Tracking Validation

outline

- ★ Introduction
- ★ Efficiency & Purity plots
- ★ Track Quality plots
- ★ Pattern Recognition performances

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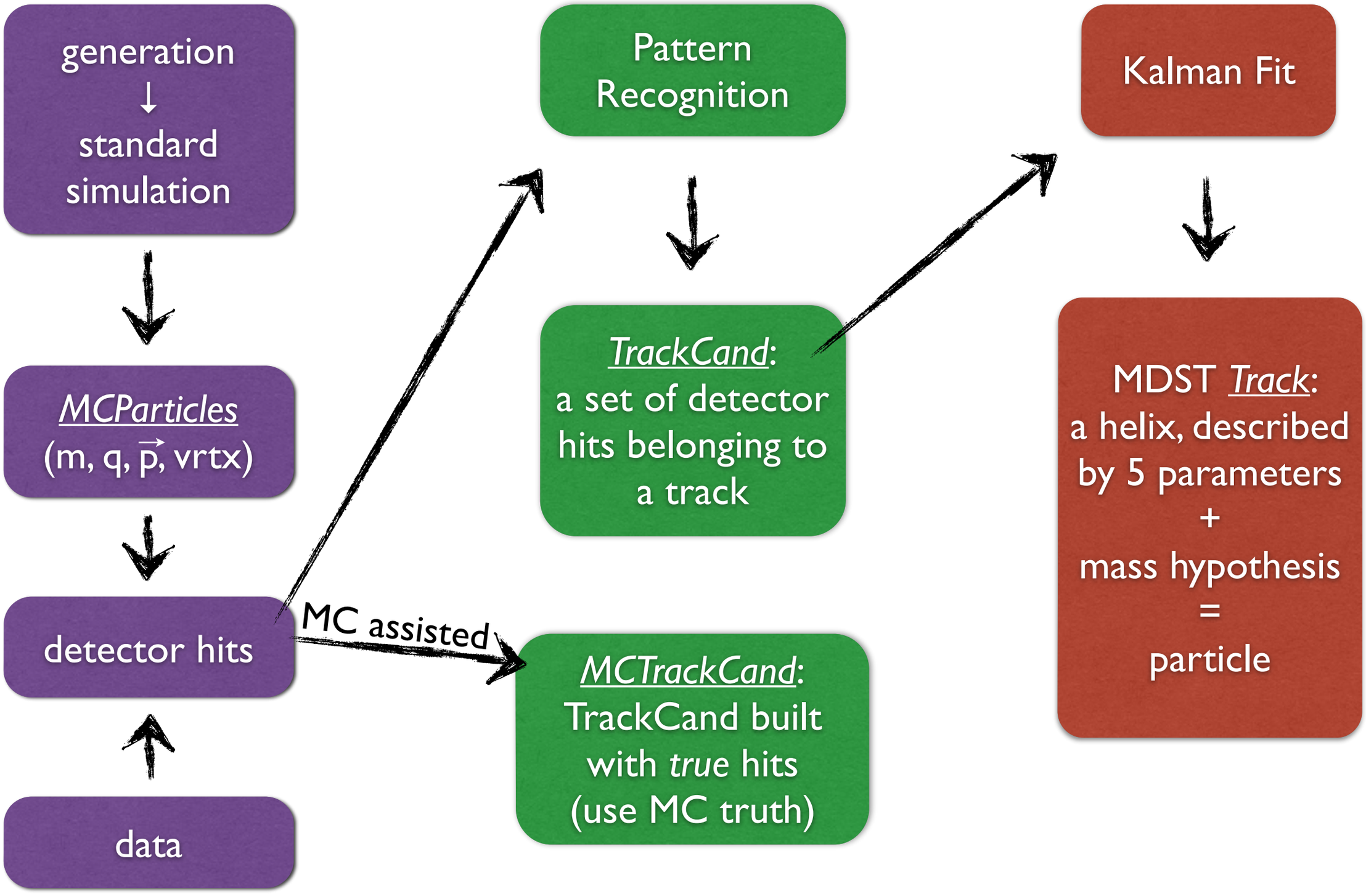
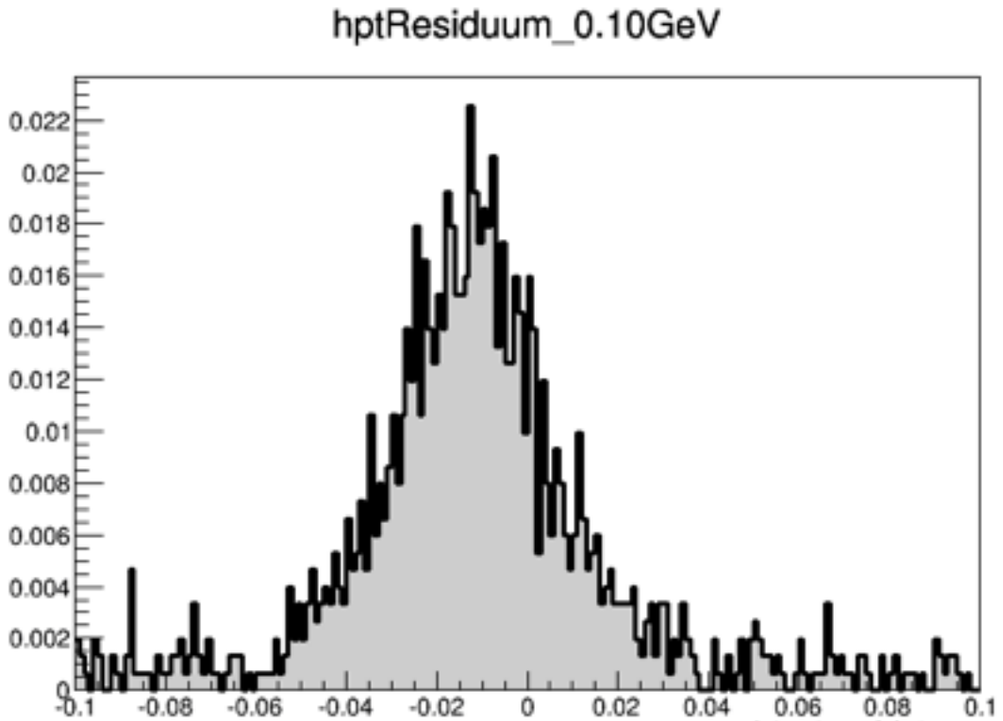
Tracking Scheme



Tracking Validation

- Main Goal of a validation *during* software development:
  - systematic control of the developed code
  - check that performances improve and no (new) bugs are
  - check how far we are from specifications
- Can take advantage of MC Truth Informations (compare measured VS generated quantities) but keep in mind that a tracking validation on data is the goal when data taking starts
- In any case: we need *reference plot* to decide if what we see is expected or not, good enough, good but not enough, …
- caveats:
  - Belle CDC pattern recognition (Trasan) is used
  - Merger of VXD TrackCand + CDC TrackCand uses MC truth information
  - no extrapolation from CDC to VXD and vice-versa

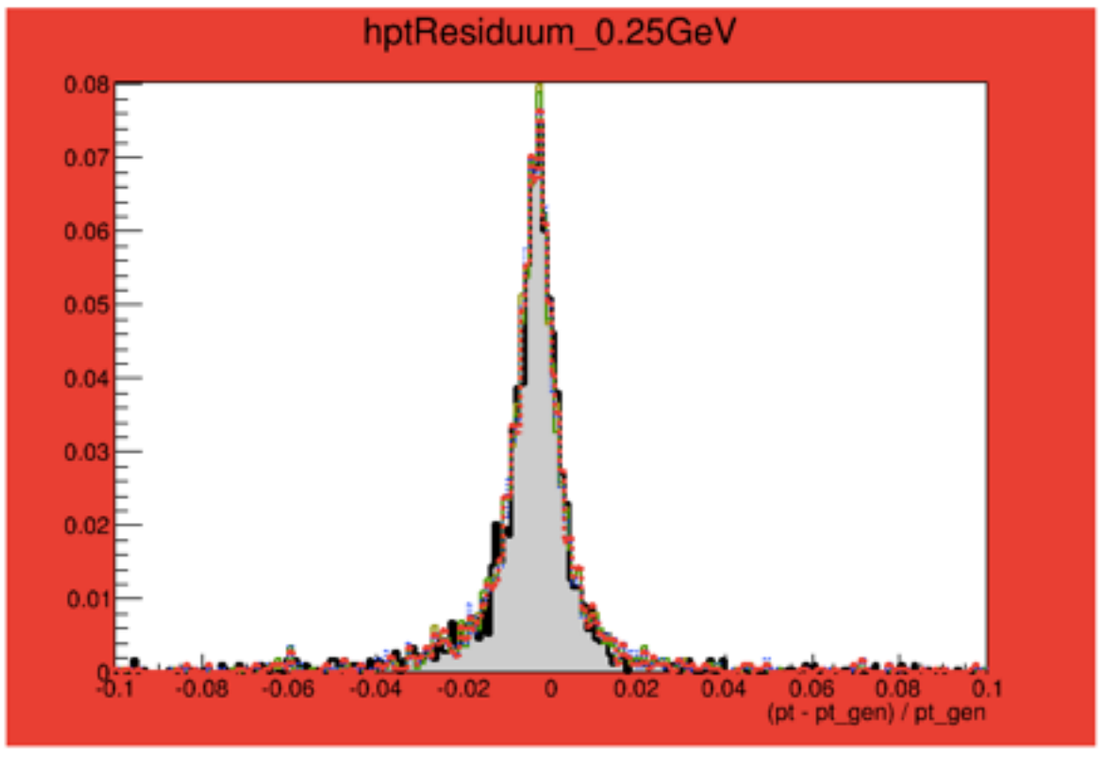
Current Tracking Validation



No current plot!

