Laser Compton Backscattering Source for Beam Diagnostics at the S-DALINAC*

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*Supported in part through the state of Hesse (LOEWE research cluster Nuclear Photonics), and DFG through GRK 2128 *AccelencE*

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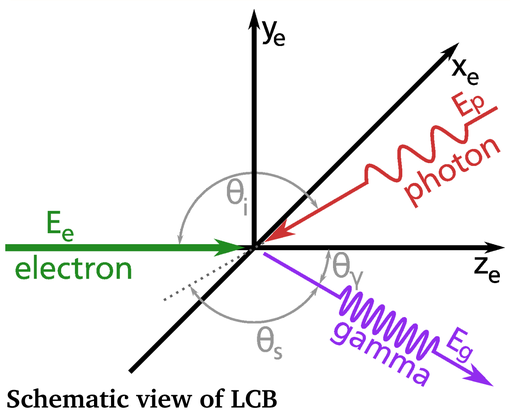
Overview

The Superconducting Darmstadt electron Linear Accelerator S-DALINAC is a thrice recirculation linear accelerator [1] providing electron beams with energies up to 130 MeV and beam currents up to 20 μA for a variety of nuclear physics experiments [2]. It has been operated as Germany's first Energy Recovery LINAC (ERL) in 2017 [3]. The electron beam is produced either in a thermionic gun or a DC photo-gun using GaAs as cathode material [4]. A new project foresees to use the S-DALINAC for Laser Compton Backscattering (LCB) to produce a brilliant quasi-monochromatic high-energy photon beam for nuclear photonics applications in photonuclear reactions and for beam diagnostics.

Compton Backscattering

Scatterd photon energy

$$E_g = \frac{(1 - \beta\cos(\Theta_i))E_p}{(1 - \beta\cos(\Theta_\gamma)) + (1 - \cos(\Theta_s))(E_p/E_e)}$$



Schematic view of LCB

Head On:

$$E_g^{max} = \frac{4\gamma^2 E_p}{1 + 4\gamma^2(E_p/E_e)}$$

$$\gamma = E_e/(m_e c^2)$$

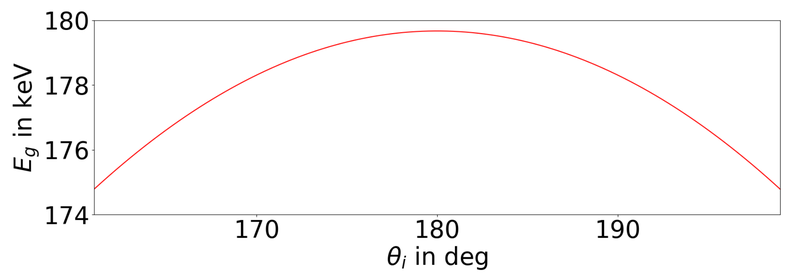
$$E_g \approx 4\gamma^2 E_p$$

Luminosity

$$L = \frac{B f N_e N_L \cos(\varphi/2)}{2\pi\sqrt{\sigma_{e,y}^2 + \sigma_{L,y}^2}\sqrt{(\sigma_{e,x}^2 + \sigma_{L,x}^2)\cos^2(\varphi/2) + (\sigma_{e,z}^2 + \sigma_{L,z}^2)\sin^2(\varphi/2)}}$$

