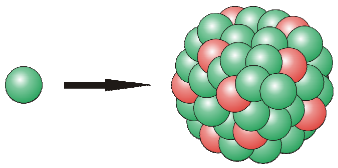
First measurements of inelastic scattering at nELBE

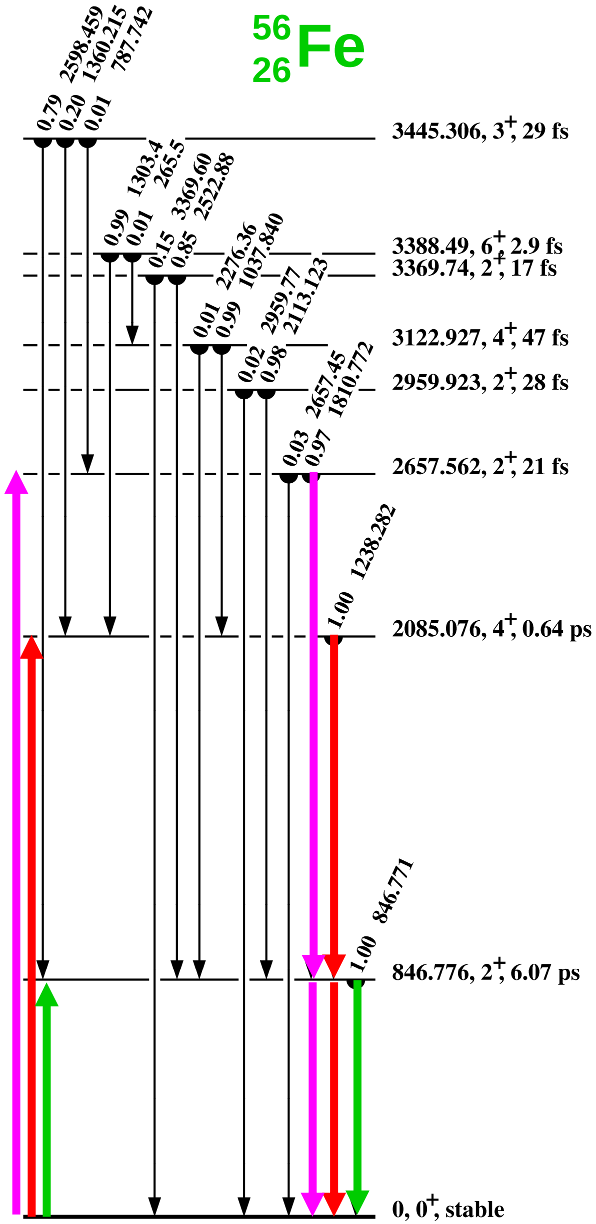
Roland Beyer

Outline

- Inelastic Scattering
- nELBE source
- nELBE detector setup and electronics
- Experimental results on ^{56}Fe
- Outlook

Inelastic neutron scattering





usual way to measure → detect emitted γ-ray

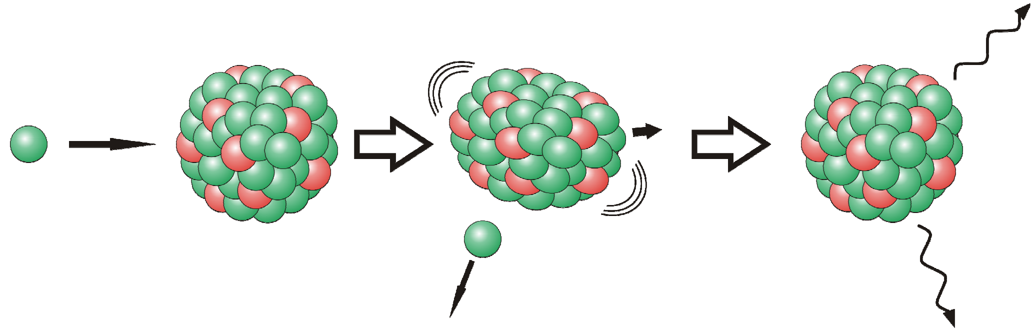
→ Problem: Ambiguity

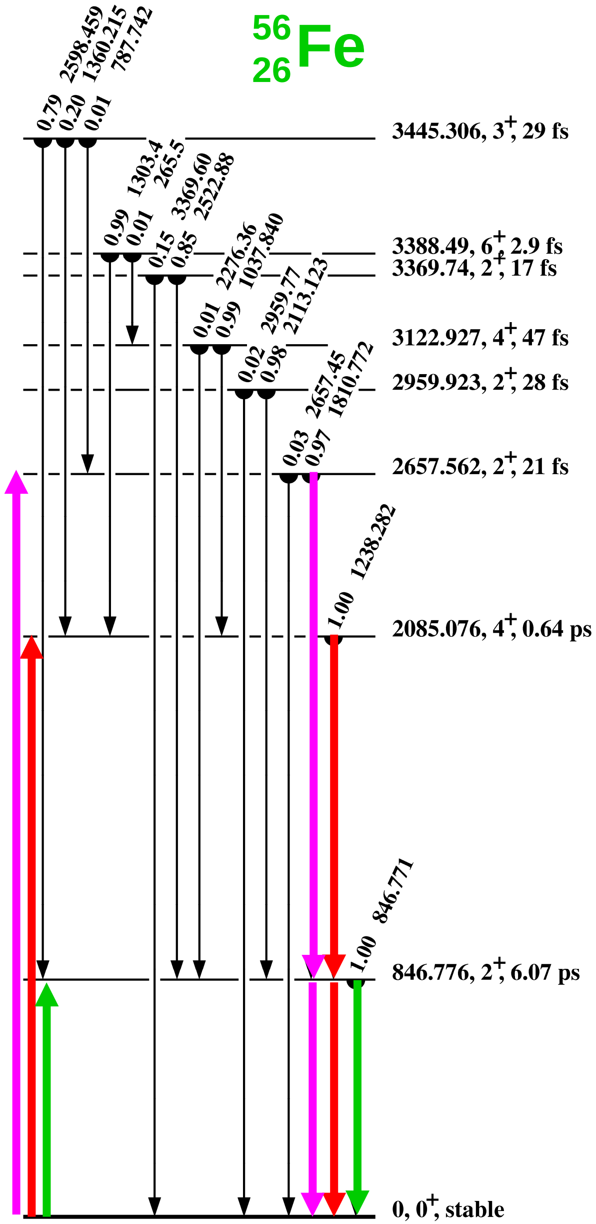
→ several levels contribute to one γ-ray energy

→ more explicit way:

detect emitted γ-ray and scattered neutron in coincidence

Inelastic neutron scattering





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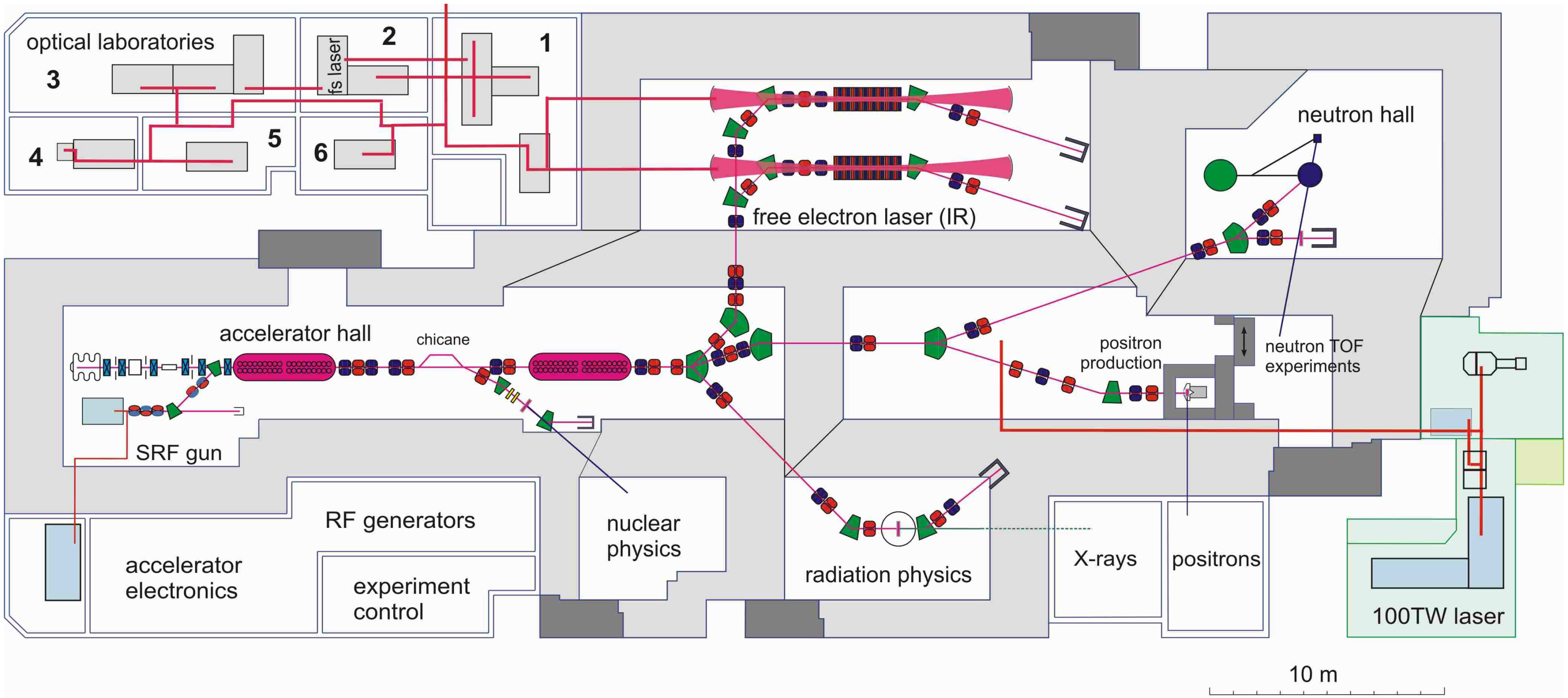
detect emitted γ-ray and scattered neutron in coincidence

nELBE – neutron facility at ELBE (Klug et al. NIMA 577 (2007) 641)