No description

No check



No description

No check

https://belle2.cc.kek.jp/internal/validation/index.html

- data consist in muons generated by Particle Gun at different p_t
  - the Y(4S) momentum and angular distribution is not correctly reproduced
- present plots:
  - d0 and transverse momentum *resolutions* in bins of p_t
  - *residuals* of p_t, vertex position in bins of p_t
  - *efficiency* as a function of cosθ in bins of p_t

Efficiency & Purity

Integrated Efficiency & Purity

	tracking(*)	VXD only	CDC only	VXD+CDC
	purity (%)	95.72±0.08	77.1±0.1	-
ε =	**efficiency (%)**	68.4±0.2	75.3±0.1	80.1±0.1
ε' =	**efficiency' (%)**	77.8±0.1	91.1±0.1	89.6±0.1

(*) numbers and plots shown are based on 8k Y(4S) events

purity = probability to find an MCParticle associated to a Track, given a Track

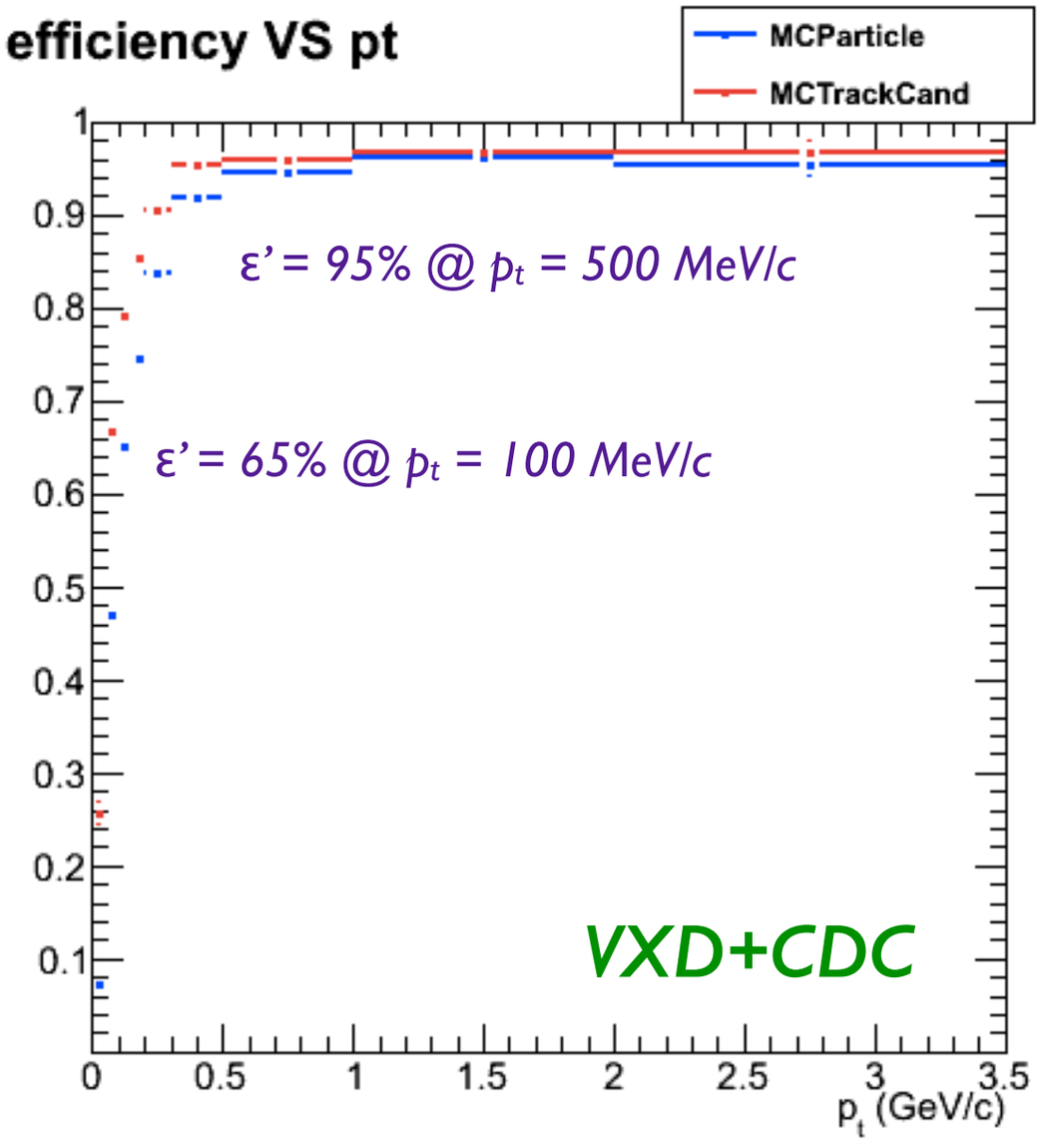
$$\varepsilon = \frac{\#\ \text{MCParticles with at least one associated Track}}{\#\ \text{MCParticles}}$$

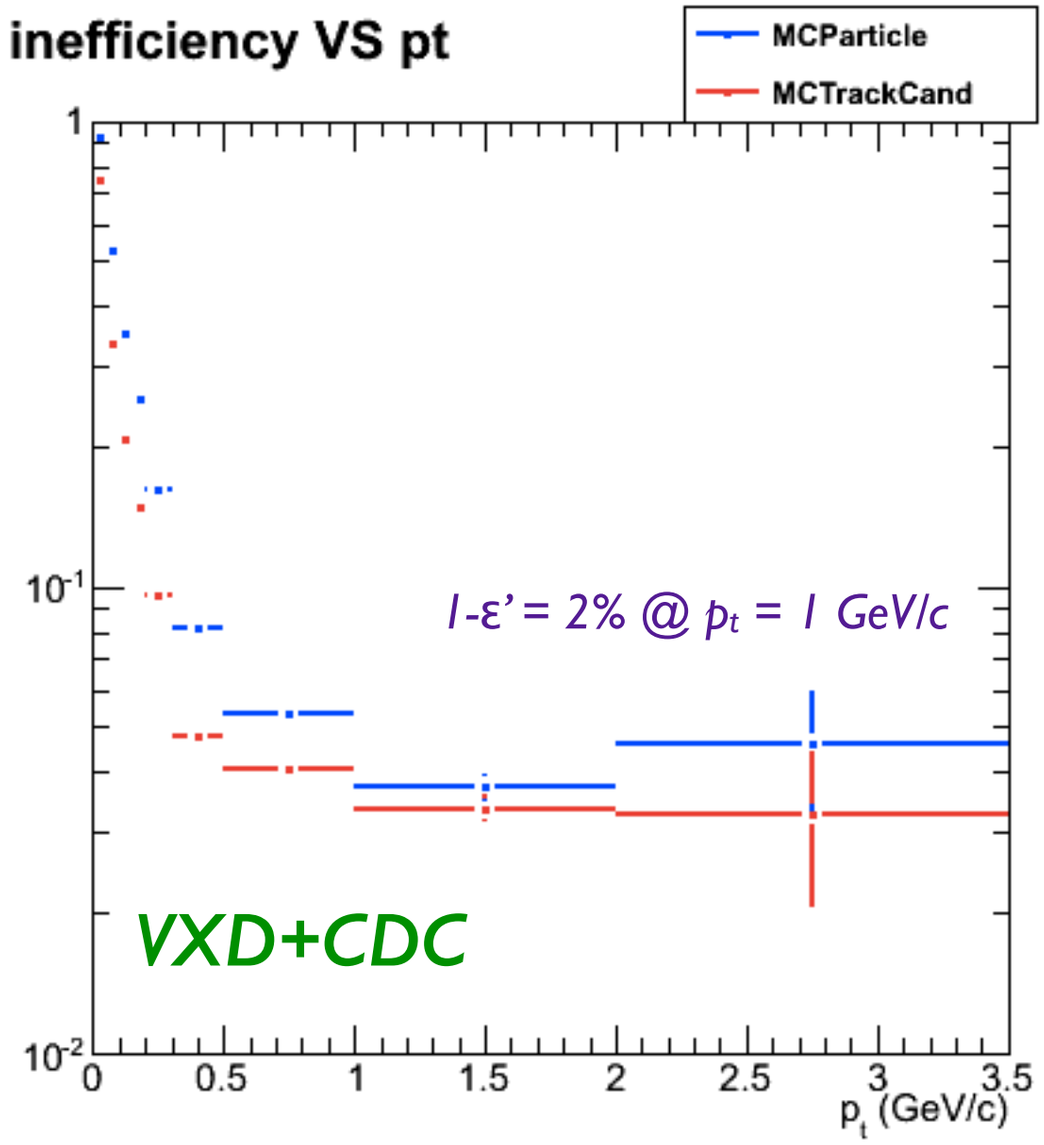
physical efficiency

$$\varepsilon' = \frac{\#\ \text{MCTrackCands with at least one associated Track}}{\#\ \text{MCTrackCands}}$$

