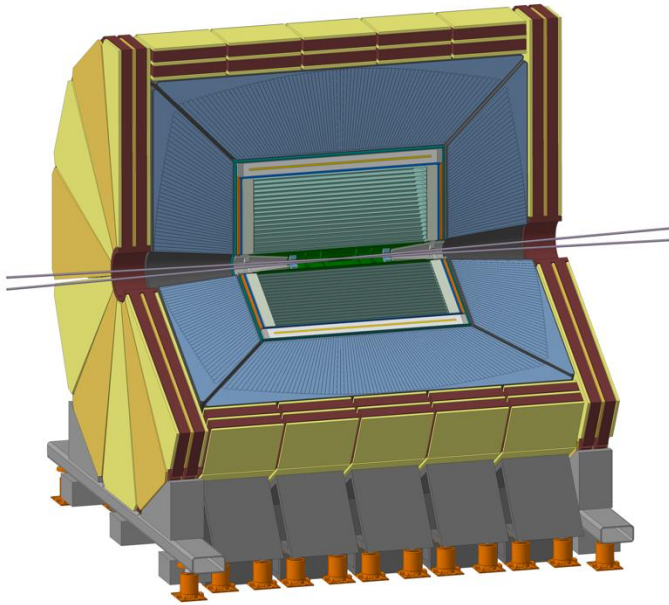
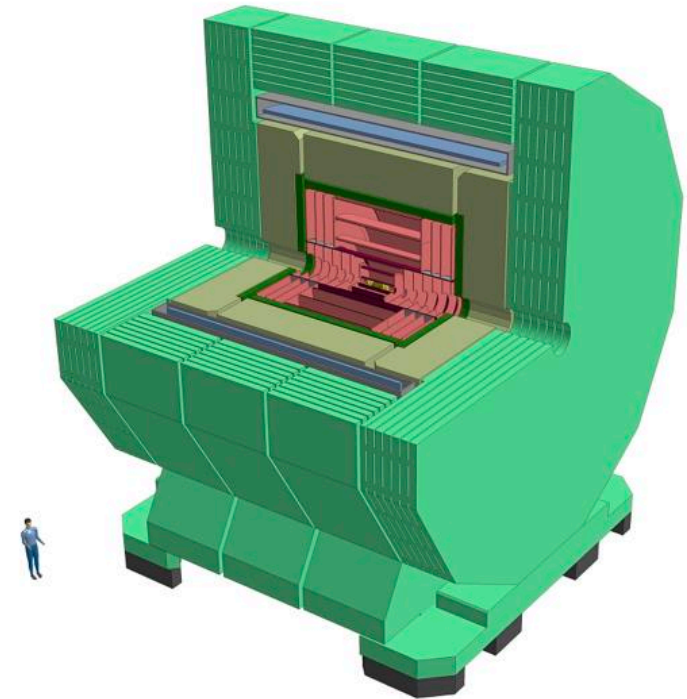


FCC-ee Detector Concepts



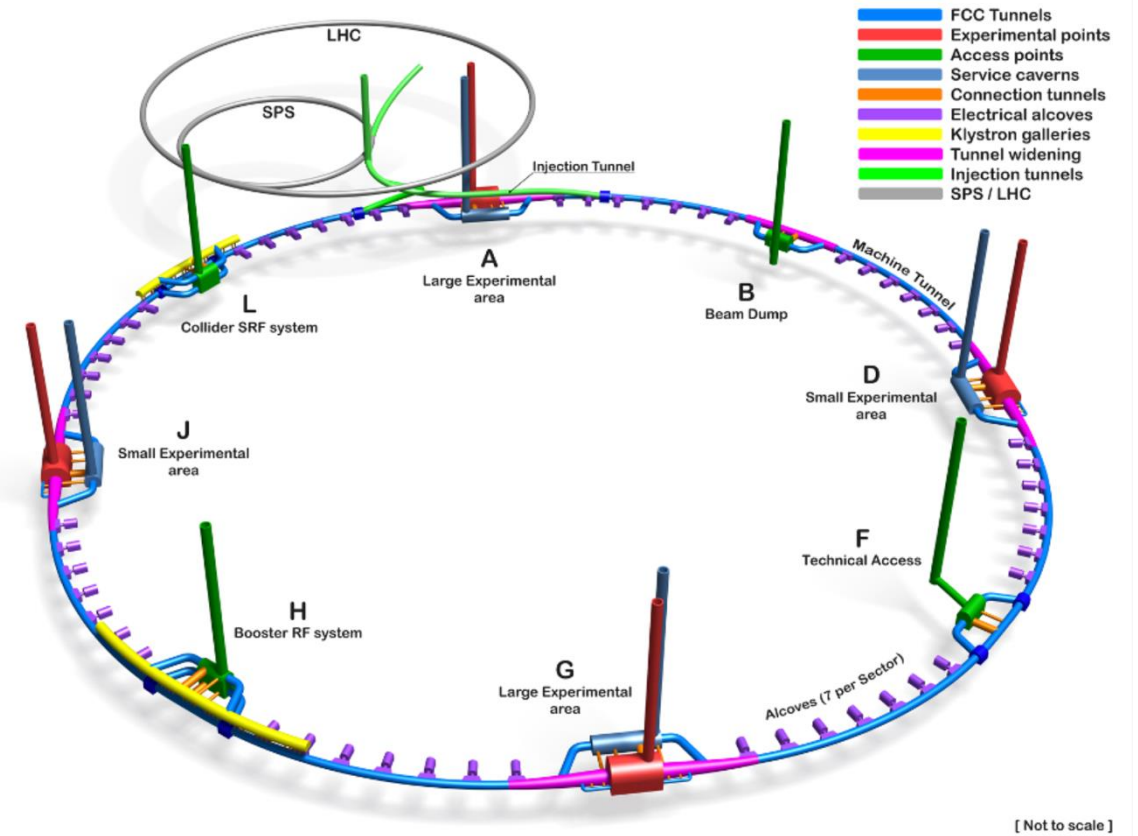
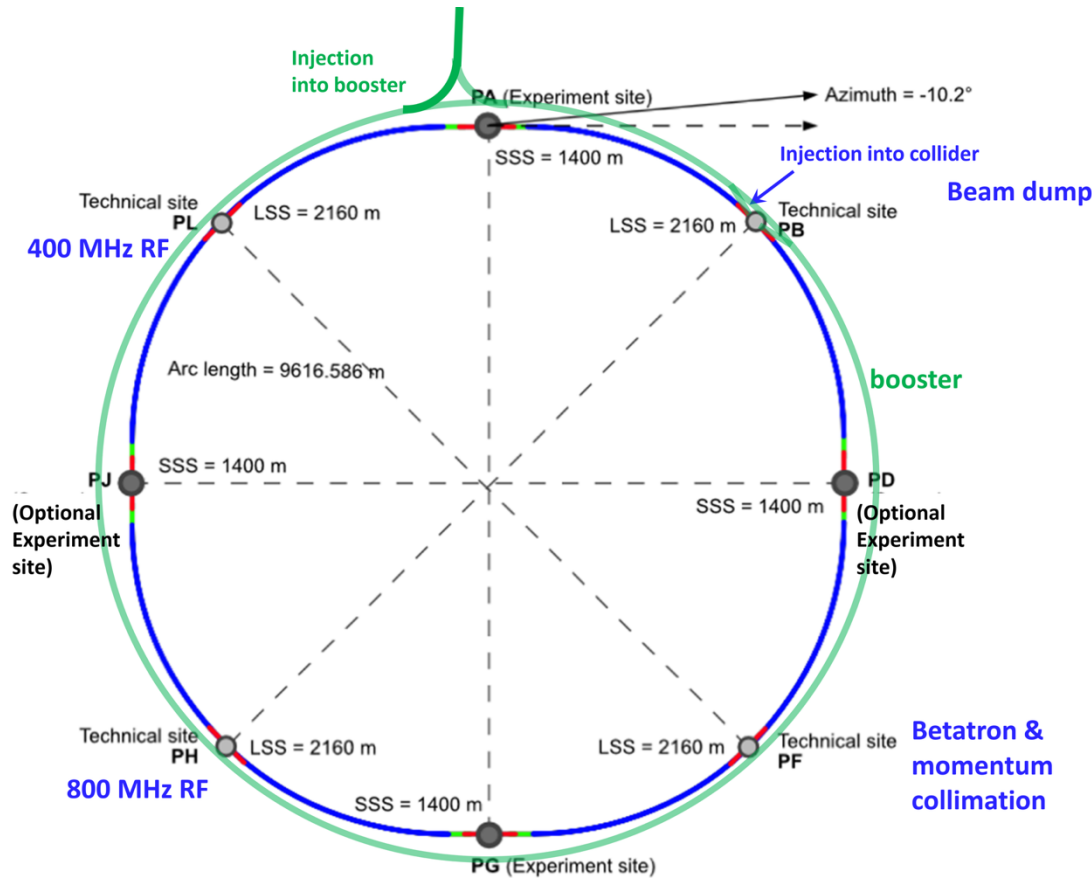
Mogens Dam
Niels Bohr Institute

ILD Meeting
CERN
14 September, 2026



- ◆ FCC-ee Experimental Conditions
- ◆ Detector Requirements and Challenges
- ◆ Detector Concepts
- ◆ Detector Sub-systems and Technologies
- ◆ Organisational Matters
- ◆ Summary

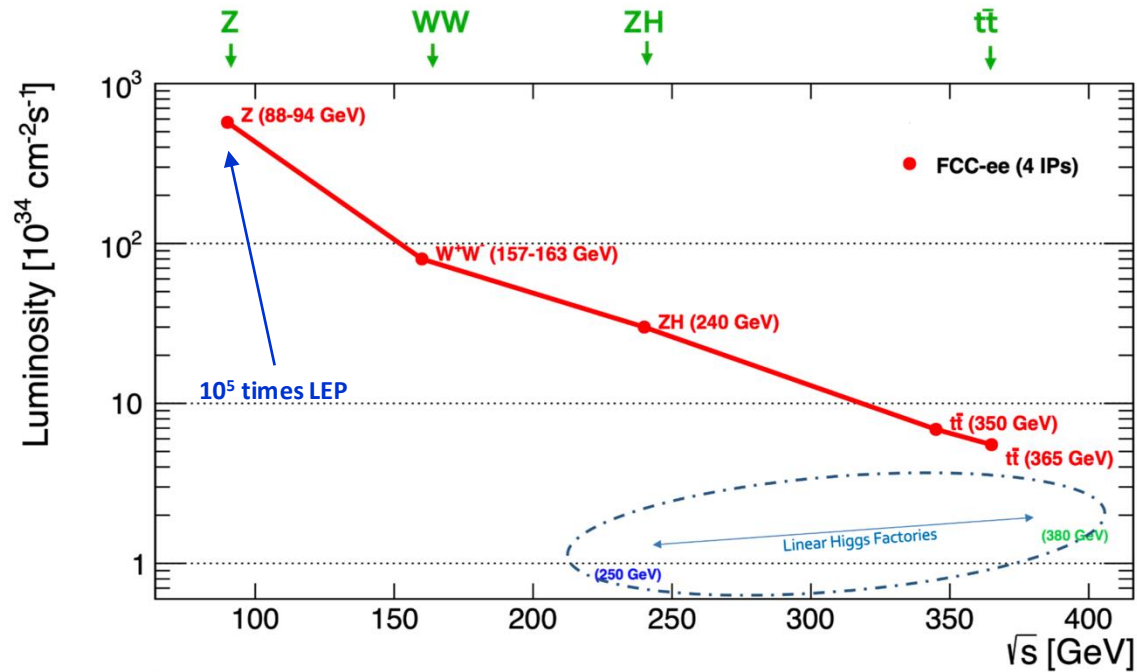
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- ◆ Double ring e^+e^- collider, 91 km
- ◆ Large crossing angle 30 mrad, crab-waist optics
- ◆ Top-up injection from separate booster ring

