Reconstruction of Long-Lived Particles (LLPs) in IDEA Tracker at FCC-ee

IDEA Geometry & Parameters

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Obedience Munkombwe | 18. September, 2025

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The Innovative Detector for E+e− Accelerator (IDEA) - OVERVIEW

Vertex detector of monolithic active pixel sensors

- **MAPS** → Min material budget, **very small pixels** → O**(μm) spatial resolution**

Drift chamber with cluster counting

- Ultra-light, up to 112 track hits with σxy ≈ 100 μm
- Cluster counting for PID

Silicon wrapper for precise last track hit

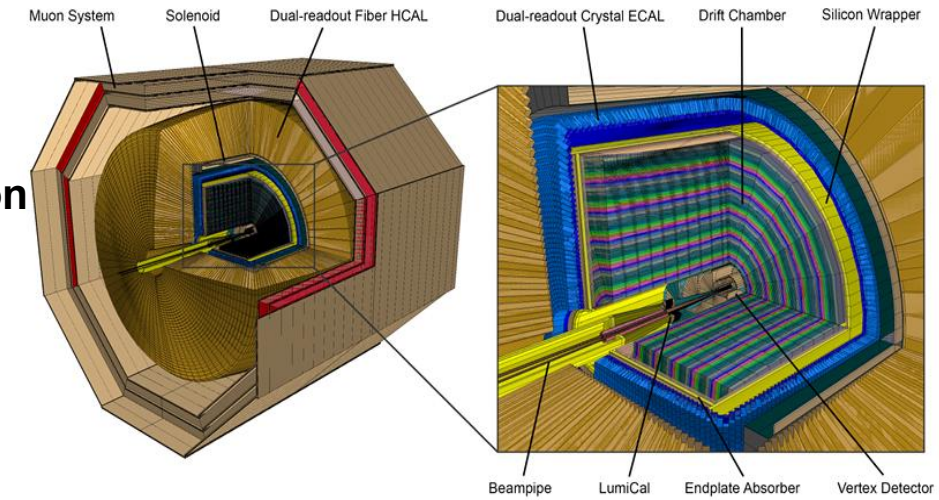
→ sharpens high-p_t momentum & polar-angle resolution

Dual readout crystal ECAL

- DR: Measures EM and hadr. shower components
- Highly-segmented

Dual readout fibre HCAL complementing ECAL

Muon detectors ; ≥ 3 layers of μ-RWELL



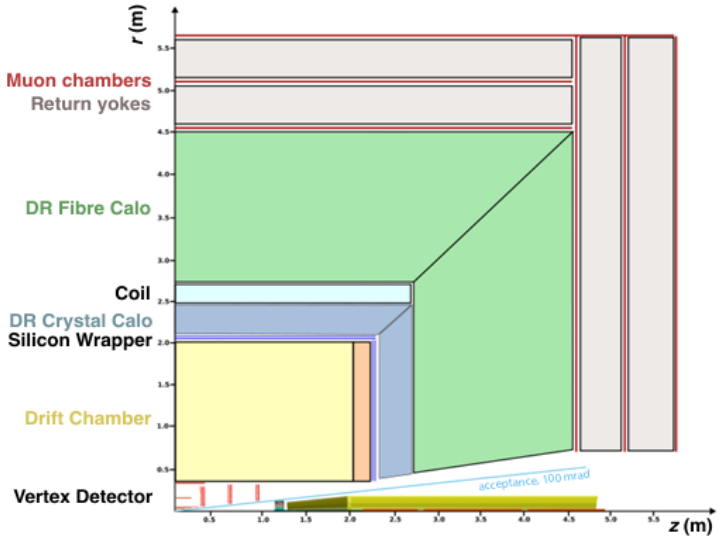


Figure 3: Overview of the IDEA detector layout.

arXiv:2502.21223v4

The IDEA Detector – Tracking System

Main tracking subsystems:

1. **Silicon pixel vertex detector**,
2. **Central Drift Chamber** (Ultra-light),
3. **Silicon wrapper** (around the drift chamber)

Global geometry:

- **Beam pipe radius:** ≈ 1.5 cm.
  → 1st vertex layer very close to IP → **excellent impact-parameter resolution**
- **Vertex detector**: 1.37–3.56 cm (inner barrels) and 13–31.5 cm (outer barrels).
- **Drift chamber**: radius 35–200 cm, |z| < 200 cm.
- **Silicon wrapper**: barrel layers at r ≈ 2.04–2.08 m and disks up to |z| ≈ 2.32 m, covering |cosθ| ≲ 0.989.

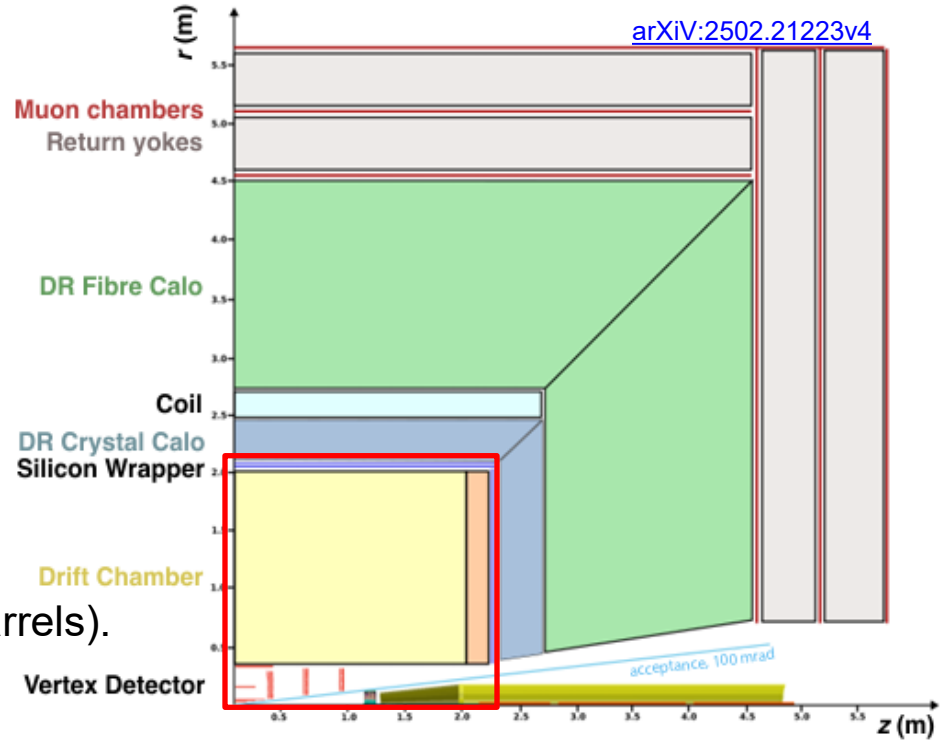
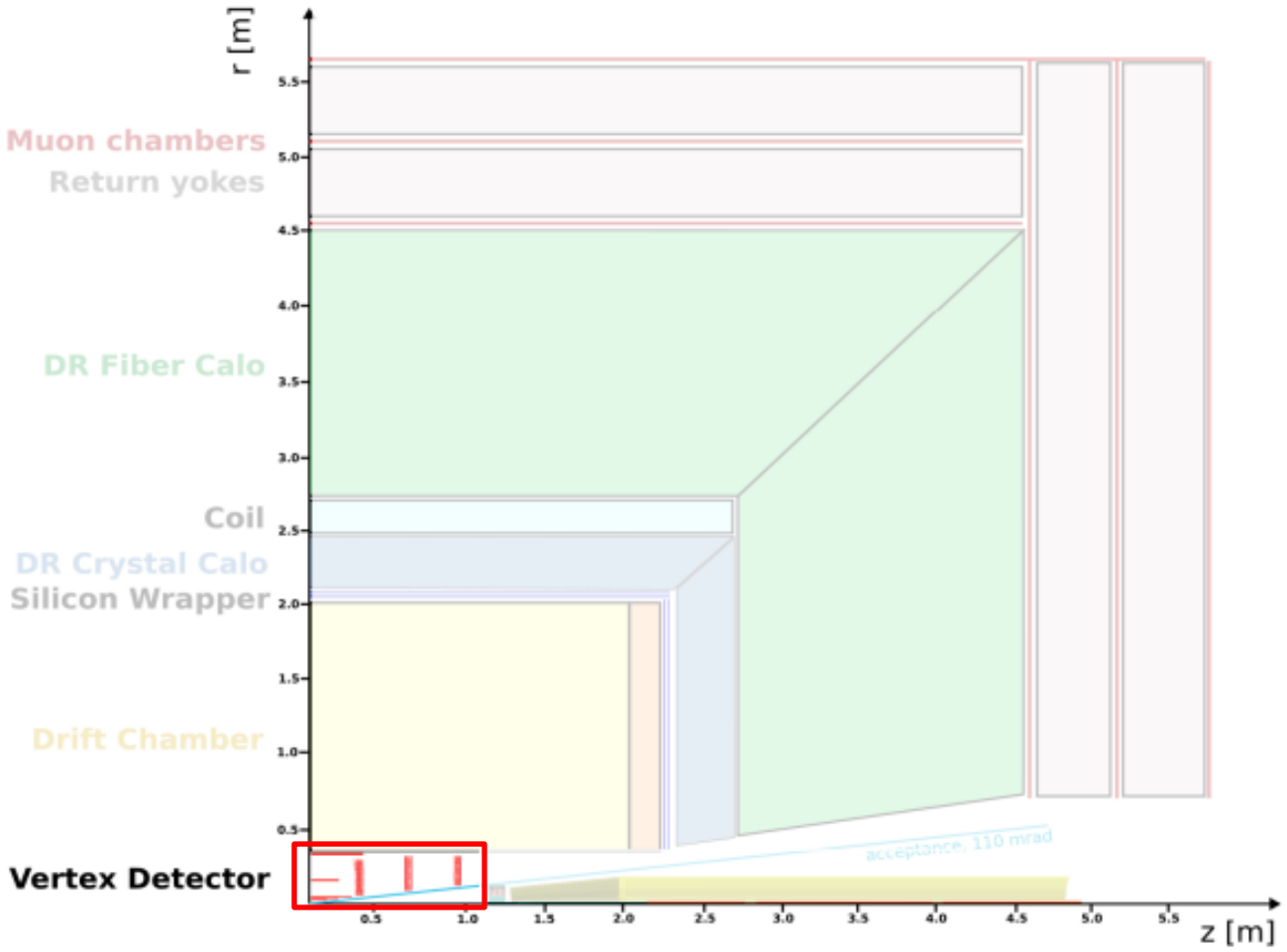


