Update on Gamma Beam Profiler Simulations

Geant4 simulation of the gamma profiler with LMA tracks.

Sensitivity study

UNIVERSITÀ DEGLI STUDI DI PADOVA

INFN

The gamma beam profiler – CAD

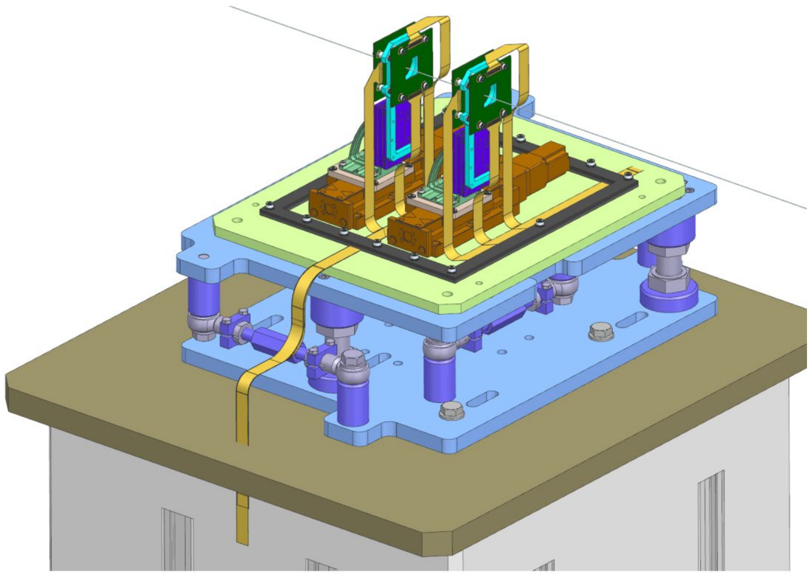


Figure 40: GBP station overview (brown: X stages; violet: Y stages)

Figure 41: X-Y stages front view. Detail of the station main dimensions. Support plate dimensions is about 35 x 35 cm^2.

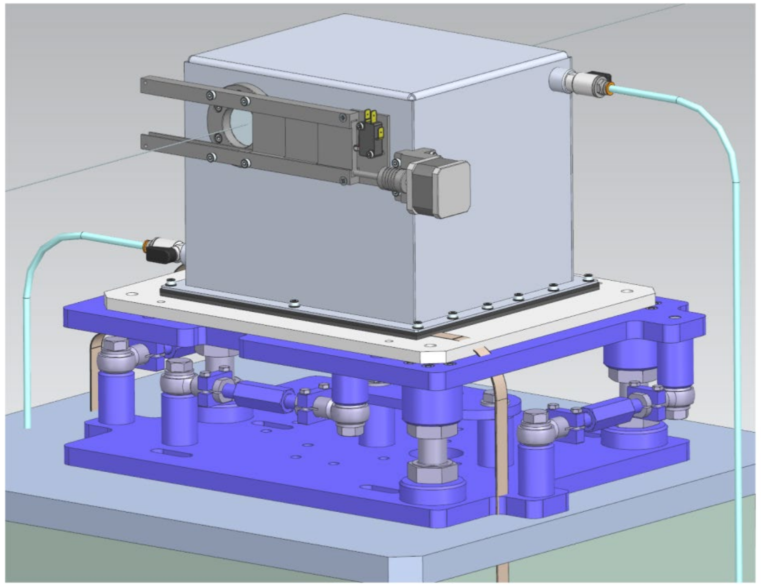


Figure 42: Faraday cage and gas enclosure with windows

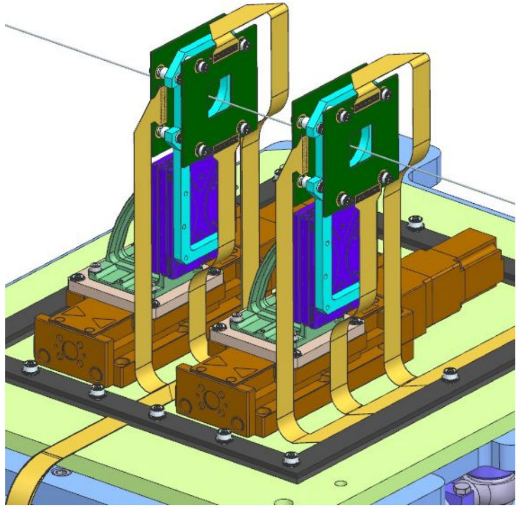


Figure 43: Signals flat cables preliminary routing

The gamma beam profiler is located at roughly 12m downstream the IP. The detector is instrumented with two identical stations, each with two 192-strip 100-um sapphire sensors. Each sensor is mounted on movable XY stages with um step precision.

The purpose of the GBP is to measure the high intensity Compton beam profile.

