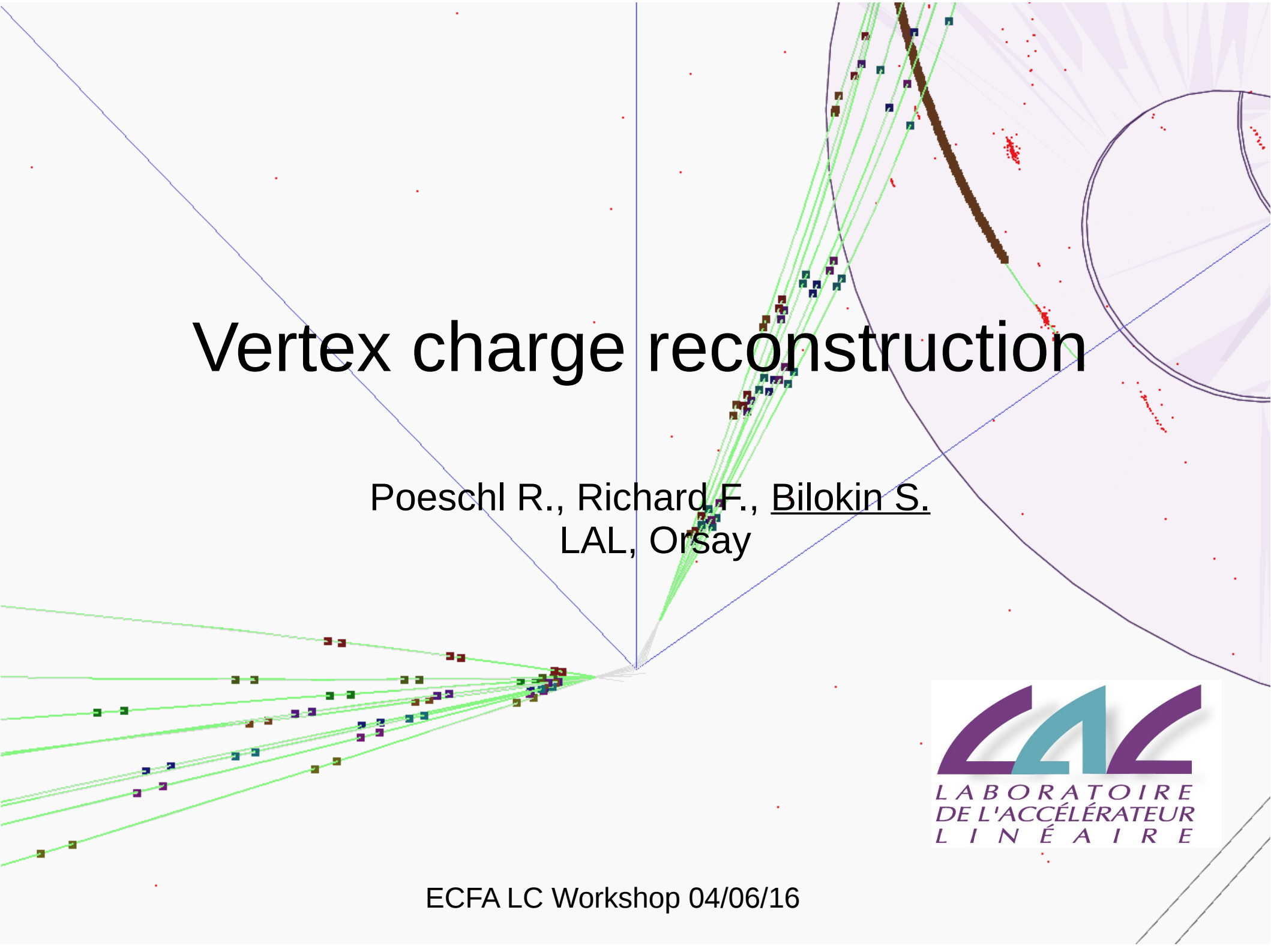


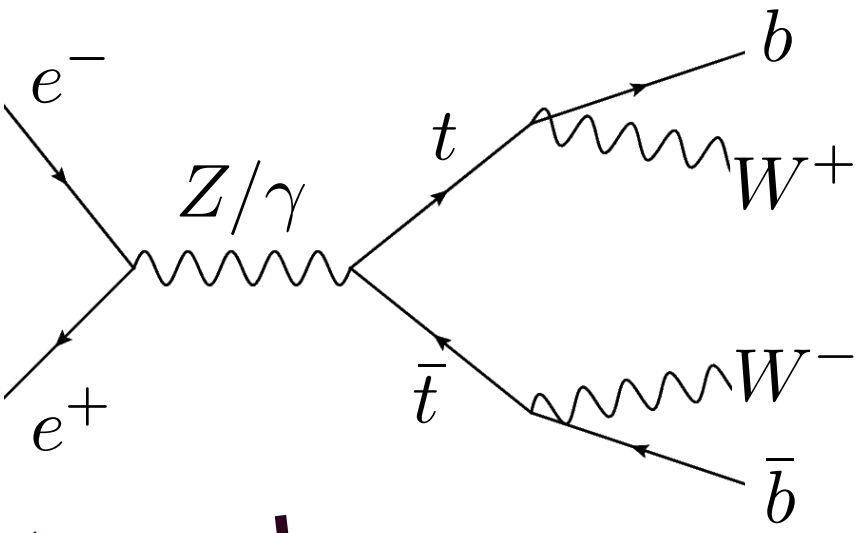
Vertex charge reconstruction

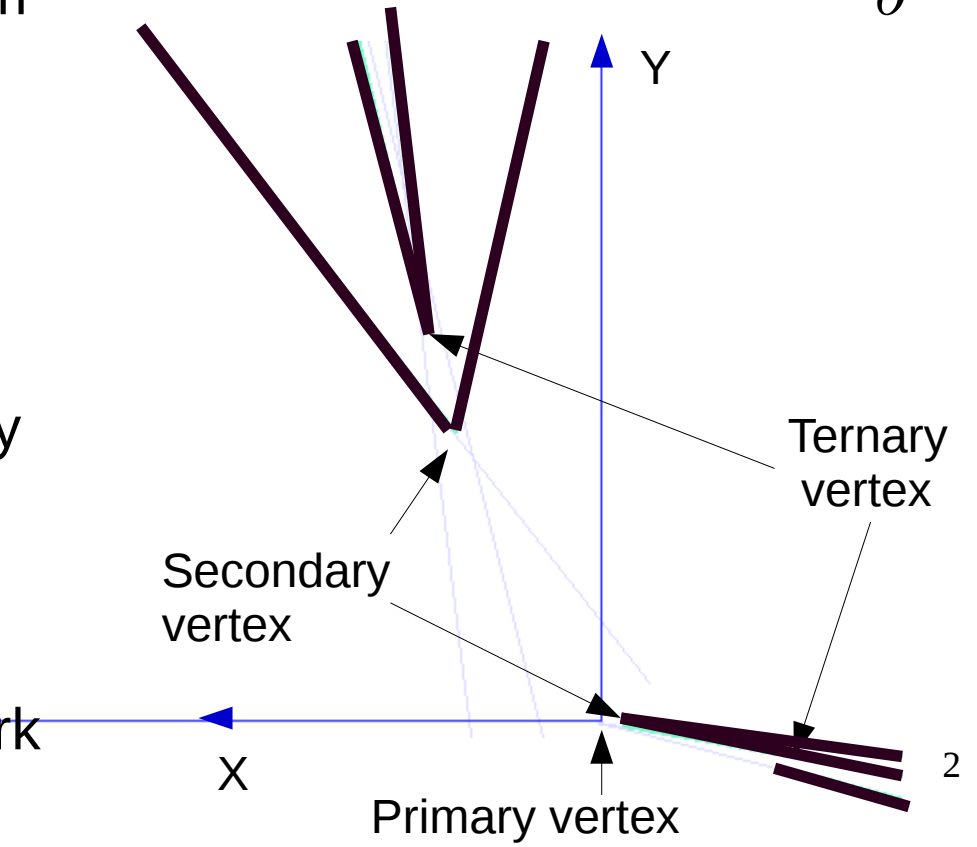
Poeschl R., Richard F., Bilokin S.
LAL, Orsay

ECFA LC Workshop 04/06/16

Objective

- 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
- Charge of the b-quark is calculated as a sum of the charges of secondary and ternary vertex particles
- The charge of K-mesons from reconstructed vertices is directly connected to the charge of t-quark

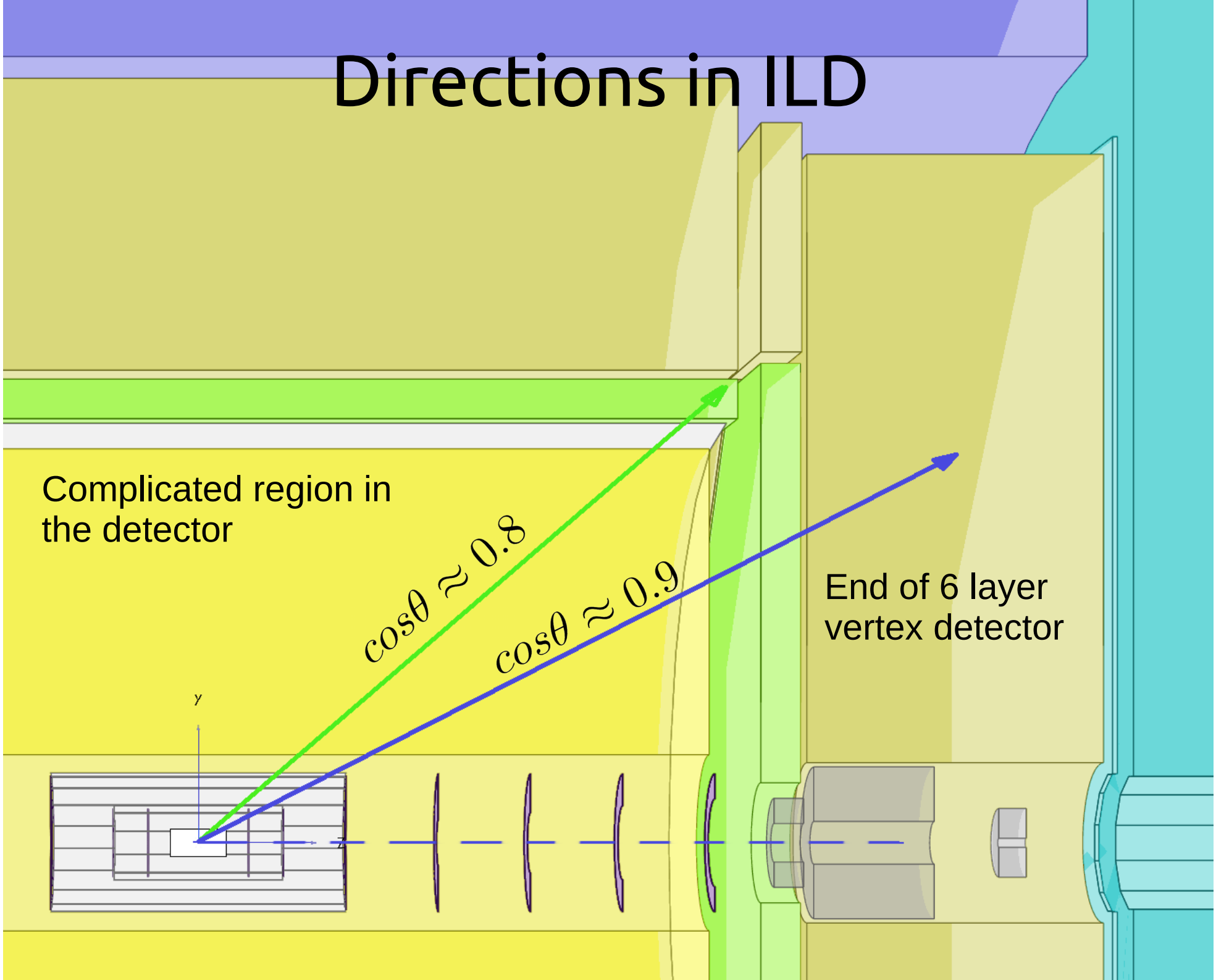




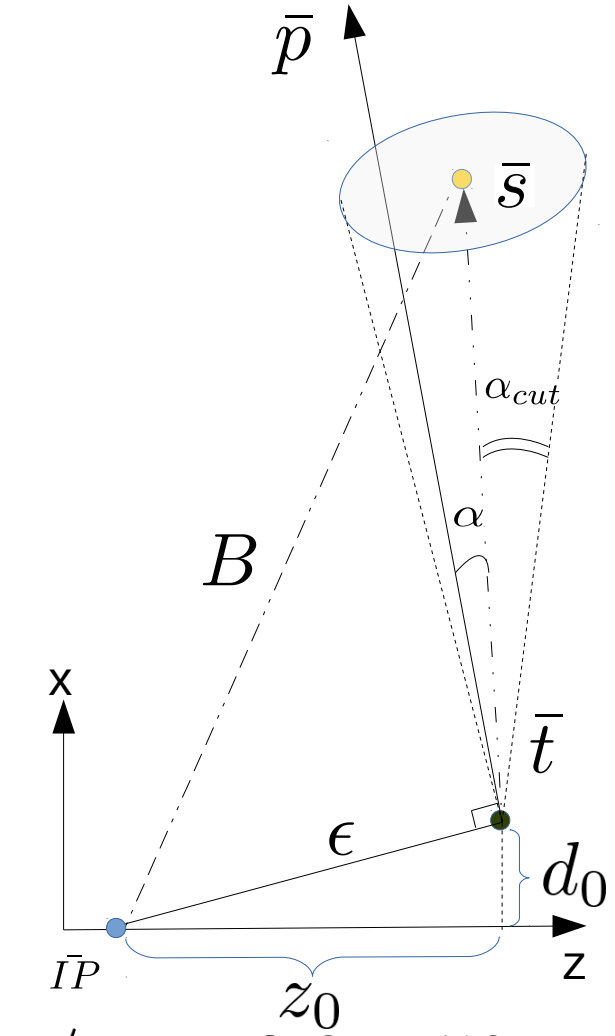
Analysis setup

- We are using 500 GeV semileptonic ttbar sample eLpR with pair background v01-16-05 (DBD)
- Same sample using CellsAutomatonMV as tracking algorithm v01-17-09 (Minivector)
- TruthVertexFinder from MarlinReco/Analysis to get the generated vertices
- Modified version of VertexChargeRecovery from MarlinReco/Analysis (Recovery)
- Technical details were given in the talk on Tuesday in Software Session of ECFA workshop 2016

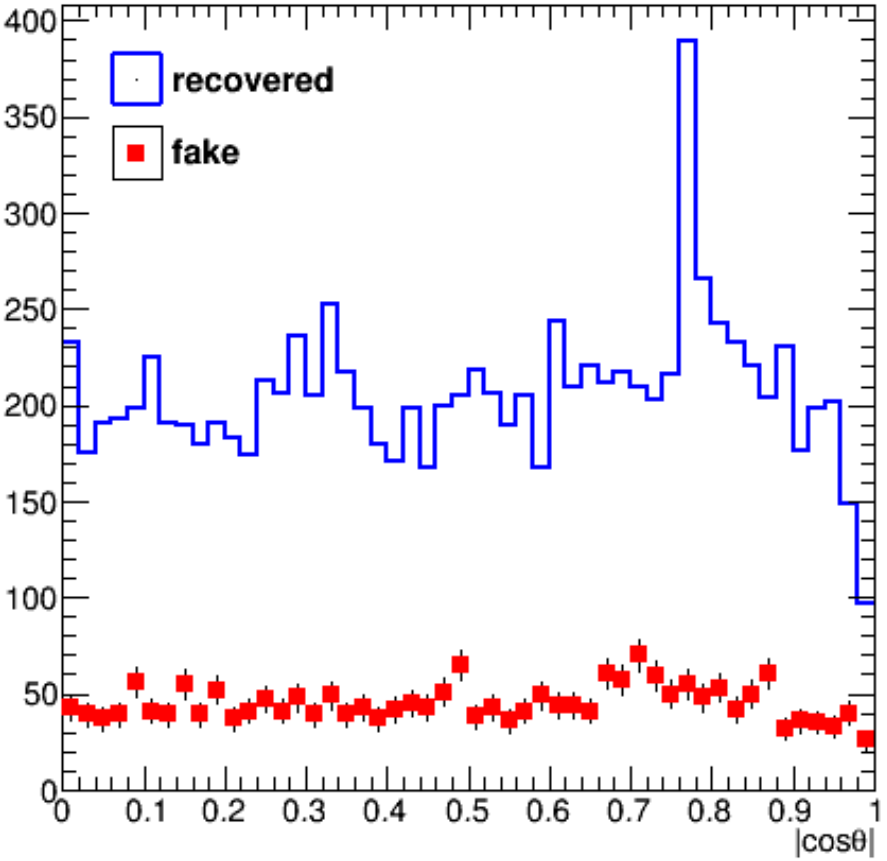
Directions in ILD



Recovery optimization



$$\epsilon/\sigma_\epsilon = |\frac{d_0}{\sigma_{d_0}}| + |\frac{z_0}{\sigma_{z_0}}|$$



$$\varepsilon/\sigma_\varepsilon > 2.0 + 50 * \alpha$$

- Angular distribution of the recovered b-tracks and background (fake) tracks. Covariance matrix is used. Minivector tracking.

