Experimental Conditions at FCCee

ILD Meeting

March 01, 2022

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DESY

Outline

Menue

- **FCCee parameters**
- **Interaction region**
- **Backgrounds in CLD**

Not really my field of expertise!

Sources of information:
- EPJ Special Focus volume
- CLD paper
- Recent “Liverpool" workshop

FCCee Parameters

Most relevant for IR

- **Z, W: KEK-B like**
- **H, tt: LEP-like**

	Z	W	H	$t\bar{t}$
Circumference (km)	97.756	97.756	97.756	97.756
Crossing angle at IP (mrad)	30	30	30	30
L^* (m)	2.2	2.2	2.2	2.2
SR power/beam (MW)	50	50	50	50
Beam energy (GeV)	45.6	80	120	182.5
Luminosity/IP ($10^{34}\text{cm}^{-2}\,\text{s}^{-1}$)	230	28	8.5	1.55
β_x^* (m)	0.15	0.2	0.3	1
β_y^* (mm)	0.8	1	1	1.6
ϵ_x (nm)	0.27	0.84	0.63	1.46
ϵ_y (pm)	1.0	1.7	1.3	2.9
σ_x^* (μm)	6.4	13.0	13.7	38.2
σ_y^* nm	28	41	36	68
Beam current (mA)	1390	147	29	5.4
Bunch population (10^{11})	1.7	1.5	1.8	2.3
Bunch number/beam (#)	16640	2000	328	48
Average bunch spacing (ns)	19.6	163	994	3396
Effective length of interaction (mm)	0.42	0.85	0.90	1.8
SR loss/turn (GeV)	0.036	0.34	1.72	9.21
Bunch length by SR /BS (mm)	3.5/12.1	3.0/6.0	3.15/5.3	1.97/2.54
Energy acceptance (%)	1.3	1.3	1.7	− 2.8 + 2.4

Interaction Region

Main constraints

Interesting challenges

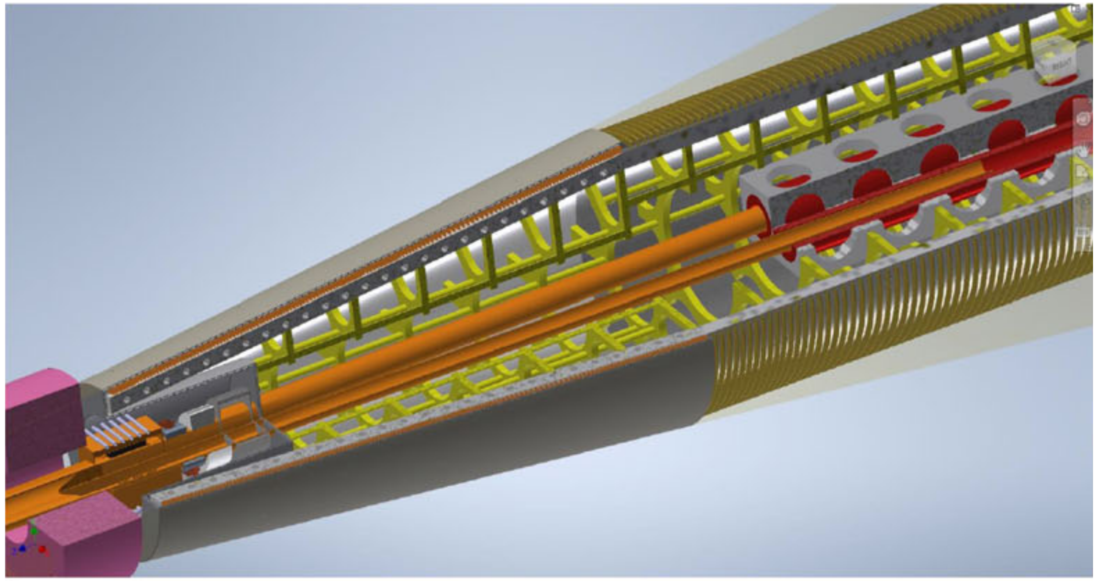
- e.g. alignment, vibrations

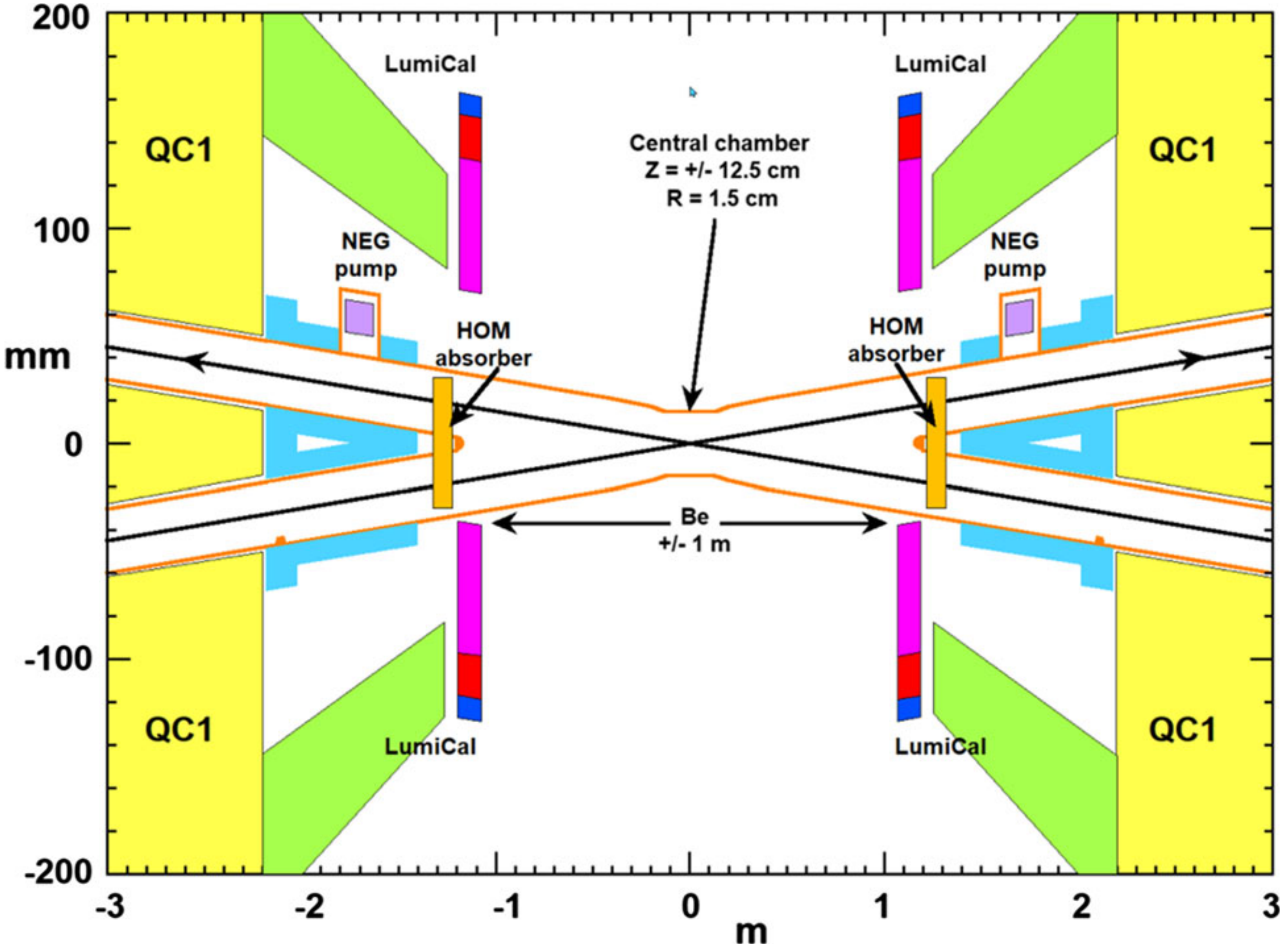
QC1 and compensating solenoids inside detector

- 150 mad acceptance limit (except LumiCal)

Max B = 2T at Z pole

- can be higher at higher E_{cm}





Cooled Beampipe

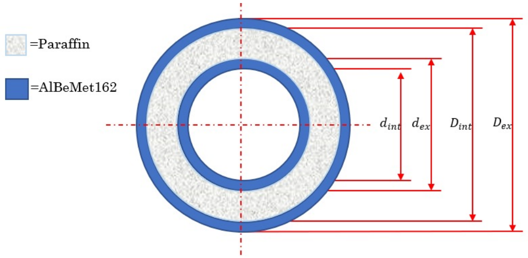
A la SiD

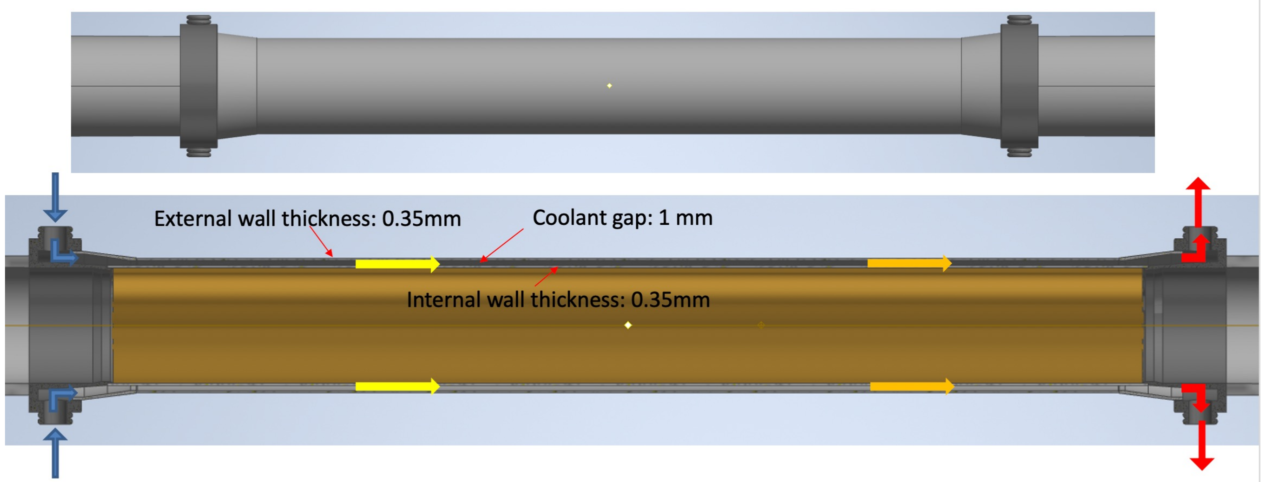
FCC 11/02/2022 5th FCC Physics workshop Manuela Boscolo

