An ultra-low-mass **Tracking Chamber** with **Particle Identification** capabilities

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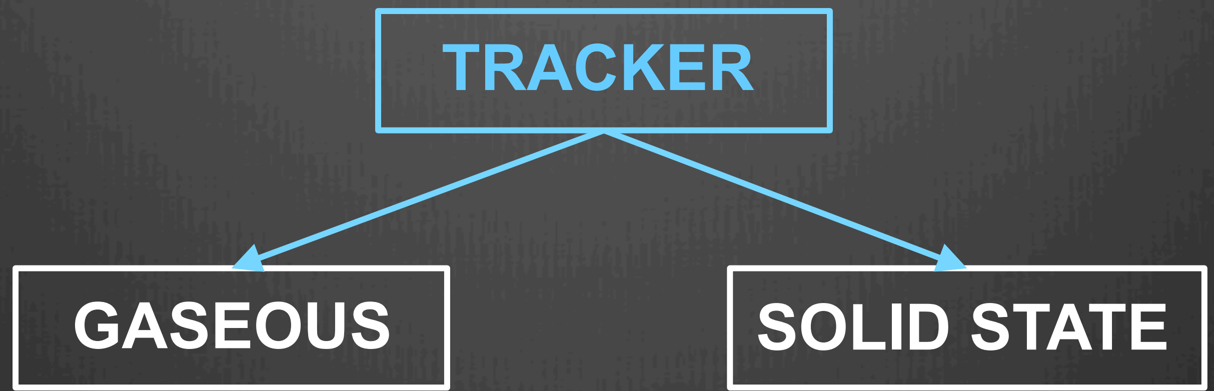
Tracker alternatives for CEPC



Solid state tracker drawbacks

- **multiple scattering**

  contribution to momentum resolution due to multiple scattering dominates up to larger momenta and larger than in a gaseous tracker

- **redundancy**

  only a limited number N of layers can be implemented, hindering the momentum resolution, proportional to $\sigma/\sqrt{N}$, despite the excellent spatial resolution σ

  inefficiencies in the reconstruction of "kinks" and "vees"

  lack of redundancy against inefficiencies and background

- **particle identification**

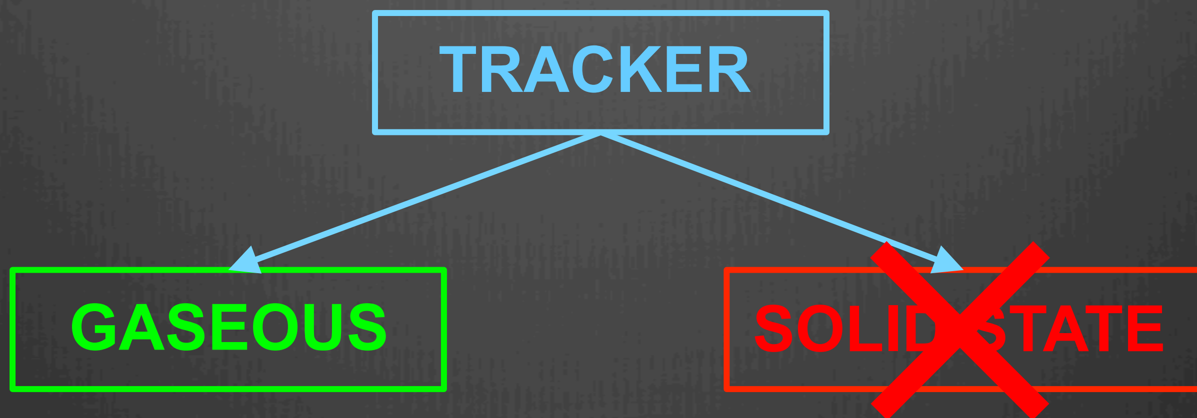
  no particle identification possible

- **system complexity**

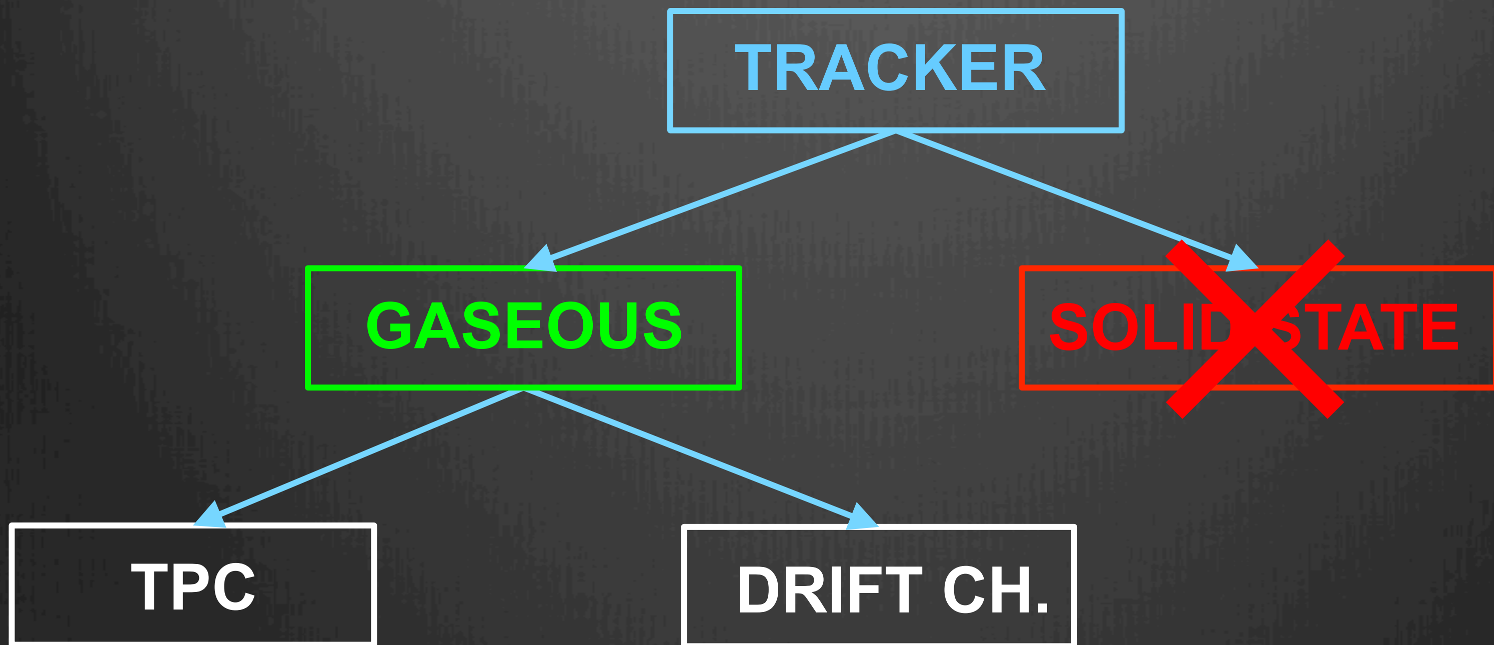
  order of $10^8 - 10^9$ channels for a limited number of space points with a lever arm compatible with the momenta to be measured

