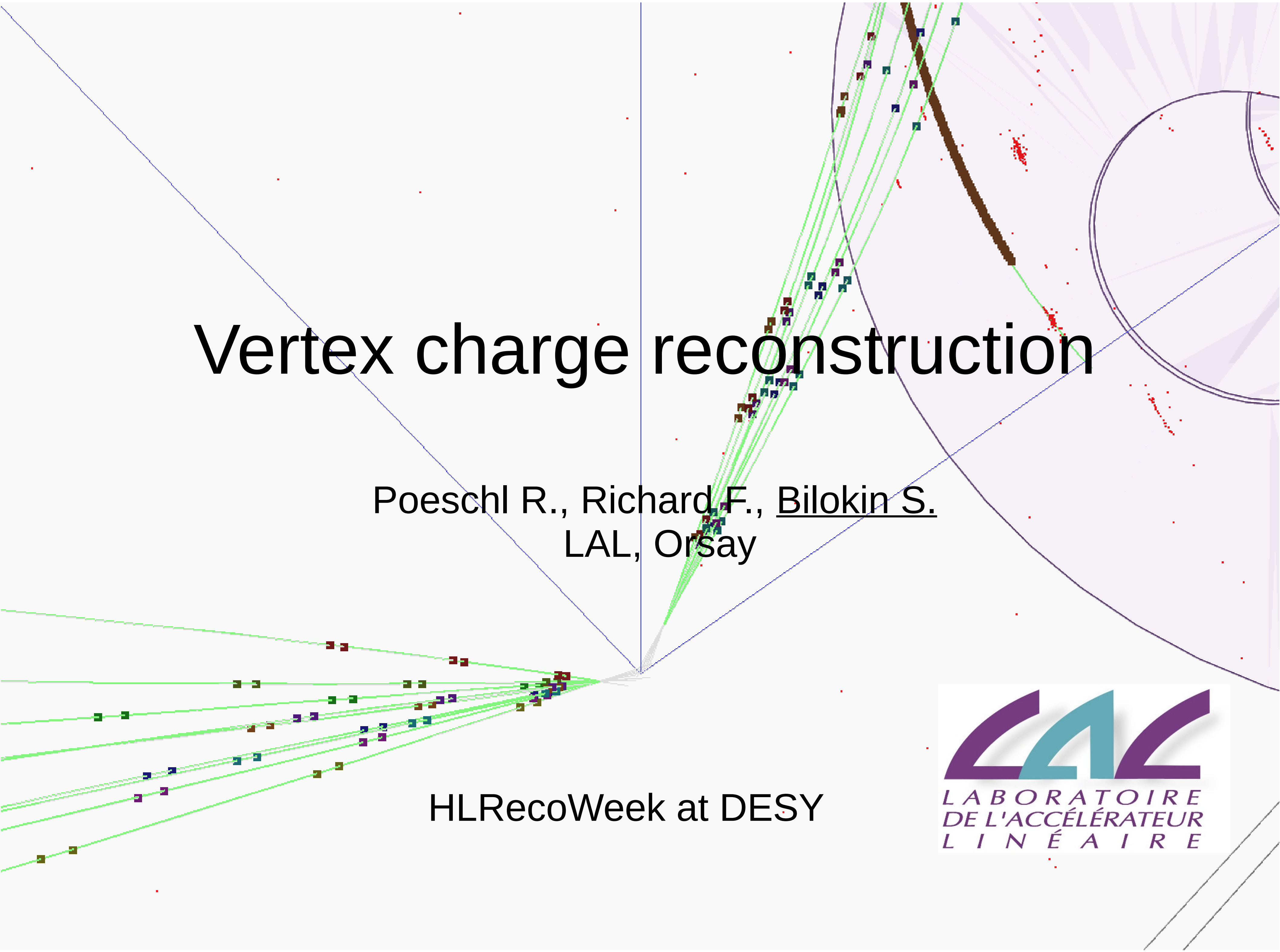


Vertex charge reconstruction

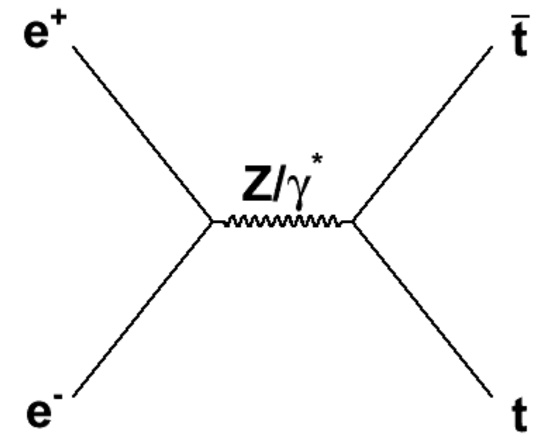
Poeschl R., Richard F., Bilokin S.
LAL, Orsay

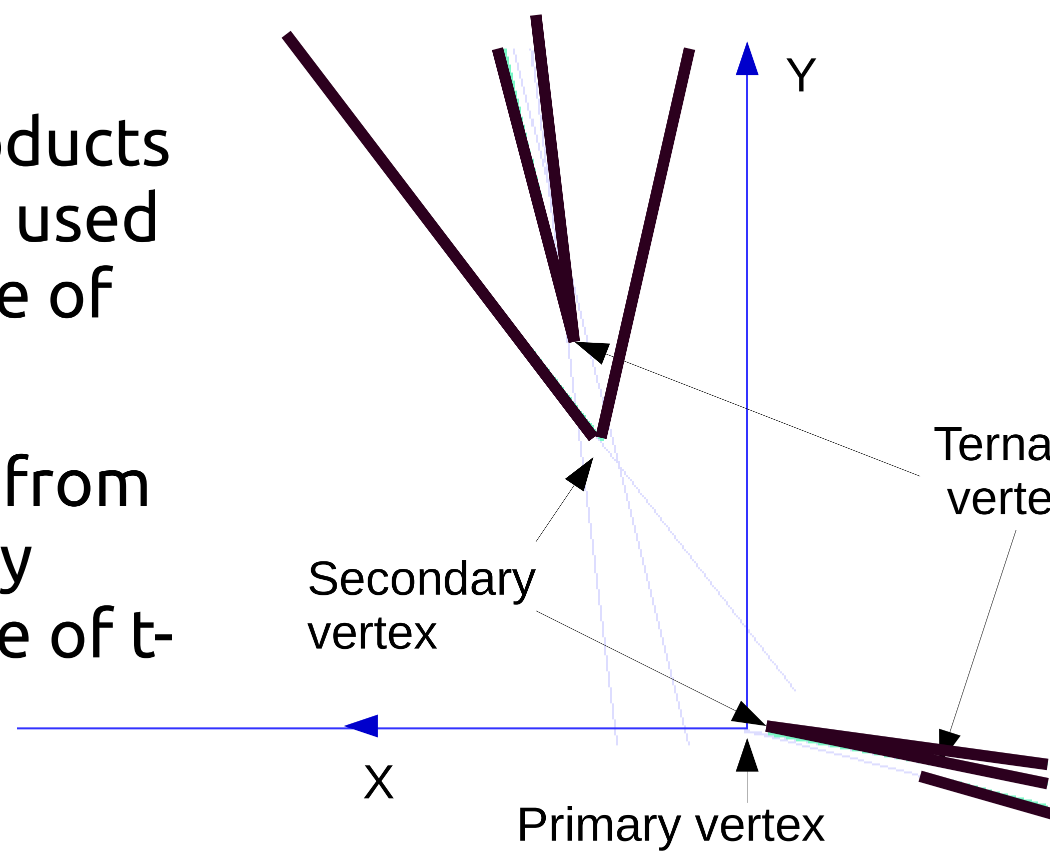
HLRecoWeek at DESY

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Research method

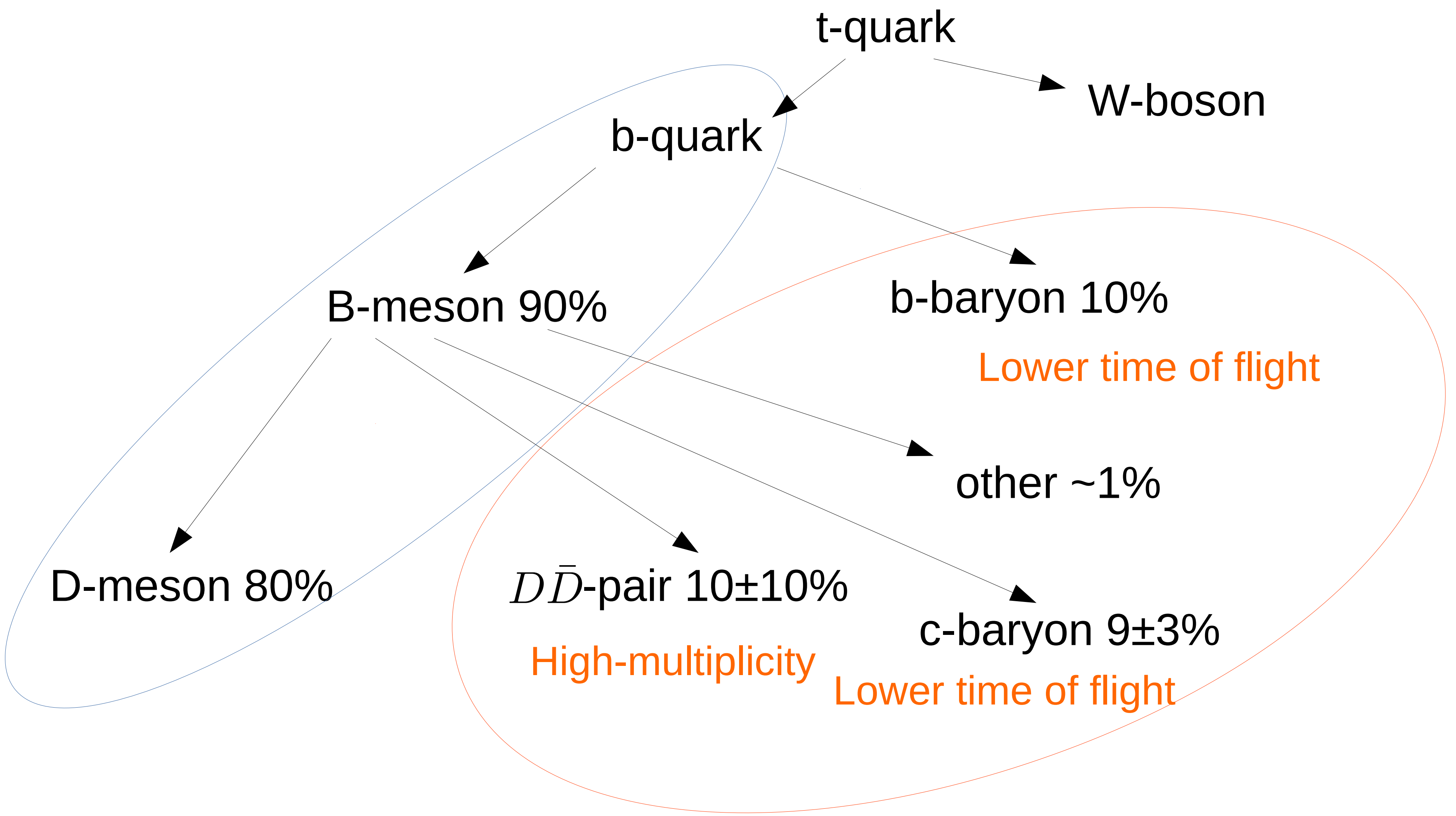
- Main purpose of this work is to detect the charge of top and antitop quarks. This is crucial for calculation of forward-backward asymmetry A_{fb} in $t\bar{t}$ process at ILC
- Properties of decay products from the B-hadrons are used to determine the charge of initial t-quark
- The charge of K-meson from ternary vertex is directly connected to the charge of t-quark





Process overview

- Hadronization and decay modes of b-quark:



Setup of study

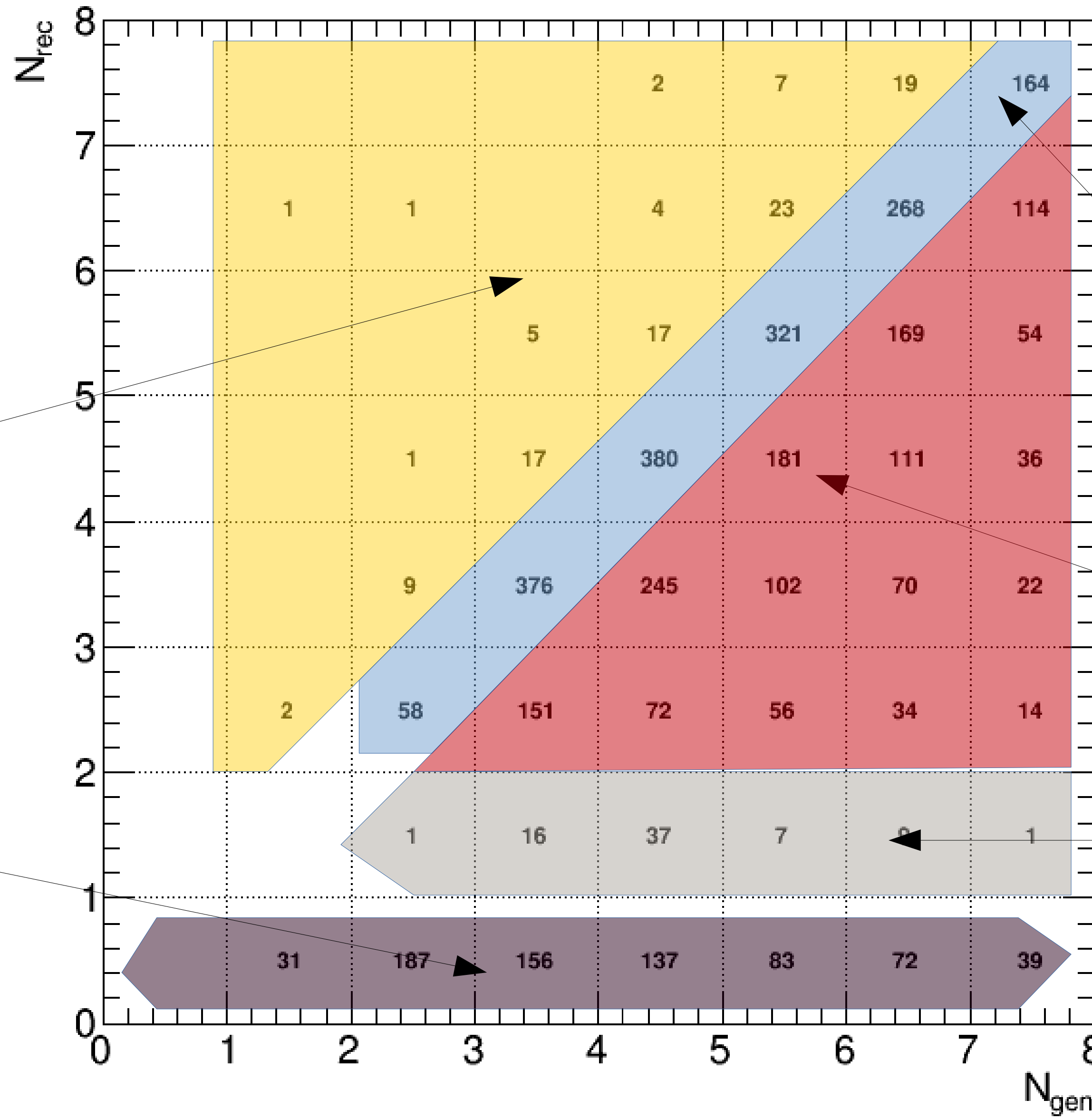
- There was developed a code that can extract B-meson vertices from generator collections by particle type or PDG
- For each generated vertex we select prongs – particles, that leave tracks in detector
- We use JetVertexRefiner collection from LCFI+ algoritm in recontructed slcio files to get the reconstructed vertices
- Tag the reconstructed one by properties of generated vertex if a difference in direction < some angle cut
- Dataset: $e_L^+ e_R^- \to t\bar{t} \to \nu l^\pm b\bar{b}q\bar{q}$ (no $\gamma\gamma$ bkg)

