ELBE pulsed neutron and gamma beams

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gELBE pELBE and nELBE beamlines at ELBE

(Electron Linear accelerator with high Brilliance and low Emittance)

National Center for High-Power Radiation Sources:

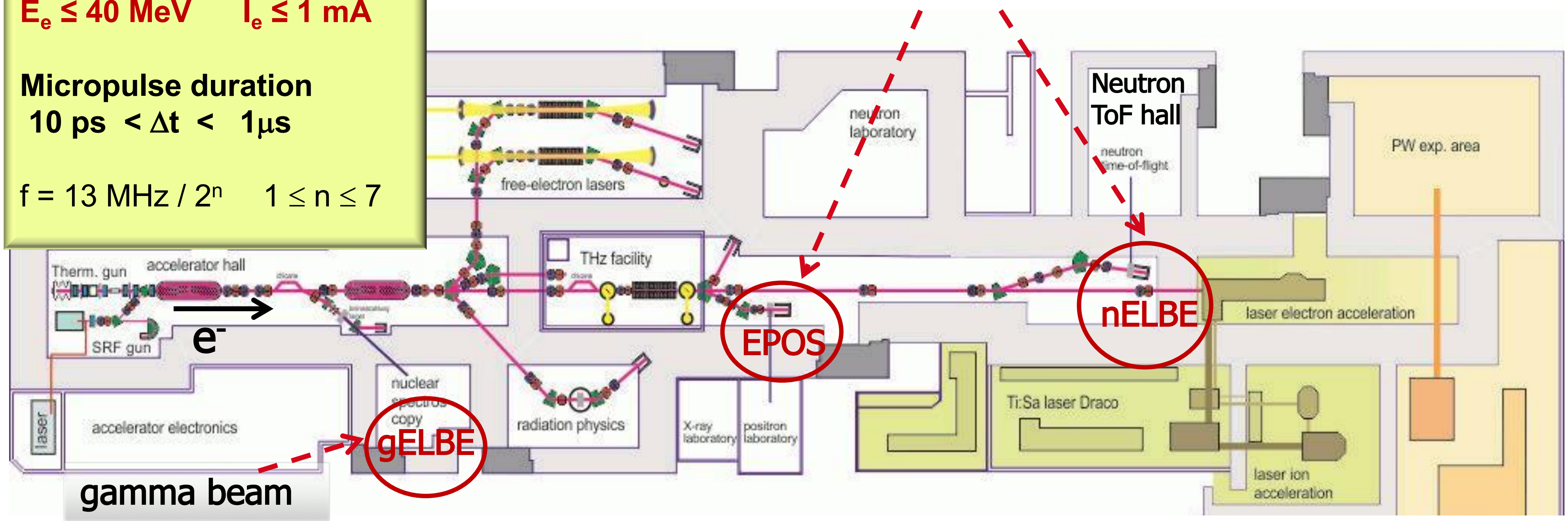
- Multiple secondary beams (neutrons, photons, positrons) & High-Power laser (PW) for electron/ion acceleration
- **nELBE**: Neutron Time-of-Light Facility for Transmutation Studies and Nuclear Physics Exp.
- **gELBE**: gamma beam facility for nuclear spectroscopy and detector tests
- **pELBE** (EPOS)

$E_e \le 40$ MeV $I_e \le 1$ mA

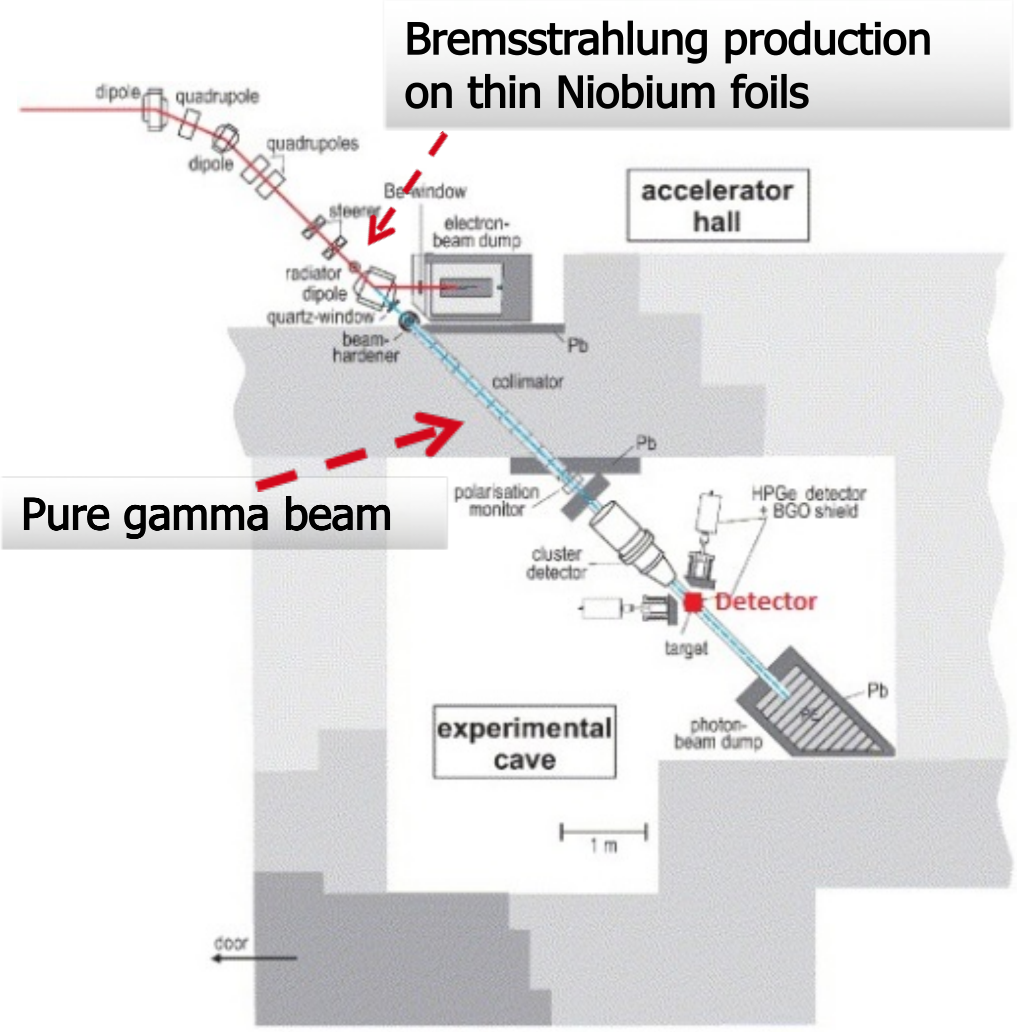
Micropulse duration
10 ps $< \Delta t <$ 1μs

