Status of Study on Tracker and Tracking at CEPC

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(on behalf of CEPC software group)

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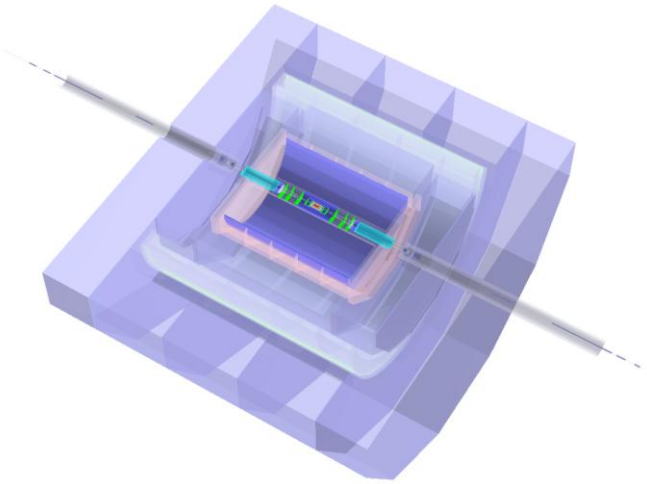
- A high energy **C**ircular **E**lectron **P**ositron **C**ollider (CEPC) as a Higgs and/or Z factory is on the stage of the Conceptual Design Report study in China, which is opened for international cooperation. Join us: http://cepc.ihep.ac.cn/

Pre-CDR	CDR	TDR	…
2015	2018	202?	

- Now, CEPC software group, together with other groups, e.g. Vertex study group, calorimeter study group, etc., are working/looking for improvement of software and optimization of design of detector. Tracker study and tracking algorithm development are parts of our missions.



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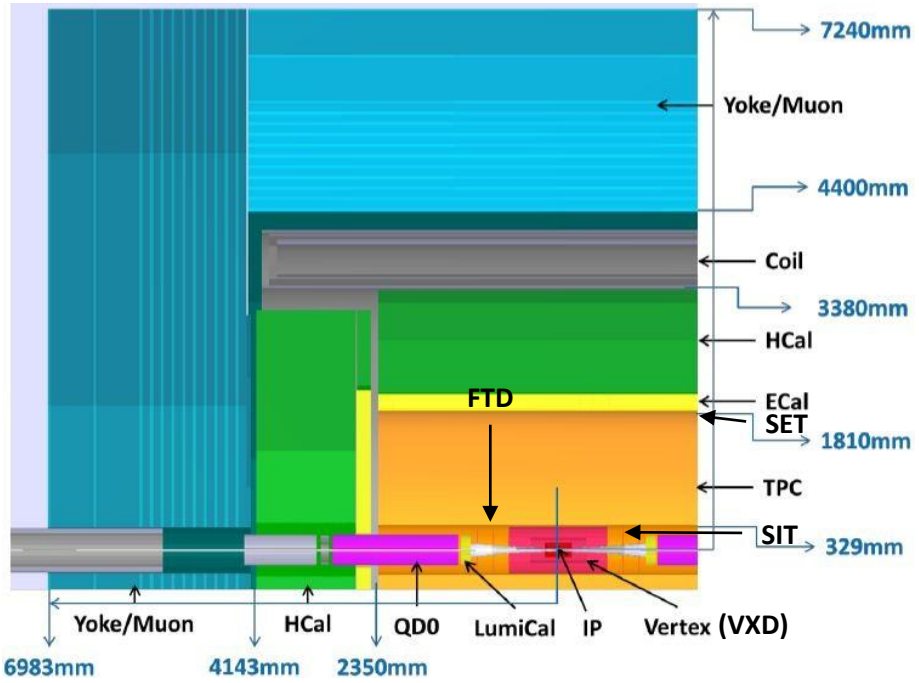
Introduction

- For simplicity, the CEPC detector started from ILD, the International Linear Collider (ILC), another further electron positron collider.
- Tracker region
  - VXD
  - SIT/SET
  - TPC
  - FTD



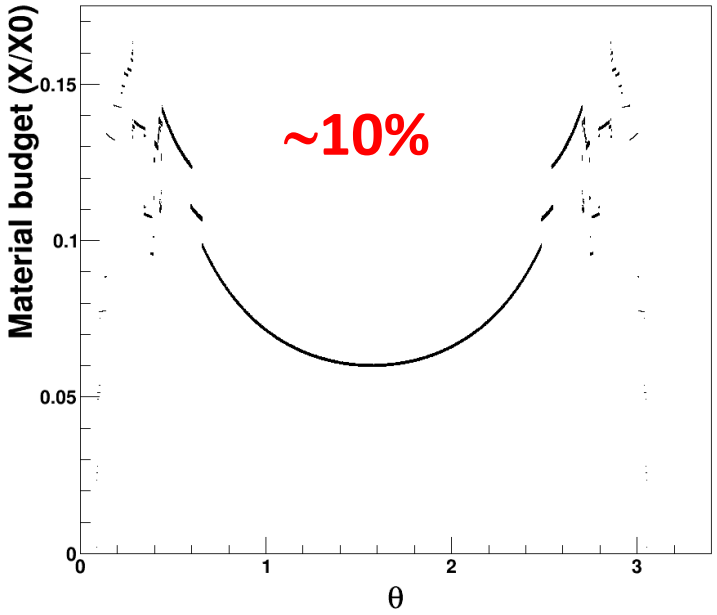
- Simulation and re-construction tools, at first step, following ILC soft-ware is taken as quick starting.
  - Mokka
  - Marlin

Tracker in CEPC v1

Sub-detector	type	construction	Resolution
VXD	Silicon-based/pixel	3-double layers	10μm, 20μm, 15μm, 15μm, 15μm, 15μm
FTD	Silicon-based/pixel+strip	2 pixel layers + 3-double strip layers	10μm, 25μm
SIT/SET	CCD	2-double layers/1-double layer	25μm
TPC	Time Projection Chamber	222 pads (6mm)	50μm(Rϕ), 400μm(Z)

Based on this version of CEPC, some modification of one or more sub-detector and comparison their performance have been done.

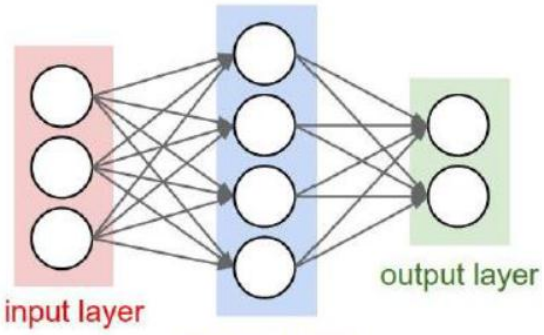
- More needed!

