GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
cfp CIEMAT física de partículas

Technical plans and opportunities at ILD

Mary-Cruz Fouz – CIEMAT

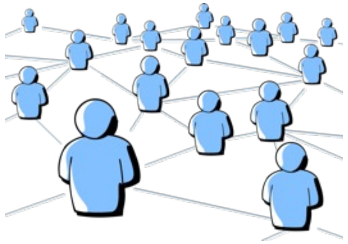
(with contributions from the technical coordinators of the different ILD areas)

Two open fronts….

Implementation of the ILD strategy 2022

Preparation towards new Detector R&D Collaborations

Europe **US**



Two open fronts….

Implementation of the ILD strategy 2022

3. ILD at a Higgs/EW/Top factory: a roadmap

…..

ILD has been developed for the ILC, and has been tuned to the particular beam conditions at the ILC. FCC-ee has very different beam parameters, which will impact the way the experiment is operated. ILD is ready to engage with these studies, and to make the case for an ILD-like detector at FCC-ee in particular. Whether or not this will eventually lead to a proposal to FCC-ee for a concrete detector concept should be decided after a period of study and based on the findings of the study. Such a concrete proposal would imply a more formal collaboration than those ILD has previously had with CLIC and CEPC. Depending on circumstances, it may become of interest to initiate similar collaborations with other collider projects.

There are some important differences between the FCC-ee and ILC that imposes us new challenges to address for designing a FCC-ee ILD-like detector

Two open fronts….

Implementation of the ILD strategy 2022

Preparation towards new Detector R&D Collaborations

Europe US

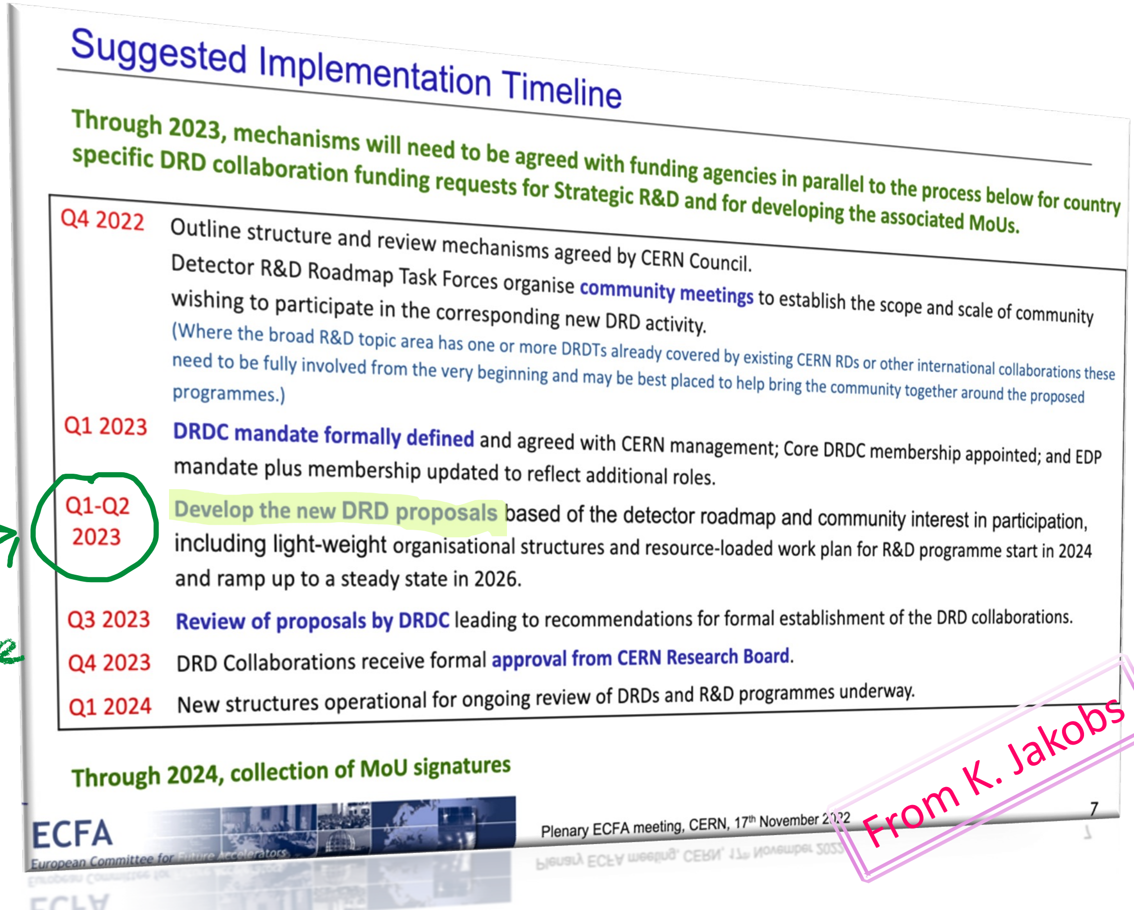
ECFA
European Committee for Future Accelerators

Detector R&D Roadmap implementation

https://indico.cern.ch/event/1197445/contributions/5034860/attachments/2517863/4329123/spc-e-1190-c-e-3679-Implementation_Detector_Roadmap.pdf

- It is proposed that the long-term R&D efforts be organised into newly established **Detector R&D (DRD) collaborations** (equivalent to the RD collaborations stablished in the 90's for LHC detector technologies)
- That collaborations will be established to address each of the **six detector technology areas identified in the Roadmap**

We are here



DRD collaborations should start work in January 2024, with a ramp-up of resources through 2024/2025, reaching a steady state by 2026.