- ◆ Four experimental areas / experiments
 - Experimental diversity - control of overall systematic uncertainties
 - Higher statistics
 - Sustainability - physics/TWh

FCC-ee Luminosity and Conditions



Z peak	$\sqrt{s} \sim 91$ GeV	4 years	6×10^{12}	$e^+e^- \rightarrow Z$
WW threshold	$\sqrt{s} \sim 160$ GeV	2 years	2.4×10^8	$e^+e^- \rightarrow W^+W^-$
ZH maximum	$\sqrt{s} \sim 240$ GeV	3 years	2.3×10^6	$e^+e^- \rightarrow ZH$
$t\bar{t}$ threshold	$\sqrt{s} \sim 365$ GeV	2 years	2×10^6	$e^+e^- \rightarrow t\bar{t}$
[s-channel Higgs	$\sqrt{s} = 125$ GeV	5? years	~ 5000	$e^+e^- \rightarrow H_{125}$

FCC-ee parameters		Z	W^+W^-	ZH	$t\bar{t}$
$\sqrt{s}$	GeV	91.2	160	240	350-365
Luminosity / IP	$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	140	20	7.5	1.5
Bunch spacing	ns	25	160	680	5000
"Physics" cross section	pb	35,000	10	0.2	0.5
Total cross section	pb	70,000	30	10	8
Event rate	Hz	100,000	6	0.5	0.1
"Pile up" parameter [μ]	10^{-6}	2,500	1	1	1

Experimentally, Z pole is the most challenging

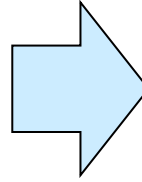
- Extremely large statistics
- Physics event rates of ~ 100 kHz
- Bunch spacing at 25 ns
 - "Continuous" beams, no bunch trains, no power pulsing
- However, no pileup, no underlying event
 - ...well, pileup of 2.5×10^{-3} at Z pole

- ◆ FCC-ee Experimental Conditions
- ◆ **Detector Requirements and Challenges**
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Very Rich Physics Programme → Challenging Detectors

Higgs Factory Programme

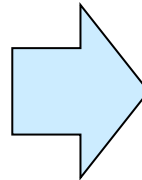
- At $\sqrt{s}=240$ and $\sqrt{s}=365$ GeV collect 2.6M HZ and 150k WW → H events
- Higgs couplings to fermions and bosons
- Higgs self-coupling ($\sim 4 \sigma$) via loop diagrams
- Unique possibility: s-channel $e^+e^- \rightarrow H$ at 125 GeV



- **Momentum resolution** $\sigma(p_T)/p_T = \text{few} \times 10^{-3}$ @ $p_T = 50$ GeV
 - $\sigma(p)/p$ limited by multiple scattering → minimise material
- **Jet** $\sigma(E)/E \simeq 3\text{-}4\%$ in multijet events for Z / W / H separation
- **Superior impact parameter resolution** for b, c tagging
- **Hadron PID** for s tagging

Precision EW and QCD Programme

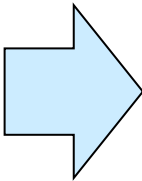
- 6×10^{12} Z and 2×10^8 WW events
- $\times 500$ improvement of statistical precision on EWPO
 $m_Z, \Gamma_Z, \Gamma_{inv}, \sin^2\theta_W, R_b, m_W, \Gamma_W, \dots$
- 2×10^8 tt events: $m_{top}, \Gamma_{top}, \text{EW couplings}$
- Indirect sensitivity to new physics up to tens of TeV



- **Absolute normalisation of luminosity** to $10^{-5} - 10^{-4}$ level
- **Relative normalisation of channels** to $\mathcal{O}(10^{-6})$ [e.g. Γ_{had}/Γ_ℓ]
 - Acceptance definition (forward) to $\mathcal{O}(10 \mu\text{m})$
- **Track angular resolution** < 0.1 mrad
- **Stability of B field** to 10^{-6}

Heavy Flavour Programme

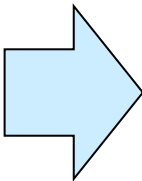
- 10^{12} bb, cc, 2×10^{11} $\tau^+\tau^-$ (clean, boosted): $10 \times$ Belle II stats.
- CKM matrix, CP measurements
- rare decays, CLFV searches, lepton universality



- **Superior impact parameter resolution**
- **Precise identification and measurement of secondary vertices**
- **ECAL resolution** at few %/ $\sqrt{E}$; sensitivity to $\mathcal{O}(100 \text{ MeV})$ photons
- **Excellent π^0/γ separation** for τ -decay-mode identification
- **PID: K/ π separation over wide p range** → dN/dx, RICH, ToF

Feebly coupled particles Beyond SM

- Opportunity to directly observe new feebly interacting particles with masses below m_Z
- Axion-like particles, dark photons, Heavy Neutral Leptons
- Long-lifetime LLPs



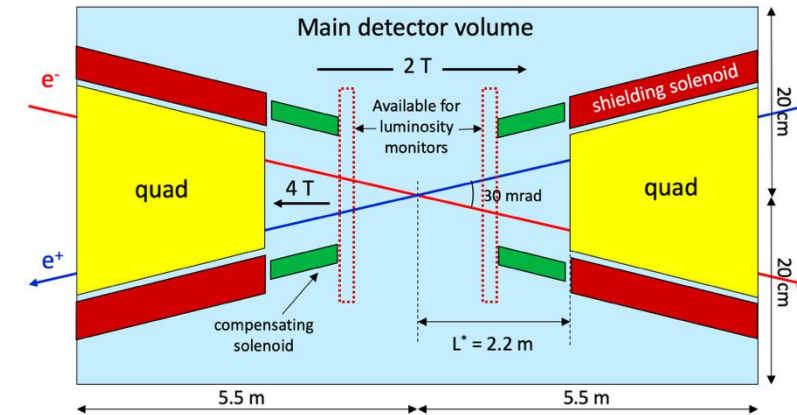
- **Sensitivity to (significantly) detached vertices** (mm → m)
 - tracking: more layers, "continuous" tracking
 - calorimetry: granularity, tracking capabilities
- **Precise timing, ToF**
- **Hermeticity**

Machine Detector Interface

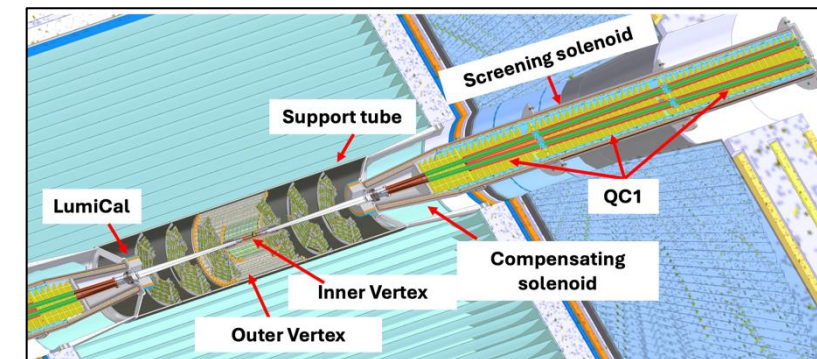
- ◆ Invasive final focus system and large horizontal crossing angle (30 mrad)
 - Mechanical integration of beam pipe, vertex detector, and luminometers
 - Detector assembly, opening, and maintenance strategy
 - Compact and extremely precise [$O(1\ \mu\text{m})$] luminometers for small-angle Bhabha scattering
 - Affects the central detector acceptance – careful MDI design required
- ◆ Detector magnetic field causes emittance blow-up affecting luminosity at the Z pole
 - Used to limit the solenoid field to 2 T with local compensation (as in the FSR)
 - Current working hypothesis: increase to 3 T with non-local compensation
 - ❖ Significant work remains to substantiate this value (IR layout, Polarisation, Acceptance ...)
 - ❖ The final choice for the magnetic field will impact the detector dimensions and performance
- ◆ Large beam-induced backgrounds (synchrotron radiation, incoherent pair creation, ...)
 - Cause significant detector occupancy (vertex, tracker, luminometers, ...)
 - May influence detector technology choices, detector segmentation, and beam pipe radius
 - ❖ Mitigation being studied with collimation, masking, shielding, optics optimisation, ...

👉 Detector and accelerator optimisation must proceed together 👉

Central part of detector volume – top view



Example of MDI integration, IDEA Concept



FCC-ee Detectors Overview

Tracking and vertexing

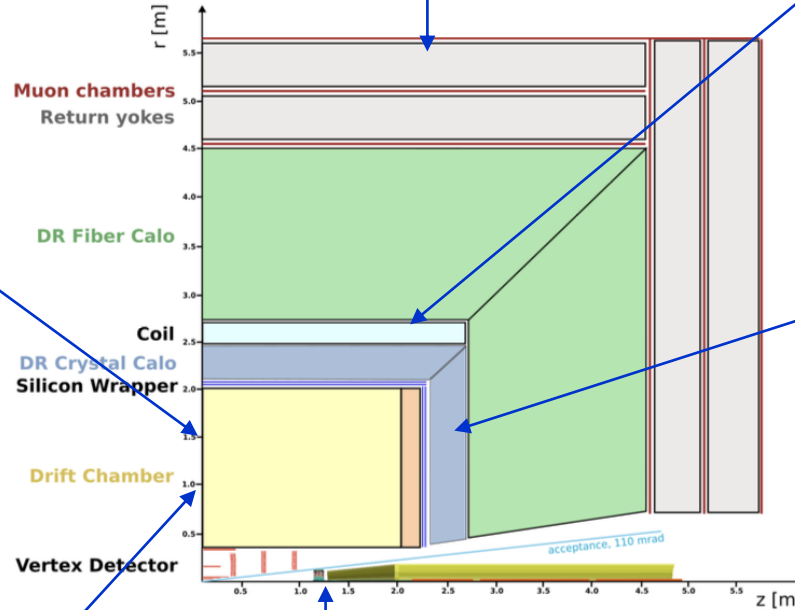
- As **lightweight** as possible
 - In the p_T range 0.1 - 50 GeV, resolution limited by multiple scattering;
 - Strong case for **gaseous** trackers
 - Also **light MAPS**
- **Few micron VXD resolution** for flavour tagging and lifetime measurements
 - Thinned **MAPS** sensors
 - Few micron space point resolution
- Moderate radiation environments
- **Nanosecond timing** for possible BXID (1 or 2 layers); **picosecond timing** only for possible ToF PID(**Si wrapper**)

Particle Identification

- **$\pi/K/p$ separation** for flavour, Higgs, and EW physics
 - Cluster counting in **gaseous** trackers
 - Compact, light **Cherenkov** detector
 - **Time-of-flight** for $p < 3 \text{ GeV}$
- **π^0/γ separation, electron ID**
 - ECAL transv. and long. granularity

Muon system

- Efficient and pure **muon ID** (tagging);
- 6-8 λ_I HCAL as muon filter



Luminometry and normalisation

- Requirement: $\lesssim 10^{-4}$ absolute; $\lesssim 10^{-5}$ relative
- **Compact, extremely precise ($\sim 1 \mu\text{m}$)**
LumiCal for small angle Bhabha scattering
- Precise endcap acceptance definition (**$\sim 10 \mu\text{m}$**) for di-photon final state

Coil and B-field

- Field restricted to **3T** (previously **2T**) to avoid beam emittance blow up
- Coil positioned **inside or outside HCAL**
- Low temp. super conductivity;
R&D needed for **HTS solution**

Calorimetry

- Relatively low energy coverage:
 - 20-25 X_0 , 6-8 λ_1 suffices
- Jet energy resolution of 3-4 % @ 50 GeV
 - **Particle flow** method: **high granularity**
 - possibly combined with **dual readout**
- **ECAL** resolutions
 - high granularity; few %/VE for flavour phys.

