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Update of double-layer BIB suppresion in the Vertex Tracking detector

including realistic beamspot

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Double layer cuts: limitations

Particles from a $\mu^+\mu^-$ collision originate from the centre of the detector (IP)

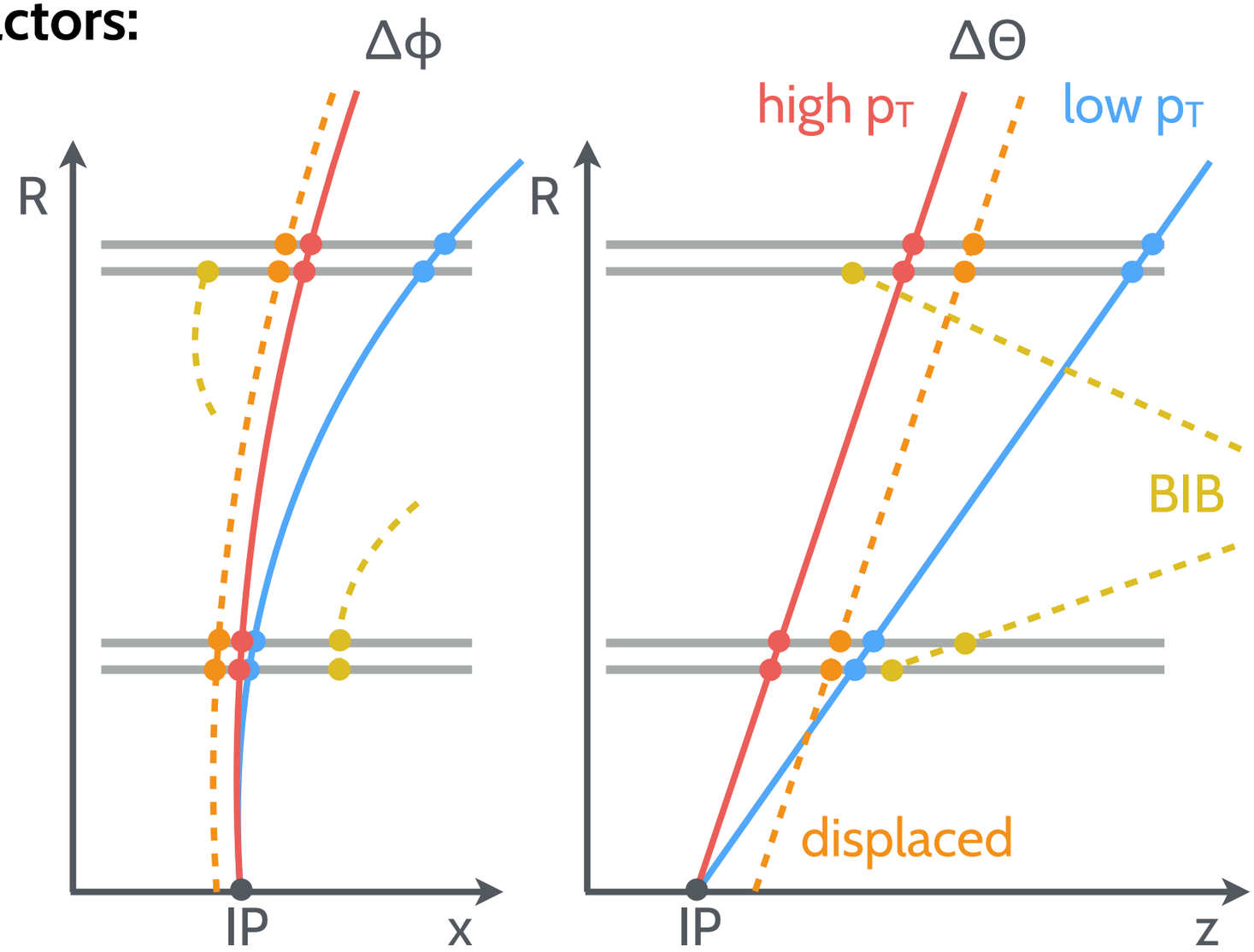
BIB particles arrive from the sides of the detector (nozzles)

Silicon sensors of the Vertex detector arranged in double layers to select pairs of hits aligned with the IP at the readout-electronics level

Effectiveness limited by several factors:

- sensor's spatial resolution limits the lower $\Delta\phi/\Delta\Theta$ threshold
- lowest reconstructable track p_T limits the lower $\Delta\phi$ threshold
- displaced track vertex limits the the lower $\Delta\phi/\Delta\Theta$ threshold at layers close to IP

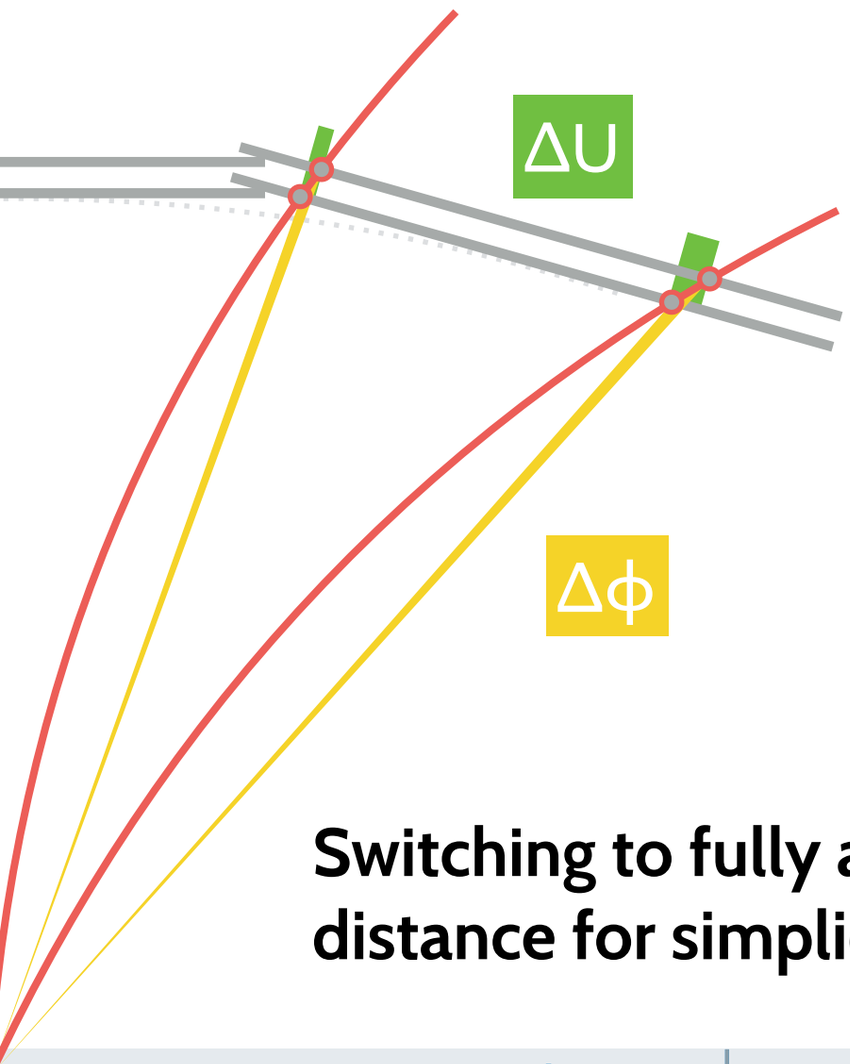
Let's check these effects on $\Delta\phi/\Delta\Theta$ of $\mu^\pm$ tracks

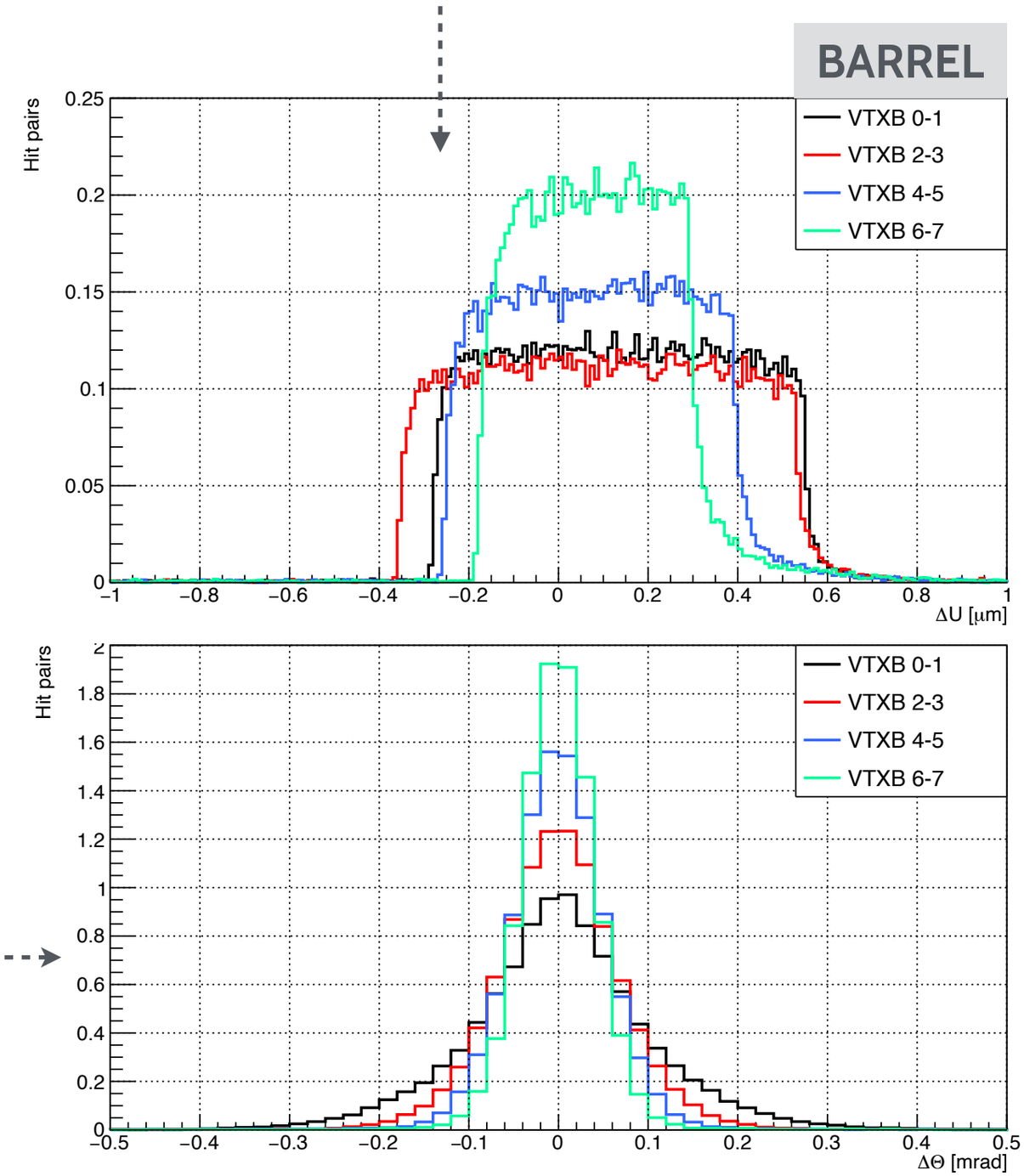


Angular vs planar distance

Previously the Double Layer cuts were not applied to the full extent

- hits were filtered only based on ΔΘ in a wide range of ΔU (on the sensor plane)
- actual ΔU changes with U for the same Δϕ



