Expressions of Interest for the Development of Sub-Detectors and Detector Concepts for the FCC

8th FCC Physics Workshop satellite meeting,
January 17 2025

Template for Sub-Detectors - **do not modify**!
Copy empty template to relevant section in slide deck and fill your copy.

Template version: 07/12/24

<ID No> <Your Technology Title>

Contact Persons:

- Name 1, email
- Name 2, email
- Name 3, email

Collaborating Institutes & expertise/facilities:

- Institute 1
  - Expertise 1, facility 1
- Institute 2
  - Expertise 2, facility 2
- Institute 3
  - Expertise 3, facility 3

Connections with DRDs:

- DRDa, WPx: …
- DRDb, WPy: …

Connections with Concept Groups:

- Engineering/Simulation studies with concept NN

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

<ID No> <Your Technology Title>

Planned activities for the next 3-5 years

- 2025: Task 1
- 2026: Task 2
- 2027: Task 3

Eye candy, prototype results, …

<For each merged EoI you may add one extra slide. >

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

Template for Detector Concepts - **do not modify!**
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<Your Detector Concept Name>

Contact Persons:

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- Institute 2
  - Expertise 2, facility 2
- Institute 3
  - Expertise 3, facility 3

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Connections with Sub-Detector EoIs:

- <EoI ID No> <EoI Short Title> : Interfaces to sub-detector developments, integration studies, (full-) simulation-based physics studies
- <OiI ID No> <EoI Short title> ….

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<Your Detector Concept Name>

Progress towards simulation model with full simulation in all sub-systems:

- Full-event properties like di-jet masses or flavour tagging available?
- Current performance vs FCC physics performance requirements?
- …

Progress towards overall engineering model:

- material budget
- sub-detector envelopes, dead spaces
- optimisation of global detector parameters and structures
- development of machine detector interface (MDI)
- …

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  - Expertise 2, facility 2
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Insert your **copy** of the template in one of the following sections and fill it there.

Detector Concepts

IDEA Detector Concept

Contact Persons:

- Paolo Giacomelli, paolo.giacomelli@bo.infn.it
- Franco Bedeschi, bed@fnal.gov

Collaborating Institutes & expertise/facilities:

- Vertex detector: INFN (IT), U. Zurich (CH), FNAL, MIT, Edinburgh U., Lancaster U.
- Drift chamber: INFN (IT), BNL, IJCLAB
- Silicon Wrapper: INFN (IT),
- DR crystal Ecal: INFN (IT), UMD (US), IP2I (F), Princeton u. (US), Caltech (US), Purdue U. (US), Baylor U. (US), ANL (US), Brandeis U. (US), U. of Michigan (US), Oak Ridge (US), Texas Tech (US), U. of Virginia (US), SLAC (US), Stony Brook U (US), Rutgers U. (US), CERN
- Superconducting solenoid: INFN LASA (IT), CERN
- DR fibre calorimeter: INFN (IT), Yonsey U. (KO), Seoul U. (KO), Sussex U. (UK)
- Muon detector: INFN (IT)

Connections with DRDs:

- DRD6
- DRD1
- DRD3
- DRD7

Connections with Sub-Detector EoIs:

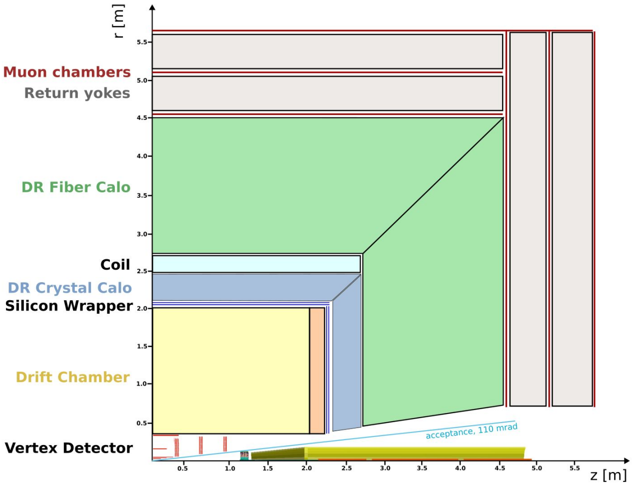
- ID069 Light weight Vertex detector design, mechanical integration and performance
- ID094 Tracking and timing detectors based on LGAD-RSD technology for use in the IDEA detector concept
- IDXXX DR crystal em calorimeter (EoI in preparation)
- IDYYY DR fibre hcal (EoI in preparation)
- ID076 Development of micro-RWELL technology for the Muon system
- ID088 Design of the interaction region, including beam pipes, IR magnets, vertex and lumical integration
- ID101 Development of an ultra-light drift chamber with PID capabilities for the IDEA detector

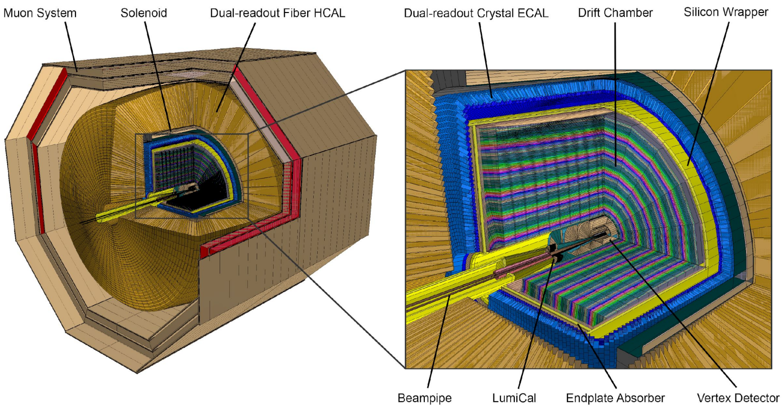
References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

IDEA Detector Concept

Innovative **D**etector for **E**$^+$e$^-$ **A**ccelerator

- IDEA is constituted geometrically of a barrel closed by two endcaps.
- It is made of the following sub-detectors (in increasing distance from the IP):
  - A vertex detector with CMOS sensors
    - 3 inner layers with 25x25 μm^2 pixels
    - 2 outer layers with 50x150 μm^2 pixels
  - An ultra-light drift chamber
    - excellent PID capability with dN/dx
    - 112 independent measurements along a track
  - An outer wrapper made of silicon strip detectors
    - LGAD detectors with precision timing resolution (100 ps) are considered as an option
  - A Dual Readout crystal electromagnetic calorimeter
    - Outstanding energy resolution
  - HTS solenoid providing a magnetic field up to 3 T
  - A Dual Readout fibre calorimeter
    - Provides an excellent hadronic jet energy resolution
  - A muon detector composed of 3 stations of μRWELL detectors
  - Two Lumicals in the forward regions to measure luminosity with high precision (<=10^{-4})





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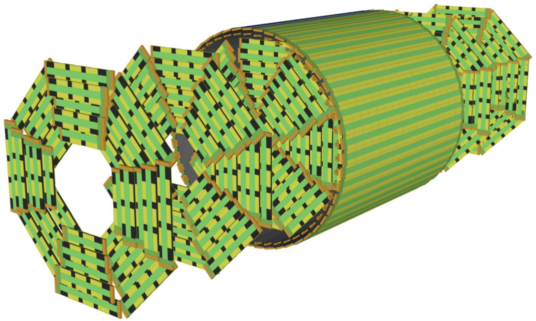
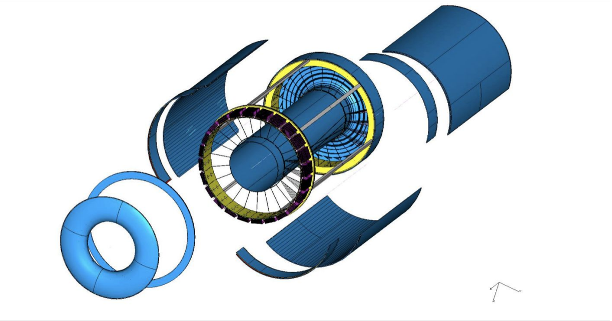
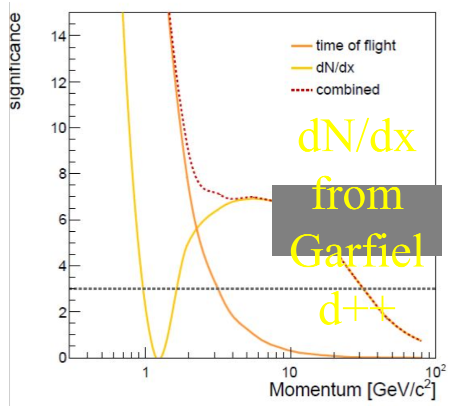
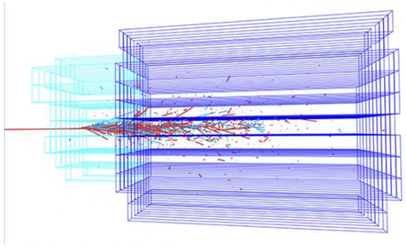
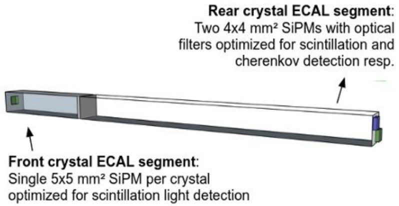
IDEA Detector Concept

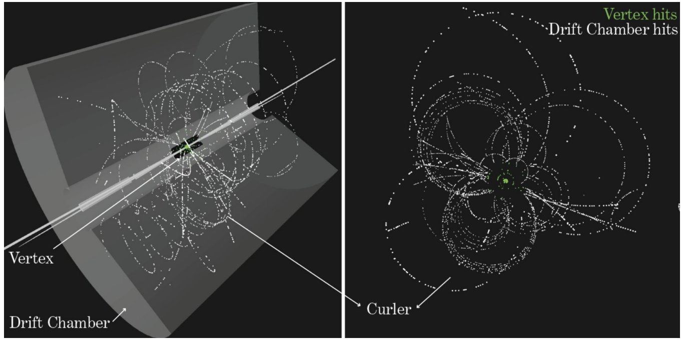












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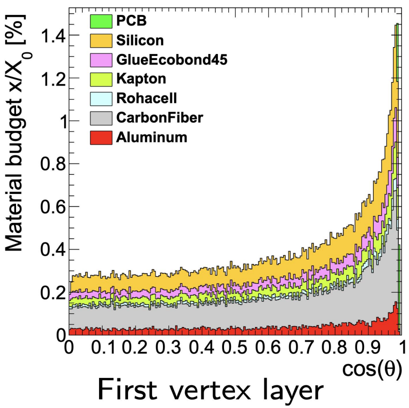
IDEA Detector Concept

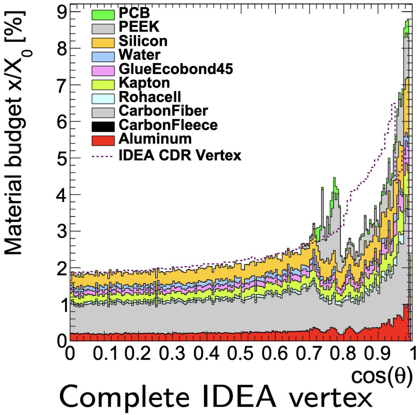
Progress towards simulation model with full simulation in all sub-systems:

- The IDEA detector concept is fully integrated into the FCC-SW (Key4hep frame-work). Full simulation of collision events can be performed in a modular approach, different sub-detectors can be tested altogether or independently, as part of the IDEA concept. New technologies can be introduced if needed.
- Current performance vs FCC physics performance requirements have been studied with simulations for all sub-detectors, including vertex tracker, drift chamber, outer wrapper, DR fibre calorimeter and muon detector. DR crystal ecal has been introduced recently in the detector concept and has started performance studies.
- Local reconstruction available for most sub-detectors.
- Global reconstruction to come soon.

Progress towards overall engineering model:

- material budget
- sub-detector envelopes
- Complete design of machine detector interface (MDI)





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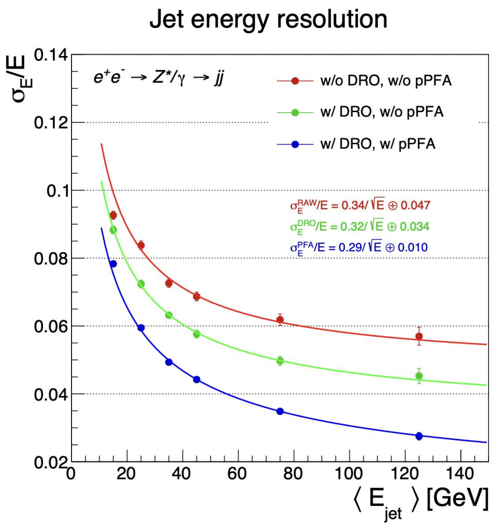
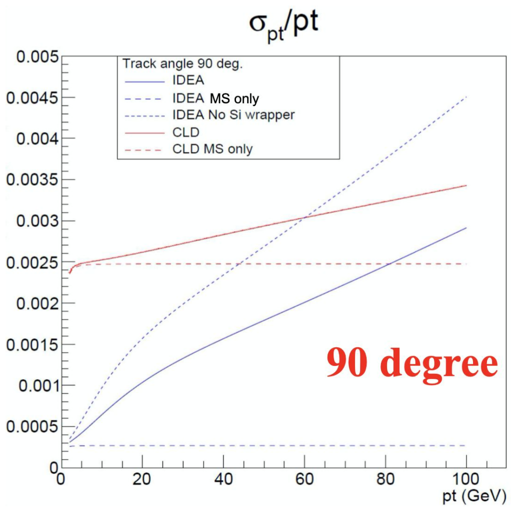
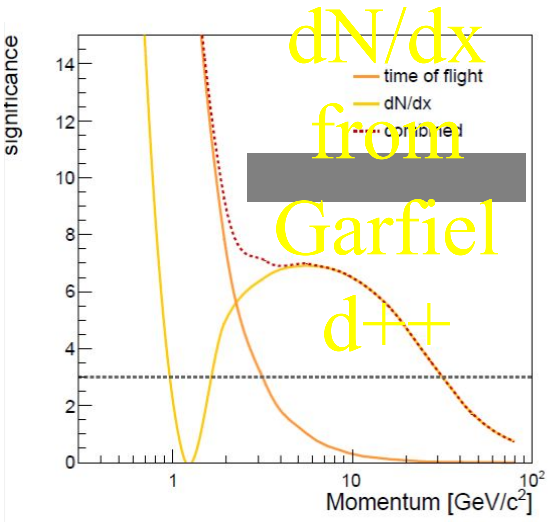
IDEA Detector Concept

Performance in simulations







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IDEA Detector Concept

Planned activities for the next 3-5 years

- Complete global reconstruction
- Study combined performances of crystal and fibre calorimeters
    - Optimise design of both accordingly
- Build complete MDI mockup
    - Use it to study possible mechanical issues
- Build full scale drift chamber prototype
- Test full size μRWELL 2D prototype
    - With x-ray gun and then beam
    - Define the best 2D option
- Define best crystals and filters for DR crystal ecal
    - Build 3x3 and then 9x9 matrix prototype

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ALLEGRO Detector Concept

Contact Persons:

- Martin Aleksa, martin.aleksa@cern.ch (presenting in person)
- Nicolas Morange, nicolas.morange@ijclab.in2p3.fr
- Marc-Andre Pleier, mpleier@bnl.gov

Collaborating Institutes & expertise/facilities:

- Vertex Detector & MDI Region: ETH Zurich (CH), Univ. of Zurich (CH), PSI (CH), BNL (US), INFN Pisa (I), INFN Frascati (I), IPHC (F), CPPM (F), LPNHE (F), APC (F), IP2I (F)
- Tracker: Univ. of Michigan (US), MPP Munich (D), BNL (US), UT Austin (US), IJCLab (F), EPFL (CH)
- Timing Layer: University of Zurich (CH), PSI (CH), BNL (US)
- Electromagnetic Calorimeter: CERN, APC (F), IJCLab (F), LAPP (F), CPPM (F), LPNHE (F), OMEGA (F), MPP Munich (D), TU Dresden (D), Charles Univ. (CZ), BNL (US), Brown Univ. (US), NYU (US), Columbia Univ. (US), SMU (US), Univ. of Arizona (US), UT Austin (US), Stony Brook (US), IFIN-HH and UPB (RO), Univ. of Kosice (SK)
- Hadronic Calorimeter: ITIM Cluj Napoca (RO), LIP (PT), IFIC Valencia (ES), Bergen (NO), FZU (CZ), Charles Uni (CZ), Tbilisi (GE), CERN
- Muon System: MPP Munich (D), Weizmann Institute (IL), Univ. of Napoli (I), Rome 1 (I), Rome 3 (I), Univ. of Michigan (US)
- Luminosity Calorimeter: University of Geneva (CH), University of Zurich (CH), Univ. of Copenhagen (DK)
- Read-Out and Trigger: CERN, Univ. of Geneva (CH), HEPIA (CH), Univ. of Zurich (CH), ZHAW (CH), MPP Munich (D)
- Software and Simulation: CERN, APC (F), IJCLab (F), LAPP (F), University of Texas (US), B.K.C College (IN)
- Detector concept optimization: all

Connections with DRDs:

- DRD6, WP2: Noble-Liquid Calorimetry
- DRD6, WP3: TileCal
- DRD1
- DRD3

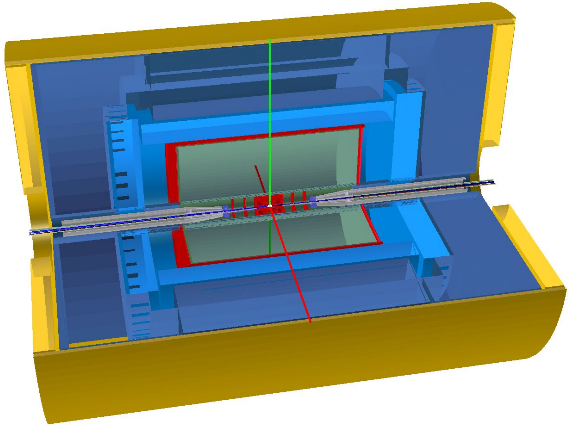
Connections with Sub-Detector EoIs:

- ID0019 Vertex Detector FCC Snail-shape vErtEx Detector (FCC-SEED)
- ID0027+0047+0069 Vertex detector design, integration
- ID0036 Vertex Detector
- ID0088 Interaction Region Elements and Integration
- ID0015 Main tracker and envelopes: A straw tracker
- ID0061 Cell geometry optimization for DC tracker
- ID0043 Gaseous trackers
- ID0085 Scintillating fibre tracker (SciFi)
- ID0080 Time of Flight and Tracking for FCC-ee with Monolithic CMOS sensors
- ID0096 R&D for large-area silicon timing layer
- ID0098+0099 Low-mass 4D tracking and TOF
- ID0023+0031+0064+0067 Noble Liquid Calorimeter
- ID0086 Tile Calorimeter
- ID0016+0078 Timing RPCs for muon system
- ID0084 Resistive Micromegas detectors for Muon systems at FCC-ee
- ID0069 Detector development and production, MPGDs or MWPC
- ID0037 A Muon System with Square Drift Tubes and Scintillator Strips
- ID0060 Scintillator + WLS fiber + SiPM for Muon Detector
- ID0104 Development of SNSPDs (quantum sensors) for FCC experiments, including possibility as luminometer
- ID0017 TDAQ
- ID0103 Wireless communications within the vertex detector

ALLEGRO Detector Concept

A Lepton-**L**epton collider **E**xperiment with **G**ranular **R**ead-**O**ut

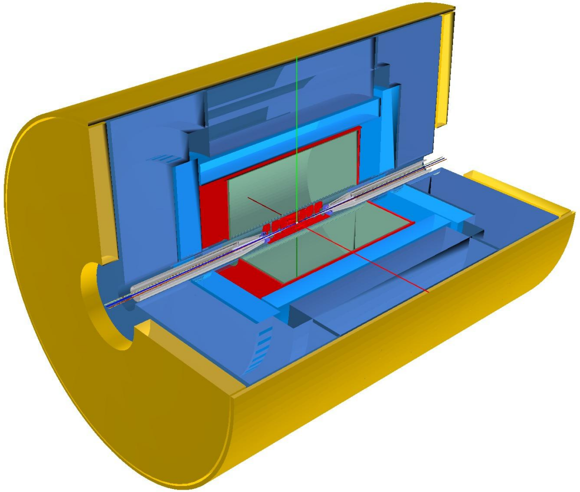
- FCC-ee detector concept centered around a high-granularity noble-liquid ECAL
- Tracking system with Si vtx detector surrounded by a gaseous, Si-based or scintillating fibre tracker
  - Vtx detector with MAPS or DMAPS + possibly an LGAD timing layer
  - Drift chamber and straw tube chamber considered as gaseous trackers
    - Gaseous tracker complemented with a silicon wrapper
- High-granularity sampling noble-liquid ECAL
  - LAr or LKr as active medium, Pb or W as absorber material
  - High granularity achieved using multi-layer PCBs as readout electrodes
- Thin 2 T solenoid surrounding ECAL, sharing ultra-light cryostat
- High-granularity HCAL based on steel and scintillator tiles
  - Acts as return yoke for the magnetic field
- Several options for muon system proposed
  - Drift tubes and scintillating strips, RPCs, MPGDs, Micromegas, Scintillators with wavelength shifting fibres …
  - Acts as a muon tagger - muon tracks from combination with tracking system
- Two LumiCals in the forward region for lumi measurement down to 10^-4

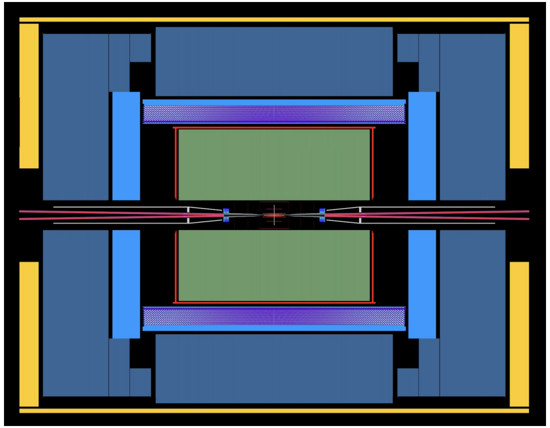


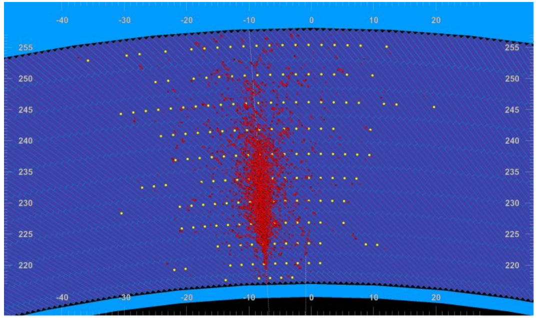
ALLEGRO Detector Concept

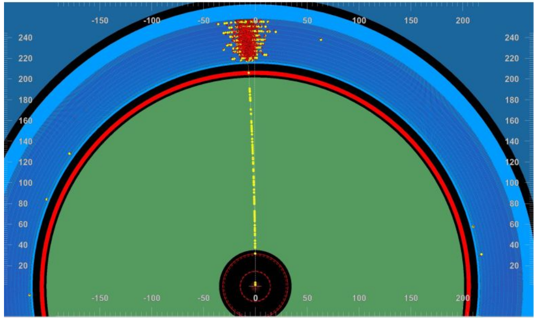
Progress towards simulation model with full simulation in all sub-systems:

- The ALLEGRO detector concept has been fully integrated into the FCC-SW (Key4hep framework). Full simulation of collision events can be performed in a very modular approach, once implemented into the software, different sub-detectors can be plugged-in and tested as part of the ALLEGRO concept, facilitating the comparison of the performance of different detector technologies.
- Simulations, currently mainly focussing on the calorimetry, are being done to evaluate physics performance. These simulations will be extended to other sub-detectors on the coming months.
- Particle flow reconstruction in development





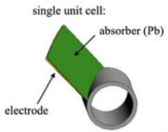


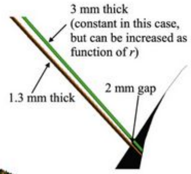


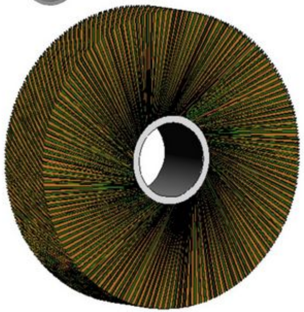
ALLEGRO Detector Concept

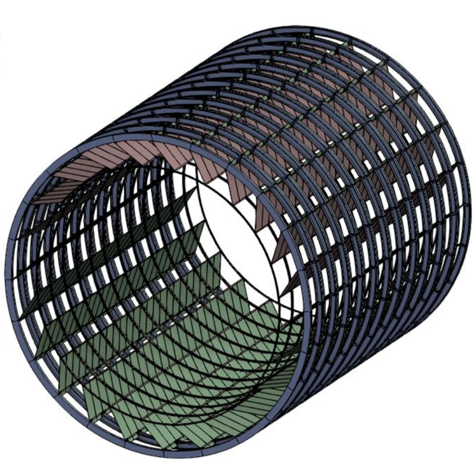
Progress towards overall engineering model:

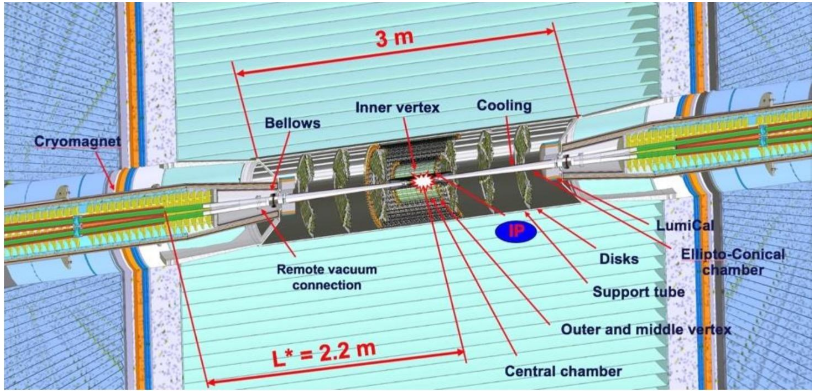
- Starting with engineering drawings of sub-detectors
- Vertex detector and MDI region design well advanced by F. Palla et al. (ID0027+0047+0069)
- First reasonable but approximate sub-detector envelopes are used, need to be better defined in the coming years
- Implementation into FCC-SW (see previous slide), extraction of preliminary material budget possible, but real material needs to be better defined.
- FCC-SW simulation allows us to work on the optimisation of global detector parameters and structures (more work to be done in the coming years)

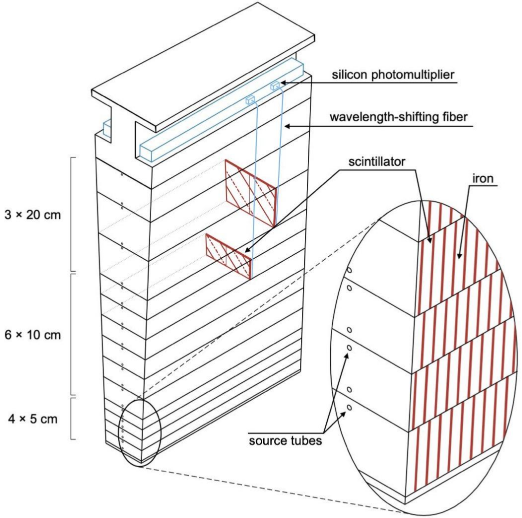


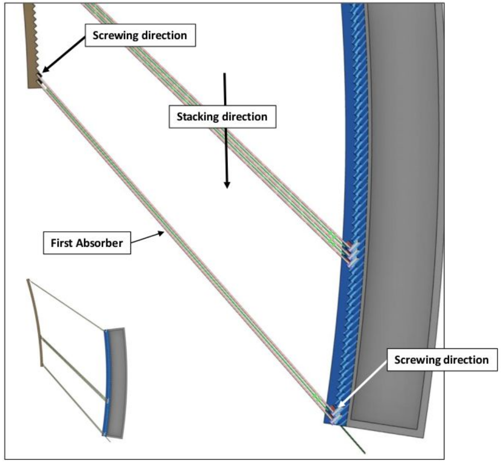








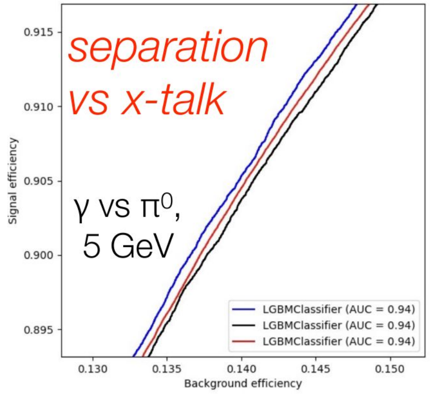




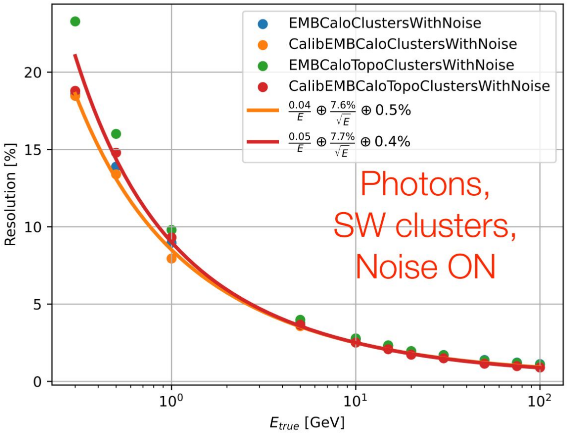
ALLEGRO Detector Concept

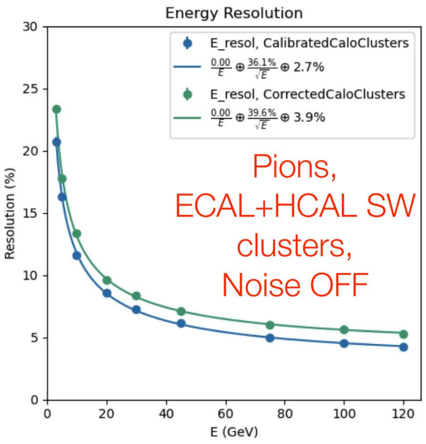
Performance in simulations

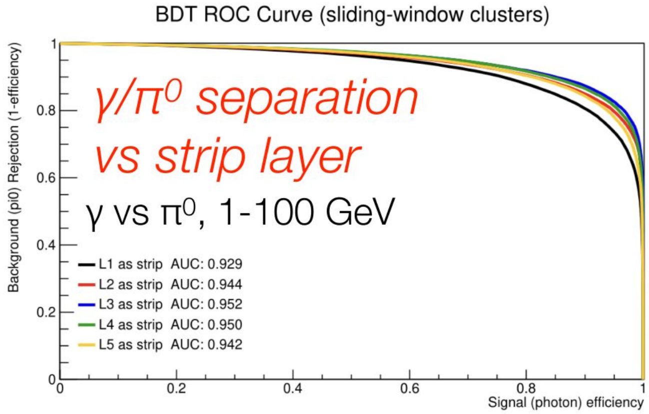
- ECAL EM resolution in the 7-8%/√E region for LAr+Pb option
  - Down to below 5%/√E with LKr as active medium
- Combined ECAL+HCAL $\pi\pm$ resolution 36-40%/√E
- Photon/π0 separation an important benchmark
  - Study the impact of x-talk
  - Optimize trip layer placement



- Blue: No cross-talk in training or test.
- Black: Cross-talk in both training and test.
- Red: No cross-talk in training but cross-talk in test.



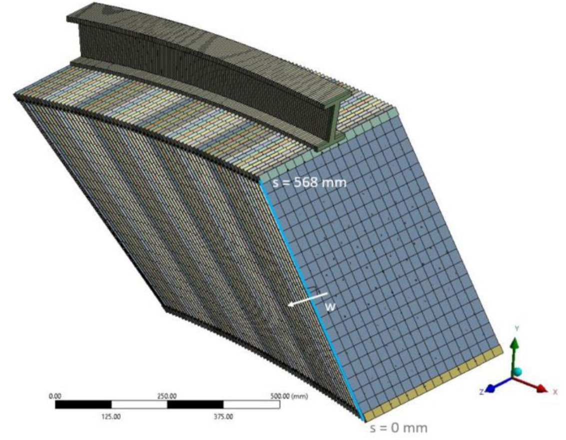


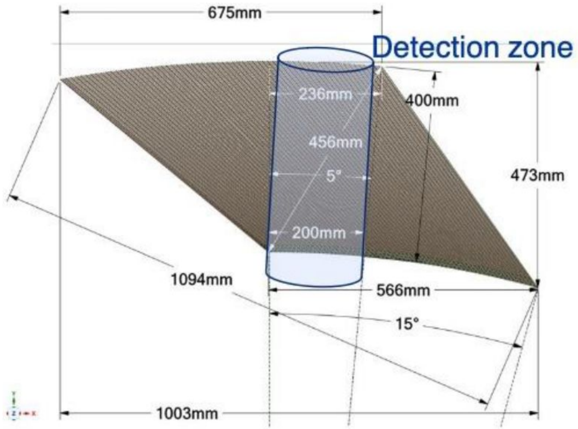


ALLEGRO Detector Concept

Planned activities for the next 3-5 years

- During a first ALLEGRO Group Meeting in Nov. 2024, many groups expressed interest to work on sub-detectors for the ALLEGRO detector concept for FCC-ee.
- It is evident that for the moment many different ideas exist for all sub detectors, some of them clearly conflicting. In the coming years we should further develop our ideas of detectors keeping the physics requirements in mind, build prototype detectors and measure their performance in testbeams.
- We have to implement all sub-detectors into the FCC-SW with realistic performance.
- We are planning for a down-selection to baseline options and the formation of a proto-collaboration once a decision on FCC-ee has been taken and the TDR-phase starts.





ILD: International Large Detector

Mary-Cruz Fouz, online presentation

Contact Persons:

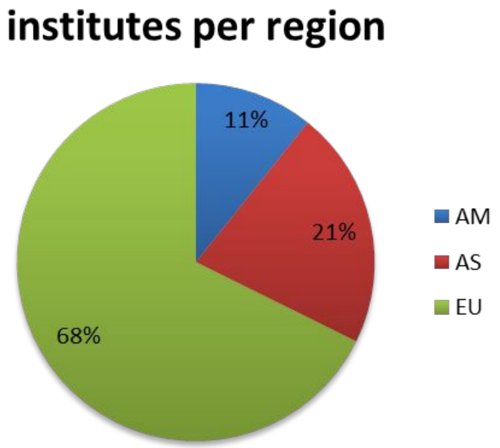
- Ties Behnke, DESY, Ties.Behnke@desy.de
- Kiyotomo Kawagoe, Kyushu Univ, Japan, kawagoe@phys.kyushu-u.ac.jp
- Daniel Jeans, KEK Japan, daniel.jeans@kek.jp

Collaborating Institutes & expertise/facilities:

- In total 58 Institutes from 20 countries

Connections with DRDs:

- DRD 1, TPC research (also LCTPC collaboration)
- DRD 3, Pixel Detector, Octopus project
- DRD 5, Calorimeter (in particular in respect to CALICE calorimeter technology)



References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

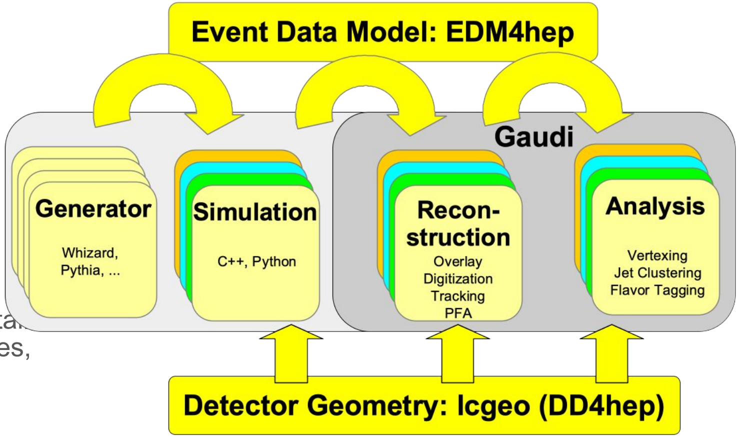
ILD: Simulation and Software

Progress towards simulation model with full simulation in all sub-systems:

- ILD has a fully developed model of the detector in full simulation
- ILD has performed a comprehensive study of Higgs factory analyses in full simulation. Th emajority of studies have been done for the ILC collider. Studies to adapt ILD to the different environment in particular in the innermost region are ongoing.

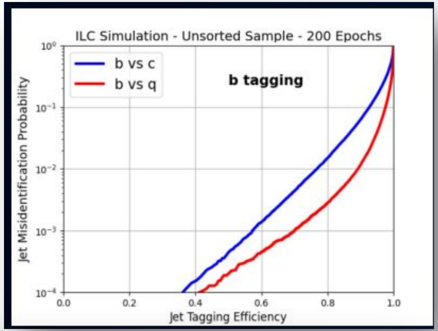
Progress towards overall engineering model:

- A detailed model of ILD exists
- Detailed models of the subdetectors are part of the ILD simulation.
  Based on the key4hep software stack, changing sub-detectors to explore different technologies is relatively easy. For some key systems (for example, calorimeter), several different options exist
- The dimensions, including envelopes for the different subdetectors, are defined and implemented in the ILD simulation.
- All key sub-detector technologies used in the ILD baseline have been validated against prototypes and test beam measurements.
- A complete integration model of ILD has been developed.
- Engineering models exist for some of the key subdetectors, at different level of deta
- Since most of the key subdetectors for ILD have been benchmarked with prototypes, zeroth order engineering models for key system exist, and have been tested.

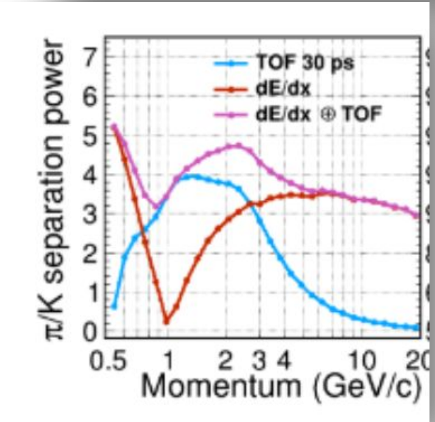


Subdetector Technologies and Performance

Flavour tagging and PID

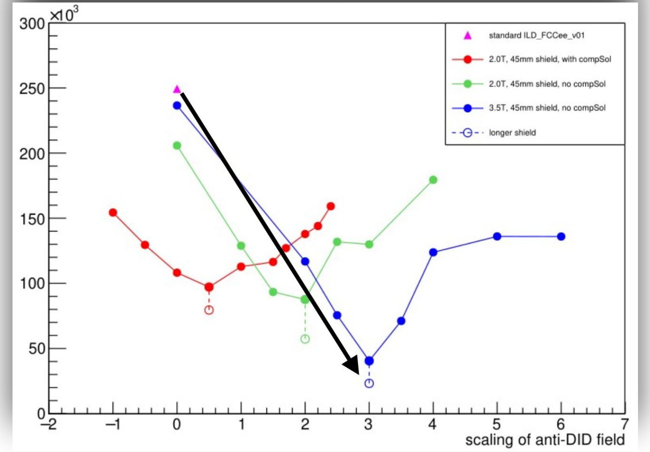


Bottom tagging with a DNN based algorithm



PID performance by dE/dx and by timing in the ILD detector

TPC at FCC-ee



TPC background and dependence of background on anti-DID field

A TPC as central tracker offer additional capabilities
Studies up to now indicate that a TPC at FCC-ee is a feasible option

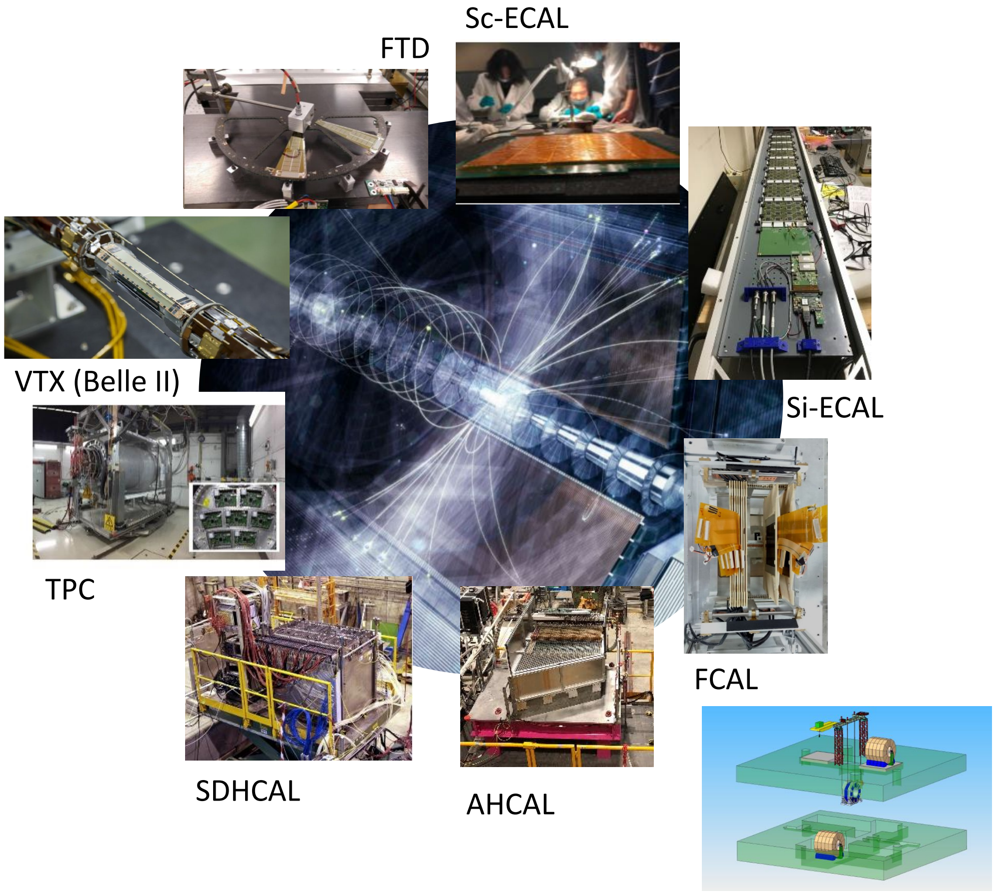
ILD Subdetectors

ILD has a concept of the detector,
well defined
with technological options where sensible

The main components of ILD have been validated and beam-tested.

A coherent System design has been developed.

A complete and detailed Geant4 model of ILD exists and is used

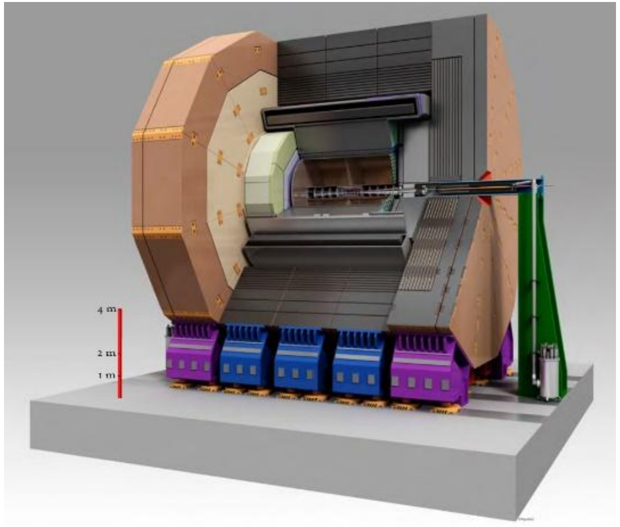


Plans of the ILD concept group

Planned activities for the next 3-5 years

- Study for the usage of a TPC in a high rate environment
- Testbeam experiment fr using a highly pixelated TPC endcap readout (Pixel TPC)
- Cooling studies for an ECAL detector adapted to continuous running as needed at the FCC-ee
- Studies of the geometry of the forward tracking detector to adapt to FCC-ee coditions
- Overall re-optimization of the detector layout to minimize the impact of the beamline-elements by FCC-ee within the detector volume.
- Calibration study to understand the requirements to calibrate ILD under realistic conditions.
- A broad program of physics studies to make the case for FCC-ee and to study the feedback from the science studies on the detector design.
- Prepare a concise document of ILD at FCC-ee

The ILD detector



Outlook

- The ILD detector concept has been adapted to the FCC-ee conditions
- The performance of the concept has been verified under FCC-ee conditions
- The combination of a particle-flow optimized calorimeter with the special capabilities of a TPC offer a powerful package
- ILD with the large code-base for simulation and reconstruction is a powerful platform for detector and science study at the FCC-ee
- ILD as an organization is looking forward to further develop the participation in FCC-ee

Vertex Detector

ID0019 (Vertex Detector) **FCC Snail-shape vErtEx Detector (FCC-SEED): Project for a Vertex Detector for FCCee**

Contact Persons:

- Auguste BESSON, IPHC-Strasbourg, auguste.besson@iphc.cnrs.fr
- Marlon BARBERO, CPPM-Marseille, barbero@cppm.in2p3.fr
- Marco Bomben, APC-Paris, marco.bomben@apc.in2p3.fr
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- Additional editors: Jérôme Baudot, Ziad El Bitar,, Didier Contardo,, Fares Djama, Elisabeth Petit, Serhy Senyukov
- and Corresponding author : Jeremy Andrea jeremy.andrea@iphc.cnrs.fr

Collaborating Institutes & expertise/facilities:

- IPHC-Strasbourg
  - Expertises: CMOS pixel sensor design, tests and characterization, microtechnics & bent sensors, facility : CYRCE 25 MeV proton irradiation line
- CPPM-Marseille
  - Expertises: CMOS pixel sensor design, tests and characterization, integration
- APC-Paris
  - Expertises: simulations, ADC
- LPNHE-Paris
  - Expertises: Pixelated detectors, integration
- IP2I-Lyon
  - Expertises: simulations and sensor design

Connections with DRDs:

- DRD3, WP1: CMOS sensors: link to OCTOPUS project
- DRD7
- DRD8: bent sensors

Connections with Concept Groups:

- Connexions with CLD and ALLEGRO.

