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CEPC

Vertex optimization and τ-finding optimization at CEPC

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Outline:part1

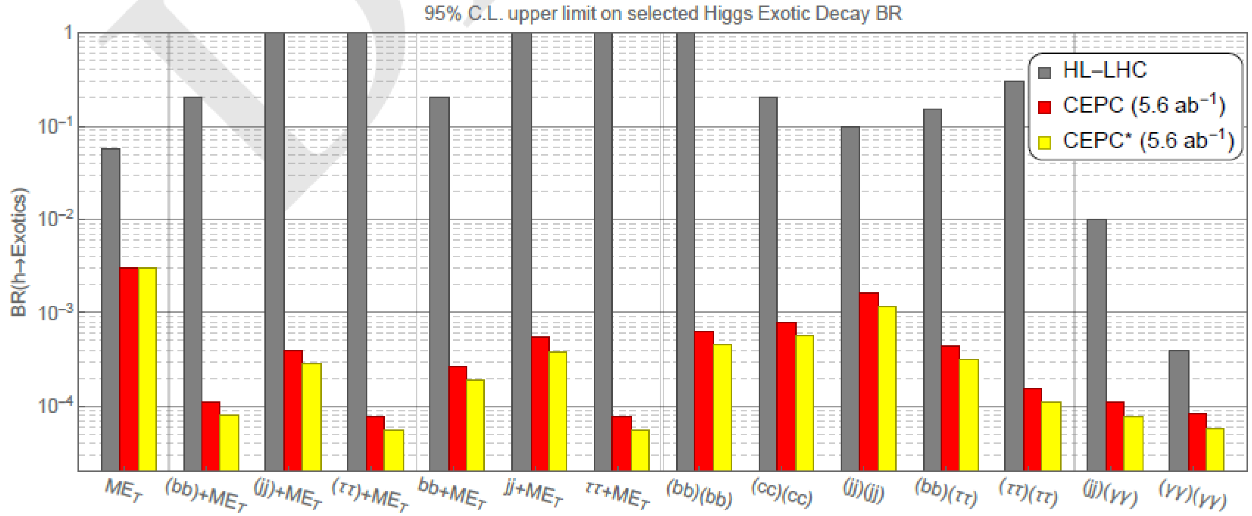
- Introduction
- Vertex baseline design
- Analytic method and simulation setup
- The flavor tagging performance and the measurement of Br (H -> bb) and Br (H -> cc)
- The τ finding performance and Br (H -> ττ) measurement

Introduction

- H -> bb, cc and ττ is the core part of the CEPC Higgs program
- Vertex system with high impact parameter resolution is crucial

Table 6.1 Required performance of the CEPC sub-detectors for critical benchmark Higgs processes.

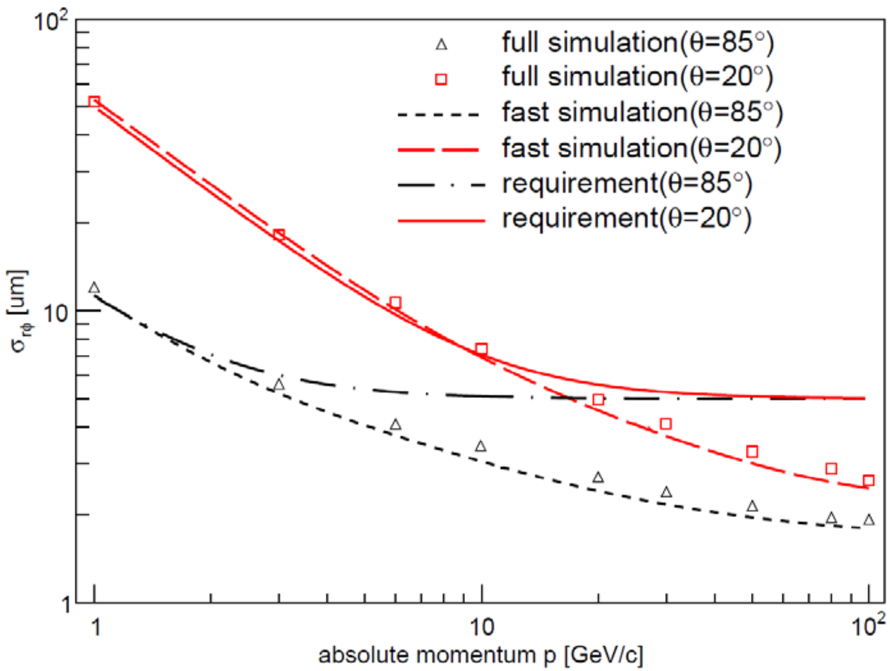
Physics Process	Measured Quantity	Critical Detector	Required Performance
$ZH \to \ell^+\ell^- X$	Higgs mass, cross section	Tracker	$\Delta(1/p_T) \sim 2 \times 10^{-5}$
$H \to \mu^+\mu^-$	$\mathrm{BR}(H \to \mu^+\mu^-)$		$\oplus 1 \times 10^{-3}/(p_T \sin\theta)$
$H \to b\bar{b},\ c\bar{c},\ gg$	$\mathrm{BR}(H \to b\bar{b},\ c\bar{c},\ gg)$	Vertex	$\sigma_{r\phi} \sim 5 \oplus 10/(p \sin^{3/2}\theta)\ \mu\mathrm{m}$
$H \to q\bar{q},\ VV$	$\mathrm{BR}(H \to q\bar{q},\ VV)$	ECAL, HCAL	$\sigma_E^{\mathrm{jet}}/E \sim 3-4\%$
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\sigma_E \sim 16\%/\sqrt{E} \oplus 1\%$ (GeV)



