Experiments with Neutrons at ELBE

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Motivations for Measurements with Neutrons

- Materials research for:
  - fission and fusion reactors
  - transmutation facilities:
    - transformation of long living isotopes into short living ones by nuclear reactions

Nuclides Important for Transmutation

Object	Nuclides/Elements
Target materials	^{209}Bi, ^{208}Pb, ^{207}Pb, ^{206}Pb, ^{204}Pb Pb, ^{186}W, ^{184}W, ^{183}W, ^{182}W, W, ^{181}Ta, Ta, Zr, Sn, Hg, U, Pu, F, Cl, Na, Fe, Al
Po production	^{209}Bi(p,xn)^{207,208,209}Po, ^{209}Bi(n,γ)^{210}Bi--> ^{210}Po
Minor actinides	^{237}Np, ^{238}Np, ^{241}Am, ^{242m}Am, ^{242}Am, ^{243}Am, ^{242}Cm, ^{243}Cm, ^{244}Cm, ^{245}Cm, ^{246}Cm, ^{248}Cm
Long-lived FP	^{79}Se, ^{93}Zr, ^{99}Tc, ^{107}Pd, ^{126}Sn, ^{129}I, ^{135}Cs
Fuel compositions	^{238}U, ^{235}U, ^{239}Pu, ^{238}Pu, ^{14,15}N, O, F, Cl
Th cycle	^{232}Th, ^{231}Pa, ^{232}Pa, ^{233}Pa, ^{233}U, ^{234}U
Structural materials	Zn, Cu, Ni, Co, Fe, Mn, Cr, Ti, Ca, Ar, Al, Mg, Na, O, N. C, B, Be, He ^{3}T
Shielding	O, Si, P, Ca, Ti, Fe

→ ^{56}Fe (n,γ) ^{57}Fe

^{56}Fe (n,n'γ) ^{56}Fe

^{209}Bi (n,γ) ^{210}Bi

Y. Ikeda, Journal of Nucl. Sci. and Technology (2002) pp. 13-18

Motivations for Measurements with Neutrons

- Materials research for:
  - fission and fusion reactors
  - transmutation facilities:
    - transformation of long living isotopes into short living ones by nuclear reactions

