LUXE Photon Detection System Background Analysis and Gamma Ray Measurements

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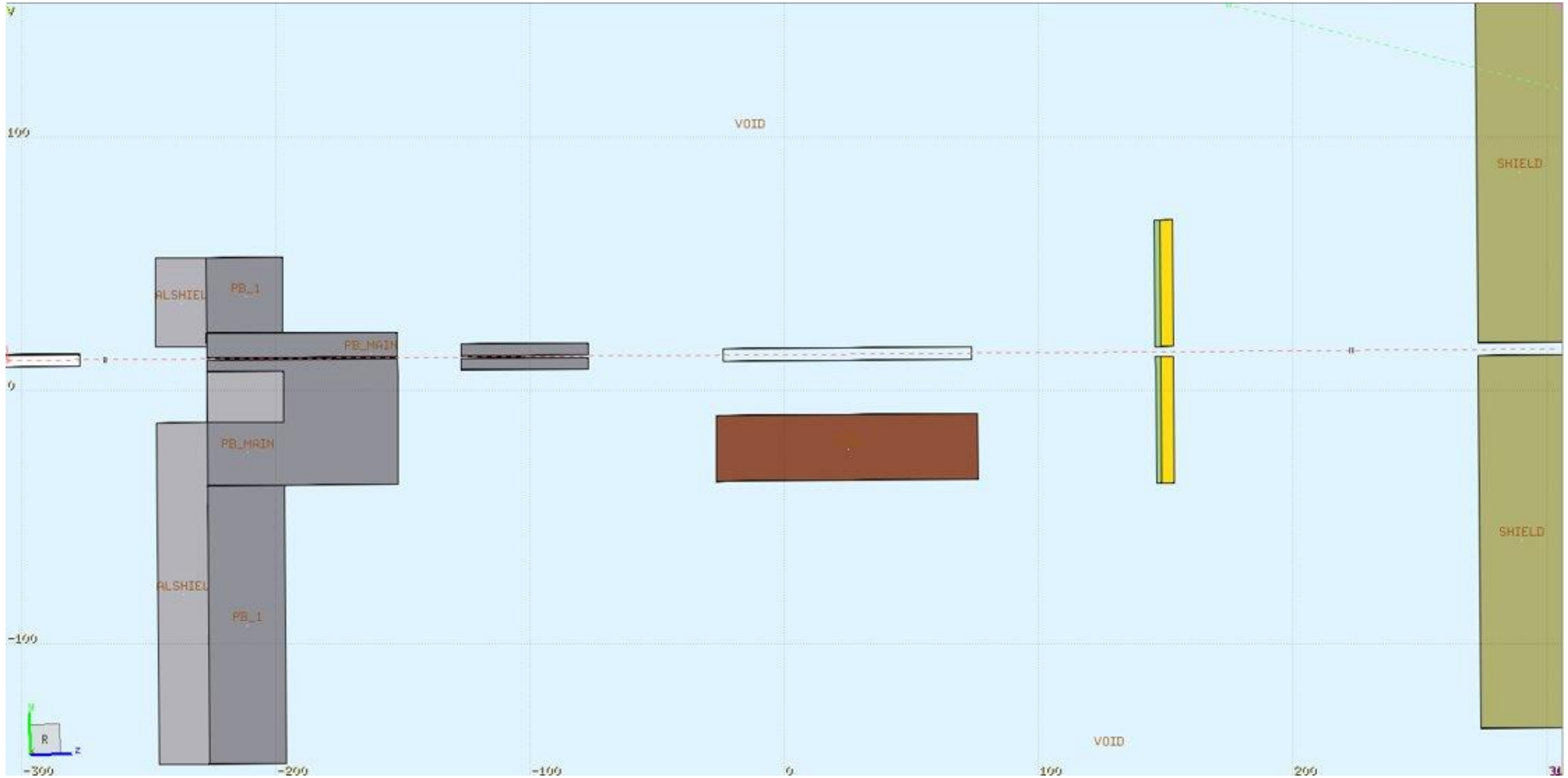
Background Simulations for Profiler

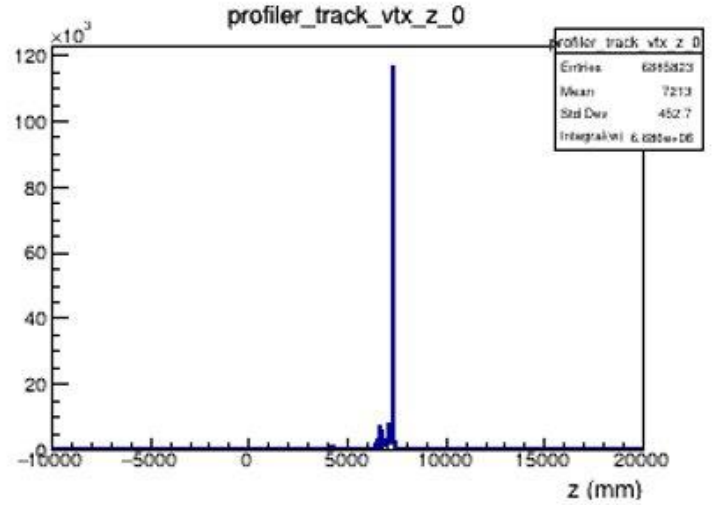
- FLUKA simulations for effect of background from electron beam on profiler previously run for low statistics (1.e5 primaries)
- Higher statistics simulations currently running for comparison checks
- GEANT4 MC now includes the 4 profiler plates – two pairs; front and rear
- Profilers extend from –50.0 mm to 50.0 mm in x and y; actual profiler size can be determined by restriction –10.0 mm to 10.0 mm
- Background for 0.1855 BX
- For profilers, sapphire (Al2O3) composition
  - Density = 3.98 g/cm**3
  - Pixel volume = 20.0cm/nx * 20.0cm/ny * 0.01 cm (nx, ny = no. bins in x, y resp.)
  - Dose conversion factor: GeV/g -> Gy = 1.60e-7