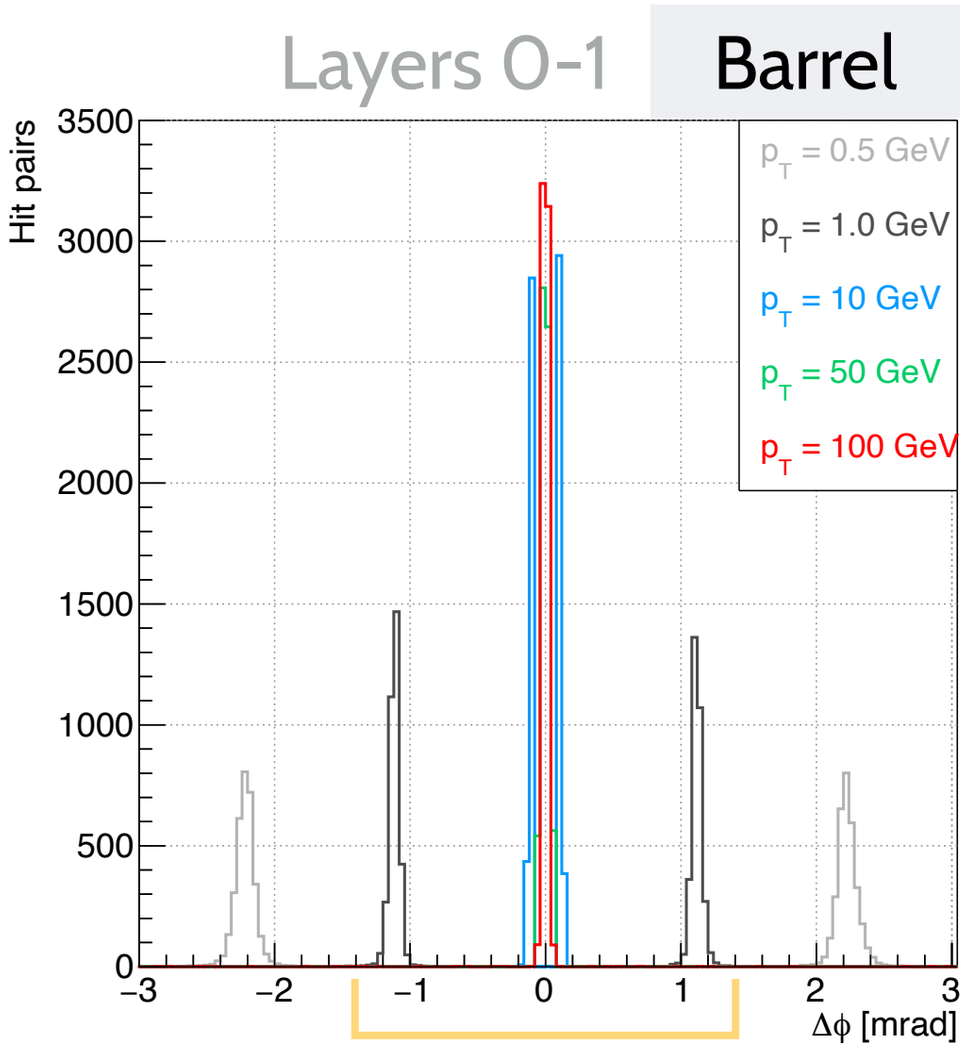


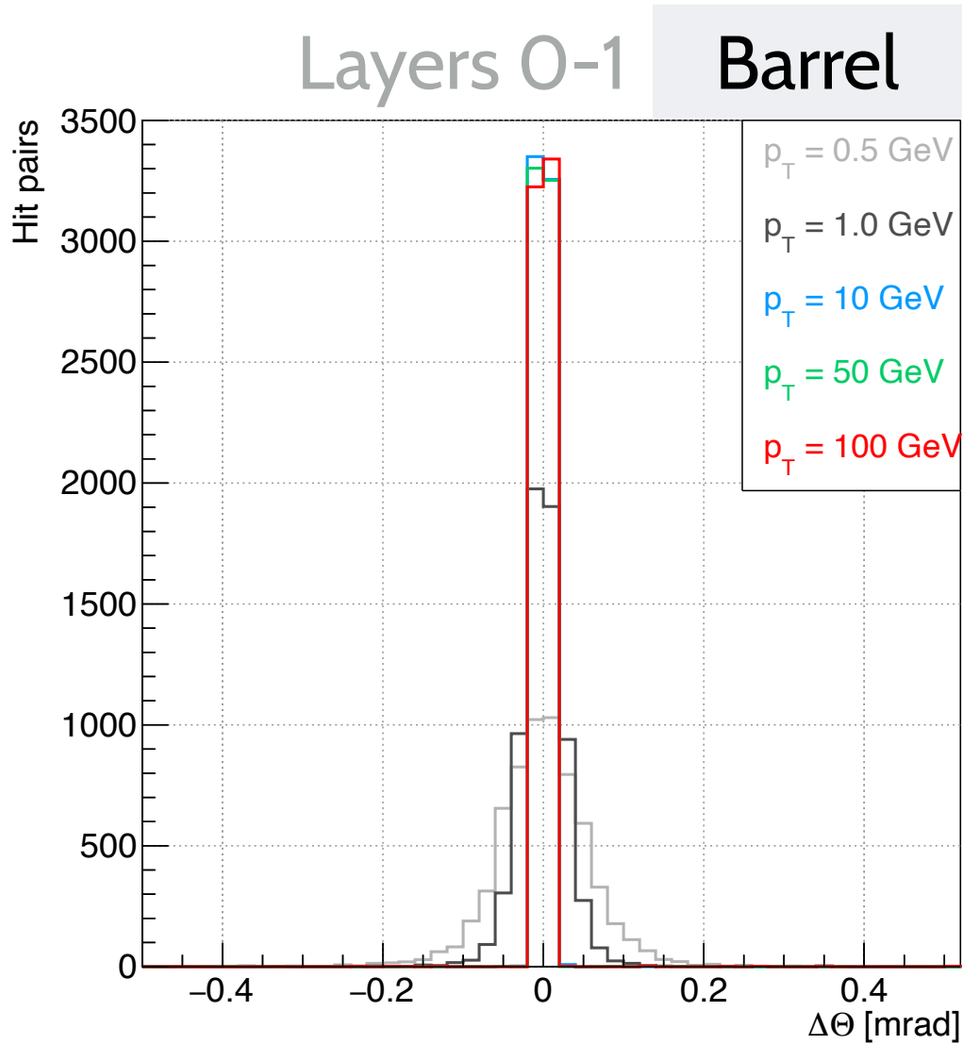
Switching to fully angular distance for simplicity: Δϕ/ΔΘ

