TRACKING EFFICIENCY DEFINITION

outline

- ★ the problem & the plan
- ★ the idea
- ★ current results
- ★ conclusions

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Belle II Face2Face Tracking Meeting ~ April, 22nd 2015

Definition of the Problem

- ➡ We need to better define our goal in terms of pattern recognition efficiency
- ➡ Not all tracks are the same: there are tracks that are *easy* to find and tracks that are *harder* to find
- ➡ The efficiency that we can reasonably achieve on tracks that are *easy* to find must be higher that the efficiency on tracks that are *hard* to find
- ➡ Let's classify the tracks in three categories:
  - tracks that are *easy to find* → very high efficiency (let's say 1)
  - tracks that are *hard to find* → lower (how much?) efficiency
  - tracks that are *very hard to find* → happier if we find it, happy anyway

The Project

- Develop a module to be placed after the TrackFinderMCTruth that produces 3 subsets of MCTrackCands:
  - tracks easy to find → easyMCTrackCands
  - tracks hard to find → hardMCTrackCands
  - tracks very hard to find → veryhardMCTrackCands
- Estimate our pattern recognition efficiencies on the three lists separately
- The VXD and CDC pattern recognition modules will have separate lists
  - problems for VXD are not the ones of the CDC and vice-versa
  - what is easy to find for the VXD can be hard for the CDC and vice-versa
- The question is: how do we decide to which category a track belongs
  - I've first focused on the VXD

TrackFinderMCTruth (1)

current PR efficiency definition:

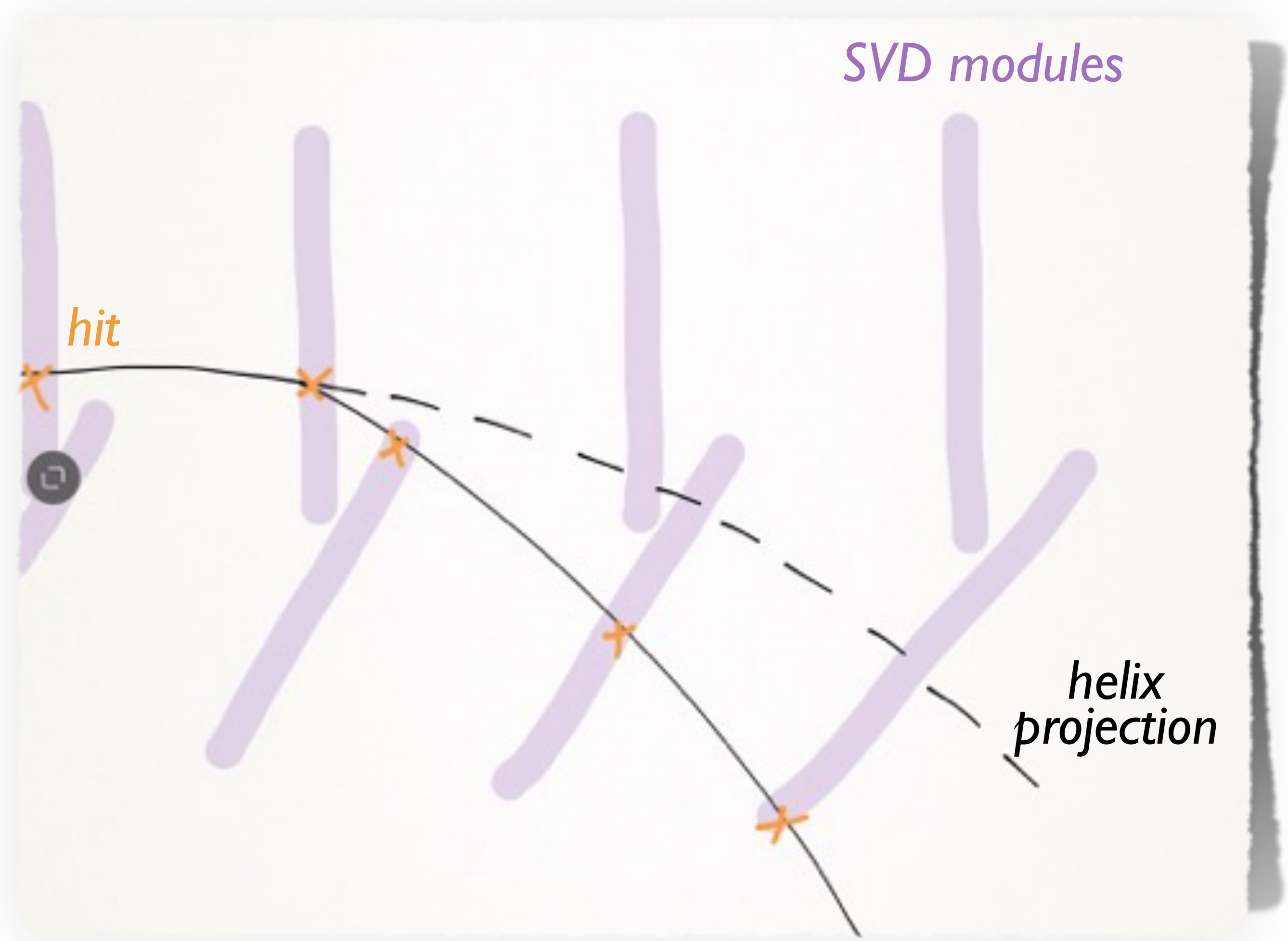
$$\varepsilon_{PR} = \frac{\text{\# MCTrackCand with at least one associated TrackCand}}{\text{\# MCTrackCand}}$$

TrackFinderMCTruth:

- ✓ factors out geometrical acceptance
- ✓ factors out detector inefficiencies
- ✓ requires a minimum number of hits
- ✓ (set relations with MCParticles)

BUT it does not handle:

- kinks & large multiple scattering
- tracking volume covering only partially the helix
- hits in both outgoing and ingoing helix arms



TrackFinderMCTruth (2)

current PR efficiency definition:

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

TrackFinderMCTruth:

- ✓ factors out geometrical acceptance
- ✓ factors out detector inefficiencies
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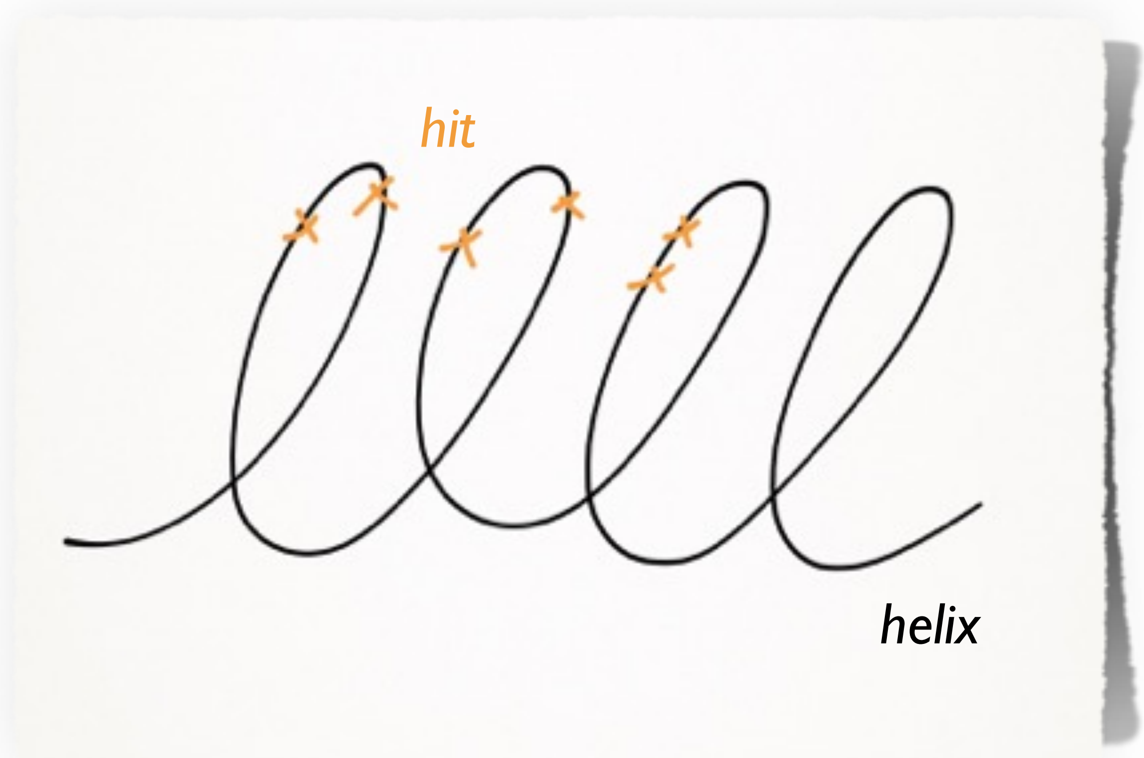

TrackFinderMCTruth (3)

current PR efficiency definition:

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TrackFinderMCTruth:

