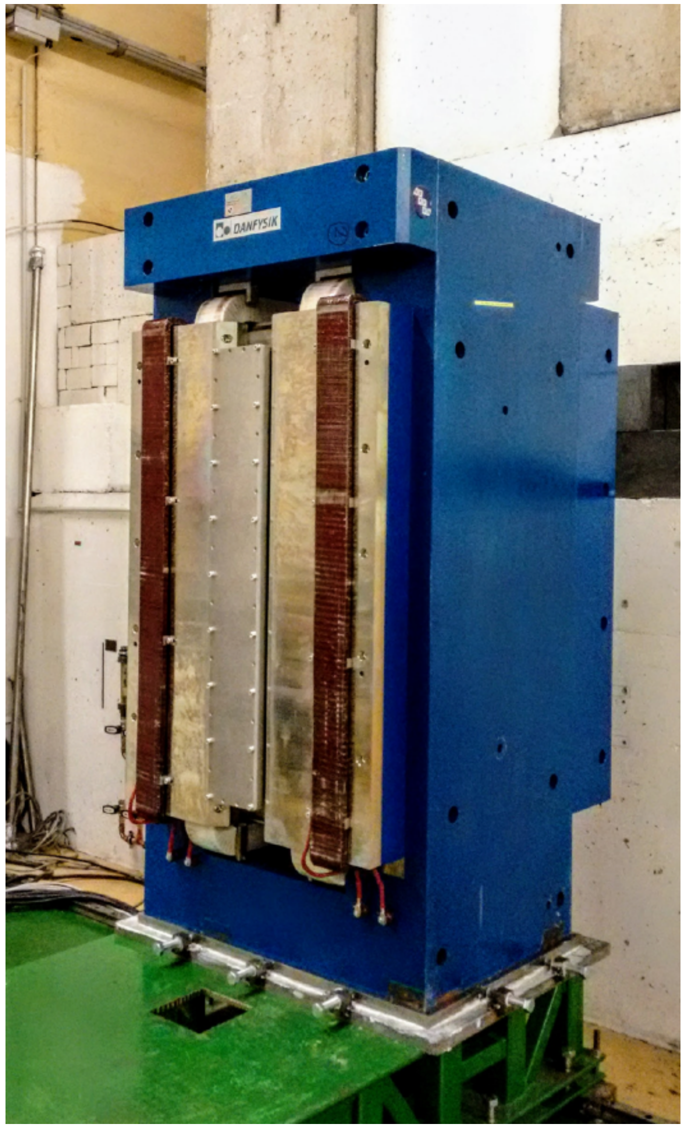
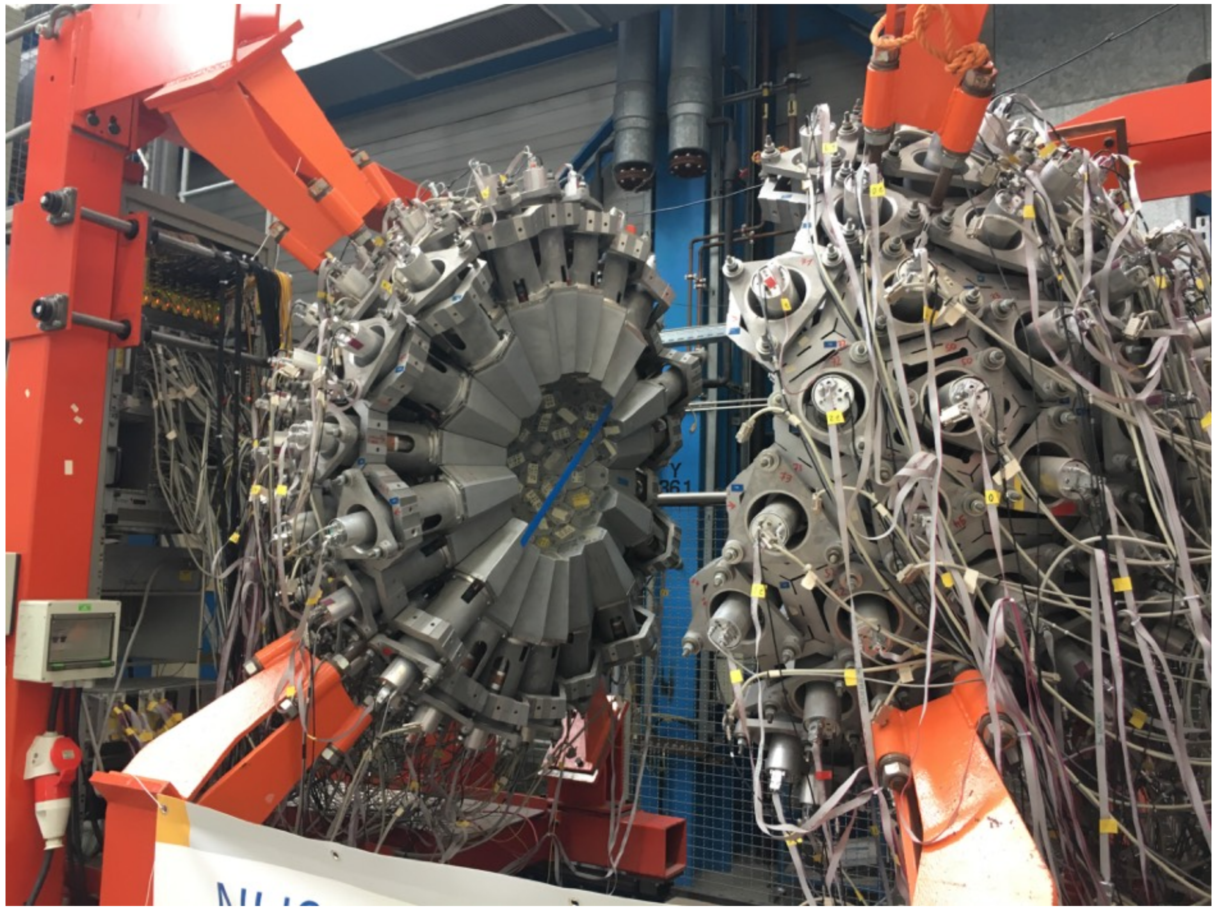
B04: Status NEPTUN Upgrade and Two-Gamma Decay Experiments

TECHNISCHE UNIVERSITÄT DARMSTADT

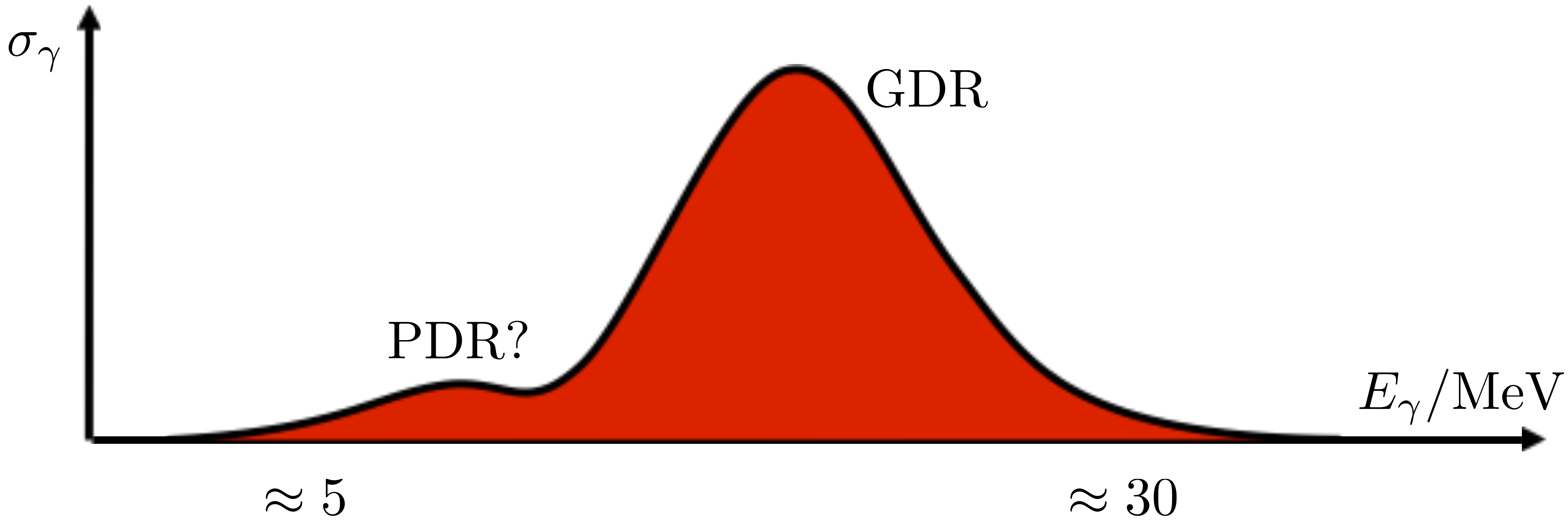
Patrick van Beek – 04.10.2017





SFB 1245

Dipole Response of Nuclei

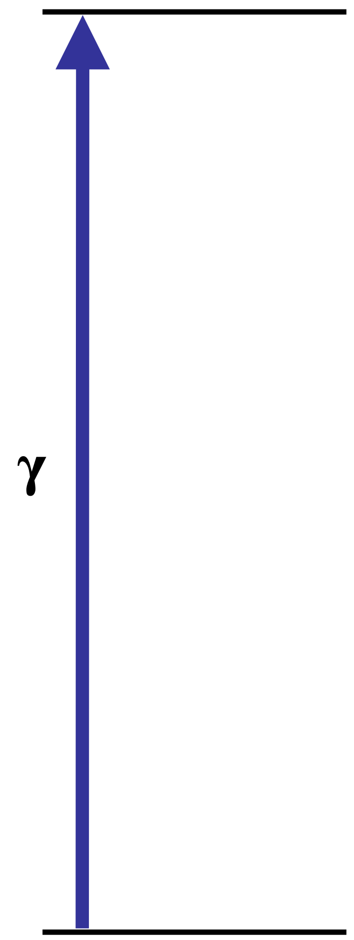


With photo nuclear cross section: calculate polarizability

$$\alpha_\mathrm{D} = \frac{\hbar c}{2\pi^2} \int_0^\infty \frac{\sigma_\gamma(E)}{E^2}\, dE$$

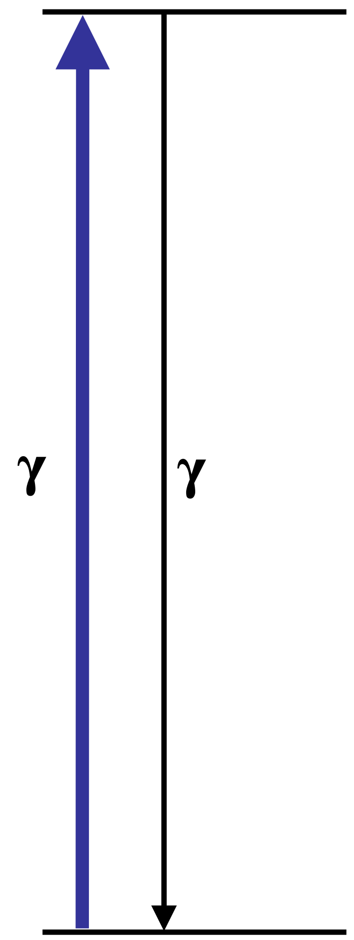
Measuring Photo Nuclear Cross Section with real Photons

$$\sigma_{\mathrm{tot}} = \sigma_{\gamma'} + \sigma_{\gamma'\gamma'} + \cdots + \sigma_n + \sigma_{2n} + \cdots + \sigma_p + \sigma_\alpha + \ldots$$



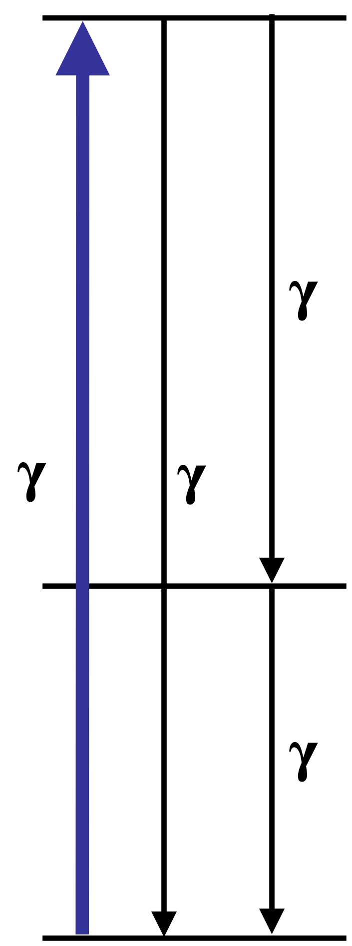
Measuring Photo Nuclear Cross Section with real Photons

$$\sigma_{\text{tot}} = \sigma_{\gamma'} + \sigma_{\gamma'\gamma'} + \cdots + \sigma_n + \sigma_{2n} + \cdots + \sigma_p + \sigma_\alpha + \dots$$



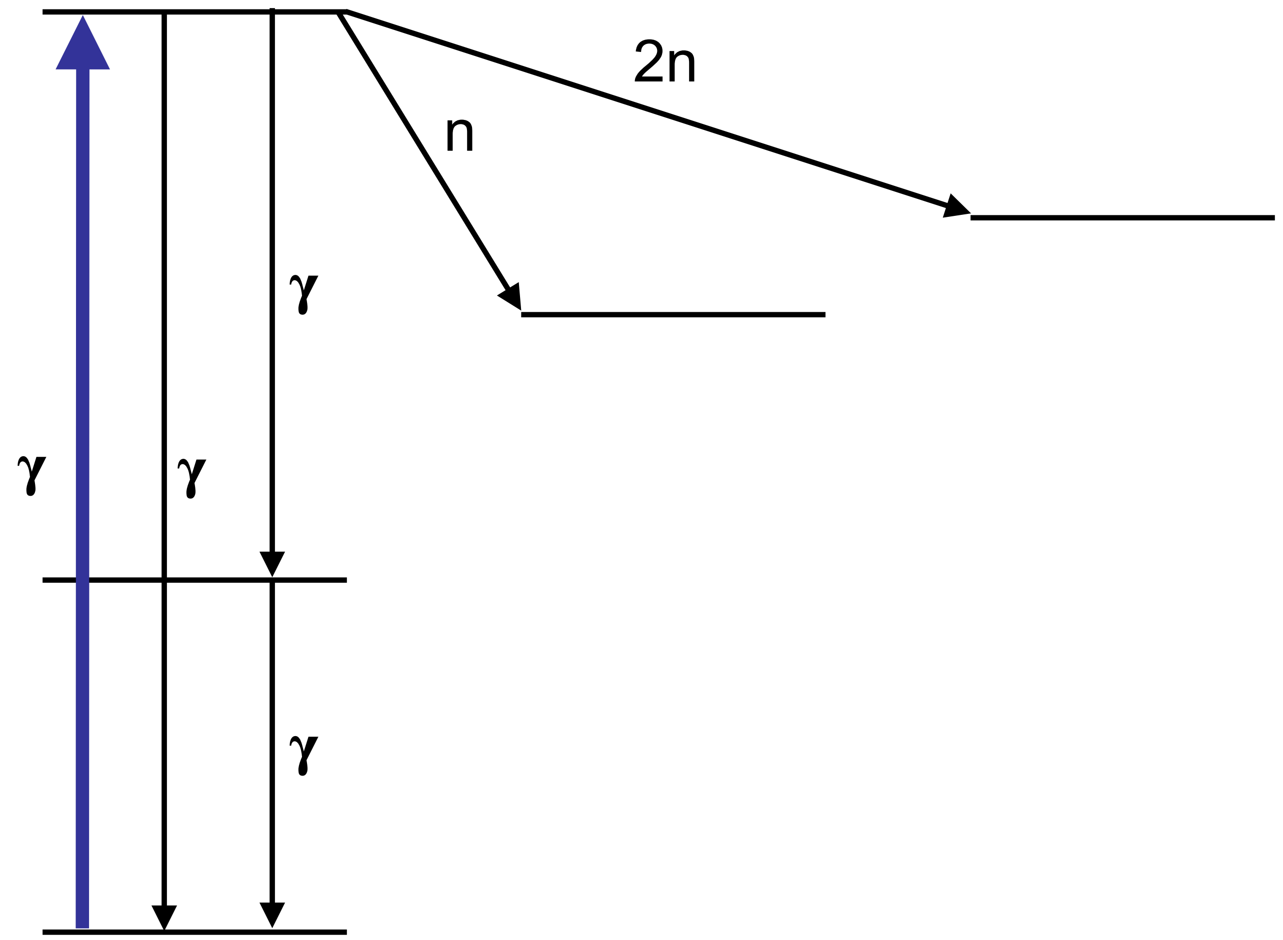
Measuring Photo Nuclear Cross Section with real Photons

$$\sigma_{\text{tot}} = \sigma_{\gamma'} + \sigma_{\gamma'\gamma'} + \dots + \sigma_n + \sigma_{2n} + \dots + \sigma_p + \sigma_\alpha + \dots$$



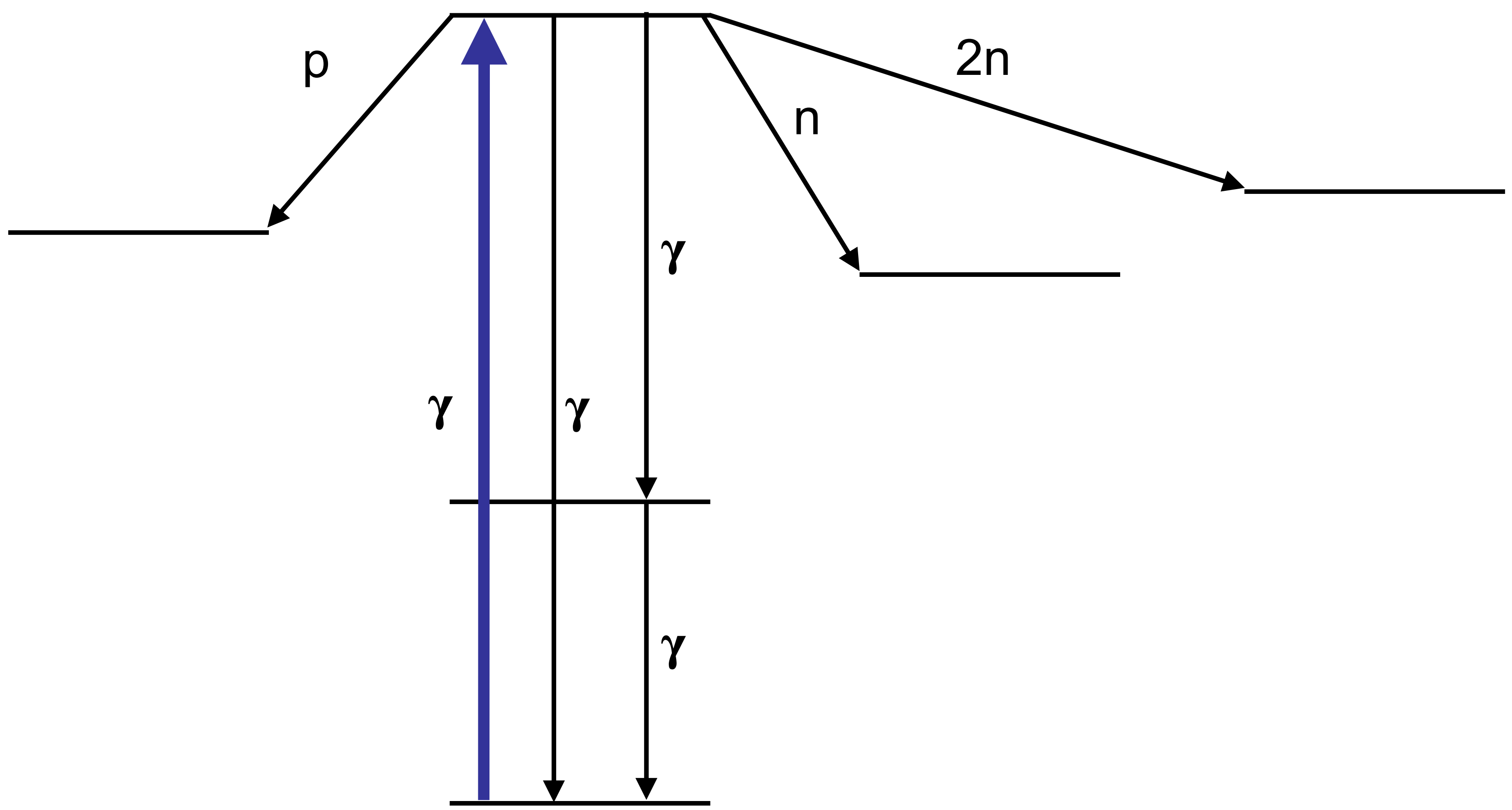
Measuring Photo Nuclear Cross Section with real Photons

$$\sigma_{\text{tot}} = \sigma_{\gamma'} + \sigma_{\gamma'\gamma'} + \dots + \sigma_n + \sigma_{2n} + \dots + \sigma_p + \sigma_\alpha + \dots$$



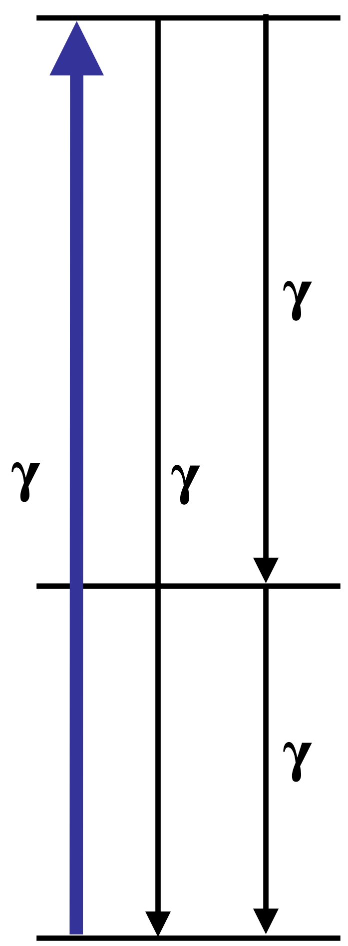
Measuring Photo Nuclear Cross Section with real Photons

$$\sigma_{\text{tot}} = \sigma_{\gamma'} + \sigma_{\gamma'\gamma'} + \cdots + \sigma_n + \sigma_{2n} + \cdots + \sigma_p + \sigma_\alpha + \ldots$$

