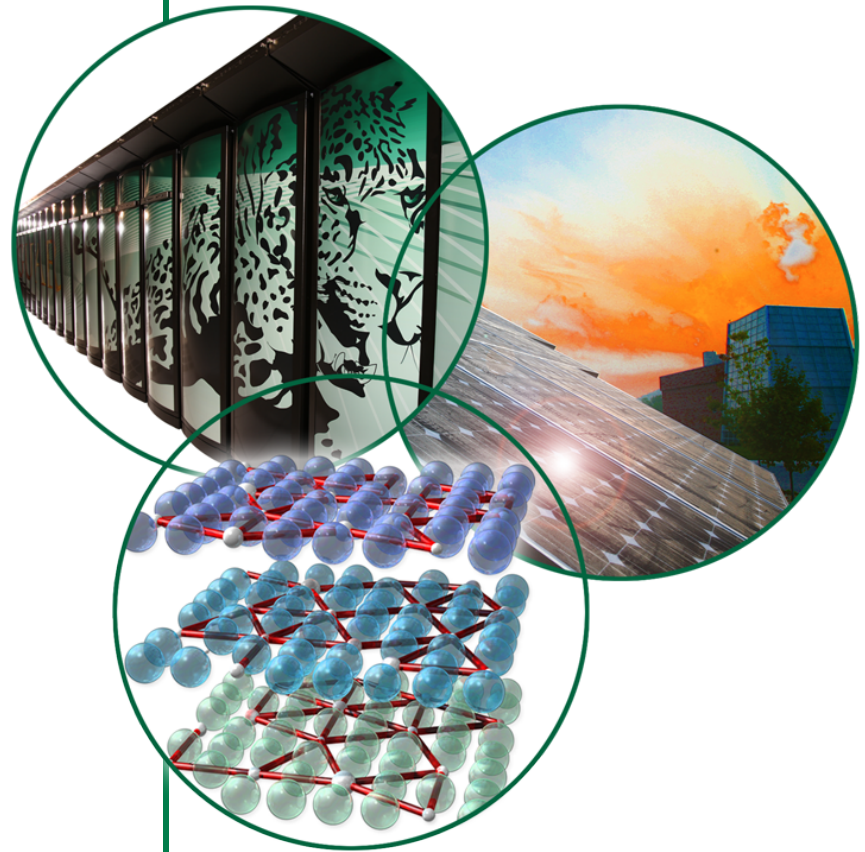


# ORNL Neutron Cross-Section Measurements Activities

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CSEWG meeting 2012



# Resonance Region Nuclear Data Work for NCSP

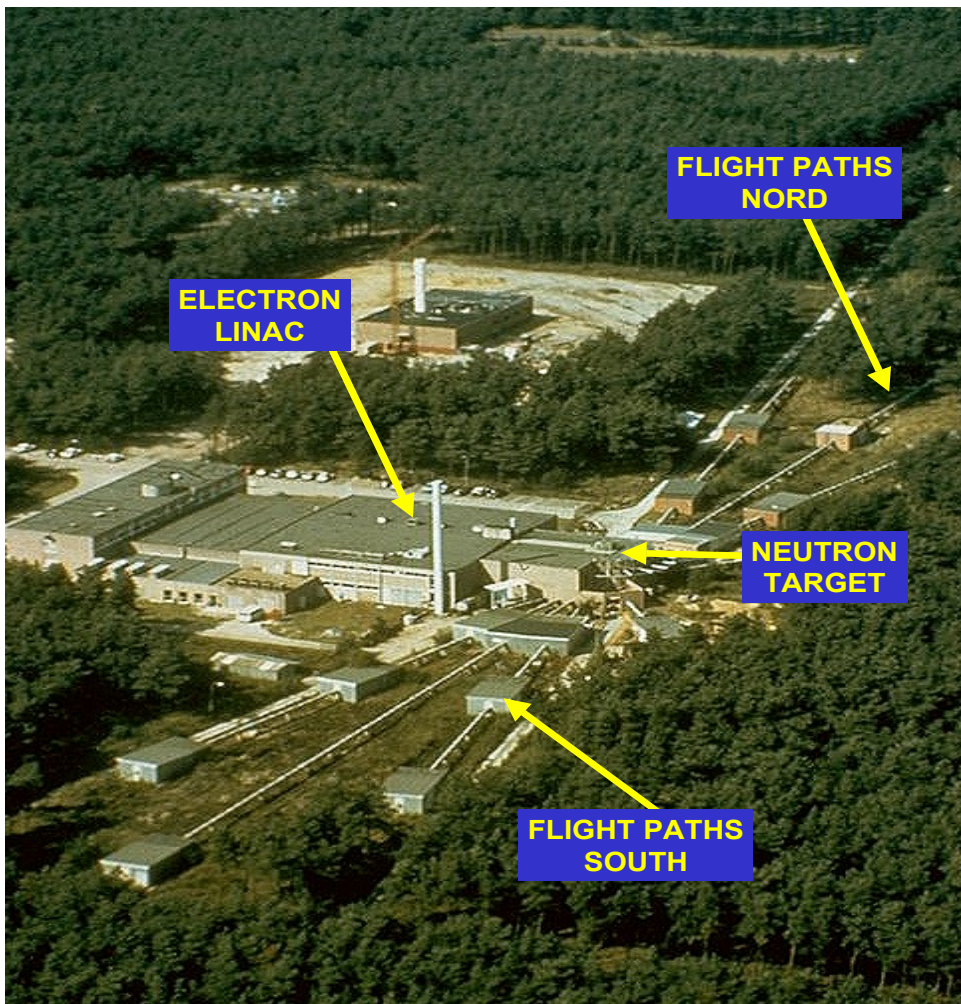
- **Objective:** Provide measured and evaluated resonance-region cross-section data to address the priority NCSP nuclear data needs
- **Vision:** Addresses multiple Nuclear Data 5- and 10-year goals and attributes identified in the NCSP Vision
- **Final product:** rigorous ENDF/B resonance evaluations 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)

