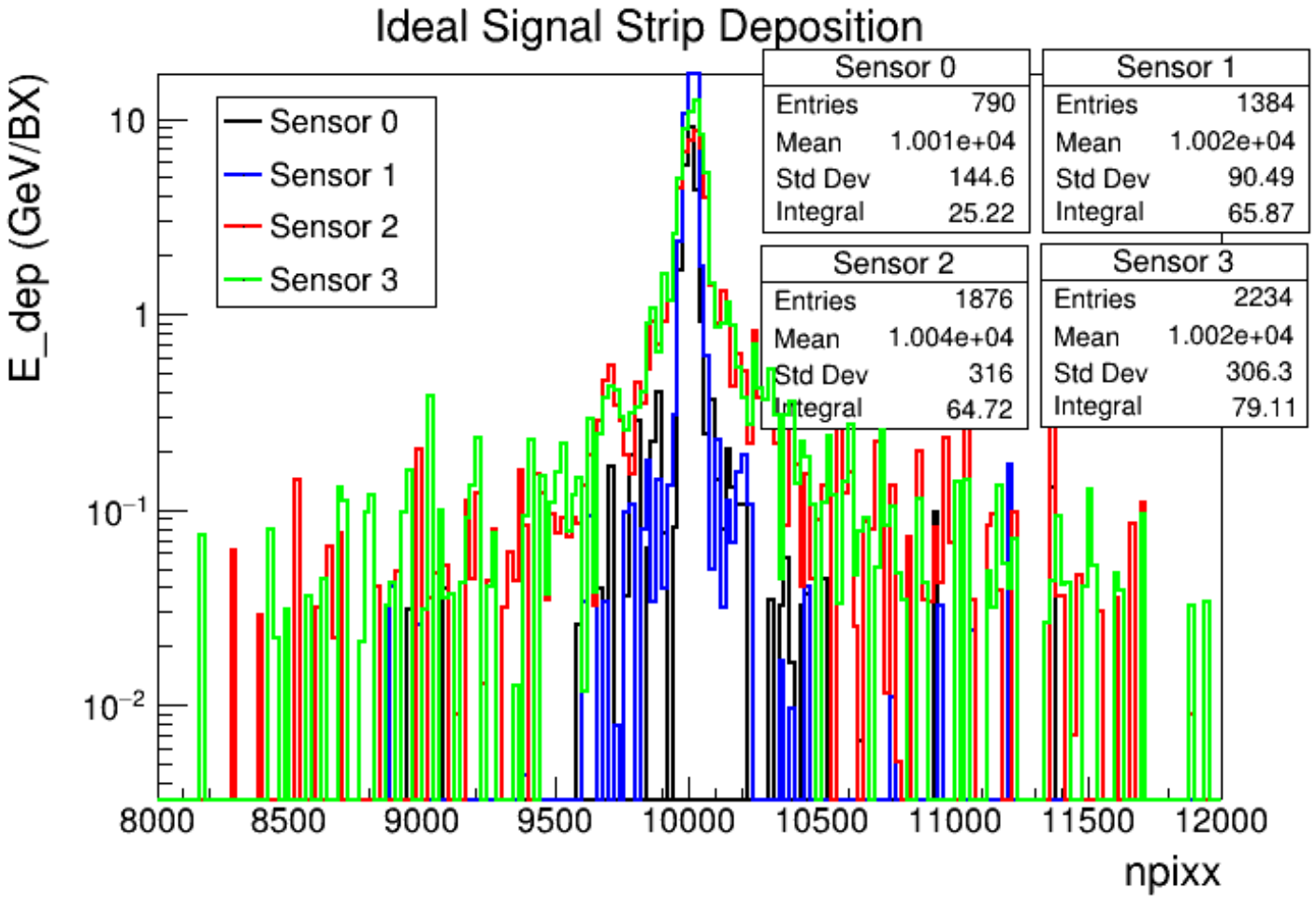
GBP-MC Simulation Update

Kyle Fleck, Niall Cavanagh and Dr. Gianluca Sarri

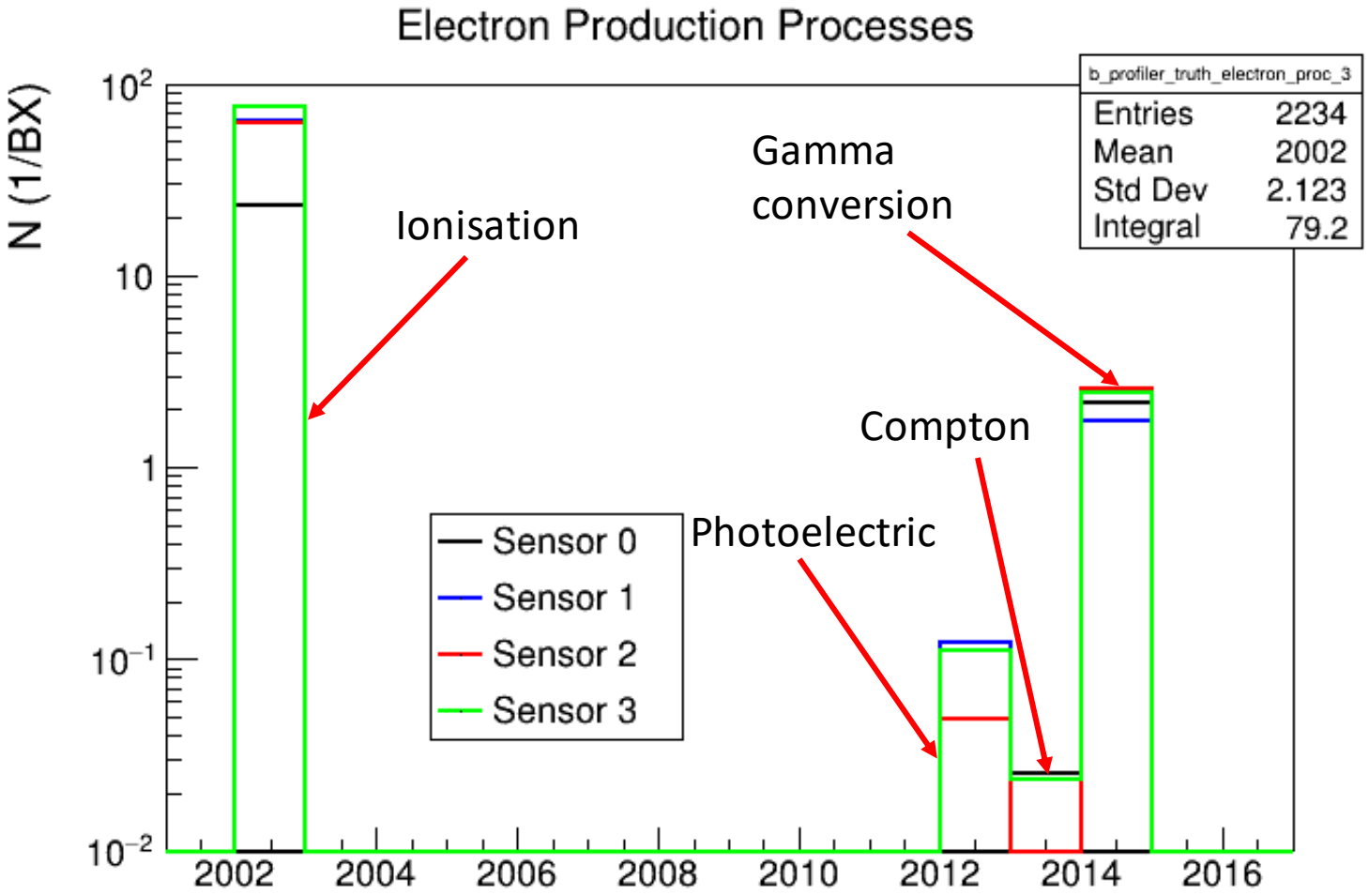
19/03/21

Truth signal



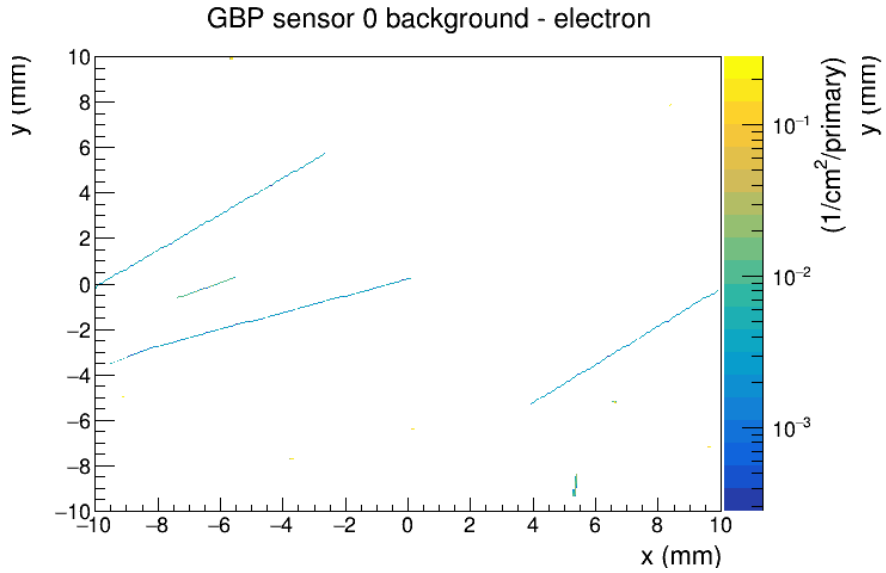
- 8000 – 12000 npixx corresponds to central –10.0 to 10.0 mm of profiler
- Range ~100 GeV across central ±2.5 mm
- Conversion from npixx to mm – 1 npixx width = 0.005mm

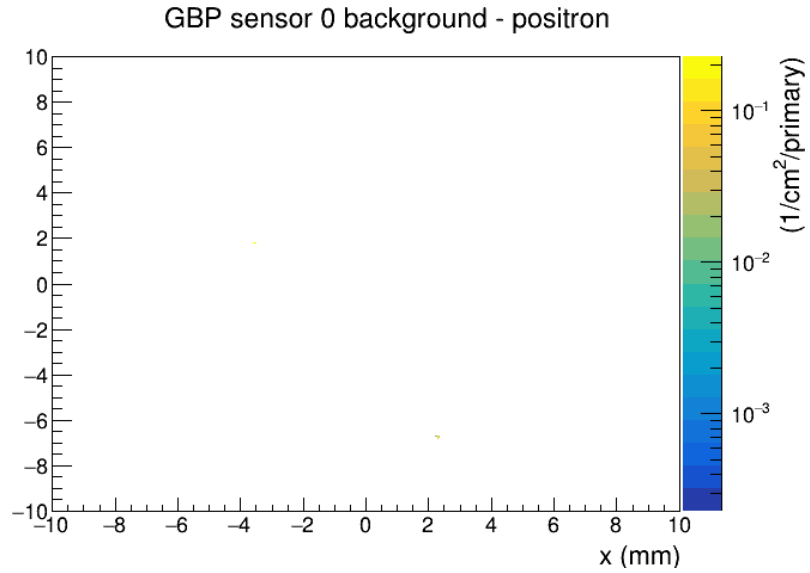
Electron production processes

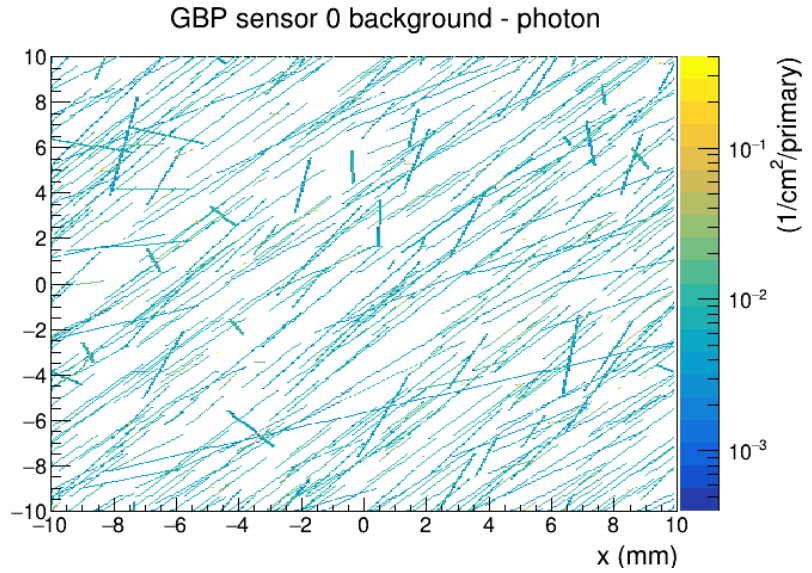


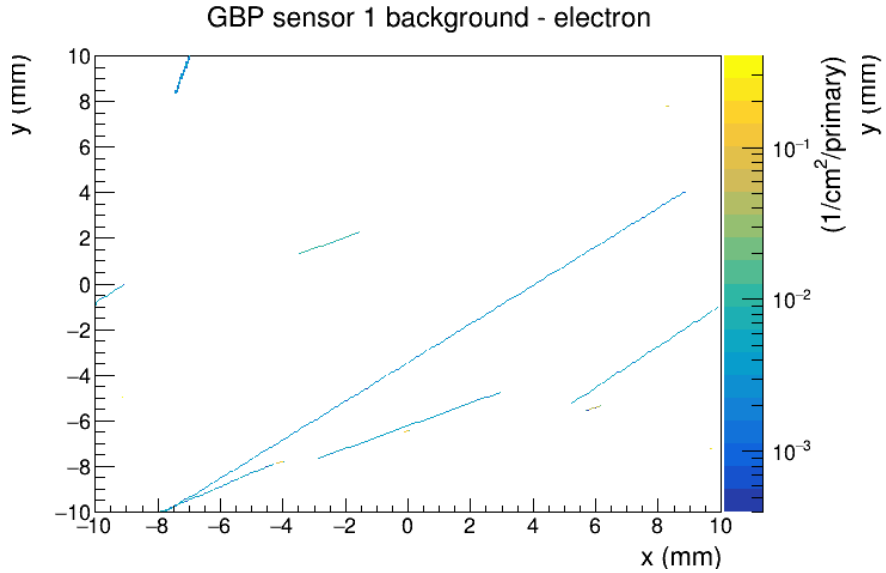
FLUKA background plots

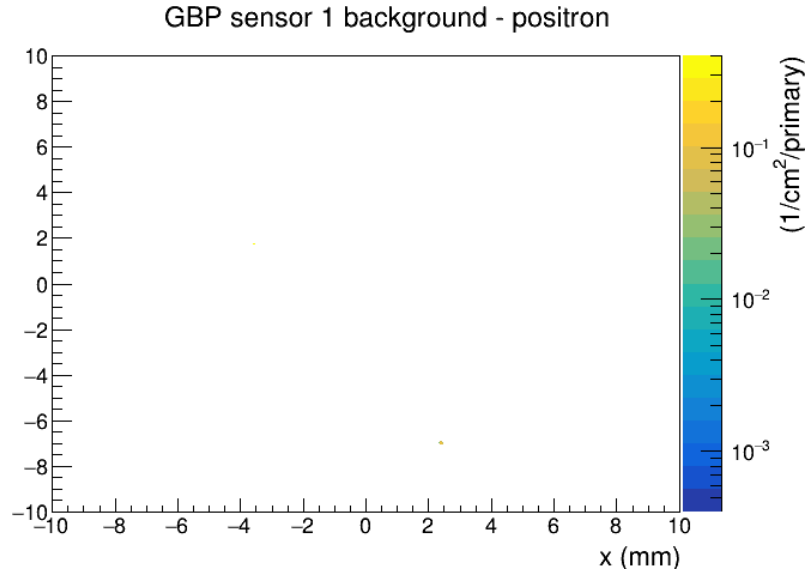
- Previous results for background contained long (projected) particle tracks in plane of profiler – problematic for energy deposition
- Two causes of this phenomenon
  - Slight misalignment of magnetic field in FLUKA caused both vertical and horizontal deflection of electron beam
  - Difference in how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