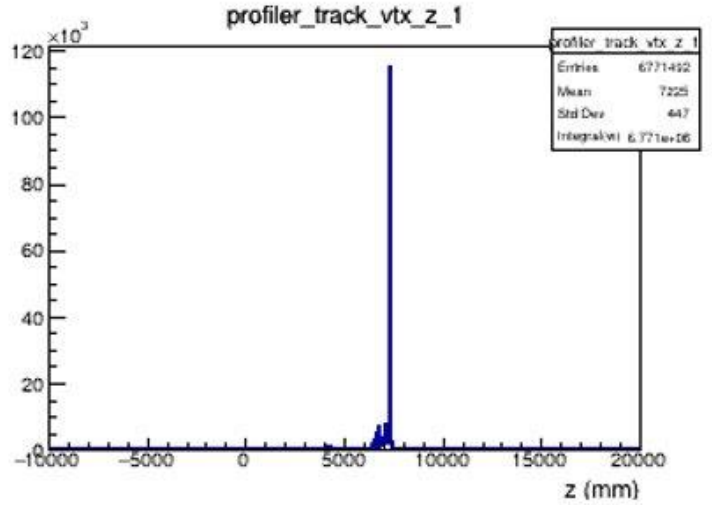
PDS Geometry (FLUKA)

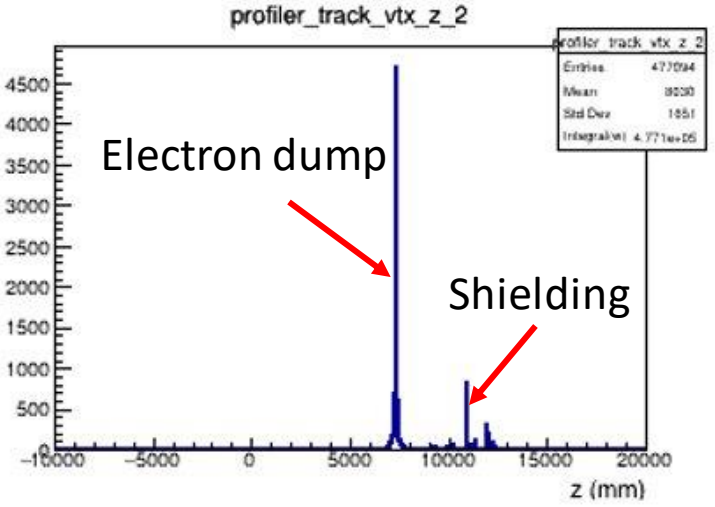


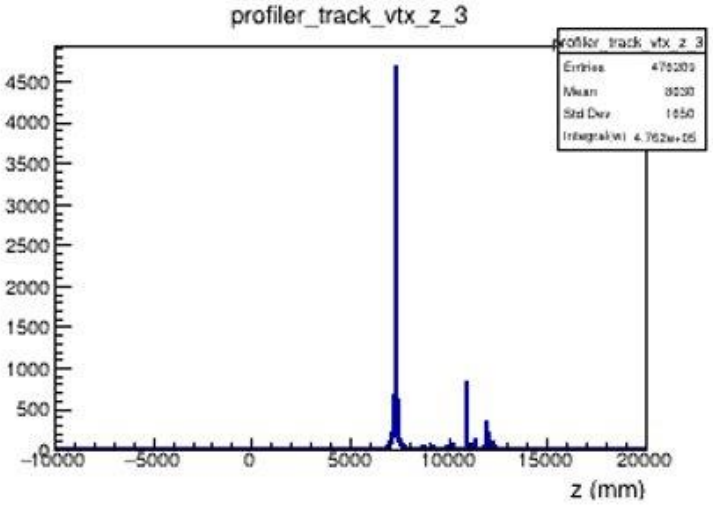
- Profiler locations indicated by red arrows
- Magnet region marked by orange dashed box
- "VOID" is air environment
- Geometry simplified in comparison to full GEANT4 geometry e.g. no supports, simplified electron dump, simplified LANEX screens (green) and Cerenkov detector (yellow)