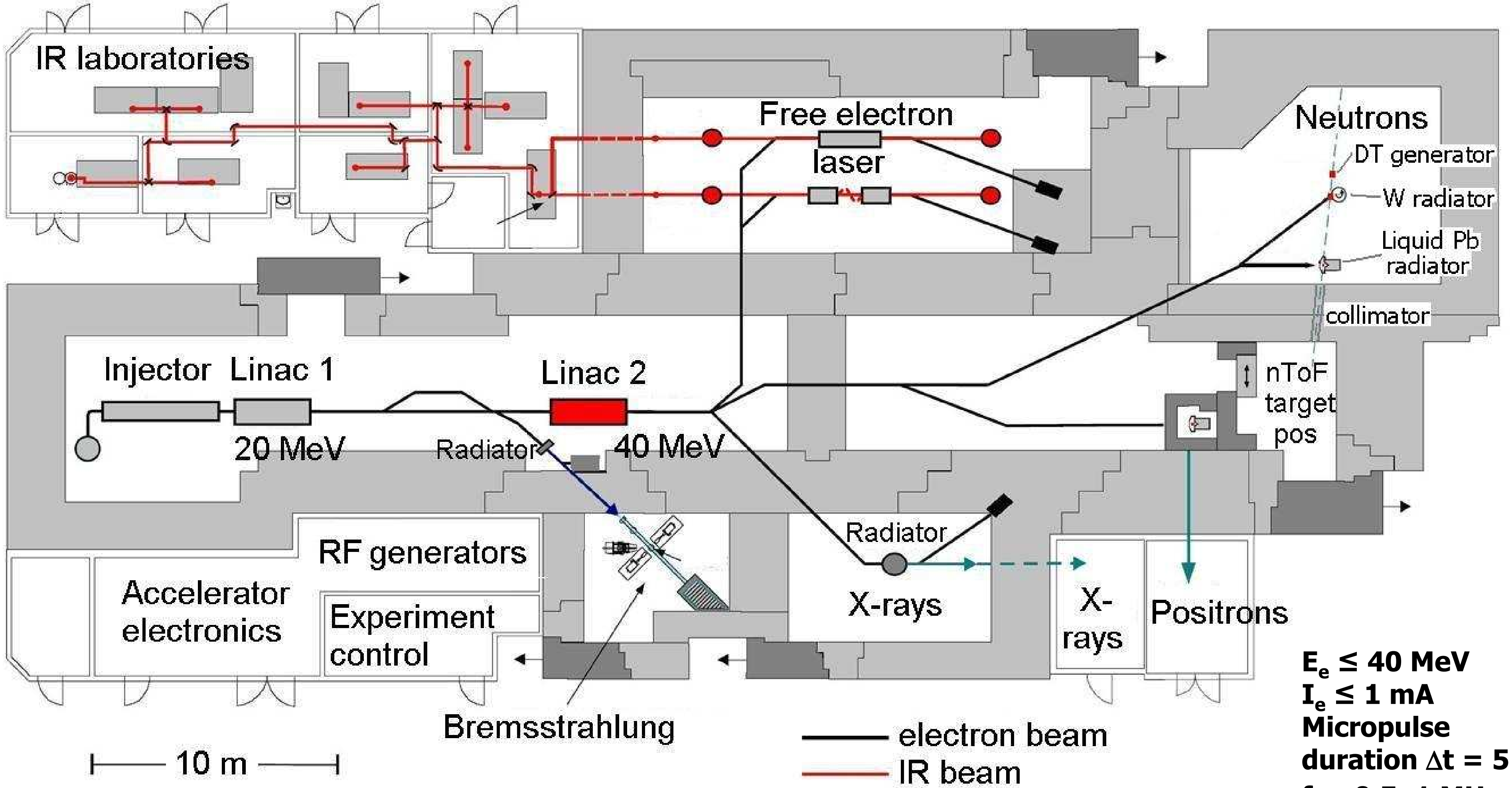
- Nuclear astrophysics:
  - investigations on nuclear reactions with relevance for the synthesis of the elements in the universe
  - e.g. $n + p \rightarrow d + \gamma$ or $d + \gamma \rightarrow n + p$

Needs:

➔ intense neutron source

➔ efficient neutron and gamma detectors

The Superconducting Electron Accelerator ELBE

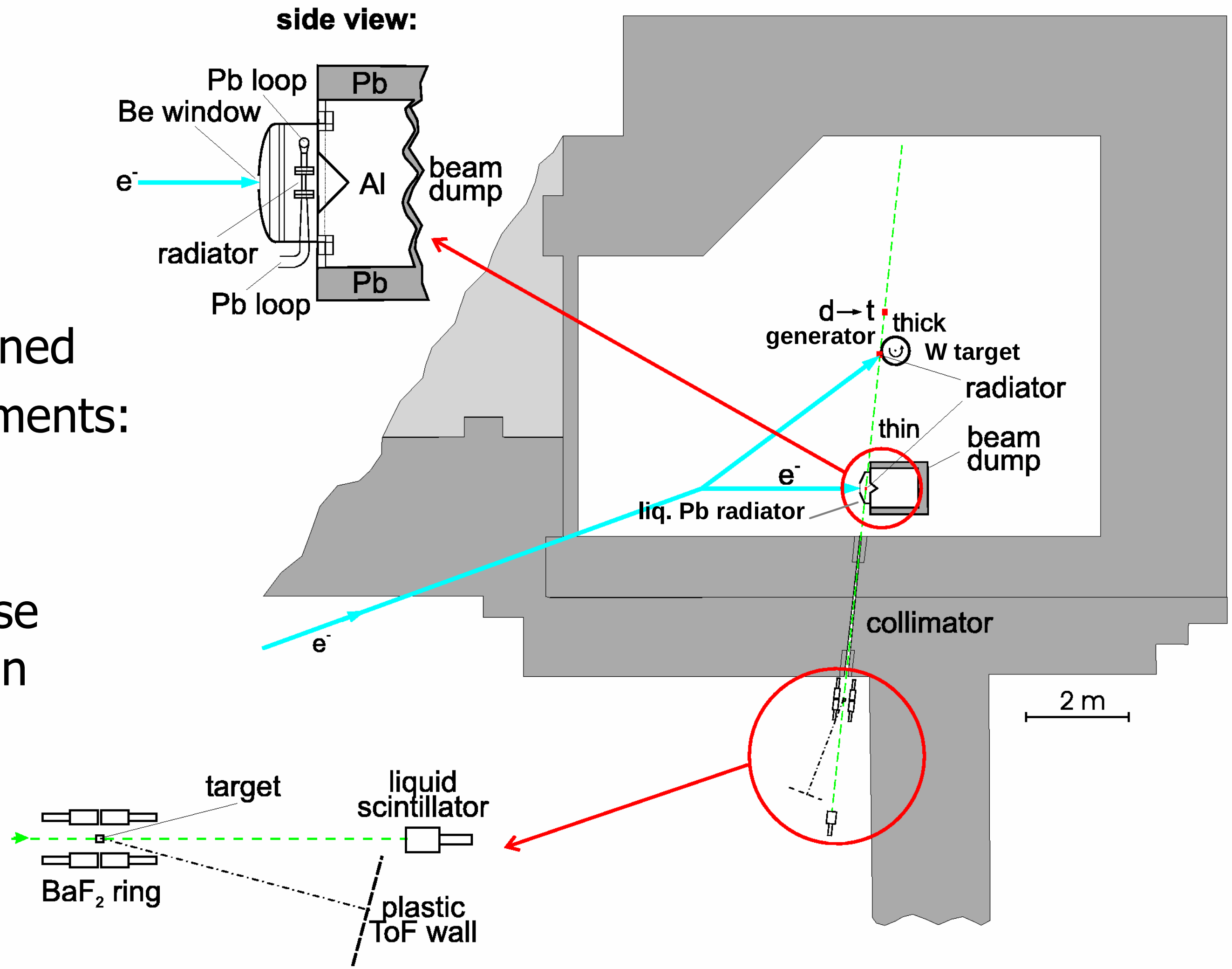


$E_e \leq 40$ MeV
$I_e \leq 1$ mA
Micropulse duration $\Delta t = 5$ ps
f = 0.5–1 MHz

