Spanish detector R&D: strategic areas of expertise for the Higgs factory

CPAN days, Future accelerators network

Valencia, Nov. 2025

Iván Vila Álvarez
Instituto de Física de Cantabria (CSIC-UC)

Instituto de Física de Cantabria

CSIC Consejo Superior de Investigaciones Científicas

UC Universidad de Cantabria

Captatio benevolentiae

- In this talk, I will simply recall a (non-comprehensive) list of the Spanish groups' areas of expertise.
- Please do not expect updated activities — the time given for preparation was too short..

Scope of the talk:

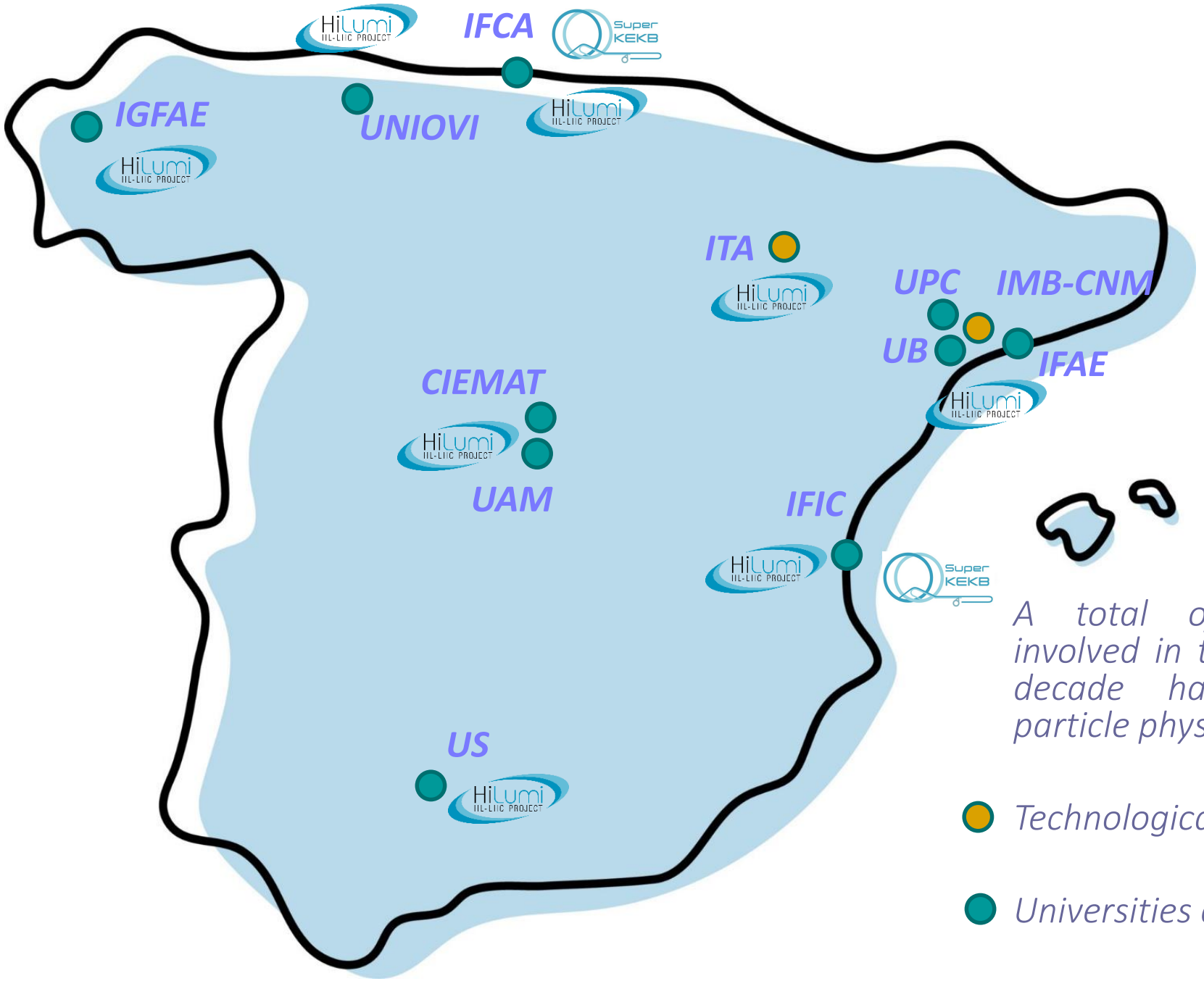
– To provide an overview of the recent activities of the Spanish Particle Physics community in the development of collider experiments, focusing on current R&D efforts for a possible electron-positron collider (Higgs factory).

– To use this a introduction for a discussion on the role of the Spanish groups in the study of the preferred future experiment by the European Strategy Update?

