SAS Meeting
GBP update

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University of Padua, INFN-Padova

Padova, 17/07/23

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GBP design main differences with respect to CDR

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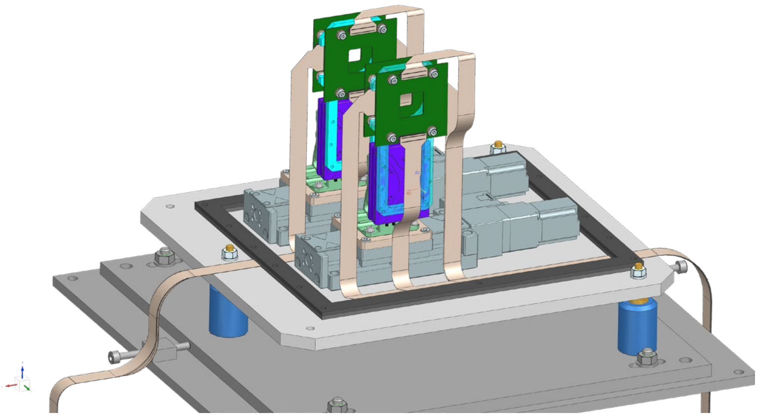
  - Broader, less intense Compton beam
  - Two station: redundancy



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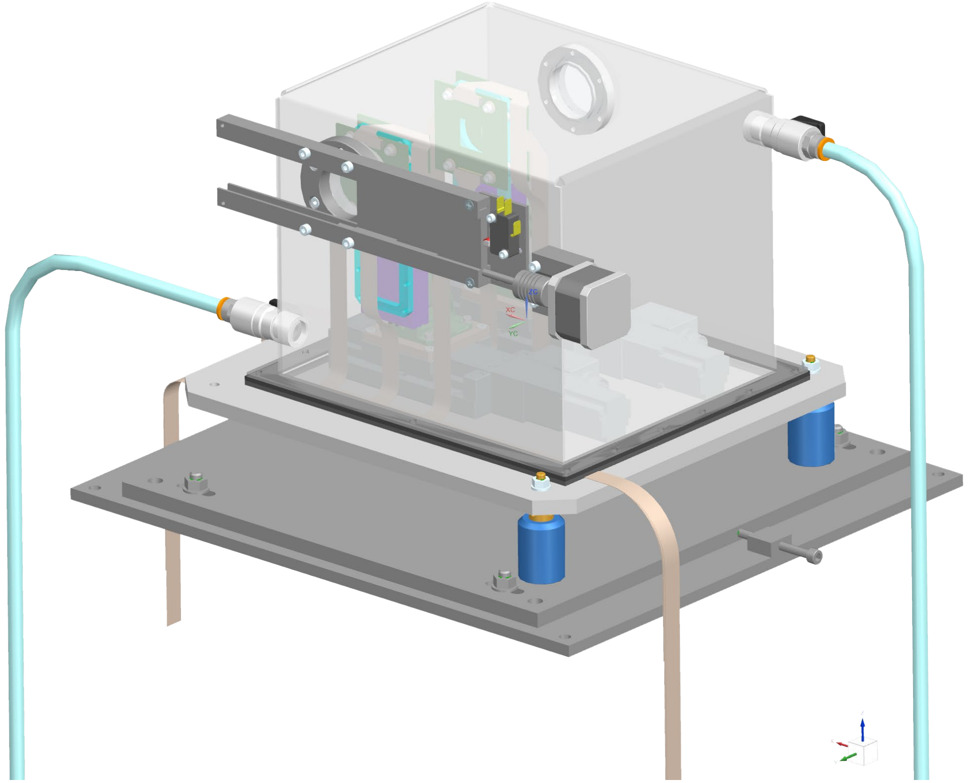

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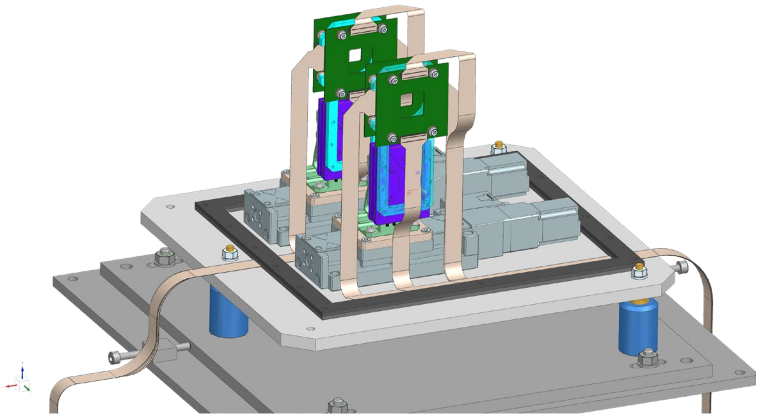

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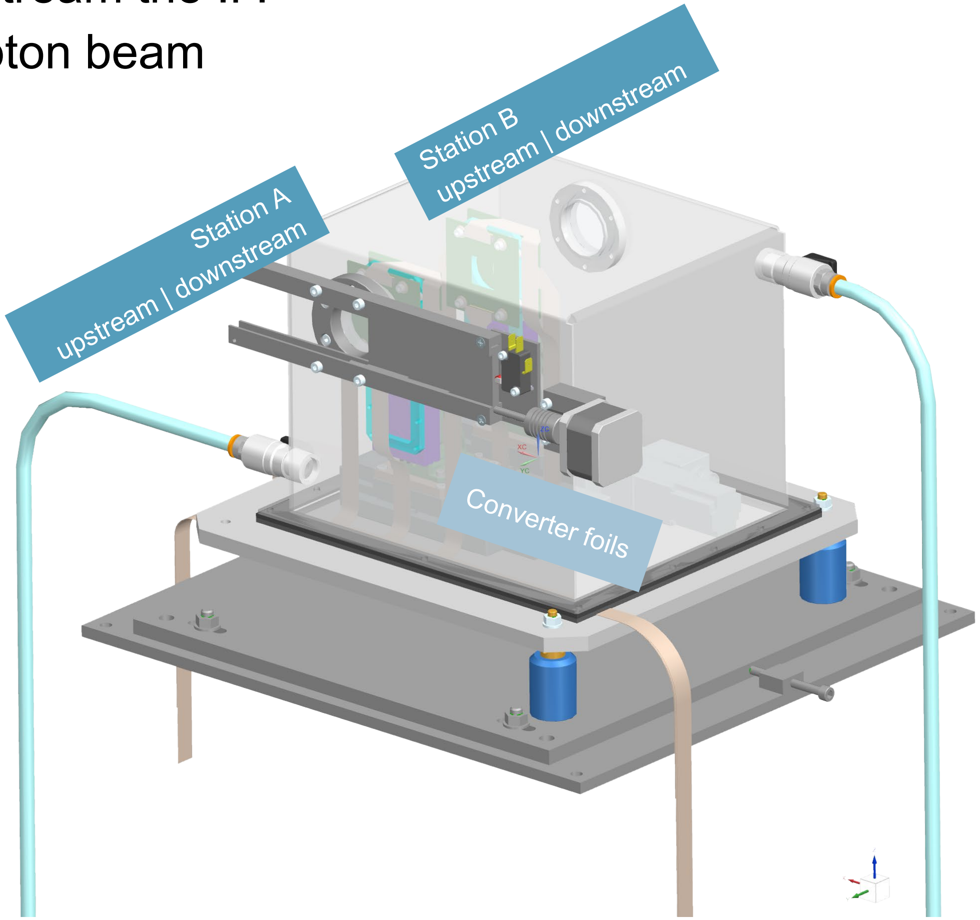

