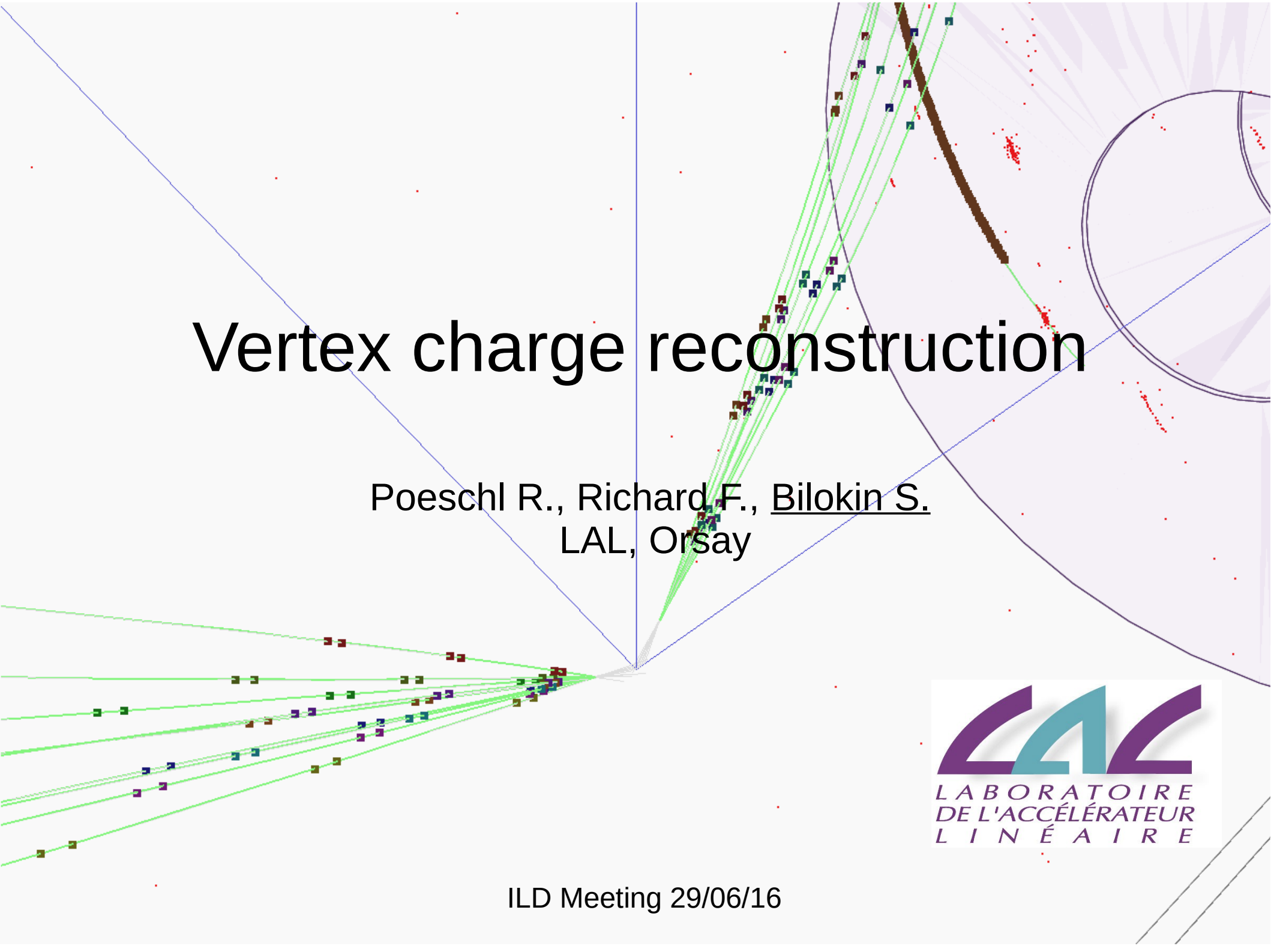


Vertex charge reconstruction

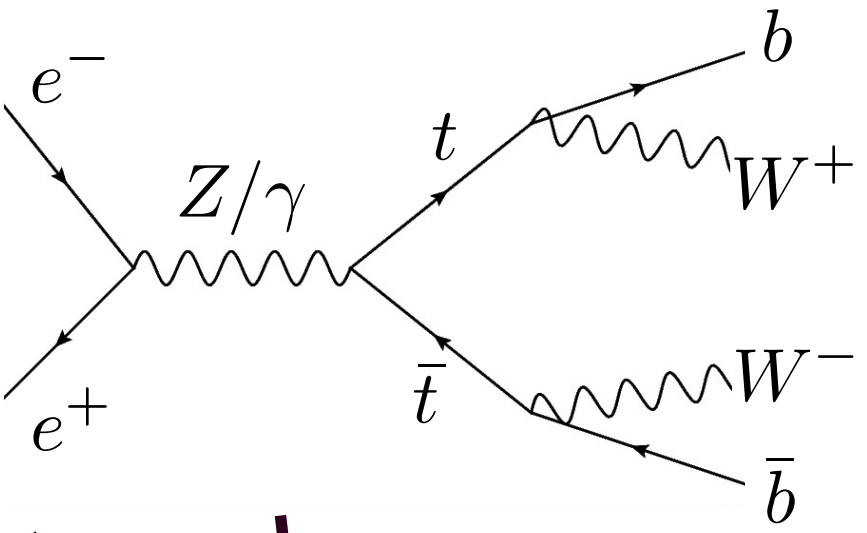
Poeschl R., Richard F., Bilokin S.
LAL, Orsay

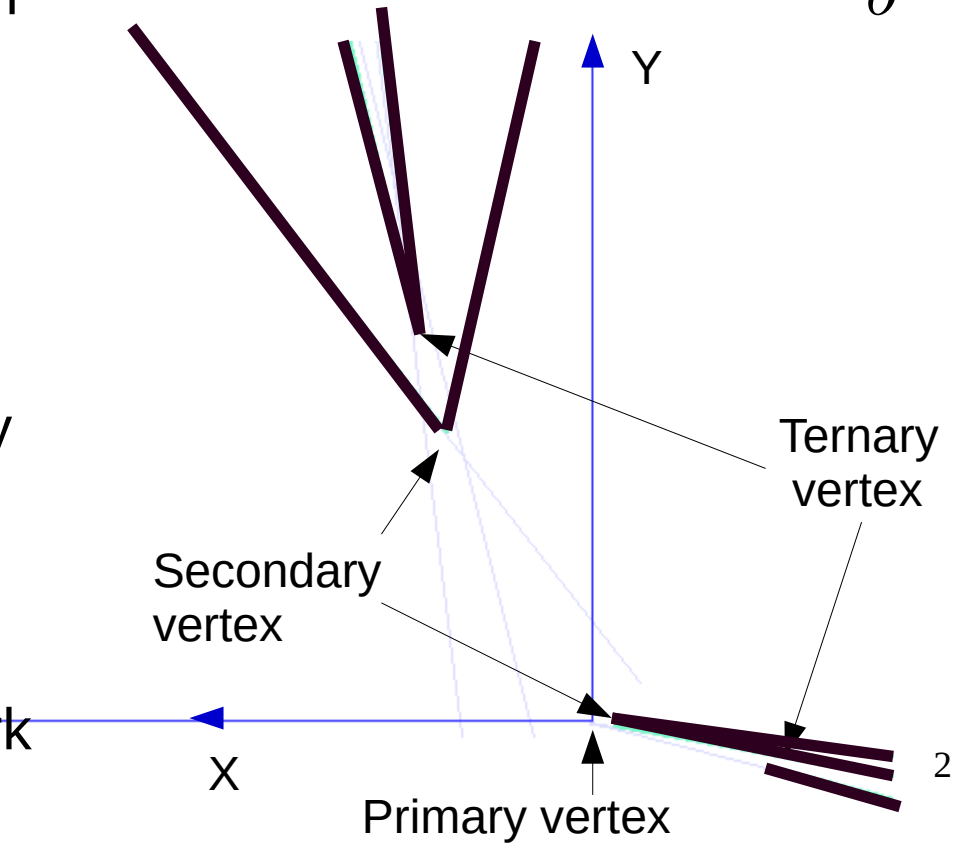
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

ILD Meeting 29/06/16

Objective

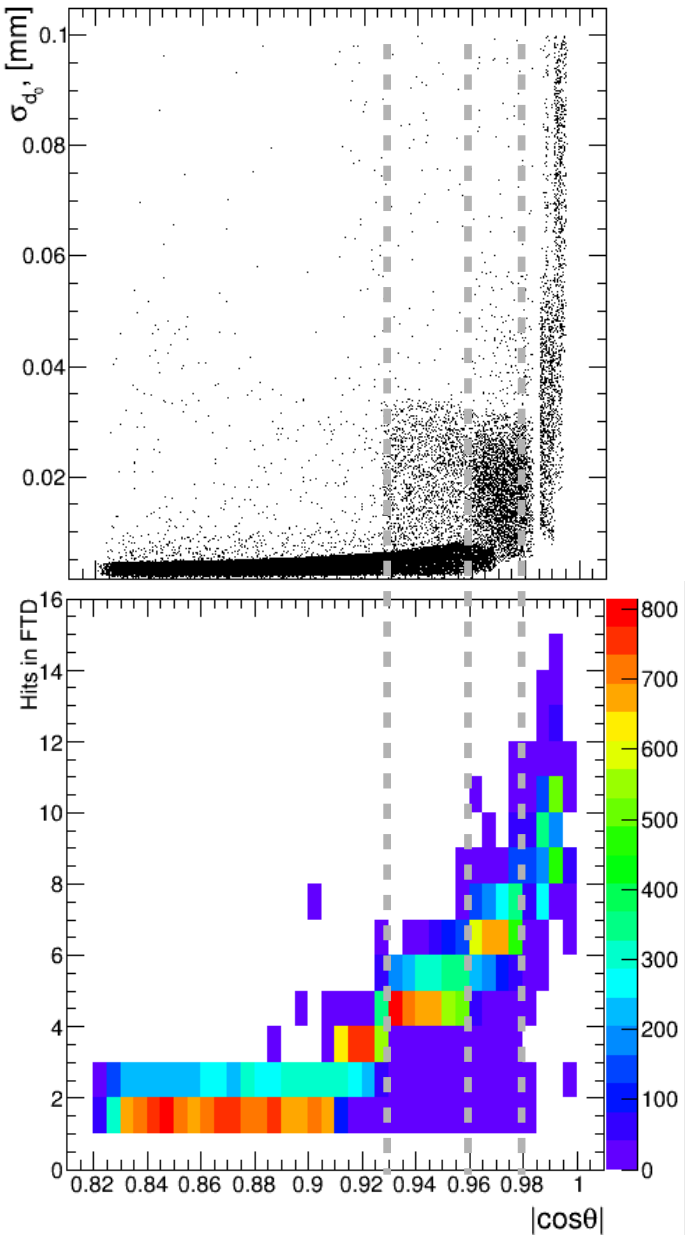
- Main purpose of this work is to detect the charge of top and antitop quarks. This is crucial for calculation of forward-backward asymmetry A_{fb} in $t\bar{t}$ process at ILC
- Properties of decay products from the B-hadrons are used to determine the charge of initial t-quark
- Charge of the b-quark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





Track parameter uncertainties

DBD



P > 10 GeV & FTD hits > 0

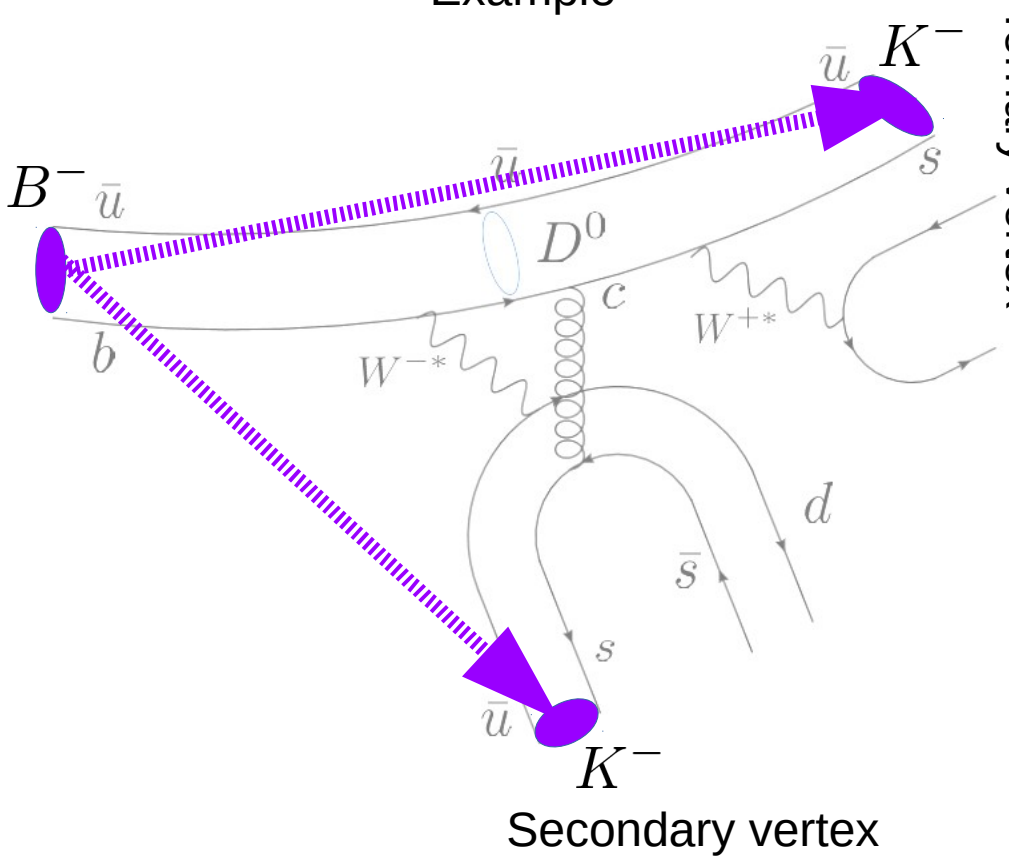
Angular distribution of d0 uncertainties for DBD tracking in the transition towards the forward region

- Tracks without barrel VXD hits have larger impart parameter uncertainties
- Step-function-like uncertainty behaviour is induced by different amount of hits in FTD

