

Total neutron cross section for ^{181}Ta

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Forschungszentrum
Dresden Rossendorf

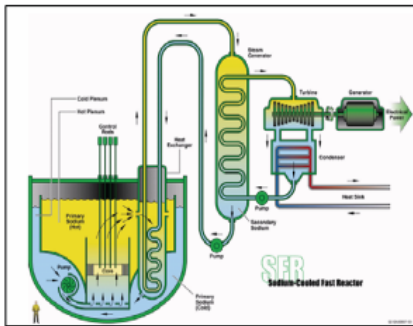
- Motivation
- Experimental setup
- Busy – time per channel correction
- Experimental data



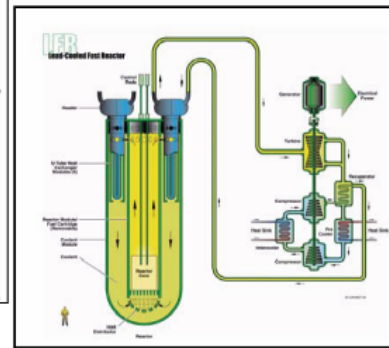
^{181}Ta in GEN IV nuclear power plants



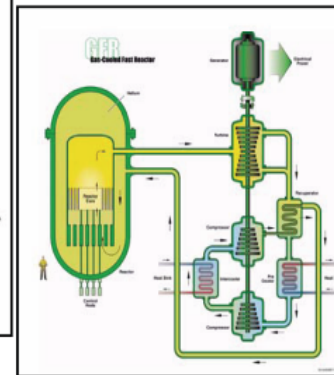
- GEN IV nuclear power plants will have capabilities for transmutation of nuclear waste.
- 3 of 6 recommended systems will work with fast neutrons
- ^{181}Ta , melting point 3290 K,
- Resistant to corrosion by acids
- There are no high resolution data for neutrons below 0.7 MeV



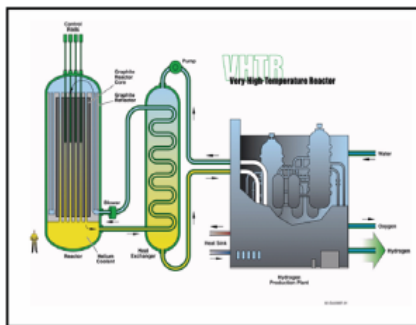
Sodium Fast Reactor



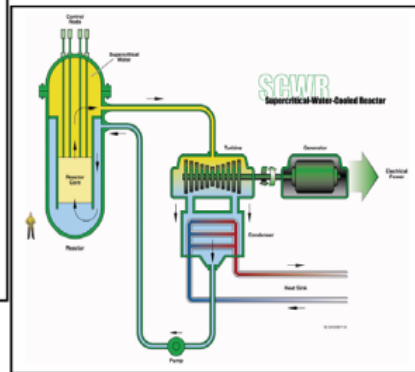
Lead Fast Reactor



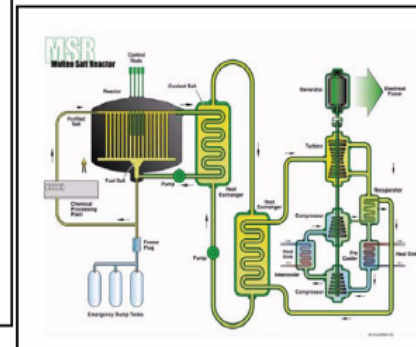
Gas Fast Reactor



Very High Temperature Reactor



Supercritical Water Reactor



Molten Salt Reactor

Neutron total cross-section σ_{TOT} gives the probability of a neutron to undergo any sort of reaction:

- radiative capture (n, γ)
- elastic scattering (n, n')
- inelastic scattering ($n, n' \gamma$)
- Fission
- (n, α), (n, p) reactions

$$\sigma_{TOT} = \sum_i \sigma_i$$

Usually measured by transmission experiments

$$I_{target} = I_{empty} \cdot \exp(-\sigma_{TOT}(E) \cdot n \cdot d)$$

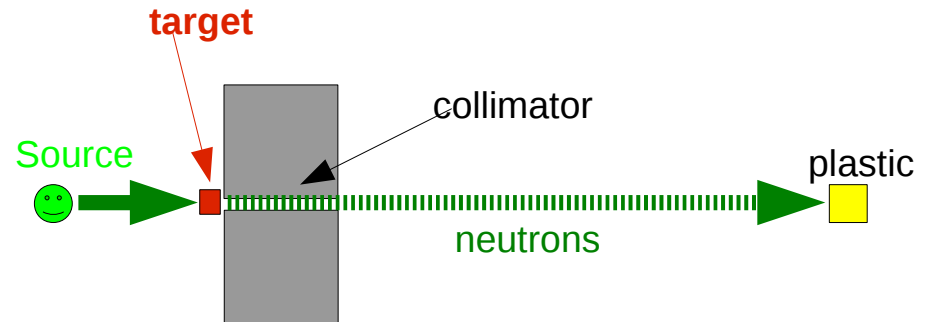
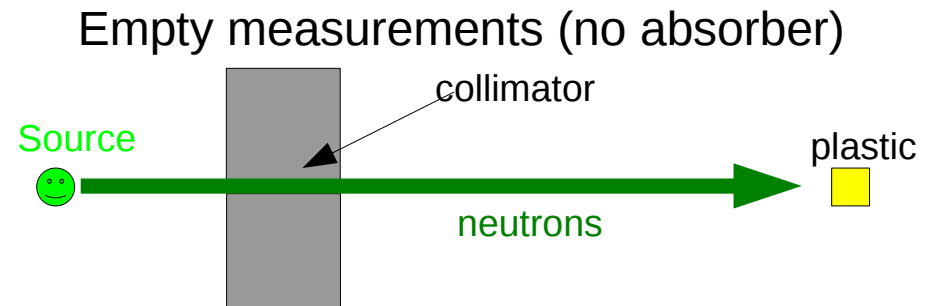
$$\text{target particle density } n \cdot d = \frac{\rho}{M} \cdot N_A \cdot d$$

