

GBP-MC Simulation Update

Kyle Fleck, Niall Cavanagh and Dr. Gianluca Sarri

12/04/21

Fitting Data

- Standard function for fitting is a Gaussian

$$f(x) = A \exp \left[-\frac{(x - \mu)^2}{2\sigma^2} \right]$$

- Another possibility is a Cauchy-Lorentz distribution – similar to Gaussian but sharper peak

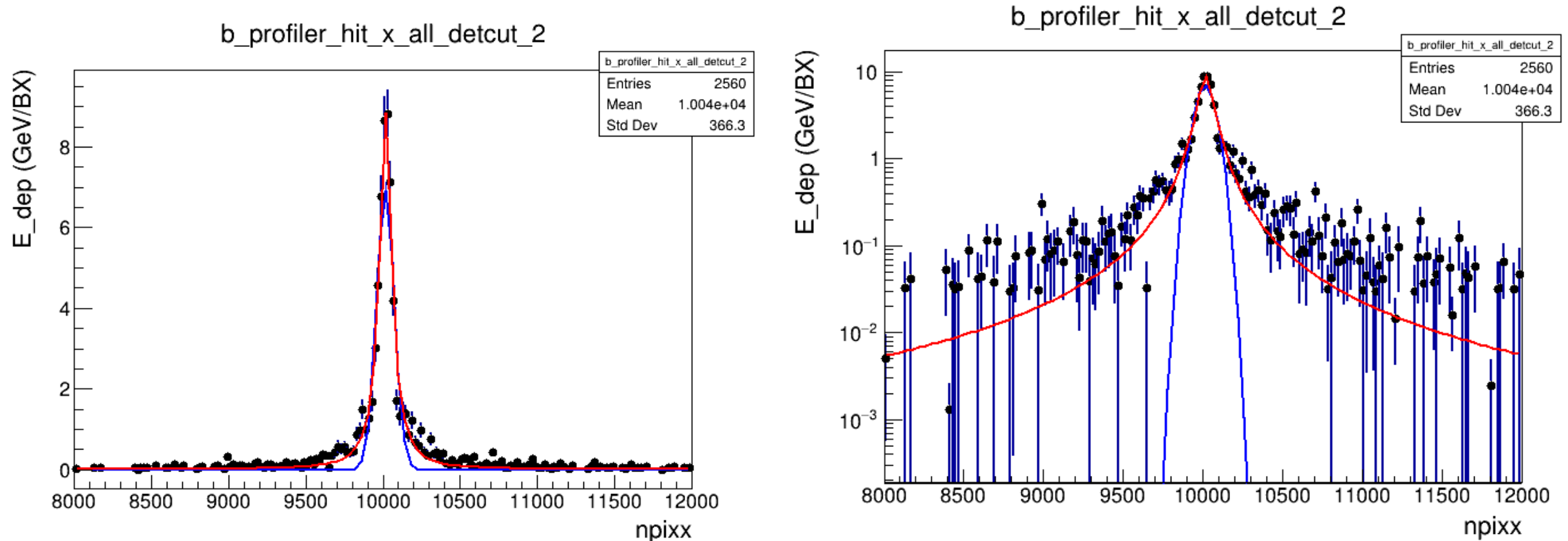
$$f(x) = \frac{A}{1 + \left(\frac{x - x_0}{\gamma} \right)^2}$$

- Positional parameters: μ for Gaussian (mean) and x_0 for CL
- Dispersion parameter: σ for Gaussian (standard deviation) and γ for CL -> related to FWHM

$$FWHM = 2\sigma\sqrt{2\ln 2}$$

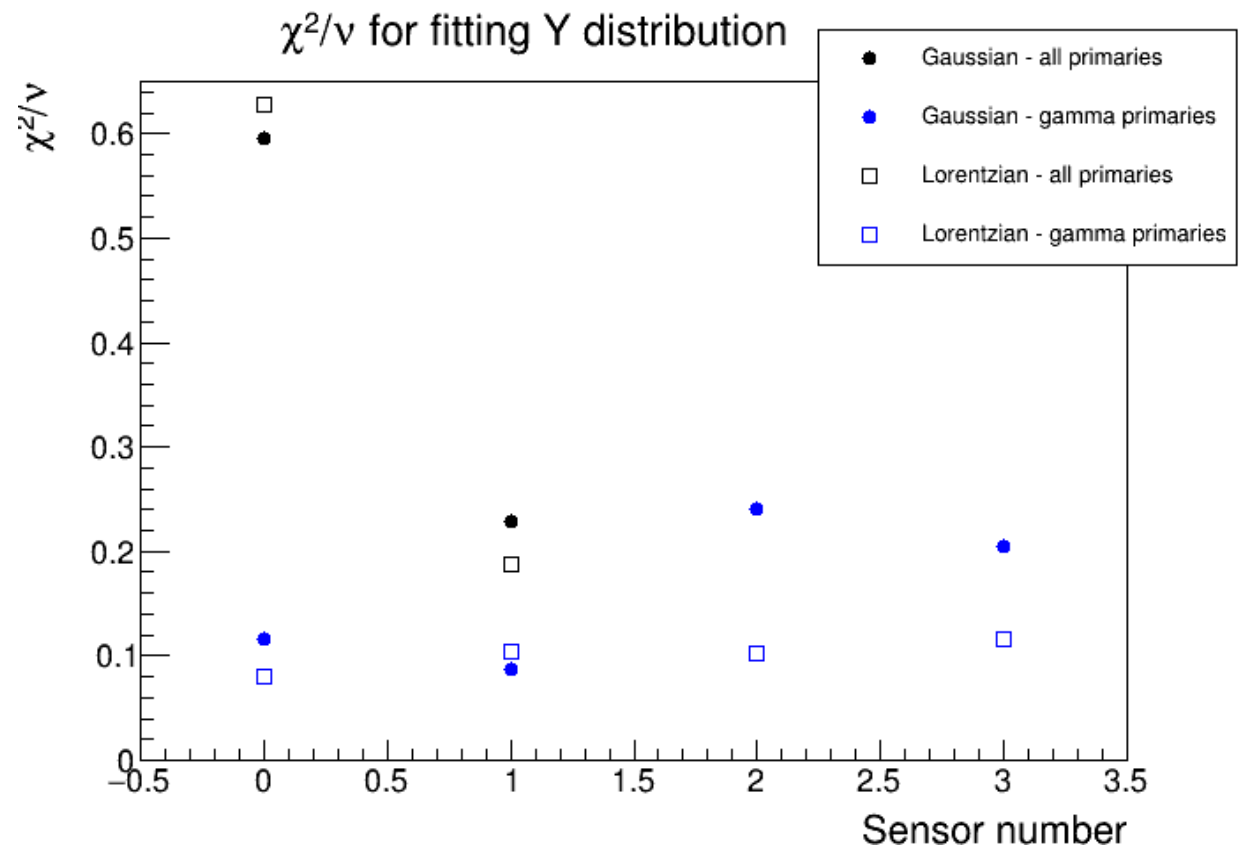
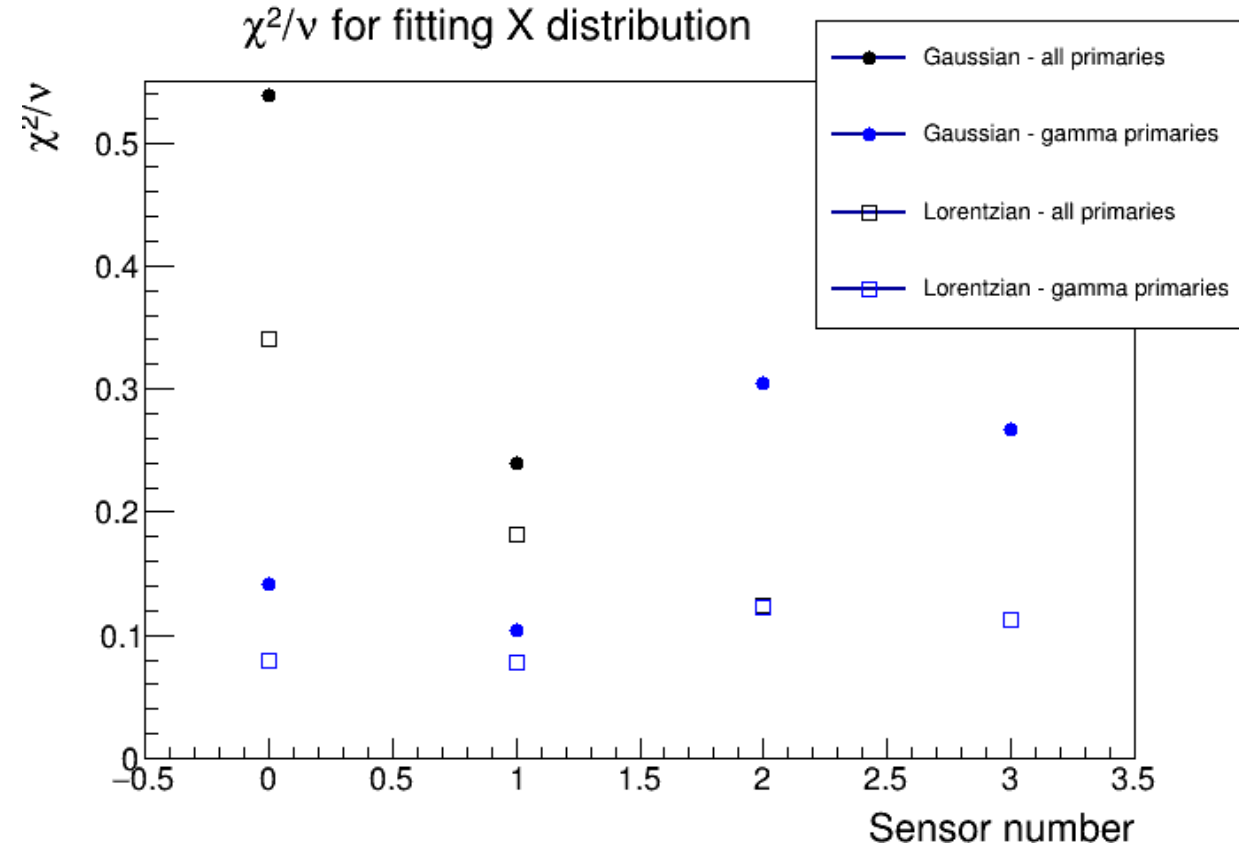
$$FWHM = 2\gamma$$

Example of fitting

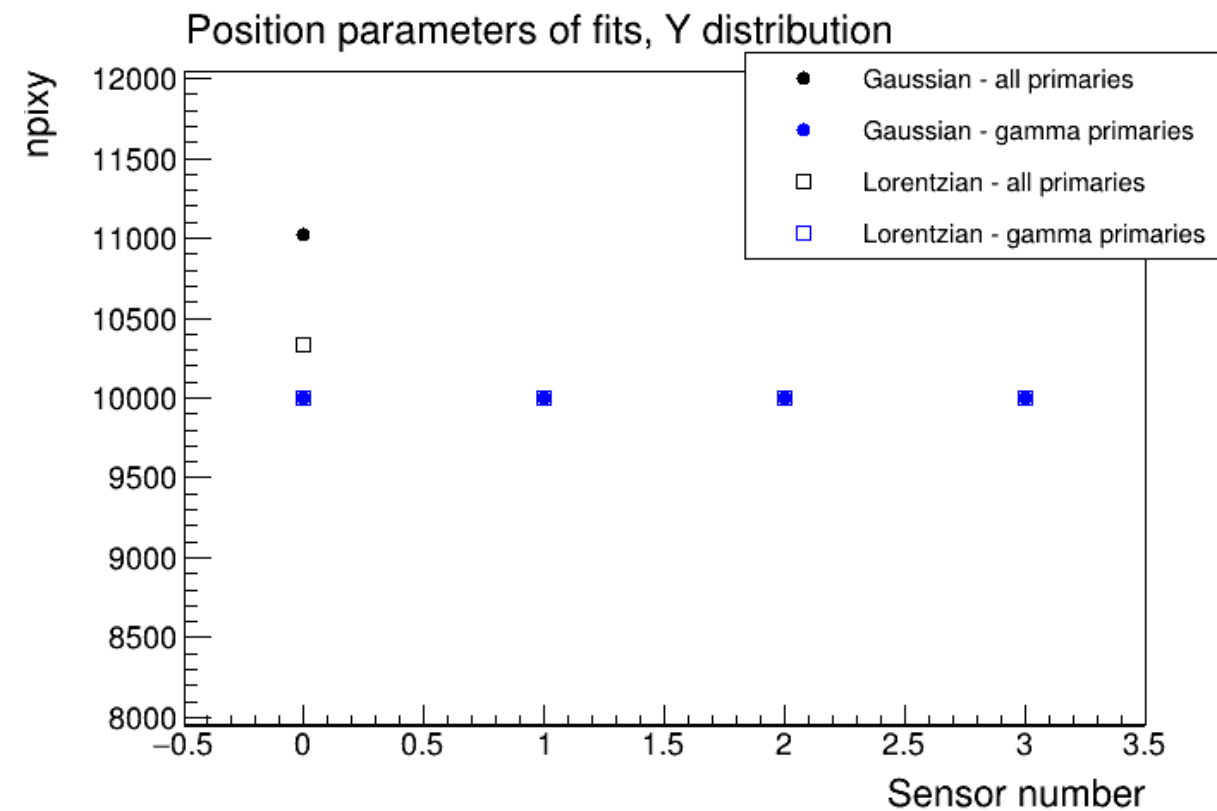
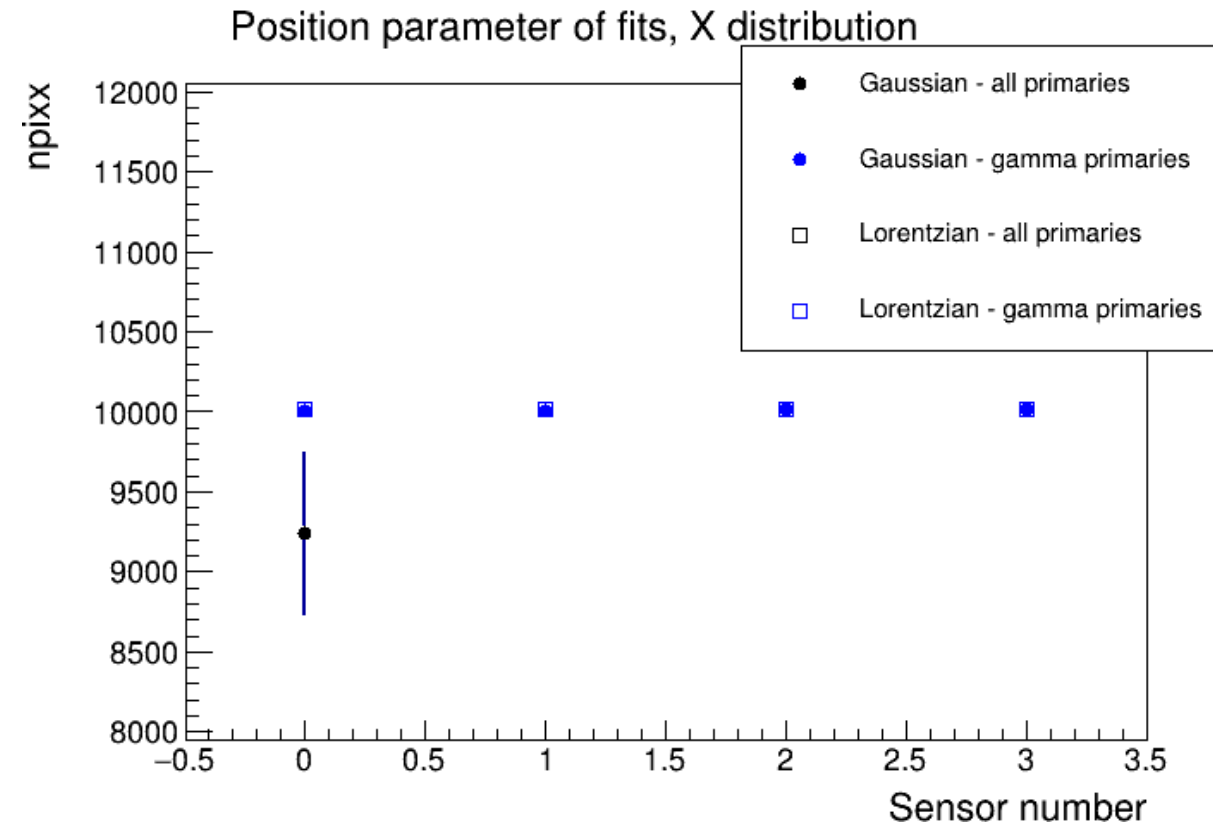


