Joint Research Centre (JRC)

Neutron cross section measurements at GELINA to improve the consistency between microscopic data and integral quantities

Peter Schillebeeckx

IRMM - Institute for Reference Materials and Measurements

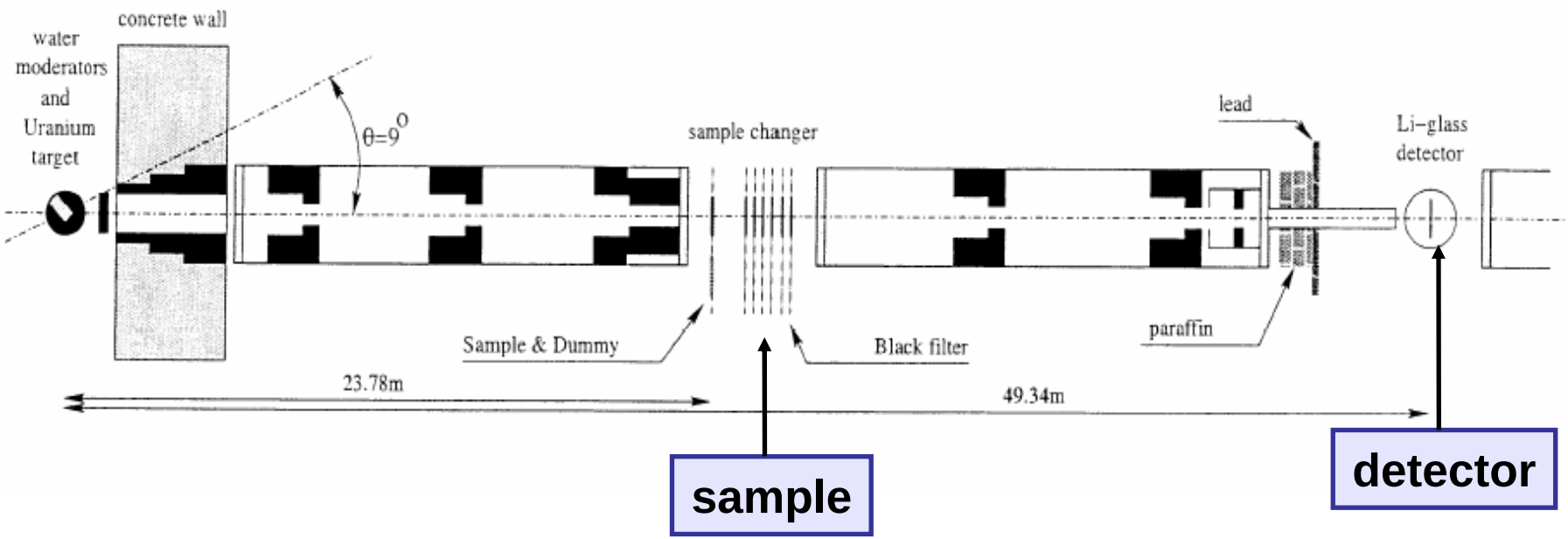
Geel - Belgium

http://irmm.jrc.ec.europa.eu/

http://www.jrc.ec.europa.eu/

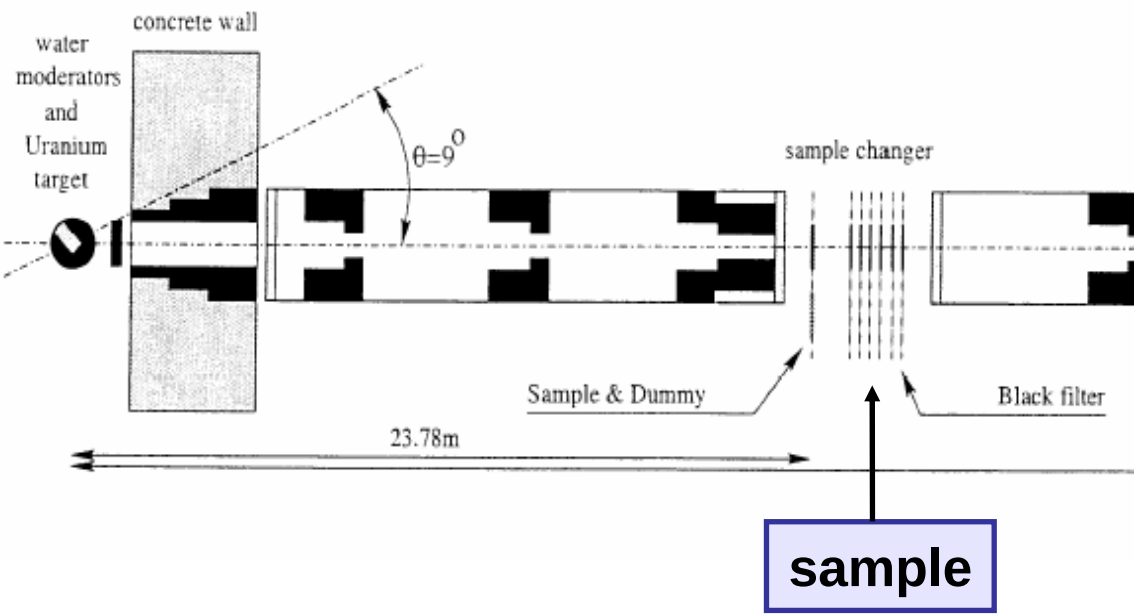
Transmission

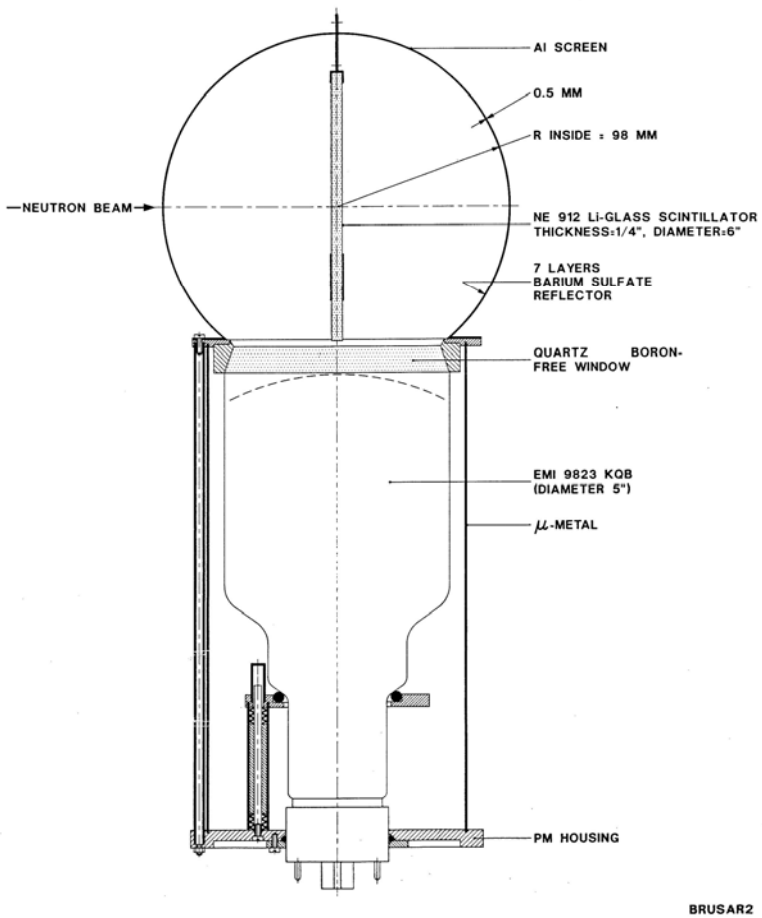
$$T = e^{-n\sigma_t} = \frac{C_s - B_s}{C_O - B_O}$$



Transmission

$$T = e^{-n\sigma_t} = \frac{C_s - B_s}{C_O - B_O}$$

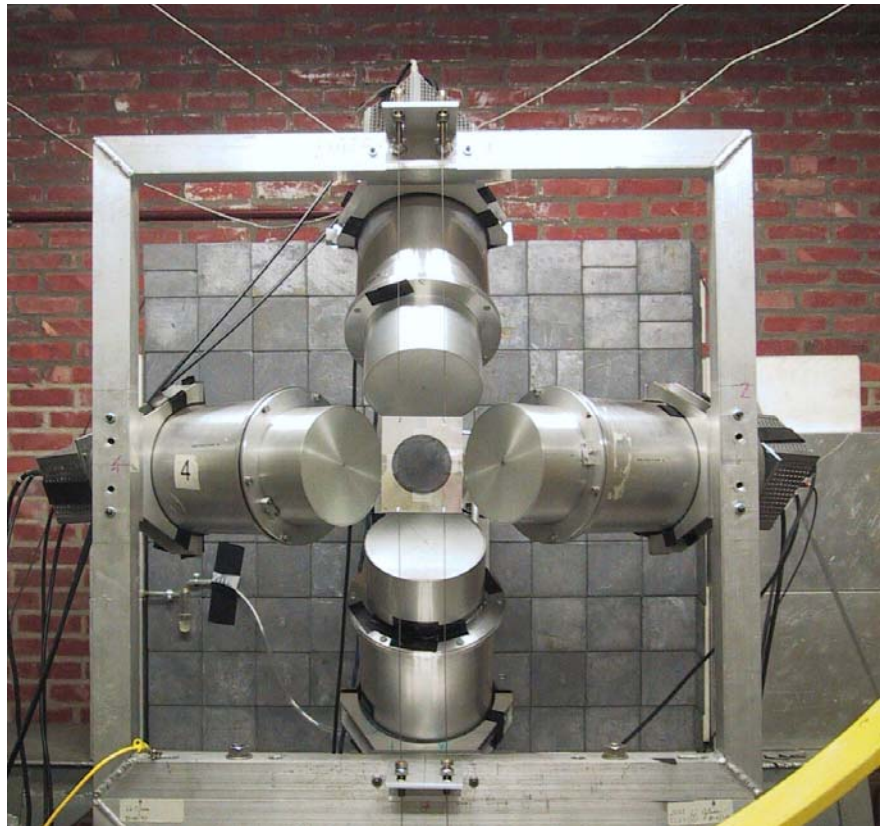




Capture cross section measurements

Total energy detection

- C_6D_6 liquid scintillators
  - 125°
  - PHWT
- Flux measurements (IC)
  - $^{10}B(n,\alpha)$
  - $^{235}U(n,f)$



Borella et al., NIM A, 577 (2007) 626
Borella et al., PR C 76 (2007) 014605

$$Y_{exp} = N \frac{\sigma_\varphi}{\varepsilon_r} \frac{C'_w - B'_w}{C'_\varphi - B'_\varphi}$$

WF : from MC simulations

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

^{197}Au + n

Objective

Establish a standard for ^{197}Au+n in resonance region

Collaboration with

University Bologna
EFNUDAT (scientific visit C. Massimi)
Jozef Stefan Institute (A. Trkov)

Status

Capture measurements in RRR and URR finalized
Transmission between 1 eV and 100 eV finalized
Transmission above 100 eV and in URR started

