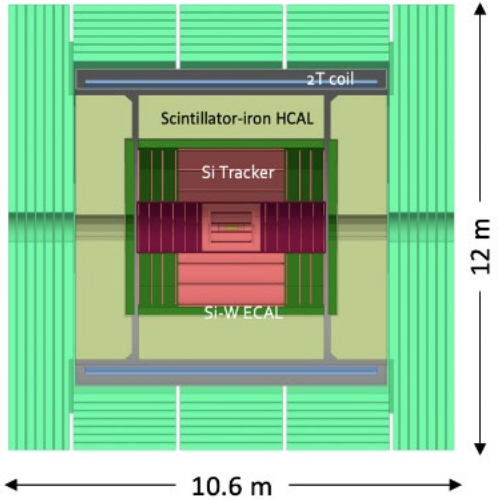
Detector Concepts Status

Mogens Dam, Marc-André Pleier, Felix Sefkow

7th FCC Physics workshop, LAPP Annecy, January 29, 2024

Current Detector Concepts

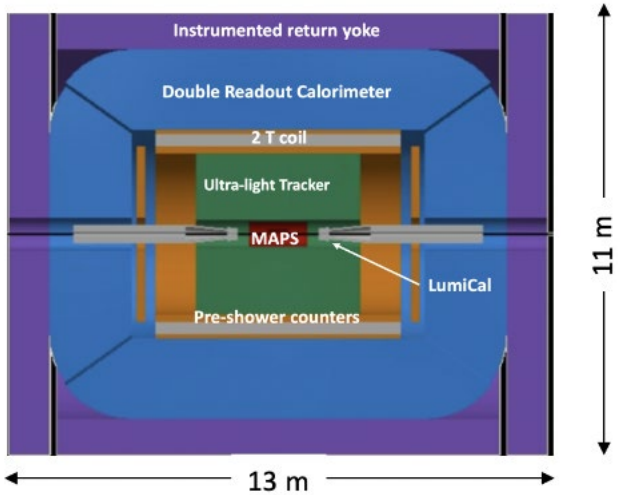
CLD



- Well established design
  - ILC -> CLIC detector -> CLD
- Full Si vtx + tracker
- CALICE-like calorimetry;
- Large coil, muon system
- Engineering still needed for operation with continuous beam (no power pulsing)
  - Cooling of Si-sensors & calorimeters
- Possible detector optimizations
  - σ_p/p, σ_E/E
  - PID ($\mathcal{O}$(10 ps) timing and/or RICH)?
  - …

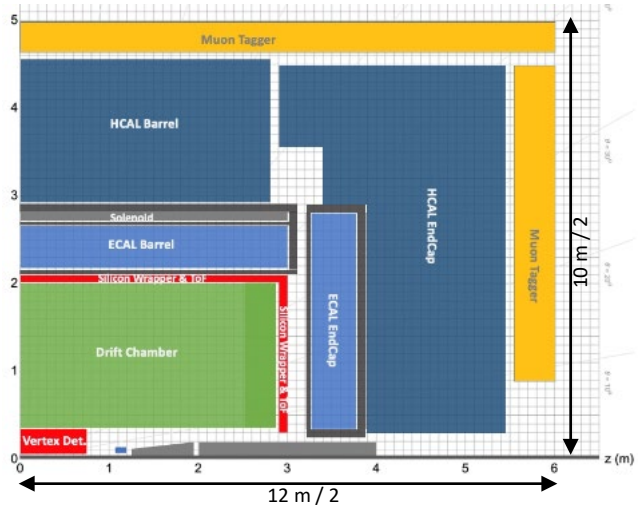
CDR

IDEA



- A bit less established design
  - But still ~15y history
- Si vtx detector; ultra light drift chamber with powerful PID; compact, light coil;
- Monolithic dual readout calorimeter;
  - Possibly augmented by crystal ECAL
- Muon system
- Very active community
  - Prototype designs, test beam campaigns, …

ALLEGRO



- The "new kid on the block"
- Si vtx det., ultra light drift chamber (or Si)
- High granularity Noble Liquid ECAL as core
  - Pb/W+LAr (or denser W+LKr)
- CALICE-like or TileCal-like HCAL;
- Coil inside same cryostat as LAr, outside ECAL
- Muon system.
- Very active Noble Liquid R&D team
  - Readout electrodes, feed-throughs, electronics, light cryostat, …
  - Software & performance studies