  stability of relative and absolute alignment

Tracker alternatives for CEPC



Tracker alternatives for CEPC



TPC drawbacks

- **very long drifting time**

  integrating over many bunch crossings

  tracking resolution might be marginal for a 2 Tesla B-field

- **positive ions backflow**

  difficult implementation of an efficient gating strategy given the very short bunch length.

  ion space charge density affects ion backflow particularly at smaller radii complicating the matching of inner track segments with vertex detector tracks

- **number of readout channels**

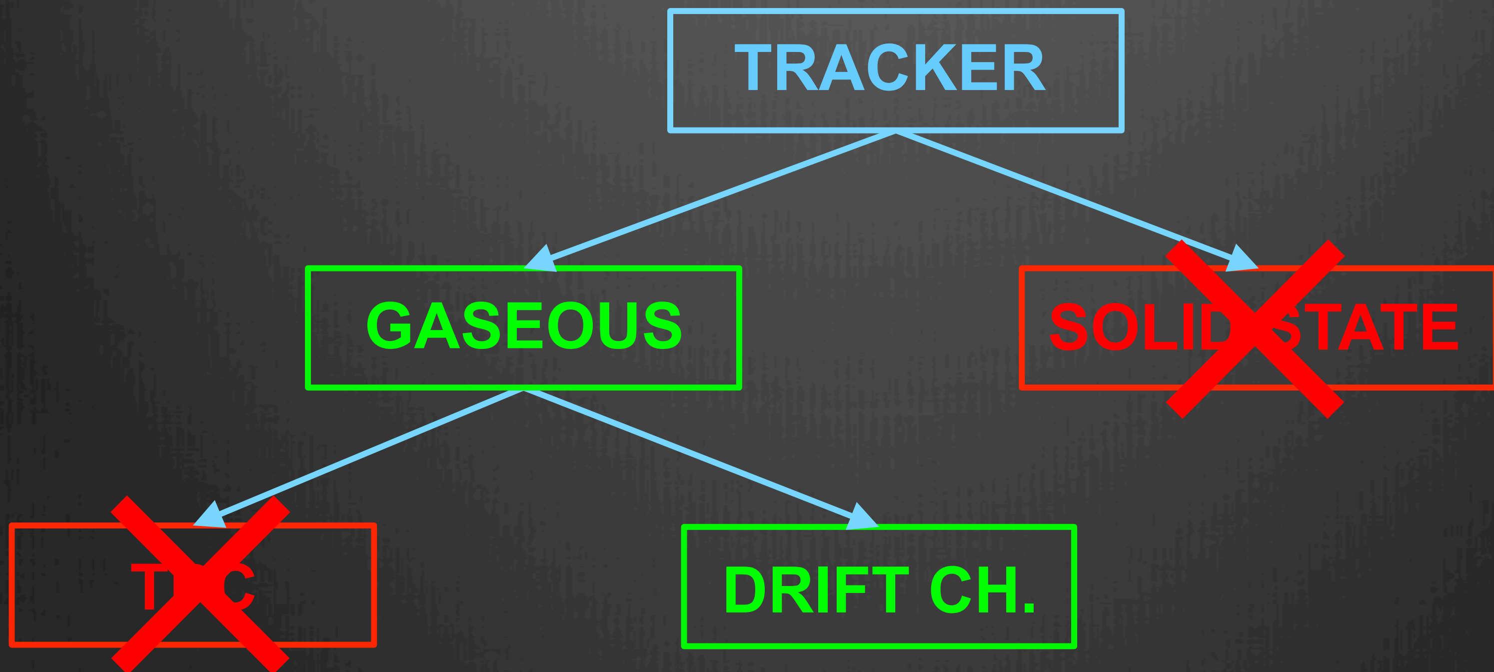
  expected spatial resolution requires readout pad sizes of a few mm^2 for a total of about one million channels per endplate.

  > 10 KW per end plate, at 10 mW/ch, require sophisticated cooling system

- **multiple scattering**

  expected > 25% of a radiation length in the endplate regions and a not negligible amount in the inner wall due to the field cage structure