Appendix B  
Nuclear Data

Priority Needs / Additional Needs		Thermal scattering (BeO, HF, D <sub>2</sub> O, SiO <sub>2</sub> , CH <sub>2</sub> , C <sub>2</sub> F <sub>6</sub> , C <sub>6</sub> O <sub>2</sub> H <sub>6</sub> , etc.), <sup>239</sup> Pu, Cr, <sup>237</sup> Np, Pb, W, <sup>55</sup> Mn, Ti, <sup>240</sup> Pu, Fe, <sup>58</sup> Ni, <sup>60</sup> Ni, <sup>63</sup> Cu, <sup>65</sup> Cu / <sup>233</sup> U, Th, Be, <sup>51</sup> V, Zr, F, K, Ca, Mo, Na, La									
Completed Evaluations (FY)		W (10), <sup>239</sup> Pu (09), <sup>58,60</sup> Ni (09), <sup>63,65</sup> Cu (09), <sup>55</sup> Mn (09), <sup>39,41</sup> K (09), <sup>19</sup> F (09)									
	Materials	Pre-FY2011	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	Post-FY2011
Measurements	Cerium (Ce)										
	Copper (Cu)										
	Dysprosium (Dy)										
	Gadolinium (Gd)										
	Strontium (Sr)										
	Tungsten (W)										
	Vanadium (V)										
	Zirconium (Zr)										
Complete Evaluations	Cerium (Ce)										
	Chromium (Cr)										
	Copper (Cu)										
	Dysprosium (Dy)										
	Gadolinium (Gd)										
	Iron (Fe)										
	Lead (Pb)										
	Manganese (Mn)										
	Minor Actinides										
	Nickel (Ni)										
	Plutonium-239										
	Strontium (Sr)										
	Tungsten (W)										
	Uranium-235										
	Uranium-238										
	Vanadium (V)										
	Zirconium (Zr)										
	Polyethylene (CH <sub>2</sub> )										
Silicon Dioxide (SiO <sub>2</sub> )											
		ORNL		RPI		LANL					

- Requests for additional IE measurements: Ni, Mo, Cr (Fe-Cr alloys), Mn in intermediate energy range (VNIITF, NCERC).
- Request for measurements and evaluation of angular distributions at high energy for Cu.
- Continuing need for thermal scattering data.





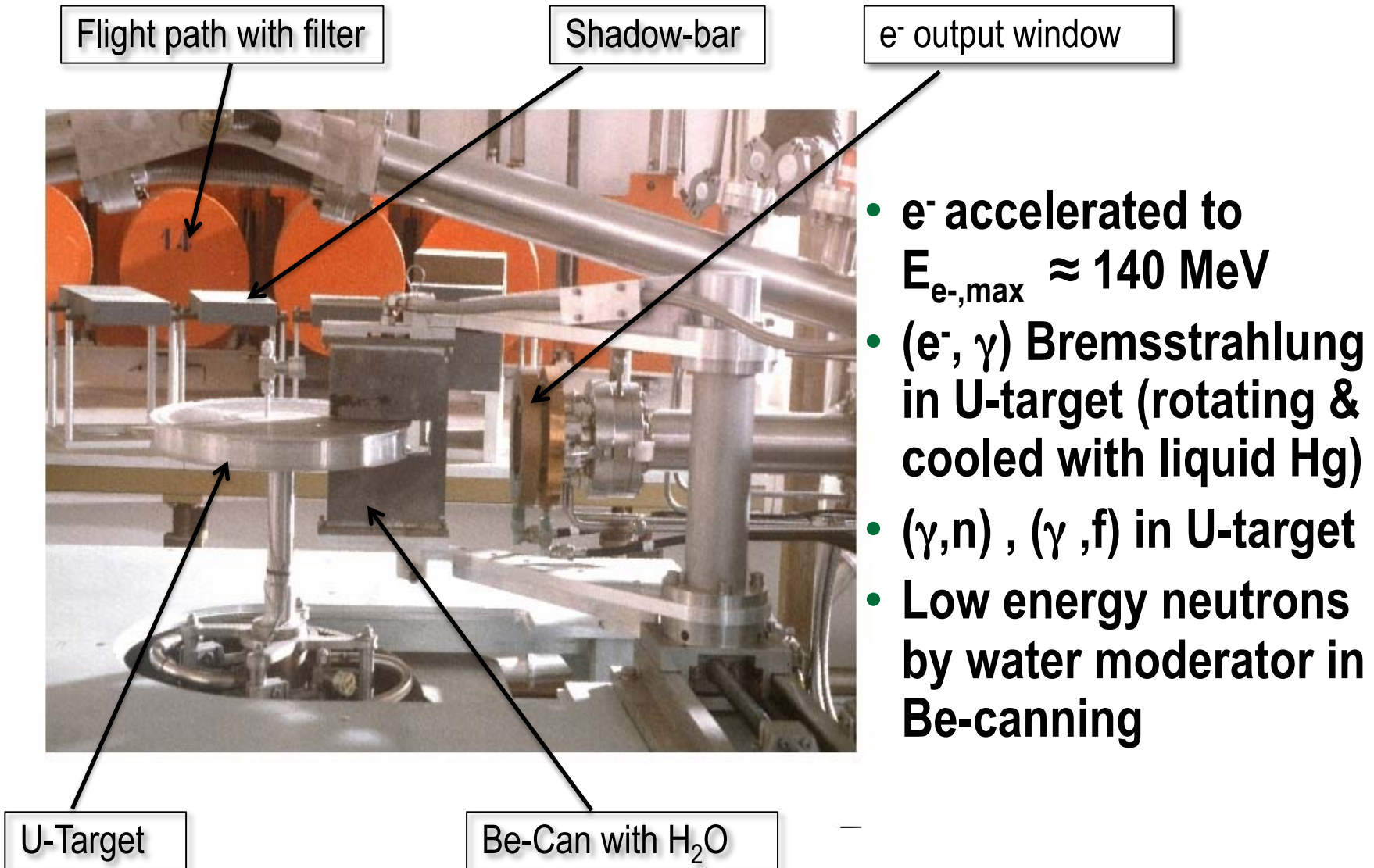
# GELINA



- Time-of-flight facility
- Pulsed white neutron source  
( $10 \text{ meV} < E_n < 20 \text{ MeV}$ )
- 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 :  $4.7 \mu\text{A} - 75 \mu\text{A}$   
 Neutron intensity :  $1.6 \cdot 10^{12} - 2.5 \cdot 10^{13} \text{ n/s}$

