ORNL Neutron Cross-Section Measurements Activities

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NCSP Technical Seminar

Oak Ridge National Laboratory

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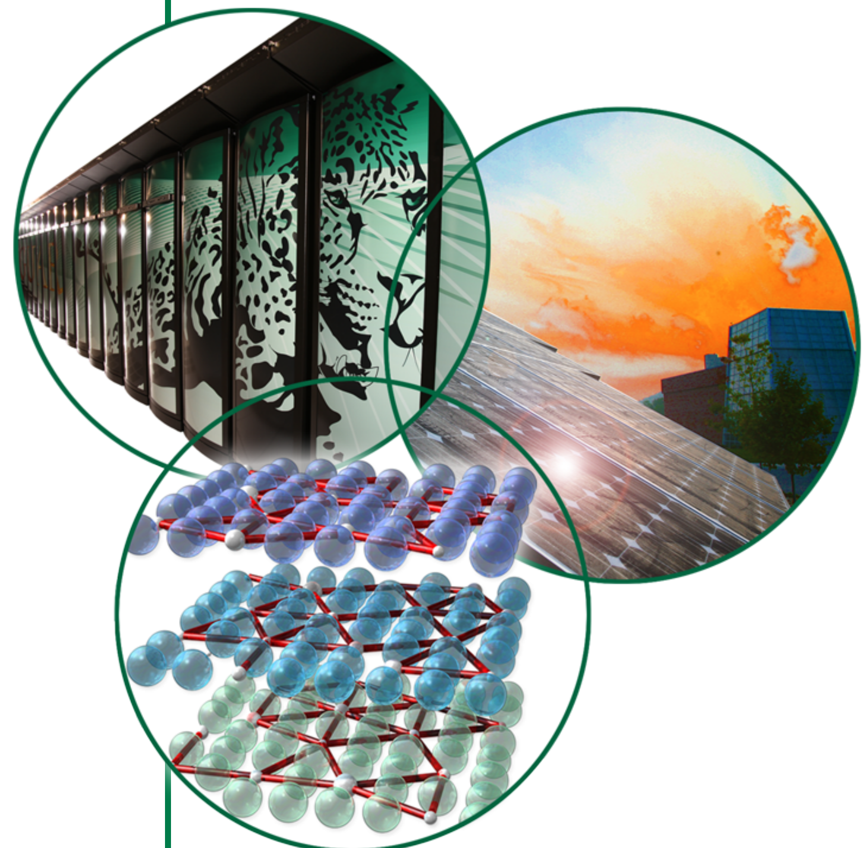

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY

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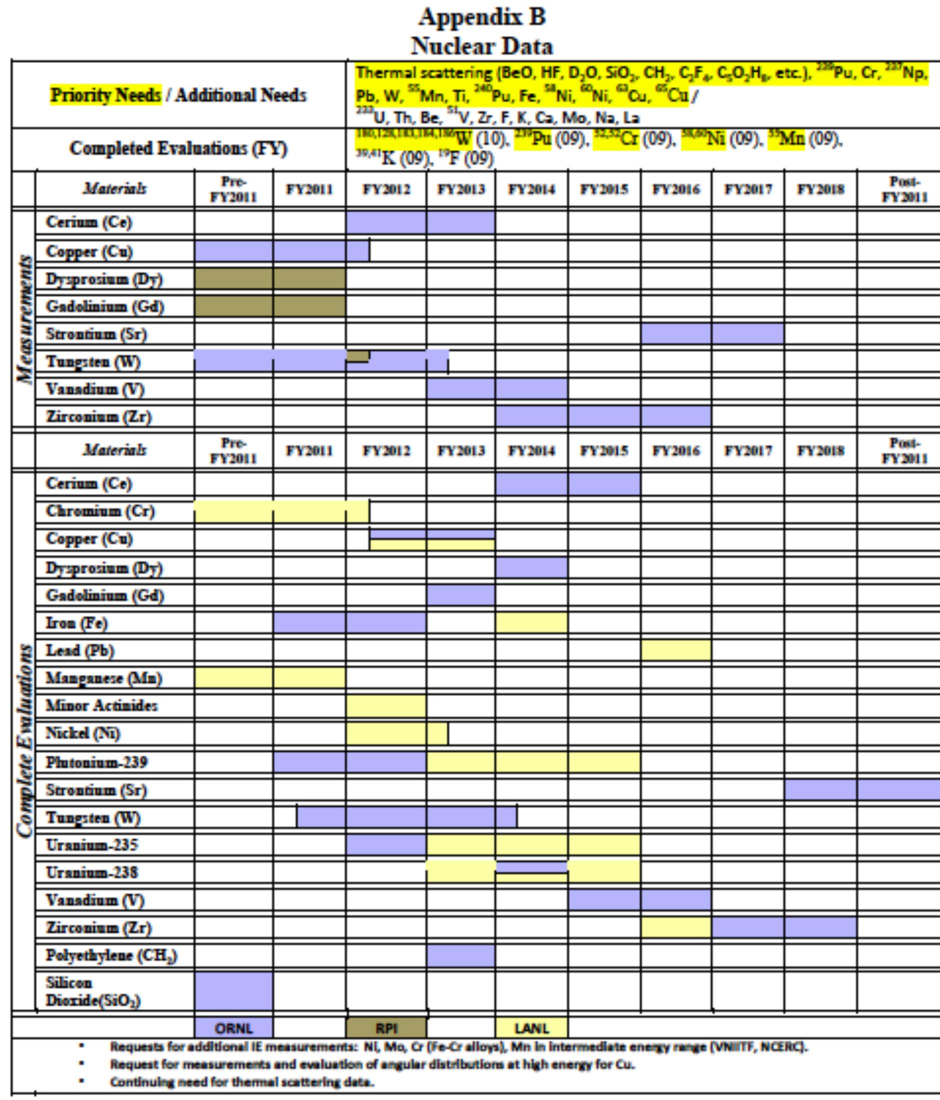
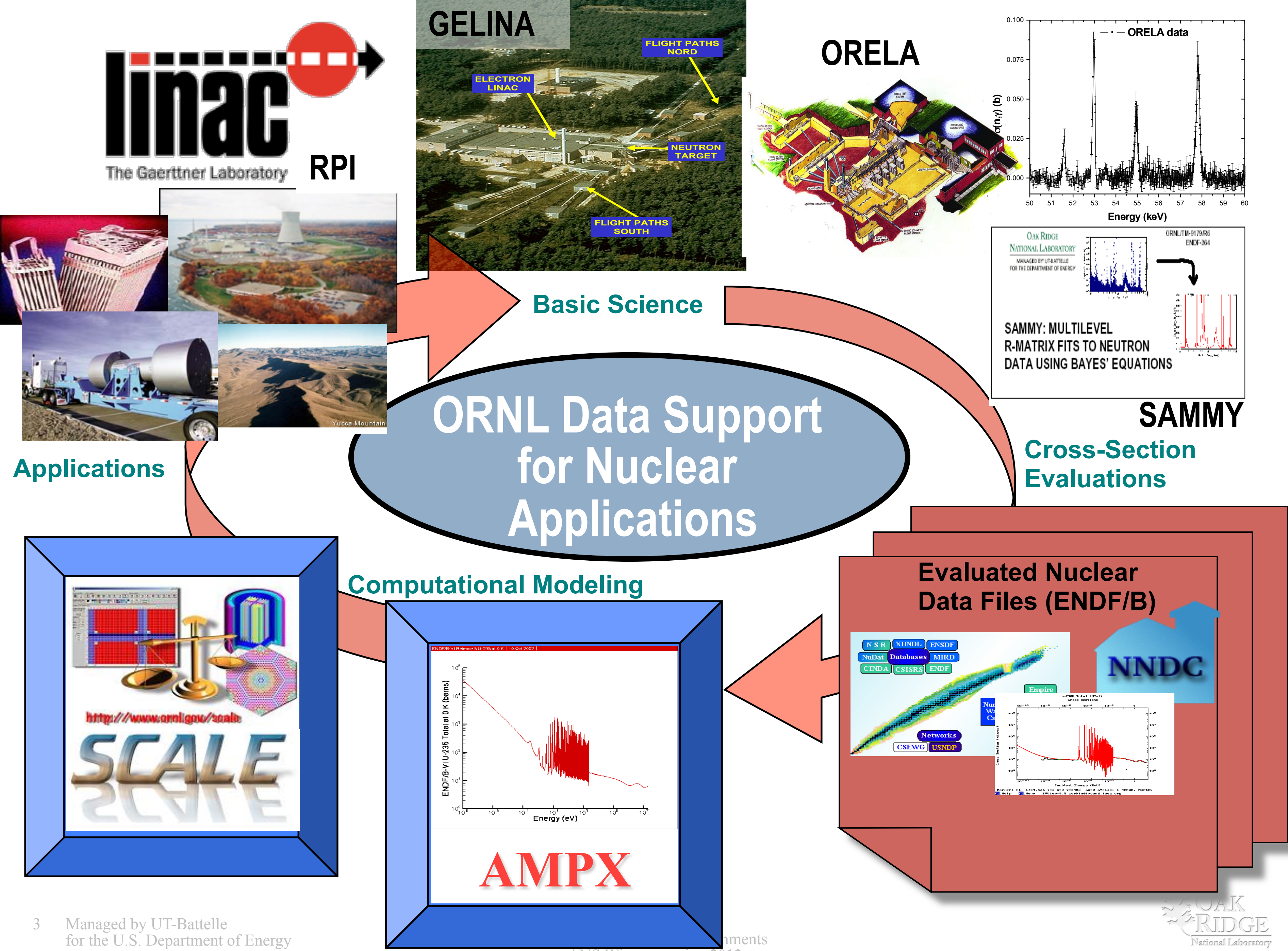
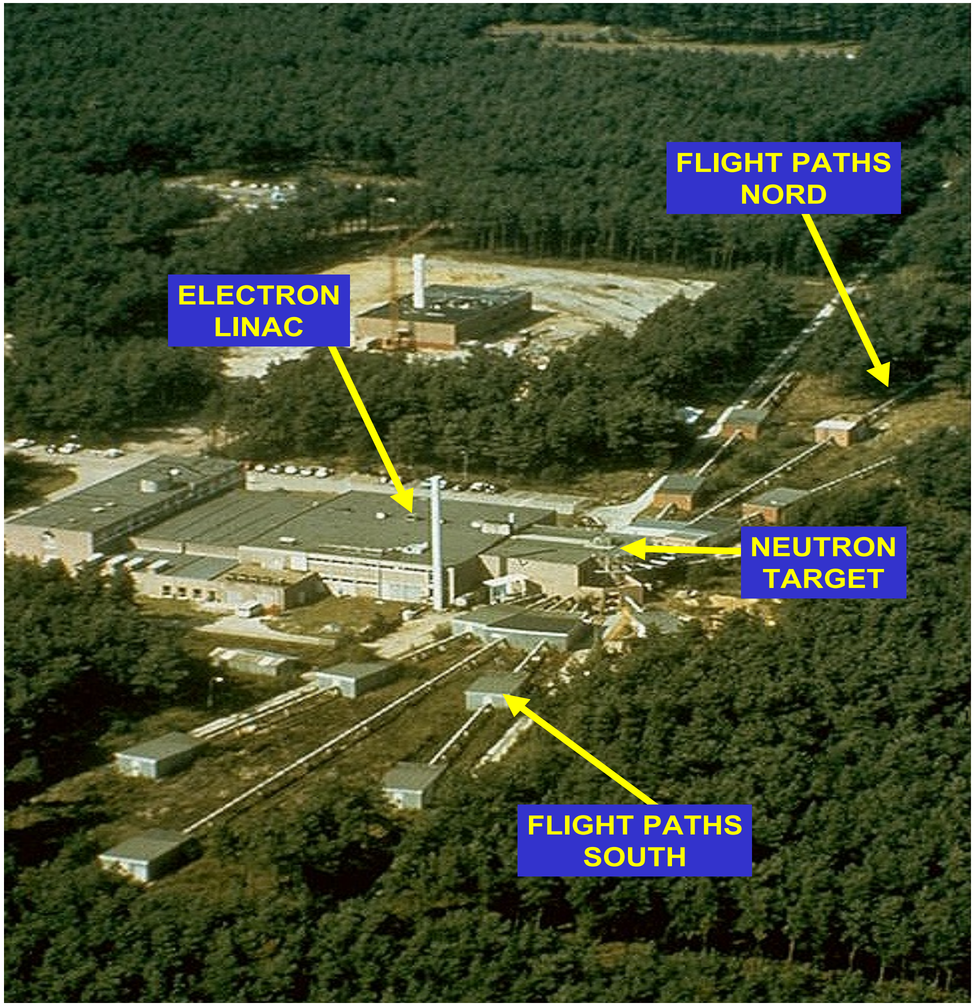
Resonance Region Nuclear Data Work for NCSP

