



Irradiation tests at HZDR

Anna Ferrari, Stefan Müller



hzdr



HELMHOLTZ
ZENTRUM DRESDEN
ROSSENDORF

pELBE and nELBE beamlines at ELBE

(Electron Linear accelerator with high Brilliance and low Emittance)

National Center for High-Power Radiation Sources:

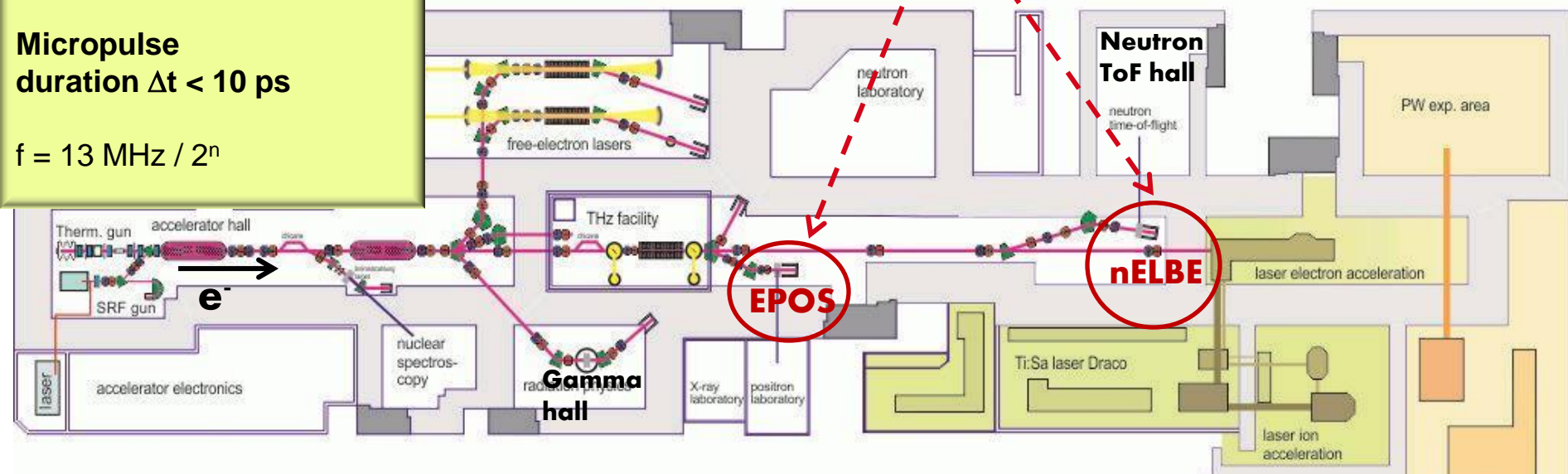
- Multiple secondary beams (neutrons, photons, positrons) & High-Power laser (PW) for electron/ion acceleration
- **nELBE**: Neutron Time-of-Light Facility for Transmutation Studies and Nuclear Physics measurements
- **pELBE (EPOS)**

