Reconstruction efforts at ILD

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LLR

CEPC Physics and Software Meeting
IHEP, March 26, 2016

Outline

- **Tracking related algorithms**
  - Low Pt tracking
  - Tracking in non-uniform B field
  - Vertex charge reconstruction

- **PFA related algorithms**
  - Arbor and ArborPFA
  - Tracking in Calorimeter
  - Particle identification

- **Summary**

Low P_t tracking

VXD

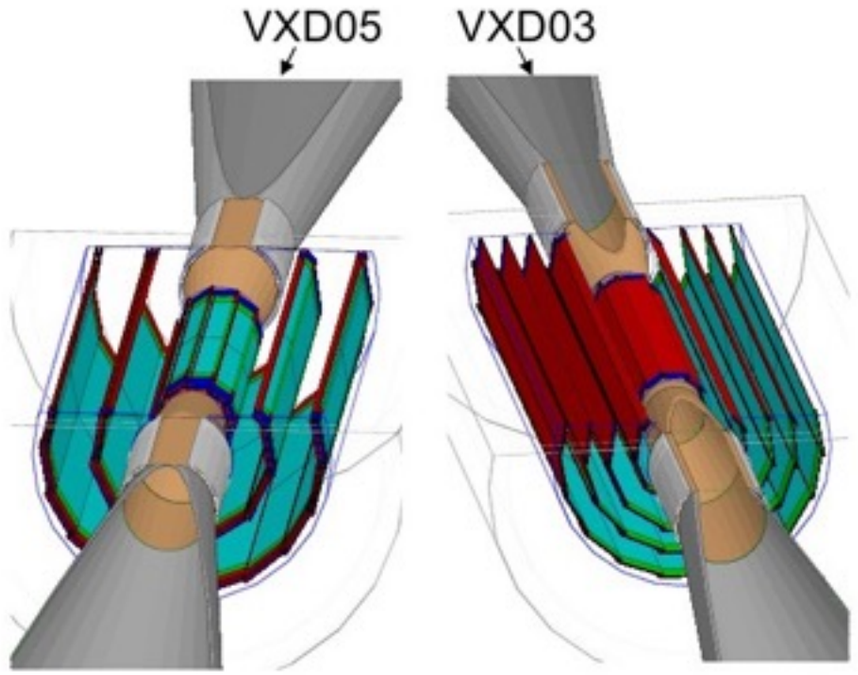
Y. Voutsinas, DESY

ILD software and optimization Workshop, Feb. 2016

- VXD is very crucial for
  - Flavor tagging

$$\sigma_{IP} = a \oplus \frac{b}{p \sin^{3/2}\theta} \qquad a \leq 5\mu\mathrm{m}, b \leq 10\mu\mathrm{m\ GeV}$$

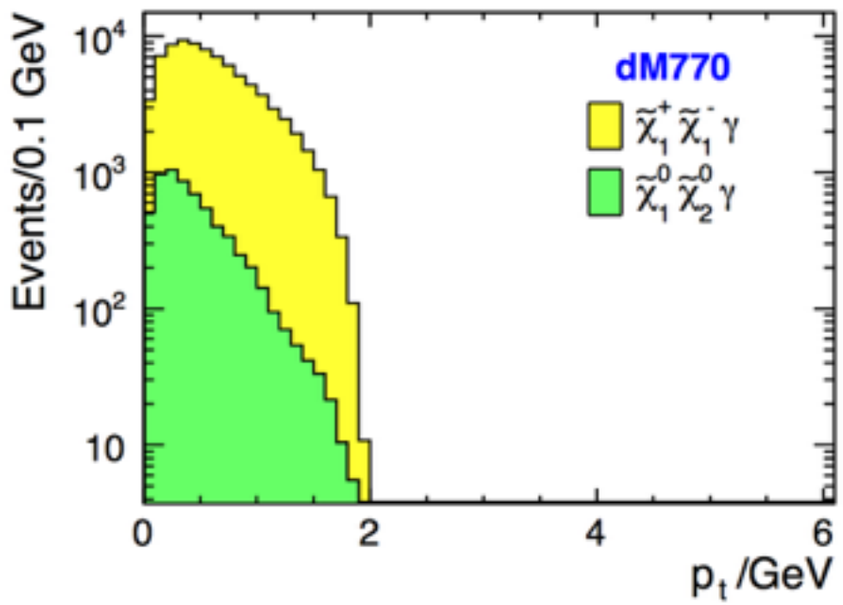
  - Reconstruction of Low Pt track
    - Reconstruction of vertex charge
      - Light higgsino study – few very soft particles in final state



- Motivation for a new VXD tracking algorithm:
  - DBD silicon tracking shows poor performance in the presence of beam bkg. (hit in ϕ sectors; brutal force combination)

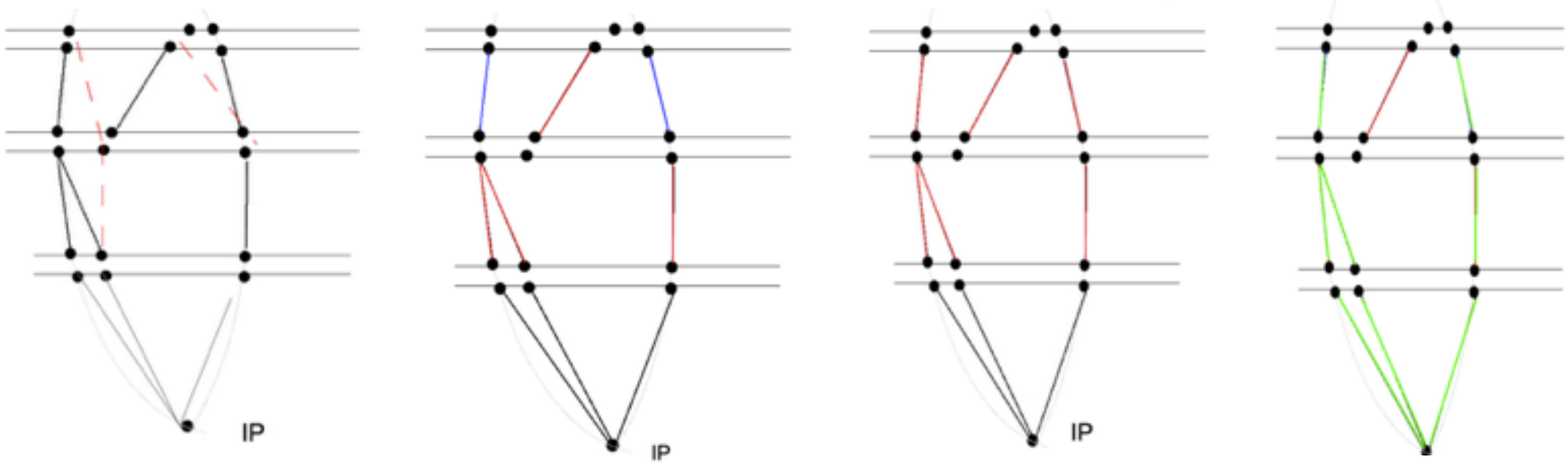
arXiv:1403.5659

- Cellular automaton: improve the tracking efficiency; reduce ghost track rate

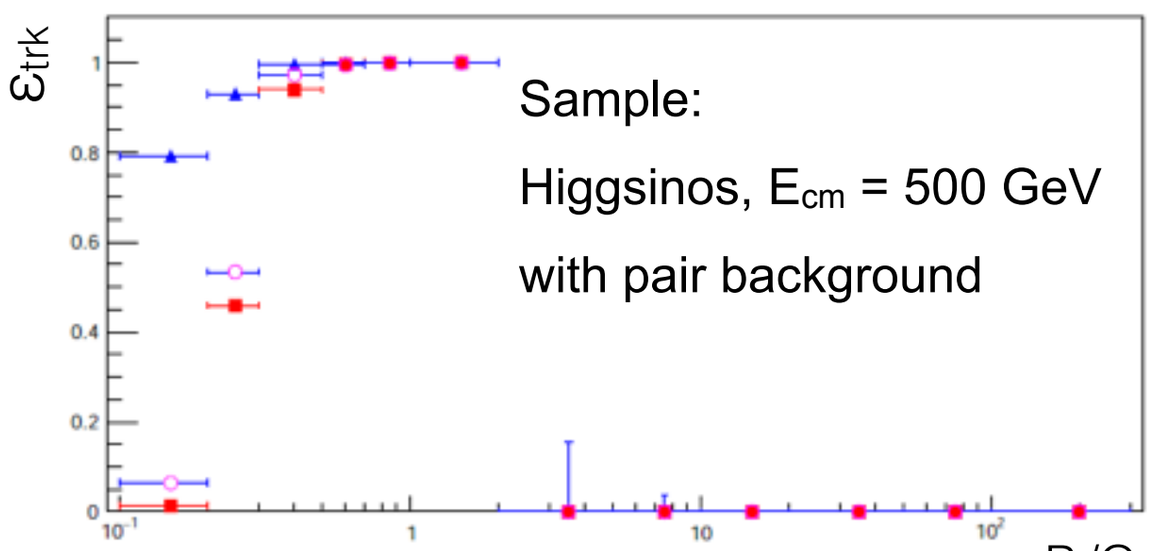


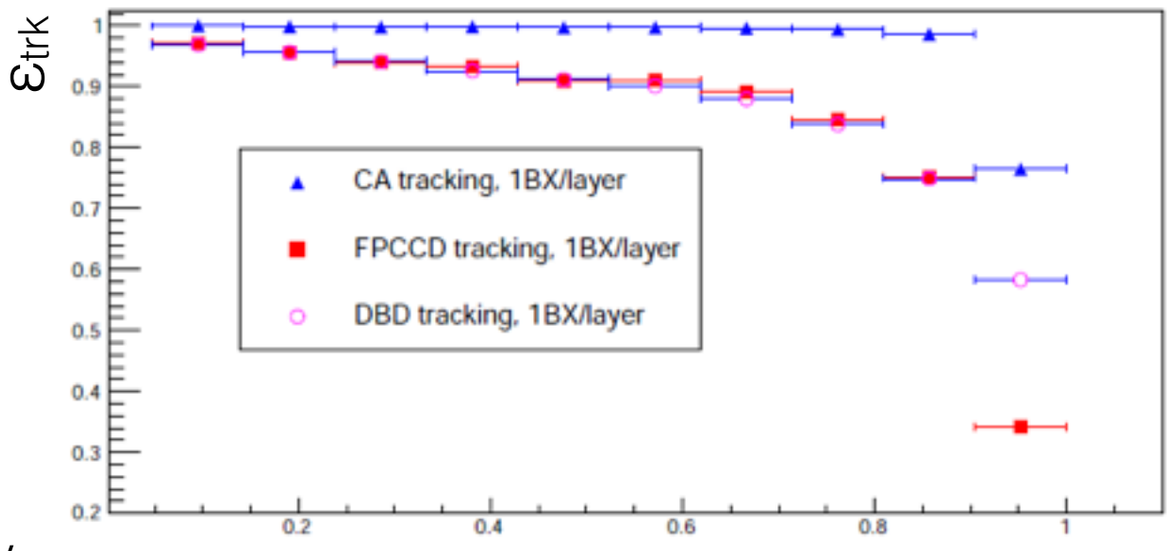
Cellular automaton

- The algorithm: **Cellular automaton (CA)** + Mini-vector Rep. Prog. Phys. **67** (2004) 553–622
  → a global optimization method



- Performance at low P_t and forward region

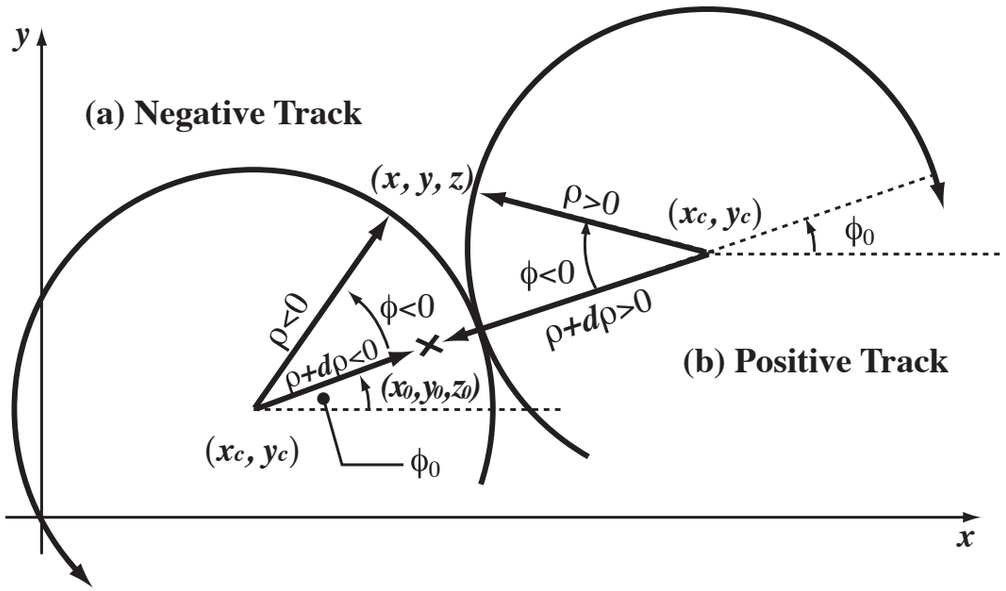




Tracking in non-uniform B field

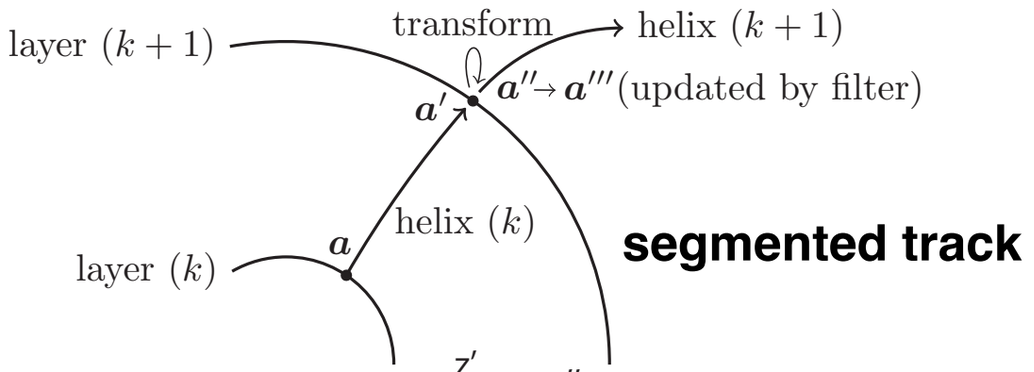
KalTest

- Helical track model in the KalTest:

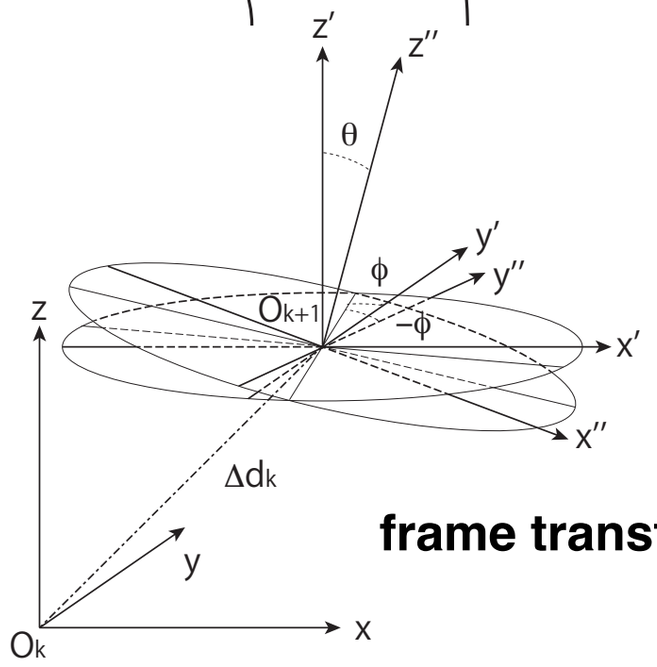


K. Fujii, Extended Kalman Filter, http://www-jlc.kek.jp/subg/ offl/kaltest

- In non-uniform magnetic field, the imperfect helix can be approximated by segmented helical track with frame transformation:



segmented track

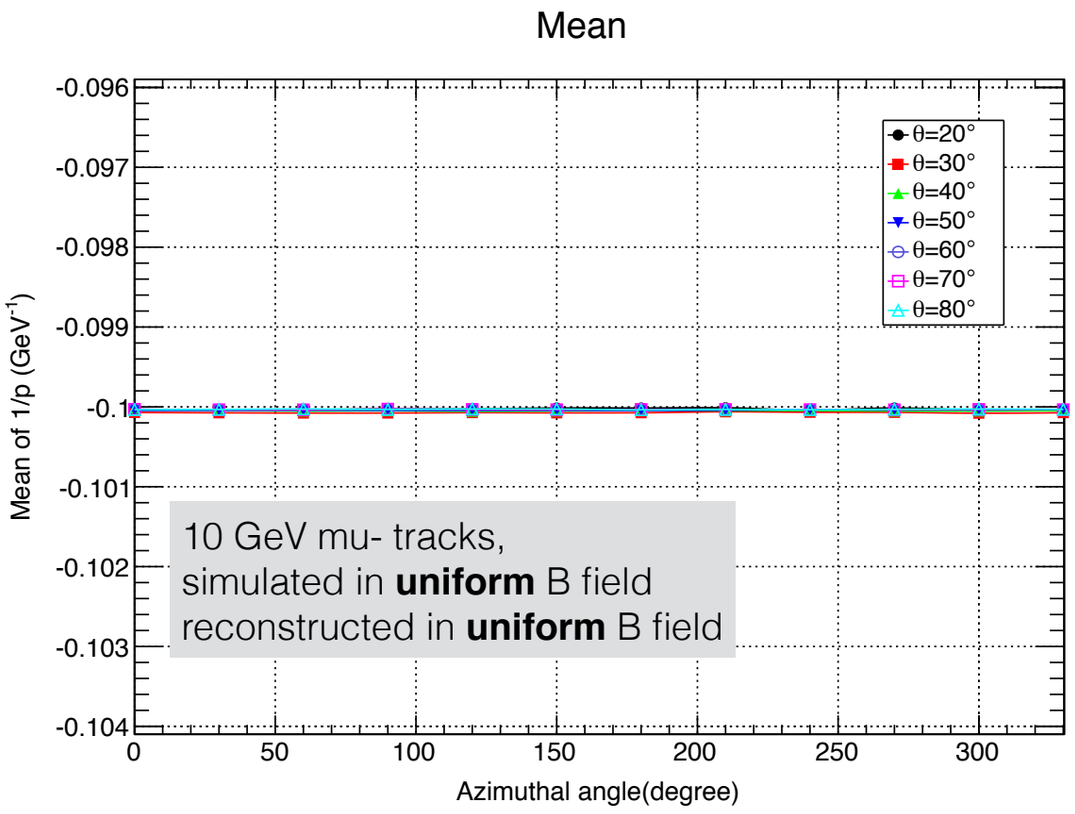


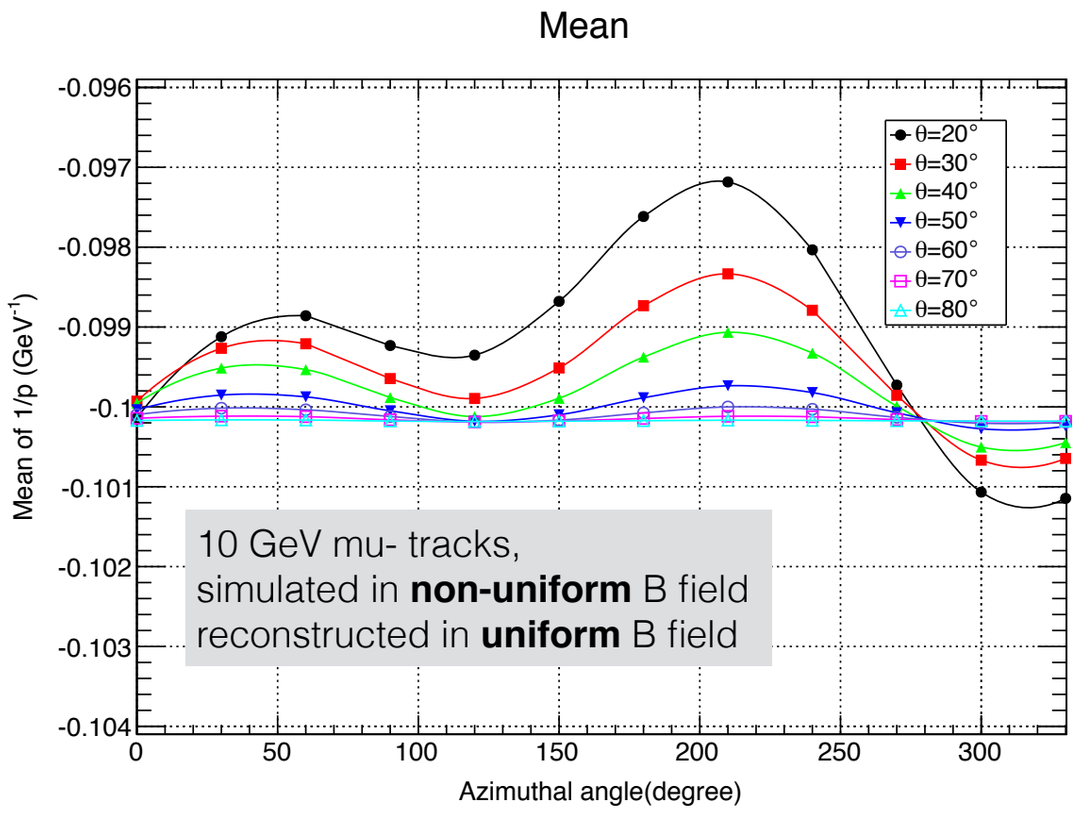
frame transformation

- KalTest for both uniform and non-uniform magnetic field is available since ILCSoft v01-17-07.
- The Anti-DID field, which was implemented in Mokka for pair background study, is used in this study.

Mean

- Mean of 1/p at different track angle:

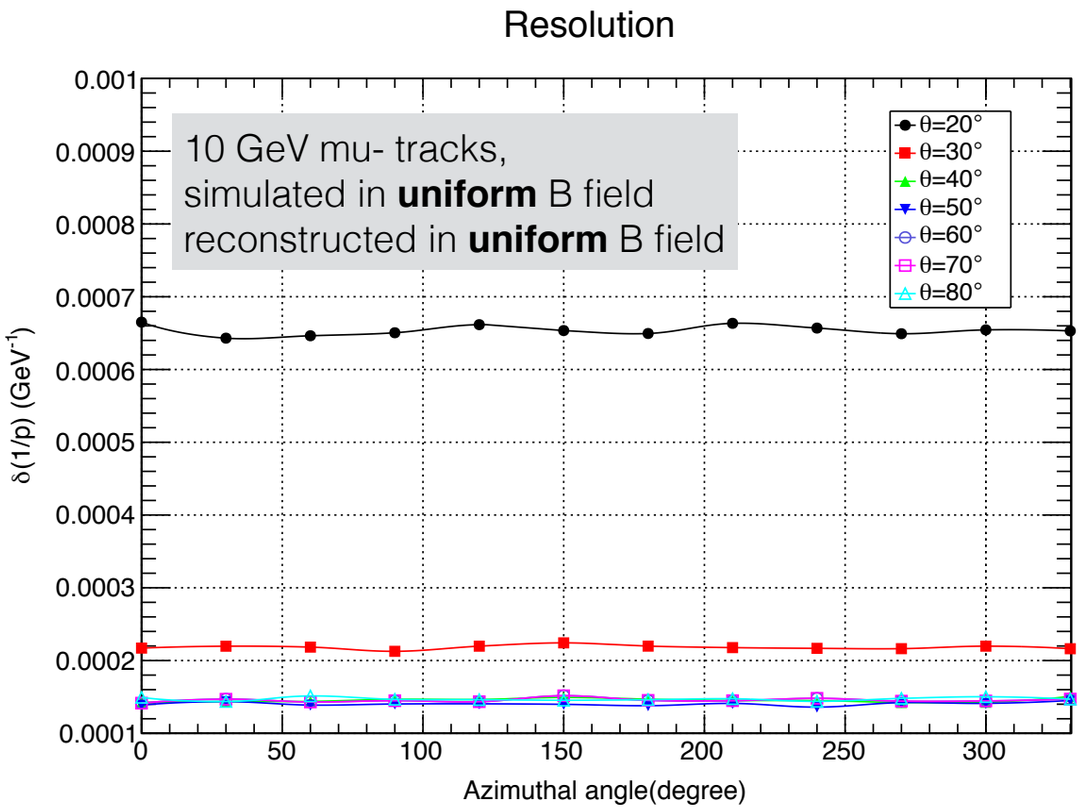


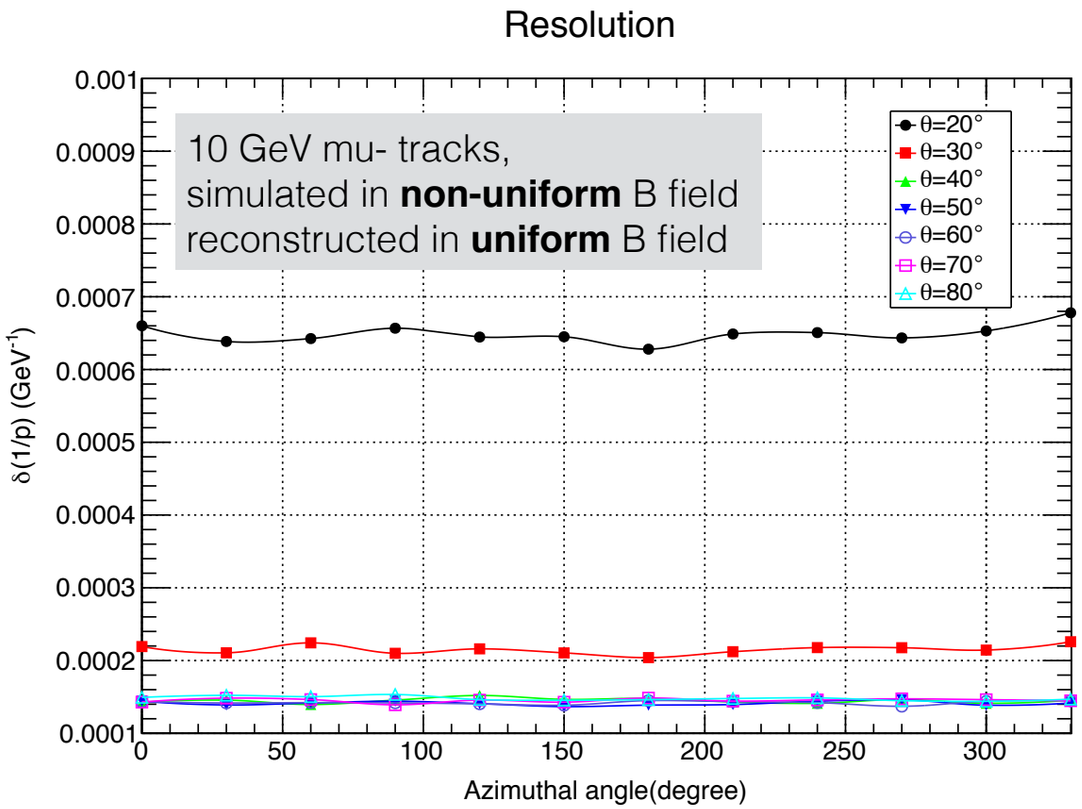


- The mean of momentum is shifted by the non-uniformity. It seems that the B field is anisotropic.

Momentum resolution

- Momentum resolution at different track angle:

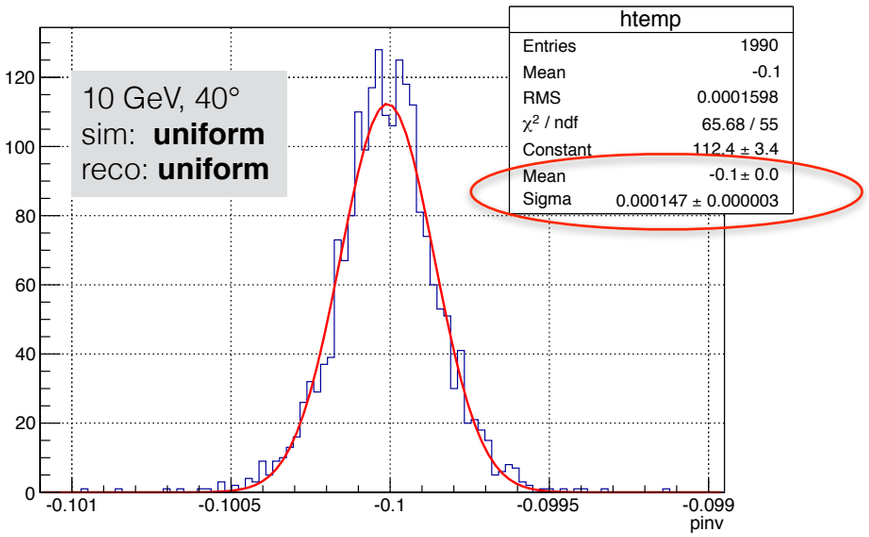


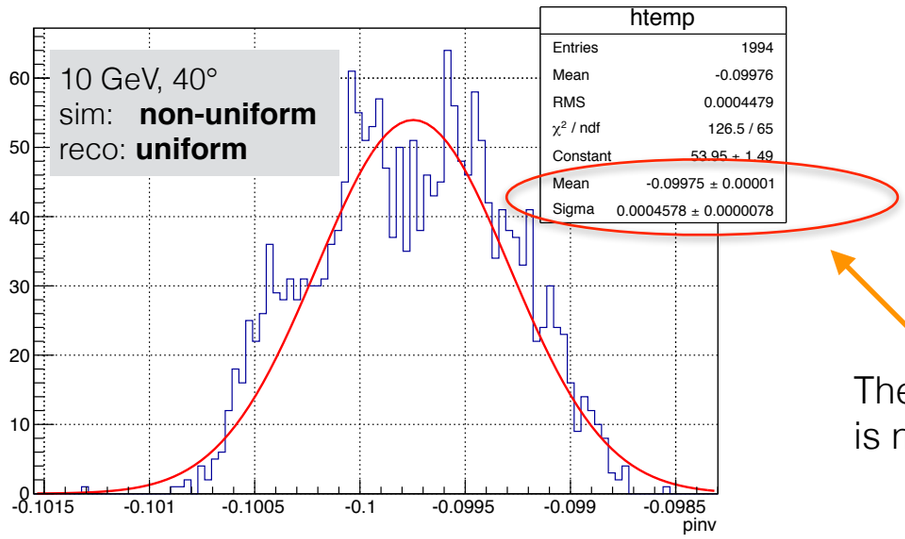


- The momentum resolution of track **with fixed angle** is **not** affected by the the non-uniformity of B field.

