The ELBE high power radiation source

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HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

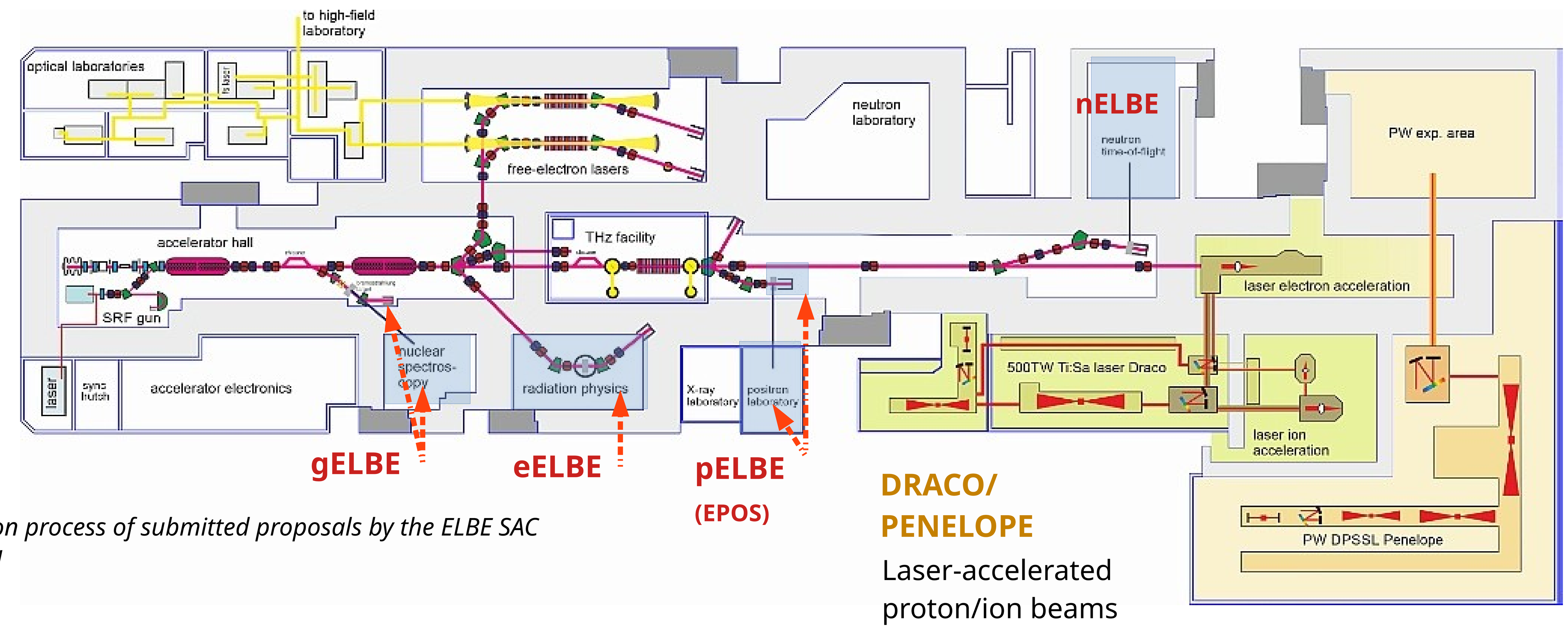
SATIF-16 May 28-31, 2024 Shielding aspects of Accelerators, Targets and Irradiation Facilities

The ELBE accelerator complex

ELBE ("*Electron Linac for high Brilliance and low Emittance*") is based on a superconducting linear accelerator, which accelerates electrons to energies in the interval **[5, 40] MeV** at a beam current of up to **1 mA**

Guiding the electron beam on suitable targets allows the production of secondary radiation:
- in addition to **electrons**, intense **photon, positron and neutron beams** are available to the users in dedicated caves
- a unique feature: **pulsed beams**, with a pulse width between 10 ps and 1 µs, a repetition rate of 26 MHz/2^n (n=1,…,7) and a charge load up to ~77 pC/pulse.