f = 13 MHz / 2^n $1 \le n \le 7$

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



gELBE: the gamma source



Bremsstrahlung production on thin Niobium foils

Pure gamma beam

Bremsstrahlung (Endpoint up to 20 MeV) is available in the nuclear physics cave

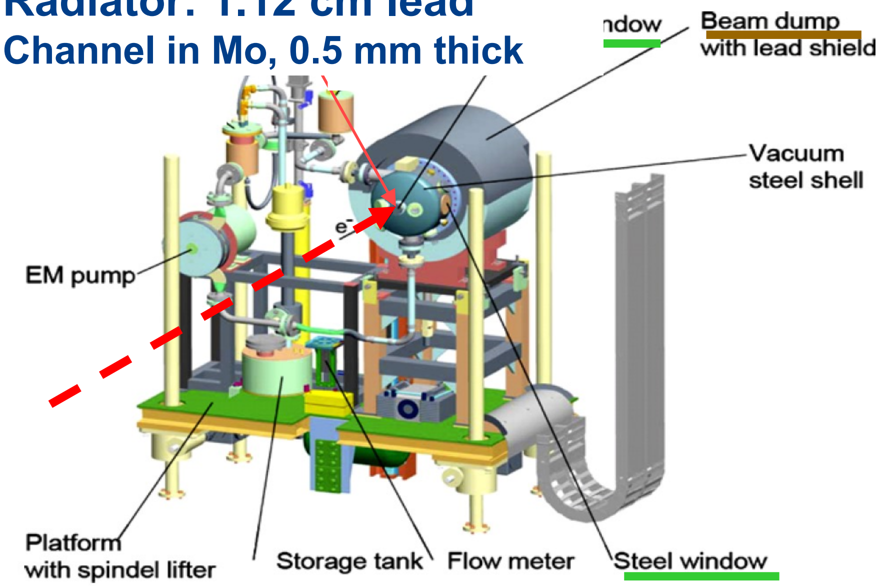
The time structure of the Bremsstrahlung radiation is defined by the electron beam which has to be operated in the micropulse mode.
The distance between the pulses can vary between 10 ps and 1000 ns.

