ORNL neutron cross section measurements for the US Nuclear Criticality Safety Program

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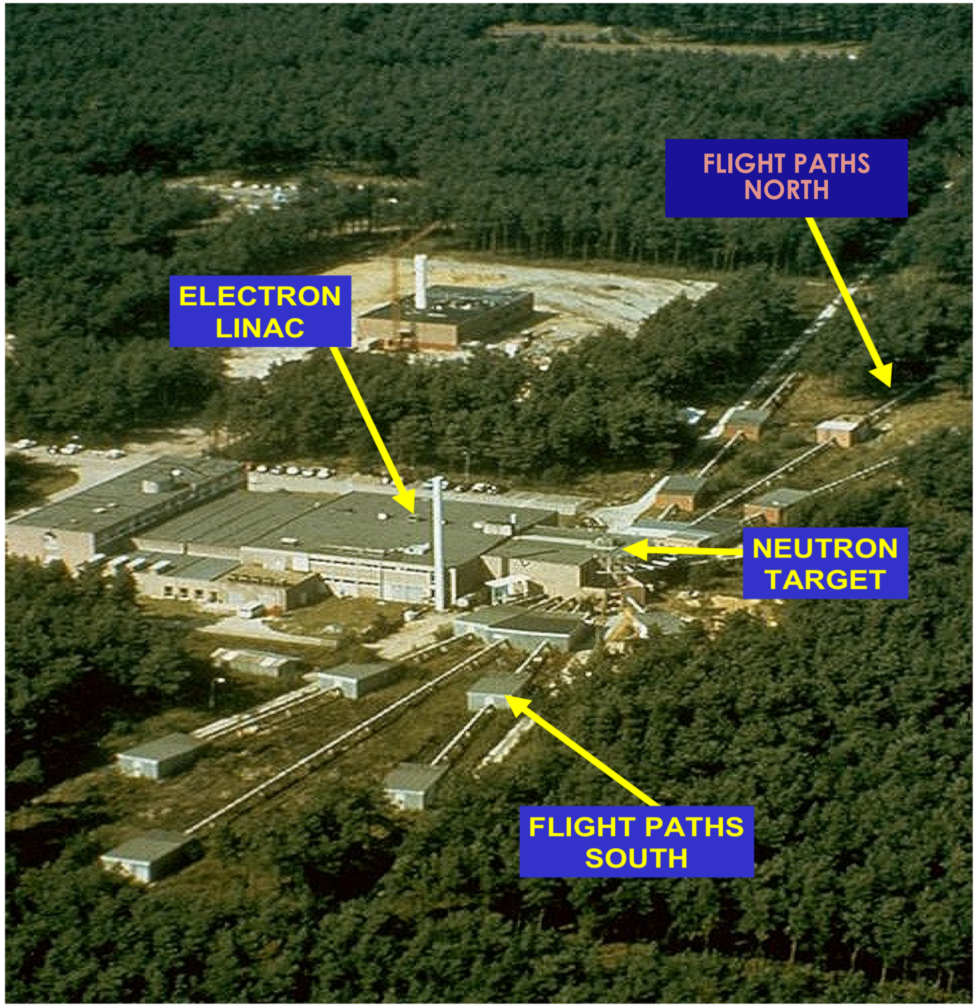
Nuclear Data Measurements & Evaluation Work for NCSP

- **Objective:** Provide measured and evaluated thermal, resonance, unresolved resonance, and fast 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 evaluations produced from cross section measurements and analyses.
- Measurement work effort focused on NCSP priorities by NCSP Nuclear Data Advisory Group (NDAG)
- NCSP 5-year plan provides a listing of Nuclear Data measurement and evaluation priorities for the program

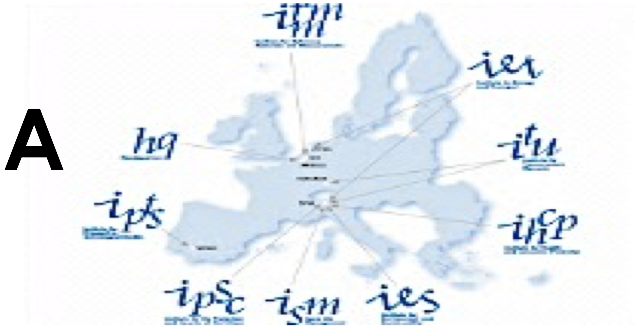
Appendix B
Nuclear Data Priorities, Basis Statements, and Milestones

Nuclear Data Measurements							
Materials	Pre-FY2019	FY2019	FY2020	FY2021	FY2022	FY2023	Post-FY2023
Cerium (^{142}Ce)							
Basis	Neutron transmission and capture of ^{142}Ce in the resonance range. Cerium is an element that is predominately ^{140}Ce (88.450 a/o) and ^{142}Ce (11.114 a/o) and can be found in chemical processing streams because it is commercially used as a catalyst or additive for chemical applications (e.g., glass polishing powder). As a result, cerium appears as an admixed material in process streams. ^{142}Ce is also a stable fission product. The primary interest for cerium cross sections is for poison credit in NCS analyses. The need for improved cerium cross sections has been specifically identified for the Hanford Plutonium Finishing Plant and other similar operations. Isotopically enriched sample required.						
Chlorine (^{35}Cl)							
Basis	Measurement of the ^{35}Cl (n,p) cross section in the resonance range. Chlorine is present in fuel cycle facilities in Pu solutions, electrorefining processes, chloride salts, and as brine/drift in some repository environments. Improved ^{35}Cl (n,p) cross sections needed for poison credit in these in these environments. A need for improved ^{35}Cl cross sections has been specifically identified at LANL and Y-12.						
Lanthanum (^{nat}La)							
Basis	Measurement of neutron transmission and yield of ^{nat}La in the resonance range. Lanthanum is an element that is predominately ^{139}La (99.910 a/o) and a stable fission product. The primary NCS interest is for fission product credit. In the latest edition of the ENDF nuclear data library, the resonance analysis is based on parameters obtain with an experimental set up which is known to have certain problems. Currently, ENDF/B-VIII evaluations for La do not have adequate covariance data based on experimental data. Improved covariance data are needed to support sensitivity/uncertainty analyses for fission product credit applications. Natural samples can be used.						
Molybdenum (^{95}Mo)							
Basis	Measurement of neutron capture in ^{95}Mo in resonance range, URR. Neutron transmission measurements previously completed at RPI. ^{95}Mo is a stable fission product and the primary absorbing nuclide in natural Molybdenum. Molybdenum isotopes are currently encountered in irradiated fuel as fission products or in molybdenum alloys in research reactors and space reactors. The current primary interest in NCS is for fission product credit for transport casks, irradiated fuel storage, and reprocessing plants (UPu-MoZr deposits in French reprocessing plant equipment for example). Needs identified by NR and IRSN for fission product credit and Y-12 for U-Mo applications (lower priority). Isotopically enriched sample required.						
Neptunium (^{237}Np)							
Basis	Measurement of ^{237}Np fission cross section in fast energy range. ^{237}Np is an actinide of interest in nuclear criticality safety for applications at ORNL and other sites. Applications include ^{238}Pu production w/ HFIR at ORNL (low NCSP priority) and fast burst reactor for LANL. Nuclear data improvements will improve critical mass estimates. On the HPRL there is a request for fission cross section in the energy range from 200 keV to 20 MeV. The application list was fast systems, and the required accuracy is 1.5-4%. This requirement comes from the desire to improve the current low accuracy in the covariance matrix (6-8%).						
Tantalum (^{181}Ta)							



