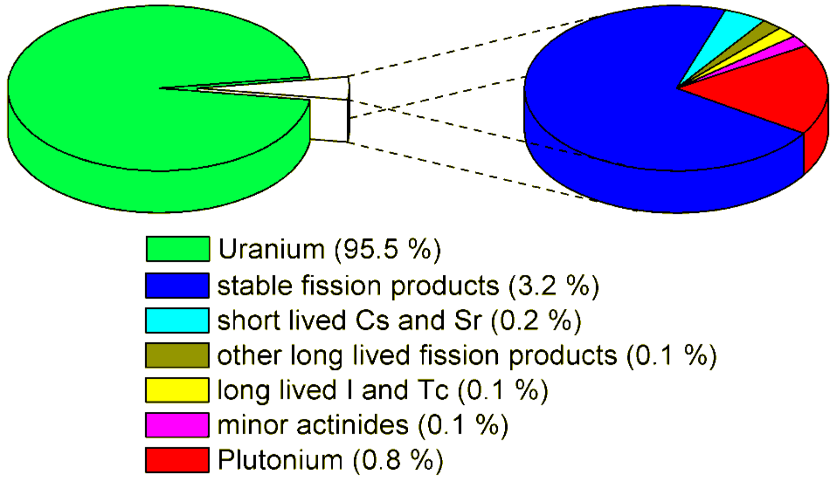
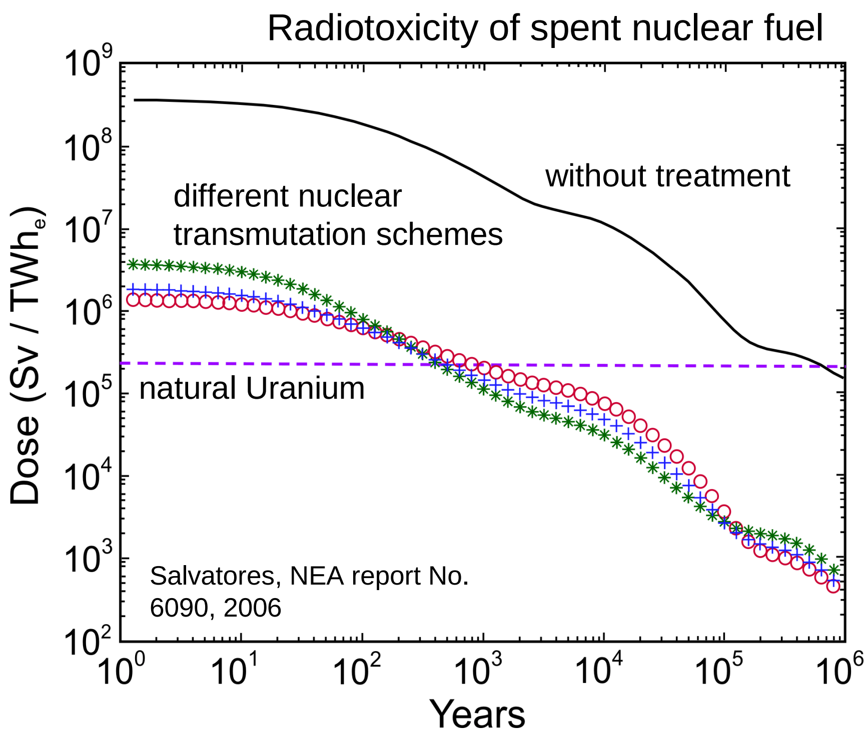
# Measurement of the inelastic neutron scattering cross section of $^{56}Fe$

Roland Beyer, Forschungszentrum Dresden-Rossendorf

# The nuclear waste problem



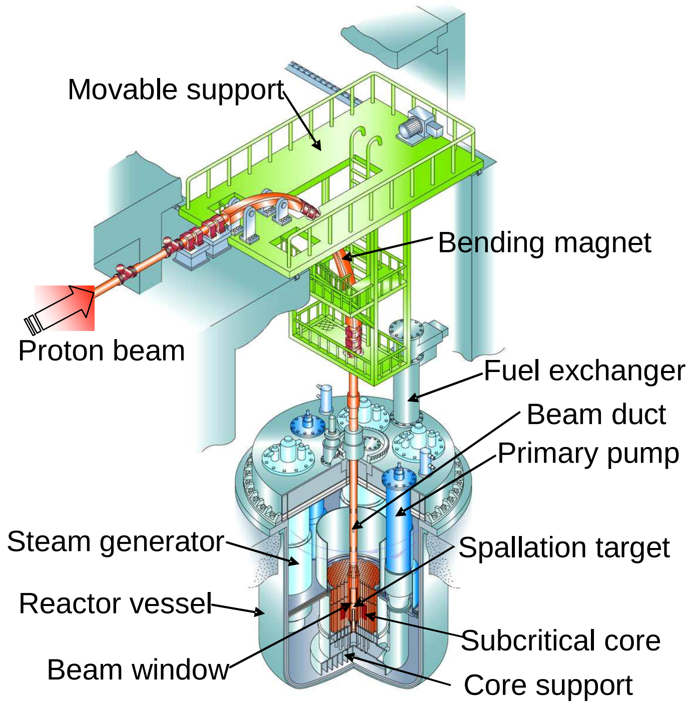



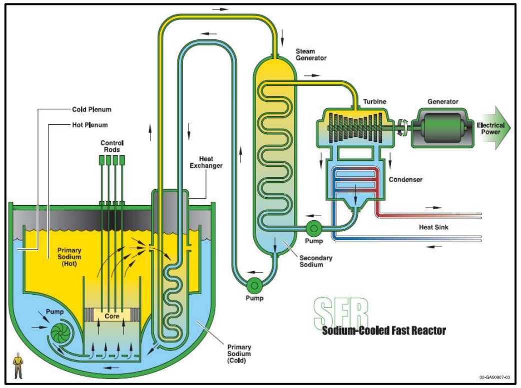

long lived isotopes cause main part of long term radiotoxicity
→ **safe disposal is necessary for more 500,000 years**

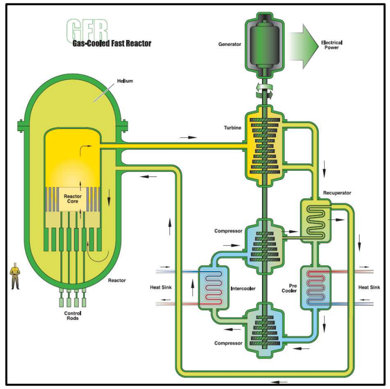
→ treatment of nuclear waste can **reduce disposal time by several orders of magnitude**
→ **Partitioning:** separate actinides from the rest
→ **Transmutation:** convert long lived isotopes into short lived ones

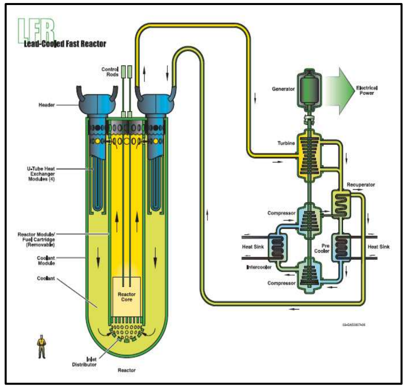
→ A.R. Junghans, HK 1.3, Mo 10:00

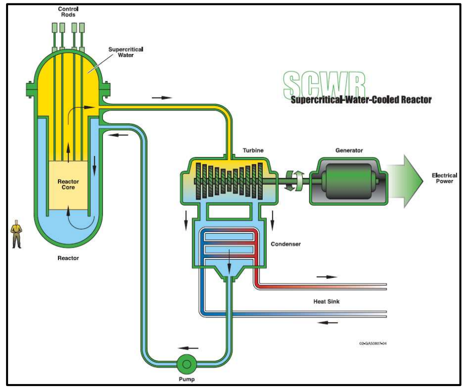
# Accelerator driven systems / Generation IV nuclear reactors