Tracker alternatives for CEPC



Road to proposal

I. **KLOE** ancestor chamber at INFN LNF Daϕne φ factory (commissioned in 1998 and operated for the last 20 years)

II. **CluCou** Chamber proposed for the **4^{th}-Concept** at ILC (2009)

III. **I-tracker** chamber proposed for the **Mu2e experiment** at Fermilab (2012)

IV. **DCH** for the **MEG upgrade** at PSI (designed in 2014, now under commissioning)

V. **IDEA** drift chamber proposal for FCC-ee and CEPC (2016)

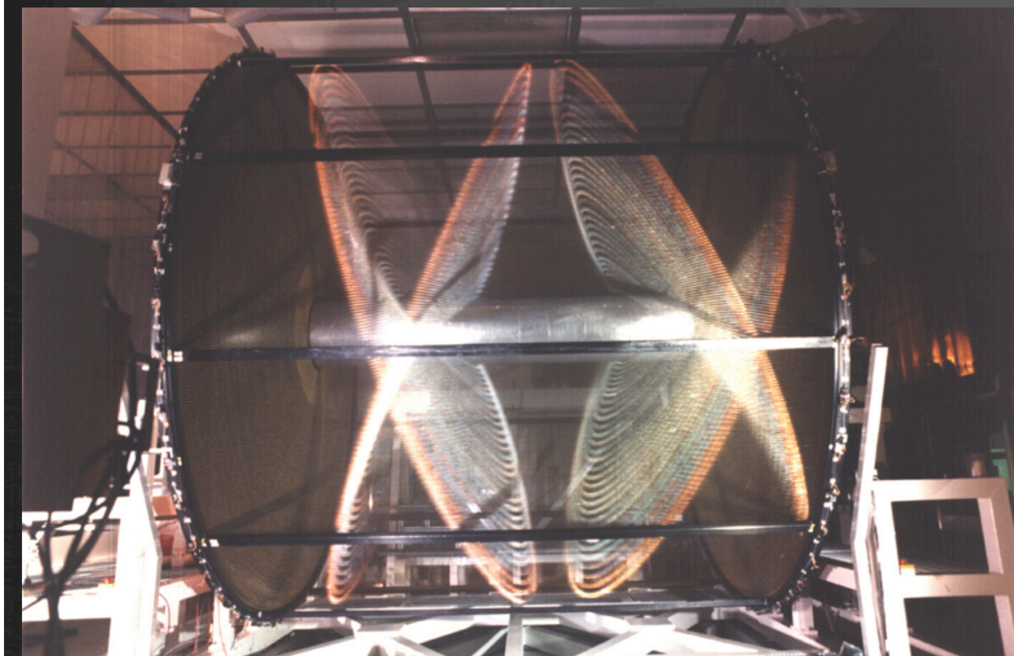
"Traditional" Drift Chamber

A cylindrically symmetric gas volume with (para-)axial wires defining a strong electric field, strung under mechanical tension for electrostatic stability and fixed at their extremities to the end walls by means of feed-through.

CONSTRAINTS:

- The **end walls**, holding the feed-through (which limit the chamber granularity), the FE electronics and the relative cabling, **must be rigid enough** to transfer the load due to the wire tension (of the order of several Tons) to the **outer cylindrical wall**, without deforming.
- The **inner cylindrical wall**, usually, does not bear any load, to minimize the multiple scattering of incoming particles.
- The **gas tightness** relies on the hermetic properties of all surfaces (including the many tens of thousands feed-through holes) and of all their relative joints.

The KLOE Drift Chamber (1998)



Innovations introduced by KLOE D.C.

Wire configuration **fully stereo** (no axial layers)

New **light Aluminum** wires

Very light gas mixture **90% He – 10% iC4H10**

Mechanical structure entirely in **Carbon Fiber**

Largest volume drift chamber ever built (45 m^3)

"Innovative" Drift Chamber

I. Separation of **gas containment** from **wire support** functions

II. New concept for **wire tension compensation**

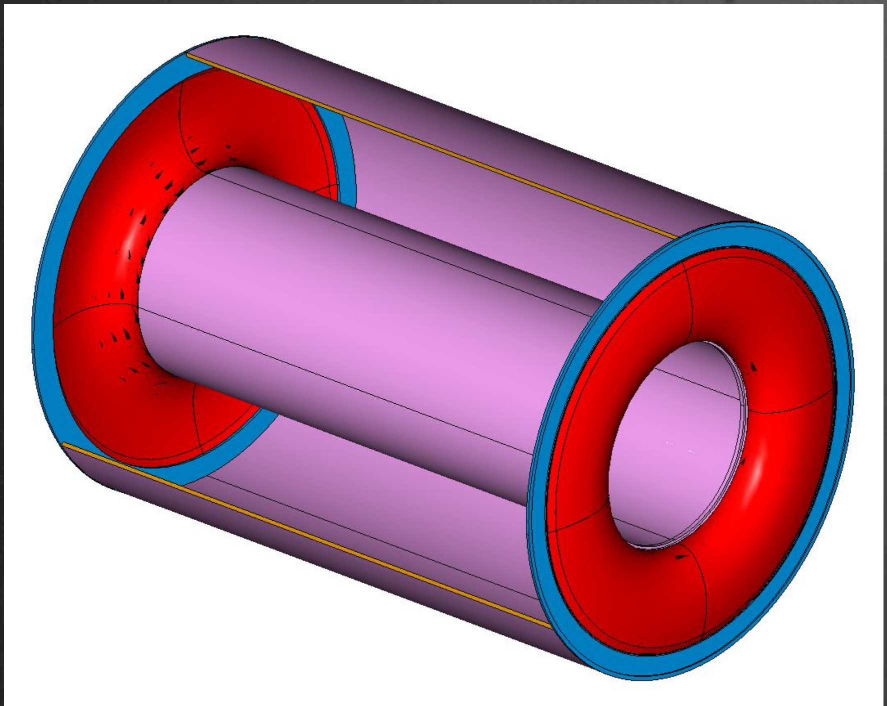
III. **Feed-through-less** wiring

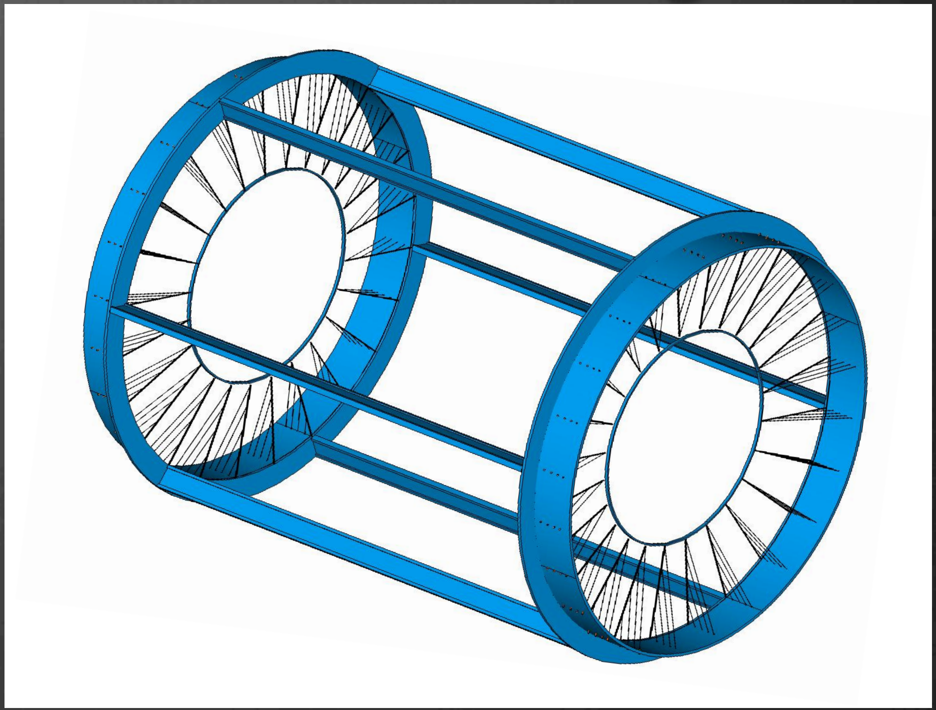
IV. **Larger number** of **thinner** (and **lighter** wires)

