



Status of Study on Tracker and Tracking at CEPC

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(on behalf of CEPC software group)

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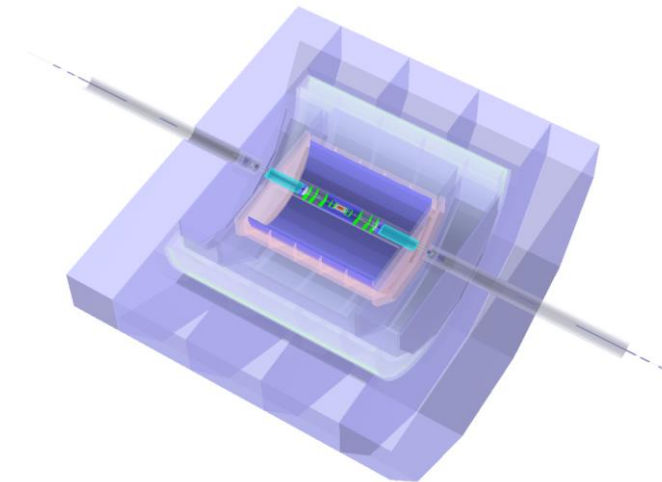
- A high energy **Circular Electron Positron Collider (CEPC)** as a Higgs and/or Z factory is on the stage of the Conceptual Design Report study in China, which is opened for international cooperation. **Join us: <http://cepc.ihep.ac.cn/>**



- 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
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 - Performance for vertex study
- Tracking for TPC
 - A track finding algorithm—Arbor
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- Tracker and tracking software at CEPC

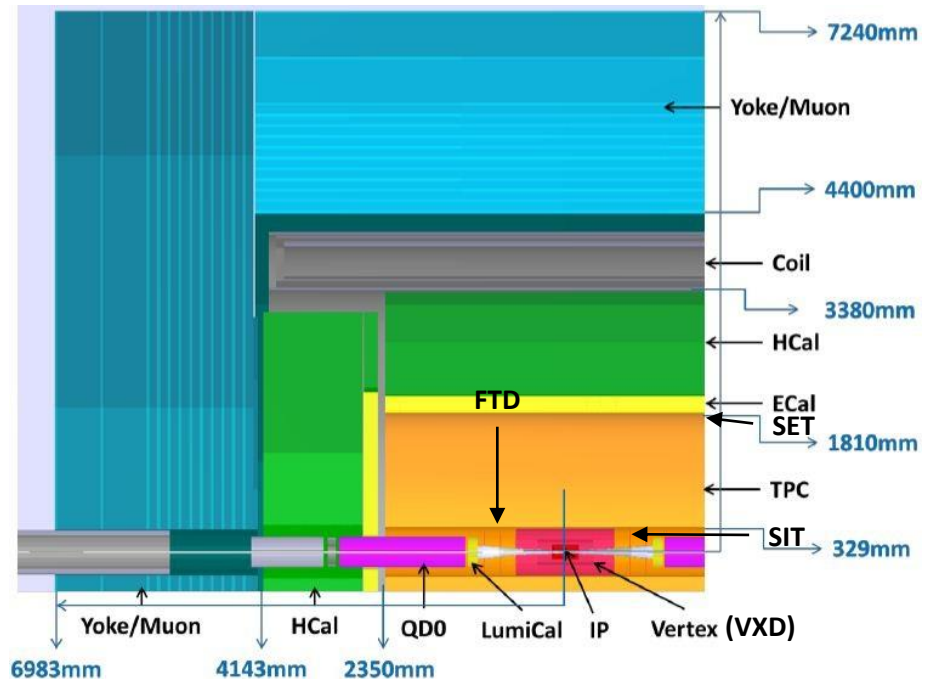


Introduction

- For simplicity, the CEPC detector started from ILDC, 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 software is taken as quick starting.

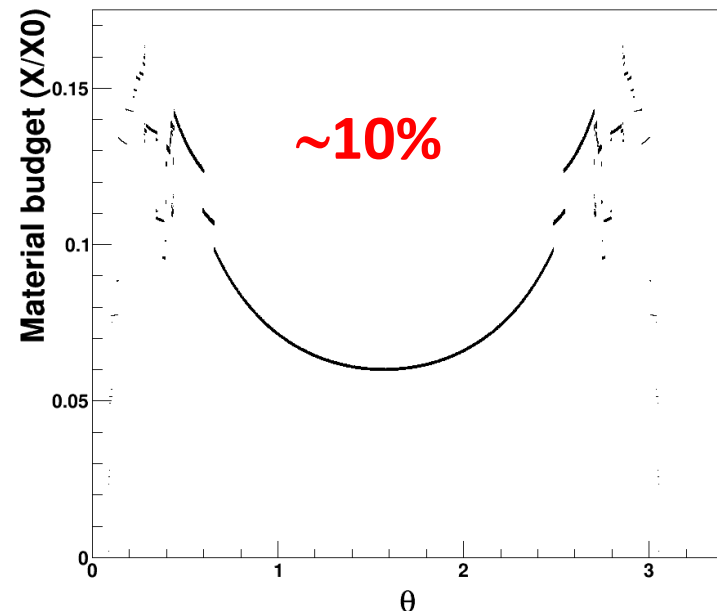
- Mokka
- Marlin

Tracker in CEPC v1

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

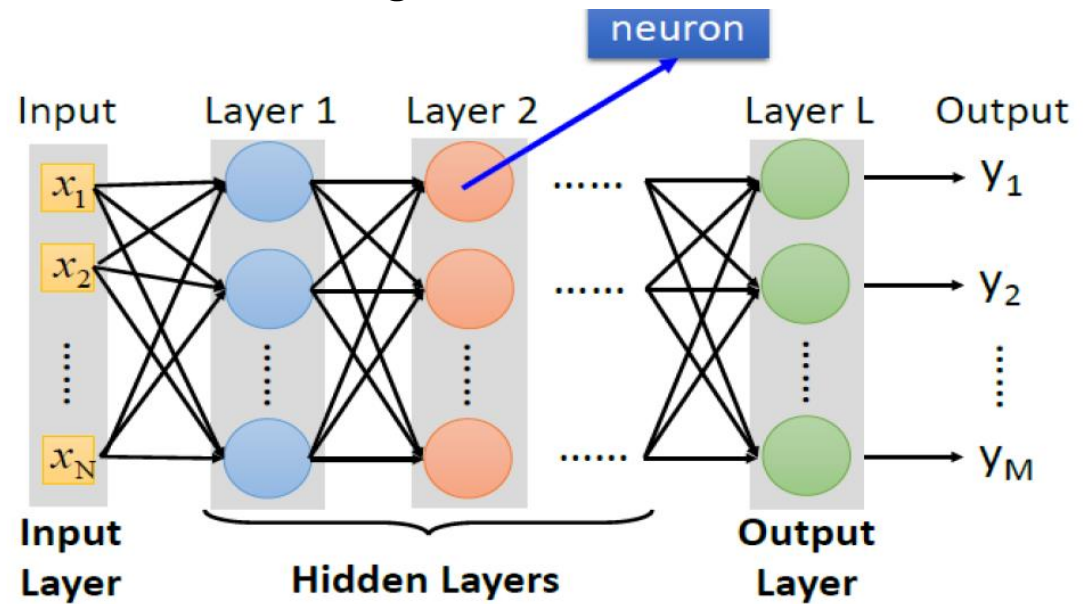
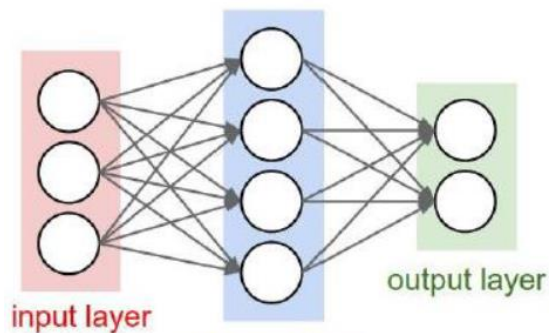
Based on this version of CEPC, some modification of one or more sub-detector and comparison their performance have been done.

