Workpackage 8 - Calorimetry and Particle ID Detectors

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INFN PAVIA Istituto Nazionale di Fisica Nucleare Sezione di Pavia

AIDAinnova 3rd Annual Meeting – March 21st 2024

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WP8 – Overview

Task 8.1. Coordination and Communication

Task 8.2. Towards next generation highly granular calorimeters

- Integration aspects of highly granular calorimeters
- Future liquid noble gas calorimeters

Task 8.3. Innovative calorimeters with optical readout

- Crystal detectors
- Large-area scintillator detectors

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

- Innovative SiPMs and future applications in PID detectors
- Development of highly granular dual-readout fibre-sampling calorimeters

WP8 - Beneficiaries and Associated Partners

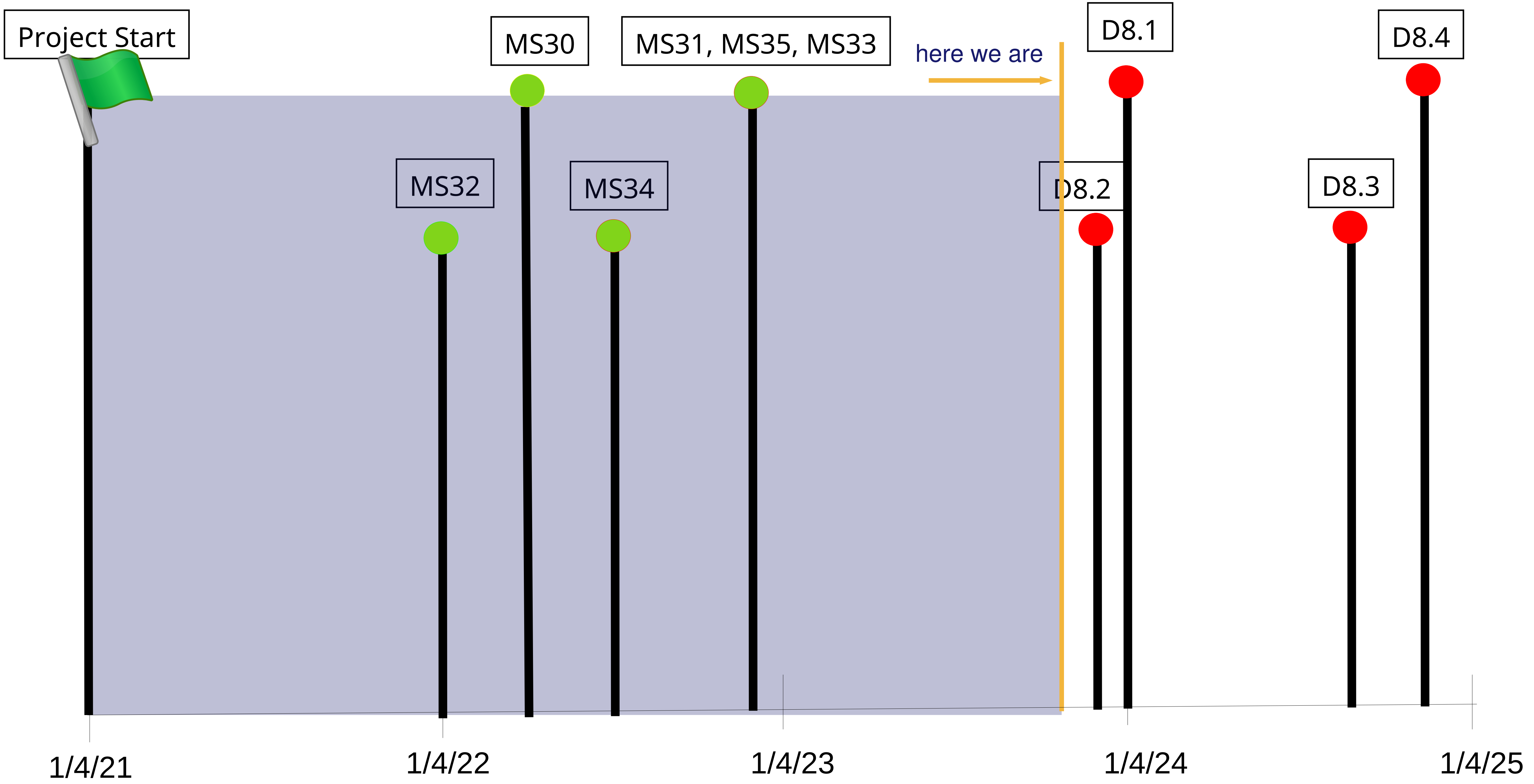
Beneficiaries:

CAEN (Industry)
CERN
CNRS-IJCLab, CNRS-LLR, CNRS-LPNHE
CUNI
DESY
FBK (“Interface to industry”)
FZU
INFN-BO, INFN-LNF, INFN-MI, INFN-PD, INFN-PG, INFN-PV, INFN-RM1, INFN-TO
JSI
JGU
MPP-MPG
TAU
University of Bergen
University of Sussex
Vilnius University

Associated Partners:

FOTON (Industry)
GLASS2POWER (Industry)
Minsk
HZDR
Crytur

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	8.2.1	M15 → M18	Report to StCom	DESY
MS31	Design and simulation of LAr readout electrode	8.2.2	M23	Report to StCom	CUNI
MS32	Test benches for testing detecting materials in picosecond and sub-picosecond domains.	8.3.1	M12	Specs data sheet	CERN
MS33	Design and test of scintillating tiles or strips with large active area suitable for large area detectors	8.3.2	M15 → M23	Operational Testbenches	MPG-MPP
MS34	Definition of SiPM requirements and performance studies with simulations of different use cases	8.4.1	M18 → M21	Report to StCom	JSI
MS35	Definition of the assembly method and of the ASIC specifications for a dual-readout calorimeter	8.4.2	M23	Report to StCom	INFN-MI

Last steps – WP8 Deliverables

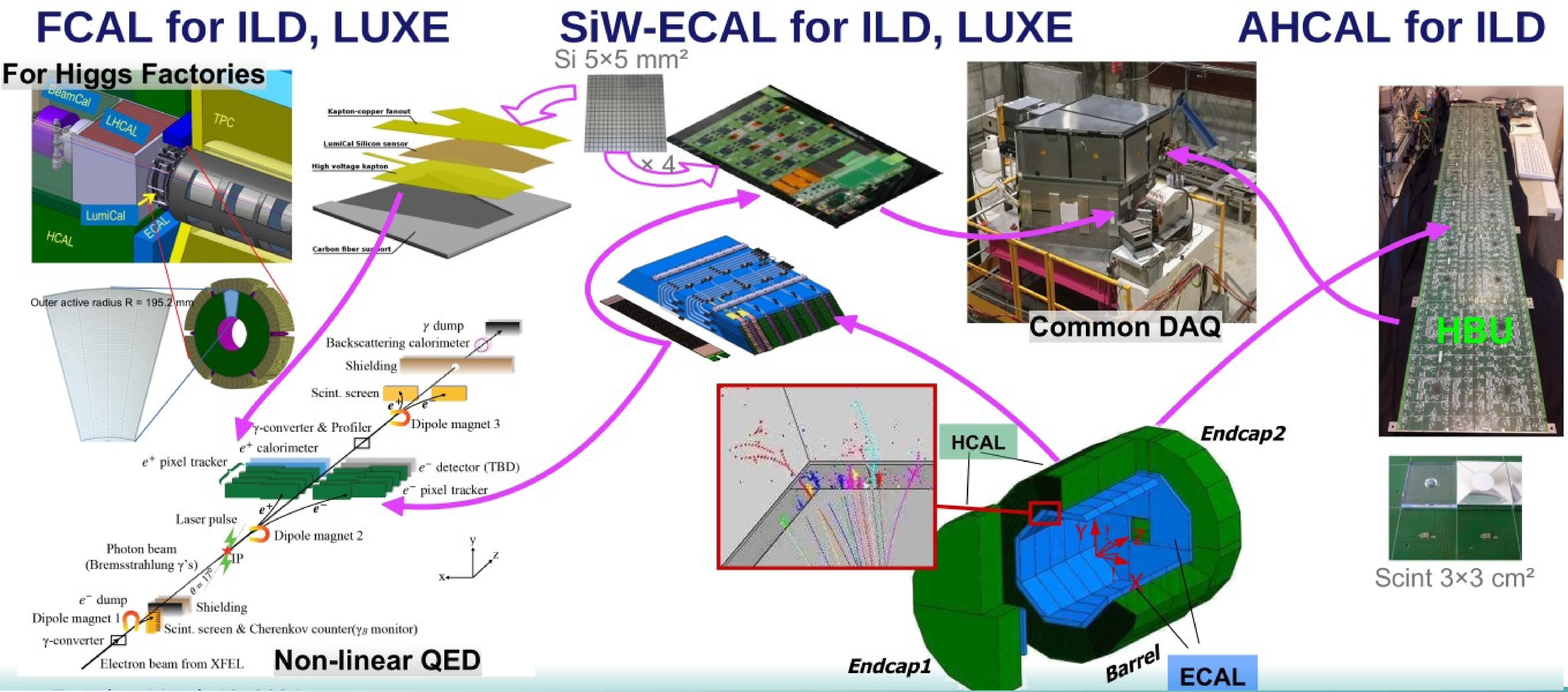
	Description	Task	Lead	Type	Dissemination	Due
D8.1	Demonstrator of a combined read-out system of highly granular electromagnetic and hadronic calorimeters	8.2	DESY	DEM	PU	M36
D8.2	Report on prototypes construction, performance and assessment of industrialisation	8.3	CERN	R	PU	M35
D8.3	Qualification of 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