ρ – target density

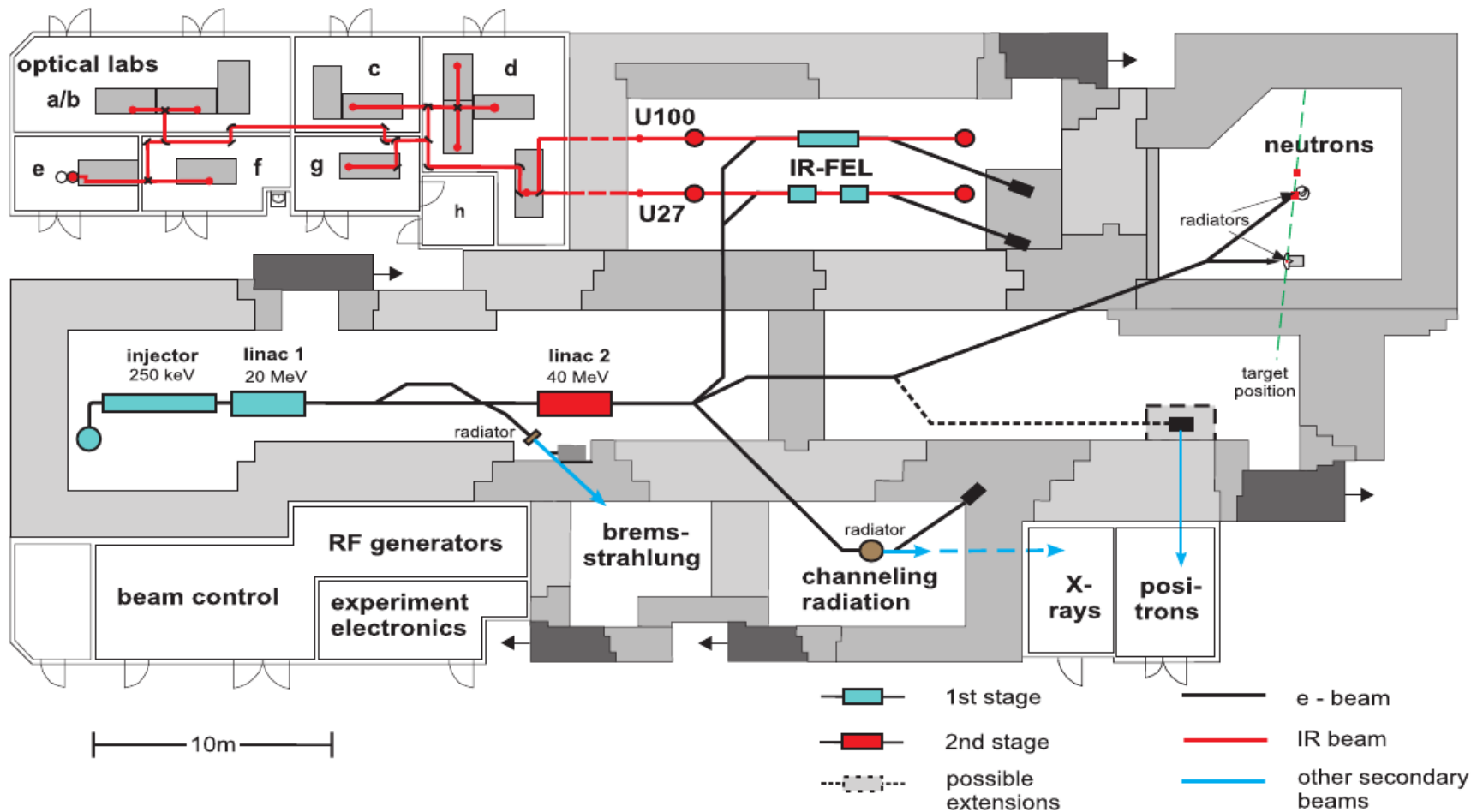
M – molar mass of the target

N_A – Avogadro constant

d – target thickness

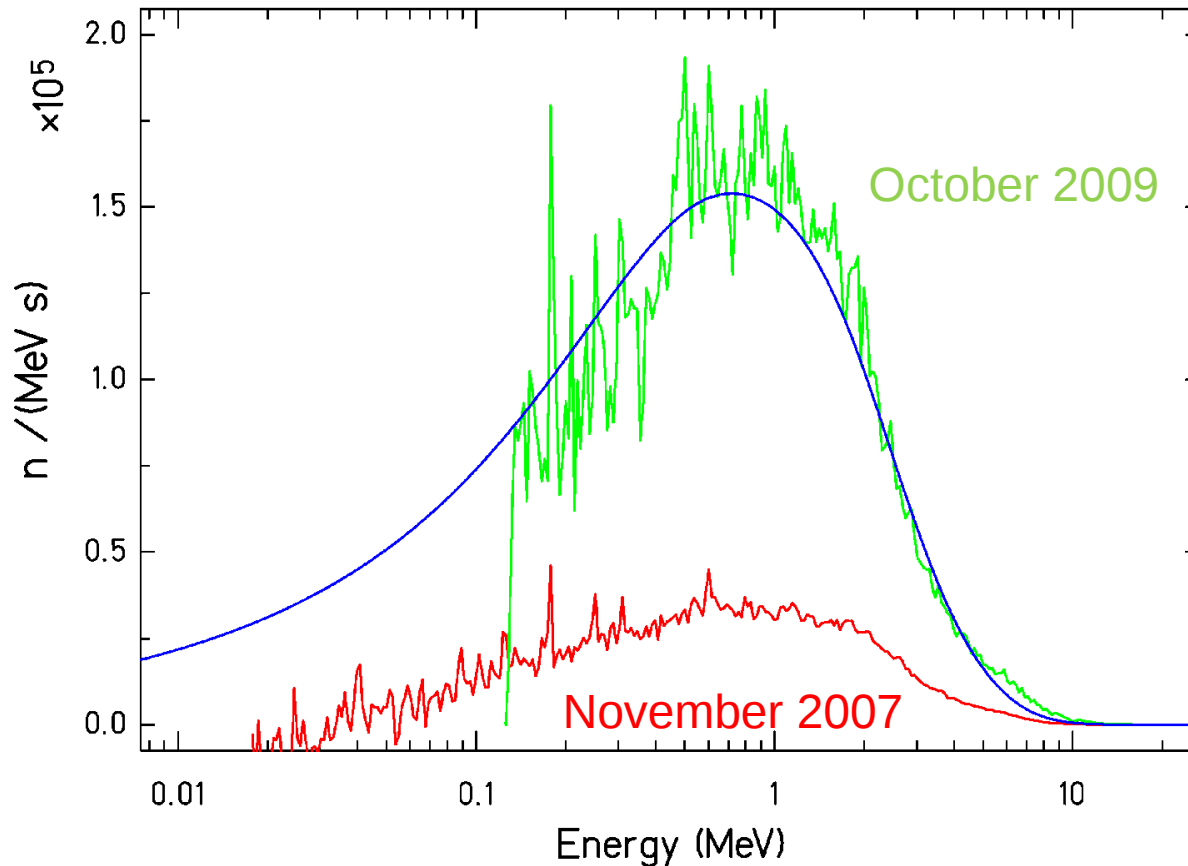


Electron Linear accelerator of high Brilliance and low Emittance



nELBE – photoneutron source



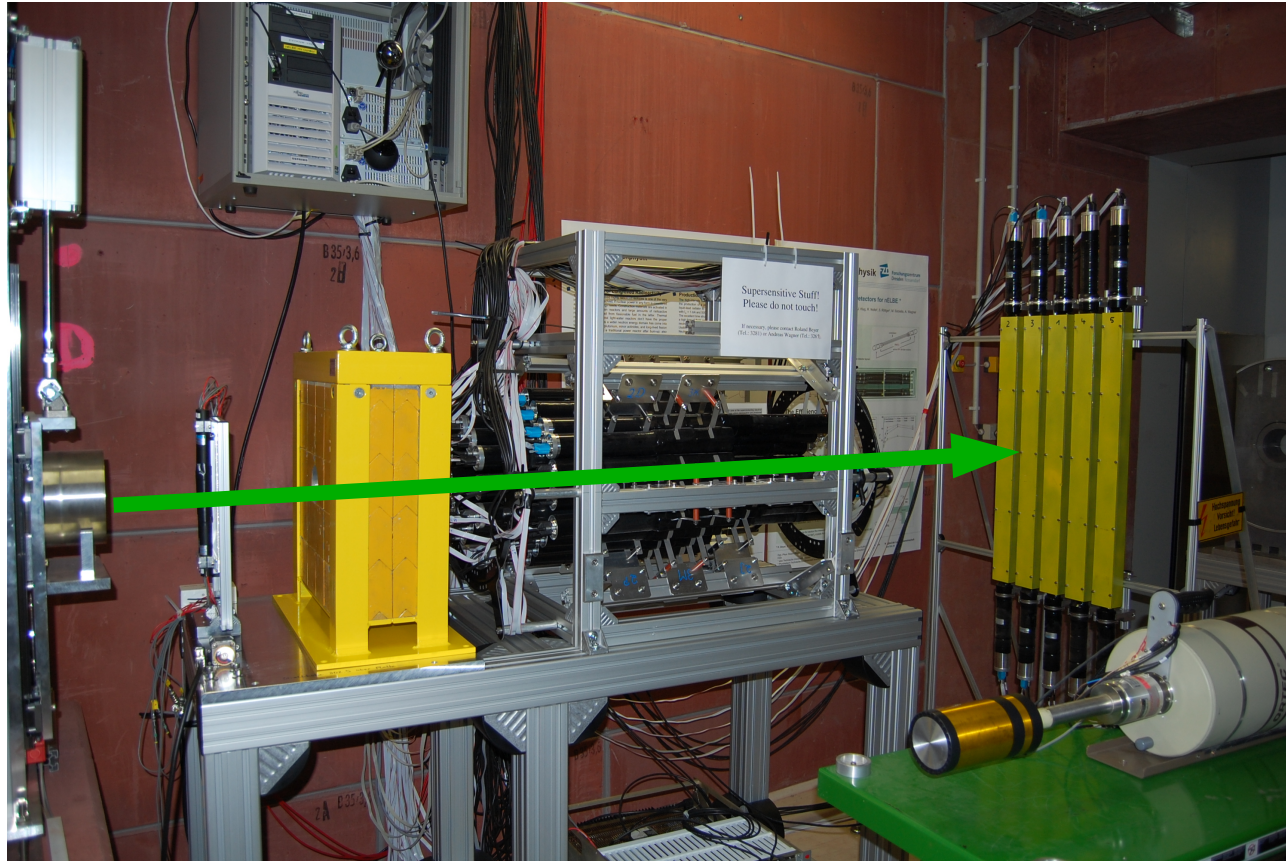


Measured with
 ^{235}U fission chamber
 $\Delta t(\text{FWHM}) = 4 \text{ ns}$
 $n_t = 5 \text{ mg/cm}^2$

