Tracking results in PbPb and pp collisions for Upgrade II UT Geometries

LHCb Upgrade II Tracking Workshop
07/03/2024

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Motivation

- Study the UT tracking performance in PbPb and pp collisions for the Upgrade II scenarios: 4 different geometries of the UT.

- We use a framework that give us the flexibility to change things that in the LHCb software would not be easy to handle (LHCbIDs with new detectors, definition of reconstructible, ...)

- The main code has been developed by *Renato Quagliani.*

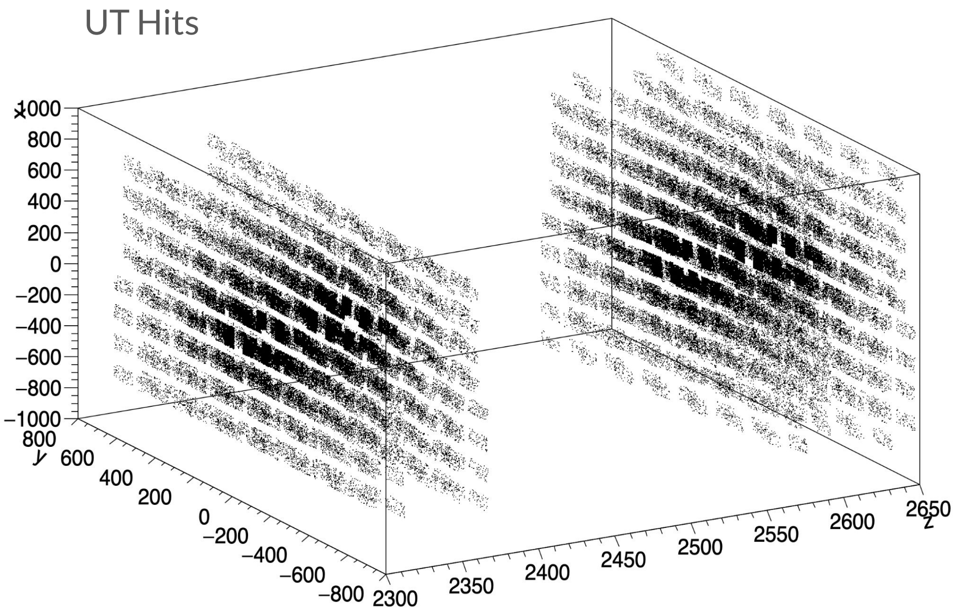
- The code was thought to be used in pp collisions but It can be used in heavy ions collisions with some modifications.

MC sample

- Start with a simulation file (.sim file)

- Make the tuples (.root file)
  - Position: (x,y,z)
  - Time: t
  - Energy
  - Vertices
  - MC Particles

- It is possible to change the geometry of the detectors (reduction mode)

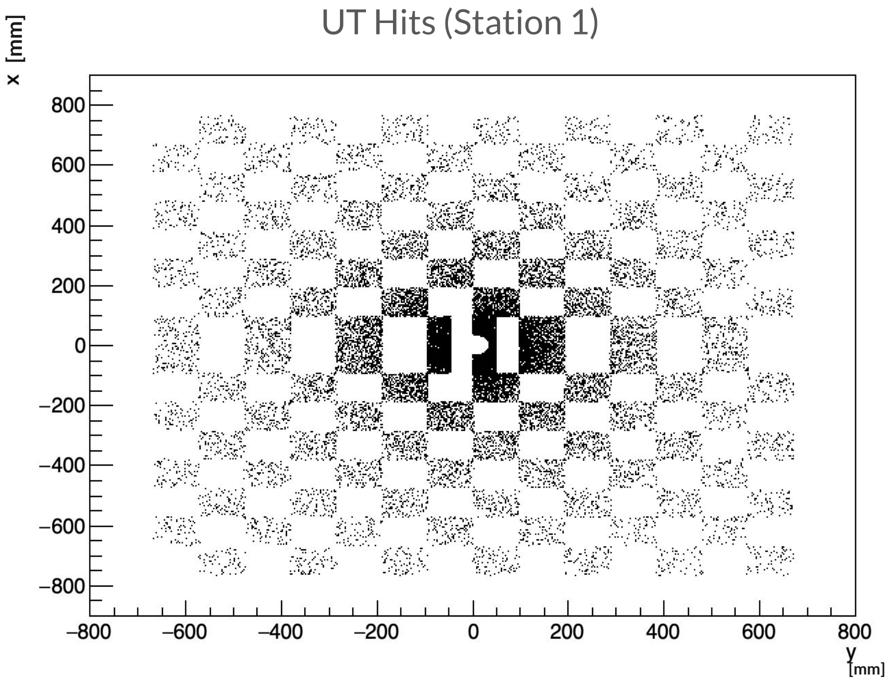


PbPb Sample

- PbPb sample of run3 detector geometry
- PbPb central collision simulation (Pythia): 5% centrality
- $\mathcal{L} = 1\ \mathrm{coll/evt}$
- 5 events