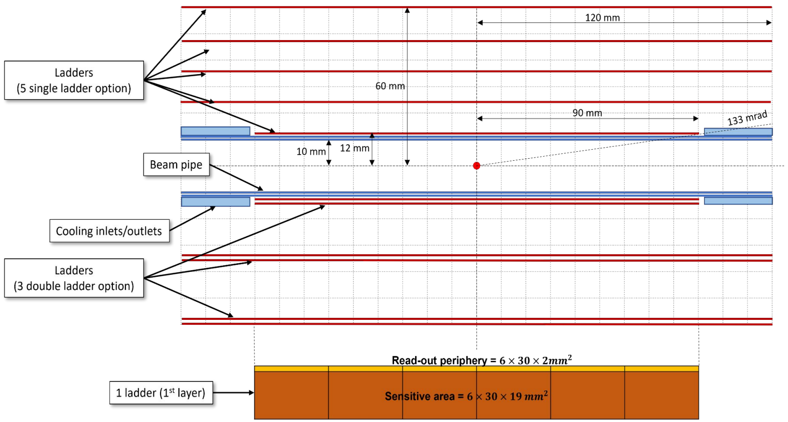
Speaker availability after 10h30 or in the afternoon
Preference for the afternoon

References: [1]: current draft of EOI

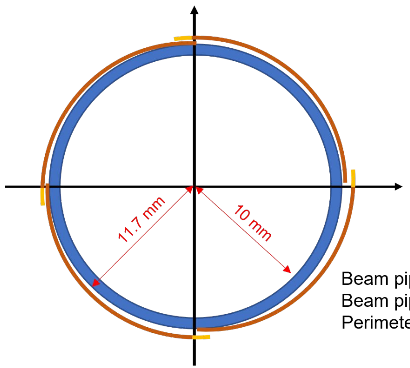
ID0019 (Vertex Detector) **FCC Snail-shape vErtEx Detector (FCC-SEED): Project for a Vertex Detector for FCCee**

Planned activities for the next 3-5 years

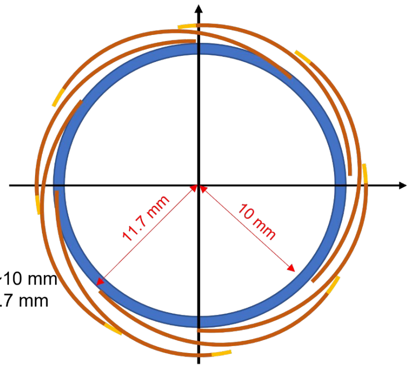
- Task1: **CMOS MAPS Chip Design for FCCee**
- Task 2: **Curved Sensors, mechanics, integration and cooling**
- Task 3: **Detector testing**
- Task 4: **Signal Digitization and Simulation**



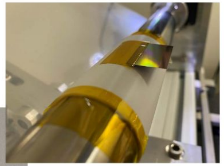
Option 1 : single layers

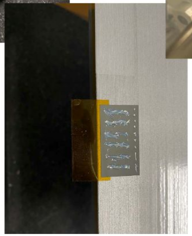


Option 2 : double layers



Beam pipe inner radius ~10 mm
Beam pipe thickness ~ 1.7 mm
Perimeter ~73.5 mm

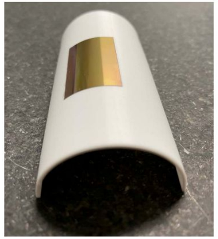




Mimosis2.1 , dimension 31x17mm épaisseur 50µm,

Collé avec Araldite sur demi-coquille

Pas de casse du silicium.



<ID 0027+0047+0069> <Vertex detector design, integration and simulation>

Contact Persons:

- Fabrizio Palla, Fabrizio.Palla@cern.ch
- Caterina Vernieri, caterina@slac.stanford.edu
- Attilio Andreazza. Attilio.Andreazza@cern.ch
- Carl Haber,chhaber@lbl.gov
- Artur Apresyan,apresyan@fnal.gov
- Nicola Bacchetta, bacchetta@fnal.gov

Presenter : Fabrizio Palla (in-person)

Collaborating Institutes & expertise/facilities:

- INFN Pisa, Perugia, Milano, Padova, Torino, Trieste, Frascati, Bari, Genova
- SLAC
- MIT
- Brown University
- LBNL
- FNAL
- ANL

Connections with DRDs:

- DRD3 WP1
- DRD7, WP7.1, 7.6
- DRD8 WP1.1

Connections with Concept Groups:

Joint EoI with 0019 and 0036 and being considered

- ALLEGRO, IDEA

References: [1]:M. Boscolo et al, EPJ Tech. Instrum 10, 16 (2023); [2]: L. Pancheri et al. JINST14, C06016 (2019); [3]: A. Ilg and F. Palla,Pos (ICHEP2024) 1062

<ID 0027+0047+0069> <Vertex detector design, integration and simulation>

Planned activities for the next 3-5 years

- Task 1: Simulation studies, including machine backgrounds and benchmark physics channels
- Task 2: Mechanical design and fabrication of vertex detector structures including bending detectors
- Task 3: Experimental validation of cooling possibilities, including air-cooling
- Task 4: Investigation of serial powering solutions for biasing the detectors
- Task 5: Realization of beam pipes and mock up of the interaction region
- Task 6: Studies of integration of power over fibre biasing and wireless data communication
- Task 7: Task on technology (LFoundry and TPSCo65nm) under discussion

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

Presenter: Armin Ilg (UZH, in-person)

ID 0036: MAPS R&D, vertex detector design and engineering towards ultra-light FCC-ee vertex detectors

Universität Zürich[UZH]

ETH zürich

PSI

Collaborating Institutes & expertise/facilities:

Strong expertise from phase-0, phase-1, phase-2 pixel detectors for CMS
- Sensors, readout ASICs, modules, HDIs, services, cooling, mechanics, commissioning, installation, …

University of Zurich (UZH)
- MAPS characterisation
- Full simulation of FCC-ee vertex detectors, flavour tagging at FCC-ee, flavour physics studies
- TCT, X-ray tube, wafer probing, etc.

Paul Scherrer Institute (PSI)
- ASIC, planar sensors and MAPS design and characterization
- Module design and pixel detector system design (including mechanics)
- Extensive lab infrastructure (wire-bonding, bump-bonding, module assembly, probe stations, x-ray, etc)

ETH Zurich (ETHZ)
- CMOS sensor design and module design
- MAPS characterisation
- ASIC and MAPS design

Connections with DRDs:

- DRD3: WP1/WG1: OCTOPUS MAPS R&D
- DRD3/DRD7: 28 nm CMOS implementation and general development of ASIC design
- DRD8: Ultra-light mechanics

Connections with Concept Groups:

- Simulation studies of baseline and ultra-light vertex design in IDEA/ALLEGRO
- Institutes involved with timing layer development: LGADs and MAPS (ID0096), and Silicon Wrapper full simulation implementation

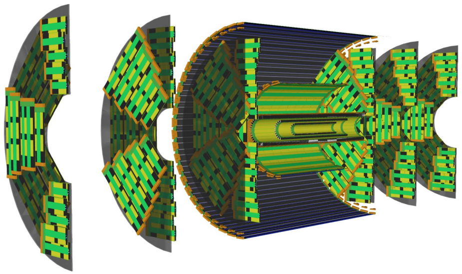
Contact Persons:

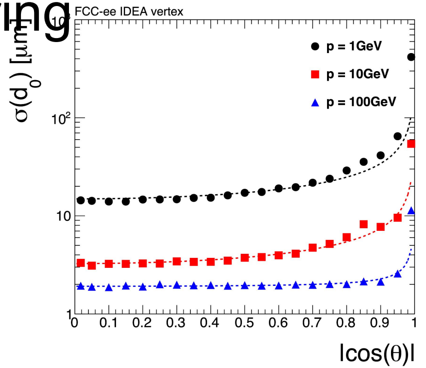
- Florencia Canelli, canelli@physik.uzh.ch
- Lea Caminada, lea.caminada@psi.ch
- Malte Backhaus, bmalte@phys.ethz.ch

ID 0036: MAPS R&D, vertex detector design and engineering towards ultra-light FCC-ee vertex detectors

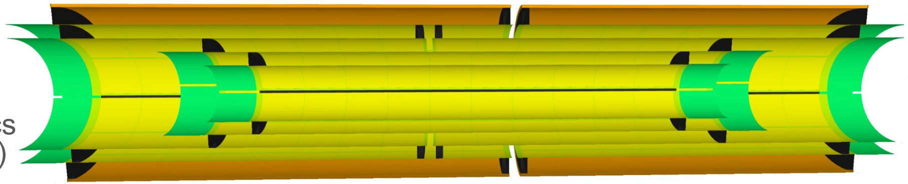
Planned activities for the next 3-5 years

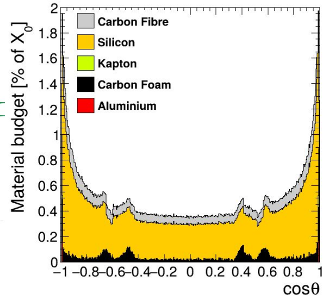
- Ultra-light vertex detector design:
  - Mechanics and cooling, engineering studies
  - Support and cooling prototypes
  - Conceptual design of advanced vertex detector options
    - Adding timing layer
    - Going inside beam pipe
- Physics performance
  - Evaluation of different detector layouts
    - Also of advanced vertex detector options
    - And given developments on wireless data transfer (ID0103)
  - Opportunities for FCC-ee physics Programme (e.g flavour physics)
- MAPS R&D in OCTOPUS [2]:
  - ASIC design
  - Lab and test beam characterization
  - Simulation (in connection to physics performance above)





Baseline IDEA/ALLEGRO vertex detector full simulation implementation and performance PoS(ICHEP2024)1062





With INFN Pisa: Leading conceptual design of ultra-light inner vertex detector

Joint EoI with 0027+0047+0069 being considered

References:
[1]: A. Ilg, F. Palla; Design, performance and future prospects of vertex detectors at the FCC-ee, PoS(ICHEP2024)1062
[2]: Fine-pitch CMOS pixel sensors with precision timing for vertex detectors at future Lepton-Collider experiments and beyond, CERN-DRD3-PROJECT-2024-004

Main Tracker and Envelopes

ID0015: Main tracker and envelops: A straw tracker

Contact Persons:

- Oliver Kortner, kortner@mpp.mpg.de (Presenter in person), Sandra Kortner sandra@mpp.mpg.de
- Junjie Zhu, junjie@umich.edu, Jianming Qiang, qianj@umich.edu, Bing Zhou, bzhou@umich.edu, Christian Herwig, herwig@umich.edu, Tom Schwarz, schwarzt@umich.edu

Collaborating Institutes & expertise/facilities:

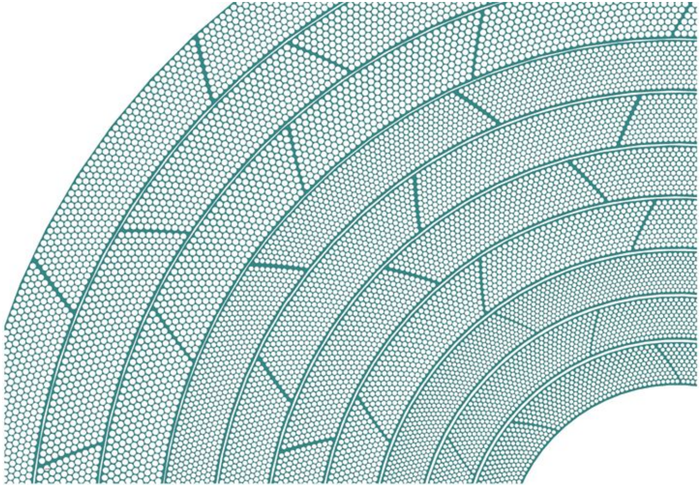
- Max-Planck-Institute for Physics, Munich
  - ATLAS (s)MDT and RPC chamber design, construction, commissioning, and operation..
  - Experience in system integratio and design.
  - Design. production, and commissioning of on- and off-chamber read-out electronics (ASIC and FPGA design)
  - Large cleanroom with granite tables and a cobot.
- University of Michigan
  - ATLAS (s)MDT chamber design, construction, commissioning, integration, and operation
  - ASIC and FPGA design for ATLAS NSW and (s)MDT detectors
  - Clean room, granite table, mechanical and electronics shop, ASIC design software and license, tier-2 and tier-3 computing clusters
- Duke, UT Austin, Tufts, UMass Amherst, Harvard, MSU, UCI, SLAC

Connections with DRDs:

- DRD1, WP3: Project A “Straw and drift tube development for future collider experiments” with Kortner and Zhu as the coordinators

Connections with Concept Groups:

- Allegro detector, also applicable to other detector concepts

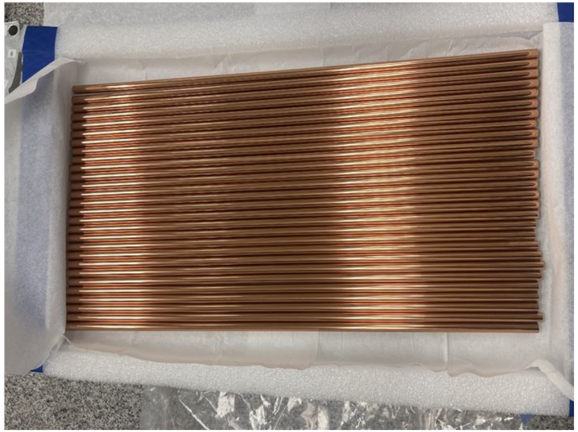


An example layout:
Coverage: r between 0.3-1.8 m and a length of 4-5 m
10 superlayers (each 10 layers)
Diameters 1.0 - 1.5 cm
Single hit resolution: ~120 μm
O(50k) straws with a wall thickness of 12 um
Stereo angle: 2-5 degrees

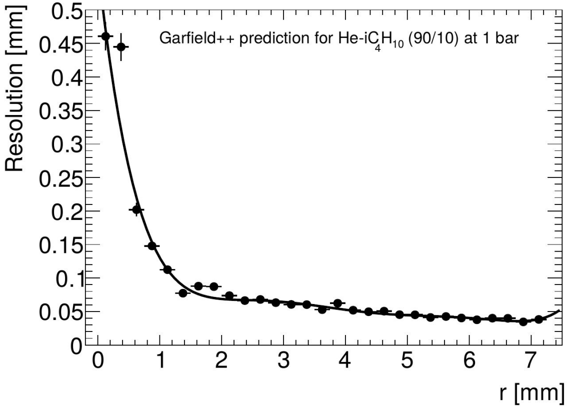
References: Overleaf document: https://www.overleaf.com/project/675ab6c0cda745e0948e870f

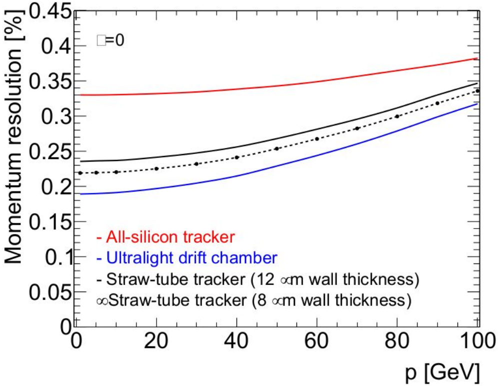
A straw tracker

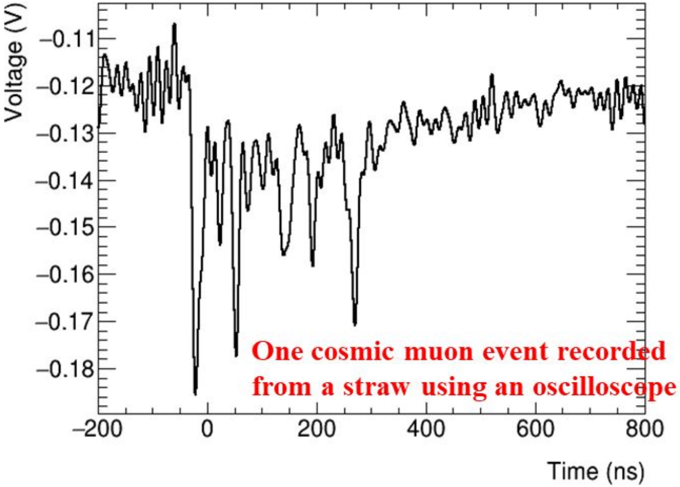
- Planned activities:
  - Detector layout and optimization
  - Track reconstruction and resolution studies
  - Build prototypes with O(100) straws and study performances
  - Electronics development and dE/dX (dN/dX) studies
  - Gas studies
  - Cosmic ray and test beam studies
  - …



28 0.5-meter straws







References: Overleaf document: https://www.overleaf.com/project/675ab6c0cda745e0948e870f

Presenter : George Iakovidis
In person

ID0061 Cell geometry optimization for DC tracker

Contact Persons:

- Charles Young (SLAC), young@slac.stanford.edu

Collaborating Institutions:

- George Iakovidis (BNL), giakovidis@bnl.gov with more focus on microscopic physics (see ID0043)

Connections with DRDs:

- DRDT1.1 and 1.2, WP2,3,4,5
- DRD7

Connections with Concept Groups:

- Any concept using drift chamber as the main tracker
- See presentation in Workshop at Michigan Workshop (https://indico.cern.ch/event/1408681/contributions/6144649/attachments/2948137/5181491/Drift%20Chamber%20Cell%20Geometry.pdf) for comparison of "cylindrical" cell *a la* straw tube and "jet" cell with linear drift as in LEP/SLD experiments
  - Cylindrical cells are effectively single-hit devices and therefore not optimal for high-density environment at small radius
  - Jet cells have achieved double-track separation of ~1 mm, significantly reducing lost hits at small radius for cylindrical cell geometry
  - Using tube rather than wires to define cell geometry likely to result in significantly more material

Presenter : George Iakovidis
In person

ID0043 - Gaseous trackers

Contact Persons:

- George Iakovidis (BNL), giakovidis@bnl.gov (USHFCC L3 co-coordinator for gaseous trackers)

Collaborating Institutes:

- Charles Young (SLAC), young@slac.stanford.edu
- Nicola De Filippis (INFN Bari and Politecnico di Bari), nicola.defilippis@ba.infn.it (DRD1 WP2 Coordinator)
- Junjie Zhu, (University of Michigan) junjie@umich.edu (USHFCC L3 co-coordinator for gaseous trackers)

Connections with DRDs:

- DRD1
  - WP1, WP2, WP3,
  - WG4, WG5, WG8

Connections with Concept Groups:

- IDEA, ALLEGRO

Planned activities (subject to funding)

- Develop microscopic simulation, signal formation, geometry (in collaboration with other groups)
- Develop tracking algorithms
- Parametrization of microscopic simulation in analysis framework (fullsim)
- Study detector performance impacts in Physics analysis (Higgs coupling)
- Study the feasibility of cluster counting, comparison of simulation and Test beam in collaboration with other groups
- Define electronics requirements for cluster counting
- Investigate participation in construction

ID0101 Development of an ultra-light drift chamber operating in helium atmosphere with PId capabilities based on cluster counting technique for the IDEA detector

Contact Persons:

- Margherita Primavera (INFN Lecce), margherita.primavera@le.infn.it
- Nicola De Filippis (INFN Bari and Politecnico di Bari), nicola.defilippis@ba.infn.it
- Edoardo Gorini (INFN Lecce and University of Salento), edoardo.gorini@le.infn.it

Collaborating Institutions:

- INFN Lecce, INFN Bari, BNL (US), IJCLAB (France)

Connections with DRDs:

- DRD1 -WP2

Connections with Concept Groups:

- Any concept using drift chamber as the main tracker

ID0080 Time of Flight and Tracking for FCC-ee with Monolithic CMOS sensors

Contact Persons:

- Roy Aleksan, roy.aleksan@cea.frl
- Gaëlle Boudoul, boudoul@ip2i.in2p3.fr
- Didier Contardo, contardo@ip2i.in2p3.fr
- Philippe Schwemling, philippe.schwemling@cea.fr

Presenter : Philippe Schwemling
Remote

Collaborating Institutes & expertise/facilities:

- CEA-Irfu
  - Sensor and analog front-end design and test
- CNRS-IP2I, Lyon
  - Sensor readout architecture, mechanical design, simulations

Connections with DRDs:

- DRD3, WP1 projects :
  - Towards large electrode CMOS sensors with intrinsic amplification for ultimate timing performance
  - TPSCo 65nm MCMOS with high precision timing (also DRD7.6 for development of TDC IP blocks)

Connections with Concept Groups:

- Participation to Si-tracker simulations in full Si concept and for wrapping layers around a large gas volume detector
- Development of a generic digitizer for full simulations, application to estimate of realistic clusters and inputs on rates (for readout architecture design, evaluation of precise timing layers impact on performance)

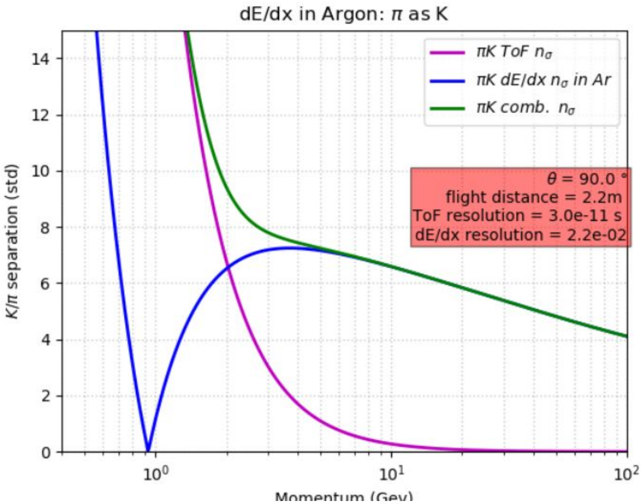
References: [1]: MiniCACTUS: A 65 ps Time Resolution Depleted Monolithic CMOS Sensor (arXiv:2309.08439, NSS 2022 conference

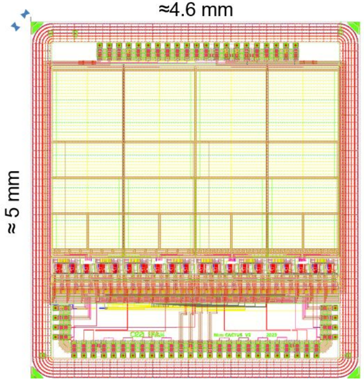
[2]:; MiniCACTUS: Sub-100 ps timing with depleted MAPS, Nucl.Instrum.Meth.A 1039 (2022) 167022, VCI 2022 conference

[3]: Our EoI in overleaf :Towards Time of Flight MCMOS tracking layers for a detector at FCC-ee https://fr.overleaf.com/read/bbttzydrmkct#4980df

Time of Flight and Tracking for FCC-ee with Monolithic CMOS sensors

- Propose a TOF detector (30 ps) combined with track position precision to minimize number of layers (independent, or possibly as a calorimeter preshower at large radius)
- Will complete the PID of Large Gas Volume Detector at low momentum
- Possibly allowing enhanced coverage at higher magnetic field and at small radius
  - Precision studies of hadronic Higgs decays
  - Flavour physics
  - Measurement of Heavy Neutral Lepton masses
- Existing demonstrator : MiniCactus V2 (Irfu, IFAE), Lfoundry LF15A process
- Best performance up to now : 60 ps (175 u thick, 500 x 500 u pixel)@350V
- Plan for the next 3-5 years
  - Pursue this development (LFoundry), also implementing intrinsic gain layer → improve resolution to 20-30 ps
  - Plan to investigate TPSCo 65 nm technology
  - Involvement in physics simulation for detector optimization





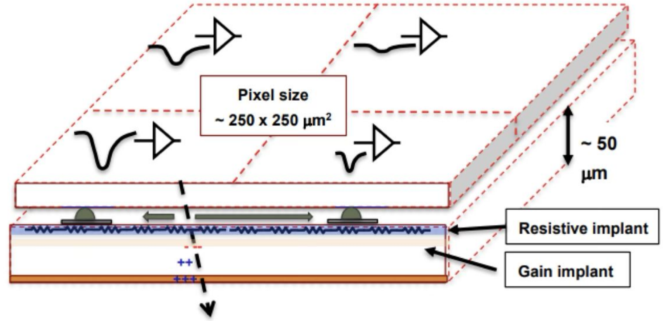
ID0094 Outer tracking and timing layer with LGAD-RSD sensors

Contact Persons:

- Enrico Robutti, enrico.robutti@ge.infn.it
- Francesco Moscatelli, moscatelli@iom.cnr.it
- Roberta Arcidiacono, roberta.arcidiacono@cern.ch

Collaborating Institutes & expertise/facilities:

- INFN & Università Genova
  - Detector simulations, sensor test
- INFN Torino & Università del Piemonte Orientale
  - Sensor simulation and design, sensor test
- INFN & Università Perugia
  - Sensor simulation and design, sensor test



Presenter: Enrico Robutti (remote)

Connections with DRDs:

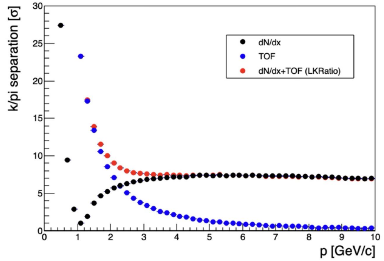
- DRD3, WG2 (Hybrid Technologies), WG4 (Simulation), WG5 (Characterisation Techniques, Facilities), WG7 (Interconnection Technologies)
- DRD3, WP2 (Sensors for 4D Tracking)

References: [1]: R. Arcidiacono et al., NIM A 1057 (2023) https://doi.org/10.1016/j.nima.2

ID0094 Outer tracking and timing layer with LGAD-RSD sensors

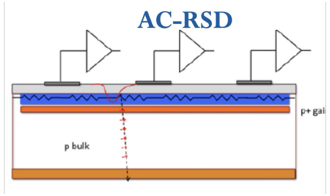
Tracking wrapper outside main tracking volume needed in several detector concepts

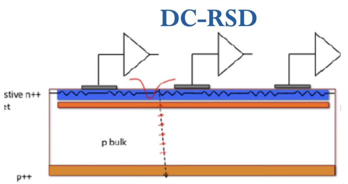
- Very large (silicon) surface, ~100 m^2
- High position resolution
- Timing capabilities ⟹ TOF ⟹ extension of PID range



Resistive Silicon Detector (RSD) technology provides high position resolution via charge sharing of signal among different large collection pads

- $\sigma_x \approx$ 3-5% a (readout pitch)
- Excellent timing resolution (~30 ps)





The EoI intends to investigate specific detector configurations suitable for use on a large area - low rate tracking and timing layer:

- cell and pad geometry;
- position and time reconstruction;
- AC-RSD vs. DC-RSD;
- cost-effective interconnection technologies

References: [2]: L. Menzio et al.,, NIMA 1065 (2024), 169526

Presenter : Lea Caminada (remote)

ID0096 R&D for large-area silicon timing layer

Universität Zürich[UZH]

PSI

Collaborating Institutes & expertise/facilities:

Strong expertise from phase-0, phase-1, phase-2 pixel detectors for CMS

- Sensors, readout ASICs, modules, HDIs, services, cooling, mechanics, commissioning, installation, …

University of Zurich (UZH)

- LGAD sensor design and characterization
- Simulation of pixelated timing layers for potential CMS TEPX upgrade beyond Phase-2
- TCT, X-ray tube, wafer probing, etc.