➤ More needed!



Flavor Tagging

- Based on TMVA **B**oosted **D**ecision **T**rees
- Use **D**eep **N**eural **N**etwork
- **T**ensor**F**low 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



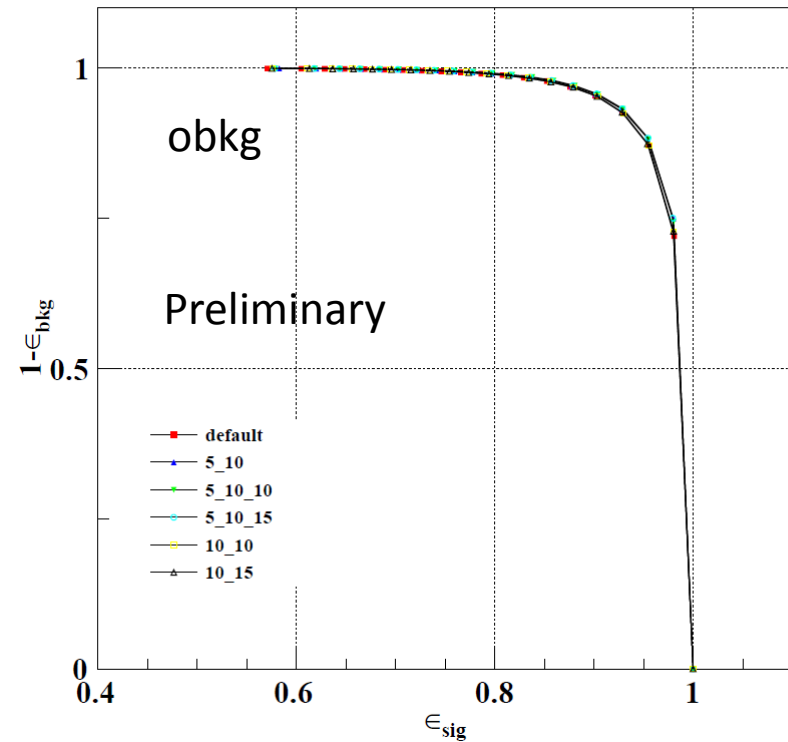
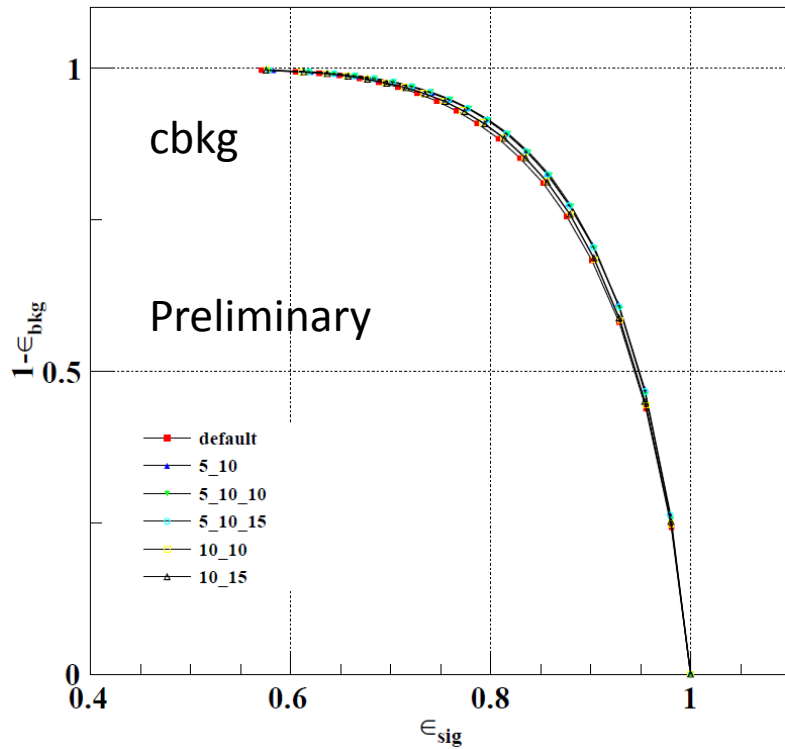
Deep means many hidden layers

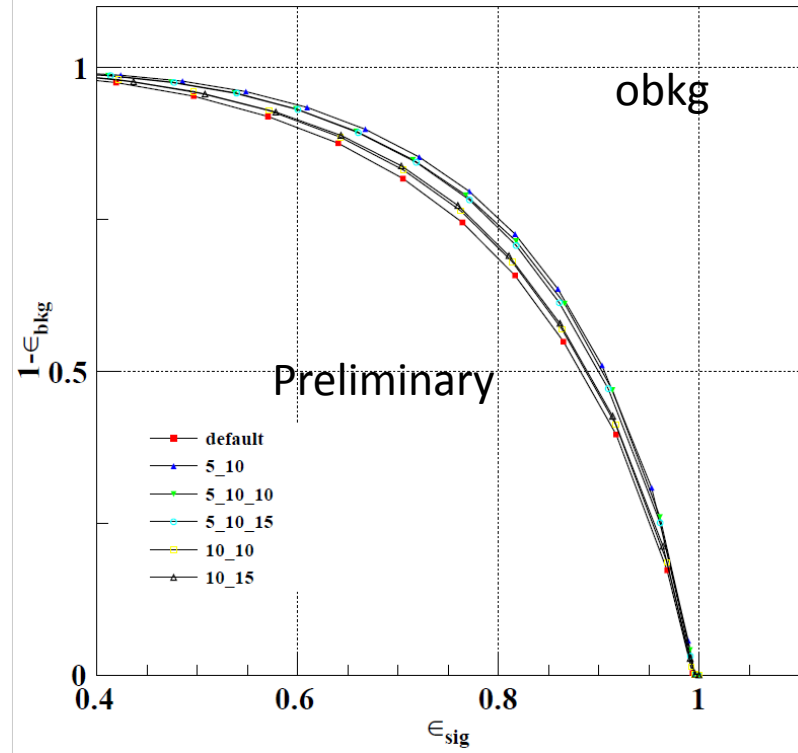
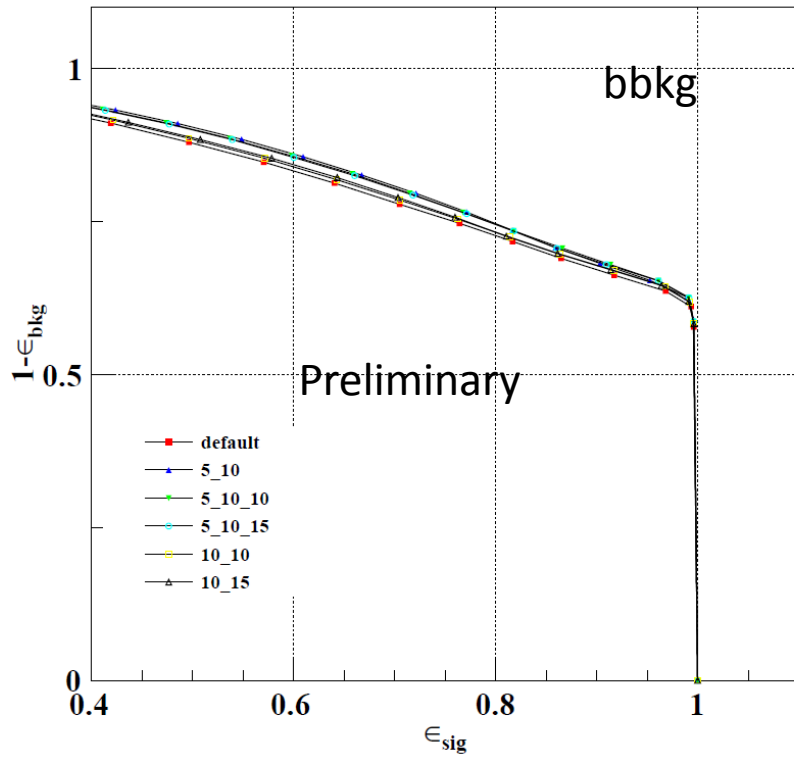


