Status of the Spanish contribution to the HL-LHC detector upgrades

Sebastian Grinstein

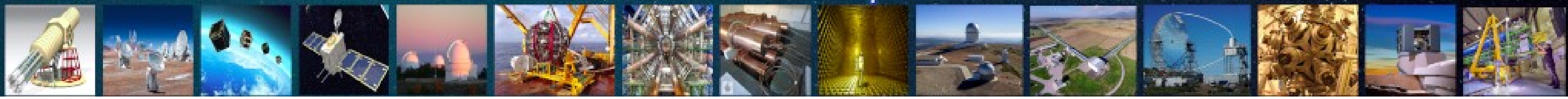
ICREA/IFAE-Barcelona

With material from: Fernando Martinez Vidal, David Gascon, Fernando Arteche, Gervasion Gomez, Ivan Vila, Luca Fiorini, Carlos Lacasta, Cristina Fernández Bedoya and Ilya Korolkov

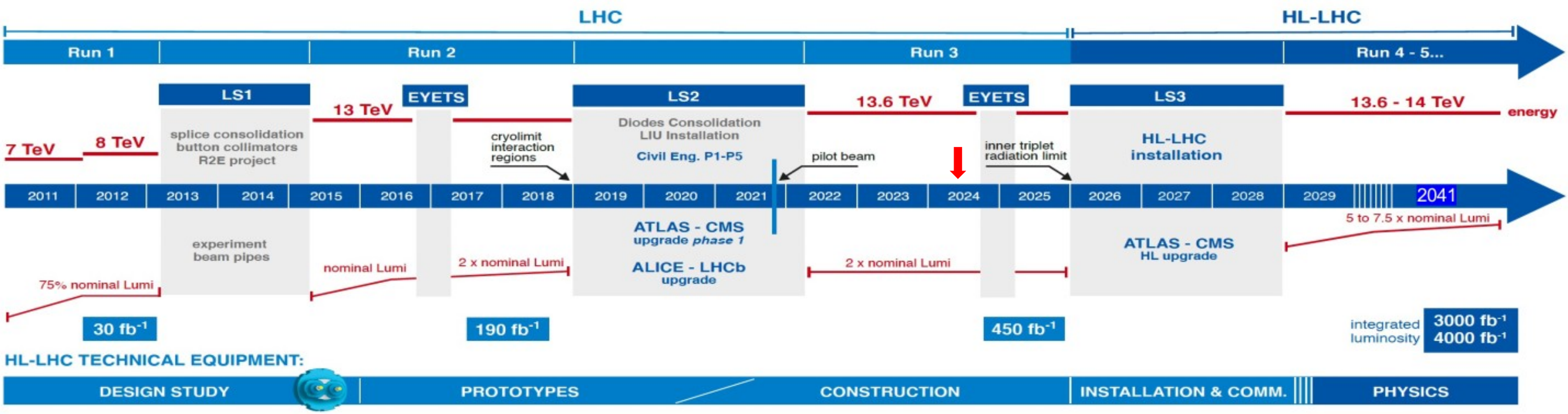
The first meeting of the Planes Complementarios AstroHEP
Zaragoza, from 5 to 7 June 2024.

1ª Reunión Nacional
Planes Complementarios de Astrofísica y Altas Energías

Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU



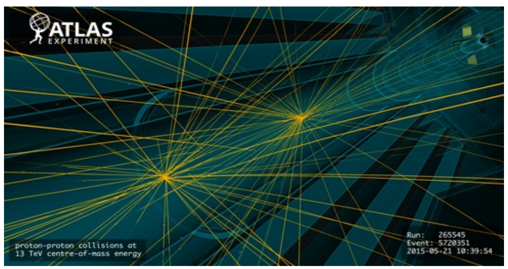
The High Luminosity LHC (HL-LHC)

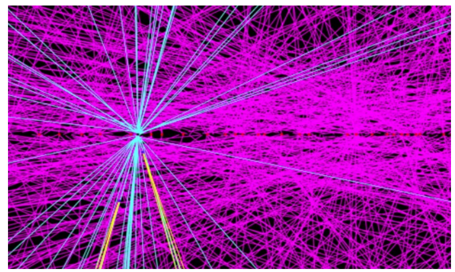


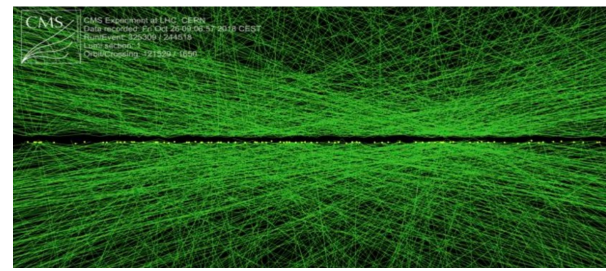
- **LHC Accelerator:**
  - LHC and its experiments have produced many results (not focus of this workshop)
  - LHC accelerator periodically upgraded to keep exploring the energy frontier...
- **HL-LHC: mayor accelerator improvement**
  - Increase of nominal luminosity by ~5-7.5
  - Integrated luminosity of 250/fb/year
  - Expected 3000-4000/fb 12 years after the upgrade
  - The “HL-LHC” period will start in ~2029 (though there have been periodic delays)

The High Luminosity LHC (HL-LHC)

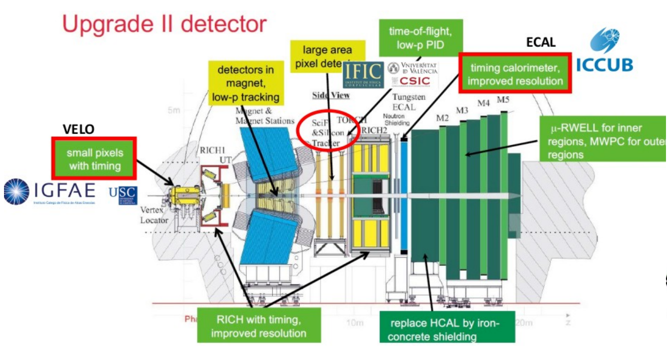
- HL-LHC upgrade impacts the detectors
  - From ~50 to ~200 collisions per beam crossing (pile-up)
  - Track multiplicity from ~700 to +10.000
- Detector demands
  - Radiation tolerant detectors and electronics to cope with unprecedented fluences
  - Increased granularity and/or timing to cope with large occupancy and track multiplicity

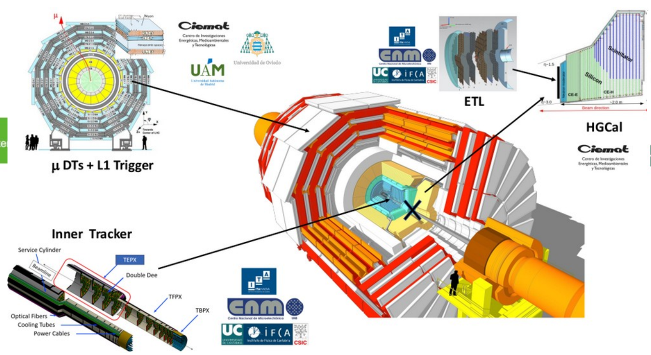


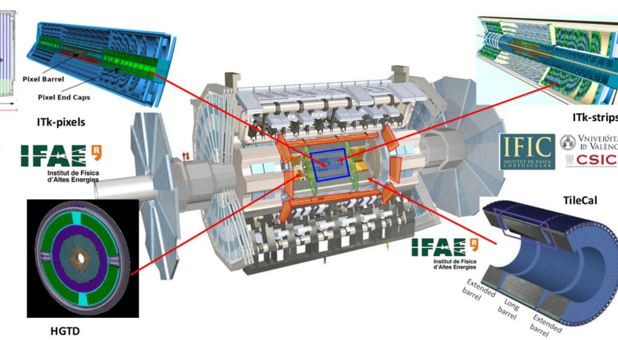




- Spanish groups working on the detector upgrades of the **LHCb**, **CMS** and **ATLAS** experiments

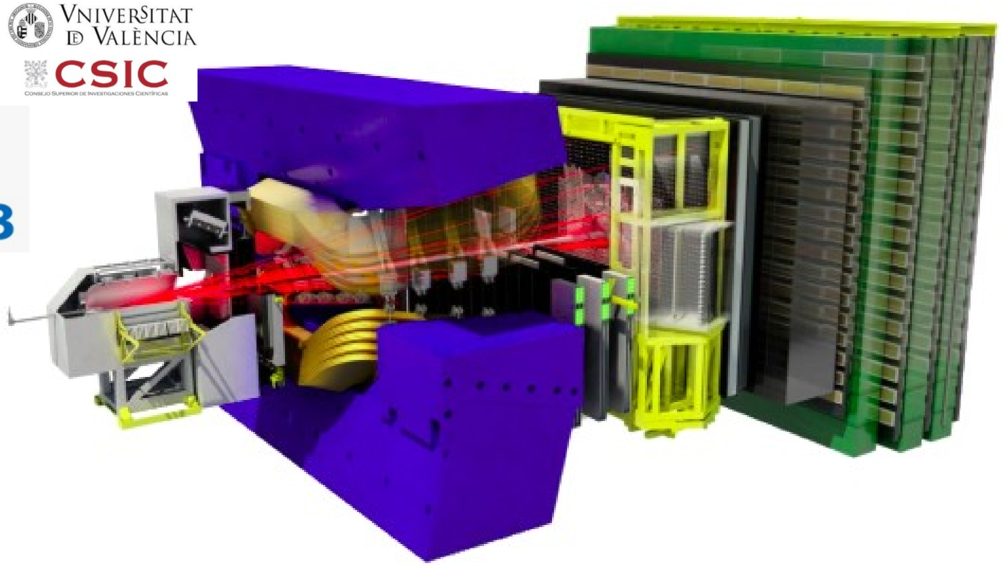






- In this presentation will show **only work in the framework of the PPCC** (for a full view of upgrade effort see, for example, G. Gomez recent CPAN talk)

LHCb Overview



- Forward spectrometer, optimized for the study of CP-violation and heavy-flavour decays
  - $2 < \eta < 5$ acceptance
- Excellent vertexing, tracking, momentum resolution < 1%, and PID ($K/\pi/p/\mu/e/\gamma$)

Wide physics program

- Mixing and CP violation in B decays
- Rare B/D/K decays
- Charm decays
- Semi-leptonic B decays
- Spectroscopy and exotic hadrons
- Hadron production
- Heavy ion physics, fixed target with SMOG
- Electroweak physics, QCD
- Exotics (dark matter, long-lived particles)

Beyond Heavy Flavour: general purpose detector in the forward region

LHCb Upgrades

LHCb —— LHCb Upgrade I —— LHCb Upgrade II

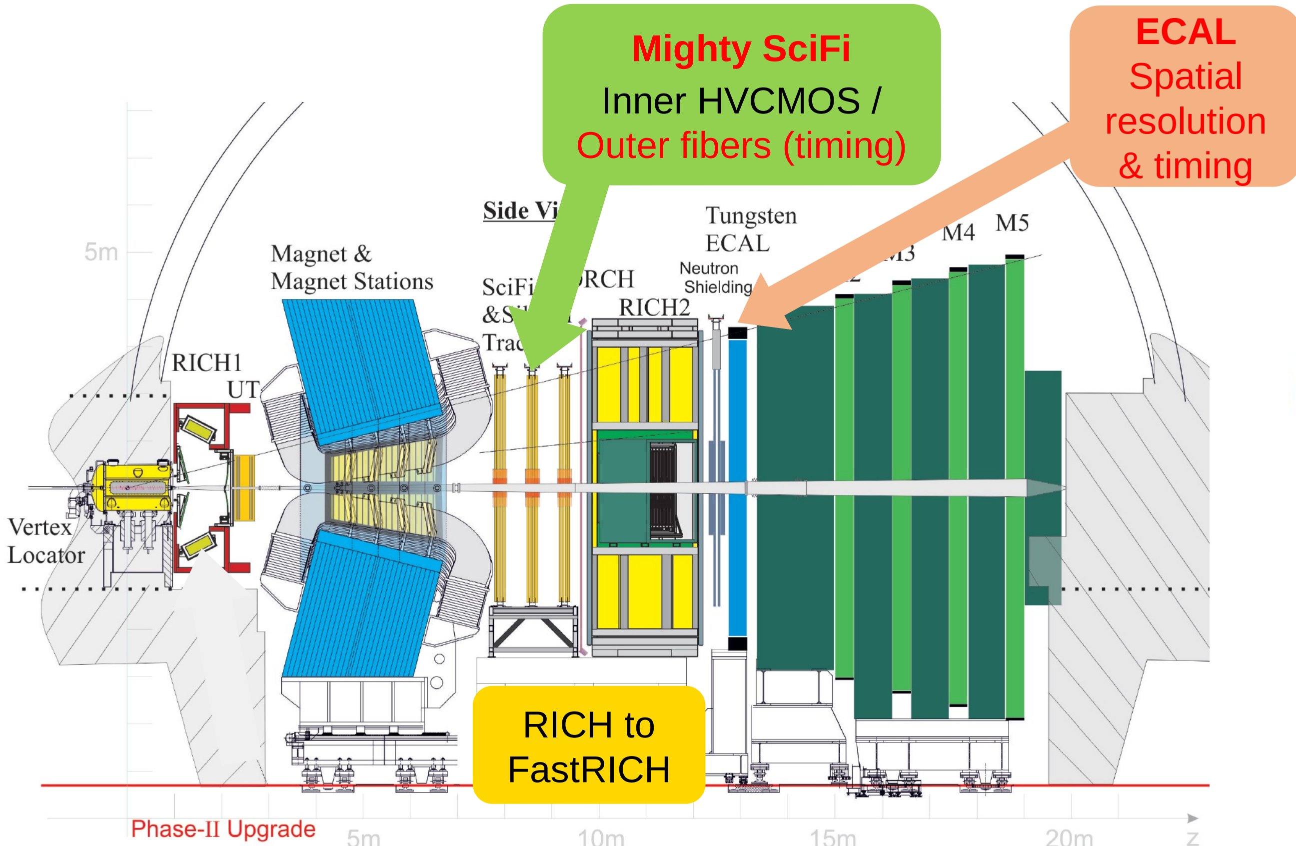
Run 1 - Run 2		Run 3		Run 4		Run 5		Run 6
$\mathcal{L}_{int}$ = 10 fb^{-1} $\mathcal{L}$ = 4 x 10^{32} cm^{-2} s^{-1}	LS2 Injector Upgrades LHCb Upgrade I	$\mathcal{L}$ = 2 x 10^{33} cm^{-2} s^{-1}	LS3 HL-LHC ATLAS/ CMS Phase 2 Upgrades LHCb Upgrade Ib (Consolidation)	$\mathcal{L}_{int}$ ~ 50 fb^{-1}	LS4 LHCb Upgrade II	$\mathcal{L}$ = 1-2 x 10^{34} cm^{-2} s^{-1}	LS5	$\mathcal{L}_{int}$ ~ 300 fb^{-1}
2010 - 2018	2019 - 2022	2022 - 2025	2026 - 2028	2029 - 2032	2033 - 2034	2035 - 2038	2039	2040 – 20XX
		Increased Lumi by x 5 Limited to ~ 6 int. per bunch crossing		Limited to ~ 6 int. per bunch crossing		~ 40 int. per bunch crossing		~ 40 int. per bunch crossing

HL-LHC

Program to improve LHCb has two phases

- **Upgrade I** (LS2)
  - Increase the luminosity from 4x10^{32} cm^{-2}s^{-1} to 2x10^{33} cm^{-2}s^{-1}
  - Detectors and electronics upgrades needed
  - Trigger and DAQ redefined
- Consolidation/enhancement phase in LS3
  - First stage of Upgrade II “**Upgrade Ib**”
  - No luminosity change (baseline)
- Main installation phase in LS4
  - Full **Upgrade II** (luminosity increase x 7.5)

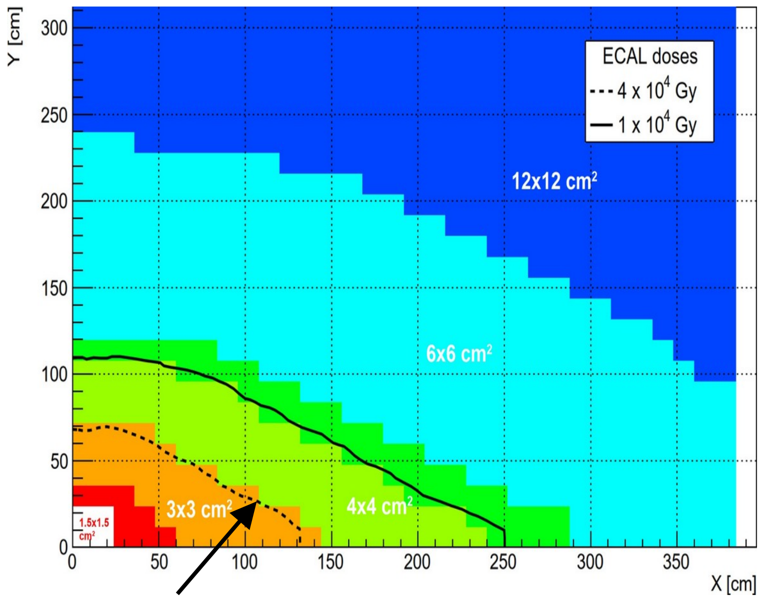
LHCb Upgrade II: Contributions*



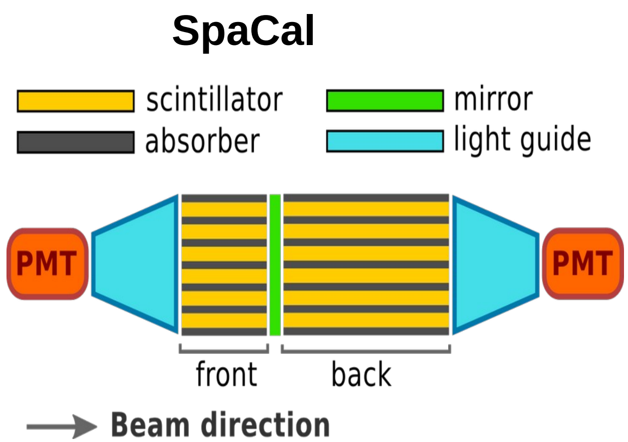
- Phase II Upgrade must deliver the same quality performance as Upgrade I with 10 times particle multiplicity, radiation damage, DAQ rate
- Same spectrometer footprint, innovative technology for detector and data processing
- Improvements are needed
  - Granularity
  - Fast timing O(10) ps
  - Radiation hardness (up to few $10^{16} n_{eq}/cm^2$)

