FUTURE CIRCULAR COLLIDER

Synchrotron radiation in detectors

First look (technical demonstration)

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Kevin André (CERN-BE), Brieuc François (CERN-EP)

Photons from BDSIM at top quark threshold energy

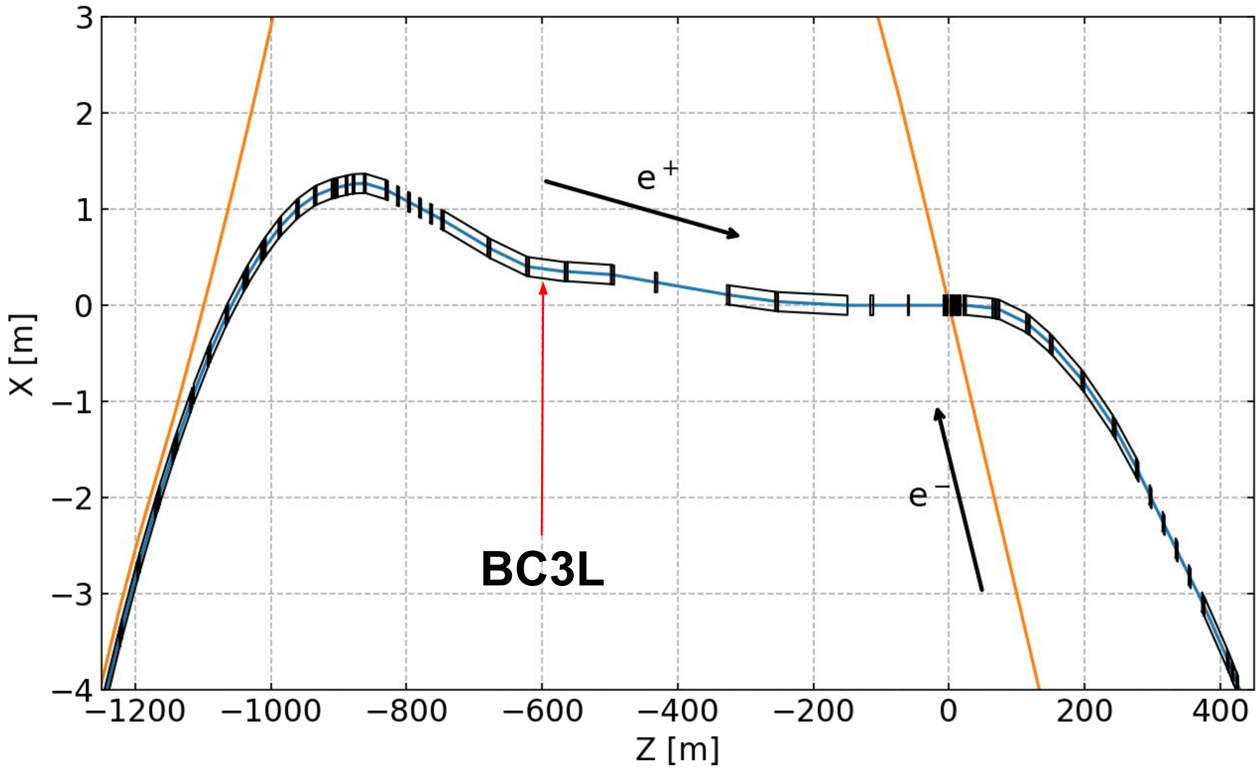
Photons obtained from the BDSIM model, **starting at BC3L dipole**, **including x-ray reflection.**