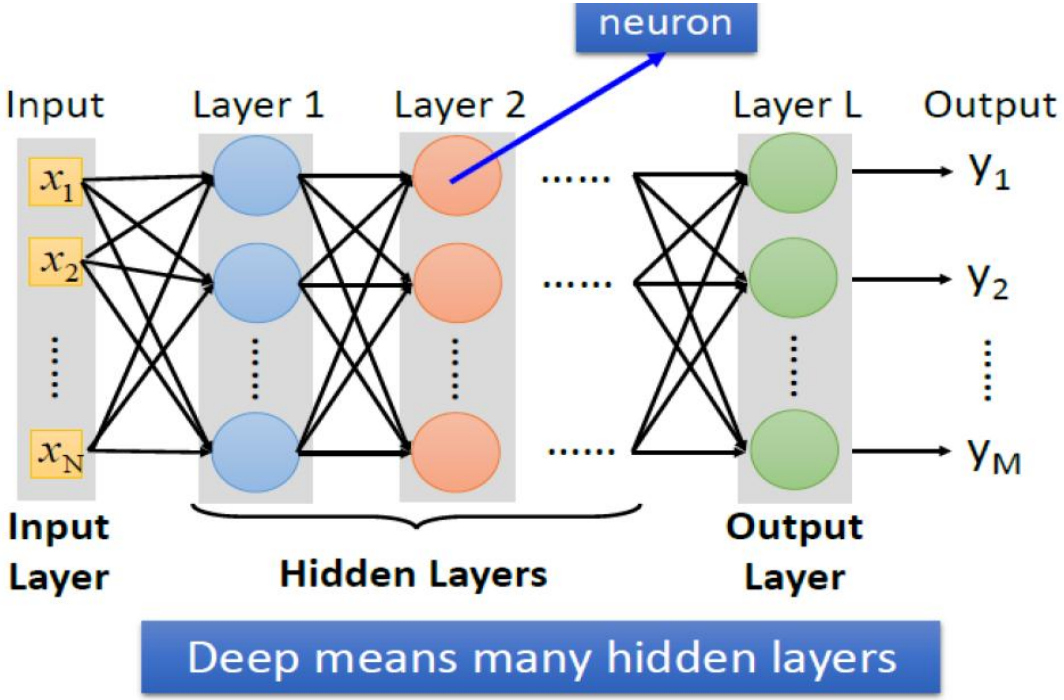


Flavor Tagging

- Based on TMVA **B**oosted **D**ecision **T**rees
- Use **D**eep **N**eural **N**etwork
- TensorFlow for training

- 63 neurons as input layer
- L=7: 512 neurons (layer 1, 2, 3, 4) and 256 neurons (layer 5, 6)
- Dropout cut 0.5 to remove neurons while training



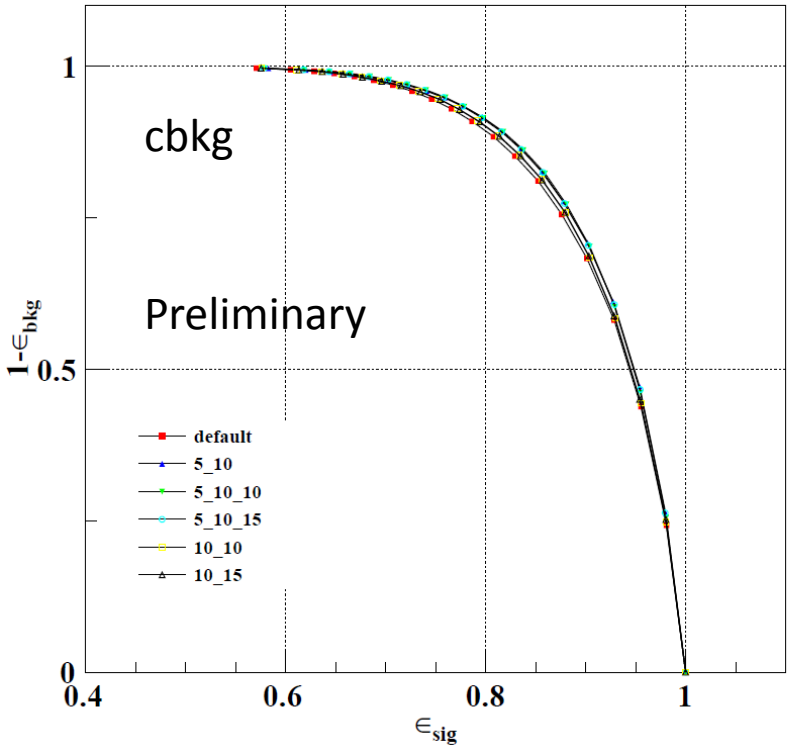


Performance for Flavor Tag

Vertex detector optimization:

- CEPC v1 as default:
- 5_10: VXD 1-6 and FTD_pixel 5μm, SIT/SET and FTD_strip 10μm
- 5_10_10: VXD 1 and FTD_pixel 5μm, VXD 2-6 10μm, SIT/SET and FTD_strip 10μm
- 5_10_15: VXD 1 and FTD_pixel 5μm, VXD 2-6 10μm, SIT/SET and FTD_strip 15μm
- 10_10: VXD 1-6 and FTD_pixel 10μm, SIT/SET and FTD_strip 10μm
- 10_15: VXD 1-6 and FTD_pixel 10μm, SIT/SET and FTD_strip 15μm

bJet


cbkg
Preliminary
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5_10_10
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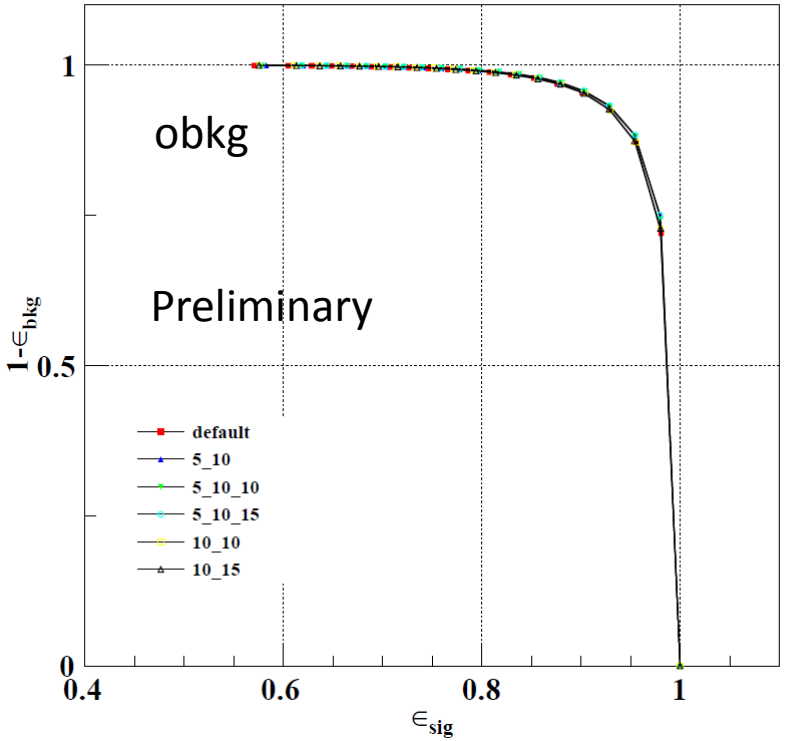
$1-\epsilon_{bkg}$
ϵ_{sig}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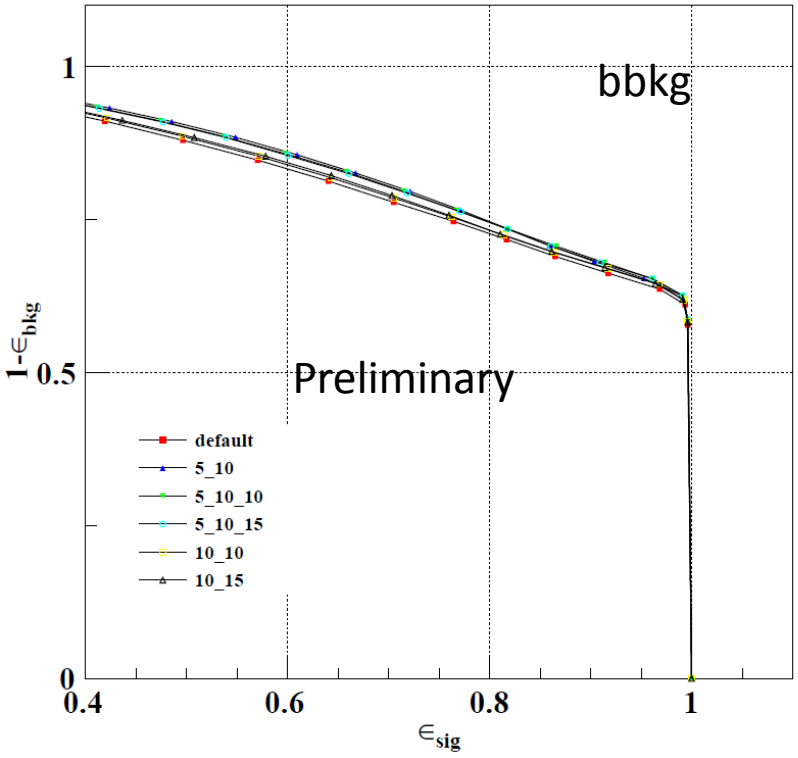
$1-\epsilon_{bkg}$
ϵ_{sig}