- **Objective:** Provide measured and evaluated resonance-region cross-section data to address the priority NCSP nuclear data needs
- **Vision:** Addresses multiple Nuclear Data 5- and 10-year goals and attributes identified in the NCSP Vision
- **Final product:** rigorous ENDF/B resonance evaluations produced from cross-section measurements and analyses
- FY11 and 12 measurement work effort focused on tungsten, copper, calcium, and cerium—identified differential nuclear data needs by NCSP Nuclear Data Advisory Group (NDAG)




linac
The Gaerttner Laboratory
RPI
GELINA
FLIGHT PATHS NORD
ELECTRON LINAC
NEUTRON TARGET
FLIGHT PATHS SOUTH
ORELA
ORELA data
σ(n,γ) (b)
Energy (keV)
Basic Science
Oak Ridge National Laboratory
ORNL/TM-9179/R6
ENDF-364
SAMMY: MULTILEVEL
R-MATRIX FITS TO NEUTRON
DATA USING BAYES' EQUATIONS
SAMMY
Cross-Section
Evaluations
Applications
Yucca Mountain
ORNL Data Support
for Nuclear
Applications
Computational Modeling
http://www.ornl.gov/scale
SCALE
Energy (eV)
AMPX
Evaluated Nuclear
Data Files (ENDF/B)
NSR
XUNDL
ENSDF
NuDat
Databases
MIRD
CINDA
CSISRS
ENDF
Empire
Networks
CSEWG
USNDP
NNDC



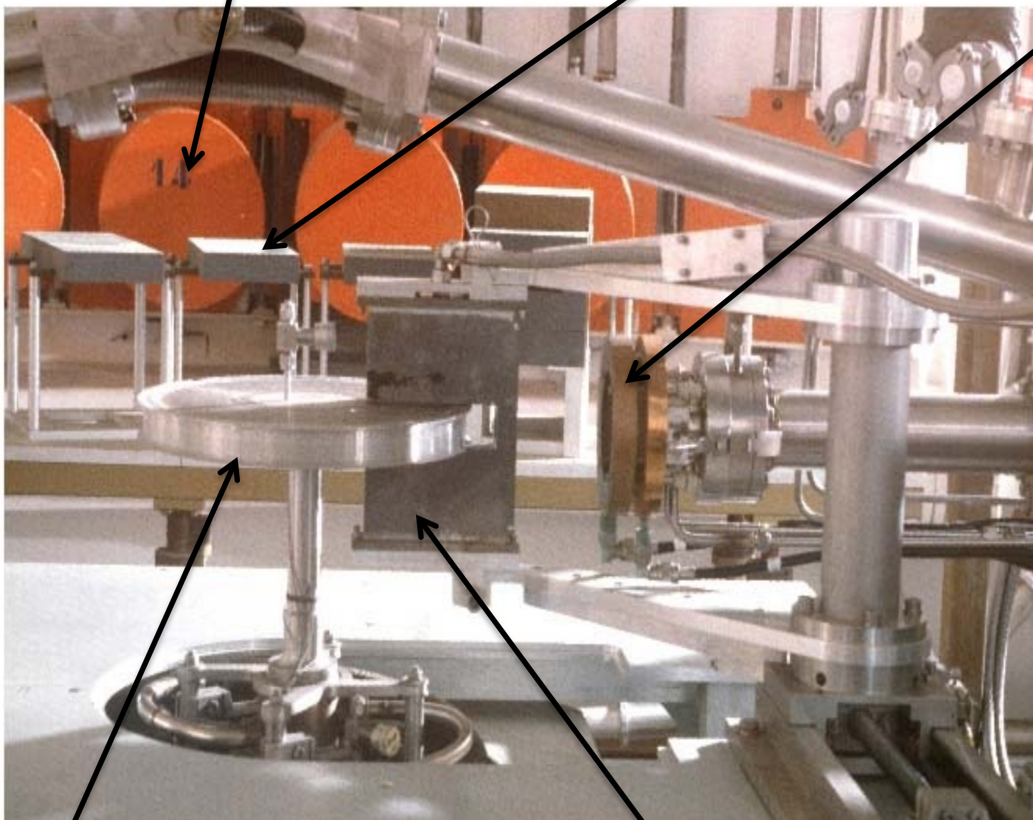
GELINA

- Time-of-flight facility
- Pulsed white neutron source

  (10 meV < E_n < 20 MeV)
- Multi-user facility with 10 flight paths (10 m - 400 m)
- The measurement stations have special equipment to perform:
  - Total cross section measurements
  - Partial cross section measurements

Pulse Width	: 1ns
Frequency	: 40 Hz – 800 Hz
Average Current	: 4.7 μA – 75 μA
Neutron intensity	: 1.6 10^{12} – 2.5 10^{13} n/s

Neutron Production



- e^- accelerated to $E_{e-,max} \approx 140$ MeV
- (e^-, γ) Bremsstrahlung in U-target (rotating & cooled with liquid Hg)
- (γ,n) , (γ ,f) in U-target
- Low energy neutrons by water moderator in Be-canning

No Euro Crisis: Major Upgrades to GELINA

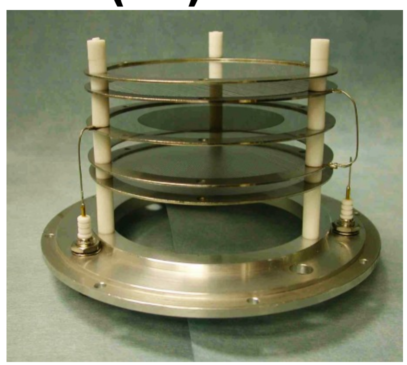
- Over the last couple of years major upgrades of GELINA
  - 4 new modulators
  - New control room, all settings of the accelerator are now computer controlled, new cables (2009)
  - New process water cooling tower (2010)
  - Upgrade and renovation of the flight stations (2011)

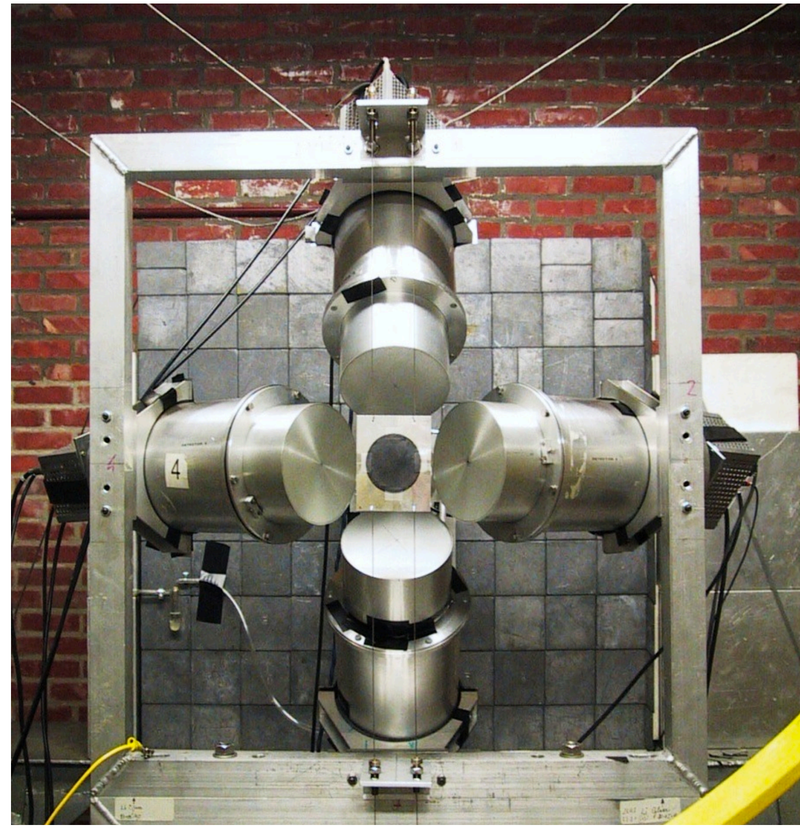
Capture Cross-Section Measurements at GELINA

L = 10 m, 30 m and 60 m

Total energy detection

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

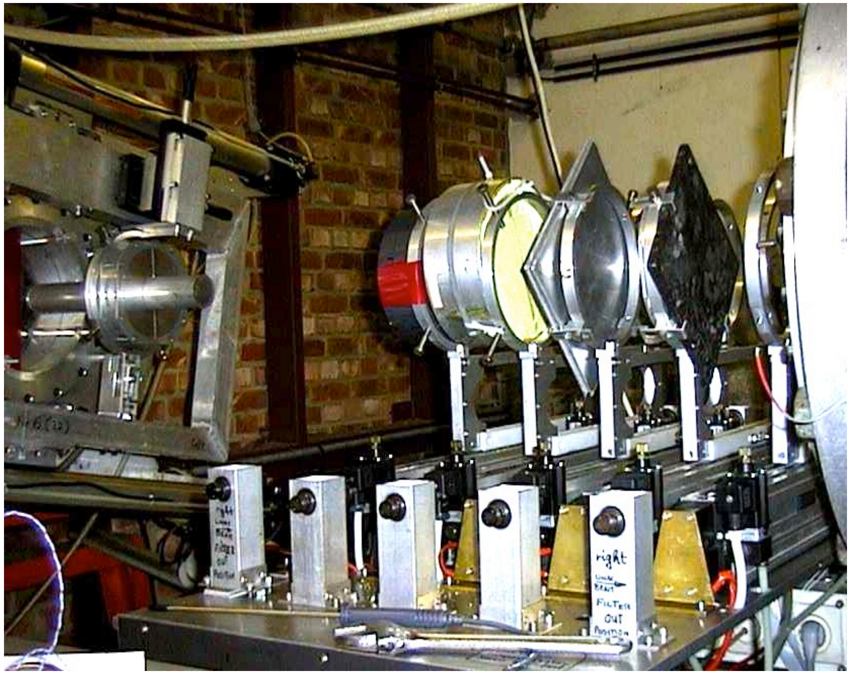




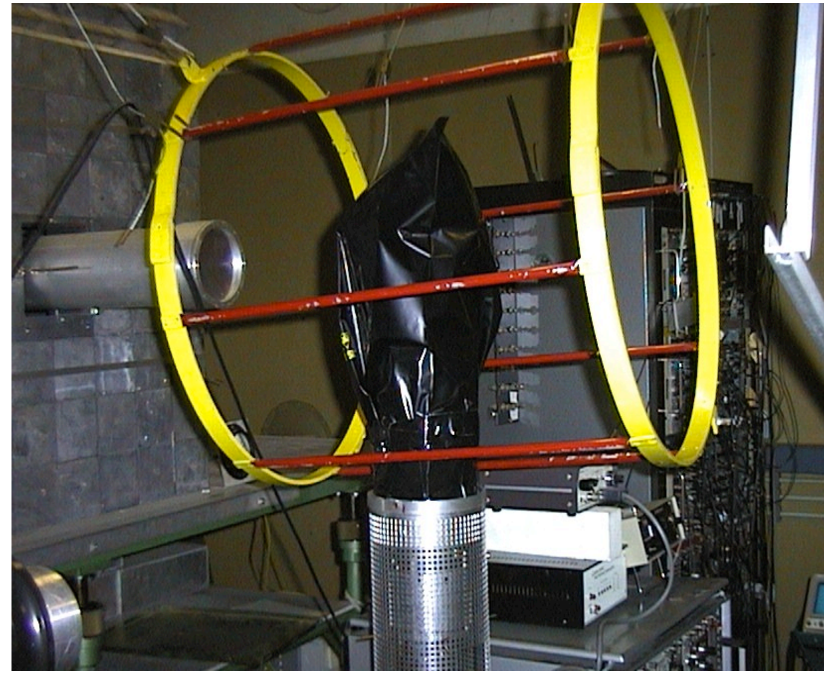
$$Y_{exp} = N\sigma_{\varphi} \frac{C_w - B_w}{C_{\varphi} - B_{\varphi}}$$