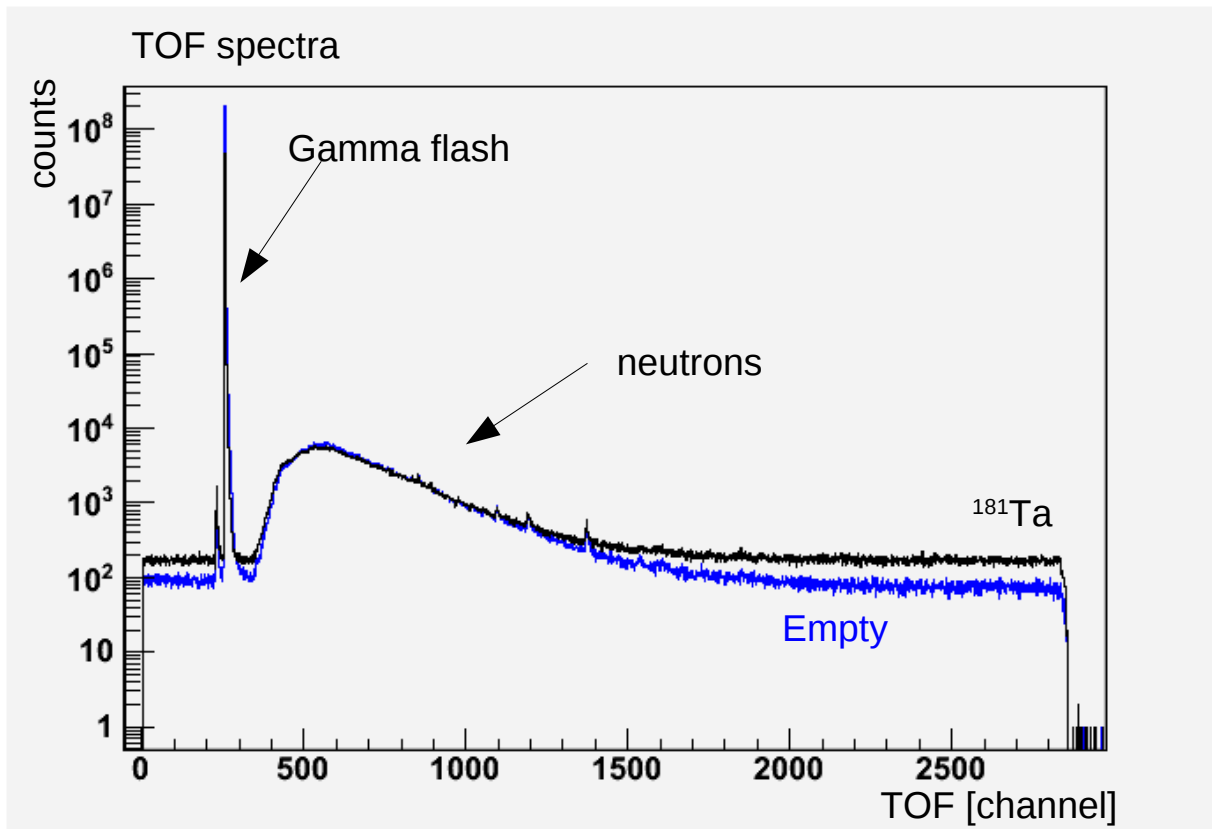
28.10.2009:
neutron source strength:
 $1.4 \cdot 10^{11} \text{ n/s}$
neutrons on target:
 $4.5 \cdot 10^4 \text{ n/(cm}^2 \text{ s)}$

$\langle I_{e^-} \rangle = 19 \mu\text{A}$
Max. thermionic injector
at 200 kHz rate

Fission chamber as primary beam monitor (from PTB, Braunschweig)
Spectrum is very similar to fast neutron spectrum e.g. $^{235}\text{U}(n,f)$ (ENDF-VII)