**Photo-neutron sources:
neutron production via photo-nuclear reactions**

$E_e \leq 40 \text{ MeV}$ $I_e \leq 1 \text{ mA}$

Micropulse duration $\Delta t < 10 \text{ ps}$

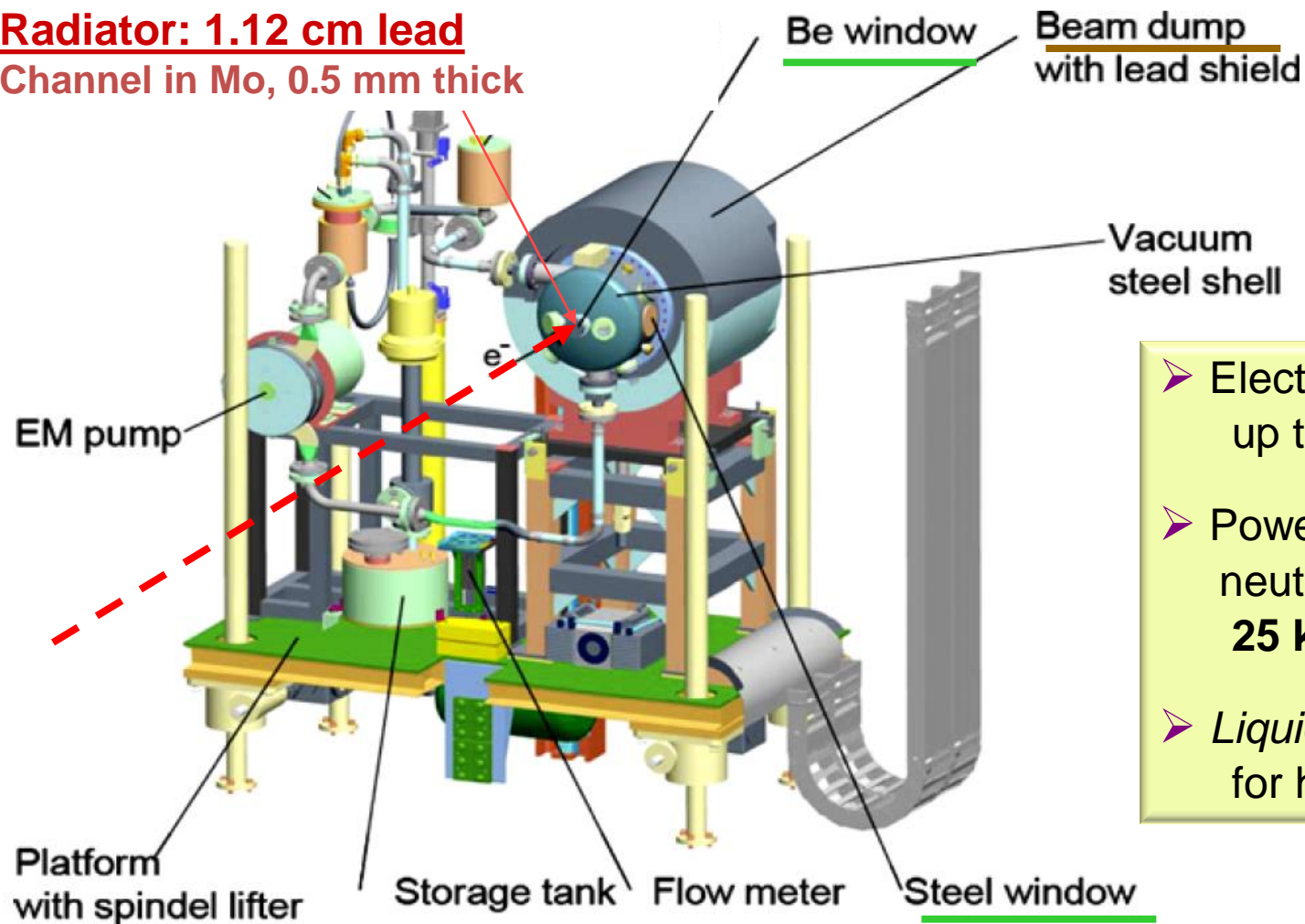
$f = 13 \text{ MHz} / 2^n$



nELBE: the photo-neutron source

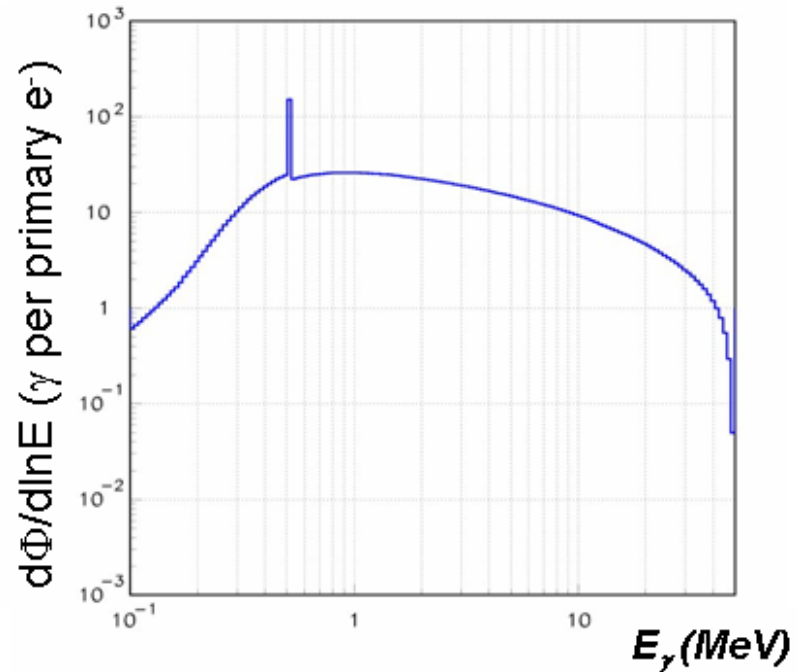
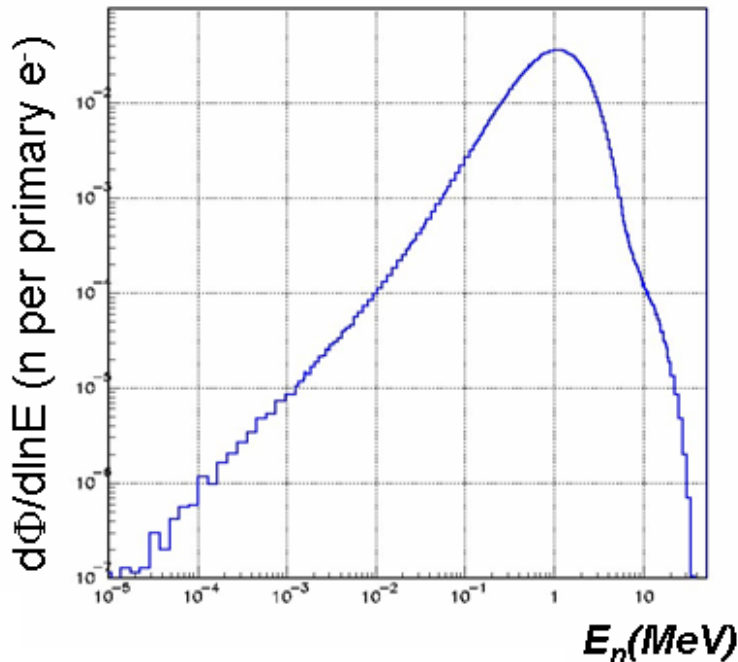
Radiator: 1.12 cm lead

Channel in Mo, 0.5 mm thick



- Electron beam power up to **40 kW**
- Power density in the neutron radiator up to **25 kW/cm³**
- *Liquid lead circuit* for heat transport

Source strength and photon/neutron yield ratio



Electron Energy (MeV)	Neutron Yield [n/e⁻] (FLUKA sim.)	Source Strength [n/s] @1 mA (FLUKA sim.)	Photon Yield [γ/e⁻] (FLUKA sim.)
30	$3.108 \cdot 10^{-3}$	$1.94 \cdot 10^{13}$	4.14


Problem: γ/n yield $\sim 10^3$!