The effective momentum resolution

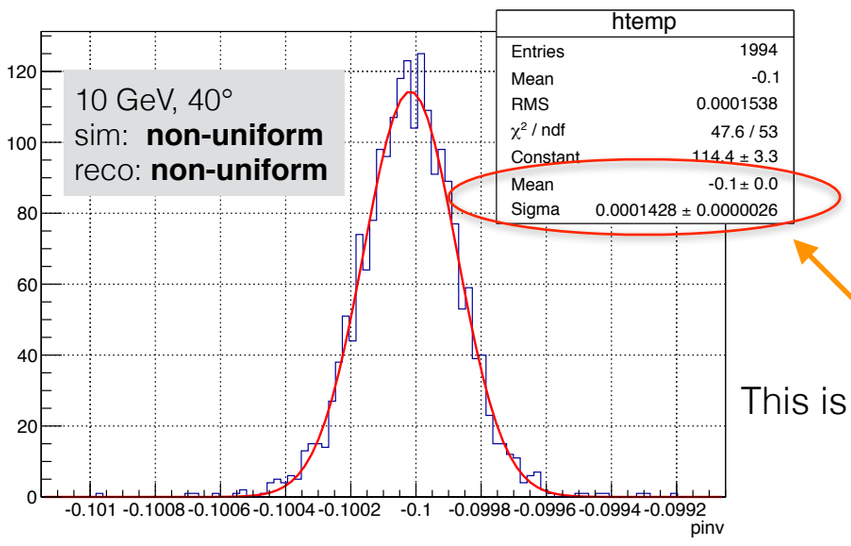
- If only fixing polar angle, the shift of mean contributes to the momentum resolution, we obtain an increased **effective** momentum resolution:





The distribution is not Gaussian.

- Track fitting by the new KalTest can recover it:



This is what we expect 😊

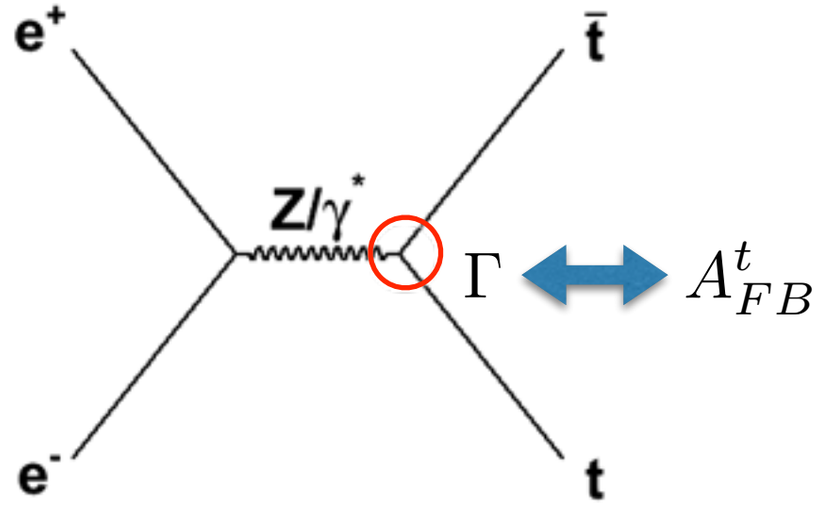
- TODO:
  - Implementation of new ILD B field with relatively stronger non-uniformity
  - The influence of non-uniform B field on physics: e.g. the Higgs recoil mass

Vertex charge reconstruction

Objective

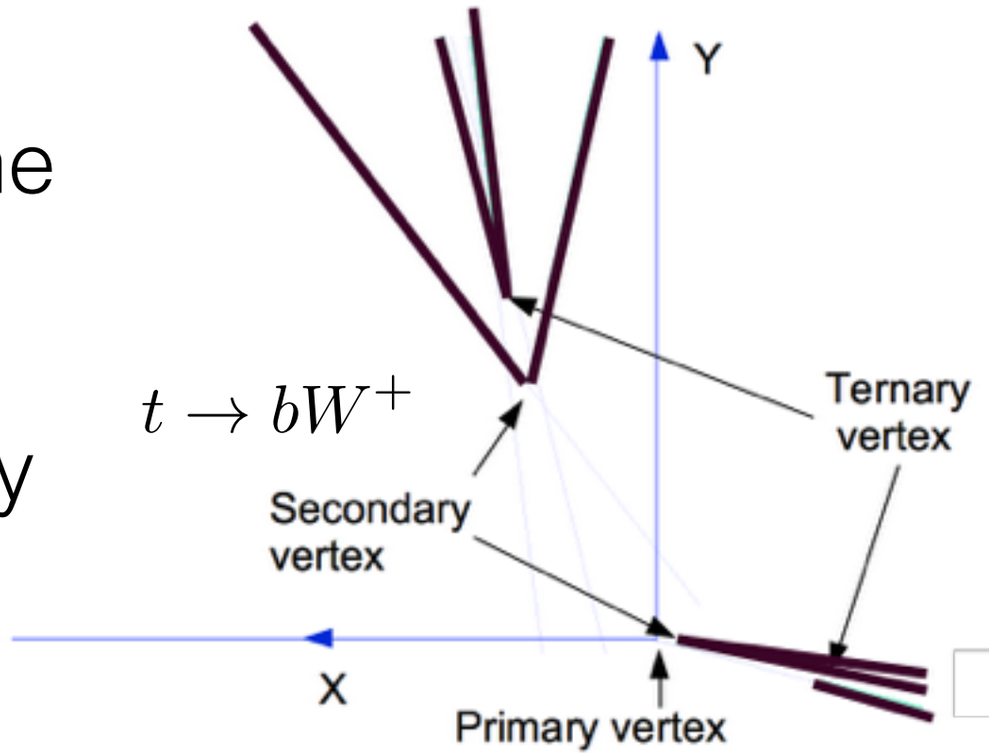
S. Bilokin

- 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}^t in $t\bar{t}$ process at ILC



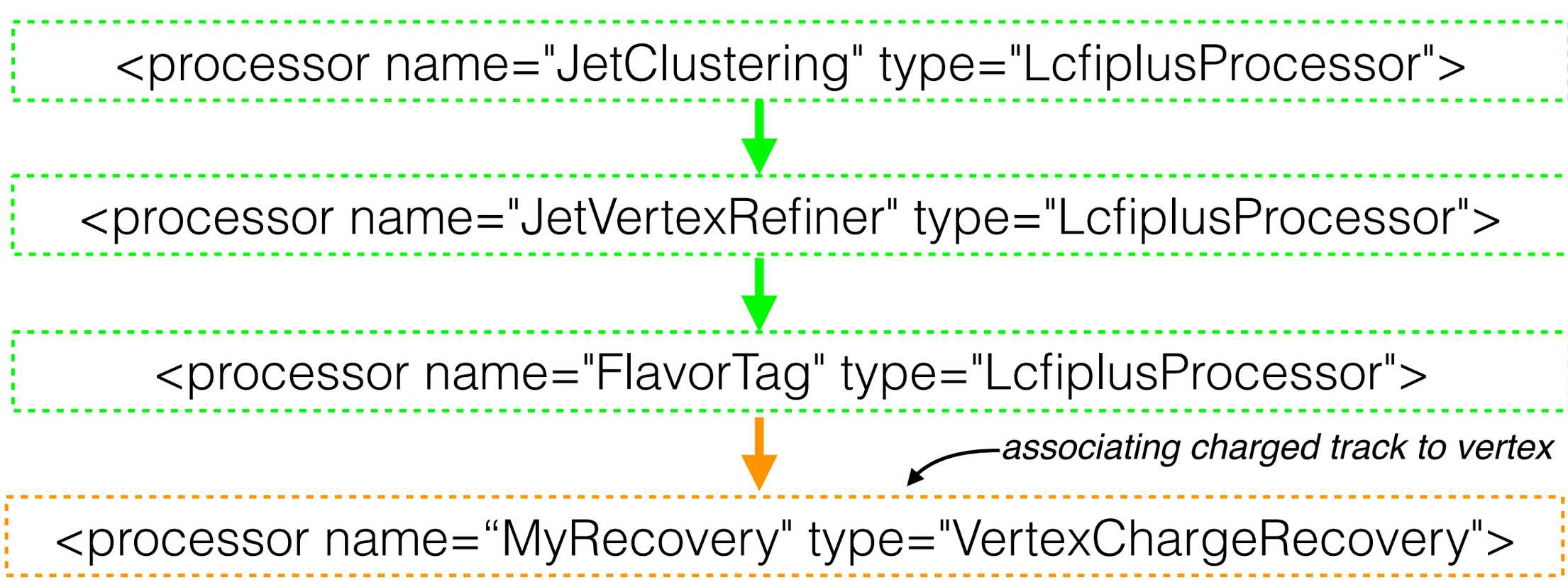
- Properties of decay products from the B-hadrons are used to determine the charge of initial t-quark

- The charge of K-meson from ternary vertex is directly connected to the charge of t-quark

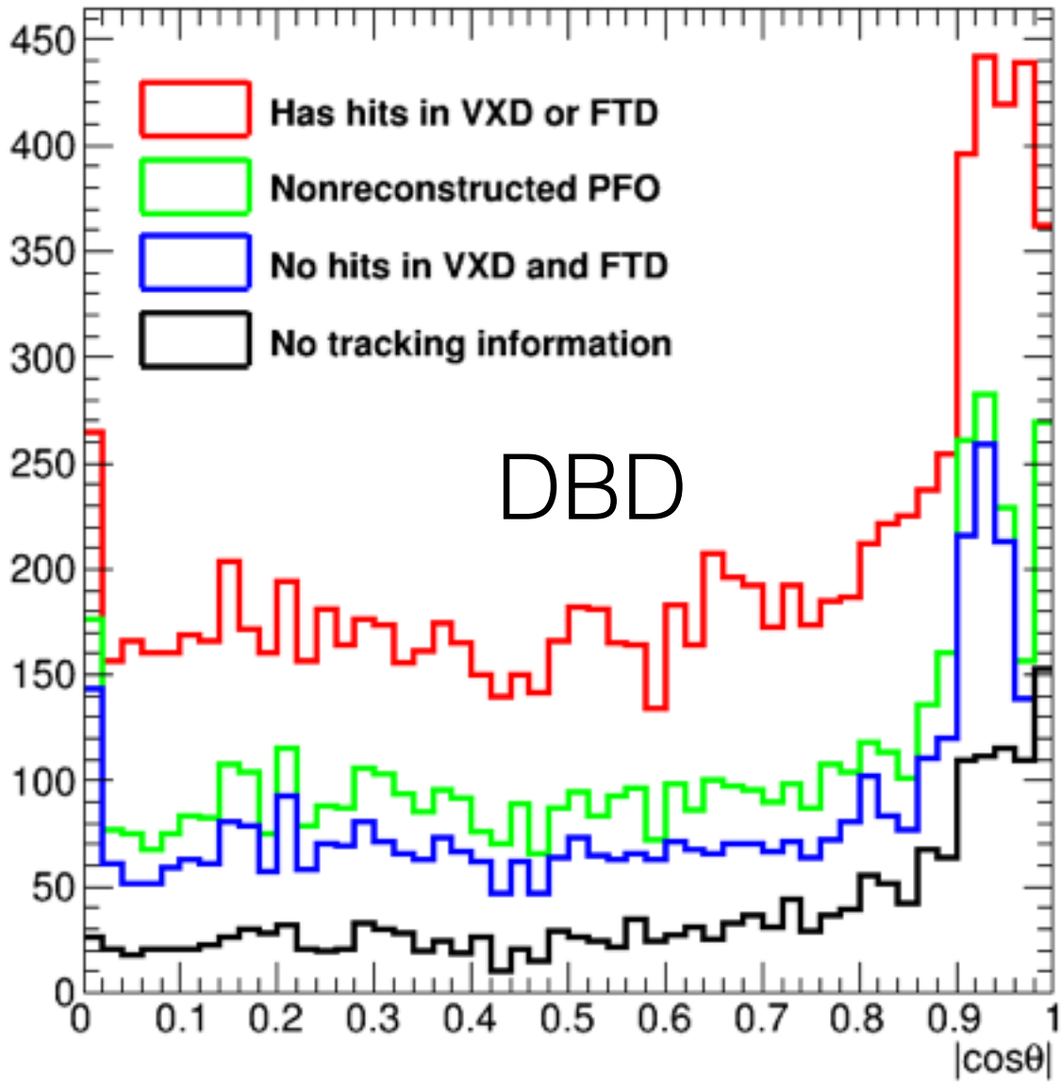


Recovery in reconstruction chain

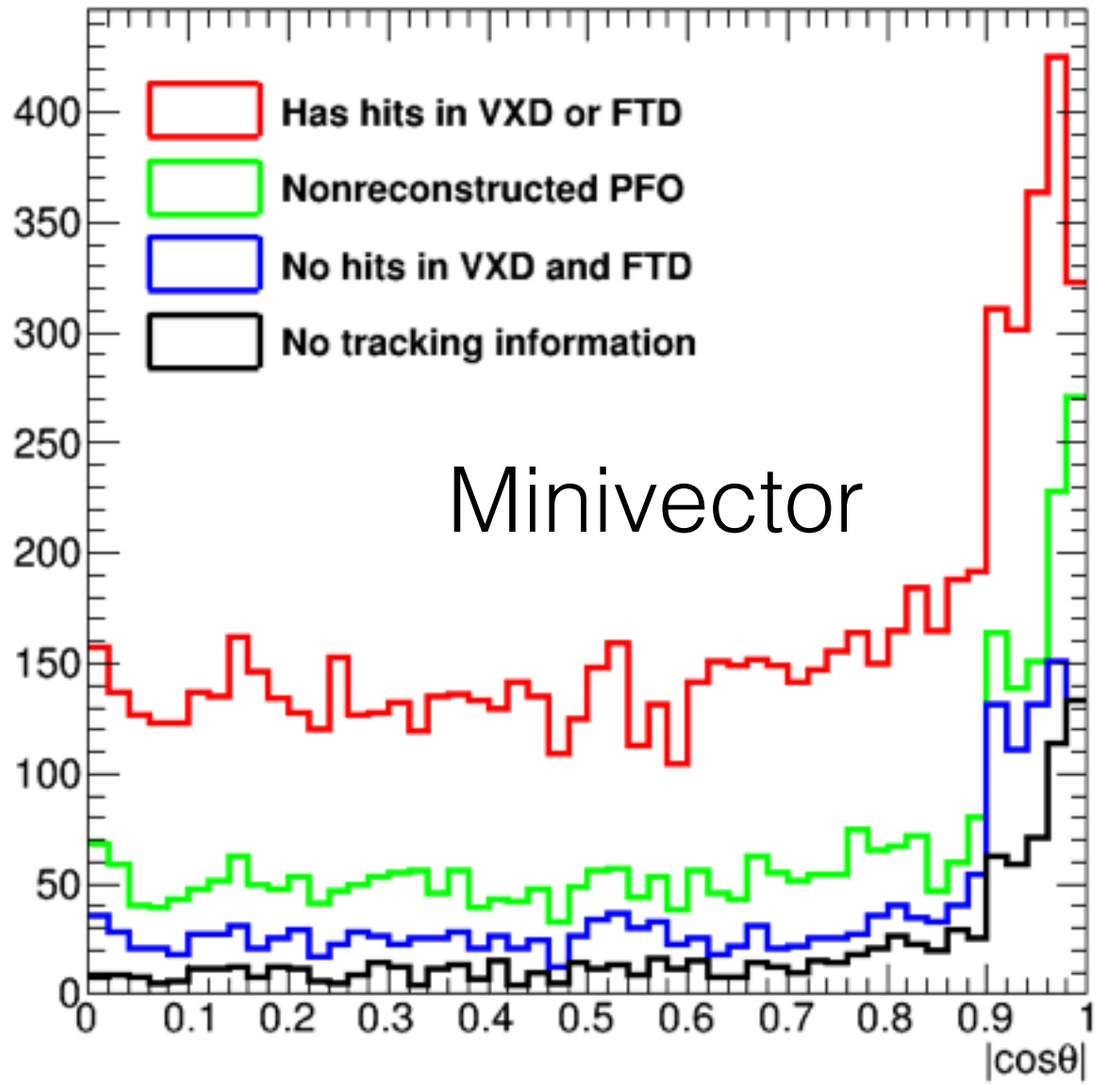
- Event sample: 500 GeV semileptonic ttbar with pair background v01-16-05 (DBD)
- **CellsAutomatonMV** as tracking algorithm v01-17-09 (Minivector)
- The algorithm is capable to create a recovered vertex collection as an output
- New recovered vertices have higher mass and multiplicity – this may affect b-tag parameter of a jet
- Current status:



Missed tracks: DBD vs Minivector+recovery



6.9% of generated

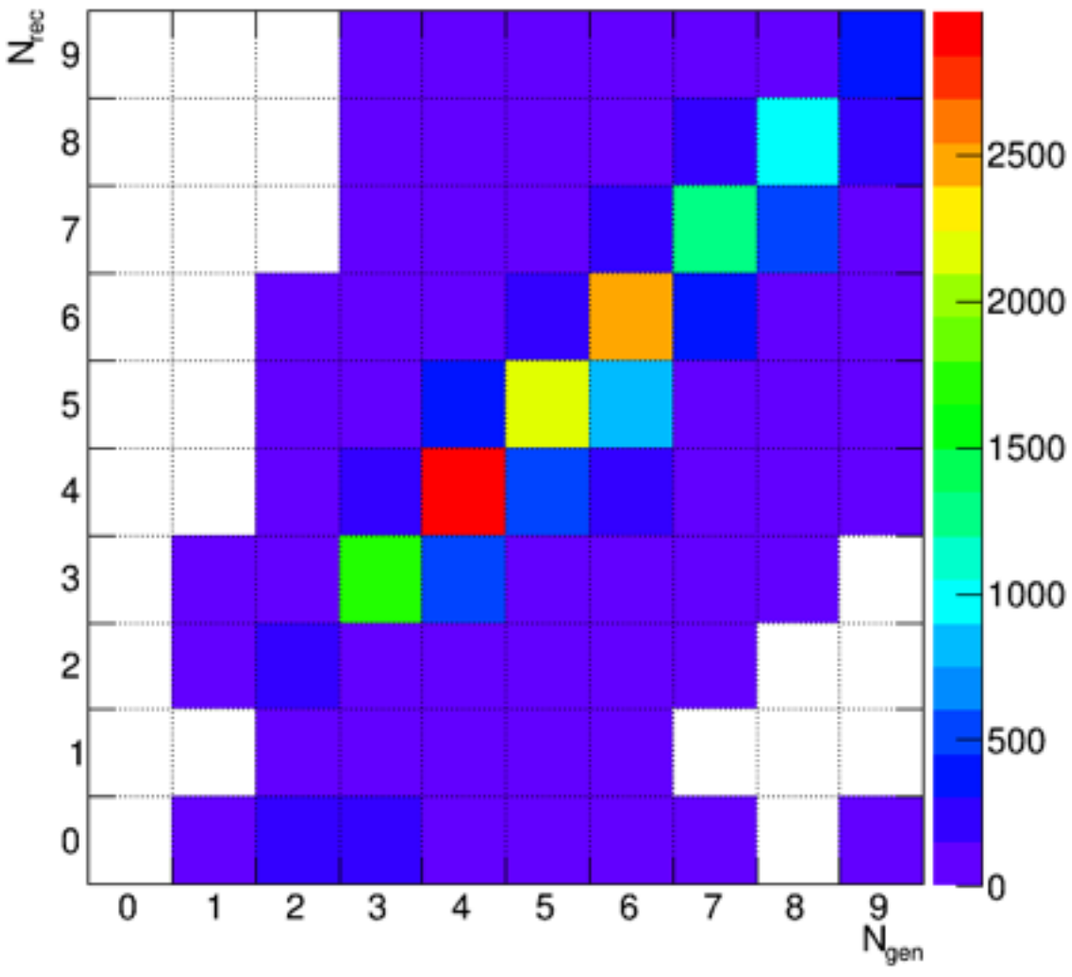


5.5% of generated

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

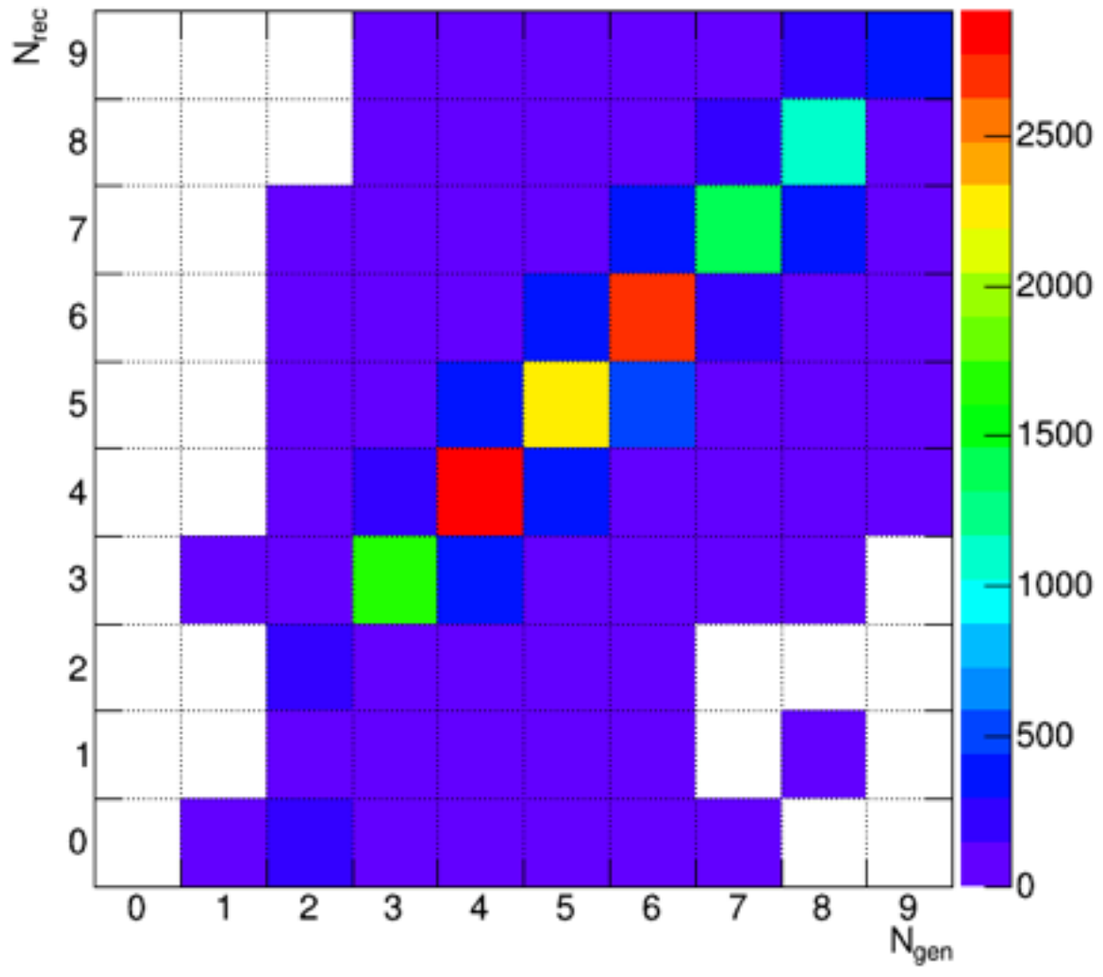
Number of tracks comparison

DBD+recovery



64.5% on diagonal

Minivector+recovery

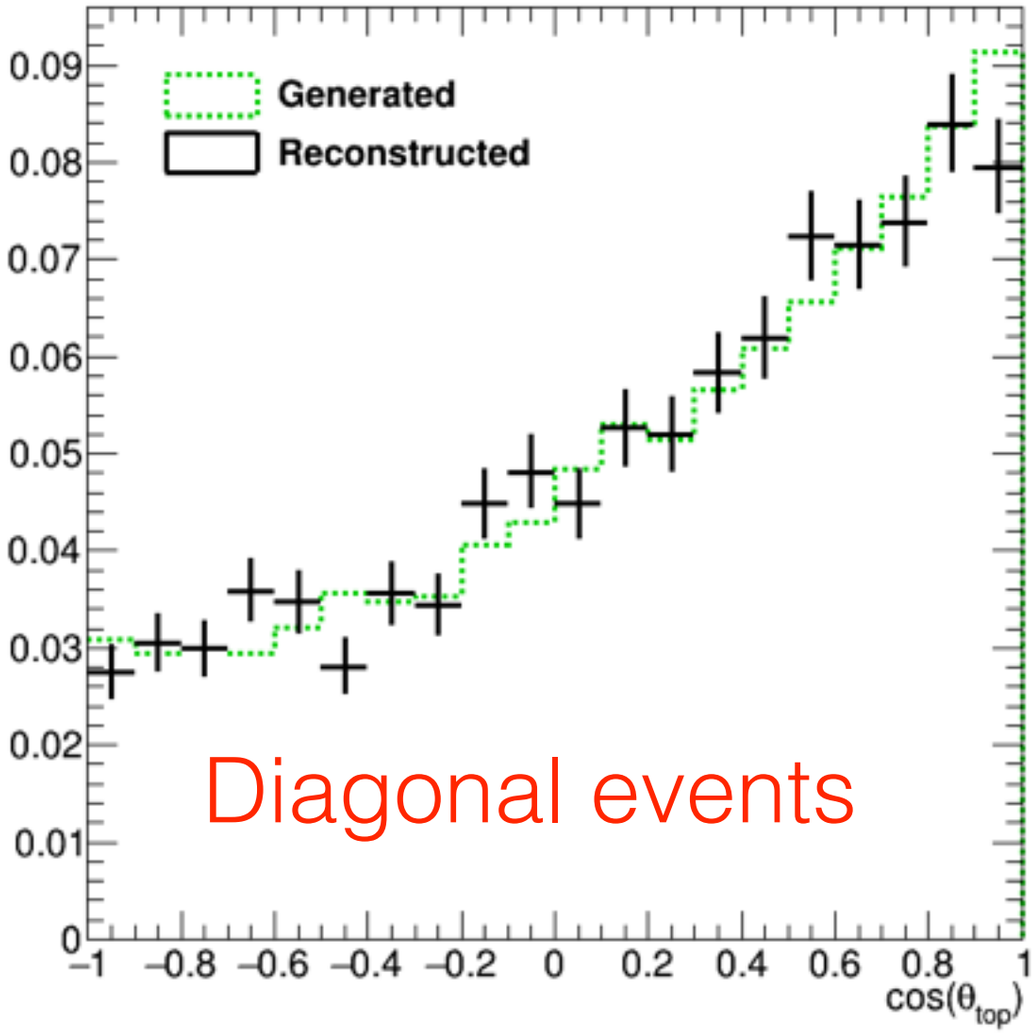


68.6% on diagonal

$B_{tag} > 0.8$ & $P_b > 15$ GeV

Top polar angle: diagonal events

- The result of top asymmetry reconstruction using **perfect** reconstructed b vertices:



95.5% precision

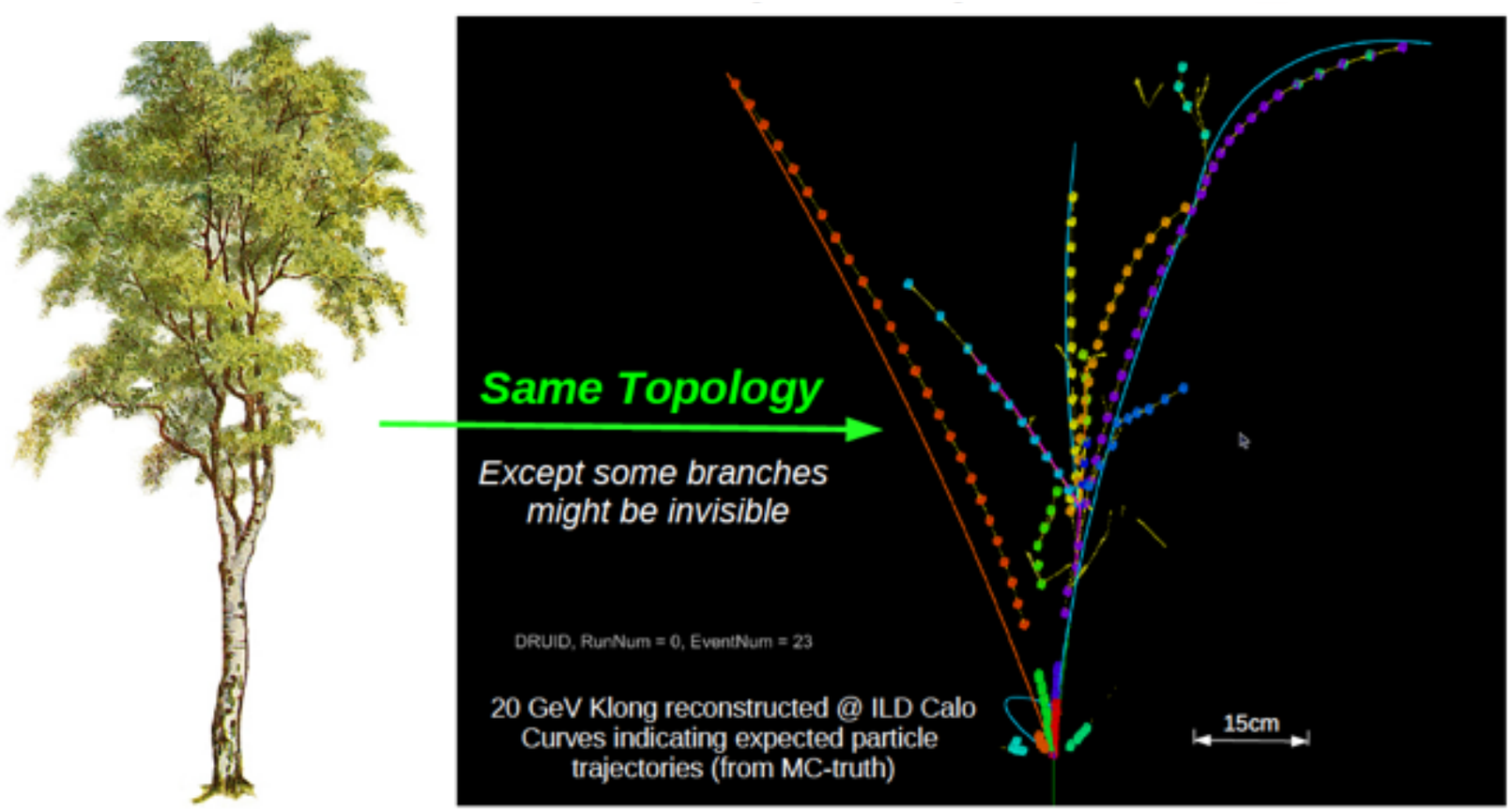
- The vertex charge reconstruction performance relies on tracking as well as vertex finding.
- **TruthVertexFinder** works correctly.
- To get good quality at experiment we should maximize the vertex reconstruction quality:
  - Recover corrupted vertices
  - Reject corrupted vertices
  - Apply different tracking algorithms
  - Use alternative vertex algorithm

Particle Plow Algorithm

(See more in Binsong's talk tomorrow)