Transmission Measurements

Sample & Background Filters



Detector



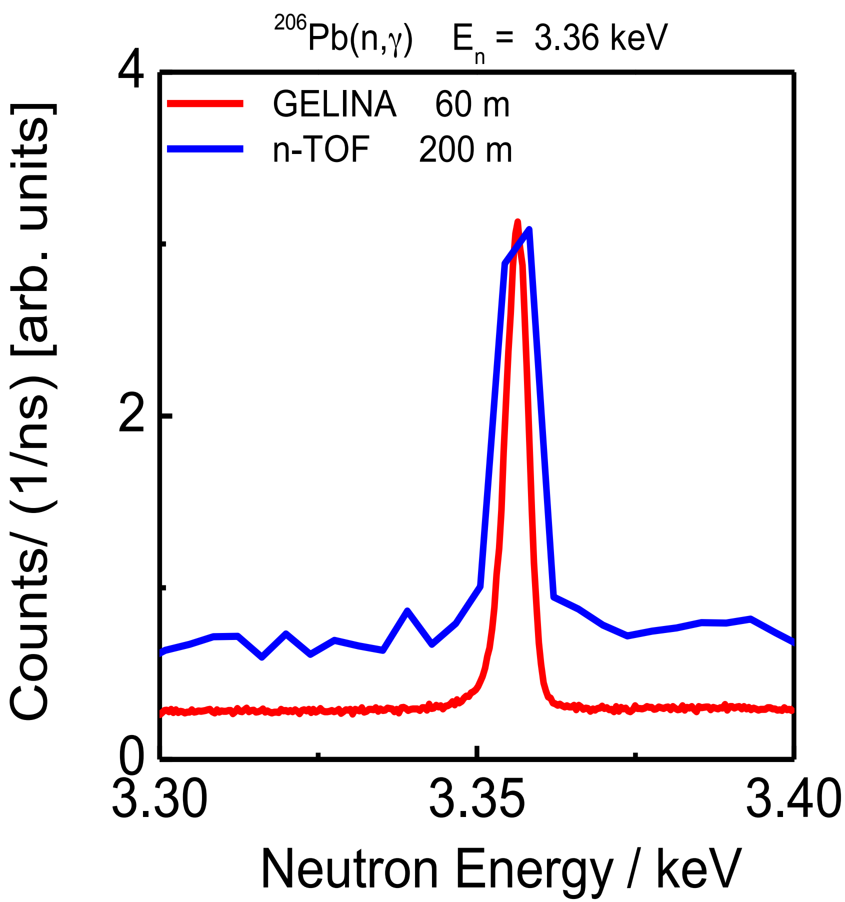
Detector stations
Moderated: L= 30 m,50 m,(100 m,200 m)
Fast: L= 400 m

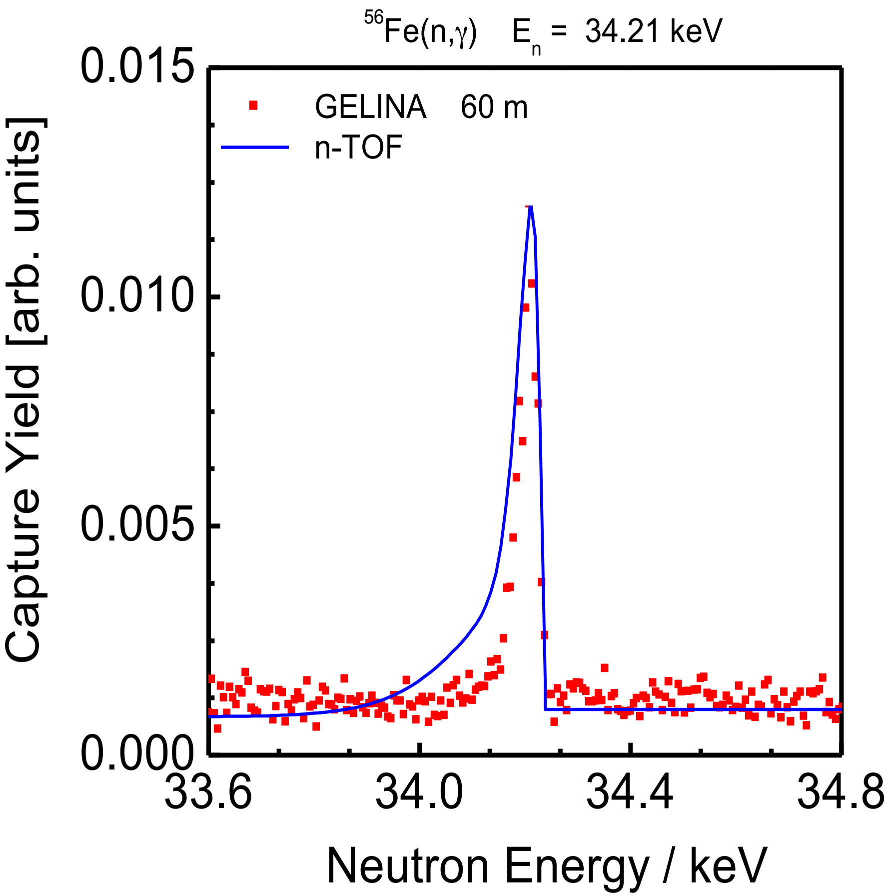
Low energy : $^{6}Li(n,t)\alpha$ Li-glass

High energy : H(n,n)H Plastic scintillator

$$T = \frac{C_{in}}{C_{out}} \cong e^{-n\sigma_{tot}}$$

n-TOF (180 m) <-> GELINA (60 m)

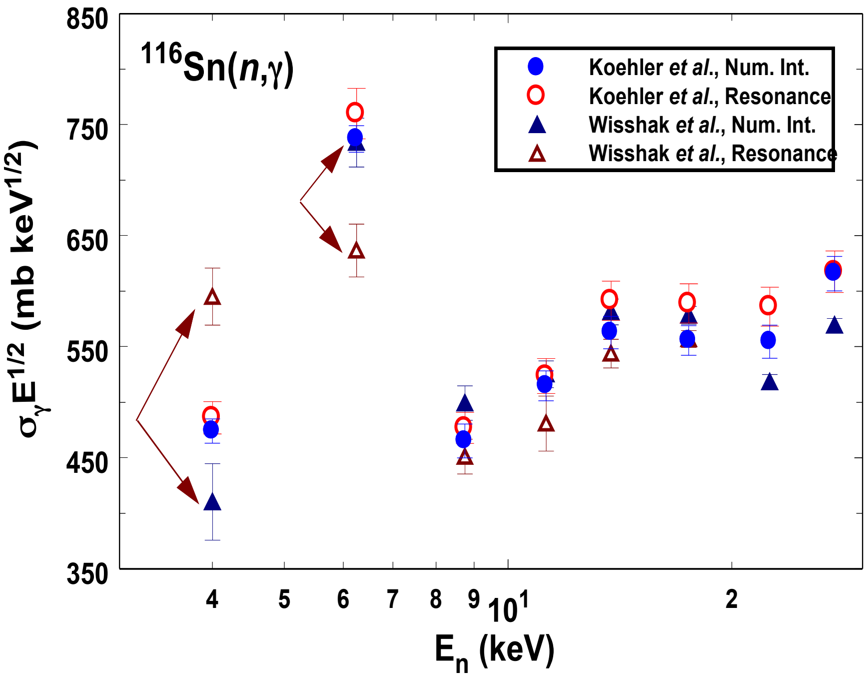




P. Schillebeeckx, IRMM

The Importance of Total Cross-Section Data

- More complete resonance parameter data will help improve nuclear statistical model.
- Is indispensable for obtaining the most accurate (n,γ) reaction rates. See resonances not visible in (n,γ) data. Improved self-shielding and multiple scattering corrections.
- Lack of good total cross section data can lead to serious errors in these corrections and hence in the cross sections.



Ex: ^{116}Sn Use of incorrect neutron widths led to incorrect low-energy cross sections (Wisshak et al. PRC 54, 2732 (1996))

thin <--> thick transmission determination of statistical factor g

$g = 2 \qquad \frac{\chi^2}{\nu} = 2.25$

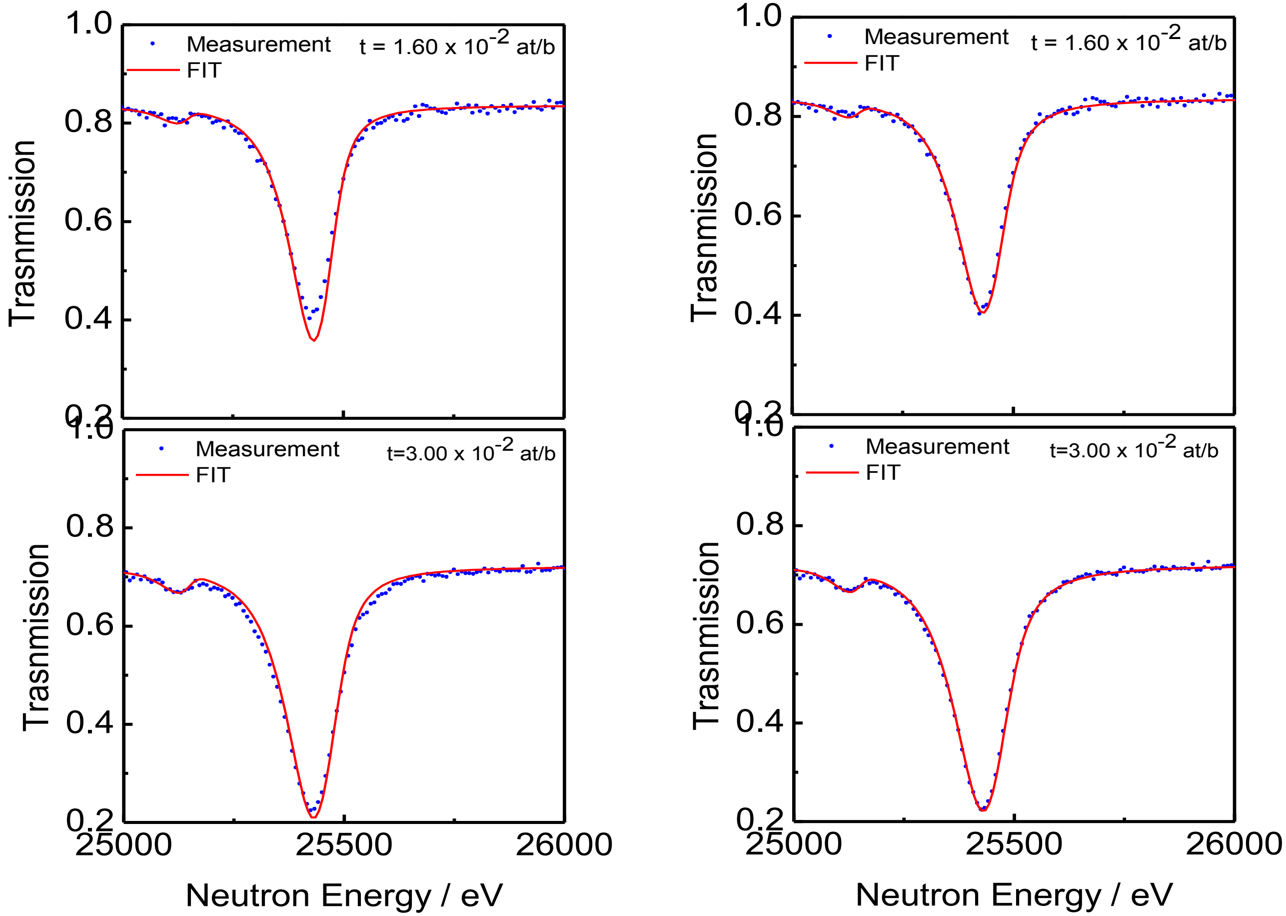
$g = 1 \qquad \frac{\chi^2}{\nu} = 0.95$