Considering the beam halo

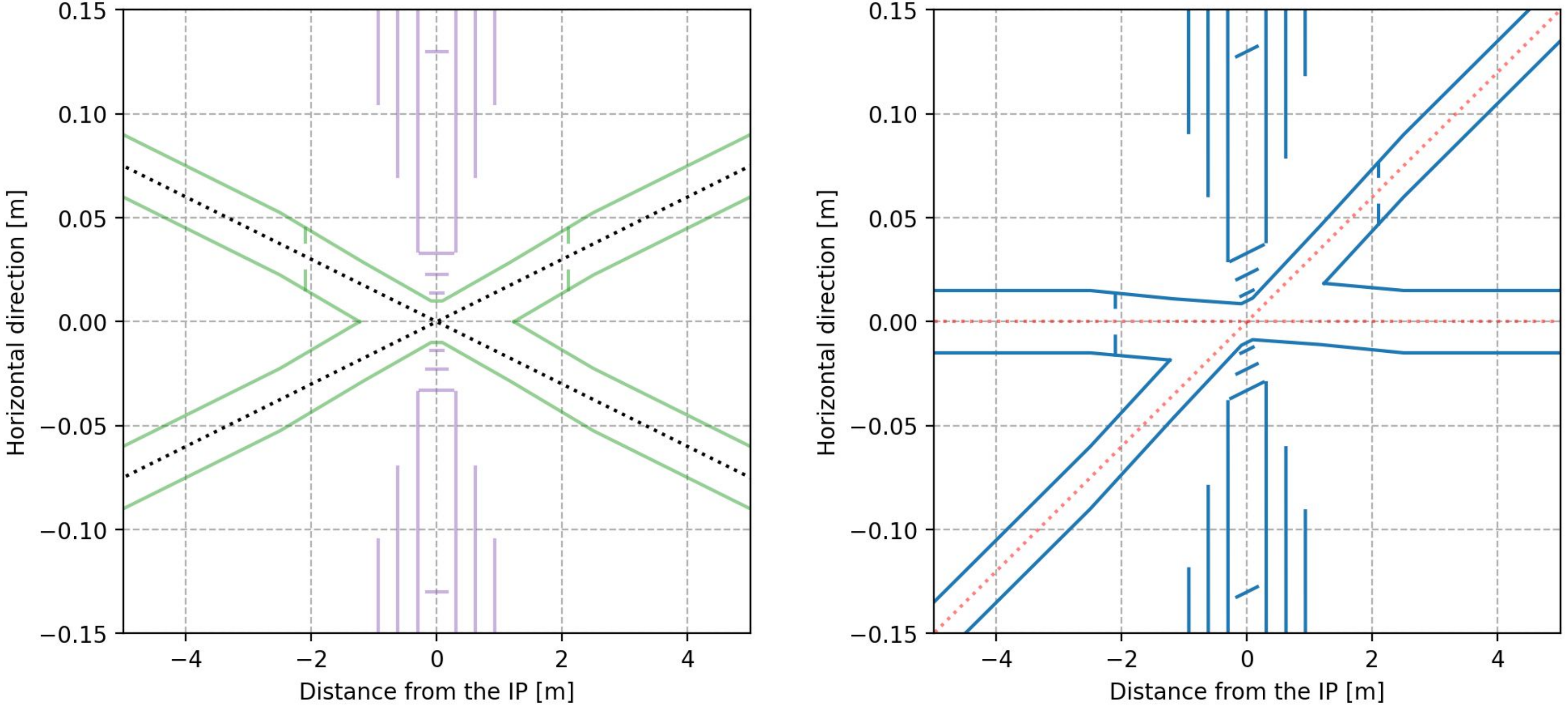
.. or the beam core with non-zero closed orbit.

Applying filters to get most relevant/harmful photons and save disk space.