Paul Scherrer Institute (PSI)

- ASIC design and MAPS design and characterization
- Module design and pixel detector system design (including mechanics)
- Vertex reconstruction and performance (simulations including timing information)
- Extensive lab infrastructure (wire-bonding, bump-bonding, module assembly, probe stations, x-ray, etc)

Connections with DRDs:

- DRD3: WP1/WG1: Development of DMAPS detectors with timing information
- DRD3: WP2/WG2: R&D on LGAD sensors
- DRD3/DRD7: 28 nm CMOS implementation and general development of ASIC design
- DRD8: Ultra-light mechanics

Connections with Concept Groups:

- Simulation of the timing layer for the IDEA detector, similar implementation could be carried out with ALLEGRO

Contact Persons:

- Lea Caminada, lea.caminada@psi.ch
- Ben Kilminster, ben.kilminster@physik.uzh.ch
- Anna Macchiolo, Anna.Macchiolo@cern.ch

ID0096 R&D for large-area silicon timing layer

Planned activities for the next 3-5 years

- Large-area timing detectors are being developed as part of the ongoing experiment upgrades for HL-LHC
- R&D towards higher segmentation (timing resolutions <50ps achieved on sensor side, main challenge is ASIC development to match timing performance and enable integrated systems)

- Simulation:
  - Develop requirements for a timing layer in terms of material budget, power consumption, segmentation, spatial and timing resolution
- Characterization of LGAD prototypes [1]
  - Determine optimal sensor geometry and processes
  - Demonstrate timing performance (~30ps), efficiency and noise levels
  - Demonstrate feasibility of producing LGAD over $100m^2$ area
- Development of timing ASIC:
  - ASIC design in 28nm CMOS technology
  - Ultra-low power ASICs, PLLs and TDC designs [2, 3]
- Evaluation of DMAPS for timing applications:
  - Investigate performance, power dissipation and scalability [4]

References: [1]: M. Senger et al., A Comprehensive Characterization of the TI-LGAD Technology, https://doi.org/10.3390/s23136225
[2] M. Senger et al., Development of a timing chip prototype in 110 nm CMOS technology https://doi.org/10.1088/1742-6596/2374/1/012081
[3] A. Ghimouz, R&D of a timing measurement ASIC for possible HL-LHC upgrade, PISA meeting 2024.
[4] A. Ebrahimi et al., MoTiC: Prototype of a Depleted Monolithic Pixel Detector with Timing, https://doi.org/10.22323/1.448.0044

ID0098,0099 Low-mass 4D tracking and TOF

Contact Persons:

- Alessandro Tricoli, alessandro.tricoli@cern.ch

Presenter : Marc-Andre Pleier (in-person)

Collaborating Institutes & expertise/facilities:

- FNAL
  - Sensors, asics, test-beams, irradiation
- KEK
  - Sensors, test-beams, irradiation
- BNL
  - Sensors, asics, test-beams

Connections with DRDs:

- DRD3, WP1, WP2: …
- DRD6

Connections with Concept Groups:

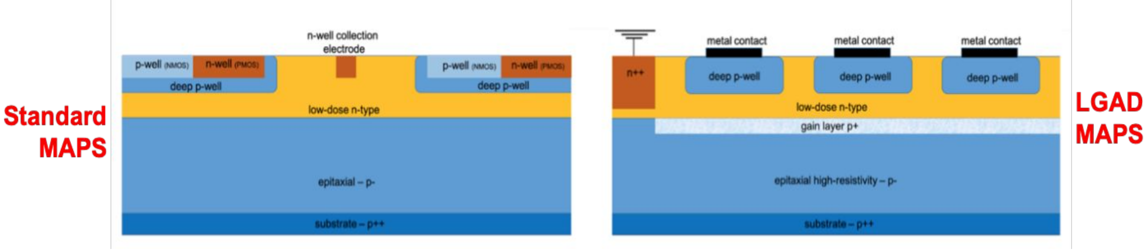
- Engineering/Simulation studies with concept ALLEGRO for Silicon Wrapper, Vertex

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

ID0098,0099 Low-mass 4D tracking and TOF

Planned activities for the next 3-5 years

- R&D for Low-mass 4D tracking and TOF using LGADs and MAPS technologies for different subsystems (Silicon Wrapper, Vertex etc.)
- Sensor R&D for LGAD-based technology, e.g. thin AC-LGADs, and its Readout (leveraging experience on HL-LHC and EIC ASICs)
- MAPS, e.g. ITS3 evolution (leveraging work on EIC)
- Monolithic AC-LGAD
- Mechanical and Integration solutions of those systems



References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

ID0053: **Fast timing layers at FCC-ee**

Presenter : Ariel Schwartzman (remote)

Contact Persons:

- **SLAC**: Ariel Schwartzman (SLAC) sch@slac.stanford.edu, Bojan Markovic, Christopher Kenney, Julie Segal, Su Dong, Rainer Bartoldus
- **CERN**: Valentina Cairo valentina.maria.cairo@cern.ch
- **Brandeis**: Aram Apyan arapyan@brandeis.edu

Collaborating Institutes & expertise/facilities:

- Development of electronics for fast timing layers and 4D tracking in 28nm node, Sub-10ps TDC, Constant fraction discriminator (CFD), ADC.
- LGAD sensors, 3D integration (SLAC-FERMILAB-LLNL)
- ToF and vertex t_0 reconstruction algorithms. Physics case and detector optimization

Connections with DRDs:

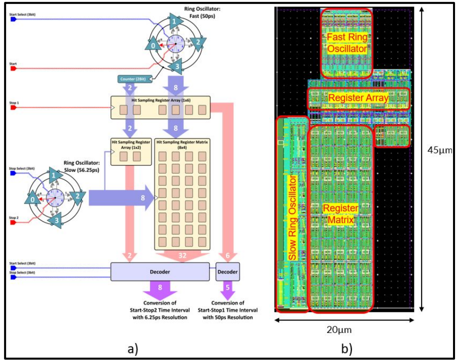
- DRD3 (Hybrid Silicon Technologies)
- DRD7.3 (4D and 5D techniques)

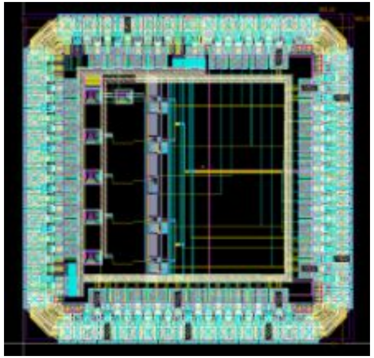
Connections with Concept Groups:

- All concepts
- Interested in investigating the interplay between timing layers in the tracker and the calorimeter. How to best utilize fast-timing information at FCC-ee.

Planned activities for the next 3-5 years

- Physics case for fast-timing layers in the tracker (silicon wrapper) and calorimeter: ToF for PID, LLP, background suppression, calorimeter resolution. Vertex t_0 determination Detector layouts and performance. 4D Tracking reconstruction algorithms.
- Sub-10ps low power TDCs in 28nm
- Fast on-chip processing to reduce data transmission needs
- LGADs using microwave annealing post-processing
- LGAD sensors in commercial 12” CMOS process and couple to dedicated front-end in 28nm with wafer-to-wafer bonding





ID0085 Scintillating fibre tracker (SciFi)

Contact Persons:

- Lesya Shchutska, lesya.shchutska@epfl.ch
- Radoslav Marchevski, radoslav.marchevski@epfl.ch

Collaborating Institutes & expertise/facilities:

- EPFL, Switzerland
  - SciFi R&D and construction for the current and future LHCb upgrades [1,2]
  - Fibre-winding facility, SiPM R&D and characterisation set-ups

Connections with DRDs:

- DRD4, WP4.1: Solid state photodetectors
- DRD4, WP4.5: SciFi and transition radiation detectors

Connections with Concept Groups:

- Will establish a connection with tracking detector for any concept

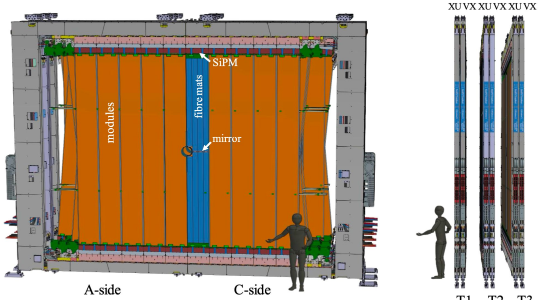
Presenter:

Radoslav Marchevski (in person)

References: [1]: “The LHCb Upgrade I”, JINST 19 (2024) 05, P05065; [2] “Framework TDR for the LHCb Upgrade II”, LHCB-TDR-023

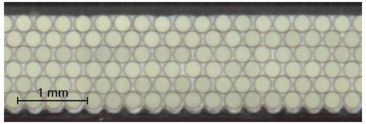
ID0085 Scintillating fibre tracker (SciFi)

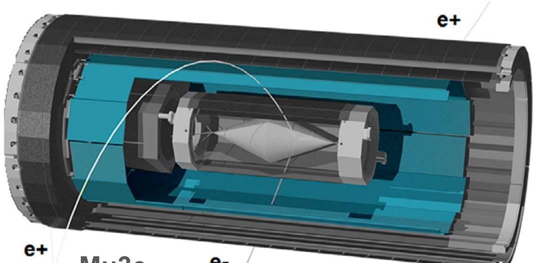
Parameter	SciFi @ LHCb (*JINST 19 (2024) 05, P05065*)	SciFi @ Mu3e (*NIMA 1050 (2023) 168099*)
Technology	Scintillating fibers with SiPM readout	Scintillating fibers with SiPM readout
Possible add-ons	300 ps timing resolution	< 500 ps timing resolution
Length	2.5 m in LHCb for half-module	0.3 m; 4π geometry
Radiation length, barrel	1.03%/module: 6 fiber layers/module 12.4% for 12 modules in LHCb	0.2%/module: 3 fiber layers/module; 1 fiber layer/module also tested
Spatial resolution	70 μm	< 50 μm



LHCb

Fibre mat





Mu3e

SciFi technology for outer tracker and/or for sensitive layers of muon system

- comparable performance to a full-silicon tracker at a lower cost
- can have lower material budget and no/little dead material in acceptance
- in the context of LLP searches, investigate a potential to add shower energy measurement with muon system

Strong collaboration with international partners

- essential for the development of the SciFi technology
- existing ties with companies which focus on SiPM and scintillator/fibre production and developments

SiPMs
Hamamatsu (Japan)
FBK (Italy)
Local Swiss companies for microlenses manufacturing

Fibres
Luxium Solutions (US)
Kuraray (Japan)

ID0085 Scintillating fibre tracker (SciFi)

Evaluate the compatibility of SciFi technology with the requirements and objectives of FCC

- simulate detector occupancy, evaluate the radiation levels of the FCC environment
- investigate barrel (4π design)/endcap options and synergy with Si trackers

Optimize performance vs material budget: **balance light collection efficiency vs noise**

- SiPM microlenses: more efficient light collection
- start development of new materials: higher light yield
- reducing material budget by using thinner fibre layers
- development of digital SiPMs with integrated readout for noise suppression, time measurement, and signal pre-processing
- digital SiPMs + double-sided readout will allow precision spatial and temporal tracking
- developments synergetic to DRD4 activities

Evaluate suitability of SciFi technology for other detector systems (e.g. muon systems for possible calorimetric application in LLP searches)

ID 0034 Large-Area Silicon Detectors

Contact Persons:

- Tony Affolder <affolder@ucsc.edu>, Vitaliy Fadeyev <fadeyev@ucsc.edu>, Mike Hance <mhance@ucsc.edu>, Simone Mazza <simazza@ucsc.edu>, Jason Nielsen <jnielsen@ucsc.edu>

Collaborating Institutes & expertise/facilities:

- Santa Cruz Institute for Particle Physics, UC Santa Cruz
  - Silicon strip and pixel systems
  - Sensor development and characterization
  - System integration

Thanks to the conveners for presenting these slides!

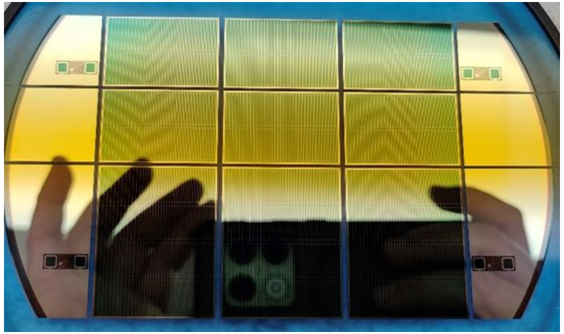
Connections with DRDs:

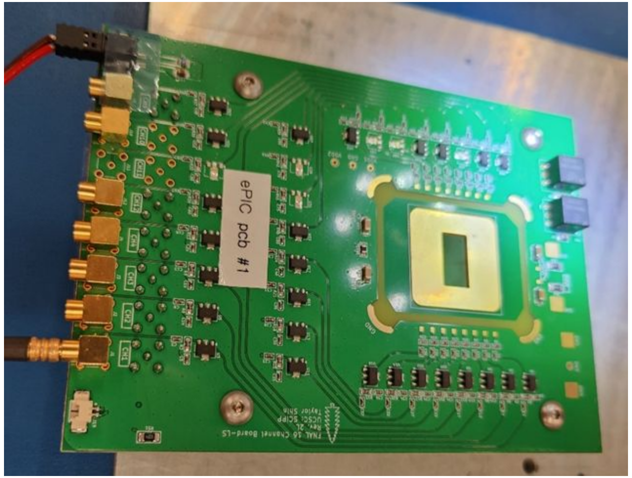
- All areas of DRD3:
  - WG1: CMOS; WG2: AC-LGADs; WG3: radiation tolerance; WG4: TCAD simulation; WG5: characterization; WG6: silicon carbide, thin films, diamond
- DRD7 WP3: electronics

Connections with Concept Groups:

- Engineering/Simulation studies with silicon outer layers/wrapper

ID 0034 Large-Area Silicon Detectors





Planned activities for the next 3-5 years relevant to FCC-ee R&D:

- HL-LHC upgrades: still a major focus
- Large scale tracker integration: mechanics, layout, readout, hermeticity
- MAPS for Imaging Calorimeter
  - Assessment of depletion region for high resistivity chips (Astropix/EIC)
- AC-LGADs
  - Development of a large scale AC-LGAD based timing layer for the ePIC detector, shown pictures are for the first full scale prototype AC-LGAD strips for ePIC (currently being tested at SCIPP) and the readout board developed at SCIPP to read out large sensors
  - Characterization of AC-LGADs of different dimensions and characteristics from various vendors (FBK, HPK, BNL, CNM), test the best layout for improved position and time resolution
- Timing readout chip
  - Development, together with external companies, of timing chips aimed at AC-LGADs that can have large input capacitance. The goal is to optimize power consumption, time resolution and position resolution. We are developing with NALU scientific a full-digitization chip for the ePIC and EIC Det II detectors.
- Thin Film sensors for HEP applications (e.g. Indium Phosphide)
  - Non-Si tracking sensors, targeting large-area, low-mass, low-cost fabrication
- Anticipate more targeted FCC R&D as US Higgs Factory program ramps up

<ID 0070+0027> <Development of modules for Vertex detector and Silicon Wrapper with combined tracking and timing capability in LFoundry 110nm technology>

Goal:

- Design outer vertex and Silicon wrapper and technology at the FCC-ee for all energies.
- Instrument the region of the outer vertex (10< r(cm)<35) and the Silicon wrapper in the IDEA detector concept.

Contact Persons:

- Fabrizio Palla: Fabrizio.Palla@cern.ch
- Manuel Rolo Da Rocha: darochar@to.infn.it
- Artur Apresyan: apresyan@fnal.gov
- Nicola Bacchetta, bacchetta@fnal.gov

Presenter : Fabrizio Palla (in-person)

Collaborating Institutes & expertise/facilities:

- INFN: Torino, Padova, Milano, Perugia, Pisa, Trieste, Bari
- FNAL, Caltech, USM Chile,

Connections with DRDs:

- DRD3
- DRD7
- DRD8

Connections with Concept Groups:

- IDEA

References: [1]:M. Boscolo et al, EPJ Tech. Instrum 10, 16 (2023); [2]]: A. Ilg and F. Palla,Pos (ICHEP2024) 1062; [3] Silicon Wrapper presentation at 2nd ECFA workshop

<ID 0070+0027> <Development of modules for Vertex detector and Silicon Wrapper with combined tracking and timing capability in LFoundry 110nm technology>

Tasks (under discussion)

1. Physics benchmarks and requirements
    - Study the position resolution needed, material budget and timing resolution
2. Geometry layout
    - Study the detector module size for the outer vertex
    - Study the detector module size for the Silicon wrapper
3. Mechanics
    - Study the outer vertex mechanics
    - Study the silicon wrapper mechanics
4. Development of sensors in LFoundry (110 nm) technology
    - Stitching
    - High speed serialisers
    - Power optimization – Serial power
    - Pitch
    - Gain layer (for timing)
5. Silicon submissions

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

ID 0071-Particle beam telescope with versatile DMAPS chip

Goal: Large area DMAPS-based telescope as FCCee tracker demonstrator system

Contact Persons:

- Carlos Marinas, cmarinas@ific.uv.es
- Abraham Gallas, abrahamantonio.gallas@usc.es

Presenter : Carlos Marinas (remote)

Collaborating Institutes and Expertise:

- Instituto de Física Corpuscular (IFIC - Valencia)
  - DMAPS design and characterization
- Instituto de Física de Cantabria (IFCA - Santander)
  - System integration, monitoring
- Instituto Galego de Física de Altas Enerxías (IGFAE - Santiago de Compostela)
  - DAQ, high speed links
- Instituto Tecnológico de Aragón (ITA - Zaragoza)
  - Grounding, power delivery
- International partners within DRD3 and Belle II VTX Collaboration (TBD)

Connections with DRDs:

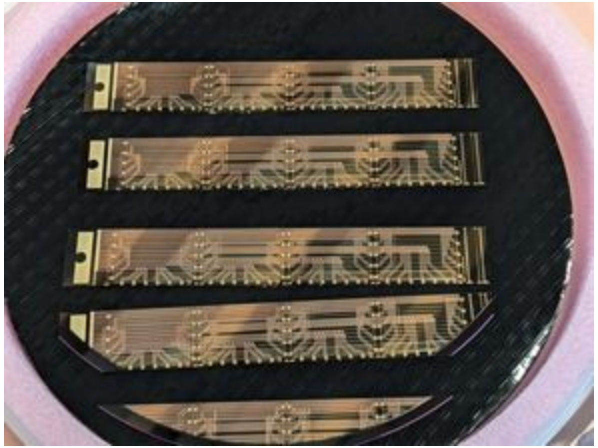
- DRD3: DMAPS, infrastructure
- DRD7: Electronics, transceivers
- DRD8: Wafer postprocessing

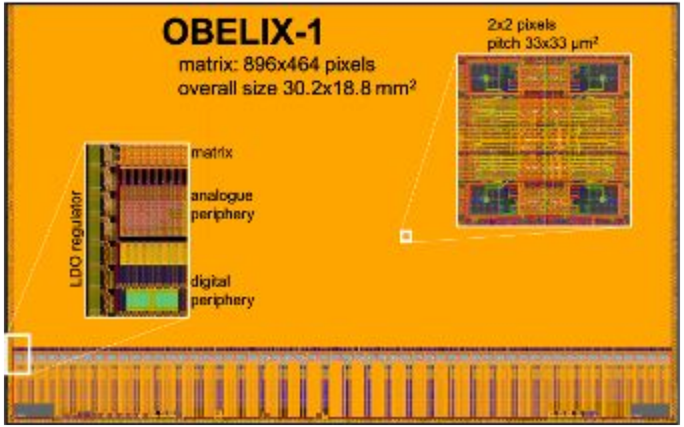
References: [1]: Nucl. Instrum. Meth. A 1072, 170164 (2025) [2]: Nucl. Instrum. Meth. A 1067, 169659 (2024) [3]: [arXiv:2406.19421 [hep-ex]]

ID 0071-Particle beam telescope with versatile DMAPS chip

Planned activities for the next 3-5 years

- Task 1: CMOS DMAPS versatile tracker chip production (OBELIX)
- Task 2: All-silicon CMOS ladders
- Task 3: Large area DMAPS telescope system





References: [1]: Nucl. Instrum. Meth. A 1072, 170164 (2025) [2]: Nucl. Instrum. Meth. A 1067, 169659 (2024) [3]: [arXiv:2406.19421 [hep-ex]]

ID0013: Carbon fibre wire chamber

Goal: A novel wire chamber concept employing carbon fiber wires for the Outer tracking device of FCC-ee. Open for additional collaborators.