- Accelerator frequency ~ 101 kHz or 202 kHz
- 32 MeV e^- beam
- Trigger rate for empty measurements 28 kHz
- Trigger rate for ^{181}Ta absorber measurements 3.5 kHz



Without an absorber

$$T_{\text{live}} \approx 36 \%$$

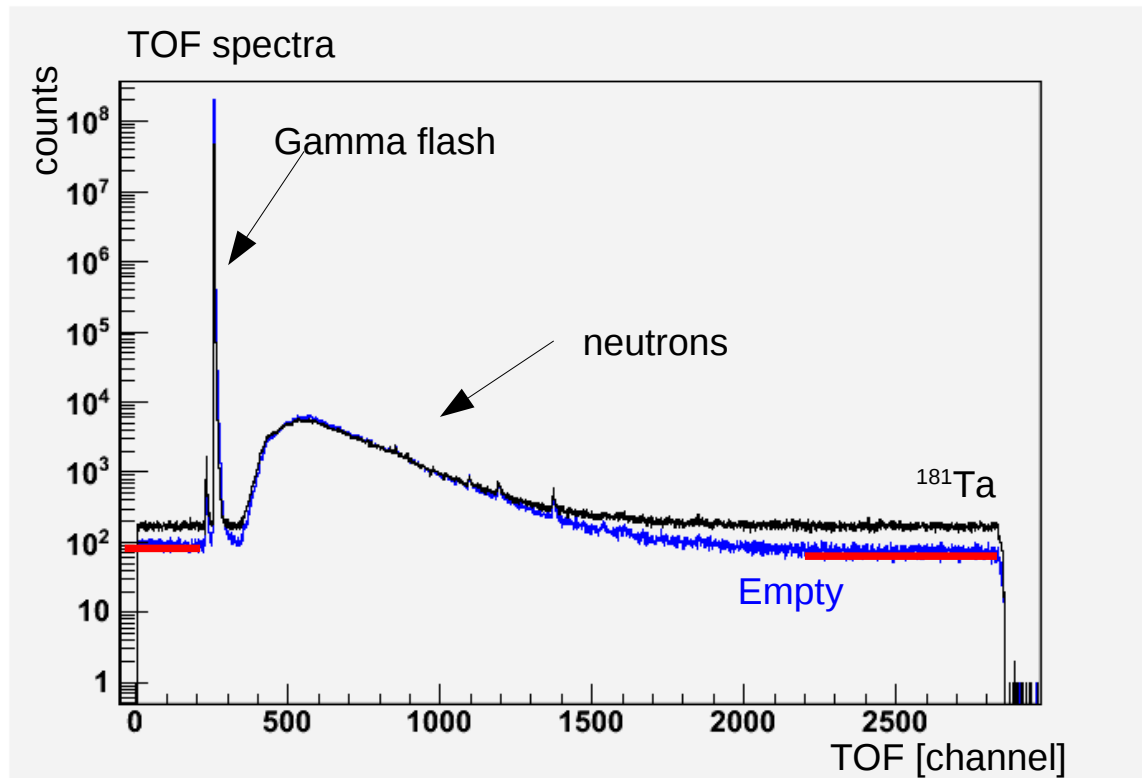
2.55 cm ^{181}Ta absorber

$$T_{\text{live}} \approx 83 \%$$

Spectra are completely dominated by gamma flash:

Without absorber neutron/gamma ratio: $\sim 0.7 \%$

^{181}Ta target neutron/gamma ratio $\sim 3.2 \%$



No target

$T_{\text{live}} \approx 36 \%$

2.55 cm ^{181}Ta absorber

$T_{\text{live}} \approx 83 \%$

No target neutron/gamma
ratio: $\sim 0.7 \%$

^{181}Ta target neutron/gamma
ratio $\sim 3.2 \%$

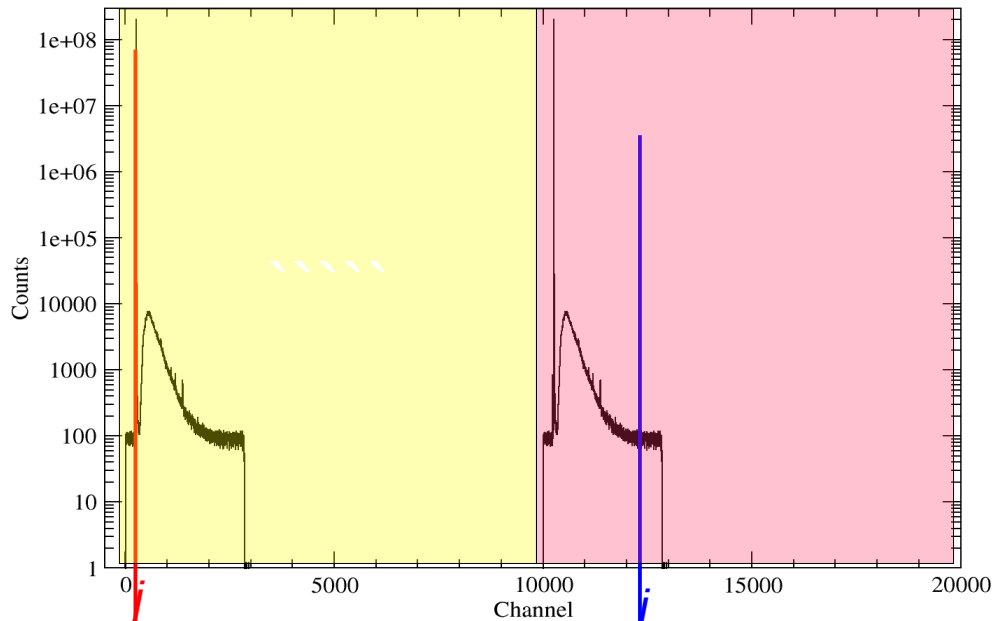
Background levels before gamma – flash and after “slow” neutrons ($E < 10$ keV) are not same.

For no target measurements they differ $\sim 20 \%$.

For ^{181}Ta absorber measurements they differ $\sim 2\%$.