Performance for Flavor Tag

Vertex detector optimization:

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





Tracking for TPC

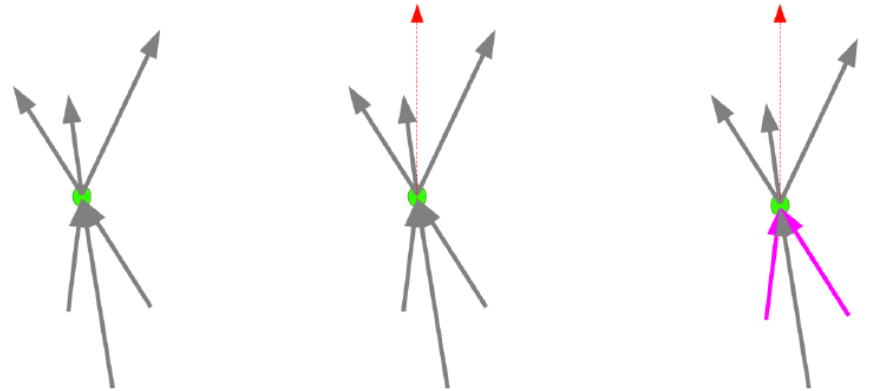


- **Clupatra** package include track finding and fit, which is being used for physical study at **CEPC**.
- New tracking algorithms are also being developed, such as **ArborTrk**.
 - Arbor for track finding
 - ArborTrk for fit and other steps
- **Arbor** is a clustering algorithm used for calorimeter reconstruction at **CEPC**. [[arxiv:1403.4784](https://arxiv.org/abs/1403.4784)]
 - Not need energy of hits
 - The hit structure of **TPC** is similar with calorimeter: hits have neighbor at any direction.

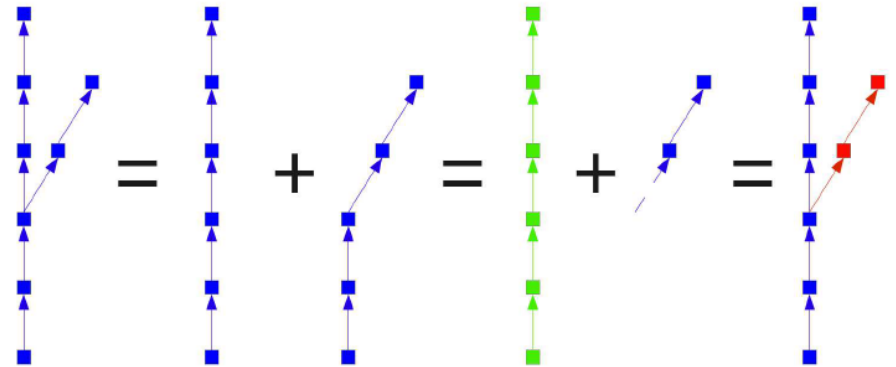
Arbor

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

- Clean connectors of hits \Rightarrow tree
 - One connector for each hit



- Separate tree \Rightarrow branch

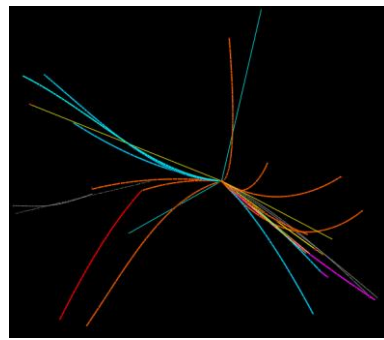


The branch composed by hits in TPC will just be candidate track.

➤ KalTest

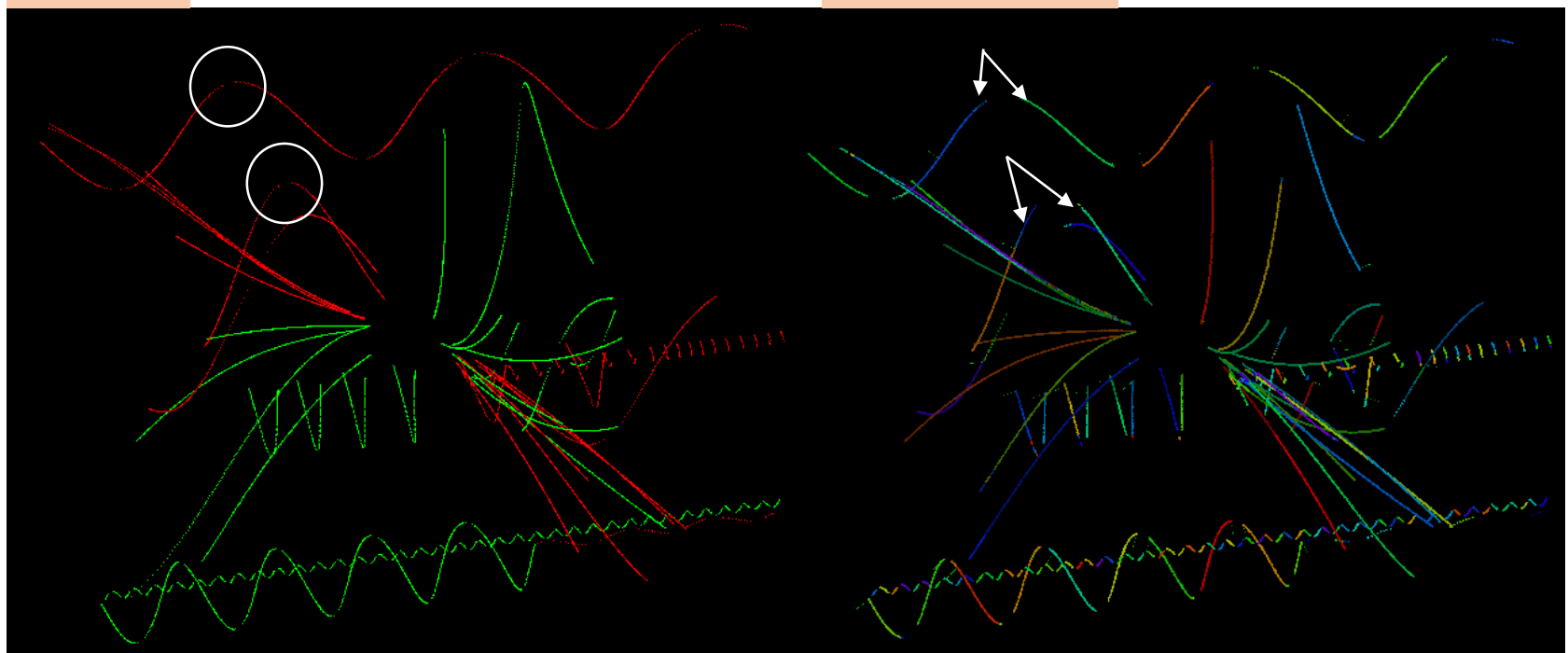
$e^+e^- \rightarrow \nu\nu H, H \rightarrow \text{anything} (\nu\nu H)$