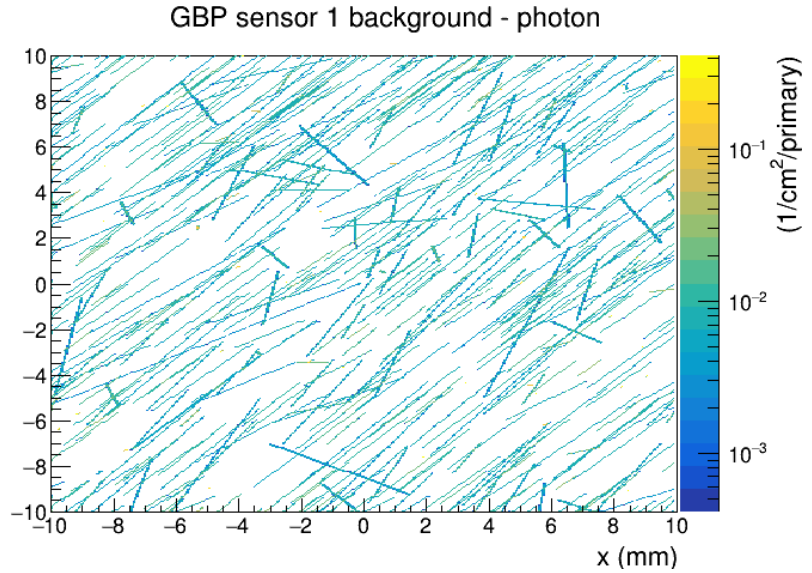

GBP sensor 0 background - electron
y (mm)
x (mm)
(1/cm²/primary)


GBP sensor 0 background - positron
y (mm)
x (mm)
(1/cm²/primary)

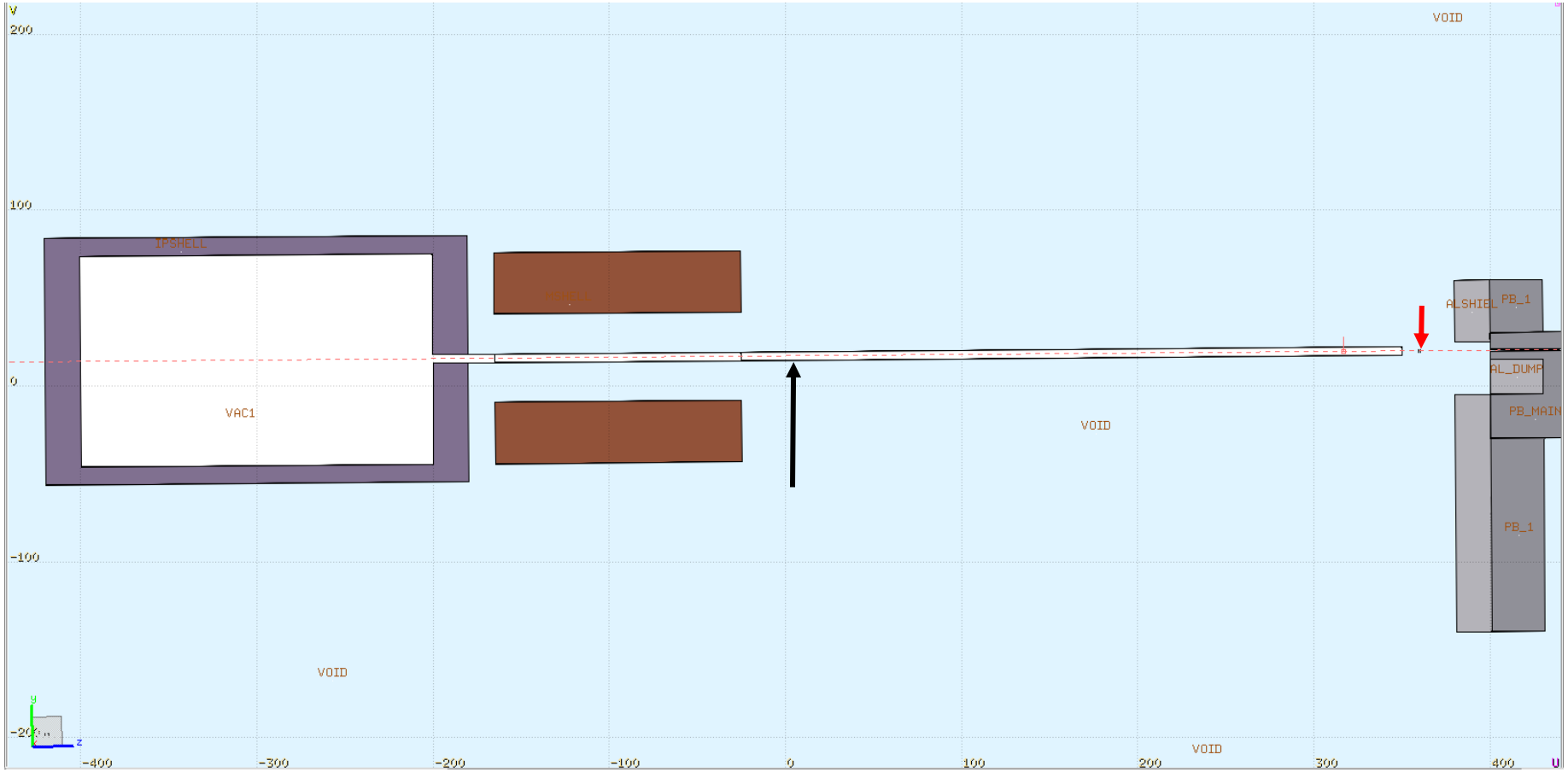

GBP sensor 0 background - photon
y (mm)
x (mm)
(1/cm²/primary)


GBP sensor 1 background - electron
y (mm)
x (mm)
(1/cm²/primary)


GBP sensor 1 background - positron
y (mm)
x (mm)
(1/cm²/primary)

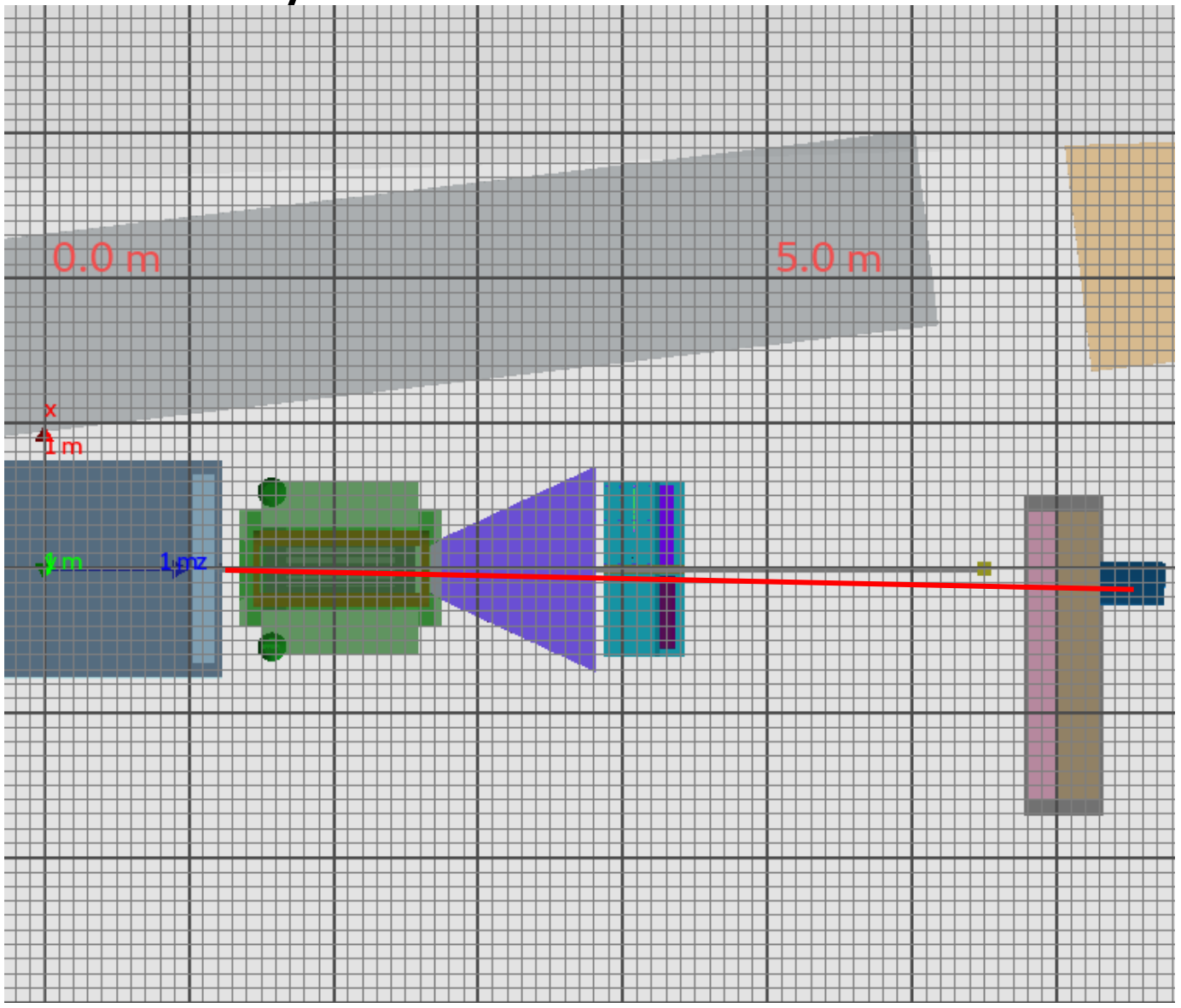

GBP sensor 1 background - photon
y (mm)
x (mm)
(1/cm²/primary)

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 = 11.8m)

GBP-MC Simulation Update

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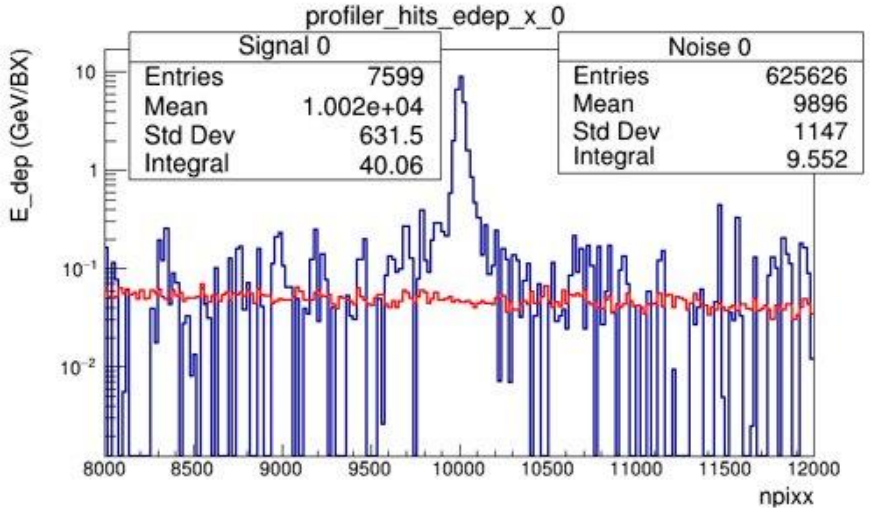
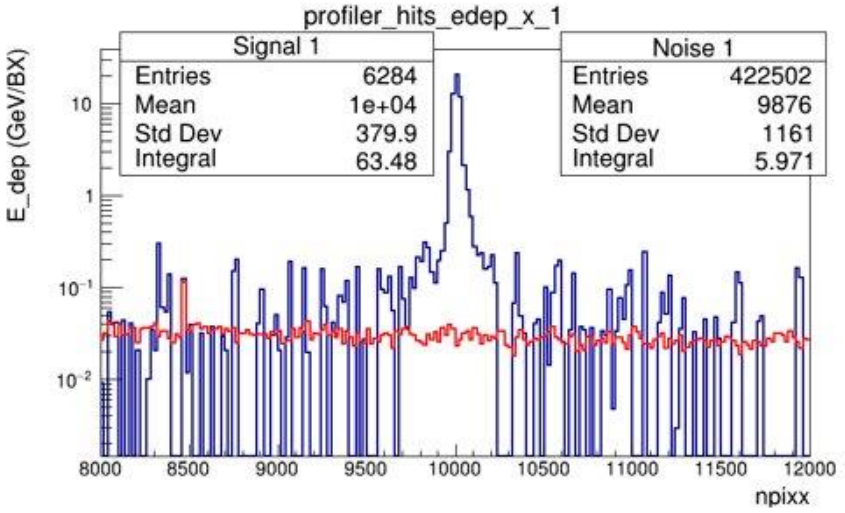
08/03/21