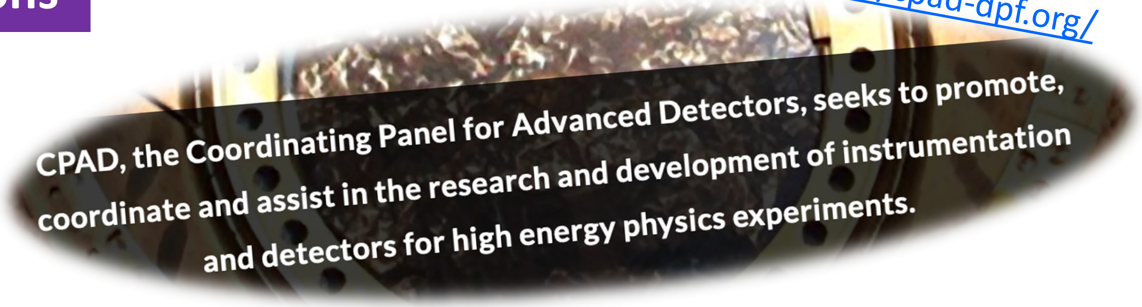
Two open fronts….

Implementation of the ILD strategy 2022

Preparation towards new Detector R&D Collaborations

Europe   **US**

https://cpad-dpf.org/



US R&D Collaborations

https://cpad-dpf.org/?page_id=1549

In a culmination of a decade of discussions within the US Detector Instrumentation community facilitated by CPAD, it has been decided at the last CPAD annual workshop to create a network of US Detector R&D Collaborations.

These Collaborations will be created covering major technology areas in line with the 2019 BRN. The goal is to bring together the community in a more persistent way than the annual CPAD workshops alone, to coordinate R&D efforts and to forge collaboration.

To this end, we have created the following mailing lists. Please sign up to your area of interest. Once we have the mailing lists filled, we will send around surveys to each to gauge everyone's specific interests with the goal to organize dedicated workshops and create work packages along the PRDs that were identified in the BRN.

- RDC1 – Noble Element Detectors
- RDC2 – Photodetectors
- RDC3 – Solid State Tracking
- RDC4 – Readout and ASICs
- RDC5 – Trigger and DAQ
- RDC6 – Gaseous Detectors
- RDC7 – Low-Background Detectors
- RDC8 – Quantum and Superconducting Sensors
- RDC9 – Calorimetry
- RDC10 – Detector Mechanics
- RDC11 – Fast Timing

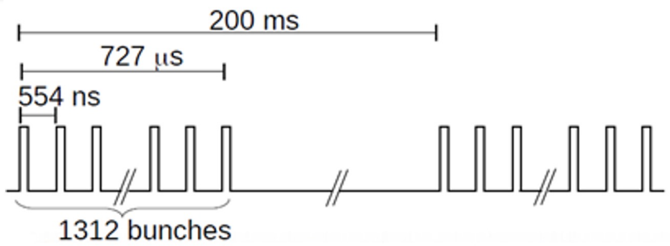
FCC-ee vs ILC: Operation Mode

Continuous beams

No power pulsing

Power consumption increased by a factor of 100

Very low duty cycle:
Train separation 200 ms



Open questions

Is **active cooling** needed for calorimeters?

Could it be avoided?

by reducing ASICs power consumption

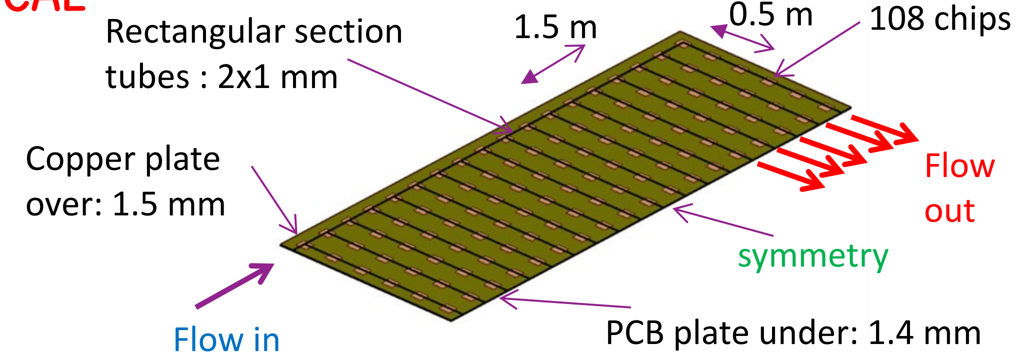
by reducing number of channels? ➔ re-optimization

Which is the impact on performance?

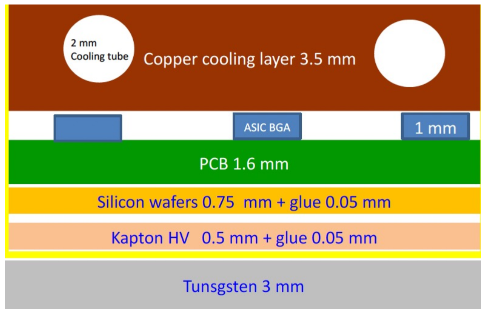
Which are the **implications on performance** of using active cooling?

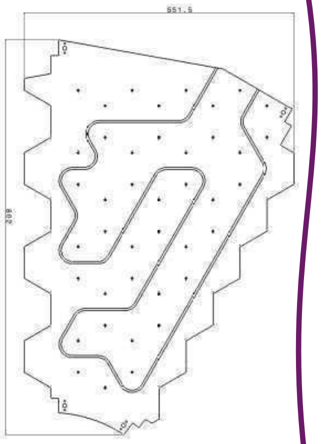
water circulation in copper pipes

SDHCAL



SiWECAL





FCC-ee vs ILC: The special case of Z-pole

Z pole: Very high Collision frequency

100 kHz collisions + 100 kHz background

Luminosity/IP (10^{34} $cm^{-2}s^{-1}$)

	Z (91GeV)	H (240-250 GeV)
ILC	0.2	1.4 (2.7)
FCCee	~200	8.5

Open questions

Which are the implications for **DAQ**? Could some kind of **trigger** be needed?

Rate capability problems for SDHCAL GRPC

➔ Developments on low resistivity materials for increasing rate capability, move to multigap GRPC (**shouldn´t be an issue**, work ongoing)

Which are the **implications for the TPC**?