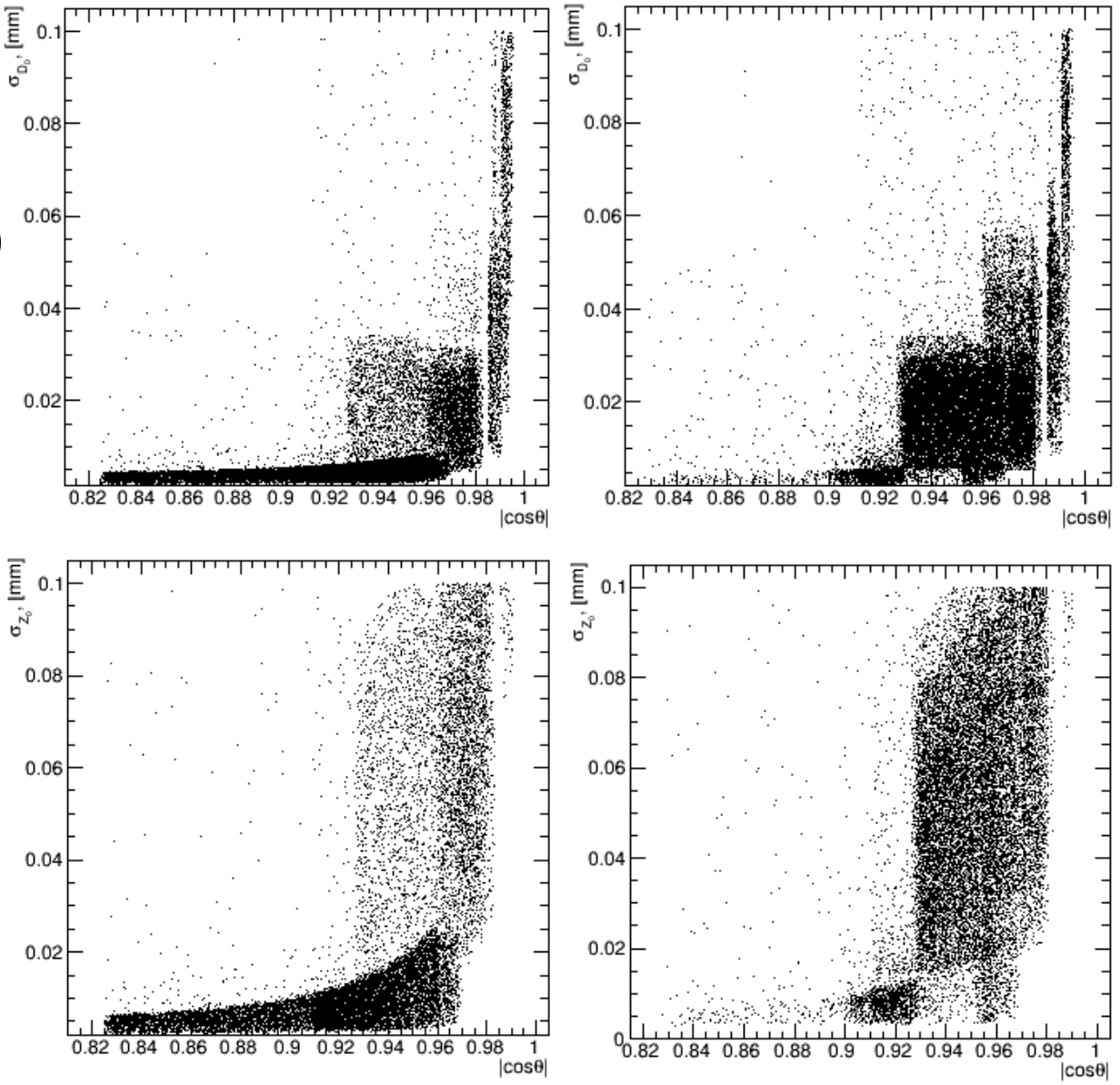
Track parameter uncertainties

DBD

Minivector

d_0

z_0

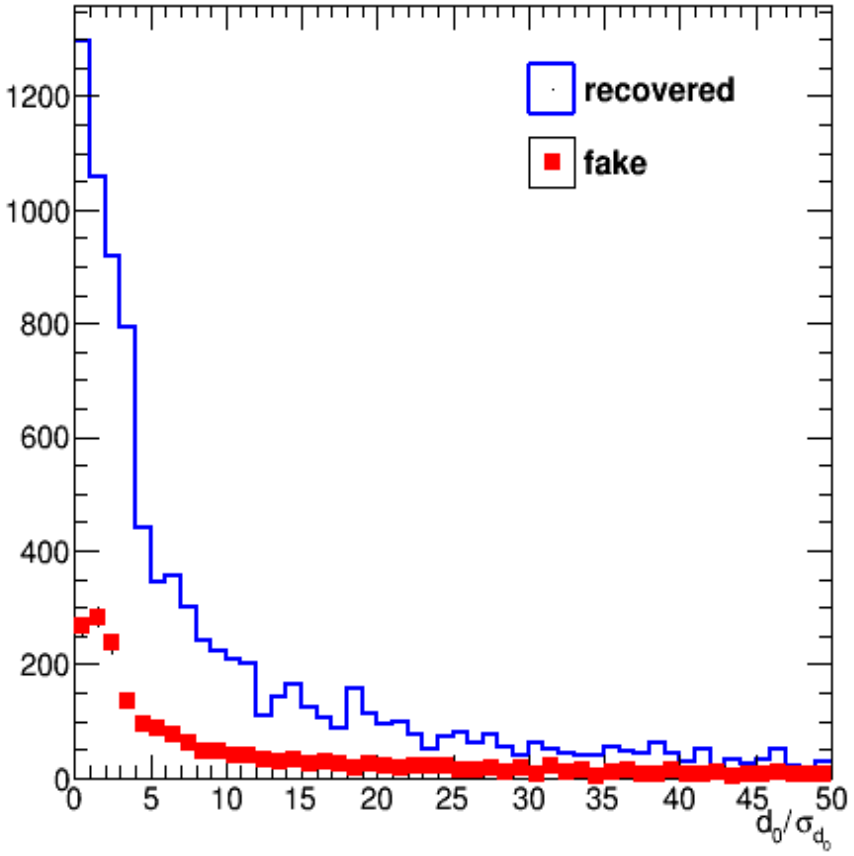


- Angular distribution of d0 and z0 uncertainties for minivector tracking.
- The transition towards the forward region may "suffer" from reducing number of space points for measurement, needs more investigation
- Step-function-like uncertainty behaviour, more pronounced for mini-vector

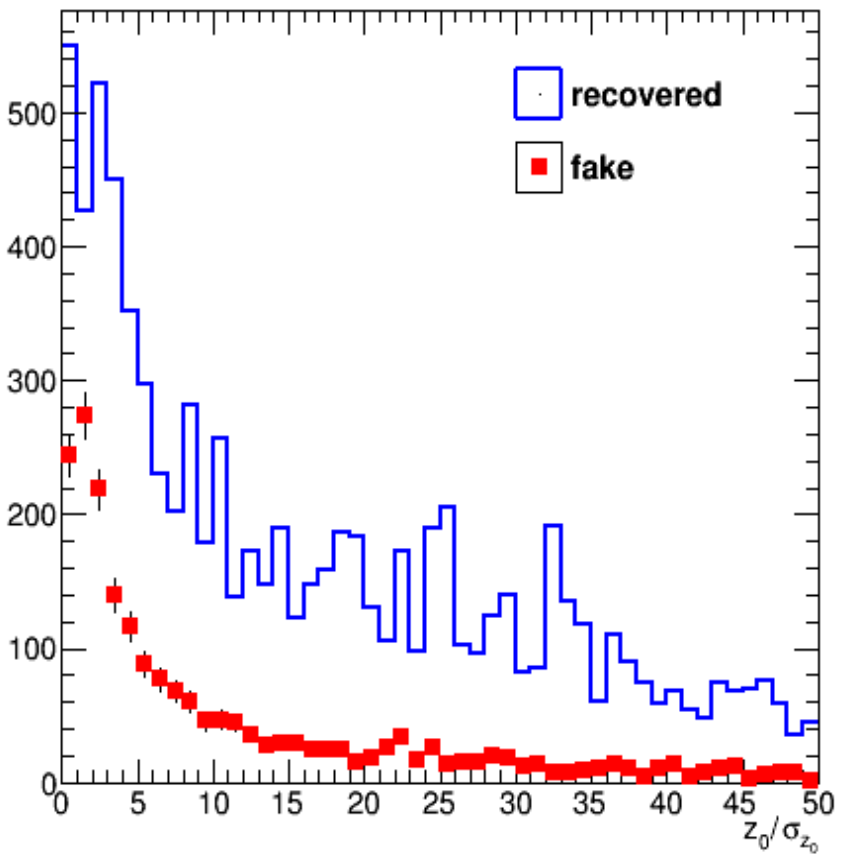
P > 10 GeV & FTD hits > 1

Components of the offset significance

d0



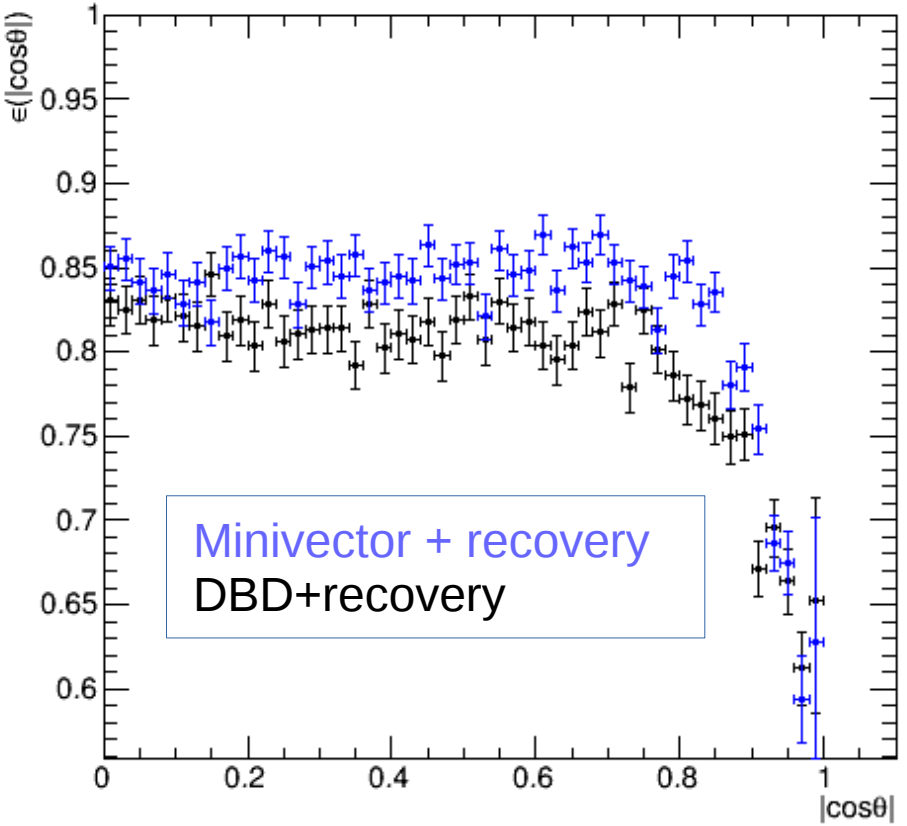
z0



- Excellent purity for d0 offset significance
- Purity of the recovery degrades towards small z0 offset significance, needs to be improved

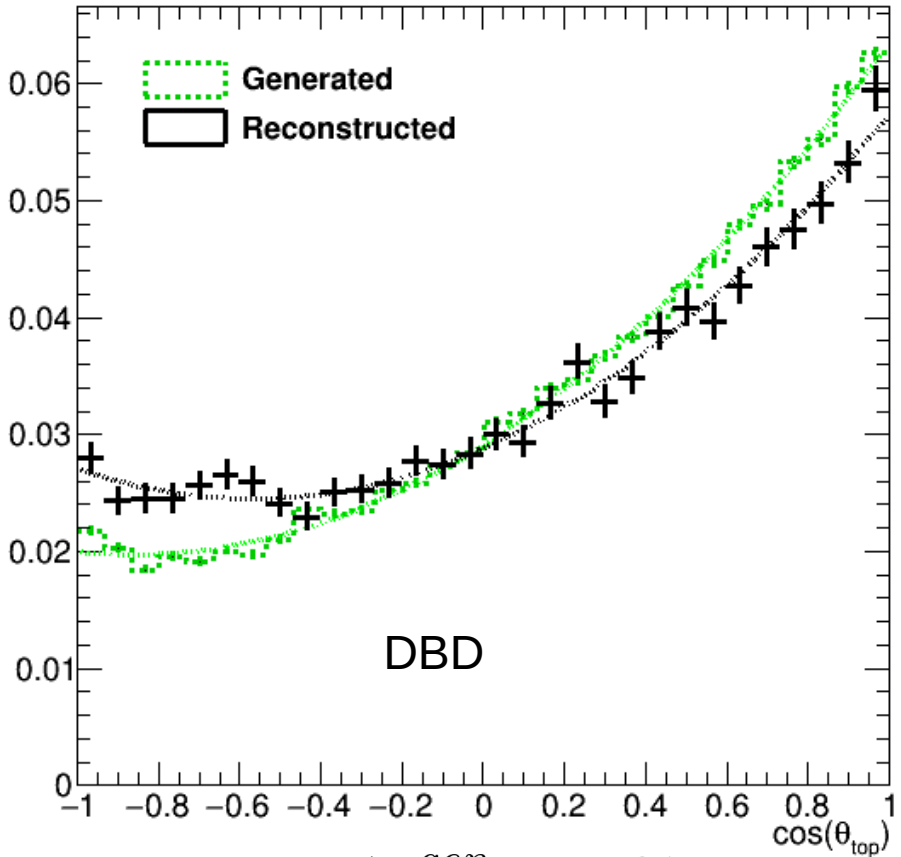
Overall charge purity

B-meson charge purity as a function of polar angle

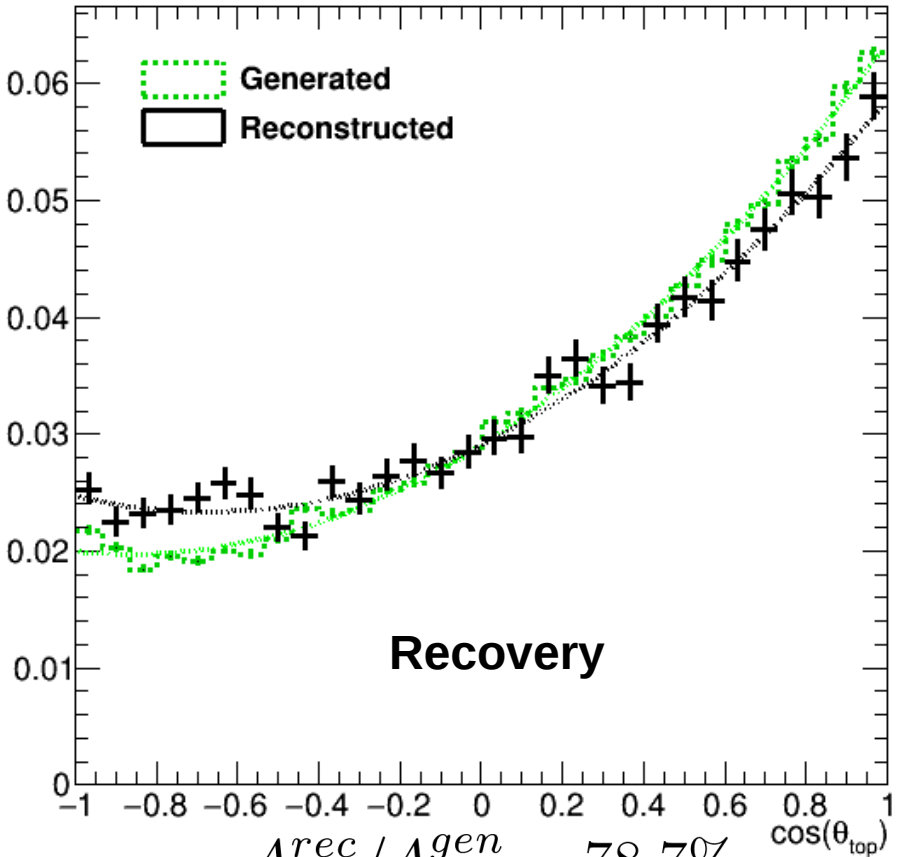


- Vertex charge purity in the barrel region 80-85%
- Degradation towards the forward region
- Minivector sample has ~3% higher vertex charge purity on average than DBD, and it has better purity in the forward region