V. **Cluster timing** for improved spatial resolution

VI. **Cluster counting** for particle identification

"Gas Envelope" and "Wire Cage"





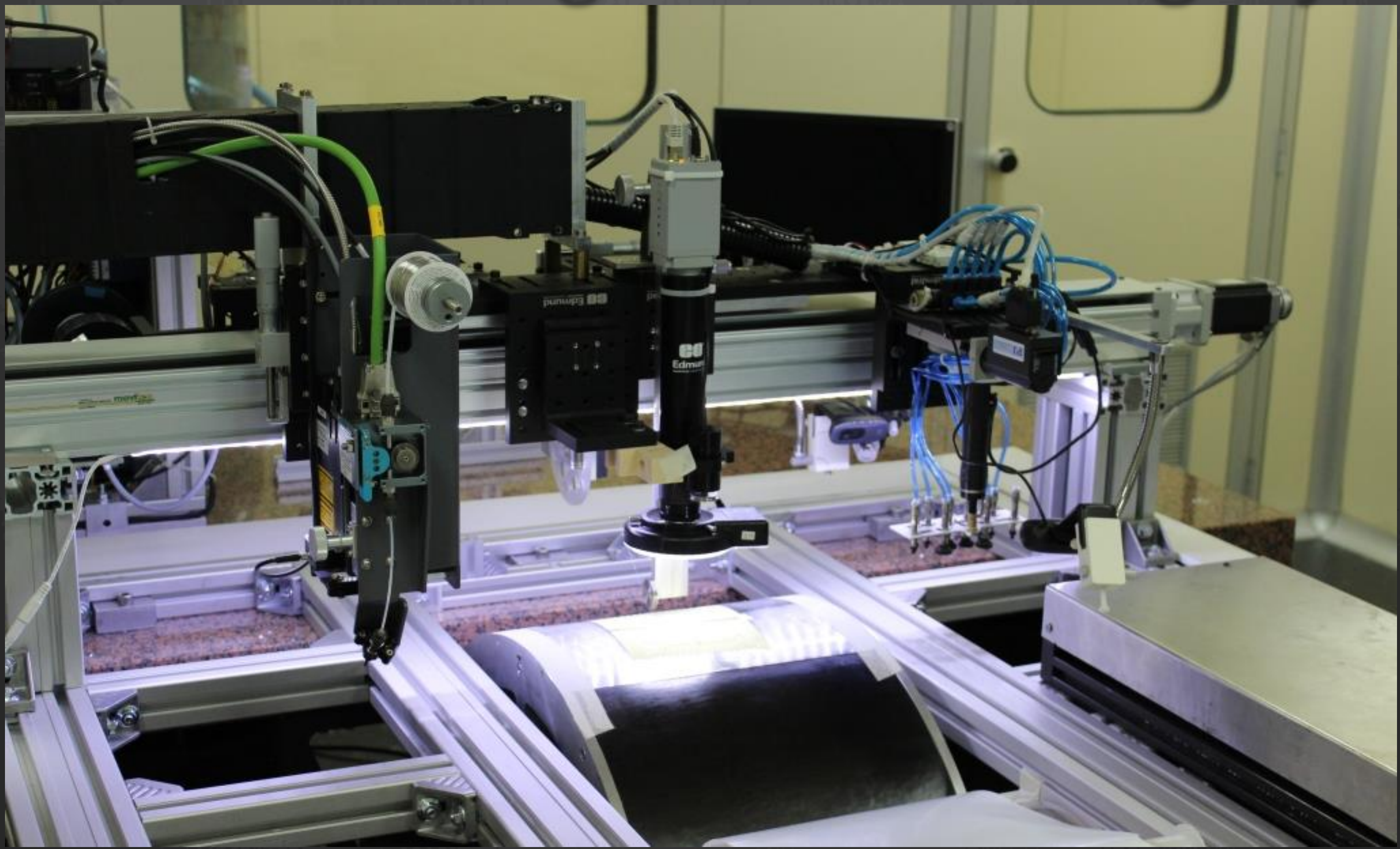
Gas containment:

Gas envelope can freely deform without affecting the internal wire position and tension.

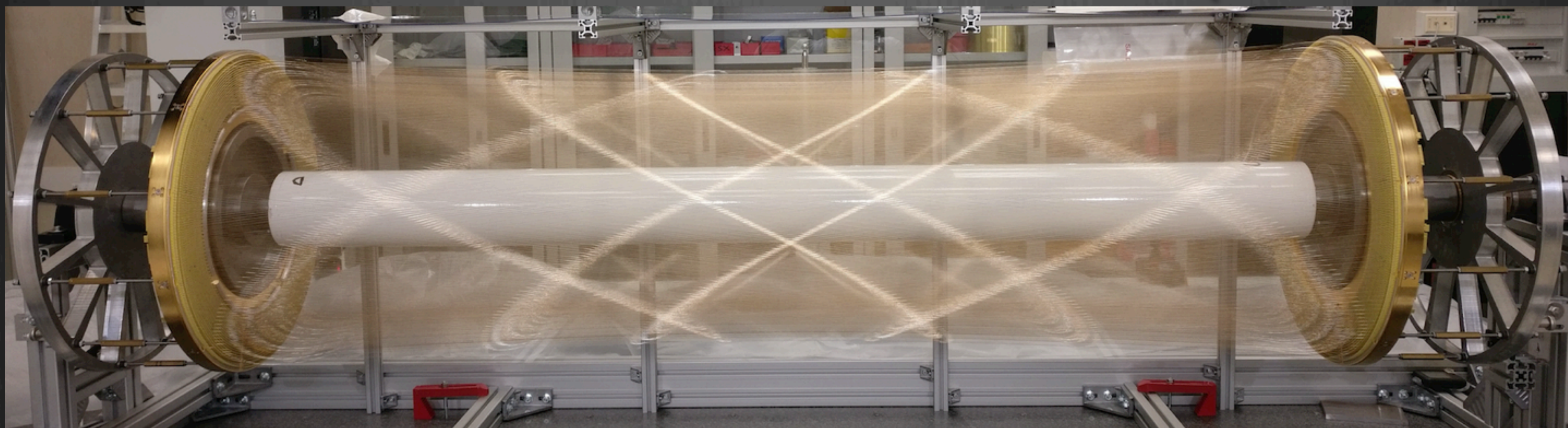
Wire support:

Wire cage structure not subject to differential pressure can be light and feed-through-less.

The feed-through-less wiring system

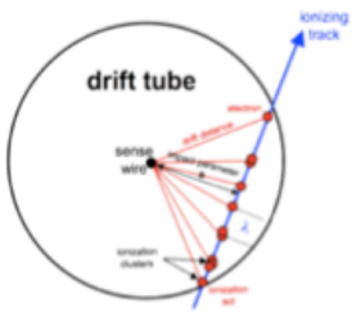


The MEG2 Drift Chamber (2018)

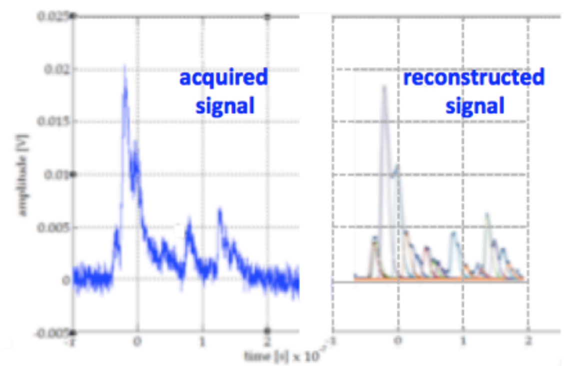


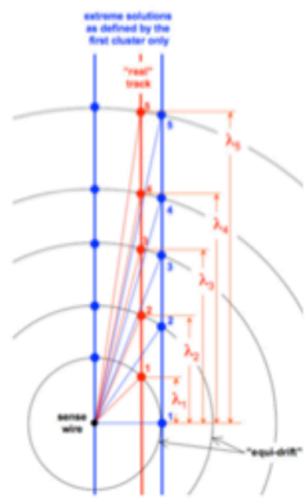
A unique volume, high granularity, all stereo, low mass cylindrical drift chamber, co-axial to B.
Rin = 18 cm, Rout = 30 cm, L = 2 m, 10 co-axial layers,
at alternating sign stereo angles from 100 mrad to 150 mrad ,
arranged in 12 identical azimuthal sectors.
Square cell size between 6 and 9 mm.
Total number of drift cells 1920. Total number of wires 12,678

Cluster Timing

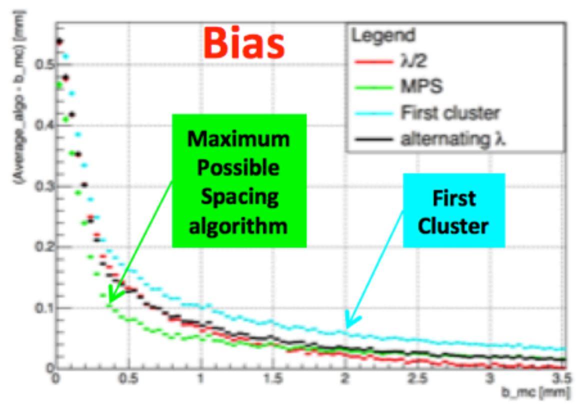


From the **ordered sequence of the electrons arrival times,** considering the average time separation between clusters and their time spread due to diffusion, **reconstruct the most probable sequence of clusters drift times:** $\{t_i^{cl}\} \quad i = 1, N_{cl}$





For any given first cluster (**FC**) drift time, the **cluster timing technique** exploits the drift time distribution of all successive clusters $\{t_i^{cl}\}$ to determine the most probable impact parameter, thus reducing the **bias** and the average **drift distance resolution** with respect to those obtained from with the FC method alone.



Cluster Counting

$$\frac{\sigma_{dE/dx}}{(dE/dx)} = 0.41 \cdot n^{-0.43} \cdot \left(L_{track}[m] \cdot P[atm]\right)^{-0.32}$$

from *Walenta parameterization (1980)*

versus

$$\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl}/dx)} = \left(\delta_{cl} \cdot L_{track}\right)^{-1/2}$$

from *Poisson distribution*

dE/dx

truncated mean cut (70-80%) reduces the amount of collected information

***n* = 112** and a **2m track** at **1 atm** give

σ ≈ 4.3%

Increasing ***P*** to 2 atm improves resolution by 20% (σ ≈3.4%) but at a **considerable** cost of multiple scattering contribution to momentum and angular resolutions.

