# Workpackage 8 - Calorimetry and Particle ID


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# Workpackage 8 – Overview

## Task 8.1. Coordination and Communication (CNRS-IJCLab, INFN-PV)

- Since last Annual Meeting: Katja Chair of Governing Board

## Task 8.2. Towards next generation highly granular calorimeters

- Integration aspects of highly granular calorimeters (DESY, DMLAB, CNRS-IJCLab, CNRS-LLR, CNRS-LPNHE, JGU, CERN, TAU, FZU, IFIC)
- Future Liquid Noble Gas Calorimeters (CERN, CNRS-IJCLab, CUNI)

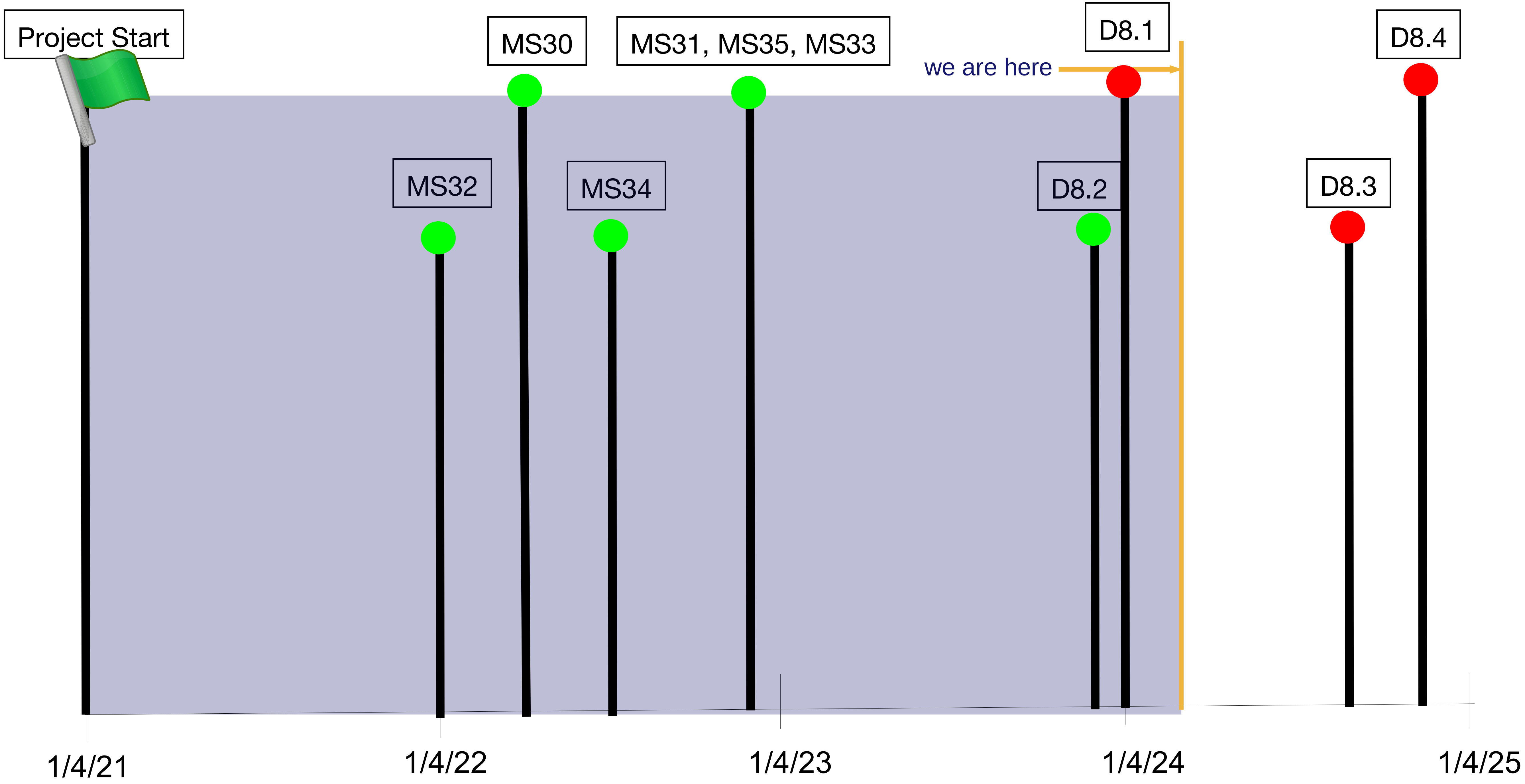
## Task 8.3. Innovative calorimeters with optical readout

- Crystal detectors (CERN, FZU, VU, INFN-PG, INFN-LNF, INFN-TO)
- Large area scintillator detectors (MPP-MPG, DESY, INFN-BO, INFN-LNF, JGU)

## Task 8.4. Innovative solid-state light sensors and highly-granular dual-readout fibre-sampling calorimetry

- Innovative SiPMs and future applications in PID detectors (JSI, INFN-PD, INFN-TO, CERN, FBK, UiB, FZU, FOTON)
- Development of highly-granular dual-readout fibre-sampling calorimeters (INFN-PV, INFN-MI, INFN-PI, INFN-BO, UOS, CAEN)

# WP8 - Timeline



# Summary – WP8 Milestones

| #MS | Description | Task | Due | Type | Lead |
|---|---|---|---|---|---|
| MS30 | Conceptual design and technical specifications of DAQ interfaces for highly granular electromagnetic and hadronic calorimeters | 8.2 | M15 | Report to StCom | DESY |
| MS31 | Design and simulation of LAr readout electrode | 8.2 | M23 | Report to StCom | CUNI |
| MS32 | Test benches for testing detecting materials in picosecond and sub-picosecond domains. | 8.3 | M12 | Specs data sheet | CERN |
| MS33 | Design and test of scintillating tiles or strips with large active area suitable for large area detectors. | 8.3 | M15 → M23 | Operational Testbenches | MPG-MPP |
| MS34 | Definition of SiPM requirements and performance studies with simulations of different use cases. | 8.4 | M18 | Report to StCom | JSI |
| MS35 | Definition of the assembly method and of the ASIC specifications for a dual readout calorimeter. | 8.4 | M23 | Report to StCom | INFN-MI |

# WP8 Deliverables

| #D | Description | Task | LEad | Type | Dissemination | Due |
| --- | --- | --- | --- | --- | --- | --- |
| D8.1 | Demonstrator of a combined read-out system of highly granular electromagnetic and hadronic calorimeters | 8.2 | DESY | DEM | PU | M36 |
| D8.2 | Report on prototypes construction, performance and assessment of industrialisation | 8.3 | CERN | R | PU | M35 |
| D8.3 | Qualification of neutron irradiated SiPMs at different temperatures. | 8.4 | JSI | R | PU | M44 |
| D8.4 | Construction and qualification with beam of 10×10 $cm^2$, 2 m long, prototypes | 8.4 | INFN-MI | DEM | PU | M46 |

- All four deliverables due between M35 (29/2/24) and M46 (31/1/25)
- Will have to shift D8.1 by 6 months
  - Details see below

# WP8 – Meetings and Communication

- Regular Taskleader Meetings
  - Among others: Reminder on publications and orientation to publication committee
    - Expect that number of publications will increase in coming months
- WP8 Face-to-Face Meeting 2024 18/1/24
  - https://indico.cern.ch/event/1344030/
- Mailing lists
  - AIDAinnova-WP8-Taskleaders@cern.ch contains all task leaders
  - AIDAinnova-WP8-Institutes@cern.ch contains one contact per group/institute
  - AIDAinnova-WP8-General@cern.ch with self-subscription, open for everyone who is interested

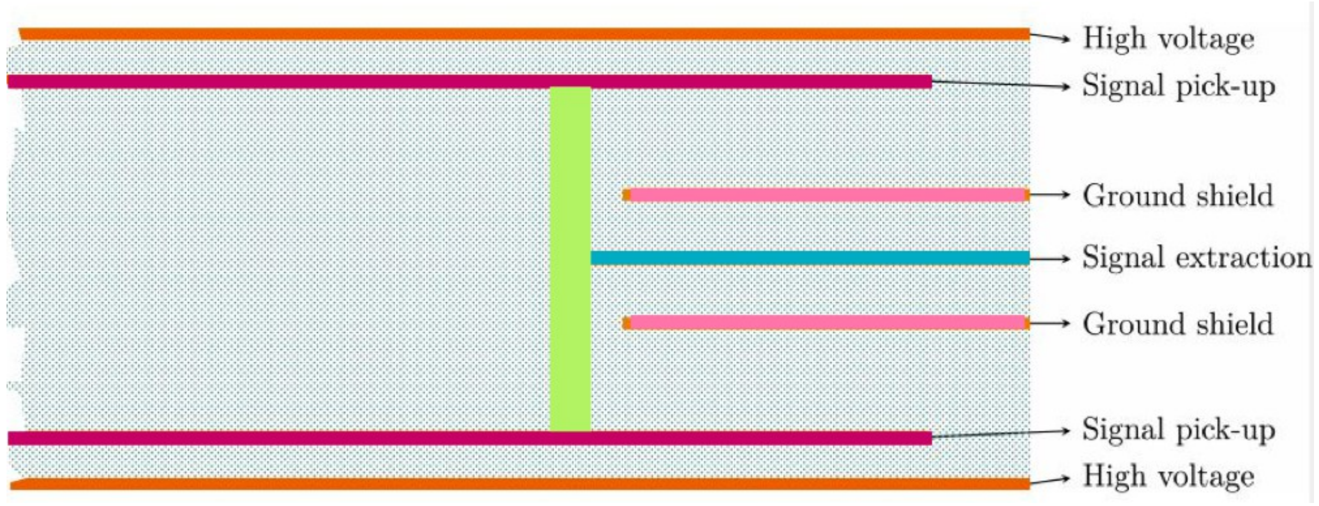
# WP8 – Reasoning for delay of D8.1

- D8.1 :
  - Demonstrator of a combined read-out system of highly granular electromagnetic and hadronic calorimeters” **was due in M36 (March, 2024)**
    - The development of common DAQ interfaces implies a knowledge/technological transfer from the SiW ECAL to the AHCAL
    - The process is started, but the board design, testing and operation are delayed
  - A technical issue prevents the delivery in due time:
    - **The SiW-ECAL wafer-PCB delamination problem needs to be solved before any further test can be made; it was raised as the highest priority on the path to the production of new ASUs.**
      - Details in backup
  - The delay of the deliverable by six months to M42 (September, 2024) allows for producing a few boards for a proof-of-principle test of the SiW-ECAL, which would then form the basis of the transfer to the AHCAL. A combined test of a couple of layers SiW-ECAL+AHCAL at DESY is foreseen for the 2nd half of 2024.
- Despite the delay there is still sizeable progress in the task (see backup)