# Neutron Production



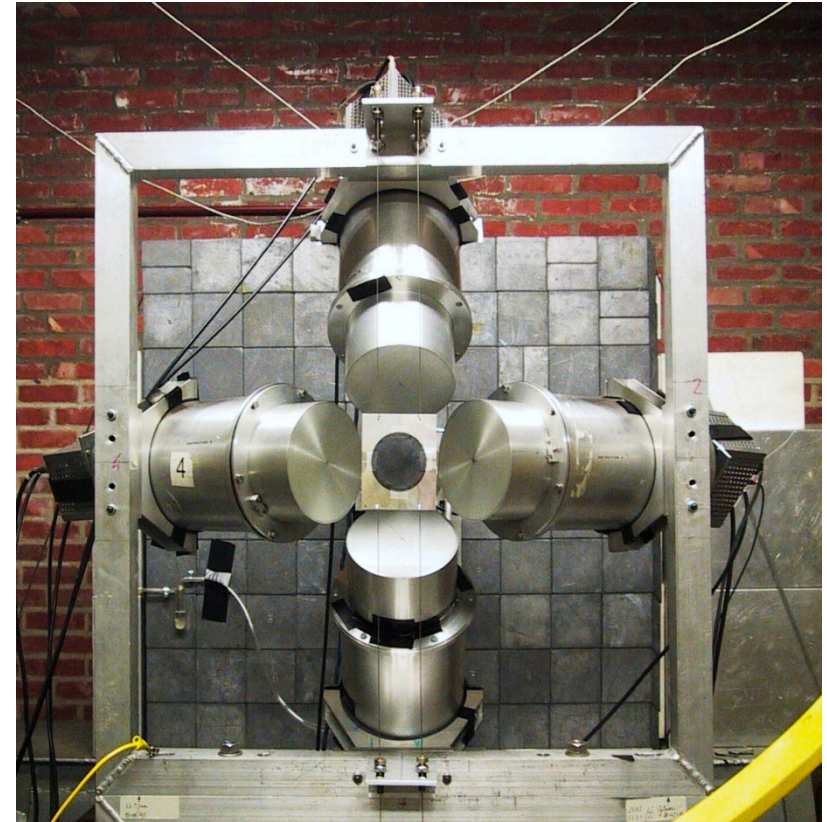
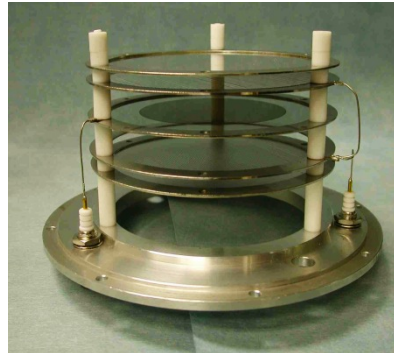
- e<sup>-</sup> accelerated to  $E_{e^-,max} \approx 140 \text{ MeV}$
- (e<sup>-</sup>,  $\gamma$ ) Bremsstrahlung in U-target (rotating & cooled with liquid Hg)
- ( $\gamma, n$ ), ( $\gamma, f$ ) in U-target
- Low energy neutrons by water moderator in Be-canning

# 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)
  - $^{10}B(n,\alpha)$
  - $^{235}U(n,f)$

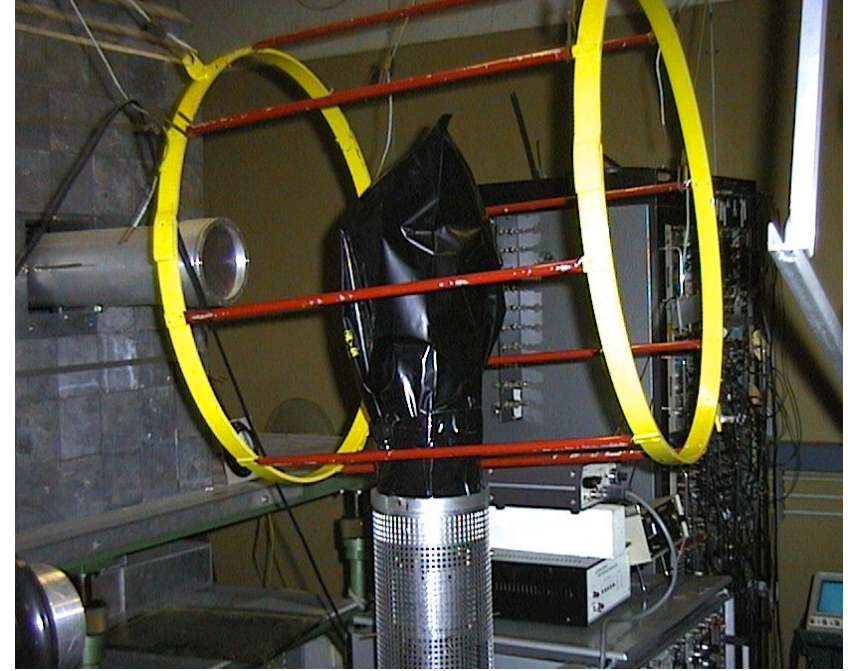


$$Y_{\text{exp}} = N\sigma_{\varphi} \frac{C_w - B_w}{C_{\varphi} - B_{\varphi}}$$

# Transmission Measurements

Sample & Background Filters

Detector



## Detector stations

Moderated: L= 30 m,50 m,(100 m,200 m)