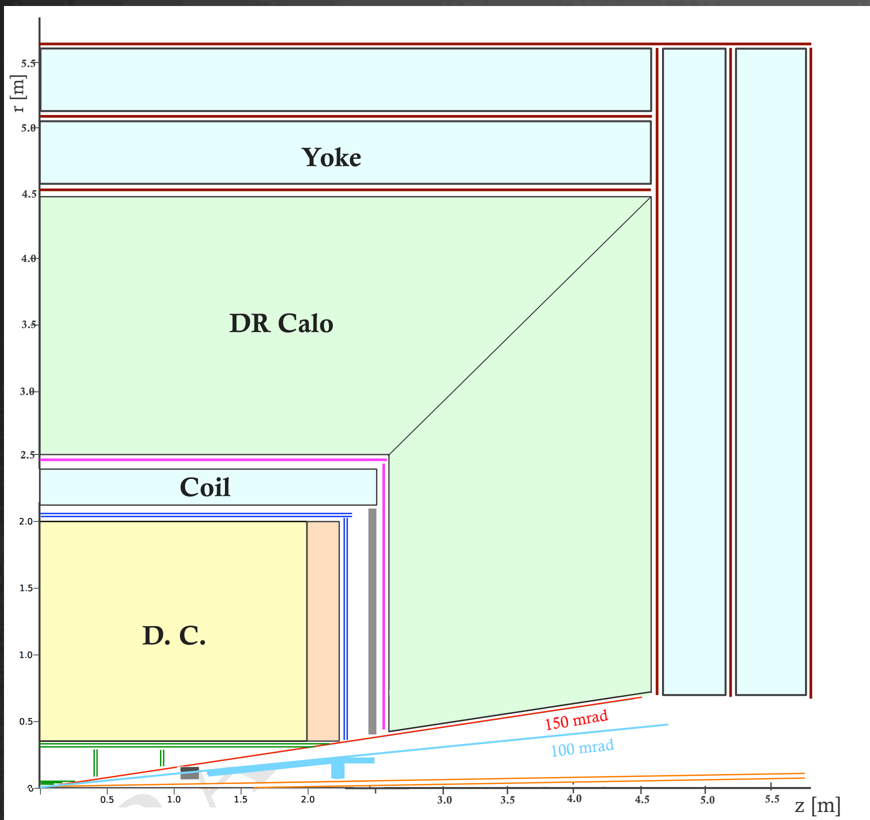
dN_{cl}/dx

δ_{cl} = 12.5/cm for He/iC_4H_{10}=90/10 and a **2m track** give

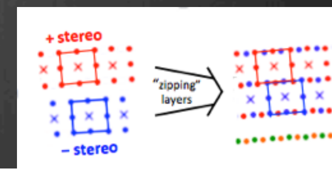
σ ≈ 2.0%

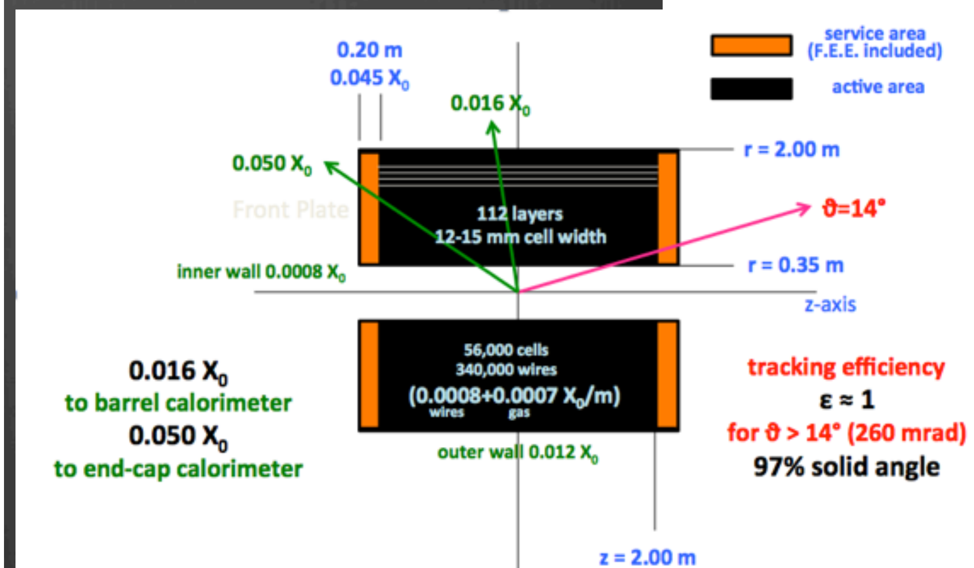
A small increment of iC_4H_{10} from 10% to 20% (δ_{cl} = 20/cm) improves resolution by 20% (σ ≈1.6%) at only a **reasonable** cost of multiple scattering contribution to momentum and angular resolutions.

The IDEA Drift Chamber



The **IDEA** Detector at
FCC-ee at CERN
CEPC at IHEP-China





The IDEA Drift Chamber

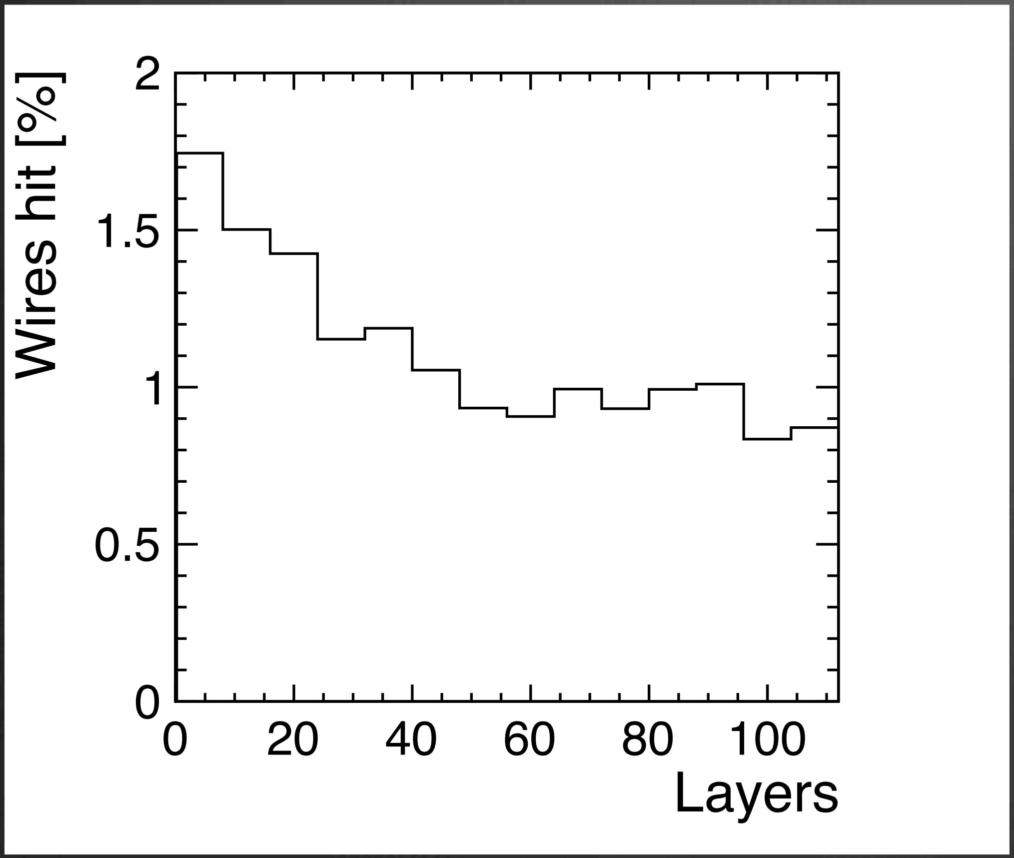
	R_{in} [mm]	R_{out} [mm]	z [mm]
active voòume	350	2000	±2000
service area	350	2000	±(2000÷2250)

	inner wall	gas	wires	outer wall	service area
thickness [mm]	0.2	1000	1000	20	250
X_0 [%]	0.08	0.07	0.13	1.2	4.5