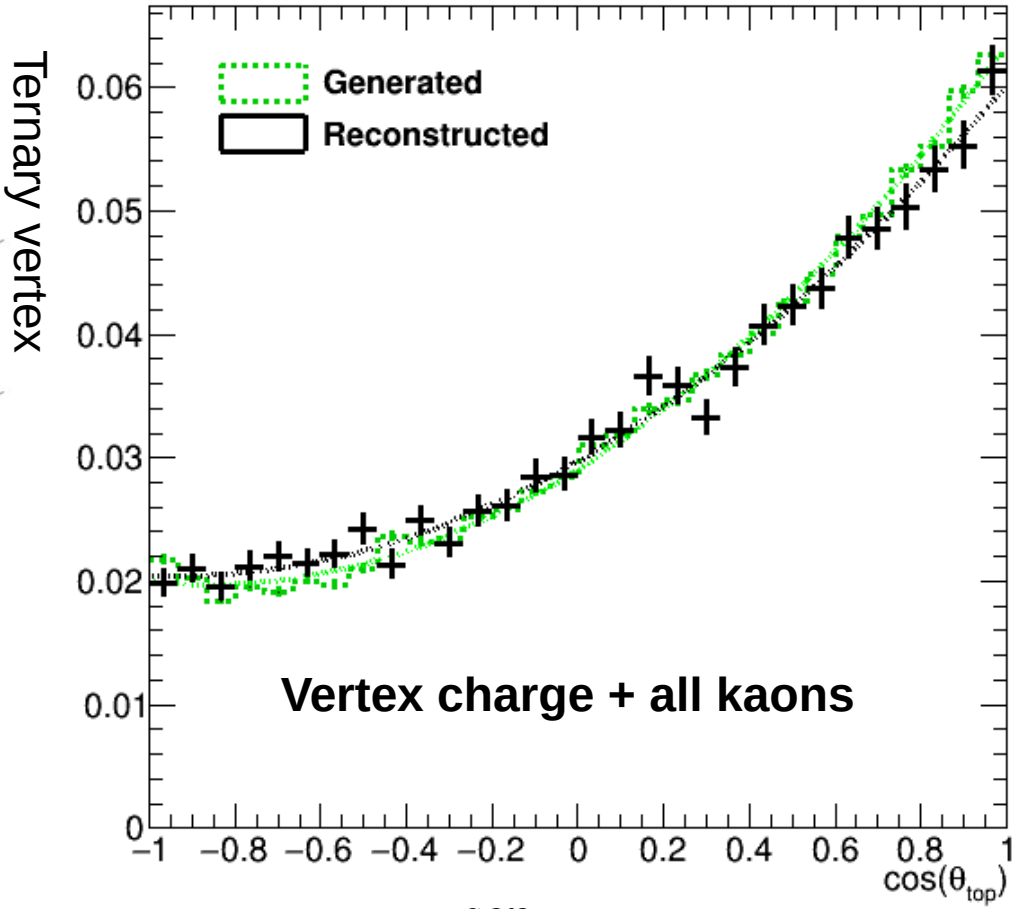
Improvement by all kaons

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

Example



Secondary vertex



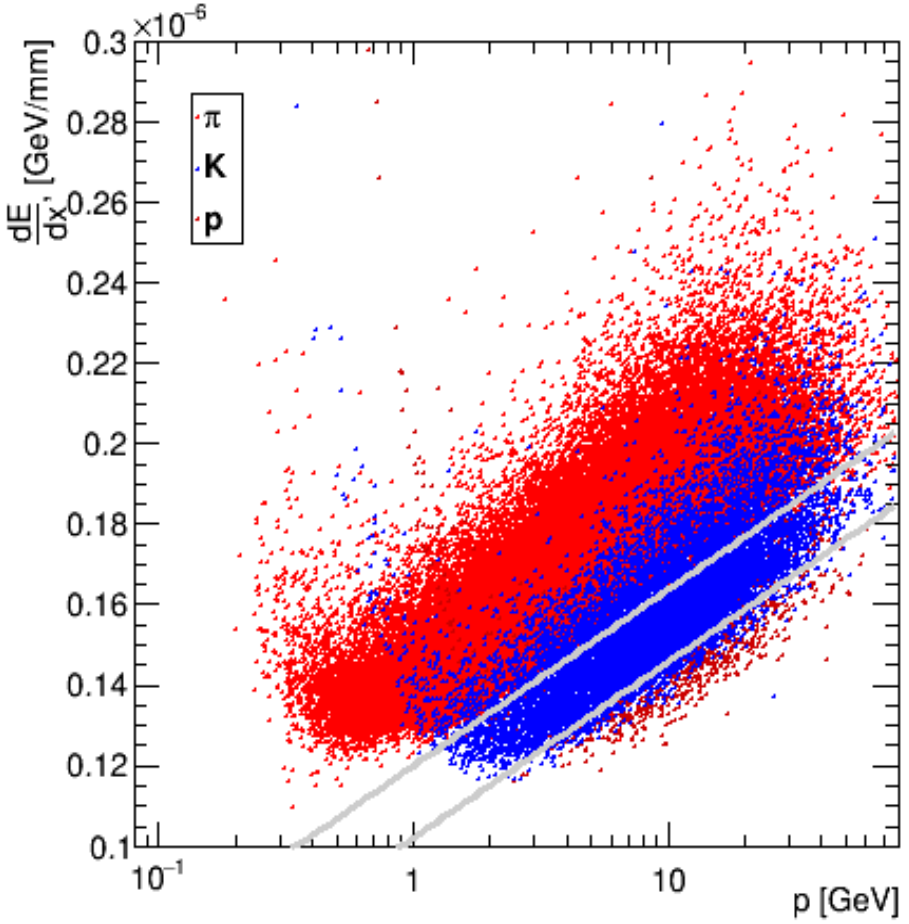
$$A_{fb}^{rec}/A_{fb}^{gen} = 92.2\%$$

~25% efficiency

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

Kaon identification

A simple cut-based algorithm allows high-purity kaon reconstruction



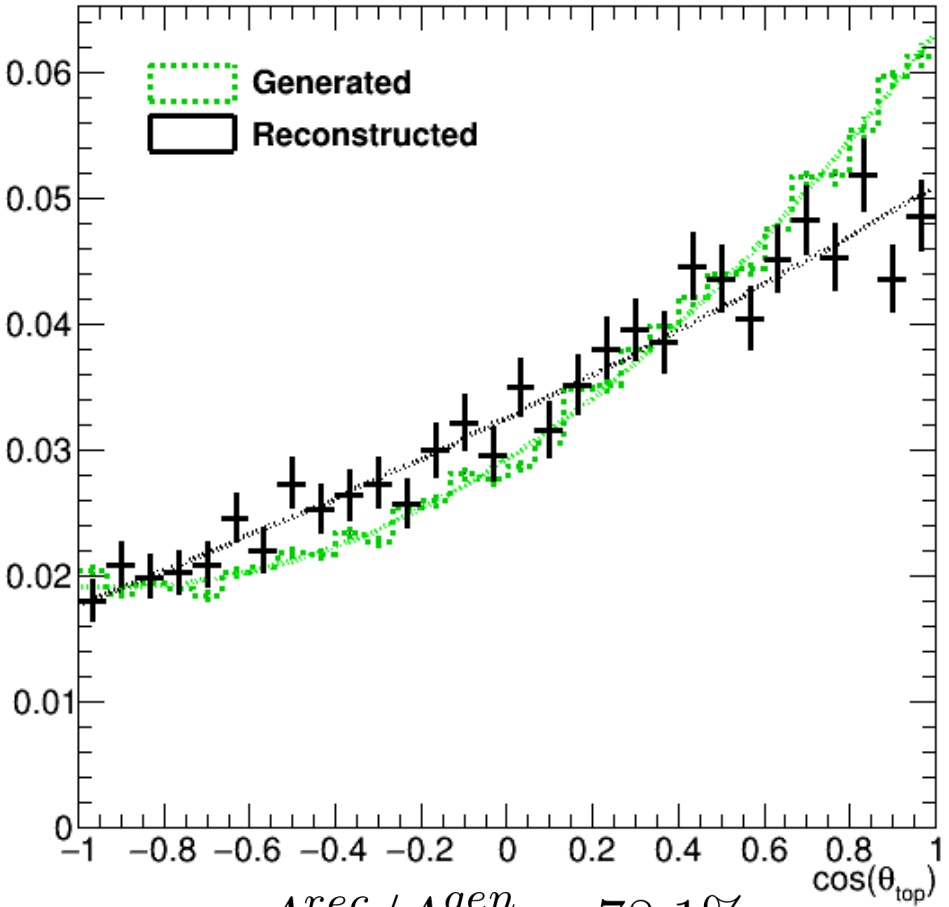
Generated \ Reconstructed	π	K	p
p	300	434	526
K	4735	7977	580
π	76897	225	15

92% purity and 60% efficiency

- This processor shows a good performance for kaon/pion separation
- Further means of kaon/proton separation
  - time of flight or cluster shower shape ?

Top polar angle using full kaon reconstruction

Preliminary results after dE/dx kaon reconstruction



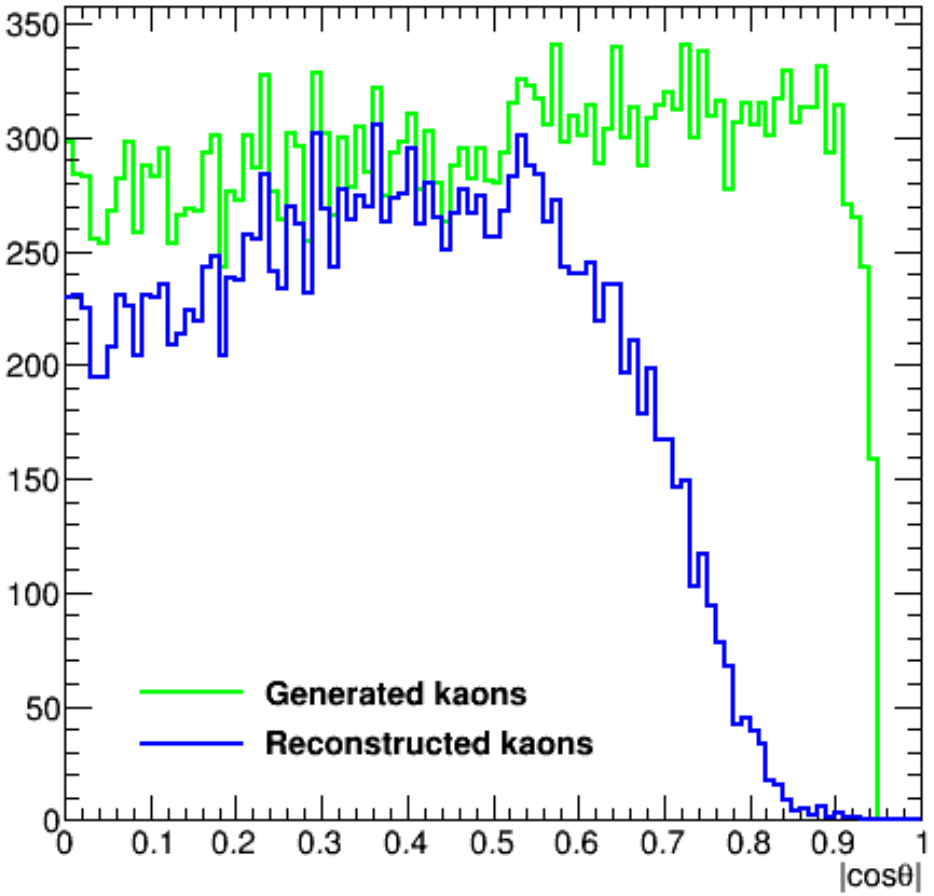
$$A_{fb}^{rec}/A_{fb}^{gen} = 78.1\%$$

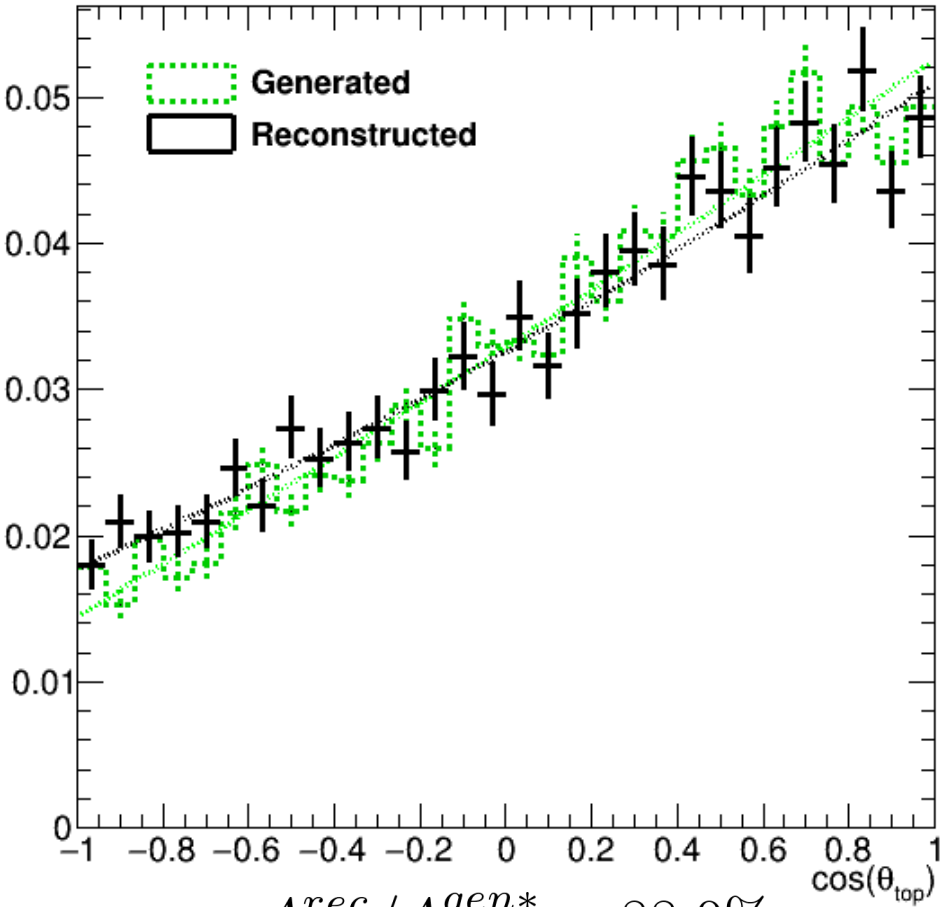
~14% efficiency

- The reconstructed top polar angle do not agree with the generated one
- **B-jet information only.**

Top polar angle using full kaon reconstruction

Preliminary results after dE/dx kaon reconstruction





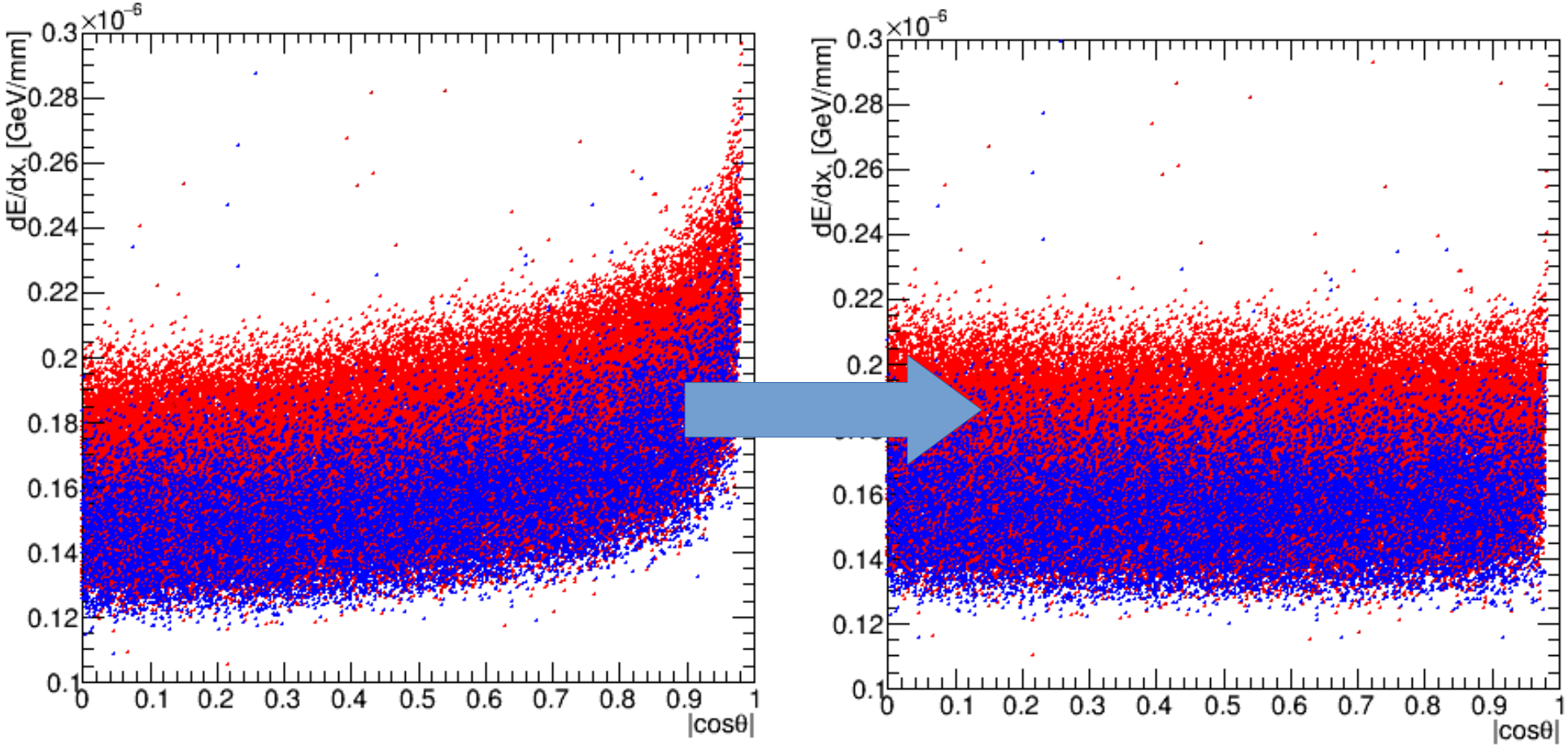
$A_{fb}^{rec}/A_{fb}^{gen*} = 88.0\%$

~14% efficiency

- After restriction to well measured b-charges there is a nice agreement
- **B-jet information only.**

Reducing angular dependence

Preliminary results for dE/dx angular dependence

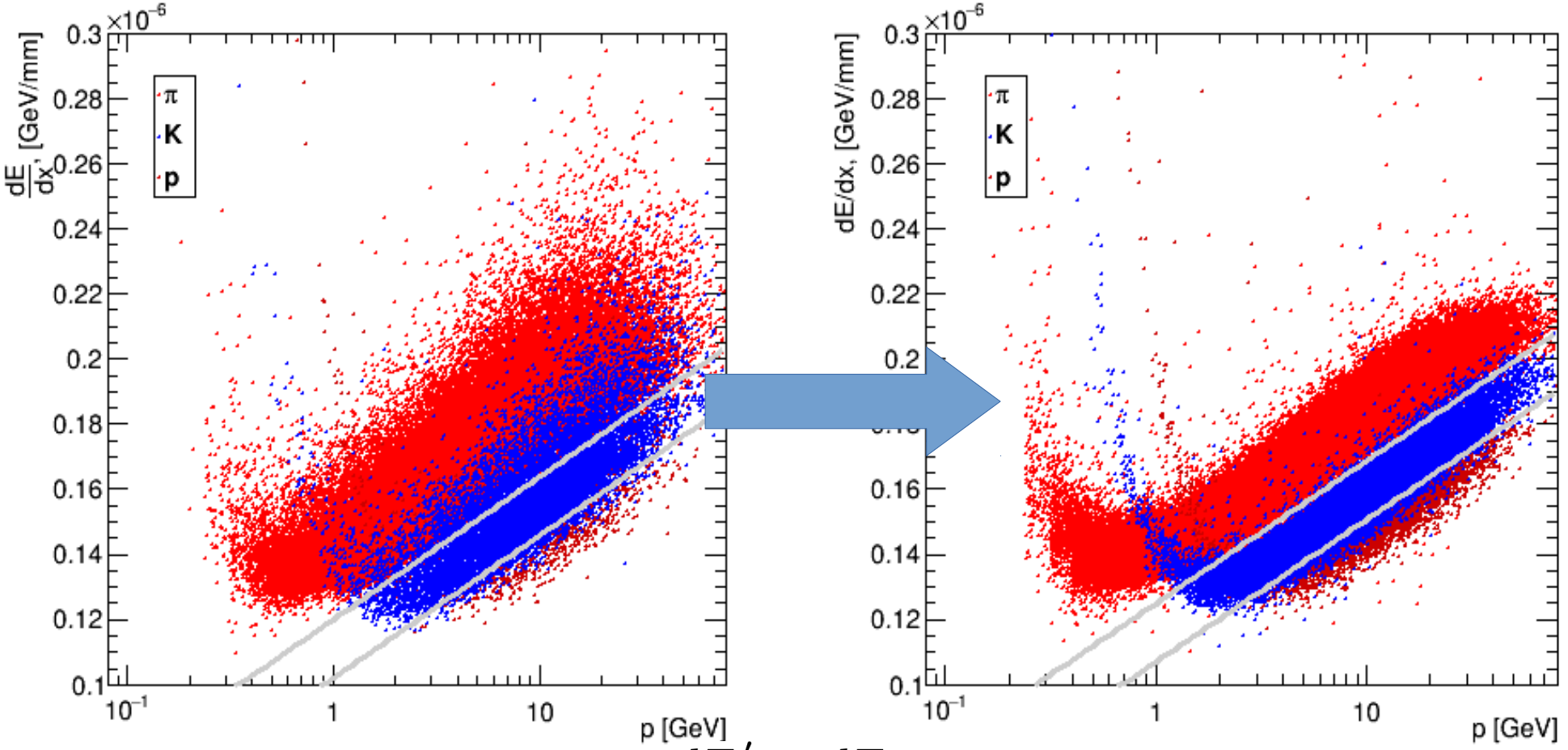


$$\frac{dE'}{dx} = \frac{dE}{dx}\theta^{0.15}$$

- After correction dE/dx does not have a dependence on track angle wrt. z axis

Reducing angular dependence

Preliminary results for dE/dx angular dependence

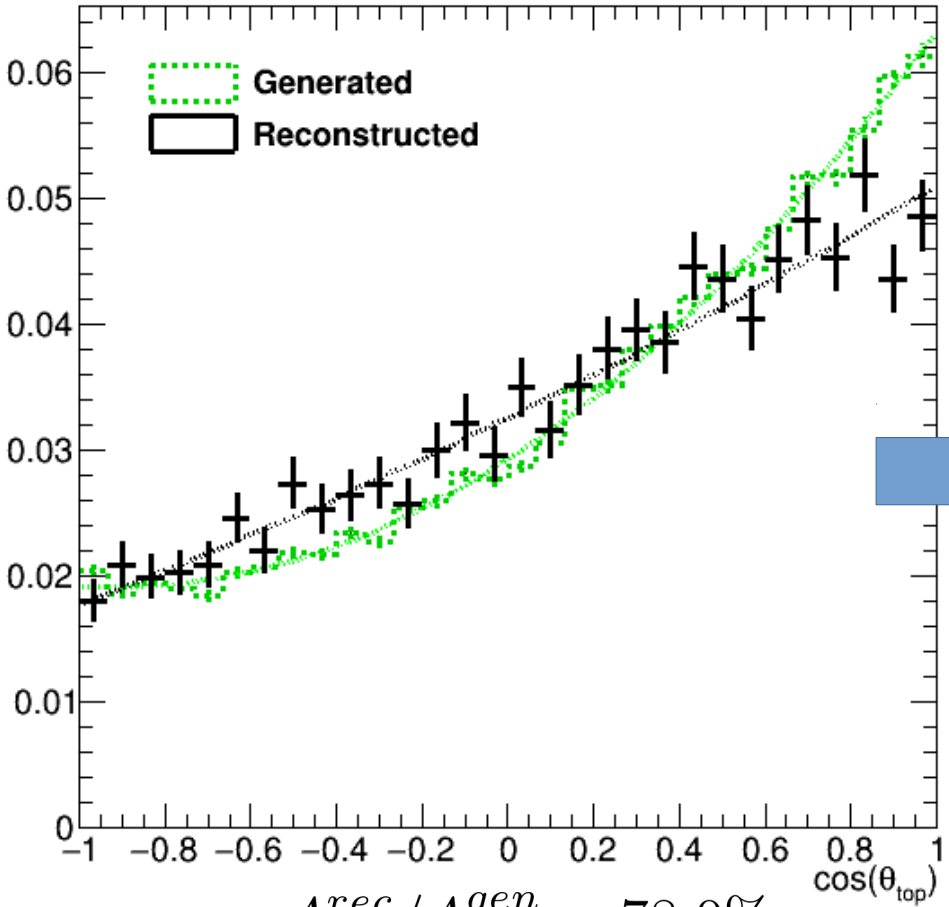


$$\frac{dE'}{dx} = \frac{dE}{dx}\theta^{0.15}$$

- After correction dE/dx does have a better kaon separation properties
- Selection cuts are optimized for dE/dx'