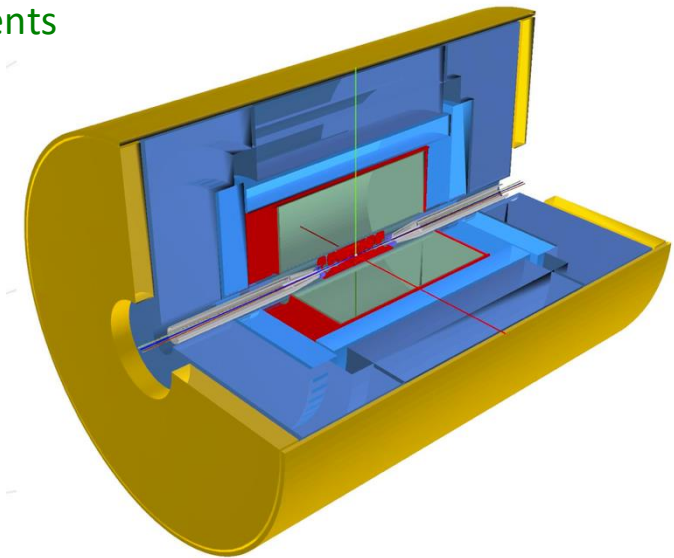
(T)DAQ

- Require “lossless” system with 10^{-6} - 10^{-5} normalisation precision between physics channels
- Two basic options: **“To TDAQ or to DAQ”**
 - i) Trigger system to activate complete detector readout – as at LEP & LHC
 - ii) Streaming out of data from autonomous sub-detectors; off-detector event building based on time-stamping

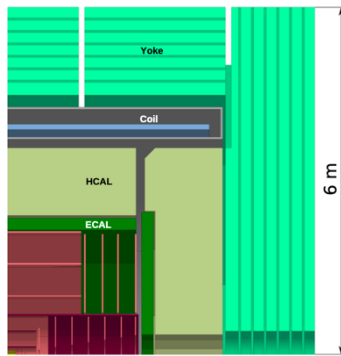
- ◆ FCC-ee Experimental Conditions
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Technologies come together into detector “concepts”

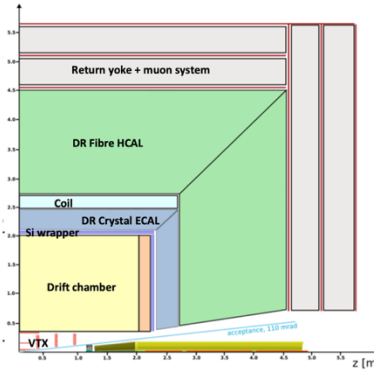
- ◆ Already six detector concepts under study – “concepts”, not experiment collaborations
 - Two new concepts, ALFA and AGORA, were presented during the FCC Week in Helsinki
 - A healthy situation at this point of the studies – further ideas are welcome
 - ❖ Shows the interest / the commitment of the particle-physicist community towards FCC-ee
 - ❖ Allows different associations of many different subsystem technologies to be explored and validated (or not)
 - ❖ Provides the framework and the motivation for innovative solutions to be proposed and tested
 - ❖ Increases the probability that four complementary detectors eventually satisfy all requirements
- ◆ Detector concepts provide the link between three different worlds
 - Translate **physics requirements** into detector performance
 - Confront ambitions with **technological and engineering capabilities**
 - Identify naturally the still **necessary R&D and test-beam campaigns**
- ◆ In practice, three ingredients are needed for a complete study
 - Full simulation of detector subsystems, including digitisation and local reconstruction
 - ❖ Provides freedom to combine technologies (“plug’n’play” in key4hep software)
 - ❖ Enables validation of single particle performance measured with prototypes
 - ❖ Realistically predicts the full event performance, and allows detector concept comparisons
 - Detailed engineering
 - ❖ Respond to and act on the constraints from the integration in the machine-detector interface (MDI) layout
 - ❖ Guide the optimisation of the global structure and parameters
 - Realistic design with progressively more mature demonstrators
 - ❖ Mechanical engineering, electronics, cooling, prototype scalability, component production strategy, ...



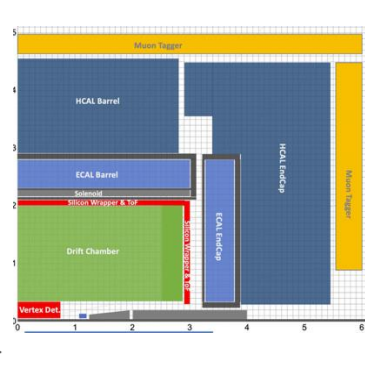
Detector Concepts: A broad spectrum of complementary ideas



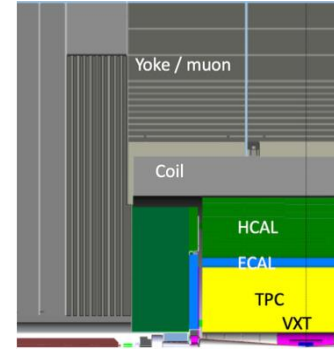
CLD



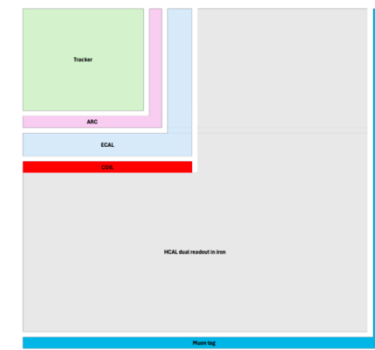
IDEA



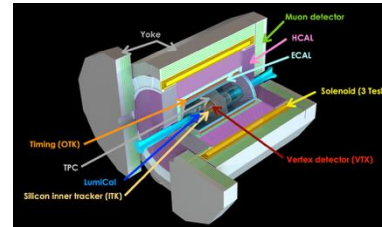
ALLEGRO



ILD



ALFA
emerging



AGORA
from CEPC, new for FCC-ee

	CLD	IDEA	ALLEGRO	ILD	ALFA emerging	AGORA from CEPC, new for FCC-ee
Vertex	Si	MAPS	MAPS	Si	MAPS	MAPS
Tracker	Full Si	Drift Chamber + Si strp	DCH / Straw / SciFi + Si	TPC + Si strips	All MAPS	TPC + Si strips
ECAL	Si-W highly granular	Crystals w. DR	Noble Liquid (LAr)	Si-W highly granular	Grainita (crystal grains)	Crystals
HCAL	Scint. sampling	Fibre DR	TileCal (steel/scint.)	Scint. or RPC	DR + steel	Glass scint. + steel
Muon	RPC in iron yoke	μ RWELL	TBD	Scint. in iron yoke	TBD	Scint. in yoke
PID	RICH (option)	tracker dN/dx (+ TOF)	tracker dN/dx (+ TOF)	tracker dN/dx (+ TOF)	Cherenkov ARC	tracker dN/dx (+ TOF)
Coil B-field	Outside HCAL 2T	Inside HCAL 2T (3T HTS R&D)	Inside HCAL 2T	Outside HCAL 3.5 T -> 2-3 T	Inside HCAL 3T	Outside HCAL 3T

- ◆ FCC-ee Experimental Conditions
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Vertex Detector

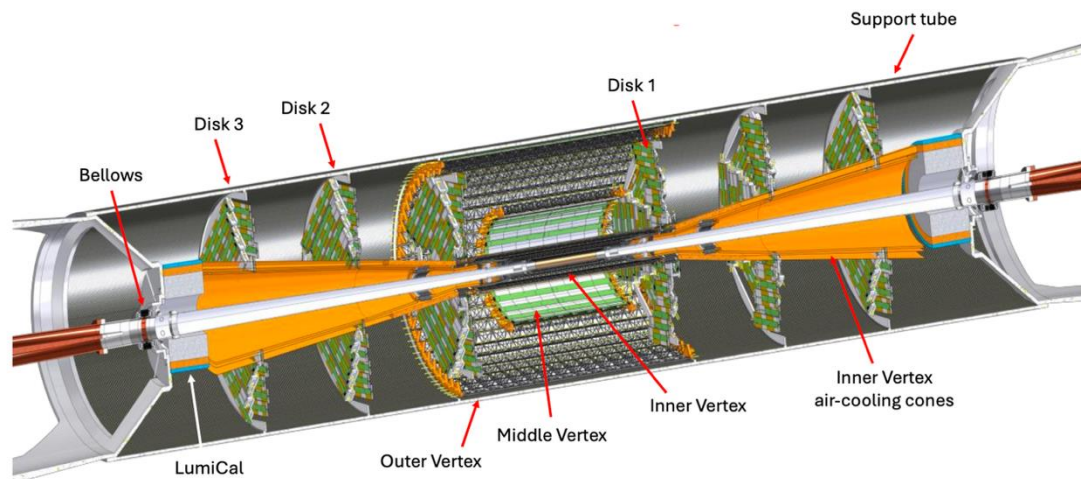
Vertex detector developments highly inspired by ALICE ITS2 and ITS3 designs

Workshop, Oct. 2025

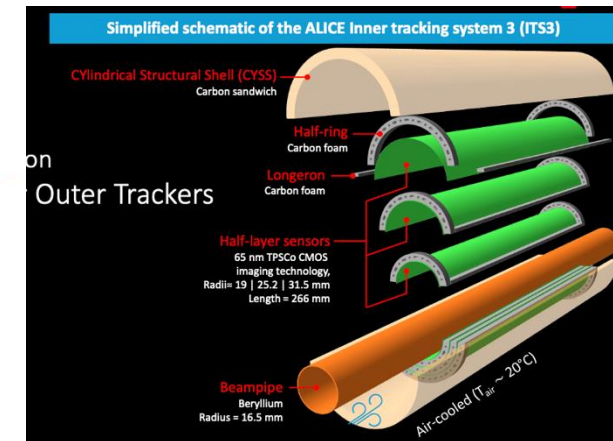
- Based on thinned and stitched MAPS
- Ultra-low material, micron-level precision, low power, lightweight mechanics and cooling, ~ 13 mm from IP

IDEA Vertex Detector design study (INFN Pisa, Frascati)

- Fully integrated in MDI design
- All sensors are $50\ \mu\text{m}$ MAPS
- Three inner barrel layers: $25 \times 25\ \mu\text{m}^2$, $50\ \text{mW}/\text{cm}^2$, air cooling
- Middle + outer barrel layers: $150 \times 50\ \mu\text{m}^2$, water cooled
- Three disks in each direction: as middle/outer barrel layers
- Hit resolution: $\sim 3\ \mu\text{m}$; material: $2.5\% X_0$ at 90°