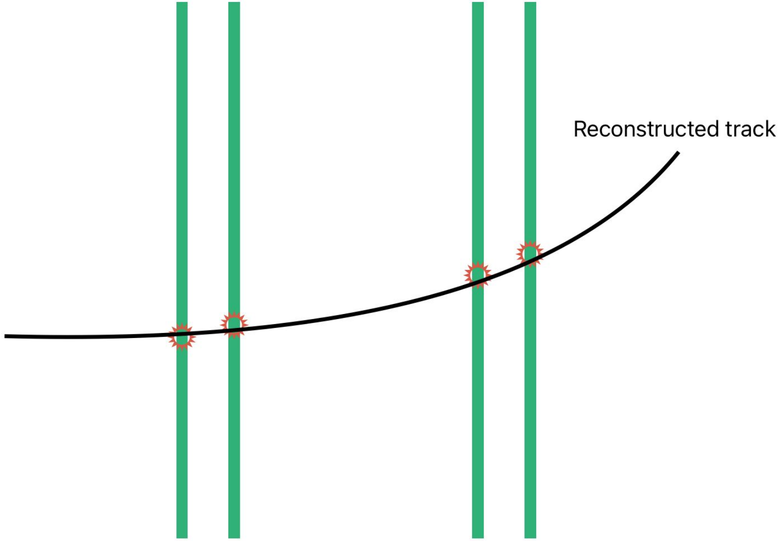
pp Sample

- pp sample of run3 detector geometry
- $\mathcal{L} = 1.3 \cdot 10^{34}\ cm^{-2}s^{-1}$
- 50 events



Cheated Algorithm

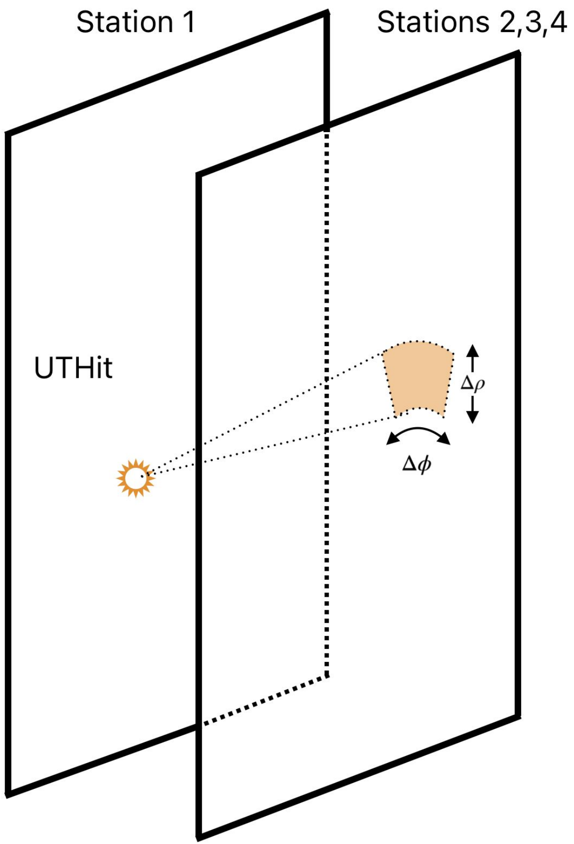
- ➢ Smear the simulated hits
- ➢ Classify the hits depending on the original track they come from
- ➢ Make the the reconstructed track with hits from the same MC track. Parabola model in x and linear model in y.



- ❖ This algorithm gives us an upper limit for performances.
- ❖ Inefficiencies come from bad fits.

Standalone Algorithm

- Pick a hit in station 1
- $|\Delta\rho|/|\Delta\phi|$ search windows in station 2 to 4 + slope windows.
- Make all the combinations of candidate hits in station 2 to station 4.
- Fit with a parabolic (linear) model in x (y) and keep the best track candidate.
    - Make the fit if there are at least 3 hits.
    - Remove used hits.
- Second pass with the remaining hits in station 1.



Settings

- Smearing:

```
"UT" : "x_pitch_size" : 0.030,
       "y_pitch_size" : 0.030,
       "hiteff" : 0.98
```

- Reconstructible criteria:

```
"hasUT" (cheated) >= 3
“hasUT" (standalone) >=3
```

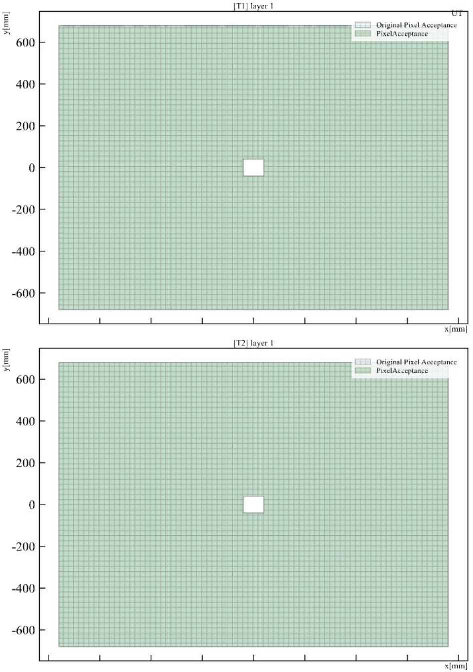
- Geometry: (for UT detector)
  - Baseline
  - Hole
  - No Border
  - 3 Stations

- Standalone fit

```
“chi2_ndofmax": 1000.
"delta_rho":
      "st1_st4": 3 * 13.458240
      "st1_st2": 3 * 29.693831
      "st2_st3": 3 * 13.176463
      "st3_st4": 3 * 33.882427
"delta_tx": 0.15
"delta_ty": 0.15
"delta_phi": 0.02
"fit_bounds_low": [-10000,-8.,-0.00015]
"fit_bounds_high": [10000,8.,0.00015]
```

