-scintillator n = 2.40 10^{-3} at/b
  - Capture 12.5 m $\Delta L \sim 2.5$ cm Total energy (C_6D_6 + WF) n = 1.92 10^{-3} at/b
  - **Capture 60 m $\Delta L \sim 2.0$ cm Total energy (C_6D_6 + WF) n = 9.56 10^{-4} at/b**

    Normalization : saturated resonance at 6.67 eV with $\Gamma_n << \Gamma_\gamma$

    Neutron flux : $^{10}B(n, \alpha) \leq 120$ keV

    $^{235}U(n,f) \geq 120$ keV

- **nELBE (HZDR, A. Junghans)**
  - **Transmission**

TOF - Facility GELINA

- **Pulsed white neutron source**

  (10 meV < E_n < 20 MeV)

- **Neutron energy : time-of-flight (TOF)**

- **Multi-user facility: 10 flight paths**

  (10 m - 400 m)

- **Measurement stations with special equipment to perform:**
  - **Total cross section measurements**
  - **Partial cross section measurements**

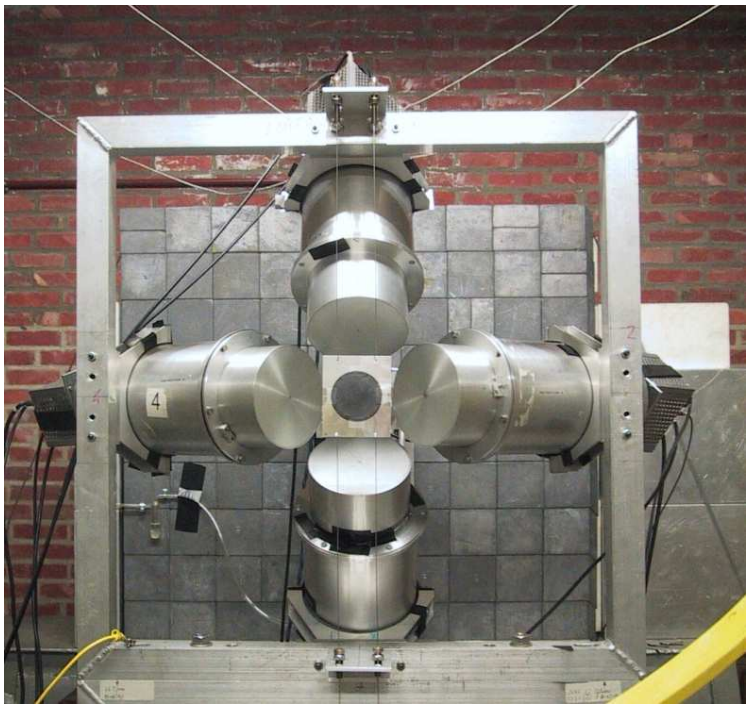
σ(n,γ) measurements at GELINA

- **Total energy detection principle**
  - C_6D_6 + PHWT
  - 125º

- **Flux measurements (IC)**
  - < 120 keV : $^{10}B(n,\alpha)$

    back – to back layer
  - > 120 keV : $^{235}U(n,f)$

L = 12.5 m and 60 m



$$Y_{exp} = N\frac{C_w - B_w}{C_\varphi - B_\varphi} Y_\varphi$$

$$\frac{\delta Y_{exp}}{Y_{exp}} \leq 2\%$$

WF : from MC simulations
Validated by experiment

$$C_w(t) = \int C_c(t,E_d)\, WF(E_d)\, dE_d$$

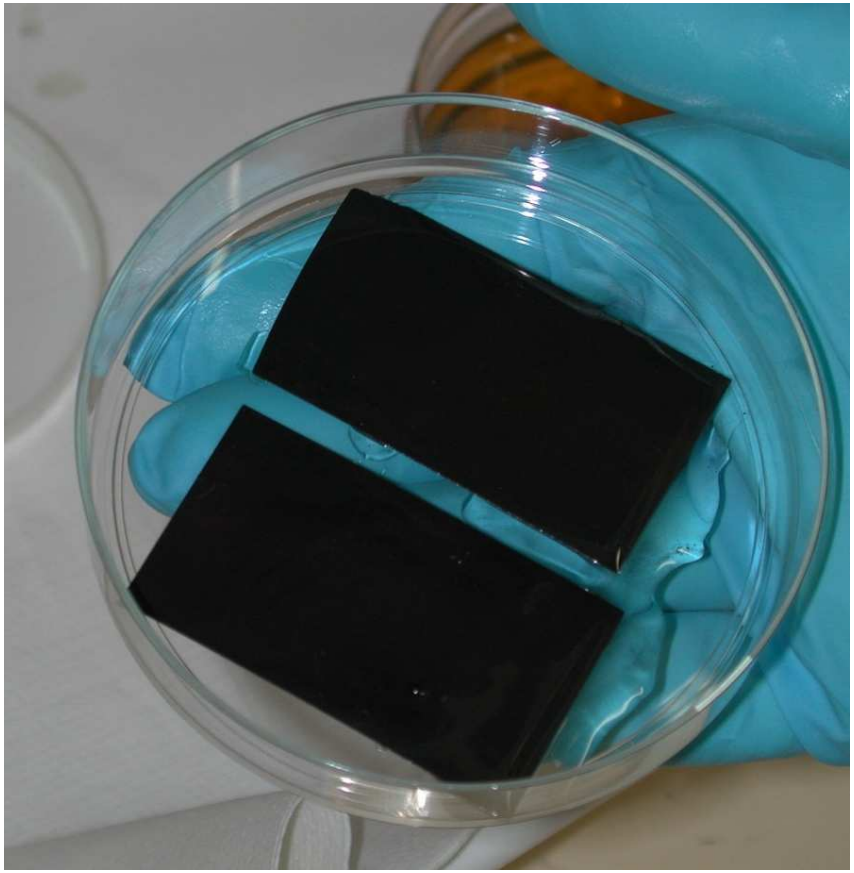
Borella et al., NIM A 577 (2007) 626

Schillebeeckx et al., Nuclear data sheets, 113 (2012) 3054 - 3100

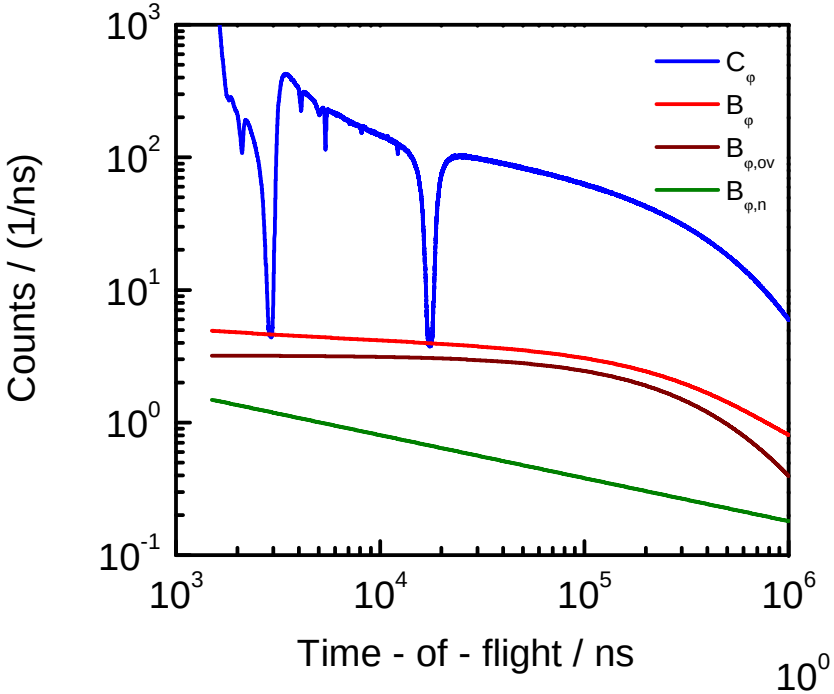
σ(n,γ) measurements for ^{238}U at 12.5 and 60 m