Figure 3: Overview of the IDEA detector layout.

✓ Overall tracker material → **Very small** thanks to He gas and thin silicon → minimizes **multiple scattering**

The IDEA Tracking System – Vertex Detector



The IDEA Tracking System – Vertex Detector

Technology: 50 µm-thick **Monolithic Active Pixel Sensors (MAPS)** → thin and low power.

Inner vertex (baseline, ARCADIA):

- 3-barrel layers at r = 13.7, 23.7, 34–35.6 mm, |cosθ| < 0.99.

  → Dense hit coverage very close to IP → µm-level impact-parameter resolution

- Pixel pitch ≈ 25×25 µm², single-hit resolution ≈ 3 µm assumed.

  → needed to reach few-µm d_0 and resolve short-lived decays

- Per layer material ≈ 0.25% X_0, total vertex ~1% X_0.

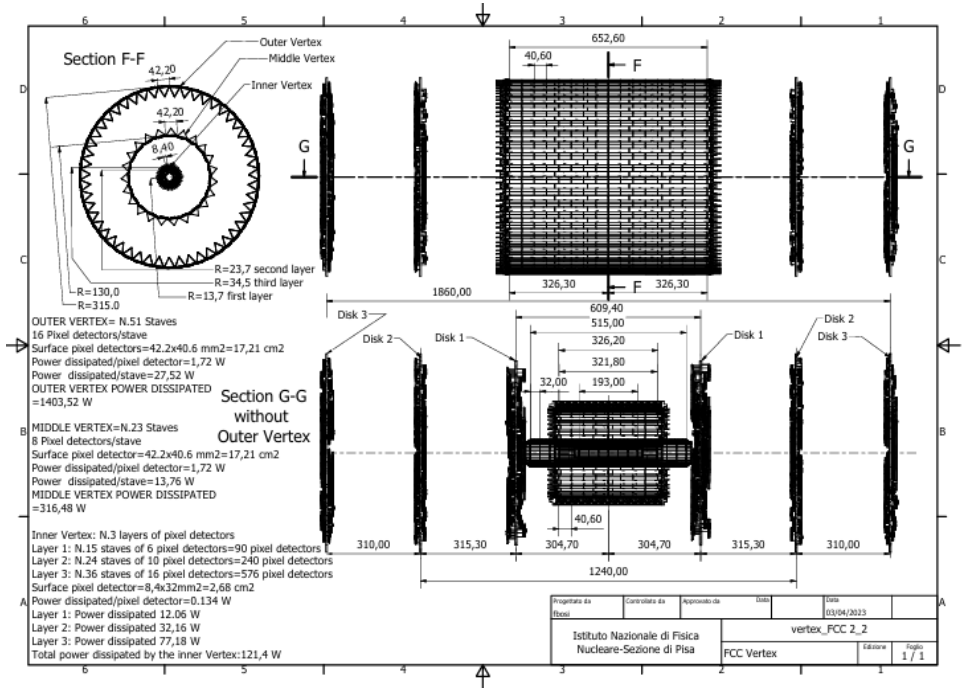
→ **ultra-light, curved-sensor option** (ALICE ITS3-like)

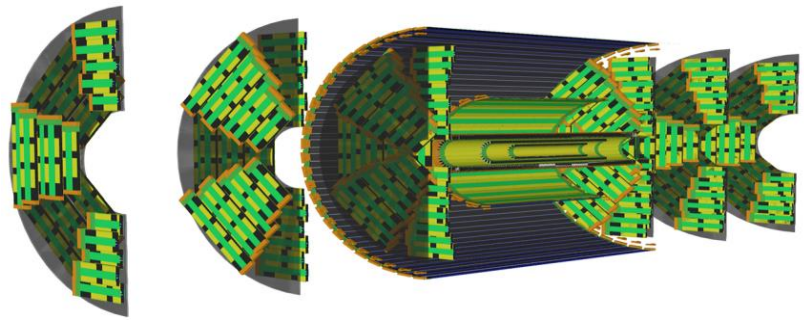
Outer vertex:

- Pixel size ≈ 150×50 µm² (ATLASPix3-like).

- 2-barrel layers at ≈ 130 mm and 315 mm, plus 3 disks per side up to z ≈ 93 cm.