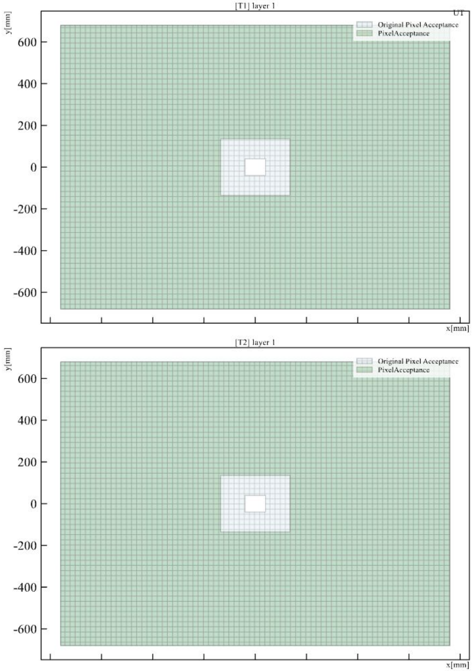
UT Geometries

Baseline



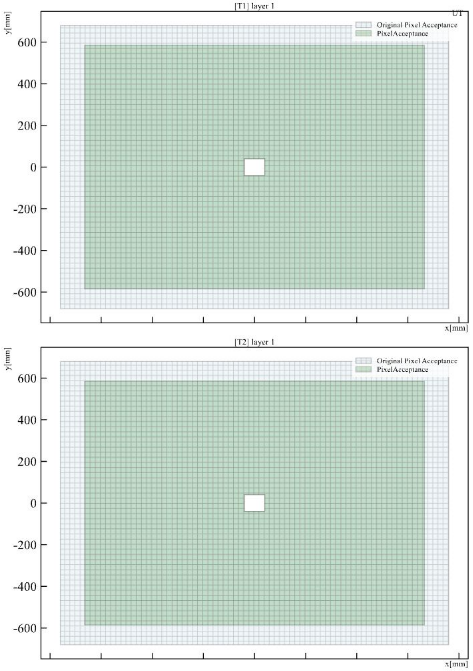
Complete acceptance of the detector

Hole



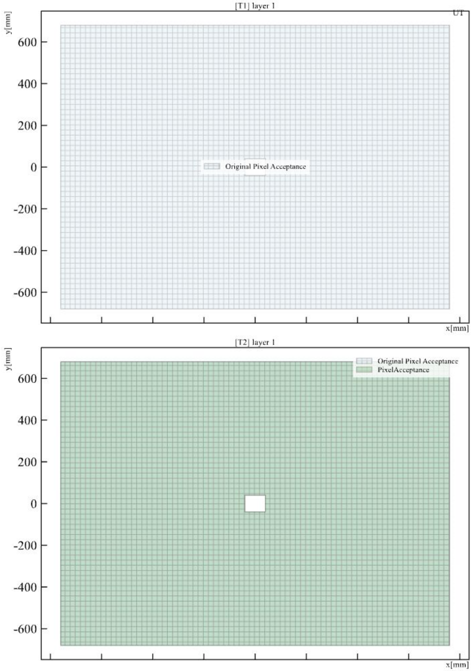
Remove a row of pixels around the beam hole