$$A_{t,thin} \propto ng\Gamma_n$$

$$A_{t,thick} \propto \sqrt{ng\Gamma_n\Gamma}$$

$$g = \frac{2J+1}{2(2I+1)}$$

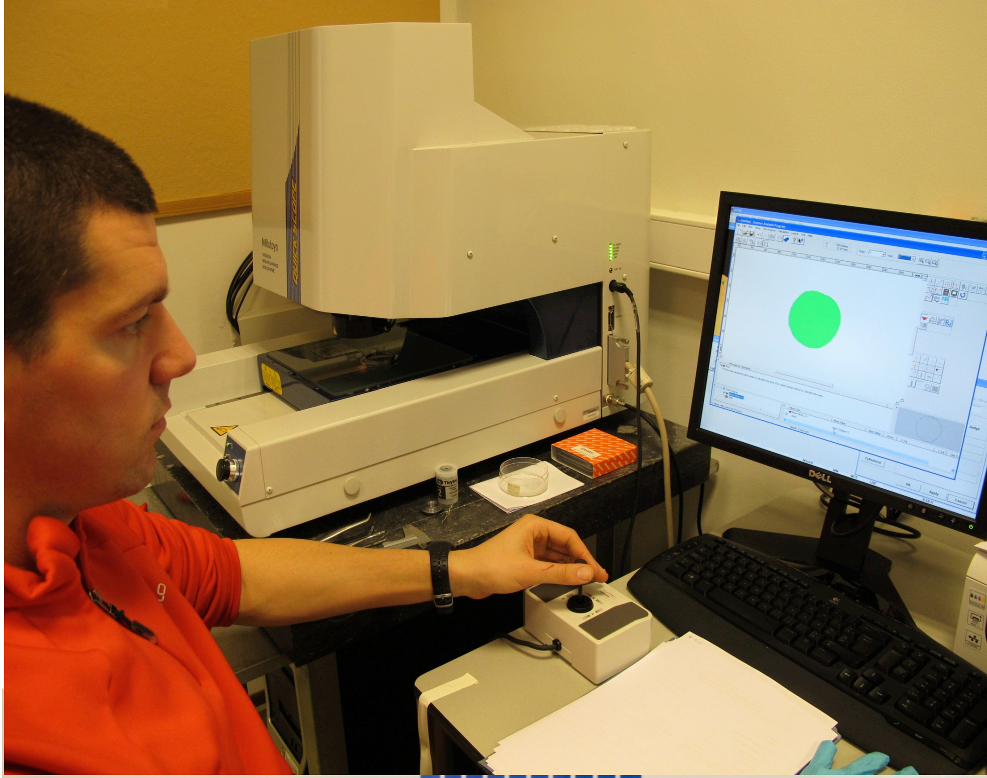
P. Schillebeeckx, IRMM

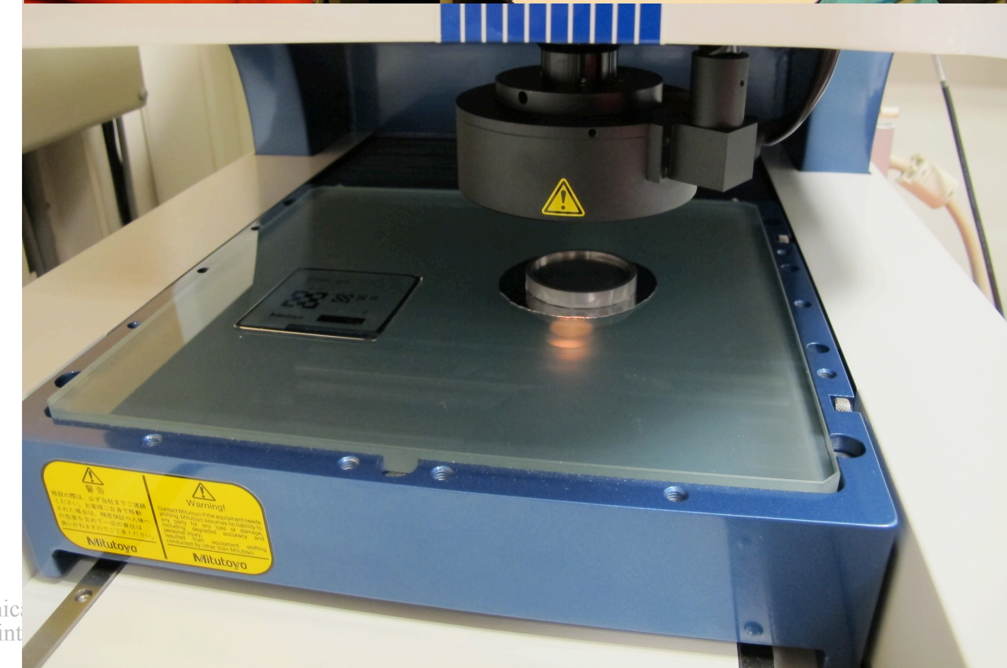


Determine Sample Characteristics

- How much material is needed to achieve sufficient count rate.
- What material and how much is available.

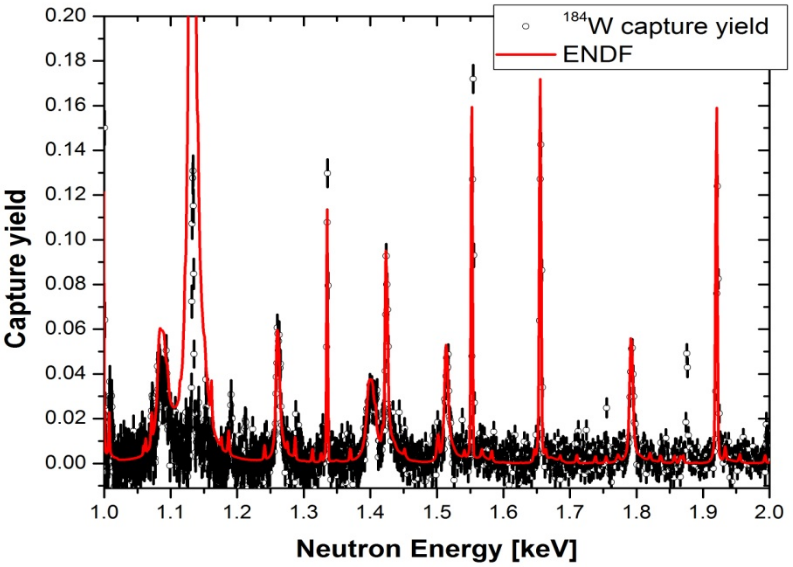
- Physical dimensions like radius, thickness, area.
- Weight, density.
- Isotopic composition.
- Number of atoms.

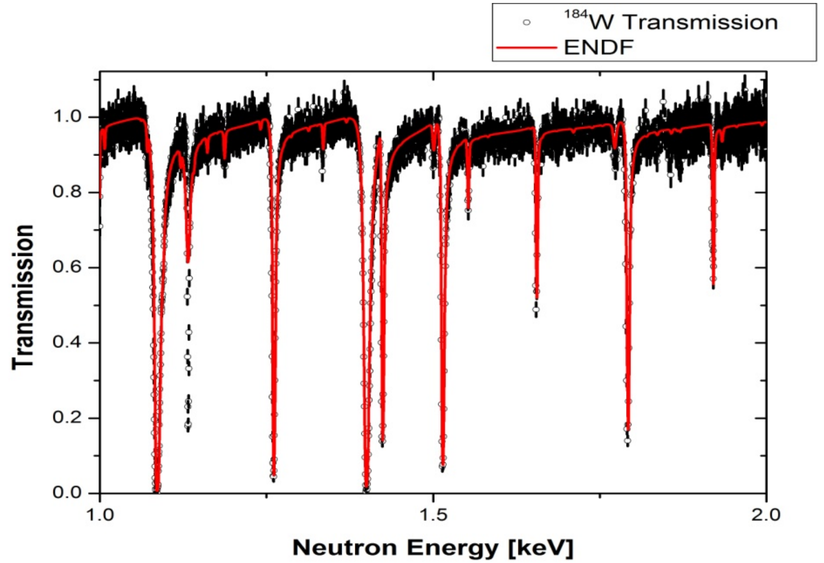




Data Taking

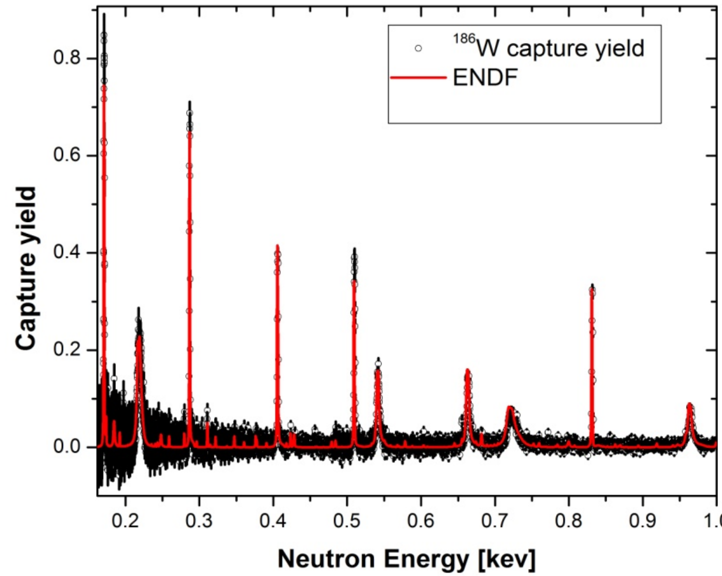
- Data are taken in list mode: TOF and pulse-height for detector(s) and flux monitor.
- Usually at least 2 experiments are performed for each isotope. For example, 4 isotopes translate to at least 8 experiments over the time frame of a couple of weeks each, depending on the nucleus.
- Presence at GELINA is required to perform and control experiments and for understanding all experimental effects, e.g., background corrections with black filters, resolution function…

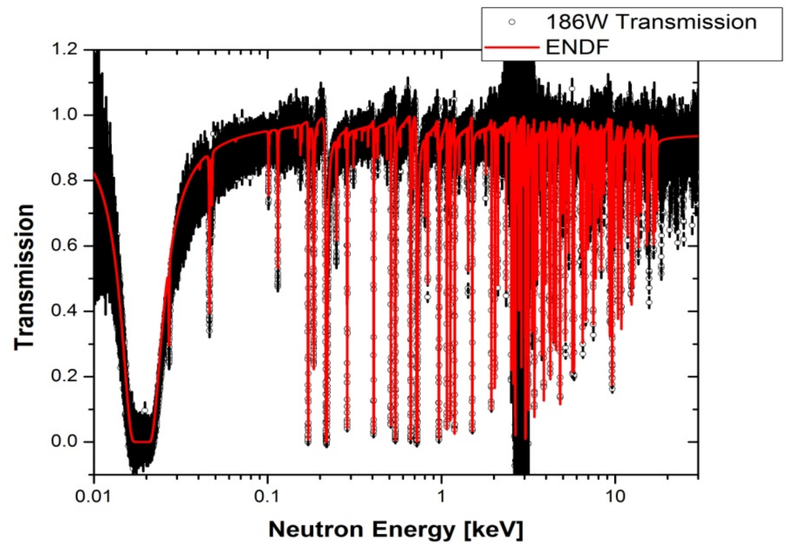




Data Reduction

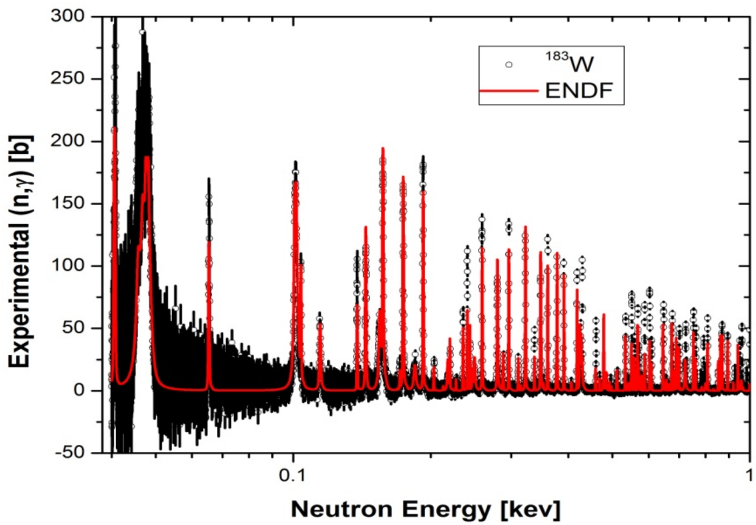
- **Presence is required because codes for data reduction are Geel specific.**
- **Data are sorted into spectra using the program package AGL (Analyze Geel List mode data). Raw data and scalers are tested for stability and consistency before sorting into final spectra (time-of-flight versus counts).**
- **The resulting spectra are then converted to cross section/transmission applying all background corrections using the AGS (Analyze Geel Spectra) code. The code is capable of a full propagation of the uncertainties for all spectra corrections and variables. A covariance matrix is generated.**
- **AGS installed on ORNL computers**