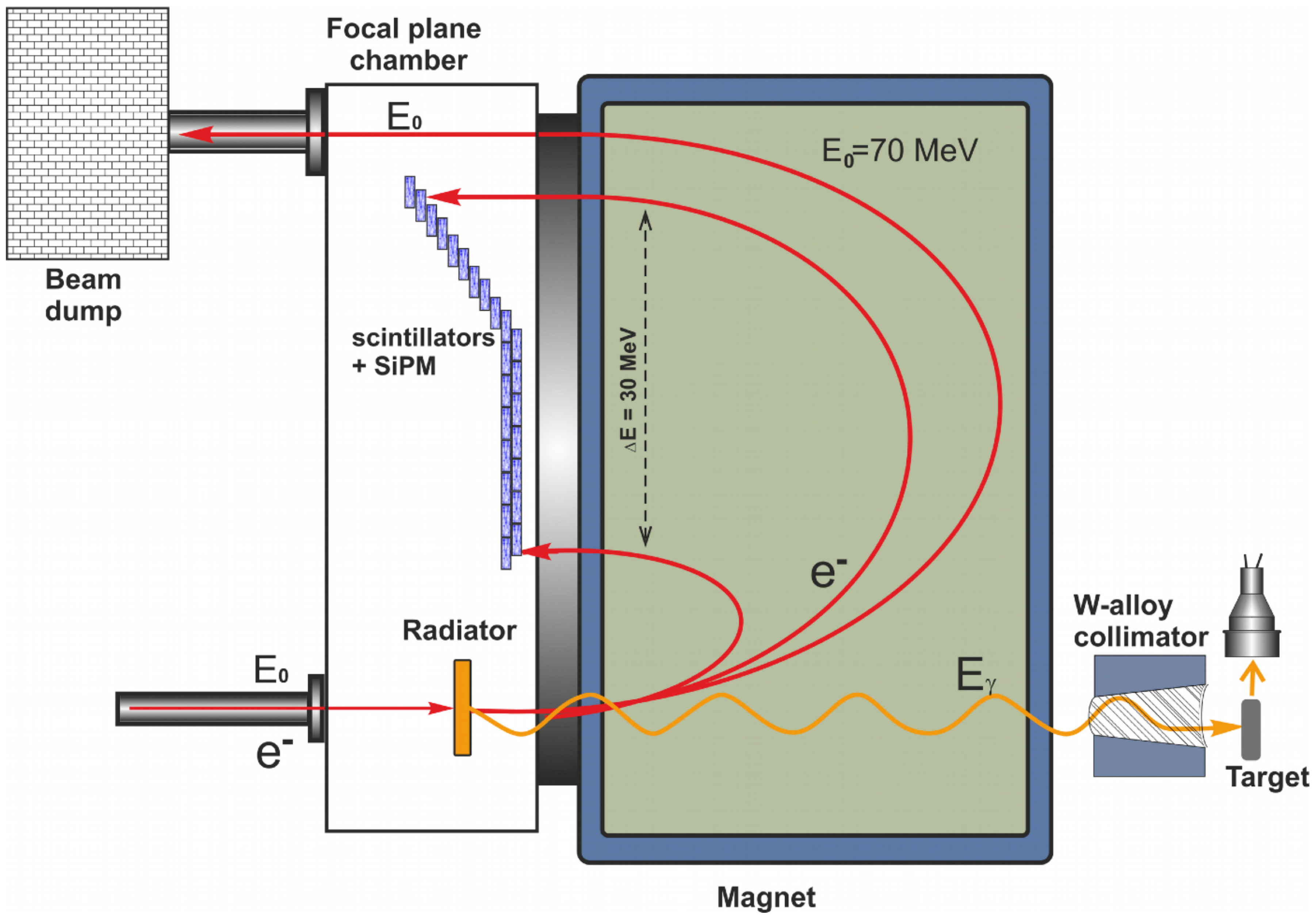


Measuring Photo Nuclear Cross Section with real Photons

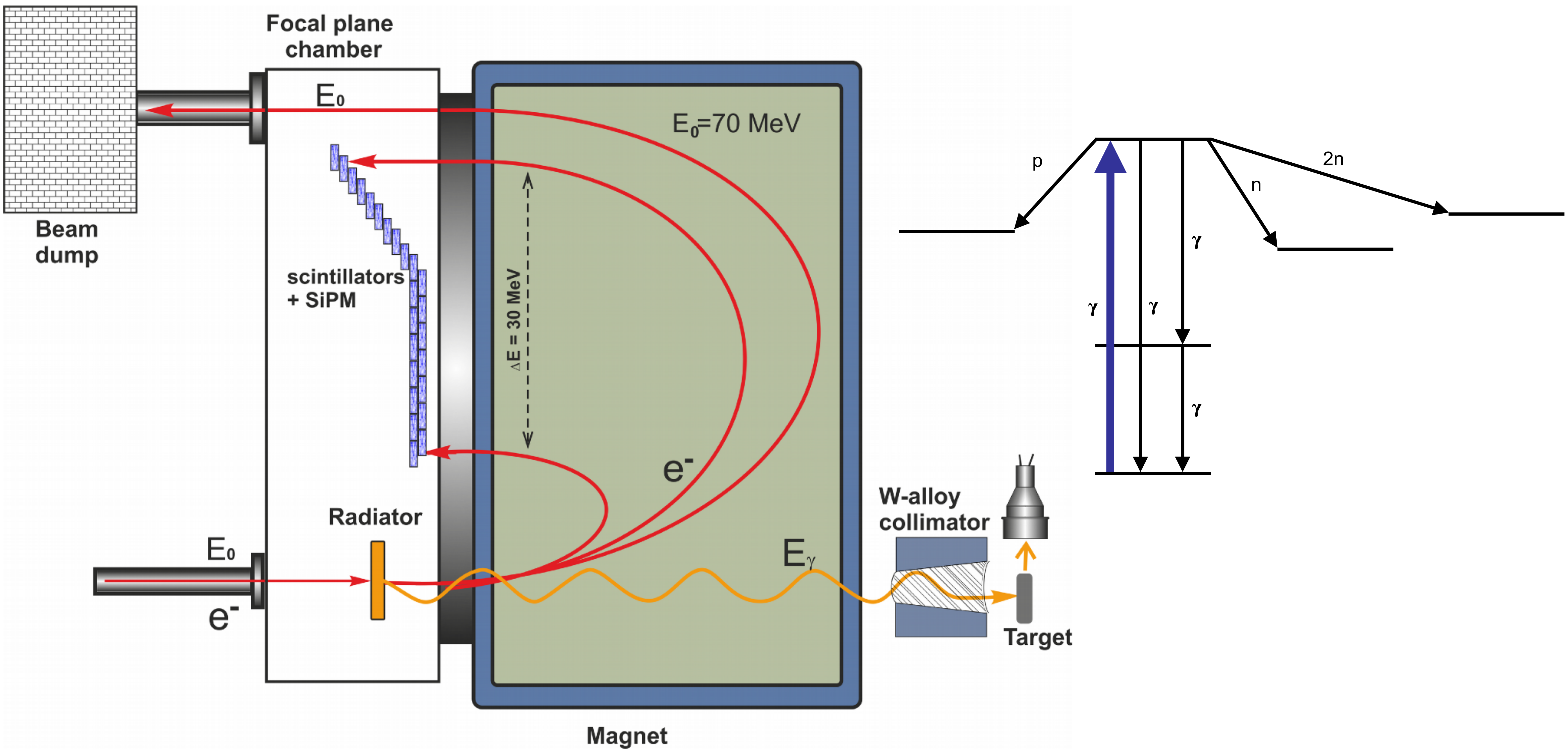
$$\sigma_{\text{tot}} = \sigma_{\gamma'} + \sigma_{\gamma'\gamma'} + \cdots + \sigma_n + \sigma_{2n} + \cdots + \sigma_p + \sigma_\alpha + \ldots$$



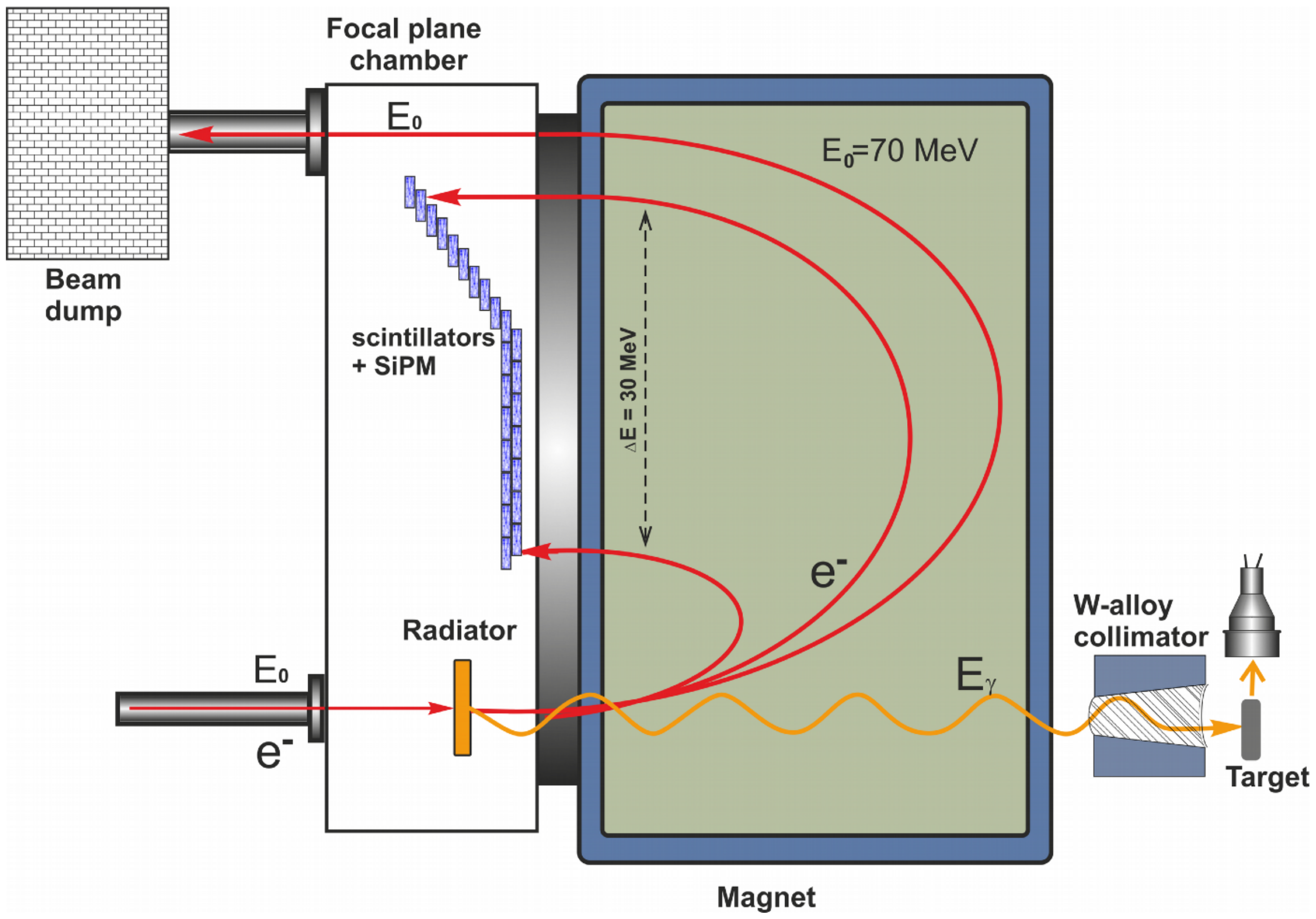
Neptun Photon Tagger – Upgrade



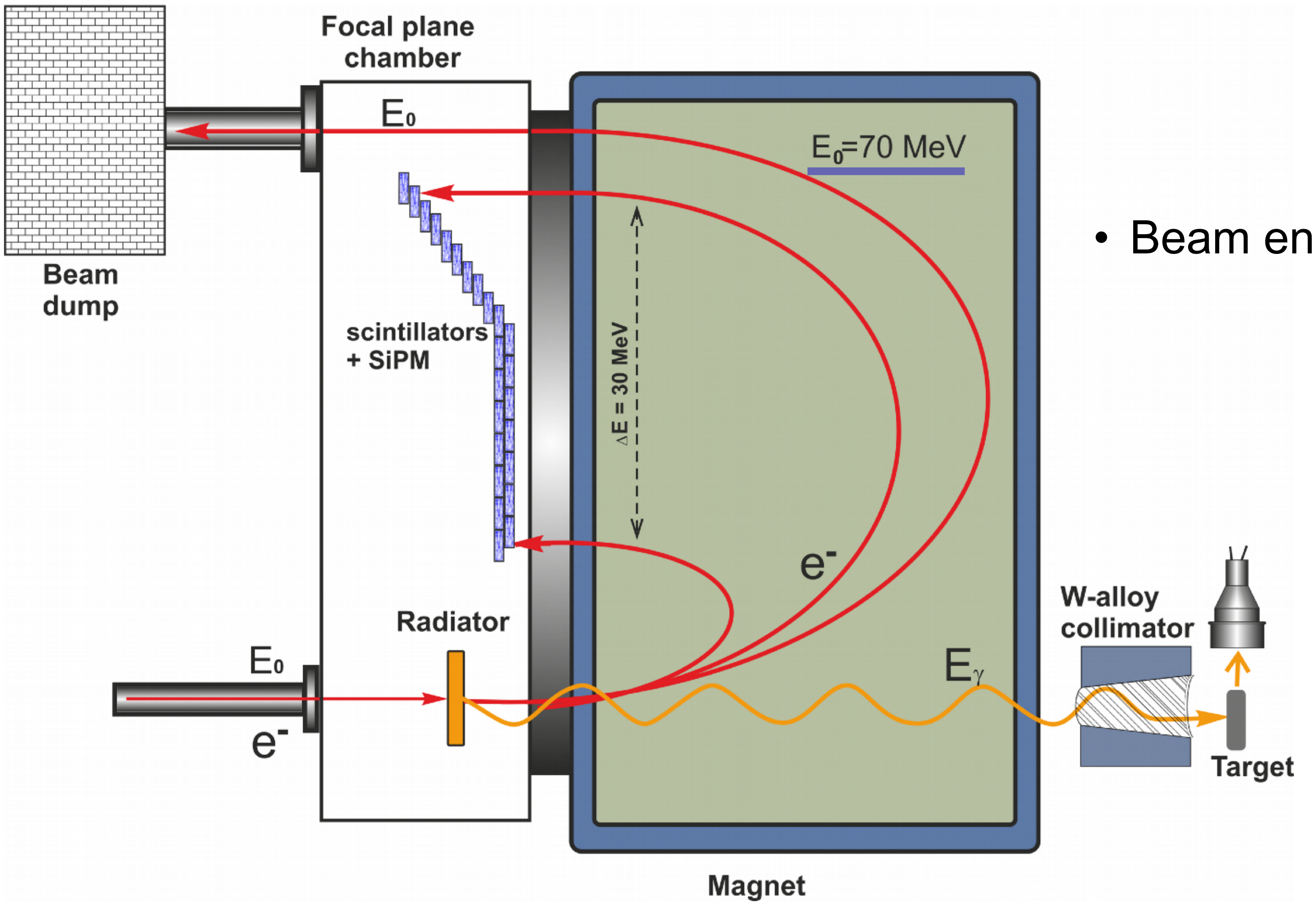
Neptun Photon Tagger – Upgrade



Neptun Photon Tagger – Upgrade

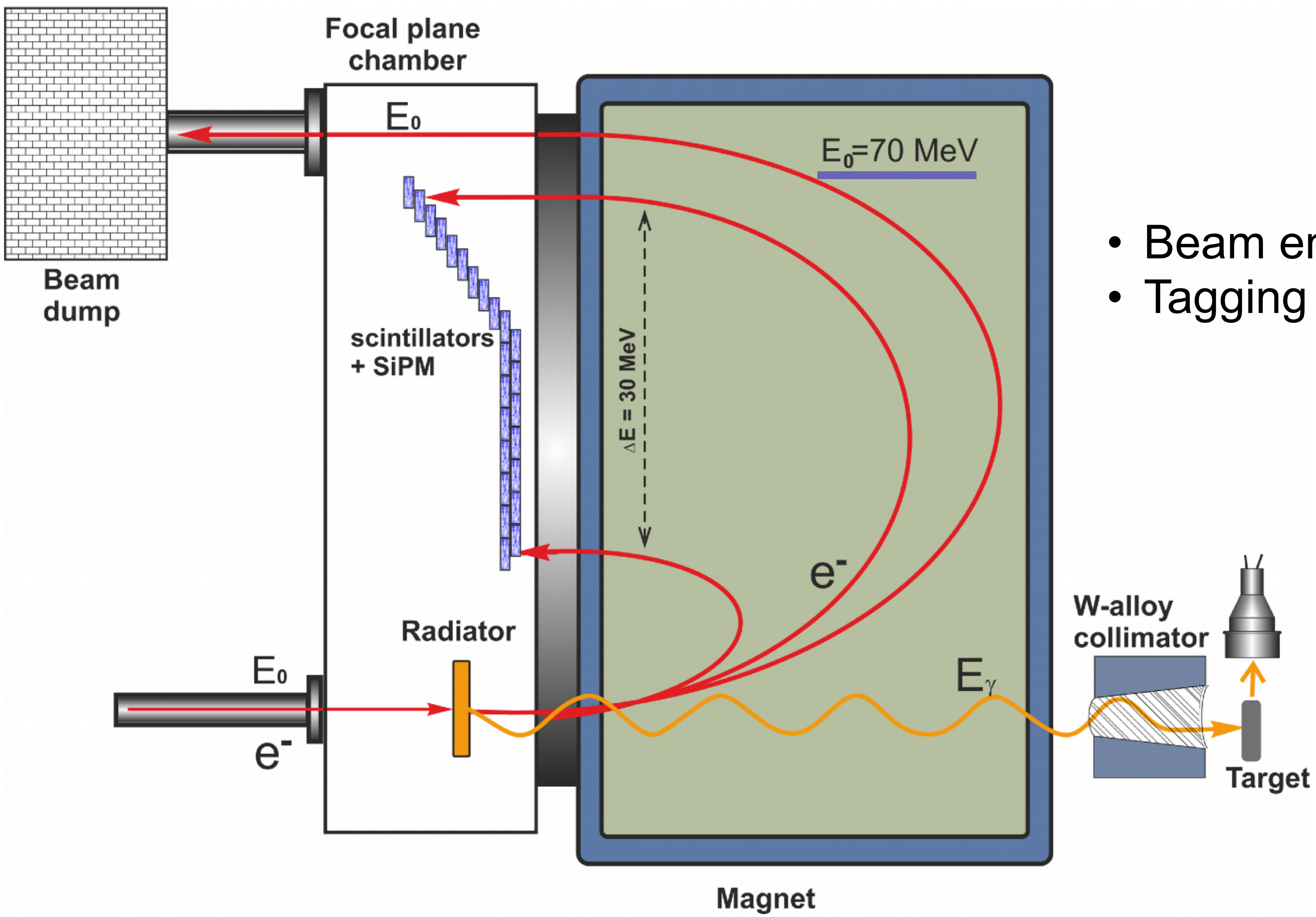


Neptun Photon Tagger – Upgrade



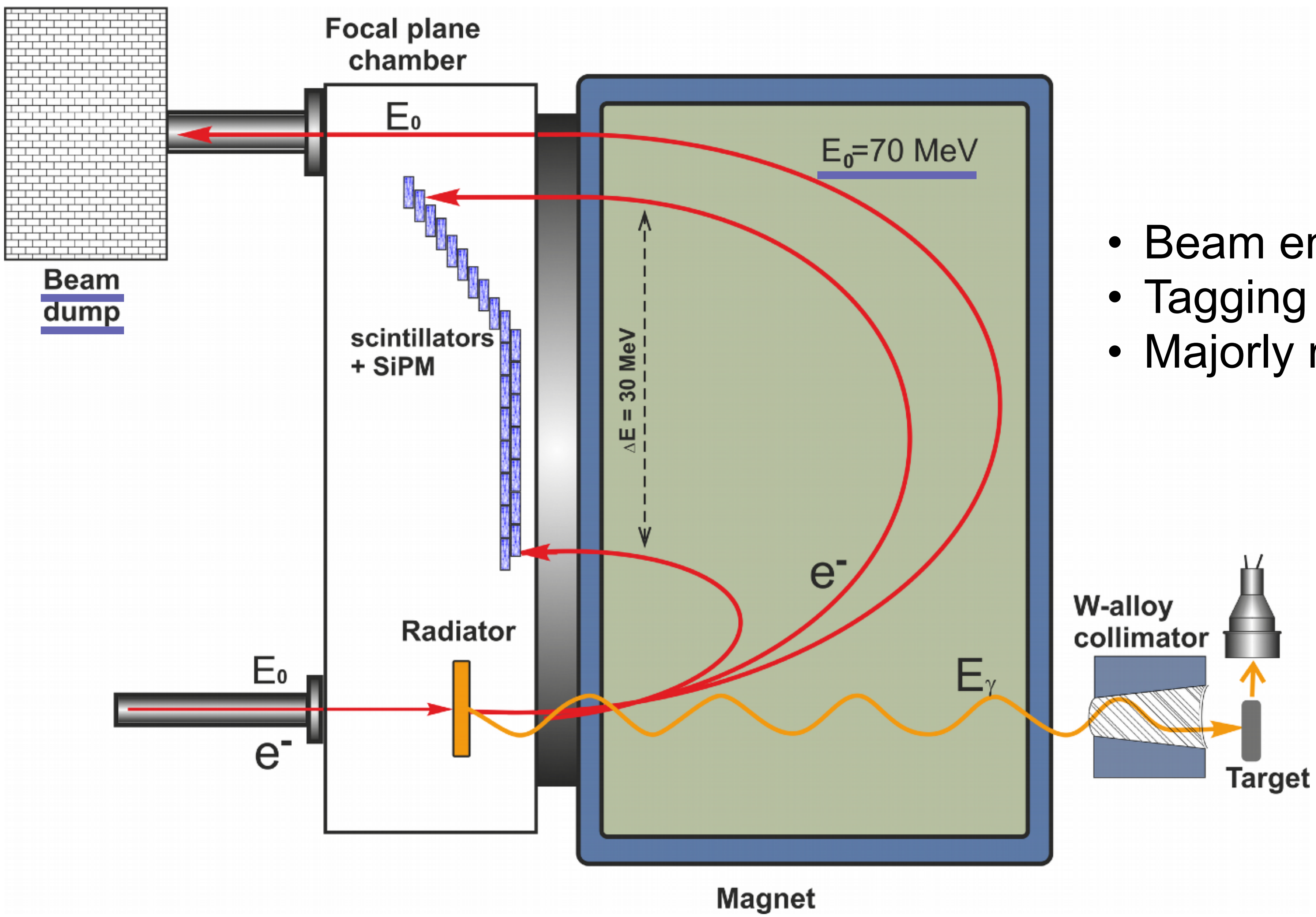
- Beam energy: 30 → 70 MeV

Neptun Photon Tagger – Upgrade



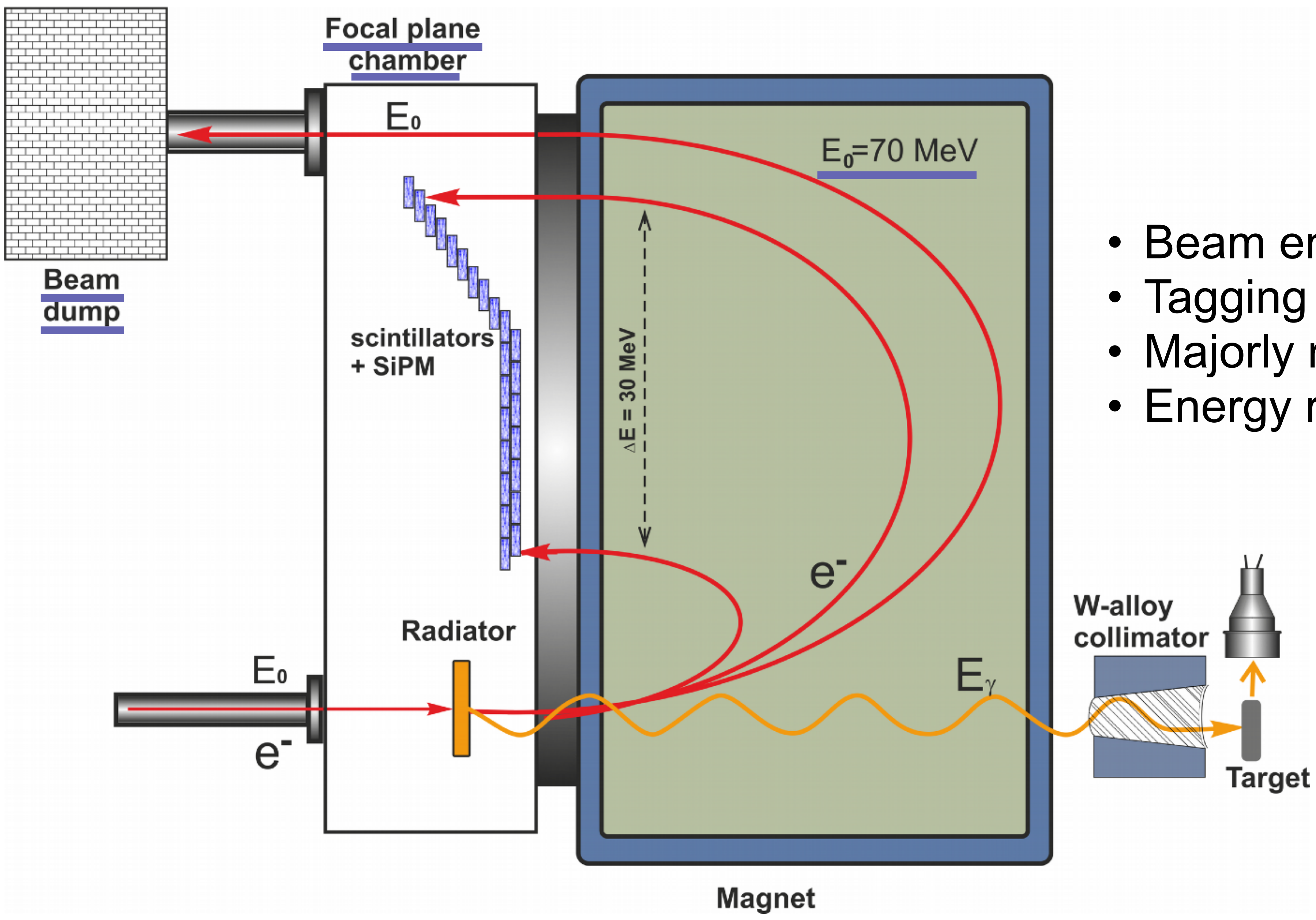
- Beam energy: 30 → 70 MeV
- Tagging ratio: 1.5 → 7.5%

