Standalone MC

Technical note status

TN: AXIS CONVENTIONS

CDR

2.9.5 Compton Beam Profiles

Besides the energy spectra of the non-linear Compton photons discussed above, also their angular distribution contains valuable information. A measurement of these Compton beam profiles open an additional possibility to infer the value of ξ in the non-linear Compton interaction [190–192].

Due to relativistic beaming effects, the Compton γ ray photons are emitted in a narrow cone around the initial electron beam direction. If the laser is linearly polarised, then the rms emission angle parallel and perpendicular to the laser polarisation scales as $\theta_{\parallel} \sim \xi/\gamma$ and $\theta_{\perp} \sim 1/\gamma$, respectively, for $\xi > 1$. With 16.5 GeV electrons, the typical gamma beam size at a position 10 m downstream the IP is thus approximately $\sim 300\mu$m in one direction and $(1 \ldots \xi) \times 0.3$ mm in the other. For the intensity parameters that will be probed at LUXE, the gamma beam width will therefore vary between 300 μm and 5 mm. A specialised detector (Gamma Profiler) is envisaged for measuring the transverse beam profiles, see Sec. 8.4.7.

The expected beam spatial distributions in the directions perpendicular to the beam direction (z): x (parallel to the laser beam polarisation axis) and y (perpendicular to the laser beam polarisation axis), have been simulated using FLUKA. The simulation shows that most of the profile is contained in a 2×2 cm^2 square, although there are long tails. In the case of the beam profiler placed just out of the vacuum pipe, at about 6 m from the interaction point, the central high-energy component of the gamma beam can be approximated with a Gaussian having standard deviations $\sigma_x = \max(1, \xi) \times 180\ \mu$m for $\xi > 1$, $\sigma_y = 180\ \mu$m (see also Sec. 2.9.5). For instance, for $\xi = 5$, $\sigma_x = 900\ \mu$m while for $\xi < 1$ the spot size remains $\sigma_x = 180\ \mu$m. By measuring σ_x with a precision of 5 μm the ξ-value can be determined with a precision better than 1% for $\xi \gtrsim 2$, exceeding the precision expected for the laser diagnostic of 5%. The total intensity per bunch crossing (BX) of the gamma beam is

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3 System Overview

The LUXE beam profiler must operate in a stable and reliable way in presence of a very intense high energy gamma ray flux. The typical photon energy is of the order of GeV, and in the following it will be assumed that electron-positron pair production in the detector is the dominant process. In the following, we will adhere to the axis convention adopted in LUXE, where z represents the main beam propagation axis, and the x and y the axes perpendicular and parallel to the laser polarisation, respectively. The expected beam spatial distributions, have been simulated using FLUKA. The geometry implemented in the FLUKA simulation is shown in Fig. 2. Two x and y planes are placed 2 cm distance from each other at 11.5 m downstream of the LUXE interaction point (IP).

4 Expected performance

The proposal is to build a LUXE beam profiler station with two sapphire strip detectors of 2×2 cm^2 area, thickness 100 μm, strip pitch 100 μm, placed at about two cm distance along the beam direction, with the y-strip detector upstream and the x-strip detector downstream. The first upstream detector will be at 11.5 m from the IP.

No consistency between x,y-axis nomenclature in the TN!

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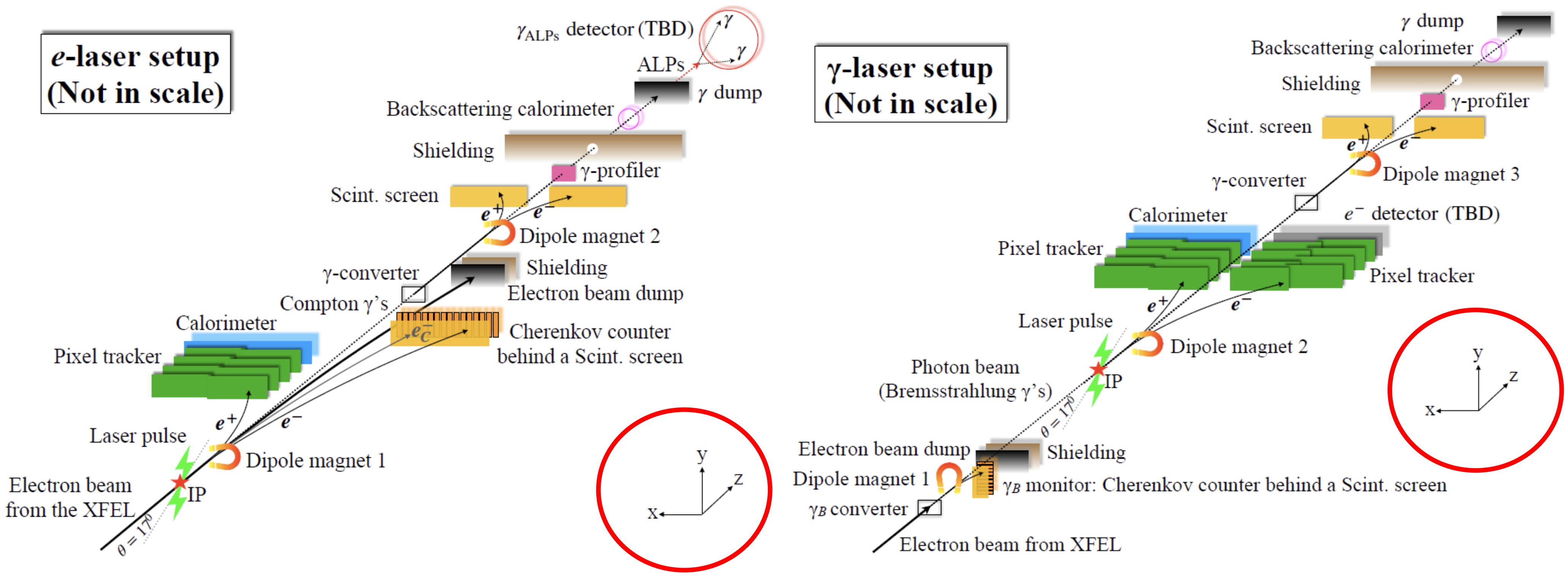