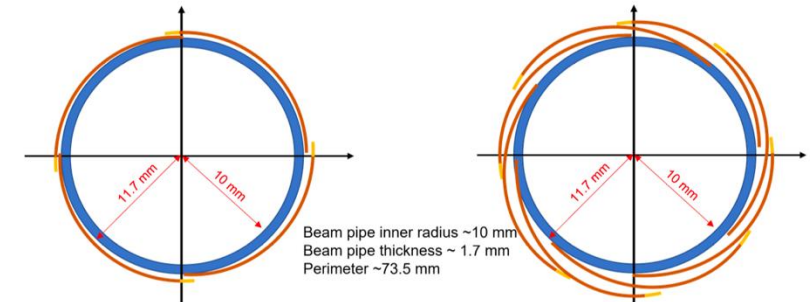


Curved sensors “wrapping” around beam pipe



12-mm curvature reached

FCC-SEED

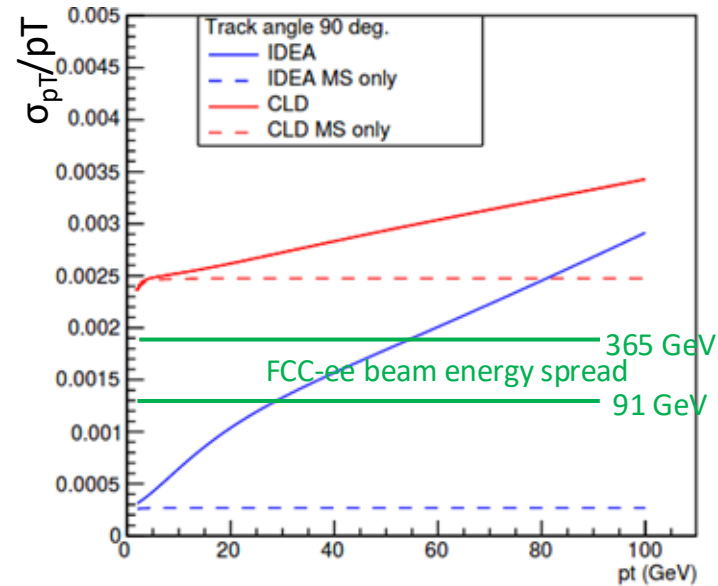


For FCC-ee energies, very light tracking systems are needed for the momentum resolution not to be limited by multiple scattering

$$\sigma(p_T)/p_T^2 = a \oplus \frac{b}{p \sin \theta}$$

mult.sc
point
resolution

Example: CLD vs. IDEA

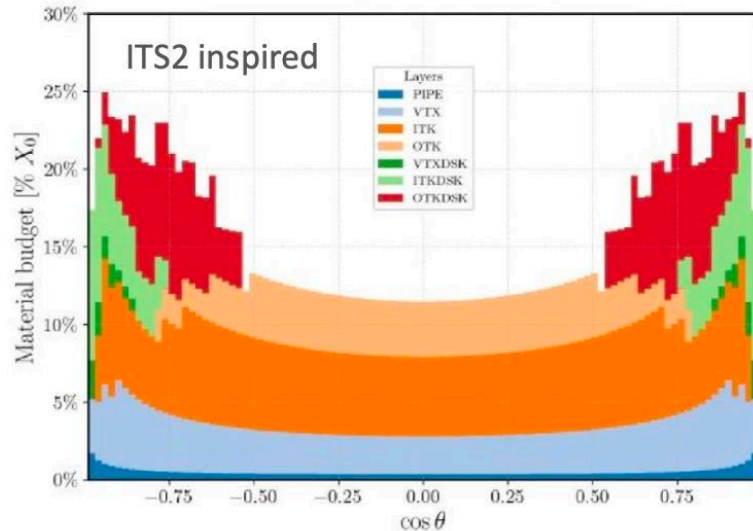


Strong case for gaseous trackers

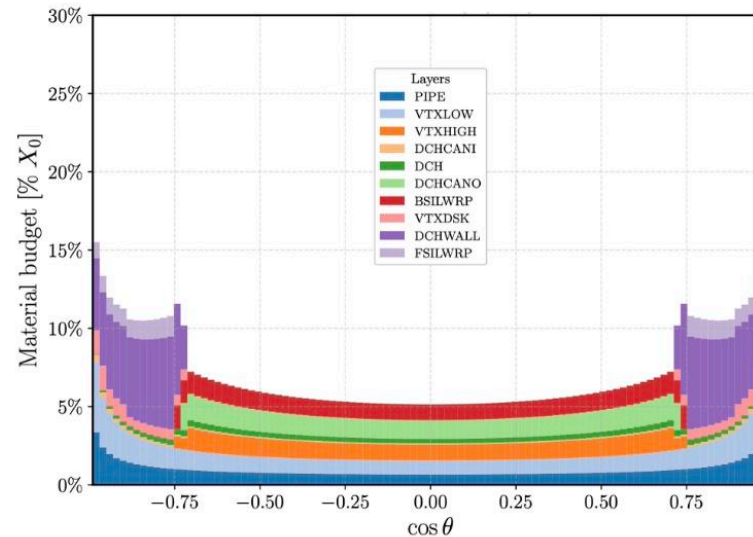
but also

New ALFA all-MAPS tracker concept with a very competitive material budget

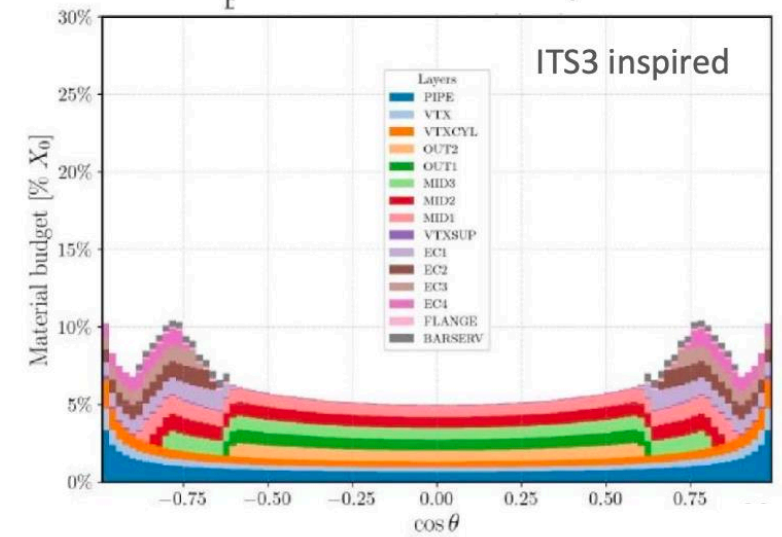
CLD Si pixel + strips



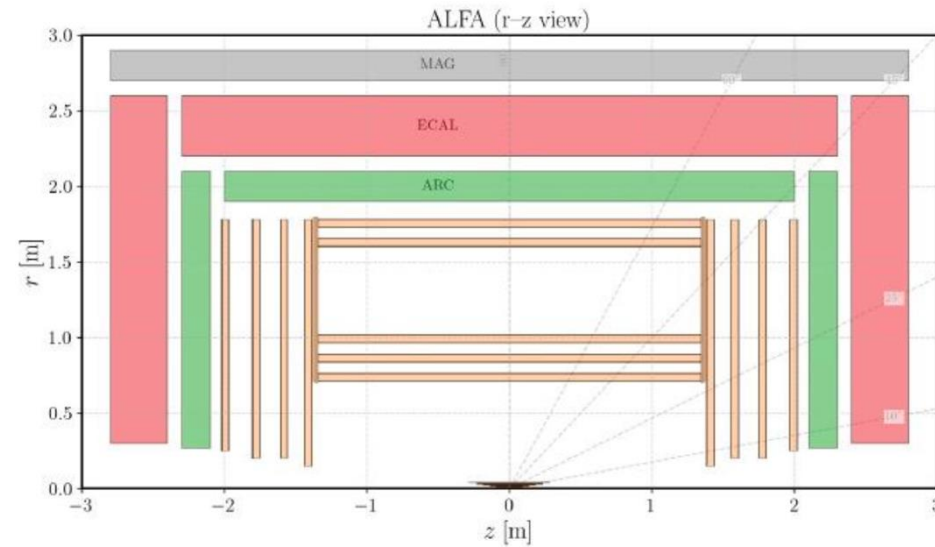
IDEA Drift Chamber + Si



ALFA full Si Maps



Central Tracker Options under Study

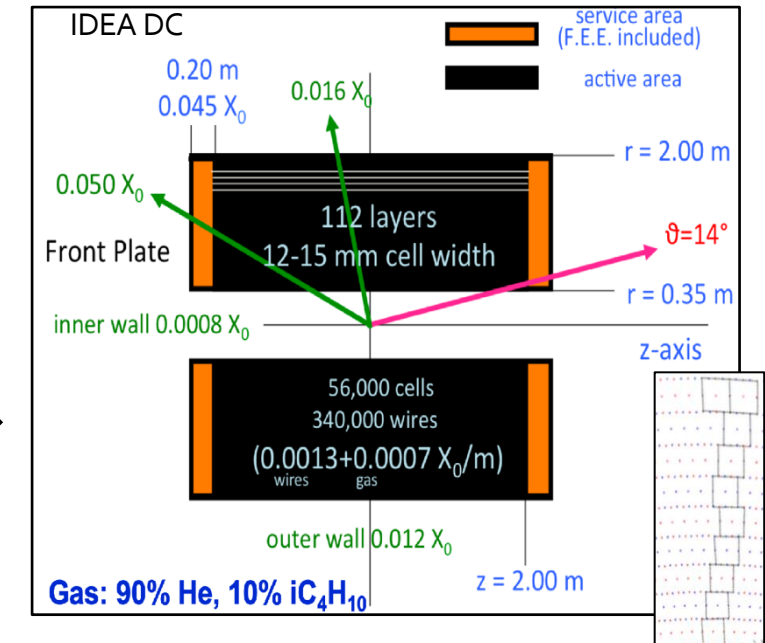


Full silicon

- CLD
- ALFA

Drift Chamber

- IDEA
- Allegro

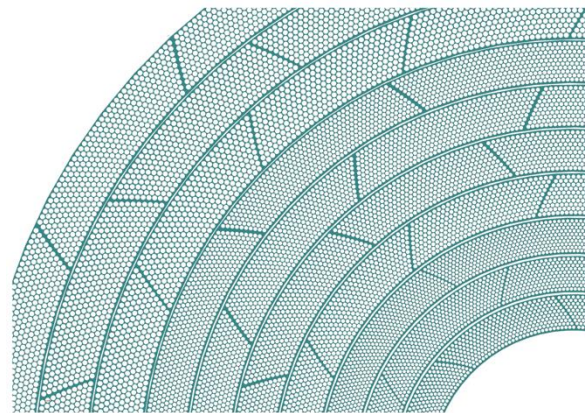


Straw Tracker (Allegro)

- Robust alternative to DCH?

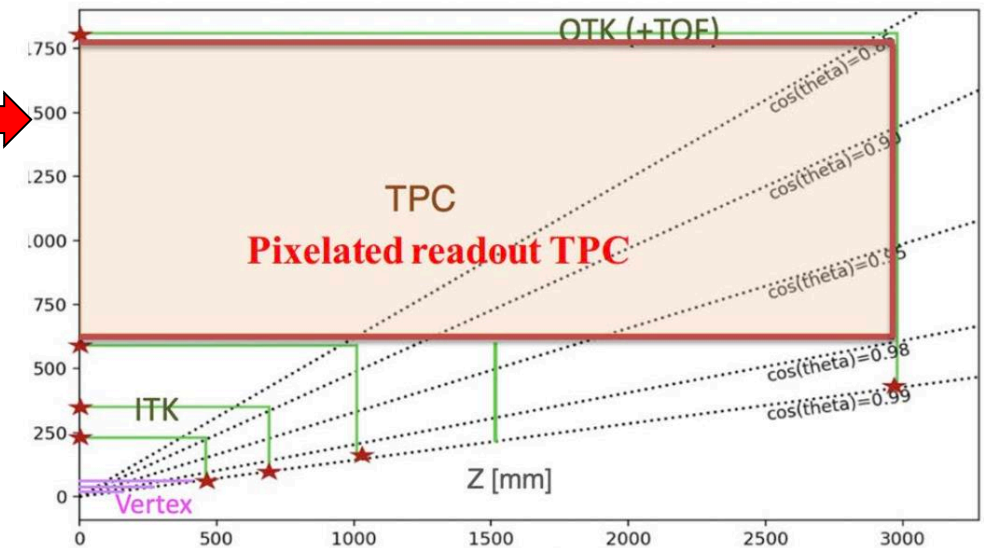
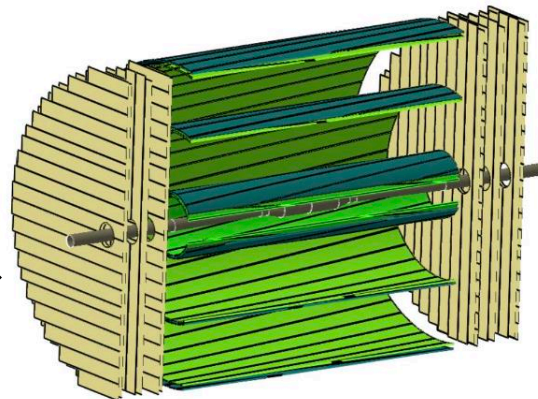
Time Projection Chamber

