The ^{197}Au(n,γ) cross-section in the unresolved resonance region

Claudia Lederer

IAEA consultants meeting on cross-section standards
Vienna, 13-15 October 2010

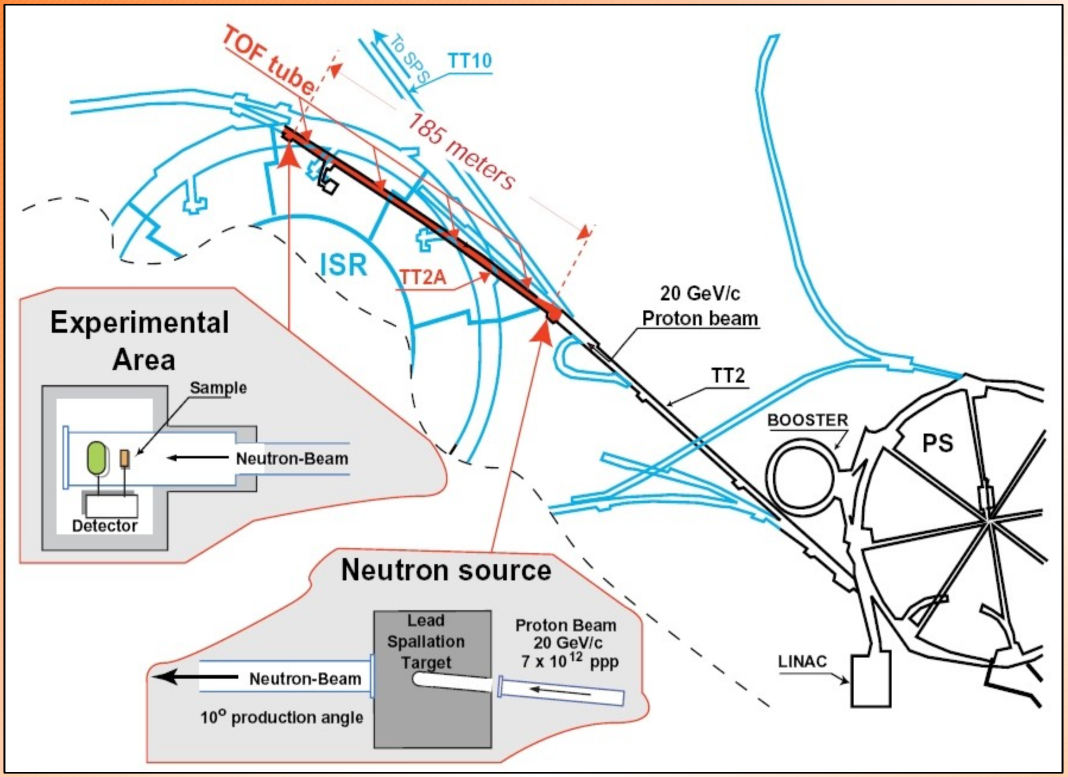
Discrepancies standard evaluation – MACS by Ratynski and Käppeler →

- new measurement of Au(n,γ) at GELINA (P. Schillebeeckx) and n_TOF
- measurement of ^{7}Li(p,n) quasi-maxwellian neutron spectrum at PTB

Measurement at n_TOF

In collaboration with: N. Colonna, C. Domingo-Pardo, F. Gunsing, F. Käppeler, C. Massimi, A. Mengoni, A. Wallner, the n_TOF Collaboration

n_TOF (neutron time-of-flight) facility at CERN



20 GeV/c protons on Pb-target
Pulse width: 7 ns
Intensity: 7 $\cdot 10^{12}$ protons per pulse

Flight path: 185 m
Neutron energy: 10^{-3}-10^{10} eV
Beam size at capture setup: Ø~4 cm

2 setups for capture measurements:

- total absorption calorimeter: 4π geometry (ε~100%)
- **two C_6D_6 detectors**

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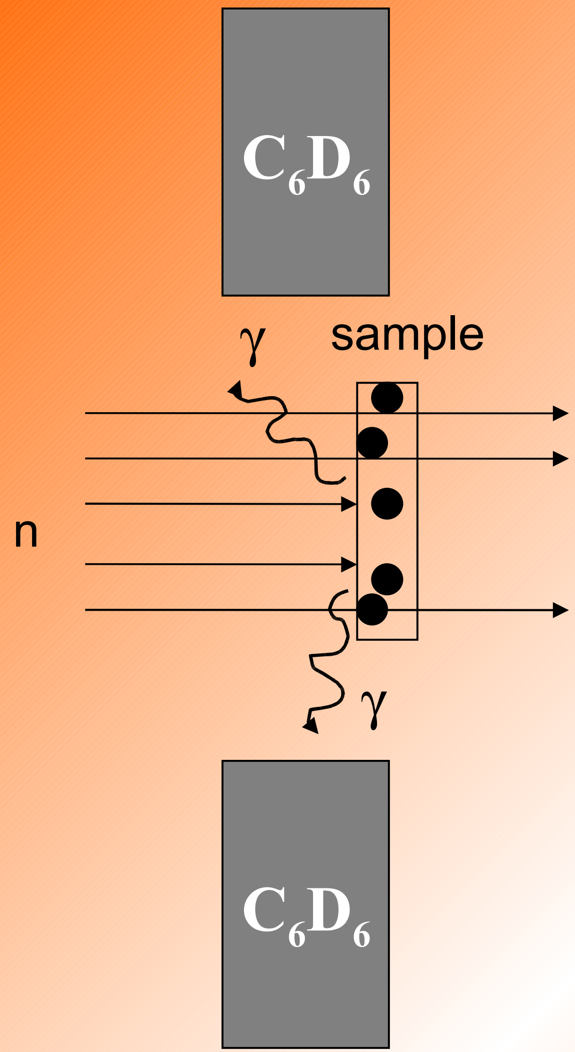

$^{197}Au + n \rightarrow {}^{198}Au^* \rightarrow {}^{198}Au + \gamma$

Detection technique:

- 2 C_6D_6 detectors
- about 20% efficiency for detecting a capture event

Sample

- 15 mm diameter
- 1299 mg mass
- $2.241 \cdot 10^{-3}$ atoms/barn
- 0.37 mm thickness

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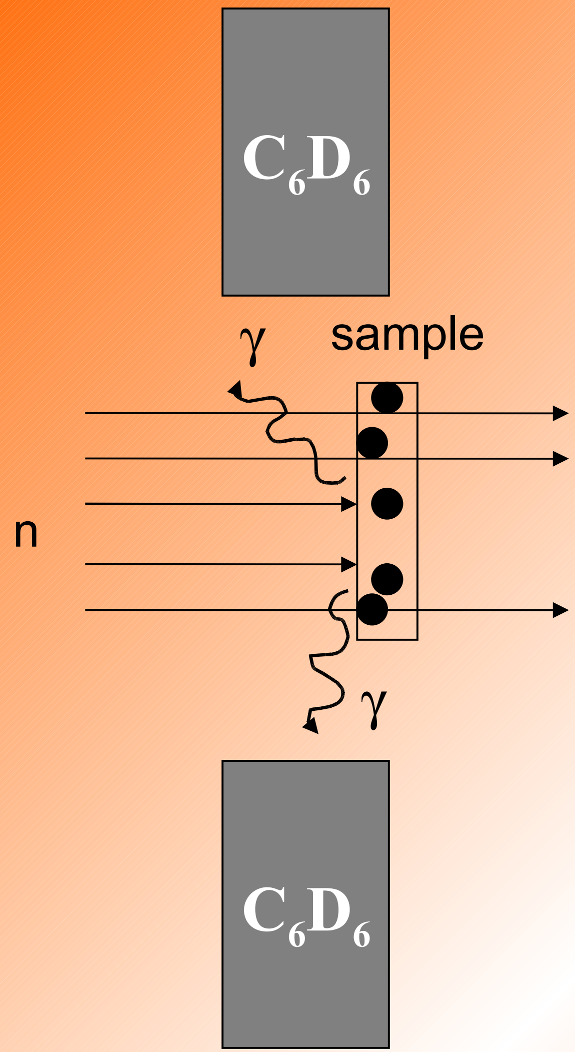
n_TOF



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$$Y_R = f_{corr} \cdot f_N \frac{C - B}{\varepsilon \cdot \Phi}$$

B.. background

ε....efficiency

f_N....normalization

ϕ...neutron flux

f_{corr}...other experimental effects

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Efficiency

- Pulse height weighting technique
- apply pulse-height dependent weight to recorded signal to achieve:

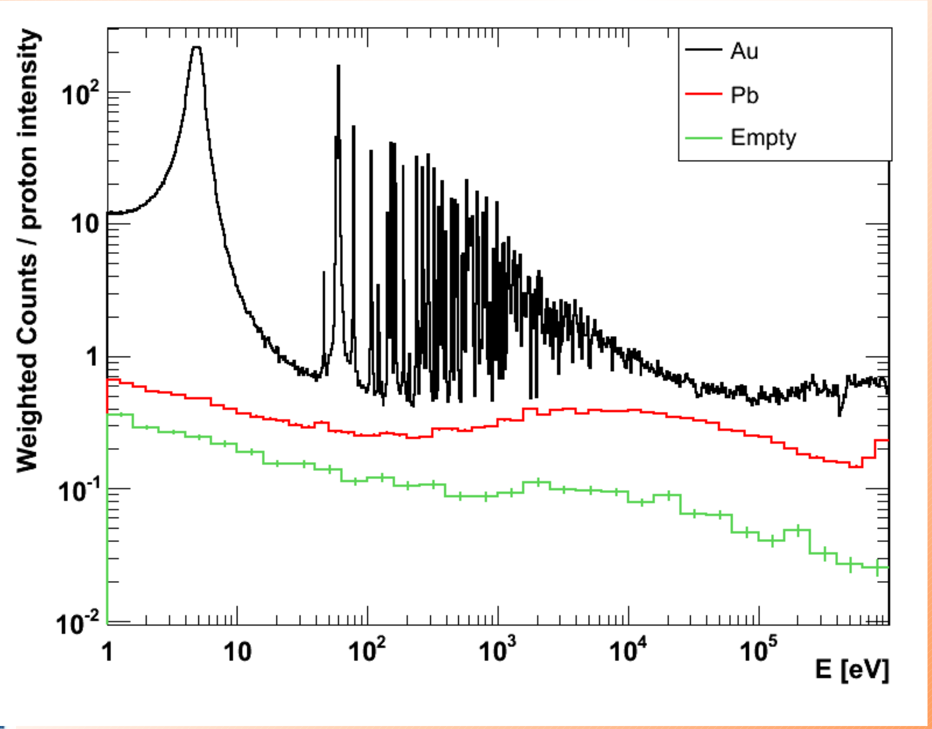
$$\varepsilon_c = k \bullet (S_n + E_n)$$

- uncertainty for weighting: 2%
- WF validity >99.4% for different neutron absorption in sample
- for details see: C. Massimi, C. Domingo-Pardo *et al*., Phys. Rev. C **81**, 044616 (2010)

Background

Components:

- neutron induced bg (energies <200 eV)
- in-beam-gamma-rays (200 eV-400 keV)
- (n,n'γ) reactions (first inelastic channel Au: 77.4 keV)



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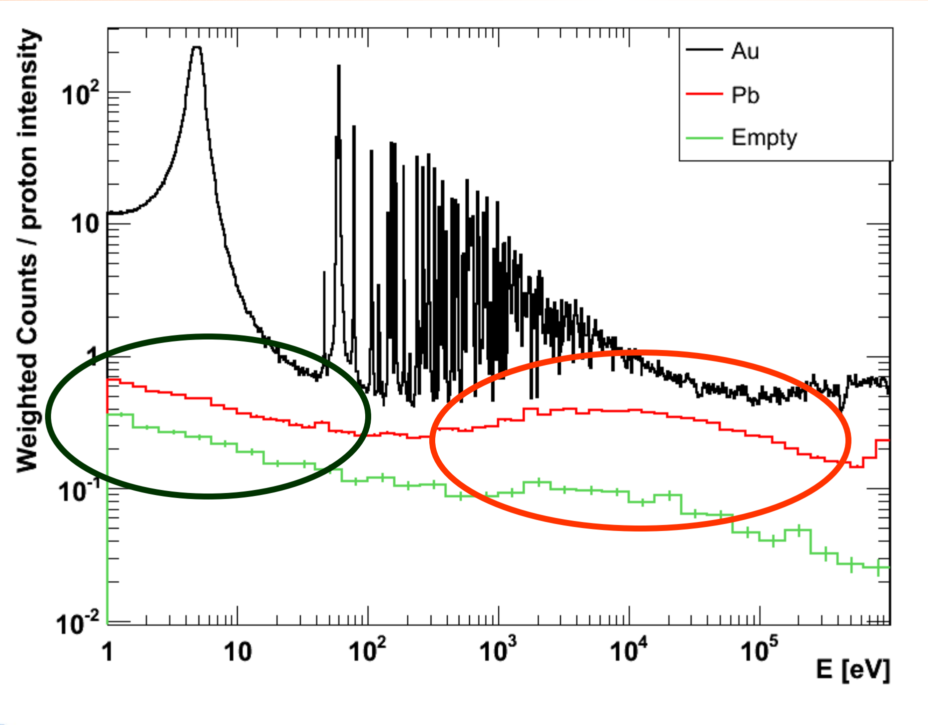