DBD top polar angle reconstruction



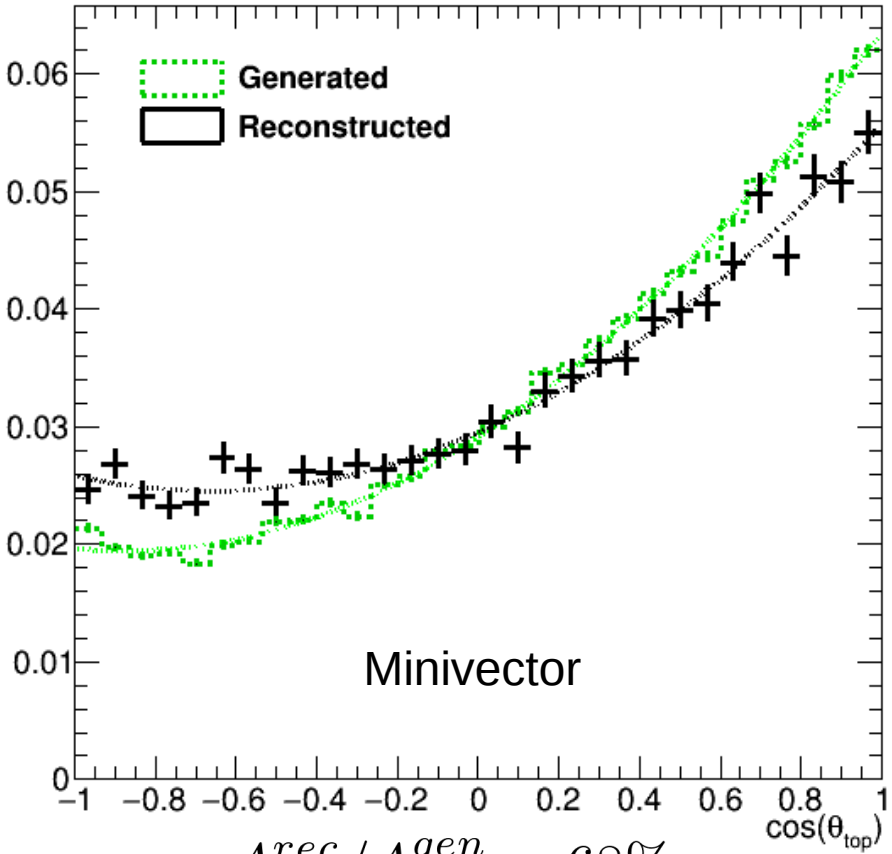
$A_{fb}^{rec}/A_{fb}^{gen} = 70\%$



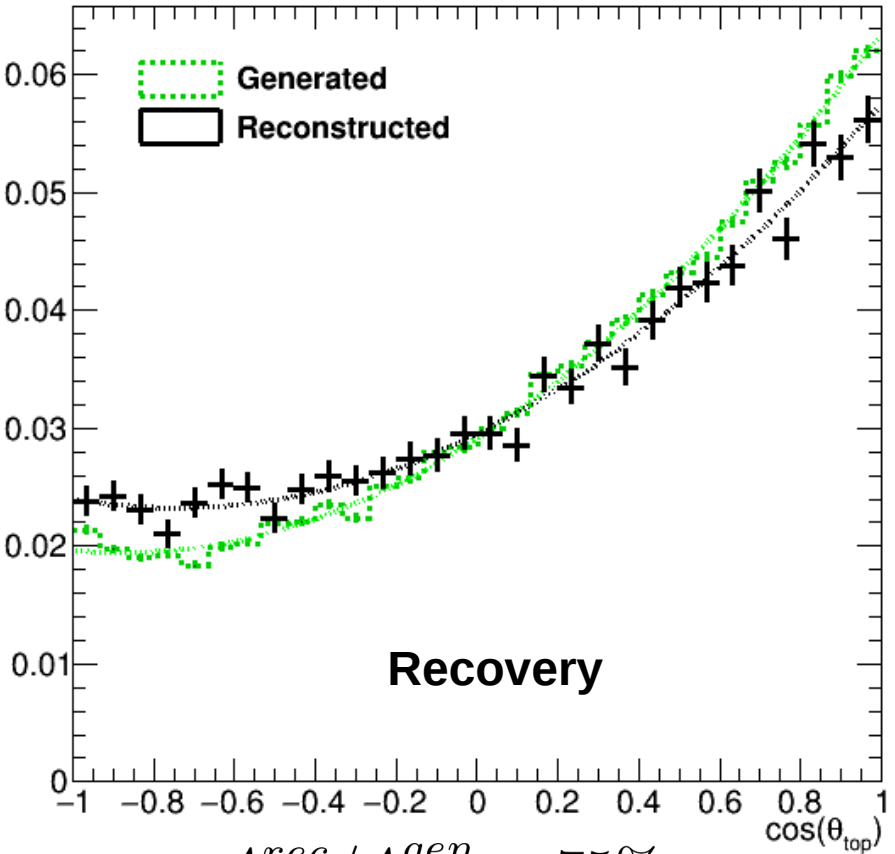
$A_{fb}^{rec}/A_{fb}^{gen} = 78.7\%$

- Recovery improves by more than 10%.

Minivector top polar angle reconstruction



$A_{fb}^{rec}/A_{fb}^{gen} = 68\%$

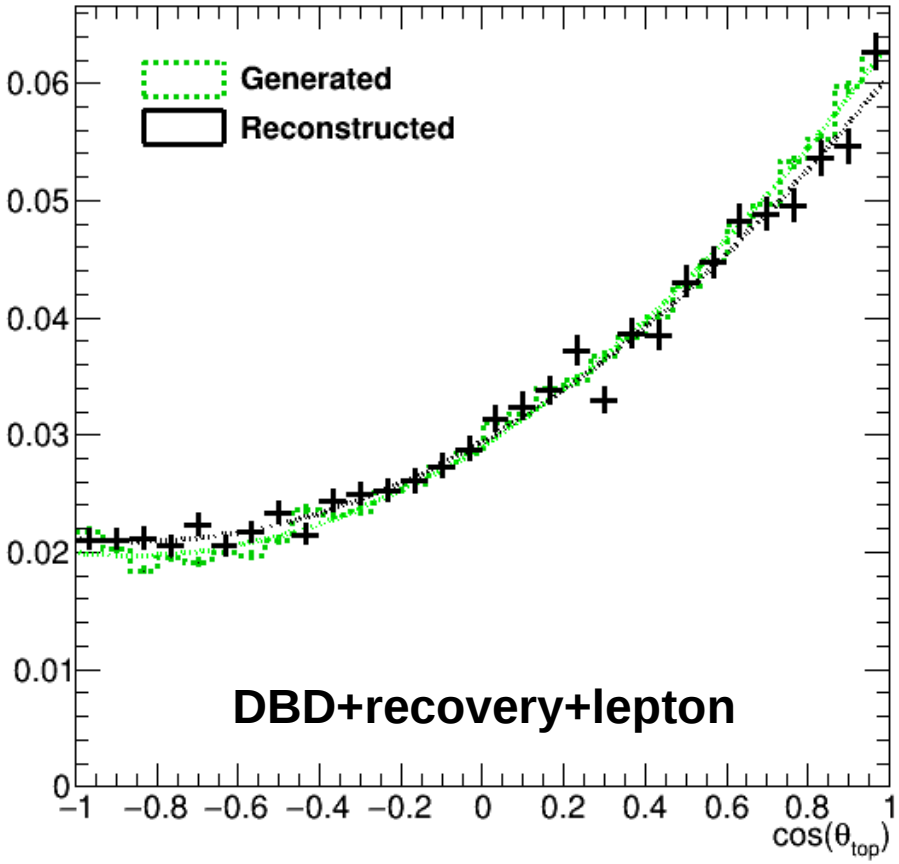


$A_{fb}^{rec}/A_{fb}^{gen} = 75\%$

- Efficiency and purity is lower than for DBD tracking
- LeptonFinder and flavour tagging are not optimized for minivector tracking

Improvement for semi-leptonic top decays

Top polar angle reconstruction for DBD using combination with lepton charge from W decay.



$A_{fb}^{rec}/A_{fb}^{gen} = 92.7\%$

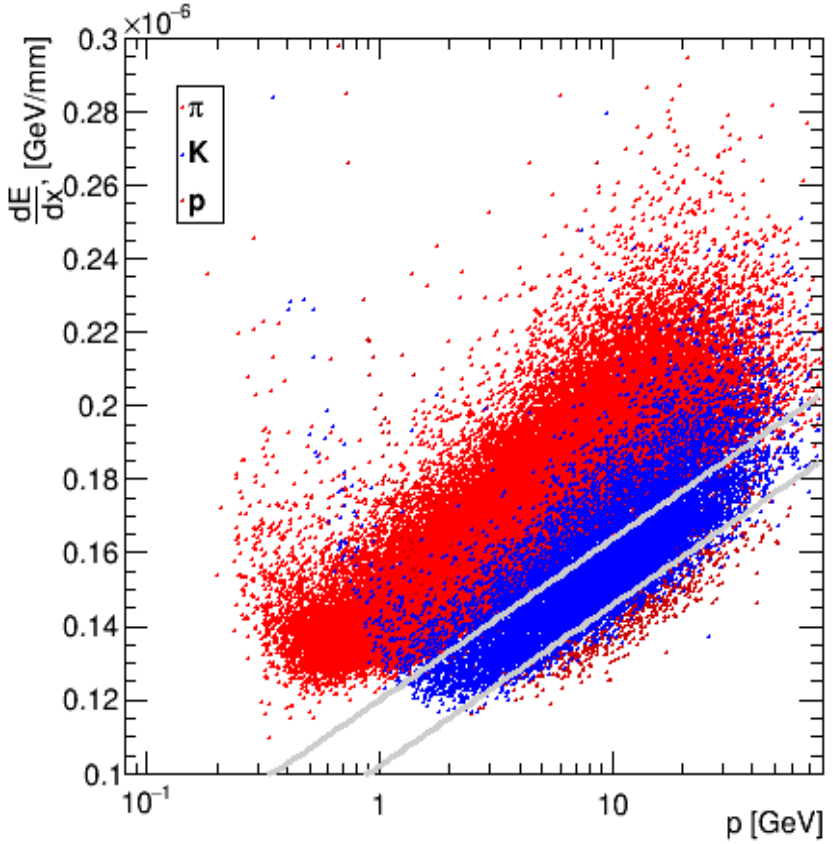
~40% efficiency

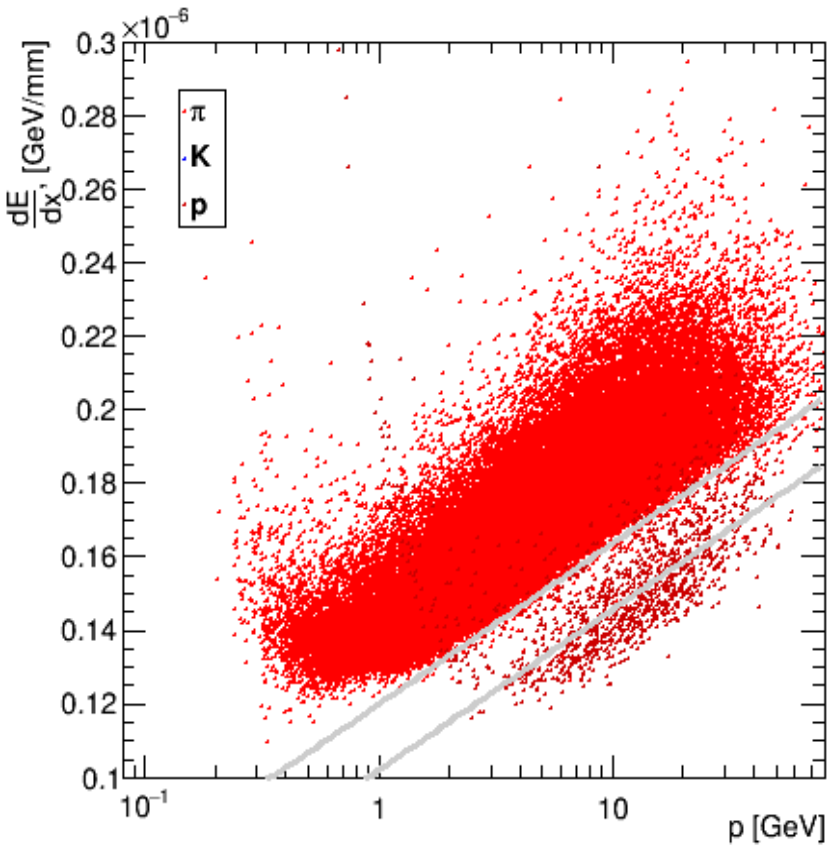
- The events are selected if there is a non-contradicting B-jet charge and lepton charge from W or $\chi_t^2 < 15$
- The efficiency of this method is ~30% higher than published result [arxiv:1505.06020, EPJC (2015) 75:512]
- The efficiency can be increased by optimizing general event selection (currently on the level of ~ 55%).

$$\chi_t^2 = (\frac{m_{rec} - m_t}{\sigma_m})^2 + (\frac{E_{rec} - E_{beam}}{\sigma_E})^2 + (\frac{p^*_{rec} - p^*_b}{\sigma^*_p})^2 + (\frac{cos\theta_{rec} - cos\theta_{bW}}{\sigma_{cos\theta_{bW}}})^2$$

Kaon identification

dE/dx as function of a track momentum for different types of particles from secondary and ternary vertices