➔ **fast neutron** induced fission is used to produce electrical power and to **burn up long lived actinides**

Hiroyuki OIGAWA
Presentation at Euratom PARTRA Cluster Meeting at FZK, Feb. 2008

http://www.gen-4.org/Technology/roadmap.htm

# Data needs

**Table 32. Summary of Highest Priority Target Accuracies for Fast Reactors**

| | | Energy Range | Current Accuracy (%) | Target Accuracy (%) |
|---|---|---|---|---|
| U238 | $\sigma_{inel}$ | 6.07 ÷ 0.498 MeV | 10 ÷ 20 | 2 ÷ 3 |
| | $\sigma_{capt}$ | 24.8 ÷ 2.04 keV | 3 ÷ 9 | 1.5 ÷ 2 |
| Pu241 | $\sigma_{fiss}$ | 1.35MeV ÷ 454 eV | 8 ÷ 20 | 2 ÷ 3 (SFR,GFR, LFR)<br>5 ÷ 8 (ABTR, EFR) |
| Pu239 | $\sigma_{capt}$ | 498 ÷ 2.04 keV | 7 ÷ 15 | 4 ÷ 7 |
| Pu240 | $\sigma_{fiss}$ | 1.35 ÷ 0.498 MeV | 6 | 1.5 ÷ 2 |
| | ν | 1.35 ÷ 0.498 MeV | 4 | 1 ÷ 3 |
| Pu242 | $\sigma_{fiss}$ | 2.23 ÷ 0.498 MeV | 19 ÷ 21 | 3 ÷ 5 |
| Pu238 | $\sigma_{fiss}$ | 1.35 ÷ 0.183 MeV | 17 | 3 ÷ 5 |
| Am242m | $\sigma_{fiss}$ | 1.35MeV ÷ 67.4keV | 17 | 3 ÷ 4 |
| Am241 | $\sigma_{fiss}$ | 6.07 ÷ 2.23 MeV | 12 | 3 |
| Cm244 | $\sigma_{fiss}$ | 1.35 ÷ 0.498 MeV | 50 | 5 |
| Cm245 | $\sigma_{fiss}$ | 183 ÷ 67.4 keV | 47 | 7 |
| Fe56 | $\sigma_{inel}$ | 2.23 ÷ 0.498 MeV | 16 ÷ 25 | 3 ÷ 6 |
| Na23 | $\sigma_{inel}$ | 1.35 ÷ 0.498 MeV | 28 | 4 ÷ 10 |
| Pb206 | $\sigma_{inel}$ | 2.23 ÷ 1.35 MeV | 14 | 3 |
| Pb207 | $\sigma_{inel}$ | 1.35 ÷ 0.498 MeV | 11 | 3 |
| Si28 | $\sigma_{inel}$ | 6.07 ÷ 1.35 MeV | 14 ÷ 50 | 3 ÷ 6 |
| | $\sigma_{capt}$ | 19.6 ÷ 6.07 MeV | 53 | 6 |

http://www.nea.fr/html/science/wpec/volume26/volume26.pdf

- for simulations and calculations to design such facilities **detailed knowledge about the neutron interactions in the relevant energy region are necessary**

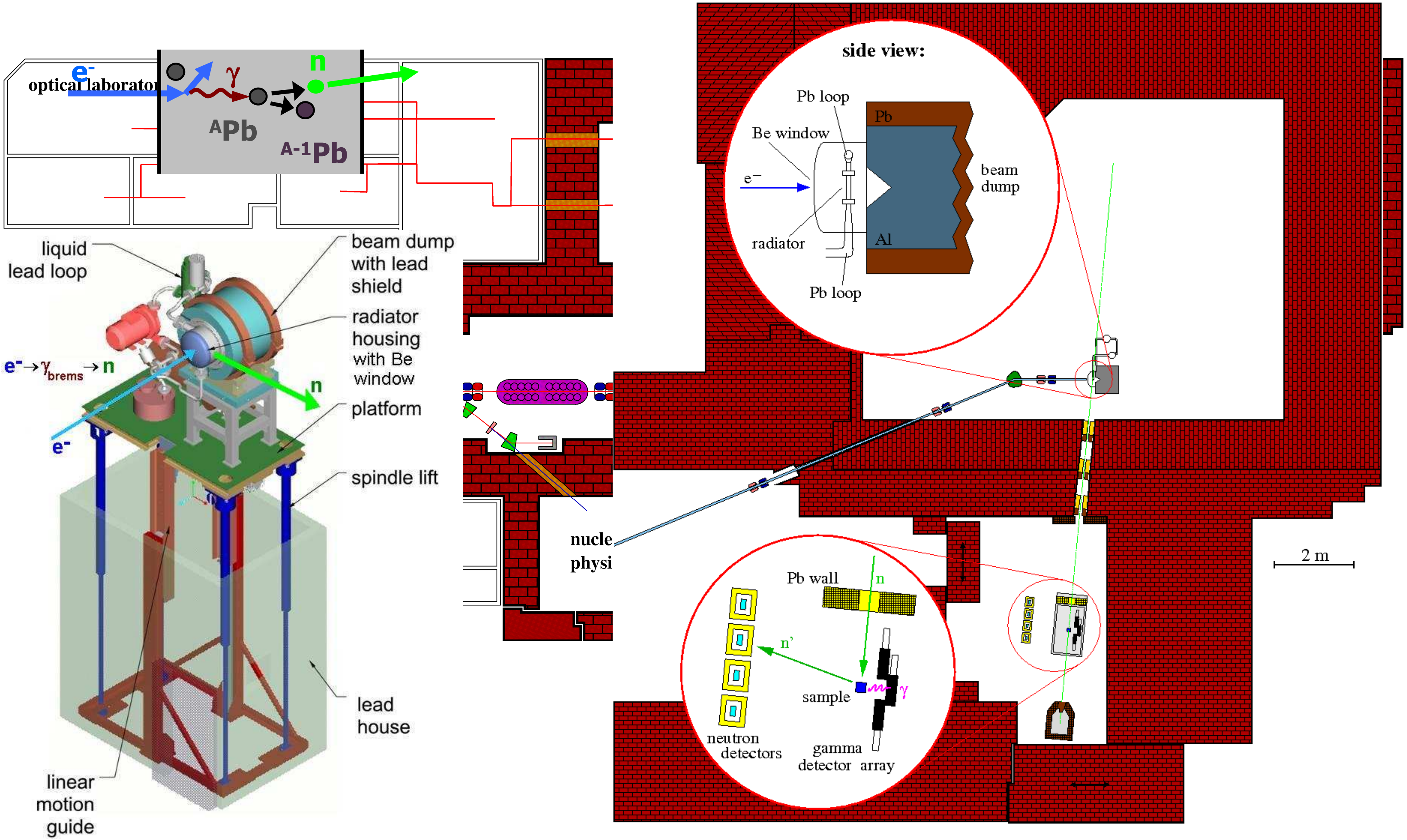
  ➔ for nuclei to be transmuted as well as for structural materials