# of layers	112	min 11.8 mm – max 14.9 mm
# of cells	56448	192 at 1st – 816 at last layer
average cell size	13.9 mm	min 11.8 mm – max 14.9 mm
average stereo angle	134 mrad	min 43 mrad – max 223 mrad
transverse resolution	100 μm	80 μm with cluster timing
longitudinal resolution	750 μm	600 μm with cluster timing

active volume	50 m^3	
readout channels	112,896	from both ends
max drift time	400 ns	800 × 8 bit at 2 GHz

D. C. Occupancy



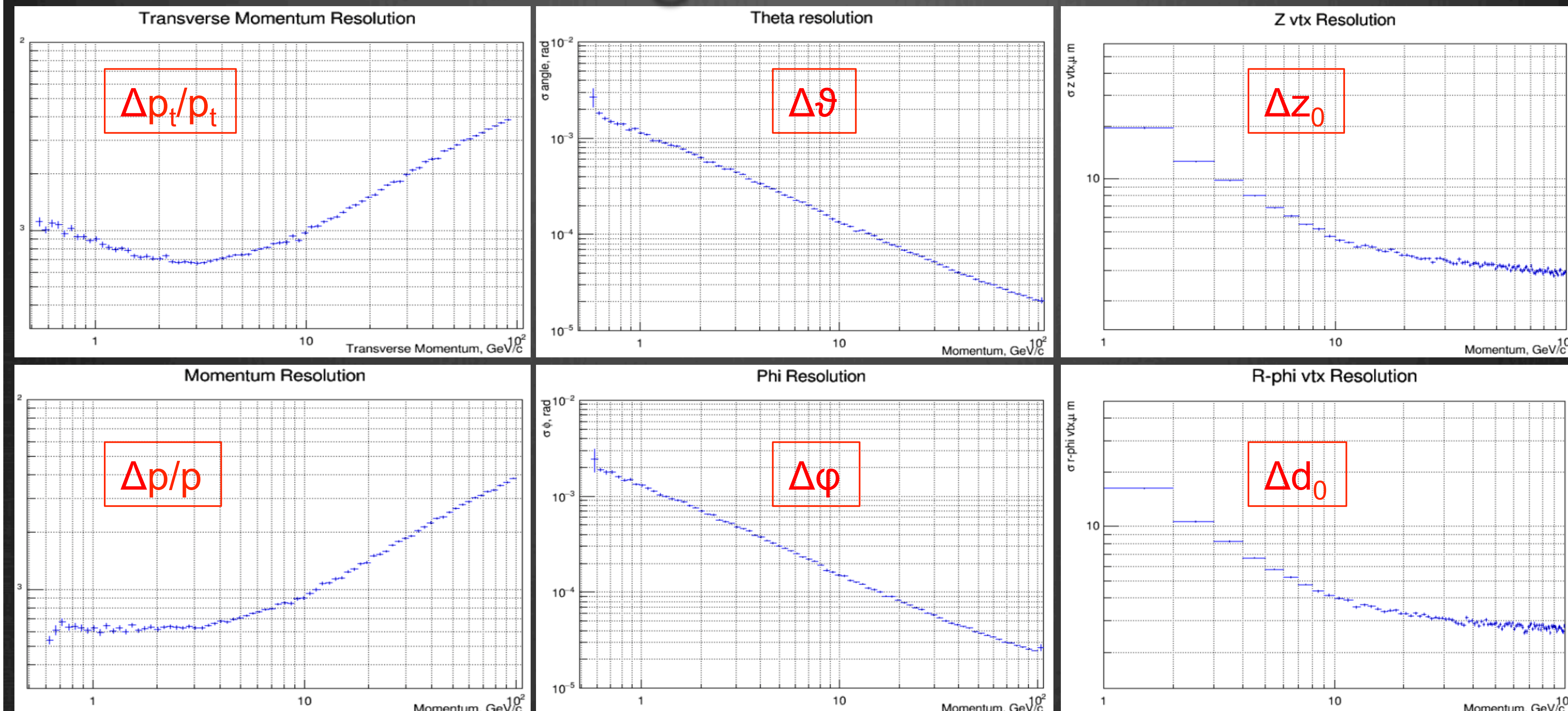
Z-pole at FCCee

Simulation of the IDEA D.C. occupancy versus the 112 layers, due to the most abundant background (incoherent pair production).