No Border



Remove a row of pixels along the border

3 Stations



Remove the first Station of the detector

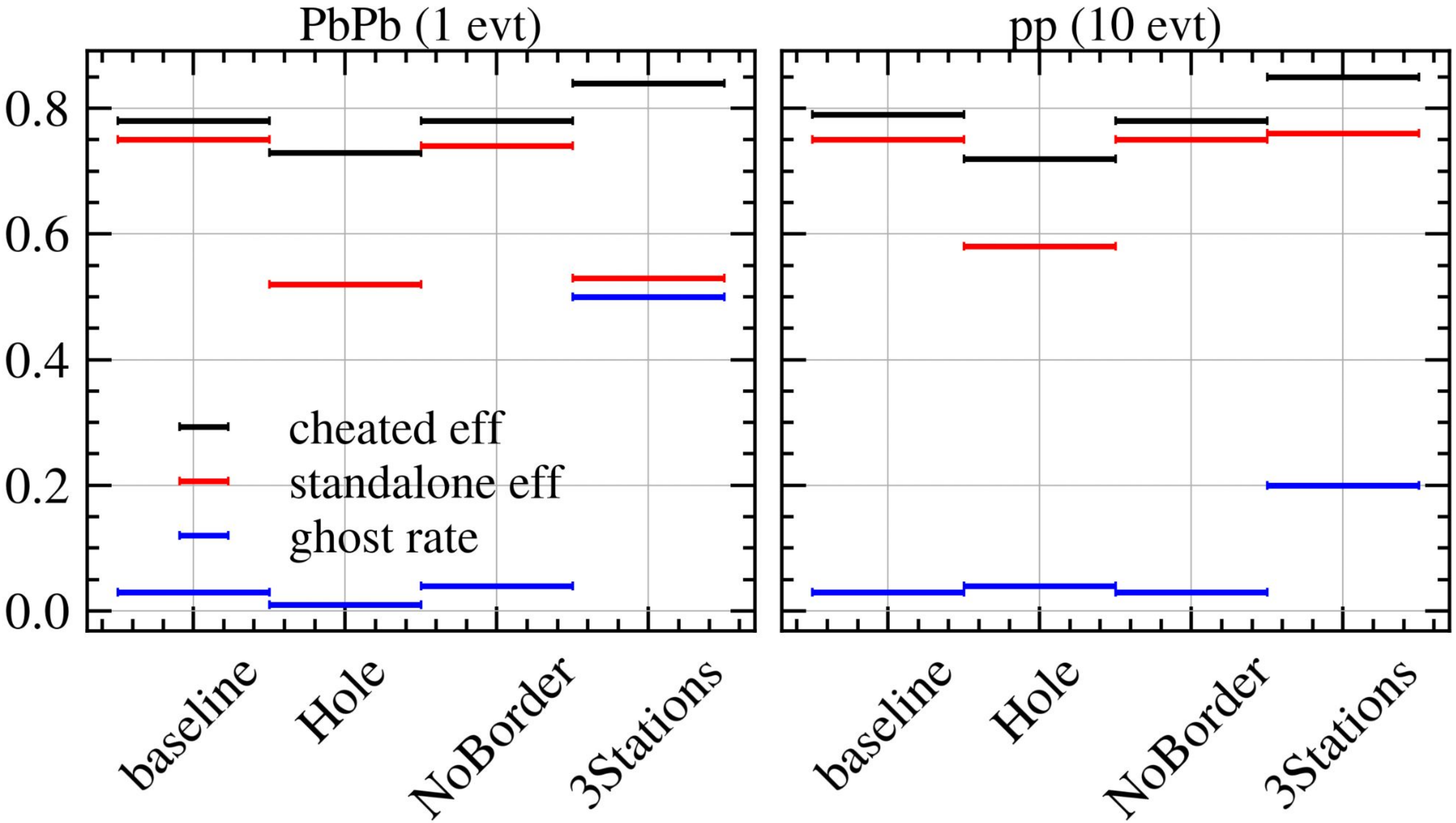
Preliminary results: Efficiencies and Ghost rates