Outline

- Introduction to the Spanish (known) community.
- Instrumentation R&D activities suitable for FCC-ee experiments, assuming also valid for linear e+e- colliders (no really true, but first order correct).
- Discussion

Experiment Builders in Spain



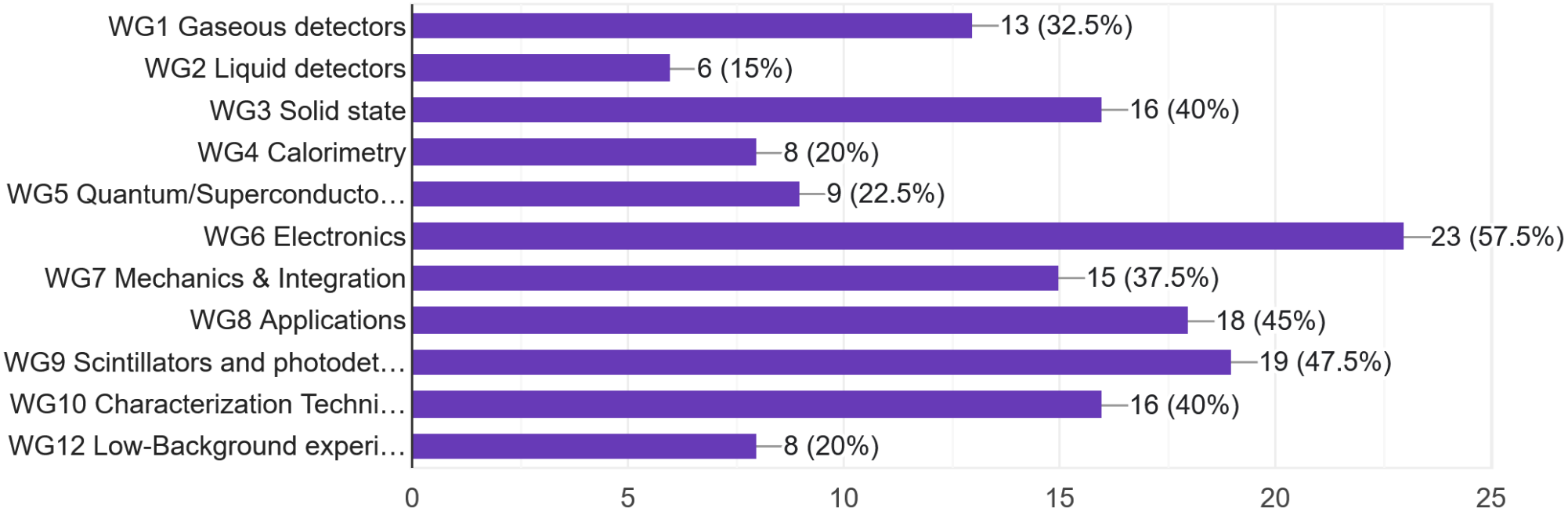
A total of eleven institutions involved in the construction of this decade hadronic and leptonic particle physics colliders

- *Technological centers*
- *Universities and Research Institutes*

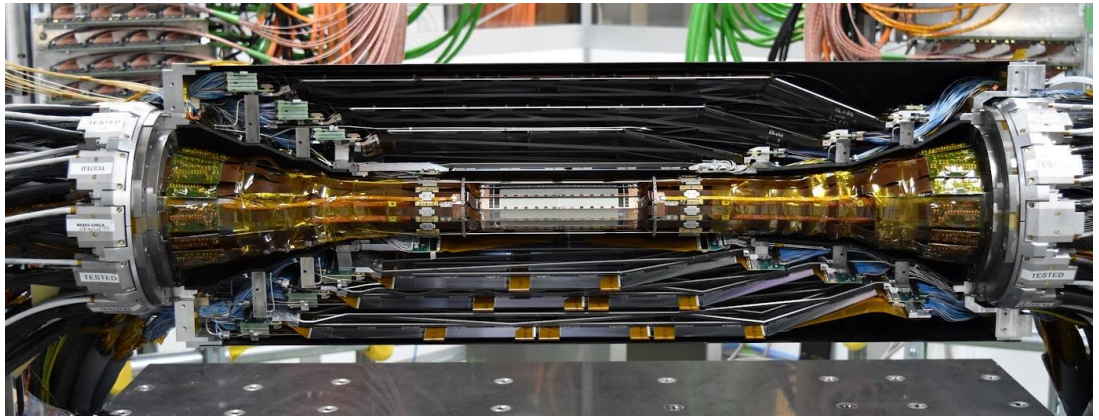
Is there a strategic area of expertise?