@ 1 m , 100 μ A e⁻ current and 30 MeV e⁻ energy:

$$1.54 \cdot 10^7 \text{ n cm}^{-2} \text{ s}^{-1}$$

To accumulate 3 \cdot 10¹¹ n/cm² only ~**5.4 h** are needed

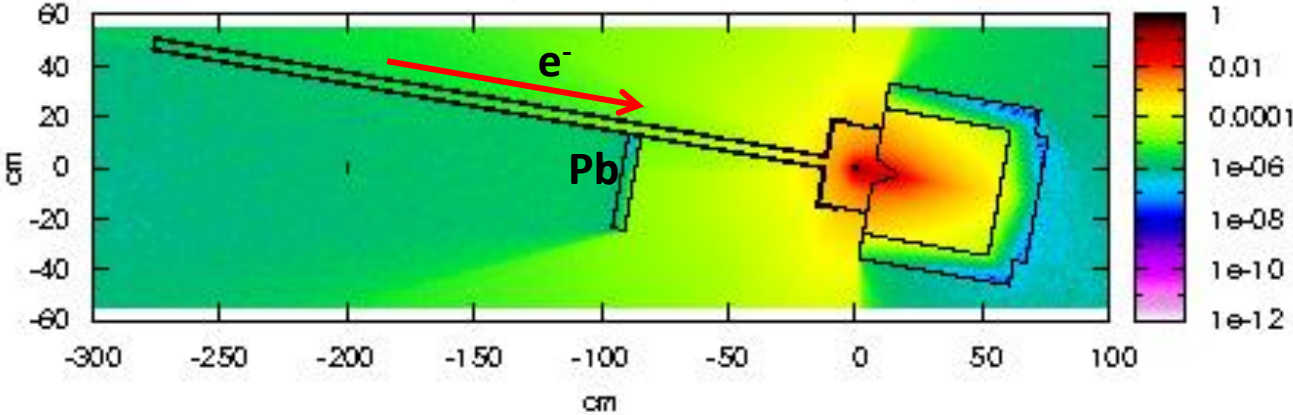
→ To suppress the gamma radiation
a local Pb shielding can be used, without
problematically losing neutron flux



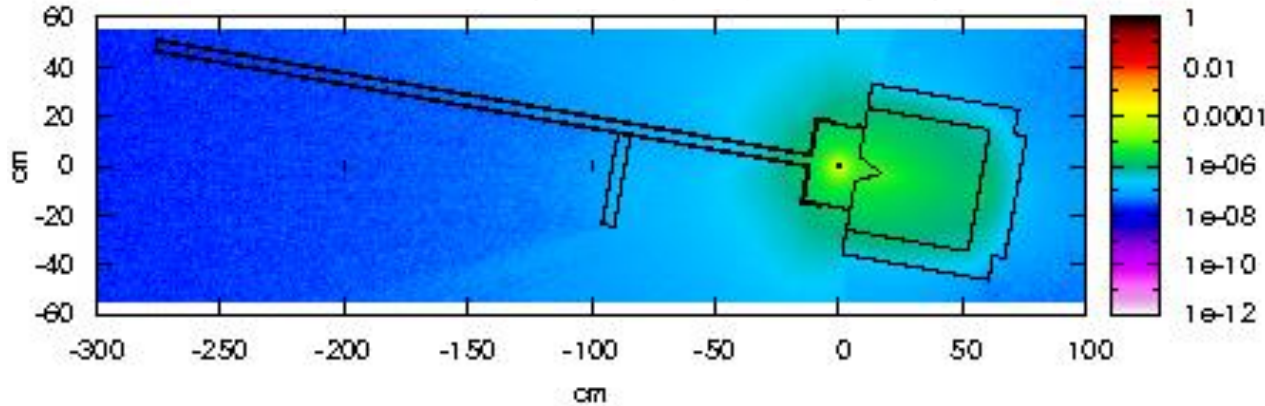
Liquid-lead
photo-neutron source

Use Pb shielding to lower the γ/n ratio

Photon fluence (n cm⁻² per primary e⁻)



Neutron fluence (n cm⁻² per primary e⁻)



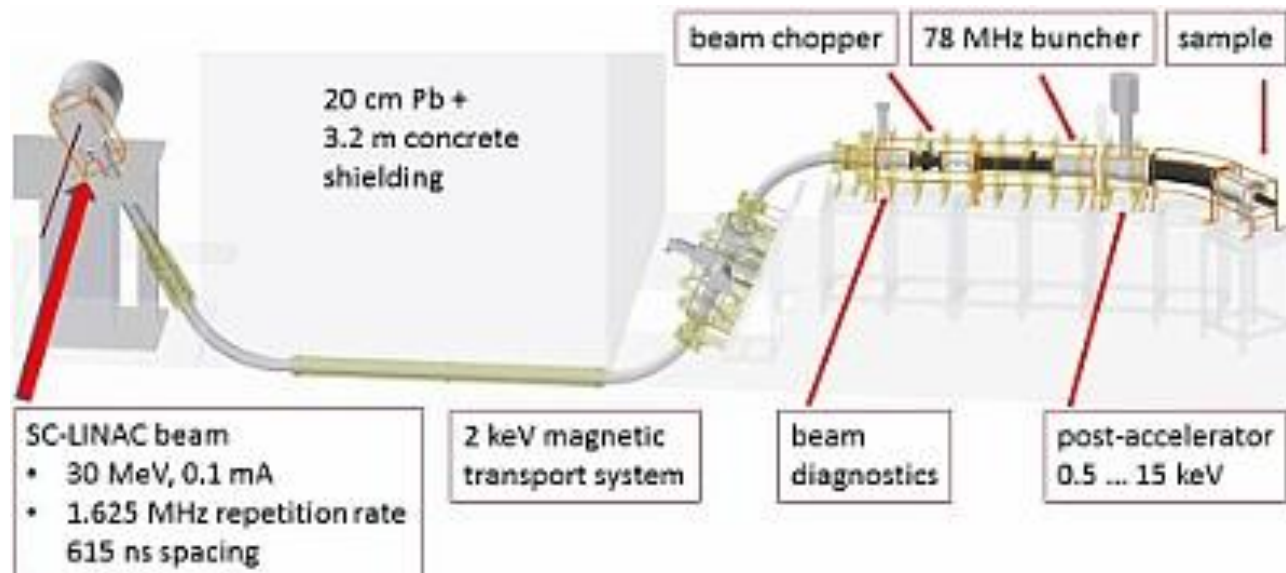
With 5 cm lead shielding
the γ/n ratio
goes down to ~ 10
beyond the lead block

