Tracking Efficiency of the K_S Decay Products

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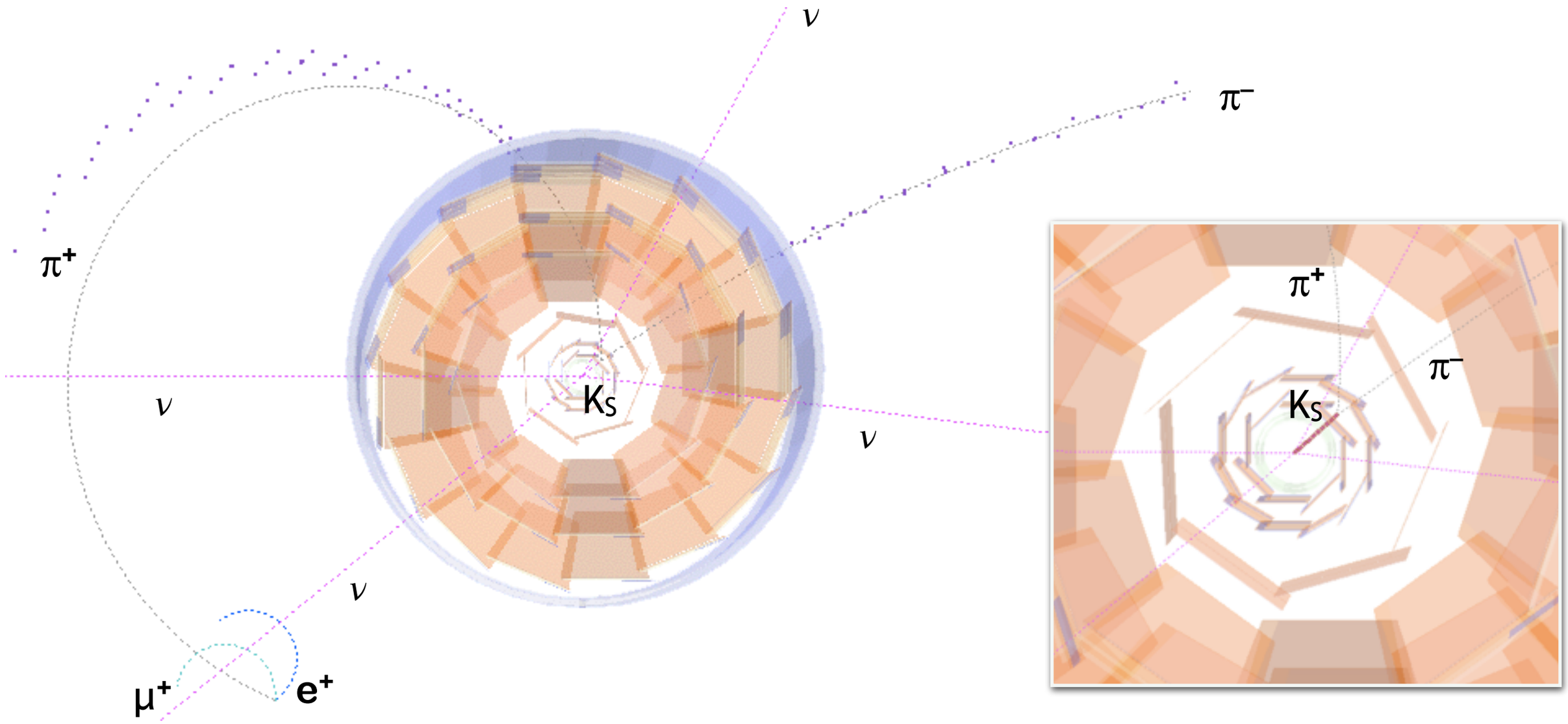
Outline

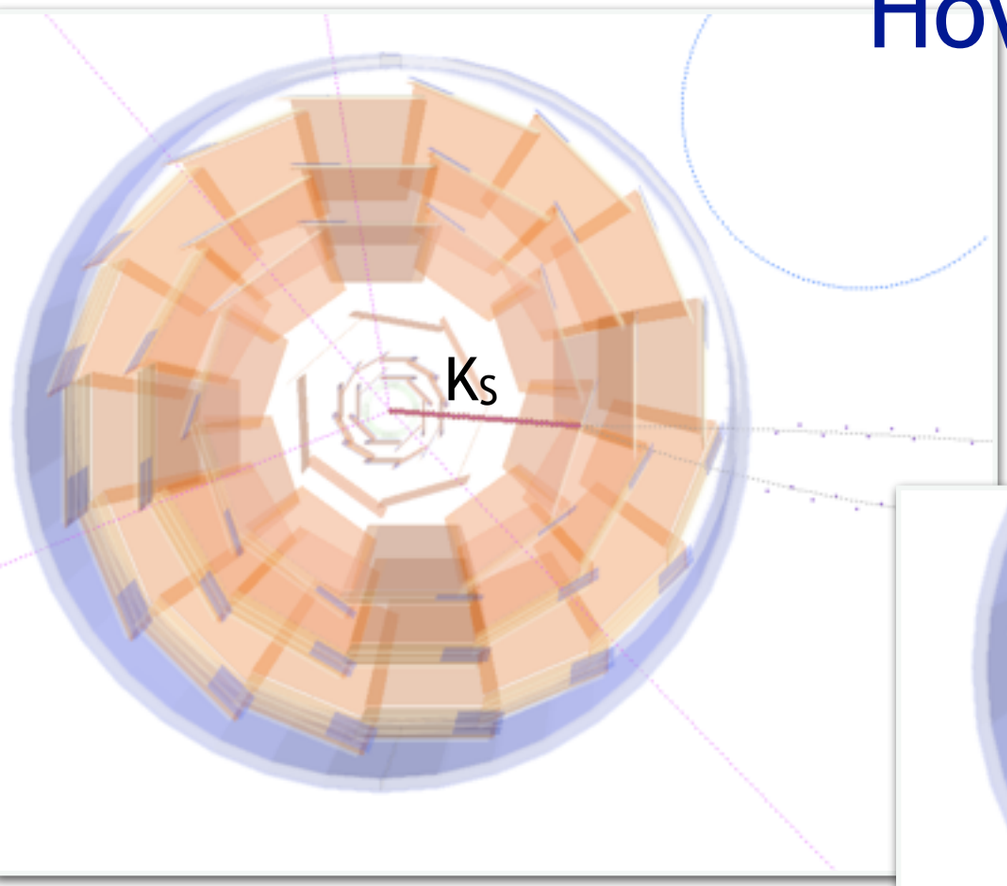
- Motivation of the Study
- The Analysis in basf2
- Performances of the pattern recognition of pions from K_S
  - using the SVD + PXD
  - using the CDC only
- Conclusions & Future Plans

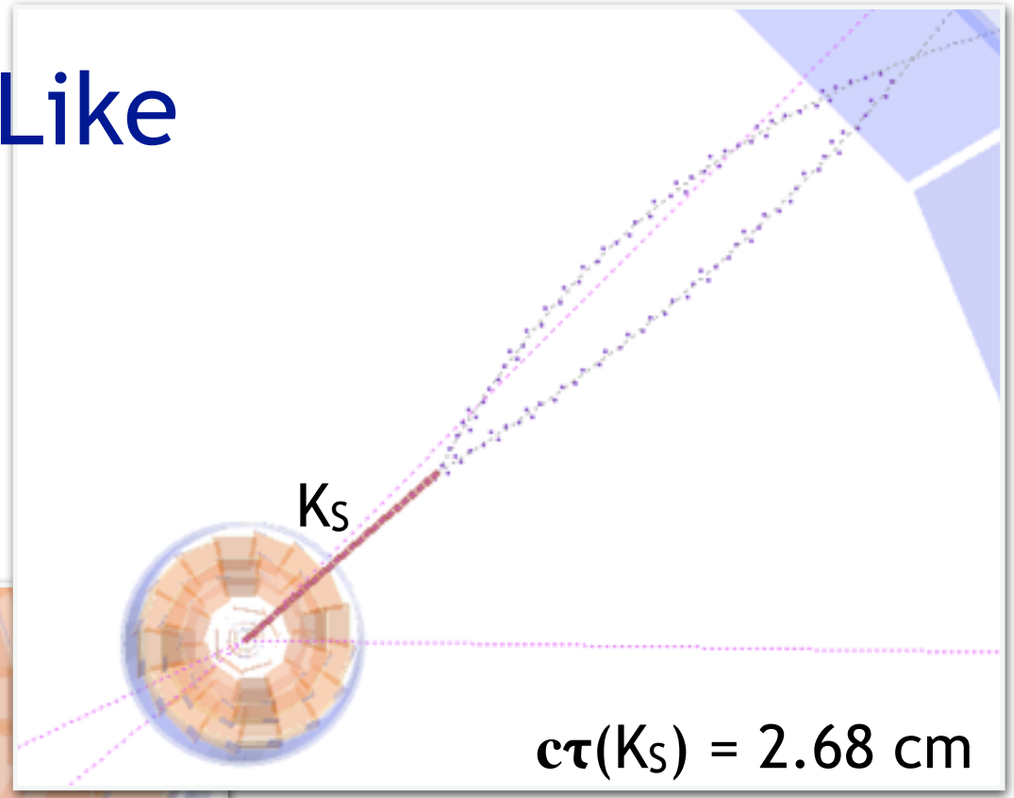
Motivation

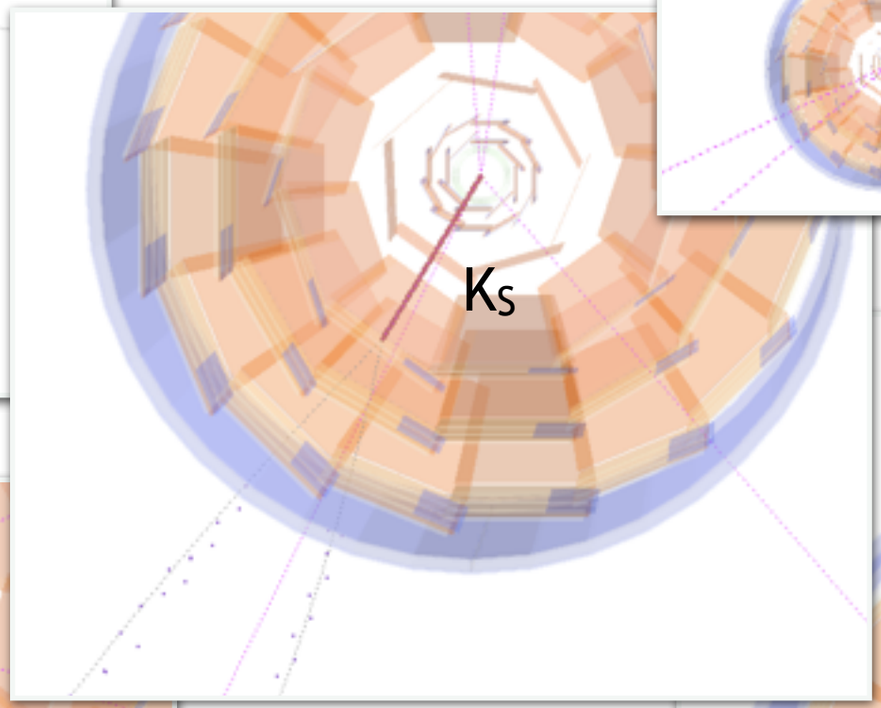
- We need an *accurate* and *efficient* K_S reconstruction for physics analysis
  - $B \to J/\psi\, K_S$, $B \to \varphi\, K_S$, $D^0 \to K_S\pi\pi$, $D^0 \to K_S\pi^0$, …
- Evaluate the efficiency of the pattern recognition for K_S daughter tracks and find the critical points and where it can be improved.