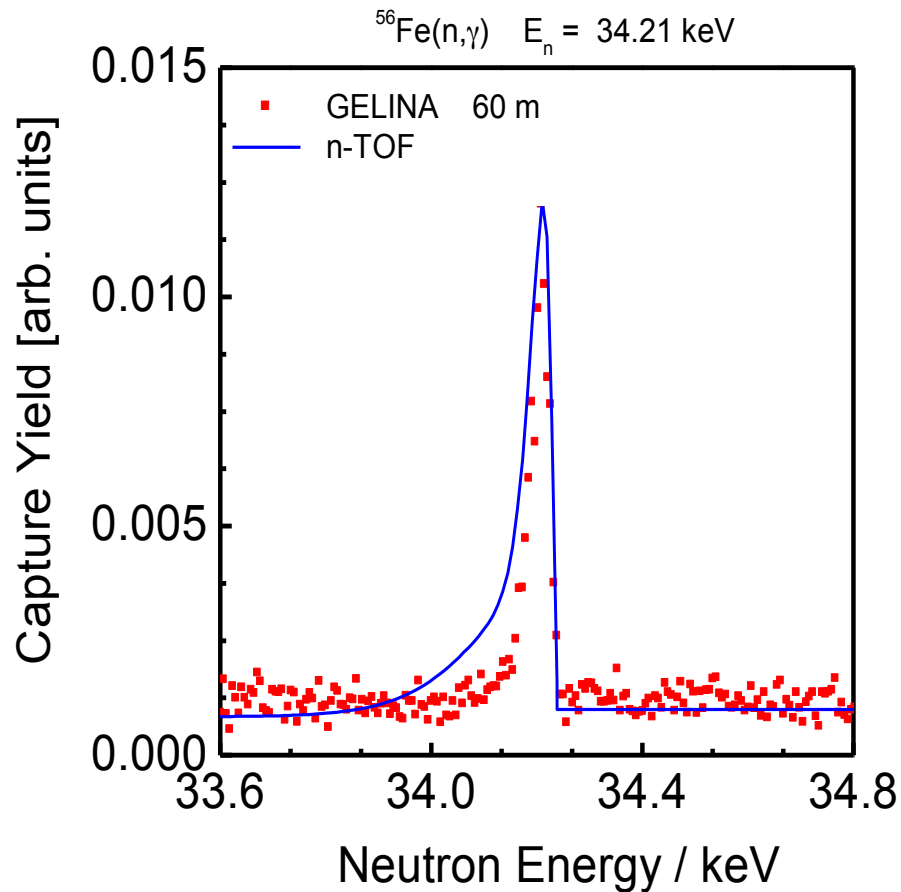
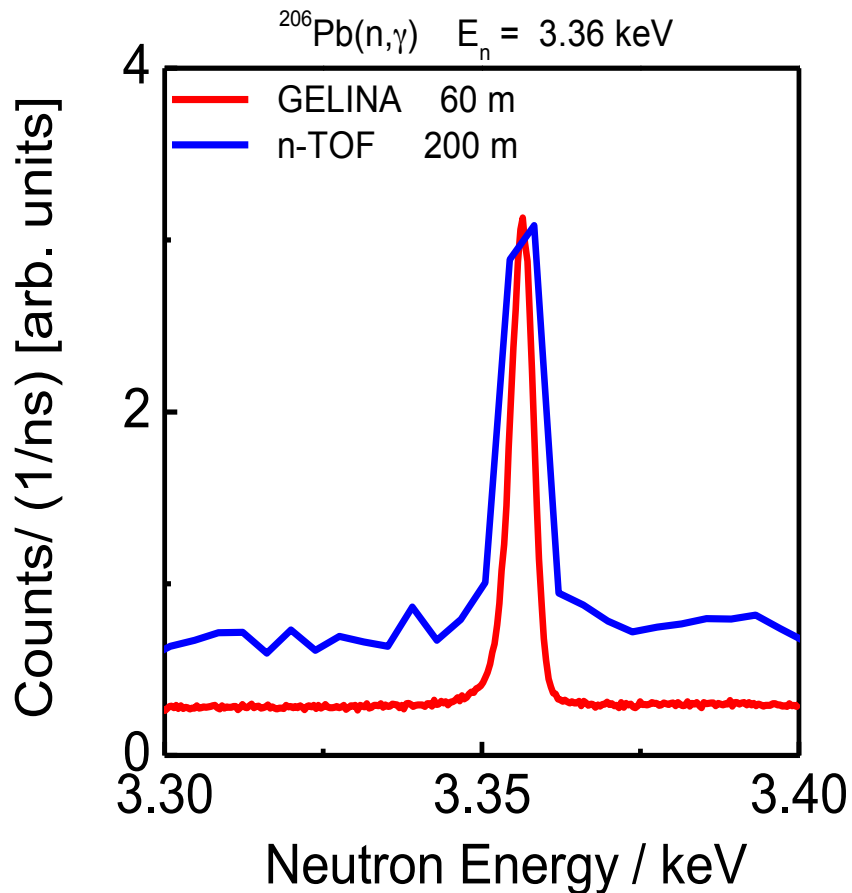
Fast: L= 400 m

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

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

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

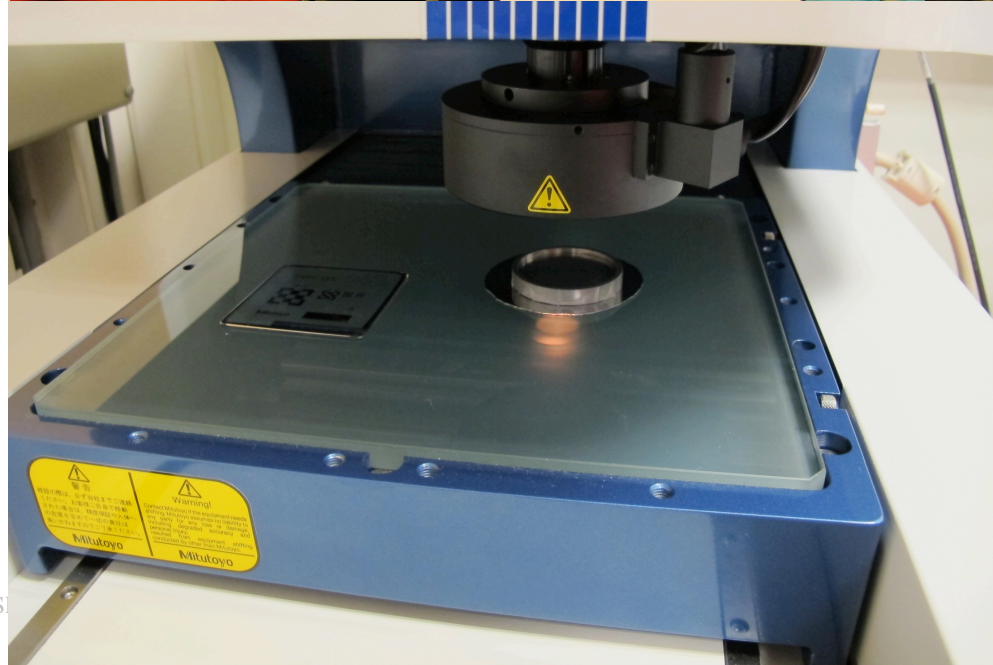
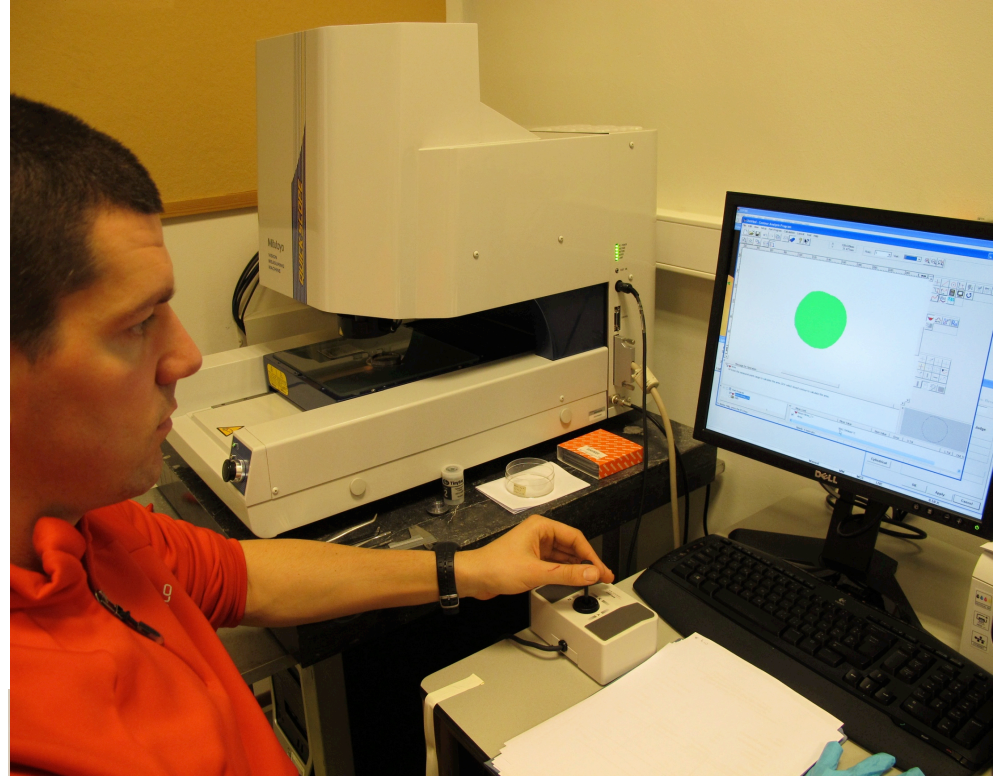
# n-TOF (180 m) $\leftrightarrow$ GELINA (60 m)



