# BIB suppression for charged-particle tracking at 10 TeV



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## Why BIB mitigation?



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# Silicon detectors digitization

- **Simplified digitization:** simulated E deposit to reconstructed position from simple Gaussian smearing informed by expected resolution (DDPlanarDigiProcessor).
- **Realistic digitization:** real particle-material interaction and emulation of detector electronics response (MuonCVXDDigitiser). Information about individual pixel hits per clusters (reconstructed position). Helps in estimating actual data readout rates.

- BIB produces several particles in the forward region.
- As a consequence, at any given energy, number of pixel hits per cluster can be much larger for BIB than signal.



(e.g. from 3 TeV MuCol geometry)



# Cluster shape analysis for BIB rejection

Using correlation between incidence angle and number of pixel hits per cluster to reject long clusters

- characteristic of BIB particles from muon decays.



BIB particles either have very short clusters at same angles as signal (due to low-pT particles) or excessively long clusters. In both cases, we can reject them to clean the tracking environment.

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### Software & workflow

- Git repo TrkHitsStudiesWorkspace
- Contains the mucol images and extra necessary libraries and configs in a self-contained environment to run detector simulation (ddsim) and realistic digitization (key4hep), followed by Cluster shape analysis for BIB mitigation.
- Finally, saving the modified collections output for running track reconstruction (ACTSTracking) later.

- Signal: Single muon gun sample, 0 < pT < 5 TeV,  $0^{\circ} < \theta < 170^{\circ}$ .
- Overlaying BIB and IPP backgrounds: EU24 lattice (vo.8)
- 10 TeV detector geometries: MAIA\_vo and MuSIC\_v2.



# Results: Realistic digitization w/ MAIA\_vo







# Cluster shape cuts w/ MAIA\_vo



(Preliminary simple cluster shape cuts)

With less than 5% loss of prompt signal clusters, we can cut down BIB clusters upto 20-30% from each layer of various subdetectors!

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combined together

# Very rough hit-rates w/ MAIA\_vo



- In VXB layer 0, ~4000 hits/BX/cm<sup>2</sup> (without BIB rejection) =  $0.4 \,\text{GHz/cm}^2$  hit-rate (BX = 100 kHz)
- For a 25µm x 25µm readout ASIC (e.g. RD53B chip for ATLAS/CMS HL-LHC upgrade), results in 2% tracker occupancy (total 153600 pixels).
- After cluster shape cuts, new hit-rate ~0.1 GHz/cm<sup>2</sup> and 0.5% tracker occupancy (comparable to HL-LHC with PU=200)!

Thus, on-chip processing can reduce bandwidth requirements with timing and cluster shape cuts.

Hit multiplicity / BX / cm<sup>2</sup>

10<sup>3</sup>

10<sup>2</sup>

10

MuGun + IPP

15

10

20

25

30

35

40

45

Layer Index

50



#### Results: MuSIC\_v2



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#### ...MuSIC\_v2 cont'd



#### Detailed selection in digi\_steer\_MuSICv2.py



Good performance in vertex barrel & endcap for rejecting BIB (~same occupancy as MAIA). Not as effective in the inner and outer tracker, although occupancy is much lesser as compared to MAIA detector.

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- Define better metrics to assess goodness of cluster shape cuts (for now only looking at fractional loss of clusters)
  - e.g. improvement in tracking performance (efficiency, fakes, computation time).
- Using ML to have robust cluster shape cuts (training features: total hits per cluster, cluster size in x & y, angle, timing, layer information, energy deposited..)
- Study the impact on displaced signal processes and/or busier environment (e.g. H→bb).



#### Other ongoing work for BIB suppression

- Playing with active sensor thickness, to look at cluster shape differences in signal vs BIB.
  - Furthermore, changing FE threshold will help in discarding smaller digitized signals from BIB.

• Using time of arrival information for rejecting overlapping hits on same pixel in same BX (in-pixel PU).









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#### Questions ? :)

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#### Extra: Hit density with MuSIC\_v2