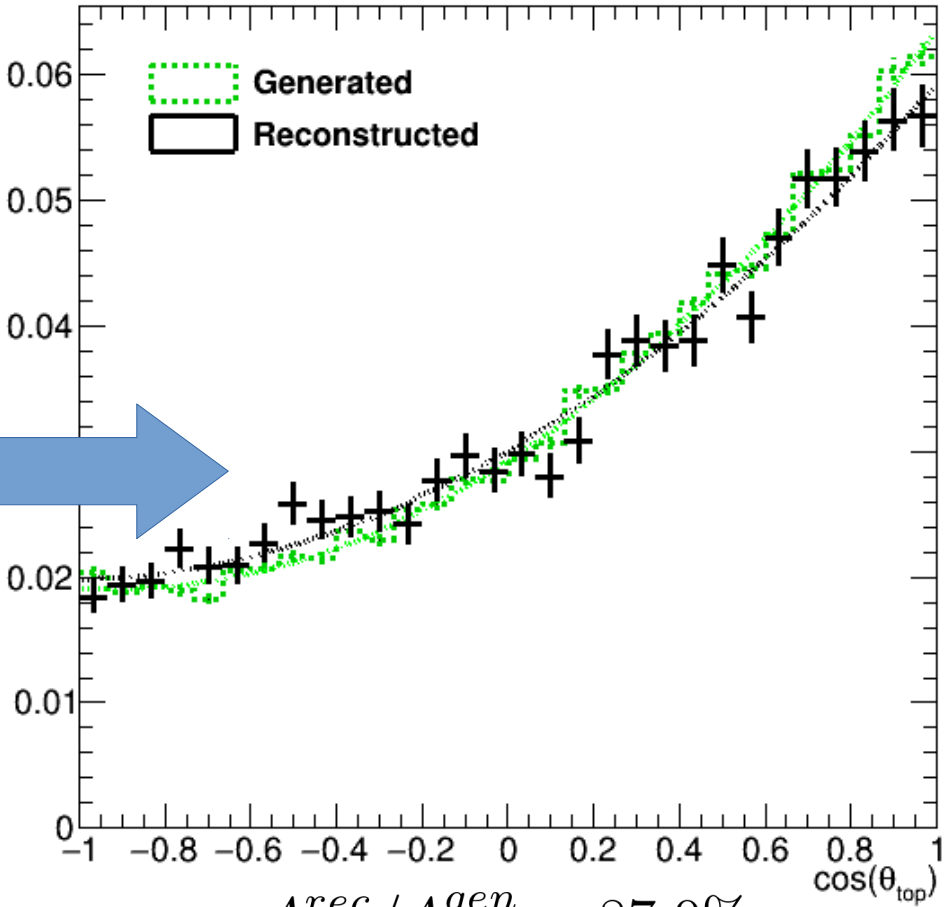
Top polar angle using full kaon reconstruction

Preliminary results after dE/dx kaon reconstruction



$A_{fb}^{rec}/A_{fb}^{gen} = 78.0\%$

~14% efficiency



$A_{fb}^{rec}/A_{fb}^{gen} = 87.0\%$

~18% efficiency

- After correction for angular dependence there is a nice agreement
- **B-jet information only.**

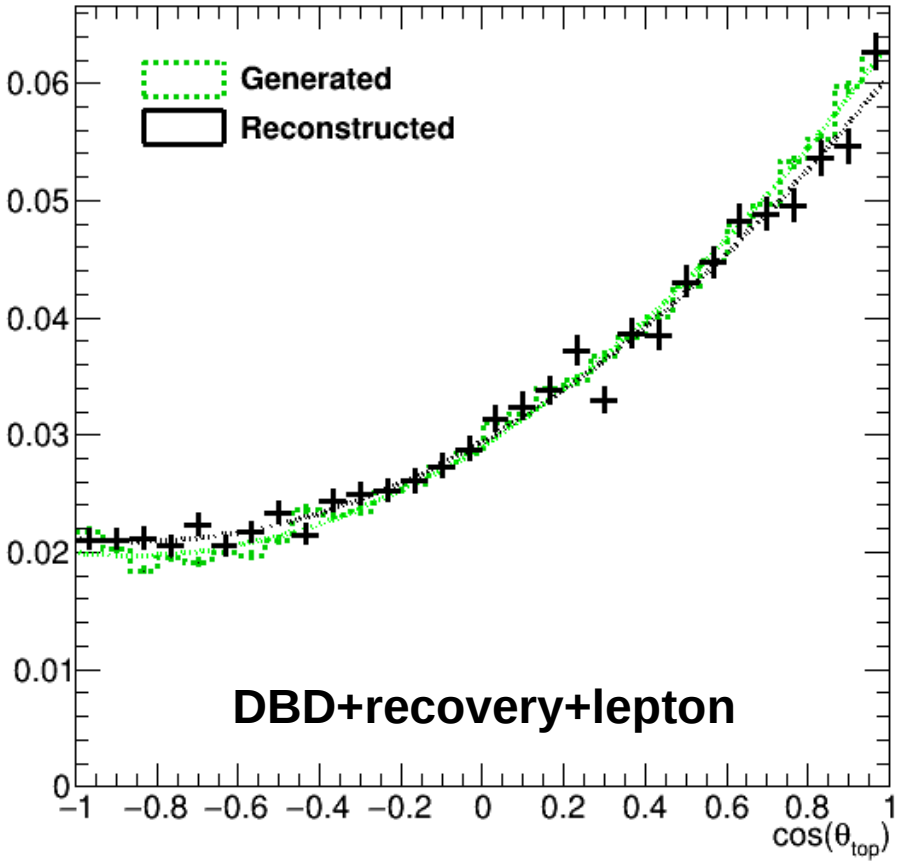
Summary

- Forward tracks without hits in the barrel VXD have big uncertainty
  - Tracks are difficult to use for vertex algorithms
- B-charge can be computed with a high purity and moderate efficiency using a combination of reconstructed vertex and kaon charges
- Research stay in Japan in July to work on new vertexing algorithm from next week (French/Japanese TYL/FJPPL funding)
- Further work:
  - Optimization of Particle ID
  - Optimize the preselection for ttbar process
  - Apply developed methods to bbar process at ILC (just started)
  - Improve purity of the VertexChargeRecovery

Thank you!

Improvement for semi-leptonic top decays

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



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

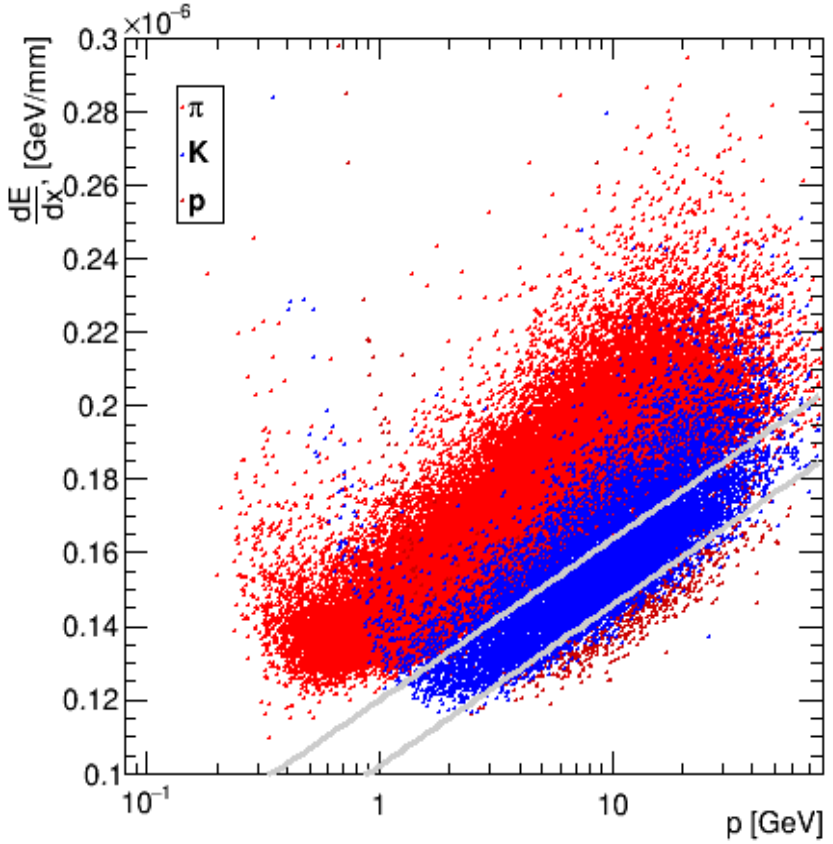
~40% efficiency

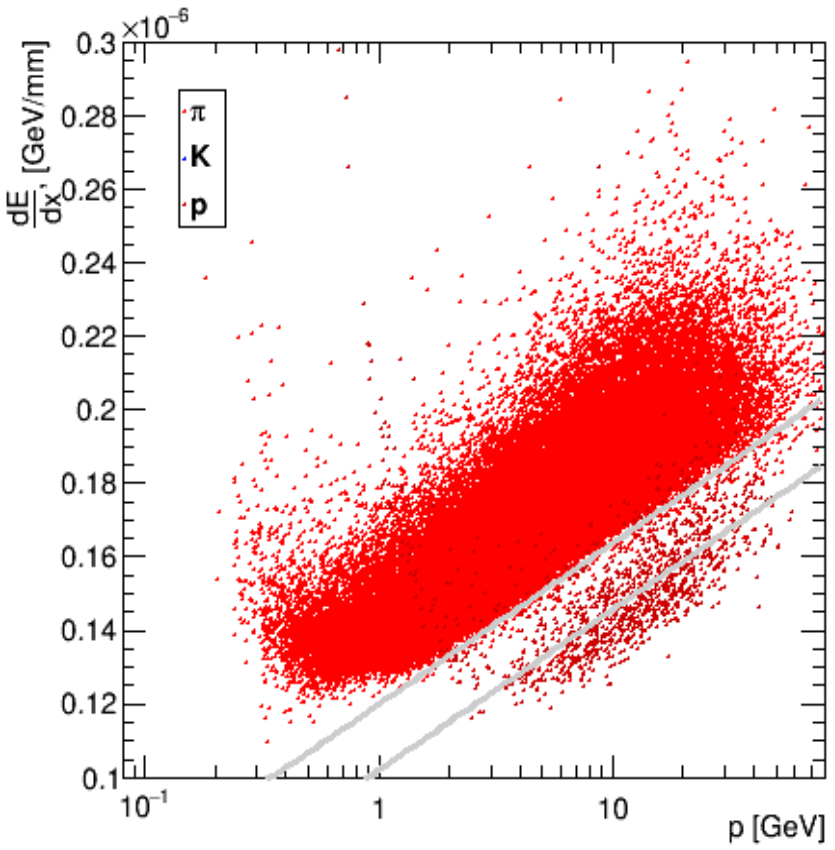
- The events are selected if there is a non-contradicting B-jet charge and lepton charge from W or $\chi_t^2 < 15$
- The efficiency of this method is ~30% higher than published result [arxiv:1505.06020, EPJC (2015) 75:512]
- The efficiency can be increased by optimizing general event selection (currently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

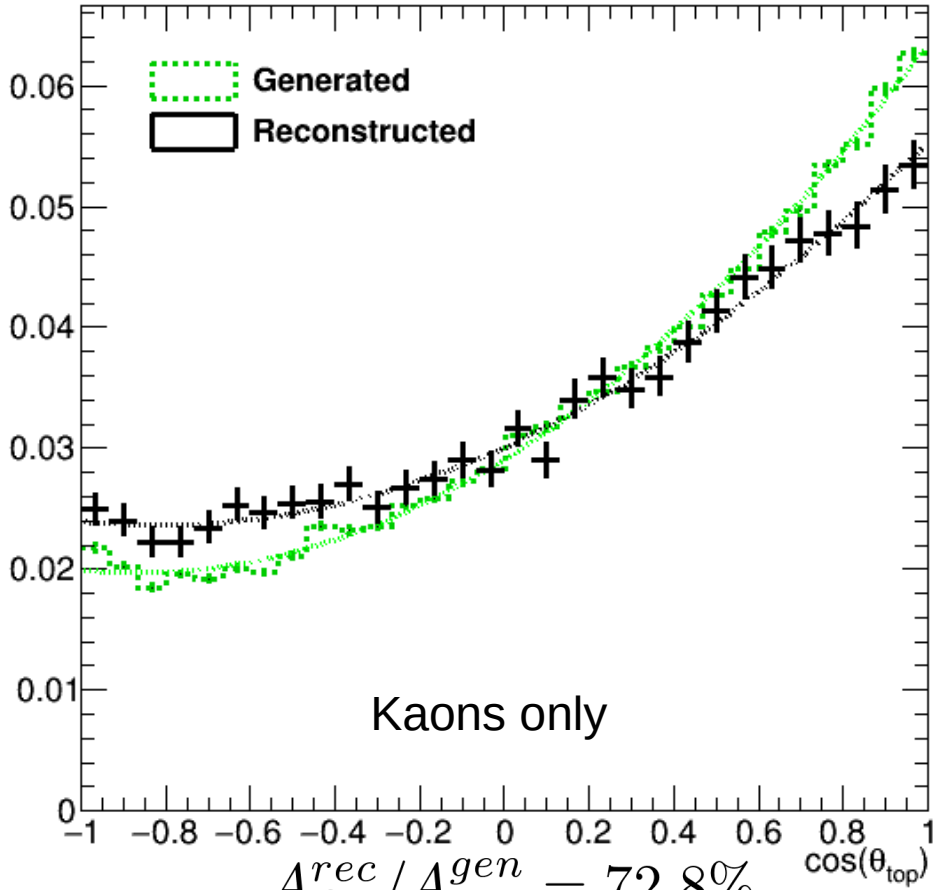




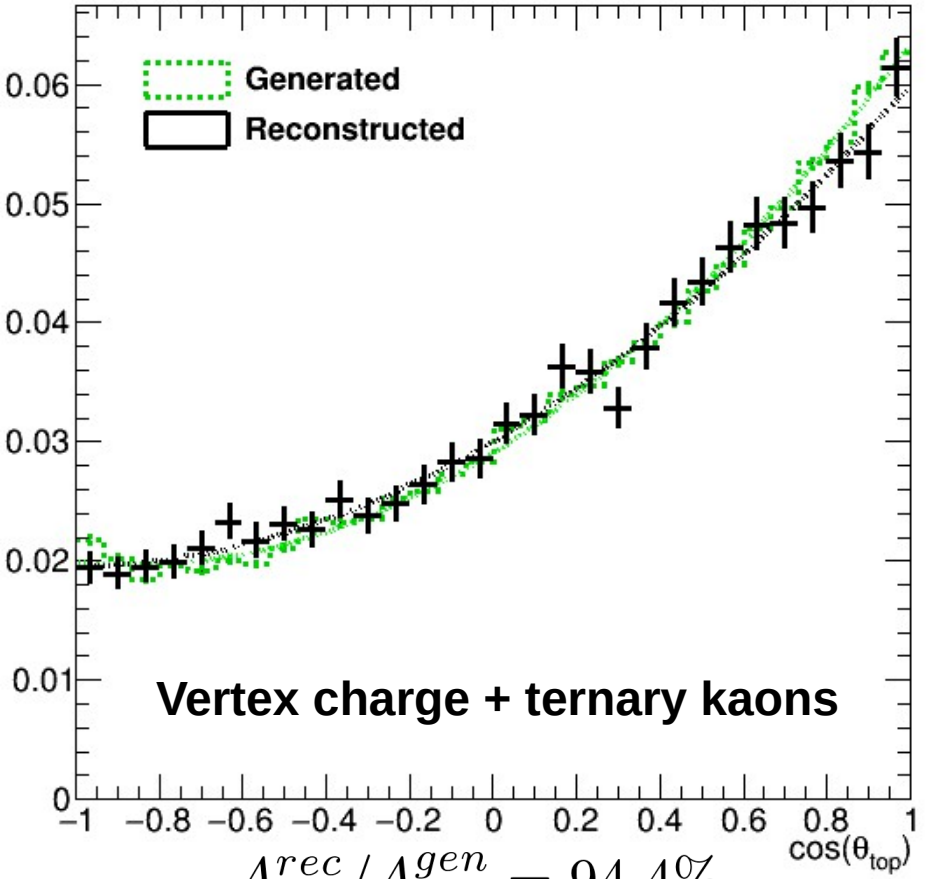
- In the following analysis kaons are selected using generator information for ternary tracks with TPC hits > 60 and $|cos\theta| < 0.95$