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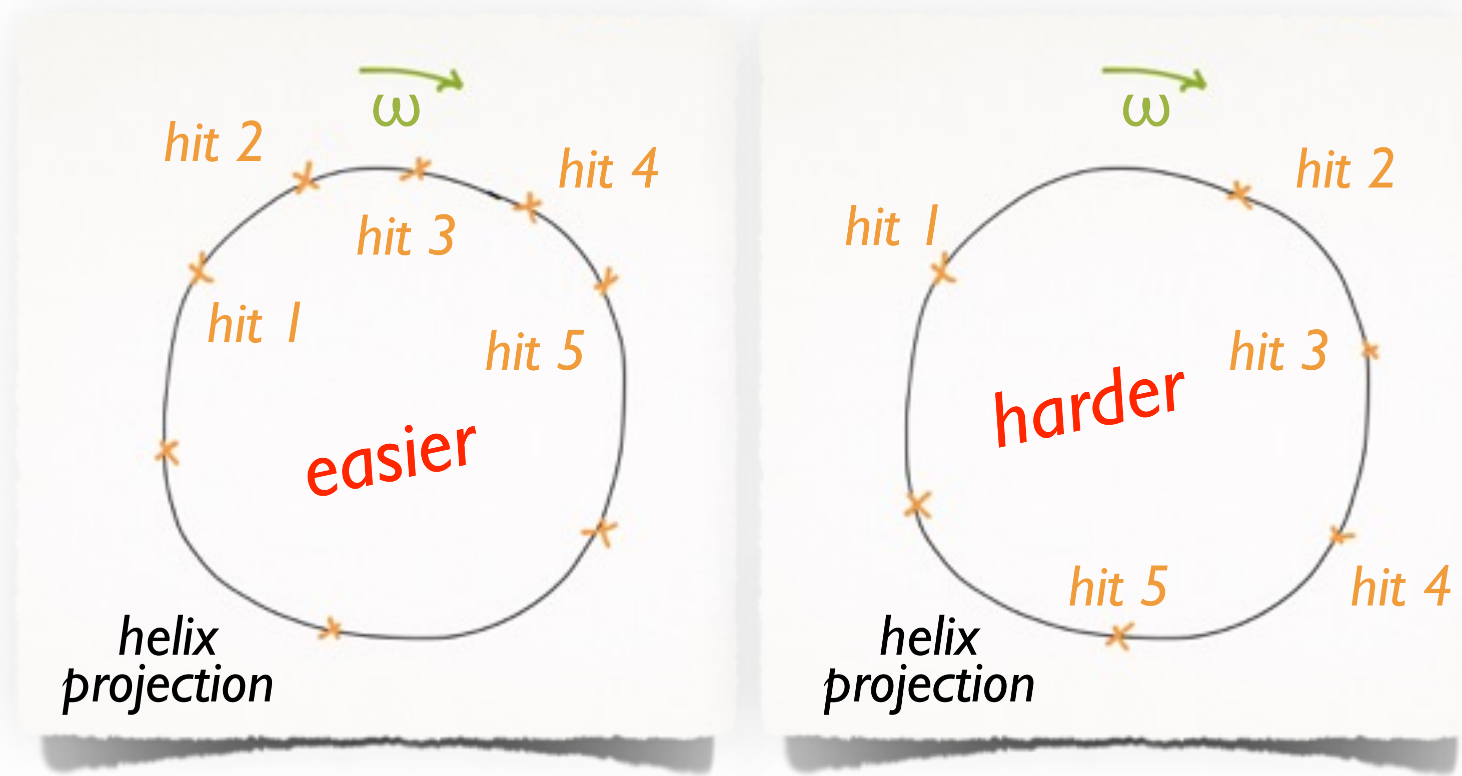
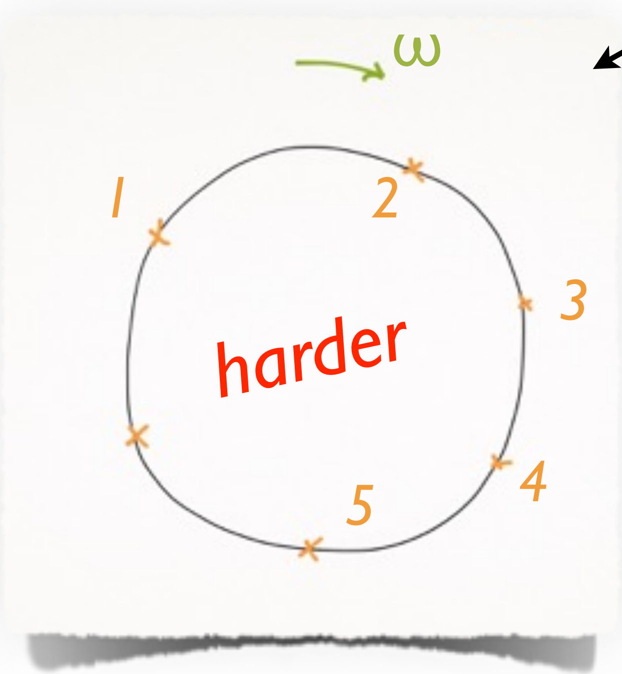
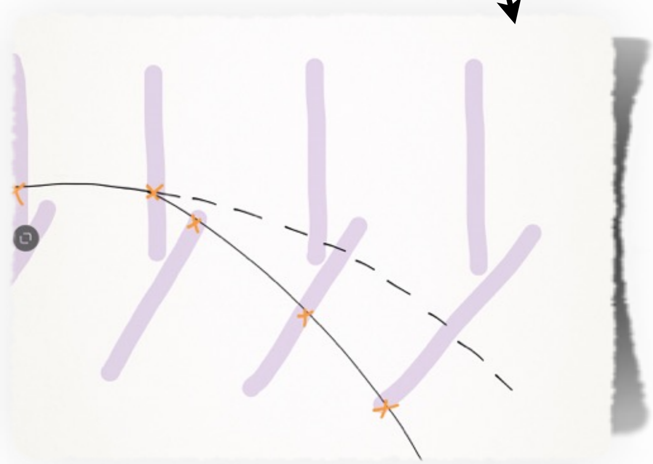
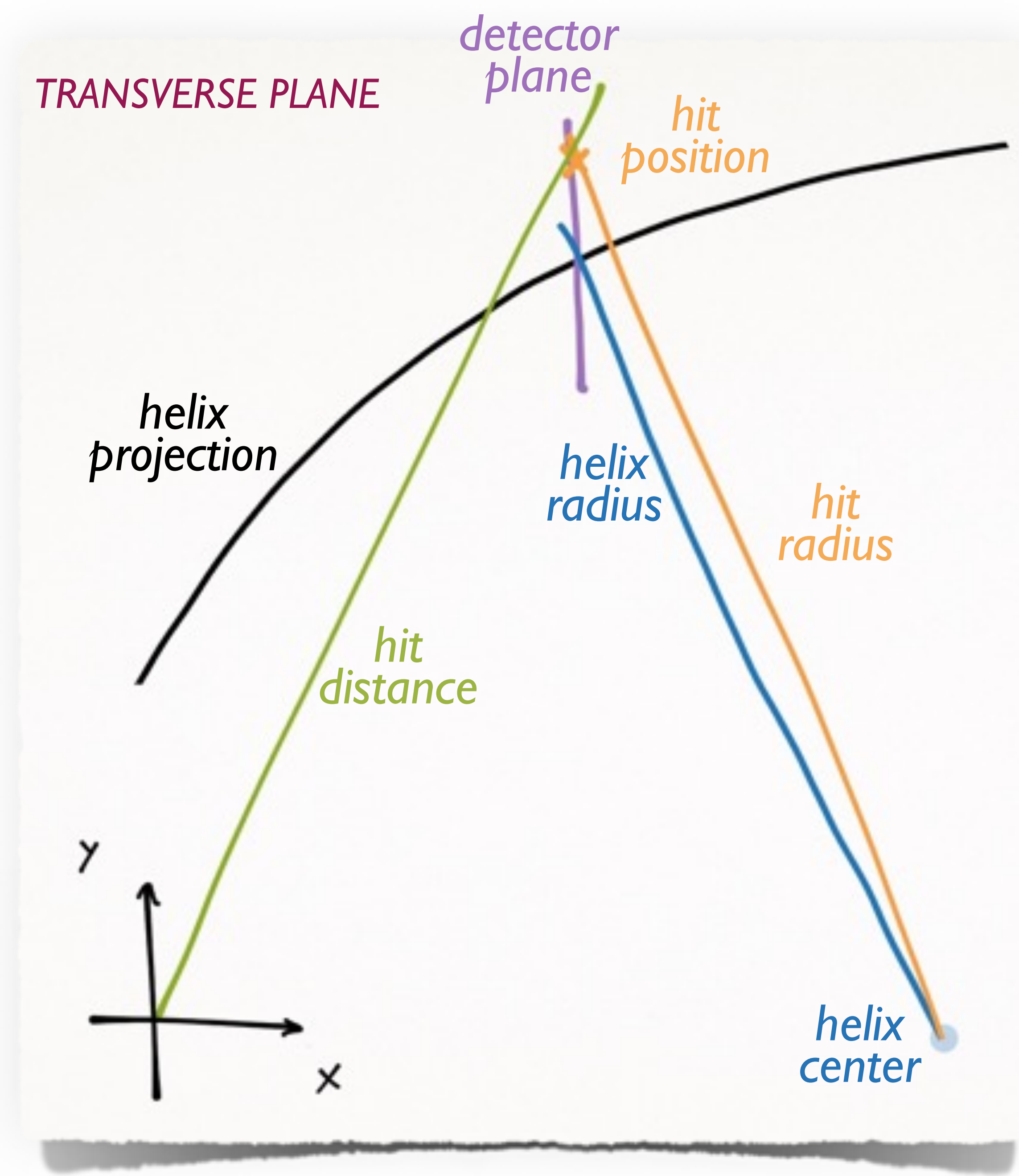


Current Status

- ➡ There maybe other classes of "MCTrackCands that are not easy to find"
- ➡ I have developed 2 criteria to reject non-easy-to-find MCTrackCands shown in the previous slides







- ➡ NOTE: the geometry of the problem is complicated, but I have tried to limit the numbers of degrees of freedom:
  - work on the transverse plane
  - hit position (distance from helix center and from 0,0)
  - helix radius
  - MCParticle informations

Criteria #1

- ➡ predict the position of the next hit on the expected detector plane, taking into account multiple scattering

$$\theta_{MS} = \frac{13.6\ \mathrm{MeV}}{\beta c p} Z \sqrt{\frac{X}{X_0}}$$

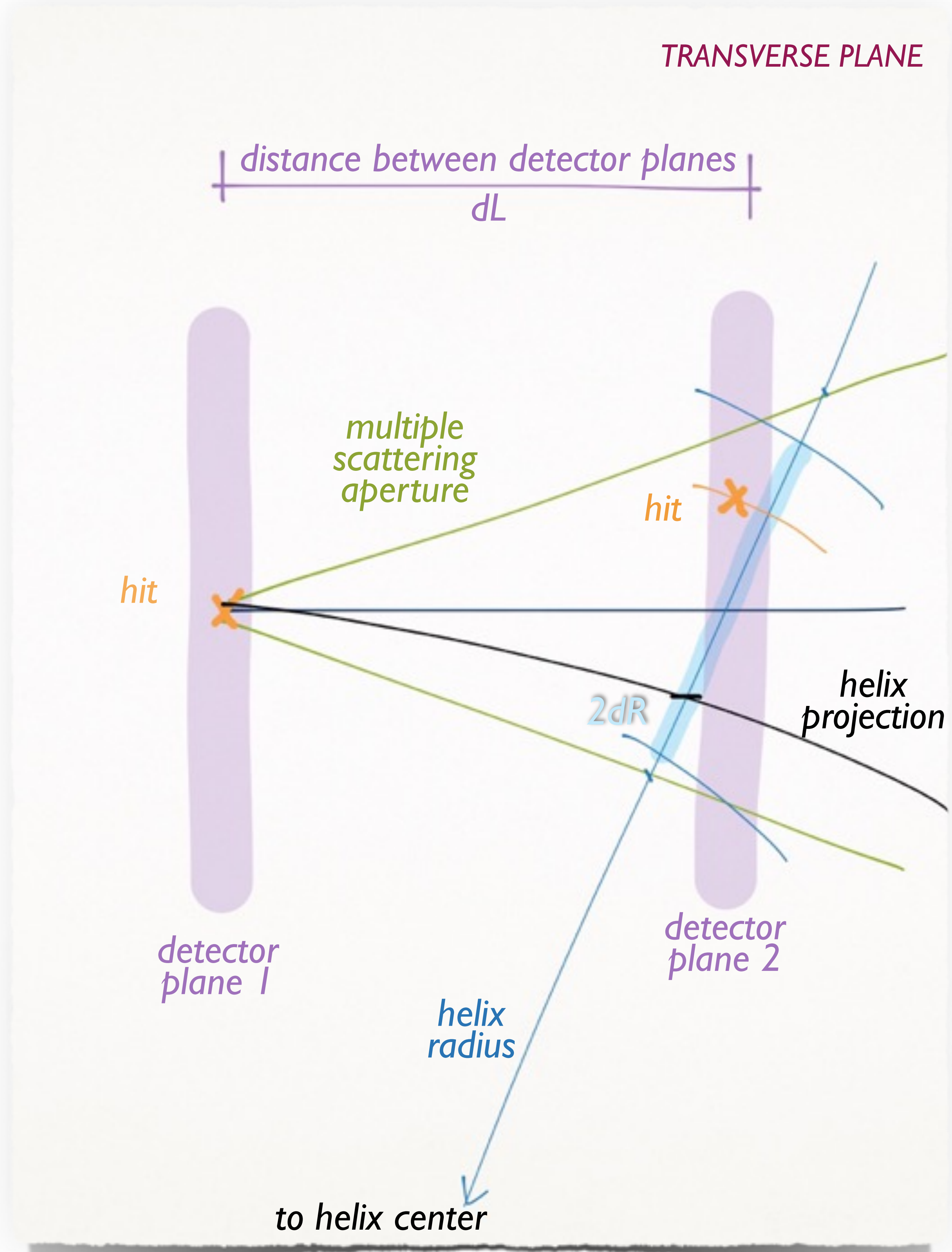
- ➡ project the region where the next hit is expected along the helix radius