Sample	Size	Mass	Areal density
	mm x mm	g	at/b
^{238}U (1)	53.67 x 30.21	6.170 ± 0.020	(9.570 ± 0.050) 10^{-4}
^{238}U (2)	53.08 x 30.03	6.030 ± 0.020	(9.628 ± 0.050) 10^{-4}

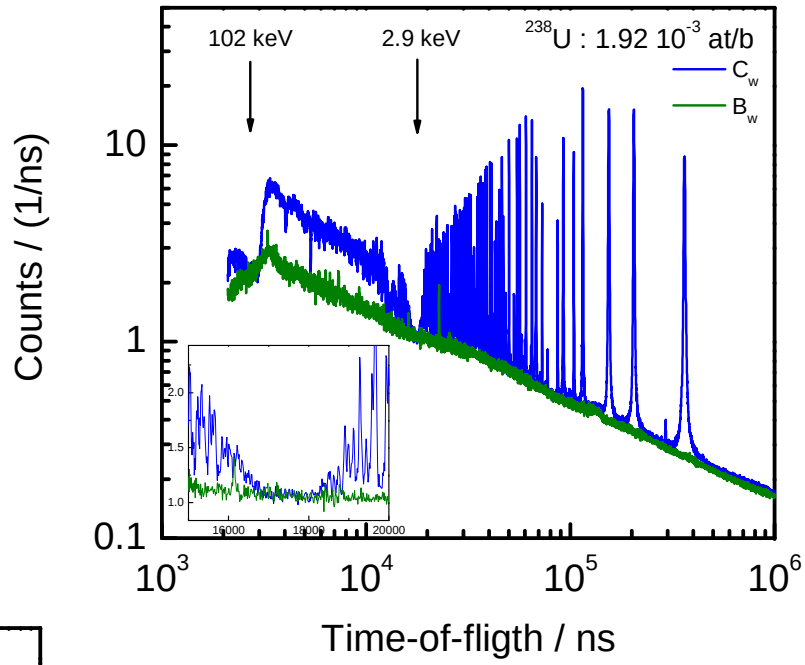
^{234}U : < 1ppm
^{235}U : 11ppm
^{236}U : < 1ppm

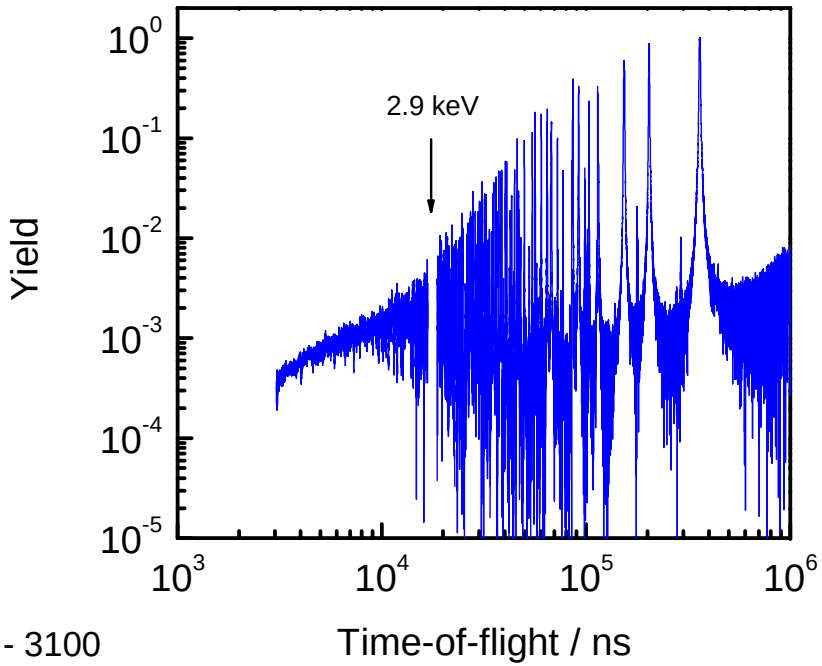


σ(n,γ) measurements for ^{238}U at 12.5 m



$$Y_{exp} = N\frac{C_w - B_w}{C_\varphi - B_\varphi} Y_\varphi$$



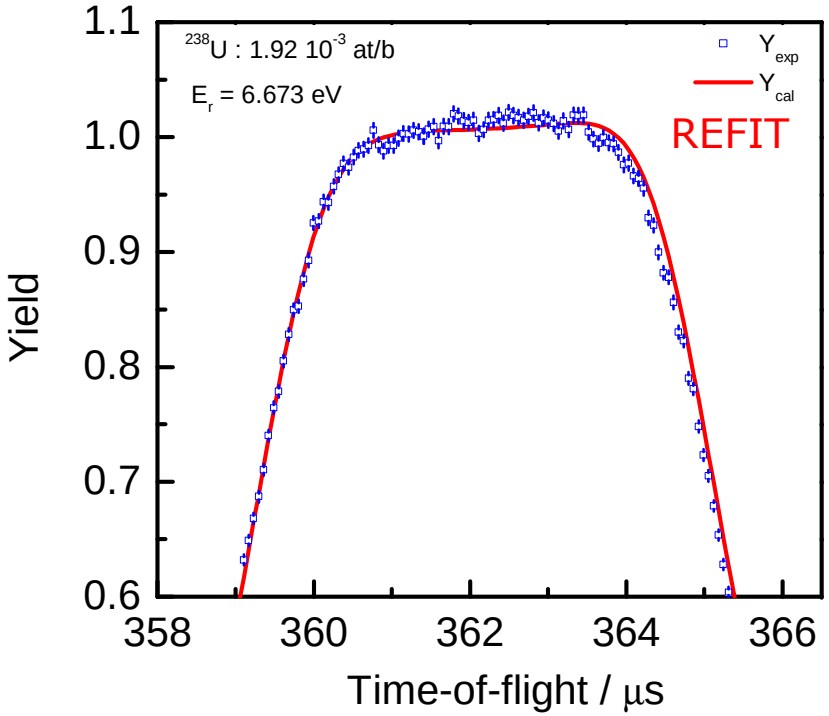


Fixed background filters

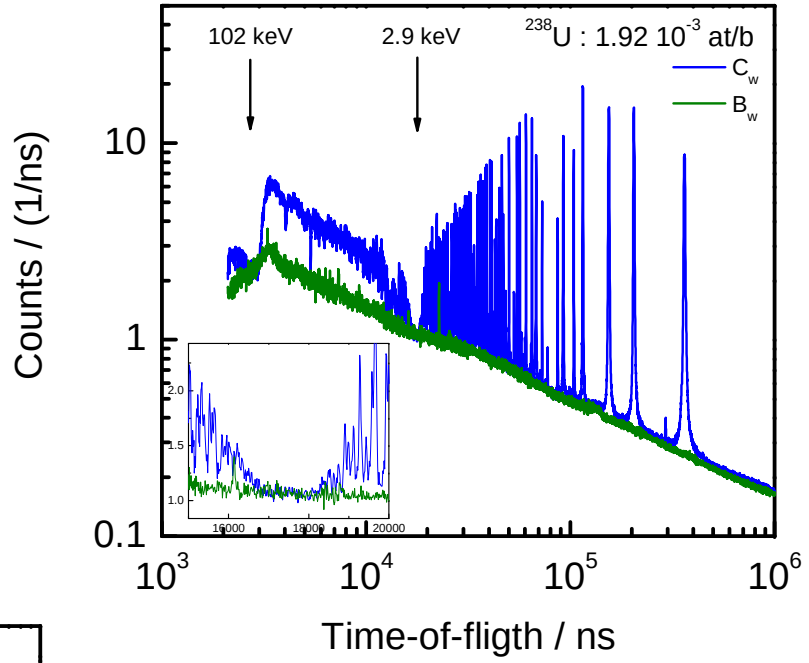
⇒ $\delta Y_{exp}/Y_{exp}$ ~ 2.5 % due to B_w