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

GELINA



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

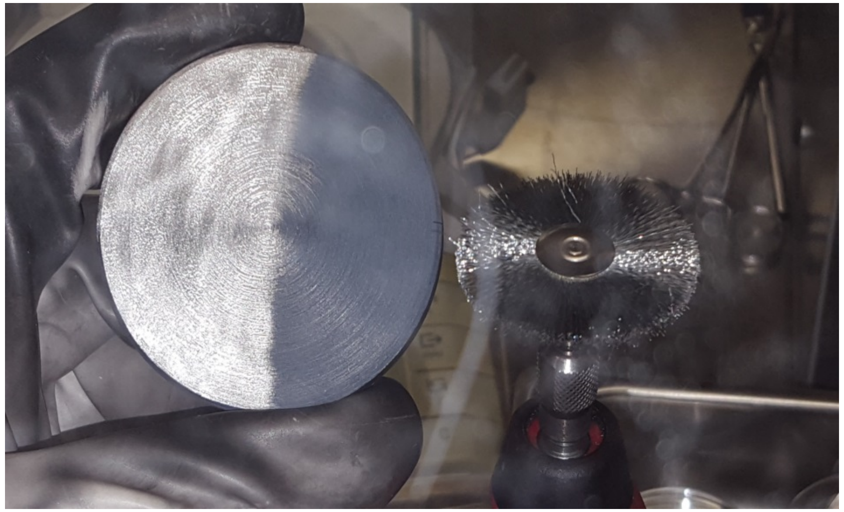
  (10 meV < E_n < 20 MeV)
- Multi-user facility with 10 flight paths (10–400 m)
- The measurement stations have special equipment to perform the following:
  - Total cross section measurements
  - Partial cross section measurements

ORNL measurement activities for lanthanum

- Natural La is 99.91% ^{139}La and 0.09% ^{138}La
- Measurements use metallic samples of natural La with different thickness
- Transmission experiments with different samples are performed at FP4 50 m station using a Li-glass detector
- Neutron capture experiments are performed at FP14 60 m using C_6D_6 detectors
- Experiments are made with different background filter combinations
- Data are recorded in listmode for the detector and flux monitor
- Capture and transmission experiments have been finalized
- Data sorting has been started

Lanthanum sample preparation

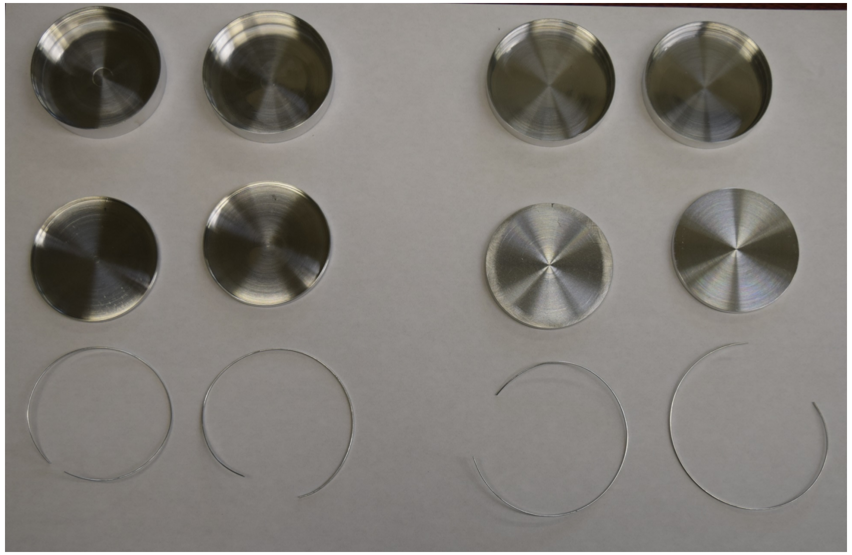
- La target delivered in oil
- Wiped free of mineral oil with ethanol and admitted into an inert atmosphere glove box
- Due to quick oxidations, samples are sealed in an Al-can
- Shown with half the original oxide removed by steel wire brush