cJet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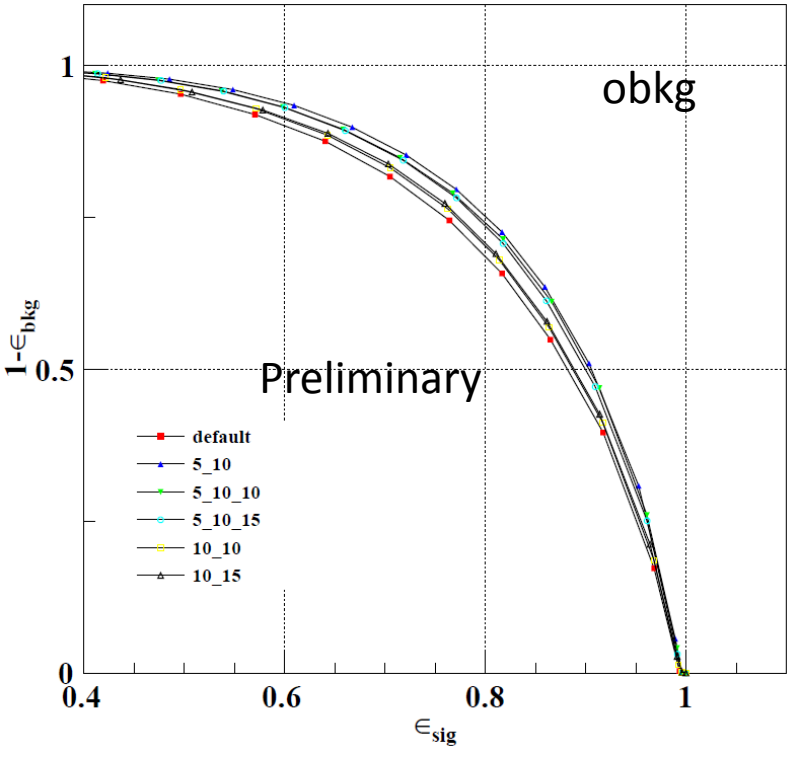
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1

Tracking for TPC

- Clupatra package include track finding and fit, which is being used for physical study at CEPC.

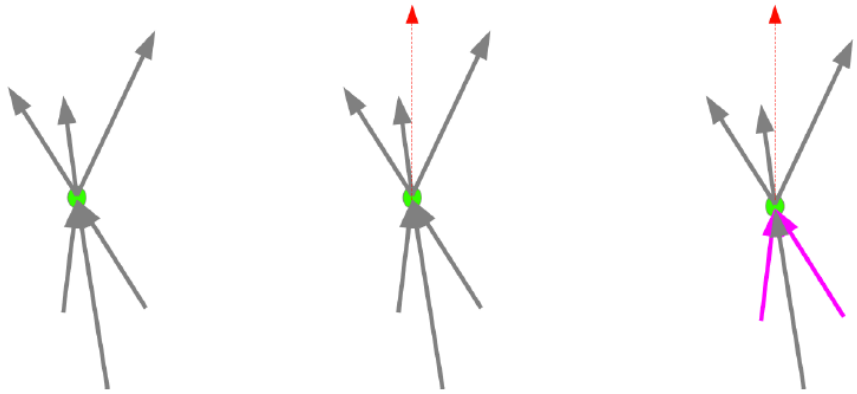
- New tracking algorithms are also being developed, such as ArborTrk.
  - Arbor for track finding
  - ArborTrk for fit and other steps

- Arbor is a clustering algorithm used for calorimeter reconstruction at CEPC. [arxiv:1403.4784]
  - Not need energy of hits
  - The hit structure of TPC is similar with calorimeter: hits have neighbor at any direction.

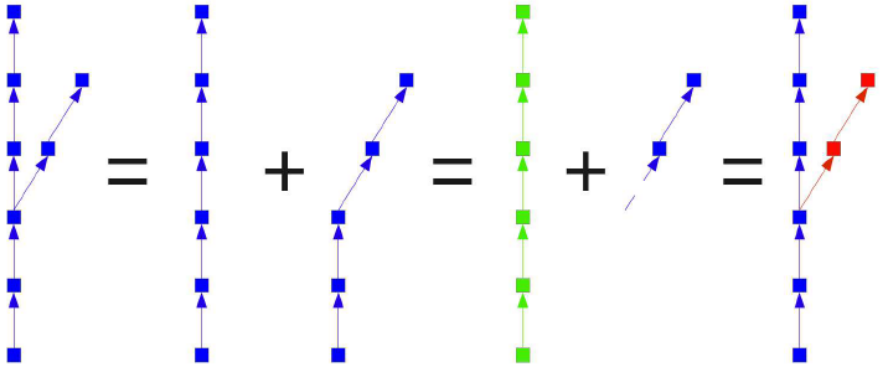
Arbor

- Arbor link any two closed (distance smaller than threshold) hits by connector (orientated arrow) first