Cauchy-Lorentz
Gaussian

Comparison of goodness of fit

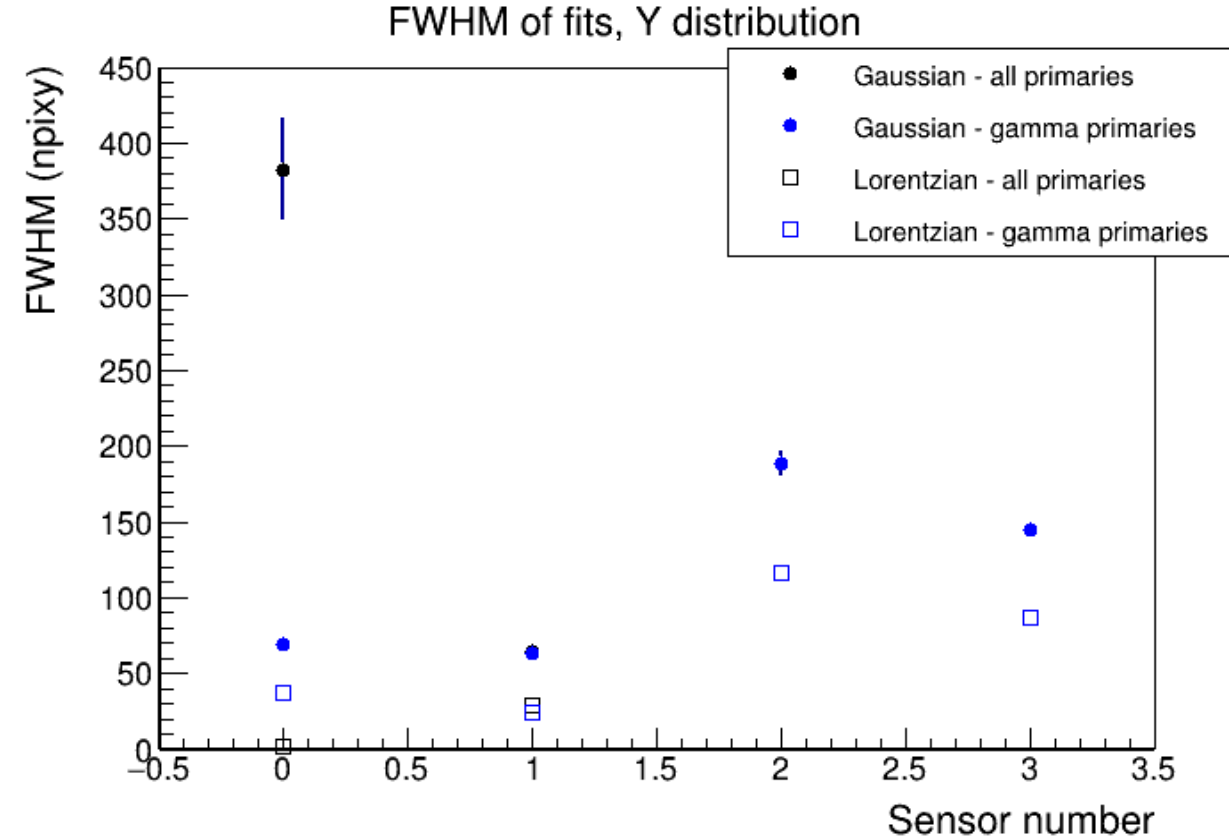
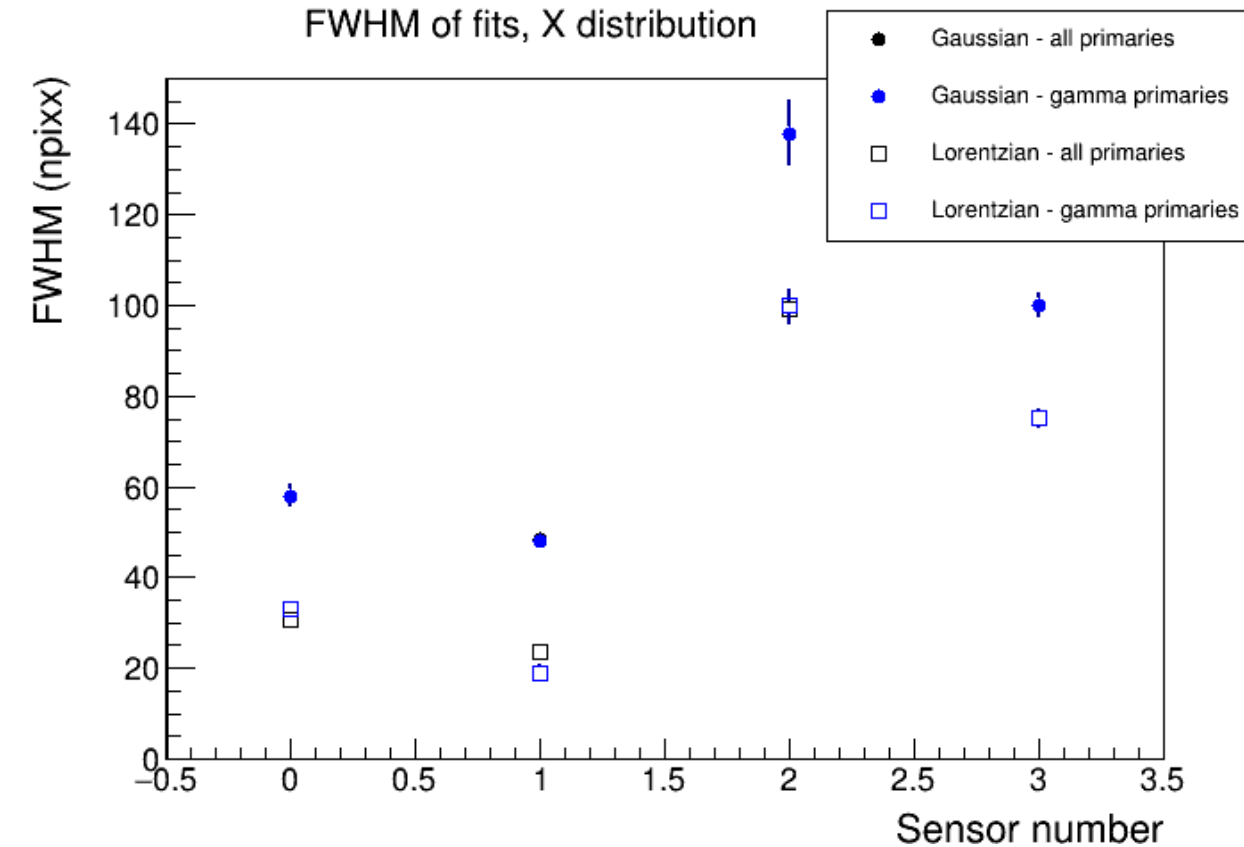


Location of centre of distributions



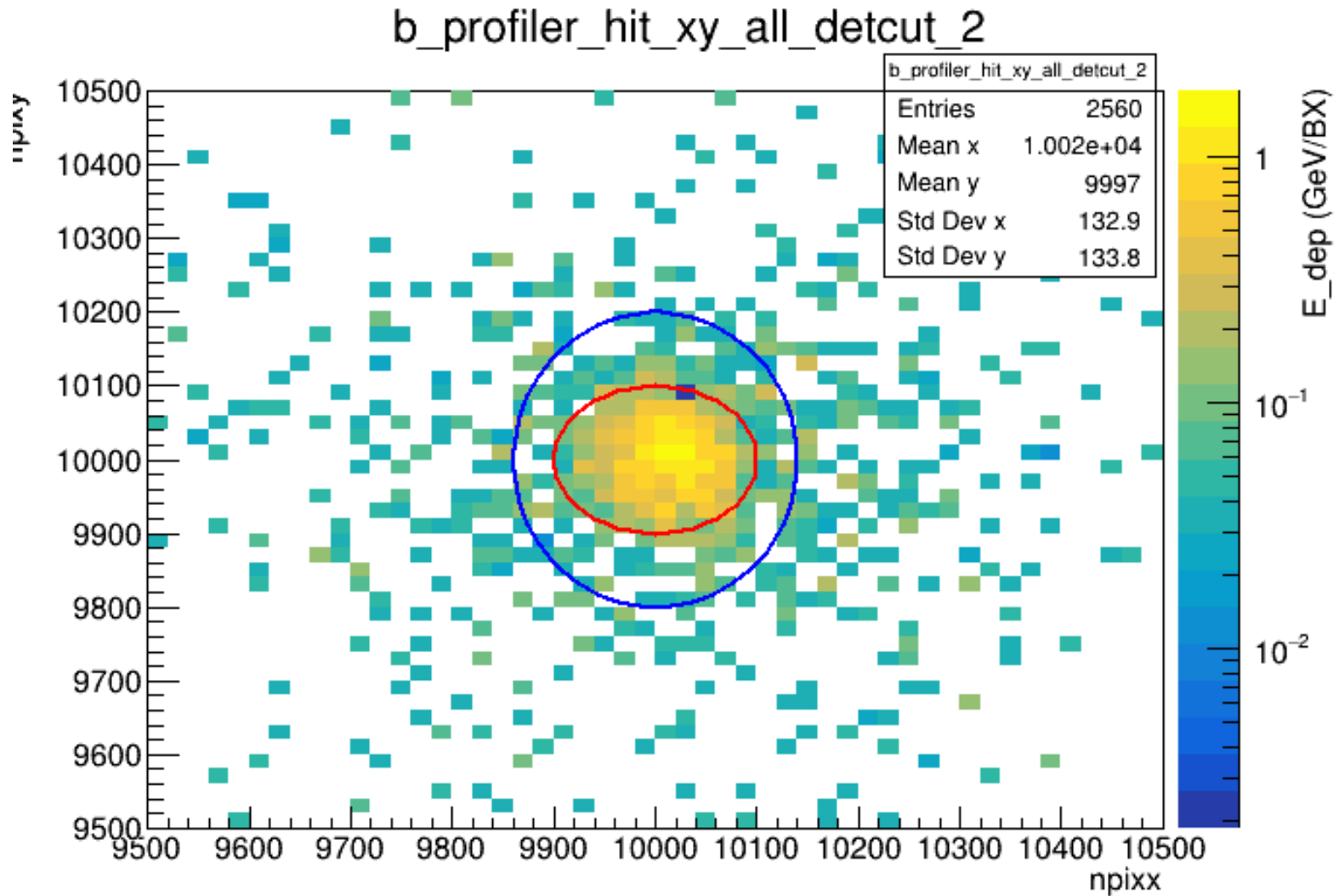
$$\text{npixx} = 200x[\text{mm}] + 10000$$

Spread of distributions



$$\Delta npixx = 200 \Delta x [\text{mm}]$$

2D Distribution



- 2D distribution of energy deposition on sensor 2 profiler – GEANT4 data
- Lines show the ellipses with radii given by appropriate FWHM from previous slide
- Red – Cauchy-Lorentz fit
- Blue – Gaussian fit

Summary

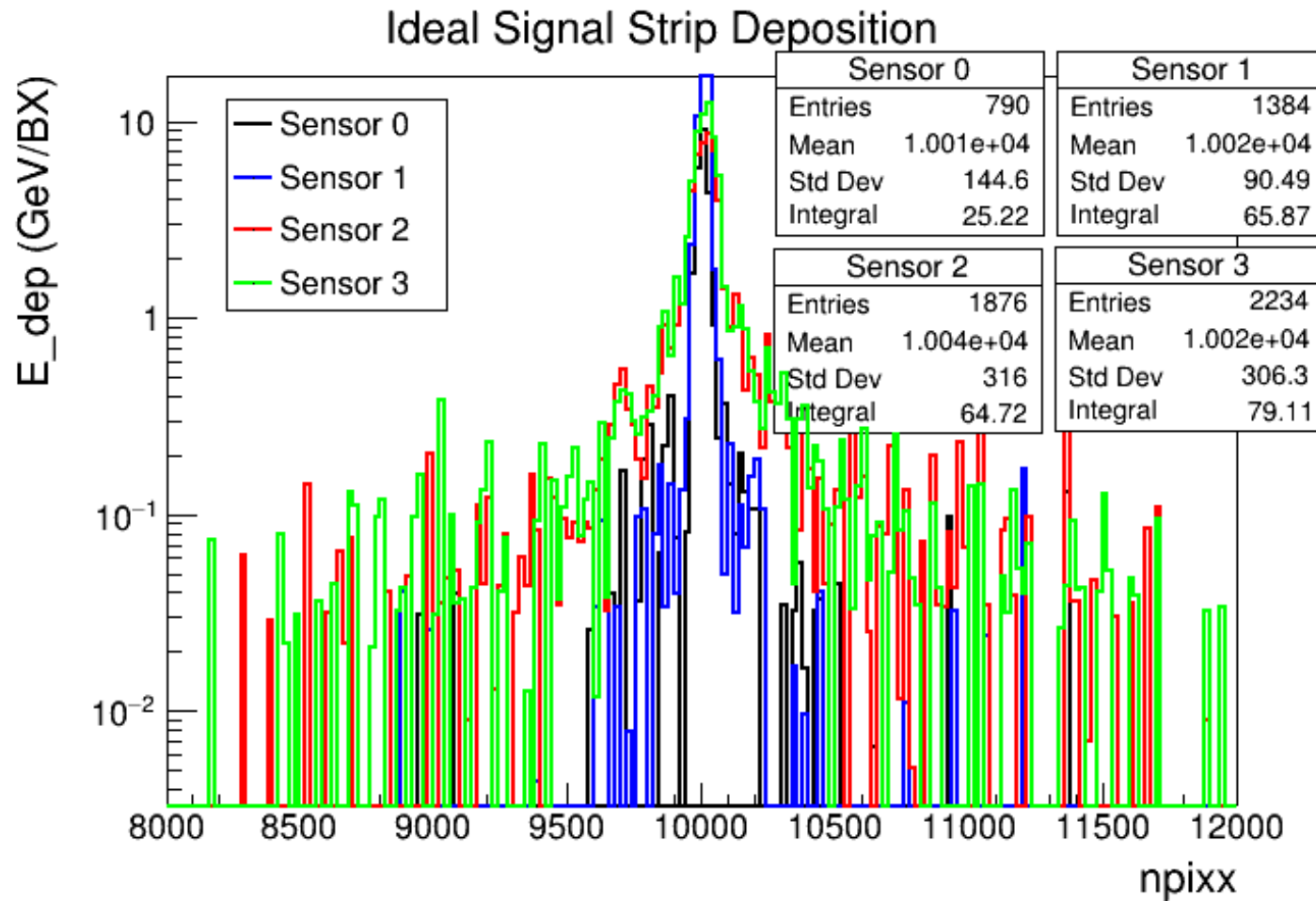
- Gaussian and Cauchy-Lorentz distributions can be used to estimate the FWHM and hence shape of the energy distribution from energy deposition measurement
- Cauchy-Lorentz gives a slightly better agreement to the shape
- Needs to be compared to the true photon distribution to determine overestimation
- FLUKA simulations for profilers of different thicknesses still running
- Effect of strip width in profiler can be done by rebinning histograms and re-running the fitting algorithm

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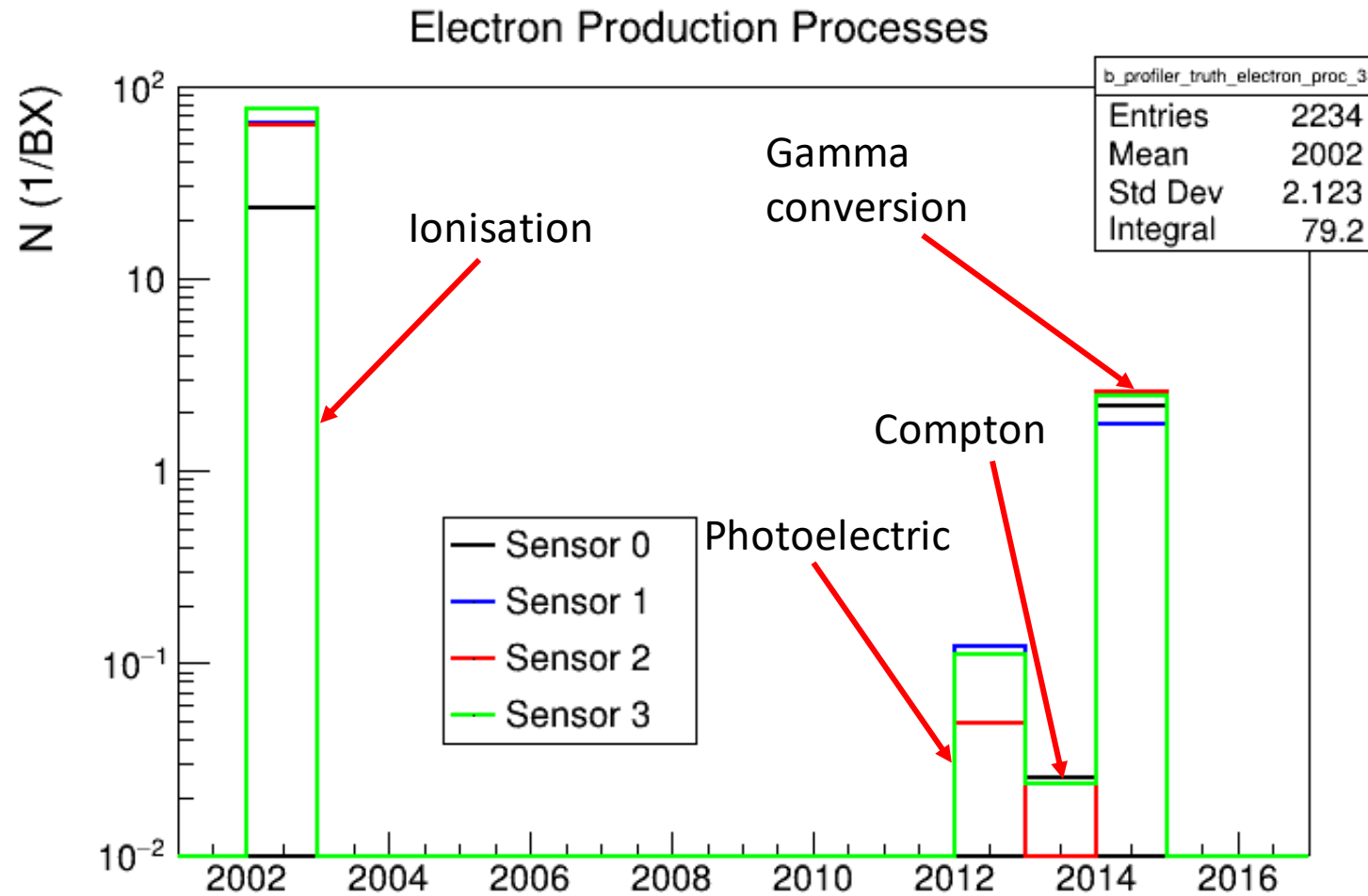
19/03/21