Figure 1.4. Schematic layouts for the *e*-laser and *γ*-laser setup. Shown are the magnets, detectors and main shielding and absorbing elements. The details are explained in Sec. 6.

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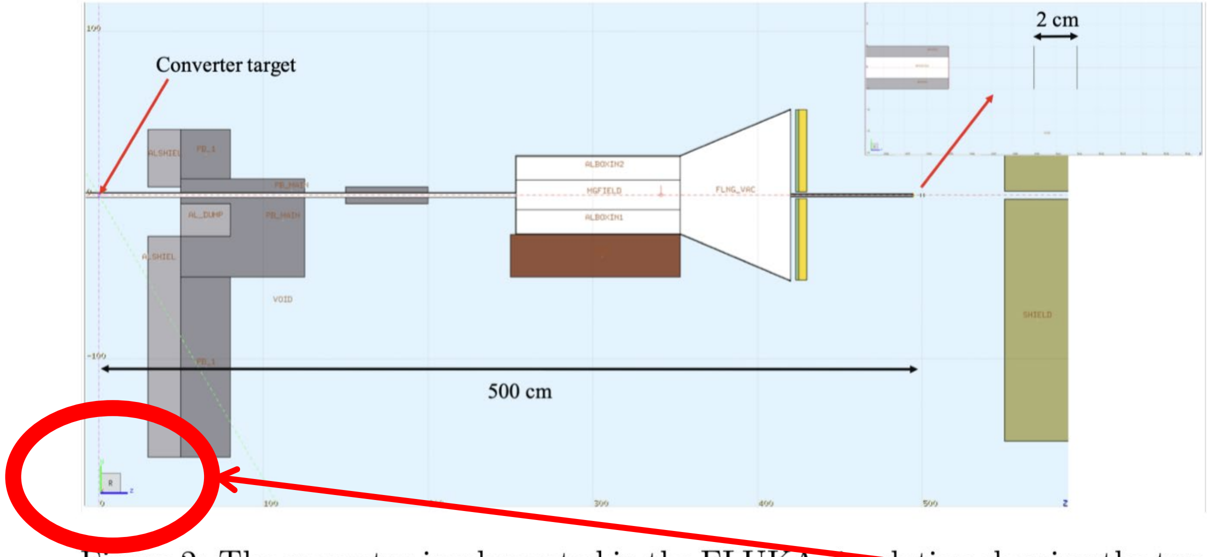
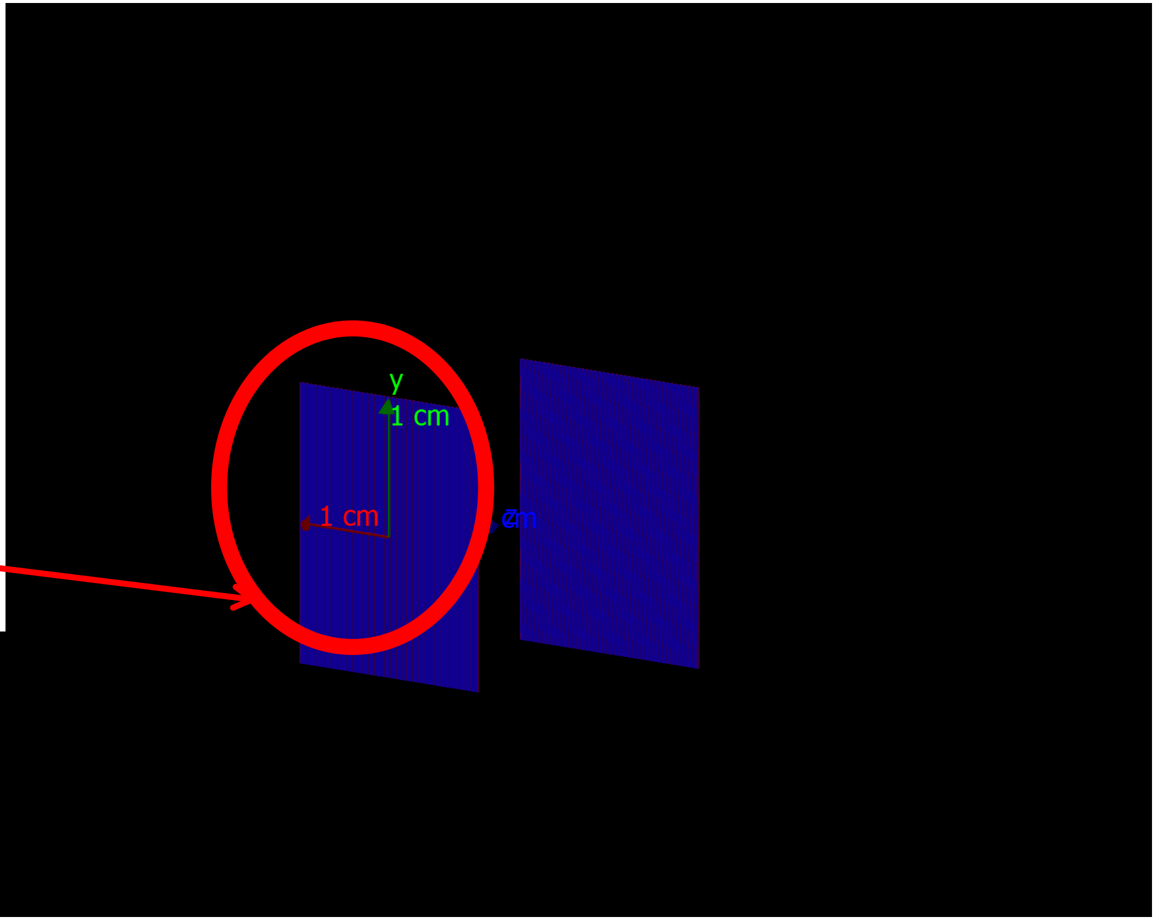