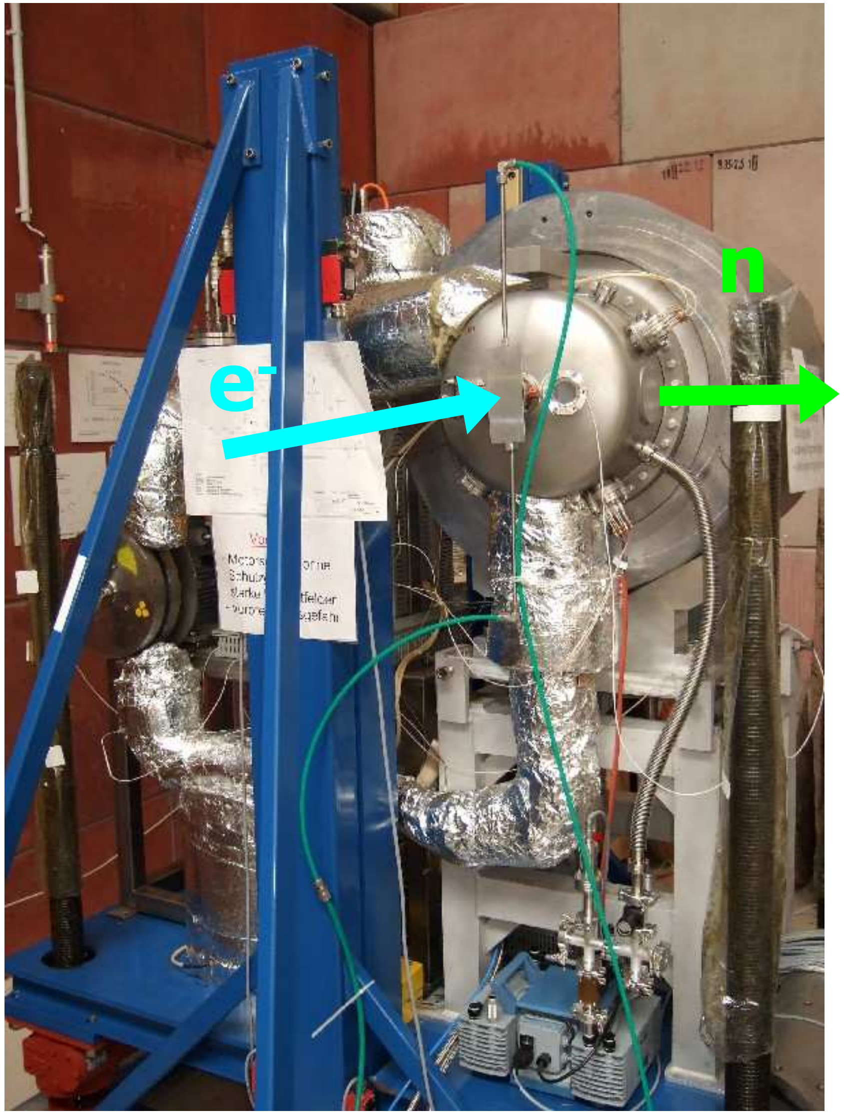
The Neutron Time of Flight Facility

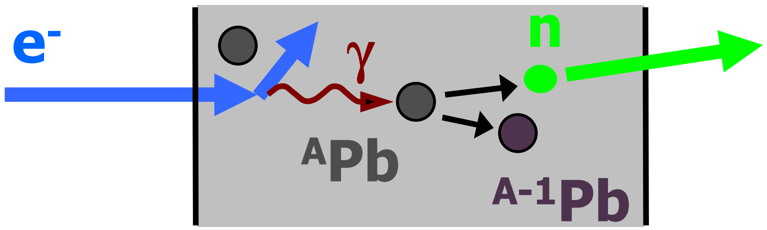
Neutron energy is determined via time of flight measurements:

- known flight path from source to detector
- start time given by pulse structure of the electron beam



