EP Department
purchasing plans and overview

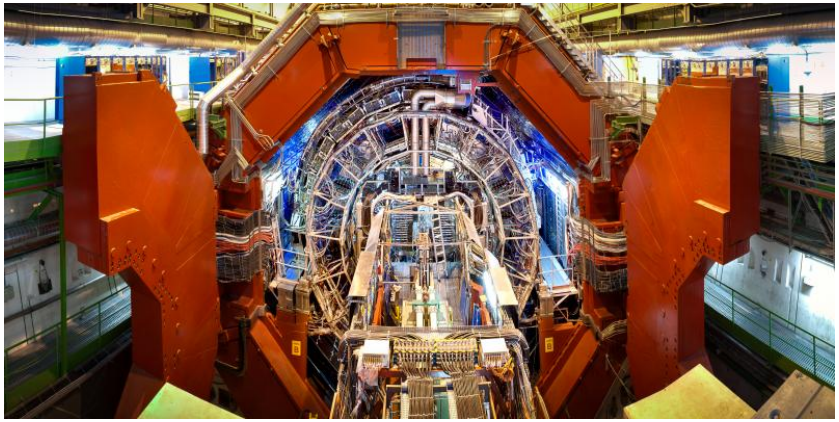
Carlos SOLANS

On behalf of the EP department

Spain @ CERN 2018

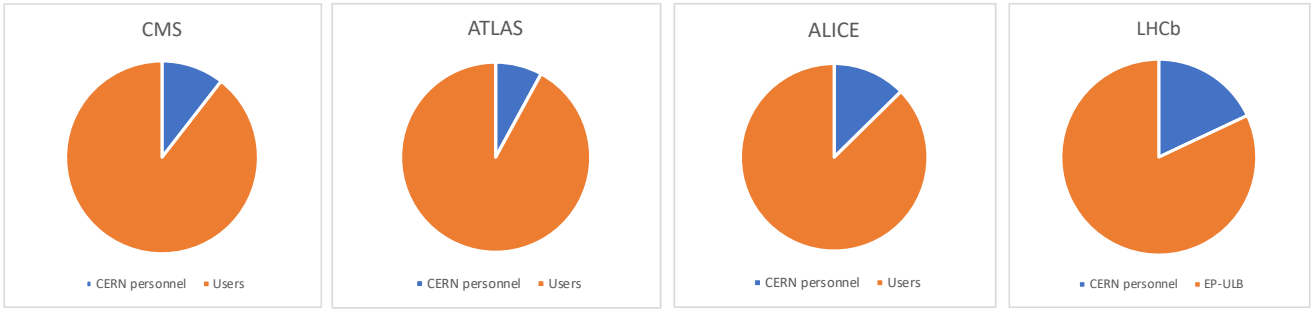
https://spain-at-cern.web.cern.ch/

The EP department



- The Experimental Physics (EP) Department carries out research in the field of experimental particle physics.
- It aims to provide a stimulating scientific atmosphere and remains an important reference center for the European physics community.
  - Contributes to the education and training of young scientists.
- EP is one of the largest departments at CERN
  - 500 staff members
  - 300 other members of personnel: Fellows, Associates, Students and Apprentices.
  - 12,000 users that visit CERN from their home institutes around the world to perform scientific research.

The role of the experiments



- Experiments make the EP department unique at CERN
- Experiments are collaborations between many institutes where CERN represents a small part
- Experiments drive R&D in their fields with the help of industrial partners
- There are also three support groups in EP

EP Groups structure

EP-DI	Office of the Department Head
EP-AGS	Administration and General Services
LHC Experiments	
EP-AID, EP-AIO, EP-AIP	ALICE
EP-ADE, EP-ADO, EP-ADP, EP-ADT	ATLAS
EP-CMD, EP-CMG, EP-CMO, EP-CMT, EP-CMX	CMS
EP-LBC, EP-LBD, EP-LBO	LHCb
Non-LHC Experiments	
EP-LCD	Linear Collider Detector
EP-NU	Neutrino Group
EP-SME	Small & Medium Experiments
Support groups	
EP-DT	Detector Technology
EP-ESE	Electronics Systems for Experiments
EP-SFT	Software Development for Experiments

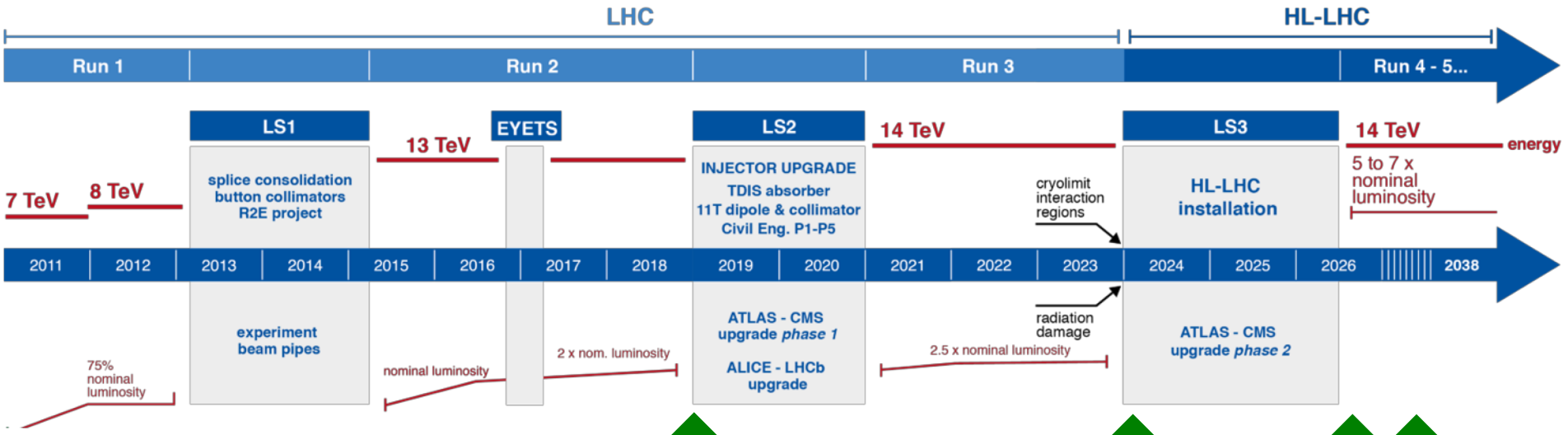
Users Groups

EP-UAD	Antiproton Users
EP-UAI	ALICE Users
EP-UAT	ATLAS Users
EP-UC3	CTF3 Users
EP-UCM	CMS Users
EP-UFT	Fixed Target Users
EP-UGC	General Collaboration Users
EP-UHC	Other LHC Users
EP-UIS	ISOLDE Users
EP-ULB	LHCb Users
EP-ULD	Linear Collider Detector Users
EP-UNT	n_TOF Users
EP-UNU	Neutrino Platform Users
EP-UOP	Other Physics Users
EP-URD	R&D Users

https://ep-dep.web.cern.ch/organisation

The LHC experiments

The LHC / HL-LHC program



Upgrade of ALICE
Upgrade 1 of LHCb

ATLAS and CMS
Approval of Phase 2 TDRs
R&D ongoing

LHCb Consolidation

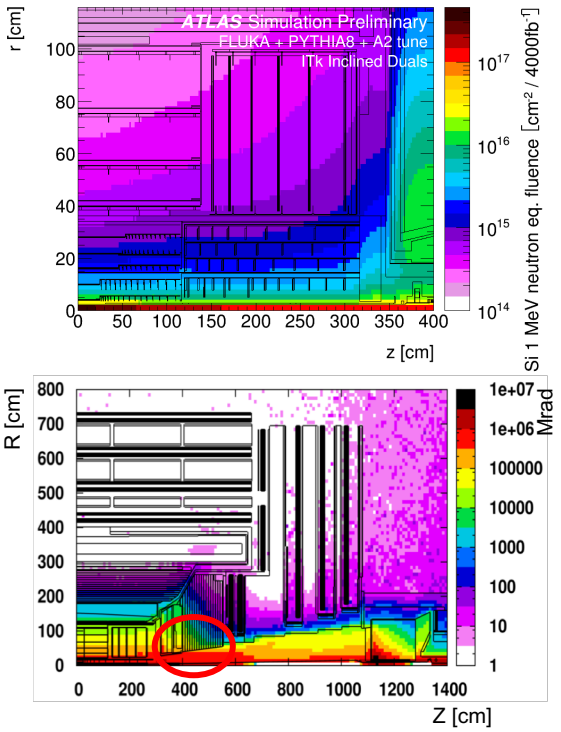
ATLAS and CMS
Phase 2 upgrade installed

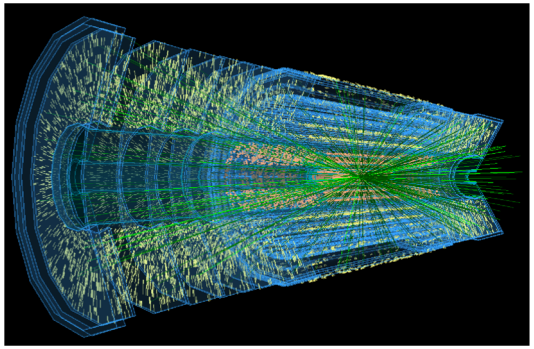
LS4: Upgrade 2 of LHCb

Substantial upgrades required for all LHC experiments

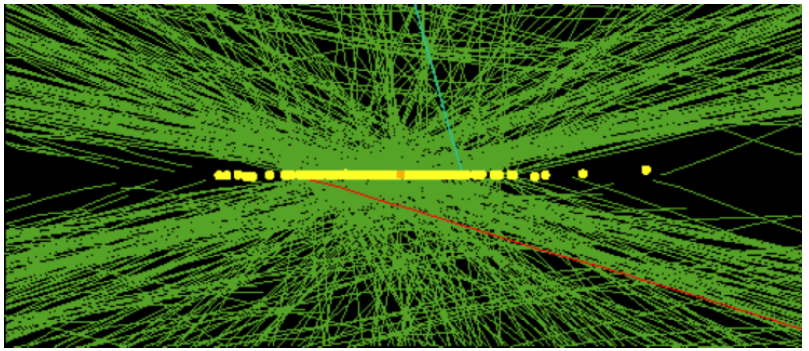
Challenges at the LHC

- Intense proton beams $L_{inst}=7.5x10^{34}$ $cm^{-1}s^{-1}$
- Large pile up μ (interactions per crossing) = 140 – 200
- Extreme radiation exposure of detectors
  - CMS: ~$1x10^{16}$ 1 MeV n_{eq} cm^{-2} @ $3ab^{-1}$
  - ~2 MGy absorbed dose in endcap calorimeters
- Extreme high data flow rate:
  - Few time total world Internet flow !
- Forefront for technologies:
  - Detectors, electronics, computing, analyses
- Upgrades necessary for the exploitation of the full potential of the LHC : Maintain detector performance !