Schillebeeckx et al., NDS, 113 (2012) 3054 - 3100

σ(n,γ) measurements for ^{238}U at 12.5 m

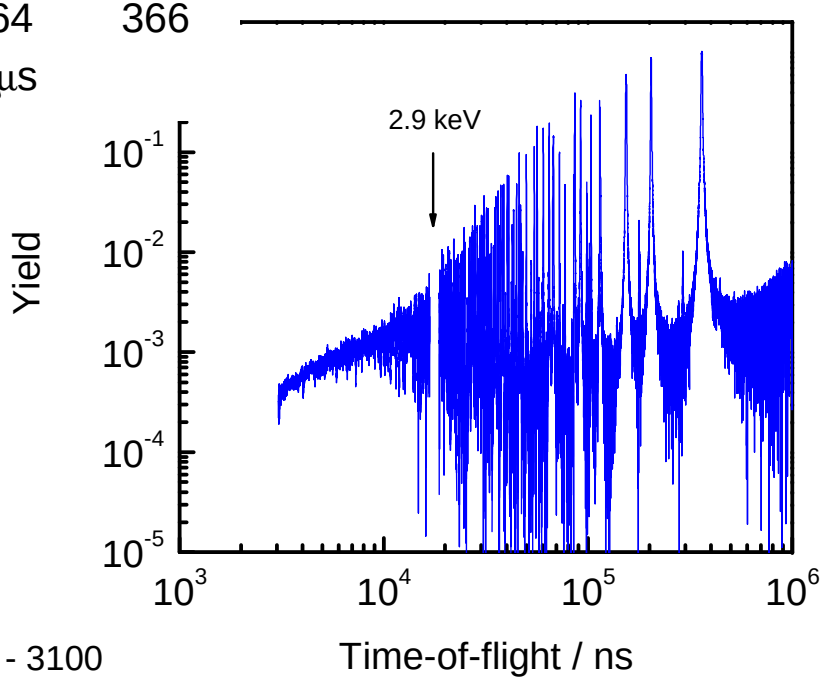


$$Y_{exp} = N\frac{C_w - B_w}{C_\varphi - B_\varphi} Y_\varphi$$



Internal normalization
+ WF depending on σ_{tot}
+ flux ^{10}B(n,α)

⇒ δN/N < 1.0 %

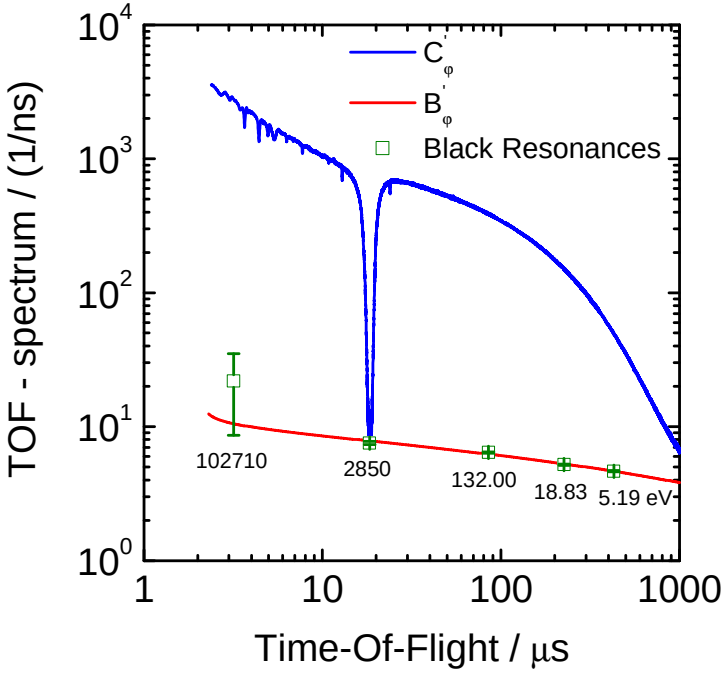


Fixed background filters

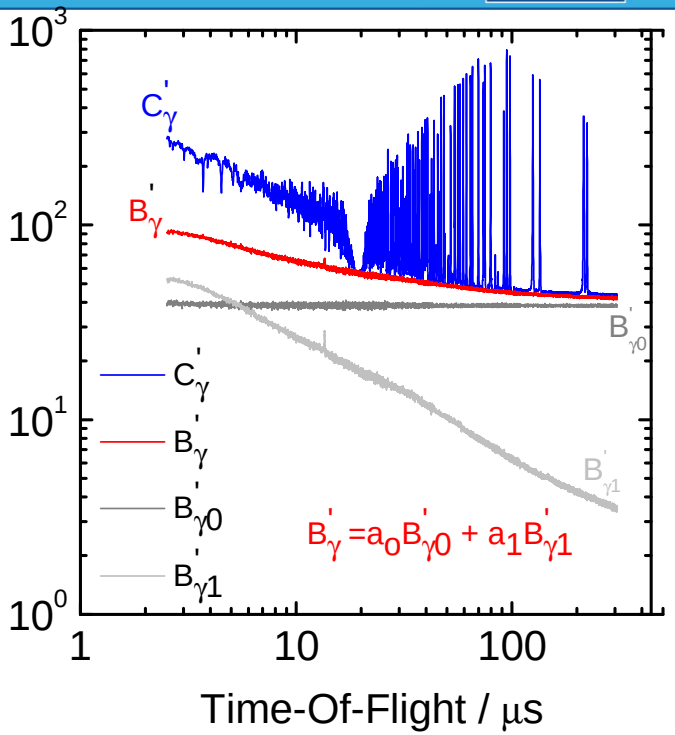
⇒ $\delta Y_{exp}/Y_{exp}$ ~ 2.5 % due to B_w

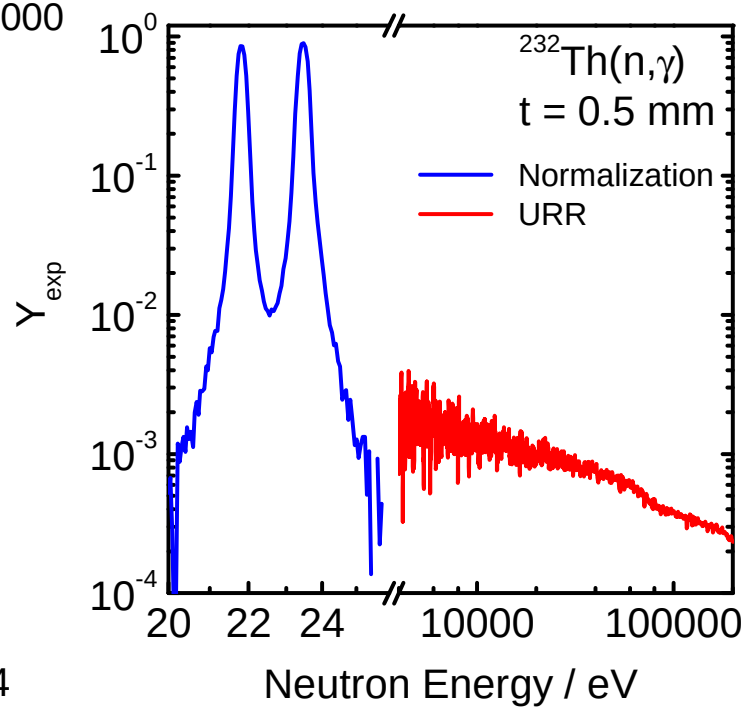
Schillebeeckx et al., NDS, 113 (2012) 3054 - 3100

σ(n,γ) measurements for ^{232}Th at 12.5 m



$$Y_{exp} = N\frac{C_w - B_w}{C_\varphi - B_\varphi} Y_\varphi$$





Internal normalization
+ WF depending on σ_{tot}
+ flux ^{10}B(n,α)