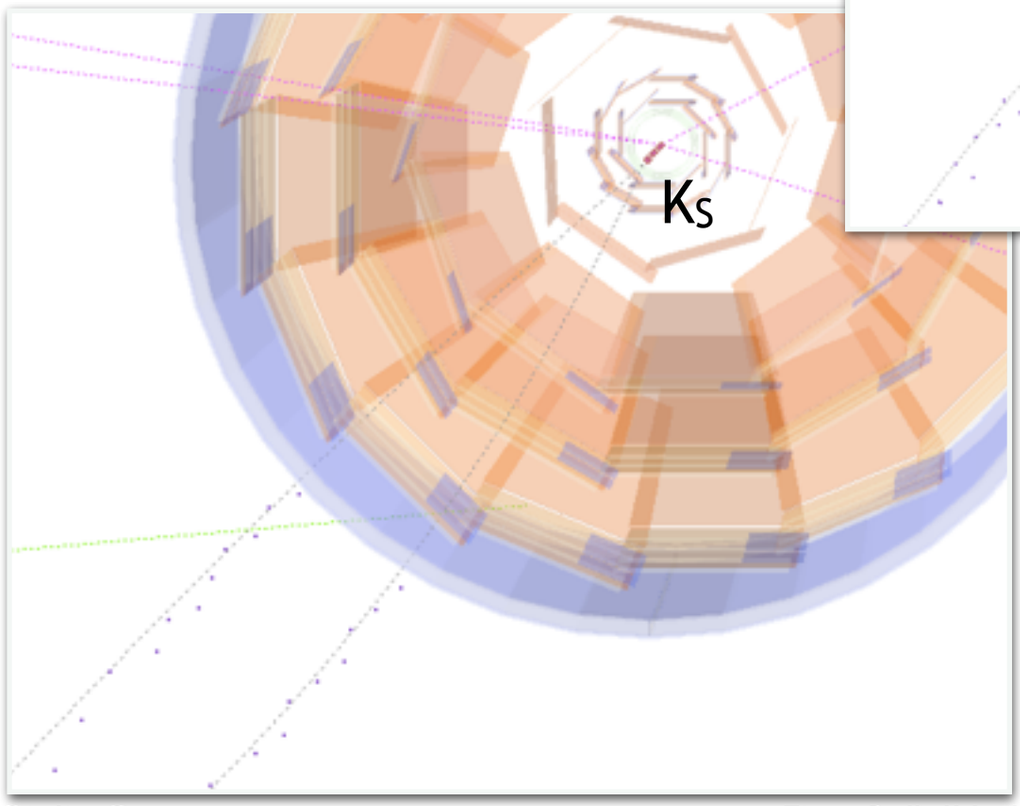


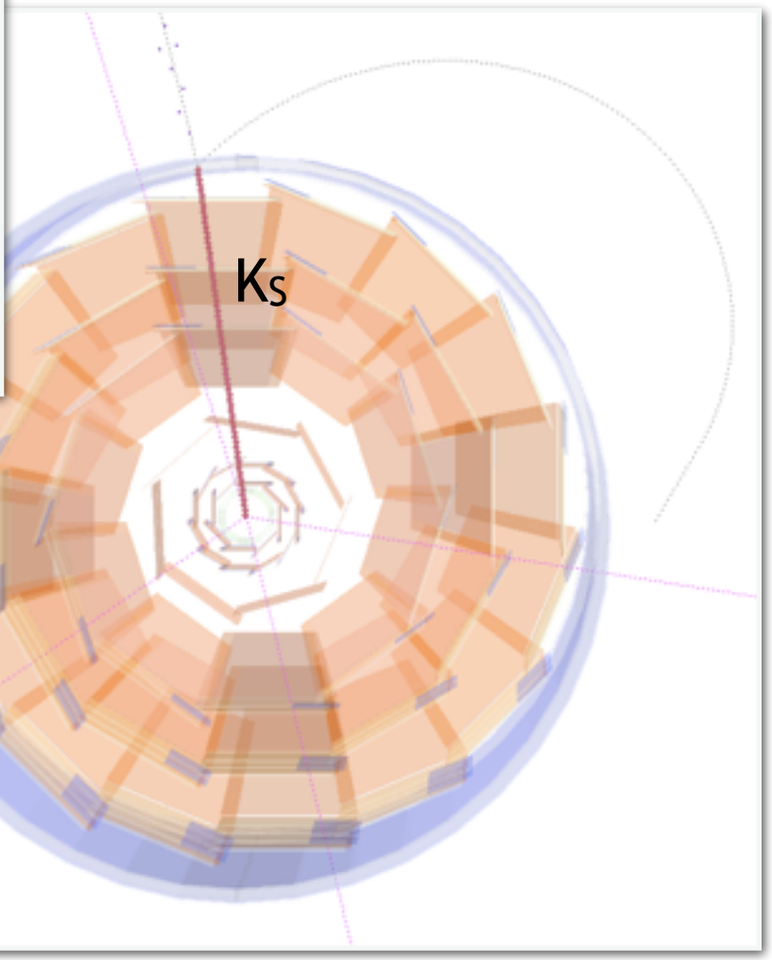
How K_S's Look Like





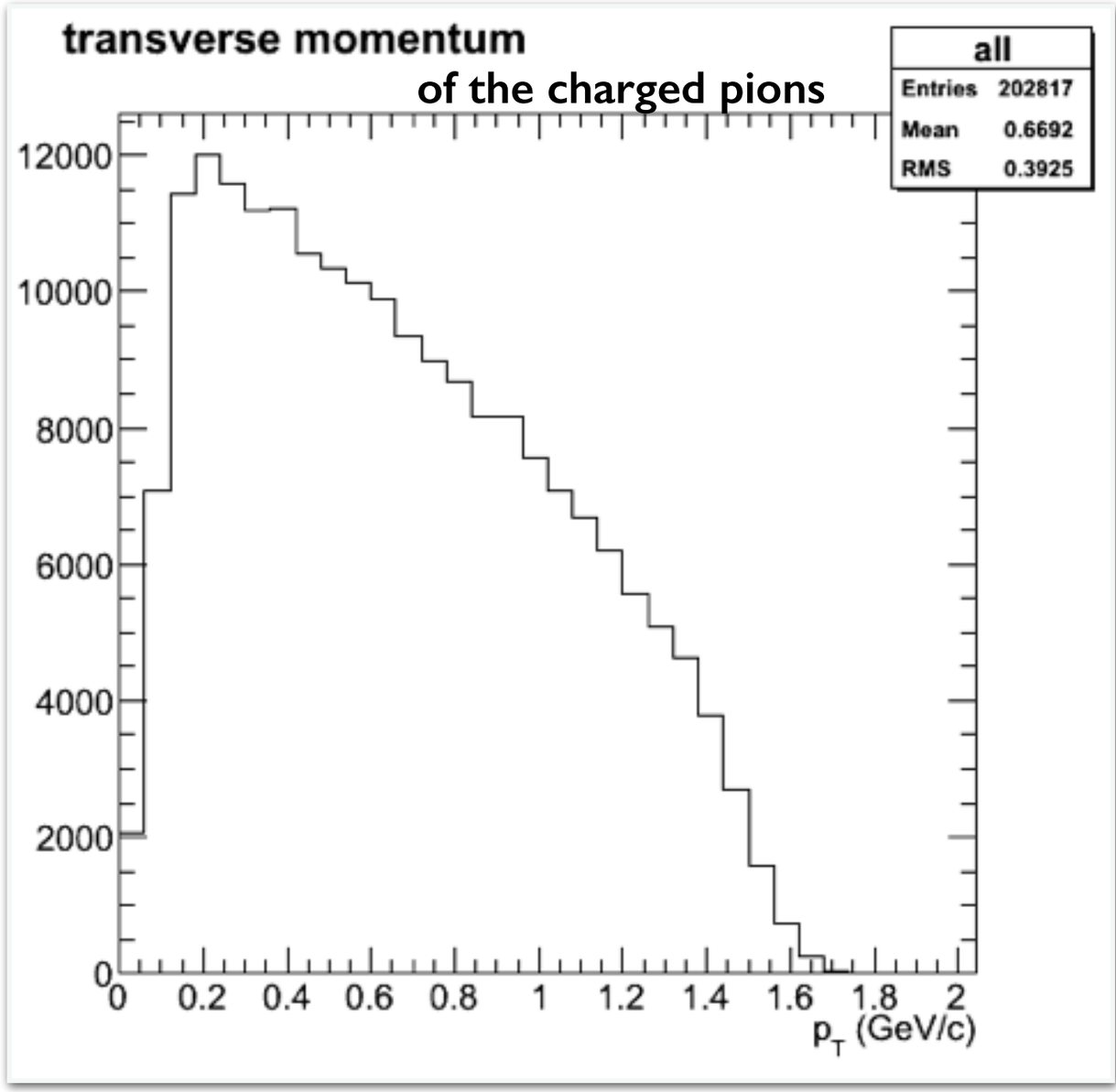


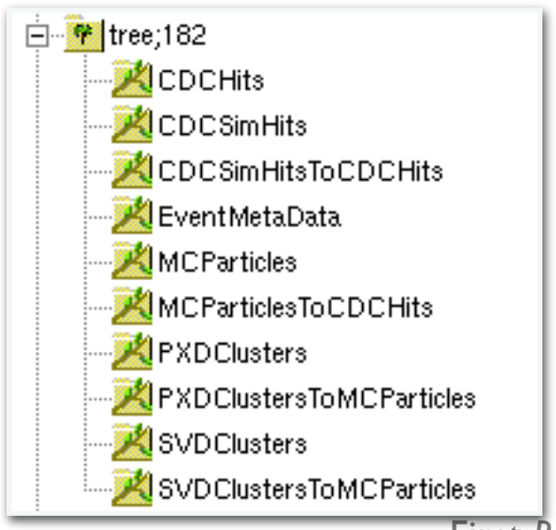




The Simulation

- used the *standard* Belle II full simulation, no background (build-2014-04-11)
- simulated 100k Y(4S) events:
- $\Upsilon(4S) \rightarrow B\,\bar{B}$
  - $B \rightarrow \nu\,\bar{\nu}$
  - $\bar{B} \rightarrow J/\psi\, K_S$
    - $J/\psi \rightarrow \nu\,\bar{\nu}$
    - $K_S \rightarrow \pi^+\pi^-$
- The output of the simulation is saved in a rootfile and then analysed with different reconstruction algorithms.





~ 6.8 kb/evt
5.2 Gb on disk

The Reconstruction

- Use the *standard* reconstruction script in the reconstruction package (build-2014-04-11):
  - CDC Track Finder: Trasan
  - VXD Track Finder (SVD only o SVD+PXD): VXDTF
  - [Track Merging: MCTrackCandCombiner(*)]
  - [MC Track Finder: TrackFinderMCTruth, need by MCTrackMatcher Module]
- Add the MCTrackMatcher module to set the McTrackId for the TrackCand
- Run different reconstruction configurations and compare the results of the performances on the *same* set of simulated events:
  - SVD only
  - SVD+PXD (=VXD)
  - CDC only
  - [VXD+CDC(*)]

(*) *use MC Truth information*

The Steering File (1)

```
import os

from basf2 import *

from simulation import add_simulation

from reconstruction import add_reconstruction

[…]

simulation = False

reconstruction = True

[…]

set_random_seed(seed)

evtgeninput = register_module('EvtGenInput')
evtgeninput.param('boost2LAB', True)
evtgeninput.param('userDECFile', os.environ['BELLE2_LOCAL_DIR']
                  + '/analysis/examples/exampleEvtgenDecayFiles/Ks_only.dec')
[…]
```

include the functions defined here:
`simulation/scripts/simulation.py`

include the functions defined here:
`reconstruction/scripts/reconstruction.py`

one single steering file to simulate and reconstruct/analyse the events:

- use boolean variables to configure the file
- use RootInput and RootOutput Modules

```
Alias MyB0 B0
Alias MyB0B anti-B0
ChargeConj MyB0 MyB0B

Alias MyJ/psi J/psi
Alias MyK_S0 K_S0

Decay Upsilon(4S)
1.0 MyB0 MyB0B VSS;
Enddecay

Decay MyB0
1 nu_e anti-nu_e PHSP;
Enddecay

Decay MyB0B
1.0  MyJ/psi MyK_S0 SVS;
Enddecay

Decay MyK_S0
1   pi-  pi+     PHSP;
Enddecay

Decay MyJ/psi
1   nu_e anti-nu_e     PHSP;
Enddecay

End
```

The Steering File (2)

```
[…]

rootBranches_param = { 'branchNames': [
        'PXDClusters',  #required by KSTrackingEfficiency
        'SVDClusters',  #required by KSTrackingEfficiency
        'CDCHits',      #required by KSTrackingEfficiency
        'CDCSimHits',
        'CDCSimHitsToCDCHits',
        'SVDClustersToMCParticles',
        'PXDClustersToMCParticles',
        'MCParticlesToCDCHits',
        'MCParticles']}
```

define the parameters to be saved/retrieved

```
rootInput = register_module('RootInput')
rootInput.param('inputFileName', 'testSimulation.root')
#rootInput.param(rootBranches_param)
```

can bypass the inputFileName parameter when launching the executable:
`> basf2 -i seed4_100kEVTs_KsToPiPi.root tracking/examples/trackingKs.py`

```
rootOutput = register_module('RootOutput')
rootOutput.param('outputFileName', 'seed4_100kEVTs_KsPiPi.root')
rootOutput.param(rootBranches_param)

[…]
```

reduces the size of the root file

The Steering File (3)

```
[…]

main = create_path()

if reconstruction:
    main.add_module(rootInput)

main.add_module(eventCounter)

if simulation:
    main.add_module(eventinfosetter)
    main.add_module(eventinfoprinter)
    main.add_module(evtgeninput)
    add_simulation(main)
    main.add_module(rootOutput)

if reconstruction:
    main.add_module(gearbox)
    main.add_module(geometry)
#    add_reconstruction(main, ['MagneticField', 'BeamPipe', 'PXD', 'SVD', 'CDC'])
    add_reconstruction(main, ['MagneticField', 'BeamPipe', 'SVD'])
    main.add_module(track_finder_mc_truth)
    main.add_module(matcher)
    main.add_module(kstfeff)

#main.add_module(display)


# Process events
process(main)
```

use the *Belle II* official standard simulation

use the *Belle II* official standard reconstruction
- with the user-required detector components

The Analysis Skeleton

In the event():

```
for (int j = 0; j < mcParticles.getEntries(); j++) {
  mother = aMcParticle->getMother();


 if ( (abs(aMcParticle->getPDG() ) != 211 )
       || ( abs(mother->getPDG() ) != 310) )
    continue;


 [. . .]
```

```
for (int i = 0; i < trackCands.getEntries(); i++)
    if (ID == trackCands[i]->getMcTrackId())
      matched = true;

 if (matched) {

[. . .]

}
  else {

[. . .]

 }
}
```

- loop on MCParticles
  - select pions from K_S only
  - compute the relevant variables (p_T, d_0, # CDC hits, # PXD/SVD clusters)
  - fill the histos of "*all*" the particles
- loop on TrackCands
  - check whether any of the TrackCand matches the MCParticle
  - if matched, fill the histos of "*matched*" particles with the infos of the matched MCParticle
  - if not matched, do something else

Integrated Efficiencies

- 199004 simulated charged pions (MCParticle) from K_S decays
  - missing 0.5% pions: not compatible with K_S decaying outside active volume, may be an effect of K_S-K_L mixing?

- 188884 MC TrackCand, 94.9% of the simulated ones (geometrical acceptance)

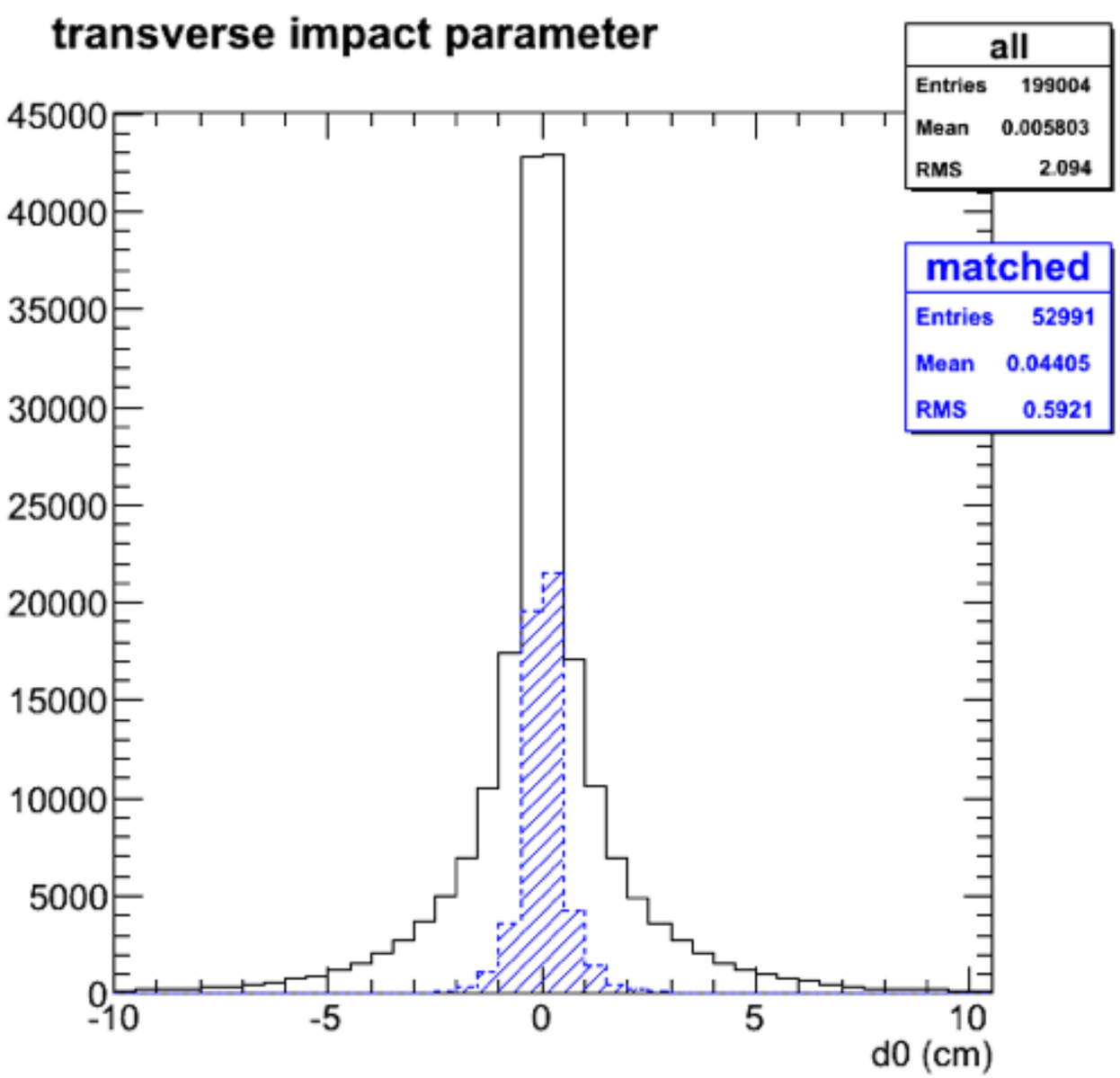
	pattern recognition →	**SVD**	**VXD**	**CDC**
	TrackCand	49202	54146	184889
PURITY:	**matched / TrackCand**	(99.69±0.03)%	(97.87±0.06)%	(93.24±0.06)%
EFFICIENCY:	**matched / MCParticle**	(24.7±0.4)%	(26.6±0.4)%	(88.63±0.07)%

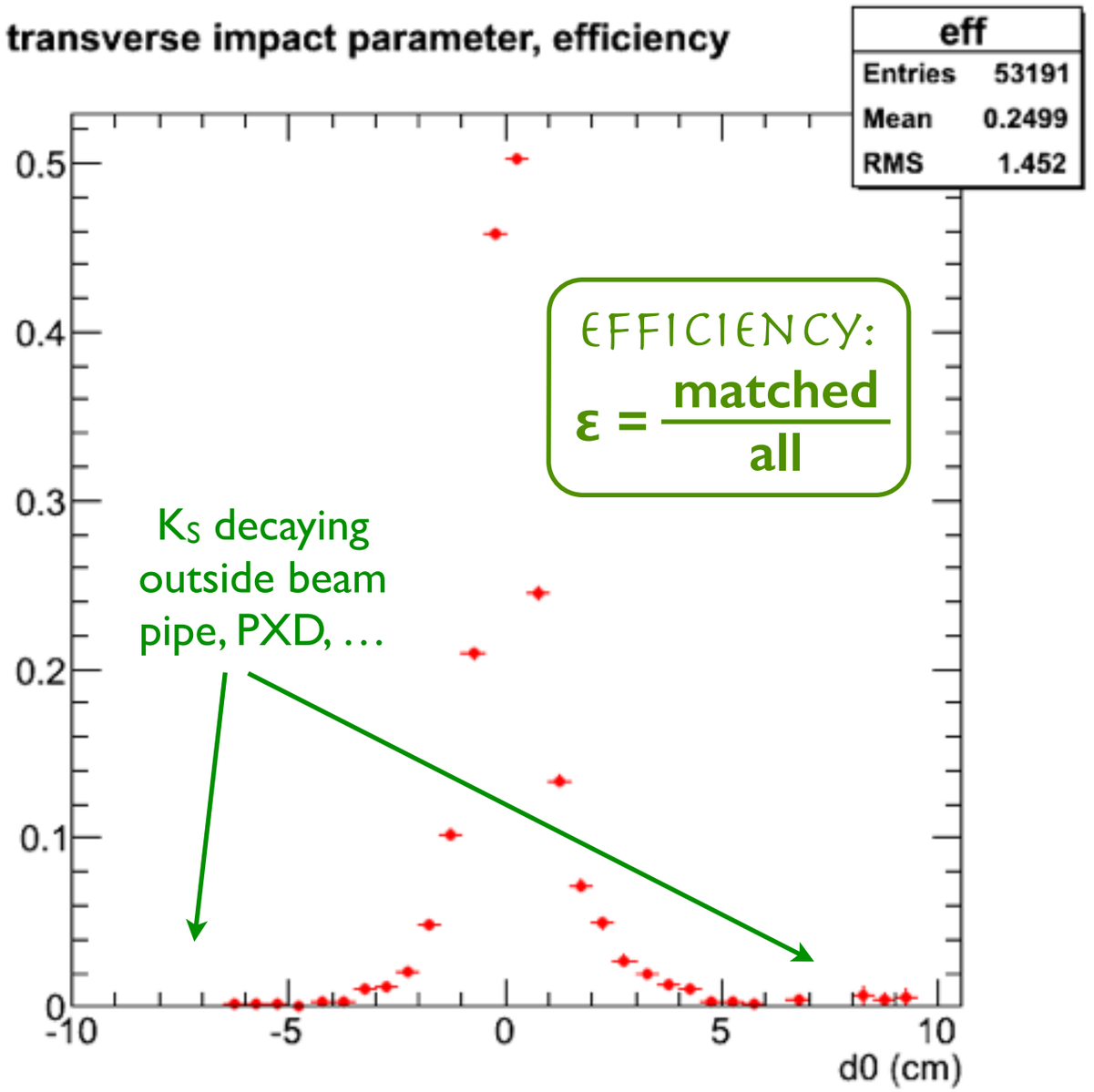
- CDC pattern recognition is much more efficient than SVD and VXD but there are also more fake tracks (most of them are removed when using VXD+CDC)