* In the framework of the PPCC

Technologies for the ECAL Upgrade Ib & II



Radiation limit of current Shashlik technology

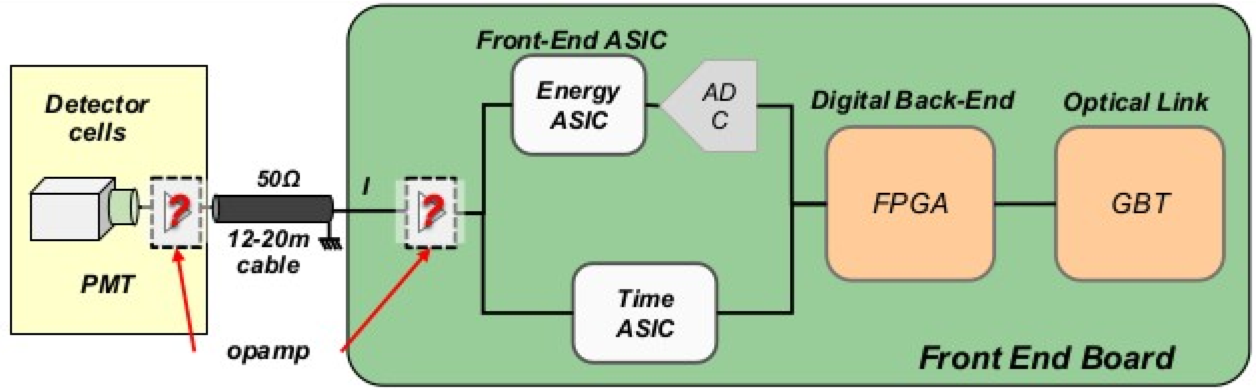


SpaCal technology for inner region **(PicoCal)**

- Innermost modules with scintillating crystal fibers and W absorber
  - Development of radiation-hard scintillating crystals
  - 1.5x1.5 cm2 cell size
- 40-200 kGy region with scintillating plastic fibers and Pb absorber
  - Need radiation-tolerant organic scintillators
  - 3x3 cm2 cell size
- Shashlik technology (as current ECAL)
- About 3300 new Shashlik modules with improved timing capability and double-sided readout
  - Possible cost optimization by refurbishing ≈2000 existing modules with fast new WLS fibers, adding ≈1300 new modules with required cell sizes

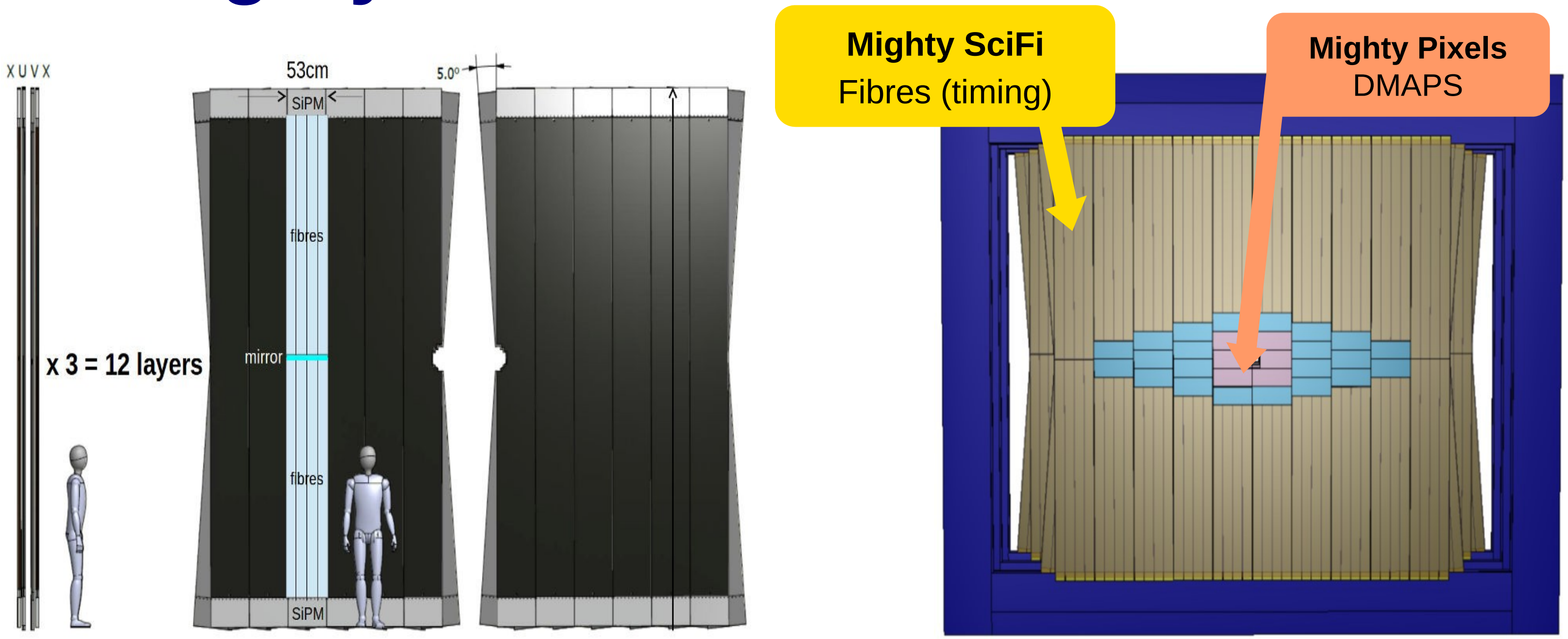
ICCUB Institute of Cosmos Sciences · IFIC Institut de Física Corpuscular · Universitat de València · CSIC

PicoCal readout electronics architecture



- Photodetectors readout solution follows the same scheme as in current ECAL
  - Minimal light transport with PMT sensors near modules
  - Electronics in crates on top of the detector (reduced radiation)
  - Connection via analog link (coaxial) up to 20m considered (IFIC)
- ASIC/chipset in TSMC **65 nm** with separate energy and timing processing
- Amplifier + Shaper circuit included on the PMT base or FEB to compensate cable attenuation, improve SNR, if necessary, and reduce spill-over effort (IFIC)
- Energy ASIC (ICECAL65) designed by IFIC, UPC and ICCUB

Mighty SciFi readout electronics



- LS4 radiation levels require new detectors/electronics! (IFIC, ICCUB, UPC)

PACIFIC
- Mostly analog design
- Multi-channel
- Simple digitization
- I2C slow control

PACIFIC++
- Analog processing chain
- Multi-channel
- Complex digital: digitization/clustering/timing
- lpGBT control/direct connection

- Analog design started, submission of **1st prototype** by end 2024/beginning 2025
- Also working on **trigger upgrade** based on FPGA boards

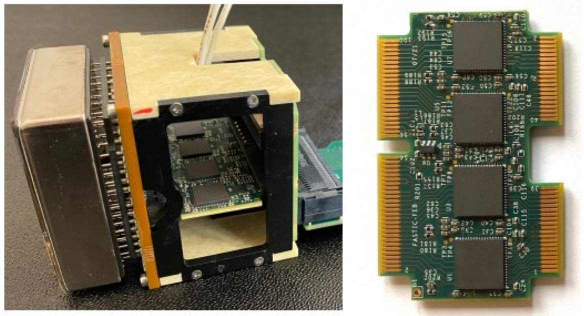
LHC Upgrade: FastRICH

The LHCb RICH LS3 enhancements

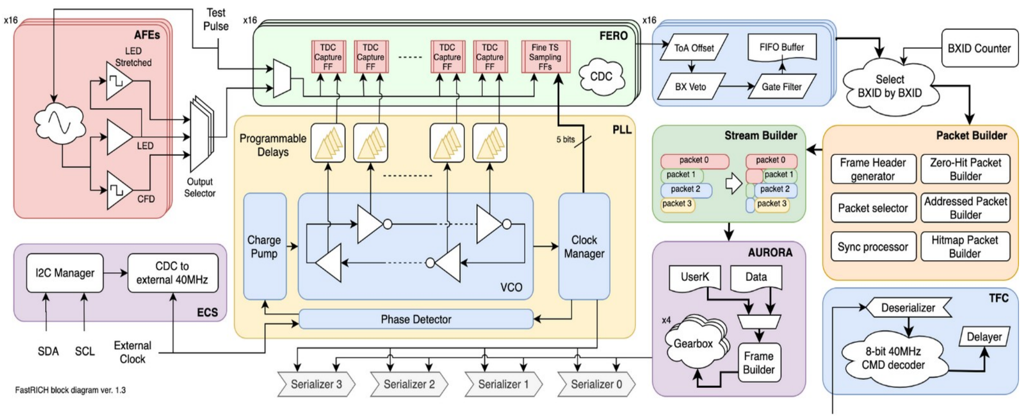
- New frontend readout electronics including the FastRICH ASIC capable of timestamping photon detector hits with ~ 25 ps time bins.

FastRICH: a dedicated 16 ch ASIC for RICH upgrade in LS3

- Optimized for single photon detection
- Compatible with PMTs and SiPMs
- CFD to deal with time walk @ high rates
- Nearly the same PLL and TDC blocks integrated in FastIC+
- Technology: TSMC 65 LP
- Schedule: submission during 2024

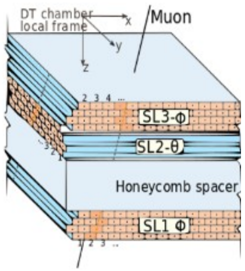


Collaboration of the ICCUB and CERN Microelectronics section



More information on: https://fastrich.docs.cern.ch/

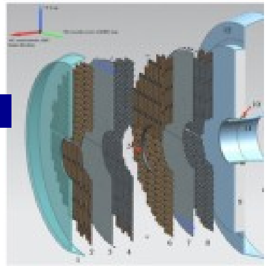
CMS Upgrade: Contributions*



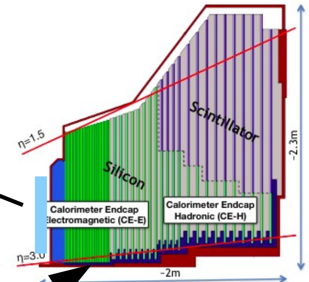
µ DTs + L1 Trigger

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

iFCA Instituto de Física de Cantabria
ita

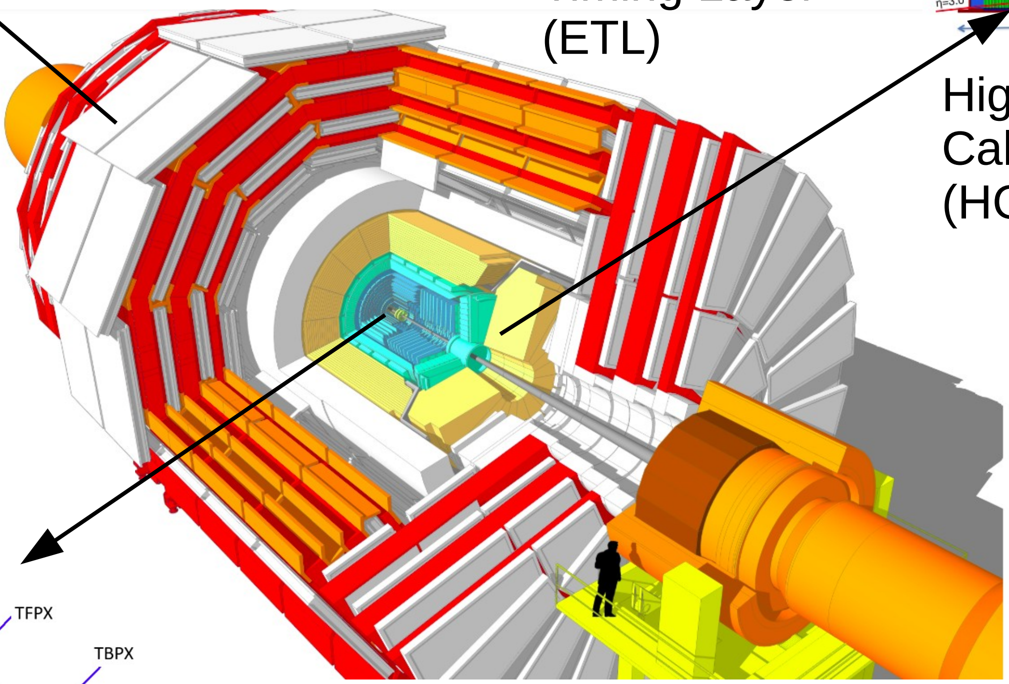


End-cap Timing Layer (ETL)

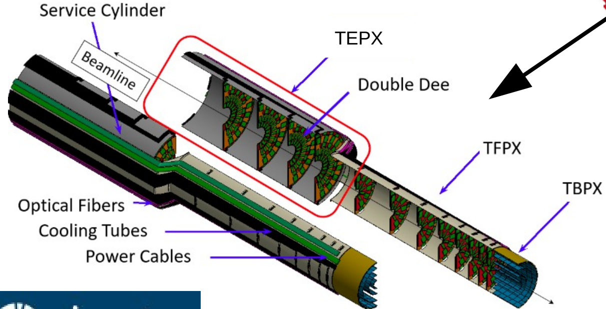


High Granularity Calorimeter (HGCal)

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas



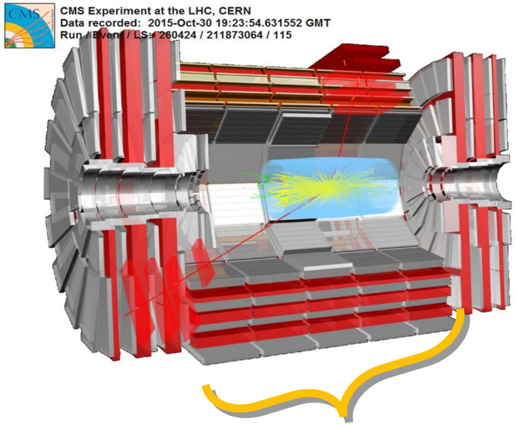
Inner Tracker



iFCA Instituto de Física de Cantabria
ita

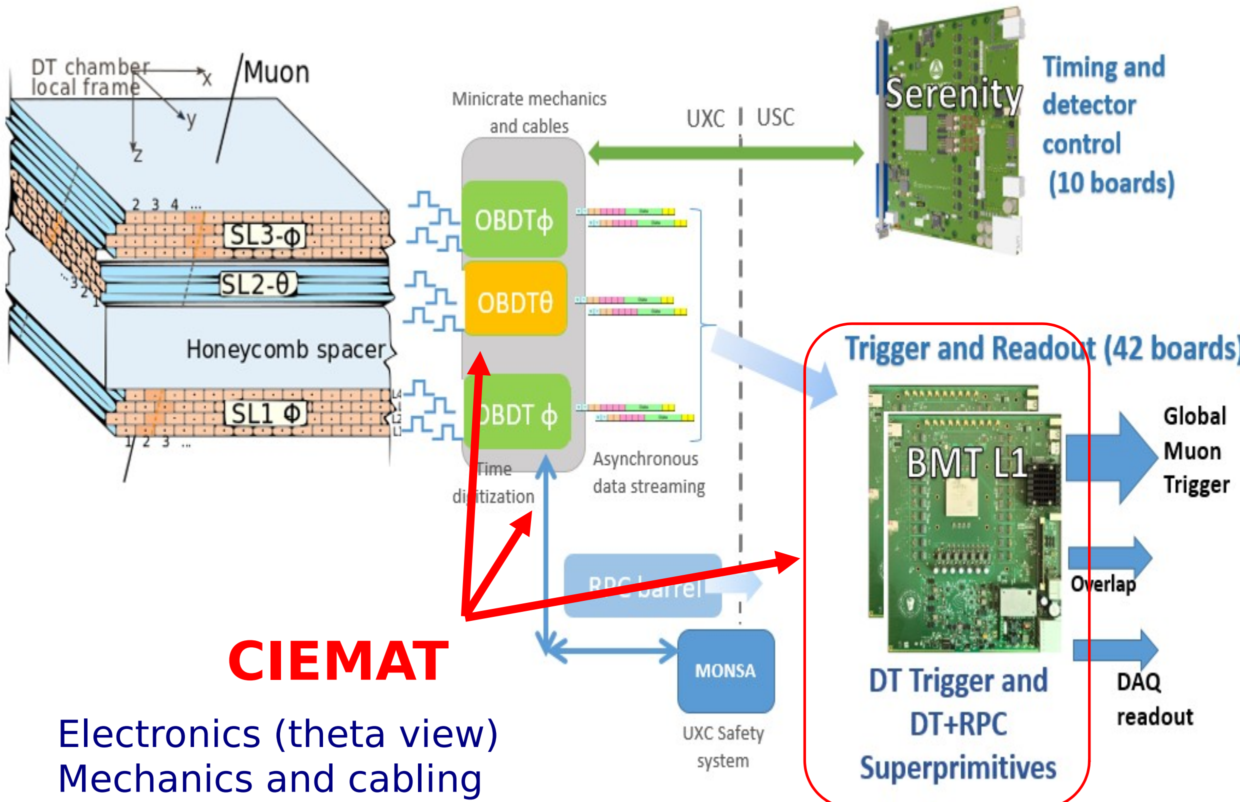
* In the framework of the PPCC

CMS Muon Drift Tube HL-LHC Upgrade



- 250 chambers to be refurbished with new electronics
- 830 boards embeded in the 250 Minicrates structures
- Full refurbishment of backend electronics with improved performance

- Drift tube chambers longevity: several years of radiation campaigns to validate its performance under HL-LHC: Efficiency loss should be acceptable
- Replace electronics to stand: L1A rate, occupancy, radiation
- Architecture upgrade for full streaming of information



CIEMAT

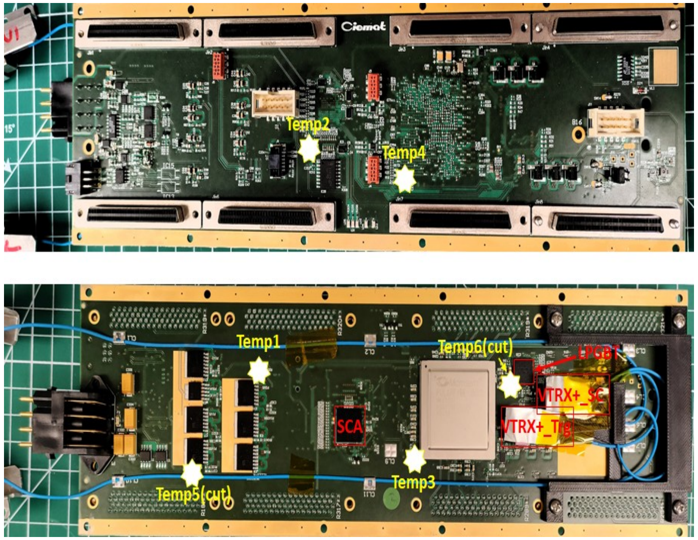
Electronics (theta view)
Mechanics and cabling
Back-end and trigger algorithm

Funded by
the European Union
NextGenerationEU
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Plan de Recuperación, Transformación y Resiliencia

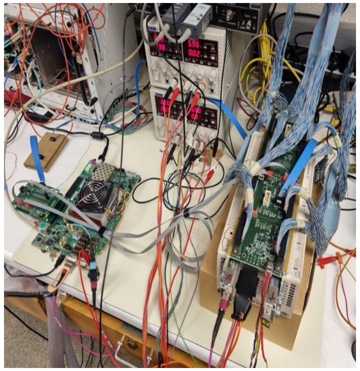
CMS Muon Phase 2: DT on detector electronics