Vertex baseline design

- ILD-like silicon pixel detector system
- Baseline design requirement

$$\sigma_{r\phi} = 5 \oplus \frac{10}{p(GeV)sin^{3/2}\theta}$$



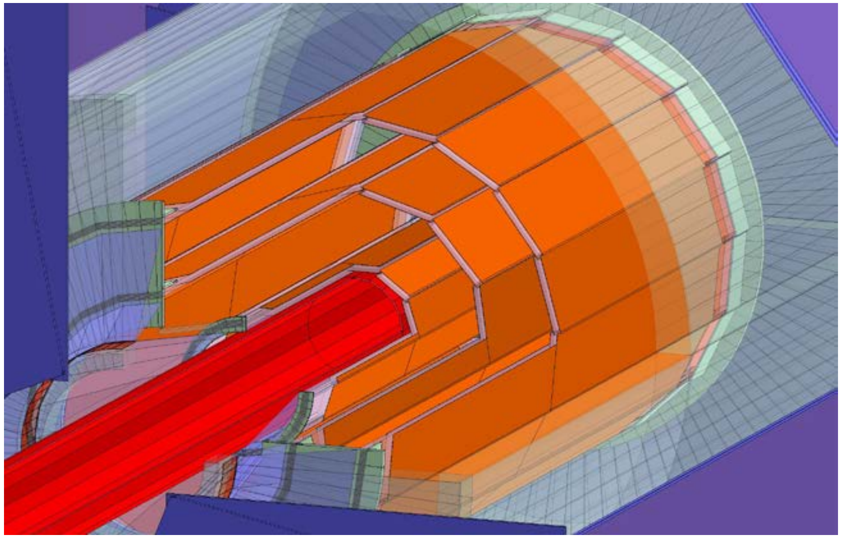
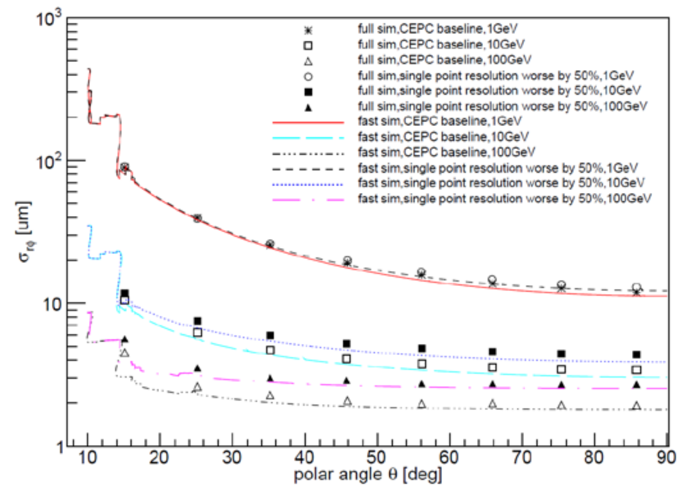


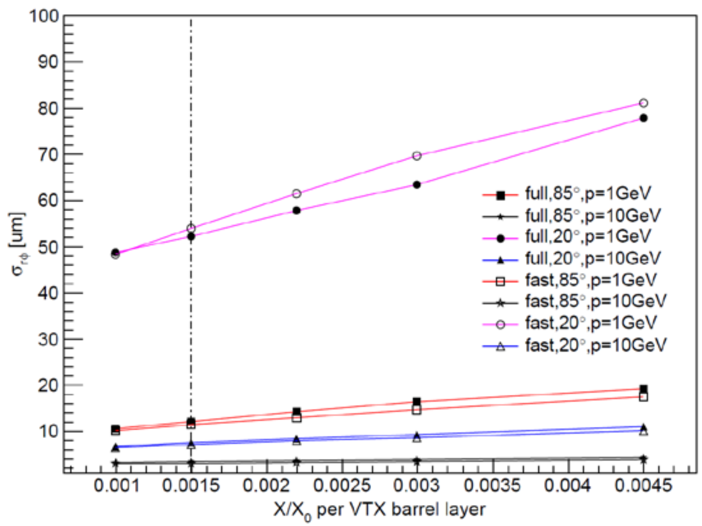
Table 1. Design parameters of the CEPC vertex system.