The same detector must run at very different rates, and Z-pole **cannot compromise the running at Higgs mod**e.

How to optimize the detector for both cases, is it possible?

(This is a question for any FCC-ee detector not specific for ILD)

FCCee	Z(91GeV)	W(160 GeV)	H (240 GeV)
Hz	92000	8.4	1

FCC-ee vs ILC: Implications for TPC

Field distortion by ions caused by

- a large amount of the primary ions from ionization of the tracks from both Z-pole events and the machine background
- the backflowing ions generated in amplification.

(gating device does not work with continuous beam)

Estimation of TPC distortion at Z-pole run

Toy MC for Z-pole run by K. Fujii and D. Jeans Z-pole 50 Hz → 22k events in the 0.44 s time frame.

Maximum distortion appears at the **innermost region**

FCC hh ee he — Primary ions: ~70 μm; Backflowing ions: ~160 μm

VS

ilc international linear collider — <5 μm

- It is now needed to adapt the simulation results obtained so far to the ILD and evaluate the impact on the physics events.
- In addition, correction of the track distortion using well known tracks (such as Z→μμ) is another subject to be considered.
- We may learn experience in ALICE experiment (50kHz, Pb-Pb collision) where the TPC is used for tracking. (*Evaluation of the track distortion and it's correction method*)

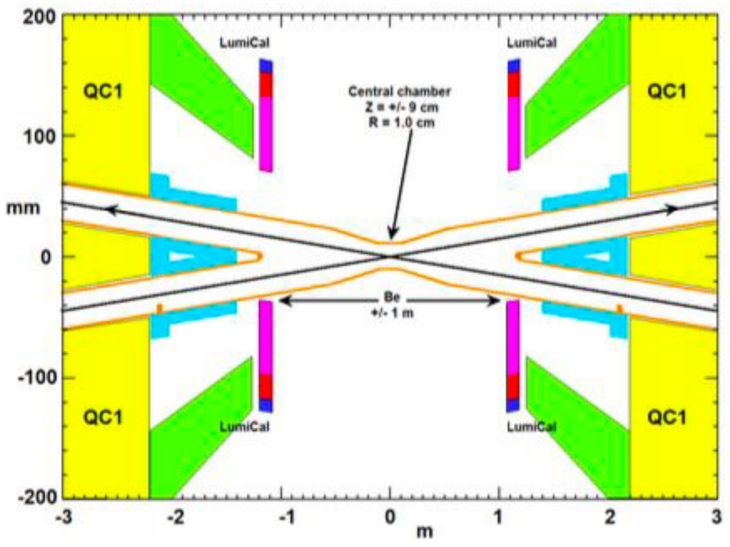
FCC-ee vs ILC: Implications for TPC (II)

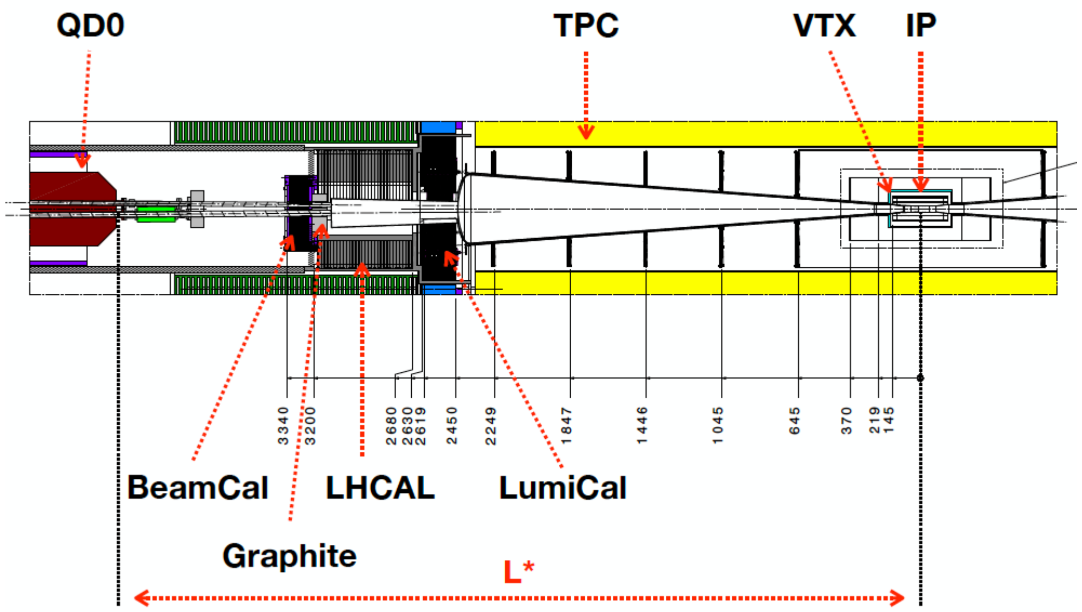
Suppress the IBF without gating

- It is **absolutely difficult to use an active gating** system for the circular machine.
- We should consider to **modify the design and configuration of the MPGD readout system** to suppress the backflowing ions.
  - It has been reported recently that a combined Micromegas with GEM readout module can suppress ion backflow*.
  - Graphene membrane might be useful**.
- It might be possible to suppress the ion backflow by **optimizing field conditions** although the collection efficiency of primary ions can be also affected.