- **OBDT-theta board: designed and produced at CIEMAT**
- Time digitization on the FPGA (228 channels/board) at 0.7 ns. Radiation tolerant FPGA Microsemi Polarfire
- **High speed optical communication** (10 Gbps/link)
- Makes use of CERN ASICs: lpGBT, VTRX, SCA
- Automatic safety mechanisms embedded (temperature, current, voltage protections)

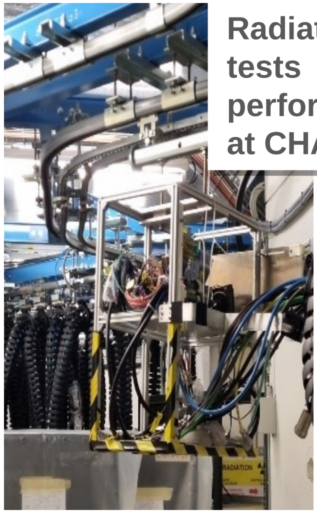
OBDT-theta board



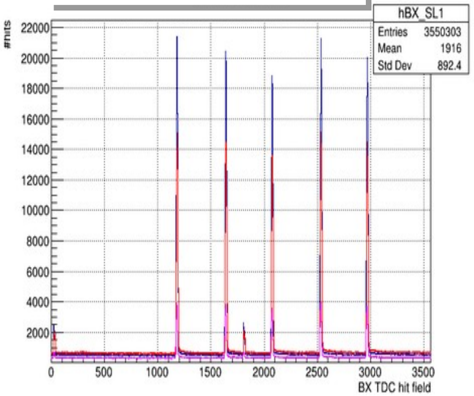
Tests stands being built



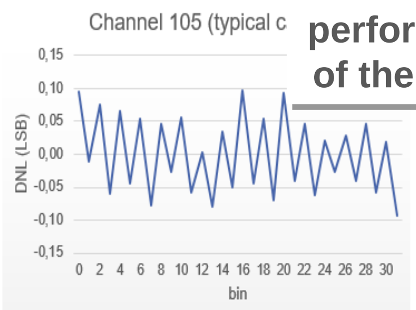
Radiation tests performed at CHARM



Board validated with collisions in CMS (Slice Test)



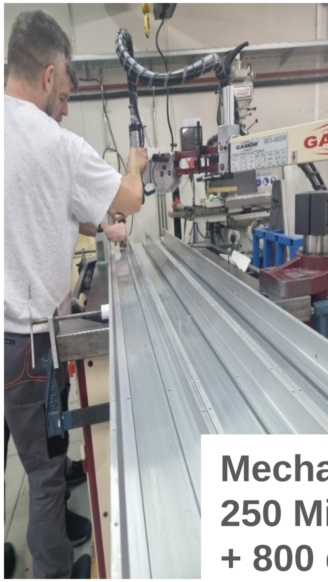
Excellent performance of the board



- Prototyping phase completed
- Pre-production validated
- Production ongoing

Funded by the European Union NextGenerationEU

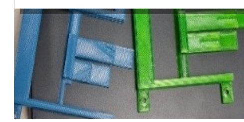
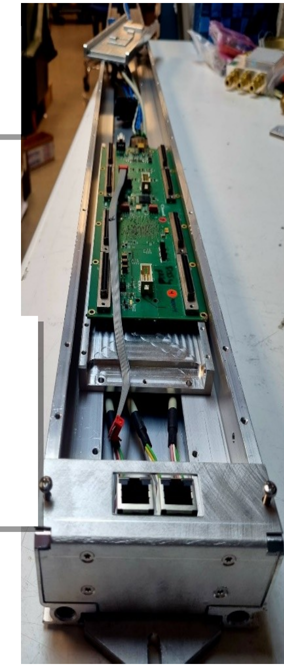
CMS Muon P2: DT Mechanics & Assembly




Mechanics fabrication
250 Mini-crates (2 m)
+ 800 different pieces

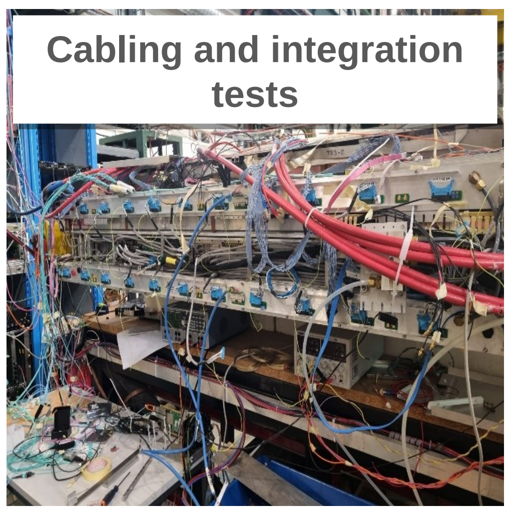
Cooling validation

3D printing for fiber routing. Validation of plastics under radiation

Preparation of assembly hall at CIEMAT and at CERN

Cabling and integration tests

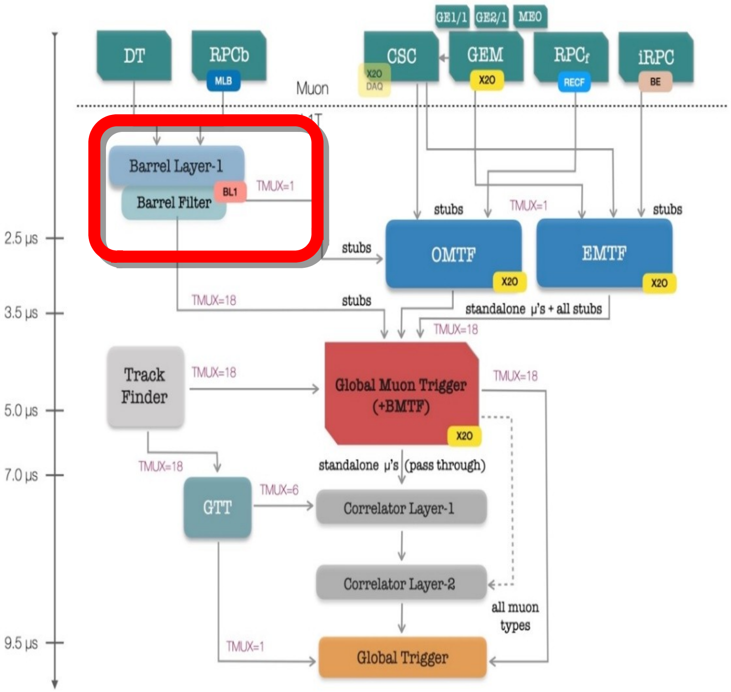


Installation exercises at CERN

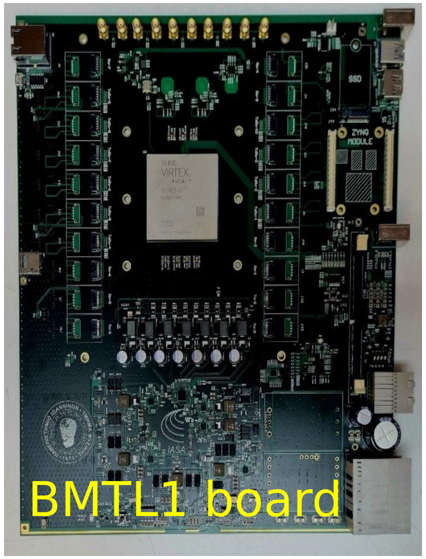
Slice Test: two CMS sectors working in parallel with upgrade electronics

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
AGENCIA ESTATAL DE INVESTIGACIÓN
Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union
NextGenerationEU

CMS Level 1 Trigger Phase 2 upgrade



- Responsible of the Muon Barrel Trigger primitives for HL-LHC



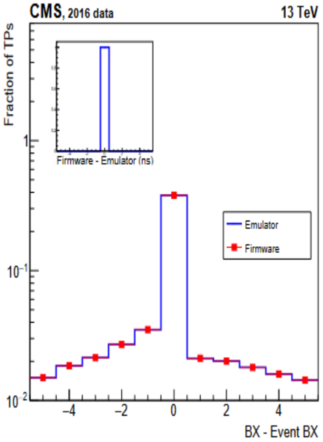
Hardware backend

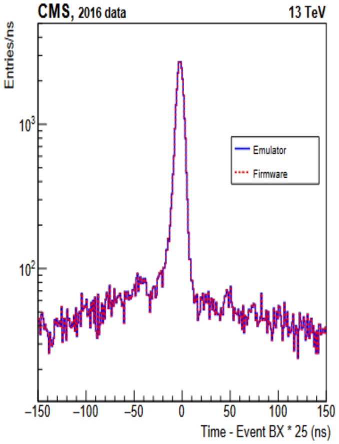
- 42 ATCA boards so called BMTL1
- AMD VU13P FPGA
- 3.8 Tpbs throughput
- Collaboration with Univ. Ioannina (PCB), CIEMAT (design of the firmware)
- Half of the production in spanish industries

Muon trigger algorithm development

- **Analytical Method** (proposed by CIEMAT) for reconstruction of the barrel (DT+RPC) trigger primitives in HL-LHC
- **Exploits maximum achievable resolution**, bringing the hw system closer to **offline performance capabilities**.

  [10.1016/j.nima.2023.168103]
- In collaboration with UAM and Univ. Oviedo

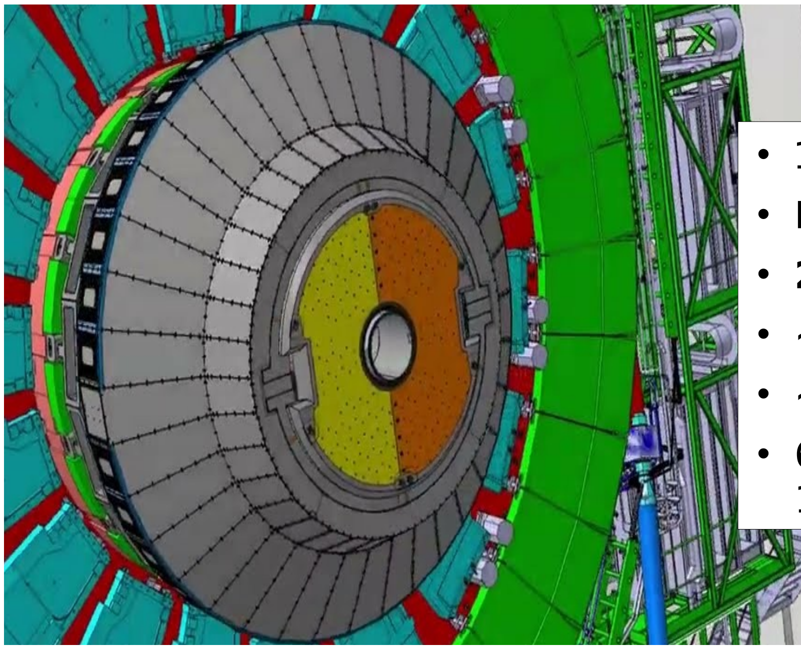




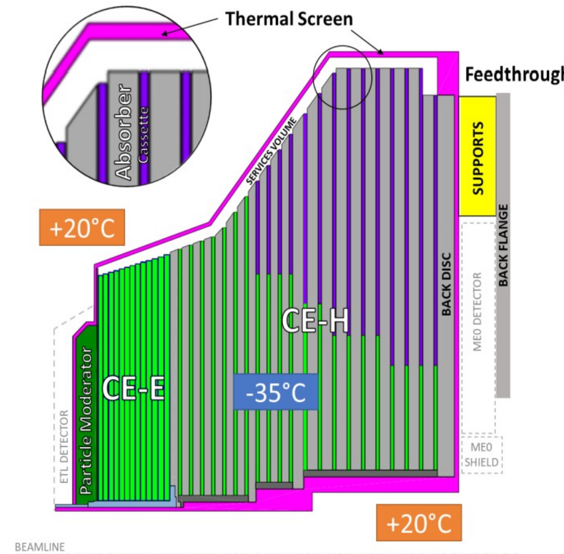
GOBIERNO DE ESPAÑA · MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES · Ciemat · Plan de Recuperación, Transformación y Resiliencia · Funded by the European Union NextGenerationEU

CMS High Granularity Calorimeter

- For HL-LHC CMS will replace the Endcap Calorimeters with new high granularity calorimetry techniques pioneered by CALICE R&D. Inner region: **Si sensors**, outer CE-H scintillator plastic. HGCAL is an innovative project deploying many silicon tracker technologies in a calorimetry environment.



- 1.5 <|η|< 3.0
- Maintained at -30ºC
- **220 tons**
- **~620m²** Si area
- **~370m²** of scint. tiles
- 6M Si channels, 0.5 or 1.1 cm² cell size

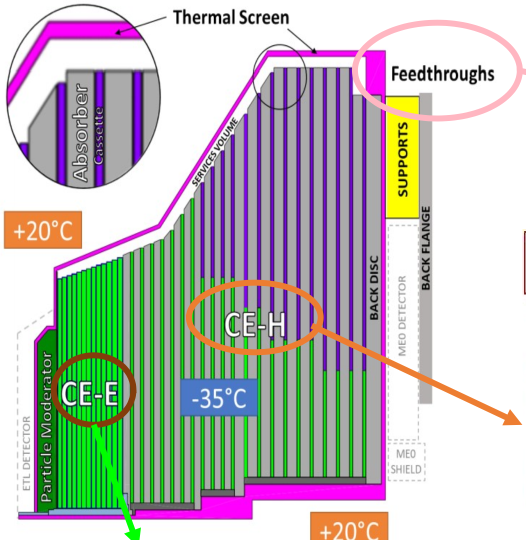


Russian institution collaboration with CERN ended due to Ukraine invasion: CMS stablished a commonly shared fund (Detector Upgrade Fund) **of 10 MCHF** to cover **shortfall in funding**

- Spain's fraction of **the DUF is 3 %**
- CIEMAT joined efforts to ensure building this detector timely, with contributions by Spanish companies.

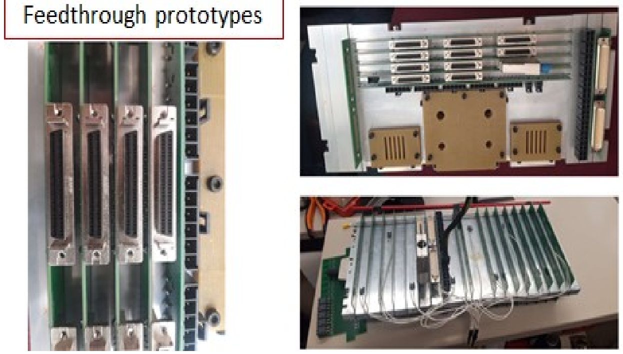
Funded by the European Union NextGenerationEU

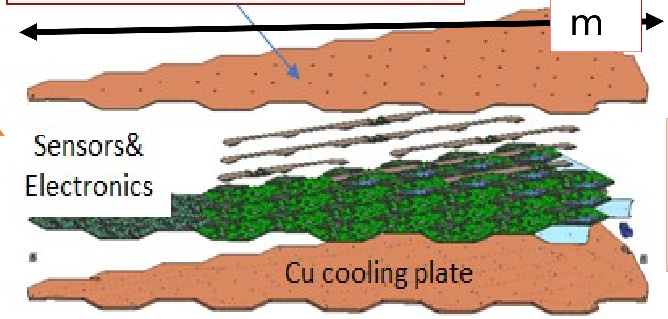
CIEMAT Contributions to CMS HGCal



Produce ~1200 PCBs allowing services cross the HGCAL thermal screen (pre-production on-going)

Feedthrough prototypes





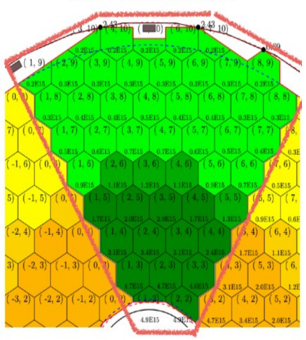
Produce a fraction of steel protection covers of the CE-H HGCAL cassettes (ordering first prototypes)

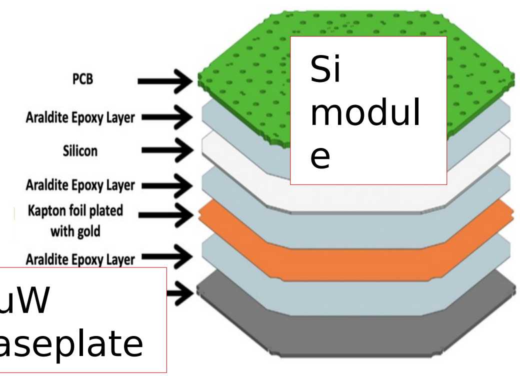
Machine ~1000 CuW thermal interface baseplates for HGCAL Si modules (7%)

- Several material measurements and irradiations at CIAMAT
- Prototypes with final material being produced in a company

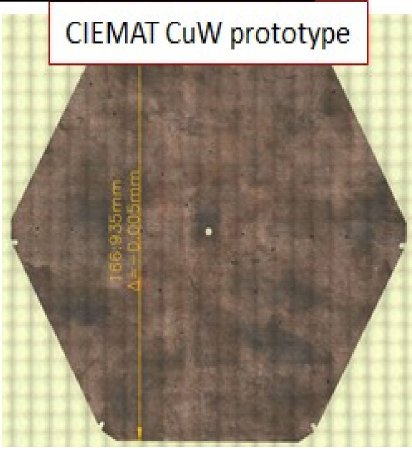
CuW baseplates provide thermal and mechanical interface to Si modules, as well as additional absorber.