FCC-ee CDR: https://link.springer.com/article/10.1140/epjst/e2019-900045-4

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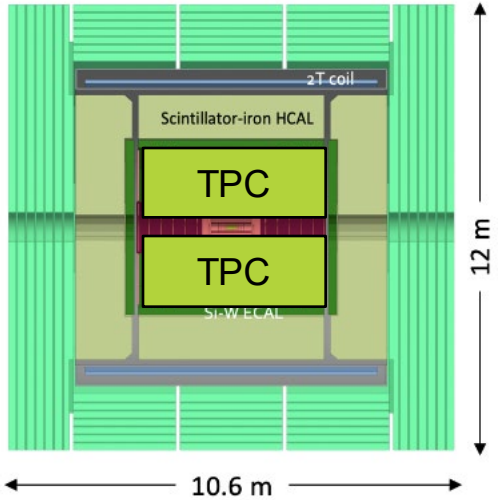
Current Detector Concepts

CLD/ILD'



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- Full Si vtx + tracker, study TPC option viability
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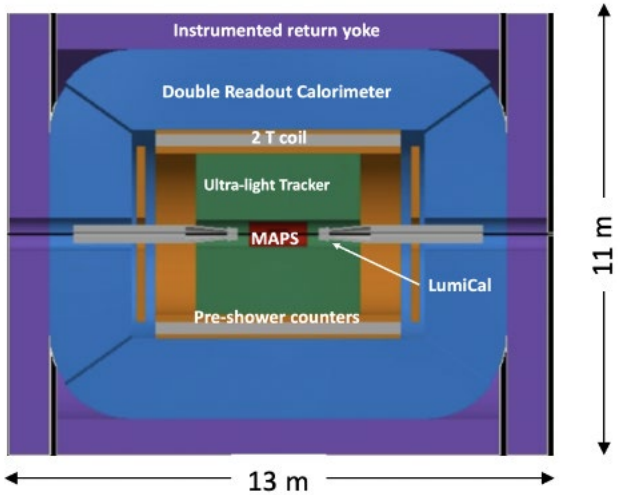

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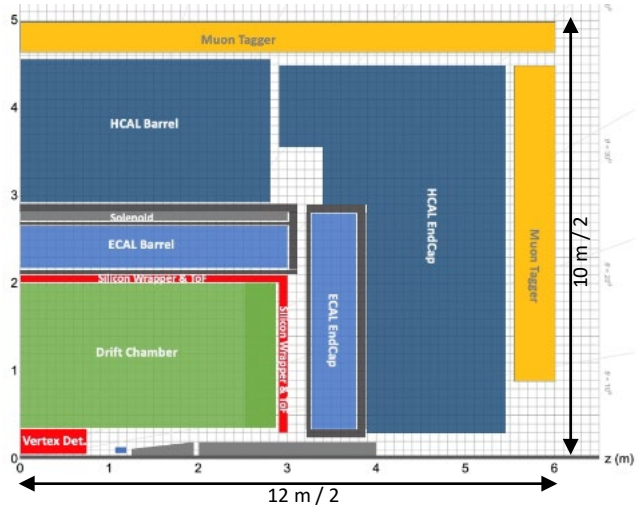

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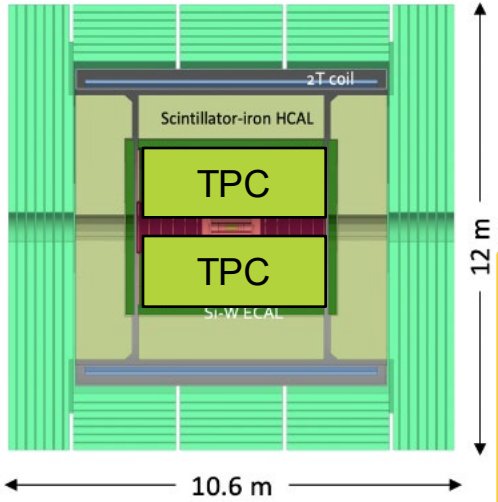

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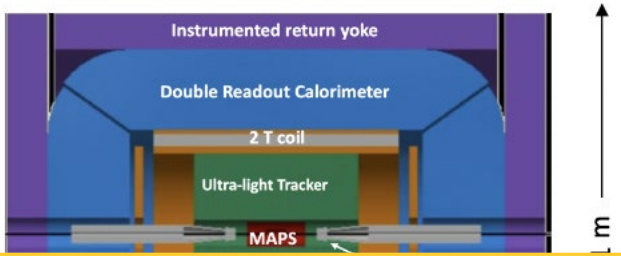