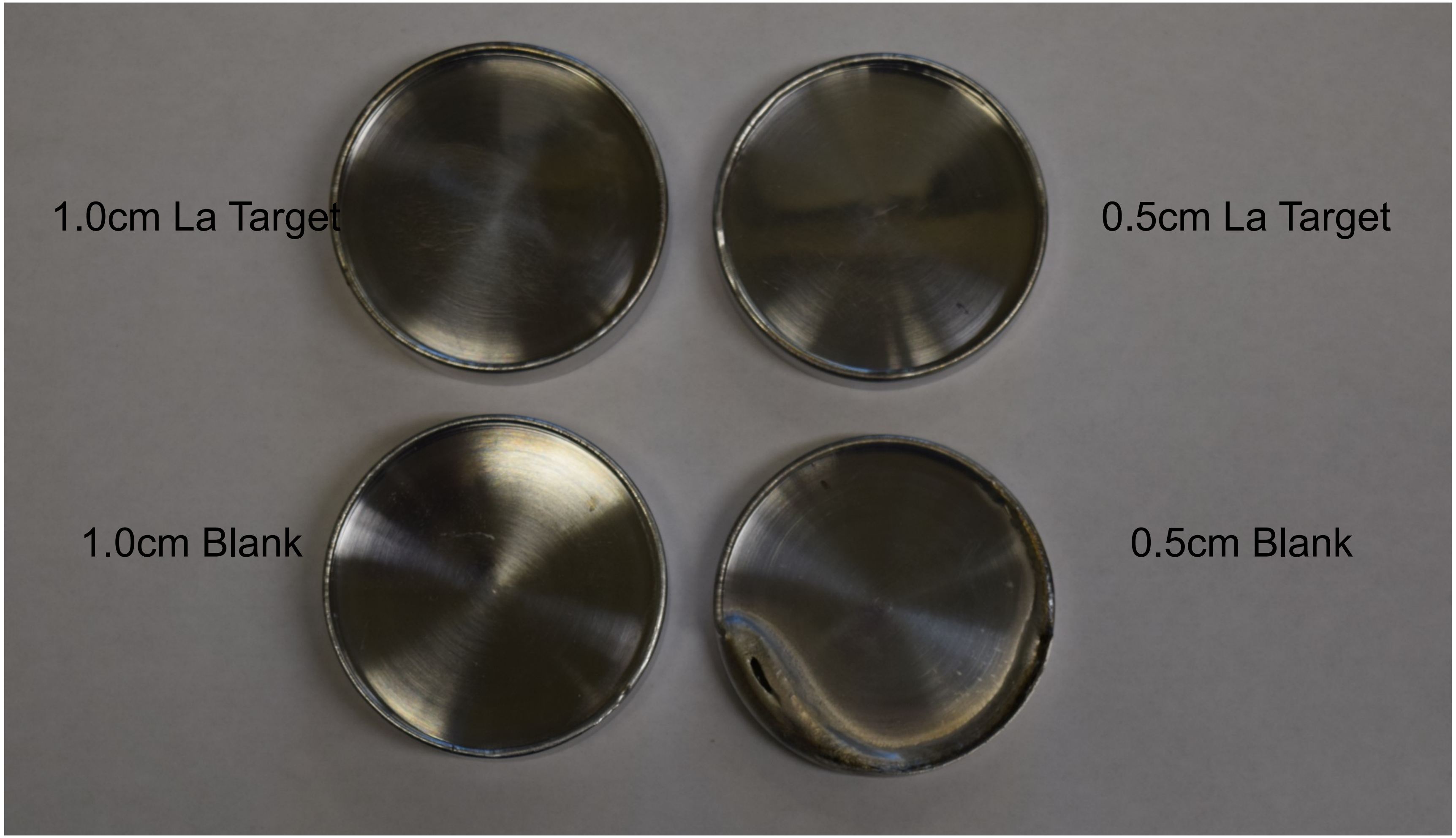
Al can for La sample

- Cans were machined from 6061 Al alloy and filler rod was swaged and rolled to fit the gap between can and lid