CE-E Cassettes





CIEMAT CuW prototype

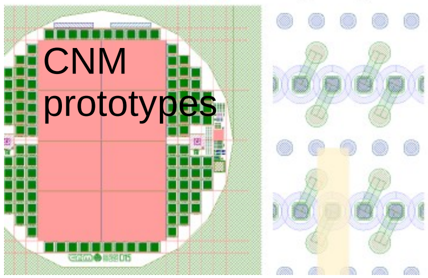


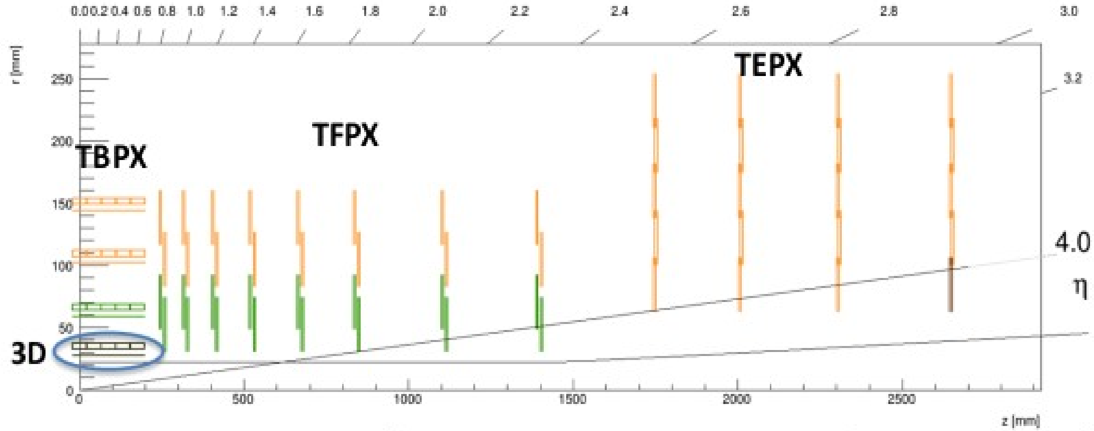
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
AGENCIA ESTATAL DE INVESTIGACIÓN
Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union
NextGenerationEU

CMS Inner Tracker Upgrade: 3D pixel activities

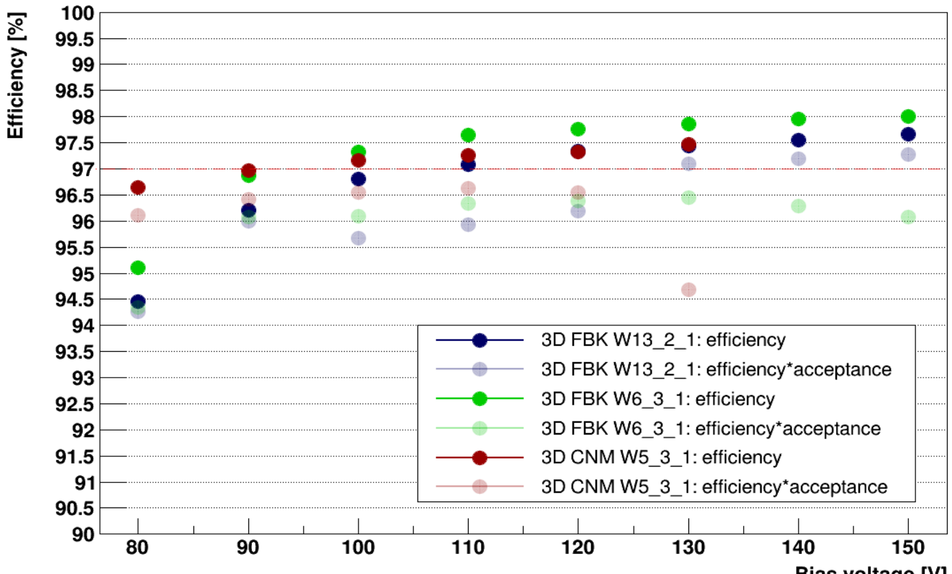
- Characterization of **3D sensors** in TB campaigns
- TBPX L1 to use 3D **25x100 μm² sensors**

CNM: 100 mm SiSi wafers (150+200 μm)
8 CROC singles 25x100 (p-stop)





Runs 4+5 TBPX L1: Fluence 1.9E16 1 MeV n_{eq} & TID 1.0 Grad



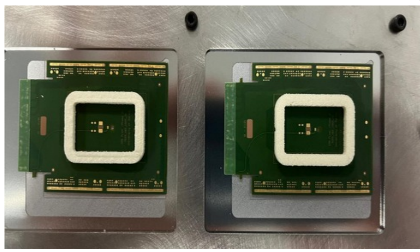
- CNM and FBK pixel sensors irradiated to **1E16 neq/cm2**
- Operated at 1000e threshold & T~-30C
- Efficiency at normal incidence: higher than **97%** for all the modules after full depletion

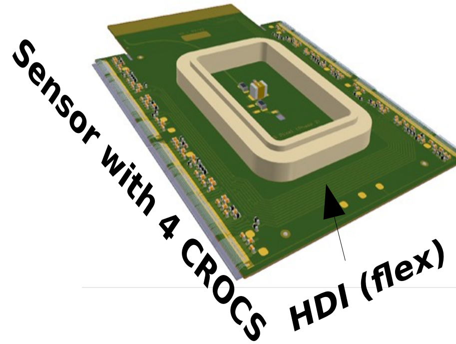
IFCA coordinates IT sensor group since 2018

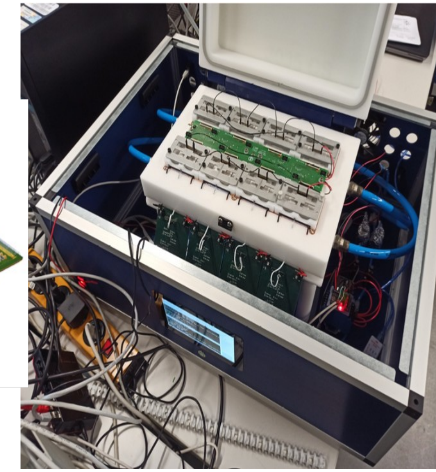
CMS IT Modules

IFCA aims to assemble: 380 TEPX 2x2 modules (planar sensors with 4 ROCs)

Glue deposition via stamping and micrometric precision using robot to assembly 6 modules in parallel

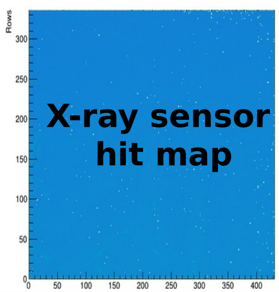






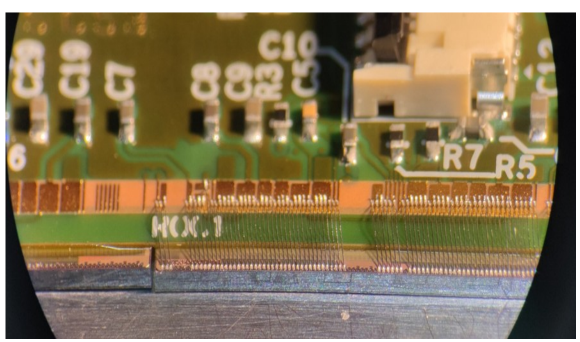
Module QC

- Thermal cycles in dedicated 8x TEPX cold box
- Pull tests on dedicated wire bond pads
- X-ray tests for pixel hit map



X-ray unit

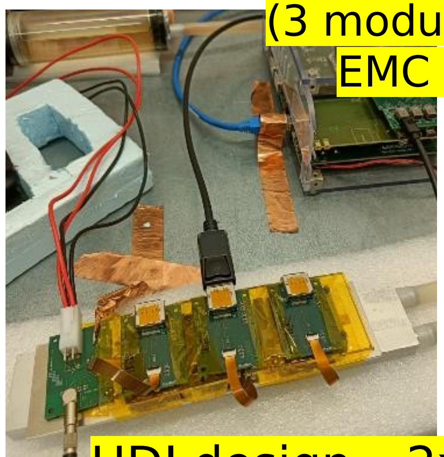
Wire bonding: ~200 wire bonds / ASIC



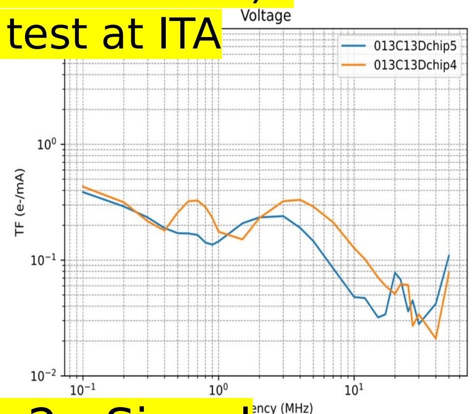
FE (CROC,ETROC, HDI), Serial Power & EMC – CMS IT & ETL

- FEE designs
  - CROC simulation models & ETROC testing (ASICs)
  - CMS-IT-HDI design
- CMS Pixel & ETL System prototyping - Electronics & DAQ
  - Serial powering
  - Hardware, gate-ware and firmware for ASIC/DAQ comm. and control.

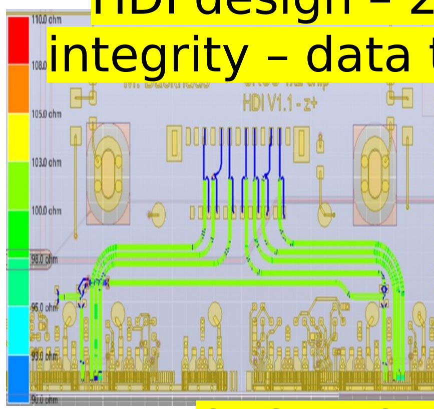
3D – RD53A based Serial Powering prototype (3 modules 1x2 HDI)

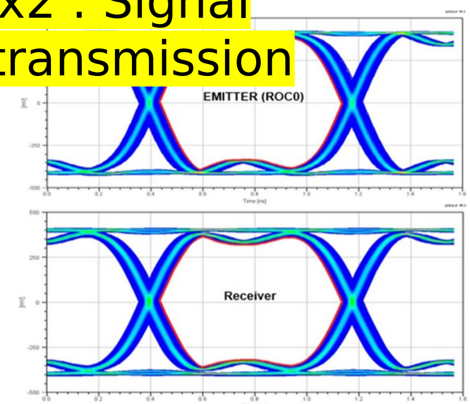


EMC test at ITA

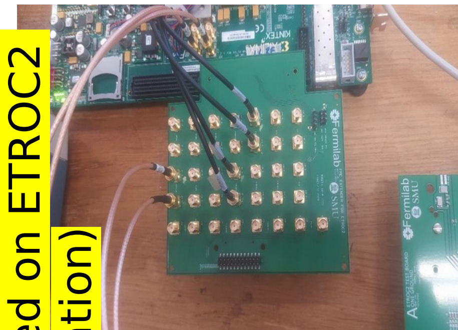


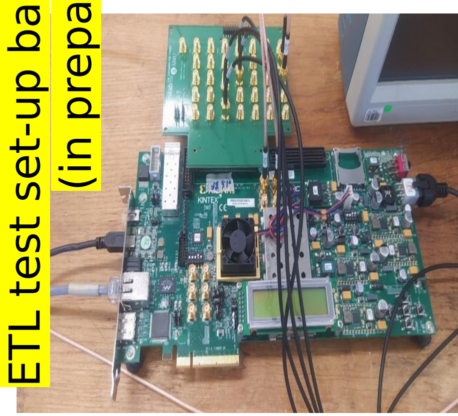
HDI design – 2x2 : Signal integrity – data transmission



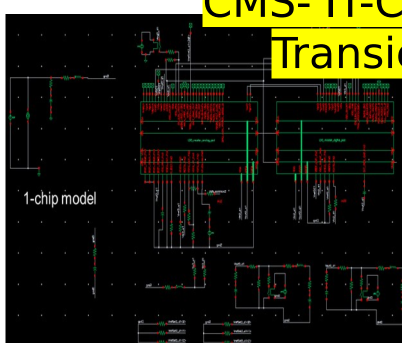


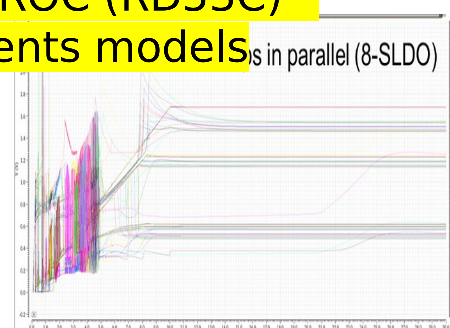
ETL test set-up based on ETROC2 (in preparation)



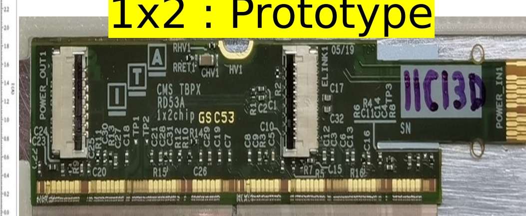


CMS- IT-CROC (RD53C) – Transients models





CMS –IT- HDI design – 1x2 : Prototype



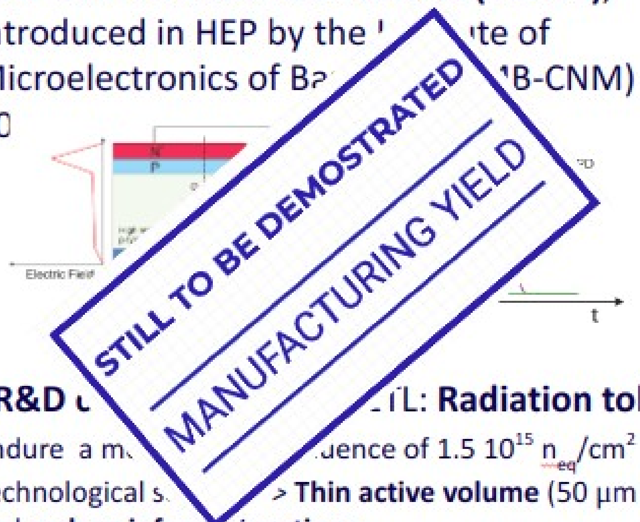
CMS Endcap Timing Layer (ETL): Sensors

- IFCA played a leading role on the LGAD R&D effort towards the ETL
- Sensor R&D and production at CMS and other foundries
- Test-beam and irradiation campaigns..

– **Requirements:** Time and Position-Sensitive Detector (TPSD) with fine time resolution O(10) picoseconds and coarse position resolution.

– **The Solution:**

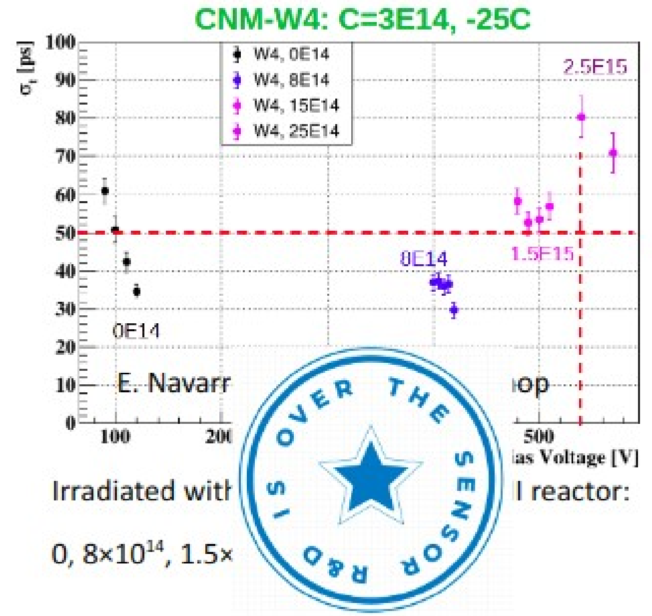
  - **Low Gain Avalanche Detectors (LGADs),** introduced in HEP by the I... ...ute of Microelectronics of Ba... ...(IMB-CNM) about 10



– The **R&D c... ...TL: Radiation tolerance**

  - Endure a m... ...uence of 1.5 10^{15} n_{eq}/cm^2
  - Technological s... > **Thin active volume** (50 µm thick) and **carbon-infus... junctions.**

– **After 10 years of R&D Several manufacturing centers achieve enough radiation tolerance: IMB-CNM, FBK, HPK,…**

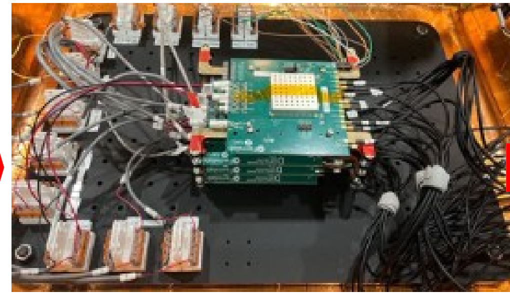


Irradiated wit... ...l reactor:

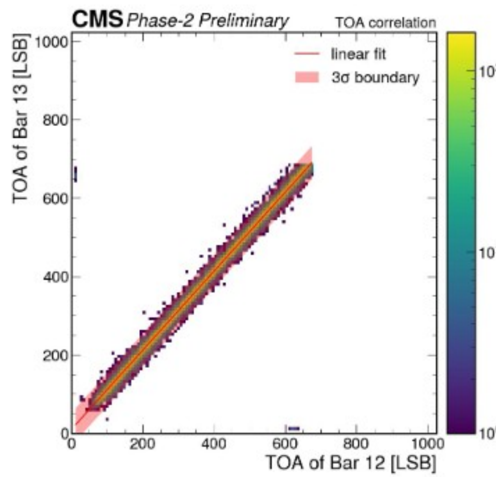
0, 8×10^{14}, 1.5×...

Moving final prototyping and productions

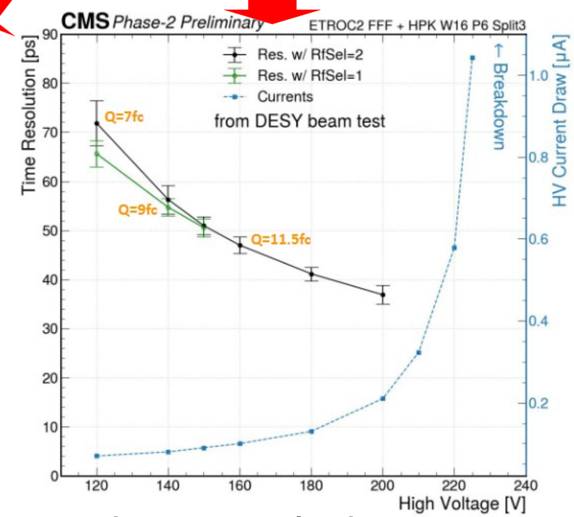
CMS ETL: Front-End Electronics



- Moving towards full system tests: hybrids
- In April 2023 first version of ETROC2 Read-out ASIC delivered
- The first full size (16x16 channels, 21mm x 23mm) and full functionality prototype for LGAD read-out.