Truth signal



- 8000 – 12000 npixx corresponds to central -10.0 to 10.0 mm of profiler
- Range ~ 100 GeV across central ± 2.5 mm
- Conversion from npixx to mm – 1 npixx width = 0.005 mm

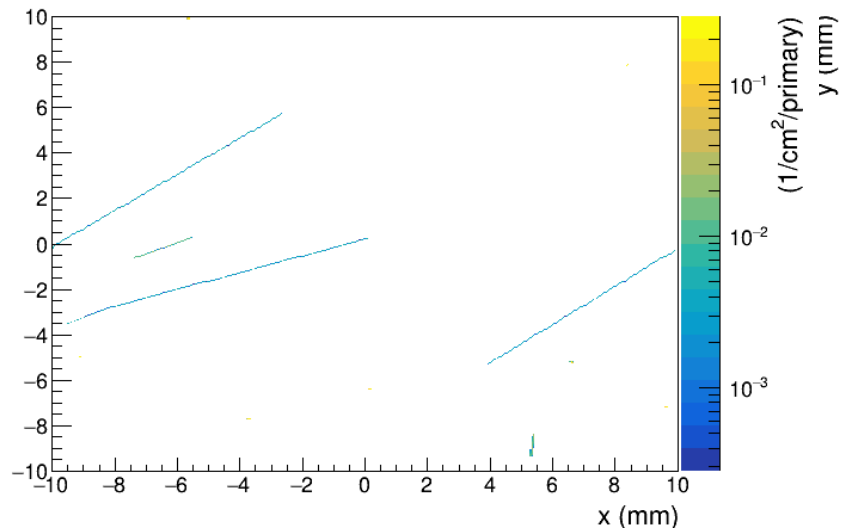
Electron production processes



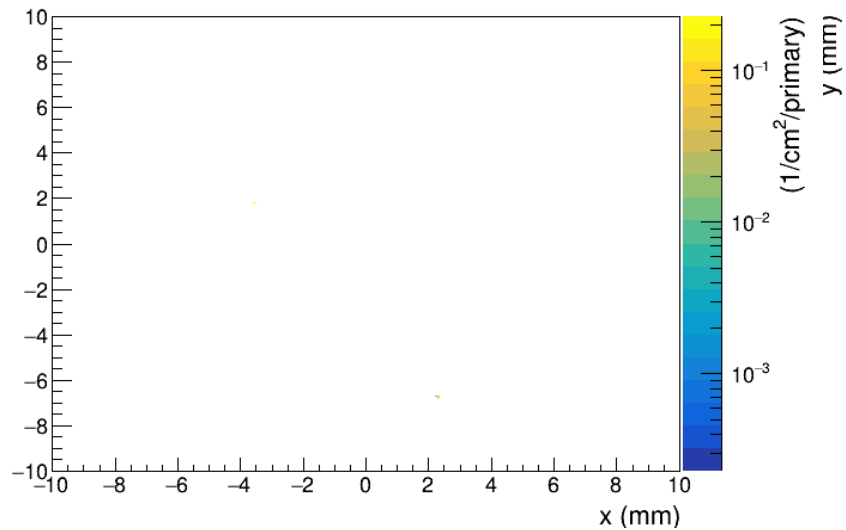
FLUKA background plots

- Previous results for background contained long (projected) particle tracks in plane of profiler – problematic for energy deposition
- Two causes of this phenomenon
 - Slight misalignment of magnetic field in FLUKA caused both vertical and horizontal deflection of electron beam
 - Difference in how beam dumping is handled in current FLUKA simulation compared to GEANT4
- First problem fixed – results shown on next slide
- Second problem requires more detailed adaptations to FLUKA geometry which affect background only, not the main signal simulations

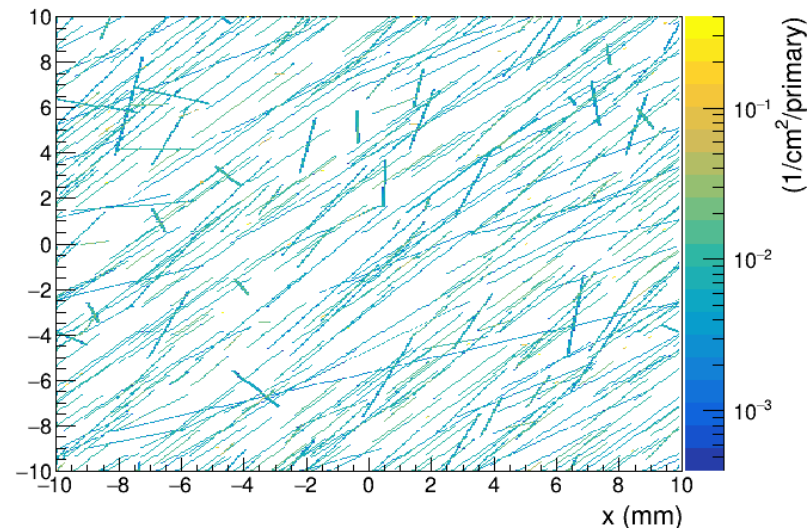
GBP sensor 0 background - electron



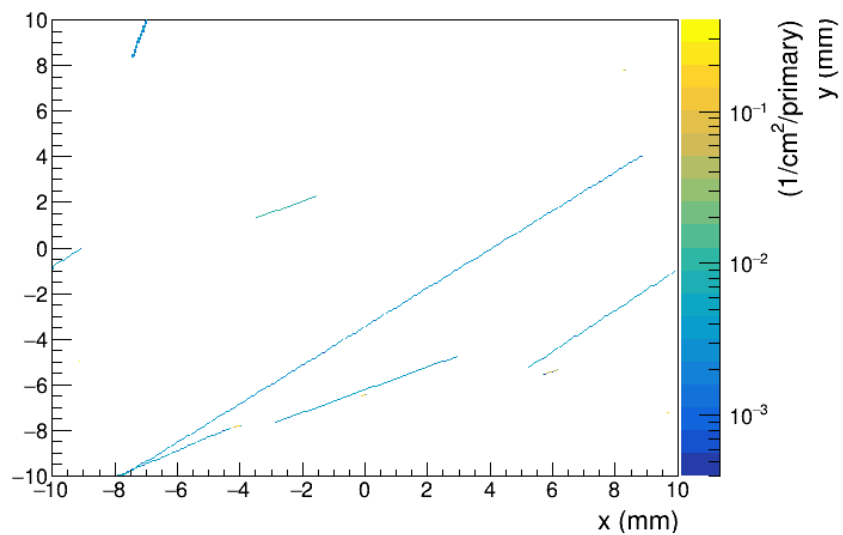
GBP sensor 0 background - positron



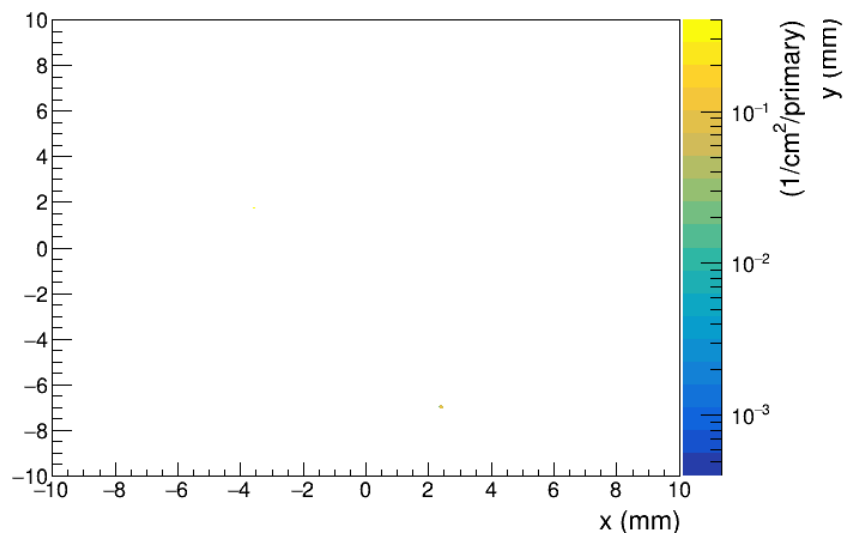
GBP sensor 0 background - photon



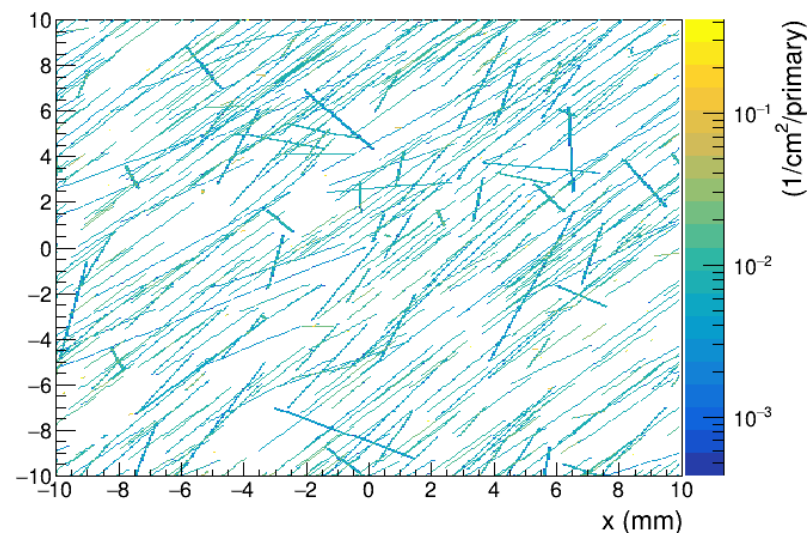
GBP sensor 1 background - electron



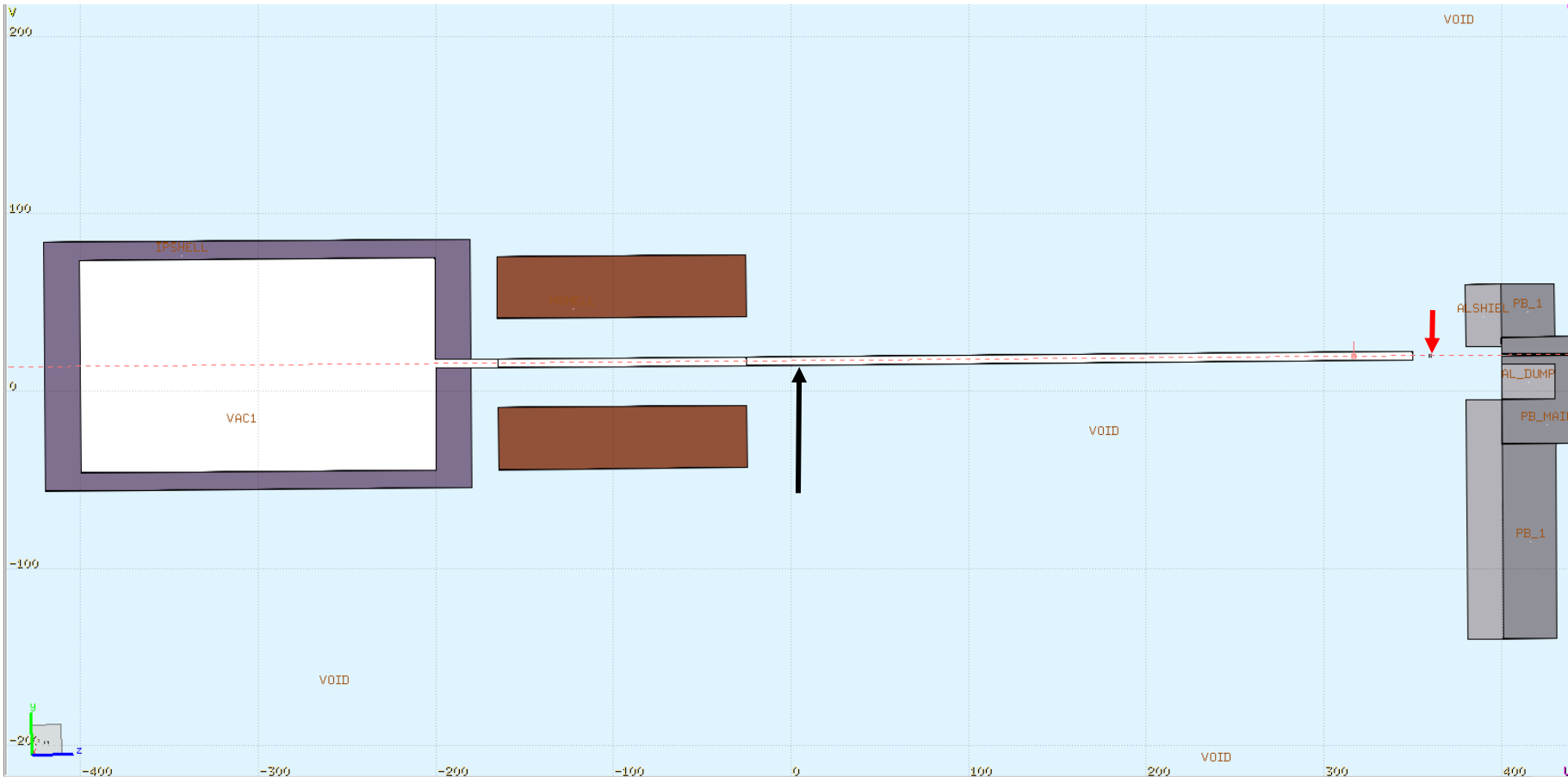
GBP sensor 1 background - positron



GBP sensor 1 background - photon

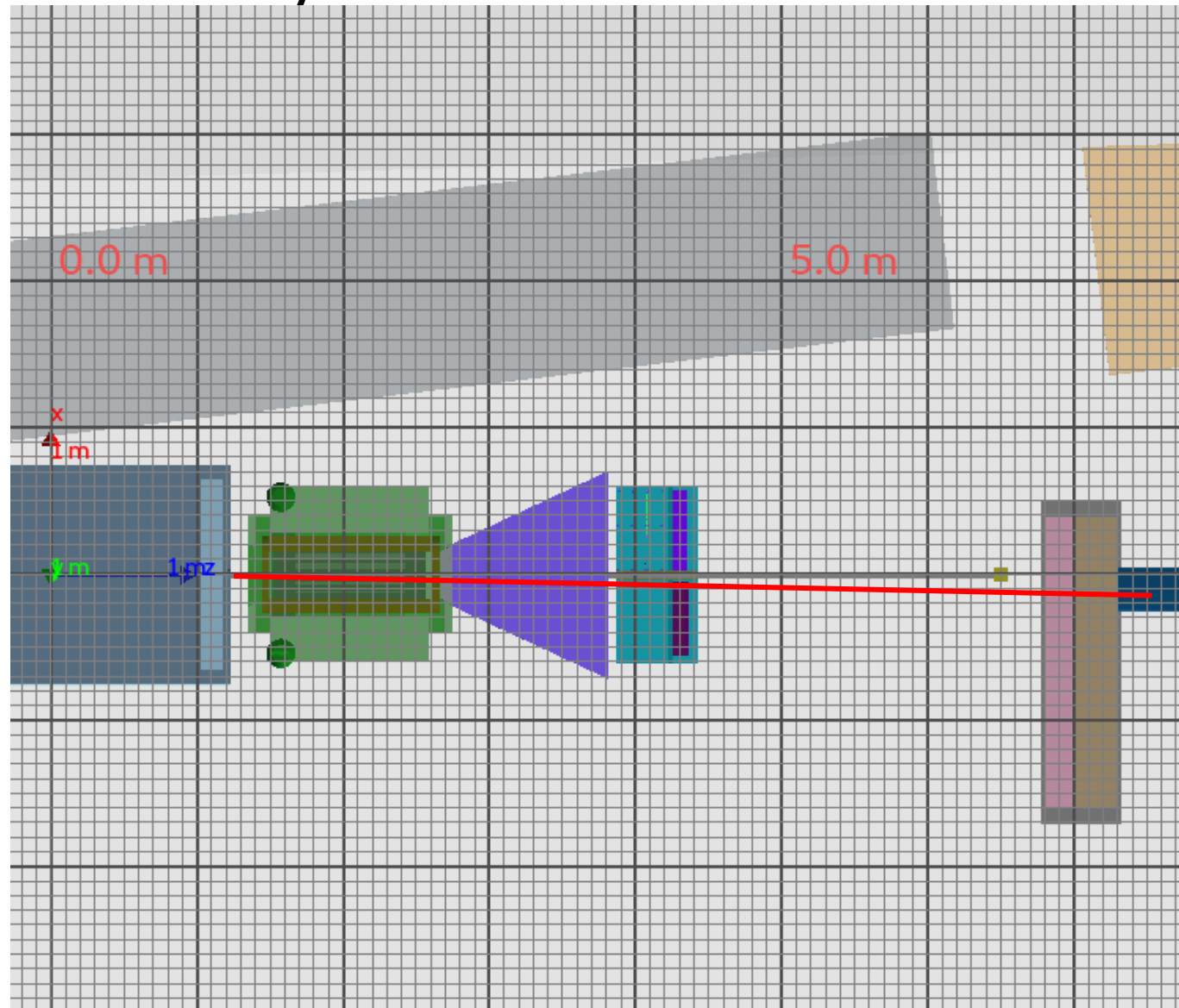


FLUKA Beam Dump Geometry



- FLUKA simulation – electron beam passed through vacuum pipe wall into dump
 - Magnetic field 1.2T
 - 16.5 GeV electrons
 - Magnet length 140cm
 - Deflection ~ 30 mrad
- GEANT4 simulation – electron beam directed through triangular fan component rather than beam pipe itself
- Reduces amount of off-axis noise reaching profilers

