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

CIEMAT CALICE ACTIVITIES

Linked to DRD1 & **DRD6**

Mary-Cruz Fouz
CIEMAT

Instrumentation for the future of particle, nuclear and astroparticle physics and medical applications in Spain

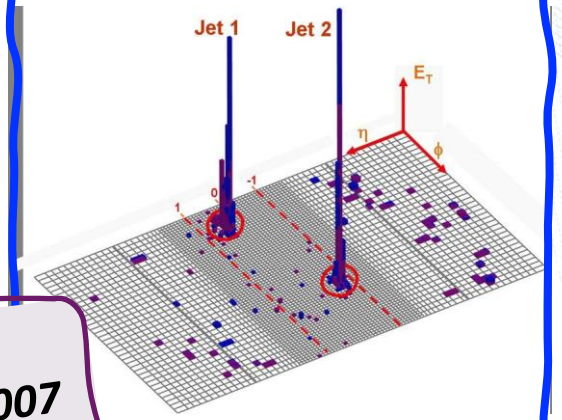
Barcelona 6-7 marzo 2023

CALICE Collaboration

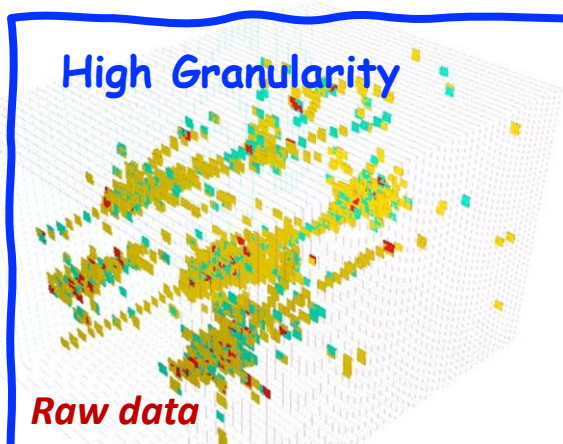
MOTIVATION

Physics at Higgs Factories requires **a jet energy resolution a factor 2 better than** the achievable with the **present calorimeters.**

Actual calorimeters©



High Granularity



Raw data

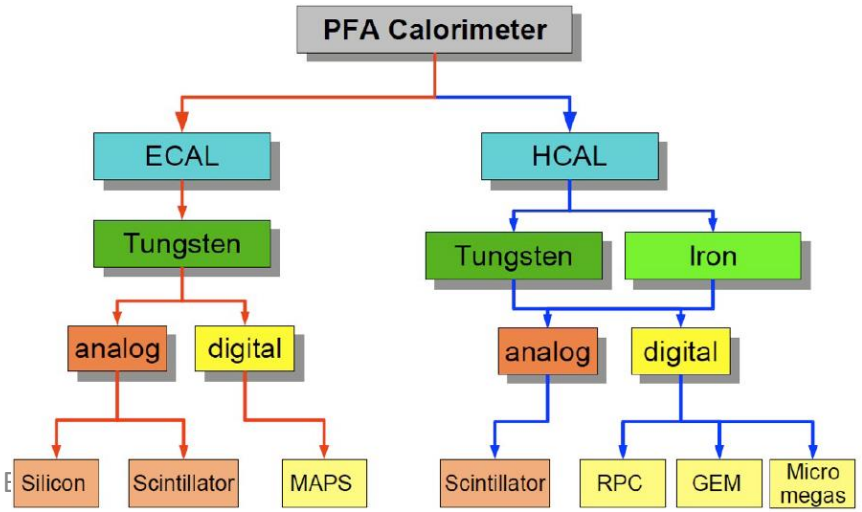
*Several particles from test beam recorded by the **SDHCAL***

The CALICE Collaboration

336 physicists/engineers from around 60 institutes and 18 countries coming from the 4 regions (Africa, America, Asia and Europe)

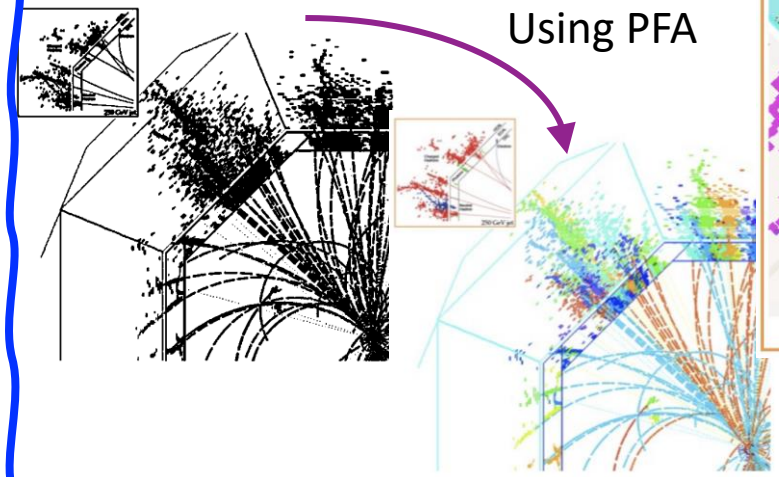
Ciemat *member since* **2007**

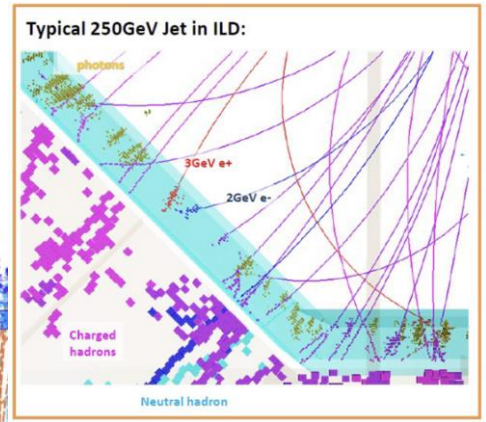
Developing highly granular calorimetry optimised for particle flow event reconstruction for future energy-frontier electron-positron coliiders.



ILD: Jet 250 GeV

Using PFA





The Semi-digital Hadronic CALorimeter (SDHCAL)

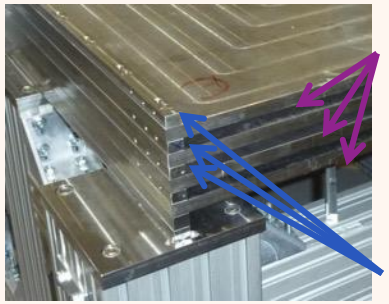
CIEMAT participates in several CALICE technologies but the **main activity is linked to the SDHCAL**

SDHCAL: **S**emi-**D**igital **H**adronic **C**alorimeter.
Fe+ Glass RPC, with **1cm2 pads** with **semidigital readout**

Coordinadores grupo SDHCAL:
Resposible: I. Laktineh (Lyon)
Deputies **M.C Fouz (CIEMAT)**, G. Grenier (Lyon)