- Report for D8.2 in hands of AIDAinnova Management → nearly accomplished
- Need to shift D8.1 by 6 months

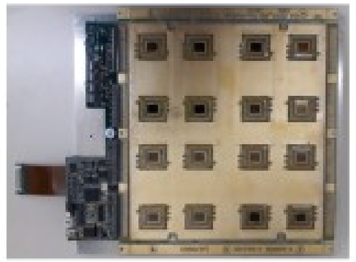
WP8 – Meetings and Communication

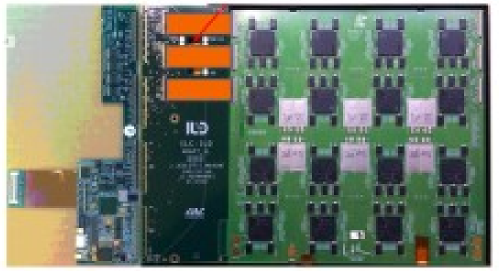
- Regular Task-Leader Meetings
  - Among others: reminder on publications and orientation to publication committee
    - Expect that number of publications increases in coming months
- WP8 Face-to-Face Meeting 18.01.2024
  - https://indico.cern.ch/event/1344030
- Mailing lists
  - AIDAinnova-WP8-Taskleaders@cern.ch → all task leaders
  - AIDAinnova-WP8-Institutes@cern.ch → one contact per group/institute
  - AIDAinnova-WP8-General@cern.ch → open for anyone interested (self-subscription)

A map to H.G.C. prototypes



SiW-ECal Beam Test at DESY & CERN





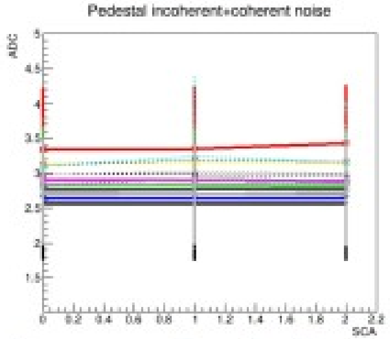
FEV10, 11, 12
- BGA packaging
- Incremental modifications
- From v10 -> v12
- Main "Working horses" since 2014

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

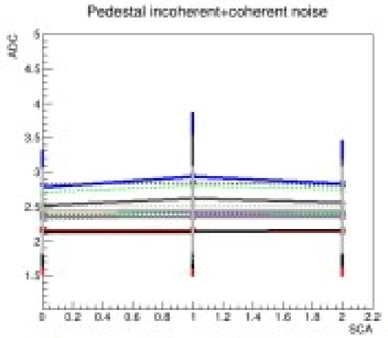
FEV13
- BGA packaging
  - Improved routing
  - Local power storage
  - Different external connectivity