4000 events in ILD DBD test sample

Number of particles comparison

SOT-Vertices = Secondary Or Ternary Vertices

SOT-Tracks = Tracks emerging from SOT-Vertices



Above diagonal, 1 or more added tracks, incorrect charge

Diagonal, Correct charge

Below diagonal, 1 or more missed tracks, incorrect charge

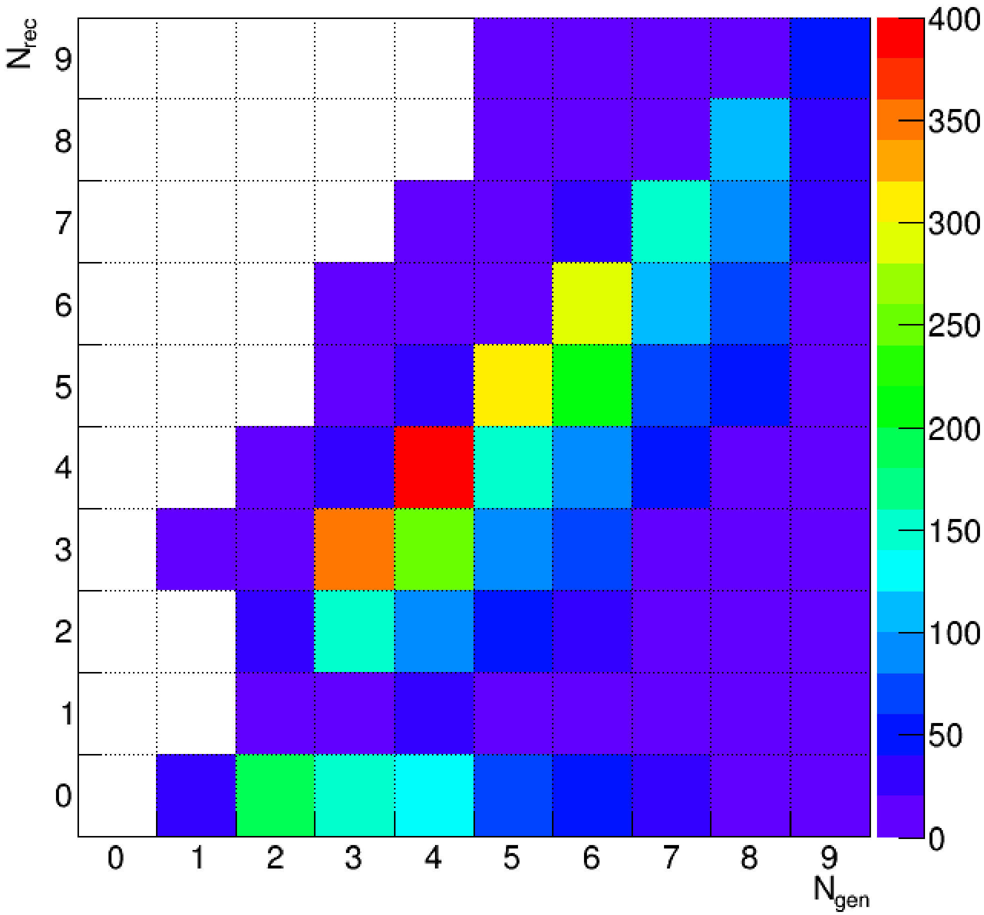
No reconstructed vertices

Populated by leptons, b charge can be calculated

One should diagonalize this table as much as possible to get a correct charge measurement

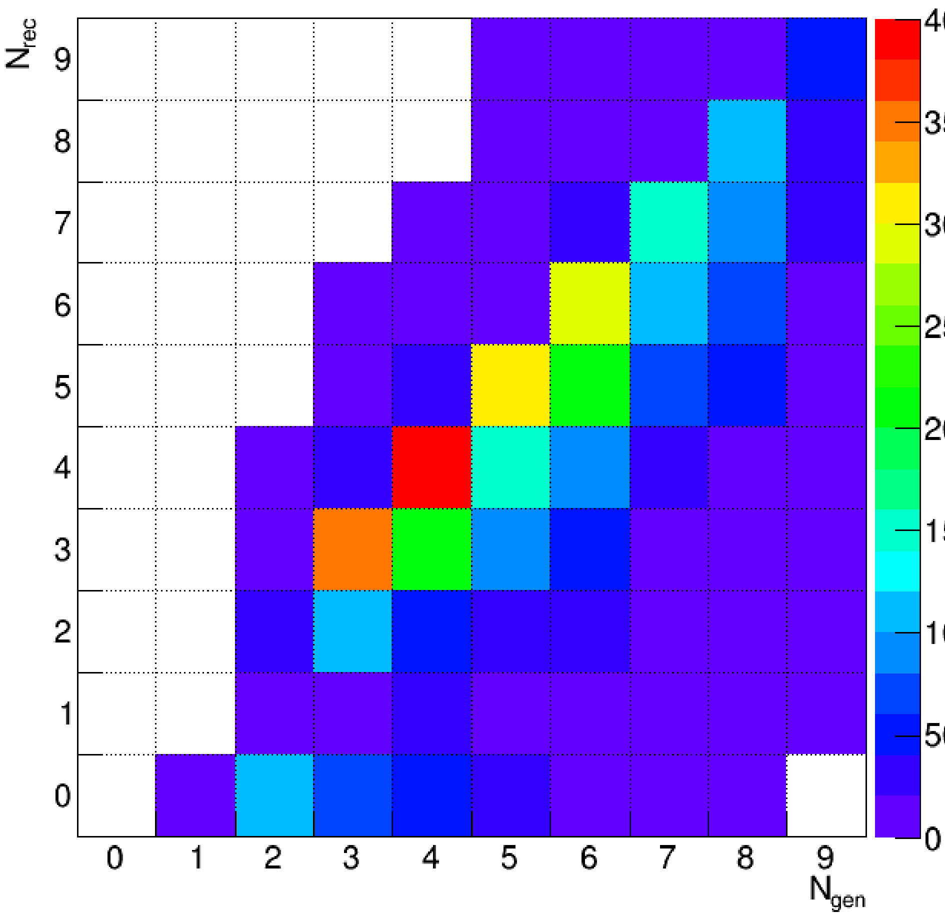
Number of tracks comparison

Raw result



45.7% on diagonal

Btag > 0.3



48.0% on diagonal

- Btag cuts reduce fraction of events without vertex and events with low multiplicity of SOT-Vertices.

Investigation of SOT- Particles

- Lost SOT-Particles (LSOT-Particles) can be divided into 2 categories:

LSOT-VTX Particles

Generated SOT-Particles that are not assigned to correctly reconstructed SOT-Vertices

LSOT-NOVTX Particles

Particles associated with an undetected SOT-Vertex

Possible reasons to lose a SOT Particle:

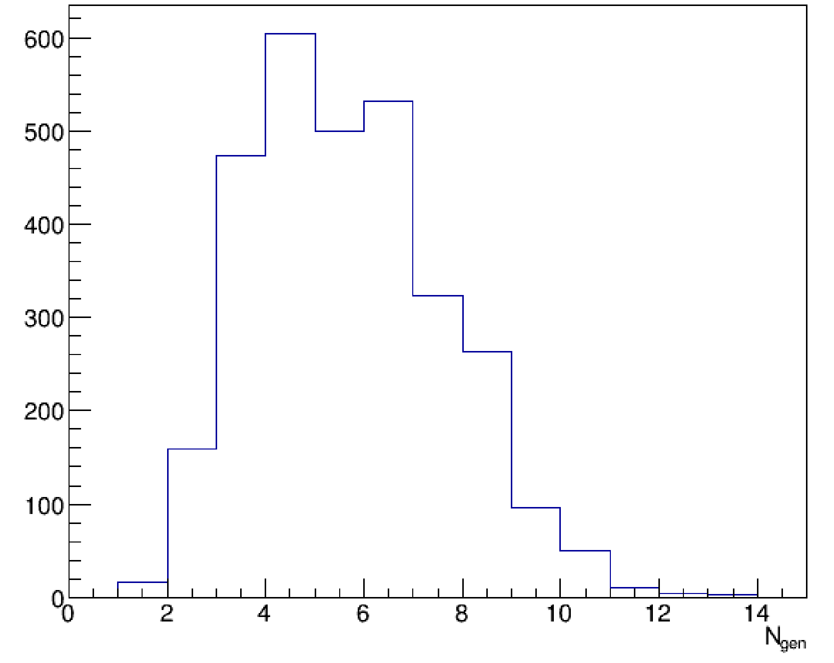
- χ^2 cuts in vertex reconstruction
- Small offset to primary vertex
- No hits in VXD
- Particle has been not reconstructed

- Forward region
- Soft B-mesons
- Short Time of Flight
- Low multiplicity
- χ^2 cuts in vertex reconstruction

Probability to lose a particle

- The calculated chance to lose a particle from reconstructed SOT vertex is ~14%:
- It subdivides into:
  - Not reconstructed as PFO ~ 5%
    - No tracking information ~ 1.5%
    - Has reconstructed track ~ 3.5%
  - No hits in VXD ~ 3%
  - Recoverable particles from 6% to 9%

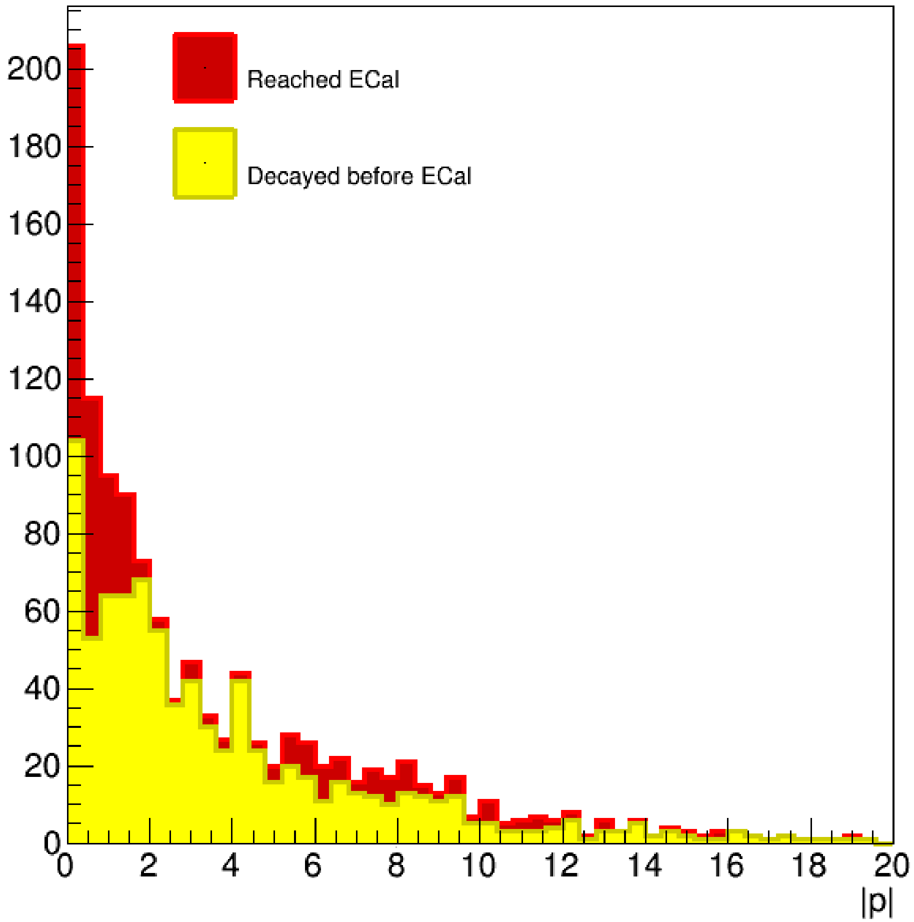
Generated B-meson multiplicity



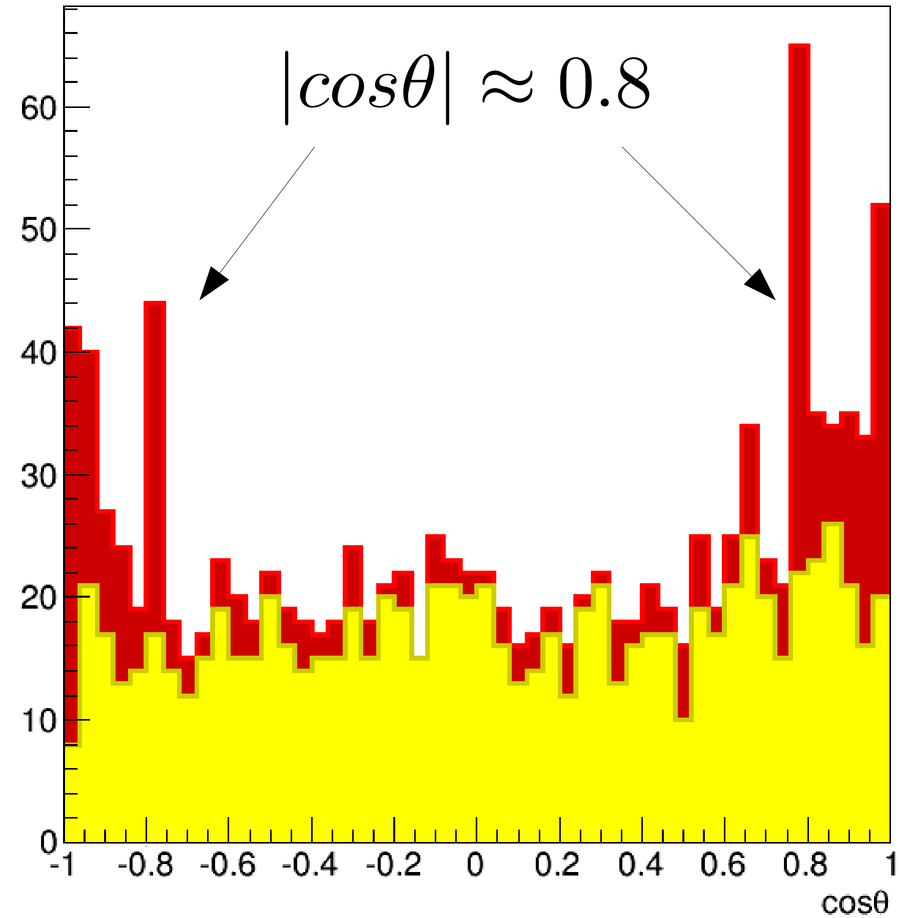
- Average B meson multiplicity is 5, and for each track we have such probability to not to reconstruct it as SOT-Vertex particle