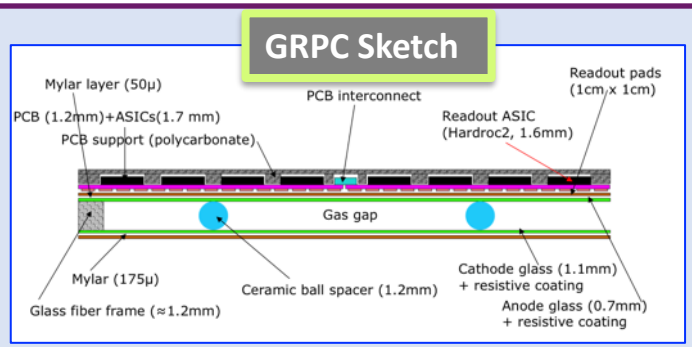
Absorber: **Stainless steel**

Absorber **plates up to ~3x1 m²** .
Surface **planarity < 1mm** ,
Thickness 15mm, tolerance **50μm**



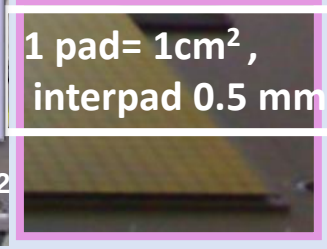
Detector: **GRPC (Glass Resistive Plate Chambers)** operating in **avalanche mode**

1x1 cm² pads. Semi-Digital Readout, 2bits **- 3 thresholds**
➔ It counts **how many** and **which pads** have a **signal larger than one of the 3 thresholds**



Embedded electronics:
PCB separated from the GRPC by a mylar layer (50μm).
➔ Bottom: **1x1cm2 pads**
➔ Top: **ASICs (HADROC)** & related connections

Power-pulsed electronics: In **stand-by during dead time** in between ILC Collisions or spills in beam tests



CIEMAT responsibilities at SDHCAL

CIEMAT participates at SDHCAL ***from the beginning of this R&D at CALICE ,*** starting with GRPC chambers R&D and following with calorimetry prototypes

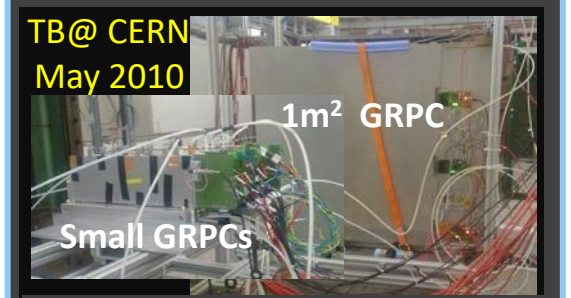
- **Responsible** for **mechanics developments and handling tools**
- **Responsible** for second version of **DIF board electronics** (Detector InterFace)
  DIF is used for control and readout or the ASICS and the communication with DAQ
- **Prototypes tests** with particle beams at CERN & DESY and **data analysis**
  (development of algorithms, PID, and performance studies)

Some Challenges

High precision mechanics
Embedded electronics
Low power consumption
Very uniform response despite the large number of channels

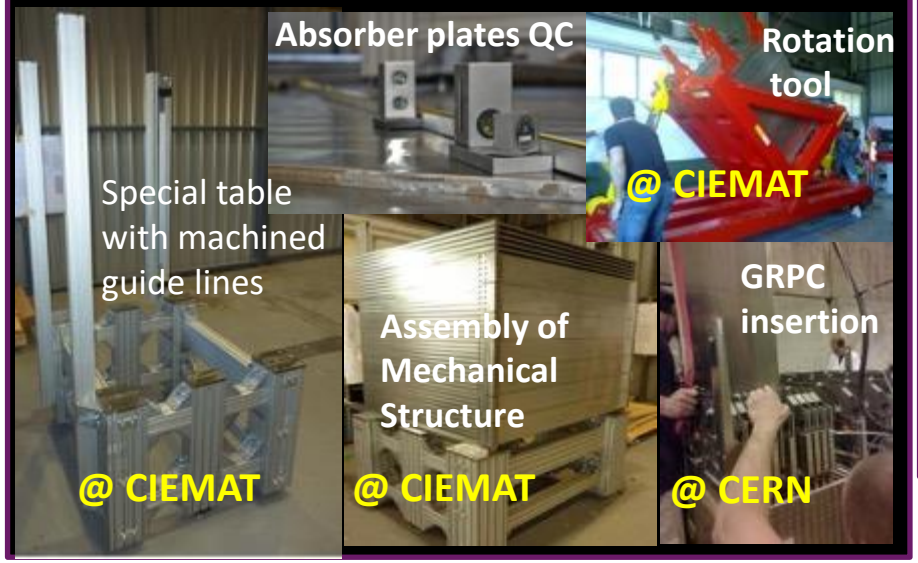
1 PhD thesis presented on 2015
A new PhD thesis next week

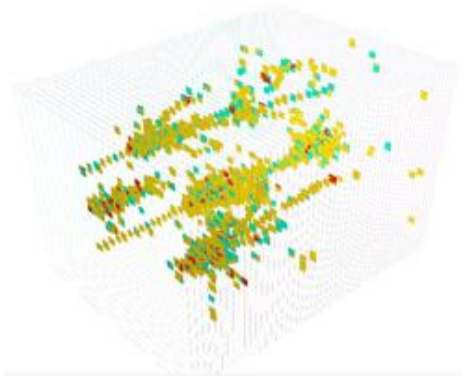
Snapshot of some SDHCAL achievements in the past