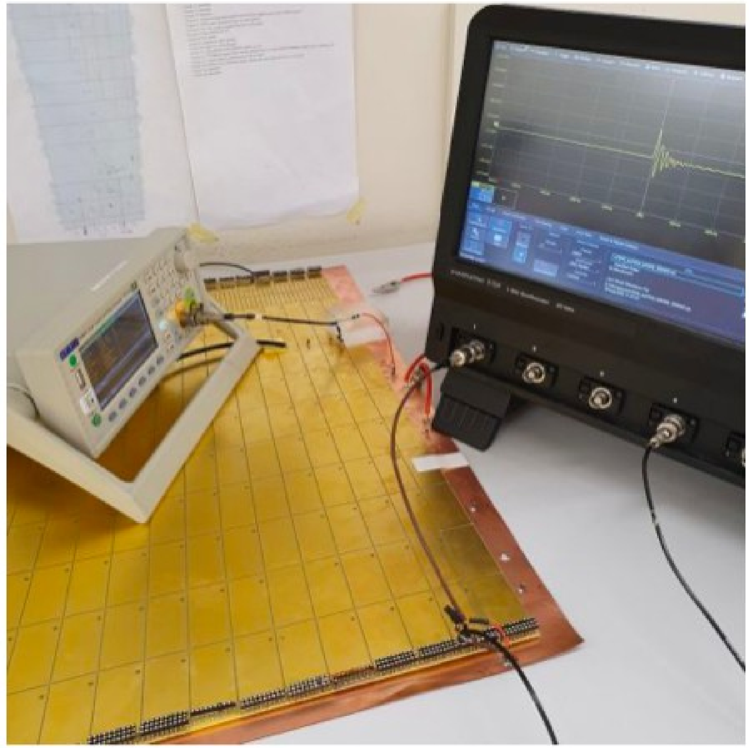
# WP8.2 - Design and simulation of LAr readout electrode

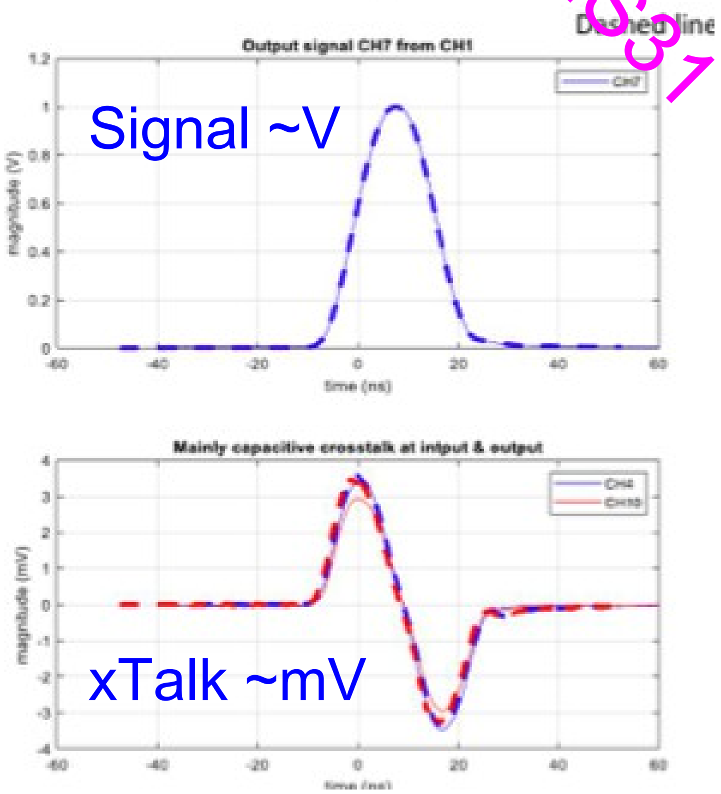
MS31

- Development of a multilayer PCB
  - HV layer on both sides
  - Readout layer on both sides
  - Connected to signal trace




- One signal trace is economical solution to reduce signal traces
- Pick-up of signal from both sides increases S/N





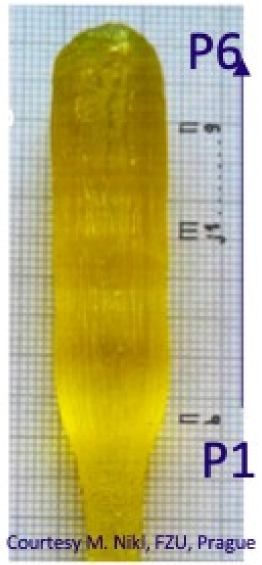

## Challenges:

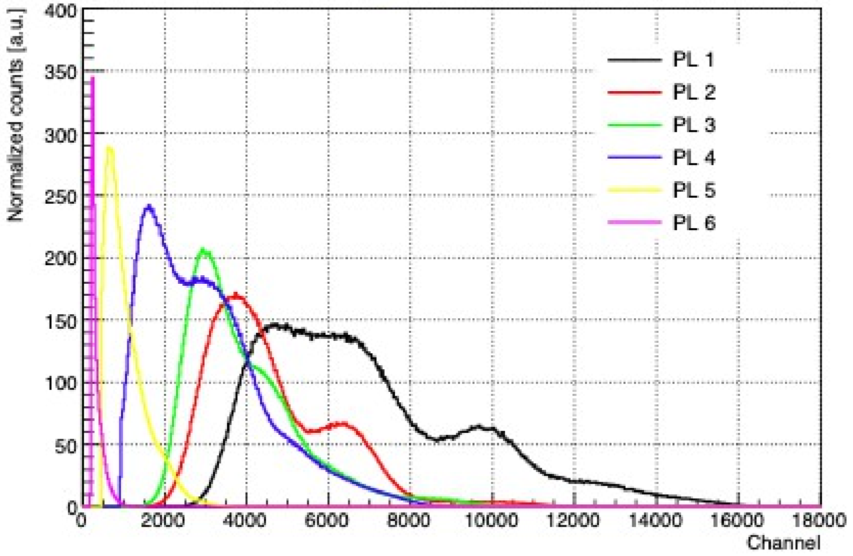
- Control number of signal traces
  - => Xtalk? Seems to be well under control
- Big number of capacitances => Noise
  - Goal is 300 keV noise for 200 pF cell (S/N > 5)
  - FCC-ee allows for higher integration times
  - Cold electronics?

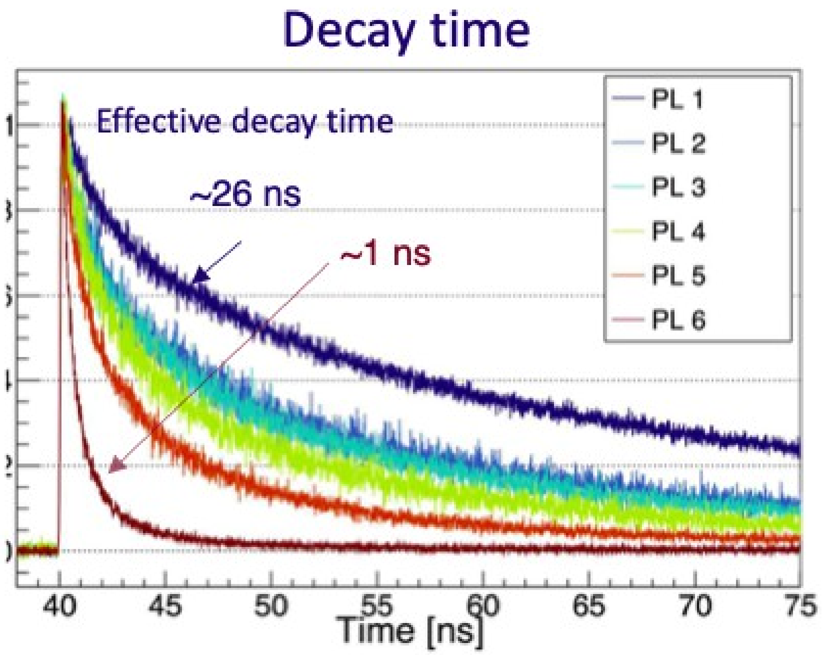
GAGG:Ce Xtal doped with Ce/Mg

D8.2

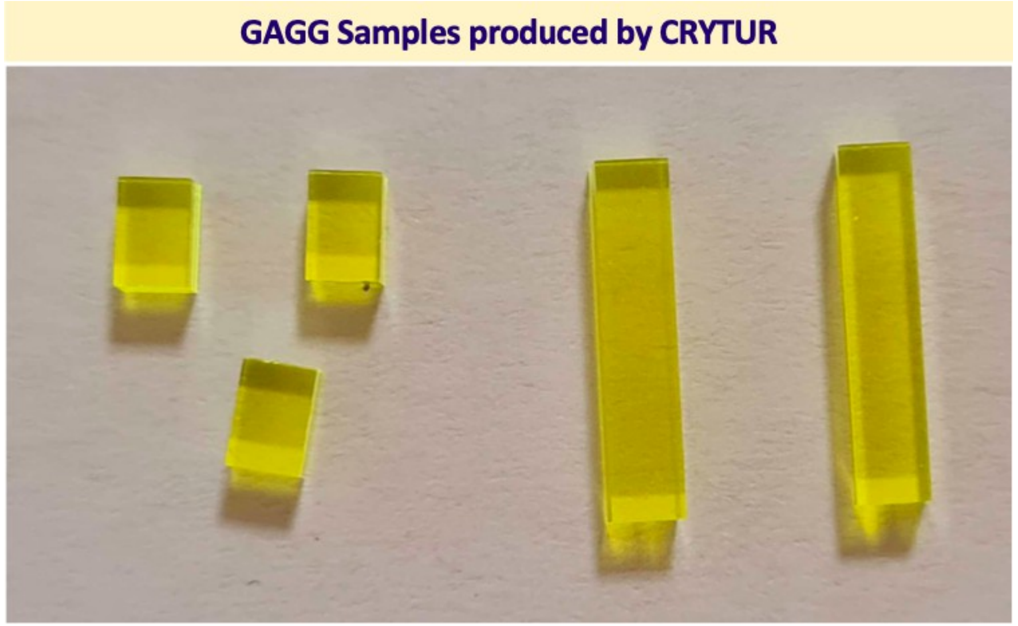
Increased concentration




Decrease of decay time with increased doping
(lower light output has
no influence on time resolution)