- Clean connectors of hits⇒tree
  - One connector for each hit

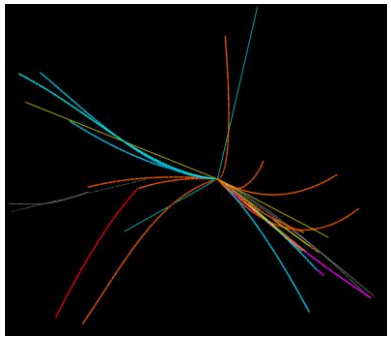


- Separate tree⇒branch



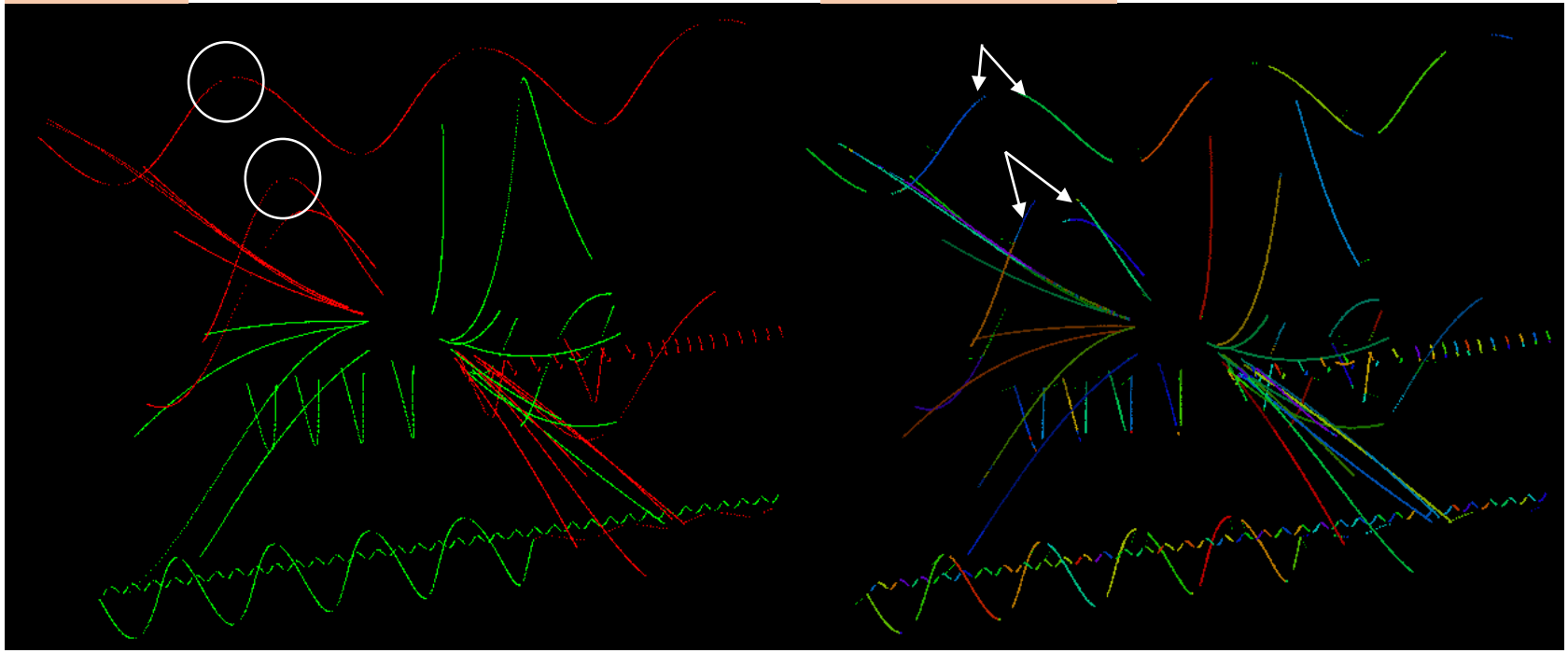
The branch composed by hits in TPC will just be candidate track.
➢ KalTest

$e^+e^- \rightarrow \nu\nu H$, $H \rightarrow$ anything ($\nu\nu H$) Example



TPC hits

Arbor branchs



MC Truth Match Algorithm

Based on LCIO

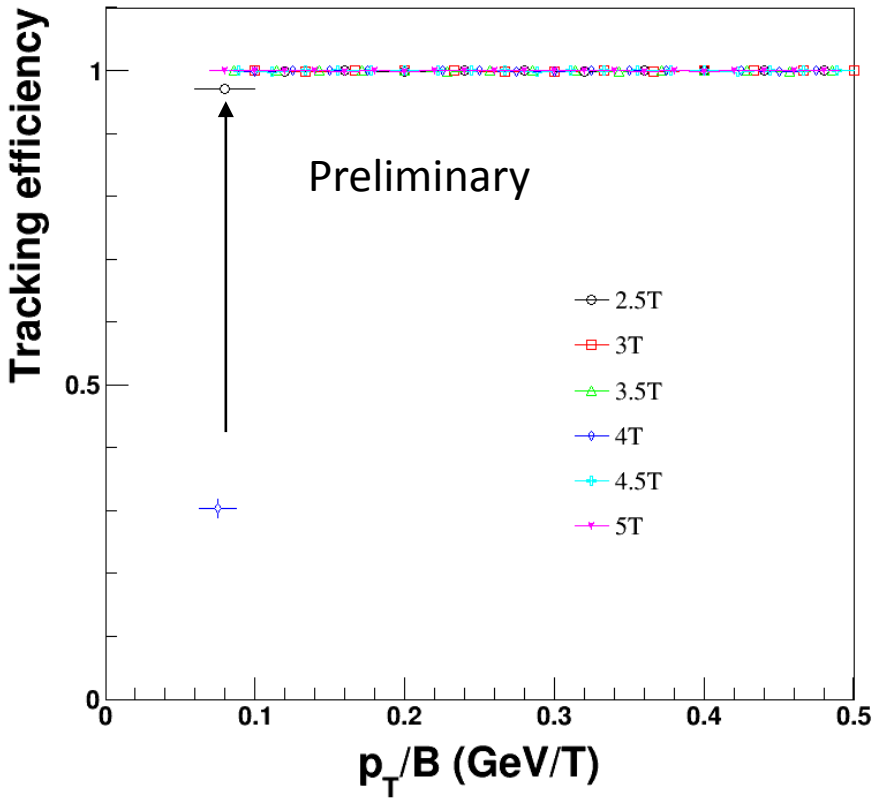
- Once a track is fitted, compare its hits (TrackerHit) with those hits (SimTrackerHit) from all MC particles (MCParticle), count the number of same hits.
  - ≥ 3
  - The MC particle which have most same hits with the track will be regarded as the truth particle of the fitted track

- Tracking efficiency is defined as the ratio of the number of matched particles and the number of all particles (limited by other conditions, e.g. vertex position, particle type)

Note: this efficiency will be a little higher than that require difference threshold.