The time structure of the electron beam is directly transferred to the secondary radiation.



Beam time for the ELBE facility is allocated following a selection process of submitted proposals by the ELBE SAC
Calls for proposals are issued twice per year, in spring and fall
At DRACO/PENELOPE proposals can be submitted any time.

Electron, positron and photon sources

eELBE

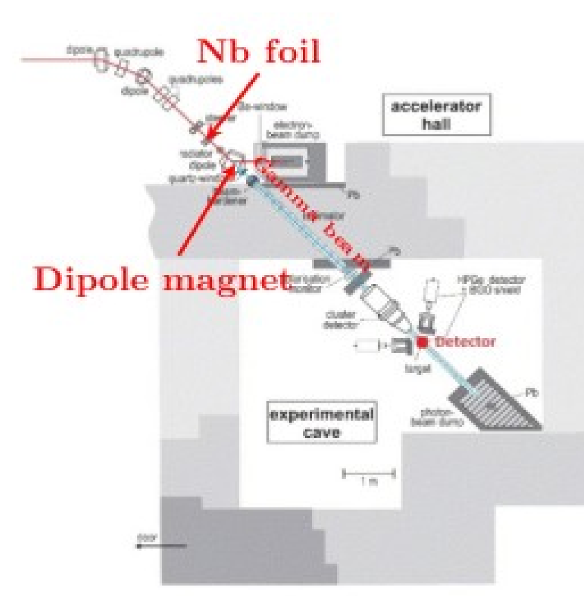
The direct electron beam of the ELBE accelerator may be coupled out to air through a thin beryllium exit window and then used for tests of detector systems or electronics.

The ELBE accelerator provides a unique combination of variability in time structure, intensity and applicable electron number.

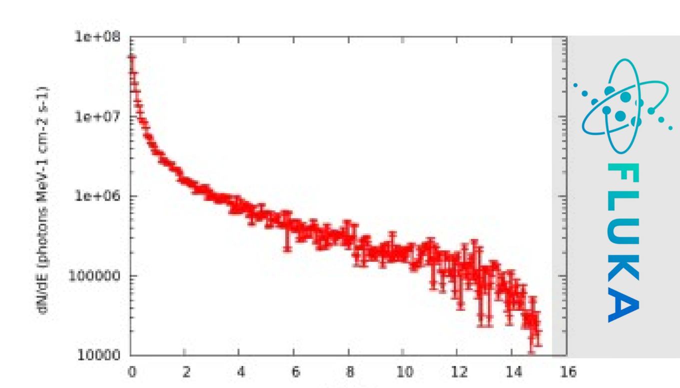
Three operation modes of the ELBE accelerator can be used:

- ***General mode***: electron bunches of high repetition rate (usual 13 MHz) deliver a continuous wave (cw) beam
- ***Single-pulse mode***: delivery of single electron bunches or bunch trains (macropulses). The bunch train can be defined by number of bunches (1 – 1.3 10^7) or train duration (0.1 – 36 ms).
- ***Single-electron-mode***: single electron bunches with time structure according to single-pulse mode, but with only one or just a few electrons in one bunch.

gELBE



Photon spectrum for a 15 MeV e- beam, using the thickest Nb target (12.4 µm)