Example



TPC hits

Arbor branches



MC Truth Match Algorithm

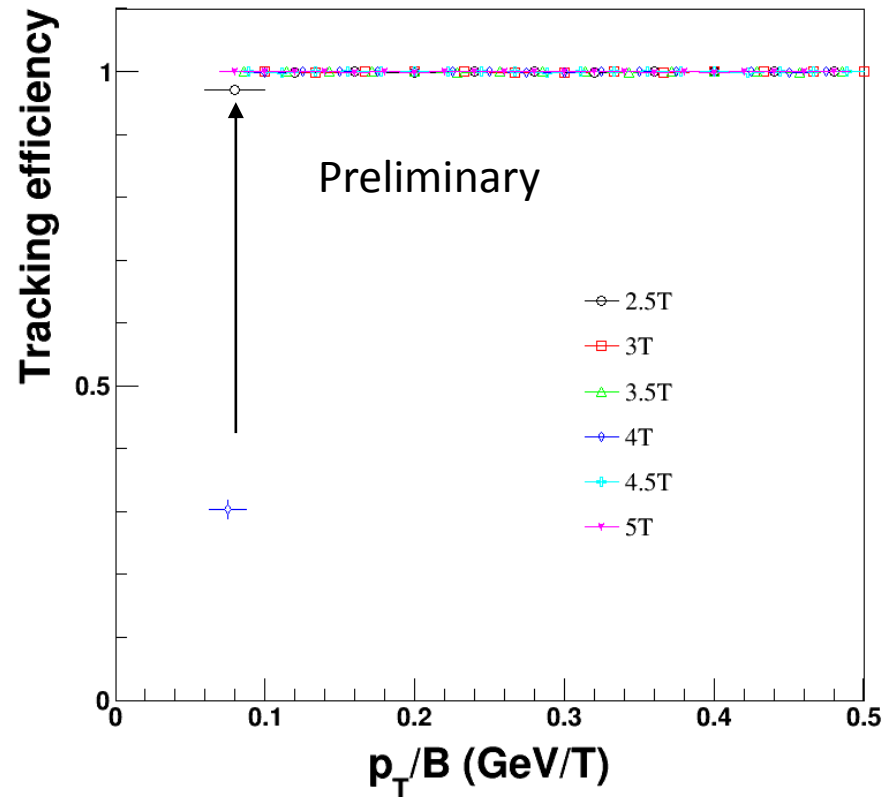
Based on LCIO

- 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.

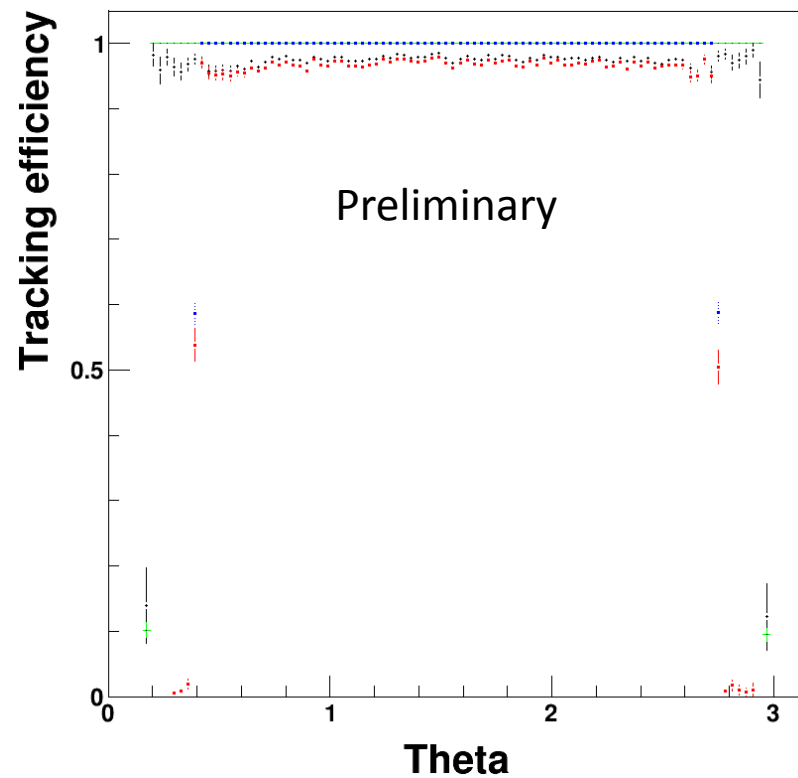
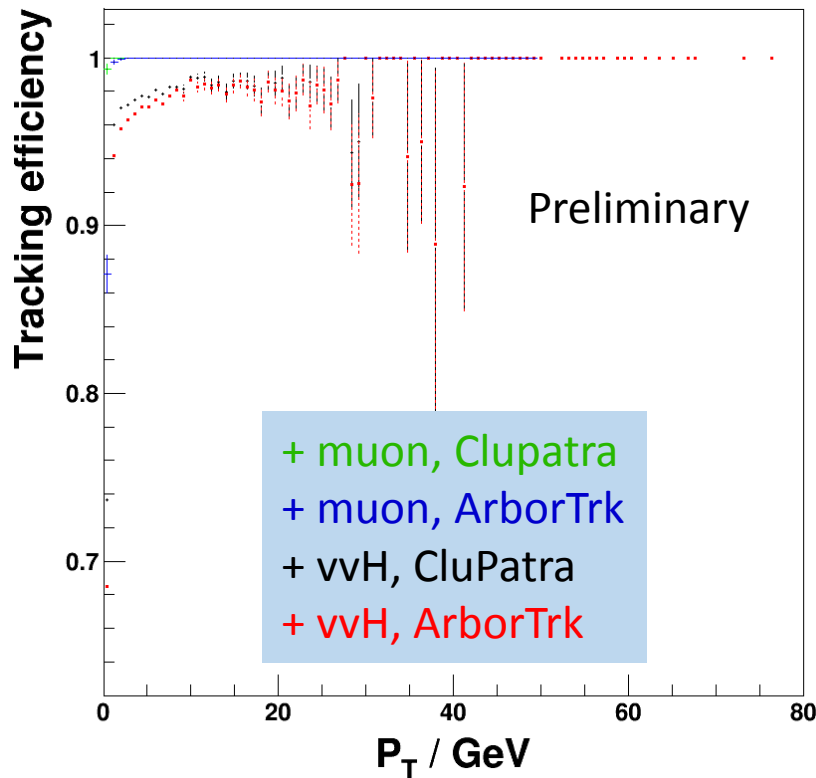
Performance at Low Momentum