MDI design integration - L. Pellegrino 10

Central chamber

Inner radius **10 mm**





[Vertex resolution vs the first vertex layer radius, Donal Hill, MDI meeting #33]

Material	*thickness*
AlBeMet162	0.35 mm
Paraffin (PF200)	1 mm
AlBeMet162	0.3 mm
Au	5 µm

AlBeMet162: 62% beryllium and 38% aluminum alloy

Thickness 1.7mm (**X/X0=0.59%**)

*Central pipe **CDR** values: **inner radius 15 mm***

1.2 mm Be + 0.5 mm H_2O for X/X0=0.47%

Experimental Conditions

Still to be optimised

Synchrotron radiation

- collimator optimisation needs realistic simulations

Beam-induced back-grounds

- beam-gas and thermal photon scattering
- radiative Bhabha
- beam loss during inejction
  - Belle experience

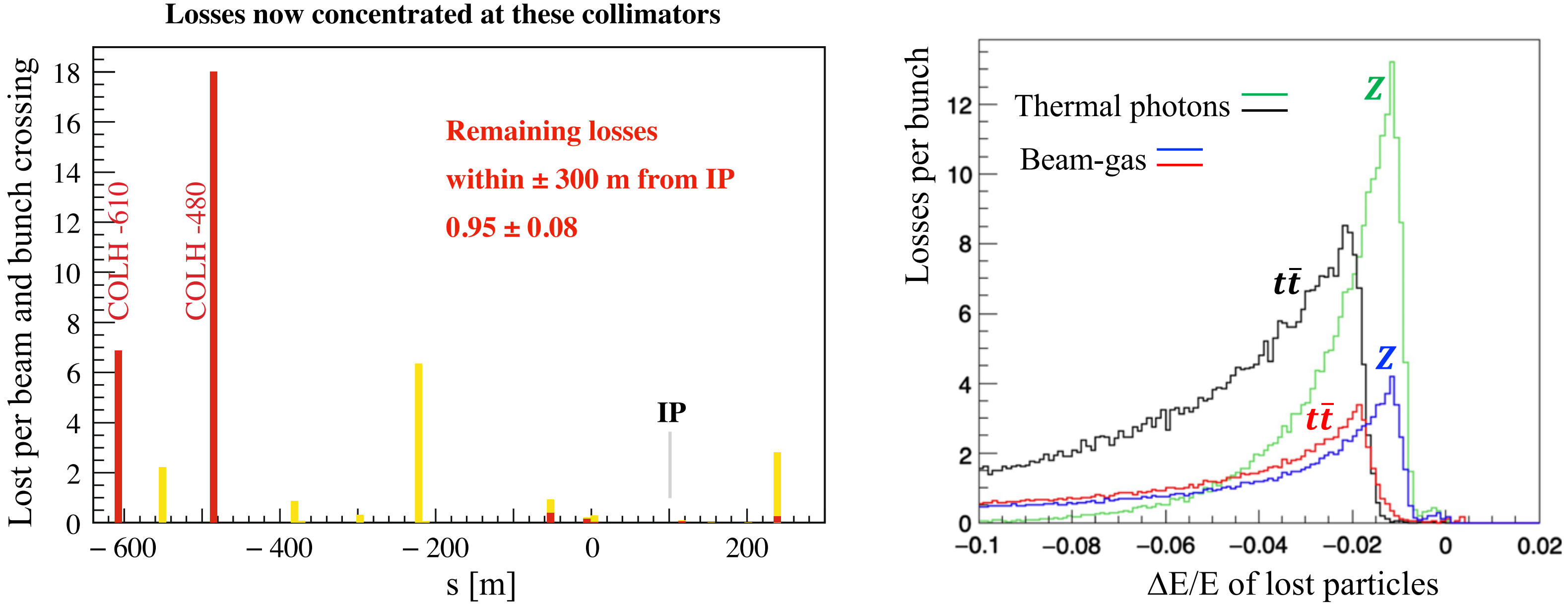


Fig. 3 Off momentum particle losses: loss map from thermal photons with (red) and without (yellow) colli-mation (left); energy spectrum of lost particles, with 0.001 $\Delta E/E$ per bin (right)

From Linear to Circular e+e- Colliders

Conceptual Adaptations

Lower energy jets and particles, less collimated jets:

- reduced calorimeter depth
- shift imaging vs. energy resolution balance towards the latter
- jet assignment ambiguities: added value of $\pi^0 \rightarrow \gamma\gamma$ mass reconstruction
- tracking even more multiple-scattering dominated: **increased pressure on material budget of vertex detector and main tracker**
  - fresh air to gaseous tracking

Limitations on solenoidal field B < 2T, to preserve luminosity:

- recover momentum resolution with tracker radius
- on the other hand larger magnetic volume also more easily affordable (coil and yoke)

Main difference: no bunch trains; collisions every 20 ns (~ at LHC)

- **no power pulsing, more data bandwidth: both imply larger powering and cooling needs**
- **adds material to the trackers and compromises calorimeter compactness - or reduce granularity, timing, speed**
- **implications strongly technology-dependent, interesting optimisation challenges**
- **Trigger and DAQ re-enter the stage**

TPC at FCCee

Operating Conditions

Feasibility has been estimated

[A GridPix TPC readout for the ILD experiment at the future International Linear Collider](#)
[Cornelis Ligtenberg]([Vrije U., Amsterdam]) (2021)
[pdf]

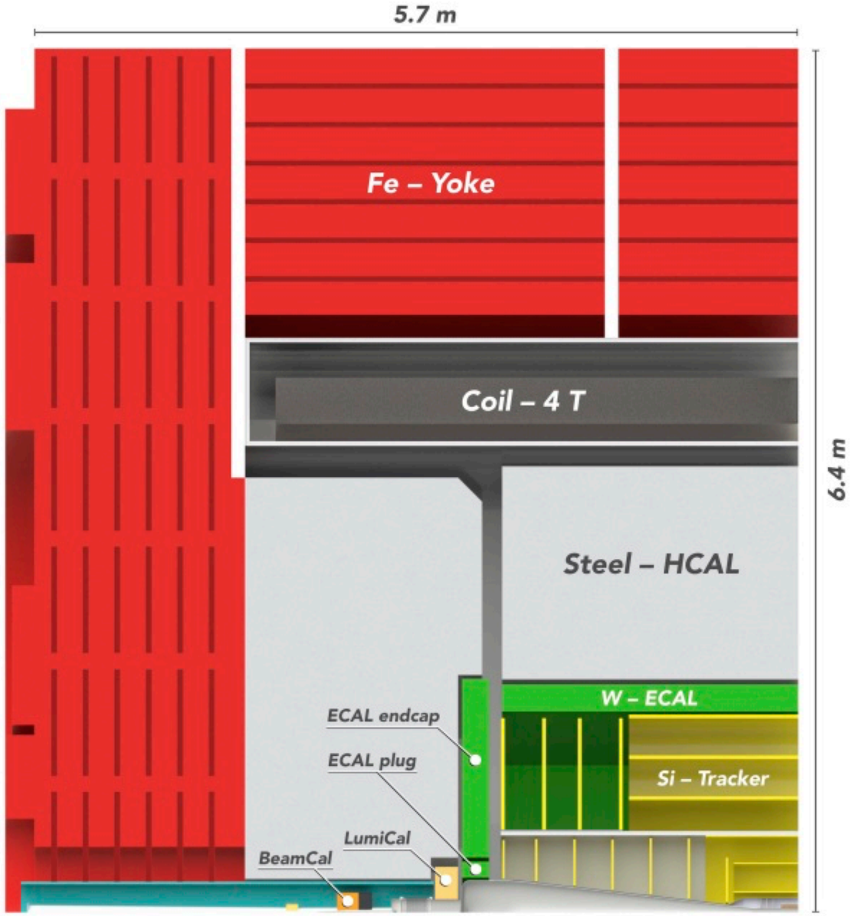
Conclusions

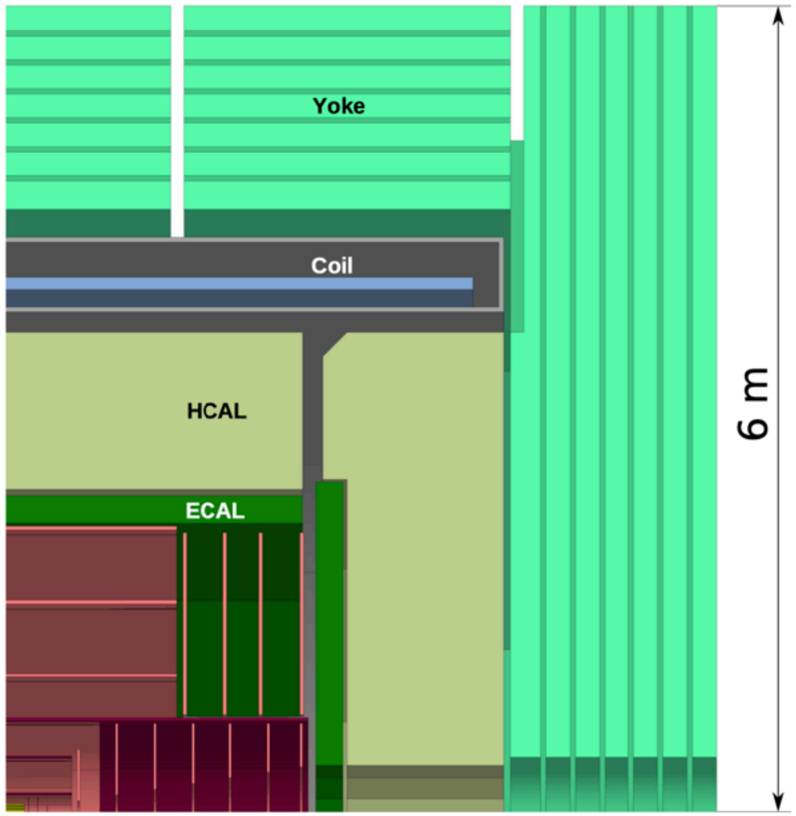
- Z pole most challenging
- low background: Z events are main source of ionisation
  - Z -> qq rate 100 kHz (L = 230e34 cm-2s-1
  - 10x more ionisation than at the ILC: large distortions
  - *“an ILD-style TPC is probably not the most suitable tracker for the FCCee"*
- ILD should formulate a common view
  - definitive, or further study?
  - consider other gaseous technologies?