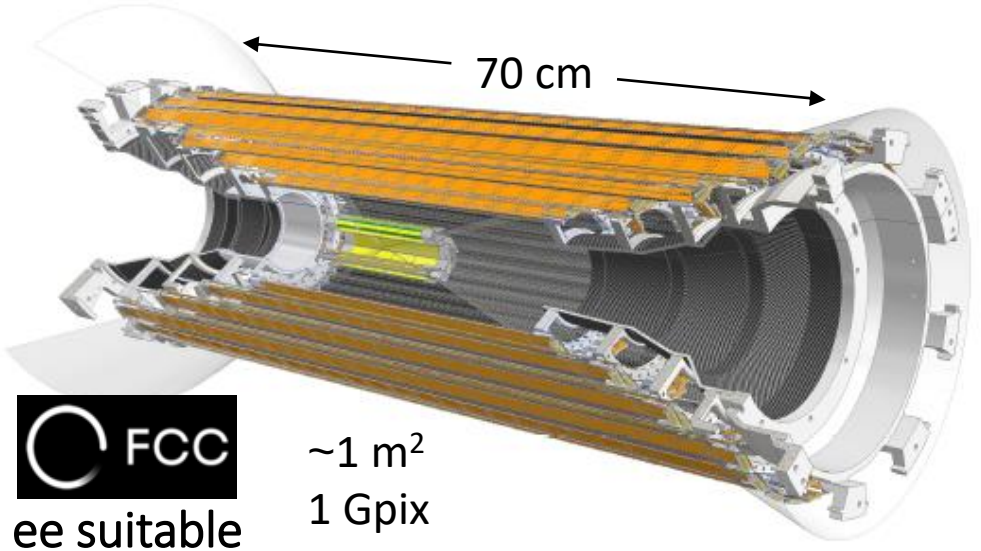
Please select the related CNID Working Groups related with your group activities (select as many as necessary)

40 responses



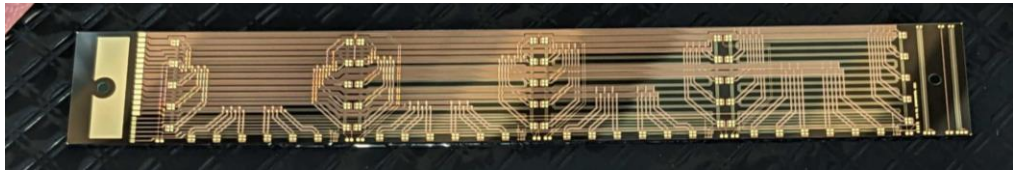
Vertex detectors - present
High-resolution monolithic pixels: DEPFET & DMAPS





FCC ee suitable

~1 m^2
1 Gpix



- Belle II PXD (evolving into VTX-CMOS) at KEK
- Belle II technical coordinator, upgrade coordinator, VTX project leader, deputy run manager
- Belle II VTX Upgrade (KEK, Japan):
  - 1 m2 Depleted CMOS pixels
- Digital design, wafer postprocessing, characterization, integration

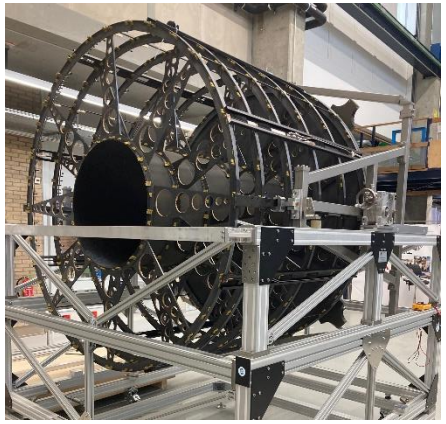
Key sensor specifications:

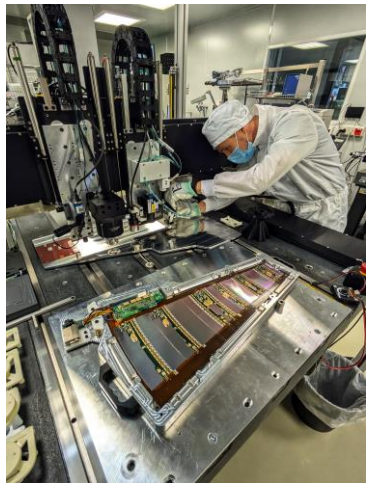
- Pixel pitch 30-40 µm
- Integration time ≲100 ns
- Radiation tolerance: 100 Mrad, 5x10^{14} n_{eq}/cm^2
- Power dissipation ≲ 200 mW/cm^2