Neptun Photon Tagger – Upgrade



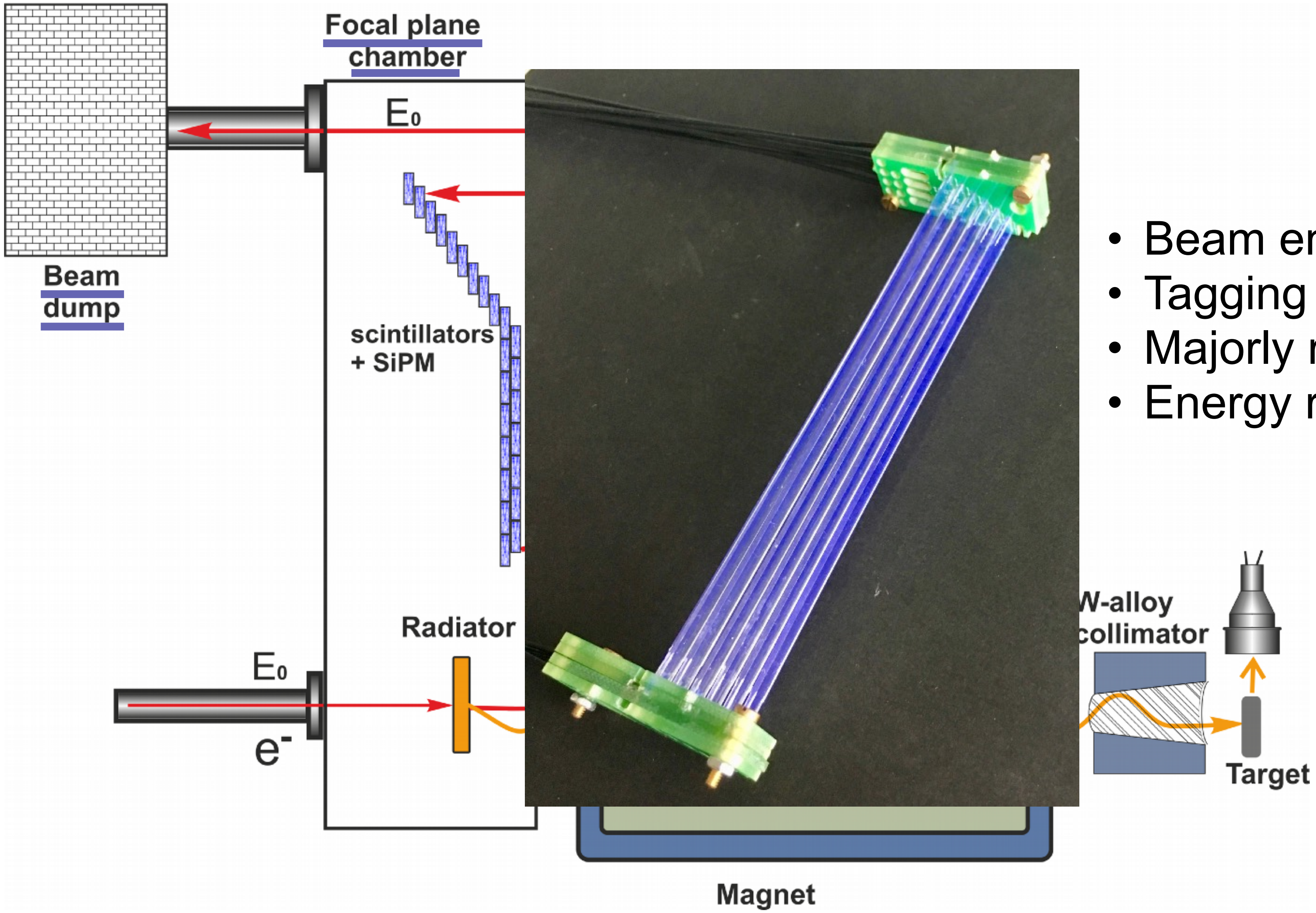
- Beam energy: 30 → 70 MeV
- Tagging ratio: 1.5 → 7.5%
- Majorly reduced background

Neptun Photon Tagger – Upgrade



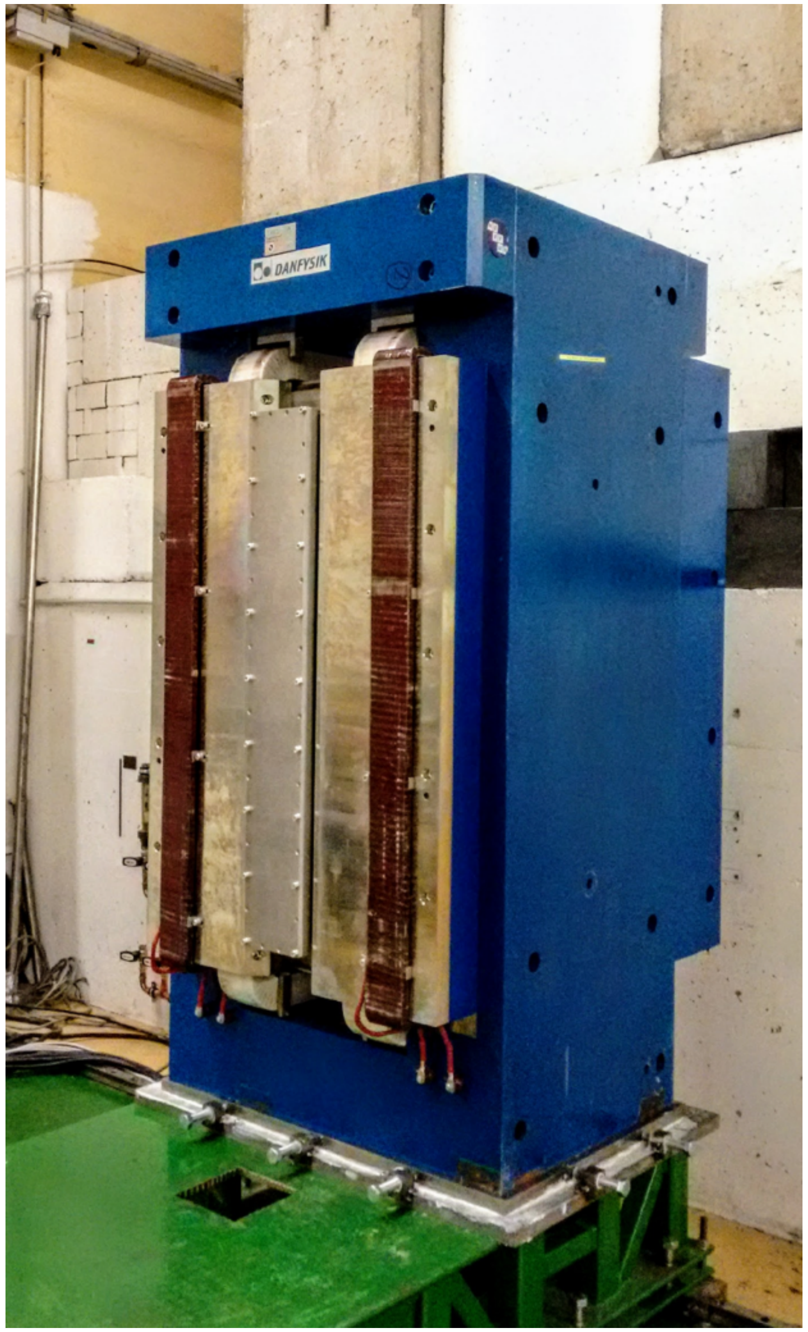
- Beam energy: 30 → 70 MeV
- Tagging ratio: 1.5 → 7.5%
- Majorly reduced background
- Energy range: 1.5 → 30 MeV

Neptun Photon Tagger – Upgrade

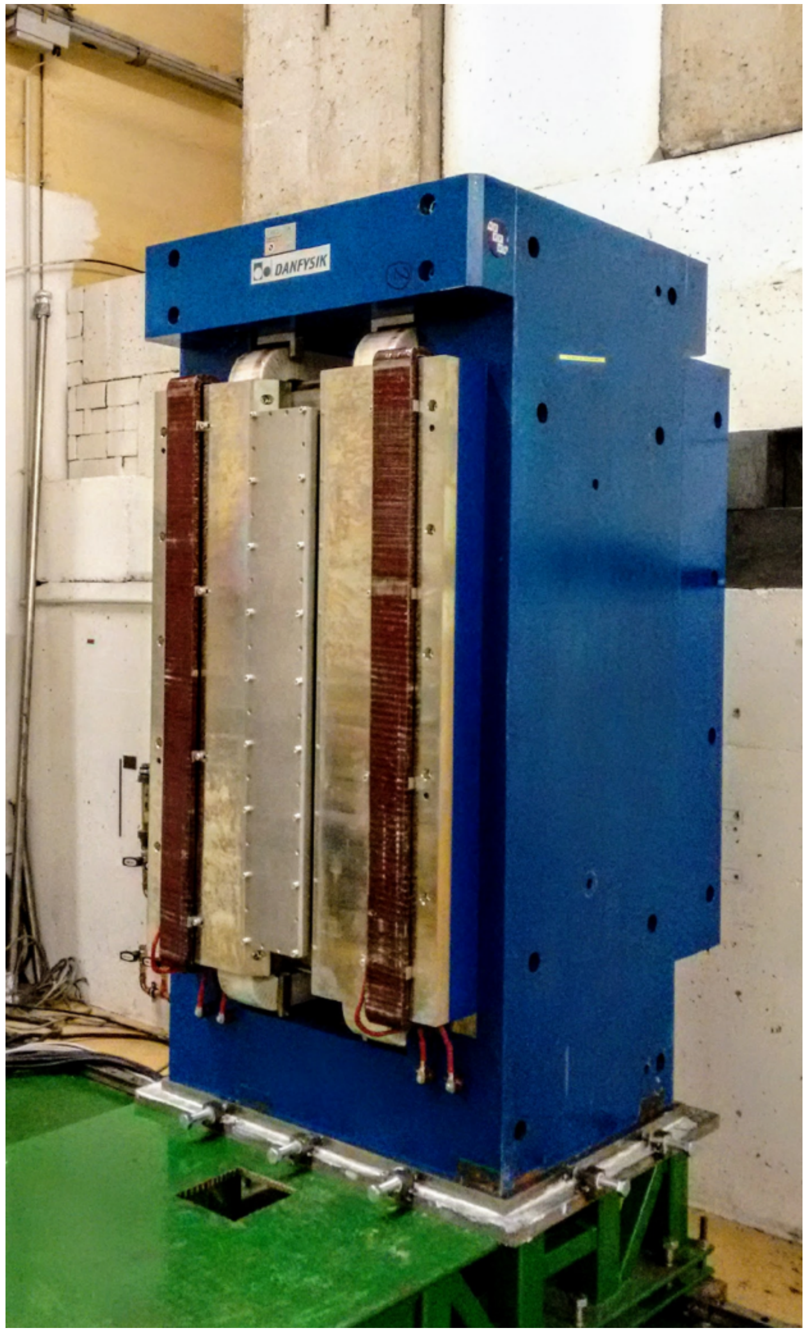


- Beam energy: 30 → 70 MeV
- Tagging ratio: 1.5 → 7.5%
- Majorly reduced background
- Energy range: 1.5 → 30 MeV

Neptun – Current Status



Neptun – Current Status

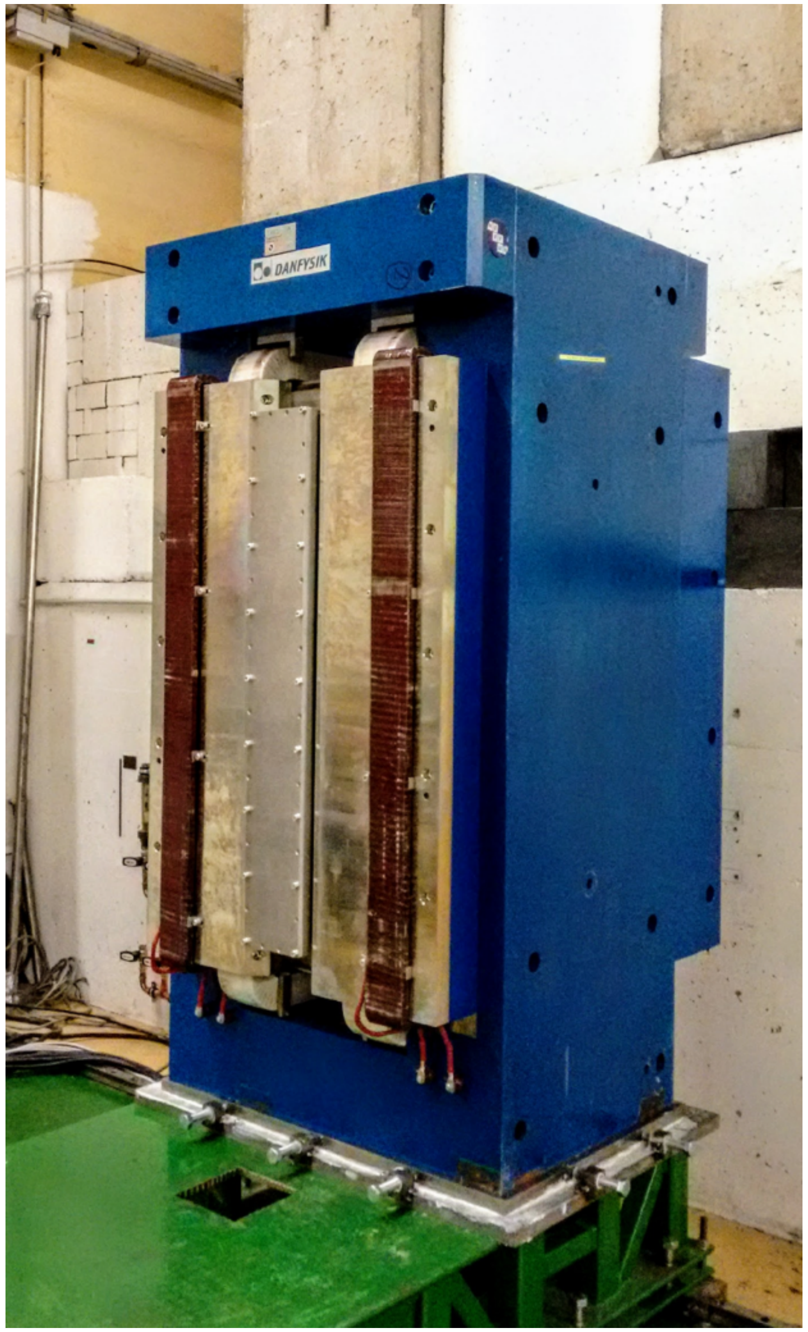


Done:

- Neptun upgrade in Denmark
- Back in IKP and reassembled
- Delivery of new beam dump

Neptun – Current Status

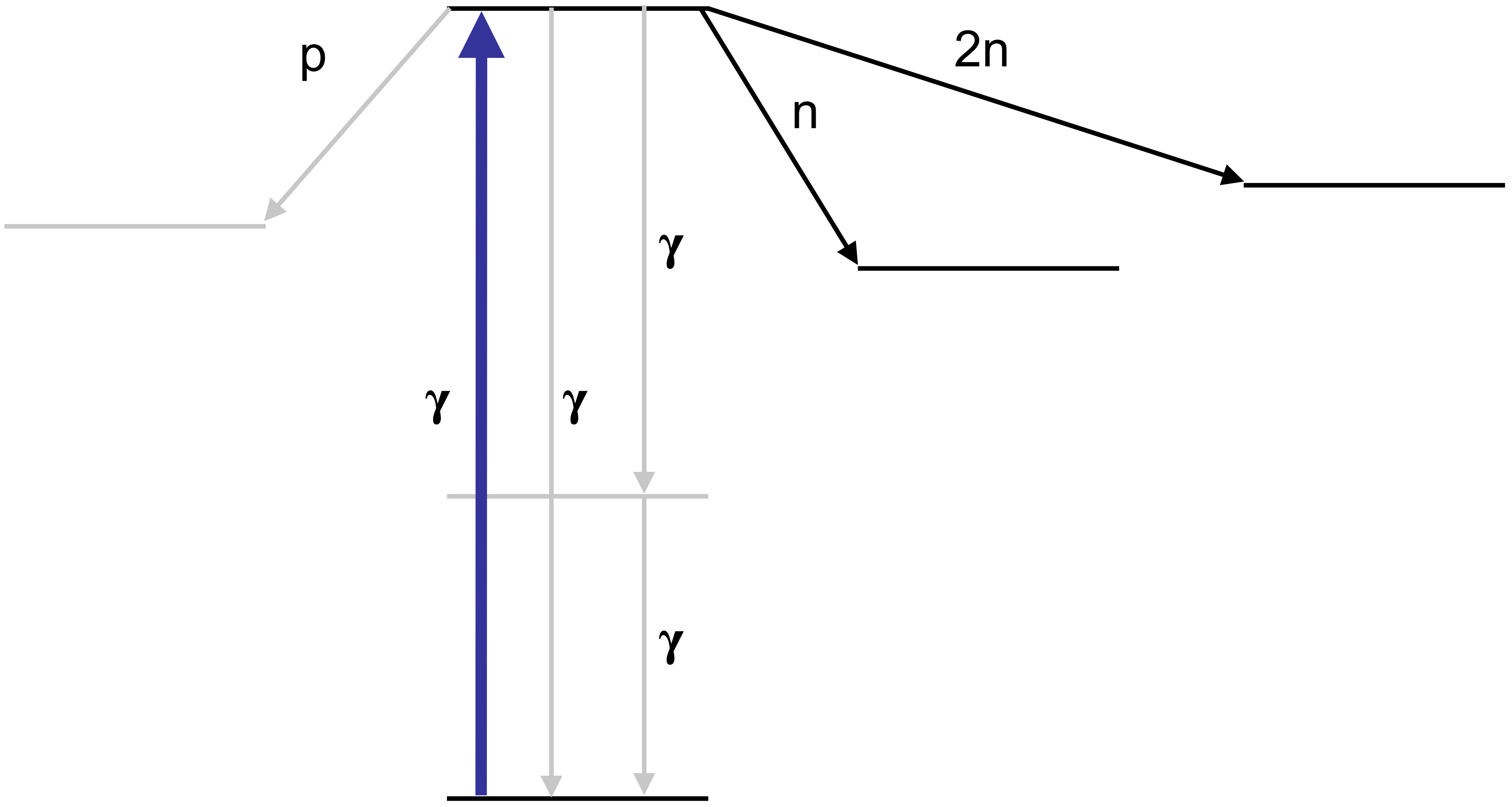
TECHNISCHE UNIVERSITÄT DARMSTADT



Done:
- Neptun upgrade in Denmark
- Back in IKP and reassembled
- Delivery of new beam dump

Near Future:
- Production vacuum chamber (end of October)
- Assembly of new beam dump
- Assembly and test of new focal plane