Angular hit separation: ideal case

Looking at the Δϕ and ΔΘ separation between closest hits on layers 0-1

Considering an ideal case: no smearing of hit positions applied



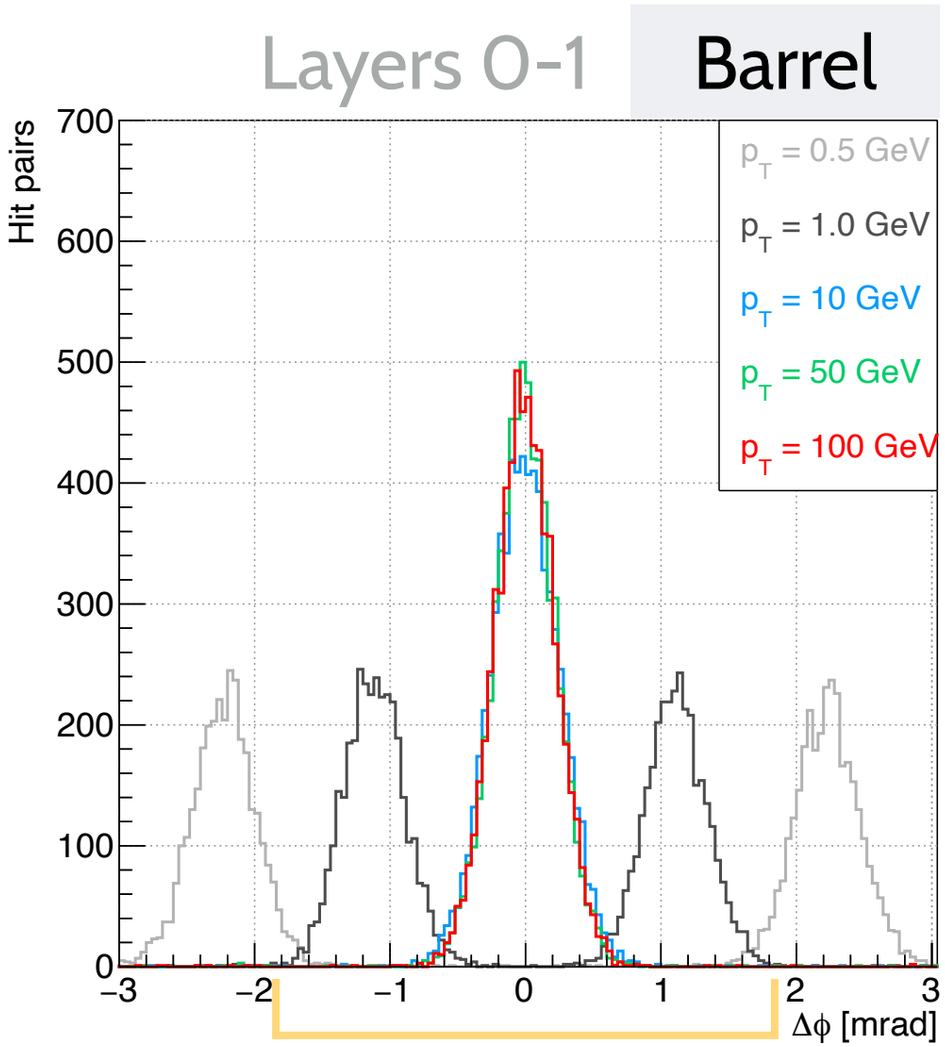


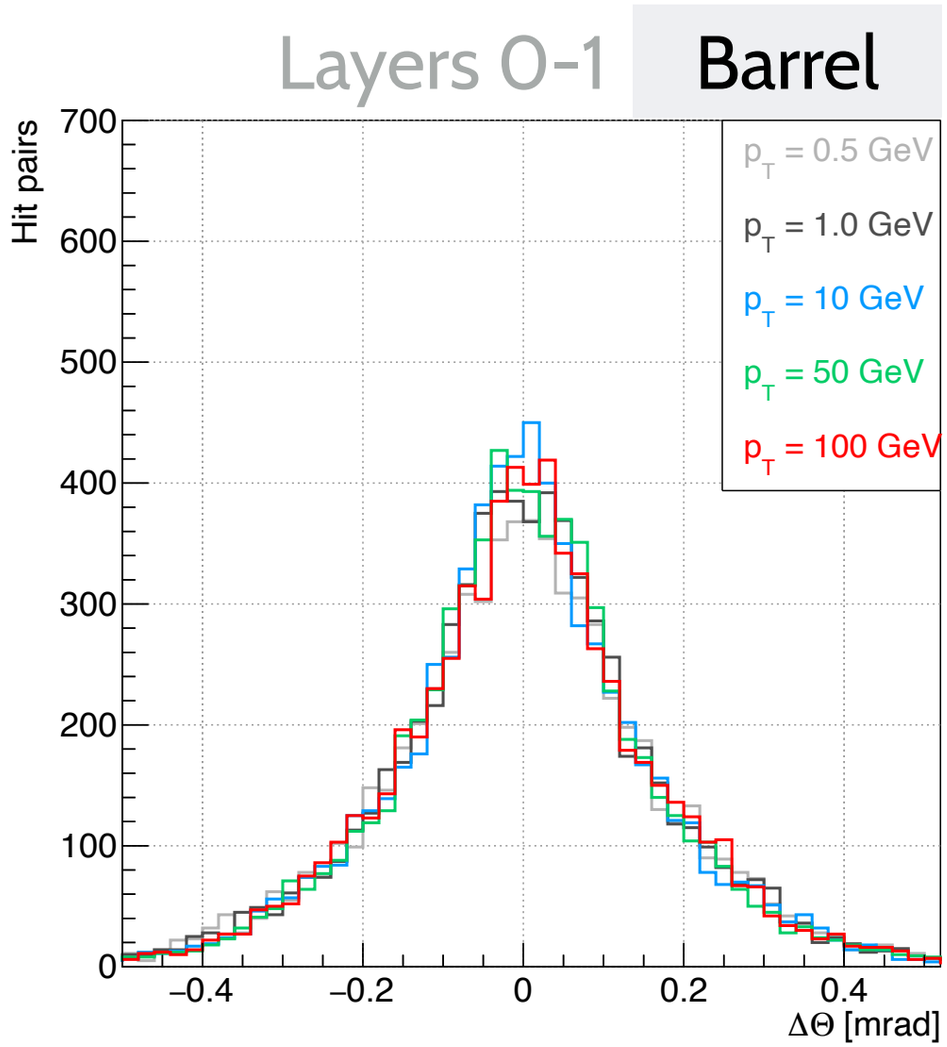
Lower p_T tracks are bent more → Δϕ becomes larger

↳ choice of the minimum track p_T we plan to reconstruct is important

Effect of spatial resolution: inner layers

Enabled the smearing of hits by the spatial resolution: σ = 5 μm





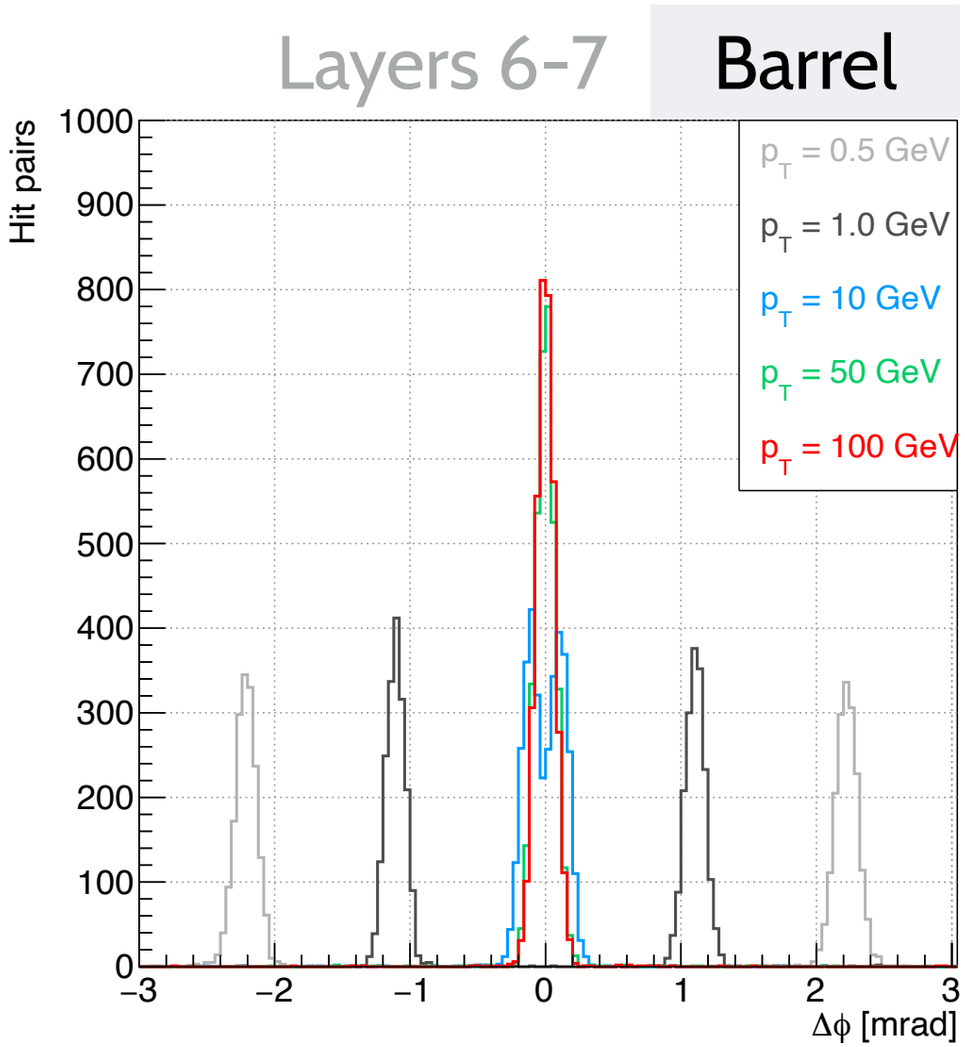
ΔΘ window significantly increased: |ΔΘ| ≤ 0.5 mrad

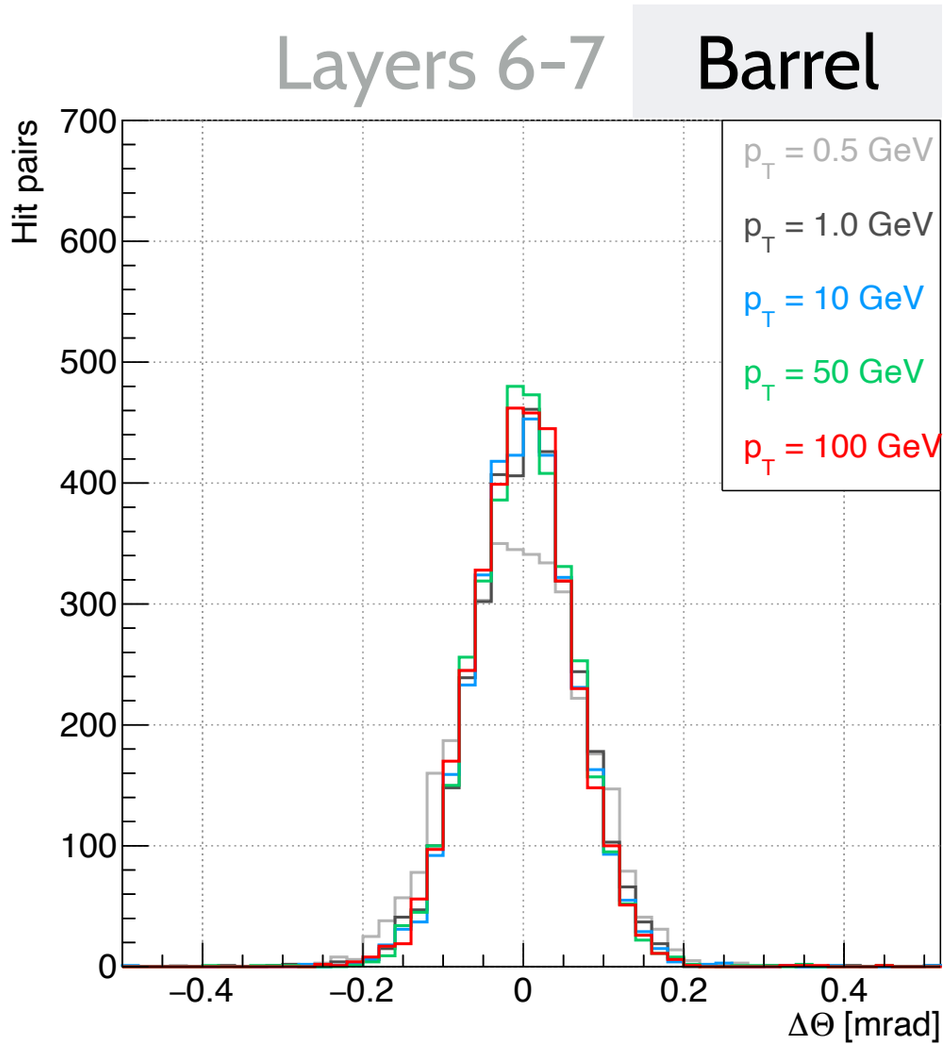
Impact on Δϕ window less significant: driven mostly by the track p_T