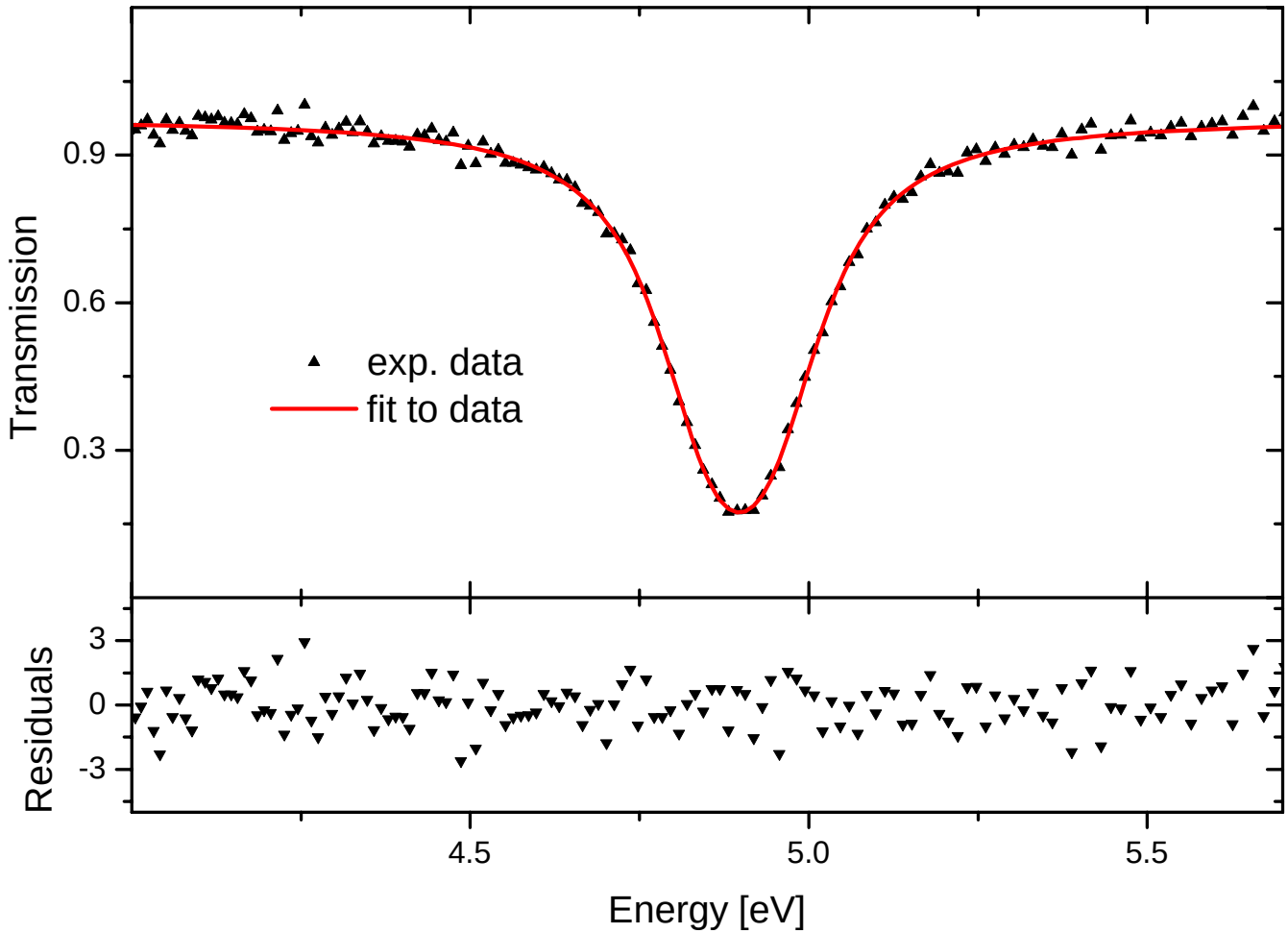
Data reduction and RSA finalized from thermal up to 100 eV

Evaluation in RRR up to 5 keV (March 2009)
Evaluation in URR (July 2009)

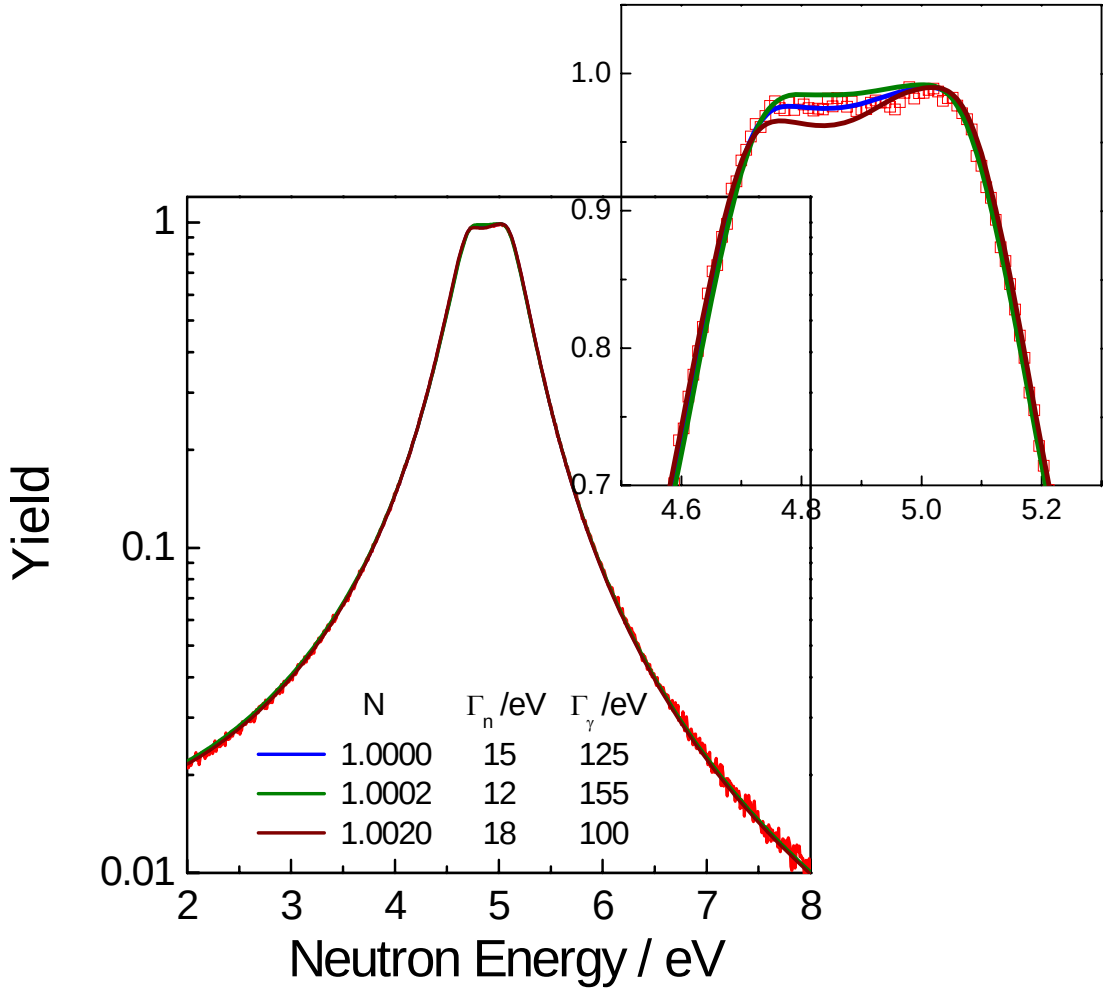
^{197}Au

thickness (atoms/barn)	type	flight path length
$2.77\ 10^{-5}$	capture	10m, 30m
$5.86\ 10^{-5}$	capture transmission	10m, 30m 50m
$2.91\ 10^{-4}$	capture transmission	10m, 30m 50m
$6.64\ 10^{-4}$	capture	10m, 30m, 60m
$3.10\ 10^{-3}$	capture	10m, 30m, 60m
$6.01\ 10^{-3}$	capture	10m, 30m, 60m

^{197}Au


Transmission
0.9
0.6
0.3
exp. data
fit to data
Residuals
3
0
-3
4.5
5.0
5.5
Energy [eV]

Normalization: saturated resonance



$$Y_{exp} = N \frac{\sigma_\varphi}{\varepsilon_r} \frac{C'_w - B'_w}{C'_\varphi - B'_\varphi}$$

$^{197}Au(n,\gamma)$: E_R= 4.9 eV

For $n\sigma_t >> 1$ and $\Gamma_n << \Gamma_\gamma$

$\Rightarrow Y_c \sim 1$

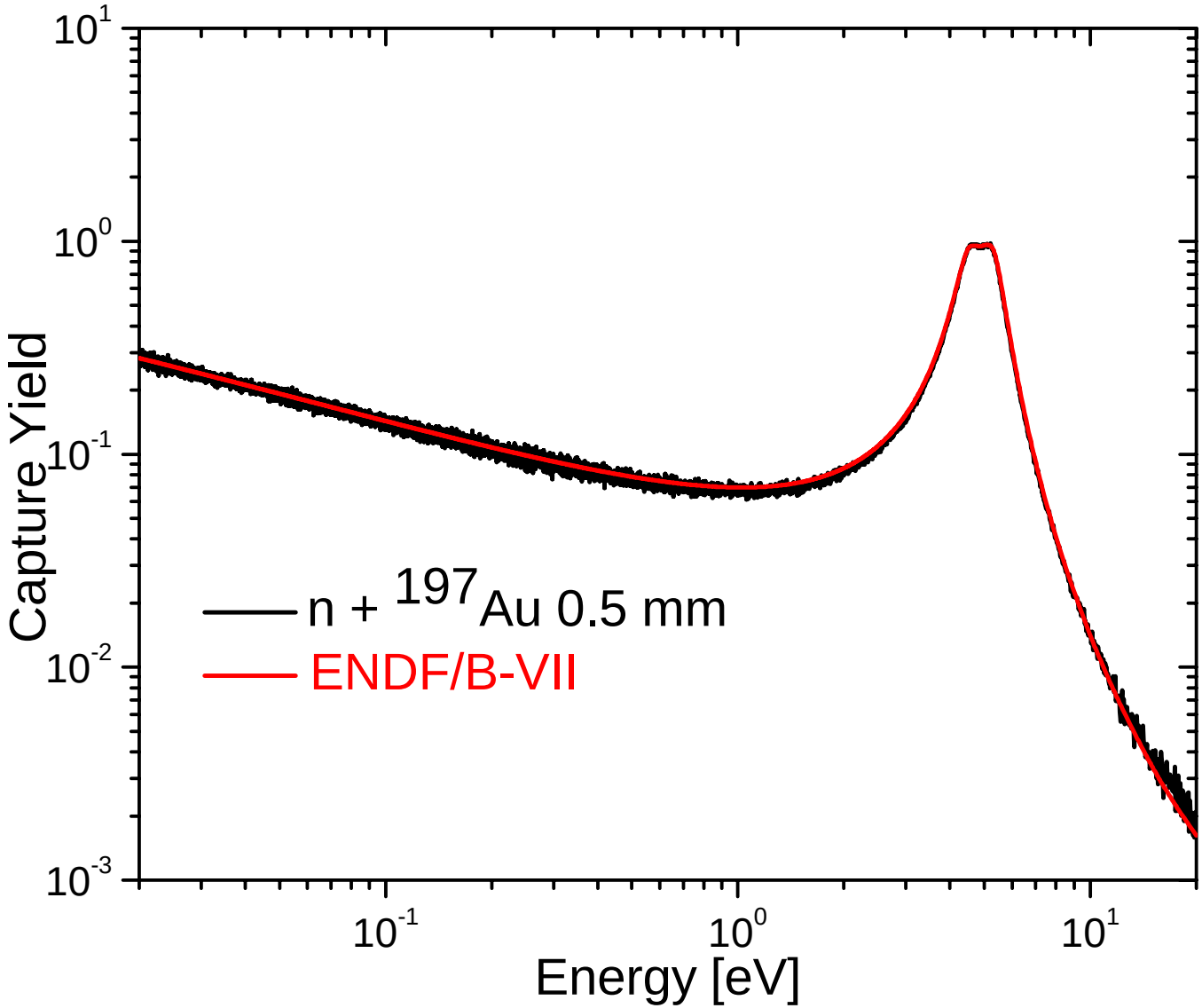
N is independent of :