Goal is to ultimately obtain the photons from a whole bunch ($O(10^{11})$, without scaling)

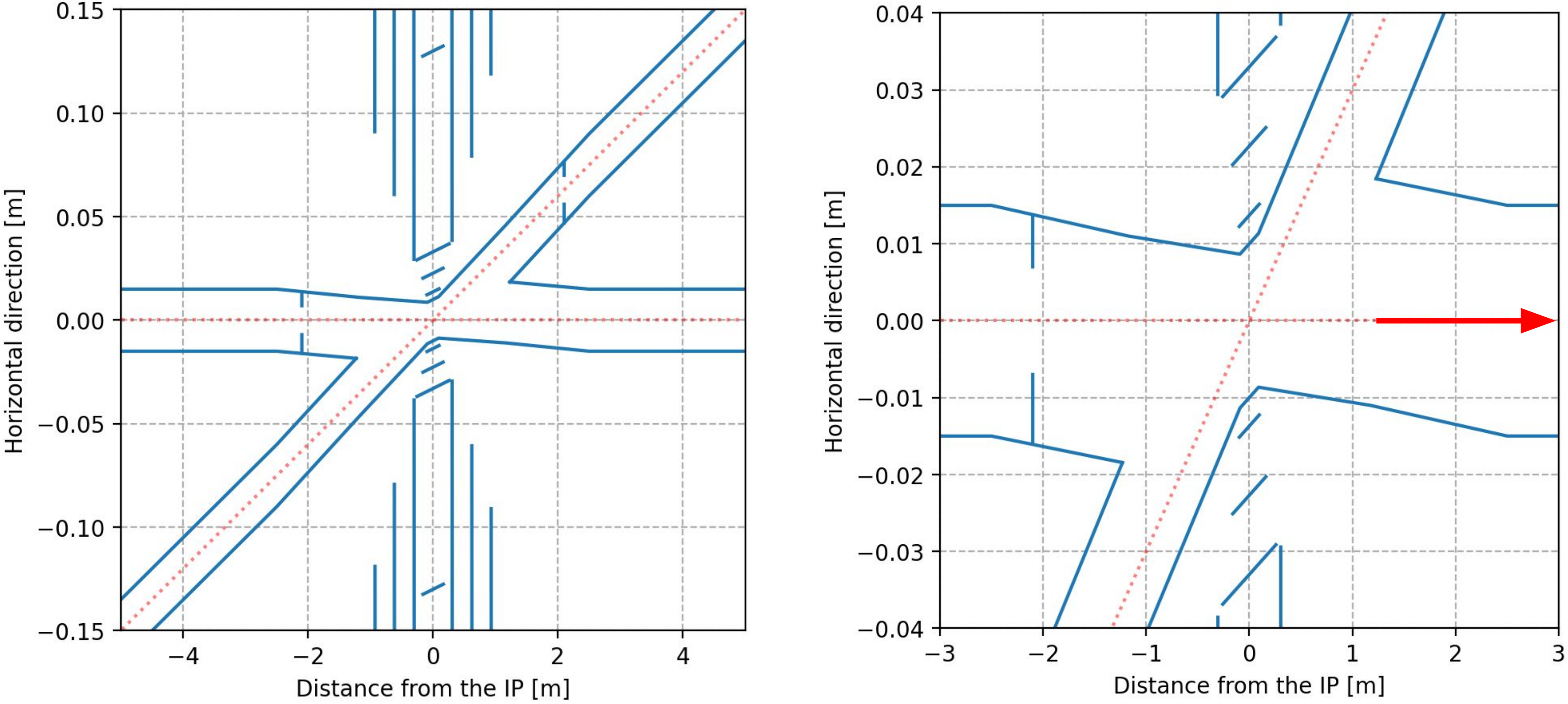


The central chamber & closest detector subcomponents



Detectors specs can be found here; https://fcc-ee-detector-full-sim.docs.cern.ch/IDEA/

The central chamber & closest detector subcomponents



Photons from BDSIM at top quark threshold energy

“Relevant” photons are filtered with the following constraints:

- 2 keV minimum
- R(s=**-**2.2m) ⩽ 15.0mm (to be refined using a second sampler at 6m)
- |x| ⩾ 7 mm (mask aperture) **OR** R(s=**+**6.0m) ⩾ 9.0mm