(γ,xn)-Decay Channel



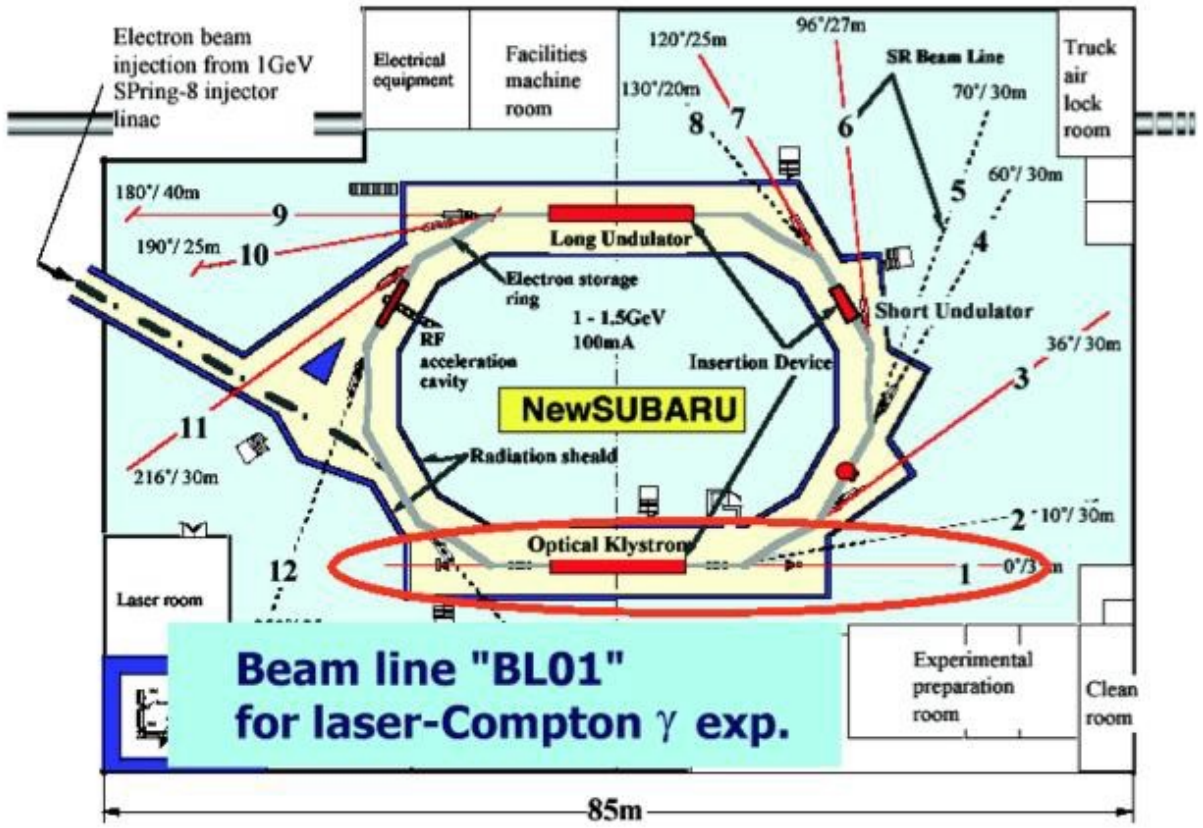
Experimental facility NewSUBARU

Electron beam:

- Beam energy injection from LINAC 1 GeV
- Beam energy in storage ring: 0.5–1.5 GeV

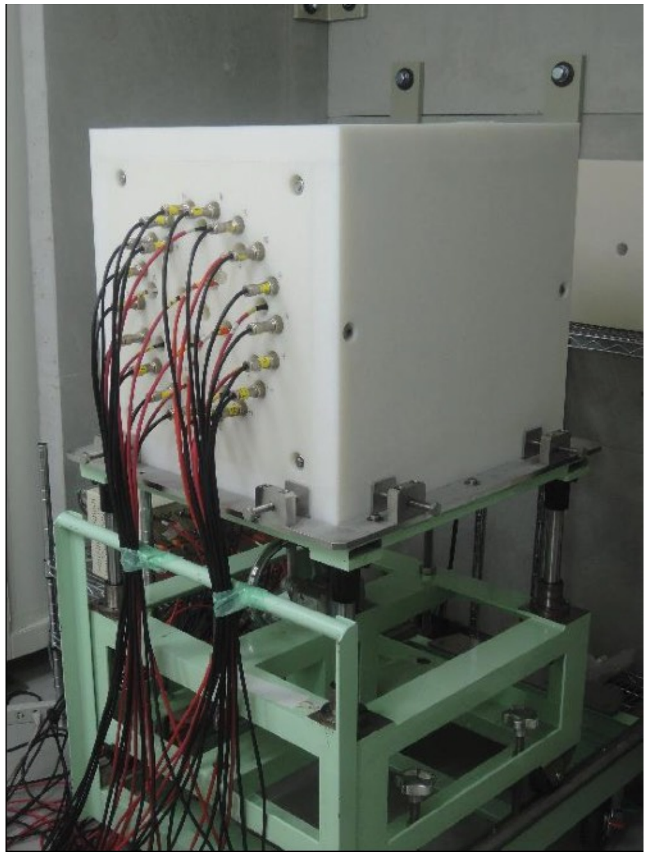
Gamma beam:

- Energy is tunable:
  1 – 34 MeV (ΔE/E ~ 5%FWHM)
- Collimated γ-flux: $5 \cdot 10^6$ γ/s



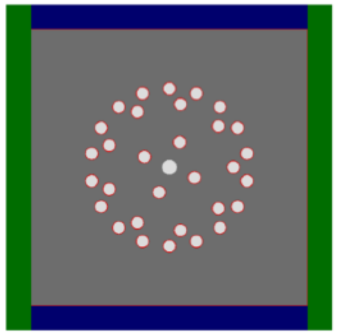
Hiroaki Utsunomia, Konan University, Japan

NewSubaru Neutron Detector

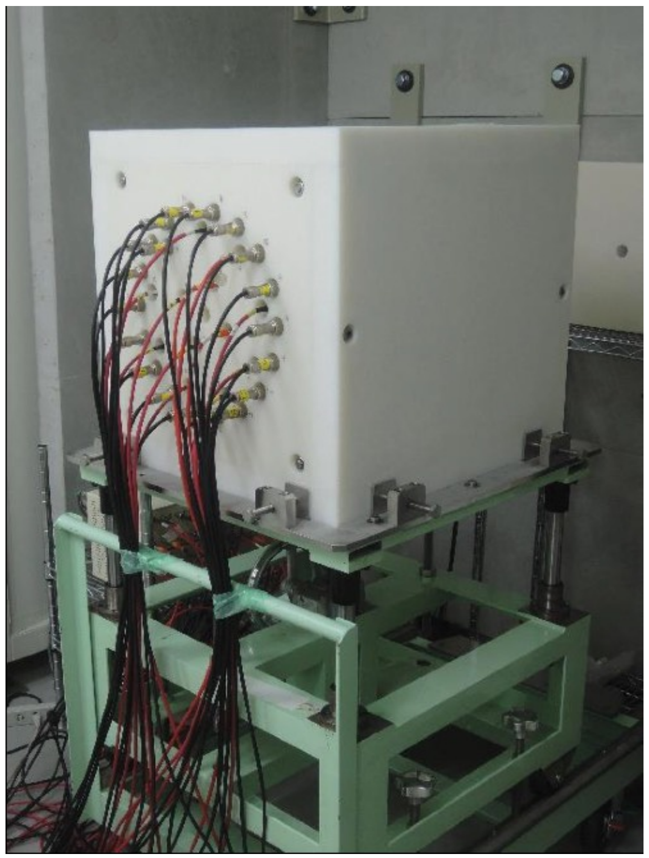


Hiroaki Utsunomia, Konan University, Japan

- 31 ^{3}He counters arranged in 3 rings
- Geometry optimized for flat efficiency in 0.1 – 5 MeV

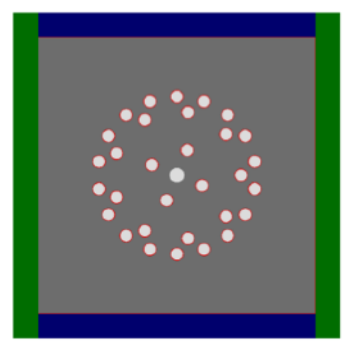


NewSubaru Neutron Detector



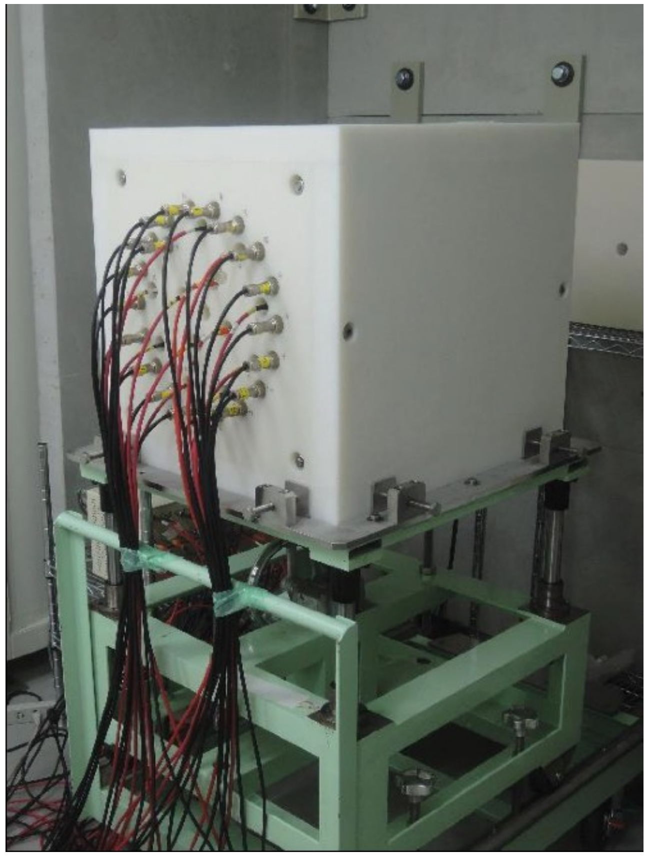
Hiroaki Utsunomia, Konan University, Japan

- 31 ^{3}He counters arranged in 3 rings
- Geometry optimized for flat efficiency in 0.1 – 5 MeV



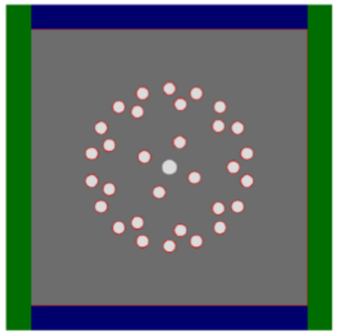
$$N_s = N_1 \cdot \epsilon(E_1) + N_2 \cdot C_1 \cdot \epsilon(E_2) \cdot (1 - \epsilon(E_2)) + N_3 \cdot C_1 \cdot \epsilon(E_3) \cdot (1 - \epsilon(E_3))^2$$
$$N_d = N_2 \cdot (E_2)^2 + N_3 \cdot C_2 \cdot \epsilon(E_3)^2 \cdot (1 - \epsilon(E_3))$$
$$N_t = N_3 \cdot \epsilon(E_3)^3$$

NewSubaru Neutron Detector



Hiroaki Utsunomia, Konan University, Japan

- 31 ^{3}He counters arranged in 3 rings
- Geometry optimized for flat efficiency in 0.1 – 5 MeV

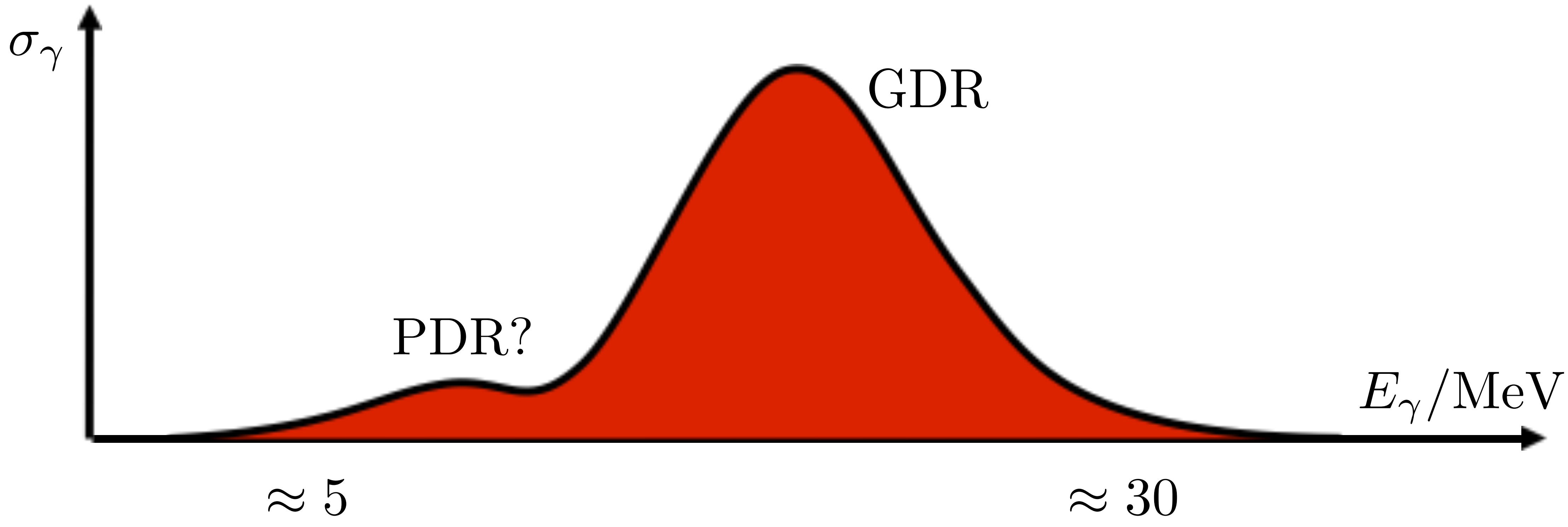


$$N_s = N_1 \cdot \epsilon + N_2 \cdot C_1 \cdot \epsilon \cdot (1-\epsilon) + N_3 \cdot C_1 \cdot \epsilon \cdot (1-\epsilon)^2$$

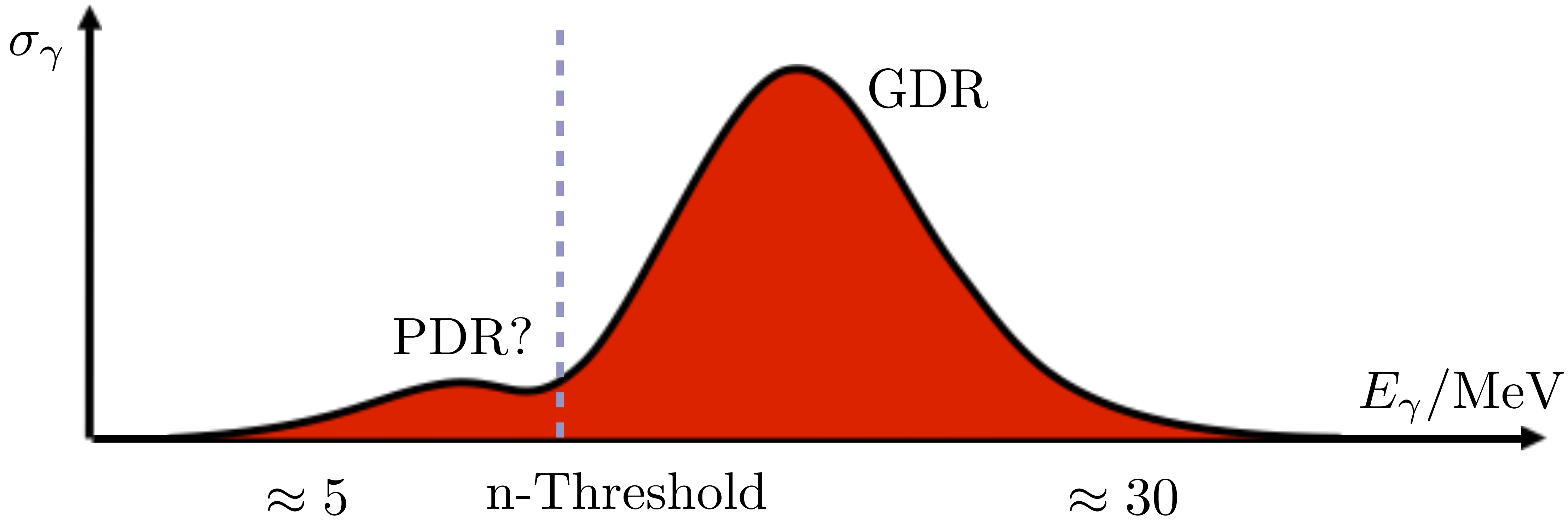
$$N_d = N_2 \cdot \epsilon^2 + N_3 \cdot C_2 \cdot \epsilon^2 \cdot (1-\epsilon)$$