Telescope planes Time correlation



Time Resolution around 40 ps

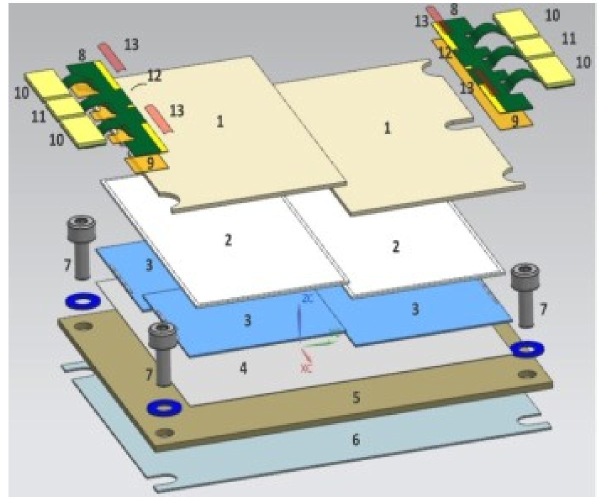
TEWPP 2023, https://indi.to/Fc6ZM

- IFCA also working on ETL simulations (back-up)

CMS ETL: Module Assembly & TT

Module assembly at IFCA

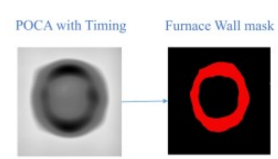
- Target 900 modules
- Gluing positioning based on SCARA robot
- Wire-bonding and testing on-site
- Activities ramping up



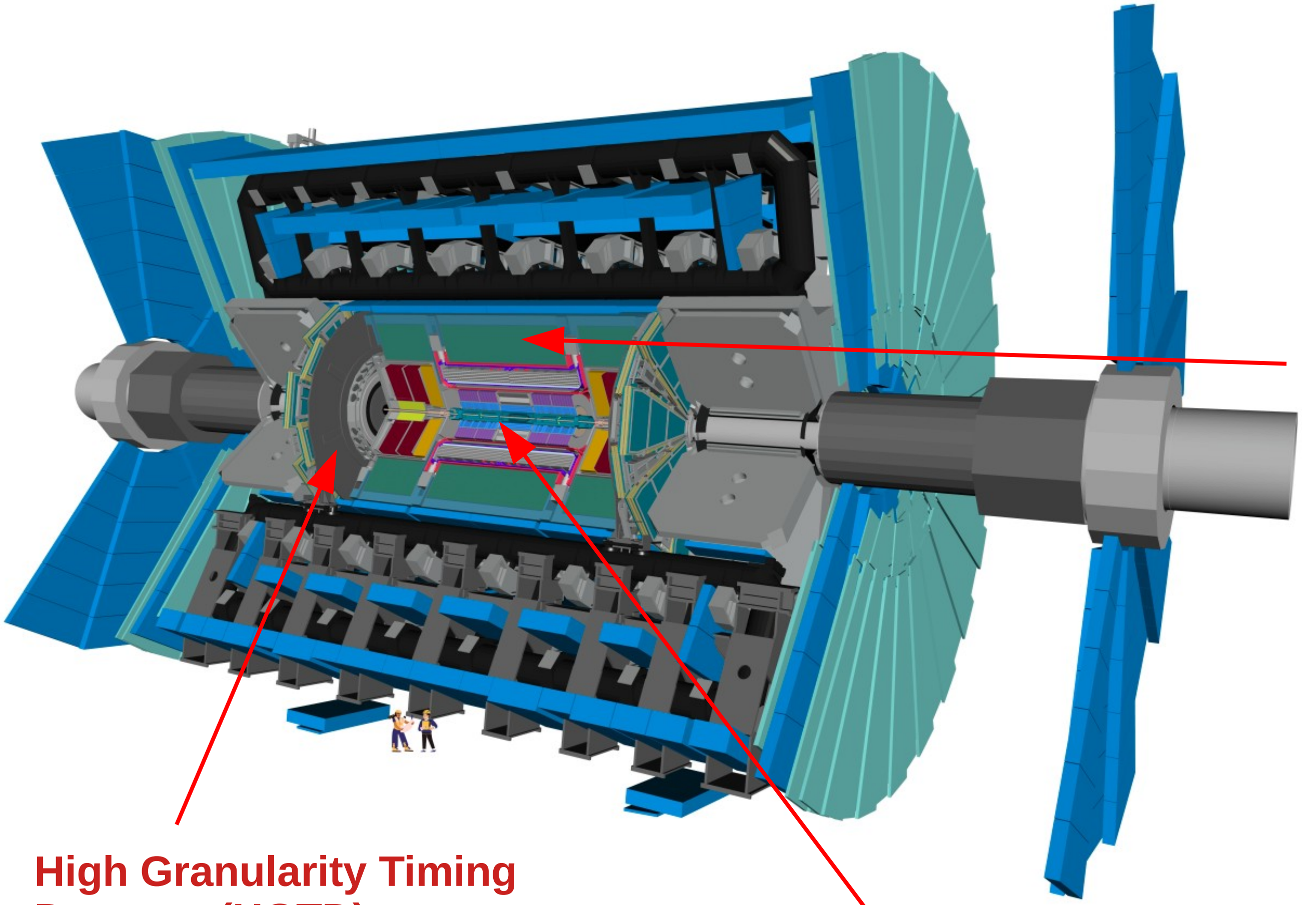
ETL technology transfer

- TOMULGAD-4D Project (PDC2021-121718) applied to Scattering Muon Tomography
  - Construction of a demonstrator w/ LGADs + ETROC2 to estimate timing
- PROTECT Project (PDC2023-145925, similar concept applied to proton Computed Tomography

Segmentation of a transversal tomography of a furnace wall



ATLAS Upgrade: Contributions*



Tile Calorimeter

- On and offdetector **electronics** and mechanical upgrade of Tile Calorimeter (TileCal)
- Mechanical housing

High Granularity Timing Detector (HGTD)

- Precision track timing (30 ps)
- Improve pile-up rejection in the forward region

New Inner Tracker (ITk)

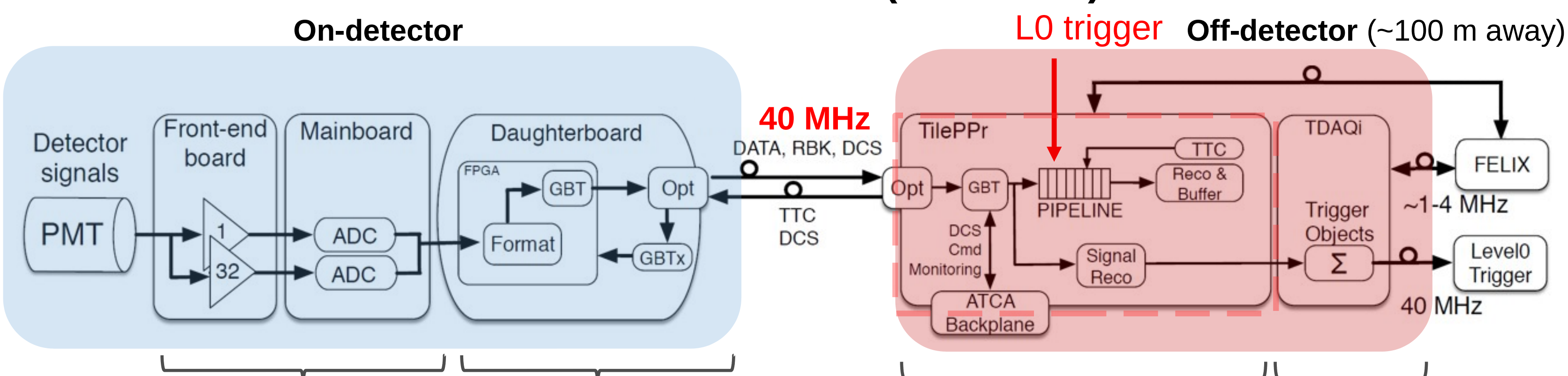
- All silicon with 9 layers up to $|\eta|=4$
- Less material finer segmentation
- Improve vertexing, tracking, b-tagging
- **Pixel** + **Strips**

** In the framework of the PPCC*

Tile Calorimeter Upgrade

- IFIC-Valencia playing mayor roles* in **TileCal upgrade** activities centered on **electronics**:
  - Active dividers for all PMTs and replacement of the 10% most exposed PMTs.
  - Complete replacement of on-detector and off-detector electronics.
  - New digital trigger system up to 40 (1) MHz read-out (accept) rate, increase by x10.
  - Increased detector read-out bandwidth – 40 Tbps for the entire TileCal.

TileCal architecture (2029-2040)



-Shaping
-Amplification (2 gains)
-Digitization
-Calibration for electronics

- Data acquitision
- Clock distribution
- Pipelines buffer
- Online energy & time reco

IFIC-Valencia responsibility

- Trigger objects computation
- Interface with ATLAS TDAQ subsystems

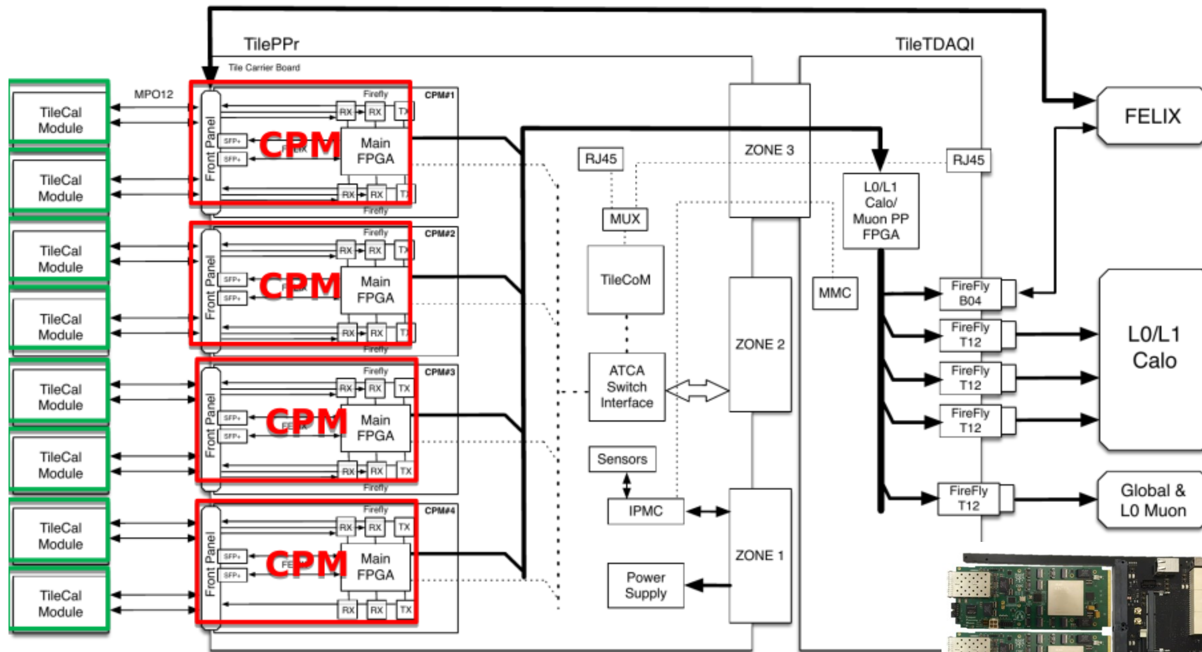
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

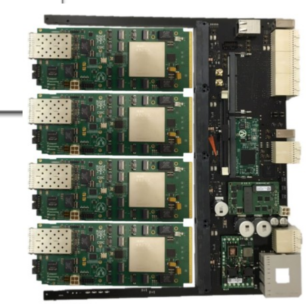
** including several leadership positions (like deputy PL)*

Tile Calorimeter Upgrade

Backend electronics: Tile **PreProcessor** (PPr) and **TDAQi** RTM systems:

- Real time data processing and reconstruction from on-detector electronics
- Provides clocks and configuration for the TileCal modules
- Interface with the ATLAS trigger and read-out systems (FELIX)





IFIC-Valencia responsible:

Design of the Tile PPr (Carrier, CPM, auxiliary System on Chip boards) & Firmware

Production of 76% of the boards.

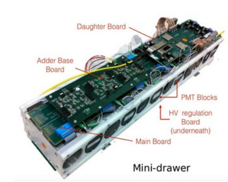
Each PPr formed by:

- 1 ATCA Carrier
- 4 Compact Processing Modules (CPM), 32 PPr in total
- Each CPM receives data from 2 modules (8 mini-drawer): 128 CPMs in total

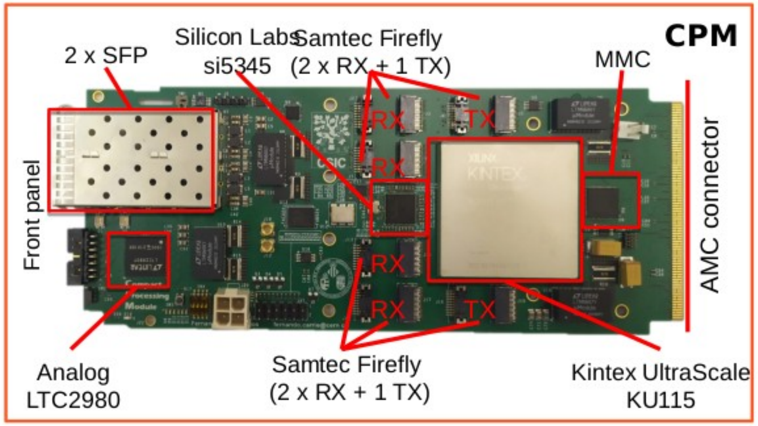
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

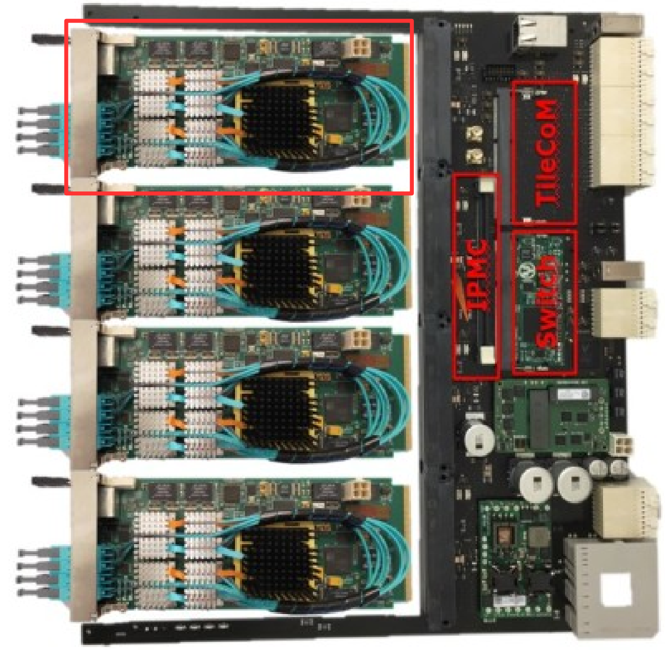
Financiado por la Unión Europea NextGenerationEU · Gobierno de España · Ministerio de Ciencia, Innovación y Universidades · Plan de Recuperación, Transformación y Resiliencia · Generalitat Valenciana, Conselleria de Educación, Universidades y Empleo · GVA NEXT

Mini-drawer info in backup



Tile Calorimeter Upgrade





CPM, Single AMC board:
- 6 Samtec Firefly modules (4 RX + 2 TX)
- 14 channels through AMC connector
- 2 SFP modules
- Xilinx Kintex Ultrascale KU115 FPGA

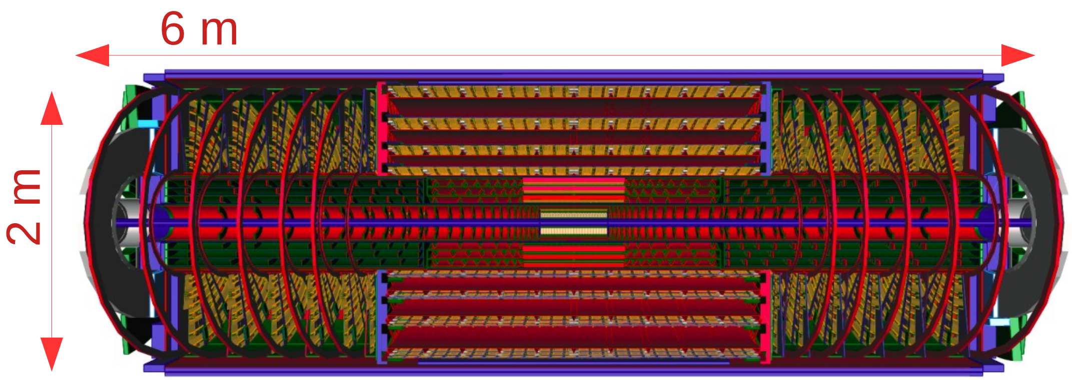
Status
- Firmware development at IFIC
- Procurement on-going at Valencia:
  - All active components for 128 CPMs received except for the FPGAs (15)
  - Tender process for 50% FPGAs assigned
  - Procurement of Firefly modules started

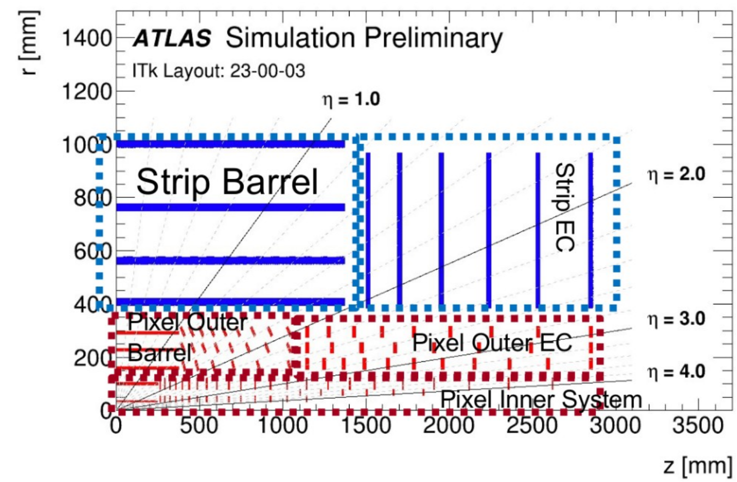
Integration tests (ATCA carrier + CPM + DAQ) on-going

More information on Carrier and TileCoM on back-up slides

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.
Financiado por la Unión Europea NextGenerationEU
Gobierno de España Ministerio de Ciencia, Innovación y Universidades
Plan de Recuperación, Transformación y Resiliencia
Generalitat Valenciana Conselleria de Educación, Universidades y Empleo
GVANEXT

ATLAS Inner Tracker (ITk)





- Complete replacement of the current Inner Detector (Pixel, SCT, TRT) with **Silicon**-only system
- **Pixel** (Inner system, outer barrel, outer end-cap, **13 m²**) and **Strip** detector (barrel, end-caps, **168 m²**)
- Increased eta coverage increases
- Reduced material and finer segmentation
- At least 9 silicon hits per track
- Radiation tolerant up to **1E16 neq/cm²** (inner Pixel)

IFAE working on **Pixel** System (innermost layer)

IFIC working on **Strip** Detector (end-caps)

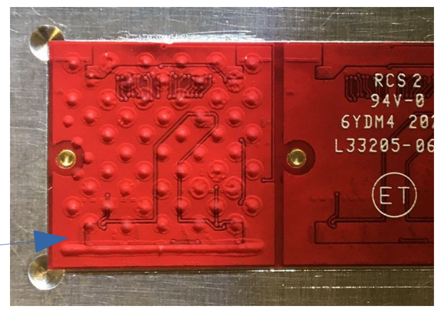
ATLAS ITk Pixel Triplet Module Assembly

- IFAE worked on sensor R&D, prototyping & qualification
- Module assembly qualification with RD53A hybrids
- Developed an assembly line based on a pick-and-place 5 µm precision machine for tight requirements of innermost barrel modules

