

Detector occupancies from incoherent pair production

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with many thanks to Daniele Calzolari, Daniel Schulte and the MDI group for the inputs

IMCC Detector and MDI workshop, 26/06/2024

Incoherent pair production inputs

Inputs and validation

Study based on:

- preliminary set of predictions from GUINEA-PIG+FLUKA (1 full BX)

Important FLUKA features:

- hard edge B field
- Scan B from 0T to 5T

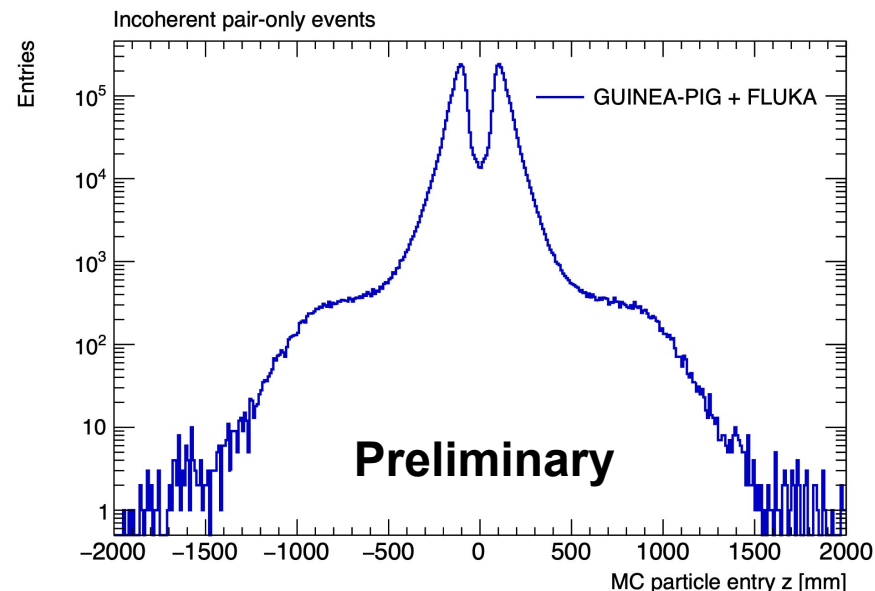
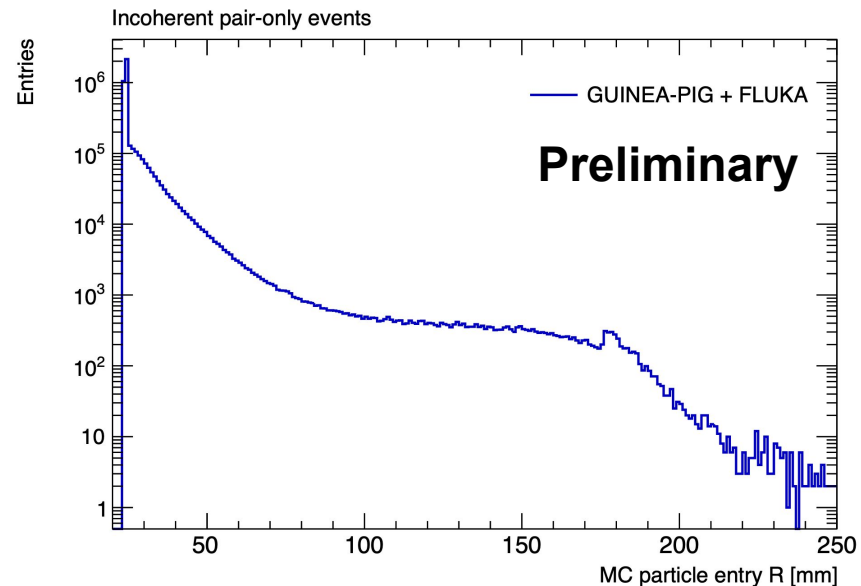
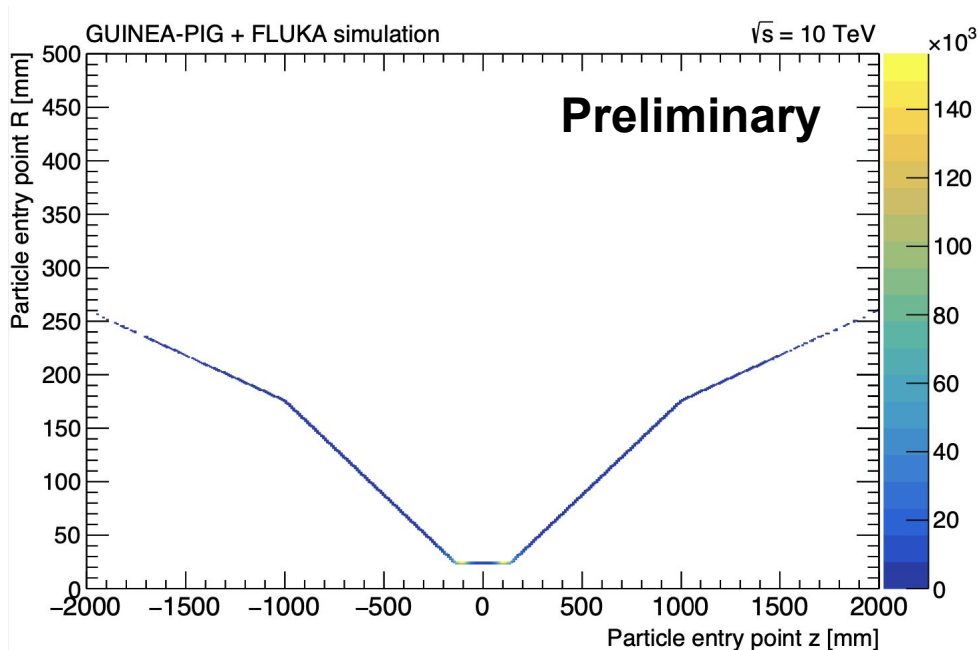
Simulation inputs

E > 0.1 MeV	B = 0 T	B = 1 T	B = 2 T	B = 3 T	B = 4 T	B = 5 T
Photons	$3.95 \cdot 10^6$	$3.96 \cdot 10^6$	$3.95 \cdot 10^6$	$3.97 \cdot 10^6$	$4.00 \cdot 10^6$	$4.04 \cdot 10^6$
Electrons	$4.01 \cdot 10^5$	$3.48 \cdot 10^5$	$2.95 \cdot 10^5$	$2.60 \cdot 10^5$	$2.32 \cdot 10^5$	$2.09 \cdot 10^5$
Charged Hadrons	57	61	54	73	50	51
Muons	0	0	0	1	2	1

Incoherent pair production sanity checks

Checking that the origin is distributed as expected

- Transport looks ok

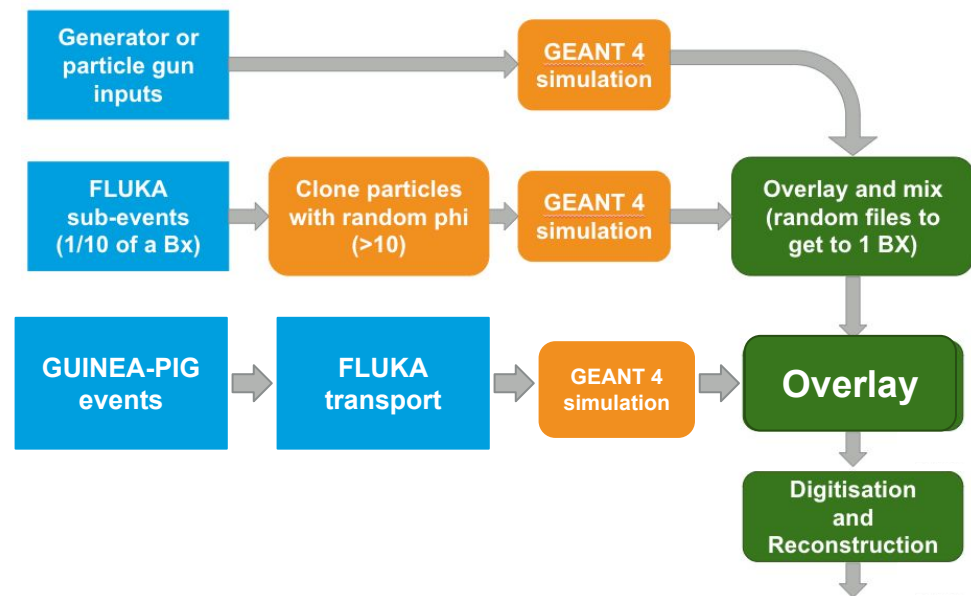


Overlay workflow

GUINEA-PIG+FLUKA stored in a similar format as BIB files (i.e. minus the information on the muon decays)

Prepared:

- Conversion scripts
- Overlay machinery
- Processing pipeline



Created PR to push

[OverlayTimingRandomMix](#)

processor to MuonColliderSoft

Digitisation

Different wrt default 30 ps
(thanks Davide for the
comment at the last
Tuesday meeting)

Used C. Sellgren / S. Pagan Griso's realistic digitiser (see talks here and here) to digitise tracker response.