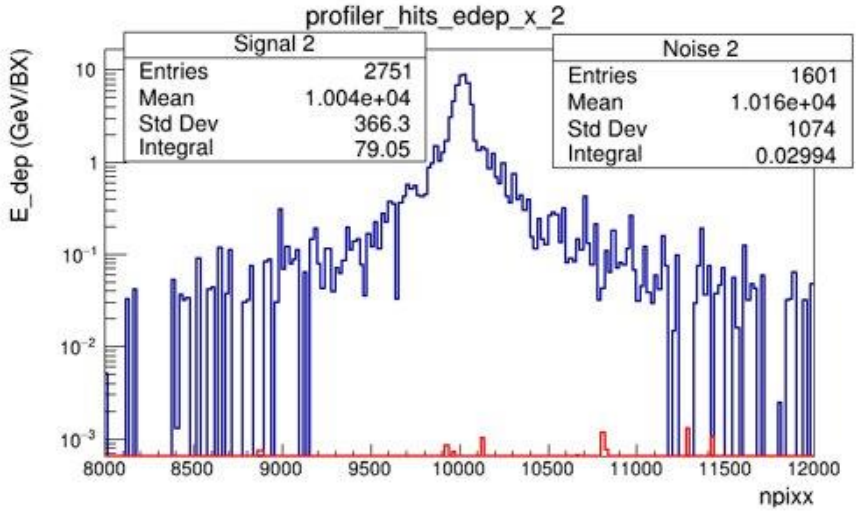
Overview

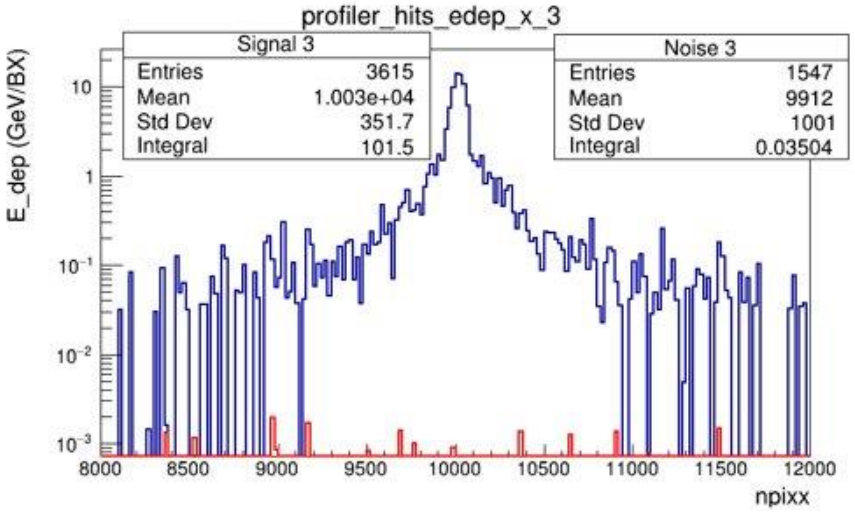
- Analysed background on profiler due to electron beam colliding with beam dump
- Managable S/B ratio on both pairs of detectors (total energy deposition)
  - S/B > 2 across central 2.5mm of plane for forward detectors
  - S/B > 500 across entire plane for rear detectors

S/B Comparison



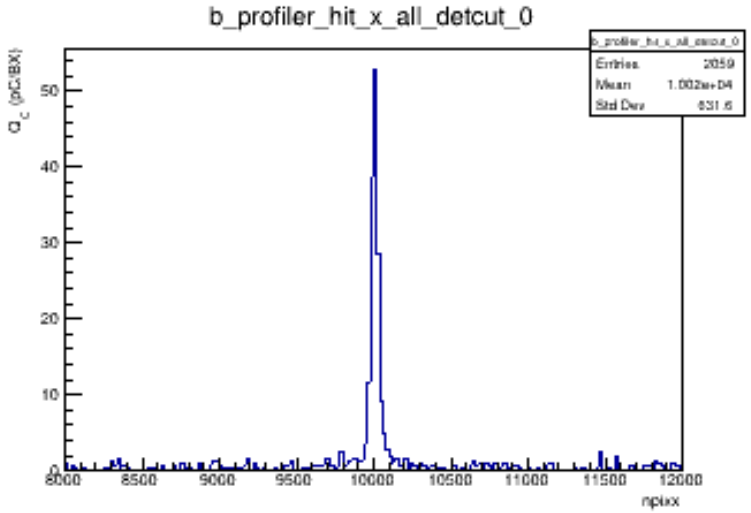


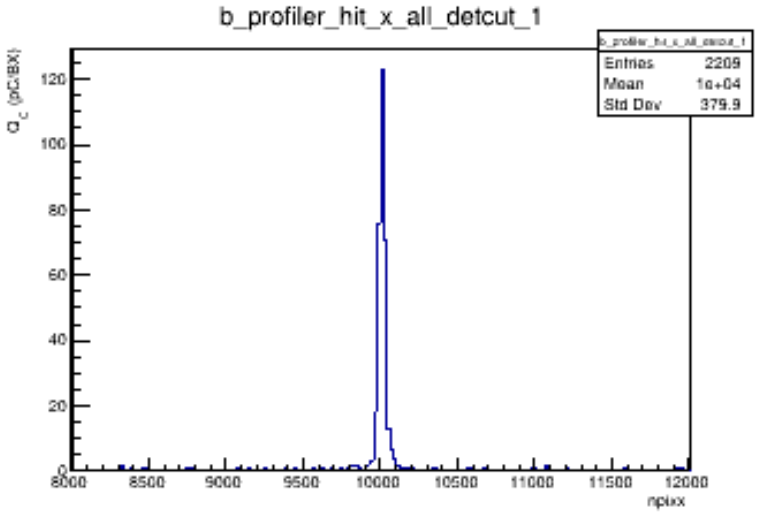


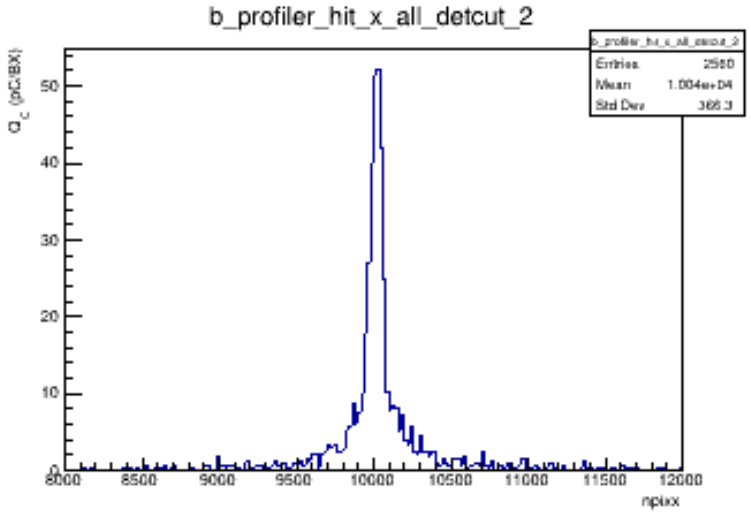


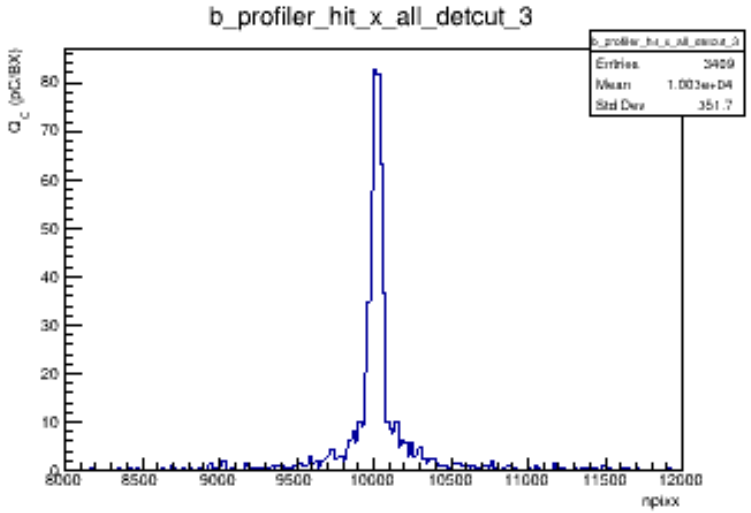
- S/B ratio > 10 between npixx = 9800 and 10200 for front profilers
- Corresponds to a spatial range of ±1 mm
- S/B ratio > 2 between 9500 and 10500 -> spatial range ±2.5 mm
- S/B ratio > 500 across entire detector for rear profiler pair
- Higher S/B ratio at front profilers due to proximity to electron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

Charge Collection Estimate







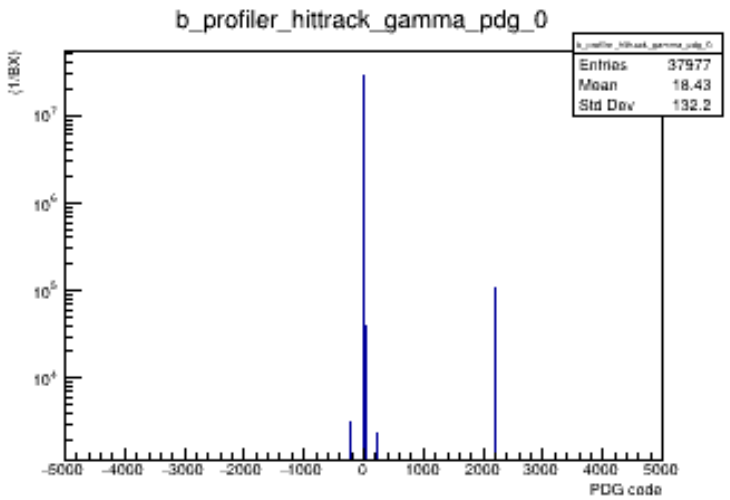


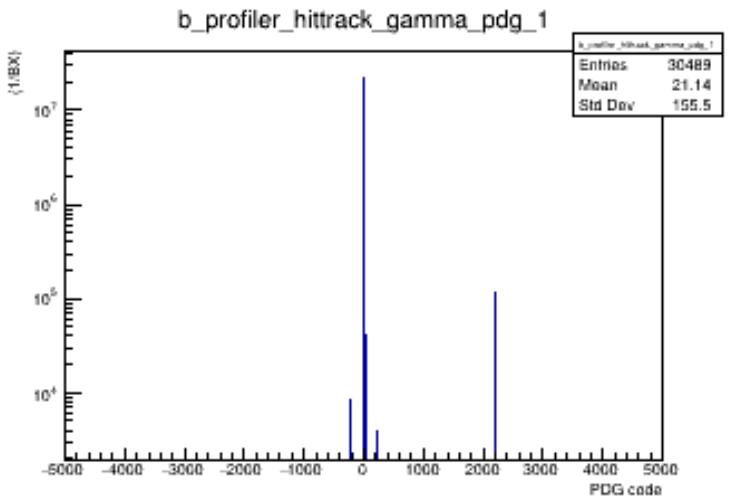
- Rough estimate of charge collected in each strip (pC/BX)

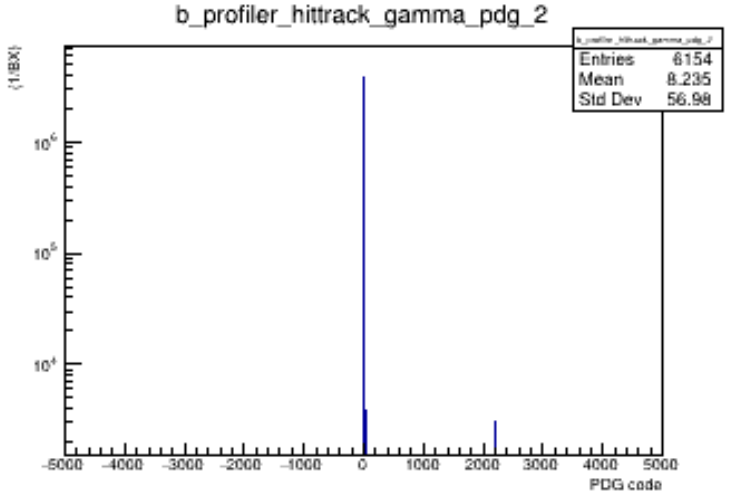
$$Q_c = \eta e N_{eh}$$

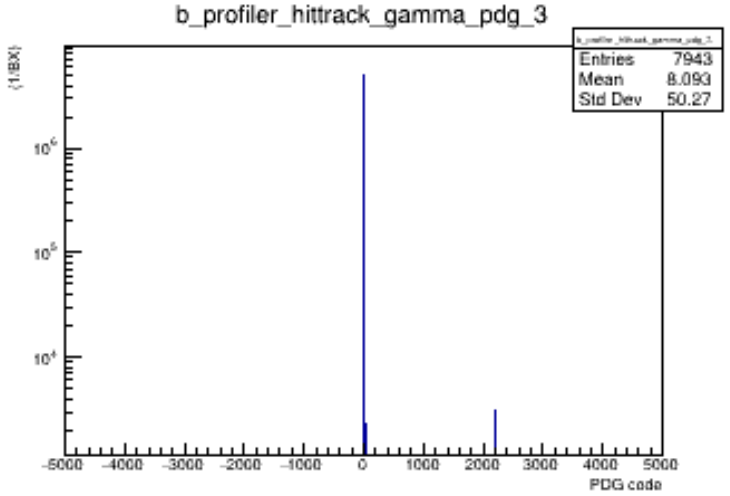
- Collection efficiency assumed to be 1.0
- From Marco's slides, energy to create e-h pair for sapphire = 27.0 eV