Background

Total background:

$$B_{tot} = f_n \bullet B_n + f_\gamma \bullet B_\gamma + B_{ambient}$$

Background - shape

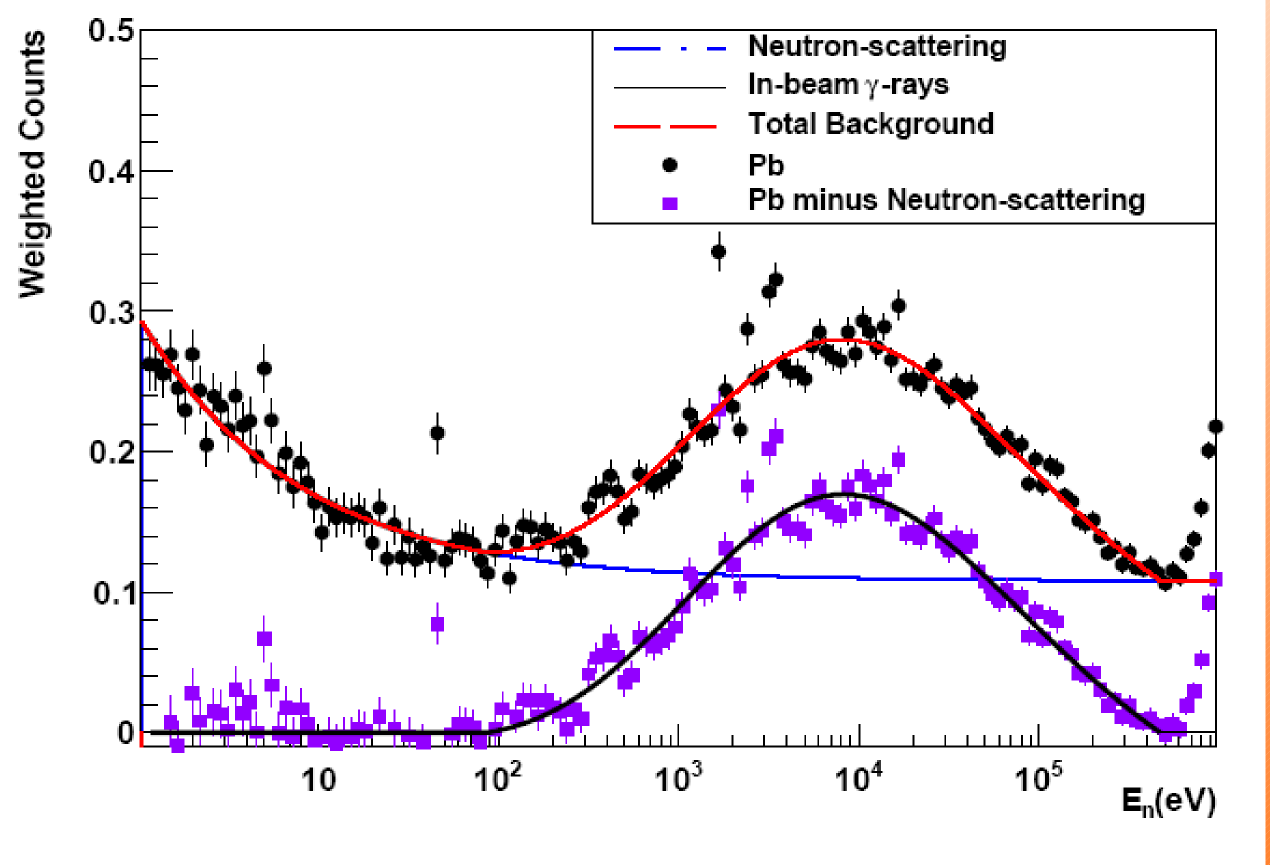
Total background:

$$B_{tot} = f_n \bullet \mathbf{B_{n,el}} + f_\gamma \bullet \mathbf{B_\gamma} + B_{ambient}$$

$\mathbf{B_n = a + b \bullet E^{-0.5}}$

$\mathbf{B_\gamma = c + d \bullet \exp(-e \bullet E^{-0.5}) + f \bullet \exp(g \bullet E^{-0.5})}$

Pb:

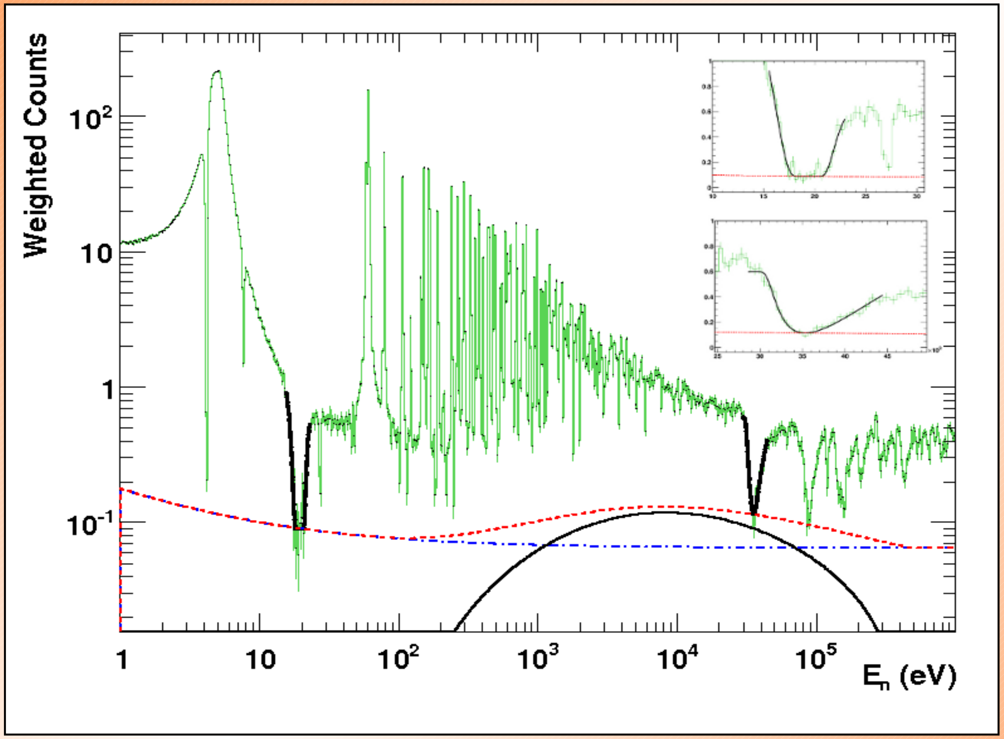


Background - normalization

Total background:

$$B_{tot} = f_n \cdot B_n + f_\gamma \cdot B_\gamma + B_{ambient}$$

- Method 1: neutron filters in beam*



- W (20.06 eV) and Al (34.7 keV)

*Au with filters scaled to Au to correct for overall neutron attenuation

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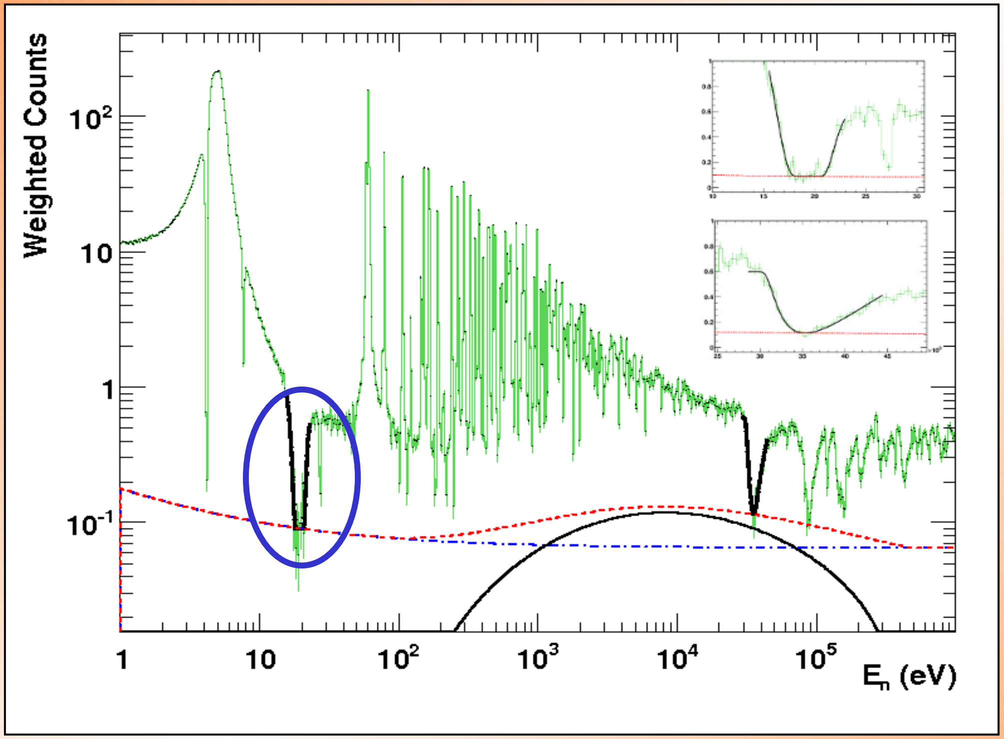

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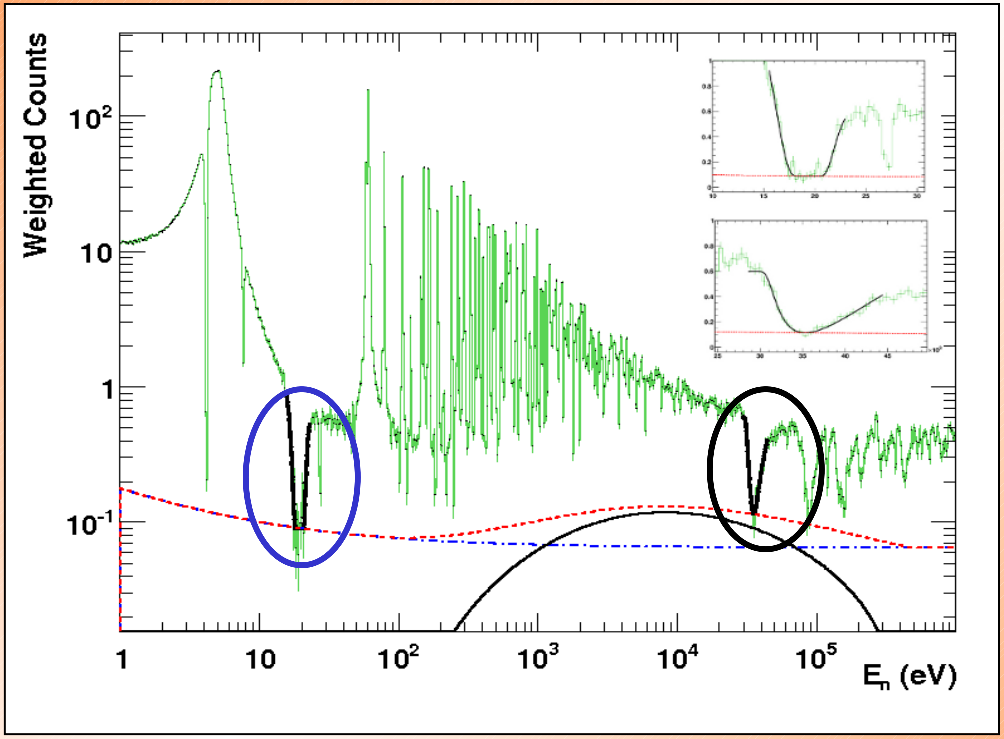