- “Default” configuration from Chris' github repository
- Ran on top of infnpd/mucoll-ilc-framework:1.7-alm alinux9

Actual mix of processors listed below:

```
!----- Tracker Digitization ----- -->
<processor name="VXDBarrelRealisticDigi"/>
<processor name="VXDEndcapRealisticDigi"/>
<processor name="InnerPlanarRealisticDigi"/>
<processor name="InnerEndcapPlanarDigiProcessor"/>
<processor name="OuterPlanarDigiProcessor"/>
<processor name="OuterEndcapPlanarDigiProcessor"/>
```

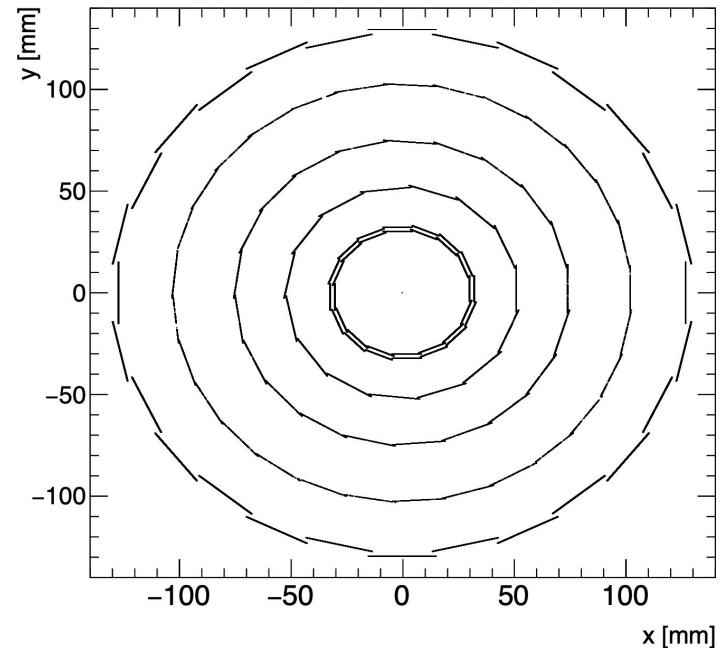
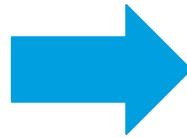
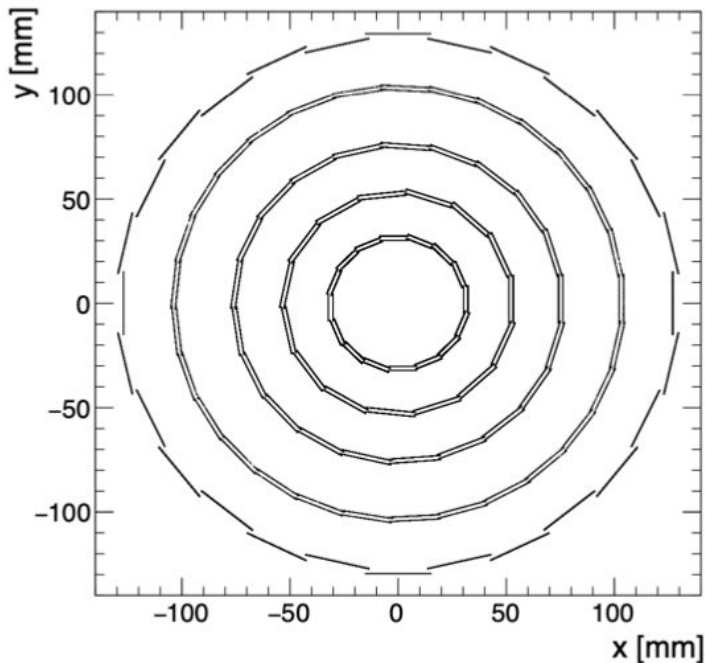
```
<processor name="VXDBarrelRealisticDigi" type="MuonCVXDDigitiser">
  <parameter name="Verbosity" type="string"> MESSAGE </parameter>
  <parameter name="CollectionName" type="string"> VertexBarrelCollection </parameter>
  <parameter name="OutputCollectionName" type="string"> VBTrackerHits </parameter>
  <parameter name="RelationColName" type="string"> VBTrackerHitsRelations </parameter>
  <parameter name="SubDetectorName" type="string"> VertexBarrel </parameter>
  <!-- store all fired pixels -->
  <parameter name="StoreFiredPixels" type="int"> 1 </parameter>
  <!-- Pixel size (mm) -->
  <parameter name="PixelSizeX" type="float"> 0.025 </parameter>
  <parameter name="PixelSizeY" type="float"> 0.025 </parameter>
  <!-- FE threshold (in electrons) and electronic effects -->
  <parameter name="Threshold" type="float"> 500 </parameter>
  <parameter name="ChargeMaximum" type="float"> 15000. </parameter>
  <parameter name="ThresholdSmearSigma" type="int"> 25 </parameter>
  <parameter name="DigitizeCharge" type="int"> 1 </parameter>
  <parameter name="ChargeDigitizeNumBits" type="int"> 4 </parameter>
  <parameter name="ChargeDigitizeBinning" type="int"> 1 </parameter>
  <parameter name="DigitizeTime" type="int"> 0 </parameter>
  <parameter name="TimeDigitizeNumBits" type="int"> 10 </parameter>
  <parameter name="TimeDigitizeBinning" type="int"> 0 </parameter>
  <parameter name="TimeMaximum" type="float"> 15.0 </parameter>
  <parameter name="TimeSmearingSigma" type="float"> 0.05 </parameter>
  <parameter name="ElectronicEffects" type="int"> 1 </parameter>
  <parameter name="ElectronicEffects" type="int"> 1 </parameter>
  <parameter name="ElectronicNoise" type="float"> 80 </parameter>
  <!--Tangent of Lorentz angle (and optional Y component); SP note: a bit large.. did not
  <parameter name="TanLorentz" type="float"> 0.8 </parameter>
  <parameter name="TanLorentzY" type="float"> 0.0 </parameter>
  <!-- Apply Poisson smearing of electrons collected on pixels -->
  <parameter name="PoissonSmearing" type="int"> 1 </parameter>
  <!--Min threshold for delta-rays (MeV)-->
  <parameter name="CutOnDeltaRays" type="float"> 0.030 </parameter>
  <!-- Diffusion coefficient, defined as sqrt(D / mu / V) and
  | | | correlated with diffusion sigma by sigma(z) = z*_diffusionCoefficient -->
  <parameter name="Diffusion" type="float"> 0.07 </parameter>
  <!-- Segment Length in mm -->
  <parameter name="SegmentLength" type="float"> 0.005 </parameter>
  <!-- Energy Loss keV/mm -->
  <parameter name="EnergyLoss" type="float"> 280.0 </parameter>
  <!-- Max delta in energy for hit in electrons -->
  <parameter name="MaxEnergyDelta" type="float"> 100.0 </parameter>
  <!-- Maximum values for track length (in mm) -->
  <parameter name="MaxTrackLength" type="float"> 10.0 </parameter>
  <!-- Number of electron-hole pairs per keV -->
  <parameter name="ElectronsPerKeV" type="float"> 270.3 </parameter>
</processor>
```

Tracker layout in “MuColl_10TeV_v0A”

Reminder of the most important change (see also [Kiley’s talk](#))

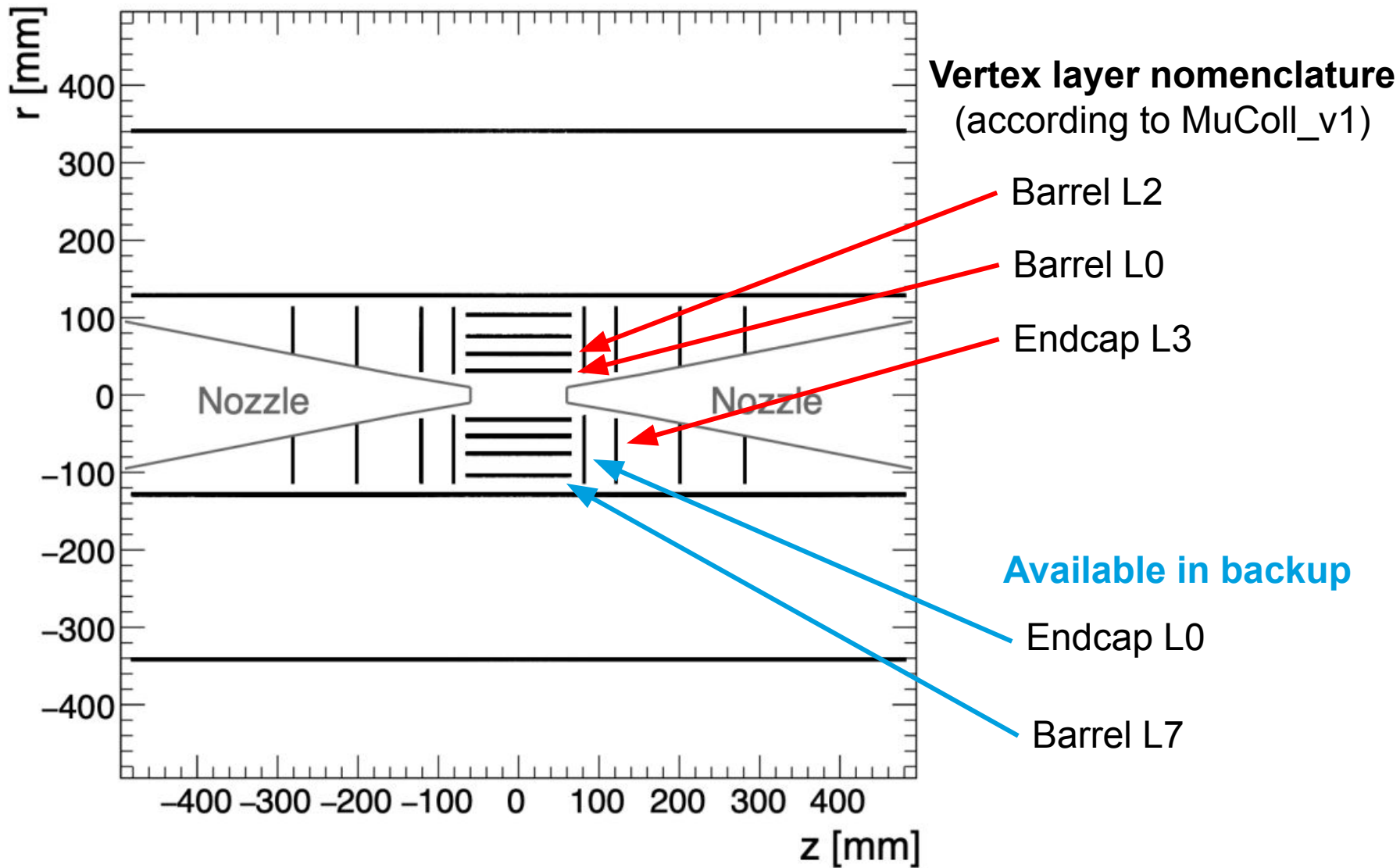
Greatly improved tracking software (based on the ACTS library) made the double layers redundant

- Barrel region of vertex detector revised keeping only one double layer pair
- Endcaps also need re-optimisation (future work)