From LCs to FCCee

From CLICdet to CLD

- A LC-inspired FCCee detector concept - retaining key performance parameters
  Evolving from CLIC to CLD





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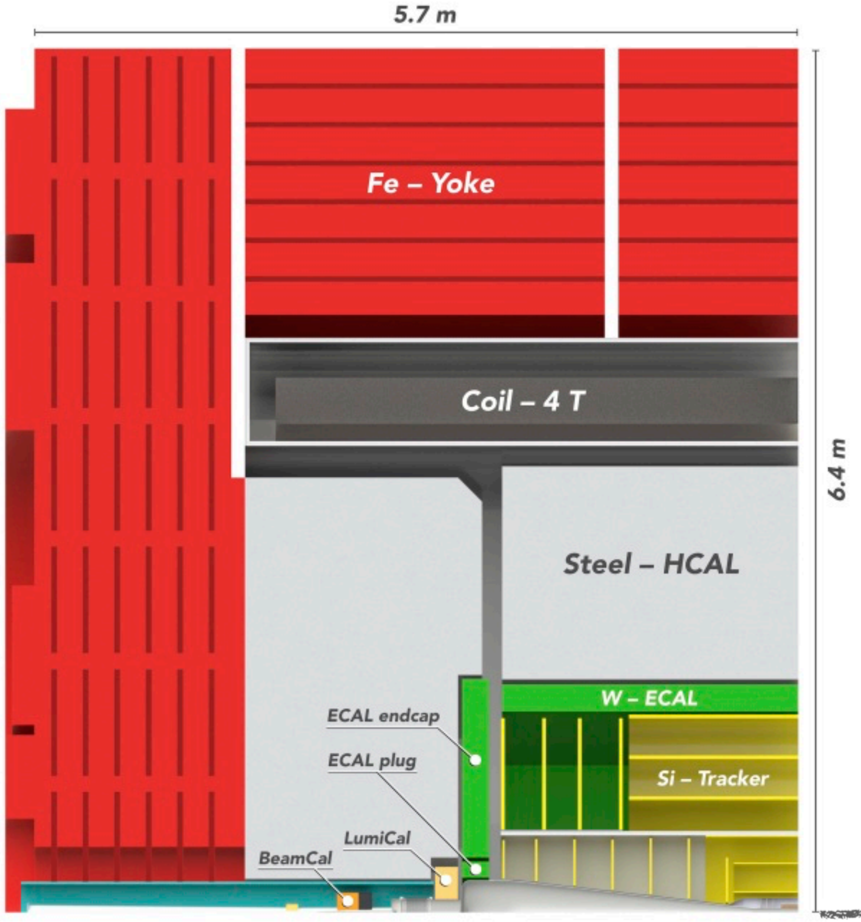
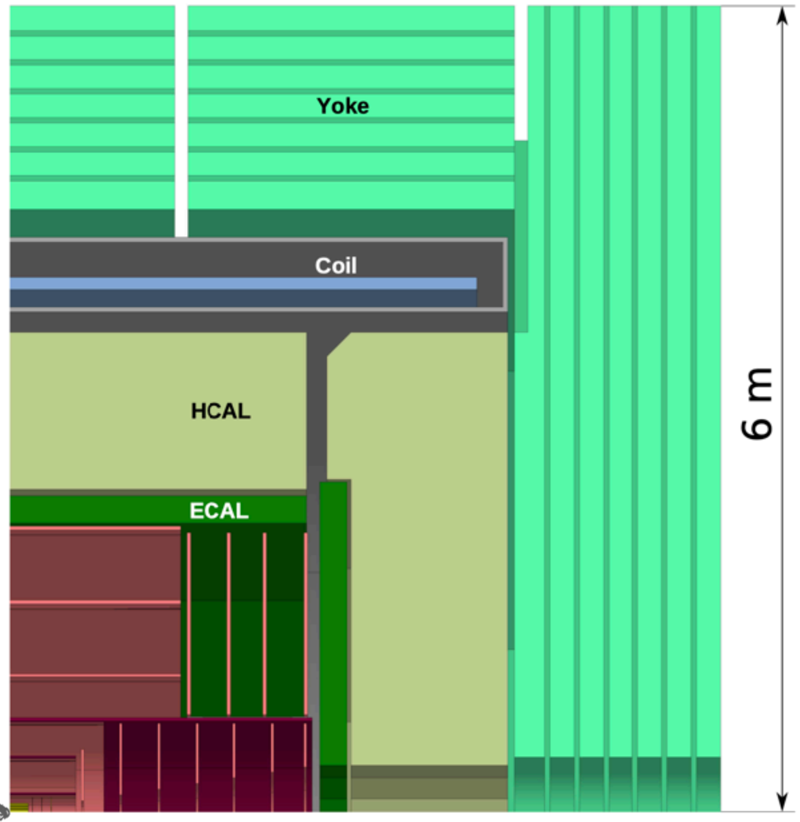


smaller VTX radius: profit from lower backgrounds, compensate material



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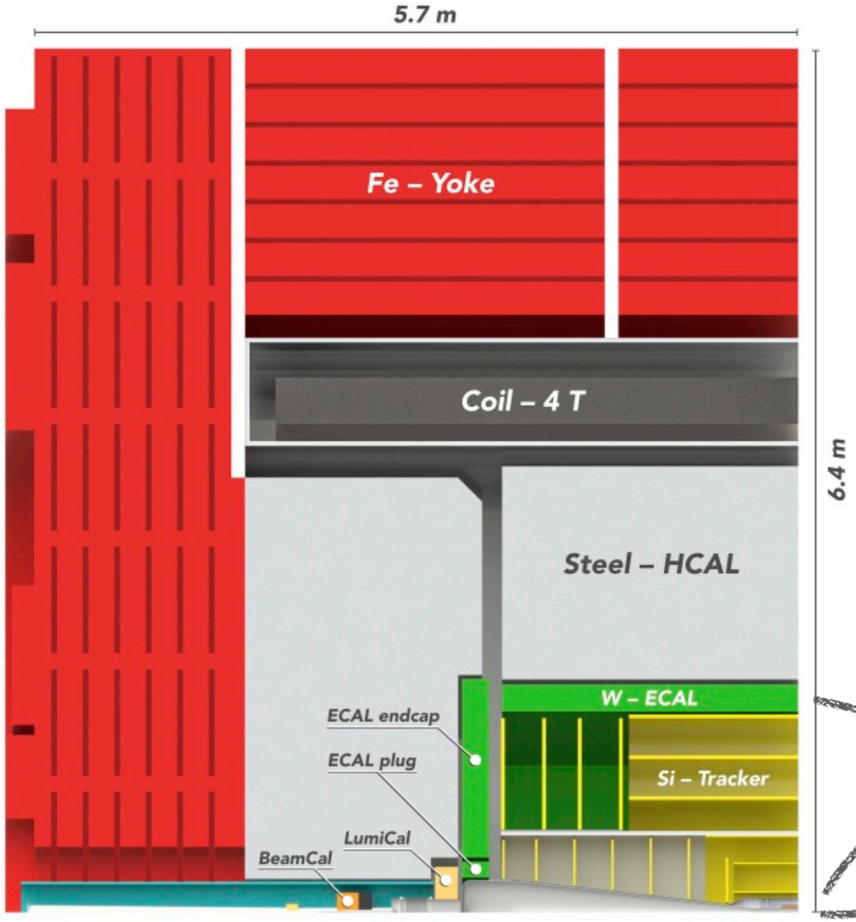
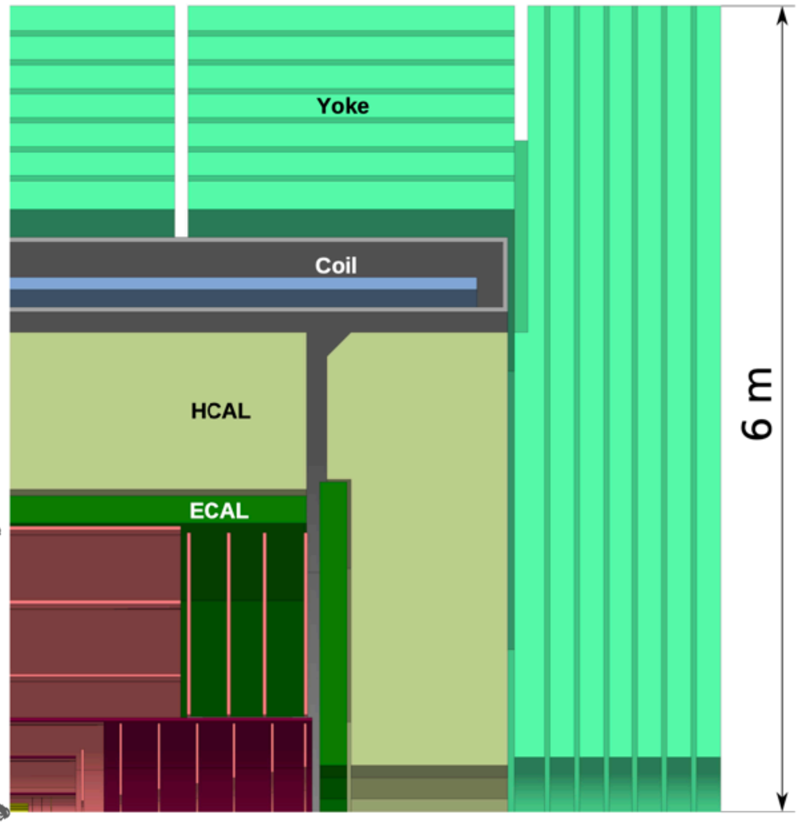


increase in tracker radius: retain p resolution

smaller VTX radius: profit from lower backgrounds, compensate material



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MAX-PLANCK-INSTITUT FÜR PHYSIK