Contact Persons:

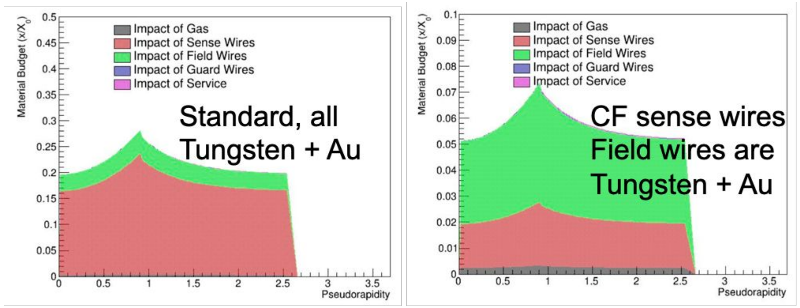
- Andy Jung, anjung@purdue.edu
- Sushrut Karmarkar, skarmar@purdue.edu

Collaborating Institutes & expertise/facilities:

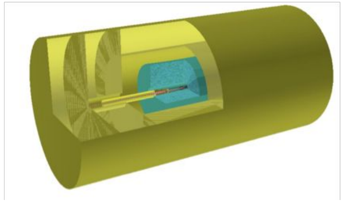
- Purdue University 1
  - Carbon Fiber, Low-mass support structures, dual-use structures, 3D printed pipes
  - Composite Manufacturing & Simulation Center
- Open for new collaborators

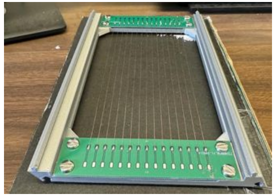
Connections with DRDs:

- DRD8, low mass tracking detectors
- US RDC10 Low mass tracking



- Reduction of material budget of factor 5-8
- Studies of dd4hep, GEANT and using IDEA as a start
- Manufacturing 1st prototype "30cm" in 2025





Calorimeter

ID0039 SiW-ECAL

Presenter : V. Boudry remote

Contact Persons:

- Vincent Boudry <Vincent.Boudry@in2p3.fr>
- Roman Pöschl <Roman.Poeschl@ijclab.in2p3.fr>

Collaborating Institutes & expertise/facilities:

- IJCLab (Orsay): Electronics (Front-End, DAQ, PCB), Mechanics, Integration, Analyse
- LLR (Palaiseau): Electronics (Front-End, PCB), Mechanics, Integration, Analyse, Design
- LPNHE (Paris): Silicon Sensors, Integration
- Omega (Palaiseau): Very-Front End (ASICs)
- DMLab: Analyse, DAQ
- IFIC (Valencia): Silicon Sensors, Integration
- CERN: Silicon Sensors
- U. Tokyo: Silicon Sensors, Integration, Analysis
- Argonne: Electronics, Sensors, Integration, DAQ

Connections with DRDs:

- DRD6, WP1: SiW-ECAL, (compact SiW-Ecal), WP4 (Electronics and DAQ)

Connections with Concept Groups:

- Engineering/Simulation studies with concept ILD, CLD

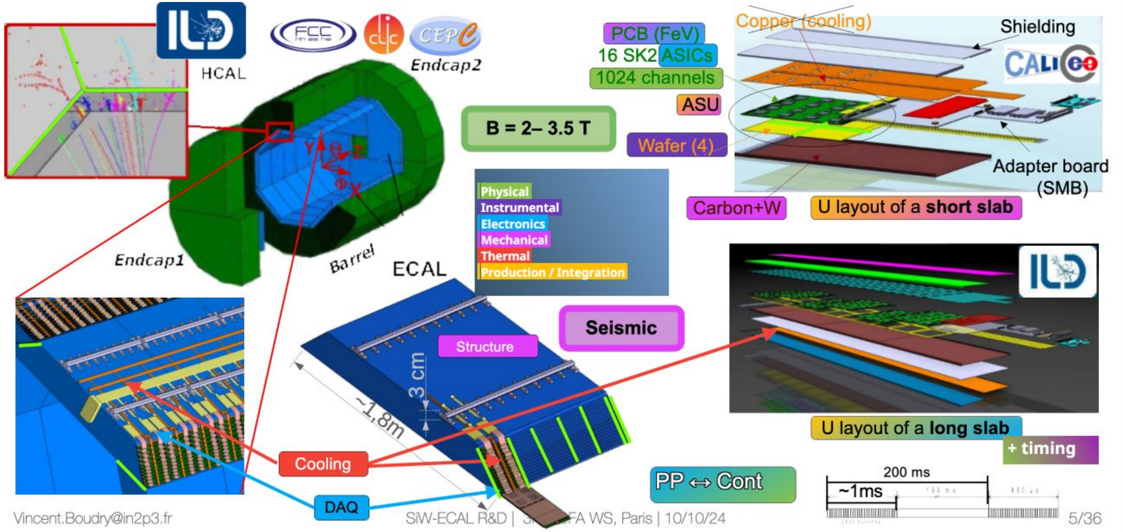
References: [1]:Nucl. Instrum. Meth. A 1051, (2023) 168185; [2]: arXiv:2003.01116 [hep-ex, physics:physics], (2020); [3]: Our EoI draft in Overleaf

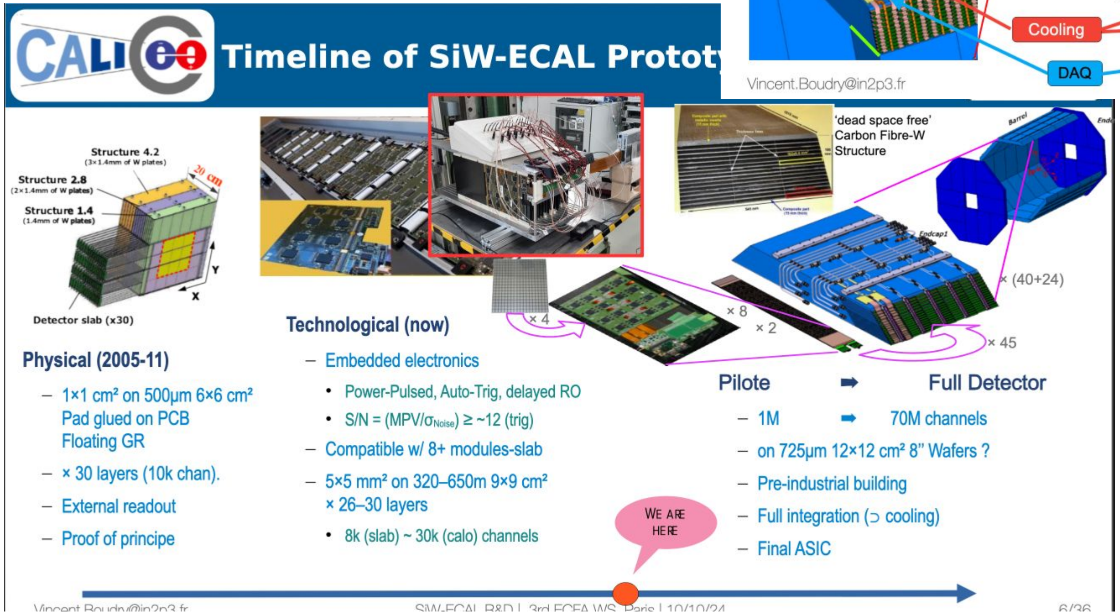
ID0039 SiW-ECAL

A SiW-ECAL for PFA exp: ILD' / CLD, …

- FullSim based on prototypes
- Adaptation from ILD for ILC
- Rates, Granularity, Timing

➞ new Electronics, Services (Cooling, DAQ), Mechanics





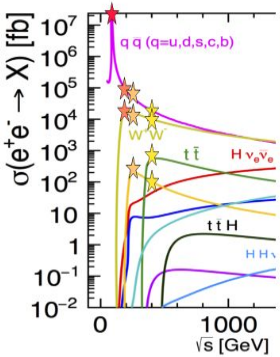
A SiW-ECAL prototype

- Completion of CALICE work (➞ DRD6)
  - Technological Prototype building
- Usability in non-collider experiments (LUXE, Lohengrin, EBES)
- Prepare path for large prototype

ID0039 SiW-ECAL

Planned activities for the next 3-5 years

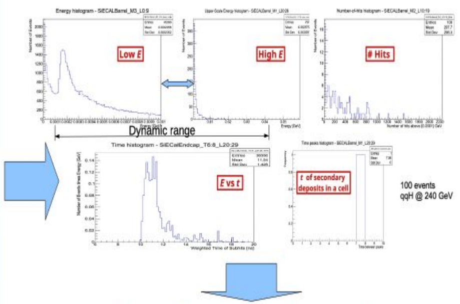
- 2025–26
  - Task 1: Dimension the electronics and cooling for the FCC-ee
  - Task 2: Provide and test a uniform 15 layers prototype with existing material
    - Improved VFE boards (noise), gluing procedure, …
    - Adaptation from non-colliding exp. (LUXE, Lohengrin, EBES, …)
  - Task 3: Design VFE for the future electronics (DRD6ROC)
  - Task 4: Assess the PFA and timing performances for key physics processes (↔ AHCAL, T-SDHCAL)
- 2027:
  - Task 5: provide a blueprint for a SiW-ECAL for the FCC-ee and large prototype (pilot module),
  - Initiate contacts with industry for assembly, tests
- 2028+ : Start building elements
- 2035+: Test Pilot module
- 2038+: Start building Detector (8 years)



Processes: min. bias

- All
  - ee → qq
  - ee → μμ, ττ
  - ee → ee (⊃ Bhabha)
  - γγ→ VV
  - Machine background (ee pairs)
- $E_{CM} \geq$ 160 GeV
  - ee → WW
- ($E_{CM} \geq$ 240 GeV)
  - ee → HZ
- ($E_{CM} \geq$ 360 GeV)
  - ee → $t\bar{t}$

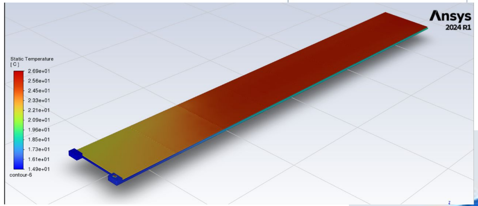
Full simulation → statistics per region

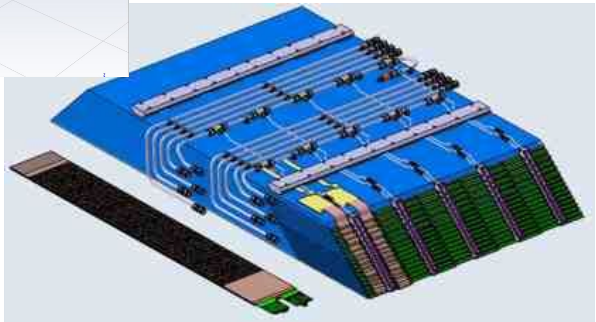


× $\mathcal{L}$ + Machine background

➡ Fluxes of hits, data, per region

➡ Power with ASIC assumptions





<ID0074> Design studies, BE and DAQ

Contact Persons:

- Anne-Marie Magnan, a.magnan@imperial.ac.uk

Collaborating Institutes & expertise/facilities:

- Imperial College London
  - Electronics (Back-End, DAQ), analysis, design studies

Connections with DRDs:

- DRD6, WP1: Design studies, analysis
- DRD7, WP7.5b: Backend Systems and Commercial-Off-The-Shelf Components

Connections with Concept Groups:

- Engineering/Simulation studies with any concept using high-granular sampling calorimeters.

ID0059 MAPS for SiW calorimeters

Contact Persons:

- Jim Brau, jimbrau@uoregon.edu
- Caterina Vernieri, caterina@slac.stanford.edu
- Alexander Paramonov, aparamonov@anl.gov

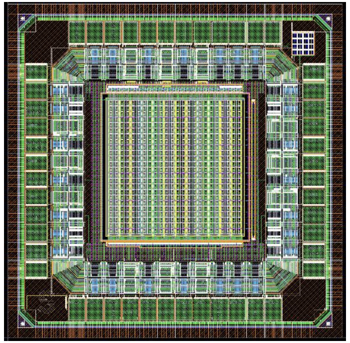
Collaborating Institutes & expertise/facilities:

- U of Oregon
  - Detector Simulations, Electronics testing, Design
- SLAC
  - Electronics & ASIC design, calorimeter design, Detector simulations
- ANL
  - Electronics and testing, calorimeter design, detector simulations

Connections with DRDs:

- DRD3
- DRD6
- DRD7

Presenter : A. Paramonov (Remote)

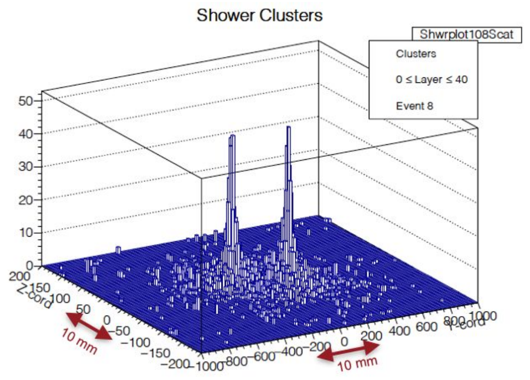


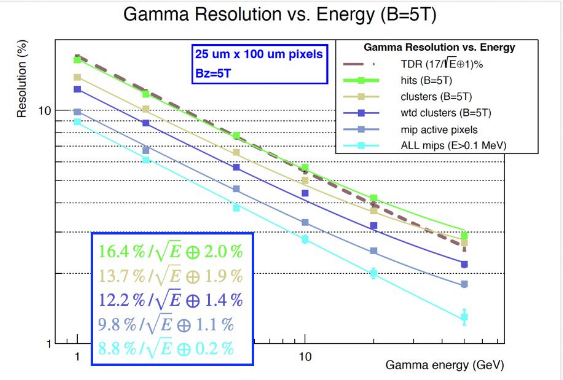
Layout of SLAC prototype for WP1.2 2022 shared submission on TowerSemi 65nm

ID0059 MAPS for SiW calorimeter

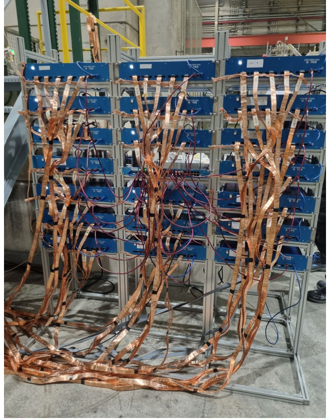
Anticipated activities for the next 3-5 years

- Pixel size optimization
- More testbeam and detector performance simulations
- Readout and on-detector data processing
- Develop power and signal distribution schemes
- Heat management engineering
- Follow-up with the tracker MAPS R&D





<ID 0022> <Dual-Readout Calorimeter>



Contact Persons: Hwidong Yoo (hdyoo@cern.ch), Yonsei University

- Prof. Sehwook Lee (seh.wook.lee@cern.ch), Kyungpook National University
- Prof. Minsuk Kim (min.suk.kim@cern.ch), Gangneung-Wonju National University
- Prof. Jason S.H. Lee (Jason.Lee@cern.ch), University of Seoul

Collaborating Institutes & expertise/facilities:

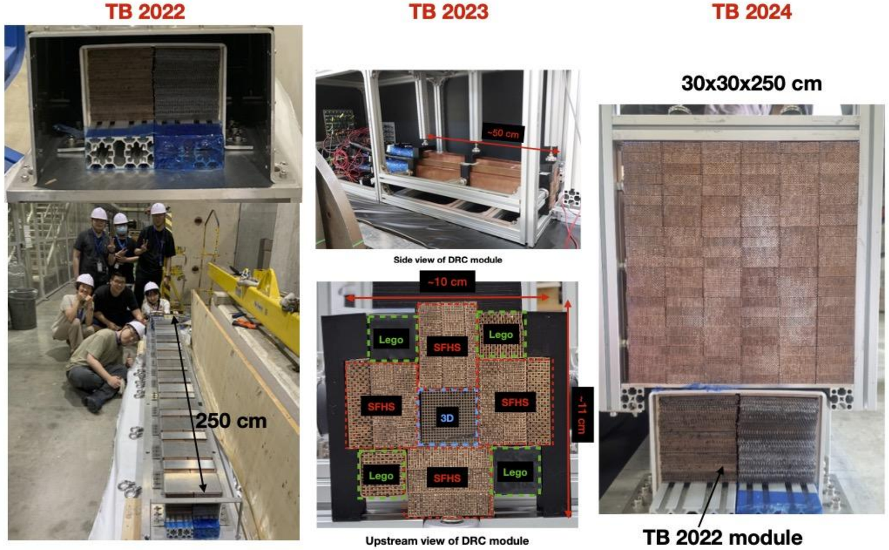
- Yonsei University
  - Module building, Electronics, DAQ, simulation, data analysis
- Kyungpook National University
  - Electronics, DAQ, data analysis
- Gangneung-Wonju National University
  - DAQ, simulaton
- University of Seoul
  - Electronics, machine learning

Connections with DRDs:

- DRD6, WP3

Connections with Concept Groups:

- Engineering/Simulation studies with concept IDEA



<ID 0022> <Dual-Readout Calorimeter>

Planned activities for the next 3-5 years

- 2025: Test-beam experiment at CERN with upgraded DAQ, electronics using TB2024 prototype
- 2026-7: get bigger funding for full-size prototype detector (full hadronic energy containing) and high granularity DAQ systems (SiPM or MCP-PMT based), building the prototype, beam-test

Lumical

<ID 0102> <Luminosity calorimeter - SiW>

Contact Persons:

- Yan Benhammou ybenham@cern.ch

Collaborating Institutes & expertise/facilities:

- Tel Aviv University
  - Silicon Sensors, Integration
- Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland
  - Electronics (Front-End, DAQ, PCB),
- Warsaw University, Poland:
  - Mechanics
  - Physics analysis
- ISS, Bucharest, Romania
  - Physics analysis

Connections with DRDs:

- DRD6 WP1: compact SiW Ecal
- DRD1, WP3a: High performance TDC and ADC blocks at ultra-low power

Connections with Concept Groups:

- Simulation of background/signal

References: Eur. Phys. J. C (2019) 79:579; [2]: Eur. Phys. J. C79 (2019) 579

ID 0104: **Development of SNSPDs (quantum sensors) for FCC experiments, including possibility as luminometer**

Presented by: Boris Korzh (in person)

Contact Persons:

- Boris Korzh, Boris.Korzh@unige.ch
- Ben Kilminster, ben.kilminster@physik.uzh.ch
- Ilya Charaev, ilya.charaev@physik.uzh.ch
- Anna Sfyrla, Anna.Sfyrla@unige.ch

Collaborating Institutes & expertise/facilities:

- University of Geneva:
  - Quantum Technology group (Korzh): SNSPD design, nanofabrication, system integration, scaling
  - Nuclear and High Energy Physics Department (Sfyrla): detector design, science case study and data analysis
  - Department of Quantum Matter Physics: superconducting material characterization facilities
- University of Zurich
  - Particle physics group (Kilminster): Detector design & characterization w/ beam tests, sources
  - Condensed Matter group (Charaev): High-temperature SNSPD fabrication, detector characterization

Connections with DRDs:

- DRD5 WP-3

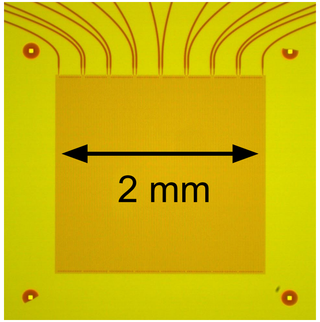
Connections with Concept Groups:

- Will require interface with MDI to understand space requirements, sharing cryogenic cooling with superconducting magnets

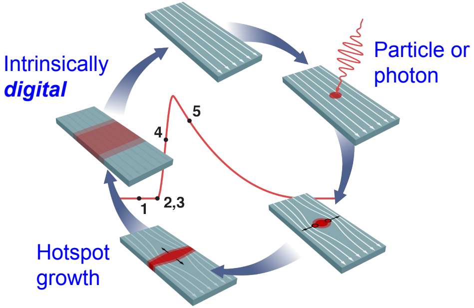
ID 0104: Development of SNSPDs (quantum sensors) for FCC experiments, including possibility as luminometer

Planned activities for the next 3-5 years

- Luminometer concept:
  - Detector design fitting in available space
  - Simulation of detector design with Bhabha scattering, incoherent pairs / beam backgrounds
  - Understanding MDI constraints for detector concept & providing cryogenics
- SNSPD development
  - Scaling of SNSPD arrays up to >cm^2 scale
  - High-temperature (~20 K) SNSPD development
  - Scalable readout chain and signal processing
  - Geometry optimization
  - Characterization of particle response
- Feedback between luminometer concept and SNSPD development
- Understanding of other applications of SNSPDs for dedicated detectors for ALPs, weakly interacting particles, etc.