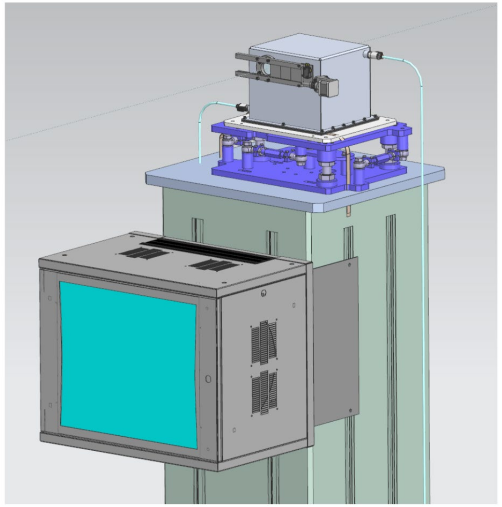
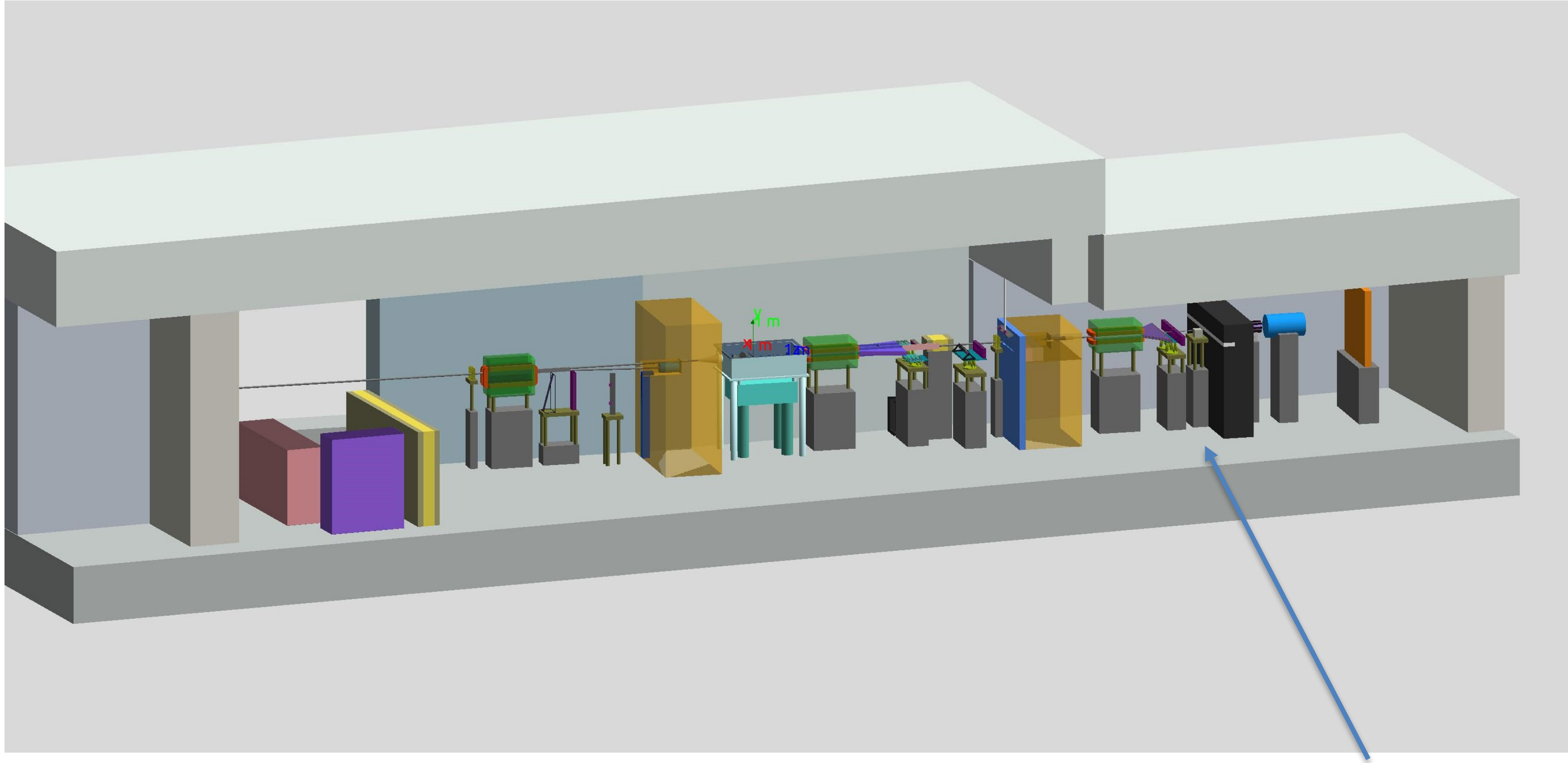