Effect of spatial resolution: outer layers

As expected, smaller impact in the outer layers

- same displacement on sensor surface has smaller angular shift



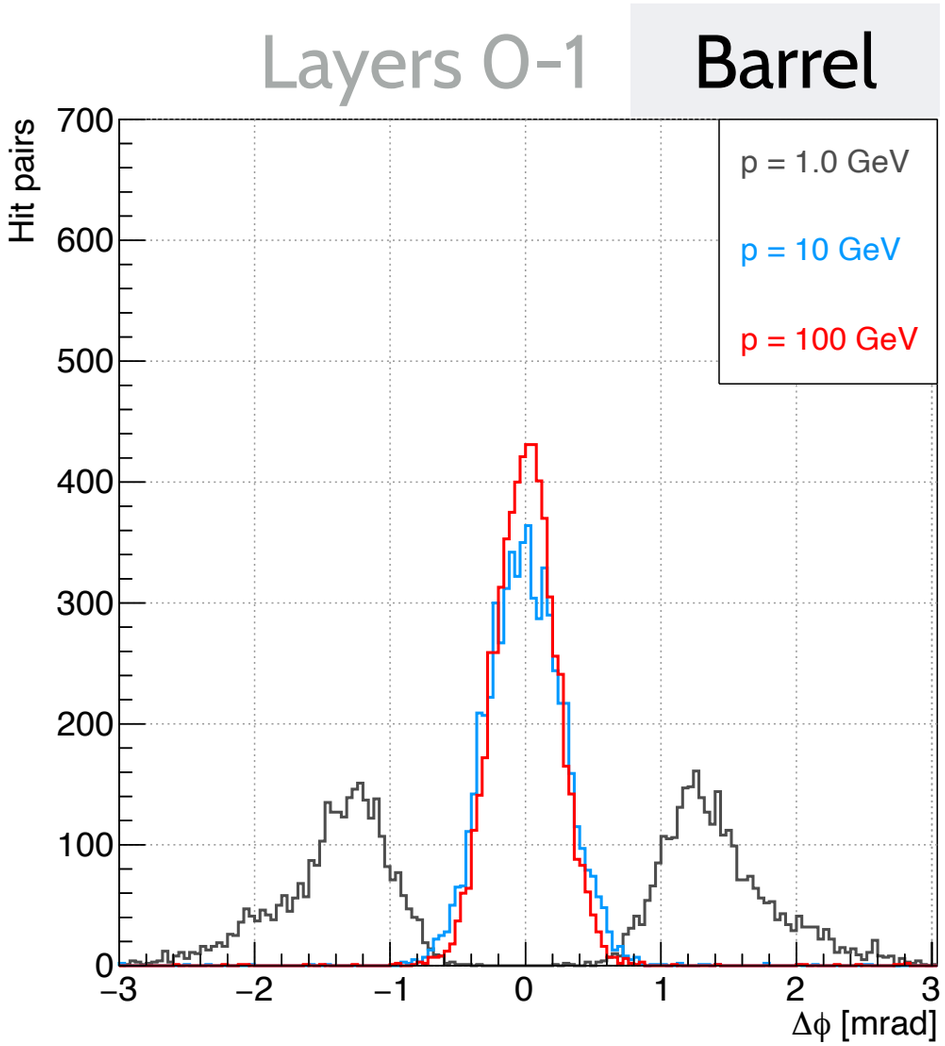


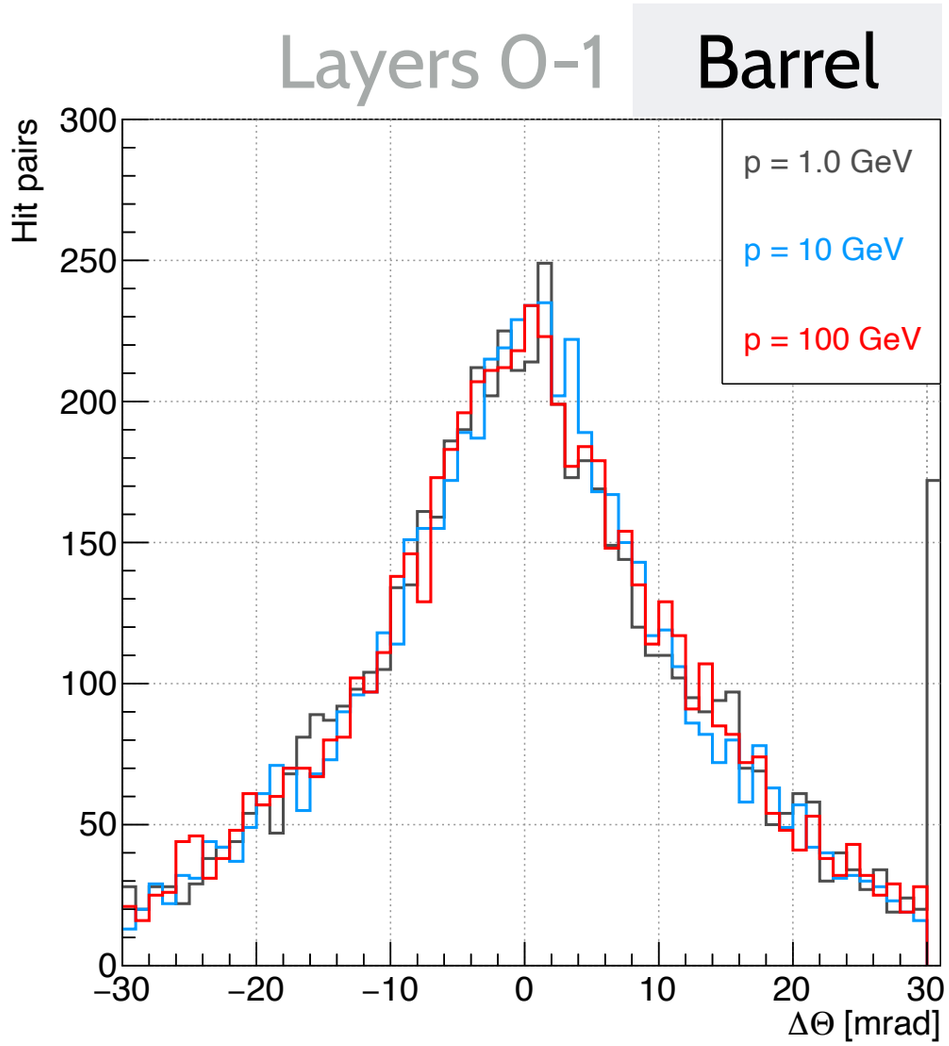
Tighter ΔΘ selection can be used at the outer layers

Effect of realistic beamspot: inner layers

Adding the realistic beamspot, IP position smeared along Z axis σ = 10mm

- **using samples generated by Massimo:** tracks have fixed p (not p_T)



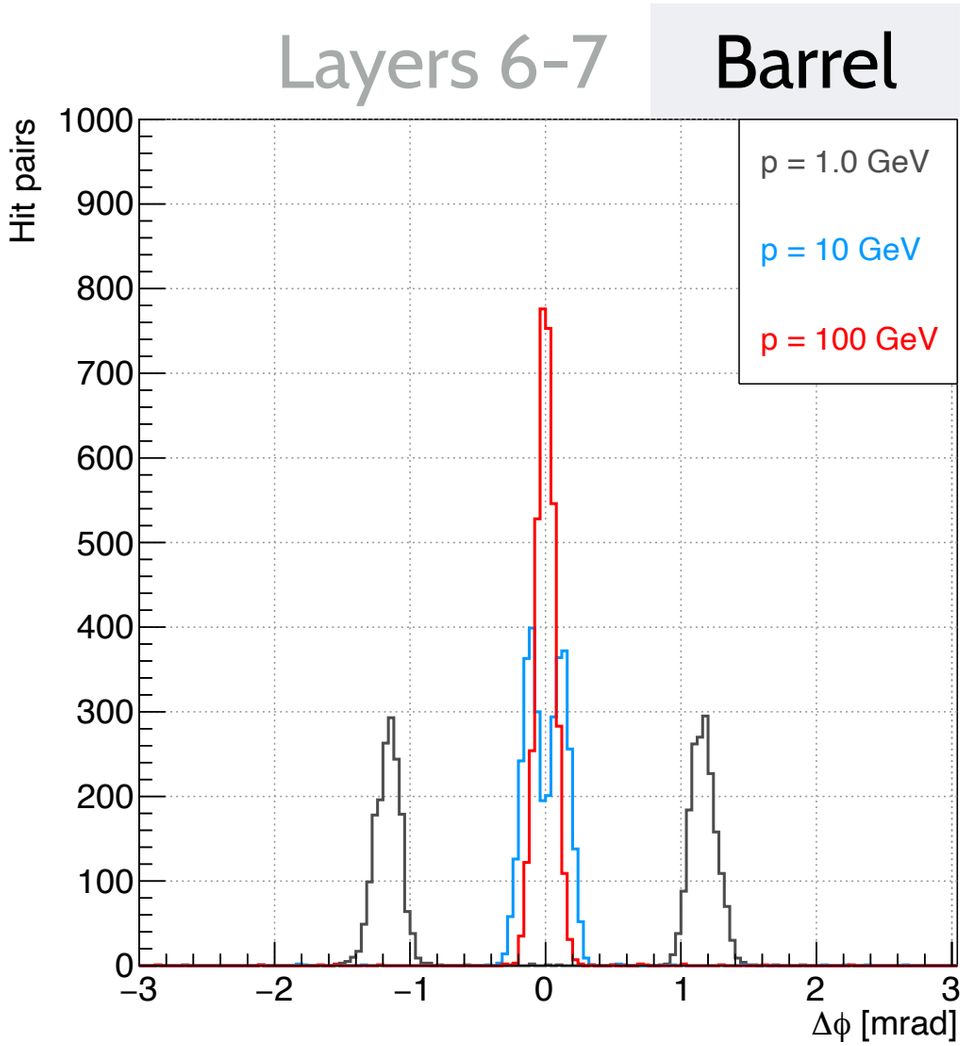


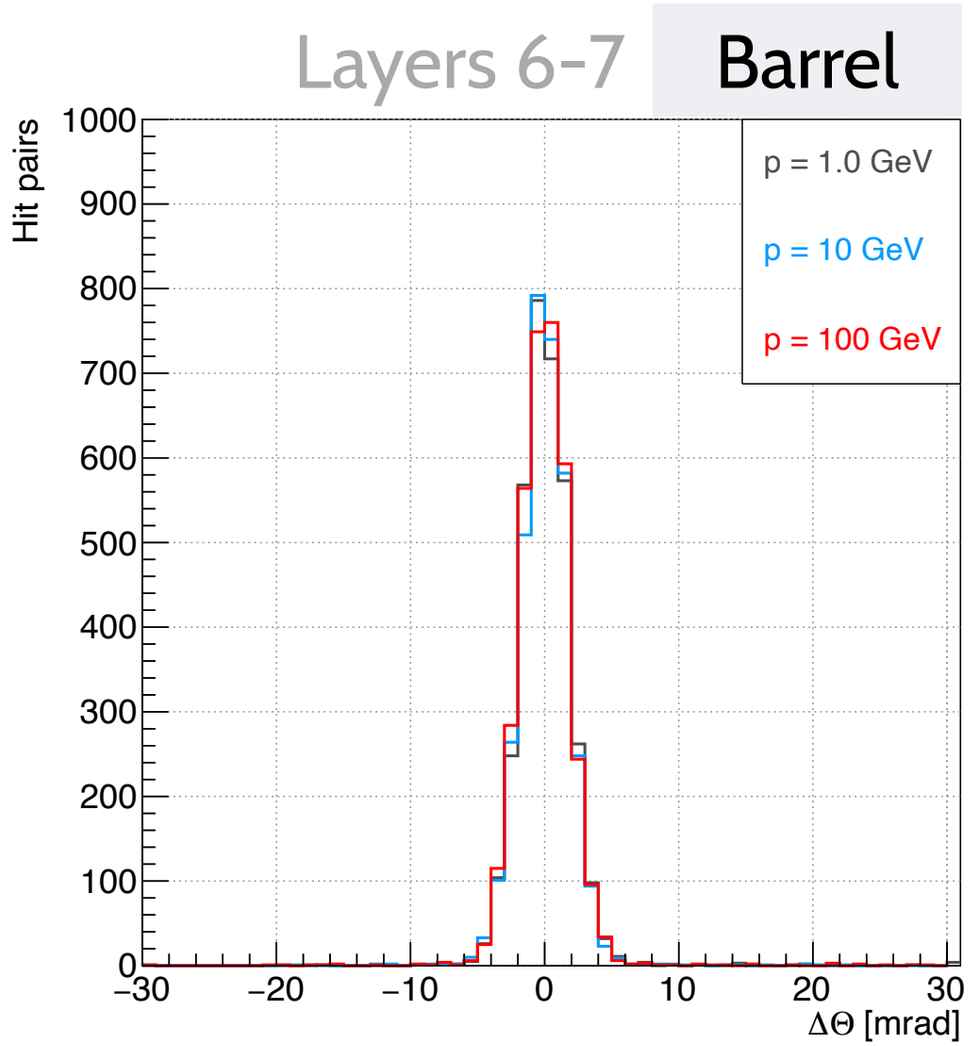
Huge impact on ΔΘ separation: 0.5 mrad → 30 mrad