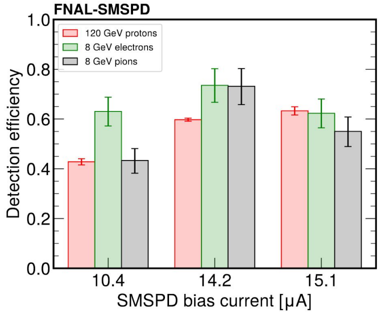


First meandered Superconducting Nanowire Single Photon Detectors (SNSPD) fabricated with scalable photolithography



Typical operating temperature: 1-20 K [6]

- Particle proof-of-concept: **protons, electrons, pions** [1]
- High efficiency: **98%** (photons) [2]
- Record energy threshold: **43 meV** [3]
- Timing resolution: **<3 ps** [4]
- Large cameras: **400,000 pixels** [5]



*Proof-of-concept **particle detection** at Fermilab Test Beam facility* [1]

References: [1] C. Peña, et al. (2024) arxiv.org/abs/2410.00251; [2] Reddy et al, Optica 7, 1649 (2020) [3] Taylor et al, Optica 10, 1672 (2023); [4] Korzh et al, Nat. Photonics 14, 250 (2020); [5] Oripov et al, Nature 622 (7984), 730 (2023); [6] Charaev et al, Nat Commun 15, 3973 (2024)

<ID0032> <SiPM-on-Tile HCAL>

Contact Persons: Frank Simon, frank.simon@kit.edu

Collaborating Institutes & expertise/facilities:

- DESY
  - Overall detector technology, front-end electronics, mechanics, overall detector integration, simulations & reconstruction
- Hamburg University
  - Photon sensors, simulations & reconstruction
- Heidelberg University
  - Front-end ASIC, Cooling
- KIT
  - Overall detector concept, readout electronics, DAQ, simulations & reconstruction
- Mainz University
  - Scintillators, cooling, simulations & reconstruction
- UT Arlington
  - Concept,, integration in SiD detector concept
- Northern Illinois University
  - Scintillators, photon sensors
- FZU Prague
  - Front-end electronics, readout electronics, DAQ

Connections with DRDs: DRD6, WP1

Connections with Concept Groups: Engineering/Simulation studies with concept CLD. ILD, SiD

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

<ID0032> <SiPM-on-Tile AHCAL>

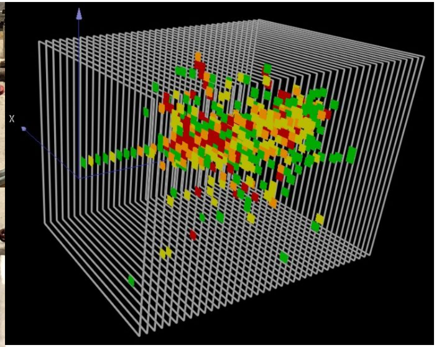
Planned activities for the next 3-5 years:

The overarching R&D goal is to develop the AHCAL technology to fully address the requirements of FCC-ee:

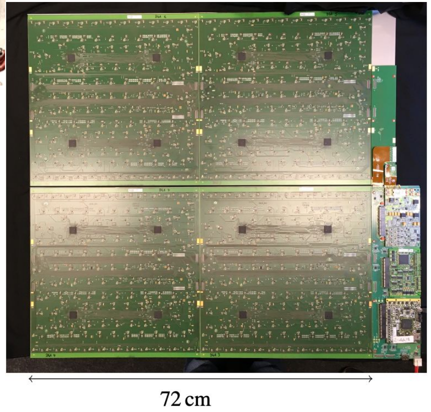
- Re-design of the full readout and powering chain for continuous read-out, data rates and possible trigger requirements of FCC-ee,
- Development of appropriate electrical, thermal and mechanical integration concepts.
- General further evolution of the technology, including alternative scintillator concepts such as megatiles and 3D-printed scintillators
- Development of reconstruction algorithms to exploit full 5D calorimeter information, studies to defined needed time resolution

Current schedule

- 2025 Readout and thermal concept
- 2026 Layer prototypes
- 2027 Multi-layer prototype, em shower containment
- Beyond: Progress to larger systems



22k channel prototype - with power-pulsed readout (2018)



2x2 HBU active layer with readout and control interfaces, 576 channels total

References: [1]: CALICE collaboration, “Design, construction and commissioning of a technological prototype of a highly granular SiPM-on-tile scintillator-steel hadronic calorimeter”, JINST 18, P11018 (2023)

<ID095> <T-SHCAL>

Contact Persons:

- Imad Laktineh , laktineh@in2p3.fr
-
- Collaborating Institutes & expertise/facilities:
- IP2I
- ○ Overall detector technology, back-end electronics, DAQ, simulation & reconstruction
- CIEMAT
- ○ Back-end electronics, mechanics &cooling
- Vrije
- ○ MRPC detector concept & services
- SJTU.
- ○ Back-end electronics & reconstruction
- Yonsei
- ○ MRPC
- SKKU
- ○ MRPC
- OMEGA
- ○ Front-end electronics
- University of Cordoba
- ○ simulation&reconstruction
- El-Manar University
- ○ simulation&reconstruction

Presenter I. Laktineh (remote)

Connections with DRDs:

- DRD6, WP1…
- DRD1, WP5, WP7

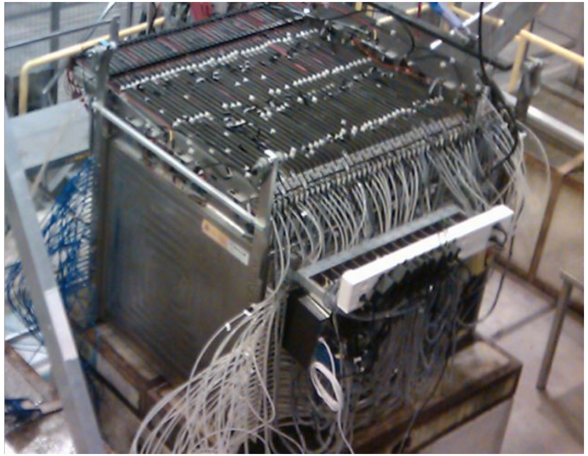
Connections with Concept Groups:

- Engineering/Simulation studies with concept ILD

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

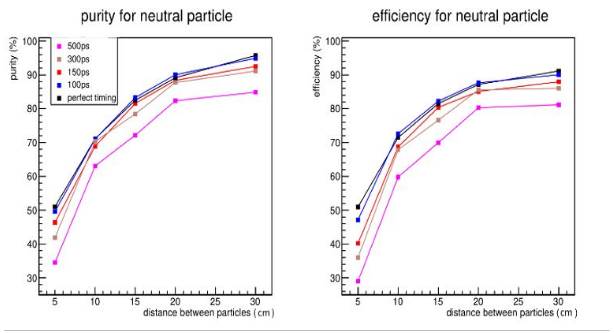
The T-SDHCAL intends preserving the excellent performances of the highly granular SDHCAL developed for ILC while adapting it to the FCCee operation mode:

- ❖ Continuous readout electronics with timing performances
- ❖ Active cooling system that reduces the dead zones
- ❖ High rate capabilities



To achieve this we are developing

- ➢ new kinds of MRPC with large surface (> 1 M^2)with very thin (< 3mm thickness) and time performance better than 150 ps and high rate capabilities (> a few kHz/cm^2)
- ➢ New electronics with internal TDC providing precise time measurements
- ➢ Robust mechanical structure that hosts an efficient cooling system with limited consequences on energy reconstruction and PFA performances



<ID0086> <TileCal HCAL for ALLEGRO>

Presenter : Rute Pedro (remote)

Contact Persons:

- Henric Wilkens, Henric.Wilkens@cern.ch
- Rute Pedro, Rute.Pedro@cern.ch
- Michaela Mlynarikova, Michaela.Mlynarikova@cern.ch

Collaborating Institutes & expertise/facilities:

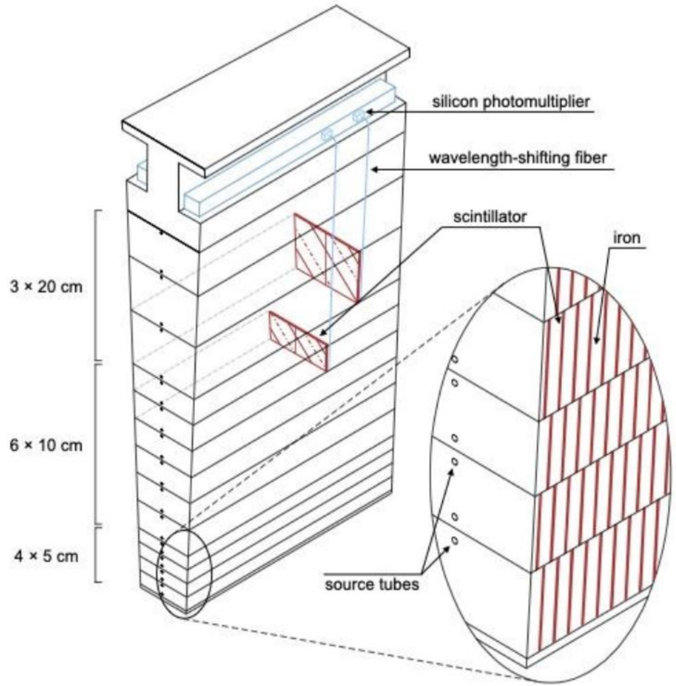
- **INCDTIM (Cluj):** Mechanics, electronics
- **LIP (Lisbon):** Scintillators, WLS fibres
- **IFIC (Valencia):** Electronics
- **University of Bergen:** Photodetectors
- **FZU (Prague):** Electronics, Photodetectors
- **Charles University:** Energy reconstruction, software
- **Tbilisi State University:** Energy reconstruction, software
- **LPC (Clermont-Ferrand):** Electronics, Energy reconstruction, Software
- **CERN:** Energy reconstruction, software

Connections with DRDs:

- DRD6, WP3.3.2

Connections with Concept Groups:

- Engineering/Simulation studies with concept NN



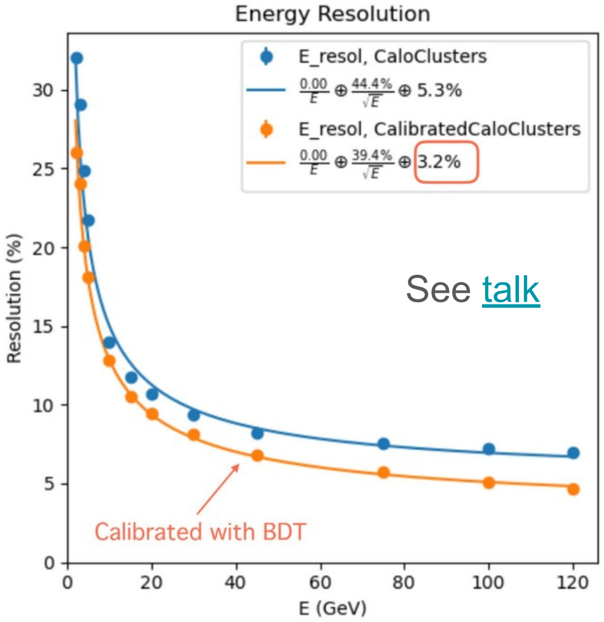
<ID0086> <TileCal HCAL for ALLEGRO>

Planned activities for the next 3-5 years

- **Performance simulation**
  - First version of barrel/endcap simulation implemented in key4hep
- **Build test beam modules**
  - First mechanical part is produced

- **Ongoing:**
  - Geometry optimisation with particle flow
  - SiPMs and SiPM-fibre coupling studies
  - Studying new scintillator materials

- 2025:
- 2026:
- 2027:



See talk

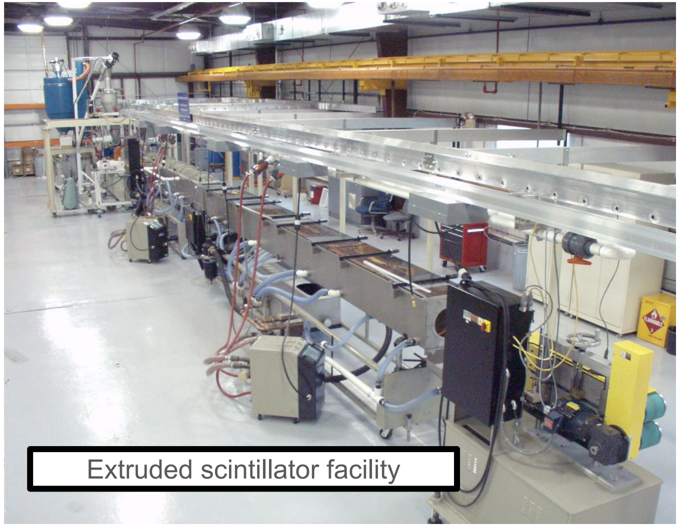
ID0028 Calorimetry R&D at Fermilab

Contact Persons:

- Grace Cummings, gcumming@fnal.gov
- Zoltan Gecse, zgecse@fnal.gov
- Lindsey Gray, lagray@fnal.gov
- Jim Freeman, freeman@fnal.gov
- Jim Hirschauer, jhirsch@fnal.gov

Collaborating Institutes & expertise/facilities:

- Fermi National Accelerator Lab Facilities
  - **Organic scintillator-based calorimetry:** extruded and injected scintillator production and R&D facility
  - **Fermilab Test Beam Facility** : including semi-permanent infrastructure for Calorimeter R&D
  - **Silicon Detector (SiDet) facility** : Silicon MAPS-based calorimetry
  - **Fermilab Microelectronics Division** : ASIC design and testing
- Active member of CalVision Consortium (fully Dual Readout Calo)



Extruded scintillator facility

Connections with DRDs:

- DRD6, WP3
- DRD7

ID0067: ALLEGRO Noble Liquid Ecal

Contact Persons:

- Nicolas Morange, nicolas.morange@cern.ch
- Marc-Andre Pleier, pleier@bnl.gov

Collaborating Institutes & expertise/facilities:

- **Institutes list:**
  APC (Paris, France), BNL (Brookhaven, USA), Brown University (Providence, USA), CERN, CPPM (Marseille, France), CUNI (Prague, Czech Republic), IFIN-HH + UNSTPB (Bucharest, Romania), IJCLab (Orsay, France), LAPP (Annecy, France), LPNHE (Paris, France), MPI Munich (Germany), NYU (NY, USA), Omega (Palaiseau, France), Southern Methodist University (Dallas, USA), Stony Brook University (USA), TU Dresden (Germany), IEP SAS Kosice (Slovakia), University of Arizona (USA), University of Columbia (NY, USA), UT Austin (USA)

- **Expertise:**
  - Many members of ATLAS LAr Calorimeter community. General expertise, electronics, ASIC design, mechanics, testbeams
  - Expertise in electromagnetic and hadronic objects reconstruction
  - Expertise in FCC SW and simulation

Connections with DRDs:

- DRD6, WP2: bijection ALLEGRO Ecal ⇔ WP2
- DRD6, WP6: Electronics for DRD6

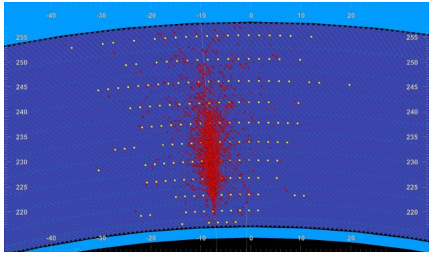
Connections with Concept Groups:

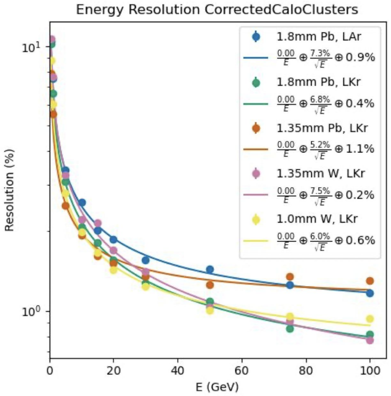
- Ecal at the core of the ALLEGRO Detector concept

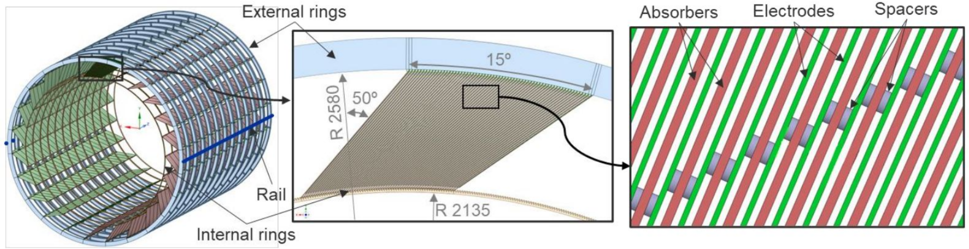
ID0067: ALLEGRO Noble Liquid Ecal

Planned activities for the next 3-5 years

- Simulations:
  - Finalize end-caps description
  - Particle Flow integration
  - Optimisation of granularity
  - Inform choice of materials (LAr/LKr, Pb/W) and geometry
- Readout electrodes:
  - Investigate HV distribution
  - Final barrel prototypes
  - End-caps electrodes design
- Mechanics
  - Absorbers prototypes
  - Studies of spacers
  - Progress on general design, support structures
- Electronics
  - First (cold) ASIC prototypes
  - Frontend boards
- Test module
  - Design of the module
  - Production







Presenter : Ariel Schwartzman (remote)

ID0052: **Calorimetry (SLAC)**

Contact Persons:

- Ariel Schwartzman, sch@slac.stanford.edu
- Su Dong
- Rainer Bartoldus
- Charles Young
- Julia Gonski
- Michael Kagan
- Lorenzo Rota
- Huang Ping-Chen
- Bojan Markovic

Collaborating Institutes & expertise/facilities:

- SiPM readout electronics, DAQ systems
- Data processing on chip
- Electronics for fast timing in 28nm node, sub-10ps TDC
- LGAD sensors for timing layers
- Calorimeter reconstruction algorithms

Connections with DRDs:

- DRD6, DRD3, DRD7.3

Connections with Concept Groups:

- All concepts, with a focus on IDEA

Planned activities for the next 3-5 years

- R&D of low-power, low-jitter analog front-end electronics for SiPM readout, and on-chip intelligent data processing for the extraction of the S/C light components of dual-readout calorimeter concepts in the front end to reduce data transmission needs (in collaboration with CalVision)
- Use of timing for longitudinal segmentation of fibre calorimeters, and to improve energy resolution
- Investigation of AI/ML approaches for fast-timing dual-readout particle flow reconstruction (5D Particle Flow)

Particle ID

ID0083 ARC - A compact RICH detector

Presenter : Sneha Malde (remote)

Contact Persons:

- Roberta Cardinale <Roberta.Cardinale@cern.ch> (Genova)
- Sneha Malde <smalde@cern.ch> (Oxford)

Collaborating Institutes & expertise/facilities:

- Genova
  - Simulation and reconstruction studies, Photodetector module for SiPM with integrated cooling.
- Oxford
  - Simulation and physics, prototype mechanics
- CERN
  - Simulation, prototype design
- Warwick
  - Software, simulation and reconstruction studies

Connections with DRDs:

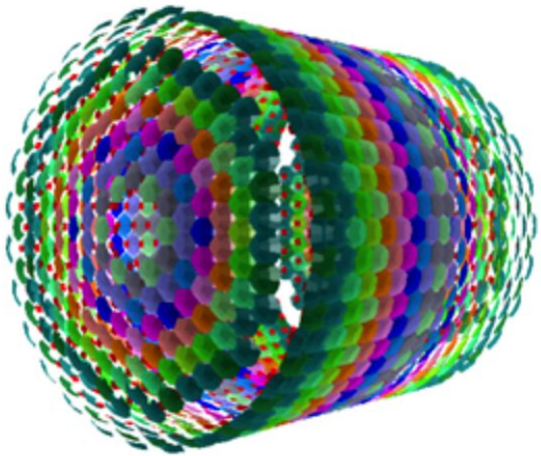
- DRD4: WP 4.3.4 : Deliverable is a prototype of an ARC cell.

Connections with Concept Groups:

- There are possible applications of this technology to all detector concepts, to enhance PID capabilities

References: Simulation and performance studies of the ARC concept https://doi.org/10.17181/6entj-pmm10

ID0083 ARC - A compact RICH detector



A lightweight modular PID detector that can be "tiled" around a tracking volume

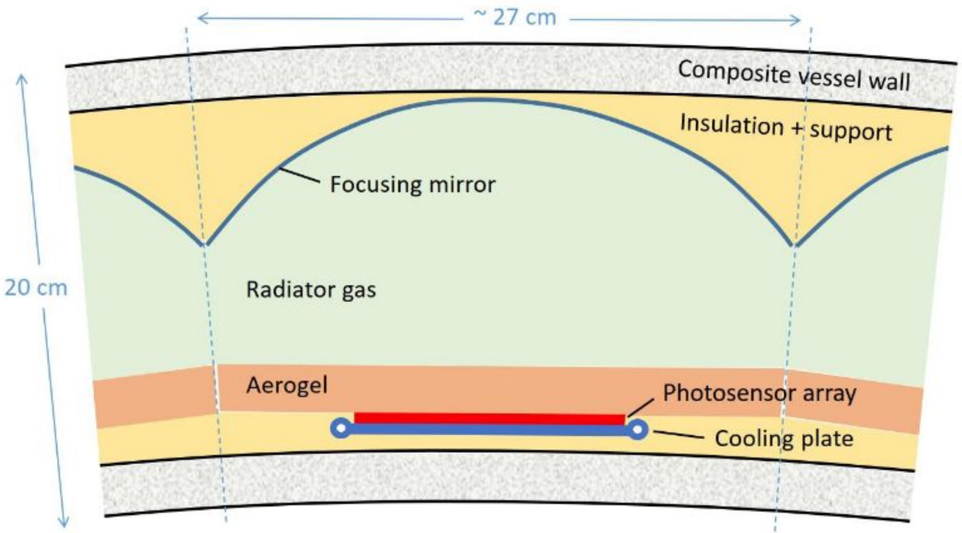
Significantly improve flavour-physics capabilities of a detector

Each cell would contain aerogel and gas radiators allowing PID capabilities up to ~40 GeV

Extensive simulation studies performed

Planned activities for the next 3-5 years:

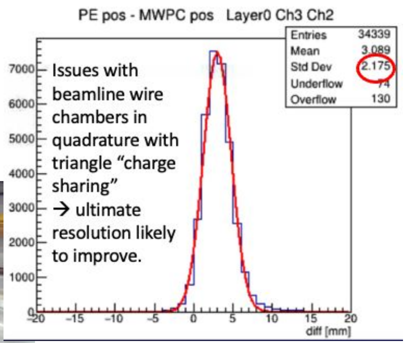
- Design and build prototype to demonstrate the concept



Coil

Muons

ID 0060: Scintillator + WLS fiber + SiPM for Muon Detector

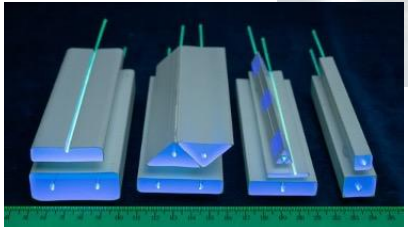


Contact Persons:

- Charles Young (SLAC) young@slac.stanford.edu

Collaborating Institutes:

- Fermilab. Jim Freeman, Alan Bross, Paul Rubinov
- Univ. Washington Seattle. Henry Lubatti, Shih-Chieh Hsu
- Michigan: Jianming Qian, Bing Zhou, Junjie Zhu

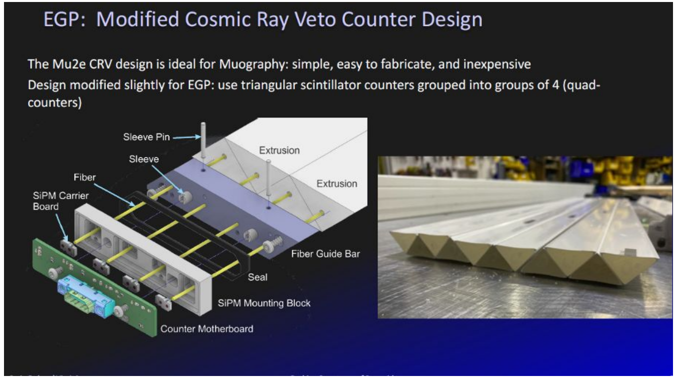


Connections with DRDs:

- DRD4 WP1

Connections with Concept Groups:

- Applicable to all detector concepts
- Simple passive detector well matched to Higgs Factory muon subsystem requirements
  - Insensitive to temperature / pressure
  - Low operating voltage (< 50 V)
  - Good position resolution (~ 2 mm by 2 mm) hit resolution
- Affordable: extrusion facility at Fermilab with 75 kg/hr capacity, SiPM
- Extensive experience in many experiments -> understanding of system behavior
- Can be combined with other detection elements where appropriate



<ID 0076> **Development of micro-RWELL technology for the Muon system**

Contact Persons:

- Marco Poli Lener, marco.polilener@lnf.infn.it
- Riccardo Farinelli, riccardo.farinelli@bo.infn.it

Collaborating Institutes & expertise/facilities:

- Laboratori Nazionali di Frascati
  - Expertise in detector design, construction and testing
  - Facility: Large cleanroom class 100 with granite tables, electronics & mechanics workshop, Detector Lab with X-ray guns, Bema Test Facility (BTF) line
- INFN Sez. Torino and Ferrara
  - Expertise on electronics development and integration
  - Facility: Cleanroom,electronics & mechanics workshop, Detector Lab.
- INFN Sez. Bologna
  - Expertise in simulation and validation of detector performance using GARFIELD++ and analysis data
  - Facility: Cleanroom,electronics & mechanics workshop, Detector Lab.