Typical gamma rates:
up to **50 kHz**
on the detector surfaces

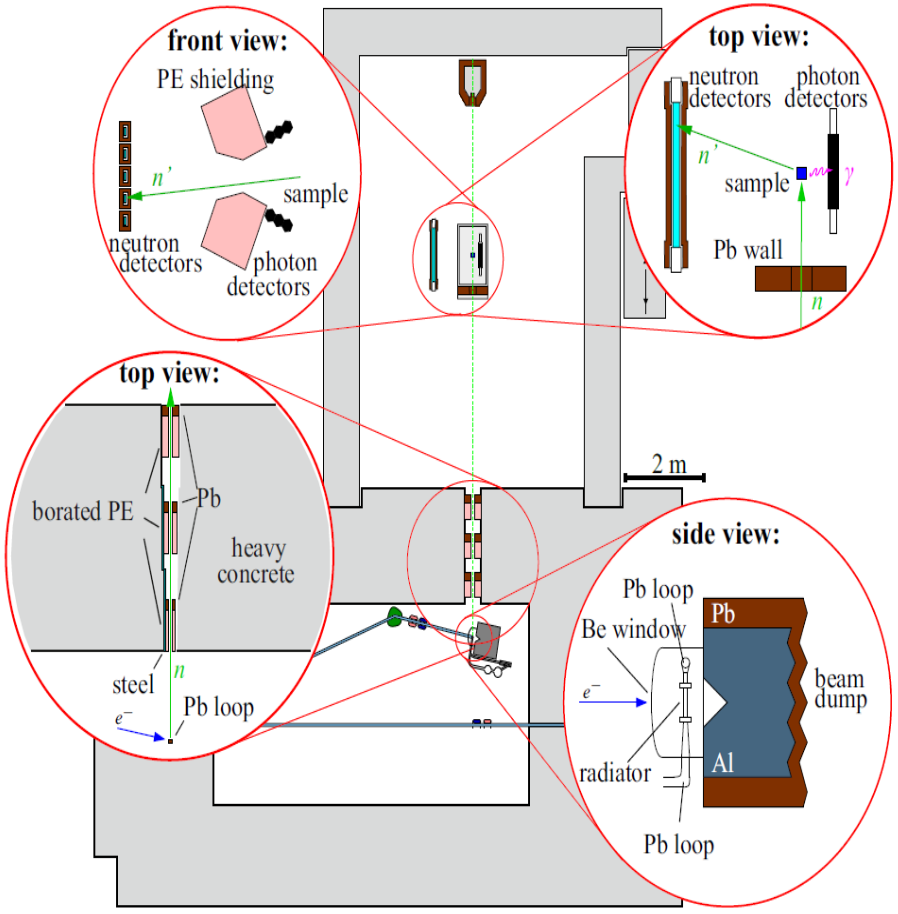
nELBE: the photo-neutron source

Radiator: 1.12 cm lead

Channel in Mo, 0.5 mm thick

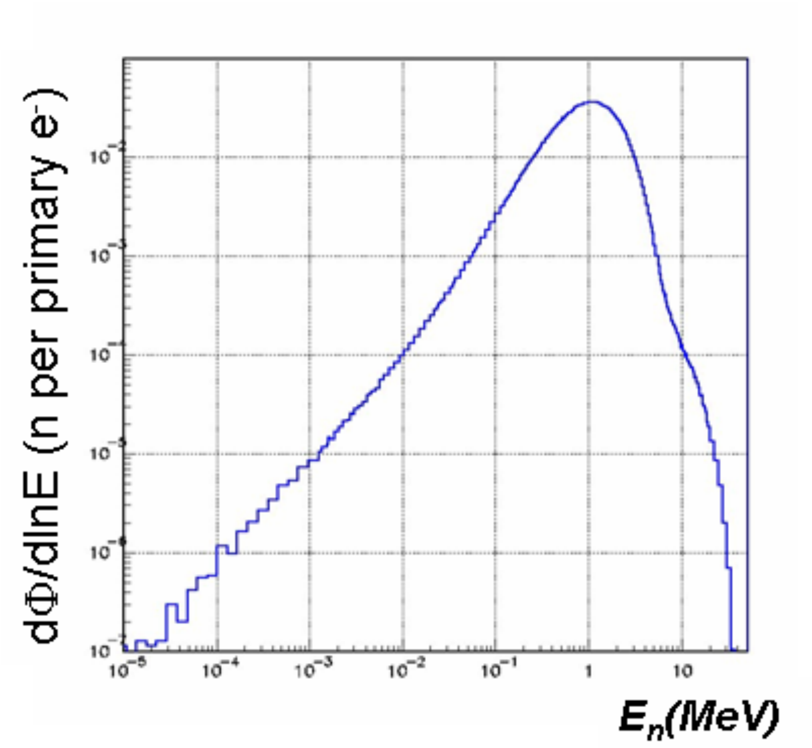


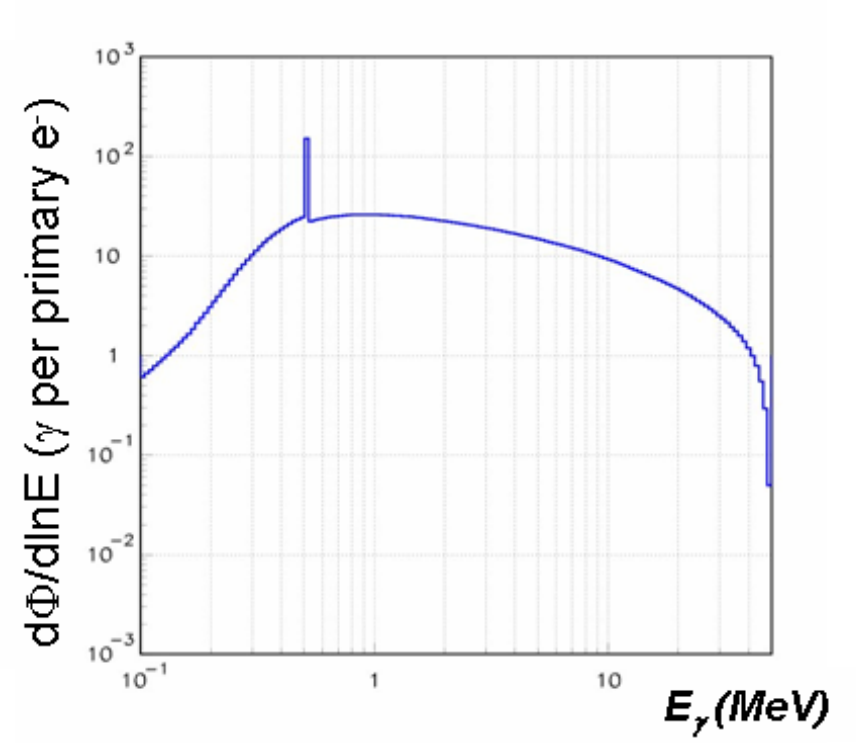
- Electron beam power up to **40 kW**
- Power density in the neutron radiator up to   **25 kW/cm^3**
- *Liquid lead circuit*   for heat transport



Floor plan of the new nELBE neutron source and low scattering experimental hall.

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	$3.108 \ 10^{-3}$	$1.94 \ 10^{13}$	4.14

Problem: γ/n yield ~ 10^3 !

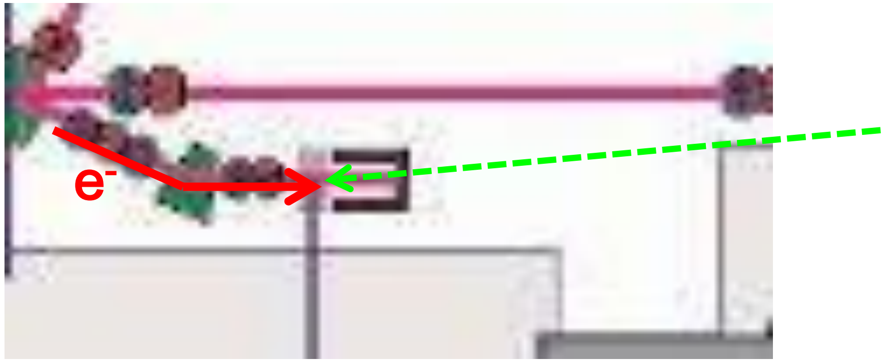
@ **1 m** , **100µA** e$^-$ current and 30 MeV e$^-$ energy:

1.54 10^7 n cm^{-2} s^{-1}

To accumulate $3 \cdot 10^{11}$ n/cm^2 only **~5.4 h** are needed

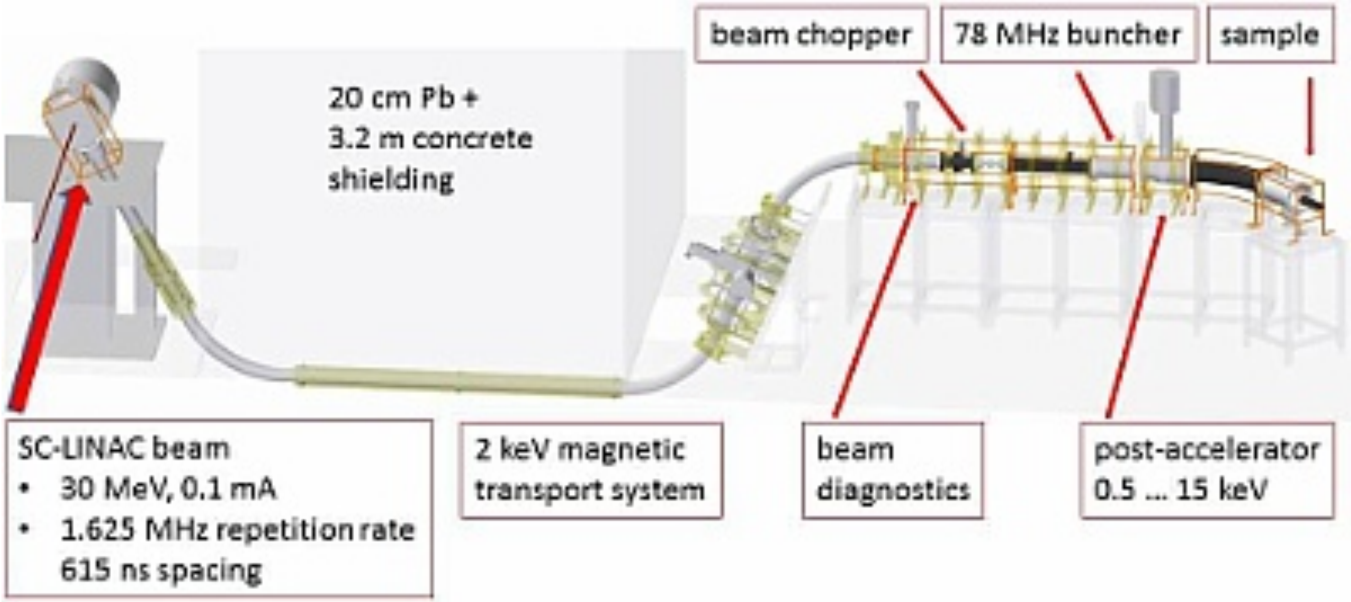
→ To suppress the gamma radiation a local Pb shielding can be used, without problematically losing neutron flux