  ➔ fast neutron spectrum

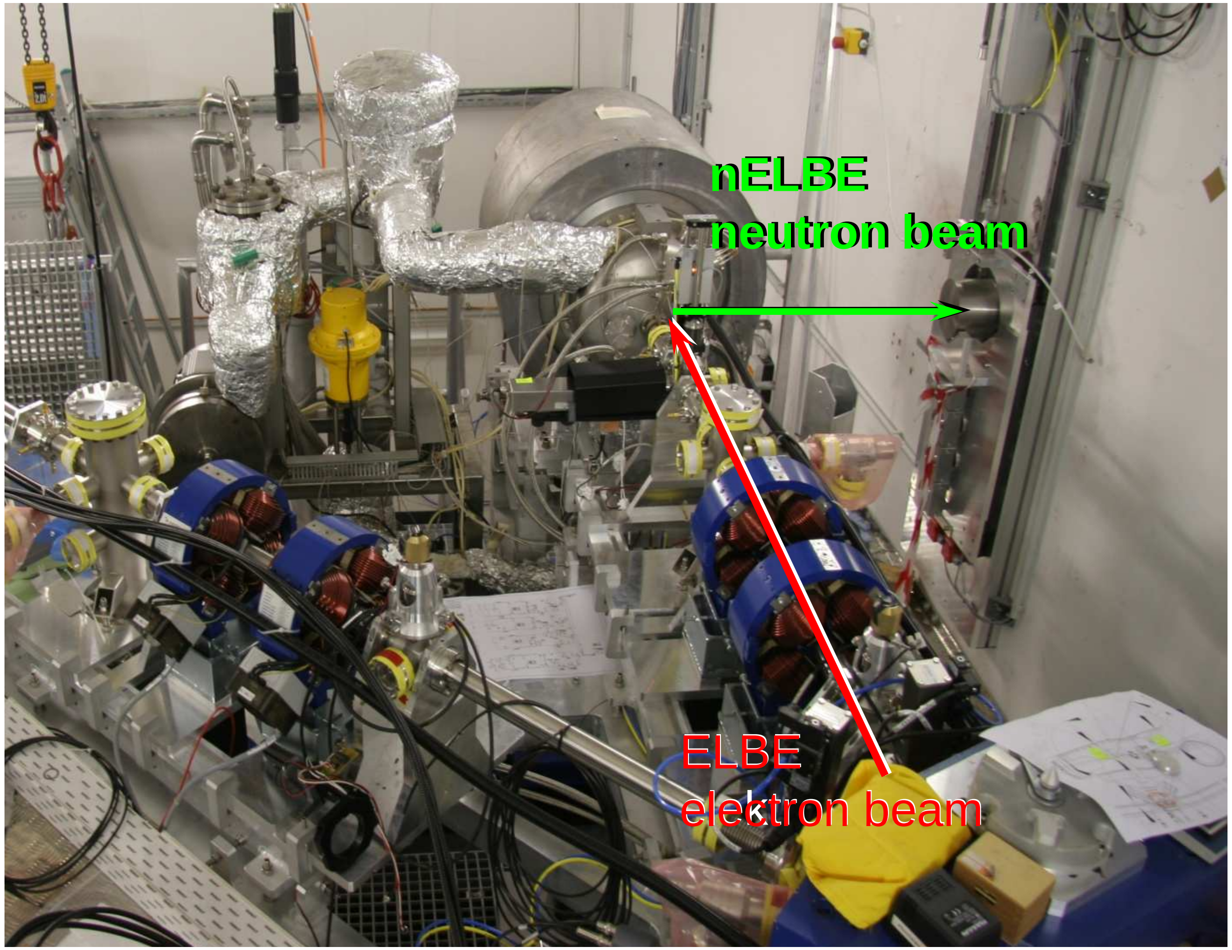
  - neutron induced fission
  - neutron capture
  - neutron inelastic scattering