Background Sources



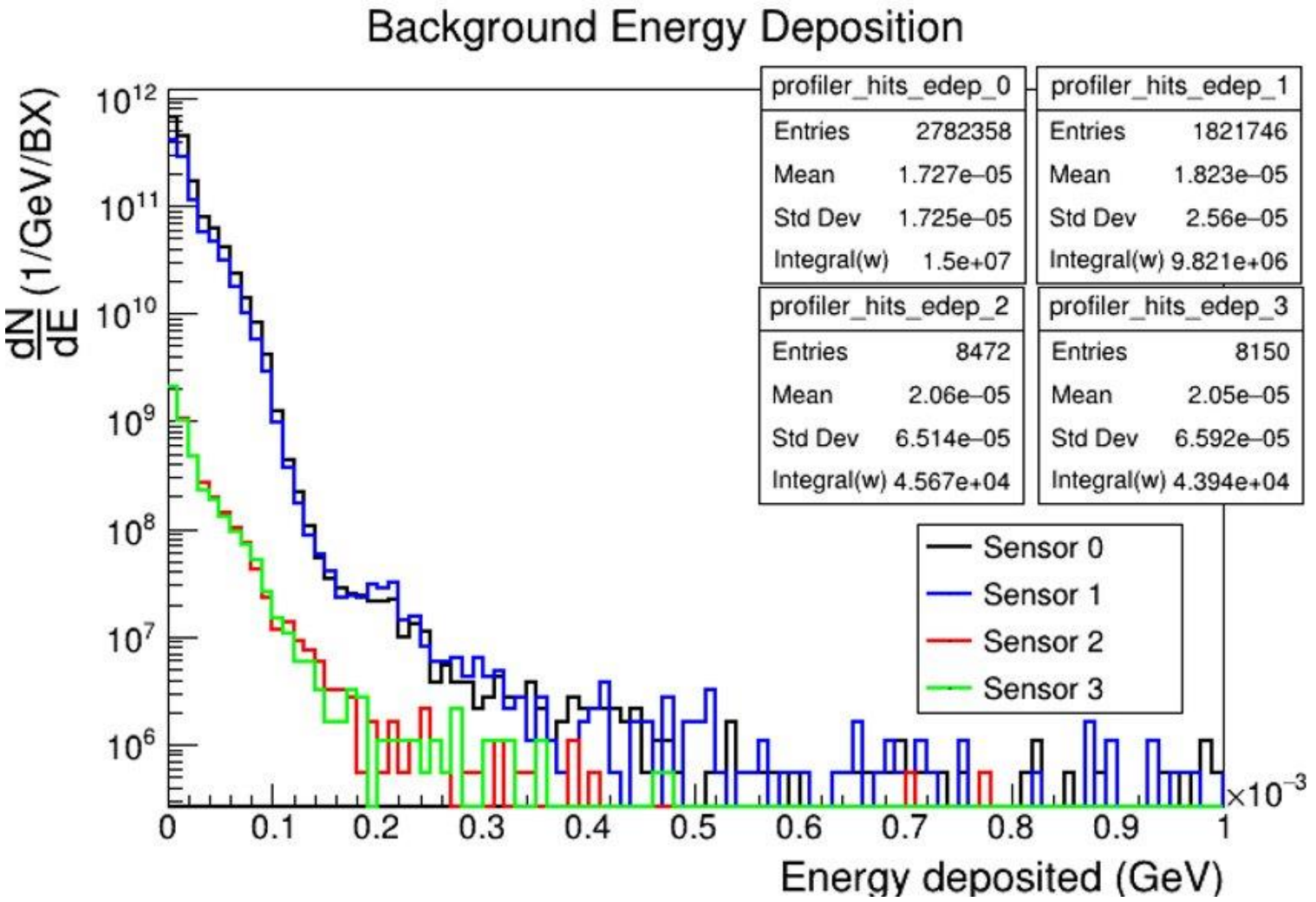






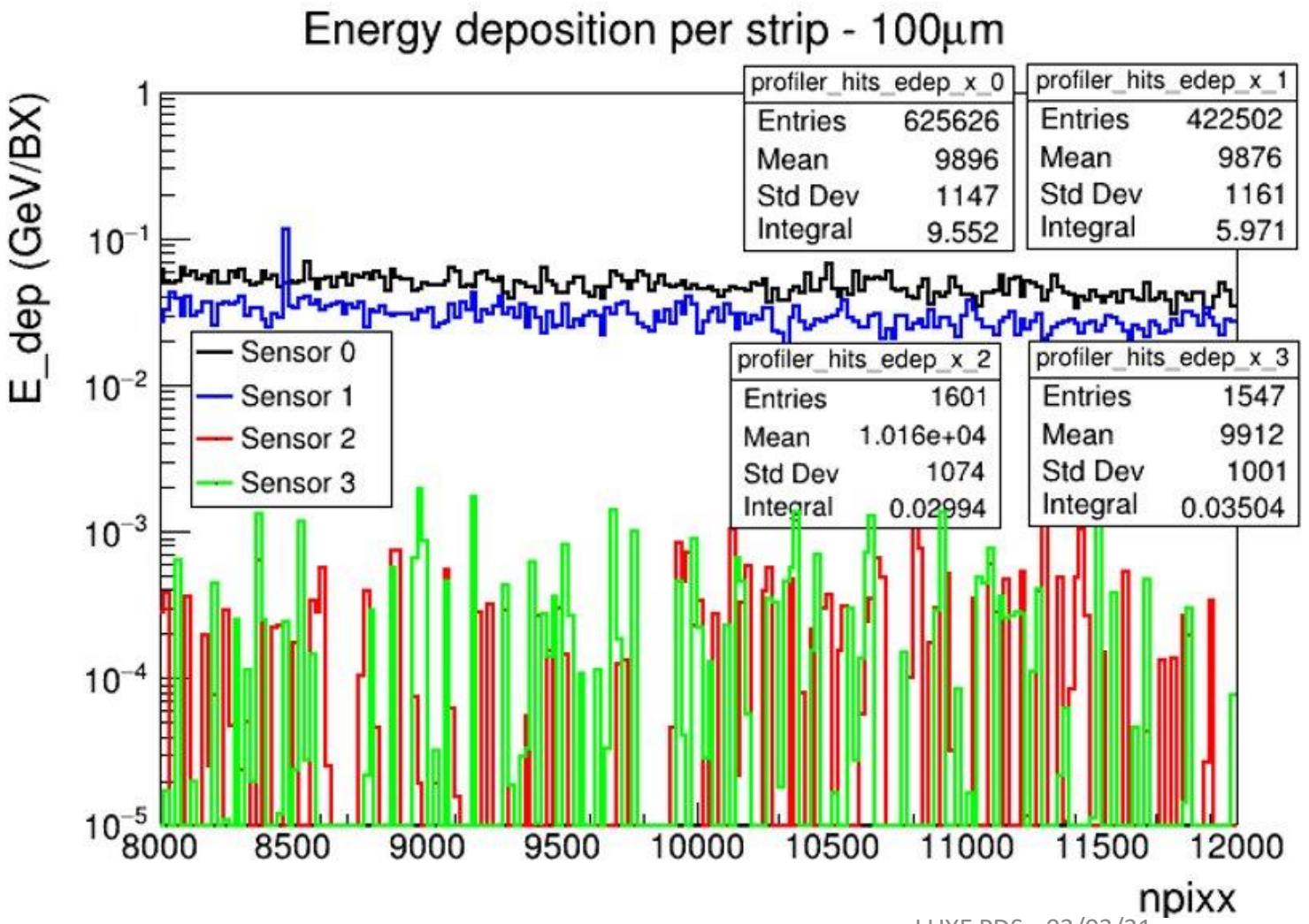
- Plots showing z production vertex of particles incident on profilers
- Main component of background comes from z = 7000mm -> electron beam dump
- Rear profiler pair also see some backscattering from shielding at z = 12000mm