Particle Types



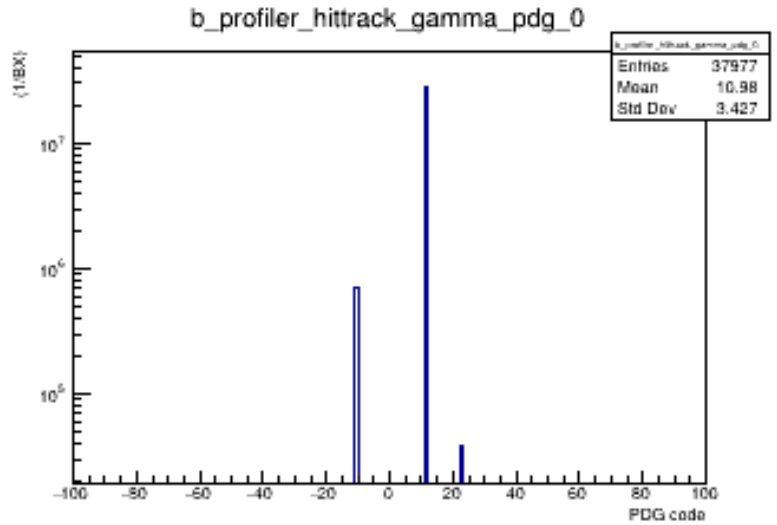


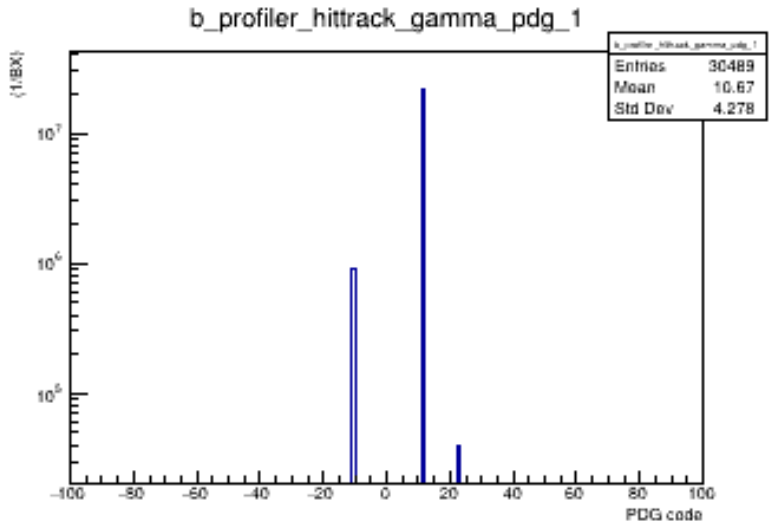


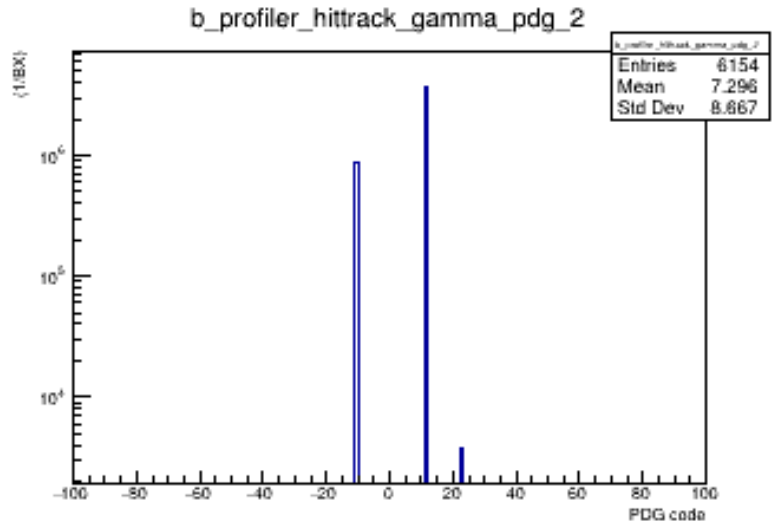


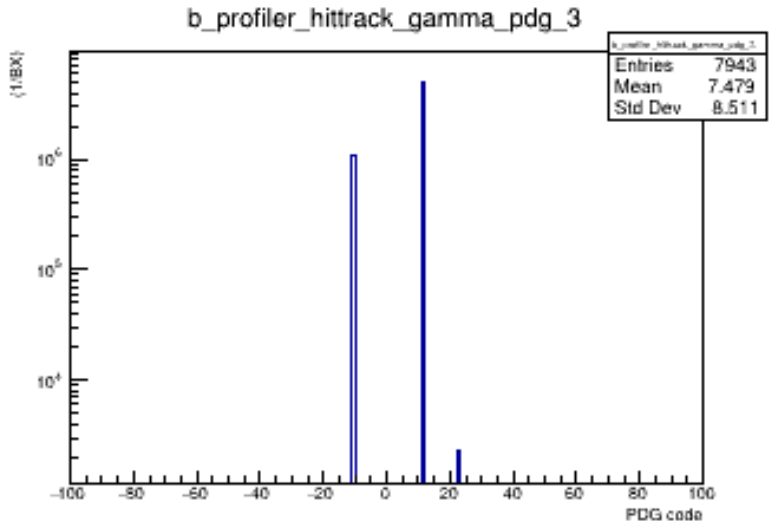
- Seems that main particles hitting profilers are
  - Electrons
  - Positrons
  - Photons
  - Pions (+/-)
  - Protons

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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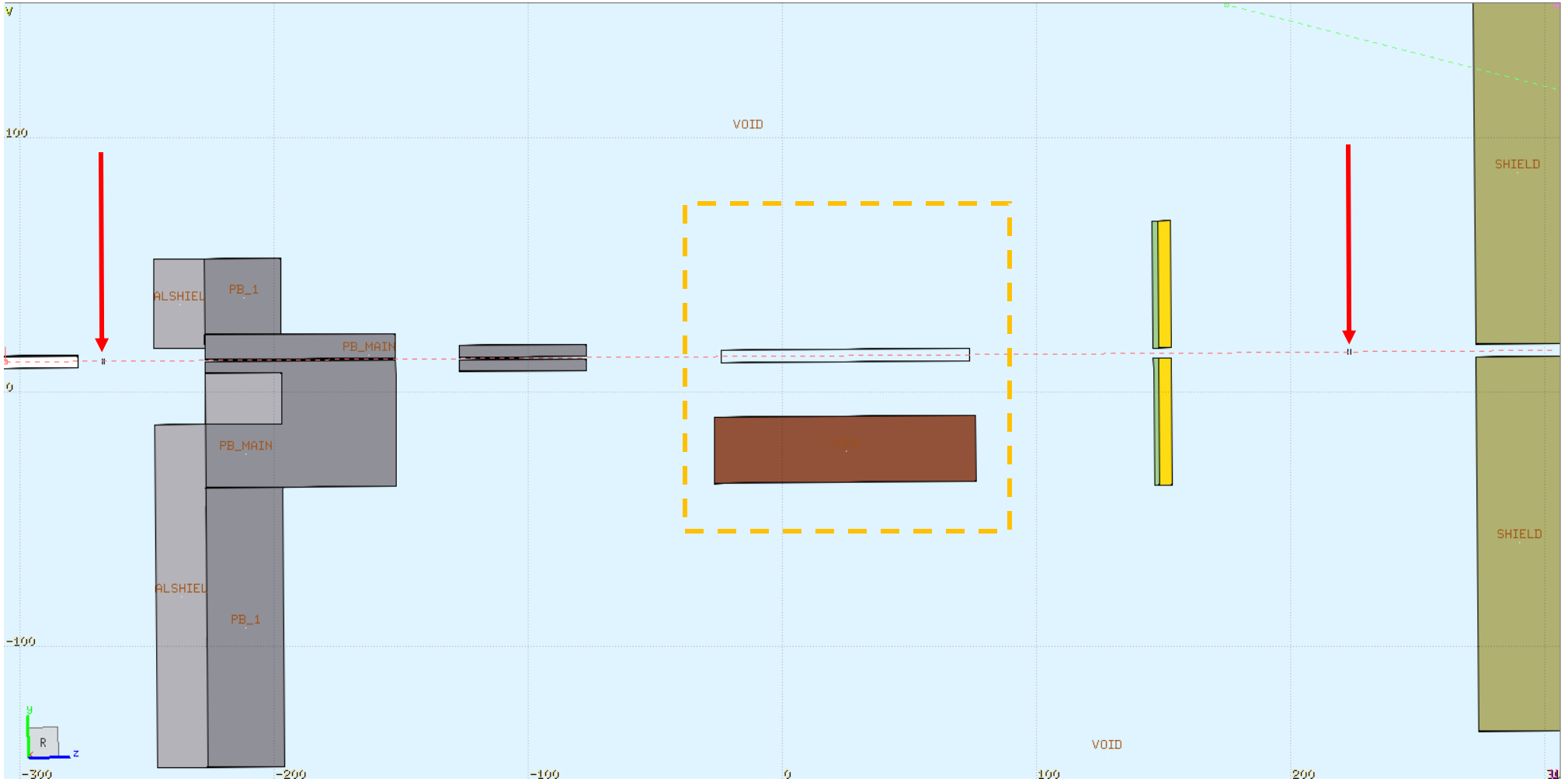
22/02/21

Overview

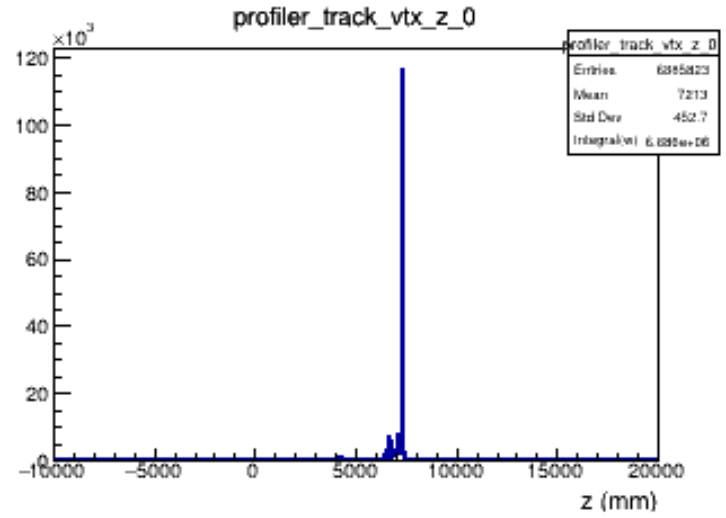
- Previous FLUKA simulations for entire forward spectrometer (PDS – photon detection system) done for 1e5 primary electrons
- Higher statistics simulation in FLUKA still running, data should be available soon
- GEANT4 MC data exists for both signal and background for entire LUXE setup – now includes 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 (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

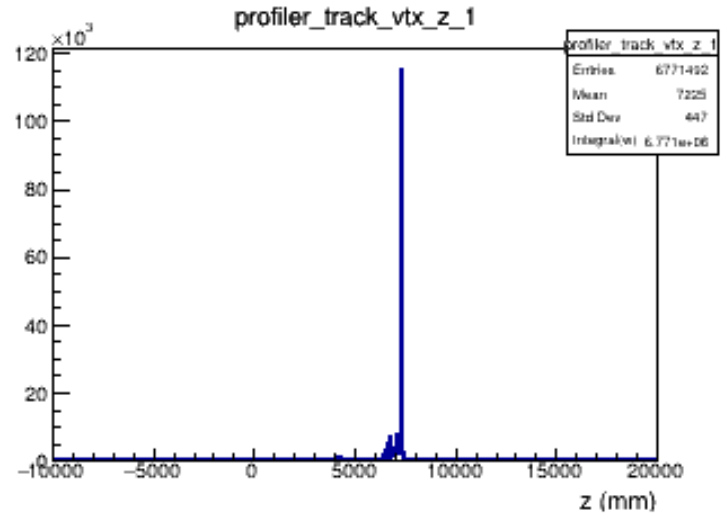
PDS geometry (FLUKA)

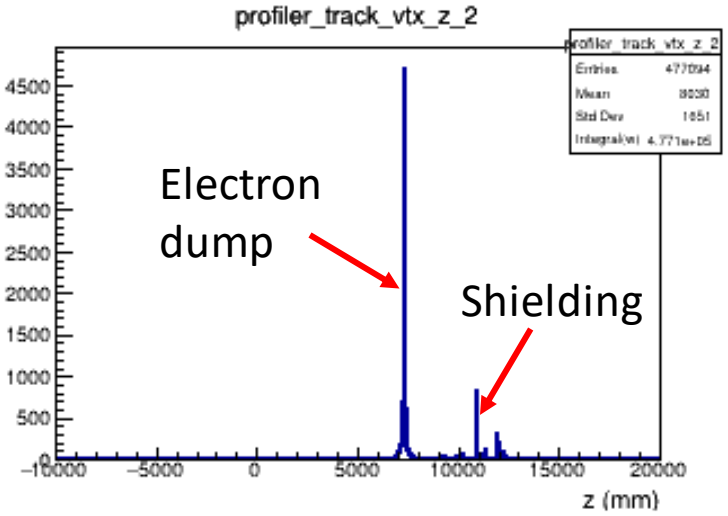


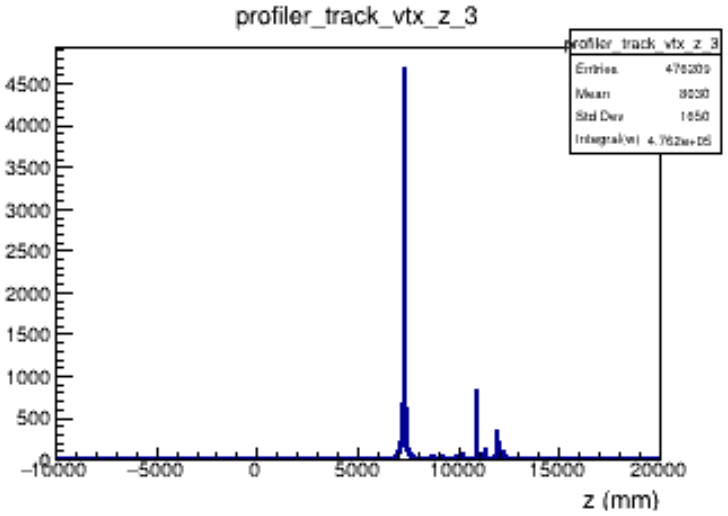
- Profiler locations indicated by red arrows
- Magnet region marked by orange dashed box
- "VOID" is air environment
- Geometry simplified in comparison to full GEANT4 geometry e.g. no supports, simplified electron dump, simplified LANEX screens (green) and Cerenkov detector (yellow)