$$N_t = N_3 \cdot \epsilon^3$$

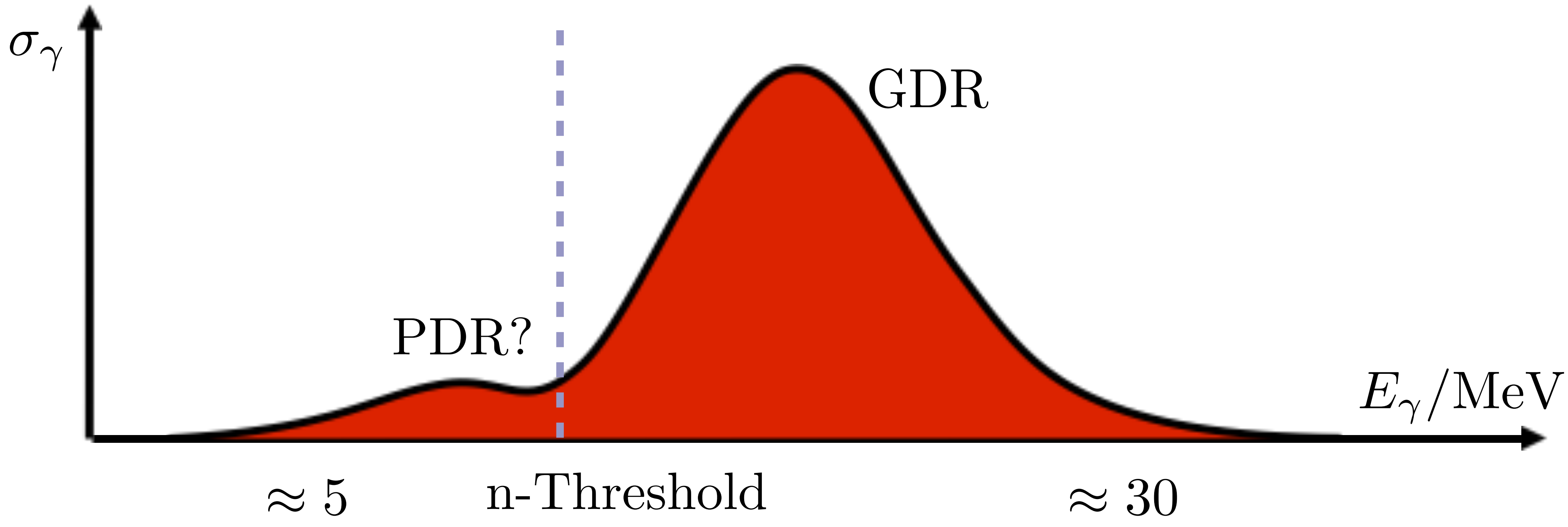
Other Approaches

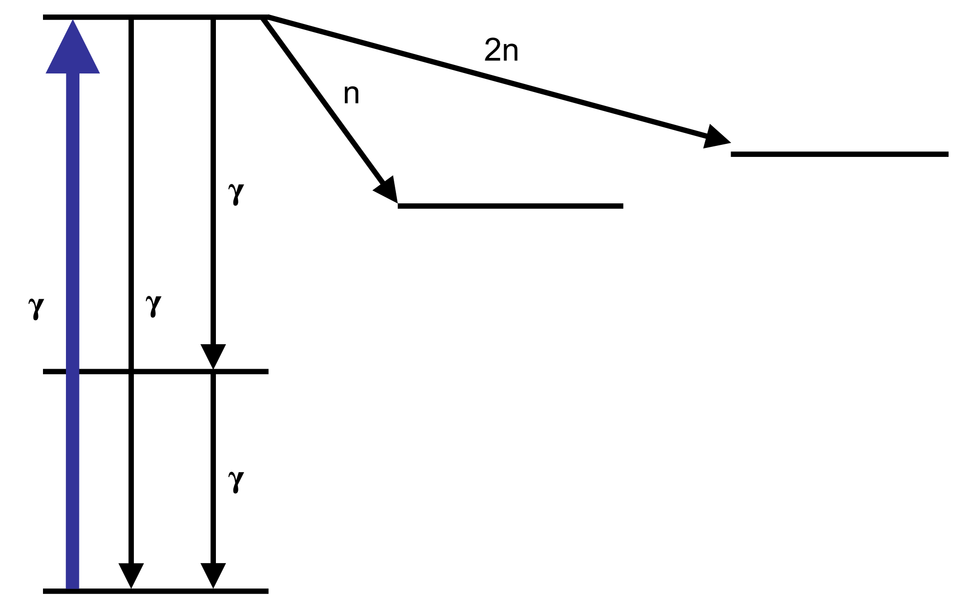


Other Approaches



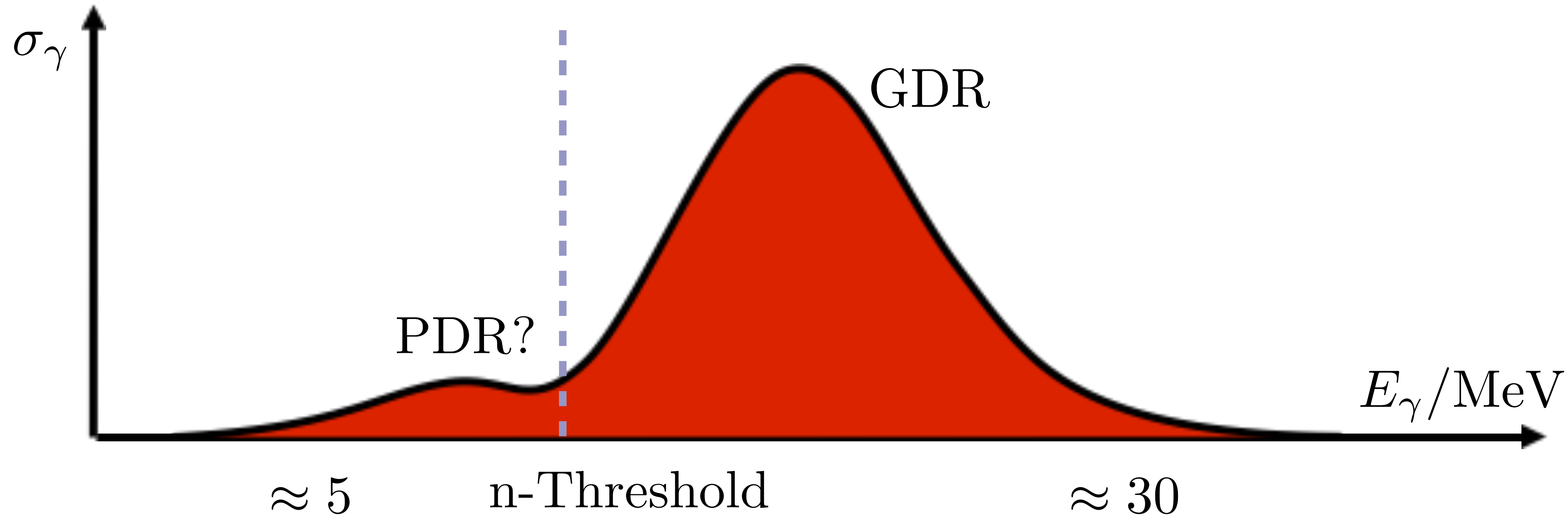
Other Approaches

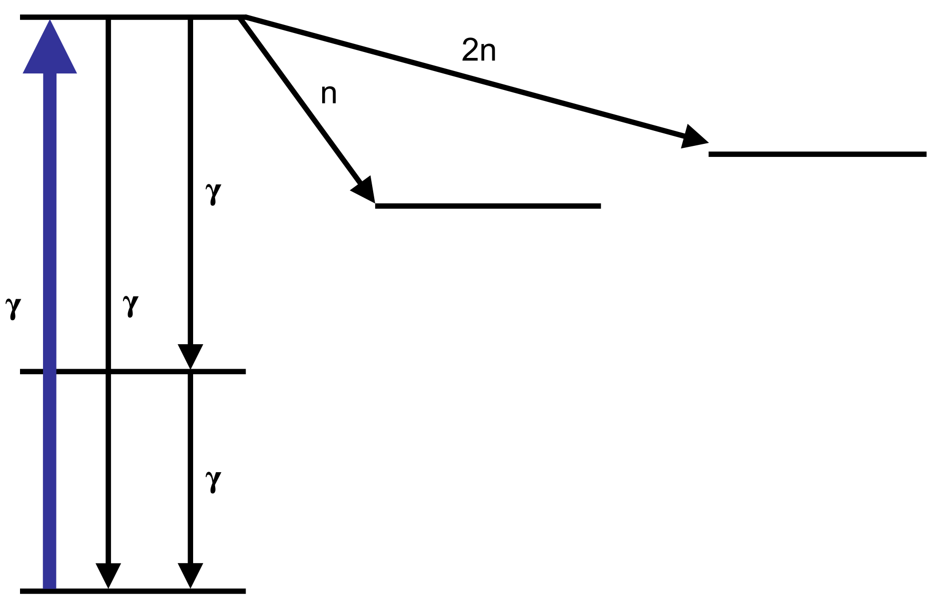




- close to n-Threshold: more reaction channels

Other Approaches

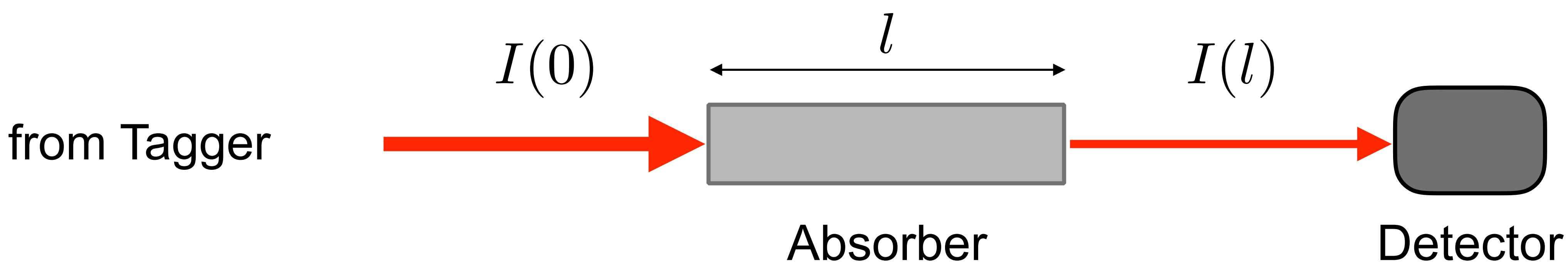




- close to n-Threshold: more reaction channels

↳measuring total absorption directly

Total Absorption Experiments – a basic Idea



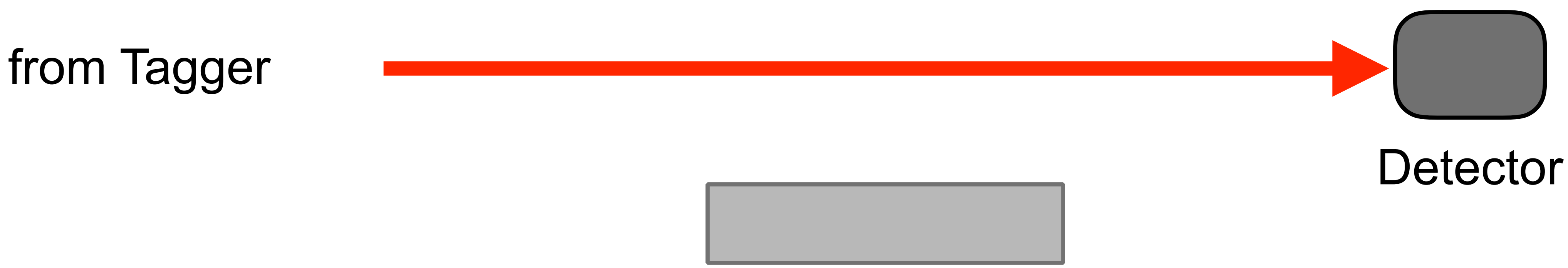
calculating the cross section:

$$I(l) = I(0) \cdot \exp\left(-\frac{N}{A} \cdot \sigma_{\text{tot}}\right)$$

$$\Rightarrow \sigma_{\text{tot}} = -\frac{A}{N} \cdot \ln\left(\frac{I(l)}{I(0)}\right)$$

I: γ-Intensity, N: #Atoms, A: Area

Total Absorption Experiments – a basic Idea



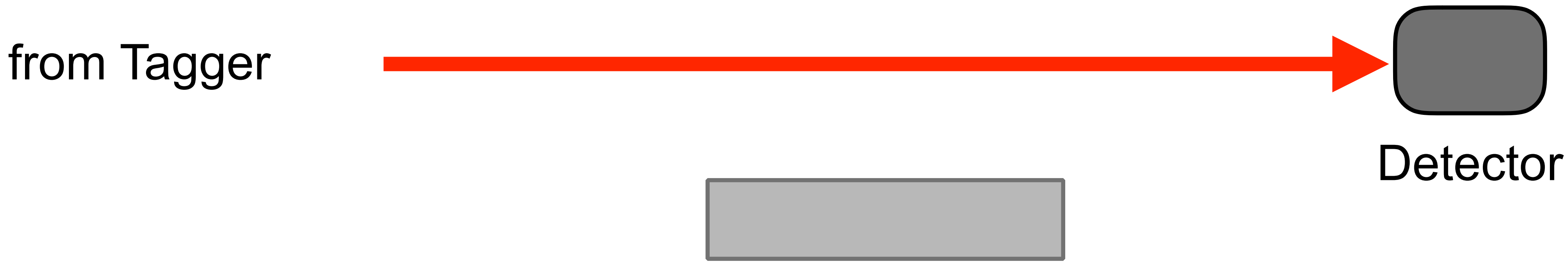
calculating the cross section:

$$I(l) = I(0) \cdot \exp\left(-\frac{N}{A} \cdot \sigma_{\text{tot}}\right)$$

$$\Rightarrow \sigma_{\text{tot}} = -\frac{A}{N} \cdot \ln\left(\frac{I(l)}{I(0)}\right)$$

I: γ-Intensity, N: #Atoms, A: Area

Total Absorption Experiments – a basic Idea



calculating the cross section:

$$I(l) = I(0) \cdot \exp\left(-\frac{N}{A} \cdot \sigma_{\mathrm{tot}}\right)$$

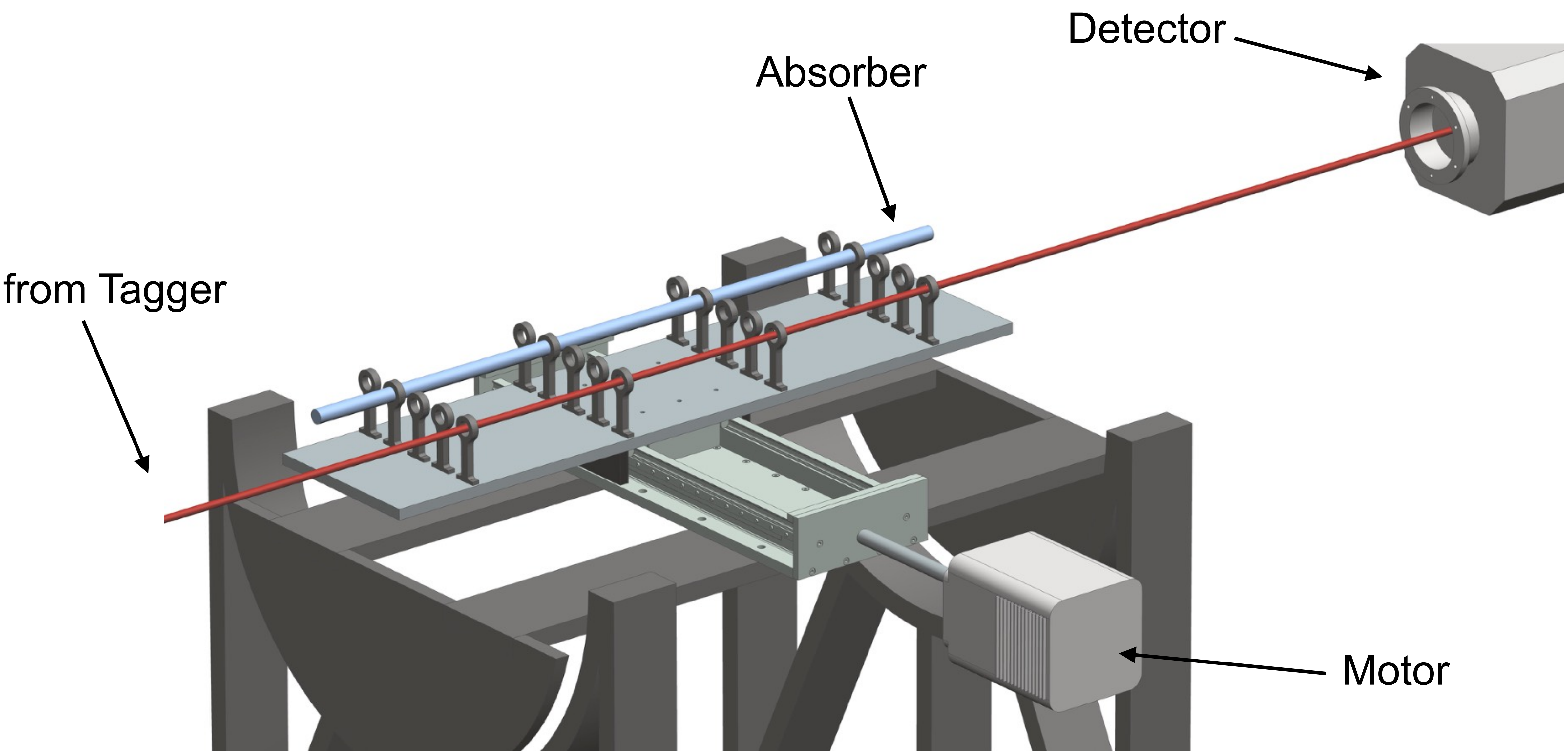
$$\Rightarrow \sigma_{\mathrm{tot}} = -\frac{A}{N} \cdot \ln\left(\frac{I(l)}{I(0)}\right)$$

Precision advantages:

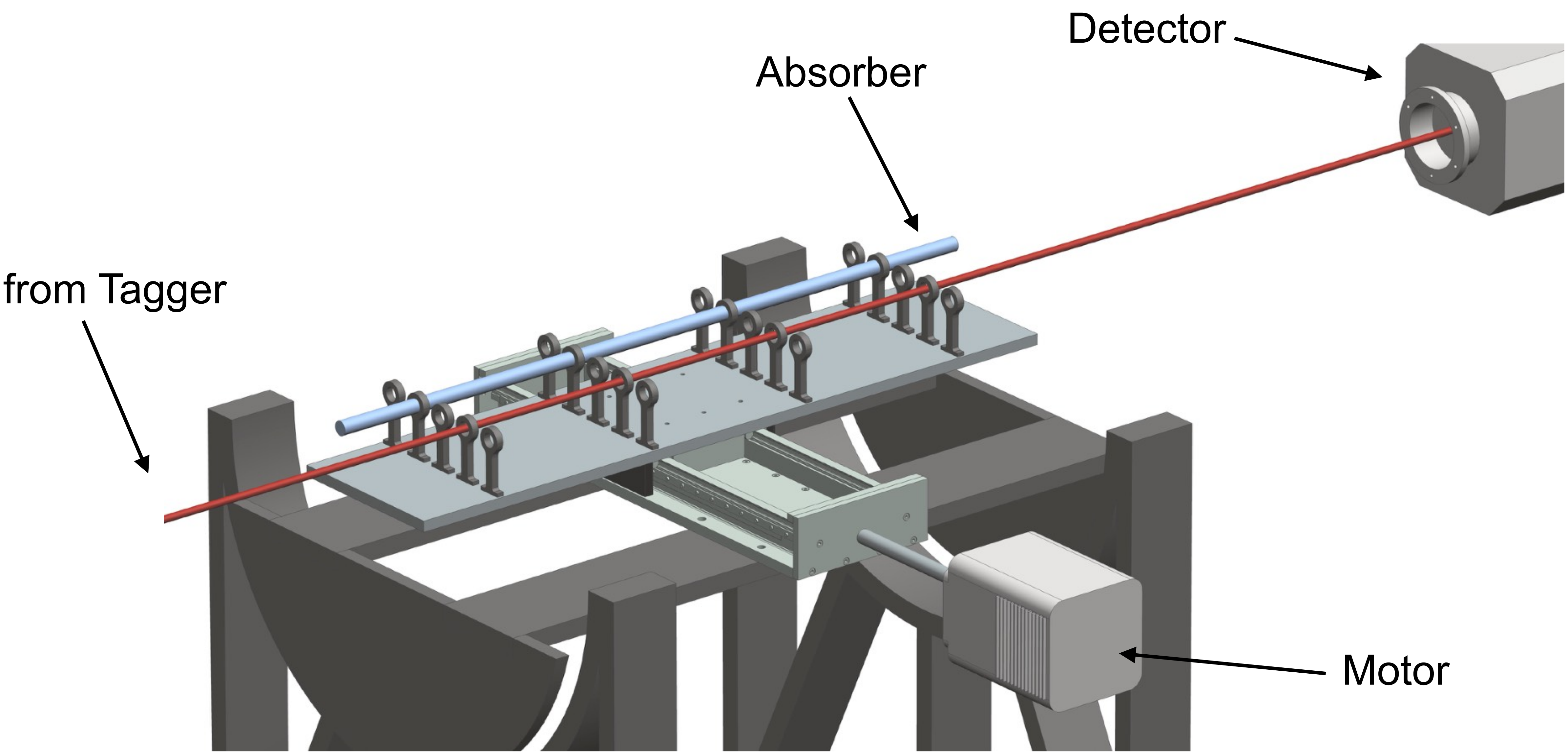
- Using single detector
- No change of its properties

I: γ-Intensity, N: #Atoms, A: Area

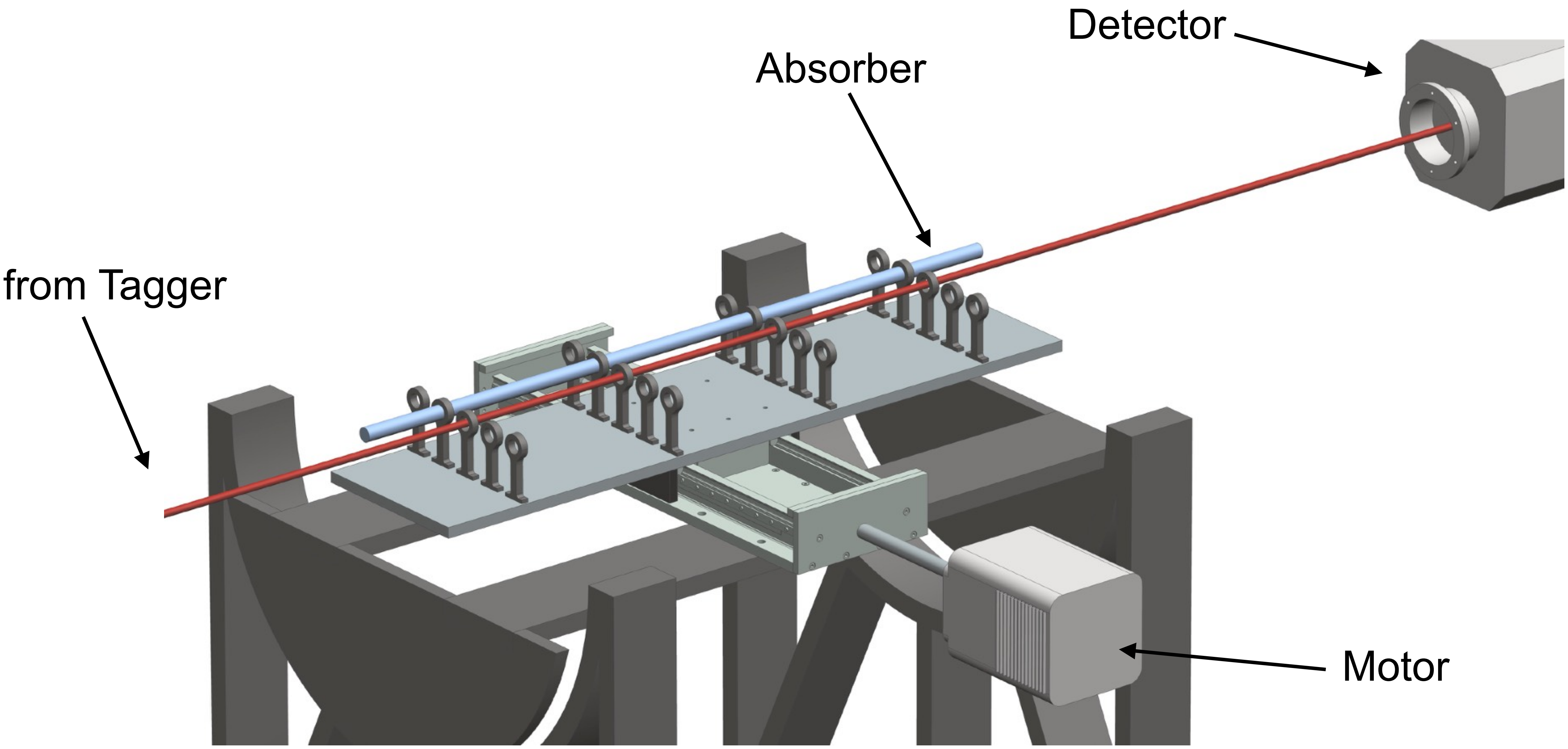
Total Absorption Experiments – the Setup



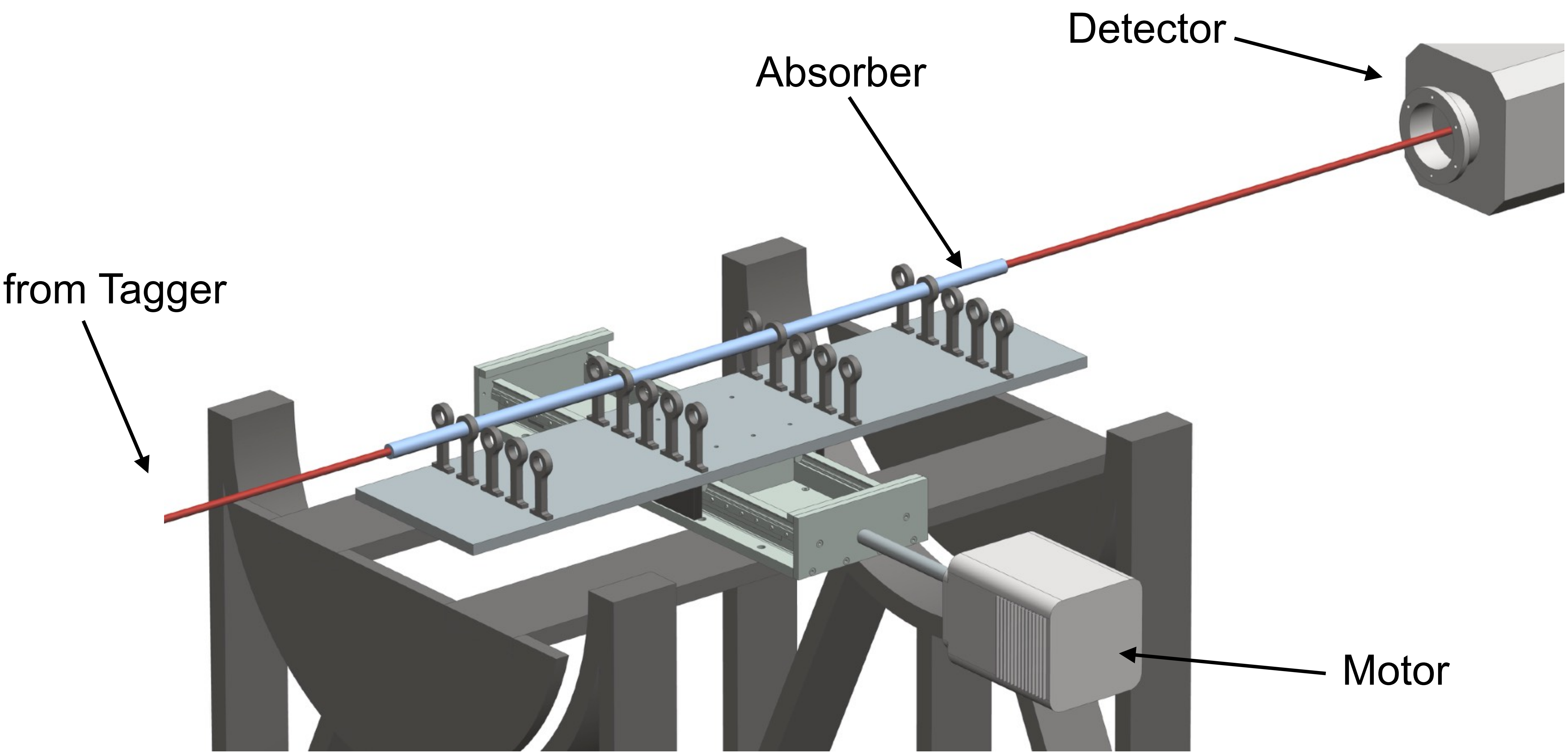
Total Absorption Experiments – the Setup