Figure 44: Overview of the GBP station on the support pillar and the rack

The gamma beam profiler – Geant4 lxsim



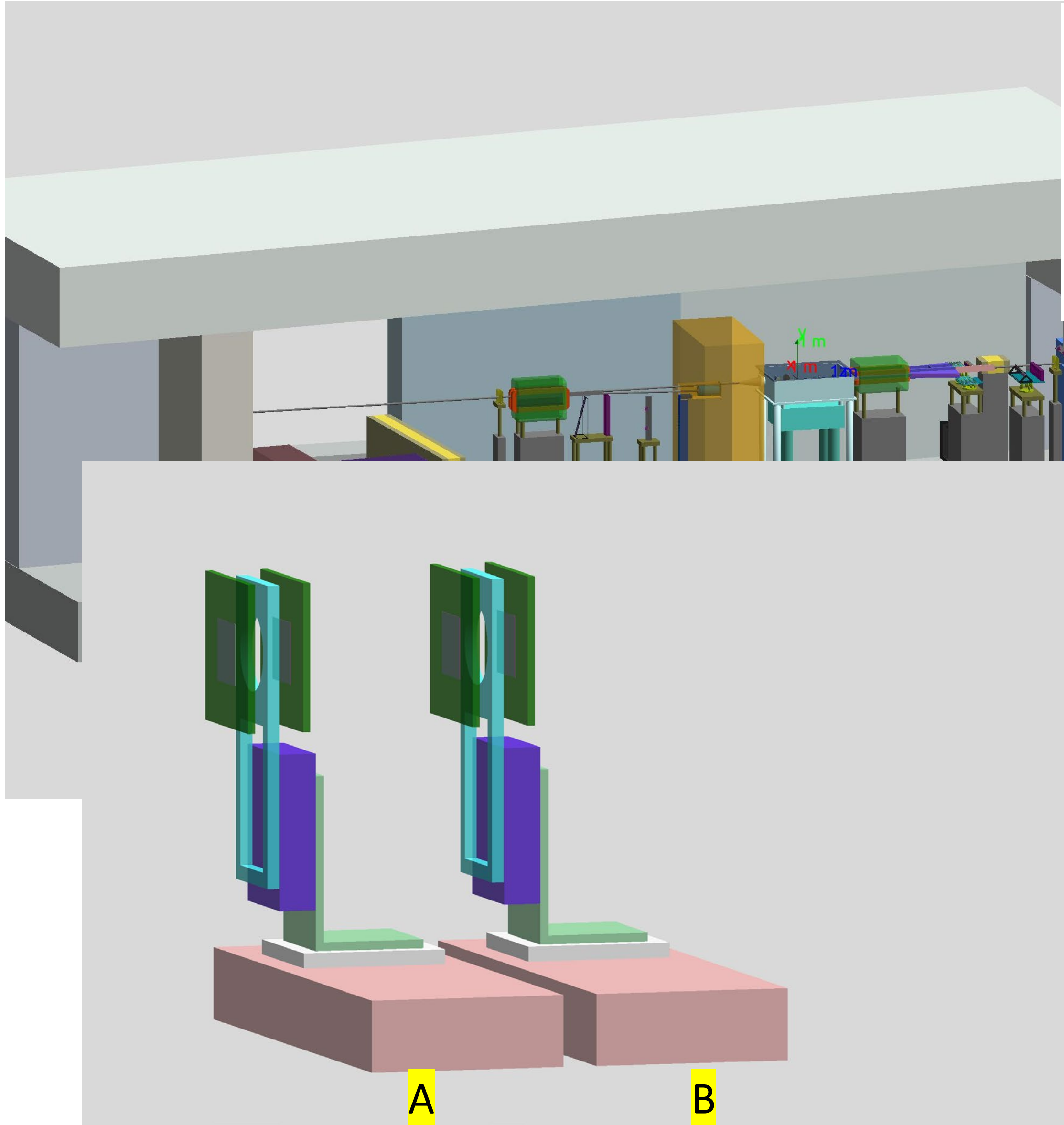
The Geant4 simulation of the LUXE experiment implements the GBP in less detail with respect to the CAD model, by reproducing only key features of the geometry.

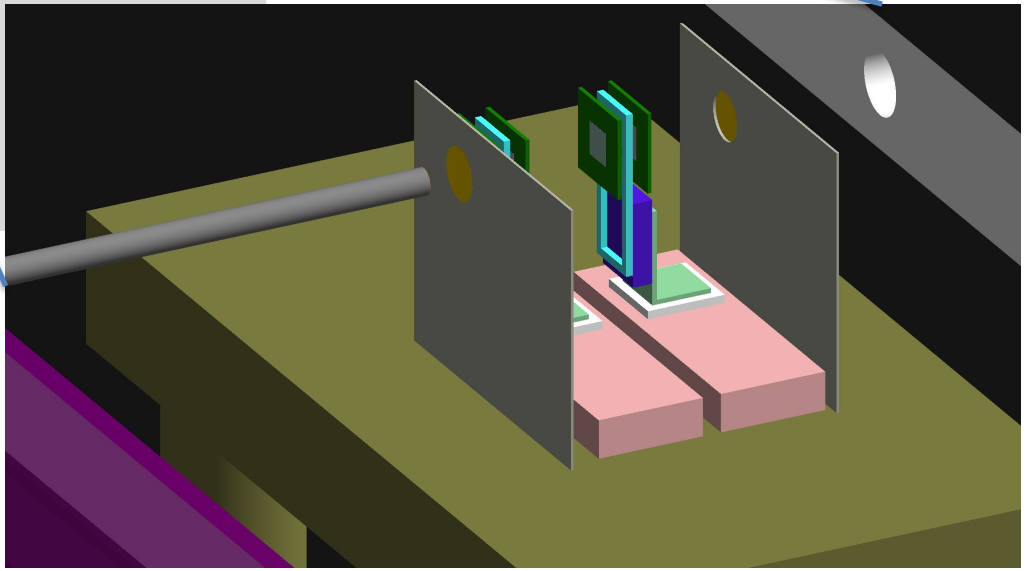
The GBP is located a few cm downstream the end of the beam pipe exit window

The gamma beam profiler – Geant4 lxsim

The geometry of the hics branch has been updated including an identical second station (B) and moving vertical motor stage down – i.e. away from the beam plane – to reduce dose delivery to such components