⇒ δN/N < 1.0 %

Fixed background filters

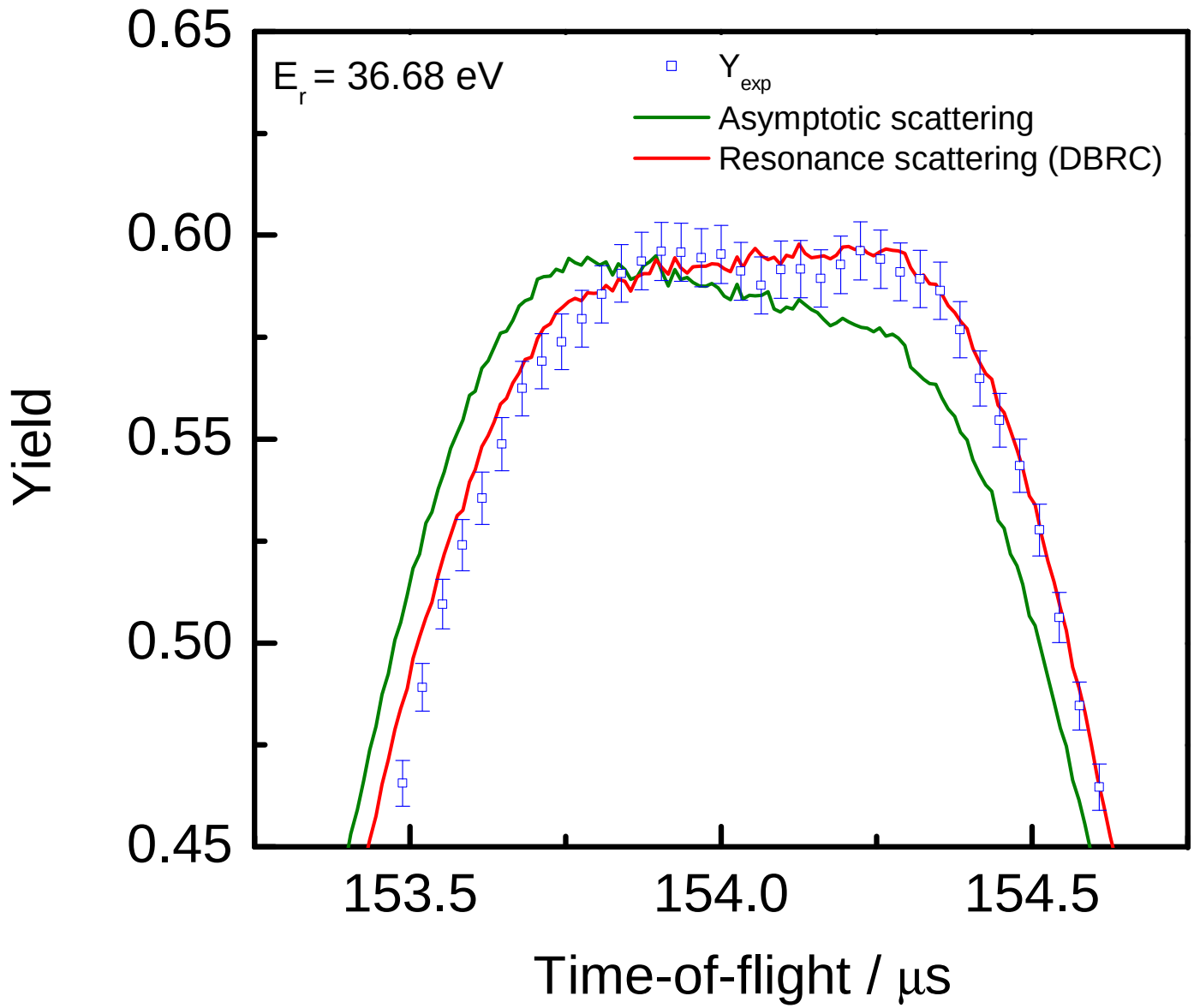
⇒ $\delta a_1/a_1 < 2$ % & $\delta a_0/a_0 < 1$%