A better solution: the EPOS source at positron extraction beamline pELBE

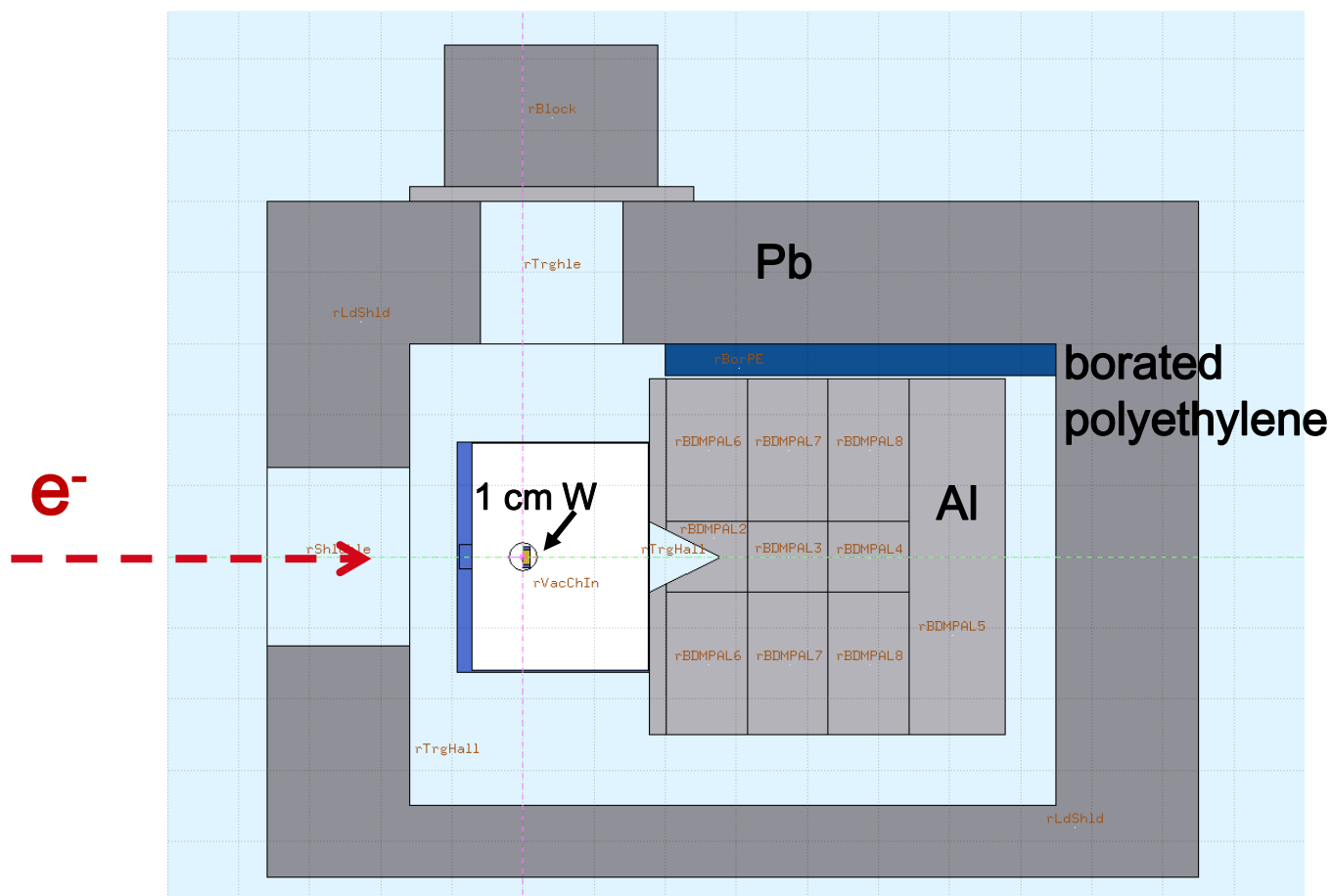


Bremsstrahlung/photoneutron
target: **1 cm W**

positron extraction beamline



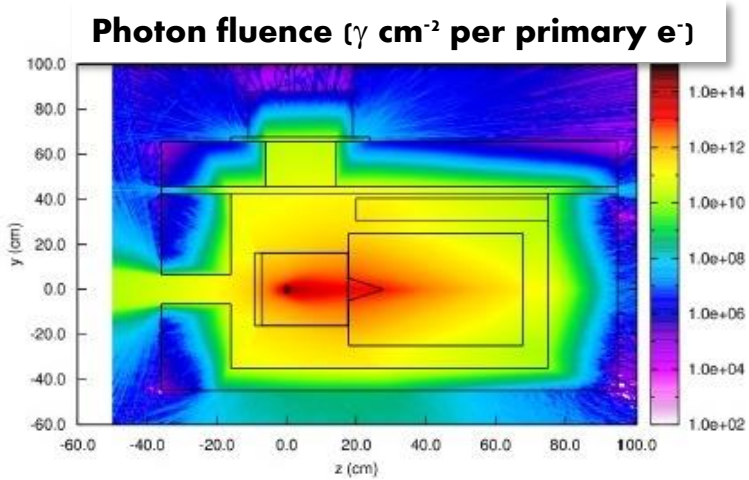
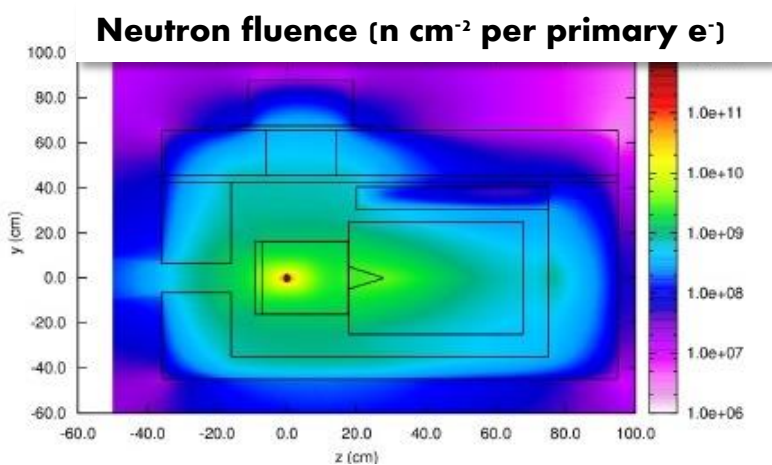
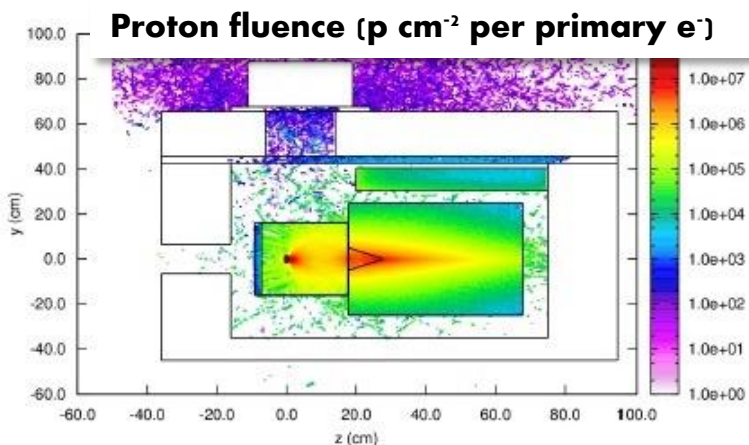
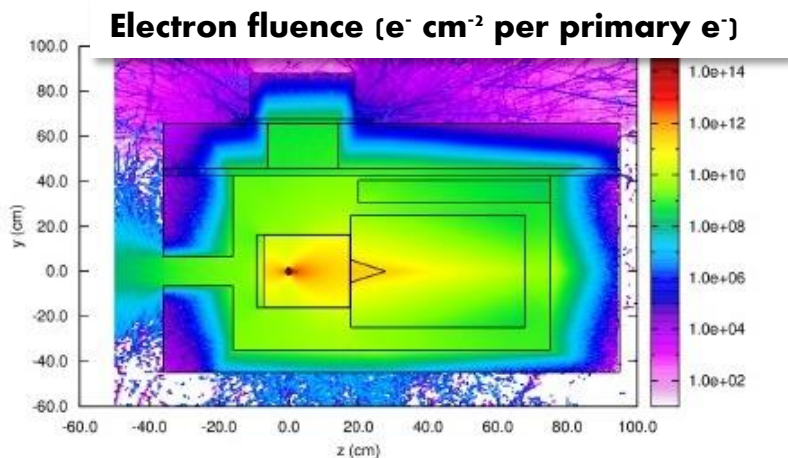
Geometry around the target



Radiation fields around the target: fluence rates