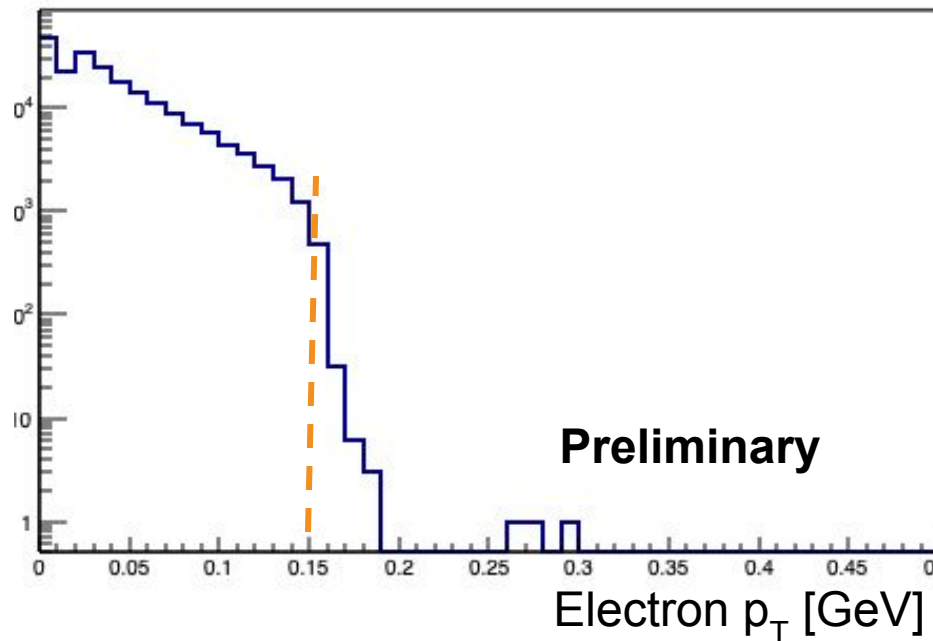


Tracker reference points

	Vertex Detector	Inner Tracker	Outer Tracker
Cell type	pixels	macropixels	microstrips
Cell Size	25 μm \times 25 μm	50 μm \times 1 mm	50 μm \times 10 mm
Sensor Thickness	50 μm	100 μm	100 μm
Time Resolution	30 ps	60 ps	60 ps
Spatial Resolution	5 μm \times 5 μm	7 μm \times 90 μm	7 μm \times 90 μm



Maximum expected hit radii

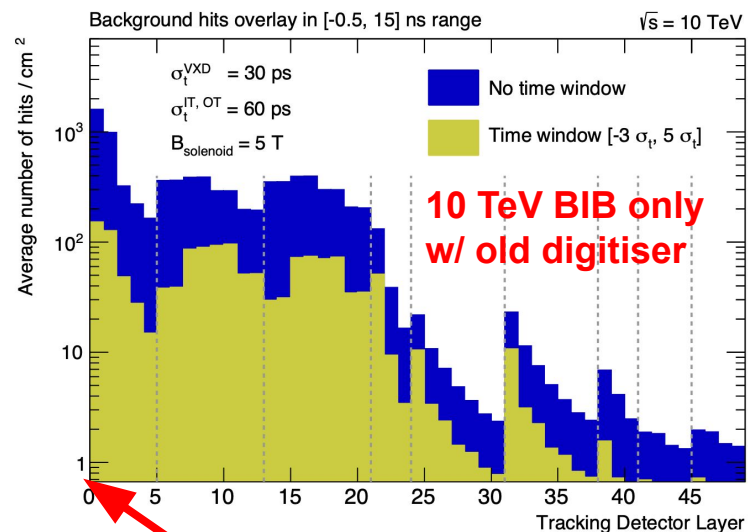
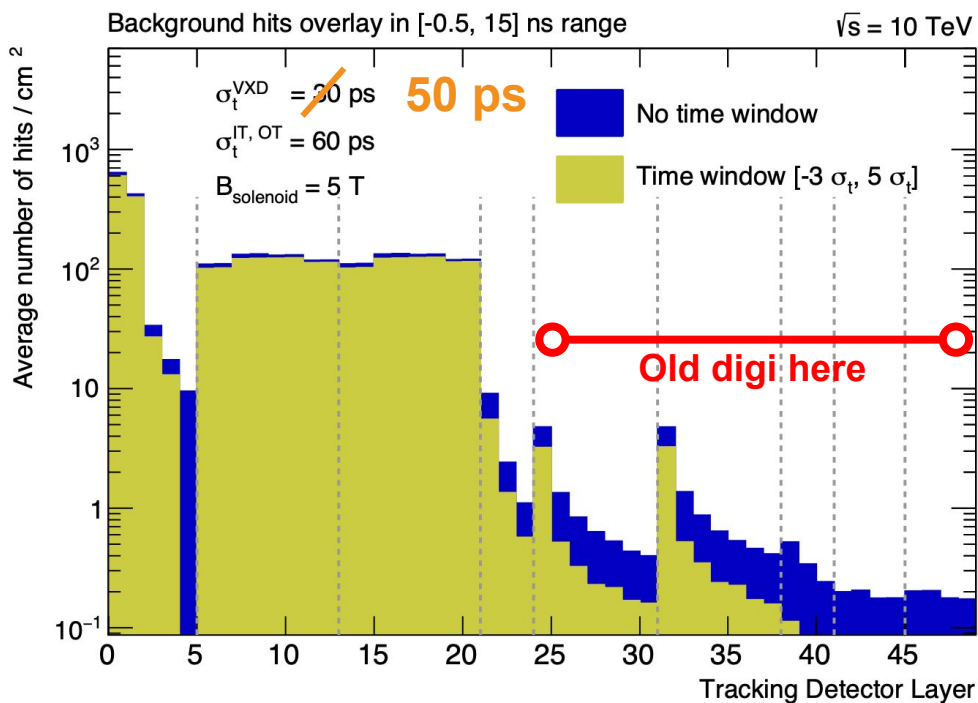


$$R \text{ [m]} = 3.3 \times p_T \text{ [GeV]} / B \text{ [T]}$$

	B = 0 T	B = 1 T	B = 2 T	B = 3 T	B = 4 T	B = 5 T
R_{endpoint} [cm]	ECAL	49.5	24.8	16.5	12.4	10
Last crossed layer	ECAL	OT0	IT1	IT0	IT0	IT0

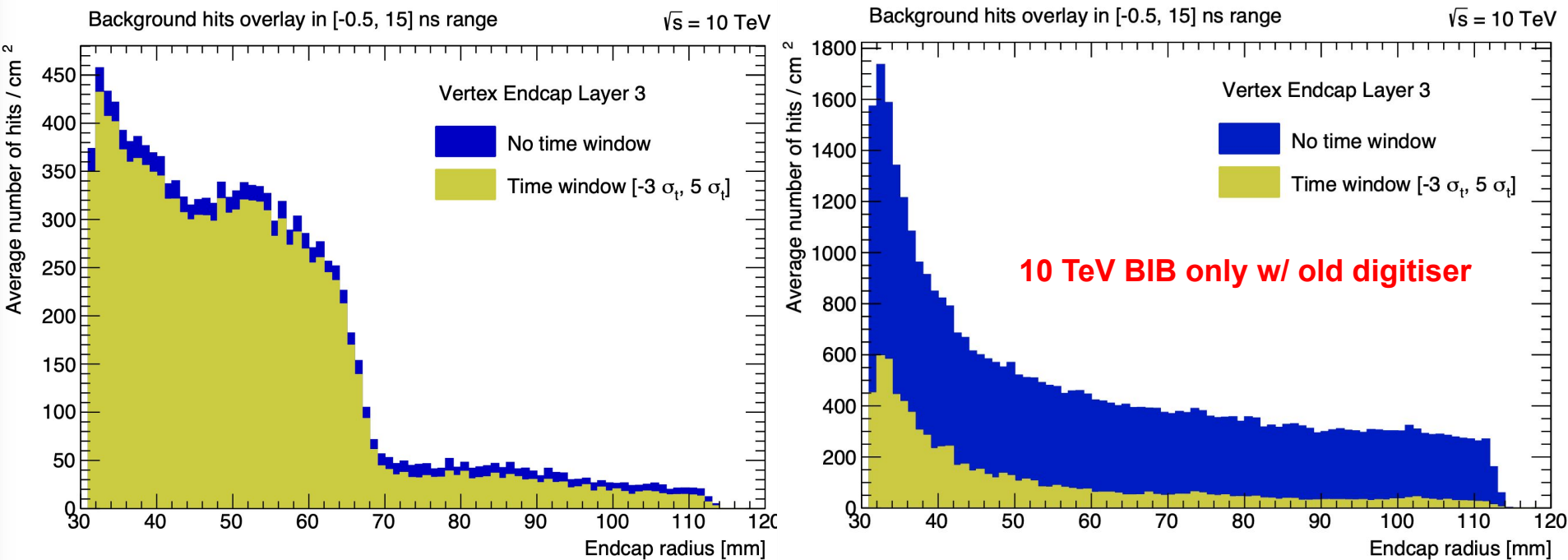
Tracker occupancy from incoherent pairs

	Vertex Detector	Inner Tracker	Outer Tracker
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Note: average occupancy in endcaps does not capture the (important) radial dependence