** https://indico.desy.de/event/33640/contributions/128390/attachments/77557/100324/ECFA_LCTPC_IHEP__Huirong_20220930.pdf*
*** Nuclear Inst. And Methods in Physics Research, A824 (2016) 571.*
Nuclear Inst. and Methods in Physics Research, A 1031 (2022) 166521.
https://indico.cern.ch/event/1219224/contributions/5130761/attachments/2567723/4427337/MPGD_Conference_2022_CERN.pptx

FCC-ee vs ILC: Machine Detector Interface





Crossing angle 30mrad
L* 2m: Final Quadrupole **inside** the detector
Solenoid magnetic field restricted to 2T maximum
Lumical at **~1m** from IP
➔ Tracker acceptance: cosθ ~ 0.984
Inner beam pipe radius 10mm

Crossing angle 14 mrad
L* 4.1 m: Final Quadrupole **outside** the detector
Solenoid magnetic field 3.5 – 4 T
Lumical at **~2.5m** from IP
Inner beam pipe radius 16 mm
Conical ➔ Tracker acceptance: cosθ ~ 0.996

FCC-ee vs ILC: Machine Detector Interface

FCCee vs ILC has a very different MDI

The biggest impact on the ILD design for the FCCee

Things to be addressed

Vertex geometry should be revisited

ILD Forward region needs to be redefined to cope with FCCee design

- Not only for the Lumi calorimeter

Backgrounds effects in the detectors and physics process to be studied

- Effects on reconstruction
- Could affect the design parameters/sensor types for the vertex?
- Extra shielding at luminometers?

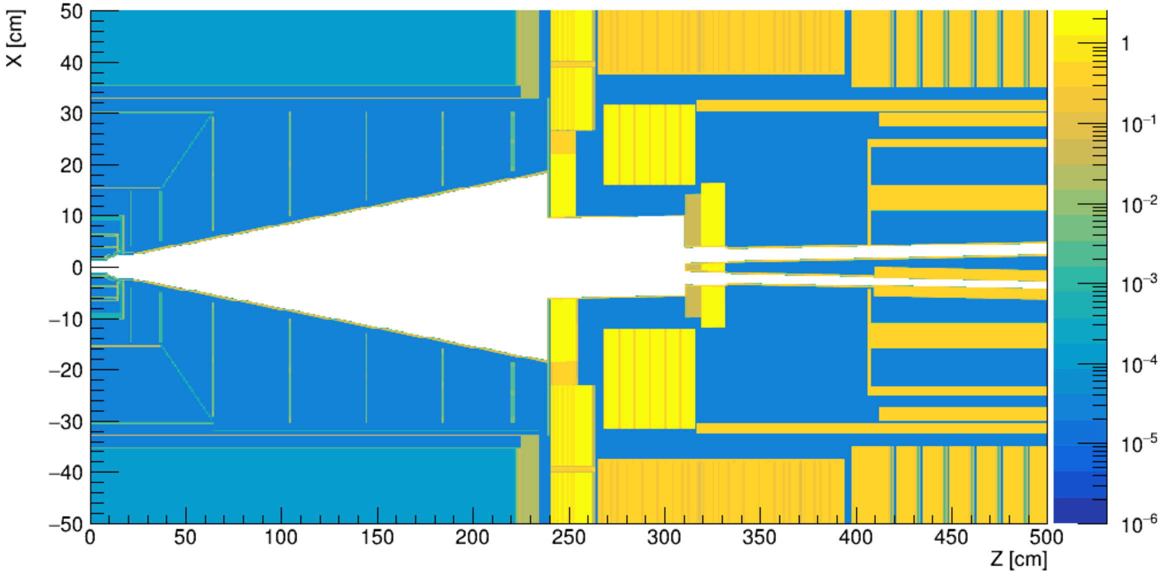
Impact of **smaller solenoid Bfiel**d (~half respect to ILC)

- On the TPC reconstruction
- On the physics performance, in particular on detector capabilities for flavor physics (b/c tagging, particle ID)

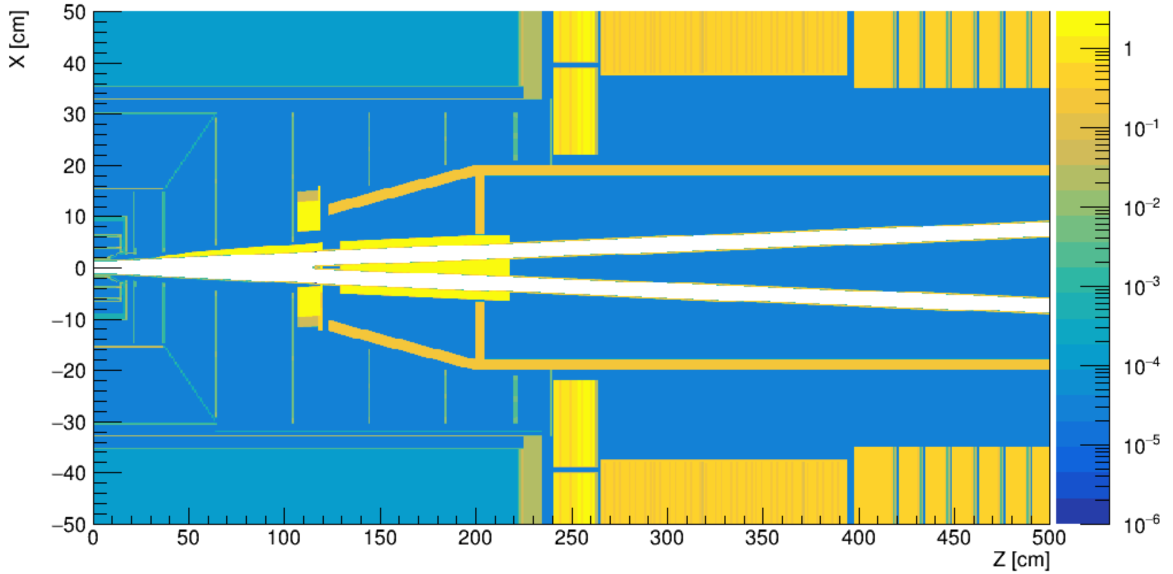
Monte Carlo Simulations are needed to evaluate backgrounds, B field effects…
To proceed after with detector optimization