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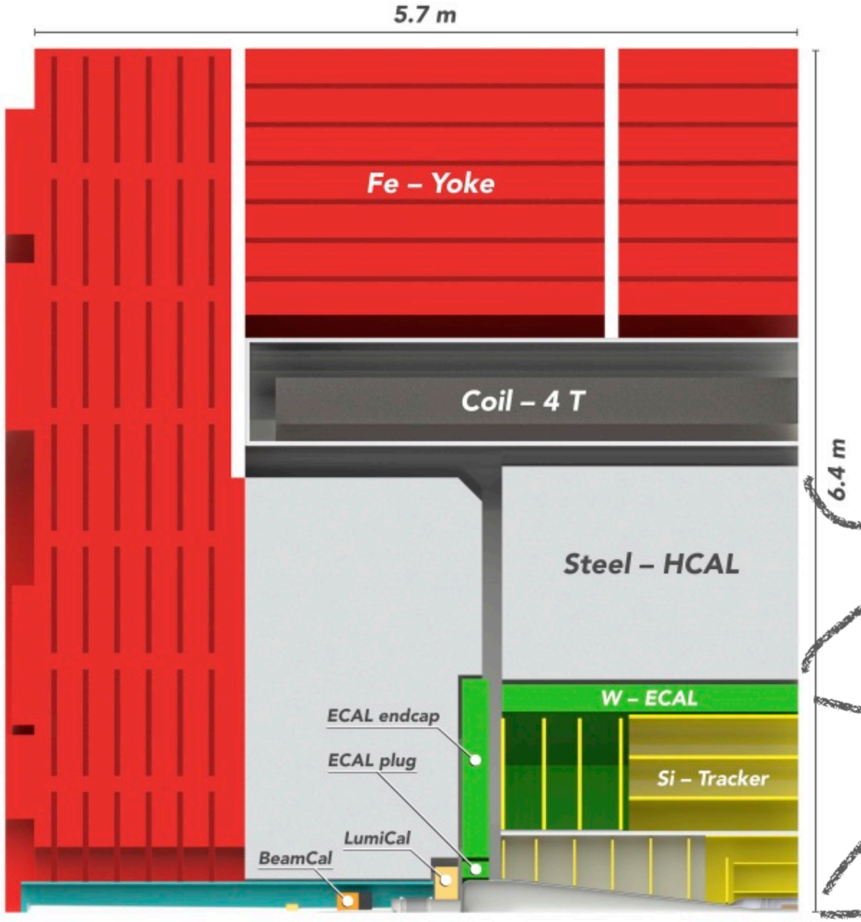
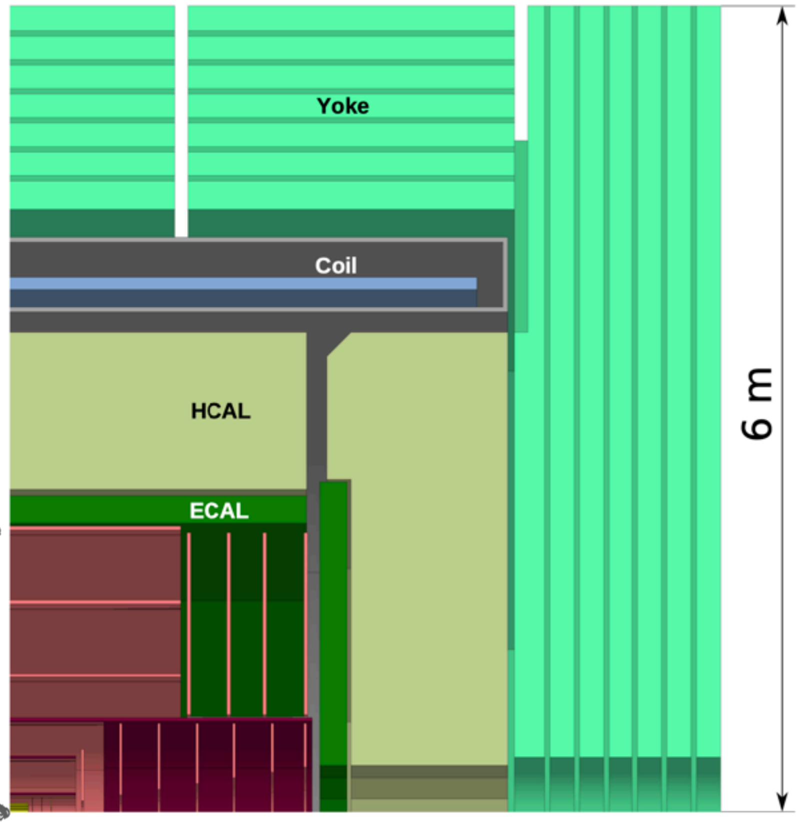


reduced HCAL thickness: enabled by lower energy

increase in tracker radius: retain p resolution

smaller VTX radius: profit from lower backgrounds, compensate material



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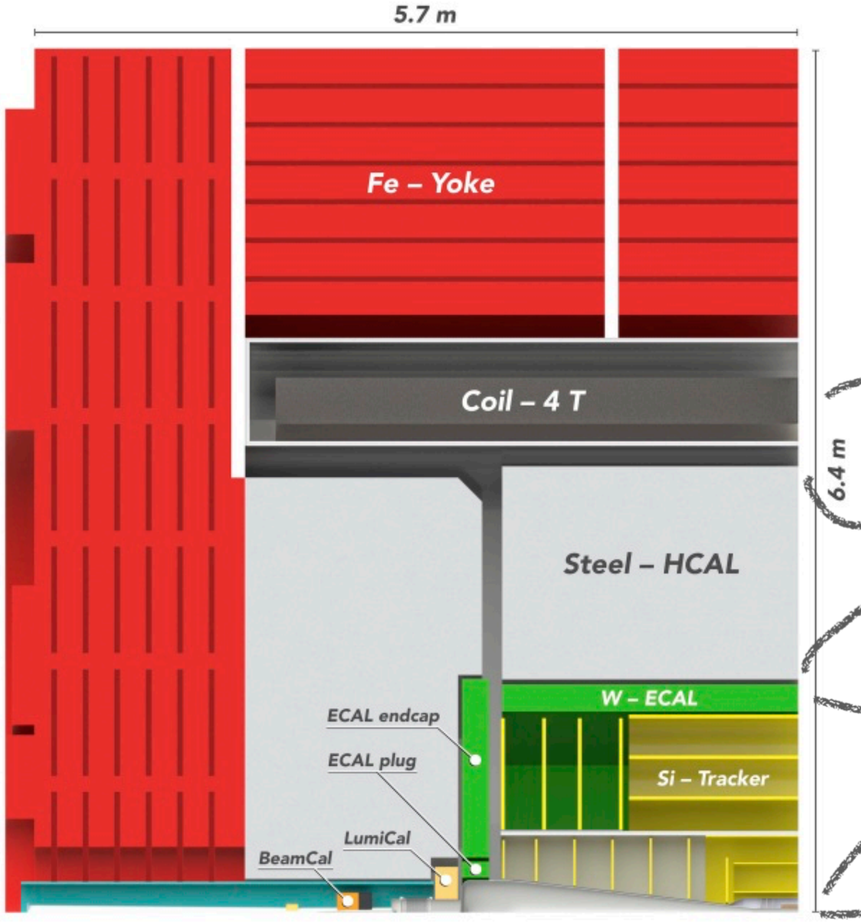
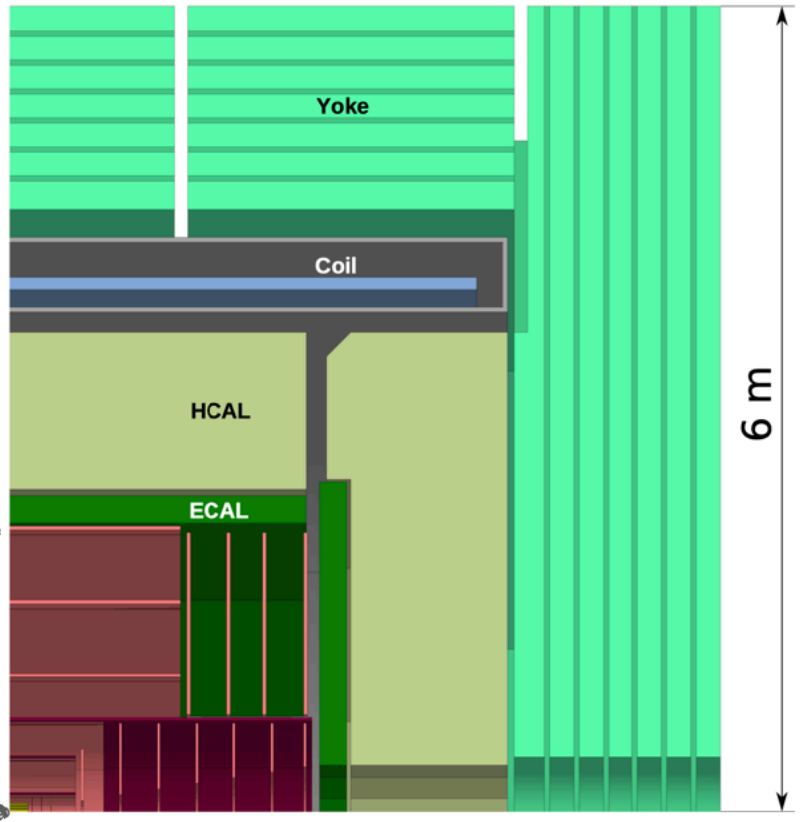


lower field: enable high luminosity in circular collider

reduced HCAL thickness: enabled by lower energy

increase in tracker radius: retain p resolution

smaller VTX radius: profit from lower backgrounds, compensate material



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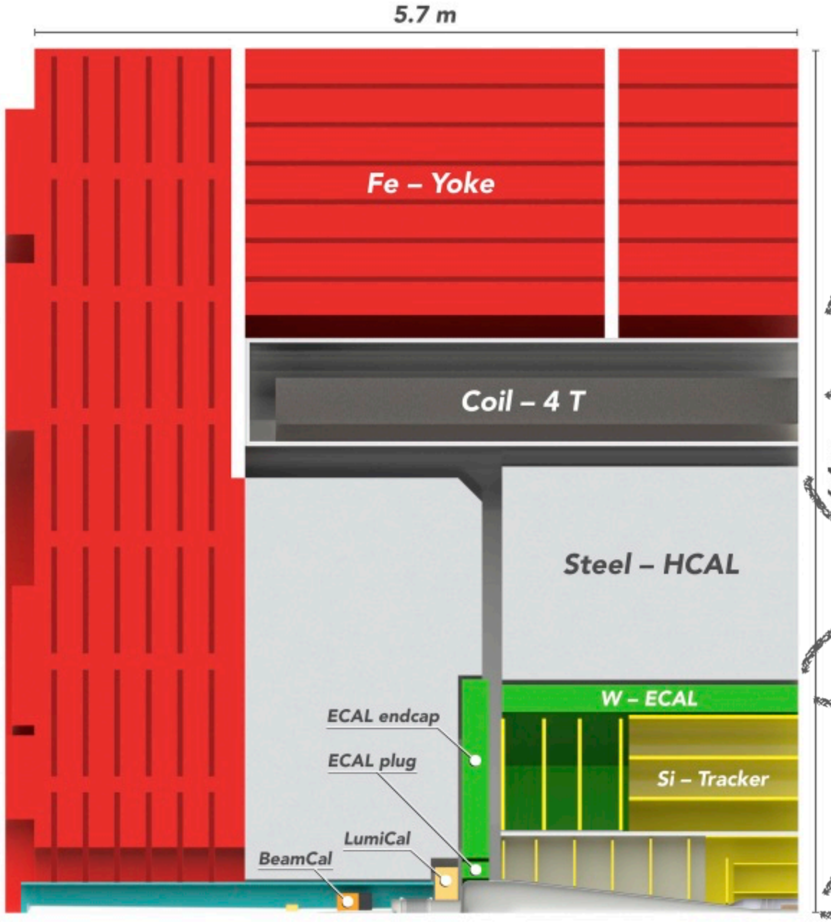