P. Schillebeeckx, IRMM

# Determine Sample Characteristics

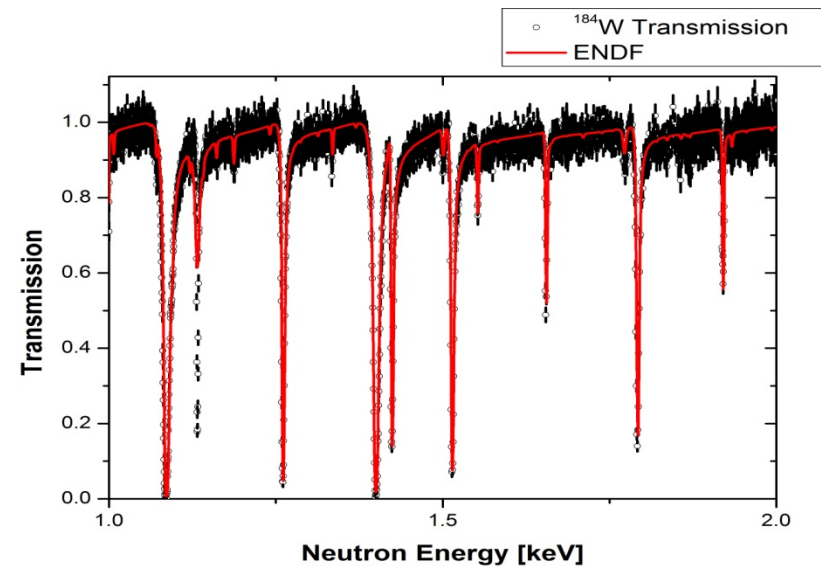
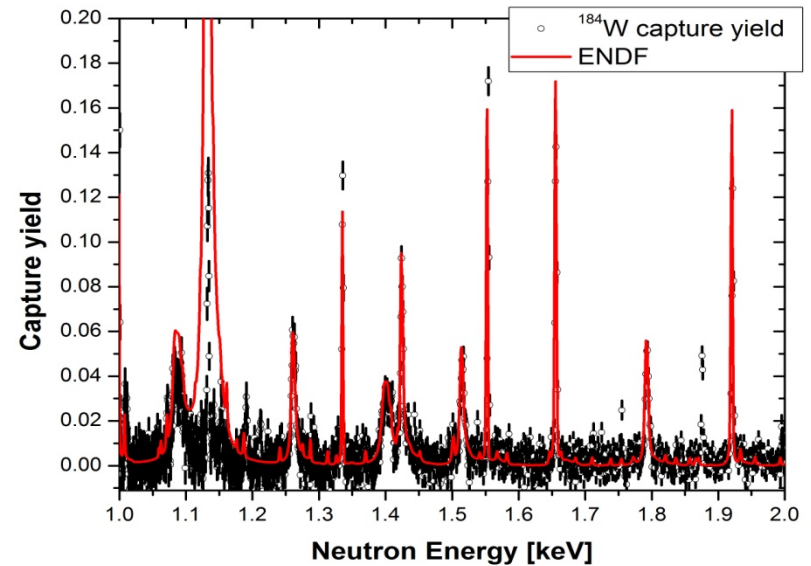
- How much material is needed to achieve sufficient count rate.
- What material and how much is available.
- Physical dimensions like radius, thickness, area.
- Weight, density.
- Isotopic composition.
- Number of atoms.