GEANT4 Geometry



Summary

- "Truth" signal generated in detector deposits predominantly within central 2.5 mm for all detector planes
- Track anomalies from FLUKA simulation accounted for – simulation needs more detail to compare with GEANT4 simulation; currently results only comparable for rear profilers (sensors 2 & 3 at $z = 11.8\text{m}$)

GBP-MC Simulation Update

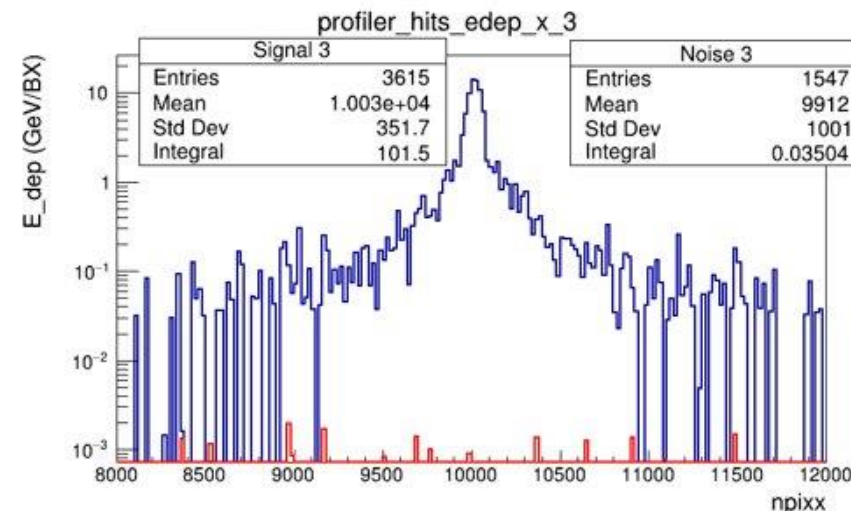
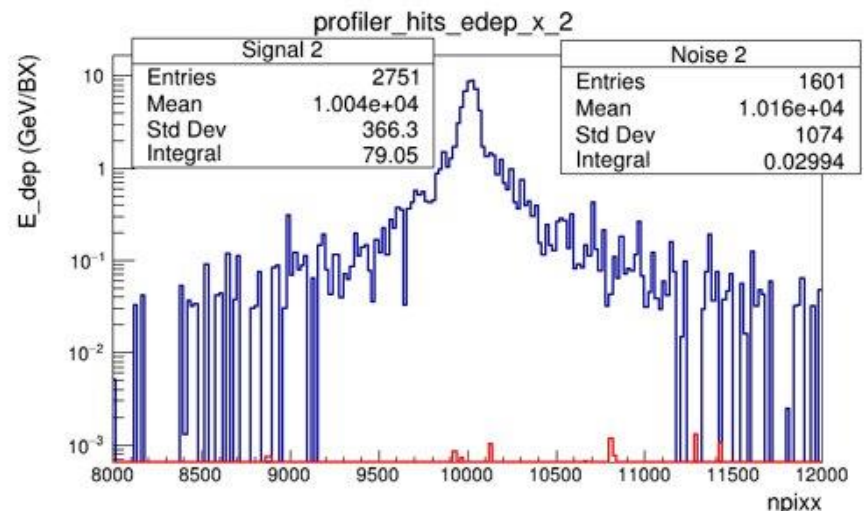
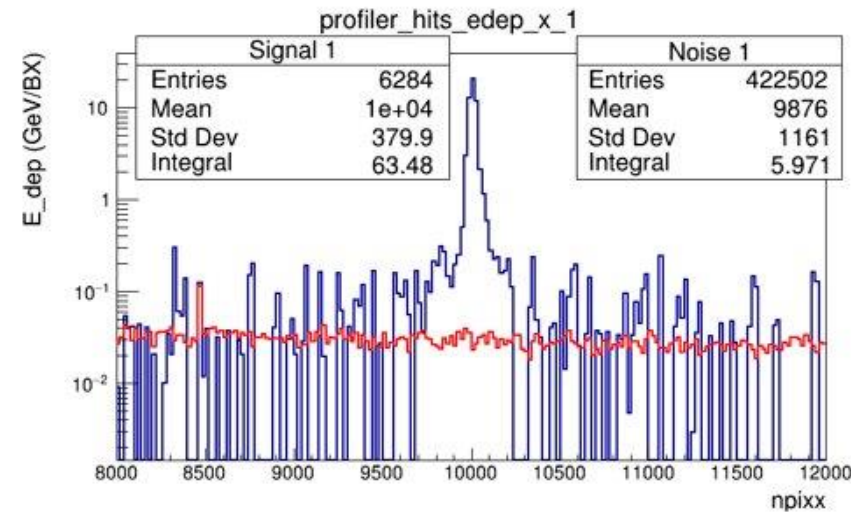
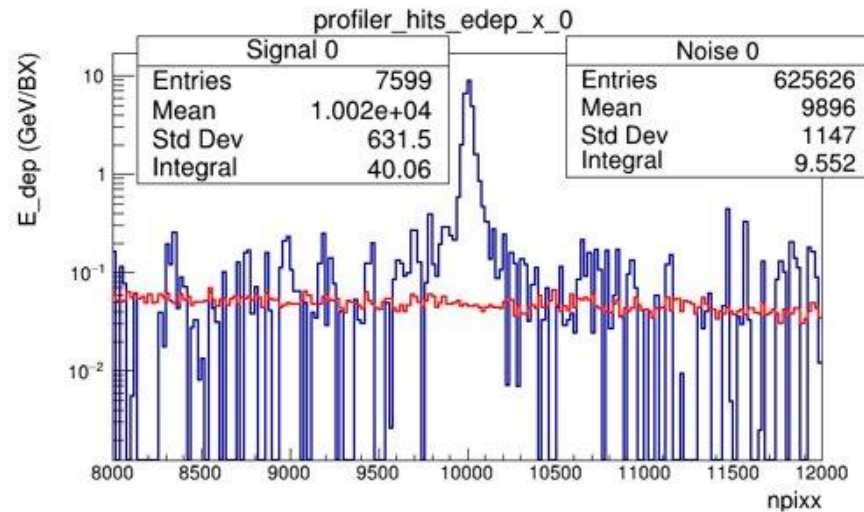
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Overview

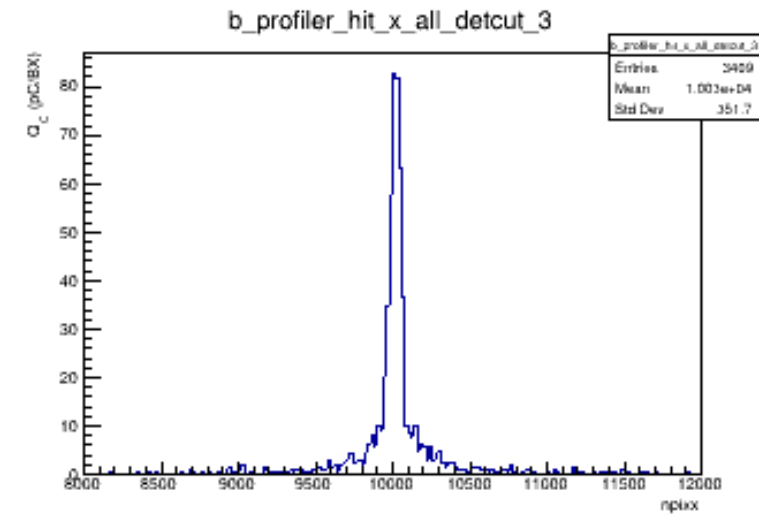
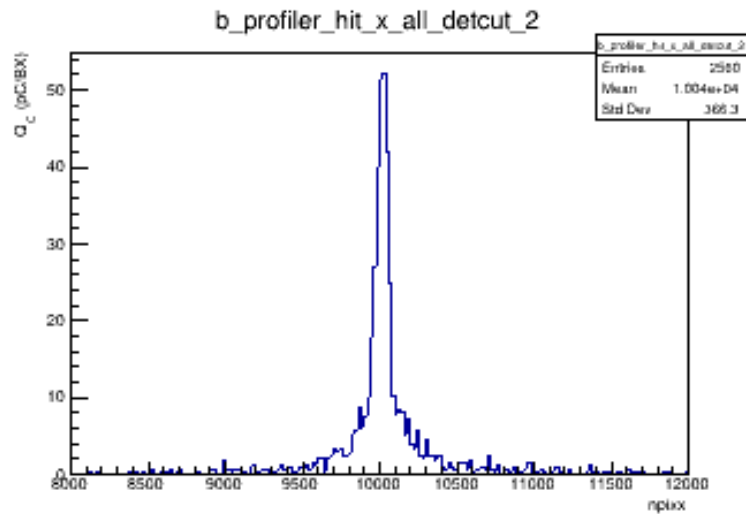
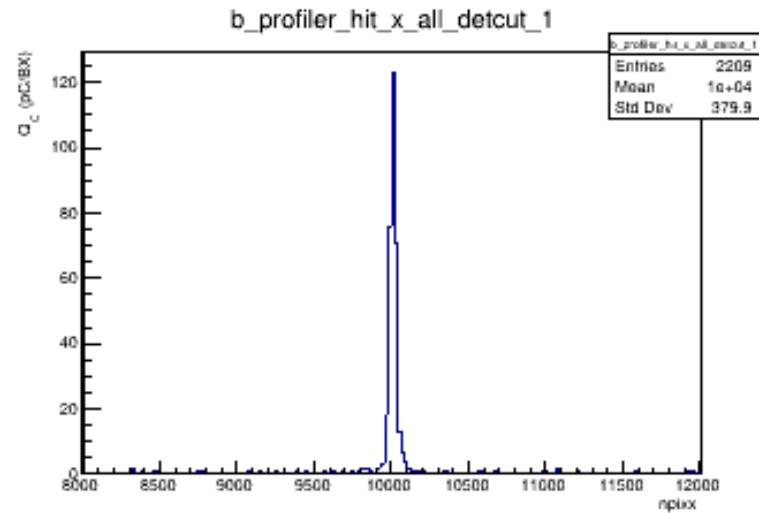
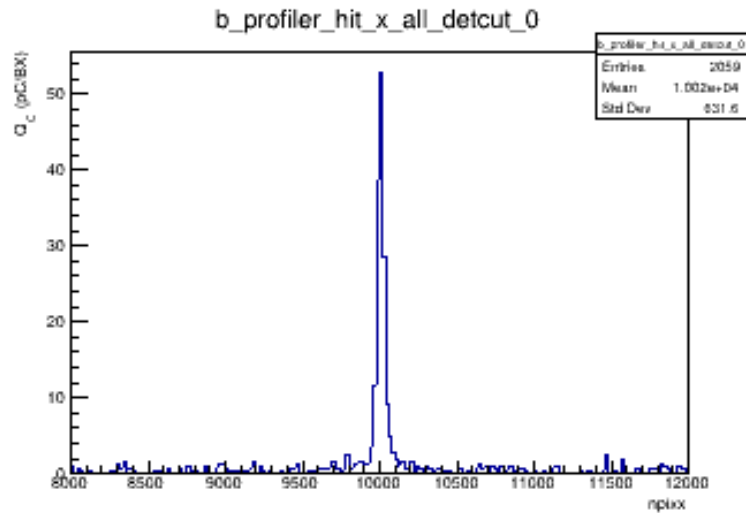
- Analysed background on profiler due to electron beam colliding with beam dump
- Managable S/B ratio on both pairs of detectors (total energy deposition)
 - $S/B > 2$ across central 2.5mm of plane for forward detectors
 - $S/B > 500$ across entire plane for rear detectors

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

Charge Collection Estimate

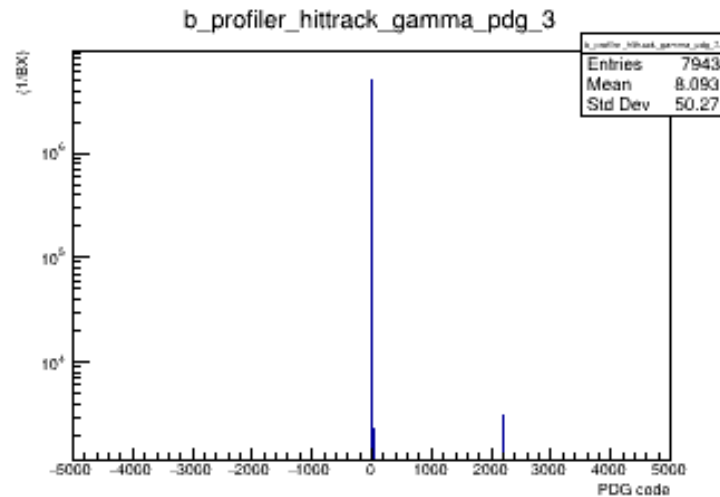
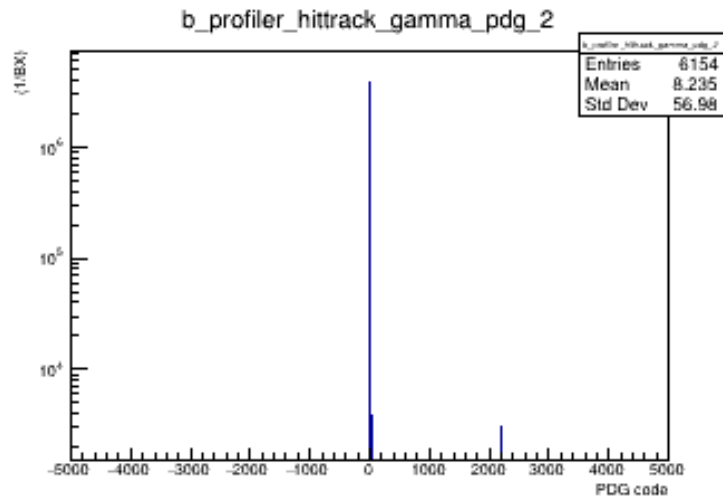
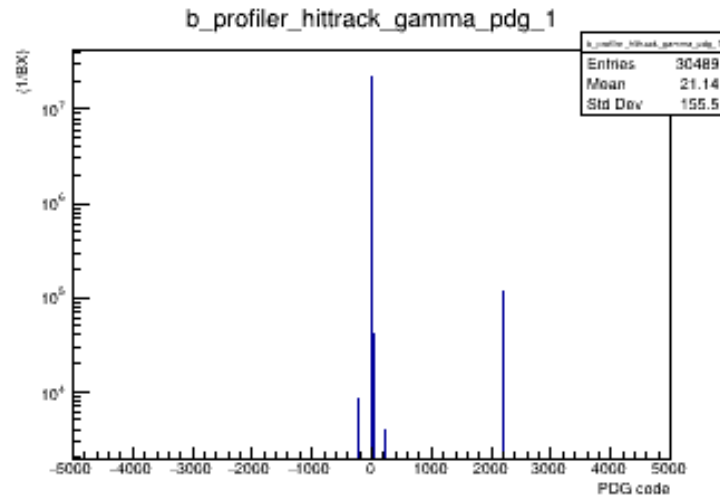
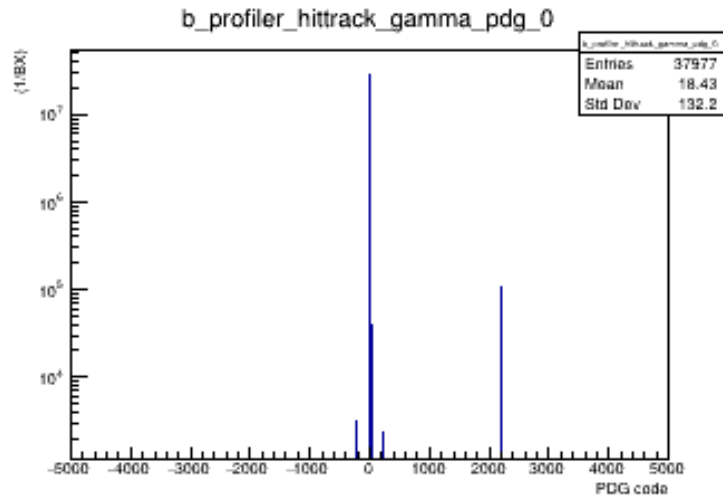