- ILD and AGORA



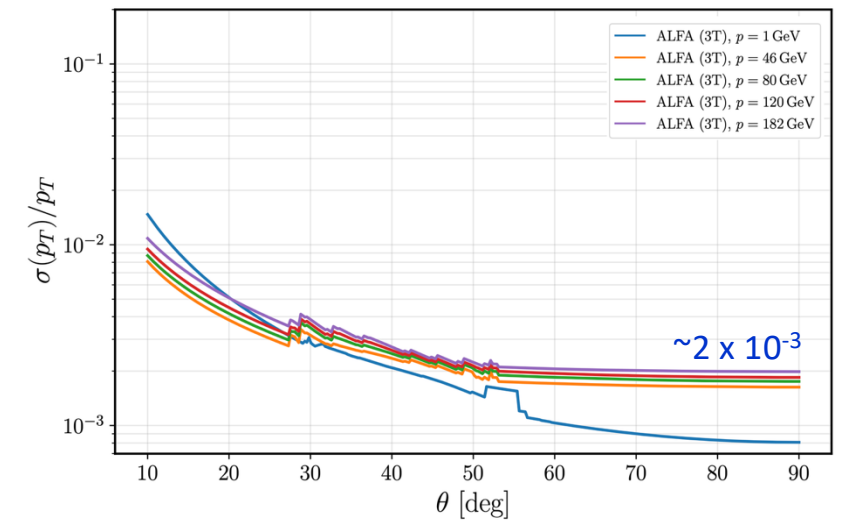
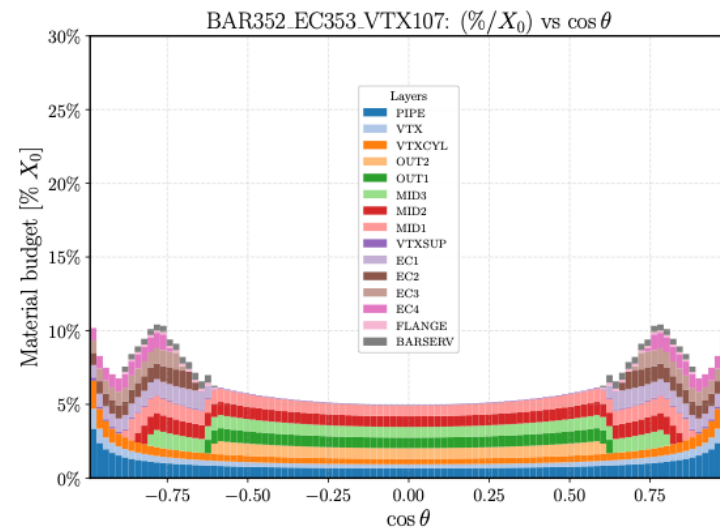
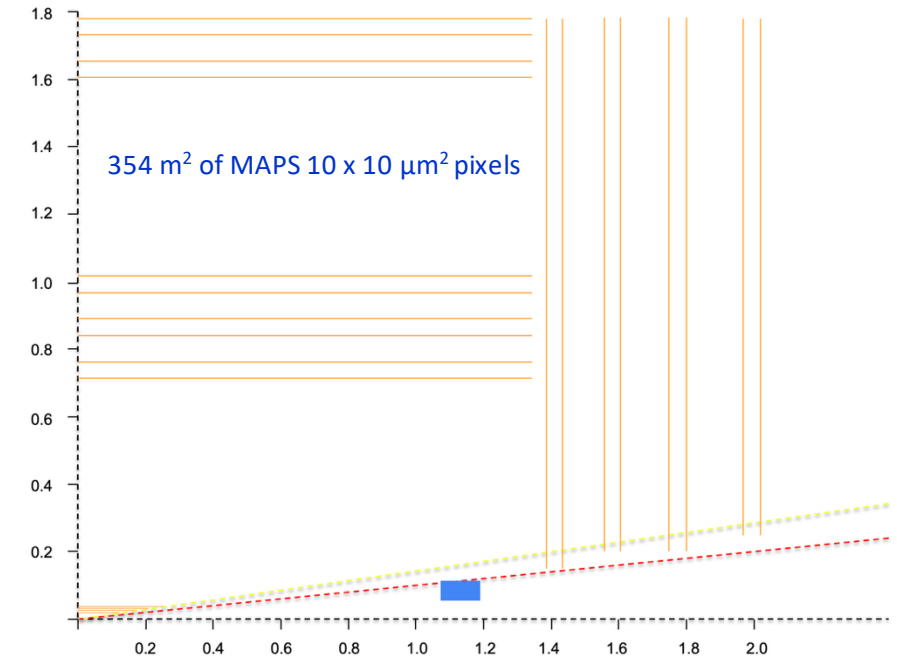
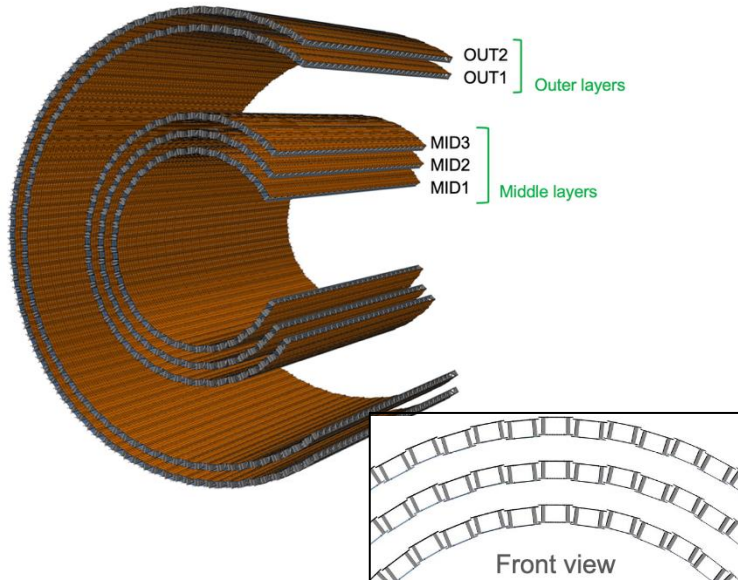
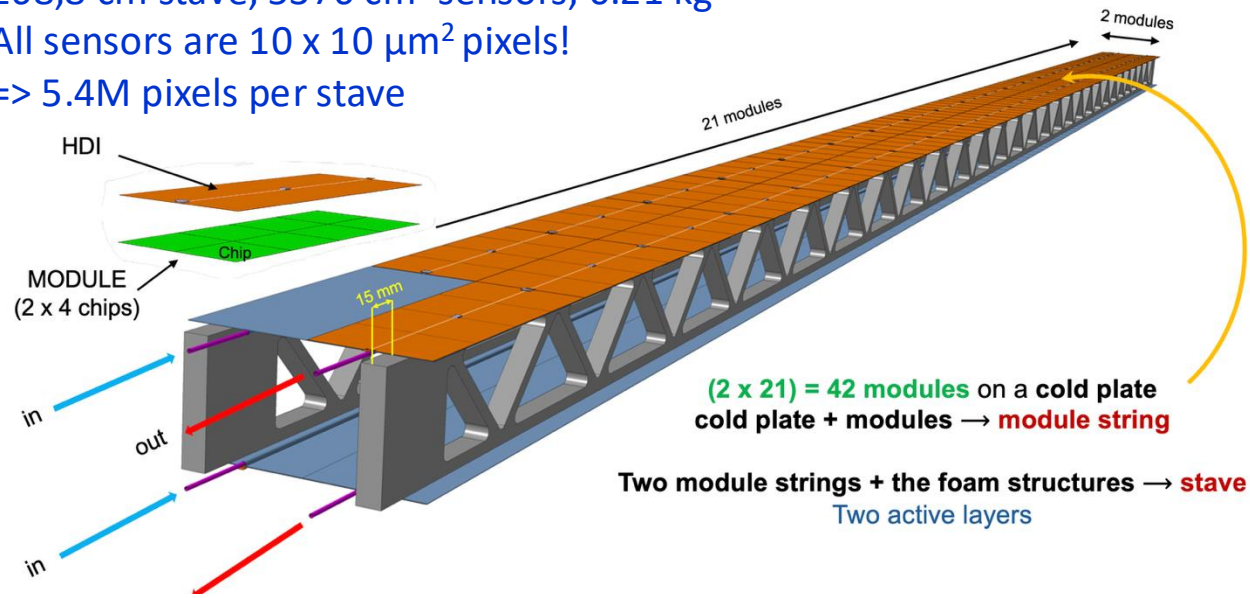
Scintillating Fibre (SciFi) Tracker