The Liquid-Lead Radiator



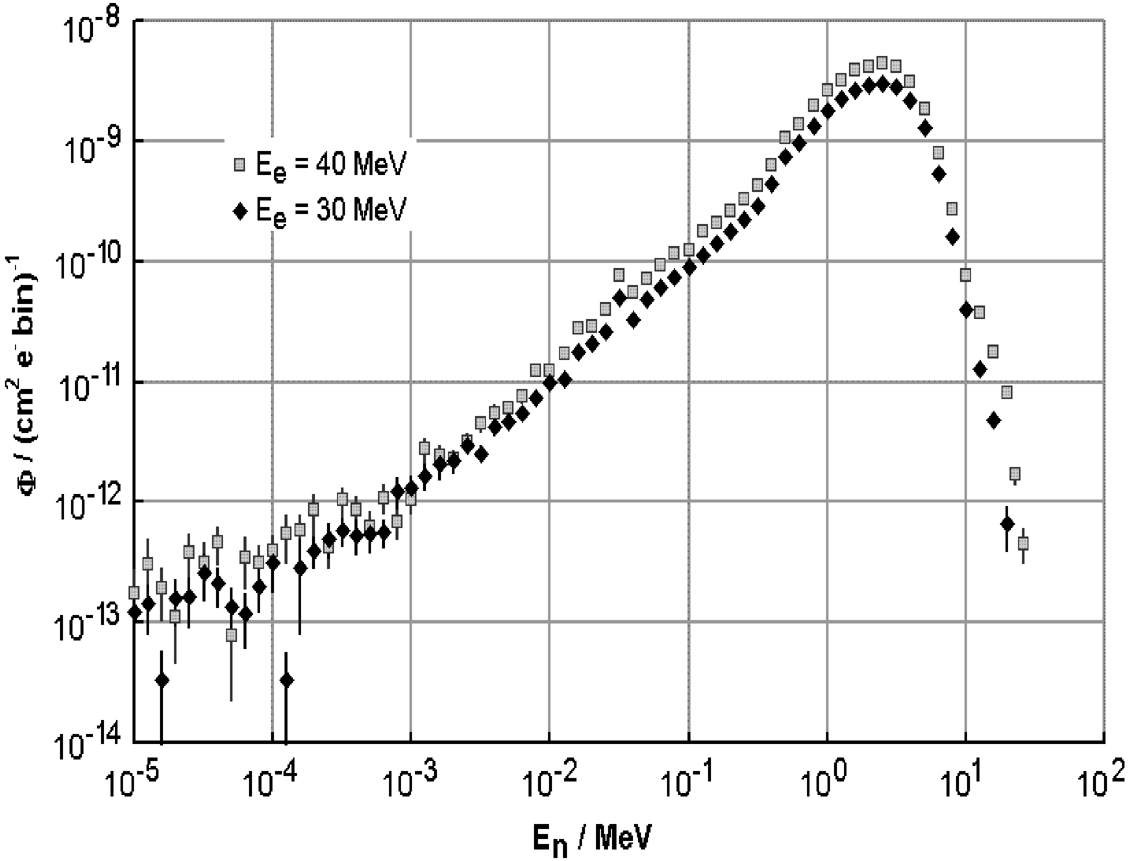


Thermal load up to 25 kW ⇒
liquid Pb radiator

Expected Properties of the nToF Facility

Neutron flux obtained with I_e = 1 mA

(MCNP simulations)



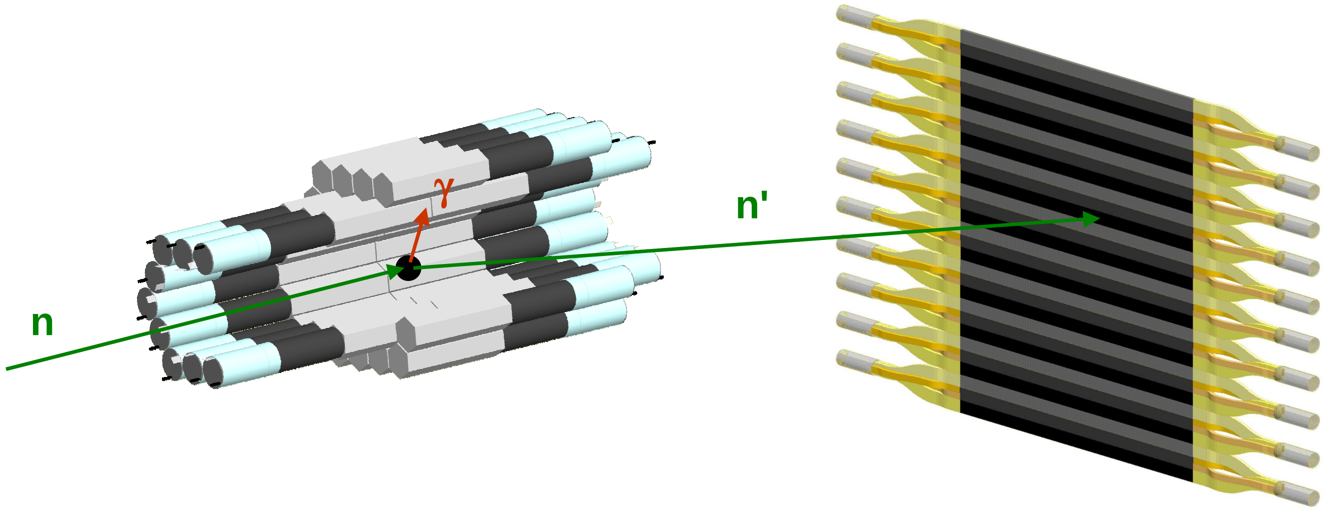
Facility	CERN n-ToF Phase-2	ELBE with photo-gun
Pulse charge / nC	ca. 10^3	1.8
Power / kW	10	40
Pulse rate / s^{-1}	0.4	$5\cdot10^5$
Flight Path / m	**Ca. 20**	**4**
n-pulse length / ns	>7	< 0.4
E_{min} / eV	0.1	$2\cdot10^4$
E_{max} / eV	$3\cdot10^8$	$7\cdot10^6$
resolution at 1 MeV / %	**5%**	**ca. 1 %**
n flux density / $s^{-1}cm^{-2}$ (E decade)$^{-1}$	**ca.10^7**	**$3\cdot10^6$**

Detector Development - Needs

Time of flight experiments at ELBE:

- Neutron kinetic energy range ca. 100 keV – 5 MeV
  flight path = 4.0 m
  ➔ $\Delta t < 1$ ns required for $\Delta E/E = 1\%$
- Measurements of (n,n) and (n,n'γ) cross section
  ➔ high efficiency for neutron detection at low kinetic energies
- Measurement of (n,γ) and (n,n'γ) cross sections
  ➔ high efficiency photon-detectors