- VXD and SVD pattern recognition are very inefficient on K_S decay products

VXD-only pattern recognition

VXD-only: transverse impact parameter



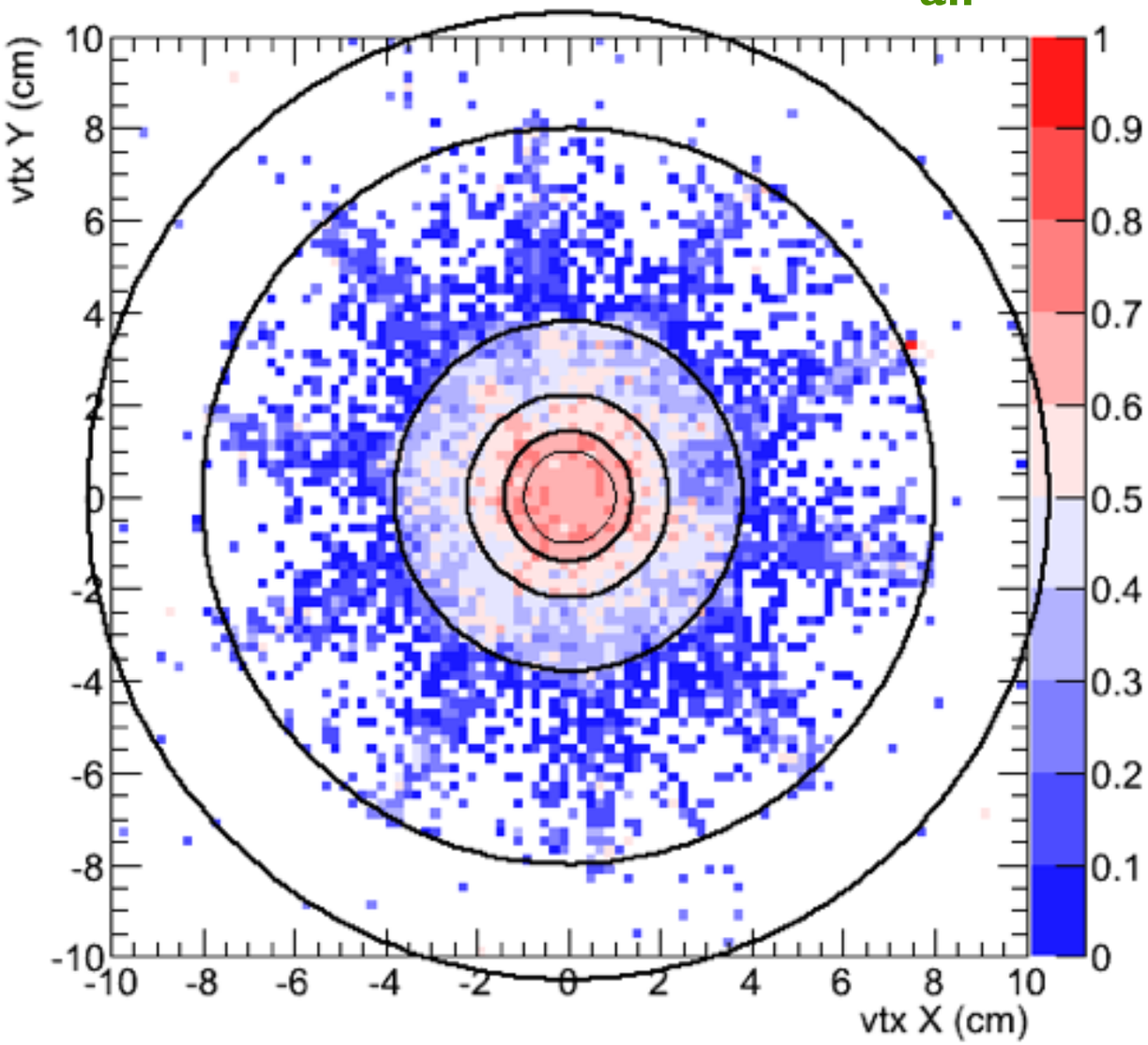


- Clear dependence on the transverse impact parameter (d_0)
- Maximum efficiency ~ 50% (with bin width = 1mm, ε goes up to 60%)

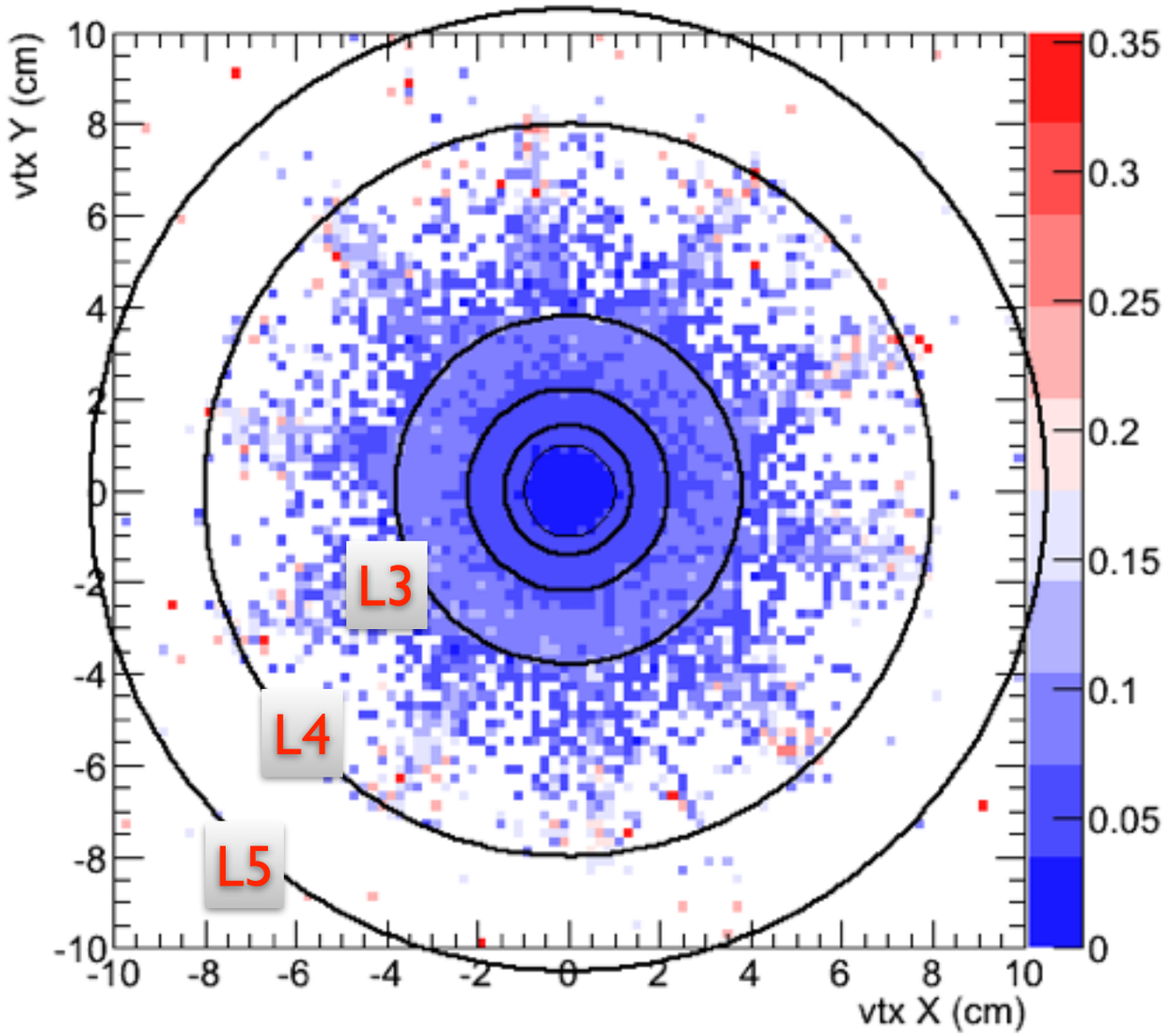
VXD-only: K_S transverse flight length

efficiency

$$\varepsilon = \frac{\text{matched}}{\text{all}}$$

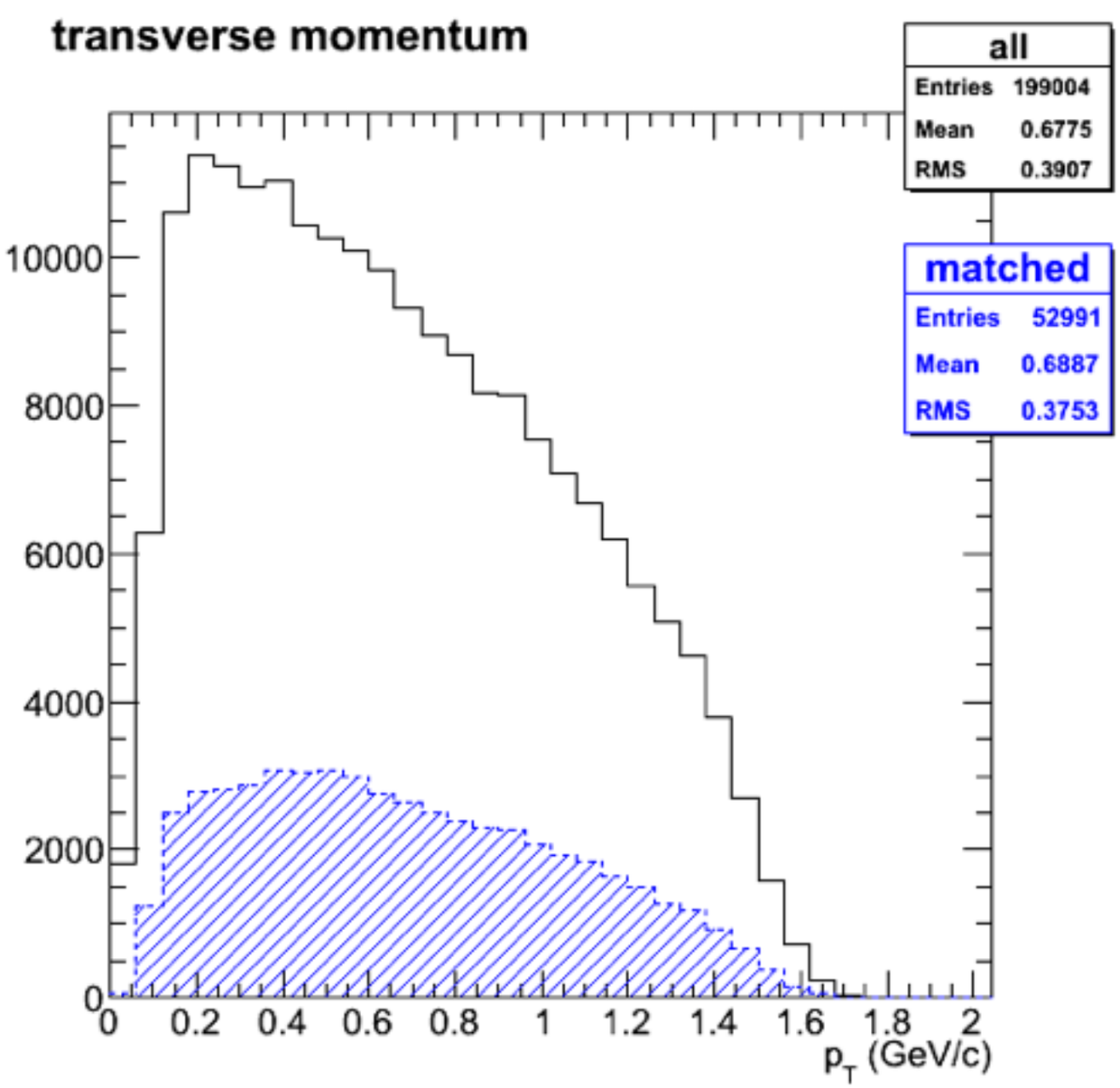


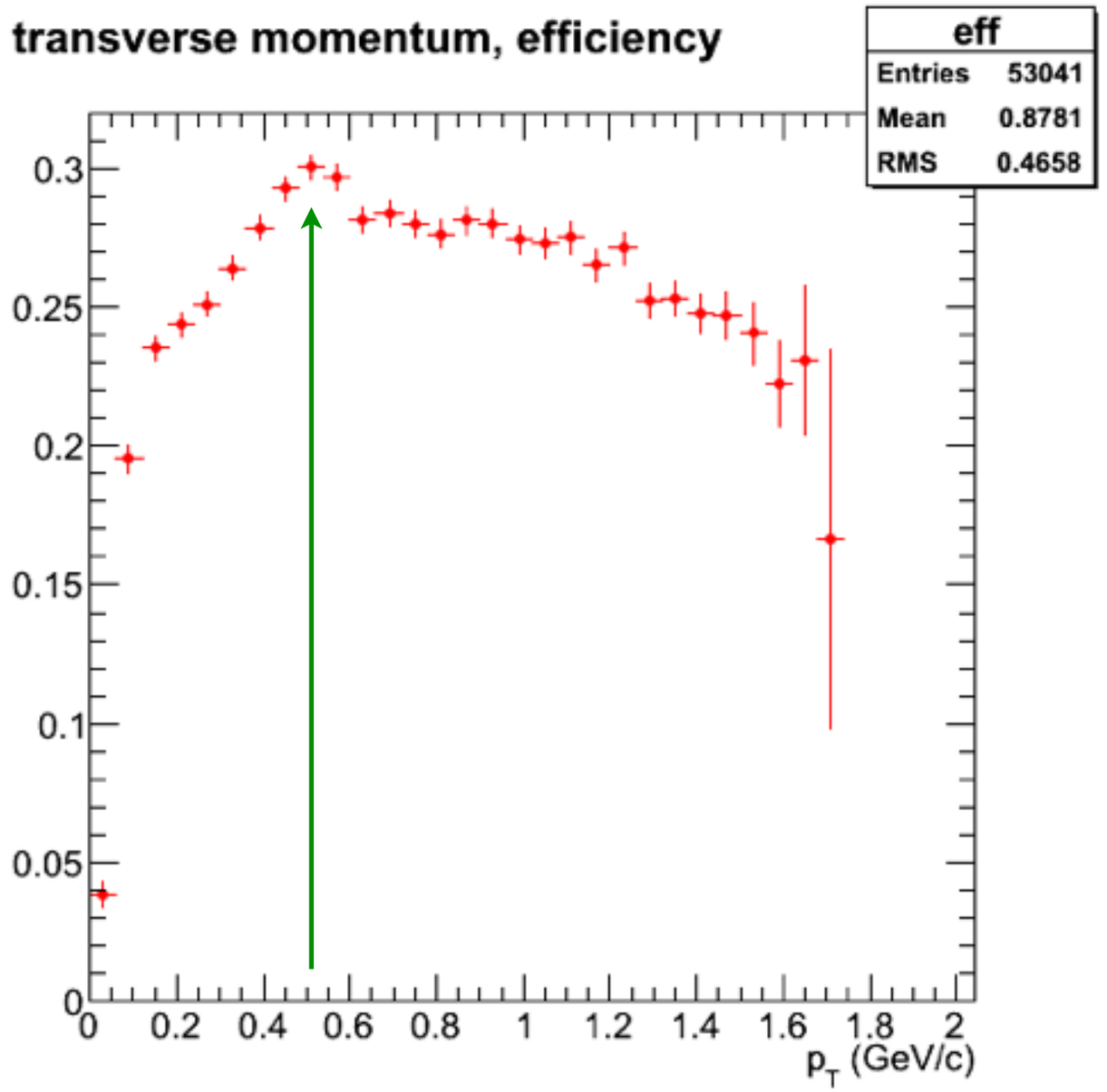
efficiency error



- Higher efficiency (75-85%) for K_S decaying inside SVD
- efficiency drop of ~25% for K_S decaying between layer2 and layer3
- wheel-like pattern between layer3 and layer4, maybe due to K_S decaying near the slanted parts of layer4 with the two pions hits associated to one track