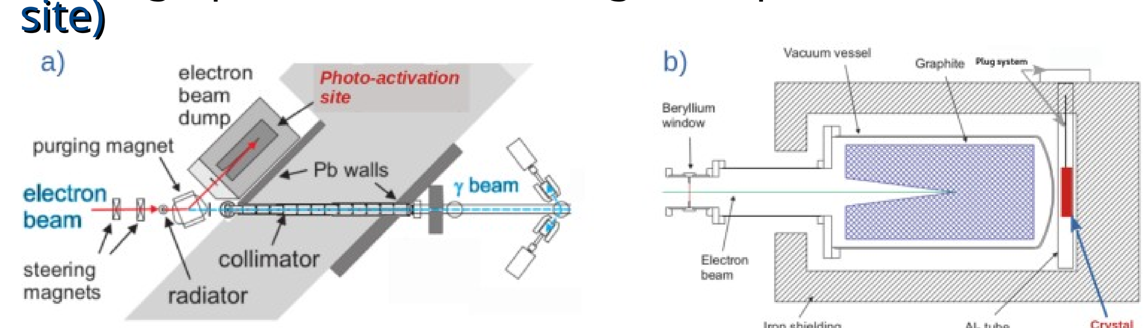


Corresponding photon flux:

~ 2.5 × 10^7 γ cm^{-2} s^{-1} per 1 µA of e^- beam current


Typical detector setup along the gELBE beamlin (left) and high.photon rate area (right)

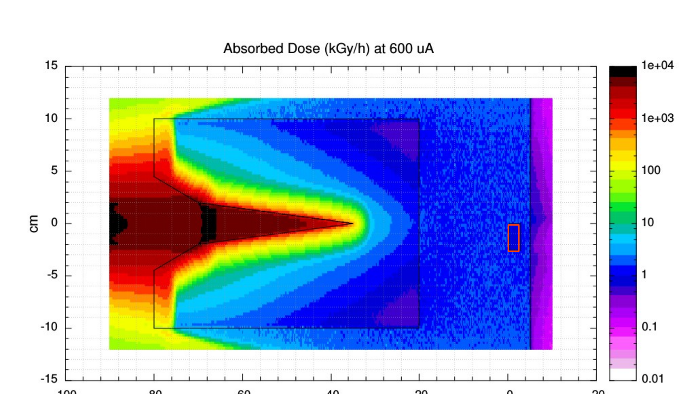
The high photon flux area at gELBE (photo-activation site)



Photon yield:

between **5·10^{-5}** and **2·10^{-4} photons cm^{-2} per primary e^-**

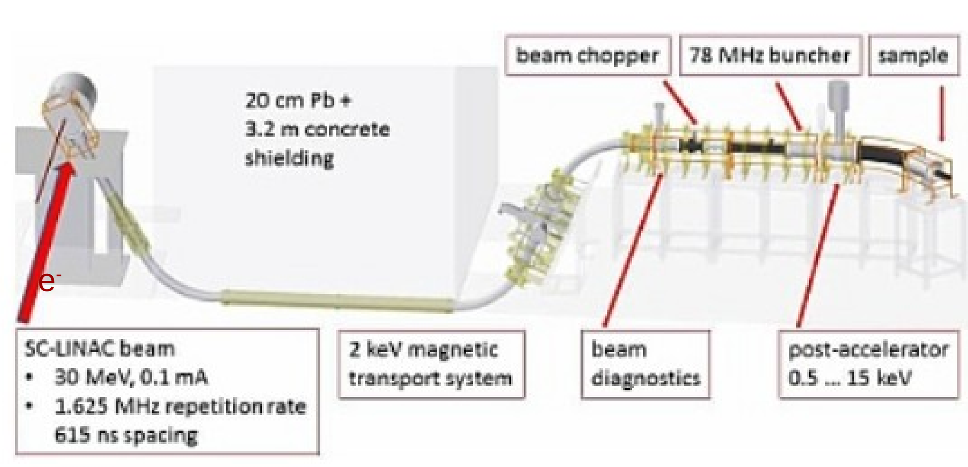
~ **1 - 2** order of magnitude more than the direct gELBE beamline



FLUKA simulation of the absorbed dose in a sample of LaBr and surrounding area at the irradiation point

pELBE

ELBE electron beam hits a 1 cm thick water-cooled W target and produces **positrons** through Bremsstrahlung and following pair production. Positrons are transported in a dedicated area for positron annihilation spectroscopy studies