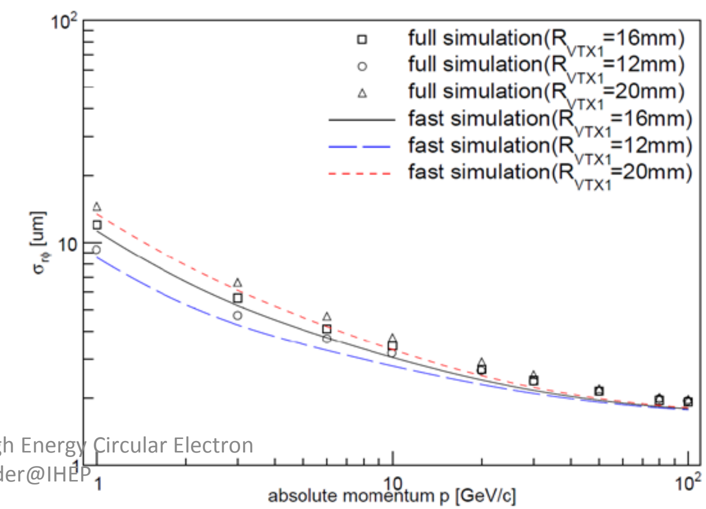
	R(mm)	| Z |(mm)	$\sigma(\mu m)$	material budget
Layer 1	16	62.5	2.8	$0.15\%/X_0$
Layer 2	18	62.5	6	$0.15\%/X_0$
Layer 3	37	125.0	4	$0.15\%/X_0$
Layer 4	39	125.0	4	$0.15\%/X_0$
Layer 5	58	125.0	4	$0.15\%/X_0$
Layer 6	60	125.0	4	$0.15\%/X_0$

Key geometry parameters

- The influence of the geometry parameters on the impact parameter resolution
  - Material budget
  - Spatial resolution
  - Inner radius







Analytic method and simulation setup

- Samples
  - Only the SM signal and the most relevant backgrounds are considered
- Full simulation tools
  - Whizard V1.9.5: MC events generator
  - Mokka-C: Geant4 based simulator
  - Arbor: CEPC reconstruction tool
  - LCFIPLUS: jet flavor identification
- Samples->Full simulation with different geometries->event selection ->signal efficiency and purity
  - $\epsilon \cdot p$ is a comparison benchmark

$$\frac{\delta_{\mu}}{\mu} \propto \frac{\sqrt{S+B}}{S} = \sqrt{\frac{1}{S}}\sqrt{\frac{S+B}{S}} \propto \frac{1}{\sqrt{\epsilon \cdot p}}.$$

Geometry scan range

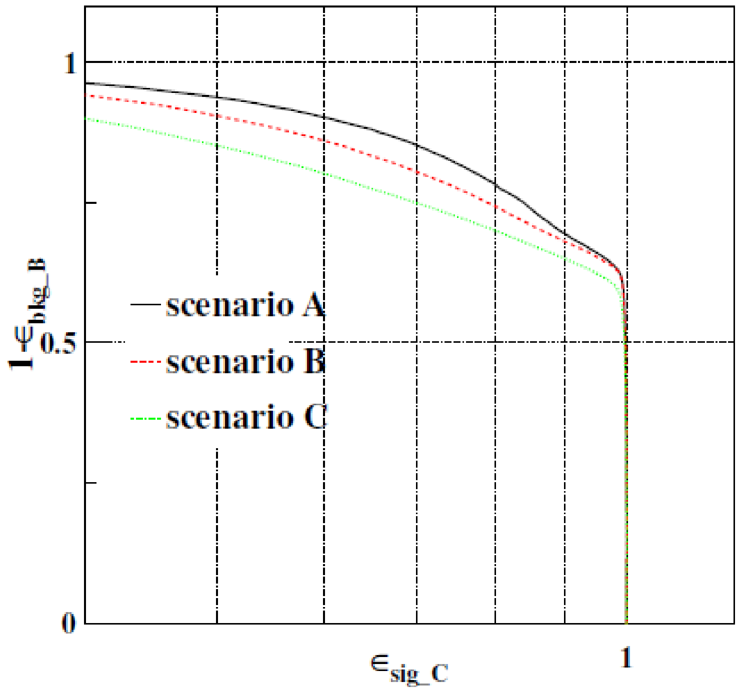
- Conservative case
  - The parameters at upgraded ALICE ITS are used
- Aggressive case
  - the parameters are half values of the baseline design

Table 2. Reference geometries

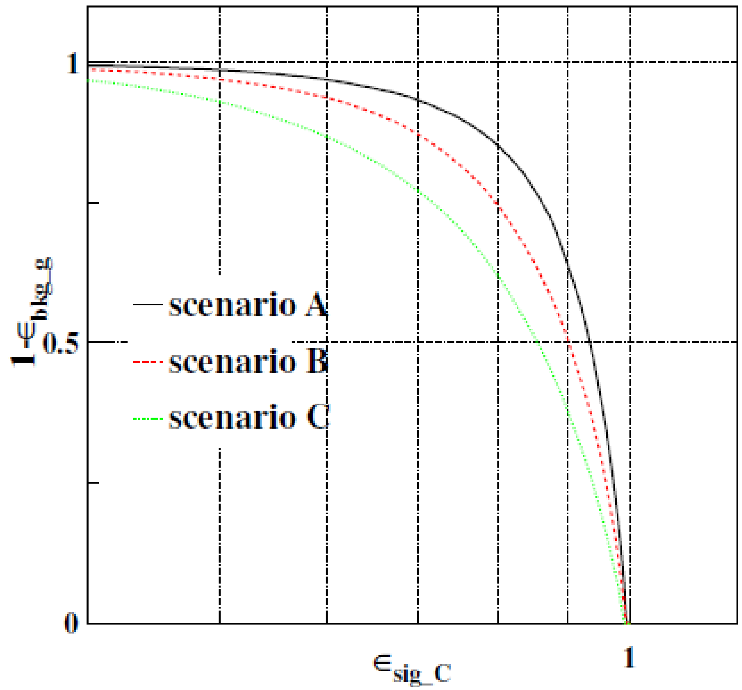
	Scenario A (Aggressive)	Scenario B (Baseline)	Scenario C (Conservative)
Material per layer/X_0	0.075	0.15	0.3
Spatial resolution/μm	1.4 - 3	2.8 - 6	5 - 10.7
R_{in}/mm	8	16	23