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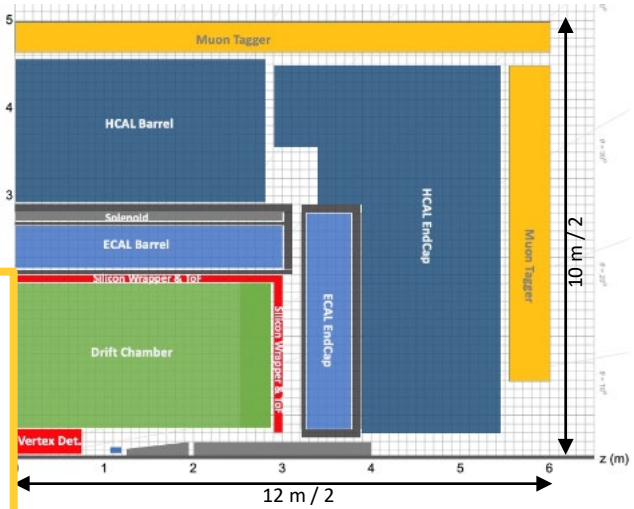

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Detector Costing exercise as part of Mid-Term Review: average cost 300-400 MCHF

(with large uncertainties: +50% -30%)

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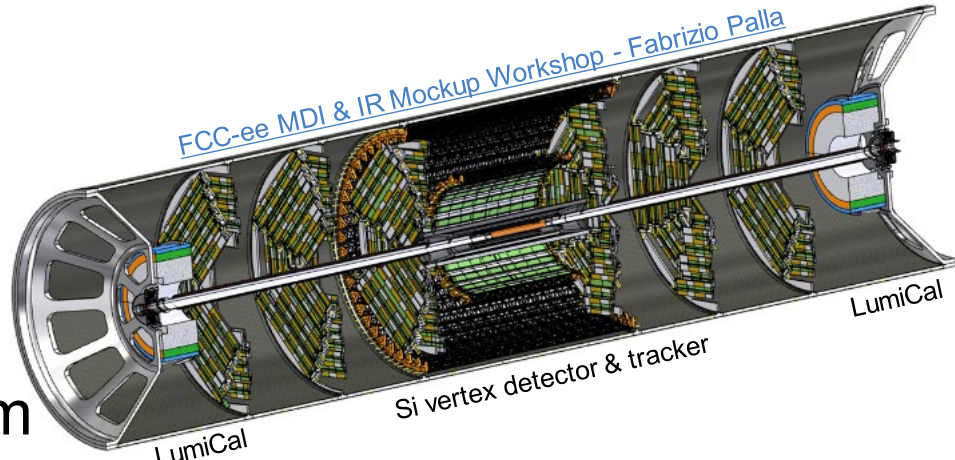
Vertex Detector & Tracking



Constraints from machine detector interface

- last focusing quadrupole at ± 2.2m from IP
- angular coverage beyond ±100 mrad
- magnetic field ≤ 2T for Z-pole run
- latest details in Detector & MDI session Tue, 9am

Challenges: material budget, power & cooling, detector stability

- Flavor tagging: low mass, small pixel size, close to IP, low power, ...
- Tracking: the lighter the better for momentum resolution, angular resolutions ≤ 0.1 mrad needed for control of beam energy spread.

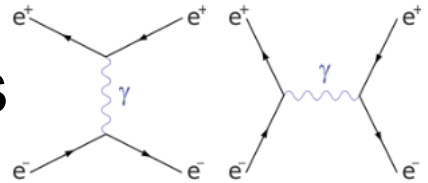
Ongoing studies:

- Vertex Detector and Silicon Wrapper talks in Detector & MDI session, Tue 09:00h
- Si detector and drift chamber talks in Tracking and vertexing session, Tue 17:45h
- Tracker optimization and TPC concept studies in Joint Detectors & Software & Computing session, Wed 11:00h