➔ $^{56}Fe(n,n'\gamma)\,^{56}Fe$

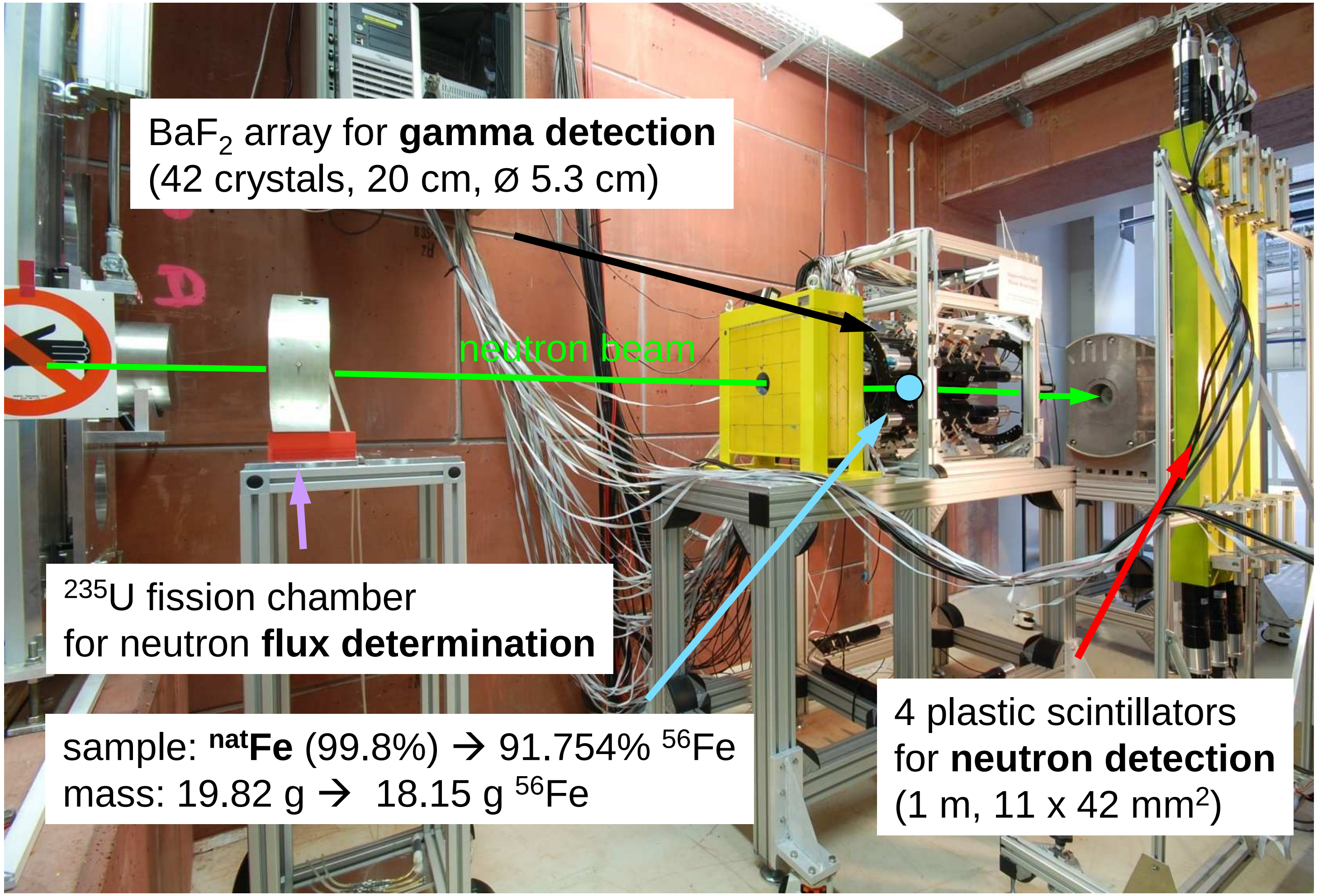
# nELBE – neutron facility at ELBE



# nELBE – neutron production



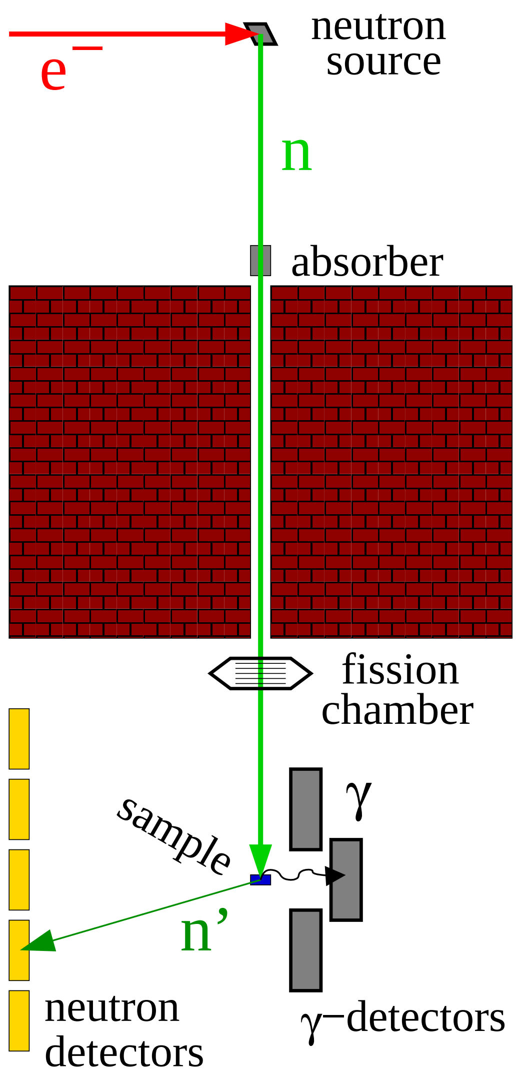
# nELBE – detector setup

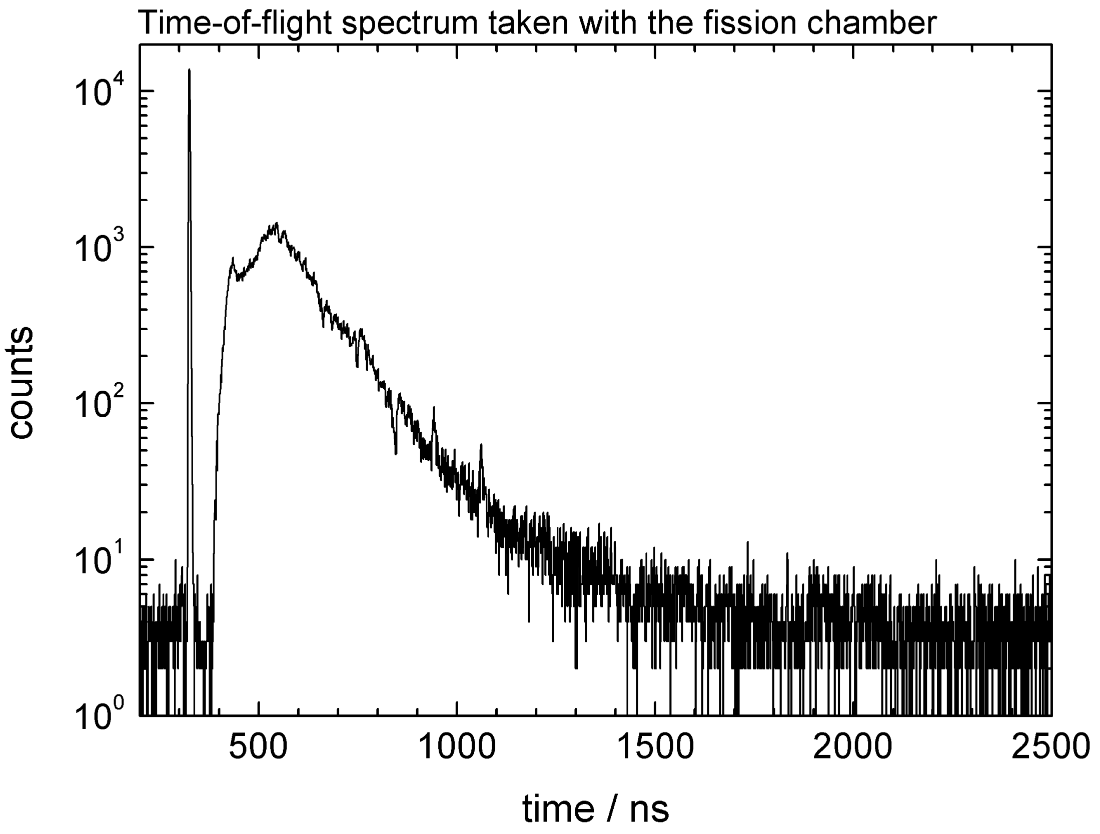



flight paths:
source – sample:
600 cm
sample – BaF$_2$ scint.:
30 cm
sample – plastic scint.:
100 cm