VXD only: transverse momentum

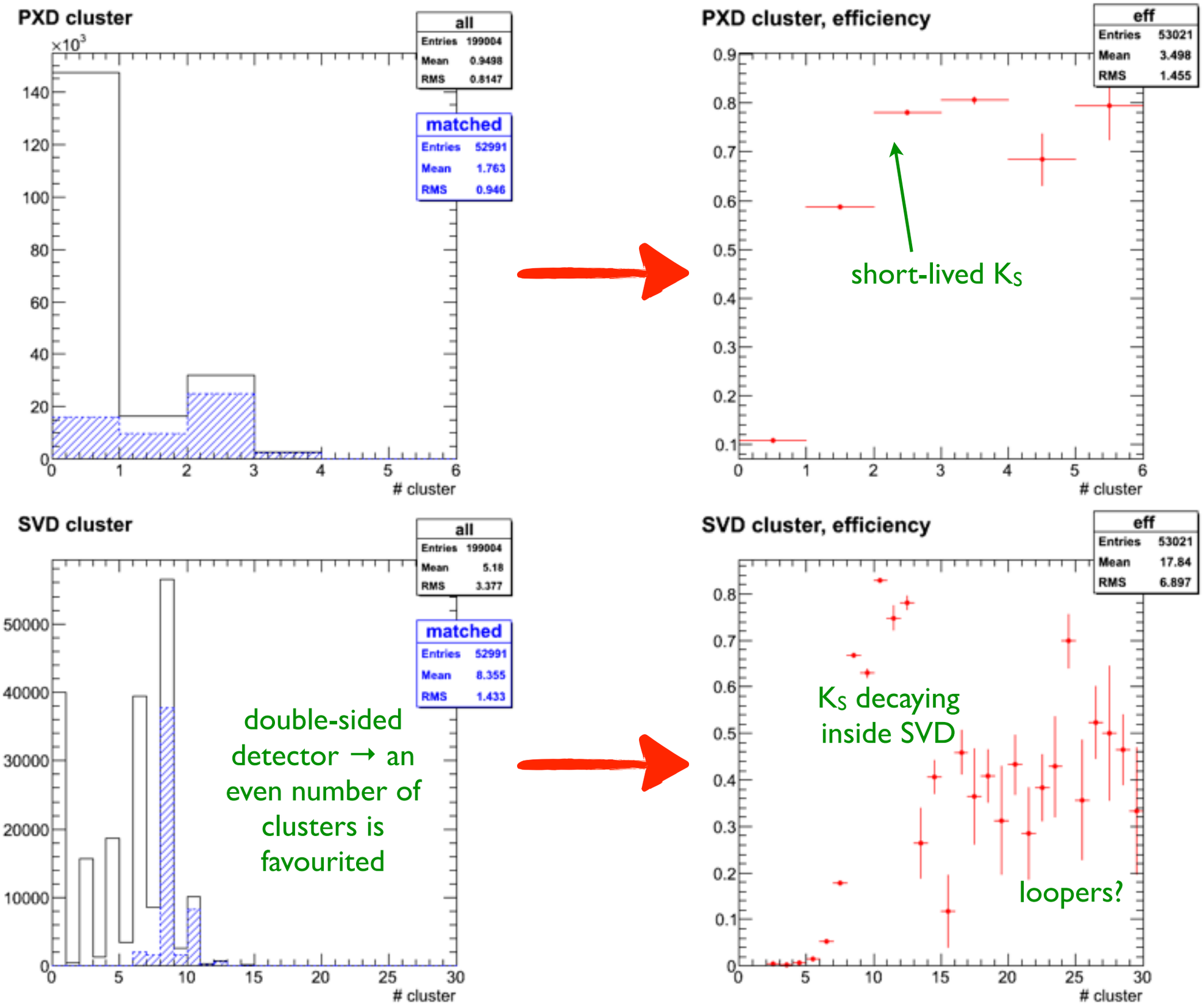




➡ Maximum efficiency (30%) at 500 MeV/c transverse momentum tracks

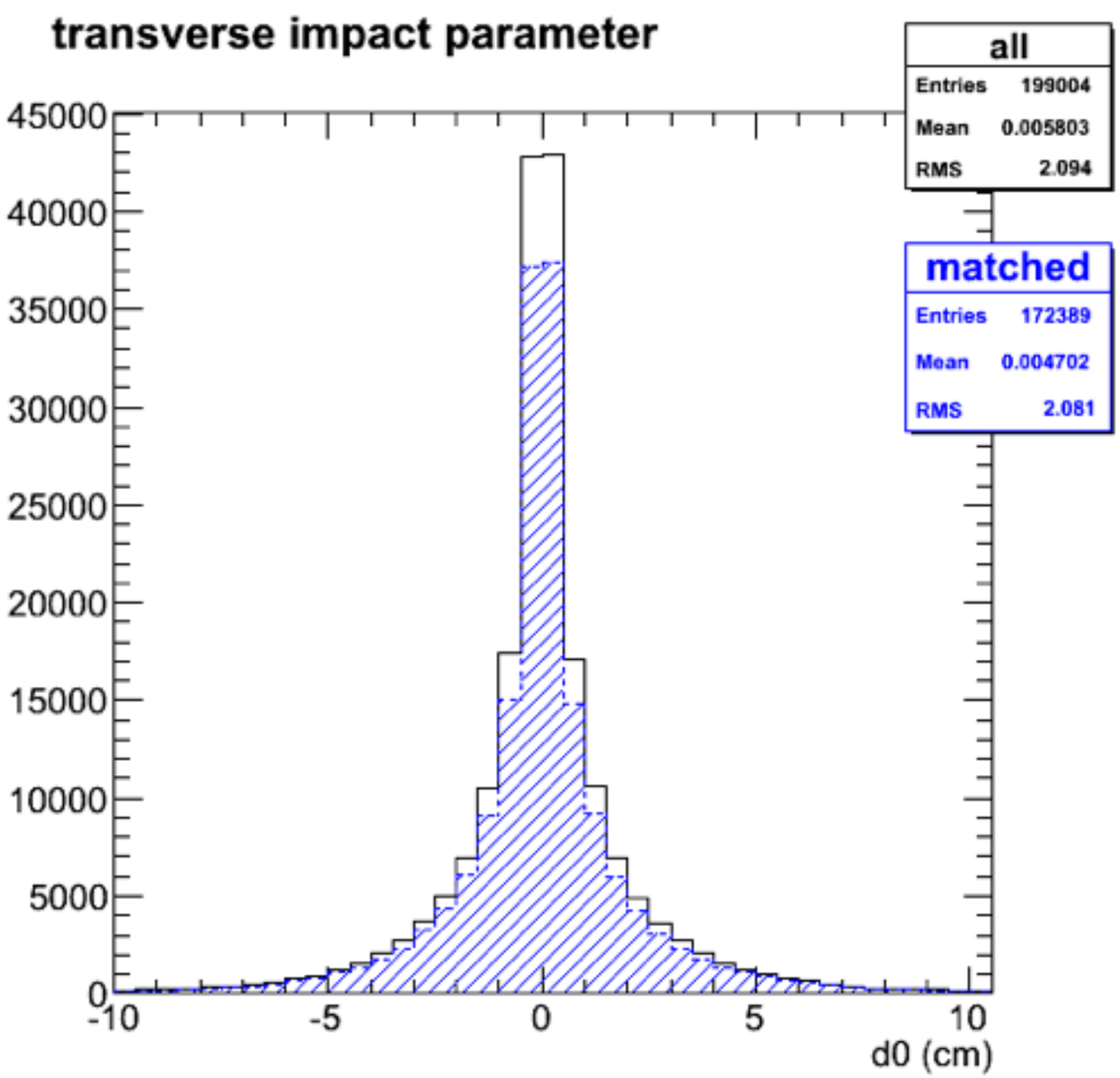
- lower p_T tracks: harder to track them in general + tracks not coming from the IP
- higher p_T tracks come from K_S with larger boost that travel outside the VXD

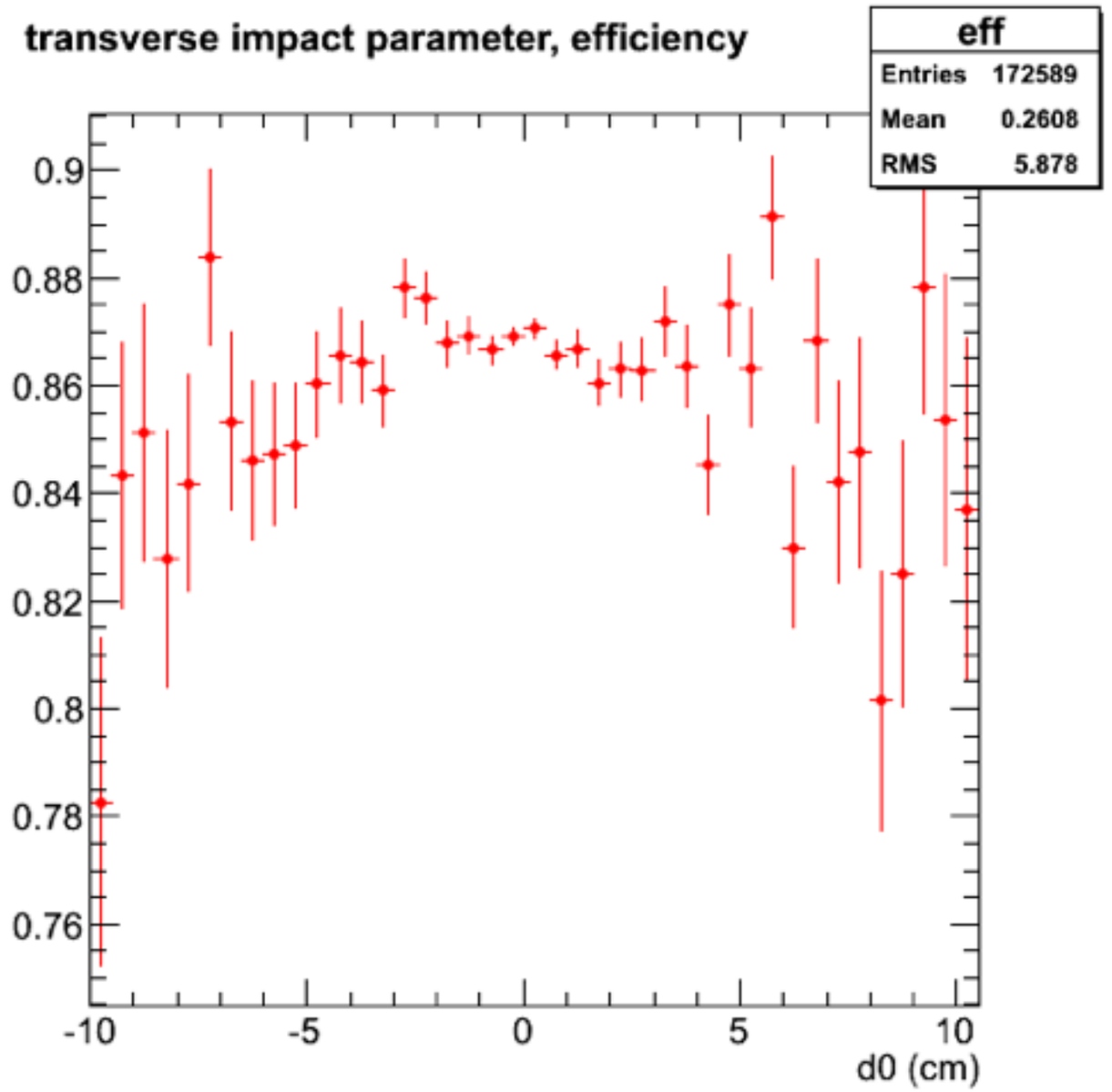
VXD only: PXD and SVD clusters



CDC-only pattern recognition

CDC only: transverse impact parameter

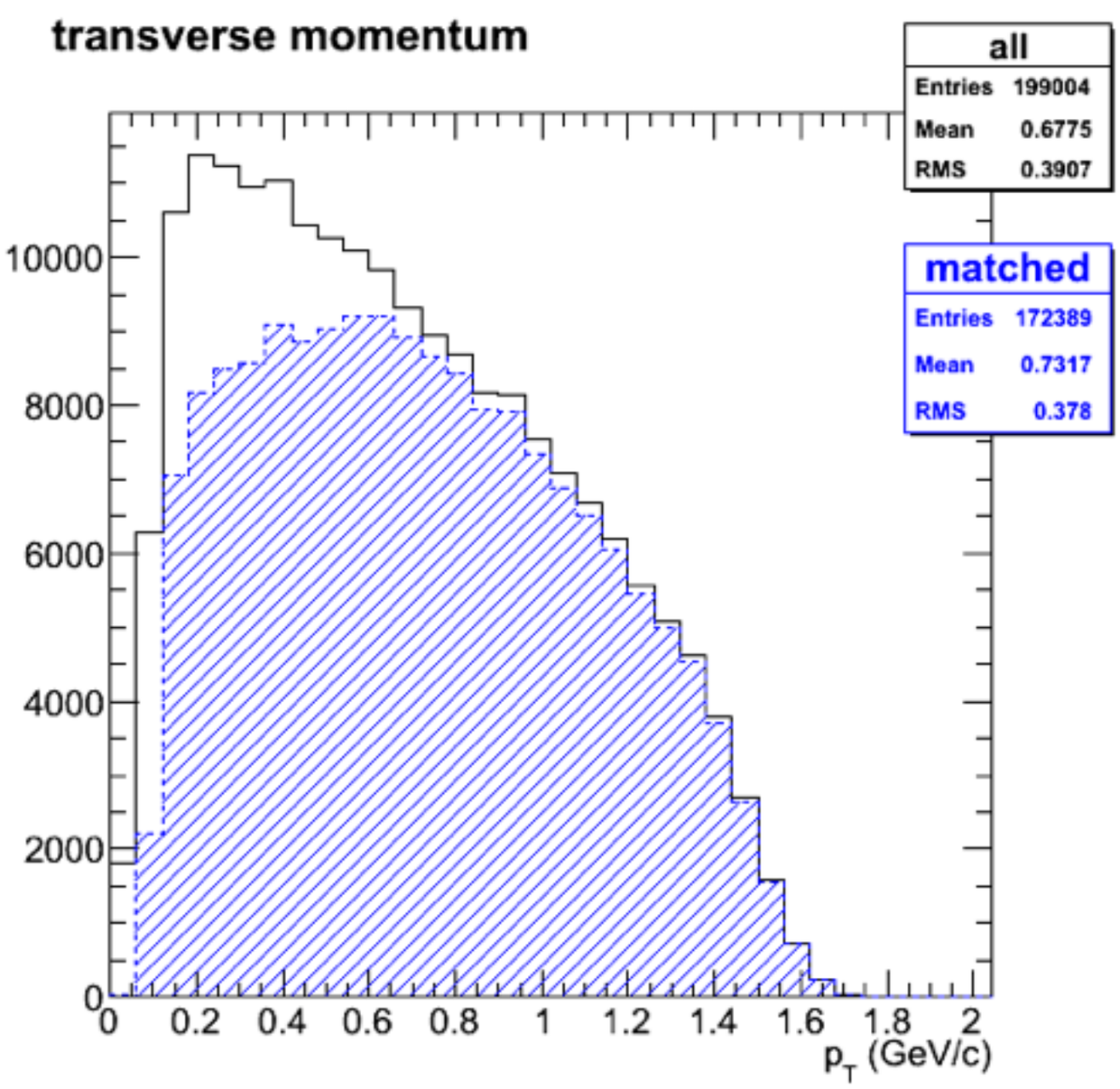


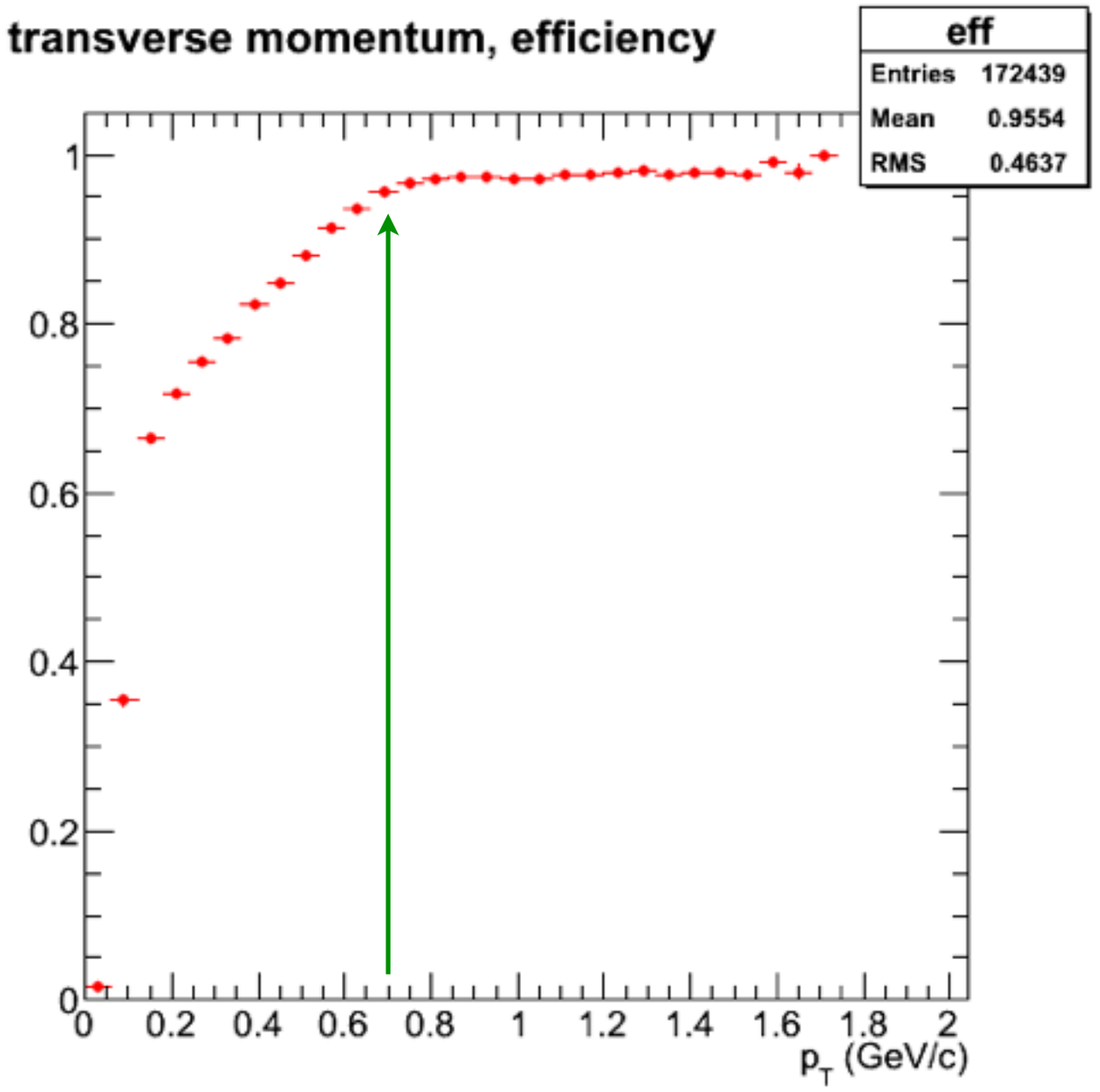


➡ No strong dependence on the transverse impact parameter (d_0)