$$dR = n\ dL\ \theta_{MS}$$

- ➡ check if the next-hit distance from the helix center (d) lies in the expected region

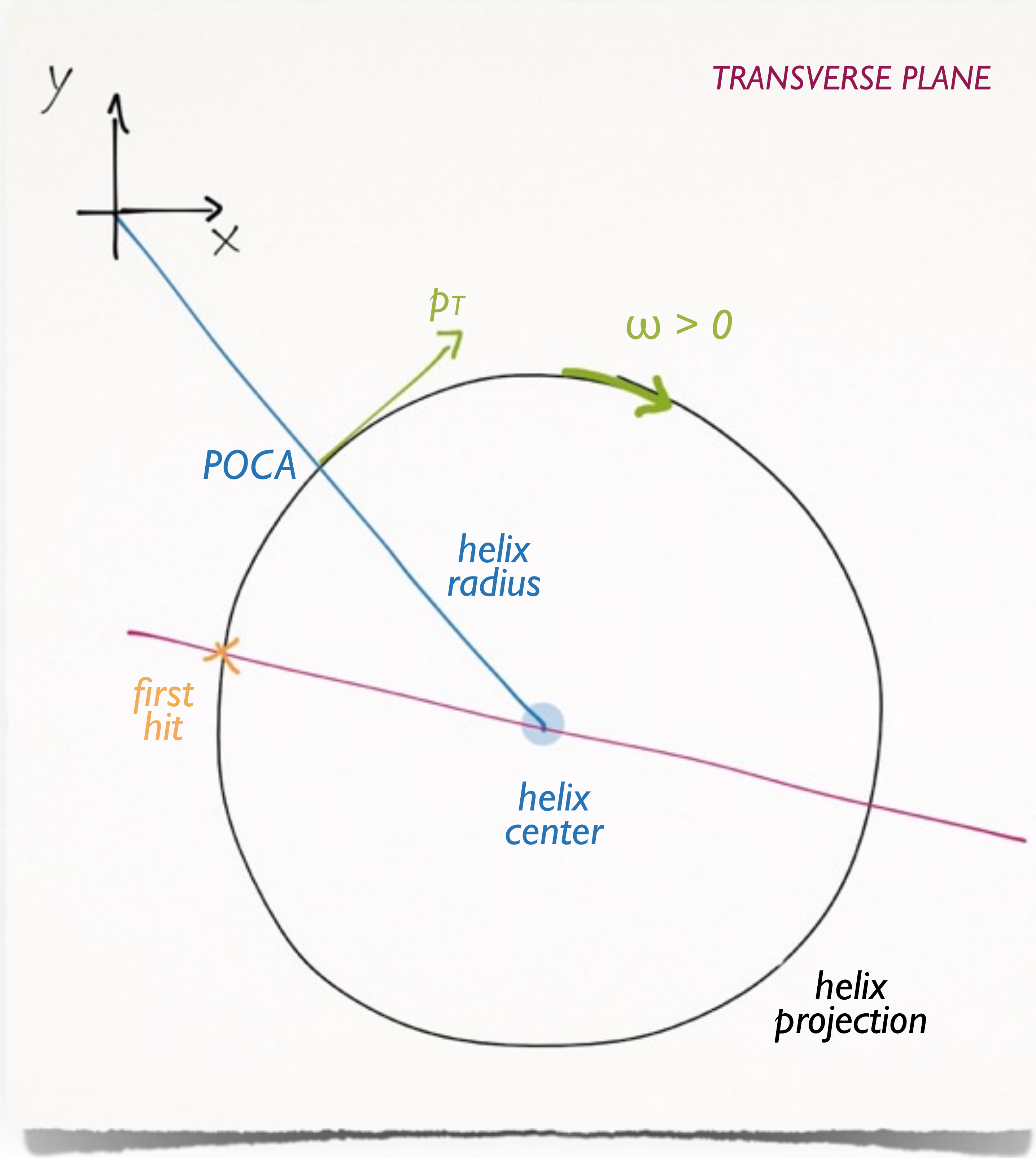
$$|d - R| < dR$$

- ➡ If the hit satisfies the criteria, check the next criteria (next slide), otherwise move to the next MCTrackCand



Criteria #2

- ➡ divide the transverse plane into 2 regions given the first hit and the p_T at POCA
- ➡ given the curvature ω and the relative position between the first hit and the helix center, predict the semi-plane where the next hit is expected to be
- ➡ if the next hit belongs to the expected semi-plane, accept the hit and move to the next one (criteria #1), otherwise move to the next MCTrackCand

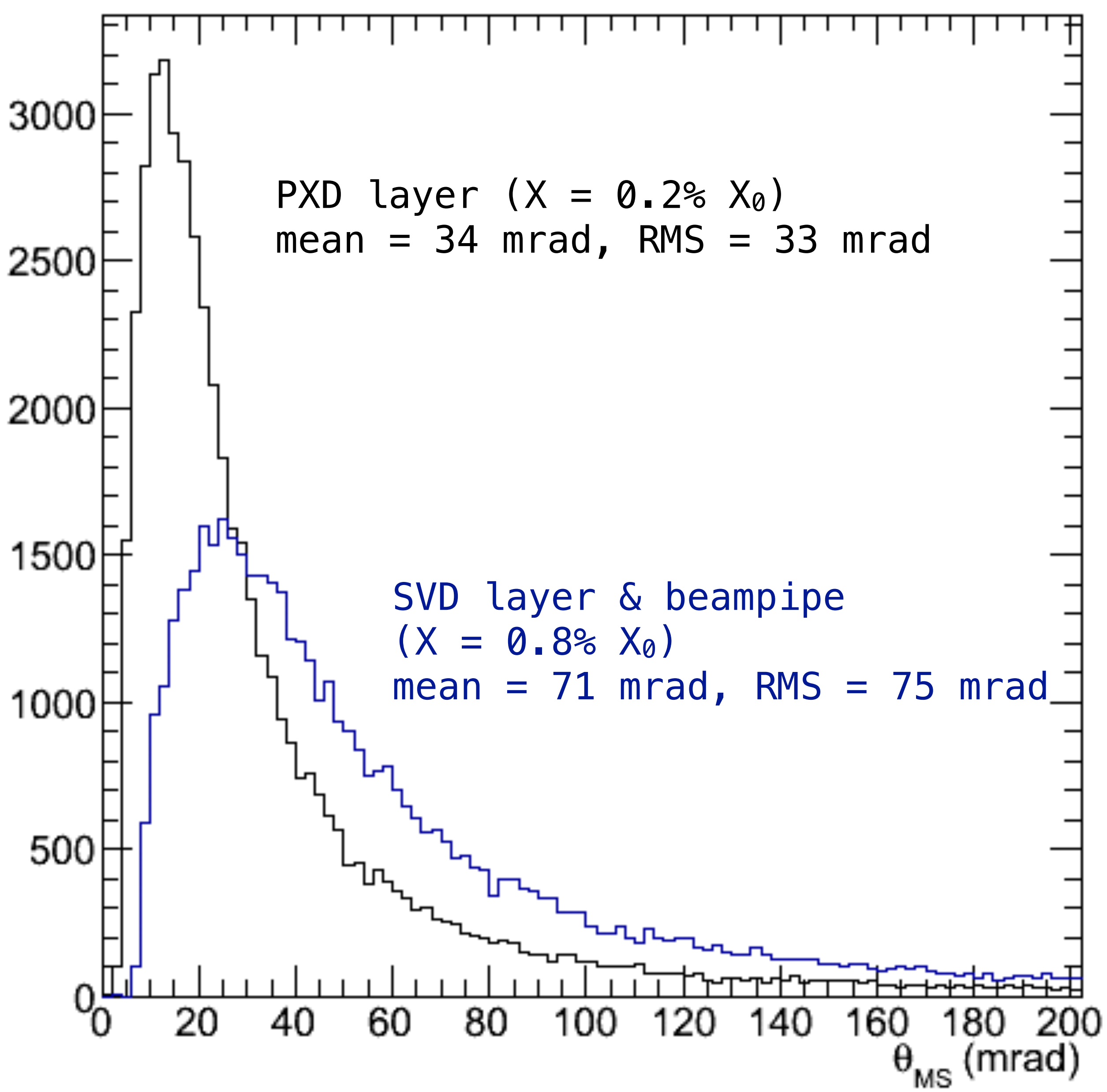


Selection Sequence

- ➡ TrackFinderMCTruth produces the list of MCTrackCands
  - use PXDHits and SVDHits
  - do not use clusters
  - minimum number of one-dimensional hits = 5
- ➡ retrieve the MCParticle related to the MCTrackCand (needed to compute helix radius and θ_{MS})
- ➡ Loop on the TrueHits (PXD and SVD):
  - if the TrueHit satisfies criteria#1 *and* criteria#2 → the hit is accepted
  - otherwise → the hit is rejected & move to the next MCTrackCand
- ➡ If at least 5 TrueHits are accepted → MCTrackCand is classified as *easy-to-find* (easyMCTrackCand)