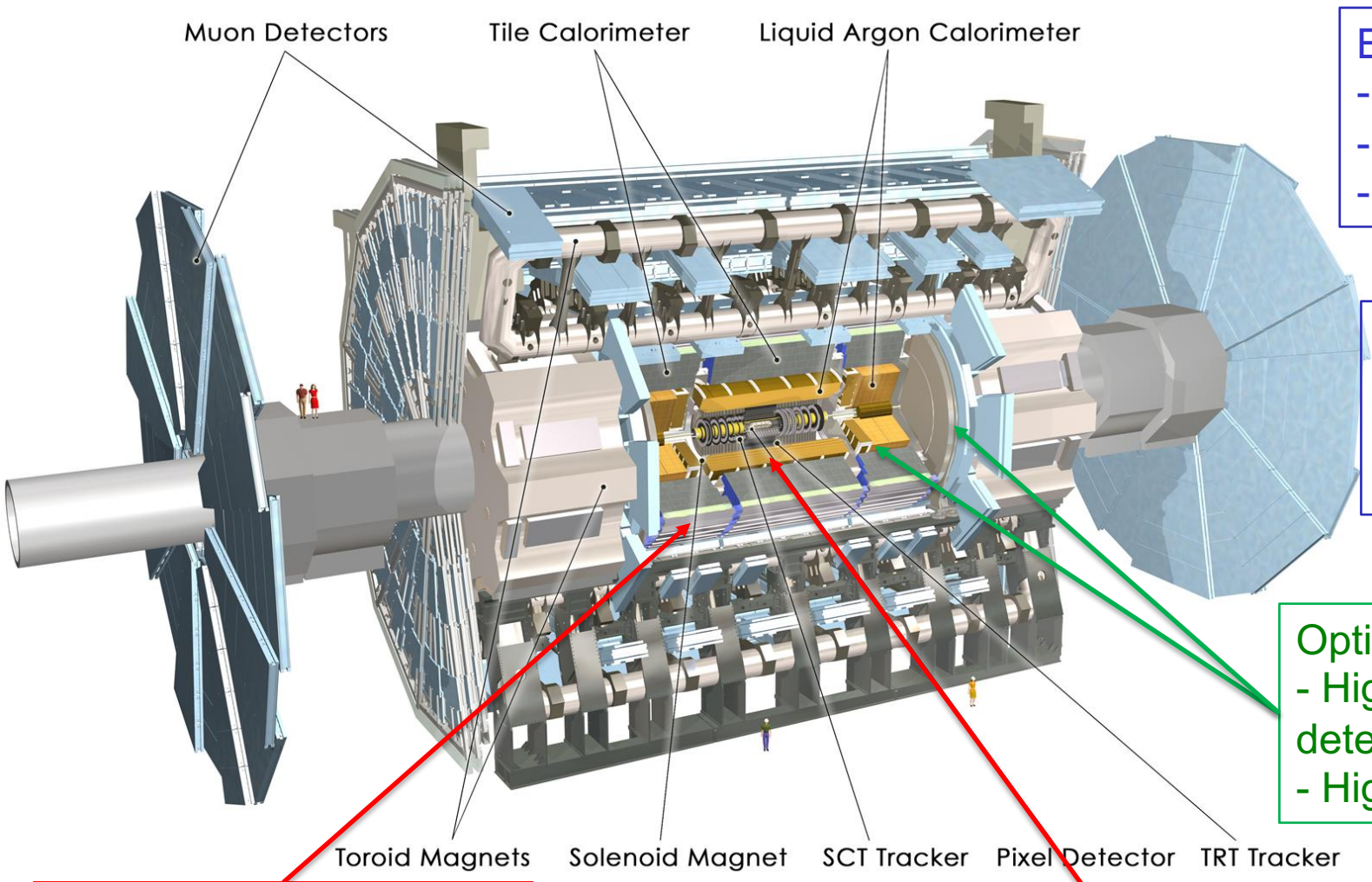


40 signal muons overlaid with 140 pile-up events



ttbar event with 140 pile-up events

ATLAS upgrades for Phase II



Electronics Upgrade :
- LAr Calorimeter
- Tile Calorimeter
- Muon system

Upgraded Trigger and Data Acquisition System:
- L0: 1 MHz
- Improved High-Level Trigger

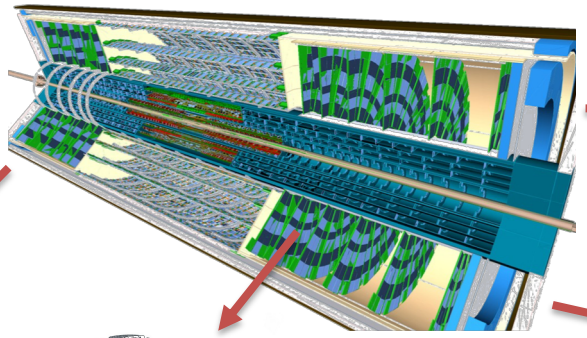
Options:
- High granularity timing detector (forward region)
- High-η muon tagger

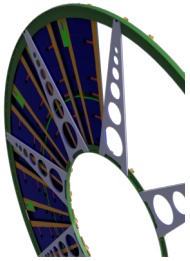
New muon chambers in the inner barrel region

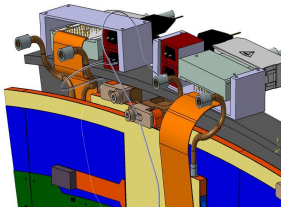
New Inner Tracking Detector (all silicon tracker, up to $|\eta| = 4$)

Spanish contribution to ATLAS ITK

IFIC INSTITUT DE FÍSICA CORPUSCULAR — EXCELENCIA SEVERO OCHOA — CSIC — Universitat de València

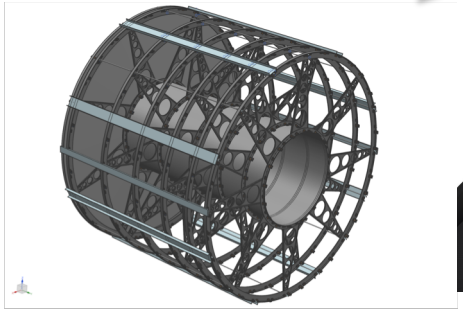


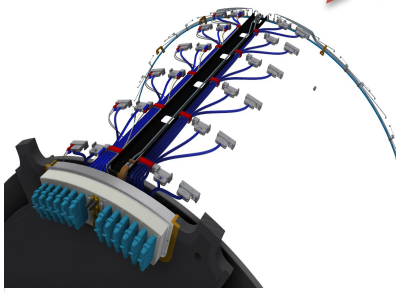


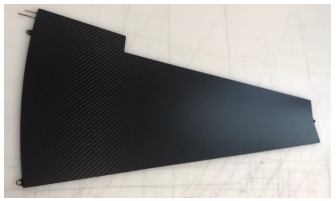


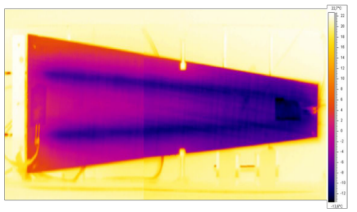
Design of Petal location and connection to services

Design of Strips
Endcap Structure



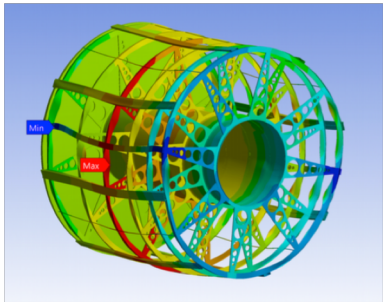






Fabrication of 400 Petals in Spanish industry.
Characterization of 200 of them.
Populating with modules 100 of them.

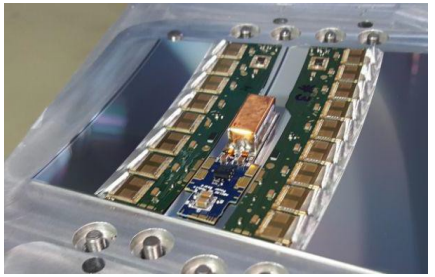
Service module design and fabrication



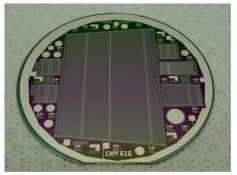
Finite Element Analysis of mechanical stability and thermal behaviour

Spanish contributions with return to the Spanish industry range from the design of large structures and high technology components (petals, modules, sensors) to assembly and QC.

Services
Design of bus tapes.

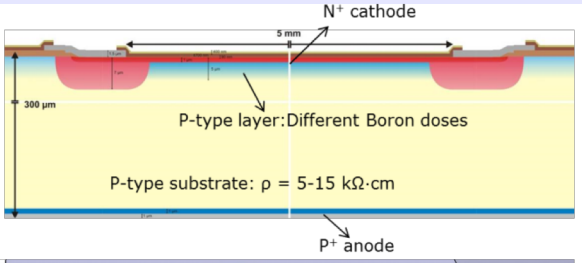


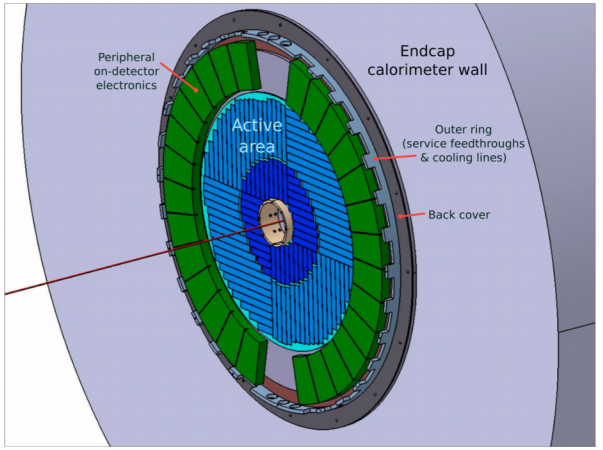
Modules:
Fab. 600 modules
QC of 1800 modules for the 100 petals.
QA and irradiation.

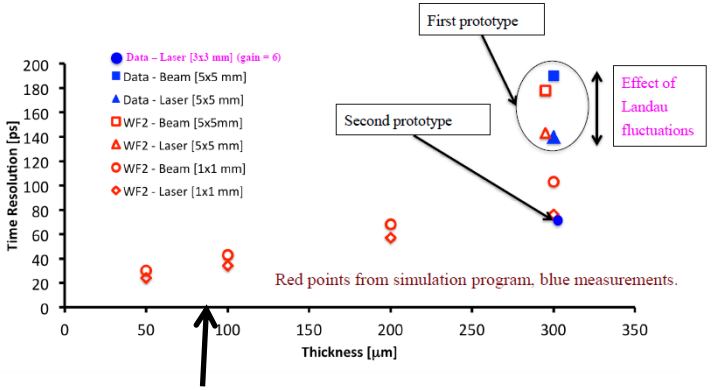


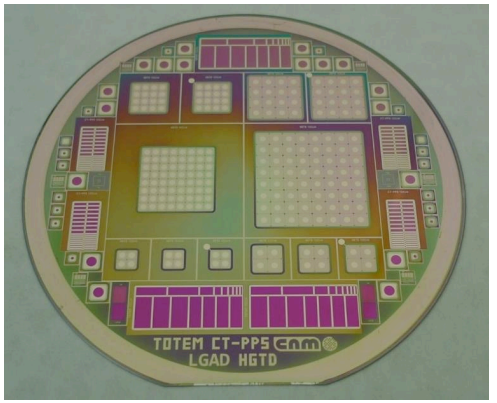
Spanish contribution to ATLAS HGTD

- Goal is a detector that combines excellent timing and position measurement with very high rate capability (no deadtime after a hit).
- Proposed technology are LGAD detectors where CNM-CSIC has a **leading role**
  - Within RD50 collaboration the **first prototype** of LGAD fabricated in 50um FZ thick substrate has been produced
  - Target **timing resolution of 30ps***.
- Possible large production for detectors
  - To be done in 6” wafers (R&D necessary).