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



Bremsstrahlung/photoneutron target: 1 cm W

positron extraction beamline



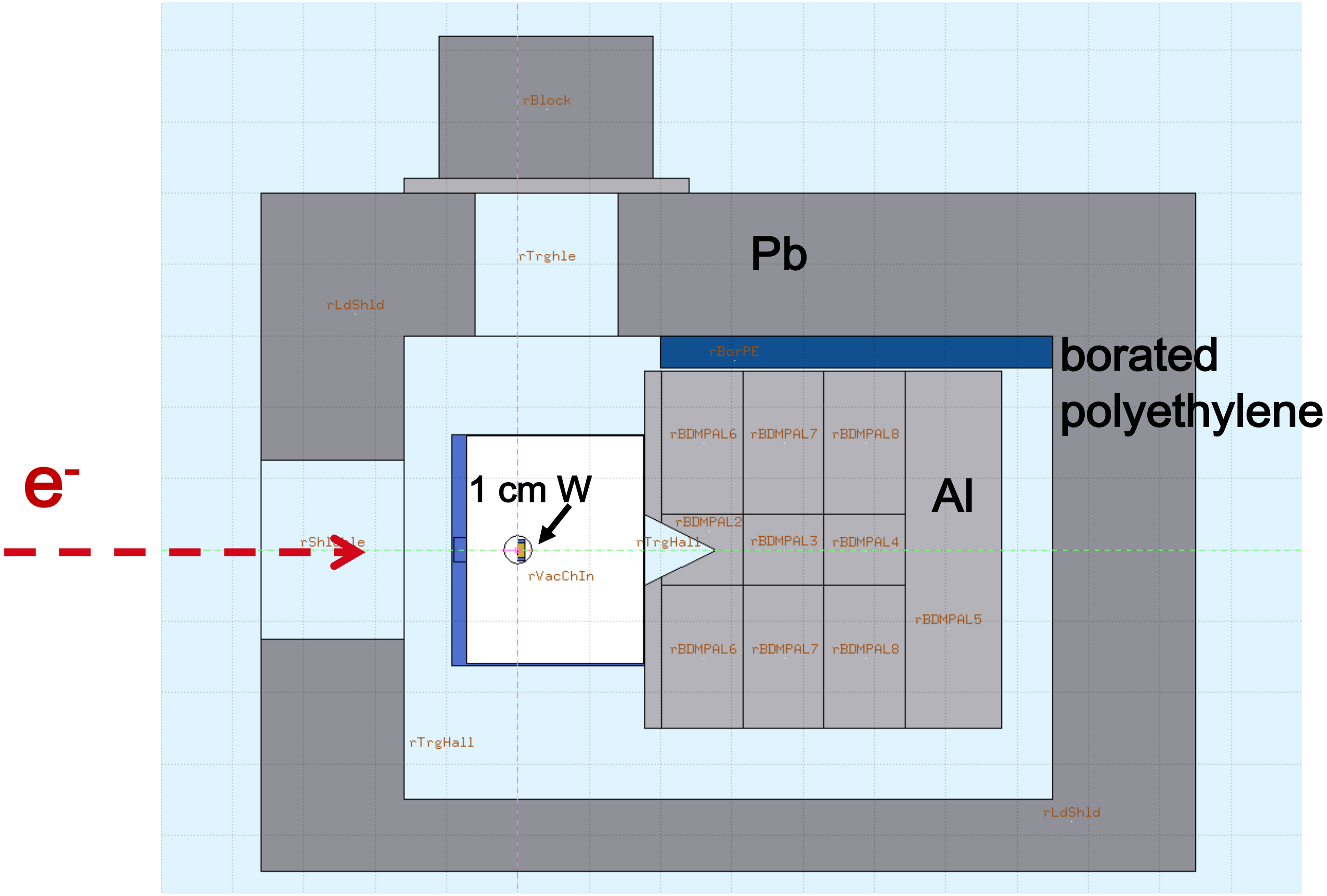
SC-LINAC beam
- 30 MeV, 0.1 mA
- 1.625 MHz repetition rate
615 ns spacing