→ R. Hannaske, HK 55.6, Thu 18:15

# Experimental methods and results – Inelastic scattering



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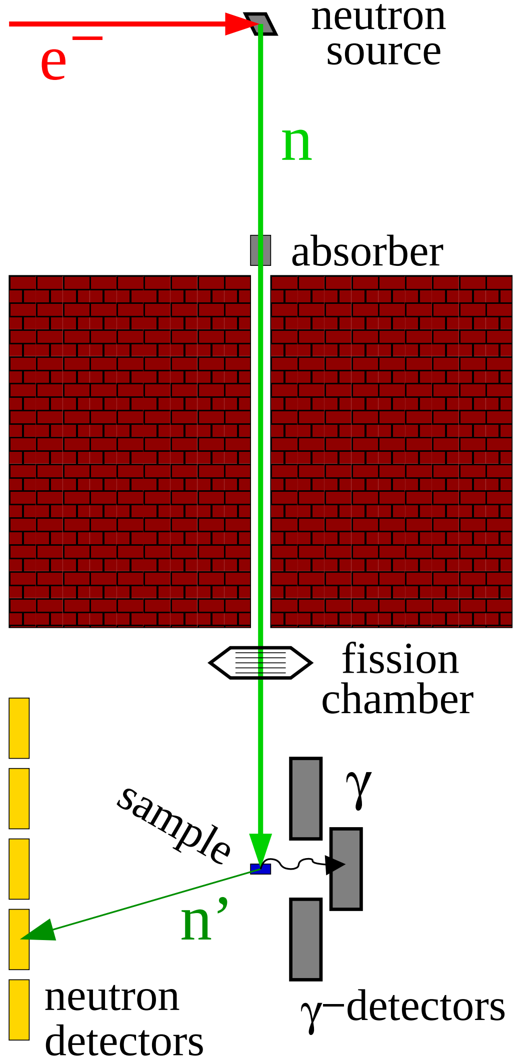
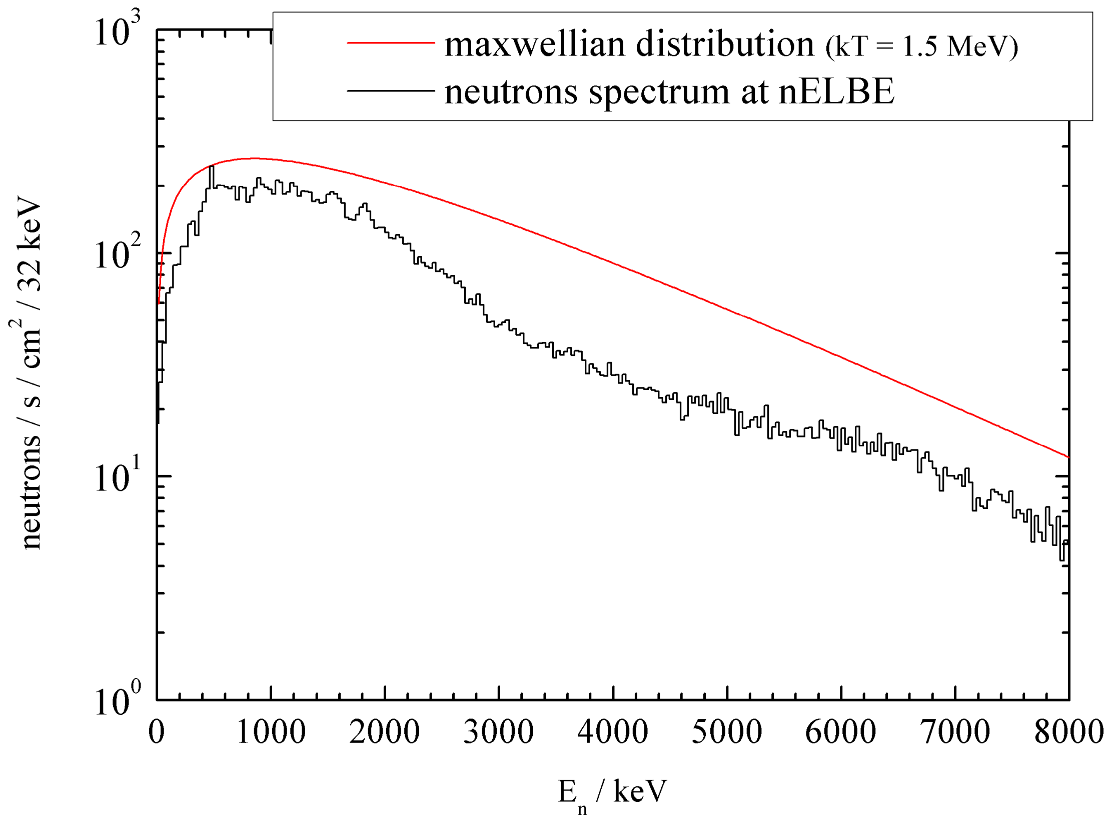



Integral at target: $2 \times 10^4$ n/s/cm$^2$



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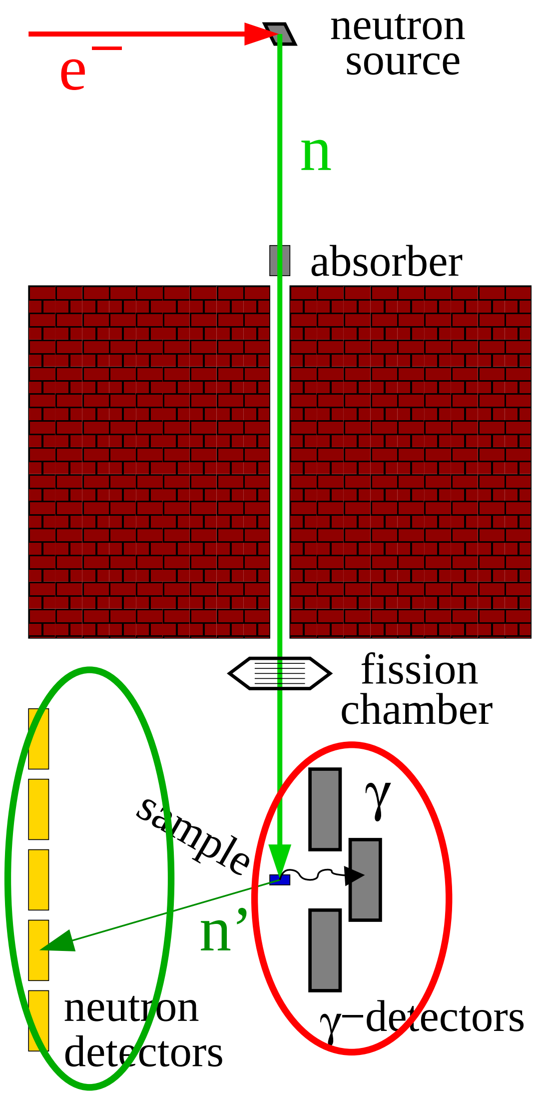
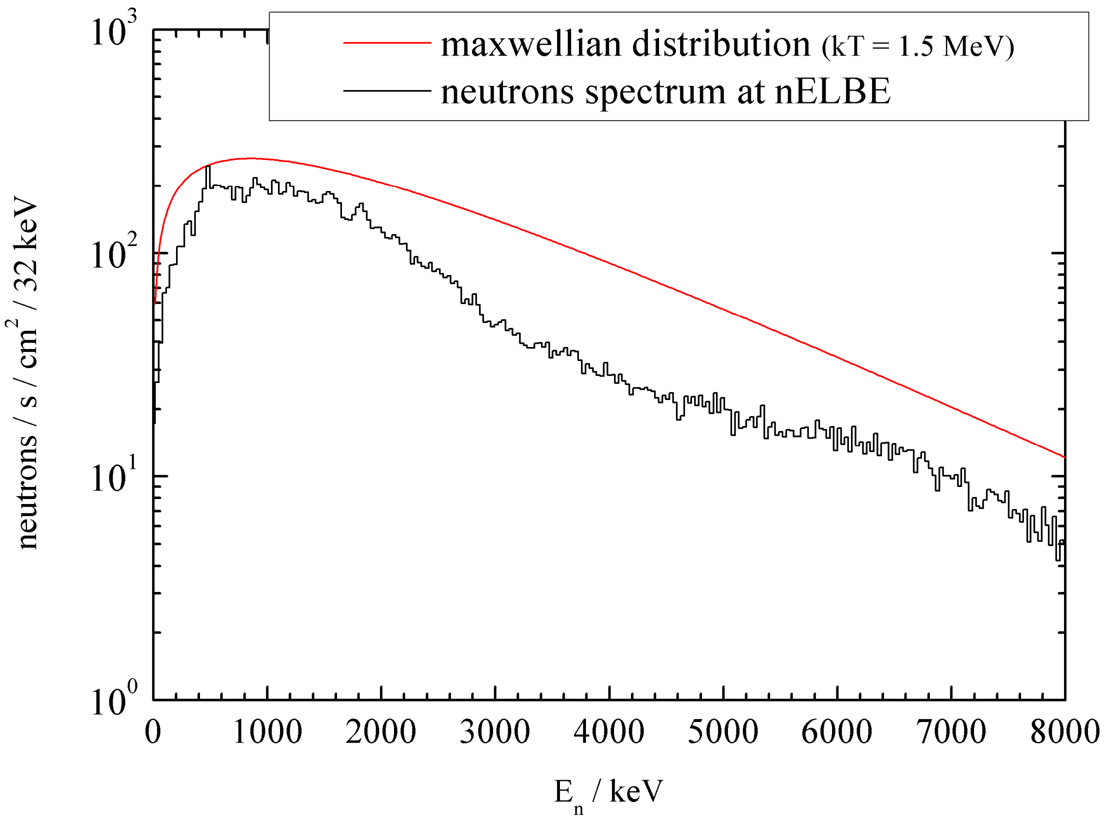