Update: lxsim has been ported to Geant4 v11.0.0





The gamma beam profiler – Geant4 StandaloneGBP

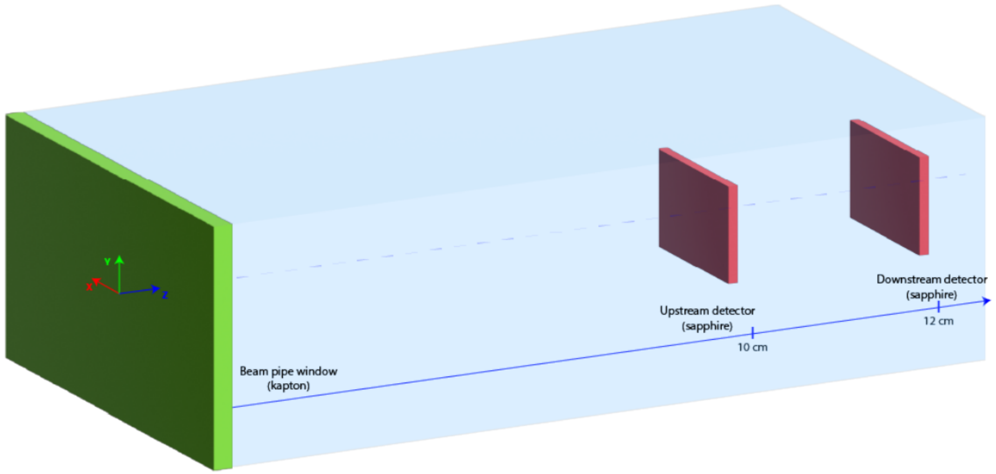
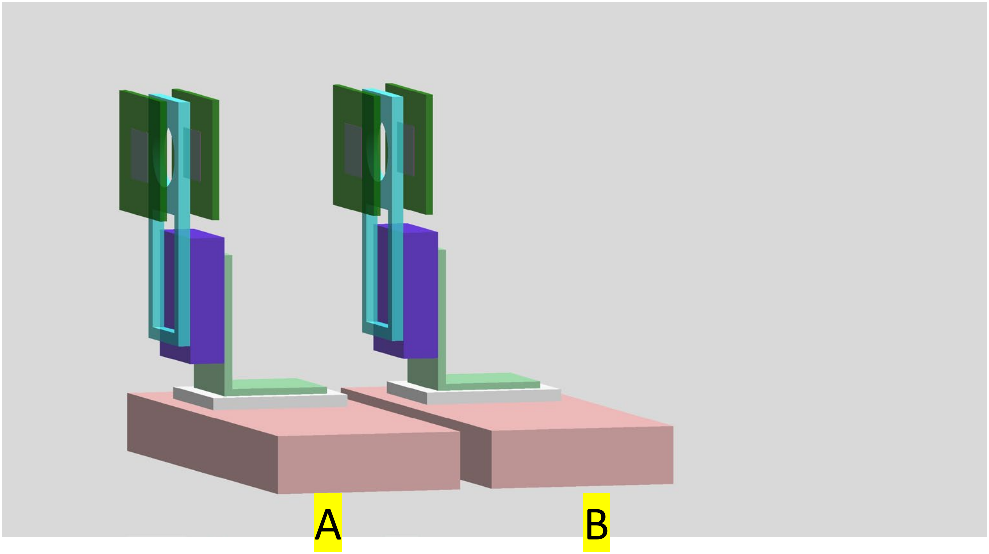


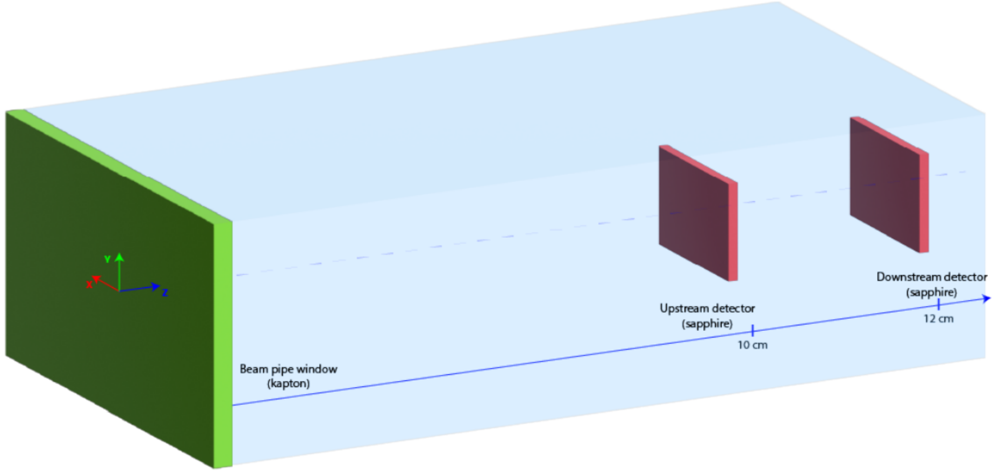
Figure 11: Illustration of the geometry for the Geant4 standalone MC simulation for the GBP. In order from left to right: the beam pipe kapton window (green), the upstream and downstream detectors of the first station.



A spacialized Geant4 simulation of the GBP, called StandaloneGBP, is set to study the profiler in more detail.

The sim. contains only the GBP assembly volume (as shown in the Fig. Bottom left) and the beam pipe exit window.