Significant spread of Δϕ separation as well

Effect of realistic beamspot: outer layers

Effect of the realistic beamspot smaller in the outer layers



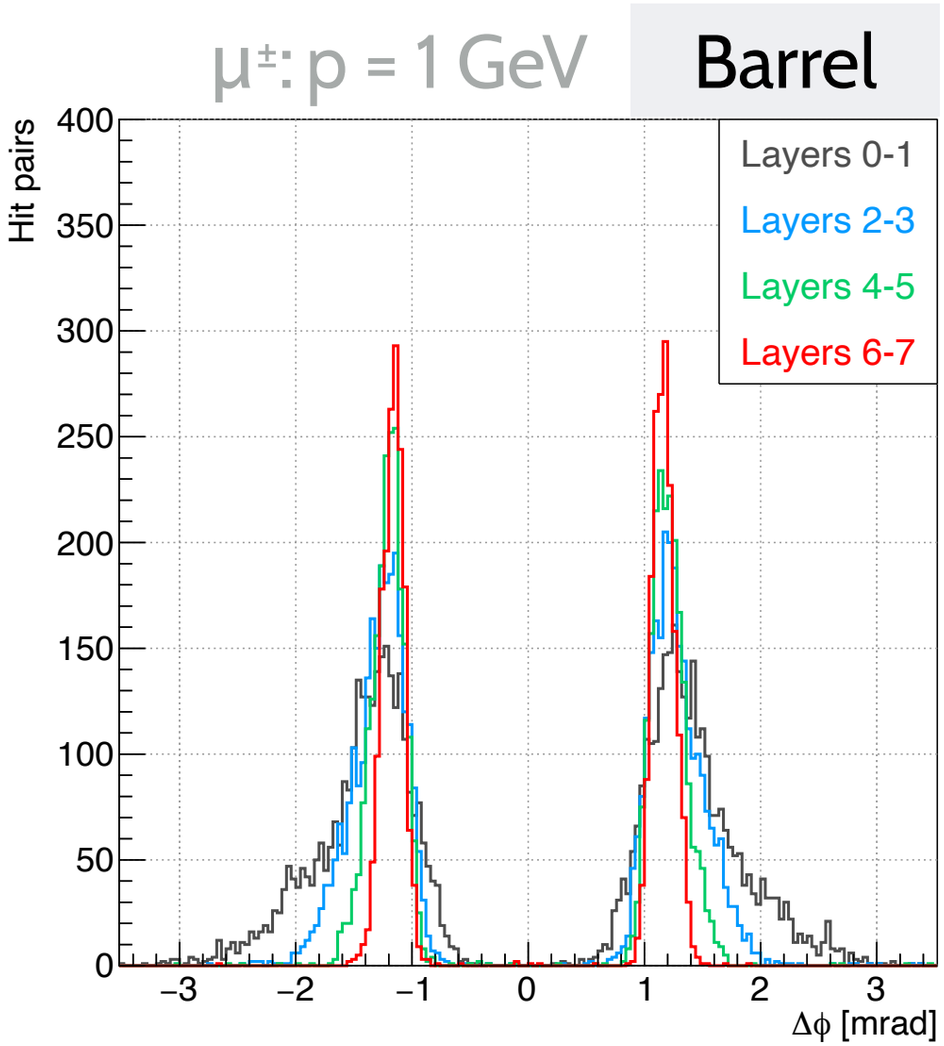


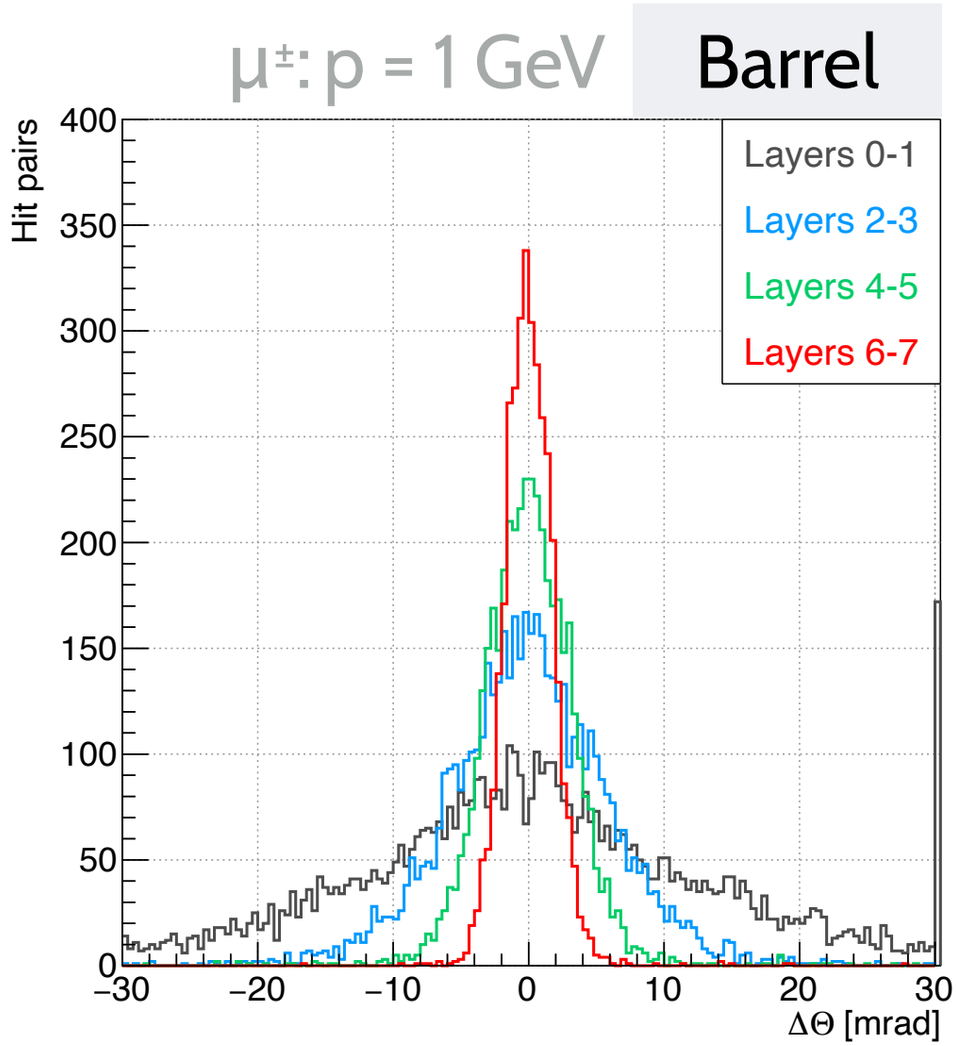
Still a noticeable impact on ΔΘ separation: 0.2 mrad → 6 mrad