2 keV magnetic transport system

beam diagnostics

post-accelerator 0.5 … 15 keV

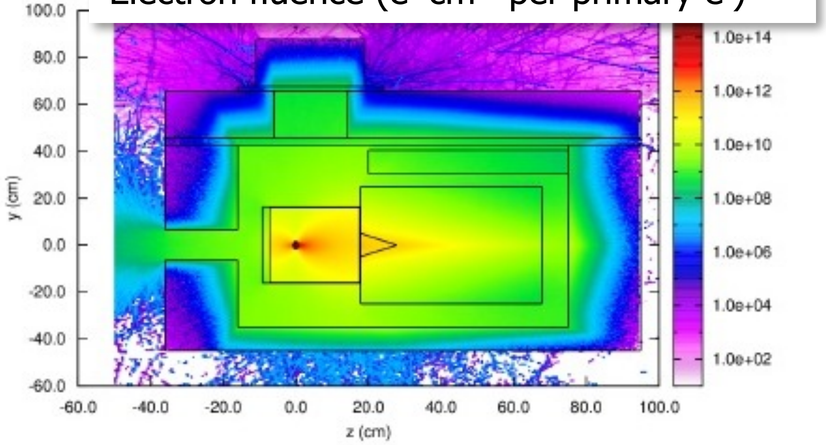
Geometry around the target



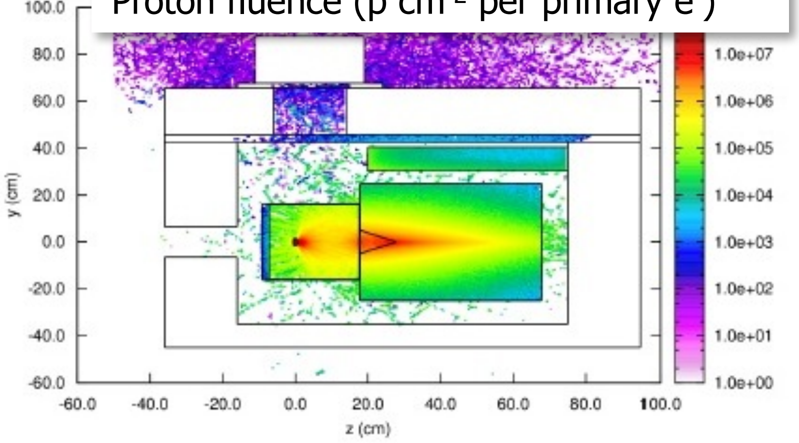
Radiation fields around the target: fluence rates

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

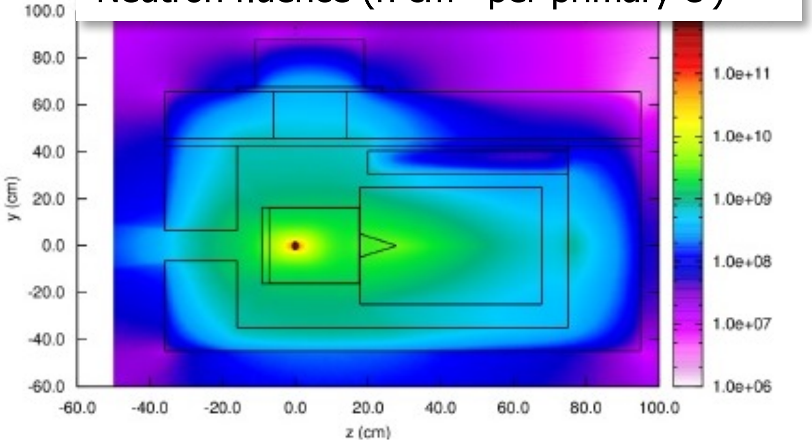
Total neutron yield coming from target: (2.83e-03 ±8.17e-07) neutrons/primary =(1.767e+12 ±3.979e+08) n/s @100µA



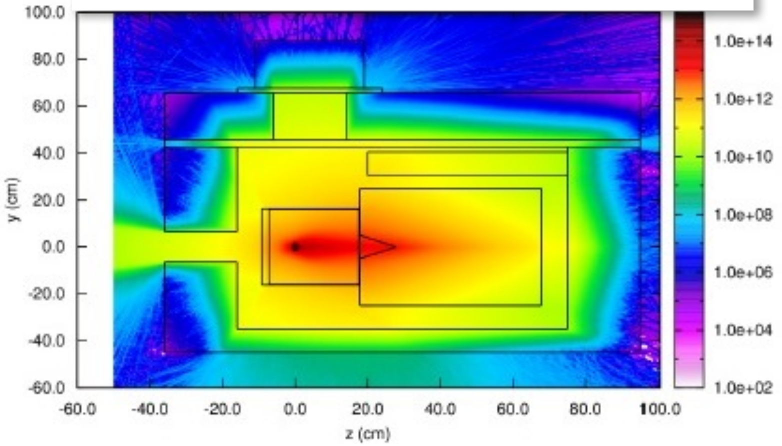
Electron fluence (e^- cm^{-2} per primary e^-)



Proton fluence (p cm^{-2} per primary e^-)



Neutron fluence (n cm^{-2} per primary e^-)

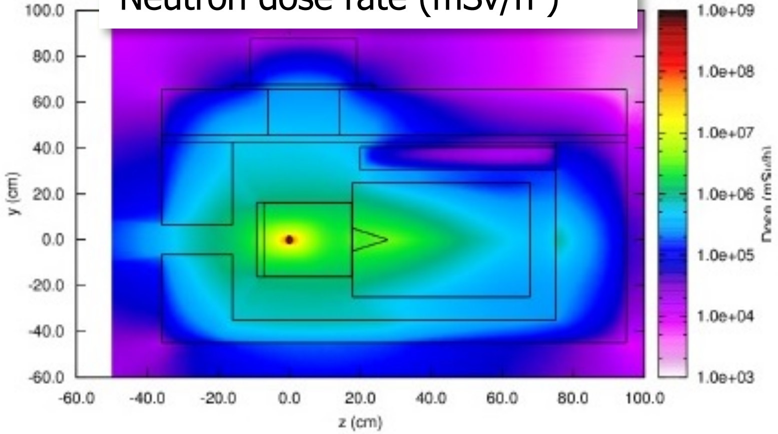


Photon fluence (γ cm^{-2} per primary e^-)

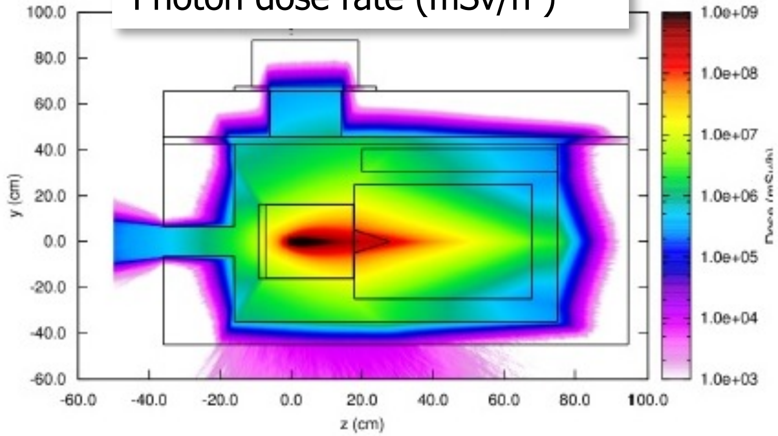
Radiation fields around the target: dose [H(10)] rates*