Nonreconstructed LSOT-VTX particles

Momentum comparison



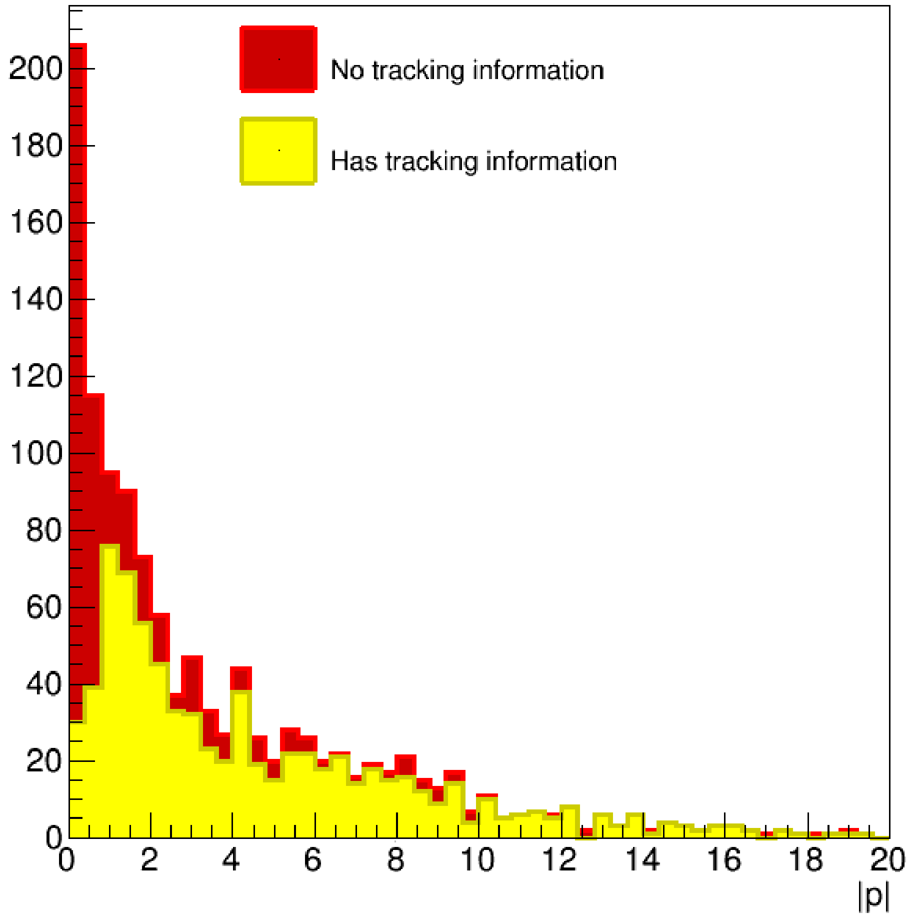
Angular comparison



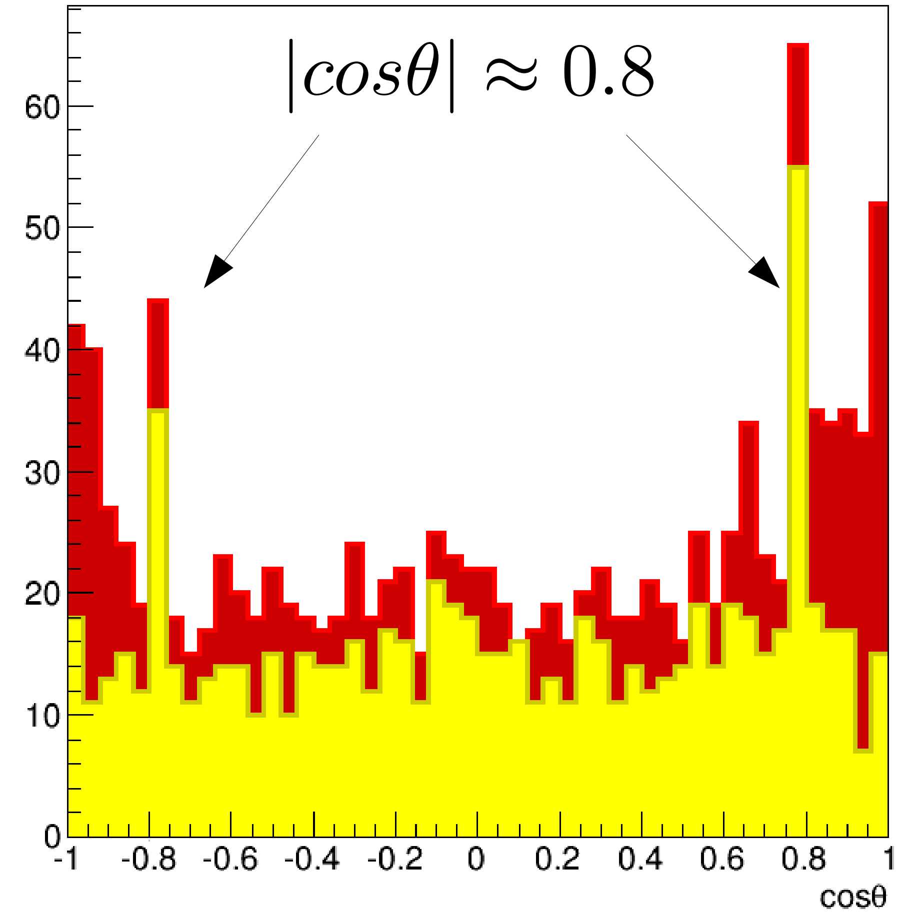
- There is a tendency to not reconstruct a PFO if particle had decayed before ECal. Otherwise nonreconstructed tracks are peaked in low momentum, forward region or when $|cos\theta| \approx 0.8$

Nonreconstructed LSOT-VTX particles

Momentum comparison

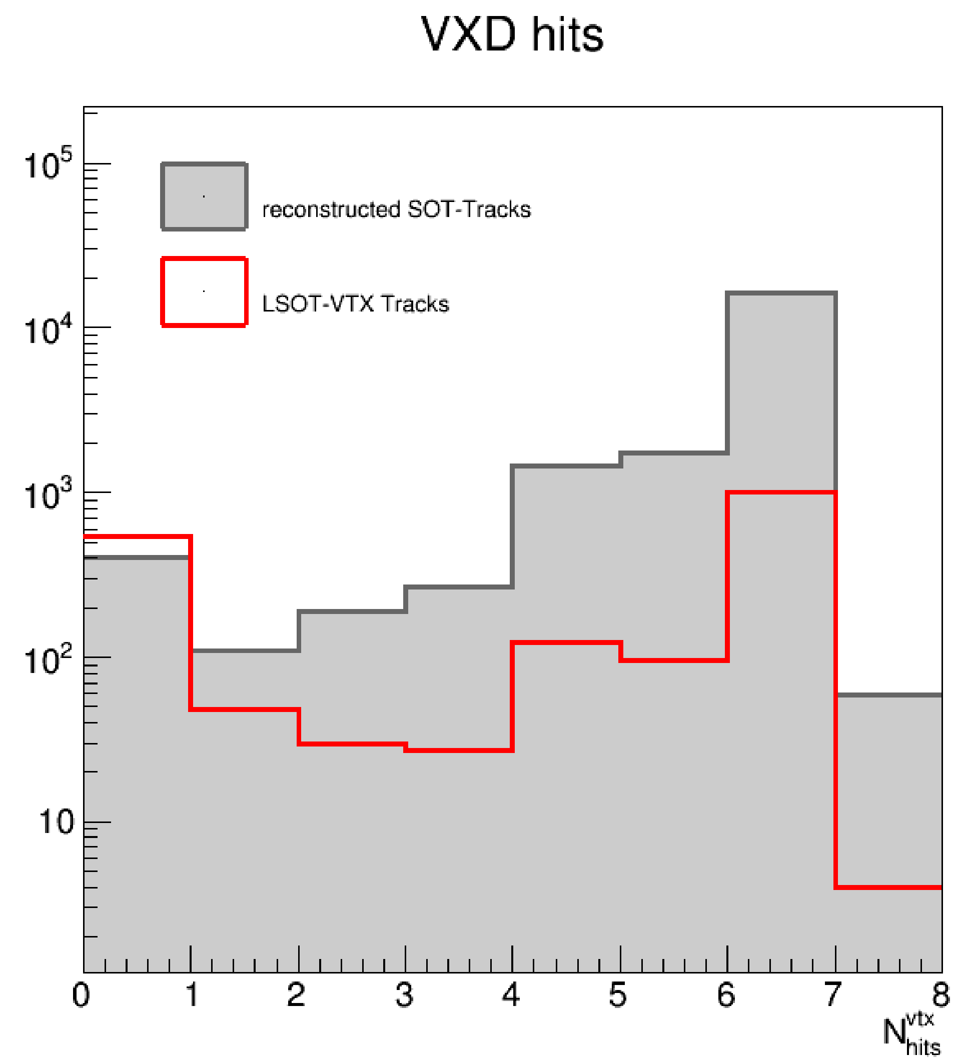


Angular comparison



- There is a tendency to not reconstruct a track as PFO if particle had decayed before ECal. Nonreconstructed tracks are peaked in low momentum and forward region only.

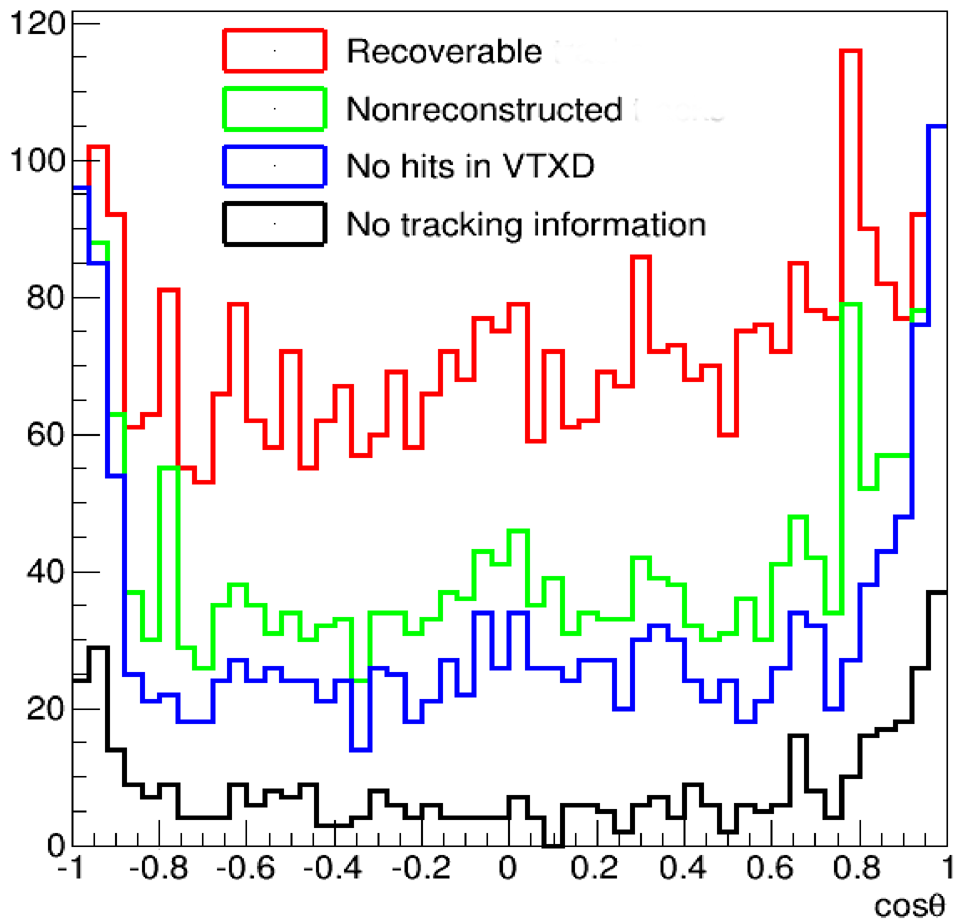
Vertex detector hits analysis



- There is an enhanced risk to lose a particle from secondary vertex if it has 0 hits in microvertex detector N^{vtx}_{hits}
- Forward Tracking Disks are not yet used

Lost particles analysis

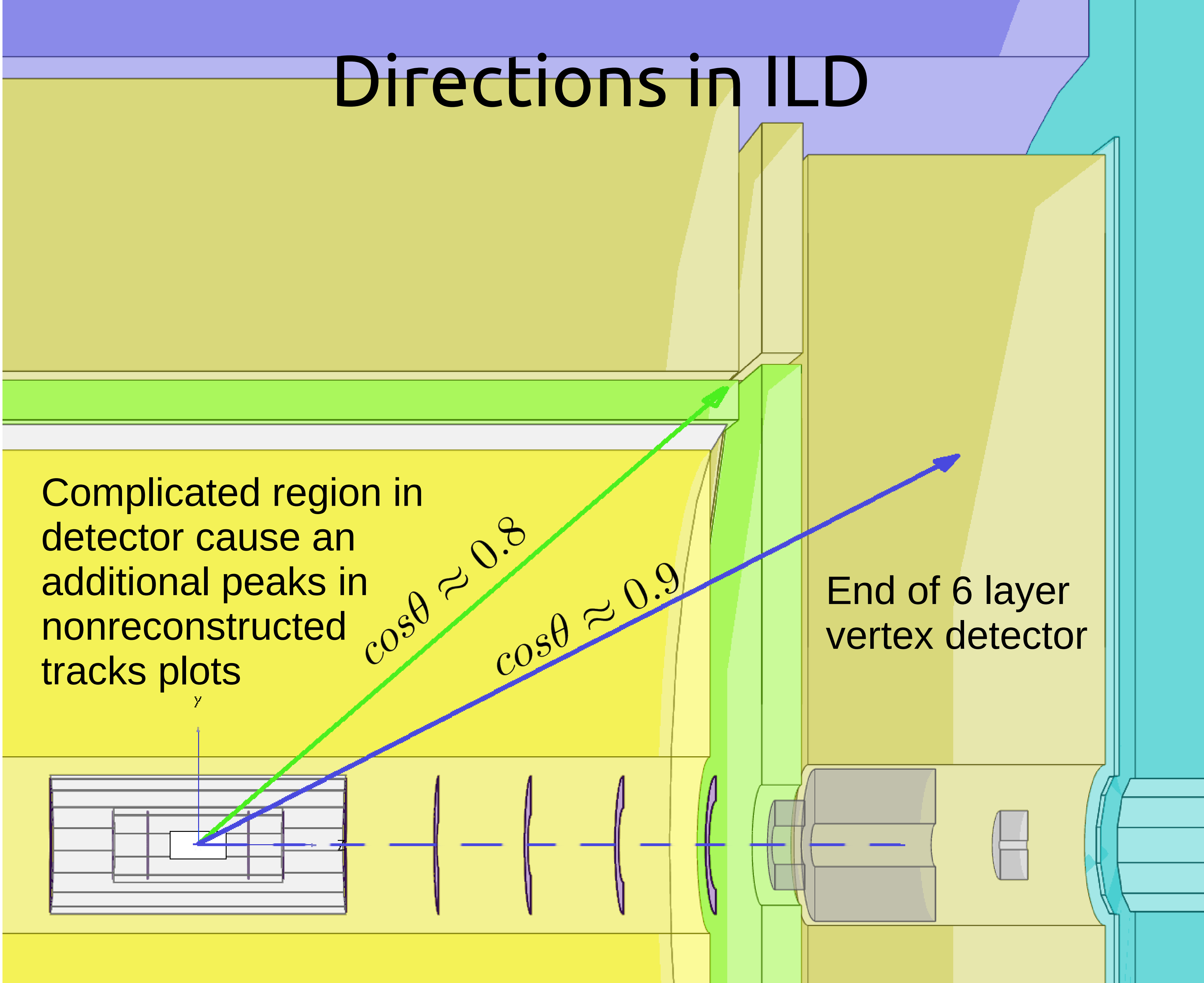
LSOT-VTX Particles



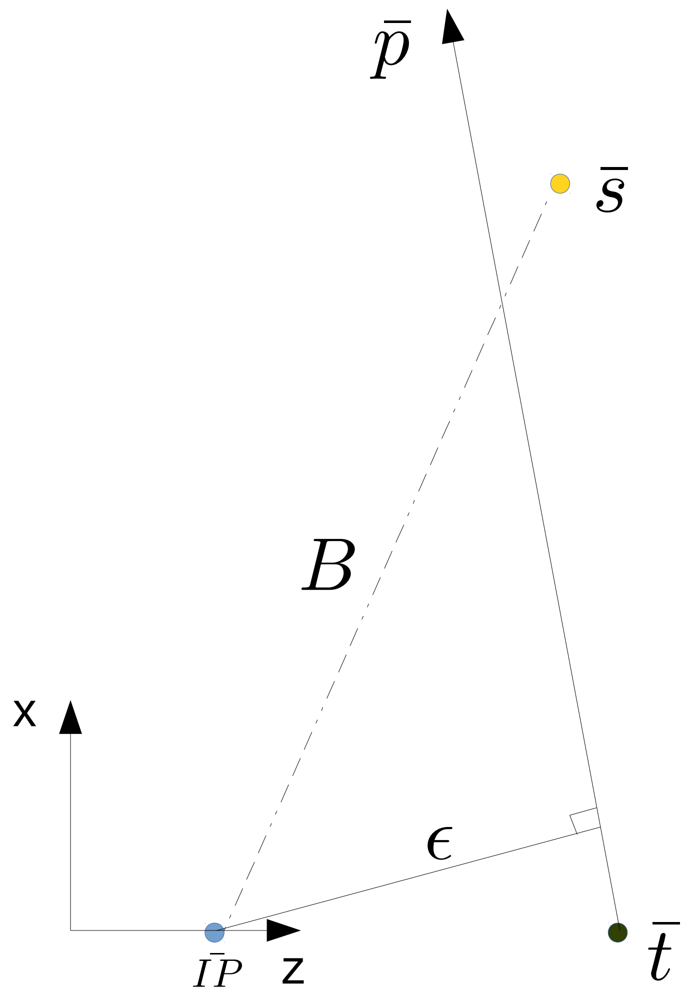
- The recovery procedure is oriented to restore recoverable and nonreconstructed particles as PFO. We consider the particles with no tracking information as not recoverable in this work

Directions in ILD

Complicated region in detector cause an additional peaks in nonreconstructed tracks plots