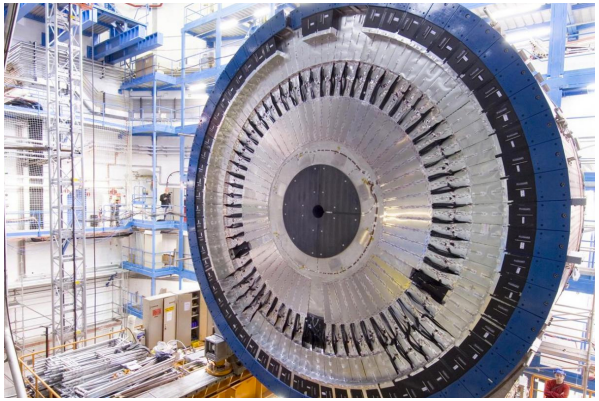






*https://arxiv.org/ftp/arxiv/papers/1608/1608.08681.pdf

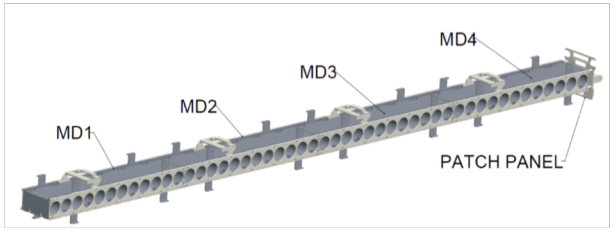
Spanish contribution to ATLAS calorimeter

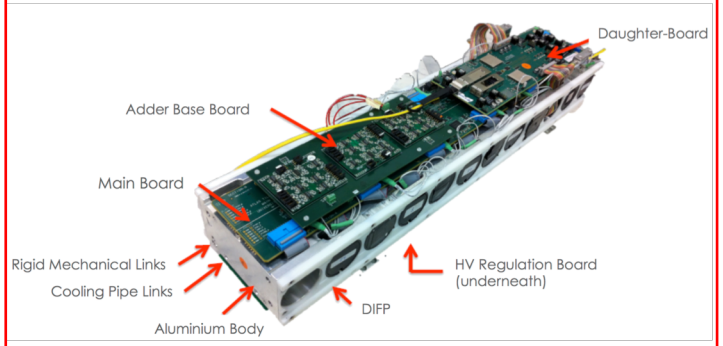


Tile Calorimeter

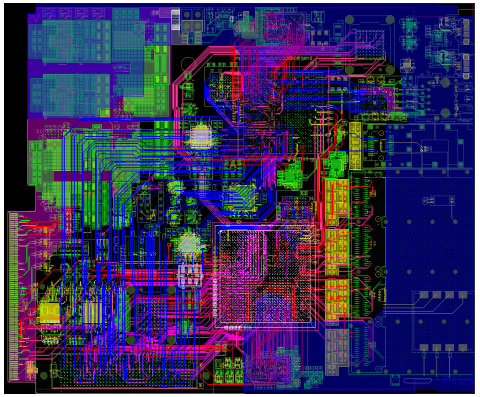
Design and production of mechanics and off-detector electronics.

Mechanics





Back-end electronics



Upgrade Testbeam

Institut de Física d'Altes Energies

IFIC INSTITUT DE FÍSICA CORPUSCULAR — EXCELENCIA SEVERO OCHOA — CSIC — Universitat de València

CMS upgrades for Phase II

L1-Trigger/HLT/DAQ

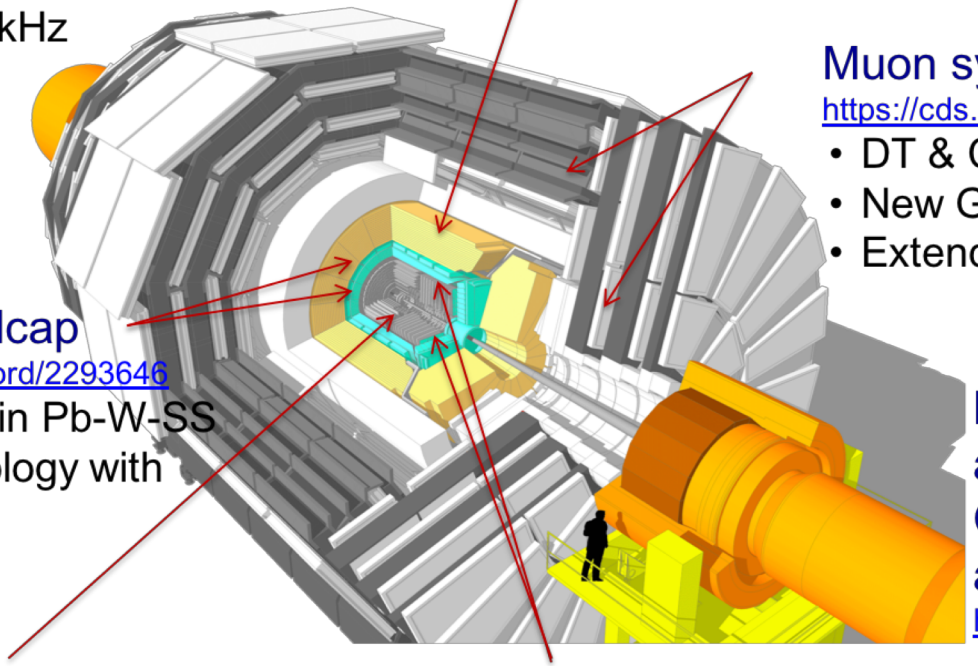
https://cds.cern.ch/record/2283192
https://cds.cern.ch/record/2283193

- Tracks in L1-Trigger at 40 MHz for 750 kHz PFlow-like selection rate
- HLT output 7.5 kHz

Barrel Calorimeters

https://cds.cern.ch/record/2283187

- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards



Muon systems

https://cds.cern.ch/record/2283189

- DT & CSC new FE/BE readout
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \simeq 3$

Calorimeter Endcap

https://cds.cern.ch/record/2293646

- Si, Scint+SiPM in Pb-W-SS
- 3D shower topology with precise timing

Beam Radiation Instr. and Luminosity, and Common Systems and Infrastructure

https://cds.cern.ch/record/2020886

Tracker

https://cds.cern.ch/record/2272264

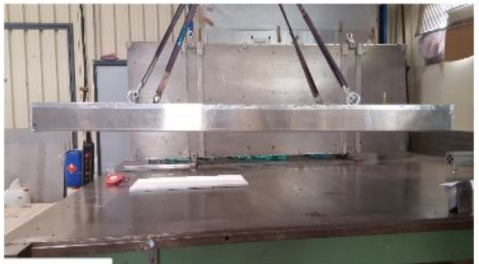
- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \simeq 3.8$

MIP Timing Detector

https://cds.cern.ch/record/2296612

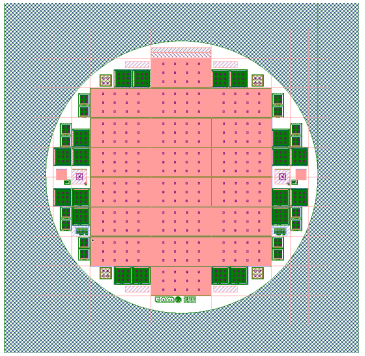
- $\simeq$ 30 ps resolution
- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

Spanish contribution to CMS upgrade

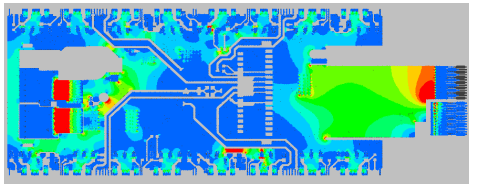


Construction of lead polyethylene shielding assemblies

Aging studies on gas detectors. Gas mixtures for aging mitigation.



Characterization and production of 3D sensors



High density interconnect studies of the Barrel Pixel

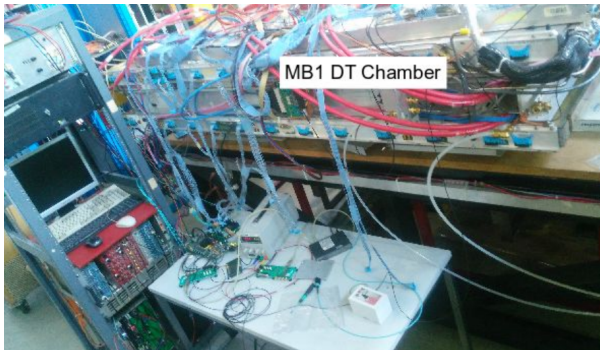
ITAINNOVA

Universidad de Sevilla

IFCA Instituto de Física de Cantabria

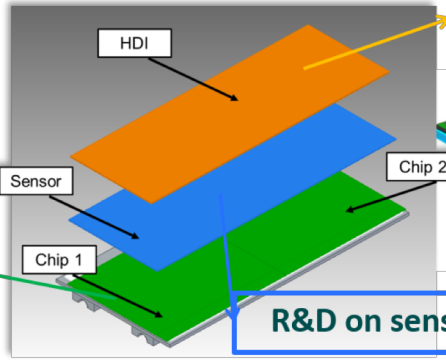
Ciemat

cnm Centre Nacional de Microelectrònica IMB

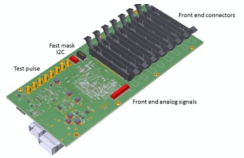


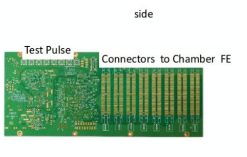
Test stands for new electronics development

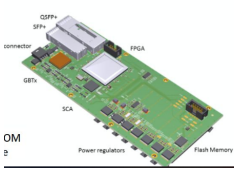
Readout ASIC (inside RD53)
Power stage performance,
PoR block