Detector Development



Photons

BaF_2-Array

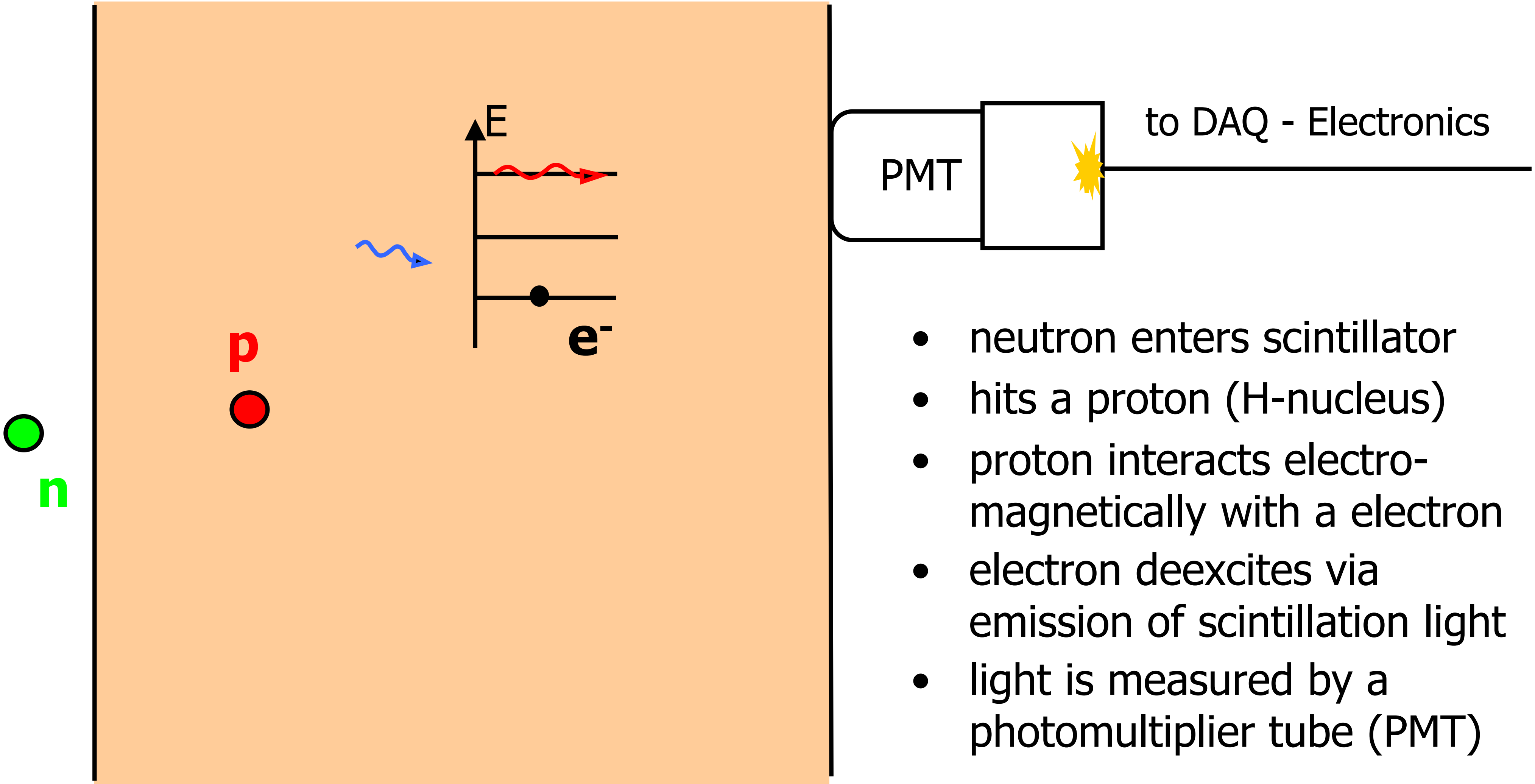
- 42 crystals
- l = 19 cm
- Ø = 53 mm
- $\Delta\Omega$: 90 % of 4π sr
- time resolution ≈ 640 ps

Neutrons

Plastic scintillators

- 10 strips
- l = 1 m
- Large (n,p) scattering cross section
- time resolution ≈ 670 ps
- detection point from two-sided readout