Pedestal widths, 1st memory cells, per asic

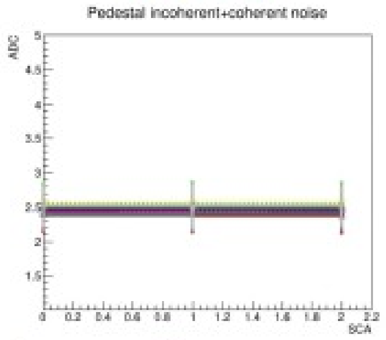
COB



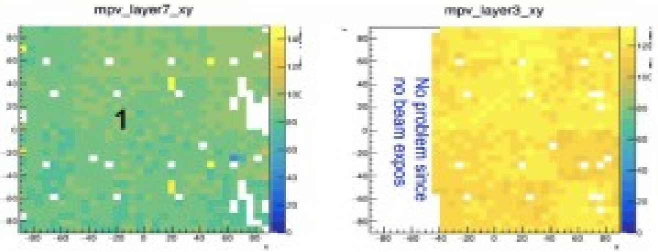
FEV12



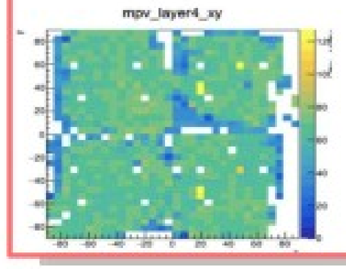
FEV13



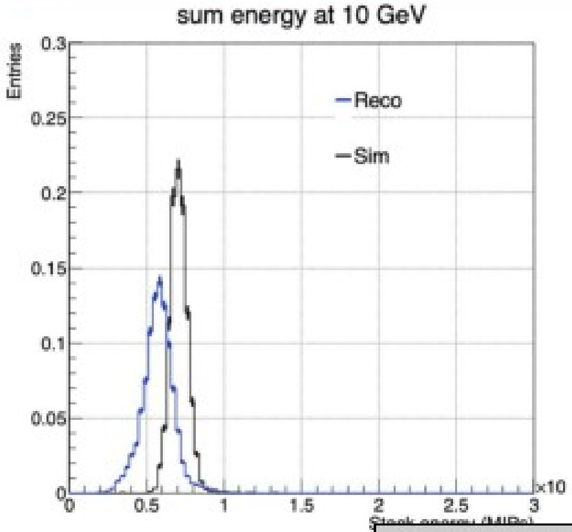
- (Average ± Standard Deviation) of Sigmas for all 64 channels in the same chip
- Latest PCBs, with optimized routing of power distribution shows better behavior
- Slightly larger spread on COB due to a near lack of decoupling capacitors



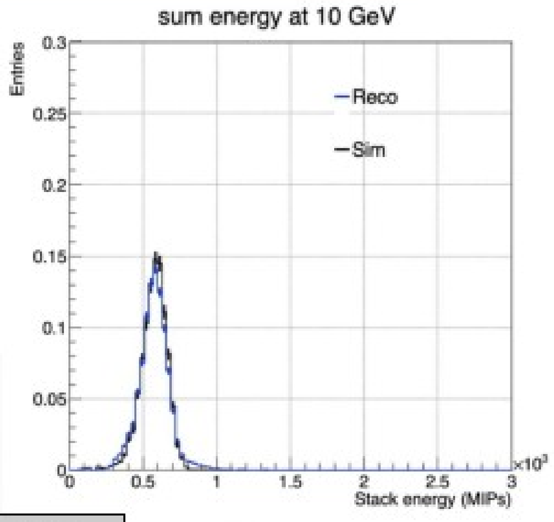
- We have good layers ...
  - Homogeneous response to MIPs over layer surface
  - Here white cells are masked cells due to PCB routing
    - Understood and will be corrected



... 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



Masking
Beam
profiling



Yuichi Okugawa (PhD in Feb.