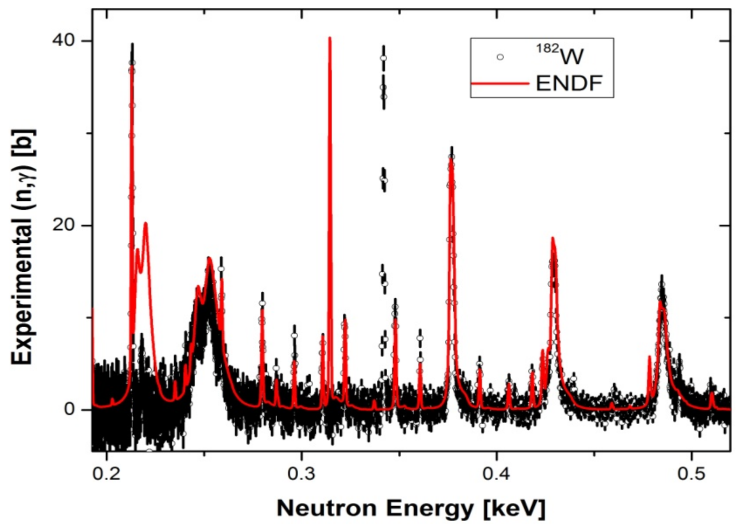




Data Testing

- Obtain all experimental information, like pulse width, repetition rate, neutron filters, flight path length, crunch table settings, sample composition and dimensions.
- Retrieve resonance parameter file for each isotope from NNDC.
- Prepare input files for SAMMY, which have to include all experimental and facility specific effects. This is for example sample characteristics, like dimensions for multiple scattering corrections, isotopic composition, correction for applying the PHWT, resolution function.
- Run SAMMY to check data.



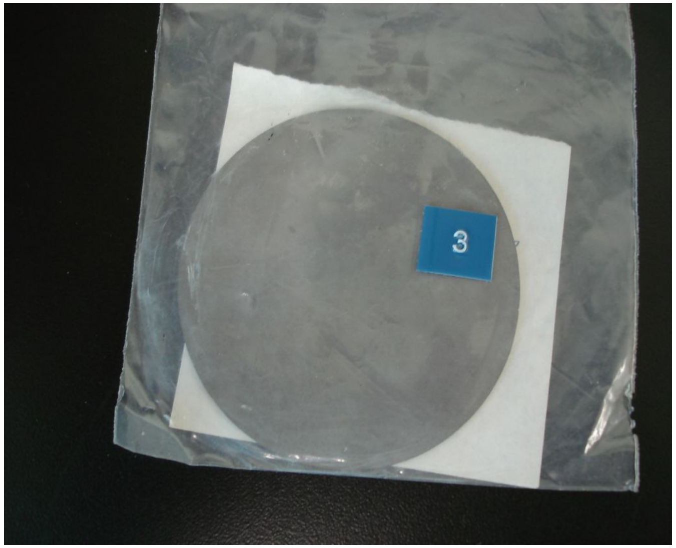


W Measurement Activities

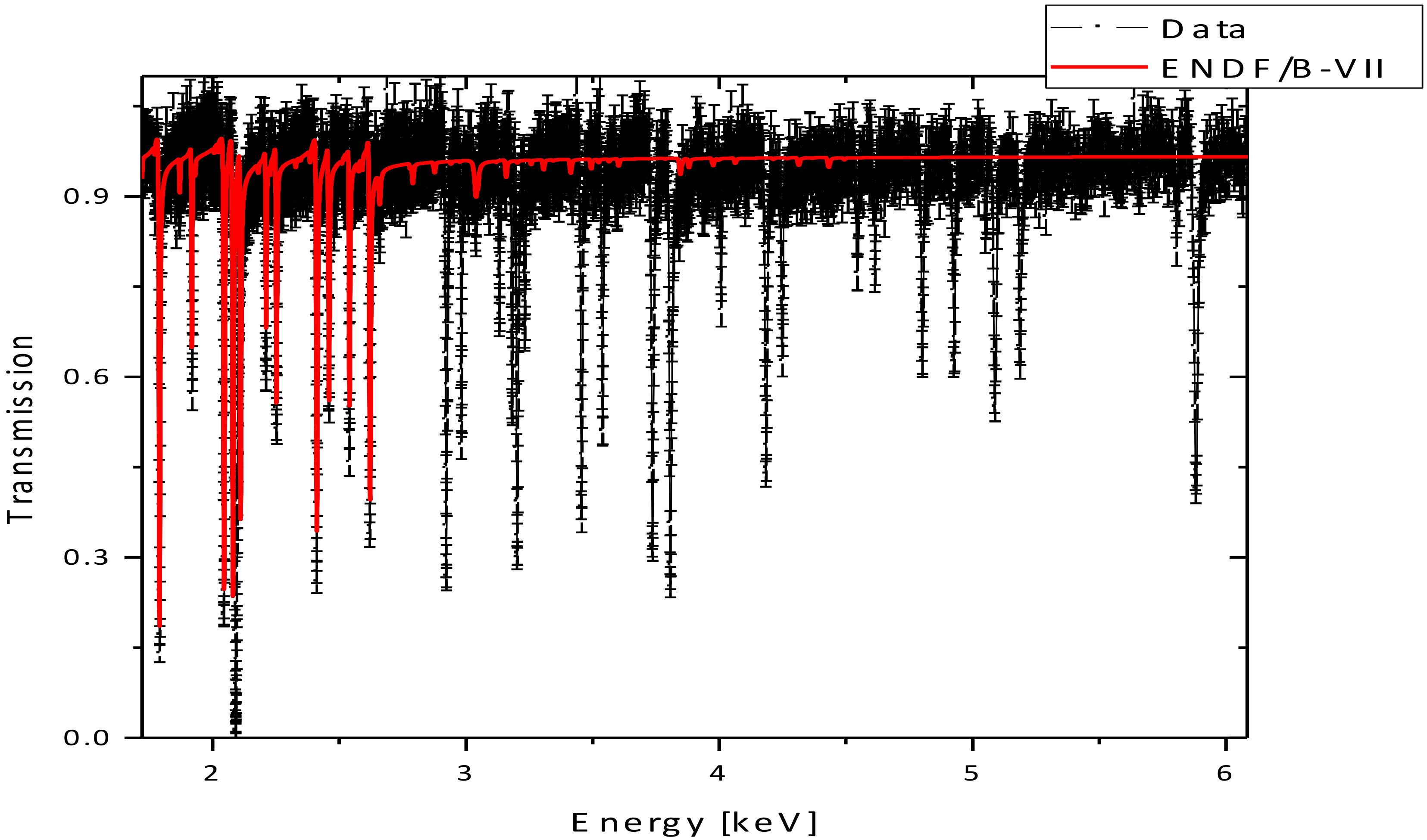
- Measurements completion of the stable W isotopes. Experiments started in FY09 using enriched samples for 4 isotopes
  → 12 experiments.
- Data sets cover now the complete resolved resonance region, as well as part of the unresolved region.
- Normalization of the capture data finalized.
- Capture data for ^{182,183,184,186}W from the high repetition run available to analyze.
- Transmission data for ^{182,183,184,186}W with different sample thickness available. But due to black resonance filters there are gaps in the data. New experiments were performed with a modified setup where filters are not in the sample data.

W samples

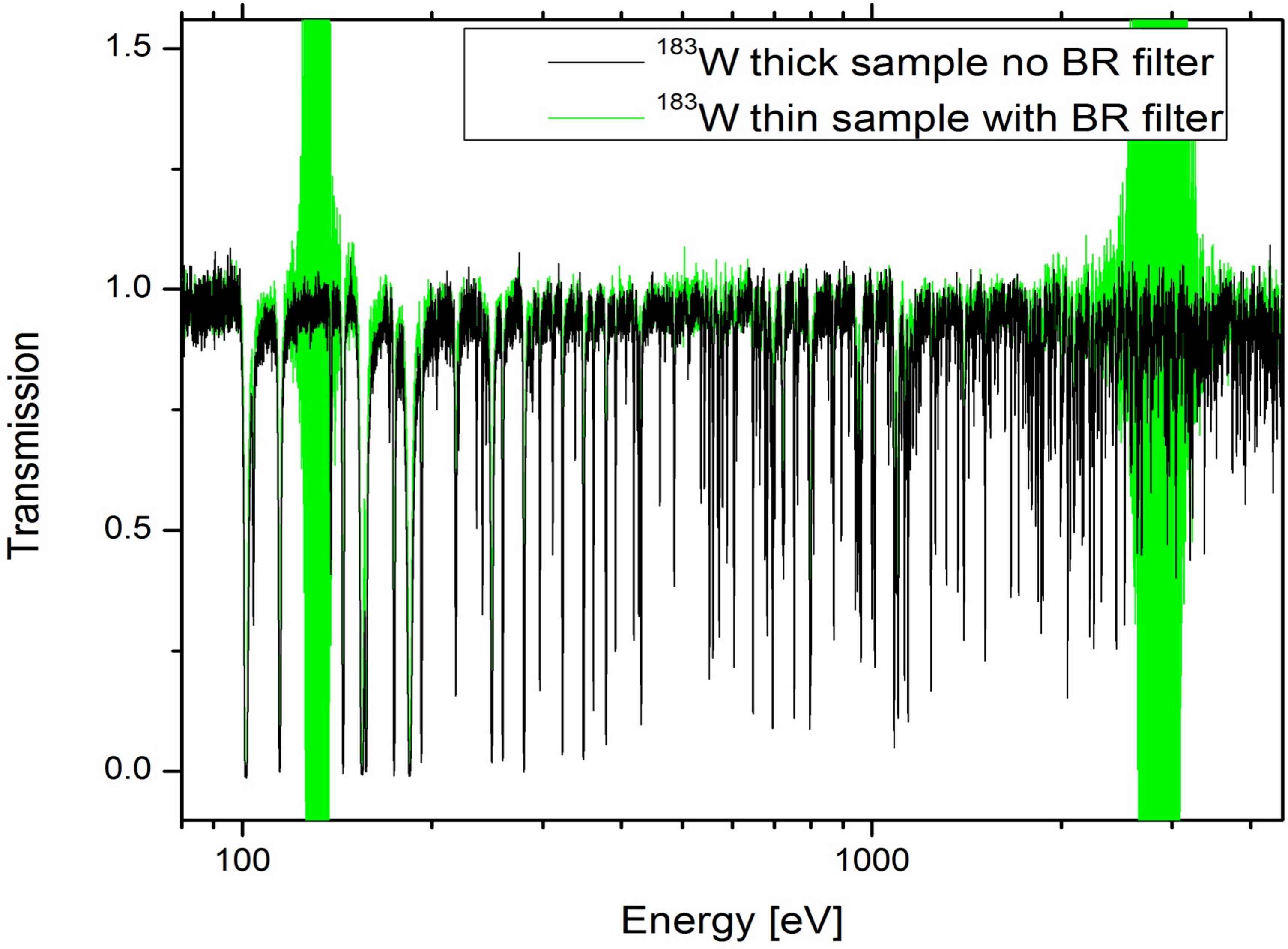
- **Metallic samples are preferred over oxide samples. Oxide is usually the inventory form of the provider**
  - The oxide produces unwanted background in (n,γ) experiments due to scattering of neutrons from oxygen
  - Oxide are hygroscopic, need to be pressed into a self-supporting disk and need to be encapsulated (additional background from canning)
- **Old metallic samples were found in the material storage at ORNL**
  - Metallic disks with 1 mm thickness and 70 mm diameter
  - Several disks for each isotope with enrichment of up to 95%, so different sample thickness could be achieved