Production Vertices



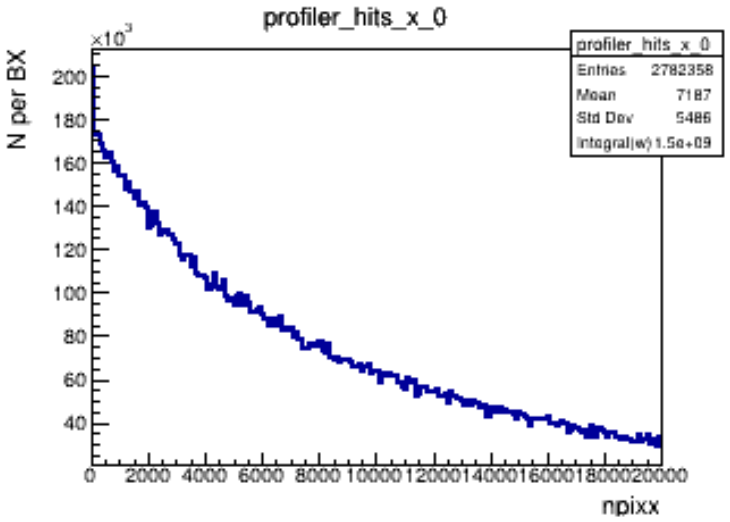


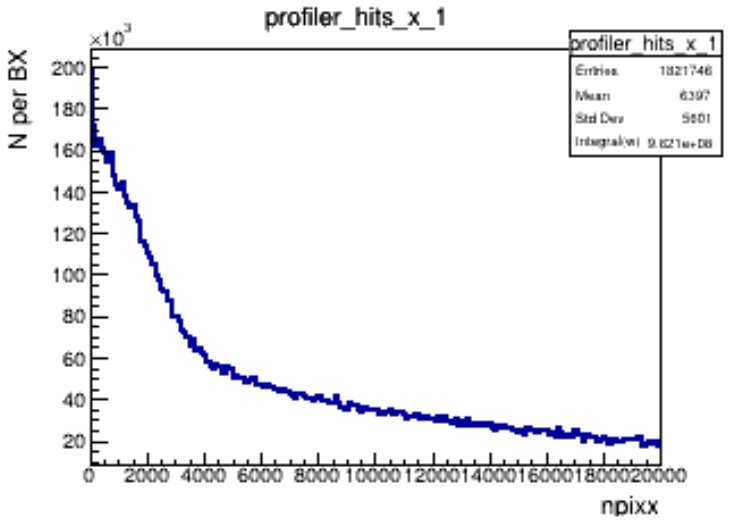


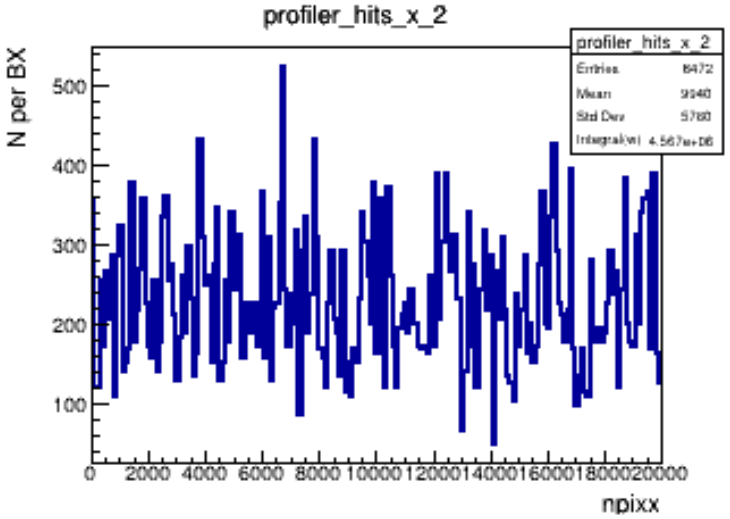


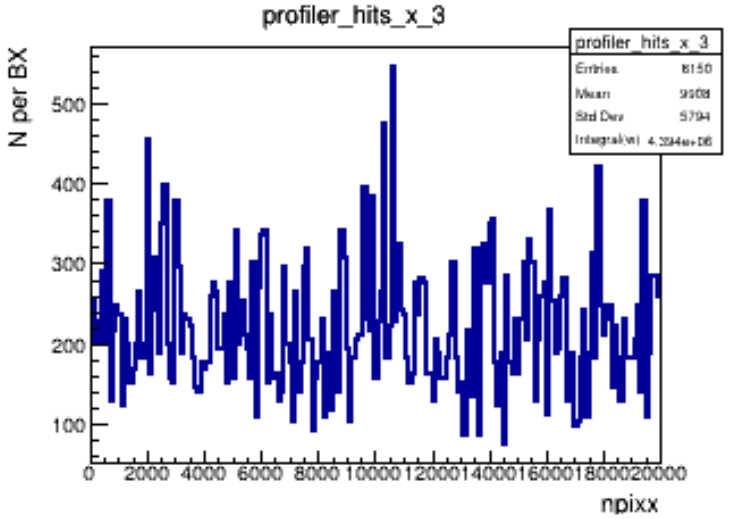
- Plots showing z production vertex of particles incident on profilers
- Main component of background comes from z = 7000mm -> electron beam dump
- Rear profiler pair also see some backscattering from shielding at z = 12000mm

Transverse hits profile (horizontal)



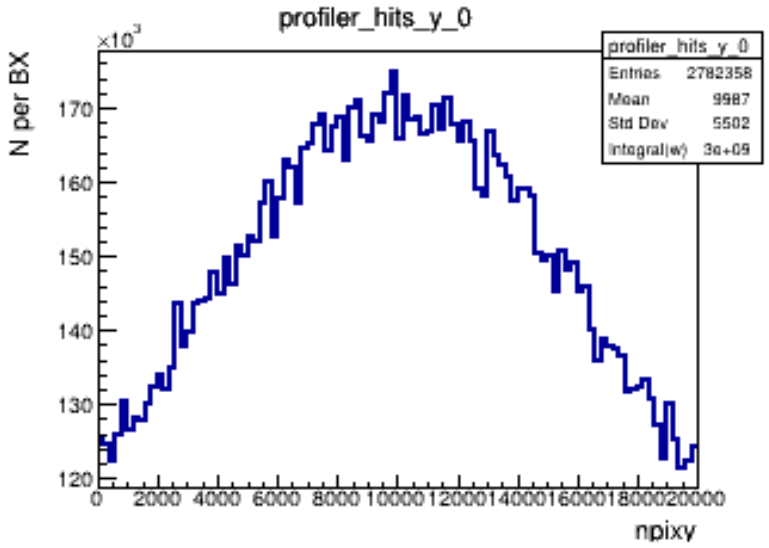


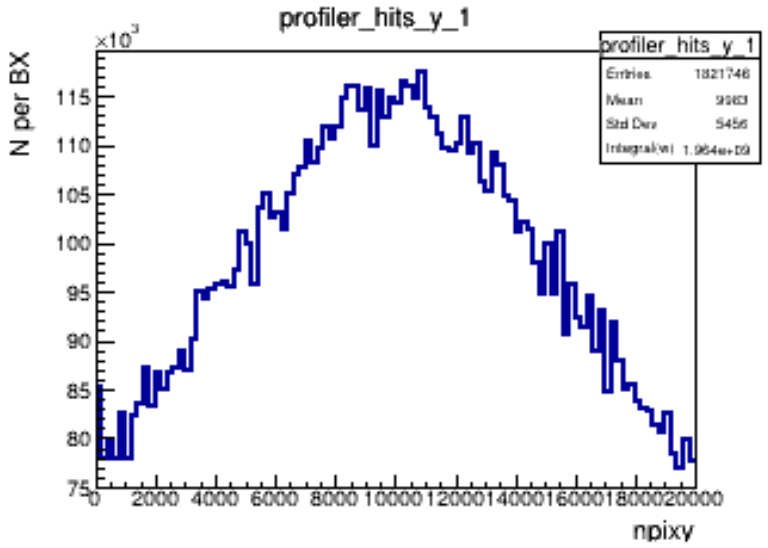


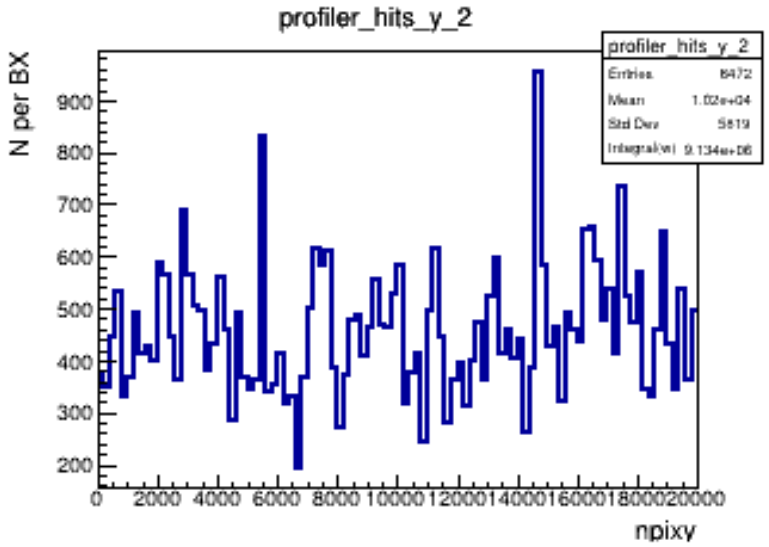


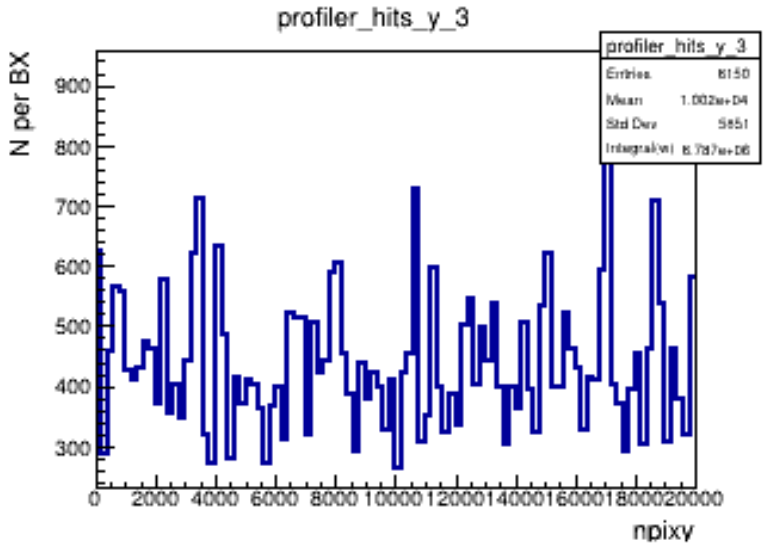
- For rear profiler pair, hits distributed uniformly across profiler in x direction
- Due to air environment and components of experiment, forward x distribution of hits not distinguishable at rear profilers
- For front pair, number of hits decreases across the detector
- Left edge (npixx = 0) corresponds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

Orthogonal hits profile (vertical)