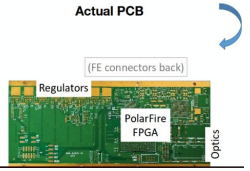


Assembly of 350/4k modules



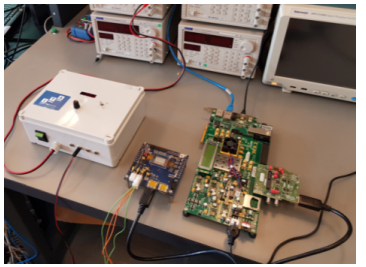






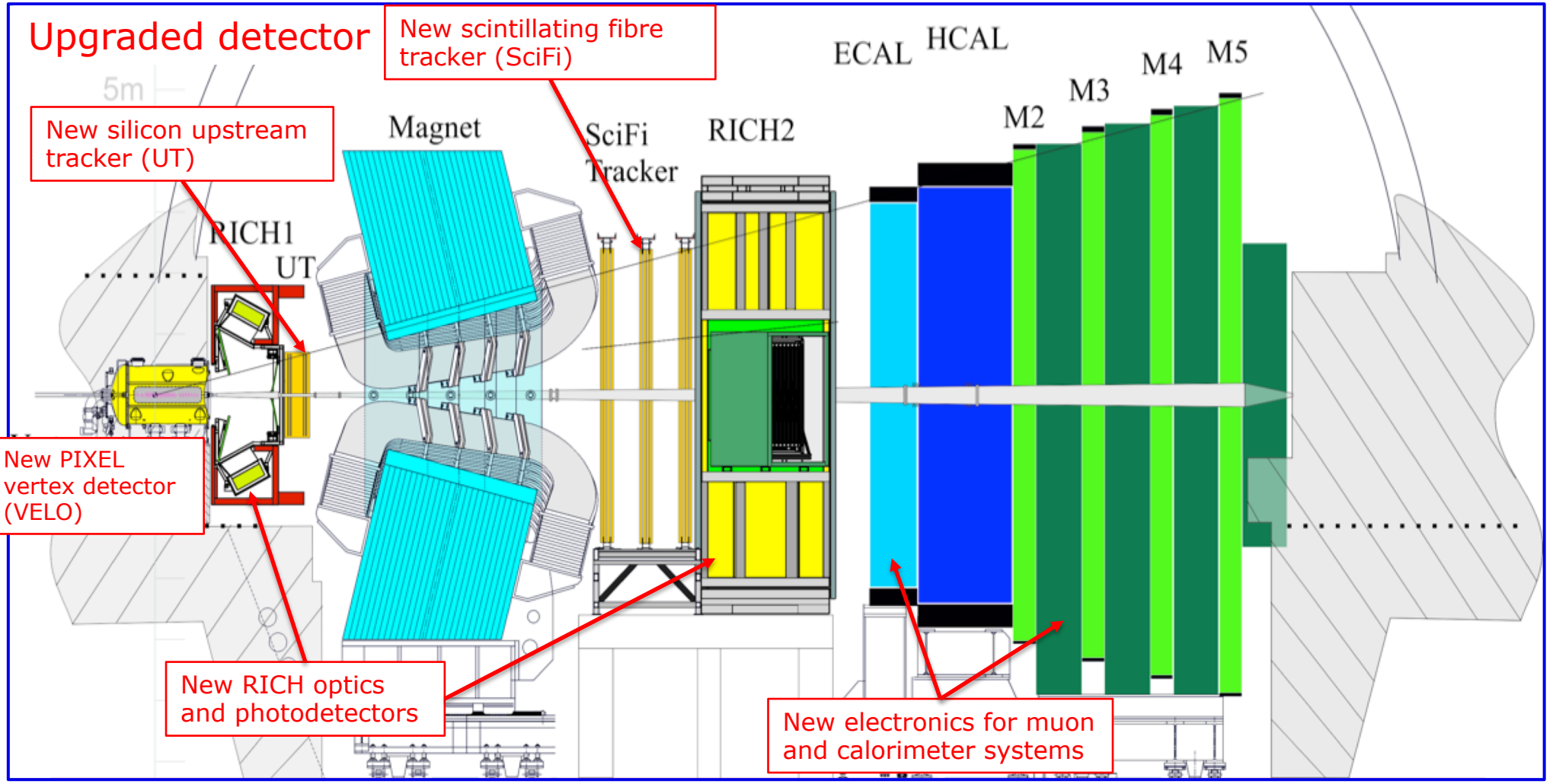
Electronics design and production: TDC on FPGA, high speed optical transmission

Studies for serial powering



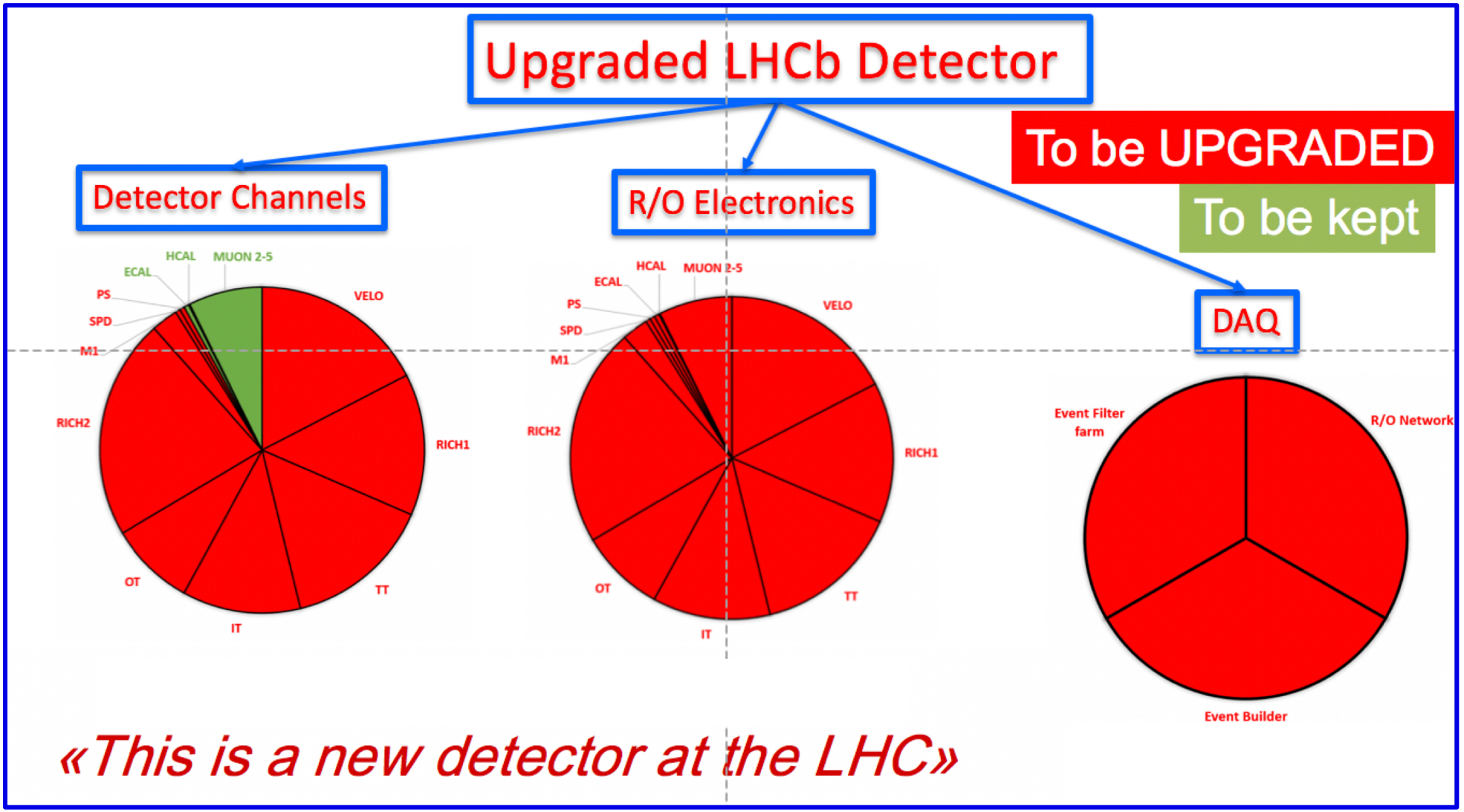
Power performance of RD53A & B chips

LHCb upgrade I



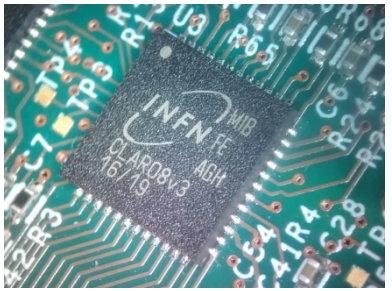
All detector read-out at bunch crossing rate (Triggerless read-out)

LHCb detector after Upgrade I

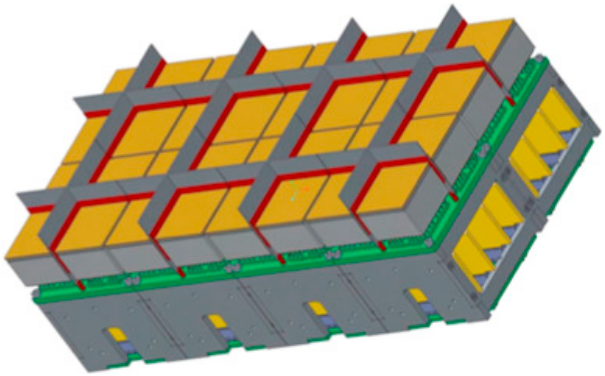


Spanish contribution to the LHCb RICH

- Replacement of the photodetectors currently installed in the RICH1 and RICH2 apparatuses by Multi Anode Photomultipliers (MA-PMT)
  - MA-PMTs from Hamamatsu with 8x8 pixels
- Signals amplified and discriminated by 33.000 ASICs called “CLARO8v3” realized in 0.35um CMOS technology by AMS foundry
  - Designed with the “Radiation Hardened By Design” (RHBD) library developed at the Instituto de Microelectrónica de Sevilla IMSE-CNM

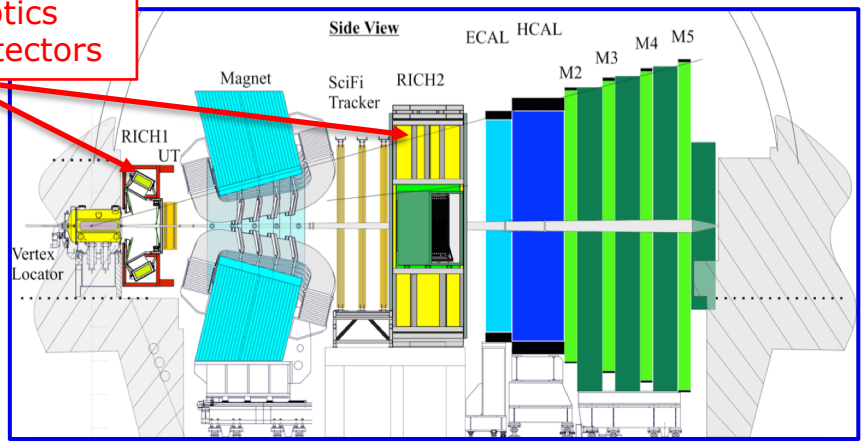


Array of elementary cells with MA-PMTs.



Array of elementary cells with MA-PMTs.