The gamma beam profiler – Geant4 StandaloneGBP



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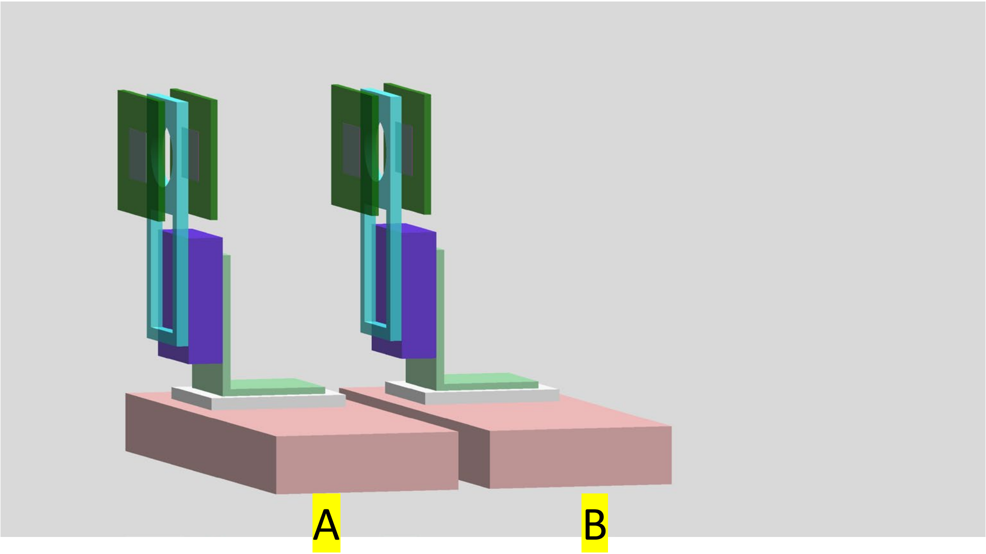

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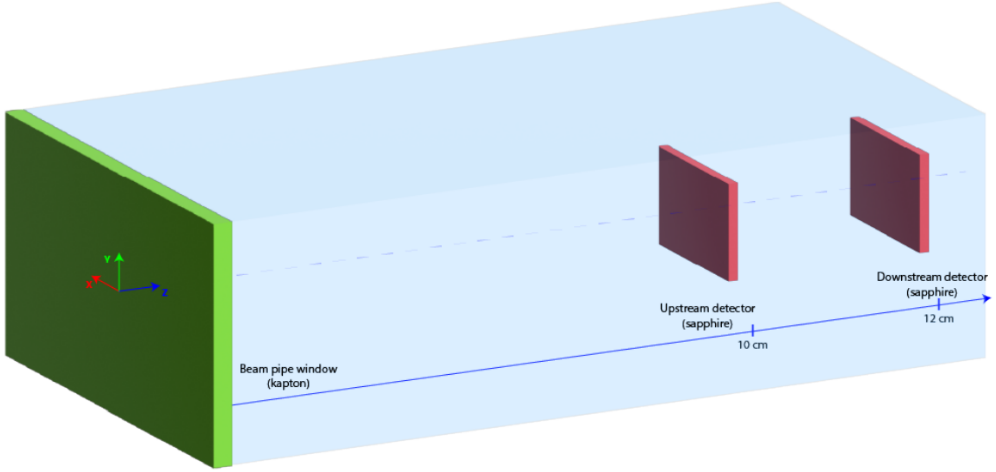
The gamma beam profiler – Geant4 StandaloneGBP



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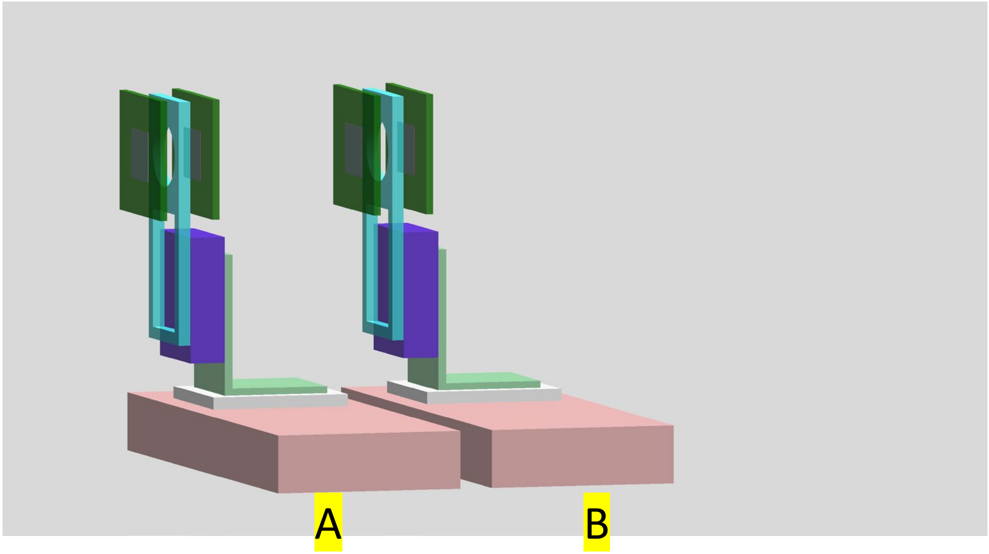

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E-laser setup in phase-0 was simulated with primary statistics of the physica BX / 150 in the **Local Cross Field Approximation (LCFA),** which assumes that the photon emission occurs at a constant electric field perpendicular to the electron momentum.

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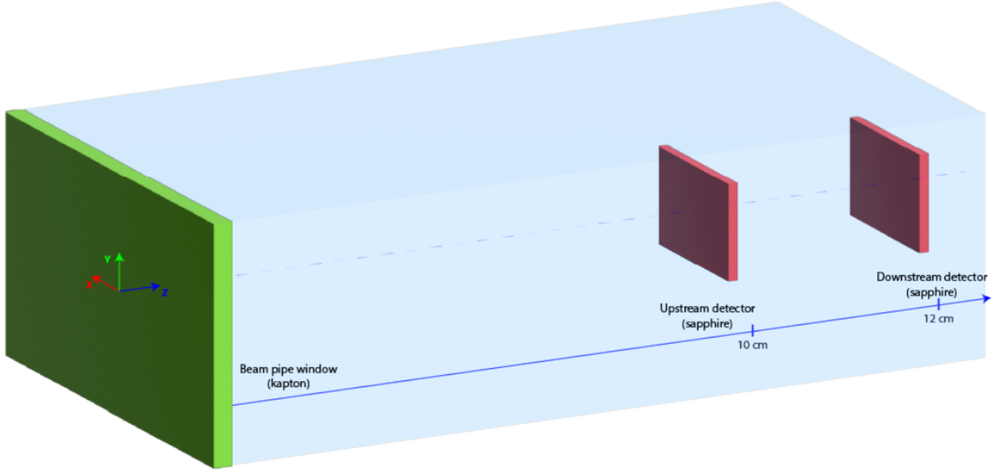