geometrical acceptance and detector efficiency are factored out

Efficiency VS Transverse Momentum

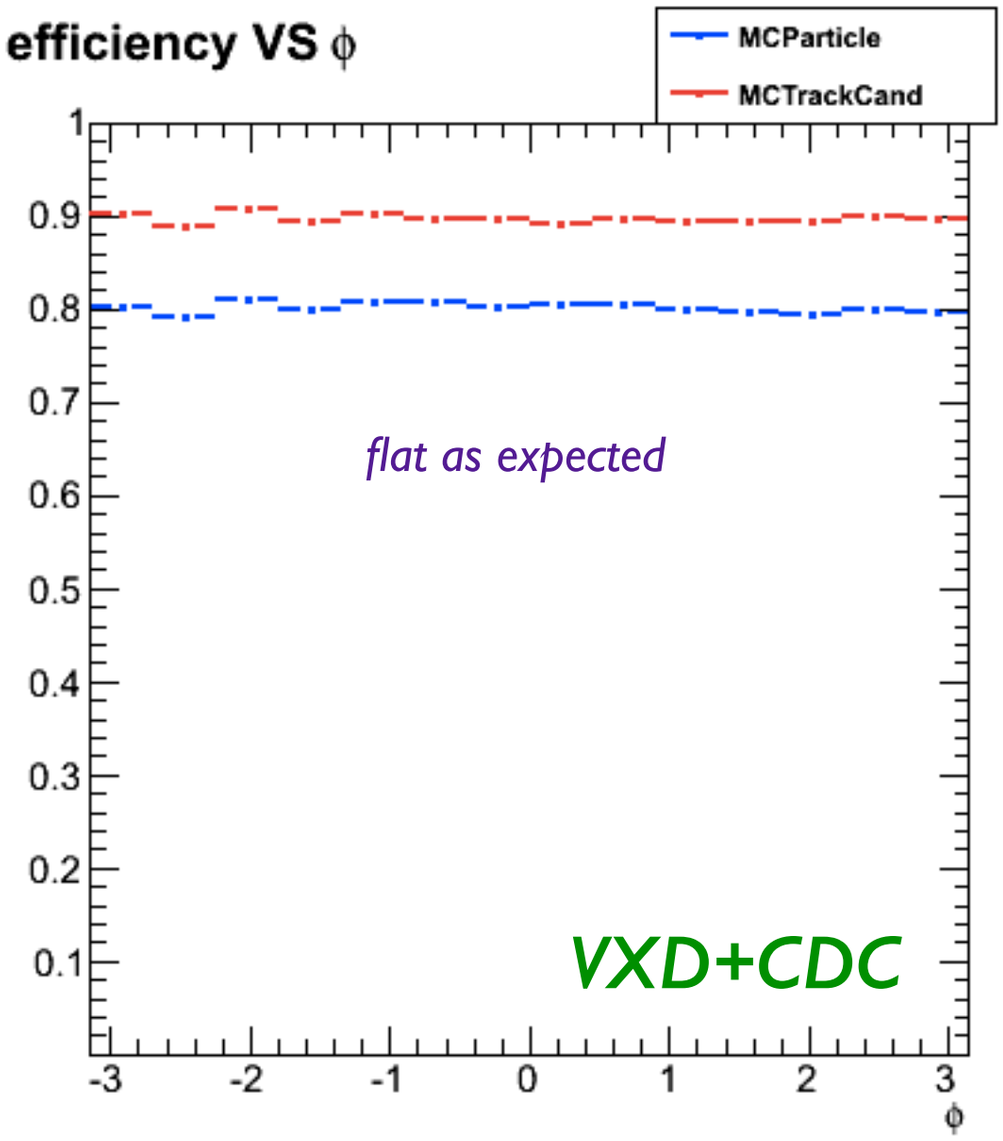


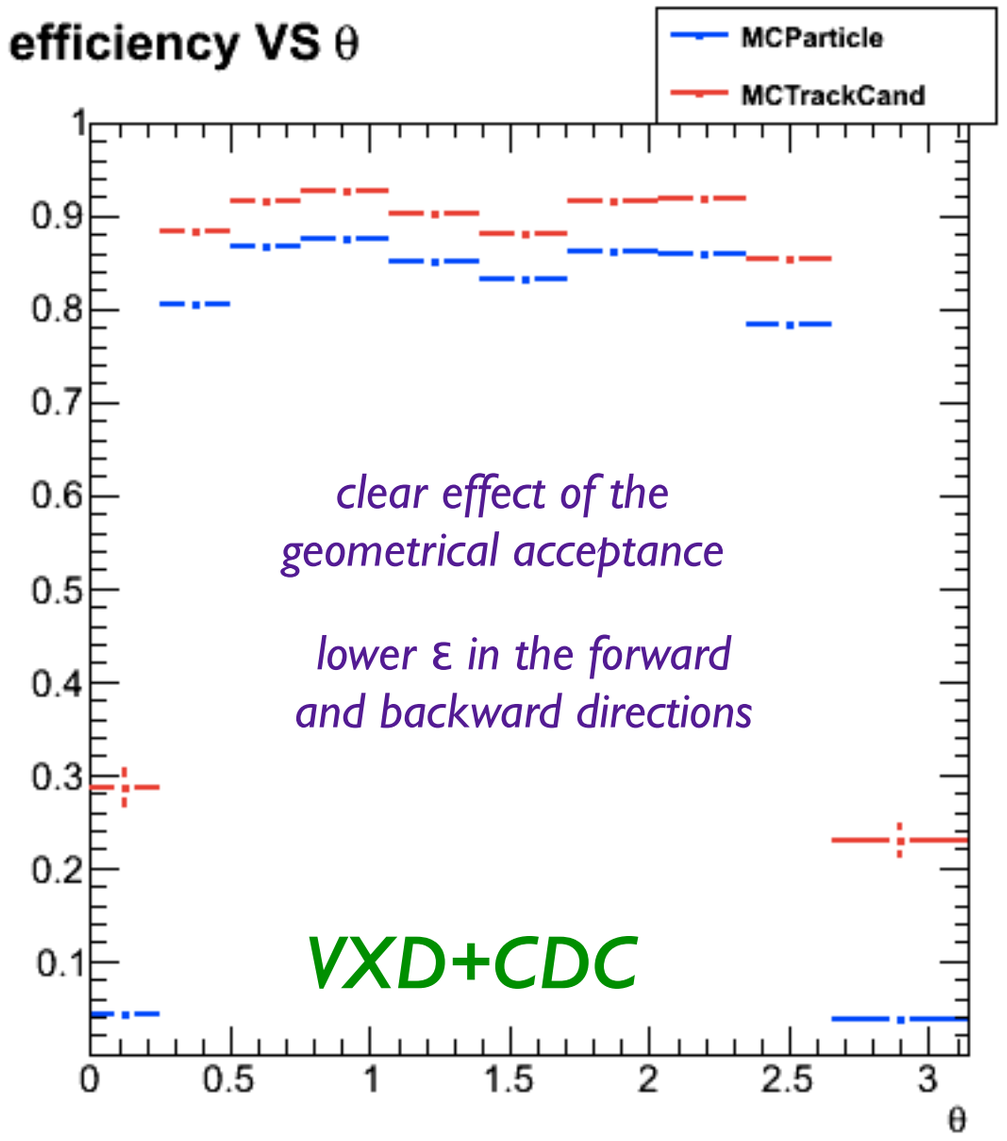


legend:

- ε, physical efficiency
- ε', geometrical acceptance and detector efficiency factored out

Efficiency VS Polar and Azimuthal Angles



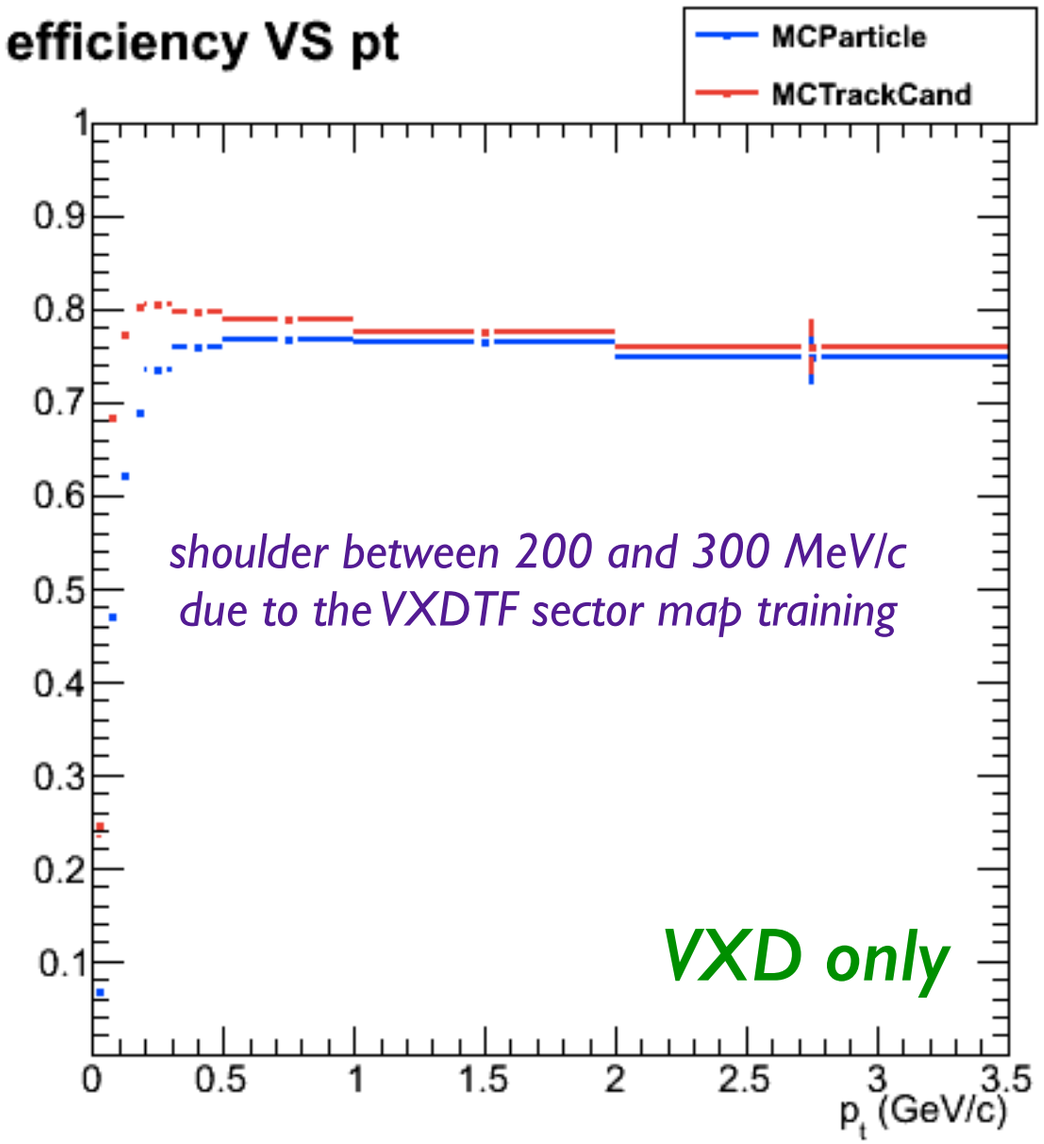


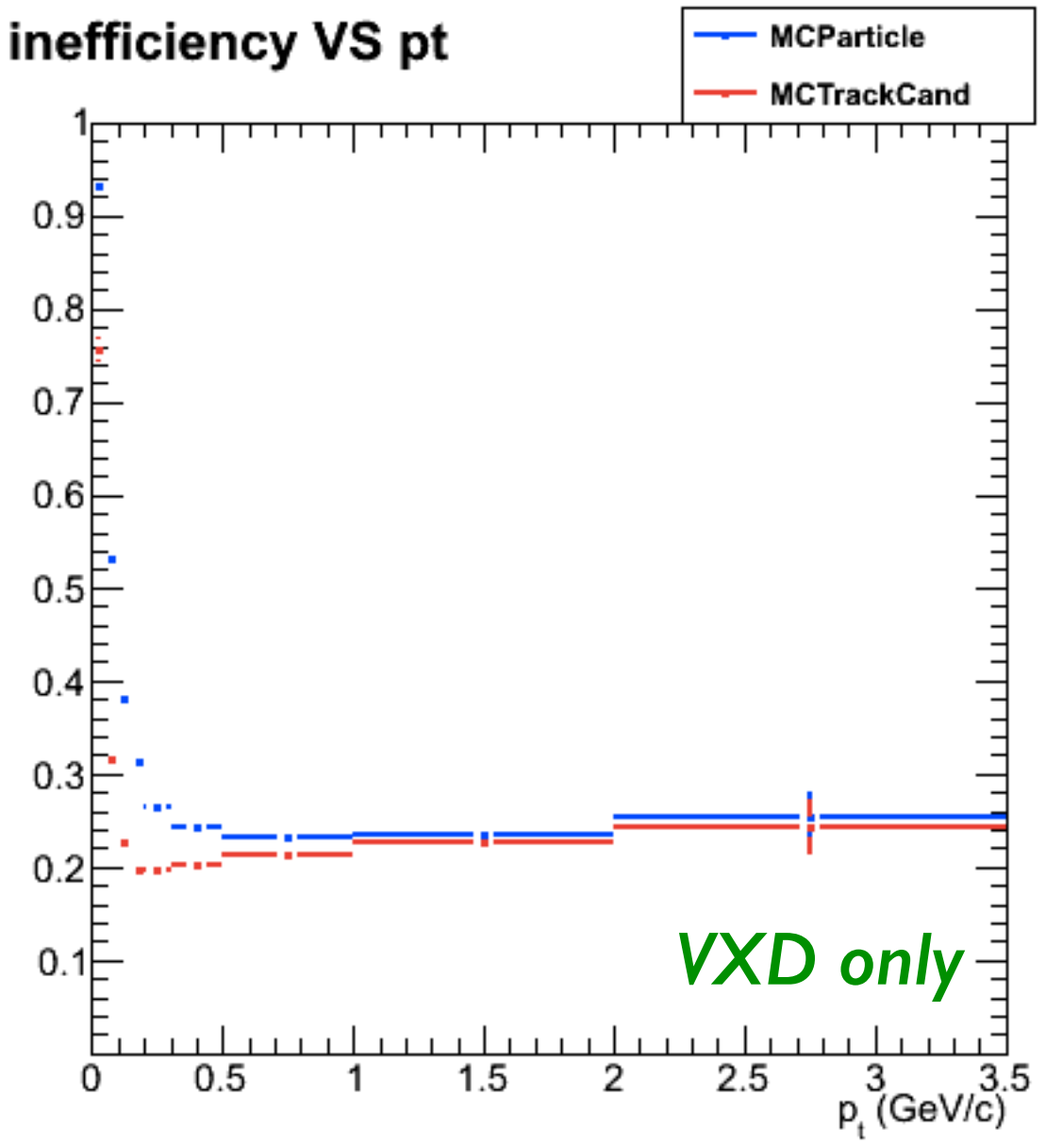
forward backward

legend:

- ε, physical efficiency
- ε', geometrical acceptance and detector efficiency factored out