standalone baseline

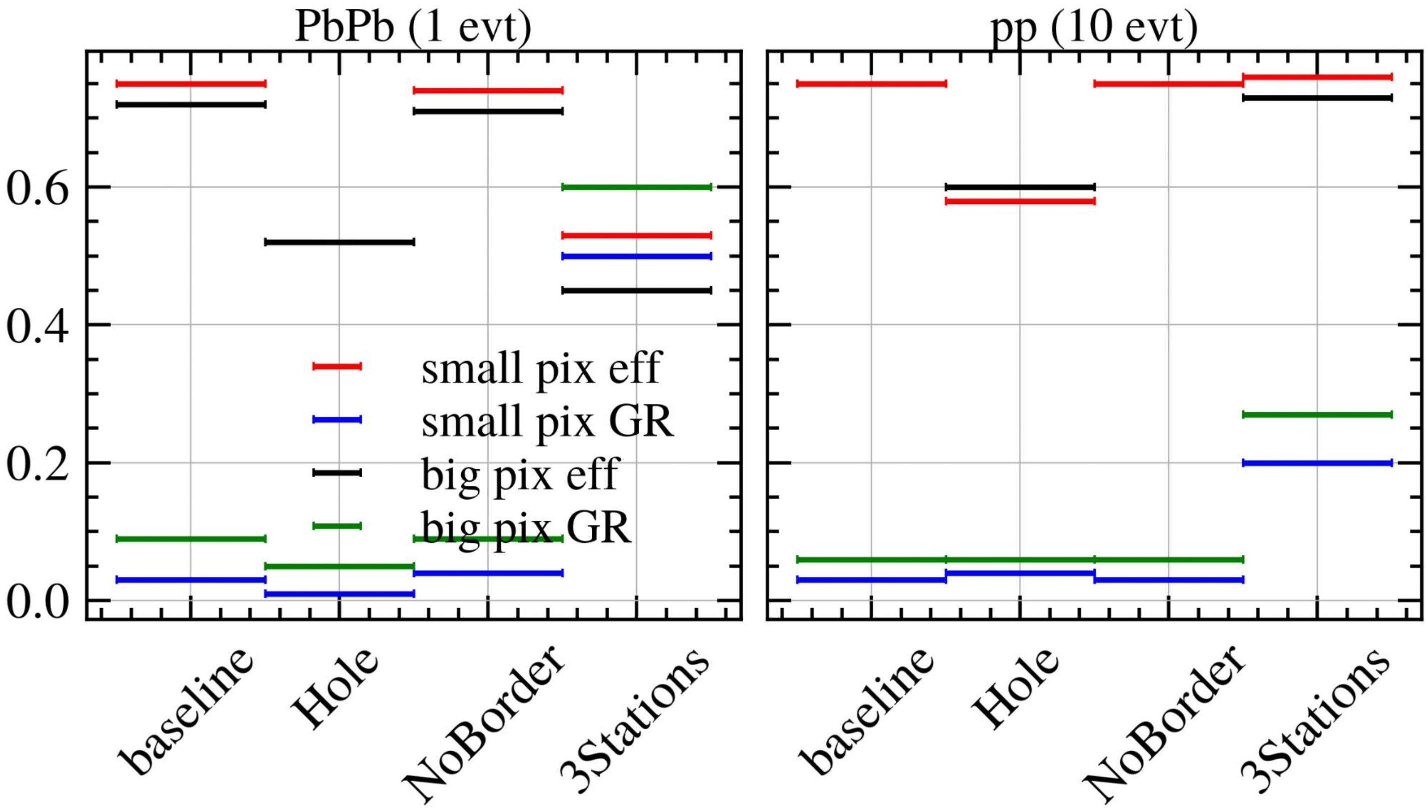
UT Tracks PrChecker

Category	# Recoed / # Recoble	Efficiency (%)	Clones (%)
HasVelo (all)	3317 / 18175	18.25 %	0 (0.00 %) [nTotMatch = 3317])
(!e) HasVelo (all)	3061 / 15846	19.32 %	0 (0.00 %) [nTotMatch = 3061])
HasVelo (all), eta>0	3317 / 11587	28.63 %	0 (0.00 %) [nTotMatch = 3317])
HasVelo (all), eta<0	0 / 6588	0.00 %	nan
HasVelo (all), eta[2,5]	3316 / 8490	39.06 %	0 (0.00 %) [nTotMatch = 3316])
HasVelo (all), eta[2,5], p > 5 GeV	2193 / 3713	59.06 %	0 (0.00 %) [nTotMatch = 2193])
HasUT (all)	4000 / 14931	26.79 %	0 (0.00 %) [nTotMatch = 4000])
(!e) HasUT (all)	3280 / 8092	40.53 %	0 (0.00 %) [nTotMatch = 3280])
HasUT (all), eta[2,5]	3996 / 12012	33.27 %	0 (0.00 %) [nTotMatch = 3996])
HasUT (all), eta[2,5], p > 5 GeV	2453 / 3253	75.41 %	0 (0.00 %) [nTotMatch = 2453])
Long (all)	2611 / 4628	56.42 %	0 (0.00 %) [nTotMatch = 2611])
Long eta[2,5]	2610 / 4216	61.91 %	0 (0.00 %) [nTotMatch = 2610])
Long eta[2,5], p>5GeV	1856 / 2643	70.22 %	0 (0.00 %) [nTotMatch = 1856])
LongUT (all)	2611 / 3940	66.27 %	0 (0.00 %) [nTotMatch = 2611])
LongUT eta[2,5]	2610 / 3870	67.44 %	0 (0.00 %) [nTotMatch = 2610])
LongUT eta[2,5], p>5GeV	1856 / 2329	79.69 %	0 (0.00 %) [nTotMatch = 1856])
(!e) Long (Pix-Pix)	1536 / 2381	64.51 %	0 (0.00 %) [nTotMatch = 1536])
(!e) Long (Pix-Pix), eta[2,5]	1535 / 2125	72.24 %	0 (0.00 %) [nTotMatch = 1535])
(!e) Long (Pix-Pix), eta[2,5], p>5GeV	1330 / 1796	74.05 %	0 (0.00 %) [nTotMatch = 1330])
(!e) LongUT (Pix-Pix)	1536 / 1834	83.75 %	0 (0.00 %) [nTotMatch = 1536])
(!e) LongUT (Pix-Pix), eta[2,5]	1535 / 1828	83.97 %	0 (0.00 %) [nTotMatch = 1535])
(!e) LongUT (Pix-Pix), eta[2,5], p>5GeV	1330 / 1513	87.90 %	0 (0.00 %) [nTotMatch = 1330])
# Events	# Recoed Tracks	# Fake Tracks	Ghost Rate
10	4145	145	3.50 %

