DRD Calo

# Detector R&D and event visualisation (FKPPL project)

Roman Pöschl

FKPPN

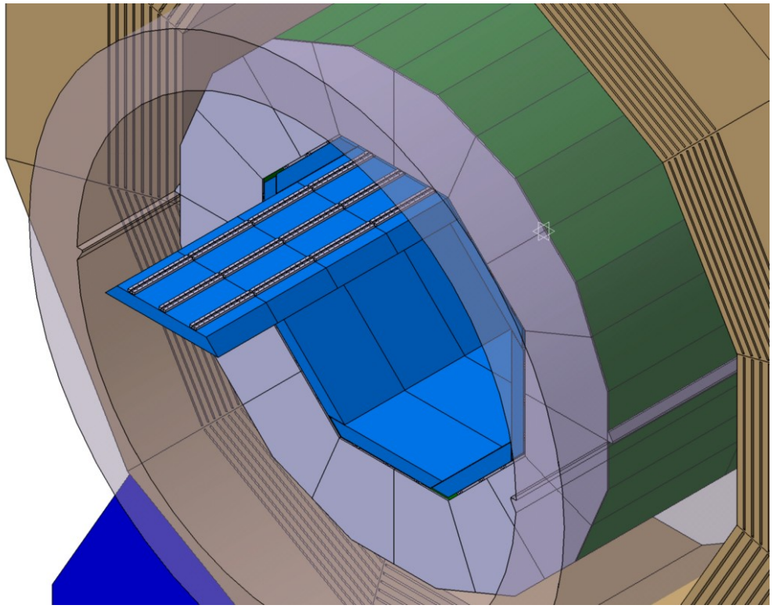
On behalf of the SiW ECAL Groups in DRD Calo:

TYL/FJPPL – FKPPL – May 2022

# Silicon Tungsten electromagnetic calorimeter

DRD Calo

- Optimized for Particle Flow: Jet energy resolution 3-4%, Excellent photon-hadron separation



The SiW ECAL in the ILD Detector

- $O(10^8)$ cells
- “No space”

=> Large integration effort

## Basic Requirements:

- Extreme high granularity
- Compact and hermetic
- (inside magnetic coil)

## Basic Choices:

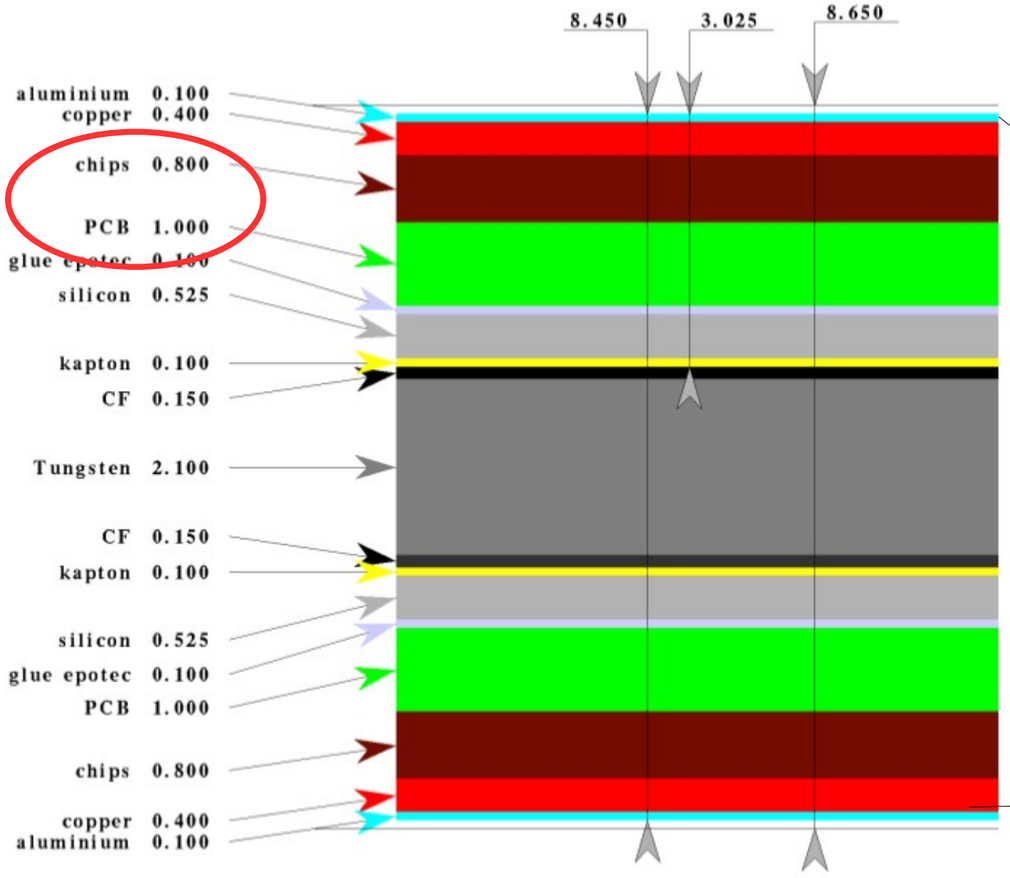
- Tungsten as absorber material
  - $X_0$=3.5mm, $R_M$=9mm, $\lambda_I$=96mm
  - Narrow showers
  - Assures compact design
- Silicon as active material
  - Support compact design
  - Allows for pixelisationRobust technology
  - Excellent signal/noise ratio: 10 at MIP level as design value

- All future e+e- collider projects feature at least one detector concept with this technology
  - Decision for CMS HGCAL based on CALICE/ILD prototypes

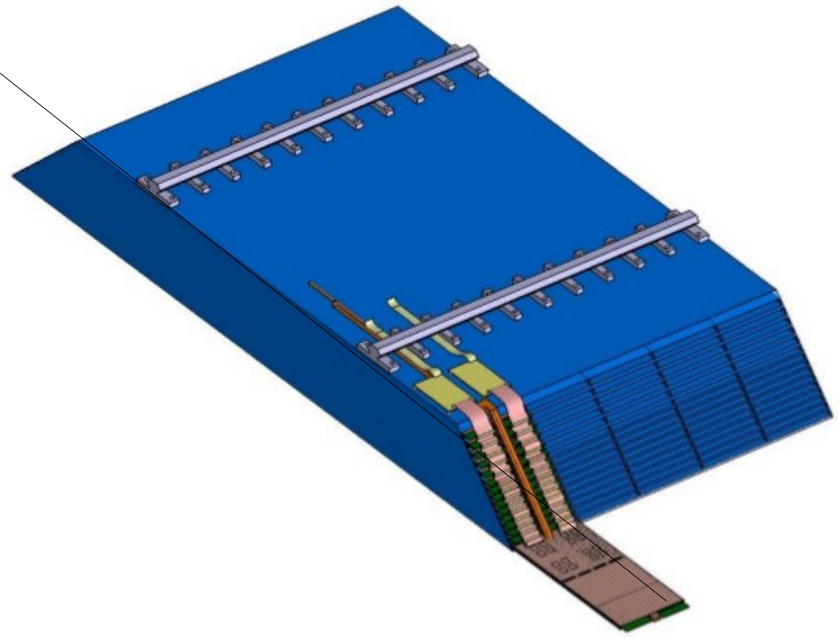
# Silicon Tungsten electromagnetic calorimeter

**DRD Calo**

Zoom into layer




Ecal alveolar structure



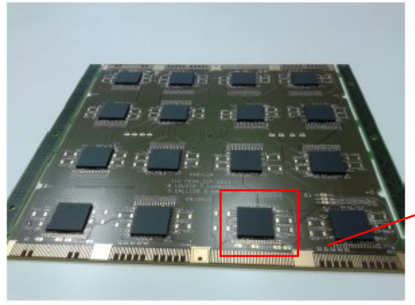
*Drawings by Henri Videau for SiW Ecal Technical Design Document*

Design: Total space for ASICs and PCB 1.8mm (was 1.2mm since ~2007)

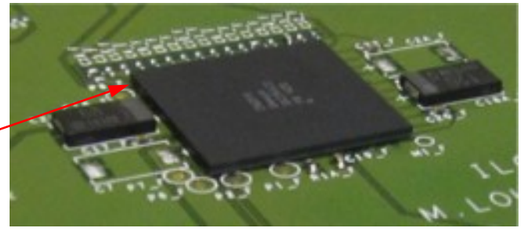
# SiW Ecal – Elements of (long) layer

**DRD Calo**

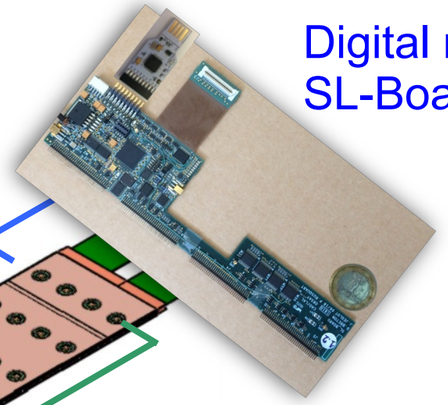
**ASIC+PCB+SiWafer**
**=ASU**
**Size 18x18 cm²**
**(IJCLab, Kyushu, OMEGA, LLR, SKKU)**