GRPCs Validation

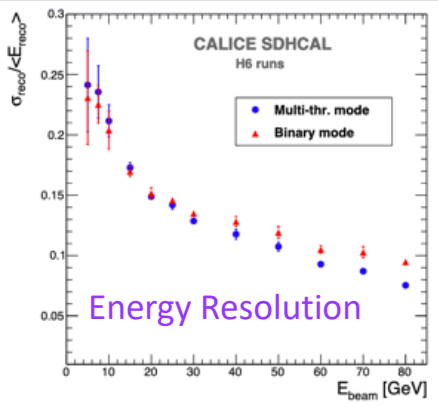
The assembly of 1.3m³ prototype



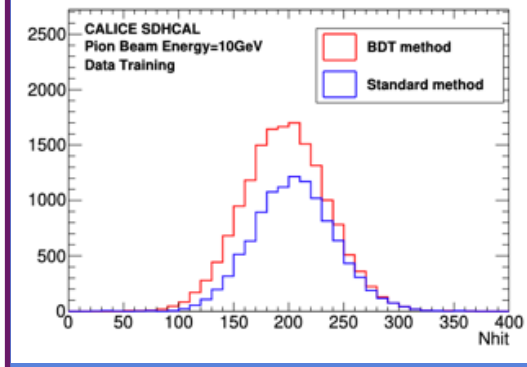


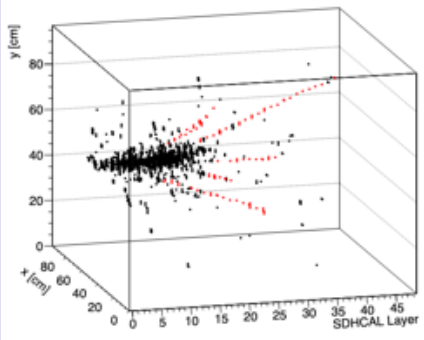
TRACKER-CALORIMETER

Technology Validation 1m³ - test beam data



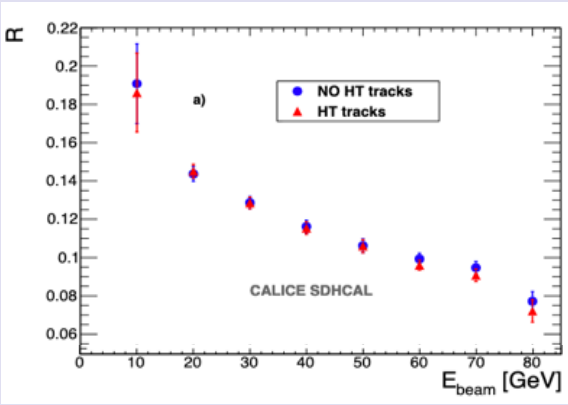
PID: BDT & MVA technique





Improved resolution

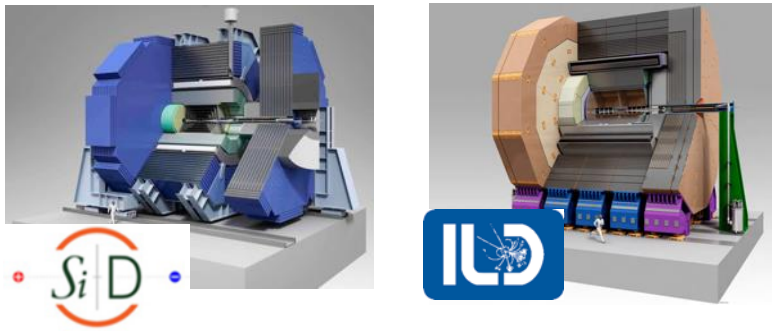
Single track reconstruction with **Hough transform** techniques



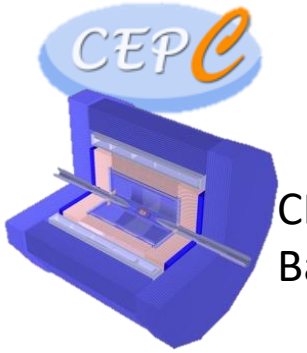
The SDHCAL & Higgs factories

(s)DHCAL is one of the technologies already under consideration for **several experiments for the *Future Higgs Factories***

Linear Colliders



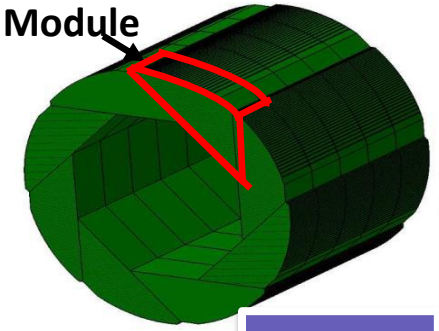
Circular Colliders

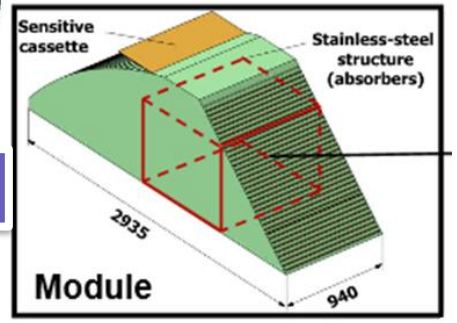


CEPC Baseline

No proposed jet
ILD is going to do
viabilibility studies

*member since **2009** (LOI 2010)*





Major responsibilities at ILD

– Editor of the calorimetry chapter of volume 4 of the ILC Technical Design Report. 2013.
(M.C Fouz)
– Since 2021. Technical coordinator and member of the executive team (M.C Fouz)

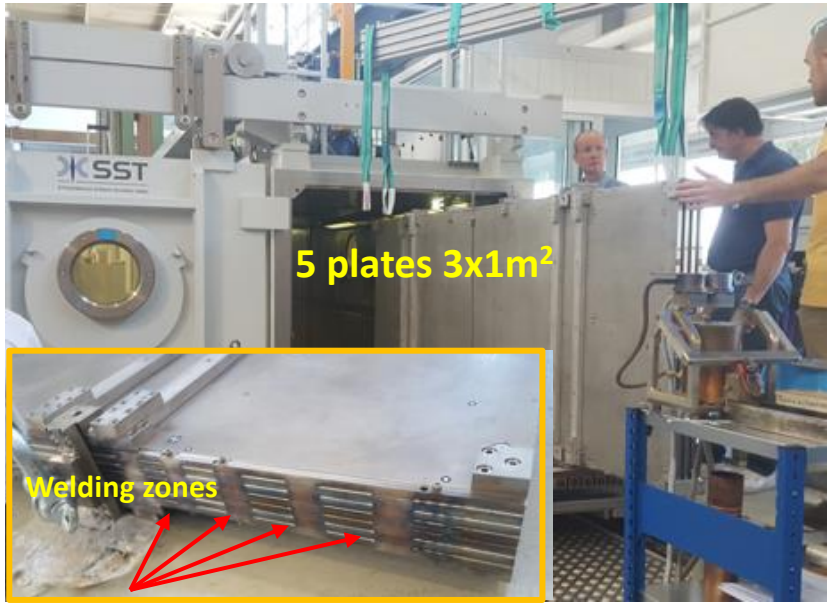
Other responsibilities related to Higgs Factories

Convener of the WG3: Detector R&D of the ECFA study on physics and experiments at e+e- Higgs/EW/Top Factories . Since June 2022 (M.C Fouz)

Present developments and future evolution: Mechanics

Procedures developed with roller leveling for improving planarity of absorber plates (1x3m^2) from several mm to ~500 microns

Development of Electron Beam Welding assembly protocols to reduce deformations introduced by welding procedures below mm level (600 microns in this test)



All work done by CIEMAT, funded by AIDA2020

Future R&D

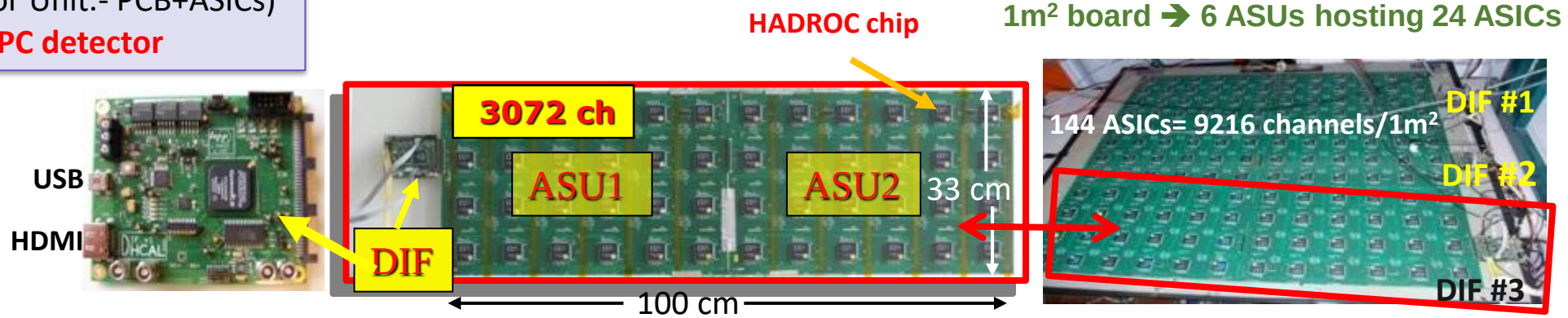
- The structure was at the limit of the machine used at CERN, **for larger modules** a bigger machine will be needed but the handling of such heavy structure **could be very complicated** (The structure needs to be moved an rotated several times)