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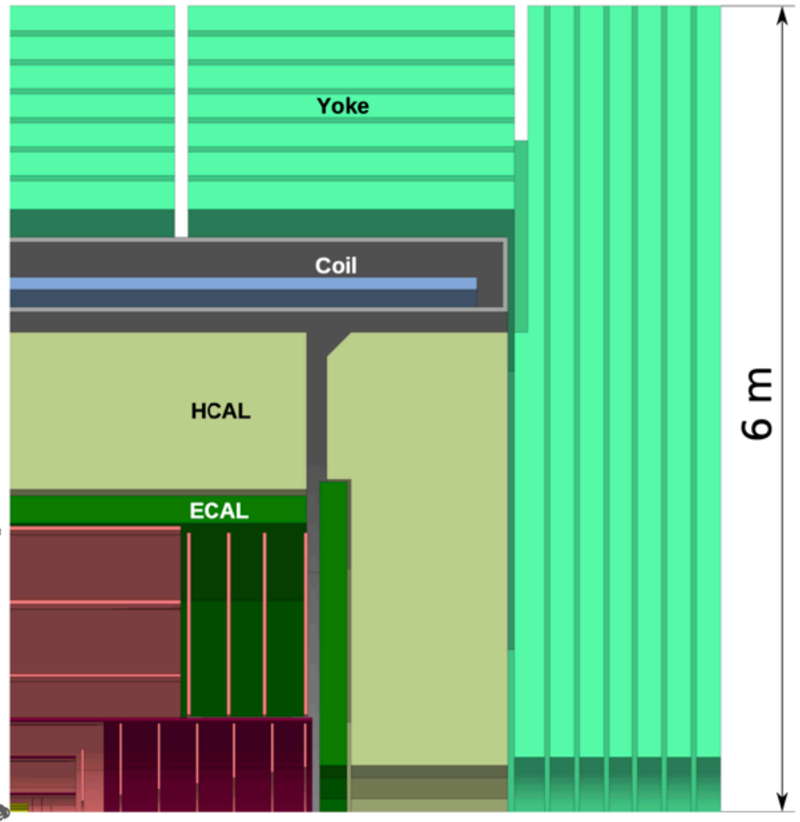
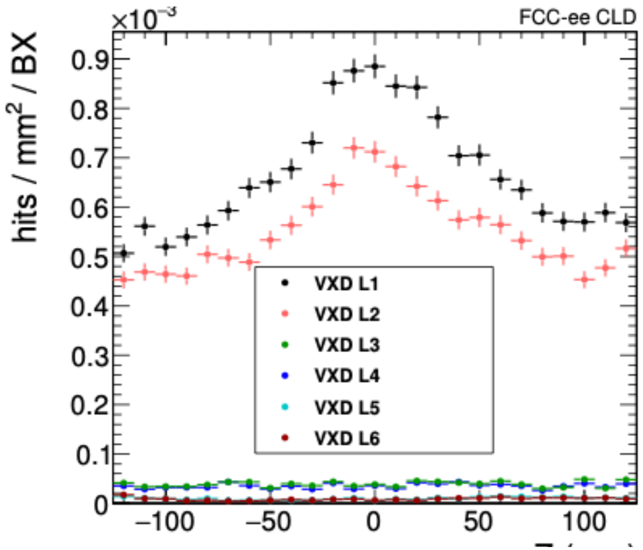
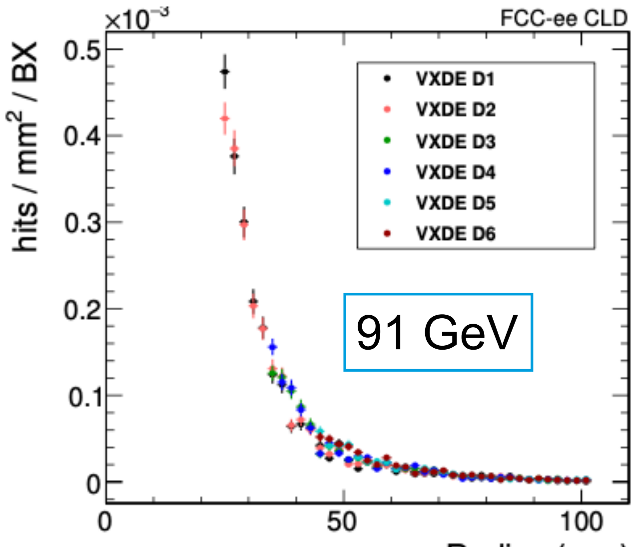
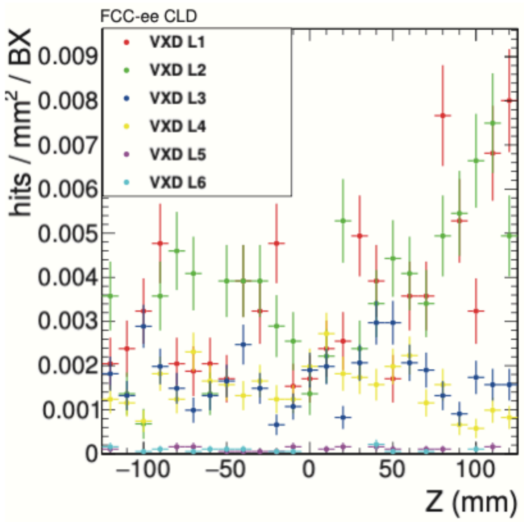


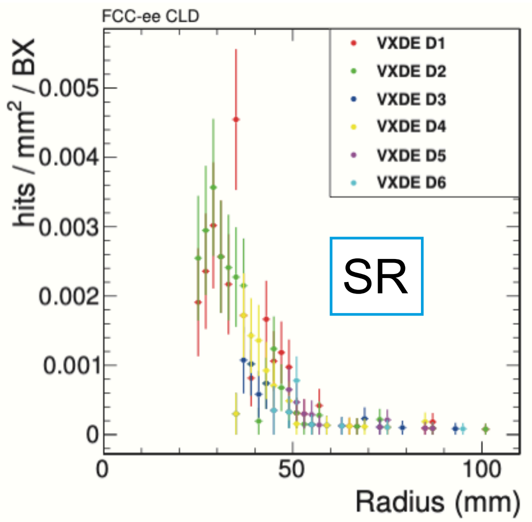
Backgrounds in the CLD Vertex Detector

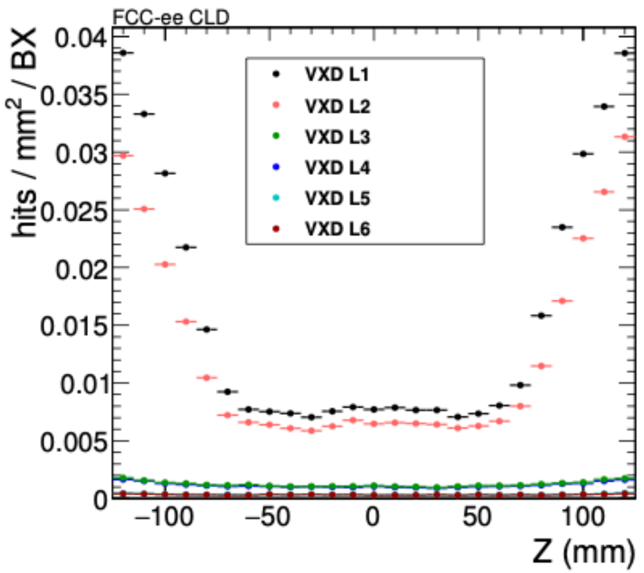
Incoherent pairs and SR (gamma-gamma negligible)