- most of the K_S decay inside the VXD

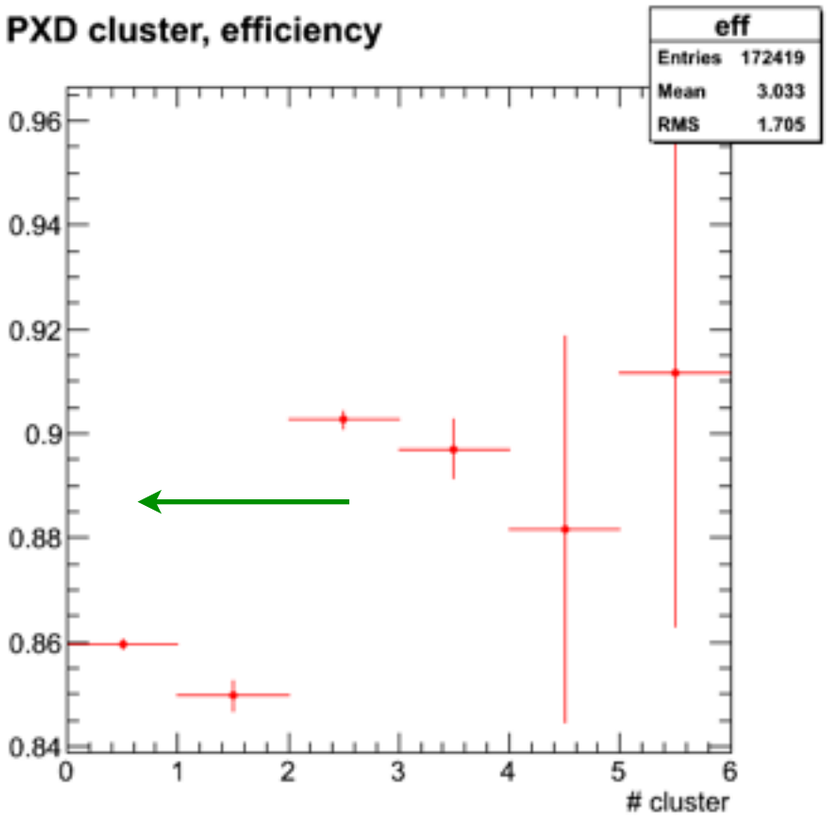
CDC only: transverse momentum

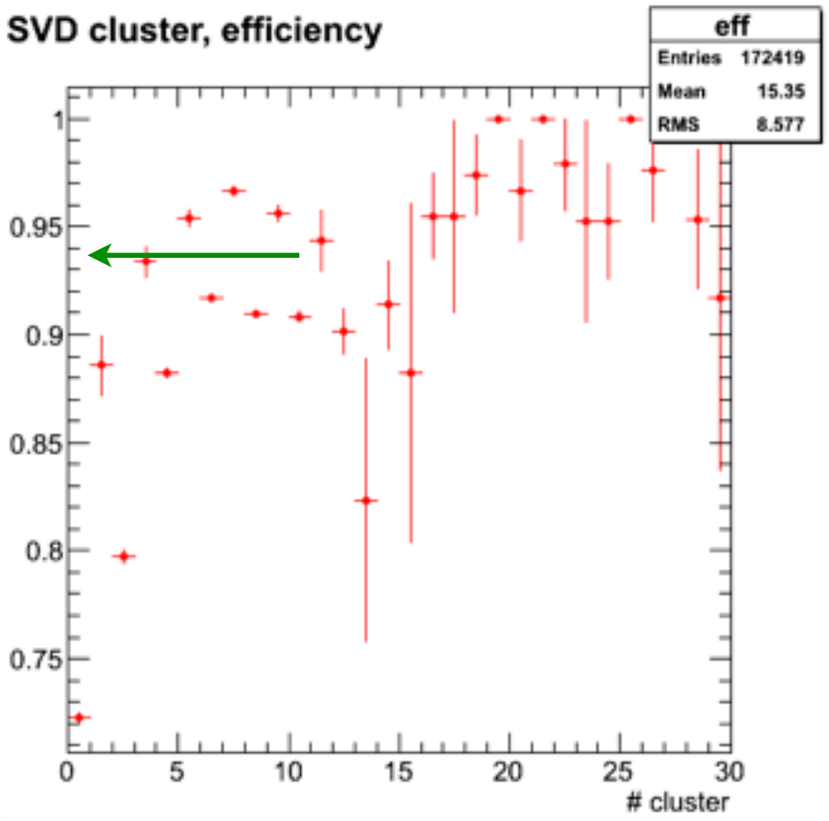


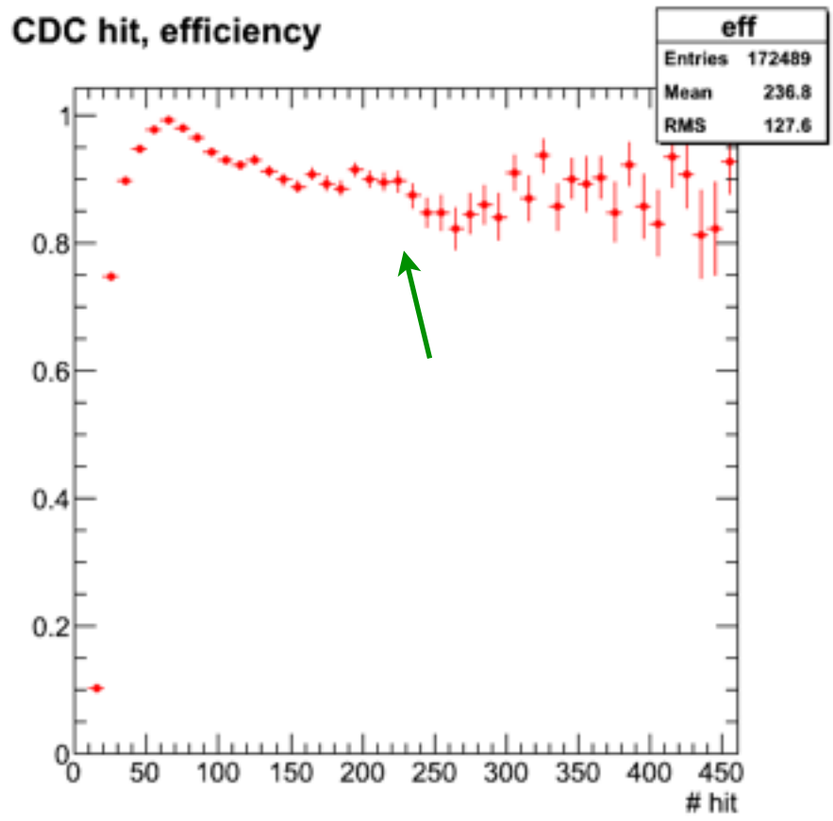


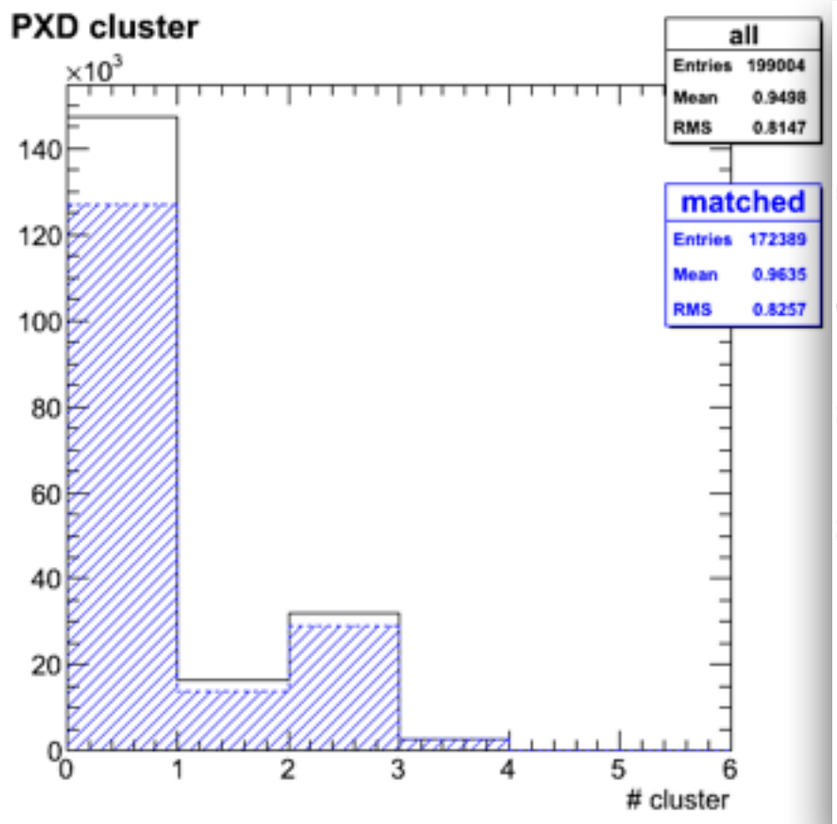
➡ Missing “low” (up to 700MeV/c!) transverse momentum tracks

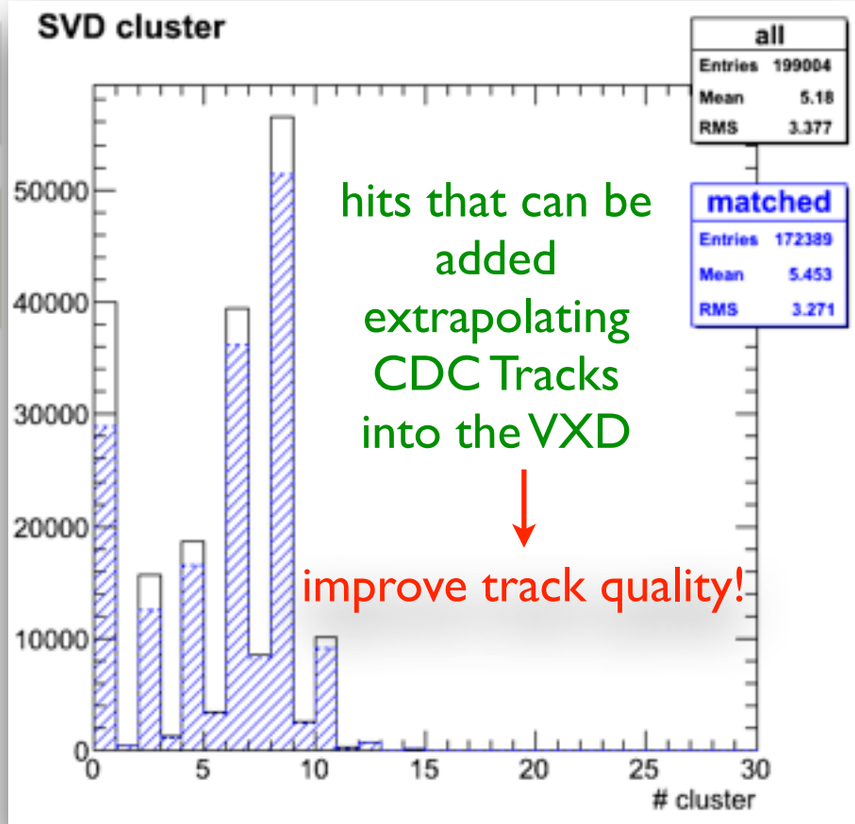
CDC only: VXD clusters and CDC Hits







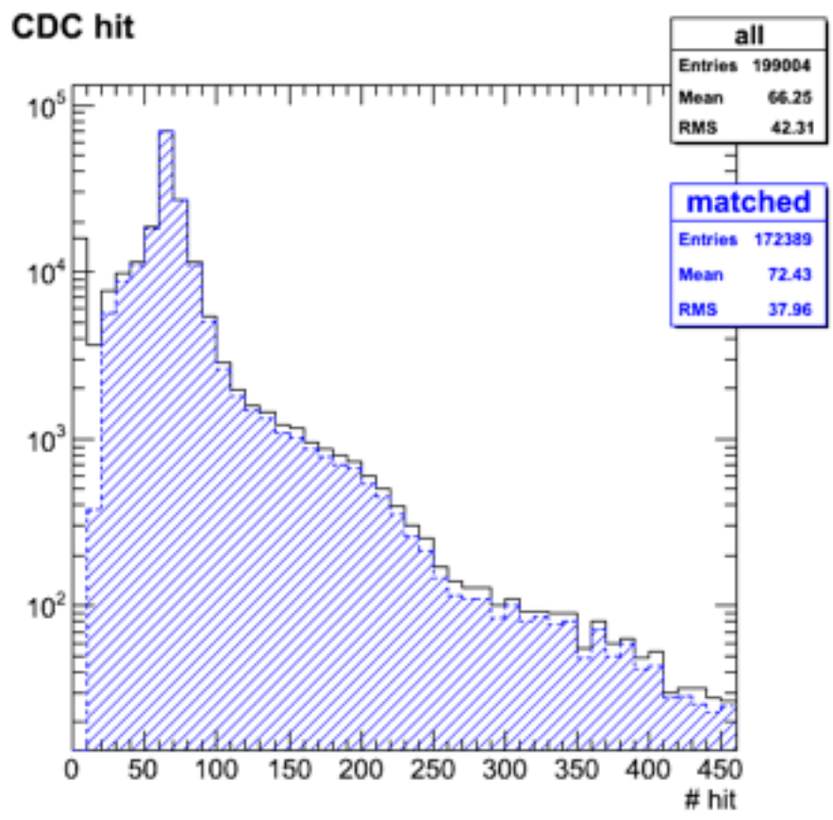




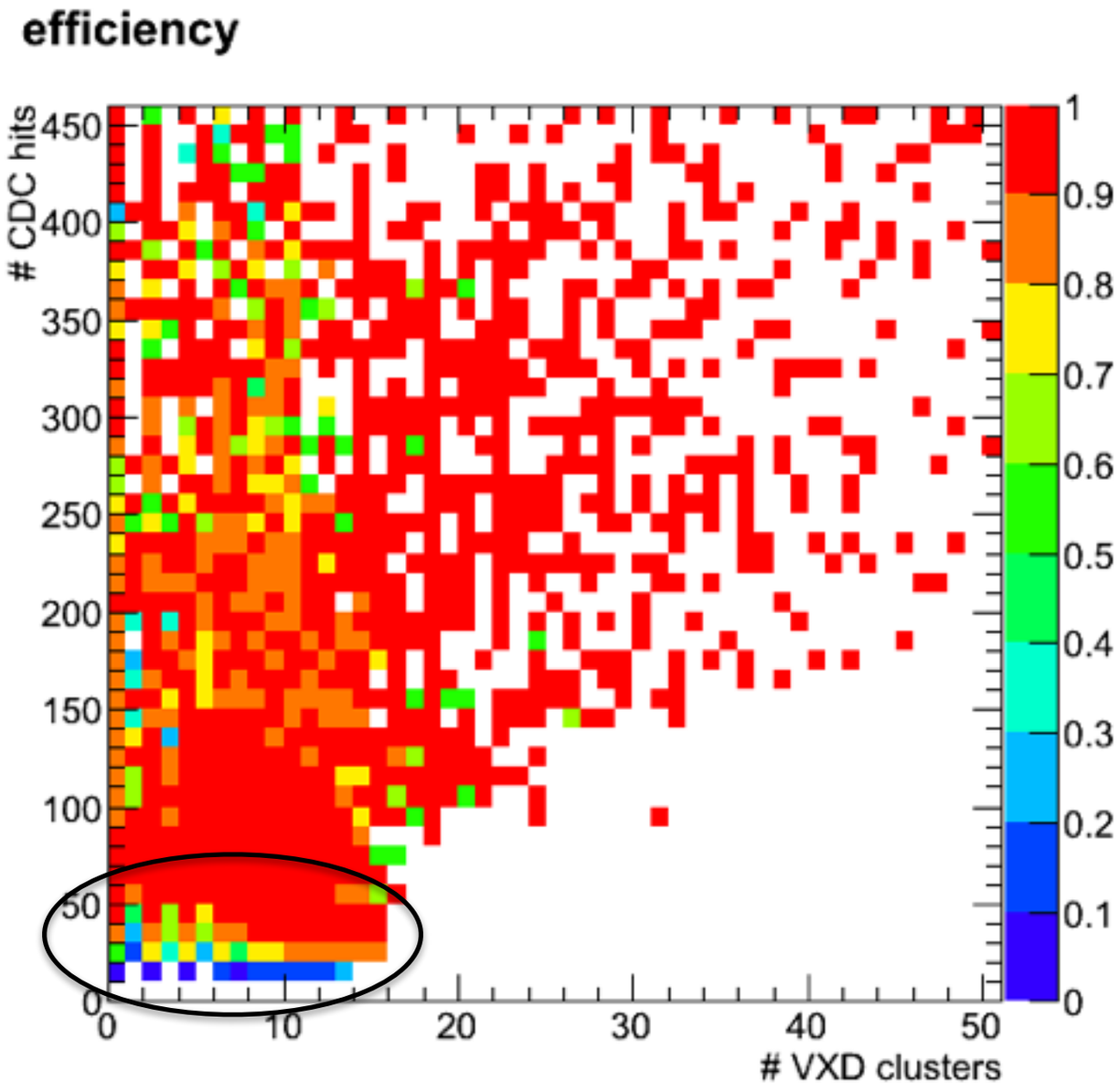
hits that can be added extrapolating CDC Tracks into the VXD