Efficiency VS transverse momentum





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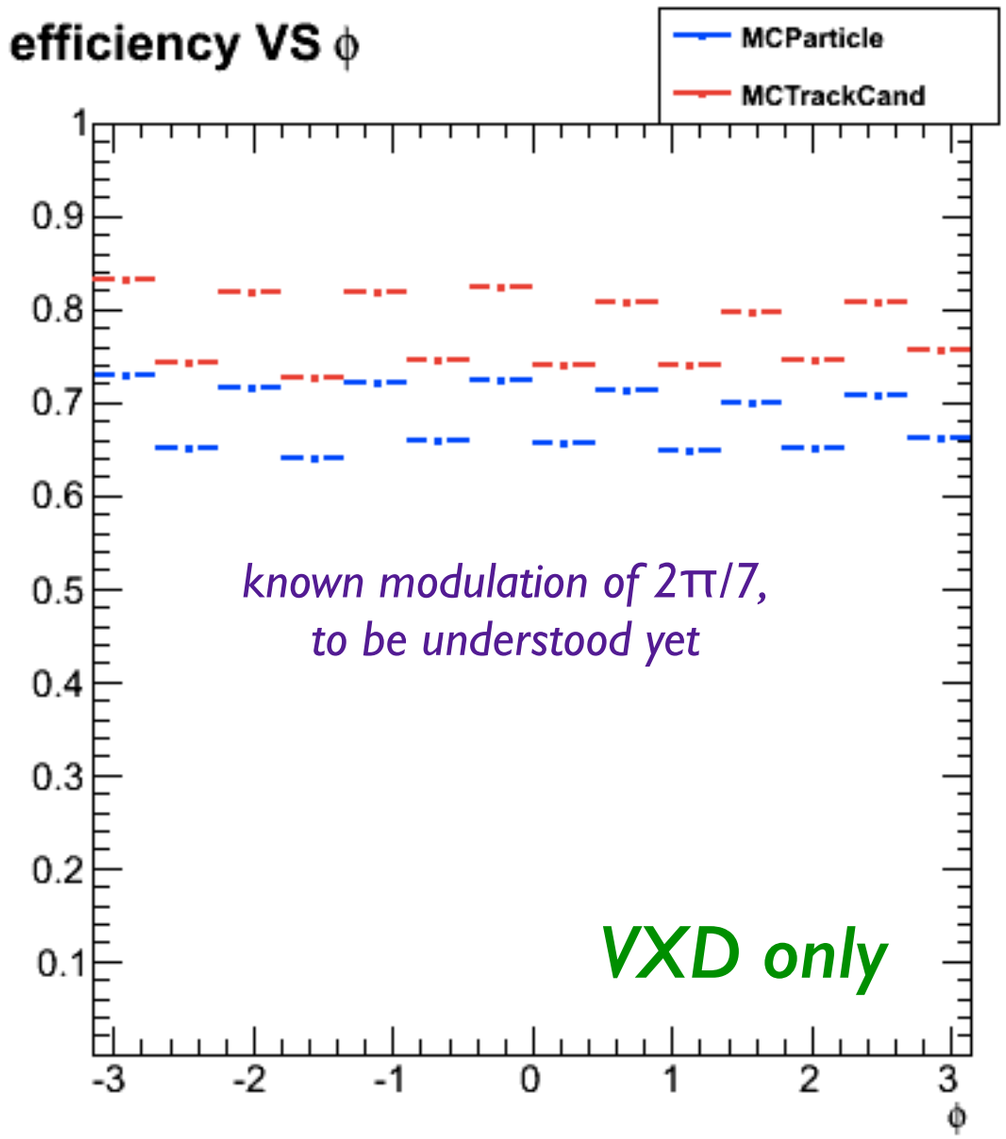
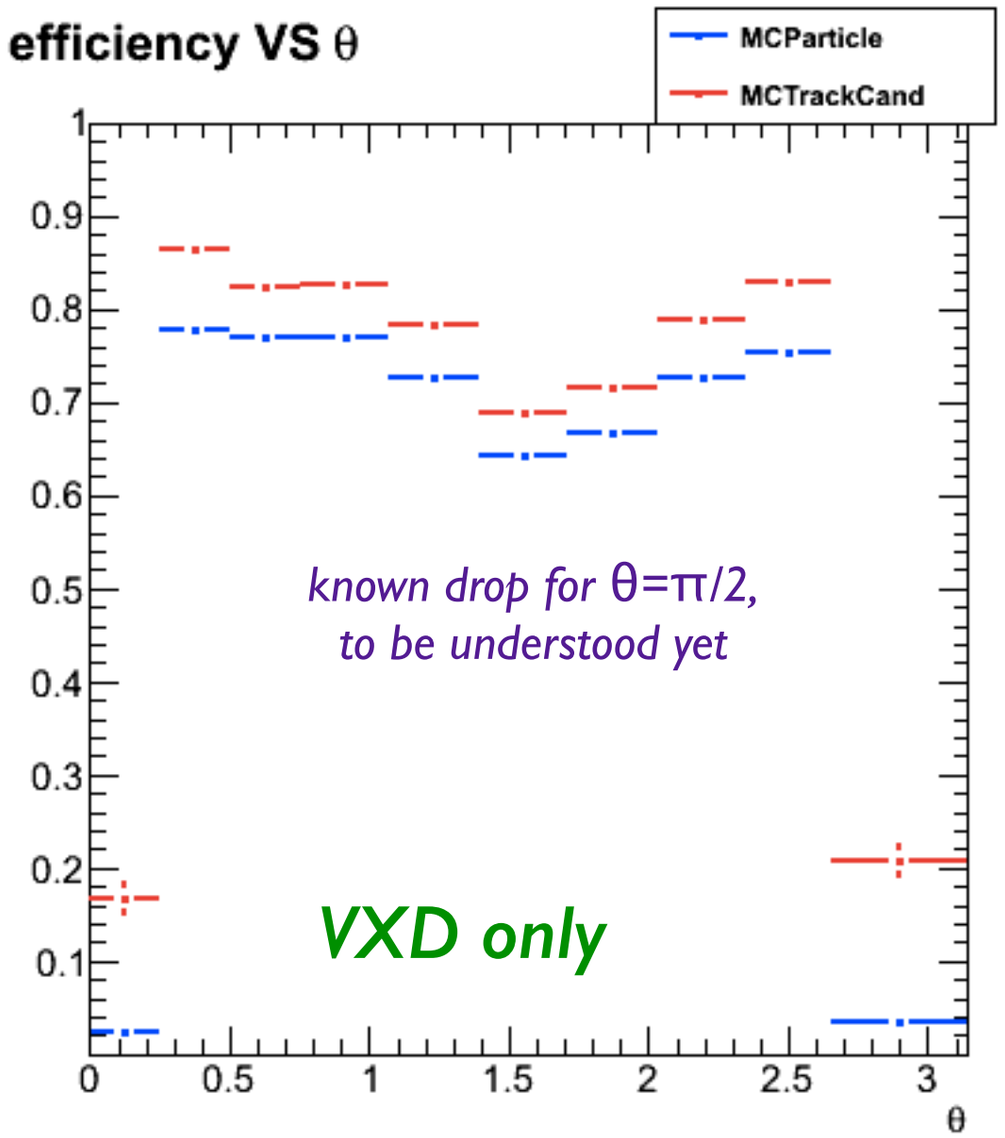
Efficiency VS polar and azimuthal angles





legend:

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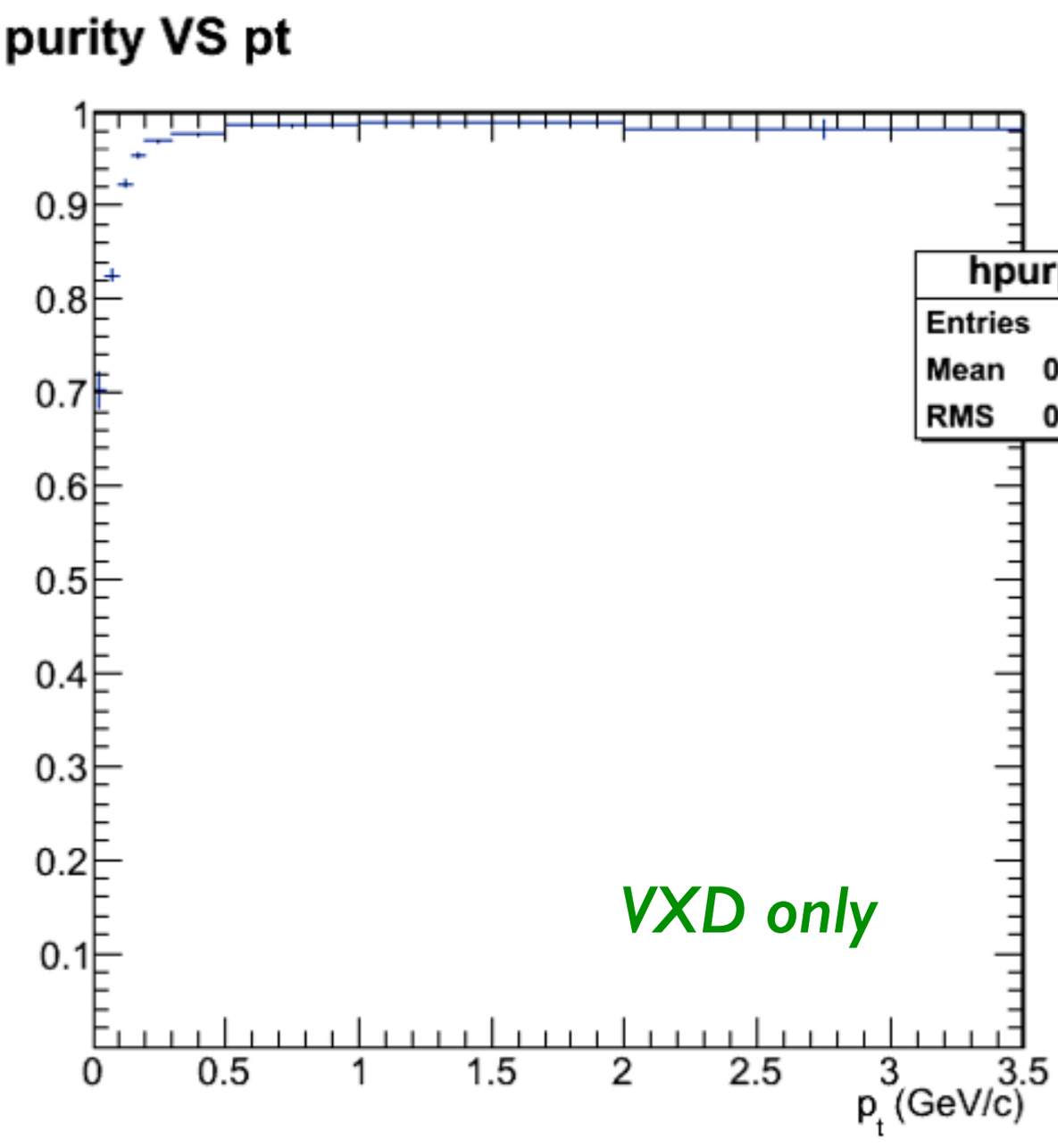
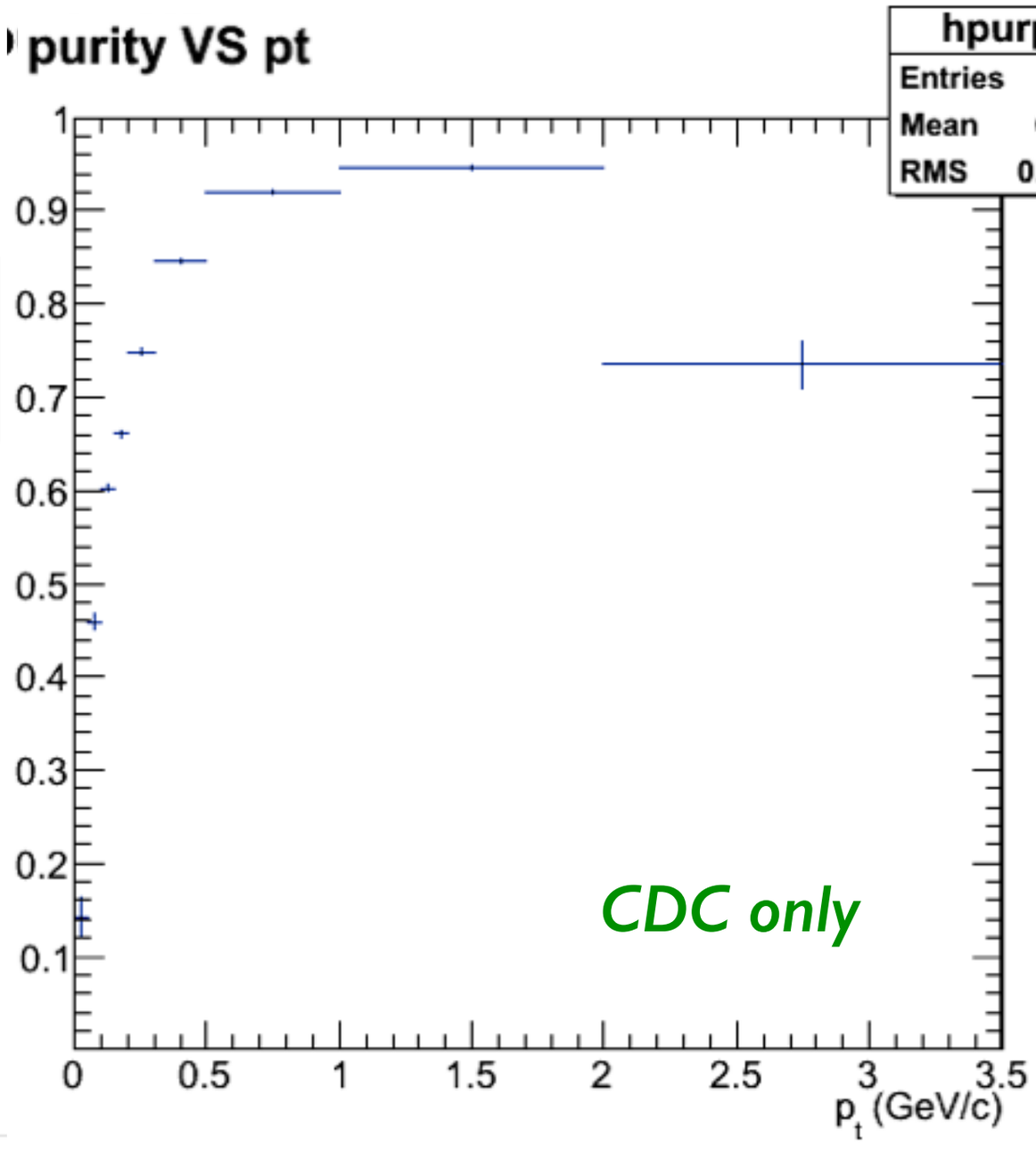
- ε', geometrical acceptance and detector efficiency factored out