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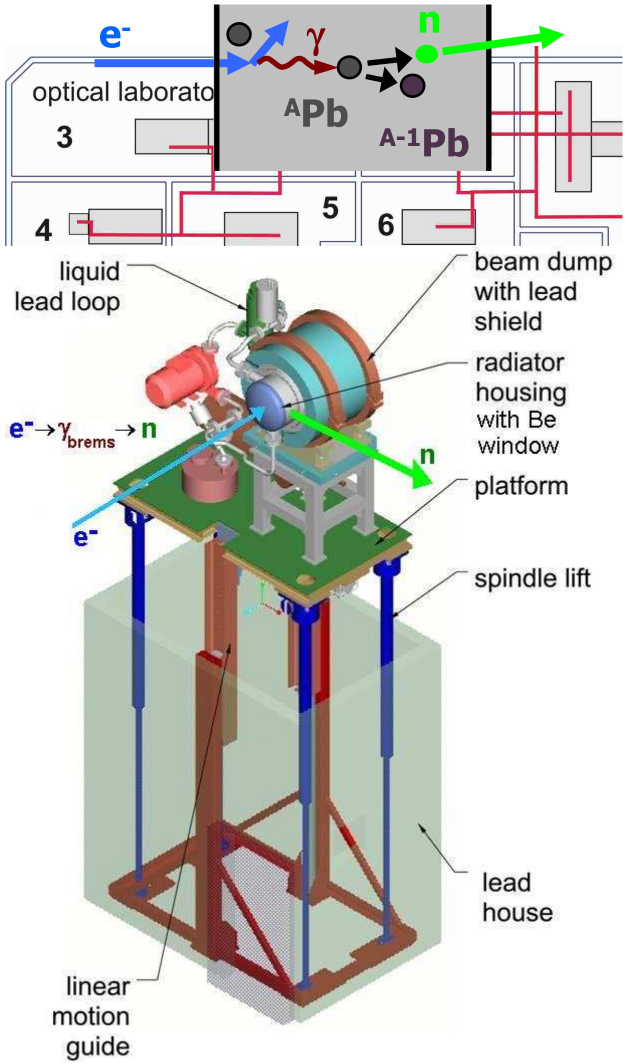
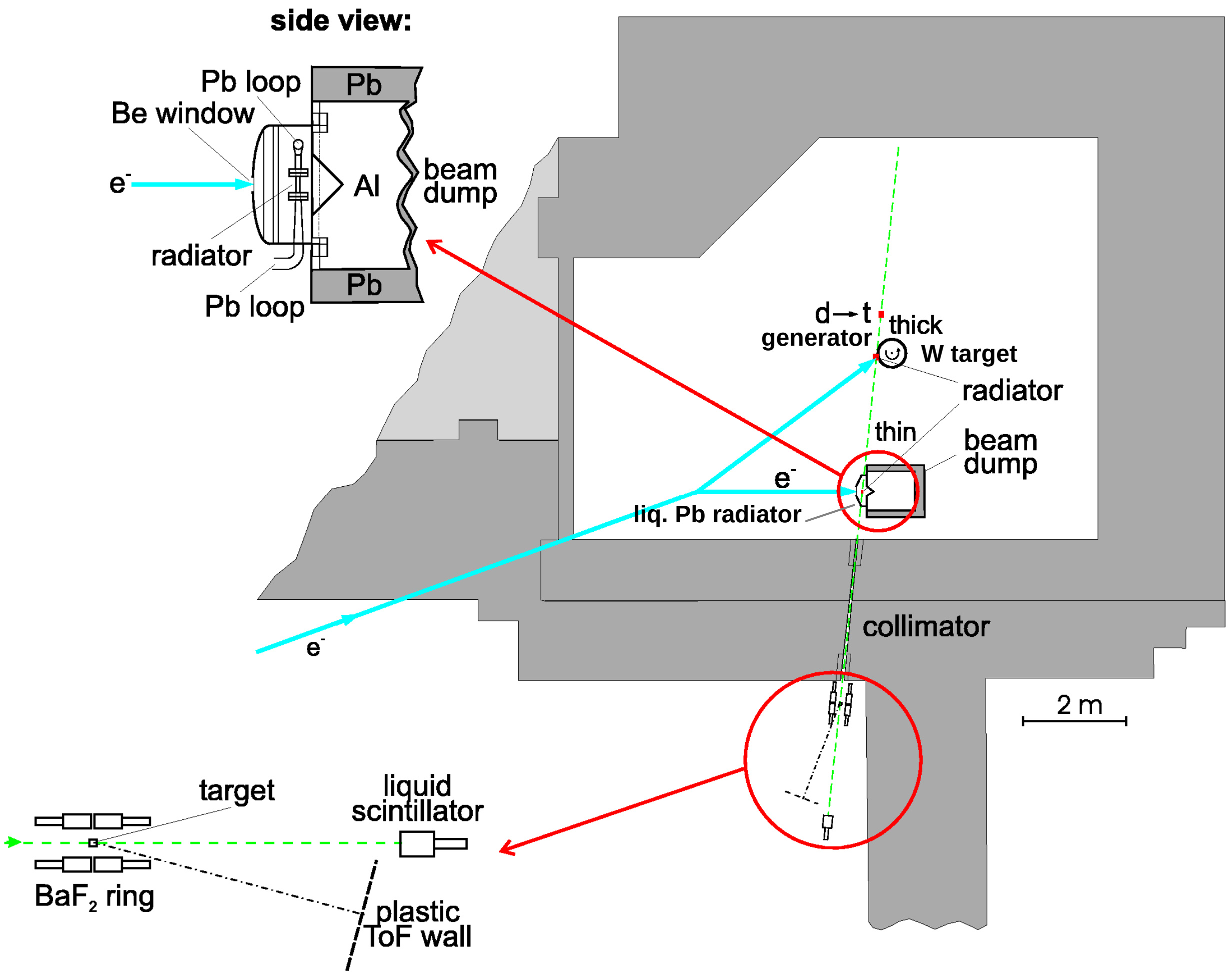
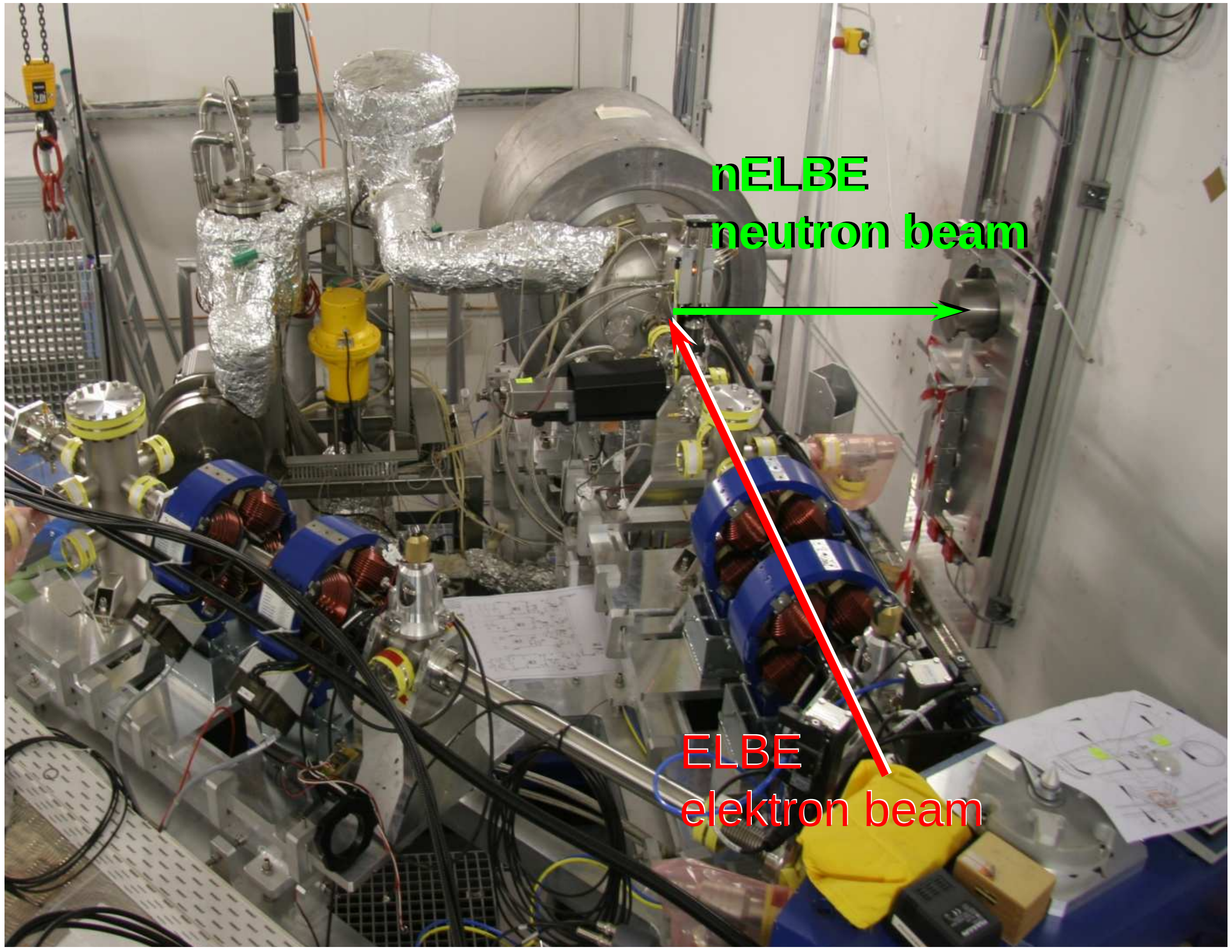