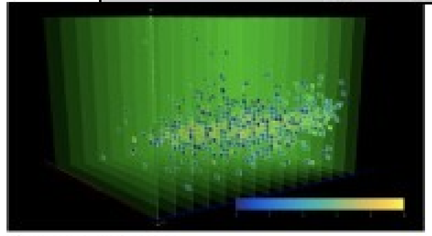


Fig. Simulation e- 100 GeV

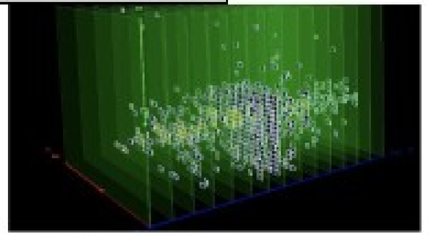
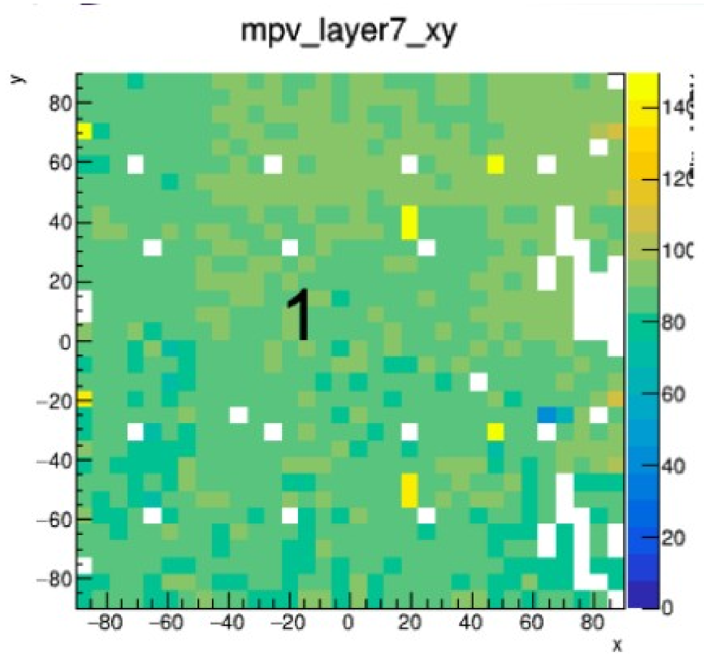