- **target thickness of reference sample**
- **nuclear data**

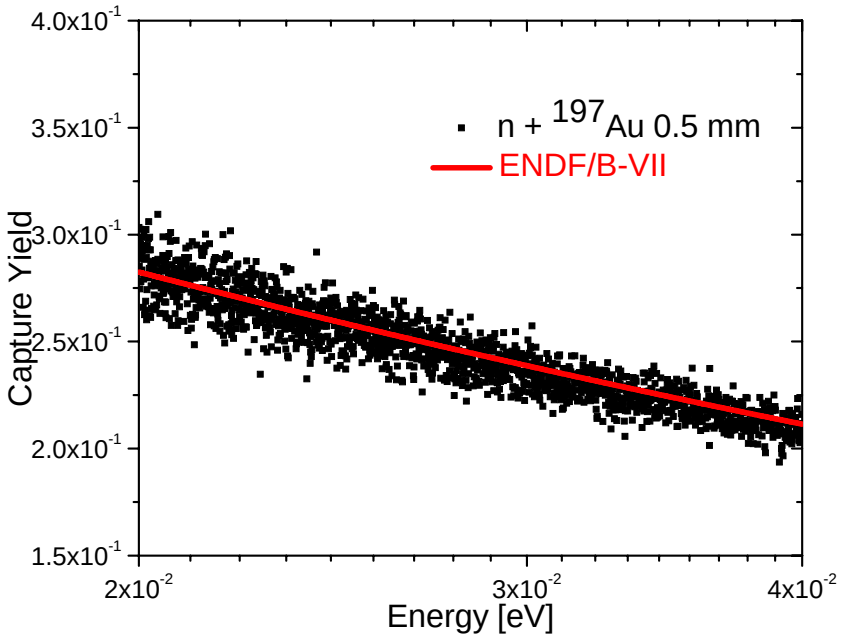
σ_φ : only the relative energy dependence is required
$\Rightarrow {}^{10}B(n,\alpha)$ which behaves ~ 1/v

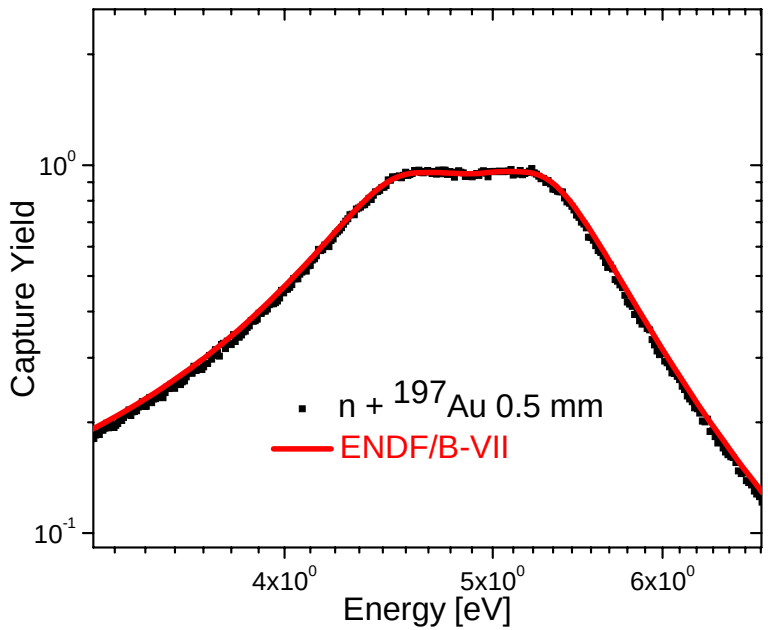
$$\frac{u_{Y_{exp}}}{Y_{exp}} \leq 2\ \%$$

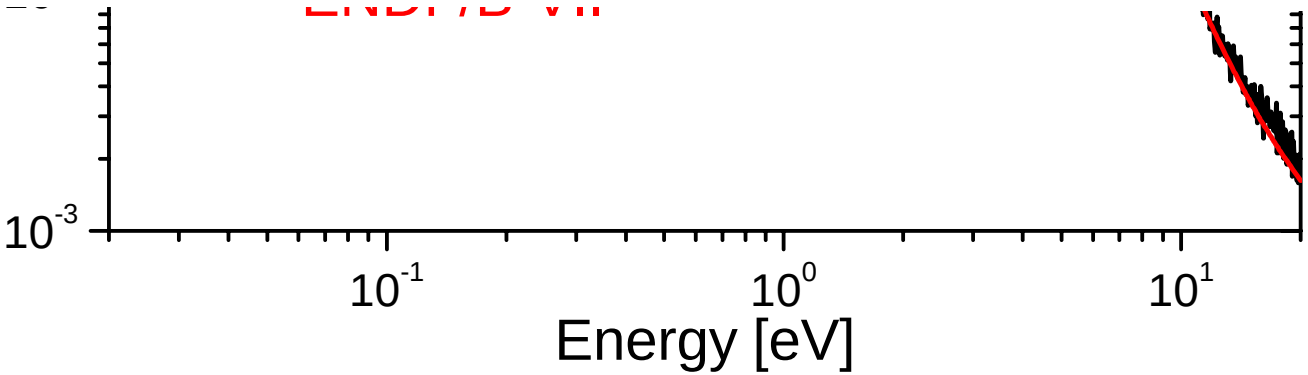
^{197}Au: $\sigma(n_{th}, \gamma)$ = (99.0 ± 1.0) b <--> (98.7 ± 0.1) b



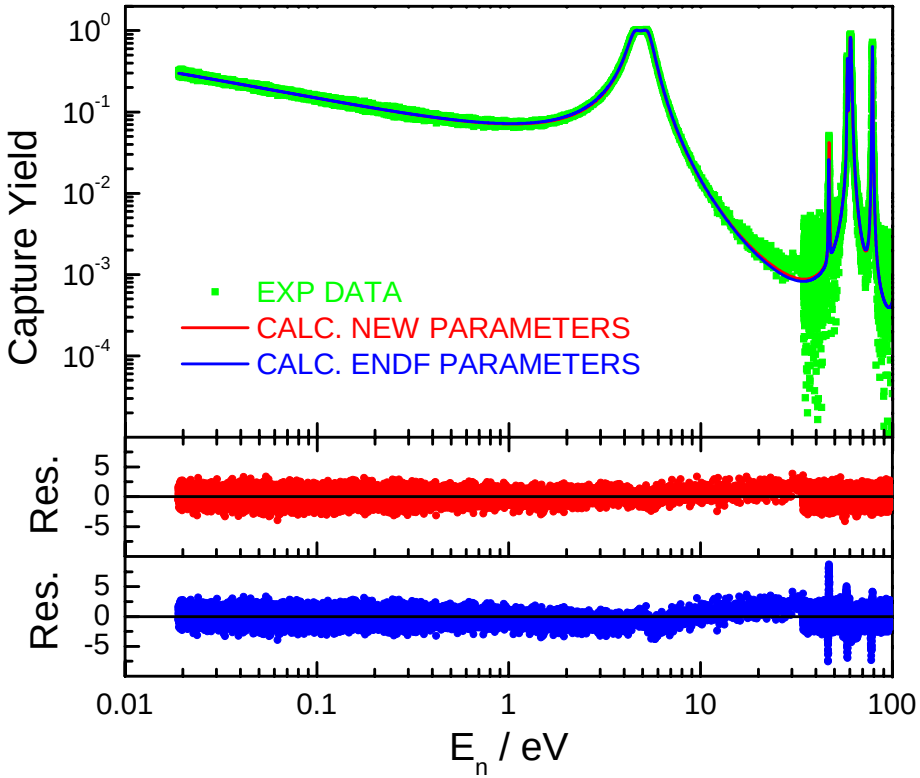
^{197}Au: $\sigma(n_{th}, \gamma)$ = (99.0 ± 1.0) b <--> (98.7 ± 0.1) b