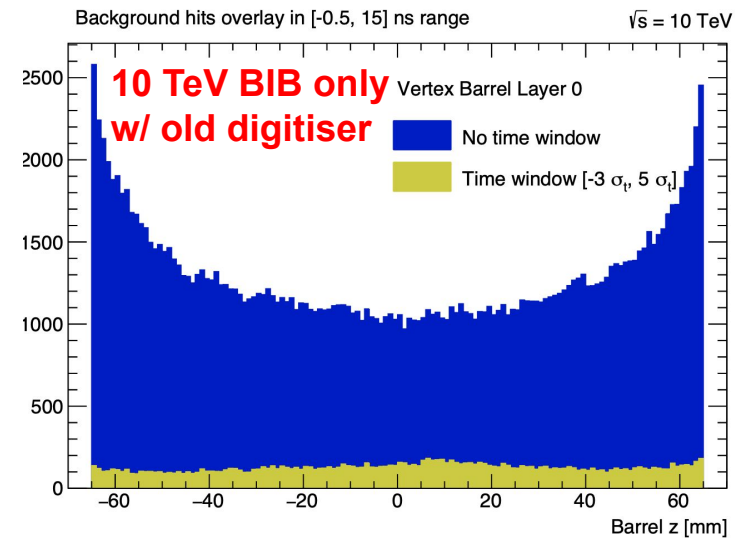
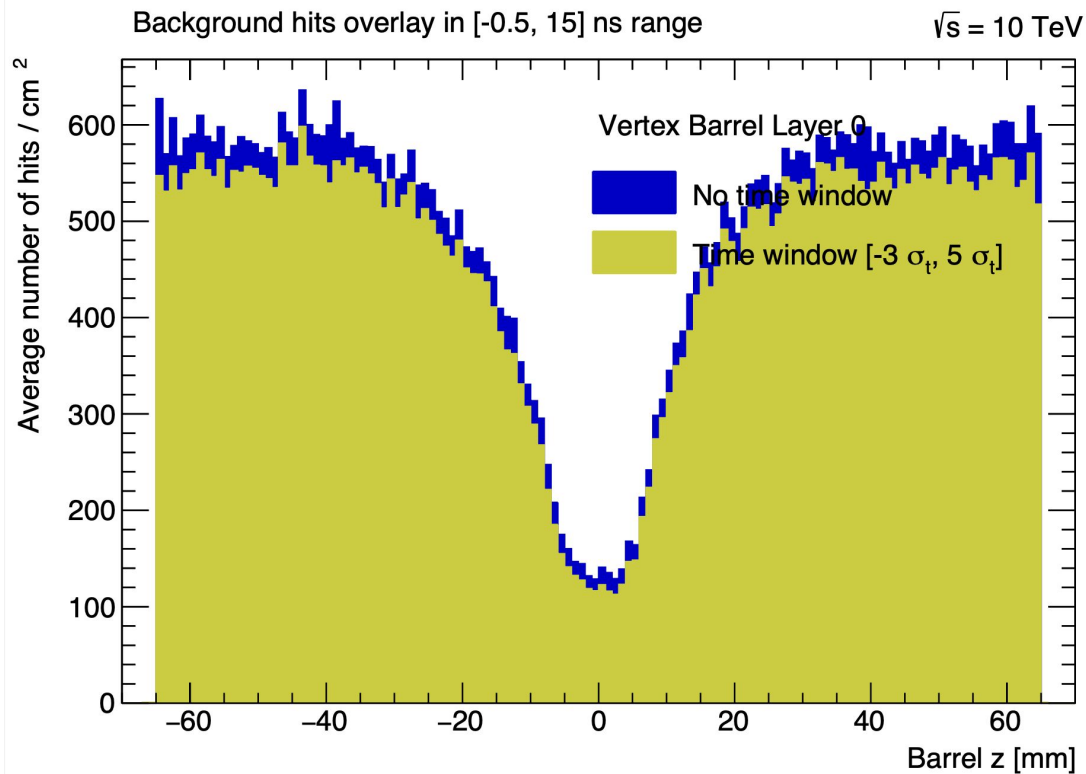
Tracker endcap radial dependence



The region closest to the nozzles has a much higher occupancy than the rest of the endcap disk

- Most of the track reconstruction time is also spent here
- Showing here Vertex Endcap layer 3 (peak of BIB contribution)

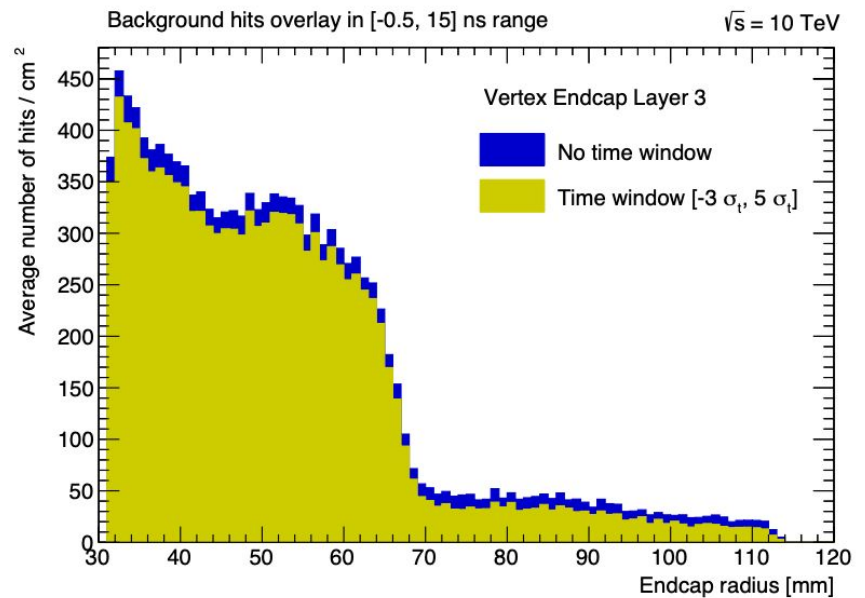
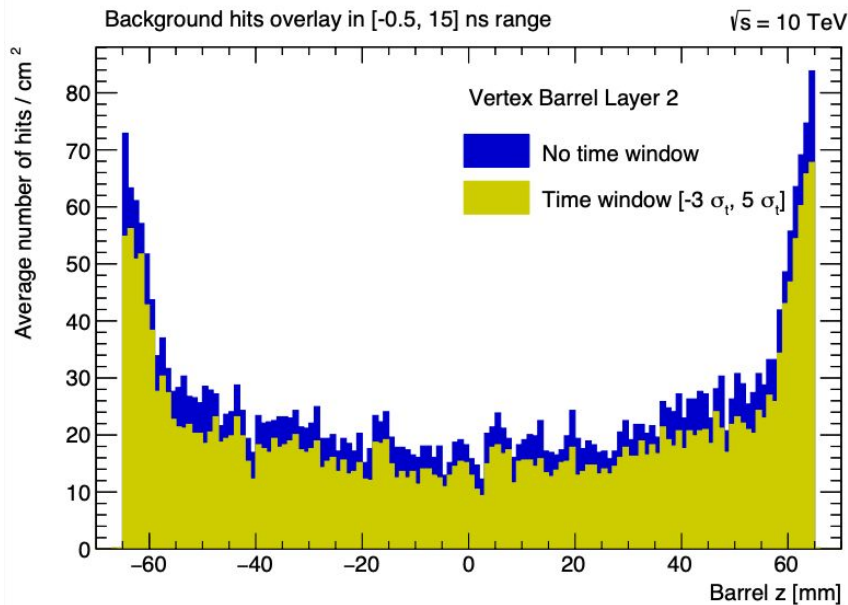
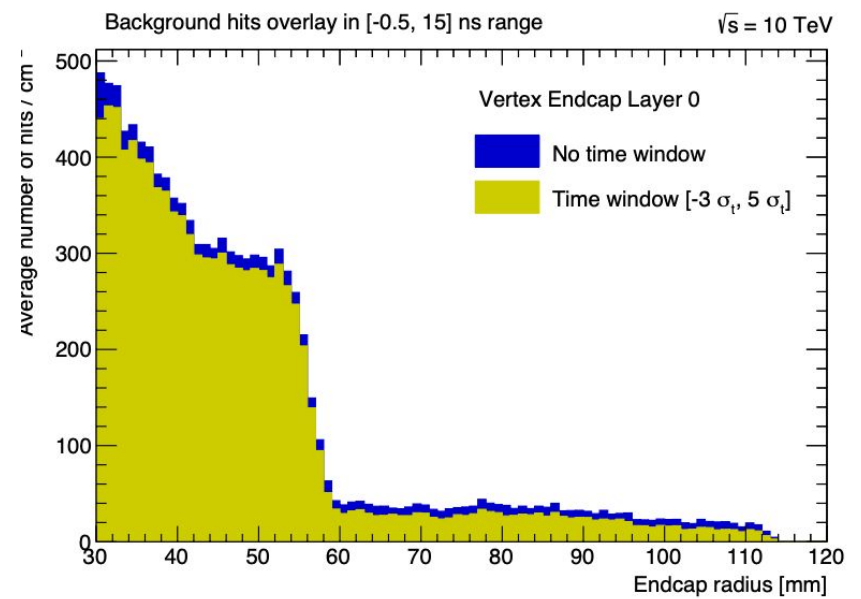
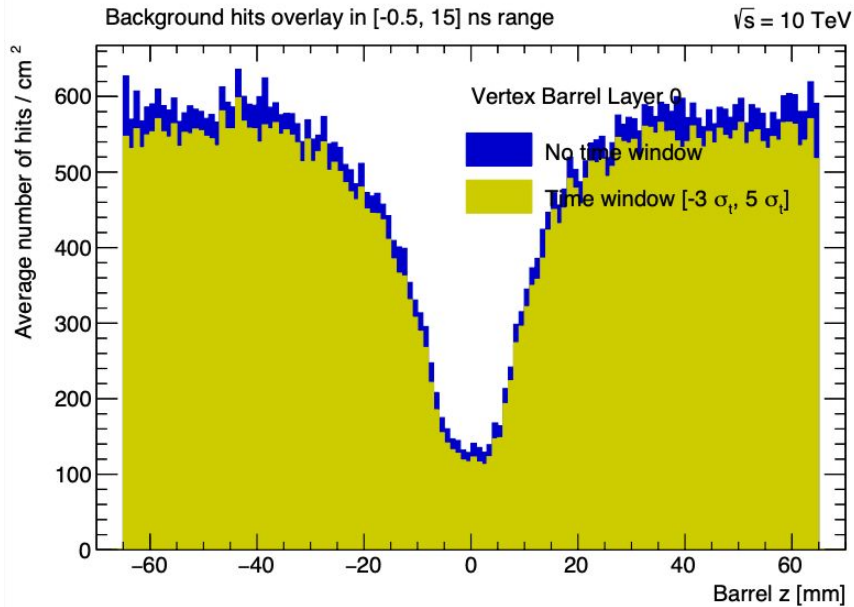
What about the z dependence in the barrel?