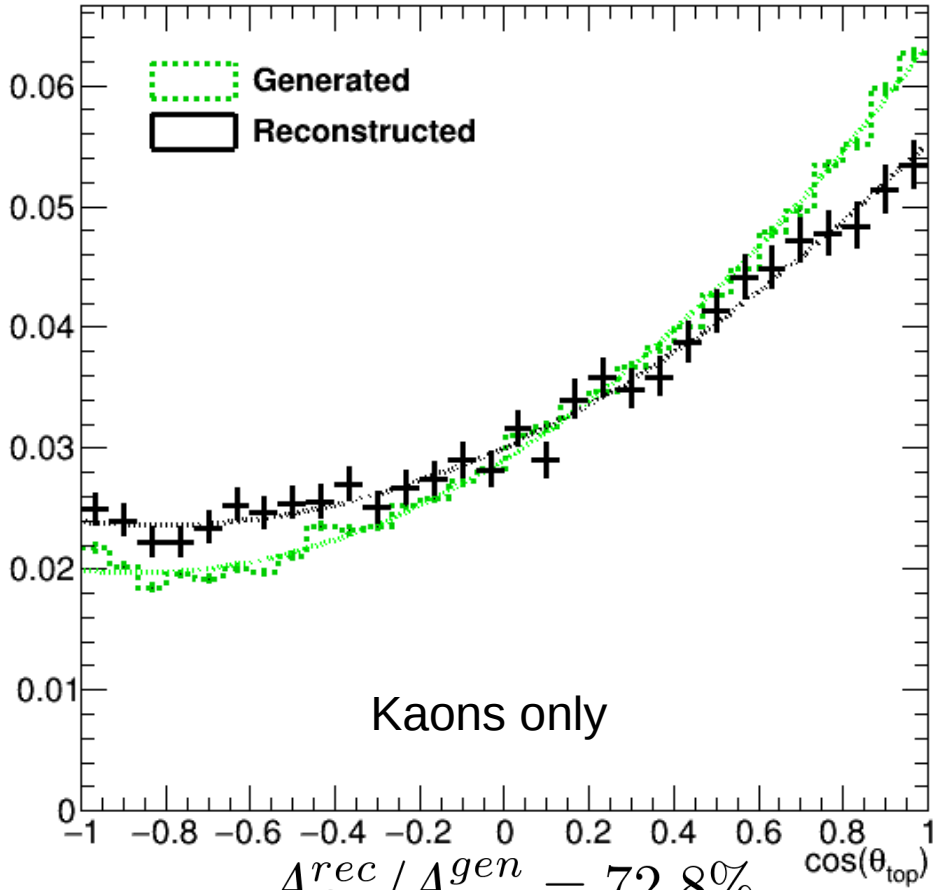




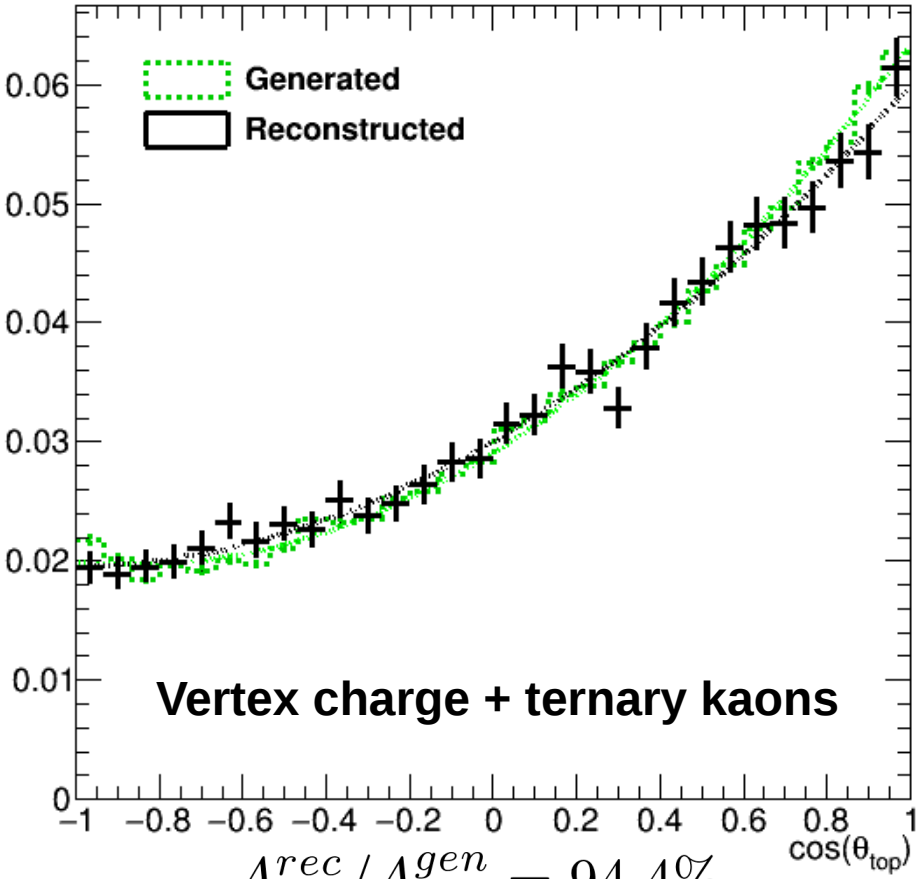
- It is possible to identify kaons with high purity
- In current analysis kaons are selected using generator information for ternary tracks with TPC hits > 60 and $|cos\theta| < 0.95$

Improvement by ternary kaons

Top polar angle reconstruction using ternary kaons and vertex charge combination.



$A_{fb}^{rec}/A_{fb}^{gen} = 72.8\%$



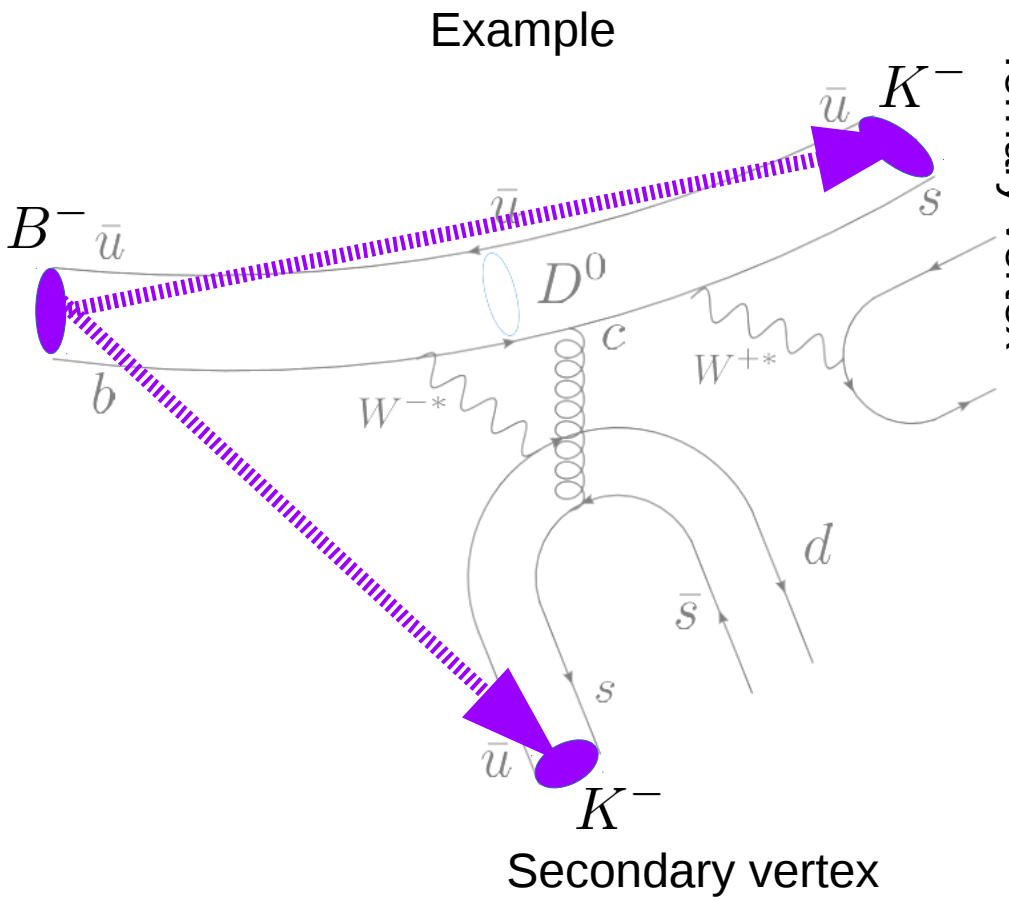
$A_{fb}^{rec}/A_{fb}^{gen} = 94.4\%$

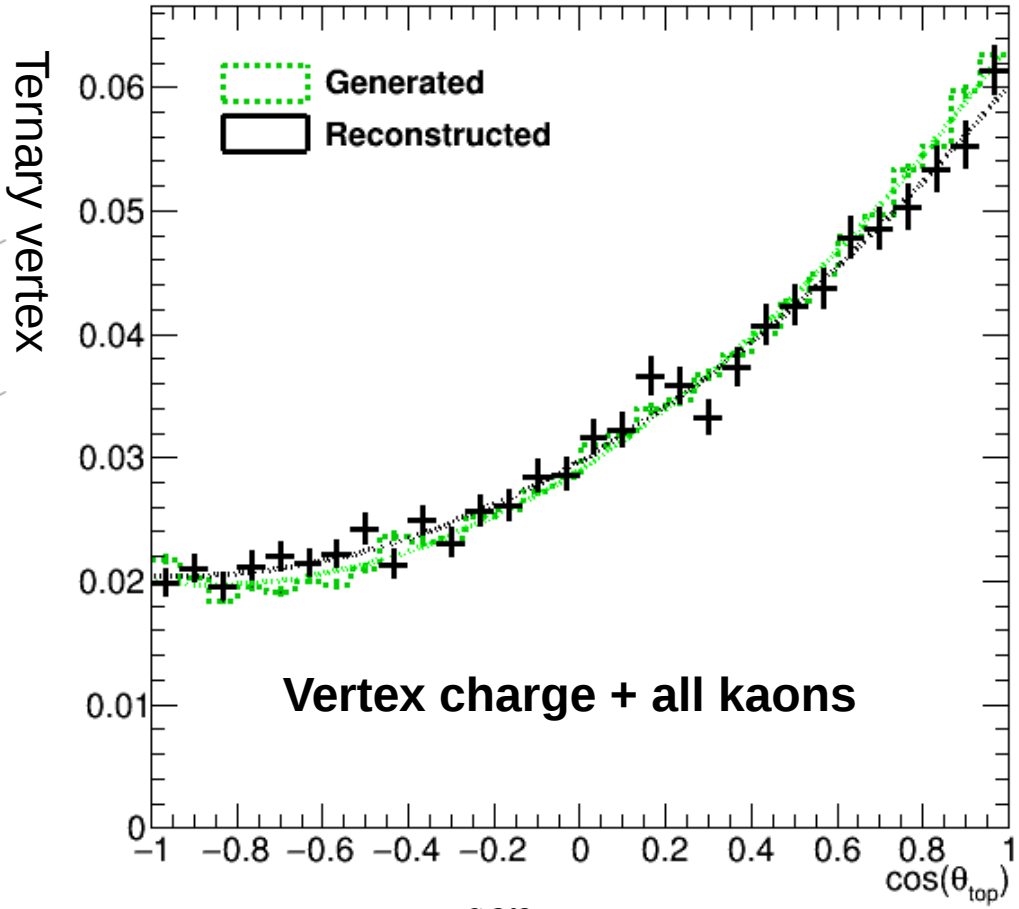
~15% efficiency

- Kaons are identified using generator information for TPC tracks.
- **B-jet information only.**

Improvement by all kaons

Top polar angle reconstruction using all kaons and vertex charge combination.





$$A_{fb}^{rec}/A_{fb}^{gen} = 92.2\%$$

~25% efficiency

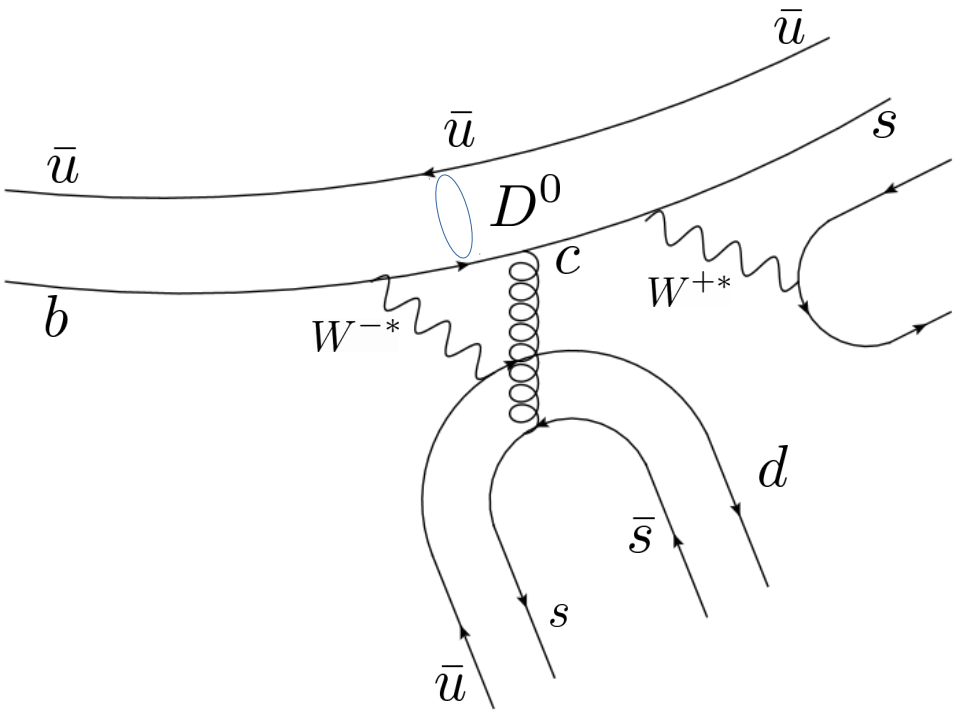
- Kaons are identified using generator information for TPC tracks.
- **B-jet information only.**

Summary

- Purity of the VertexChargeRecovery is increased in the forward region by using uncertainties for d0 and z0 separately
- Efficiency is reachable for semileptonic sample using the b and W charge as compared to 30% in previous studies
- Application of kaon reconstruction leads to almost perfect b charge purity with ~25% efficiency
- Research stay in Japan in July to work on new vertexing algorithm (Application for French/Japanese TYL/FJPPL funding)
- Further work:
  - Use full kaon reconstruction
  - Optimize the preselection for ttbar process
  - Apply this method to bbar process at ILC
  - Improve purity of the VertexChargeRecovery
  - Study the efficiency decrease for minivector tracking

Thank you!