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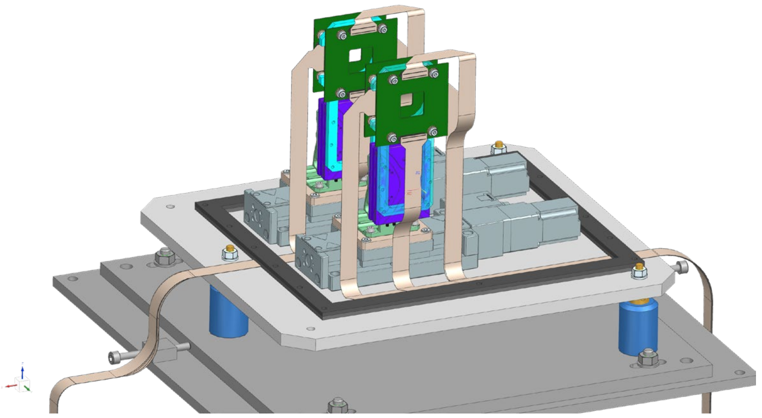

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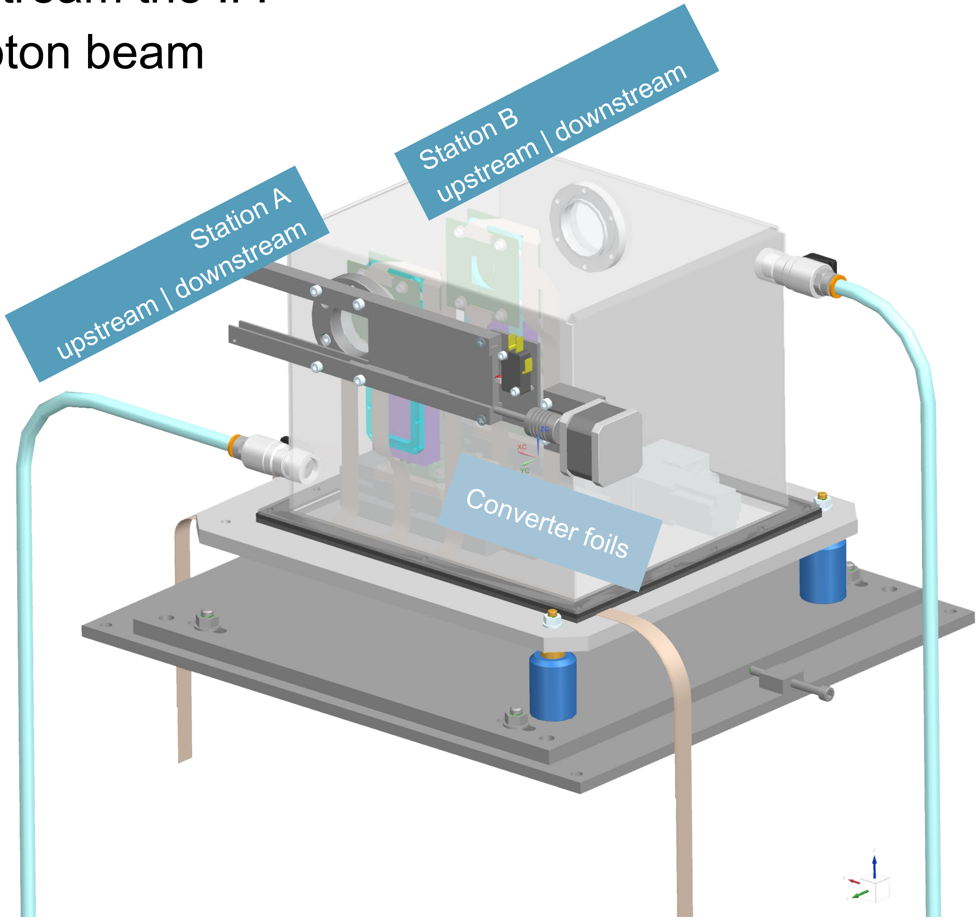

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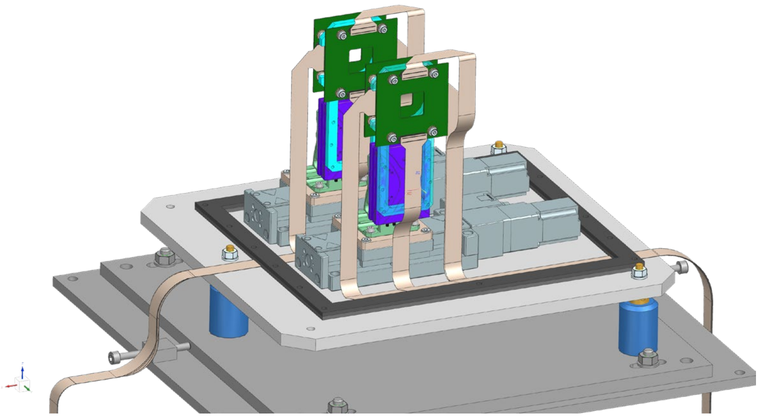