And saved with the .hepevt format
Events
1 partID p0 p1 d0 d1 px[Gev/c] py[Gev/c] pz[Gev/c] E[GeV] m[GeV/c^2] x[mm] y[mm] z[mm] t[mm/c]

301739
1 22 0 0 0 0 -2.108e-09 7.084e-10 2.775e-05 2.775e-05 0 -8.237 5.284 -2200.0 -2200.0111
1 22 0 0 0 0 -4.952e-09 1.710e-09 6.337e-05 6.337e-05 0 -8.633 5.408 -2200.0 -2200.0111
…

Beam distribution halo & Non-Zero Closed Orbit (NZCO)

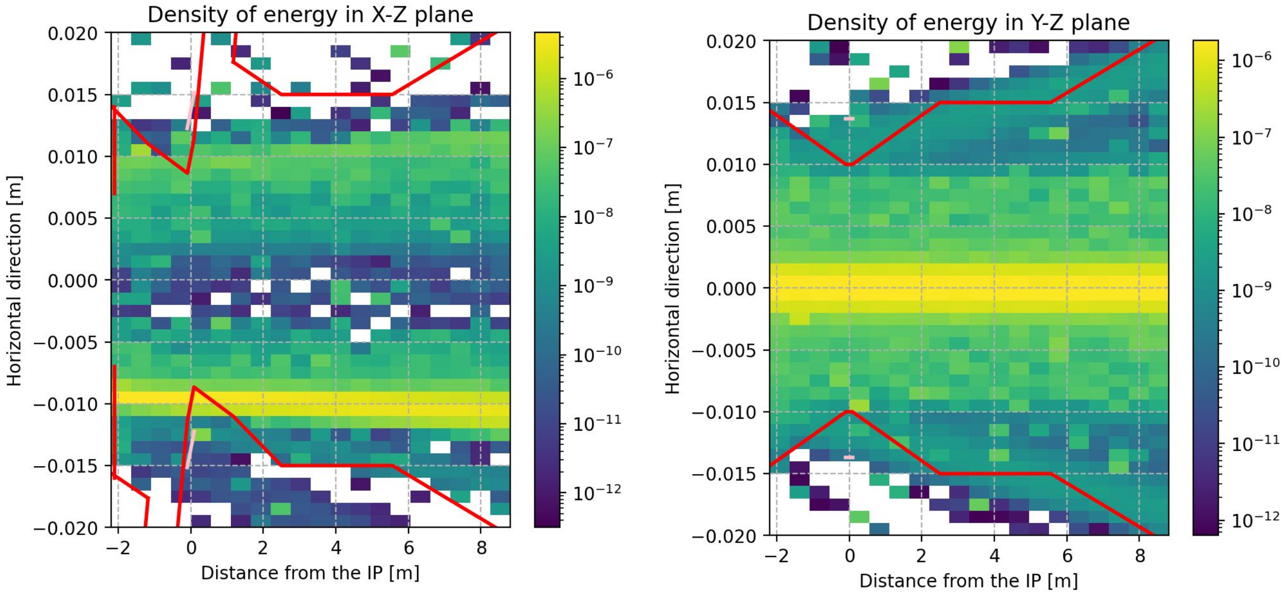
1. The beam halo (assumed to be 1% of the total 1.64e11ppb) is defined as the particle outside the core starting from 3.5 sigma to 11 and 65 vertically limited by the primary collimator aperture.

   25 jobs with 200 000 primaries - total 5M macroparticles (3×10^{-3} scaling)

2. The NZCO beam core (assumed to be 99% of 1.64e11ppb) studies consider an effective model resulting from a lattice with errors that has been corrected. Each seed assumes a beam core with a closed orbit as follows:
   - X_0,Y_0= Gaussian(μ=0, σ=100μm) & Px_0,Py_0= Gaussian(μ=0, σ=6μrad). Each Gaussian is truncated at 2.5 sigmas.