Multiple Scattering Angle

distribution of θ_{MS} for generic Y(4S) events

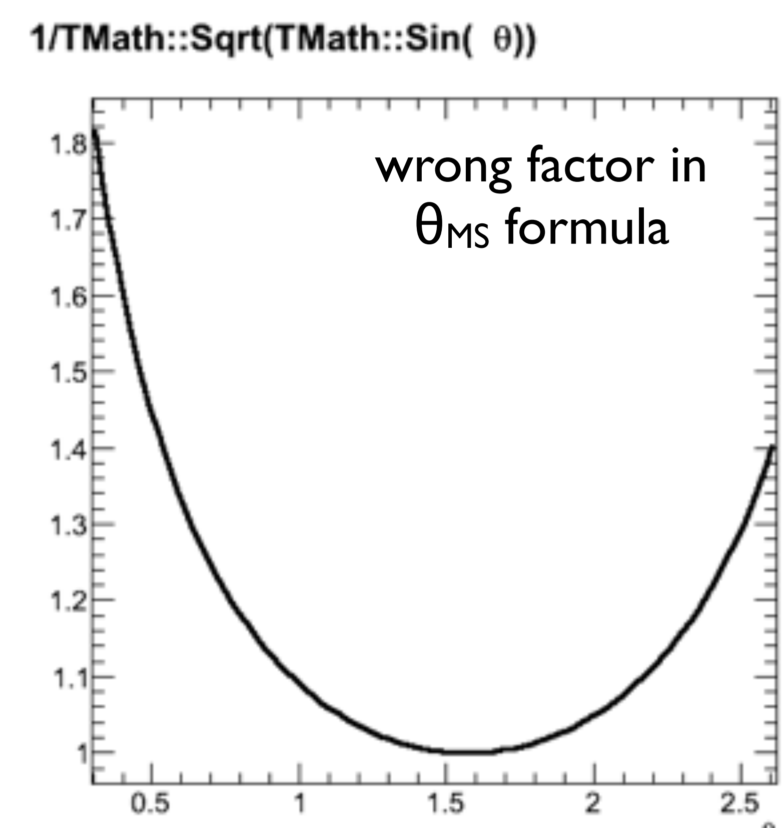


the distribution is ~right within a factor 2 in θ_{MS}.

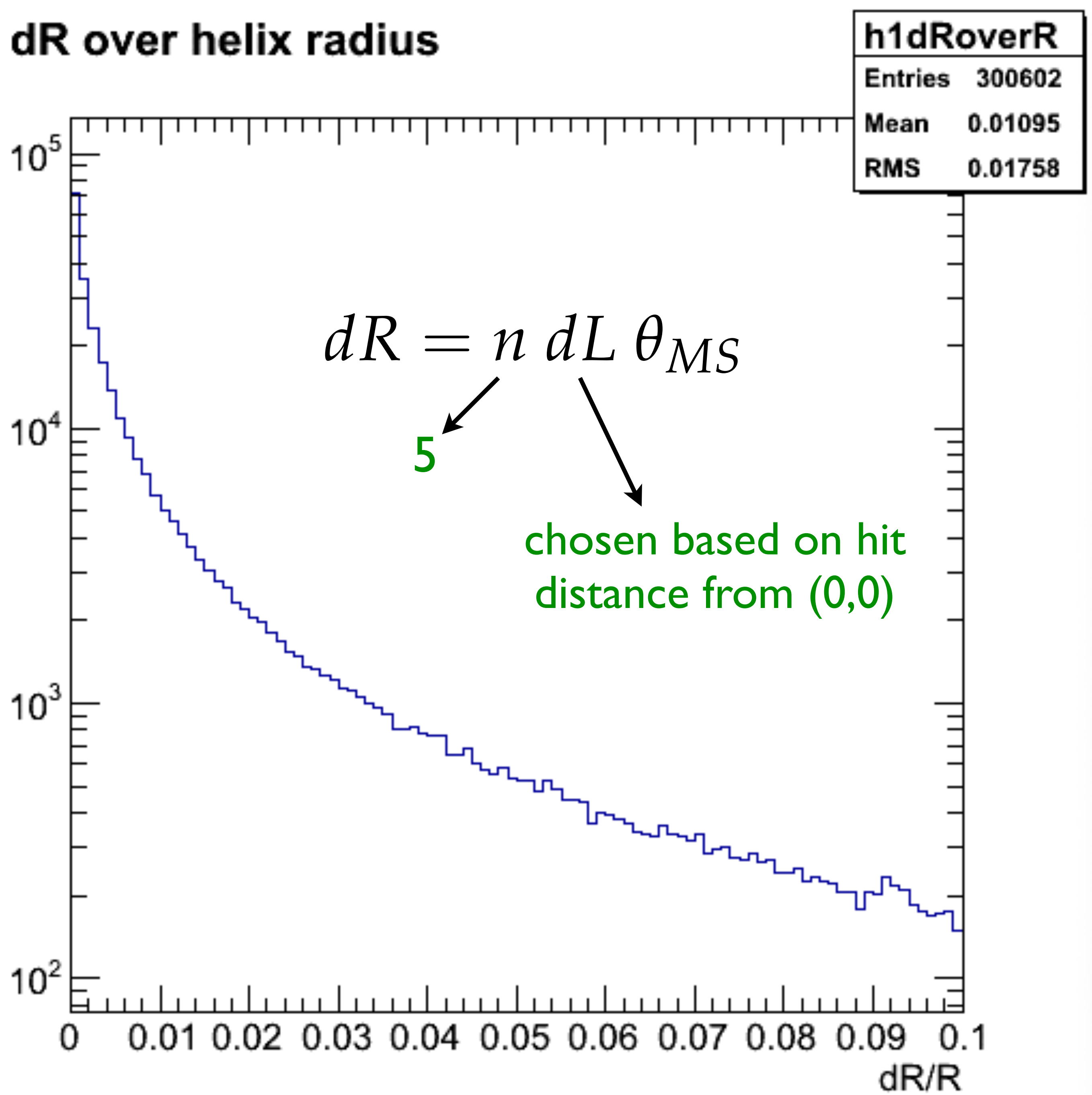
➡ MS angle is computed as

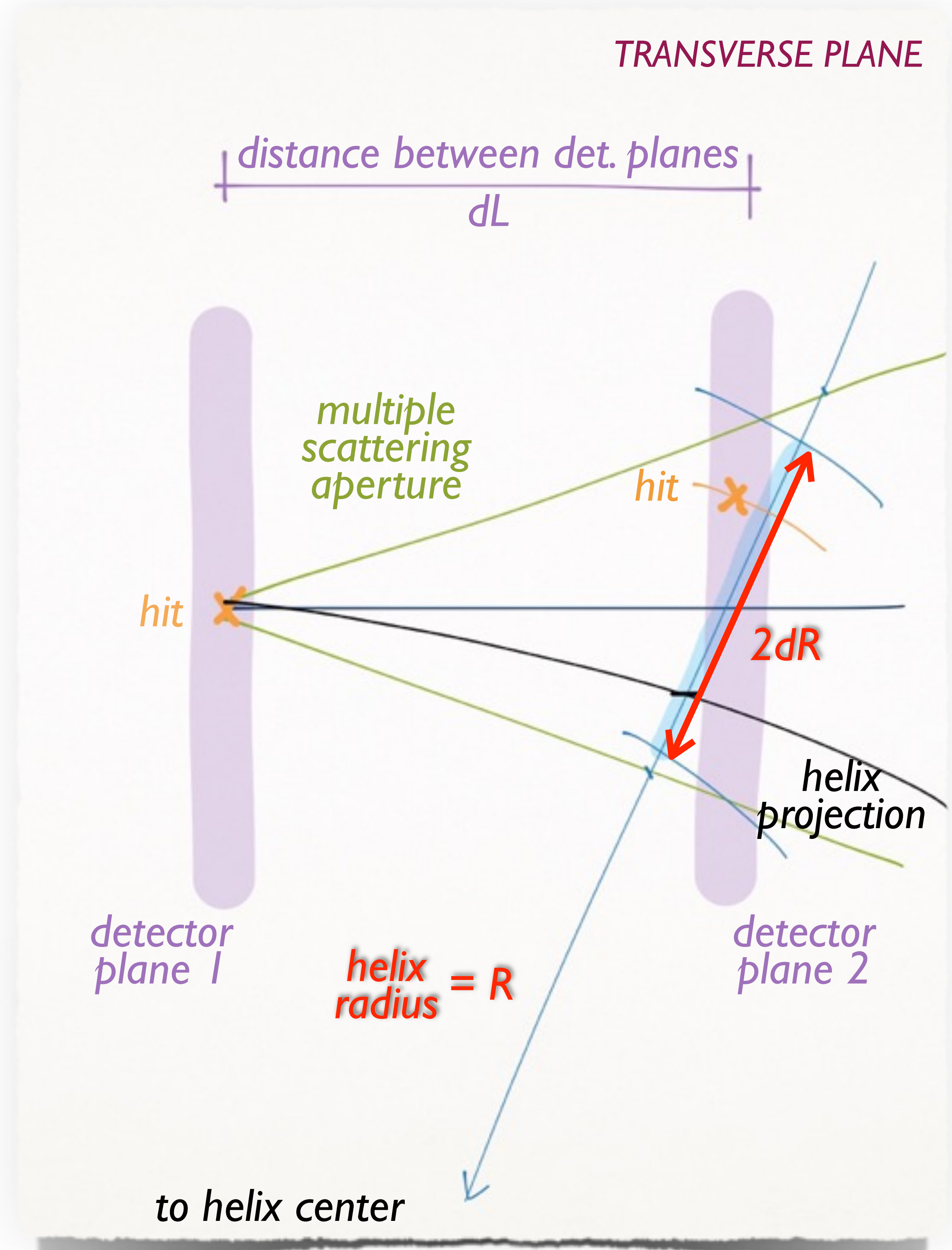
$$\theta_{MC} = \frac{13.6\text{MeV}}{\beta c p_T} Z \sqrt{\frac{X/\sin\theta}{X_0}}$$

➡ polar angle correction is wrong in this study: θ is computed at the vertex, it's not the incident angle on the detector plan