- Rough estimate of charge collected in each strip (pC/BX)

$$Q_c = \eta e N_{eh}$$

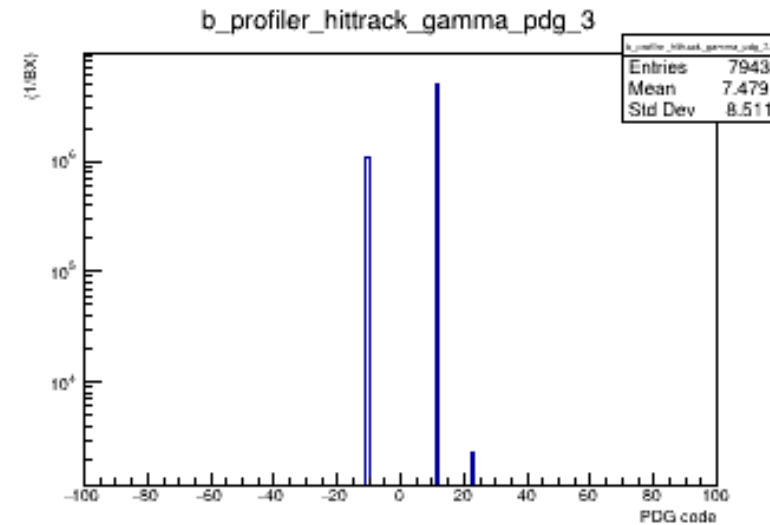
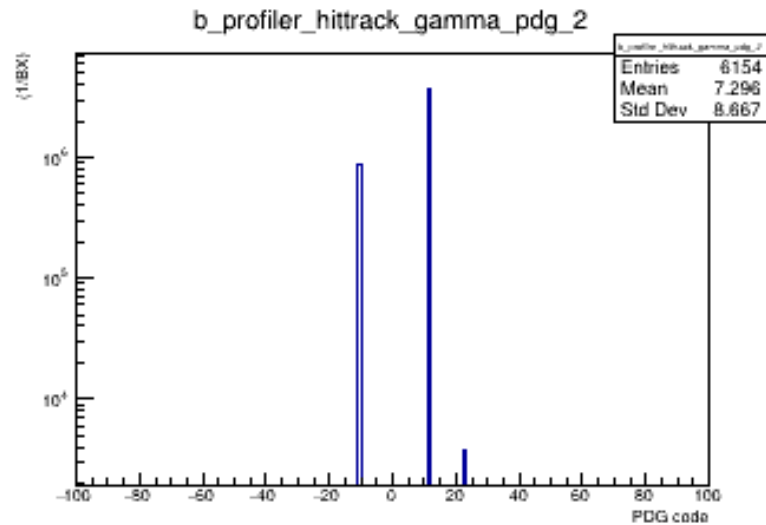
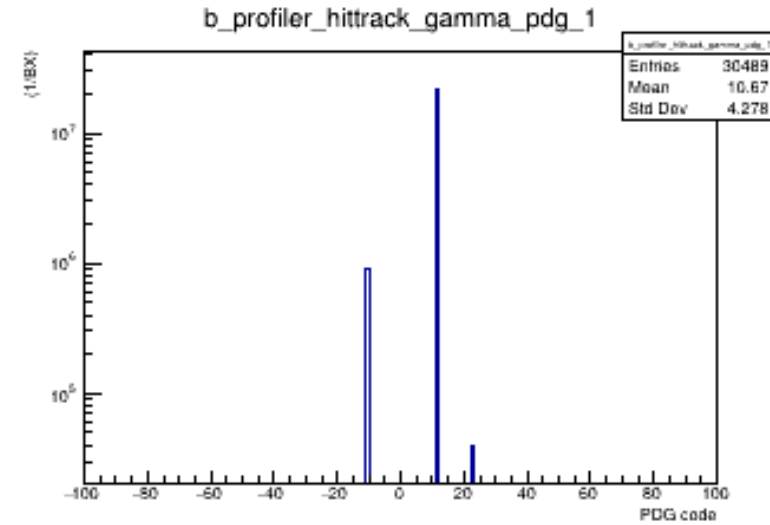
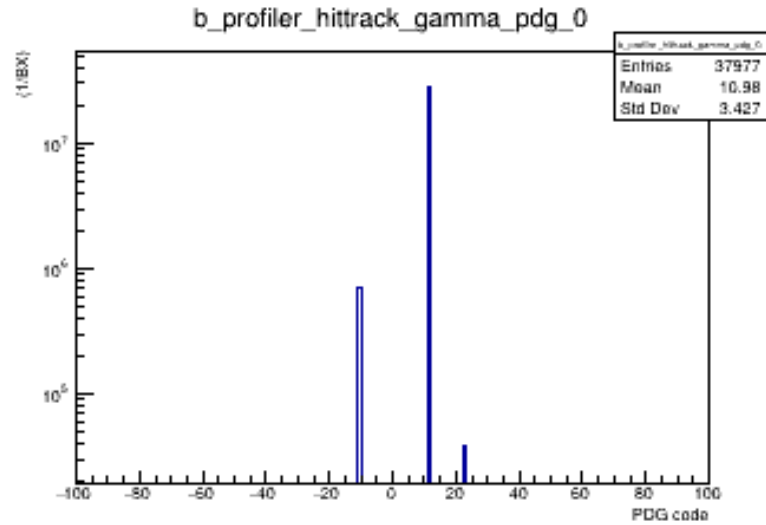
- Collection efficiency assumed to be 1.0
- From Marco's slides, energy to create e-h pair for sapphire = 27.0 eV

Particle Types



- Seems that main particles hitting profilers are
 - Electrons
 - Positrons
 - Photons
 - Pions (+/-)
 - Protons

Particle Types



Summary

- Still in process of analysing signal on profiler
- Want to look at electrons generated within each profiler by gamma beam – this is "ideal" signal
 - Main processes to consider photoelectric effect, Compton scattering, pair production etc.
- Determine particle fluences on profiler

GBP- MC Simulation Update

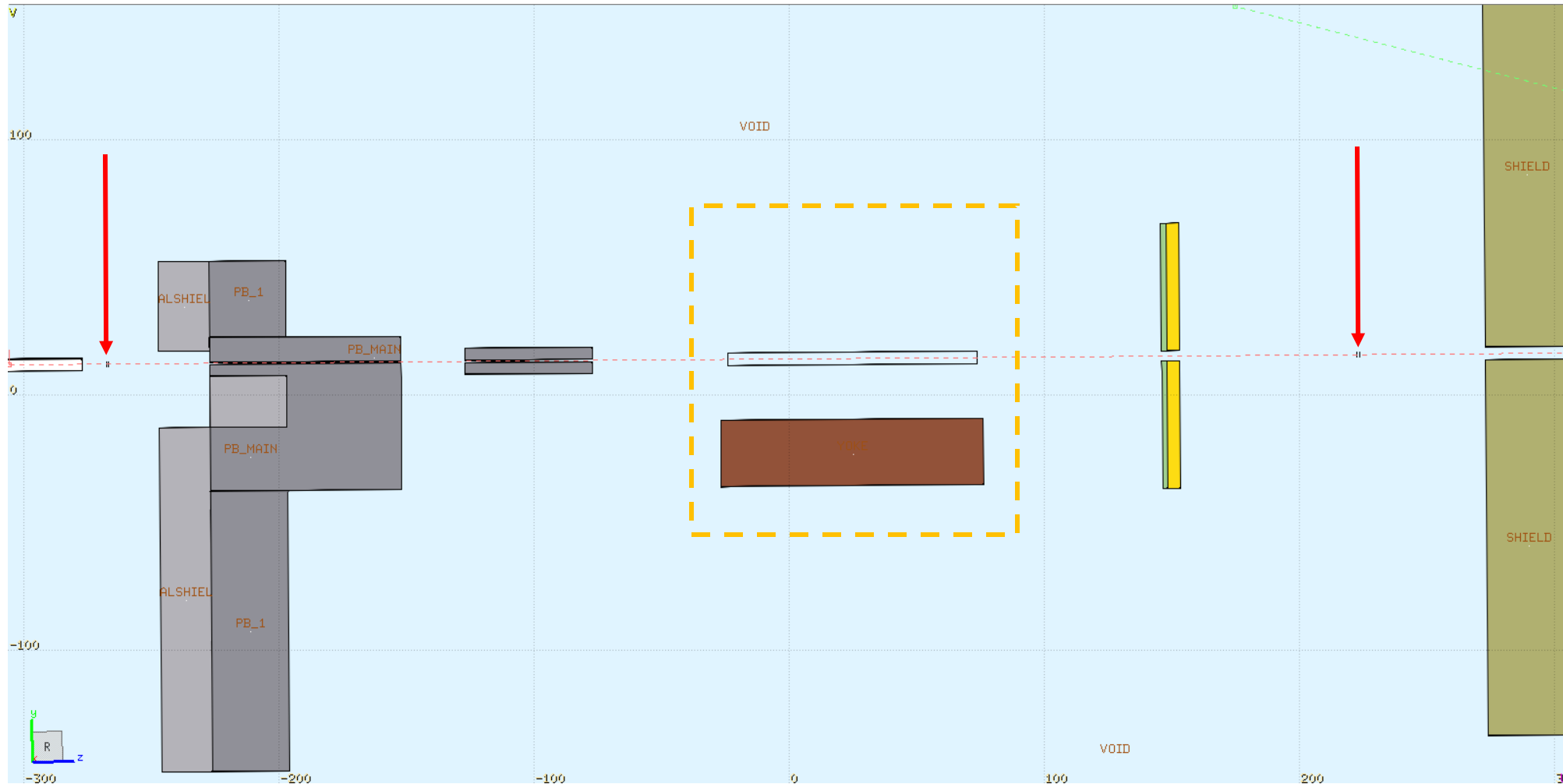
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22/02/21

Overview

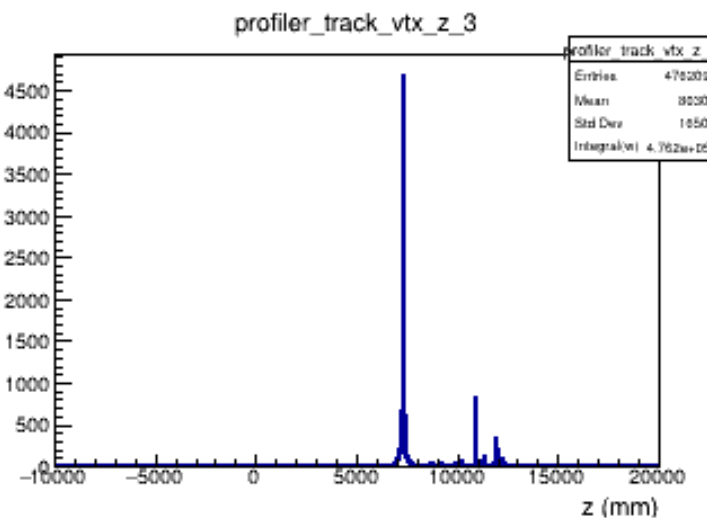
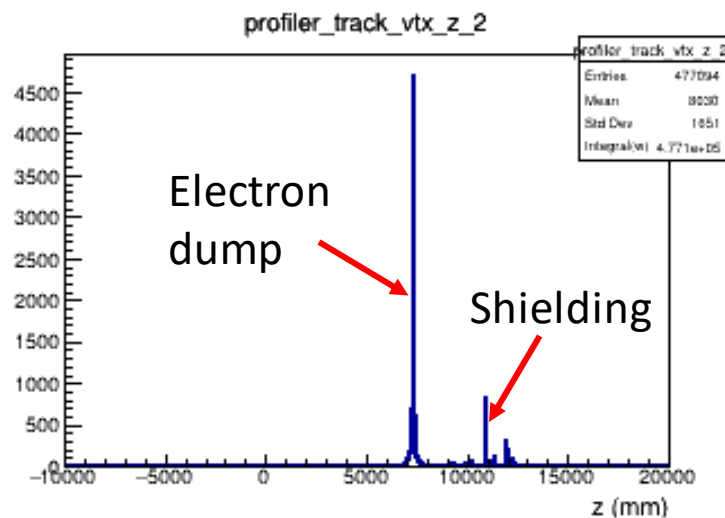
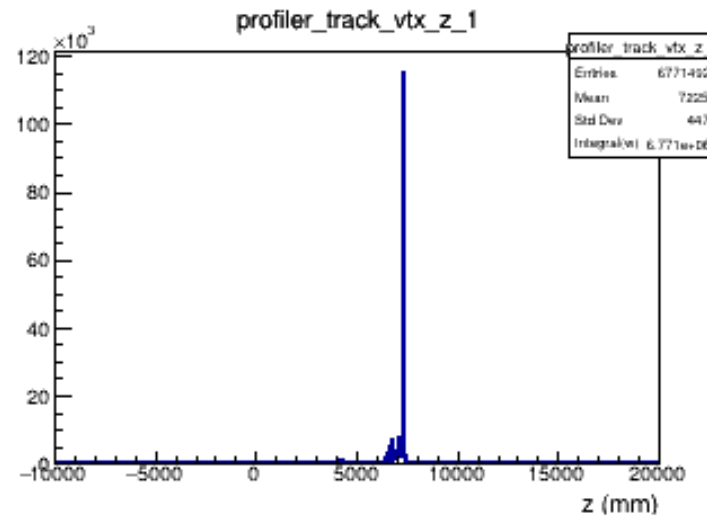
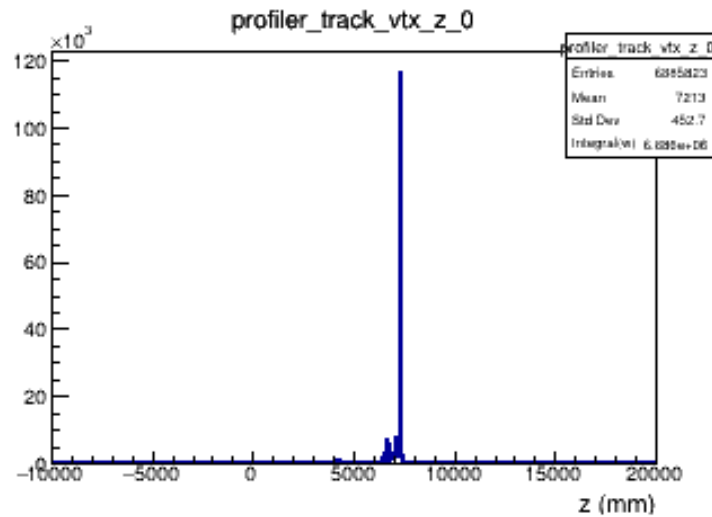
- Previous FLUKA simulations for entire forward spectrometer (PDS – photon detection system) done for $1e5$ primary electrons
- Higher statistics simulation in FLUKA still running, data should be available soon
- GEANT4 MC data exists for both signal and background for entire LUXE setup – now includes beam profilers
- 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 (Al_2O_3) composition
 - Density = 3.98 g/cm^3
 - Pixel volume = $20.0 \text{ cm}/n_x * 20.0 \text{ cm}/n_y * 0.01 \text{ cm}$ (n_x, n_y = no. bins in x, y resp.)
 - Dose conversion factor: $\text{GeV/g} \rightarrow \text{Gy} = 1.60e-7$

PDS geometry (FLUKA)



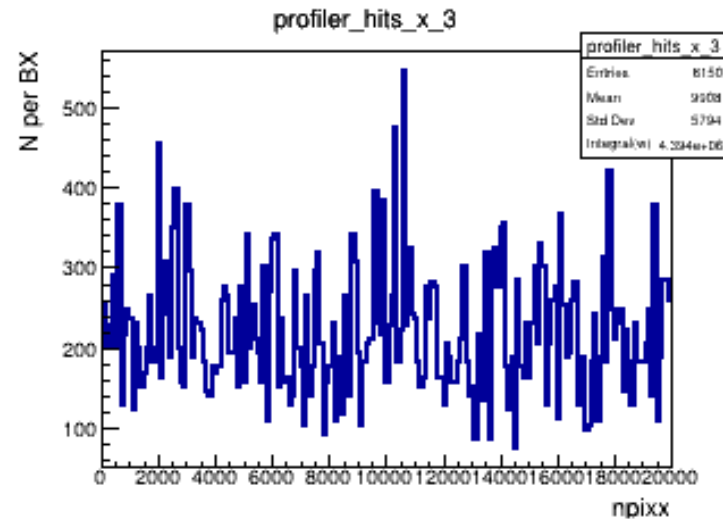
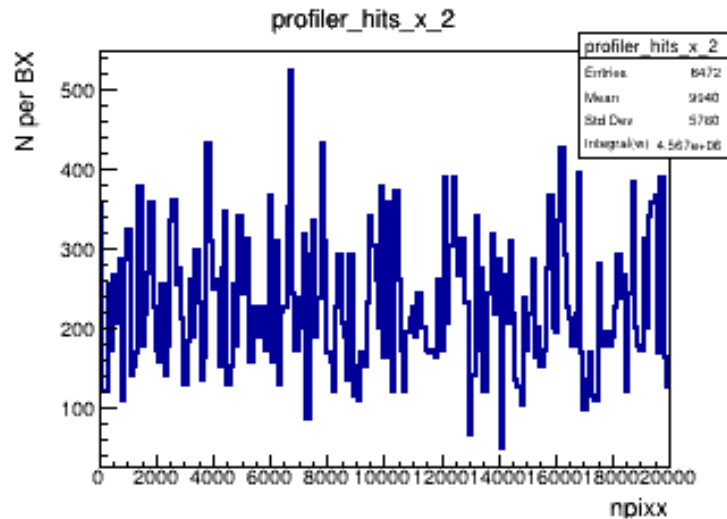
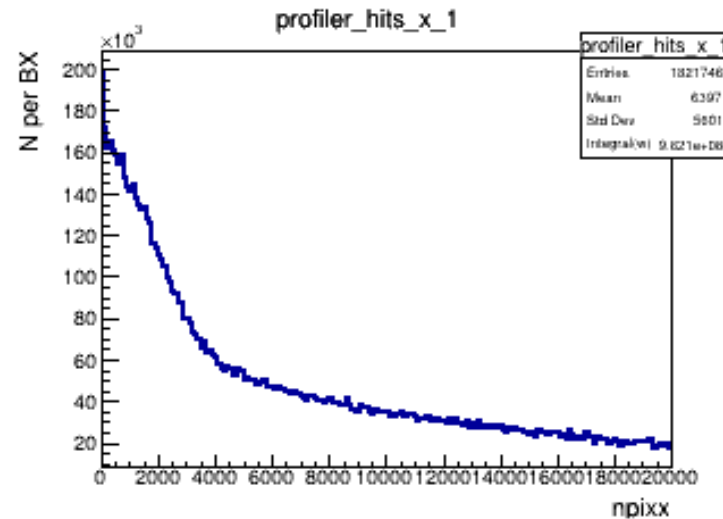
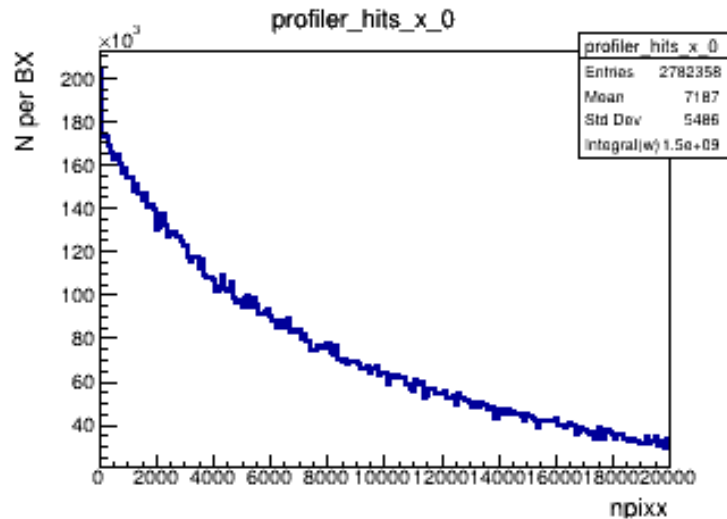
- Profiler locations indicated by red arrows
- Magnet region marked by orange dashed box
- "VOID" is air environment
- Geometry simplified in comparison to full GEANT4 geometry e.g. no supports, simplified electron dump, simplified LANEX screens (green) and Cerenkov detector (yellow)