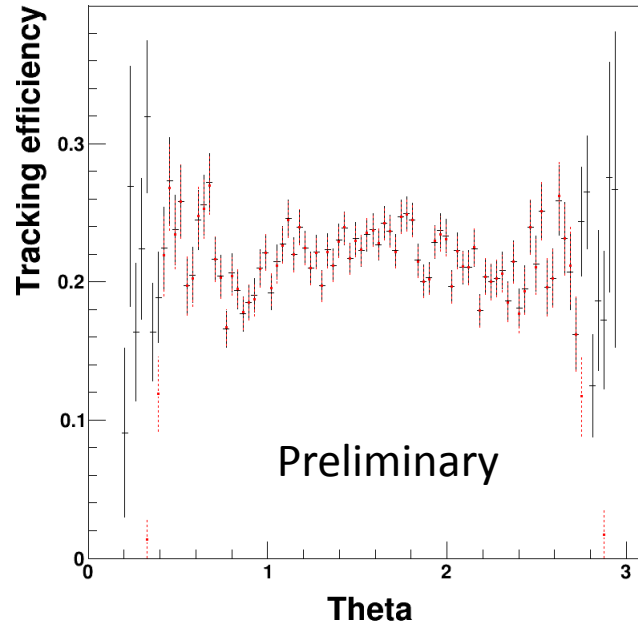
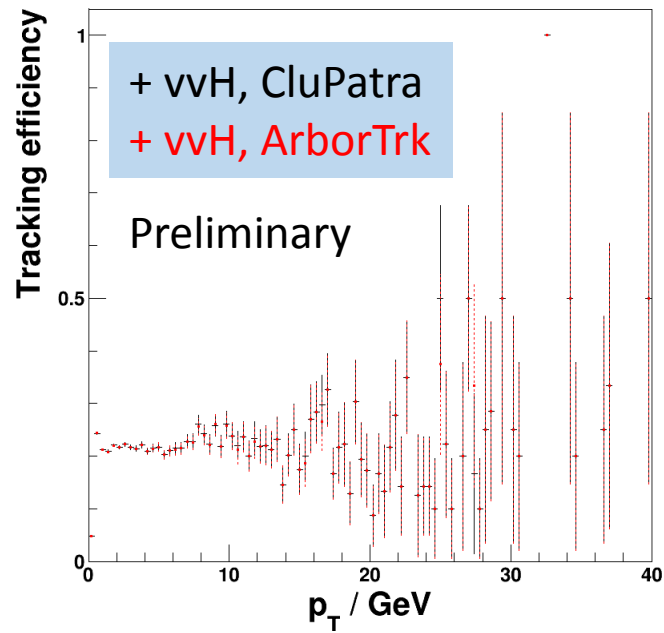
- Single muon
- The low limit of transverse momentum for track reconstruction is about $0.08 \times B(\text{Tesla}) \text{ GeV}$
 - 280MeV at 3.5T



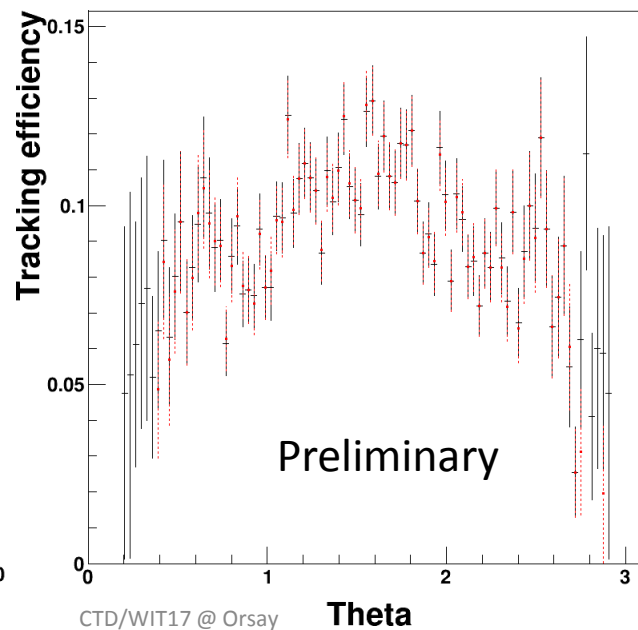
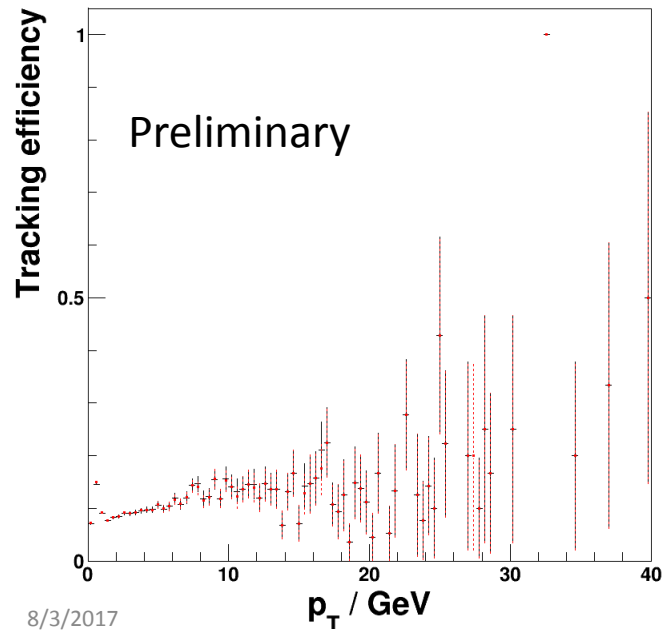
Tracking Efficiency