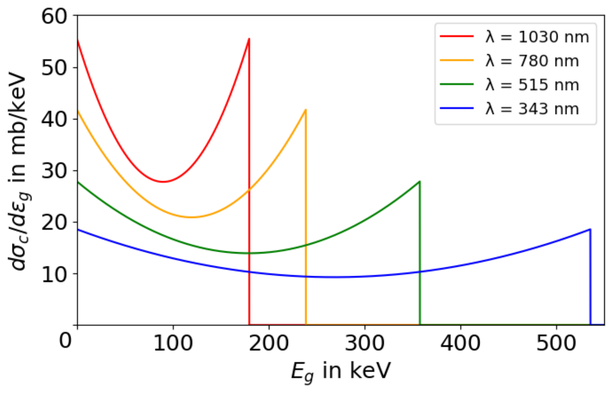
$$\varphi = \Theta_i - \pi$$

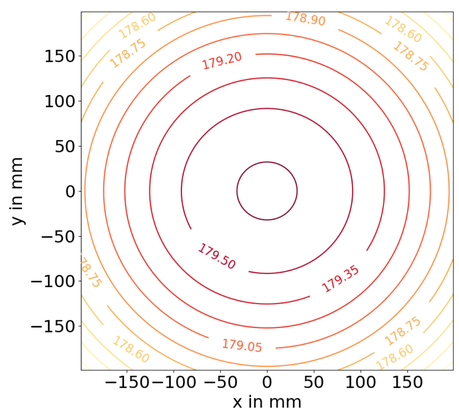
Flux $F = \sigma_c L$



y energy of inverse Compton scattering for 1.2 eV incident photons over the angle between laser and electron beam at 98.8 MeV.

Energy-differential cross section of inverse Compton scattering with 98.9 MeV electrons and four different laser wavelengths (1030 nm: 1.2 eV, 780 nm: 1.6 eV, 515 nm: 2.4 eV, 343 nm: 3.6 eV).





Scattered photon energy angle distribution on an observation plane, 10 m away from the interaction point. Photon energies are given in keV for E_p = 1.2 eV and E_e = 98.8 eV.

[1] M. Arnold, Dissertation, TU Darmstadt (2017).
[2] N. Pietralla, Nucl. Phys. News 28(2), 4 (2018).
[3] K. Sonnabend, Physik Journal 10, 7 (2017).
[4] Y. Poltoratska et al., J. Phys.: Conf. Series 298, 012002 (2011).
[5] A. Tsunemi et al., Proc. PAC 99(4), 2552 (1999).

Scientific Goals

- **Accelerator physics development** in the field of artificial γ-sources of fourth generation
  - Compton backscattering on a relativistic, high repetition electron beam produced by a superconducting linear accelerator with ERL mode
- **Non-destructive beam diagnostics** of the S-DALINAC to measure energy, energy bandwidth and emittance

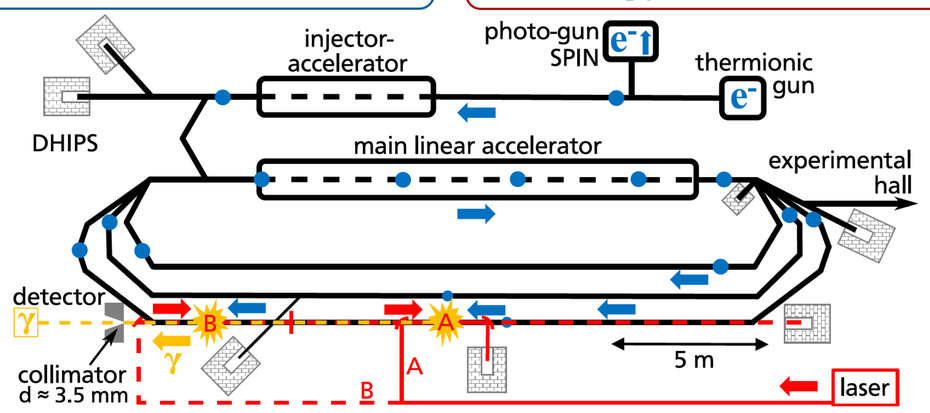
S-DALINAC & Laser Compton Backscattering

39MeV - 98,8 MeV & 10 µA(~3 fC) @3 GHz

Reconstruction for lower limit: 15 MeV

1.2 eV (1030 nm) & 10 mJ Puls Energy @10 kHz (100 W)

Power upgrade (Phase 2): ≤ 500 W



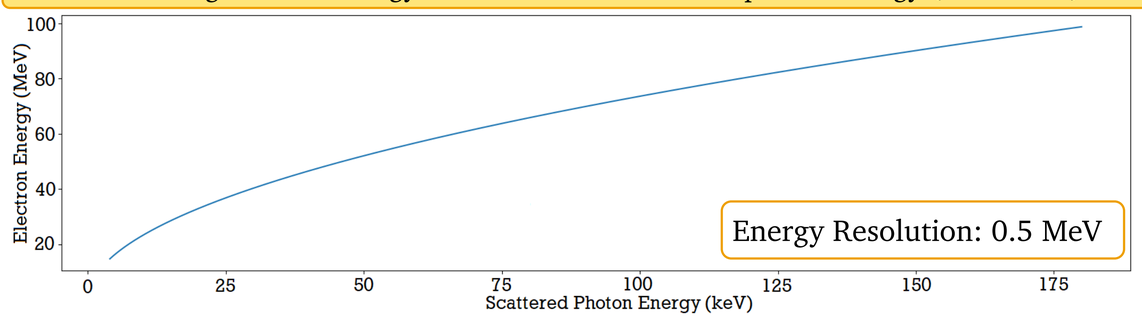
Up to 17 photons/s @28keV (4.15 keV) - 179.7 keV, $\Delta E/E < 0.01$,