⇒ $\delta Y_{exp}/Y_{exp} \sim 1$ % due to B_w

Borella et al., NSE 152 (2006) 1-14

See also ^{197}Au by B. Becker

σ(n,tot) RRR: Experimental data ↔ evaluation

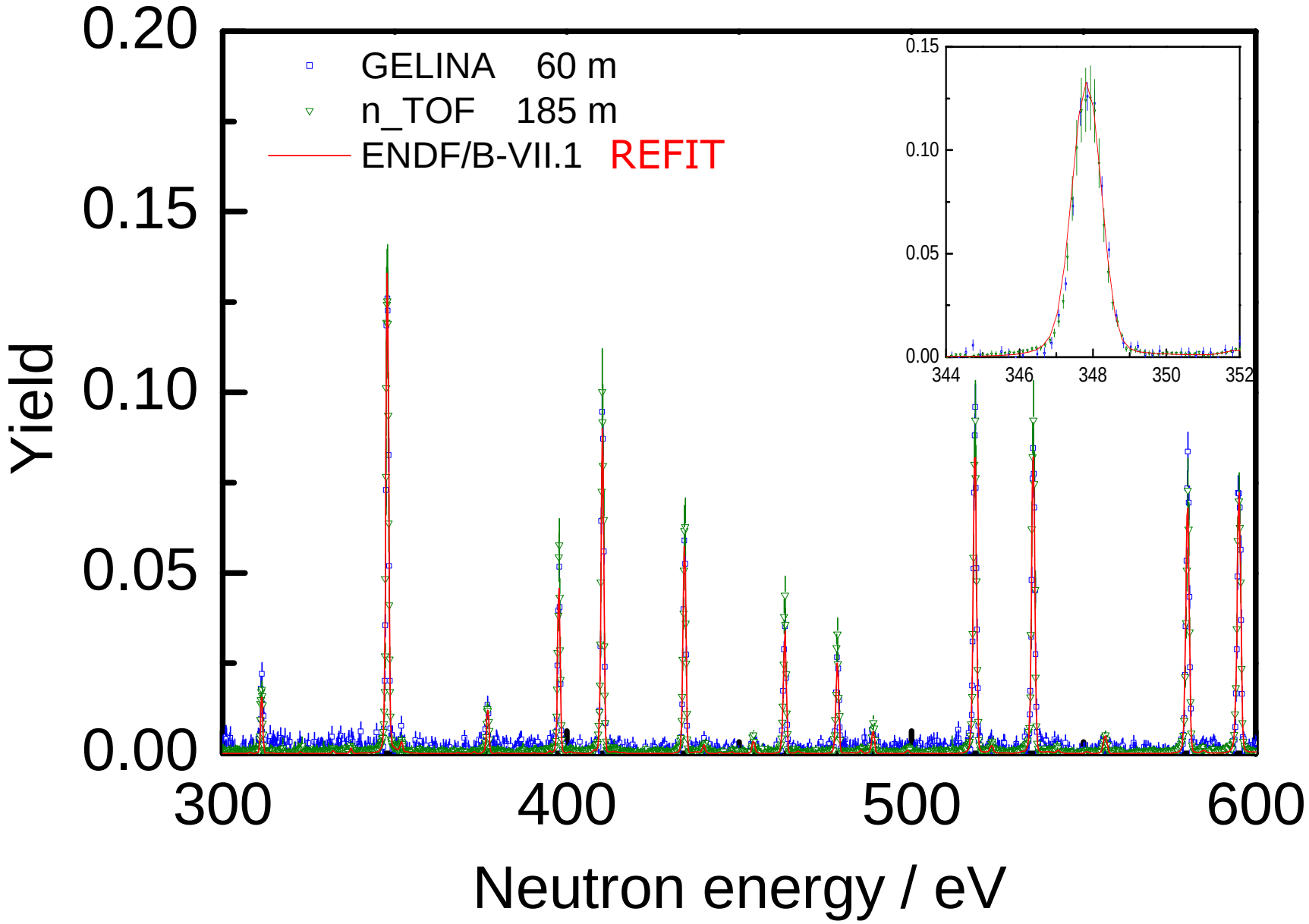


EC-JRC-IRMM and KIT
B. Becker and R. Dagan

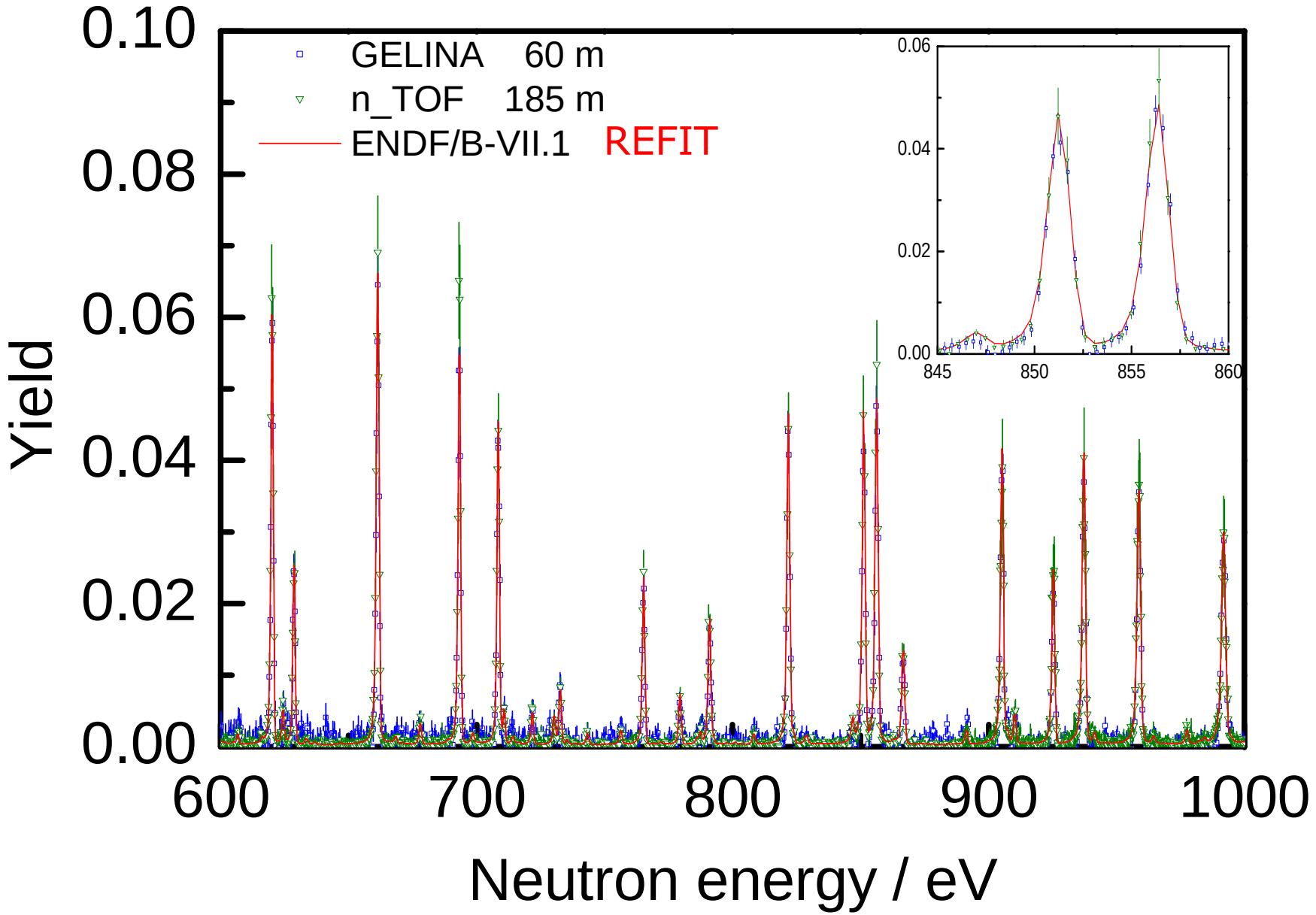
Capture at 12.5 m (GELINA)

Dagan et al., ND2013

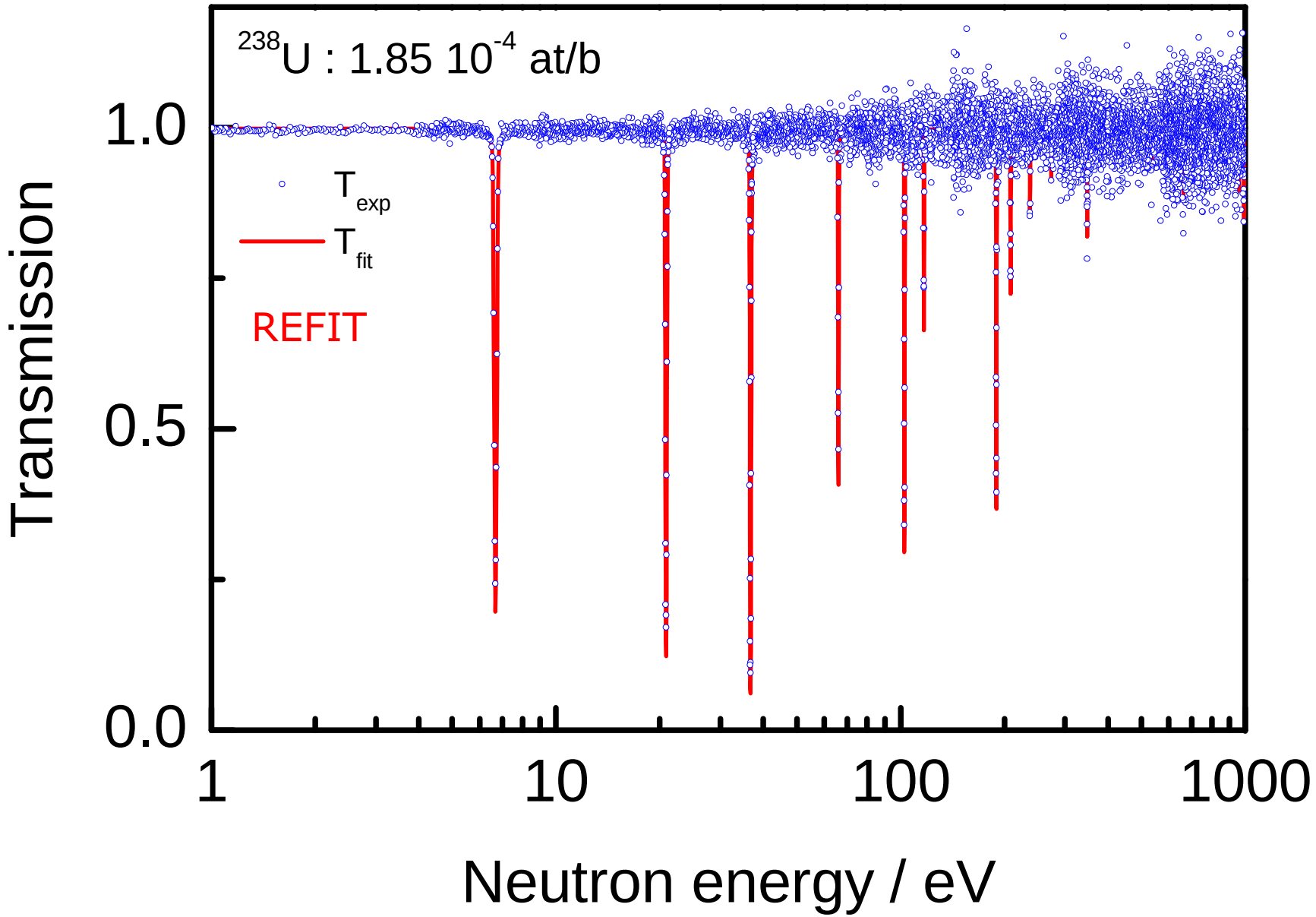
σ(n,tot) RRR: Experimental data ↔ evaluation