Energy Distribution of Noise



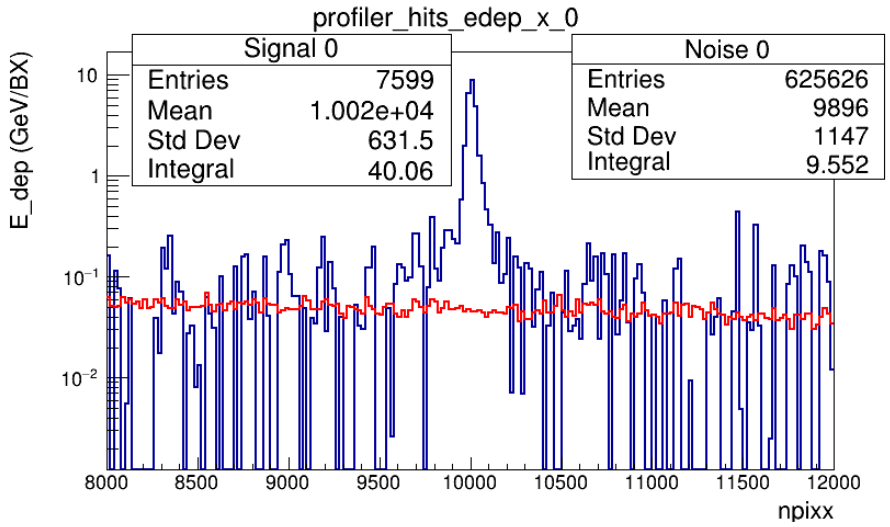
- For all detectors, large number of particles which deposit low amount of energy (E<0.2 MeV)
- Total number of hits given by value "Integral(w)"