**ASIC SKIROC2(a)**
**(OMEGA)**
**Wire Bonded or**
**In BGA package**
**(IJCLab, Kyushu, LLR)**



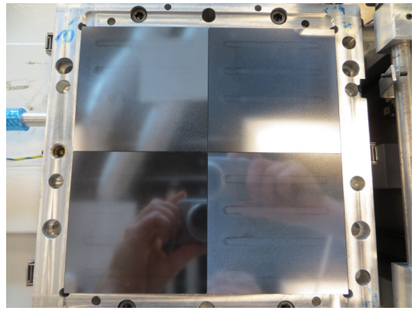
Interconnection
(IJCLab)



Digital readout
SL-Board (IJCLab)




**SiWafers glued onto PCB**
Pixel size
5.5x5.5 mm²
(LPNHE, IFIC)



Note that an additional hub for hardware Development is being set up at IFIC/Valencia

- The beam test set up will consist of a **stack of short layers** consisting of one ASU and a readout card each

# Prologue – “The FEV Zoo”

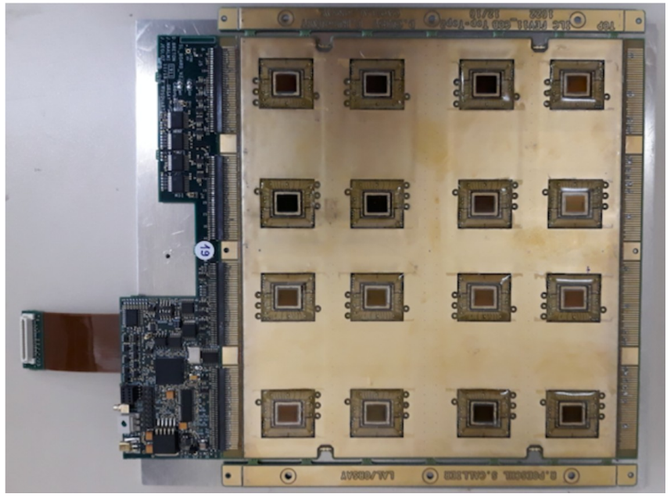


- In recent years the SiW ECAL has developed and used several PCB variants
  - To make sure that you don't get lost, here comes an introduction

## FEV10-12

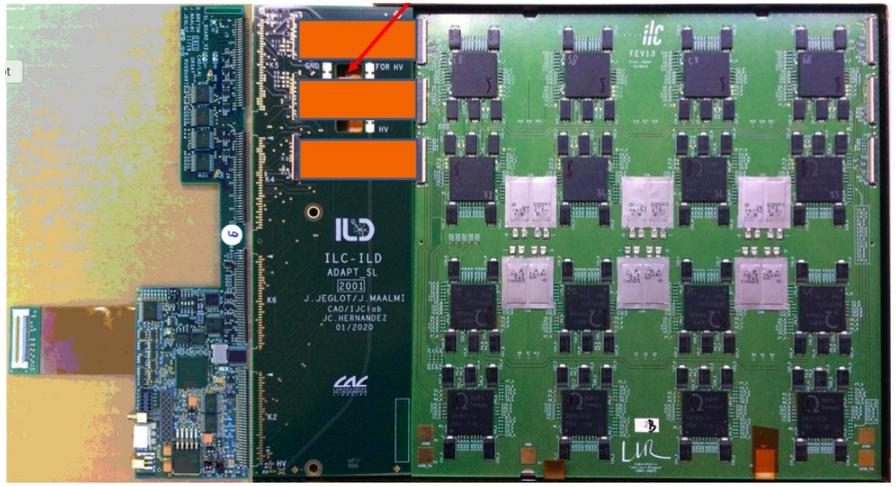
- ASICs in BGA Package
- Incremental modifications
  From v10 -> v12
- Main “Working horses” since 2014

## FEV_COB



- ASICs wirebonded in cavities
  - COB = Chip-On-Board
- Current version FEV11_COB
- Thinner than FEV with BGA
- External connectivity compatible with BGA based FEV10-12

## FEV13




- Also based on BGA packaging
- Different routing than FEV10-12
- Different external connectivity

Current prototype (see later) is equipped with all of these PCBs

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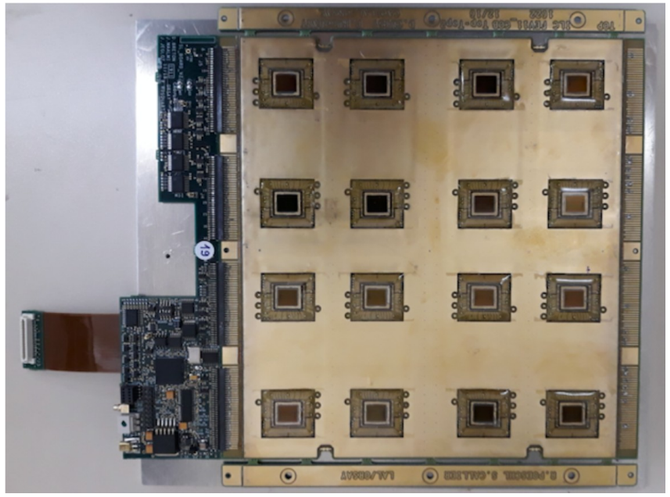

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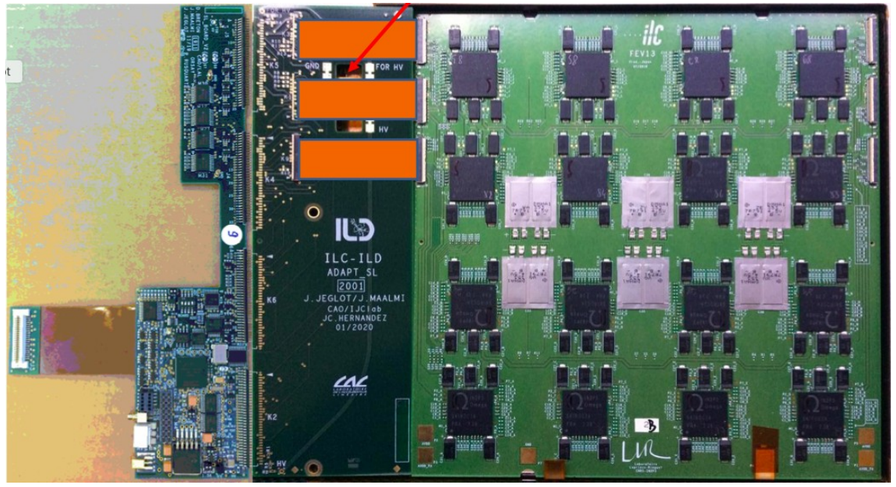


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# CALICE/FKPPL – The current team

**DRD Calo**

## FKPPL Project Proposal (2022)

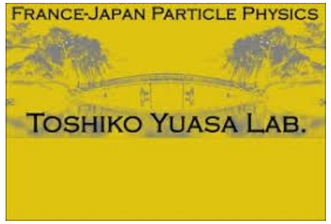
*Red info should be replaced by the appropriate text in black*

| Acronym: | Full title: ILC/CALICE | Main French and Korean institute: CNRS/IN2P3 (France), SKKU/ITAEC (Korea) |
|---|---|---|

**Domain:** Experimental particle physics and applications

| | French Group | | | Korean Group | | |
|---|---|---|---|---|---|---|
| | **Name** | **Position** | **Lab./Institute** | **Name** | **Title** | **Institute** |
| **List of participants** | Leader: Roman Pöschl | Dr. | CNRS/IN2P3 /IJCLab | Leader: Mitra Ghergherehchi | Prof. | SKKU, ITAEC Center |
| | Stephane Callier | Dr. | CNRS/IN2P3 /OMEGA | Jong-Seo Chai | Prof. | SKKU, ITAEC Center |
| | Dirk Zerwas | Dr. | CNRS/IN2P3 /IJCLab | | | |
| | Jimmy Jeglot | Dr. | CNRS/IN2P3 /IJCLab | | | |
| | Remi Cornat | Dr. | CNRS/IN2P3 /LPNHE | | | |