An effect dominated by count rate (gamma -flash)

Two TOF spectra are printed for an illustration

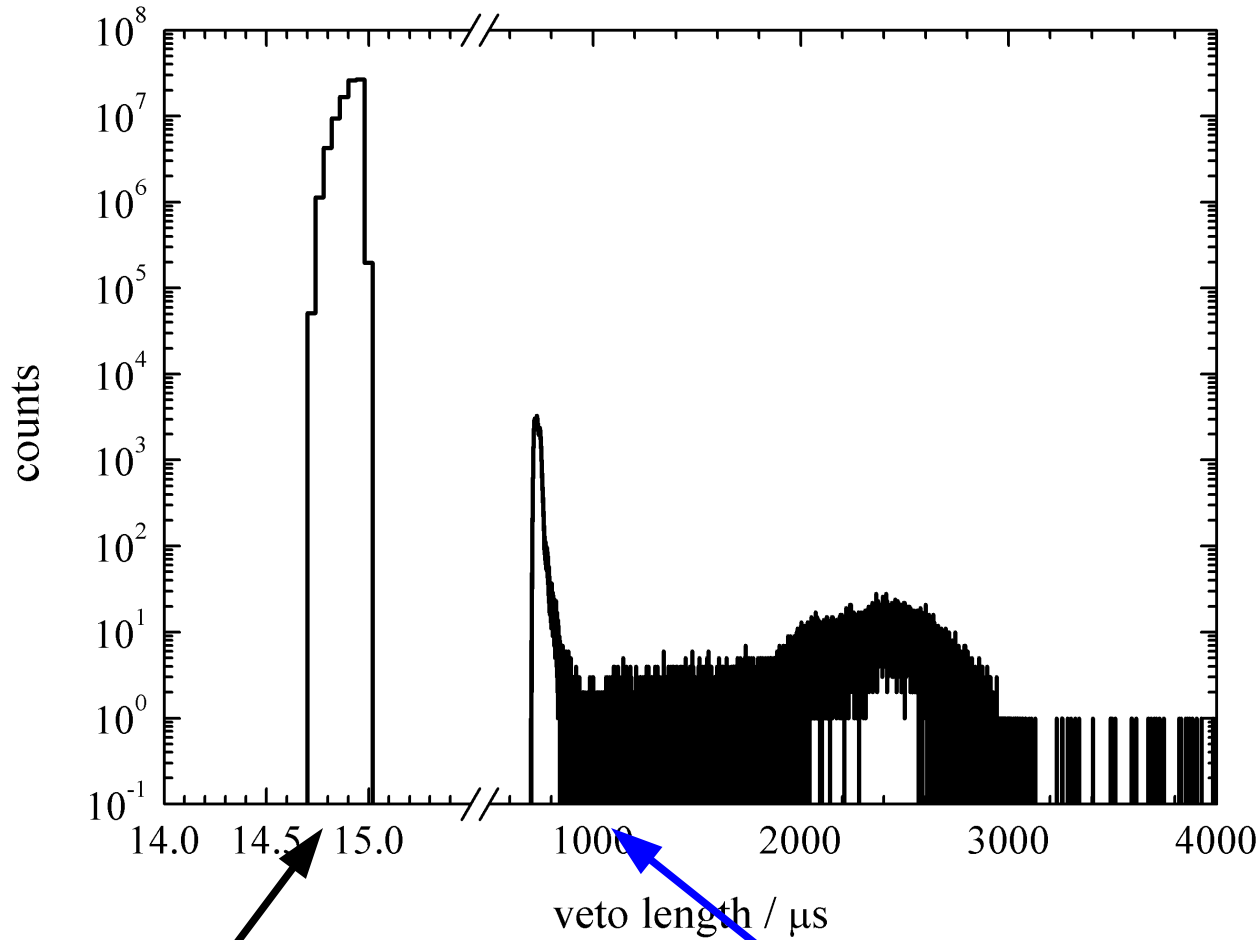


Period between 2 bunches is
 $10 \mu\text{s} \sim 10000$ channels



2 different DAQ systems are used for
nELBE experiments.

Mean conversion busy time for 1st DAQ $\sim 7.5 \mu\text{s}$,
Mean conversion busy time for the 2nd DAQ $\sim 14 \mu\text{s}$



Conversion busy time

Transfer busy time

$$I(i) = \frac{O(i)}{N_{acc} \cdot \alpha(i)}$$

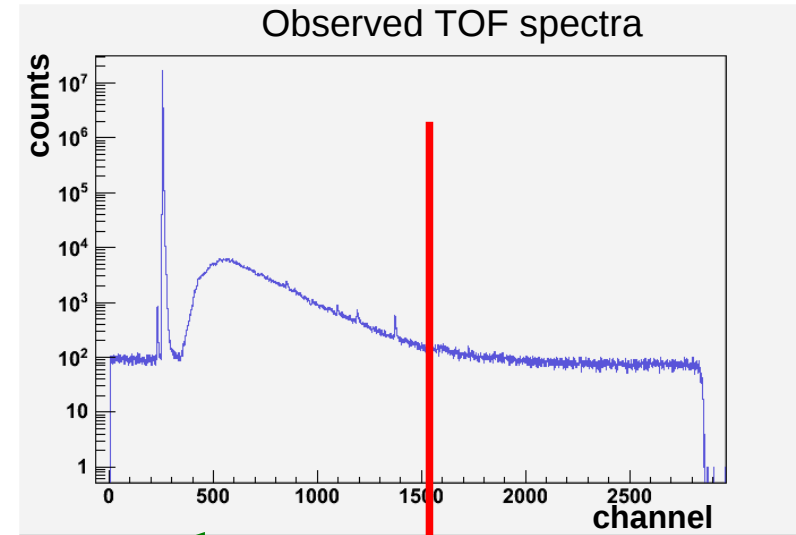
$O(i)$ – observed events in channel i

from observed spectra we need to recreate count rate per accelerator bunch

$\alpha(i)$ – fraction of bunches when detection is possible

$N_{acc} = T_{real} \cdot 101 \text{ kHz}$ – number of accelerator bunches

$I(i)$ – number of counts per accelerator bunch in channel i



Summing over channels which block channel i

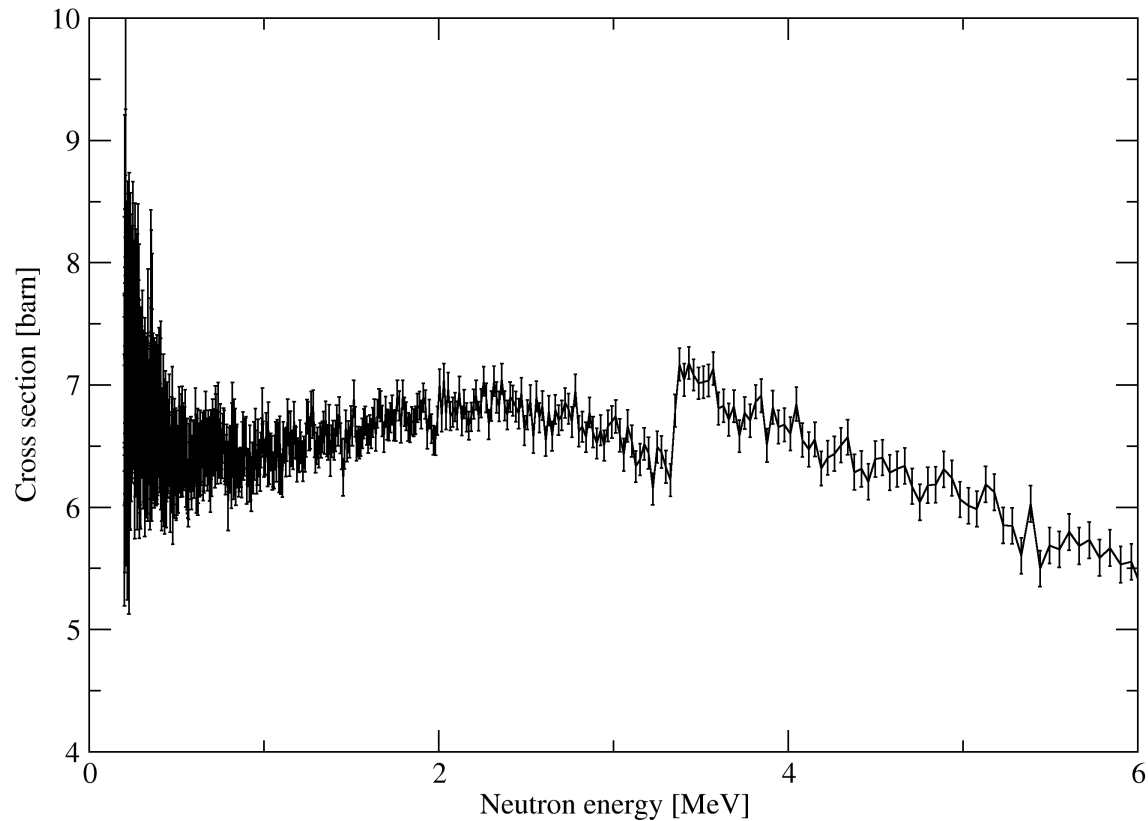
we use mean conversion busy time and mean transfer busy time for correction