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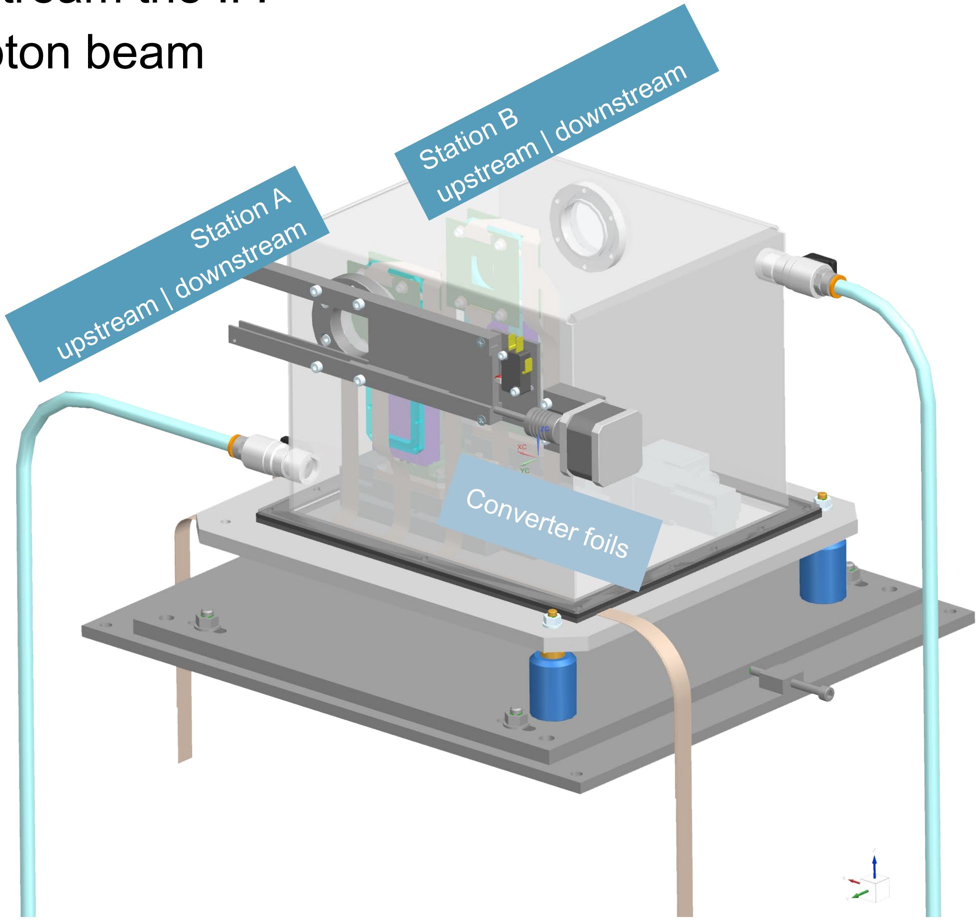

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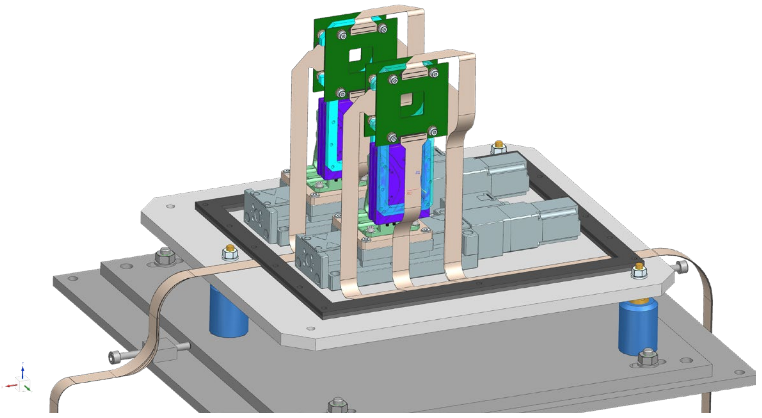

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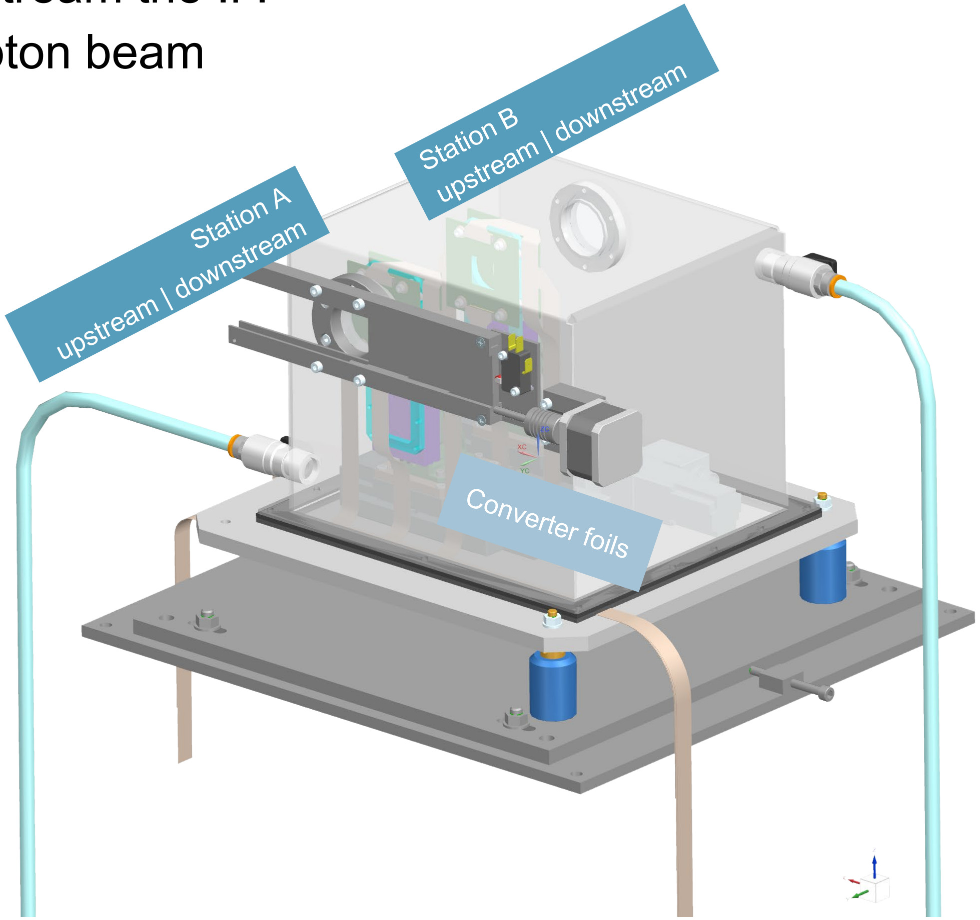

- Motor stages moved away from the beam XZ plane, to reduce dose delivered
- Converter materials before the entrance window, to improve signal at low ξ
- Gas flanges for cooling (*no practical differences in the sim.*)
- Electronics rack inserted in the pedestal (at y=-1m)

Design implemented in the LxProfiler class

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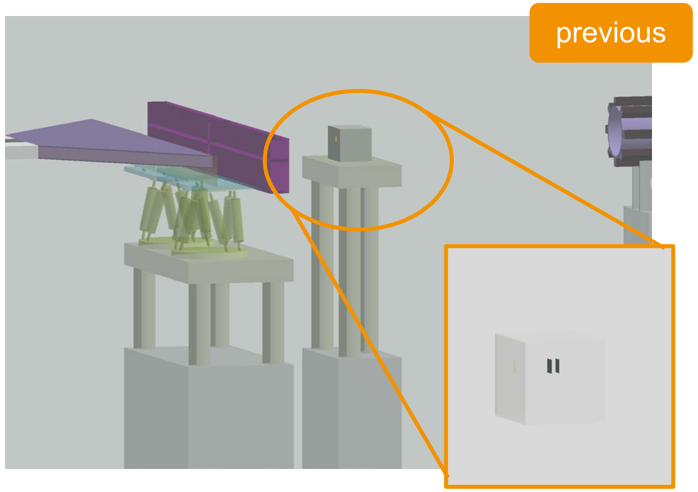