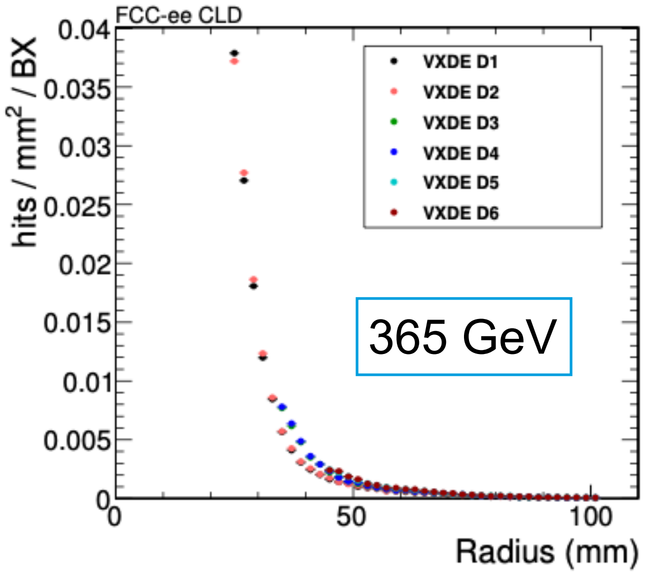












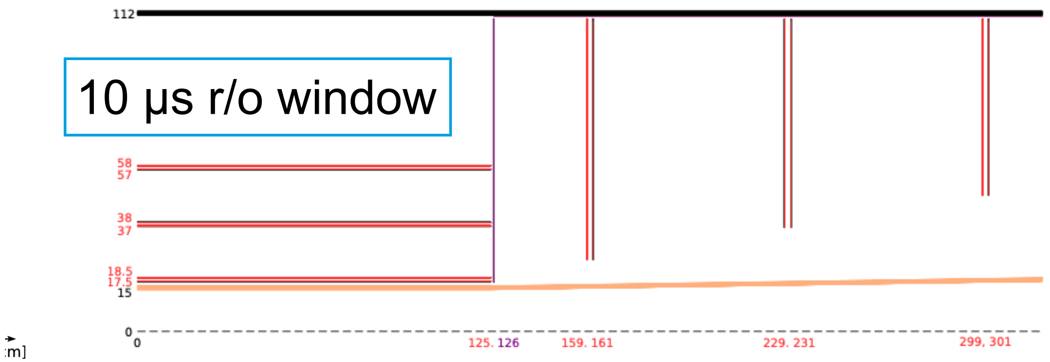
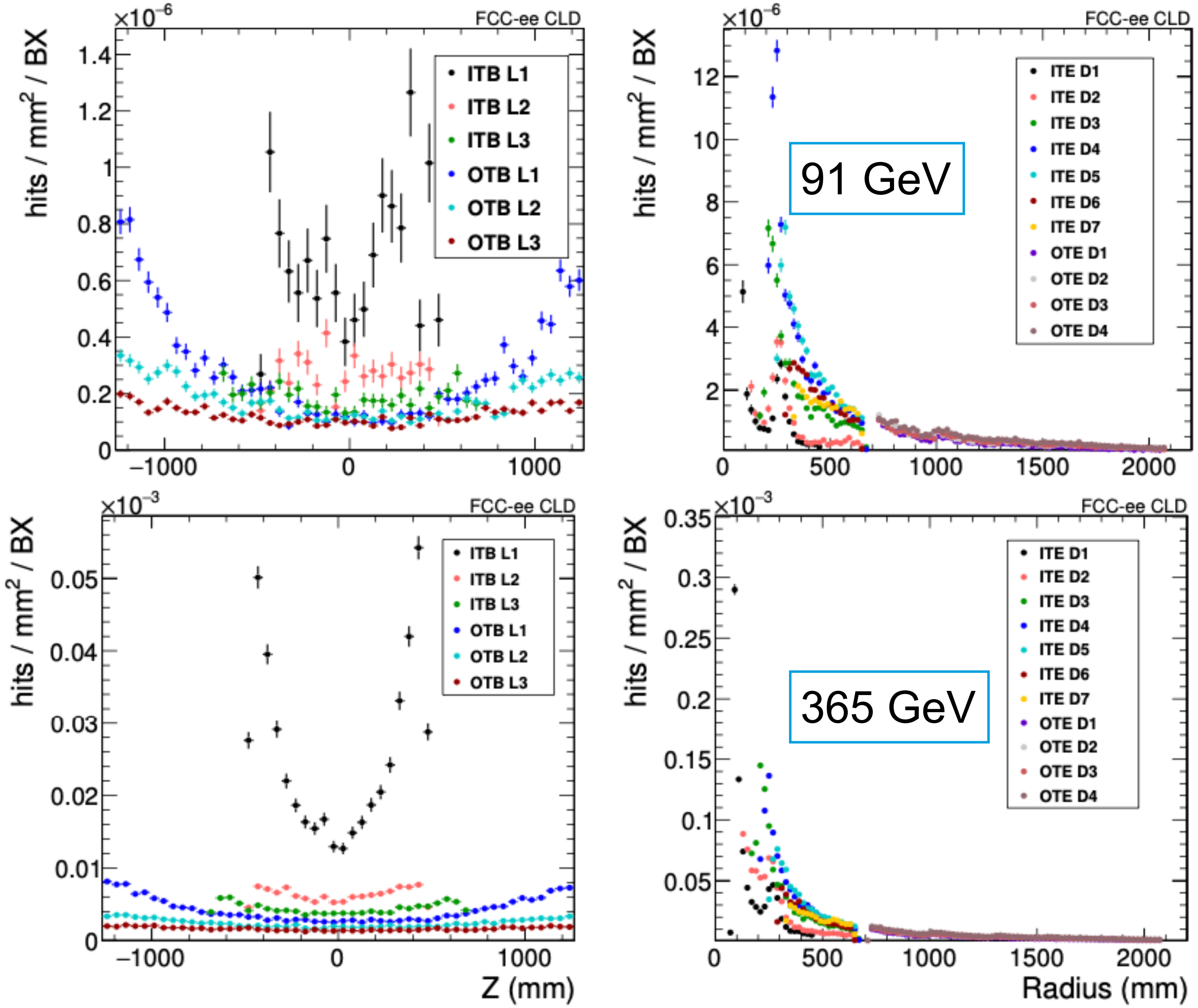
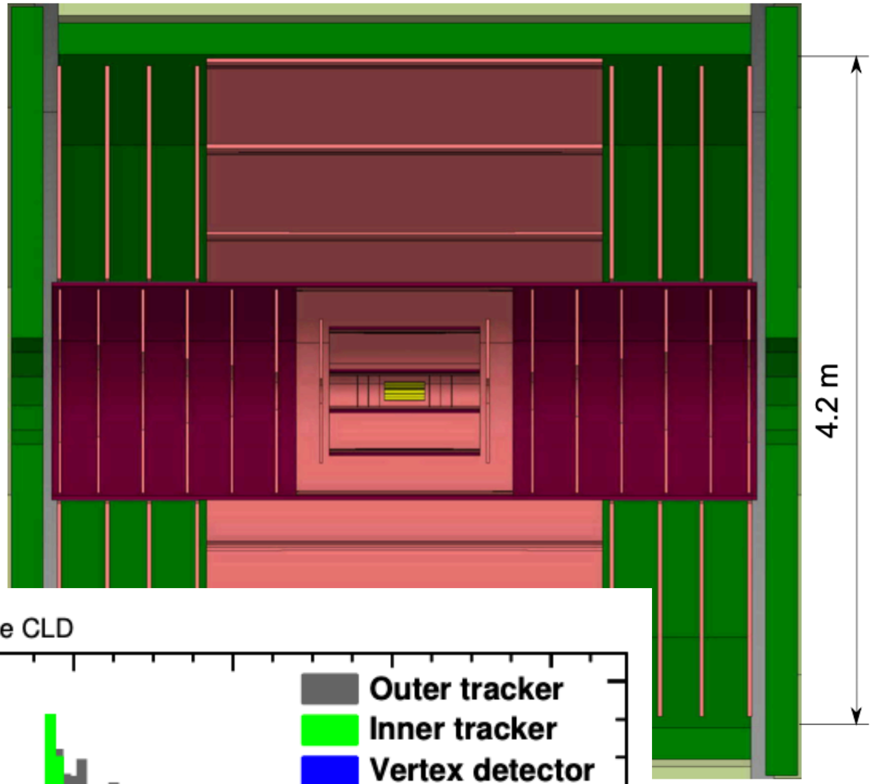


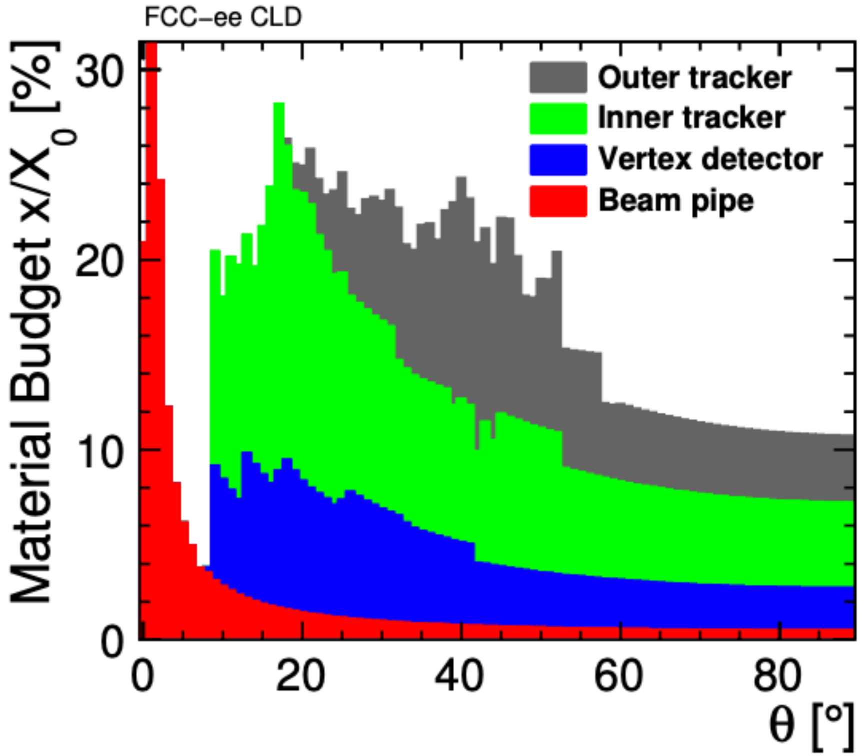
Figure 4: Sketch of the vertex detector barrel and forward region (in the ZR plane) of the CLD simulation model. Dimensions are given in mm. Red lines indicate sensors, black lines support structure, while magenta lines show cables. The vacuum beam pipe is shown in orange colour.

Backgrounds in the CLD Tracking Region

Incoherent pairs







Conclusion

Preliminary

Crossing angle and low L* represent significant MDI challenges

- low solenoidal field favours a large detector

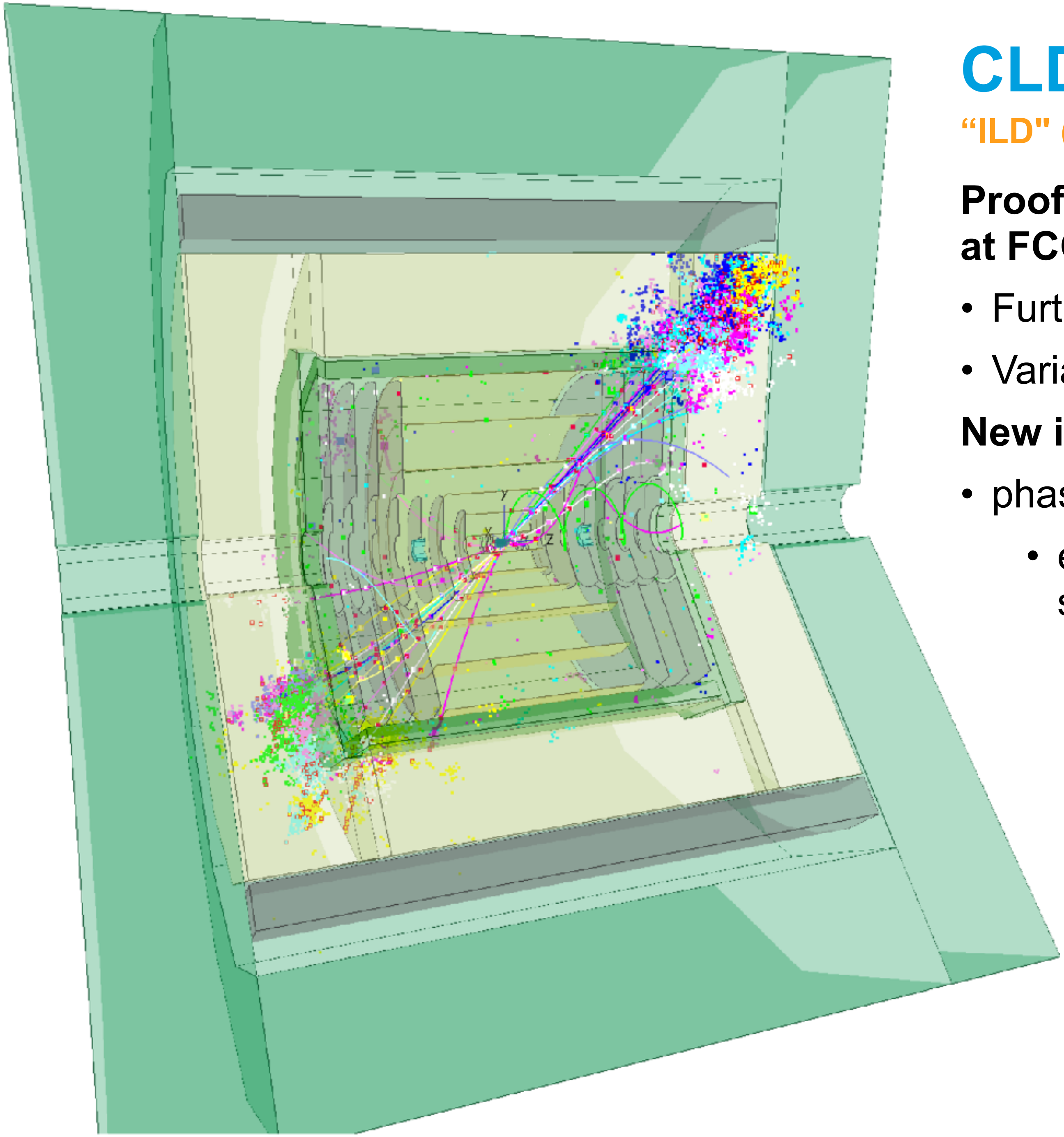
Beam-induced back-grounds appear benign for CLD