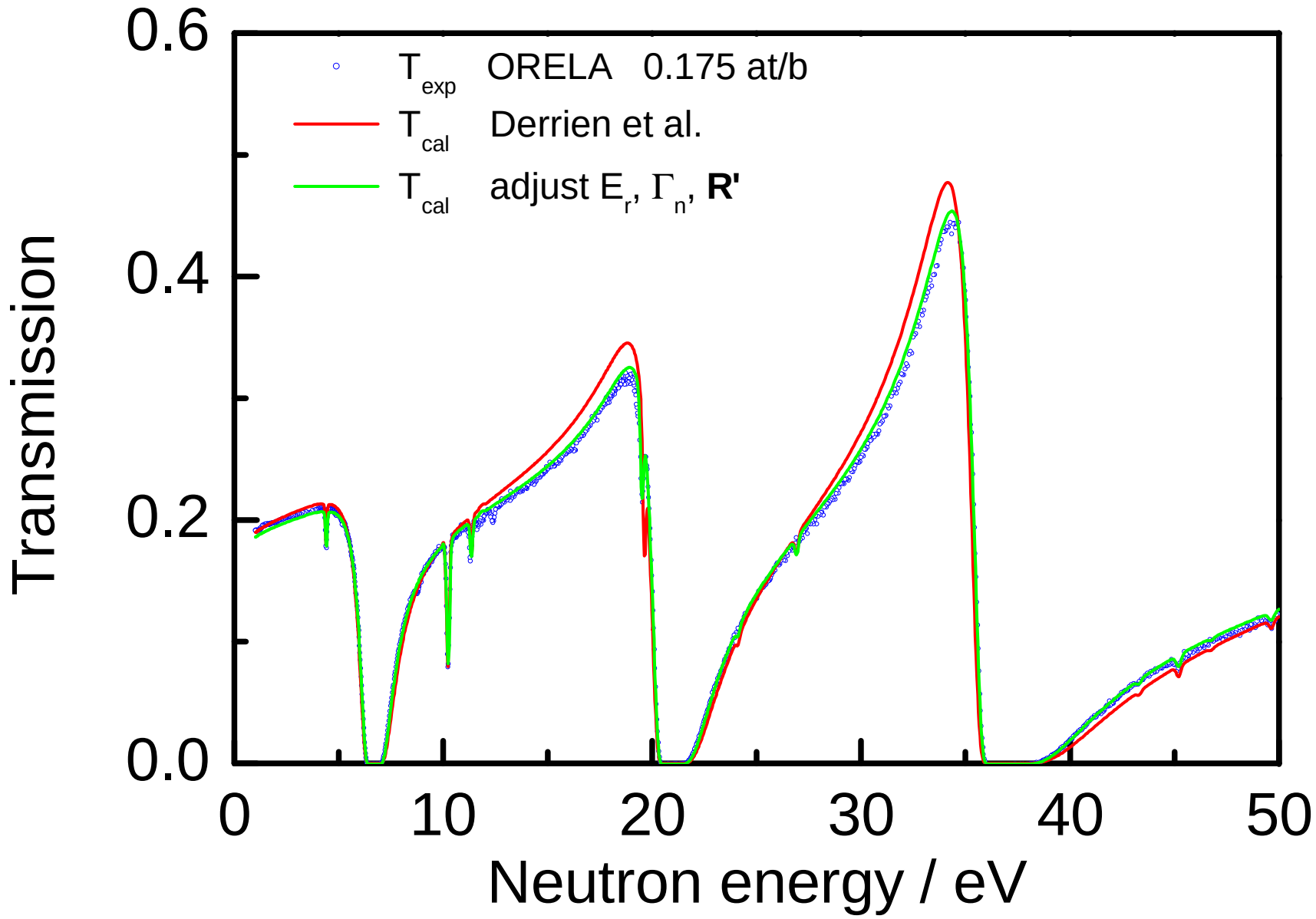
σ(n,tot) RRR: Experimental data ↔ evaluation



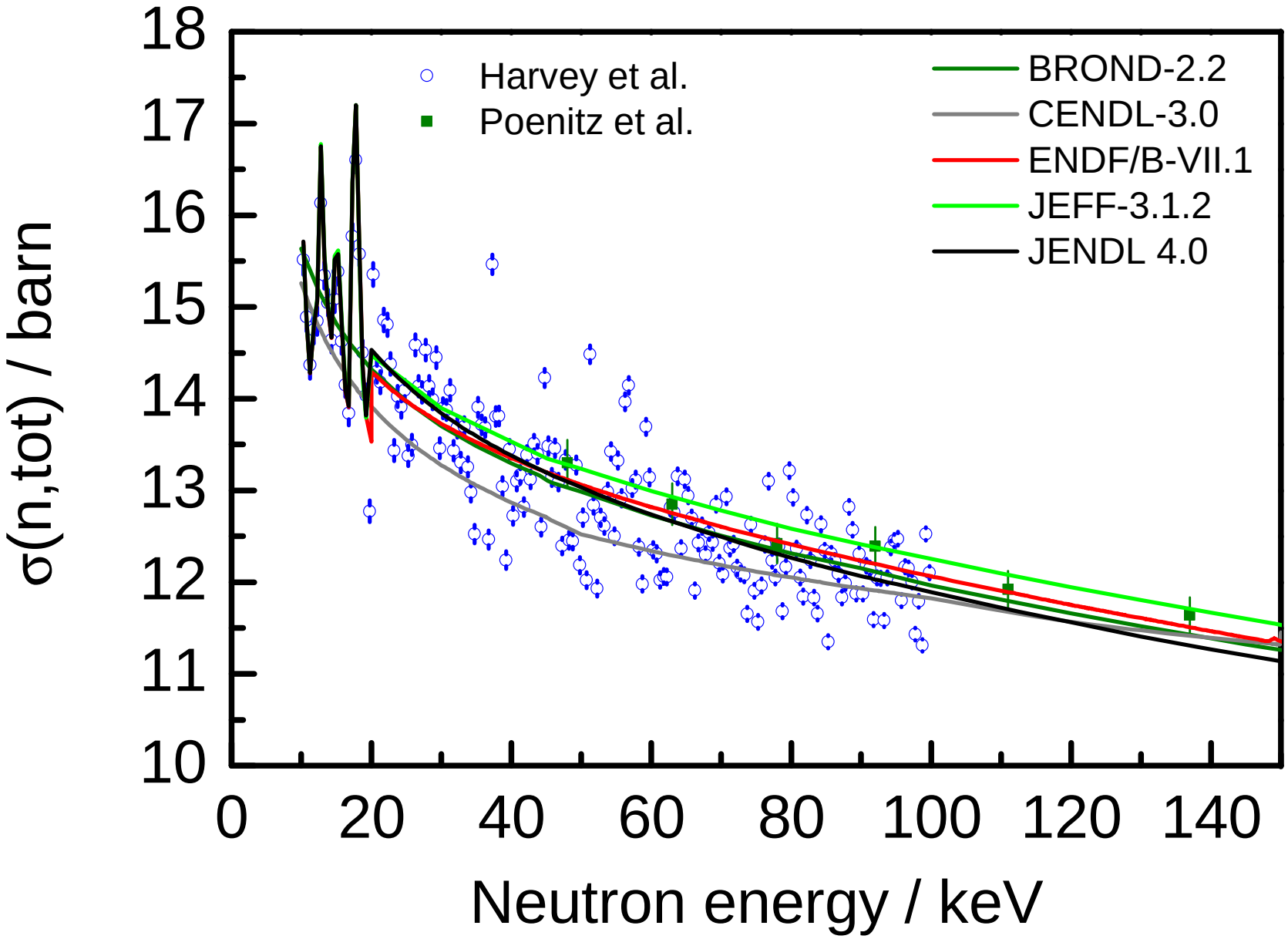
σ(n,tot) RRR: Experimental data ↔ evaluation