EPOS simulations: Prompt radiation@30 MeV pencil beam ($\sigma_{x,y}=0.3\text{cm}$) with $100\mu\text{A}$

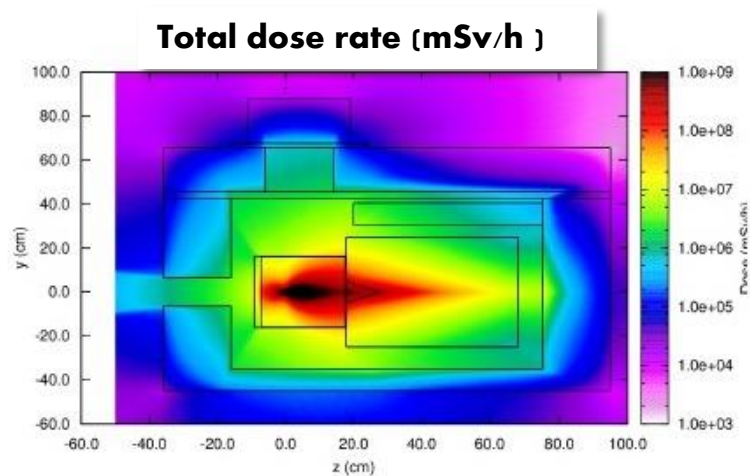
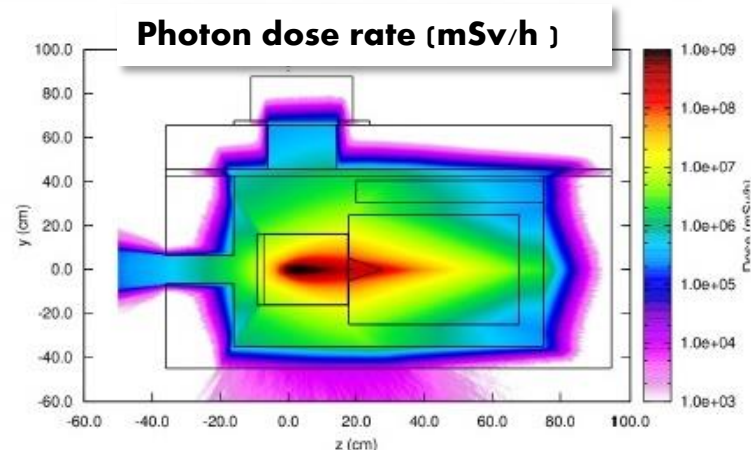
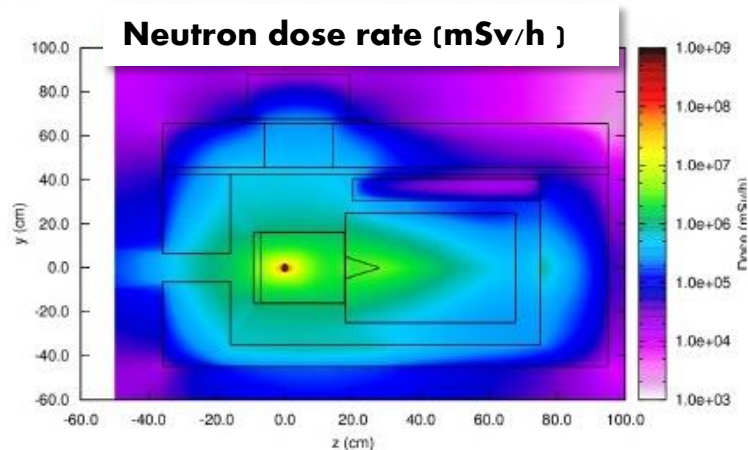
Total neutron yield coming from target: $(2.83\text{e-}03 \pm 8.17\text{e-}07)$ neutrons/primary $= (1.767\text{e+}12 \pm 3.979\text{e+}08)$ n/s @ $100\mu\text{A}$