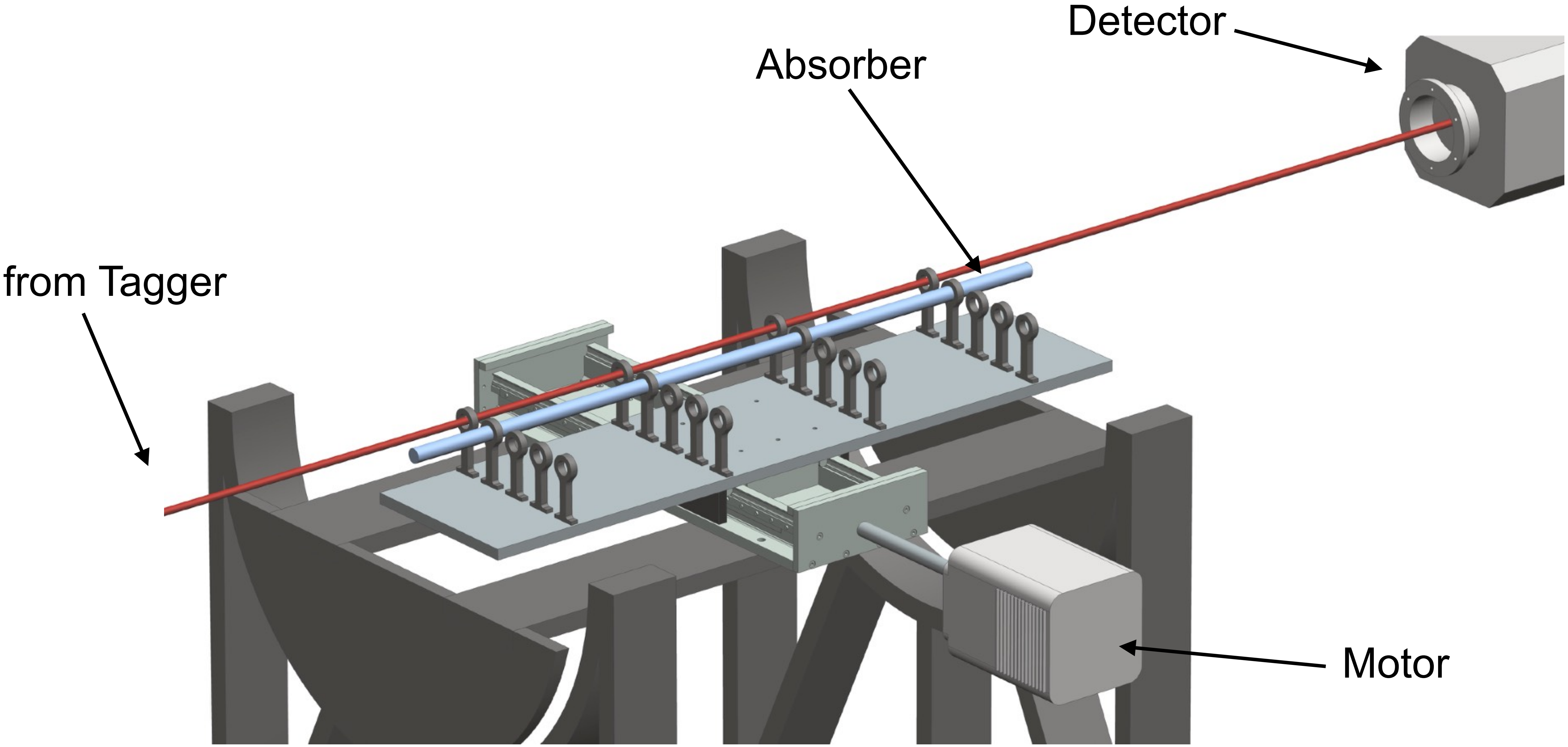
Total Absorption Experiments – the Setup



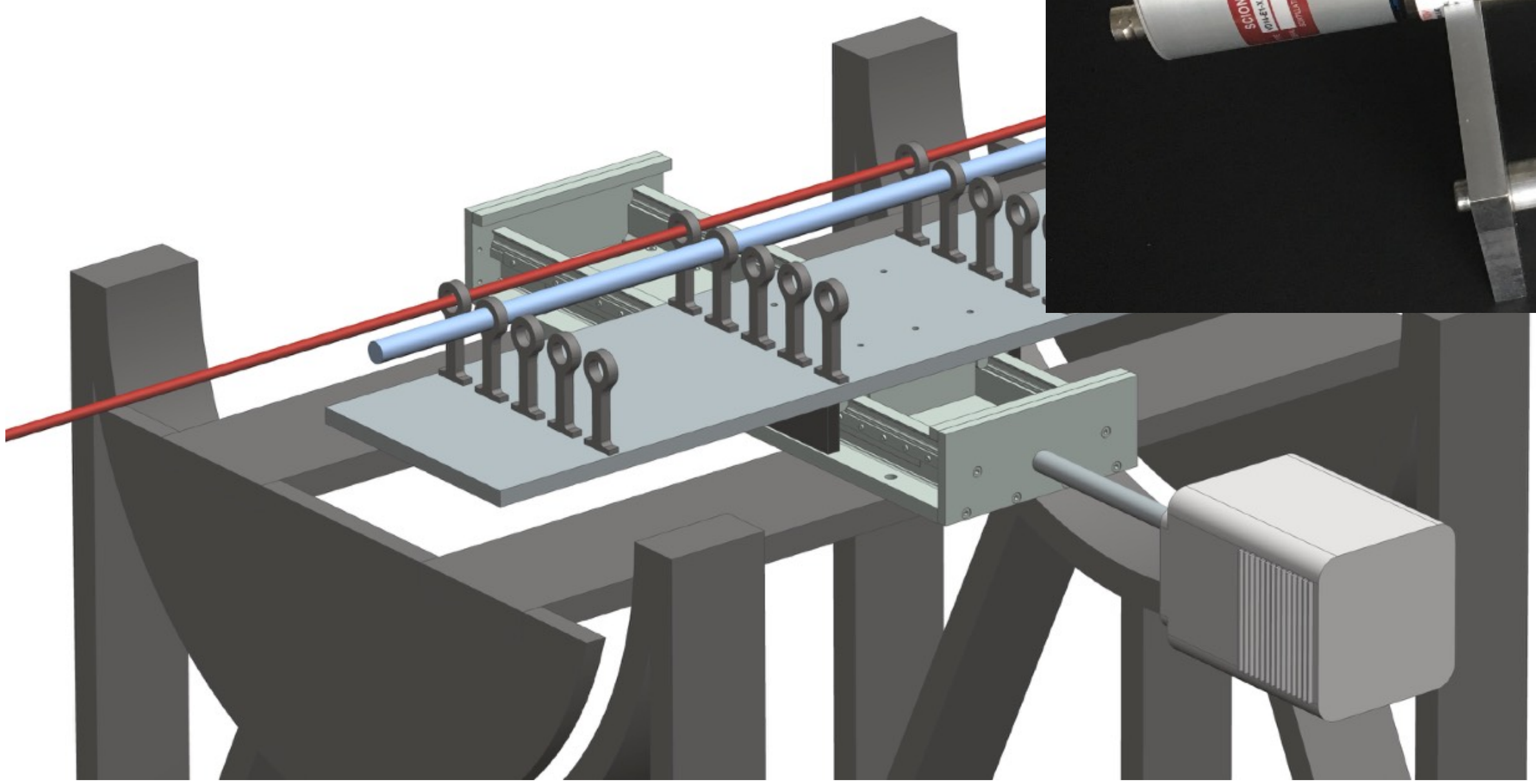
Total Absorption Experiments – the Setup

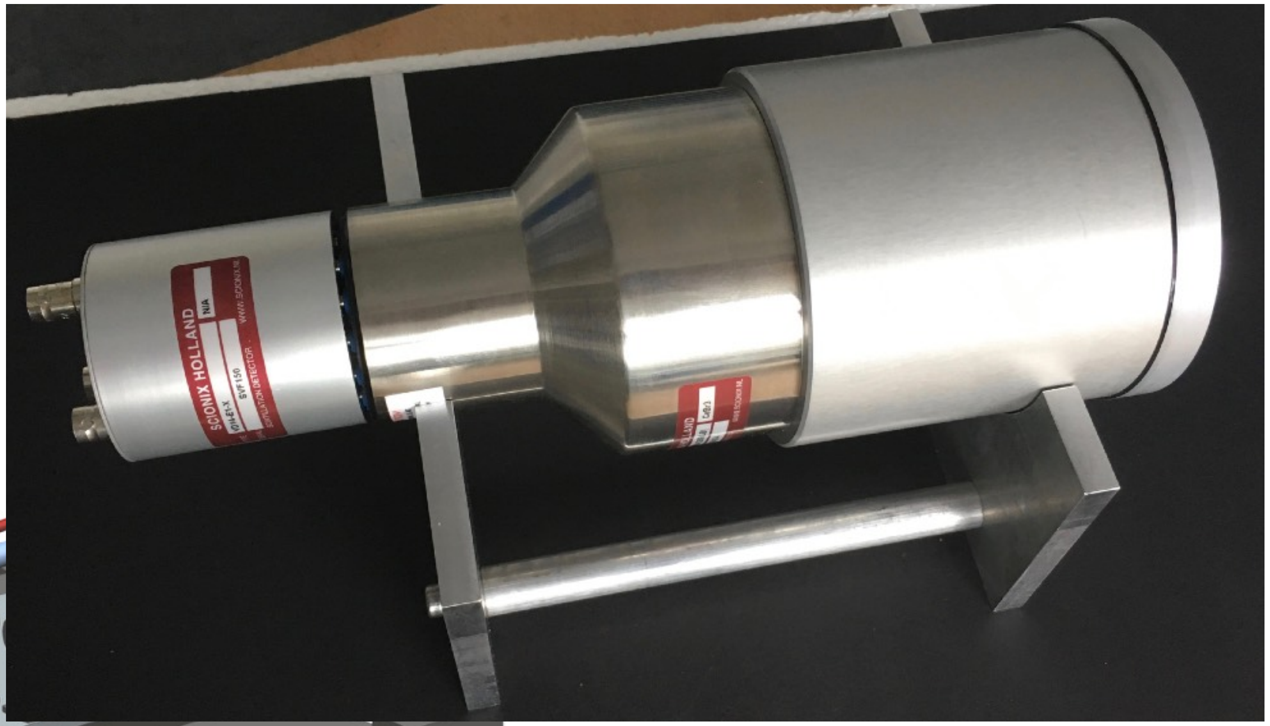


Total Absorption Experiments – the Setup



Total Absorption Experiments – the Setup





4" x 4" CeBr

Similar Experiment from 1974

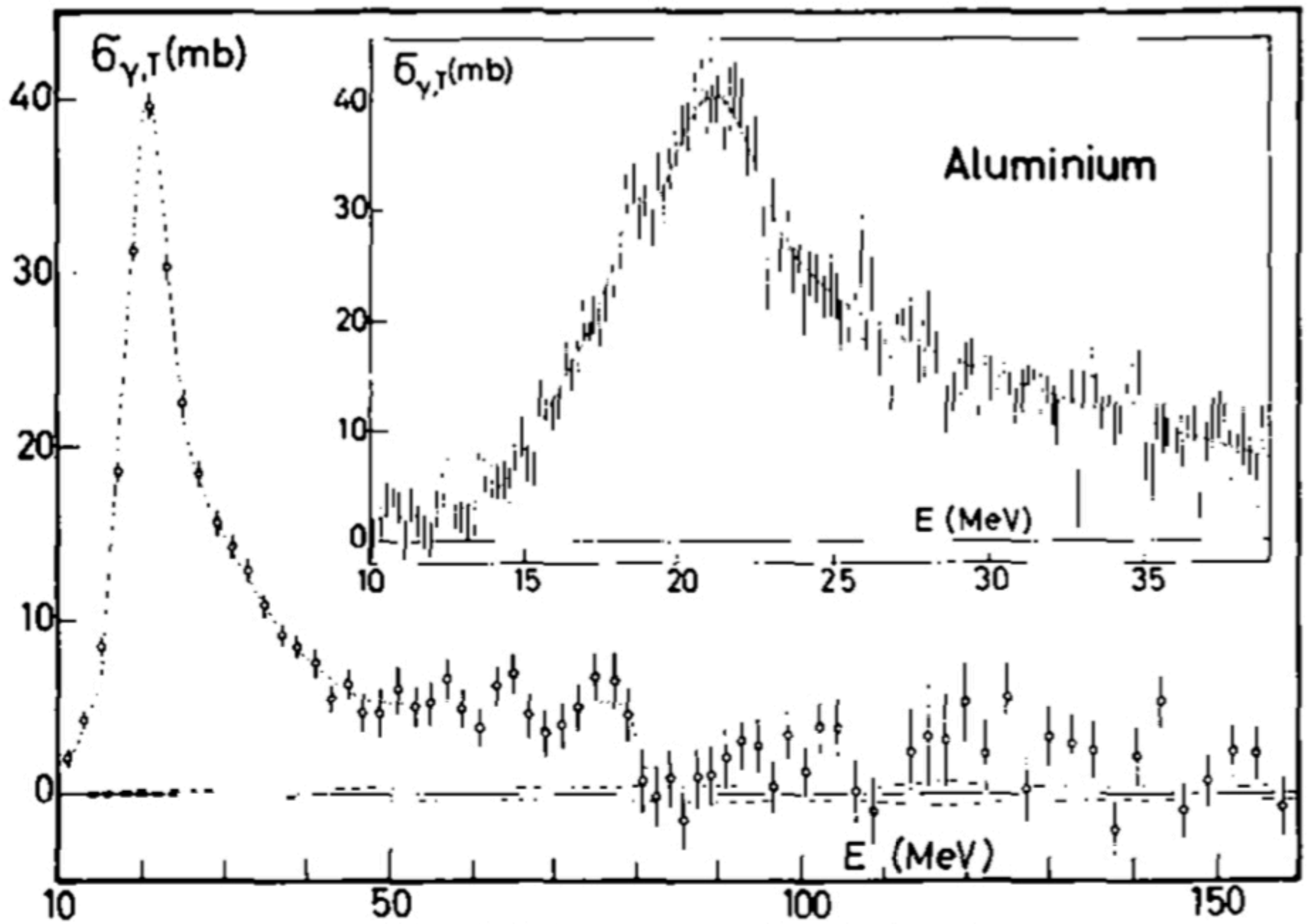
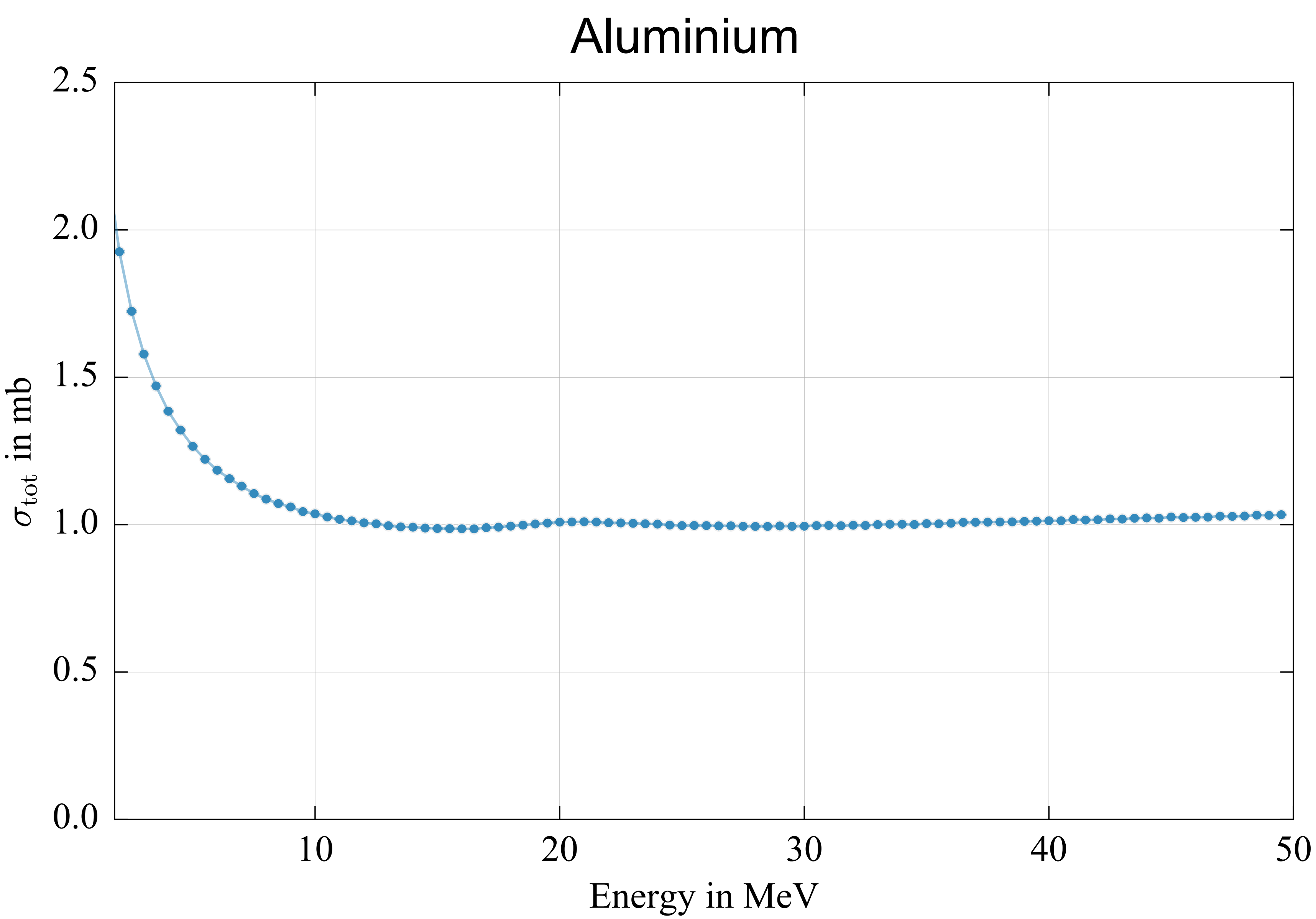


Fig. 6. The same as fig. 2 for Al.

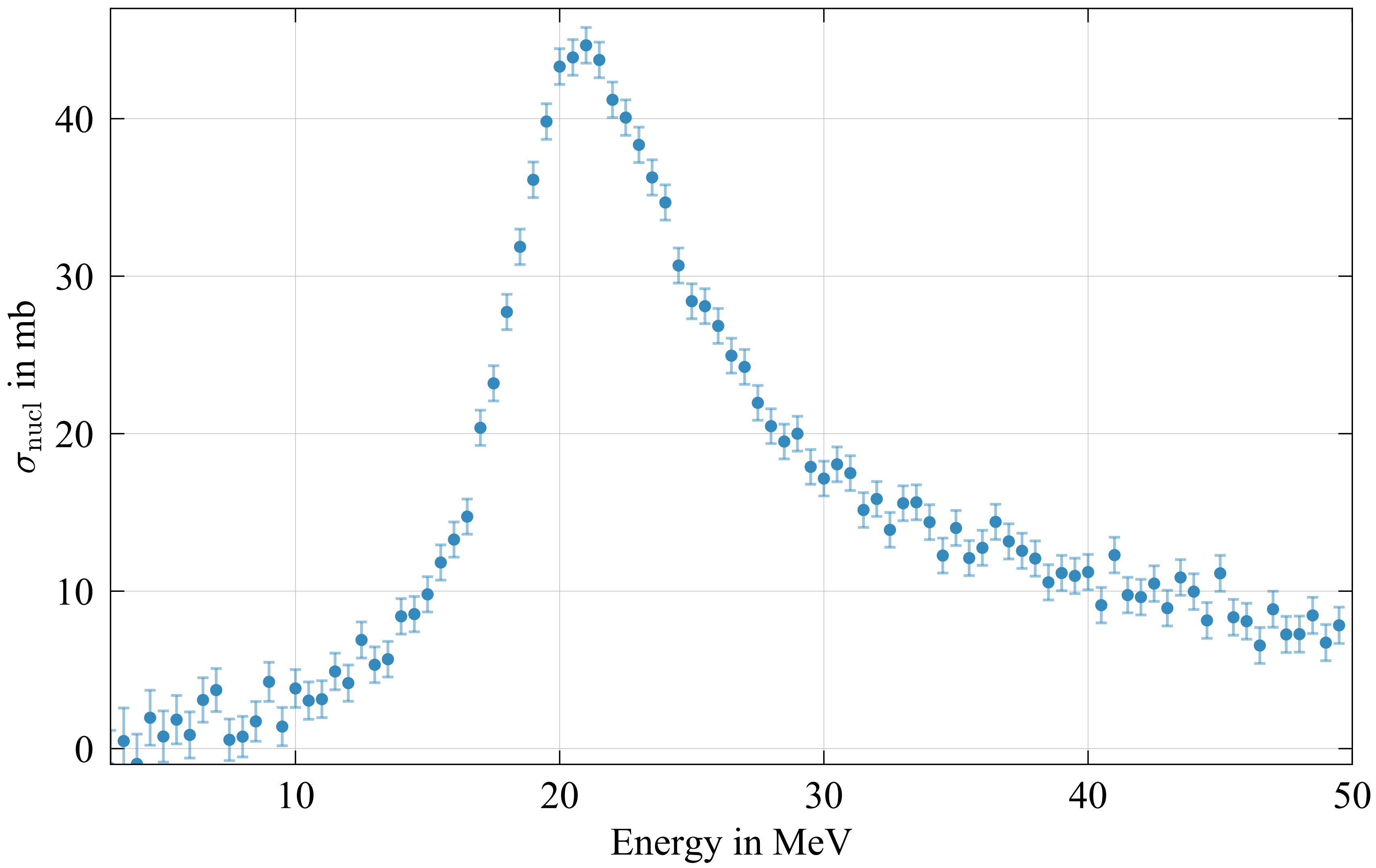
J. Ahrens et al, Total nuclear photon absorbtion cross sections for some light elements, Nuclear Physics, Section A, Vol. 251, p. 479–492, 1974