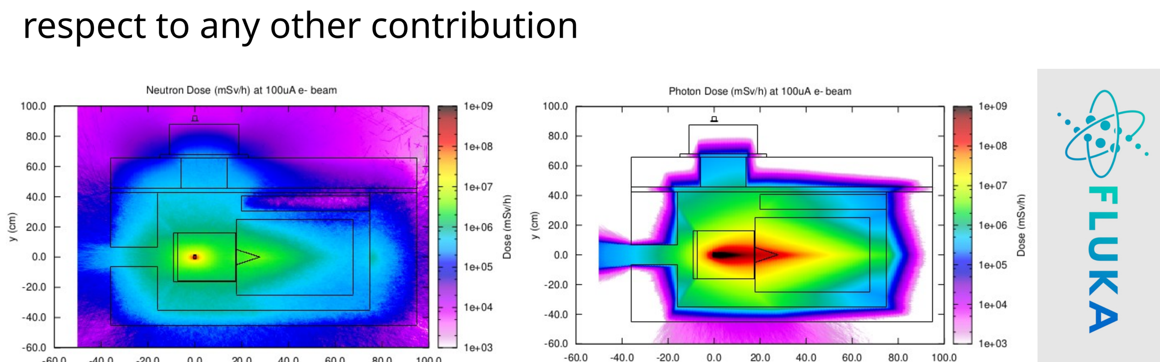
In the tungsten target, the electron beam induces **neutron photo-production**, allowing the definition of an optimal neutron irradiation area

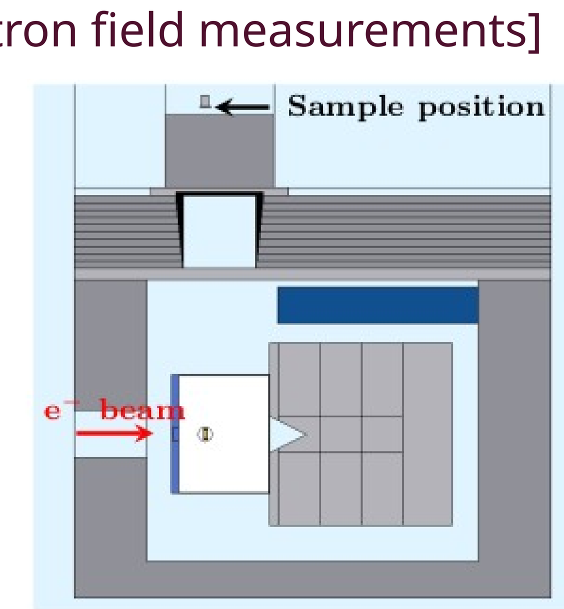
Neutron sources / Non conventional, laser-generated proton and ion sources

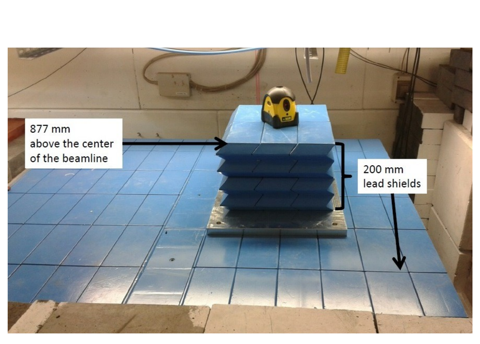
EPOS along the nELBE beamline

[see F. Chiarelli presentation for neutron field measurements]

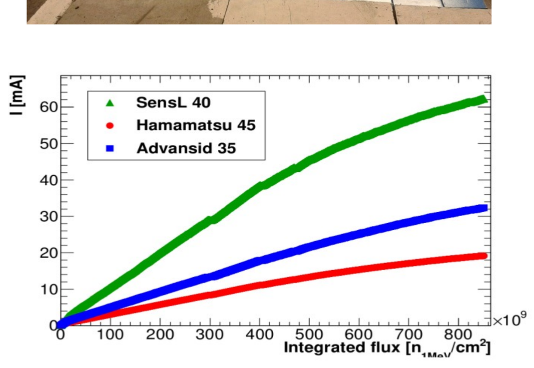
At the measurement position **neutron dose** is completely dominant respect to any other contribution