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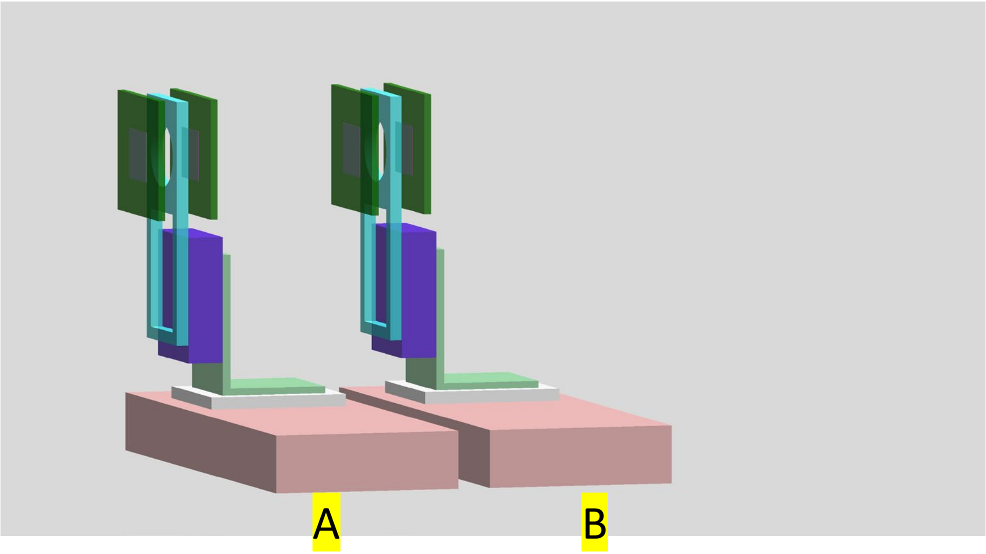

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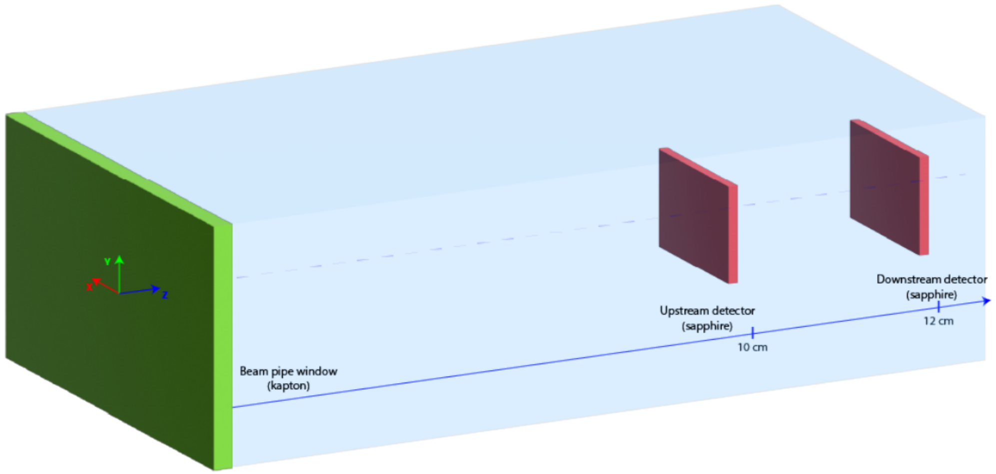
A *more accurate approximation* is based on the **Local Monochromatic Approximation (LMA)**. These new more accurate simulations of the gamma-ray beam profiles evidence a clearer relation between the laser intensity and the angular distribution of the Compton-scattered photons *(see Kyle's talk)*

The gamma beam profiler – Geant4 StandaloneGBP



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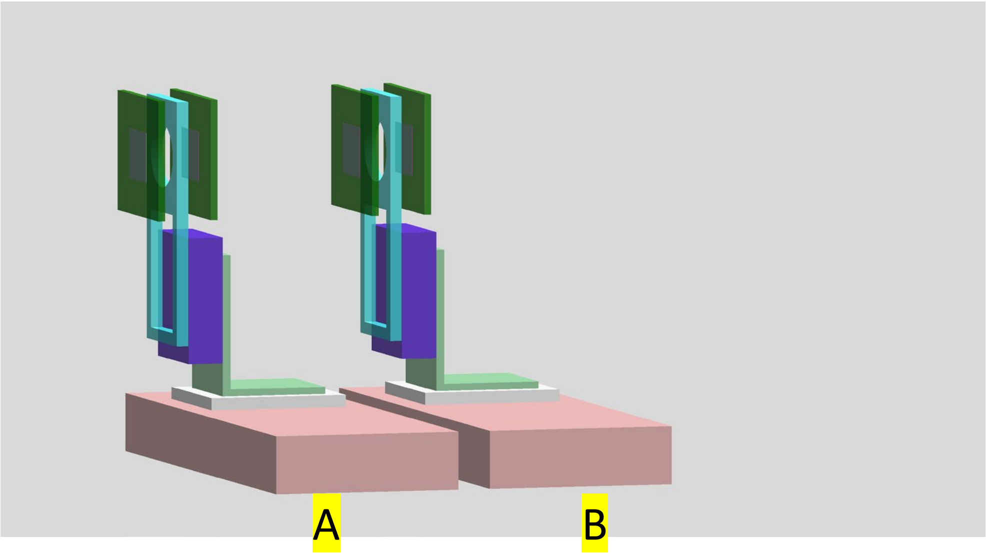