Multiple Scattering Effect

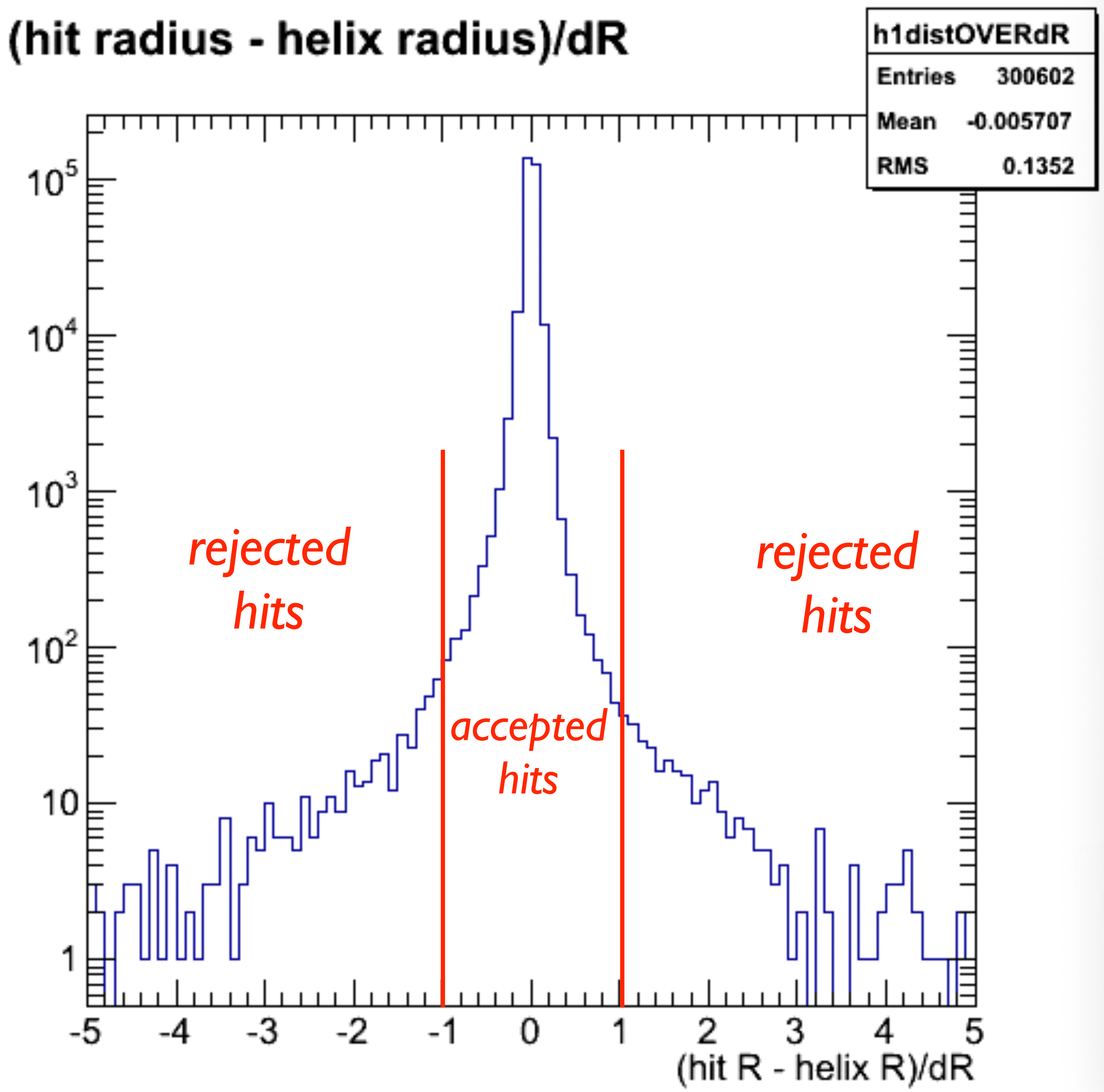


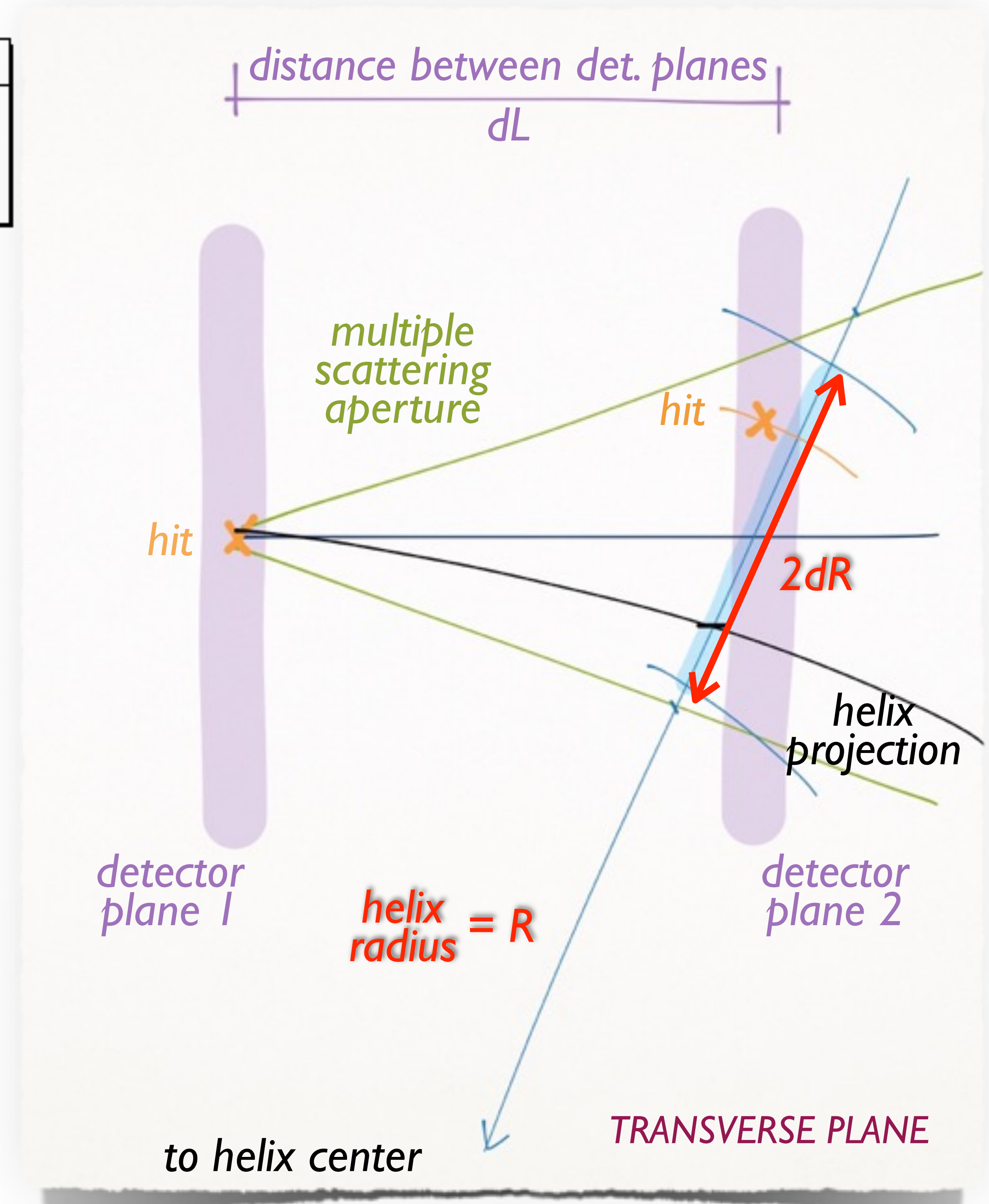


➡ Multiple Scattering perturbs the helix by 1% on average

Criteria #1 at work

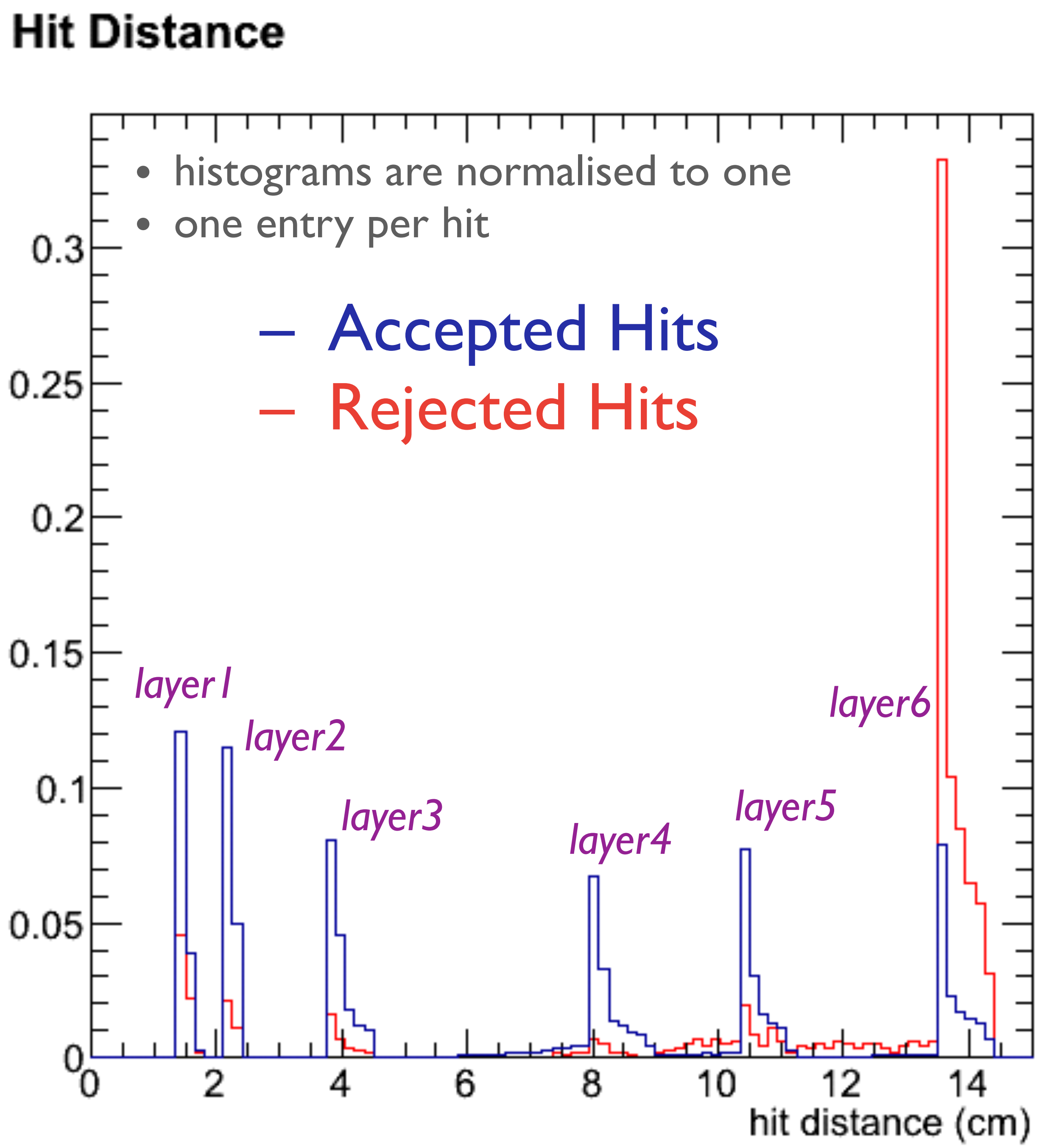
$$|d - R| < dR$$

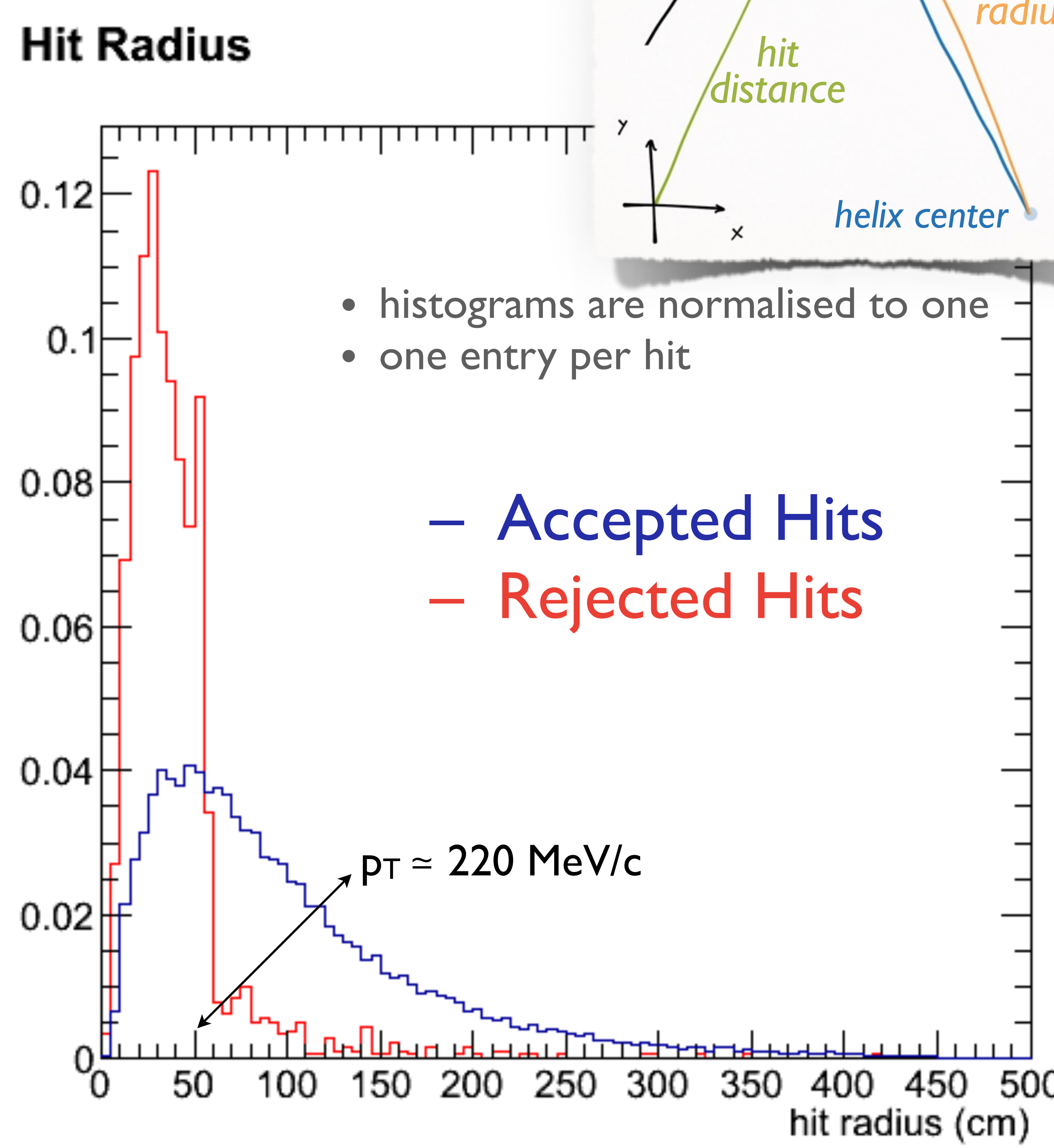


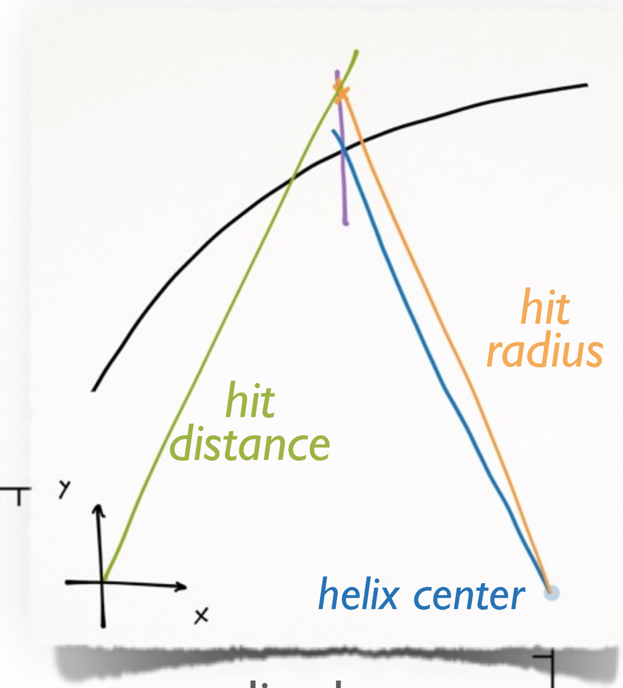