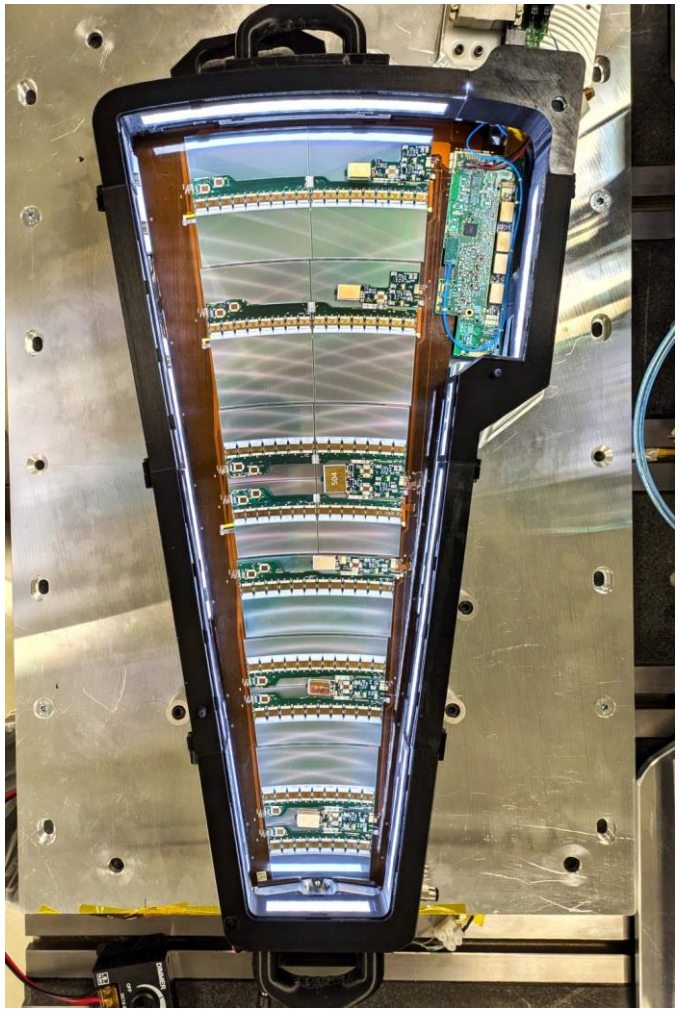
Tracking detectors - present
Tracker systems: rad-hard n-in-p strip sensors

FCC
hh suitable

FCC
ee suitable







ATLAS EXPERIMENT

IFIC INSTITUT DE FÍSICA CORPUSCULAR

CNM Centro Nacional de Microelectrónica CSIC

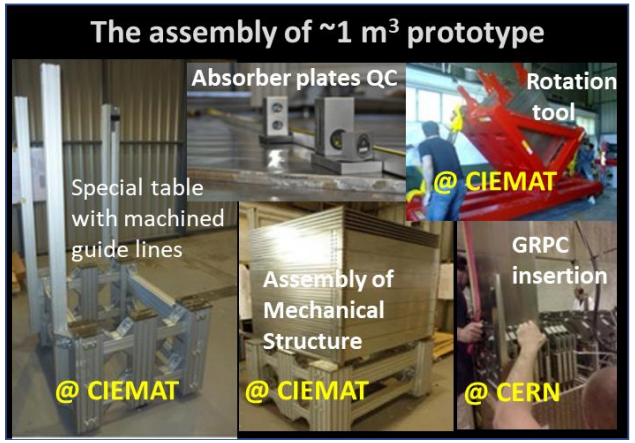
- ATLAS ITk: 100 m2 Silicon strip sensors
- Involved from early R&D stages all the way down to system development, integration, commissioning and data taking
- Main positions held: ATLAS ITK-Strips deputy project leader, Level 3 coordinators (sensors, integration, production management, services, supports)
- At IFIC Material engineering, interconnections, system integration, module manufacturing, QA/QC.

Calorimeters – present

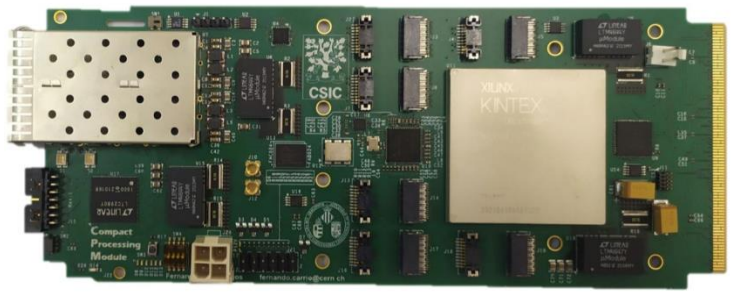
Highly segmented imaging calorimeters.