forward

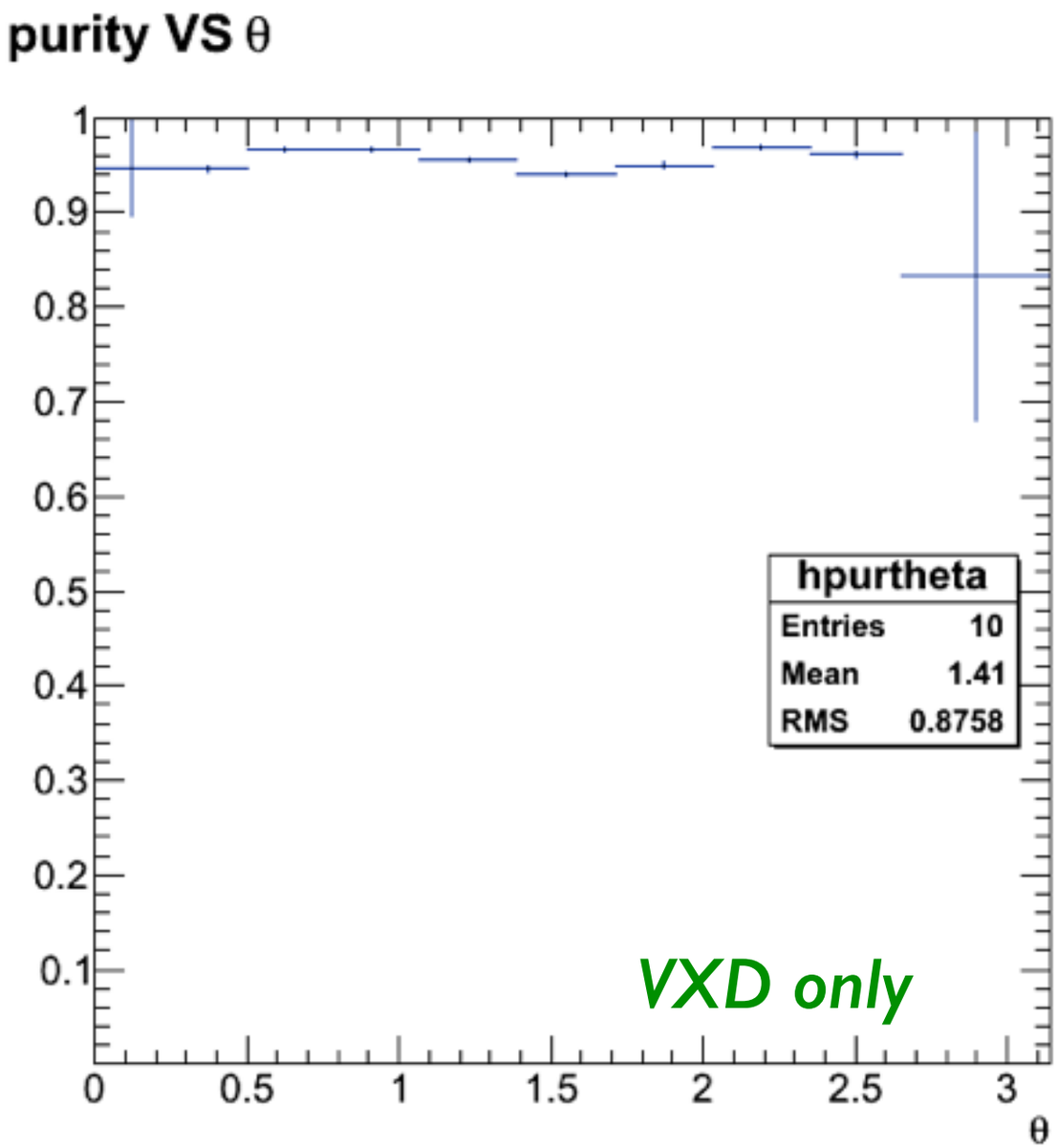
backward

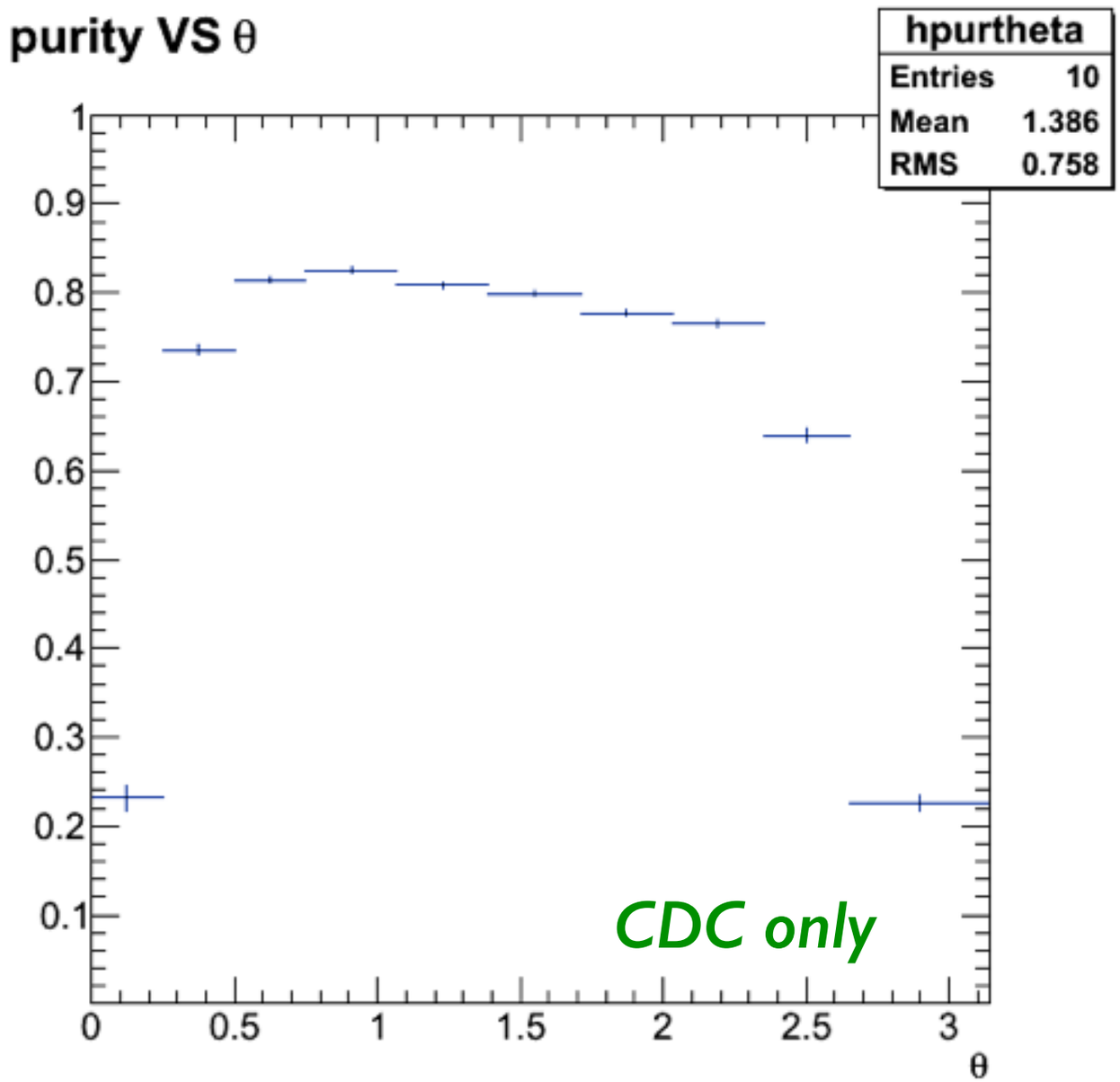
Purity VS transverse momentum





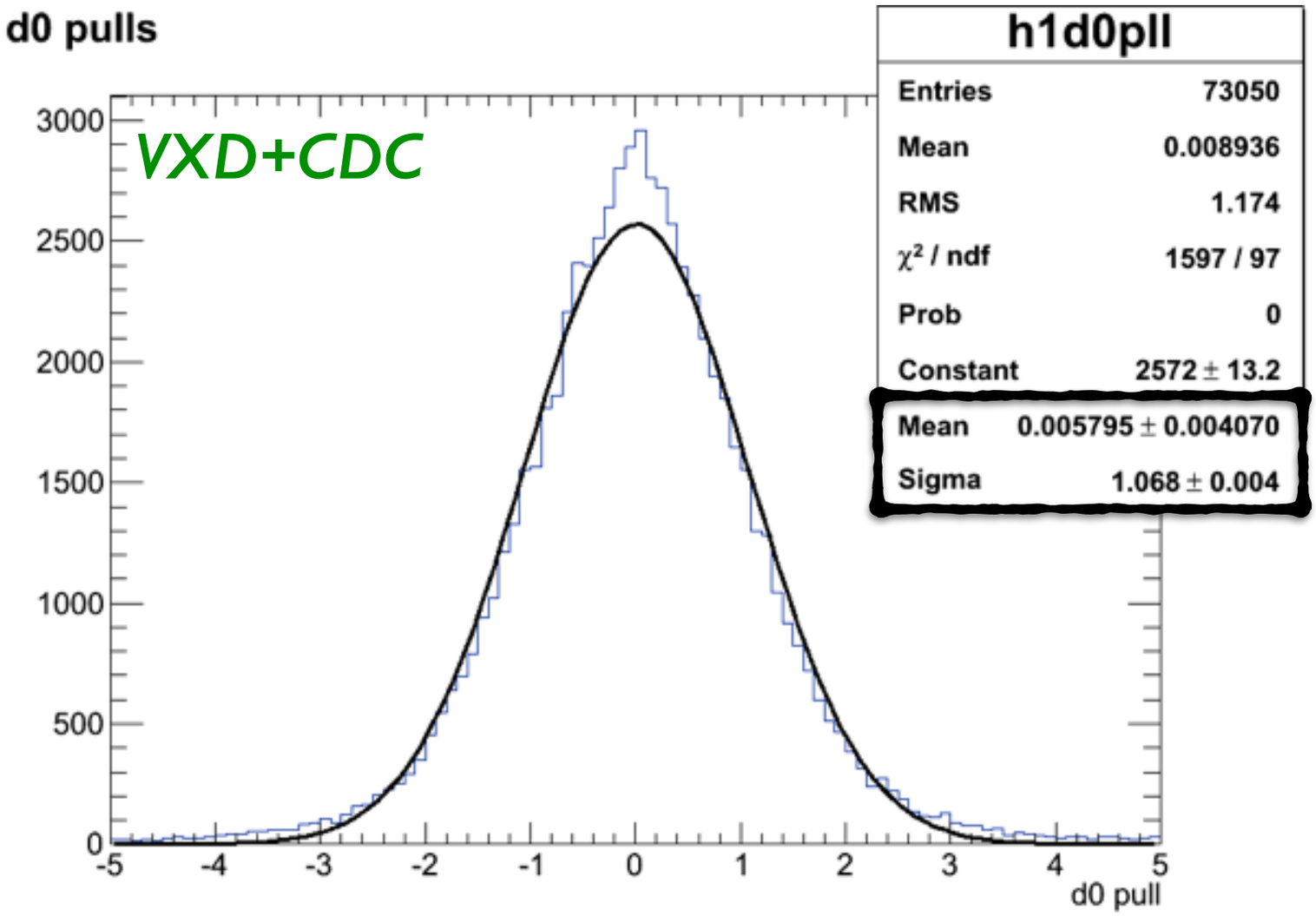
Purity VS polar angle

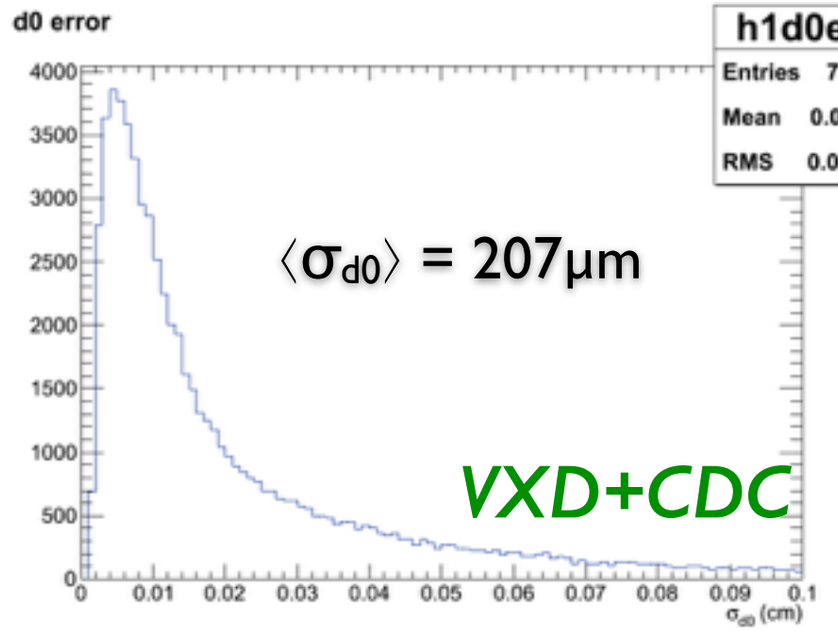