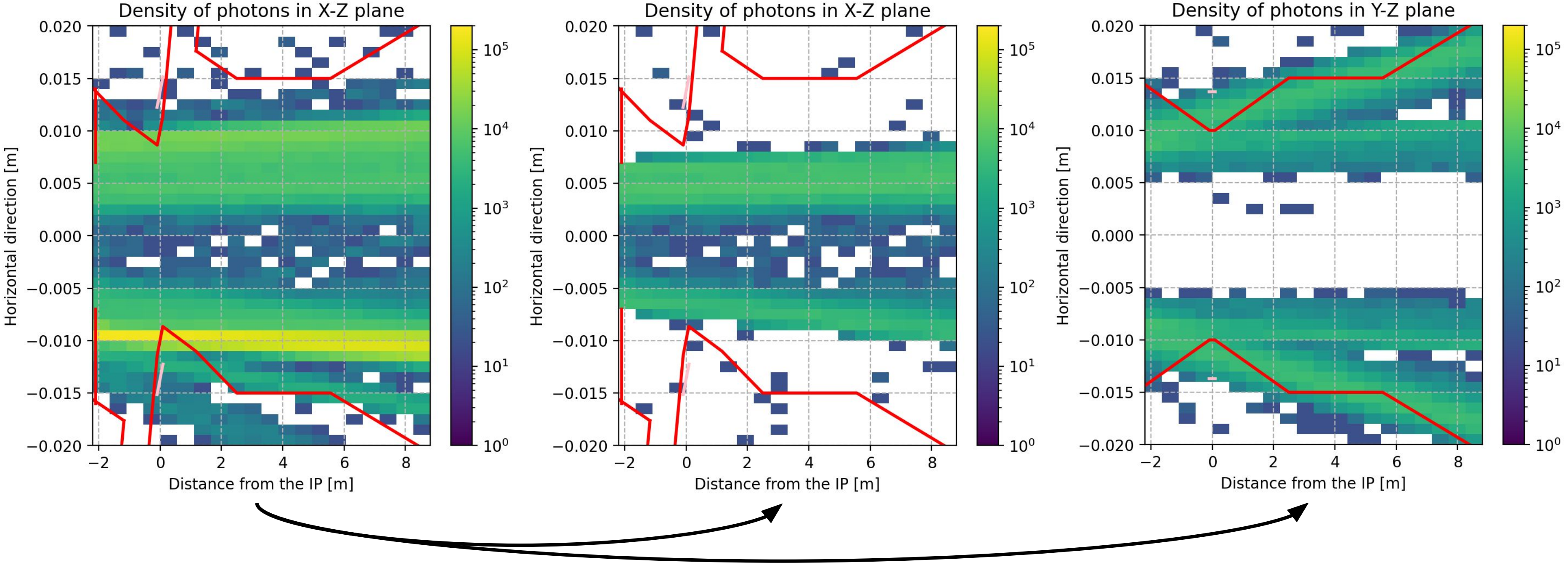
   100 jobs with 100 000 primaries - total 10M macroparticles (6×10^{-5} scaling)