Total Absorption Experiments – Simulation



Total Absorption Experiments – Simulation

Aluminium



Simulated Beamtime: 3 – 4h

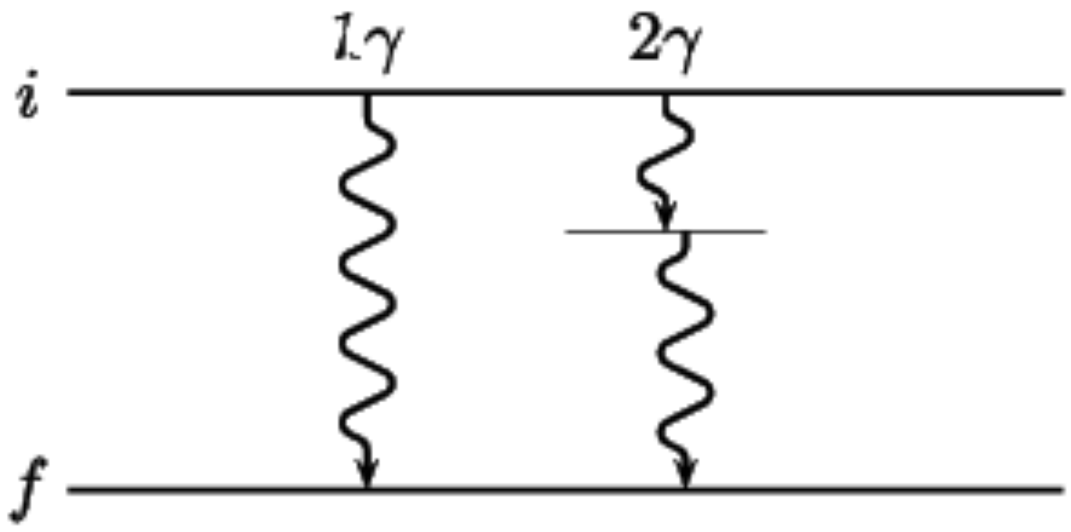
Stat. uncertainty: ±1.2mb

Total Absorption Experiments – Future Plans

TECHNISCHE UNIVERSITÄT DARMSTADT

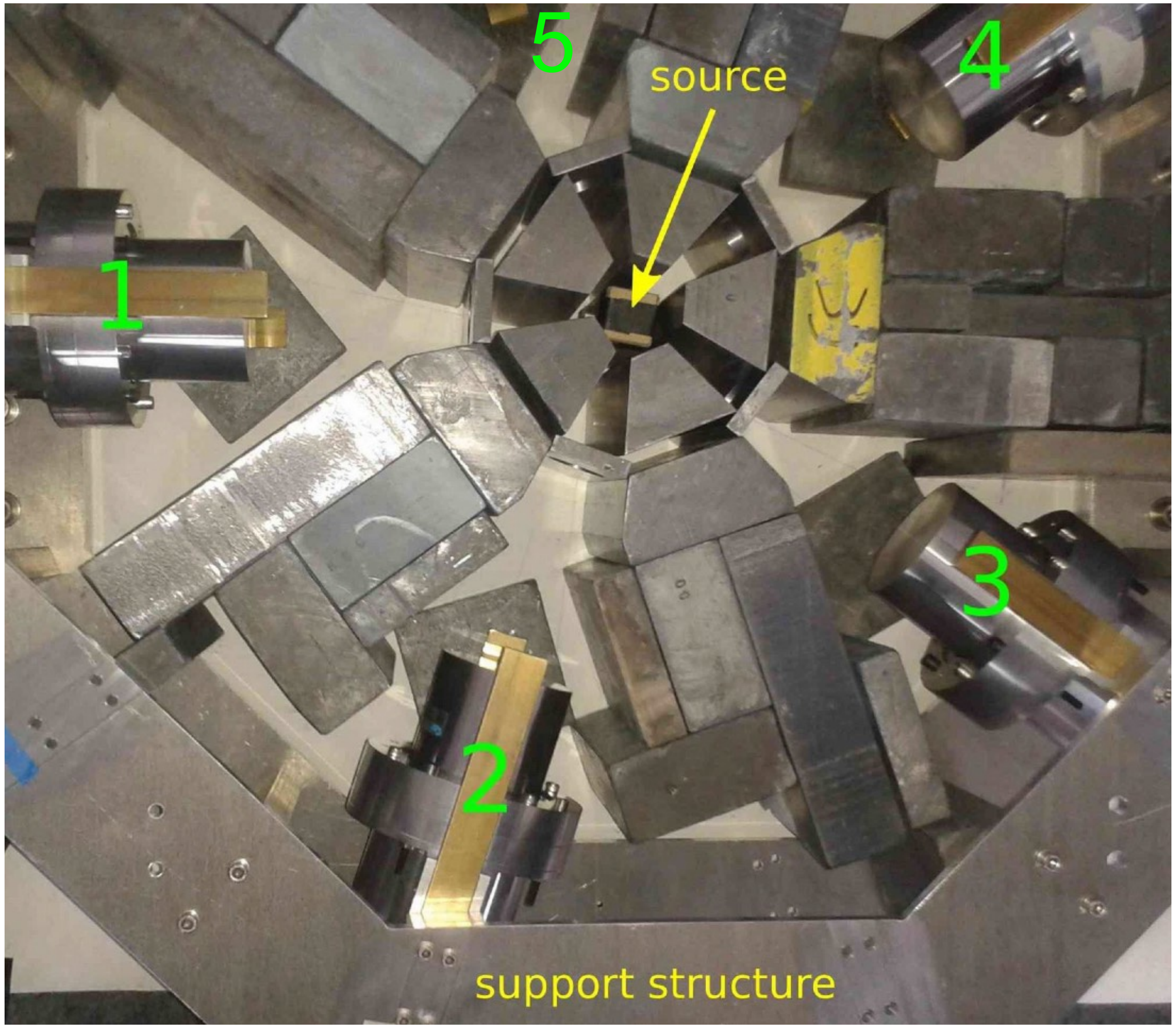
- Planing and constructing the Setup
- Reestablish the method
- First experiments with Al
- Further elements like Li, Be, B, O, …, Ca, …, Sn, …, Pb

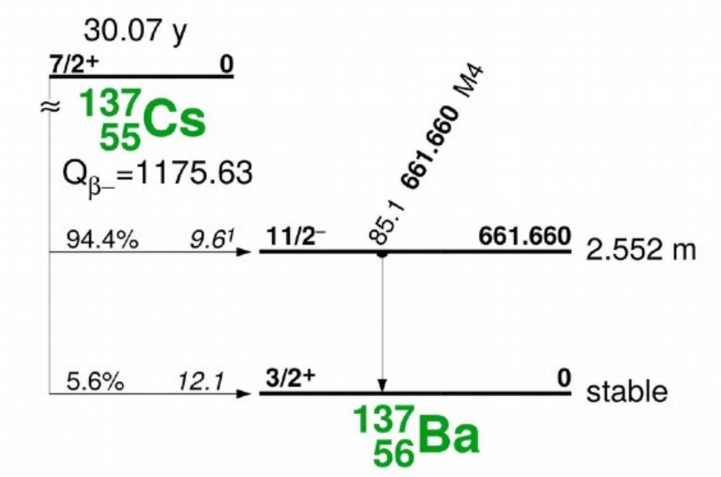
Competitive 2-Gamma Decay

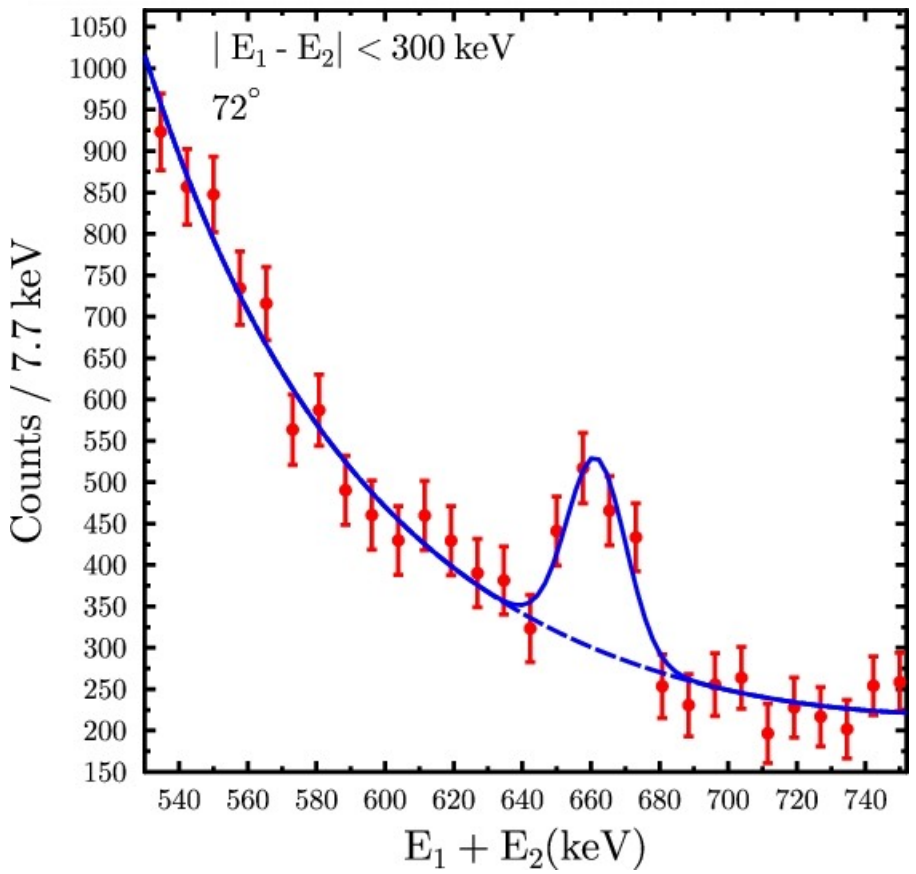


- 2-gamma decay can occur
- QM process of second order

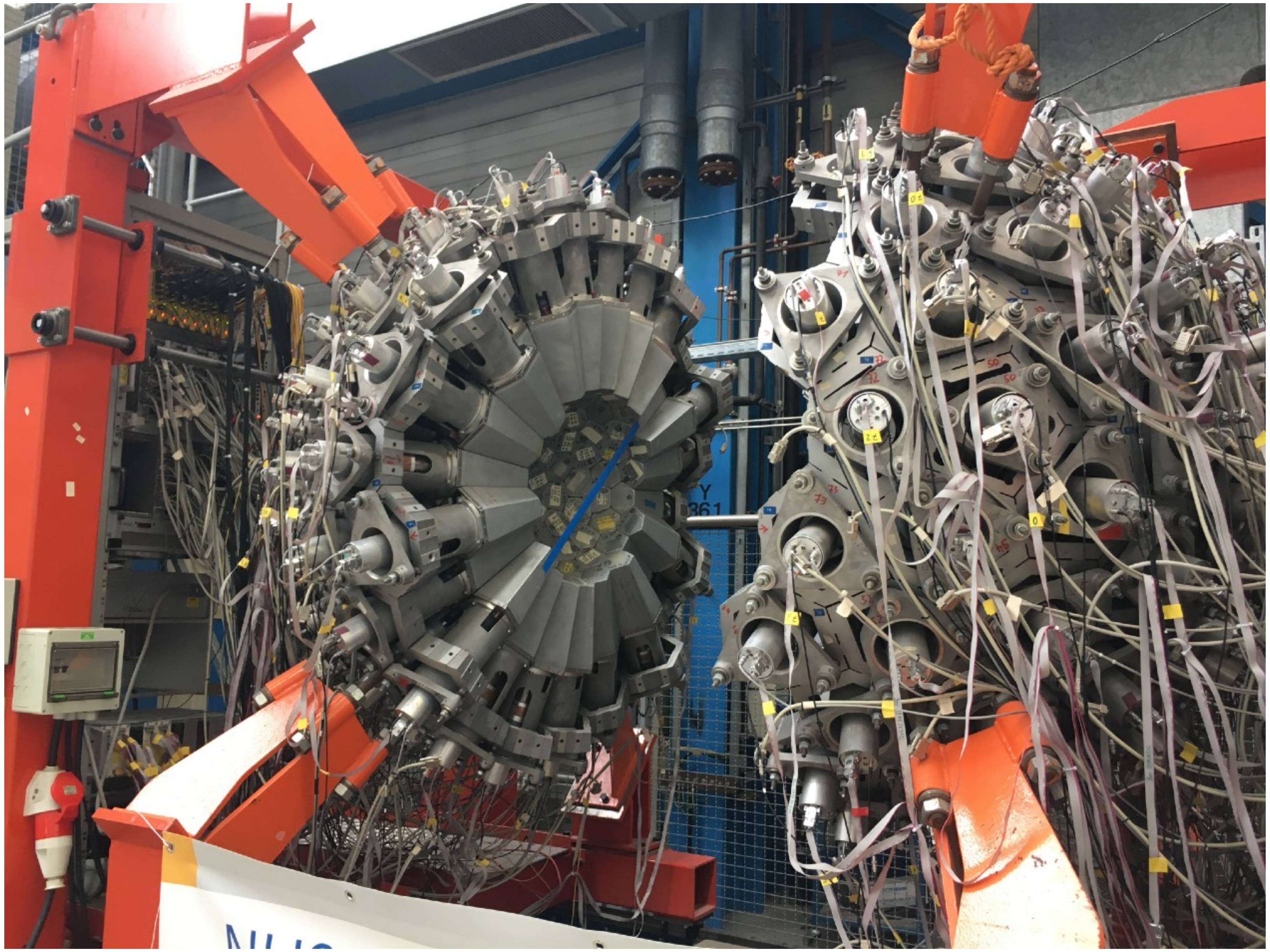
Competitive 2-Gamma Decay – Original Setup





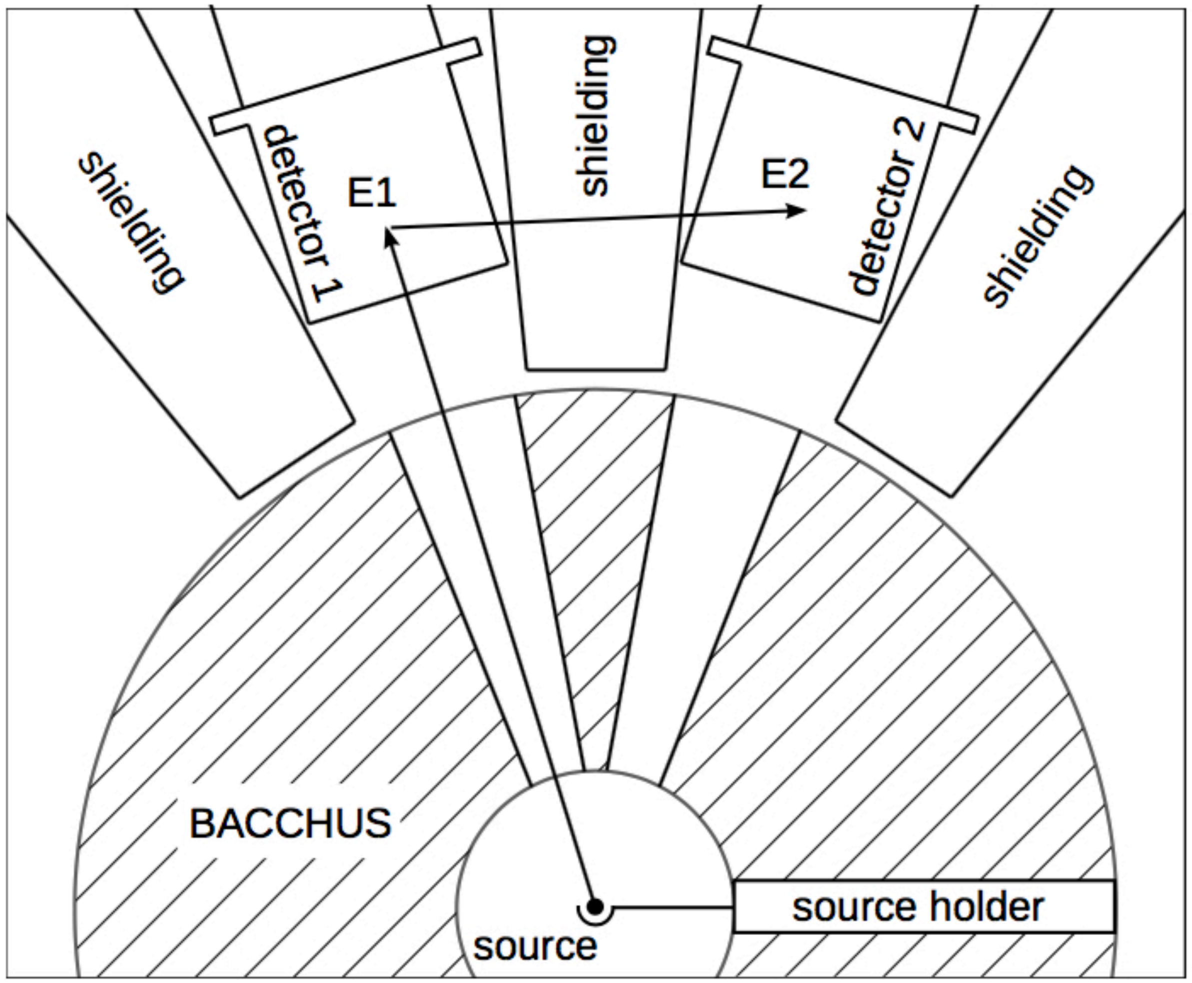


2-Gamma Decay – Current Setup



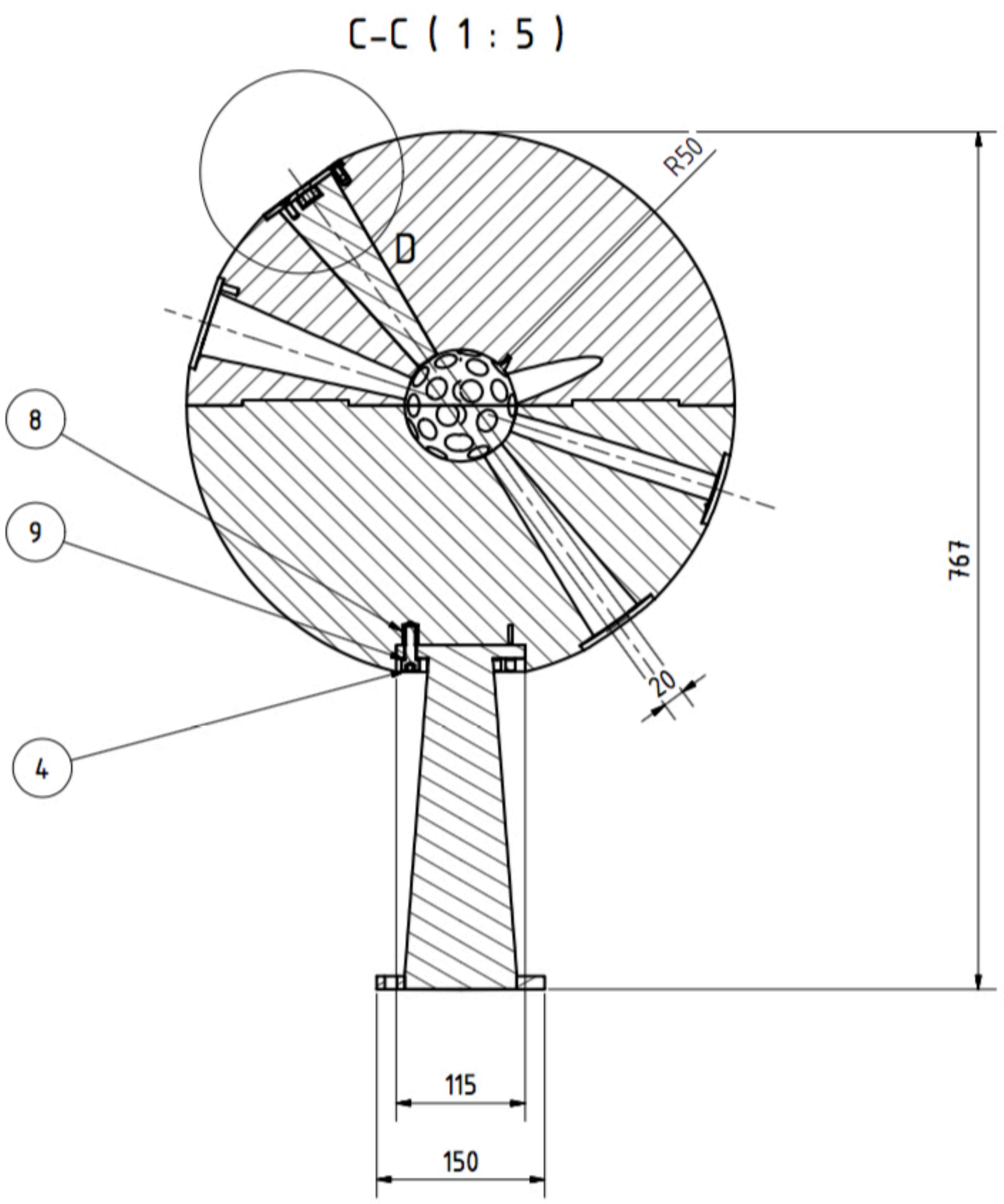
- Heidelberg-Darmstadt CrystalBall
- Solid angle: 4 pi
- 162 NaI-detectors

Principle of new Measurement



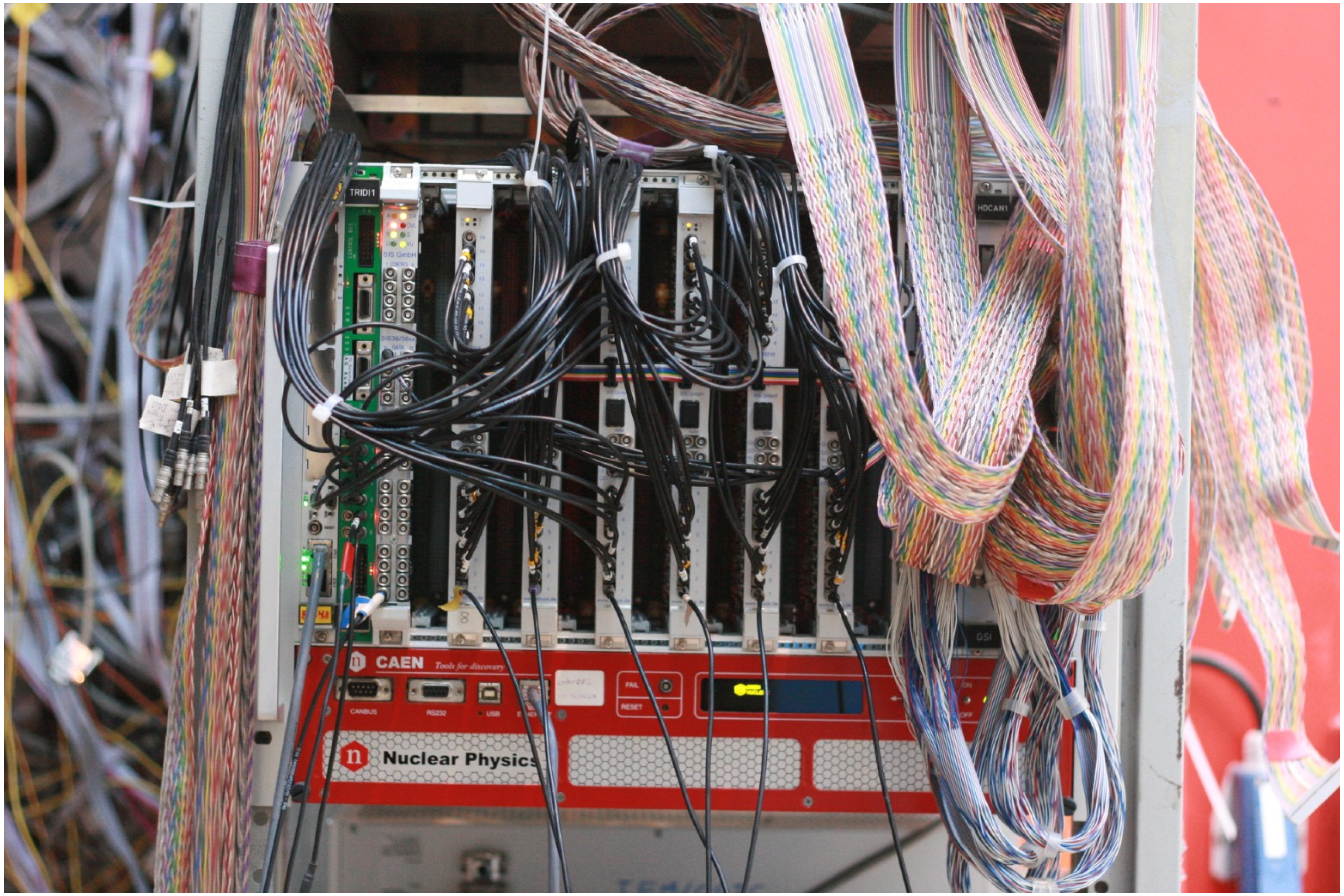
- Using LaBr-detectors for measurement
- Active shielding: NaI
- Holes serve as collimators