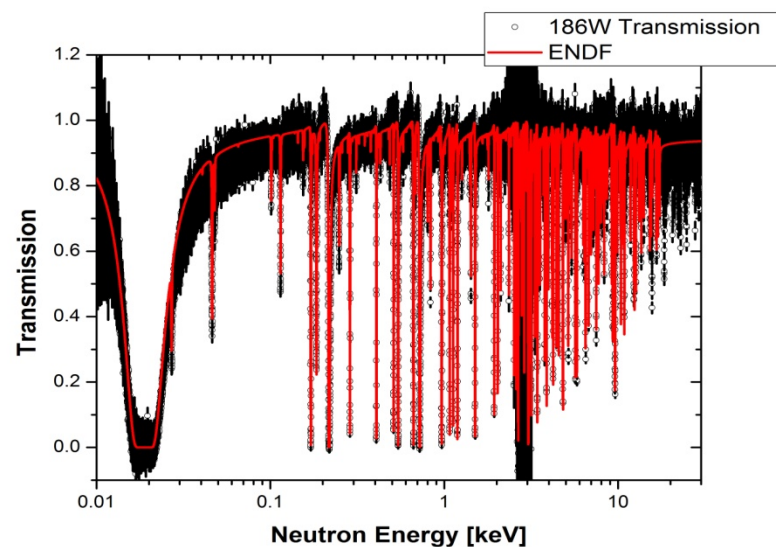
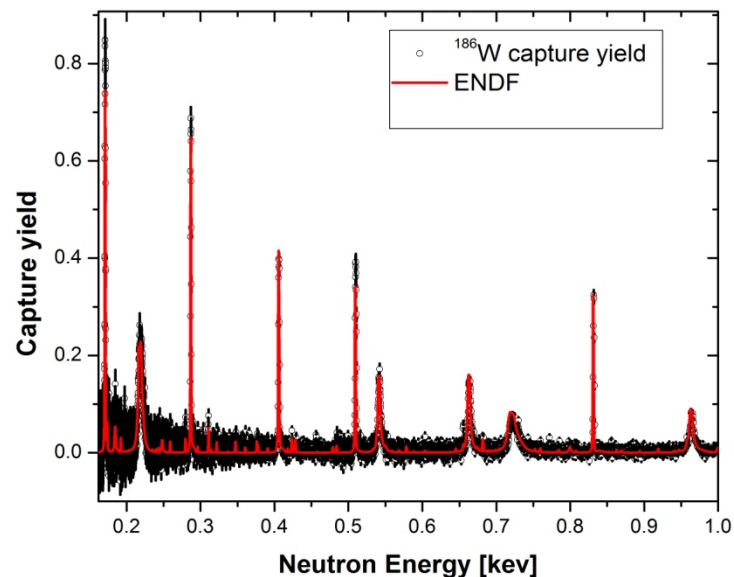
# Data Taking

- 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

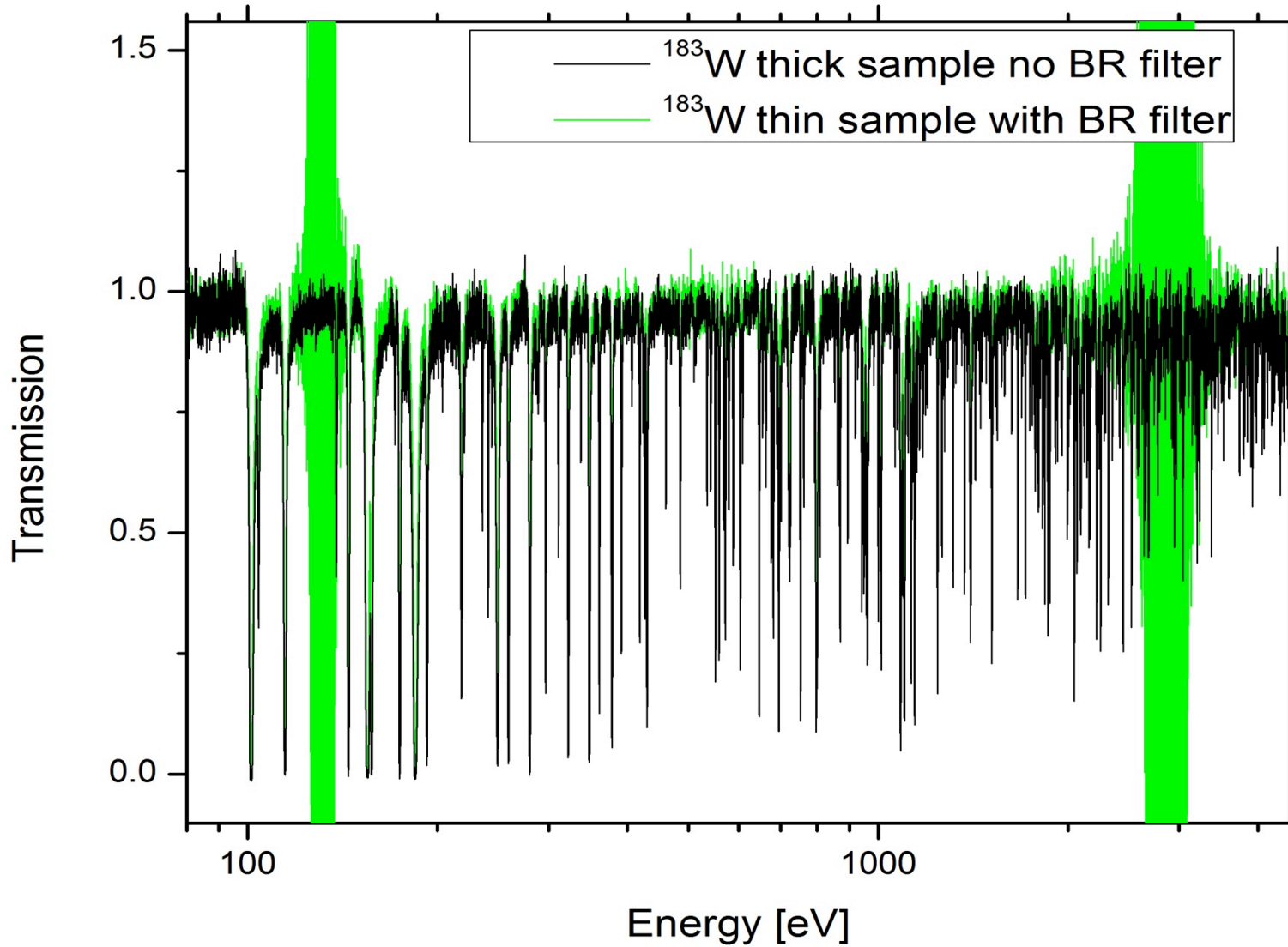
- Data are sorted into spectra using the program package AGL (Analyze Geel List mode data). Raw data and scalers are tested for stability and consistency before sorting into final spectra.
- The resulting spectra are then converted to cross section applying all background corrections using the AGS (Analyze 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