Connections with DRDs:

- DRD1, WP1: development of novel detector architectures for future collider experiments,
- DRD1, WP8: knowledge-sharing and testing campaigns in collaboration with DRD1 partner institutions

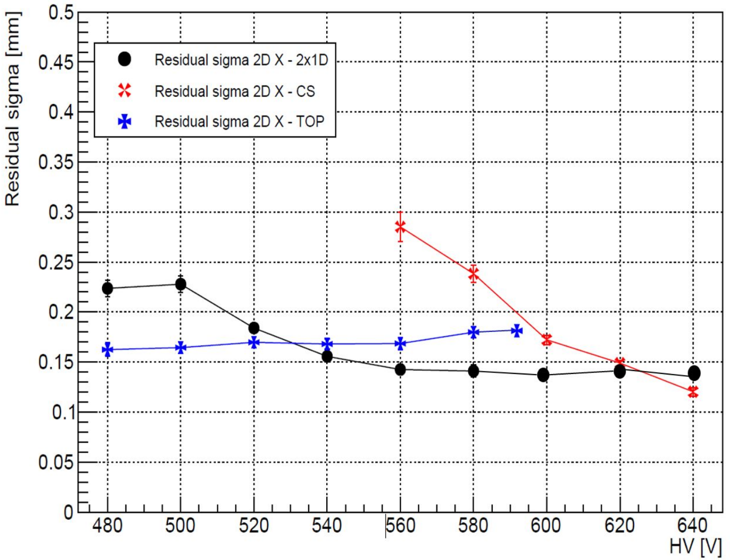
Connections with Concept Groups:

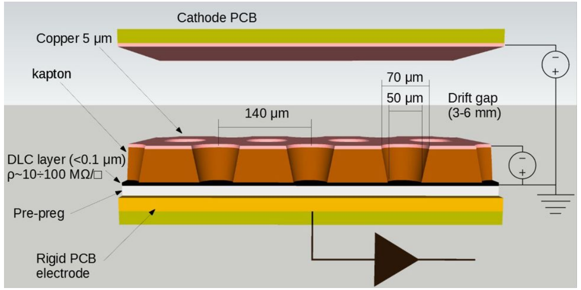
- Engineering/Simulation studies with concept IDEA

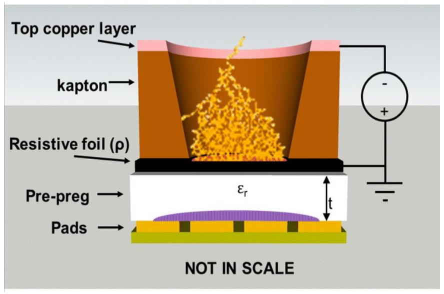
<ID 0076> **Development of micro-RWELL technology for the Muon system**

Planned activities for the next 3-5 years

- 2025: 1. Optimization of Detector Performance
  2. Simulation Detector performance
- 2026: 1. Characterization and Beam Tests
  2. Validation of the simulation with experimental data
  3. Design of new front-end electronics
- 2027-29: 1. Development of Modular and Scalable Designs
  2. Production of the front-end electronics
  3. Electronics Integration and Readout Optimization







References: [1]: G. Bencivenni et al., The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD, 2015 JINST 10 P02008

ID0084 Resistive Micromegas detectors for Muon systems at FCC-ee

Contact Persons:

- Paolo Iengo, paolo.iengo@cern.ch
- Mauro Iodice, mauro.iodice@cern.ch

Collaborating Institutes & expertise/facilities:

- INFN Sezione di Napoli & Universita' Federico II, Naples, Italy
- INFN Sezione RomaTre and Universita' RomaTre, Rome, Italy

Both Institutes have similar expertise and facilities:

  - Expertise in development, construction, operation and maintenance of Micromegas, RPC, wire chambers. Expertise in large detector system.
  - Facilities: electronics and mechanics workshops; clean room; detector testing lab

Connections with DRD:

- DRD1 Gaseous Detectors:
  - WP1 (Tracking/Hodoscope Large area Muon Systems),
  - WP5 (calorimetry) Hadron sampling calorimeters with MPGDs

Connections with Concept Groups:

- Recently joined. Establishing contacts with IDEA (alternative proposal for Muon System) and with ALLEGRO

ID0084 Resistive Micromegas
Planned activities for the next 3-5 years

2025 – 2027:

- Develop the concept of capacitive sharing to reduce the number of readout channels, while preserving good spatial resolution. Investigate the limits of this technology balancing number of layers/pad-size/signal response
- Optimisation of the resistive protection scheme - Design optimisation for single-layer DLC for large area modules (resistivity / detector-size / Voltage drop)
- Advance the technology transfer for construction in the industry (with ELTOS S.p.A., this process has started for resistive Micromegas with bulk mesh).

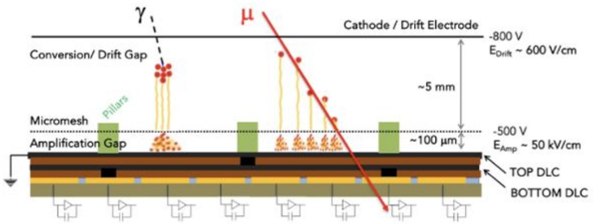
2026 – 2028:

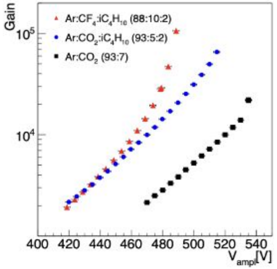
- Optimisation of readout electronics. Comparison of available ASICs and analysis of system scalability. → Synergies with other MPGD groups
- Enhancement of time resolution while avoiding the use of high-GWP gases.

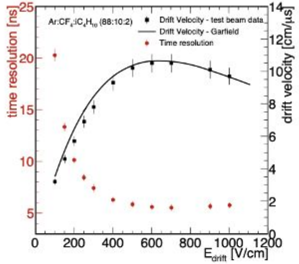
2027 – 2029:

- Ageing studies, aimed at ensuring the integrity and operational stability of the systems over extremely long data-taking periods.
- Participation in the design, if needed, of new ASICS

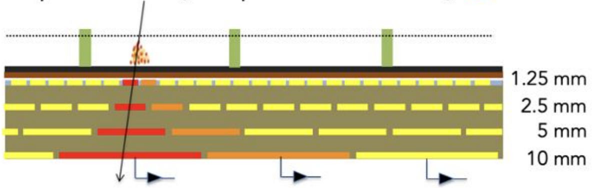
The High-Rate Version: DOUBLE LAYER DLC Layout [1]

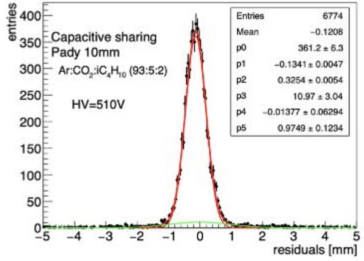






The Medium/Low-Rate Version Implementing Capacitive Sharing [2]





[1] M. Alviggi et al., "Resistive fine granularity Micromegas: characterization and performance for different spark protection resistive schemes ", 2025 JINST 20 P01012

[2] M. Iodice "Resistive High Granularity Micromegas for Future Detectors. Status and Perspectives – MPGD 2024 https://indico.cern.ch/event/1453371/

<ID 0049> **Detector development and production, MPGDs or MWPC**

Contact Persons:

- Shikma Bressler, shikma.bressler@cern.ch
- Luca Moleri, luca.moleri@weizmann.ac.il
- Maryna Borysova, maryna.borysova@weizmann.ac.il

Collaborating Institutes & expertise/facilities:

- Weizmann Institute of science
  - MPGD & MWPC, R&D and mass production facility
- Institute 2
  - Expertise 2, facility 2
- Institute 3
  - Expertise 3, facility 3

Connections with DRDs:

- DRD1, WPx: …
- DRD6, WPy: …

Connections with Concept Groups:

- Engineering, Simulation studies with concept NN

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

<ID 0049> **Detector development and production, MPGDs or MWPC**

Planned activities for the next 3-5 years

- 2025: Compare performance of resistive MPGDs
  DLC based MWPC
- 2026:
- 2027:

Eye candy, prototype results, …

<For each merged EoI you may add one extra slide. >

References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

IDs 0016 & 0078 Timing RPCs for muon system

Contact Persons:

- PD Dr. Oliver Kortner, kortner@mppmu.mpg.de, Dr. Sandra Kortner sandra@mppmu.mpg.de
- Dr. Dayron Ramos Lopez, dayron.ramos@ba.infn.it
- Prof. Giuseppe Iaselli, giuseppe.iaselli@ba.infn.it

Presenter : Dayron Ramos (remote)

Collaborating Institutes & expertise/facilities:

- INFN and Politecnico Bari
  - Expertise on detector design, performance studies with eco-friendly mixtures
  - RPC laboratory
- Korea University and Hanyang University
  - Expertise in RPC production, testing and electrodes R&D
  - KODEL facility
- MPI
  - Expertise on design and construction of thin-gap RPCs
  - Expertise on designing a muon system and system integration
  - Expertise on eco-friendly gases
  - Expertise on read-out electronics for gaseous ionization detectors
- Laboratorio Nazionale di Frascati
  - Expertise in detector design, construction and testing
  - Large cleanroom class 100 with granite tables
- INFN Torino
  - Expertise in eco-friendly gases
  - RPC laboratory muon telescope

Connections with DRDs:

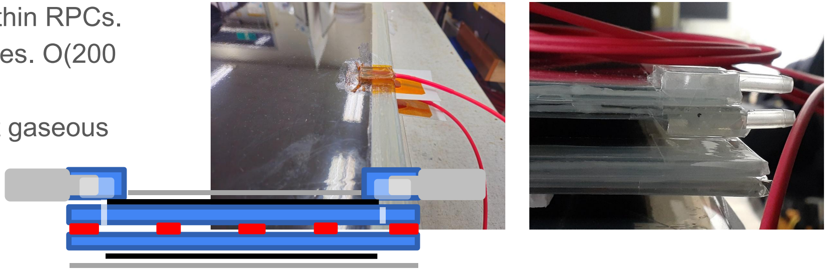
- DRD1, WP1: Large area muon systems (new structures, ecofriendly gaseous mixtures R&D)
- DRD1, WP7-project B: High rate, large, precise timing (M)RPC (large scale RPC for high timing performance)

IDs 0016 & 0078 Timing RPCs for muon system

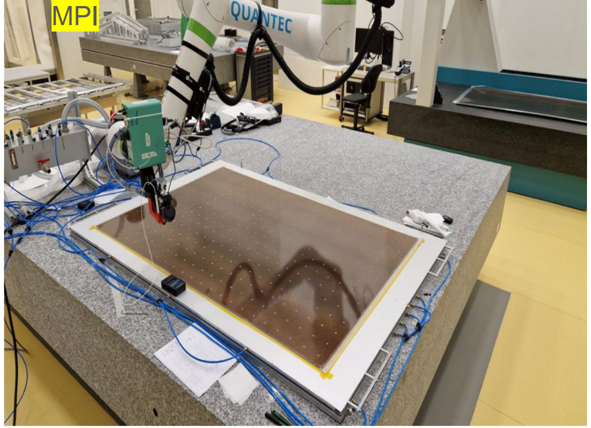
Planned activities for the next 3 years

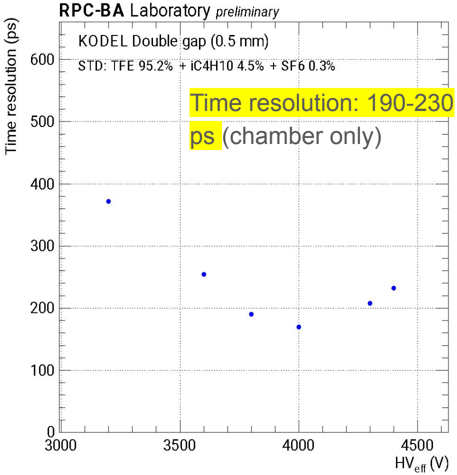
- 2025: Task 1: Study of several electrode materials and gap configurations for thin RPCs. Task 2: Preliminary test on small prototypes of thin RPCs for timing with time res. O(200 ps) and space res. 500 um.
- 2026: Task 3: Performance study operating the RPC with eco-friendly and fast gaseous mixtures.
- 2027: Task 4: Performance study on large scale RPC prototypes O(m^2)

thin gaps built in KODEL laboratory : 500um gap thickness, soda-lime glass electrodes 1.1 mm thickness

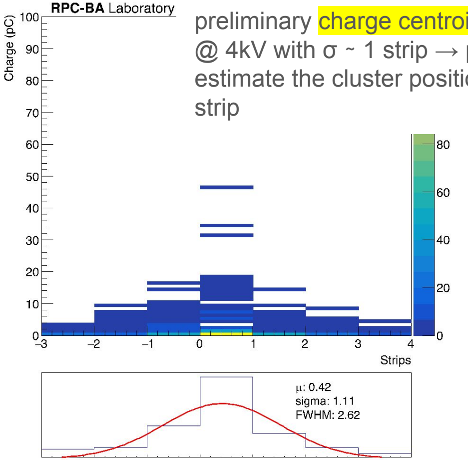


RPC production assembly table form MPI





Time resolution: 190-230 ps (chamber only)



preliminary charge centroid analysis @ 4kV with σ ~ 1 strip → possibility to estimate the cluster position inside the strip

ID0037: A Muon System with Square Drift Tubes and Scintillator Strips

Contact Persons:

- Junjie Zhu, junjie@umich.edu, Jianming Qiang, qianj@umich.edu, Bing Zhou, bzhou@umich.edu, Christian Herwig, herwig@umich.edu, Tom Schwarz, schwarzt@umich.edu
- Verena Martinez Qutschoom, vimartin@umass.edu
- Reinhard Schwienhorst, schwier@msu.edu,

Collaborating Institutes & expertise/facilities:

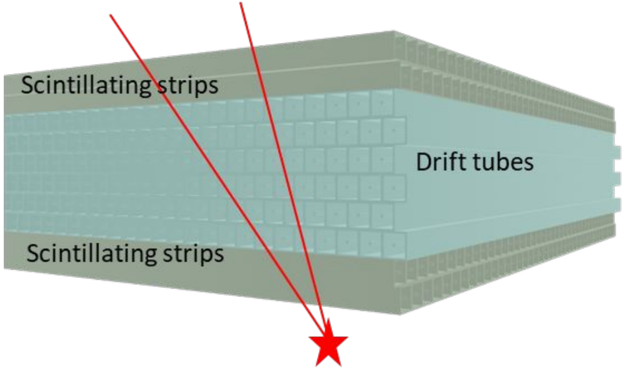
- Michigan State University
  - ATLAS sMDT tube construction and commissioning.
  - Clean room, mechanical shop, tier-2 and tier-3 computing clusters
- University of Michigan
  - ATLAS (s)MDT chamber design, construction, commissioning, integration, and operation
  - ASIC and FPGA design for ATLAS NSW and (s)MDT detectors
  - Clean room, granite table, mechanical and electronics shop, ASIC design software and license, tier-2 and tier-3 computing clusters
- UMass, Harvard, Tufts, UC Irvine
- Fermilab, SLAC, and Rome 1 on scintillator strips

Connections with DRDs:

- DRD1, WP2: Project A “Drift chamber for future collider experiments”

Connections with Concept Groups:

- Muon detector



An illustrative layout:

Multiple layers of drift tubes for bending-plane spatial measurements with a hit resolution of σ_{xy}~100μm

•Reconstruction of track segments,

•Reconstruction of decay vertices of long-lived particles

Scintillator strip layers for the z-coordinate and timing measurements with σ_z~1mm and σ_t~200ps

•Triggers & TOF information for massive stable particles…

Easily extended to 2-3 such layouts for independent momentum measurements

References: https://indico.slac.stanford.edu/event/9297/contributions/11148/attachments/4897/13185/Muon%20System-for-FCC-ee-SLAC-Dec19-2024.pptx

Ongoing and Planned Activities on Square Drift Tubes and Scintillator Strips

Simulations

- Garfield on the drift cell configurations, performance with drift gases and HV working points
- GEANT4 to study the muon detector configuration, muon tag (track matching with inner tracker), hadronic punch through rate, and capability of detection of LLP

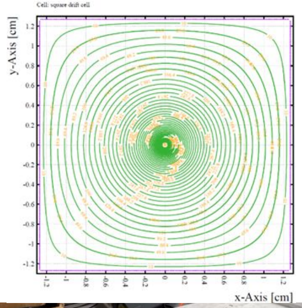
Gas studies with default ArCO2 gas

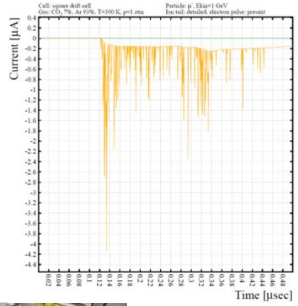
Drift tube chamber prototype and tests

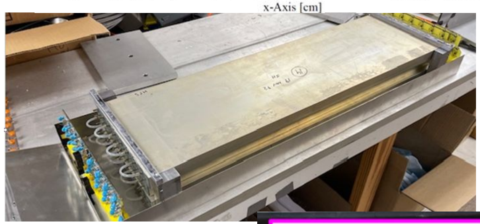
- Starting the prototypes with the existing drift tubes and with ATLAS MDT readout system
- Test the performance with cosmic rays and test beams using different gas mixtures

Scintillator strip prototype and readout with SiPM

- Build one-layer triangle shape scintillator strips (2 cm base size) with WLS
- Study the signal characterization and the performance (spatial and timing resolutions) using Hamamatsu SiPMs readout

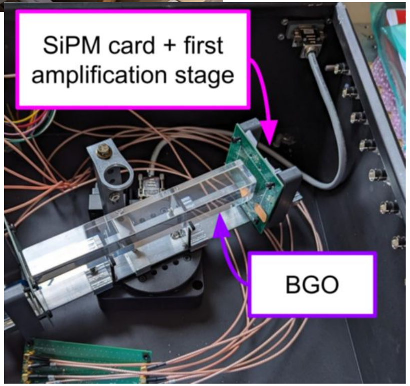






Collaboration with Fermilab, SLAC, and Rome 1

- Build a small scintillator strip prototype (2 cm base triangle strips) with SiPM readout to test the performance with cosmic rays and test beams
- Readout SiPM experience of the UM group in FCC-ee dual-readout R&D



References: https://indico.slac.stanford.edu/event/9297/contributions/11148/attachments/4897/13185/Muon%20System-for-FCC-ee-SLAC-Dec19-2024.pptx

Trigger/DAQ/Electronics

ID00017 TDAQ

Speaker: Davide Cieri (in person)

Merged with ID0046, ID0066, ID0068, ID0081, ID0092, ID0106, ID0058, ID0048, ID0082

Contact Persons:

- Contact persons for previous EoIs in spreadsheet

Collaborating Institutes & expertise/facilities:

- Germany: Max-Planck-Institute for Physics, Munich, Germany
- Switzerland: Université de Geneve
- US: SLAC, BNL, Indiana University, Florida Tech, Princeton, Boston U, Northwestern U, Cornell, U of Pitt, CMU, The Ohio State U, MIT, UC Irvine, SMU, Duke, FNAL, ANL, LBNL, Baylor U, U of Hawaii, U of Michigan
- UK: University of Birmingham

Experience with real-time electronics system (ATLAS/CMS online/offline trigger), FPGA development, electronics R&D, heterogeneous computing systems, DAQ

Connections with DRDs:

- DRD7
- DRDb, WPy: …

Connections with Concept Groups:

- All detector concepts

ID00017: TDAQ Architectures under evaluations

Interest in trigger and data acquisition for FCC. Real-time algorithm developments (including with ML). Heterogeneous computing.

We would like to explore feasibility of different (T)DAQ architectures and concepts and their impact on detector design and (T)DAQ technical implementation

- Triggerless
  - Readout every single bunch crossing at 50 MHz
  - Need reasonable estimate of beam background and total expected bandwidth
  - Data processing is handled offline (heterogeneous computing farm)
  - Novel DAQ technologies (SiPho, WDM VCSEL) for higher bandwidth, lower power consumption, and lower mass.
- Traditional Trigger
  - Dedicated hardware development required
  - Triggering at 200 kHz
  - Most probably on FPGA-based electronics
  - Alternative technologies (analogue electronics, AMs) must also be investigated
  - Can be a single- or multi-stage trigger, depending on the final output bandwidth

References:

- Steven Schramm: Ideas on getting started with FCCee TDAQ activities
- Davide Cieri: Concept of a first-level track trigger system for the FCC-ee

ID00017: TDAQ Ongoing activities and future R&D

- Dense wavelength division multiplexing VCSELs - fiber-optical data links
- Wavelength Division Multiplexing Silicon Photonics data links
- Wireless data links for trackers (See ID0065)
- Rad-hard commercial FPGAs for detector readout and on-detector triggering
- Emerging heterogeneous computing and Edge ML
- Embedded FPGAs (See ID0045)
- On-detector analog compute
- Autonomous TDAQ with AI/ML
- ML in FE electronics and DAQ using FPGAs
- Dataflow and data processing simulations
- Data Compression on different hardware platforms (CPU vs FPGAs)
- Real-time algorithm developments (traditional and ML-based)

ID0065: Develop ASIC for wireless communication in the vertex detector

Contact Persons:

- K.K. Gan, gan.1@osu.edu
- Bora Tar, tar.2@osu.edu

Collaborating Institutes & expertise/facilities:

- The Ohio State University: Department of Physics
  - Previously worked on high-speed/rad-hard optical links for ATLAS Pixel detector
  - Clean room with automatic wire bonders/probe stations/environmental chambers
- The Ohio State University: ElectroScience Laboratory
  - Shane Smith et al.
  - RF design

Connections with DRDs:

- DRD7, WP7.1c

Connections with Concept Groups:

- Vertex detector of all detector concepts

ID0065: Develop ASIC for wireless communication in the vertex detector

Developing a sophisticated 60 GHz wireless transmitter designed for high-radiation environments, targeting a data rate of 10 Gbps over a propagation distance of 30 cm.

- 2025: Proof-of-Concept and Design of ASIC 1
    - Validate design concepts in MATLAB environment.
    - Develop a proof-of-concept using off-the-shelf components to evaluate feasibility and basic functionality.
    - Design key circuit blocks:
        - Voltage-controlled oscillator (VCO) for generating the 60 GHz signal.
        - Basic modulator, phase-locked loop, power amplifier.
    - Perform simulation-based evaluations of system-level integration for 10 Gbps data rates.
- 2026: Advanced Prototyping and Initial Testing
    - Tape-out and test the first prototype ASIC 1
    - Evaluate the performance under simulated environmental conditions:
        - Integrate a miniature high-gain directional antenna and optimize for beamforming capabilities.
        - Short-range propagation effects, atmospheric absorption at 60 GHz.
    - Design of ASIC 2:
        - Improved VCO and phase-locked loop (PLL) for frequency stability.
        - Advanced modulation techniques such as on-off keying (OOK) or QPSK for simplicity and performance balance.

ID0065: Develop ASIC for wireless communication in the vertex detector

Developing a sophisticated 60 GHz wireless transmitter designed for high-radiation environments, targeting a data rate of 10 Gbps over a propagation distance of 30 cm.

- 2027: Development and Testing of ASIC 2, Planning of ASIC 3
  - Tape-out and test ASIC 2:
    - BER performance over 30 cm.
    - Thermal and power consumption analysis under load.
  - Begin planning and designing ASIC 3, focusing on full system integration and performance optimization.
- 2028: Finalization of ASIC 3 and Comprehensive Testing
  - Develop and tape-out ASIC 3:
    - Integrate all components into a cohesive, high-performance system.
    - Optimize for high spectral efficiency to maximize data throughput within the allocated bandwidth.
    - Enhance directivity to minimize crosstalk.
  - Conduct comprehensive testing:
    - Validate system performance against project targets (30 cm, 10 Gbps).
    - Test radiation hardness and environmental resilience.
    - Measure spectral efficiency under operational conditions to ensure high data rates and efficient bandwidth usage.
    - Test directivity and assess crosstalk reduction in side-by-side deployments, ensuring minimal signal leakage.
  - Prepare detailed documentation for potential commercialization or further deployment.