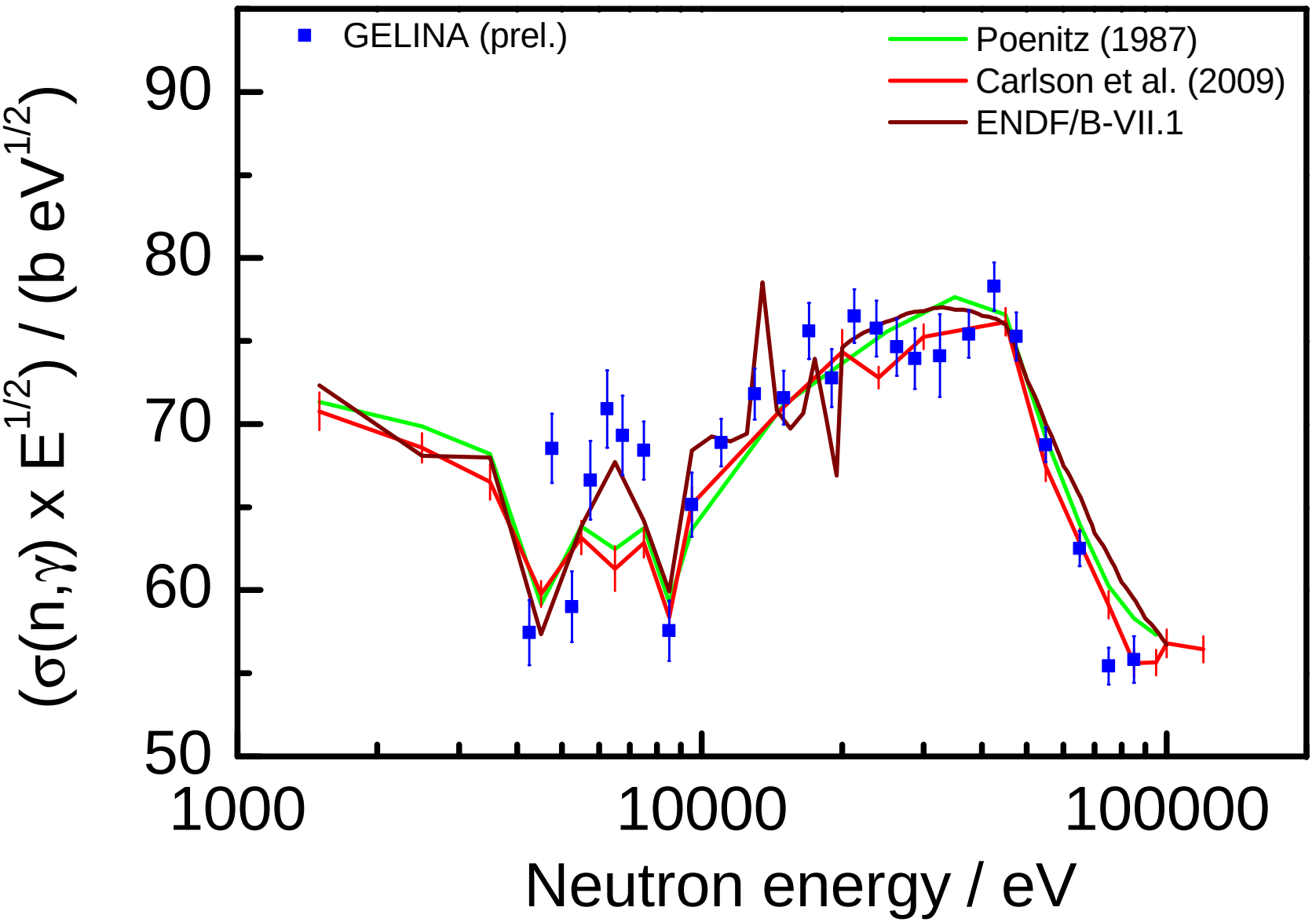
σ(n,tot) RRR: Experimental data ↔ evaluation



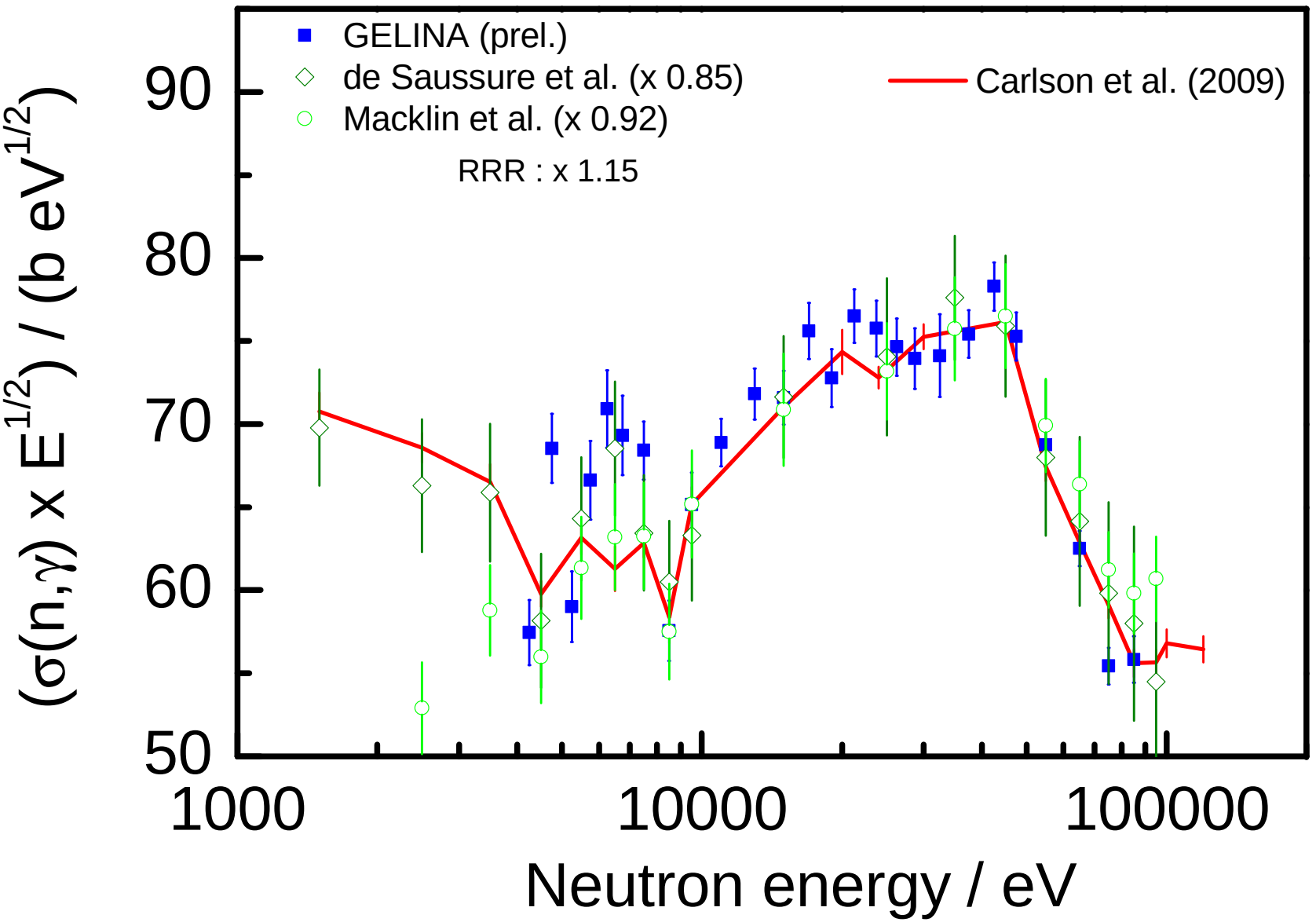
σ(n,tot) URR: Experimental data ↔ evaluation