Kaon charge correlation

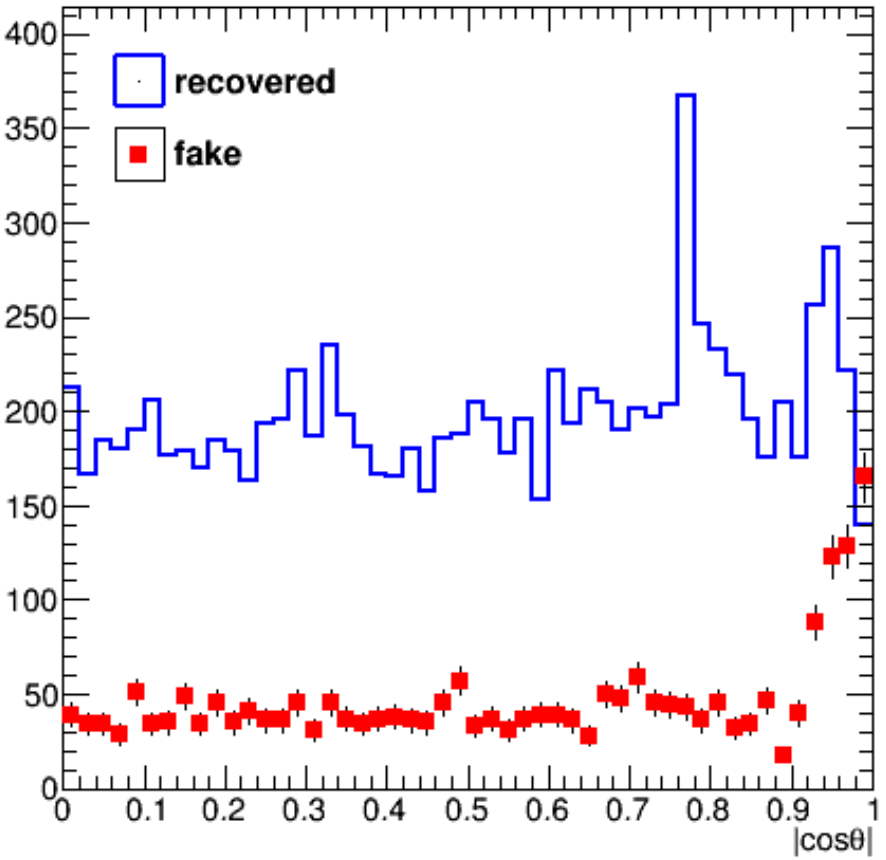


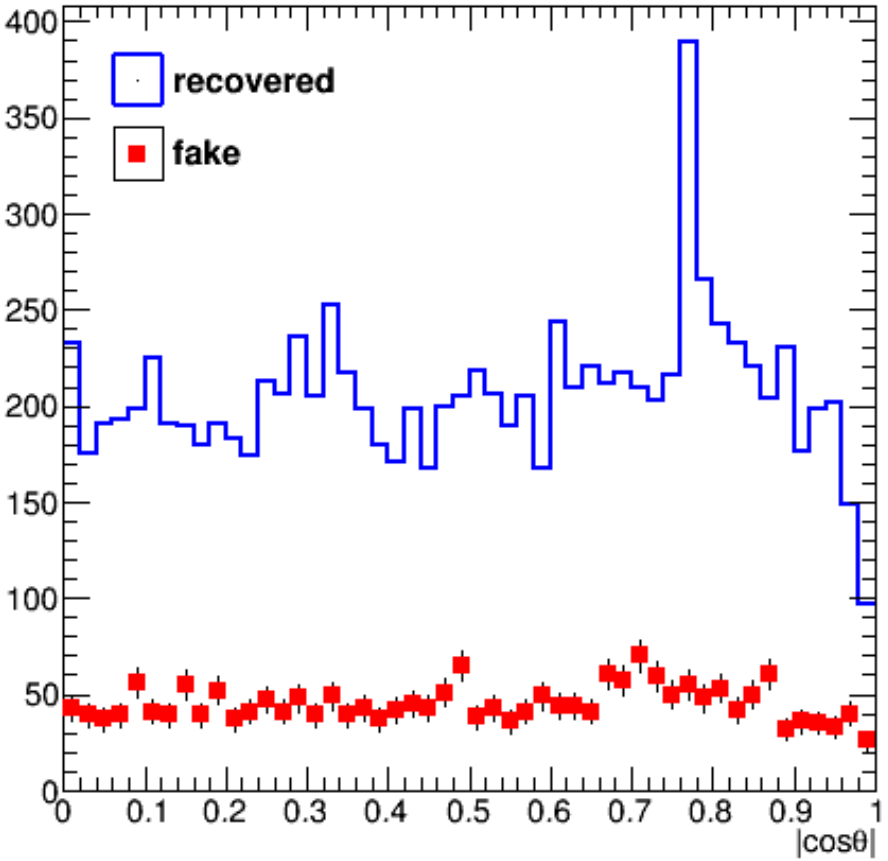
- Example of B-meson decay with secondary and ternary kaons.

Old offset vs new offset

$$\frac{\varepsilon}{\sigma_\epsilon}$$

$$|\frac{d_0}{\sigma_{d_0}}| + |\frac{z_0}{\sigma_{z_0}}|$$

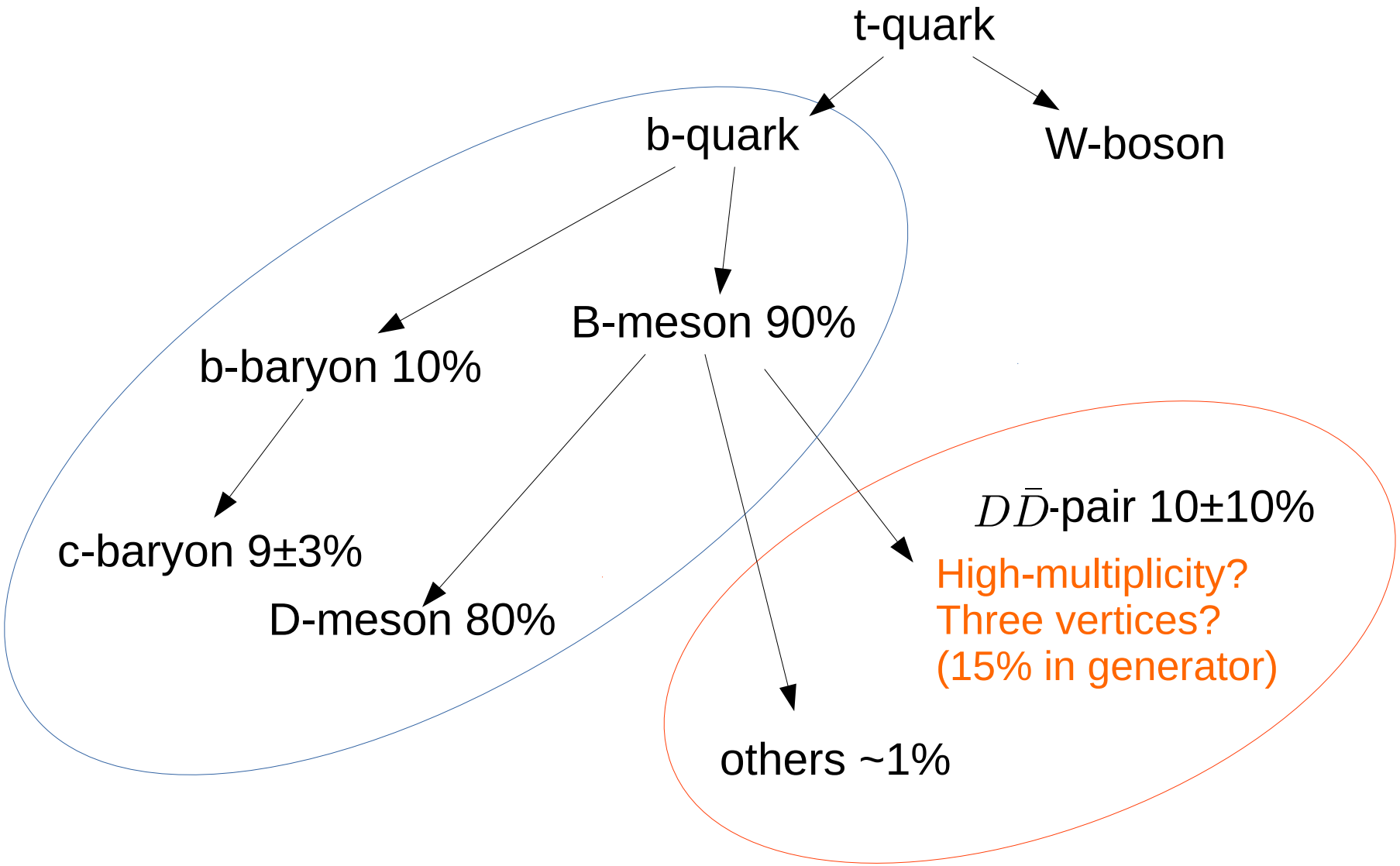




- Angular distribution of the recovered b-tracks and background (fake) tracks. Minivector tracking.

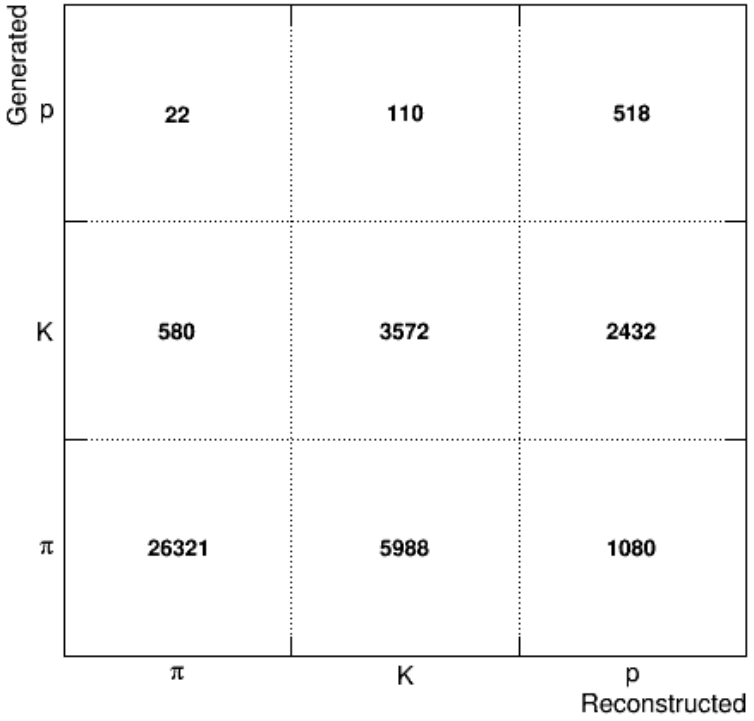
Process overview

- Hadronization and decay modes of b-quark:

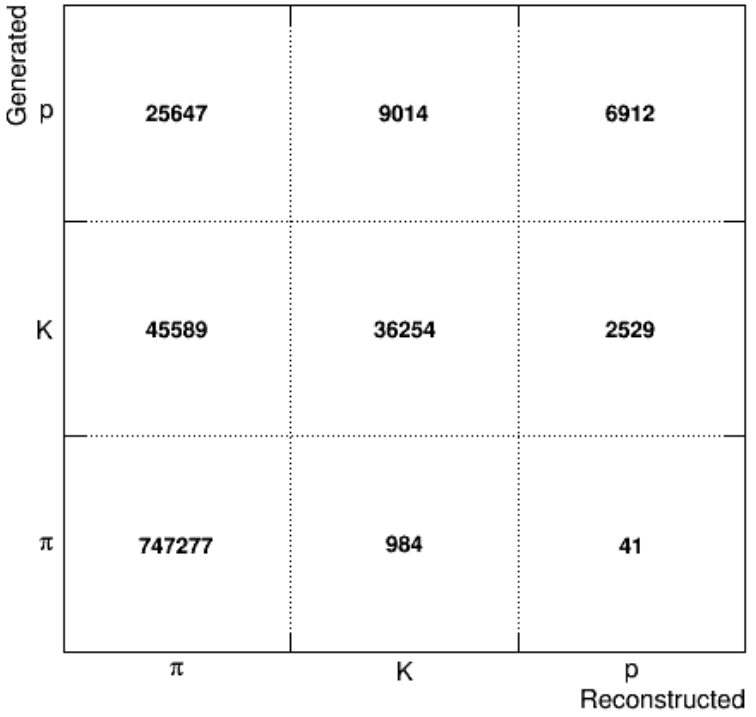


Kaon reconstruction

PIDTools, dE/dx algorithm

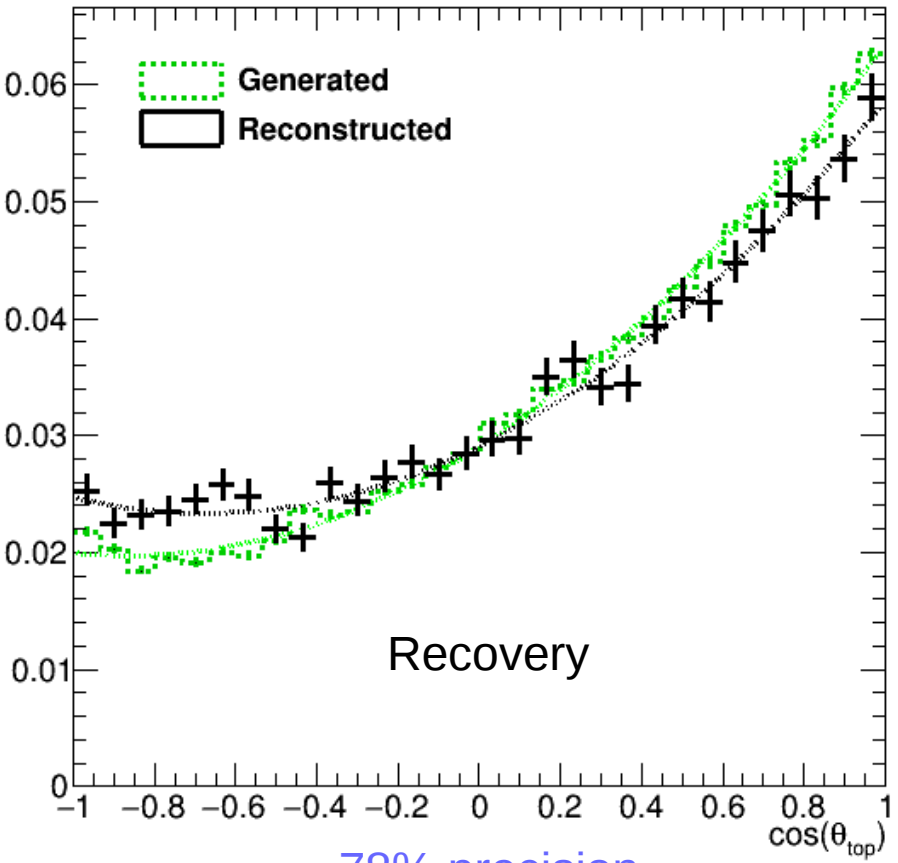


Cut based

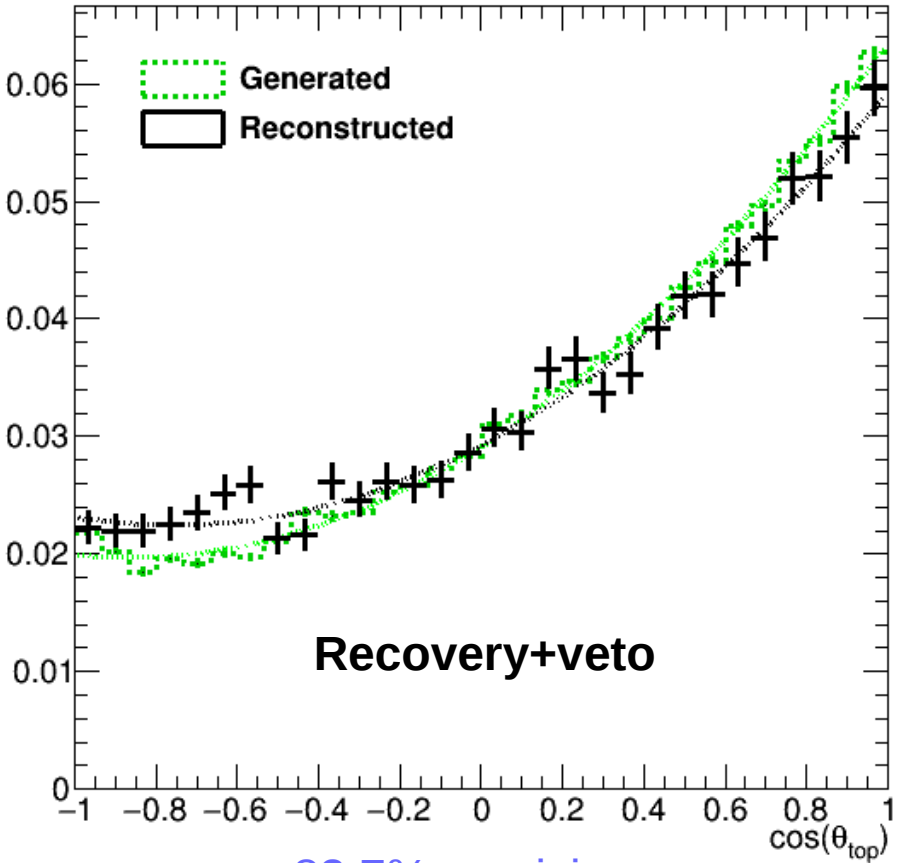


- Comparison of two kaon reconstruction methods (preliminary)