New RICH optics and photodetectors

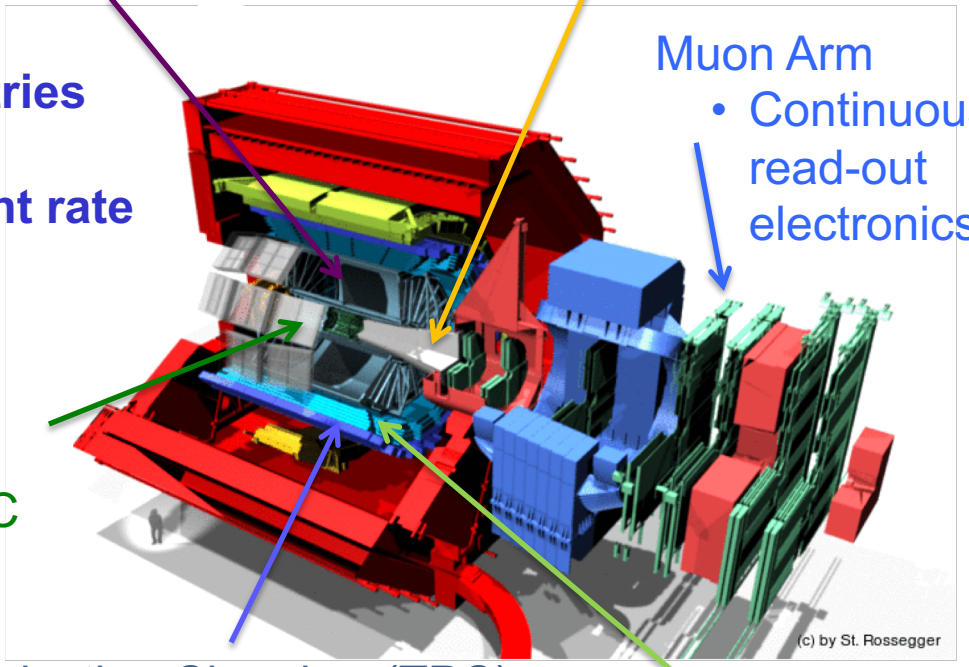


ALICE LS2 Upgrade

New Muon Forward Tracker (MFT)
- Si tracker
- Improved muon pointing precision

New Trigger Detectors (FIT)

- **1800 members, 177 institutions, 41 countries**
- **Major upgrade being prepared for LS2**
- **Continuous read-out at 50 kHz PbPb event rate**



Muon Arm
- Continuous read-out electronics

New Inner Tracking System (ITS)
- Entirely new detector
- Improved pointing precision
- Less material -> thinnest tracker at the LHC

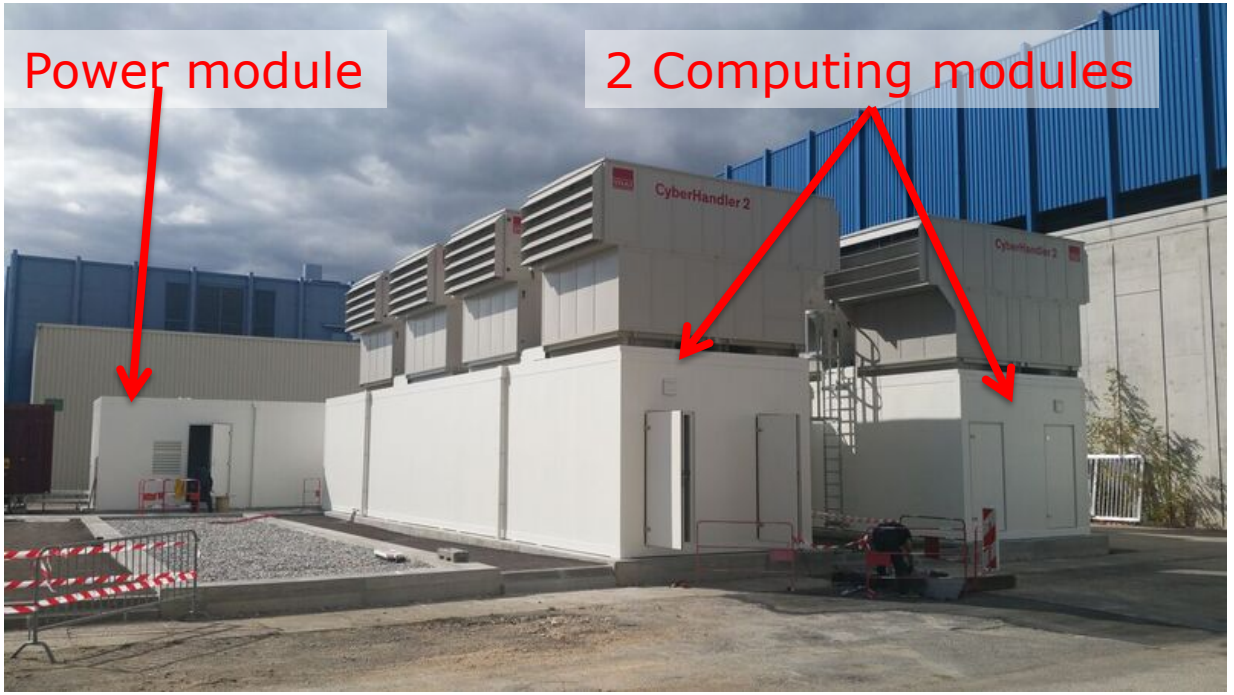
Online and Offline Computing
- Entirely new system (new CTP)
- On line tracking & data compression

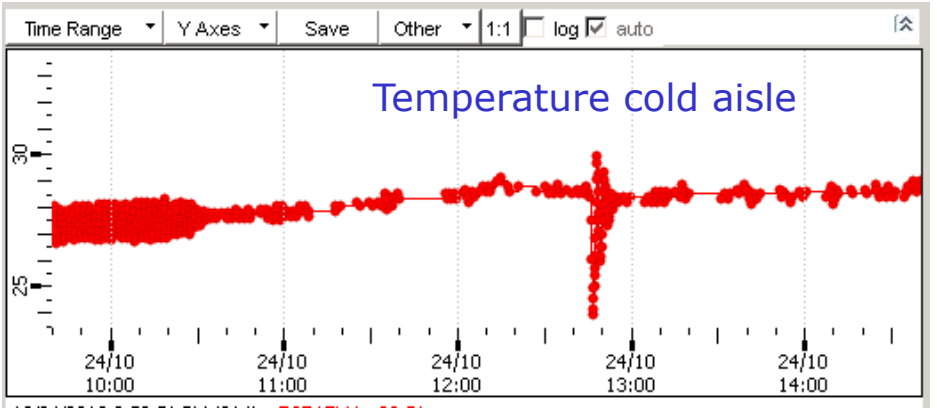
Time Projection Chamber (TPC)
- New GEM technology for the readout chambers
- Continuous read-out
- Faster readout electronics

TOF, TRD, ZDC
- Faster read-out

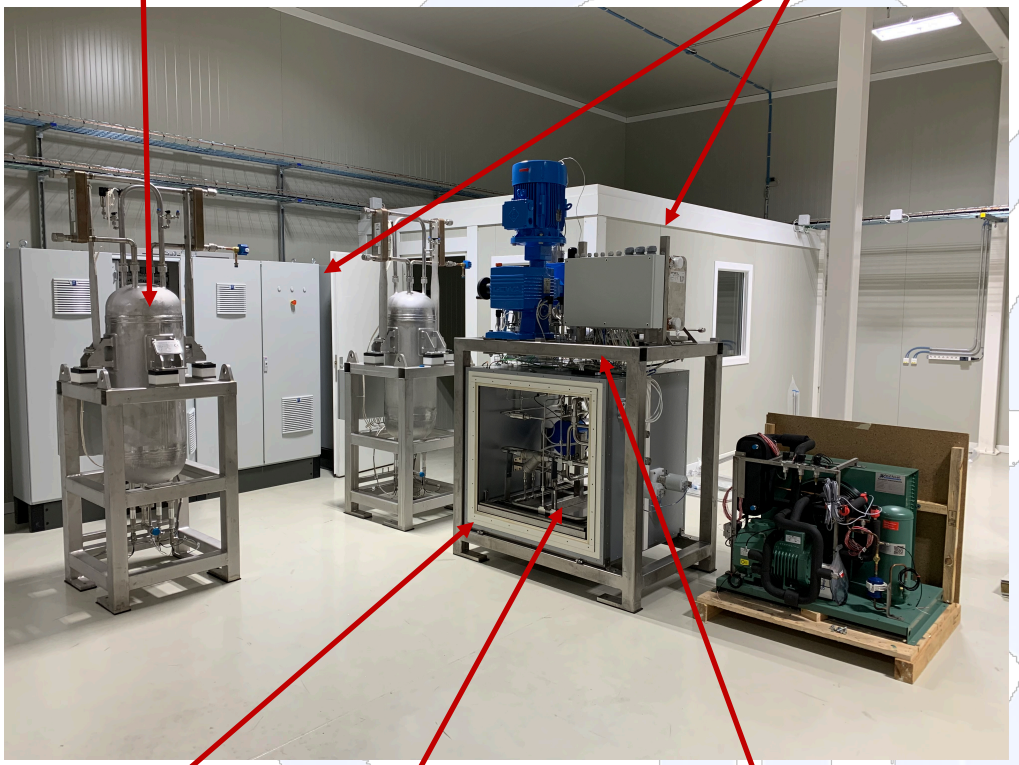
Spanish contribution to ALICE upgrade

- Spanish institutes are not directly involved in the ALICE upgrade
- New computing rooms added at the experimental area for the online farm
- Site acceptance test in progress at the ALICE site
- Common tender between LHCb and ALICE
  - ALICE : 4 computing modules (2 delivered so far)
    LHCb: 6 computing modules (1 delivered this week)
- Contract assigned to a Dutch company which sub-contrated a Spanish company for the cooling units
  - Air to air heat exchangers





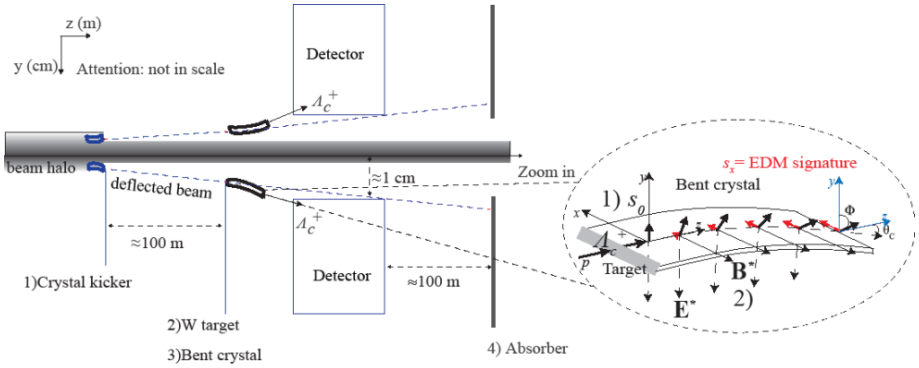
Needs for CO2 cooling systems



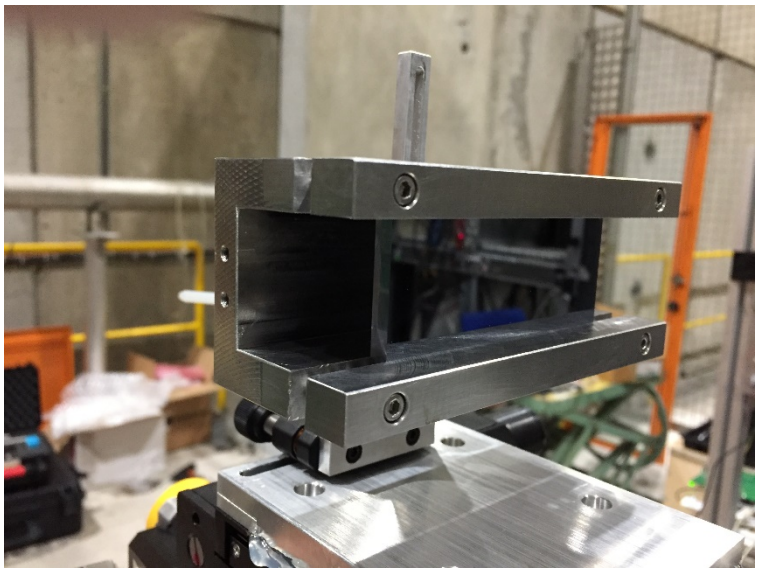
- High pressure piping assemblies and components with typical design specs for all components and assemblies:
  - Design pressure: 100 bar (143 bar proof pressure)
  - Design temperature range: +30ºC to -60ºC
- Typical pipe sizes:
  - Pipe sizes: DN6 to DN50
  - Compact full metal flanges
- Typical component concepts
  - Cryogenic extensions to bring sensitive equipment into warm area
- Sealing technologies:
  - No elastomer O-rings
  - Full metal sealing
  - Some plastics can be used in special applications (Teflon, Vespel, etc)
- High pressure vessels needed
  - <500L (100 bar, +30ºC to -60ºC)
  - >5m3 (60 bar, +20ºC to -20ºC)
- Extra needed technologies
  - Insulated cold boxes
  - Insulated pipes (foam and vacuum)
  - Dry-air and vacuum systems
  - Electronic racks for control systems
  - 3D metal printing for special components