- Can is sealed via electron beam welding

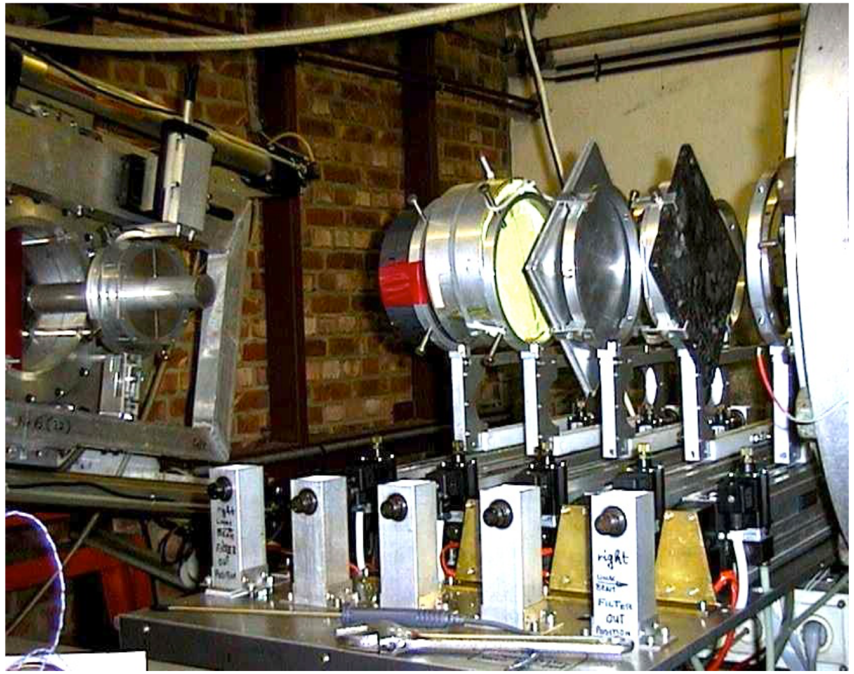


Finished La targets and blank samples



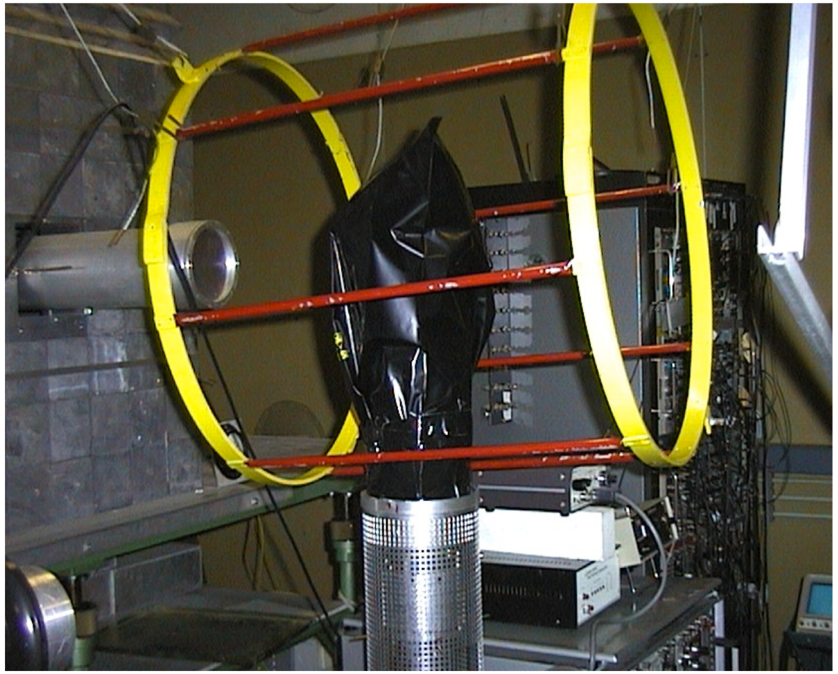
Total cross section/transmission measurements