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

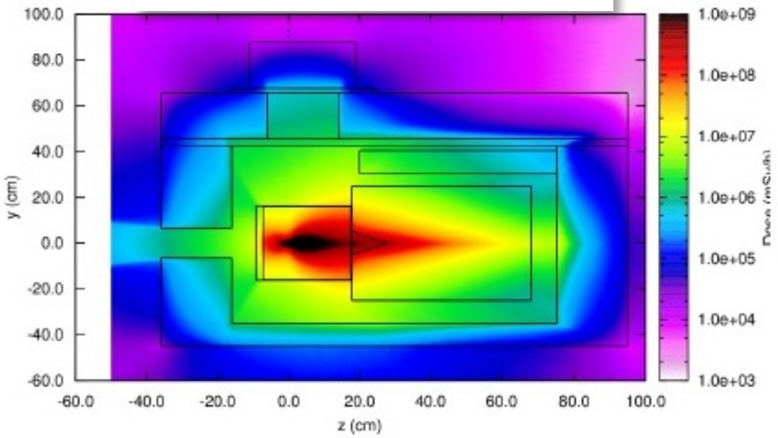
Total neutron yield coming from target: (2.83e-03 ±8.17e-07) neutrons/primary =(1.767e+12 ±3.979e+08) n/s @100µA



Neutron dose rate (mSv/h)

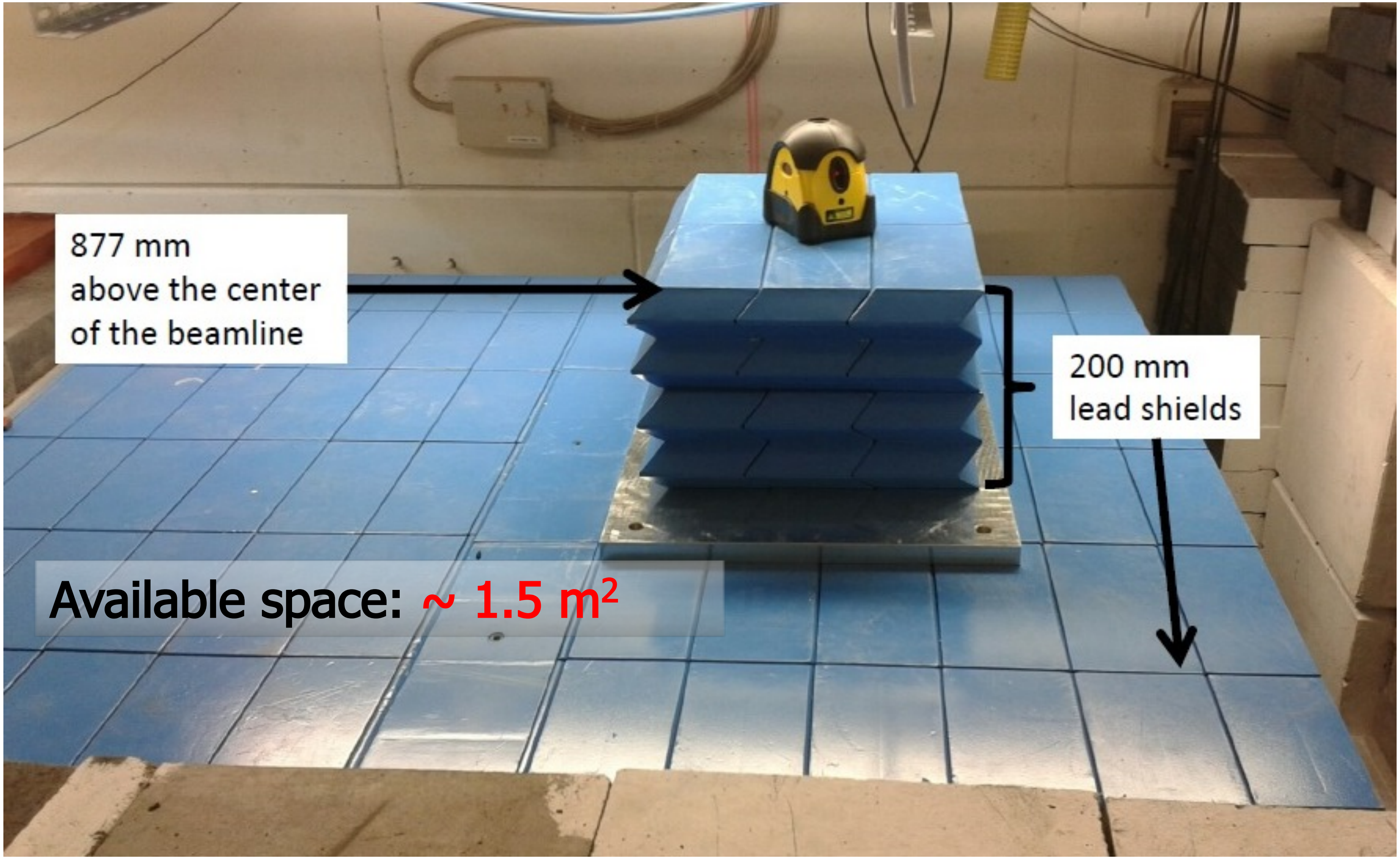


Photon dose rate (mSv/h)



Total dose rate (mSv/h)