Geant4 geometry

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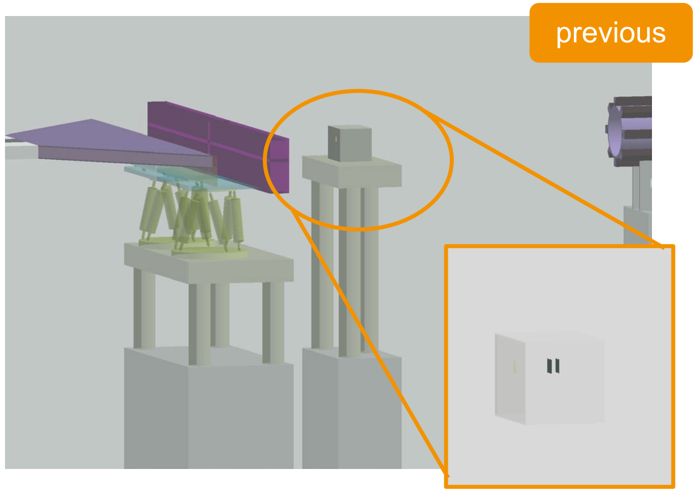

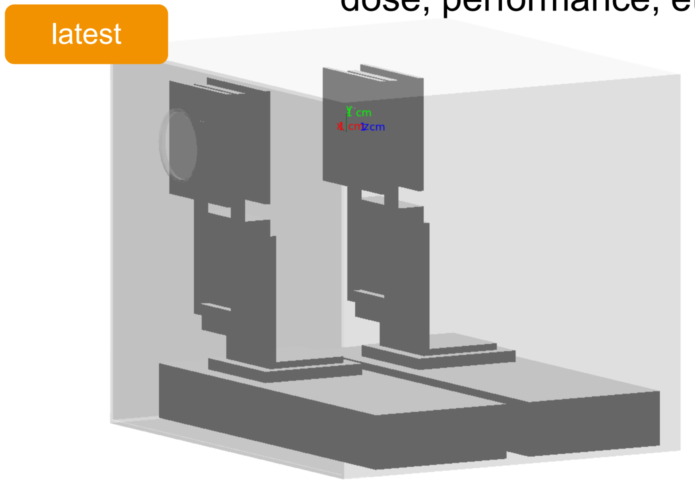

Geant4 geometry

- StandaloneGBP is a Geant4-based simulation specialized of the profiler to evaluate in detail dose, performance, etc.

- Sapphire charge production and digitization is simulated separately with Allpix^2, although only preliminary results so far.

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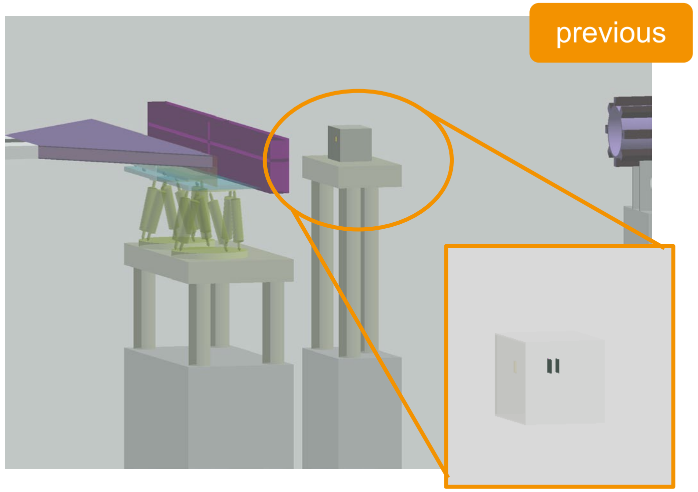

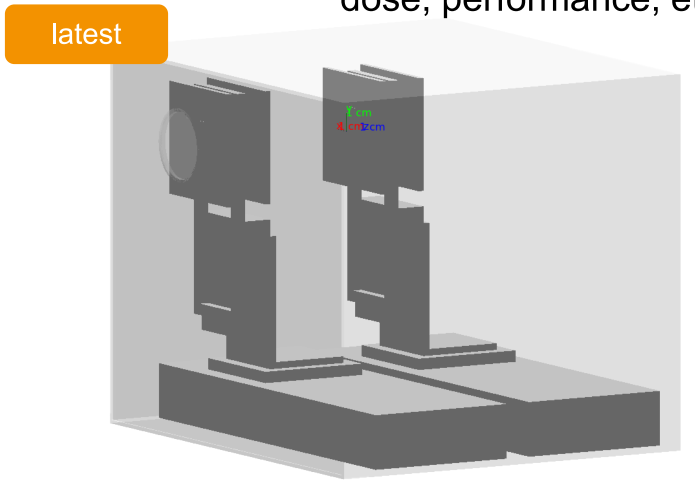

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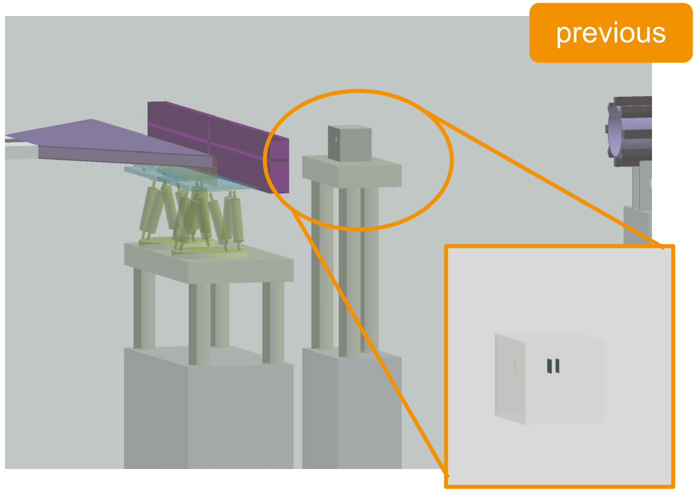
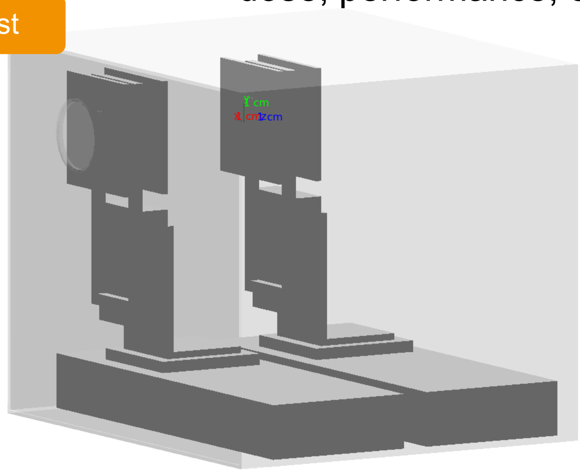
  - Motors, flat cables, supports are sensitive and dose delivery is scored
  - The entrance window is effectively used as the converter (mat./thick. changeable by macro cmd.s)

previous



latest



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StandaloneGBP. How it works?