Sample and background filters



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

Detector

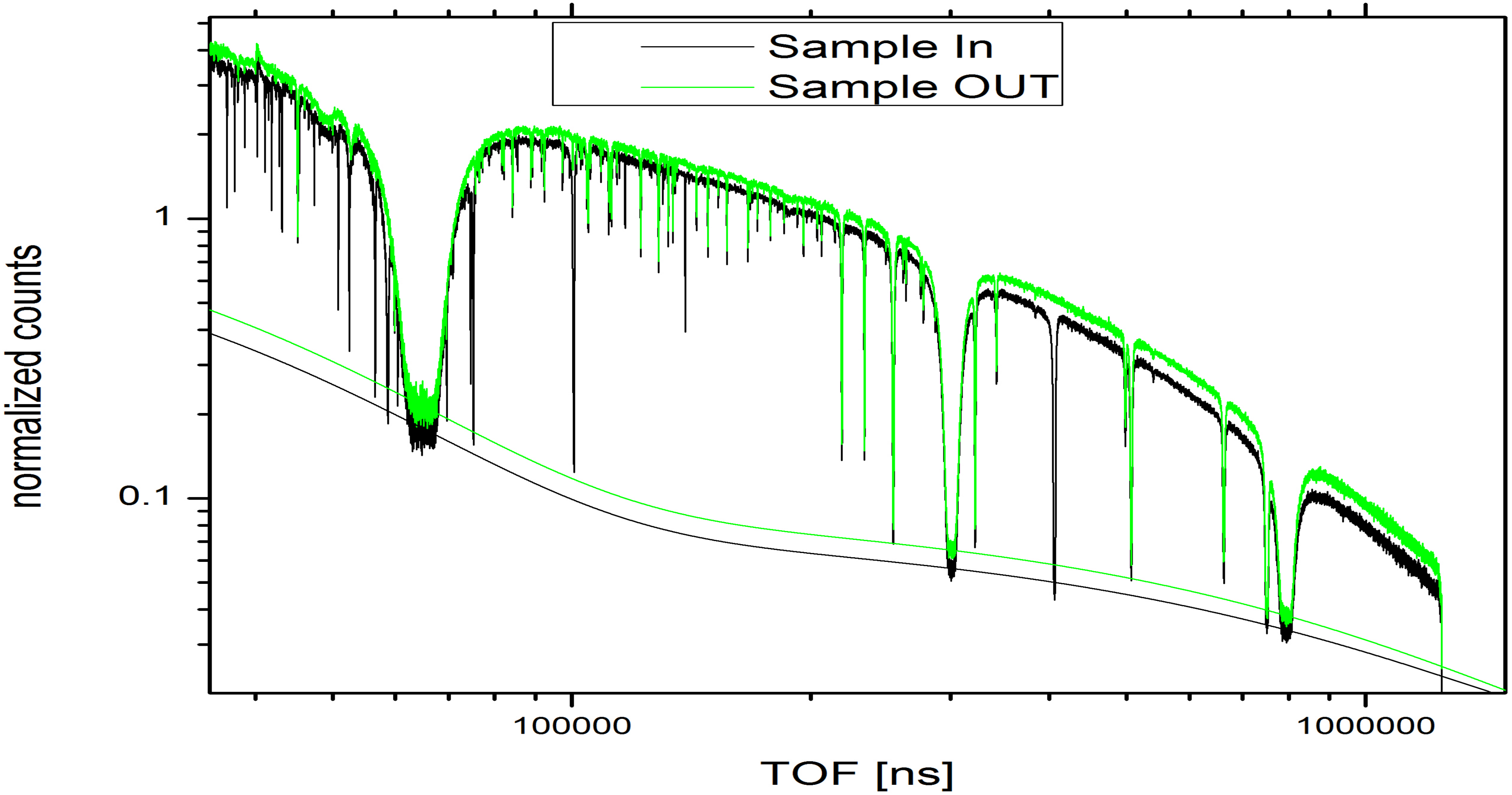


Low energy : $^{6}Li(n,t)\alpha$ Li-glass

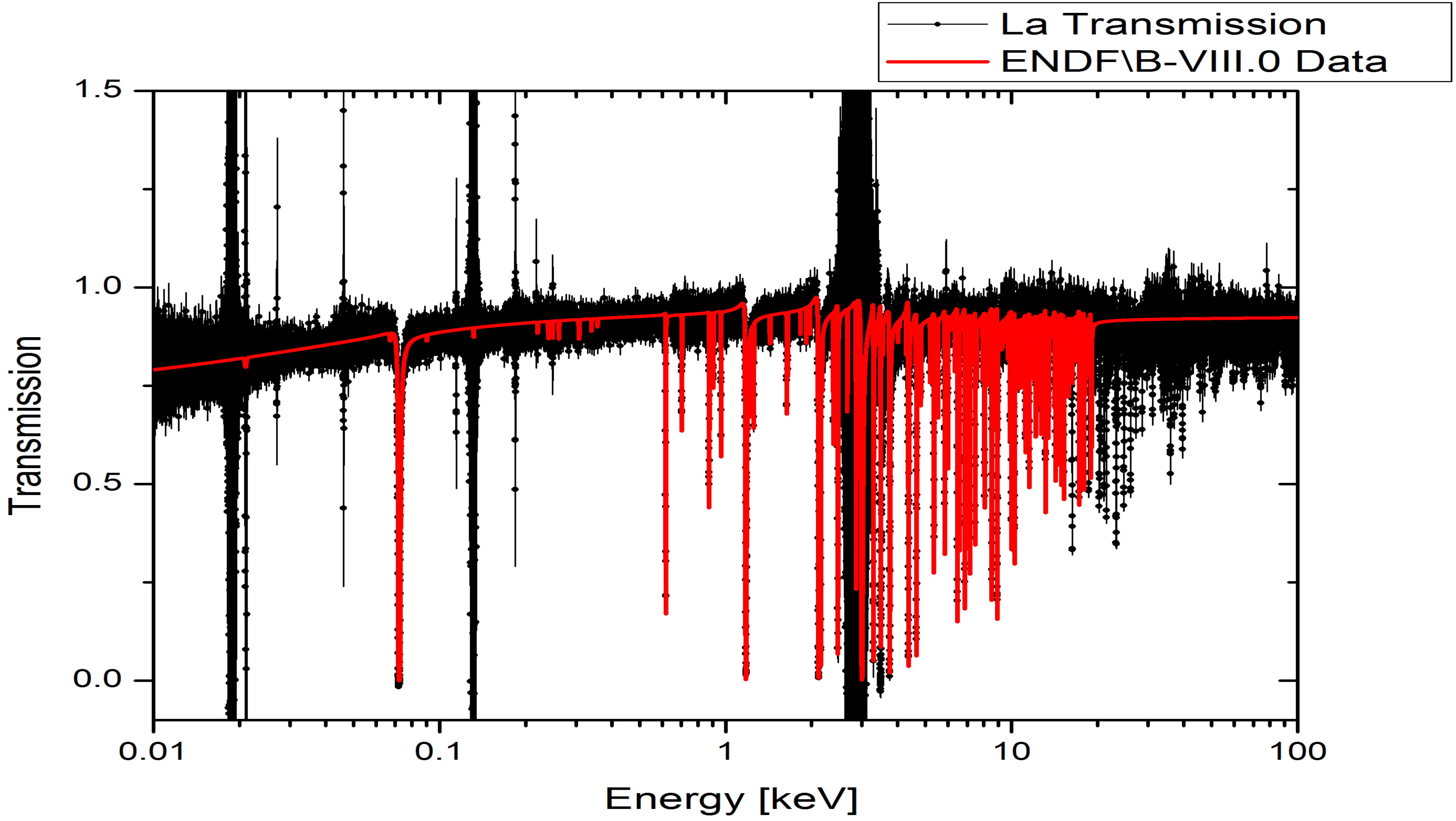
High energy : H(n,n)H Plastic scintillator

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

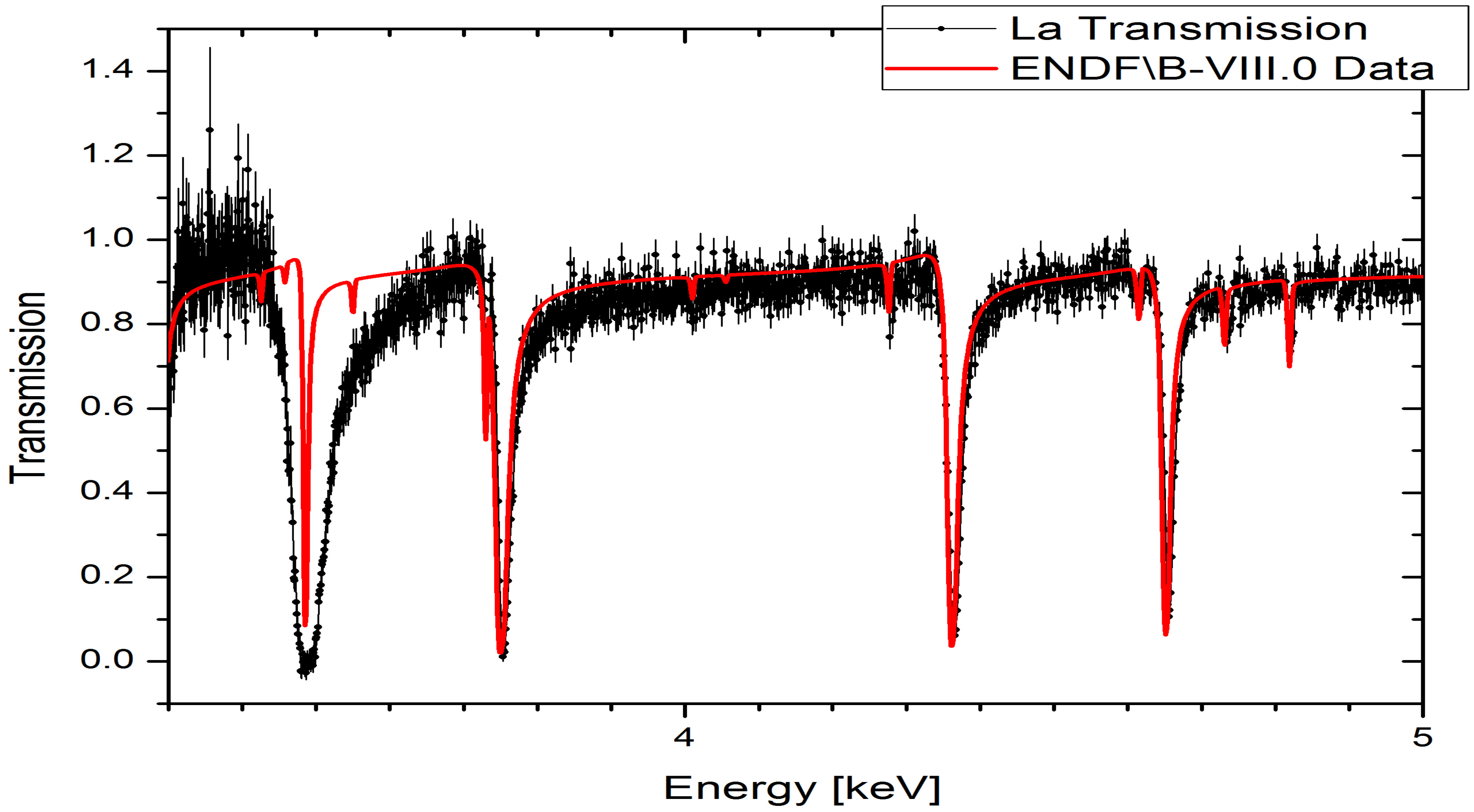
La transmission background correction with black filters