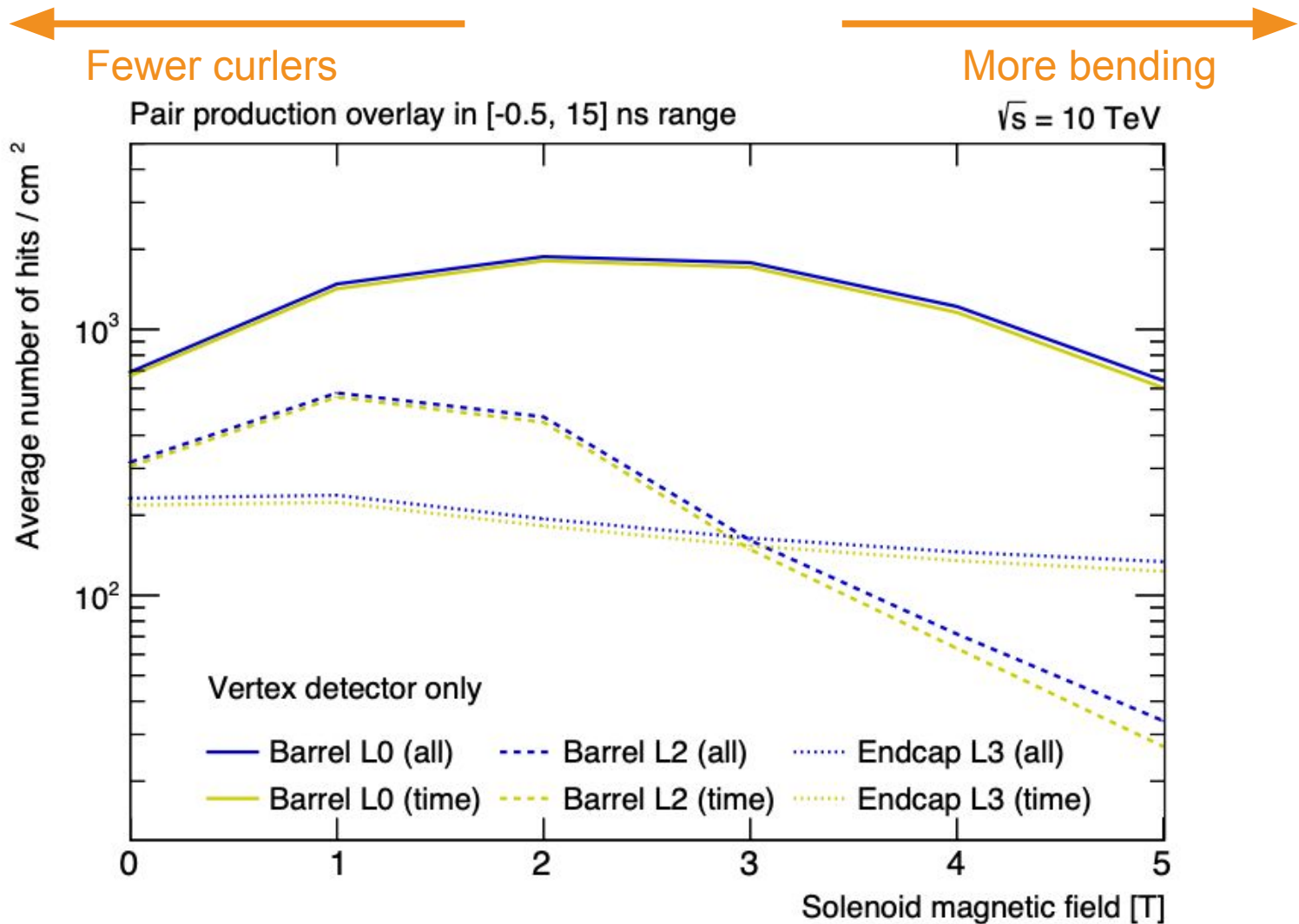
Sizeable occupancy throughout most of the barrel layer

- May require online filtering (previous projections already were assuming tighter window with max 1ns in this region)

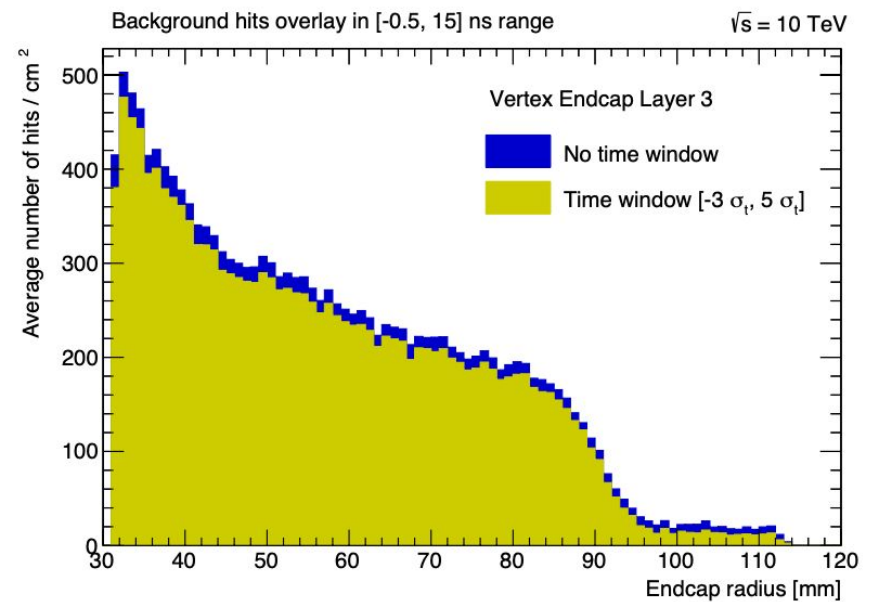
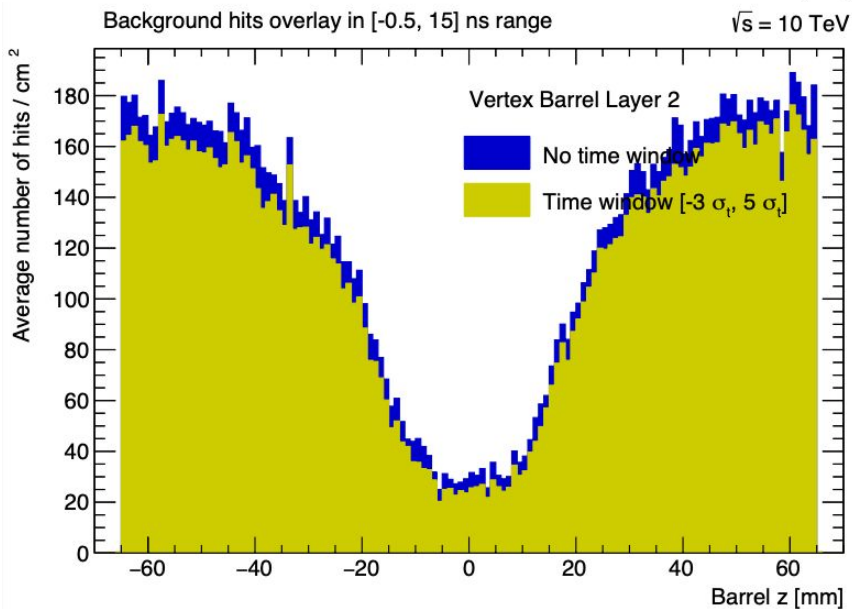
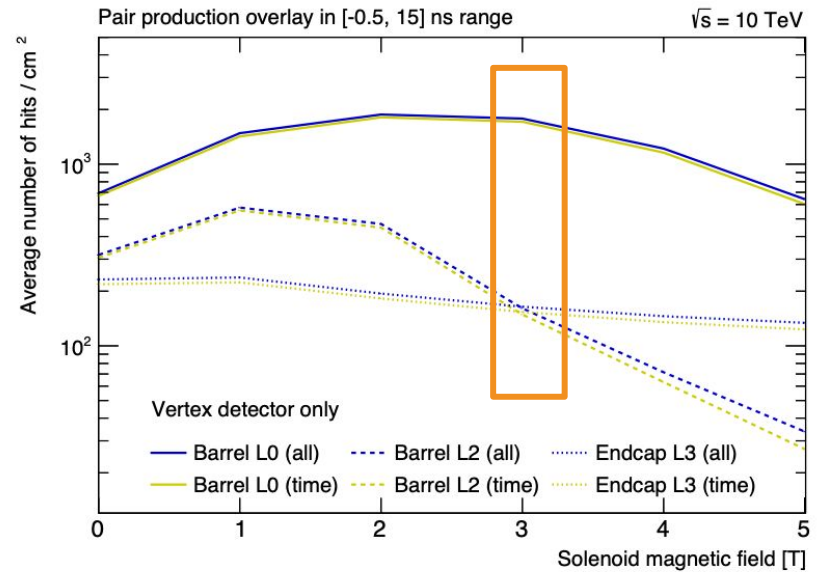
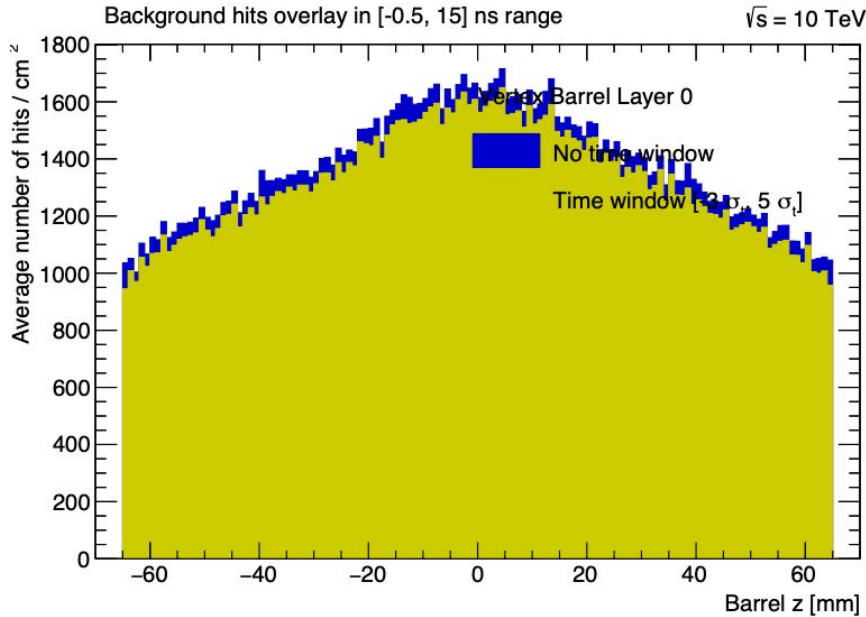
B = 5 T