→ Requires a new ILD model

FCC-ee vs ILC: ILD Model Simulation



"Standard" ILD



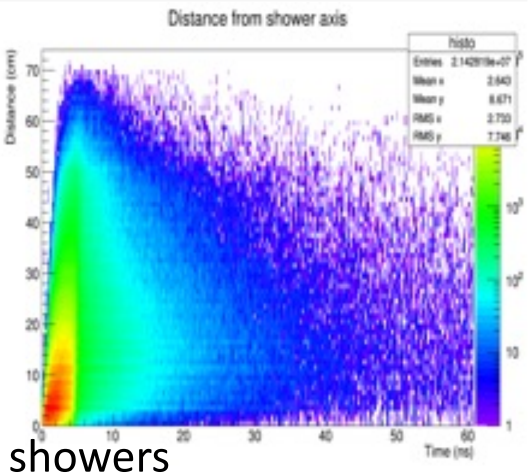
ILD for FCC "work in progress model". (by Daniel Jeans)

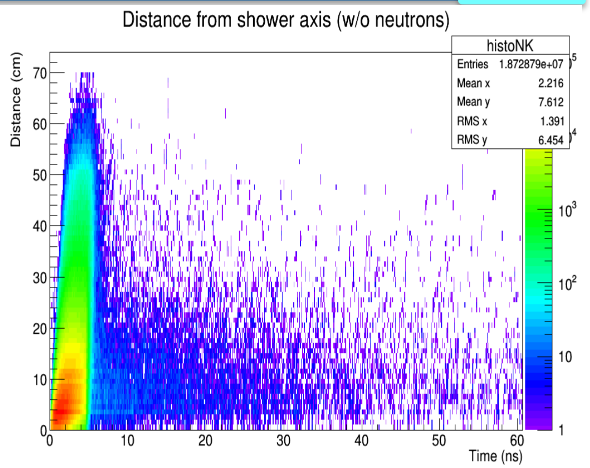
The **beampipe/lumical etc** are taken from the **FCCee model**.

The **forward disks** are brought in as much as possible, leaving only a very small gap to the machine elements.

Probably very unrealistic from a mechanical point of view but enough at this moment for the intended purposes

Timing studies - Calorimeters (ILC & FCCee)





Precise timing will play an important role

Improve PID

Beam-induced background rejection

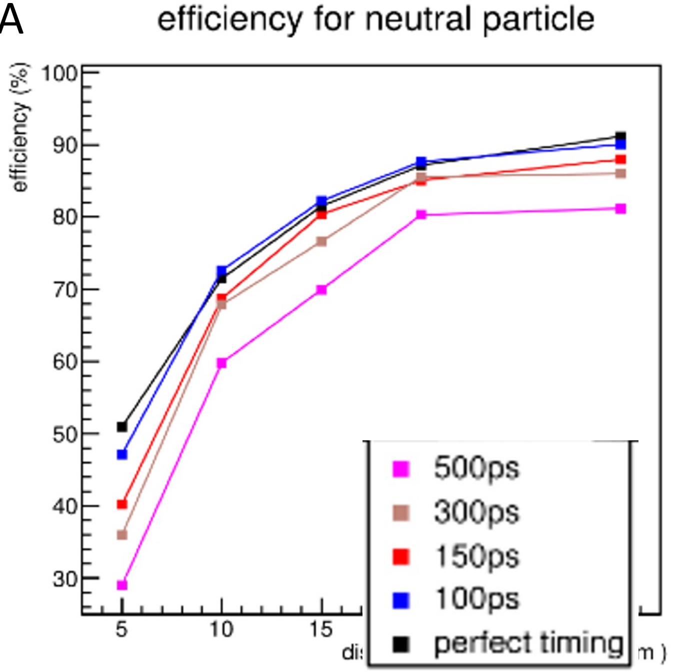
Pile-up rejection

But also, if used in the calorimeters

- **Improve calorimeter/tracker matching** and separation for closer showers

  ➔ reducing the confusion term on PFA

- **Improve the calorimeter energy resolution**



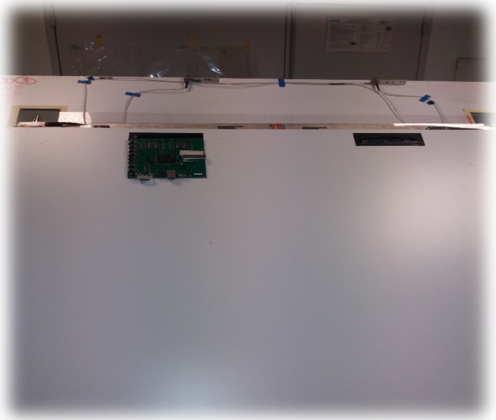
Some MC Simulation studies with SDHCAL adding Time

Including time information in the simulation to separate hadronic showers (10 GeV neutral particle from 30 GeV charged particle) using techniques similar to ARBOR's ones.

Some work already ongoing by the SDHCAL group in the AIDAInnova framework

CAVEAT: Adding timing to electronics will increase power consumption

SDHCAL Multigap GRPC Chamber + Electronic tests
1x1m2 chamber



Readout by: PETIROC+ external TDC
Same cards as the ones developed for upgraded CMS RPC
2 PETIROC2 + FPGA Cyclone V + ethernet

Multi-gap:
two times 4-gap
PCB inserted between the two

1cm Strip width

At the moment 64 strips in total can be read out but can be extended on future if needed.

Some tests to be done in incoming weeks

Don´t forget also…

A central challenge for a detector like ILD, optimized for precision physics, is the delivery of an excellent and stable **calibration and alignment** environment.

These considerations need to be included from early on in the design.

The different **running conditions and beam conditions might impact** the way the detector is to be calibrated and aligned, and need to be studied.