Distribution of energy from beam halo/tails



Photons off-centered horizontally, mostly centered vertically

Distribution of photons from beam halo/tails



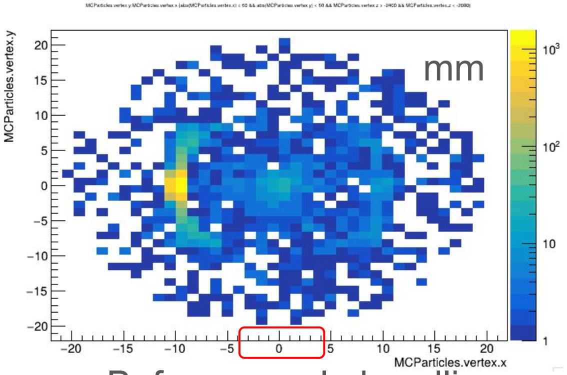
Including the
mask aperture

Translation to the detector simulation

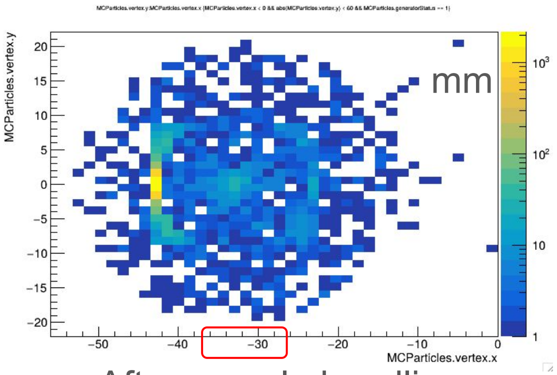
Very first look (just to show that it can be done)

From BDSIM (Machine) to DDSim (Detector)

- First iteration done with the hepevt format
  - Easy, already supported by DDSim (detector simulation tool)
  - Next iteration will be done with HEPMC3 which is a more modern standard
- SR photons produced by BDSim in the beam reference frame
  - Time reference frame: distance between BDSim sampling surface and IP (speed of light)
  - Effect of crossing angle handled in DDSim (--crossingAngleBoost 0.015)
- Propagated to the IDEA detector Geant4 simulation
  - 8171 photons → ~1 min



Before x-angle handling



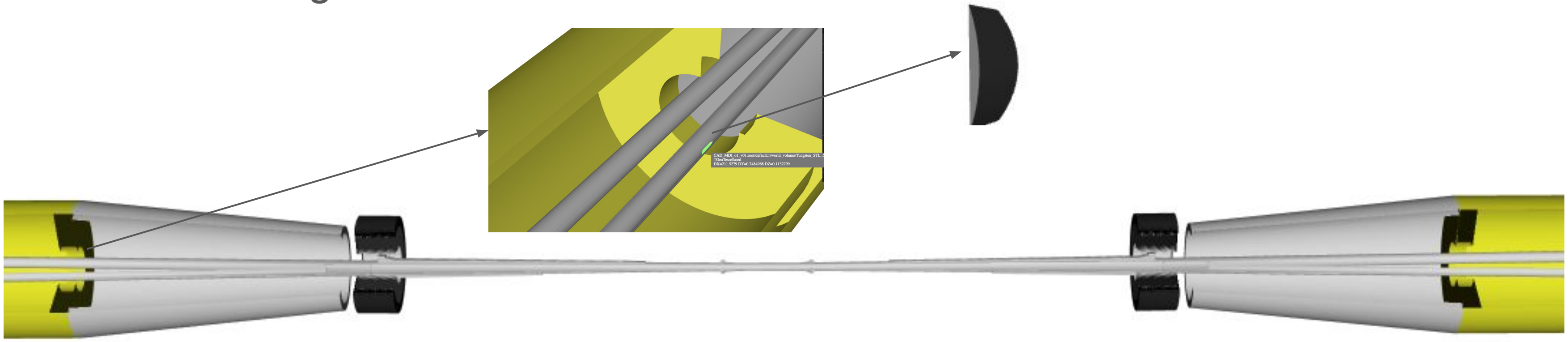
After x-angle handling

Simulation set-up

IDEA_o1_v03 from Key4hep (nightlies 2024-10-14)

CAD model beampipe from k4geo (MDI_o1_v01)