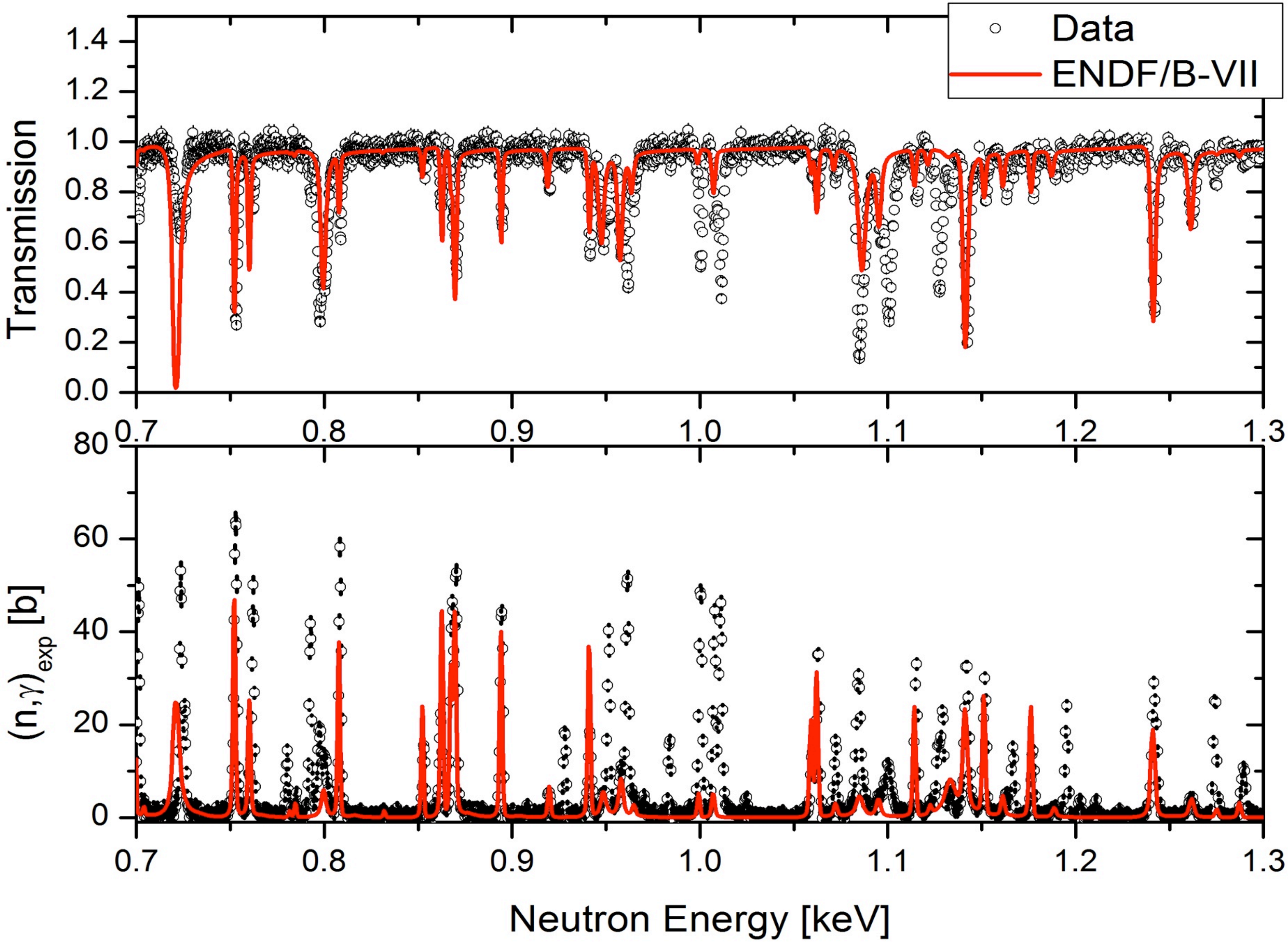
Transmission Data for 1 mm ^{184}W Compared to ENDF/B-VII: Terra Incognita



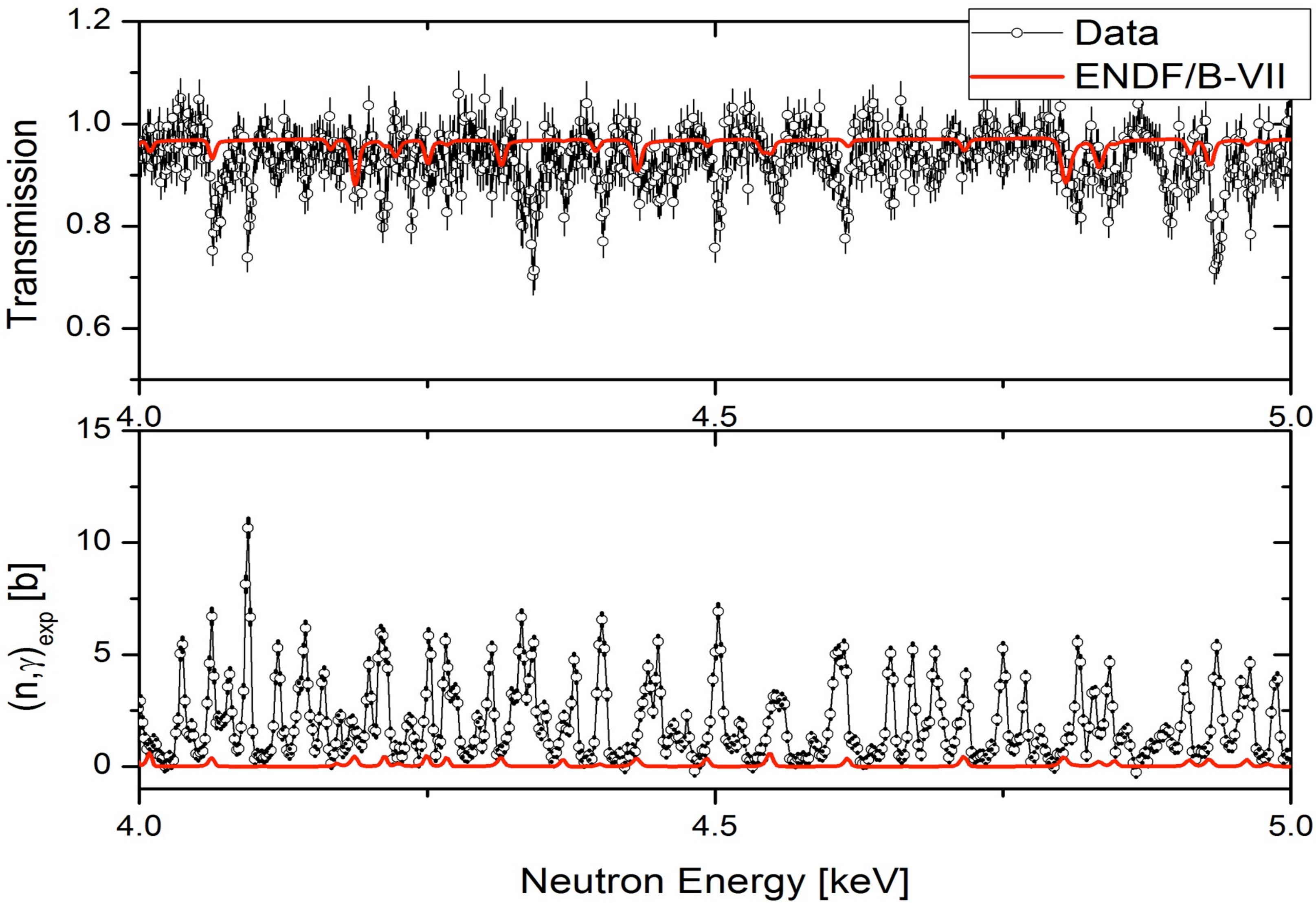
^{183}W Comparison thin thick sample



^{183}W Comparison with ENDF/B-VII



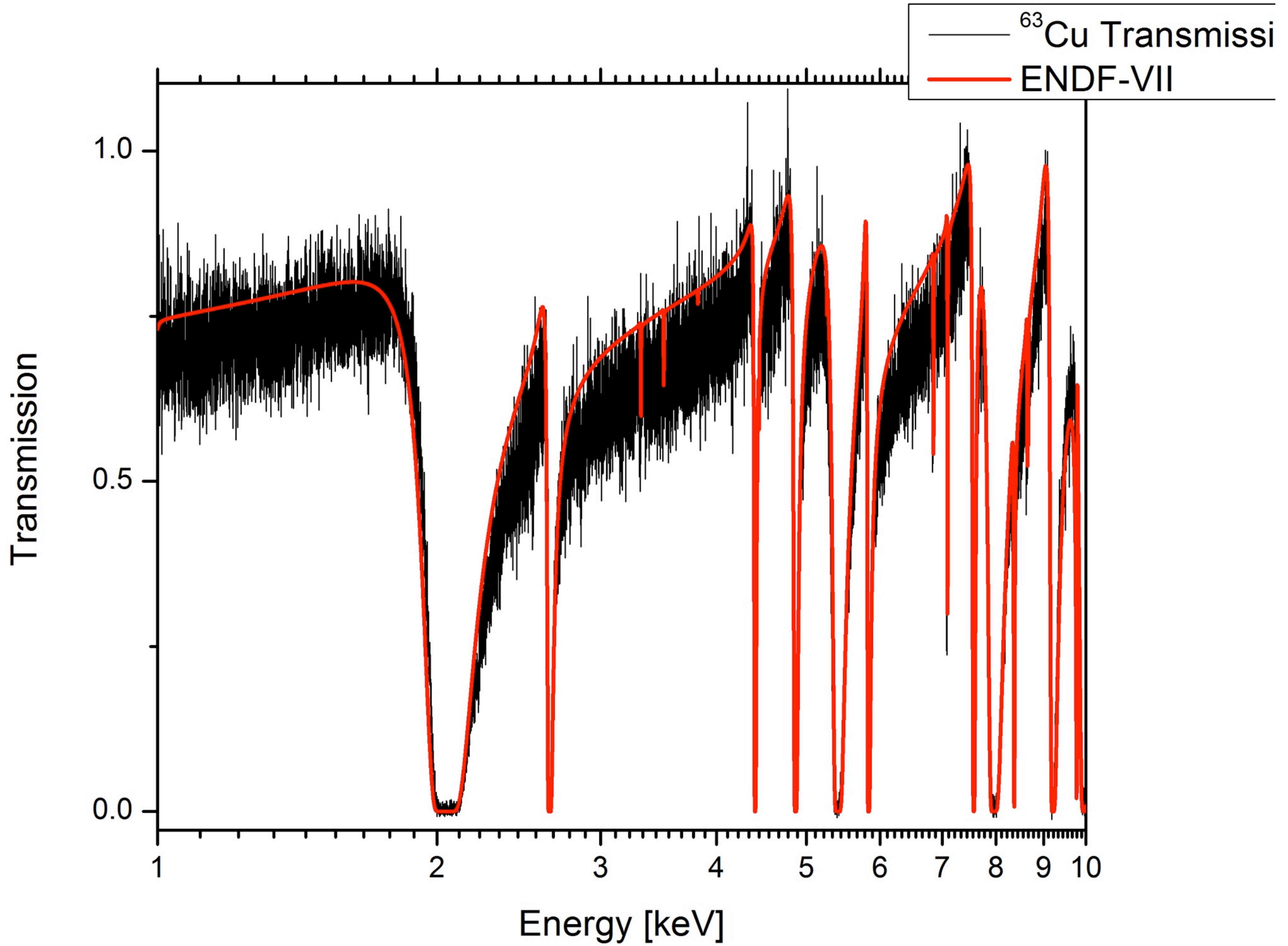
^{183}W Comparison with ENDF/B-VII at High Energies