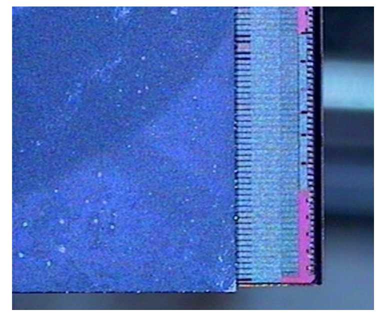
Sensor and assembly coordination roles

- ITk 3D hybrid 25x100 um2 for linear triplet
- Triplet flexible PCB

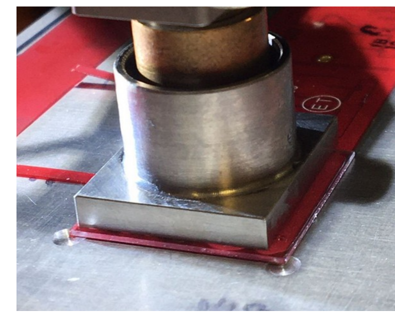
(1) Deposit glue on flex



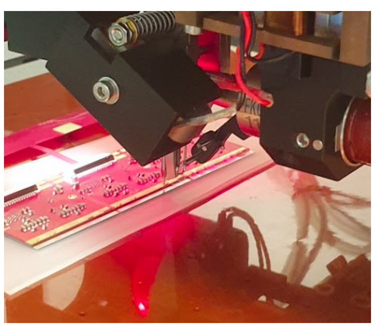
(2) Align hybrids and flex



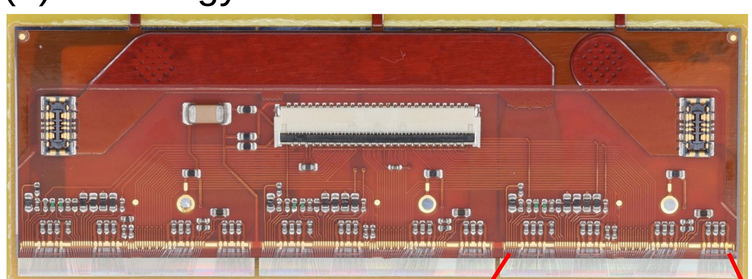
(3) Place hybrid on flex let it cure



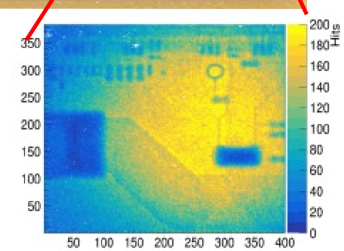
(5) Wire-bond



(6) Metrology



(7) Testing…
Threshold tuning,
Detection with Sr90,
Climate chamber, etc



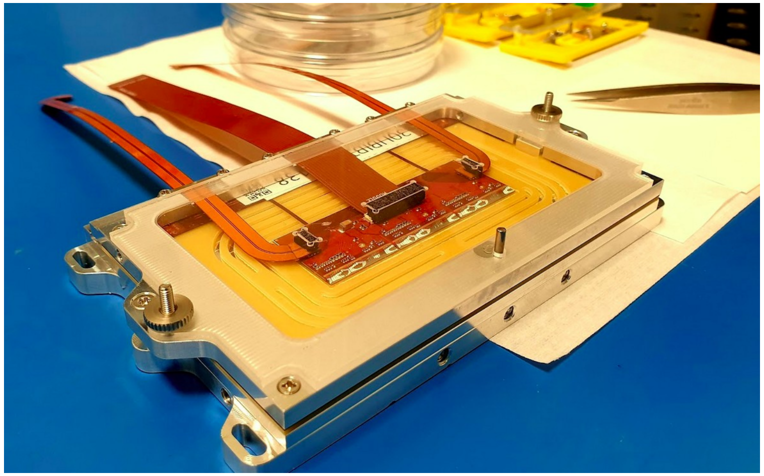
Several metrology steps
- Length
- Rotation
- Flatness
- Glue coverage (in glass dummies)
- Glue weight
- …

IFAE

ATLAS ITk Pixel Triplet Module Pre-production

- Triplet pre-production well underway at **IFAE**
- Out of 9 triplets assembled so far only 1 has currently has a critical failure

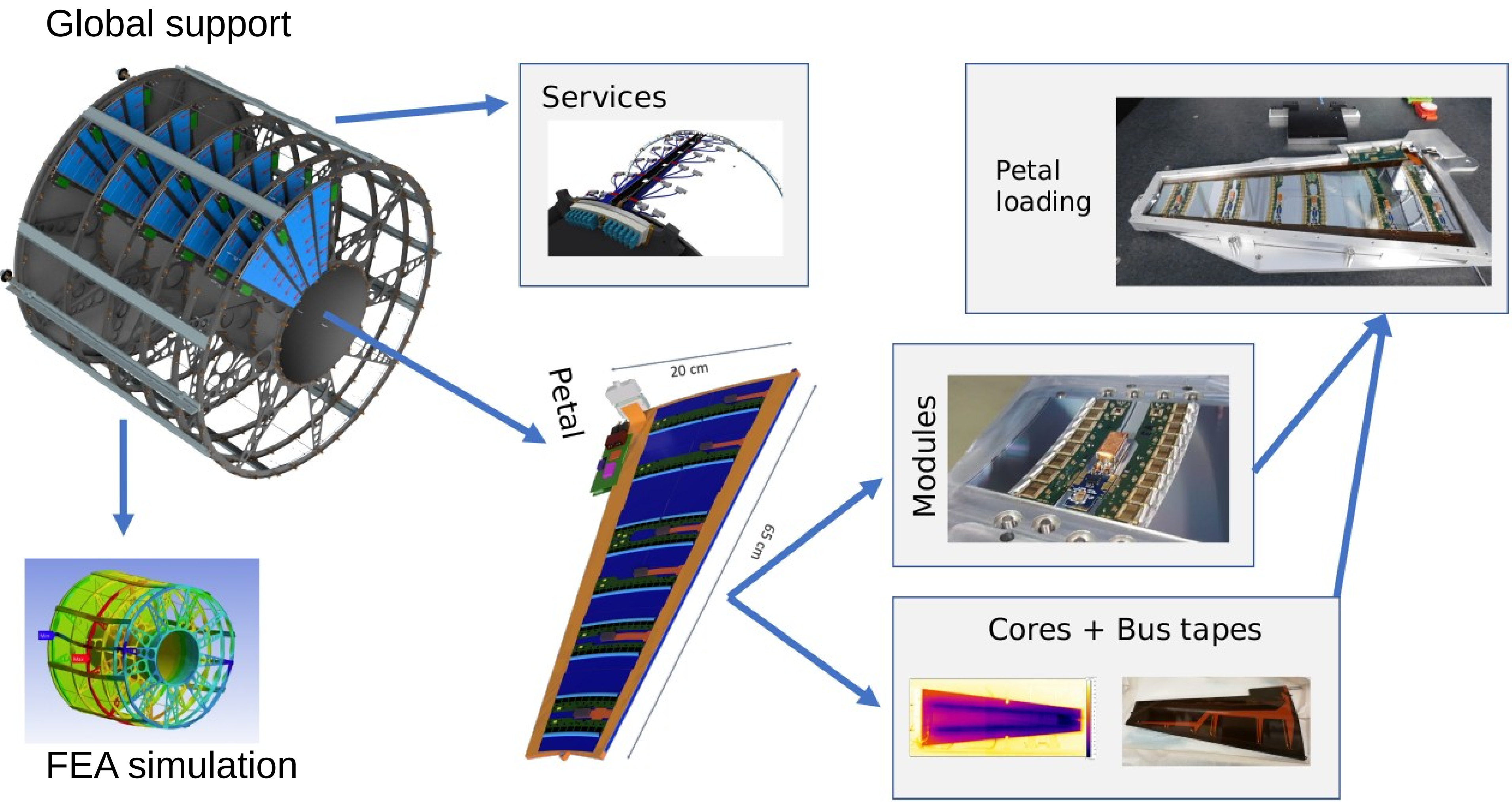
	SN	BMs	Part Rec.	Assembly	WB	Warm	Cold	TC+PFA	Sta+PFA	F. Warm	F. Cold	Comments
Pre-0	20UPIMS2102138	Sin50-IZM	DONE	DONE	DONE	DONE	DONE	DONE	Not Yet	Not Yet	Not Yet	Some disc. areas (expected)
Pre-1	20UPIMS2102134	FBK25-LND	DONE	DONE	DONE	FAIL	NO	NO	NO	NO	NO	No communication (Ship to Berkeley)
Pre-2	20UPIMS2102133	FBK25-LND	DONE	DONE	DONE	DONE	DONE	DONE	Not Yet	Not Yet	Not Yet	Disc areas. Increased after TC
Pre-3	20UPIMS2102132	FBK25-LND	DONE	DONE	DONE	DONE	DONE	DONE	Not Yet	Not Yet	Not Yet	Disc areas. Increased after TC
Pre-4	20UPIMS2102141	FBK25-LND	DONE	DONE	DONE	DONE	DONE	DONE	Not Yet	Not Yet	Not Yet	So far, OK
Pre-5	20UPIMS2102142	FBK25-LND	DONE	DONE	DONE	DONE	DONE	NO	Not Yet	Not Yet	Not Yet	Source scan crash // LPmode error
Pre-6	20UPIMS2102143	FBK25-LND	DONE	DONE	DONE	DONE	DONE	NO	Not Yet	Not Yet	Not Yet	Source scan crash
Pre-7	20UPIMS2102144	FBK50-IZM	DONE	DONE	DONE	DONE	DONE	Not Yet	Not Yet	Not Yet	Not Yet	So far, OK
Pre-8	20UPIMS2102146	FBK50-IZM	DONE	DONE	DONE	DONE	On going	Not Yet	Not Yet	Not Yet	Not Yet	
Pre-9	20UPIMS2102147	FBK50-IZM	DONE	DONE	DONE	DONE	On going	Not Yet	Not Yet	Not Yet	Not Yet	
Pre-10	?	?	Not Yet	Not Yet	Not Yet	Not Yet	Not Yet	Not Yet	Not Yet	Not Yet	Not Yet	



- Modules to be shipped to SLAC (USA) for loading onto staves
- Triplet production (*ie final modules*) to start end of 2024
- Contribution of **130 triplet modules for the innermost pixel layer**

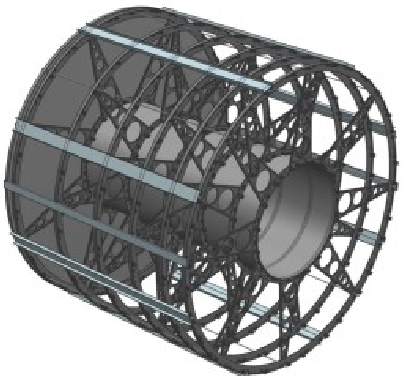
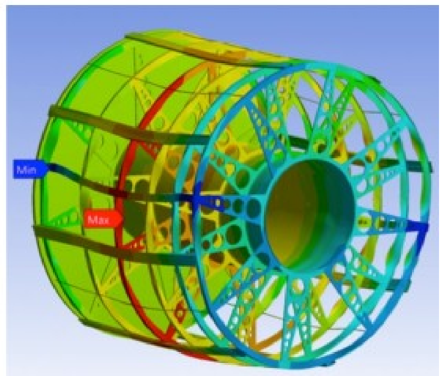
IFAE

ATLAS ITk Strips

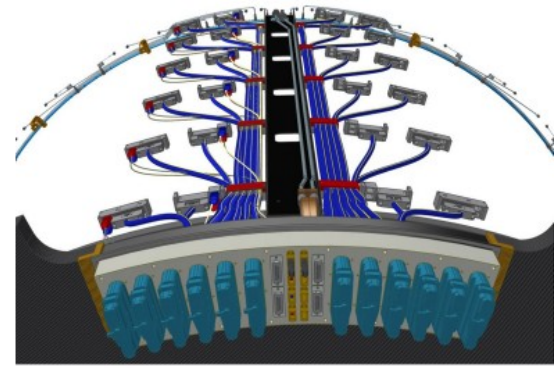


IFIC played & plays several coordination roles, including Strip deputy PL, etc

ATLAS ITk Strips: Global Support & Services

- Designed the global support structure and petal fixation to the structure together with NIKHEF and DESY

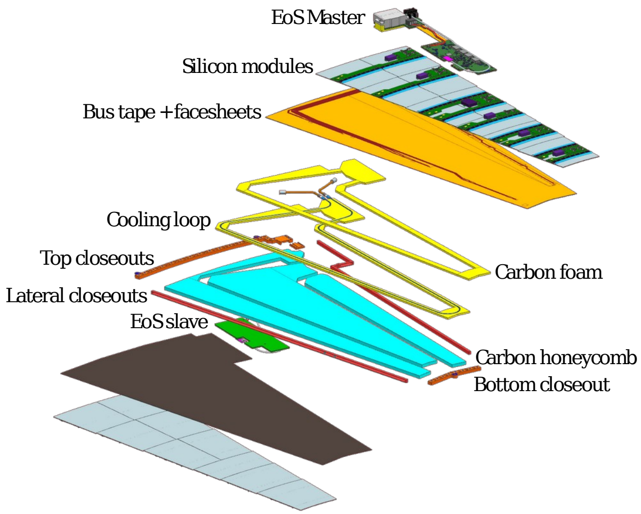


- Design of the service module bringing power, control signals and cooling to the petals + patch panels and customized cables and connectors.



- Real size mock-up to check envelopes and train connection of services
- Assemble and test the 16 service modules and install them in the EC mechanical structures

ATLAS ITk Strips: Petals and Modules



- Sensors glued on local supports (Petals), which are the building blocks of the end-cap Strip system
- It is a carbon fiber sandwich with integrated cooling and electronics
- Double sided object with 18 sensors (70 cm length, 10-20 cm width)

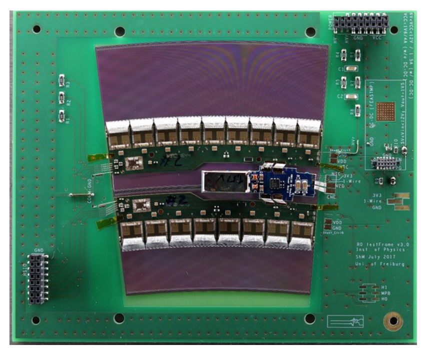
Petal Cores:

Final design ready. **Production in industry** (AVS, Spain).

IFIC and DESY responsible of **QC/QA during production** (200 cores each).

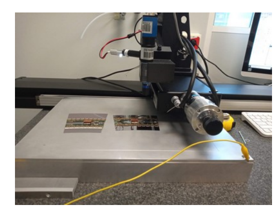
Module: sensor + glue + hybrid PCB

- Control glue thickness to 10 µm
- Control positioning to 10 µm
- Wire-bonding (7k chips, 1.8 M wires!)



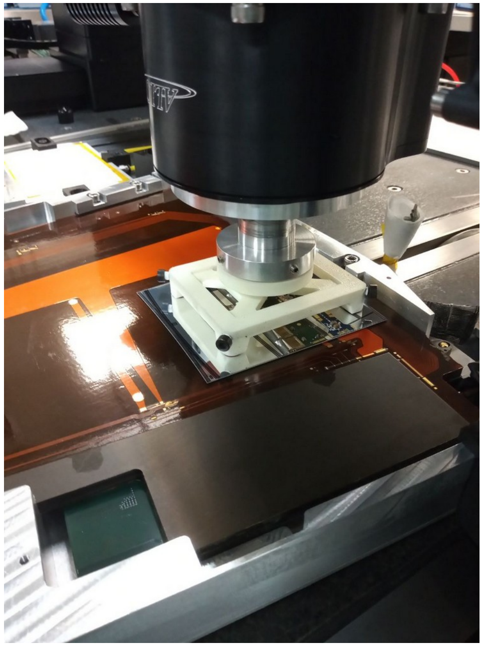
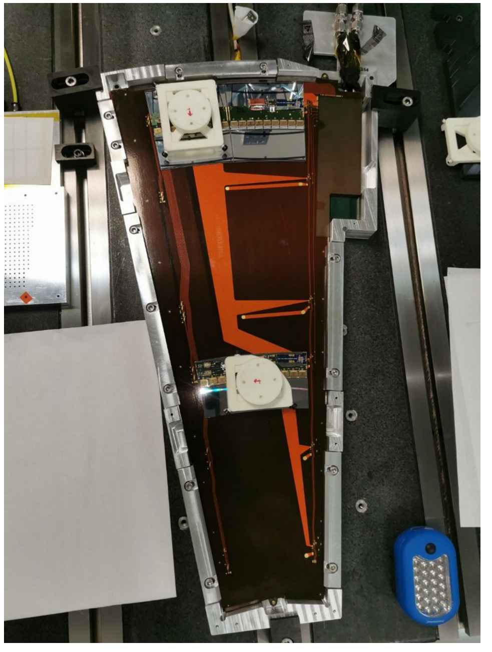
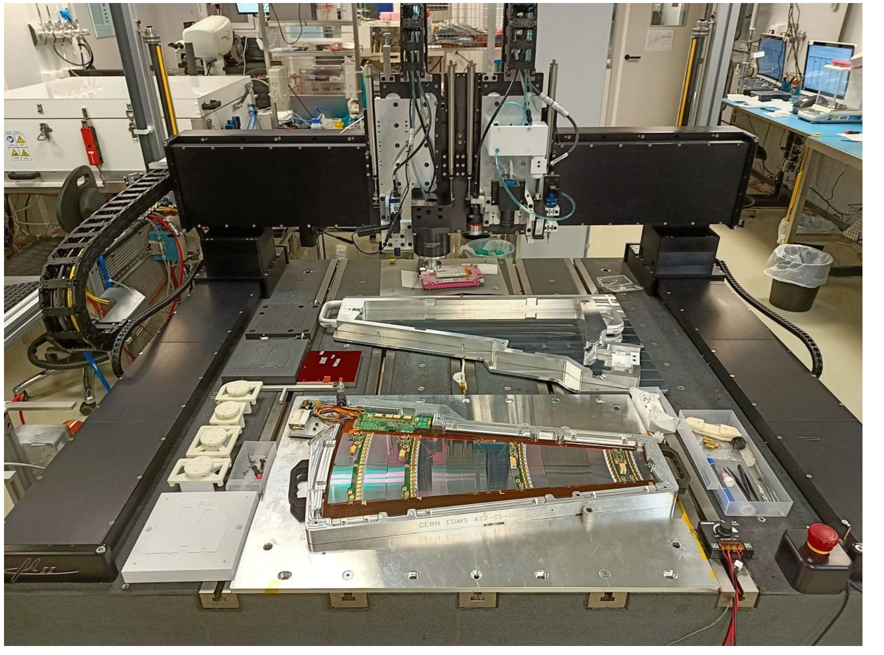
First module assembled at Valencia

- Metrology
- Electrical testing



CSIC IFIC INSTITUT DE FÍSICA CORPUSCULAR VNIVERSITAT DE VALÈNCIA

ATLAS ITk Strips: Module Loading

IFIC will ”populate” **100 petals**. With gantry machine that

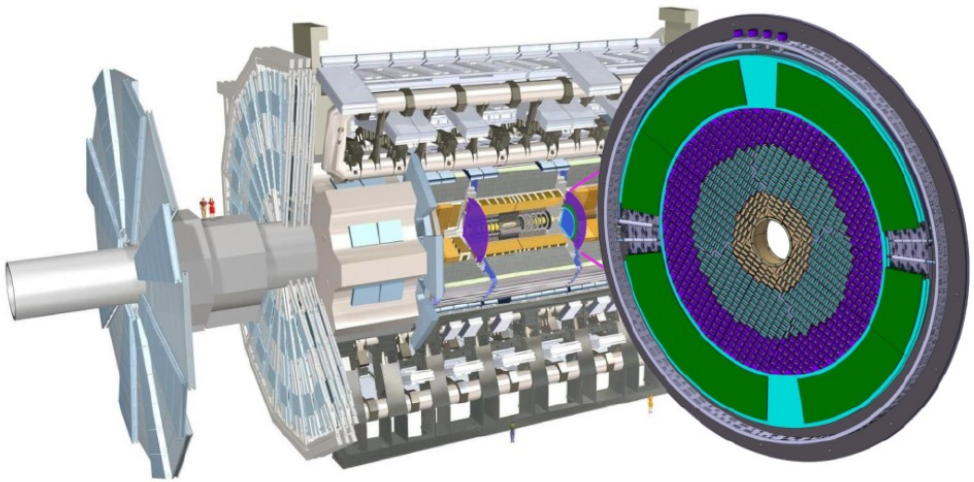
- Dispenses the glue on the petal
- Positions the module with 20 μm precision
- And does the final metrology