The CALICE SiW ECAL receives aleo great support via TYL/ FJPPL



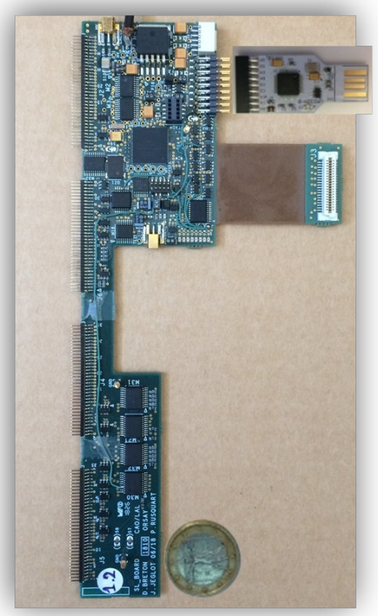

More information in talk by Cristina on Wednesday morning

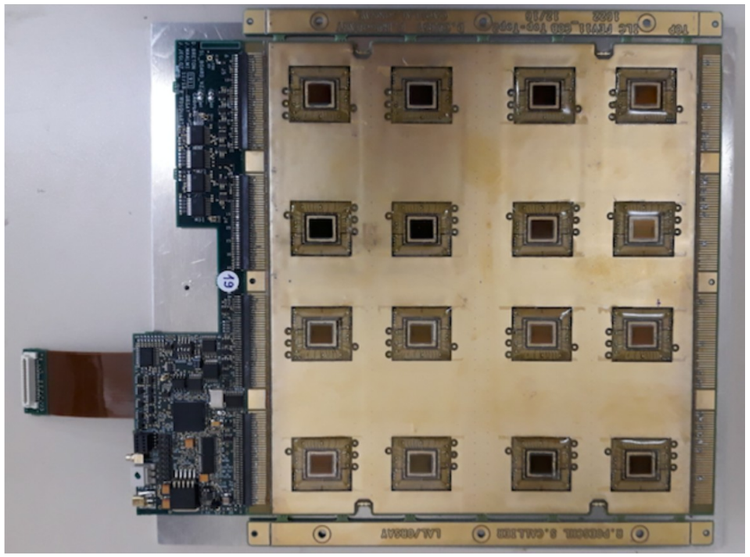
***+ Yuichi Okugawa (IJCLab and Tohoku U)***
***Allow me to add Adrian Irles (member until 2020, now IFIC) w/o whom many of the results shown today would not have been possible***

# COBs and compact readout system

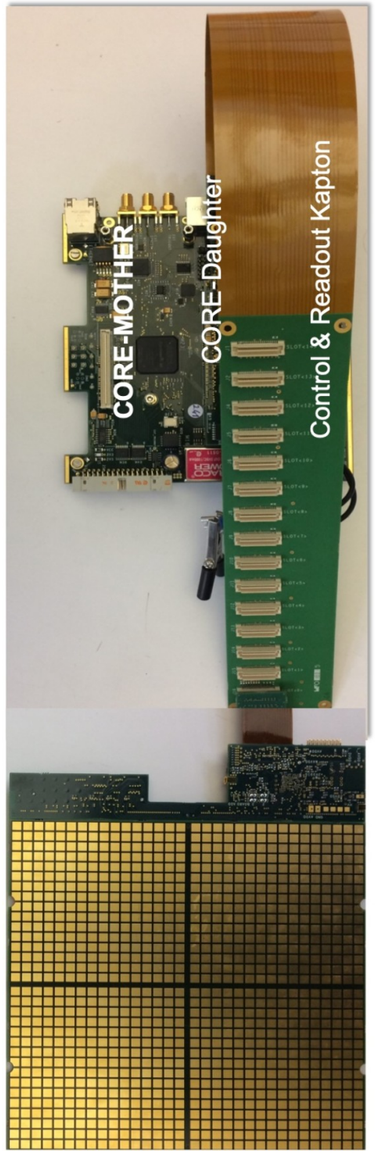


## Current detector interface card (SL Board) connected to COB





## Complete readout system

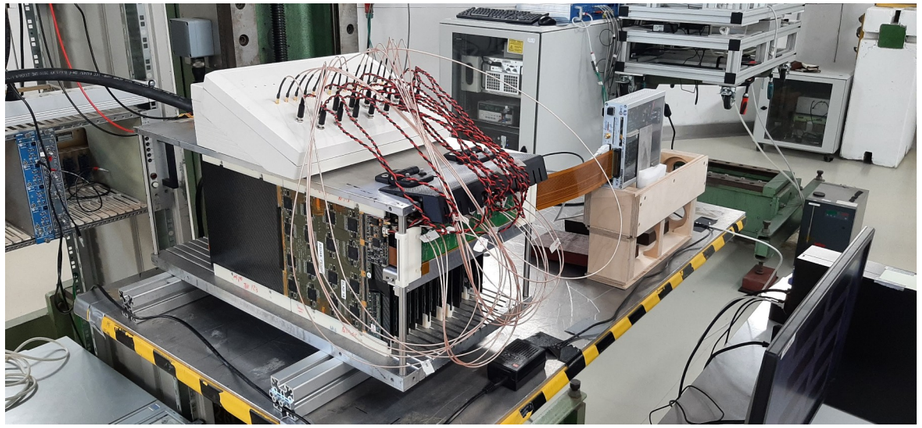



- “Dead space free” granular calorimeters put tight demands on compactness
- Current developments in CALICE (IJCLab) meet these requirements
- Can be applied/adapted wherever compactness is mandatory
- Components will/did already go through scrutiny phase in beam tests

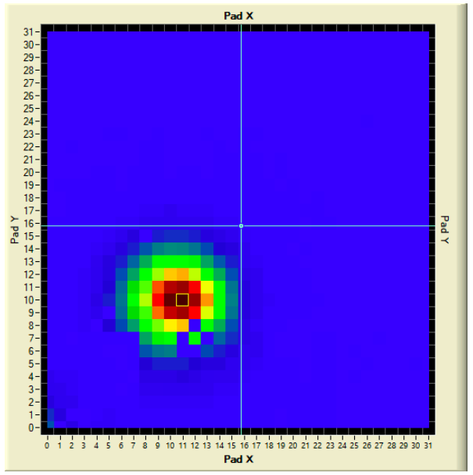
# SiW-ECAL in beam test @ DESY 2022



## Detector Setup



- Testbeam with 15 layers equivalent to 15360 cells
- Two COB layers were part of the setup

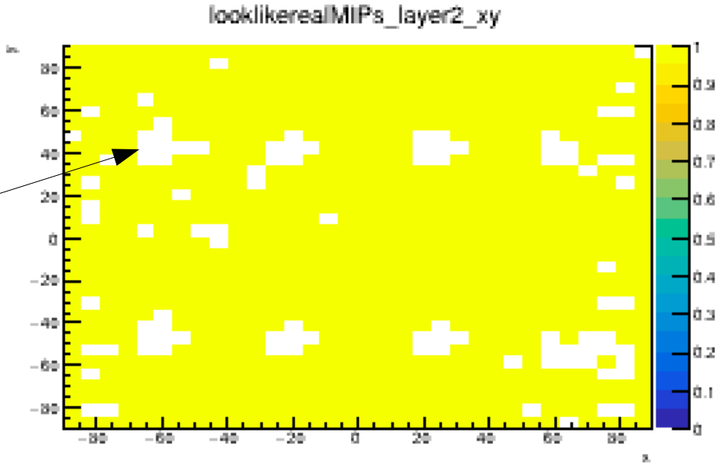



Clear beam spot in COB based layers

## Detector in beam position


- Homogeneous response of board(s) to MIPs
- ~10% noisy cells had to be masked
  - Nearly all on digital line, curable with decoupling capacitances