- **A promising option** is to **build sub-modules** and after **weld them using laser welding**. The procedure should introduce reasonable deformations (the rigidity of the modules is much higher than for individual plates.
  - ***This will be tested using some of the prototypes already produced.***

Present developments and future evolution: Electronics

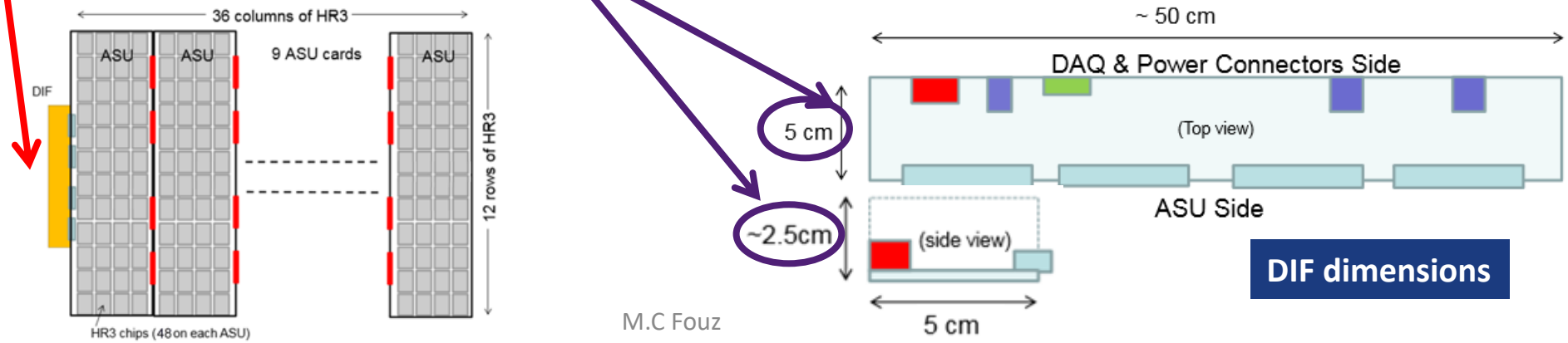
Readout electronics for the 1m3 prototype

1 DIF for 2 ASU (Active Sensor Unit.- PCB+ASICs)
➔ **3 DIFs for ONE 1m2 GRPC detector**

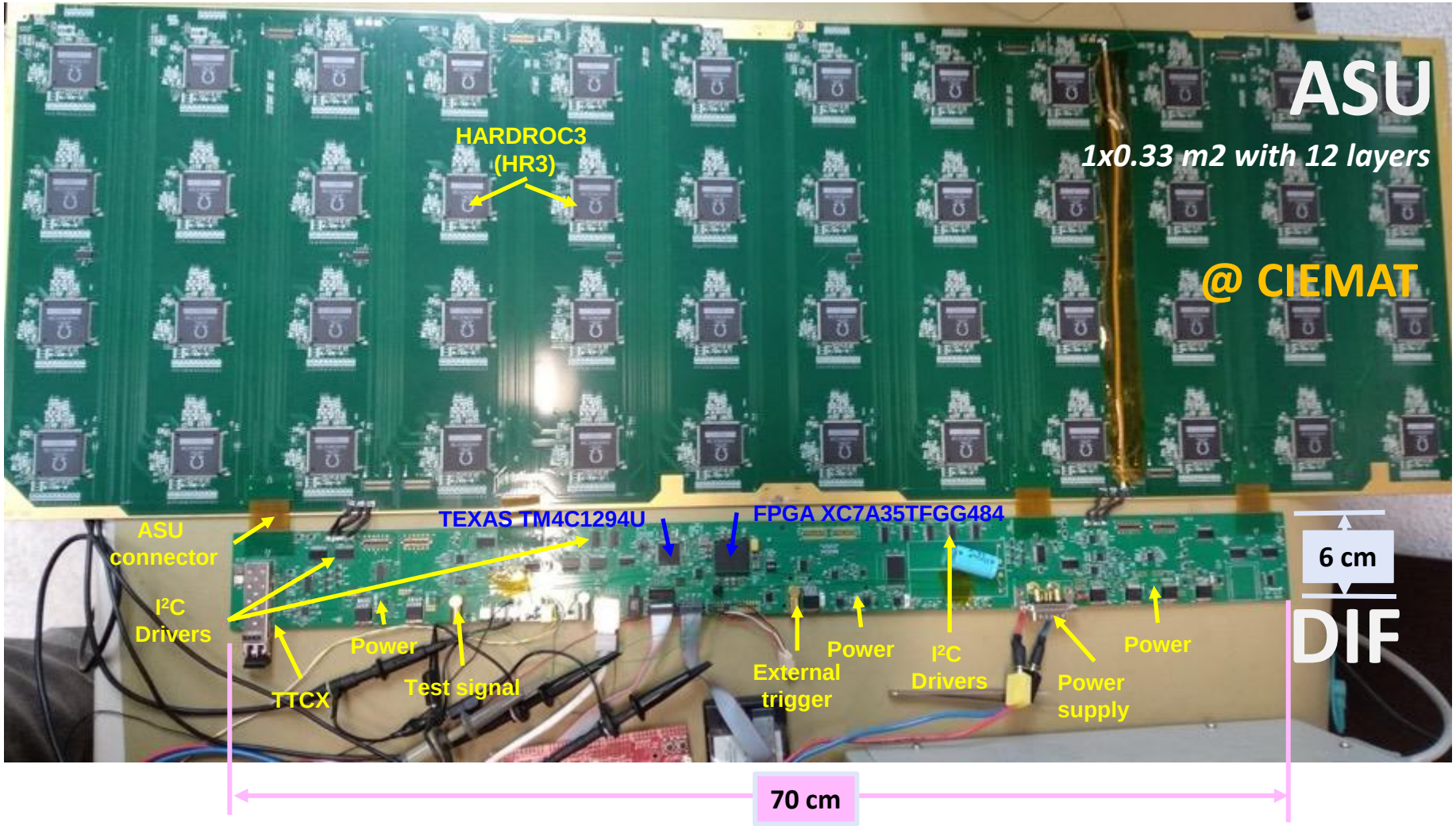


New Readout electronics: New ASIC + new DIF

Only **1 DIF per GRPC (any dimension)** with small dimensions to fit in the **small** space available at the final detector