Irradiation position

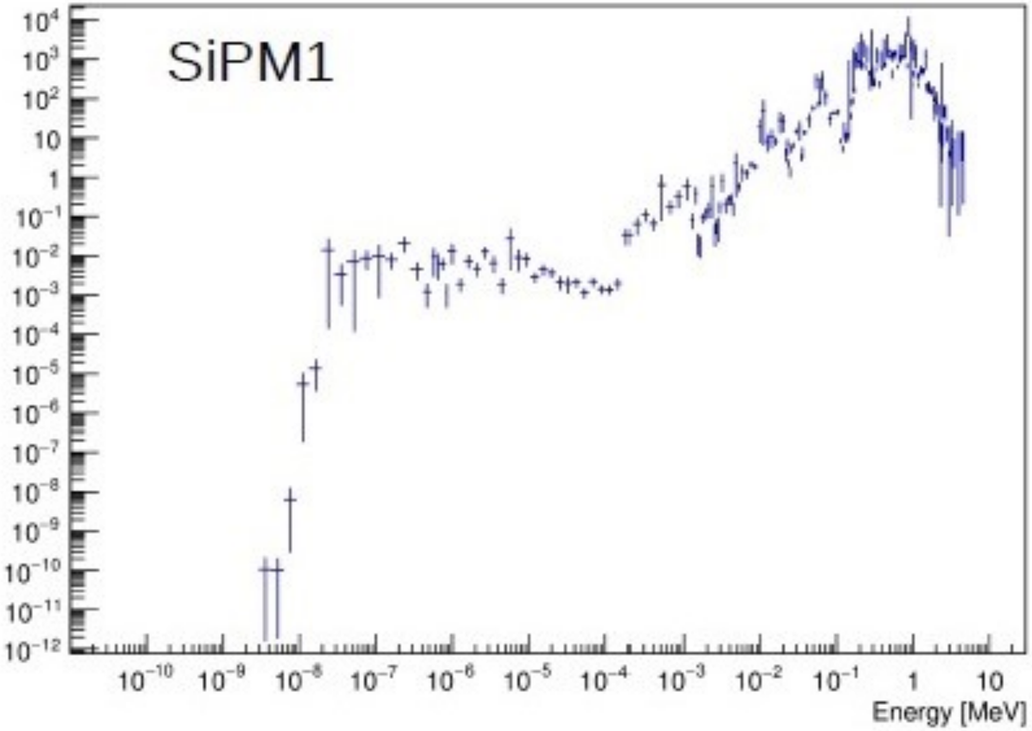


877 mm
above the center
of the beamline

200 mm
lead shields

Available space: ~ 1.5 m^2

1 MeV-equivalent neutron spectra at the irradiation position

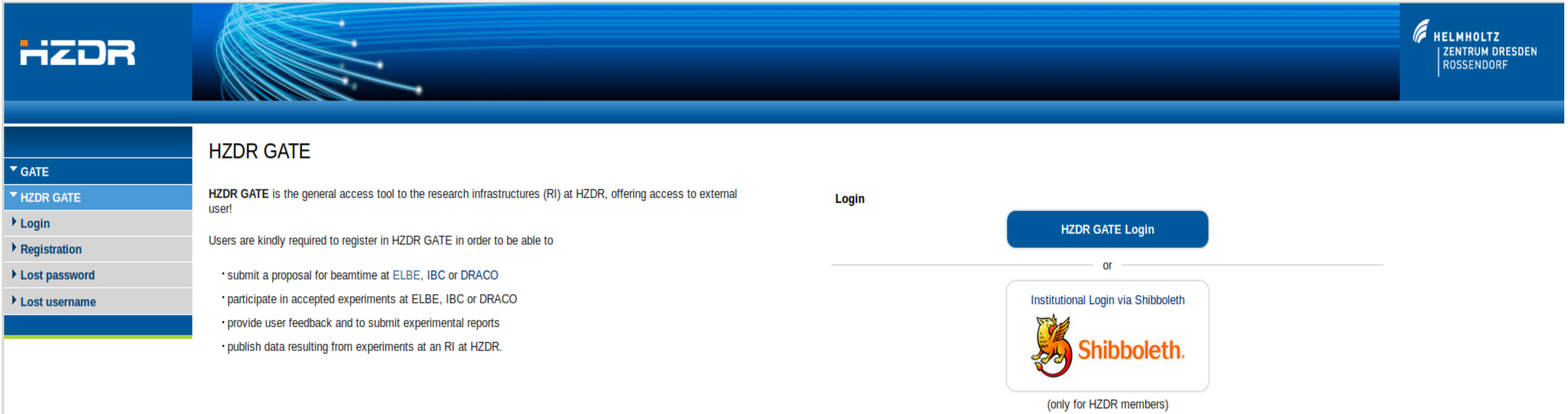


Total 1 MeV-equiv. neutron fluence at 1 µA electron beam: ~ 8 10^{4} n cm^{-2} s^{-1}

@ 200 µA electron beam: ~ 1.6 10^{7} n cm^{-2} s^{-1} ⇨ **in 72 hours: ~ 4.15 10^{12} n cm^{-2}**

Planning the irradiation tests: how to apply

Ask dedicated beamtime via the HZDR GATE page:
https://gate.hzdr.de/cgi-bin/gate



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.

2 documents to be prepared:

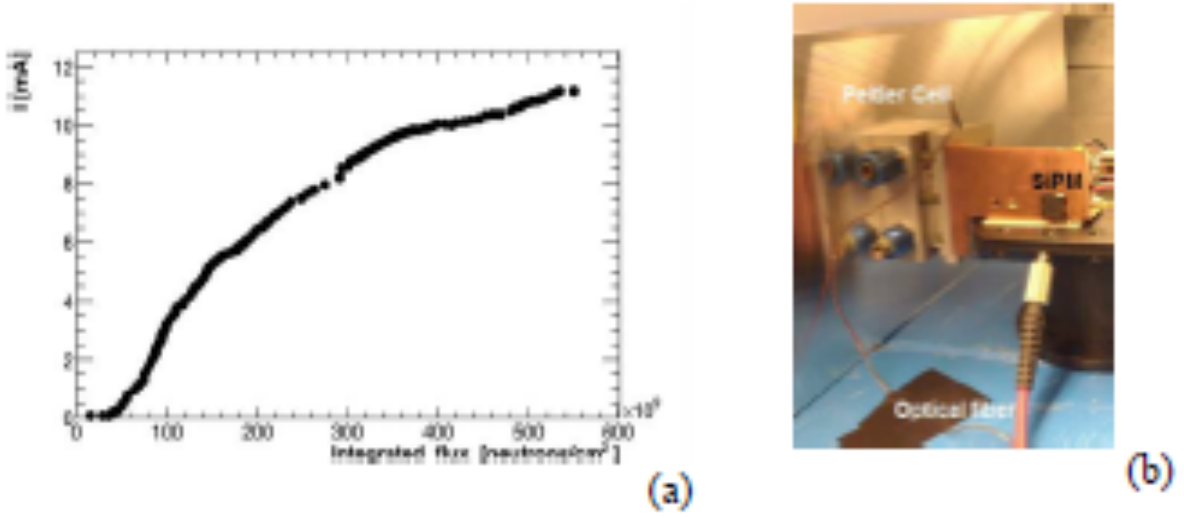
- Scientific case (2 pages)
- Experimental plan (1 page)

Next deadline: April 15, 2017
for the beamtime period 1 Jul 2017 – End 2017

Success story in 2016 (1)

One irradiation period in parasitic way
in April 2016

Figure 1: (a) Leakage current vs integrated 1 MeV-equivalent neutron fluence, obtained at EPOS during the April 2016 parasitic run. The accumulated statistics corresponds to 6 years Mu2e operation
(b) Photosensor position at the measurement place, at the top of the EPOS shielding cage.