➡ asymmetric distribution, higher left tail since no energy loss taken into account: the correction is symmetric while the physical effect (energy loss) is not.

Which Hits are Rejected?



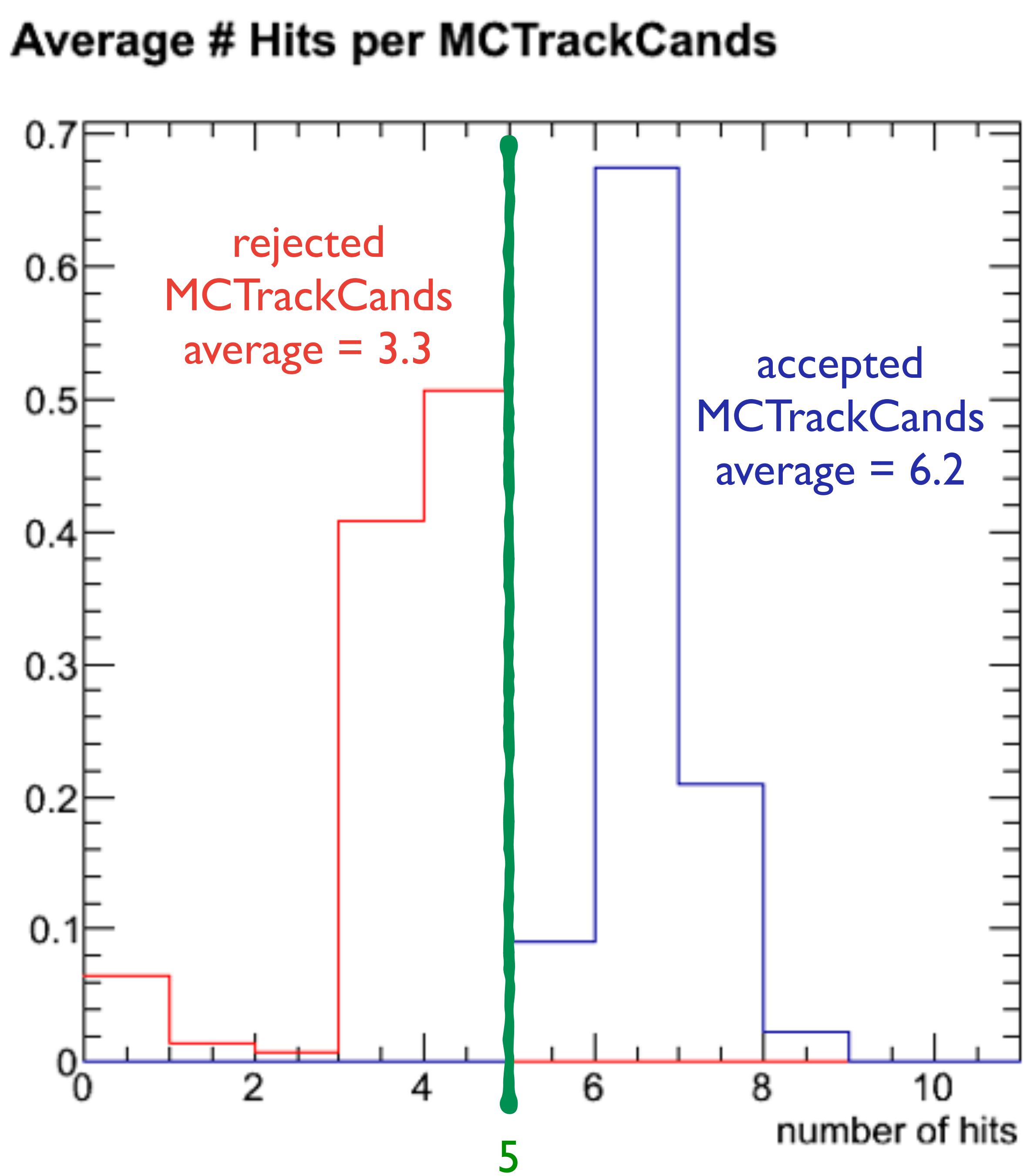




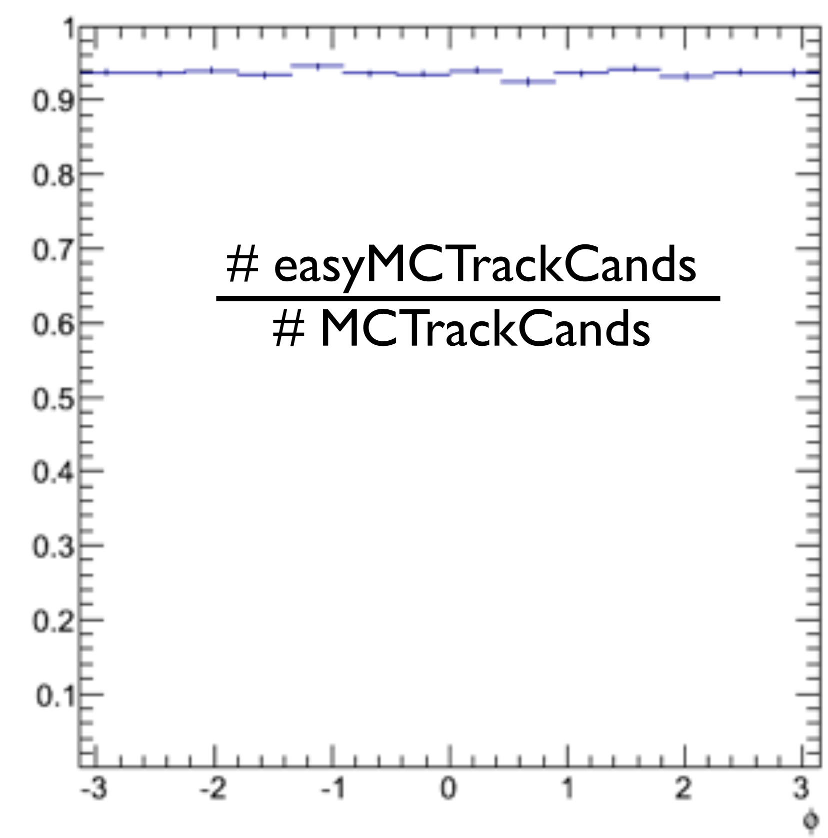
➡ Most of the reject hits are in Layer6, and a smaller fraction in the wedge part of the SVD