At present, the GBP technical document has been updated with latest LMA simulations for $\xi = 0.1 \rightarrow 25$

Key-points

- The IP tracks are geometrically projected downstream and the interaction with GBP is simulated with StandaloneGBP code (no *very detailed* sim. of the background, but conclusions from LCFA still valid)
- MC statistics at IP is the one of a physical BX / 15000

- E-laser interaction is simulated both using realistic e-beam shape and with a pencil electron beam. Angular distributions are very consistent. Therefore, pencilbeam case is used as reference for further analysis (mainly due to the shorter sim. Time) *(see Kyle's talk for more details)*

Geant4 simulation setup

- Standalone GBP simulation is used
  - two sensors, each 100um-thick with 192-strips, separated 2cm each others;
  - beam pipe exit kapton window with thickness 200um;
  - FPFP_BERT hadronic physics list used;
  - simulation in air;
  - default cuts;
  - absorber placed in front of the upstream det. 2cm apart.

- The event simulates the interaction of ~~a monochromatic~~ LMA photon beam ~~with sigmaX=sigmaY=0~~ shooting the center of the strip detectors (X=Y=0) and starting right before the beam pipe exit window.

E-laser phase-0 IP with LMA

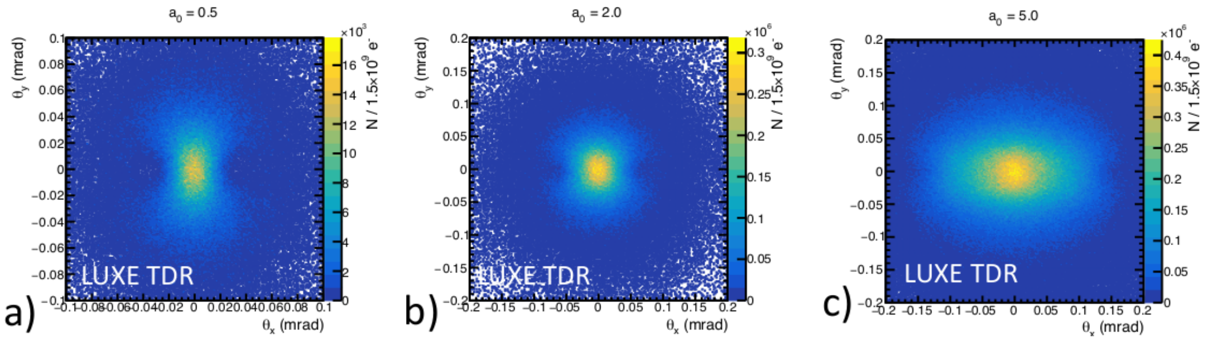

Figure 16: Examples of the angular distributions of the number of Compton-scattered photons at the interaction point for **a.** $\xi = 0.5$, **b.** $\xi = 2$, and **c.** $\xi = 5$. The laser polarisation is along the horizontal axis. As justified in more detail later, we show here the distribution of photons with an energy exceeding 1 MeV.

11.5m downstream at GBP

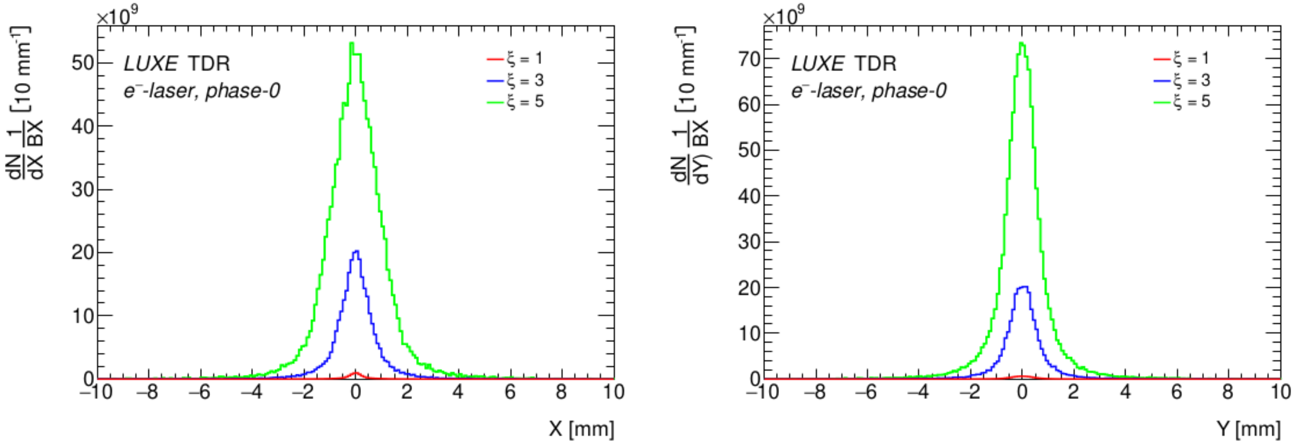

Figure 3: Beam profile for $\xi = 1$, $\xi = 5$ and $\xi = 10$ along the X-direction (left) and Y-direction (right) at the entrance of the GBP in the e⁻-laser phase-0 LUXE setup.