- With SR tungsten masks

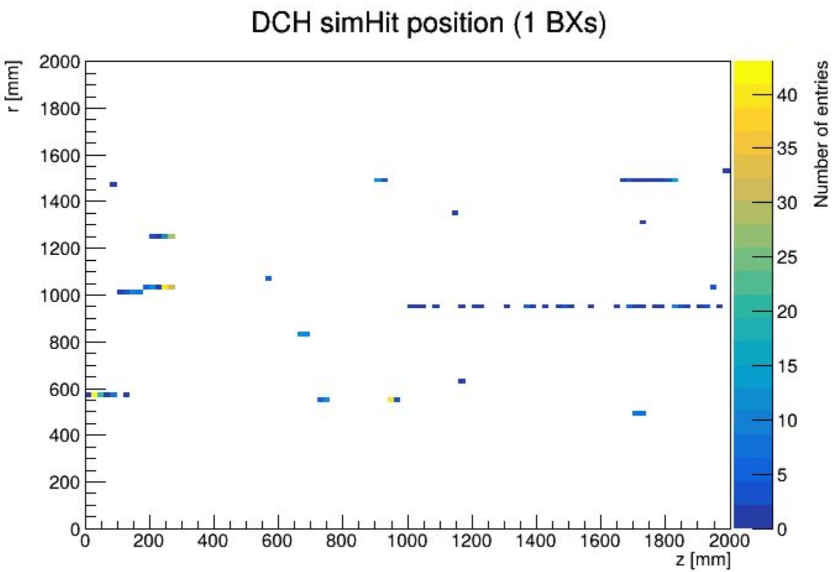


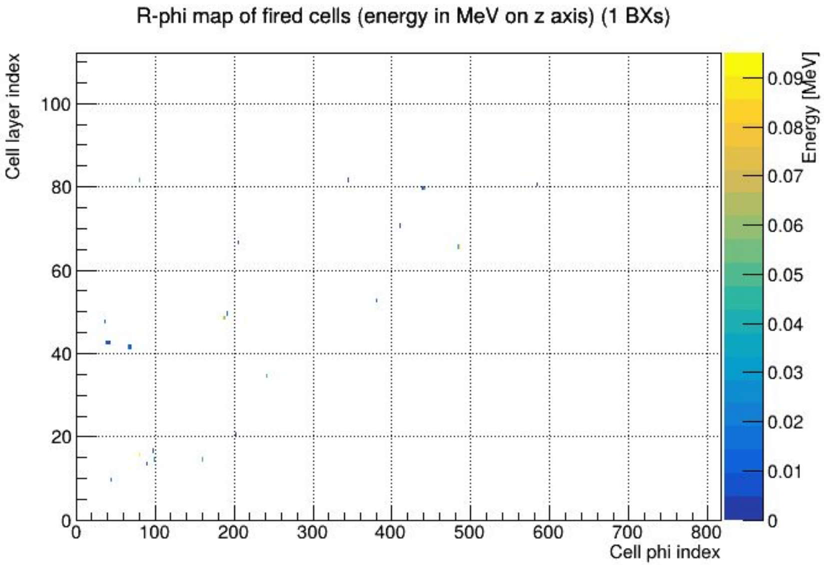
Habemus Detector Hits: drift chamber

Very preliminary, let's refrain from deriving physics conclusions

SR photons from a single positron bunch at the top threshold

- 17 particles left a signal in the drift chamber, 36 cells fired (0.06% occupancy)
  - Average energy of particles hitting the drift chamber: 230 keV → feedback for the filters
- Failed so far to see the impact of the SR tungsten mask (running without → 34 fired cells)
  - Mask placement in detector simulation (and other things) to be investigated





Summary and Outlook

- Method to get the photons from BDSIM in a readable input for DD4Sim has been developed using the .hepevt format.
- Generation of photons has been ‘optimized’ to filter the most relevant photons, though it can be refined.
- A first look at resulting detector occupancies was presented
- Next steps
  - Validate the filtering method: make sure we do not reject relevant photons
  - Investigate the ddsim crossing angle treatment
  - Investigate the impact of the macro particles approach
  - Simulate more bunches to account for detector signal integration time (e.g. drift chamber ~20BX)
  - Improve photon sampling (high radius one have to be sampled outside of detector extent)
  - Perform an actual physics study
  - Check what happens at the Z-pole (more photons, less energy)
  - Migrate to the HEPMC3 format: higher chances to be maintained on the long run

Where do the hit come from/go?

Where do primary particles die?