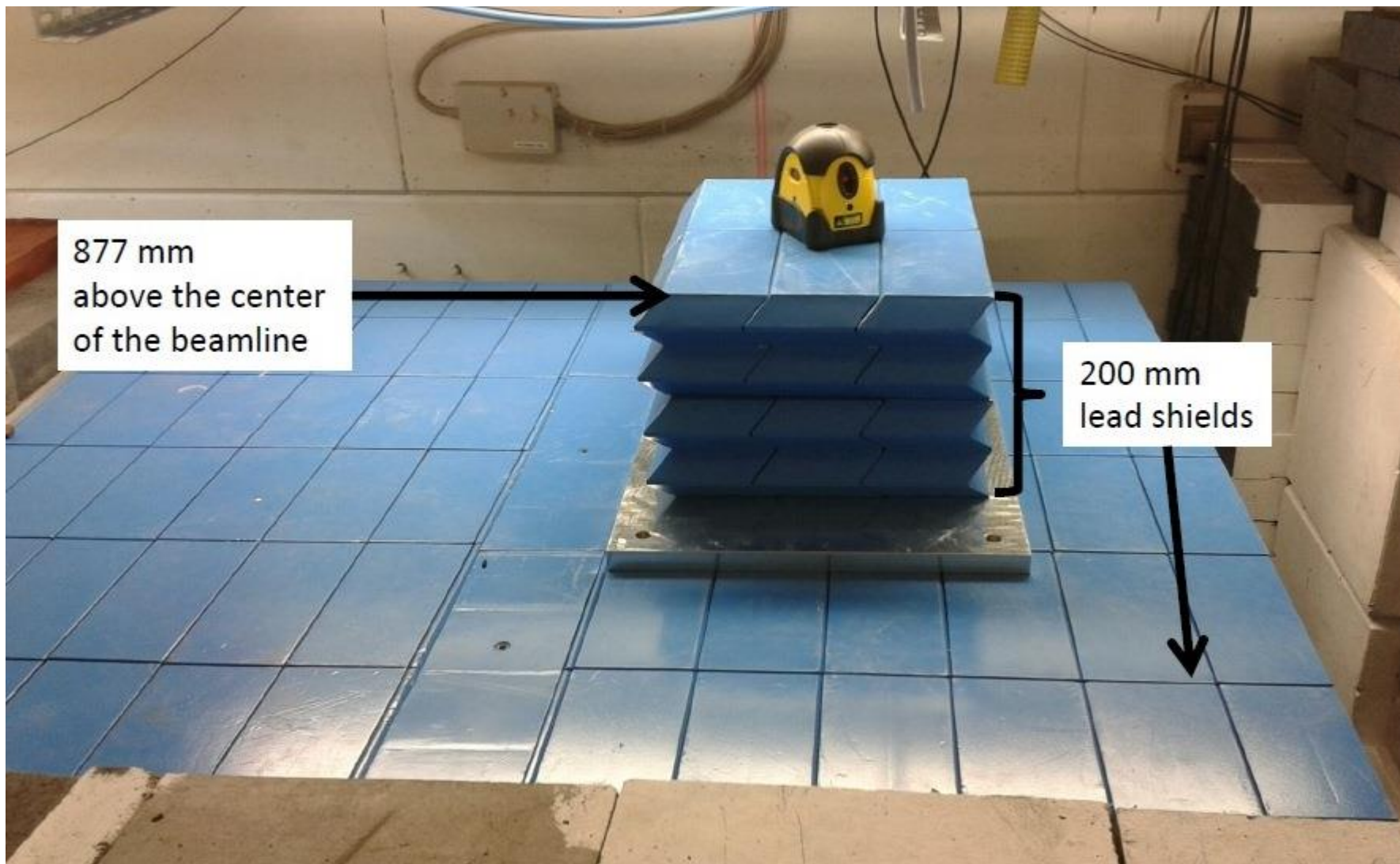
Radiation fields around the target: dose [$H^*(10)$] rates

EPOS simulations: Prompt radiation@30 MeV pencil beam ($\sigma_{x,y}=0.3\text{cm}$) with $100\mu\text{A}$