Track Quality

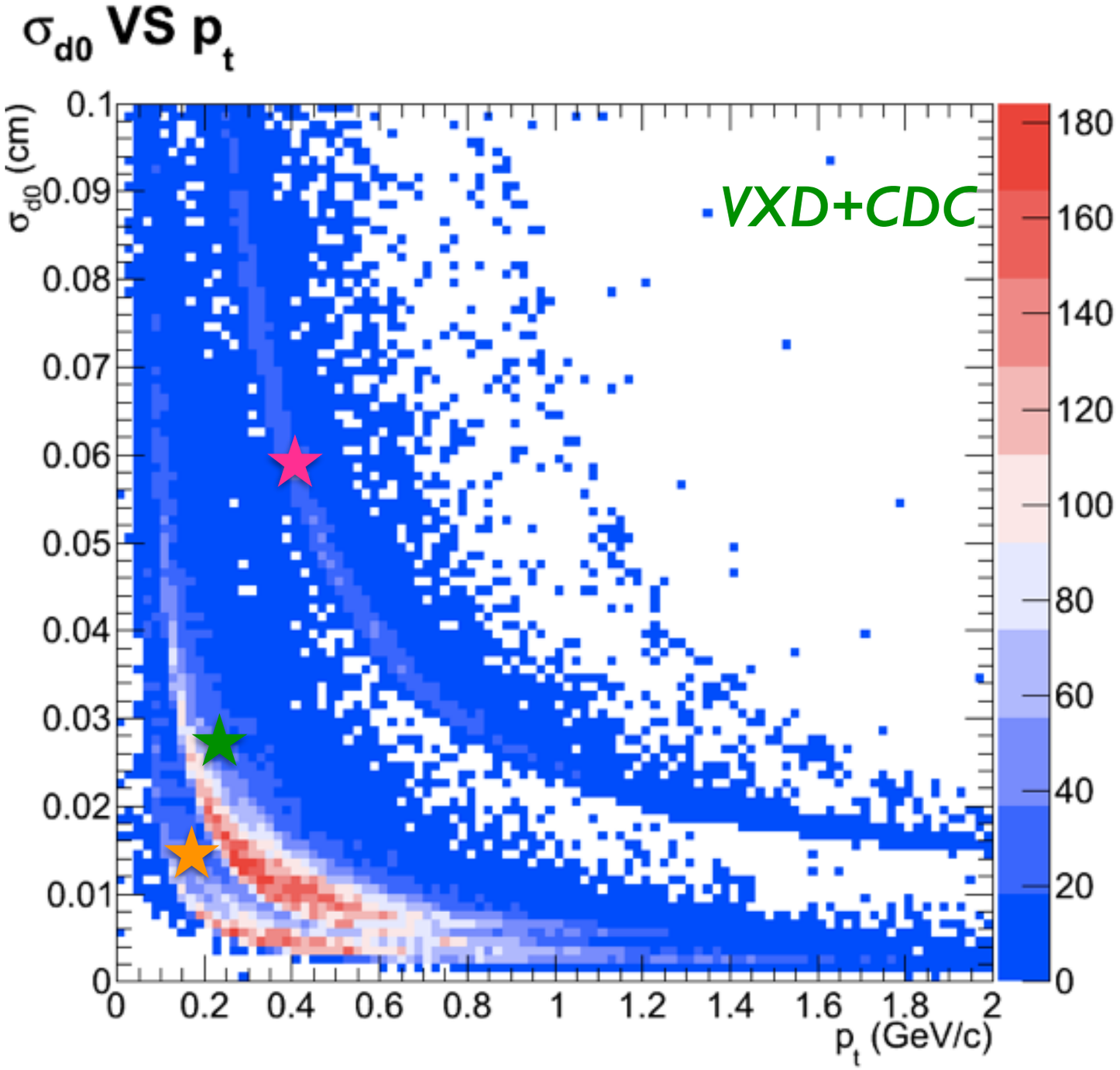
Transverse Impact Parameter





➡ almost gaussian pulls distribution

σ_{d0} VS transverse momentum



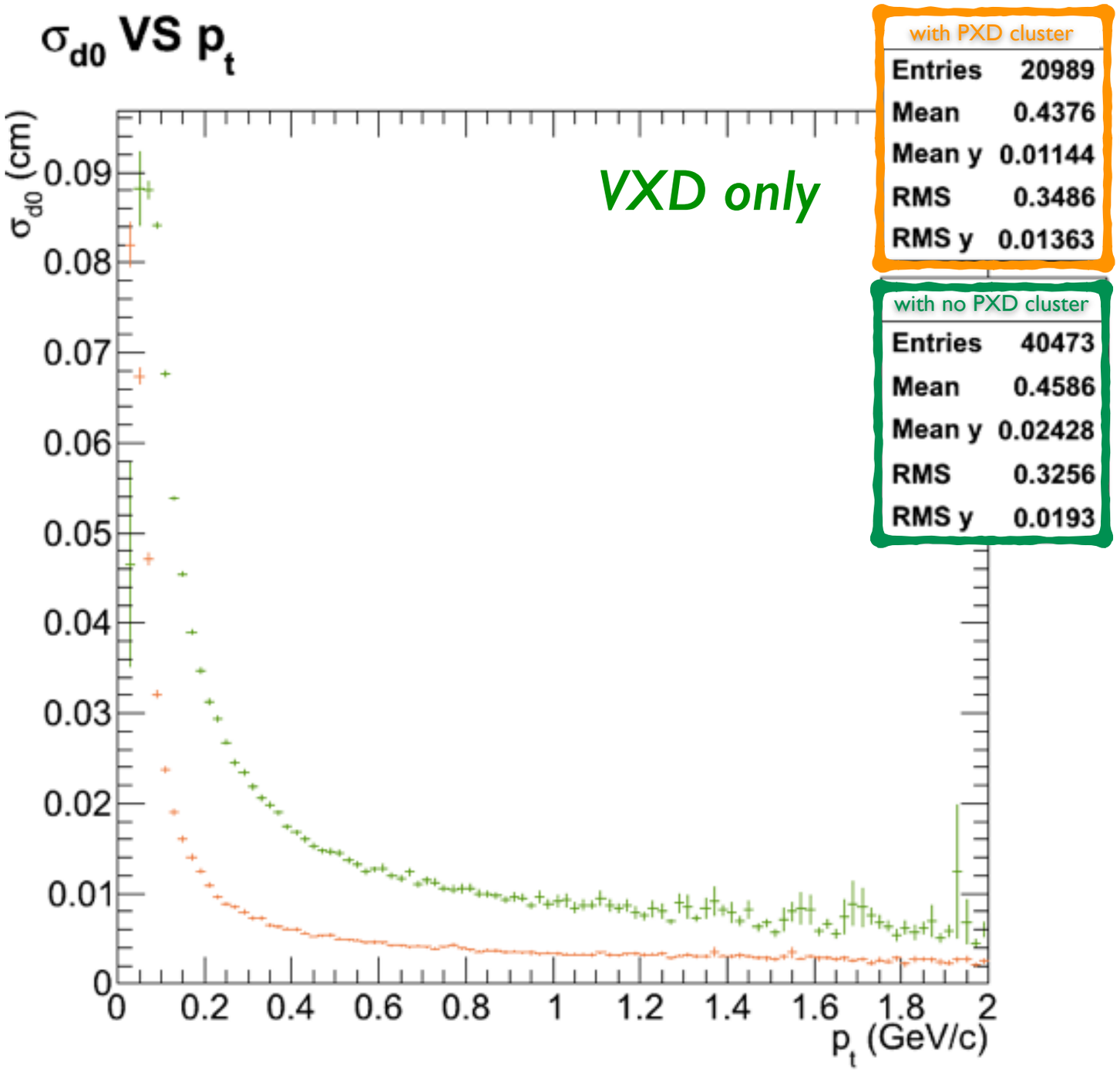
➡ 3 families of tracks:

★ CDC only tracks

★ tracks with no PXD clusters attached

★ tracks with PXD clusters attached

Classification of VXD Tracks



➡ 2 families VXD tracks:

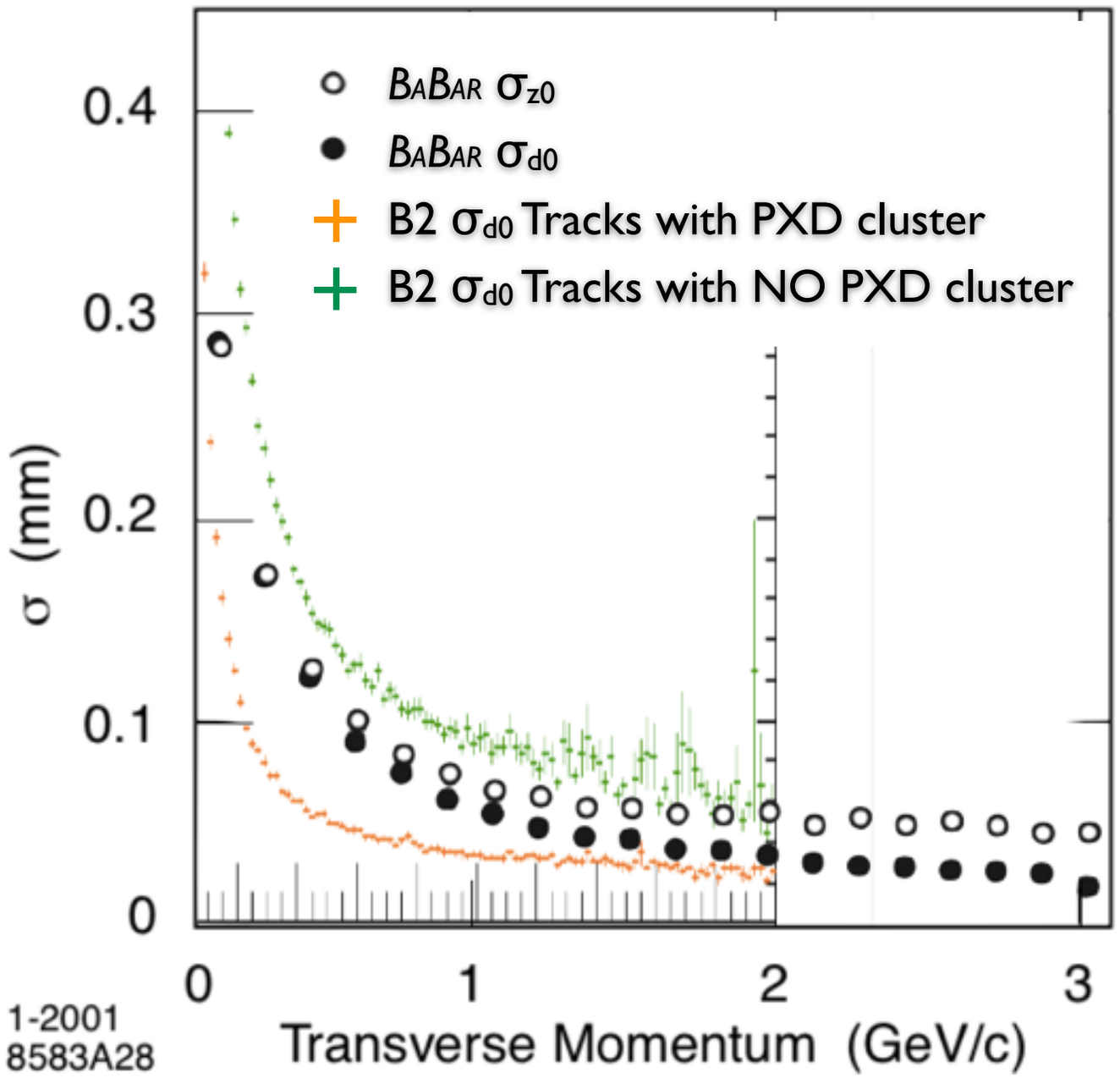
★ *tracks with at least one PXD cluster attached*:

- $\sigma_{d0} \simeq 35\mu m$ @ 1 GeV/c
- $\sigma_{d0} \simeq 50\mu m$ @ 500 MeV/c
- $\sigma_{d0} \simeq 120\mu m$ @ 200 MeV/c
- $250 < \sigma_{d0} < 300\mu m$ @ 100 MeV/c

★ tracks with no PXD clusters attached

- factor 2 worst

Comparison with *BABAR* Tracking



- ➡ Belle2 VXD Tracking when with PXD clusters are used in the track fit performs better than BABAR
- ➡ Belle2 Tracking when no PXD clusters are used in the track fit performs worse than BABAR