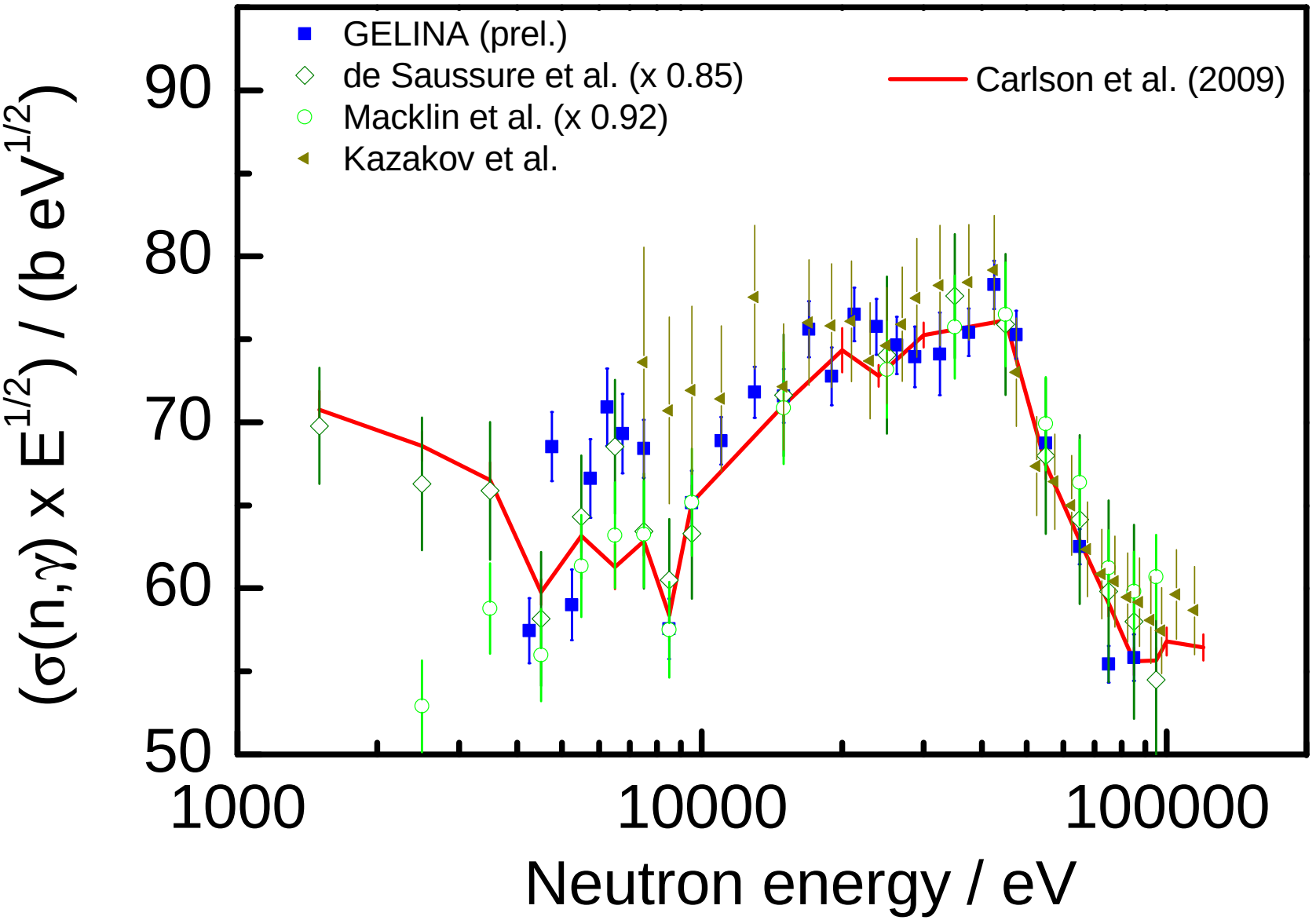
σ(n,γ) URR: Experimental data ↔ evaluation



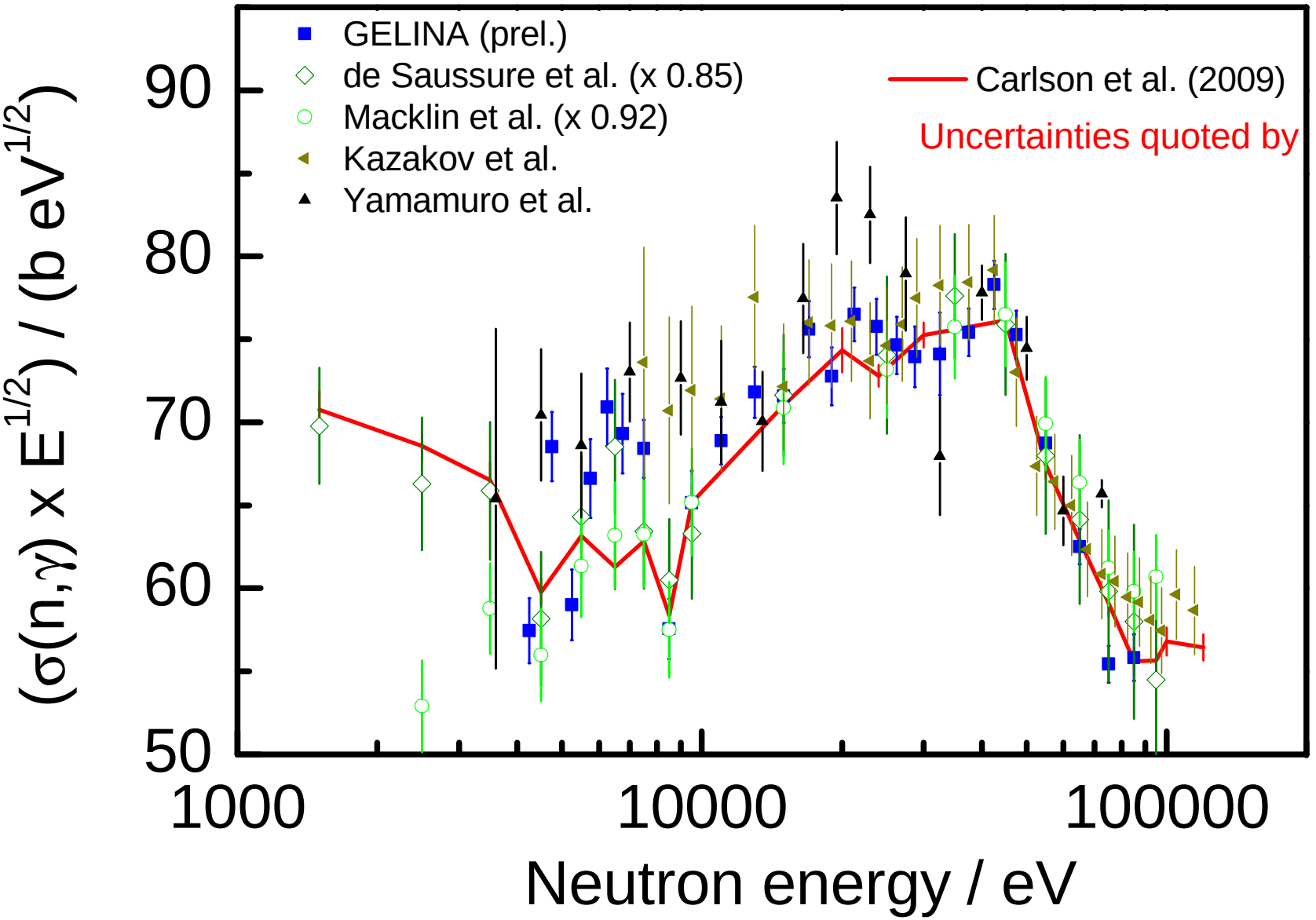
σ(n,γ) URR: Experimental data ↔ evaluation



σ(n,γ) URR: Experimental data ↔ evaluation



σ(n,γ) URR: Experimental data ↔ evaluation



Summary

- **Evaluation in RRR**
  - Derrien et al.
    - Transmission from ORELA
    - Only capture data from ORELAST
    - Capture data suffers from a bias on the normalization
- **Evaluation in URR**
  - Total
    - Harvey et al. (ORELA 200 m) and Poenitz et al.
  - Capture
    - Based on experimental data (LSQ) (Carlsson et al.)
    - Only 1 data set from C_6D_6

⇒ Improvements by including new data from measurements

- **(n,γ) : at GELINA (C_6D_6 at 12.5 and 60 m) and at n_TOF (C_6D_6 & BaF_2)**
- **(n,tot) : at nELBE and GELINA (transmission)**

Perspectives

- **New evaluation in RRR**
  - Transmission from ORELA, including Harvey et al. (+ limited data set from GELINA)
  - Capture data from ORELAST
  - Capture data from GELINA with C_6D_6 at 12.5 m and 60 m
  - Capture data from n_TOF with C_6D_6 and BaF_2

- **New evaluation in URR**
  - Total
    - Harvey et al. (ORELA 200 m) and Poenitz et al.
    - + data from measurements at GELINA and nELBE
  - Capture
    - Based on experimental data (LSQ) (Poenitz et al., Carlsson et al.)
    - + data from measurements with C_6D_6 at n_TOF and GELINA (12.5 m and 60 m)
  - Methodology applied for ^{232}Th and ^{197}Au : link with optical model
    - ^{232}Th : Sirakov et al. ANE 35 (2008) 1223
    - ^{197}Au : see presentation B. Becker (Sirakov et al., accepted in EPJA)

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Thank you for your attention