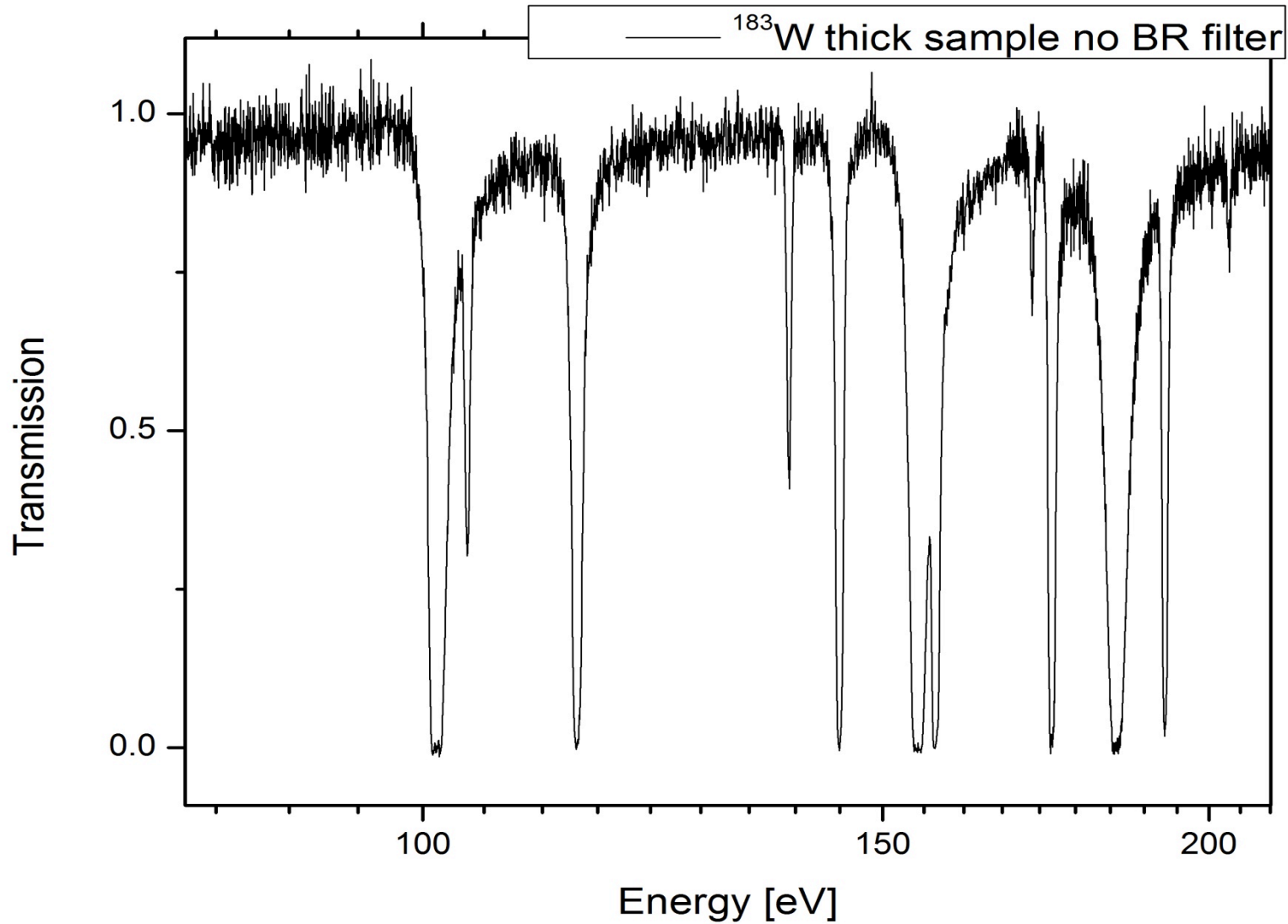
# W Measurement Activities

- **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  $^{182,183,184,186}\text{W}$  from the high repetition run available to analyze.**
- **Transmission data for  $^{182,183,184,186}\text{W}$  with different sample thickness available. But due to filters there are gaps in the data. New experiments without filter and new set up performed.**

# $^{183}\text{W}$ Comparison thin thick sample



# $^{183}\text{W}$ thick sample detail



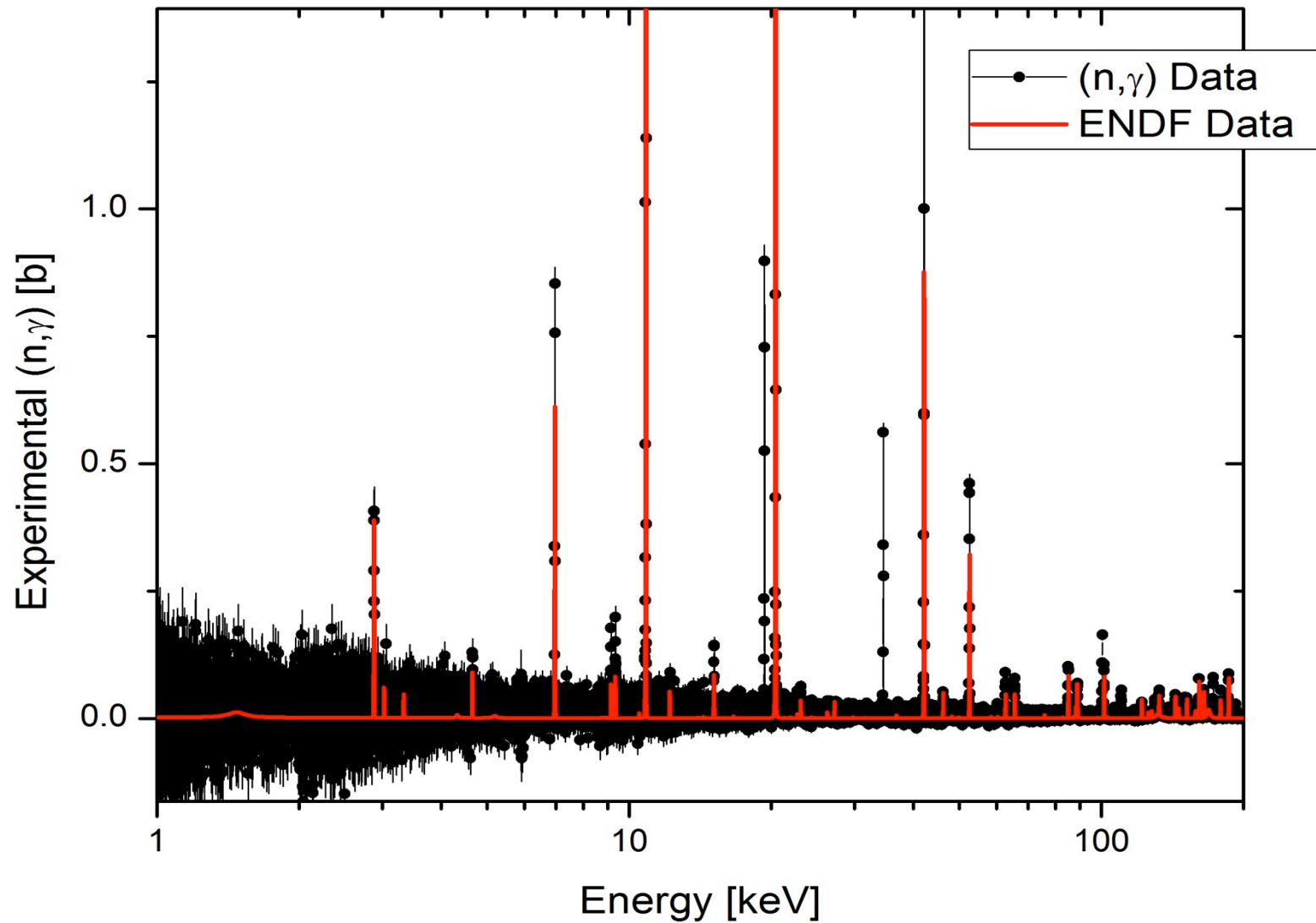
# ORNL Measurement Activities for Calcium