La Transmission above 19 keV no resonances in ENDF



La Transmission detailed view misassigned resonances



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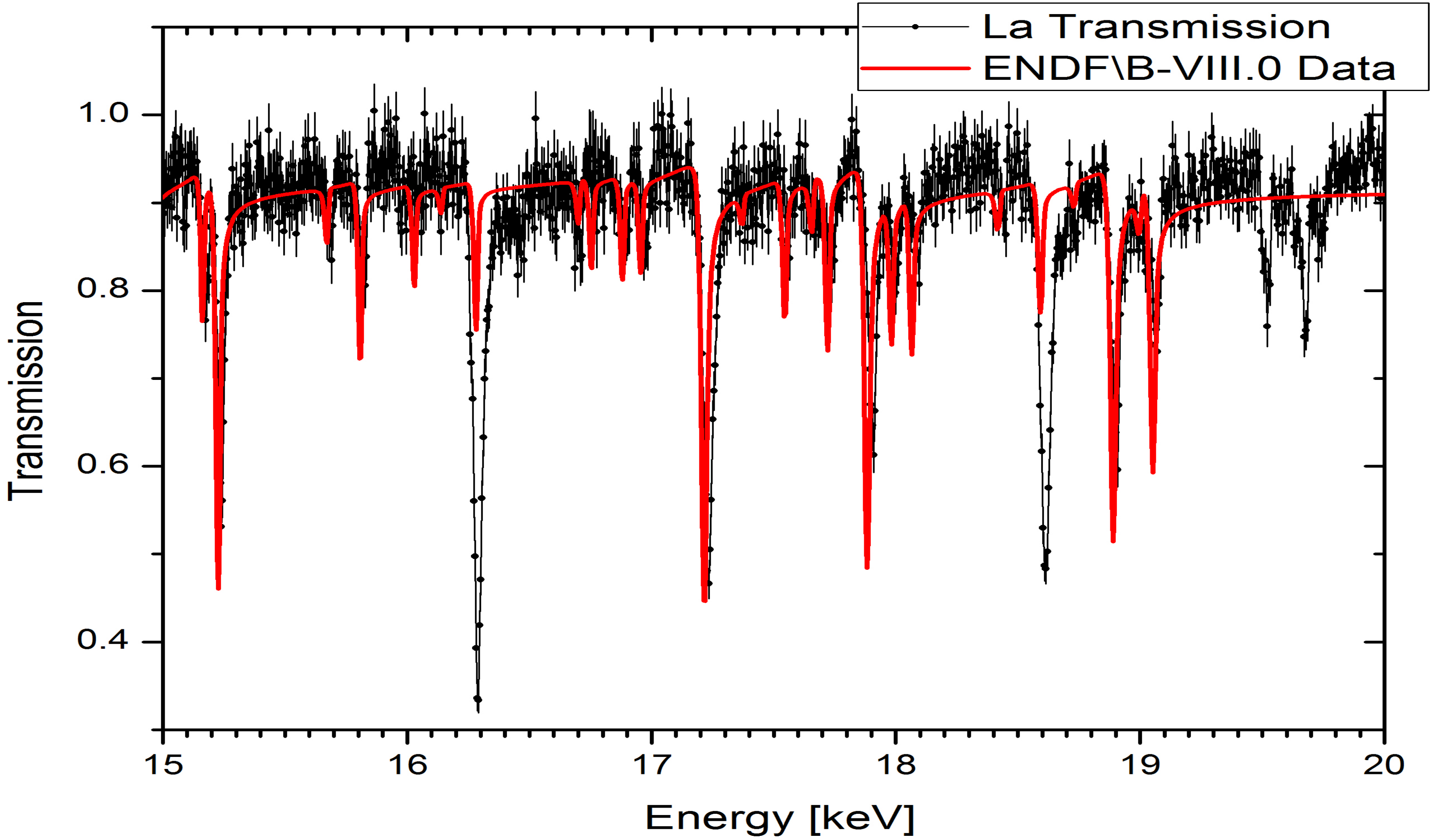
La Transmission detailed view misassigned resonances