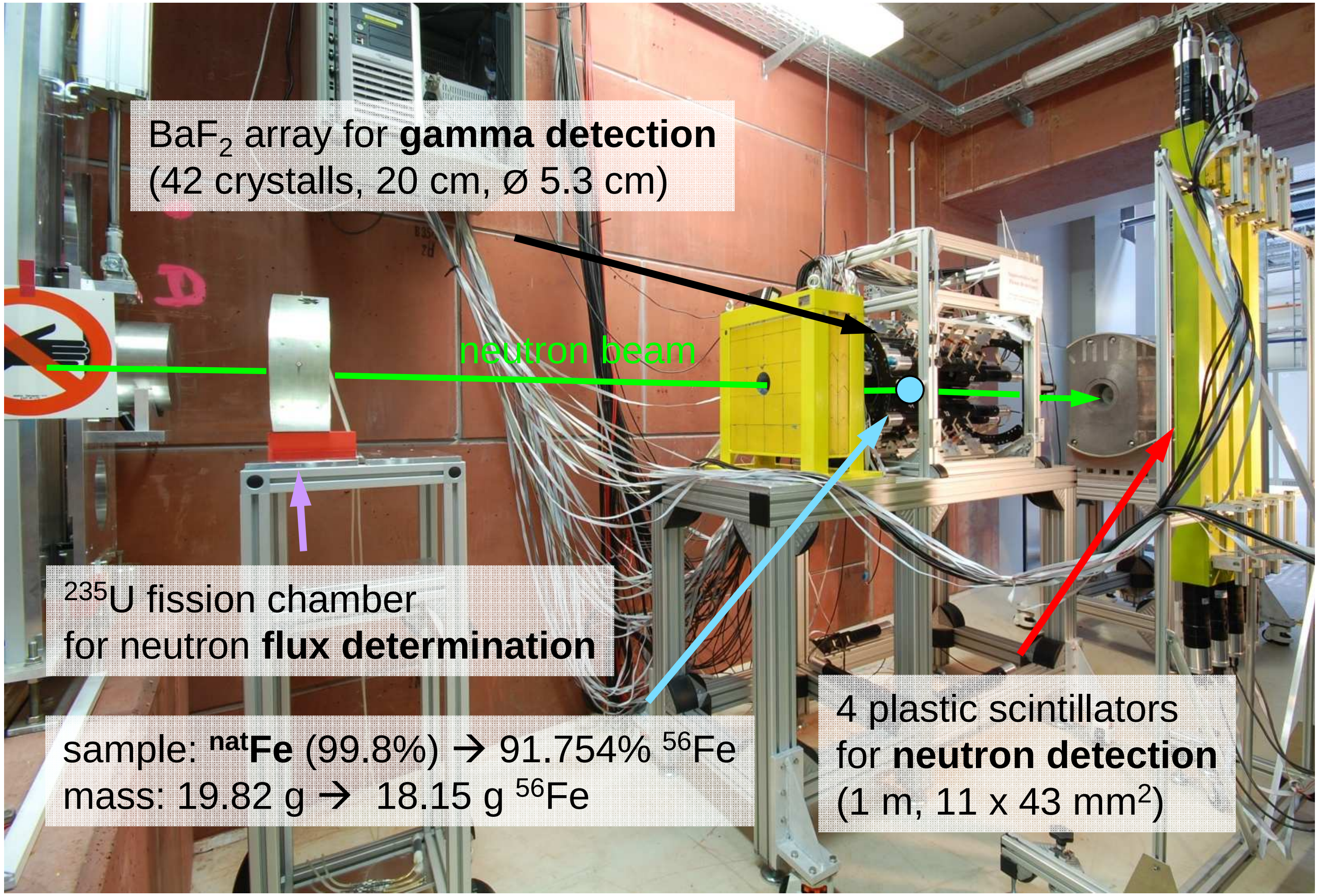


nELBE – neutron production



→ Arnd Junghans, Session IX

nELBE – Detector Setup

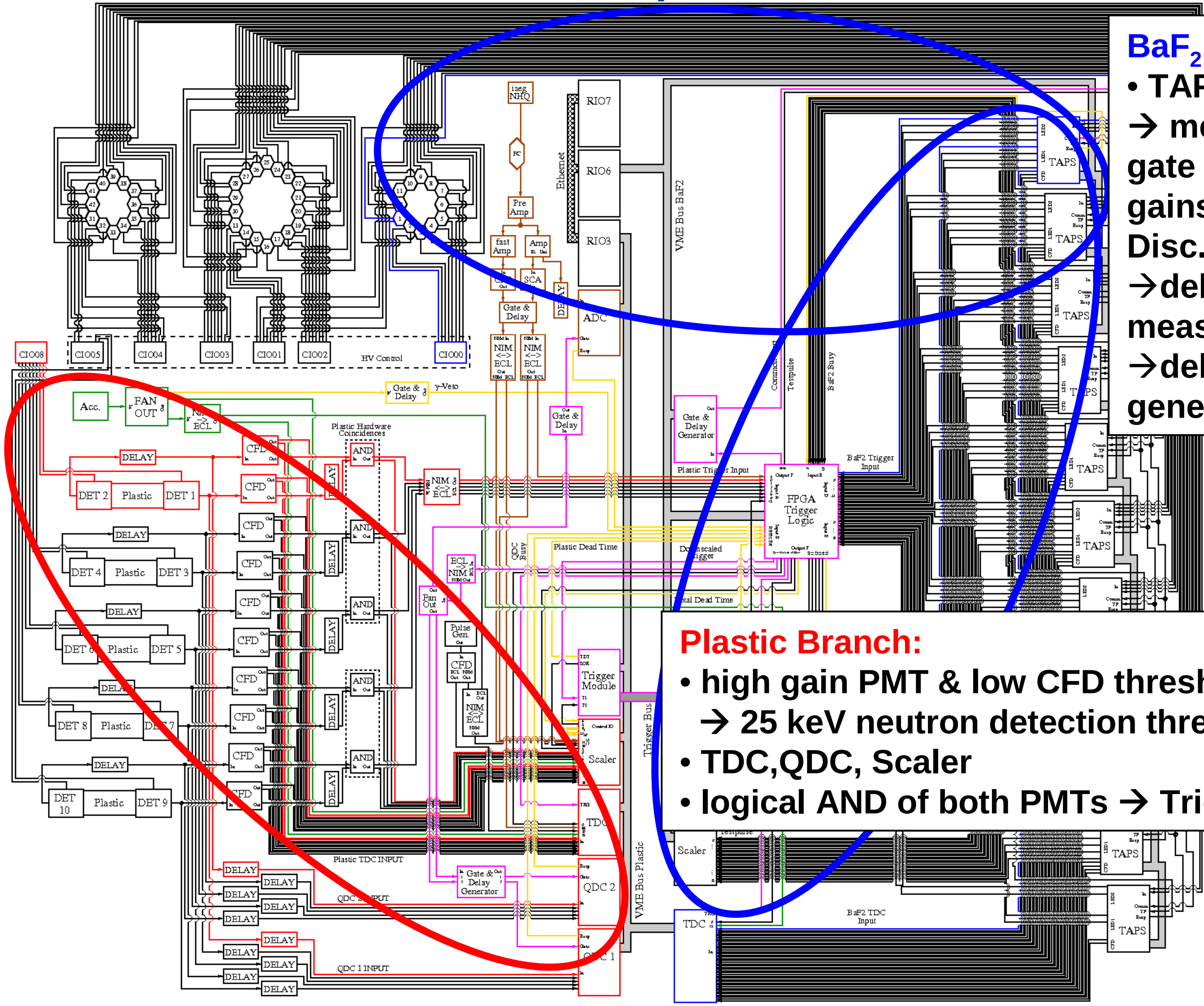


flight paths:
source – sample:
600 cm
sample – BaF2:
30 cm
sample – Plastics:
100 cm

Neutron detection
threshold = 25 keV,
20-40 % intrinsic
efficiency

Beyer et al.,
NIMA 575 (2007) 449

The electronics setup



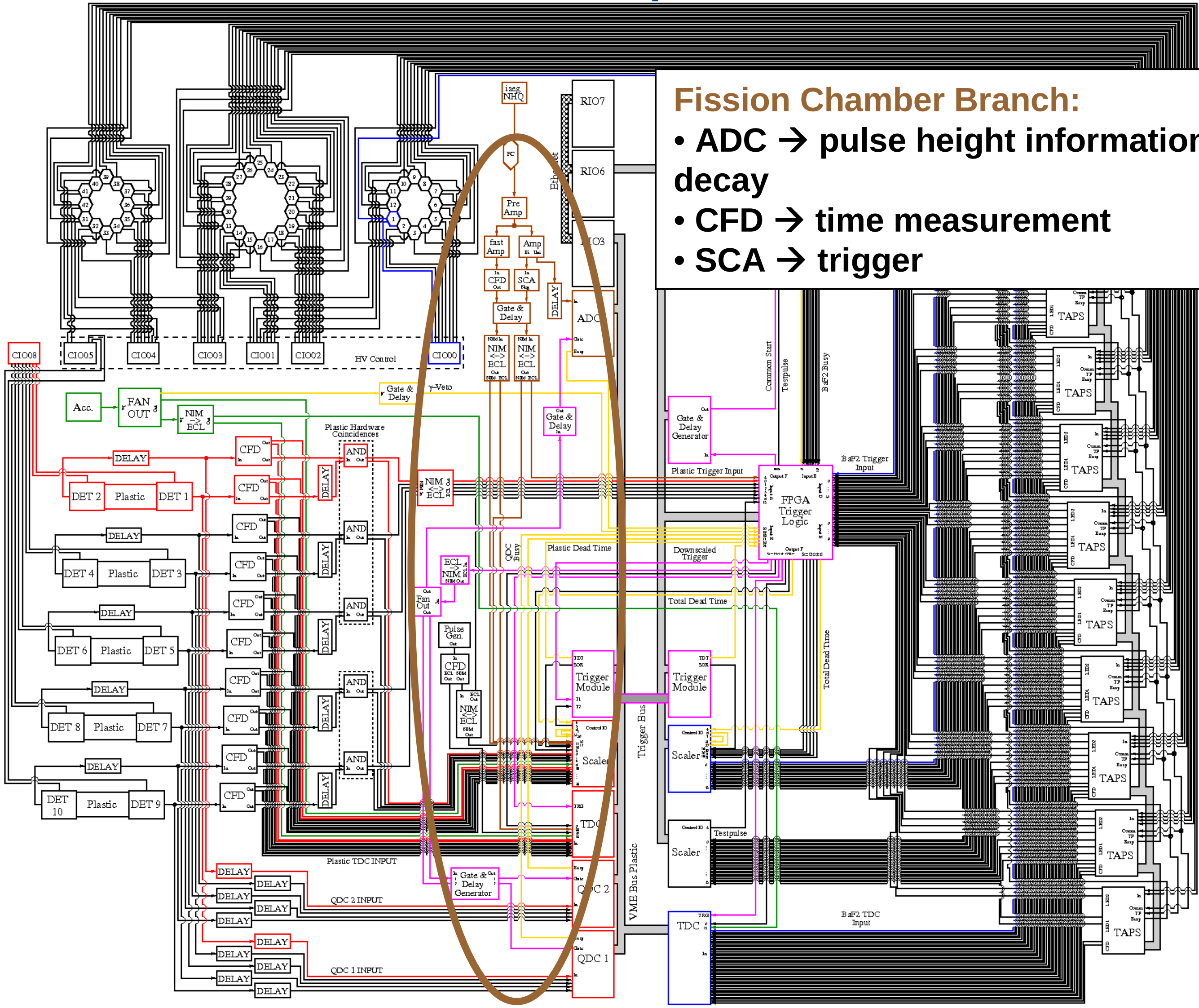
BaF$_2$ Branch:

- **TAPS modules:**
  - **→ measure long gate and short gate integrals (with two different gains 1x and 5x) for Pulse Shape Disc. of Alpha Background**
  - **→deliver CFD siganal for time measurement**
  - **→deliver LED for Trigger generation**

Plastic Branch:

- **high gain PMT & low CFD threshold**
  - **→ 25 keV neutron detection threshold**
- **TDC,QDC, Scaler**
- **logical AND of both PMTs → Trigger**

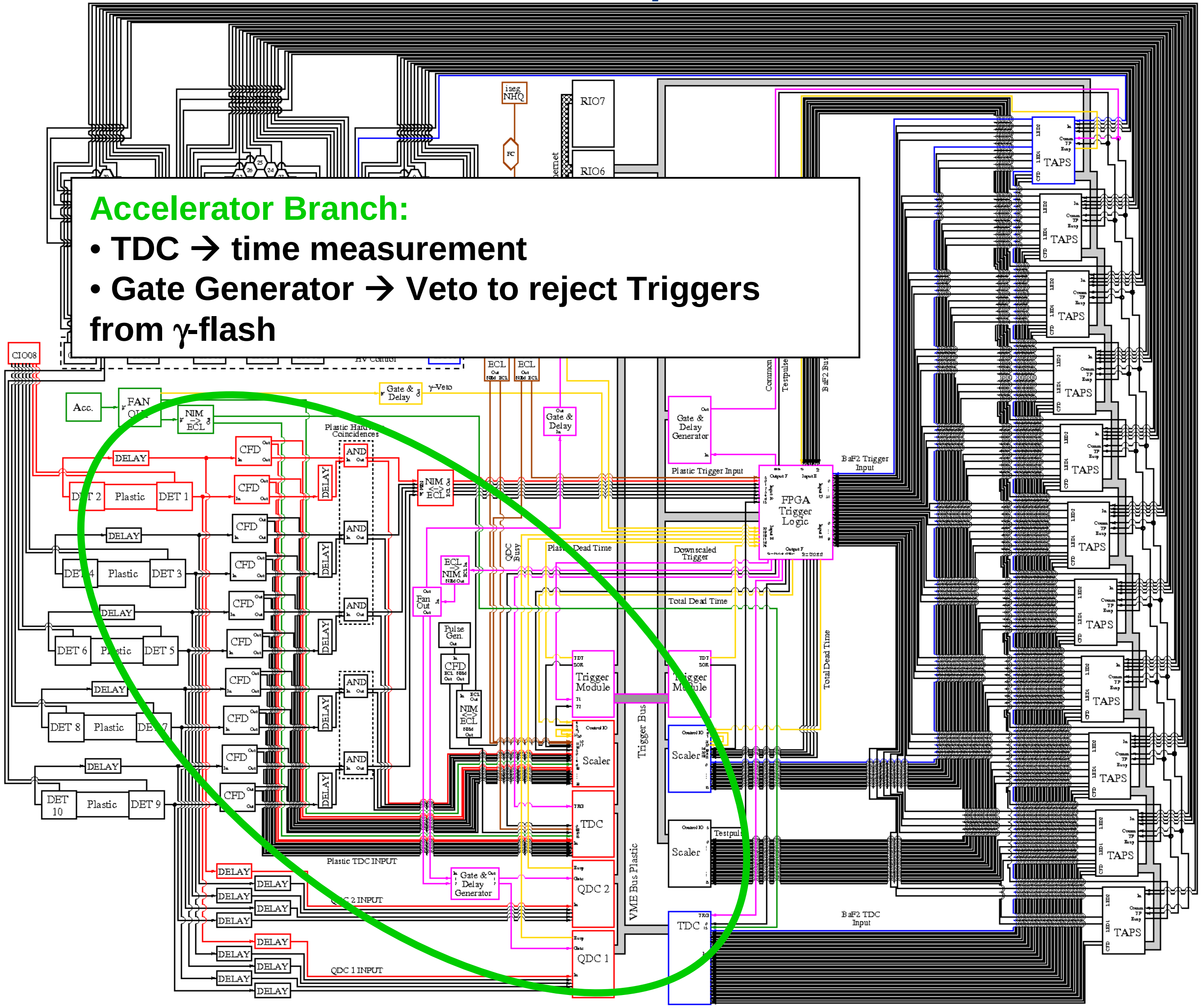
The electronics setup



Fission Chamber Branch:

- ADC → pulse height information to reject αs from natural decay
- CFD → time measurement
- SCA → trigger

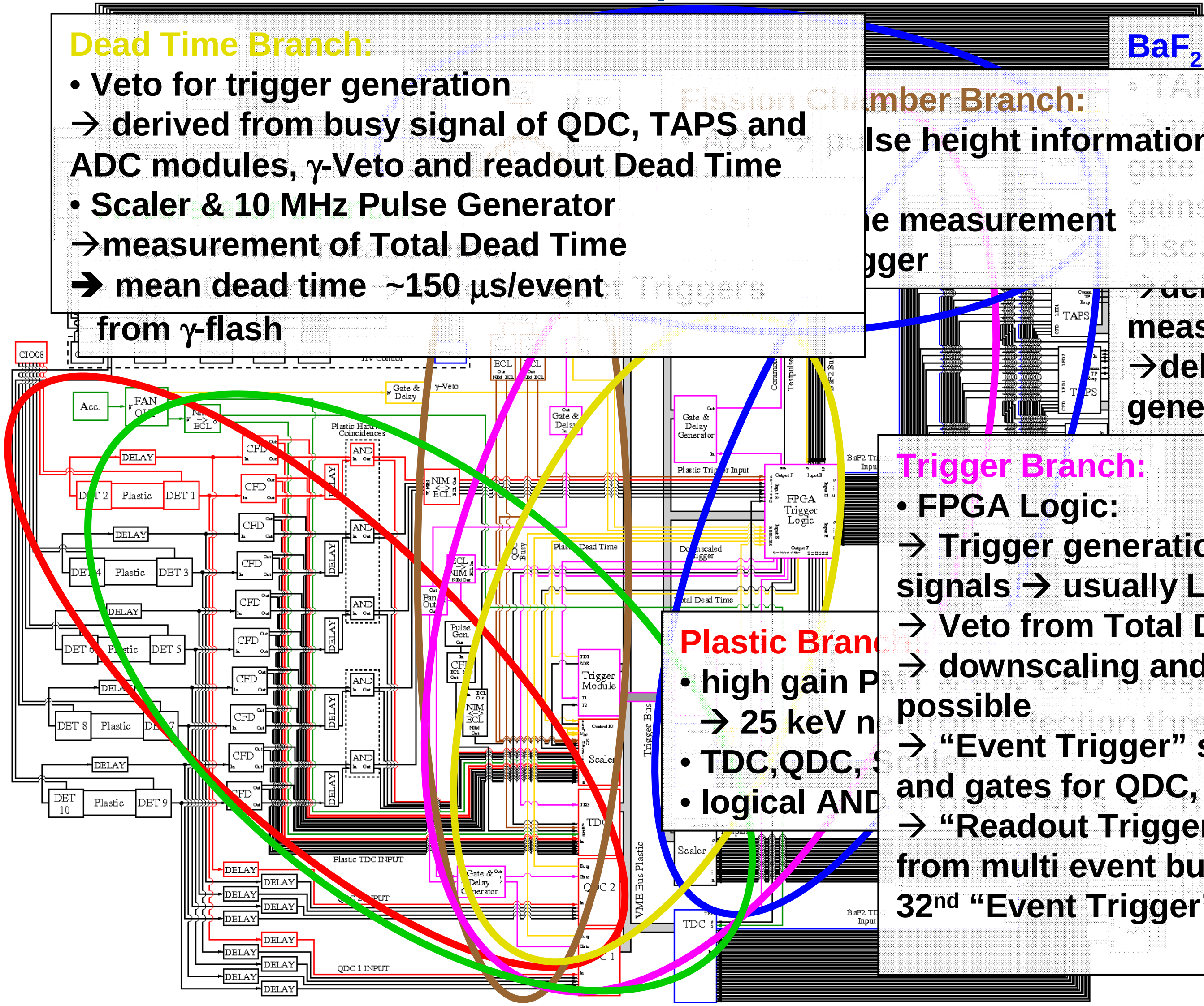
The electronics setup



Accelerator Branch:

- **TDC → time measurement**
- **Gate Generator → Veto to reject Triggers from γ-flash**

The electronics setup



Dead Time Branch:
- Veto for trigger generation
→ derived from busy signal of QDC, TAPS and ADC modules, γ-Veto and readout Dead Time
- Scaler & 10 MHz Pulse Generator
→measurement of Total Dead Time
➔ mean dead time ~150 µs/event from γ-flash

Fission Chamber Branch:
- ADC → pulse height information to reject αs from natural
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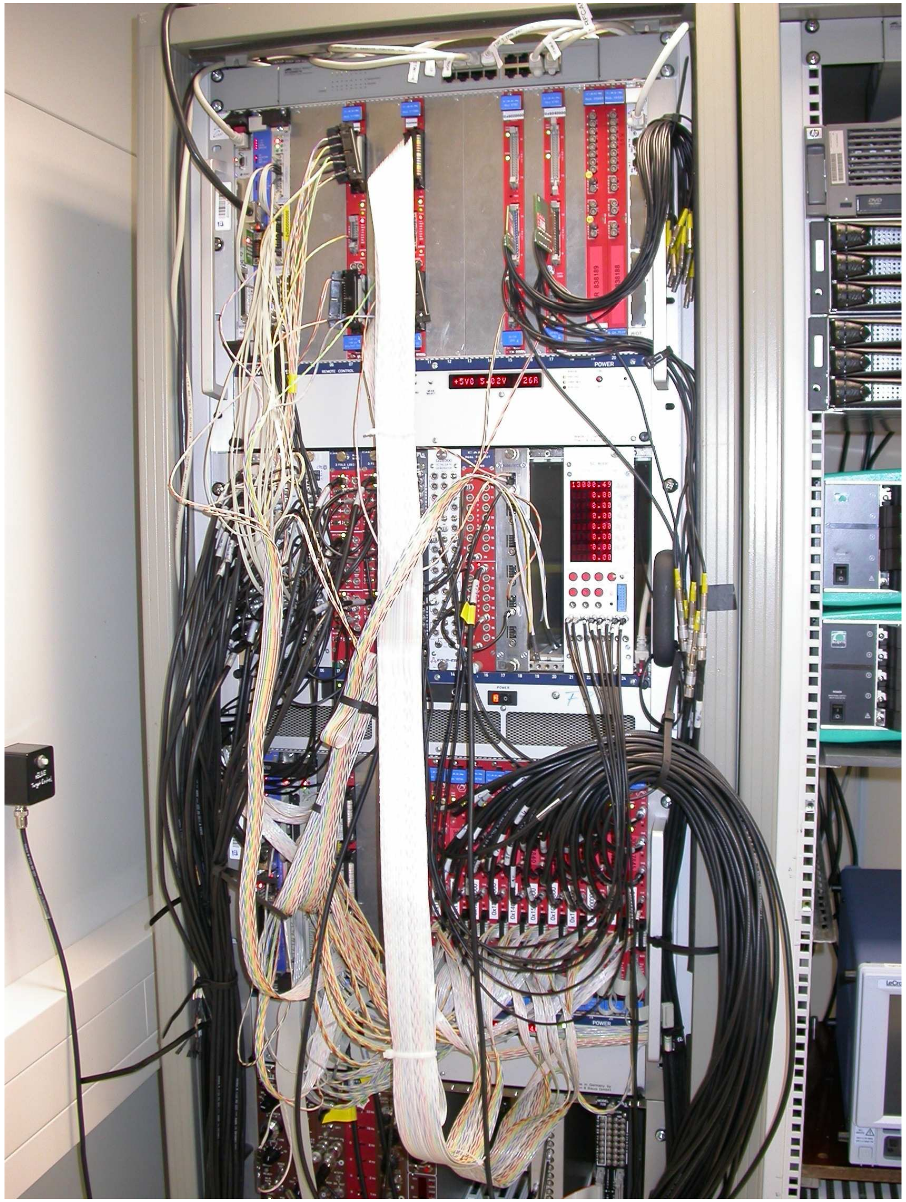
BaF$_2$ Branch:
- TAPS modules:
→ measure long gate and short gate integrals (with two different gains 1x and 5x) for Pulse Shape Disc. of Alpha Background
→deliver CFD signal for time measurement
→deliver LED for Trigger generation

Trigger Branch:
- FPGA Logic:
→ Trigger generation from Plastic, FC and BaF$_2$ signals → usually Logical Or of Plastics and FC
→ Veto from Total Dead Time
→ downscaling and inhibiting of input channels possible
→ "Event Trigger" starts TDC match windows and gates for QDC, ADC and TAPS modules
→ "Readout Trigger" triggers readout of data from multi event buffer of the modules every 32nd "Event Trigger"

Plastic Branch:
- high gain PMT & low CFD threshold
→ 25 keV neutron detection threshold
- TDC,QDC, Scaler
- logical AND → Trigger