$$^{56}\mathrm{Fe}(n,n'\gamma)^{56}\mathrm{Fe}\;\begin{cases} ^{56}\mathrm{Fe}+n \rightarrow {}^{56}\mathrm{Fe}^{*}+n' \\ \quad ^{56}\mathrm{Fe}^{*} \rightarrow {}^{56}\mathrm{Fe}+\gamma \end{cases}$$

Integral at target: $2\mathrm{x}10^{4}$ n/s/cm$^{2}$



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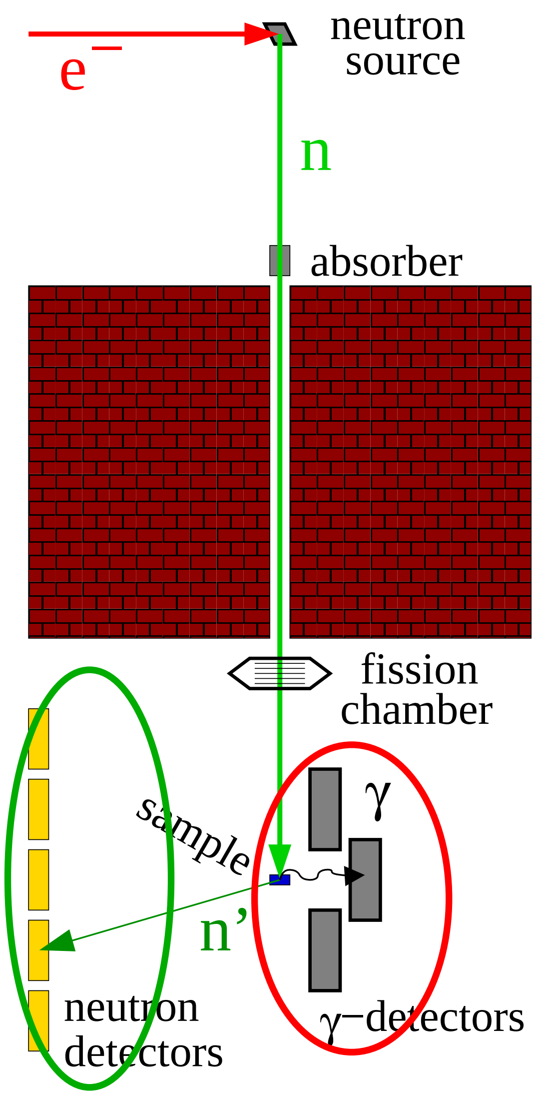
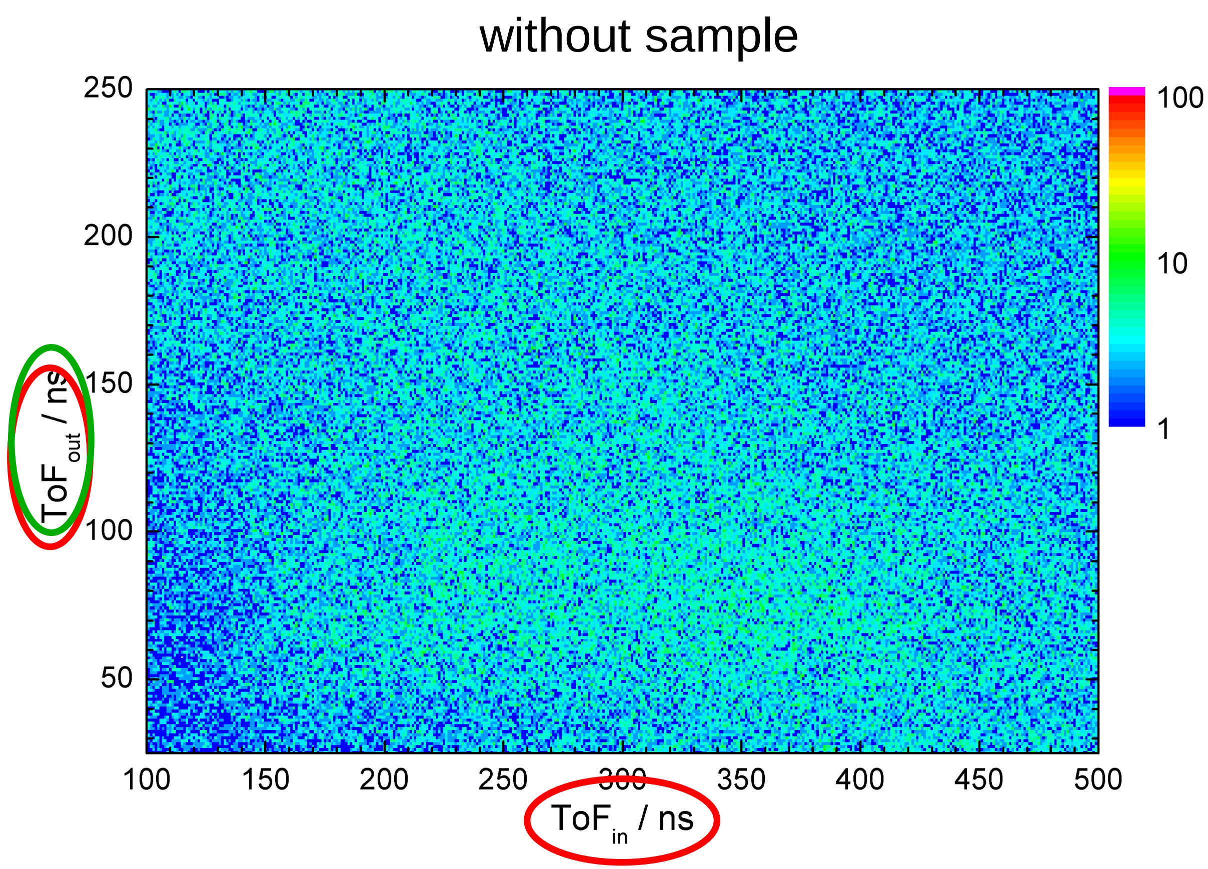



$$^{56}\mathrm{Fe}(n,n'\gamma)^{56}\mathrm{Fe} \left\{ \begin{array}{l} ^{56}\mathrm{Fe} + n \rightarrow {}^{56}\mathrm{Fe}^{*} + n' \\ \qquad\qquad {}^{56}\mathrm{Fe}^{*} \rightarrow {}^{56}\mathrm{Fe} + \gamma \end{array} \right.$$