Flavor tagging performance

- Only di-jet final modes (bb, cc, gg) are considered
- ROC curve at different scenarios
  - Scenario A will have better c-tagging performance



(a) b background



(b) g background

Br (H -> cc) measurement

- The purity and ϵ·p as a function of the signal efficiency
  - relatively flat curve of the ϵ·p
  - The maximum value of the ϵ·p: 0.095 (ϵ:46%, p:21%)
- ϵ·p at different scenarios
  - A significant improvement for scenario A
  - A->B: 41%, C->B:-22%

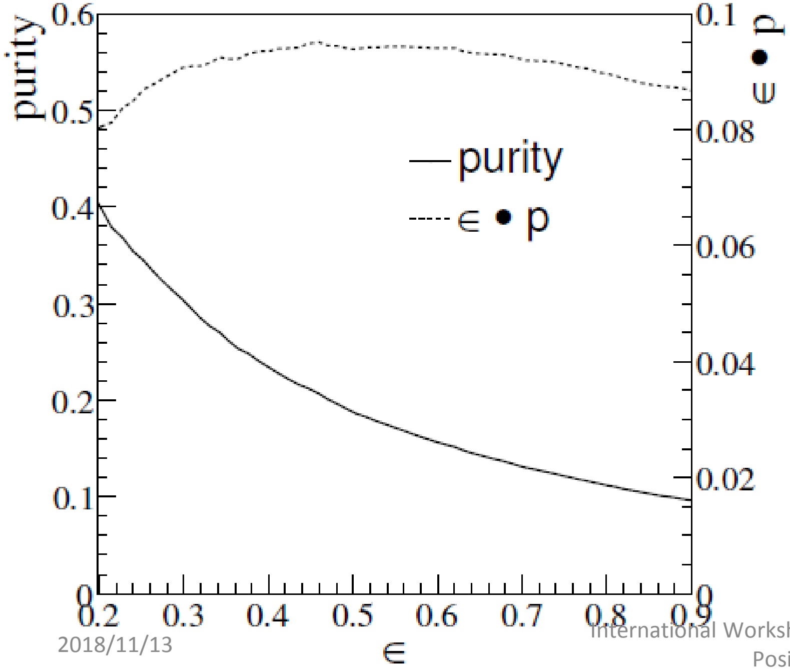
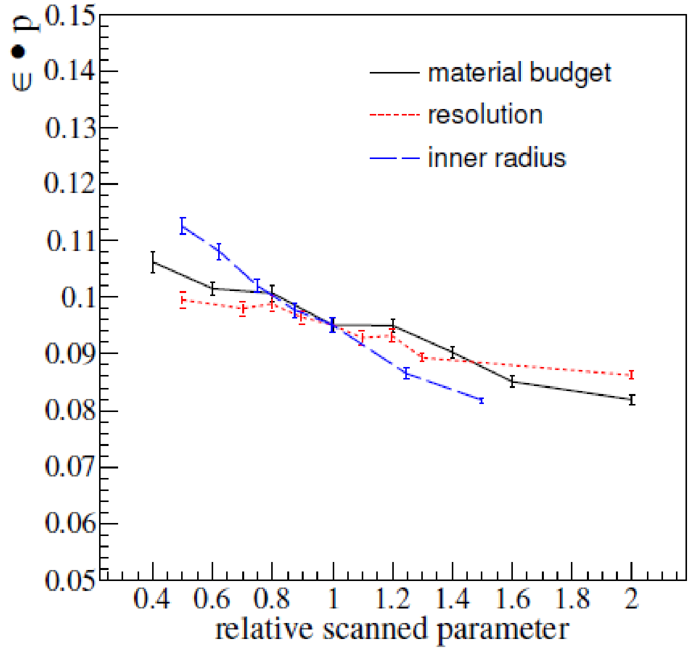


Table 3. $\epsilon \cdot$ p comparison for the $Br(H \to c\bar{c})$ measurement.

	Scenario A	Scenario B	Scenario C
$\epsilon \cdot$ p	0.133±0.002	0.095±0.001	0.078±0.001

Br (H -> cc) measurement

- The ϵ·p as a function of the scanned geometry parameters
  - Inner radius is the most sensitive parameter



$$\epsilon \cdot \mathrm{p} = 0.095(1 - 0.14\frac{\Delta x_{material}}{x_{material}})(1 - 0.09\frac{\Delta x_{resolution}}{x_{resolution}})(1 - 0.23\frac{\Delta x_{radius}}{x_{radius}})$$

Br (H -> bb) measurement

- The purity and ϵ·p as a function of the signal efficiency
  - Decent result for b-tagging
  - The maximum value of the ϵ·p: 0.914 (ϵ:97%, p:94%)
- ϵ·p at different scenarios
  - not demanding in the vertex optimization
  - A->B: 1%, C->B:-1.5%