Present developments and future evolution: Electronics



New DIF capable to handle up to the 30000 readout channels of a 3x1m^2 RPC

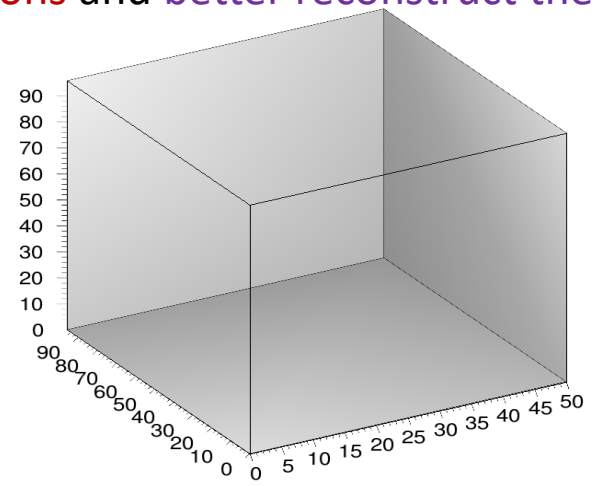
Designed, produced and tested by CIEMAT

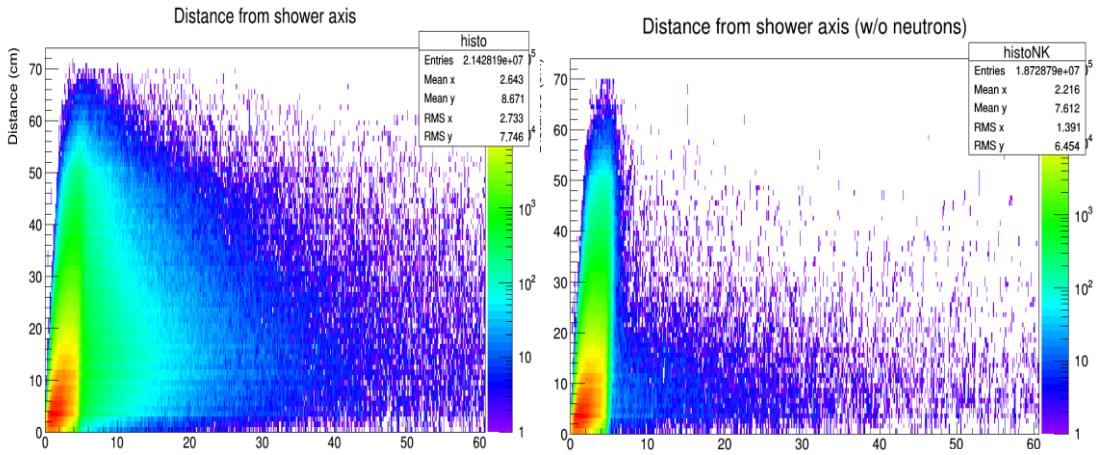
- Now under integration with DAQ in collaboration with the Lyon Group
- To be tested with RPC in beam tests

Short term evolution: 5D Calorimeter

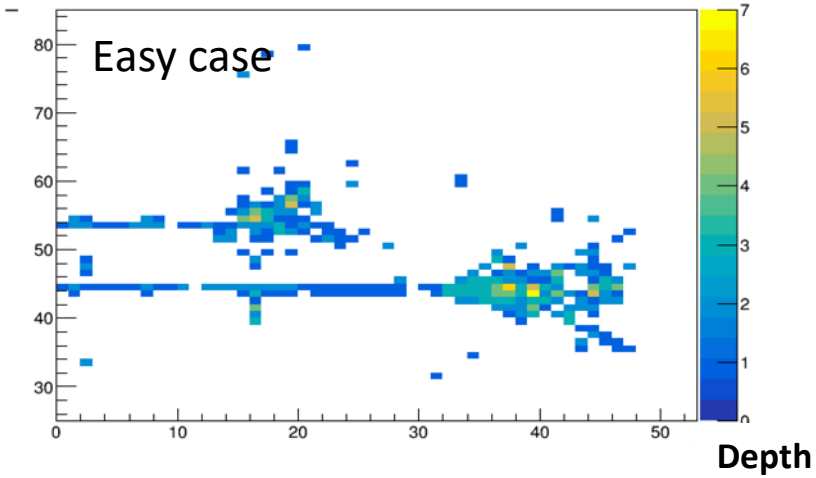
Motivation for including time information

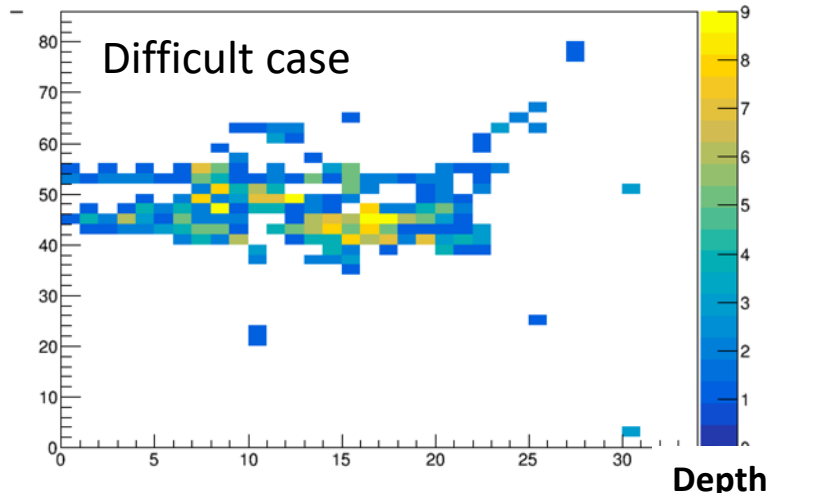
Timing could be an important factor to identify delayed neutrons and better reconstruct their energy





Time information can help to separate close by showers and reduce the confusion for a better PFA application.
Example: pi-(20 GeV), K-(10 GeV) separated by 8 cm.





Short term evolution: 5D Calorimeter

General goal: Extending the Semi-Digital Hadronic CALorimeter (SDHCAL) to include timing information (100 -200ps resolution) for a **5D-calorimetry (space, amplitude & timing)**

Implementation: **Build small multi-gap RPC (MRPC)** equipped with a **new version of electronics** with **timing capabilities** to prove the final performance

MRPC will improve the intrinsic timing of the detector

Present readout Chip **HARDROC3**. Time Stamping=**200ns**

➔ ***New chip needed***

➔ ***New readout electronics (ASU, DIF, DAQ)***

- 32 channels Time resolution below 40ps

Developed at CNRS-OMEGA partially thanks to AIDA2020 for CMS-muon upgrade

Embeds the preamp, the TDC , a QDC

Limited digital logic, difficult to chain, deadtime

weeroc

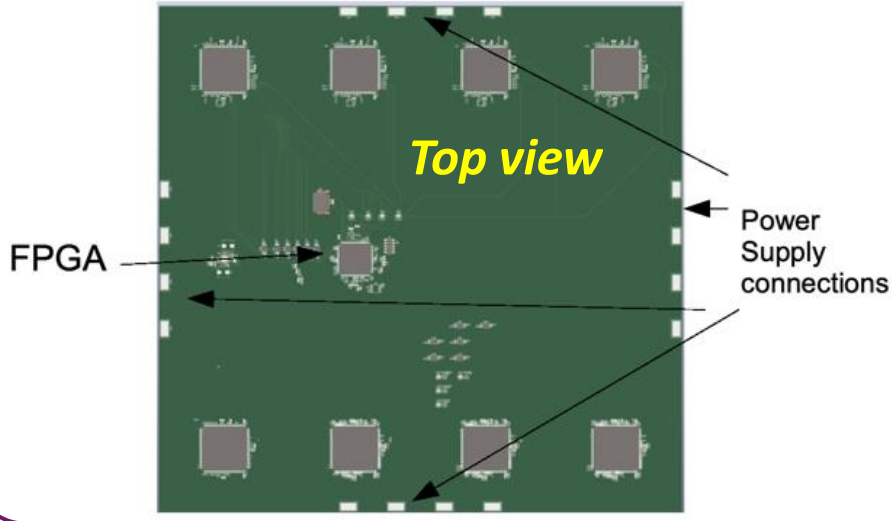
LiROC (Weeroc, 2022) single-ended, 64 ch.