- Used in LHCb, studied for Allegro



ALFA all-MAPS Tracker

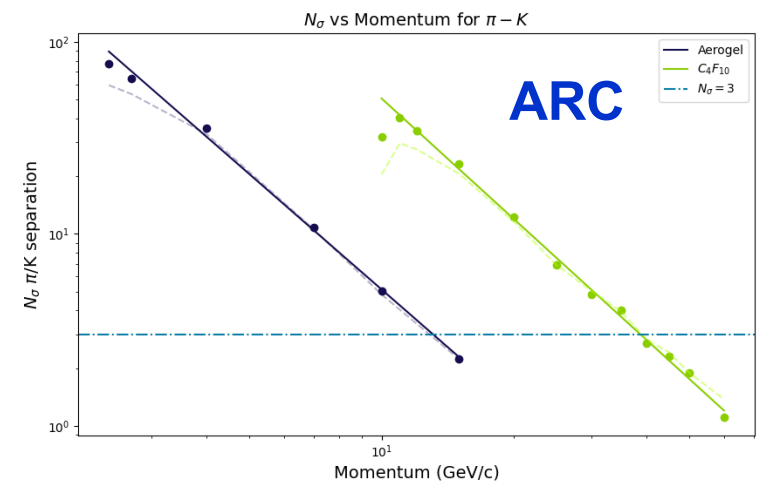
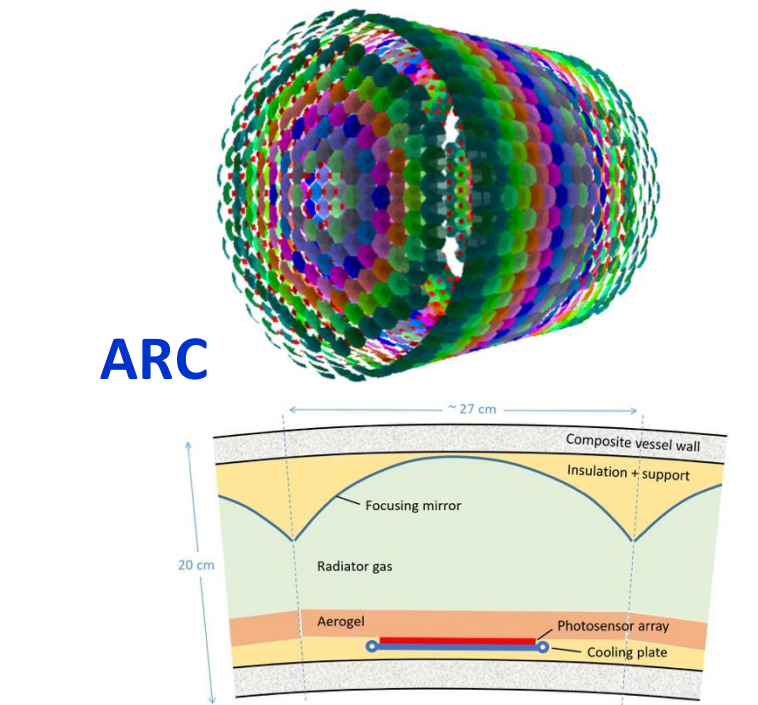
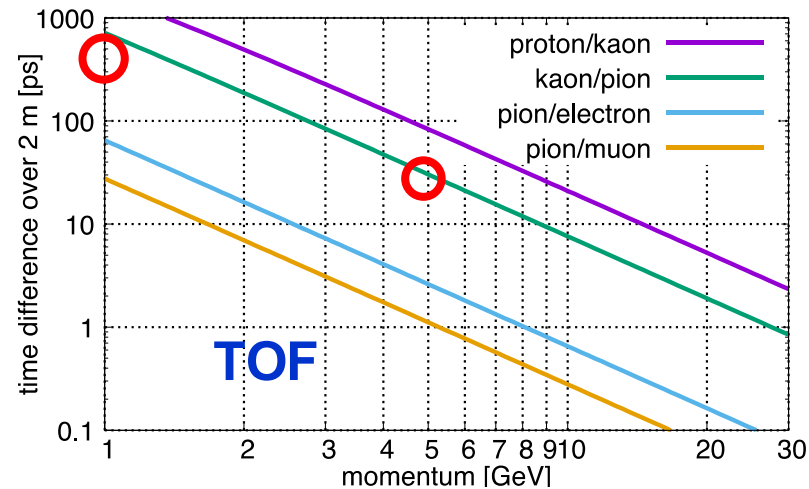
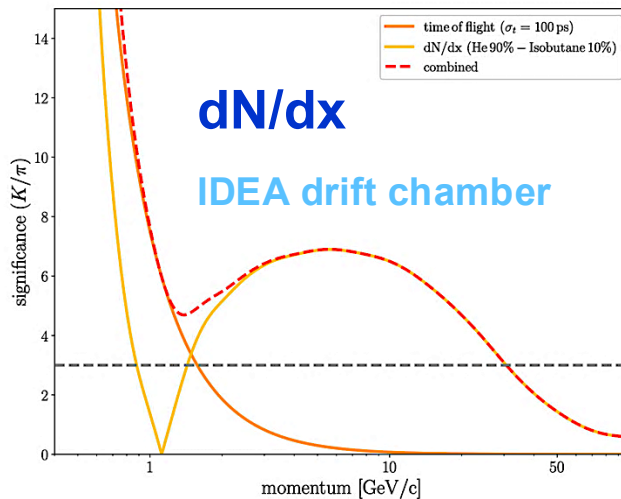
268,8 cm stave, 5376 cm² sensors, 0.21 kg
All sensors are 10 x 10 μm² pixels!
=> 5.4M pixels per stave



Charged Particle Identification

PID capabilities across a wide momentum range is essential for flavour physics

- ◆ Drift Chamber and Straw Tracker promise $>3\sigma$ π/K separation up to ~ 35 GeV based on **cluster counting**, **dN/dx** . Similar performance from TPC.
 - ionisation cross-over window at 1 GeV, can be alleviated by unchallenging TOF measurement of $\delta T \lesssim 100$ ps
- ◆ **Time of flight (TOF)** to cover cross-over window around 1 GeV
 - With unchallenging time resolution of $\sigma_t \sim 100$ ps
 - With $\sigma_t \sim 100$ ps, TOF alone could provide 3σ π/K separation up to ~ 5 GeV (LGAD)
- ◆ **RICH counter** being investigated (for CLD and ALFA): **Array of RICH Cells – ARC**
 - Compact geometry (depth: 20 cm, $0.1 X_0$) via use of SiPMs
 - Aerogel + Gas (C_4F_{10} or pressurised Xe): 3σ π/K separation in 2.5 - 50 GeV range
 - Below 2.5 GeV, no signal from K $\Rightarrow$ veto mode separation



Calorimeter Technologies being pursued

All concepts aim at Particle Flow reconstruction

- with different emphasis on granularity, energy resolution, stability
- R&D activities concentrated within DRD6 (DRDcalo)

Eur.Phys.J.Plus 136 (2021) 10, 1066, [arXiv:2109.00391](https://arxiv.org/abs/2109.00391)

Noble Liquid ECAL + Tile HCAL:

- fine longitudinal sampling (w.r.t. ATLAS, 4 → 12 layers)
- Pb+LAr or denser W+LKr; cold (or warm) electronics
- CALICE or ATLAS style scintillating tile HCAL

Segmented crystals with Dual Readout:

- Fine transverse segmentation, two longitudinal layers; SiPMs
- Excellent EM energy resolution of $\sim 3\%/ \sqrt{E}$
- Combined with fibre-based DR calorimeter as HCAL

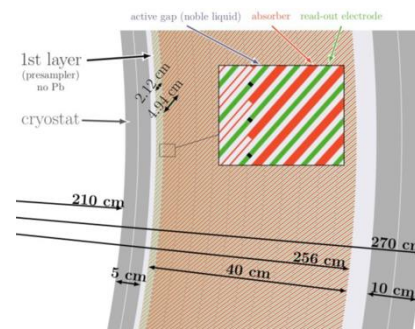
Fibre-based Dual-Readout :

- copper or steel matrix; Cherenkov and scintillating fibres, SiPMs
- very fine transverse granularity, (some) longitudinal inf. via timing

CALICE-style sandwich with embedded front-end electronics:

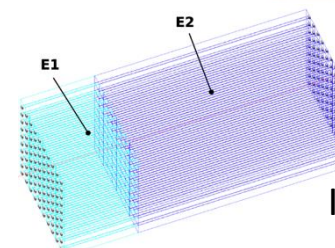
- Tungsten-silicon ECAL; Extremely fine segmentation: $(0.5 \text{ cm})^3$
- Steel-scintillator HCAL; SiPM-on-Tile; Fine segmentation: $(2.5 \text{ cm})^3$
 - alternatives: scintillator strip ECAL, gaseous (digital) HCAL

EM: $\sigma(E)/E \approx 8\text{-}10\%/\sqrt{E}$
Jet: $\sigma(E)/E \approx 4\% @ 50 \text{ GeV}$



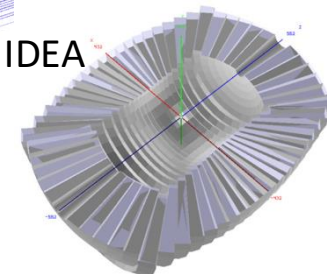
Allegro

EM: $\sigma(E)/E \approx 3\%/\sqrt{E}$
Jet: $\sigma(E)/E \approx 3\text{-}4\% @ 50 \text{ GeV}$



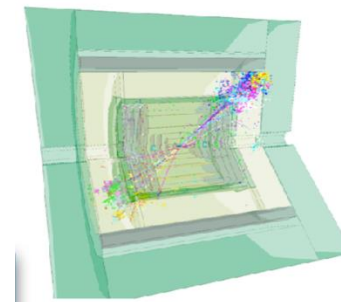
IDEA

EM: $\sigma(E)/E \approx 11\%/\sqrt{E}$
Jet: $\sigma(E)/E \approx 3\text{-}4\% @ 50 \text{ GeV}$



EM: $\sigma(E)/E \approx 16\%/\sqrt{E}$
Jet: $\sigma(E)/E \approx 3\text{-}4\% @ 50 \text{ GeV}$

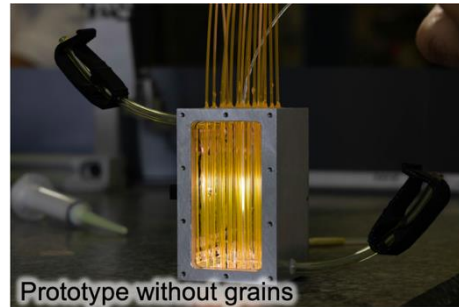
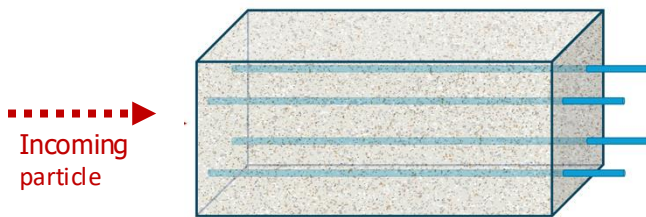
CLD, ILD



Calorimetry – new additions

ALFA: Grainita ECAL concept

- 1-mm crystal grains (ZnWO_4) immersed in heavy transparent liquid (sodium-tungstate-water solution) or, better, resin
- Light emitted by crystal grains collected by WLS fibres spaced 7 mm

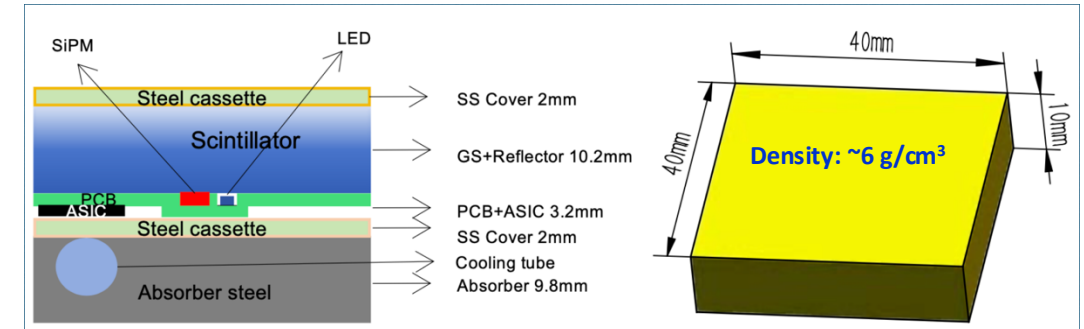


- Excellent energy resolution, high transverse granularity
- Cost-effective grains compared to homogenous crystals
- First (small) prototype: 28x28x55 mm³

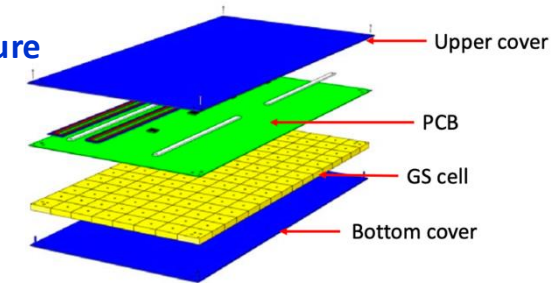
ALFA: Dual-Readout Tile HCAL

- E.g., CALICE-like Steel / Quartz / Scintillator Tile HCAL
- Also functioning as magnet return yoke