Definition of Estimators



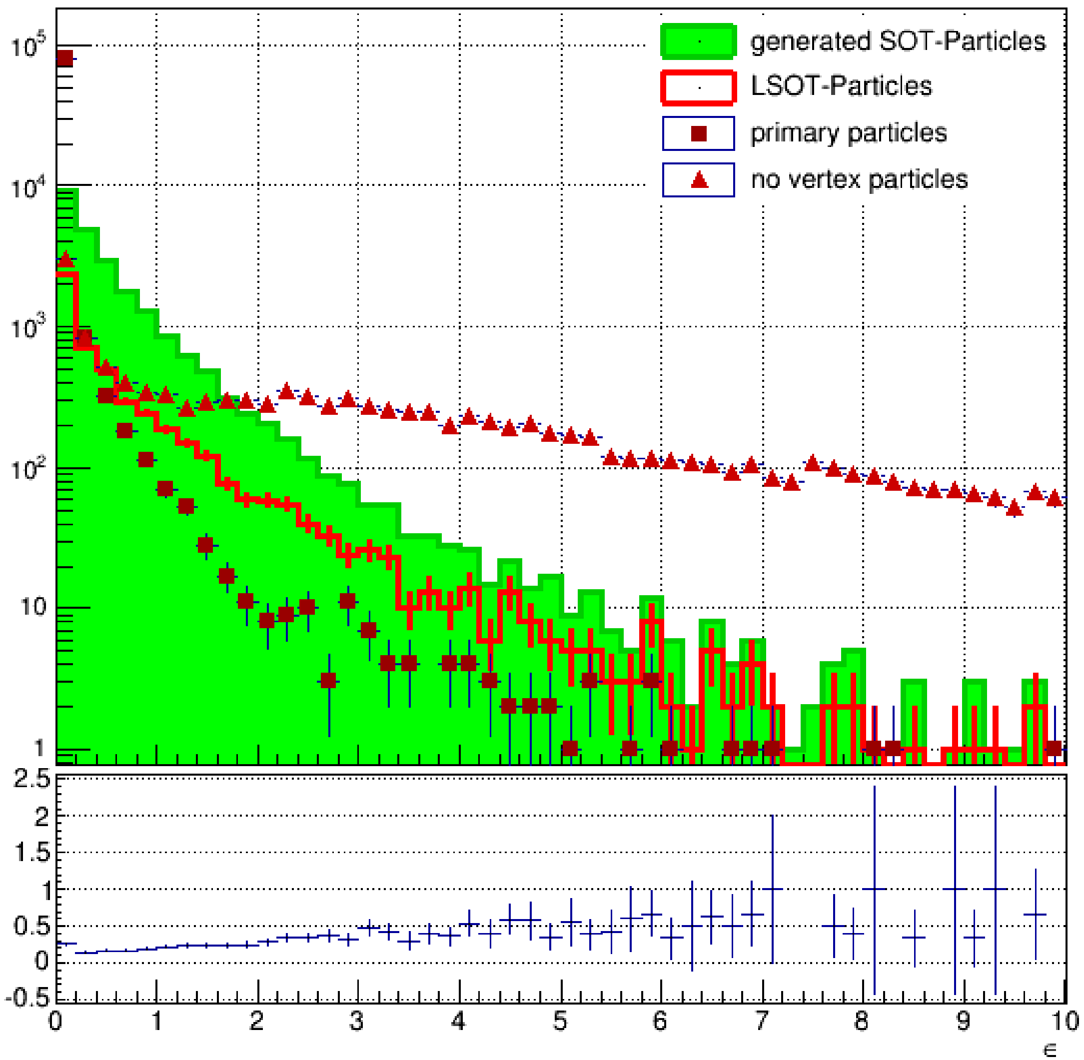
- To compute the offset we are using the linear approximation of tracks
- The resolution on the offset can be approximated by a formula from DBD:

$$\sigma = a \oplus \frac{b}{|p| sin^{2/3}\theta}$$

$$a = 5\mu m; b = 10\mu m \cdot GeV$$

- **IP** – interaction point (primary vertex) , **s** – secondary vertex, **t** – point of closest approach of a track, **p** – reconstructed momentum, ϵ - offset of a track from primary vertex

Comparison of offsets

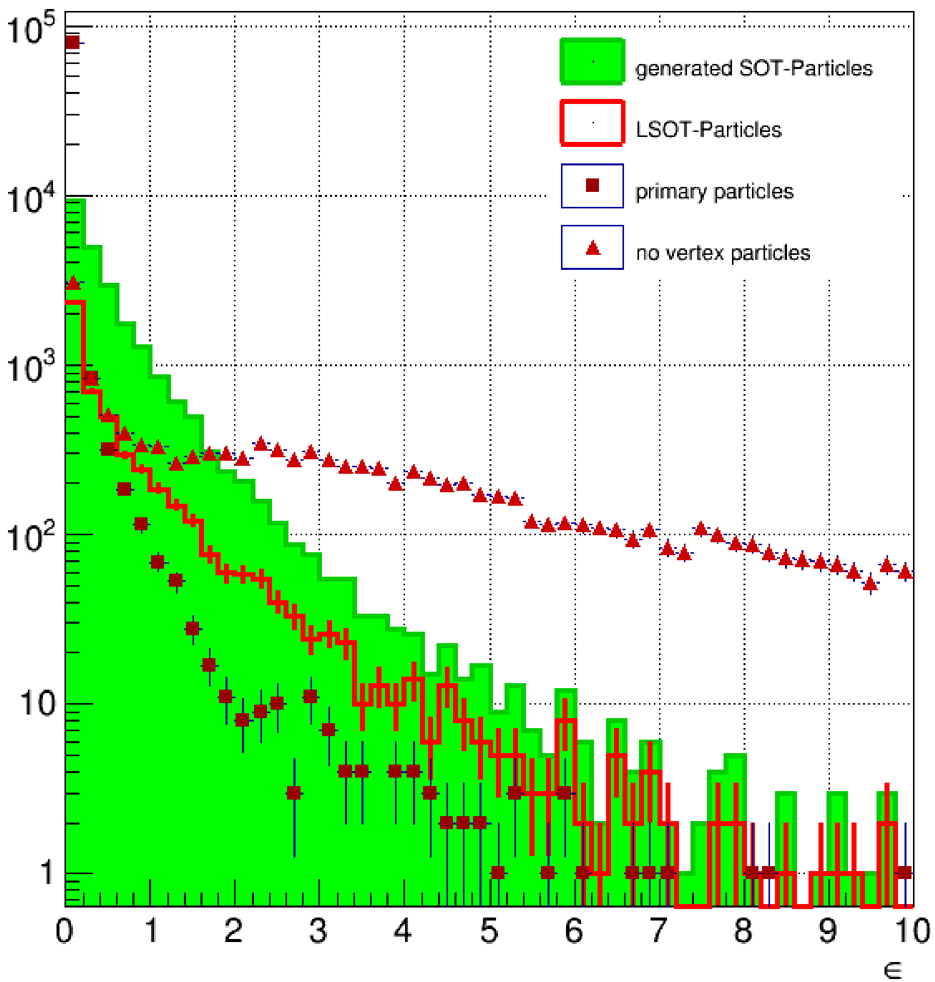


- The secondary and missed particles are generated particles from B-mesons.
- The "no vertex" particles are tracks that had not been attached to neither primary nor secondary vertex.
- "No vertex" particles and primary vertex tracks are reconstructed tracks.

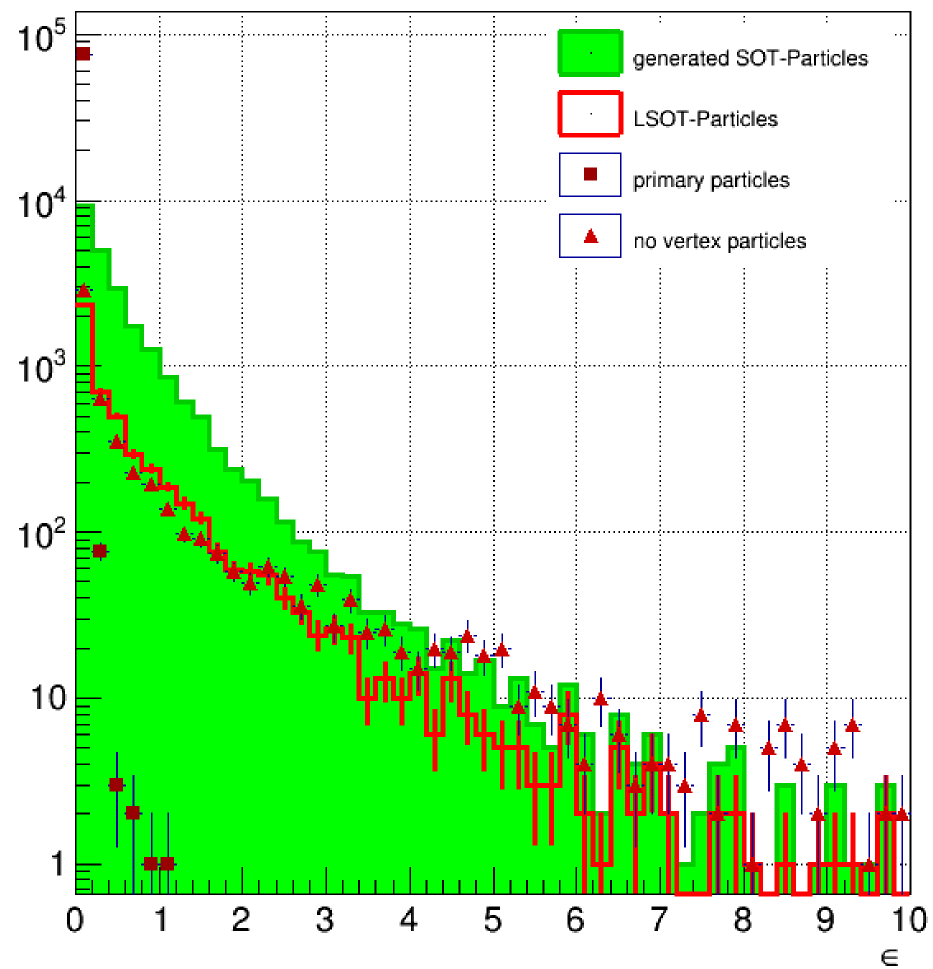
- True secondary particles are excluded from primary and "no vertex" particles histograms

Comparison of offsets

All primary and “no vertex” particles

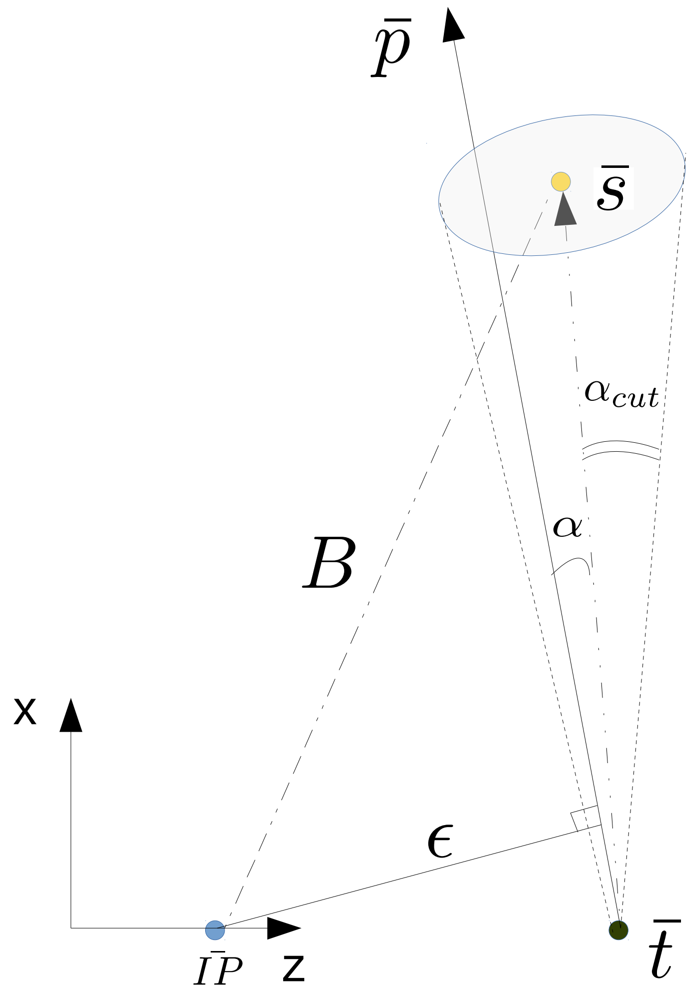


Particles with >3 hits in VXD



- After VXD hits cuts the main background is “no vertex” particles. Primary particles have low offsets after cuts.

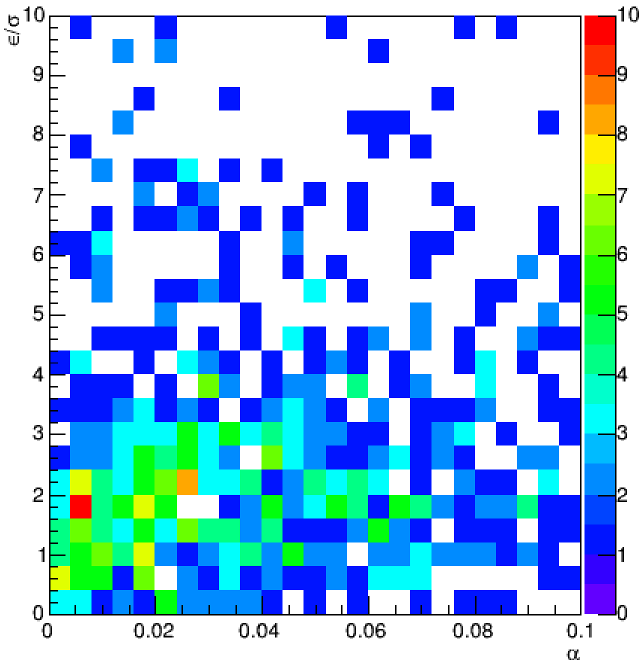
Recovery of vertices



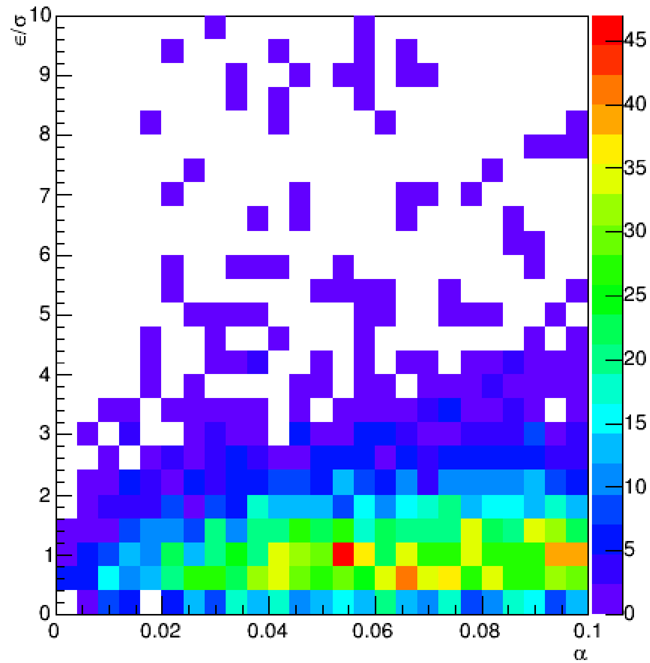
- **IP** – interaction point (primary vertex) , **s** – secondary vertex, **t** – point of closest approach of a track, **p** – reconstructed momentum, ϵ - offset of a track from primary vertex