FAST VIEW OF OTHER WORKS ONGOING INCLUDING SOME PROPOSALS FOR DRD

Tracking Detectors

TPC

Work ongoing for studying operability of a TPC in the FCC/CEPC TeraZ environment

DRD1 (gaseous detectors) proposal draft written. Contains a TPC Work package

CMOS R&D

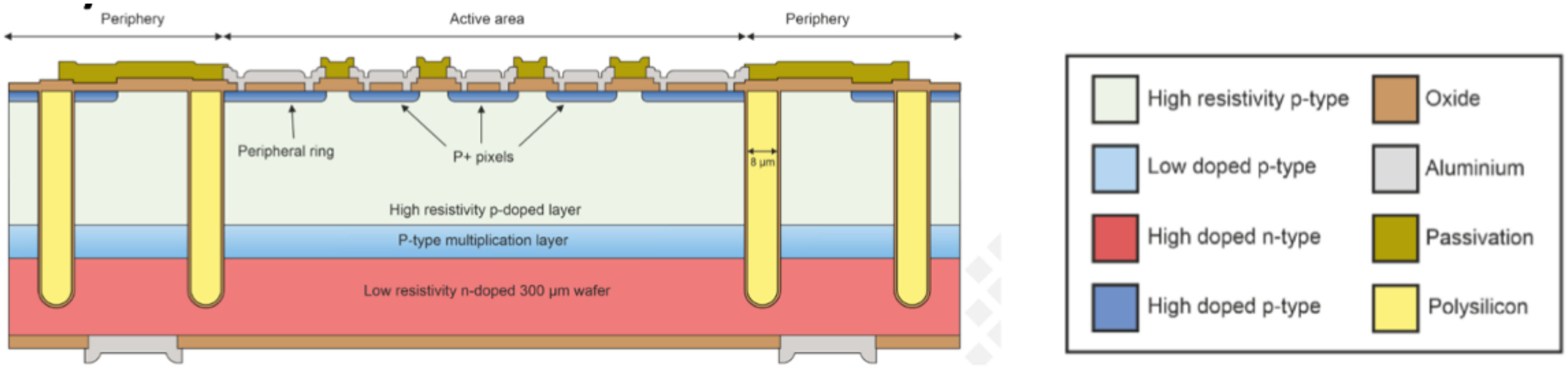
Proposal (**DRD3**) of CMOS 65 nm technoogy R&D targetting a vertex detector chip demonstrator by several groups (including IPHC, CERN, DESY, APC-Paris, Zurich)

New partners are welcome

ILGAD sensors R&D

New production of thin iLGAD ongoing @IMB-CN;

Basic layout for thin single-sided ILGADs



Highly Granular Scintillator-strip Electromagnetic Calorimeter

DRD 6

•Institutes

- China: USTC, IHEP, JSTU, Japan: UTokyo, Shinshu

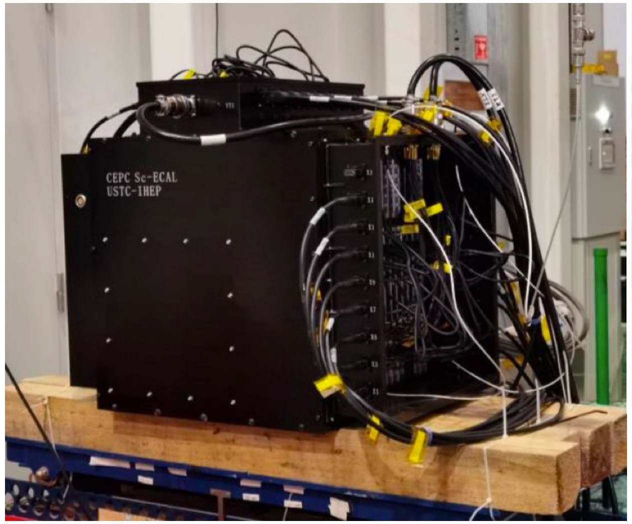
•R&D items

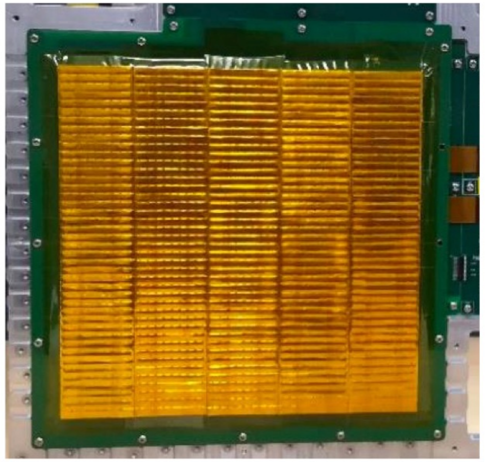
- Engineering work for large scale production
- Improved timing performance
- Scintillator material performance (light yield, time constant, quantum dot,…)
- Strip performance (reflector, double SiPM readout,…)
- Active cooling system
- Electronics
  - Low-power and high-performance readout ASIC
  - Full length slab
- Trigger-DAQ system

•Deliverable

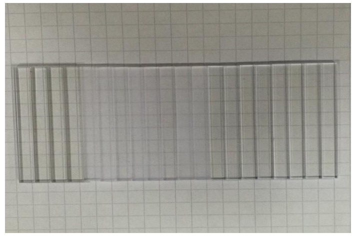
- Build an improved technological prototype where the items developed in this program are integrated and demonstrate the performance in test beam experiments.

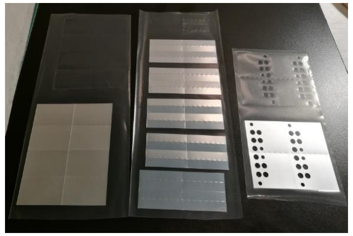
Technological prototype

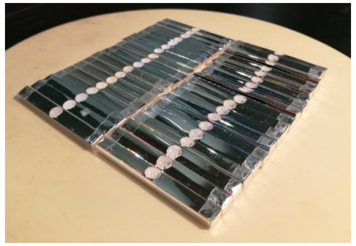




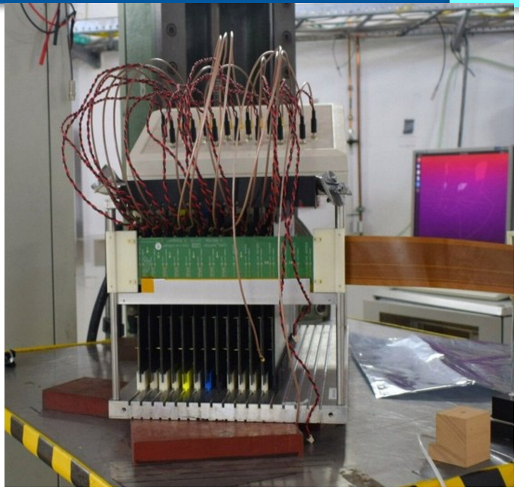
Strip wrapping and assembly on EBU was done by hand (Shanghai Institute of Ceramic)