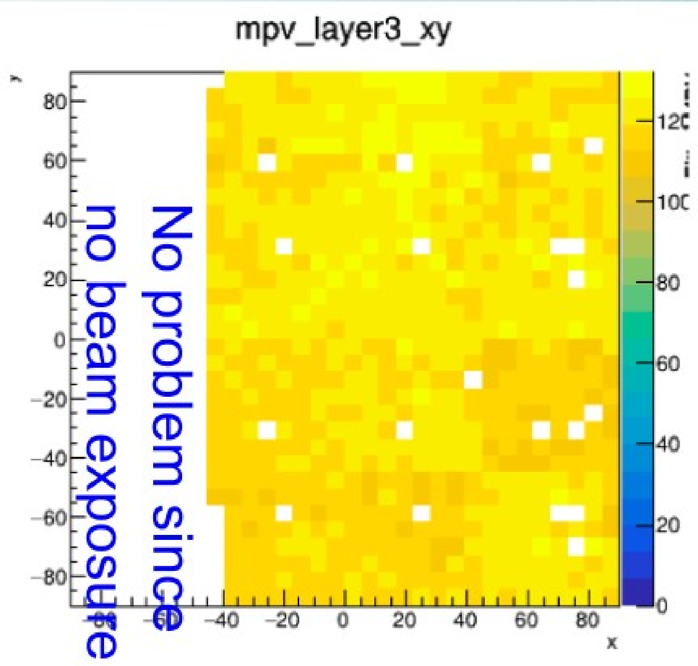
Fig. Reconstructed e- 100 GeV

Calorimeters for ILD' | 16/01/24, CE... 5/13

→ Homogeneous Prototype

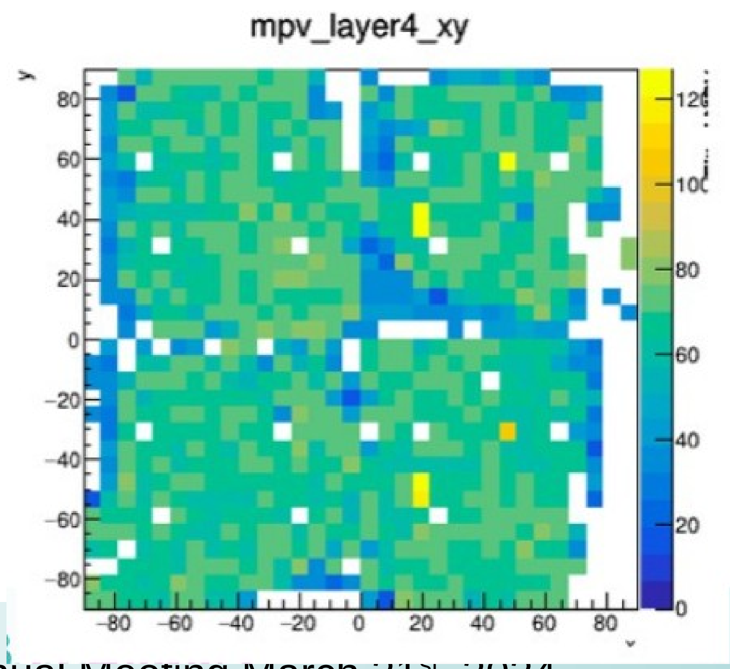
Main issue: contact PCB–sensor (details in Roman's talk)





We have good layers ...

- Homogeneous response to MIPs over layer surface
- > 90% efficiency for MIPs
- Here white cells are masked cells due to PCB routing
  - understood and will be correcte



... and bad layers

Inhomogeneous response to MIPs

- Partially even no response at all, in particular at the wafer boundaries
- Visusl inspection confirmed with electrical tests show that the sensor
- Got delaminated from the PCB -> glus dots have failed
- ***Intensive topic of study***

Understanding Sensor Delamination

- Understanding sensor delamination → heart of current R&D

- Systematic studies throughout 2023
  - Screening machines at IJClab and IFIC
  - Metrology seems to indicate that component mounting is not cuprit for deformation
  - Drying seems to help → avoid humidity ?
  - Discrepancies between screening results at IJCLab and IFIC to be understood

- Progress on two methods for for hybridisation
  - Underfill
  - Double sided tape (after all a “pre-polymerised” material)
  - Have to learn now how to build ASUs using these technologies
    - Proper perforation and placement of perforated tape
    - Application of underfill to 18×18 cm^2 surface

- Tensile test stand operational and first results available

Calice TAU 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).

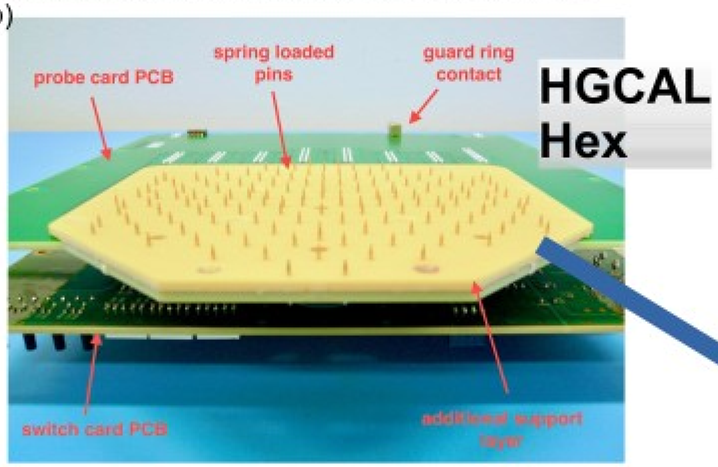
December :