100 petals contain 1800 modules, build 600 of them and reception-test 1200 modules

Fully loaded petals have to be electrically tested and operated at -35 ^{O}C

CSIC IFIC INSTITUT DE FÍSICA CORPUSCULAR VNIVERSITAT DE VALÈNCIA

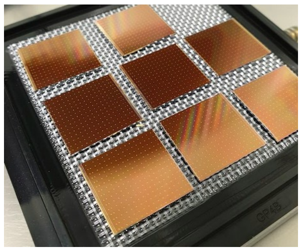
ATLAS: High Granularity Timing Detector



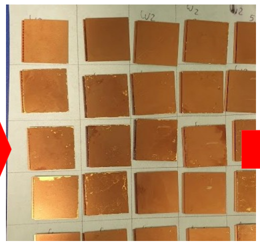
- HGTD designed to improve ATLAS performance in the forward region in view of increased HL-LHC pile up
- Timing based on LGAD sensors
- Also provides luminosity information
- Total active area about 10 m^2

IFAE making critical contributions:

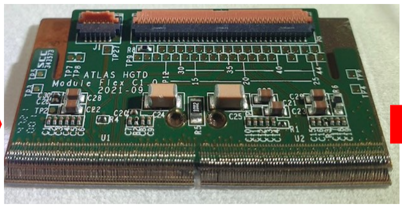
LGAD Sensor R&D(with CNM)



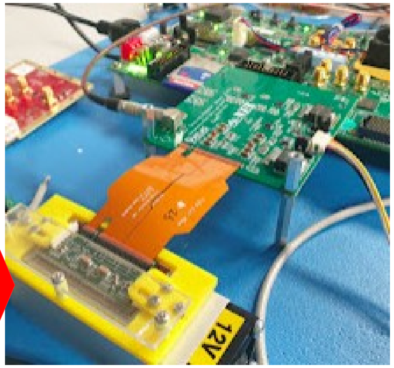
ASIC design (ALTIROC)



Hybridization, developed process (in-house)



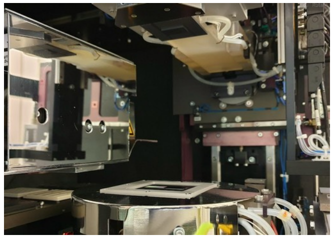
Module assembly and loading



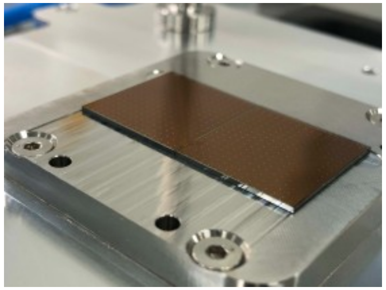
Module testing (Alvin Readout system developed at IFAE)

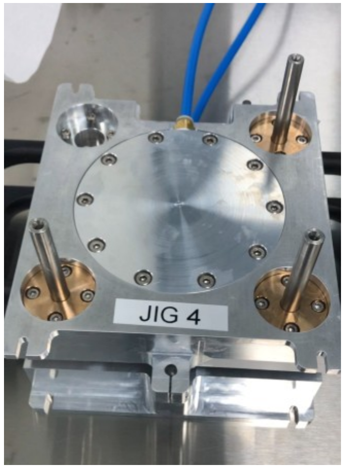
ATLAS HGTD Module Assembly

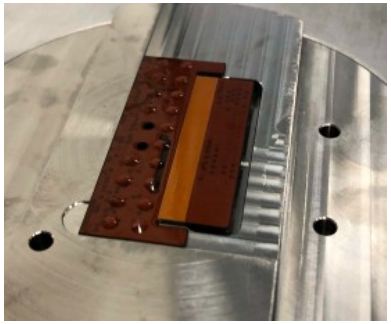
Hybridization (in house)



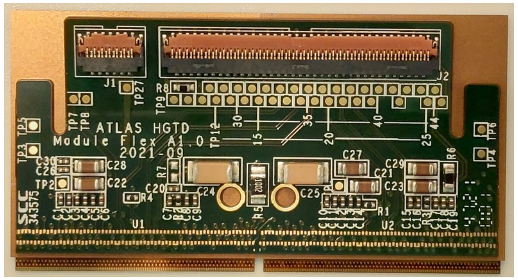
Flex/hybrid alignment and gluing



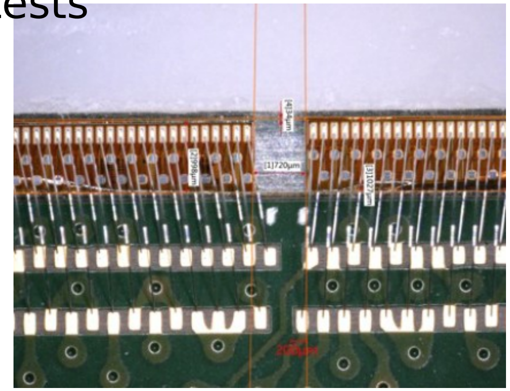




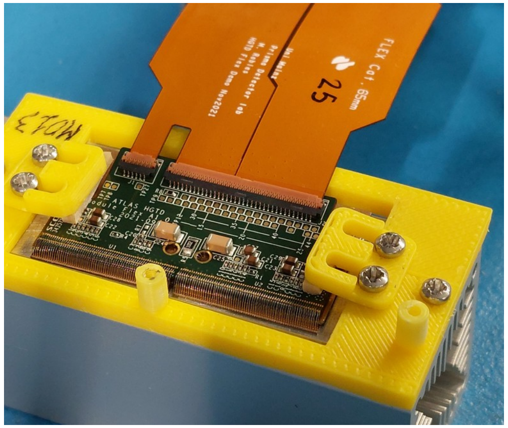
Metrology

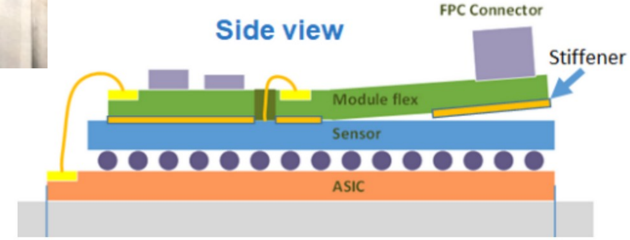


Wire-bonding and pull tests



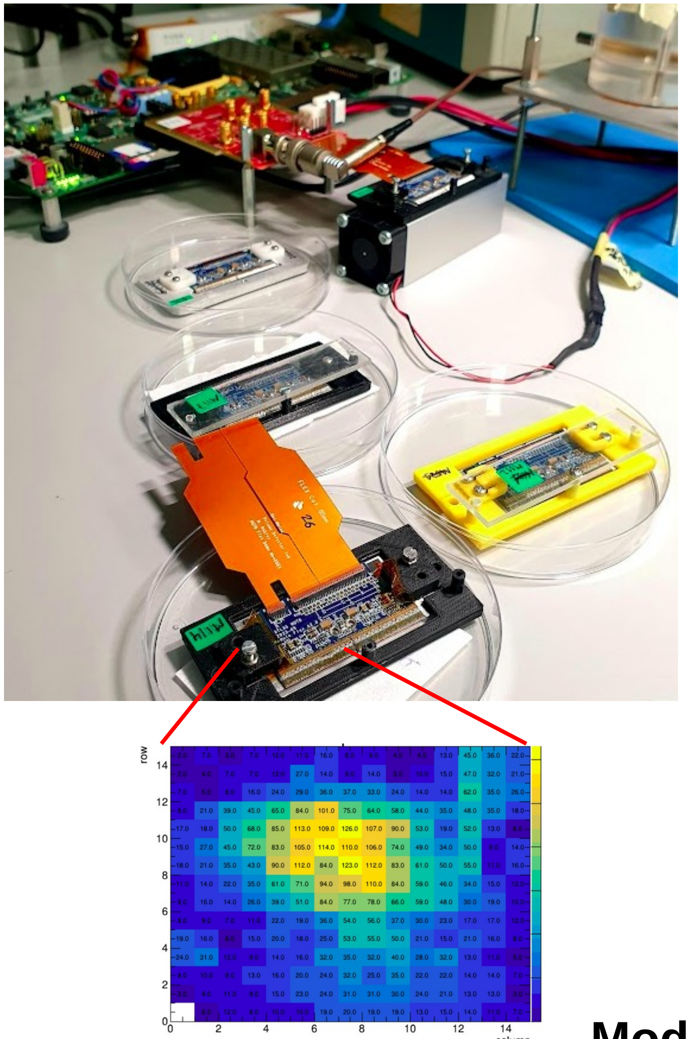
Final module testing

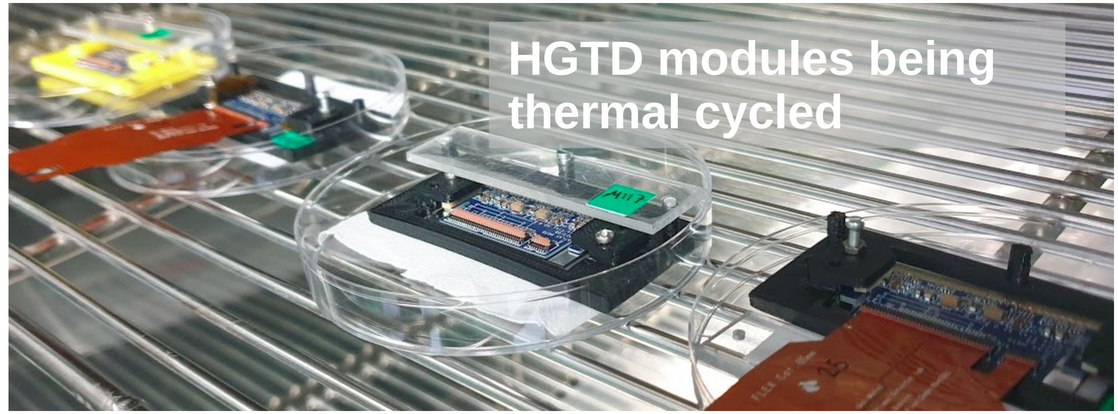




- IFAE leading prototyping
  - Hundred+ hybrids produced (ALTIROC2/3)
  - 40+ double chip modules produced
- IFAE contribution is about 10% of the modules (~1k)

ATLAS HGTD Module Testing



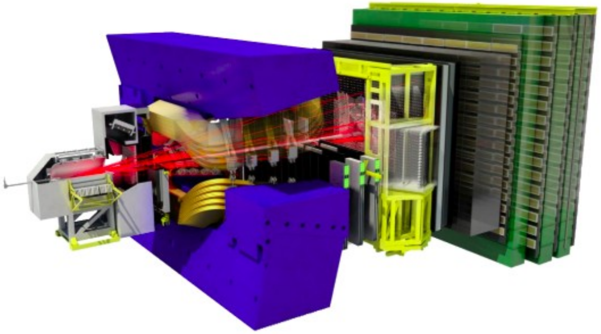


- Extensive testing of prototype modules on-going:
  - Module electrical performance
  - Verification of timing resolution
  - Thermal cycles
  - Test-beam campaigns (40-50 ps achieved with ALTIROC3 hybrids)
- To do: **module loading** onto support units (space constrains to be resolved...)

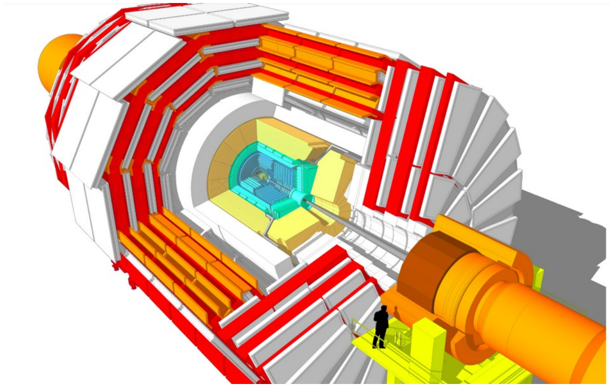
Module pre-production set to start end of 2024

Last words

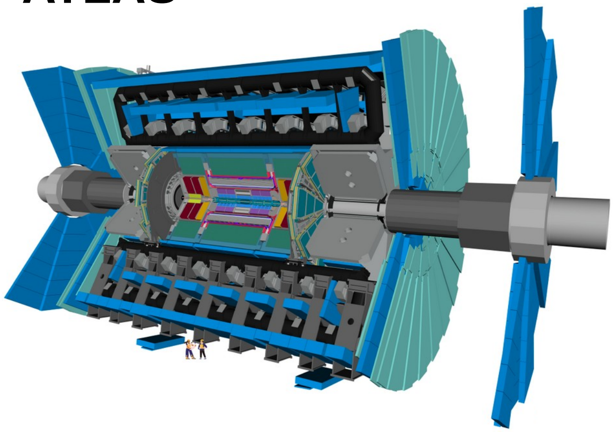
LHCb



CMS



ATLAS

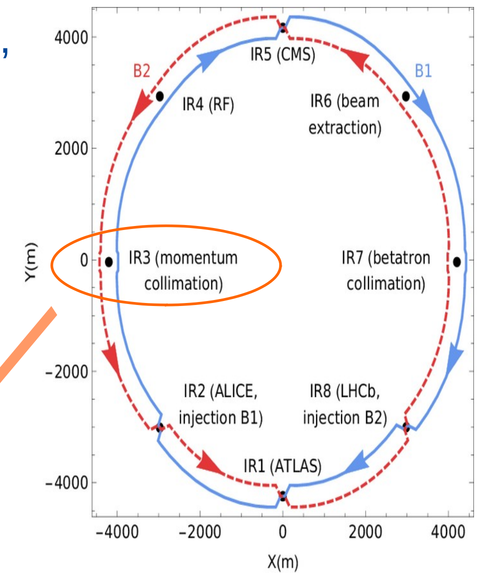


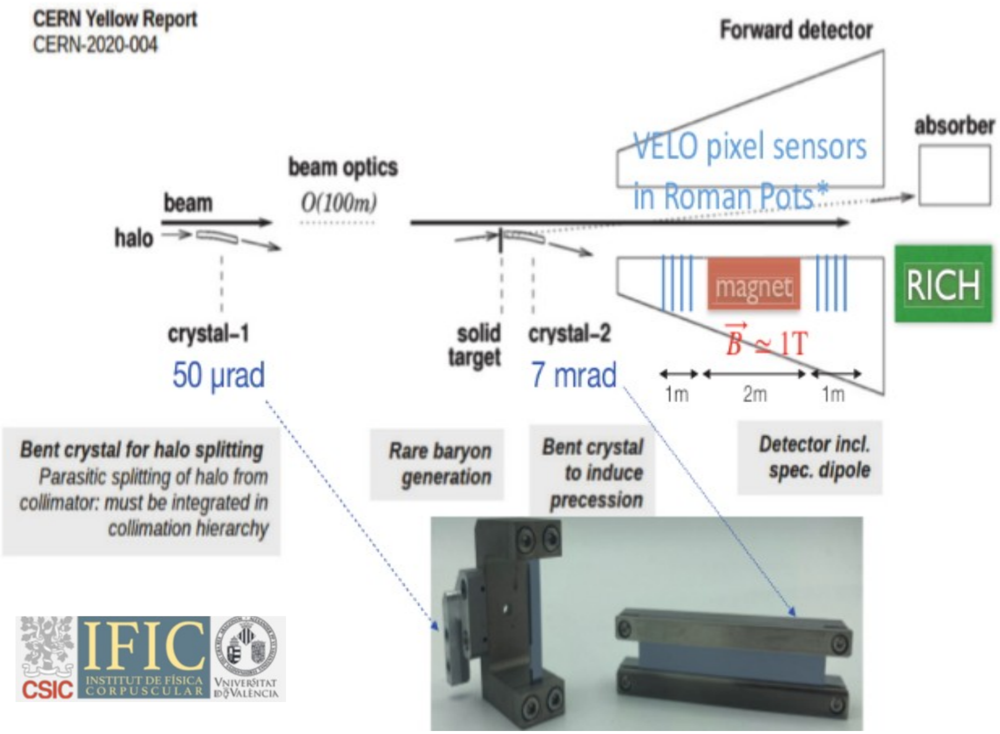
- Spanish groups playing a critical role in the upgrade activities of the LHC experiments
- Spanish participation in the new generation of particle physics experiments enhanced through the PPCC
- We are all looking forward to physics with the HL-LHC and beyond

Back Up Slides

PoP crystal-based EDM/MDM experiment @ LHC

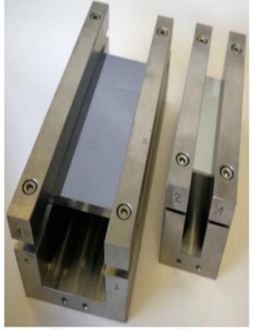
- Experiment for direct measurement of magnetic and electric dipole moments of charm baryons at LHC. Letter of Intent (LoI) in preparation. Ultimately explore τ lepton
- Proof-of-Principle (PoP) at IR3 in 2025 (TWOCRYST, installation in next YETS) approved by the LMC
- Proto-collaboration (MoU signed): CERN, INFN, IJCLab, IFIC,

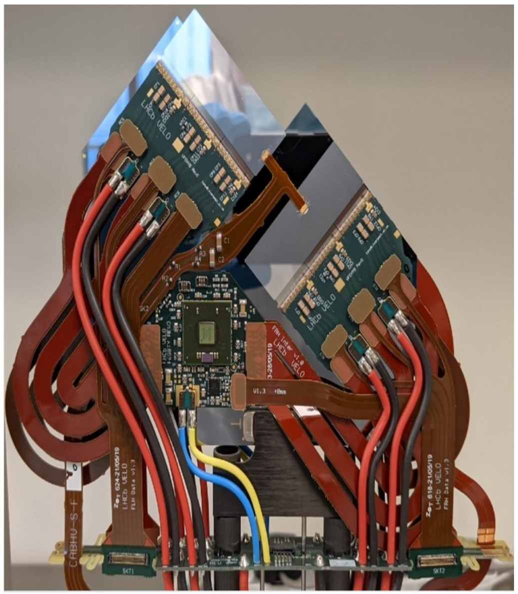




- Machine operation & demonstration of achievable PoT
- Detector setup & measurement of TeV regime channeling

TWOCRYST Technology





- Machine: beam manipulation using bent crystals
  - Bent crystals: Si with mechanical bending as baseline. Ge and/or anodic bonding for potential upgrade
  - Deflection of beam halo towards W target
  - Goniometers for precision bent crystal positioning
- Magnet: compact spectrometer dipole magnet
  - Warm dipole magnet already available in situ (1.9 T m) as baseline
  - Compact dipole magnet with higher field (4.0 T m) in 20K HTS technology for potential future upgrade
- Detector: compact with high granularity, covers very forward region
  - LHCb VELO silicon pixel sensors inside Roman Pots (from ATLAS-ALFA)
  - RICH detector for p, K, p PID up to 1 TeV energies