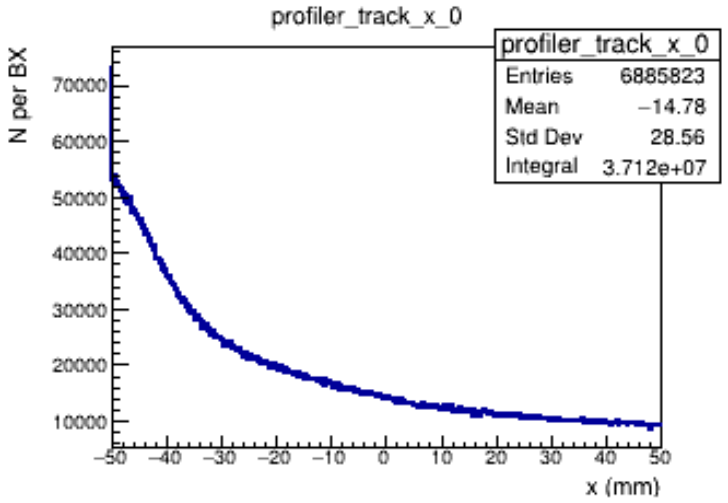


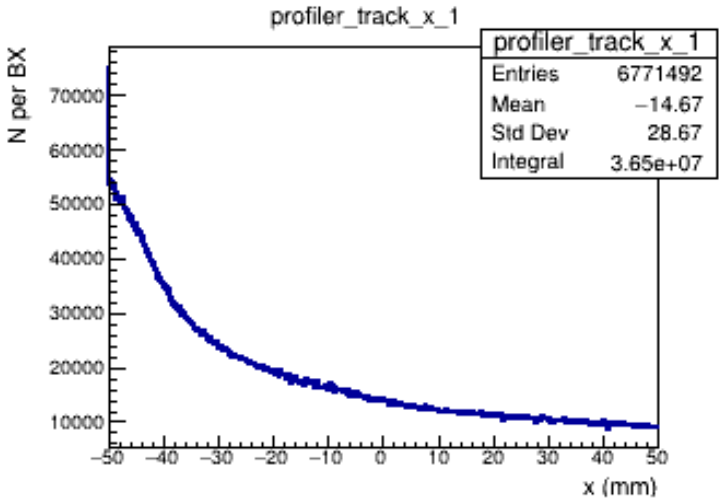


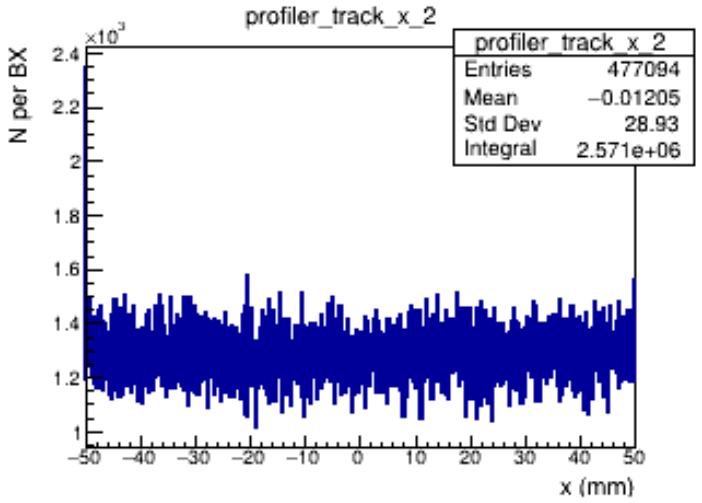


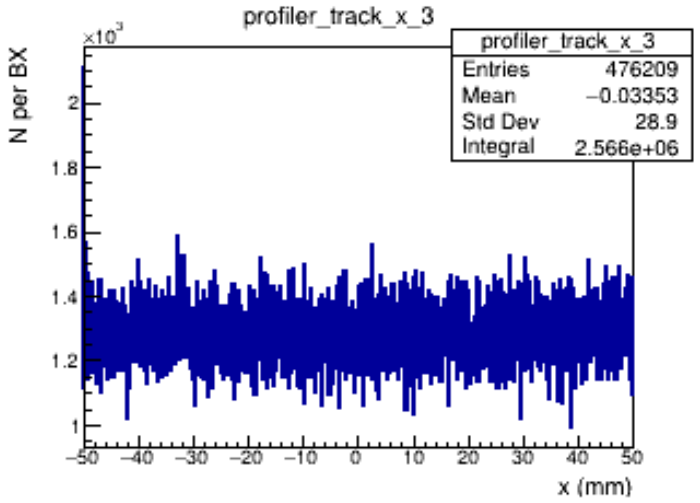
- Uniform distribution of hits for rear profilers
- Front profilers have peak at npixy = 10000 -> y = 0.0 mm
- This corresponds to the plane in which electron dump is vertically centred

Transverse tracks profile



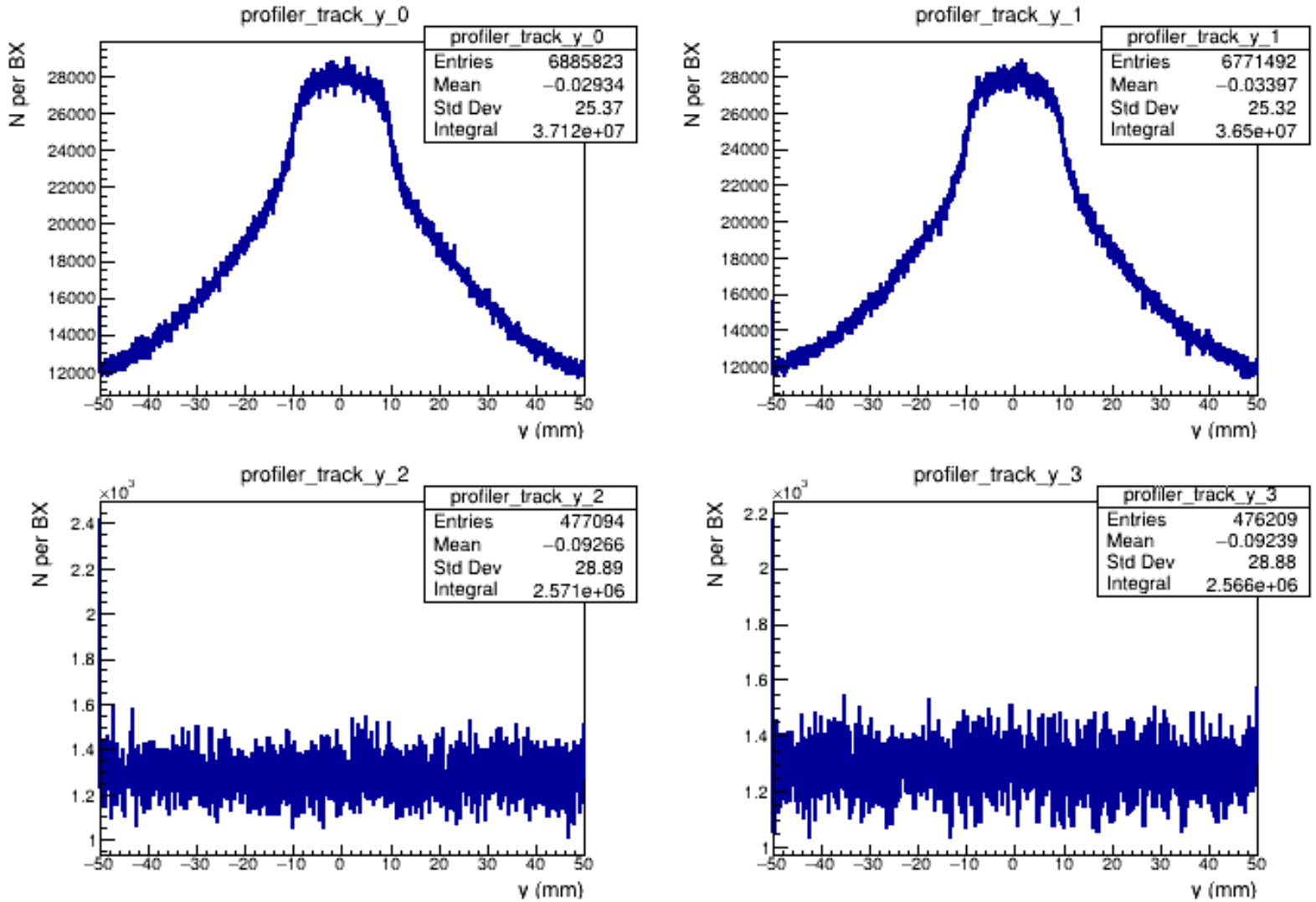




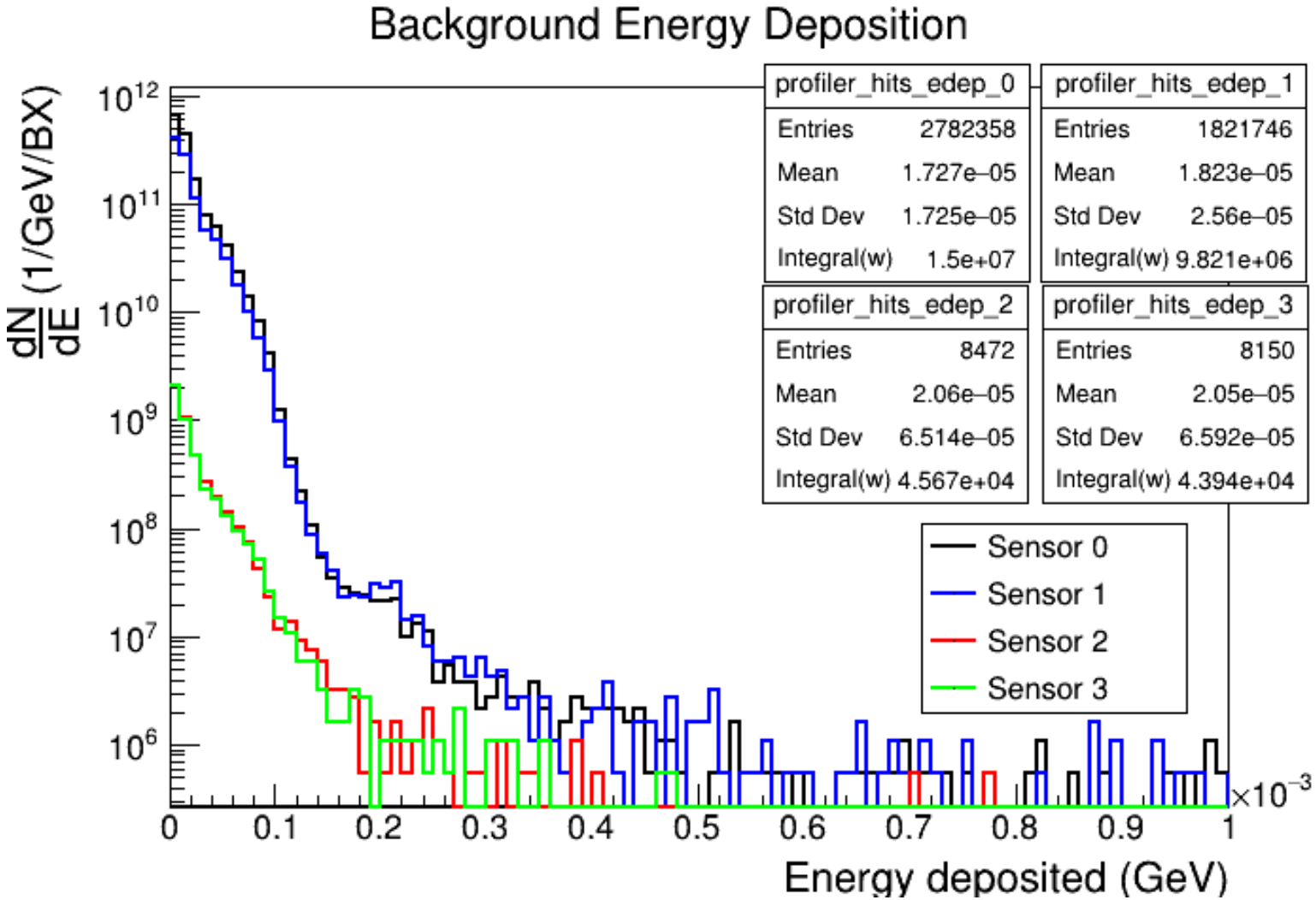


- Similar trend to hits profiles
- Rear profiles have a uniform distribution in transverse direction of background
- Front pair is highly skewed due to location of electron dump