The philosophy of Arbor

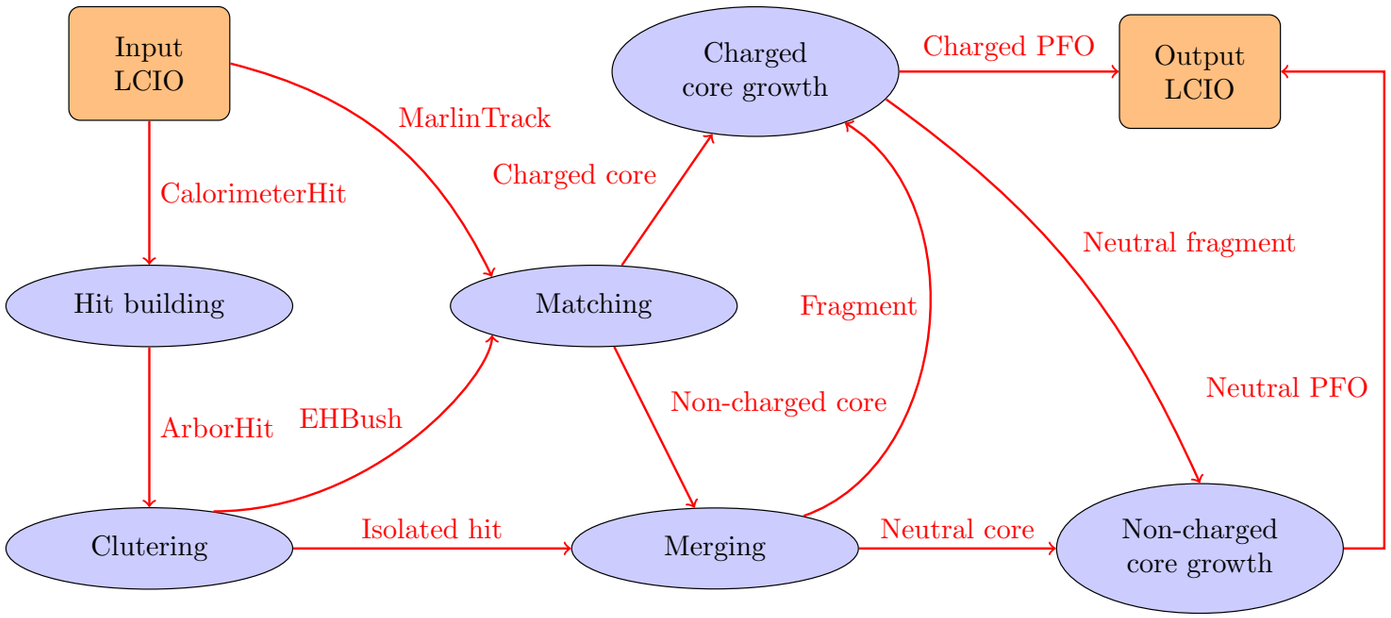
- Arbor is a PFA software package for high granularity calorimeter implemented in the framework of ILCSoft.
- The original idea is from Henri Videau.



- The necessity of Arbor for ILD: validate and cross check the PFA under different detector configurations (i.e. detector optimization).
- Two branches: Arbor and ArborPFA

To the new algorithm

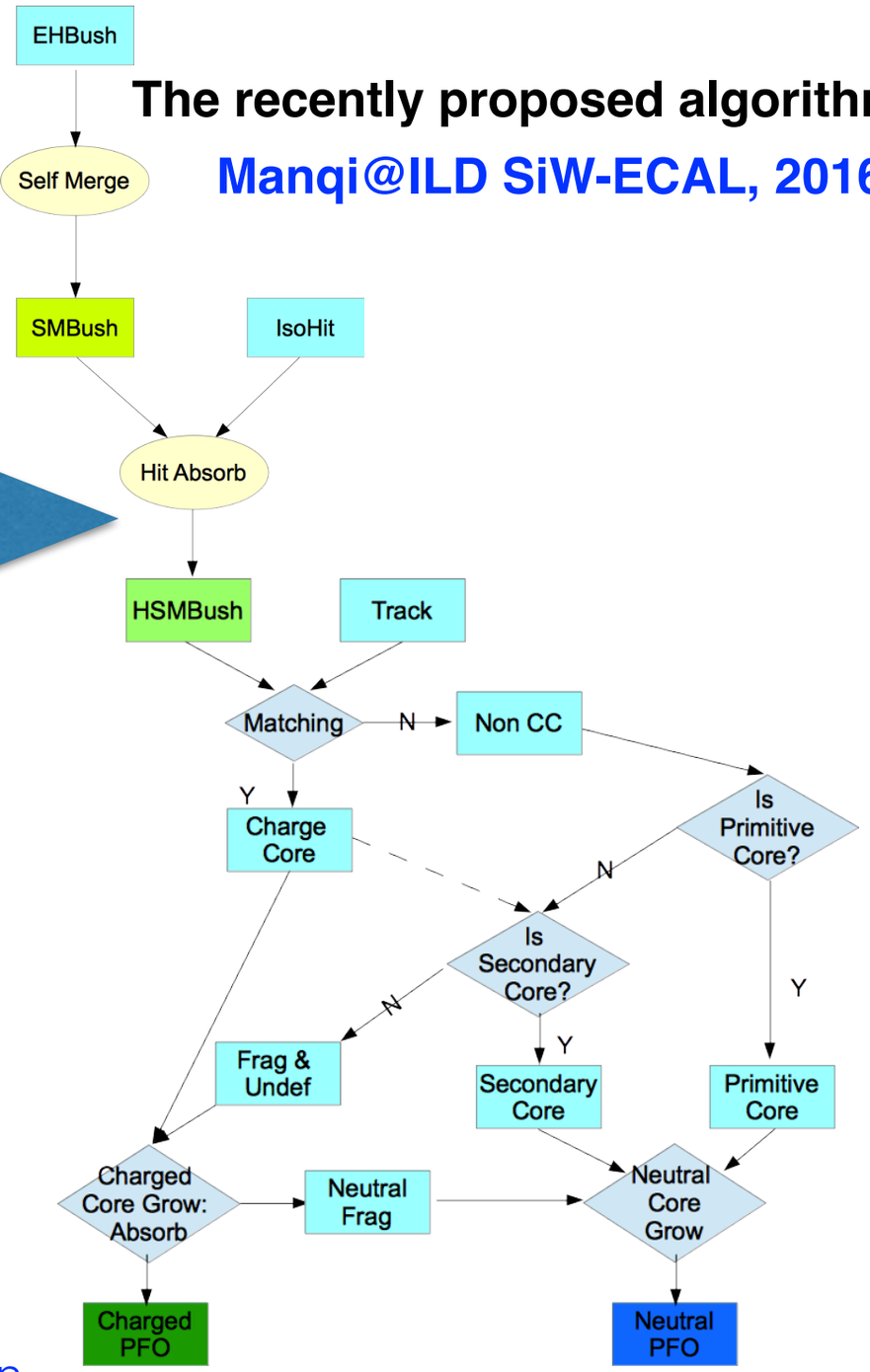
The current Arbor algorithm (presented by data flow digram)



- **Performance studies:**
  - Clustering
  - Track-cluster matching
  - Core growth
  - Isolated hit merging
  - PID
- ***Diagnosis functionalities*:**
  - Parameters: calibration & cut
  - Detector geometry
  - Energy scale

The recently proposed algorithm

Manqi@ILD SiW-ECAL, 2016



- **Members**: M. Ruan(IHEP), V. Boudry, B. Ma(IHEP), D. Yu, B. Li
  - Regular group meeting every other week
  - Arbor code is available at gitlab repository: http://cepcgit.ihep.ac.cn

The performance of Arbor reconstruction

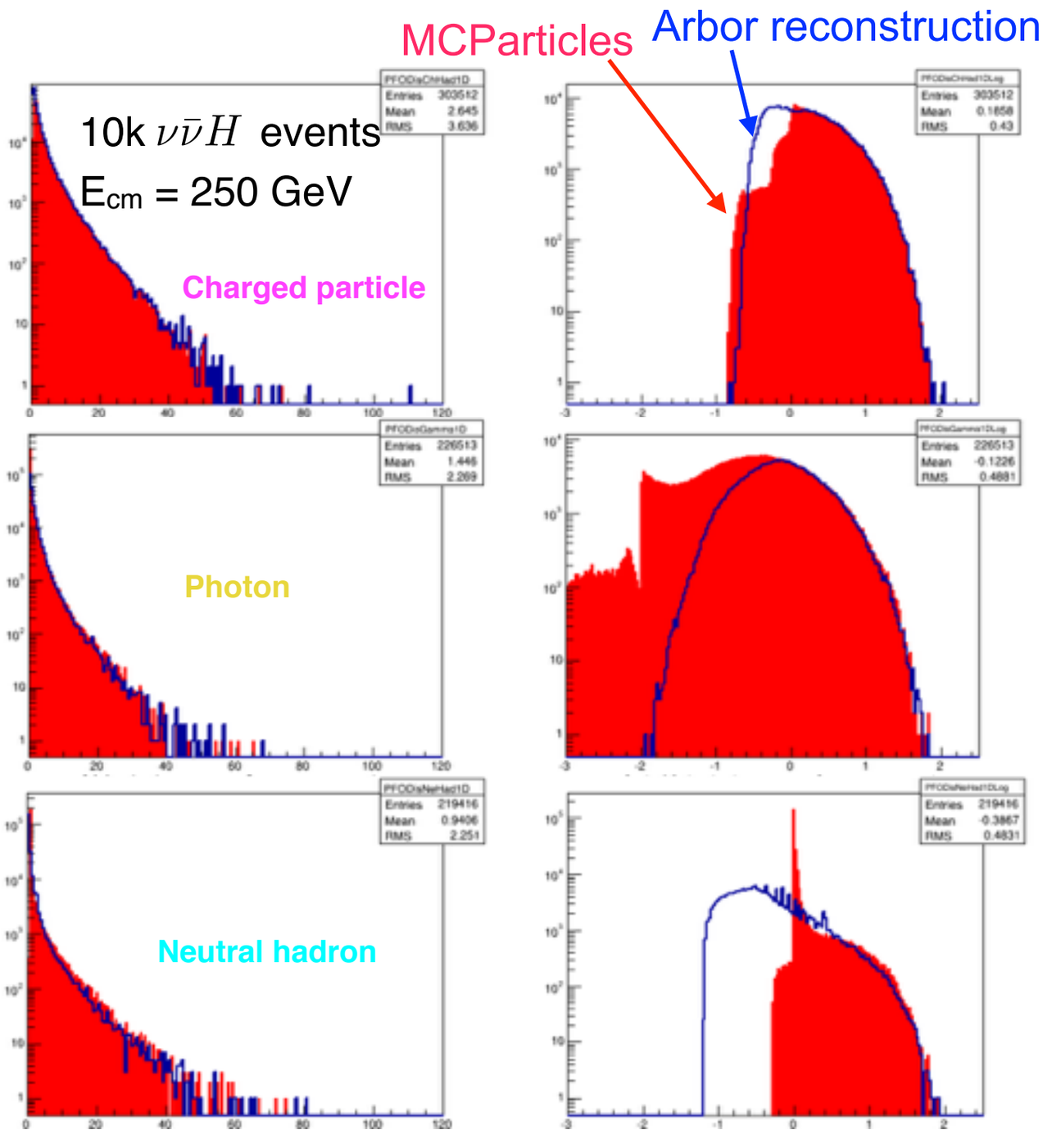
- High efficiency for E > 1 GeV :)

- **Charged particle**: **low energy helix double counting**

- **Photon**: efficiency limited by detector (1 MIP ~ 0.02 GeV in ECAL)

- **Neutral hadron**: fragments, rest mass & energy scale – intrinsic neutral hadron energy resolution

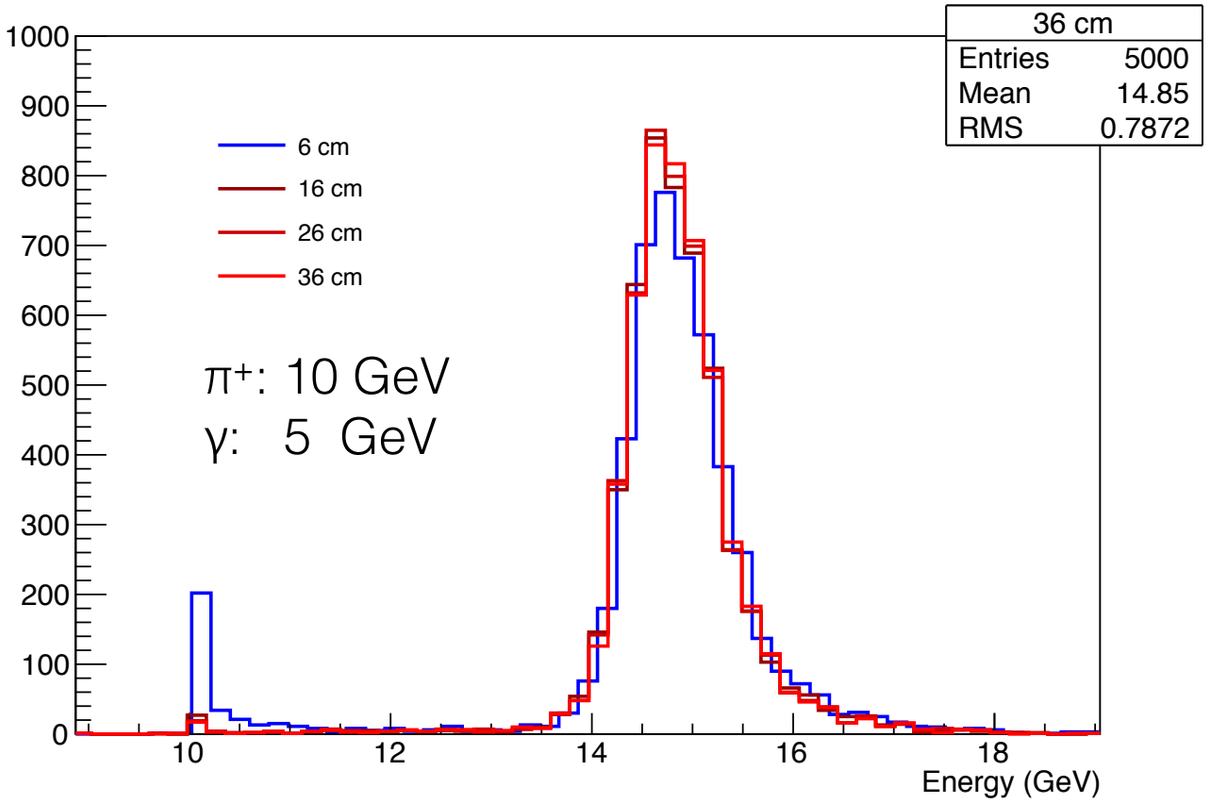
Manqi@ILD SiW-ECAL, 2016



The performance of Arbor reconstruction

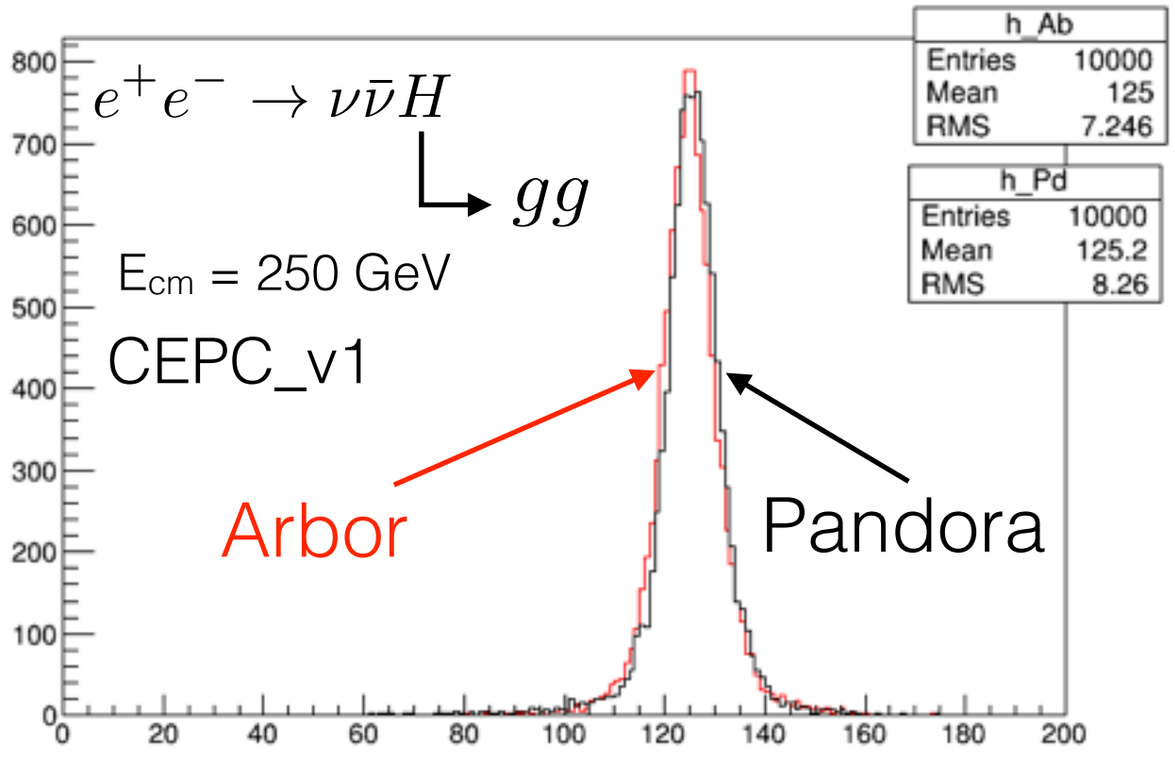
Binsong Ma, IHEP

- Overlaid particles of at different distances:



- The performance of reconstruction for overlaid particles is increased by optimizing the clustering algorithm.