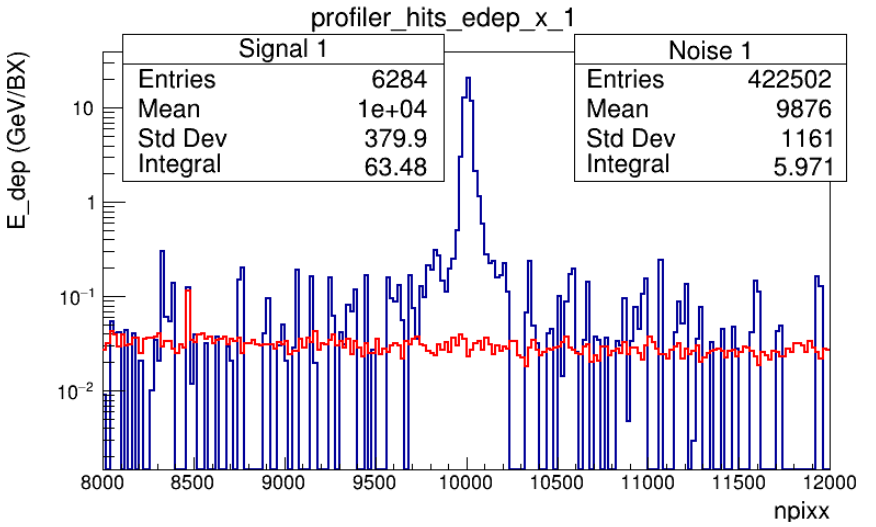
Energy Deposited in Profiler

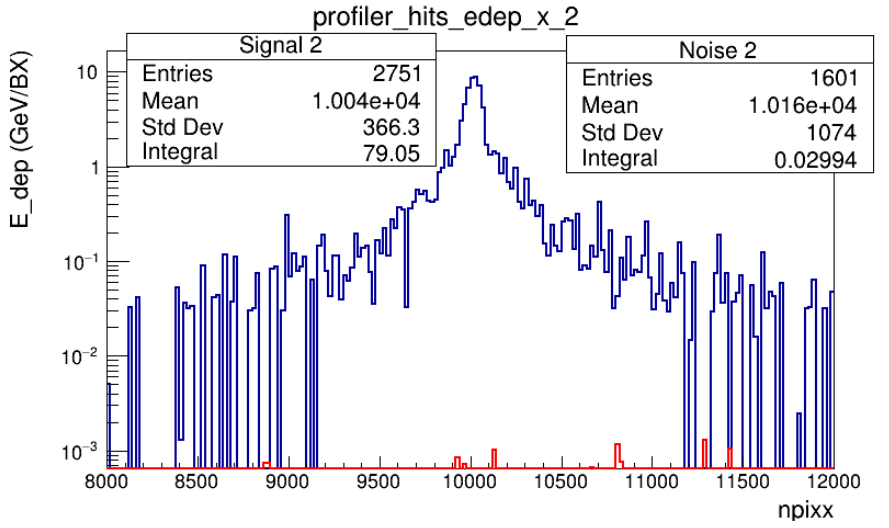


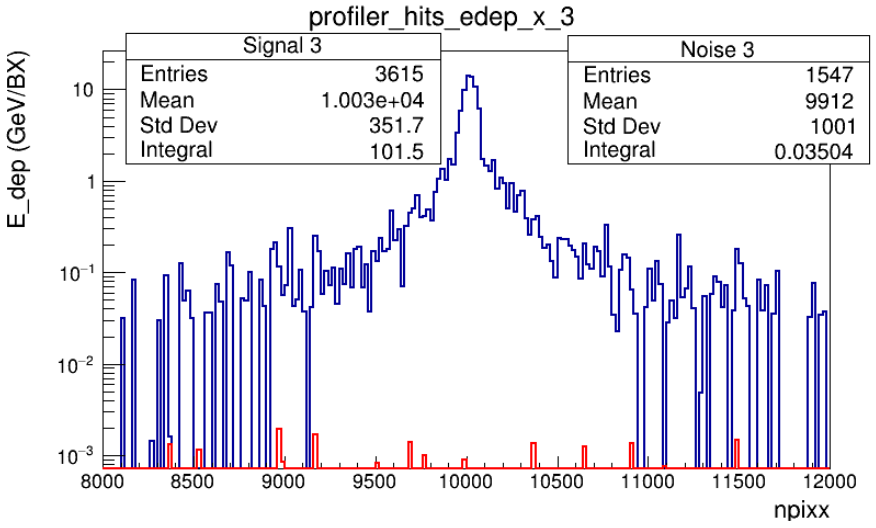
- Npixx range from 8000 to 12000 corresponds to spatial range –10.0mm to 10.0mm with 200 bins
- For forward pair, energy deposition is uniform across strips with Edep ~ 0.05 GeV/BX
- Rear profiler pair has energy deposition ~0.0001 GeV/BX
- Total energy deposited over all strips is given by integral value in GeV/BX

S/B Comparison









- S/B ratio > 10 between npixx = 9800 and 10200 for front profilers
- Corresponds to a spatial range of ±1 mm
- S/B ratio > 2 between 9500 and 10500 -> spatial range ±2.5 mm
- S/B ratio > 500 across entire detector for rear profiler pair
- Higher S/B ratio at front profilers due to proximity to electron dump

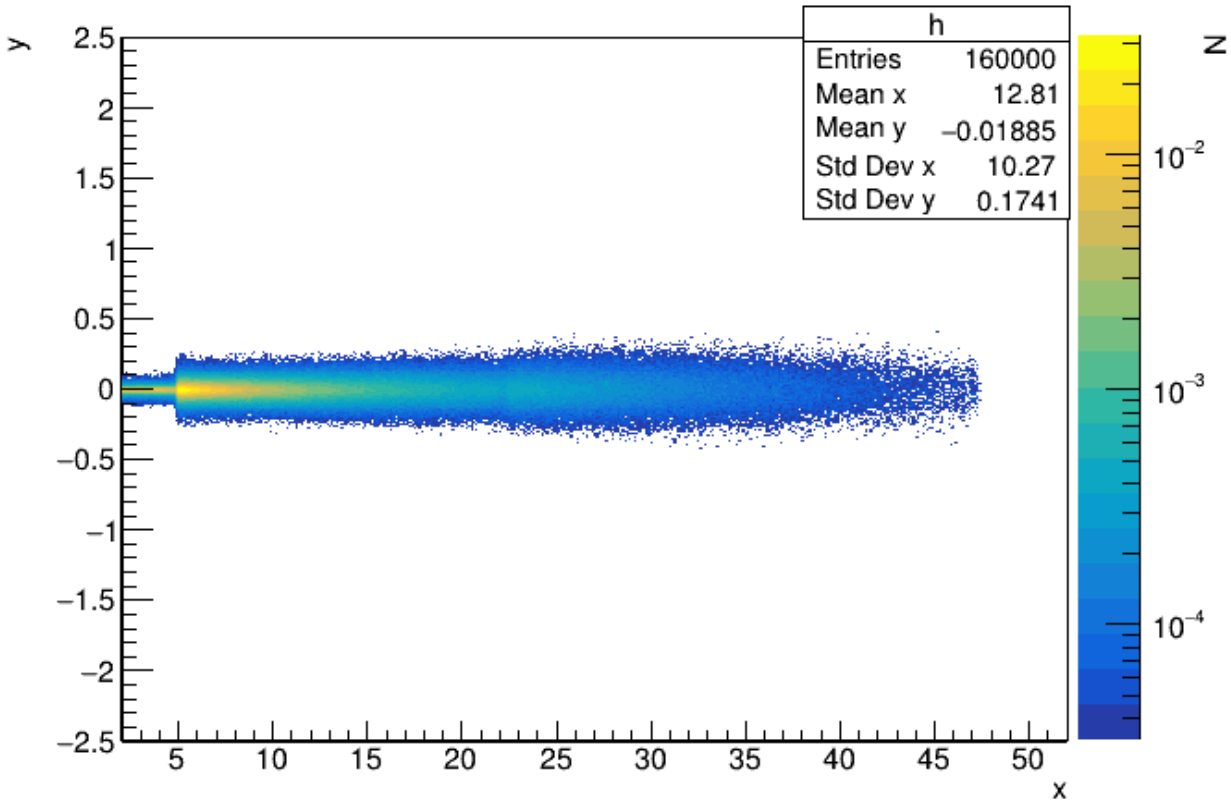
Reconstruction of Double-differential Photon Spectrum