**=> technology transfer**

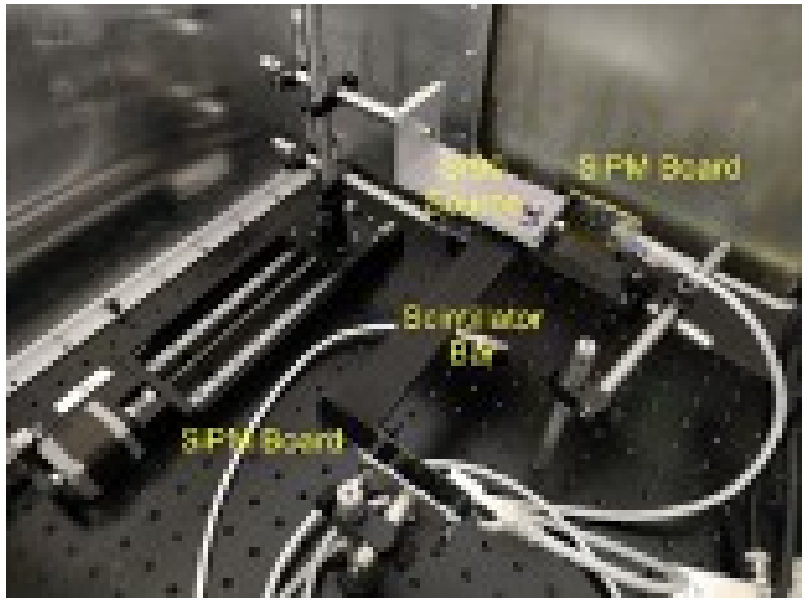
Industrial Czochralski growth in CRYTUR was adapted
=> able to grow first ingot: Ø 25mm, first task was to obtain HOMOGENEOUS COMPOSITION AND CHARACTERISTICS within the crystal body

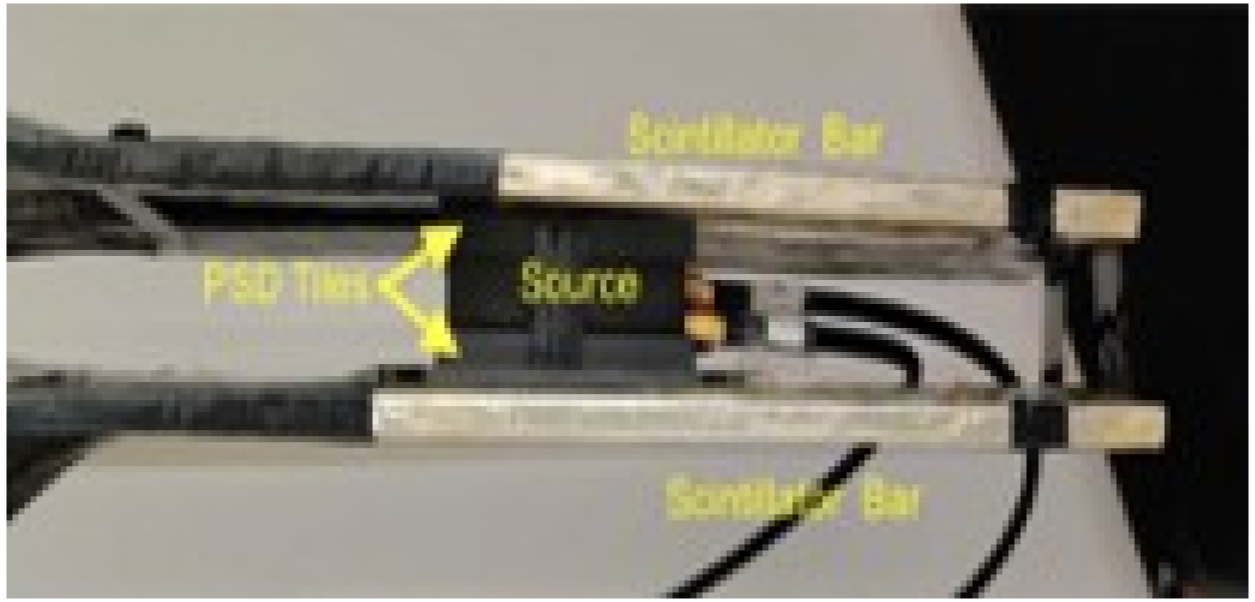
# WP8 – Task 8.3.2 – Large area scintillators

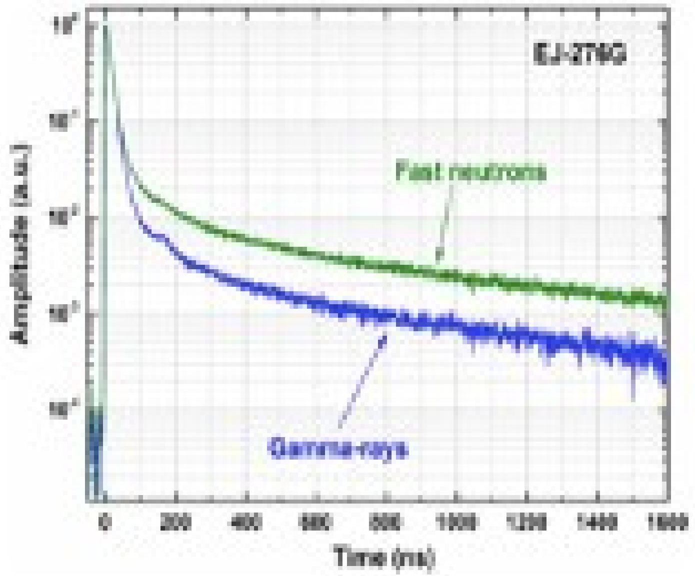
*MPI-MPP: Long scintillator bars*

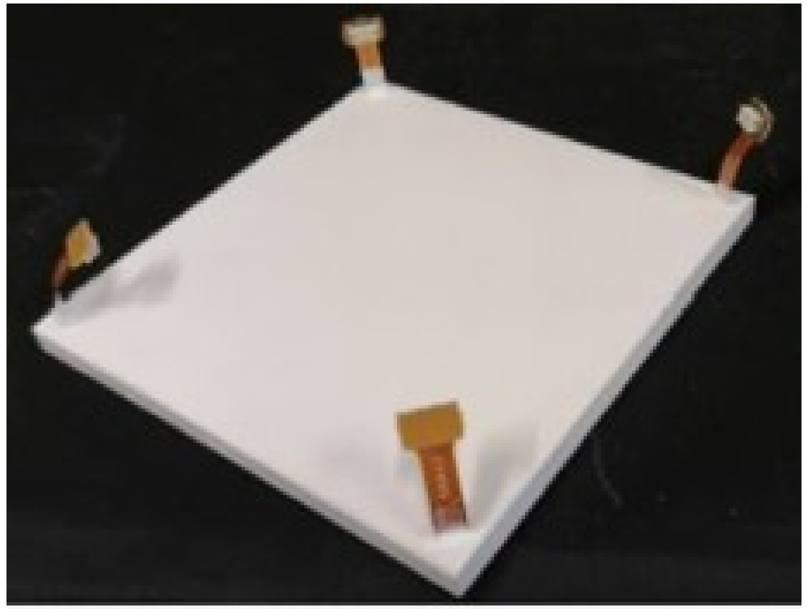
*JGU: Neutron gamma discrimination using an AmBe source*