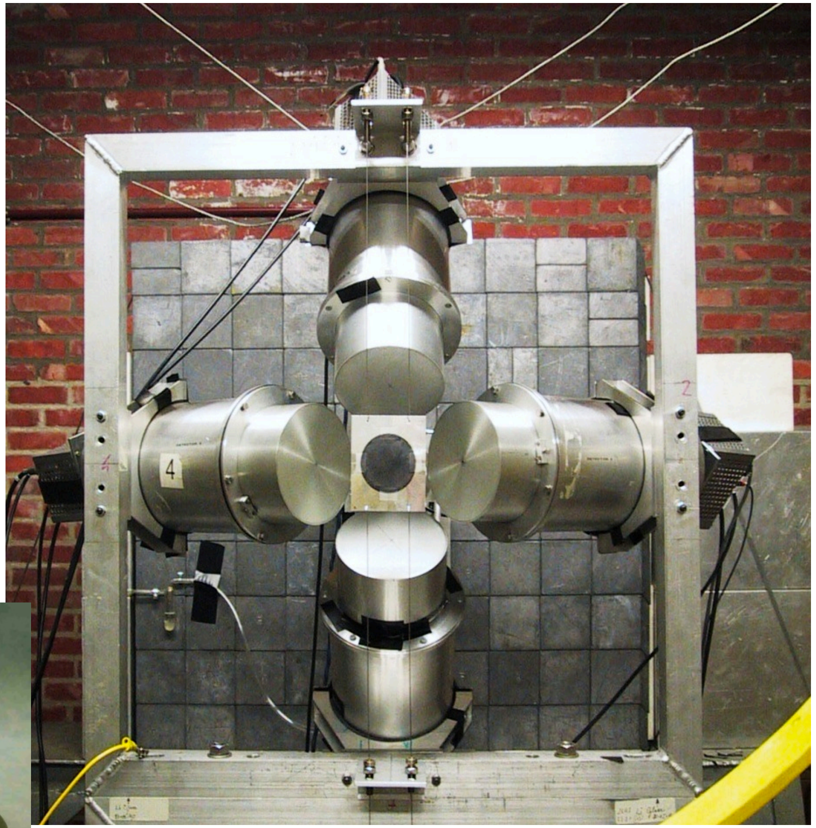
Capture cross section measurements at GELINA

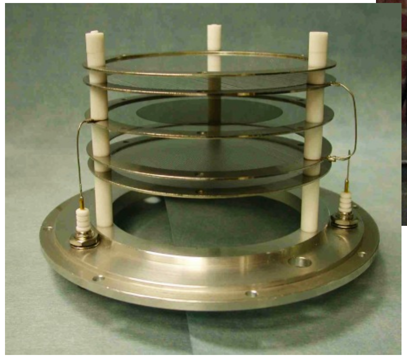
Total energy detection principle

- C_6D_6 liquid scintillators
  - 125°
  - Pulse height weighting technique
  - Weighting function from Monte Carlo simulations
- Flux measurements (IC)
  - $^{10}B(n,\alpha)$
  - $^{235}U(n,f)$

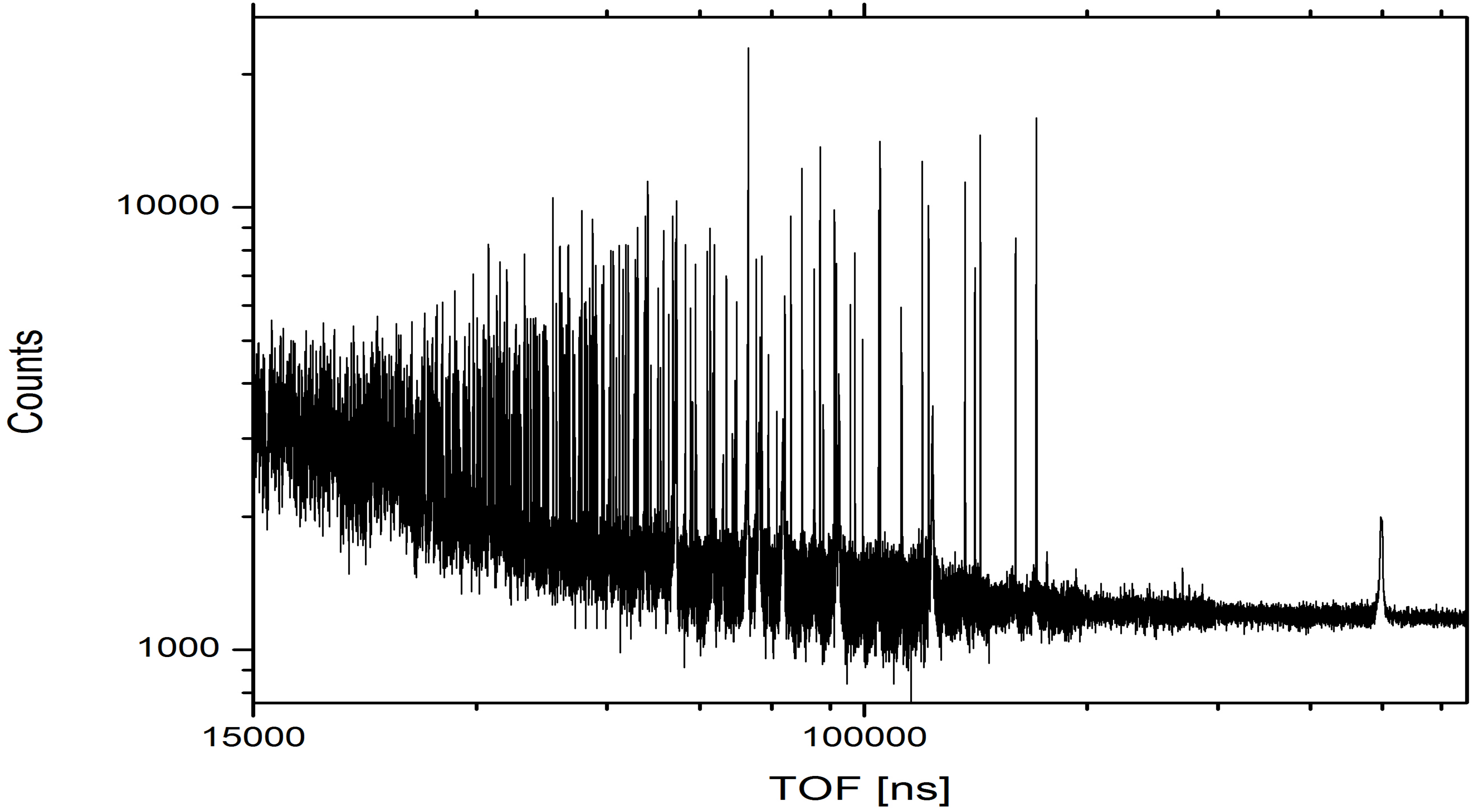
$$Y_{exp} = N\sigma_{\varphi} \frac{C_w - B_w}{C_{\varphi} - B_{\varphi}}$$