- however still rather idealistic studies

TPC not favoured at first glance

- may deserve a closer look

Back-up



CLD: CLIC-like Detector for FCCee

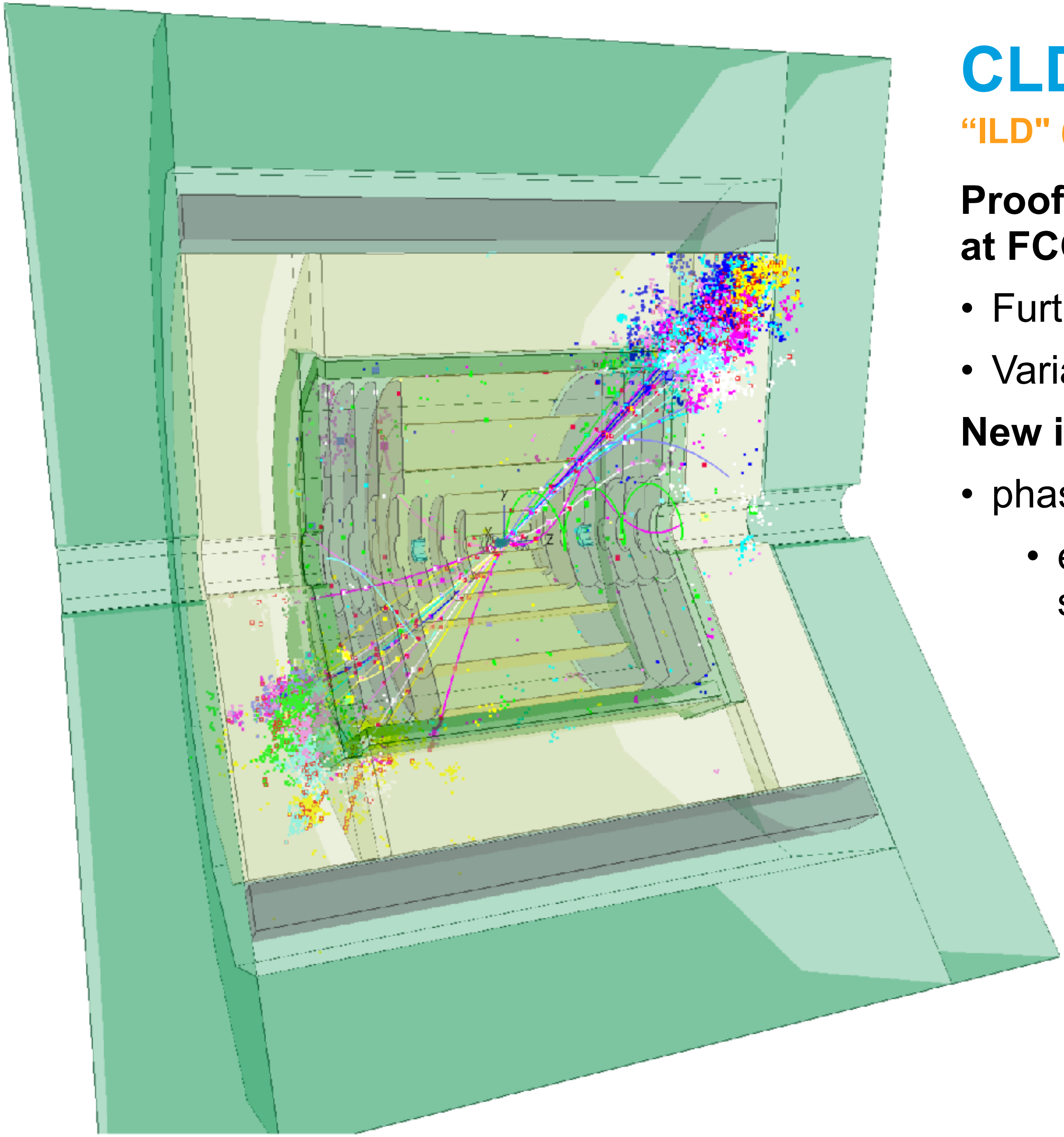
“ILD" (with Gaseous Tracking) also Possible

Proof-of-principe for a particle-flow detector concept at FCCee

- Further optimisation possible - and likely
- Variants also (e.g. gaseous tracker, gaseous HCAL,…)

New ideas and technologies

- phase space largely overlaps with that for LCs
    - e.g. fast timing for particle ID, new tracker read-out schemes, more compact electronics,…



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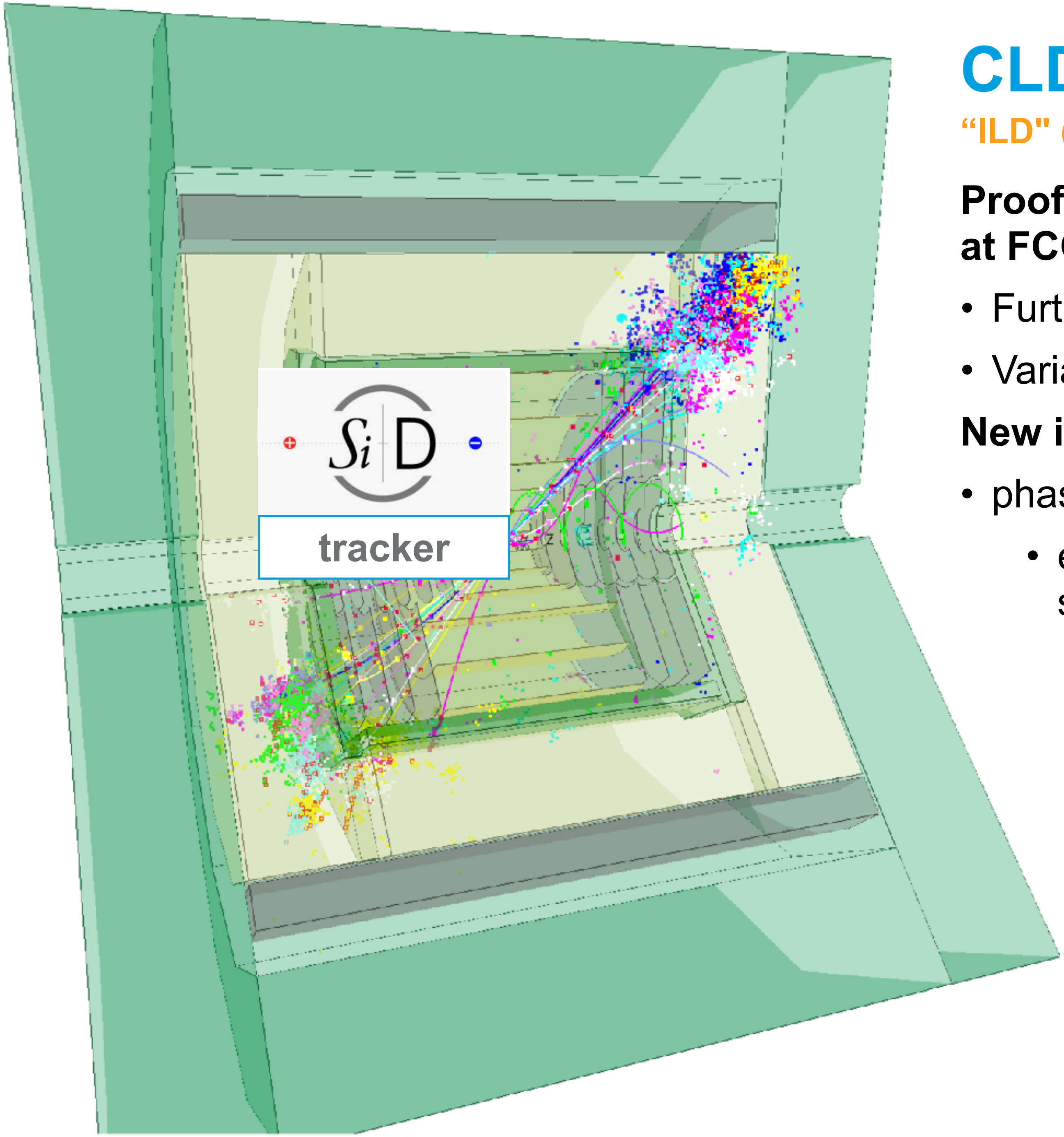
Inherits ILC and CLIC assets

- software framework **key4HEP (DESY)**
- performance validation with prototypes

However, in most if not all cases feasibility of continuous readout, including power and cooling is still to be demonstrated - clear R&D path

- benefit from HL-LHC upgrades, e.g. CMS HGCAL
- **need engineers already in R&D phase**