MS33



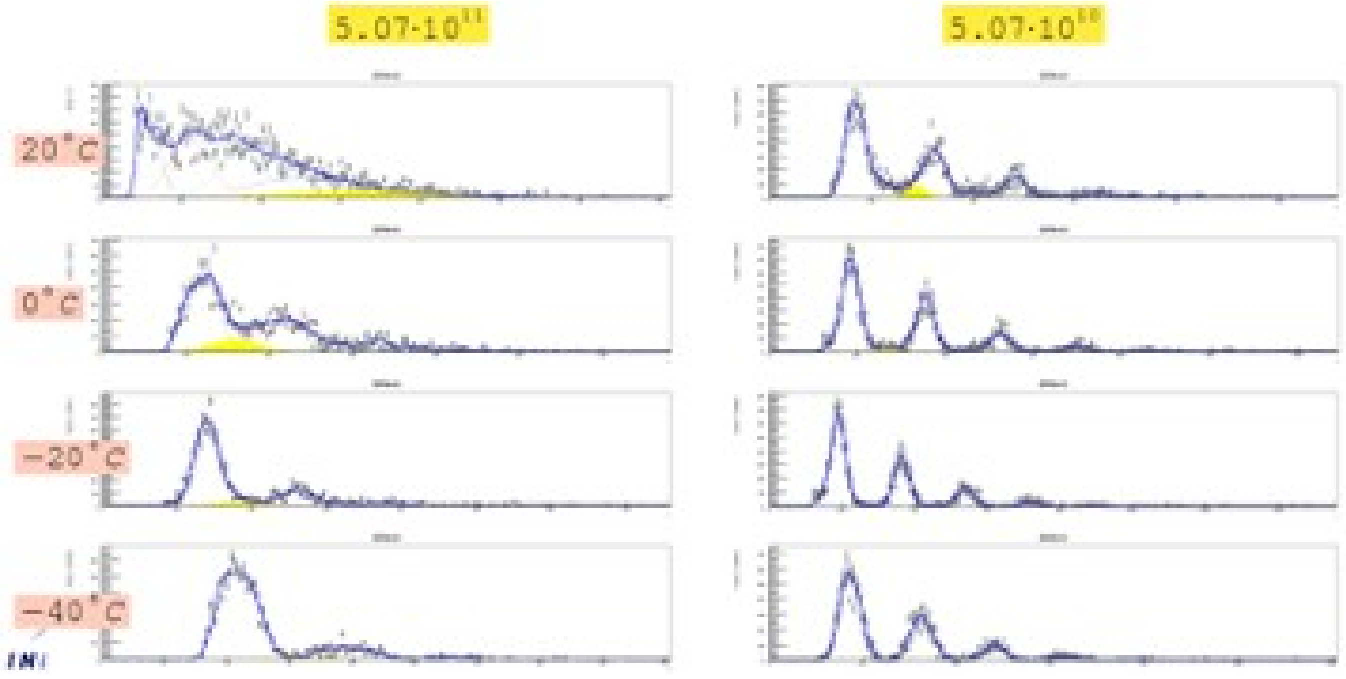



*Left: Large (15x15 cm²) tile*
*Right: Wall constructed from 15 large tiles*

# WP8 – Task 8.4.1 – SiPM and future applications in PID Detectors

MS34

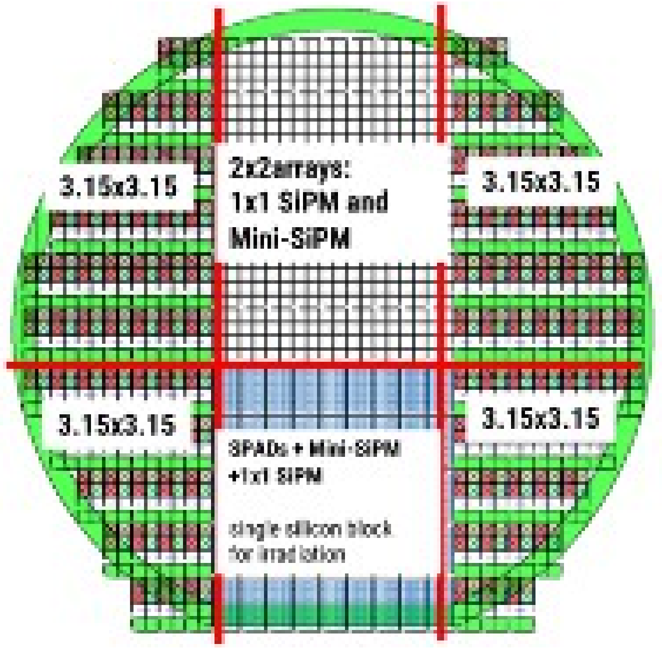
Standardised protocols
for SiPM characterisation
Toward "AIDAinnova Standard"




*Hamamatsu SiPMs irradiated at different doses and at different operating temperatures*

Developments with (semi) industrial partners

FBK (I)

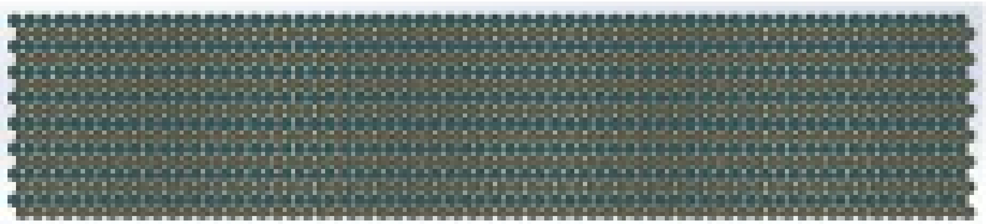


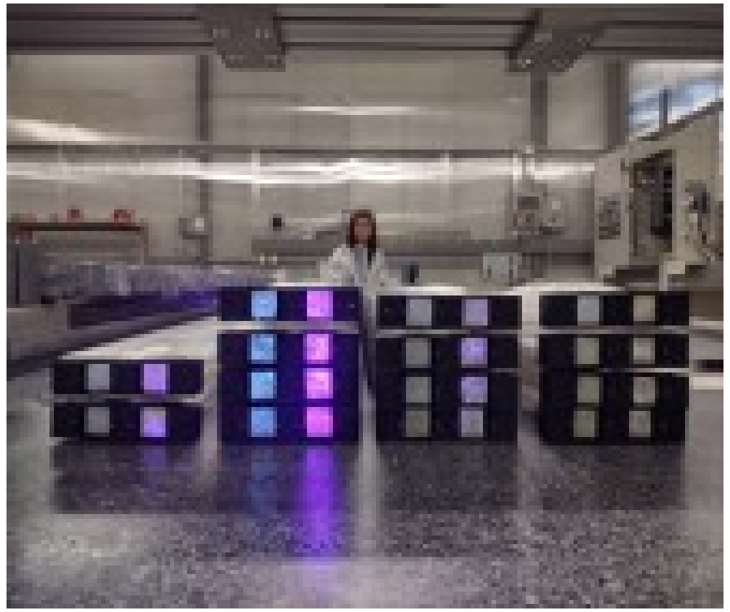

*AIDAinnova funded production FBK NUV-HD SiPMs wafer composition*

FOTON (CZ)

*ADAPOWER 4100, adaptive power supply for SiPMs*

# WP8 – Task 8.4.2 – highly granular dual-readout fibre-sampling calorimeter



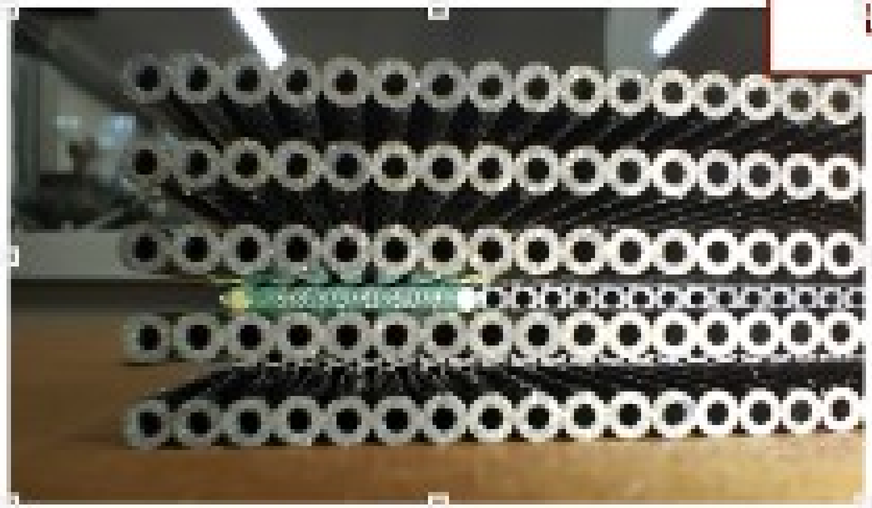


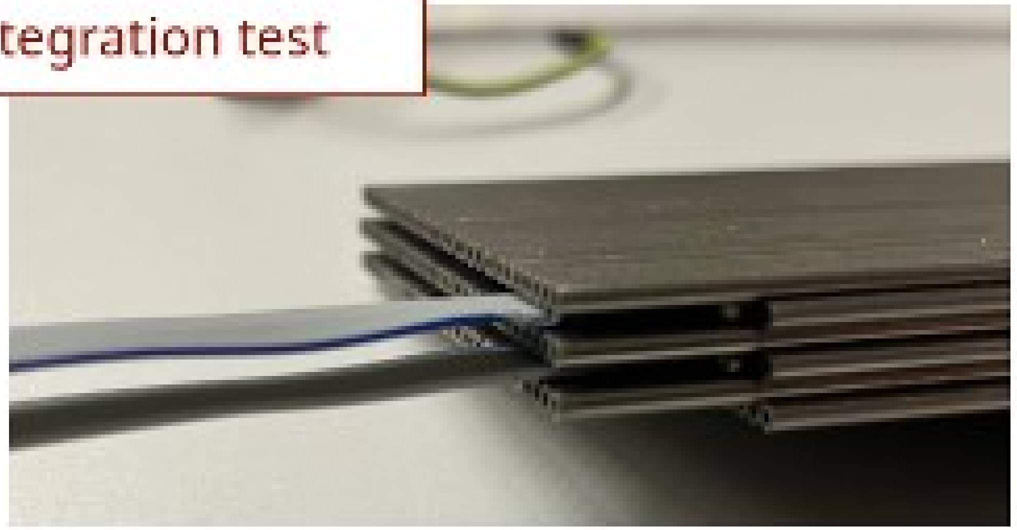
HiDRa minimodule (left)

assembled minimodules (right)

Mechanical test for mini-frontend board installation

Board-integration test





Need for compactness triggered R&D on digital SiPM (see backup)

# WP8 – Summary and outlook

- WP8 on track
  - All milestones have been achieved
  - First deliverable achieved
  - One deliverable delayed due to unforeseen technical problems
    - Solution will lead to new competences!
  - Two more deliverables between now and end of project on March 31st 2025

- Time to harvest the results --> Publications !!!!
  - 13 publications recorded in Zenodo portal
  - ... more to come

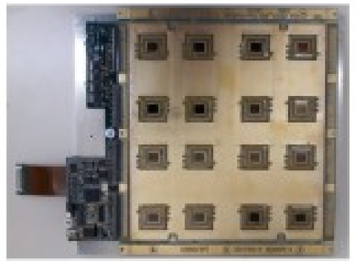
- Education and outreach
  - Material developed within AIDAinnova (and its predecessor AIDA-2020)
  - Used at instrumentation school
  - See OnTrack article in backup

# Backup

# Task 8.2.1 – SiW-ECal Beam Test at DESY & CERN - Lessons

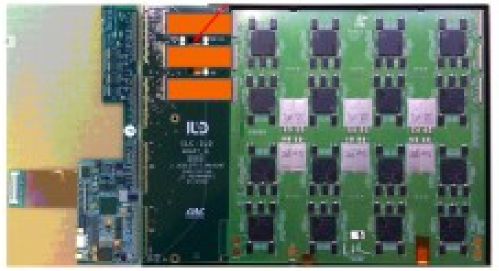
**FEV10, 11, 12**

- BGA packaging
- Incremental modifications
- From v10 -> v12
- Main "Working horses" since 2014



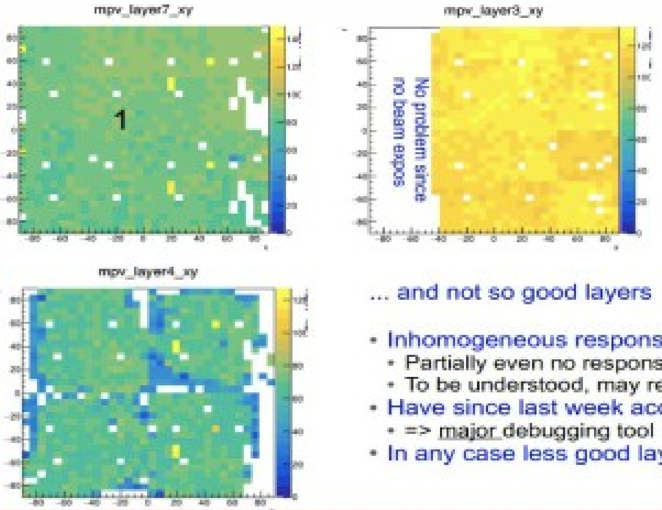
**FEV-COB**

- Chip-On-Board : ASICs wirebonded in cavities
  - Thinner than FEV with BGA
- Based on FEV11
  - External connectivity compatible