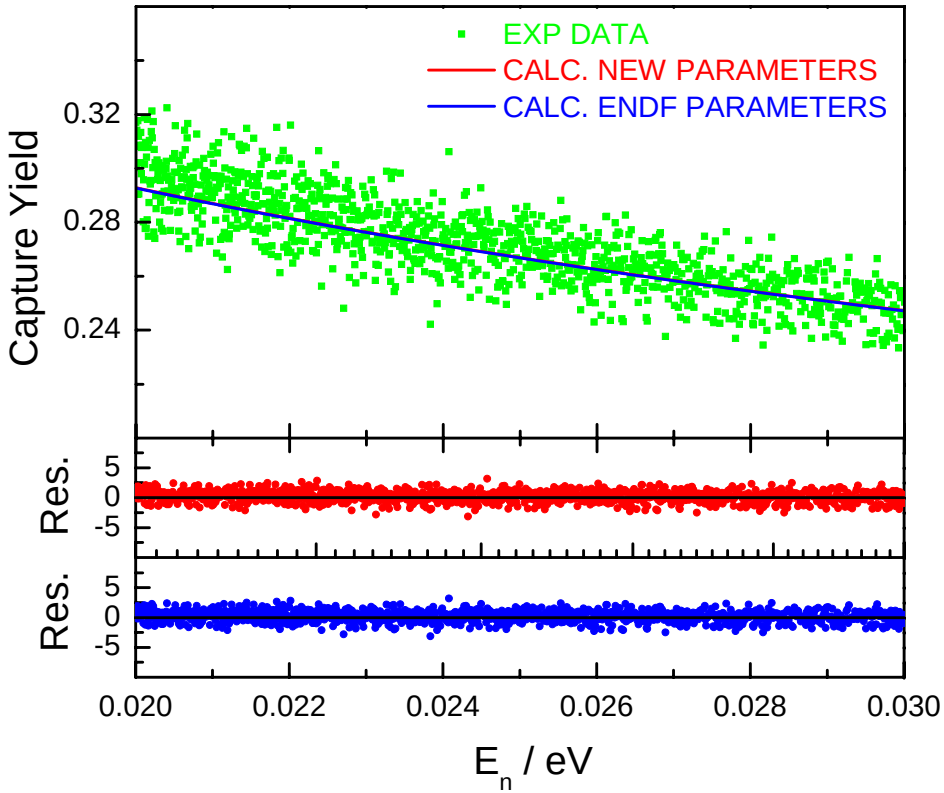




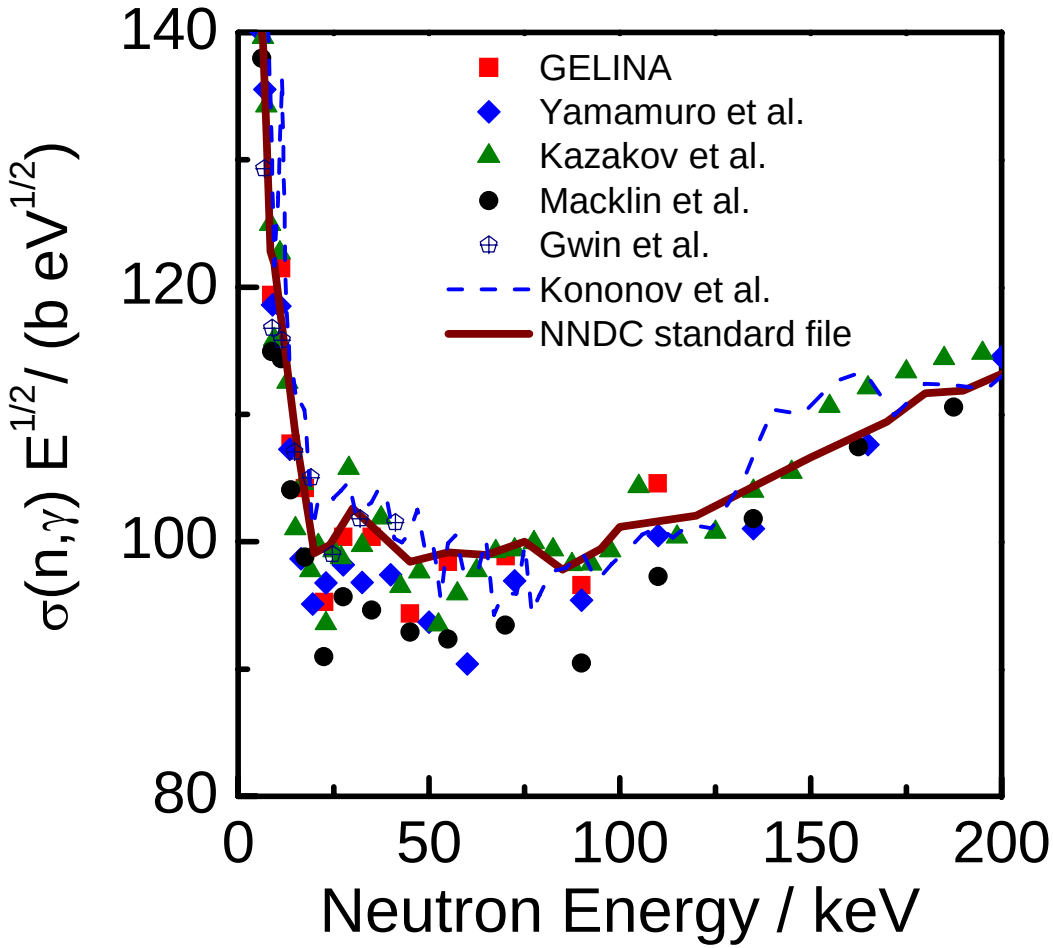


^{197}Au + n


Capture Yield
EXP DATA
CALC. NEW PARAMETERS
CALC. ENDF PARAMETERS
Res.
Res.
E_n / eV


Capture Yield
EXP DATA
CALC. NEW PARAMETERS
CALC. ENDF PARAMETERS
Res.
Res.
E_n / eV

^{197}Au


GELINA
Yamamuro et al.
Kazakov et al.
Macklin et al.
Gwin et al.
Kononov et al.
NNDC standard file
σ(n,γ) E^1/2 / (b eV^1/2)
140
120
100
80
0
50
100
150
200
Neutron Energy / keV

^{103}Rh + n

Objective

Evaluation of ^{103}Rh+n in resonance region

Collaboration with

Jozef Stefan Institute (A. Trkov)
ORNL

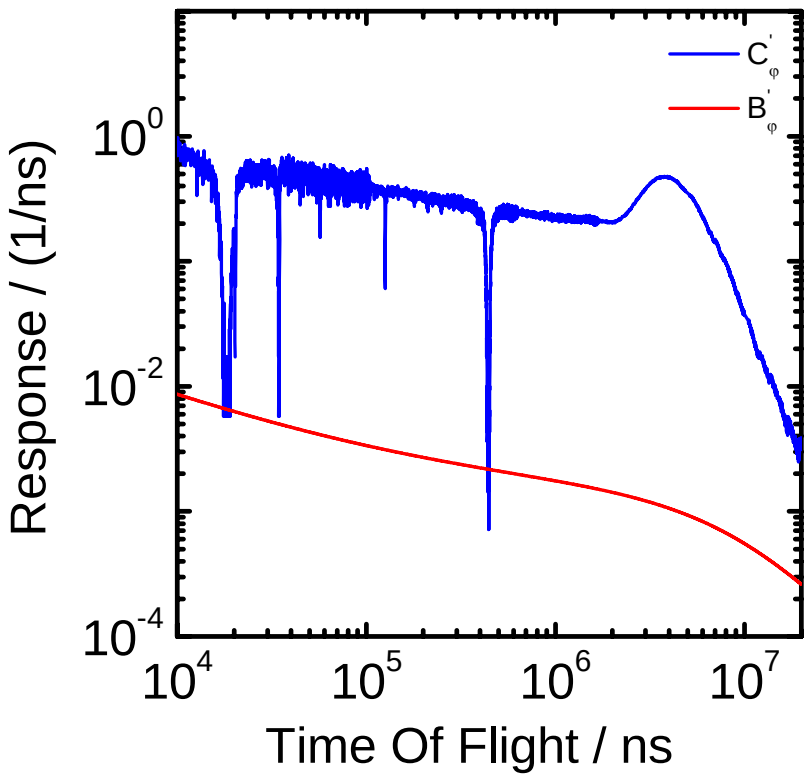
Status

Capture measurements in RRR and URR finalized
Transmission measurements in RRR and URR finalized
Data reduction and RSA in RRR finalized
Data reduction URR (reviewed)

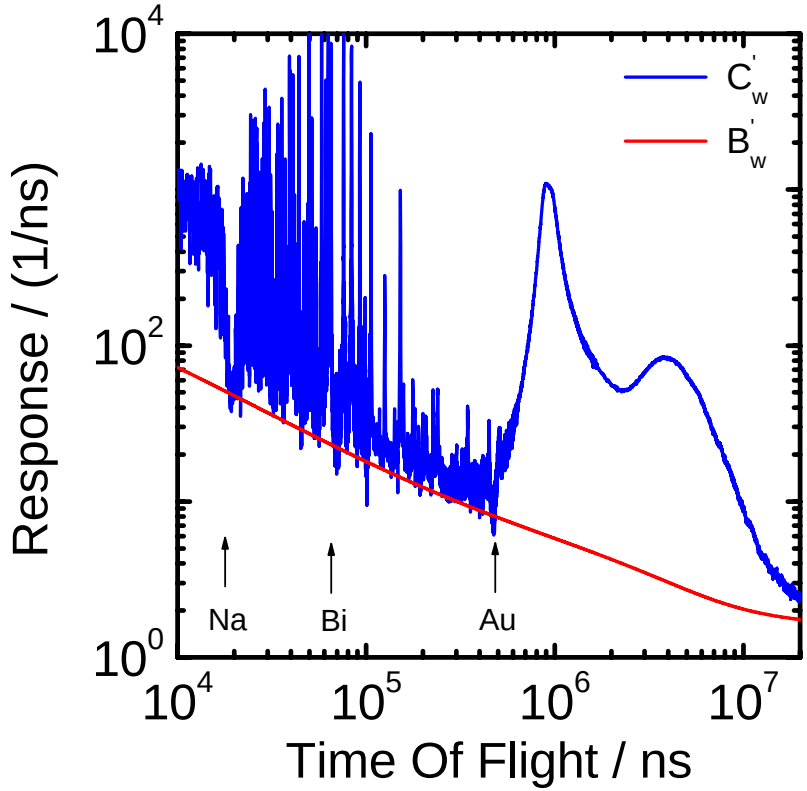
ENDF compatible RRR file < 4000 eV (in progress)
Evaluation in URR (March 2009)

σ(n,γ) measurements ^{103}Rh(n,γ)

Flux measurement



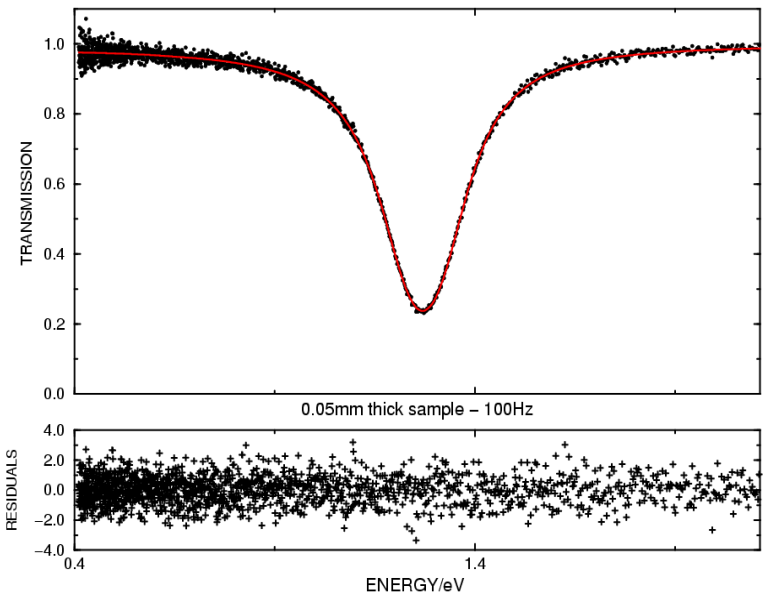
Capture measurement



$$Y_{exp} \propto \sigma_{\varphi} \frac{C'_w - B'_w}{C'_{\varphi} - B'_{\varphi}}$$