Summary of updated TN results

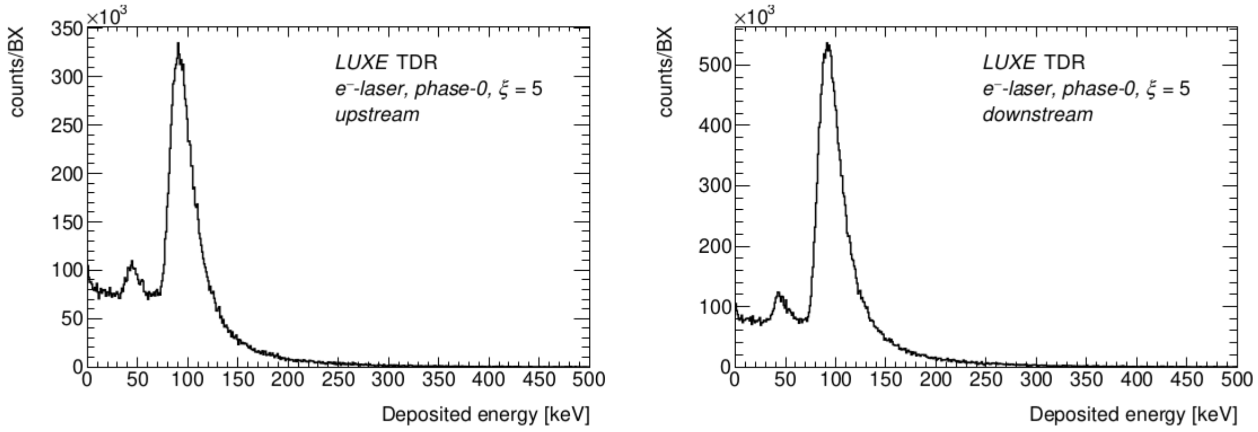

Figure 13: Spectrum of energy deposits by signal particles in the sapphire upstream (left) and downstream (right) profilers.

Main results in a nutshell

- Dose delivery to the detector greatly improved, but main results of the previous TN are preserved, since estimates for the design were very conservative.

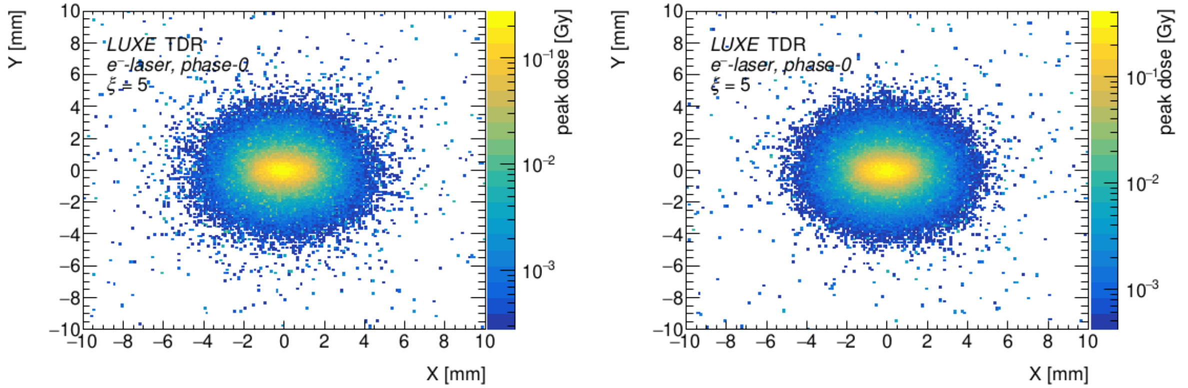

Figure 15: Dose distribution profile for the upstream (left) and downstream (right) detectors. Energy depositions from the Compton beam signal are considered. Points where no depositions occurred are blank.

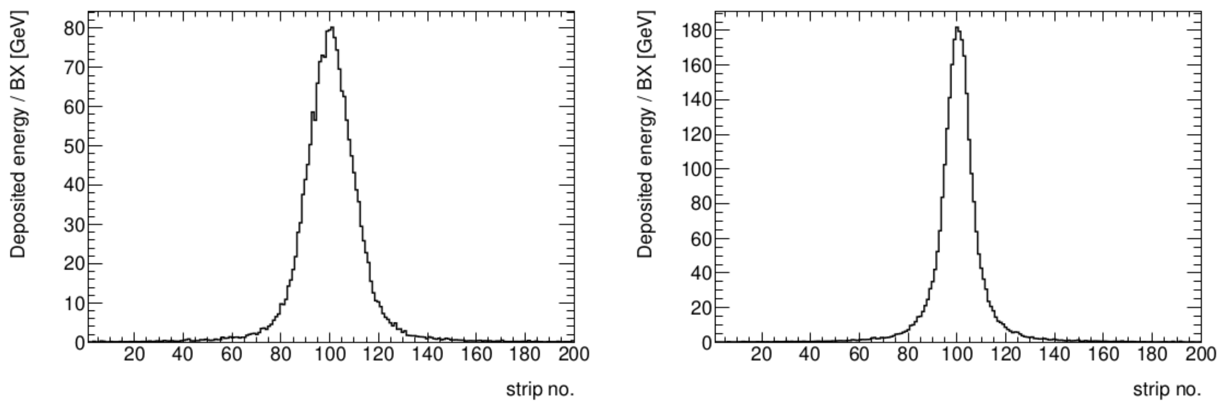

Figure 14: Energy deposited in the strips for the upstream (left) and downstream (right) detectors, from the Compton gamma beam signal.