"MIP Map" of one COB




*Plots by A. Irles, IFIC*

# MIP Signals - COB vs. BGA

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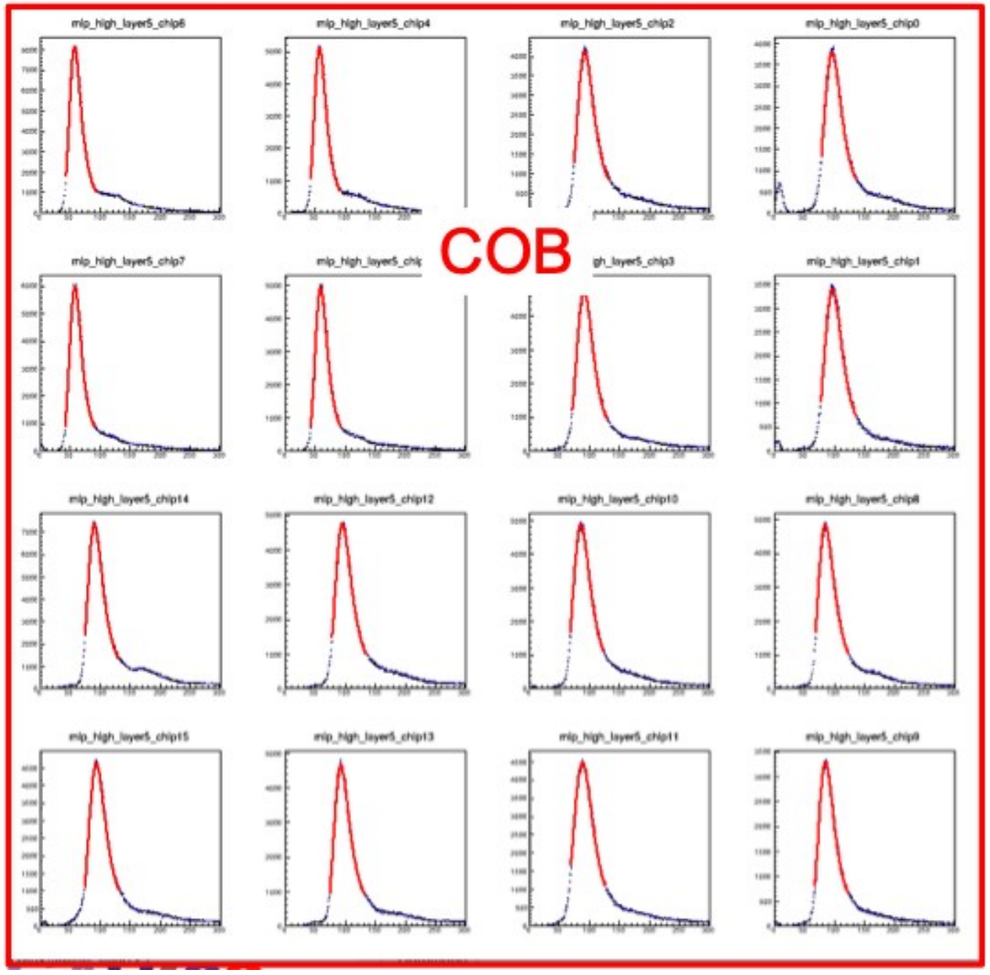
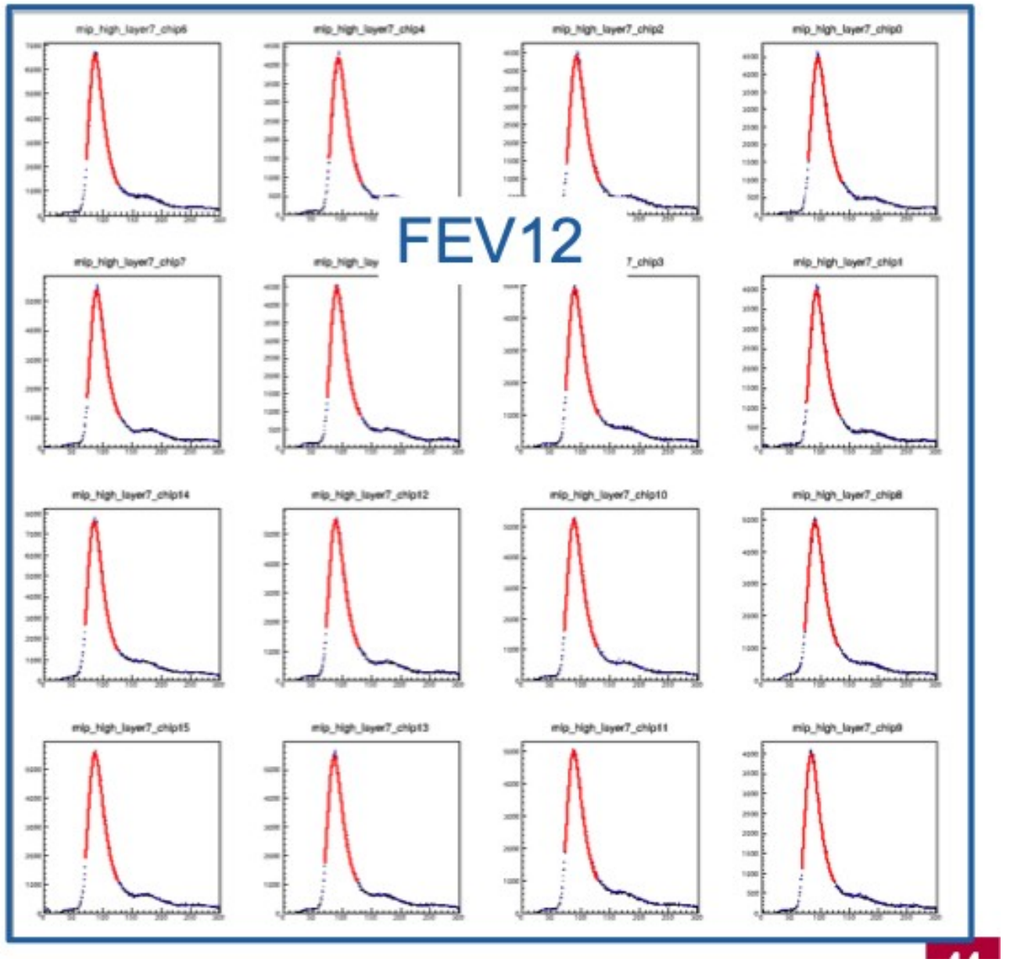
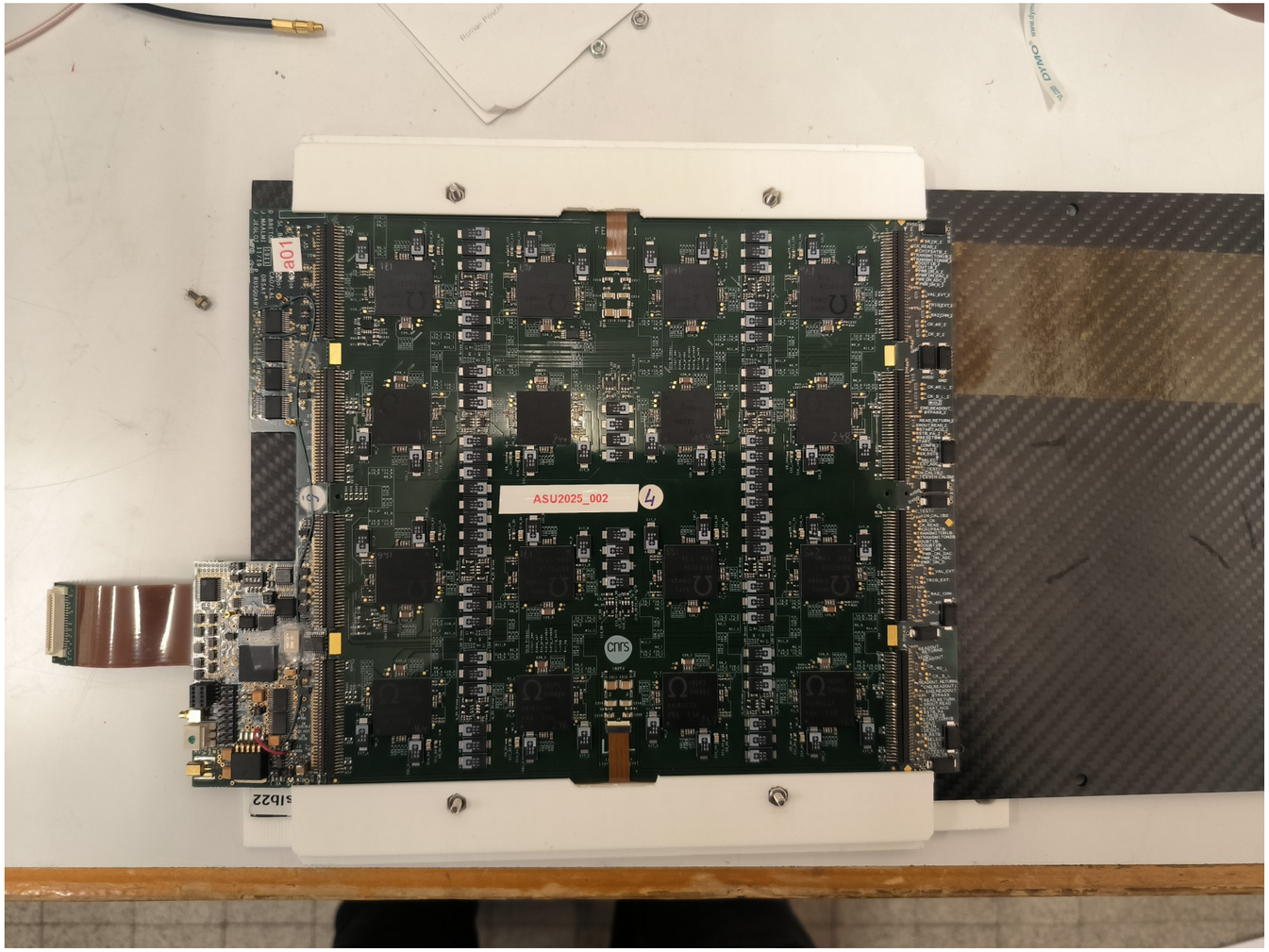