SiW-ECAL Technological prototype – Recent tests



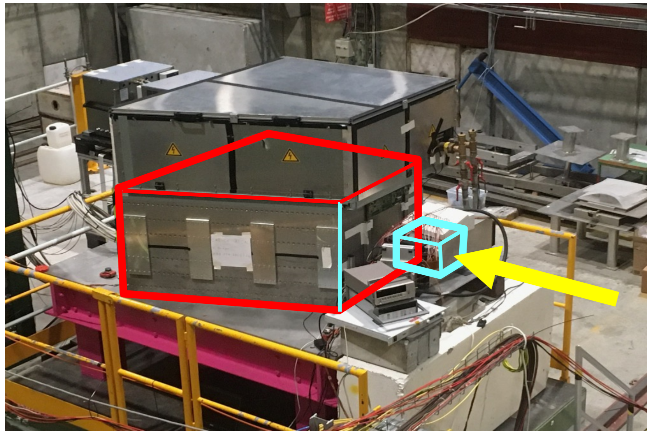
Nov. 2021 + March 2022 : electrons of 1–6 GeV (4th attemp…)

– 15 layers of 1024 cells + Compact "ILD-like" DAQ

- 5 types de VFE boards (FEV10, 11, 12, 13, COB) ⊗ 3 Wafer thicknesses (320, 500, 650 µm)
- 2 Tungsten absorbers configurations.

8-22 June 2022

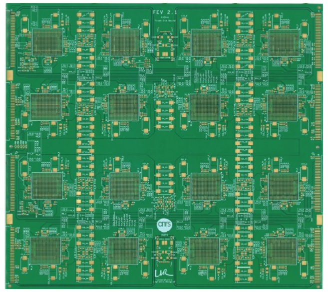
"Full" SiW-ECAL + AHCAL



SiW-ECAL
- **15 layers 18×18 cm²**
- **0.5×0.5 cm² Si cells**
- **2.8+5.6 mm W (24 X0)**

AHCAL :
- **38 layers 72×72 cm²**
- **3×3 cells scintillator + SiPM**
- **1.7 cm Stainless Steel (~4λ)**

Some defects showed up, are being corrected
- Peripheral sensor delamination
  ➞ gluing review @ IFIC
- HV and stability
  ➞ FEV2.1 at LLR and IJClab in prod.



➔ Improved prototype in 2024

Plans to review the ILD SiW-ECAL parameters esp. for FCC-ee in 2023 and 2024

Power & Performances ⟷ Electronics

SiW-ECAL Prototyping

– **2023**: Build a prototype with uniform layers

(FEV2.1 + 500 μm Sensors)

All material avail.

– **2024**: Test in beam (standalone, w AHCAL)

Prepare setup with 2 towers

- 7–12 layers, same ASUs + 40 Wafers (*if funding*)
- ➞ Dark **γ**, QED exp: LUXE@XFEL, EBES@KEK, Lohengrin@ELSA

– **Far Side :** new prototype
➞ pilote module (1M ch)

SiW-ECAL Design for Detectors (↔ ECFA WG3 &ILD)

– **2023**: Prepare specifications for low occupancy, continous operations ASICs

- power, rates, etc. Test of various ASICs hypothesis, Check for active cooling needs in ECAL
- Specifiy requirement on precision on timing in PFA/PID

Dedicated layers (LGADs) vs Bulk Timing

– **2024**: Prepare design

- Electronics, DAQ
- Integrated cooling, *if needed*
- Optimisation of the ECAL (granul, resolutions *E, t*)
- Mechanics & monitoring

– **2025**: Blueprint (EDR) of pilote module for Higgs factory

Developing a T-SDCHAL

Proposal sent to **DRD6**

New SemiDigital Hadronic Calorimeter with Multigap GRPC including timing capabilities

Groups involved IP2I, OMEGA, CIEMAT, Cordoba Univ., VUB, Yonsei, GNWN, SJTU, Tunis

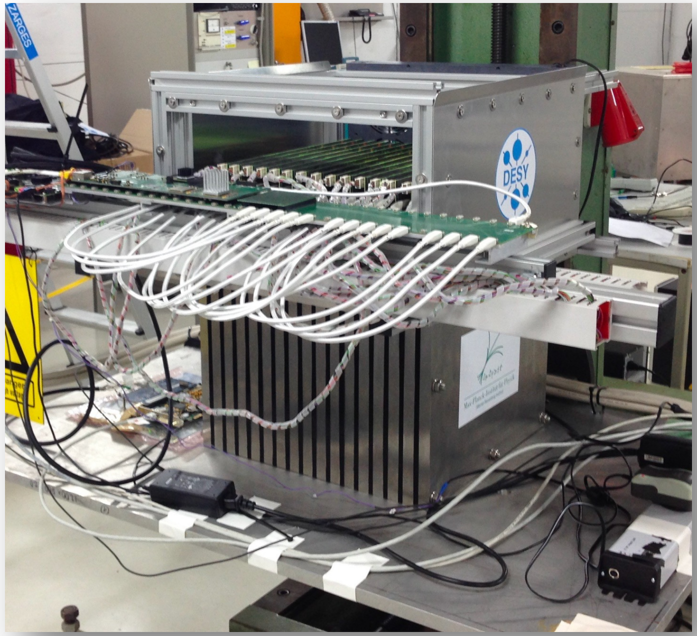
OBJECTIVES

1. **Simulation** study of **hadronic showers with time information**
2. **Simulation** study of **cooling system** required for the T-SDHCAL unit based on the present knowledge of the Liroc ASIC power consumption as well as the other components to be used.
3. **Mechanical structure** with the cooling system
4. Conception and production of **fast-time electronics** (PETIROC/Liroc+TDC)
5. Conception of a **thin and large ASU** hosting the readout electronics to be associated to the MRPC in a cassette.
6. A **DAQ system** allowing the communication and the synchronization of a few T-SDHCAL units.
7. Construction of a **few T-SDHCAL units**.
8. **Construction** of cooling units for the T-SDHCAL units.
9. **Validation** of the new T-SDHCAL units **in beam tests** first in independent way and then with the other SDHCAL units.
10. Comparison with the simulation.