Time resolution 12 ps

Under study by our Korean collaborators

Under design

8 Petiroc ASICS to readout
a **50 cm x 30 cm** detector with **2cm x 2 cm pads**.



5D Calorimeter related activities planned at CIEMAT

- **Monte Carlo simulation studies and software developments to evaluate the impact of timing on shower reconstruction.**

  (Calorimeter level and some Physics benchmark channel)

  Using the framework of the ILD concept group for ILC where the SDHCAL simulation is implemented and simulation samples are available

- **New electronics with timing implementation**

- **Detector mechanics for new Multigap GRPCs**

- **Tests of new multigap GRPC prototypes.**

  Developments ongoing at U. Shanghai Jiao Tong (China) & IP2I (Lyon-France)

Future interesting tests using the 1m3 SDHCAL prototype

- **Tests with beams at CERN substituting part of the present GRPCs by the new Multigap GRPCs**

- **Combined tests with SiWECAL**

  Some attempt in the past but difficulties when trying to synchronizing the data

  ➔ Extra work needed at the DAQ and software levels to allow interesting studies

  Of interest for *PID and new reconstruction algorithms*

  In the longer term, the inclusion of several layers of tracking could be envisaged

Person power at CIEMAT & extra budget

1 FTE senior Physicist - staff
0.3 FTE mechanic engineer - staff
1 FTE electronic engineer *(till last year, plan to hiring a new one along this year with the recent approved national project)*
1 FTE technician (mechanics) – staff
Other CIEMAT support
Mechanical Workshop of CIEMAT
Electronic Workshops

1 PhD student during last 4 years, defending his thesis next week and no replacement foreseen due to lack of resources. (no FPI assigned to the project)

The project would benefit a lot from some PhD student and young post-doc
The lack of electronic technicians makes very difficult the implementation and tests of the electronic boards

Apart from the AEI project there is some mall budget from the ***EU AIDAInnova project***. ~20Keuros for next 3 years
Gas detector WP, for timing developments with multigap RPC for calorimetry
M.C Fouz coordinator of those activities at AIDAInnova: 4 groups involved *(CNRS - IP2I - France , CIEMAT – Spain, Shanghai Jiao Tong University – China, Gangneung–Wonju National University – South Korea)*

Caveat: *Madrid Community Government does not consider fund any kind of experimental high energy physics projects, FPI like or postdoc figures.*


THANK YOU
FOR YOUR
ATTENTION

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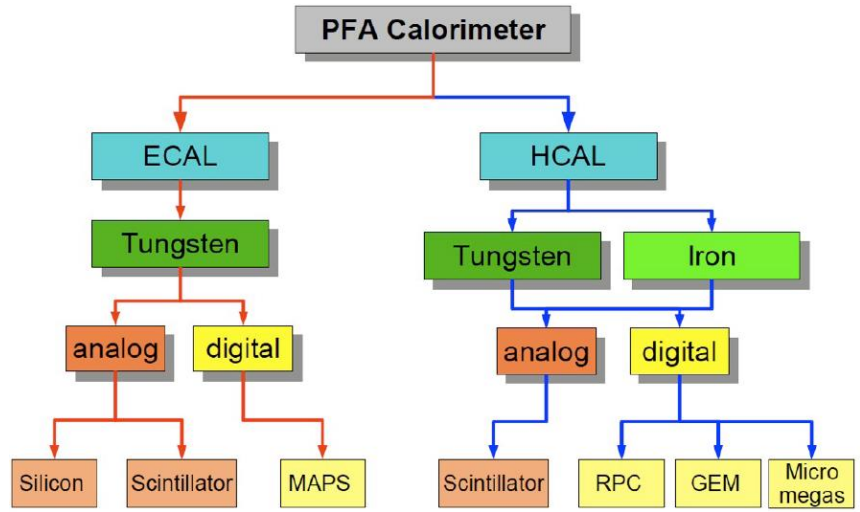
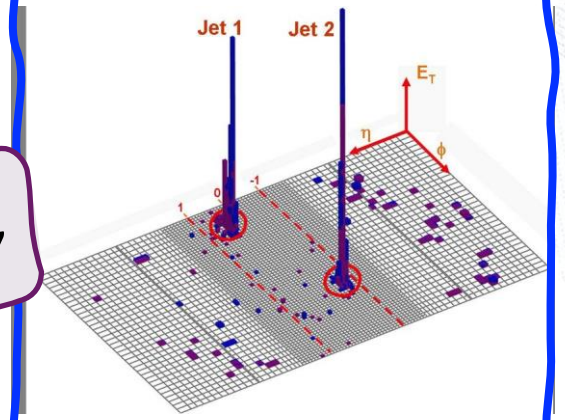


Actual calorimeters



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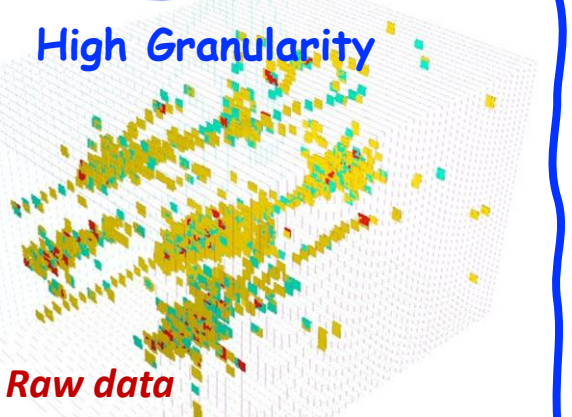
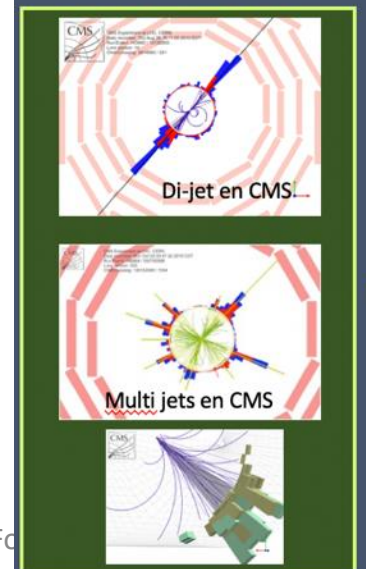