The electronics setup



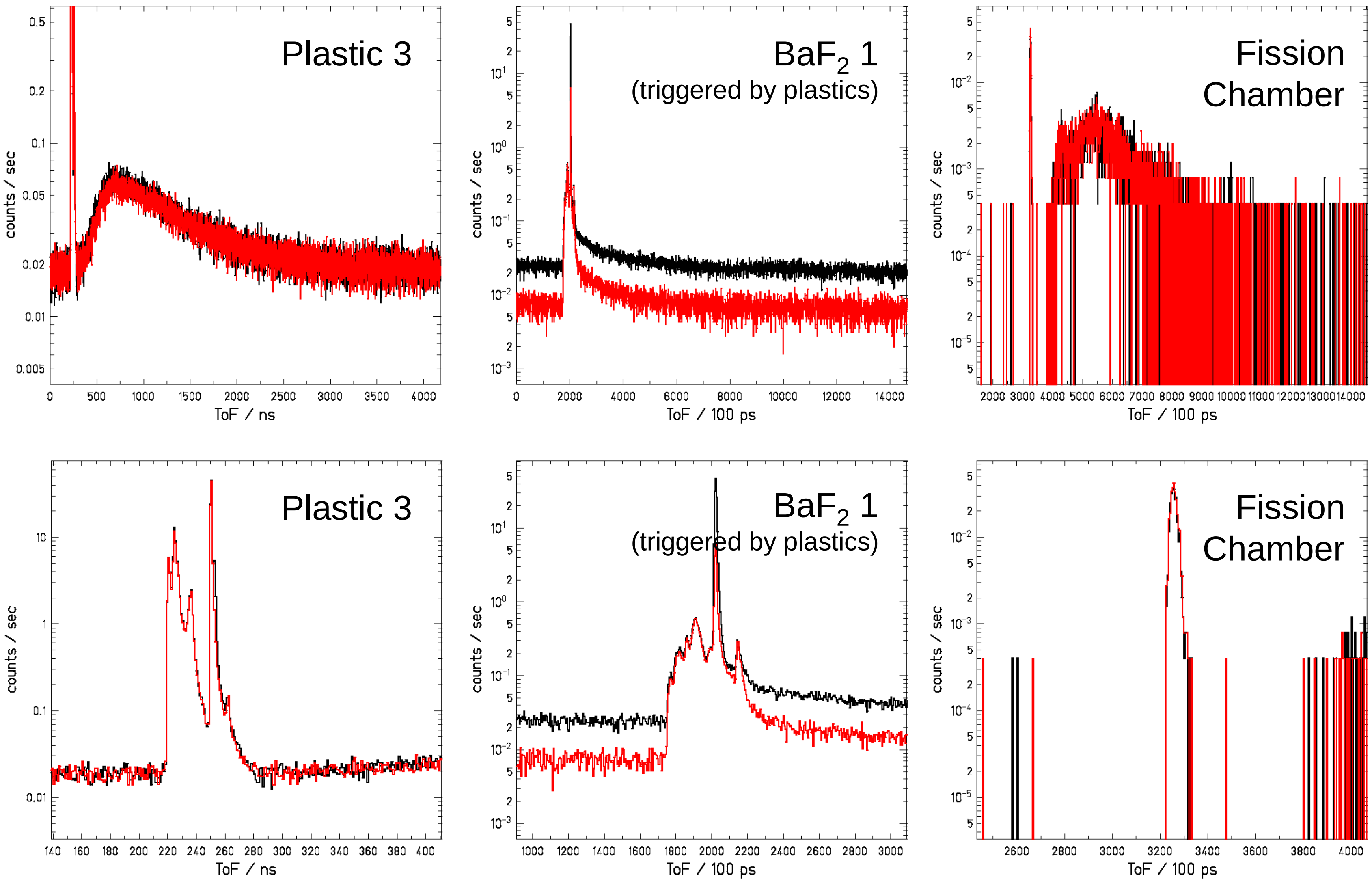
Time of Flight Spectra

^{nat}Fe, t_{real} = 3536 s, t_{live} = 2489 s

empty, t_{real} = 3535 s, t_{live} = 2522 s

complete spectrum

gammas



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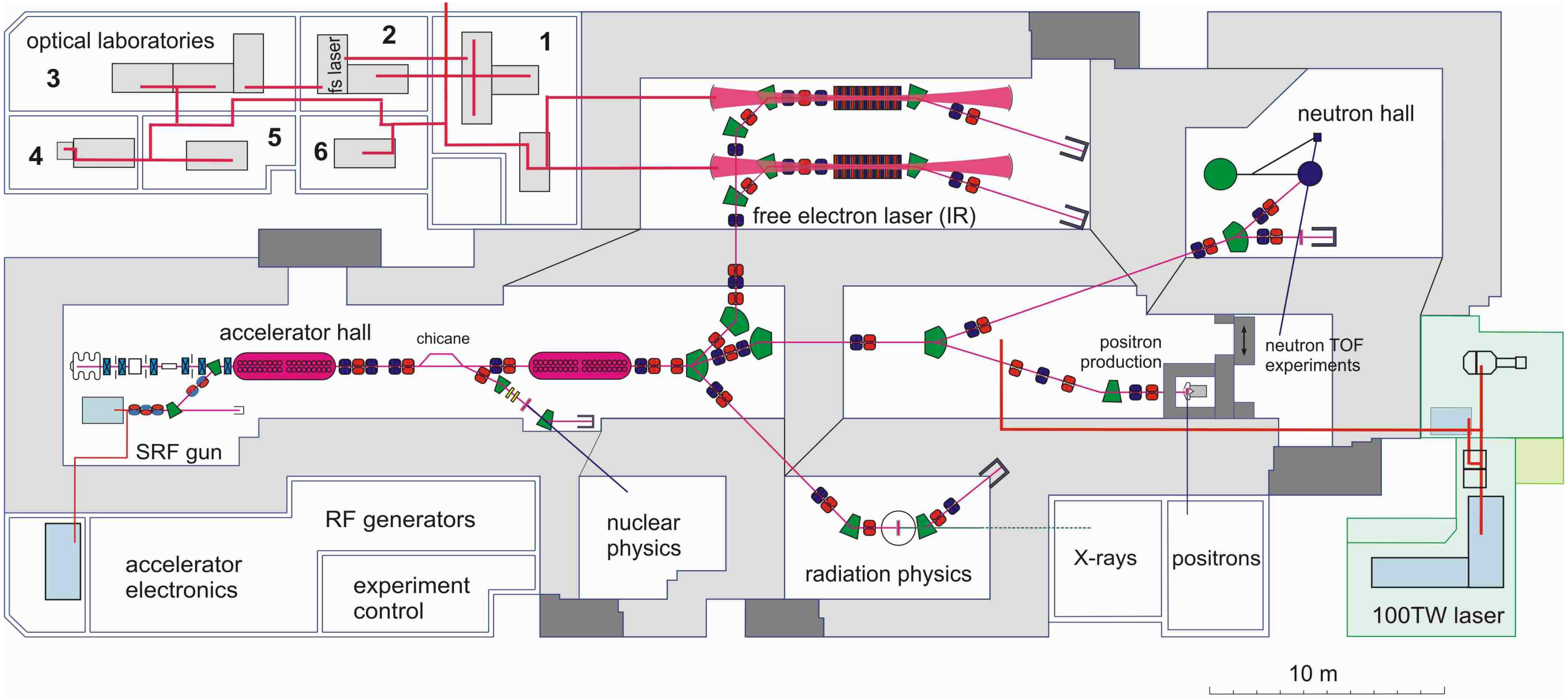
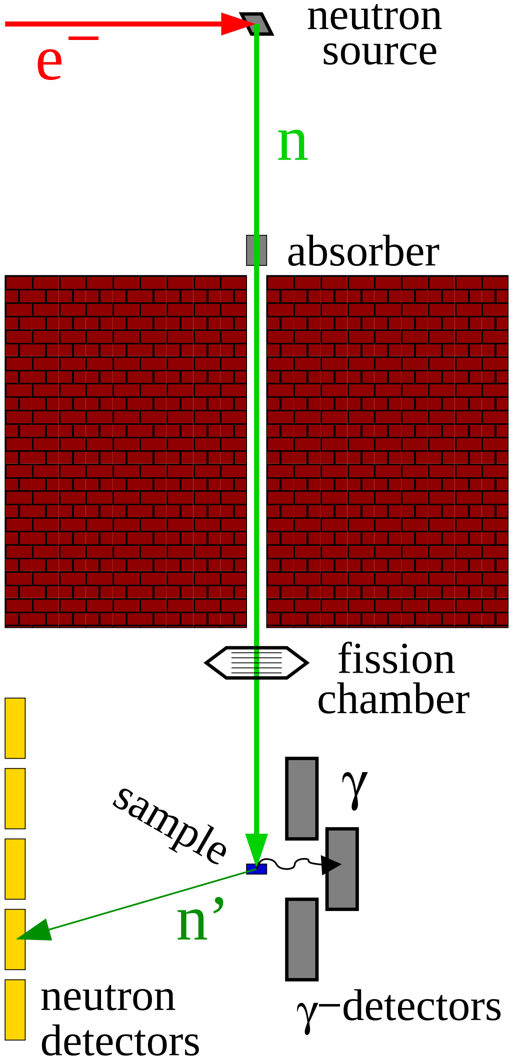
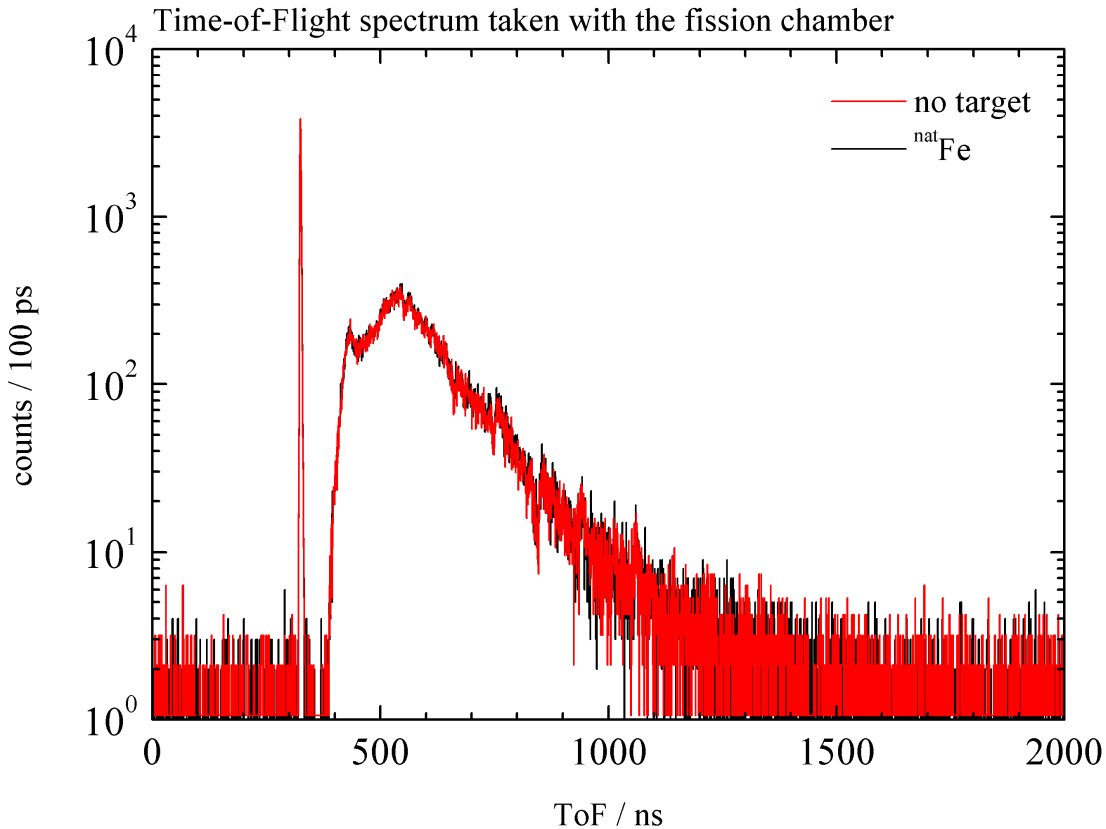