ee suitable

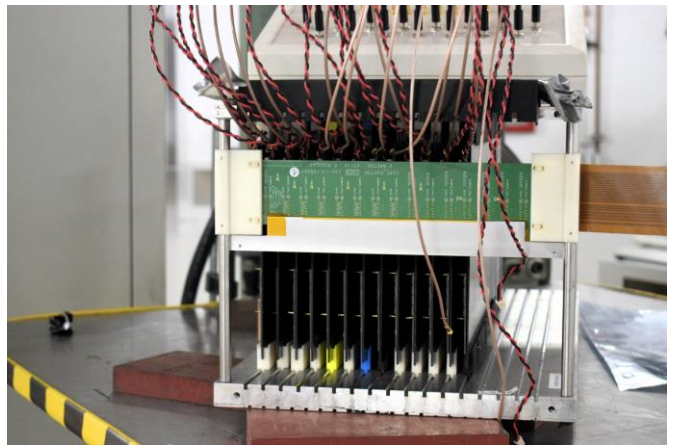
SDHCAL



Hadronic TiCAL



SiW ECAL

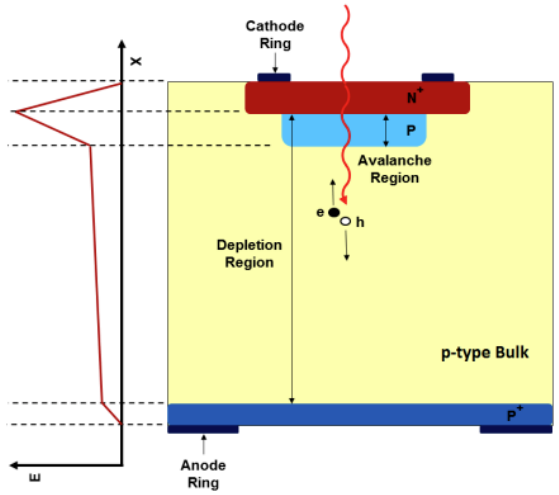


- Detector: GRPC, Absorber: Stainless Steel. Embedded electronics: 1x1 cm2 pads. Semi-Digital Readout, 2bits - 3 thresholdsR&D.
- high precision mechanics (tolerances 50μm, deformations<500μm)

- 32 PreProcessor boards in ATCA format.
- Interface between on-detector electronics and the trigger and data acquisition system
- Online energy reconstruction of the calorimeter cells at 40 MHz

- Sampling calorimeter that uses silicon (Si) as active material and tungsten (W) as absorber material.
- Main role in the commissioning of the SiW-ECAL prototype for beam tests .

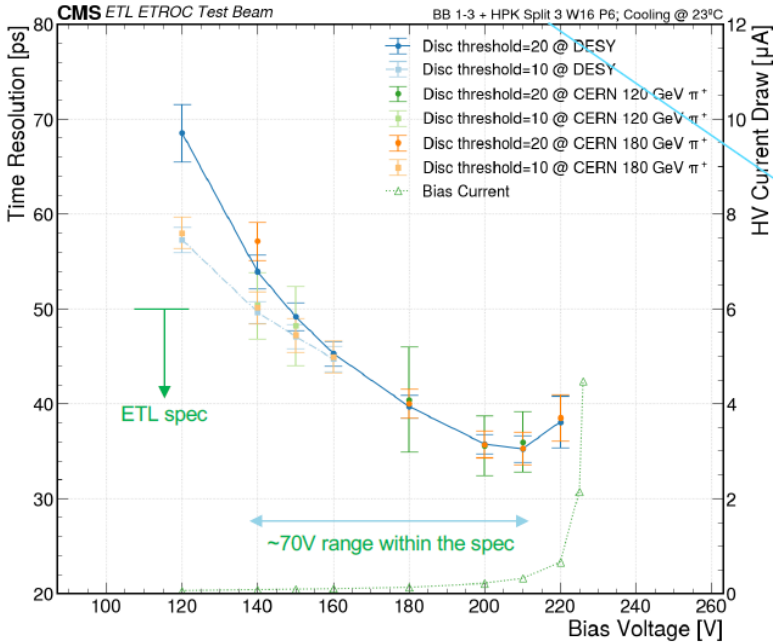
Timing detectors - present
Internal Gain : LGAD sensors



hh suitable

ee suitable

Centro Nacional de Microelectrónica CSIC



ATLAS EXPERIMENT

IFAE

- Contribution to the R&D of LGAD sensors
- Assembly of modules of the HGTD and hybridization.
- Coordination HGTD detector.

CMS

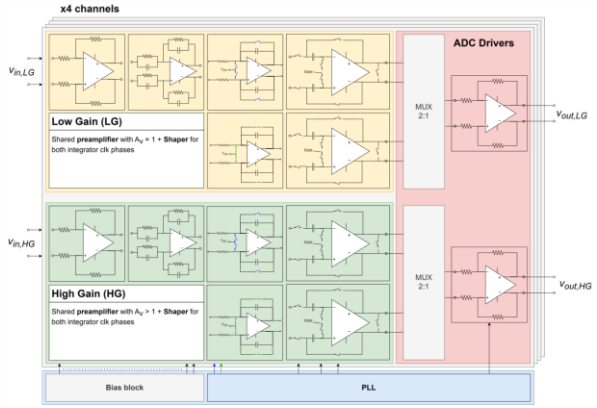
IFCA Instituto de Física de Cantabria

- Contribution to the R&D of LGAD sensors.
- Assembly 900 modules of the Endcap Timing Layer: Automated procedure using SCARA robot, artificial vision for dynamic alignment of components, integrated control of camera, robot arm and vacuum lines
- Coordinators of the Data Performance Group of the MTD : Integration of the MTD in the general CMS tracking