Pre-study of recovery

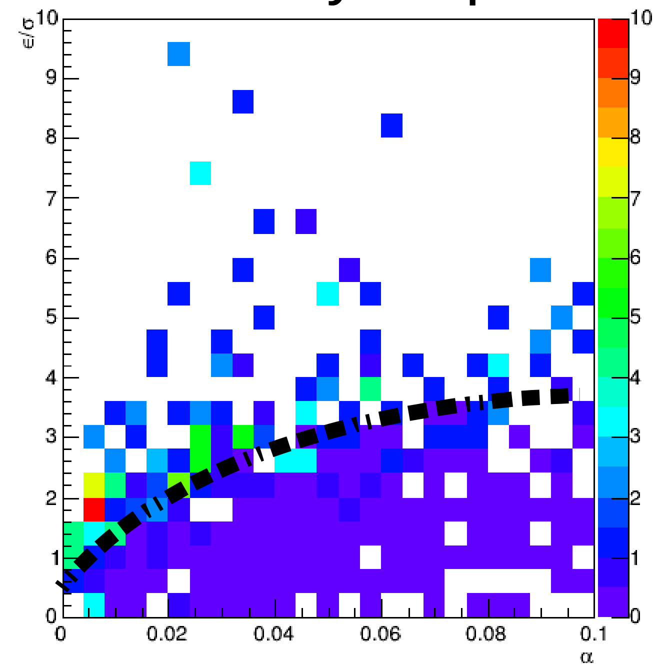
Recovered SOT



Fake

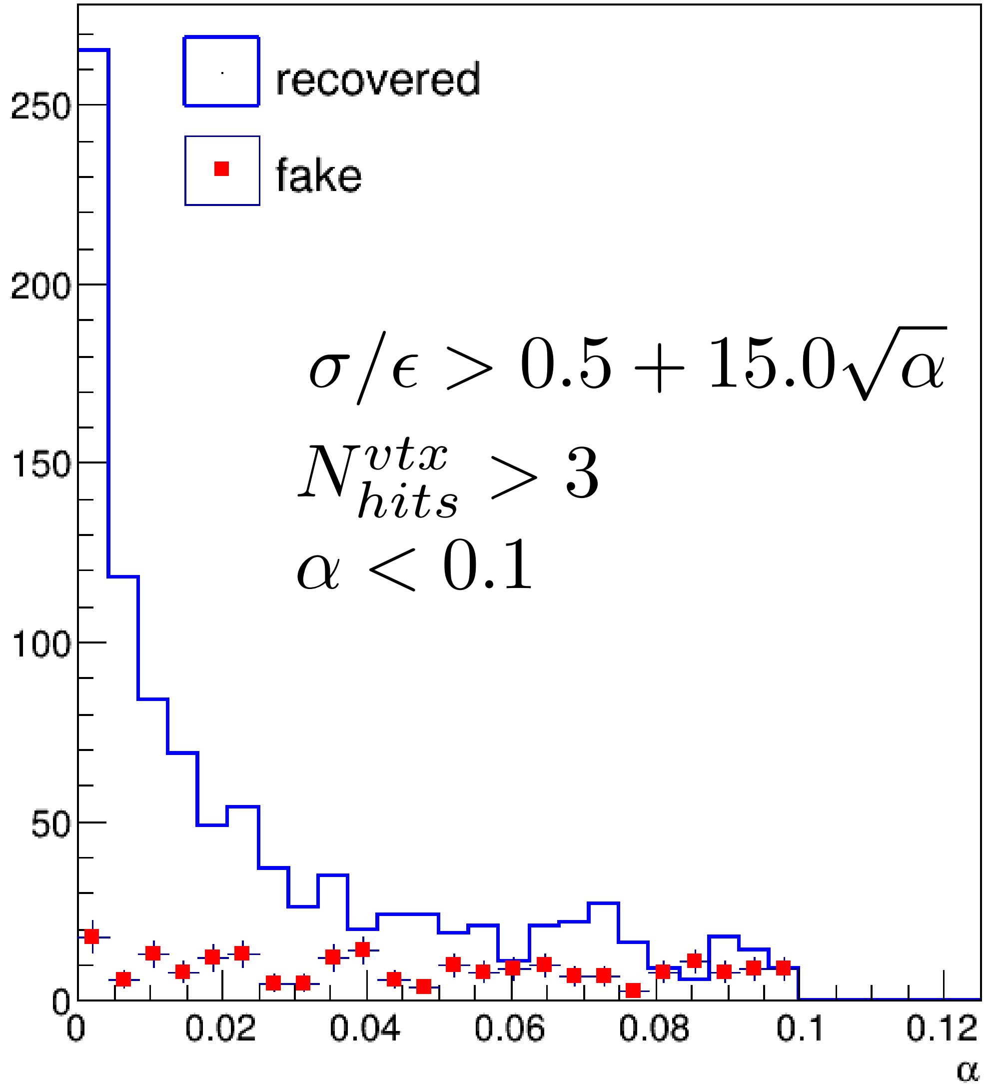


Purity map



- These plots show offset significance and angle dependence of different categories of particles, taken by recovery algorithm:
  - Recovered are true missed particles from B-meson (LSOT-VTX)
  - Fake are all other particles
- One should avoid low purity regions by setting cuts $\epsilon/\sigma = f(\alpha)$

Preliminary results of recovery

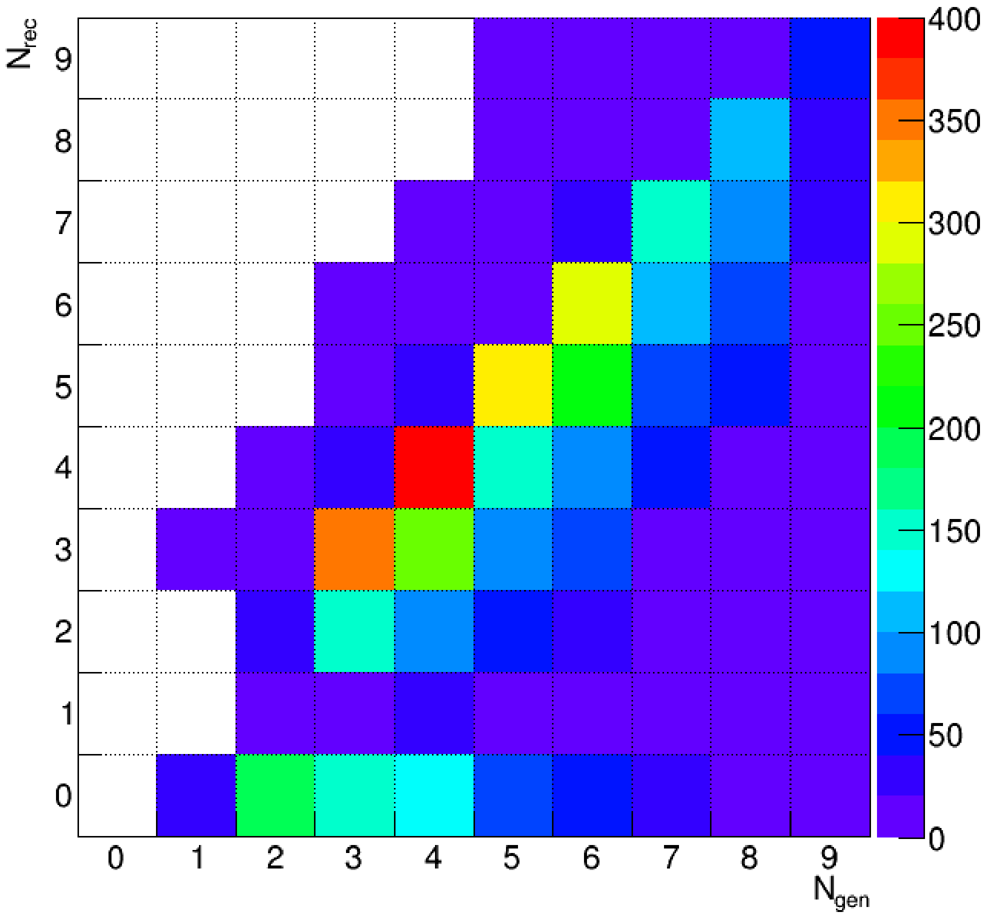


- Histogram of α angles for recovered LSOT particles and fake particles taken by algorithm
- Up to 67% of target particles can be recovered with 82 % of purity
- The recovery procedure should be optimized by charge reconstruction quality
- Technical issues will be discussed at HLRecoW

- The number of recovered particles can be increased by injecting tracks that were not used by PFA in the recovery

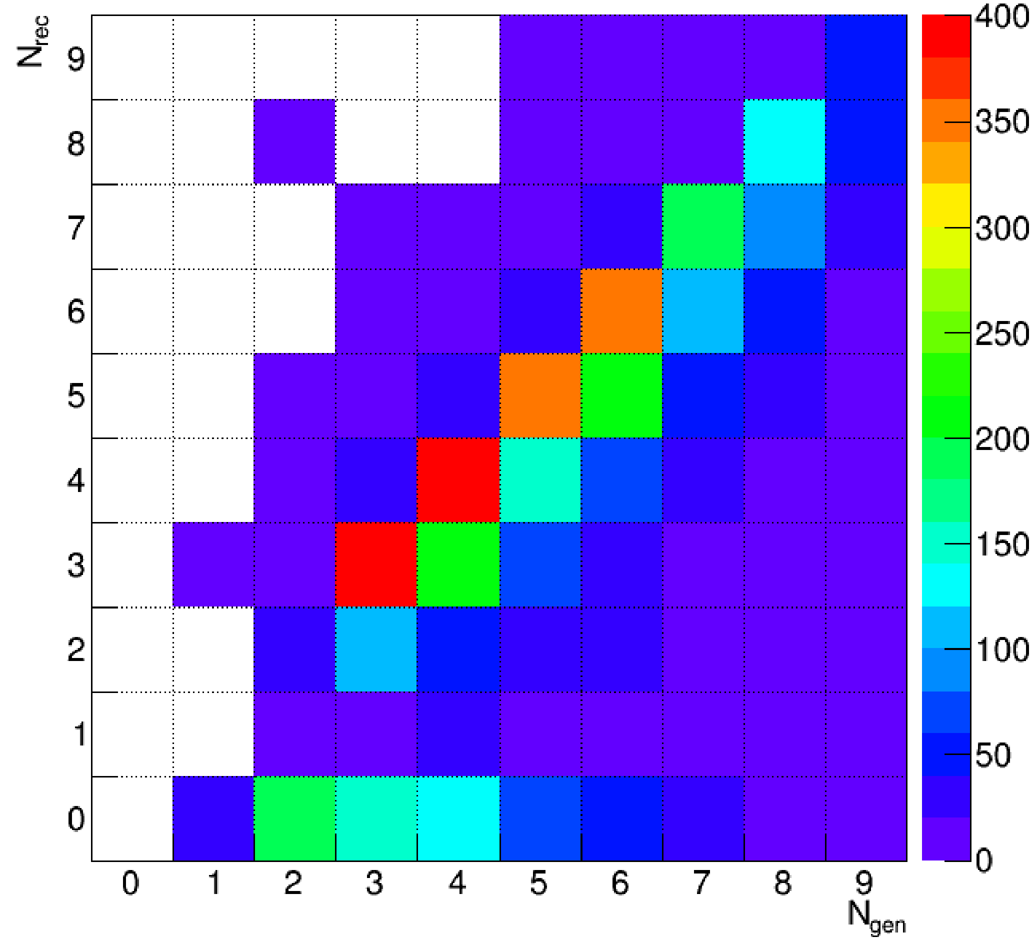
Number of particles

Before recovery



45.7% on diagonal

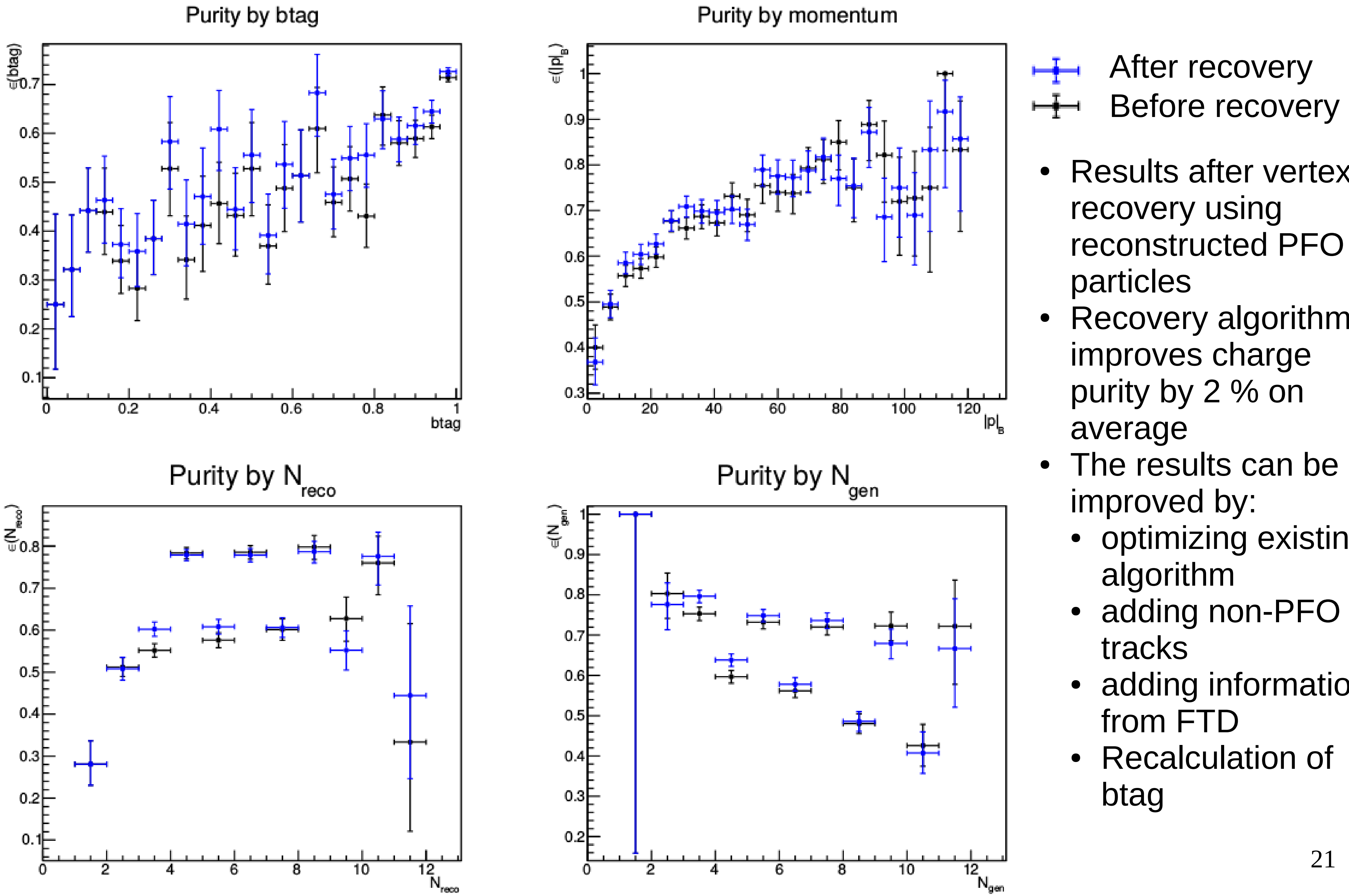
After recovery



52.3% on diagonal

- Recovery improves diagonal by ~6.6%

Preliminary charge recovery



- Results after vertex recovery using reconstructed PFO particles
- Recovery algorithm improves charge purity by 2 % on average
- The results can be improved by:
    - optimizing existing algorithm
    - adding non-PFO tracks
    - adding information from FTD
    - Recalculation of btag

Plans for recovery output

- The algorithm is capable to create a recovered vertex collection as an output
- New recovered vertices have higher mass and multiplicity – this affects b-tag parameter of a jet
- Future plans:

<processor name="**JetClustering**" type="**LcfiplusProcessor**">

<processor name="**JetVertexRefiner**" type="**LcfiplusProcessor**">

<processor name="**MyVertexRecovery**" type="**VertexRecovery**">

<processor name="**FlavorTag**" type="**LcfiplusProcessor**">

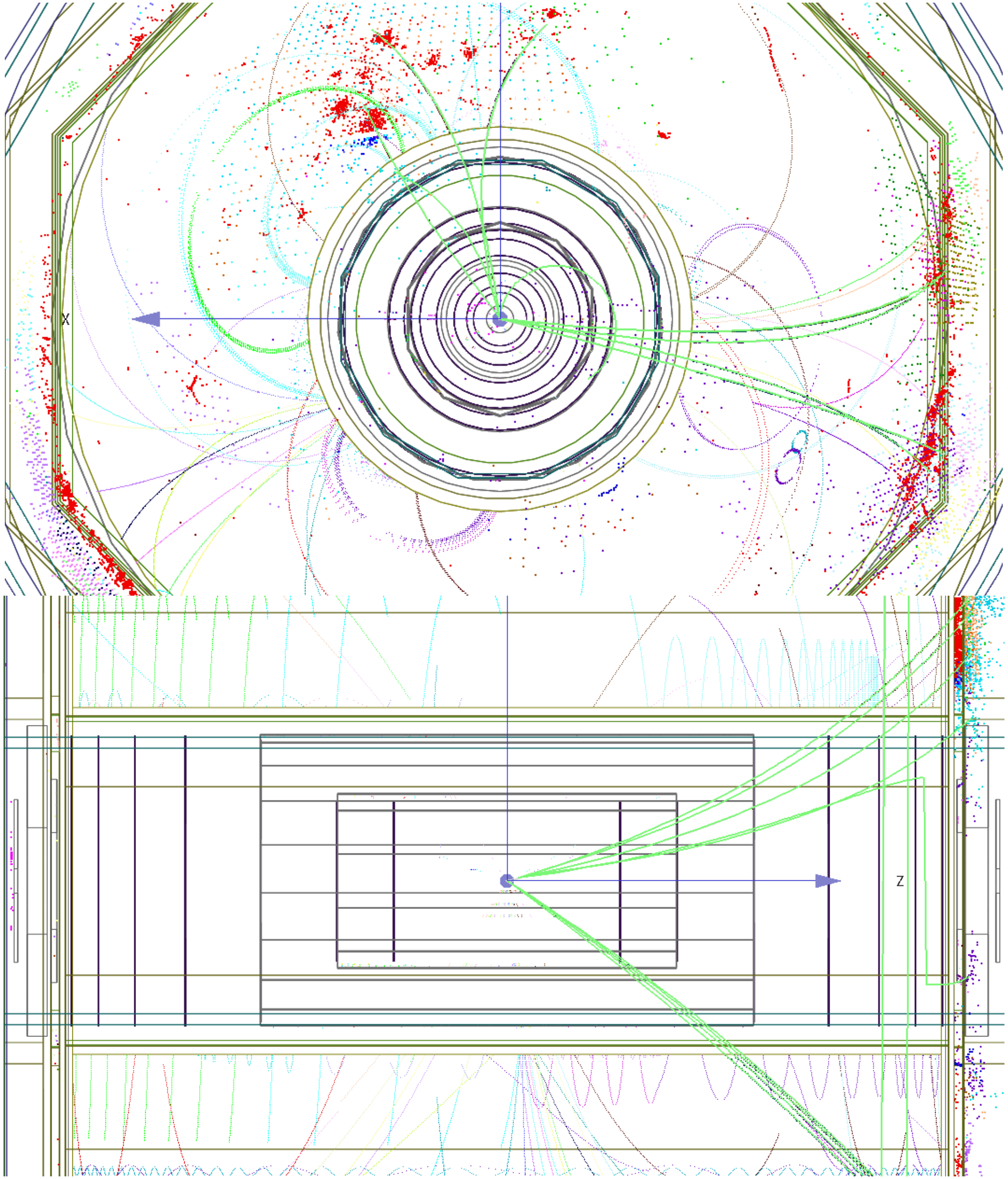
- This combination should boost b-tag of recovered events and it should increase quality of asymmetry reconstruction