Improvement by ternary kaons

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



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



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

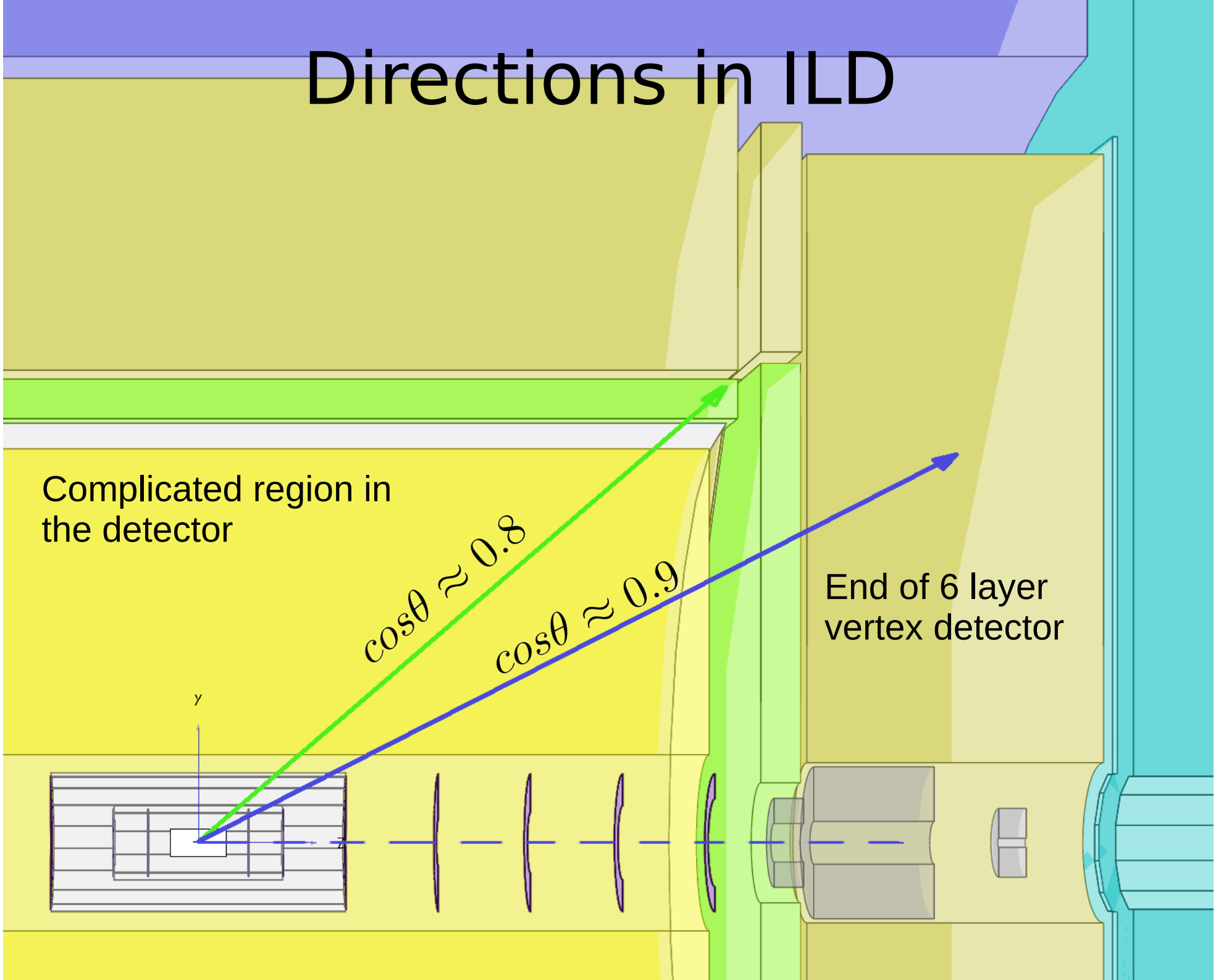
~15% efficiency

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

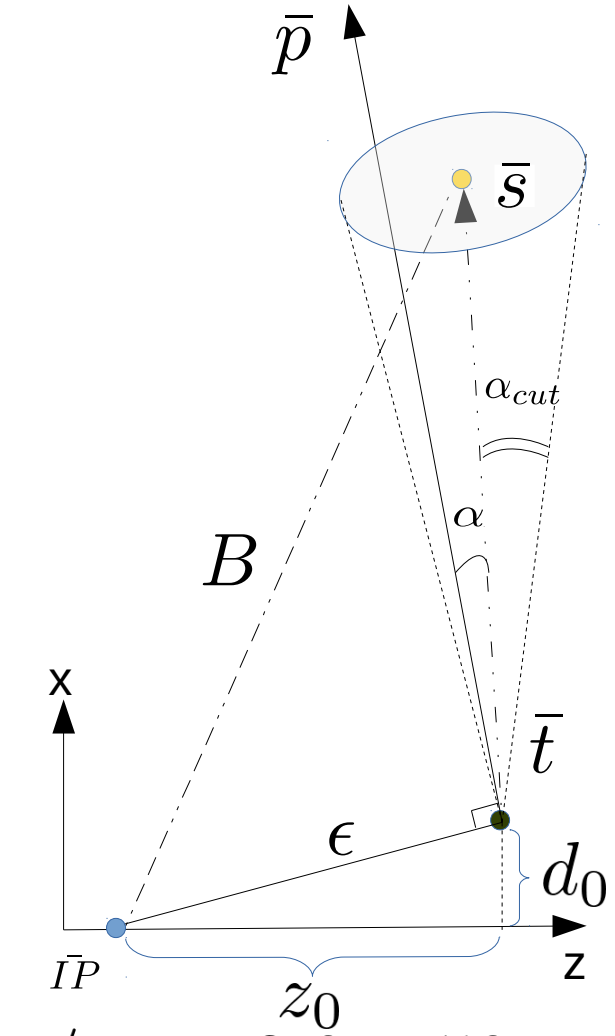
Analysis setup

- 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

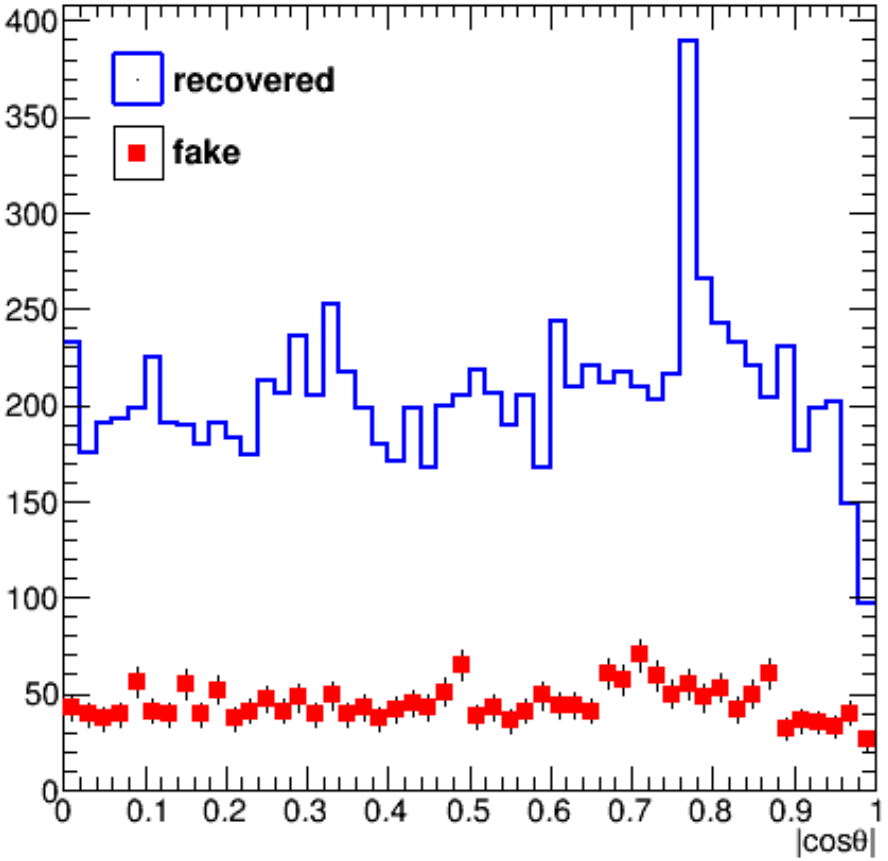
Directions in ILD



Recovery optimization



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

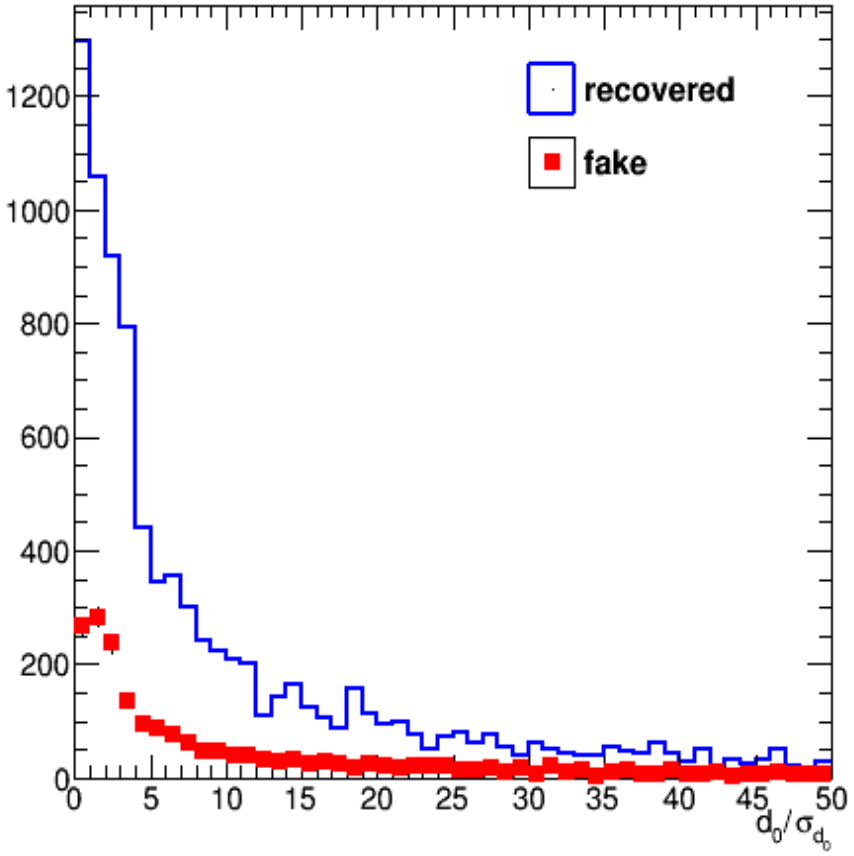


$$\varepsilon/\sigma_\varepsilon > 2.0 + 50 * \alpha$$

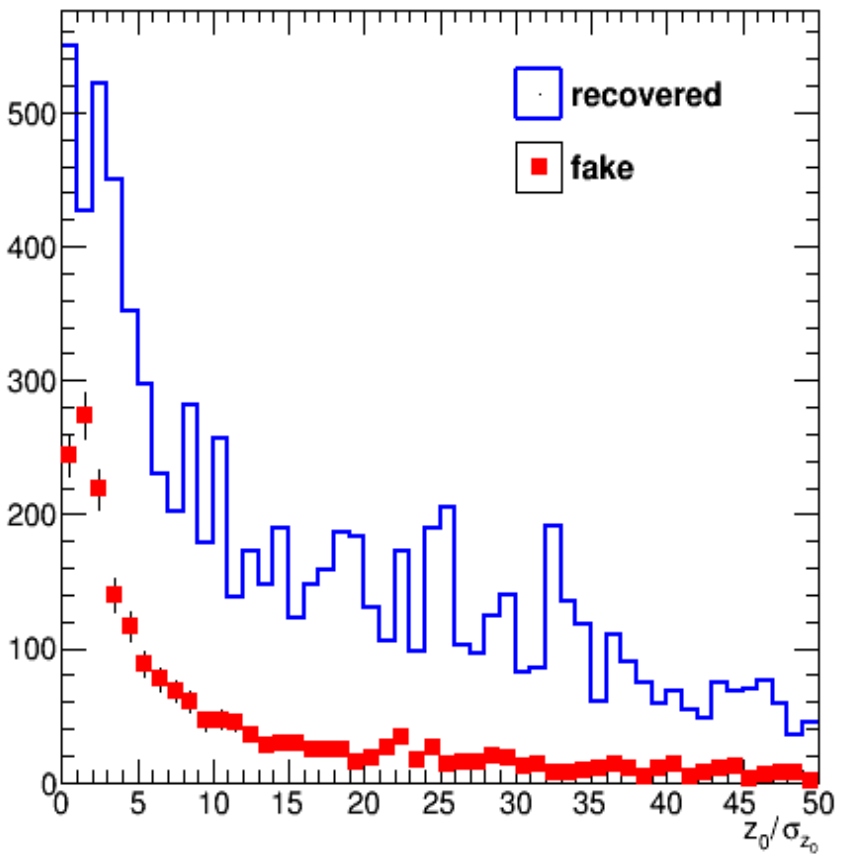
- Angular distribution of the recovered b-tracks and background (fake) tracks. Covariance matrix is used. Minivector tracking.

Components of the offset significance

d0



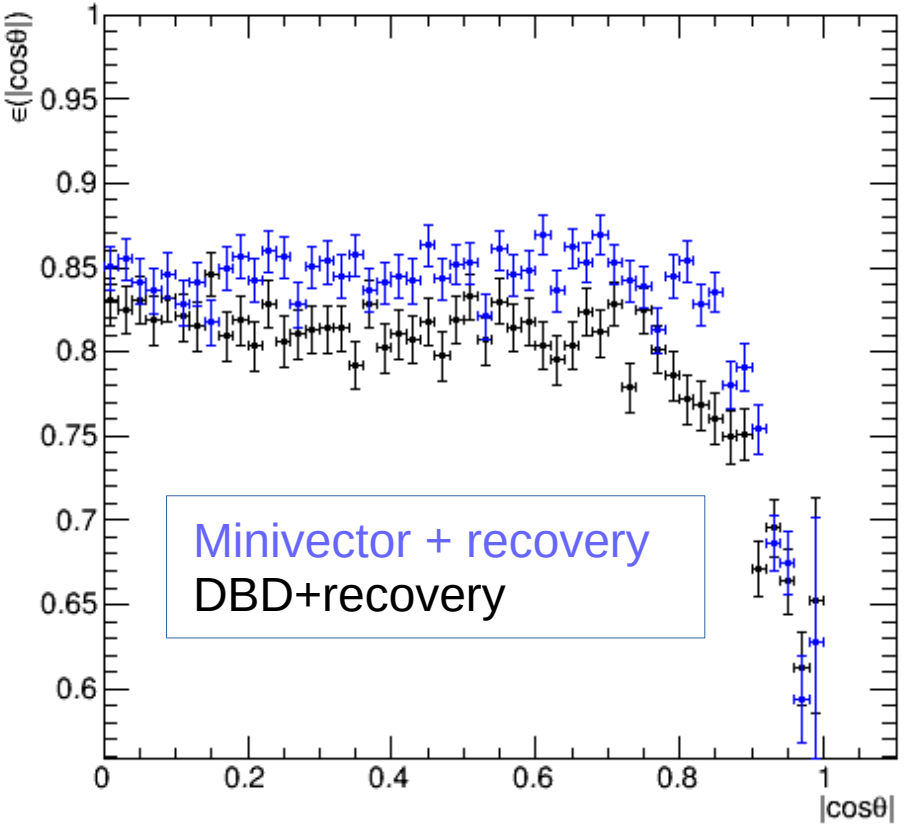
z0



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

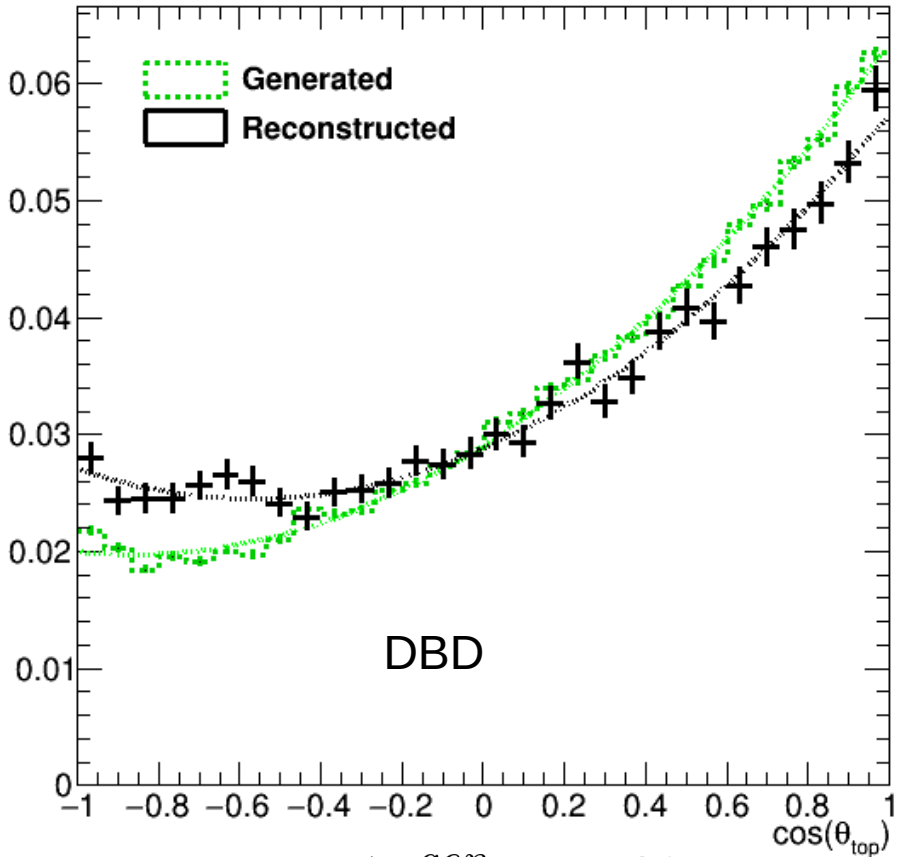
Overall charge purity

B-meson charge purity as a function of polar angle

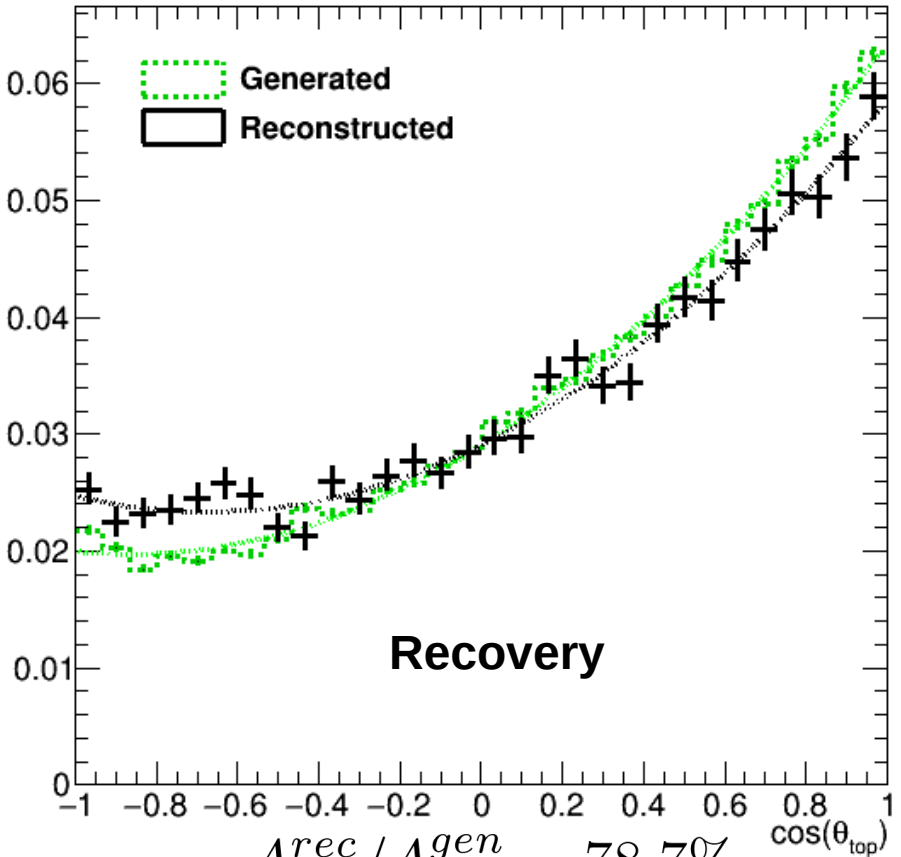


- Vertex charge purity in the barrel region 80-85%
- Degradation towards the forward region
- Minivector sample has ~3% higher vertex charge purity on average than DBD, and it has better purity in the forward region