➡ Most of the reject hits belong to low transverse momentum tracks (R < 70 cm ↔ p_T < 300 MeV/c)

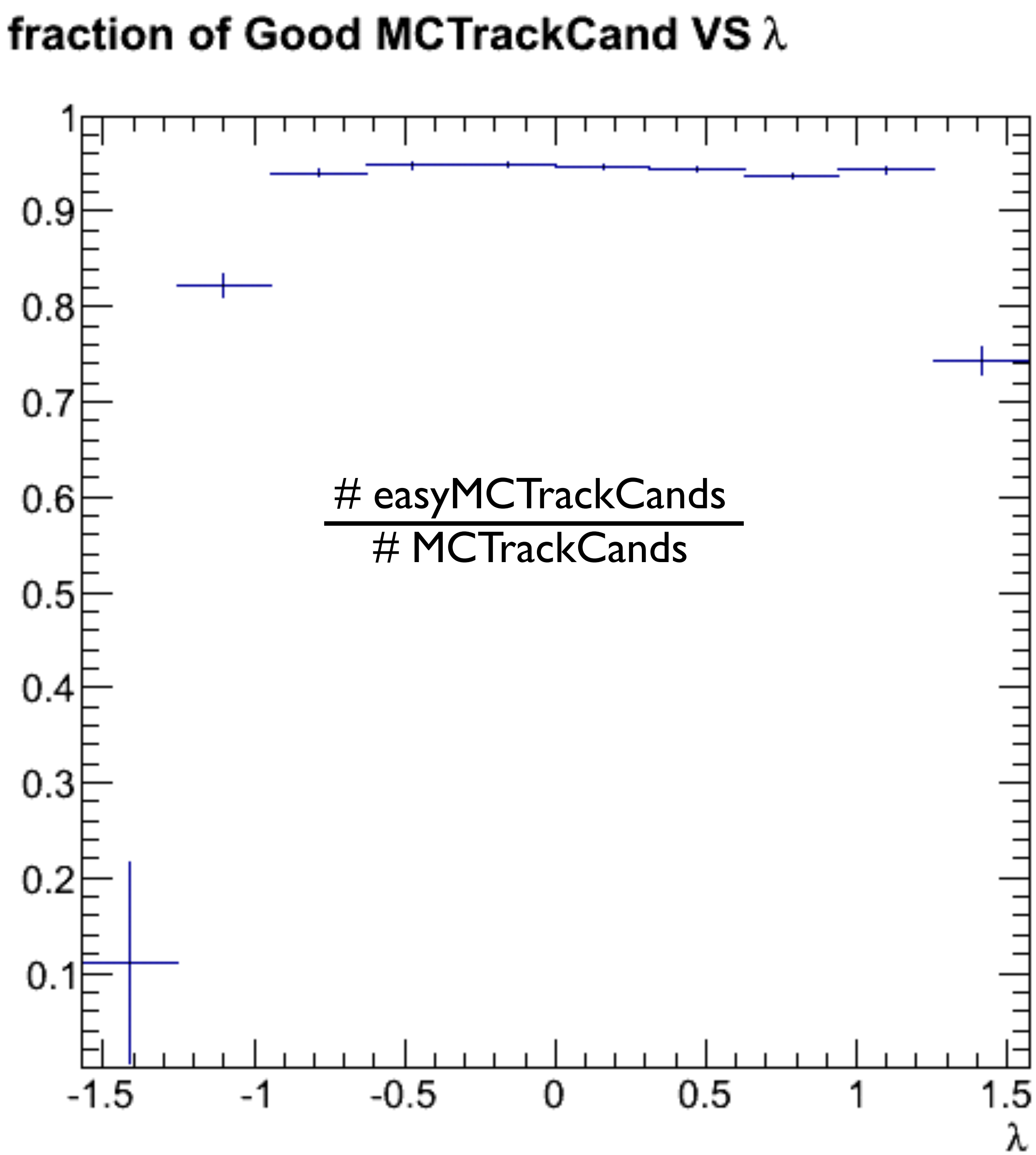
Fraction of easyMCTrackCands/MCTrackCands



- ➡ 5k Υ(4S) generic decays, *Belle II* geometry
- ➡ 50k MCTrackCands (PXD&SVD TrueHits, no use of clusters, # of 1-D hits > 5)
- ➡ fraction of MCTrackCands classified as *easy to find* = **(93.7±0.1)%**, homogeneously distributed in ϕ:

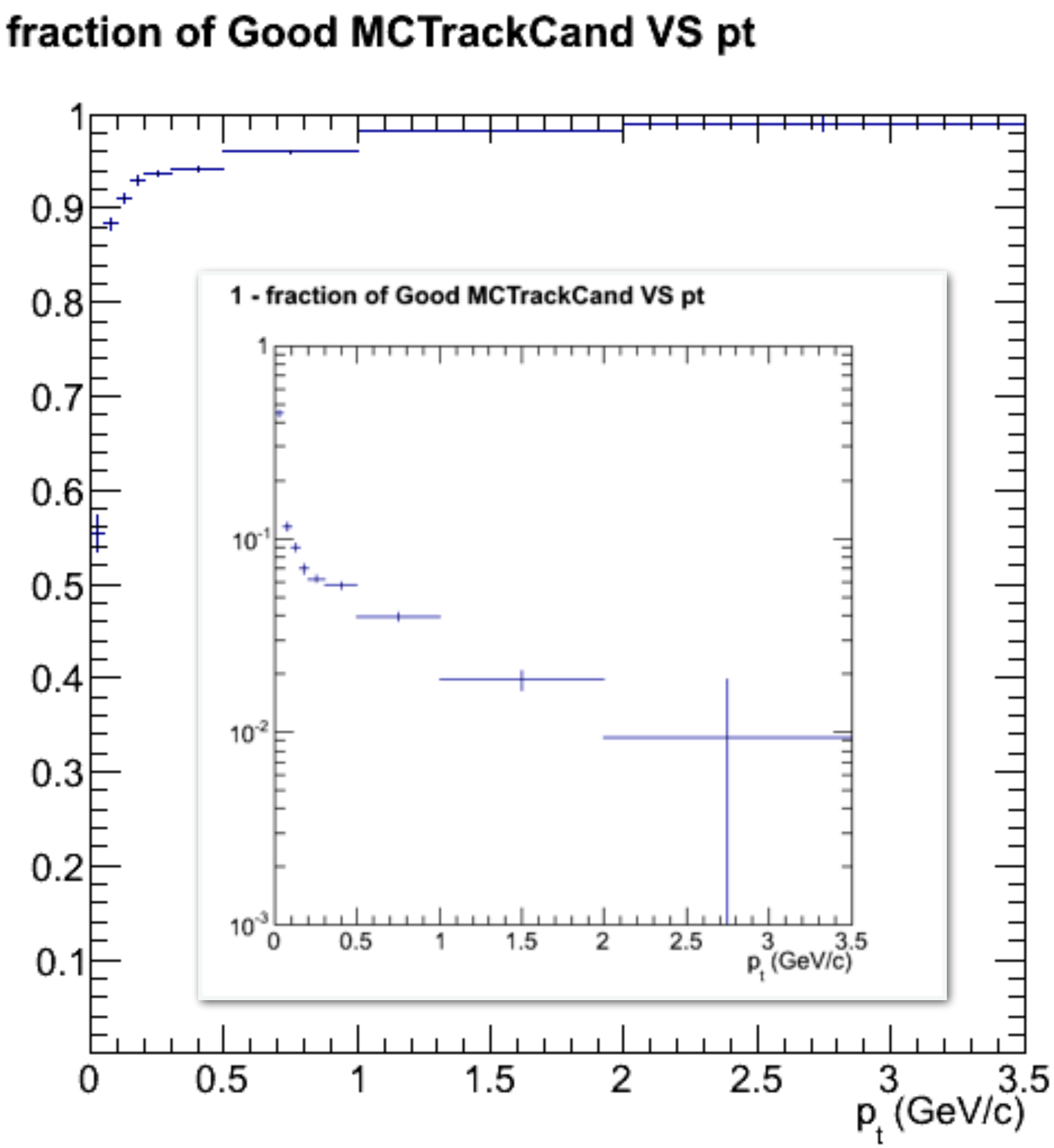


easyMCTrackCand Acceptance



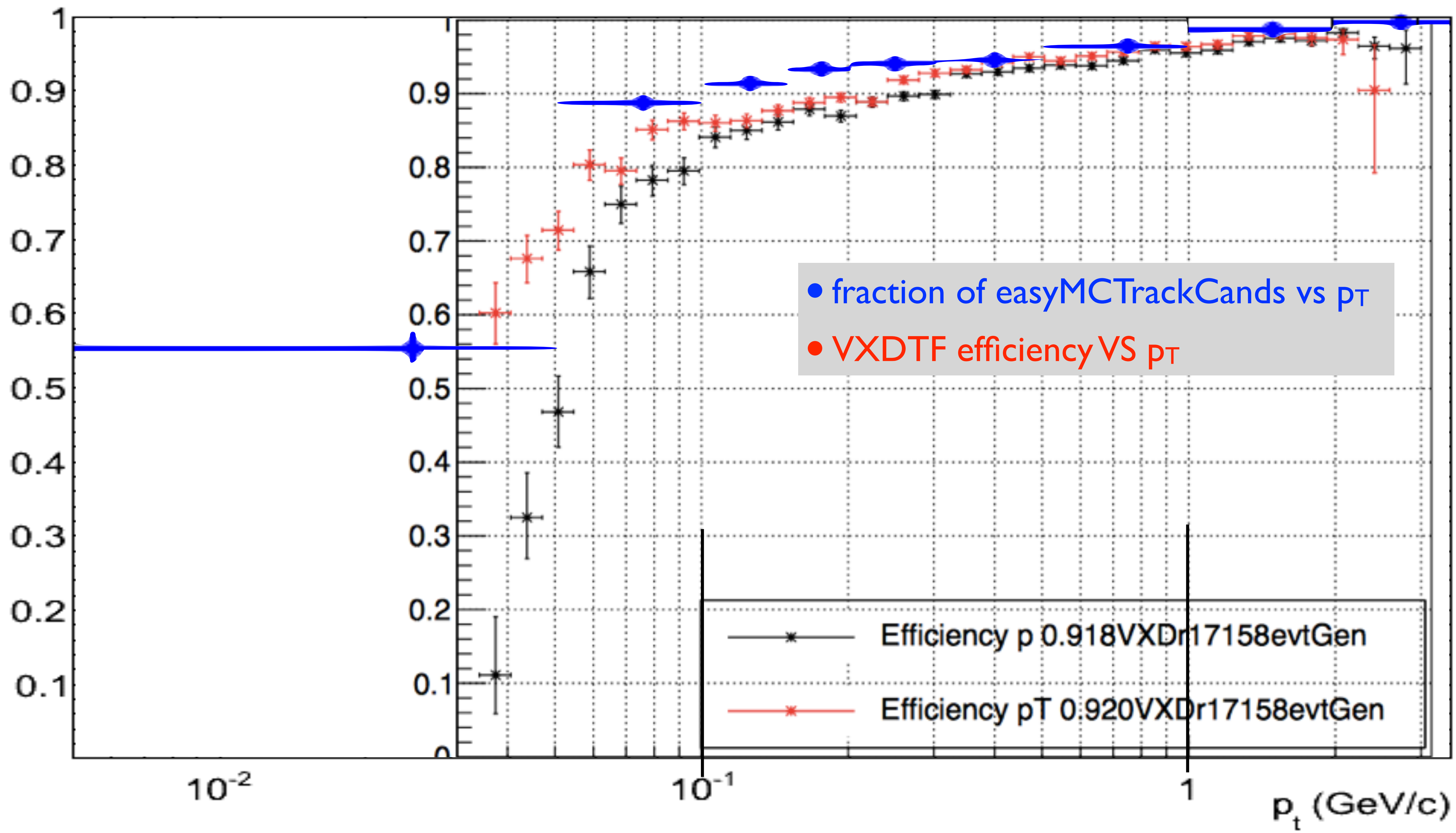
- only ~10% of MCTrackCands in the backward direction are easy to find, but there is low statistics there
- 75% of MCTrackCands are easy to find in the forward direction
  - selection criteria applied to hits in the *wedge* part of the SVD results in a looser selection
- 95% of the MCTrackCands in the central region are easy to find

easyMCTrackCands VS p_T



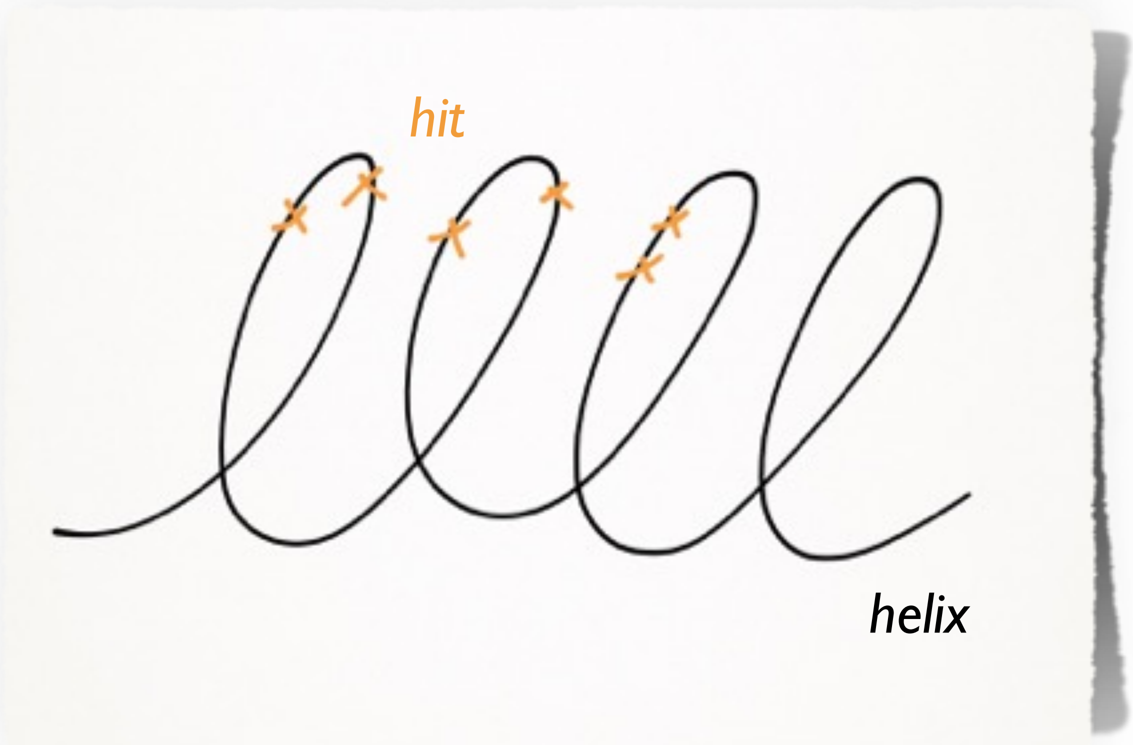
- ➡ 55% of tracks with p_T < 100 MeV/c are easy to find
- ➡ fraction of easyMCTrckCands jumps to 88% for 100 MeV/c < p_T < 200 MeV/c
- ➡ p_T > 2GeV/c only 1% of tracks are not easy-to-find

Comparison with the VXDTF efficiency



Possible Improvements in the Selection Criteria

- ➡ correct the computation of θ_{MS} using the incident momentum (from TrueHit)
- ➡ can take into account (small) energy loss
  - same approach as MS: allow for a "small" energy loss and recompute the helix radius and position
- ➡ should get rid of MCTrackCands as:



- can use the time information associated to the hit:
  - estimate the time needed to complete one lap in the transverse plane (using E and p_T)
  - cut on the next-hit time

Conclusions

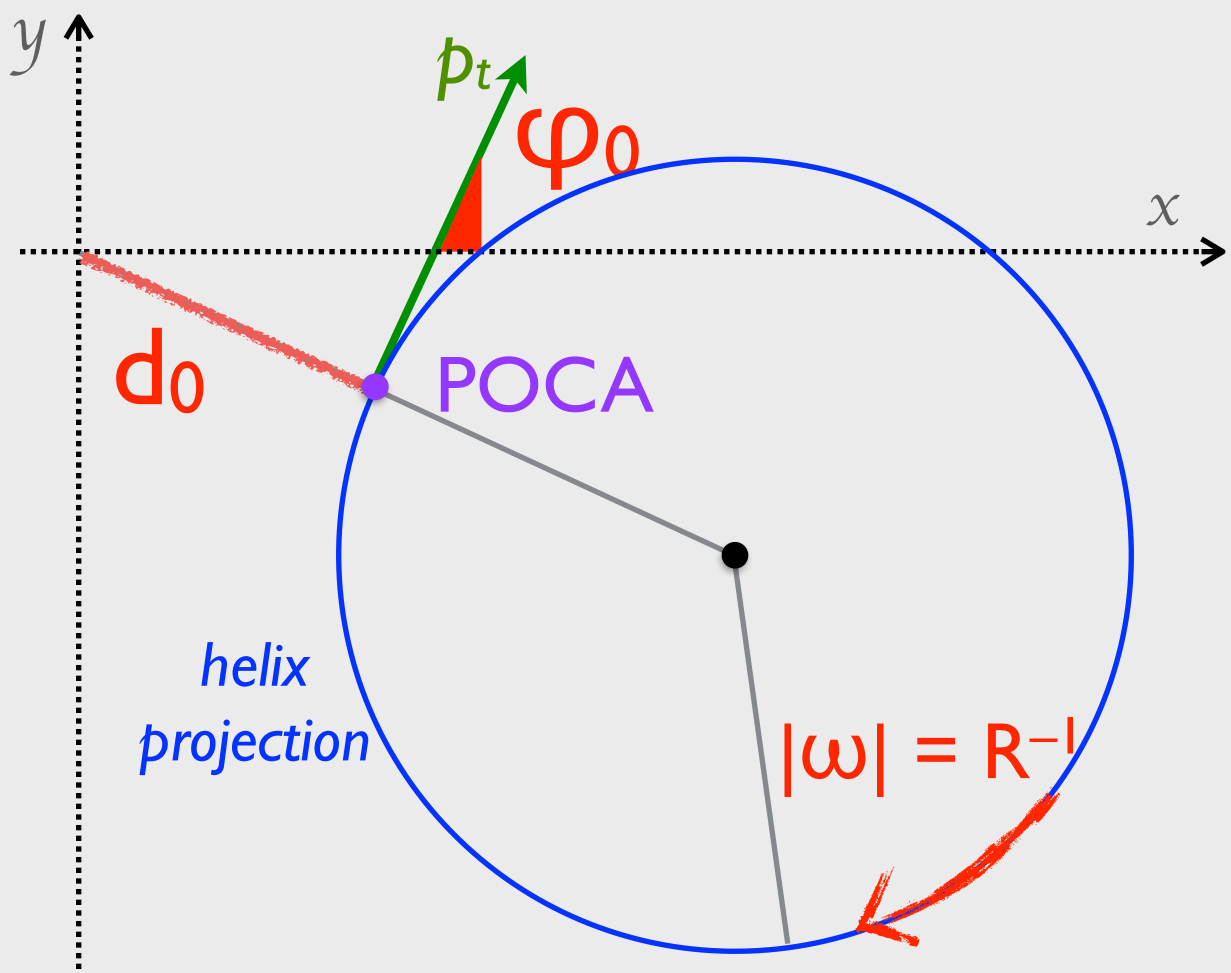
- The results of the first studies for a re-definition of efficiency for our pattern recognition have been shown
  - reasonable results, probably going in the right direction
- Already have ideas to improve the selection criteria for silicon
- Should soon start to design the module:
  - it should be flexible enough to add/change the selection criteria
  - can help in the development and study of the criteria since the produced TrackCand lists can be studied in more details (e.g. using the display).
- PXD is in the game, we should remove it and see what happens
- the problem in the CDC needs a similar dedicated effort

Thank You!

backup slides

Track Parameterisation

TRANSVERSE PLANE



- POCA = Point Of Closest Approach
- d_0 is the 2d signed distance of the POCA from the z axis, the sign depends on the angular momentum of the track (>0 in the fig.)
- φ_0 is the angle between p_t and the x axis at the POCA, $\varphi_0 \in [-\pi,\pi]$
- the sign of ω, the curvature, is the same as the charge of the track (>0 in the fig.)

LONGITUDINAL VIEW

- $\tan\lambda$ is the ratio of p_z and p_t, $\lambda \in [-\pi,\pi]$
- z_0 is the signed distance of the POCA from the transverse plane