Total neutron yield coming from target: $(2.83\text{e-}03 \pm 8.17\text{e-}07)$ neutrons/primary $= (1.767\text{e+}12 \pm 3.979\text{e+}08)$ n/s @100 μA



Irradiation position

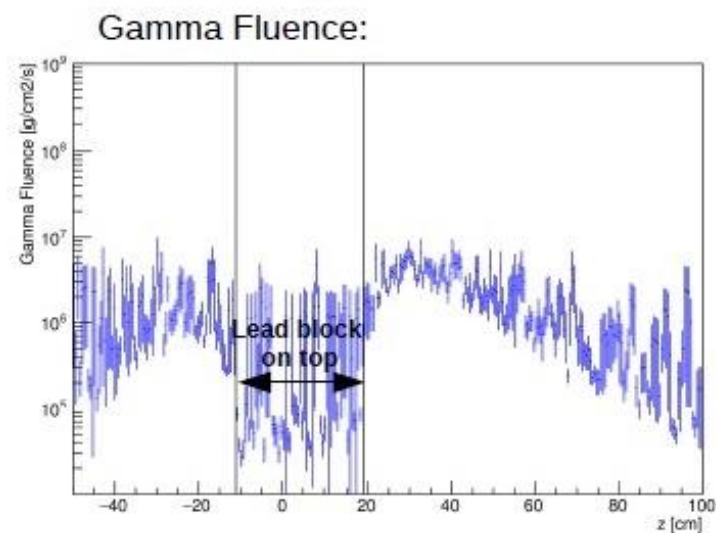
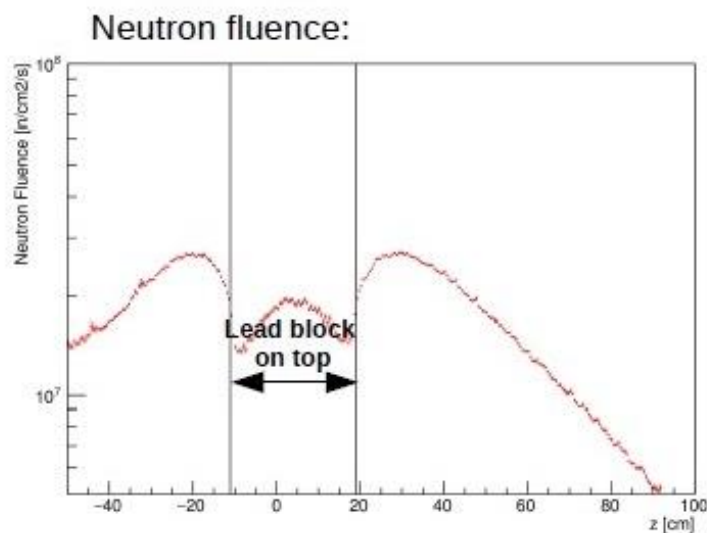


Fluence profiles at the irradiation position

EPOS simulations: Prompt radiation@30 MeV pencil beam ($\sigma_{x,y}=0.3\text{cm}$) with $100\mu\text{A}$

Total neutron yield coming from target: $(2.83\text{e-}03 \pm 8.17\text{e-}07)$ neutrons/primary $= (1.767\text{e+}12 \pm 3.979\text{e+}08)$ n/s @ $100\mu\text{A}$

Slices between $88. < y < 88.5$ cm (above lead block):

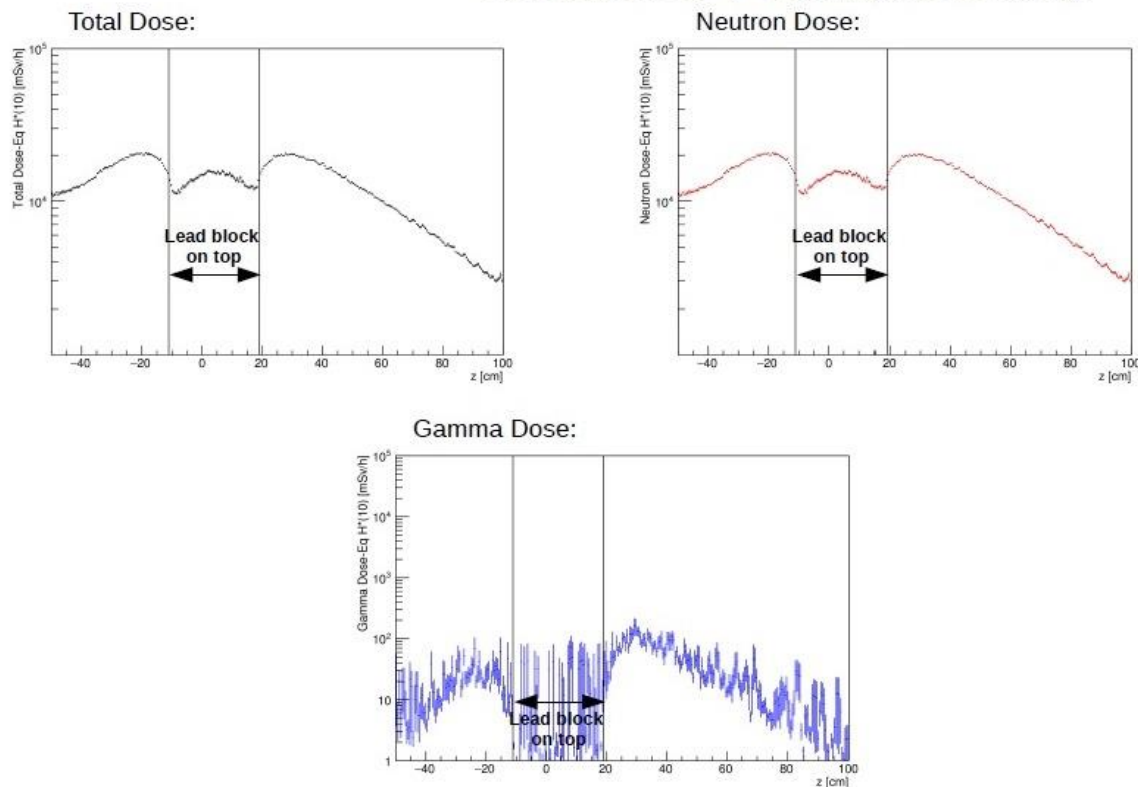


Dose profiles at the irradiation position

EPOS simulations: Prompt radiation @ 30 MeV pencil beam ($\sigma_{x,y} = 0.3\text{cm}$) with $100\mu\text{A}$