Experimental method





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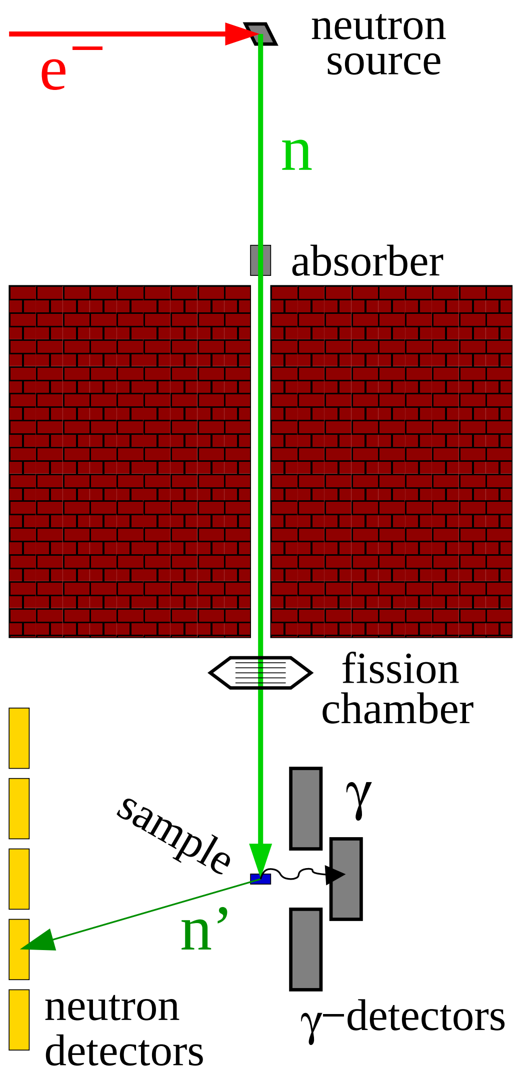
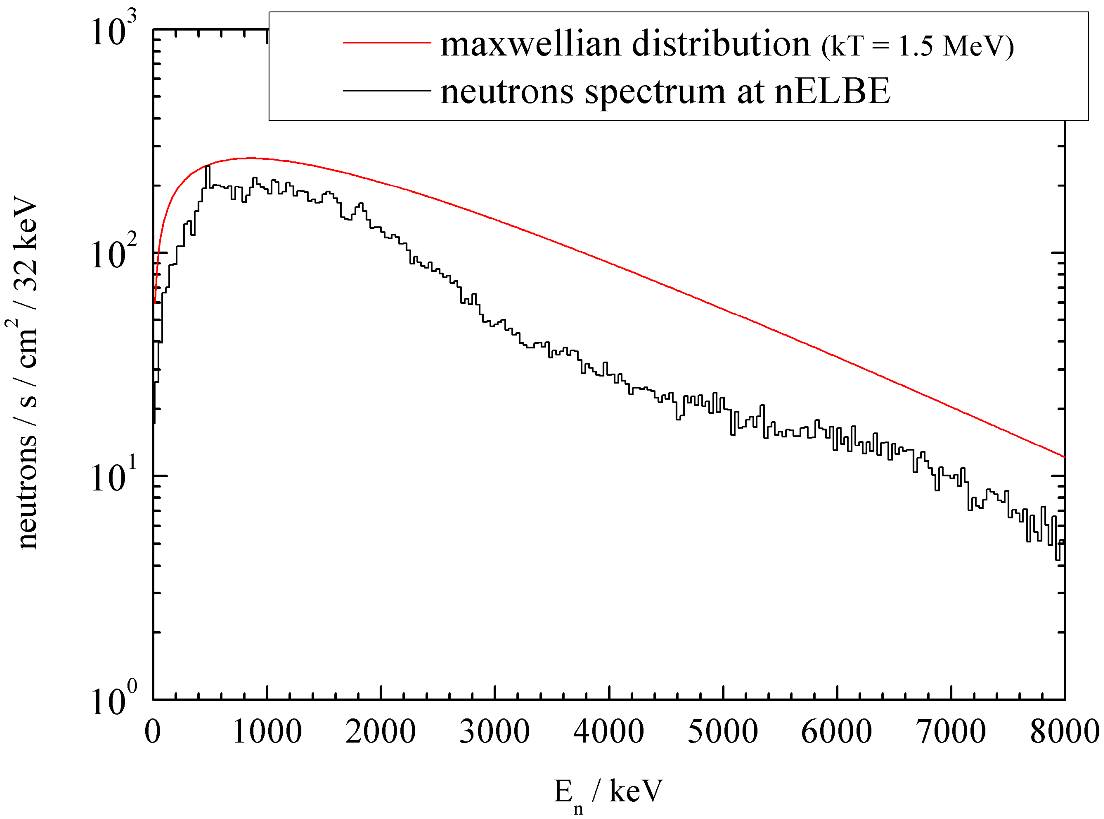


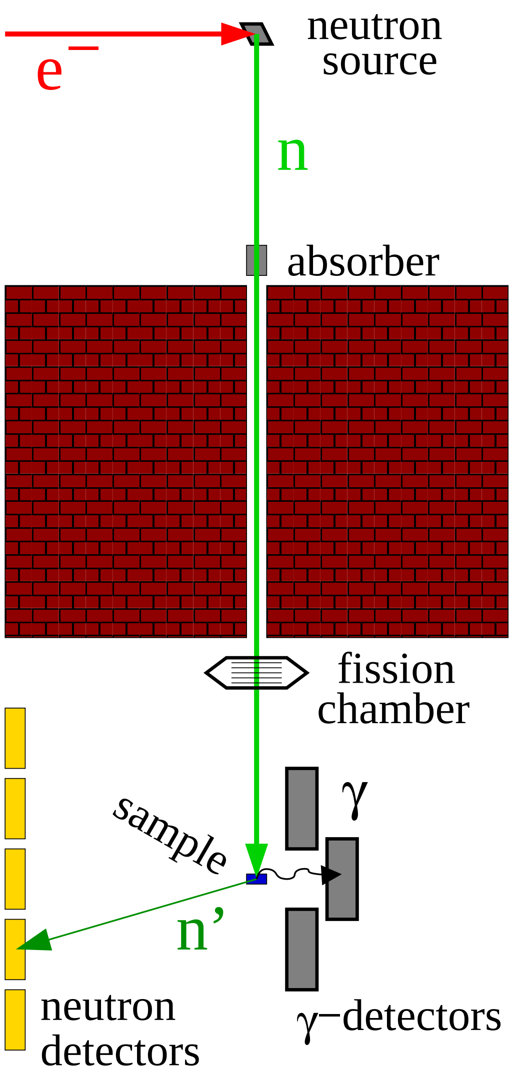
$$^{56}\mathrm{Fe}(n,n'\gamma)^{56}\mathrm{Fe} \begin{cases} ^{56}\mathrm{Fe}+n \rightarrow {}^{56}\mathrm{Fe}^{*}+n' \\ {}^{56}\mathrm{Fe}^{*} \rightarrow {}^{56}\mathrm{Fe}+\gamma \end{cases}$$

Integral at target: 2×10^4 n/s/cm²



Experimental method

measurement time:
34,9 h with sample
32,2 h without



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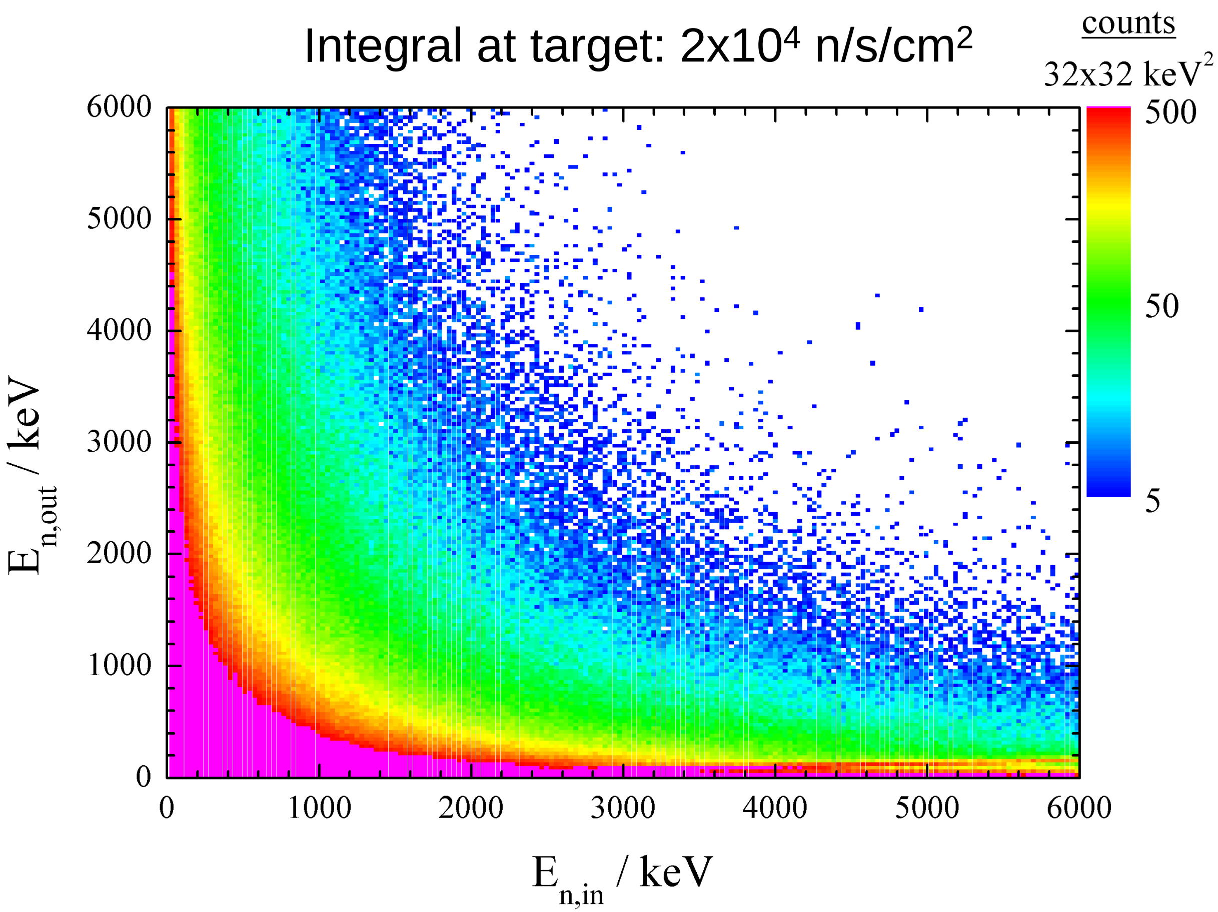

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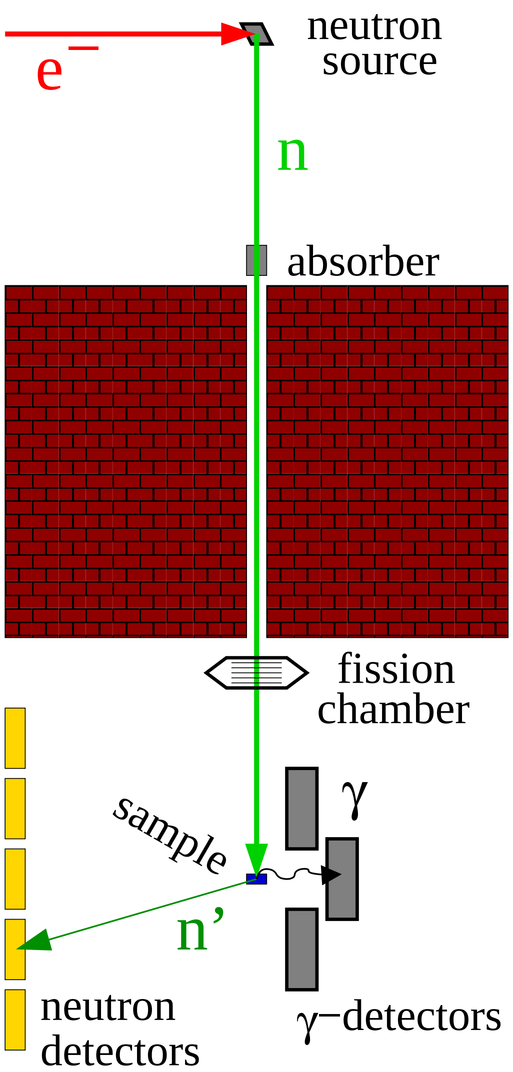