DBD top polar angle reconstruction



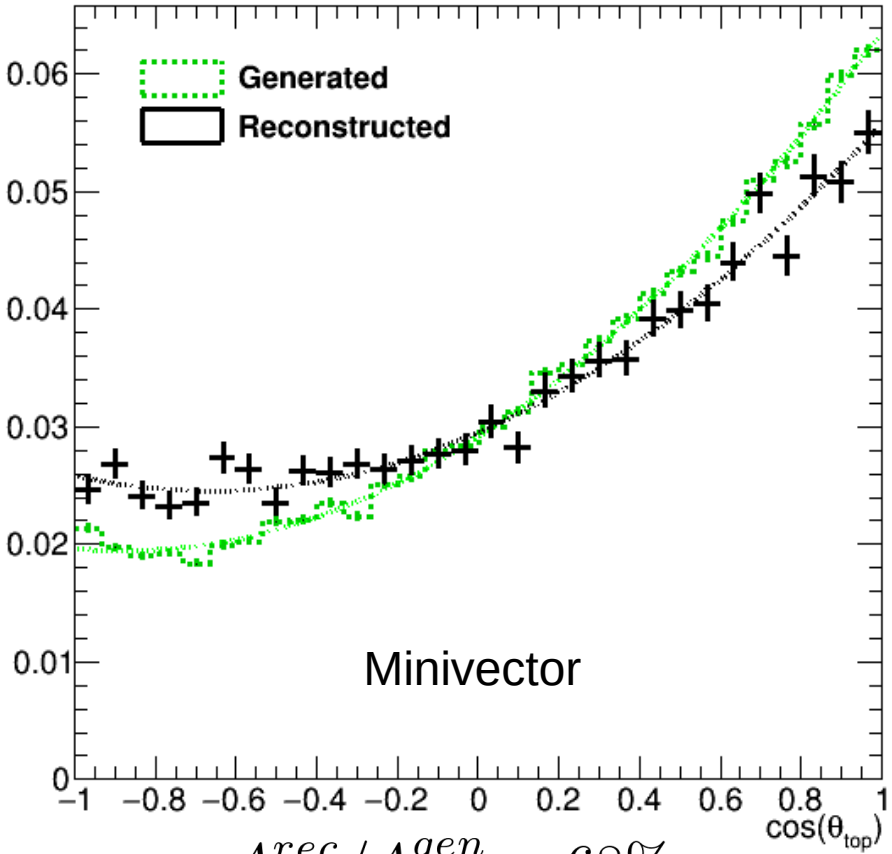
$A_{fb}^{rec}/A_{fb}^{gen} = 70\%$



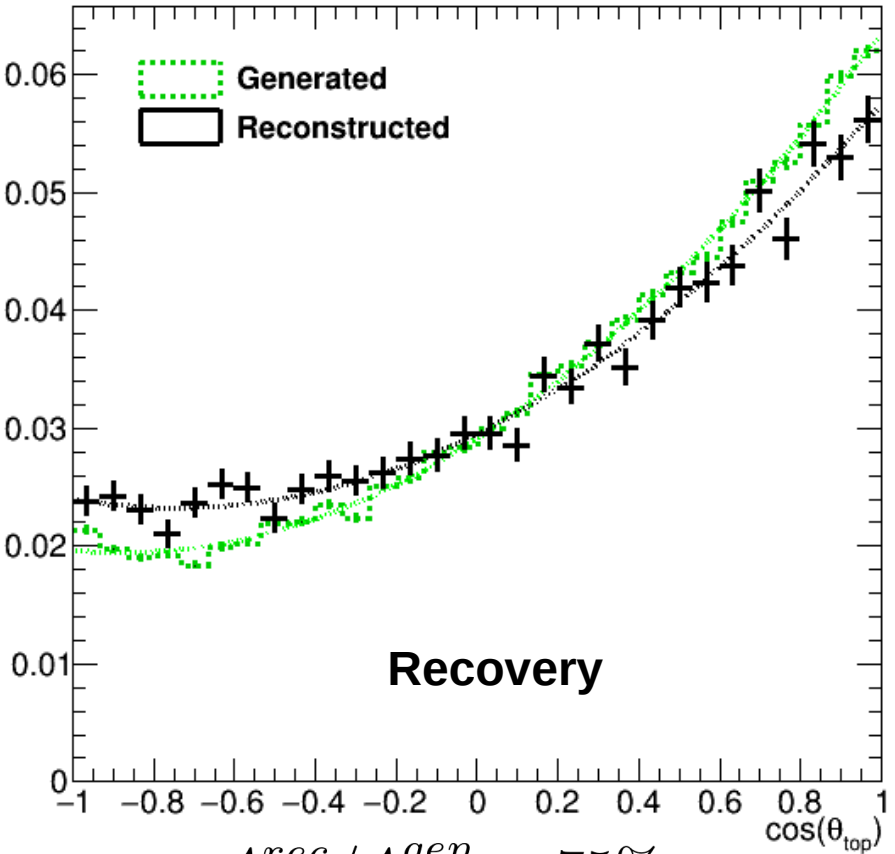
$A_{fb}^{rec}/A_{fb}^{gen} = 78.7\%$

- Recovery improves by more than 10%.

Minivector top polar angle reconstruction



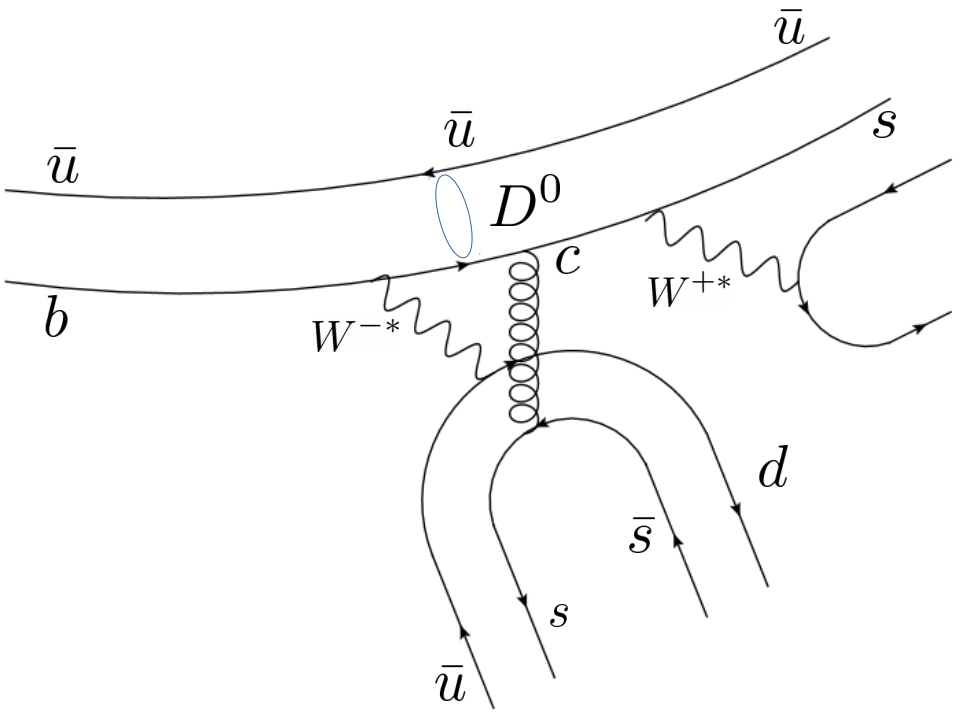
$A_{fb}^{rec}/A_{fb}^{gen} = 68\%$



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

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

Kaon charge correlation

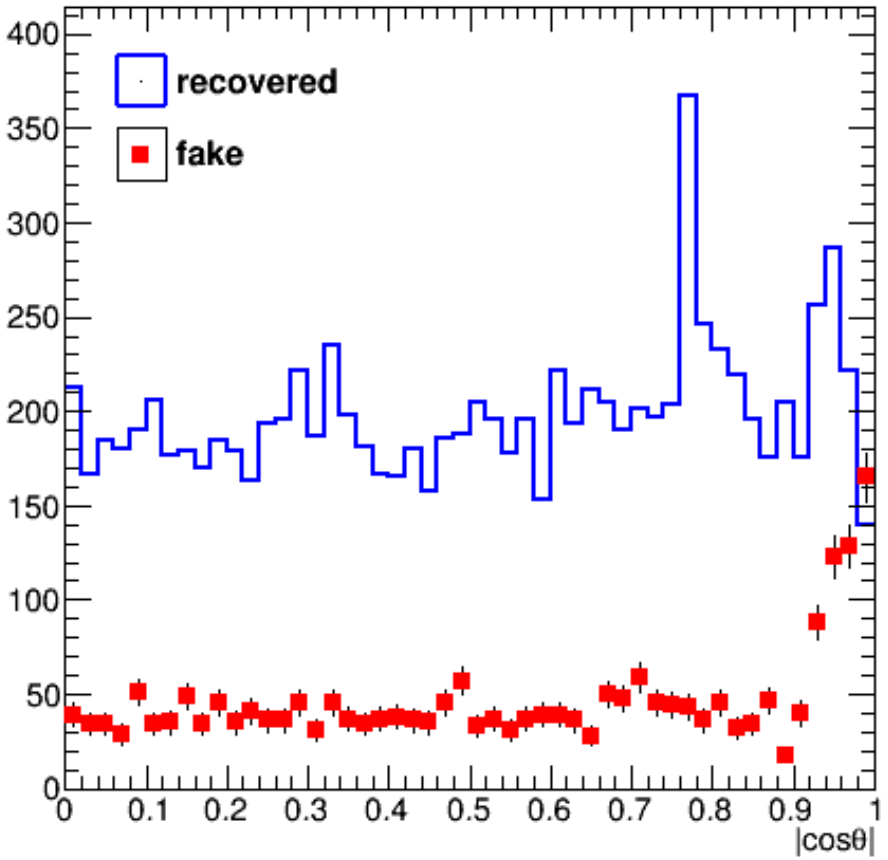


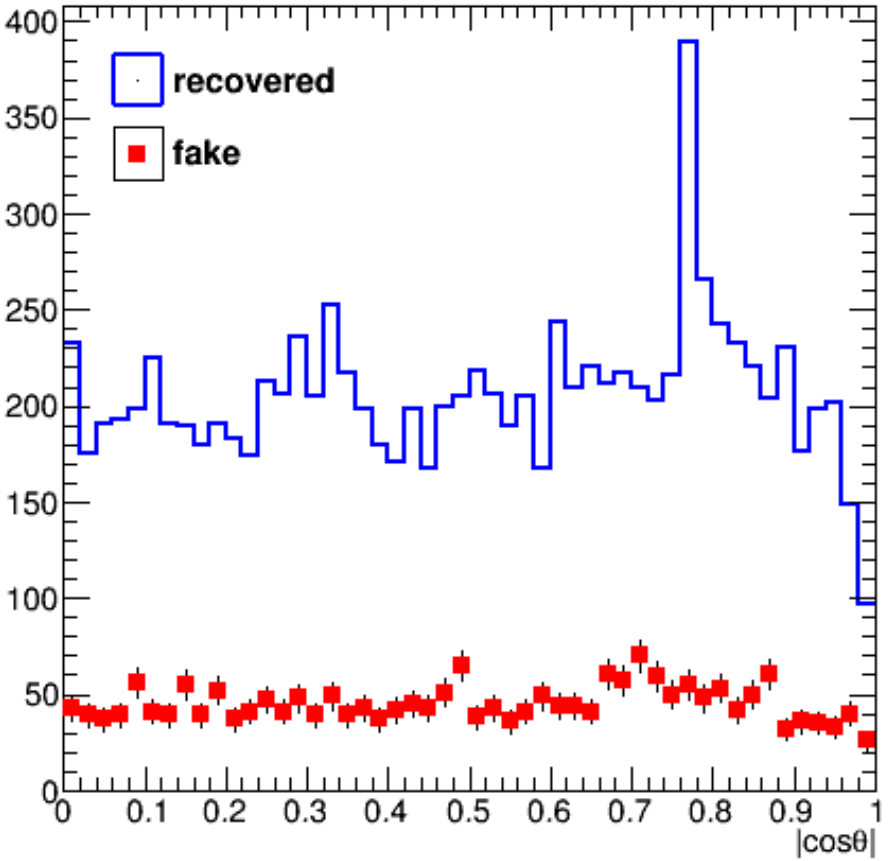
- Example of B-meson decay with secondary and ternary kaons.

Old offset vs new offset

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

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

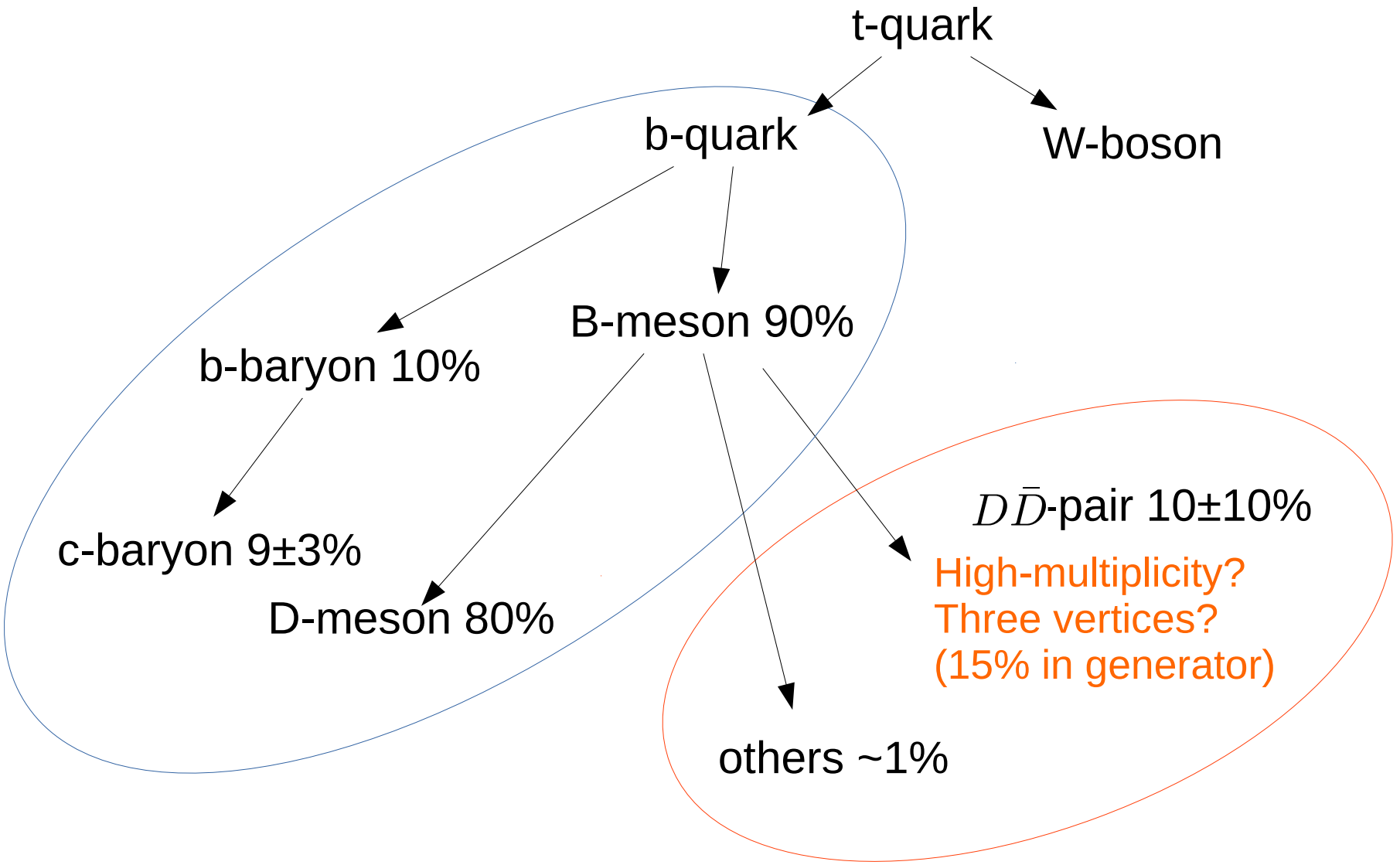




- Angular distribution of the recovered b-tracks and background (fake) tracks. Minivector tracking.