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$$\bullet \mathbf{F f_\gamma = f_f \bullet f_{att}}$$

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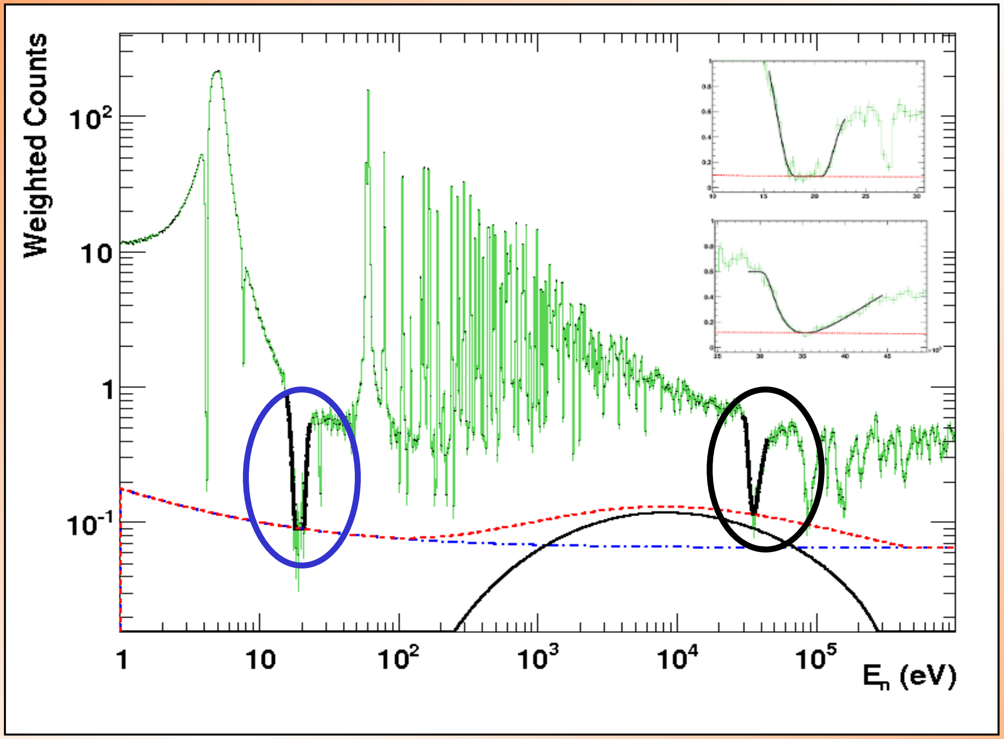

- W (20.06 eV) and Al (34.7 keV)
- f_n = **0.556±5%**
- f_f = **0.354 ±7%**
- $f_{att,sim}$ = **1.83 ± 8%**

Background - normalization

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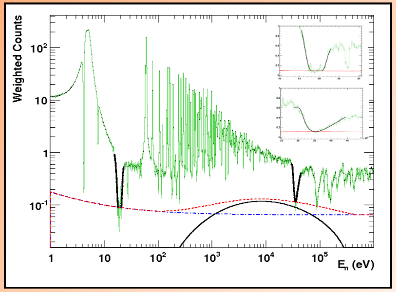

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- Method 2: simulations of f_γ

- GEANT3: $f_\gamma = 0.625$
- MCNPX: $f_\gamma = 0.669$

Background - normalization

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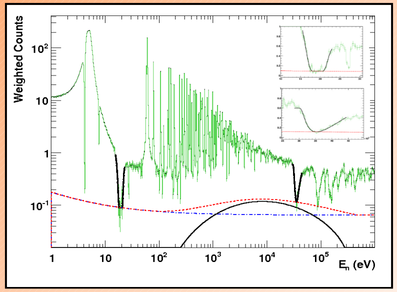

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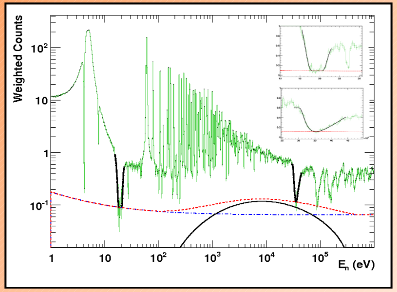

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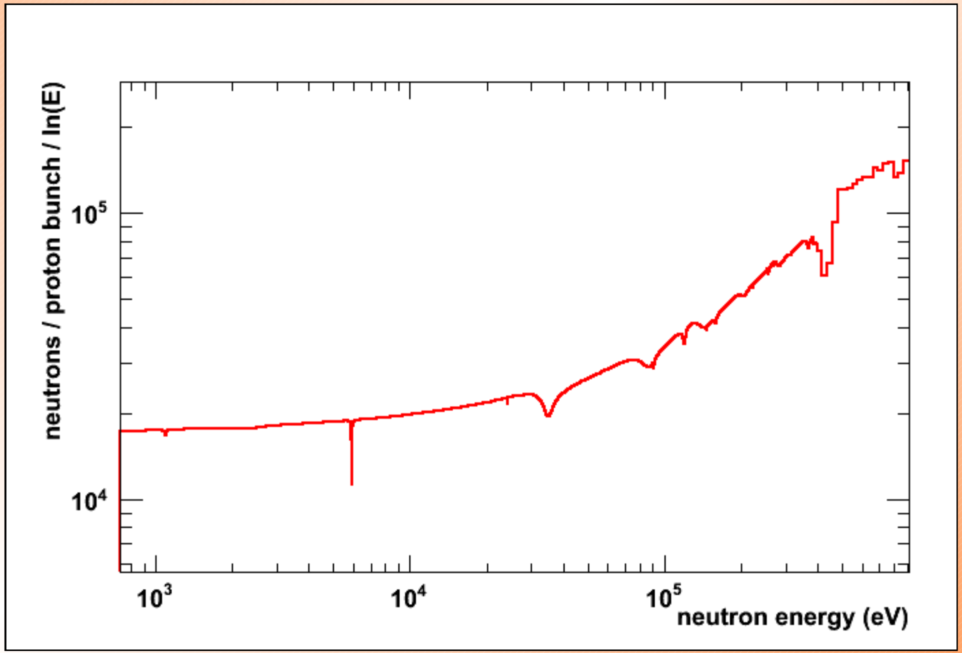
→ uncertainty in cross-section around 1.6 % !

Neutron flux



- Parallel plate fission chamber loaded with ^{235}U
- Uncertainty: 2% (apart from the dips)

Normalization

- Saturated resonance technique
- 4.9 eV resonance in Au: no neutrons transmitted
- Fit top of resonance
- Uncertainty : 1%

Further Corrections/Checks

- energy dependence of neutron beam profile max. 4.5%
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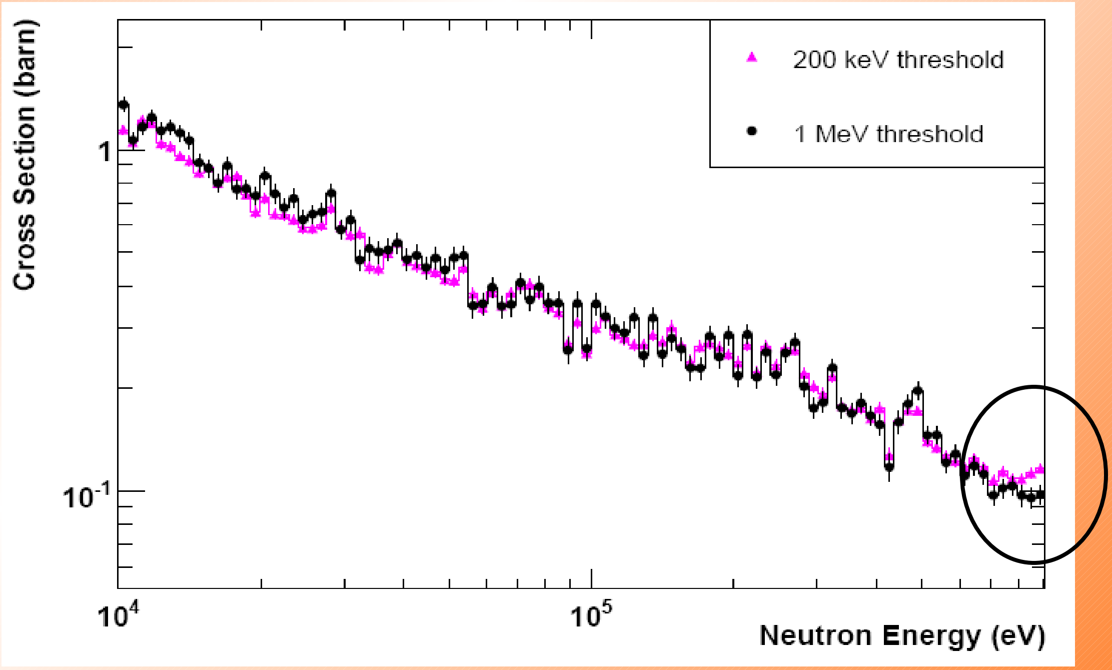
- Background due to inelastic channels:

  compare spectra with 200 keV and 1MeV threshold:



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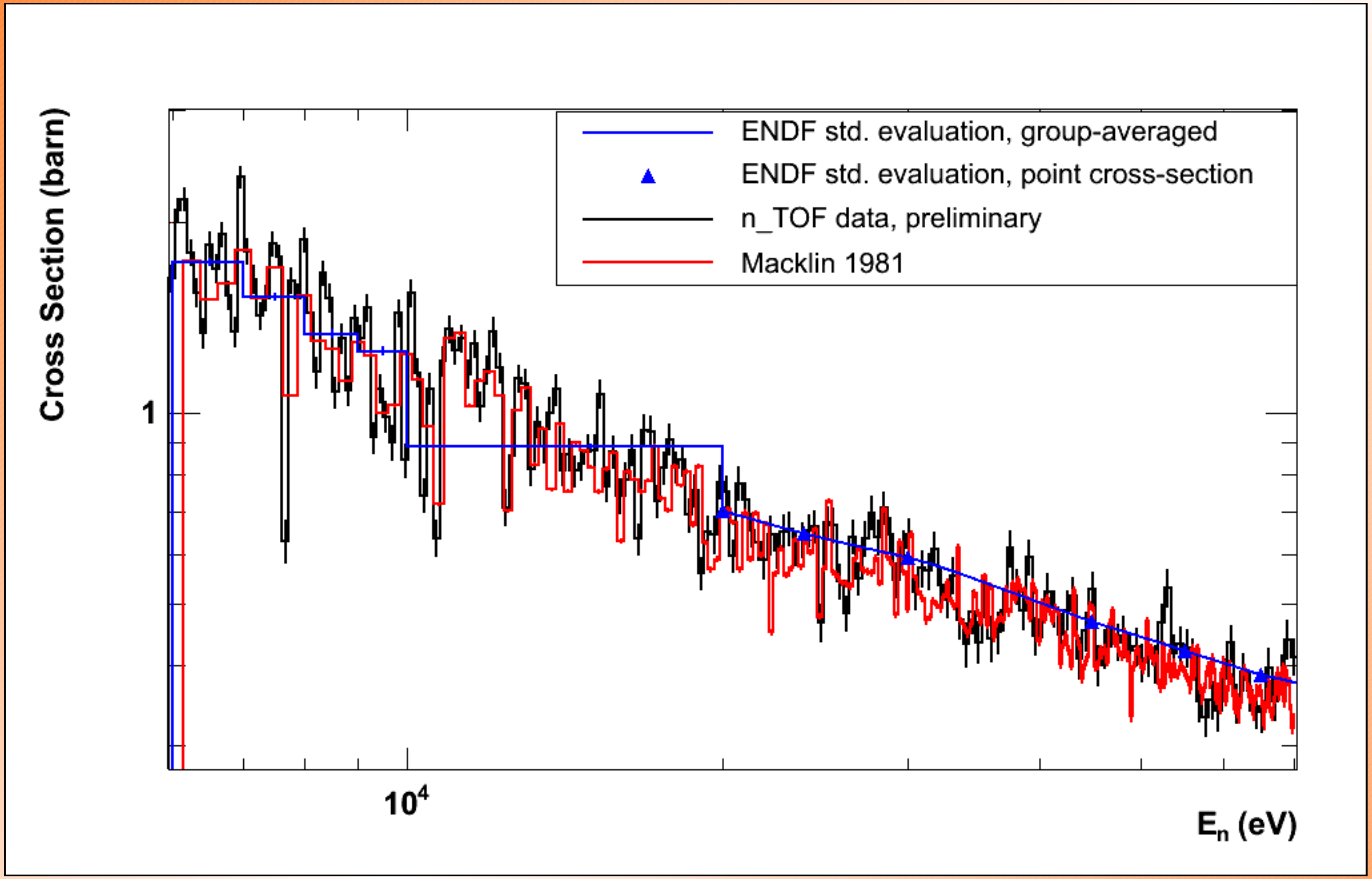
- Missing: comparison of capture yield using different thresholds