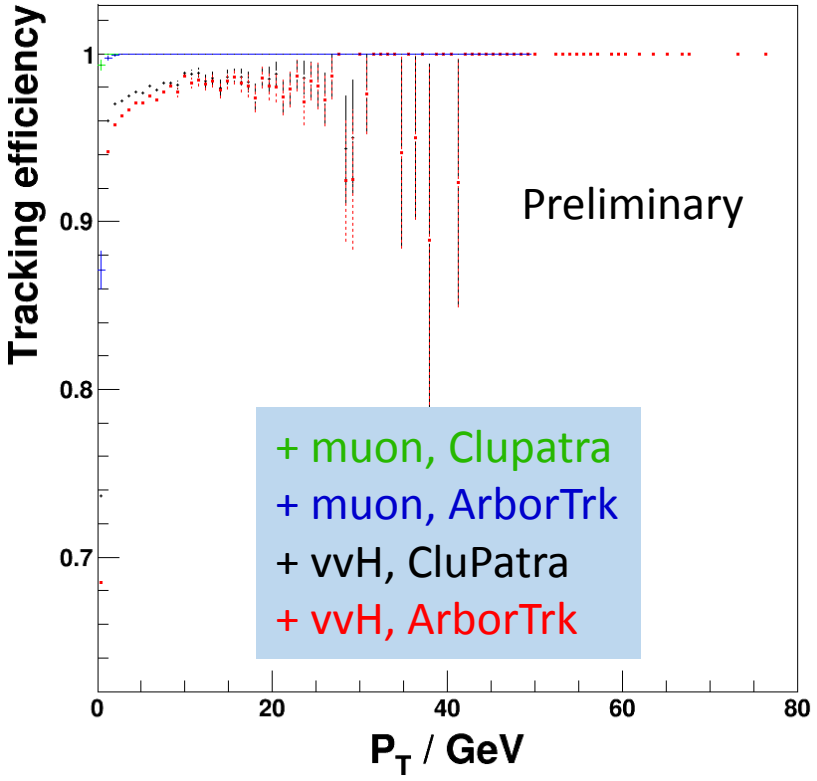
Performance at Low Momentum

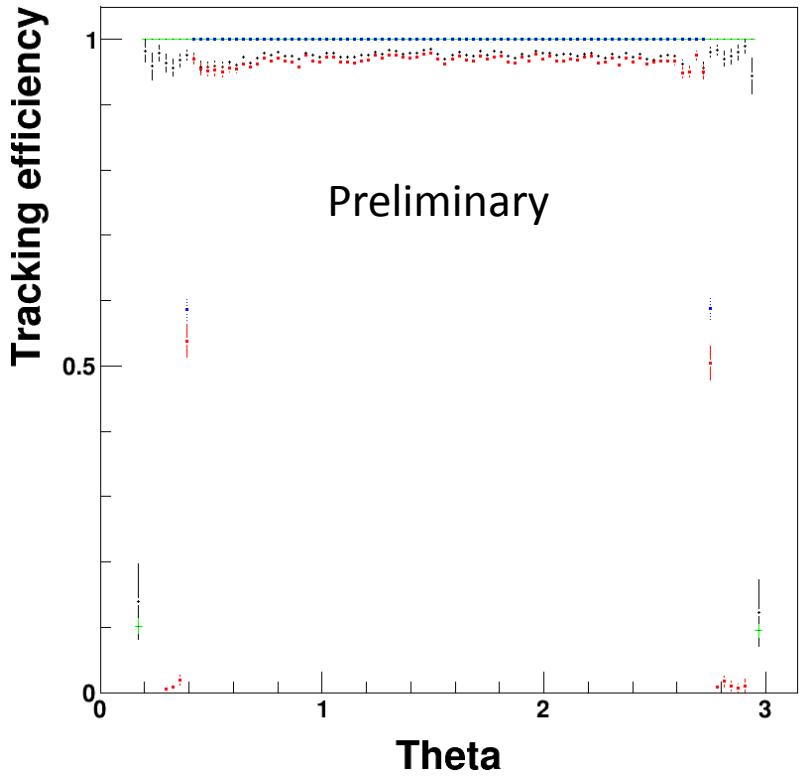
- Single muon
- The low limit of transverse momentum for track reconstruction is about 0.08×B(Tesla) GeV
  - 280MeV at 3.5T

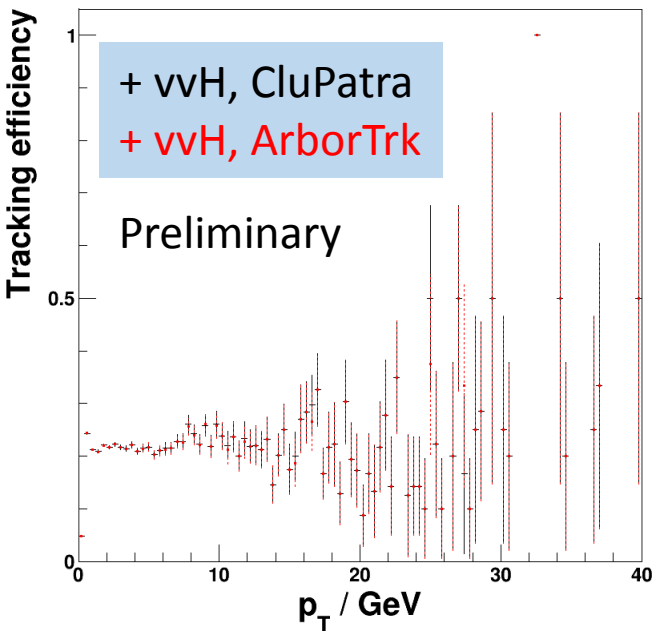


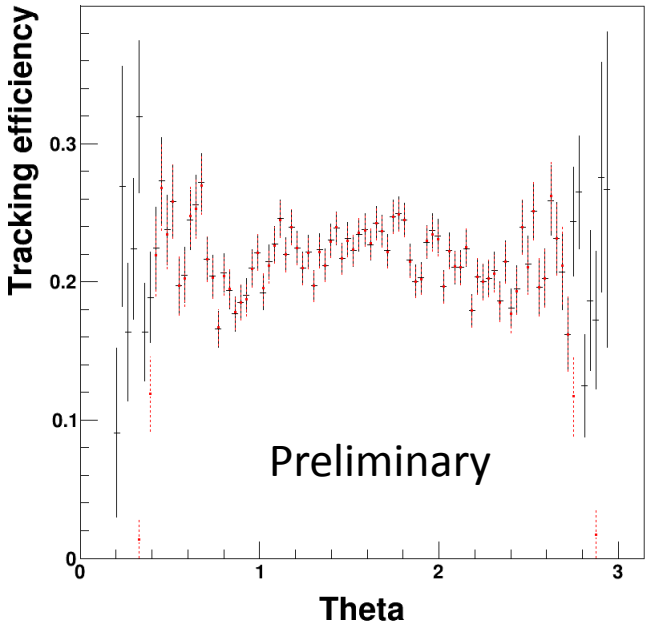
Tracking Efficiency

- ArborTrk cannot find out those tracks at small angle, it is understood caused by the threshold of the distance of two hits, it is possible to be fixed by letting threshold changed with θ
  - in two neighbor pads: proportional to 1/sinθ