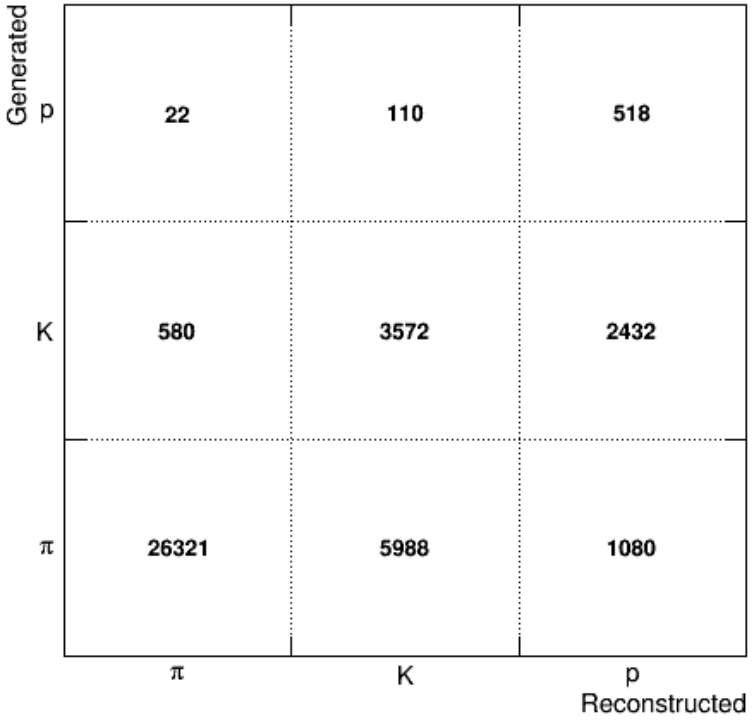
Process overview

- Hadronization and decay modes of b-quark:

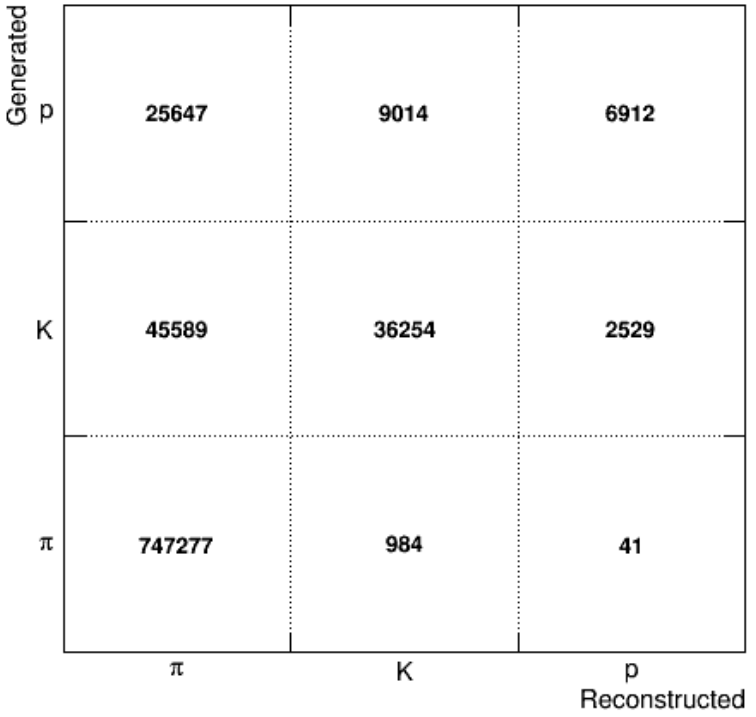


Kaon reconstruction

PIDTools, dE/dx algorithm

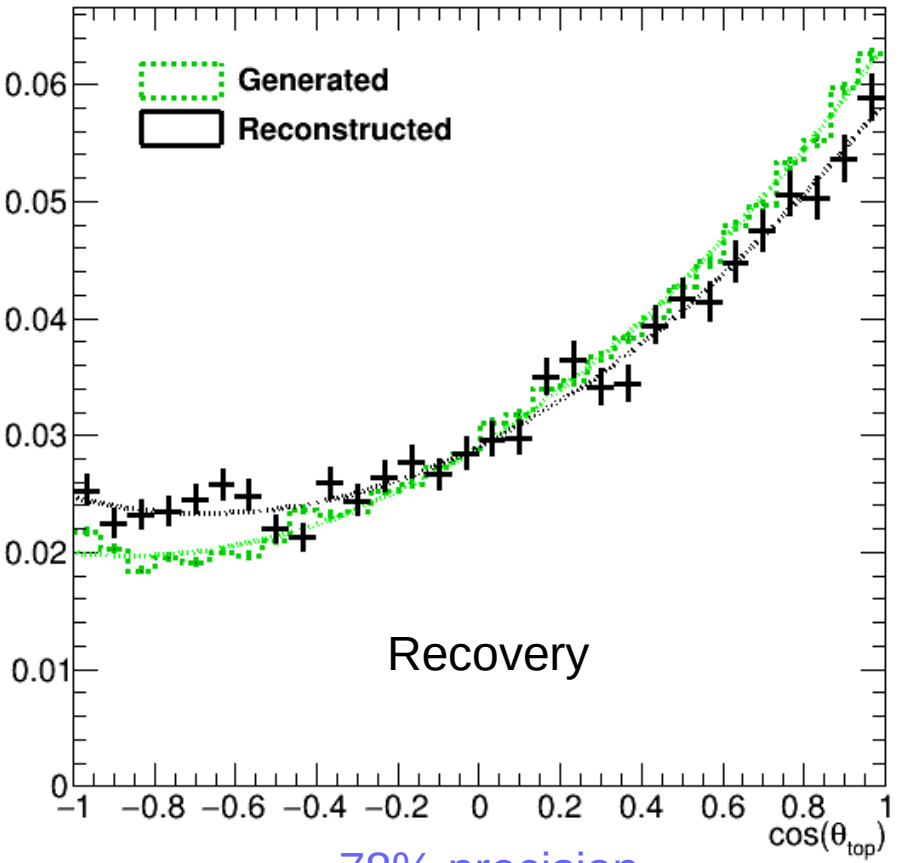


Cut based

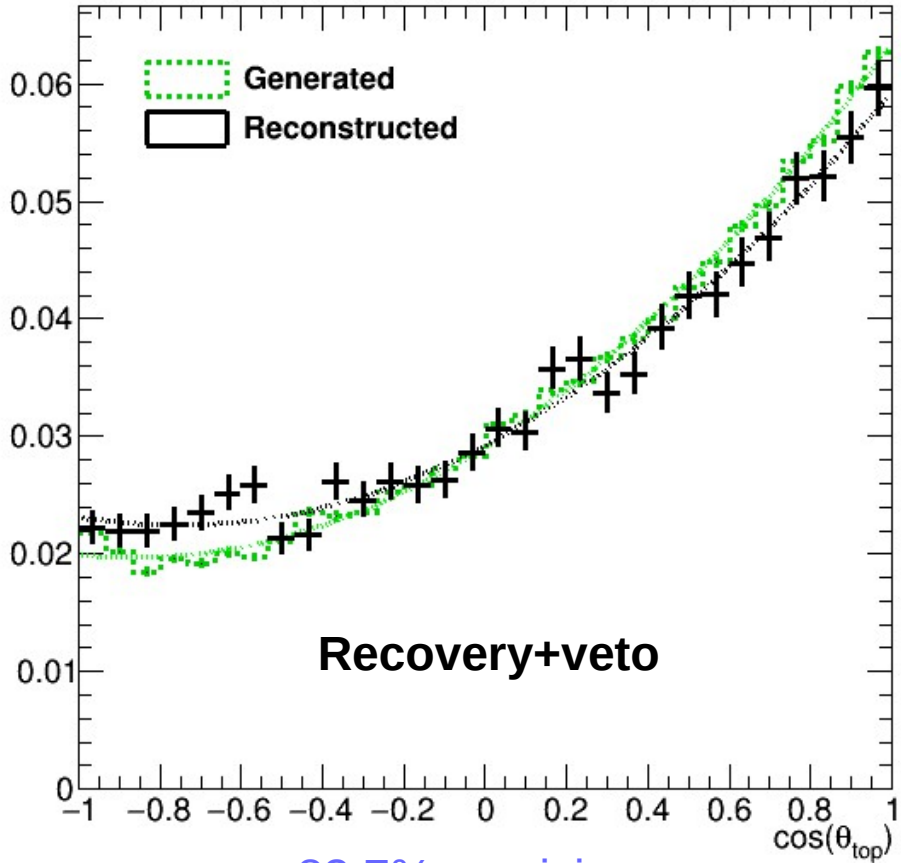


- Comparison of two kaon reconstruction methods (preliminary)