AGORA: Heavy-Glass Scintillator HCAL



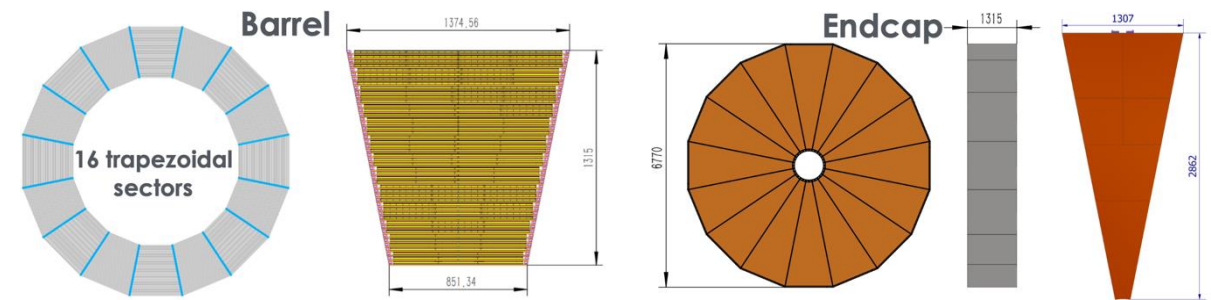
Single layer structure



Total of 85 m³ glass scintillator

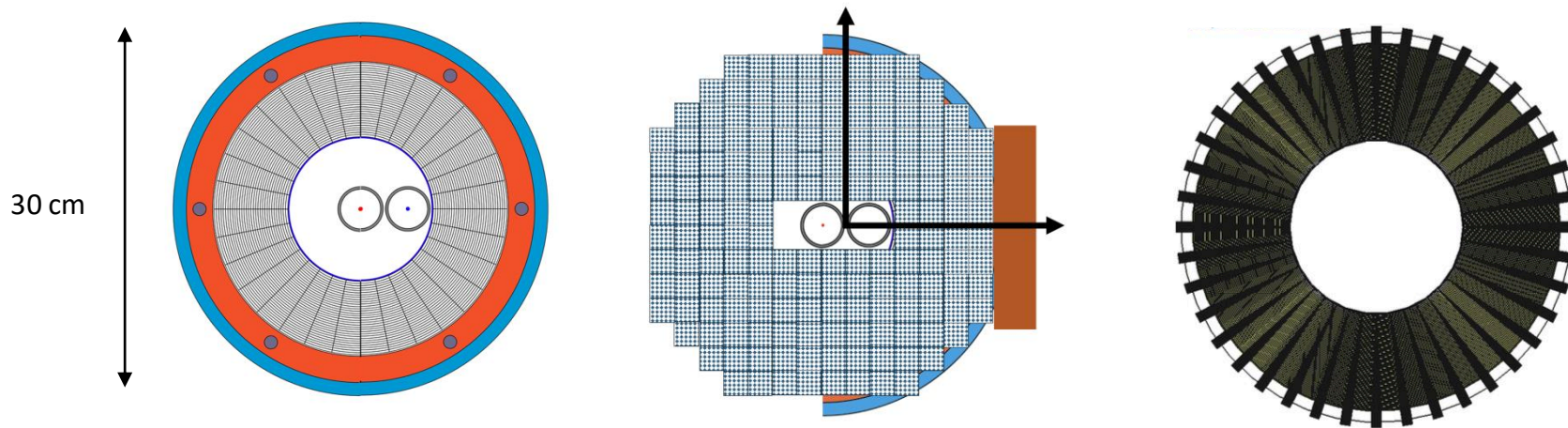
- High sampling fraction (~30%)
- Good energy resolution ~30%/VE

48 layers stacked per module



Interaction Region

- ◆ Common luminometer developments, most likely compact SiW calorimeter
 - Cover polar angles from ~ 45 to ~ 100 mrad, about 1 m from interaction point
 - Micrometer geometrical tolerances for a 10^{-4} precision on the luminosity measurement
 - Sensors: Si strips (à la FCAL), MAPS (à la ALFA), superconducting nanowires



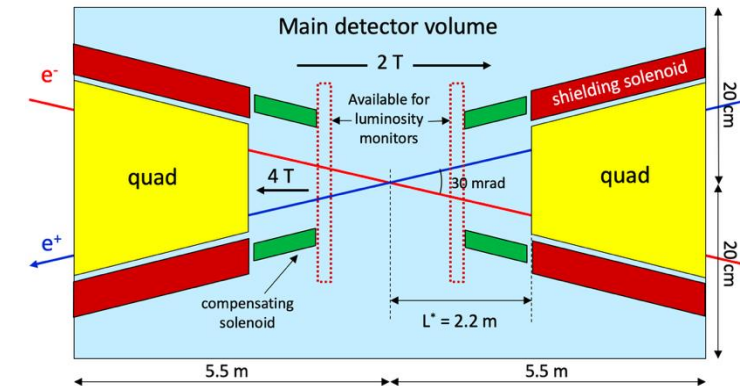
- Mechanical support & stability; alignment (2 LCAL, $100 \mu\text{m}$), temperature stability (1°C)

- ◆ R&D on lightweight (carbon-based?) beampipe, with adequate thermal management

- Material is not negligible in the current design

- ◆ More generally; detailed engineering of the interaction region (BP, VTX, LCAL)

- Support, extraction, maintenance, acceptance preservation (down to 100 mrad?)

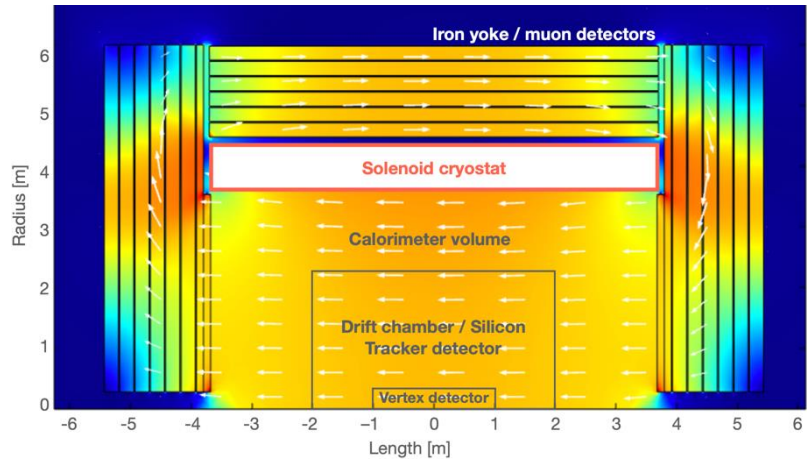


Recent Luminometer Workshop

Detector Solenoid

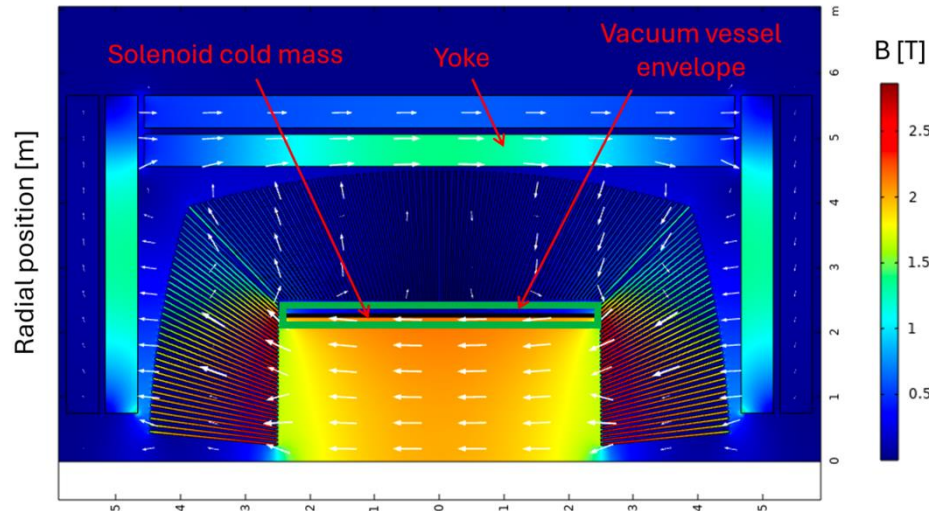
Two placement options being pursued

Coil outside calorimeter system



CERN detector magnet group:
Conceptual design of thin,
ultra-light 2T solenoid

Coil between ECAL and HCAL



Future common R&D efforts identified during recent Detector Solenoid workshop:

- ◆ Moving from 2T to 3T
- ◆ Explore HTS technology (ReBCO, Iron, MgB_2 , ...)
- ◆ Quench protection
 - Design driver, especially for HTS
- ◆ Stabilised Aluminium conductor production
 - Potential bottleneck
- ◆ Single-piece coil vs. modular design
- ◆ Integrated design
 - Cryostat, cryogenic system, thermal shield, services
 - Minimise material if between ECAL and HCAL
- ◆ From CERN magnet group:
 - "Experience tells that development & construction of large superconducting coil takes $\gtrsim$ a decade"*
 - Early design needed as input to general detector design
 - Need to identify labs with appropriate expertise

CLD, ILD, AGORA

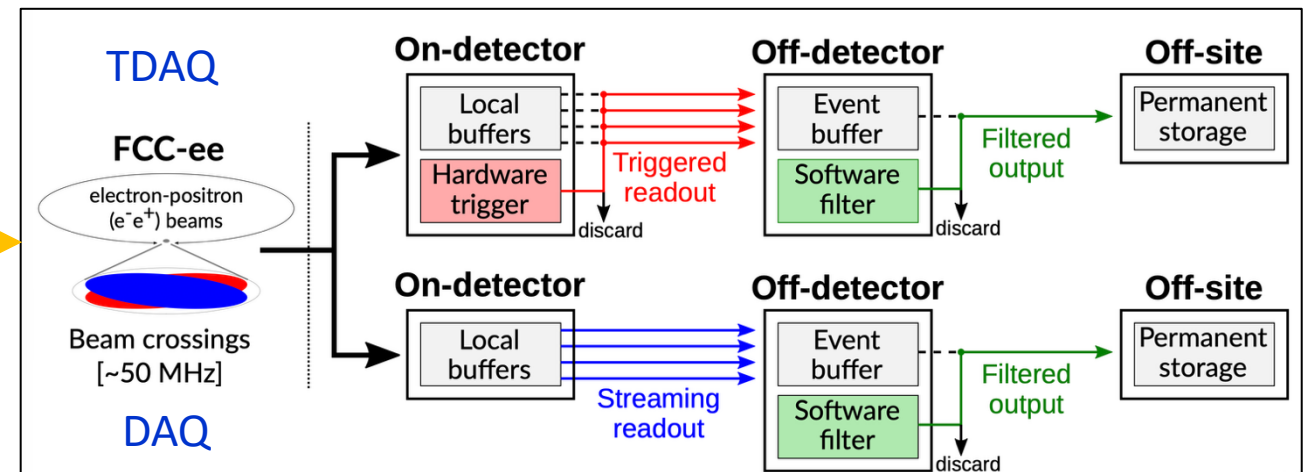
IDEA, ALLEGRO, ALFA

FCC-ee Data Acquisition System

DAQ system goal

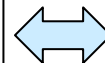
- Full efficiency for all SM annihilation physics events
 - Aiming at $\mathcal{O}(10^{-6} - 10^{-5})$ relative normalisation between channels
- No loss of potential BSM signatures
e.g., heavy (slow) particles decaying late, LLPs

“To TDAQ or to DAQ”
Does FCC-ee need a trigger system?



Trigger option (as at LEP and LHC)

- Which sub-detectors could trigger decision be based on?
- Need identical deadtime for all detector elements
In particular LumiCal vs. rest
- High BX rate: Need for local **latency buffering** a la LHC?
Material / power / cooling for on-detector buffering?