- Adaption of the (energy) spectral deconvolution to the 2D electron signal taken from the LANEX detector to determine the angular distribution of the incident photons
- Angular and spectral components can be combined to give double differential
- Key assumption – in the ultrarelativistic limit, the pair-produced electron has a divergence given by

$$\theta_e^2 \simeq \theta_\gamma^2 + \frac{1}{\gamma_e^2}$$

Reconstruction Method

- From 2D electron distribution in energy-angle space, consider electrons of highest energy Emax
- These electrons produced by photons of equal energy
- Measure divergence of electrons with this energy and calculate the photon divergence
- Generate the electron response to a monoenergetic photon beam with fixed divergence from calculation
- Subtract response from signal and repeat for next highest energy

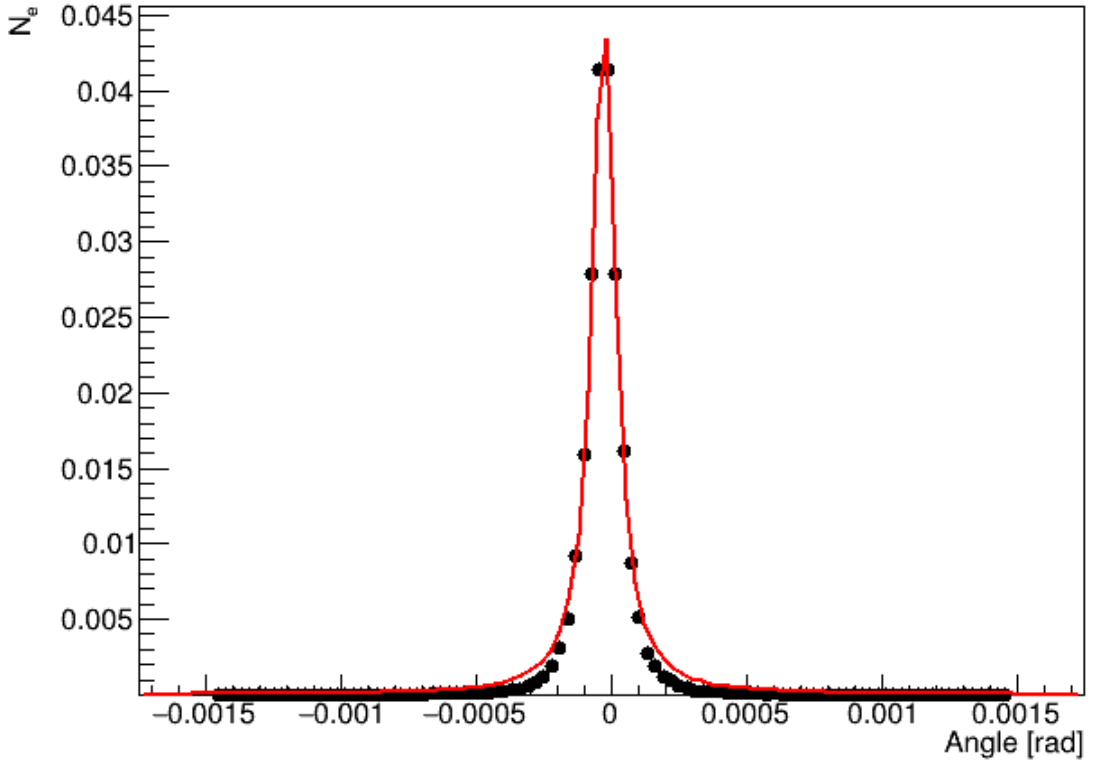


Estimation of electron divergence

- Electron divergence assumed to be given by

$$\theta_e^2 = \theta_\gamma^2 + \frac{1}{\gamma_e^2} \Rightarrow \frac{1}{\theta_e^2} = \frac{1}{1/\gamma_e^2}\left[\frac{1}{1+\left(\frac{\theta_\gamma}{1/\gamma_e}\right)^2}\right]$$