Pattern Recognition

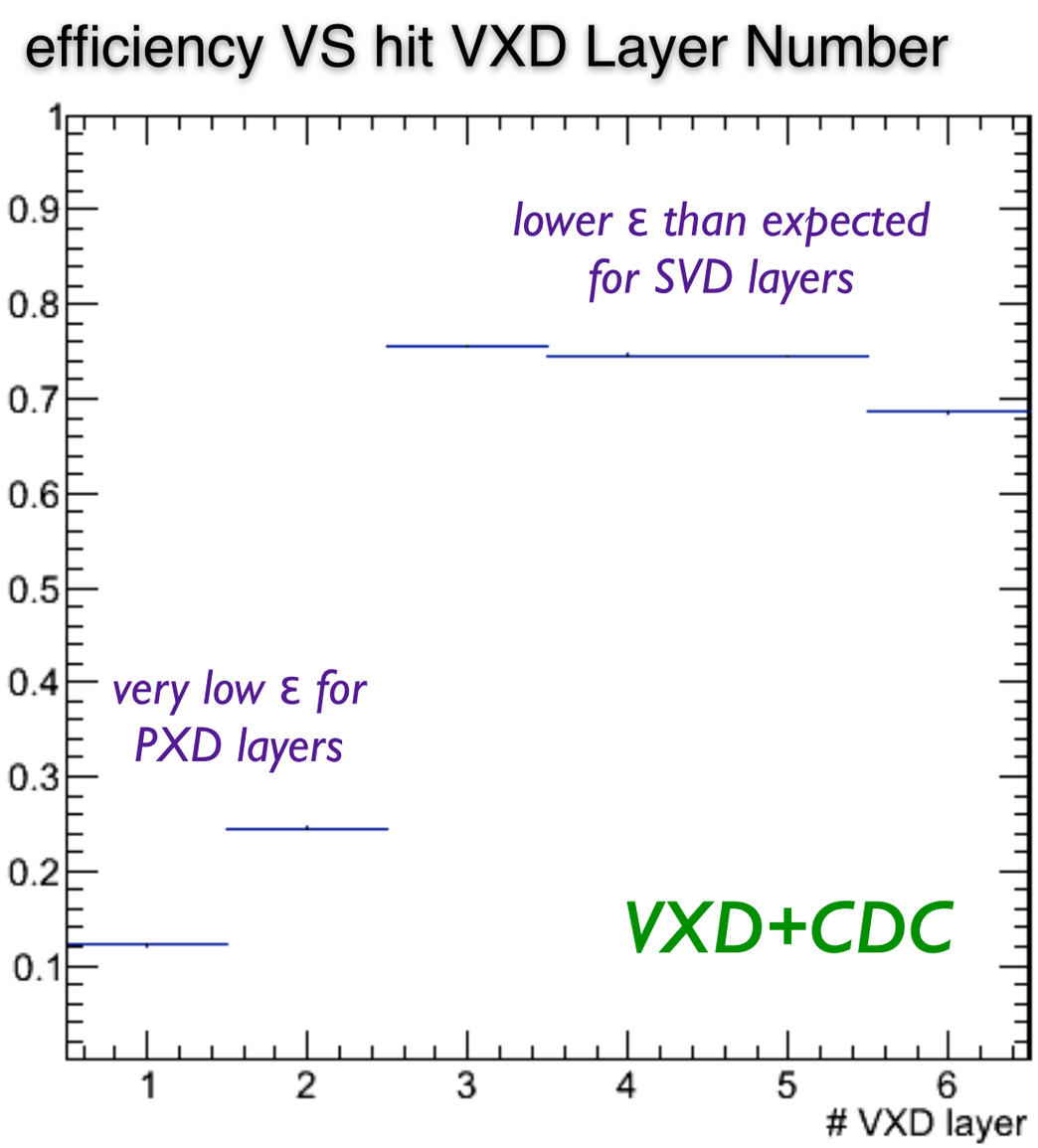
Patter Recognition Efficiency & Purity

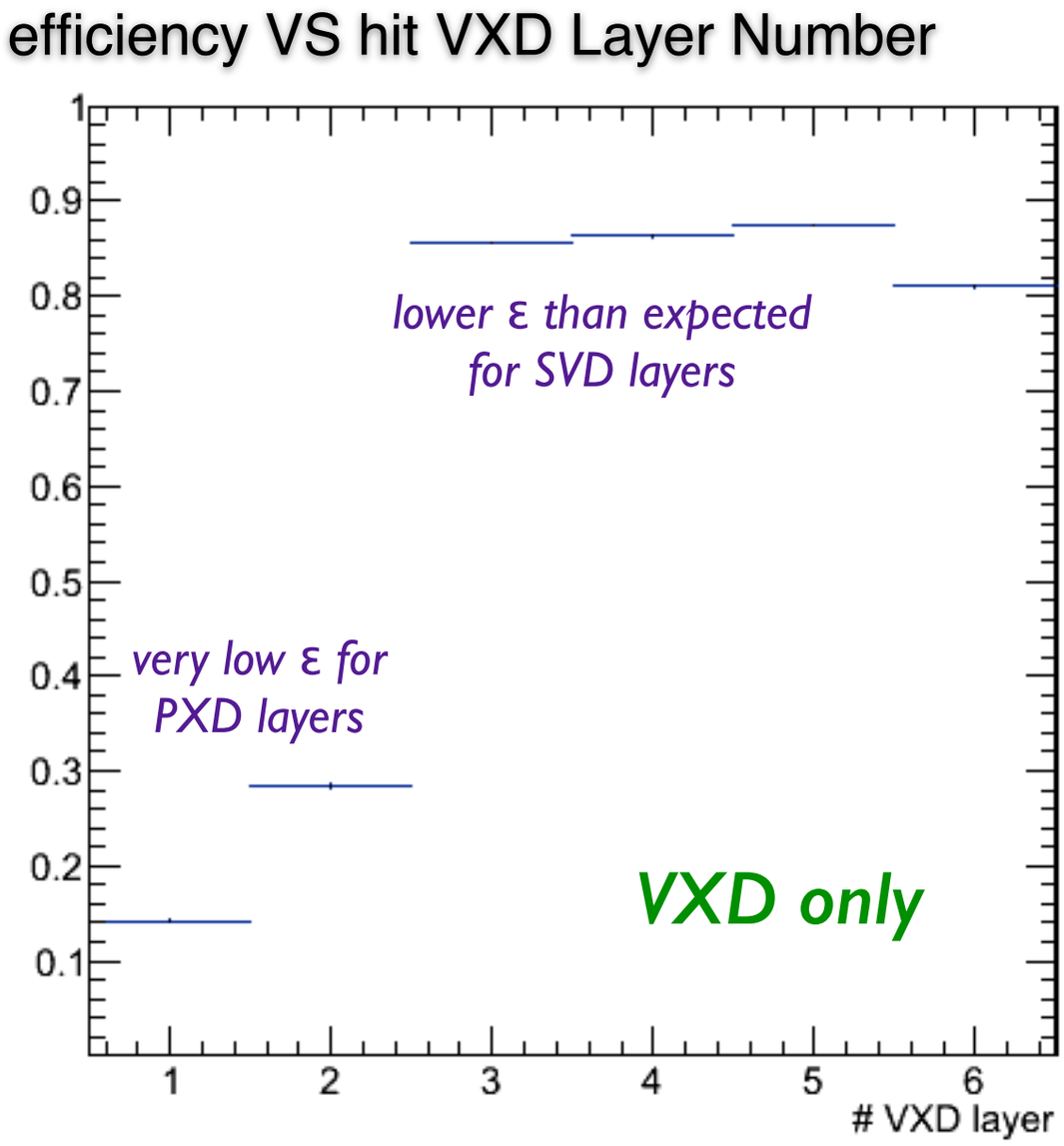
Pattern Recognition	**VXD only**	**CDC only**	**VXD+CDC**
purity (%)	94.88±0.08	75.5±0.1	-
efficiency (%)	79.3±0.2	91.3±0.1	94.3±0.1

purity = probability to find an MCTrackCand associated to a TrackCand, given a TrackCand

$$\varepsilon = \frac{\#\ \text{MCTrackCand with at least one associated TrackCand}}{\#\ \text{MCTrackCand}}$$

Pattern Recognition Efficiency

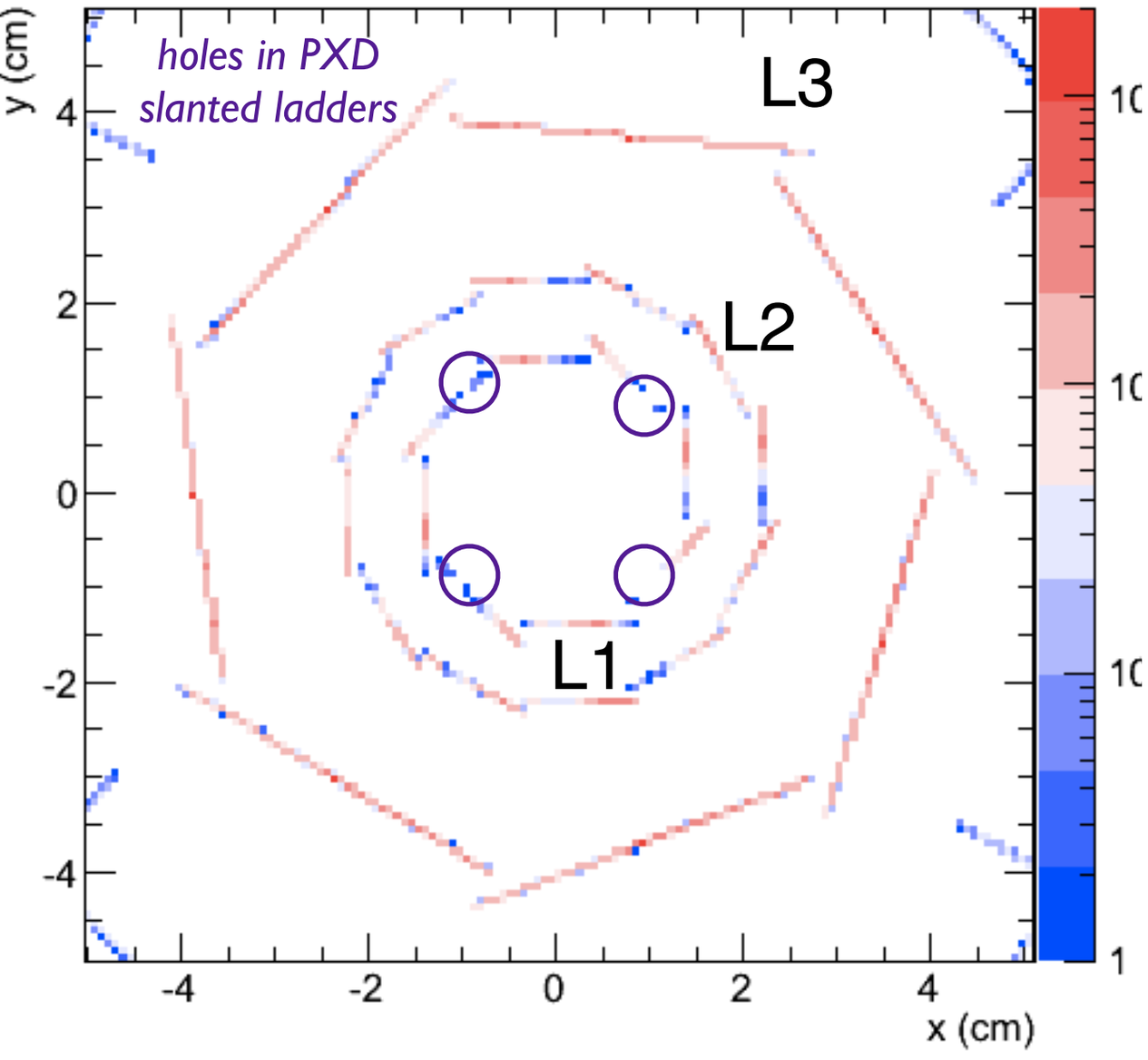




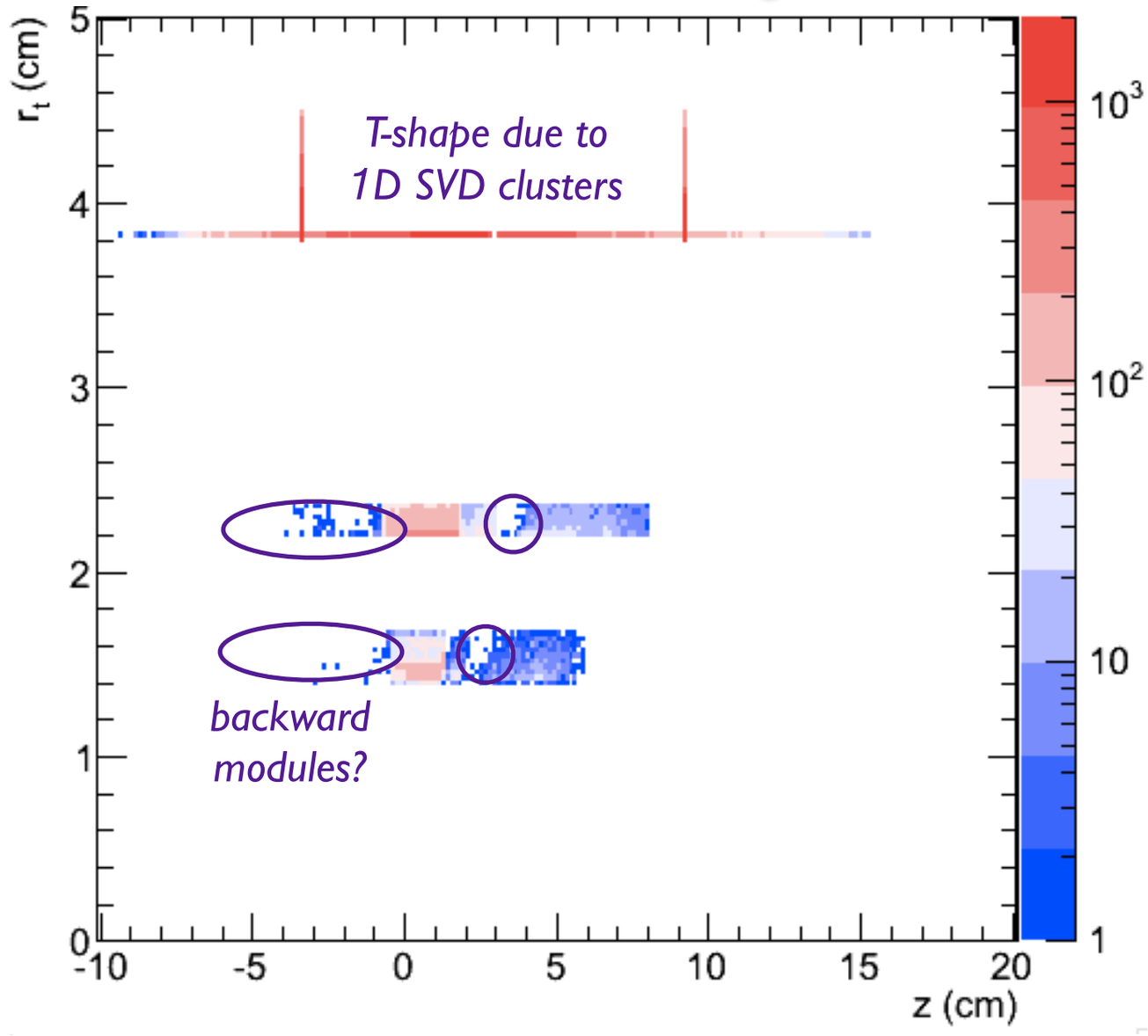
- Low ε for PXD layers is a known "feature" of the VXD TrackFinder
- In the VXD+CDC there is a loss of efficiency on VXD Layers
  - is the merger responsible? to be investigated.

VXD Clusters used in the Track Fit

used in the Track Fit: transverse view



hits used in the Track Fit: longitudinal view



Conclusions

- Tracking Validation is important to spot the critical problems and to give feedback to the developers
- A new Tracking Validation code has been developed and has produced the first results
- Future Plans:
  - collaborate with Thomas Hauth (KIT) to the validation
    - add validation of MCTrackFinding and MCTrackMatching tools
  - develop 2-step validation:
    1. write one or more ntuples with the relevant quantities
    2. produce histograms
  - define the relevant plots to be checked by the shifters, and the "expert-plots"
  - find or define the reference plots

Thank You!

backup slides

Geometrical Acceptance