$$T_{busy_time} = N_{trans_bunch} \cdot 750 \mu s + 7.5 \mu s \cdot \sum_{i=0}^{3000} O(i)$$

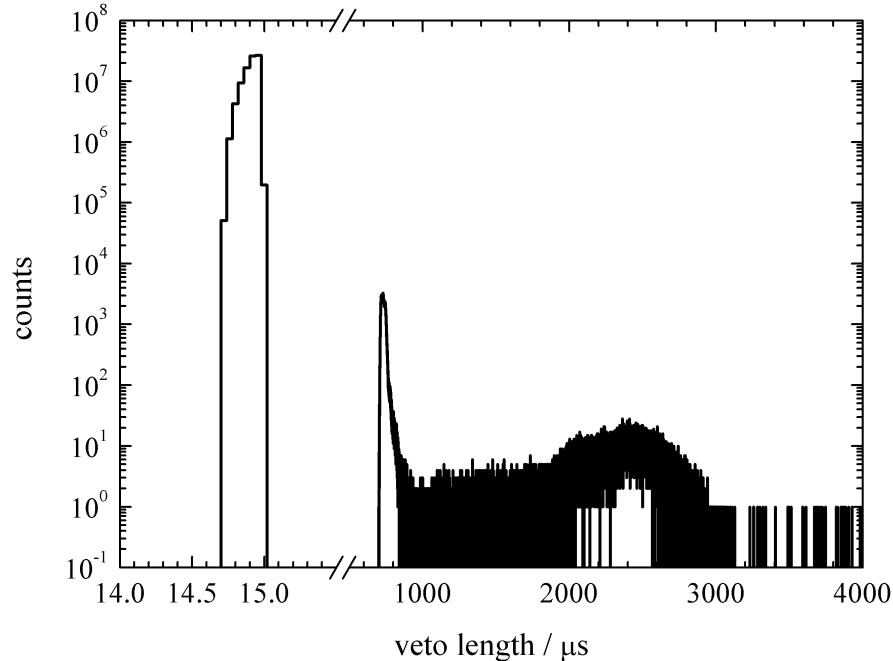
$$\alpha(i) = \frac{N_{acc} - N_{trans_bunch} - \sum_{l=i-k}^{i-1} O_l}{N_{acc}}$$

k – is the numebr of channels which are blocking channel i

Arbitrary taken 11 μ s dead time



Taken and average value of 11 μ s produce an artificial step in cross section, due to the gamma flash peak



we use randomly generated conversion busy time and uniformly distributed time transfer – busy, these busy time values are generated on base of simulated spectra

$$\alpha(i) = \frac{N_{acc} - N_{trans_bunch} - \sum_j N_{conversion_blocking_channels}(j)}{N_{acc}}$$

It is not possible to simulate 100% realistic spectra

Spectra changes with number of detectors, trigger levels and ..

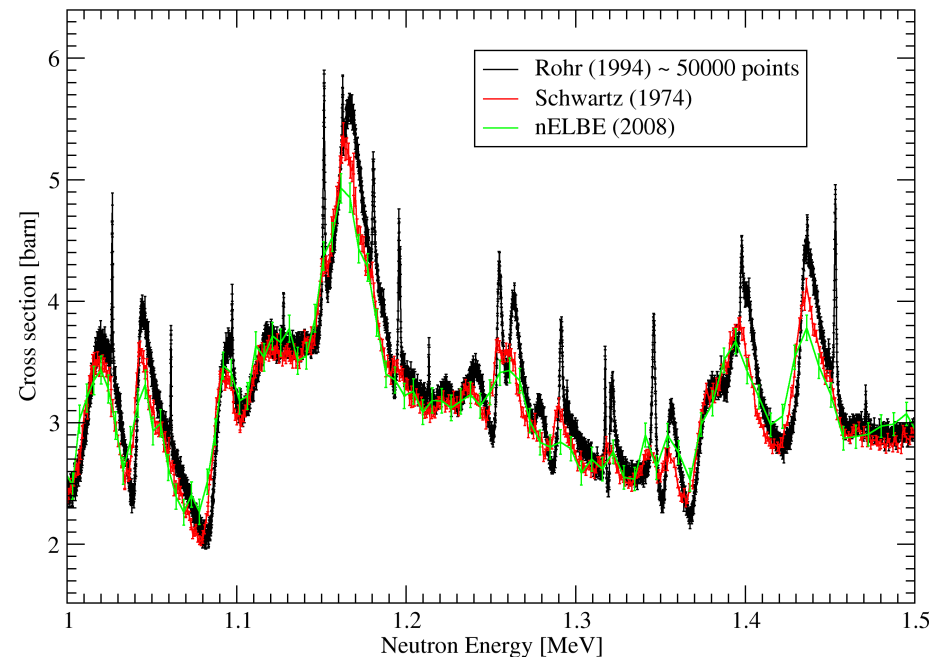
$$\frac{dI}{I} = -n \cdot \sigma_T \cdot dx \Rightarrow \frac{I}{I_0} = \exp(-n \cdot t \cdot \sigma_T) \text{ only if } \sigma_T \text{ is constant over a bin}$$

General case: $f(E)dE$ – fraction of incident neutrons with energy in range between E and $E + dE$

$$T = \int f(E) \exp[-n \cdot t \cdot \sigma_T(E)] dE \text{ sample of thickness } t$$

^{27}Al cross section varies a lot over one energy bin, our cross section is smaller than Geel measurements.