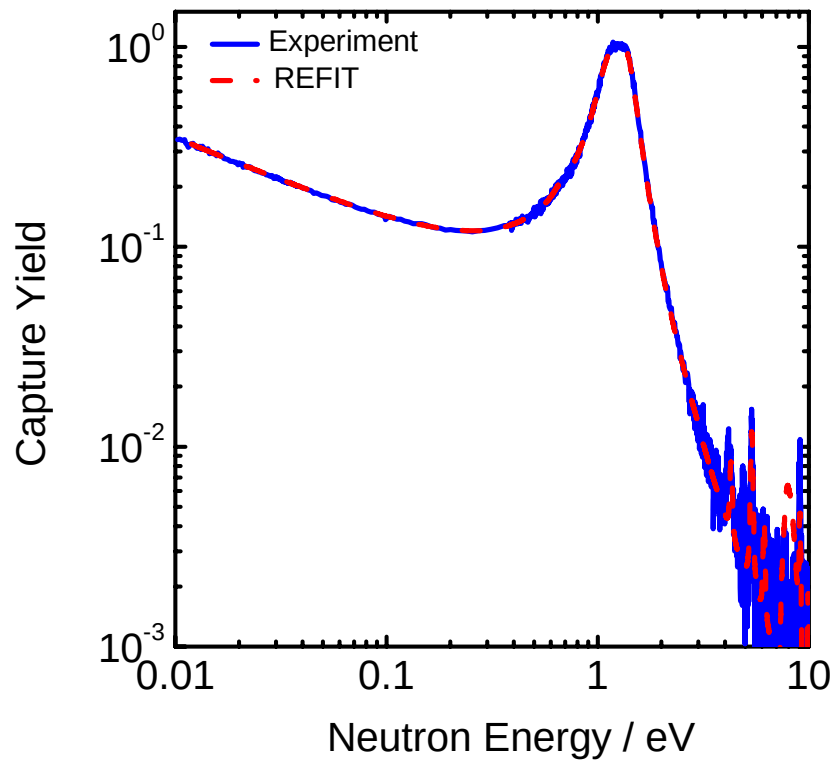
Thermal capture : $^{103}Rh(n,\gamma)$

100 Hz at 50 m (with Cd-overlap)



REFIT
RP + N
⇔

40 Hz at 15 m



E_r	=	1.260 eV
Γ_n	=	0.464 (0.006) meV
Γ_γ	=	156 (3)meV
g	=	3/4

Δ_D	=	35 meV
Δ_R	=	3 meV (15 m)
Δ_R	=	1 meV (50 m)

$\sigma(E_n$=25.3 meV ,$\gamma)$ = 142.0 (1.5) b
1.0 % normalization
0.5 % uncorrelated

Independent cross sections at 0.0253 eV

- **Transmission (total absorption)**

  $^{10}B(n,\alpha)$ = 3837 (9) b

  $^{197}Au(n,\gamma)$ = 98.7 (0.1) b

- **Time decay of thermalized pulsed neutron beam**

  $^{1}H(n,\gamma)$ = 332.6 (0.7) mb

- **Capture**

  $^{197}Au(n,\gamma)$ = 99.3 (1.5) b

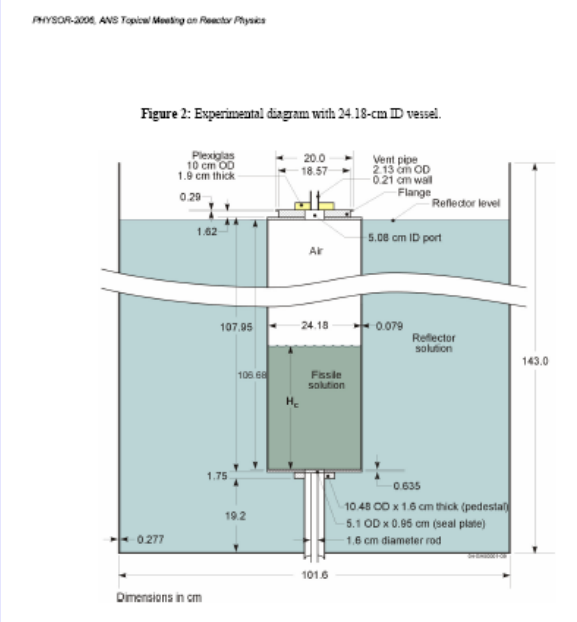
  $^{103}Rh(n,\gamma)$ = 142.0 (1.5) b

Objective

New evaluation for ^{nat}Cd+n in RRR

Collaboration with

NUDAME
University Bologna
M. Moxon (Univ. Birmingham)



Status

Transmission and Capture measurements in RRR finalized
Data reduction and RSA finalized

ENDF-file produced
Testing ongoing (benchmark)

^{nat}Cd

thickness (atoms/barn)	type	flight path length
$1.38\ 10^{-4}$	capture	10 m
$3.40\ 10^{-4}$	capture	10 m
$5.40\ 10^{-4}$	transmission	50 m
$1.10\ 10^{-3}$	capture	30 m
$2.36\ 10^{-3}$	capture	30 m
$4.67\ 10^{-3}$	capture	30 m
$9.34\ 10^{-3}$	capture transmission	10 m 25 m, 50 m
$2.34\ 10^{-2}$	transmission	50 m
$1.20\ 10^{-1}$	transmission	25m, 50m

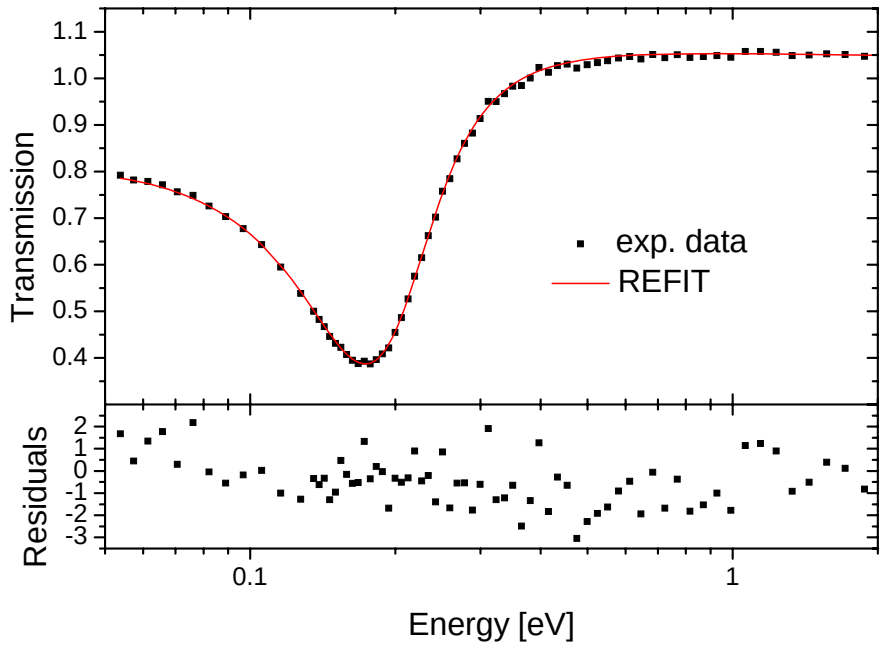
^{nat}Cd

thickness (atoms/barn)	sample type	flight path length
$1.40\ 10^{-4}$	solution	25 m
$1.36\ 10^{-4}$	foil	50 m
$2.24\ 10^{-4}$	foil	50 m
$2.80\ 10^{-4}$	solution	25 m

$\sigma(n_{th},\gamma) = 20270$ b for ^{113}Cd

^{nat}Cd

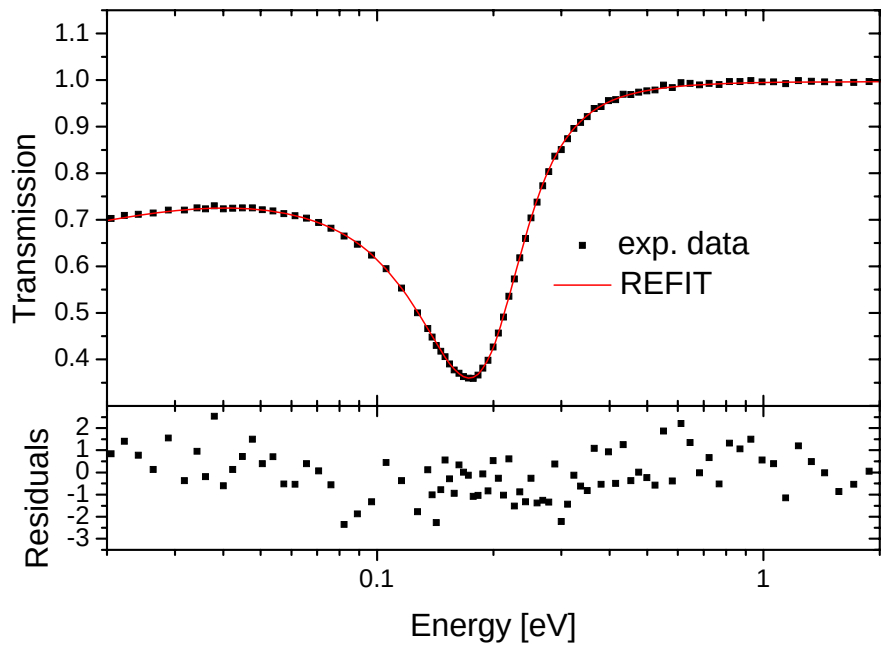
thickness (atoms/barn)	sample typ
1.40 10^{-4}	solution
1.36 10^{-4}	foil
2.24 10^{-4}	foil
2.80 10^{-4}	solution



$\sigma(n_{th},\gamma)$ = 20270 b for ^{113}Cd

^{nat}Cd

thickness (atoms/barn)	samp
1.40 10^{-4}	so
1.36 10^{-4}	
2.24 10^{-4}	
2.80 10^{-4}	so