- Quality of MIP signals comparable between COB and BGA variants of PCB

# SiW ECAL ASU 2025





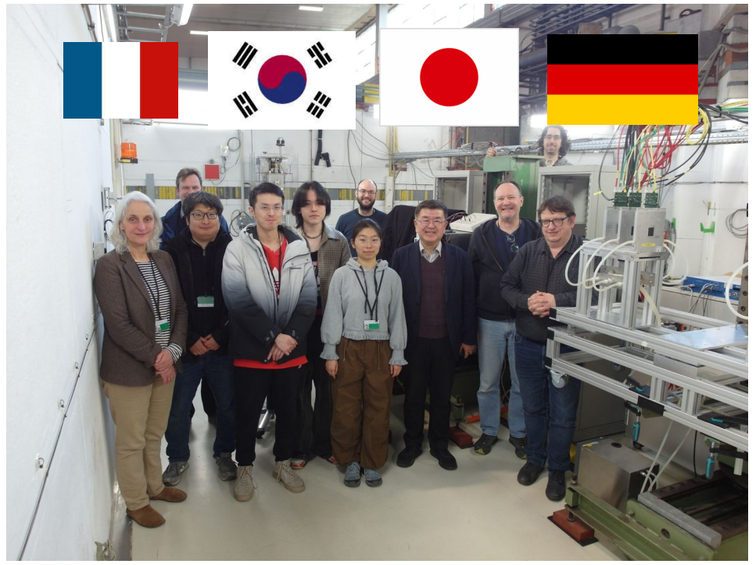

- Looks like the old one but has a lot of new features
  - Better shielding of AVDD and DVDD
  - Local energy storage and LDO to power ASICs locally
  - Inrush current limited to 200 mA
  - Clean clock distribution
  - Two partitions
  - Readout of analogue probes via ADC on SL Board -> New firmware

# 2022 → 2025 – Testbeam at DESY

**DRD Calo**

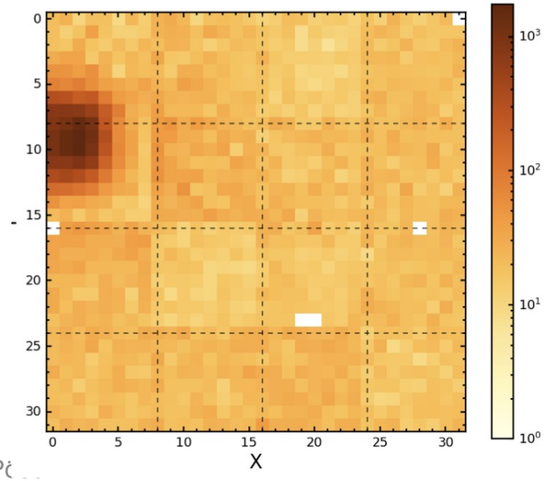
## (Combined) Setup Ecal/AHCAL

## Team at DESY

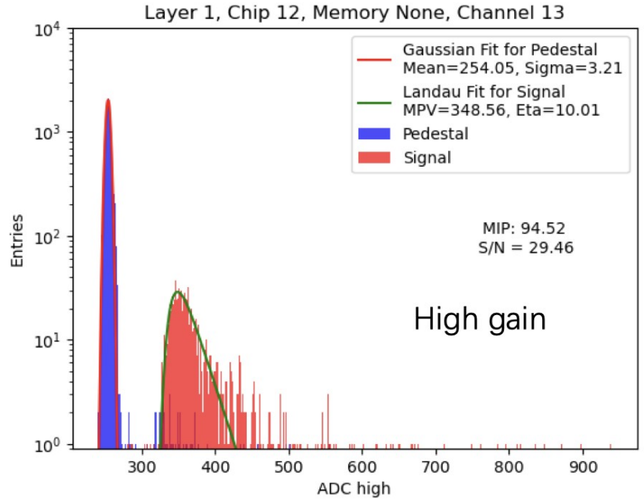


## New SiW ECAL Modules - Performance

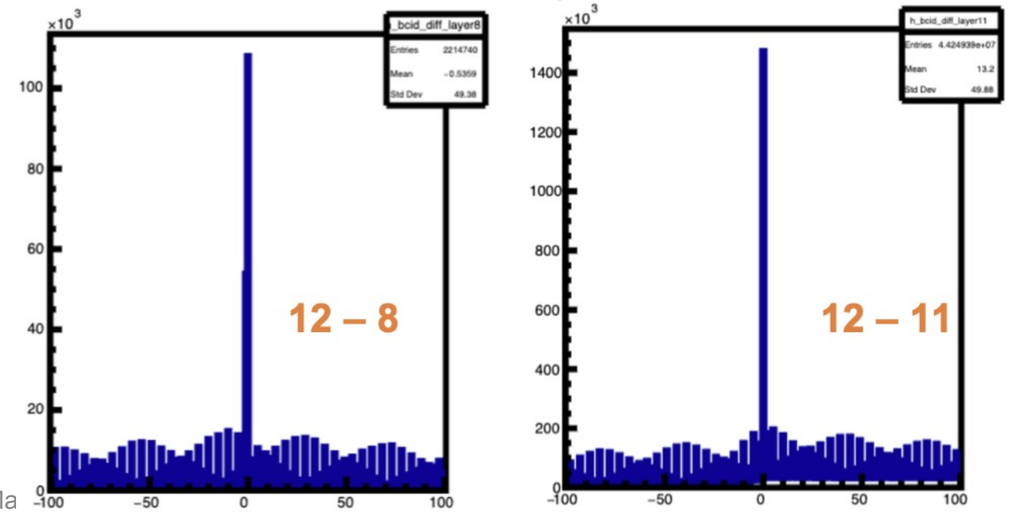
### (Almost) no noisy cells




### Clear S/N Separation




### Detectors in sync



# KORASIC - Introduction



KoRASIC
KOREA RADIATION SAFETY ICT CENTER

1. Establishment : Sep 1. 2023
2. Governance

Ministry of Science and ICT

National Research Foundation

Convergence Research Center; KORASIC & 7 centers

Directed by Jong Seo Chai

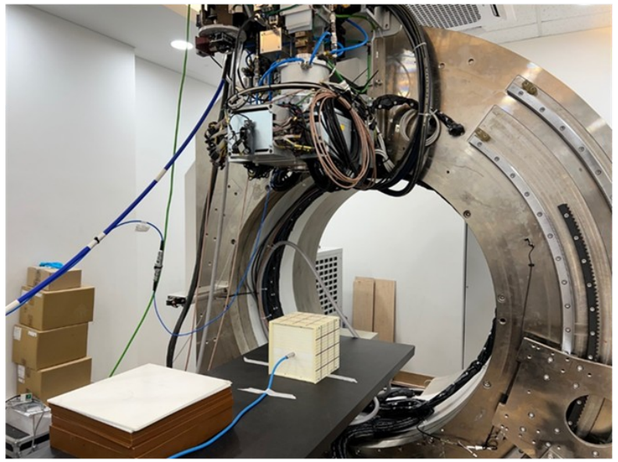
R & D

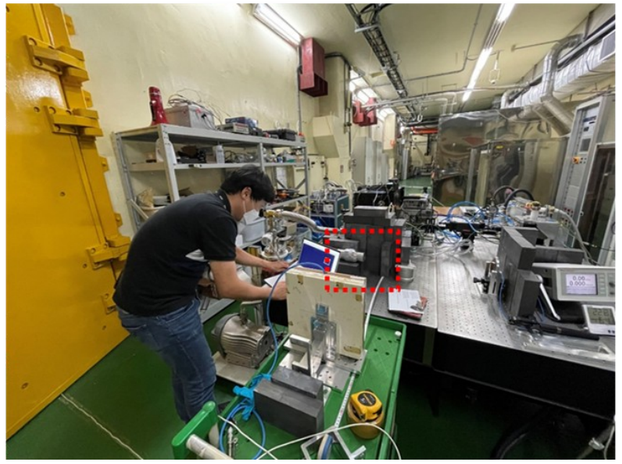
1. High-performance radiation detectors, microelectronics and devices.
2. AI-based visualization software, Augmented Reality, and Virtual Reality
3. Public communication and enhancement of social acceptance for radiation