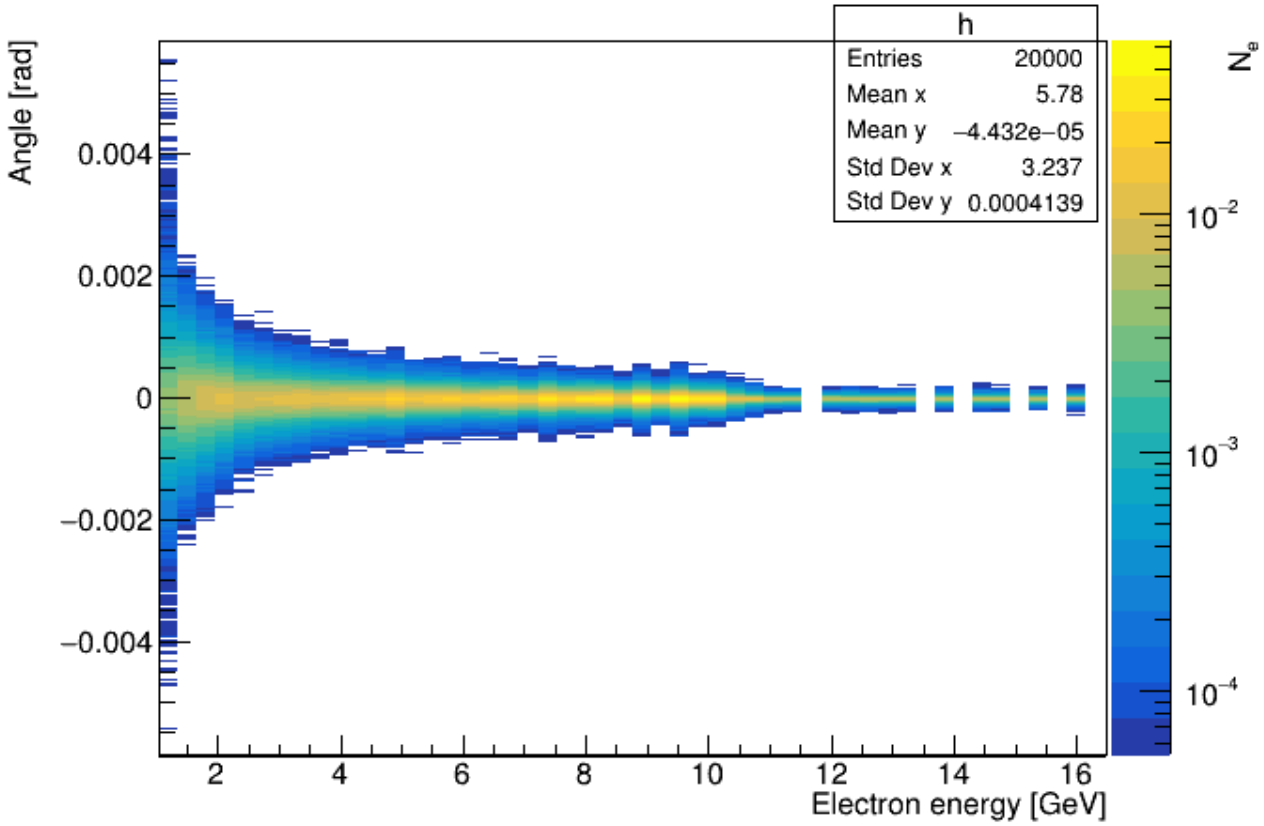
- Reciprocal squared angle is Cauchy-Lorentz distributed – inverse distribution is also Cauchy-Lorentz
- From electron signal, take an energy slice and fit to Cauchy-Lorentz function
- Electron divergence given by FWHM of distribution



$$f(x; x_0, \gamma) = \frac{A}{\pi\gamma}\left[\frac{\gamma^2}{\gamma^2 + (x - x_0)^2}\right]$$

Generation of Response

- For a given photon divergence (assumed to be fixed), electron divergence can be calculated across all energies
- Each slice of response is generated by a Cauchy-Lorentz function
  - FWHM given by calculated electron divergence
  - Amplitude given by number of electrons in current energy bin – requires correct normalisation of distribution and knowledge of spectral deconvolution