  → can reduce the 2% uncertatinty in PWHT!
- expected final uncertainty: 4-5%

Results: structures in cross-section



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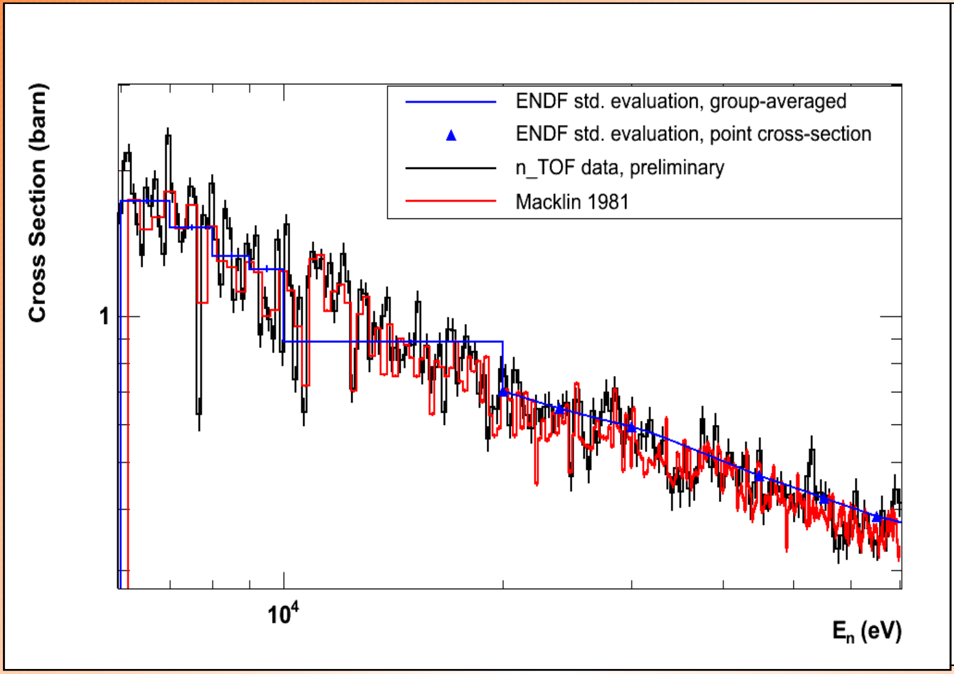

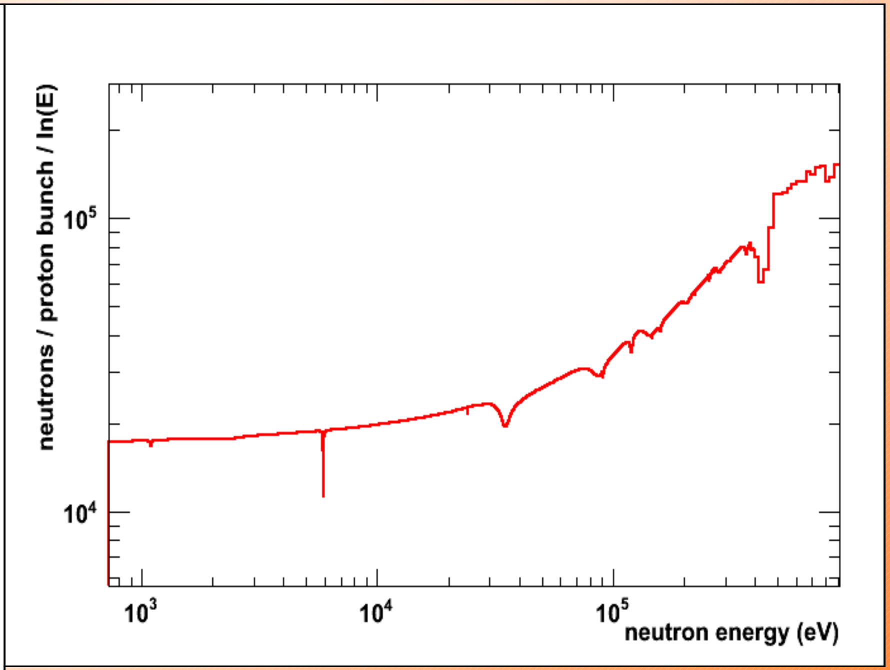

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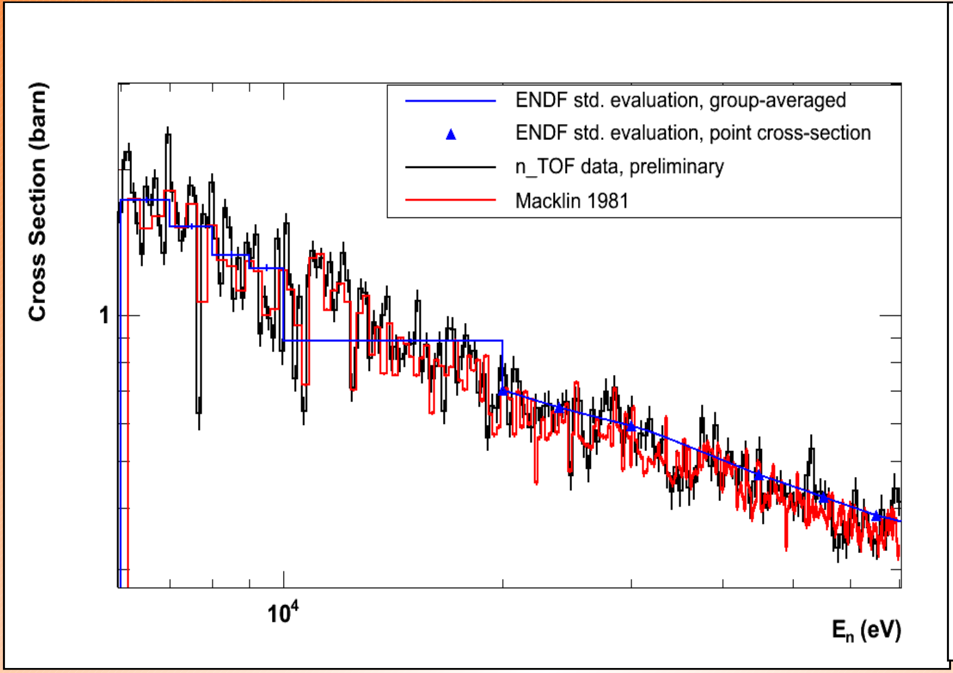

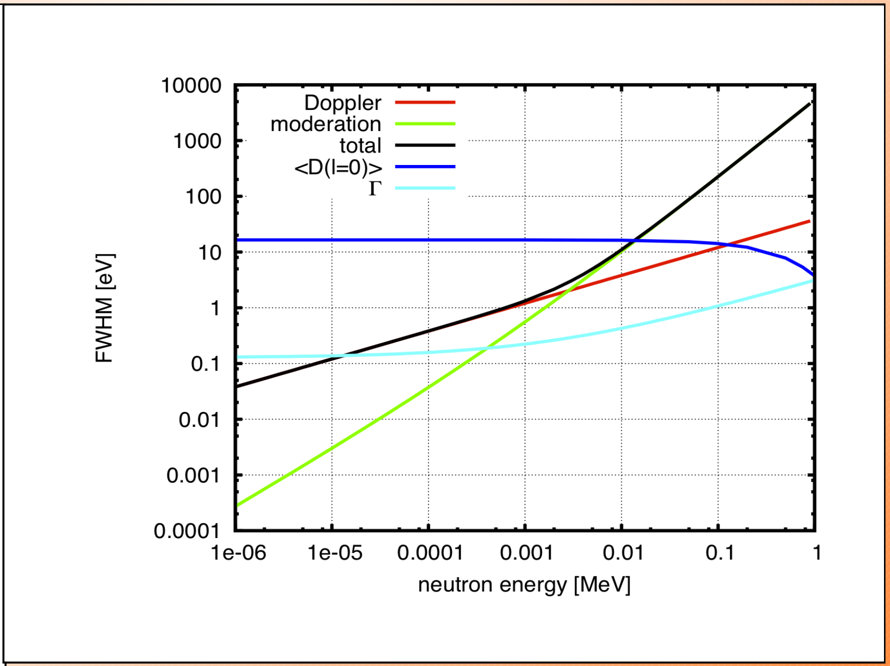

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• Simulation of cross section using artificial sets of resonances plus Doppler broadening (T=4560K) →

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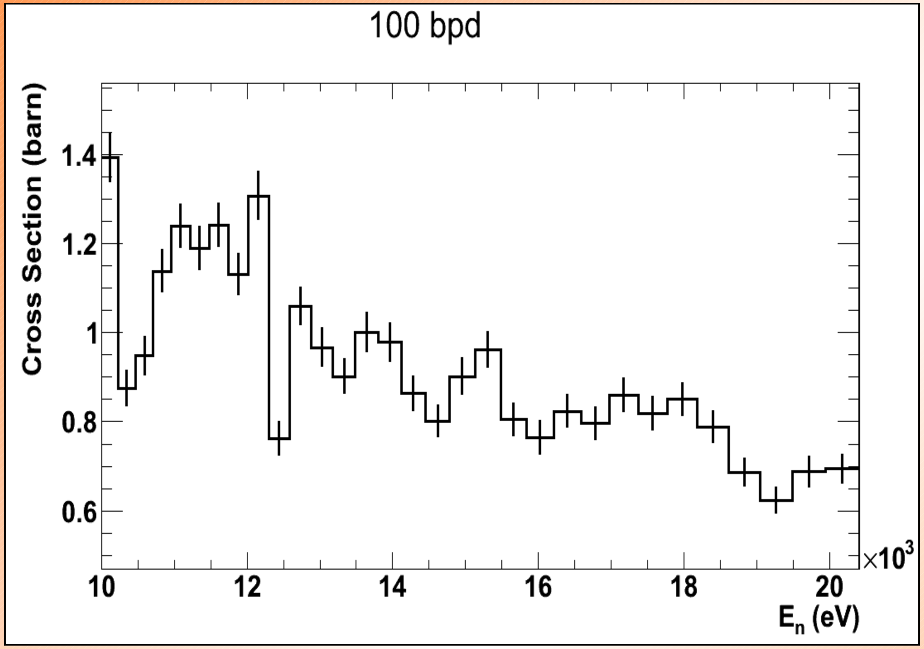

experimental

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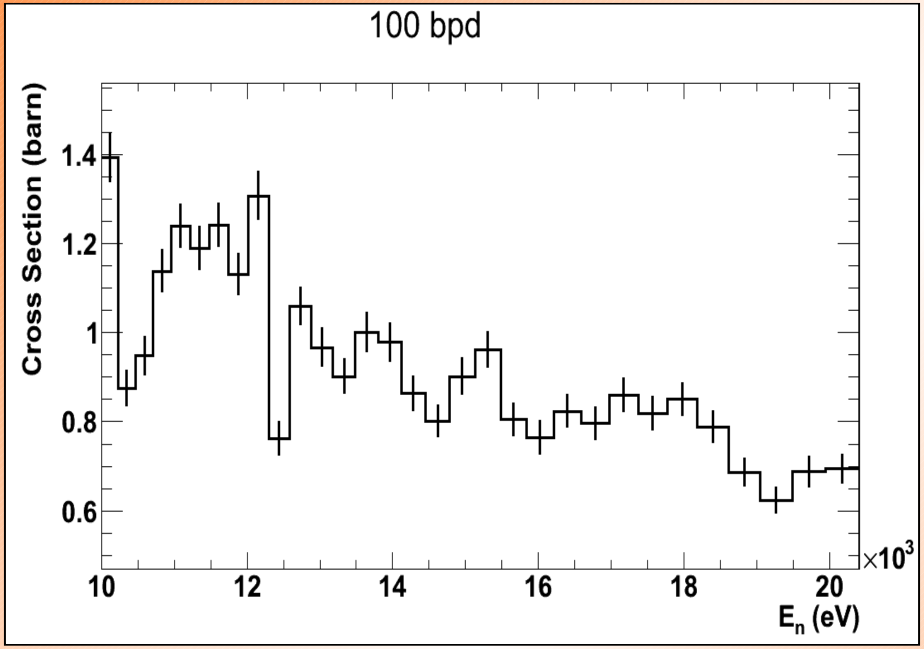