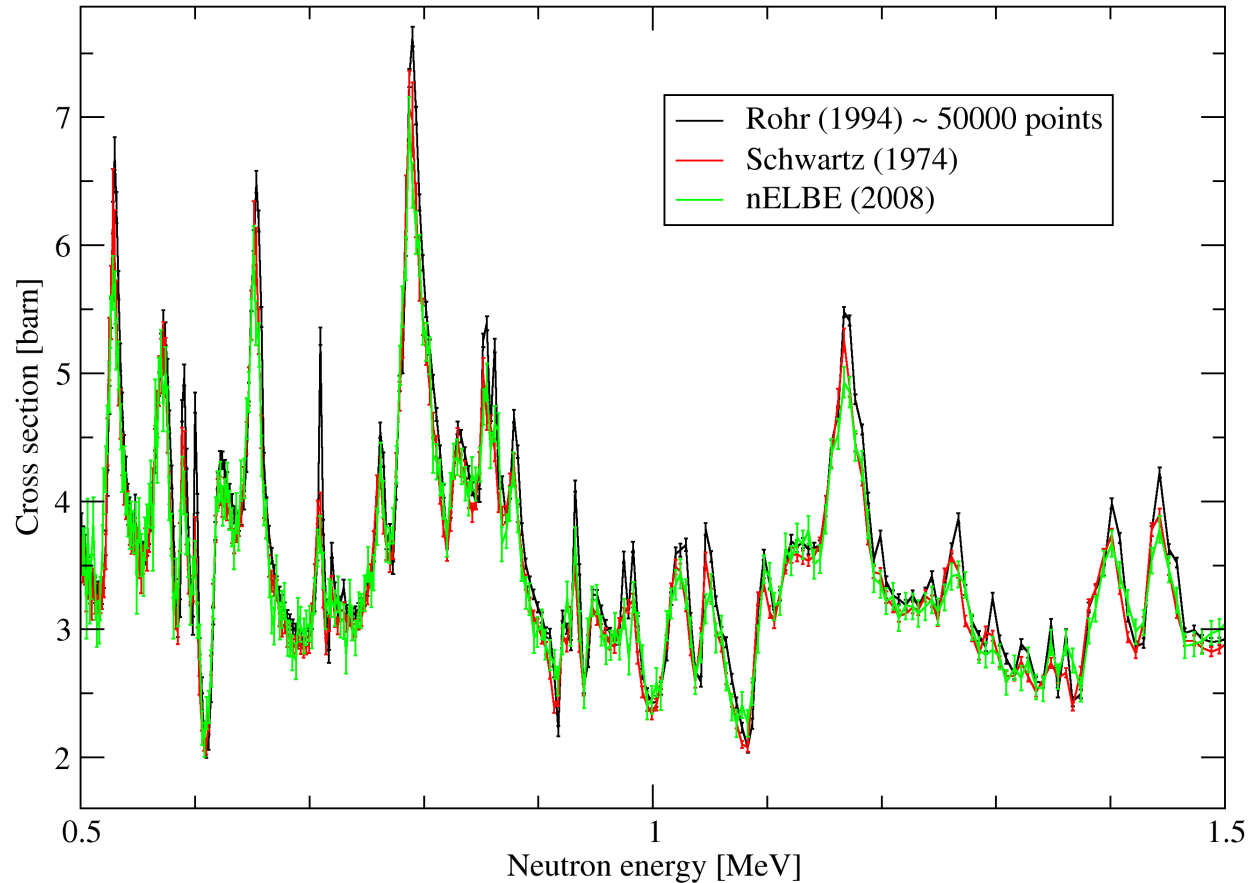
Hardening effect for ^{27}Al total cross section



We measured an “averaged” cross section for ^{27}Al . Schwartz data has closer energy resolution to our measurements.

Averaged neutron total cross section for ^{27}Al

Geel and Schwartz data are averaged on nELBE energy resolution



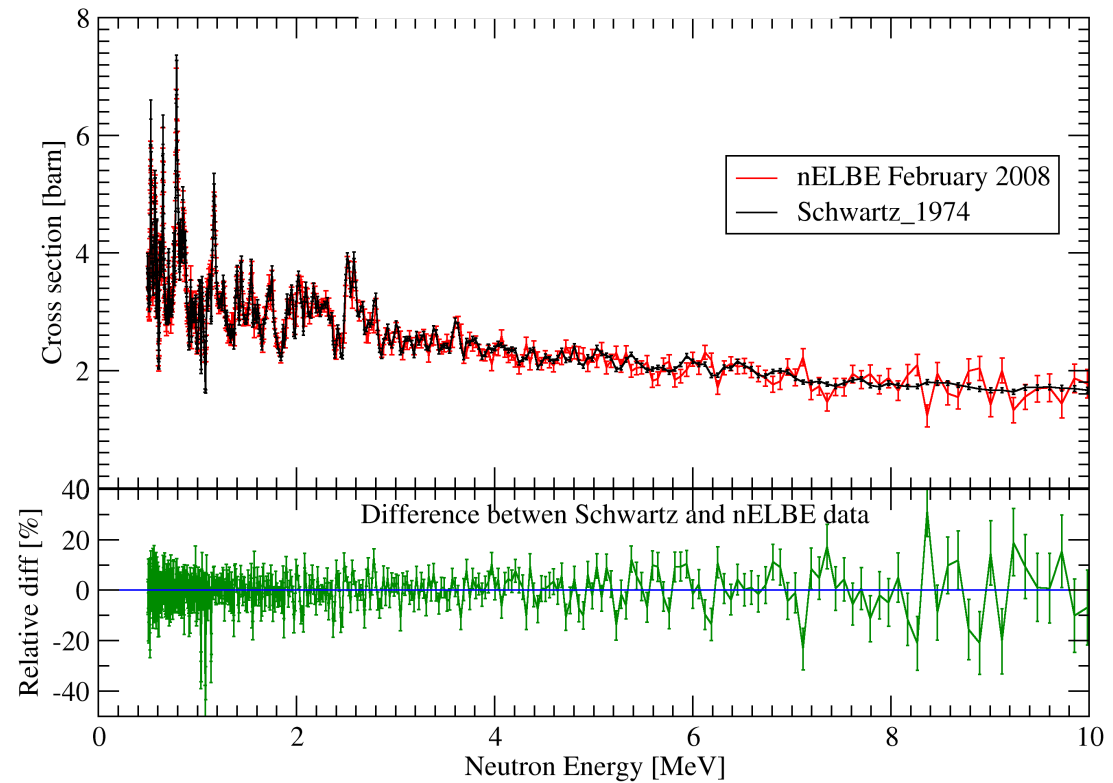
Conversion time of 7.5 μs , realistic.