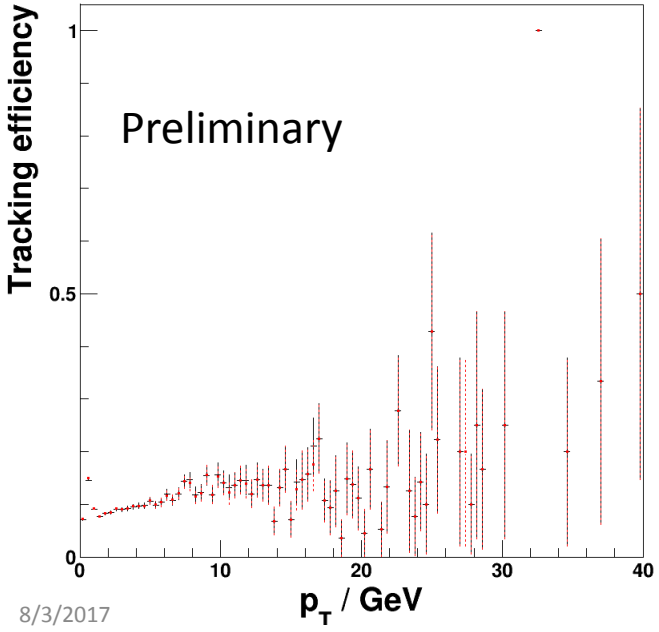


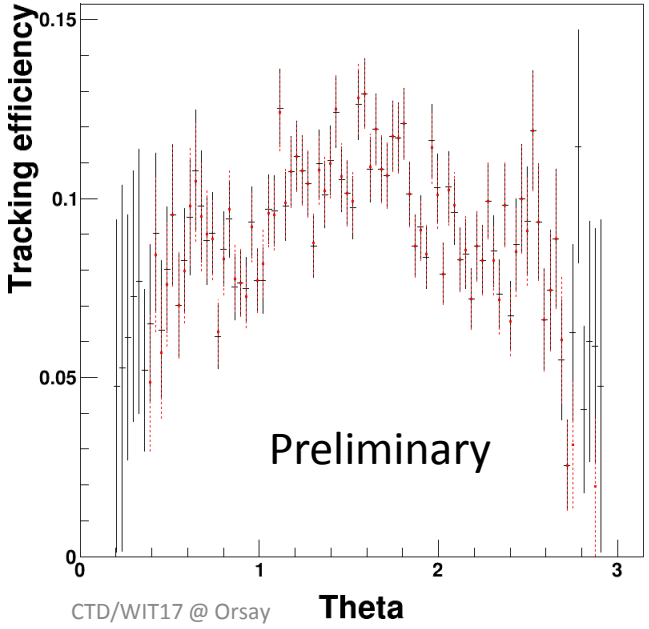




Vertex of particles:
Generated in

- VXD region



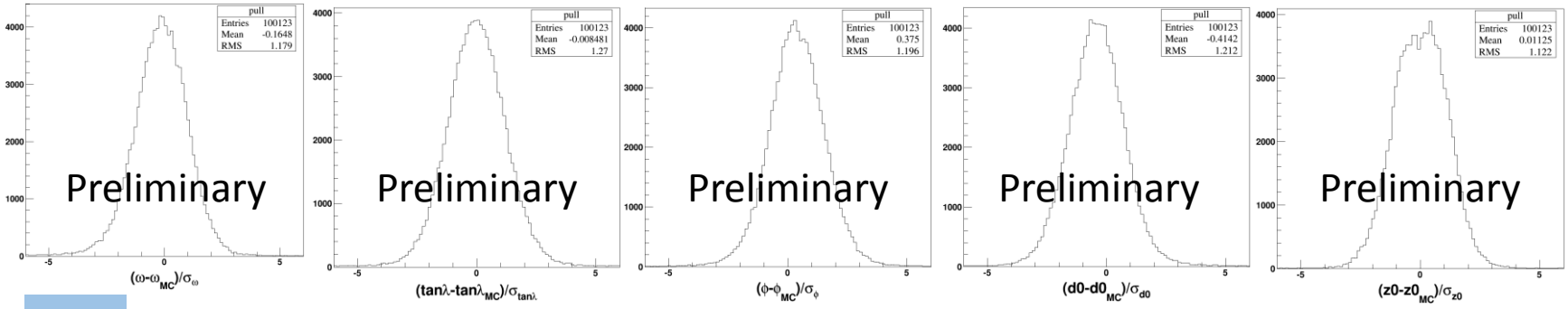


- TPC

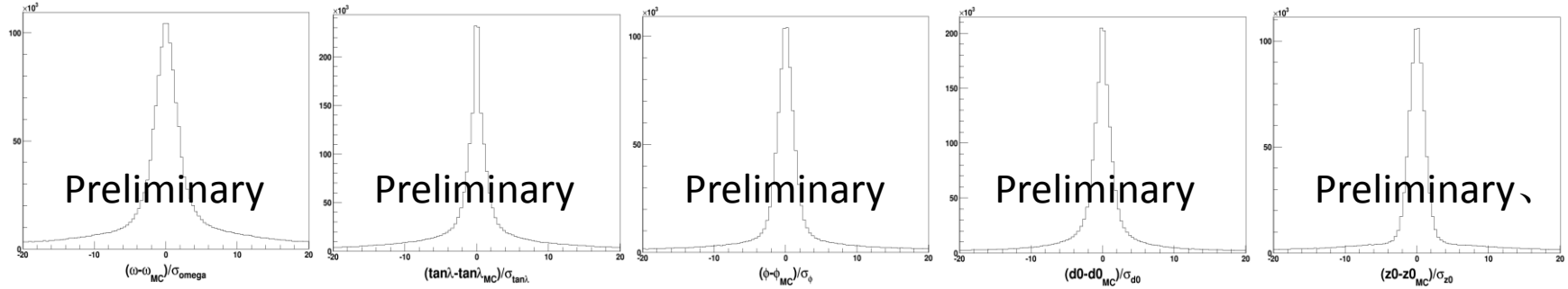
Pull Distribution

- Expectable to reduce the shift of mean after adding vertex hit to track

Single muon (0.5GeV,49.5GeV)