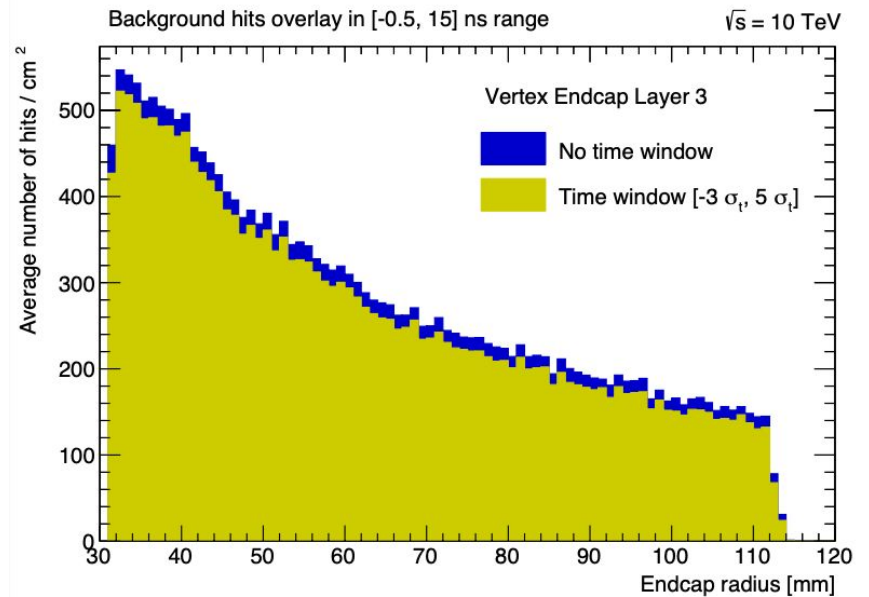
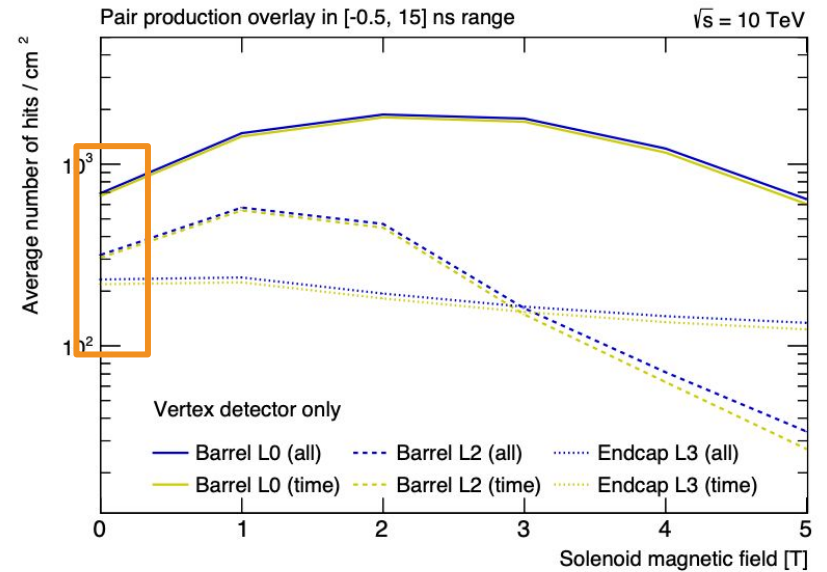
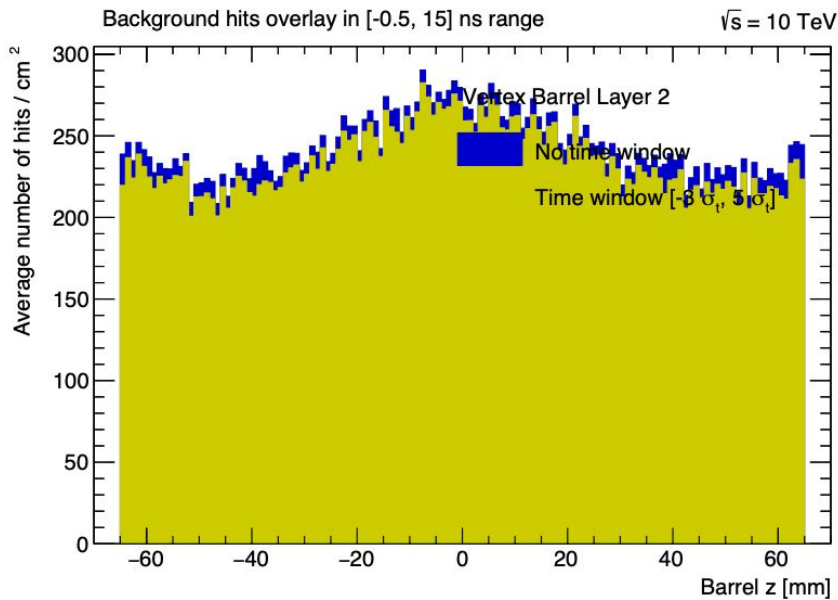
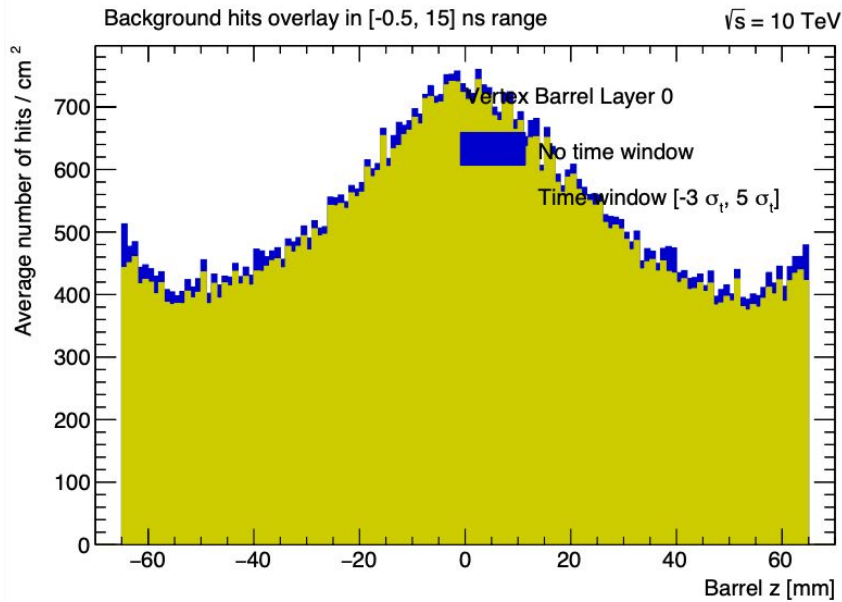
Incoherent pair-related occupancy vs B