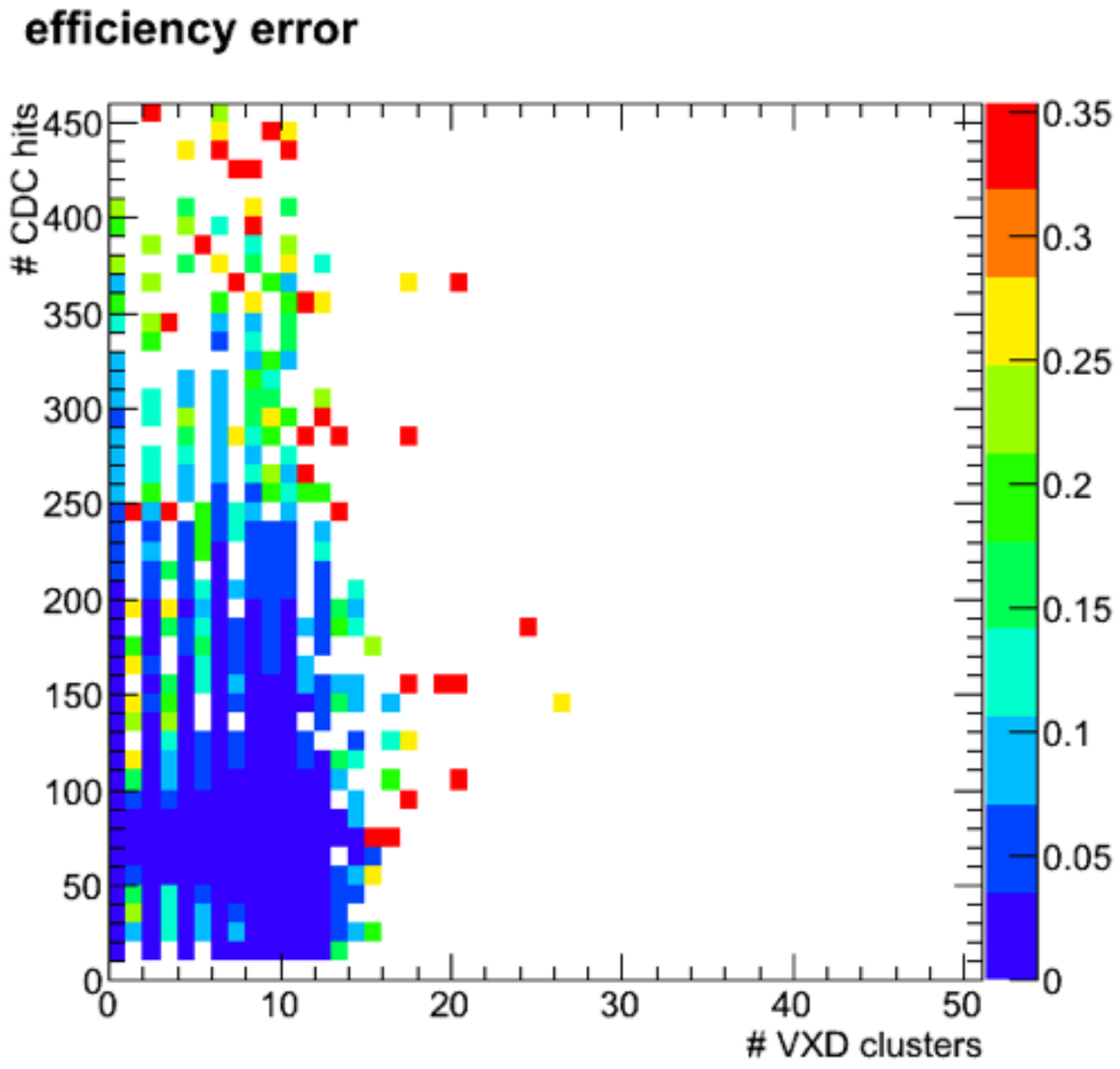
↓

improve track quality!



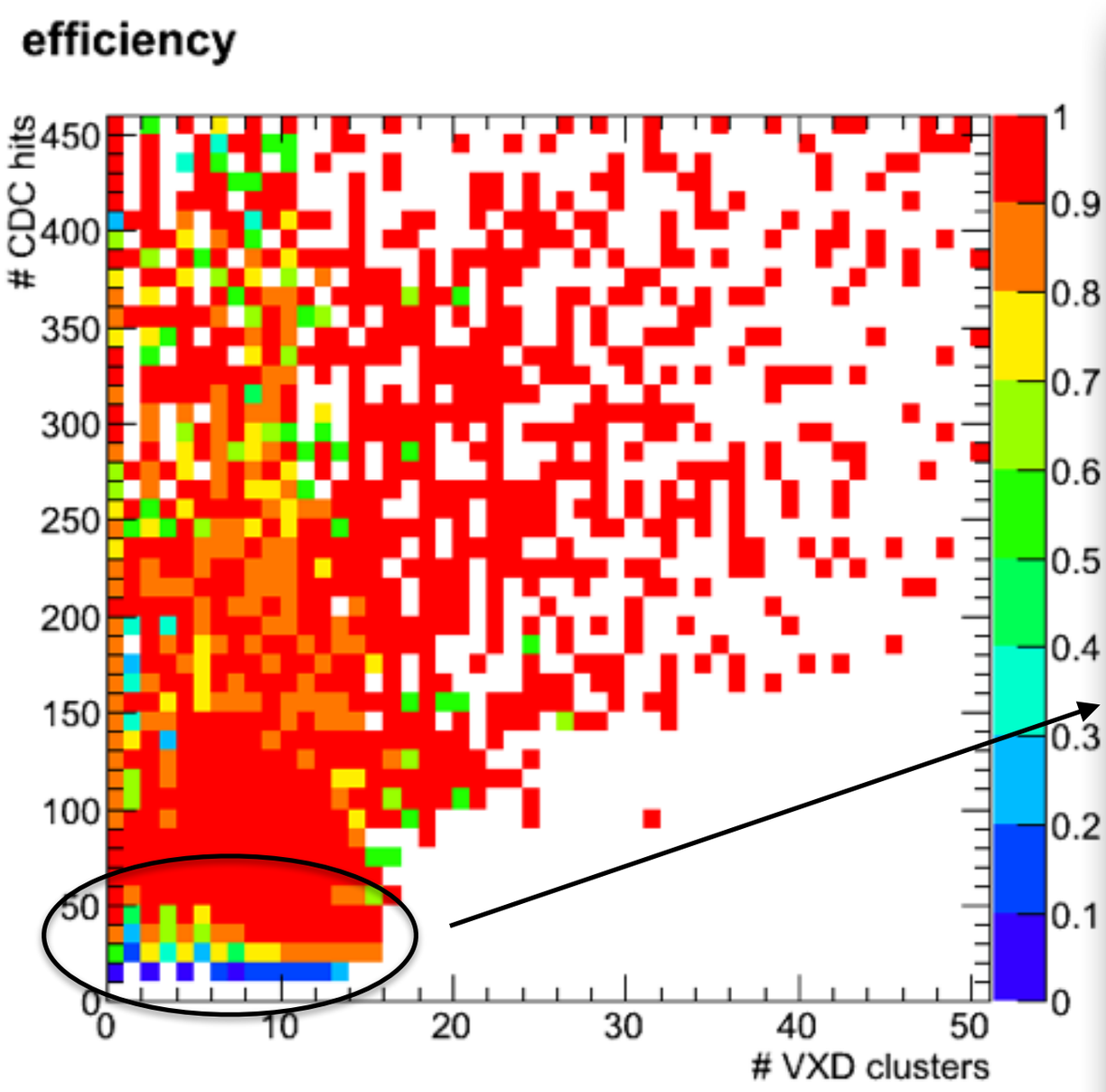
CDC only: CDC hits vs VXD clusters

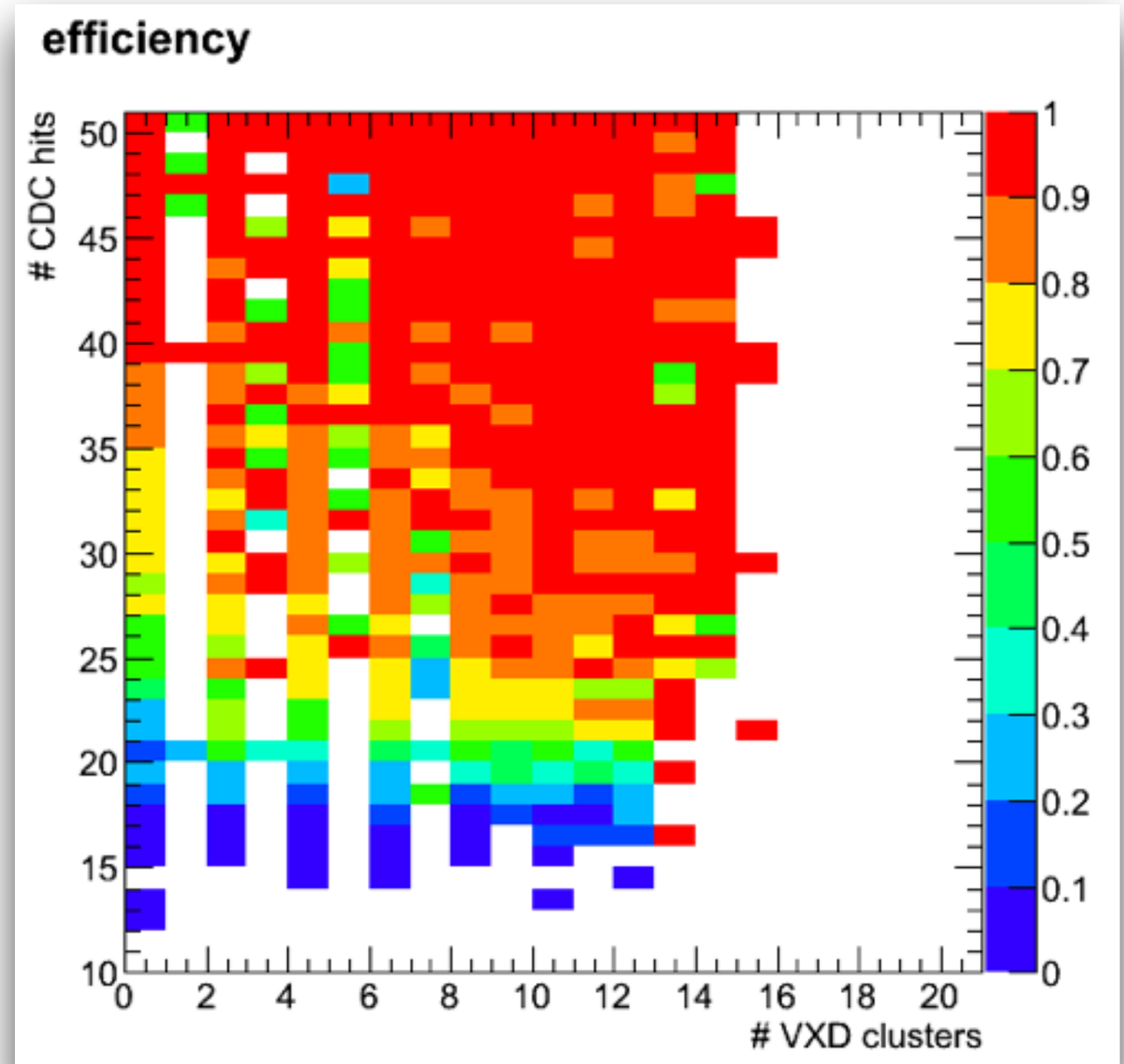




➡ hint of a correlation between CDC hits and VXD clusters?

CDC only: CDC hits vs VXD clusters





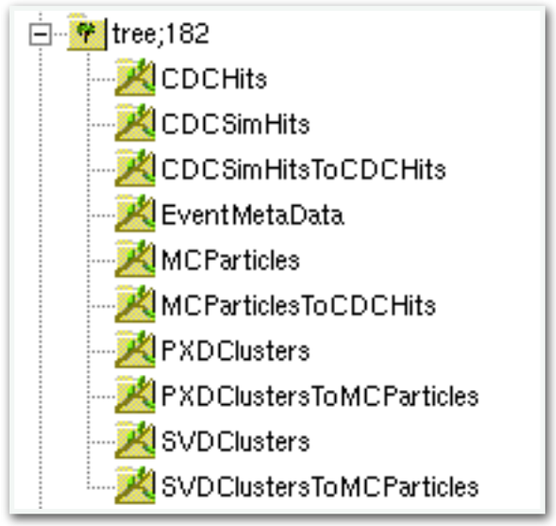
➡ hint of a correlation between CDC hits and VXD clusters?

- in the region # CDC hits < 50 it seems that there is an increase of efficiency for larger number of VXD clusters

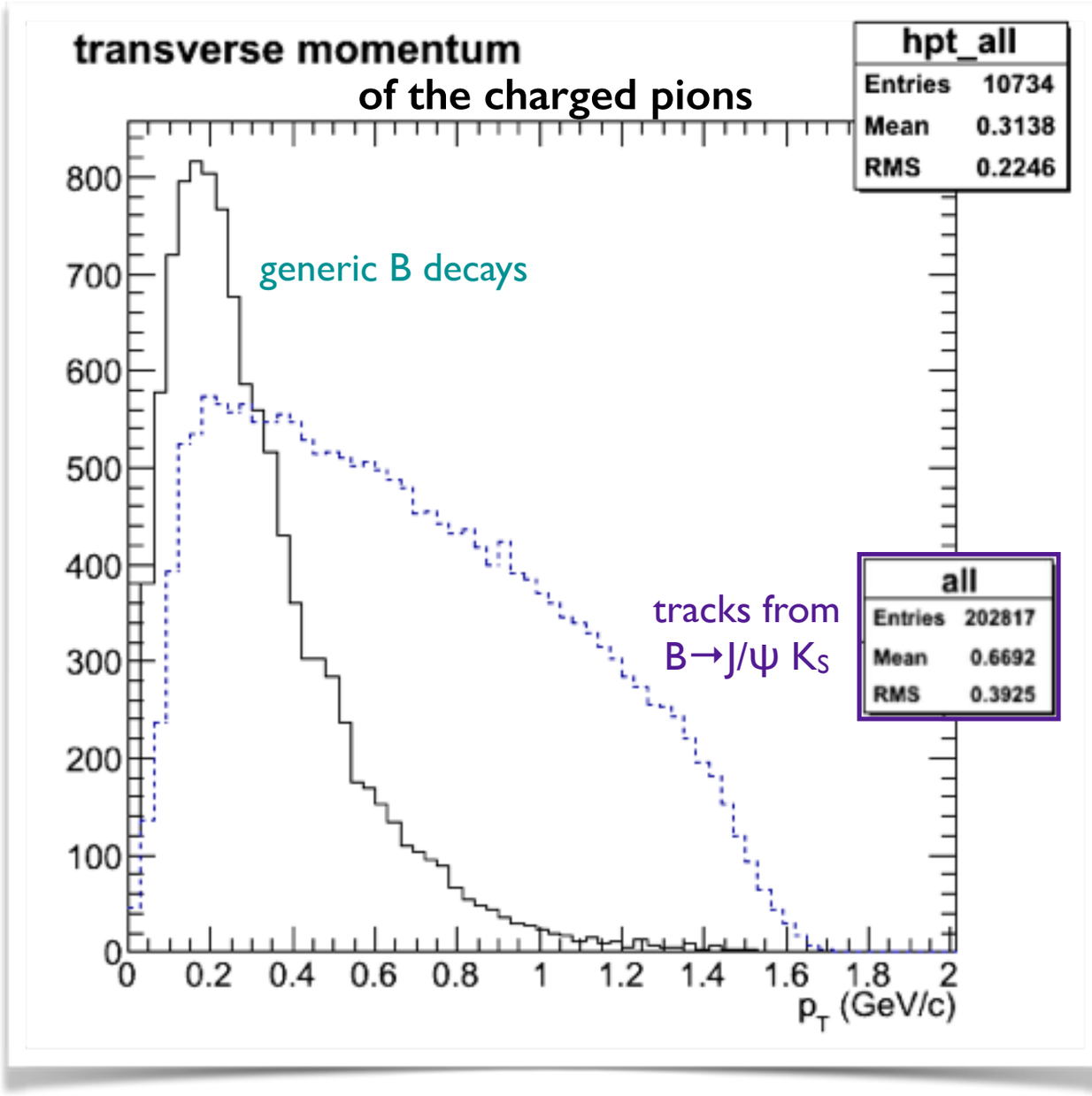
What about K_S from generic B decays?