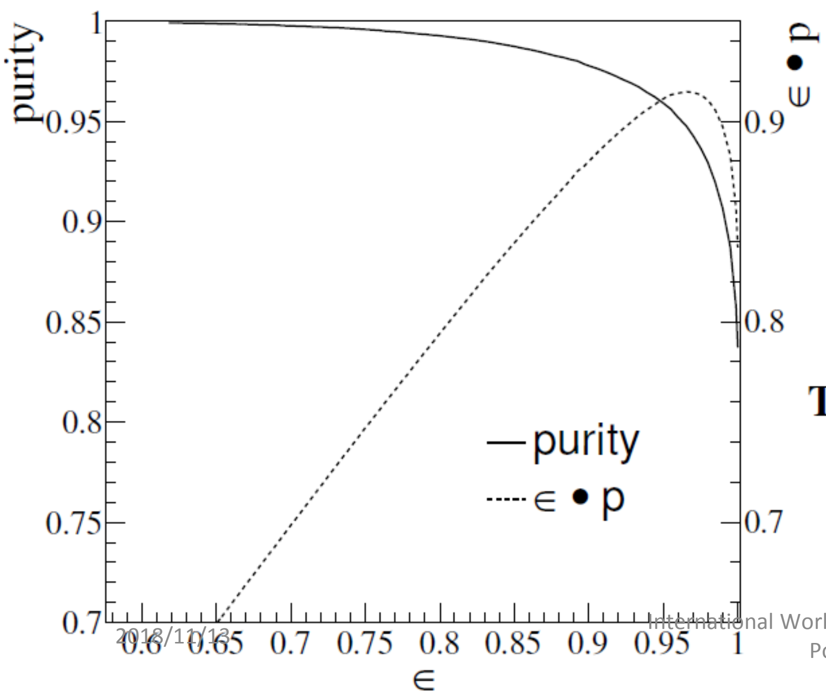


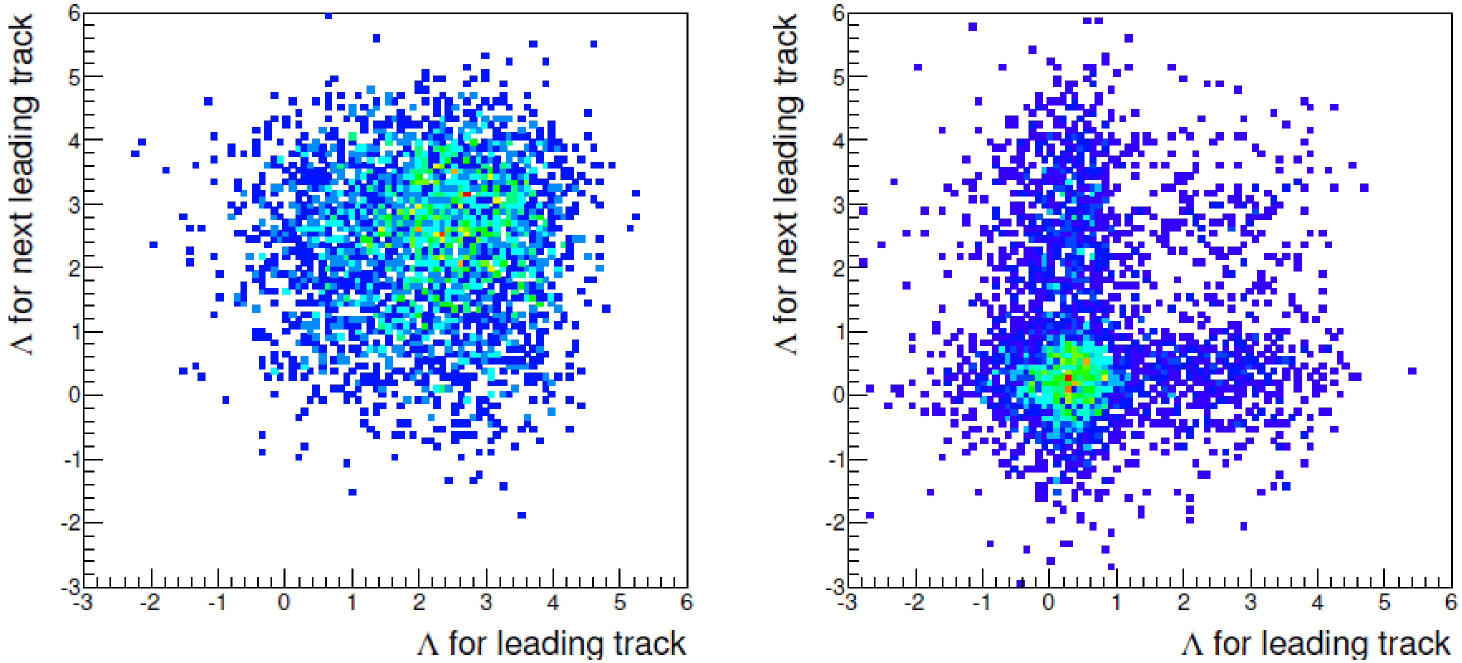
Table 4. $\epsilon \cdot$ p comparison for the $Br(H \to$ bb) measurement.