- Higgs mass resolution



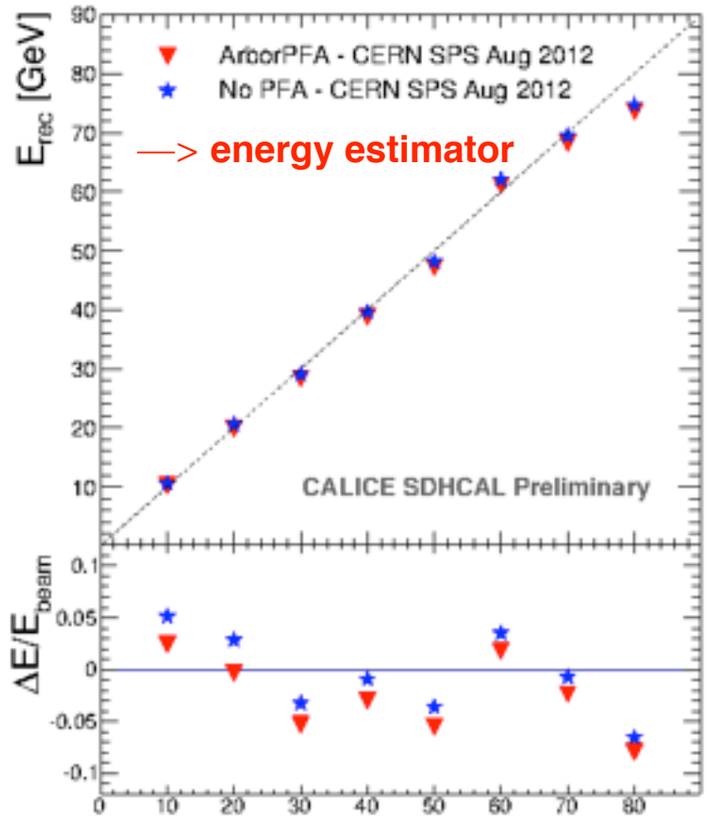
- The energy resolution of Arbor in this channel is consistent with that of Pandora
- More works are needed for Pandora to be adapted to the CEPC detector geometry (especially for forward region)

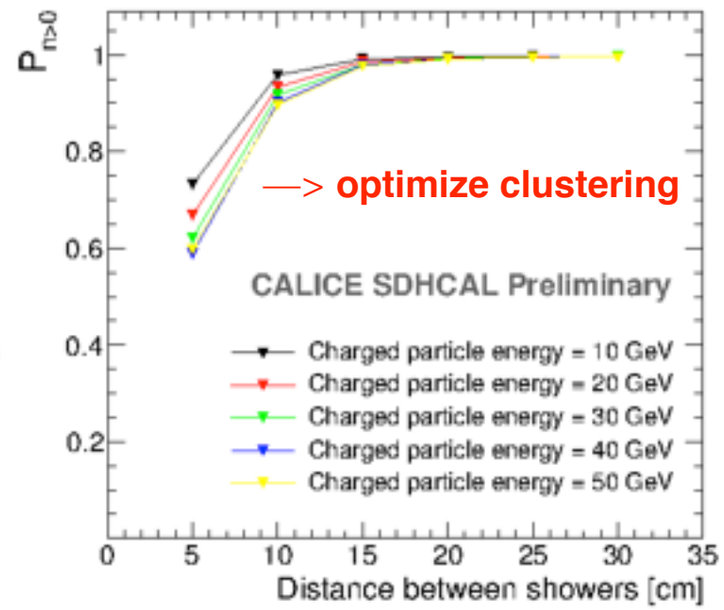
ArborPFA

an implementation of ARBOR in PandoraFramework

R. Été

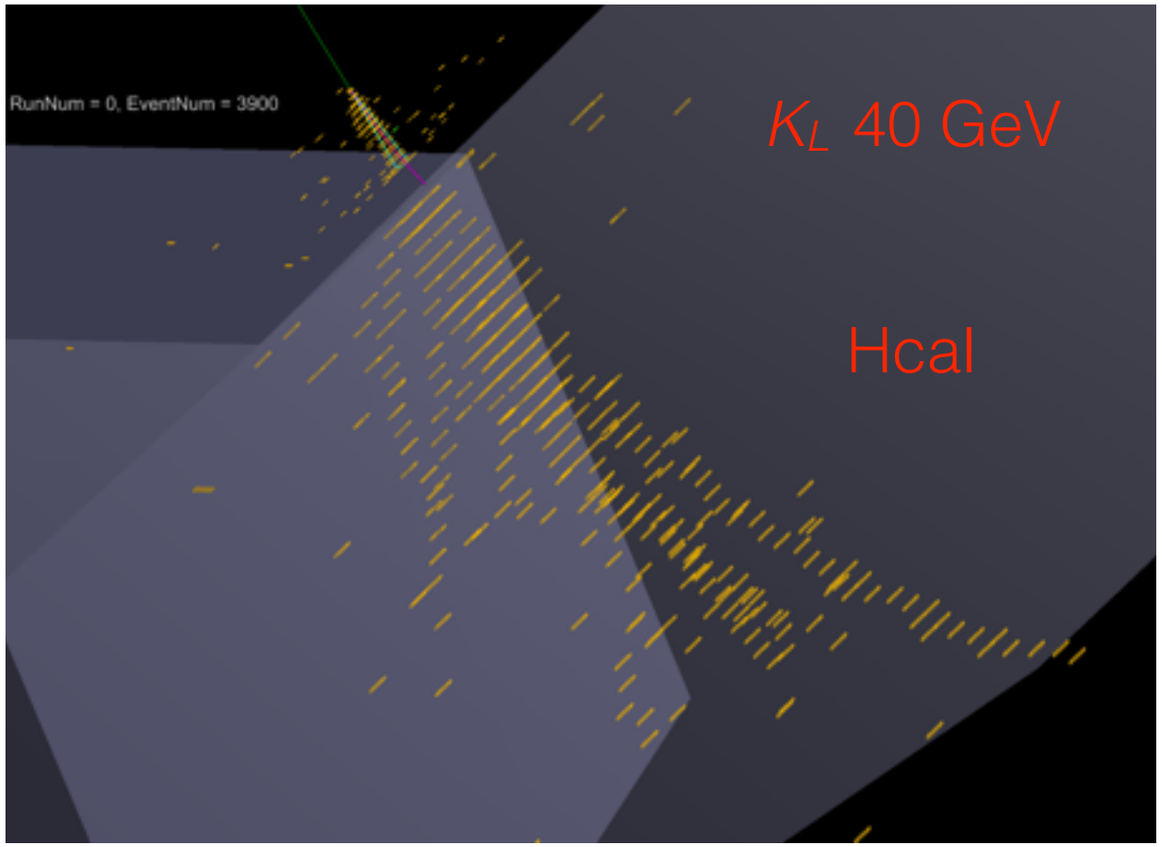
- **Packages**
  - Hosted on github : https://github.com/ArborPFA
- **Sub packages**
  - PandoraSDK: PFA development toolkit
  - PandoraMonitoring: PFA root TEve monitoring
  - ArborContent: ArborPFA algorithms implementation
  - MarlinArbor: ArborPFA Marlin interface
  - SDHCALArborPFA: SDHCAL specific implementation
  - 30+ algorithms in total
- **Current status**
  - SDHCAL : single particle and separation of overlaid particles.
  - Missing: Standalone photon reconstruction; PID tools
  - Calice Analysis Note 054 approved.
  - JINST publication on road …



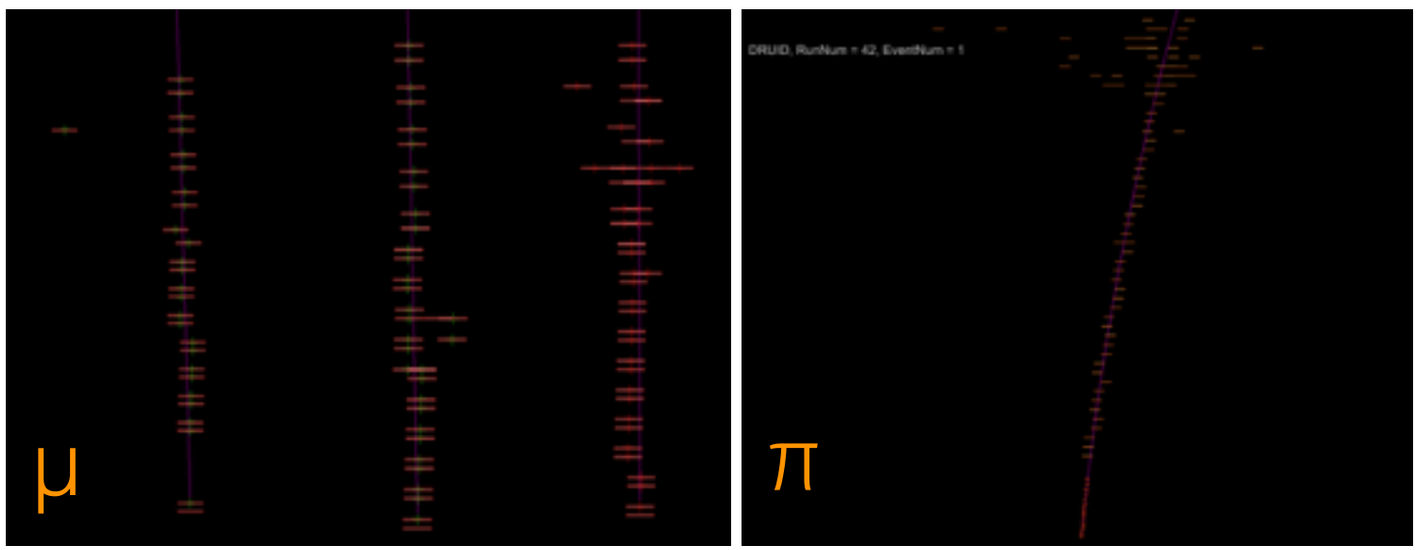


Tracking in calorimeter

- Motivation
  - save energy leakage
  - improve energy resolution
  - improve cluster separation

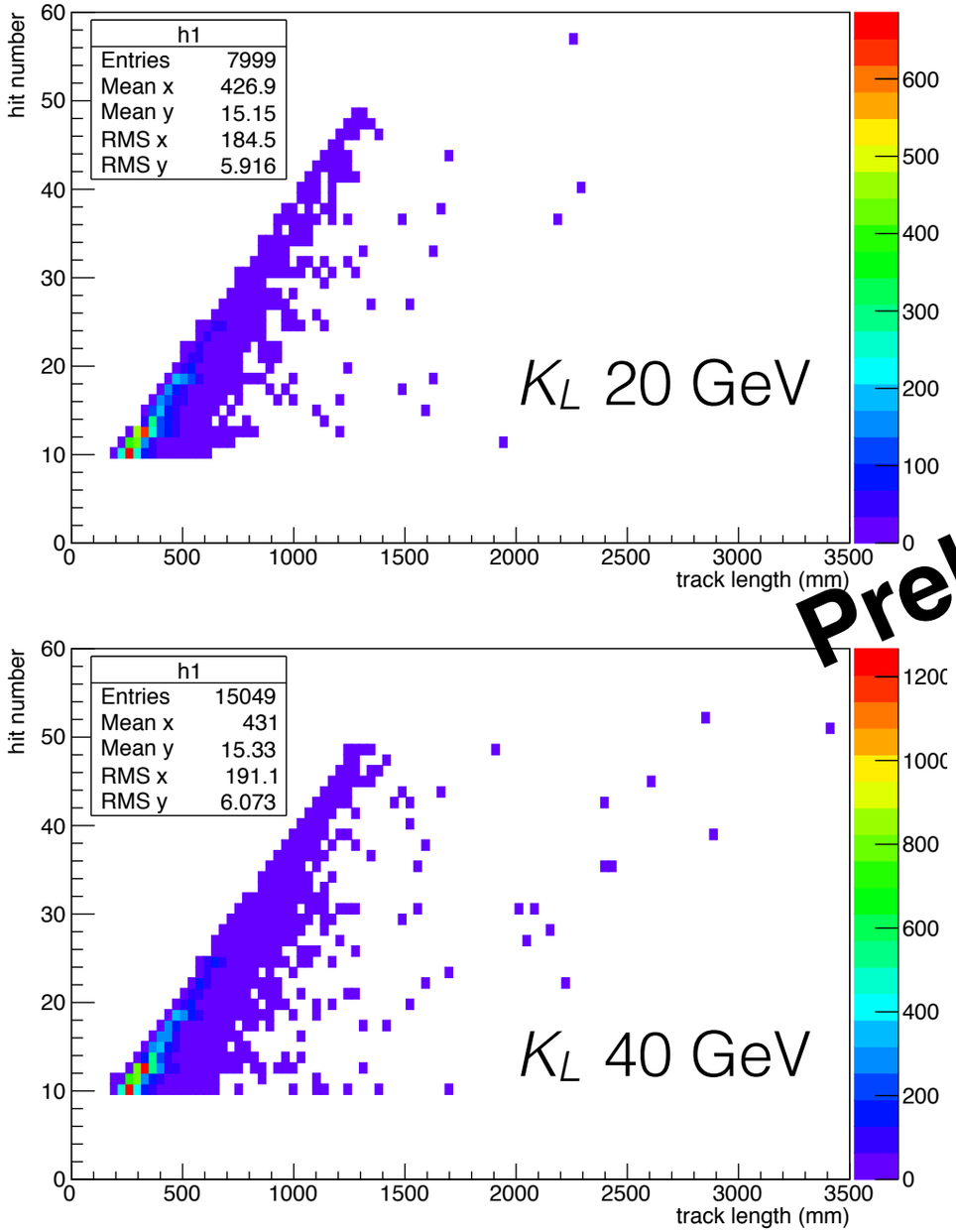


- Track fitting
  - KalTest
  - increased multiple scatter and spatial resolution
  - For Ecal, the track information from tracker is useful