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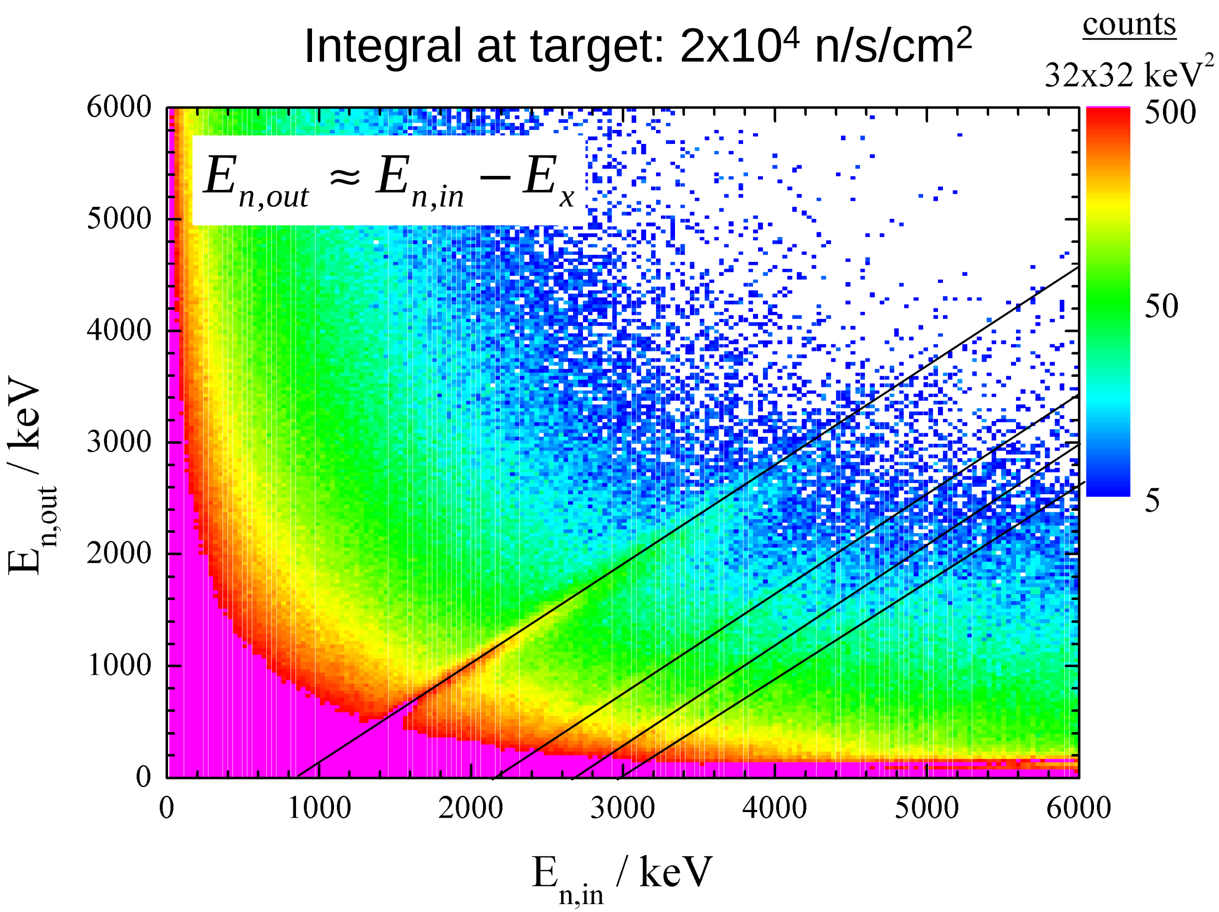
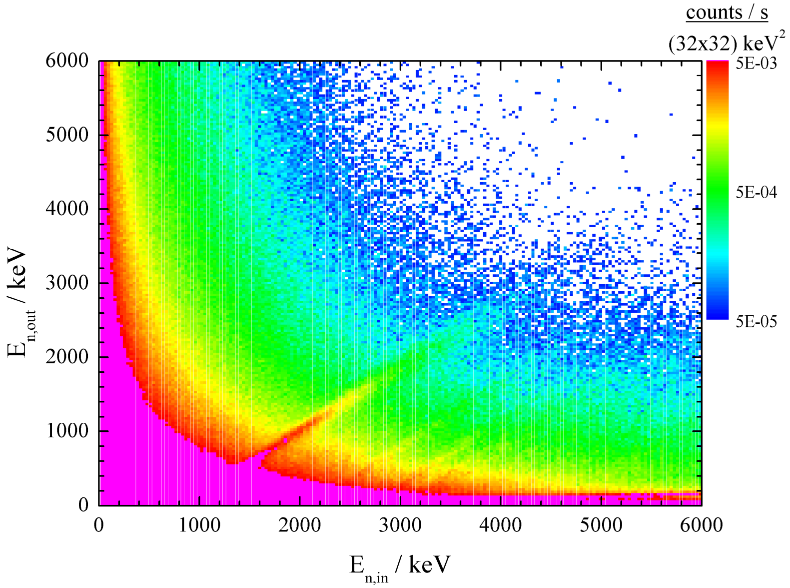
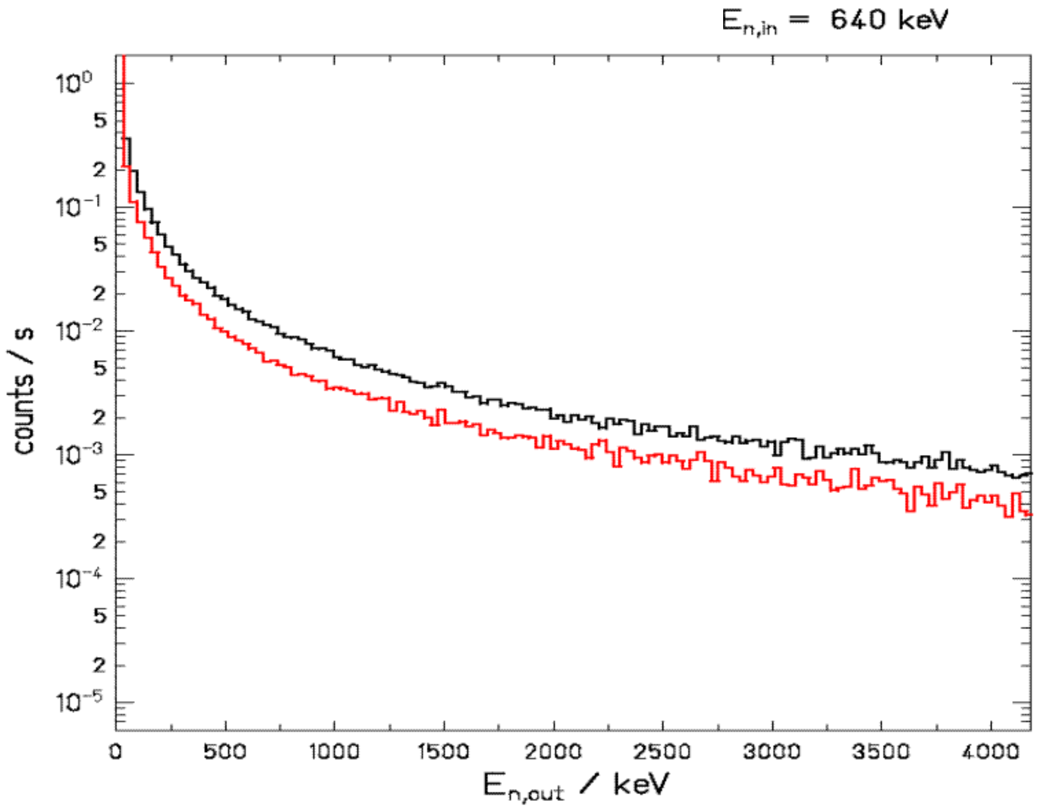


Data Analysis





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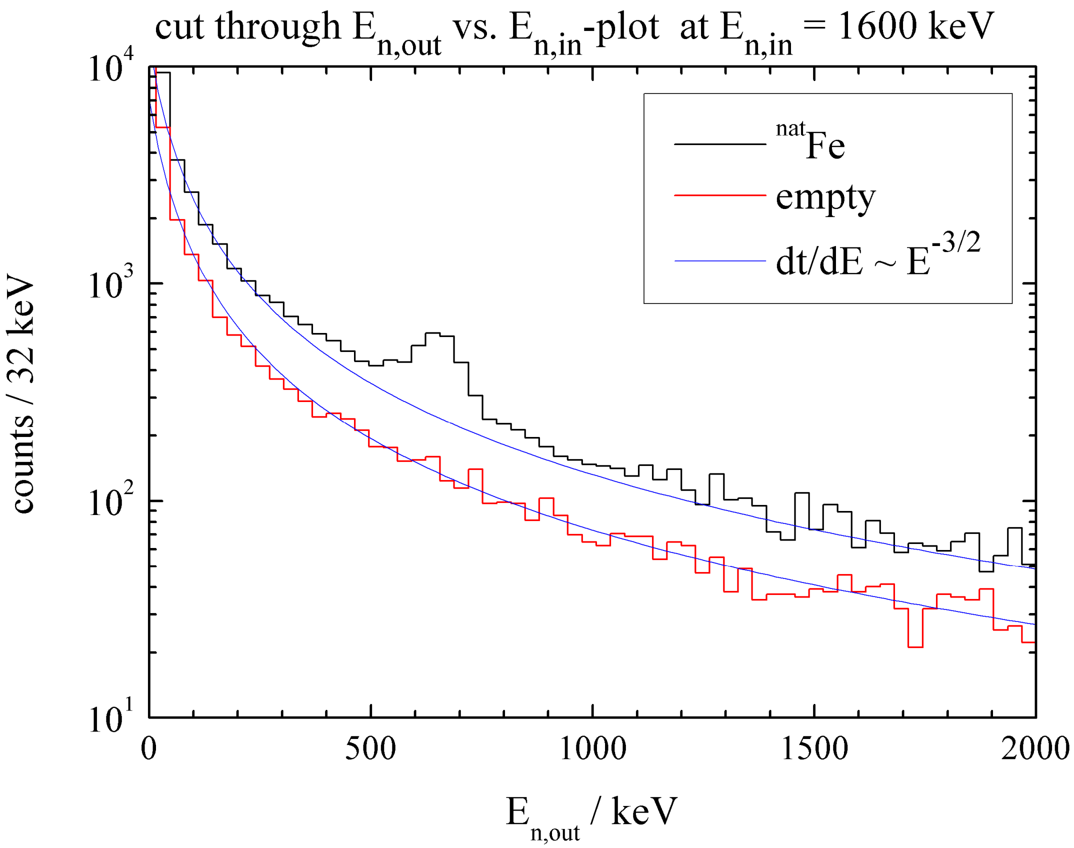

$$\frac{dN}{dE} = \frac{dN}{dt} \cdot \frac{dt}{dE}$$

$$E = \frac{mc^2}{2}\left(\frac{s}{t \cdot c}\right)^2 \Rightarrow t = \sqrt{\frac{mc^2}{2E}}\,\frac{s}{c}$$

$$\Rightarrow \frac{dt}{dE} = \sqrt{\frac{mc^2}{2}}\,\frac{s}{c}\,E^{-3/2}$$

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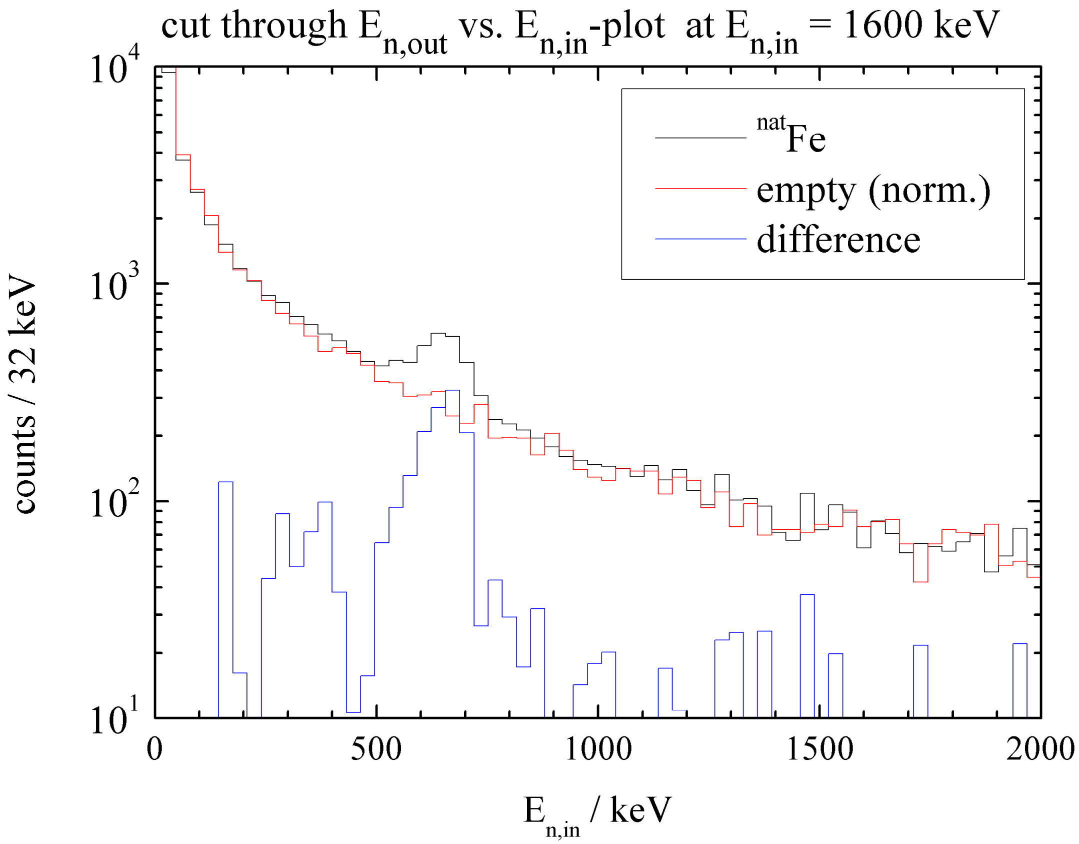