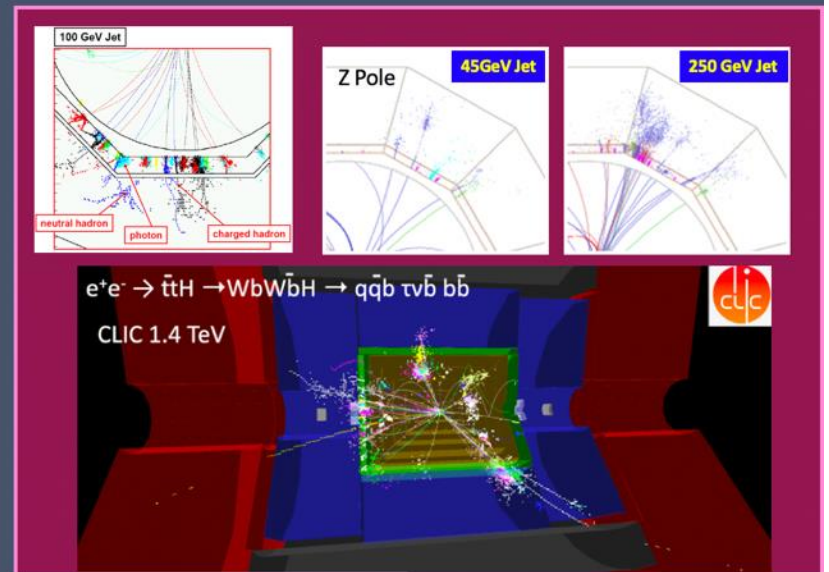
Raw data

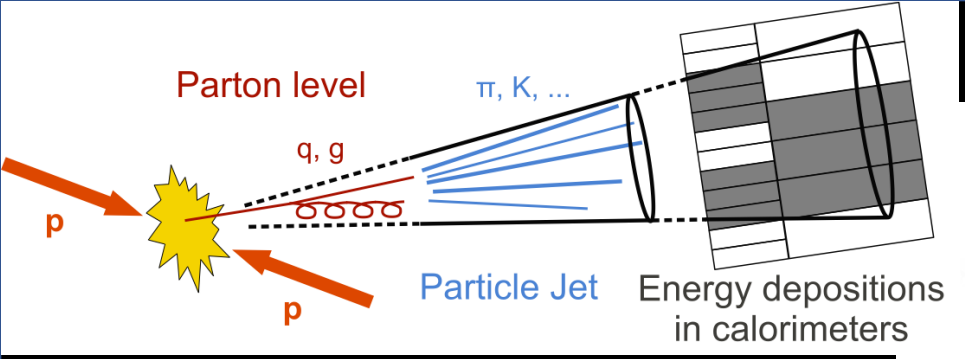
*Several particles from test beam recorded by the **SDHCAL***

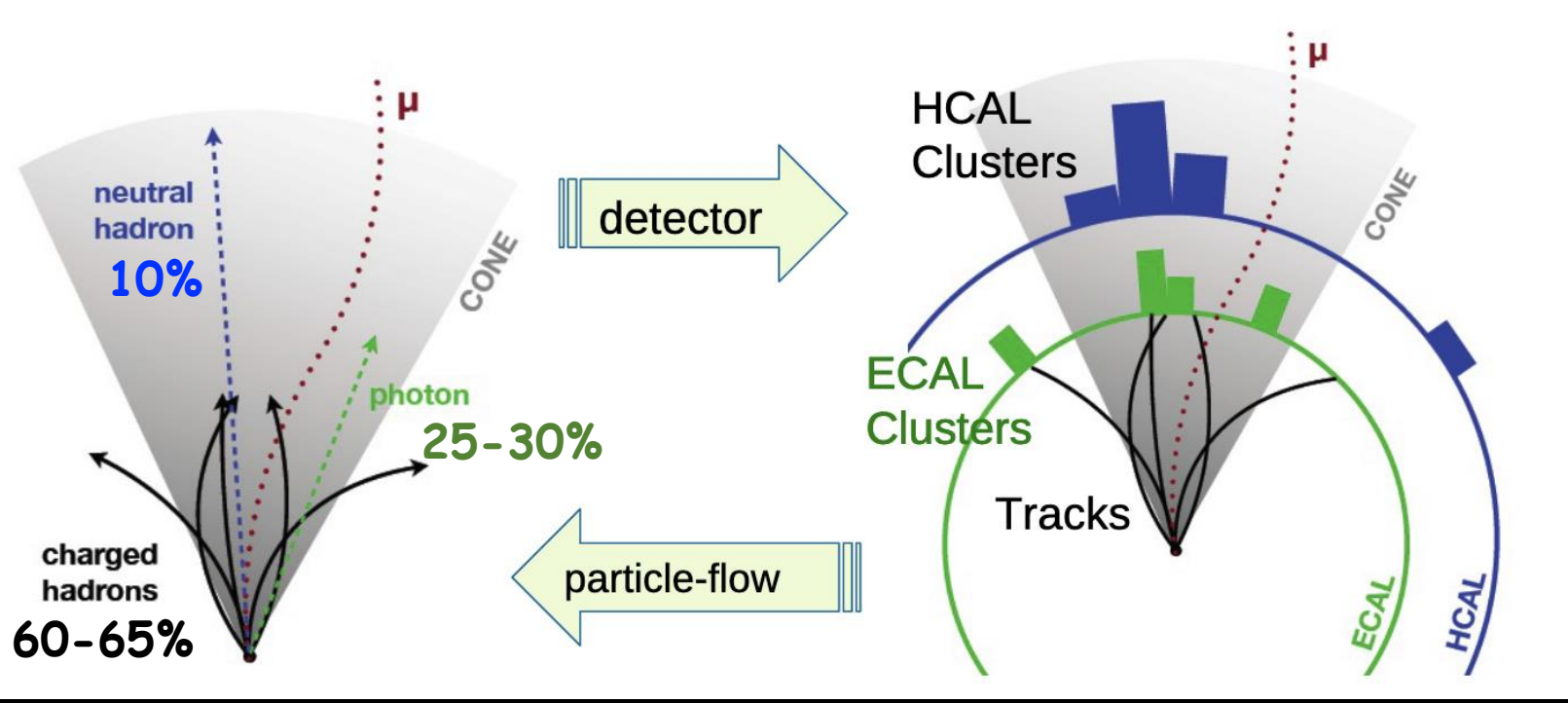
Cómo se verán los jets usando calorímetros altamente segmentados?



VS







Jets – Reconstrucción de la energía

Tradicionalmente Medida de la energía en ECAL+HCAL. (~ 70% energía en HCAL, resol: $\sigma/E \sim 60\%/\sqrt{E}$)

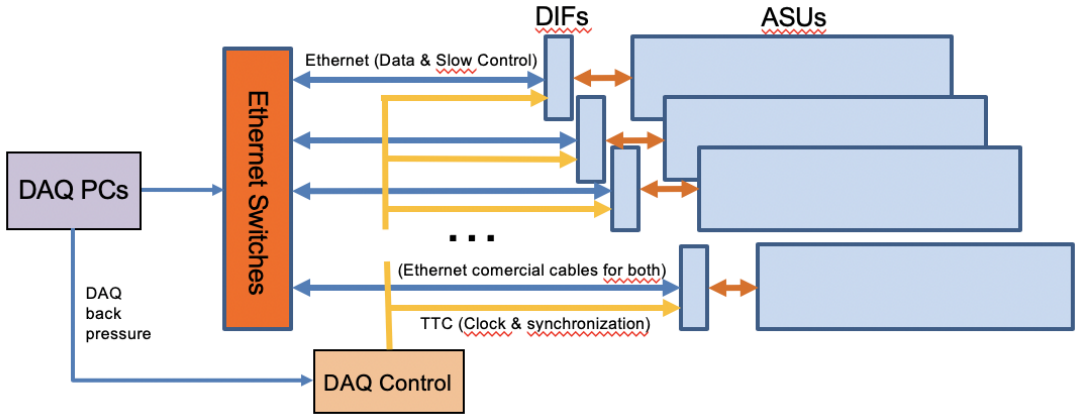
PFA. Particle Flow algoritms Partículas cargadas SOLO en el tracker (se mide el momento, esencialmente perfecto)
Fotones – ECAL $\sigma/E < 20\%/\sqrt{E}$
Sólo hadrones neutros (~ 70% energía en HCAL, resol: $\sigma/E \sim 60\%/\sqrt{E}$)