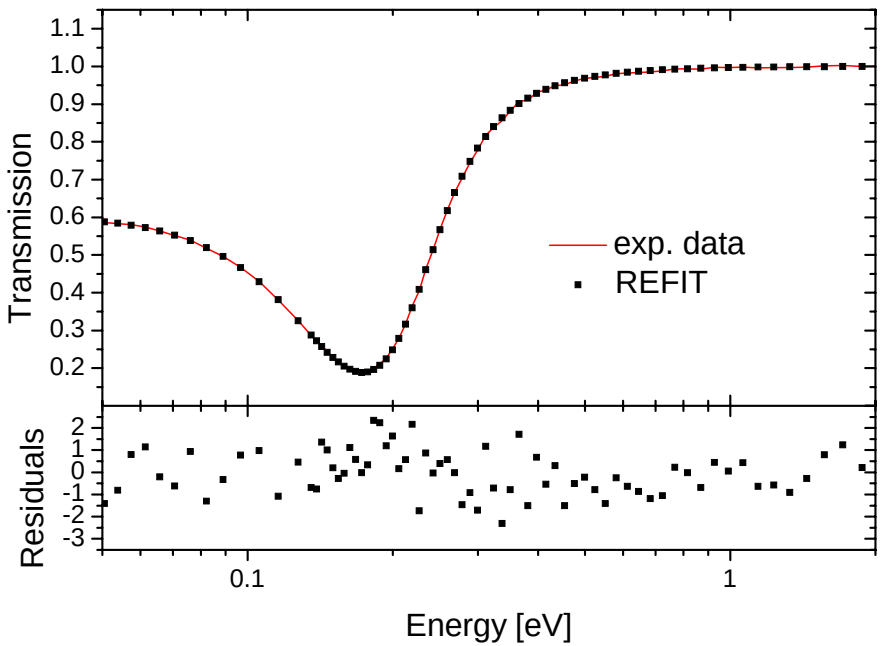


$\sigma(n_{th},\gamma)$ = 20270 b for ^{113}Cd

^{nat}Cd

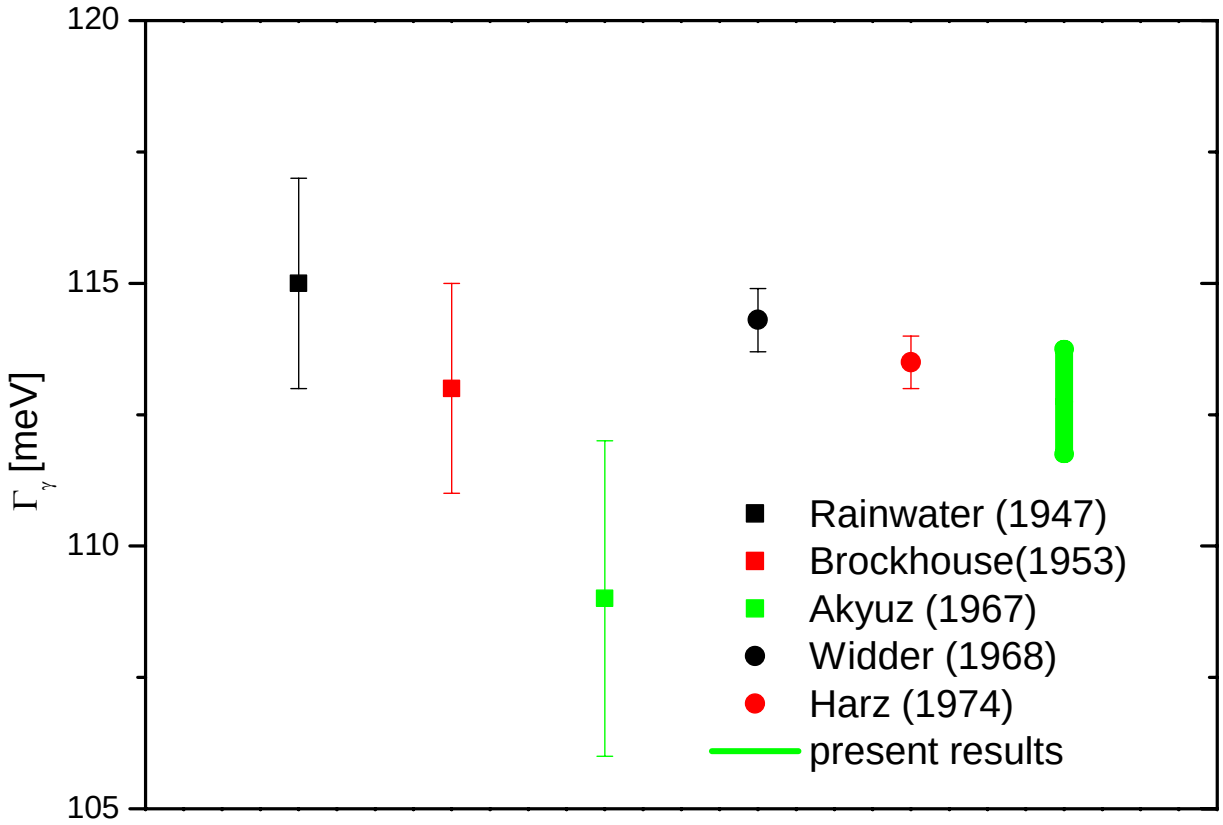
thickness (atoms/barn)
1.40 10^{-4}
1.36 10^{-4}
2.24 10^{-4}
2.80 10^{-4}