- 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 $1/\sin\theta$





Vertex of particles:
Generated in r
● 16-329mm region

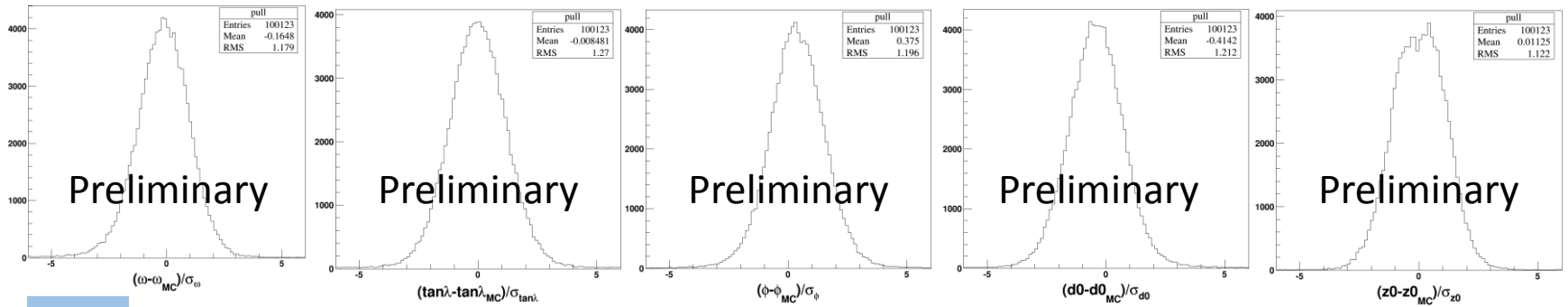


● >329mm

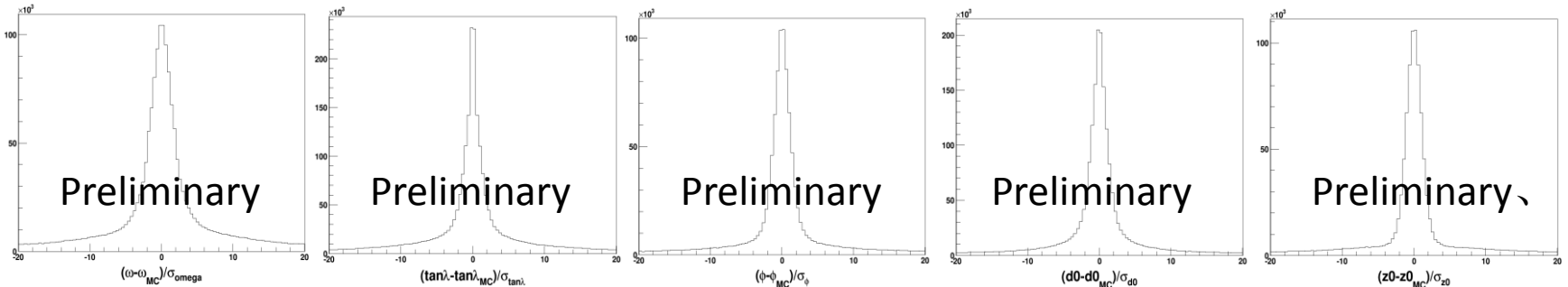
Pull Distribution

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

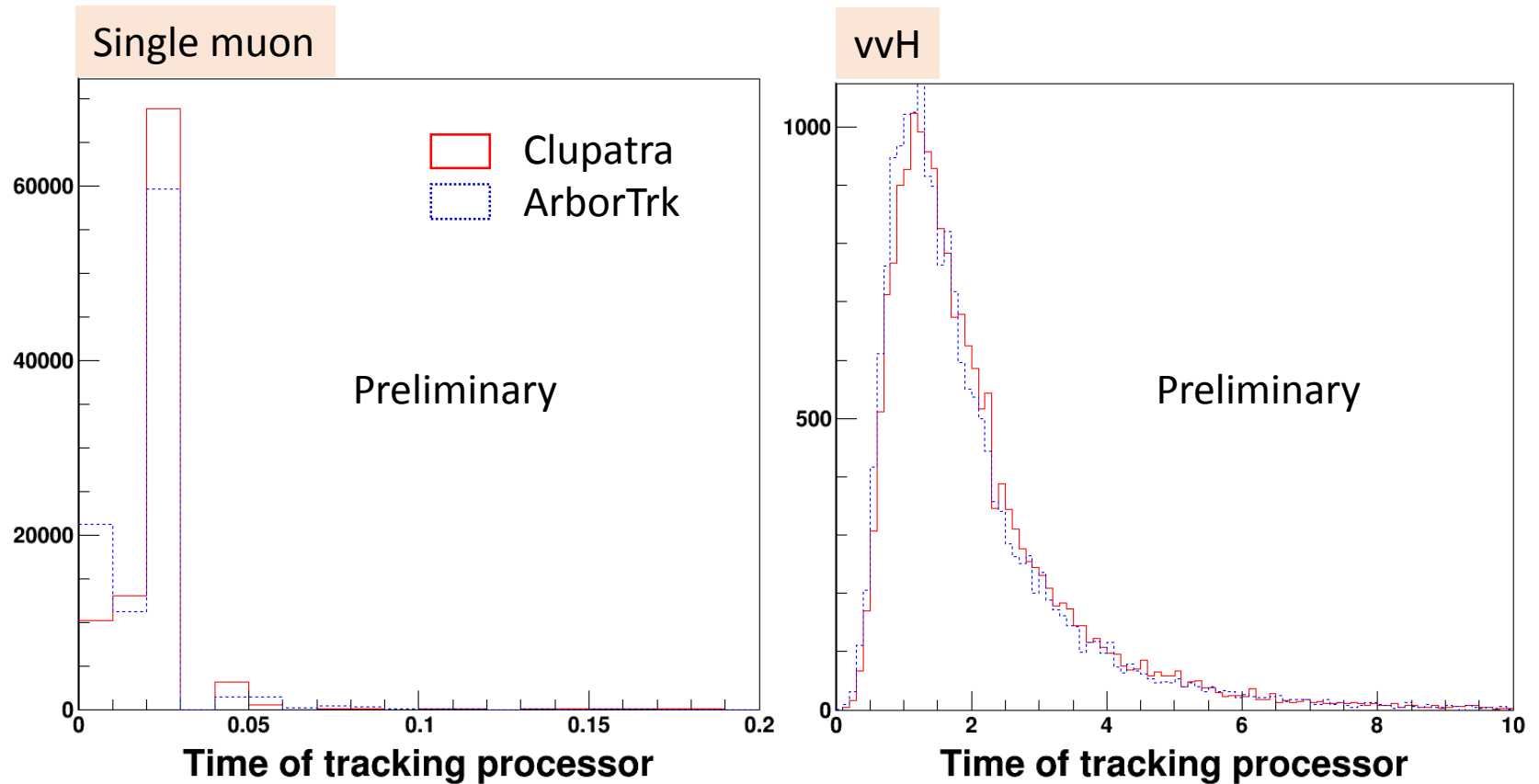
Single muon (0.5GeV,49.5GeV)