Magnetic moments of heavy baryons

- **Heavy baryons**, and **tau leptons**, can be channelled in a bent crystal for **magnetic and electric dipole moments**
- Require proton extraction from LHC beam halo at required flux and collimation system for the disposal of the “split” beam and other products
  - ~8 cm, ~15 mrad Si and Ge bent crystals: INFN-Ferrara
  - High precision positioning systems (goniometers, ~μrad) mounted on retractable device, slow-control and feed-back systems
- Aiming for a 1st phase (low luminosity) installation in LHCb during YETS Run3, 2nd phase (high luminosity) in dedicated experiment (long term)



Schematic diagram of experiment



Si crystal recently tested on beam at SPS (courtesy of A. Mazzolari, INFN-Ferrara)

Spanish institutes at CERN-EP

- Spanish institutes are deeply involved in HL-LHC upgrades with important responsibilities.

Studies on gaseous detectors (CIEMAT, U. Oviedo)

Design and production of new on detector radiation tolerant electronics (CIEMAT)

CMS chambers shielding (CIEMAT)

New trigger algorithms and ATCA backend system (CIEMAT, UAM, U. Oviedo)

R&D on Power systems (IFIC, ITANNOVA, U. Sevilla)

R&D on 3D pixel sensors (CNM, IFCA)

R&D on silicon sensors for timing detectors (IFCA, CNM)

R&D on pixel system high density interconnections (IFCA, IFIC, ITANNOVA)

Design and production of global and local support structures (IFIC)

Design and production of read-out modules (IFIC)

Silicon sensors modules production and integration (IFCA, IFIC, CNM, ITANNOVA, U. Sevilla)

Project coordinators at Spanish institutes

- ATLAS
  - IFIC: Carmen García
  - IFAE: Martine Bosman
  - UAM: Fernando Barreiro
  - CNM: Manuel Lozano
- CMS
  - CIEMAT: Juan Alcaráz
  - U.Sevilla: Fernando Muñoz
  - IFCA: Celso Martínez
  - UAM: Jorge Fernández
  - U.Oviedo: Javier Cuevas
- LHCb
  - IFIC: Fernando Martínez
  - USC: Abraham Gallas
  - UB: Eugeni Grauges
- GRID
  - IFAE: Manuel Delfino
  - IFIC: Jose Salt
  - UAM: Jose del Peso
  - IFCA: Francisco Matorras
  - CIEMAT: Jose Felix
  - UB: Ricardo Graciani
  - USC: Juan Jose Saborido

Technologies developed for HEP might be of interest to industrial partners

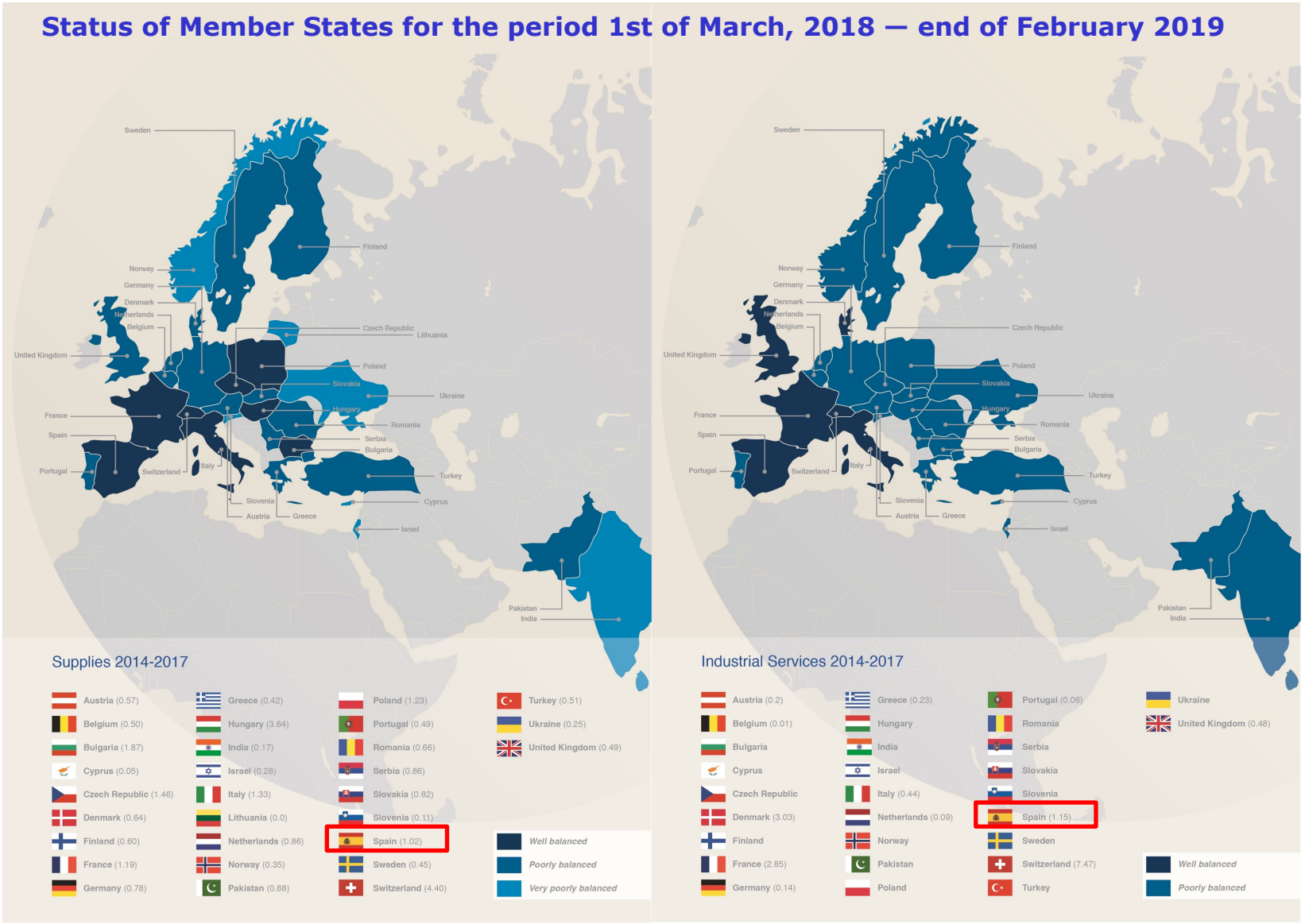
Summary

- EP carries out fundamental research on experiments at CERN inside the framework of collaborations between many institutes
- Experiments deeply immersed into upgrade programs
- Phase 2 upgrades tendering will be starting next year including tendering from EU institutes inside the collaborations
- Contact between Spanish companies and institutes is important
- Encourage Spanish ILO to be proactive in reaching out for Spanish companies and meet standards for EU tendering
- R&D is a must for full exploitation of LHC potential and beyond

Bonus

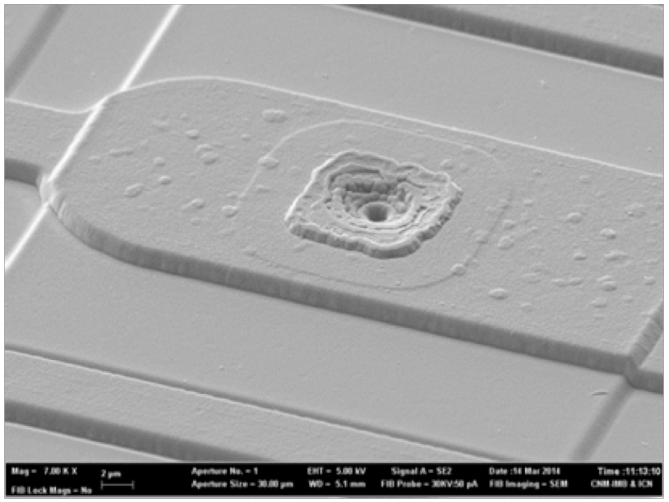
Supplies and industrial services return

Status of Member States for the period 1st of March, 2018 — end of February 2019

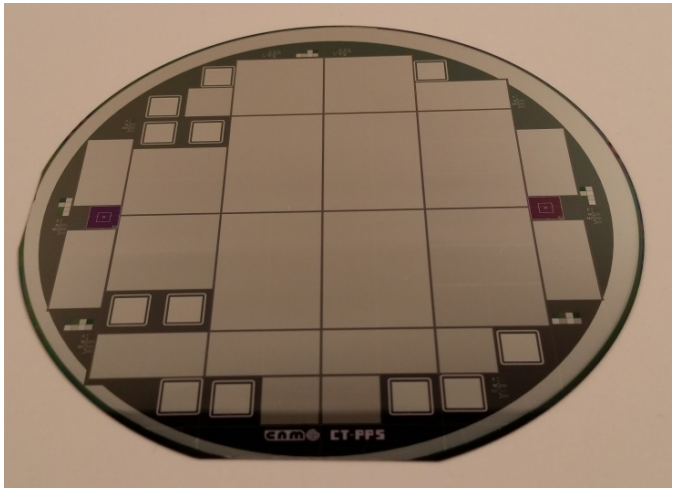


3D Pixel sensors fabricated at CNM-CSIC

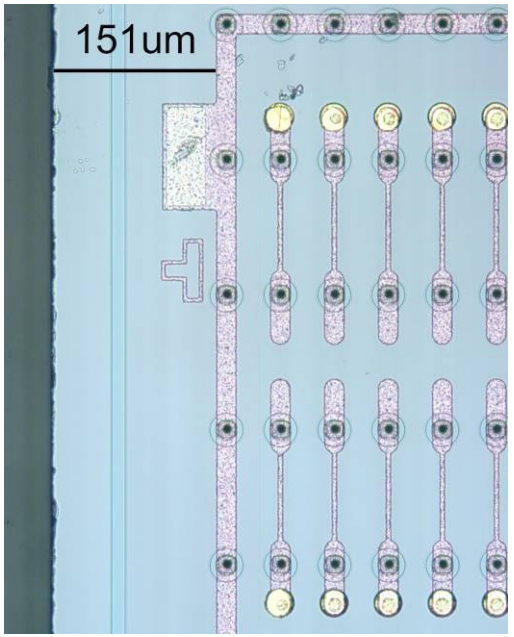
- ATLAS IBL (Insertable b-Layer)
- AFP (ATLAS Forward Proton)
- CT-PPS (CMS-TOTEM Precision Proton Spectrometer)