Analog Hadronic CALorimeter - AHCAL

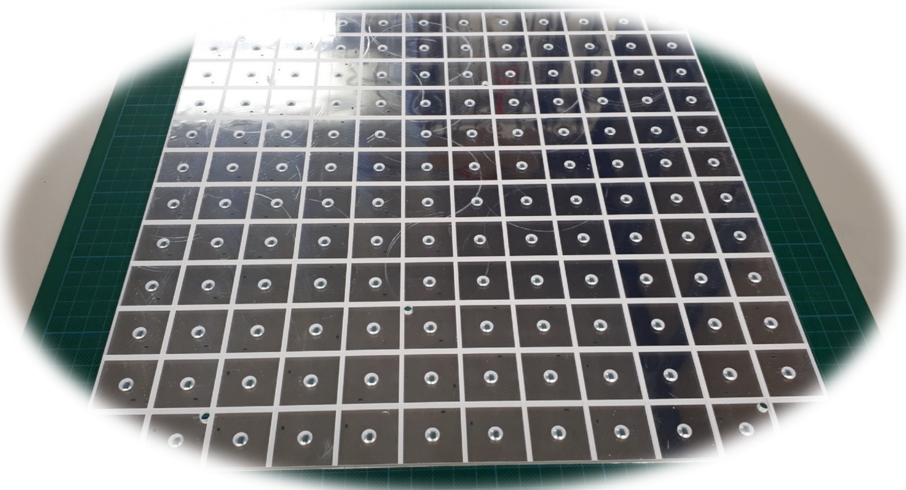
DRD6 plans and people

Build a small AHCAL prototype ("EM stack") with continuous readout with hit timing capability

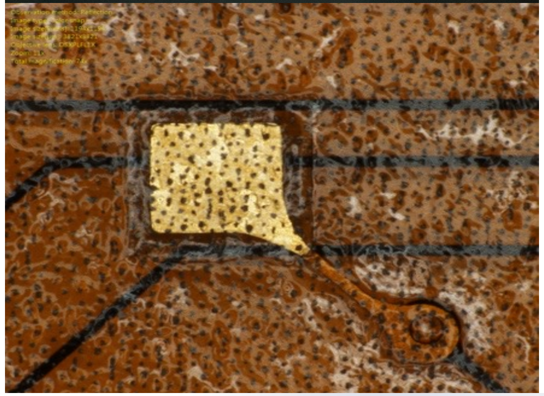


Task sharing between institutes working on CALICE AHCAL
(DESY, U Göttingen, U Hamburg, U Heidelberg, KIT, U Mainz, Prague, Omega)

- Front-End ASIC (HD, Omega)
- Back-End / DAQ (KIT, Mainz, Prague)
- Megatiles (Mainz)
- Mechanics & Cooling (Mainz, HD, DESY)
- Common tasks for all: software, testbeams, analysis, …



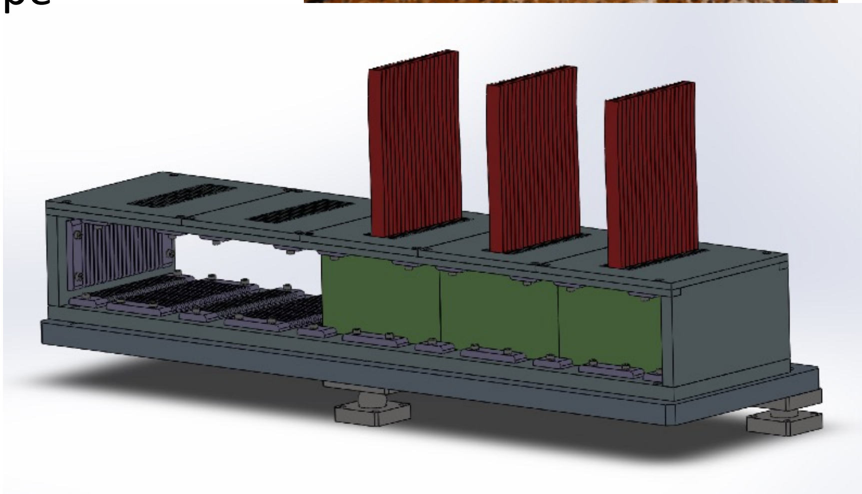
Forward Calorimeters



Work on going on the LumiCal :

a major part of the collaboration is building an electromagnetic calorimeter for the LUXE experiment based on the LumiCal

- Silicon sensors (GaAs with traces have been also studied)
- New gluing technics under study
- Tungsten planes (1X0)
- Distance between tungsten planes : 1 mm
- Mechanical frame under study
- Electronic dedicated for collider (FLAME) has been slightly modified to cope with the low trigger rate of LUXE (1Hz)



To close...

The previous list of activities is not completed

Even if we are more centered now on the evaluation of the ILD for the circular machines, the work for ILC is not yet finish

We lack money and personpower

- For hardware developments
- For simulation studies related to background and detector optimization (For ILC and FCCee)
- For more general integration aspects

We are open to new collaborators and also to new ideas which can improve our detector including new technologies

There is lot of interesting things to do

Thank you for your attention...