BACCHUS LeadBall



- LeadBall BACCHUS with 37 holes
- To be placed inside CrystalBall
- Shields gamma rays (20cm of lead)
- Delivery in Q4/17

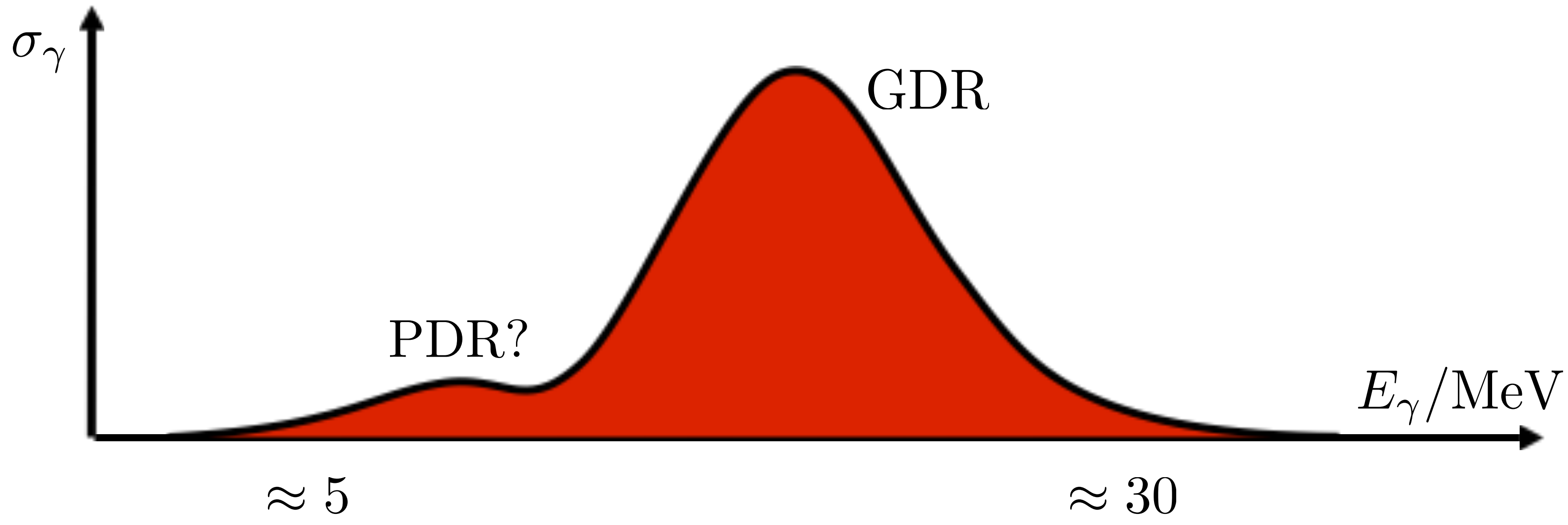
New Digital Data Acquisition



Status of 2-Gamma Decay Experiment

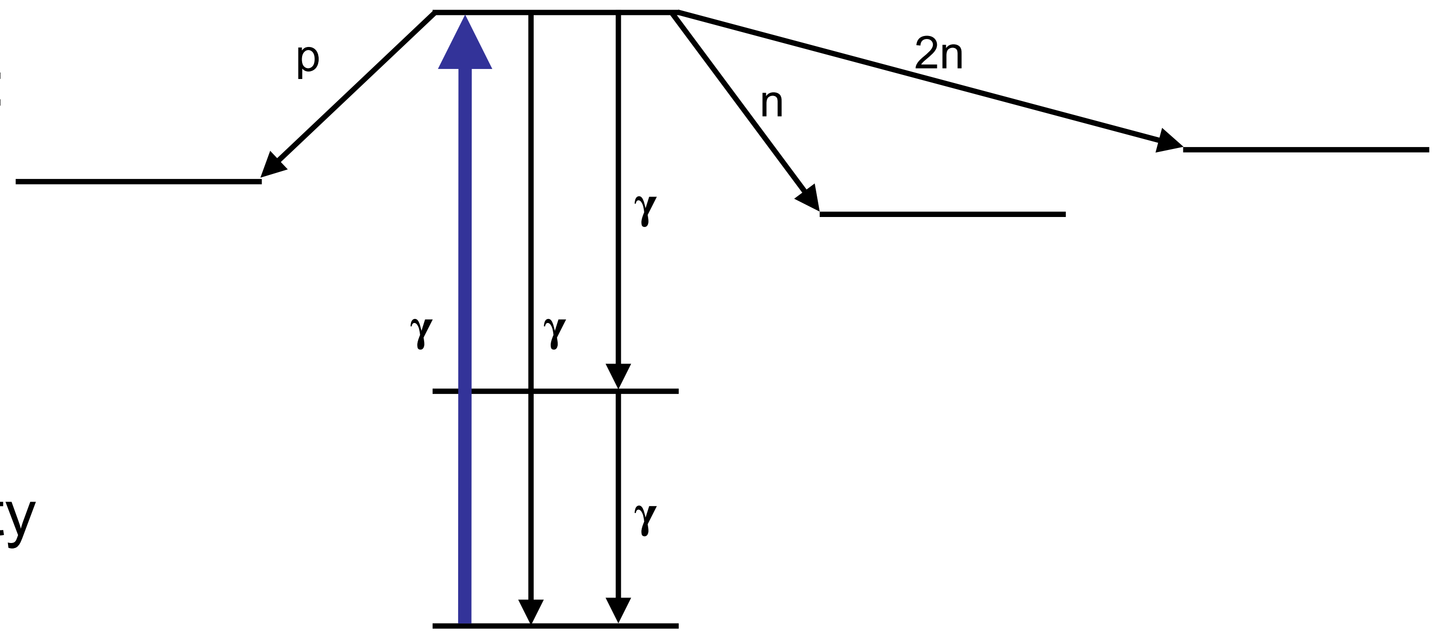
- New digital DAQ
- Arrival of LeadBall in Q4/17
- First tests with Sr-90
- Measurements with Cs-137
- Measurements with Mn-54 ($2^+ \rightarrow 0^+$)

Summary



Measuring photo nuclear cross section:

- Neptun for (**γ**,**γ**')-experiments
- NewSUBARU for (**γ**,xn)-experiments
- Total absorption for all channels
- 2-**γ**-decay for generalized polarizability



Thanks!

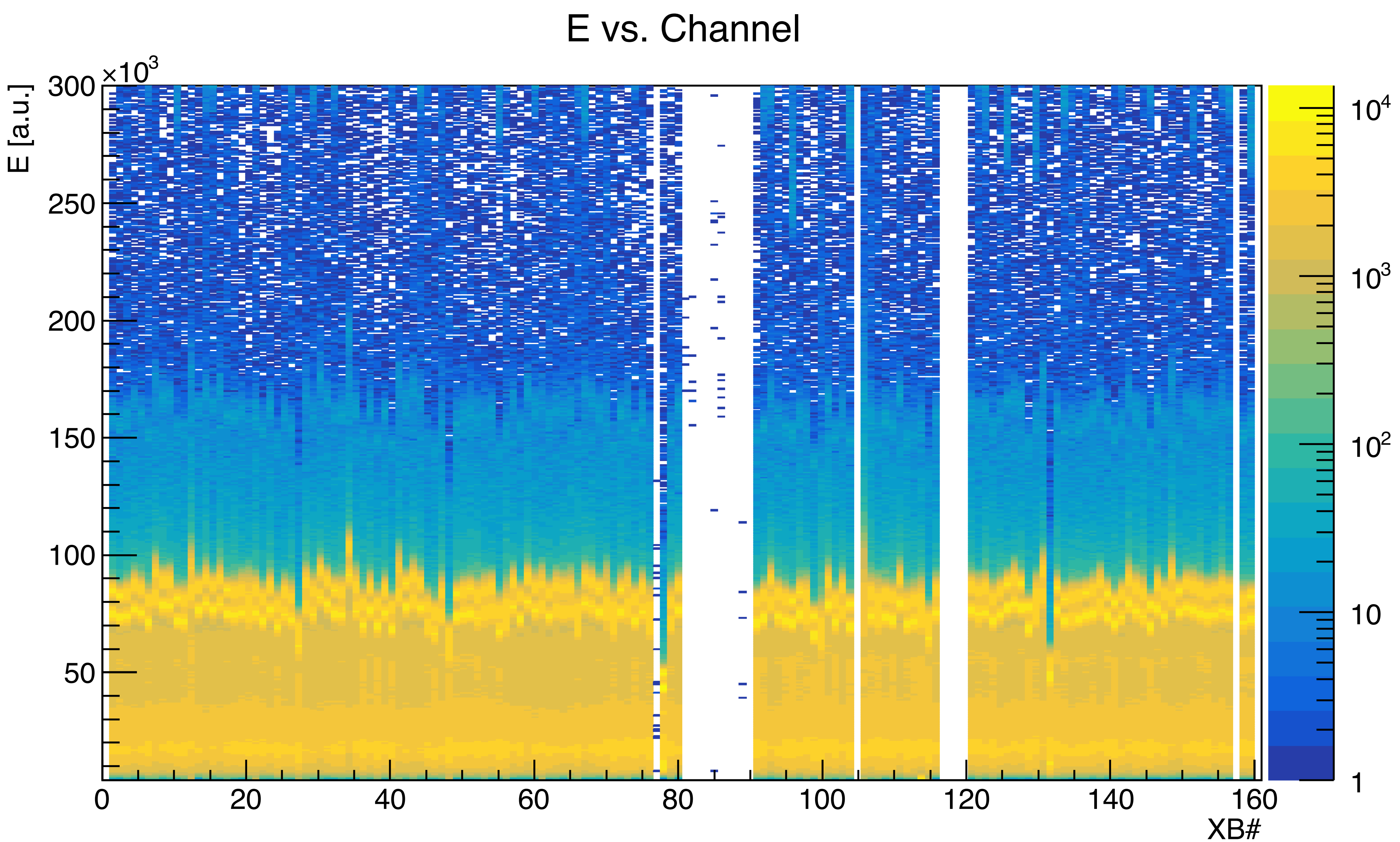
Thank you for your attention!

Questions?

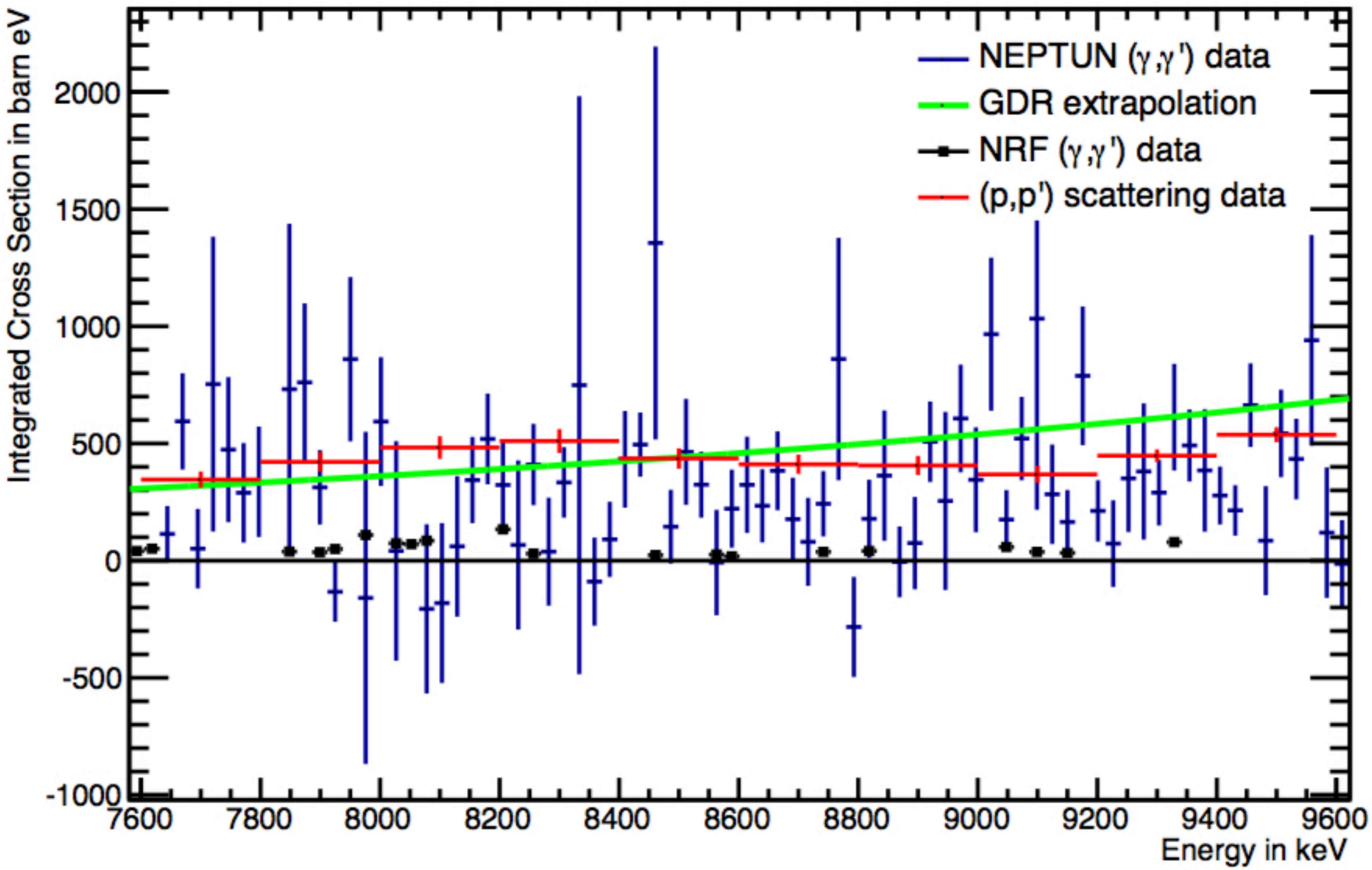
Appendix

TECHNISCHE UNIVERSITÄT DARMSTADT

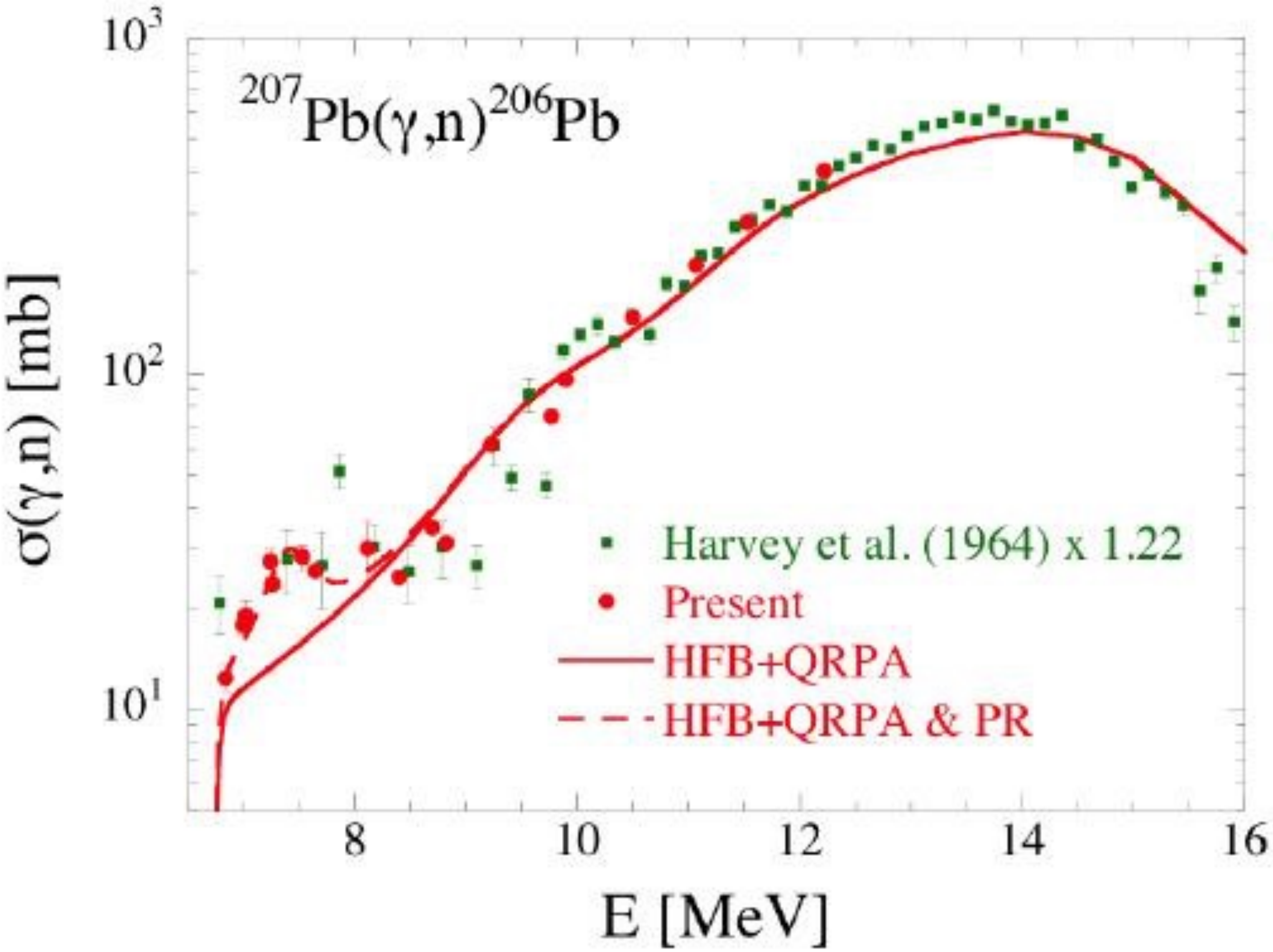
Test Data Acquisition



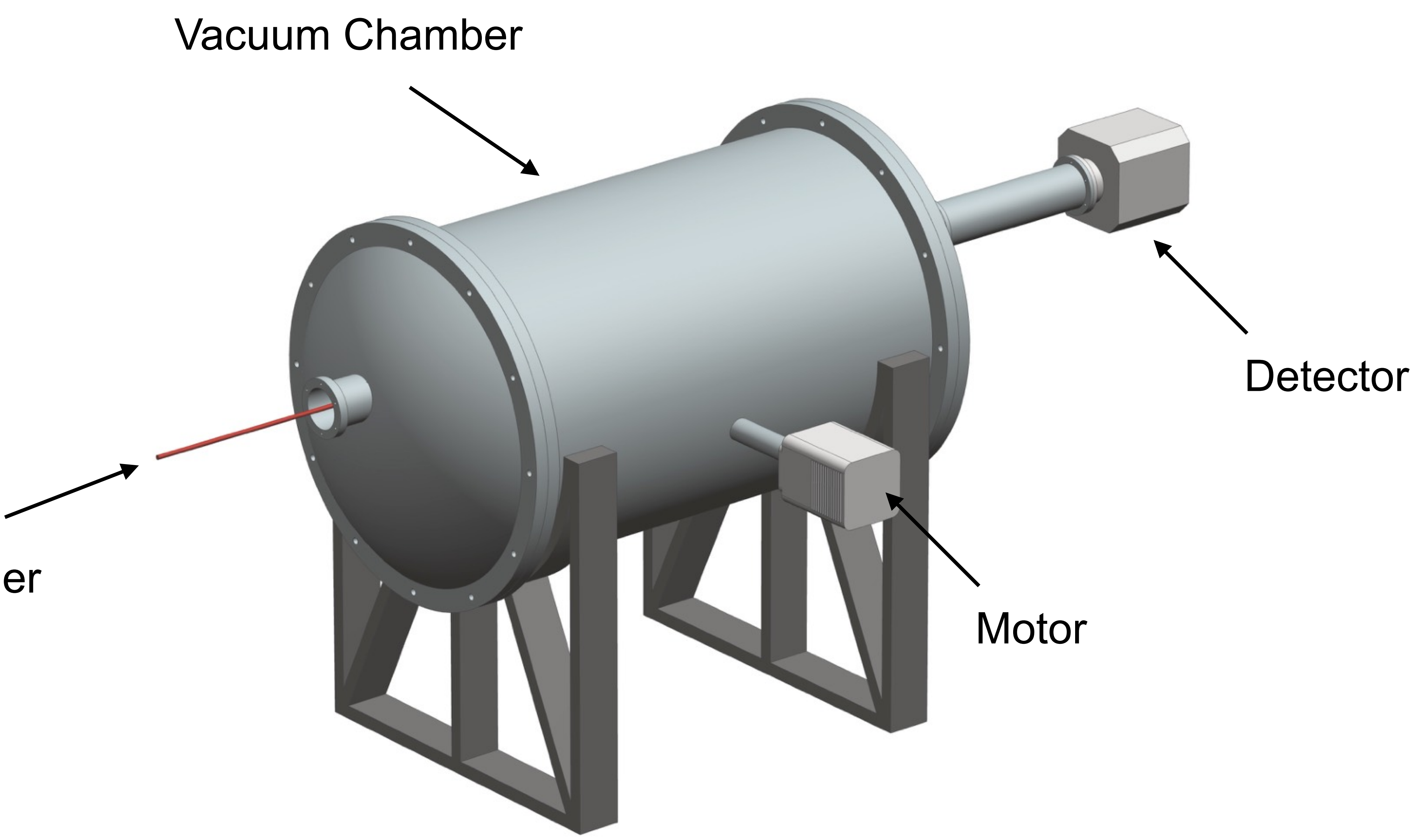
Dipole Strength



Results for (γ,n) Reactions



Total Absorption Experiments – the Setup



2-Gamma Decay and Polarizability

Dipole polarizability:

$$\alpha_D \propto \sum_n \frac{< i|E1|n >< n|E1|i >}{E_n}$$

Generalized polarizability:

$$\alpha_{if} \propto \sum_n \frac{< i|E1|n >< n|E1|f >}{E_n - \Delta E_{if}}$$

Parameter	Exp	QPM
$\Gamma\gamma\gamma/\Gamma\gamma$ (10^{-6})	2.05 (37)	2.69
αE2M2 (e^2 fm^4 MeV^{-1})	+33.9 (2.8)	+42.6
αM1E3 (e^2 fm^4 MeV^{-1})	10.1 (4.2)	+9.5