Overall top polar angle improvement



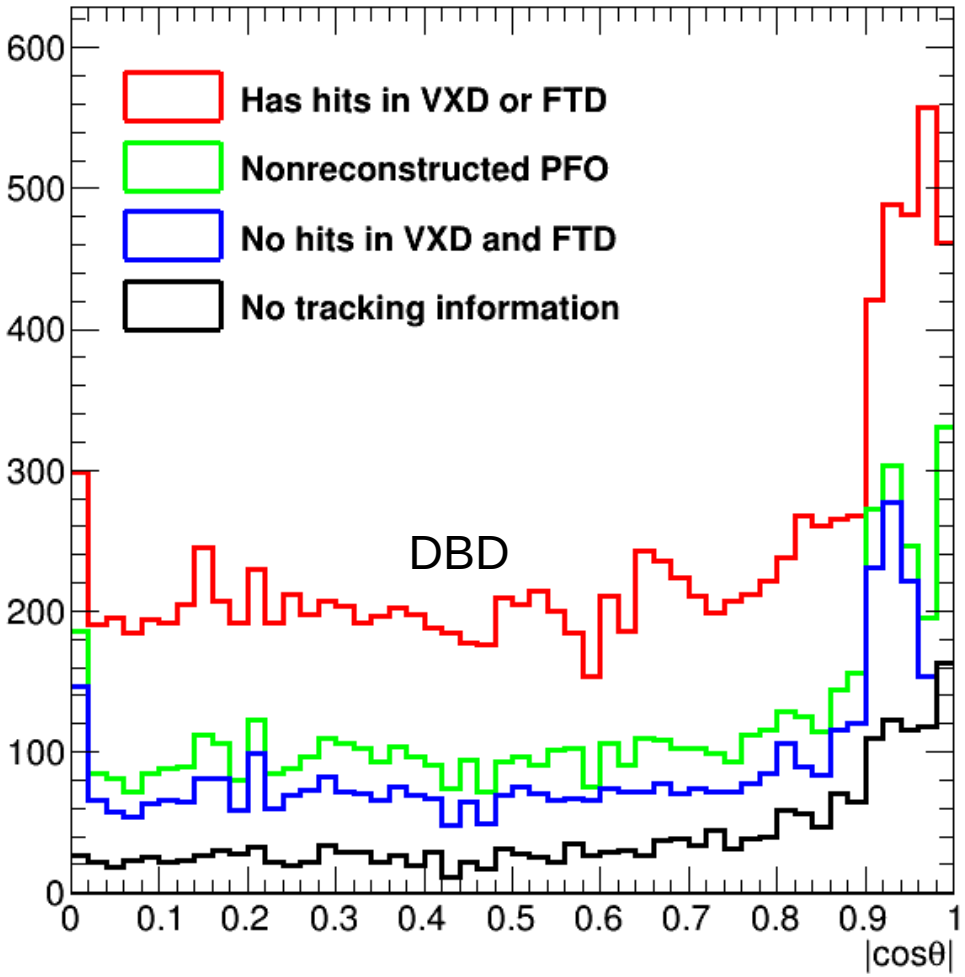
78% precision

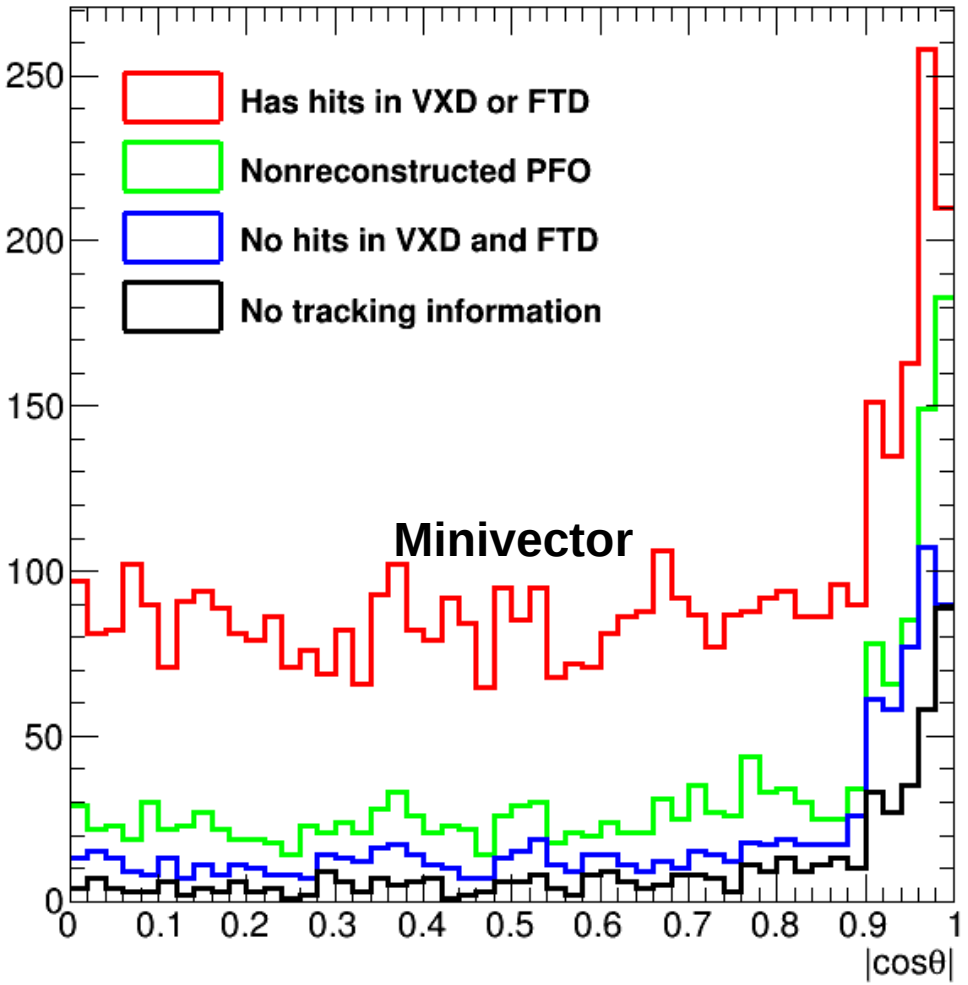


83.7% precision

- Top polar angle reconstruction for DBD. Veto: The DDbar events are excluded using generator information

Missed tracks DBD vs Minivector+recovery





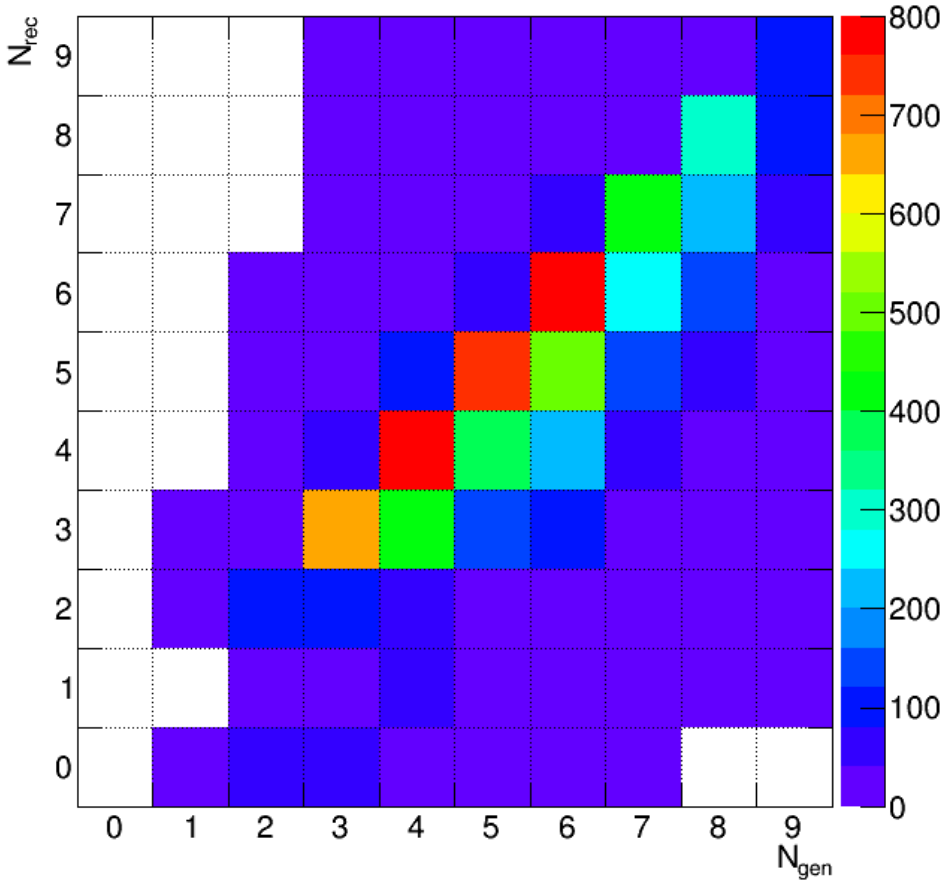
8.1% of generated

7.4% of generated

- Angular distribution of the missed tracks from reconstructed vertices. VertexChargeRecovery is used