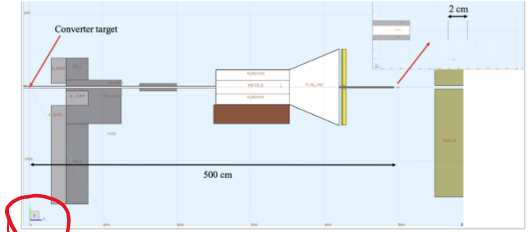
Figure 2: The geometry implemented in the FLUKA simulation showing the two planes of sapphire strips placed at 5 m from the converter target and 11.5 m from the IP.



TN: sec.3

3 System Overview

The LUXE beam profiler must operate in a stable and reliable way in [illegible] of a very intense high energy gamma ray flux. The typical photon en[illegible] of the order of GeV, and in the following it will be assumed that electron[illegible] pair production in the detector is the dominant process. In the following, we will adhere to the axis convention adopted in LUXE, where z represents the main beam propagation axis, and the x and y th[illegible] perpendicular and parallel to the laser polarisation, respectively. The e[illegible] beam spatial distributions, have been simulated using FLUKA. The geo[illegible] implemented in the FLUKA simulation is shown in Fig. 2. Two x and y planes are placed 2 cm distance from each other at 11.5 m downstream of the LUXE interaction point (IP).



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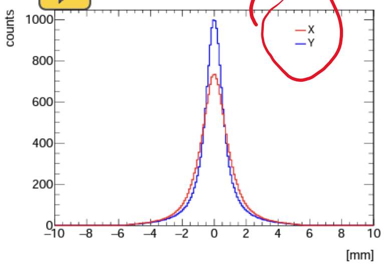

Figure 3: x and y beam profiles at the entrance of the GBP for a $\xi = 10$ value.

The simulation (see Section 4.2 for details) shows that the beam width increases with ξ, that beam profile projections are characterized by long tails and most of the profile is contained in a 2×2 cm^2 square as can be seen from Fig. 3 (simulation performed at $\xi = 10$, one of the highest values expected for LUXE[illegible] minimum beam width which will be measured by the profiler will be abo[illegible] μm, as discussed in Section 2. The maximum intensity per bunch crossing (BX) of the gamma beam is $\phi = 10^9$ photons/BX in the e-laser mode. In Fig. 4 the Compton photon energy distribution per BX at the input of the GBP detector is shown (e-laser mode).