ID 0103 **Wireless communications within the vertex detector**

Contact Persons:

- Ben Kilminster, ben.kilminster@physik.uzh.chl
- Teddy Loeliger, teddy.loeliger@zhaw.ch

Collaborating Institutes & expertise/facilities:

- University of Zurich
  - Vertex detector R&D / construction (CMS phase-0/1/2, FCC-ee)
- Zurich University of Applied Sciences
  - Applied R&D in ensor electronics and wireless communications

Connections with DRDs:

- DRD3, WP1, DRDT 3.2: Monolithic CMOS sensors (monolithic integration into DMAPS sensors …)
- DRD7, WP7.1c: Wireless Data And Power Transmission (WADAPT)

Connections with Concept Groups:

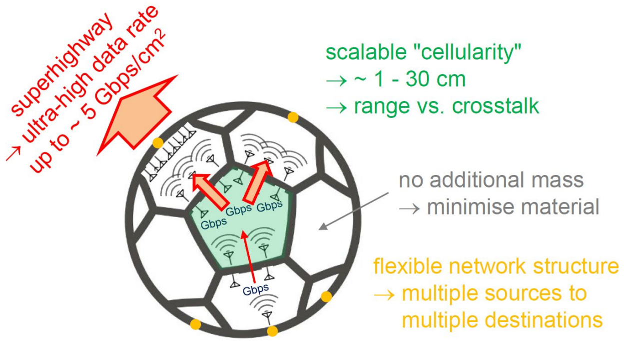
- Engineering/Simulation studies with vertex detector concept

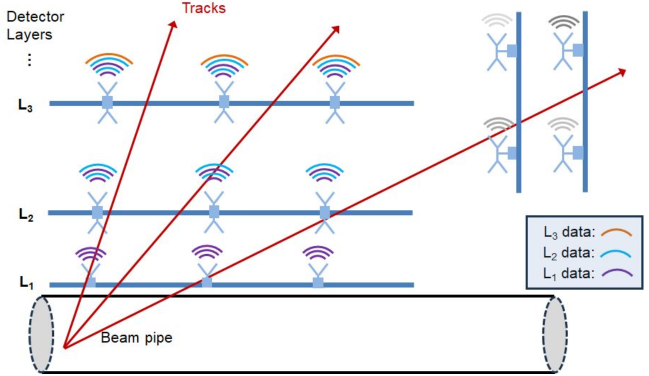
References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

ID 0103 **Wireless communications within the vertex detector**

Planned activities for the next 3-5 years

- **2026**: COTS devices wireless links:
  - Commercial-off-the-shelf (COTS) short-range millimeter-wave wireless transceiver ICs (at 60 GHz)
  - Implementation of wireless links
- **2027**: Multi-Gbps wireless data transmission channel:
  - Prototype implementation of wireless transmission channel in vertex environment based on COTS devices
  - Implementation of advanced antenna designs
  - Full performance characterization of wireless links
- **2028**: Wireless links with increased data rate density:
  - Concepts for increased spectral efficiency
  - Simulations of advanced wireless transceivers
- **2029**: Wireless superhighway:
  - Prototype implementation of scalable wireless superhighway cells for vertex detectors
  - Exploration of maximum scalability (incl. data rate, range, power consumption, and link density)
  - Full performance characterization and conclusion on reduction potential in mass of material and power budget





References: [1]: A detailed write up of technology A, NIM-A, vvv, pppp, 2024; [2]: A detailed write up of technology B, JINST, vv, ii, 2021; [3]: Our EoI draft in overleaf <link>

ID0045: Embedded FPGAs for ML-based Readout

Speaker: Sagar Addepalli (in person)

Embedded FPGAs offer reconfigurable digital logic in an ASIC, enabling **machine learning** for low-latency/low-power applications. We aim to explore eFPGA applications to FCCee, from front-end readout to common electronics and hardware accelerators.

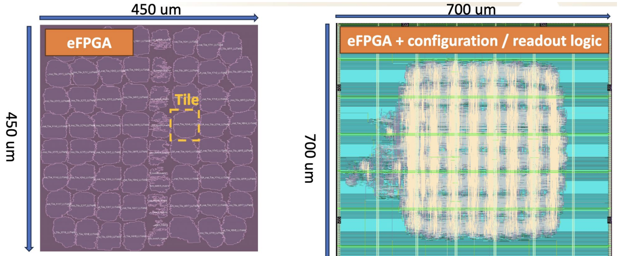
Contact Persons: Julia Gonski, jgonski@slac.stanford.edu

Collaborating Institutes & expertise/facilities:

- SLAC
  - JG, Rainer Bartoldus (physics), Ryan Herbst, Hyunjoon Kim, Larry Ruckman (instrumentation/engineering/chip design)
  - Past work: 2404.17701
- LBNL
  - Carl Grace, Jyothisraj Johnson
  - Past work: 2404.14436
- Fermilab: Jim Hoff, Neha Kharwadkar
- U.S.: Baylor University, University of Michigan, University of Hawaii
- Swiss (ID0105): University of Zurich, Zurich University of Applied Sciences
  - Ben Kilminster, Anna Macchiolo, Armin Ilg, Vagelis Gkougkousis
  - Expertise on vertex detector design & construction (CMS phase-0/1/2, FCC-ee curved sensors)

Connections with DRDs:

- DRD7
- US Higgs Factory Coordinating Consortium (AI, Integration, & Microelectronics)
- US CPAD RDC4
- DRD3 OCTOPUS



eFPGA consists of:
- Array of 8x8 tiles (scalable & configurable)
- Switch matrix

Connections with Concept Groups:

- Presentation at IDEA Study Group, 19 Nov 2024

ID0045: Embedded FPGAs for ML-based Readout

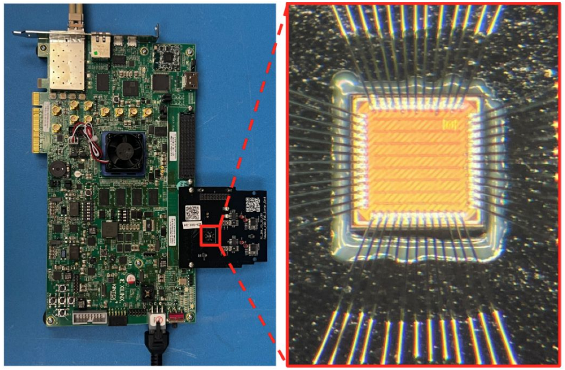
So far:

- Taped out small (<500 LUTs) prototype eFGPAs (130nm and 28nm) with open-source FABulous framework
- Proof-of-concept pileup regression BDT configured to 28nm eFPGA, 100% operational accuracy w.r.t. quantized software result!

Planned activities for the next 3-5 years

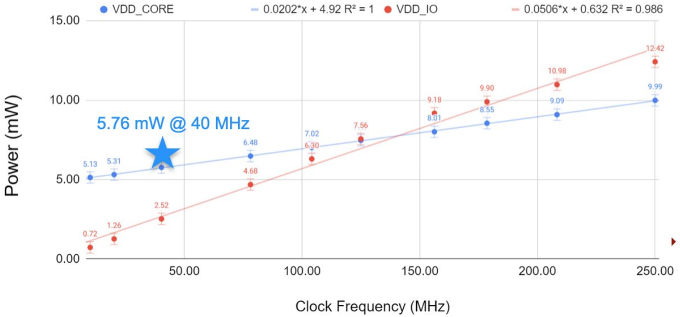
- **2025:** Physics studies exploring ML-based front-end readout across FCC subdetectors:
  - Discussions with dual readout, drift chambers, liquid argon, high granularity sampling silicon calorimeters, & more
- **2026**: Tape out larger eFPGA for more complex algorithms, hardware verification, and power studies
- **2027**: Implement radiation-hardness and/or cryogenic tolerance at design level
- **2028**: Hope to deliver eFPGAs as a viable readout technology for future Higgs factory detector designs!
- **2025-2028:** Swiss groups: Explore application for data reduction and algorithms in vertex detectors using LHC data, understanding constraints on ultra-light FCC vertex detector design, connection to curved sensors

Looking for collaborators: please get in touch!



28nm eFPGA prototype @ SLAC

2404.17701



‣ Area: 1 mm^2

Algorithms (including AI)

ID0050: Machine Learning for Particle Flow

Contact Persons:

- Michael Kagan, makagan@slac.stanford.edu
- Ariel Schwartzman, sch@slac.stanford.edu
- Javier Duarte, javier.m.g.duarte@gmail.com
- Joosep Pata, joosep.pata@cern.ch
- Lukas Heinrich, l.heinrich@tum.de
- Tobias Golling, tobias.golling@unige.ch
- Anna Sfyrla, anna.sfyrla@unige.ch
- Maurizio Pierini, maurizio.pierini@cern.ch
- Maria Girone, maria.girone@cern.ch

Collaborating Institutes & expertise/facilities:

- SLAC – ML for particle reconstruction and b-tagging, foundation models
- UCSD – Developer of MLPF algorithm [1]
- KBFI / NICBP – Developer of MLPF algorithm [1]
- TUM – Developer of HGFlow algorithm [2], foundation models
- UniGe – ML for b-tagging, foundation models, heterogeneous computing
- CERN – Developer of MLPF algorithm [1], heterogeneous computing

Connections with DRDs:

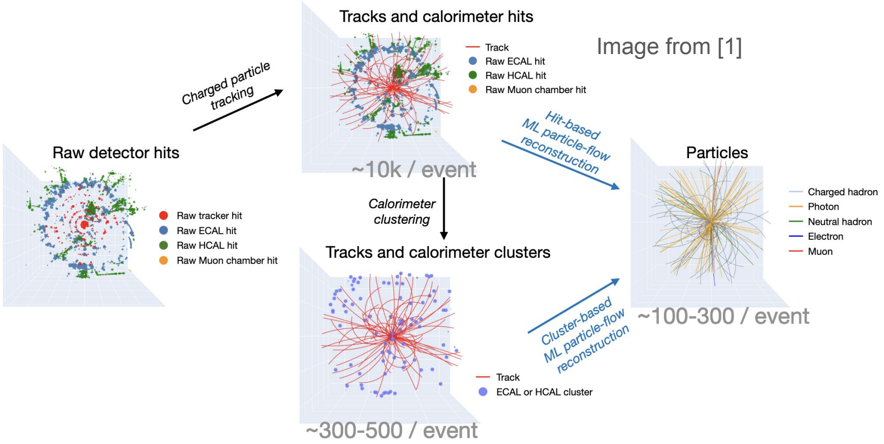
- Is there a clear place for reconstruction in DRDs?

Connections with Concept Groups:

- First works [1] used CLICDet, working now on CLD, and other concepts in future

Planned activities for the next 3-5 years

- Algorithm development and adaptation to FCC data,
- Examining necessary changes for different detector types
- Examining heterogeneous computing for running ML+Pflow
- Develop end-to-end reconstruction prototype
- Use for performance estimation to aid design optimization



Recent Work References: [1]: Comm. Phys. 7, 124 (2024); [2]: 2410.23236;

Speaker In-Person: M. Kagan

ID0051: AI Aided Detector Design Optimization

Contact Persons:

- Michael Kagan, makagan@slac.stanford.edu
- Lukas Heinrich, l.heinrich@tum.de
- Tobias Golling, tobias.golling@unige.ch

Collaborating Institutes & expertise/facilities:

- SLAC
  - Surrogate-based optimization and trust-region optimization [1], differentiable programming and differentiable GEANT[2][3]
- TUM
  - Differentiable programming and differentiable GEANT [2][3]
- UniGe
  - Surrogate-based optimization

Connections with DRDs:

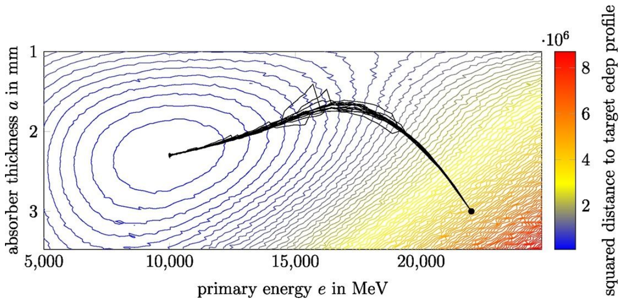
- DRD8, e.g. WP1 and WP4

Connections with Concept Groups:

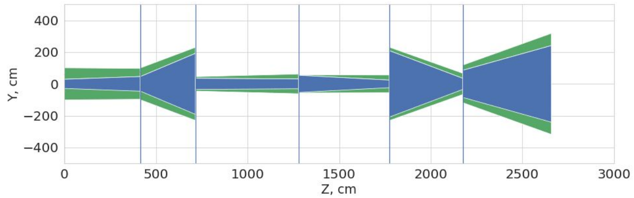
- MODE Collaboration - https://mode-collaboration.github.io/
- EuCAIF - https://eucaif.org/

Planned activities for the next 3-5 years

- Develop differentiable simulations and surrogate based methods
- Develop optimization methods & applications to geometry design
- Tooling development
- Application in collaboration with detector groups



Calo Design w/ differentiable Geant [2]



Magnet Design w/ local surrogates [1]

References: [1]: NeurIPS 2020 ; [2]: 2308.16680 ; [3]: Comp. Phys. Comm. 2024

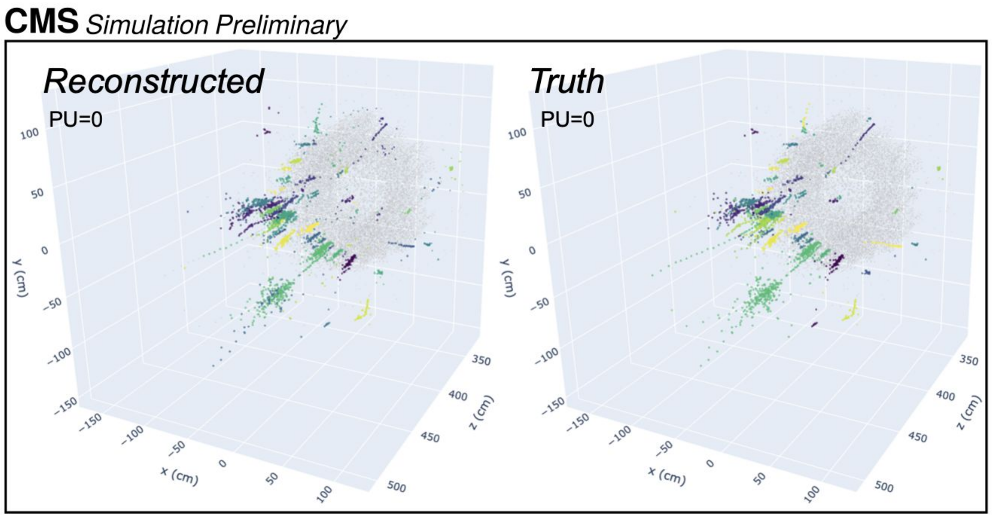
Machine Learning for shower reconstruction in granular calorimeters

Contact person:

- Saptaparna Bhattacharya
- New team of students and postdocs from the Bhattacharya group at SMU
- Reaching out to additional groups (for example, Fermilab)

Outline of project:

- Use GEANT-based model of the CLD detector (specifically the granular calorimeter) to study particle showers using GNNs and/or other ML-based algorithms
- Project is based on similar work at the LHC, specifically for the High Granularity Calorimeter (HGCAL) that will be installed in the upgraded version of the CMS detector for the HL-LHC
- Proof of principle in place
- Students and postdocs will train on the CLD dataset, quantify the improvement in shower reconstruction in terms of physics driven metrics



Proof of principle with the HGCAL: A slew of particles produced by the hadronic decay of τ leptons in the HGCAL. The simulation of the shower is shown in the right plot, while the plot on the left shows the signal hits as identified by a GNN. Clusters predicted by the algorithm (left) that overlap with the truth (right) are represented by the same colors. Almost all signal hits are identified by the algorithm in an environment full of noisy hits, shown here as the diffused gray band. Ref: S. Bhattacharya, L. Gray et al. GNN-based end-to-end reconstruction in the CMS Phase 2 High- Granularity Calorimeter. *J. Phys. Conf. Ser.*, 2438(1):012090, 2023.

Software

ID0025 MC Simulation & Theory systematics

Contact Persons:

- Max Knobbe, mknobbe@fnal.gov
- Frank Krauss, frank.krauss@durham.ac.uk
- Steffen Schumann, steffen.schumann@phys.uni-goettingen.de
- Federico Silvetti, federico.silvetti@durham.ac.uk
- Stefan Höche, shoeche@fnal.gov

Collaborating Institutes & expertise/facilities:

- Durham U
    - Non-perturbative models & uncertainty assessment
- FNAL & Göttingen
    - Precision parton-showers & interface to hadronization

Connections with DRDs:

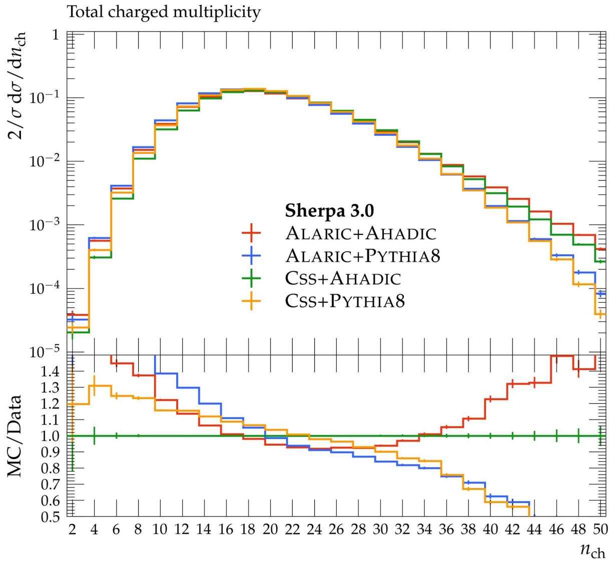
- N/A

Connections with Concept Groups:

- TBD

Planned activities for the next years

- 2025: Assessment of uncertainties in present physics models
- 2025+: Higher-precision pQCD computations,
  Improved npQCD models, OTF uncertainties



References: N/A

ID0029 Comp. inf., framework, sim, algos, analysis tools

Contact Persons:

- Lothar Bauerdick, bauerdick@fnal.gov
- Daniel Elvira, daniel@fnal.gov
- Lindsey Gray, lagray@fnal.gov

Collaborating Institutes & expertise/facilities:

- FNAL
  - Large data processing center, heterogeneous computing (co-processors), , storage, Artificial Intelligence, experiment frameworks, physics generators, detector simulation, end-analysis tools
- OSG, HSF
  - Institutions in the context of the Open Science Grid and the HEP Software Foundations
- CCE, IRIS-HEP
  - Institutions in the context of the DOE Center for Computational Excellence and the NSF Institute for Research and Innovation in Software for HEP

Connections with DRDs:

- N/A

Connections with Concept Groups:

- S&C infrastructure is essential to the work of Concept Groups (facilities, framework, simulation and analysis tools). Detector simulation implementation and reconstruction algorithms are direct contributions to the detector concept groups.

References: Talks

Planned activities for the next 3-5 years

- Maintain local computing infrastructure, including the analysis facility, and user support
- Contributions to the improvement of software frameworks (Key4Hep ecosystem), concurrency/multithreading capabilities, enabling co-processors (e.g., GPUs)
- Adaptation of columnar-based user analysis framework
- Generator interfaces, simulation implementations reconstruction in the context of detector benchmarks

Machine Detector Interface

ID0030 Beam Induced Background Simulations

Contact Persons:

- Lindsey Gray, lagray@fnal.gov
- Caterina Vernieri, caterina@slac.stanford.edu
- Loukas Gouskos, loukas_gouskos@brown.edu

Collaborating Institutes & expertise/facilities:

- FNAL
  - PIC codes, hadron photoproduction, GEANT, FNAL computing facilities
- SLAC
  - PIC codes, hadron photoproduction, GEANT, SLAC computing facilities
- Brown
  - B-tagging and vertex reconstruction expertise
- MIT
  - B-physics and two-photon background expertise, subMIT computing facility

Connections with DRDs:

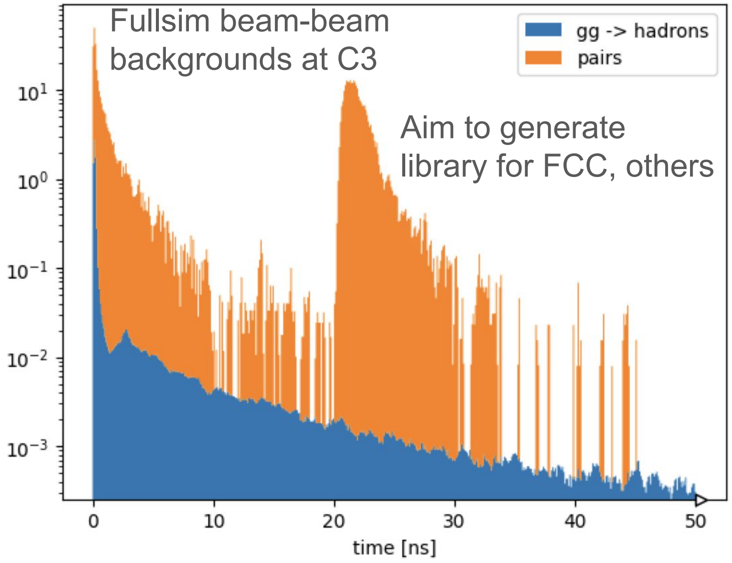
- Will eventually work with DRD8 since these backgrounds affect data rate

Connections with Concept Groups:

- Simulation studies need close contact with accelerator design and Vertex Detector

Planned activities for the next 3-5 years

- 2025: Develop background generation workflows for FCC to produce event libraries
- 2026: Help detector groups estimate occupancy/physics impact
- 2027: Generate fully-mixed samples



References: Talks

ID0088 Interaction Region Elements and Integration

Contact Persons:

- Manuela Boscolo, manuela.boscolo@lnf.infn.it
- Fabrizio Palla, fabrizio.palla@pi.infn.it
- John Seeman, seeman@slac.stanford.edu

Presenter : M. Boscolo (in-person, after 11am)

Collaborating Institutes & expertise/facilities:

- INFN
- BNL
- SLAC

Connections with DRDs:

- DRD8, WP1.1 (The vertex Region of Future Particle Physics Experiments)

Connections with Concept Groups:

- ALLEGRO, IDEA

References: [1]: M. Boscolo, F. Palla et al., “Mechanical model for the FCC-ee interaction region”, EPJ Techn. And Instrum.10:16, https://doi.org/10.1140/epjti/s40485-023-00103-7 , 2023; [2]: M. Boscolo, H. Burkhardt, K. Oide, M.K. Sullivan, “IR challenges and the machine detector interface at FCC-ee”, EPJ Plus 136:1068 , https://doi.org/10.1140/epjti/s40485-023-00103-7, 2021.

ID0088 Interaction Region Elements and Integration

Planned activities for the next 3-5 years

Under discussion

- Task1 Direct-wind IR SC corrector magnet designs (BNL, …)
- Task 2 IR cryostat design and splice boxes (SLAC, BNL,…)
- Task3 IR mock-up (Frascati, CERN)
- Task 4 IR HOM calculation and design (SLAC)
- Task 5 Beam Induced backgrounds (INFN, CERN, …)
- Task 6 Anti-solenoid (e.g. screening and if needed compensation solenoid) design (BNL, …)
- Task 7 Cryostat supports (tbd, BNL, …)
- Task 8 Detector end cap movement (tbd)
- Task 9 Q1/Q2 vacuum chamber design (tbd)
- Task 10 IR accelerator diagnostic package (tbd)

To be noted the "singularity" of this EoI:
mostly accelerator-related, but with strong connection with detector, namely for the beam backgrounds studies and for the machine-detector-integration studies (supports, assembly, opening scenarios, …).