# KORASIC – Test Infrastructure



1. Electron LINAC : 6 MeV electron, 6 MV X-ray



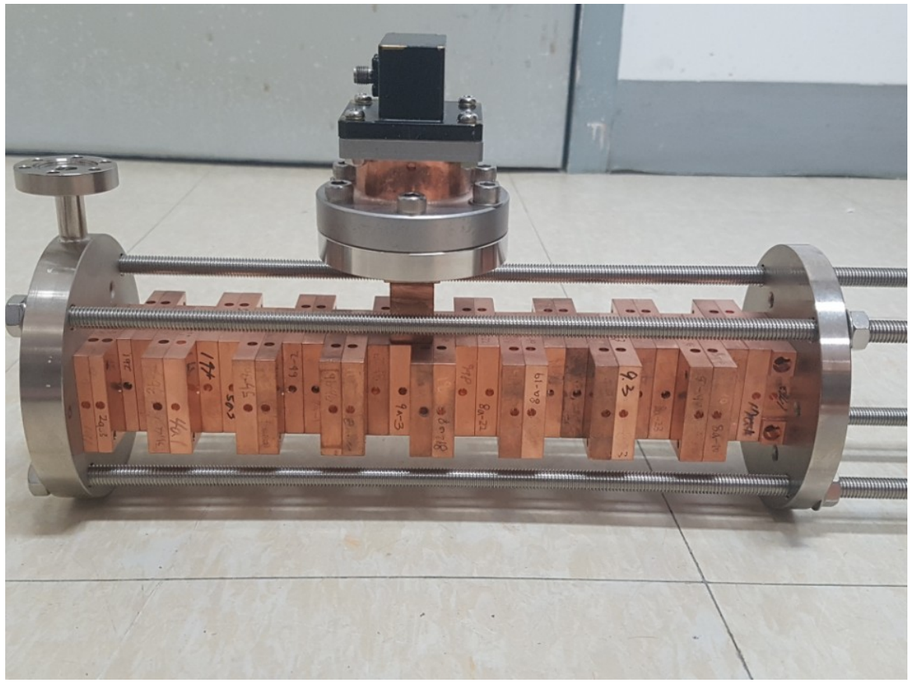


2. AVF Cyclotron : 13 MeV proton

# Collaboration KORASIC/ICT – Detector Validation?

DRD Calo

Small S-Band Accelerator see previous
5-10 MeV Electrons



~20cm

- Well, this idea is pending since 2018
- Interrupted by pandemic

- Would like to study whether the accelerator can be be used for detector development

- Electrons would act as MIPs in detector material (5-10 MeV is close to typical critical energy of detector materials)

Advantages:

- Higher rates than cosmics
- (Might) be better controllable than sources

Issues to be addressed:

- Control of accelerator rate
- Mechanical installation to hold/move detector elements
- For sure a lot of other points including safety aspects

Premises

- Accelerator exists
- FEV11_COB as first “guinea pigs”
- In passing, equipped FEV11_COB can serve ”immediately” for the radiation protection system
  -> Detectors, readout system and analysis tools are at hand

# Collaboration KORASIC/ICT – Detector Validation?

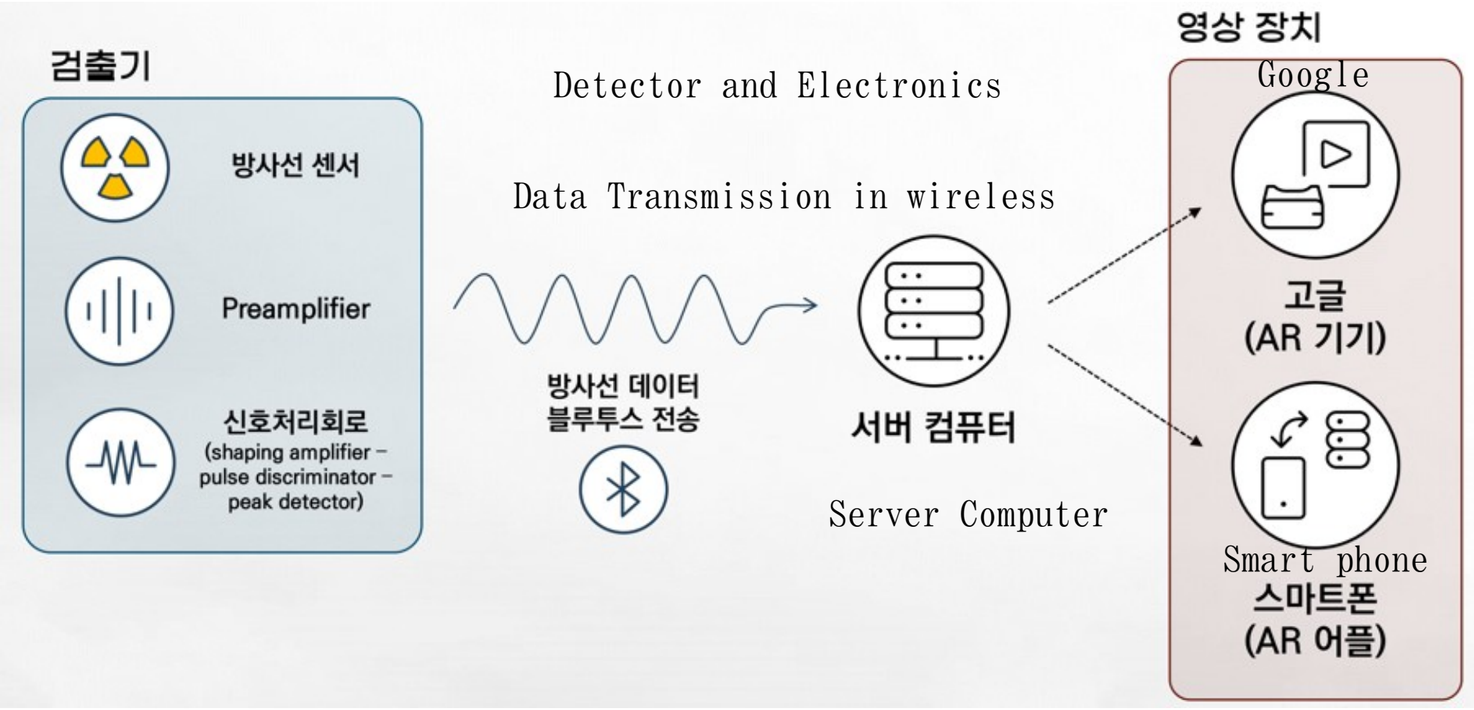


SiW ECAL testbench at instrumentation school in South Africa

- Plan to install SiW ECAL Testbench at ICT
- Setup flexible and highly mobile
  - Fits into a regular suitcase
- Typically up an running after 30 minutes
- Intutive user interface
- ~One week at ICT enough to make usefule tests
- Sucess would have impact beyond the actual project