Total neutron yield coming from target: $(2.83\text{e-}03 \pm 8.17\text{e-}07)$ neutrons/primary $= (1.767\text{e+}12 \pm 3.979\text{e+}08)$ n/s @ $100\mu\text{A}$

Slices between $88. < y < 88.5$ cm (above lead block):

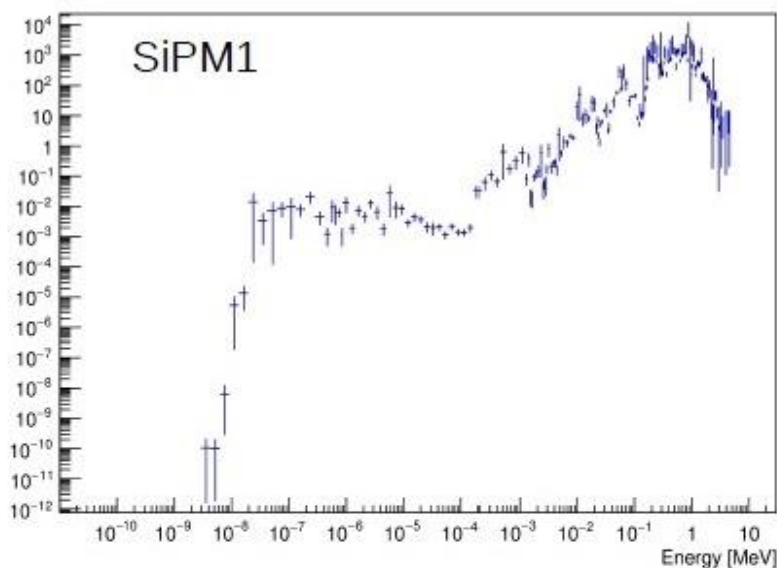


EPOS is an optimal neutron source for radiation damage studies

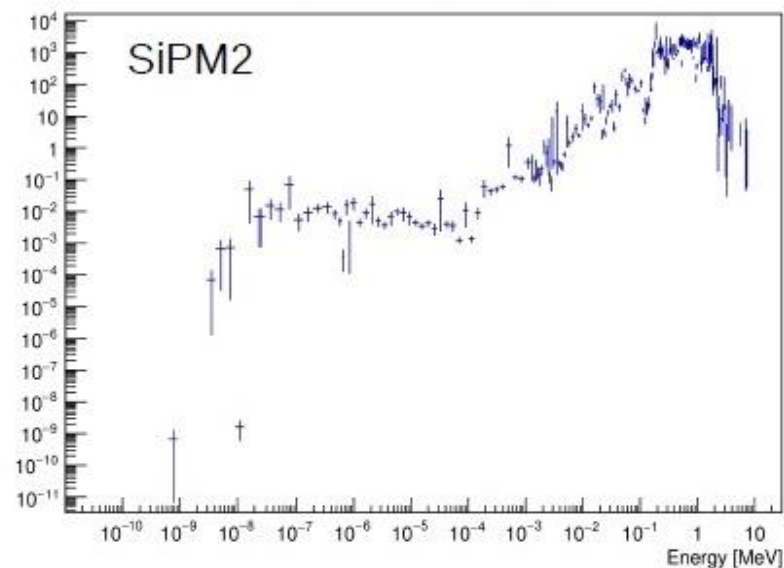
1 MeV-equivalent neutron spectra

The 2 plots refer to different irradiation positions of the SiPMs

1 MeV Neutron-equiv. fluence in [n/cm²/s] at 1 uA e- current



1 MeV Neutron-equiv. fluence in [n/cm²/s] at 1 uA e- current



Total 1MeV-equiv. fluence at 1microAmp e- beam: (69438.5+6990.84) n/cm²/s (SiPM1)

Total 1MeV-equiv. fluence at 1microAmp e- beam: (90229.8+6682.47) n/cm²/s (SiPM2)

Planning the irradiation tests

2 options:

- Running in parasitic way -> we completely depend on the main user needs
- **Asking for dedicated beamtime**



The screenshot shows the HZDR GATE website interface. On the left is a navigation menu with items: GATE, HZDR GATE, Login, Registration, Lost password, and Lost username. The main content area is titled 'HZDR GATE' and contains the following text:

HZDR GATE
 HZDR GATE is the general access tool to the research infrastructures (RI) at HZDR, offering access to external user!

Users are kindly required to register in HZDR GATE in order to be able to

- submit a proposal for beamtime at ELBE, IBC or DRACO
- participate in accepted experiments at ELBE, IBC or DRACO
- provide user feedback and to submit experimental reports
- publish data resulting from experiments at an RI at HZDR.

On the right side of the page, there is a 'Login' section with a blue button labeled 'HZDR GATE Login'. Below it, separated by 'or', is an 'Institutional Login via Shibboleth' section featuring the Shibboleth logo and the text '(only for HZDR members)'.

Next deadline: November 1, 2016
 for the beamtime 1 Jan 2017 – 30 Jun 2017