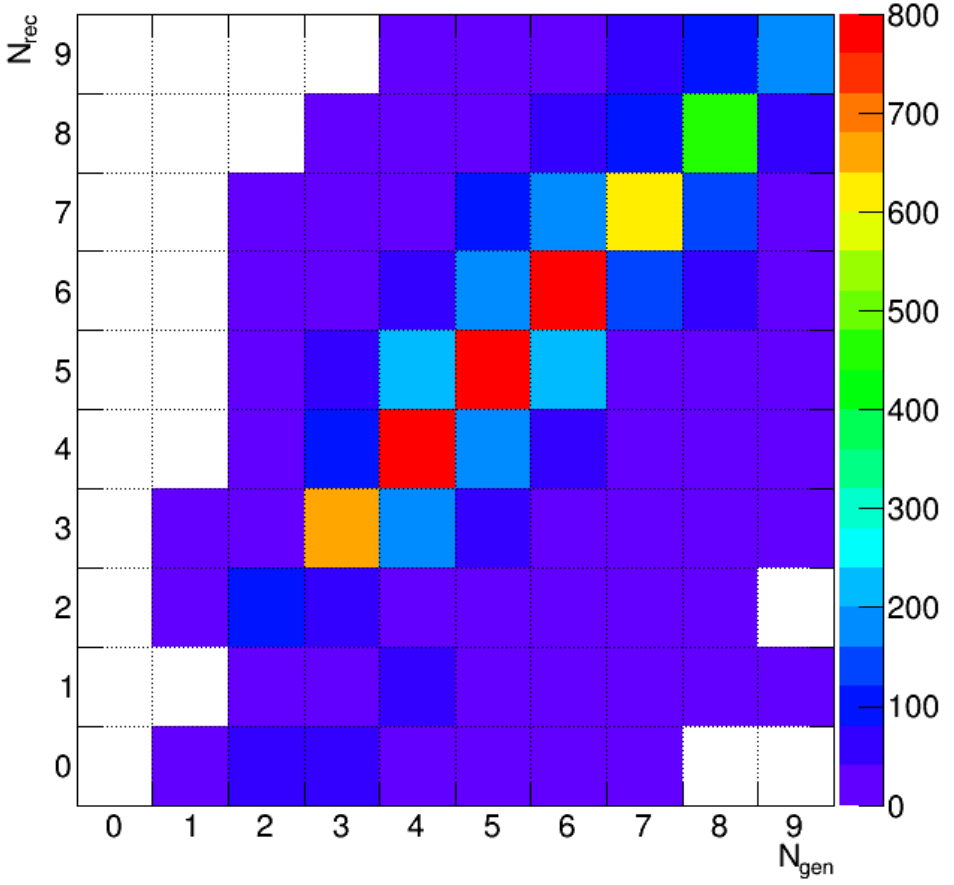
Number of tracks comparison Minivector

Original



51.0% on diagonal

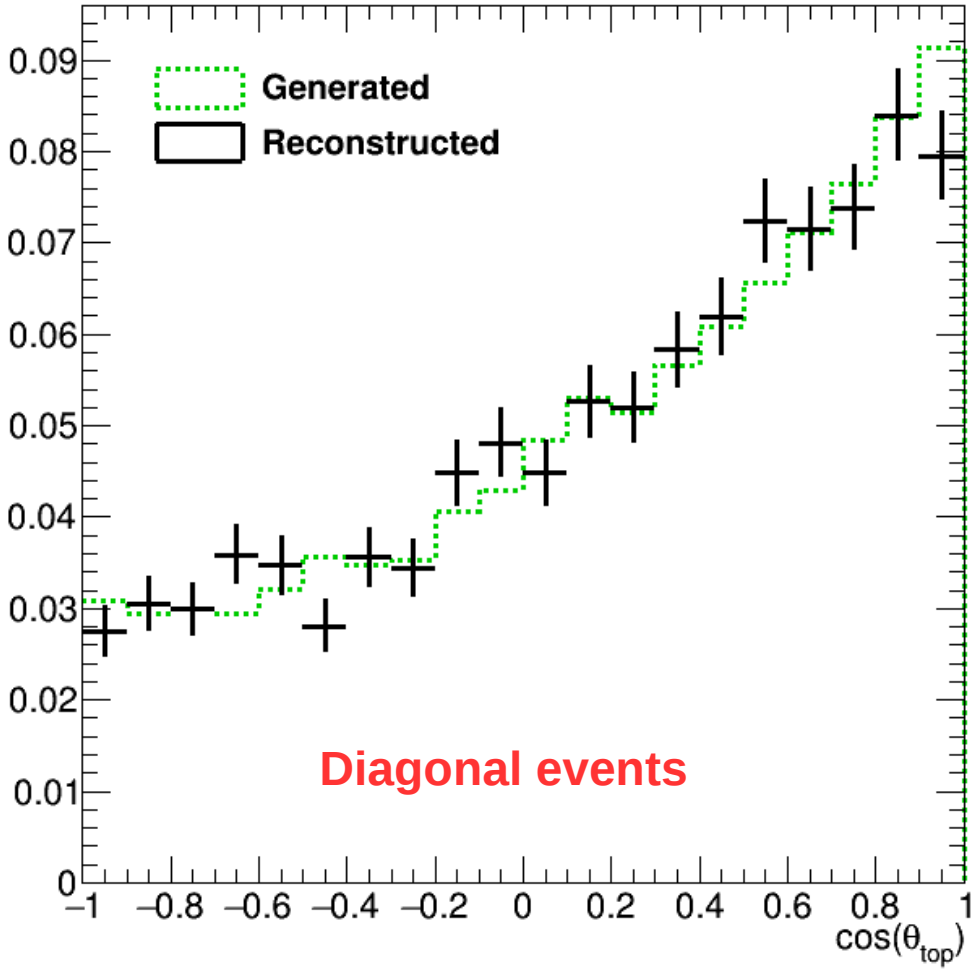
Recovery



63.3% on diagonal

Btag > 0.8 & Pb > 15 GeV

Top asymmetry: diagonal events

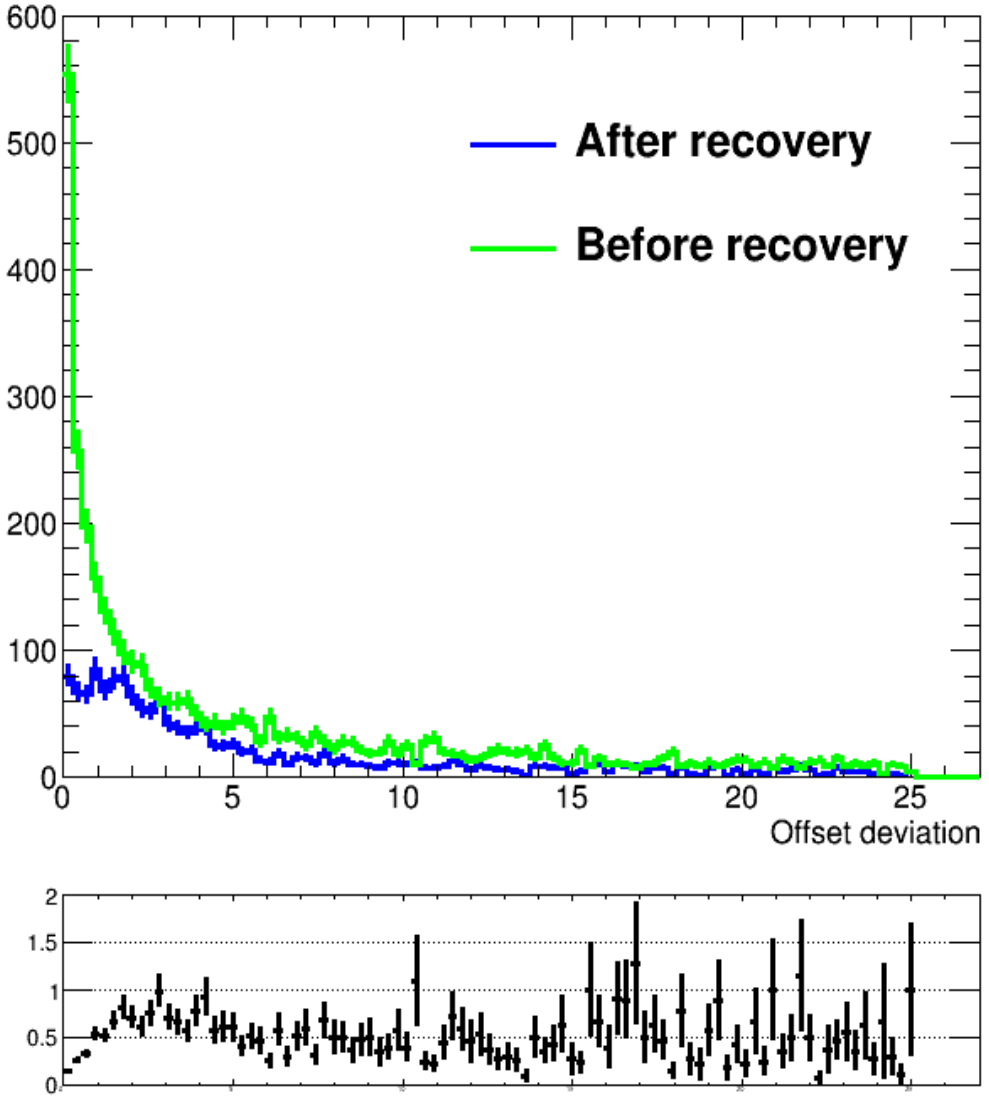


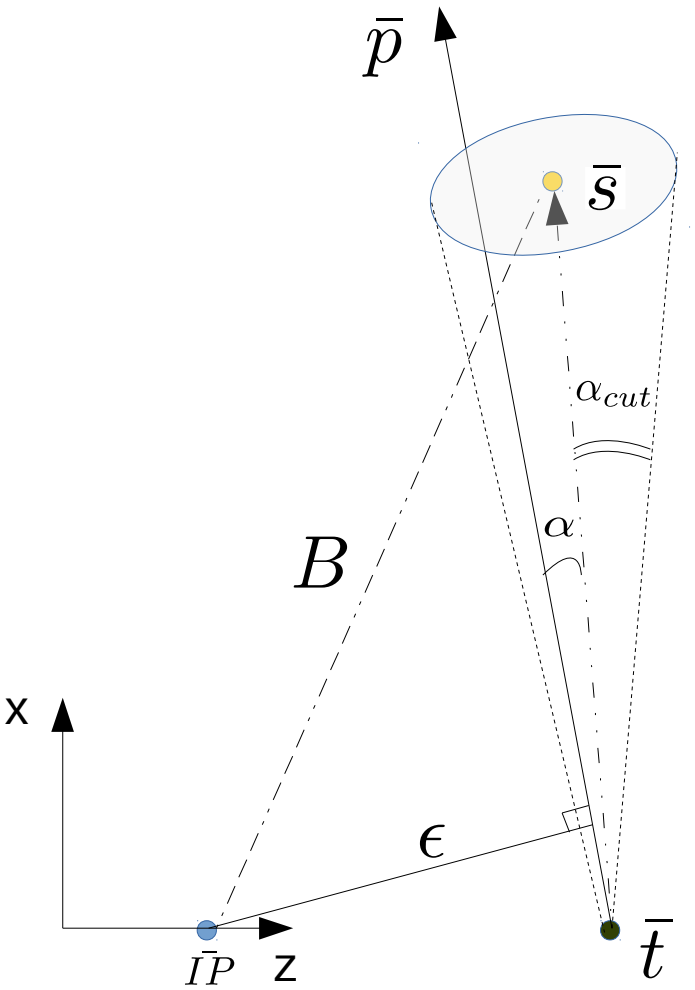
95.5% precision

- TruthVertexFinder works correctly!
- To reach this quality we should maximize the vertex reconstruction quality:
  - Recover corrupted vertices
  - Reject corrupted vertices
  - Apply different tracking algorithms
  - Use alternative vertexing algorithm

- The result of top asymmetry reconstruction with correctly reconstructed b vertices.

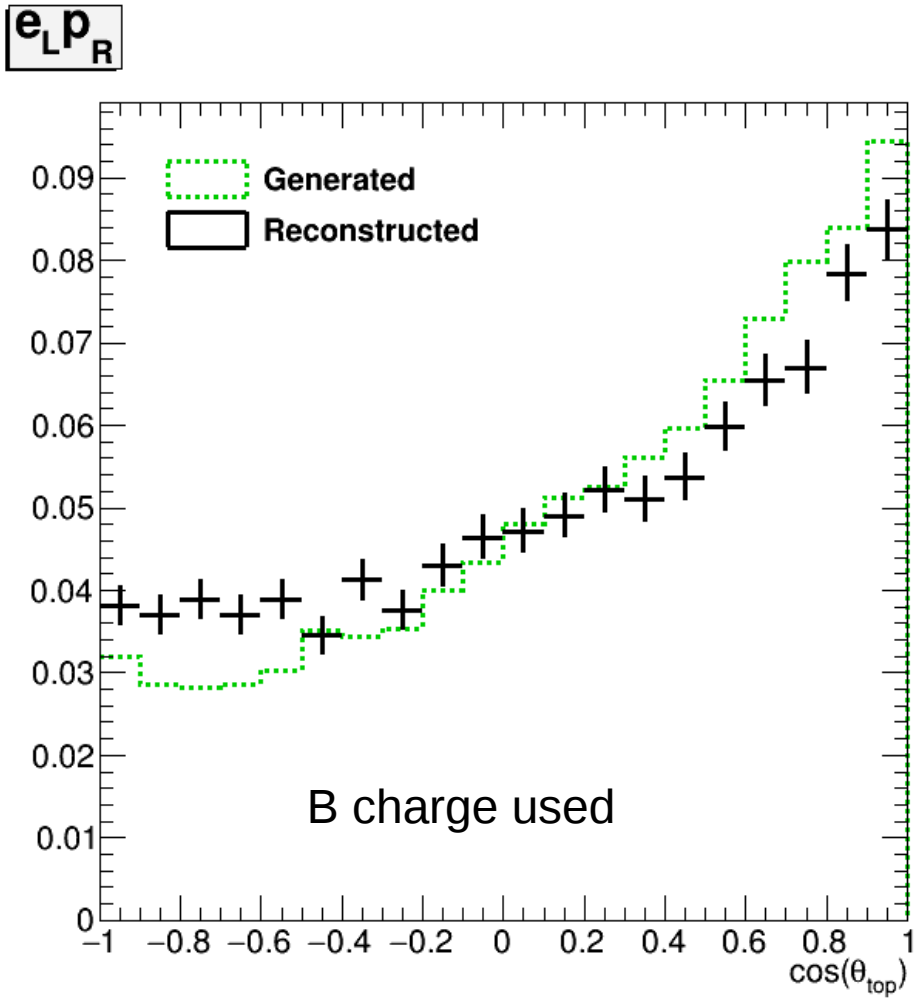
Offset deviation - Minivector reconstruction



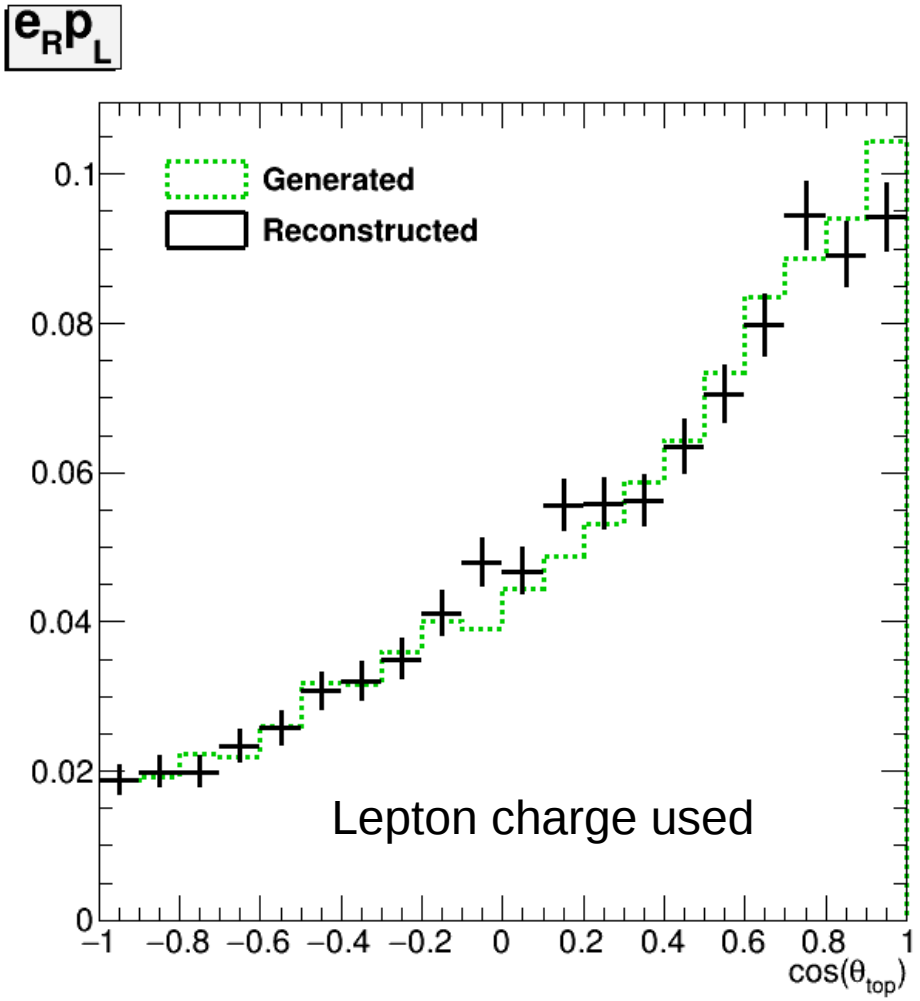


- Majority of missed tracks have low offsets. These tracks can be recoverable if their angle w.r.t. secondary vertex is small

Top asymmetry DBD



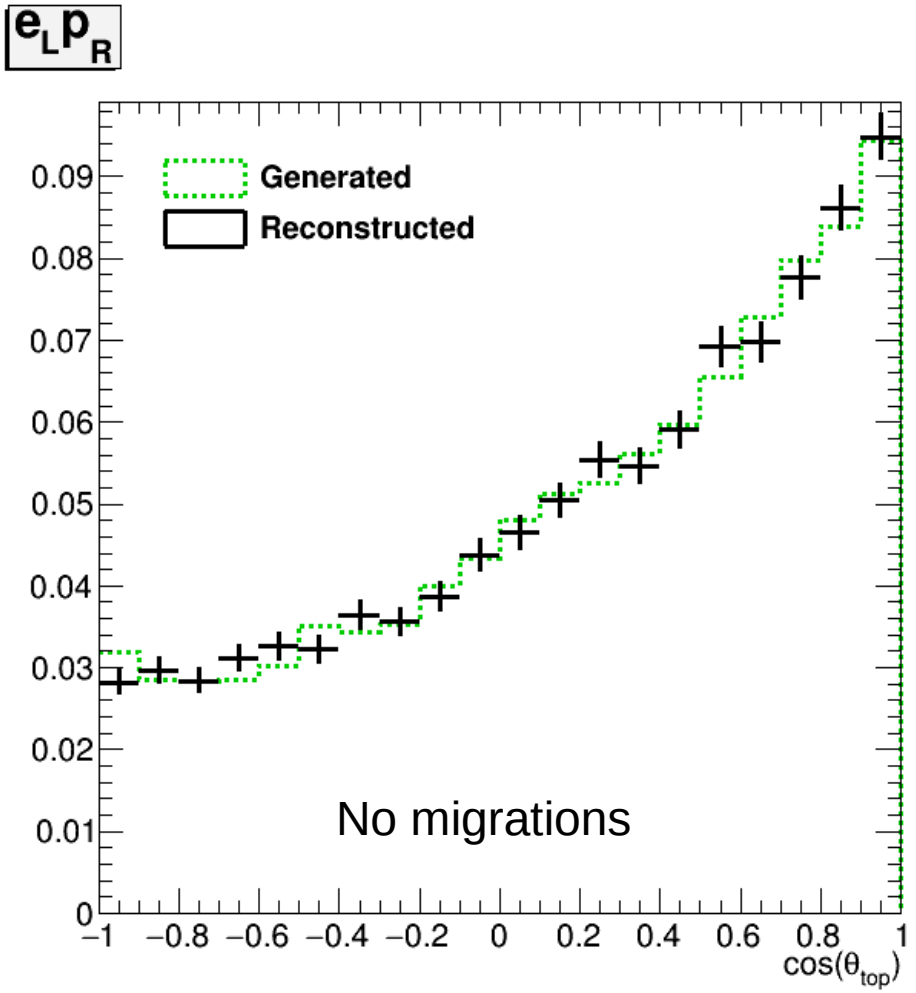
65.5% precision



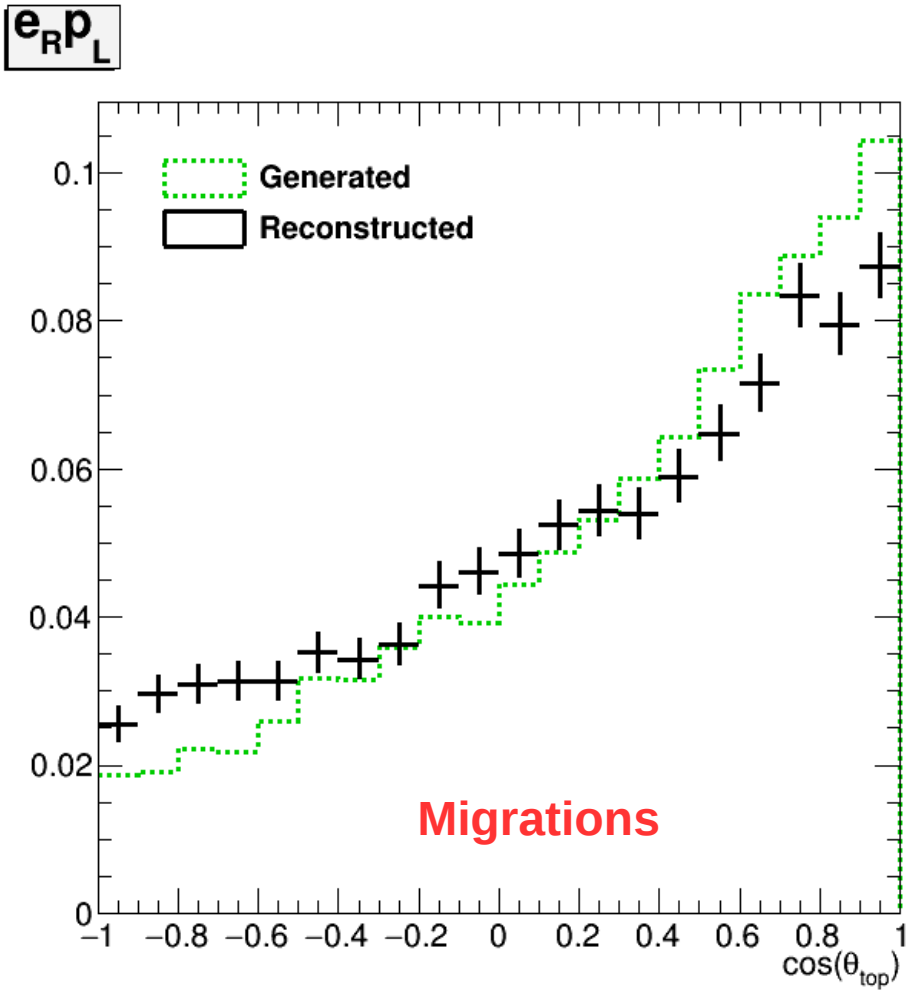
96.3 % precision

- The result of top asymmetry reconstruction with real b charge measurement. DBD tracking, no recovery