sam

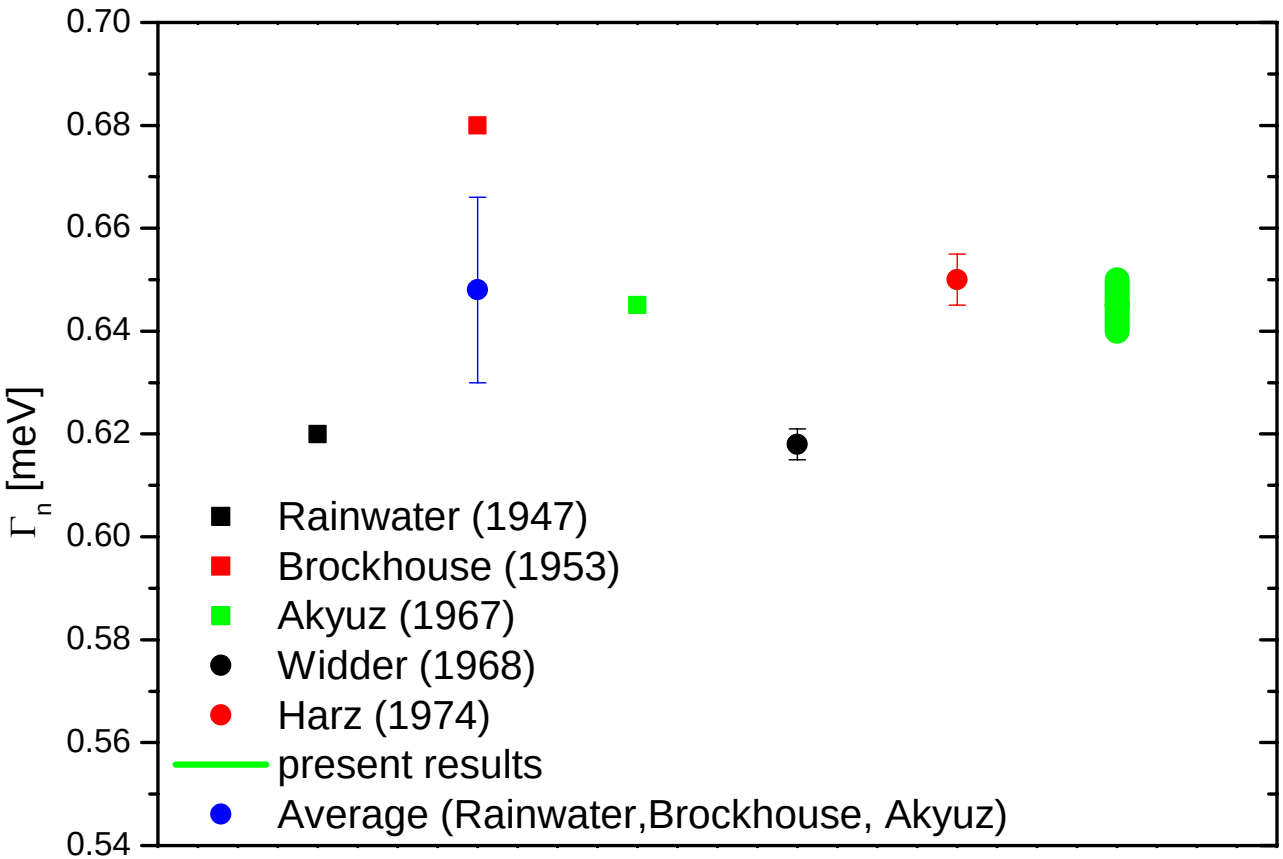


$\sigma(n_{th},\gamma)$ = 20270 b for ^{113}Cd

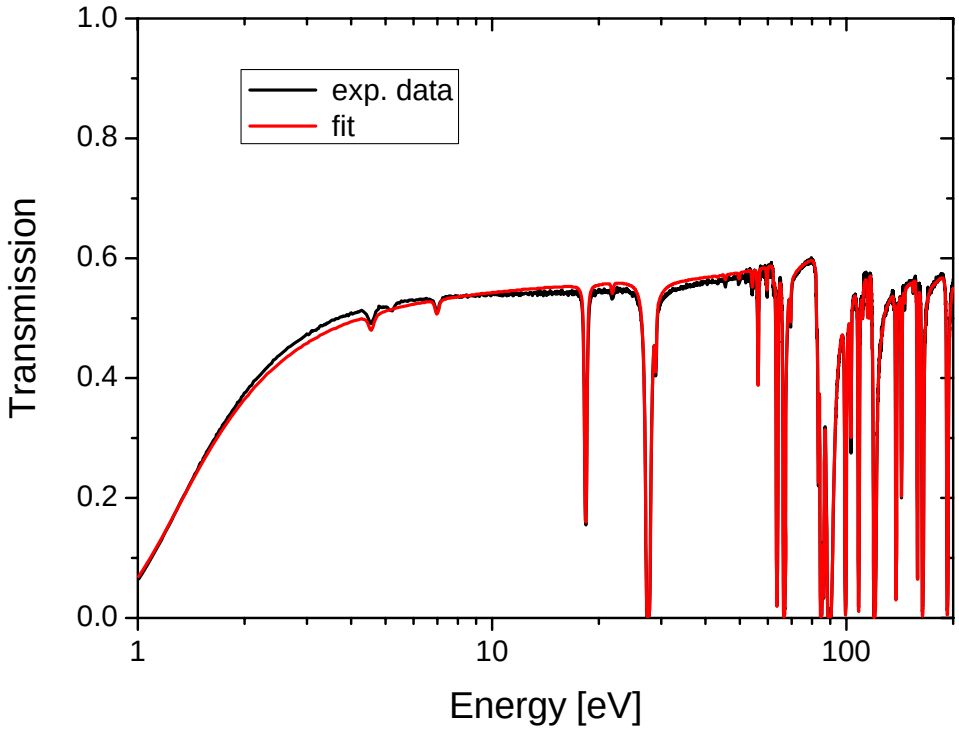
Capture Width

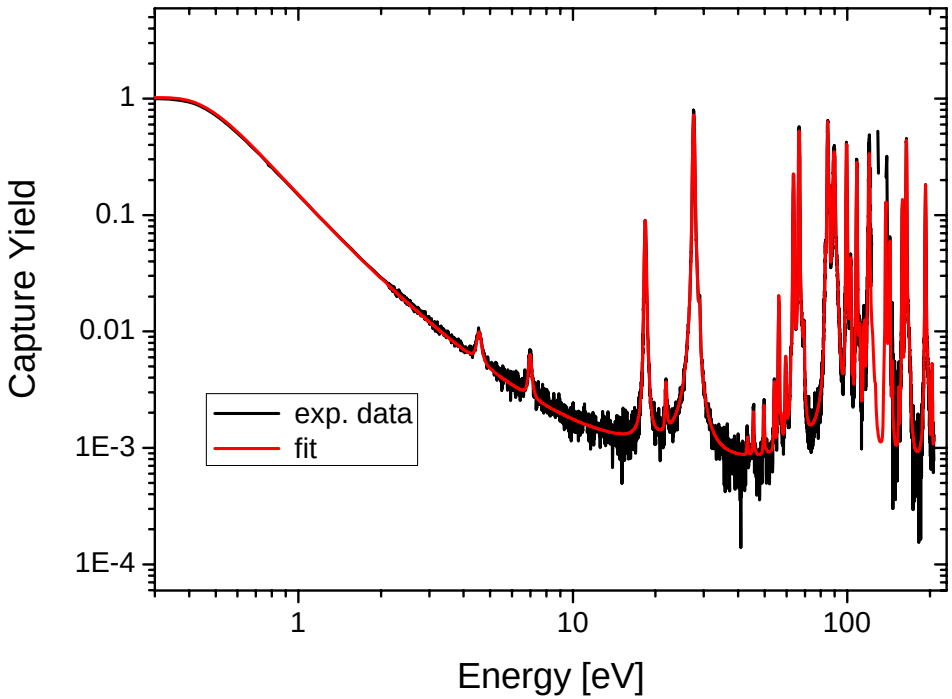


Neutron Width



^{nat}Cd


exp. data
fit
Transmission
Energy [eV]
1.0
0.8
0.6
0.4
0.2
0.0
1
10
100


exp. data
fit
Capture Yield
Energy [eV]
1
0.1
0.01
1E-3
1E-4
1
10
100

$^{96}Zr + ^{nat}Zr$

Objective

New evaluation for Zr+n in RRR and URR

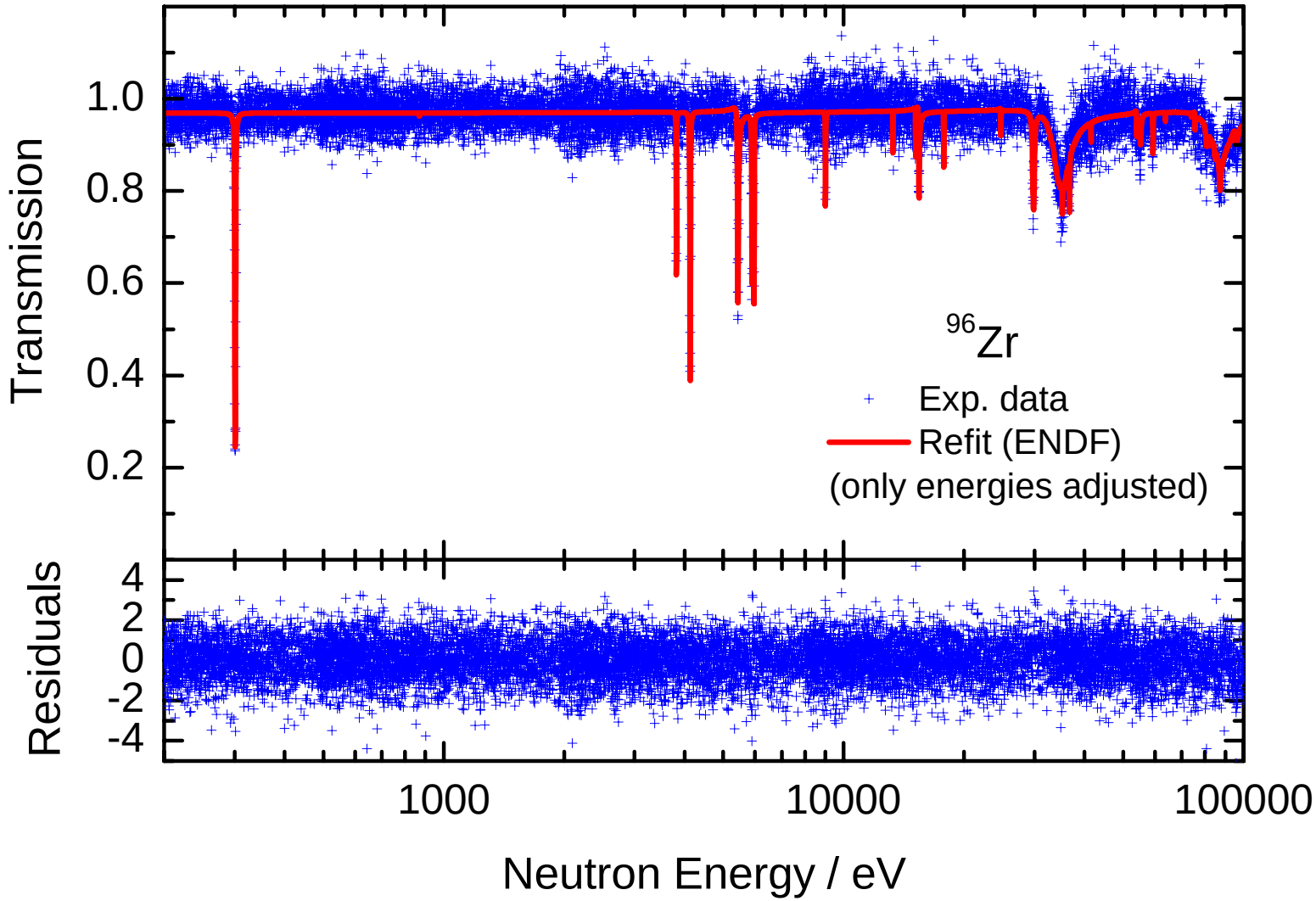
Collaboration with

INFN Bari
Ghent University

Status

Capture measurements in RRR & URR finalized
Normalization measurements scheduled (mixed $^{nat}Zr + ^{nat}Fe$ sample)
Transmission measurements ongoing

^{96}Zr + n : transmission at 50 m



$^{182,184}W + ^{nat}W$

Objective

New evaluation for $^{182,184,nat}W$+n in RRR and URR

Collaboration with

INFN Bari
ORNL

Status

Capture measurements in RRR (finalized)
Capture measurements in thermal and URR to be done
Transmission measurements ongoing

Conclusion

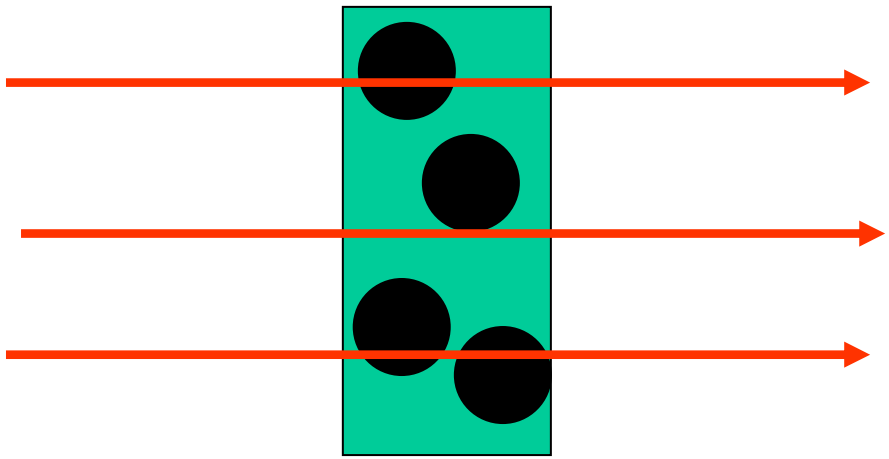
- **^{nat}Cd + n**
  - Evaluation in RRR finalized
  - ACE files to be produced and tested (end 2008)
- **^{197}Au + n**
  - Evaluation < 100 eV finalized
  - Updated ENDF-compatible file to be produced (end 2008)
  - Testing of integral quantities and ACE files
- **^{103}Rh**
  - Evaluation in RRR (< 4000 eV) finalized
  - ENDF-compatible file to be produced (end 2008)
  - Testing of integral quantities and ACE files
- **W & Zr**
  - Ongoing

Correlation matrix (only counting statistics)

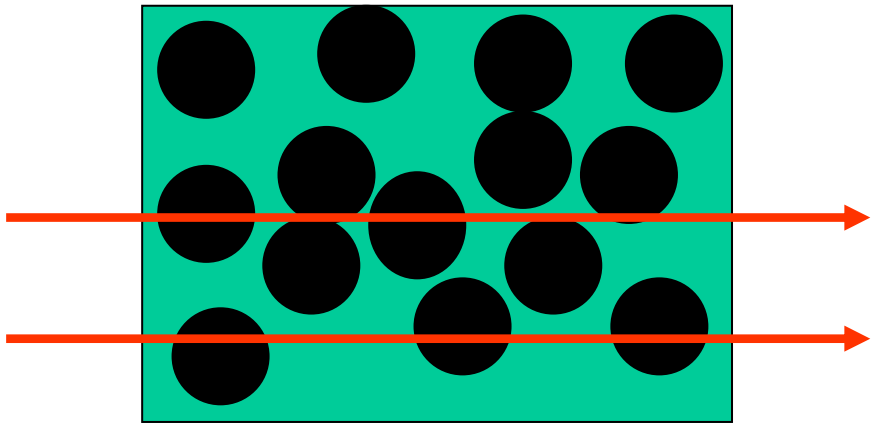
	$\rho(E_R, \Gamma_\gamma)$	$\rho(E_R, \Gamma_n)$	$\rho(\Gamma_\gamma, \Gamma_n)$
Sample 1	**0.44**	**0.70**	**0.49**
Sample 2	**0.41**	**0.68**	**0.40**
Sample 3	**0.24**	**0.30**	**0.90**
Simultaneous fit	**0.41**	**0.68**	**0.44**