Summary

- Identified various sources of inefficiencies
- Discovered a set of tracks that was not used by PFA and it is carrying b-charge information
- Angular distribution of nonreconstucted PFOs has additional peaks
- The developed method of recovery can provide up to 67% of good LSOT-VTX particles.
- Further work:
  - Optimize recovery algorithm by charge reconstruction quality
  - Include tracks that were not used for PFO
  - Use alternative tracking algorithms
  - Try to recover tracks from missed vertices
  - Use particle id for to identify kaons and use ternary vertex information

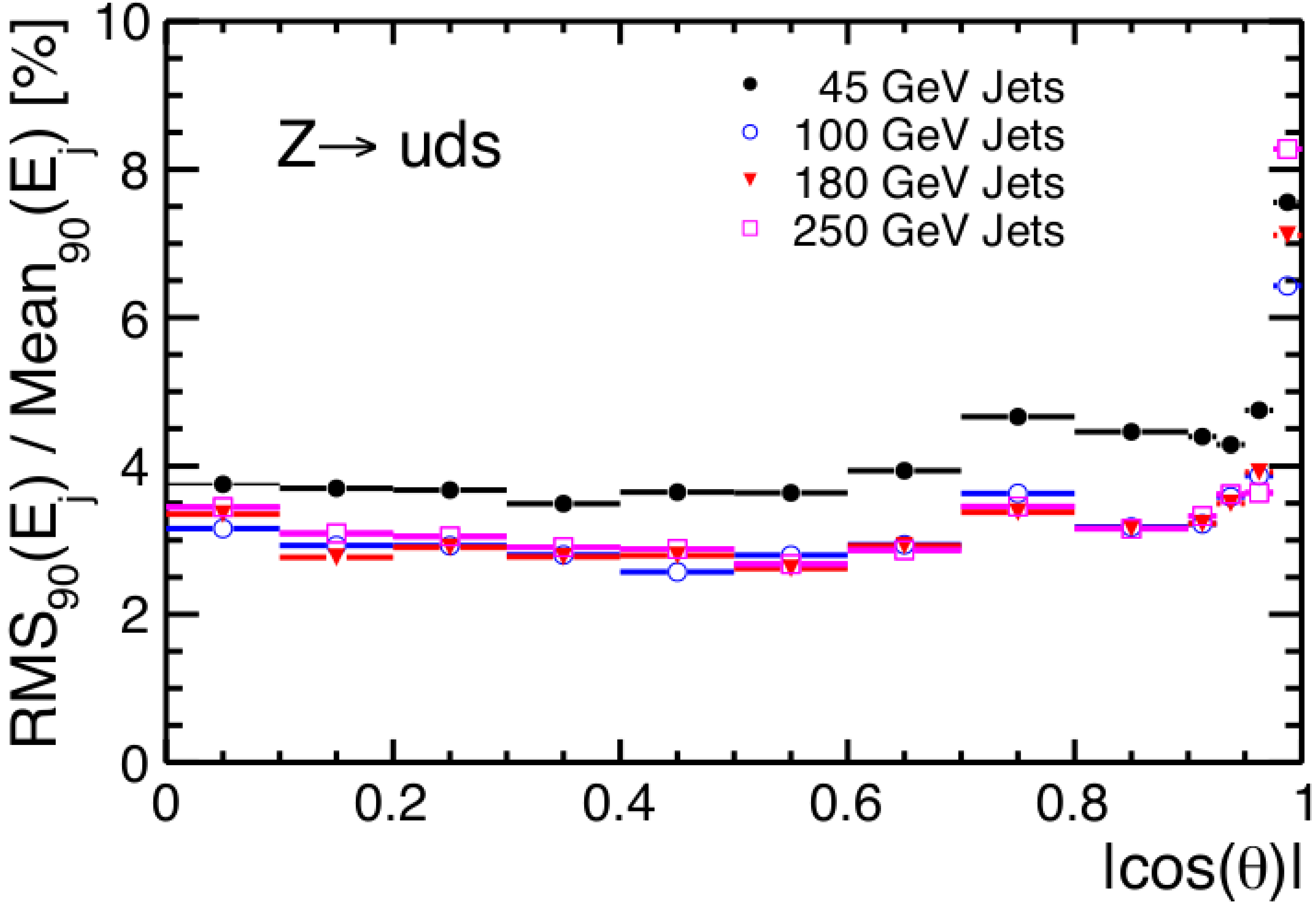
Thank you!

C Event Display



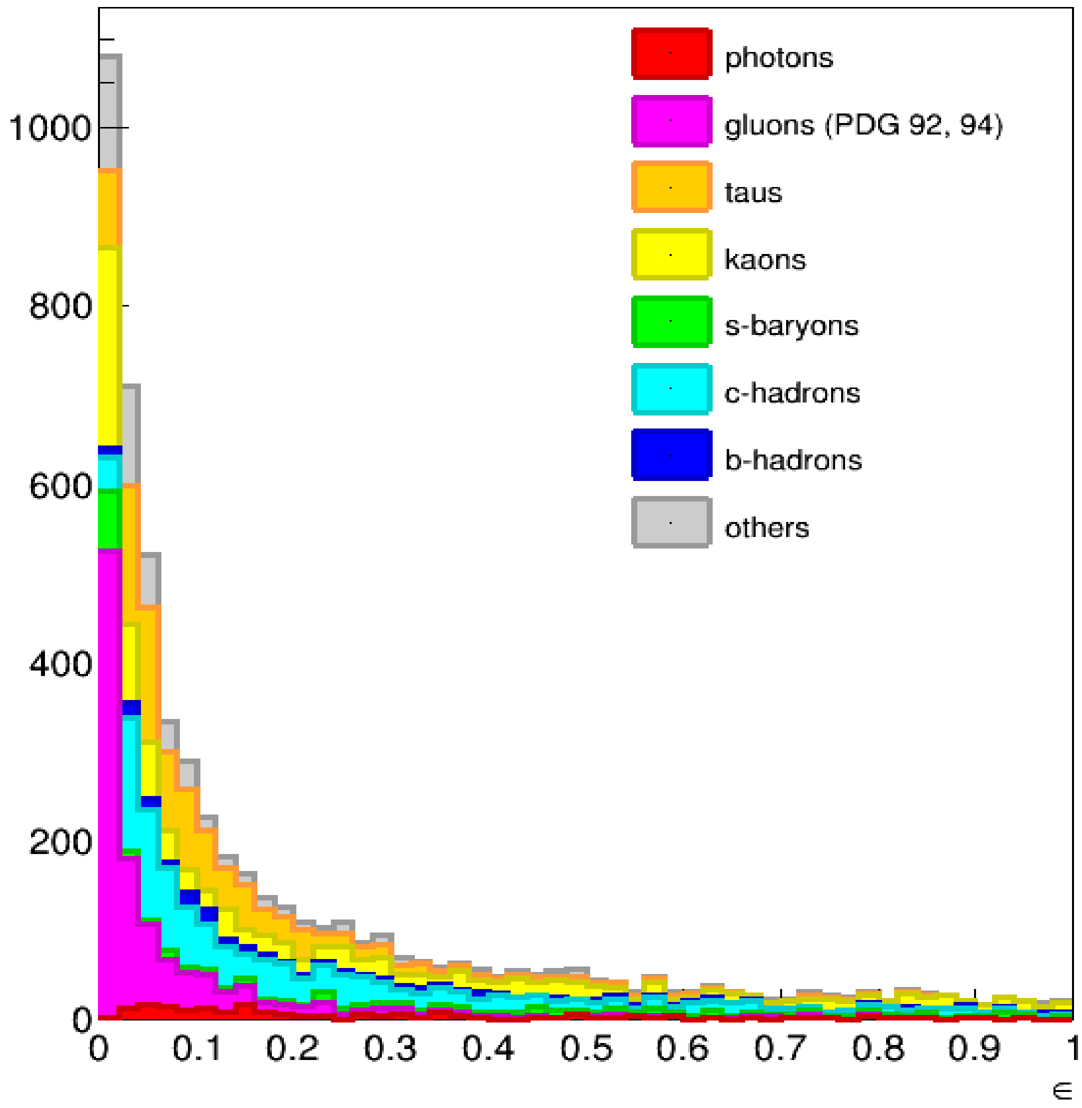
- Front and side projection of ILD event in CED.
- It was configured to show only prongs from b-hadrons
- View can be switched between generated particles to reconstructed ones

JER in ILD TDR



Complicated region in detector cause an additional bump in jet energy resolution plots

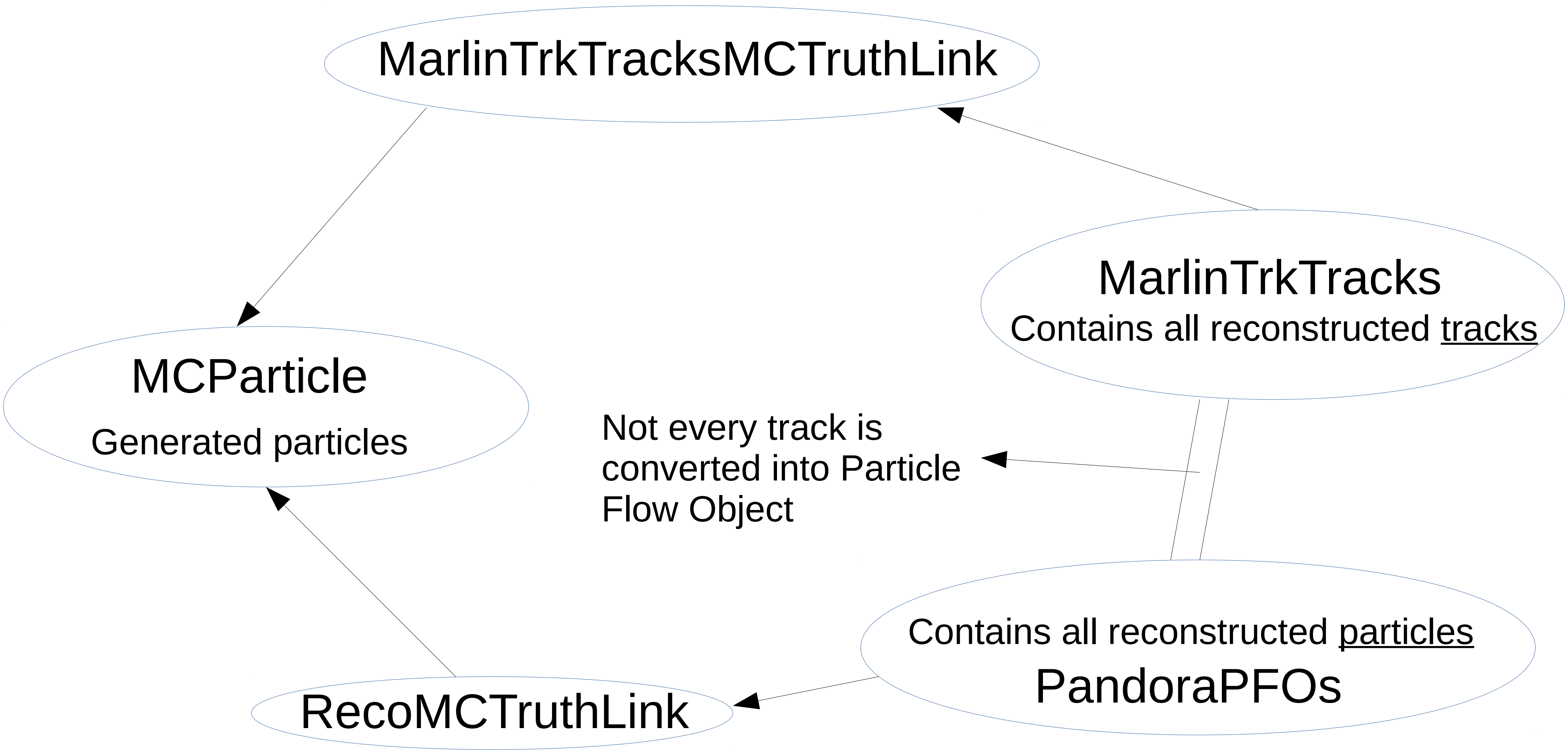
Origin of no vertex tracks



- This is offset histogram of “no vertex” tracks subdivided by different origin of a track using generator truth after VXD hits > 3 cut.
- Main contributions are coming from c- and s-hadrons, taus and “gluons”

- Majority of c-hadrons and tau-leptons should come from W-jets, and these tracks have to be separated from b-jets by large angle

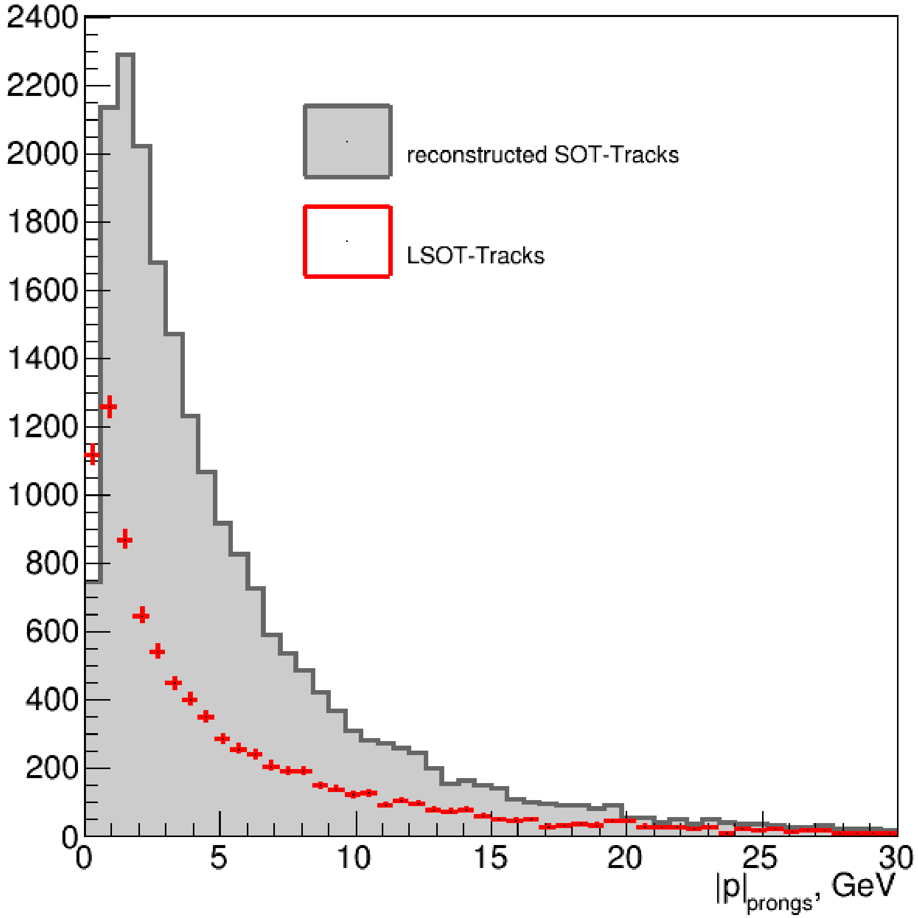
Truthlinks used



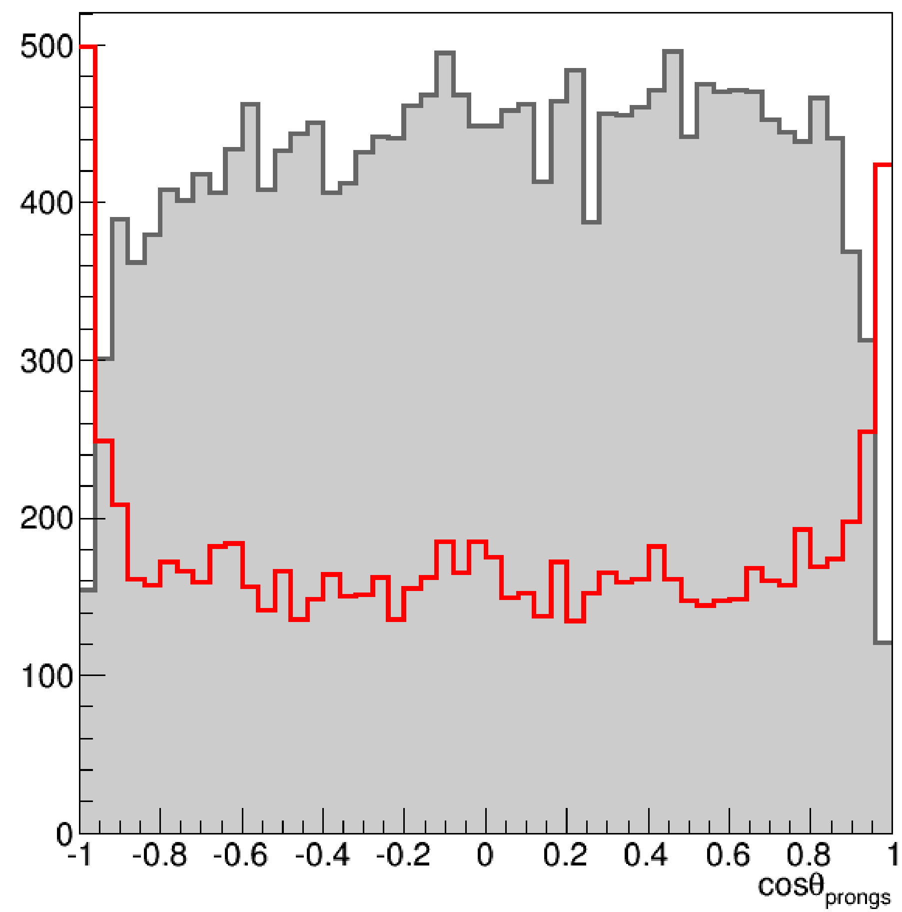
There is ~3% uncertainty between these truthlinks