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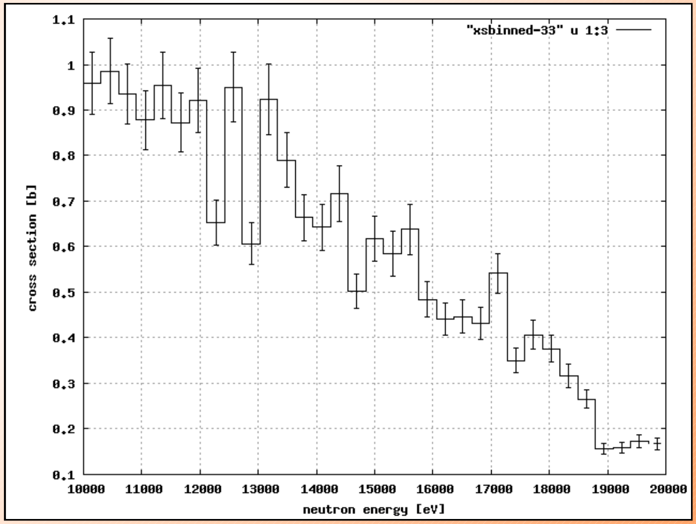

trial 1

simulation

Results: structures in cross-section

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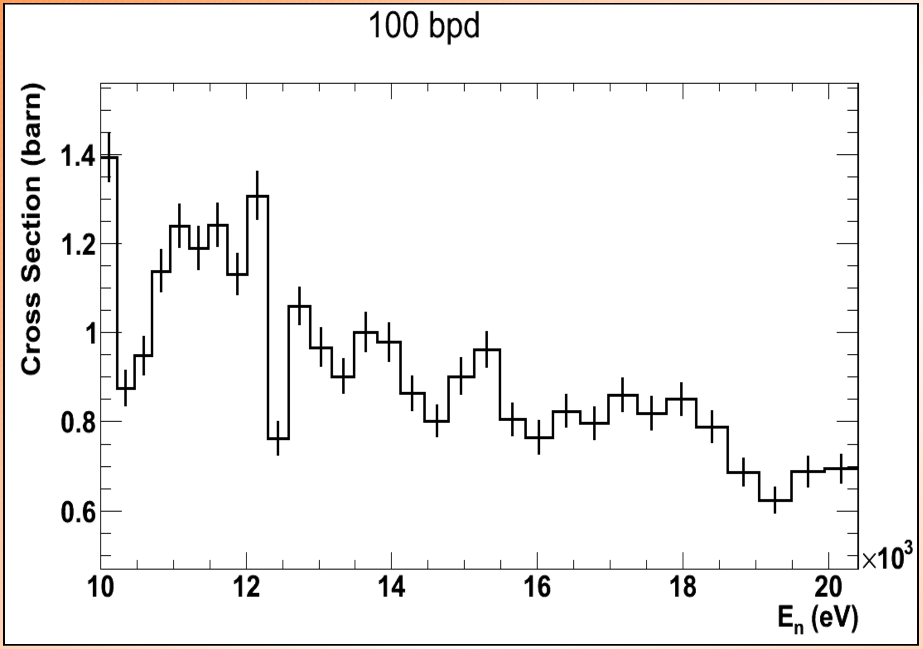

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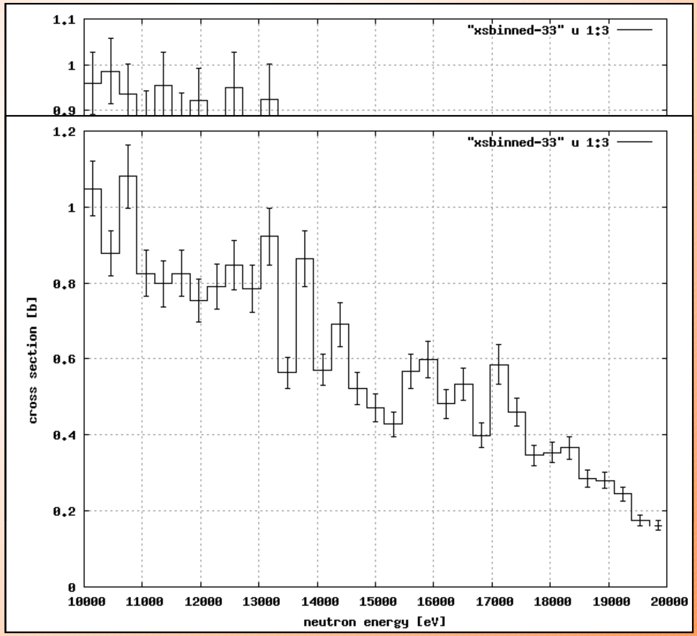
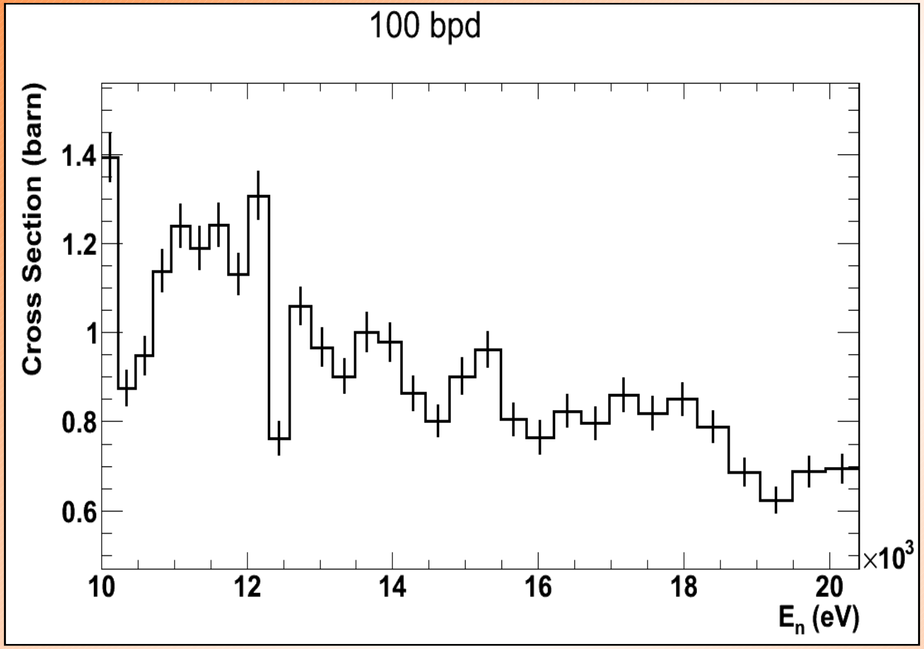


trial 2

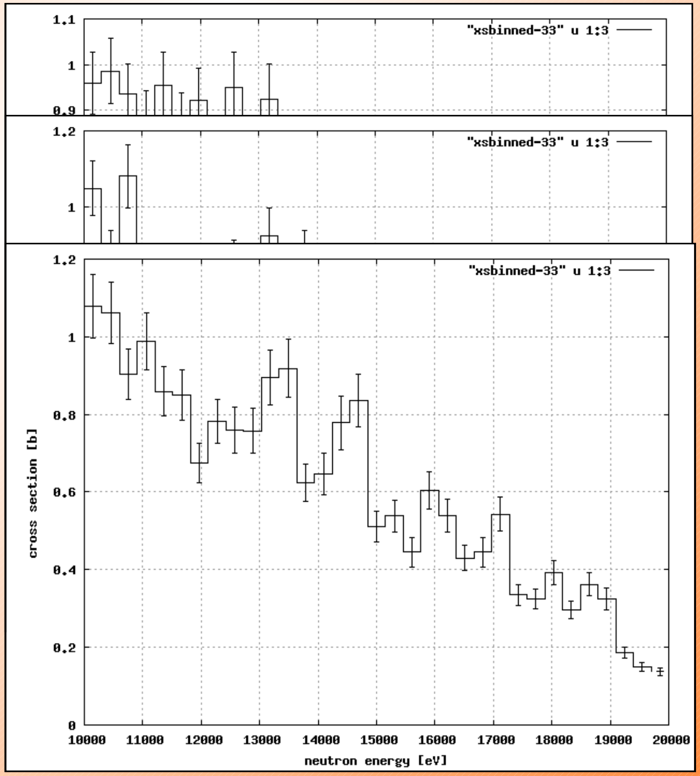
simulation

Results: structures in cross-section

• Simulation of cross section using artificial sets of resonances plus Doppler broadening (T=4560K) →



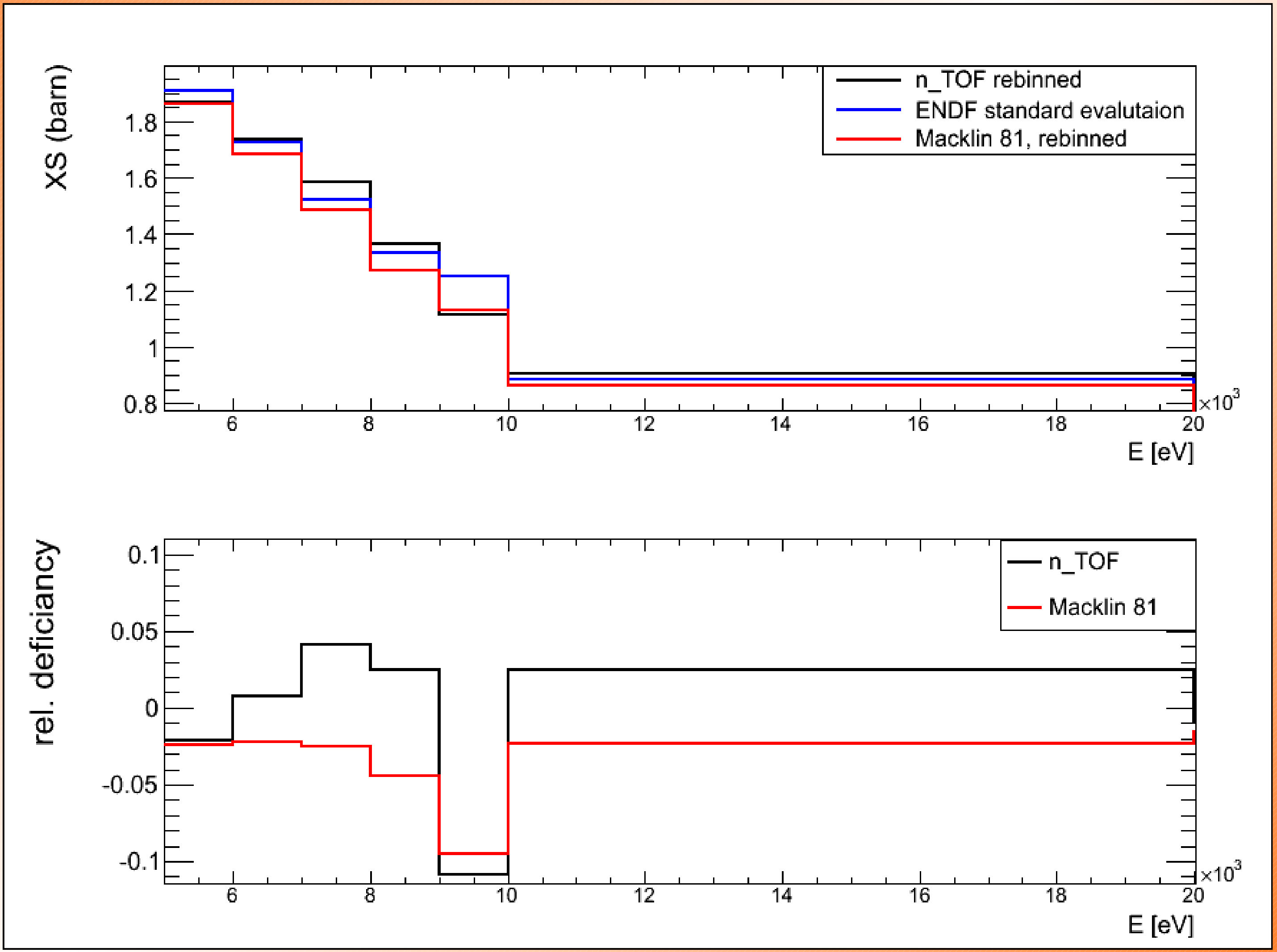
experimental



simulation

trial 3

Results:



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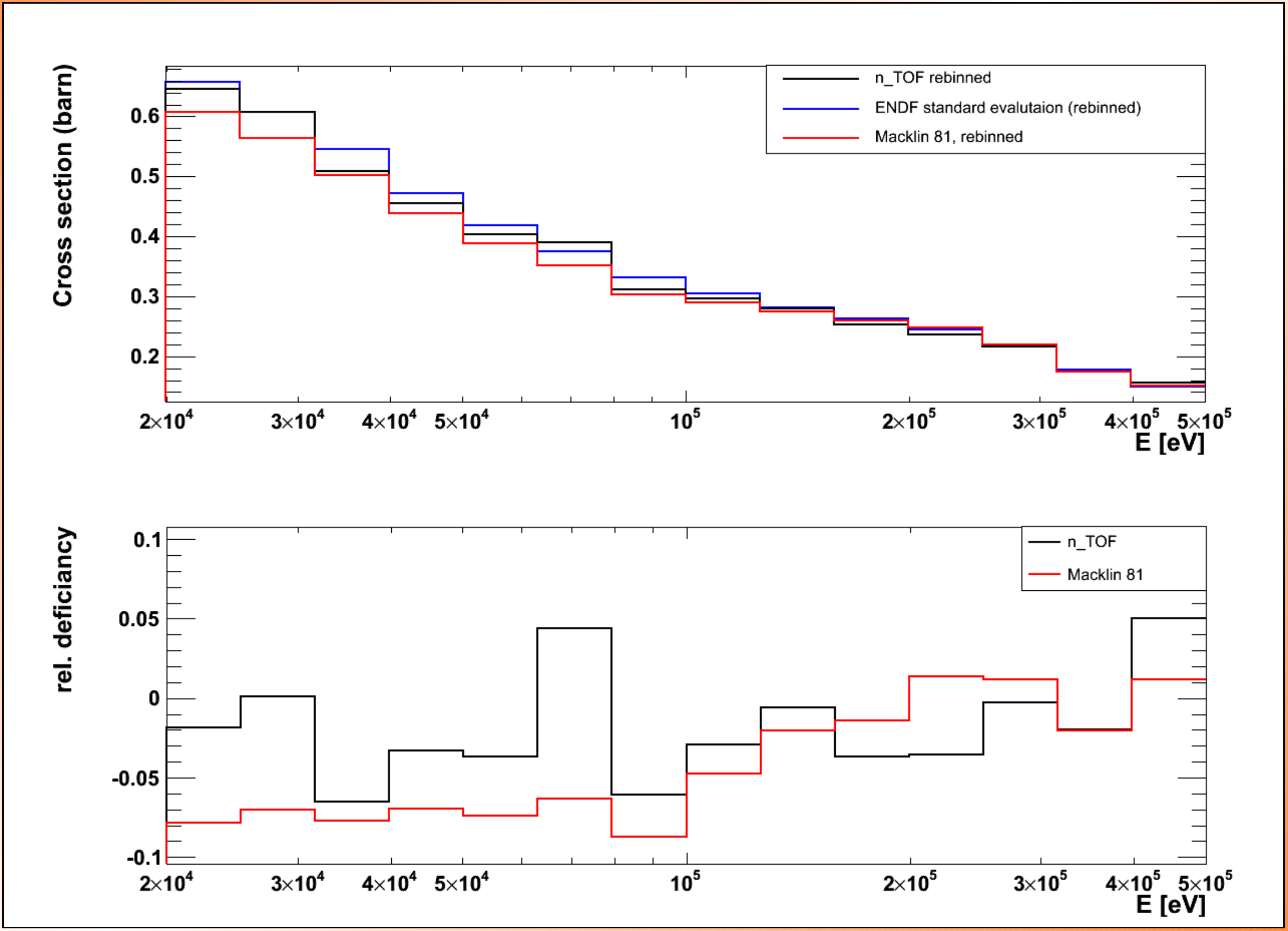
Results:

10 bpd



Cross-sections folded with Ratynski Käppeler spectrum:

- neutron energy from 5 keV

Macklin, 1981:	537 mb
ENDF/B-VII:	571 mb
ENDF std. eval.:	575 mb
n_TOF (preliminary):	564 ± 23 mb → 2% to ENDF std → 4.7% to Macklin

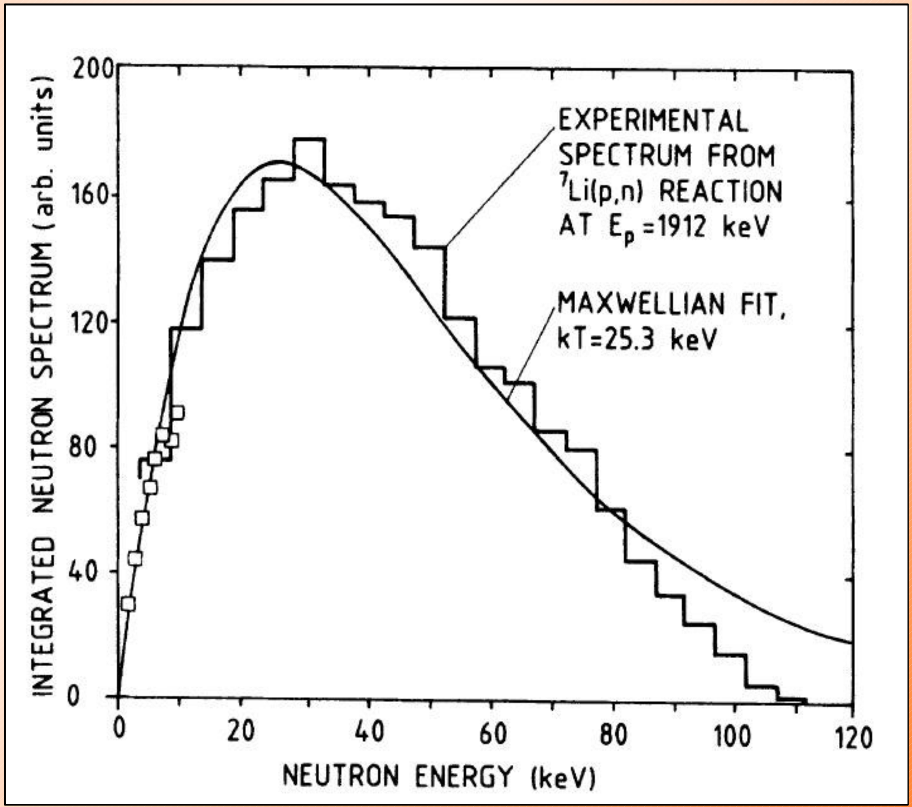
Measurement of the $^{7}Li(p,n)$ neutron spectrum with E_p=1912 keV at PTB

Physikalisch Technische Bundesanstalt
Braunschweig und Berlin

In collaboration with: I. Dillmann, U. Giesen, F. Käppeler, A. Mengoni, M. Mosconi, R. Nolte, A. Wallner

$^{7}Li(p,n)^{7}Be$ as neutron source

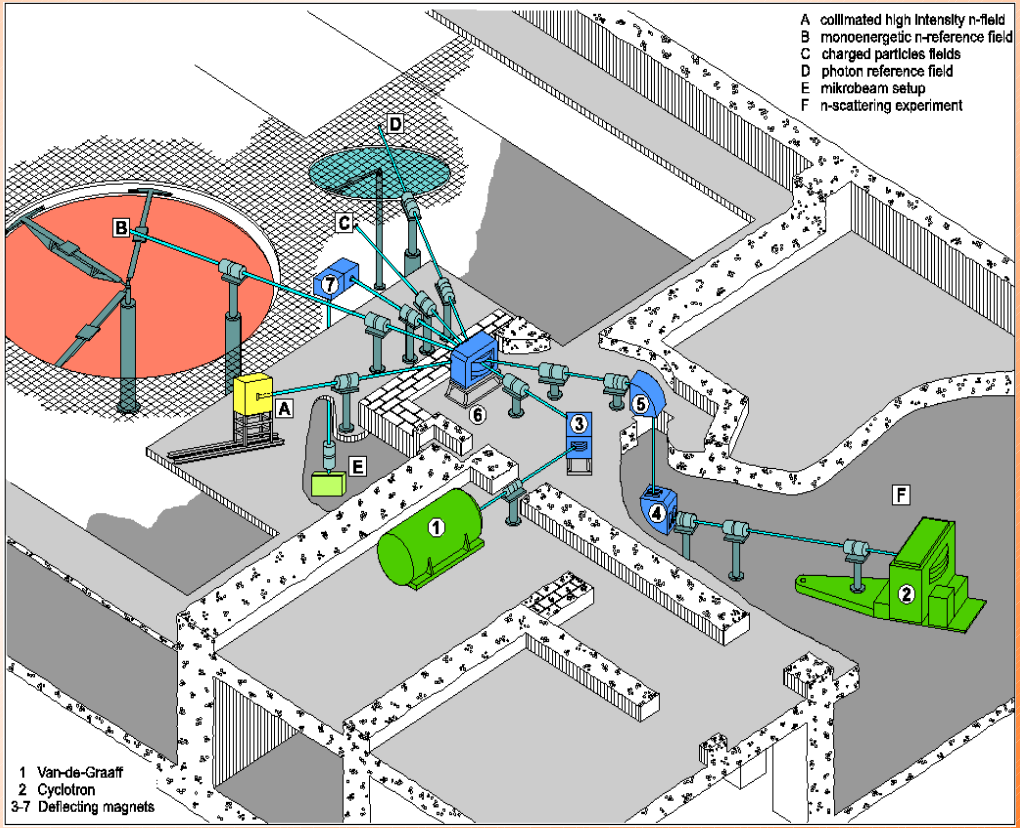
- for E_p=1912 keV → quasi-maxwellian energy distribution with kT=25 keV
- neutron emission: forward peaked with 120° opening angle
- Au(n,γ) cross section measured at KIT using this spectrum with 1.4% uncertainty



Ratynski and Käppeler, Phys. Rev. C **37** (1988)

Experimental setup at PTB

- calibrated setup for angular distribution measurements
- Proton source: 3.75 MV Van de Graaff
- E_p=1912±1 keV
- Repetition Rate: 0.625 MHz
- Pulse width (FWHM): 3ns
- Average proton current: 0.5-0.8 μA



Experimental setup at PTB

Target:

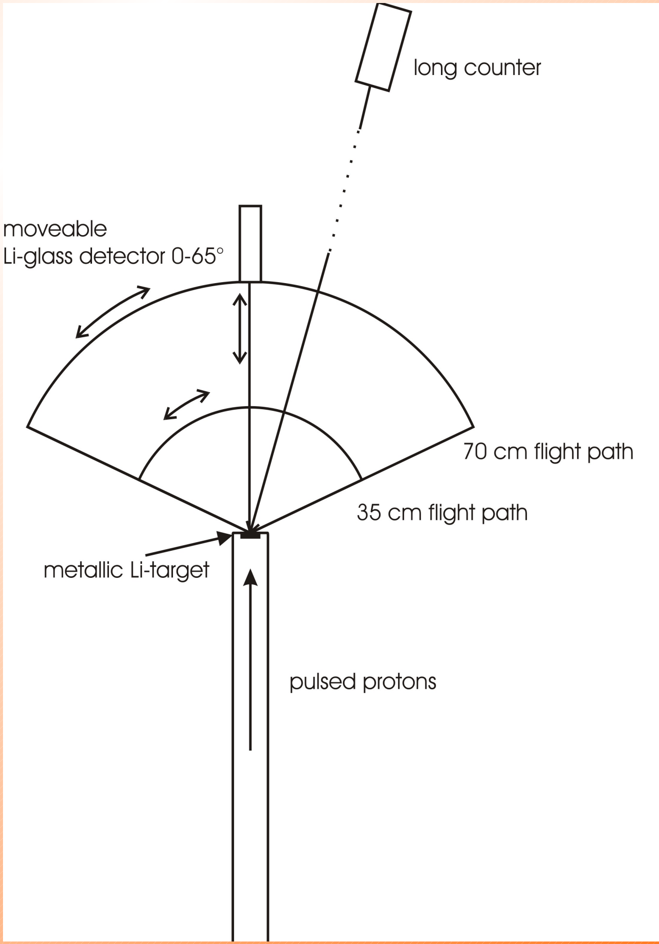
- Metallic Li evaporated on Ta
- 10 µm thickness (565 µg/cm²) → protons slowed down below reaction threshold (E_{thres}=1881 keV)