Top asymmetry: Using generated b charge



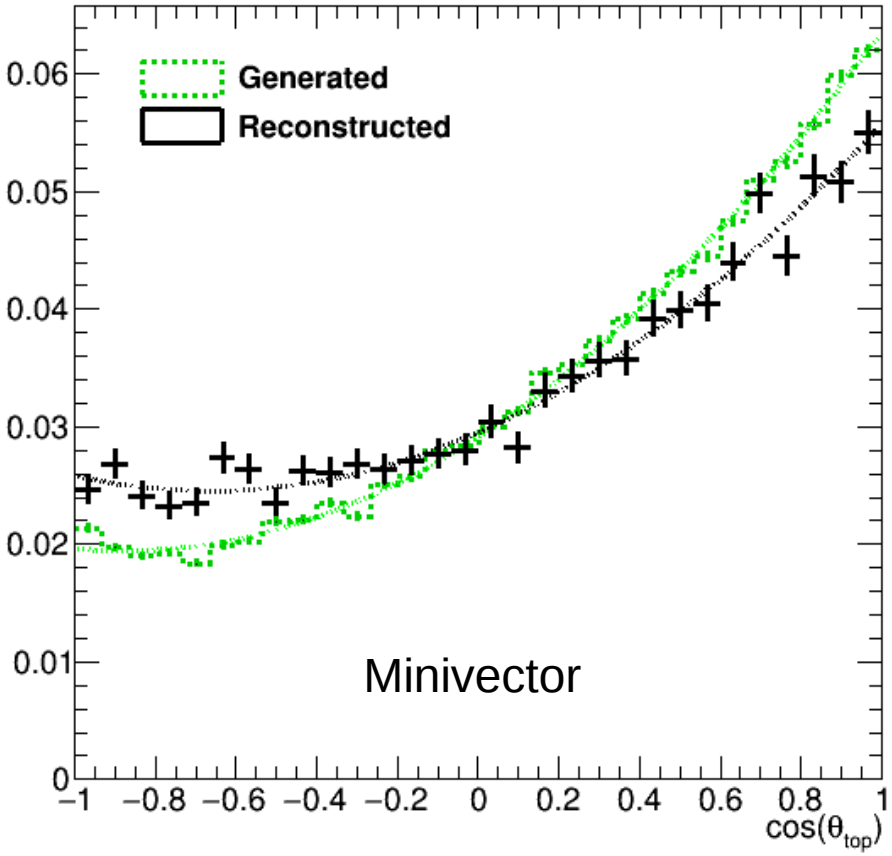
99.4% precision



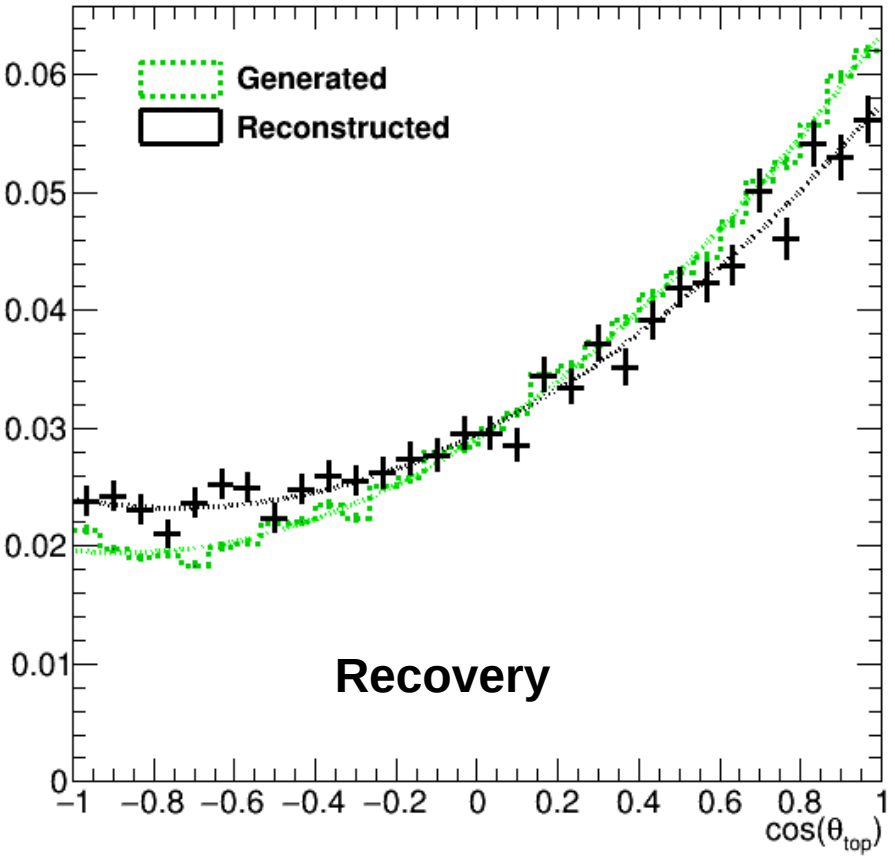
72.5% precision

- The result of top asymmetry reconstruction with 100% purity and efficiency of b charge.

Overall top polar angle improvement



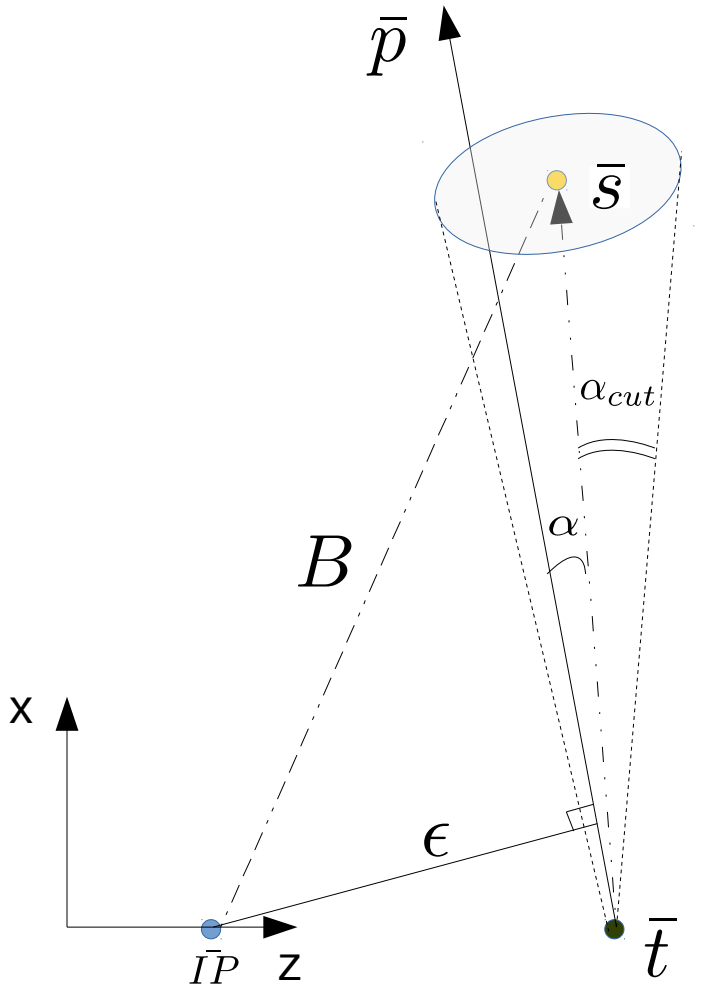
68% precision



75.% precision

- Top polar angle reconstruction for Minivector and Minivector + new recovery.
- LeptonFinder and flavour tagging is not optimized for minivector tracking

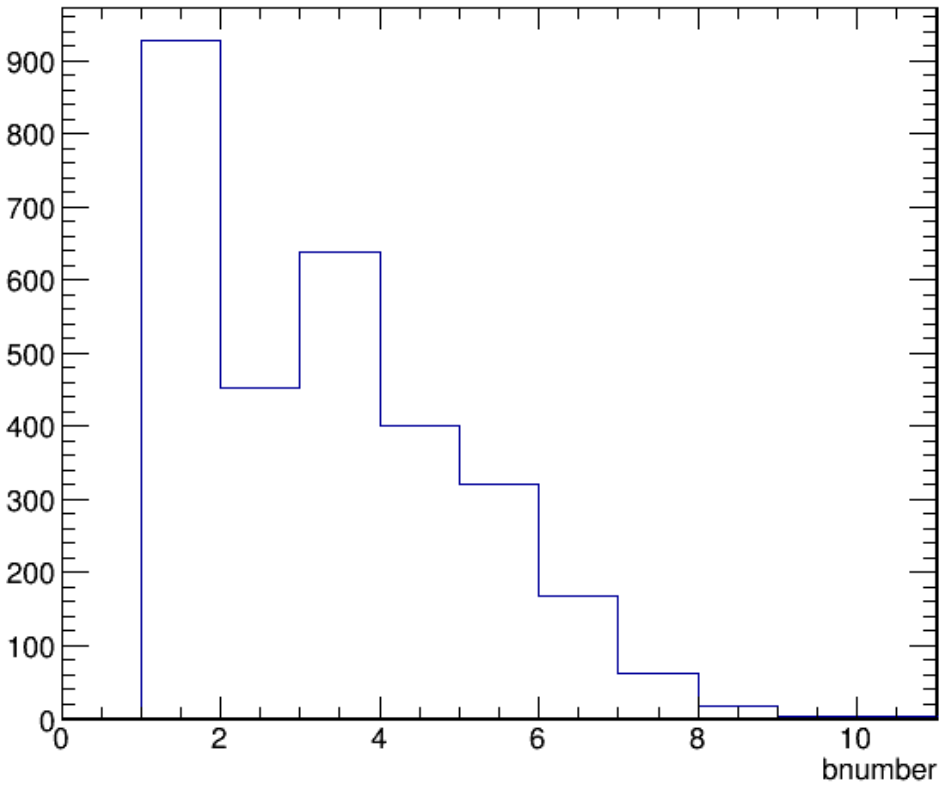
Recovery of vertices



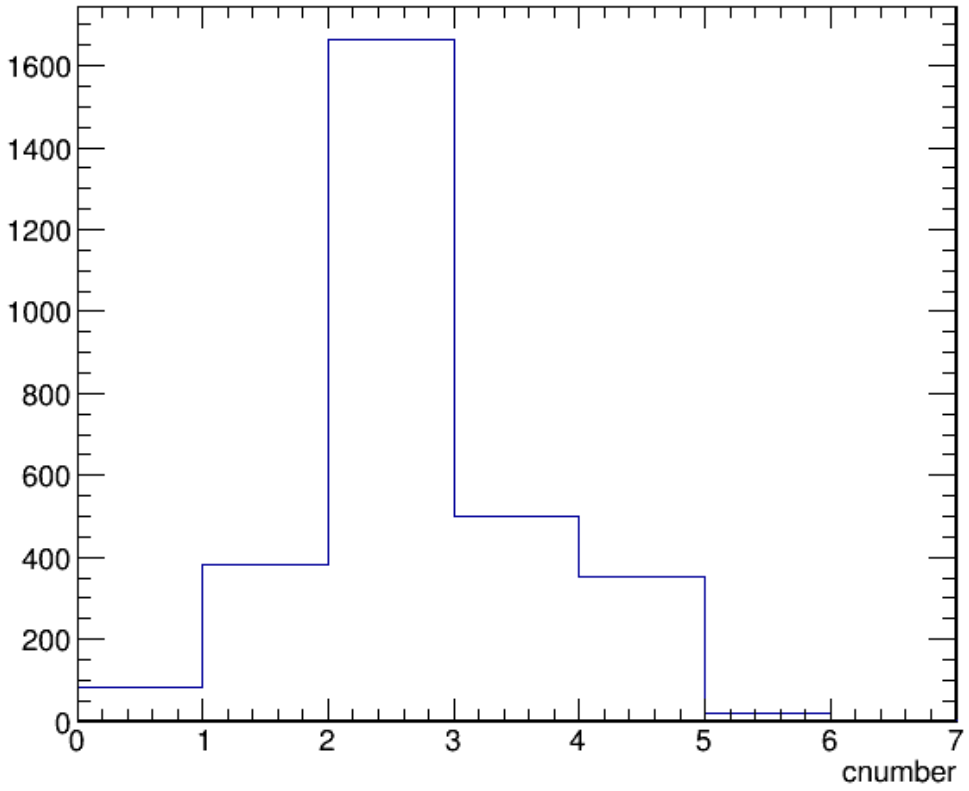
- **IP** – interaction point (primary vertex) , **s** – secondary vertex, **t** – point of closest approach of a track, **p** – reconstructed momentum, ϵ - offset of a track from primary vertex

Multiplicity of b-c vertices

b-vertex

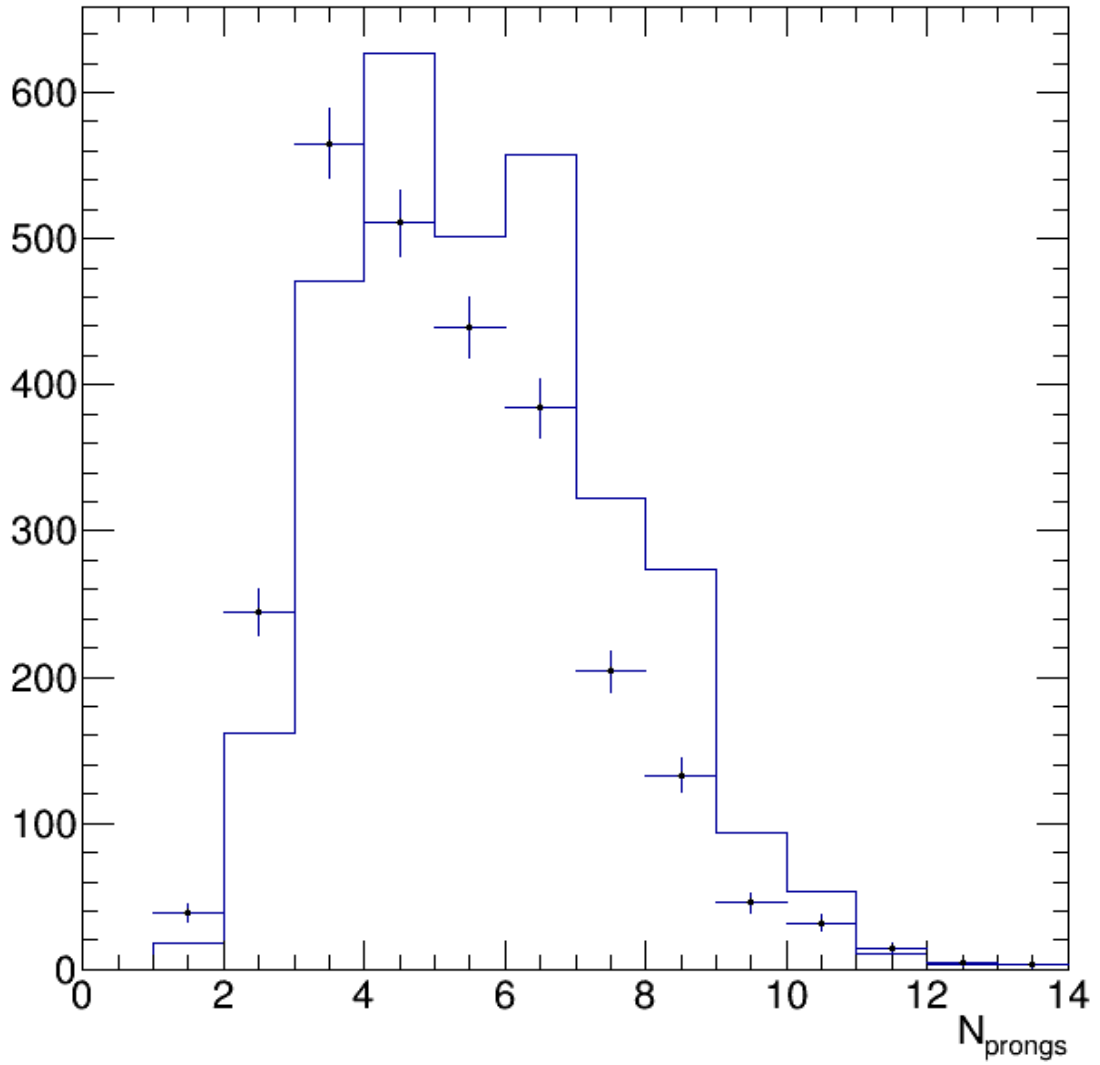


c-vertex



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

Reconstructed vertices



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