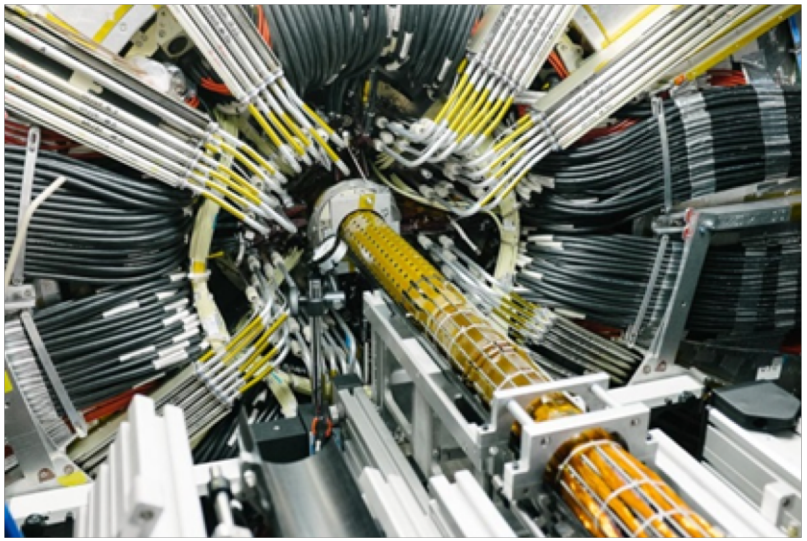
FE-I4 pixel



CT-PPS Detectors



AFP detectors with slim edges

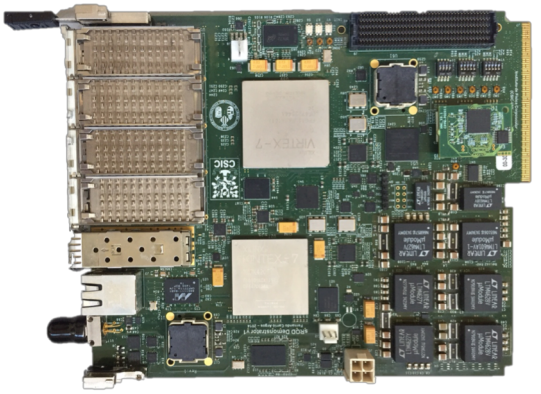


ATLAS IBL insertion

Production of PCBs for the calorimeter

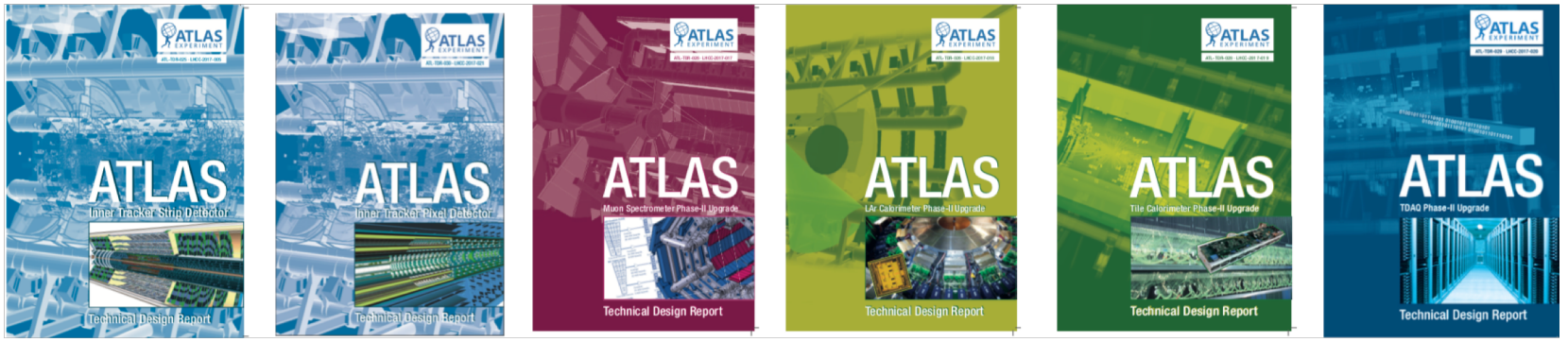
- Re-production of old design
- Design made by LAPP in 2003. Complex design : 10 layers, high component density, high number pin connectors , 7 BGA components.
- Strong collaboration with company to find replacement of obsolete components
- 2017/18 - Production of two batches (80+60) for Tile and LAR
- Technical contact in Valencia – procurement through CERN

- Prototype of new processing board for Phase-II Upgrade
- New design with state-of-the-art components: 16 layers, NELCO dielectric, Xilinx Series 7 FPGAs (Virtex/Kintex), QSFP, >10Gbps serial lines
- Technical contact and procurement in Valencia
- Production of several modules for other universities (UTA, Stockholm)



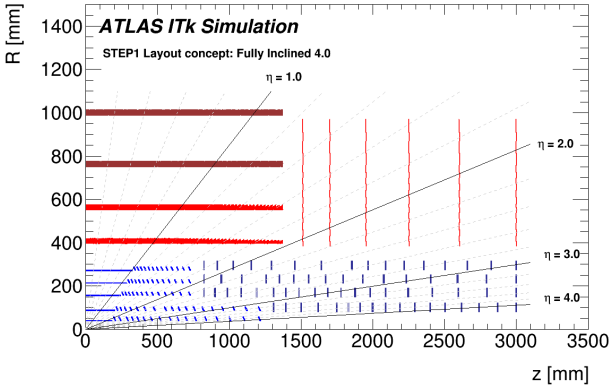
ATLAS upgrade status

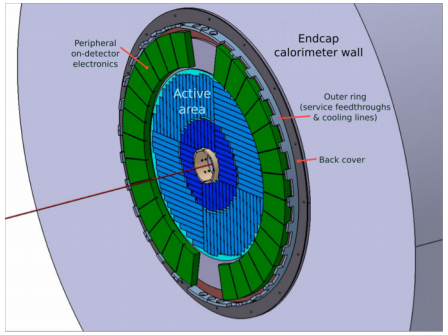
- Phase-I upgrades to be installed by end of LS2
  - Parts already installed (LS1) or coming during Run 2 (FTK)
  - Parts to come in LS2 (NSW, LAr electronics, L1 Calo, L1 Muon, and FELIX)
- Phase-II upgrades for installation in LS3 in 2024 - 2026
  - TDR for six major upgrade projects approved, followed by TDR for high-granularity timing detector in April 2019
  - Design and prototyping phase ongoing
  - Tendering to start by next year



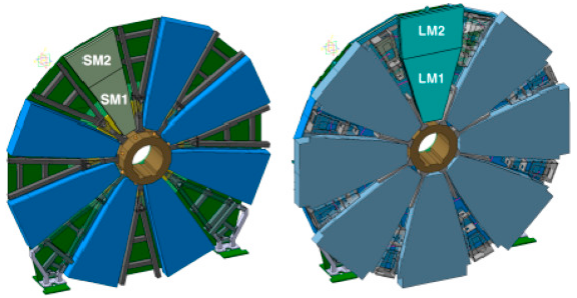
Upgraded ATLAS detector

- New all-silicon inner tracker with increased coverage of |η|<4 and increased radiation tolerance (HL-LHC)
  - Pixel: 5 inner barrels and forward disks
  - Strips: 4 extended barrels and 6 disks
- Proposed High Granularity Timing Detector for improved bunch crossing ID and pile-up suppression, 2.4<|η|<4.3 (HL-LHC)
- Readout electronics replaced in the LAr and Tile calorimeters
- Replace inner end cap muon stations with a New Small Wheel composed of MicroMeGaS and sTGC for improved tracking and trigger performance (Phase I)
- New RPC layers in the barrel Muon system (|η|<1) for increased trigger coverage and performance (HL-LHC)
- Trigger
  - Hardware trigger with L0<1 MHz and L1<400 kHz
  - High Level Trigger with 10 kHz output (permanently recorded data)
  - “Custom hardware” triggers for data streaming at rates 1-40 MHz
  - New Inner Tracker, Calorimeter, Muon triggers



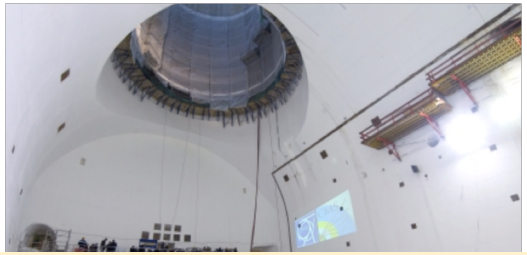


High Granularity Timing Detector



New Small Wheel

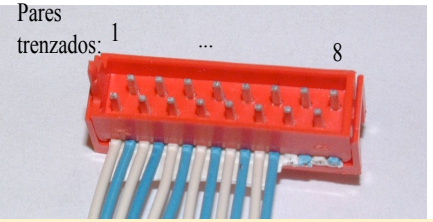
Spanish participation in CMS



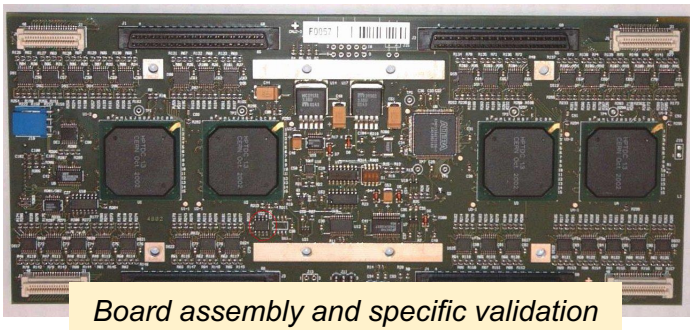
CMS cavern construction by Dragados S. A. (Spain) and Seli (Italy)

2 Cranes of 80 T at CMS Point 5 (SX5) by TAIM WESER S. A. (Zaragoza, Spain)

Manufacturing of 2 hadronic wedge calorimeters for CMS Detector (Felguera Construcciones Mecánicas S. A. (Barros, Spain))



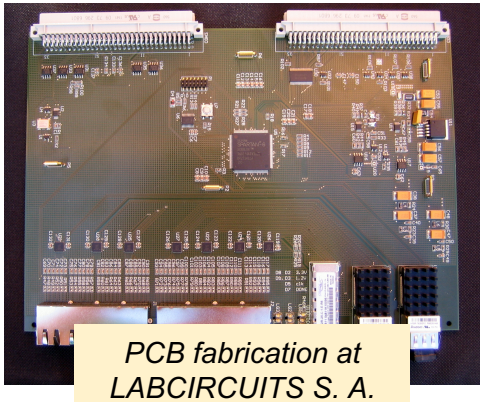
Custom cables assembly SINTERSA S. A.