Luminosity Measurement

Aim for σ(L) / L of 10^{-4} from low-angle Bhabha events

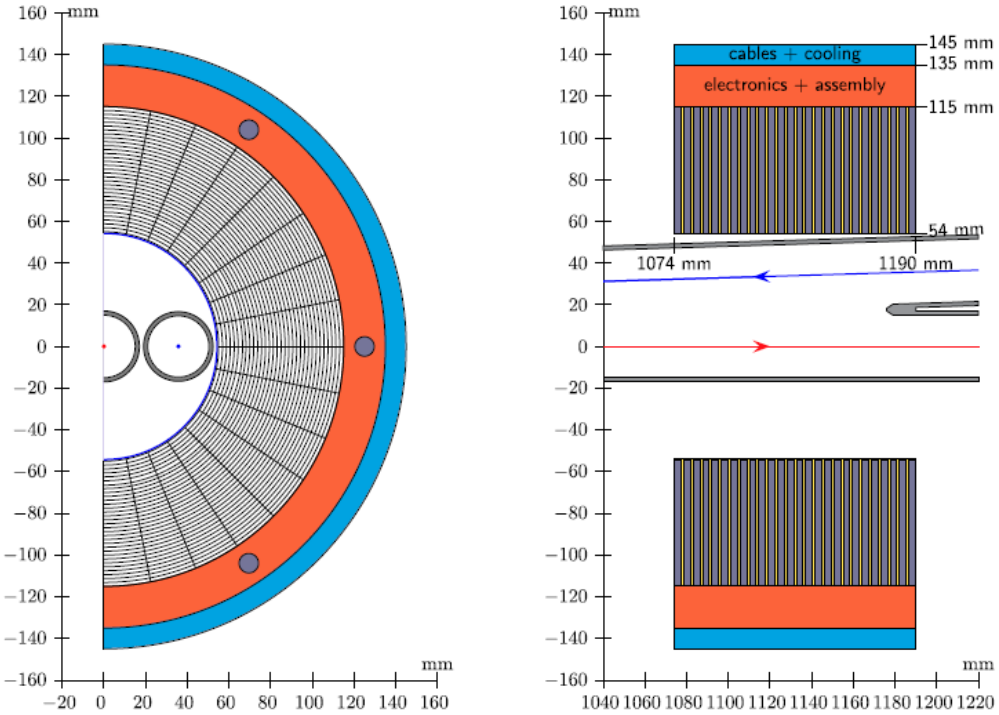
- match expected theo precision of Bhabha cross section
- inner radius of the LumiCal must be known to 1.6μm



Challenges:

- operational stability
- copper cooling manifold around beampipe: scattering background levels?

FCC-ee CDR



Ongoing studies:

- Full simulation studies ongoing
- See status report in Wed 14:00 plenary

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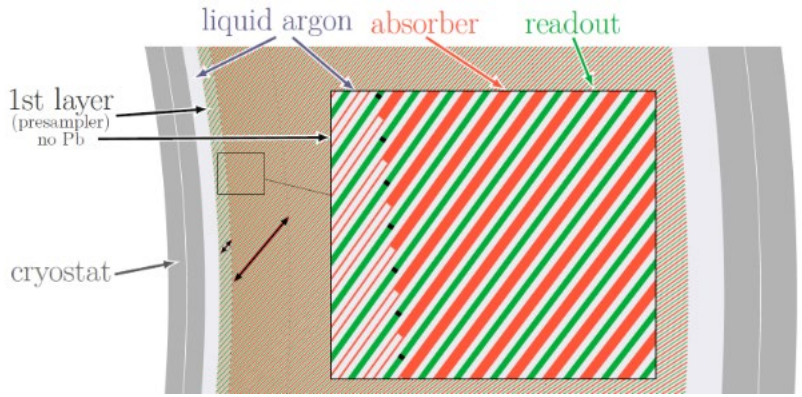
Calorimetry

EMcal to enable photon and pion reconstruction
- 10-15% / √E for photons (~25% of jet E) suffices for jets
- higher em resolution needed for flavor physics and helps jet reco
- e/γ and e/π separation study needs full sim/reco

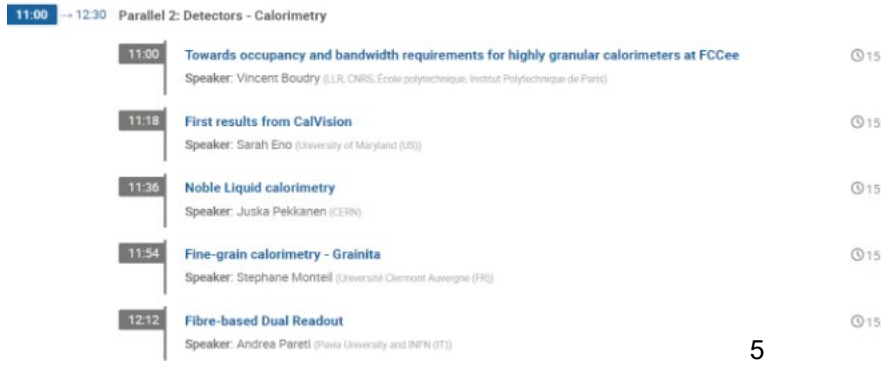


arXiv:1912.09962

Aim for jet energy resolutions of ~3-4% at 50GeV:
- jet E reco via angles for kinematically constrained final states
- Particle Flow reconstruction (-> high granularity!)
- dual read out to correct for non-compensation