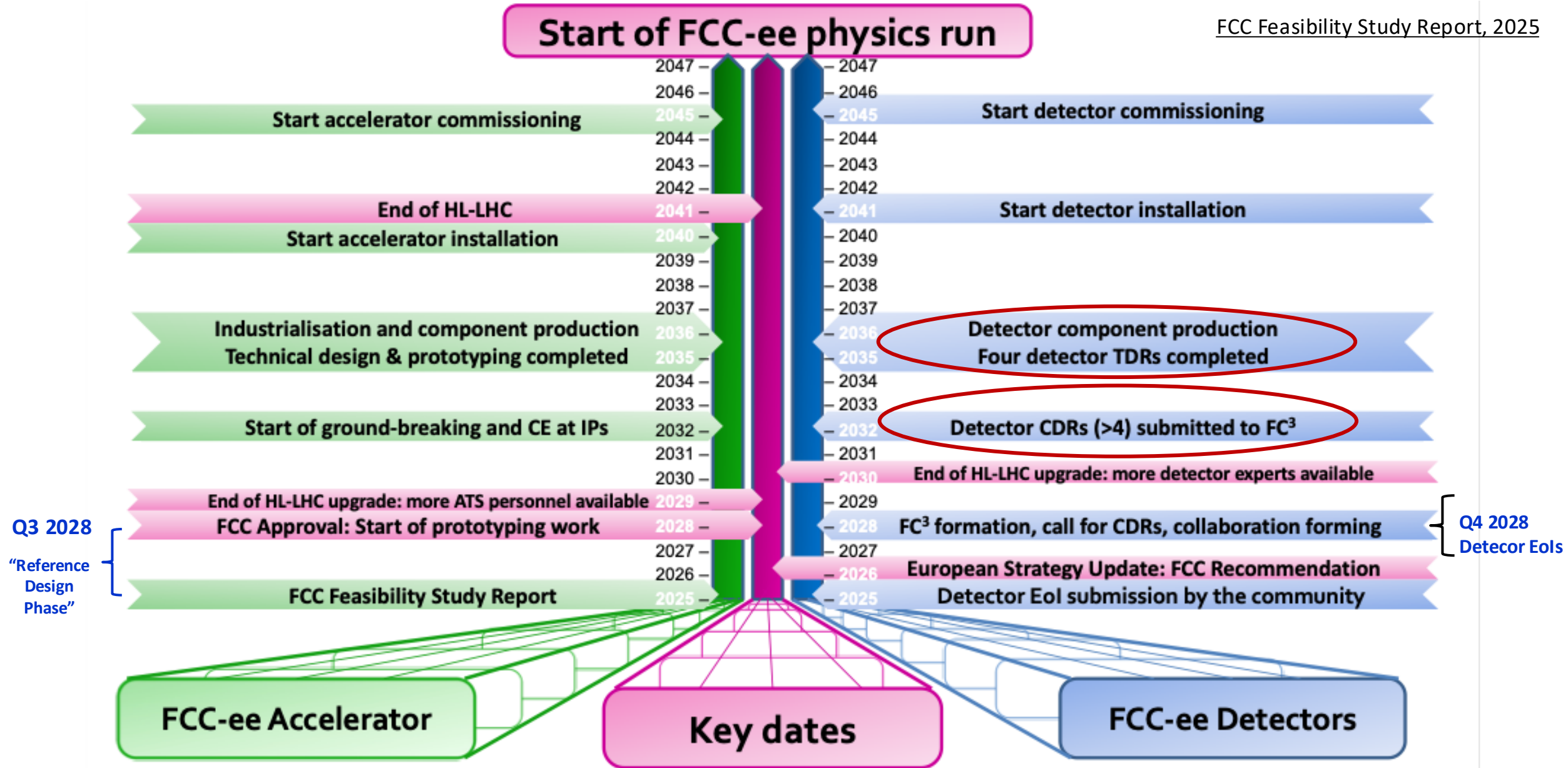
No Trigger option (as being developed for EPIC @ EIC)

- **Free streaming** of *self-triggered* detector sensors
- Off-detector event building based on time-stamping (BXID) and topological combinations
- Potential enormous data rates out of sub-detectors
Easily Tbit/sec from VXD alone. Technical feasibly? Power needs,...?

- ◆ FCC-ee Experimental Conditions
- ◆ Detector Requirements and Challenges
- ◆ Detector Concepts
- ◆ Detector Sub-systems and Technologies
- ◆ **Organisational Matters**
- ◆ Summary

FCC-ee Possible Timeline

FCC Feasibility Study Report, 2025



Evolution of Detector Concepts Work Package

In DRDs:

RnD / technologies

- Gaseous Detectors (DRD1)
- Liquid Detectors (DRD2)
- Semiconductor Detectors (DRD3)
- Photodetectors & PID (DRD4)
- Quantum Sensors (DRD5)
- Calorimetry (DRD6)
- Electronics (DRD7)
- Mechanics (DRD8)

US R&D Collaborations (RDCs) focus on generic (non-targeted), interdisciplinary and blue sky R&D – will collaborate where possible.

In FCC Detector concepts:

a) Generic system-level studies

(create structure as needed or organize workshops)

- Tracker (e.g. Si + straw tracker) & PID
- Calorimetry
- Muons
- TDAQ
- Luminometry
- Magnet

[Mandate for the
Detector Subsystem
subgroup](#)

b) Concept-specific studies

(using specific envelopes/support structures, or physics benchmarks)

- ALFA
- Allegro
- CLD
- IDEA
- ILD
- ...

[Mandate for the Detector
Concept Study subgroup](#)



Non-exclusive membership; preserve synergies and unity of the community!

How to get involved

Group name	Email	Signup	Indico
Calorimetry	FCC-PED-DetectorConcepts-Calorimetry@cern.ch	click	click
Luminometry	FCC-PED-DetectorConcepts-Luminometry@cern.ch	click	click
Magnet	FCC-PED-DetectorConcepts-Magnet@cern.ch	click	click
Muon	FCC-PED-DetectorConcepts-Muon@cern.ch	click	click
TDAQ	FCC-PED-DetectorConcepts-TDAQ@cern.ch	click	click
Tracker & PID	FCC-PED-DetectorConcepts-Tracker@cern.ch	click	click
ALFA	FCC-PED-DetectorConcepts-ALFA@cern.ch	click	click
ALLEGRO	FCC-PED-DetectorConcepts-ALLEGRO@cern.ch	click	click
CLD	FCC-PED-DetectorConcepts-CLD@cern.ch	click	click
IDEA	FCC-PED-DetectorConcepts-IDEA@cern.ch	click	click
ILD	FCC-PED-DetectorConcepts-ILD@cern.ch	click	click

- As a bonus, signing up to any of the above adds you to "FCC-PED-DetectorConcepts@cern.ch". For free! Not even a click!
- Indico categories for [Detector Subsystems](#) and [Concept Studies](#)
- [FCC-PED homepage](#) with upcoming meetings
- Indico meeting [calendar](#)

Concept Studies

ALFA

ALLEGRO

CLD

IDEA

ILD

Detector Subsystems

Calorimetry

Luminometry

Magnet

Muon

TDAQ

Tracker & PID

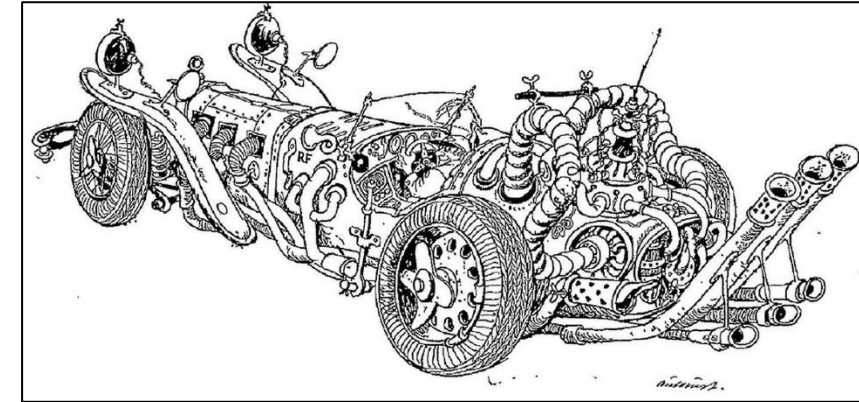
- ◆ FCC-ee Experimental Conditions
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- ◆ Detector Concepts
- ◆ Detector Sub-systems and Technologies
- ◆ Organisational Matters
- ◆ **Summary**

Summary

- ◆ Extremely rich physics programme $\Rightarrow$ formidable detector challenge
 - Very high rates; very high precision; advanced detectors called for
- ◆ Aiming for 4 experiments
- ◆ Currently, six concepts are being pursued
 - FCC Software (key4hep based) allows “plug & play”
 - $\Rightarrow$ Selection of optimal combinations of subdetectors
- ◆ Evolving organisation of Detector Studies effort
 - Detector (sensor) R&D concentrated inside DRD collaborations
 - Detector sub-groups for coordination of sub-detector efforts
 - Detector concept study groups for development of specific concept
- ◆ Ample room for new ideas and technologies
- ◆ Many interesting challenges ahead!



Il Tempo Gigante.



... from dream to reality ...

Extras

FCC Detector Expressions of Interest

Input to ESPPU2026, March 2025

- ◆ Build community of institutes interested in development of dedicated sub-detectors
- ◆ Trigger interactions in the community to get (self-) organised around sub-detectors
- ◆ 39 documents received
 - ❑ **ESPPU submissions:** <https://indico.cern.ch/event/1530285/>
 - ❑ **Individual Eols:** <https://indico.cern.ch/event/1529896/>

Topic	Number of Eols
Detector Concepts	4
Vertex Detector	2
Main Tracker and Envelopes	10
Calorimeters	8
Luminometers	2
Particle ID	1
Coil	1
Muon	5
Trigger/DAQ/Electronics	3
Algorithms, AI	2
Machine Detector Interface	1

Progress since Eol submission:

- ➔ Now, two additional concepts
- ➔ Vertex Detector Workshop, Pisa, Oct. 2025
- ➔ Tracker Workshop, BNL, May 2025, and CERN Nov. 2026
- ➔ DRD6 meetings
- ➔ Workshop at CERN, 27-28 July 2026
- ➔ Workshop in Milan, 2-3 July 2026
- ➔ Workshop to be arranged
- ➔ 1st FCC TDAQ Workshop, CERN, November 2025
- ➔ Series of monthly meetings

Work Ahead

◆ Vertex Detector & MDI Region:

- ❑ Sensor technology exists (MAPS, DRD3); lightweight support structures, low-material power and cooling infrastructure to be developed
- ❑ Continue and strengthen engineering effort on MDI region, support of vertex detectors + LumiCal; develop MDI for all detector concepts

◆ Tracking:

- ❑ Different proposals: Scintillating Fibre, Si tracker (DRD3), gaseous tracker (DRD1): drift chamber, straw tracker, TPC
- ❑ Establish whether (long) drift times are compatible with high-rate Z-pole operation and related backgrounds (synchrotron radiation, beamstrahlung, radiative Bhabha scattering)
- ❑ Minimize material, start engineering of support structures, services, power, cooling, ...

◆ Particle ID:

- ❑ Consolidation of cluster-counting method for DCH and straw
- ❑ Potentially complement Si tracker with ARC Cherenkov detector; need for low GWP gasses
- ❑ ToF detectors (e.g. LGADs)

◆ Calorimetry

- ❑ Continue building prototypes of all proposed calorimeters, testbeams (DRD6)
- ❑ Define needed granularity, performance optimisation
- ❑ Engineering

◆ Muon system:

- ❑ Large area scintillator and gas detector technologies exist; need for low GWP gasses
- ❑ Need to define what is needed for optimal physics reach

◆ Luminometry

- ❑ LumiCals satisfying extreme precision requirements to be developed
- ❑ Consolidation of luminosity measurement via large-angle di-photons

◆ Magnet coils

- ❑ Effort to re-establish availability of reinforced aluminum-stabilized Nb-Ti conductors needed;
- ❑ Investigate novel HTS-based conductors technology

◆ Cryostats

- ❑ Development of low-material carbon-composite cryostats as well as carbon fibre and aluminum honeycomb
- ❑ Construction and test of prototypes

◆ Trigger and DAQ:

- ❑ Is a trigger needed or can all (zero-suppressed) data be streamed out
- ❑ Closely linked to studies of occupancies caused by backgrounds

◆ Software:

- ❑ Full simulation of detector concepts gradually becoming available; important for performance and detector optimisation studies.
- ❑ Detailed digitizers important for quantification of background rates
- ❑ Reconstruction including particle flow appearing