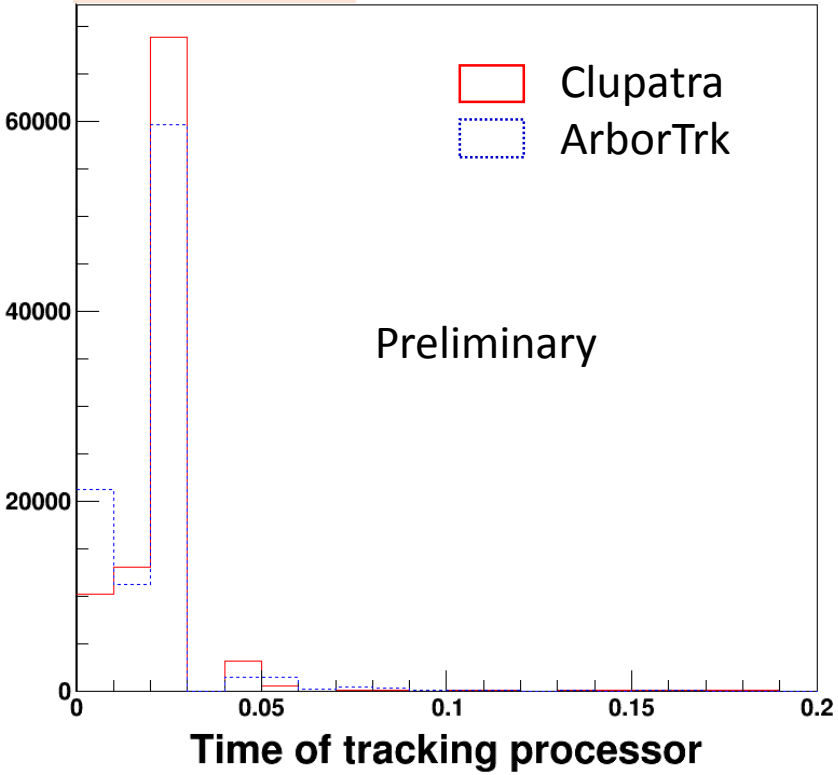


vvH

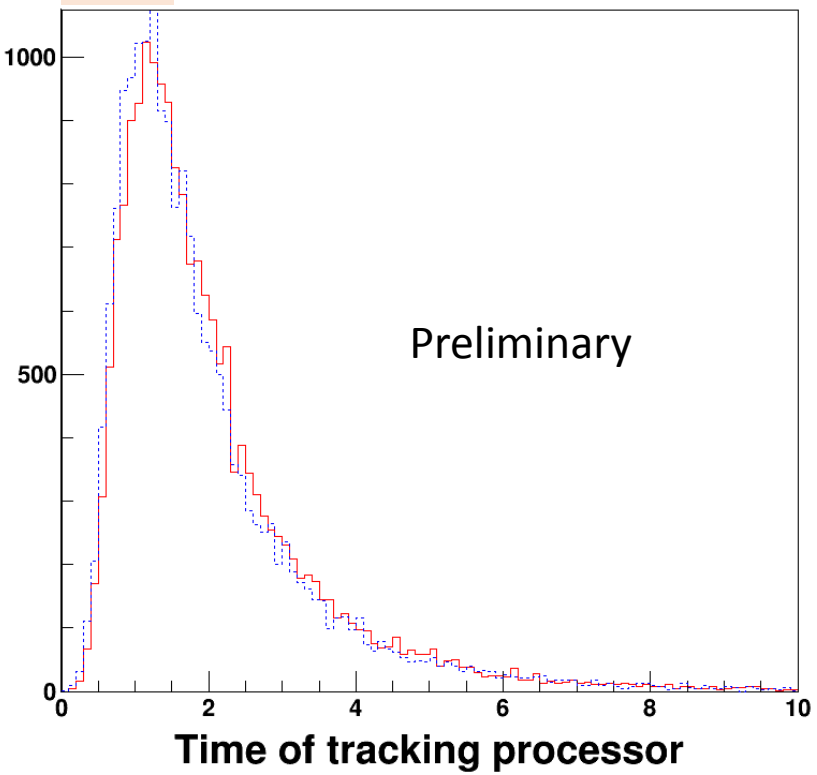


Time

Single muon

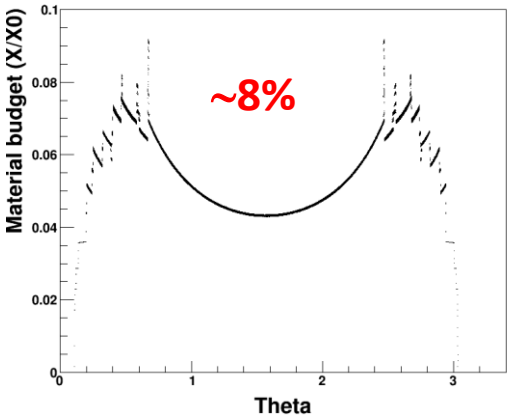


vvH



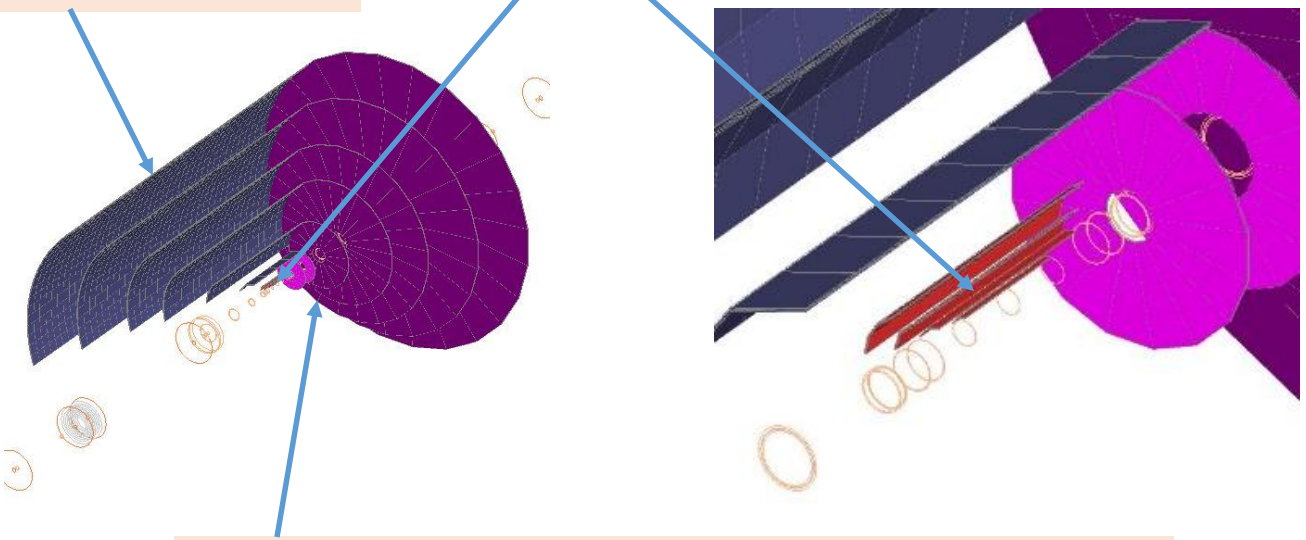
Full Silicon-based Tracker

- Preliminary design by Weimin YAO (BNL)



SIT: 6 double-layers

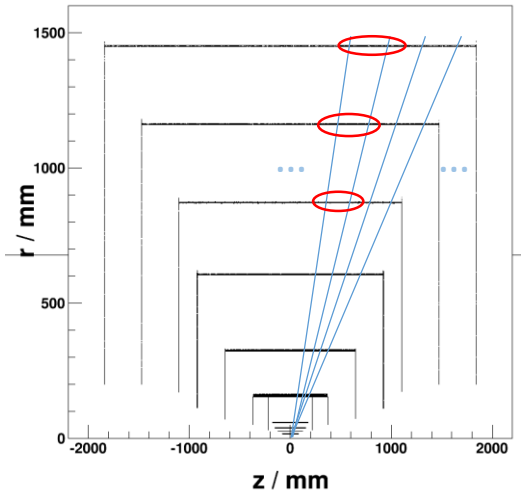
VXD: 3 double-layers

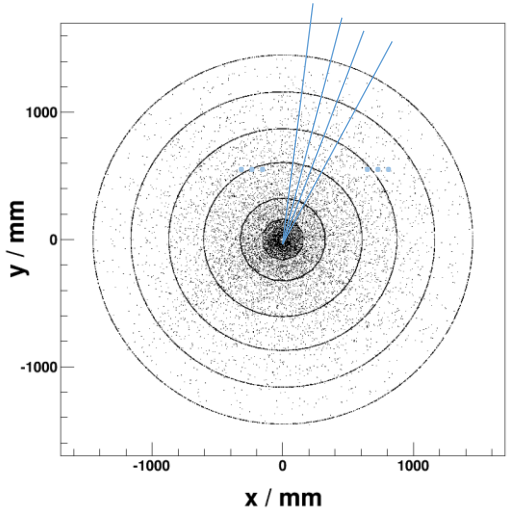


FTD: 2 single-layers of pixel + 5 double-layers of strip

SiliconTracking

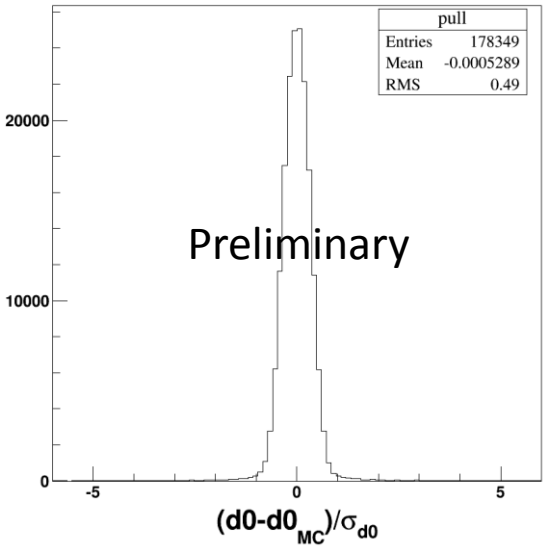
- SiliconTracking is one of algorithms in Marlin, used for tracking by VXD and SIT
  - Divide detector to theta-phi sectors for Triplet searching.

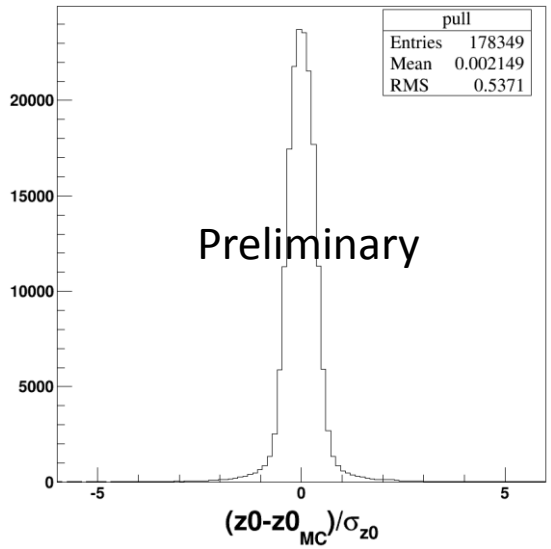




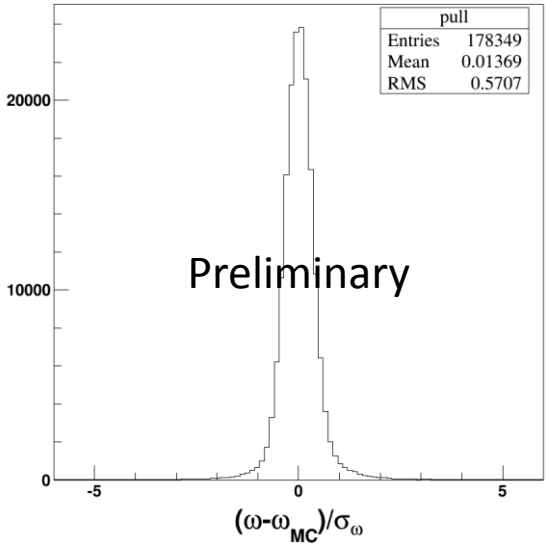
- This algorithm works well for only VXD and one SIT, now it is tried for more SITs. Some issues will happen.