Orthogonal tracks profile

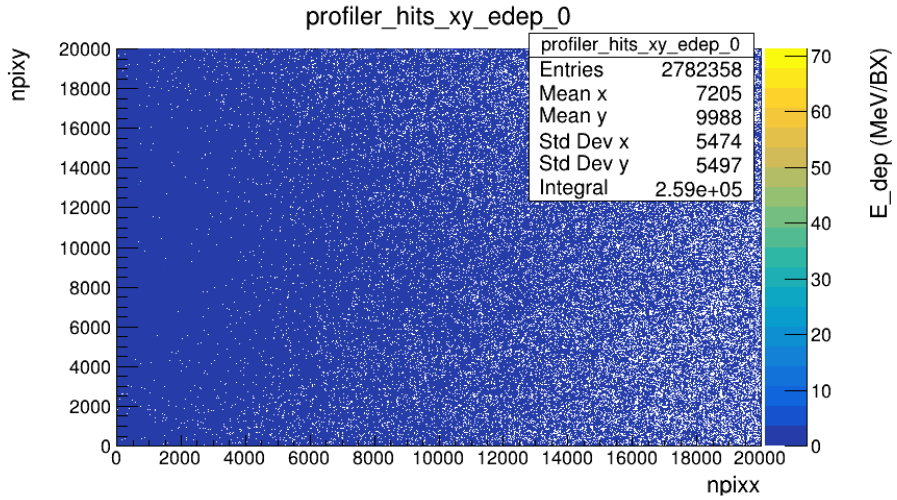


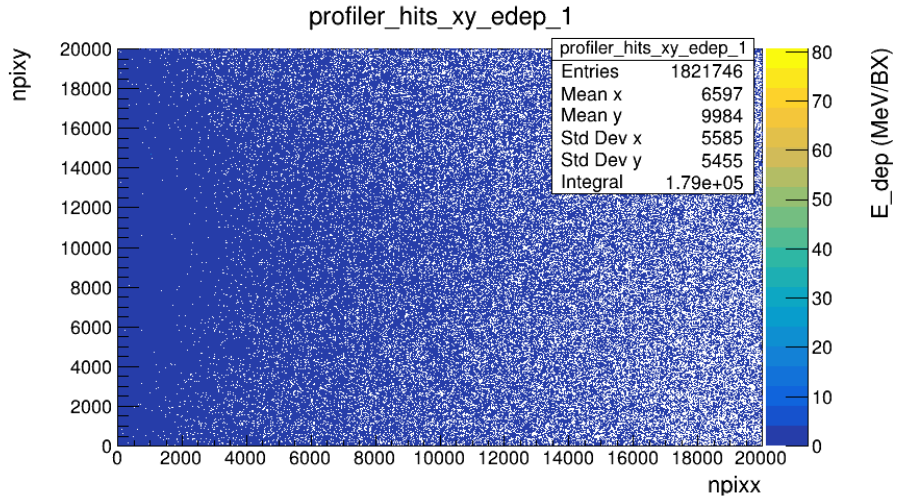
Spectrum of deposited energy

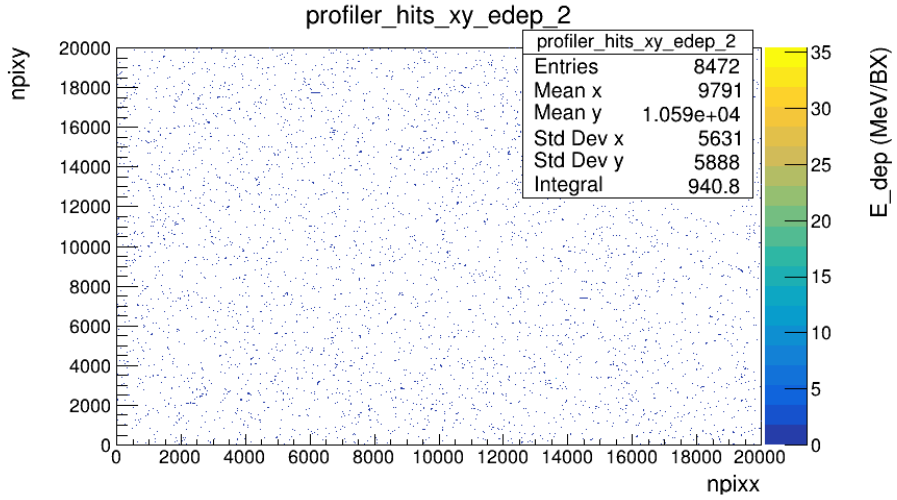


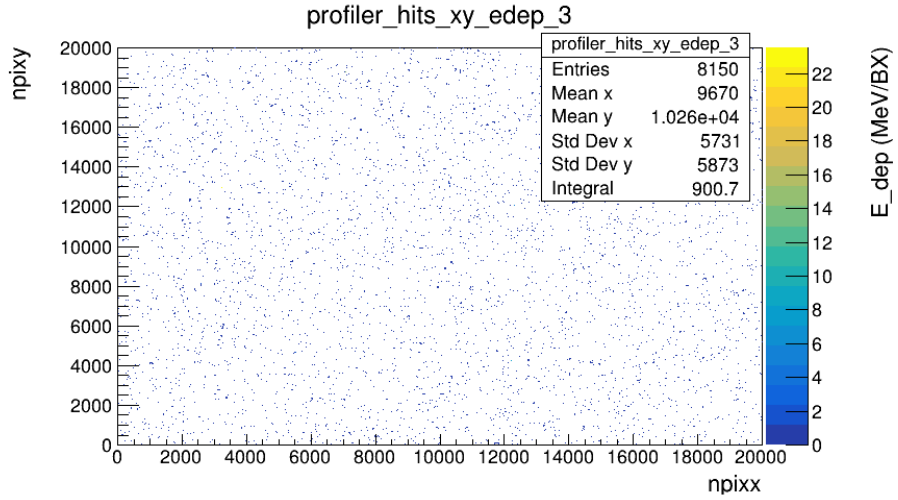
- For all detectors, large number of particles which deposit low amount of energy (E<0.2 MeV)
- Total number of hits given by value "Integral(w)"

Energy Deposition



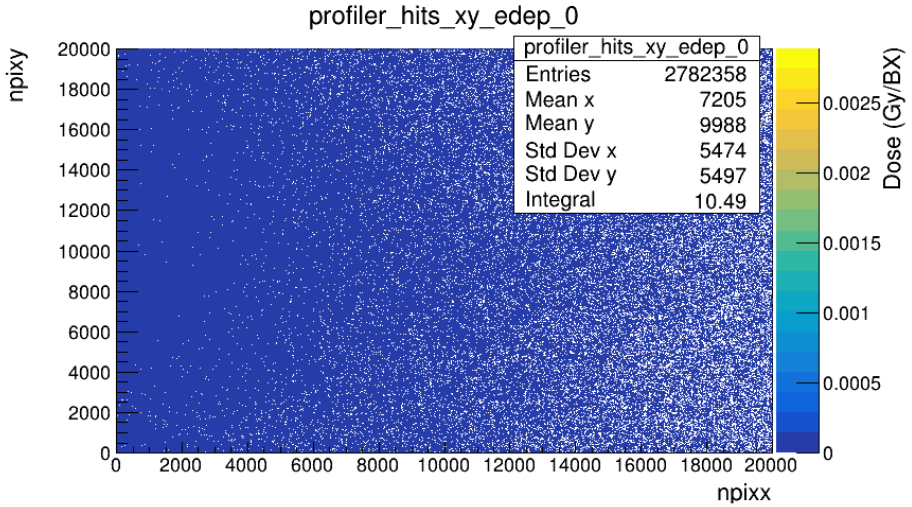


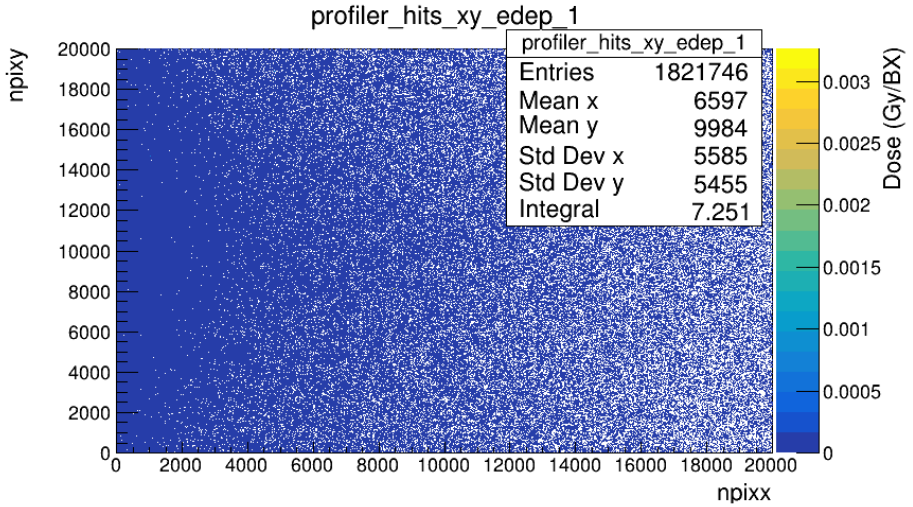


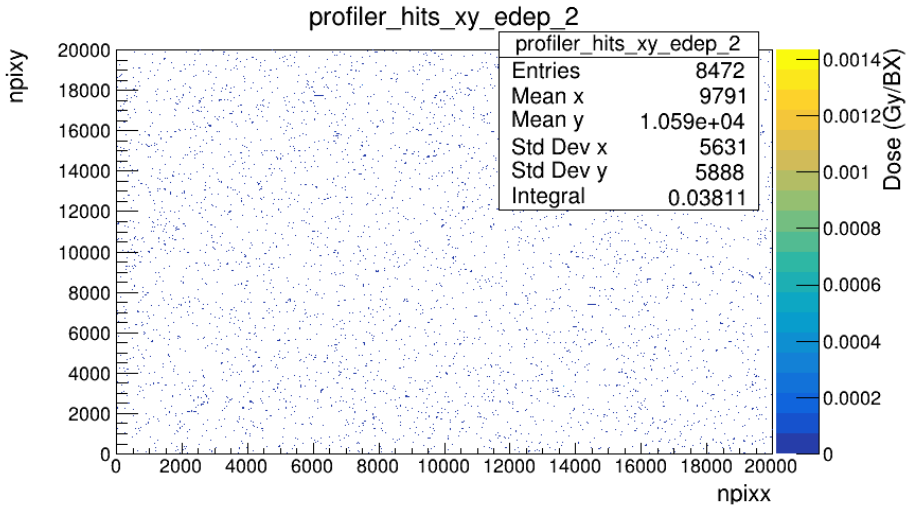


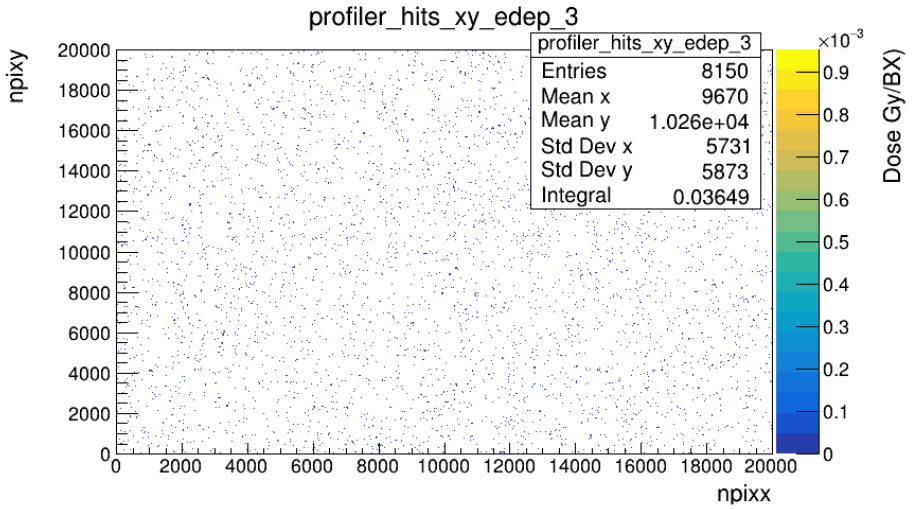
- Front profilers have a much higher energy deposition from background due to proximity to electron dump
- Random/uniform distribution of noise apparent on rear profilers