HasUT (all) ($2<\eta<5$, p>5 GeV) & Ghost rates

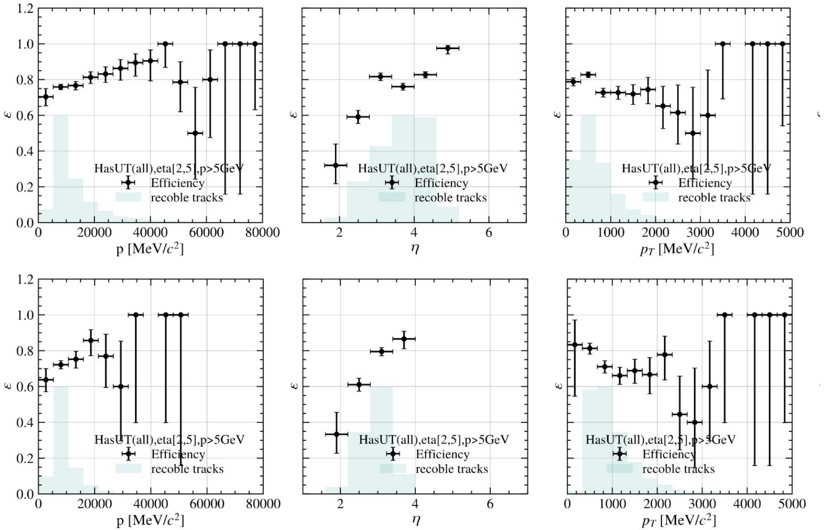


Pixel size comparison



- Small Pixel: 30μmx30μm
- Big Pixel: 55μmx55μm

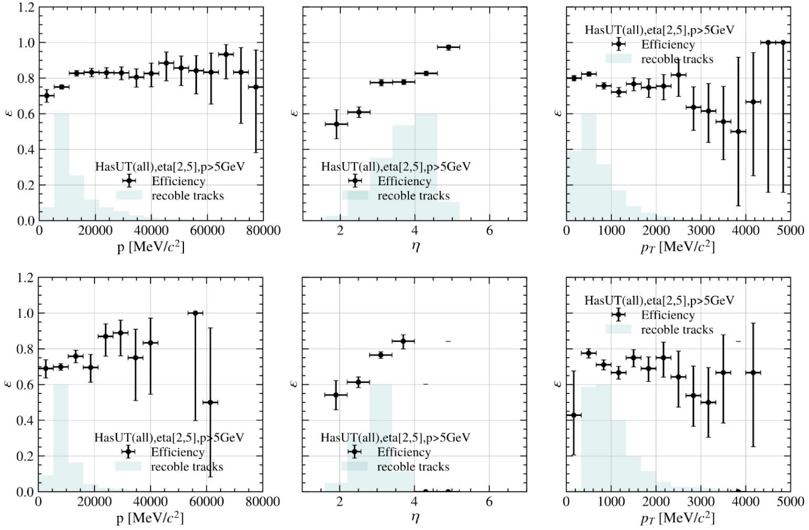
Efficiencies PbPb : cheated algorithm



Baseline

Hole

Efficiencies pp : cheated algorithm



Baseline

Hole

Summary

- ➢ The density of hits in the peripheral region of the UT is very low. Remove this region hardly affects the results.
- ➢ Remove the central region of the UT (higher density of hits) drops the ghost rate but this also results in a drop of the efficiency.
- ➢ The 3 Station geometry is the worst-case scenario we have in terms of efficiency and ghost rate (specially for PbPb) using the actual standalone algorithm.
- ➢ The pixel size matter (specially for PbPb). Reduce the size of the pixels result in a grow of the efficiency and a drop of the ghost rate.

TODO list

- Include more statistics to improve our results.
- Compute the results testing new pixel size (55μmx150μm).
- Optimize and improve the UT standalone algorithm
- Develop other tracking algorithms: VeloUT and DownStream algorithms.

Thanks for your attention!

BACKUP

HasUT (all) ($2<\eta<5$, $p>5$ GeV) & Ghost rates

PbPb (1evt)	Baseline	Hole	No Border	3 Stations
Cheated	Eff: 78% G.R.: 0%	Eff: 73% G.R.: 0%	Eff: 78% G.R.: 0%	Eff: 84% G.R.: 0%
Standalone	Eff: 75% G.R.: 3%	Eff: 52% G.R.: 1%	Eff: 74% G.R.: 4%	Eff: 53% G.R.: 50%

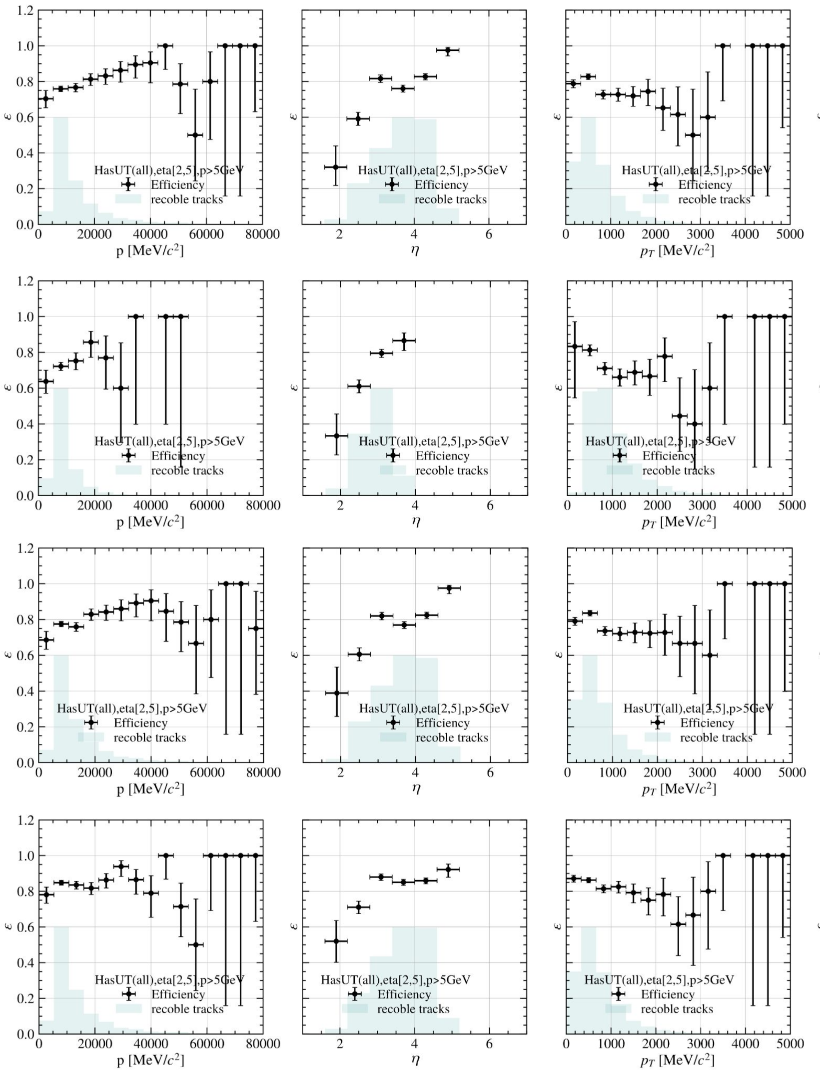
pp (10 evts)	Baseline	Hole	No Border	3 Stations
Cheated	Eff: 79% G.R.: 0%	Eff: 72% G.R.: 0%	Eff: 78% G.R.: 0%	Eff: 85% G.R.: 0%
Standalone	Eff: 75% G.R.: 3%	Eff: 58% G.R.: 4%	Eff: 75% G.R.: 3%	Eff: 76% G.R.: 20%