Funding request to FKPPN to cover these test

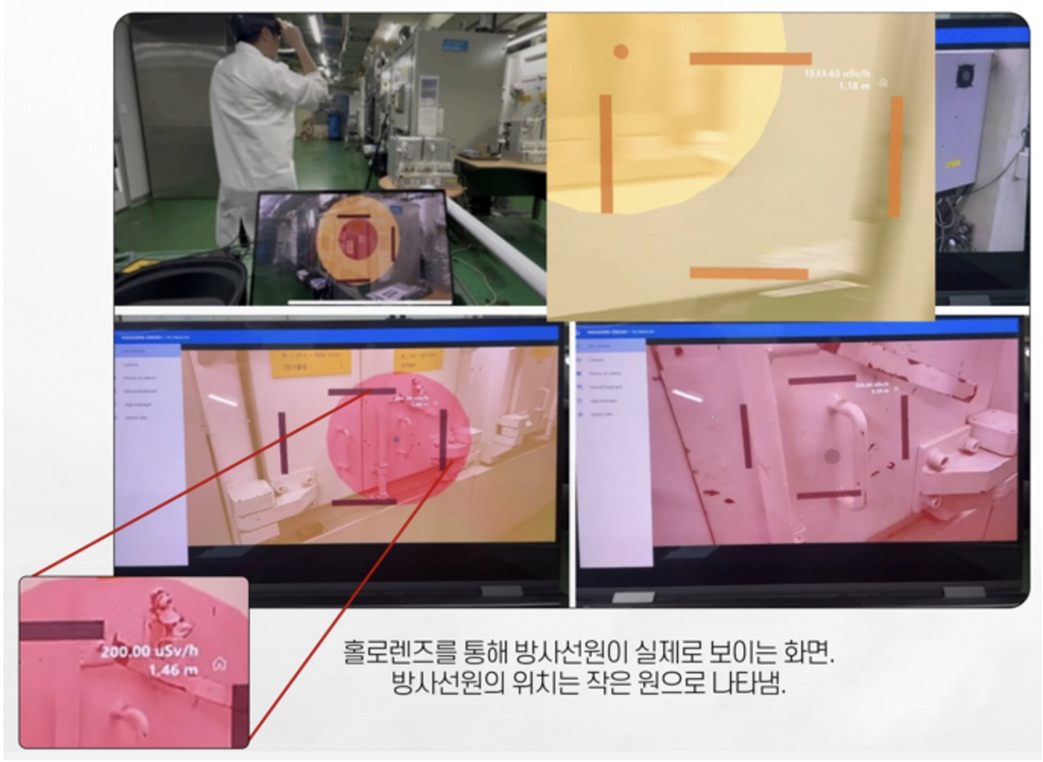
# Concepts of Augmented Reality



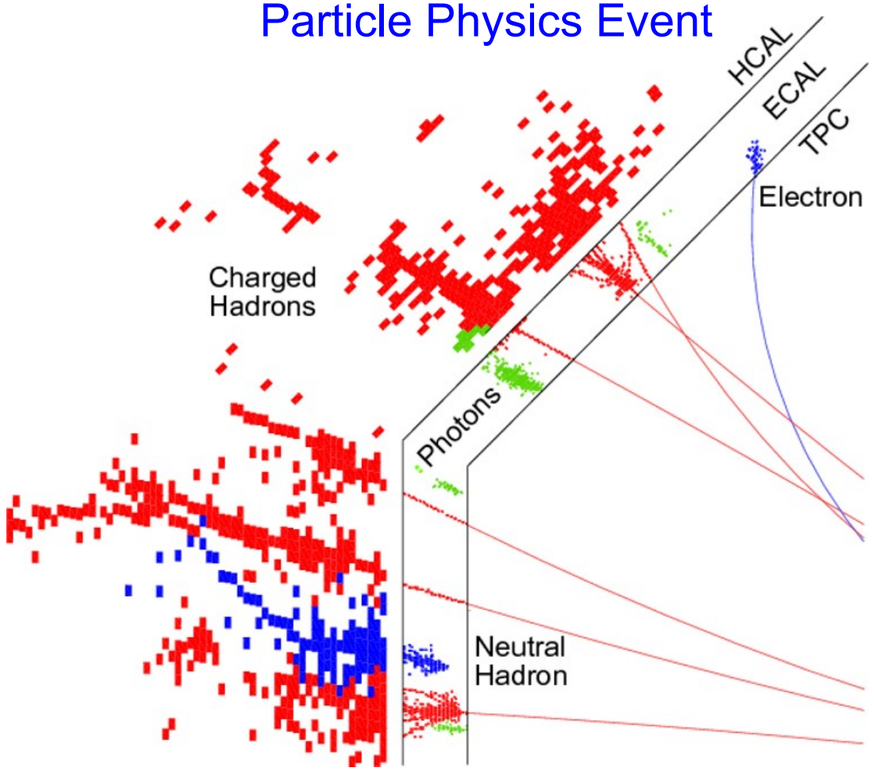

# Visualisation and reconstruction?



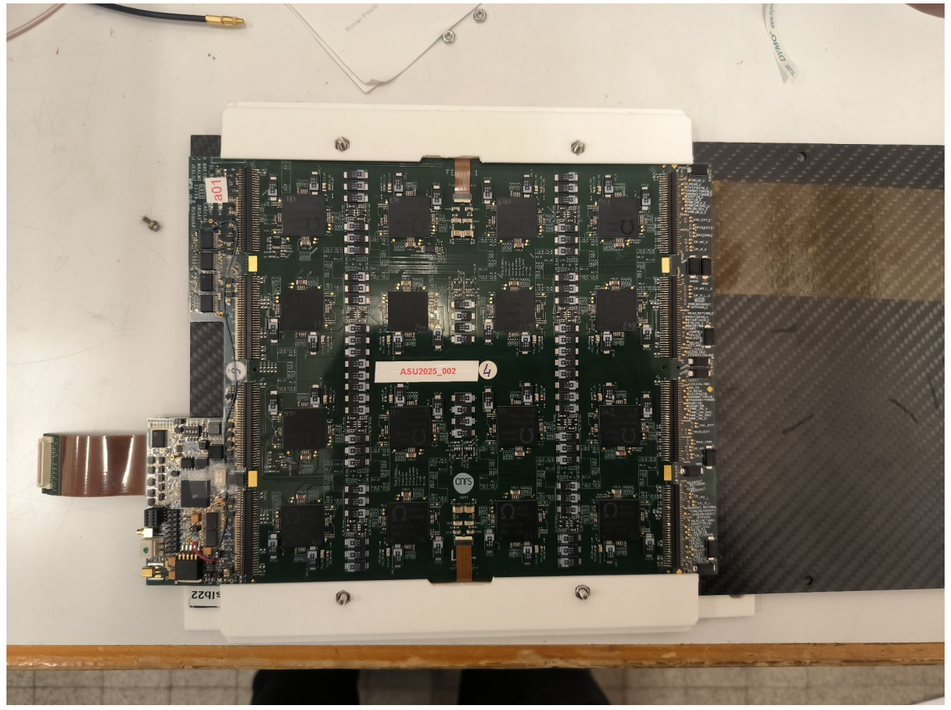
## Visualisation of zones with radioactivity

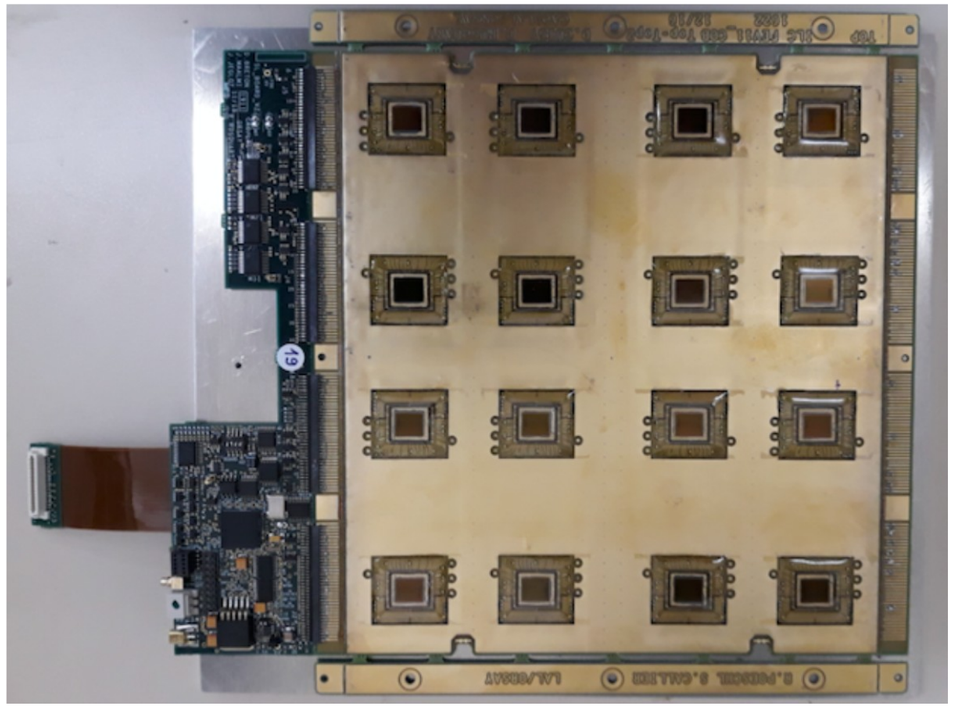



## Particle Physics Event




- Projects on visualisation
  - Integration of SiW ECAL layer in radioprotection system of ICT and visualisation of results
    - Development of interface SiW ECAL <-> AR
    - Spin-off:  Study of wireless technology for HEP Detectors
  - 3D event displays of particle physics events
    - Useful tool for event reconstruction!?
    - Interface HEP software to Augmented Reality



- Feedback of developments of new SiW ECAL ASU in updated COB design?
- In general all future HEP detectors require low power electronics
  - Competences on French and on Korean side
- Korean Contributions to future SiW ECAL prototypes