Defining the cuts: Barrel

Taking tracks with p = 1 GeV as the softest tracks to be efficiently readout

- defines the Δϕ window to search for an aligned hit on the 2nd sublayer



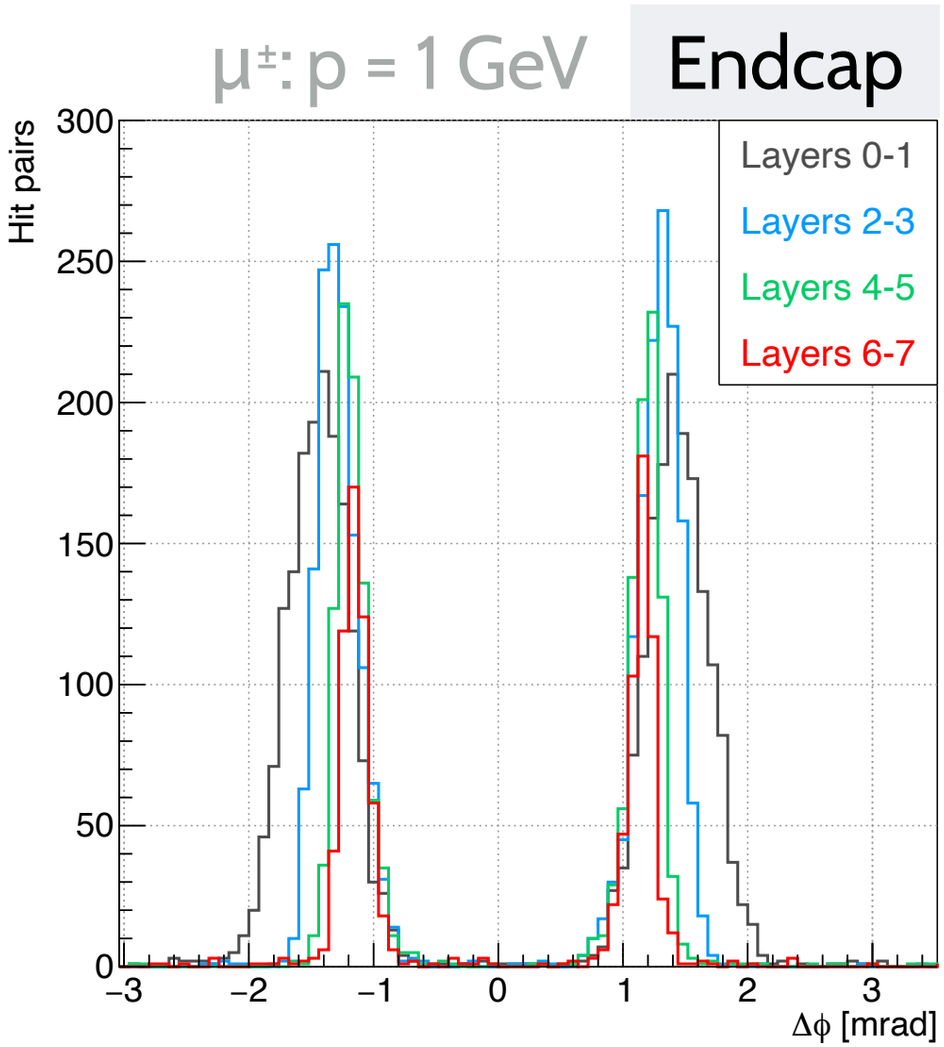


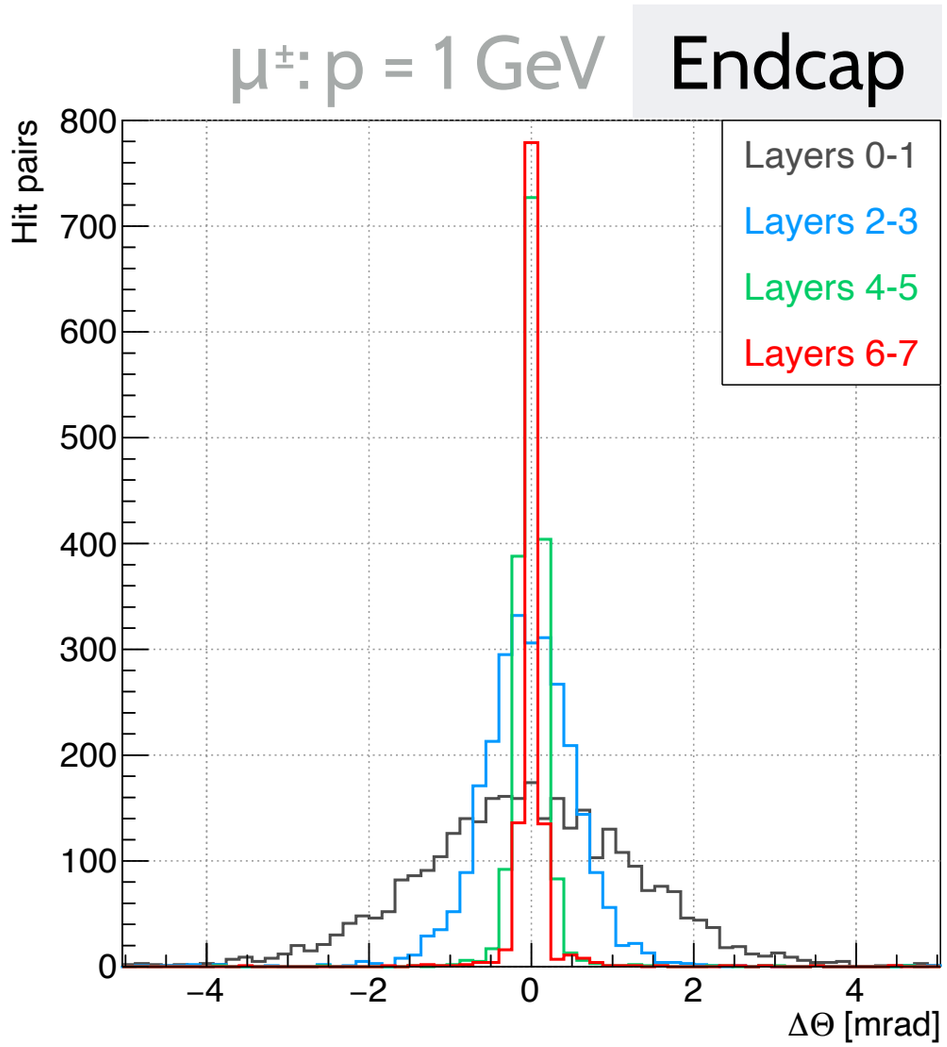
MAX Δϕ|ΔΘ for each double layer:

2.8|35.0 2.0|18.0 1.7|10.0 1.5|6.5

Defining the cuts: Endcap

Smaller angular separation in the Endcaps





MAX Δϕ|ΔΘ for each double layer:

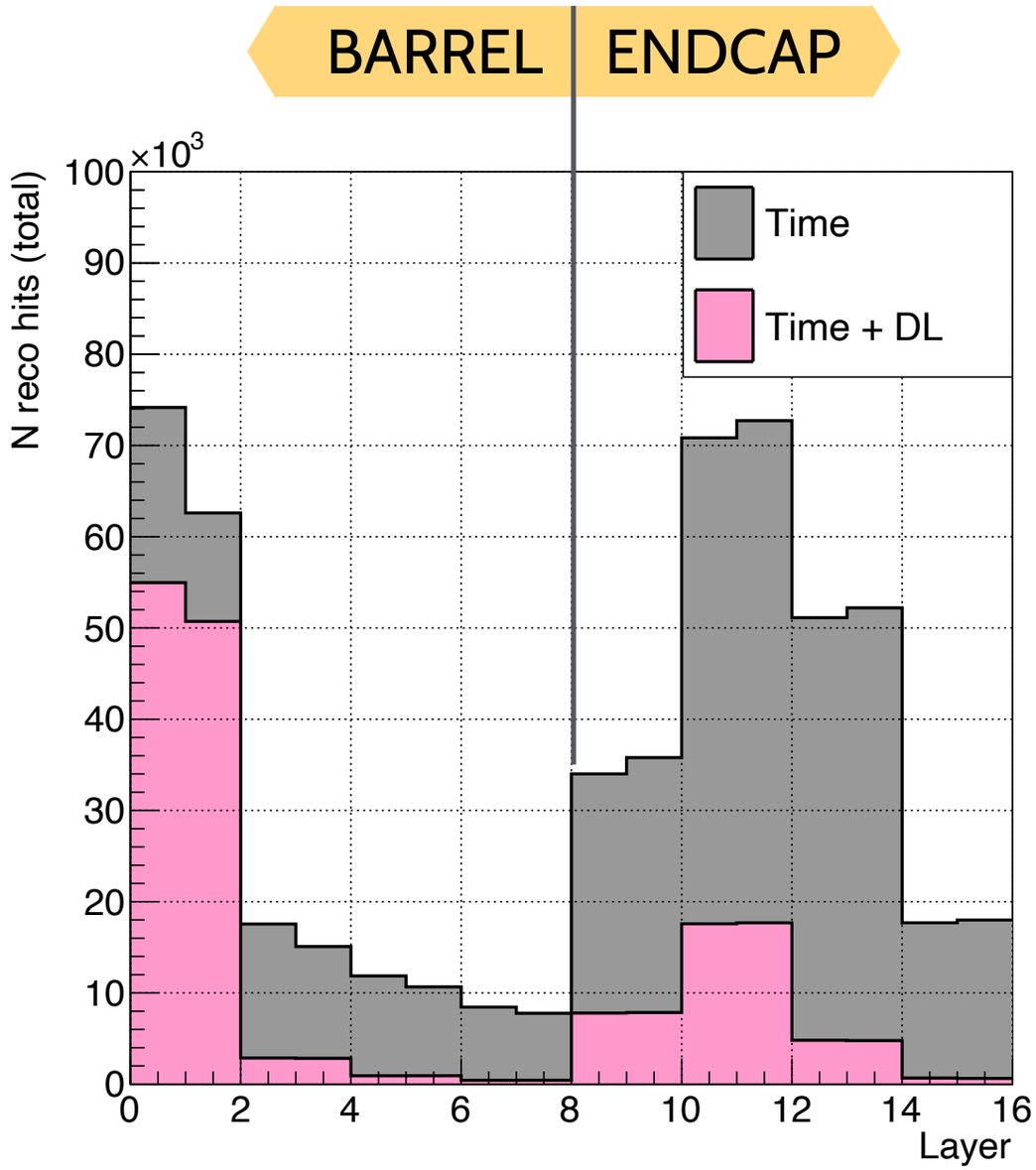
2.1|3.5 1.7|1.5 1.6|0.7 1.5|0.5

Checking the effect: hit multiplicity

Improved BIB suppression power from Δϕ is counterweighted by the need for acceptance of the finite beamspot size

Resulting reduction of # hits in the Vertex detector is still not great

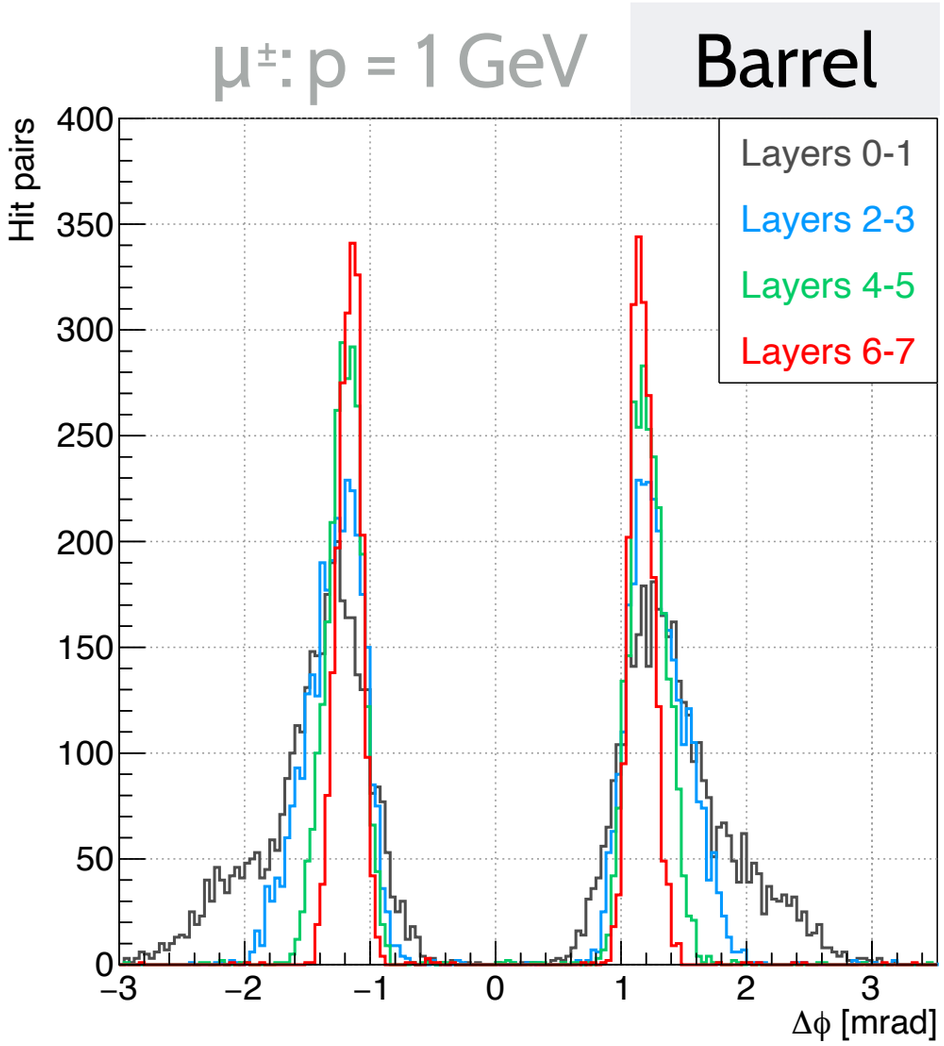
	timing		timing + DL	%
BARREL	208158	→	114084	55%
ENDCAP	352378	→	61802	18%