**FEV13**

- BGA packaging
  - Improved routing
  - Local power storage
  - Different external connectivity

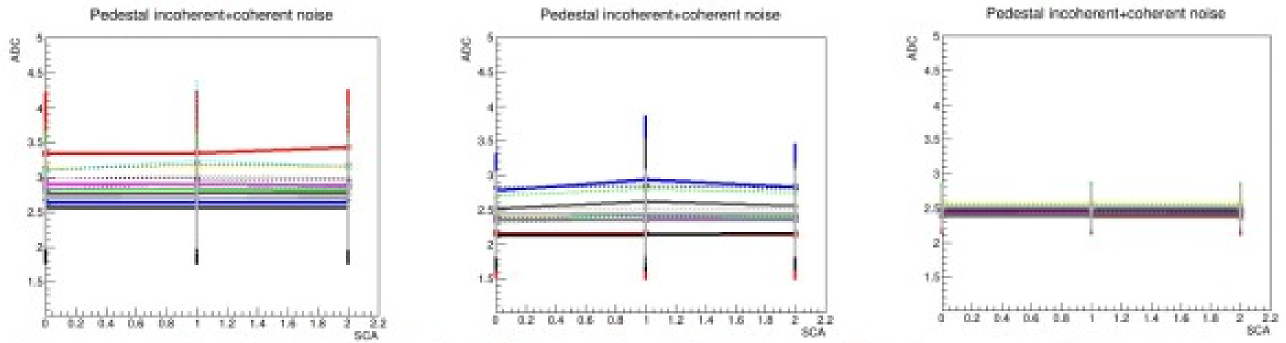



- We have good layers ...
  - Homogeneous response to MIPs over layer surface
  - Here white cells are masked cells due to PCB routing
    - Understood and will be corrected

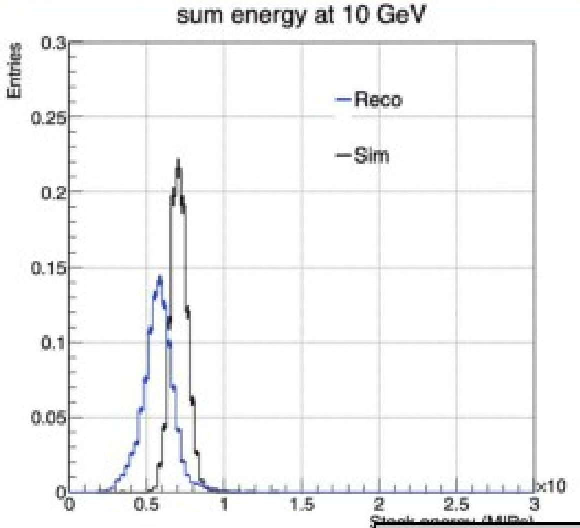
... and not so good layers

- Inhomogeneous response to MIPs
  - Partially even no response at all, in particular at the wafer boundaries
  - To be understood, may require dedicated aging studies
- Have since last week access to the different stages of the ASICs
  - => major debugging tool
- In any case less good layers will be replaced in coming months

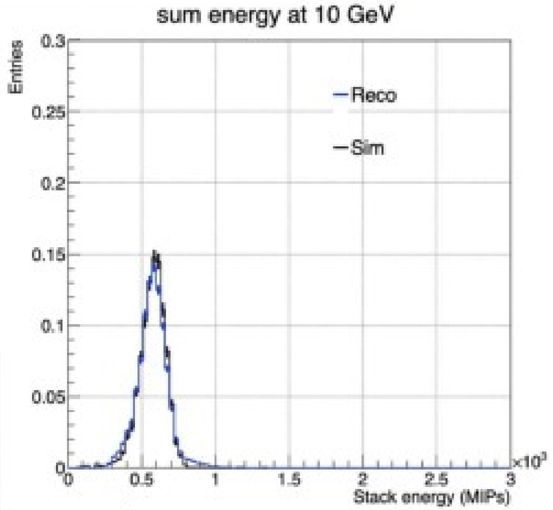
## Pedestal widths, 1st memory cells, per asic



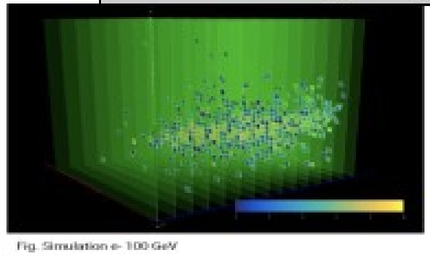

- (Average ± Standard Deviation) of Sigmas for all 64 channels in the same chip
- Latest PCBs, with optimized routing of power distribution shows better behavior
- Slightly larger spread on COB due to a near lack of decoupling capacitors

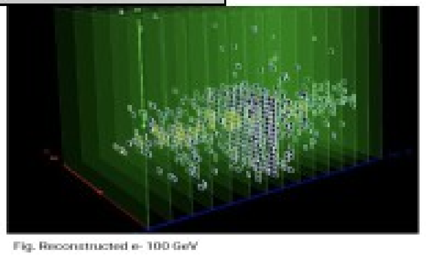



Masking Beam profiling




Yuichi Okugawa (PhD in Feb.





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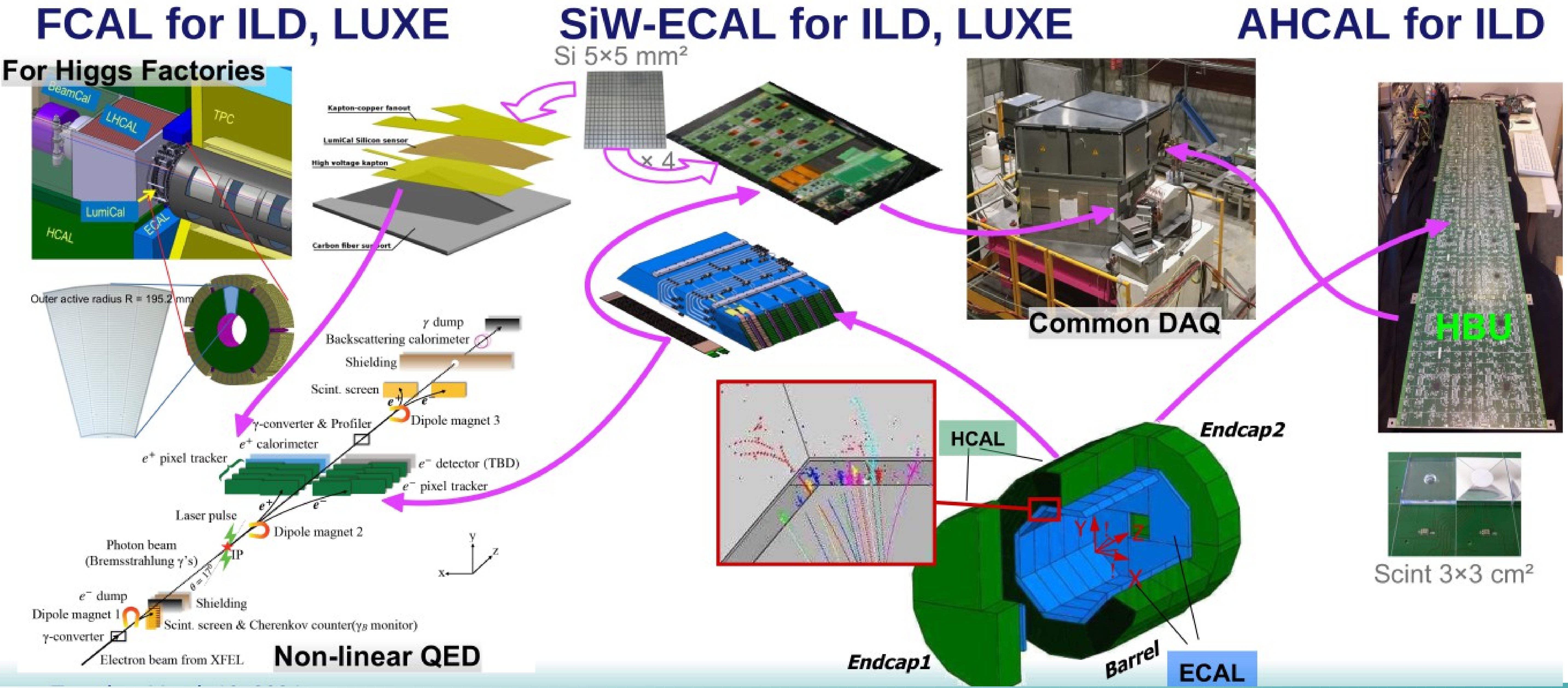
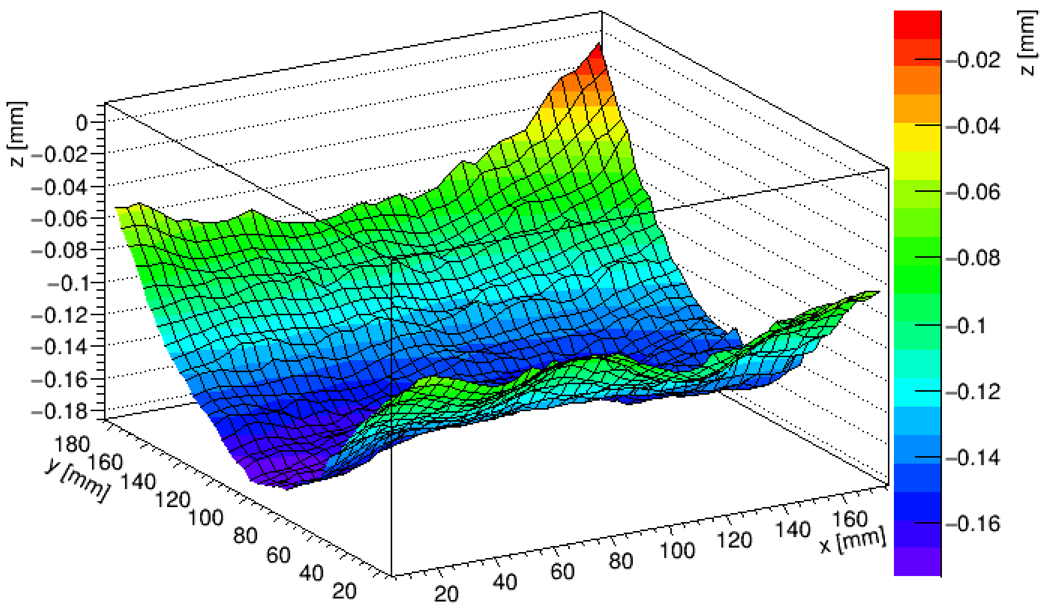
# A map to H.G.C. prototypes