	Scenario A	Scenario B	Scenario C
$\epsilon \cdot$ p	0.925±0.001	0.914±0.001	0.900±0.001

Br (H -> ττ) measurement

- Samples
  - Signal: H -> ττ
  - Background: H -> WW -> llνν, l = e μ τ
- Different impact parameter for sig and bkg

$$\Lambda = log_{10}[(\frac{D_0}{\sigma_{d_0}})^2 + (\frac{Z_0}{\sigma_{z_0}})^2].$$



(a) signal (b) background

Br (H -> ττ) measurement

- The purity and ϵ·p as a function of the signal efficiency
  - The maximum value of the ϵ·p: 0.71 (ϵ:80%, p:88%)
- ϵ·p at different scenarios
  - not crucial comparing to the Br (H -> cc) measurement.
  - A->B: 8%, C->B:-4%

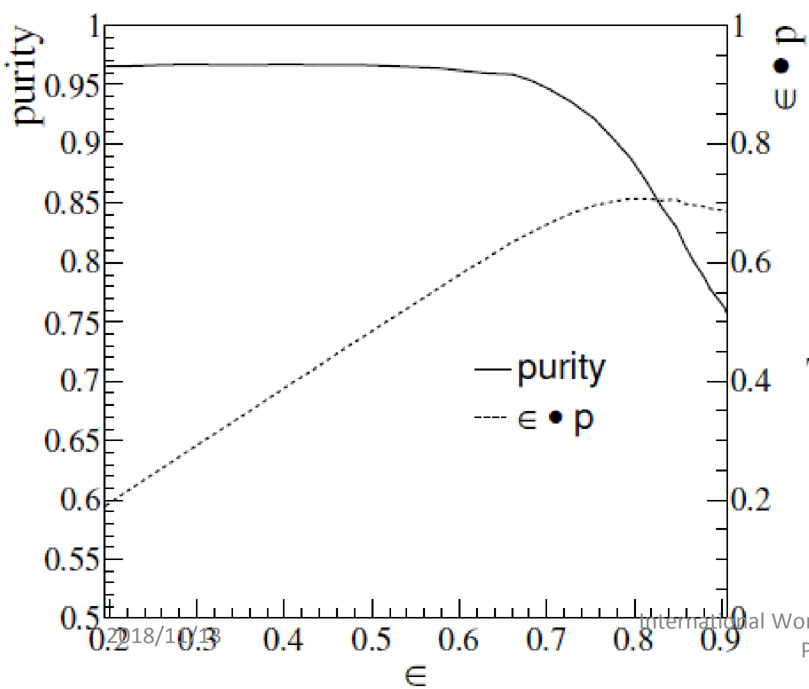


Table 5. $\epsilon \cdot$ p comparison for the $Br(H \rightarrow \tau^{+}\tau-)$ measurement.

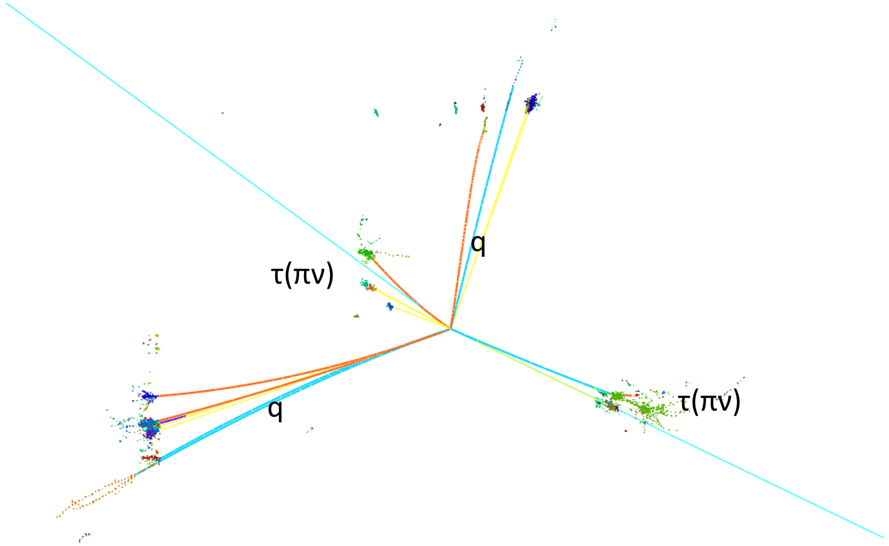
	Scenario A	Scenario B	Scenario C
$\epsilon \cdot$ p	0.77±0.01	0.71±0.01	0.68±0.01

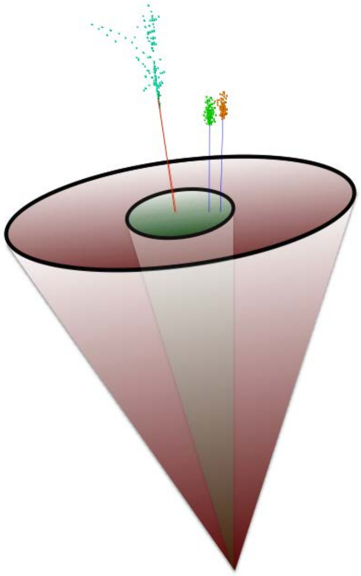
Outline:part2

- Introduction: Taurus and motivation
- Optimization method
- Parameter optimization
  - qqH -> ττ
  - WW -> qqτν

Introduction: Taurus

- Motivation
  - A τ finding algorithm is necessary to separate the tau candidate from hadronic decay
- Taurus
  - Two cone based algorithm
  - The initial version from Dan Yu[1)]