Board assembly and specific validation tests at IMPELEC S. A.

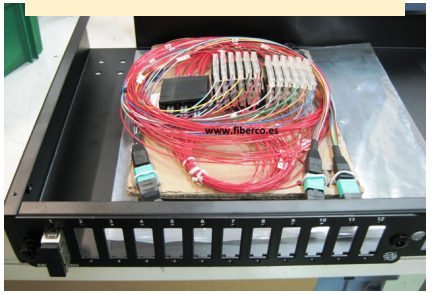
Moreover, material procurement for:

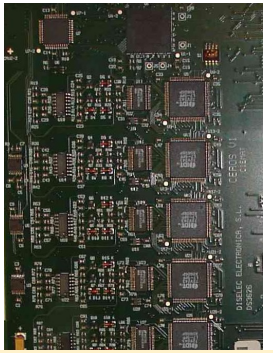
- Muon Drift Tube chambers,
- Mechanics material, welding and assembly,
- Electronics components purchasing
- Cabling, optical fibers
- Large variety of instrumentation



PCB fabrication at LABCIRCUITS S. A.

Custom MTP splitter FIBERCO S. A.

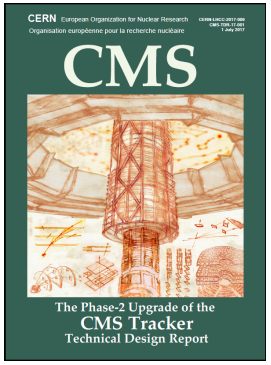


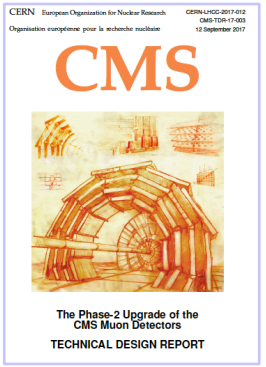


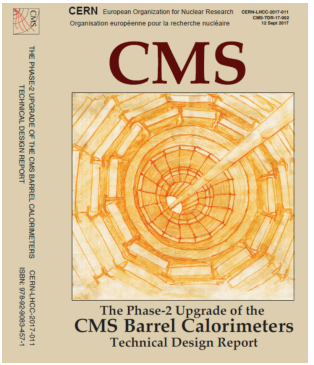
Board layout at DISELEC S. A.

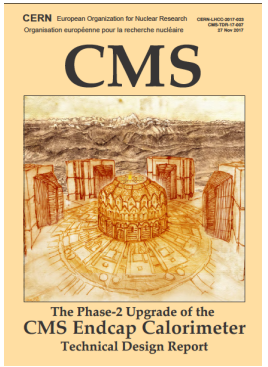
CMS upgrade status

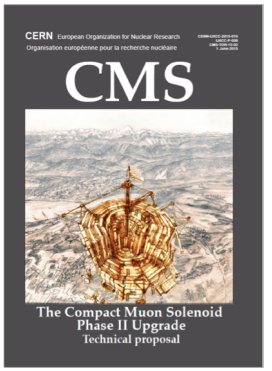
- Phase 1 upgrades to be culminated by end of LS2
  - Already installed CSC, RPC, L1 trigger, hadron forward calorimeter, hadron end-cap calorimeter front-end electronics, Pixels upgrade
  - Front-end electronics and photosensors for hadron barrel calorimeter pending
- Phase 2 upgrades for installation in LS3 in 2024 - 2026
  - New all silicon tracker, L1 track-trigger, high granularity endcap calorimeter, extended coverage in eta, precision timing, new muon chambers
  - TDR for five upgrade projects approved
  - Design and prototyping phase ongoing
  - Tendering to start by next year





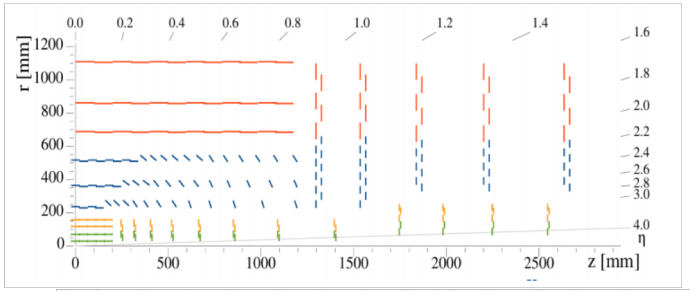


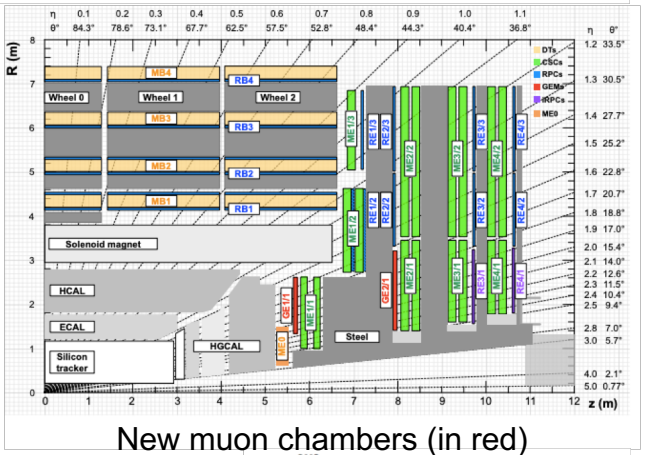




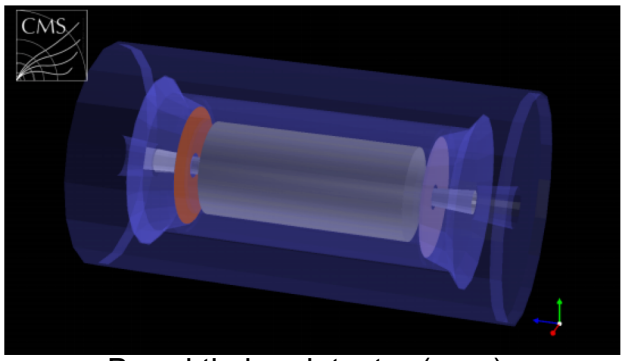
Upgraded CMS detector

- New all-silicon inner tracker (200 m^2 of silicon) with increased coverage of $|\eta|<4$
  - Inner tracker: 4 layers of pixel and forward disks
  - Outer tracker: 3 layers of pixel+strip at r<60 cm and 3 layers of strip+strip at r>60 cm
- Extended muon coverage up to $\eta=3$ based on GEM technology
  - Able to trigger on long lived particles
- High granularity end cap calorimeter
  - 3D mapping of the particle shower development
  - Combine scintillator and silicon
- LYSO crystal based timing detector in the barrel
  - Precision timing of all objects to combat pile-up

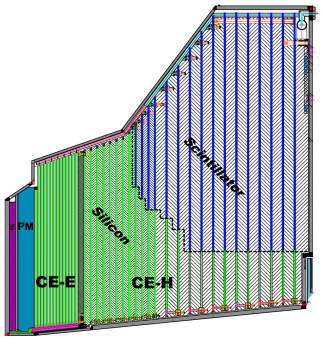


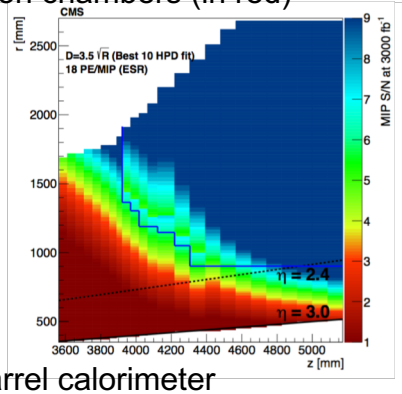


New muon chambers (in red)



Barrel timing detector (grey)



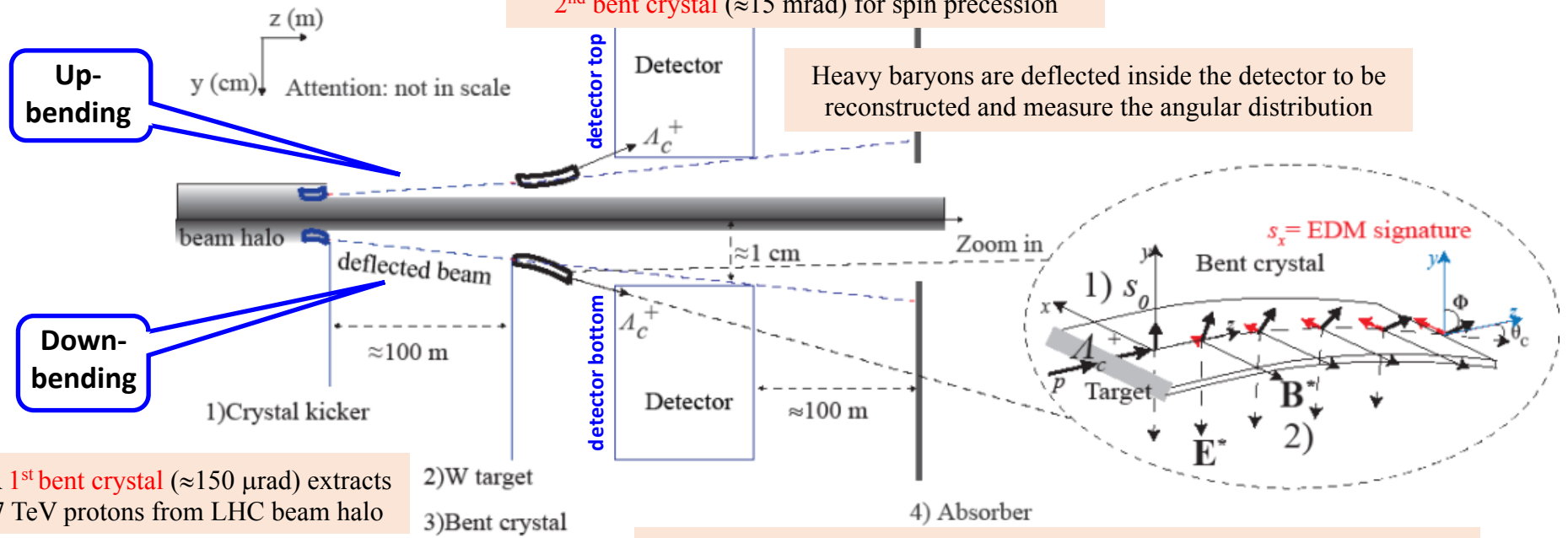


End cap barrel calorimeter

Layout for bent crystals experiment

Extracted *p* beam is directed on W target paired to a 2nd bent crystal (≈15 mrad) for spin precession

Heavy baryons are deflected inside the detector to be reconstructed and measure the angular distribution



A 1st bent crystal (≈150 μrad) extracts 7 TeV protons from LHC beam halo

Non-interacting protons, non-channeling particles and most secondary interactions follow the beam pipe to be absorbed downstream the detector

- The high electric field between the crystallographic planes makes the heavy baryon spin precess, giving access to the MDM/EDM of short-lived particles