Challenges: operational stability, cost, compactness despite cooling

Ongoing studies:
- Calorimetry session, Tue 11:00h
- ALLEGRO s/w implementation, Wed 11:00h
- Software & Computing: Reconstruction, Thu 11:00h



Particle Identification

Need excellent PID capabilities over wide momentum range
- e/γ and e/π separation,π/K, muon/hadron separation

Various approaches under study
- IDEA drift chamber
  - >3 σ π/ K separation up to 100 GeV, except around ~1GeV (analytic estimate)
- Time of flight (ToF)
  - Si wrapper or calorimeter
- RICH detectors, e.g. Array of RICH Cells (ARC):
  - could give 3 σ π/ K separation from 2 GeV to ~50 GeV
- Muon ID
  - how many layers needed (CLD: 7, IDEA: 3)?

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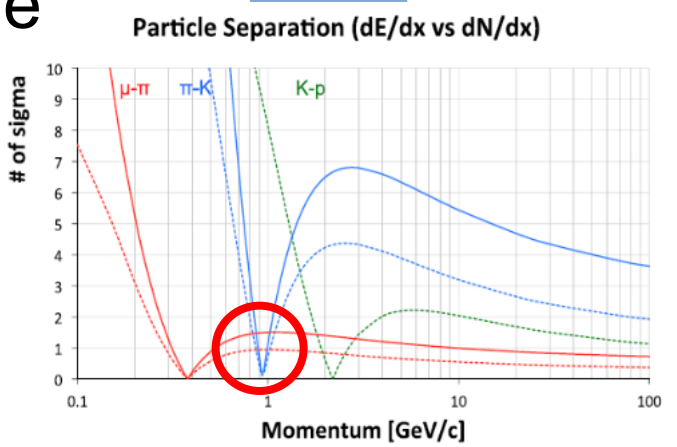
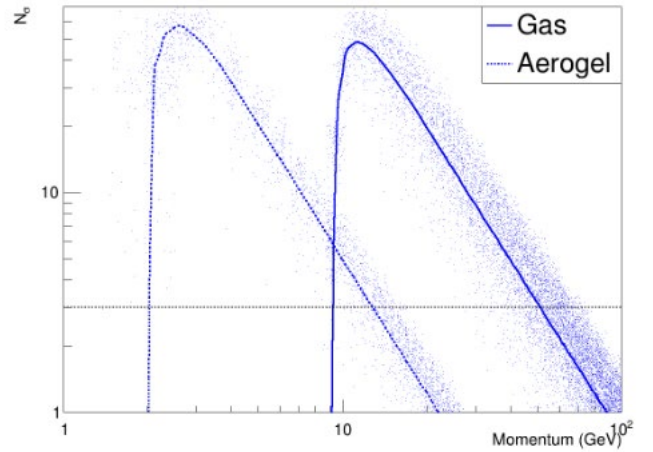


Figure by Martin Tat



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Trigger and DAQ

arXiv:2111.04168

Physics process	Rate (kHz)
Z decays	100
$\gamma\gamma \rightarrow$ hadrons	30
Bhabha	50
Beam background	20
Total	$\sim$ 200

Requirements are driven by Z-pole running with physics event rate of ~200kHz

Major question: do we need a trigger?

- Can all systems self-trigger independently and get data out with margin, without dead-time?
- Or do some require external trigger signals?
- And so do others have to provide trigger input - and buffer their data with sufficient (what?) latency?

General conditions

- occupancies and hit data volumes - event sizes and bandwidth needs
- do we have the tools to estimate these - including machine-induced and physics backgrounds
- non-“textbook" events: radiative Bhabha, gamma-gamma, beam-gas and halo, synchrotron radiation bursts, pick-up
- needs for on-detector hit processing and data reduction beyond zero suppression, and how to control / monitor this
- signal formation and propagation times (latencies)

Ongoing studies:

- Calorimetry session, Tue 11:00h
- Detectors: Electronics, Trigger and DAQ session, Thu 17:45h

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Summary / Outlook

Availability of full simulation and reconstruction code are crucial to study full detector performance with particle flow, e/π separation…

- A lot of effort ongoing (see software and computing sessions!), but more is needed ->synergies with nascent DRD collaborations?
- In the interim, studying performance at sub-detector level

Need well-understood Trigger and DAQ requirements for detector design

- Starting to (re-)evaluate requirements for each detector concept: impacts sub-detector design and their readout
- Understand background rates (for each interaction point)
- Starting with this workshop!