Lost SOT-Tracks analysis

Momentum comparison

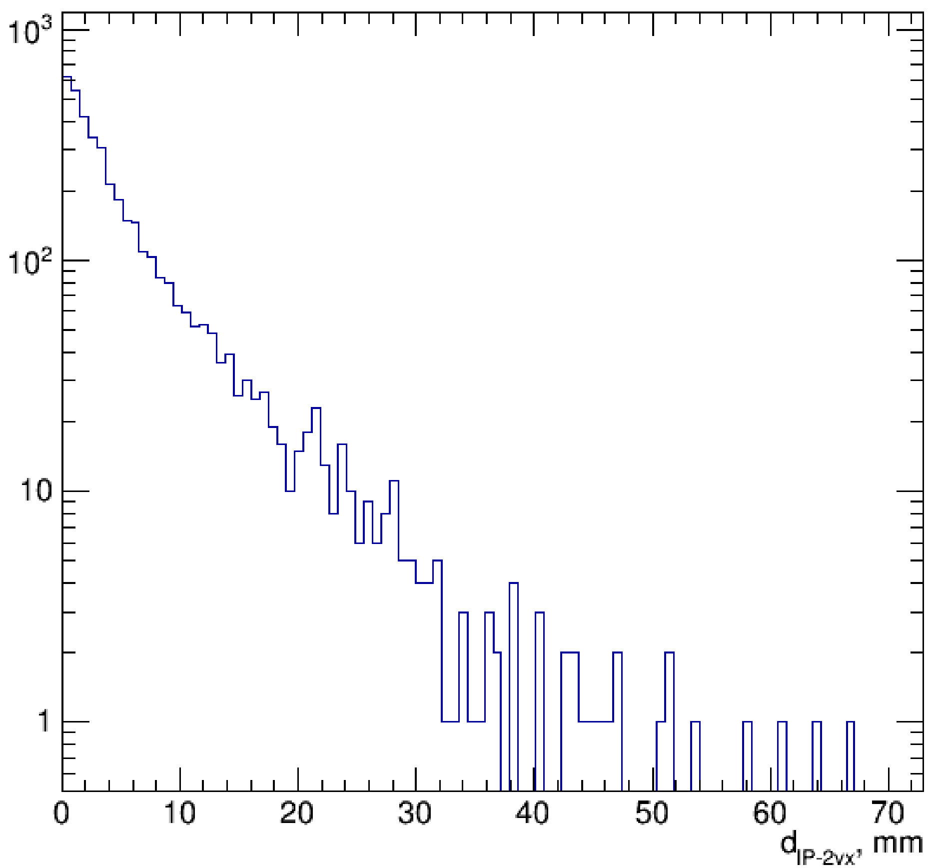


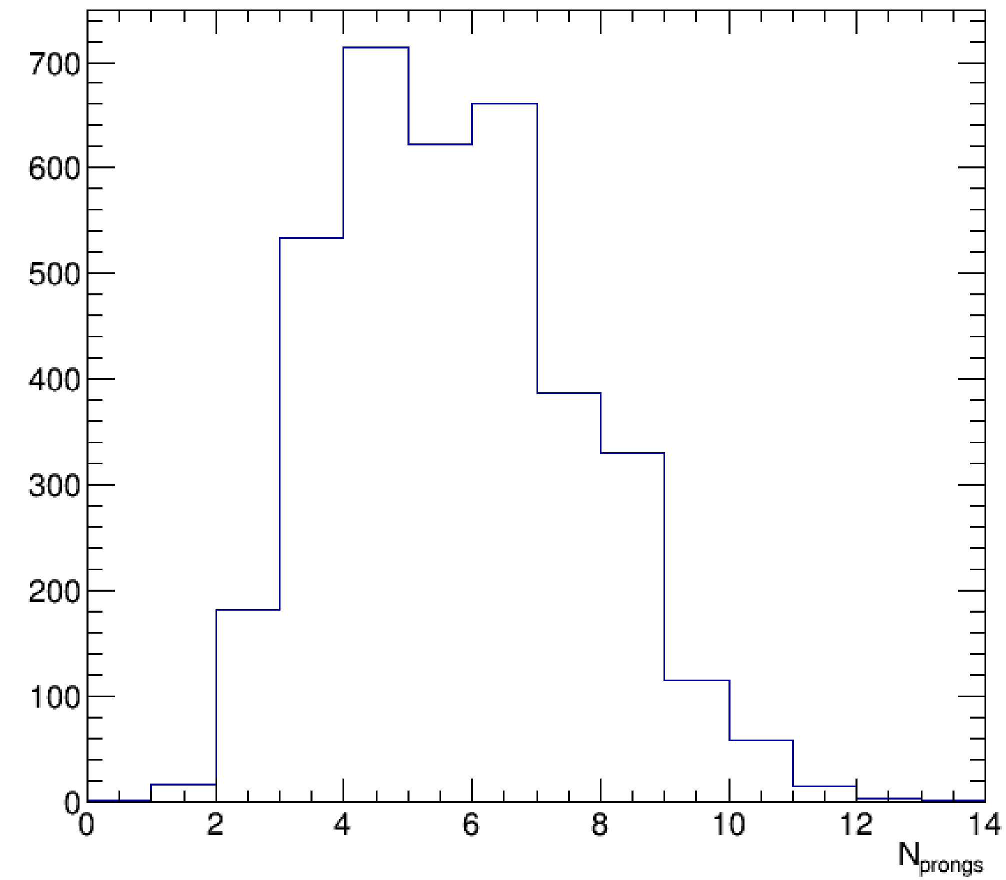
Angular comparison



- There is a tendency to lose a track with low momentum or in forward region. We should investigate all the reasons to lose a track

Generated vertices

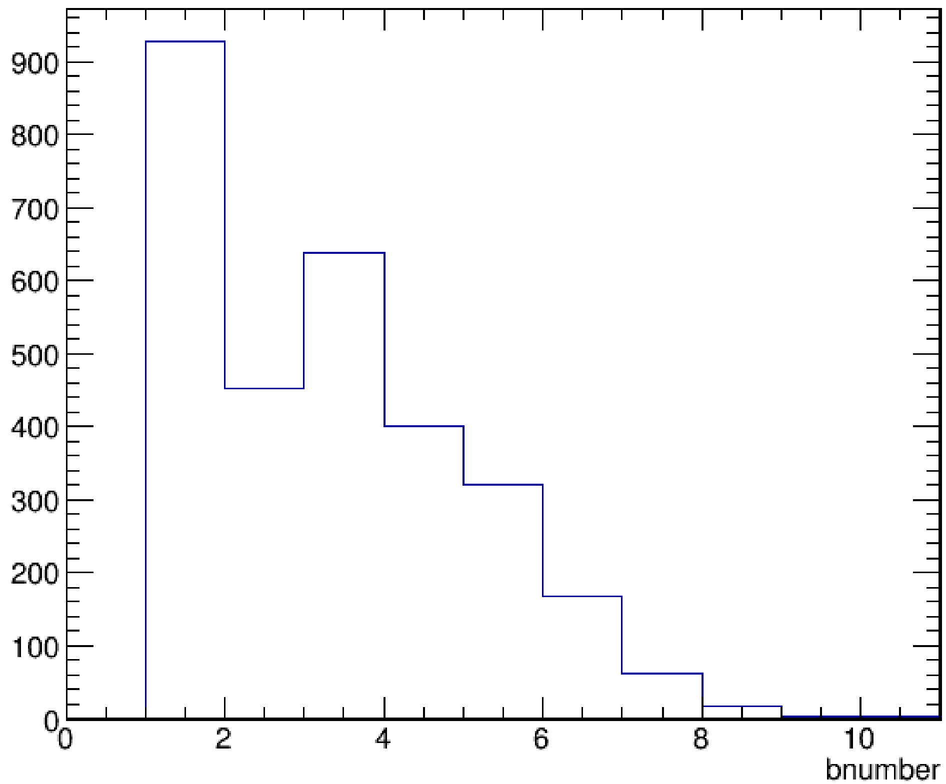




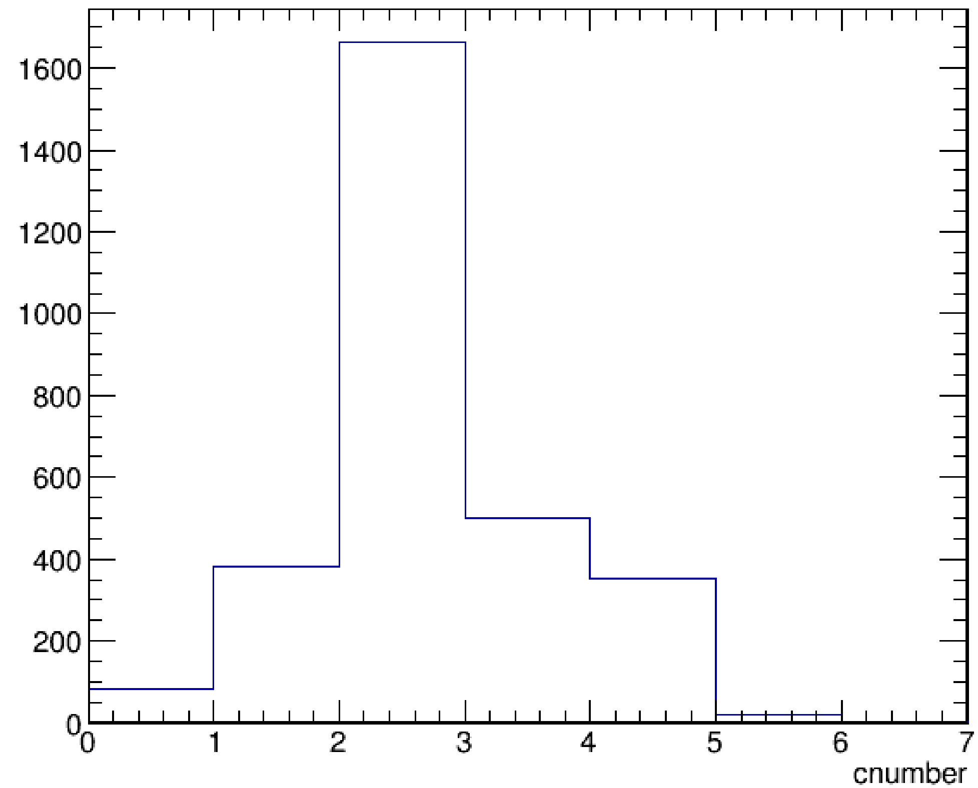
- Distance from IP to B-meson decay vertex (left), prongs of initial B-meson (right)

Multiplicity of b-c vertices

b-vertex



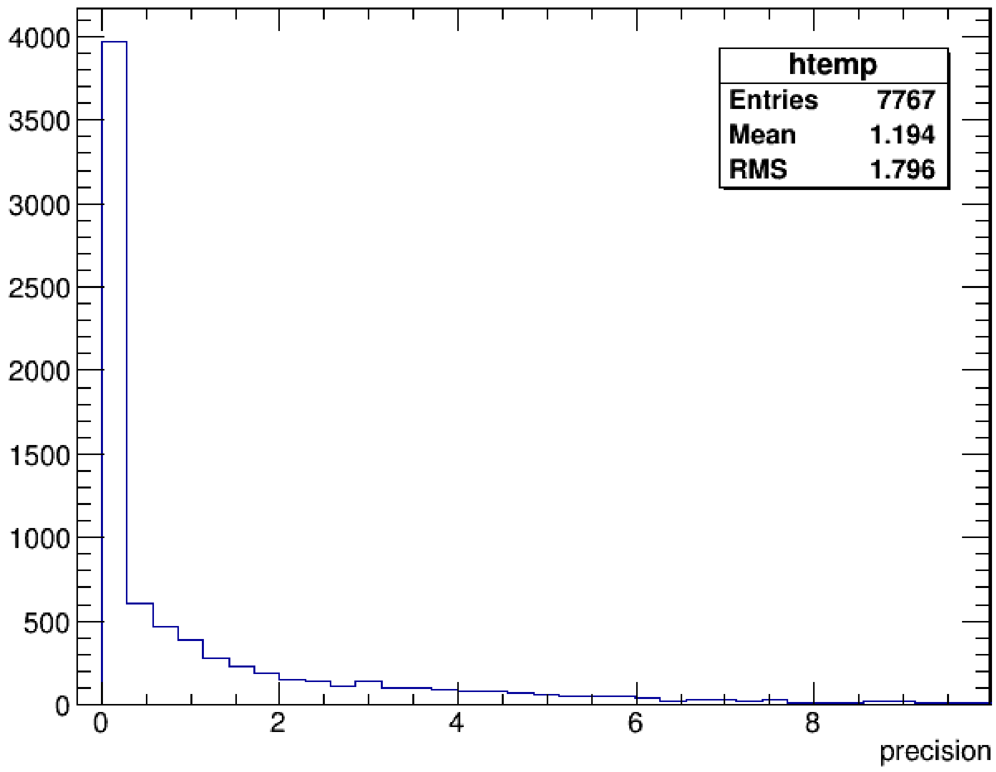
c-vertex



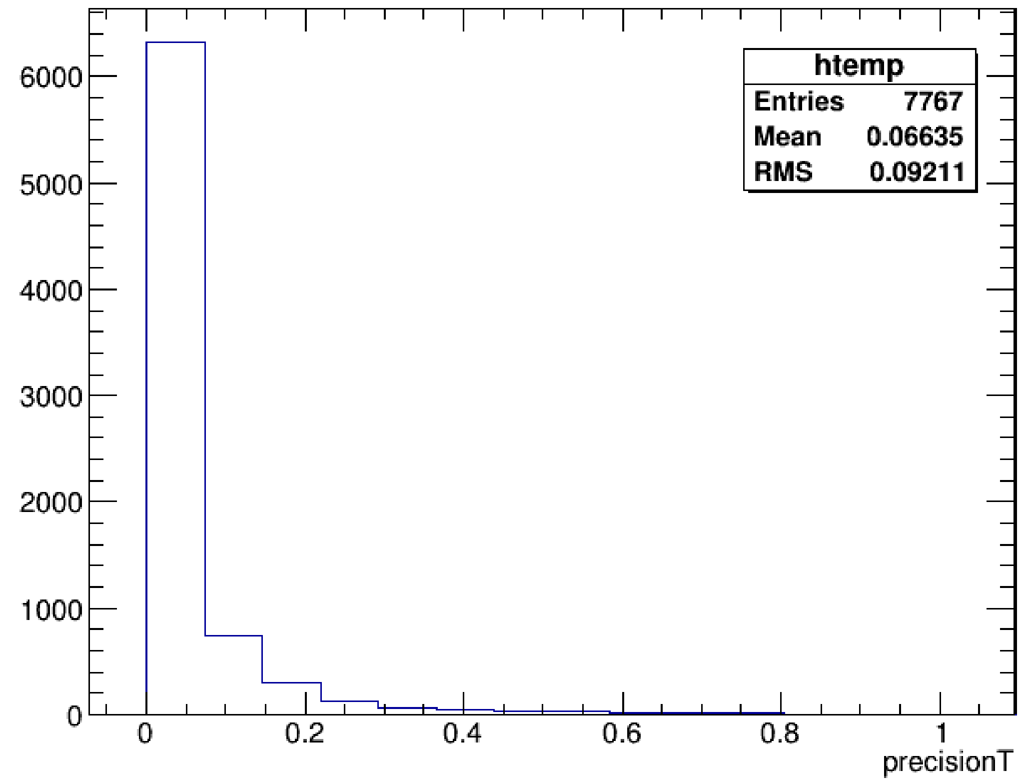
- Number of tracks for b and c vertices. For charge measurement the 1-prong decay is dangerous and it is present in both vertices