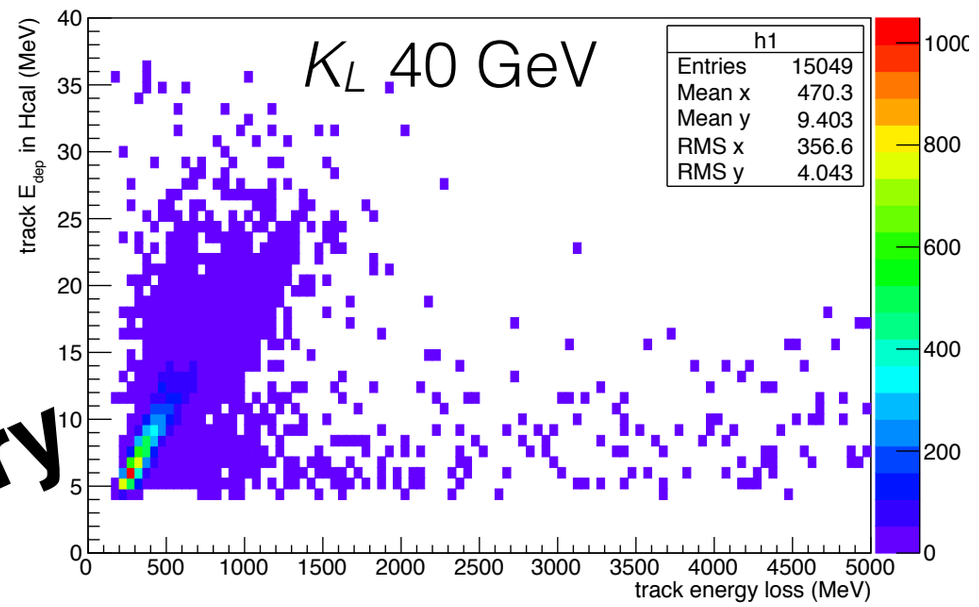


Simulation with Mokka

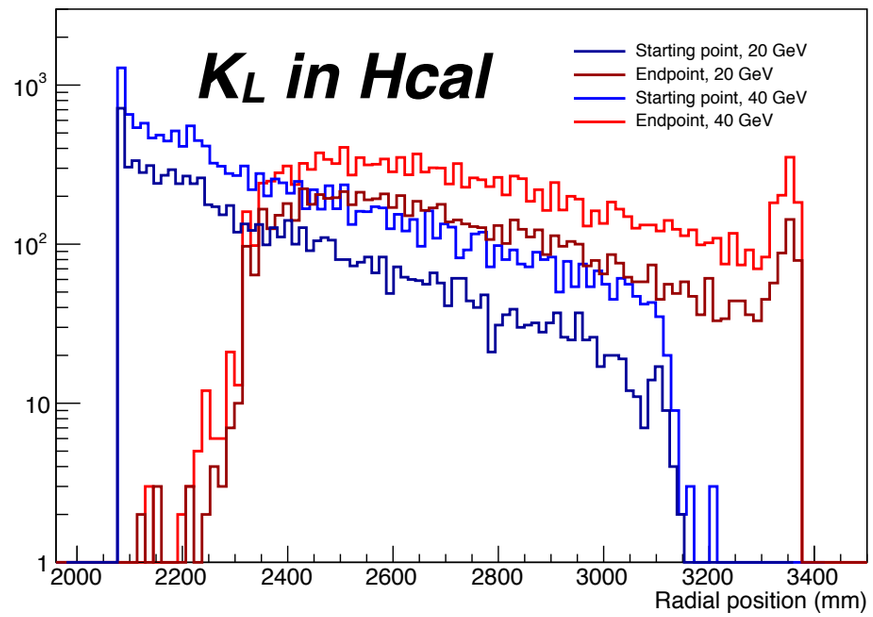
track length VS hit number of charged particles in hadronic shower



track energy loss VS deposited energy in SD charged particles in hadronic shower



Preliminary



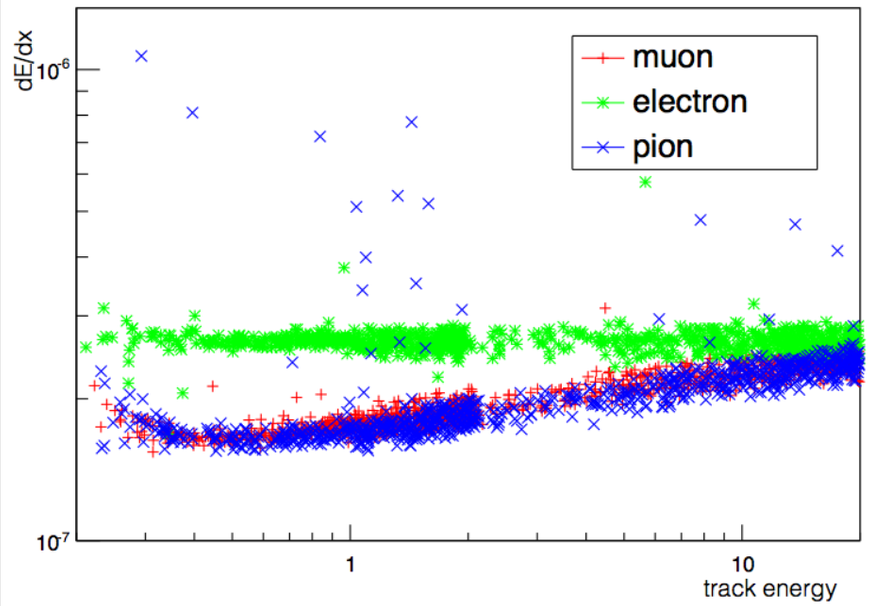
Particle identification

Particle identification

D. Yu

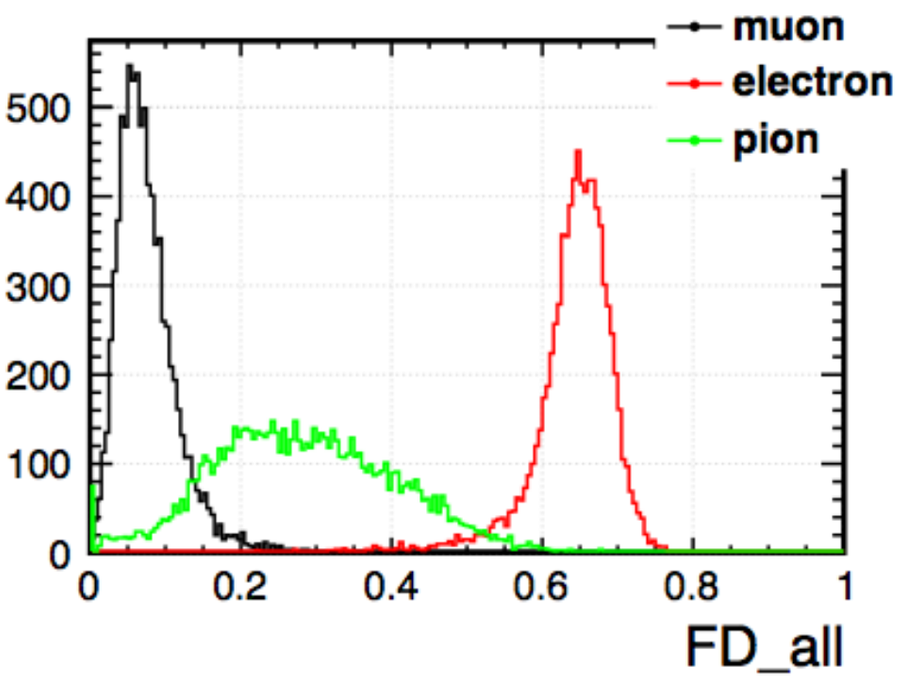
- Use of very high granularity of calorimeter
  - (SiW-ECAL+SDHCAL) + ARBOR
  - new means of PID (**MVA**)

- **dE/dx**
  - energy deposited in TPC, Landau distribution
  - the average of the energy loss [10%–70%]



- **Fractal dimension**: reveals detailed information of the spatial configuration of the shower
  - α: scale at which the shower is analyzed (by grouping hits)
  - N_α: the number of hits at scale α
  - $R_{\alpha,\beta} = N_\beta/N_\alpha$: ratio of hit number at different scales
  - $\mathbf{FD_\beta} = \langle \log(R_{\alpha,\beta})/\log(\alpha) \rangle + 1$

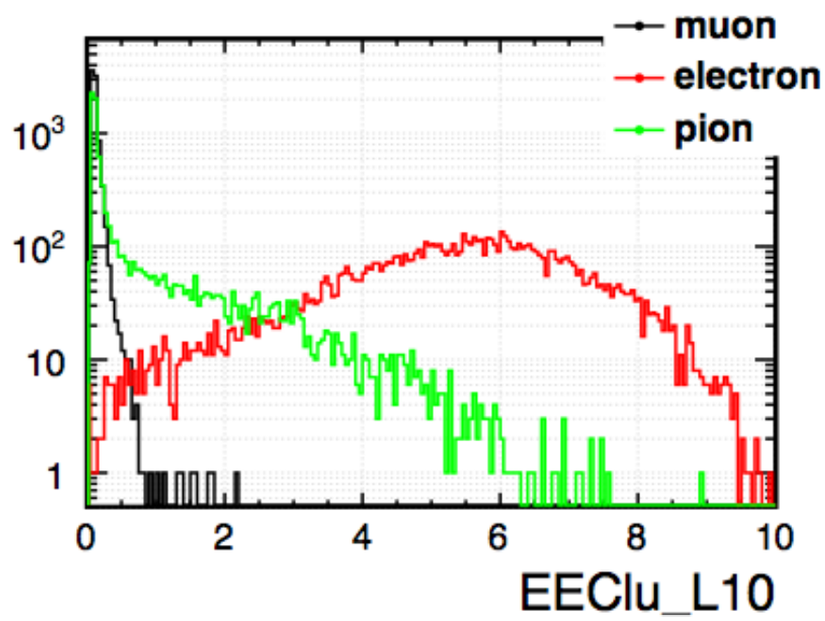
- Other 13 variables



Variable Plots (10 GeV)

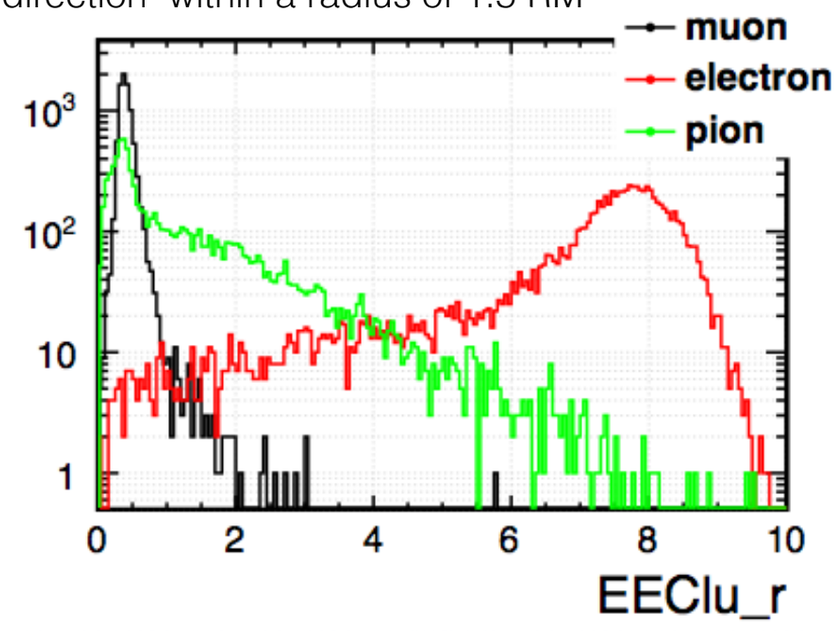
EEClu_L10

energy deposit in the first 10 layers of ECAL



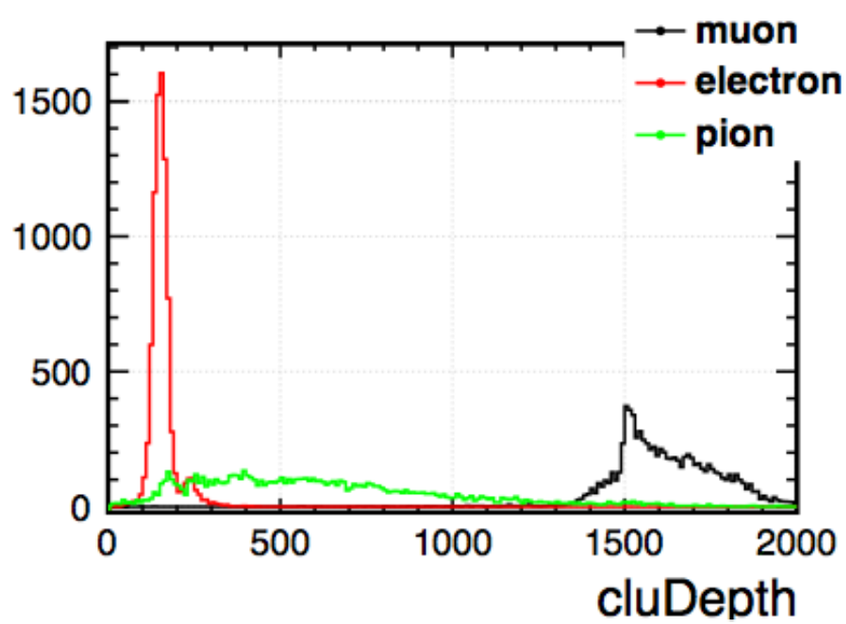
EEClu_r

energy deposit in a cylinder around the incident direction within a radius of 1.5 RM