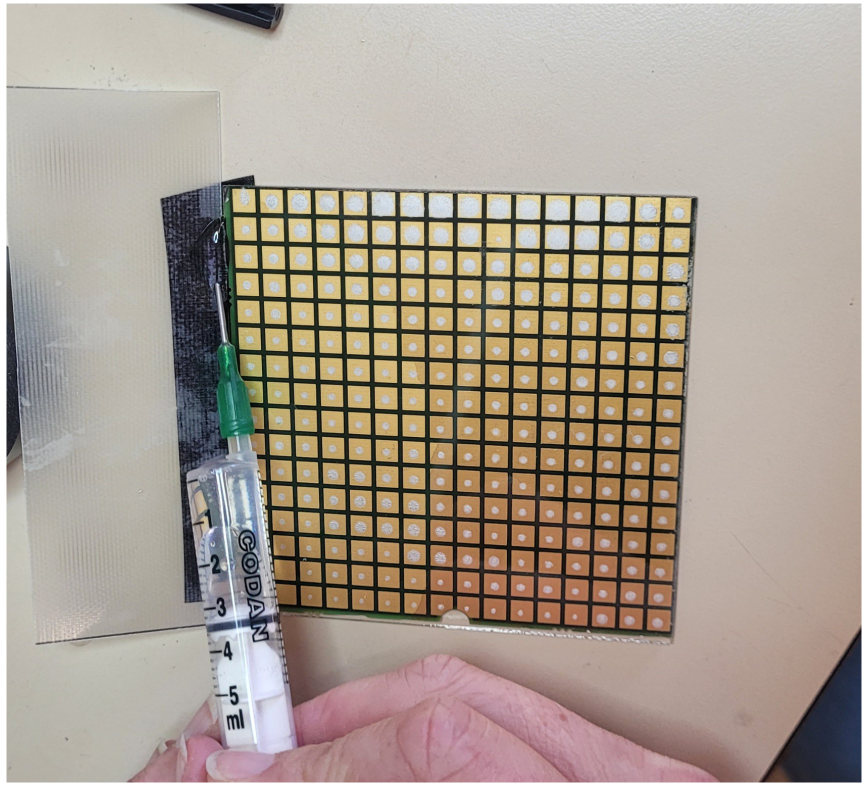
# Task 8.2 – Sensor delamination, systematic studies

## Control of PCB Deformation



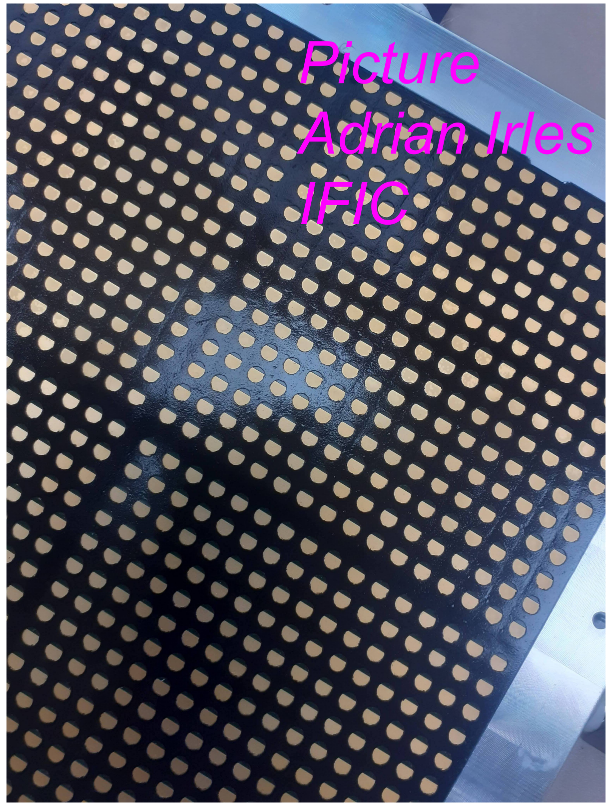

- We suspect mechanical deformation of PCB to be at the origin of the delamination
- => Control PCB shape at different steps of manipulation (e.g. After heating during cabling)

## "Underfill"




- Low viscosity glue flows around glue dots
- Development in close contact with Epotek
- Seems to work but requires second curing step
- First mechanical tests encouraging

## "Double sided tape"




- Underfill "replaced" by double-sided tape
  - Holes with laser
- Encouraging first experience
- Close consultation with 3M

# Task 8.2 – Sensors for LUXE

**90 CALICE sensors received mid November**

**A probe card was designed and received in November from CERN** (paid by TAU and IFIC).

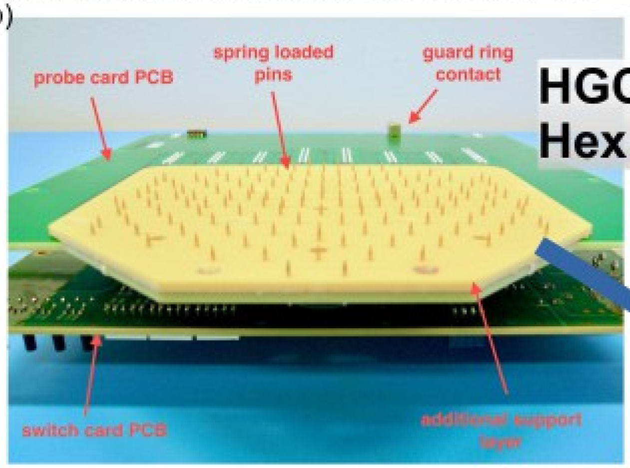
**December :**

- **modification of the probe station mechanics and installation of the probe card**

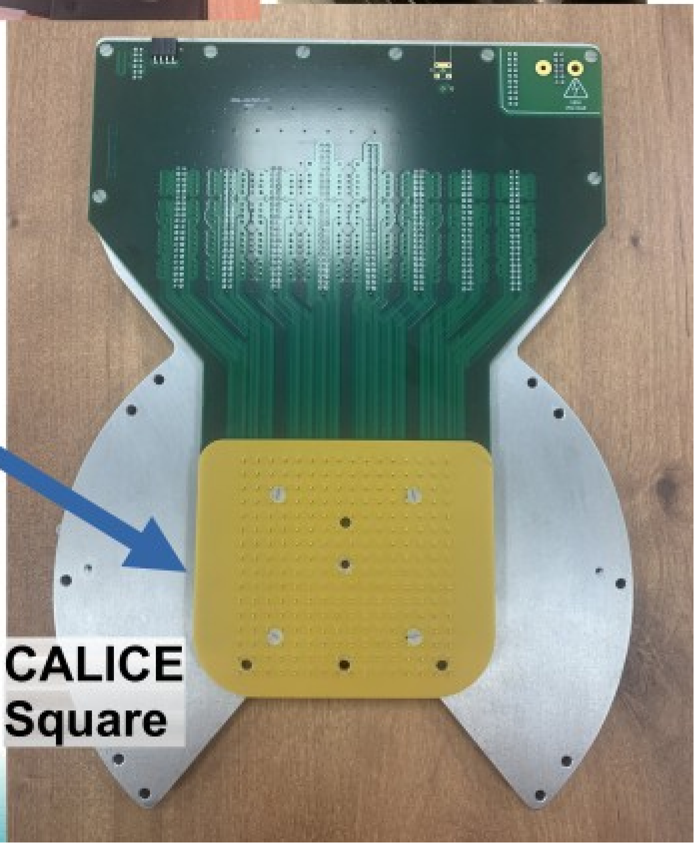
**January :**

- **we checked the LUT of the pins (pins number m DAQ channel)**
- **Started to test first sensors.**
- **Taking time to define the test procedure**

System needed for electrical sensor characterisation in prototyping phase and for quality control in mass production (IV, CV, $V_{BD}$, $V_{FD}$, $C_{FD}$)



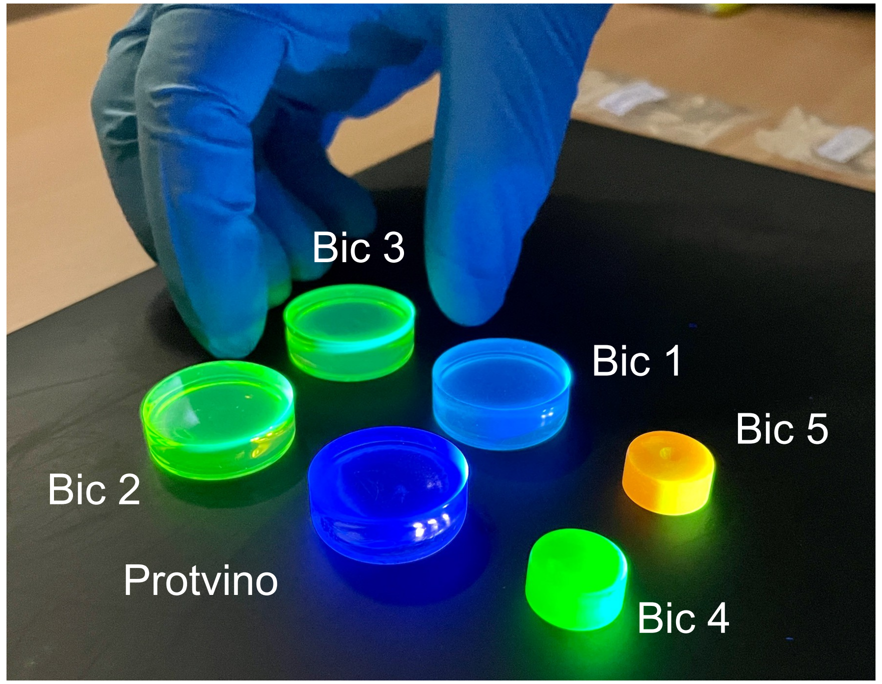

HGCAL Hex

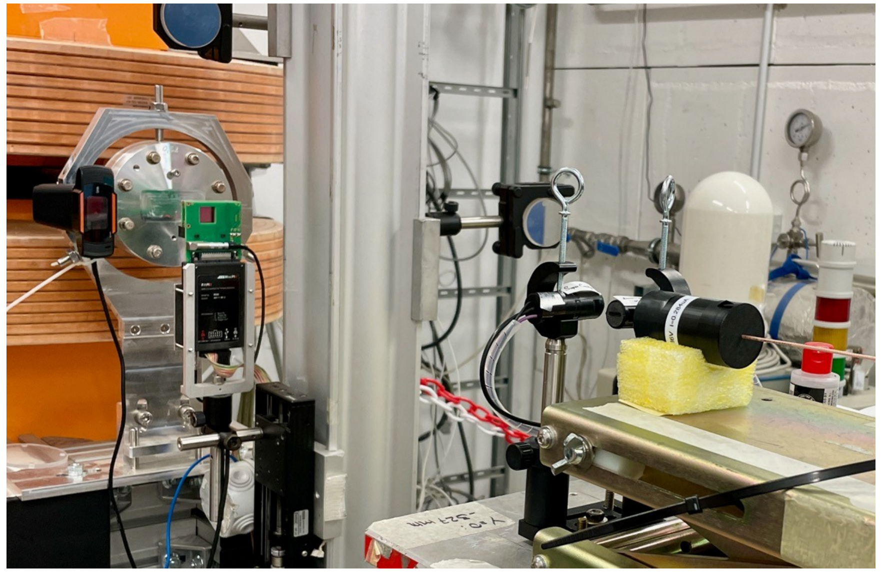


CALICE Square

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 |
| 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 |
| 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 | 221 | 222 | 223 | 224 |
| 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 |
| 177 | 178 | 179 | 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 |
| 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 |
| 145 | 146 | 147 | 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 |
| 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 | 144 |
| 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 |
| 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 |
| 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 |
| 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 |
| 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |

# WP8 – Task 8.3.1
# Crystal Detectors



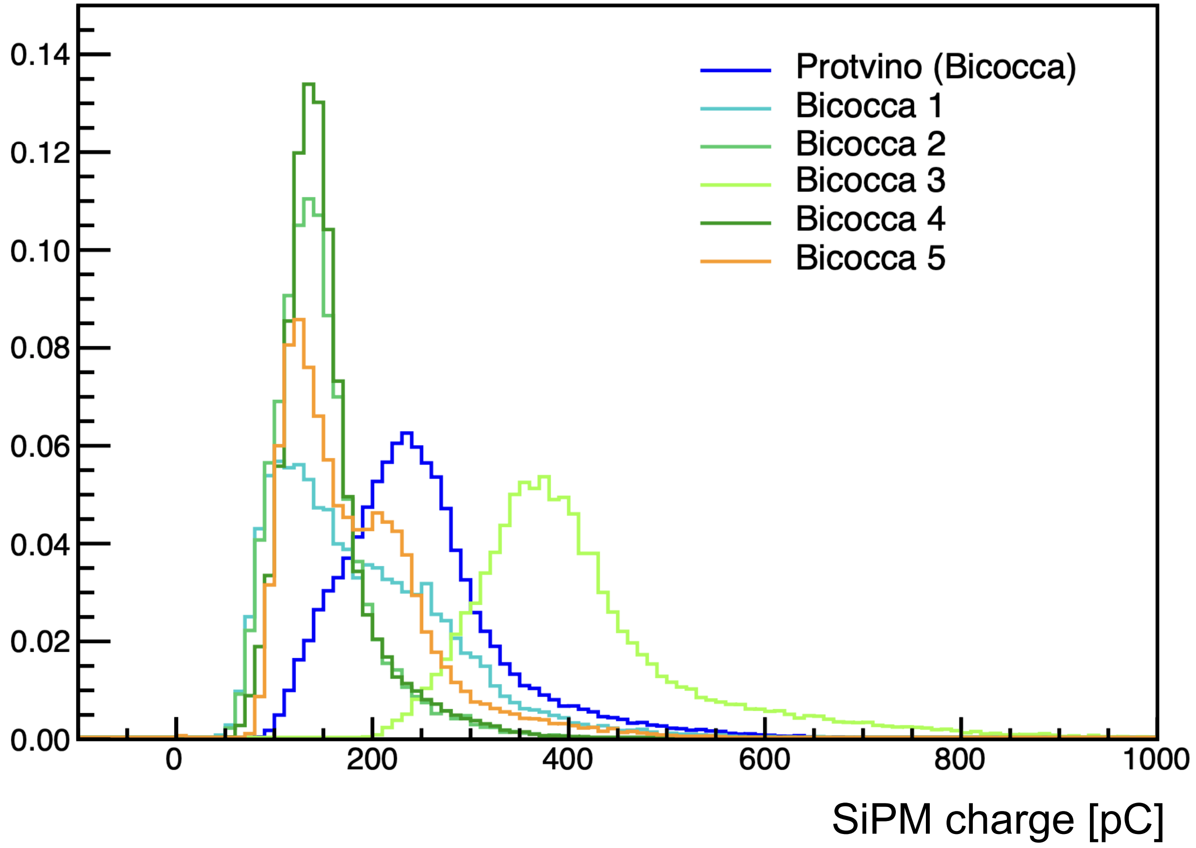
NanoCal

TB with nanocomposite scintillators
→ fast & rad-hard

Tests with mip and $e^-$
@ CERN PS and Frascati BTF

- Protvino, Bic 1-3: custom-produced conventional organic scint.s
- Bic 4-5: nanocomposite scint.s

Normalised charge spectra
Single 450 MeV $e^-$ events




- Reference sample: 1.5% PTP + 0.04% POPOP in PVT (“Protvino”)
- Bicocca 4, 5: CsPbBr3:Yb perovskites in PVT have ~50% light yield of ref. sample

**First nanocomposites with good mip response!**

- Bicocca 3: Coumarin-6 (green) scintillator with ~160% light yield of ref. sample

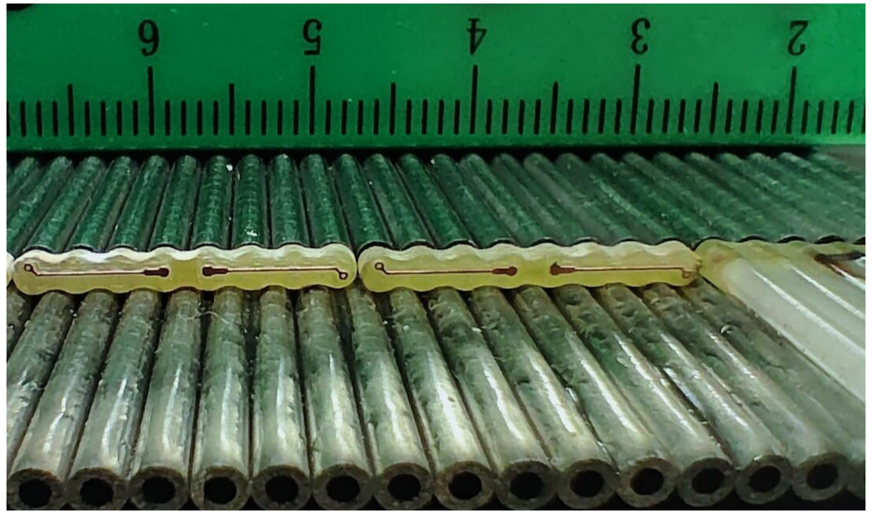
Many new samples to be tested in next BTF run

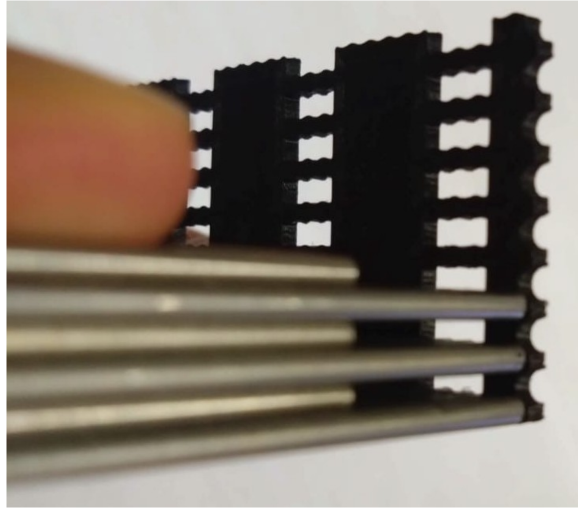
# WP8 – Task 8.4.2
# Highly granular dual-readout calorimeter

- Started series production ...
- 18 MiniModules (MMs) completed

  ~5-10% rejection for both sci-fibres and capillary tubes
- Estimated production rate: ~ 2 MMs / week

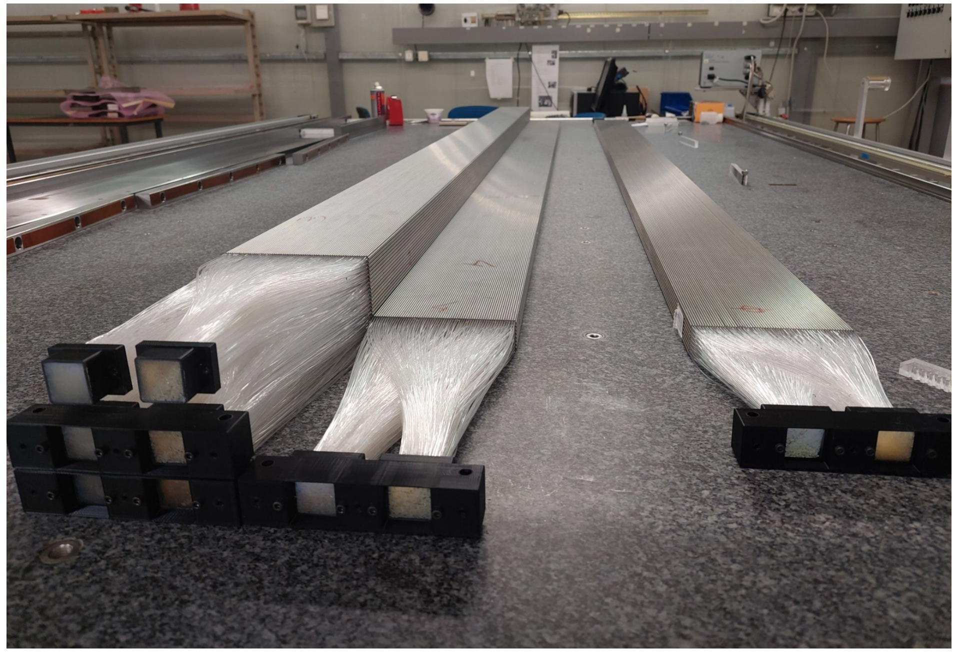
•SiPM readout: Integration tests w/ dummy components:

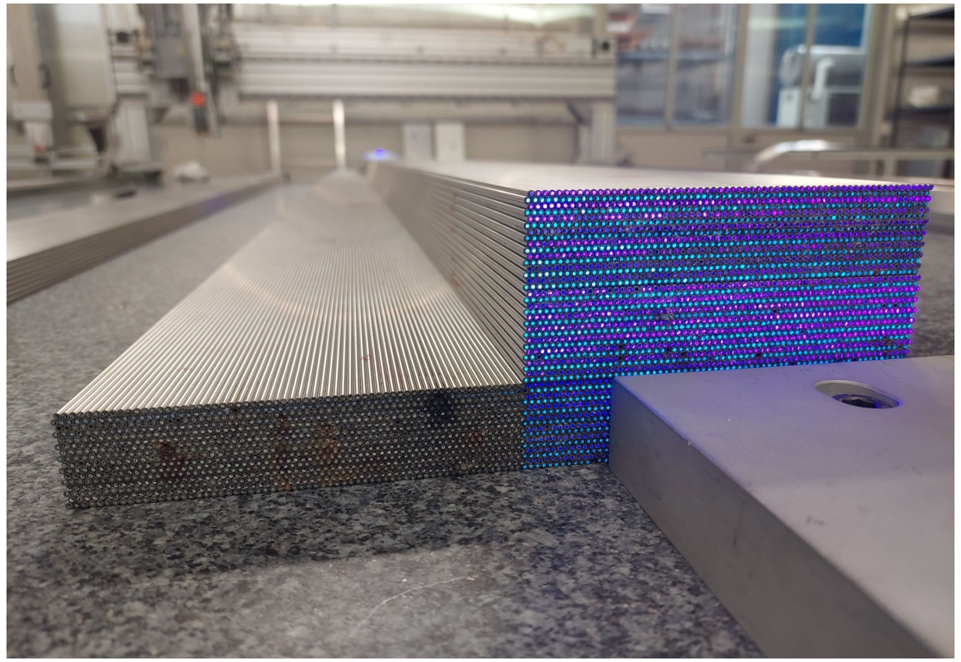




- Waiting for (hopefully) final pieces

- Aiming at beam test of few modules w/ PMT readout in 2024





# Highly granular dual-readout calorimeter

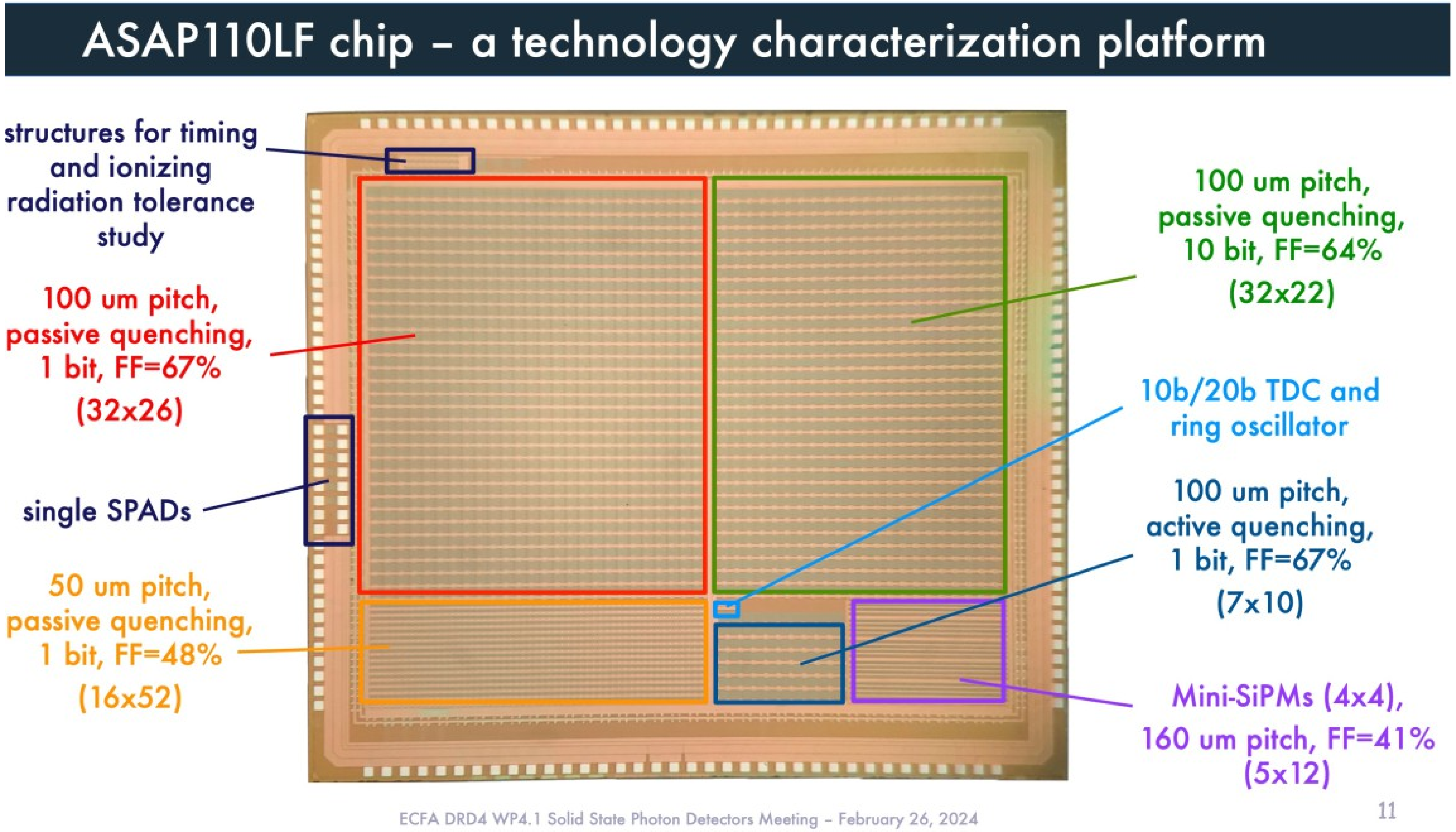
New:

R&D on digital-SiPMs (SPAD arrays in 110 nm CMOS technology)

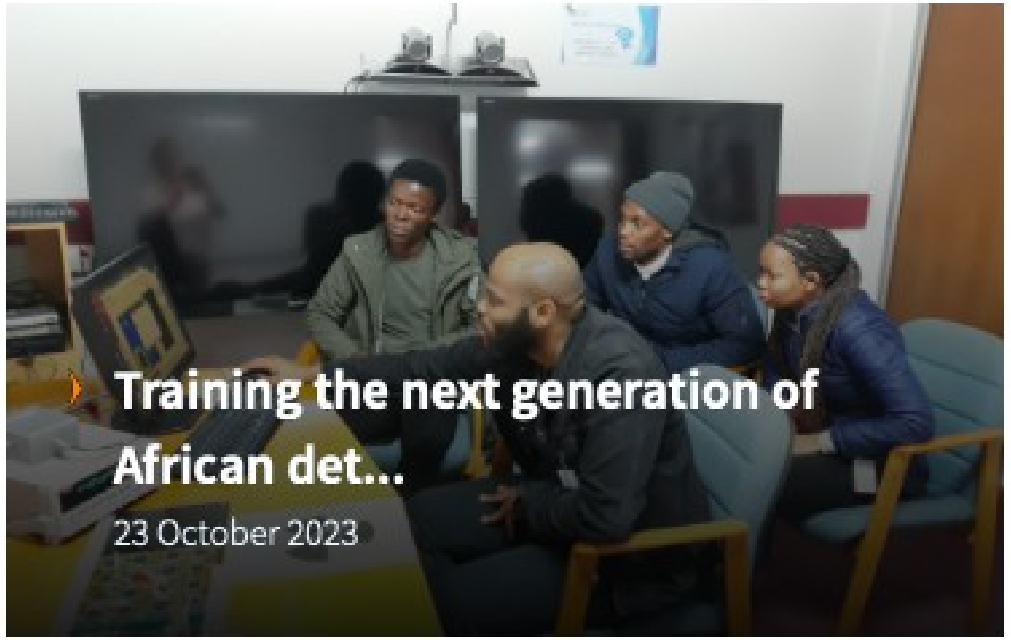
→ FBK project

→ Explore both fully digital & mixed analog+digital approach

→ Develop demonstrator chip
8 × 1 $mm^2$ SiPMs



# WP8 – On Track Article




## Training the next generation of African detector students

**At the end of August, AIDAinnova detector scientists travelled to South Africa to organise an Instrumentation School.**

By Antoine Le Gall (CERN)

The next generation of African detector scientists is eager to learn. Last August, just before the TIPP conference, the Instrumentation School in Particle, Nuclear and Medical Physics took place at iThemba LABS in the Western Cape, in South Africa.

Over the course of one week, 25 MSc and PhD students coming from many different African countries – South Africa, Cameroon, Botswana, Egypt, etc. – took part in a series of lectures about particle detectors. Some of the students had already worked on detector experiments, at ATLAS and ALICE for instance, and were happy to learn about other types of detectors.

The school was punctuated by five sessions with hands-on experiments led by international instructors. "The students had the opportunity to cut their teeth on different detectors - silicon pixel ones, micro-pattern gas ones, cloud chambers, calorimeters, etc. –, operate their many parameters – calibration, signal – while using the same software and tools that we are using for real research", explain Roman Poeschl from IJCLab. "This hands-on experience will be scaled up with real experiments".

The school is sponsored by CERN, Germany's DESY, France's IJCLab and South Africa's NRF. The first three labs all play a major role in AIDAinnova. "I am happy that we could use for the school hardware developed in the frame of AIDAinnova's predecessor AIDA2020.", adds Roman.

The positive feedback is testimonial to the importance to tie links with African institutes, some of which are already or are to become members of several experiments.

**Link**

**Current Issue**
On

**Newsletter Issue**
October 2023

- Article realised with Antoine Le Gall
- Encouragement to try to get more on track articles

# Workpackage 8 - Beneficiaries and Associated Partners

**Beneficiaries:**

CAEN (Industry)
CERN
CNRS-IJCLab, CNRS-LLR, CNRS-LPNHE
CUNI
DESY
FBK (“Interface to industry”)
FZU
INFN-BO, INFN-LNF, INFN-PD, INFN-PG, INFN-PV, INFN-TO
JSI
JGU
MPP-MPG
TAU
University of Bergen
University of Sussex
Vilnius University

**Associated Partners:**

FOTON (Industry)
GLASS2POWER (Industry)
Minsk
HZDR
Crytur