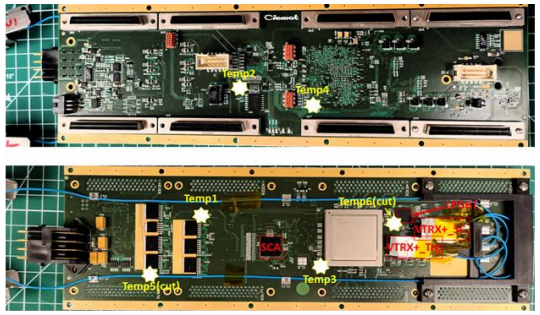
Front-End, Back-End Electronics, DAQ and triggering

ee suitable

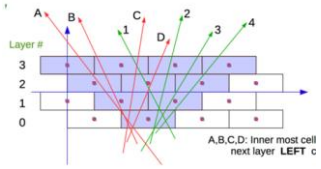
hh suitable

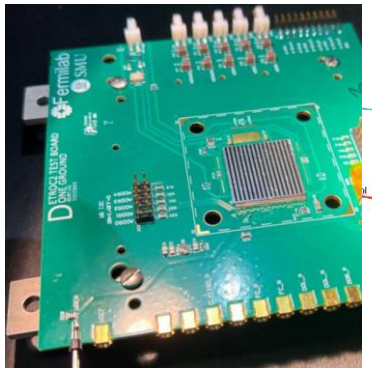


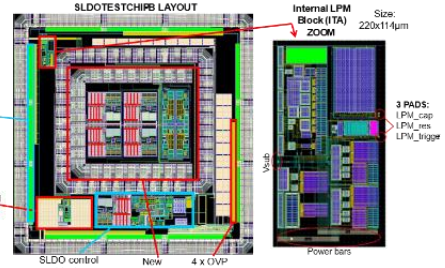
PicoCal ASIC for LHCb ECAL



OBDTtheta :
DT Frontend TDC&Readout







RD53A

- ASIC/chipset in TSMC 65 nm with separate energy and timing processing paths.
- Energy ASIC designed by the UB in collaboration with the UPC and the IFIC.

- DT Frontend TDC & Readout using radiation tolerant flash-based FPGA
- Trigger and Readout back-endo n BMTL1 ATCA board Exploring advanced ML / AI based algorithm for muon reconstruction in CMS.

ASIC design & testing - RD53 A/B & CROC for CMS IT (Low power mode circuit, PoR)
Initial Characterization of the ETROC2 ASIC for the ETL timing detector

Vertex/Tracking detectors - Strategic R&D
Hybrid sensors for 4D-tracking

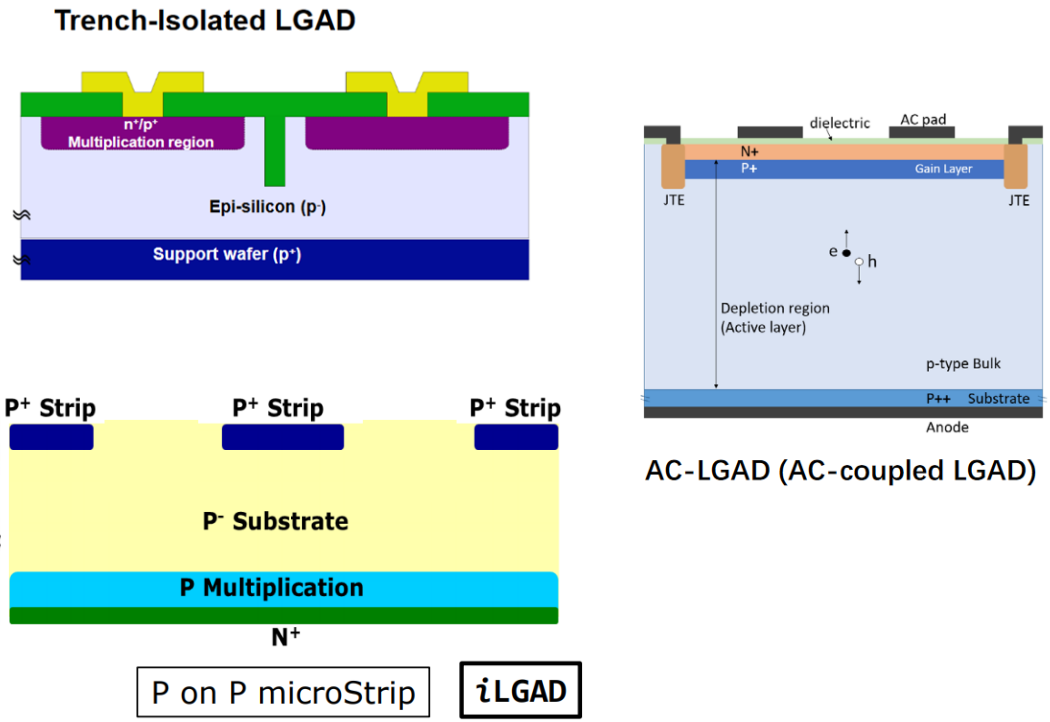
FCC hh suitable

FCC ee suitable

DRD3

IFCA

– Towards 100% fill factor, small pixel LGADs (many compiting options)