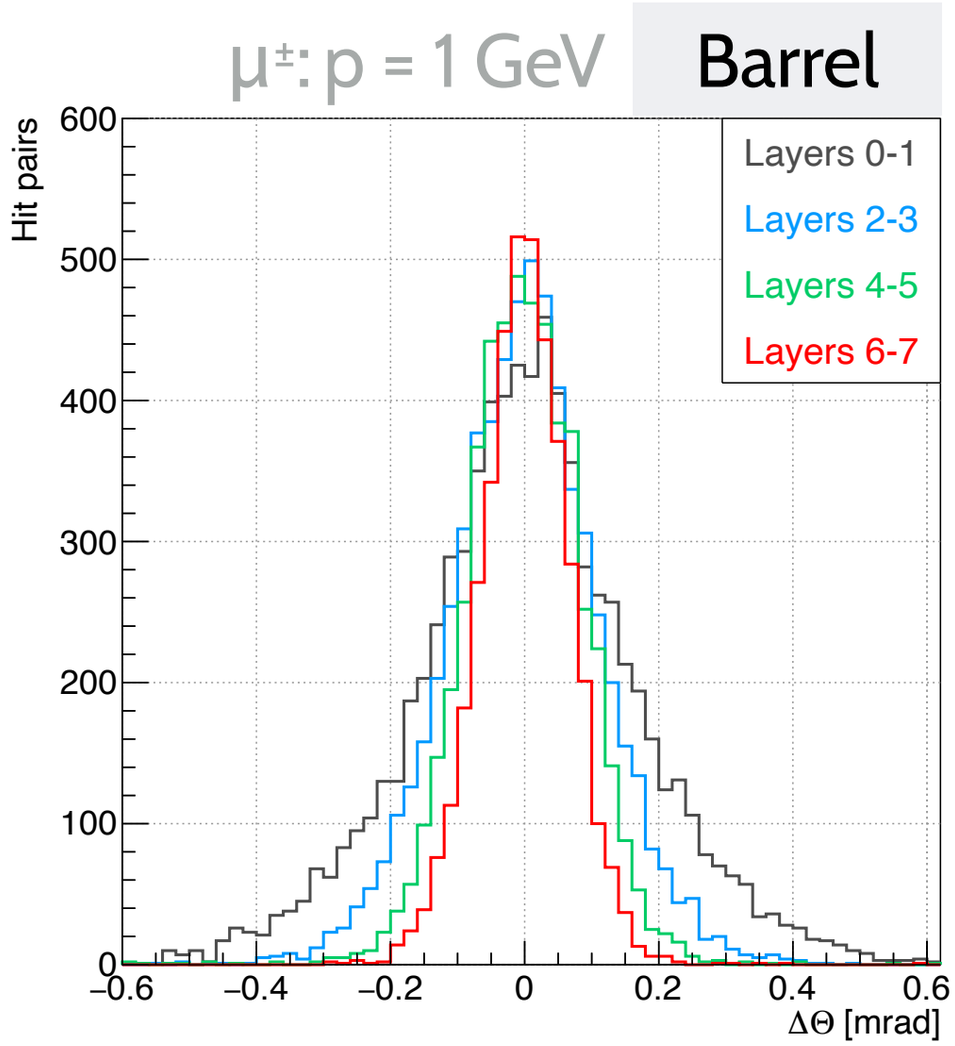


If beamspot was perfect: Barrel

Much tighter cuts can be applied if we ignore the smeared beamspot

- smearing only the hits but not the IP position





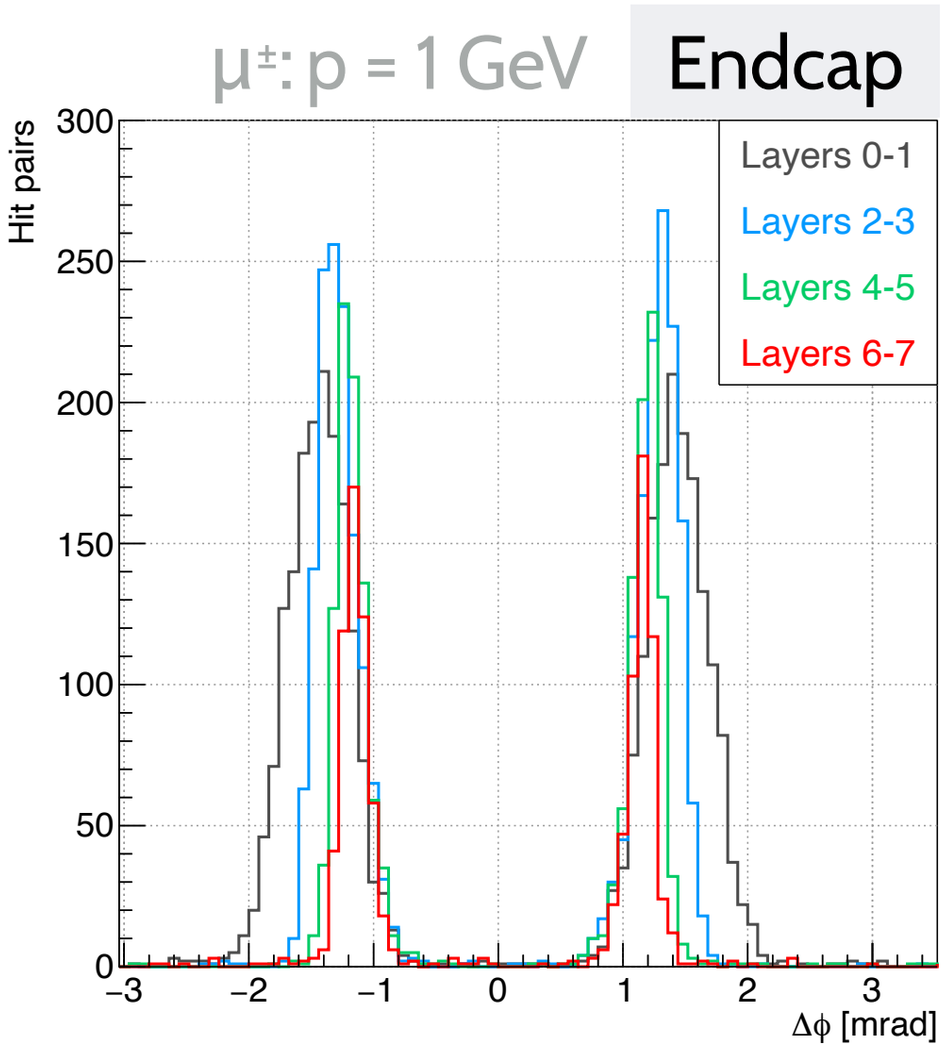
MAX Δϕ|ΔΘ for each double layer:

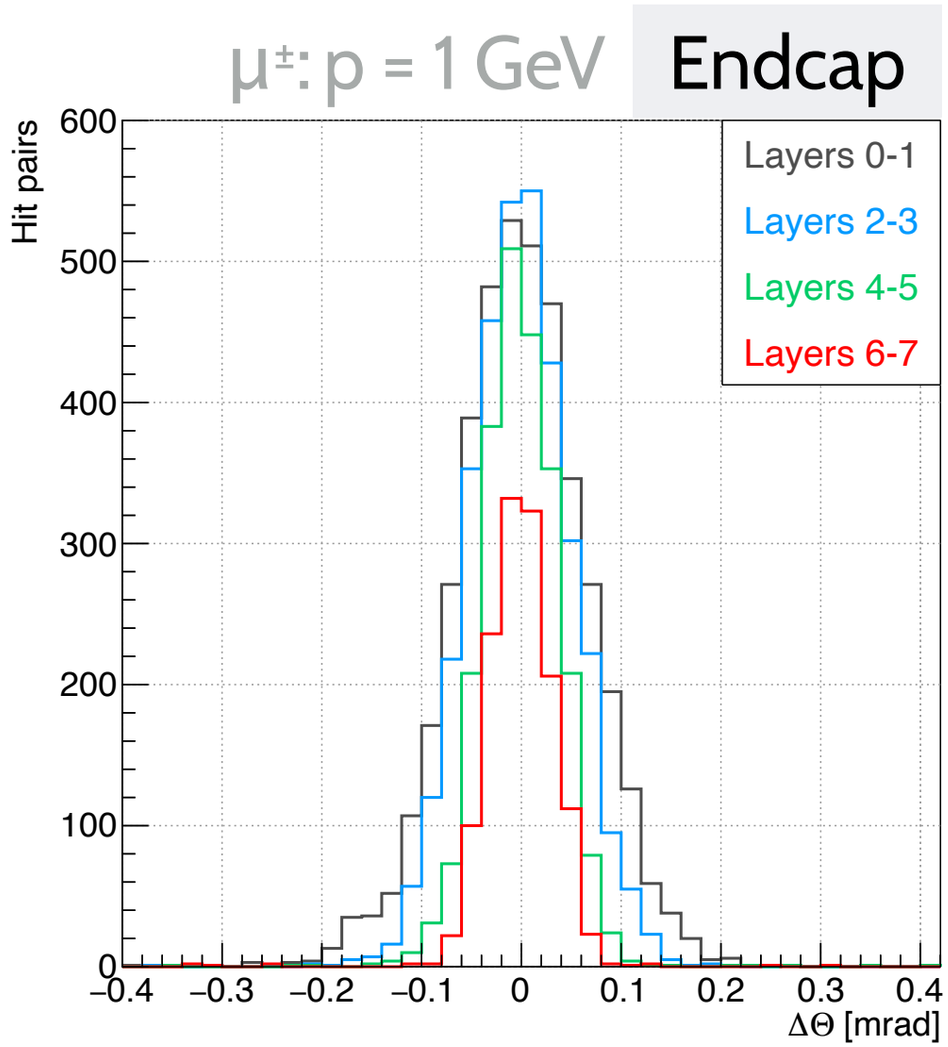
3.0|0.5 2.0|0.4 1.6|0.3 1.5|0.25

ΔΘ: ~30 mrad → ~0.6 mrad

If beamspot was perfect: Endcap

Also substantial tightening of the cuts in the Endcaps is possible





MAX Δϕ|ΔΘ for each double layer:

2.2|0.2 1.8|0.18 1.7|0.12 1.6|0.1

ΔΘ: ~4 mrad → ~0.2 mrad

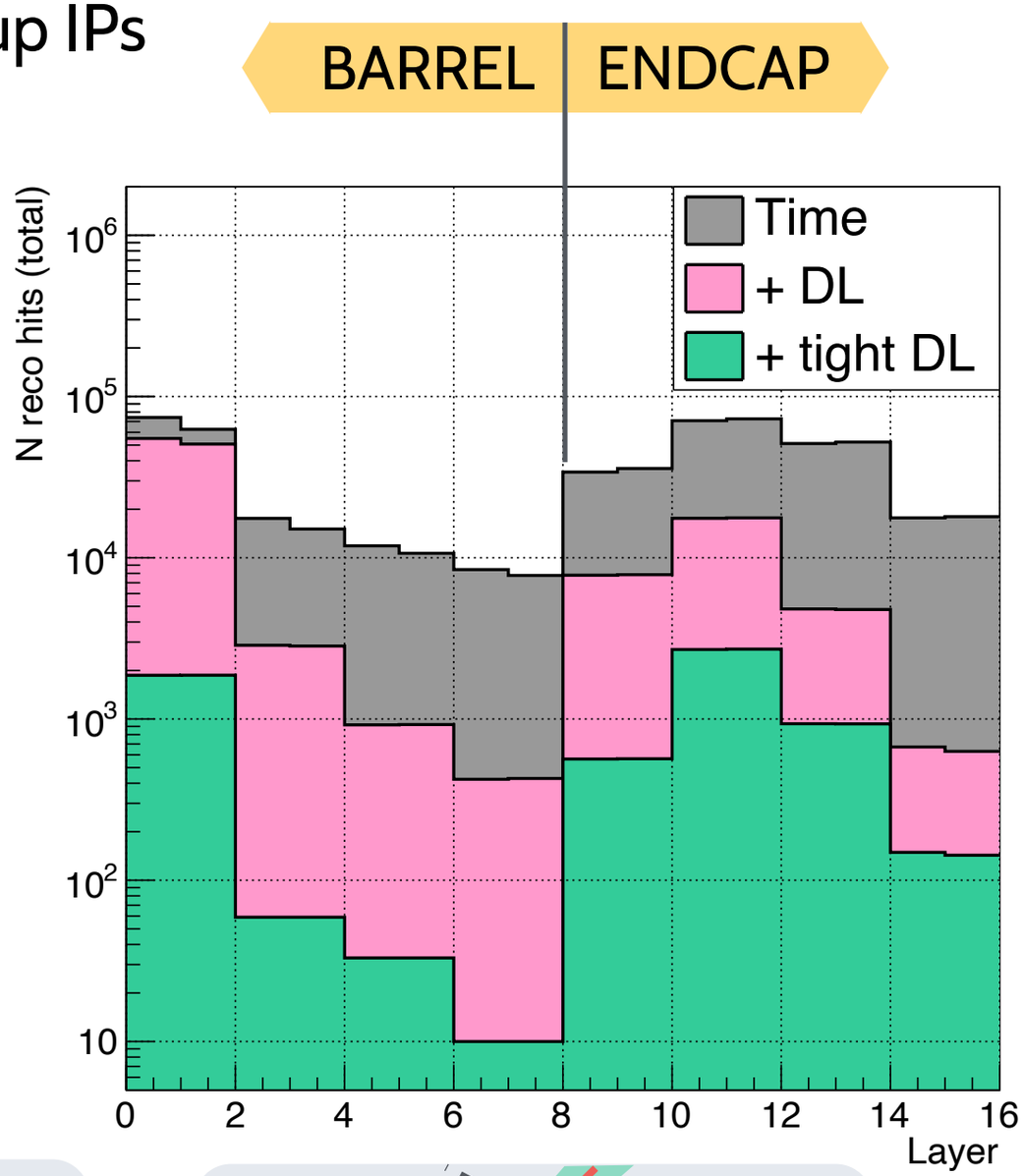
Can we correct the beamspot?

We can't make beamspot smaller → Double Layer cuts can't be so tight ONLINE

BUT it's not a hadron collider with ~100 pile-up IPs

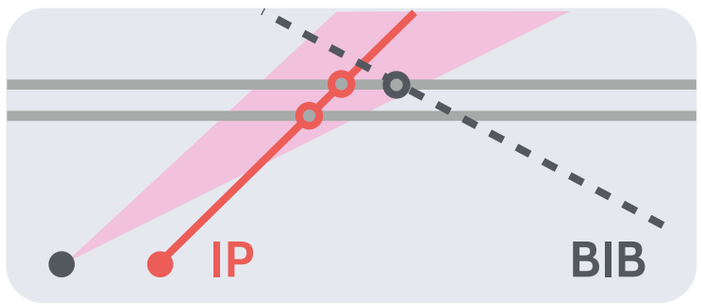
↳ there is only one real IP that might be possible to identify beforehand

	timing	+ loose DL	+ tight DL	%
BARREL	208158 →	114084 →	3942	2%
ENDCAP	352378 →	61802 →	8705	2%



With this amount of hits we can reconstruct 1 event with 100% BIB in ~3 minutes

Knowing the precise position of the IP would dramatically simplify the track reconstruction



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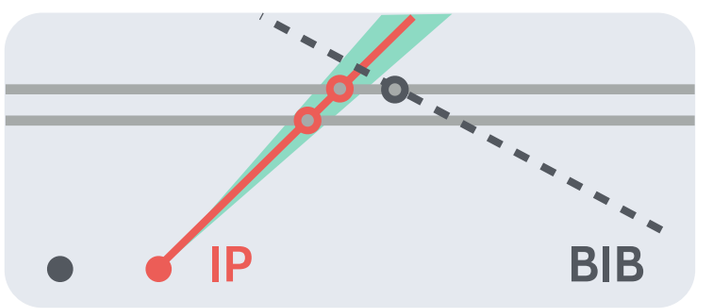
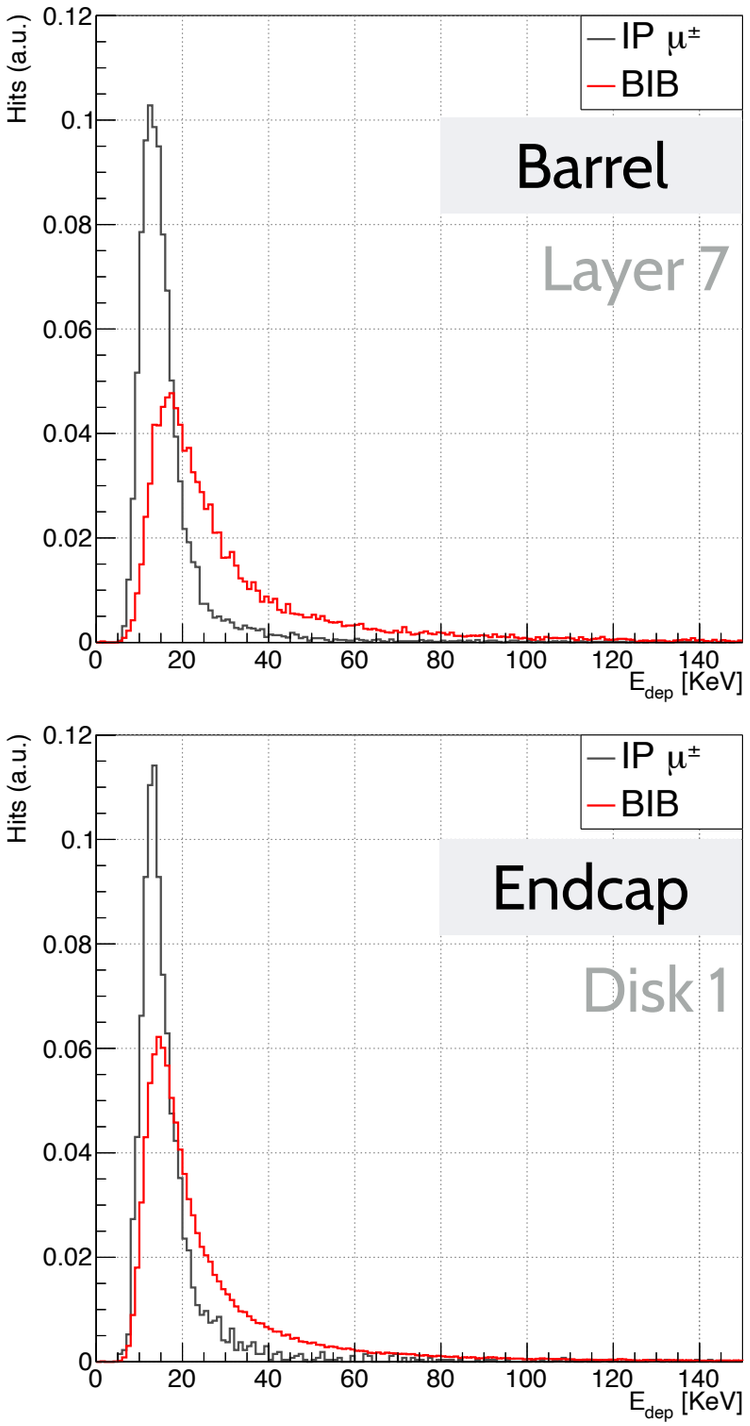
Determine IP position
- simpler track reco?
- muon detector?
- calorimeters?

→

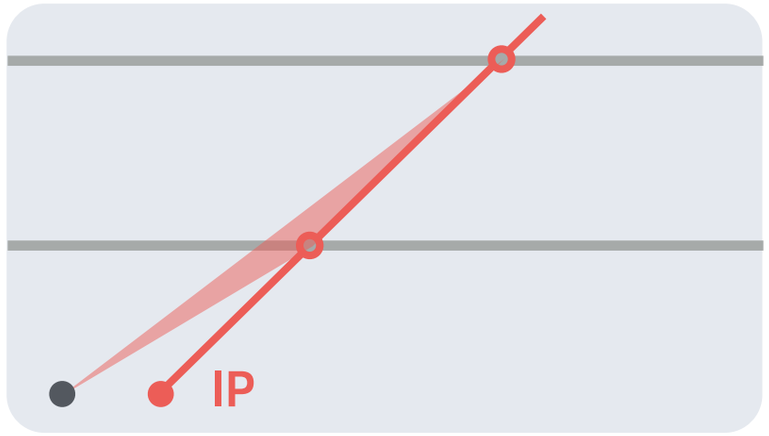


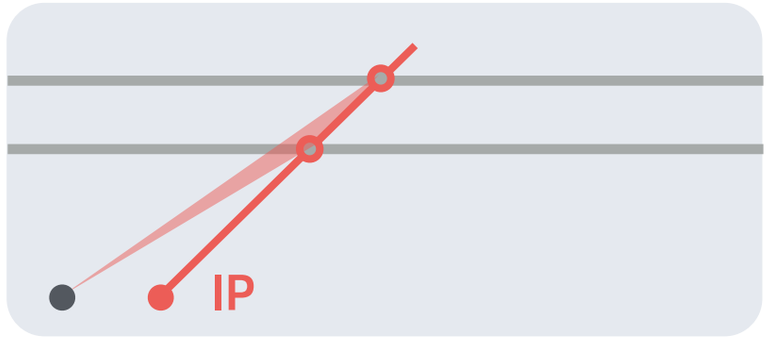
A nother minor handle

BIB hits tend to have more deposited energy: longer path inside silicon?



Reduce double-layer separation in the central region





Summary

Effectiveness of the Double Layer BIB suppression is strongly limited by the precision of the Interaction Point (IP) position

Possible ways of improving it before full-scale track reconstruction should be explored