| Acronym: | Full title: DRDCALO/ECAL | | Main French and Korean institute: CNRS/IN2P3 (France), ICT (Korea) | | |
|---|---|---|---|---|---|
| **Domain:** Experimental particle physics and applications | | | | | |
| **List of participants** | **French Group** | | | **Korean Group** | |
| | **Name** | **Position** | **Lab./Institute** | **Name** | **Title** | **Institute** |
| | Leader: Roman Pöschl | Directeur de Recherche | CNRS/IN2P3 /IJCLab | Leader: Mitra Ghergherehchi | Prof. | ICT Center |
| | Xin Xia | PhD student | CNRS/IN2P3 /IJCLab | Jong-Seo Chai | Prof. | ICT Center |
| | Jesus Hernandez | Postdoc | CNRS/IN2P3 /IJCLab | | | |
| | | | | | | |
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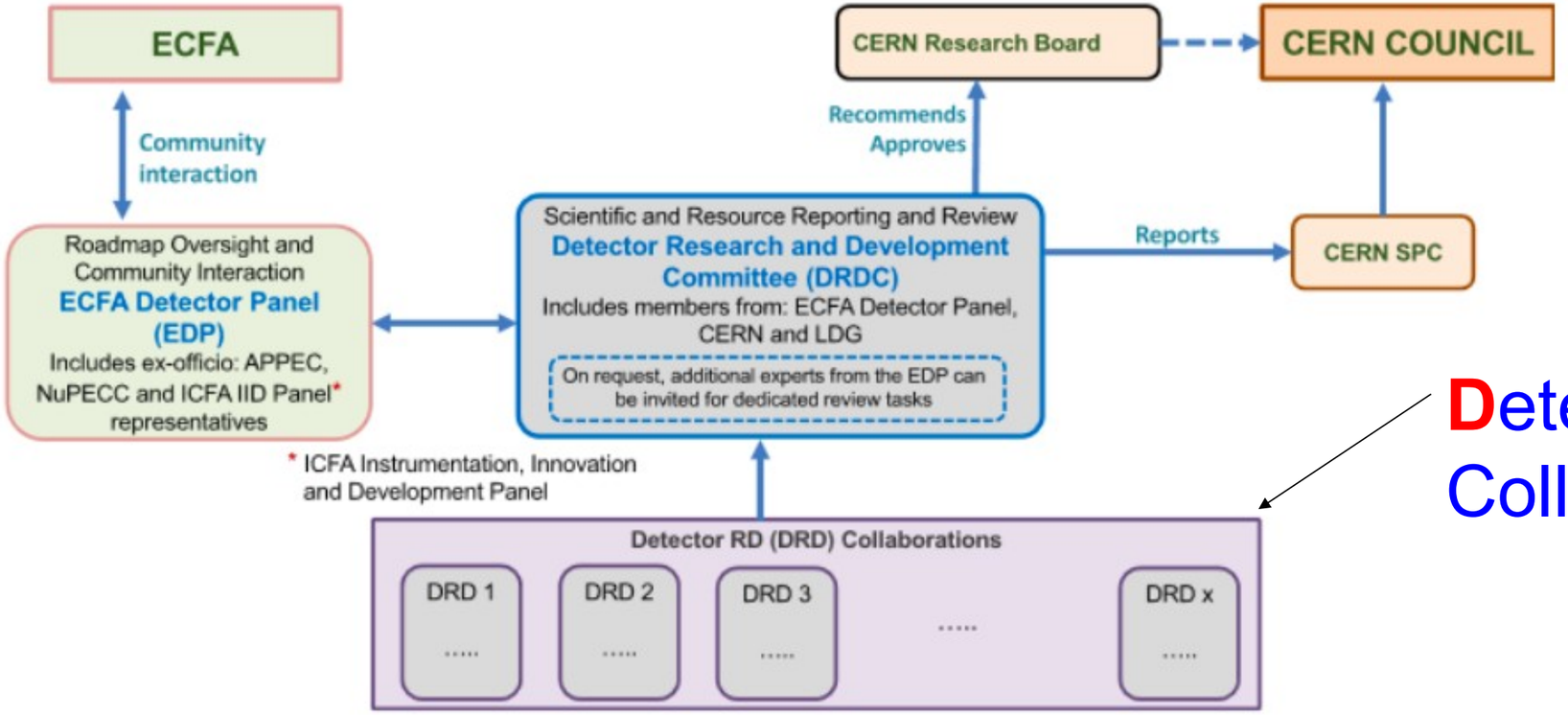
# Future Organisation of Detector R&D (in Europe)




Detector R&D Collaborations

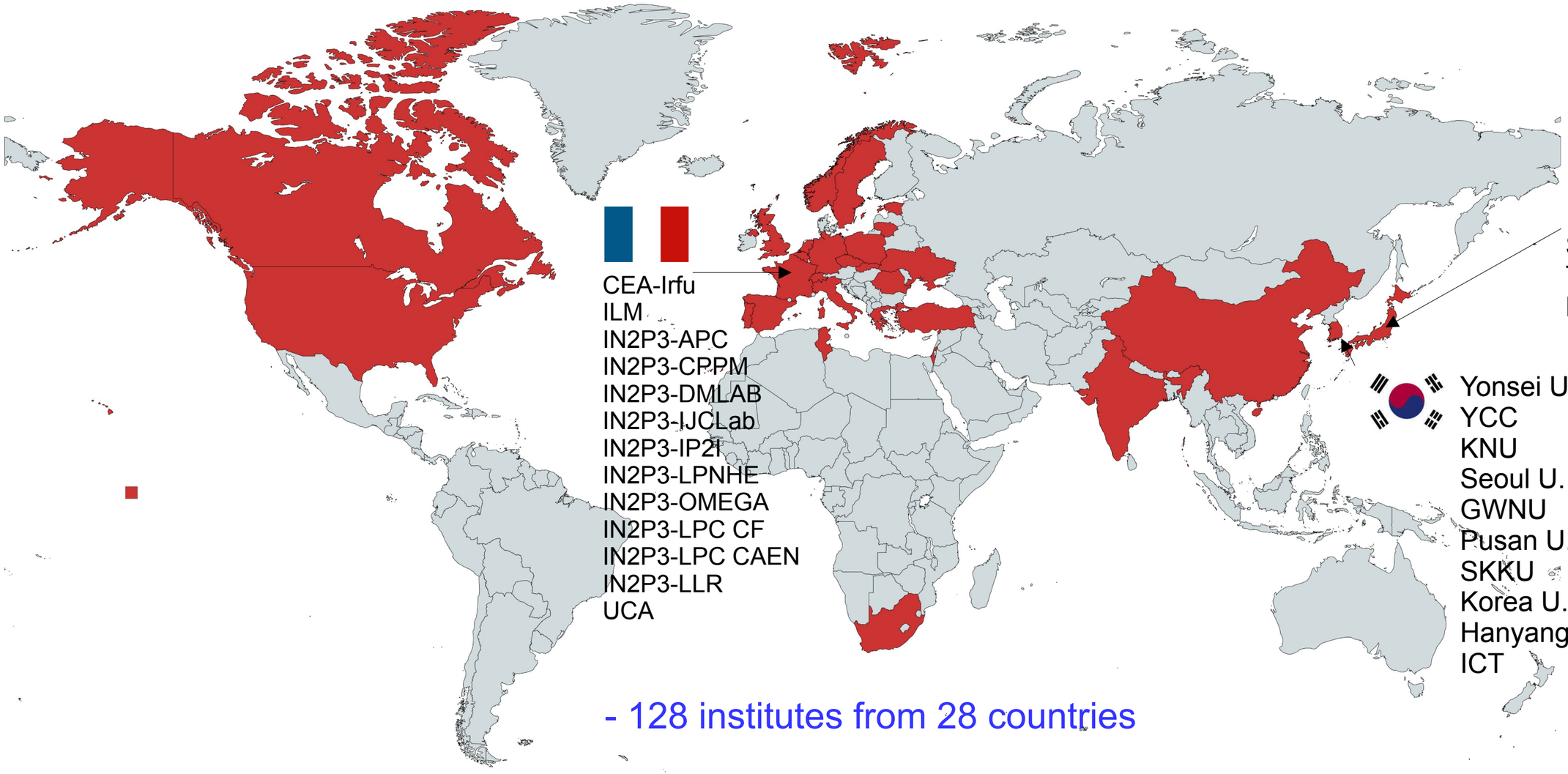
- DRDs are hosted by CERN and are therefore legally CERN collaborations
  - World wide collaborations!
- The progress and the R&D overseen by a DRDC that is assisted by ECFA
  - https://committees.web.cern.ch/drdc
  - Chair Thomas Bergauer of ÖAW/Austria
- The funding will come from national resources (plus eventually supranational projects)

# DRD Calo - Mission

- The DRD-on-Calorimetry develops calorimeter concepts required for future high-energy physics experiments.
- The DRD-on-Calorimetry shares the development of tools and infrastructure of common interest among the different projects.
- Electromagnetic and hadronic calorimeters are developed in a unified approach.
- The DRD-on-Calorimetry carries out test beam campaigns with prototypes of different sizes.
  - The maturity of a concept will have to be demonstrated with full-scale prototypes.
- The Collaboration organises the task sharing between the prototype projects, to benefit from synergies between them and maximise the use of common infrastructures, building blocks and frameworks, as well as simulation code and data samples.
- It also aims at enabling common test beams with electromagnetic and hadronic calorimeters.

# DRD Calo – Where and who

**DRD Calo**




- 128 institutes from 28 countries

# Summary and outlook



- Successful operation of COBs marks a milestone in the French-Korean Collaboration
  - Possible through steady FKPPN support
- New opportunities for collaboration
  - Detector validation using ICT accelerators
  - Visualisation techniques
  - Front end electronics for future HEP Detectors
- FKKPN support would be vital to kick-off these activities
- Work will carried out in frame of DRD Calo Collaboration