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Data Analysis

Neutron Flux at target position: $$\Phi_{n,target}(E_{n,in}) = \frac{N_{FC}(E_{n,in})}{\varepsilon_{FC}(E_{n,in})} \cdot F_{geom}$$

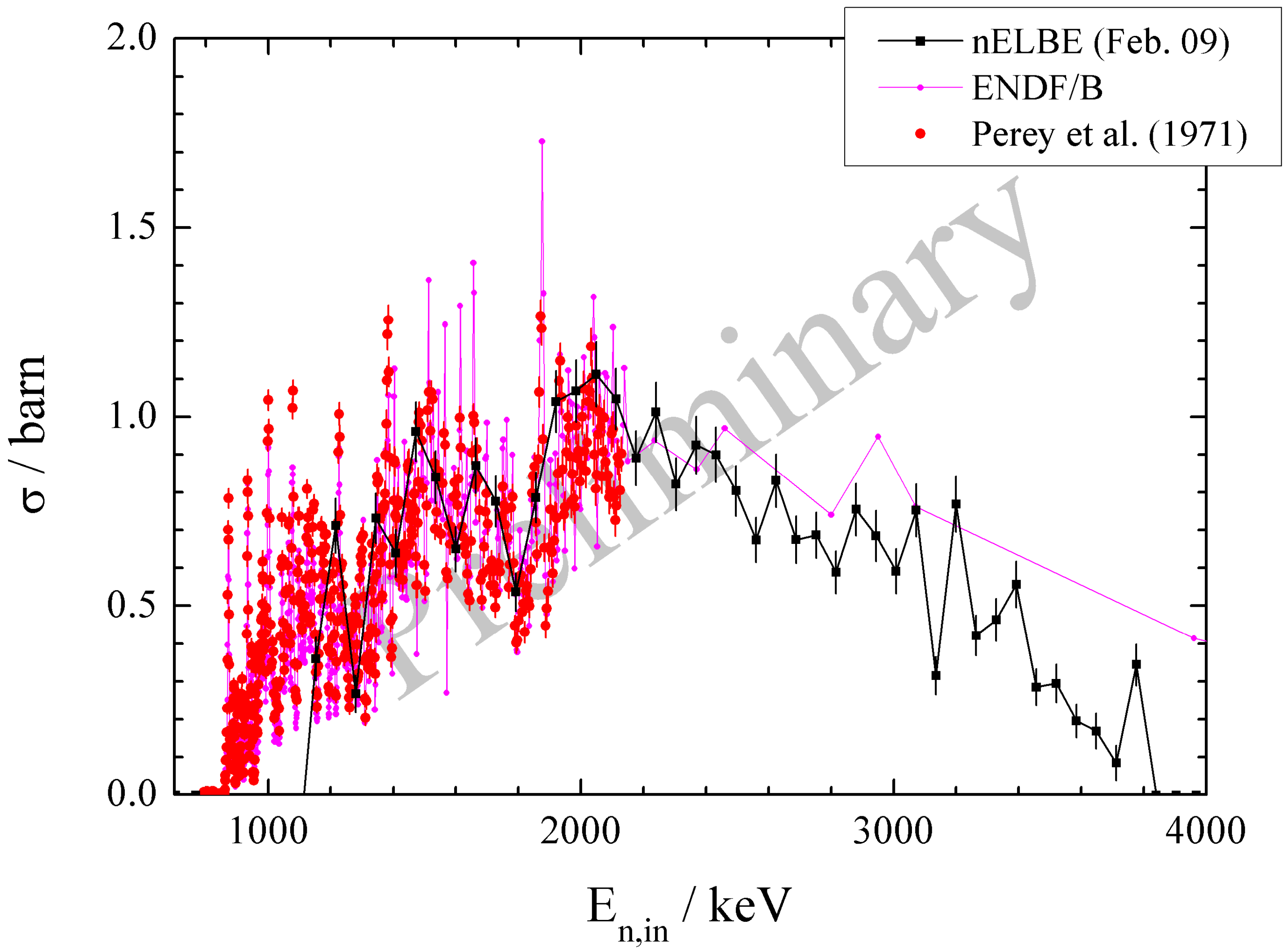
Number of detected reactions:

$$N_{det}(E_{n,in}) = \frac{N_{Fe}(E_{n,in}) - N_{back}(E_{n,in})}{\varepsilon_{Plastic}(E_{n,in}) \cdot \varepsilon_{BaF_2}(E_{n,in})}$$

Cross section:

$$\sigma(E_{n,in}) = \frac{N_{det}(E_{n,in})}{\Phi_{n,target}(E_{n,in}) \cdot N_{target}}$$

The $^{56}Fe(n,n'\gamma)$ cross section for 1st excited level



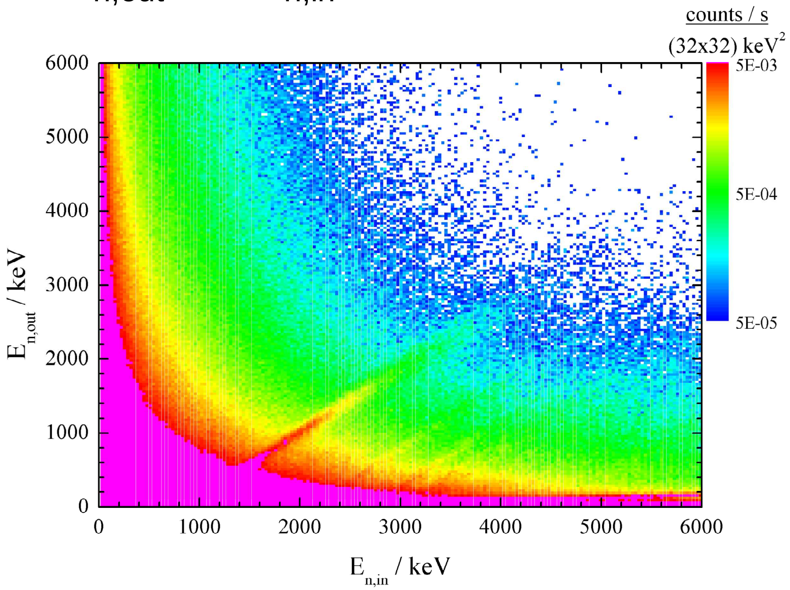
Background Sources

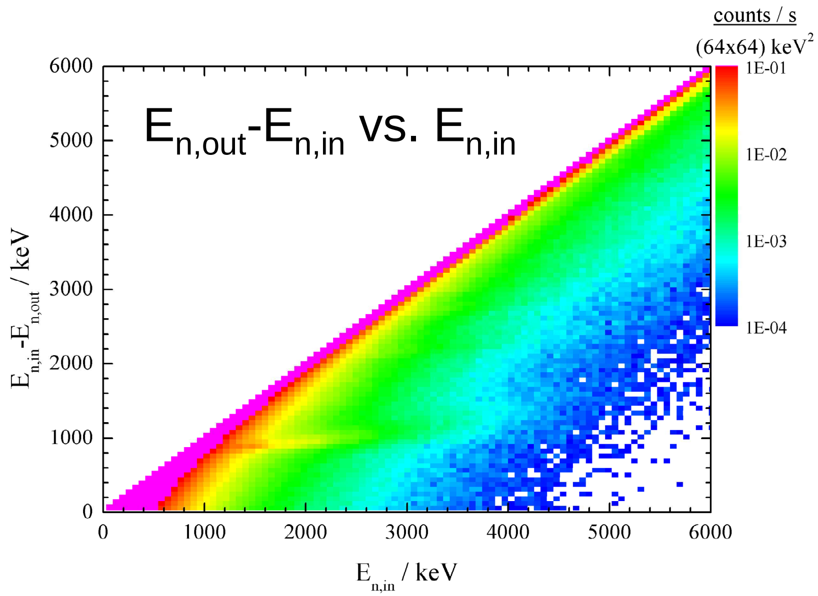
- false coincidences from elastic scattering
- multiple processes inside target → reduction of incoming and scattered neutrons
- beam halo from collimator
- direct and secondary radiation produced by electron beam
- …

→ MCNP simulations ongoing (E. Birgersson, Session VII)

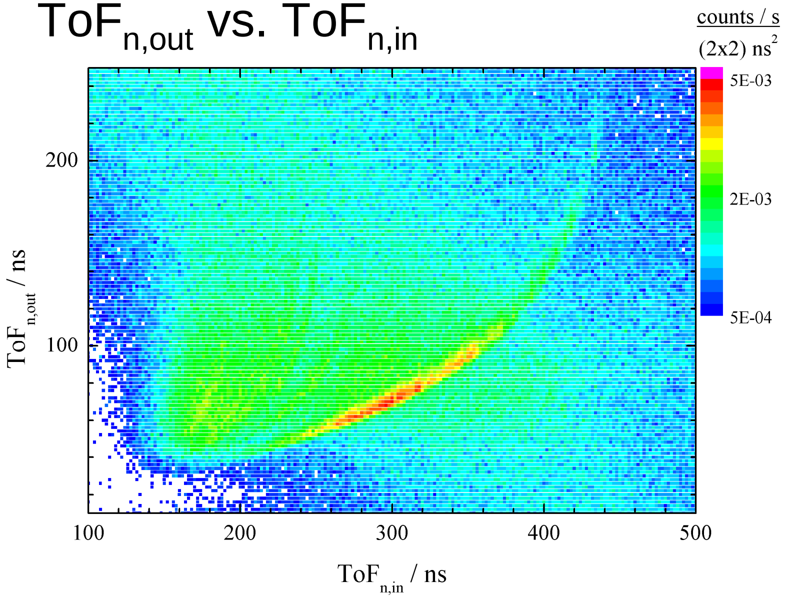
Outlook

$E_{n,out}$ vs. $E_{n,in}$





$ToF_{n,out}$ vs. $ToF_{n,in}$



Summary and Outlook

- nELBE is intended to deliver data on fast neutron induced reactions
- the ELBE electron beam delivers high neutron flux, new injector will deliver ~60 times more
- first experiments were performed on inelastic neutron scattering using a double time of flight setup
- further investigations have to be done to determine and reduce all sources background

Thanks to all Collaborators

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FZD, Department Radiation Protection and Safety:

B. Naumann

FZD, Department Research Technology:

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