20 ns bunch crossing
400 ns maximum drift time
50 ns track separation time

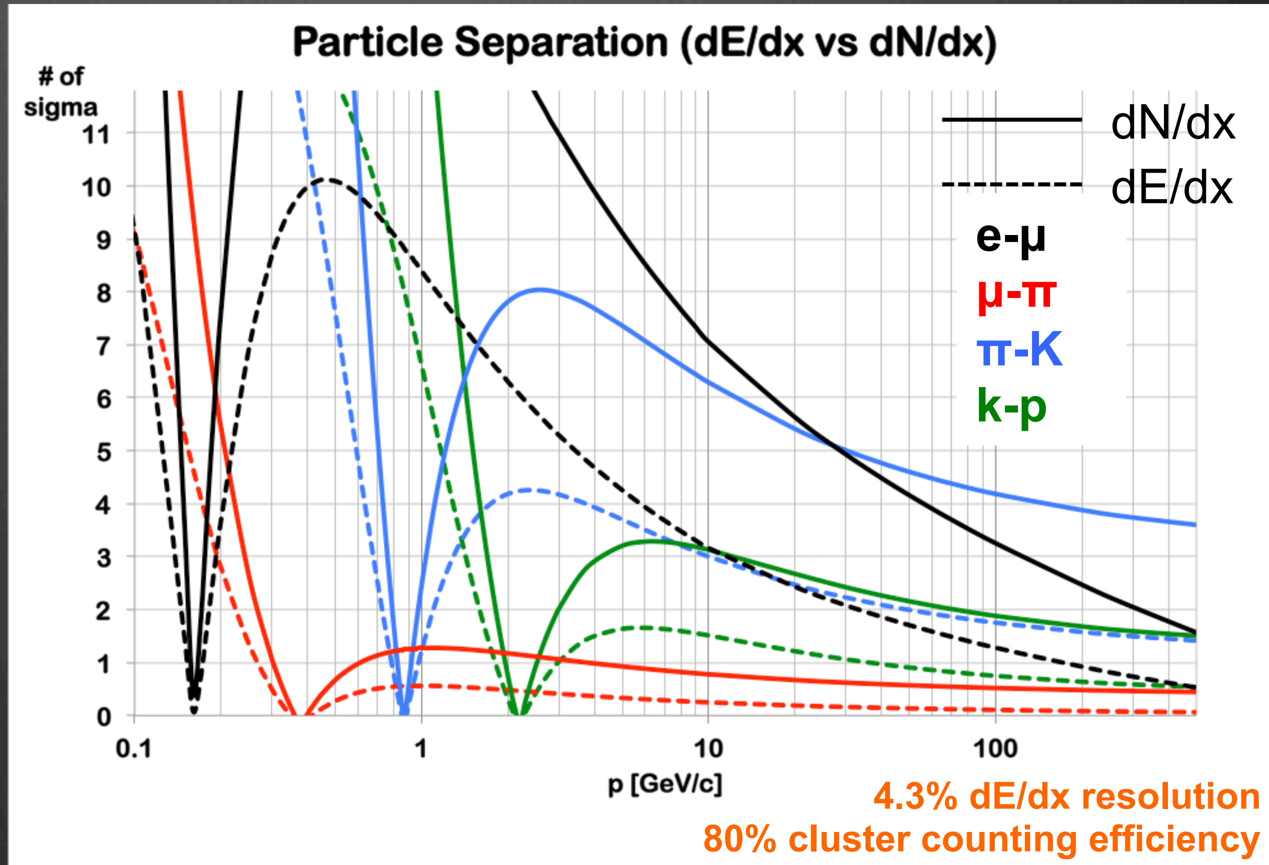
full simulation in the CEPC framework to be done soon.

Tracking Performance

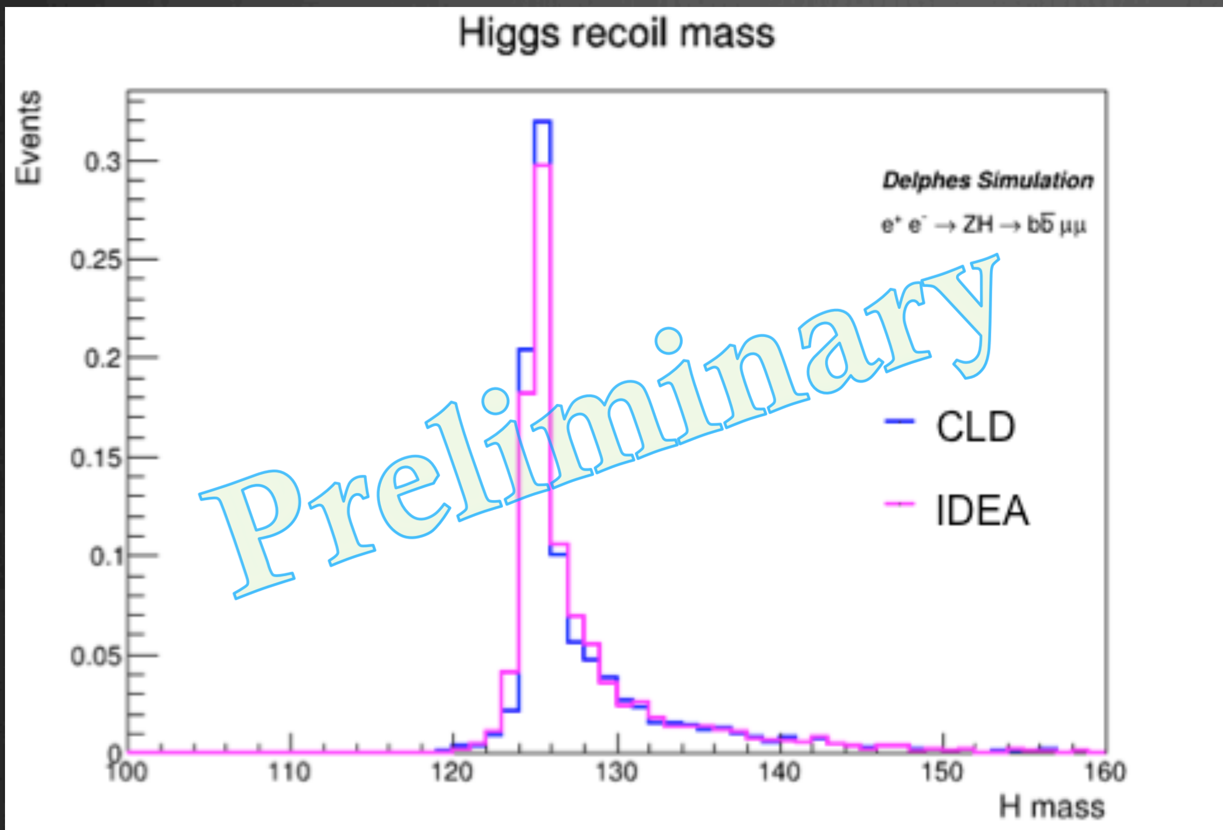


The IDEA Drift Chamber Performance

Analytical calculations
to be checked with
detailed simulations
(in progress)
and **beam tests**



The IDEA Tracking Performance



Delphes simulation of Higgstrahlung with **Z → μμ** comparing the two FCCee detectors (full Si tracker for CLD)