  → Extend precise tracking into the forward region →
  better angular resolution and forward secondary vertices





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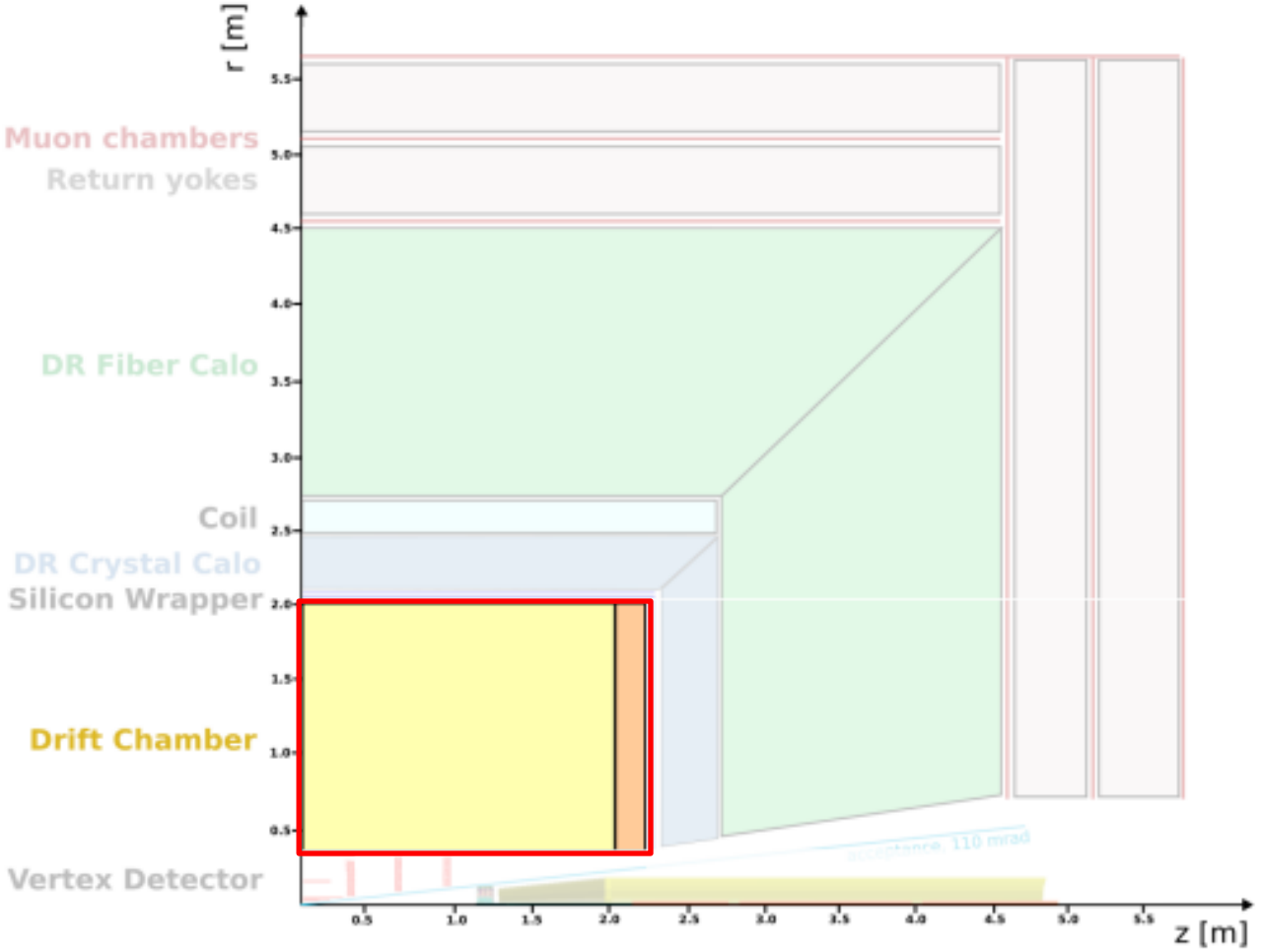
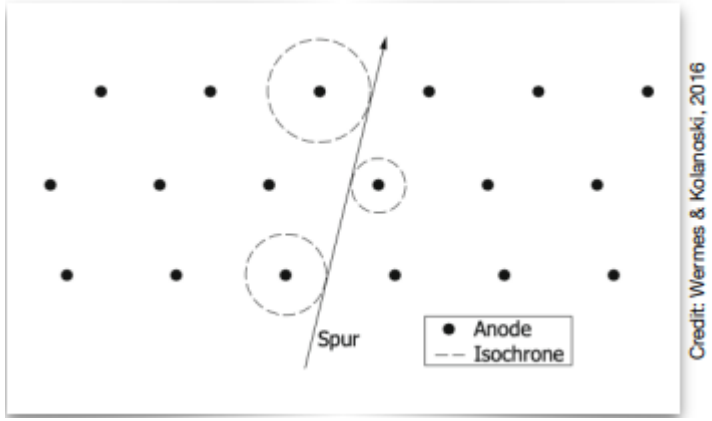
The IDEA Tracking System – The Central Drift Chamber