- Only GBP ‘sub-volume’ in the geometry. Background studies are done by creating all the tracks scored from **lxsim** in the boundaries of the volume in Fig.11

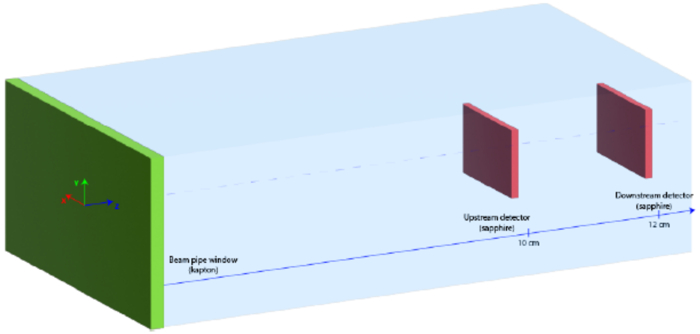

Figure 11: Illustration of the geometry for the Geant4 standalone MC simulation for the GBP. In order from left to right: the beam pipe kapton window (green), the upstream and downstream detectors of the first station.

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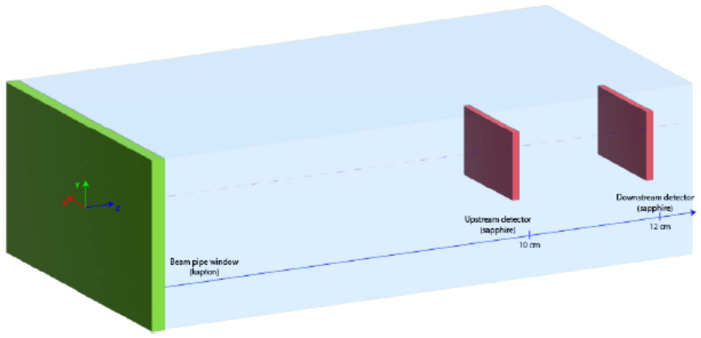

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- Appropriate family-tree clustering of the particles must be done to ensure the correct event-by-event energy deposition

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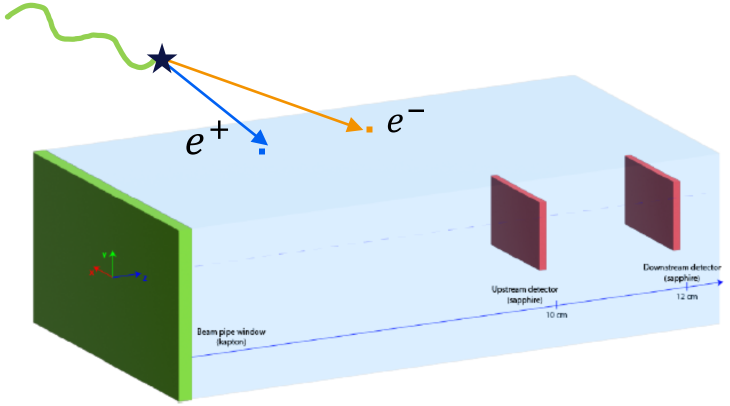

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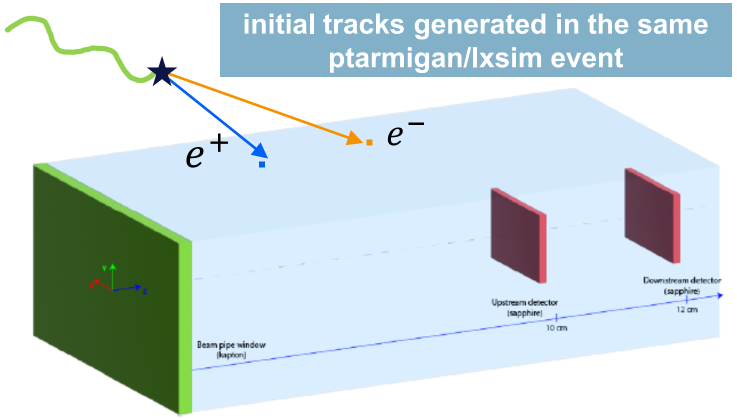

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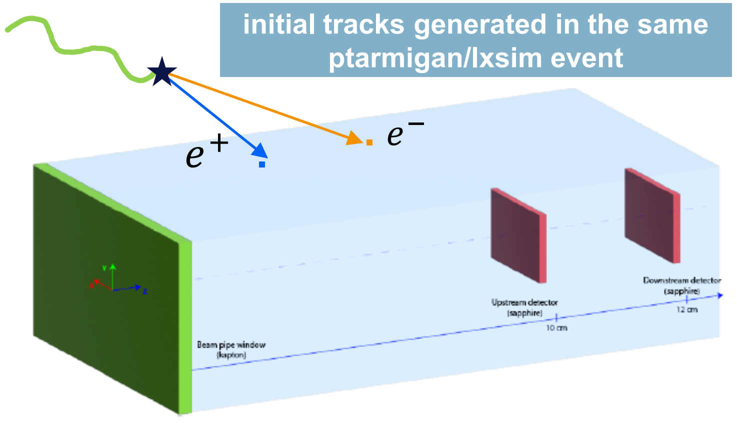

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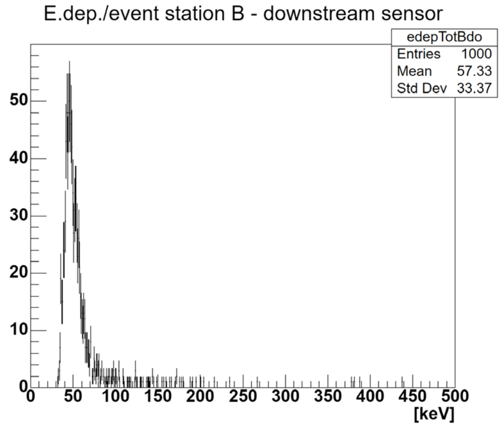
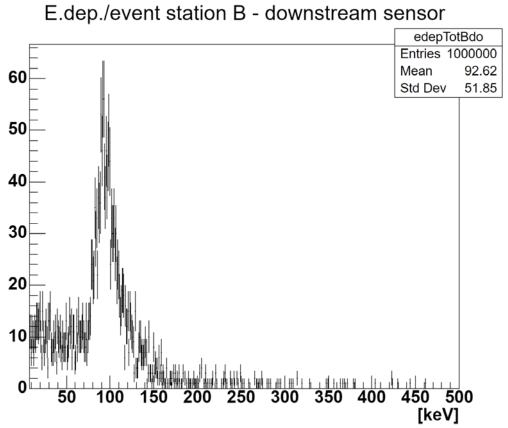


Tracks imported in different events



Tracks in same event.
(as many G4 vertices as part.s made in the lxsim/ptarmigan event)