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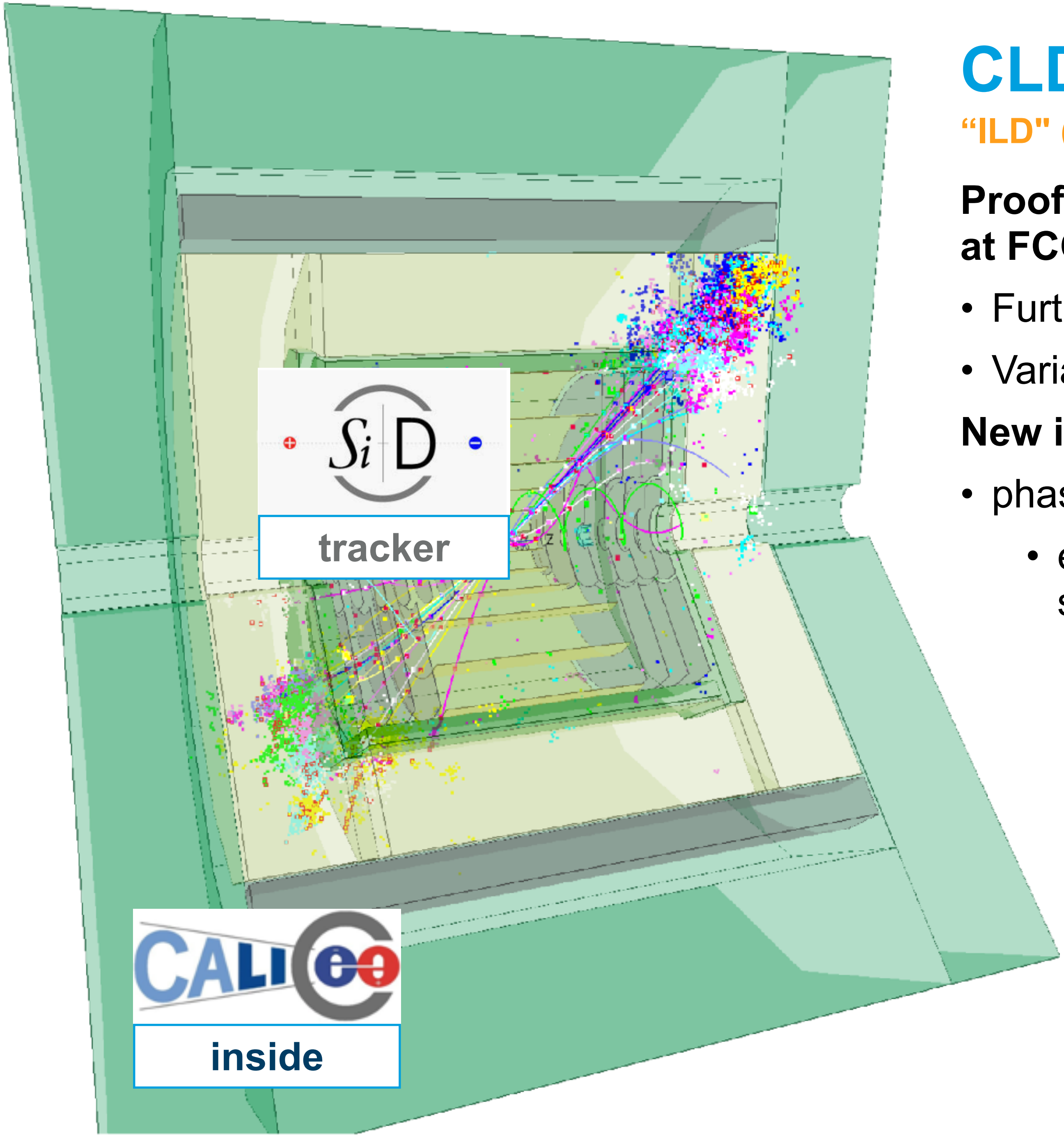

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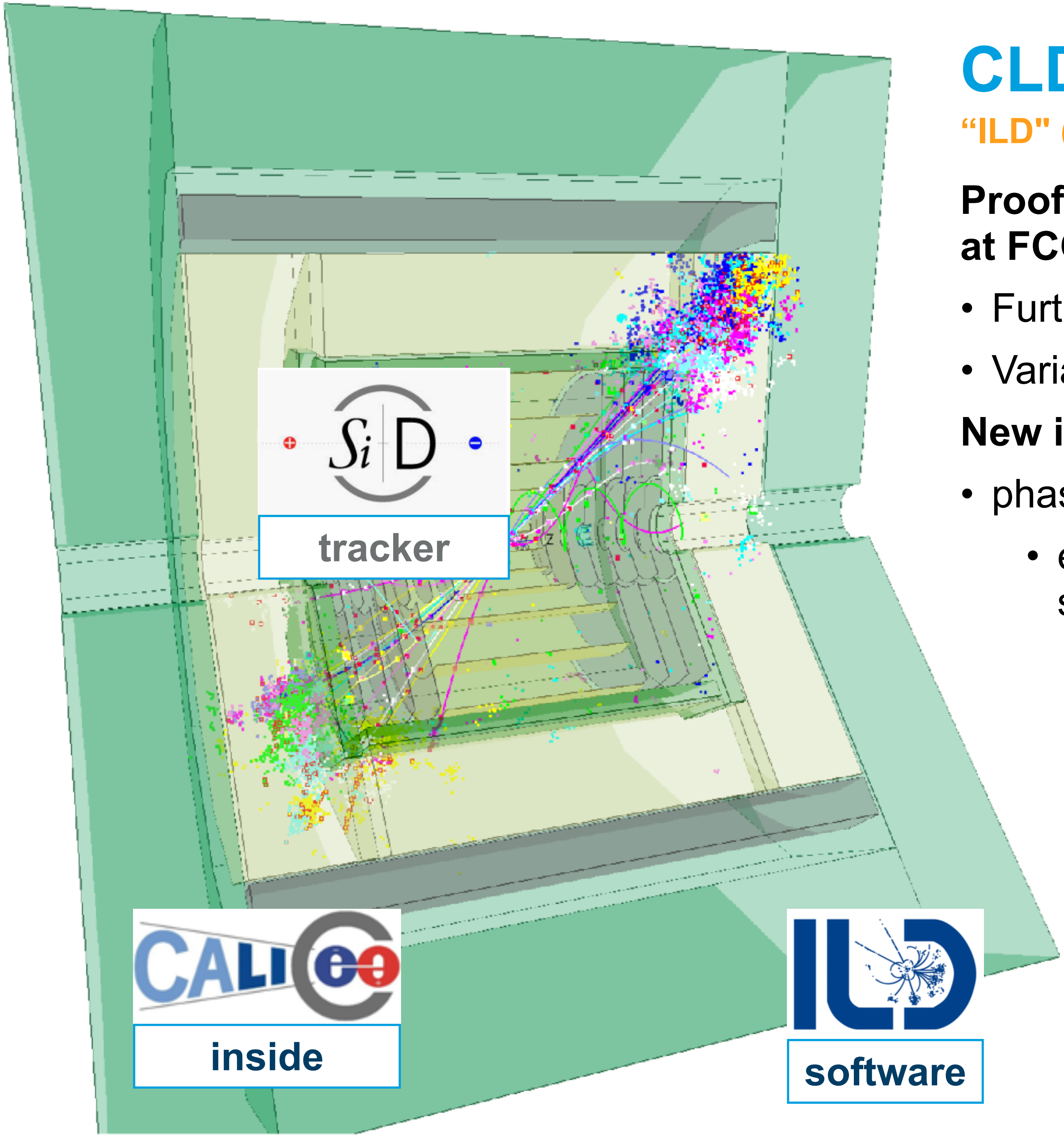

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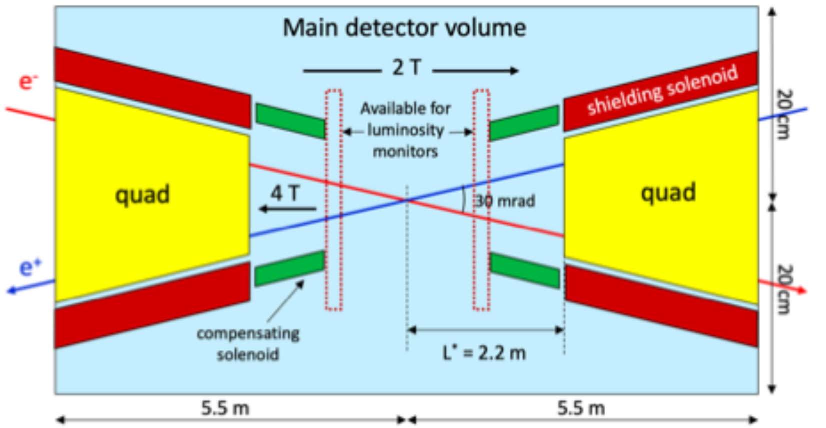
FCCee Experimental challenges

- 30 mrad beam crossing angle
  - Detector B-field limited to 2 Tesla at Z-peak operation
  - Very complex and tightly packed MDI (Machine Detector Interface)
- ”Continuous” beams (no bunch trains); bunch spacing down to 20 ns
  - Power management and cooling (no power pulsing)
- Extremely high luminosities
  - High statistical precision – control of systematics down to 10^{-5} level
  - Online and offline handling of $\mathcal{O}(10^{13})$ events for precision physics: ”Big Data”
- Physics events at up to 100 kHz
  - Fast detector response ($\lesssim$ 1 µs) to minimise dead-time and event overlaps (pile-up)
  - Strong requirements on sub-detector front-end electronics and DAQ systems
    - At the same time, keep low material budget: minimise mass of electronics, cables, cooling, …

Central part of detector volume – top view



- More physics challenges
  - Luminosity measurement to 10^{-4} – luminometer acceptance to 1 µm level
  - Detector acceptance to ~10^{-5} – acceptance definition to few 10s of µm, hermeticity (no cracks!)
  - Stability of momentum measurement – stability of magnetic field wrt E_{cm} (10^{-6})
  - Impact parameters, detached vertices – Higgs physics (b/c/g jets); flavour and τ physics, life-time measurements
  - Particle identification (π/K/p) without ruining detector hermeticity – flavour and τ physics (and rare processes)

R&D Overview

Synergies Dominate

Detector Technology	Linear & Circular Colliders common R&D	Differences
All	test infrastructure prototype electronics software for reconstruction and optimisation	readout rates power and cooling requirements
Silicon Vertex and Track Detectors	highest granularity and resolution, timing ultra-thin sensors and interconnects simulation and design tools low-mass support structures cooling micro-structures	emphasis on timing (background) and position resolution
Gaseous Trackers and Muon Chambers	ultra-light structures for large volumes industrialisation for large area instrumentation eco-friendly gases	DC and TPC presently considered only at some colliders
Calorimeters and Particle ID	highly compact structures and interfaces advanced photo-sensors and optical materials ps timing sensors and electronics	emphasis on granularity and stability DR and LAr pesresently only considered for circular