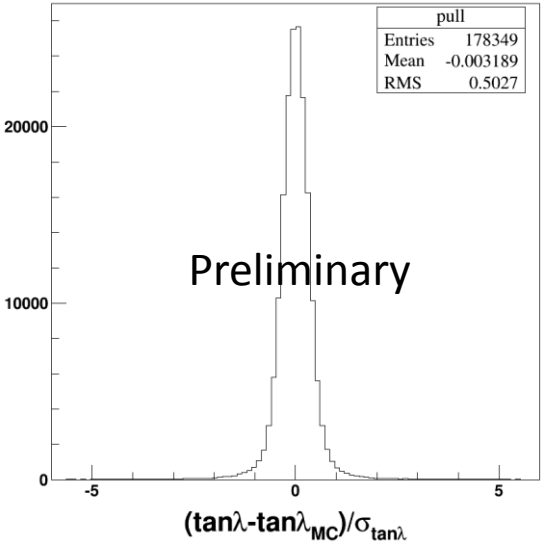
Pull Distribution

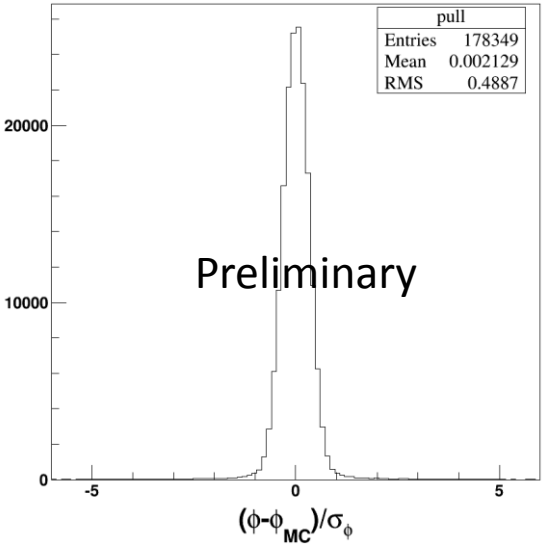




The pull distributions are narrow than (0,1) normal distribution, about half of, need to be fixed.

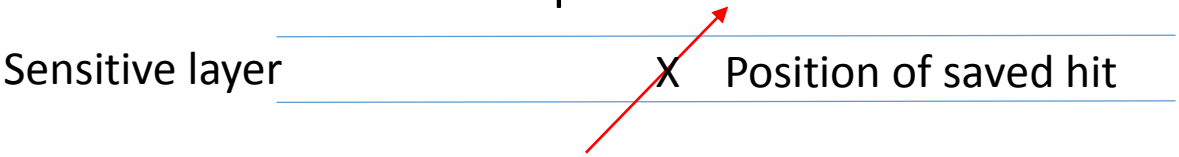




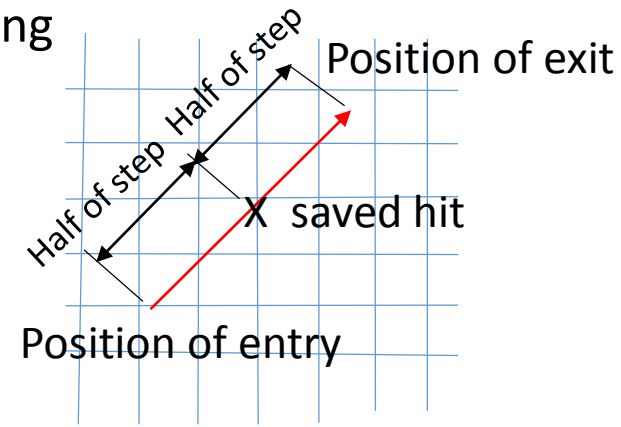


Digitization for silicon-tracker

- Hits in sensitive detector (silicon) is created as SimTrackerHit
  - Position of center of each step

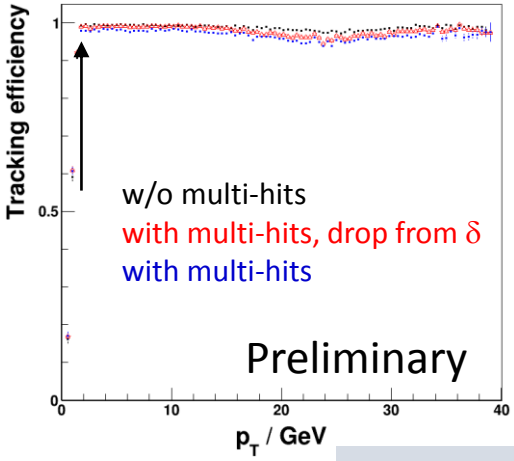


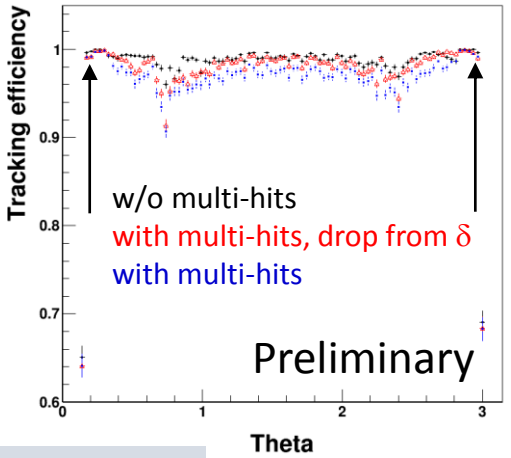
- Simple digitization in Marlin process
  - center of pixel/strip
    - Merge all hits in same pixel/strip
    - multi-hits caused by passing through and delta electron
    - Considering other effects are ongoing



Issues

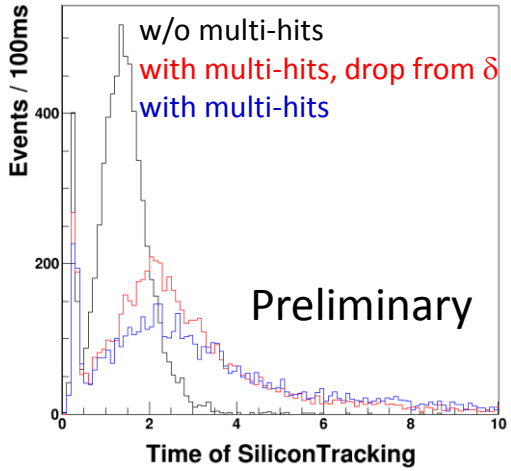
- Tracking efficiencies at low momentum are low. It can be improved through expand the sectors where search for the Triplet.





$e^+e^- \rightarrow ZH$ ($Z \rightarrow \mu^+\mu^-$, $H \rightarrow$ anything)

- While many multi-hits
  - Part of tracks will lose because of the cut on maximal number of hits allowed in one theta-phi sector.
  - The SiliconTracking processor will spend more time.



IF no maximal number limit, some events will even take days time.

A clustering algorithm needed while multi-hits included!

Tracker and Tracking Software at CEPC

- Vertex study through flavor tag
- Tracking algorithm ArborTrk for TPC
- Full silicon-based tracker pre-design & tracking
- More tracker design is being considered, e.g. wire chamber
- Based on Mokka simulation tool, sub-detector is easy to be integrated into the CEPC detector simulation. But for reconstruction, the corresponding algorithm should be optimized.

Many to do list (10+ years plan) & Need man power/ideas

Welcome to join us!

Thanks