vvH

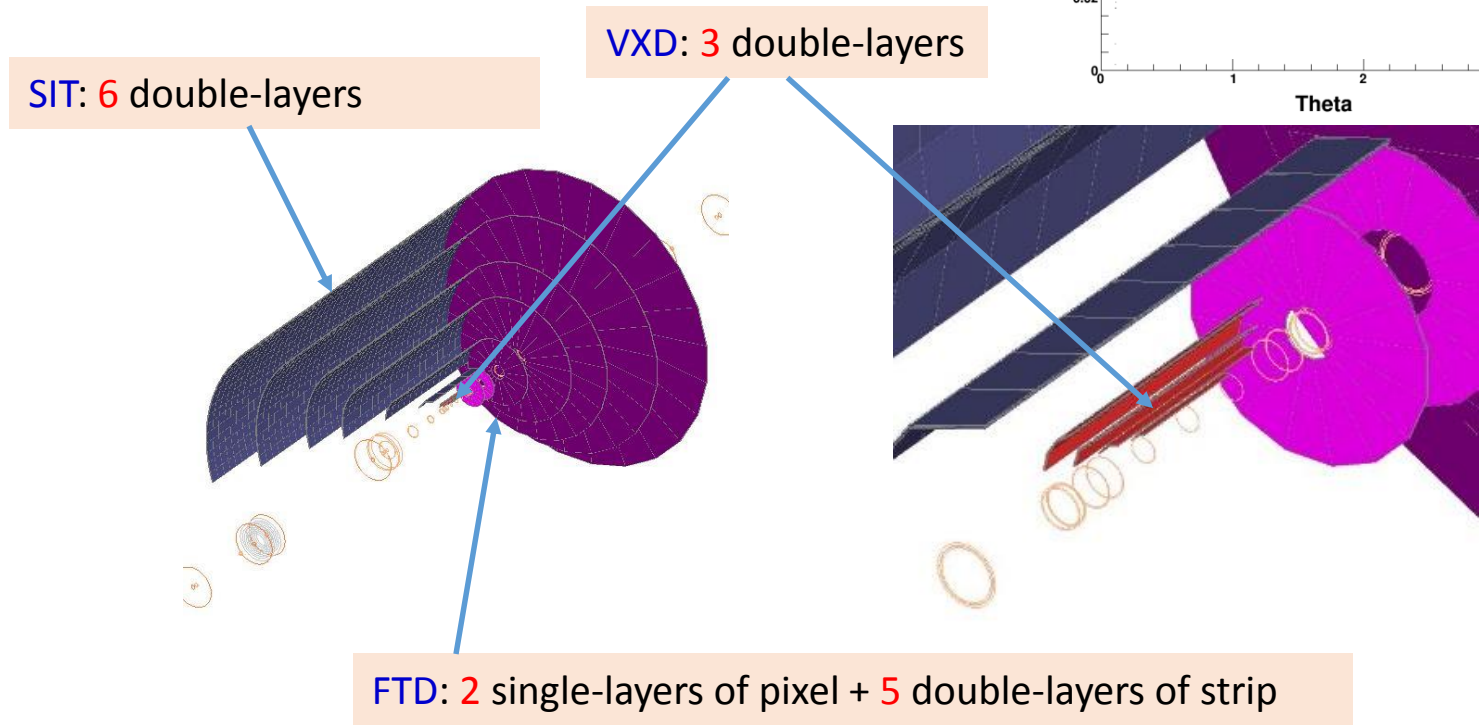
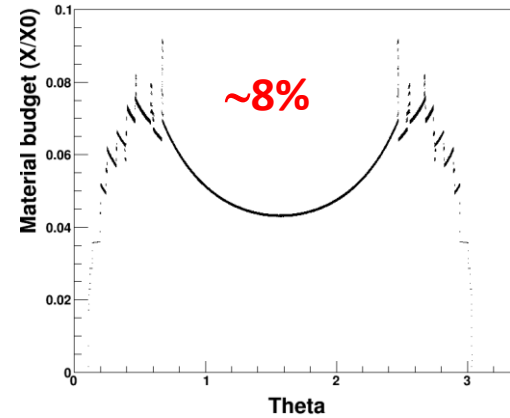


Time



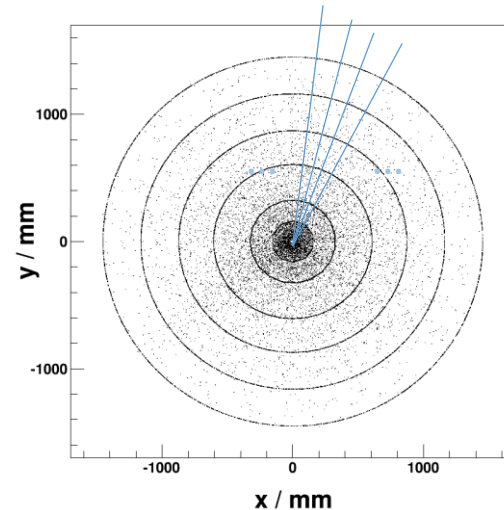
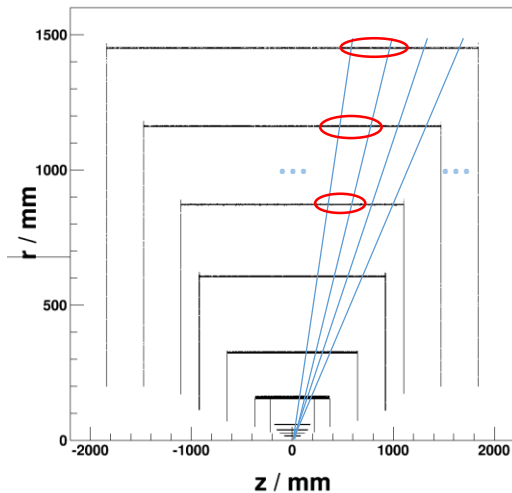
Full Silicon-based Tracker

- Preliminary design by Weimin YAO (BNL)



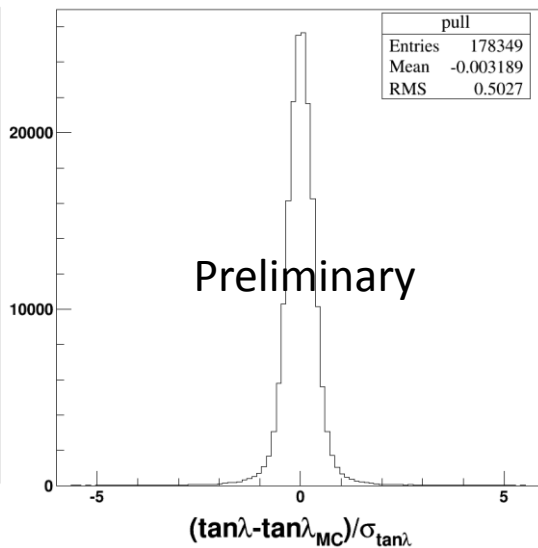
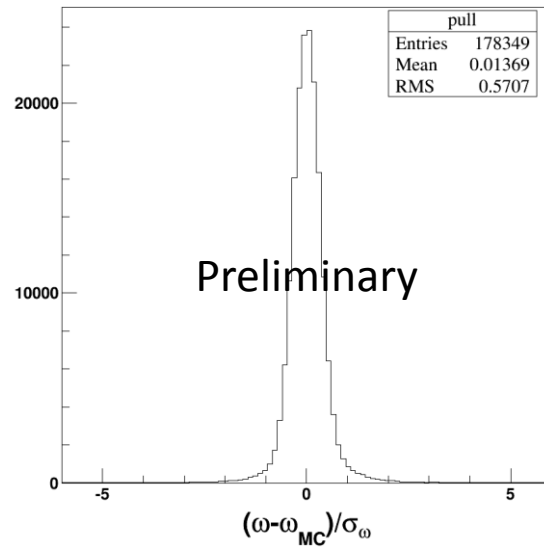
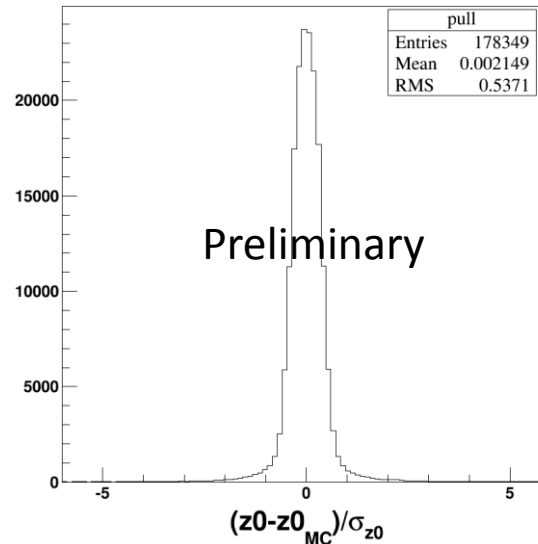
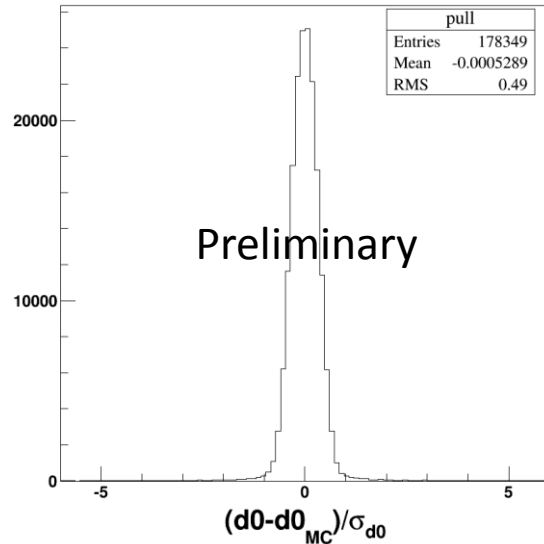
SiliconTracking