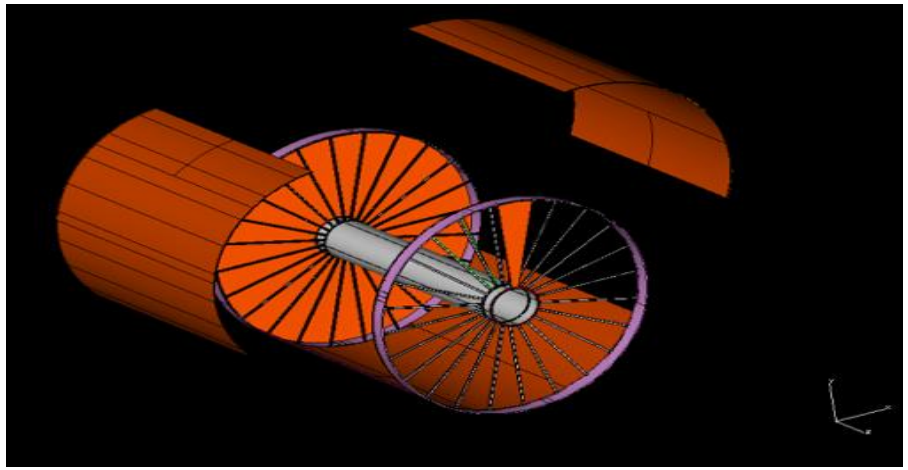


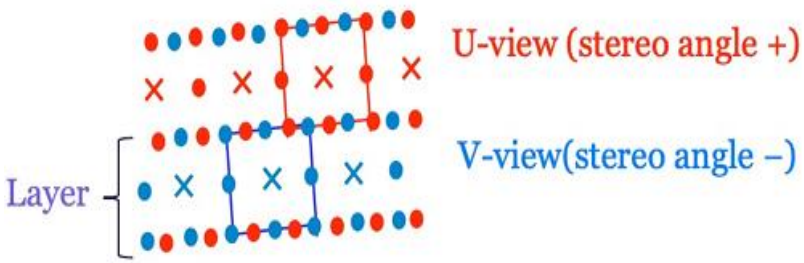
The IDEA Tracking System – The Central Drift Chamber

Working Principle



- Charged particle crosses the **gas volume** → it **ionizes** the gas , creating electrons and positive ions along its path.
- **Electric field** inside each drift cell makes the **electrons drift** towards the sense wire.
- The **drift time** is measured by the electronics → distance of closest approach of the track to the wire (drift radius).
- Each sense wire gives one **space point** → reconstruct a full **3D track** and its curvature in the magnetic field → momentum.