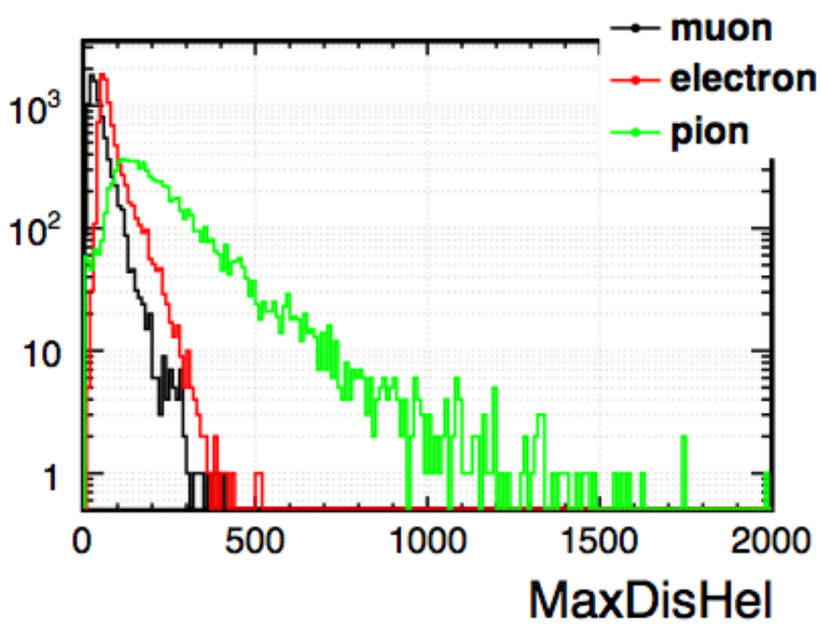
cluDepth

the depth between the outer most hit and inner most hit of cluster



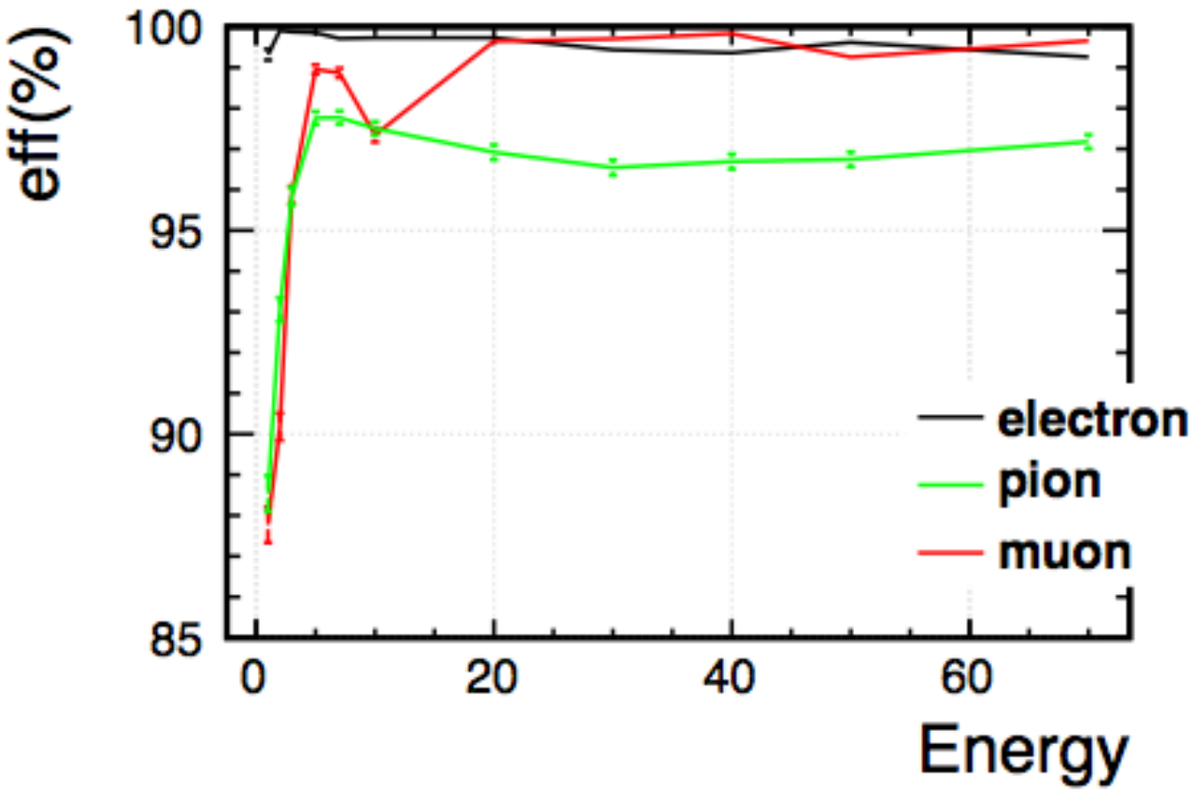
MaxDisHel

the maximum distance between a hit and the helix

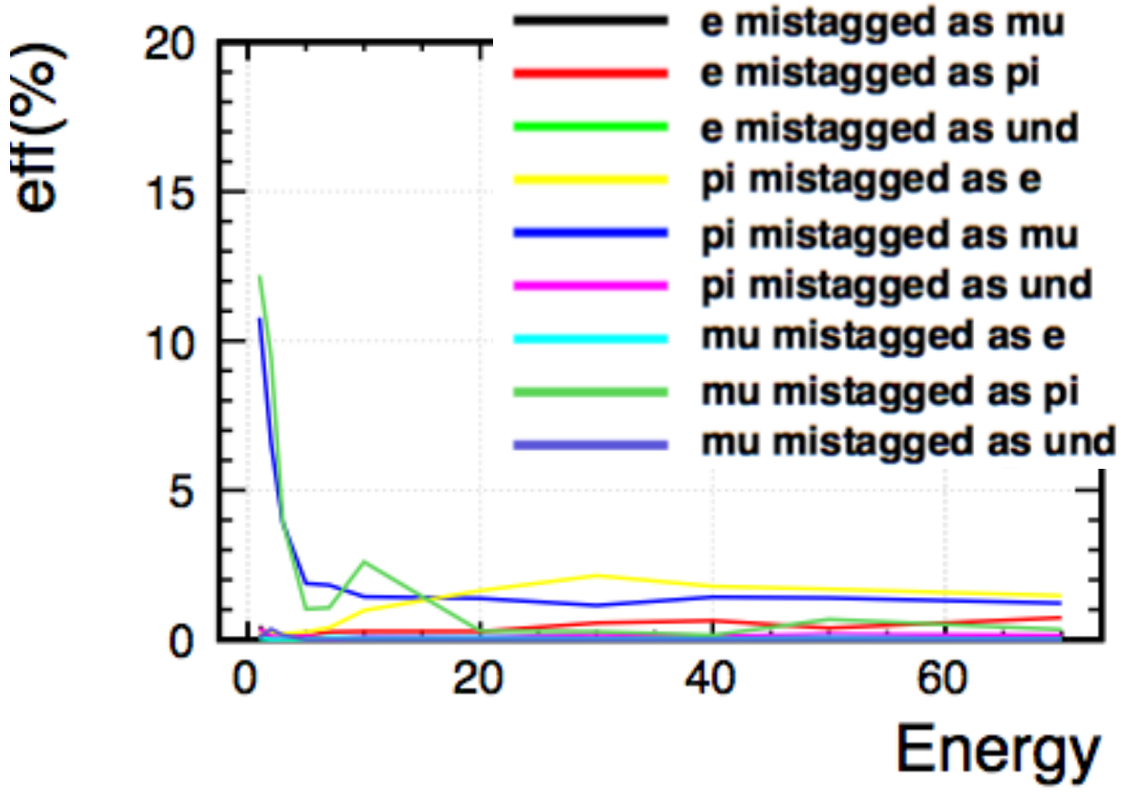


Performance

- PID efficiency



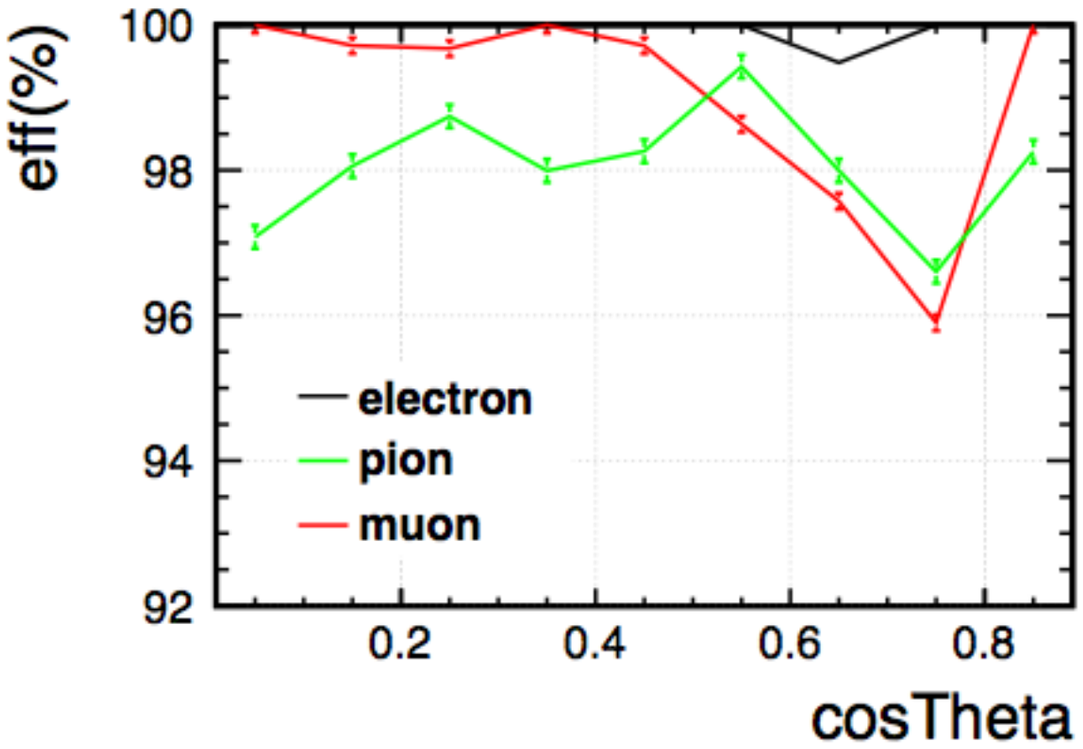
- PID mis-tagging probability



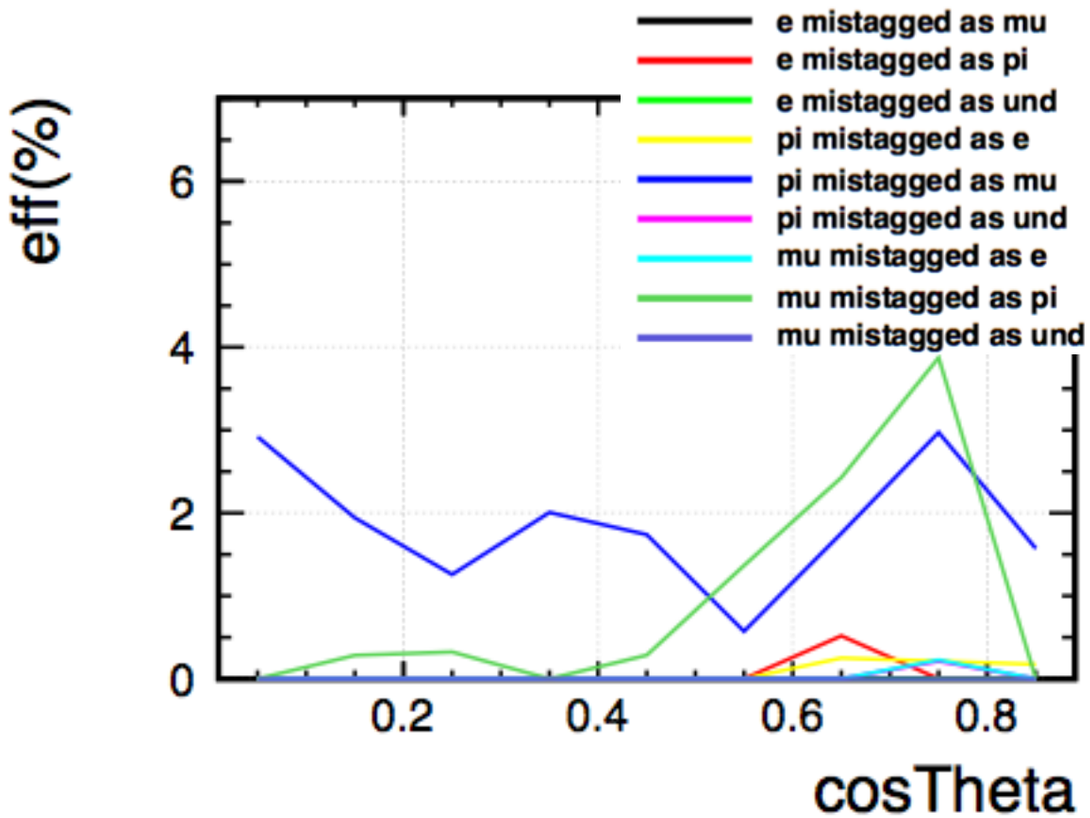
- Efficiency ≥ 99% for electron
- ≥99% for μ @ E ≥ 20 GeV (to be checked @ 10 GeV, dE/dx effect ?)
- ~97% for π @ E ≥ 5 GeV
- Purity ≥ 97% @E ≥ 5 GeV (excl. μ @10 GeV)

Angular Dependence

- PID efficiency (5 GeV)



- PID mistagging probability(5 GeV)

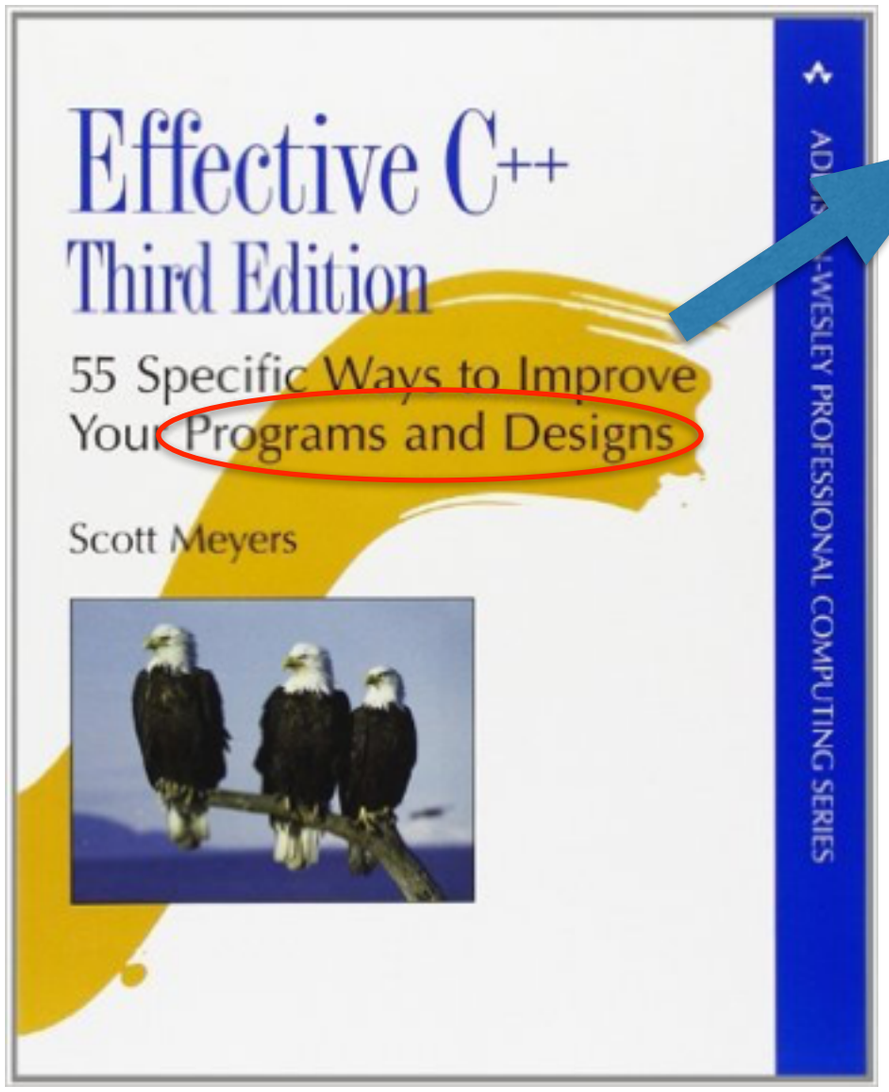


- pion and muon confusion at the gap between barrel and endcap
- not much influence on electrons
- TODO: Angular dependence studied
  - check PFA at the gap of between barrel and end cap
  - check at more energy points

Summary

- The cellular automaton VXD tracking algorithm improves the performance at low Pt and forward region.
- Non-uniformity of real magnetic field should taken into in tracking algorithm, KalTest.
- Vertex charge reconstruction depends on tracking and vertexing (which has room to improve) performance.
- A new Arbor version is ongoing: renovated blueprint of algorithm, new functionalities (self-merging, tracking…)
- Algorithm taking advantage of calorimeter developed for MVA based PID.

Summary



Item 1: view C++ as federation of language.

Item for us: view ILD reconstruction algorithms as federation