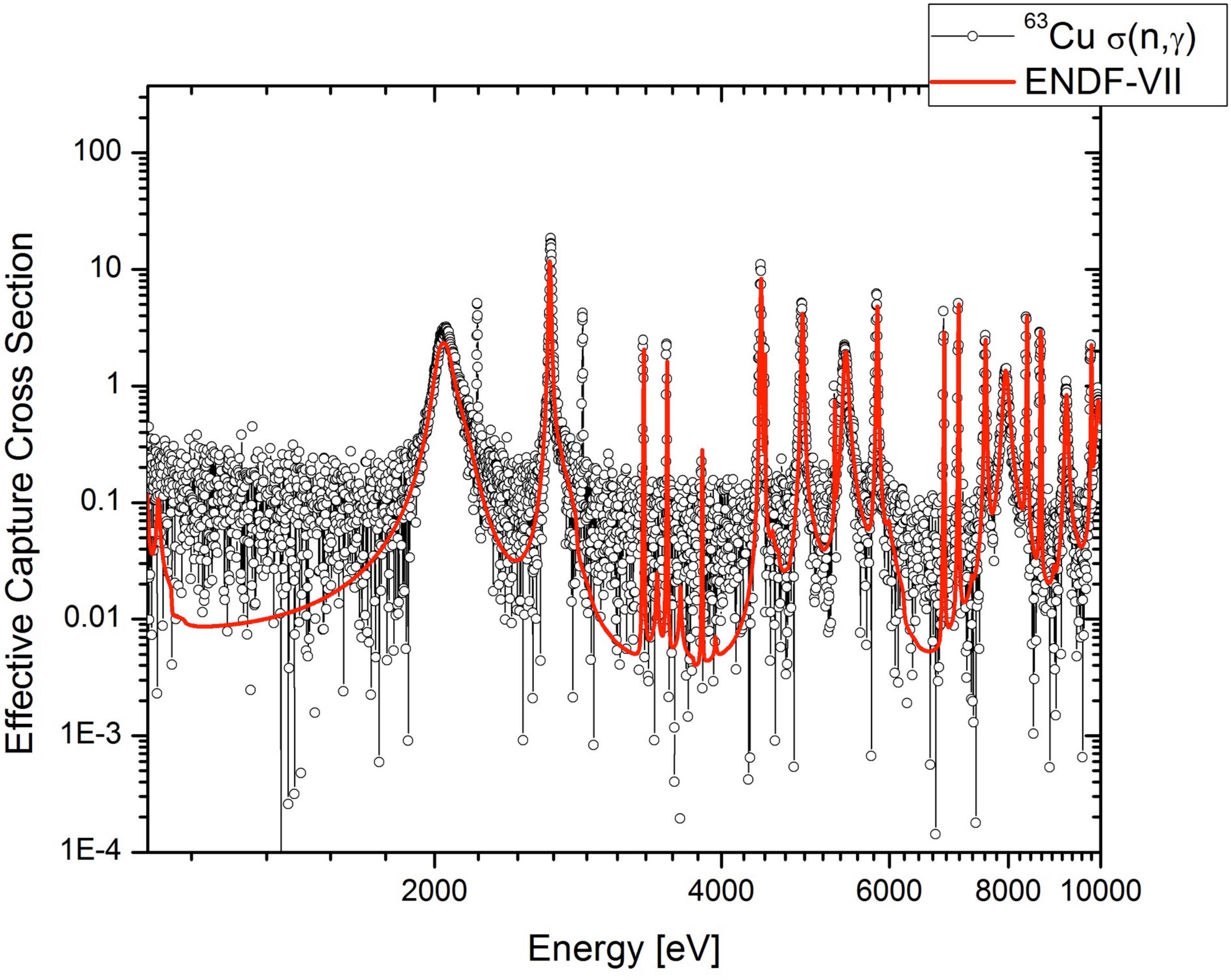
ORNL Measurement ^{63}Cu and ^{65}Cu

- **Use of metallic Cu samples, >99% isotopic enrichments; 8 cm diameter disks with 1 mm thickness**
- **Finalized neutron capture measurements for ^{63,65}Cu at GELINA using set up at FP14, 60-m station**
- **Performed measurements with ^{235}U fission chamber to determine flux at high energies**
- **Include old ORELA transmission data in evaluation**

- **Observation: Resonances are missing in ENDF file, even though reported in literature.**

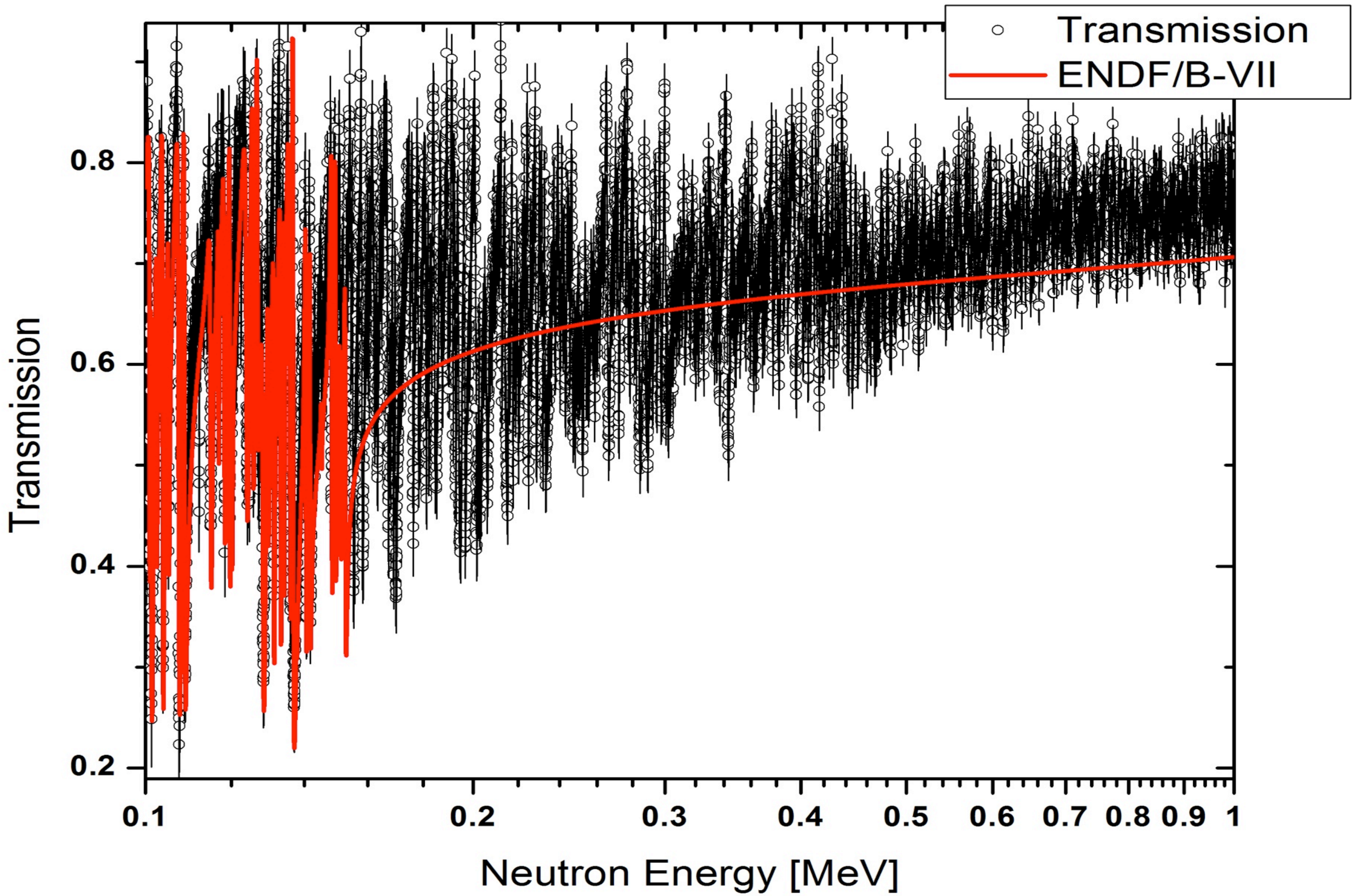


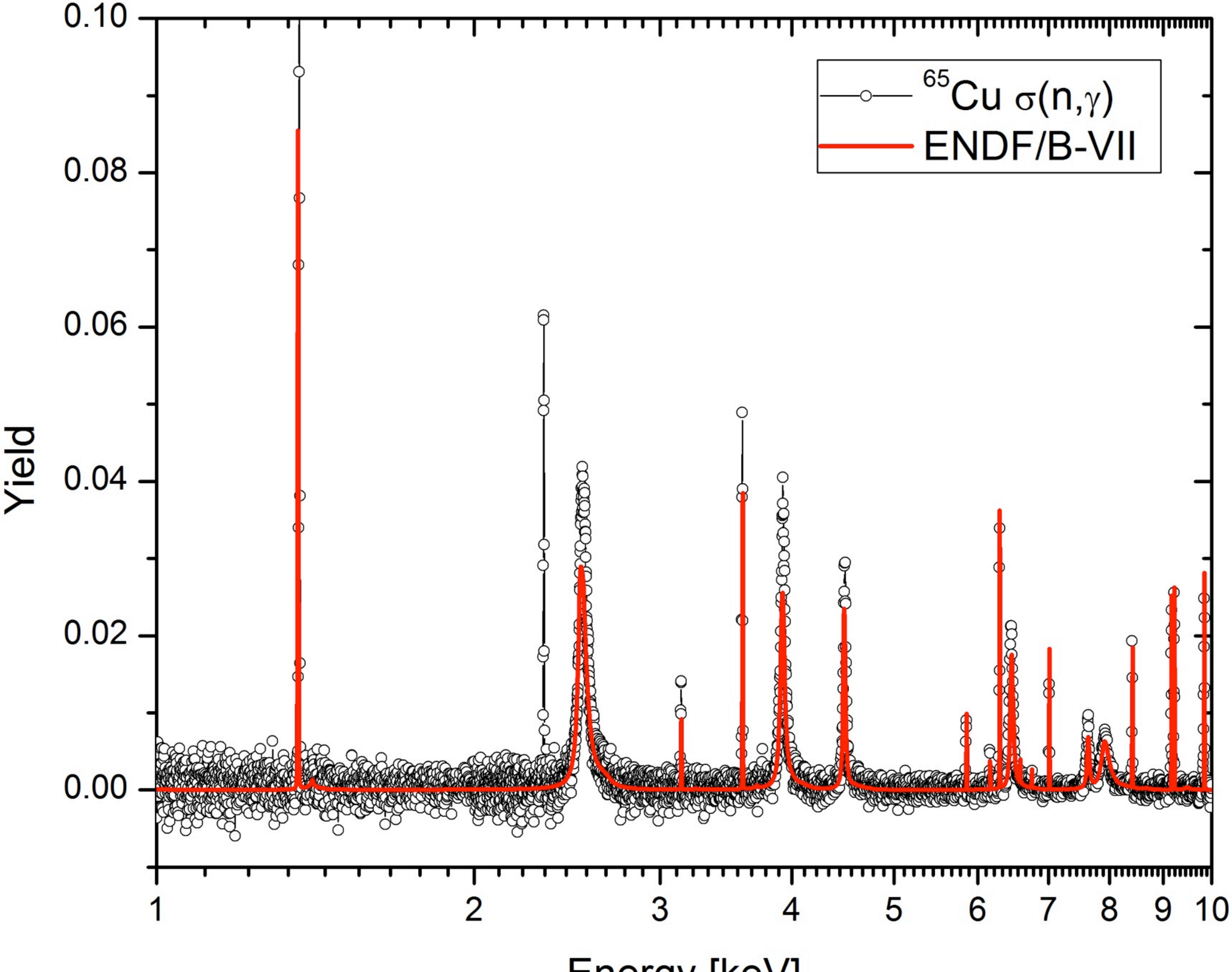
^{63}Cu Transmissi
ENDF-VII
Transmission
1.0
0.5
0.0
Energy [keV]
1
2
3
4
5
6
7
8
9
10