- Accumulated observables (total energy, dose, profile) are insensitive

Main conclusions of the TN

- Using early sim.s (LCFA) it holds that uncorrelated* background particles – i.e., secondaries from other SDs reaching GBP with the γ – do not contribute to profile reconstruction ($N_{bck}/N_{\gamma} < 0.02\%$) **lxsimgbp**

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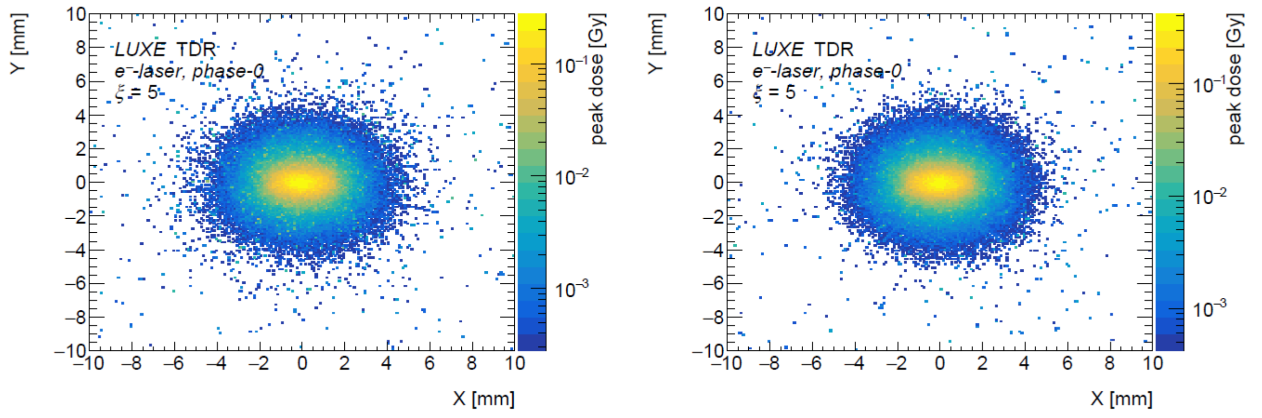

Figure 15: Dose distribution profile for the upstream (left) and downstream (right) detectors. Energy depositions from the Compton beam signal are considered. Points where no depositions occurred are blank.

- Peak dose in a cube L=100um (station A)
  - **0.278 Gy/BX upstream**
  - **0.418 Gy/BX downstream**

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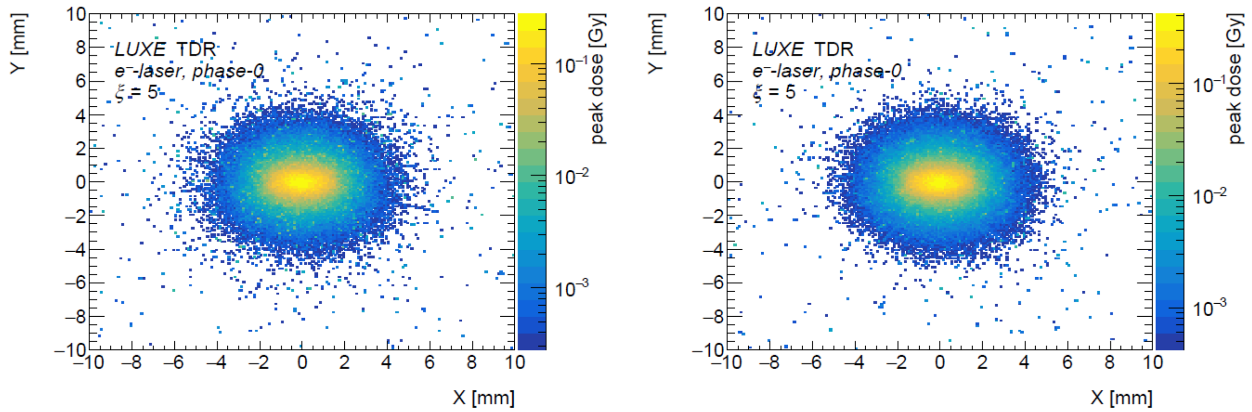

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Volume size is an educated guess based on det. thickness. This choice has been validated to be insensitive to simulation dependent effects (events sim.s and production cut).

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Beyond the TN

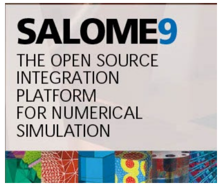
- No definitive estimator allowing to uniquely determine ξ value from the hor./vert. profiles of e.dep.s has been developed
- Non-linear detector response may be involved in signal production and collection (charge creation, propagation, front-end). A first attempt to study detector-response has been done with **Allpix²**

Allpix^2 for sapphire

- Allpix-squared is an open-source framework for simulating (originally) silicon-pixel detectors from incident radiation to detector response.
- Common ground in Geant4, for the energy deposition part

Allpix^2 for sapphire

- A full open-source approach based on Salome, Elmer, Paraview is developed to simulate sapphire strip detector with Allpix-squared



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2. Meshing

Features

- Parametric design is excellent for detector design optimization (i.e. with ML alg.)
- Advanced meshing alg.s

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- User has complete control on solver settings.
- MT by default.
- Different simulation models available (i.e. one can simulate thermal stresses for free)

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mesh_converter
+CSVParser

1. Parametric geometry
2. Meshing
3. Finite-element Electrostatic/Ramo field calculation
4. Fields interpolation and resampling over uniform structured grid
5. Export to CSV
6. Import CSV (single or multiple observables)
7. Convert to APF
8. Ad-hoc sapphire implementation
9. Simulate

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- User has complete control on solver settings.
- MT by default.
- Different simulation models available (i.e. one can simulate thermal stresses for free)

- Powerful visualization tools
- Advanced interpolation alg.s
- Data filtering (i.e. rejection of odd regions)
- Resampling over different meshes/datasets

- Conversion of CSV/ROOT file to Allpix Proprietary Format (APF)
- MeshMap coordinate offset and scaling
- Automatic Ramo potential renormalization feature

Validation of the tool with literature

- The ad-hoc implementation has been validated by comparing simulation results with experimental data from a test-beam available in the literature