The Simulation, Reconstruction and Analysis

- used the standard Belle II full simulation, no background simulated
- simulated 10k Generic Υ(4S) events
  - softer transverse momentum distribution
- the output of the simulation is saved in a rootfile and then analysed with different reconstruction algorithms.



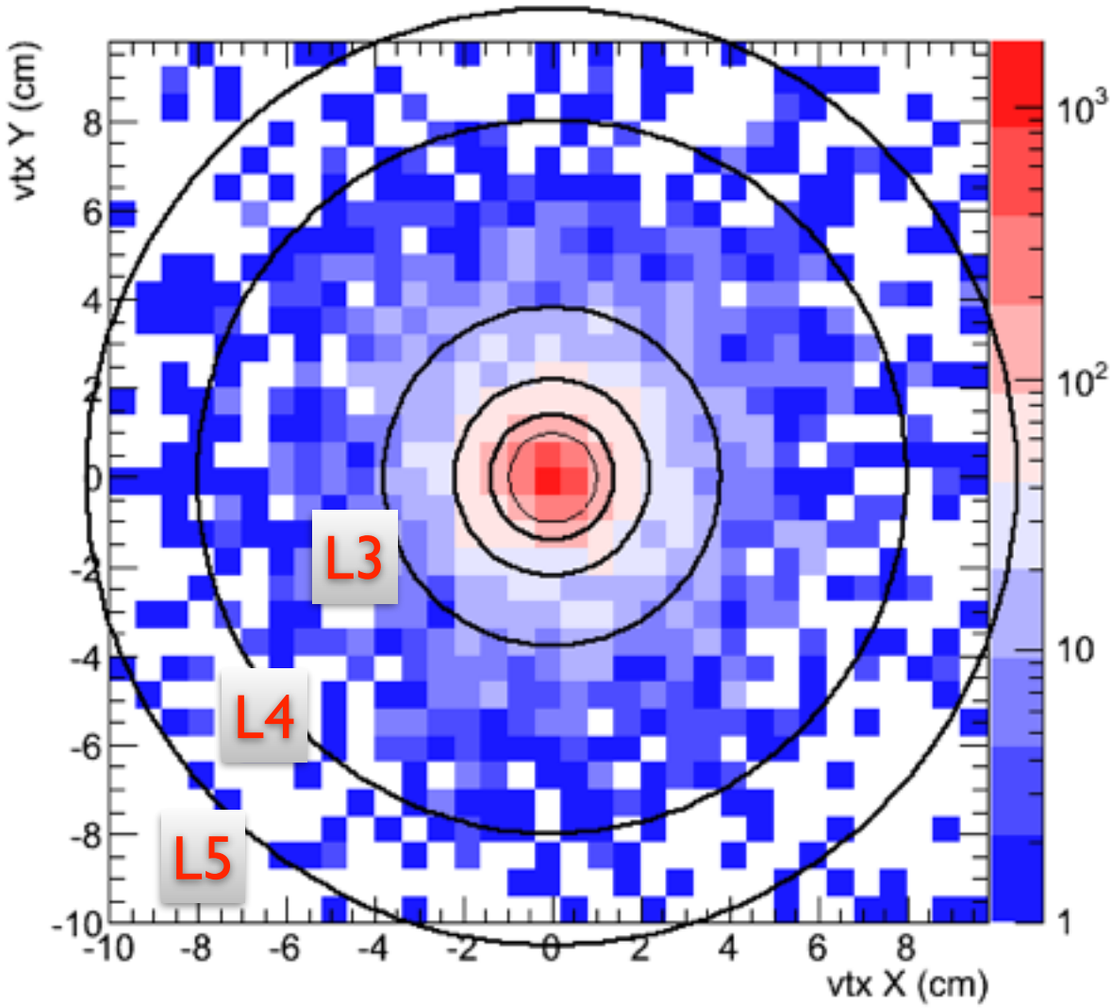
~ 48.5 kb/evt
3.7 Gb on disk



- reconstruction and analysis are unchanged.

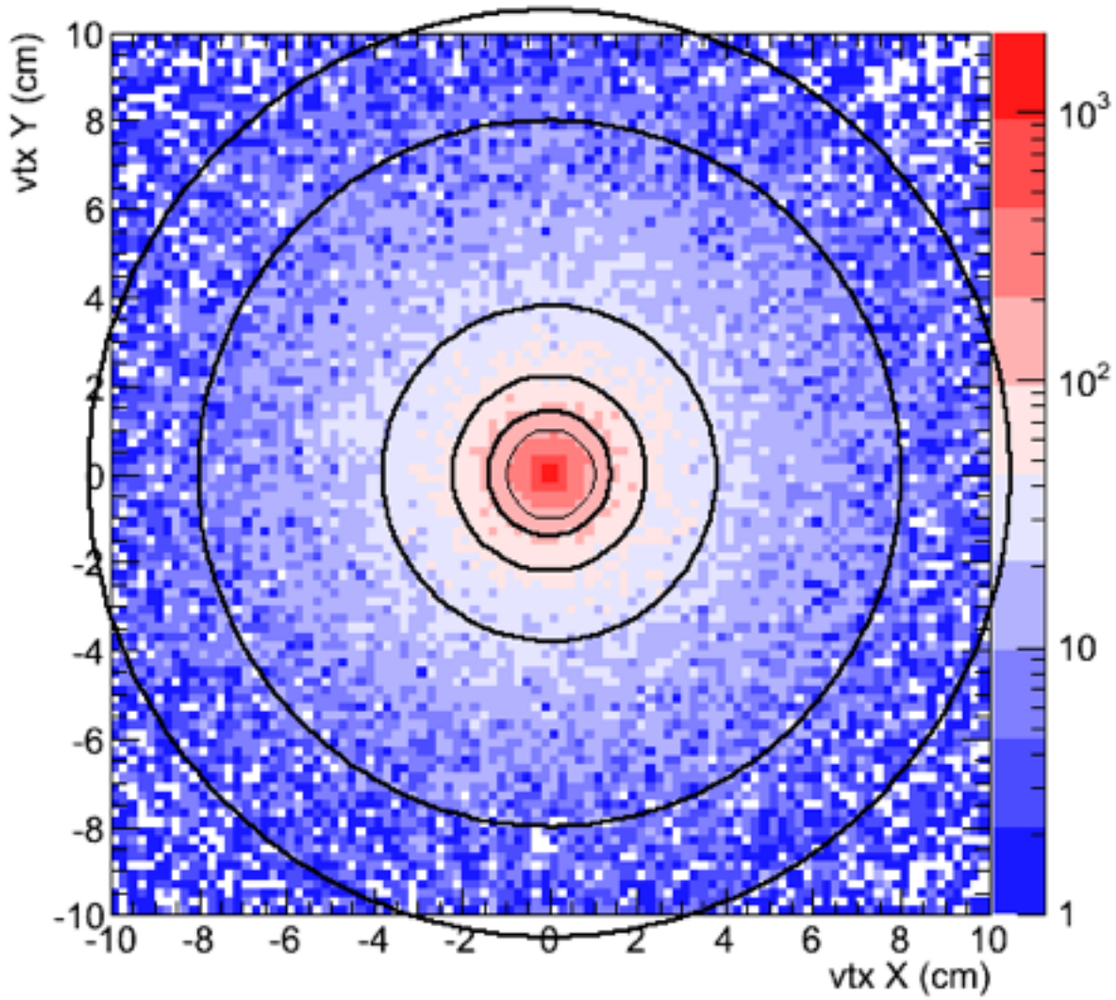
K_S Decay Vertices on the Transverse Plane

K_S from generic B decays:



average K_S transverse flight length = 2.9 cm

K_S from dedicated $B \to J/\psi\ K_S$



average K_S transverse flight length = 7 cm

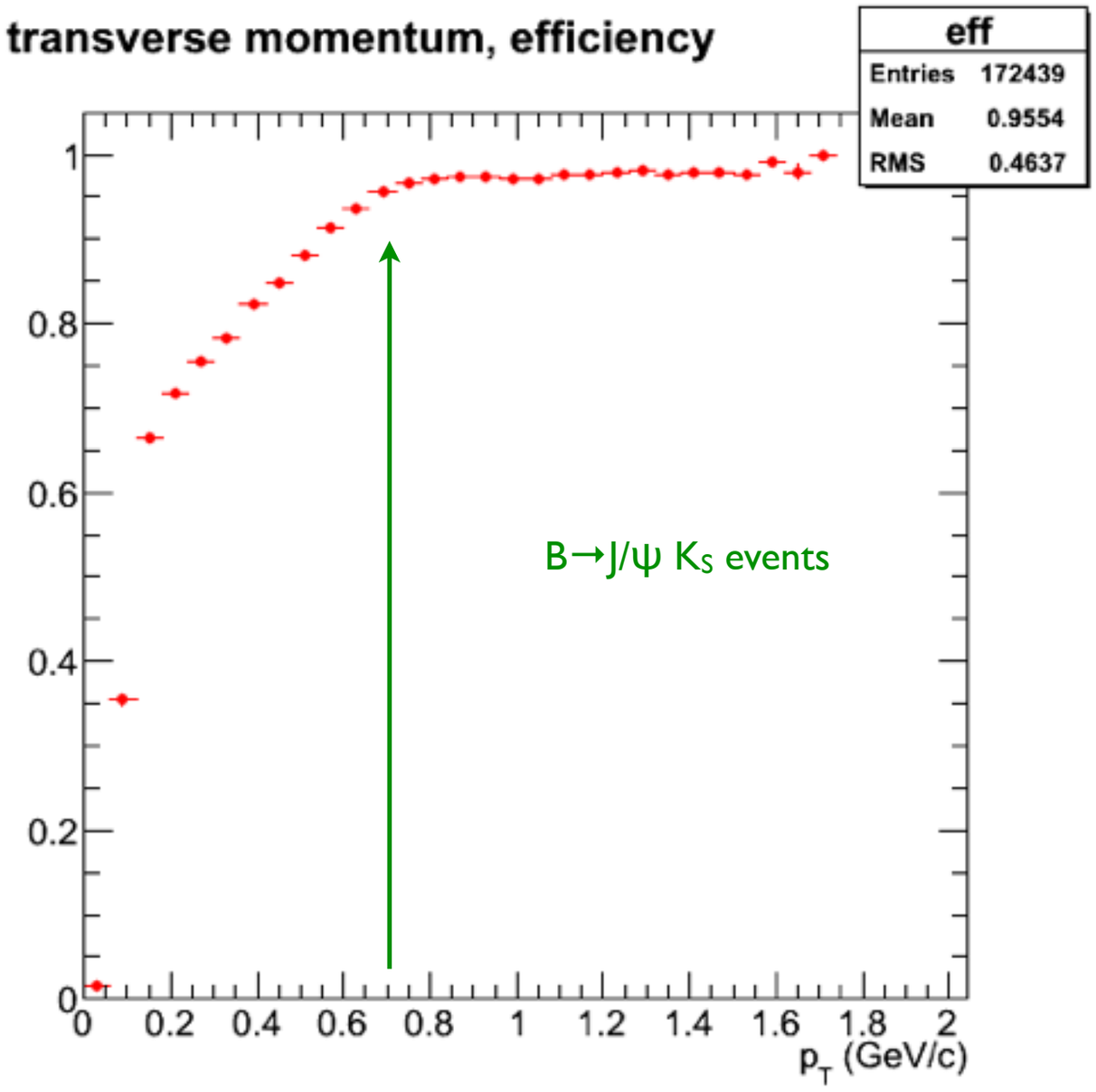
Integrated Efficiencies for Generic B decays

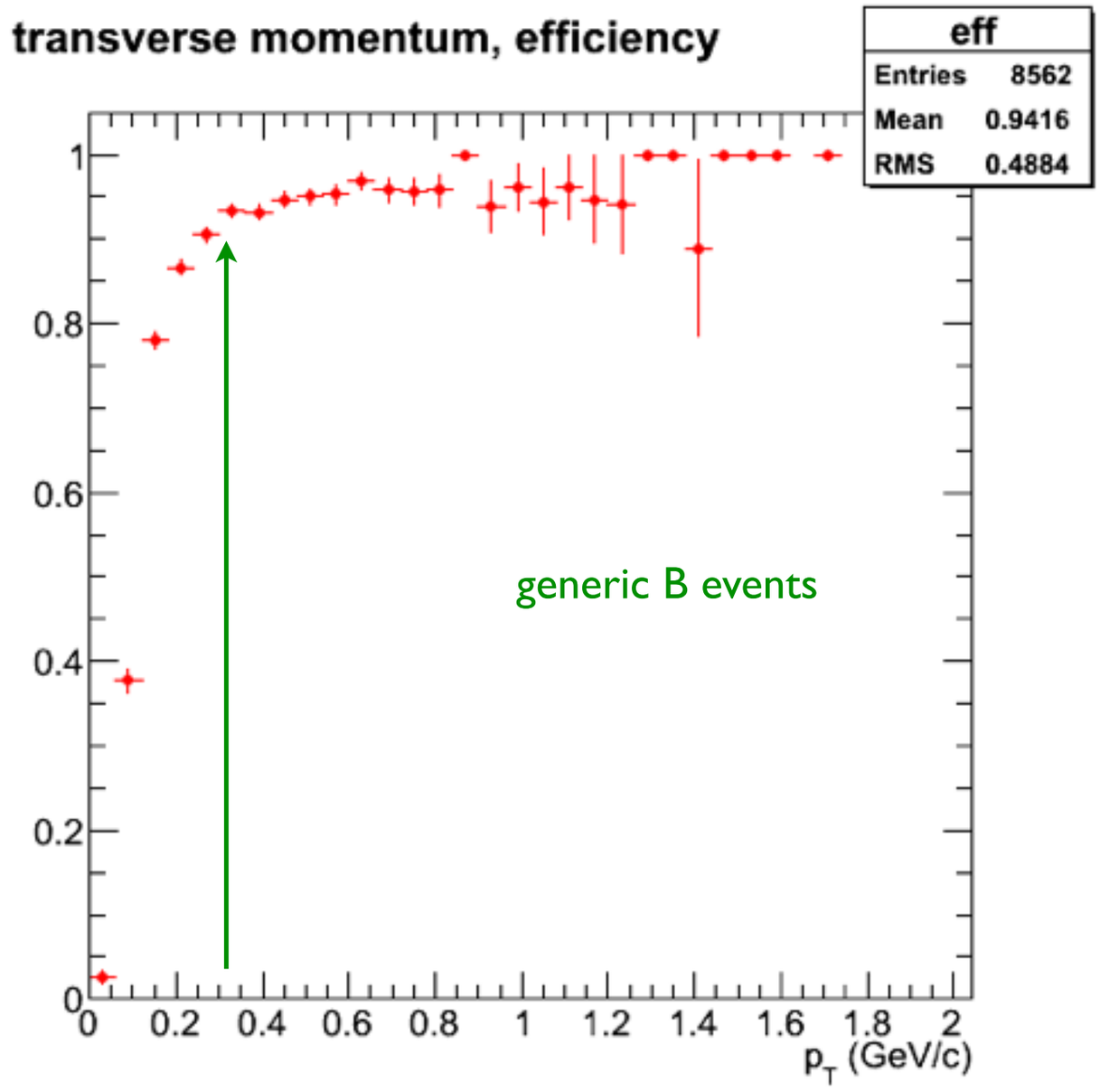
- 10724 simulated charged pions (MCParticle) from K_S decays in generic B decays
- 10242 MC TrackCand, 95.5% of the simulated ones (geometrical acceptance)

pattern recognition →	SVD	VXD	CDC	
TrackCand	49202	54146	184889	$B \to J/\psi K_S$
	4370	5132	10507	generic B decays
PURITY: matched / TrackCand	(99.69±0.03)%	(97.87±0.06)%	(93.24±0.06)%	
	(99.6±0.1)%	(96.1±0.3)%	(81.0±0.4)%	
EFFICIENCY: matched / MCParticle	(24.7±0.4)%	(26.6±0.4)%	(88.63±0.07)%	
	(41±1)%	(46±1)%	(79.4±0.4)%	