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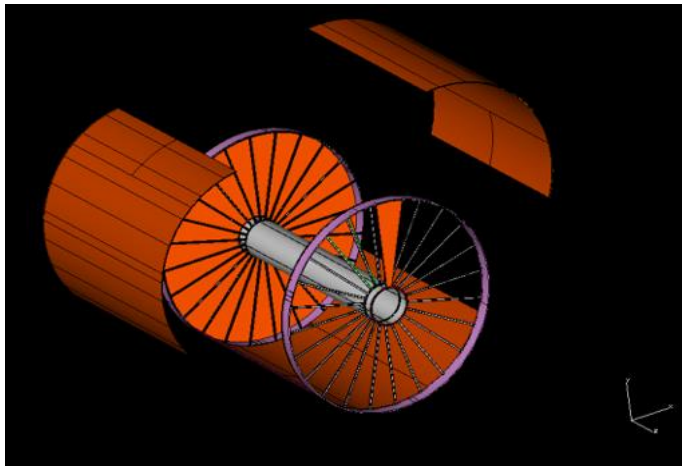
The IDEA Tracking System – The Central Drift Chamber

Geometry: Cylindrical single-volume, R_{in} = 35cm, R_{out} = 200cm, **L** = 400cm and angular coverage = **θ** ≈ 13°

- Large **V** → LLPs decay inside the DCH → displaced vertices in the gas volume
- Large **R** → big lever arm → curvature measurement
- Long **L** → good coverage for forward tracks (boosted objects and LLPs).



Layers: 14 super-layers × 8 layers = 112 layers → ~112 hits/track

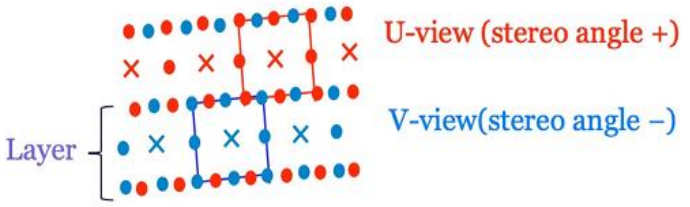
- More hits → **better curvature fit and pattern recognition**, especially for displaced tracks

Gas: 90% He + 10% i-C_4H_{10}.

- He: extremely low multiple scattering, i-C_4H_{10} = **fast, good for quenching**

Drift cells: size 12–14.5 mm ~ drift time of about 400 ns ~ drift velocity of 2.2cm/μs

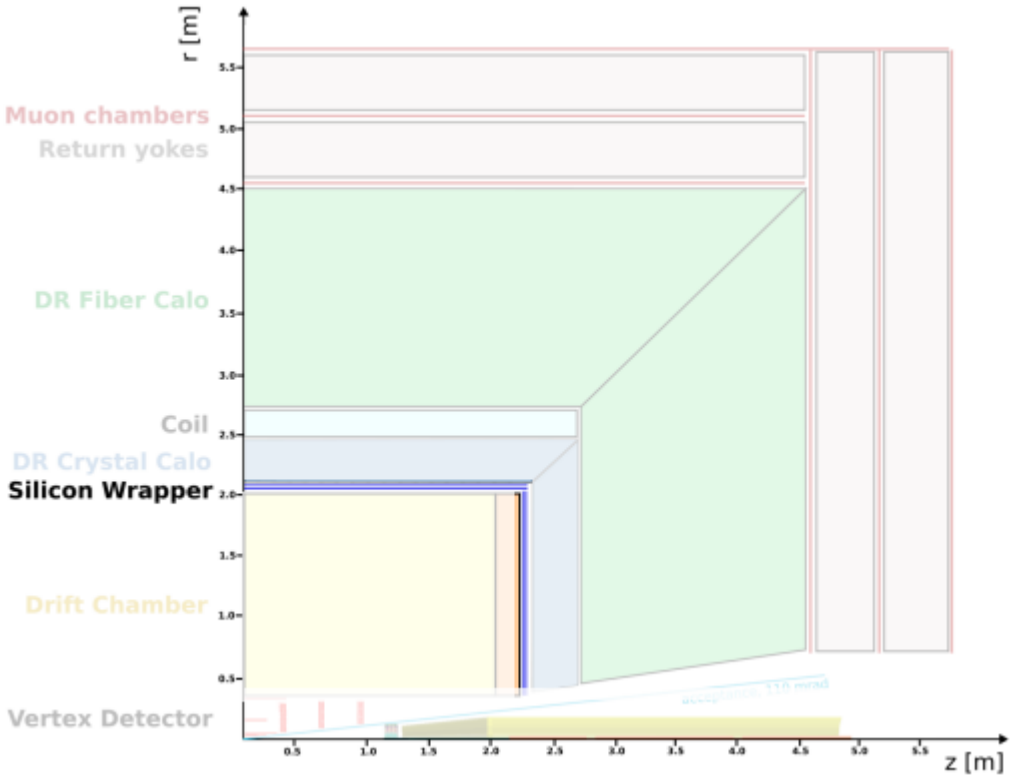
- Short drift distances → spatial resolution ≲ 110 μm
- Excellent two-track separation (~2 mm) → close tracks from displaced vertices