(a)

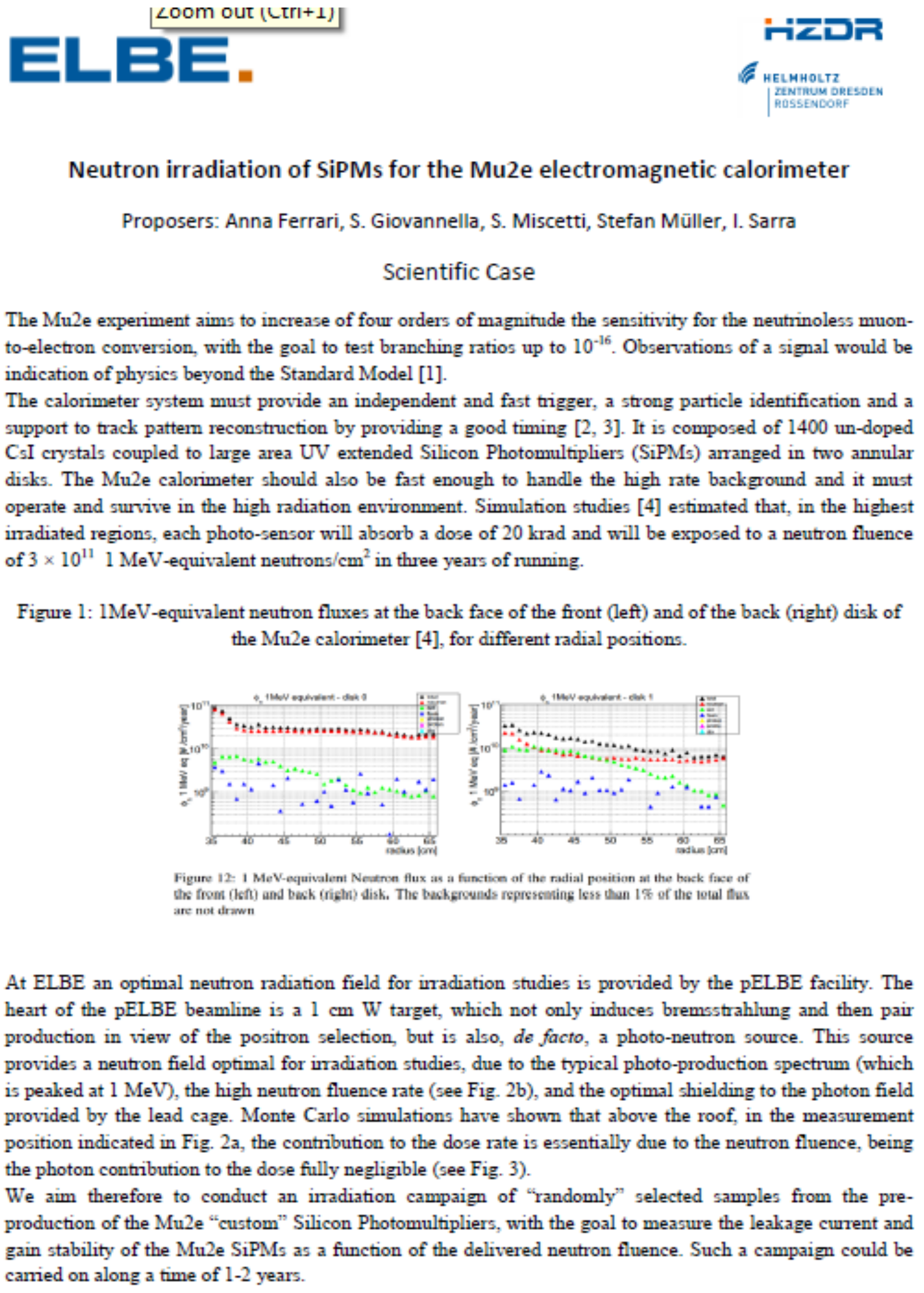
(b)

Success story in 2016 (2)

Successfull submission
in November 2016!

Next irradiation time:

8-10 March 2017
(72 hours irradiation)



Neutron irradiation of SiPMs for the Mu2e electromagnetic calorimeter

Proposers: Anna Ferrari, S. Giovannella, S. Miscetti, Stefan Müller, I. Sarra

Scientific Case

The Mu2e experiment aims to increase of four orders of magnitude the sensitivity for the neutrinoless muon-to-electron conversion, with the goal to test branching ratios up to 10^{-16}. Observations of a signal would be indication of physics beyond the Standard Model [1].

The calorimeter system must provide an independent and fast trigger, a strong particle identification and a support to track pattern reconstruction by providing a good timing [2, 3]. It is composed of 1400 un-doped CsI crystals coupled to large area UV extended Silicon Photomultipliers (SiPMs) arranged in two annular disks. The Mu2e calorimeter should also be fast enough to handle the high rate background and it must operate and survive in the high radiation environment. Simulation studies [4] estimated that, in the highest irradiated regions, each photo-sensor will absorb a dose of 20 krad and will be exposed to a neutron fluence of 3×10^{11} 1 MeV-equivalent neutrons/cm^2 in three years of running.

Figure 1: 1MeV-equivalent neutron fluxes at the back face of the front (left) and of the back (right) disk of the Mu2e calorimeter [4], for different radial positions.

Figure 12: 1 MeV-equivalent Neutron flux as a function of the radial position at the back face of the front (left) and back (right) disk. The backgrounds representing less than 1% of the total flux are not drawn

At ELBE an optimal neutron radiation field for irradiation studies is provided by the pELBE facility. The heart of the pELBE beamline is a 1 cm W target, which not only induces bremsstrahlung and then pair production in view of the positron selection, but is also, *de facto*, a photo-neutron source. This source provides a neutron field optimal for irradiation studies, due to the typical photo-production spectrum (which is peaked at 1 MeV), the high neutron fluence rate (see Fig. 2b), and the optimal shielding to the photon field provided by the lead cage. Monte Carlo simulations have shown that above the roof, in the measurement position indicated in Fig. 2a, the contribution to the dose rate is essentially due to the neutron fluence, being the photon contribution to the dose fully negligible (see Fig. 3).

We aim therefore to conduct an irradiation campaign of "randomly" selected samples from the pre-production of the Mu2e "custom" Silicon Photomultipliers, with the goal to measure the leakage current and gain stability of the Mu2e SiPMs as a function of the delivered neutron fluence. Such a campaign could be carried on along a time of 1-2 years.

Proposals….

- Possibility to use the next neutron irradiation beamtime dedicated to SiPM (8-10 March 2017)
  for other **radiation damage studies**

- Possibility to expose detectors at the gELBE beam in parasitic way end of March 2017

- **Prepare the next beamtime request by April 15,**
  for irradiations during the second semester 2017