– Dedicated project in preparation in WG2 of DRD3

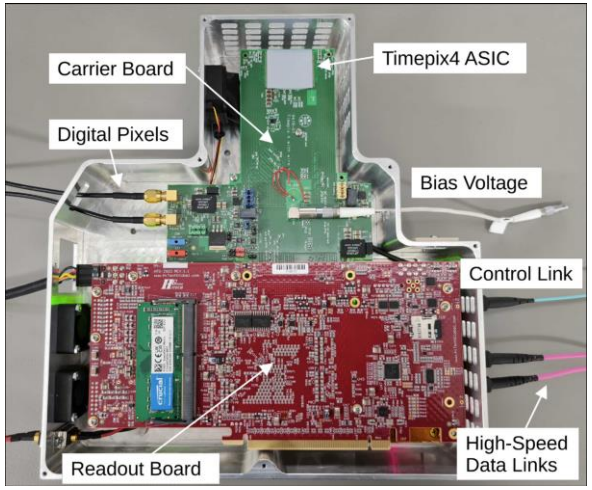
IFIC Instituto de Física Corpuscular

CNM Centro Nacional de Microelectrónica CSIC

IGFAE Instituto Galego de Física de Altas Enerxías

ITAINNOVA Instituto Tecnológico de Aragón

IFCA Instituto de Física de Cantabria

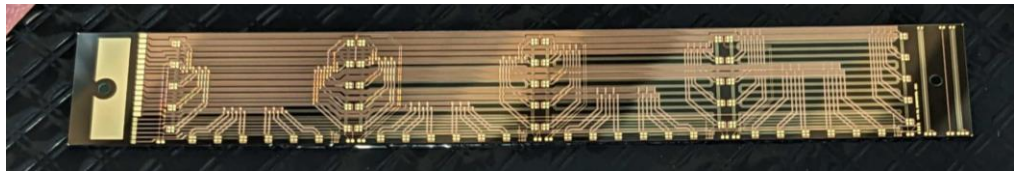


Hybrid design requires ASIC with high-precisión time stamping and positon resolution (TIMEPIX4)

Vertex/Tracking detectors - Strategic R&D Depleted MAPS

ee suitable

Belle II VTX upgrade a stepping stone toward FCCee vertex detector.



High hit efficiency at large hit rate:

- Spatial resolution < 15 µm
- Temporal resolution < 100 ns
- Max. hit rate 120 MHz/cm^2

Material budget:

- 0.2% X_0 (L1+L2), 0.3% - 0.8% X_0 (L3, L5)

Demonstrator building as part of DRD3 WG2 project

- IFAE working on DMAPS design, fabrication and characterization since 2014
  - **CEPC vertex detector** will use monolithic devices, total area ~0.5 m2, resolution 3-5 µm, power 40 mW/cm2, low material
- IFAE worked on the design and characterization of the first and second DMAPS prototypes:
  - TaichuPix1 and Taichupix2
  - Pixel size: 25x25 µm2, matrix: 64x192, hit driven readout
- IFAE plans to continue to work on DMAPS and other novel silicon technologies for future colliders in the context of the DRD3
- IFAE is organizing next CEPC Workshop in Barcelona (May 5th-8th 2025)

Calorimeters - Strategic R&D
5D - Calorimetry

DRD1 & DRD6

FCC ee suitable

FCC hh suitable

Hadronic Calorimeters(DRD1 & DRD6)

- High precision mechanics R&D for real scale calorimeter.
- 5D Calorimeter t-SDHCAL
  - Introducing precise timing (tens of picoseconds) with MultiGap-RPC
- t-SDHCAL for FCCee.
  - Continuous beam, No power-pulsed electronics, higher rates (mainly at Z pole)

Electromagnetic Calorimeter (DRD6)

- IFIC will become the hub for module hybridization R&D / production / commissioning for DRD6 Si-ECALs and for both ECALs for the LUXE experiment
- Considering LGAD for 5D calorimetry.