Parasitic irradiations in conjunction with positron physics beamtimes have been carried out routinely



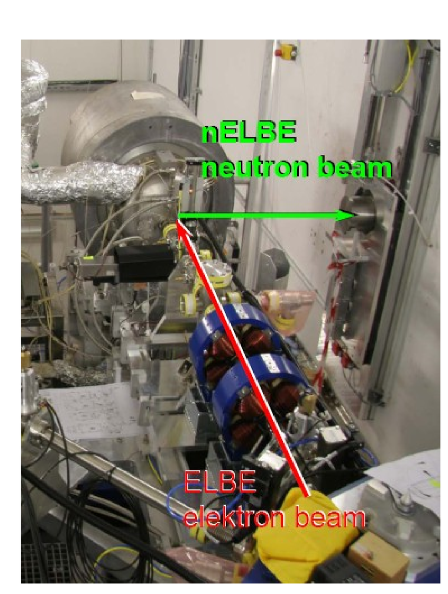
Dark current of the SiPM cells from three vendors as a function of the integrated neutron flux

Total delivered fluence:
> 10^{12} n_{1MeV}/cm^2
(irradiation time: 2 days)

nELBE

nELBE neutron beam is produced via (gamma,n) reaction on liquid lead target

Neutron flux:
~ 5 × 10^7 n cm^{-2} s^{-1}



The **Liquid lead target** (up) and (down) the the 6m x 6m x 9m **Time-of-flight hall**

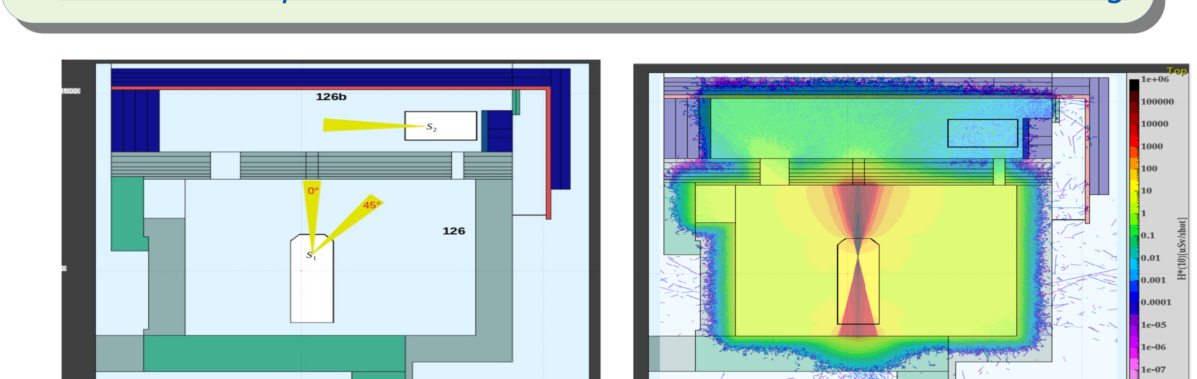
HI Laser-generated protons and ions: DRACO and PENELOPE

With DRACO (DResden laser ACceleration sOurce) and the PENELOPE PW laser, HZDR operates state-of-the-art, high-power ultra-short pulse laser systems, dedicated and optimized the first for the investigation of relativistic laser plasma physics, and the second for medical applications.

High intensity, high power laser (from 150 TW up to 1 PW) are able to deliver protons up to (routinely) ~ 100 MeV
Goal. 200-250 MeV for medical applications

Typical currents: up to **50-60 nC/laser shot** Rep. rate goal: ~ 1Hz

*Need of **Dosimetry experiments** to fully characterize the radiation environment:*
In addition to proton and, ions, associated intense bremsstrahlung



The new Athena area, for biological sample irradiation at high dose/high rates