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

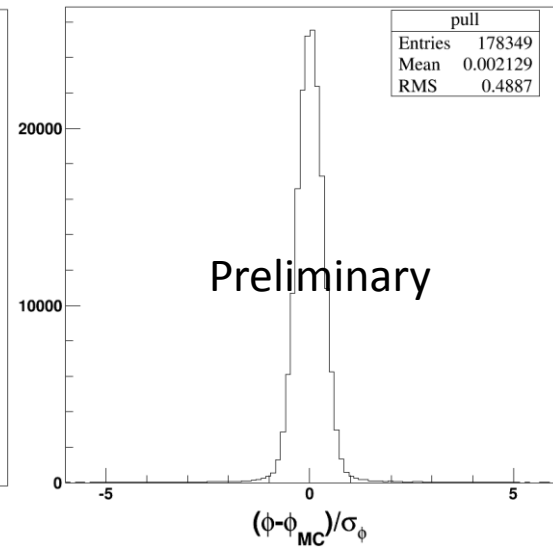


- This algorithm works well for only **VXD** and one **SIT**, now it is tried for more **SITs**. Some issues will happen.

Pull Distribution

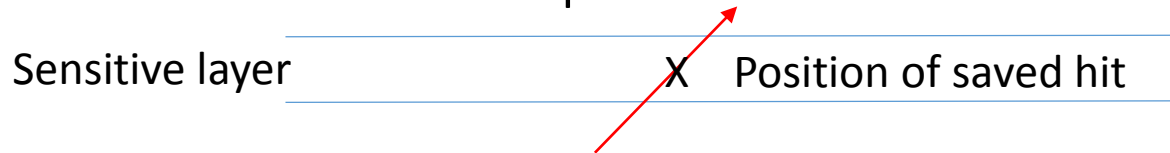


The pull distributions are narrow than (0,1) normal distribution, about half of, need to be fixed.



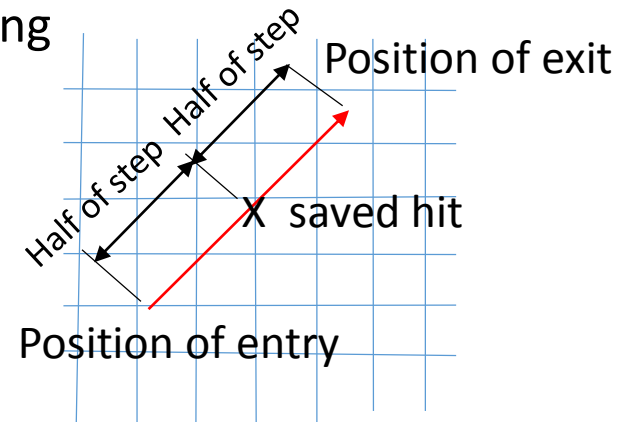
Digitization for silicon-tracker

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



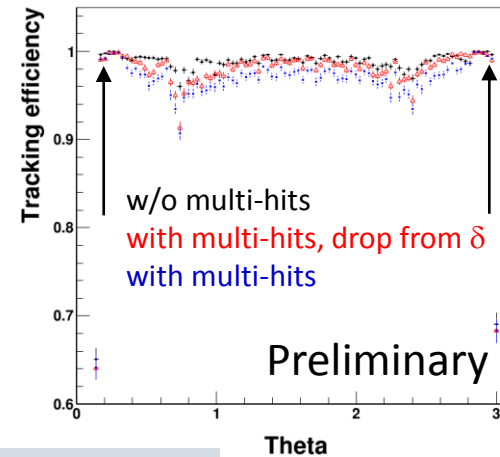
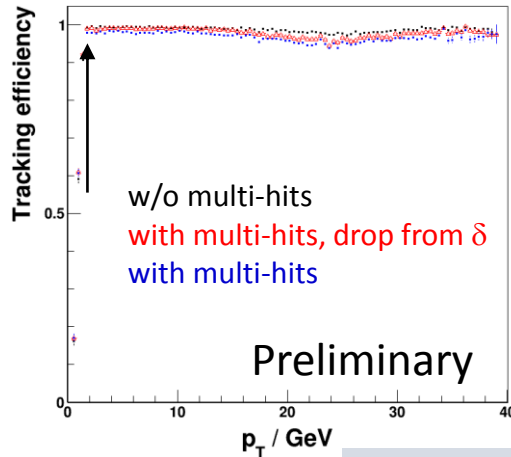
- Simple digitization in **Marlin** process

- 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.

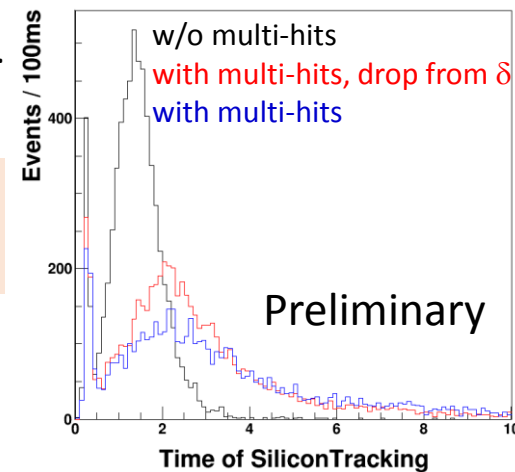


$e^+e^- \rightarrow ZH$ ($Z \rightarrow \mu^+\mu^-$, $H \rightarrow$ anything)

- 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



- 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