Wire ratio: field:sense = 5:1

- more field wires → **more uniform E-field → better timing & position**

The IDEA Tracking System – Silicon wrapper

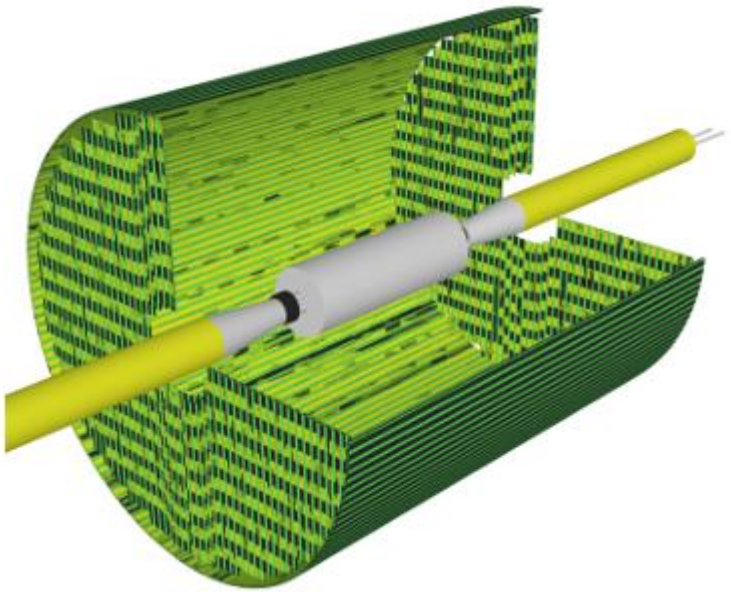


The IDEA Tracking System – Silicon wrapper

- Surrounds the drift chamber ($r < 2$ m, $|z| \leq 2.25$ m), total area **>100 m²**.

  Current implementation in DD4hep

  - 2-barrel layers: at $r \approx 2.04$ m and 2.08 m, $|z| < 2.4$ m.
  - 2 disks per side: at $z \approx \pm 2.30$–2.32 m, with radii 0.35–2.04 m.
  - Coverage: $|\cos\theta| < \sim 0.989$, so almost full solid angle.
  - Spatial resolution: ≈ O(10 μm) in both coordinates



→ Precise polar angle & outer radius measurement → tight high-p_t momentum resolution and well-defined acceptance

Summary & Outlook

In the context of LLPs study:

Lifetime range	Where it decays	Signature & why tracker helps
Short (≲ few mm)	Inside **Vertex detector**	Displaced vertices + large impact parameters; measured with µm precision from the **MAPS vertex layers**
Intermediate (cm-1m)	**DCH**	Multi-hit displaced vertices in low-material gas; many hits/track → **great reconstruction**
Long (up to ≈ 2 m)	Near / inside **silicon wrapper**	Non-pointing, possibly delayed tracks; outer Si hit and timing help **distinguish from prompt background**

Thank You!

Questions & Feedbacks are welcome.

BACKUP