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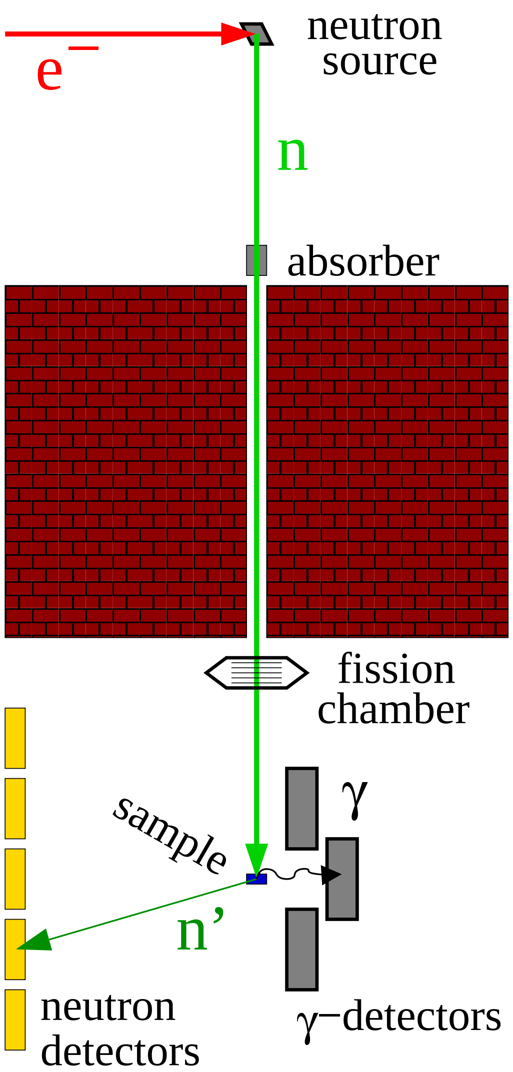
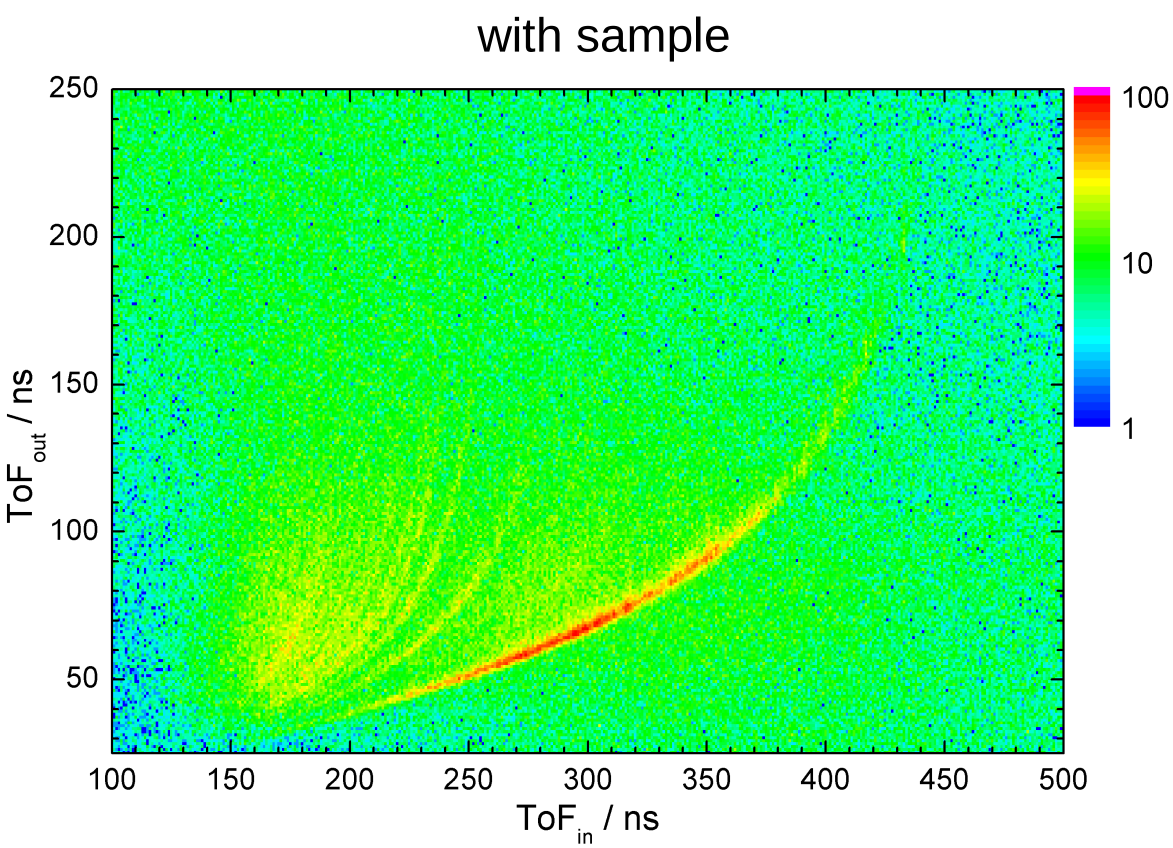



$$^{56}\mathrm{Fe}(n,n'\gamma)^{56}\mathrm{Fe} \quad \begin{cases} ^{56}\mathrm{Fe}+n \rightarrow {}^{56}\mathrm{Fe}^{*}+n' \\ \qquad\qquad ^{56}\mathrm{Fe}^{*} \rightarrow {}^{56}\mathrm{Fe}+\gamma \end{cases}$$