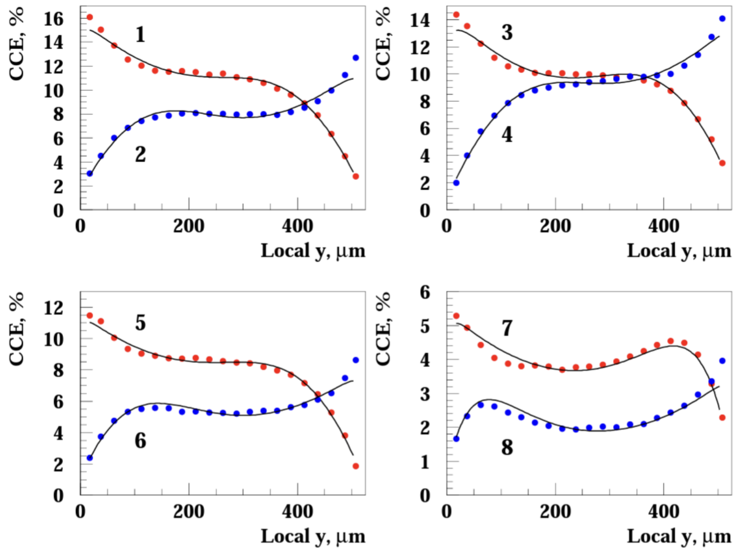
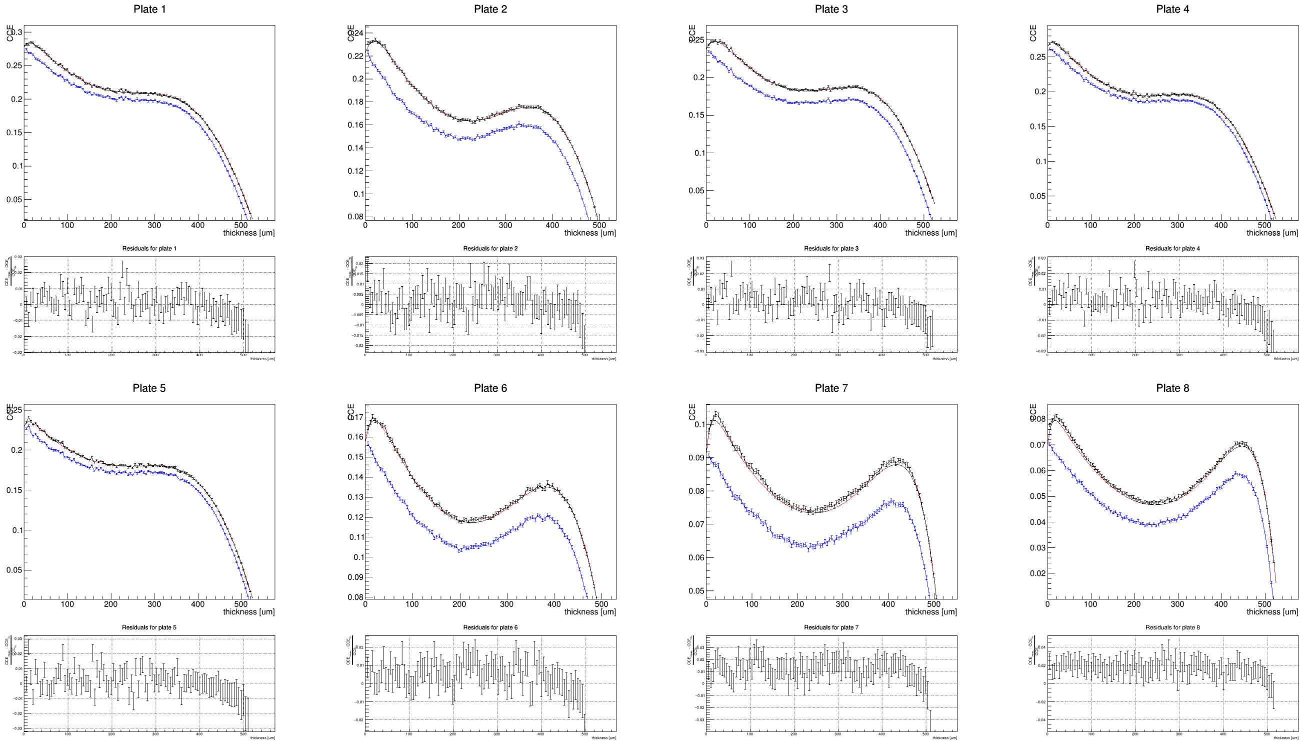


Figure 7: The CCE measured as a function of the local y coordinate inside a plate in slices of 25 μm for all plates of the sapphire stack. Blue dots are for the electric field in the direction of y and red dots for the opposite field direction. The lines are the result of a fit including both electron and hole drift. The fit parameters are given in Table 3.



Literature:
DOI 10.1088/1748-0221/10/08/P08008

Allpix-squared simulation

(Test beam)-related simulations

- A long experimental campaign, starting since May 2022, *is running* to investigate sapphire as radiation detectors.

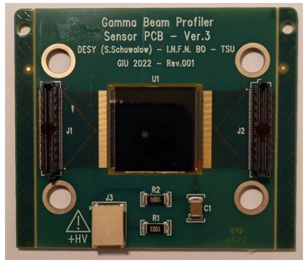
- Most of the effort has been spent in data collection & analysis.

- Test beams. Experimental activity and support from simulations
  - TB1-pad Frascati CCE and Allpix2 for fringe effects
  - TB2-4 strip at CLEAR (CERN) evaluation of the CCE and accumulated dose from an electron beam
  - TB3-192, TB4-192, TB5-192 evaluation of deposited charge for CCE calculation. Estimagte of systematic uncertainties

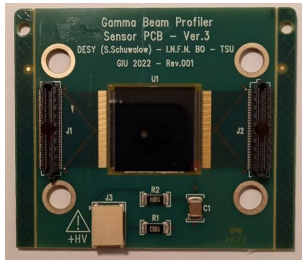
Sapphire pads
(May 22, INFN-LNF)

Sapphire 4-strip
(Sep. 22, CERN)

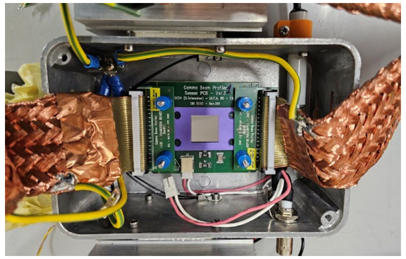
Sapphire 192-strip
(Dec. 22, CERN)

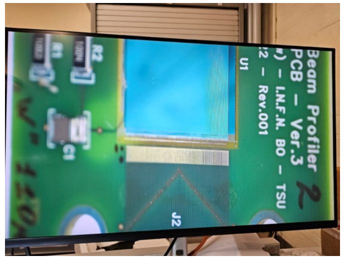


Sapphire 192-strip
(Mar. 23, CERN)