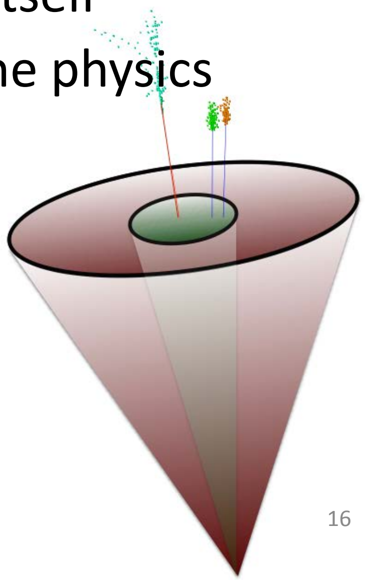




1) https://agenda.infn.it/getFile.py/access?contribId=91&sessionId=23&resId=0&materialId=slides&confId=14816

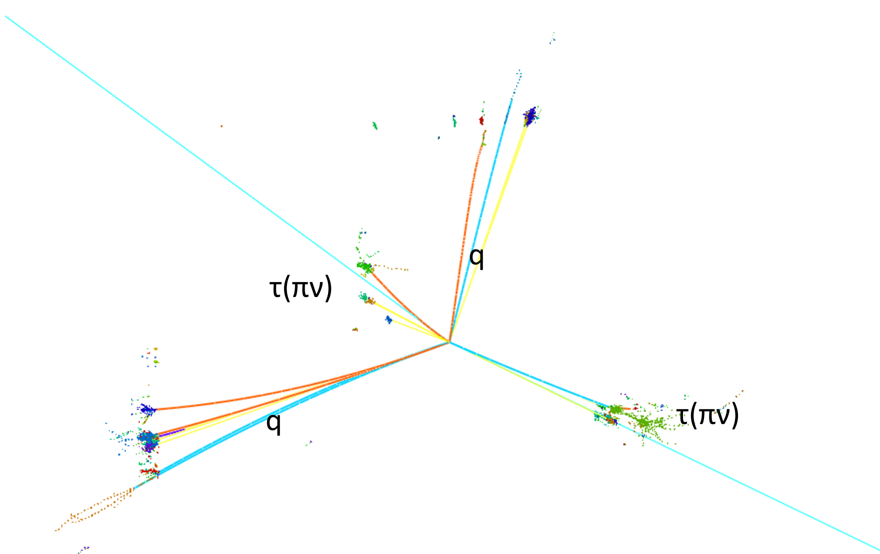
Optimization method

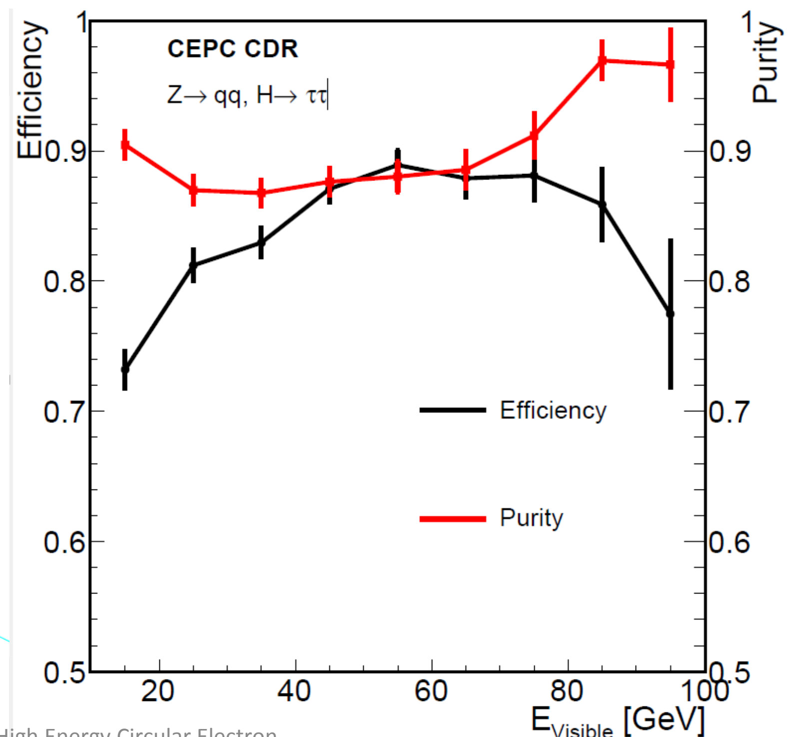
- Parameters
  - Leading Track Energy: algorithm starts with a seed track with its energy above the LTE
  - smallTrackCone: charged and neutral particles in the small cone form the tau candidate
  - Invariant mass: is required to be in the range of 0.01--2GeV
  - TrackCone: a large cone is defined to make sure the τ candidate is isolated
  - E_par: the total energy in smallTrackCone divided by the energy in TrackCone
  - Multiplicity: the number of charged particle and photon
- Invariant mass, Multiplicity are related to physics of τ itself
- smallTrackCone, TrackCone and E_par are related to the physics channel of τ production
  - Need to be optimized for different physics channels
- Parameter scan method is applied
  - ϵ·p is a optimization benchmark