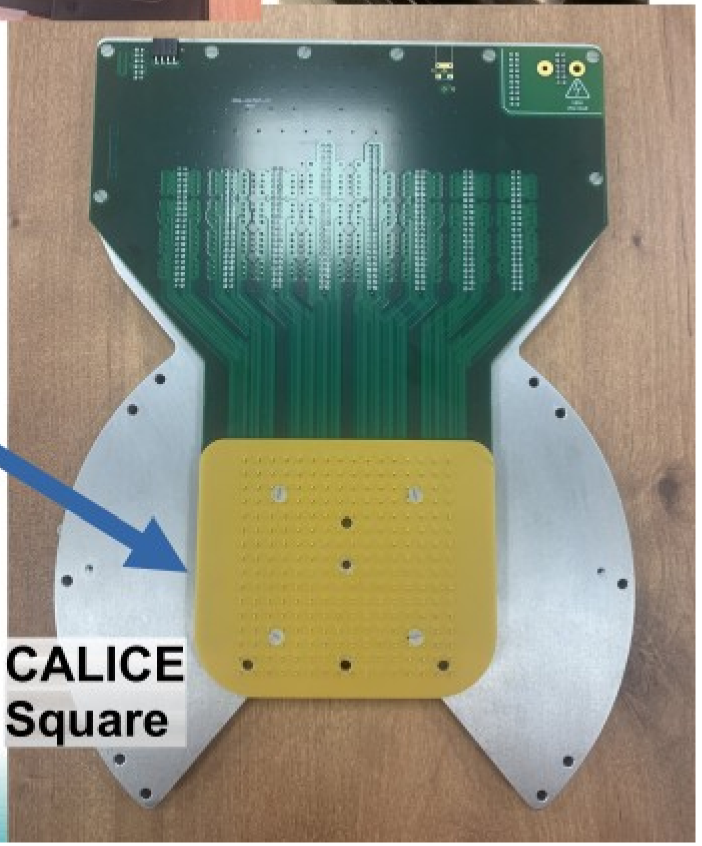
- **modification of the probe station mechanics and installation of the probe card**

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, VBD, VFD, CFD)





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 8.2.2
Liquid Noble Gas Calorimeters

Simulation studies in key4hep

Lots of ground work in 2023 !

- Correct cells geometry was used in simulation but not in digi/reco
  - Now proper θ/ϕ positions used consistently everywhere
  - Much more flexible fullsim geometry:
    - Can easily change cells and layers sizes
    - Can adapt the granularity per layer
- Improvements in clustering
  - Topo-clustering and fixed-size clusters adapted to new geometry
  - Super nice tool to visualize showers and clusters
  - Topo-clustering using ECal+HCal
- Technical work
  - Follow FCC software evolution (k4geo)

Designs for the endcaps: first ideas

Endcaps designs more complex than that of the barrel:

- "Turbine" design
  - More similar to barrel design
  - Symmetric in ϕ
  - Issue: increase in the size of the Noble liquid gaps
  - Need to stack several cylinders

Each el
24 tim

0.4

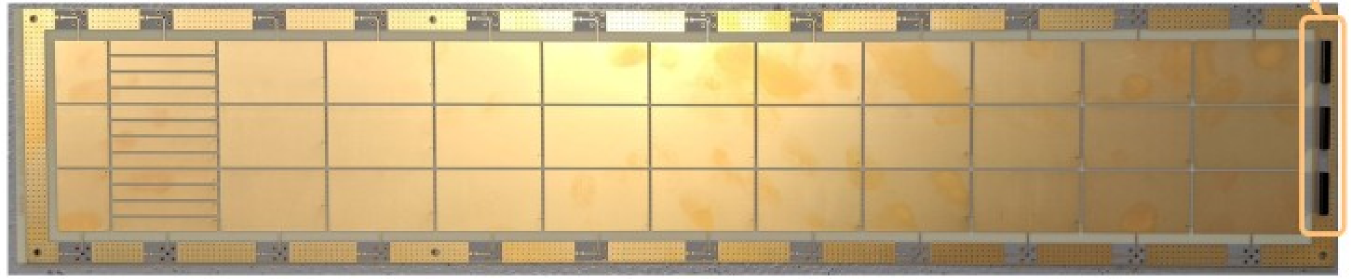
N. Morange (IJCLc

)AInnova Annual meeting, 19/03/2c

Prototyope 2024 @ IJCLab

Learning from the previous generation

- Next prototype at IJCLab
  - All layers, 3 towers
  - **Readout all cells at the back**
    - Best for material budget in calo, worst for cross-talk
  - Study options for **additional shielding**
  - **Connectors** for easy readout/injection
  - Possibility to merge several PCBs
  - Received January 2024