L = 10 m, 30 m, and 60 m

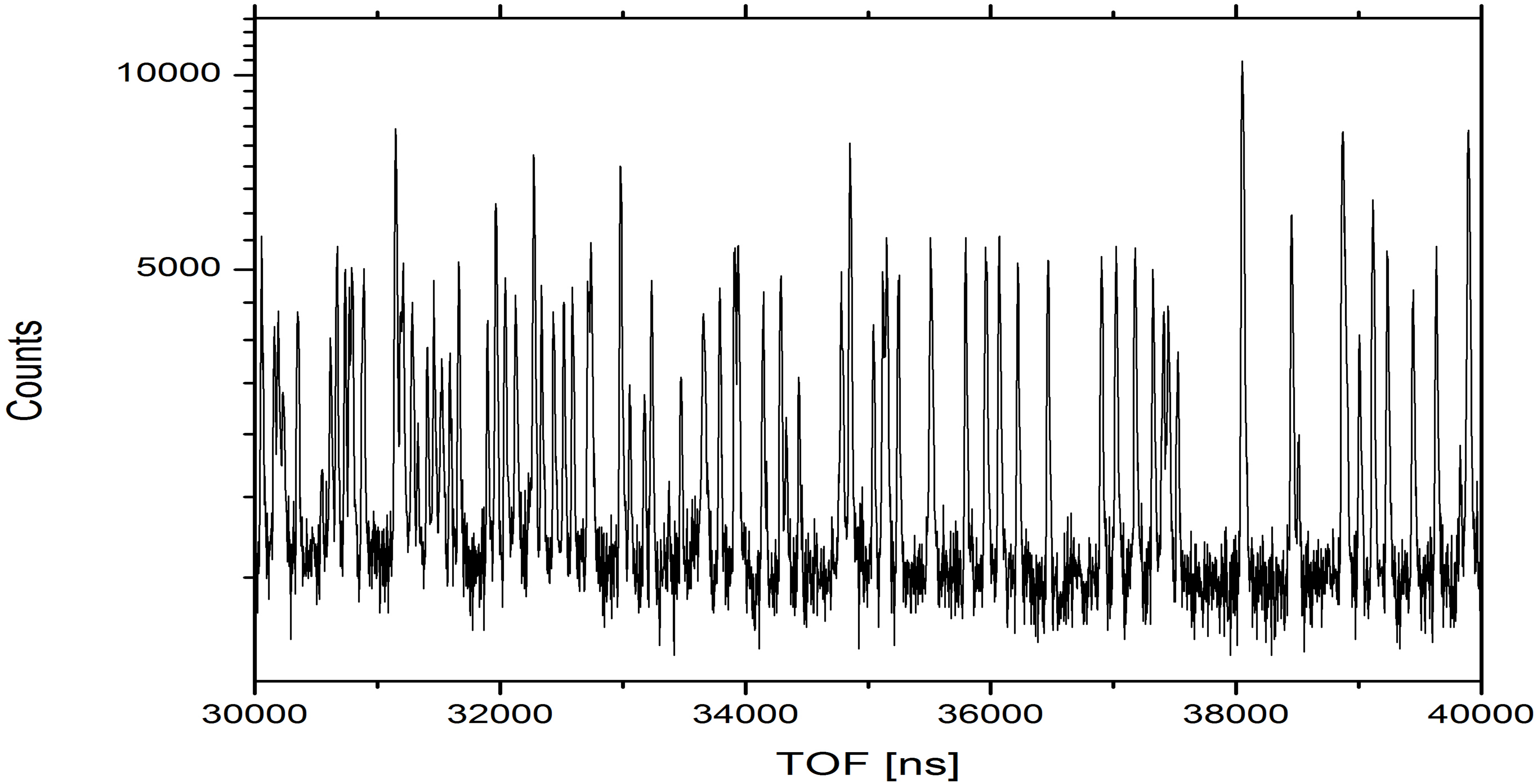




La capture 60m TOF spectrum



La capture 60m detail TOF spectrum



Status of NCSP experiments at EC-JRC

	W	Cu	Ca	Ce	V	Zr	La
Sample	metallic disks 182,183,184,186 2009–2011	metallic disks 63 and 65 2011–2012	metallic disks nat Ca 2013–2014	metallic disks Nat Ce, Ce-142 2014–2015 2018	metallic disks 2015–2016	Nat Zr metallic disks $^{90,91,92,94}Zr$ 2016-2017	Nat La metallic disks 2017-2018
Experiments GELINA	60m, 30m (n,γ) transmission	60m (n,γ)	60m (n,γ) transmission	Nat Ce 60m (n,γ) Nat Ce transmission ^{142}Ce sample problems Starting this Fall	60m (n,γ) transmission	Nat Zr 60m (n,γ) + transmission started $^{90,91,92,94}Zr$ sample problems	60m (n,γ) transmission
Data sorting	finished 60m + transmission	finished 60m	finished 60m transmission	finished for thin and thick sample	finished for thin and thick sample	finished for thin and thick natural sample	started
Reduced to cross section	X-section, transmission	X-section	X-section transmission 0.6, 1.0, 5 cm samples	2mm X-section 2mm transmission 10mm transmission	thin X-section 0.35 and 2mm transmission		Preliminary transmission
Data testing	Data ready for evaluation	Data ready for evaluation	Data ready for evaluation	In progress	In progress		
Analysis and evaluation	Finalized and submitted to NNDC	Finalized and submitted to NNDC	Finalized and submitted to NNDC	Started			

People Involved in the Experiments

- Peter Schillebeeckx, EC-JRC Geel
- Carlos Paradela, EC-JRC Geel
- Stefan Kopecky, EC-JRC Geel
- Peter Siegler, EC-JRC Geel
- Ruud Wynats, EC-JRC Geel
- Clint Ausmus, Mike Zack, ORNL

People Involved in the Evaluations

- Marco Pigni, ORNL
- Vladimir Sobes, ORNL