Overall top polar angle improvement



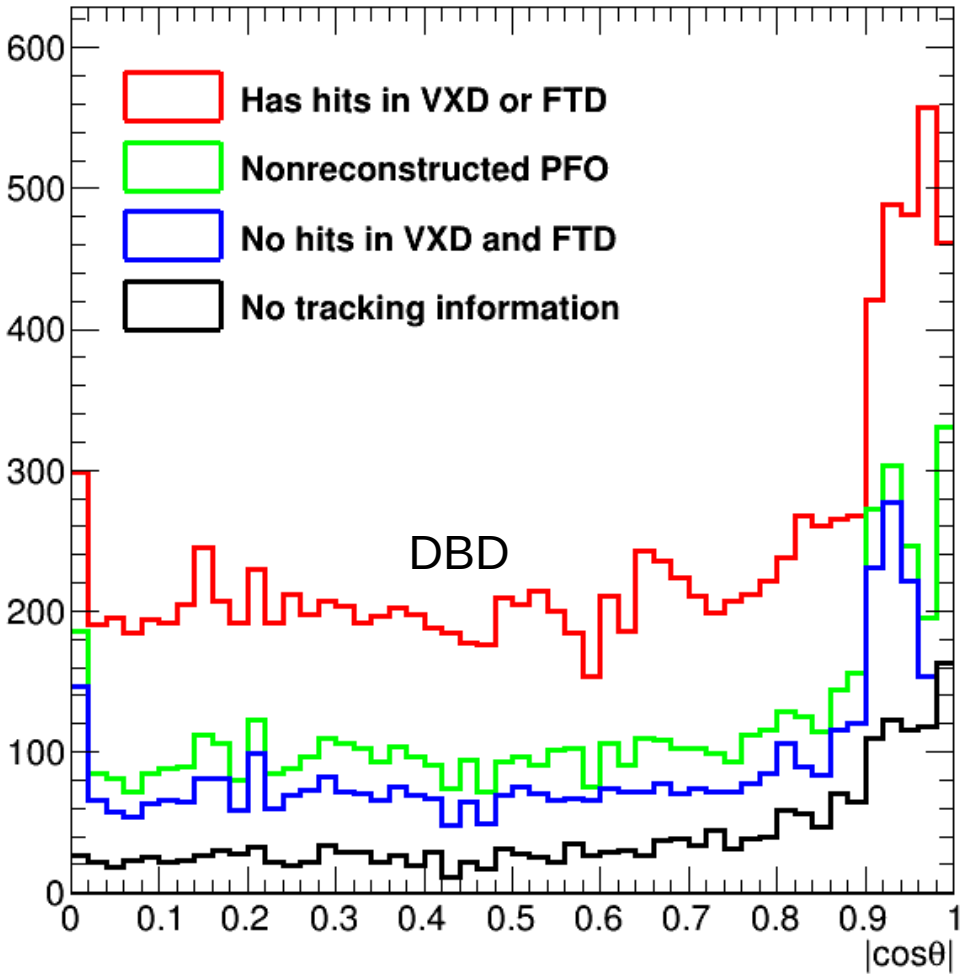
78% precision



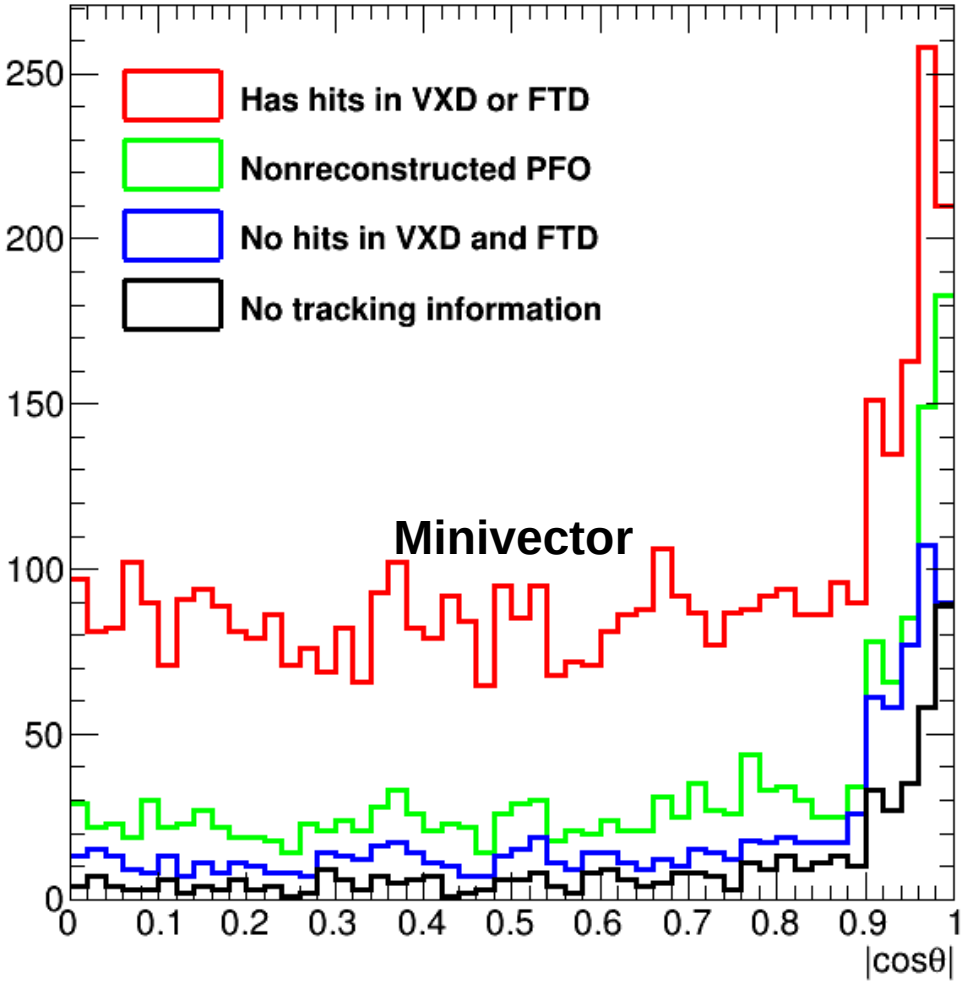
83.7% precision

- 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

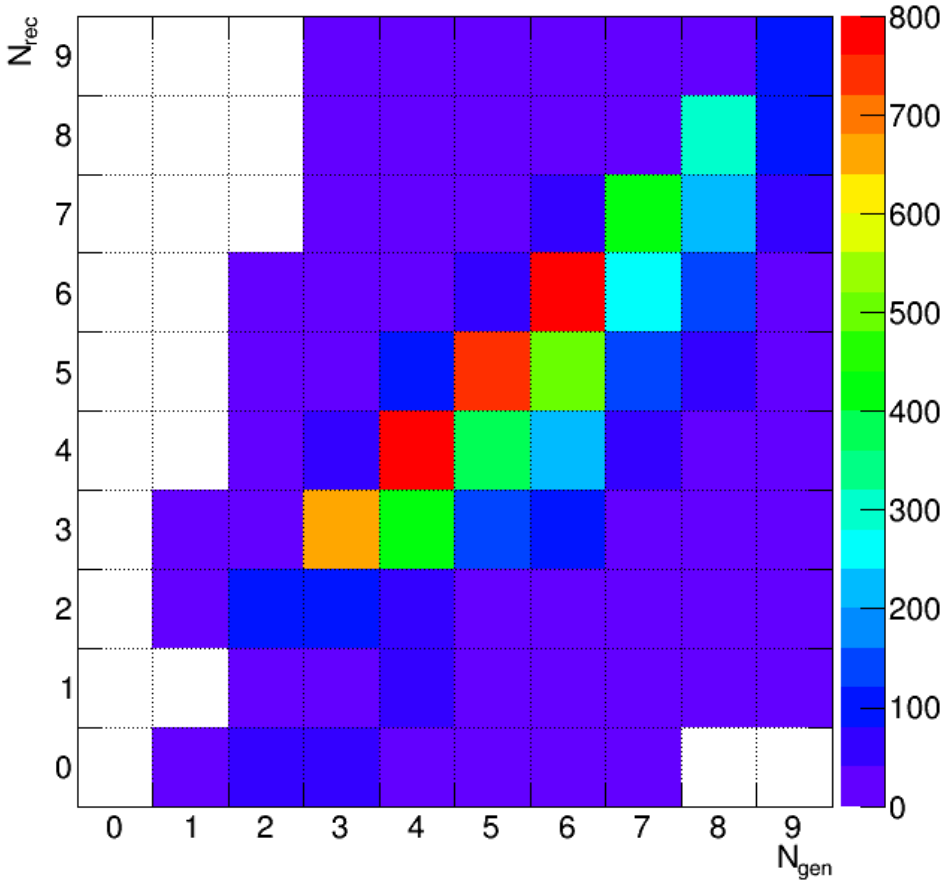


7.4% of generated

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

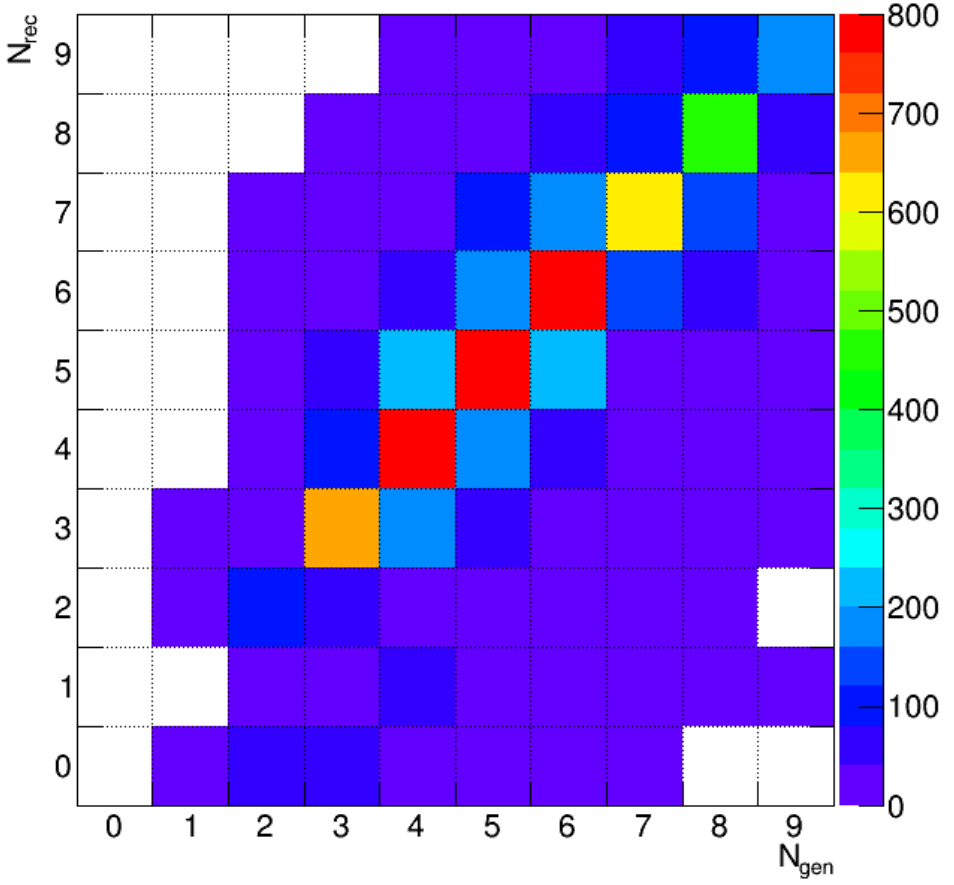
Number of tracks comparison Minivector

Original



51.0% on diagonal

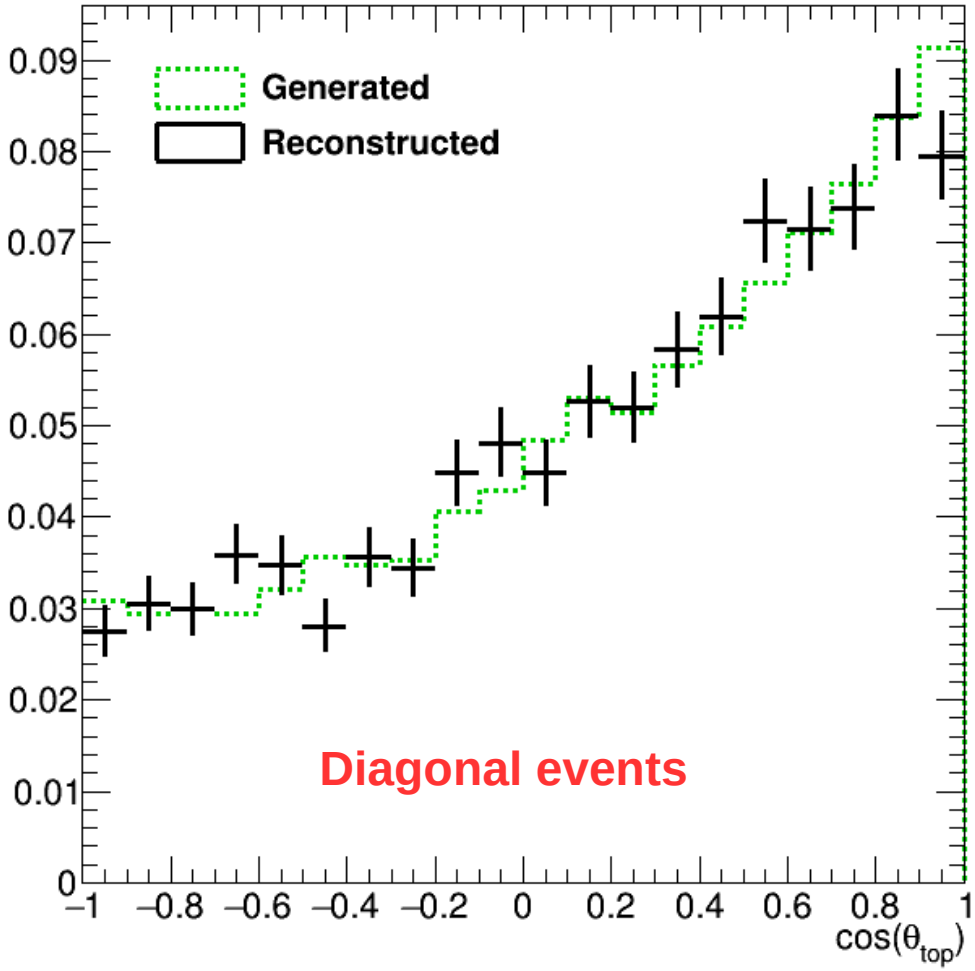
Recovery



63.3% on diagonal

Btag > 0.8 & Pb > 15 GeV

Top asymmetry: diagonal events

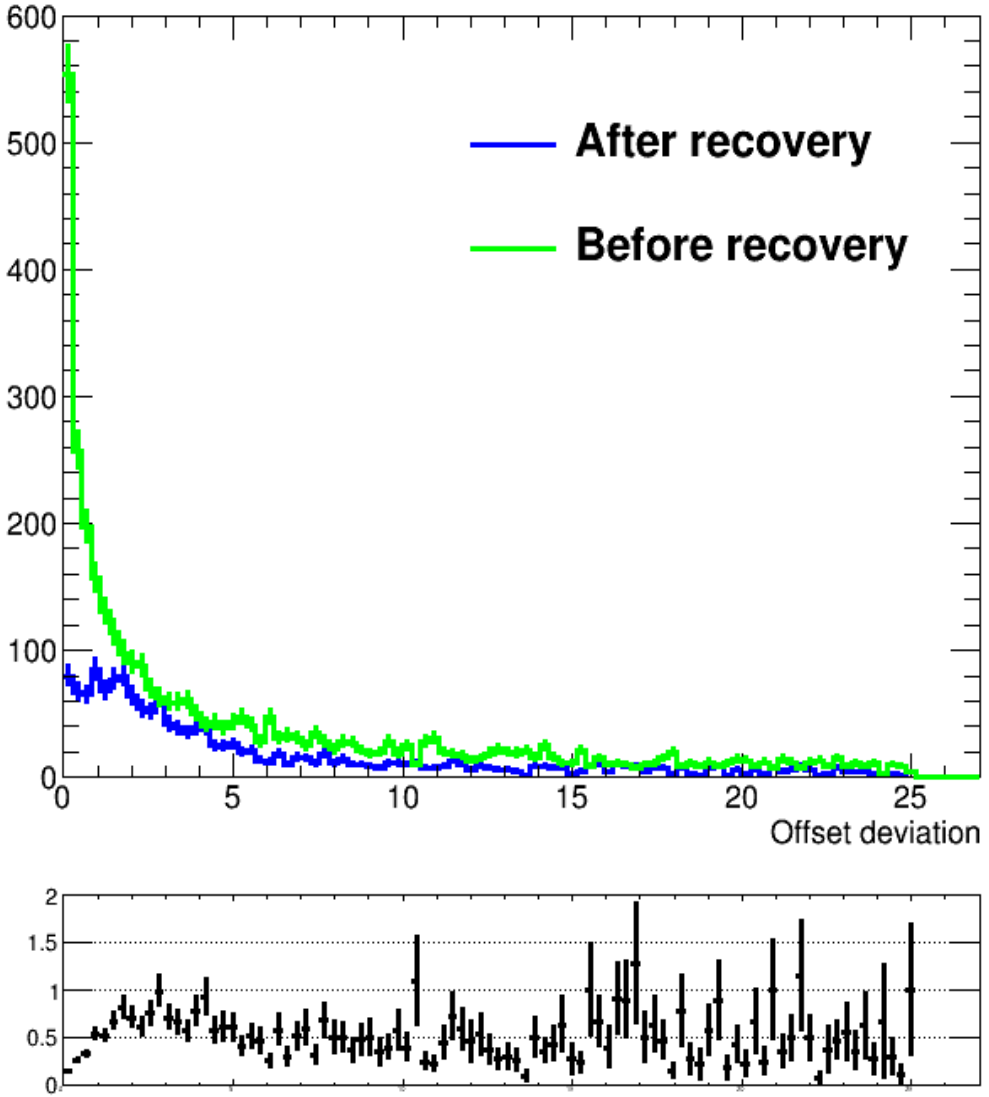


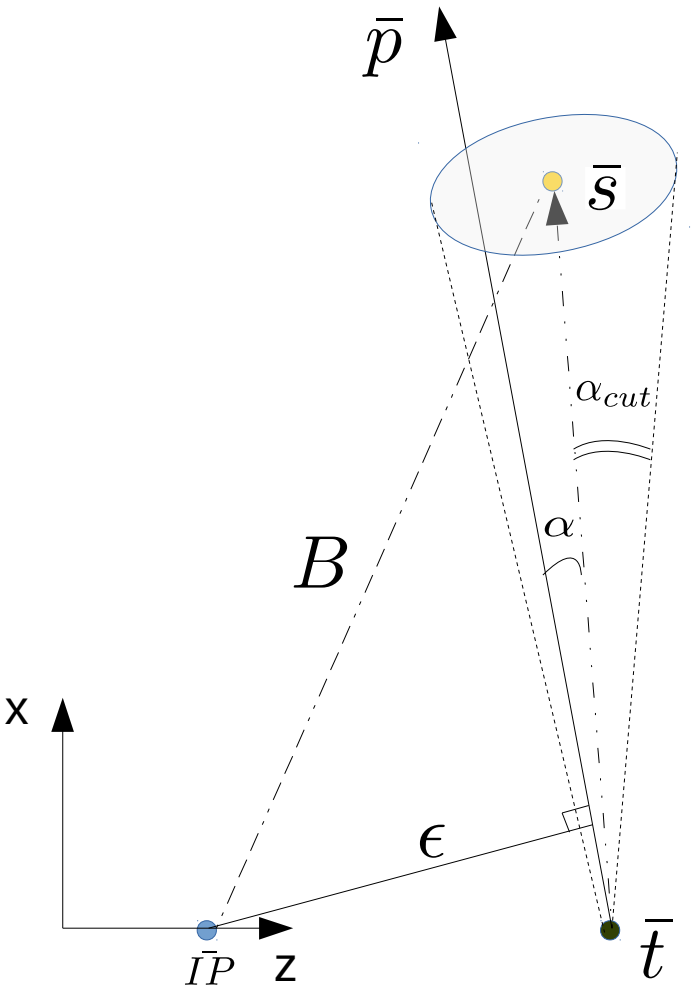
95.5% precision

- 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.

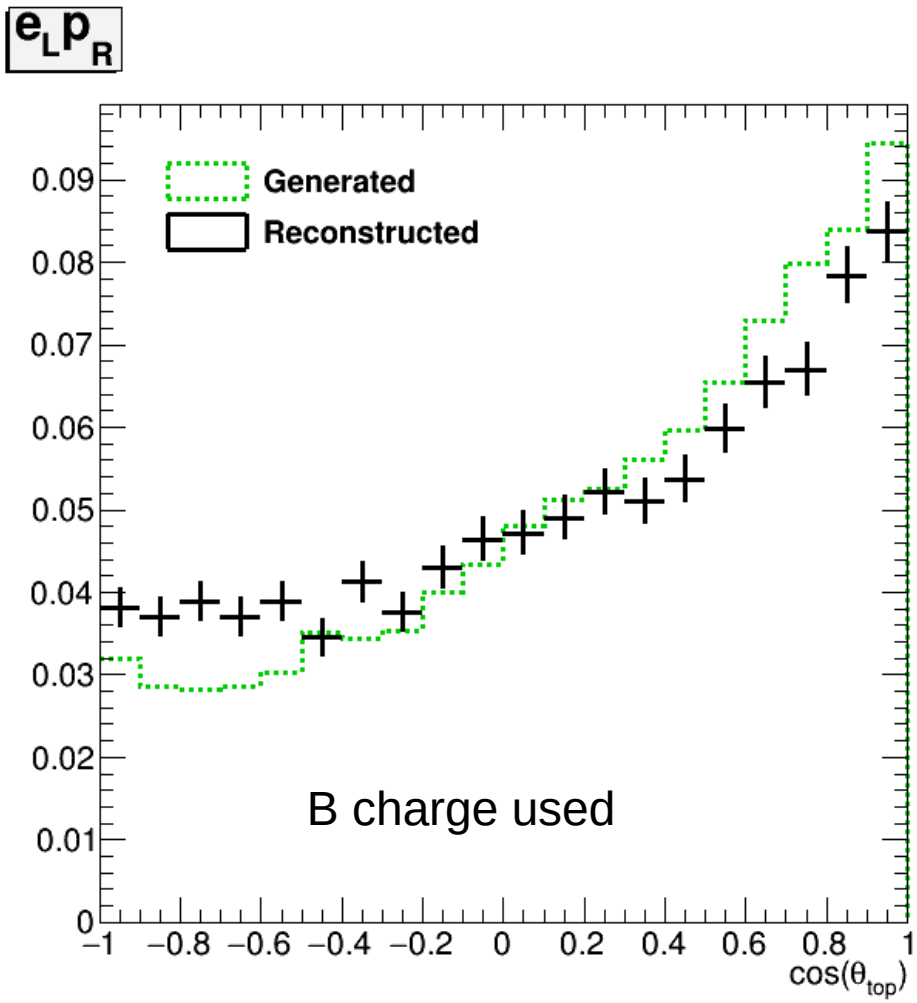
Offset deviation - Minivector reconstruction



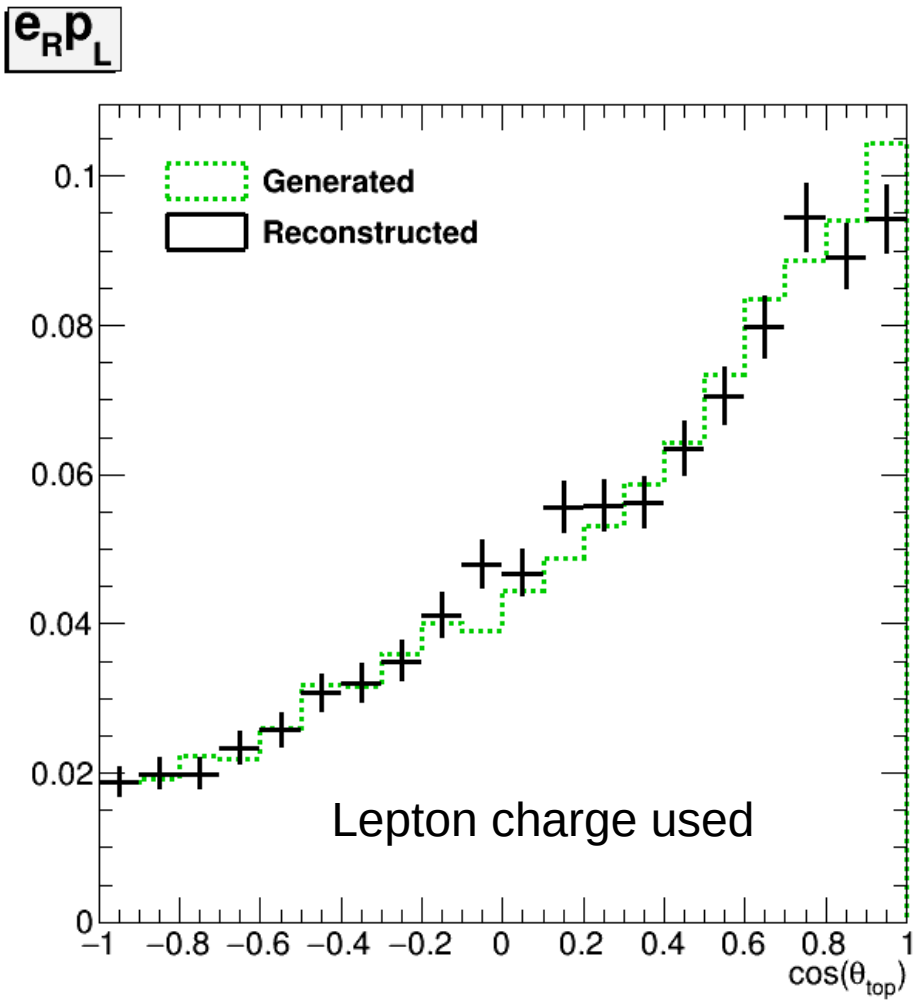


- Majority of missed tracks have low offsets. These tracks can be recoverable if their angle w.r.t. secondary vertex is small