Electronics - Strategic R&D

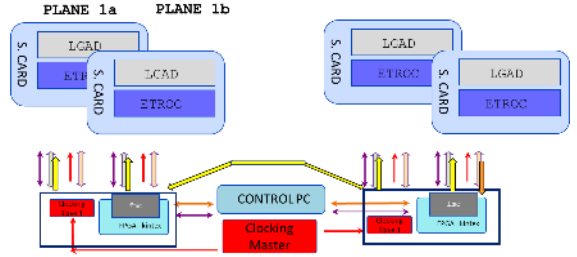
Power and timing

DRD7

ee suitable

hh suitable

- WG7.1b aims to develop power distribution systems suitable for future particle physics application (ITA)
  - ITA is developing a Radiation-Tolerant GaN based DC-DC Converter for serial powering
- WG7.3b2 aims to study and propose strategies to optimize and assess ultimate precision and determinism of timing distribution systems for future detectors
  - Ciemat: Precise & deterministic timing distribution study with Microsemi FPGA. FCC-ee environment could allow use of Flash-based FPGAs coupled with SEU mitigation techniques in most regions of the detector
  - ITA: evaluate a prototype of a distributed clock network based on White Rabbit Technology to measure the time of flight of particles with accuracies in the sub-nanosecond range.
- DRD7.5a: “TDAQ” in “COTS electronics (Ciemat)



Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

ITAINNOVA
INSTITUTO TECNOLÓGICO DE ARAGÓN

Electronics - Strategic R&D DRD4 DRD7

Trigger and ASIC Design

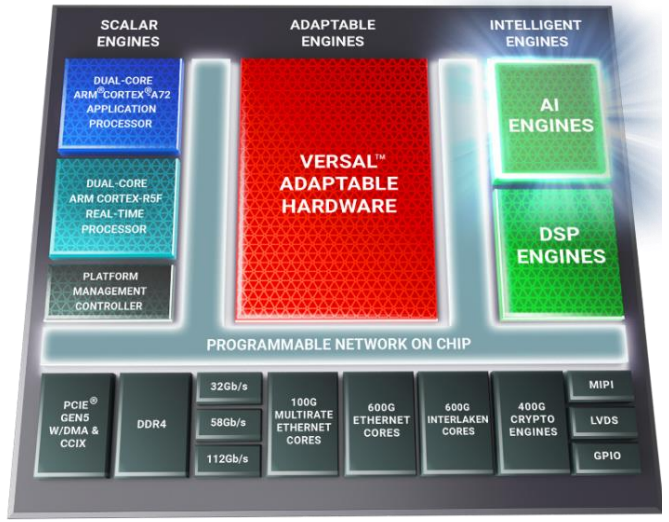
ee suitable

hh suitable

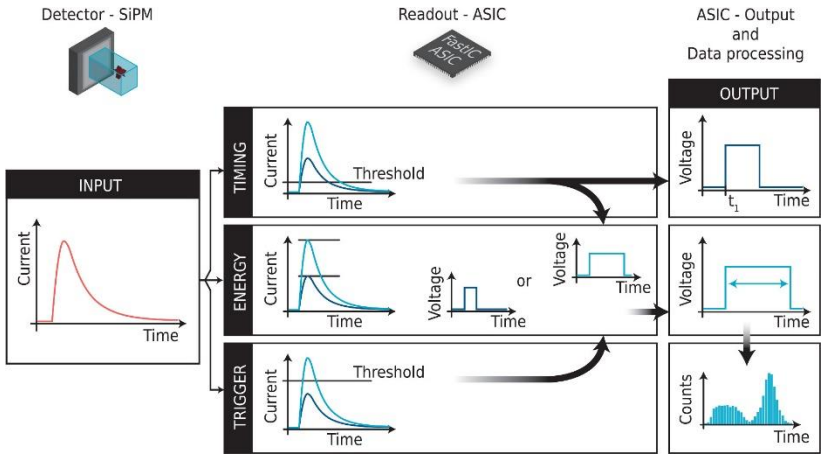
- UNIOVI: Muon trigger (in collaboration with CIEMAT): expand existing low-latency algorithms to detect and trigger on non-standard signatures such as hadronic showers or slow charged particles.
- GNN for real-time (O(μs)) muon reconstruction, using Versal ACAP and the AI engines.
- Hardware/Setup:
  - Setting up a local test stand for benchmarking firmware.
  - Various devices available for testing: Xilinx Kintex, Virtex Ultrascale+, Versal 7nm AI.

Universidad de Oviedo
Universidá d'Uviéu

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas



- UB: fast low-noise full readout chain of PMT/MCP/SiPM, targeting single-photon counters inside de DRD4 collaboration in photodectors.
- FastIC ASIC family, currently under development by Barcelona and CERN to read out fast timing detectors with an intrinsic gain of ~10^5-10^6, such as Silicon PhotoMultipliers, Micro Channel Plates, or Photomultiplier tubes.



UNIVERSITAT DE BARCELONA

DISCUSSION

- Now that the FCC-ee (+hh) appears to be the next flagship priority for the European EPP community, what should our strategy be as detector-building groups?
- How should individual groups articulate their commitments? Should we consolidate activities across groups to improve focus, impact, and visibility—fostering natural synergies without forcing artificial mergers?