- 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



# Natural Ca ( $n,\gamma$ ) compared to ENDF

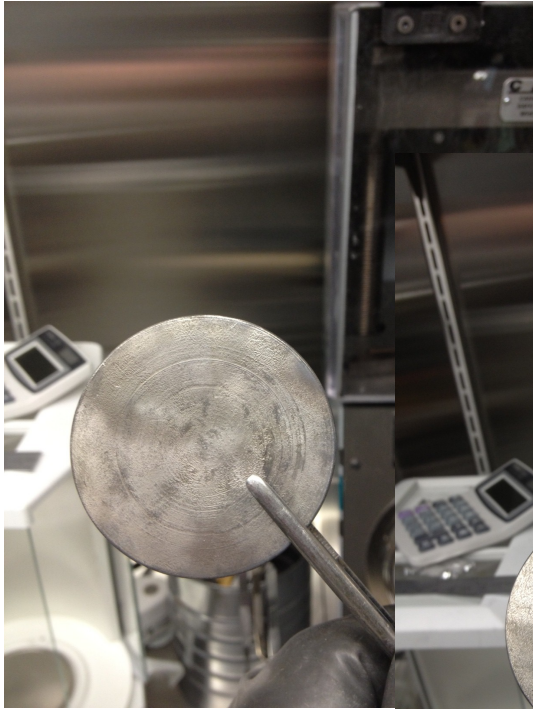




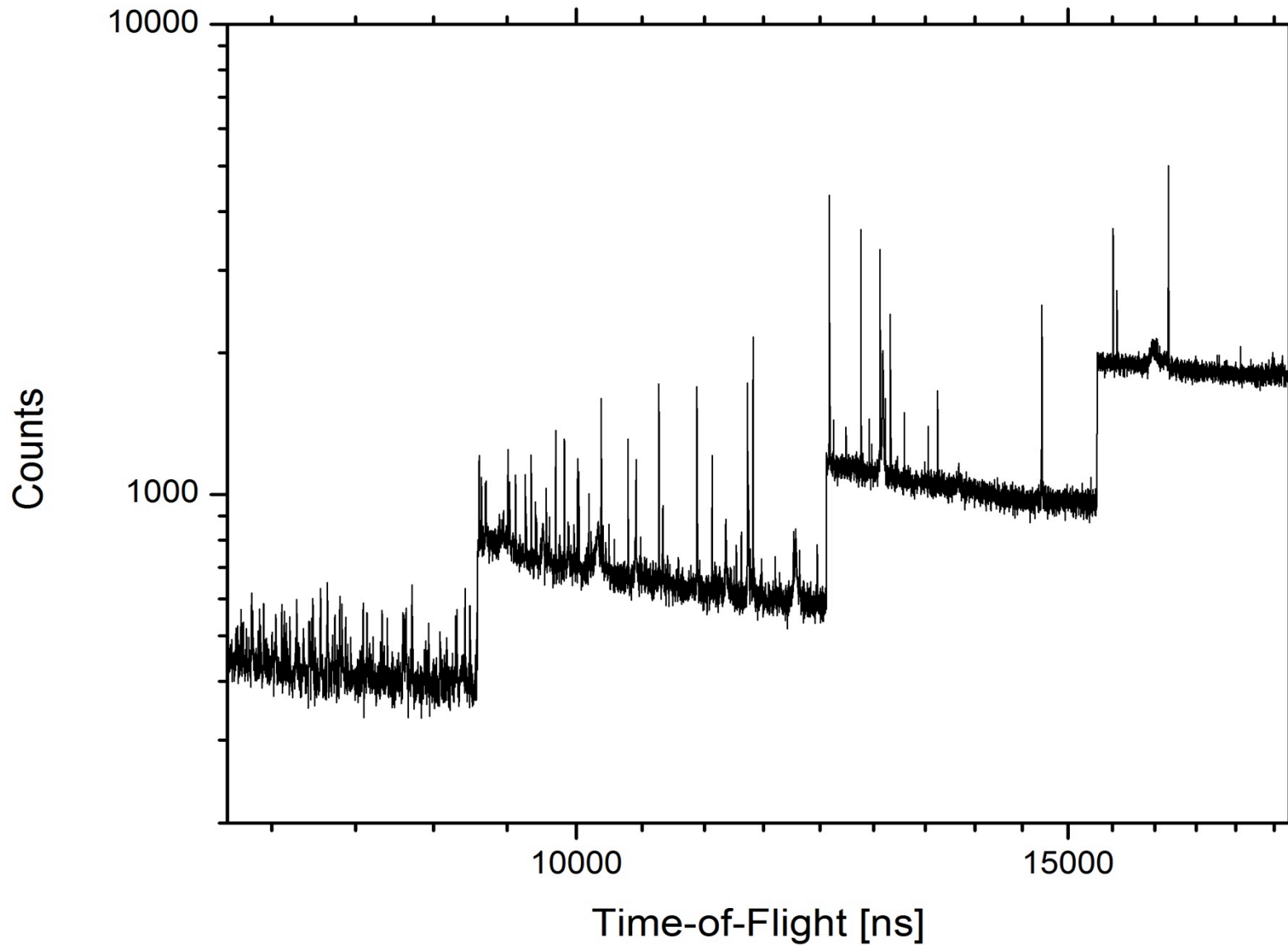
# ORNL Measurement Activities for Cerium

- 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 ( $n,\gamma$ )



# Status of Experiments at GELINA

	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, $\gamma$ ) transmission	60m (n, $\gamma$ )	60m (n, $\gamma$ ) transmission	60m (n, $\gamma$ ) 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, CEA**
- **Peter Schillebeeckx, IRMM**
- **Stefan Kopecky, IRMM**
- **Peter Siegler, IRMM**
- **Ruud Wynats, IRMM**
- **Clint Ausmus, ORNL**