Top asymmetry DBD



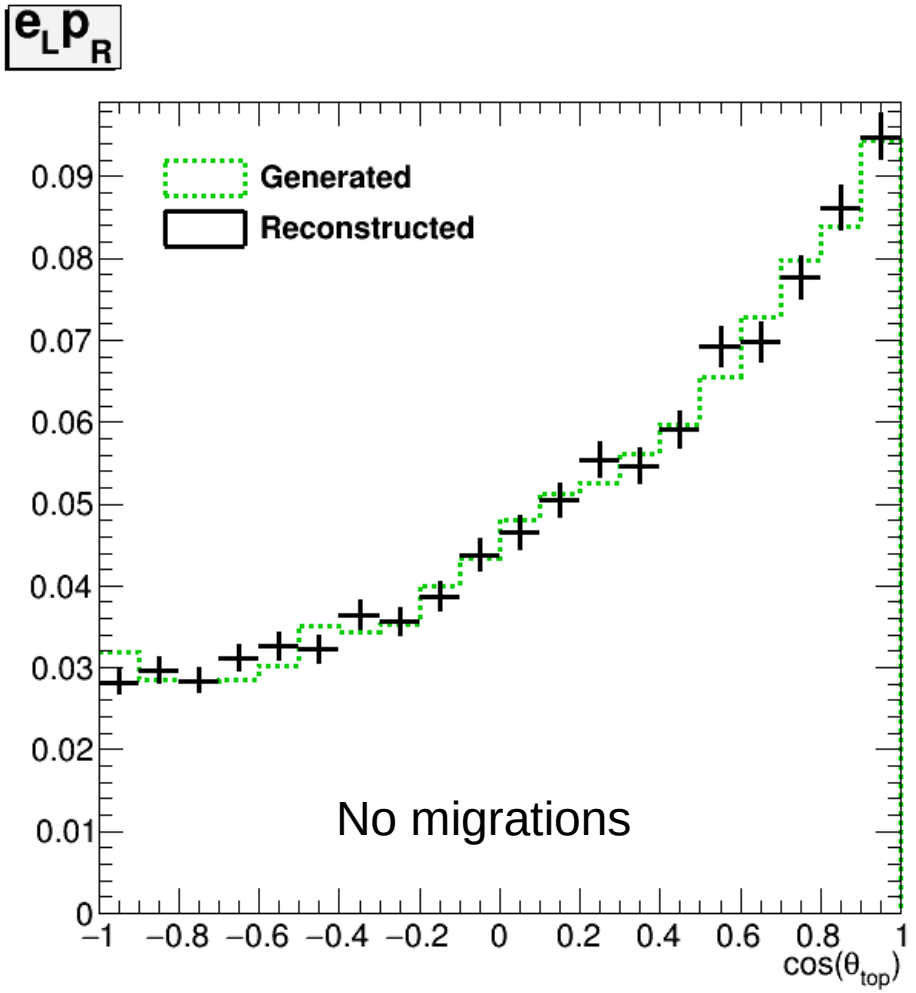
65.5% precision



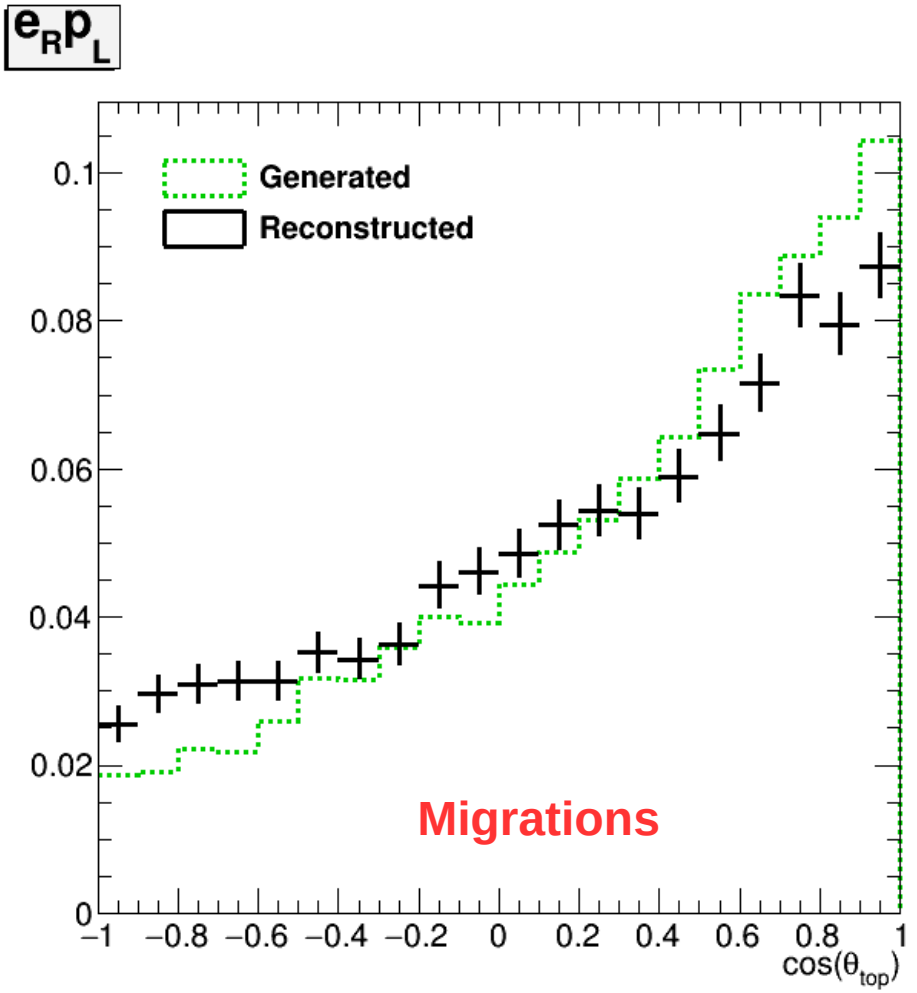
96.3 % precision

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

Top asymmetry: Using generated b charge



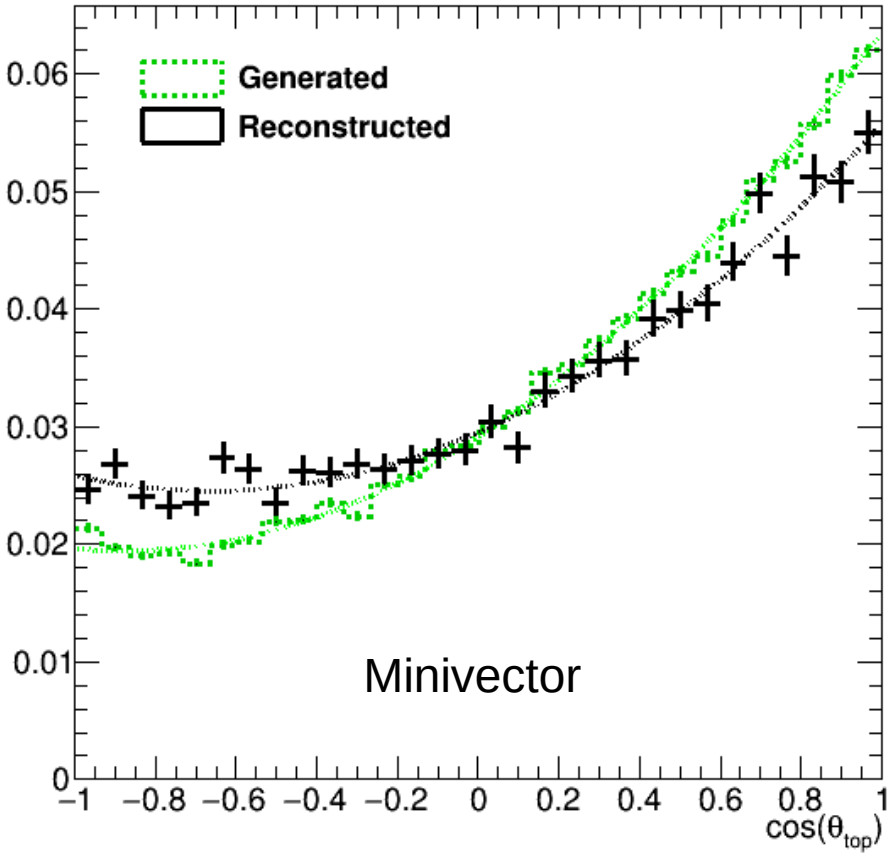
99.4% precision



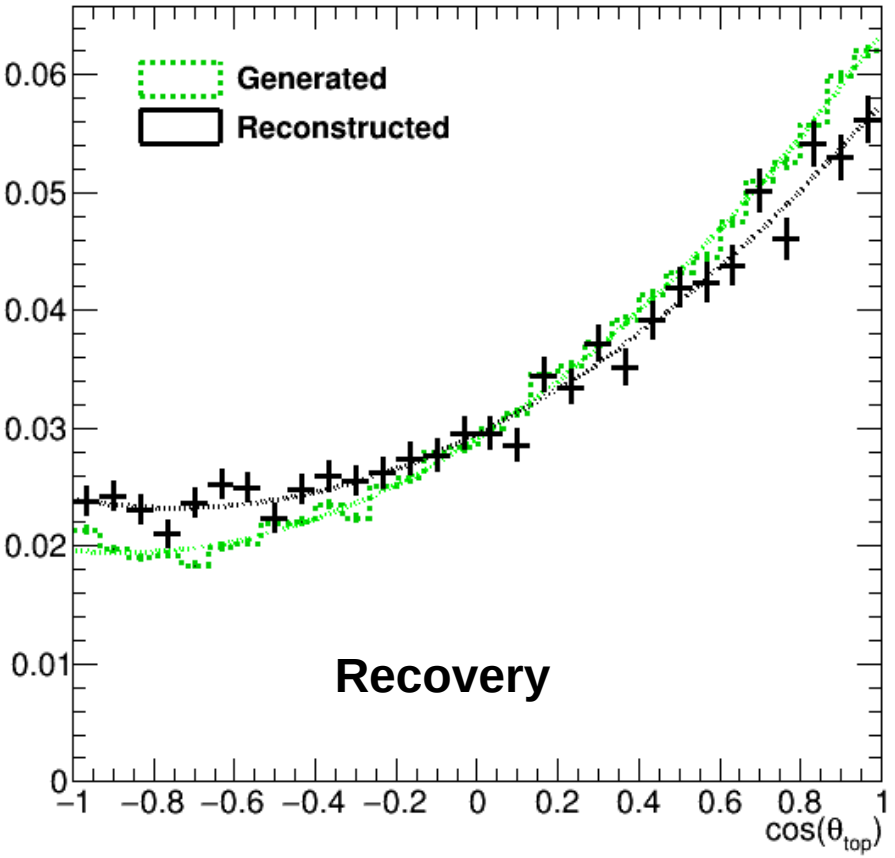
72.5% precision

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

Overall top polar angle improvement



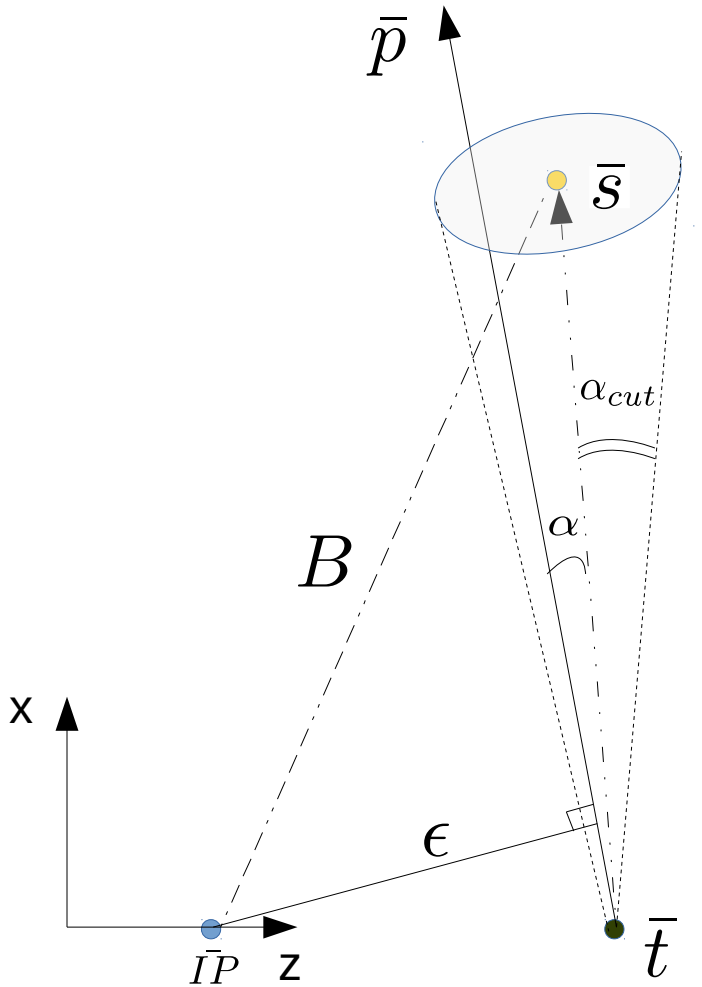
68% precision



75.% precision

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

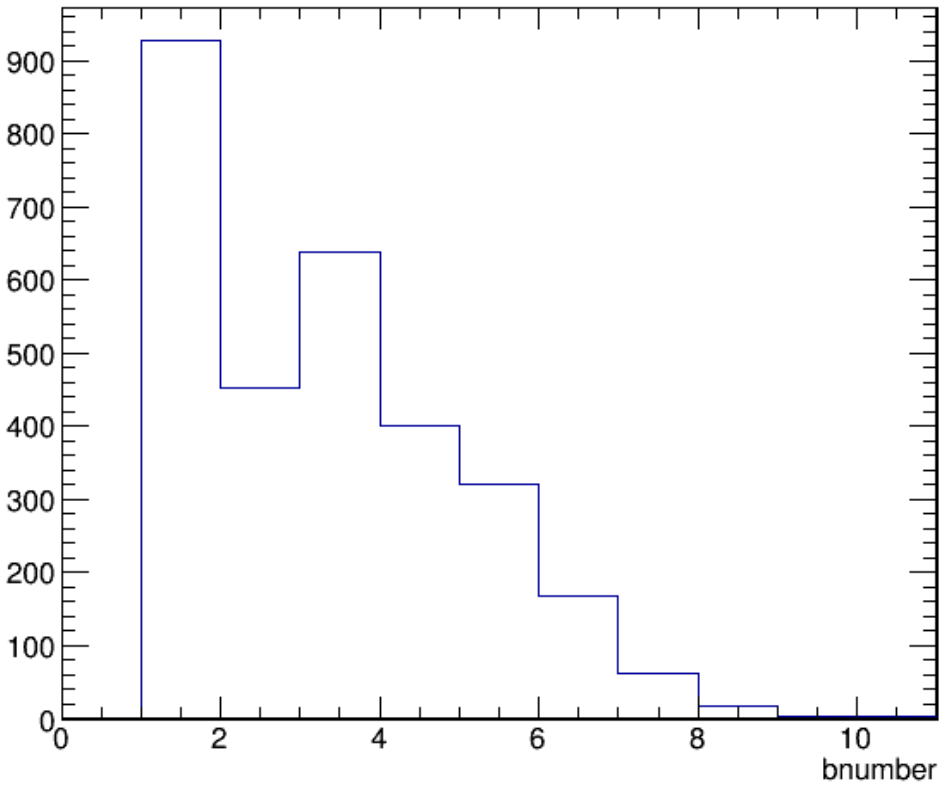
Recovery of vertices



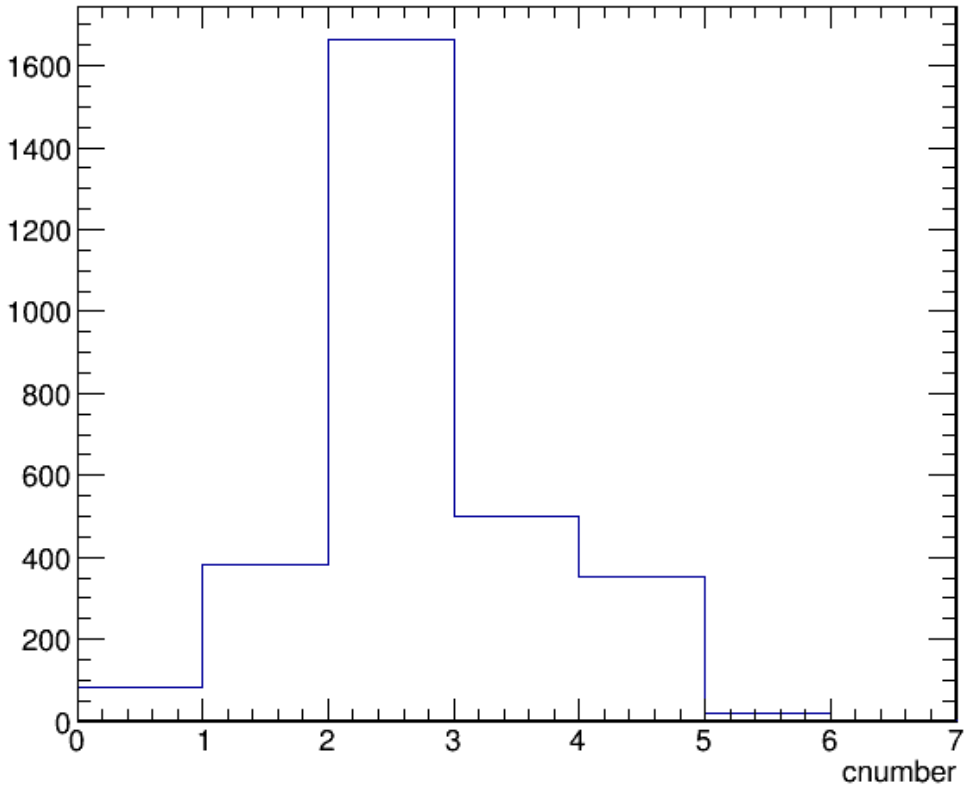
- **IP** – interaction point (primary vertex) , **s** – secondary vertex, **t** – point of closest approach of a track, **p** – reconstructed momentum, ϵ - offset of a track from primary vertex

Multiplicity of b-c vertices

b-vertex

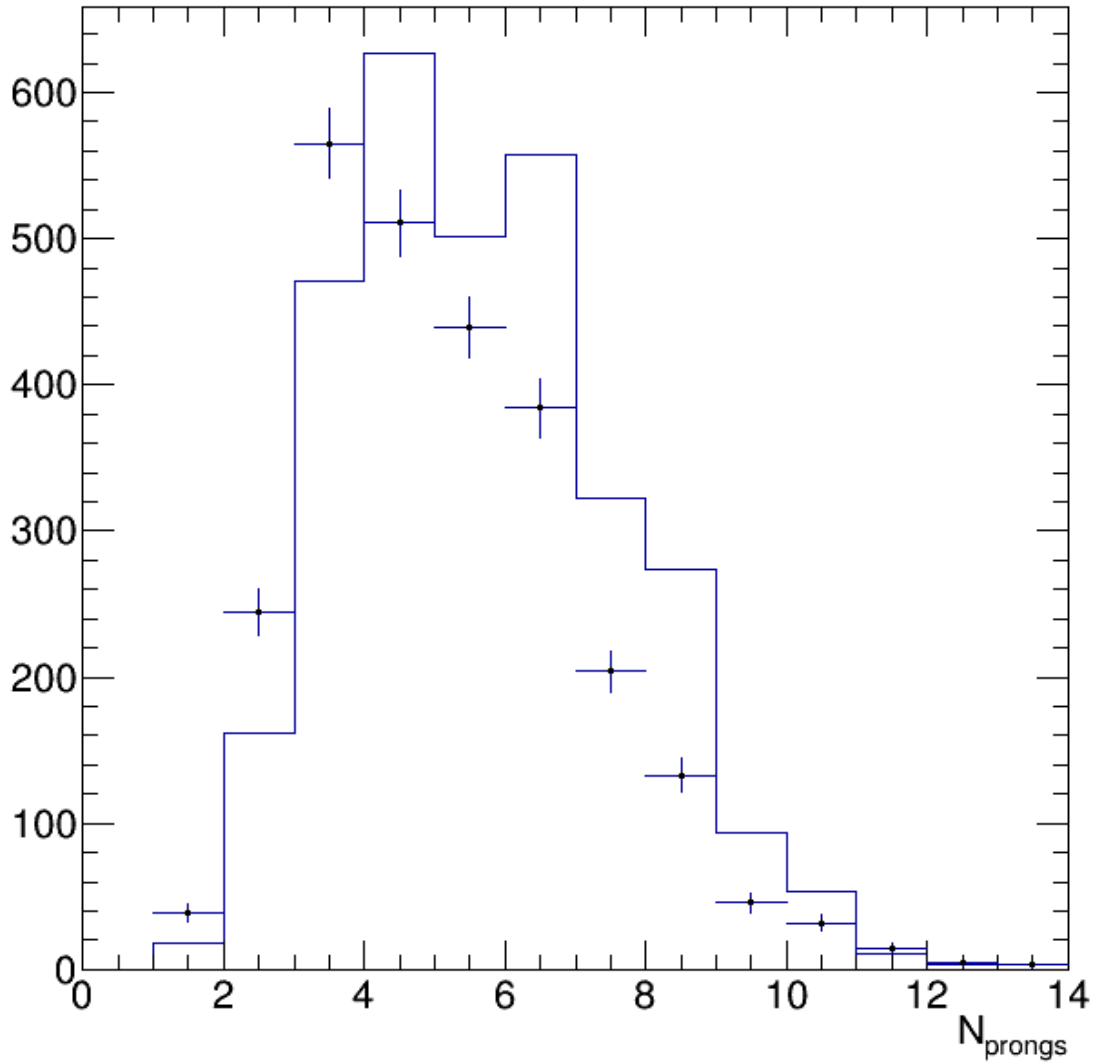


c-vertex



- 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