Positions:

- two flight paths: 35 cm and 70 cm
- angles: 0-65 deg, steps of 5 deg

Detectors:

- moveable Li-glass
- Long counter (fluence determination)



Data reduction

- dead-time correction and background subtraction
- time-of-flight to neutron energy conversion
- detection efficiency: $^{6}Li(n,t)^{4}He$ cross-section – standard (simulation underway)
- neutron fluence: long-counter
- solid angle correction

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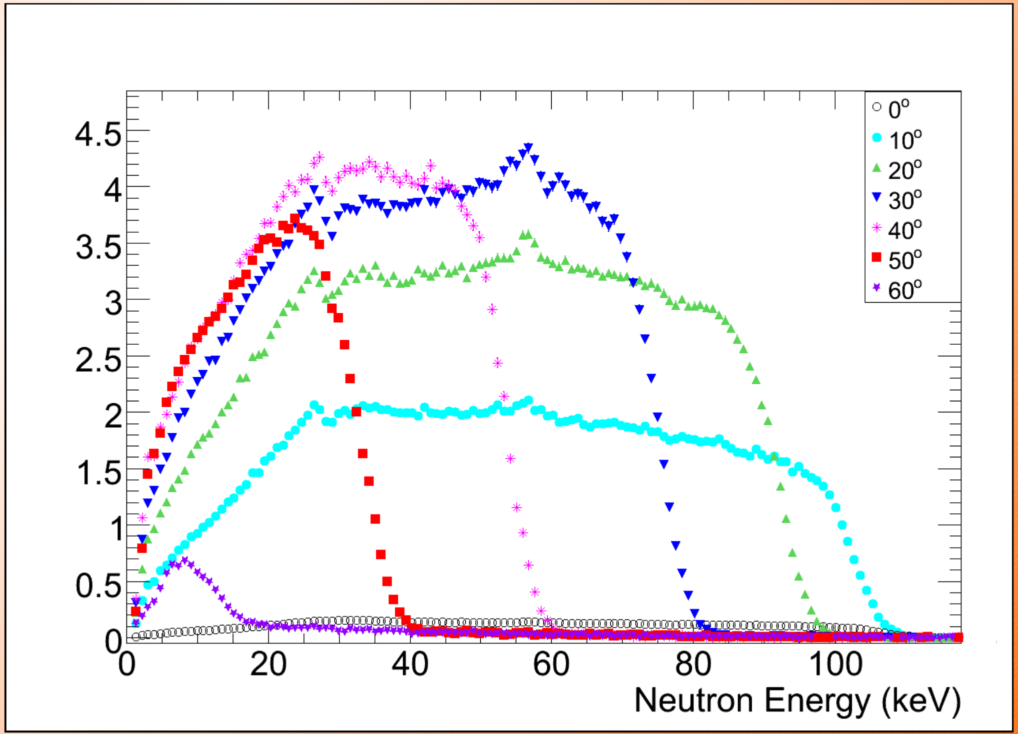

70 cm flight path

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Data reduction

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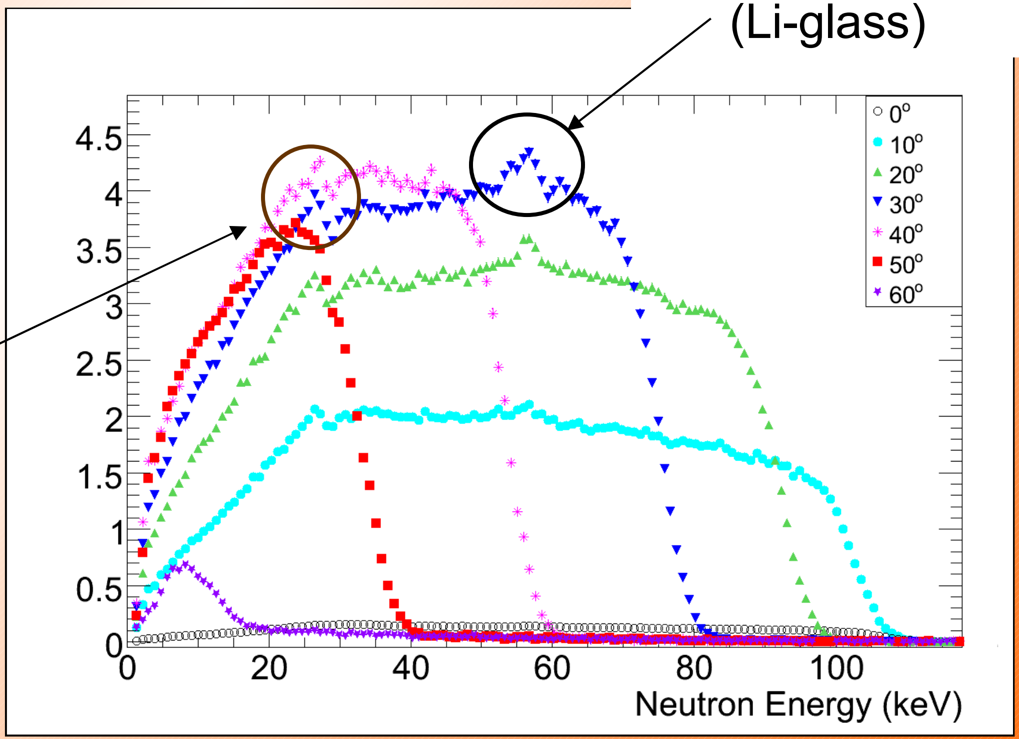
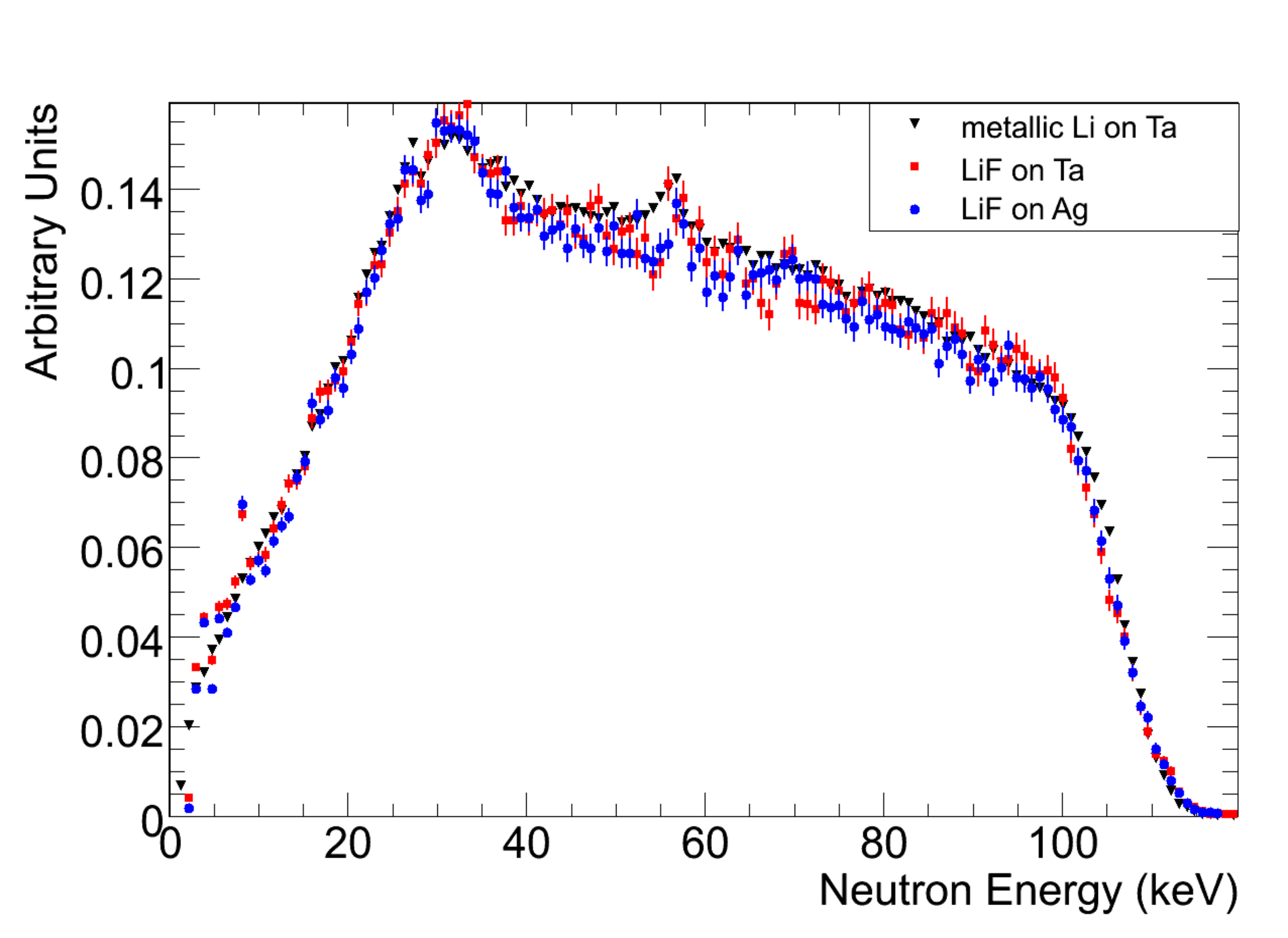
^{28}Si-resonance
(Li-glass)



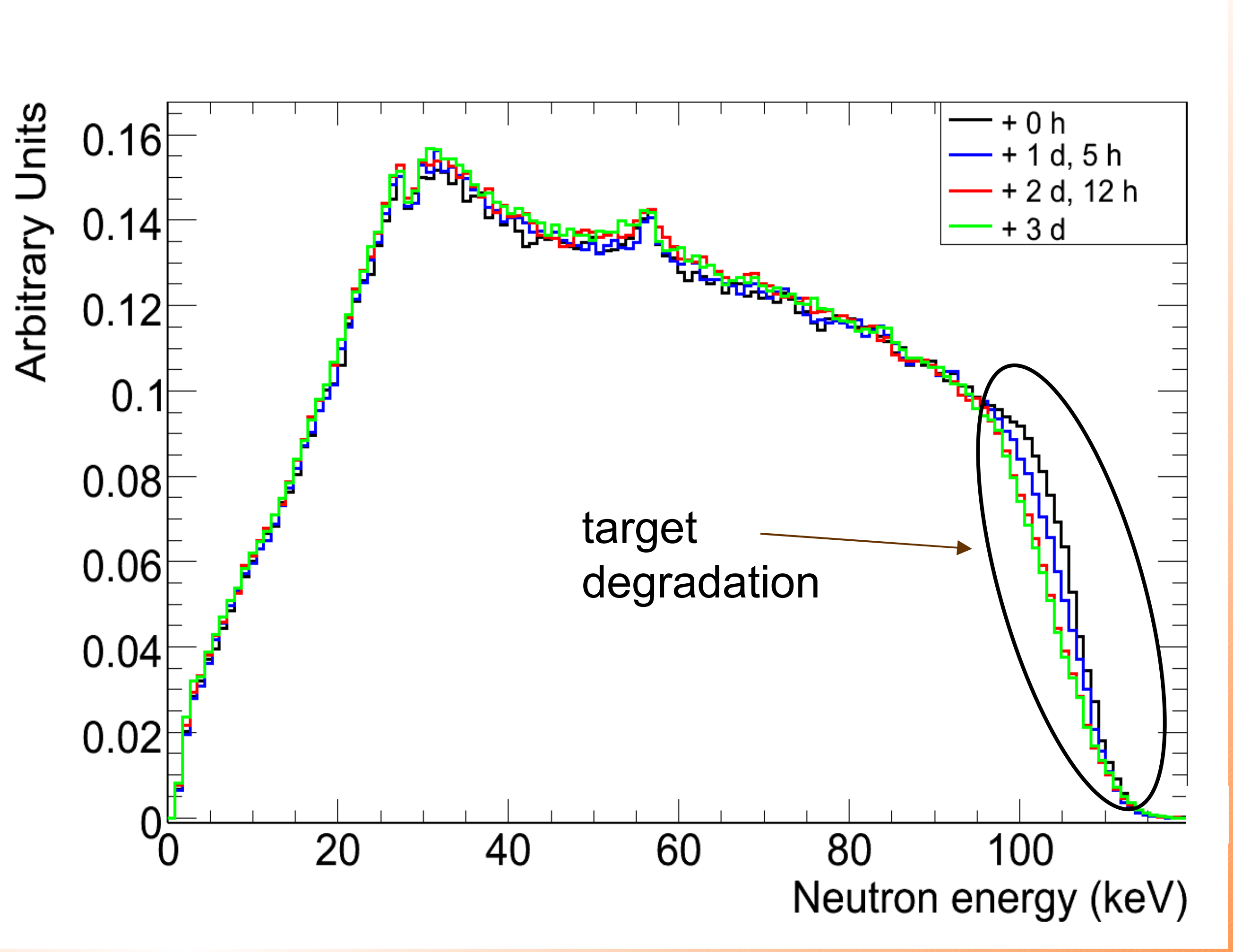
^{56}Fe-resonance
(detector cover)