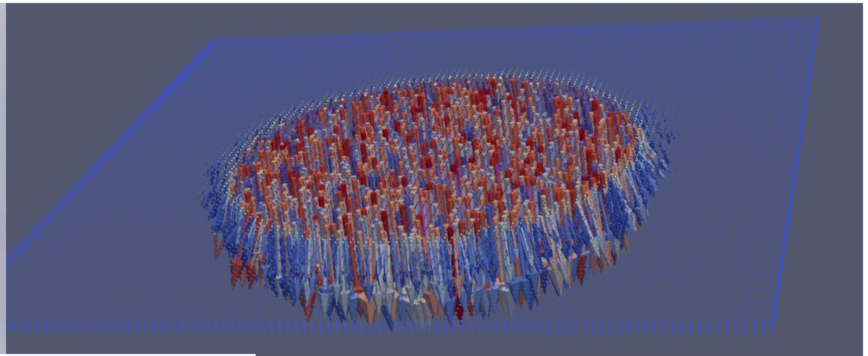


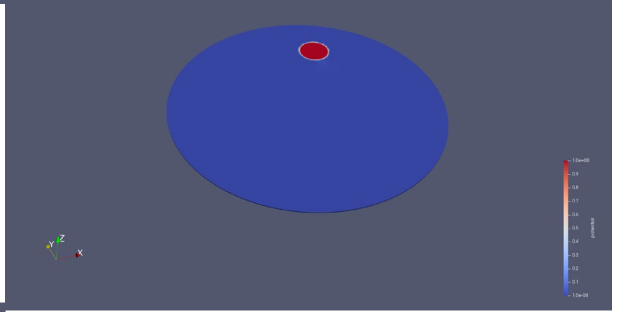
Sapphire 192-strip
(Jun. 23-today CERN)



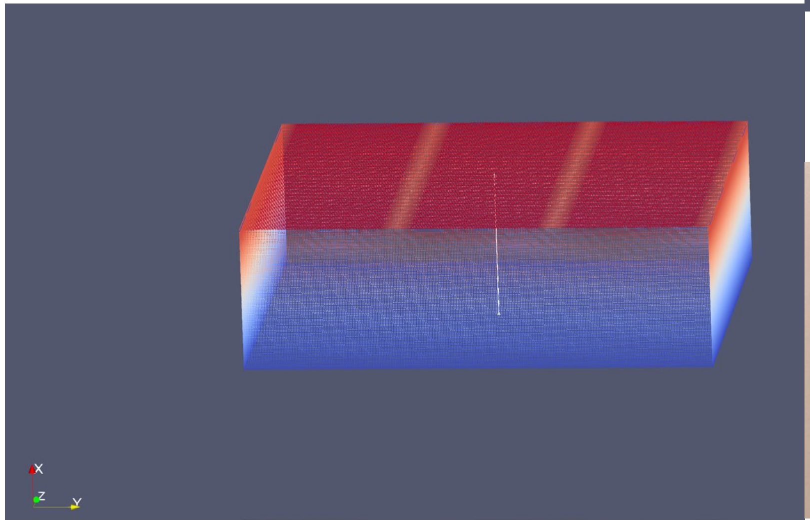


Examples with Allpix2





Sapphire pads *(May 22)*
Simulation for test beam at *INFN-Frascati*
Two sapphire pads (d=1.6, 5.5 mm) of thickness 110um, 150um



Sapphire strip detector LUXE
Simulation for test beam at *CERN* of the LUXE 192-strip prototype

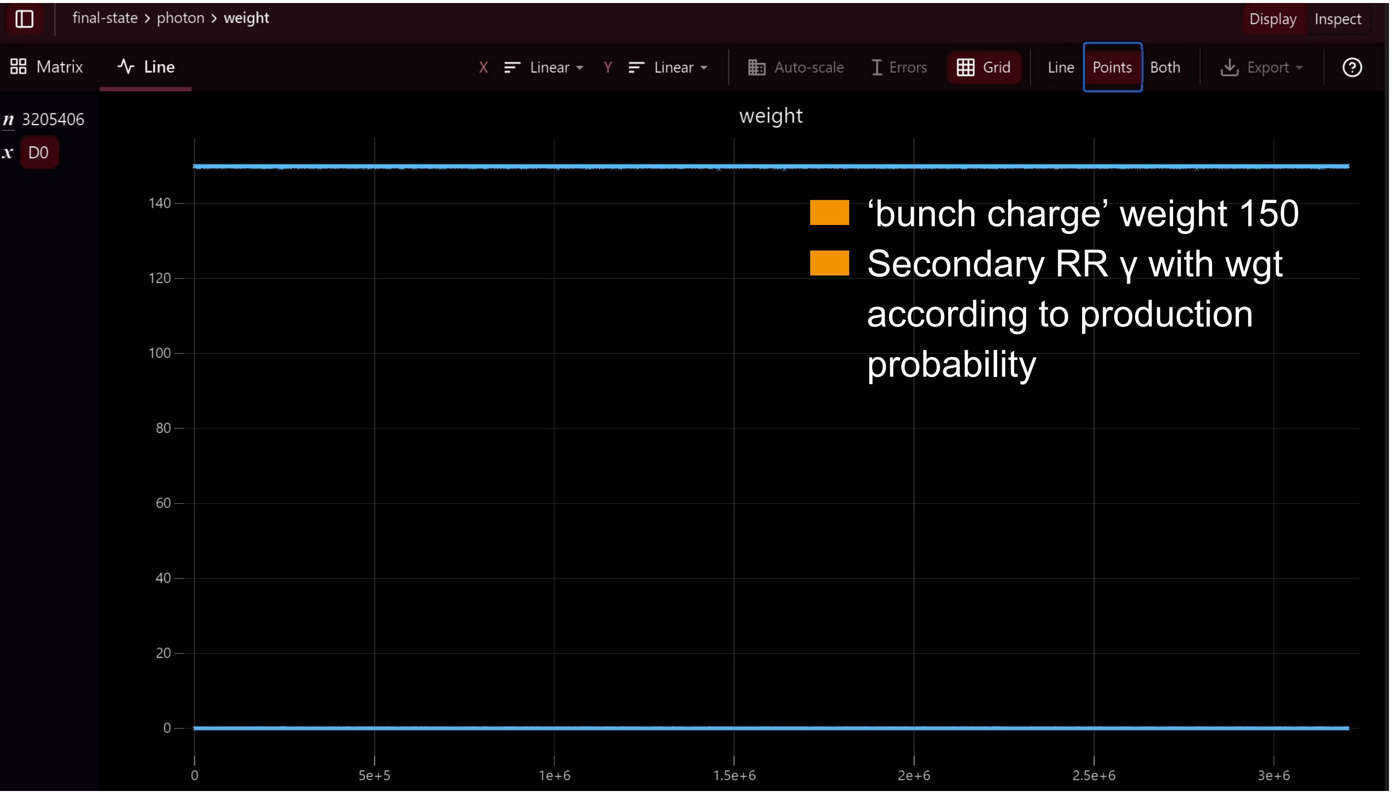
GBP with a YAG:Ce

- Detailed knowledge of the beam shape is required for test with CLEAR electron beam.
- A scintillator screen equipped with a camera has been used. This seems a promising backup solution for the GBP in case sapphire won’t work as predicted.
- A branch of the StandaloneGBP Geant4 simulation has been created with a single station equipped with a 100um YAG:Ce screen and a camera. A converter, represented by 1mm of tungsten is used to generate electron/positron pairs enhancing the scintillation light produced in YAG.
- Work is progress

backup

Compton’s energy spectrum

LMA (July) $\xi = 5$
Ptarmigan weight



- ‘bunch charge’ weight 150
- Secondary RR γ with wgt according to production probability