- Lower efficiency for the CDC-only tracking, probably due to the softer spectrum of the tracks that also influence the purity
- Higher efficiency for the SVD and VXD tracking, probably due to the shorter average flight length of the K_S

CDC only: transverse momentum





➡ In generic B events the knee comes at lower p_T (300 MeV/c vs 700 MeV/c)

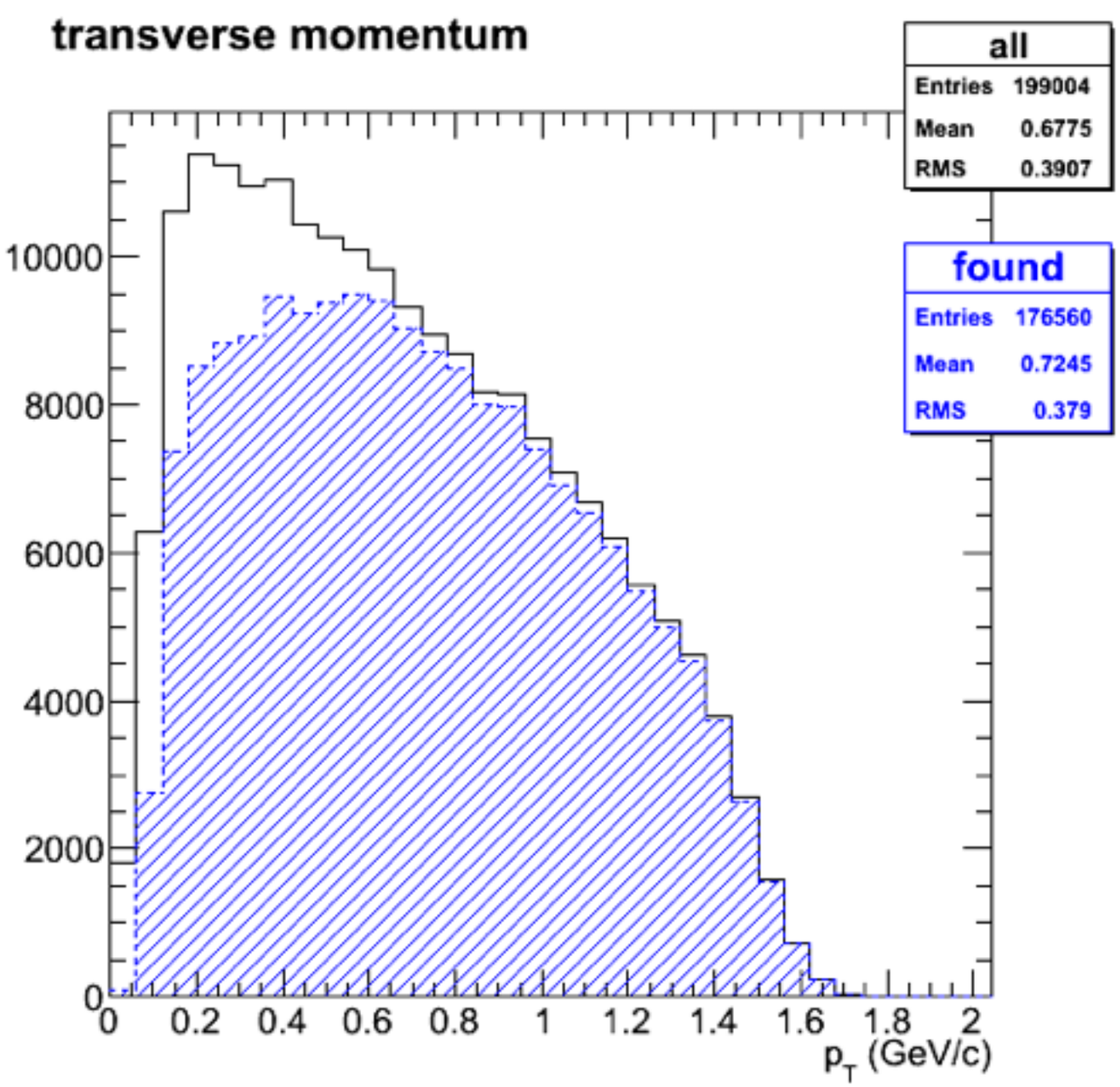
Conclusions & Future Plans

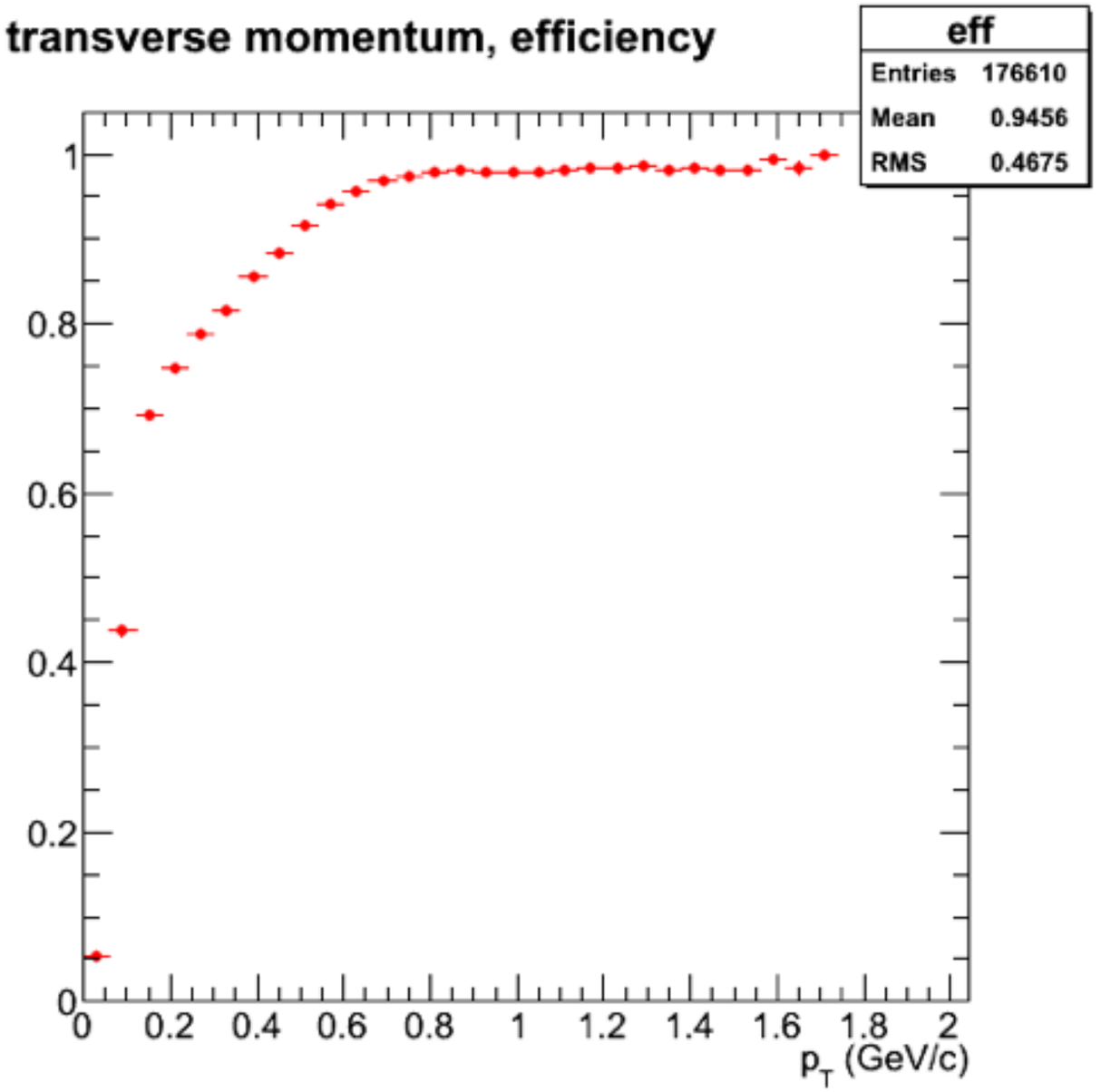
- First results of the have been presented, some features still to be understood
- There is room for improvement in both efficiency and accuracy:
  - improvements of the single track finders
  - track-quality improvement with the addition of VXD hits to CDC tracks (and vice-versa). [to be quantified]
- Repeat the study (reconstruction + analysis) on the same set of simulated events with the improved versions of the tracking package (new CDC TrackFinder, Track Combiner module, …)
- Use the analysis module to perform similar studies on other particular types of tracks:
  - soft pions from D* decays

Thank You!

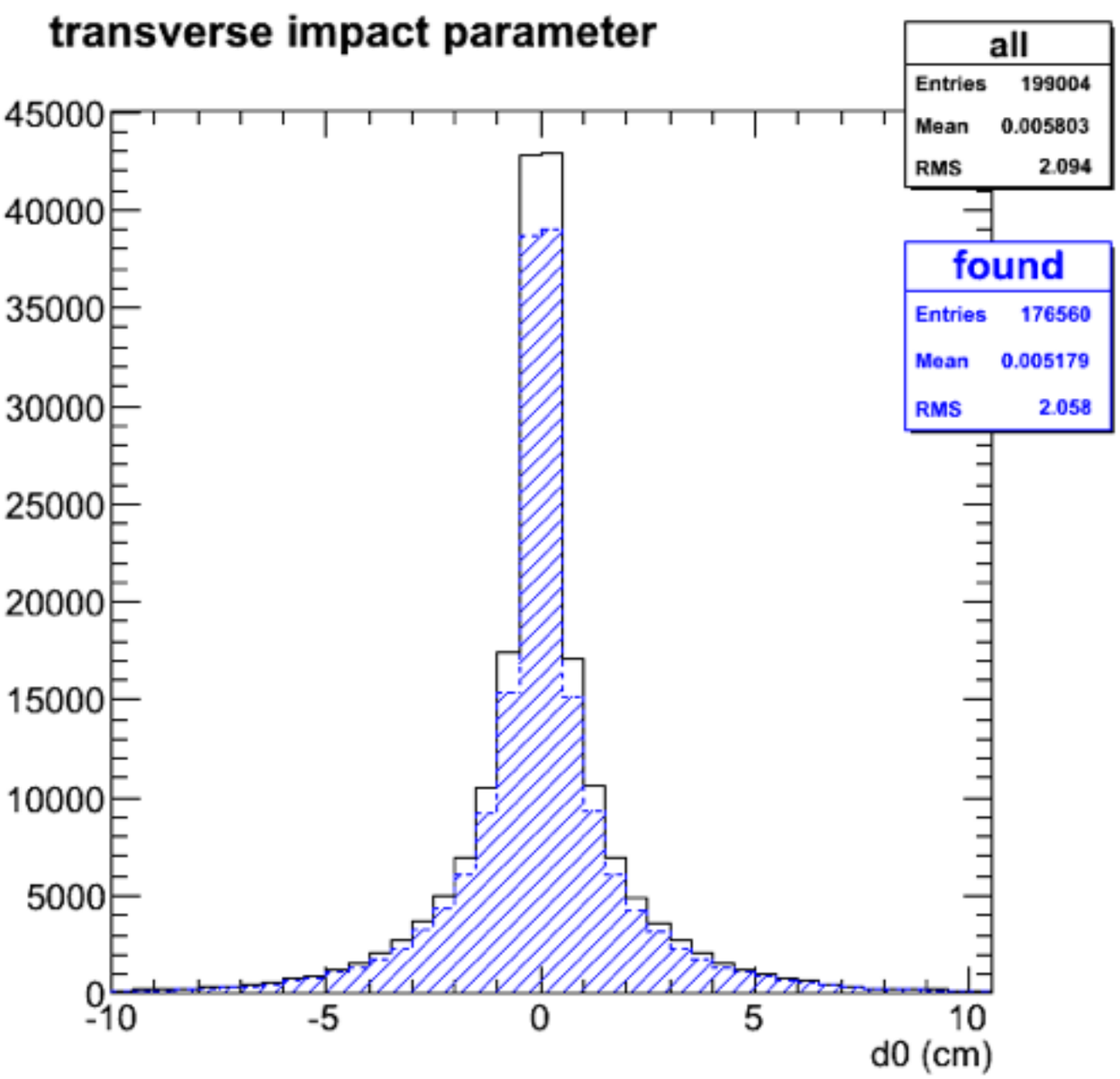
backup slides

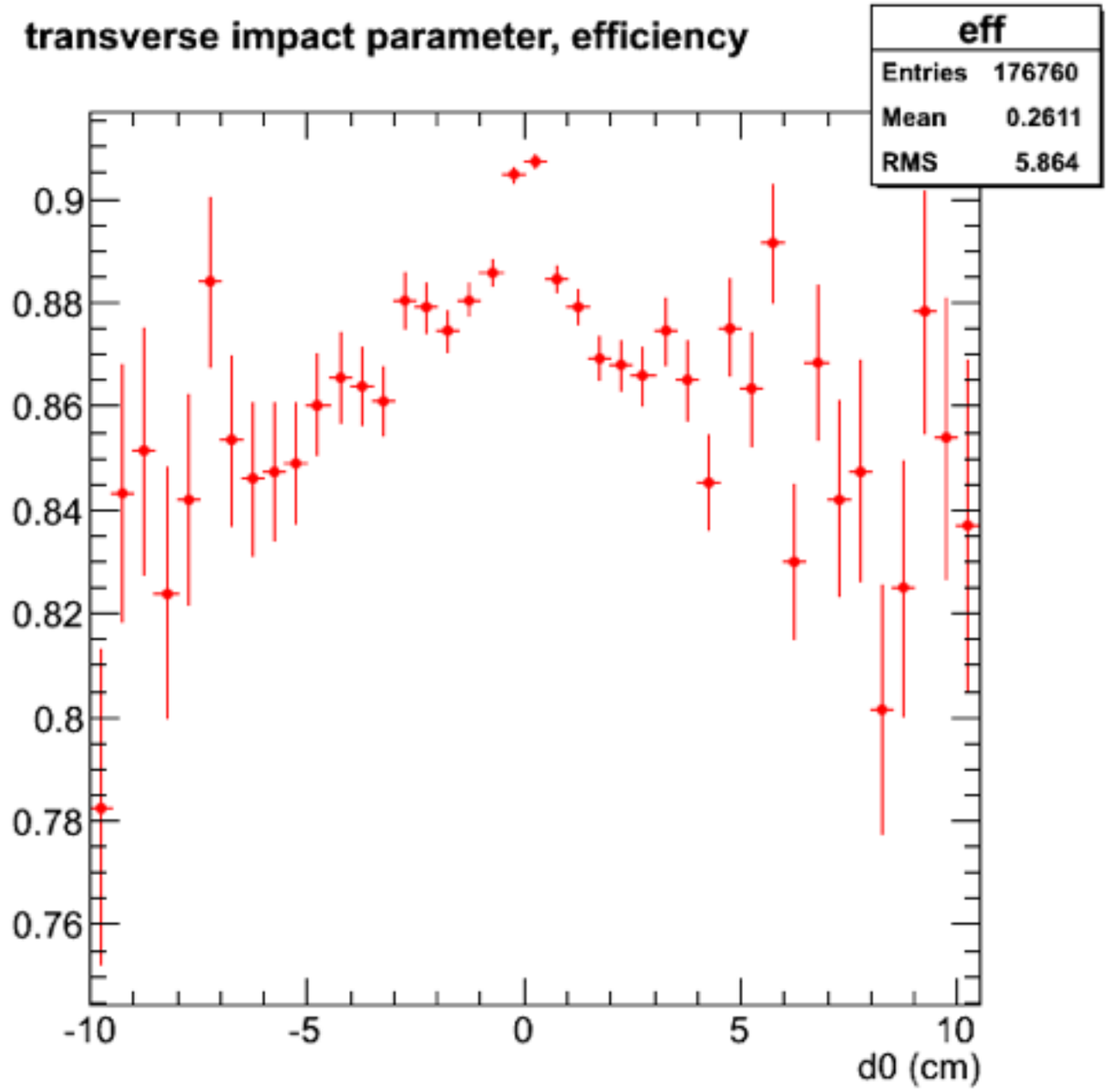
VXD+CDC: transverse momentum





VXD+CDC: transverse impact parameter





VXD+CDC: CDC Hits and VXD clusters

$B \rightarrow J/\psi\ K_S$ events