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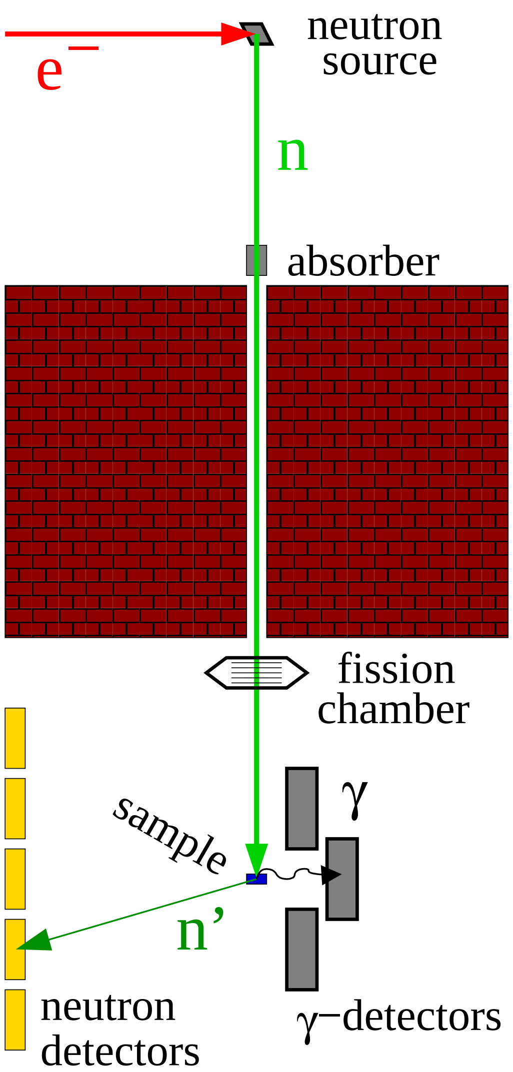
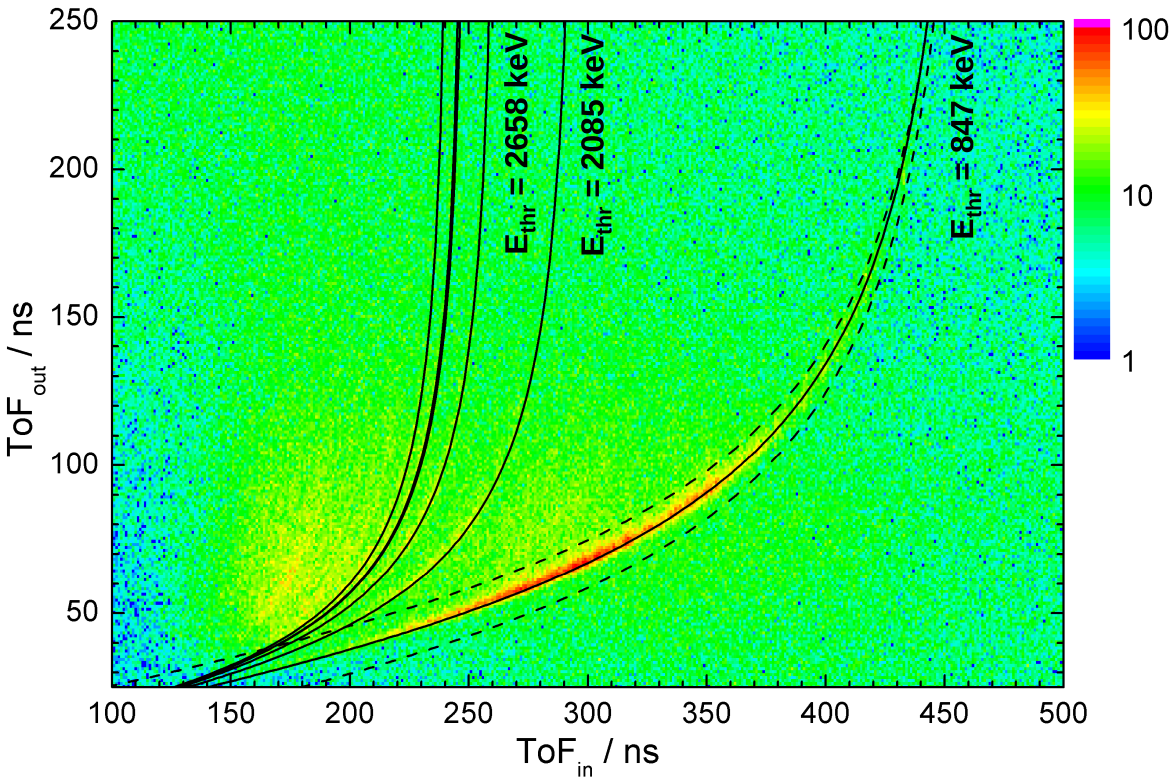
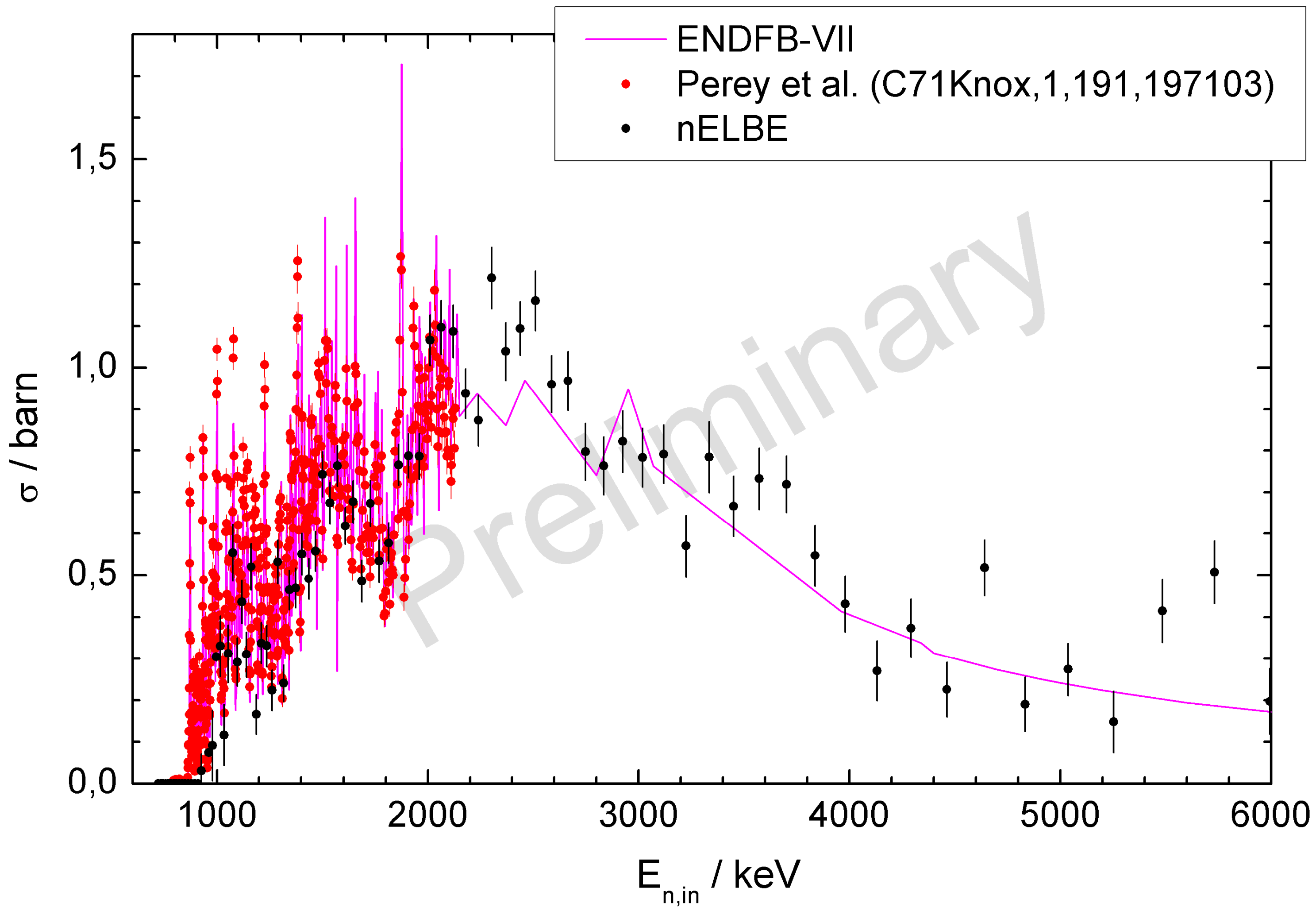



$$^{56}Fe(n,n'\gamma)^{56}Fe \left\{ \begin{array}{l} ^{56}Fe + n \rightarrow {}^{56}Fe^{*} + n' \\ \qquad\qquad {}^{56}Fe^{*} \rightarrow {}^{56}Fe + \gamma \end{array} \right.$$

with sample + kinematics calculation



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



# 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, and to
  - correct for angular effects

# Thanks to all collaborators

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