Parameter optimization

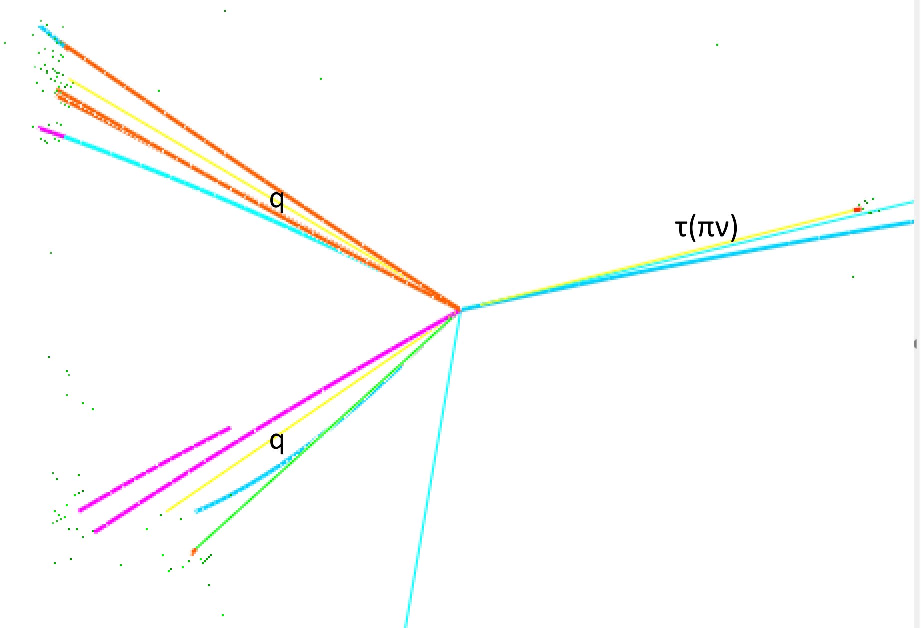
- Efficiency of 83.2%, purity of 88.4% is achieved @Sample: qqH-> ττ
  - TrackCone 0.31
  - smallTrackCone 0.12
  - E_par 0.92

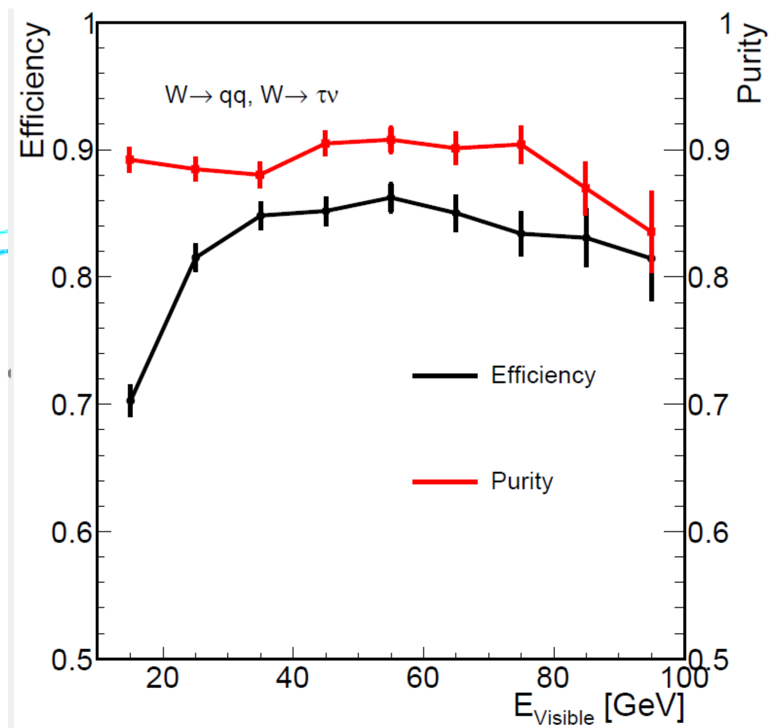




Parameter optimization

- Efficiency of 81.5%, purity of 89.2% is achieved @Sample: WW->qqτν
  - TrackCone 0.46
  - smallTrackCone 0.15
  - E_par 0.95





Summary:part1

- Br (H -> bb) is not really sensitive to the vertex design
  - A->B: 1%, C->B:-1.5%
- Br (H -> cc) is extremely sensitive to the vertex design
  - A->B: 41%, C->B:-22%
  - Inner radius is the most sensitive parameter
- Br (H -> ττ) measurement has a medial dependence on the vertex geometry
  - A->B: 8%, C->B:-4%

Table 2. Reference geometries

	Scenario A (Aggressive)	Scenario B (Baseline)	Scenario C (Conservative)
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R_{in}/mm	8	16	23

Table 6. $\epsilon \cdot$ p comparison for all three benchmarks.

Benchmark	Scenario A	Scenario B	Scenario C
$Br(H \to c\bar{c})$	0.133±0.002	0.095±0.001	0.078±0.001
$Br(H \to b\bar{b})$	0.925±0.001	0.914±0.001	0.900±0.001
$Br(H \to \tau^+\tau^-)$	0.77±0.01	0.71±0.01	0.68±0.01

Summary:part2

- A general τ finding algorithm Taurus is developed and the performance is evaluated and optimized
- Taurus are optimized for different physics channels
  - qqH-> ττ, WW->qqτν
  - An efficiency of about 80% and purity of about 90% are achieved for ZH and WW situation

Next step:

Tau decay branching ratio measurement at CEPC

Thanks for your attention!