Production Vertices



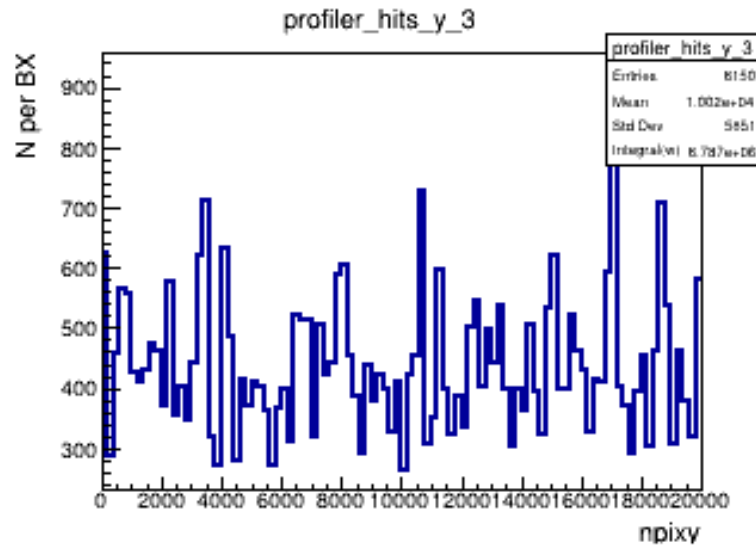
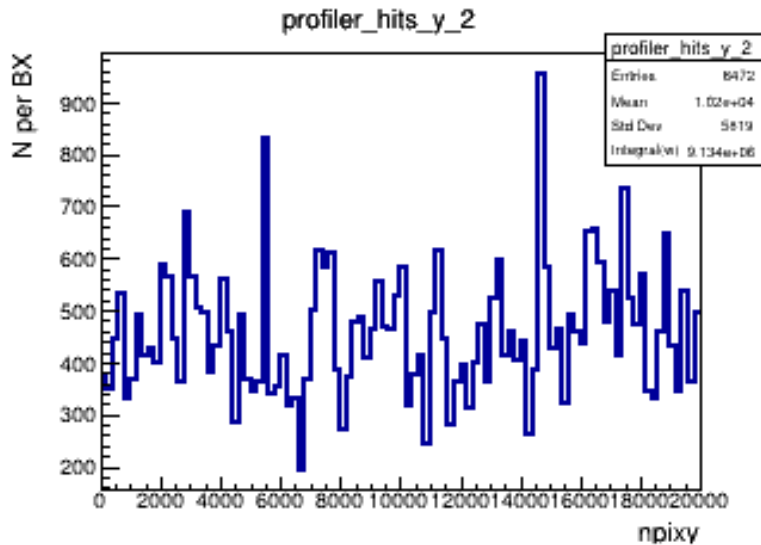
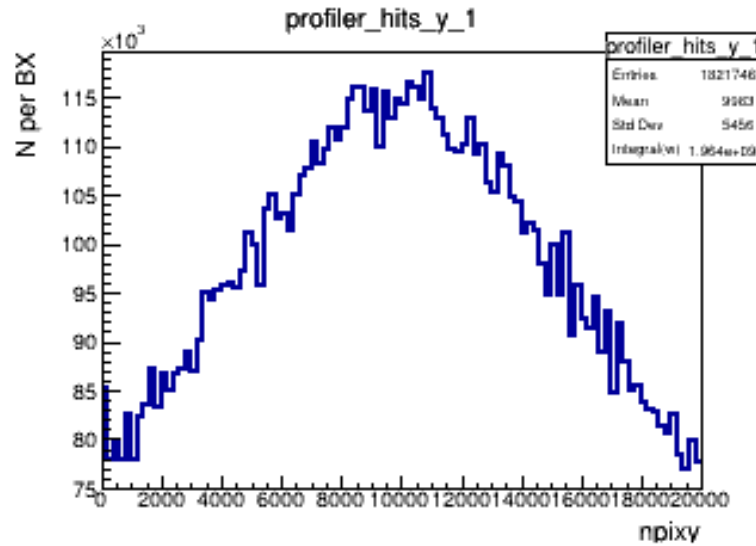
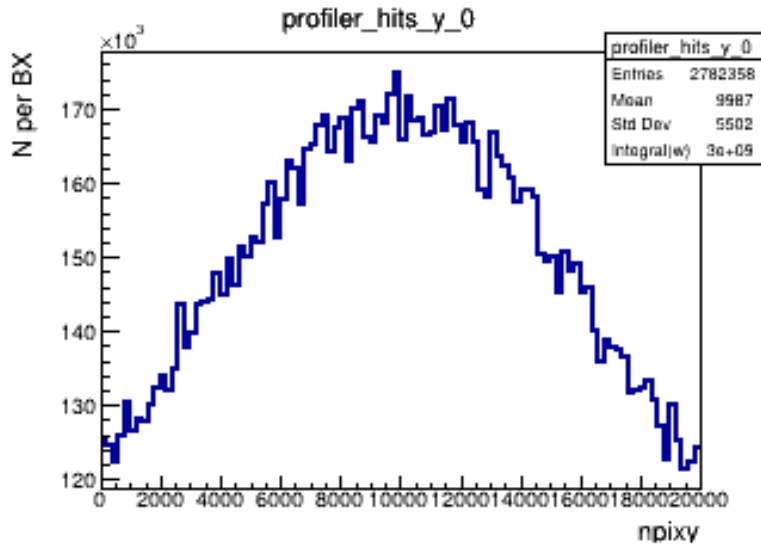
- Plots showing z production vertex of particles incident on profilers
- Main component of background comes from $z = 7000\text{mm}$ $\rightarrow$ electron beam dump
- Rear profiler pair also see some backscattering from shielding at $z = 12000\text{mm}$

Transverse hits profile (horizontal)



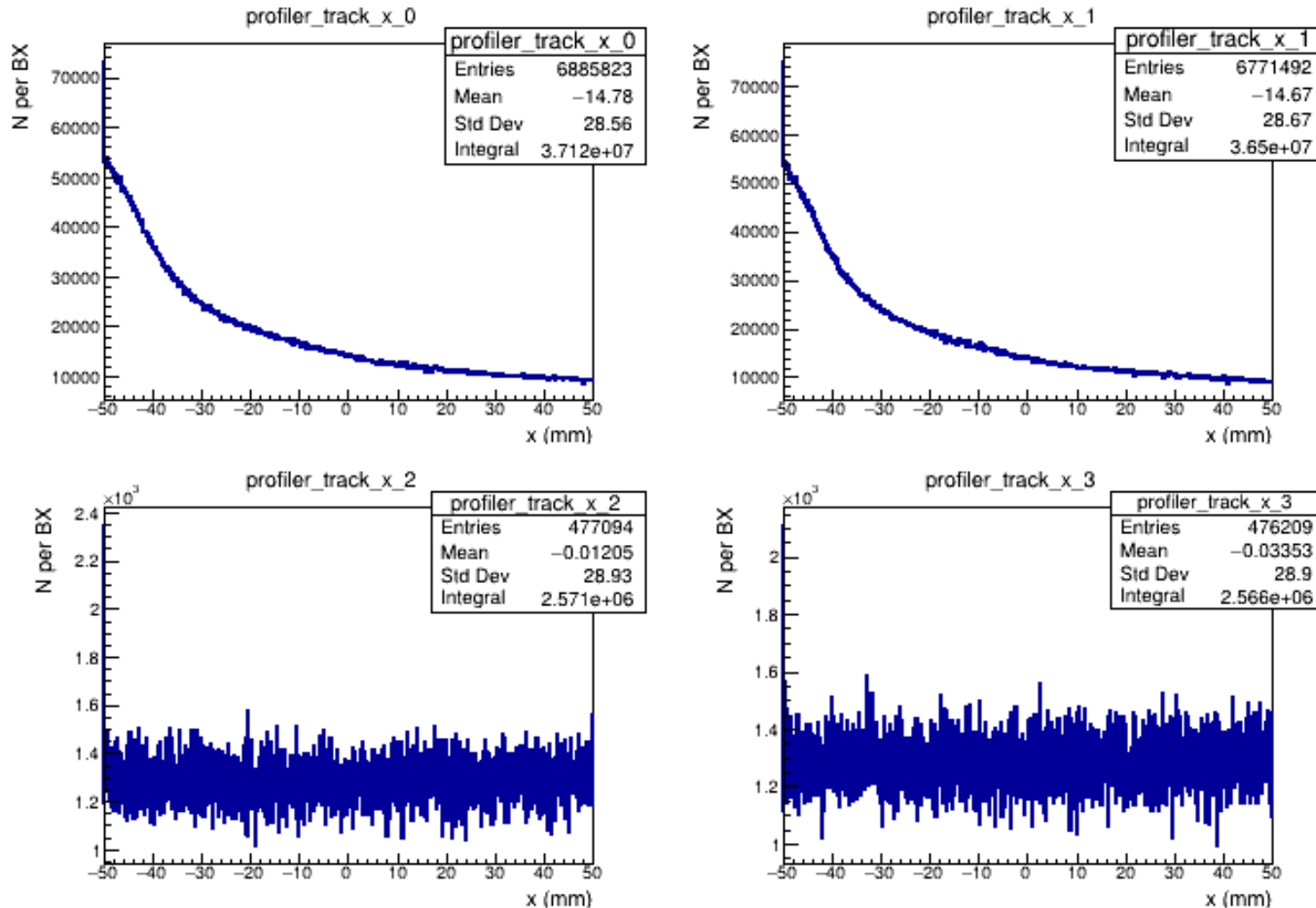
- For rear profiler pair, hits distributed uniformly across profiler in x direction
- Due to air environment and components of experiment, forward x distribution of hits not distinguishable at rear profilers
- For front pair, number of hits decreases across the detector
- Left edge (npixx = 0) corresponds to edge closest to electron dump

Orthogonal hits profile (vertical)



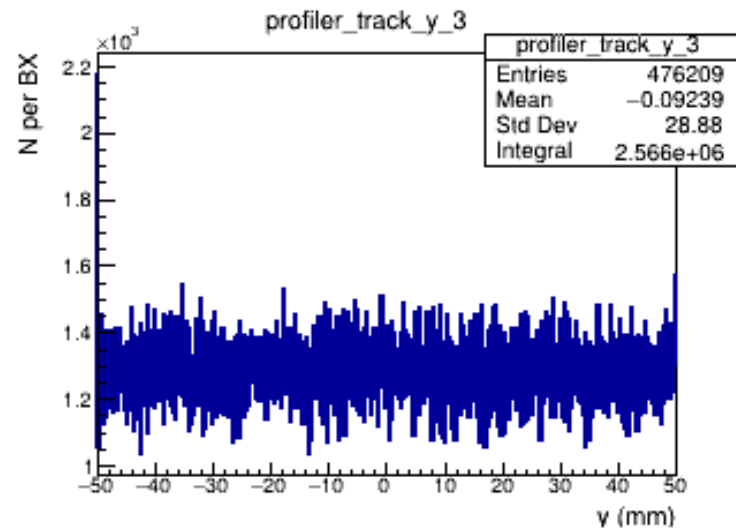
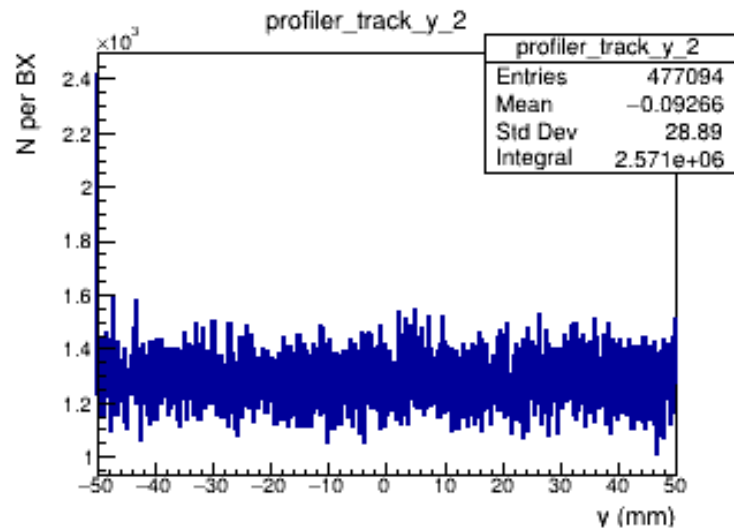
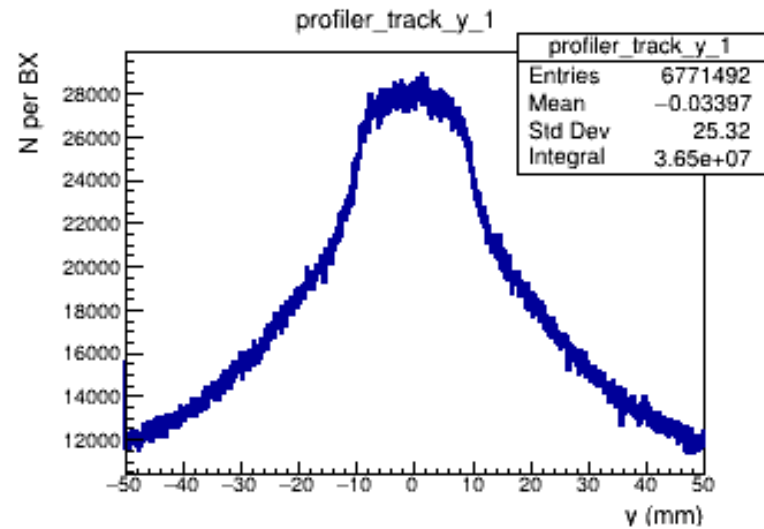
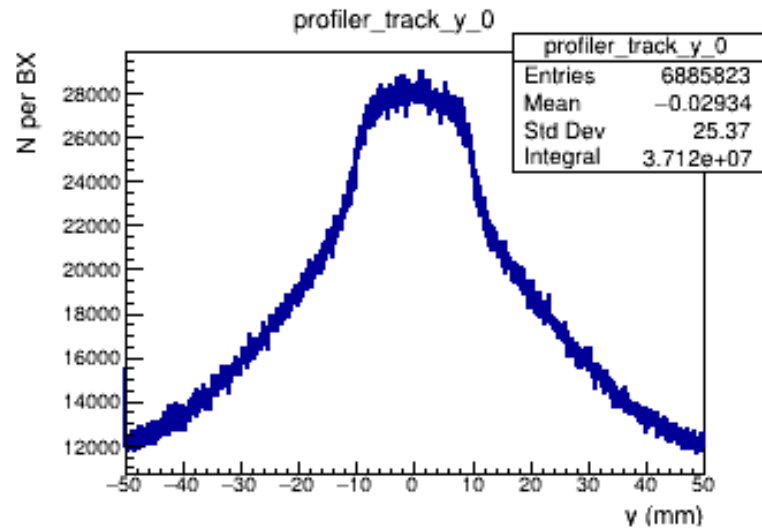
- Uniform distribution of hits for rear profilers
- Front profilers have peak at npixy = 10000 $\rightarrow$ $y = 0.0$ mm
- This corresponds to the plane in which electron dump is vertically centred