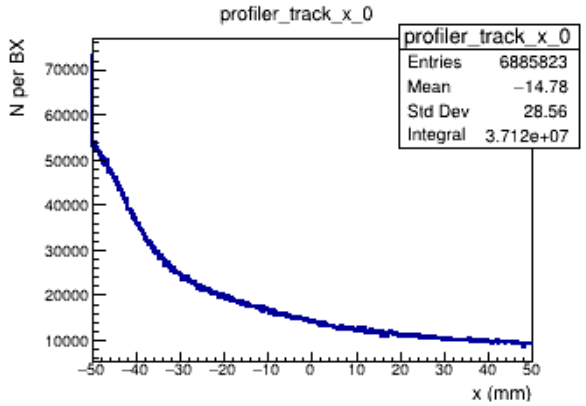


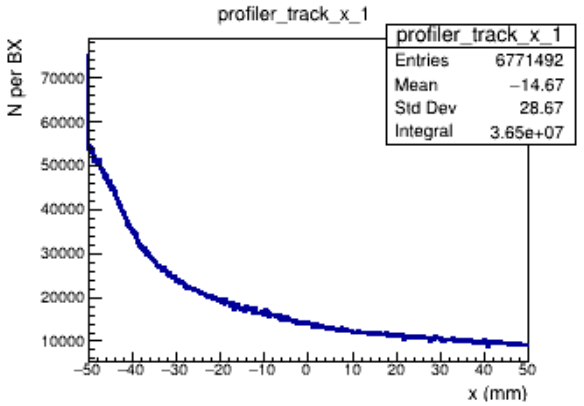
Summary

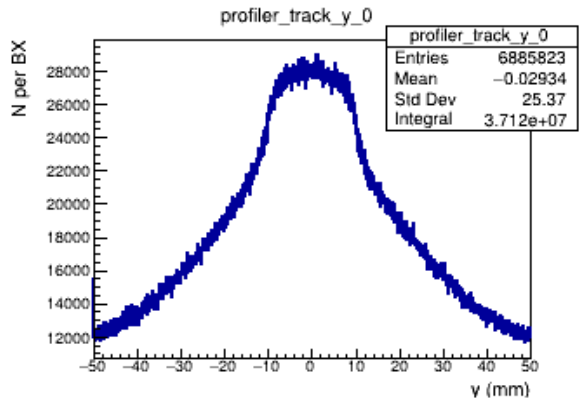
- Background analysis on profiler
  - Largest contribution to noise comes from electron dump; for rear profilers, backscattering from shielding also contributes
  - Energy deposition from noise is low, < 0.2 MeV, which is much less than that expected from the signal, ~10.0 GeV
  - S/B ratio is >2 across central 2mm of forward detectors; rear detectors have S/B > 500 across entire plane
- Angular deconvolution
  - Adapted algorithm to the 2D electron signal is being tested to reconstruct angular distribution of incident photons
  - Currently in the process of running first tests

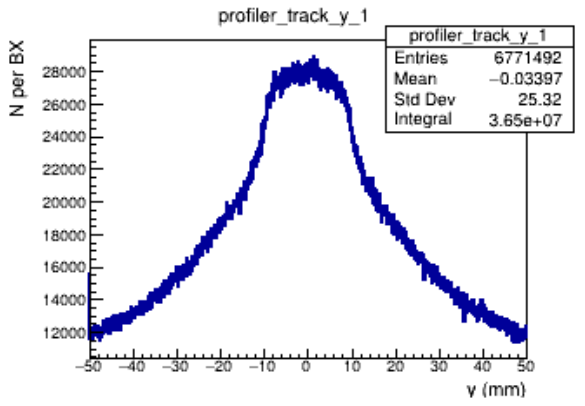
Backup

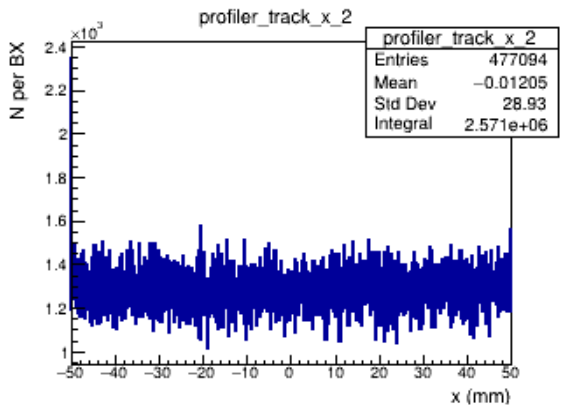
GBP – Tracks Profiles

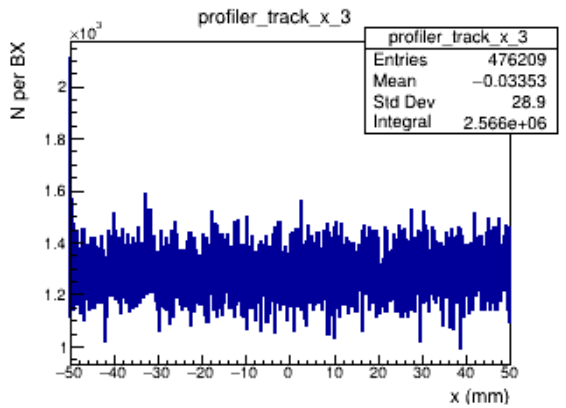


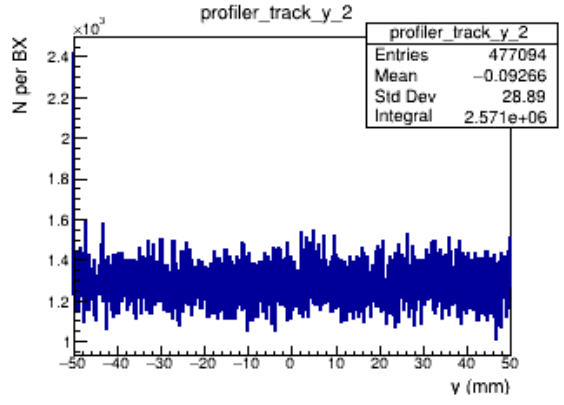


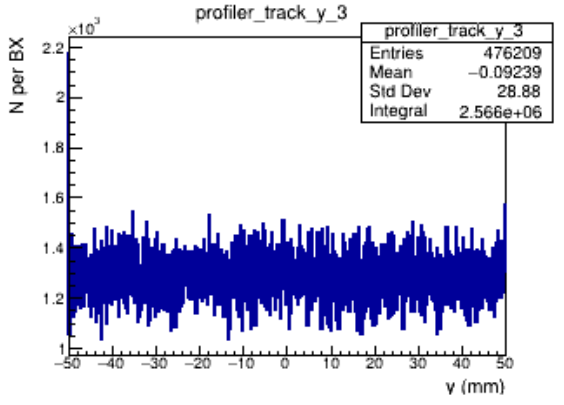












GBP- Background Dose Rates