Reuse of VELO electronics as much as possible

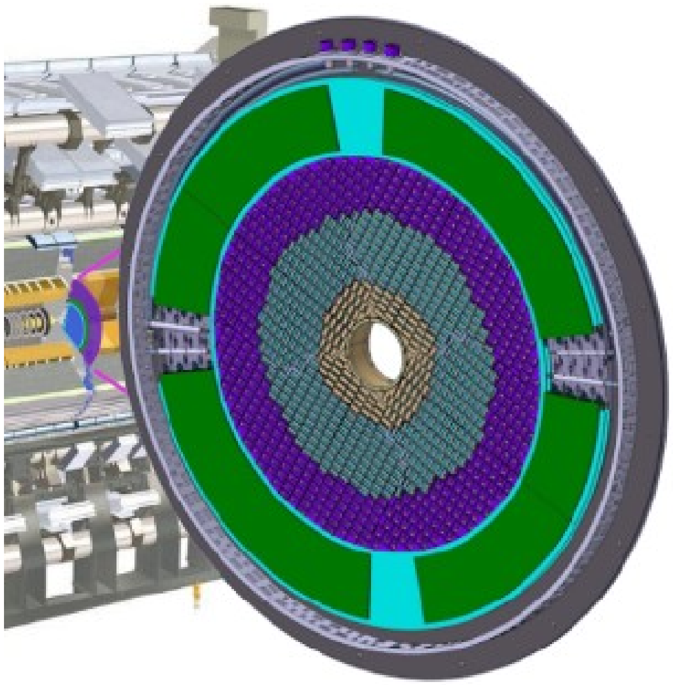
- Different vacuum enclosure
  - → New feed-through system
- Different mechanical support & cooling
- Different sensor layout
  - → New flexes & sensor hybrid and flex integration
- Same OPB (interface w/ powering, data & control)
- Same back-end electronics & DAQ/control software

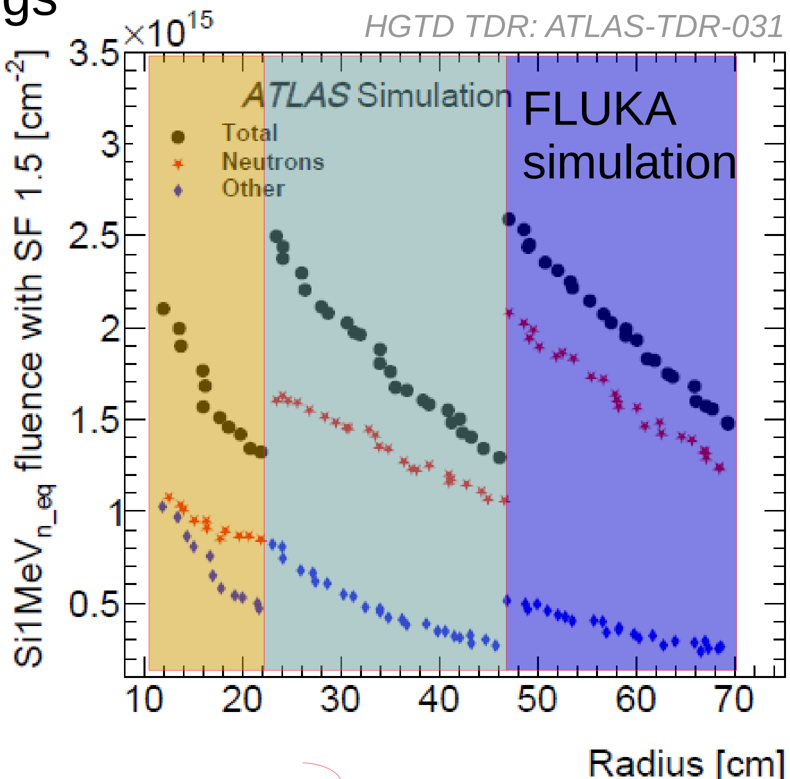
@ IFIC

- Feed-through
- Flexes & integration with hybrid
- Monitoring system (temp. & humidity inside RP)
- HV/LV powering & distribution
  - → Power supplies, patch panels
  - → Tree segment cabling: crates + tunnel ~300 m + setup

HGTD Radiation Hardness

- The strategy to cope with the high radiation environment is to segment the detector into replaceable rings

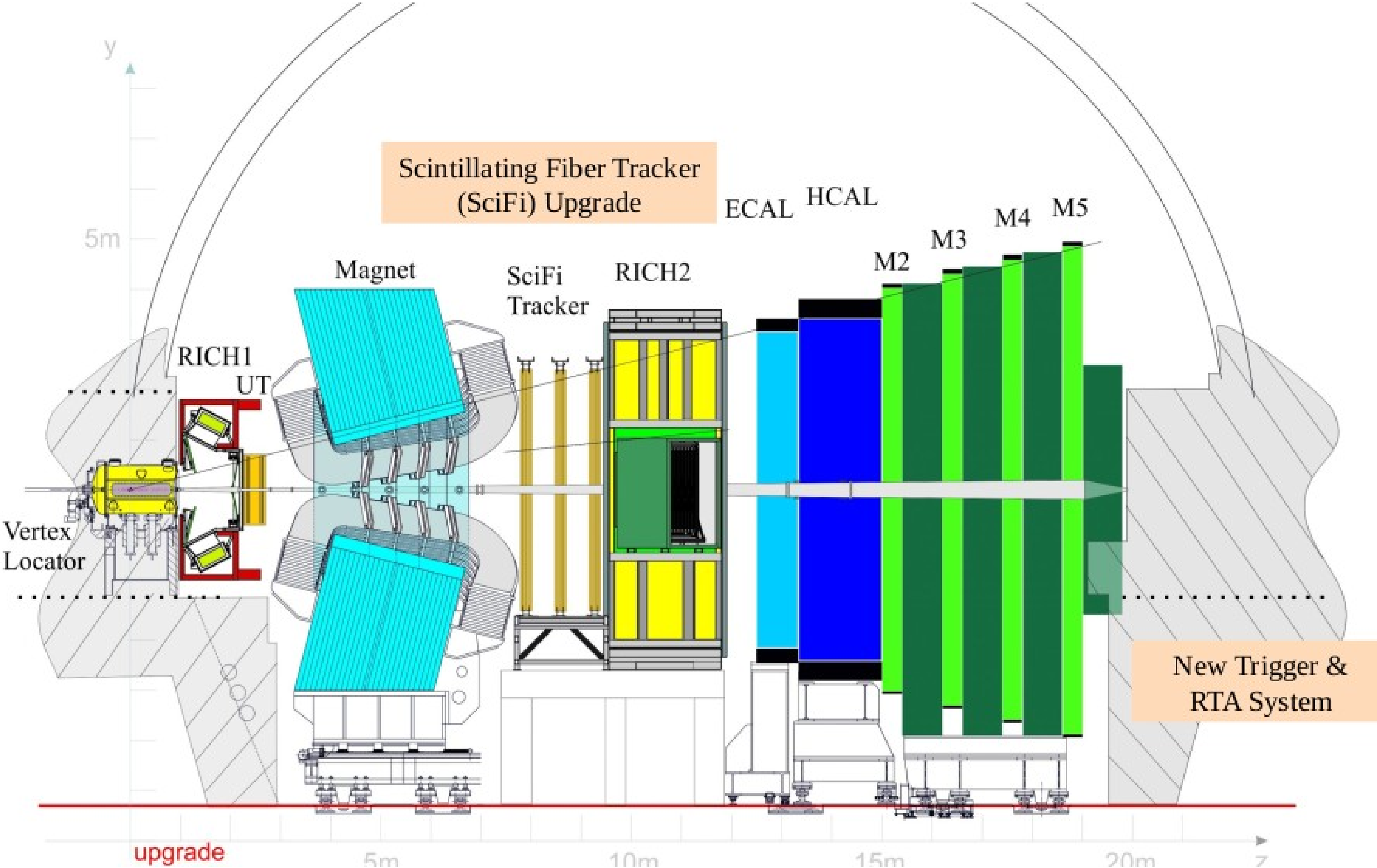




- Inner ring (12-23 cm) replaced every 1000/fb
- Middle ring (23-47 cm) replaced every 2000/fb
- Outer ring (47-64 cm) never replaced

Maximum fluence: **2.5E15 1MeV n_{eq}/cm²** and 2MGy at the end of HL-LHC (4000/fb)

LHCb Upgrade I



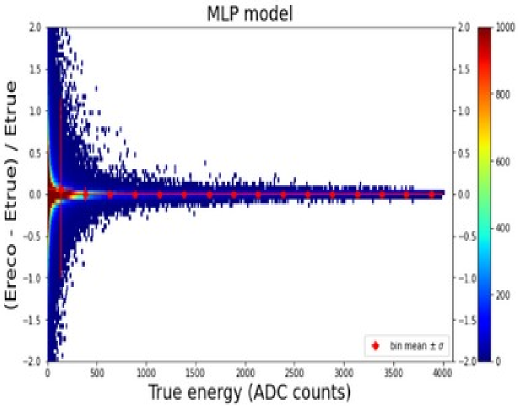
Signal Reconstruction

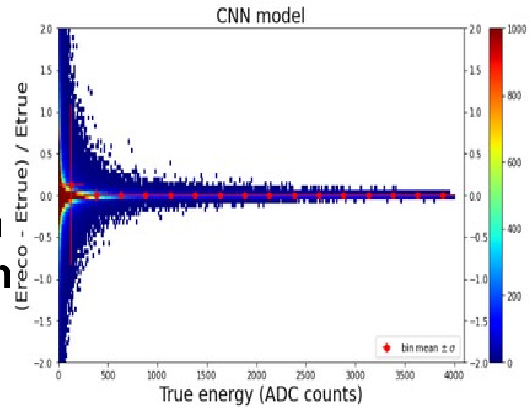
For the HL-LHC, calorimeter signals will be processed for each BC, before the trigger accept signal, and passed to the first level of trigger. Signal will be processed by FPGAs, which have much higher processing power than the current DSPs.

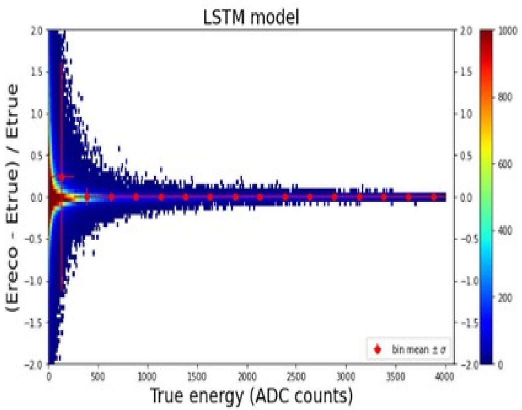
Pileup values will be much for HL-LHC requiring more sophisticated signal reconstruction techniques

We are developing AI techniques to run real-time in the FPGA to reconstruct the Tile Calorimeter signals.

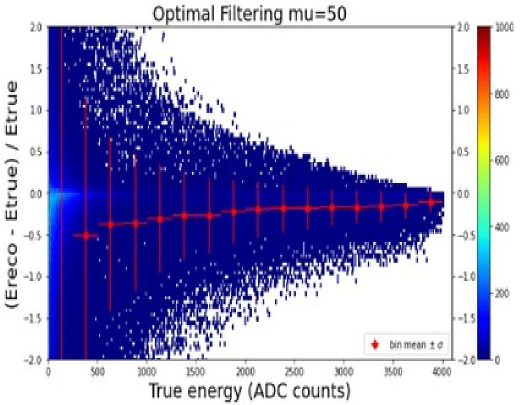
Reconstruction algortihms for Phase-II perform much better than current algorithm







Current Run 3 algorithm



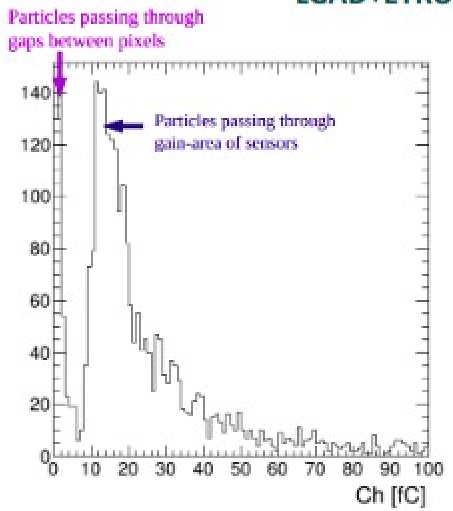
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

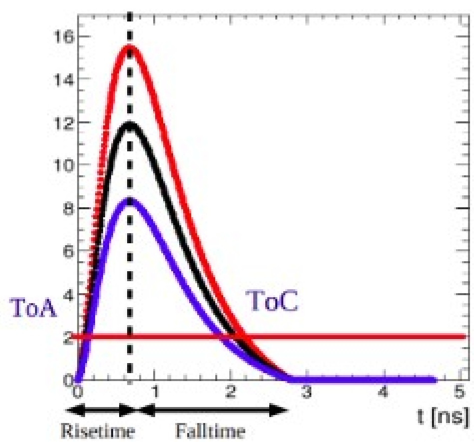
Financiado por la Unión Europea NextGenerationEU

Endcap Timing Layer (ETL) of CMS: Geometry/Simulation/Reconstruction

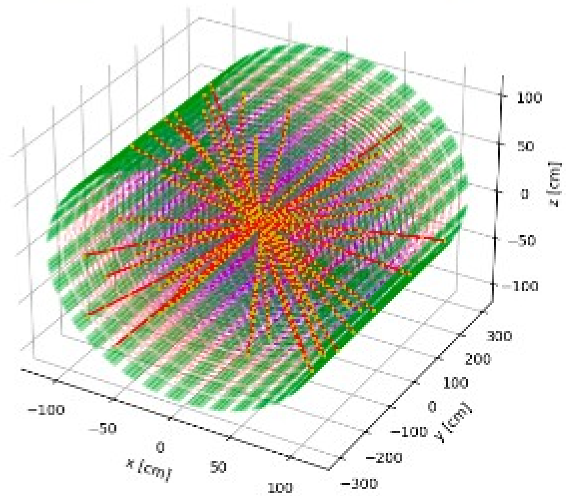
- In charge of the Mips Timing Detector (MTD) Data Performance Group (DPG) 2019-2023
- Implementation of the full software chain for the MTD from geometry to high level reconstruction
  - Latest developments: realistic LGAD-ETROC simulation in CMSSW and implementation of offline time-walk corrections
  - Updated ETL Geometry including 16x16 sensors with 2x2 sensor modules
- From 2024 in charge of the alignment of the MTD (initial studies + software infrastructure)

LGAD+ETROC simulation in CMSSW





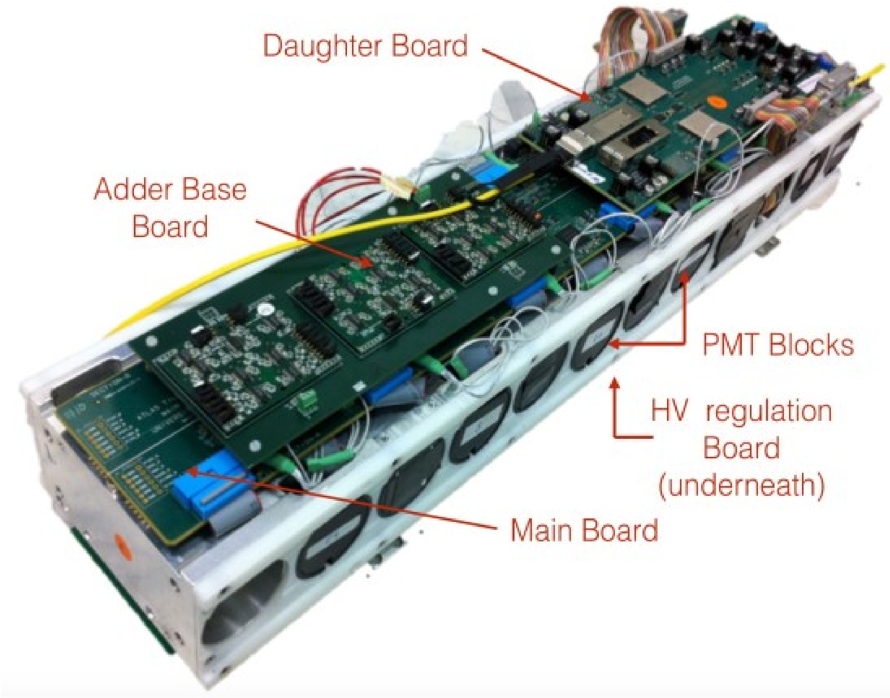
Alignment with tracks initial study



ATLAS TileCal: Mechanics

- Mechanical housing of TileCal front-end electronics (**mini-drawers**) proposed and designed by IFAE

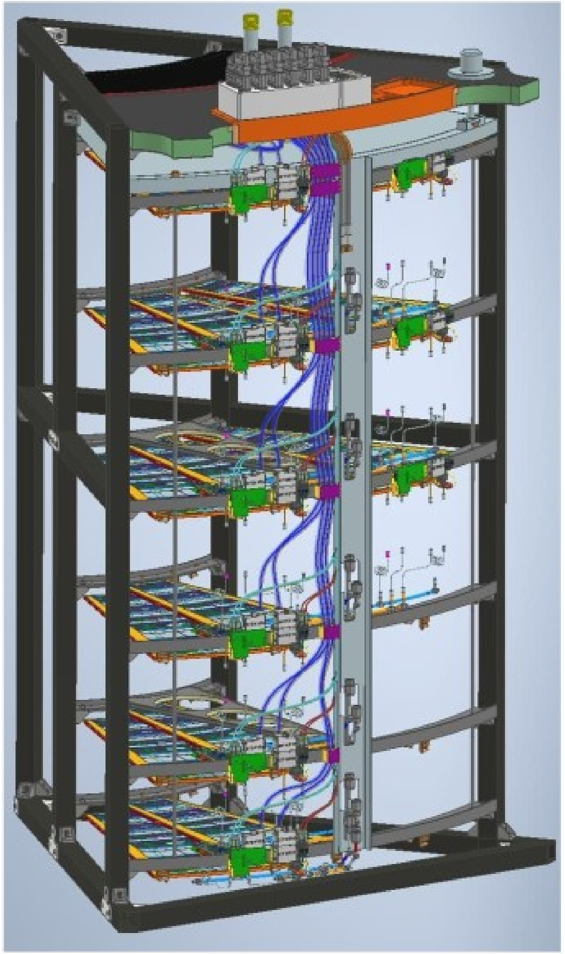
- Production of 40% mini-drawers in-house
- Completed **on-time** and delivered to CERN



Other TileCal Activities:

- Implementation of the Tile-based luminosity measurement to Run 4
- Investigation of possible fine granularity readout for the TileCal latest stages of HL-LHC

System test



- ✓ We design the mechanical structure for a system tests setup that will be operated first at DESY and later at CERN.
  - ➔ The setup will operate more than one petal a a time and will serve to test several aspects of the system.
- ✓ We will participate in the preparation and operation of such system.