PFA en la actualidad Los hadrones neutros se identifican como $E_n = E_{tot} - (E_{ECAL}+E_{HCAL})$

PFA en el futuro Reconstrucción directa de los hadrones neutros con calorímetros de altísima granularidad y software complejo

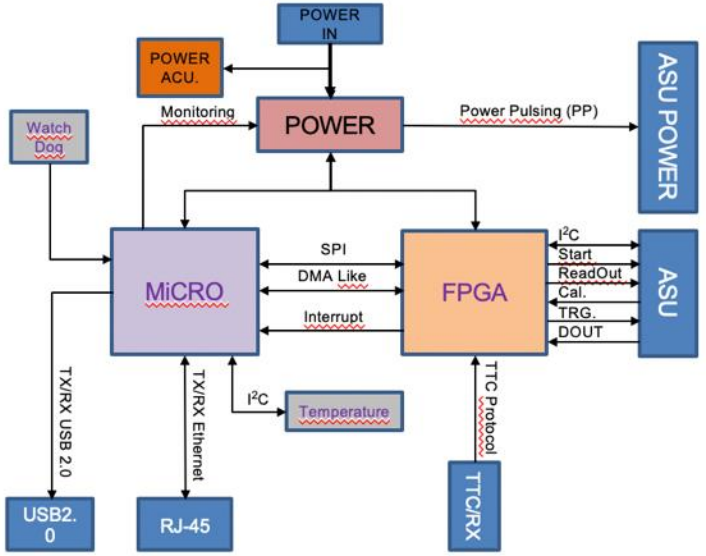
SDHCAL DAQ architecture

A ***central PC*** **collects data** from all the ***ASUs*** (containing de ***ASIC chips***) through an ***Ethernet switch*** acting in such a way **as data concentrator** and **generates the required commands for *ASU* and *DIF (Detector Interface)* configuration generating at the same time synchronization signal** required for a correct data acquisition process.



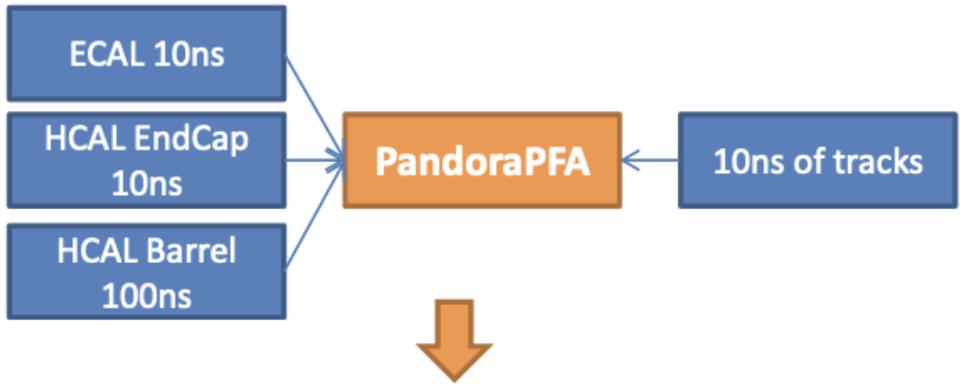
DIF architecture

- Only **one DIF per plane** (instead of **three** at 1m3 prototype)
- DIF handle up to **432 HR3 chips** (vs **48 HR2** in previous DIF)
- **Clock and synchronization** by **TTC** (already used in LHC)
- **93W Peak power supply** with super-capacitors (vs **8.6 W** in previous DIF)
- Spare I/O connectors to the FPGA (i.e. for GBT links)
- Upgrade **USB 1.1** to **USB 2.0**



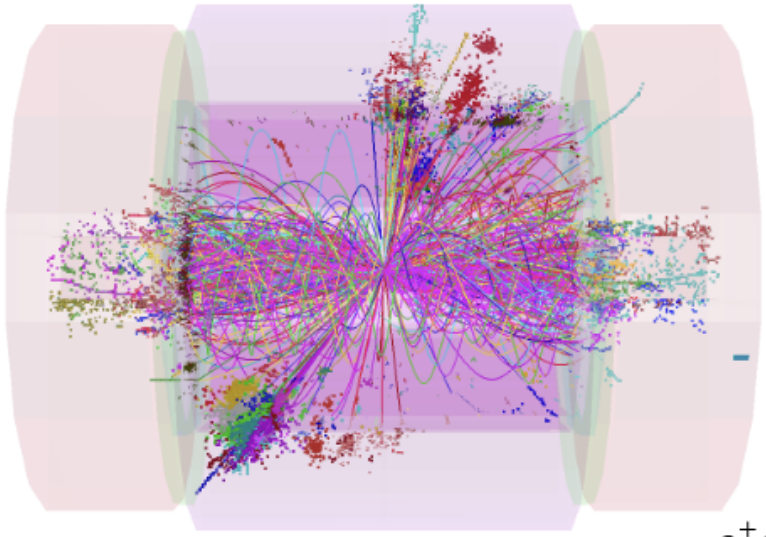
Background Suppression

1. Input to reconstruction:



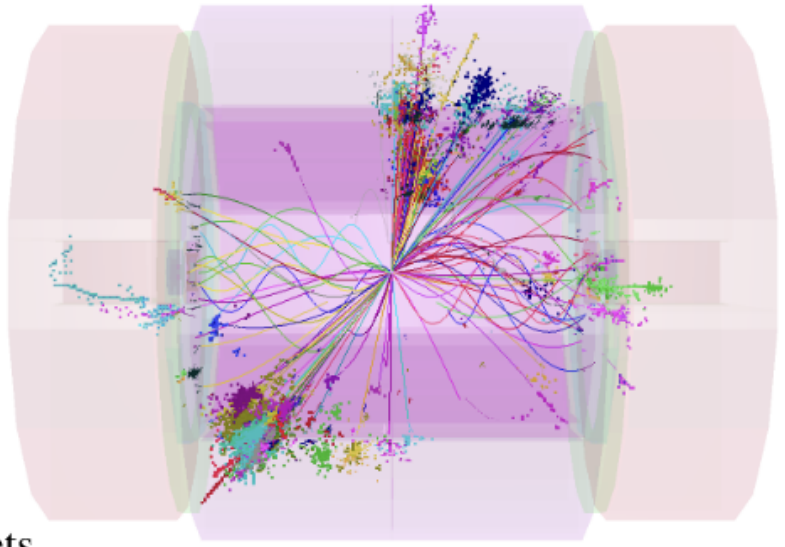
Subdetector	Reco Window	Hit Resolution
ECAL	10 ns	1 ns
Fe HCAL EndCap	10 ns	1 ns
W HCAL Barrel	100 ns	1 ns
Si Detectors	10 ns	10/√12
TPC (CLIC_ILD)	Entire train	n/a

2. Reconstructed particles, total energy 1.2TeV:



Apply selection cuts to PFOs

3. Selected particles, total energy 85GeV:



$$e^+e^- \rightarrow H^+H^- \rightarrow t\bar{b}\bar{b}t \rightarrow 8\ \text{jets}$$