I used 8 μs in order to ^{181}Ta be in better agreement

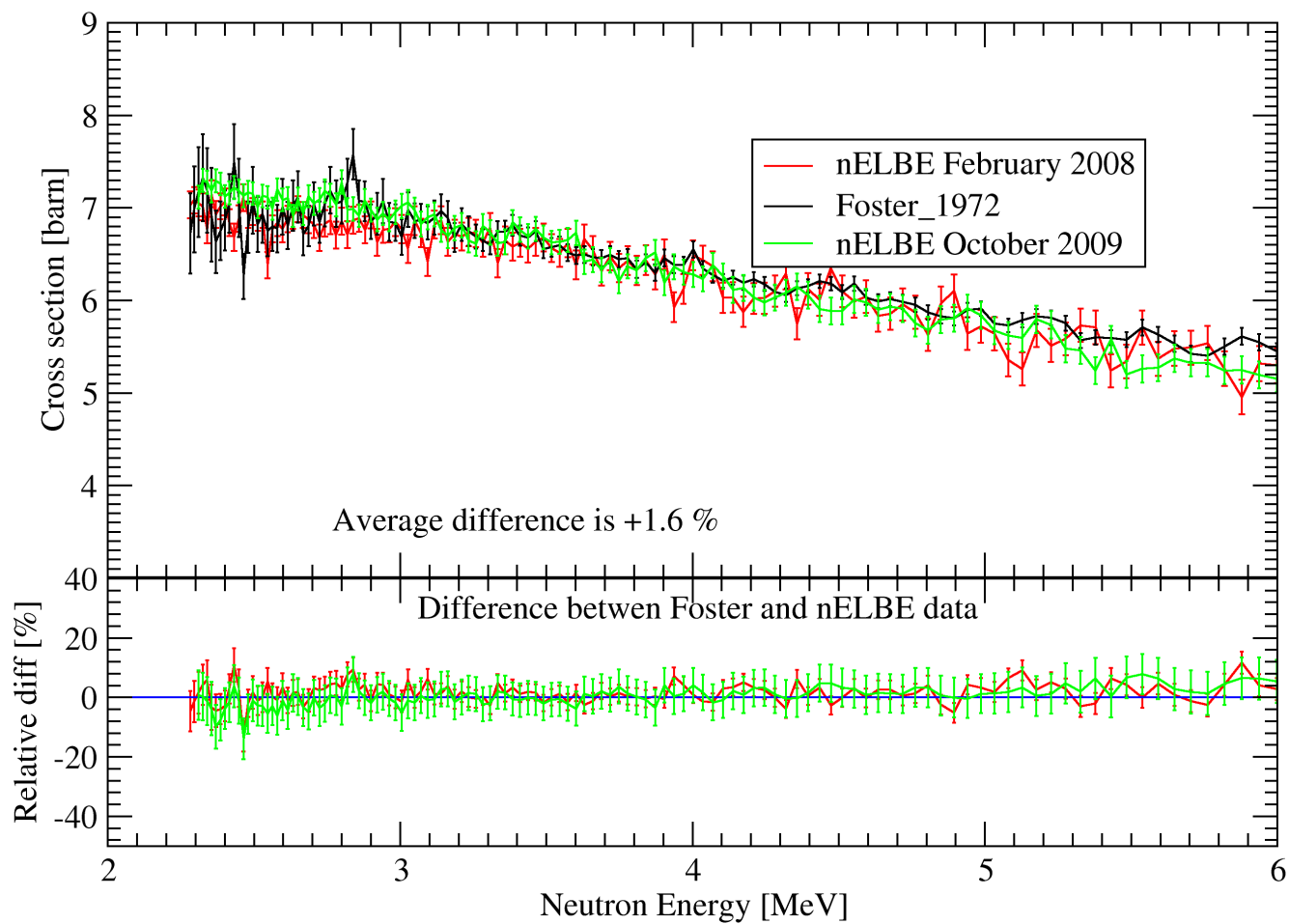
Average difference from Schwartz data:

For 8.0 μs : -0.7 %

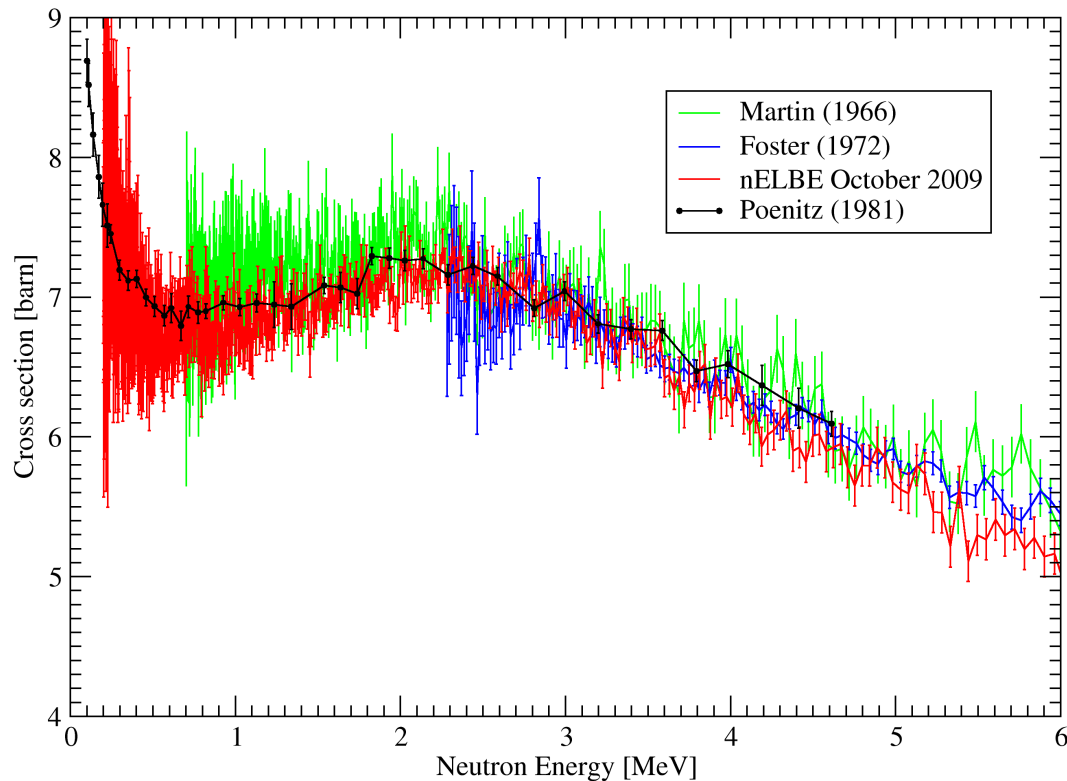
Total neutron cross section for ^{27}Al



Total neutron cross section for ^{181}Ta



Total neutron cross section for ^{181}Ta



Reference data are rebinned according to our energy resolution

After 30 h of beam time we obtained a statistical error between 3 % -8 % for an energy region 0.2 MeV – 0.8 MeV

- Sufficient statistics is accumulated in short measurement time
- Total neutron cross section measured for ^{181}Ta , ^{27}Al , natural C, PE
- Dead – time correction is used to analyze previous data
- Dead – time correction needs to be tuned
- We understand our TOF spectra
- **New DAQ system records records transfer dead time and conversion dead time**
- **For new experiments we do not need this complicated procedure (A. Junghans $^{56}\text{Fe}(n,n')$ measurements)**
- Total neutron cross section for ^{197}Au is planed