Transverse tracks profile



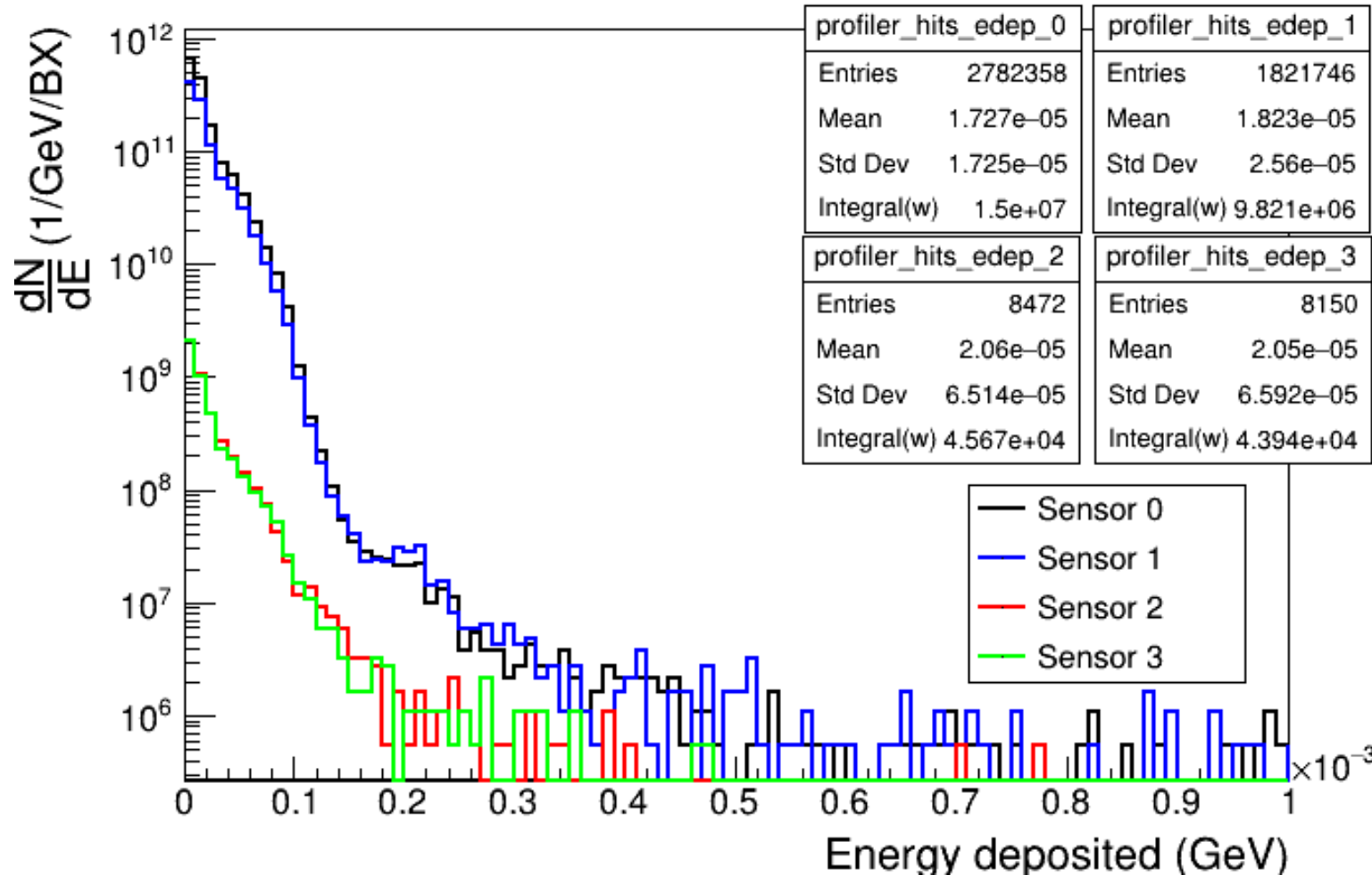
- Similar trend to hits profiles
- Rear profiles have a uniform distribution in transverse direction of background
- Front pair is highly skewed due to location of electron dump

Orthogonal tracks profile



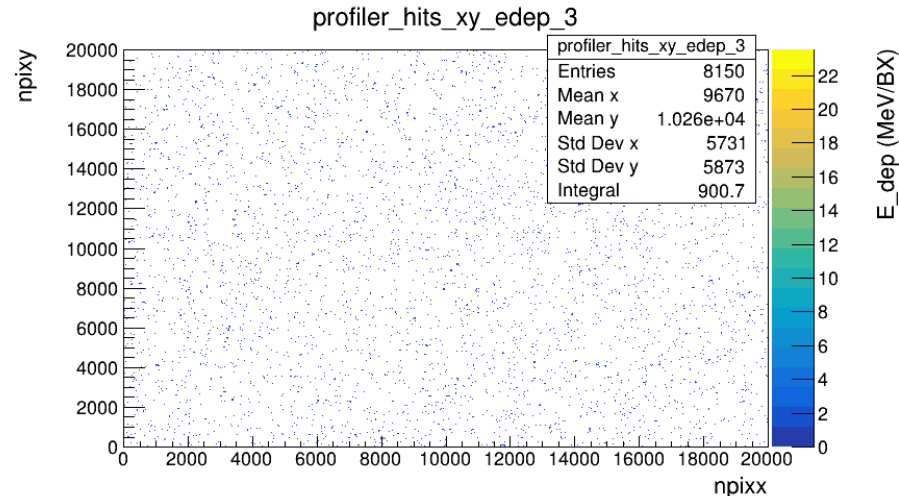
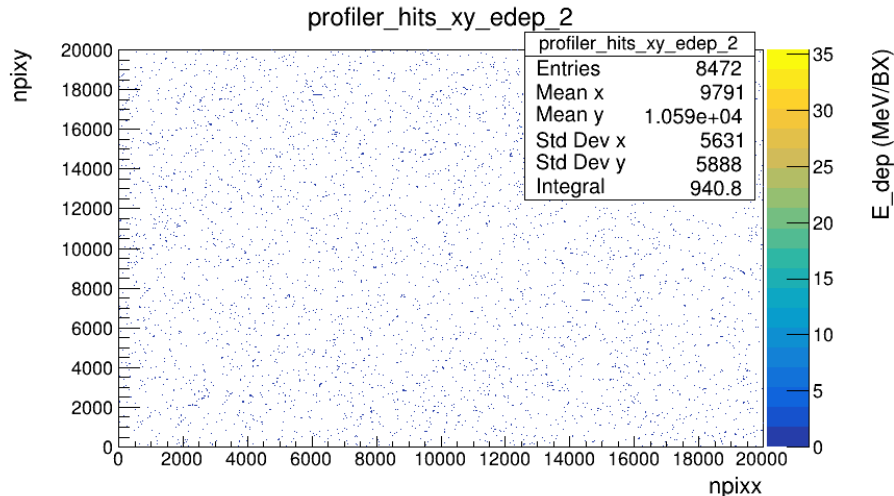
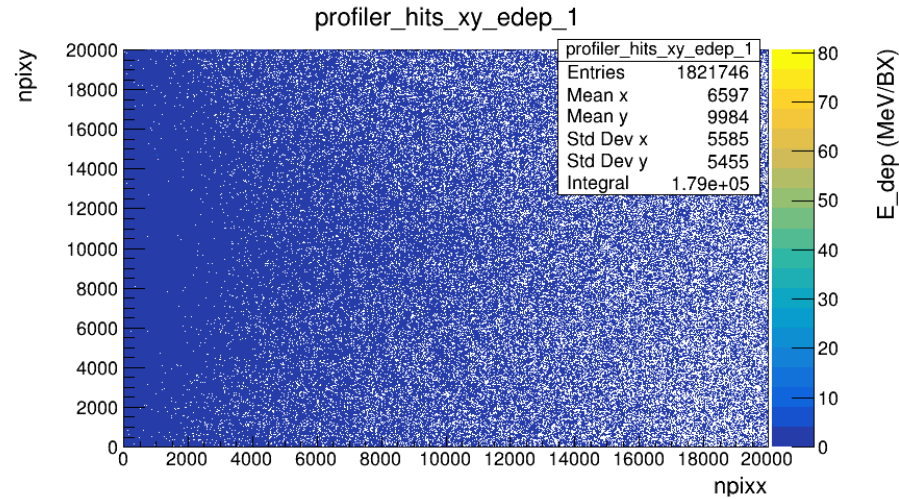
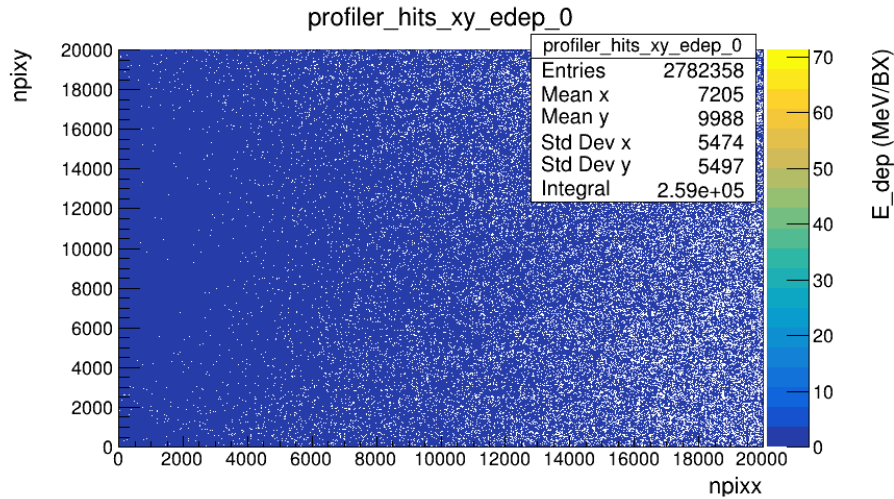
Spectrum of deposited energy

Background Energy Deposition



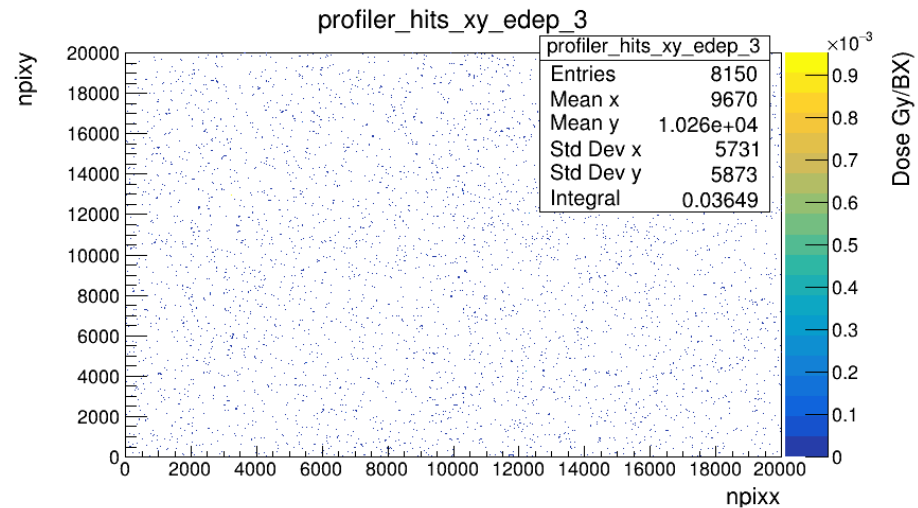
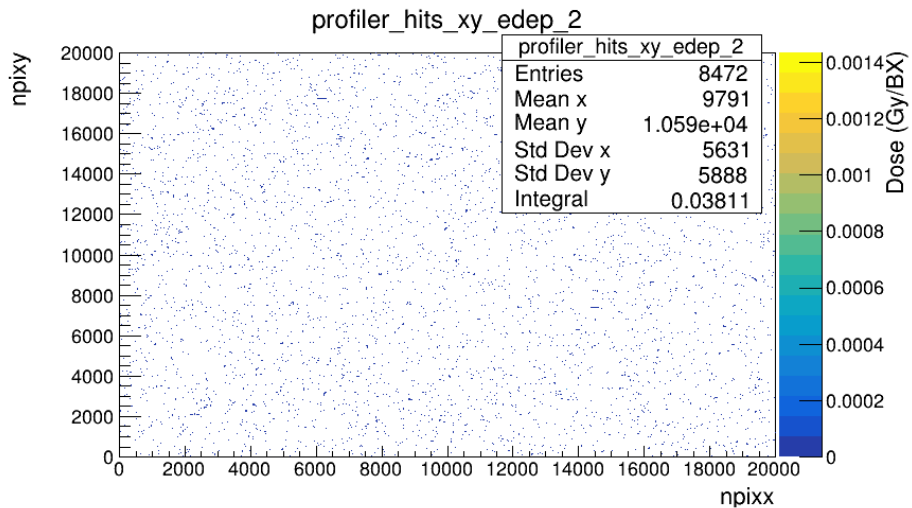
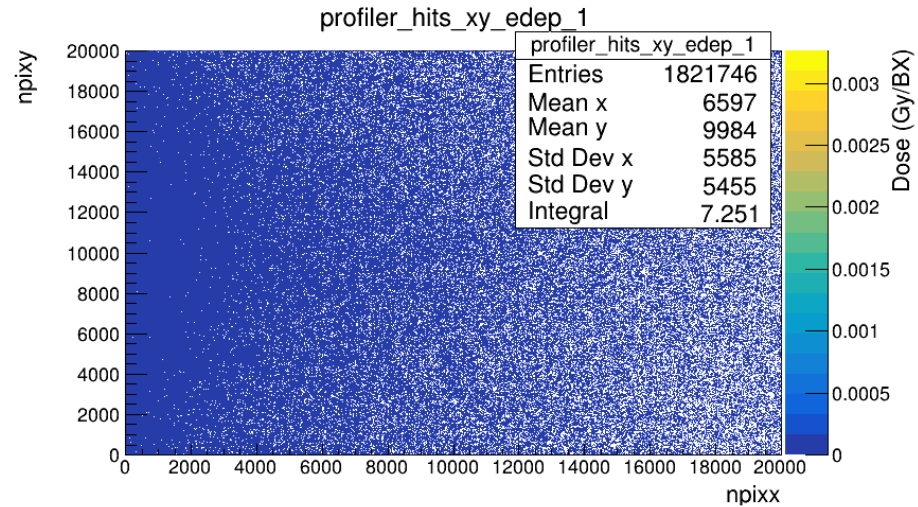
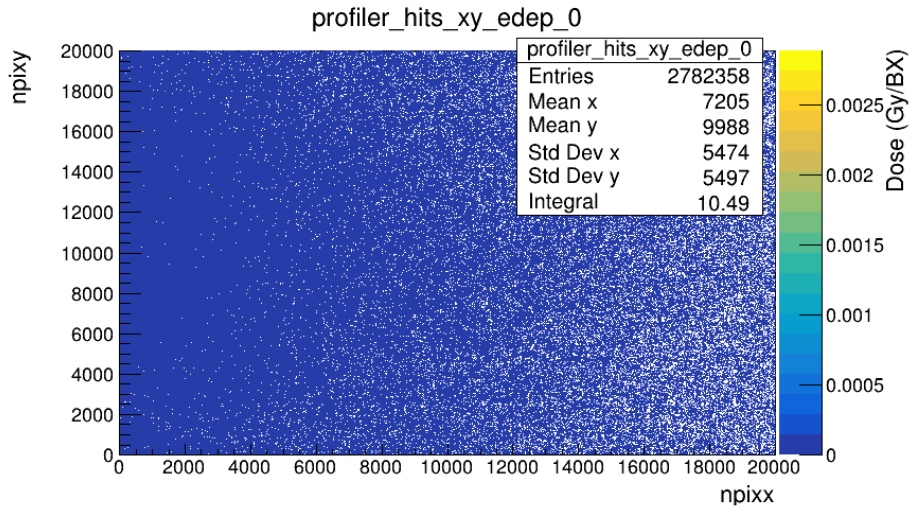
- For all detectors, large number of particles which deposit low amount of energy ($E < 0.2$ MeV)
- Total number of hits given by value "Integral(w)"

Energy Deposition



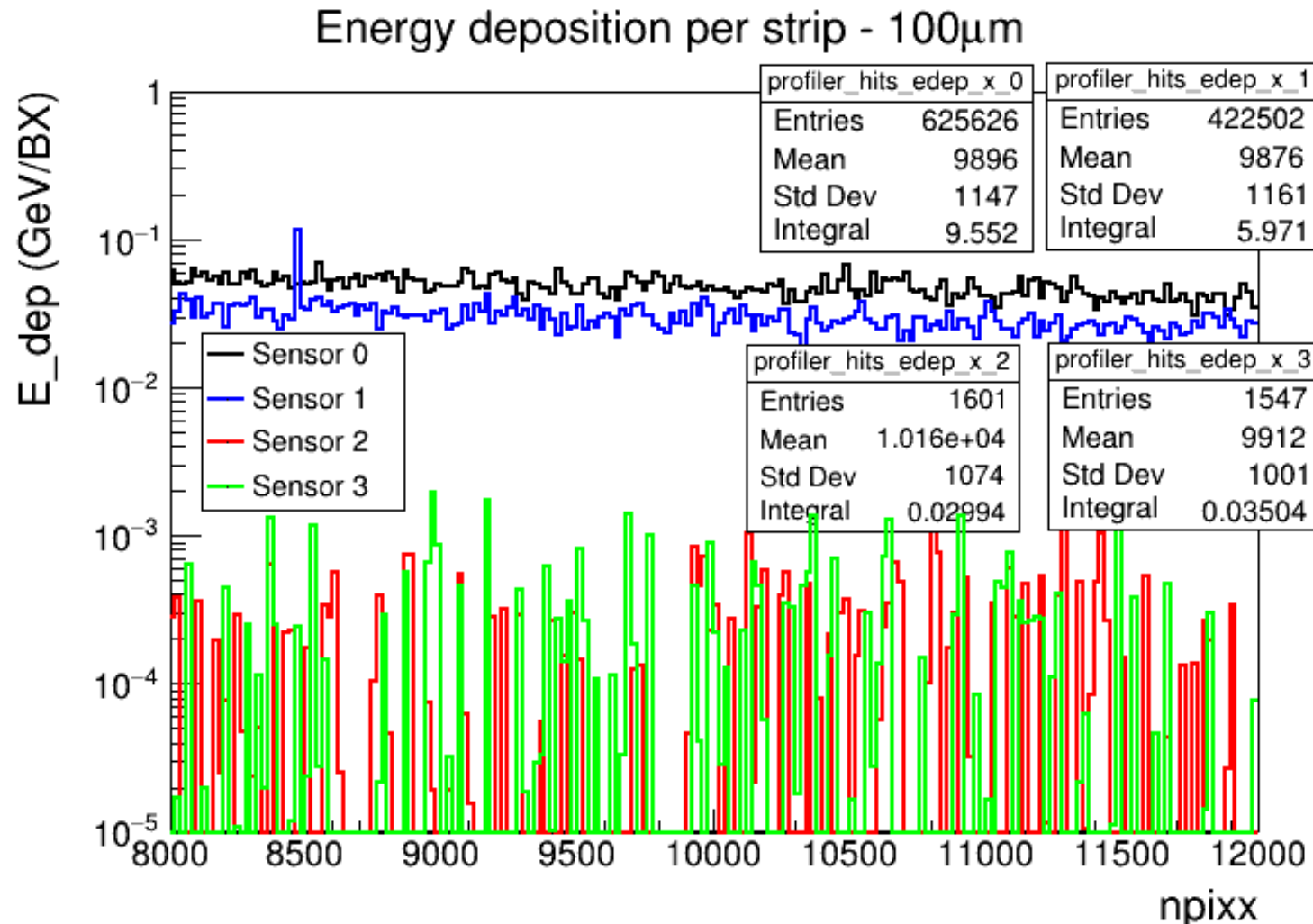
- Front profilers have a much higher energy deposition from background due to proximity to electron dump
- Random/uniform distribution of noise apparent on rear profilers