Upgrade (Phase 1): bunch charge (< 350 fC) & beam sizes (> 50 μm): < 7000 photons/s

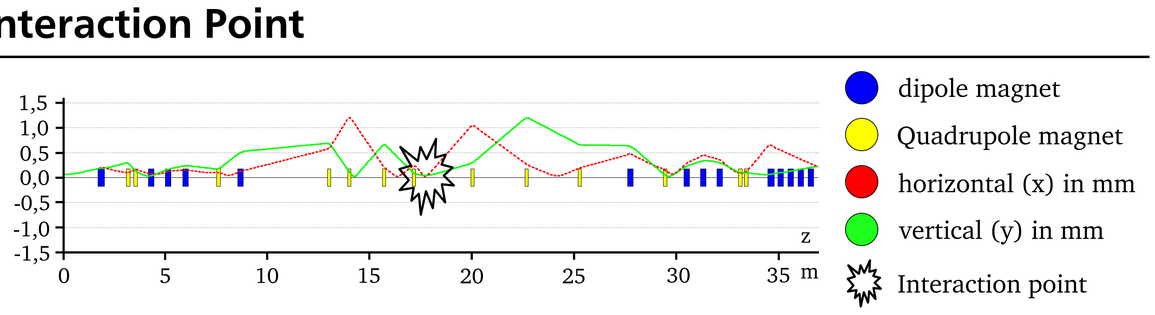
Upgrade (phase 2): < 35000 photons/s

Schematic view of the S-DALINAC [2] with the LCB setup. The 3 GHz pulsed electron beam collides with laser pulses at the center of the third recirculation. The boosted photons will be detected behind the dipole magnet.

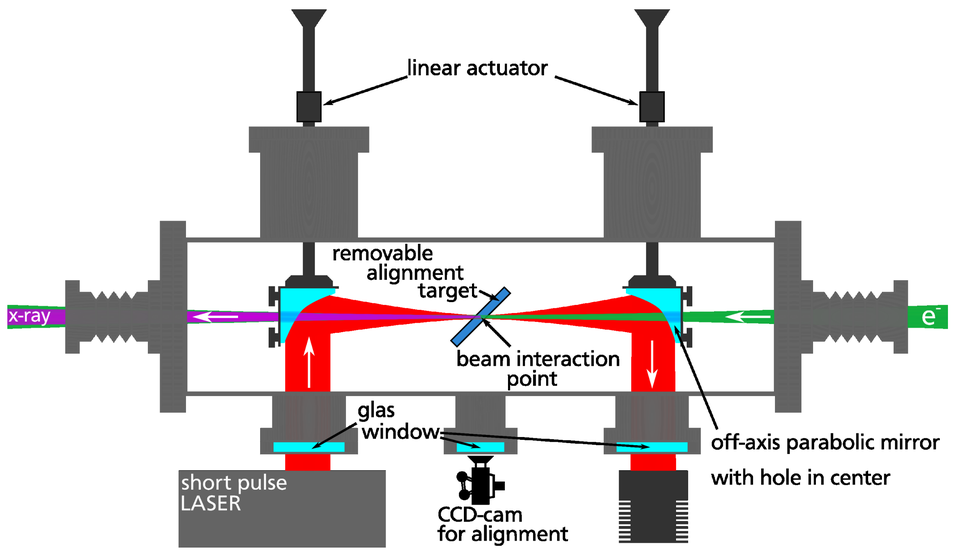
Beam diagonostics: energy of electron over scattered photon energy (simulation)



Interaction Point



Preliminary electron beam simulation at interaction point. Beam envelope (1σ) simulation at third recirculation. Beam foucs at interaction point.



Preliminary design of the chamber located at the interaction point in the third recirculation. Concept adapted from [5].