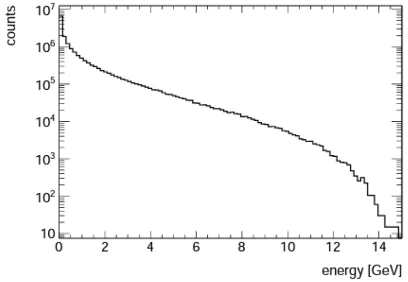

Figure 4: Energy distribution per BX of particles at the entrance of the GBP detector (e-laser mode).

Given the very high dose that the detectors will withstand, a sapphire strips detector is proposed, being this material very resistant to the radiation dose (up to 10 MGy [4]). The choice of a strip readout will allow to keep the readout electronics in a low irradiated area. The use of two successive strip detectors (with strips placed perpendicular between themselves) will cause a beam broadening due to the Coulomb scattering in the first detector the beam will hit, but this has been proven to be negligible in MC simulation which assumed a distance between the two detectors of about 2 cm. Also, the second detector will be submitted to an approximately double dose and will have higher signal amplitude, but the benefit to save the readout electronics by high irradiation level will compensate these drawbacks which are anyway expected to be tolerable.
The detector should be as thin as possible to minimize the dose absorbed by the more downstream plane but still preserving an acceptable signal level. The minimum detector thickness that can be manufactured still having a good mechanical stability is about 100 μm. In the following a sapphire detector having 2×2 cm^2 area, $dz = 100$ μm thickness and $\Delta x(\Delta y) = 100$ μm strip pitch will be considered. It must be mentioned here that in the present time sapphire samples from different companies are under test, and some company could only manufacture wafers having 150 μm thickness (which has been shown in some studies not reported here still acceptable).
Given the very high beam intensity and occupancy per strip, the beam position and the beam width can be reconstructed with the desired precision by using an analog readout and a charge center-of-gravity (COG) and/or fit to spatial distributions algorithms. A total of about 400 channels will be needed to readout two orthogonally placed strip detectors.

- Different conventions in axis labelling is a cause of confusion.
- The problem arises from fluka and geant4 different conventions.
- LUXE convention is such that parallel laser polarisation is over x-axis

4 Expected performance

The proposal is to build a LUXE beam profiler station with two sapphire strip detectors of 2×2 cm^2 area, thickness 100 μm, strip pitch 100 μm, placed at about two cm distance along the beam direction, with the y-strip detector upstream and the x-strip detector downstream. The first upstream detector will be at 11.5 m from the IP.

TN: sec.3.1

It was shown recently [4] that optical grade sapphire can be used directly as a detector material even without extra purification with the advantage of low cost and superior radiation hardness.

Material properties	sapphire	diamond	silicon
density [g/cm3]	3.98	3.52	2.33
bandgap [eV]	9.9	5.47	1.12
mean energy to create an eh pair [eV]	27	13	3.6
dielectric constant	9.3-11.5	5.7	11.7
dielectric strength [MV/cm]	0.4	1.0	0.3
resistivity [Ohm cm] at 20^o C	1.0E+16	1.0E+16	1.0E+05
electron mobility [cm2/(V s)] at 20^o C	600	2800	460
MIP eh created [eh/mm]	22	36	73

Table 1: Overview of sapphire material characteristics with respect to diamond and silicon.

?

Signals collected from sapphire detectors are limited by a relatively small amount of 22 electron-hole (eh) pairs produced per micron of MIP track and by the low charge collection efficiency that has been measured to range between 2% and 10% in 500 μm thick detectors [4]. This intrinsic small MIP signal amplitudes should still be suitable for the GBP case given the large fluxes of particles simultaneously hitting the detector. Extremely low leakage current (~pA) at room temperature even after high dose irradiation makes sapphire detectors practically noiseless.

A typical detector design includes thin sapphire plate with continuous metallization on one side and a pattern of electrodes (pads or strips) on the opposite side. Aluminum is proven to be a good material for metallization, usual thickness is a few microns. The operation voltage of the detector is a few hundreds volt,

TN – Standalone MC.
What to include in the update? In which order?

1. Initial beam
   - Is it useful to include a small subsection about the way the initial particle beam is selected form the full geant4 luxe dataset?
2. Detector performance in the profile reconstruction
   - Marco/Mauro's results
3. Dose evaluation
4. Background contribution to the reconstructed profile
   - Semilog scale plot with full profile + background only (statistics of the background)
   - Spectrum of the background only?
5. Proposal to introduce a converter
6. Spectrum of energy depositions