70 cm flight path

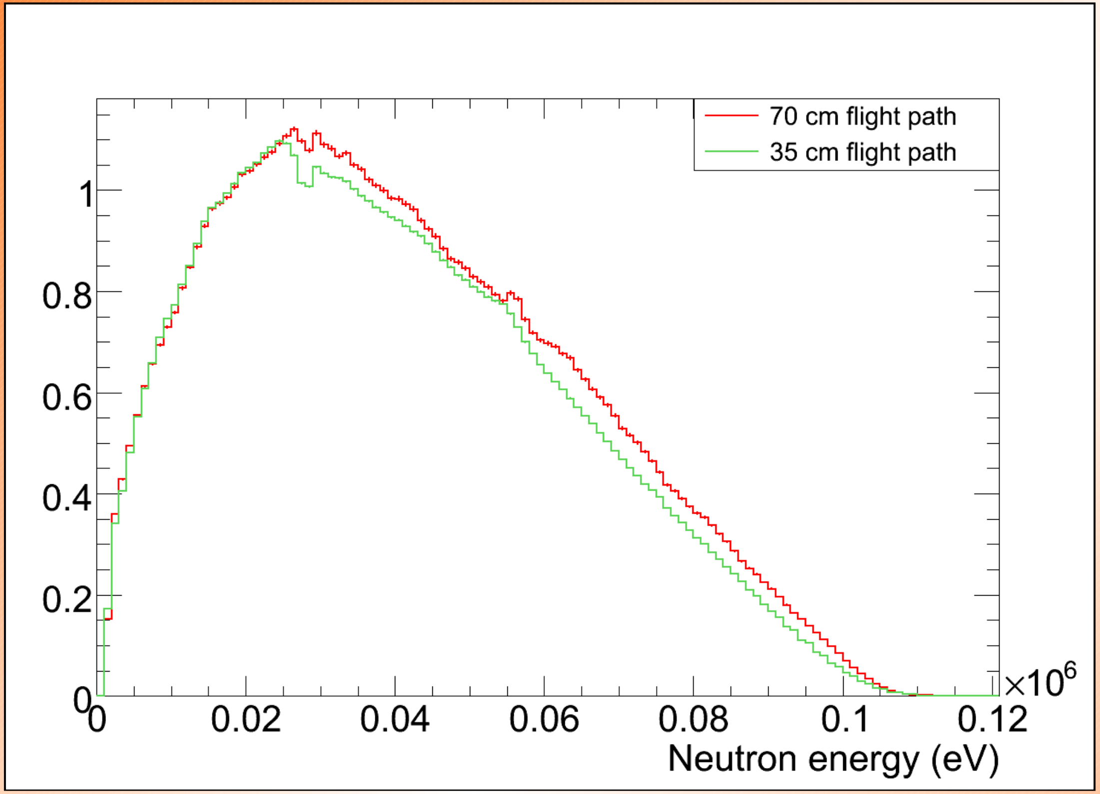
Reference Runs: different targets



Reference Runs: target stability

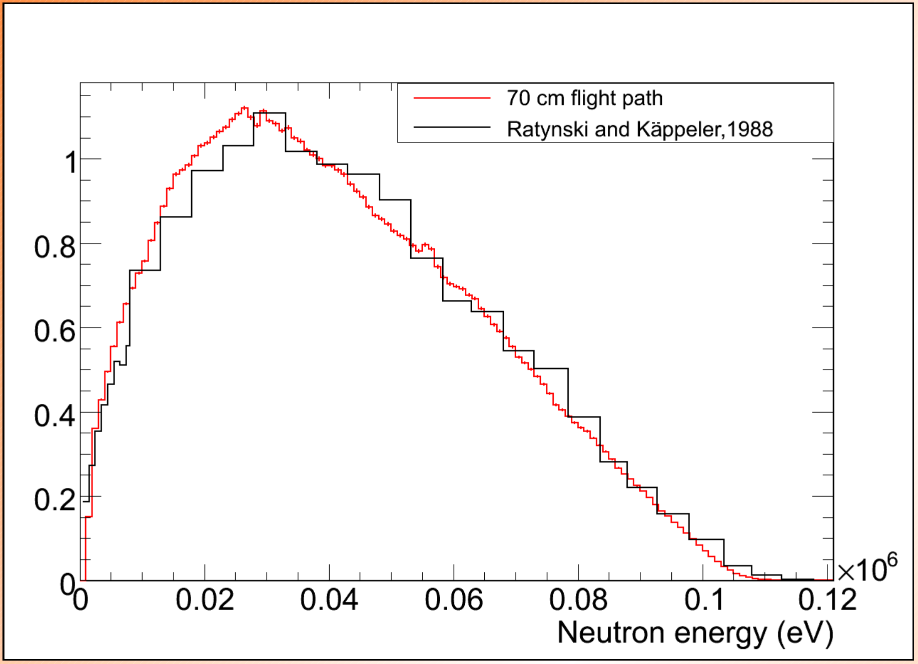


Summed spectra



- less high energy neutrons for 35 cm flight path
- reason still unclear, simulations of setup underway
- effect also visible at consecutive runs (→ probably not target degradation)
- overlap in solid angle for 35 cm

Summed spectra



- W. Ratynski and F. Käppeler, Phys. Rev. C **37**, 595 (1988)

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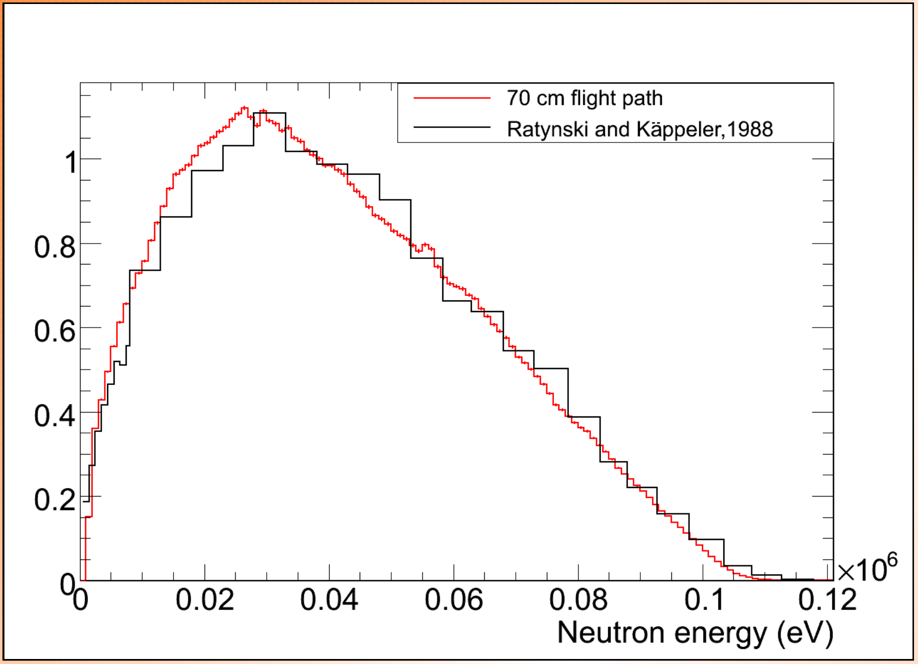
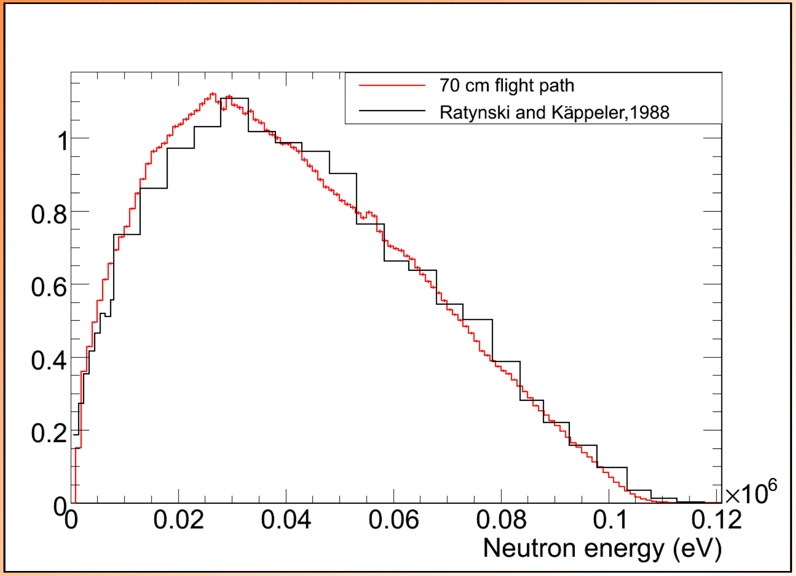
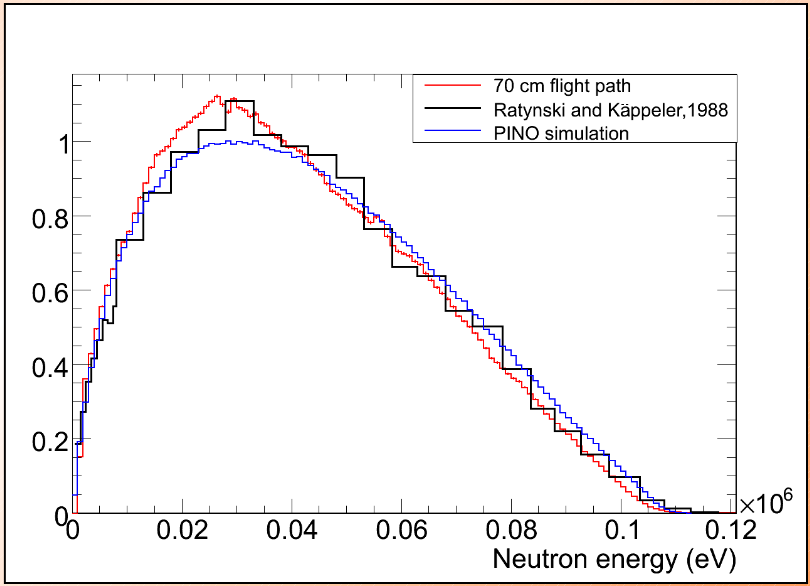


- $^{197}Au(n,\gamma)$ (ENDF-B7 library)
- 633 mb for Ratynski and Käppeler spectrum
- 630 mb for PTB spectrum
- only 0.5 % difference !

- W. Ratynski and F. Käppeler, Phys. Rev. C **37**, 595 (1988)

Summed spectra





- W. Ratynski and F. Käppeler, Phys. Rev. C **37**, 595 (1988)

- PINO- a tool for simulating neutron spectra resulting from the $^{7}Li(p,n)$ reaction, R. Reifarth et al. , Nucl. Instr. Meth. A 608, 139 (2009)

Conclusions

n_TOF measurement

- preliminary results of Au(n,γ) cross section measured at n_TOF more in favour of the ENDF standard evaluation,
- Uncertainty in n_TOF measurement of 5% could be reduced (check with different detection thresholds)

PTB measurement

- ^{7}Li(p,n) spectrum measured at PTB shows small differences, but effect on averaged Au cross section only 0.5%, since cross section is very smooth in this energy region.
- MC simulations of exp. setup at PTB underway → changes in results are still possible