Powder Sample

N=1

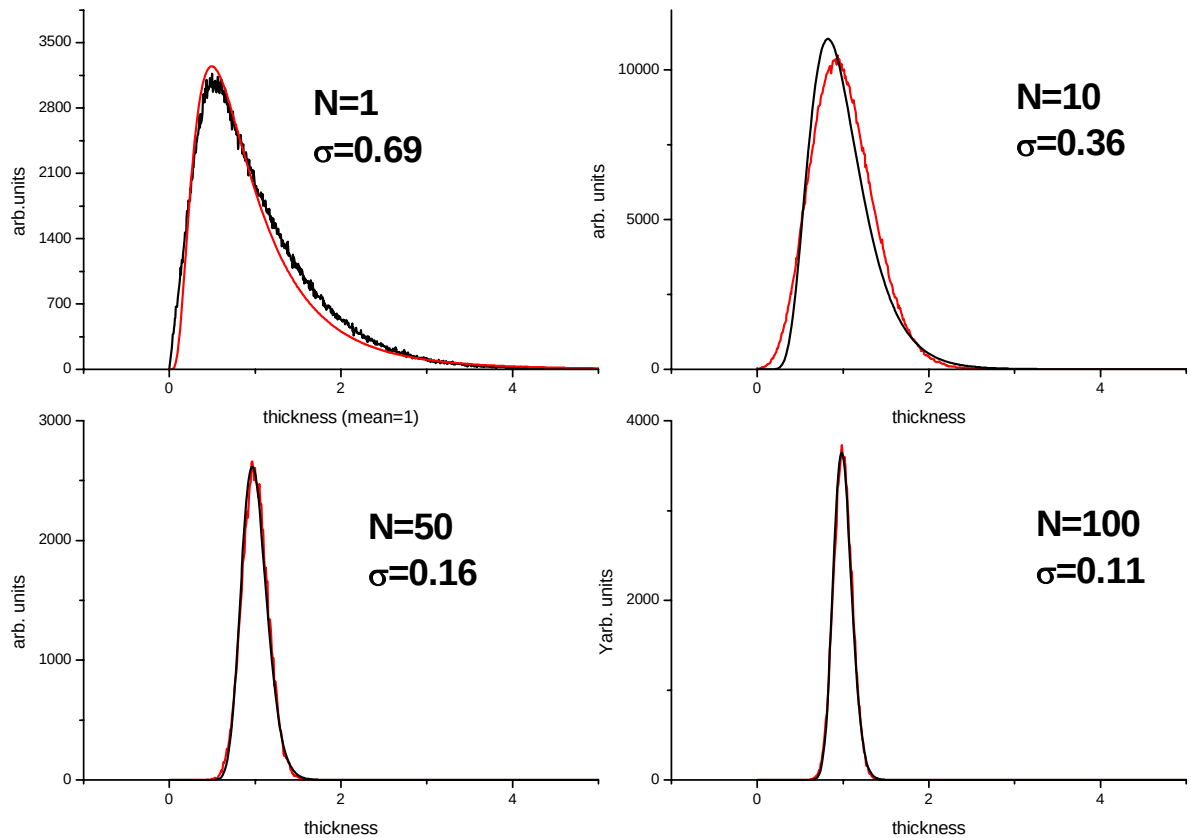


N=3.5



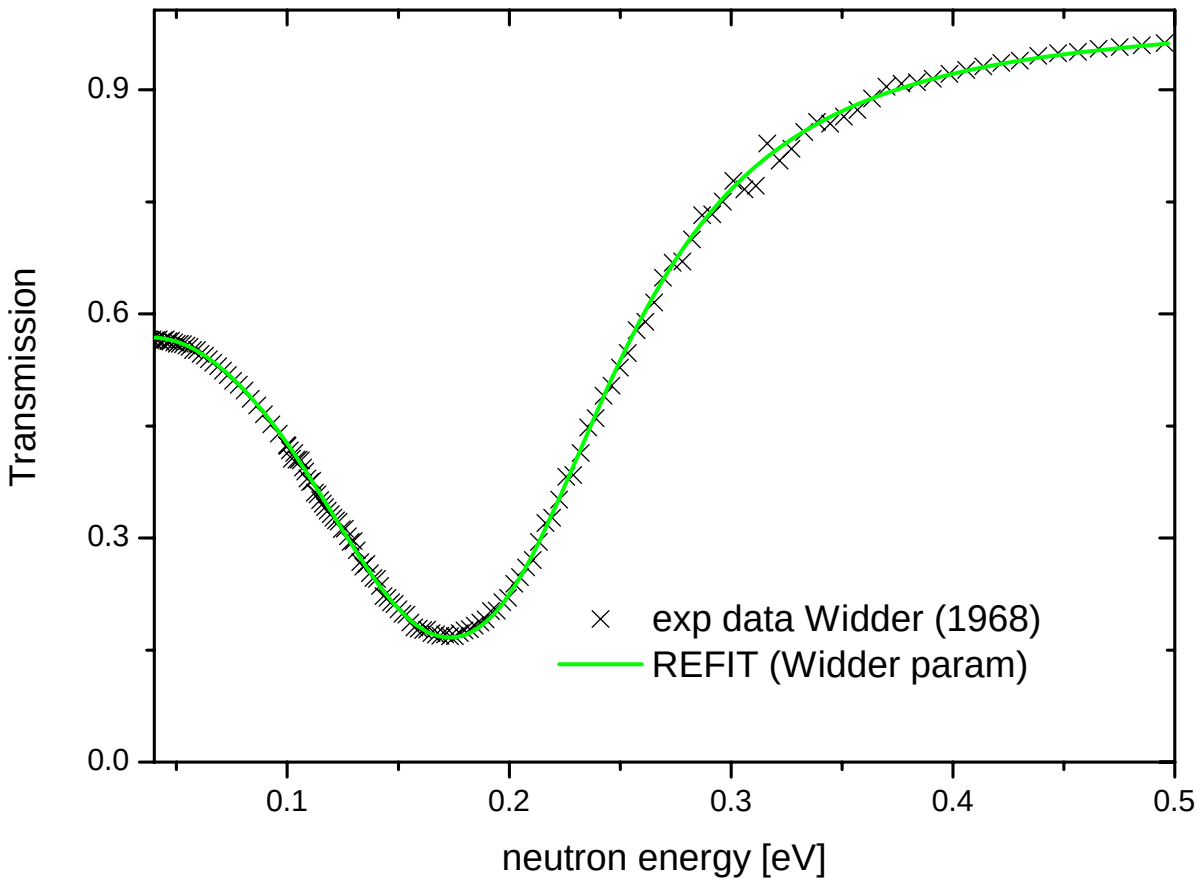
Probability that a neutron “sees” n particle, given by Poisson-statistics

Powder Sample

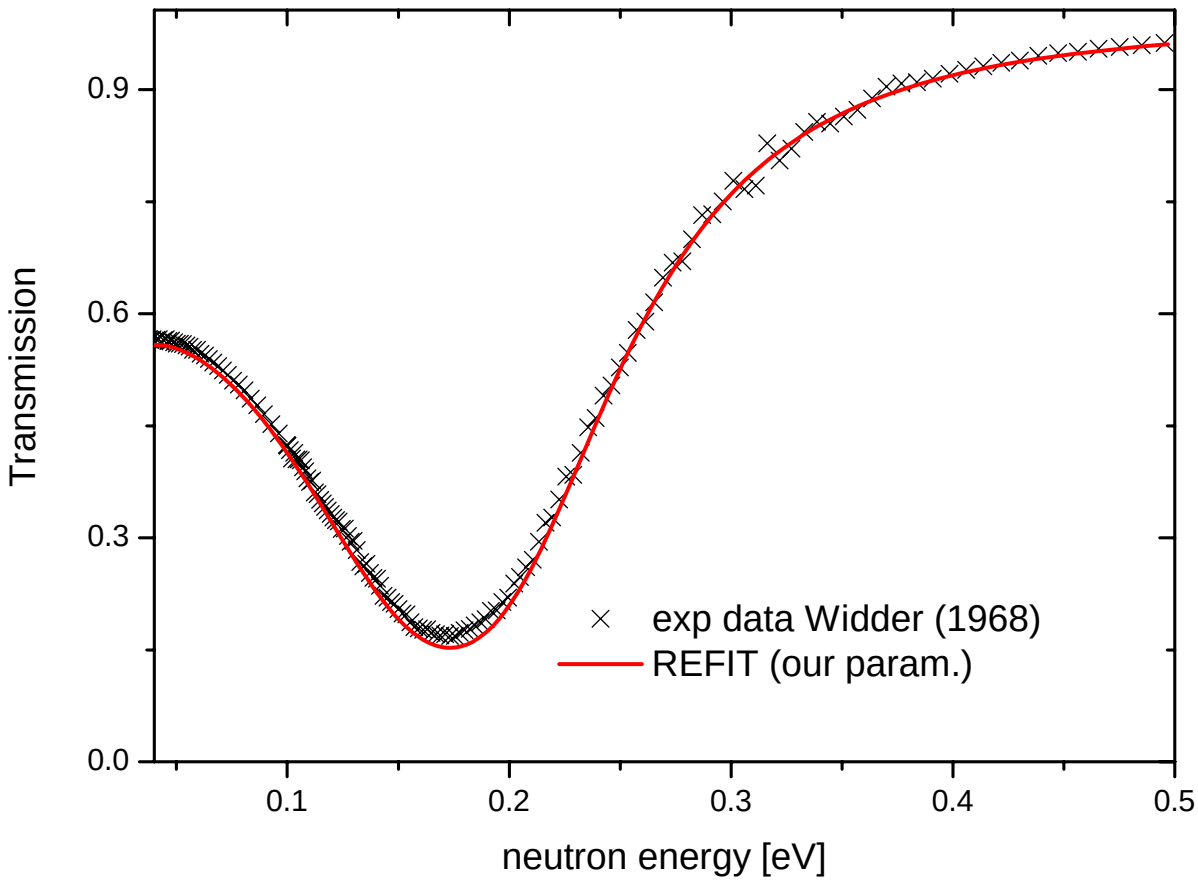


- Poisson distribution
- Spheres
- Radius lognormal
- Black line MC
- Red line lognormal fit

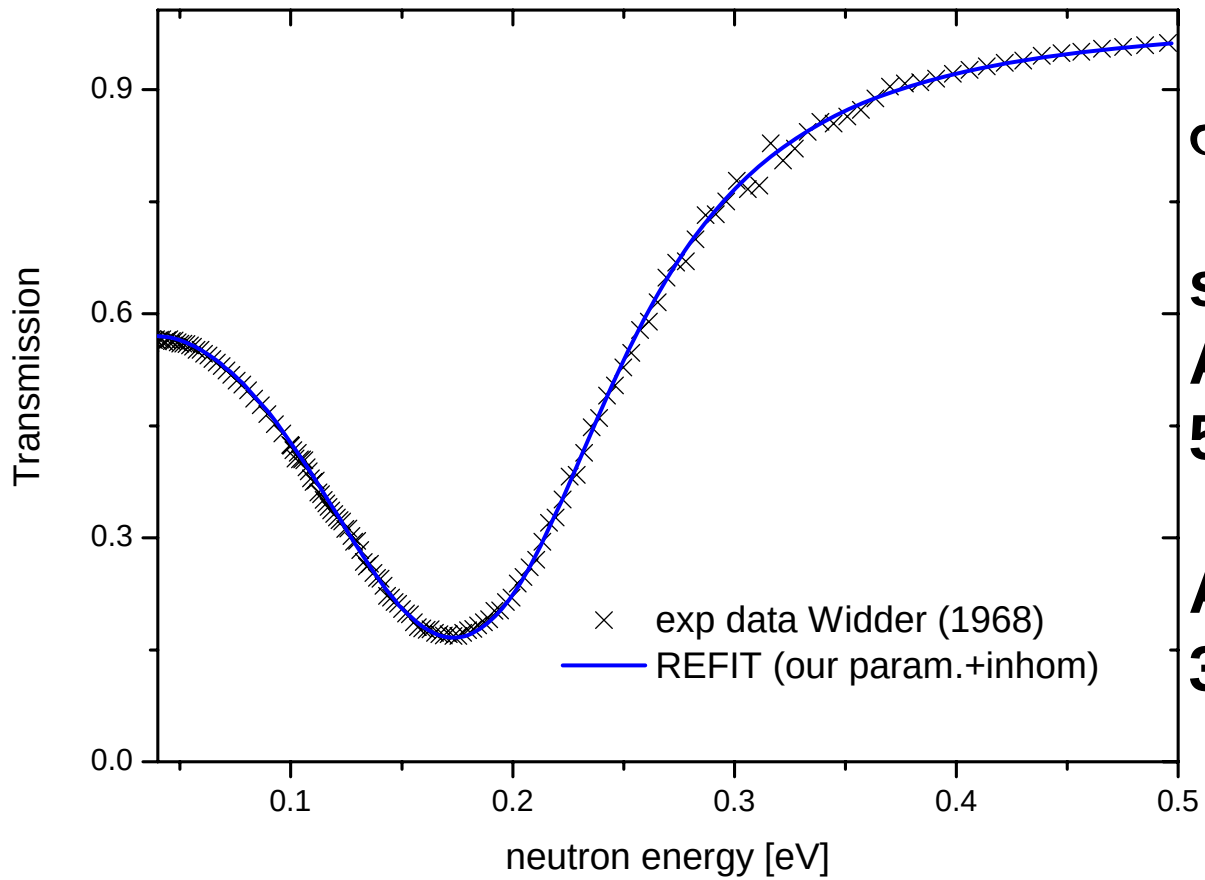
Fit to Widder et al. (1/3)



Fit to Widder et al. (2/3)



Fit to Widder et al. (3/3)



σ_{inhom}=0.096

sample thickness:
Approx. 50 μm
50-200 layers (estim)

Average particle size
300nm – 1μm (estim)

Comparison Calculations