Absorbed dose



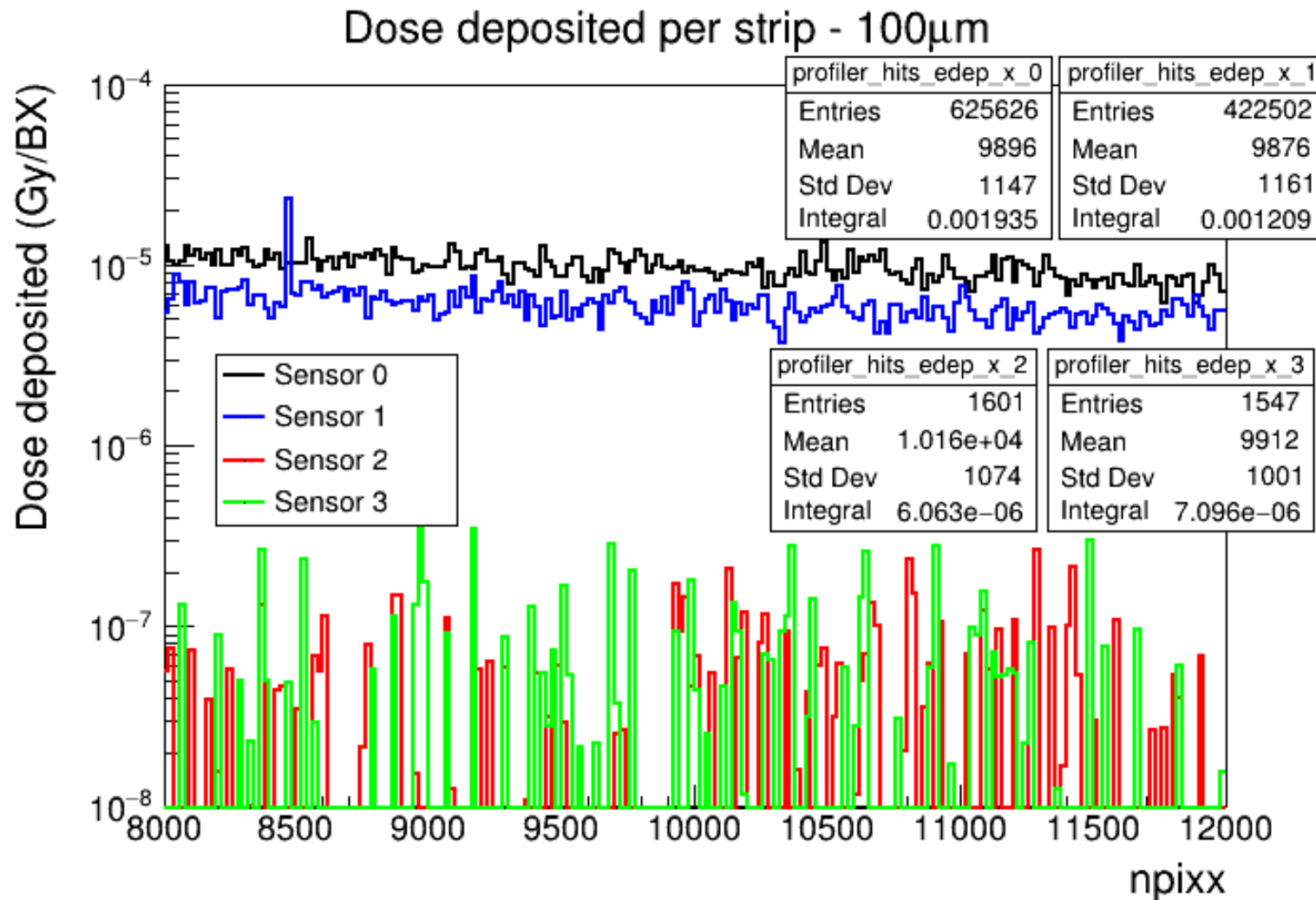
- Calculated from energy deposition map by dividing by bin volume and using scaling factor from slide 2
- For front profilers, total dose $\sim 1e-5$ Gy/BX from total energy deposited in previous slide
- Rear profilers experience $\sim 0.5e-2$ times this = $5e-8$ Gy/BX

Energy deposition in segmented strips



- N_{pixx} 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 $E_{dep} \sim 0.05 \text{ GeV/BX}$
- Rear profiler pair has energy deposition $\sim 0.0001 \text{ GeV/BX}$
- Total energy deposited over all strips is given by integral value in GeV/BX

Absorbed dose in segmented strips



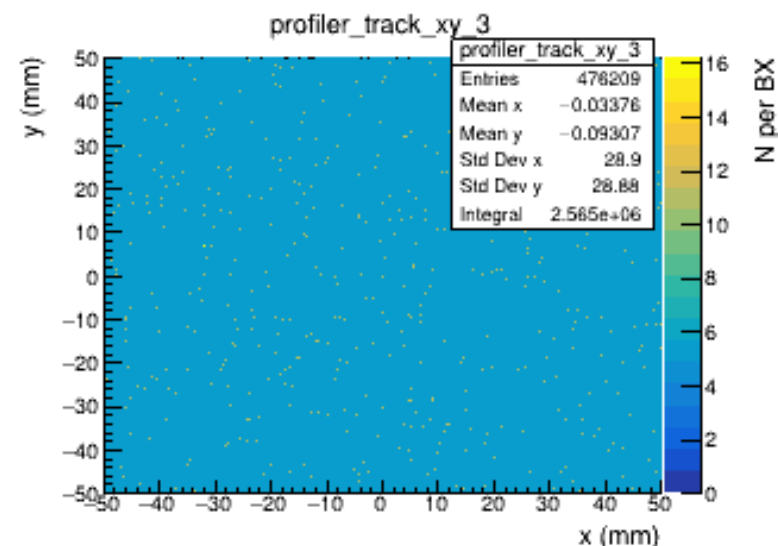
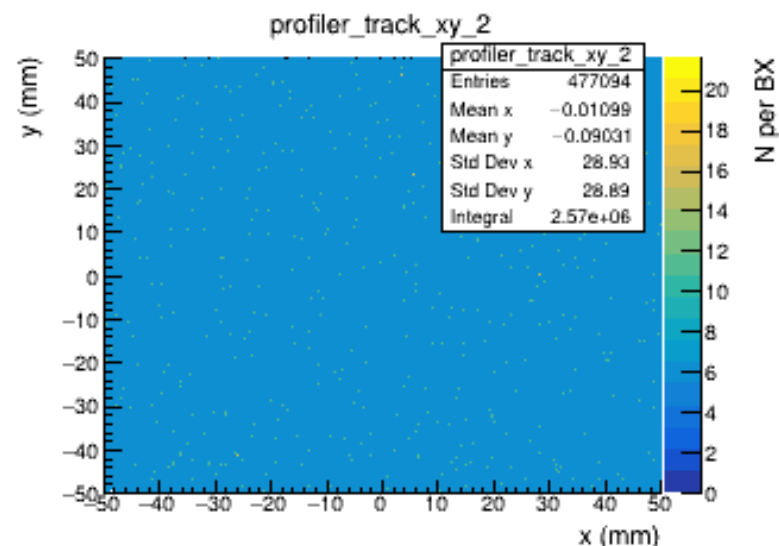
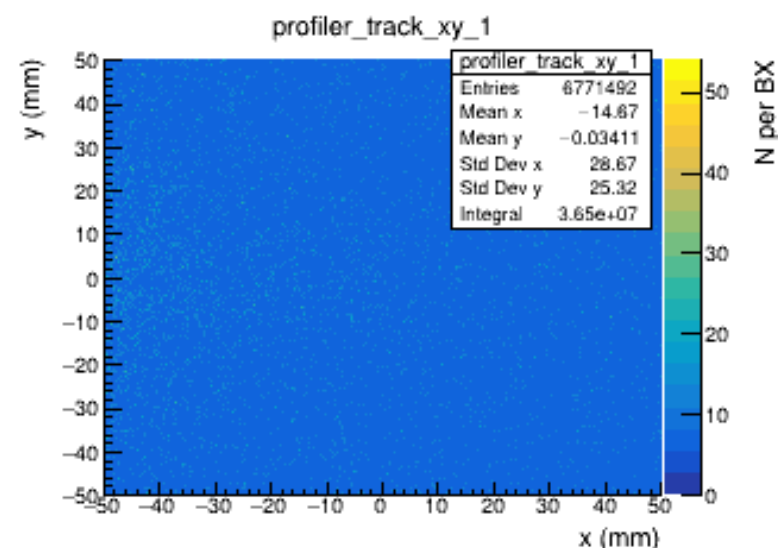
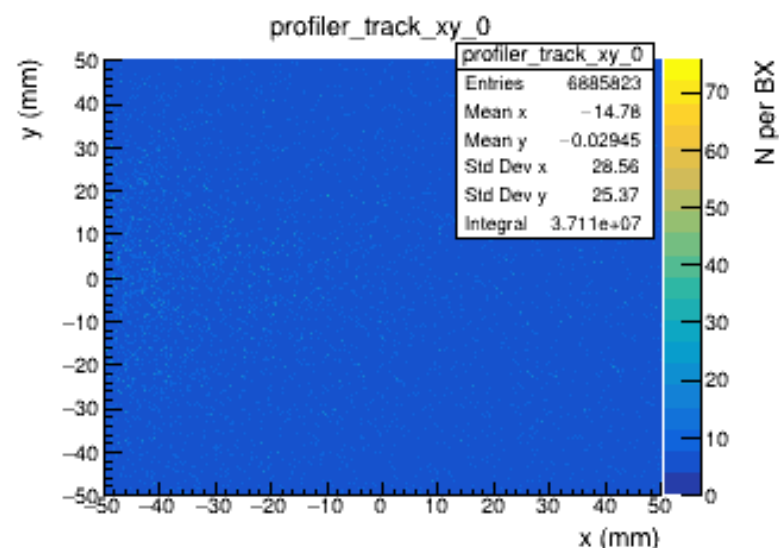
- Dose calculated from energy deposition in previous slide using volume of each strip
 - $Vol = 2.0/200 * 2.0 * 0.01 \text{ cm}^3$
- Total dose can be calculated from total energy deposition over entire 0.04 cm^3 volume of each detector

Summary

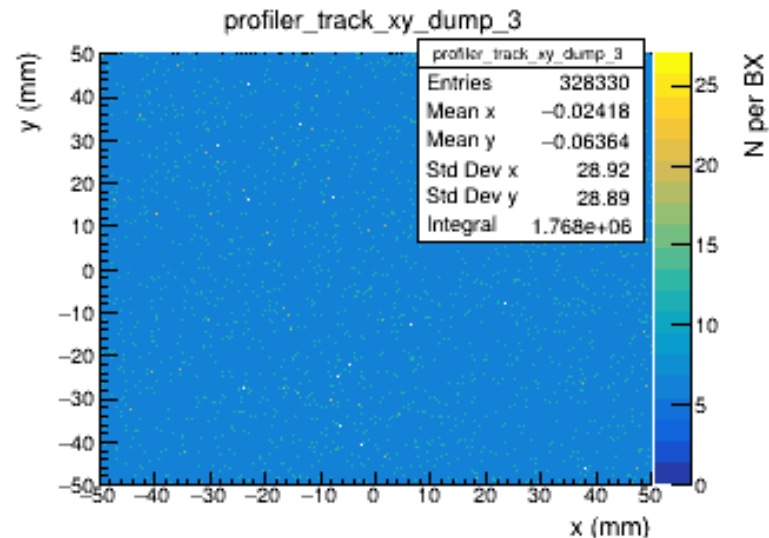
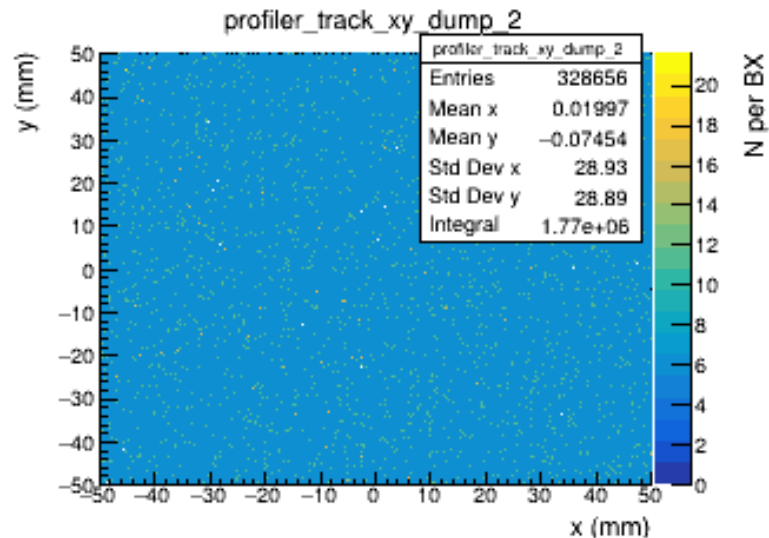
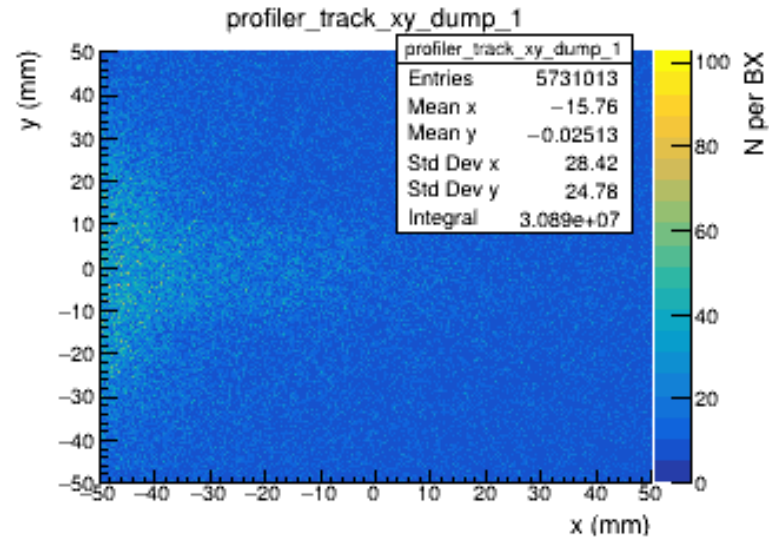
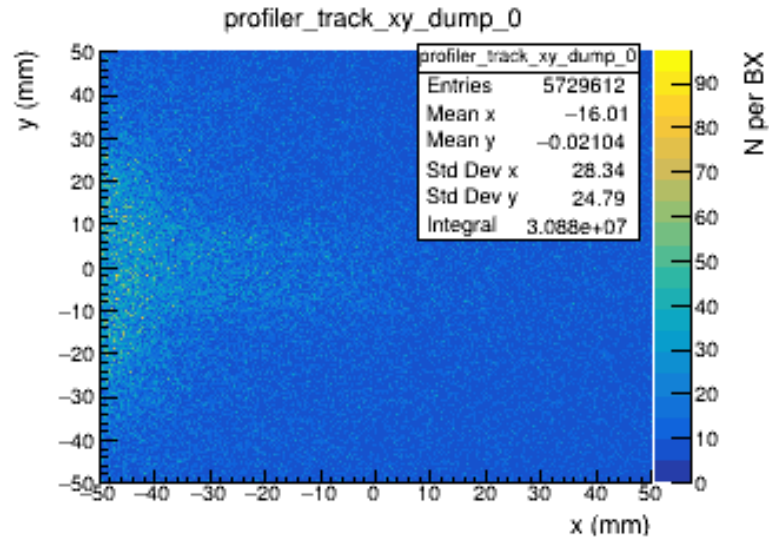
- Background has been analysed using GEANT4 data for 0.1855 BX
- For front profiler pair, background which deposits energy is expected to be $\sim 1e7$ particles/BX
- For rear pair, background $\sim 5e4$ particles/BX
- Background deposition mostly low energy < 0.2 MeV
- Maximum dose per strip depends on profiler location (front or rear) but in either location does not exceed $\sim 3e-5$ Gy/BX
- Flux and current response still to be calculated

Backup

Background tracks



Background tracks – vtx_z in electron dump



Background tracks – vtx_z in shielding