The Principle of Neutron Detection

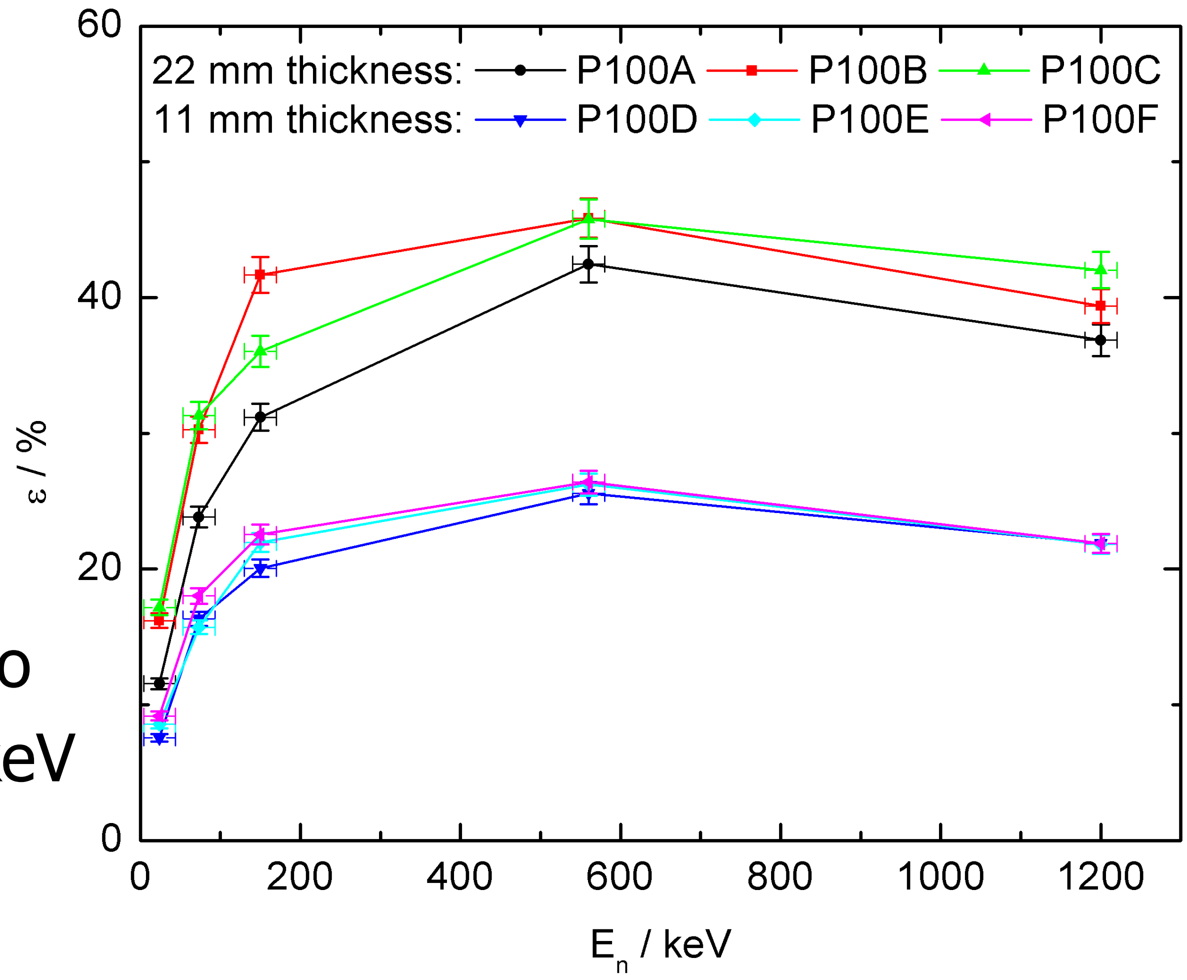


- neutron enters scintillator
- hits a proton (H-nucleus)
- proton interacts electro-magnetically with a electron
- electron deexcites via emission of scintillation light
- light is measured by a photomultiplier tube (PMT)

Efficiency of the Proton Recoil Detectors

- efficiency calibration at Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig

➔ high efficiency down to a region of some tens of keV



Thank You