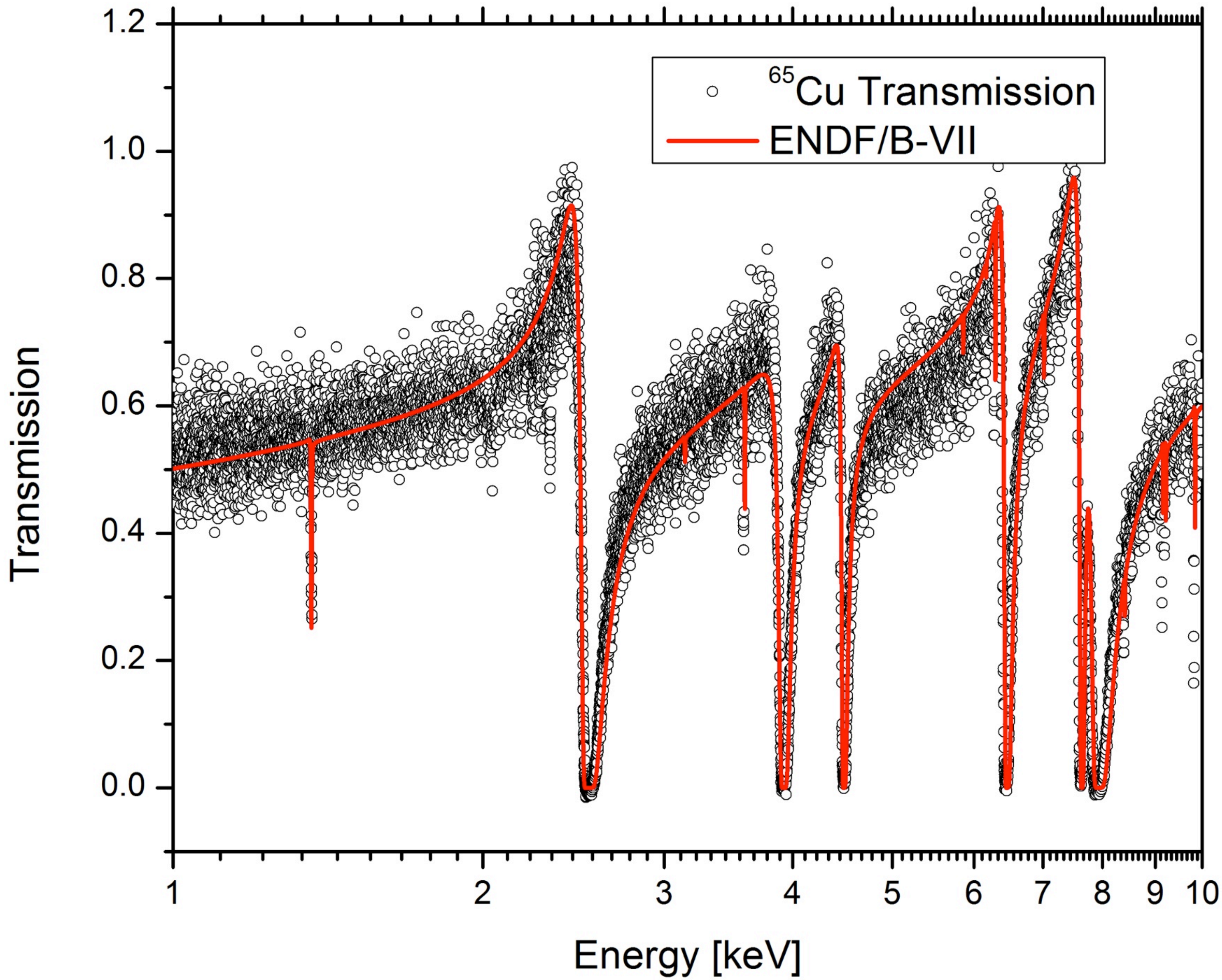
^{63}Cu σ(n,γ)
ENDF-VII
Effective Capture Cross Section
100
10
1
0.1
0.01
1E-3
1E-4
2000
4000
6000
8000
10000
Energy [eV]

^{63}Cu: no resonance data in ENDF at high energies





0.10
0.08
0.06
0.04
0.02
0.00
Yield
1
2
3
4
5
6
7
8
9
10
Energy [keV]
65Cu σ(n,γ)
ENDF/B-VII



65Cu Transmission
ENDF/B-VII
Transmission
Energy [keV]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10

ORNL Measurement Activities for Calcium

- Measurements of Ca using metallic samples
- The samples are in Al canning due to reactivity with air
- Transmission experiments with different sample thickness available using FP4, 50 m
- Neutron capture using detector system at FP14, 60 m
- Capture Data reduced to cross section

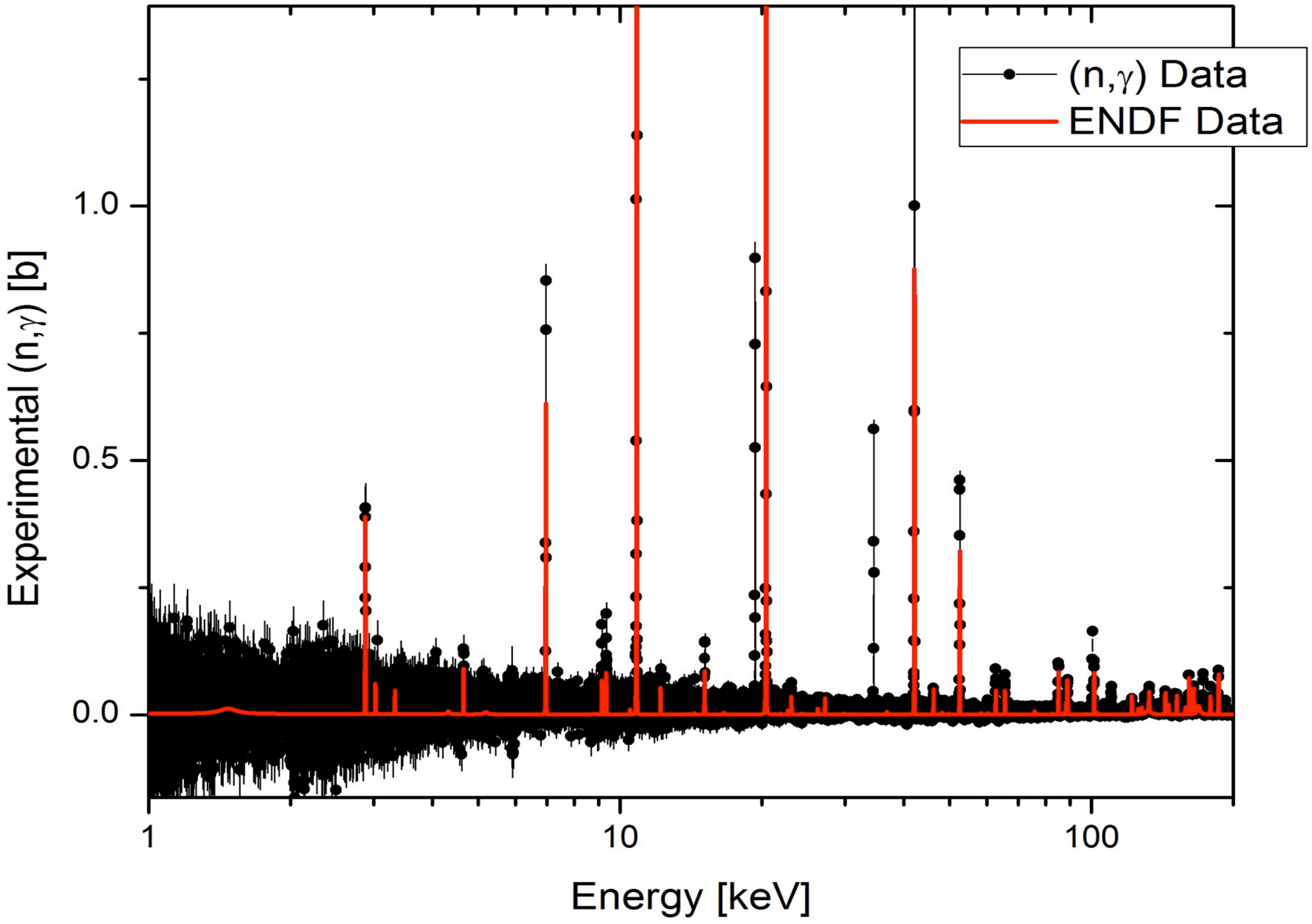
- Observation: Resonances are missing in ENDF file, even though reported in literature.

Ca Samples


Mitutoyo
ABSOLUTE
60.00 mm
ON / OFF
ZERO / ABS


Mitutoyo
10.04 mm
CARVER

Natural Ca (n,γ) compared to ENDF

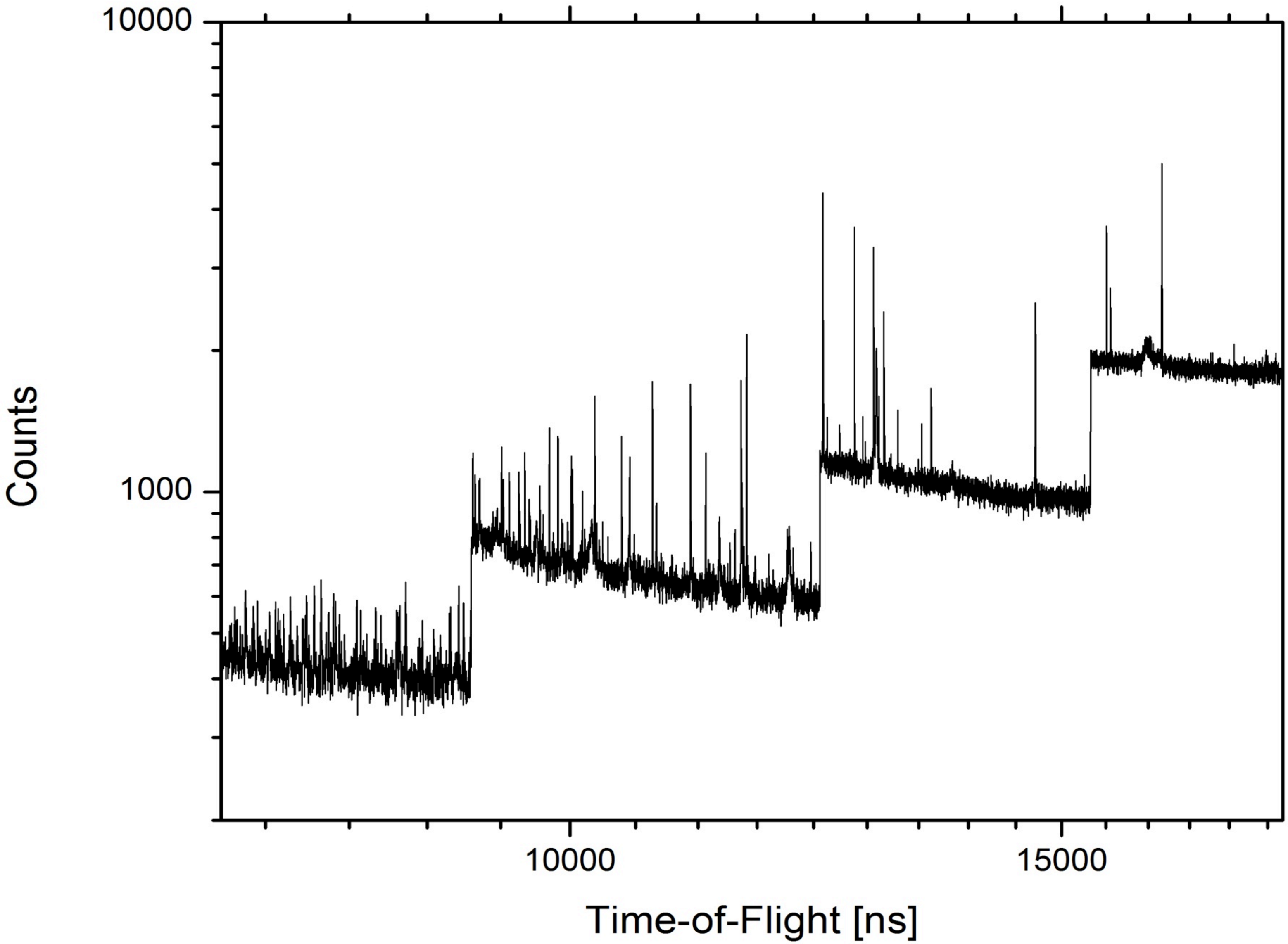


ORNL Measurement Activities for Cerium

- Measurements of Ce using natural metallic samples
- The samples are in Al canning due to reactivity with air
- Transmission experiments with different sample thickness are scheduled using FP4, 50 m
- Neutron capture using detector system at FP14, 60 m
- Capture Data experiments started

Cerium Samples

Natural Ce (n,γ)



Status of Experiments at Geel

	W	Cu	Ca	Ce
Sample	metallic disks 182,183,184,186	metallic disks 63 and 65	metallic disks nat Ca	Metallic disks Nat Ce, 142
Experiments GELINA	60m, 30m (n,γ) transmission	60m (n,γ)	60m (n,γ) transmission	60m (n,γ) started
Data Sorting	finished 60m + transmission	finished 60m high E need to be finalized	finished 60m Transmission under way	
Reduced to Cross section	X-section, transmission	X-section	X-section	
Data Testing	Data ready for evaluation	Data ready for evaluation	Under way	
Analysis and Evaluation	Started	Started		

People Involved in the Experiments

- Christos Lampoudis, IRMM
- Peter Schillebeeckx, IRMM
- Stefan Kopecky, IRMM
- Peter Siegler, IRMM
- Ruud Wynats, IRMM
- Clint Ausmus, ORNL