Absorbed dose



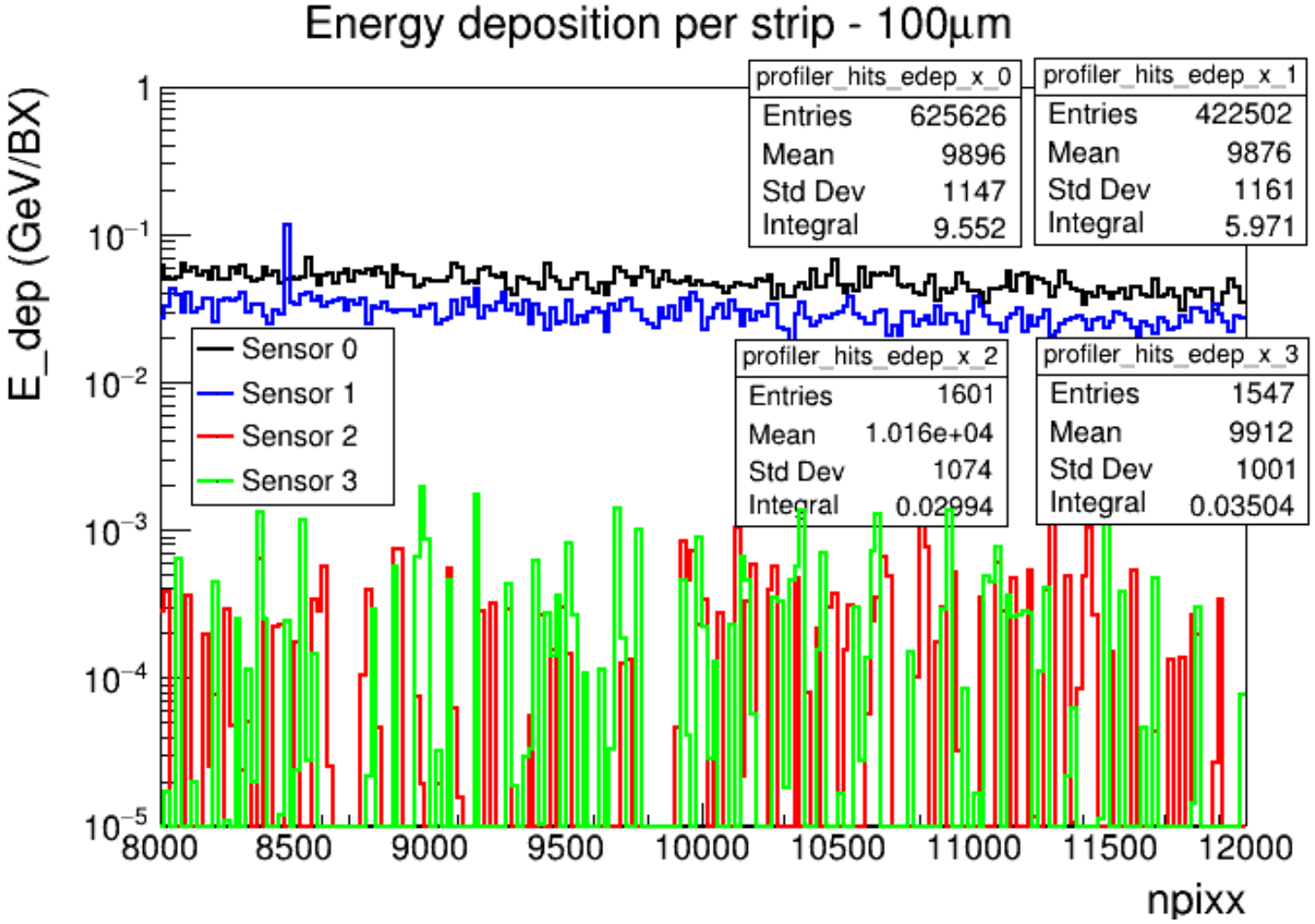






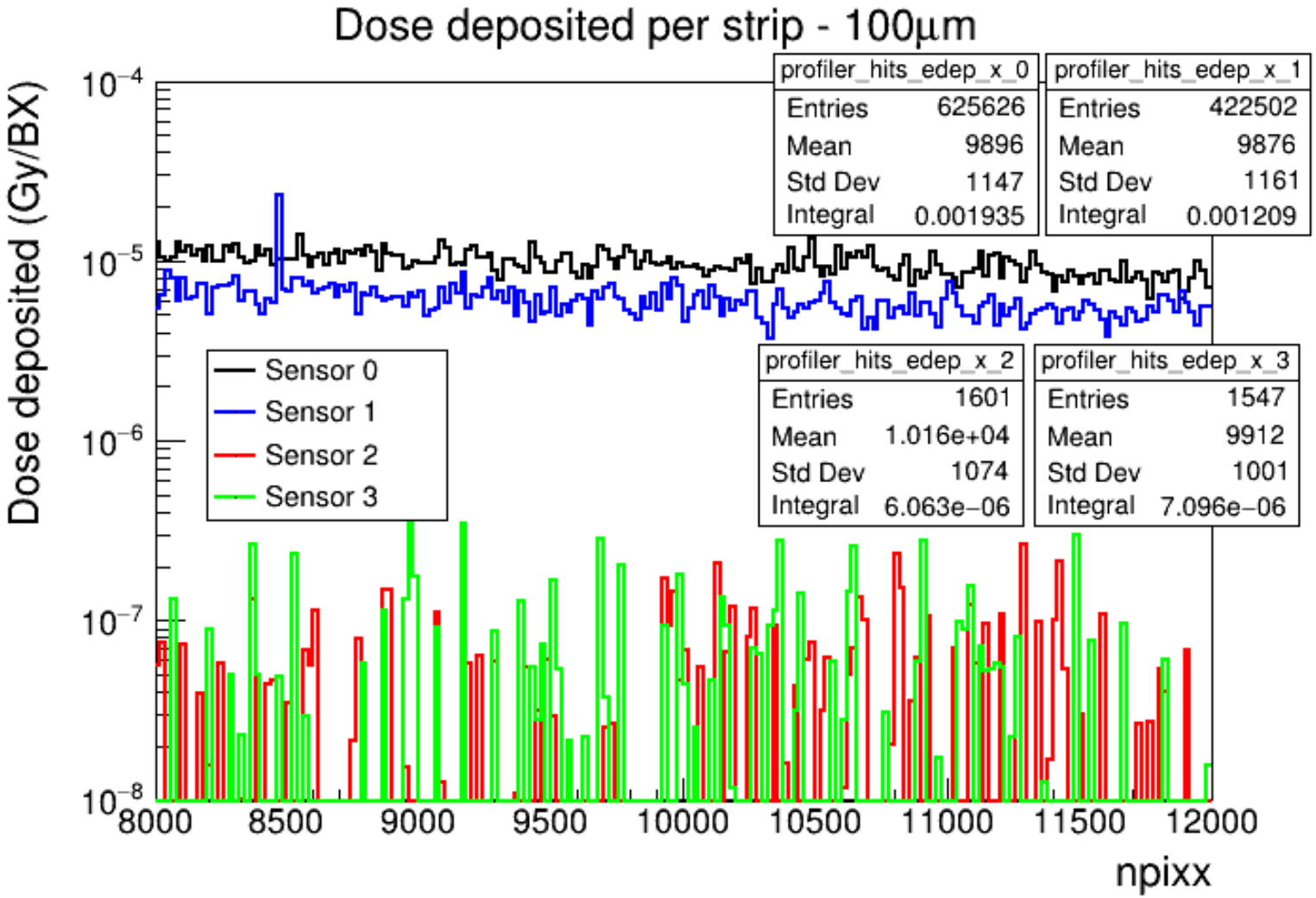
- Calculated from energy deposition map by dividing by bin volume and using scaling factor from slide 2
- For front profilers, total dose ~1e-5 Gy/BX from total energy deposited in previous slide
- Rear profilers experience ~0.5e-2 times this = 5e-8 Gy/BX

Energy deposition in segmented strips



- 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

Absorbed dose in segmented strips



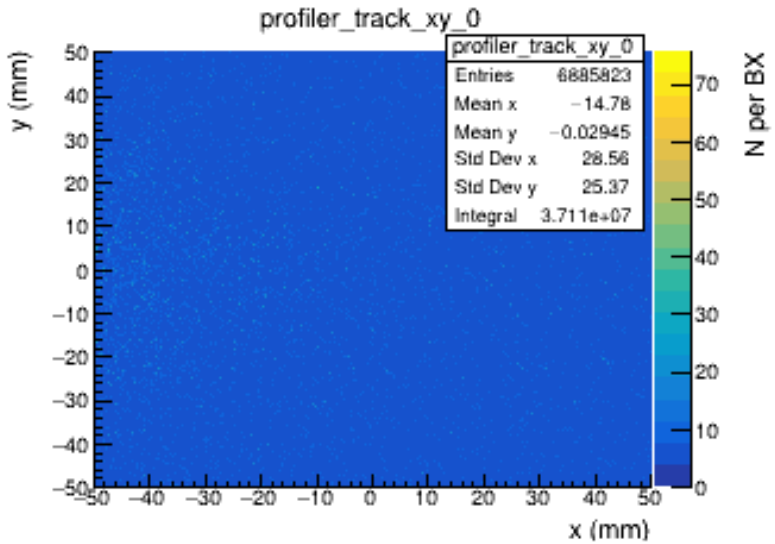
- Dose calculated from energy deposition in previous slide using volume of each strip
  - Vol = 2.0/200 * 2.0* 0.01 cm**3
- Total dose can be calculated from total energy deposition over entire 0.04 cm**3 volume of each detector

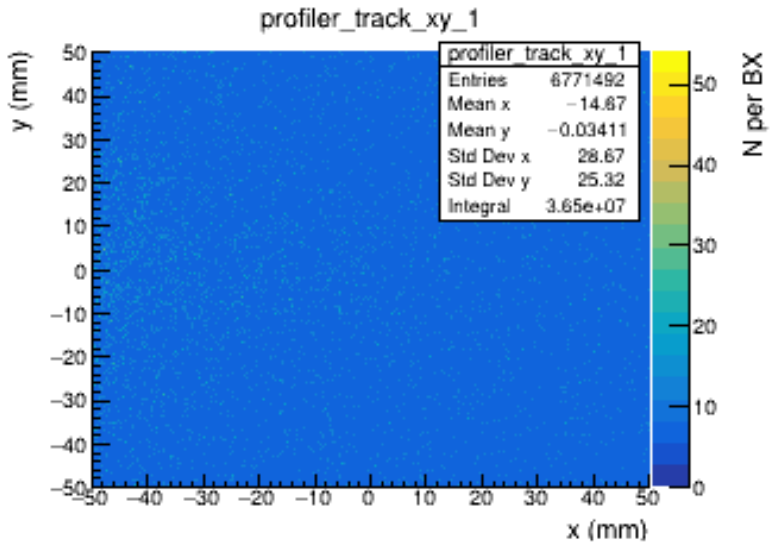
Summary

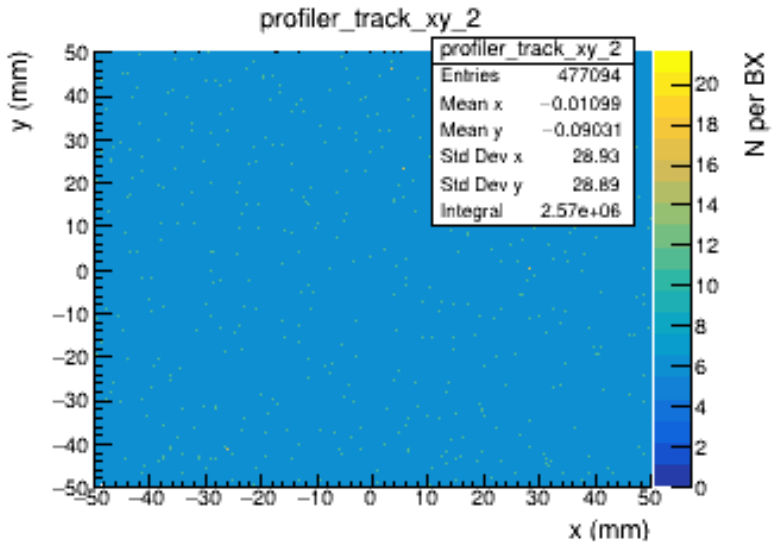
- Background has been analysed using GEANT4 data for 0.1855 BX
- For front profiler pair, background which deposits energy is expected to be ~1e7 particles/BX
- For rear pair, background ~5e4 particles/BX
- Background deposition mostly low energy < 0.2 MeV
- Maximum dose per strip depends on profiler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

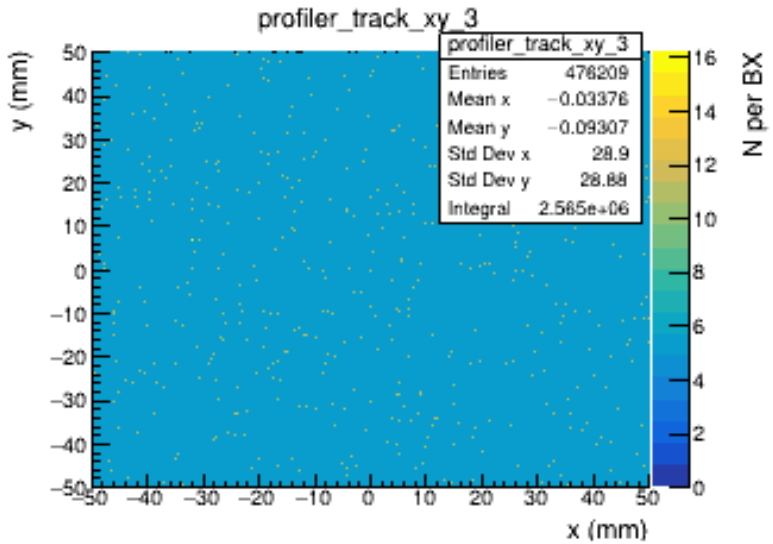
Backup

Background tracks

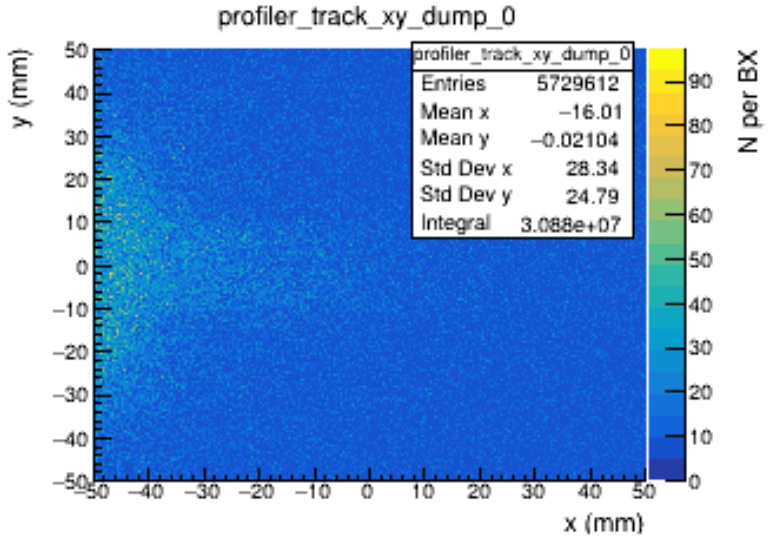


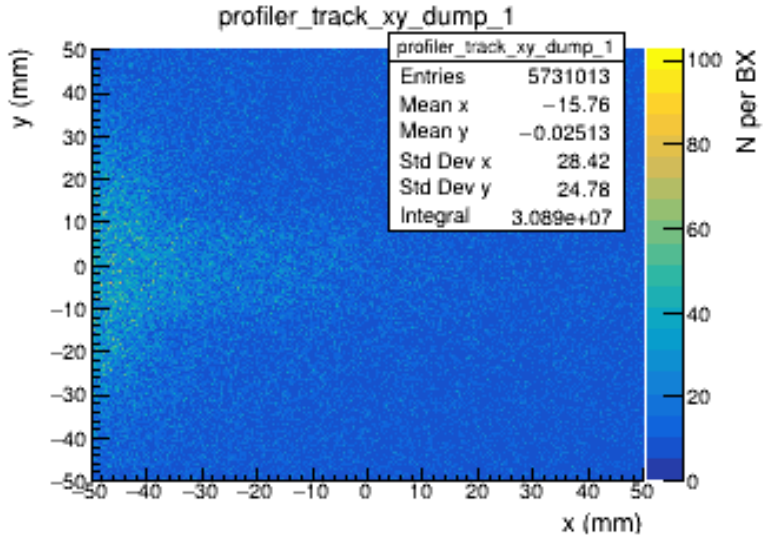


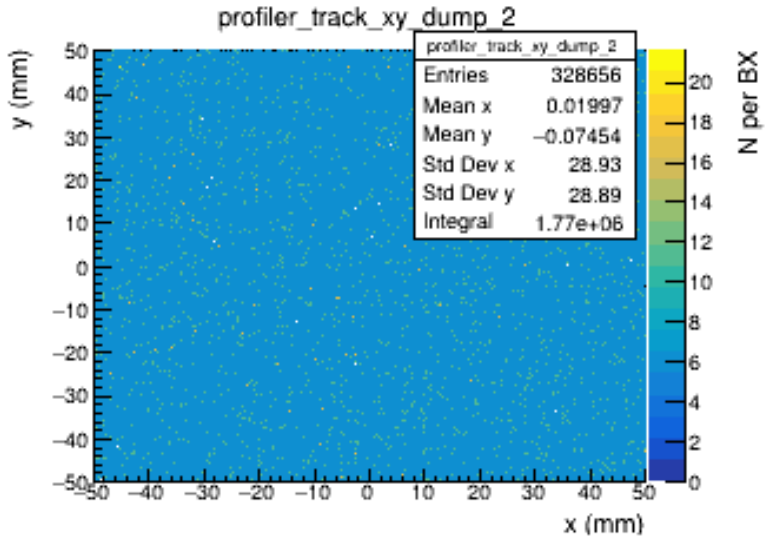


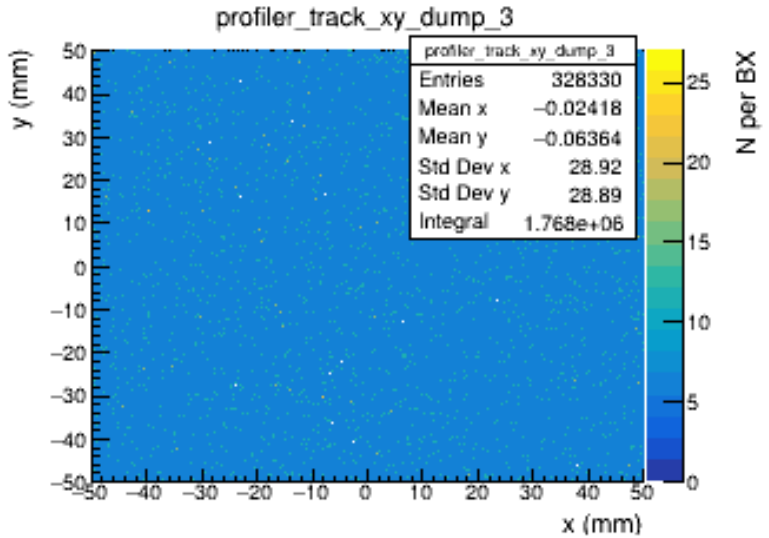


Background tracks – vtx_z in electron dump









Background tracks – vtx_z in shielding