Precision of vertex position

Distance

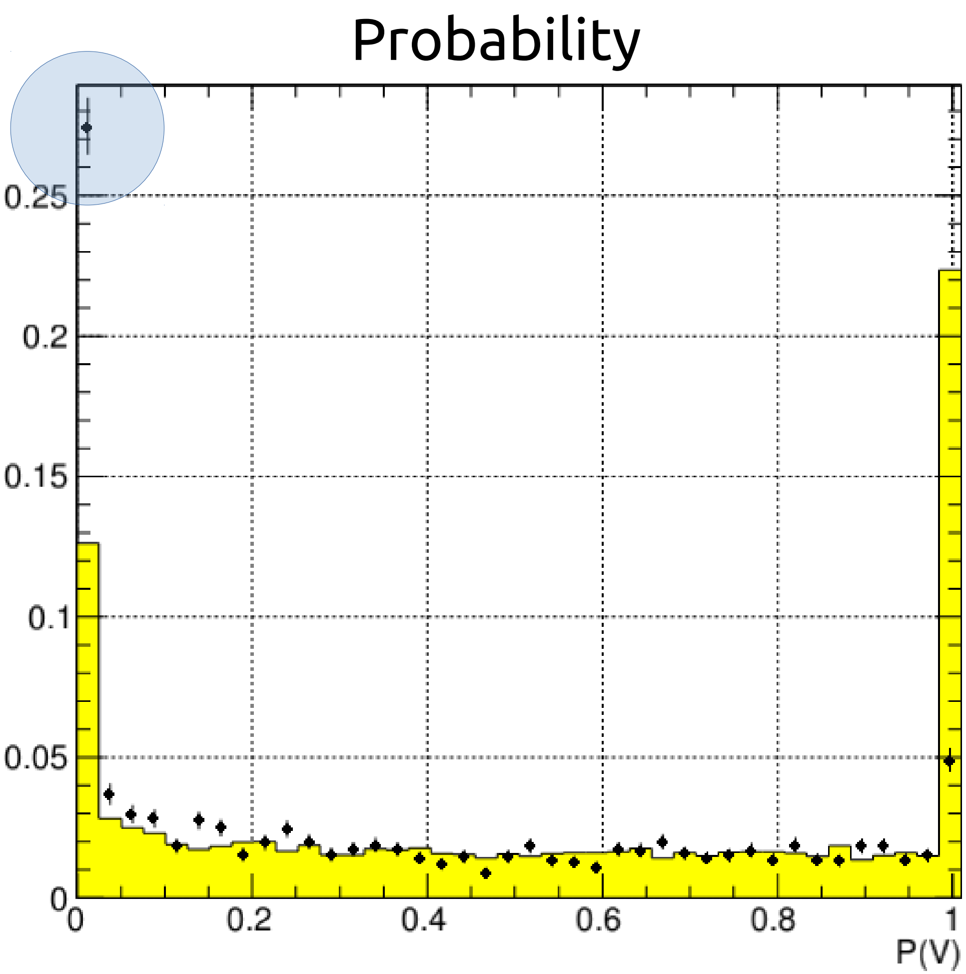


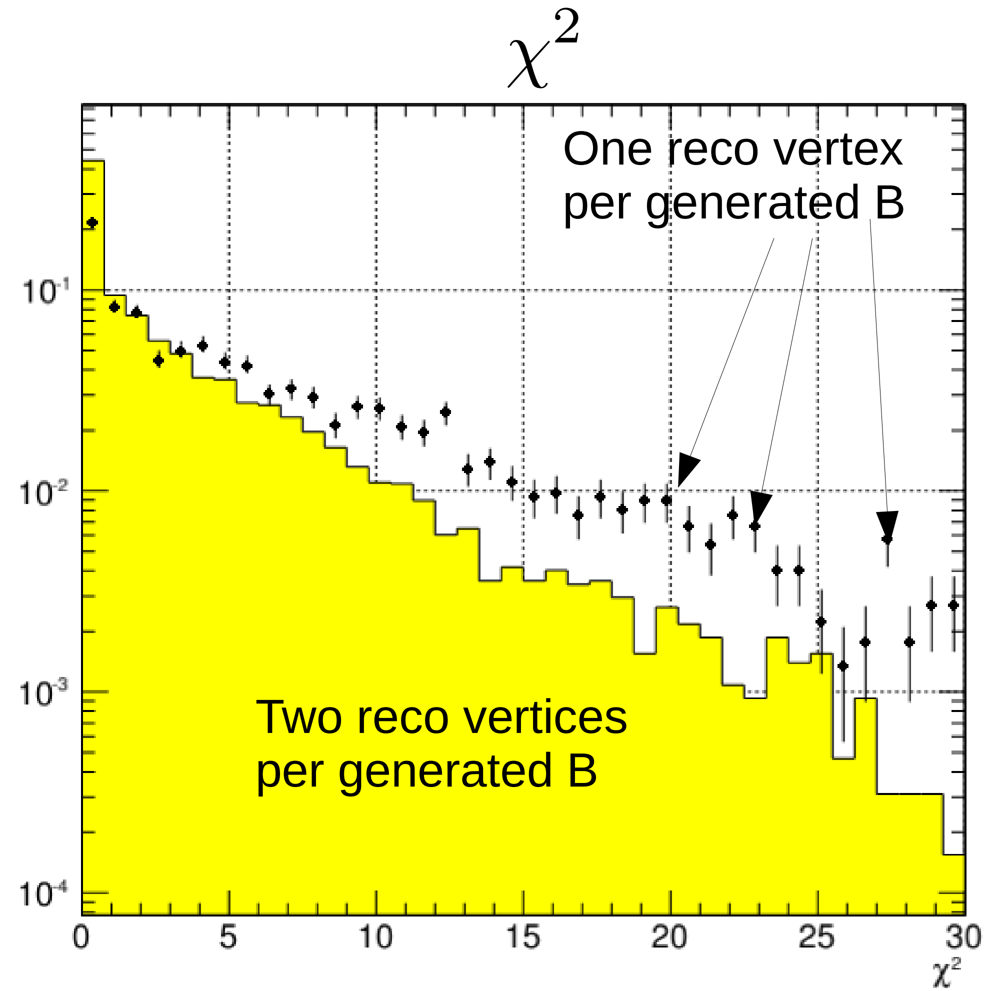
Transverse distance



- Distance between reconstructed and generated vertices. The direction of b-hadron known precisely.

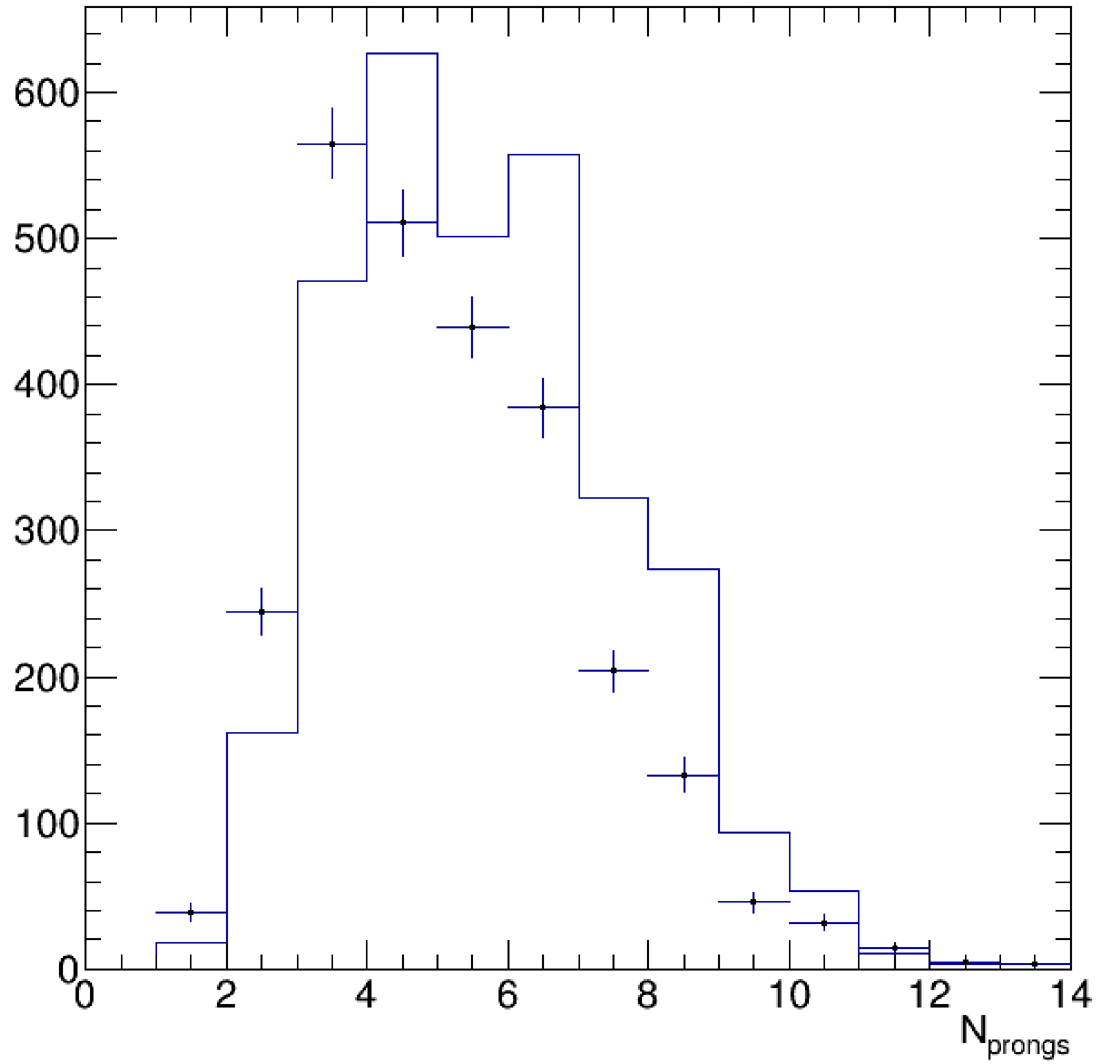
Reconstructed vertices





- Probability (left) and chi-square from LCFI+ (right) comparison for 1 vertex per b-jet (dots) and 2 vertices per b-jet (yellow). The presence of ternary vertex increase chi-square value of vertex fitting.

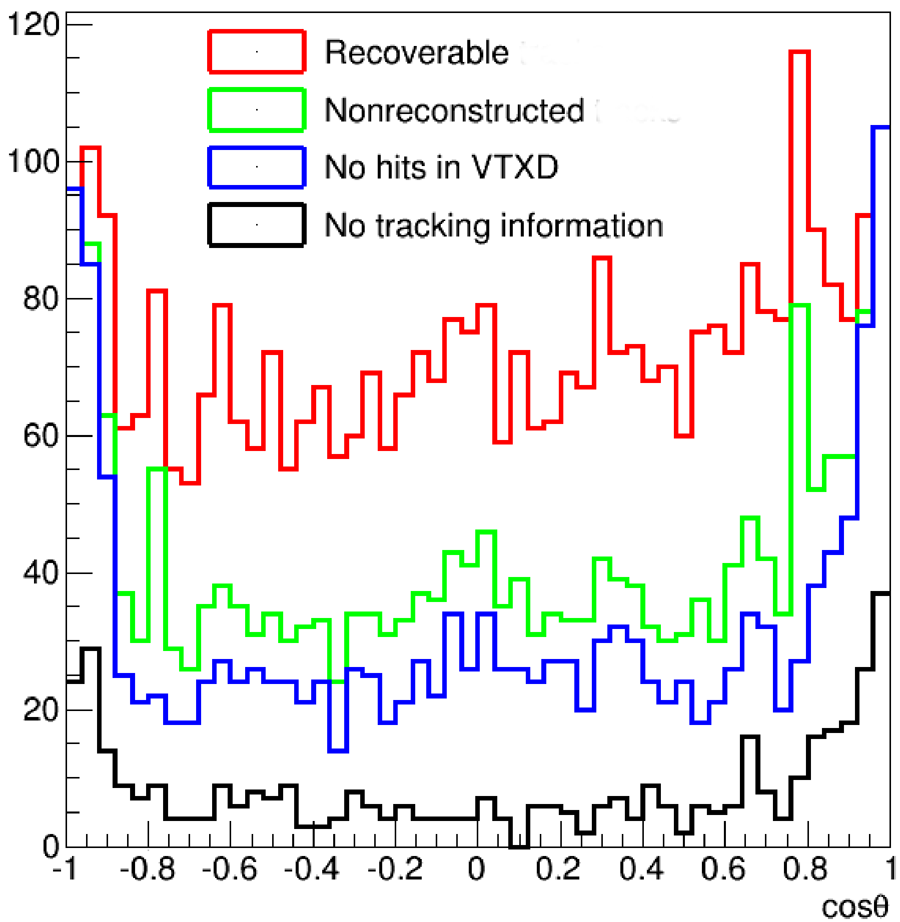
Reconstructed vertices



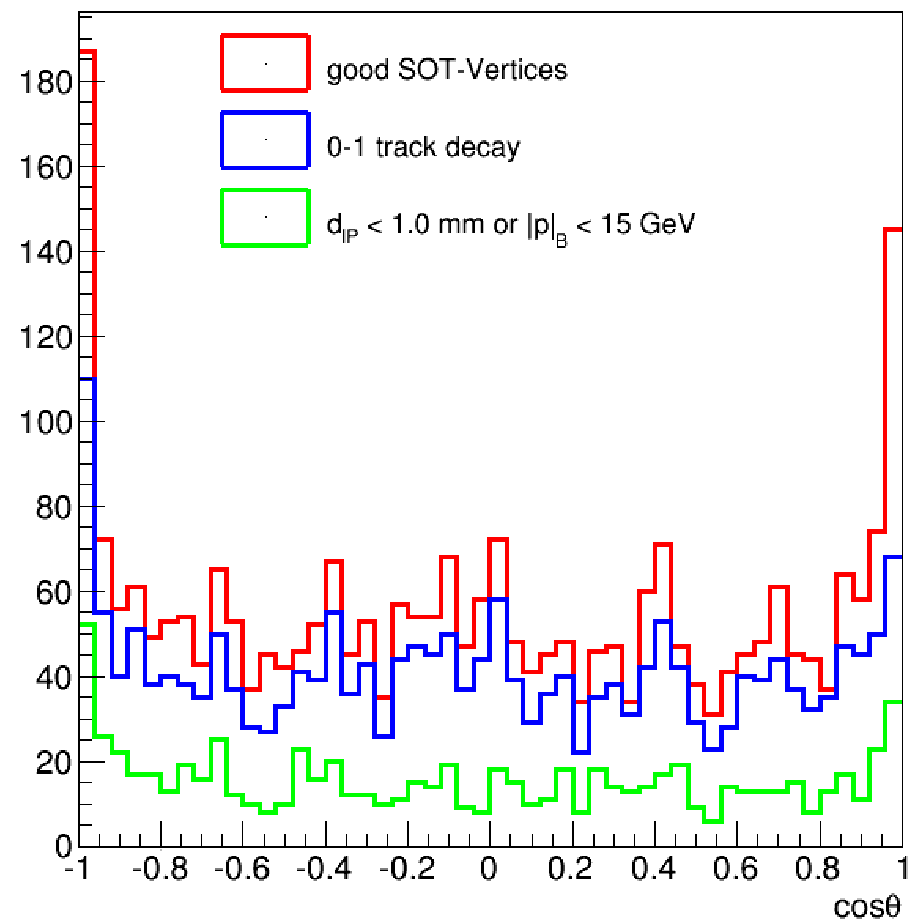
- Number of tracks from generated vertices (yellow) and reconstructed (crosses). Distributions do not coincide

Lost particles analysis

LSOT-VTX Particles



LSOT-NOVTX Vertices



- There is an enhanced risk to lose a 1-track decay vertex and high chances to miss any SOT vertex in forward region