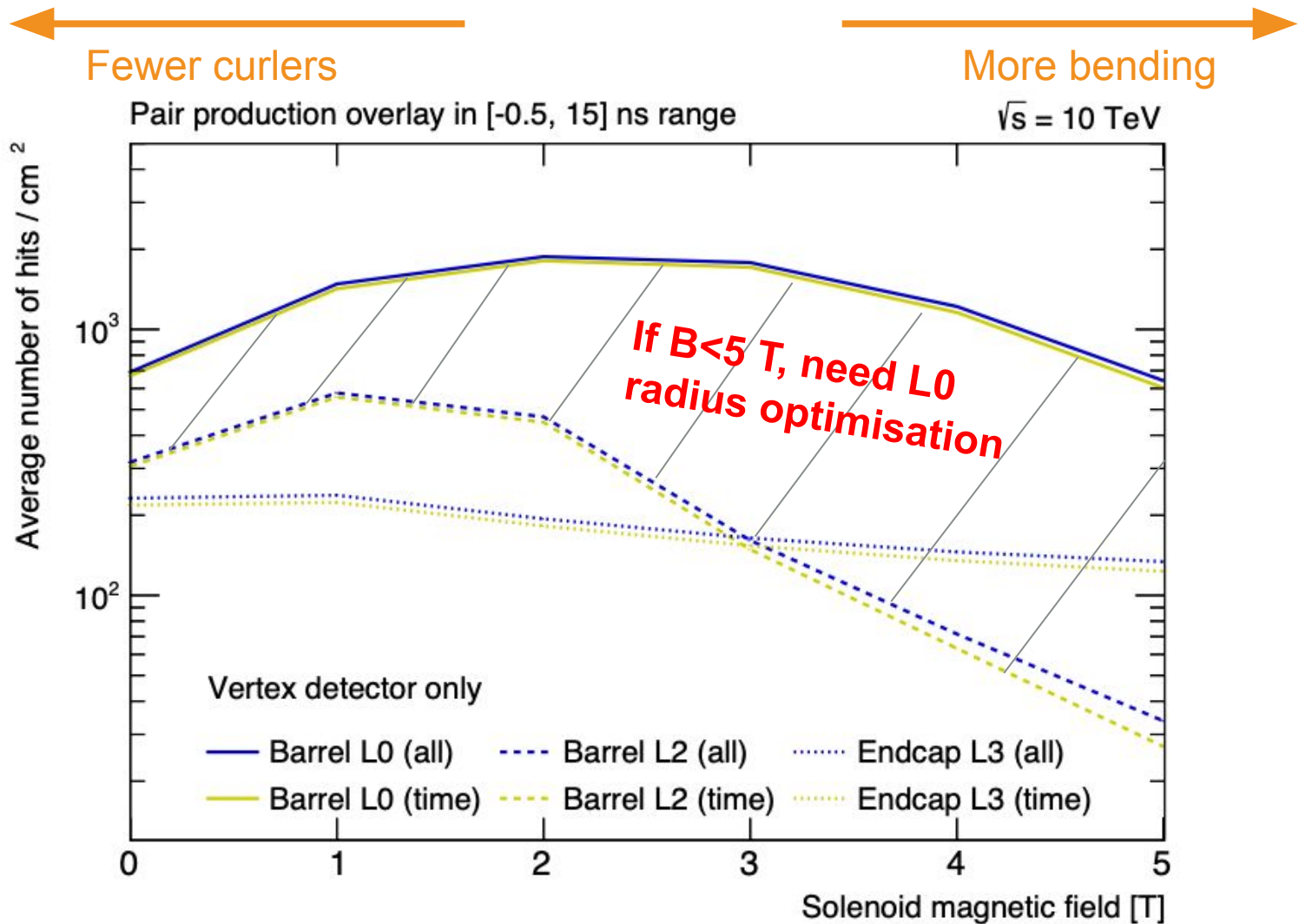
B = 3 T



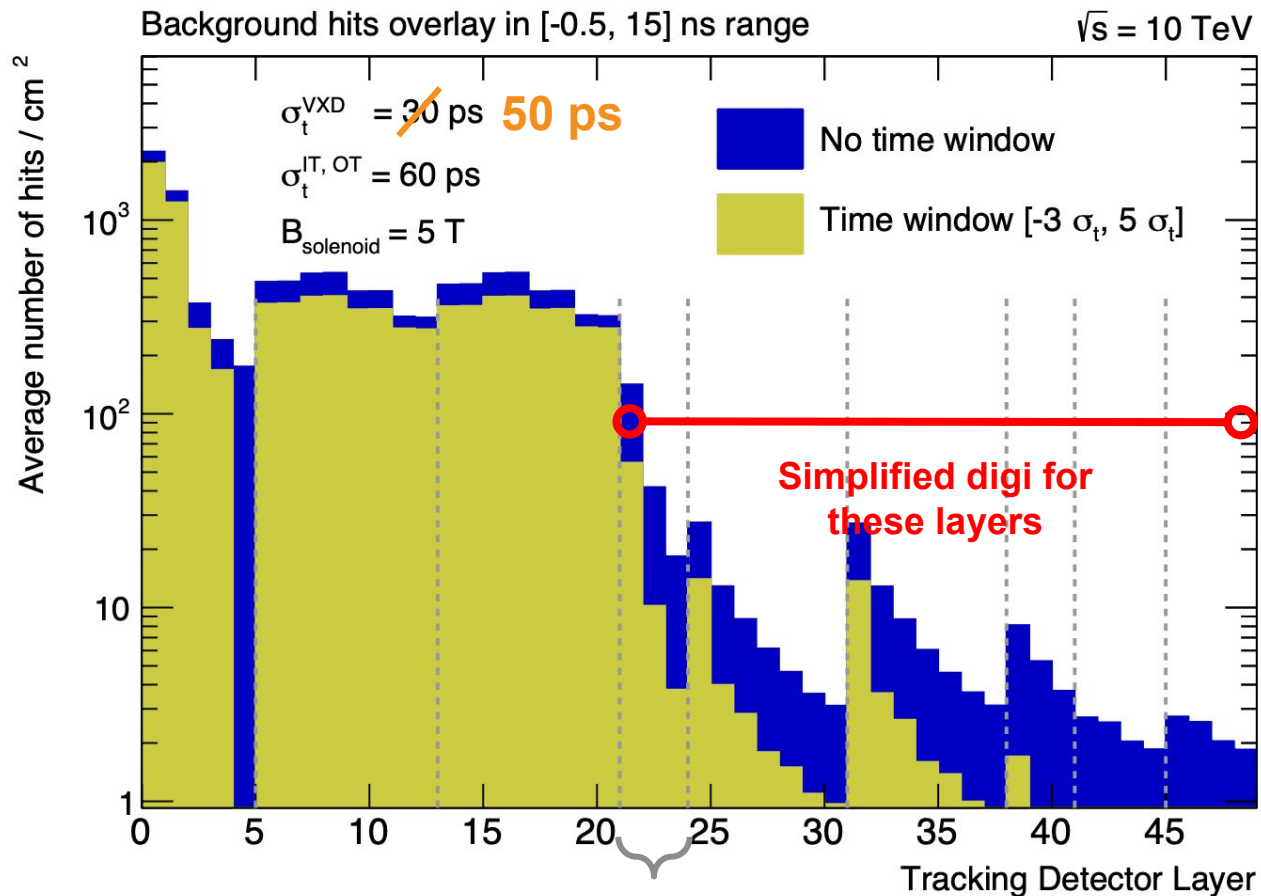
B = 0 T



Incoherent pair-related occupancy vs B



Total tracker occupancy (pairs + BIB)



Realistic digitiser didn't fit into RAM (32 GB)

Summary

Studied occupancy from incoherent pairs vs magnetic field

- Strong radial dependency

If we stick to the same layer positioning, $B \geq 5$ T seems desirable

Lower B fields may require re-optimising the radial position of Vertex Barrel L0

- Effects on flavour tagging to be evaluated in some detail

First look at combined BIB + incoherent pairs with realistic silicon digitiser

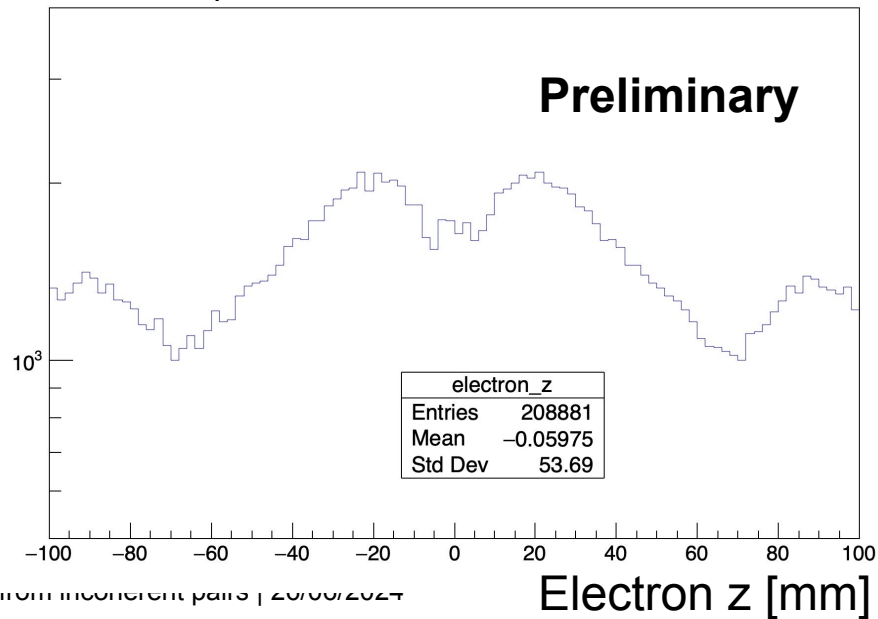
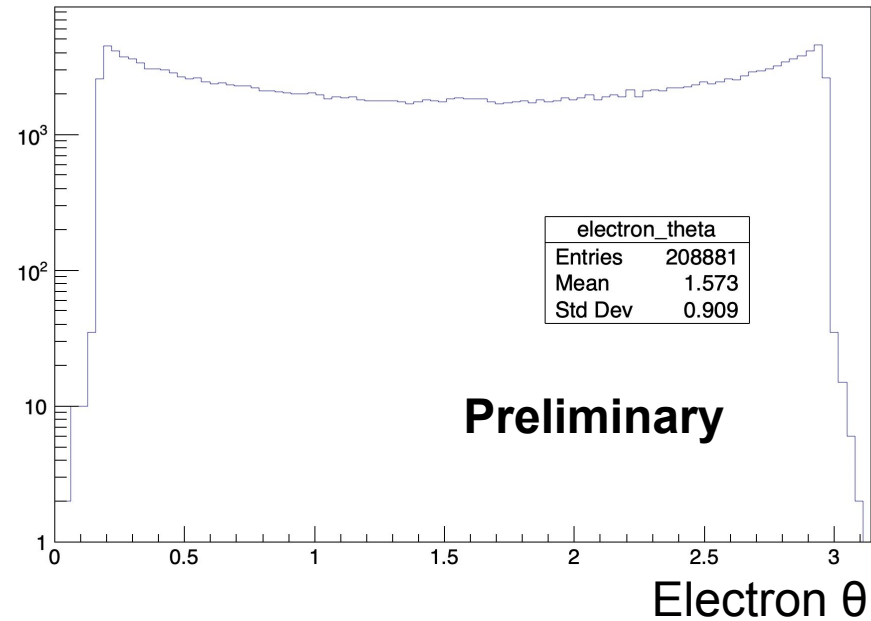
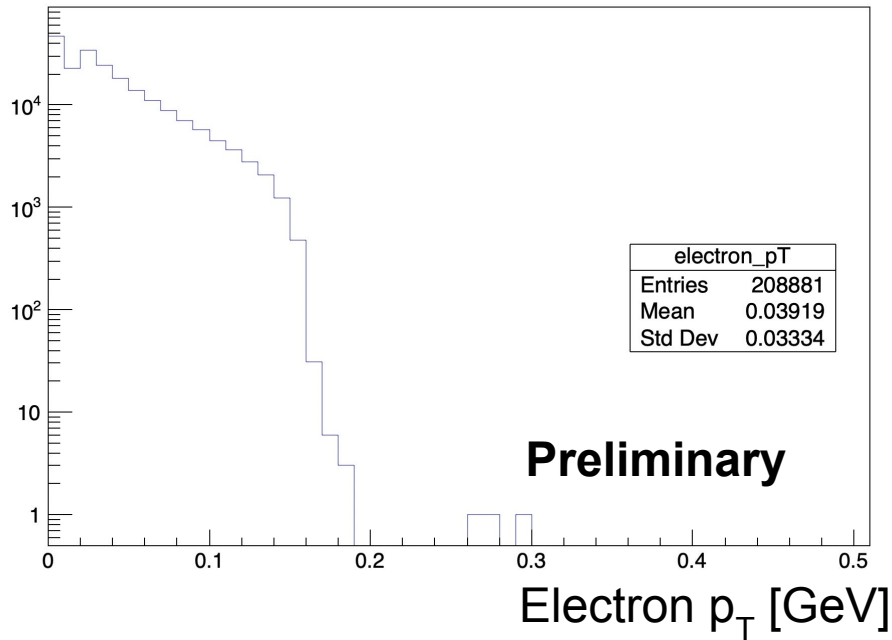
- L0/L1 possibly problematic
- BIB data with B scan would be an asset

Next steps:

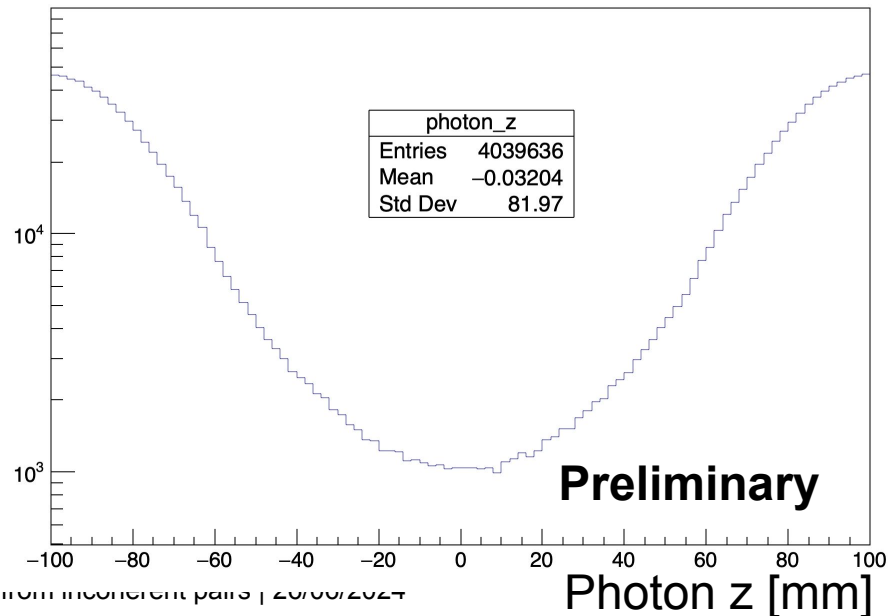
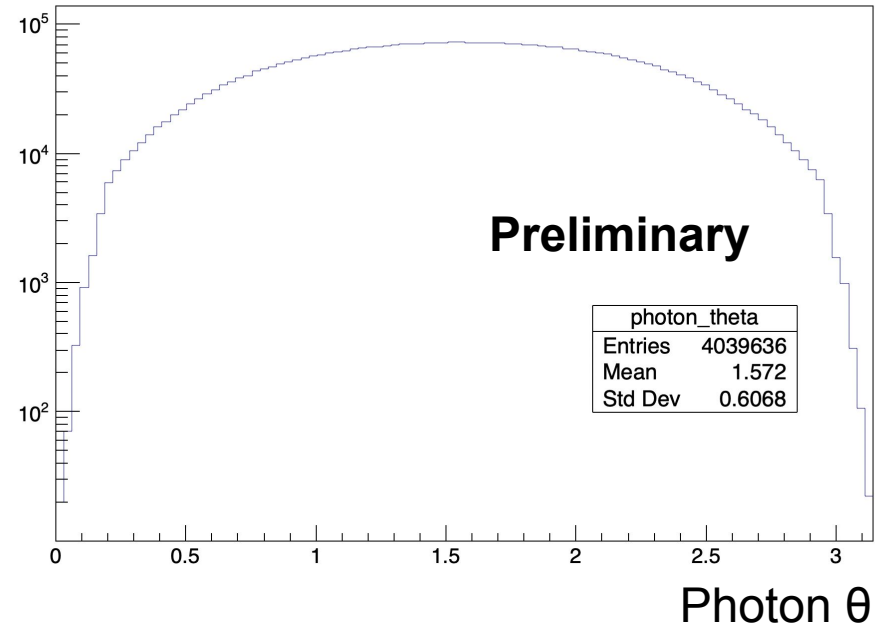
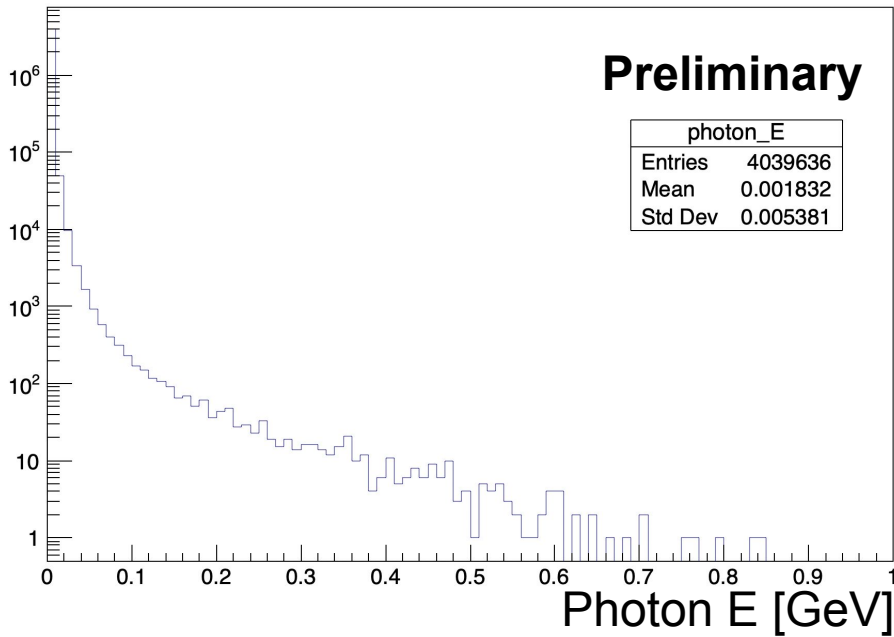
- Run tracking (sorry didn't manage to get this done by this meeting)

Thank you!

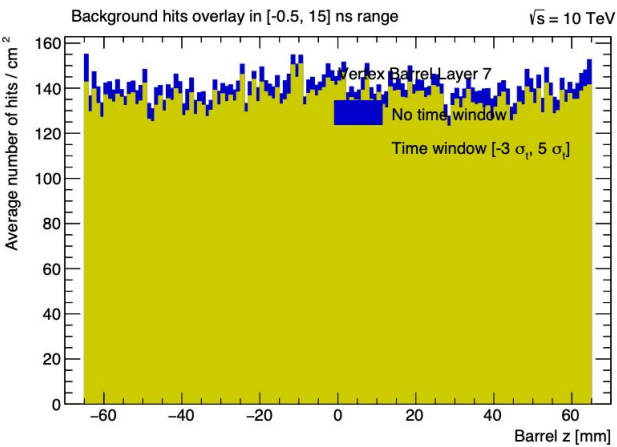
Additional distributions (electrons)



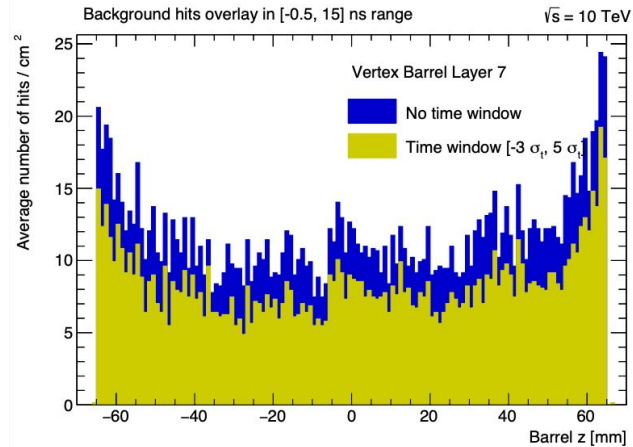
Additional distributions (photons)



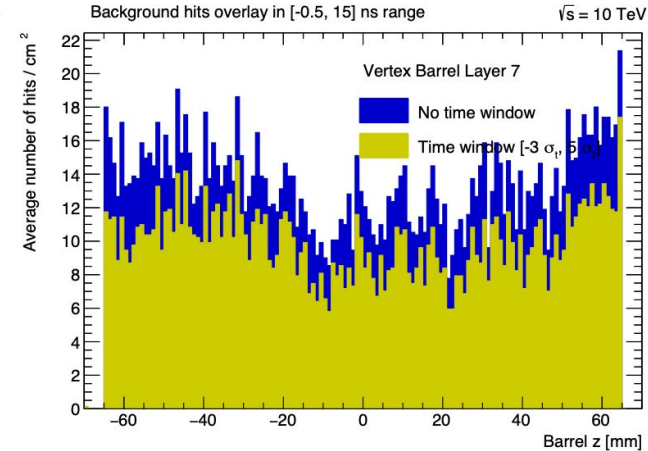
Barrel layer 7



B = 0T

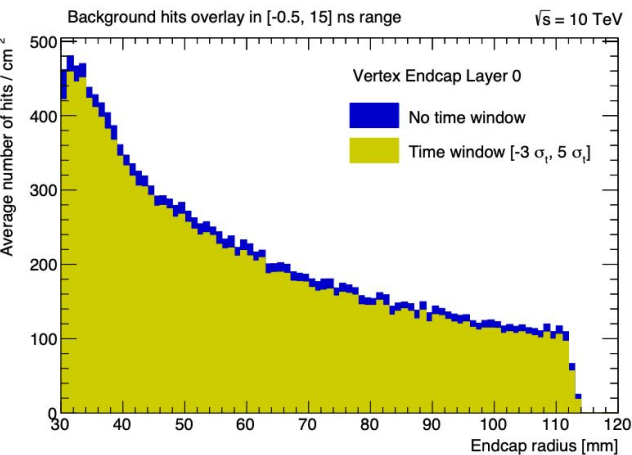


B = 3T

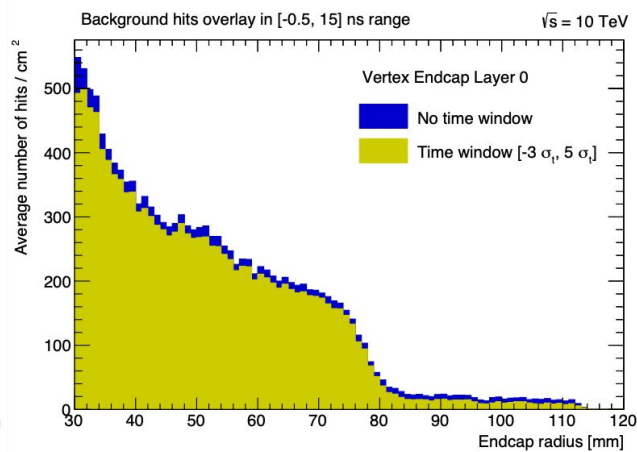


B = 5T

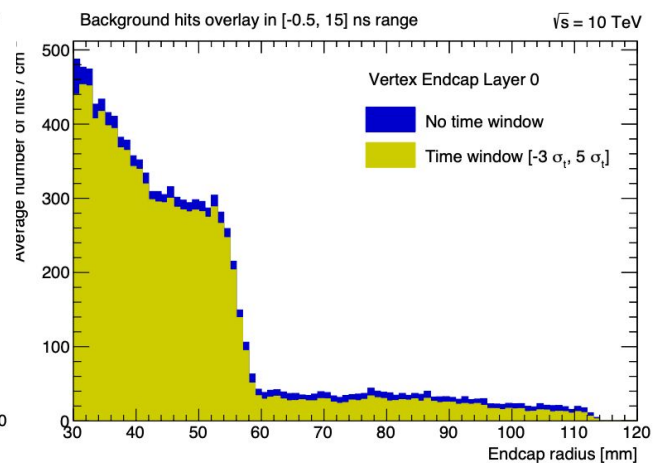
Endcap layer 0



B = 0T



B = 3T



B = 5T