Pixel size comparison

PbPb (1evt)	Baseline	Hole	No Border	3 Stations
Standalone: 30μmx30μm pix	Eff: 75% G.R.: 3%	Eff: 52% G.R.: 1%	Eff: 74% G.R.: 4%	Eff: 53% G.R.: 50%
Standalone 55μmx55μm pix	Eff: 72% G.R.: 9%	Eff: 52% G.R.: 5%	Eff: 71% G.R.: 9%	Eff: 45% G.R.: 60%

pp (10 evts)	Baseline	Hole	No Border	3 Stations
Standalone: 30μmx30μm pix	Eff: 75% G.R.: 3%	Eff: 58% G.R.: 4%	Eff: 75% G.R.: 3%	Eff: 76% G.R.: 20%
Standalone 55μmx55μm pix	Eff: 75% G.R.: 6%	Eff: 60% G.R.: 6%	Eff: 75% G.R.: 6%	Eff: 73% G.R.: 27%

Efficiencies PbPb : cheated algorithm



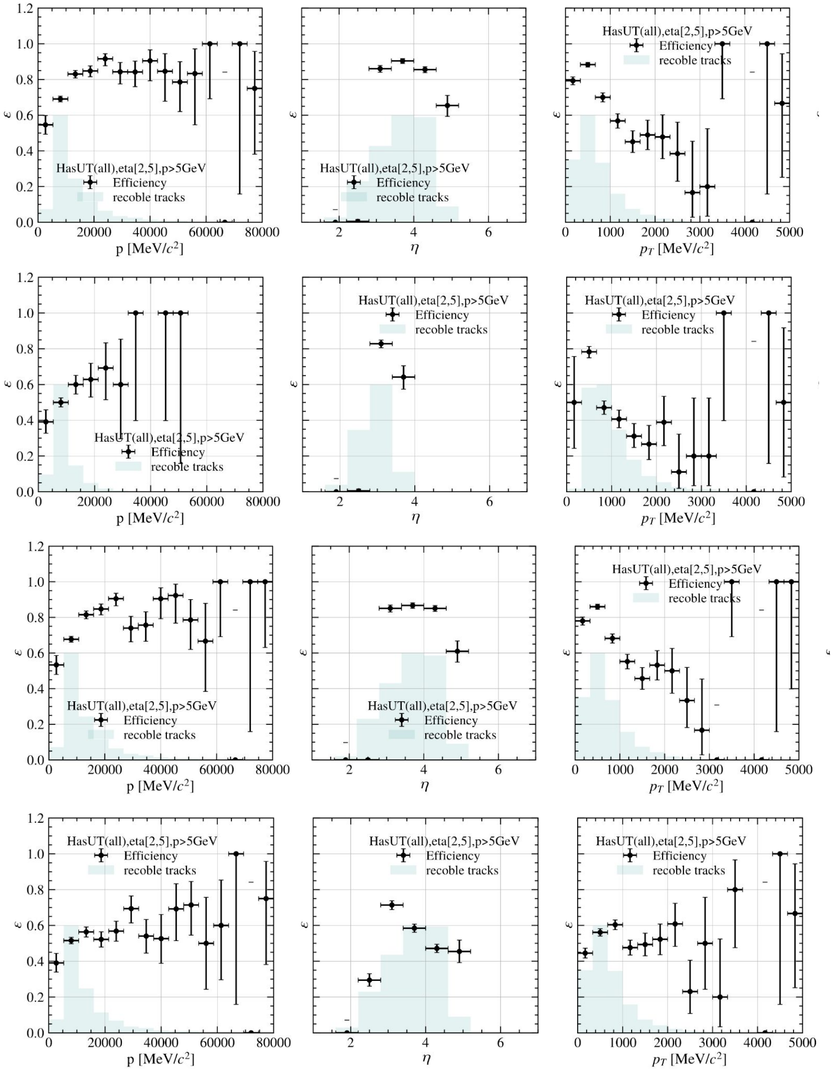
Baseline

Hole

No Border

3 Stations

Efficiencies PbPb : standalone algorithm



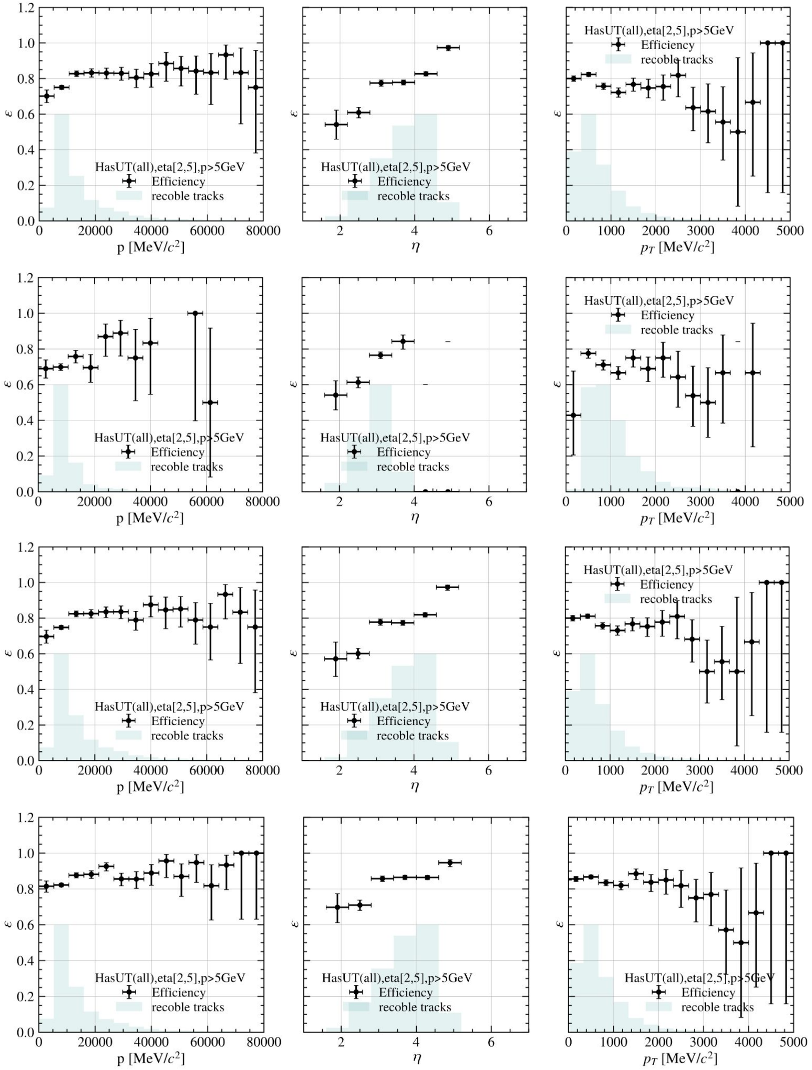
Baseline

Hole

No Border

3 Stations

Efficiencies pp : cheated algorithm



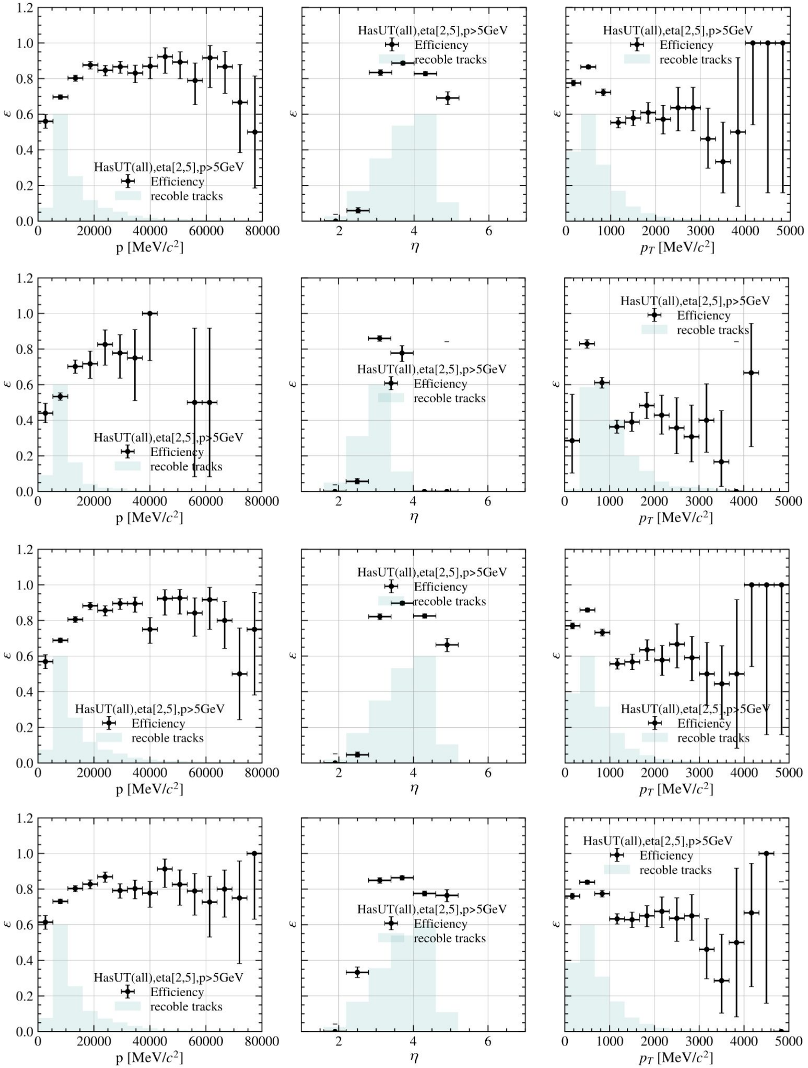
Baseline

Hole

No Border

3 Stations

Efficiencies pp : standalone algorithm



Baseline

Hole

No Border

3 Stations