Conclusions

Even if milestone has been achieved in 2023, work on Noble liquid gas calo electrodes continue

- Simulations
  - Road to as accurate simu as possible to inform the design is long !
  - Great progress achieved in 2023
  - Expect conclusions from granularity optimisation studies in 2024
  - Other aspects of simulation progressing towards physics performance evaluation
- Electrode prototypes
  - Previous generation of prototypes very successful at demonstrating the concept
  - New electrode @ IJClab: validate detailed understanding on realistic scale electrode and demonstrate scaling up of measurements system
  - Next steps @ CERN: new full-scale prototype

WP8 – Task 8.3.1
Crystal Detectors

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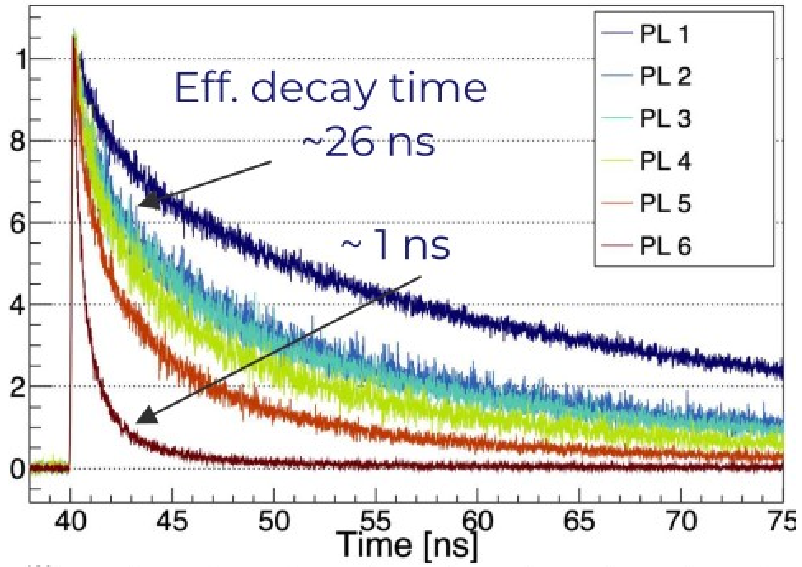
Deliverable D8.2 submitted on Feb 28, 2024

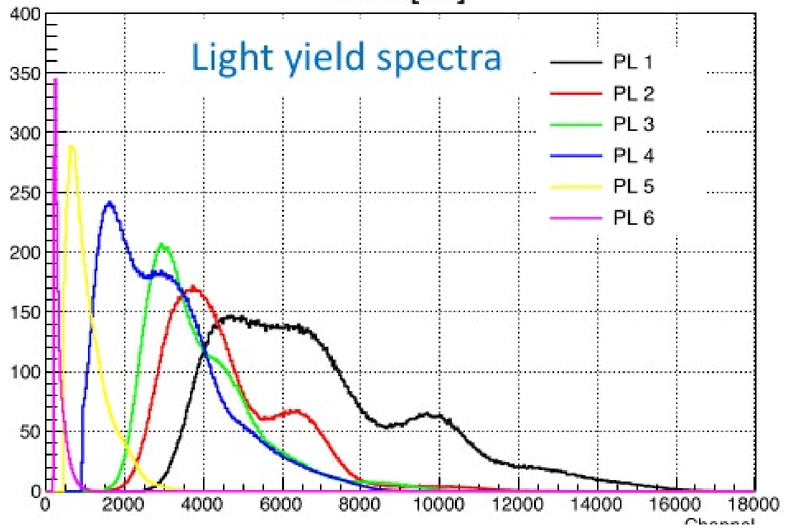
WP8 – Task 8.3.1
Crystal Detectors

GAGG:Ce Scintillation acceleration by heavy Ce/Mg doping

No loss of time resolution!
Light output reduction ⇔ decay time decrease

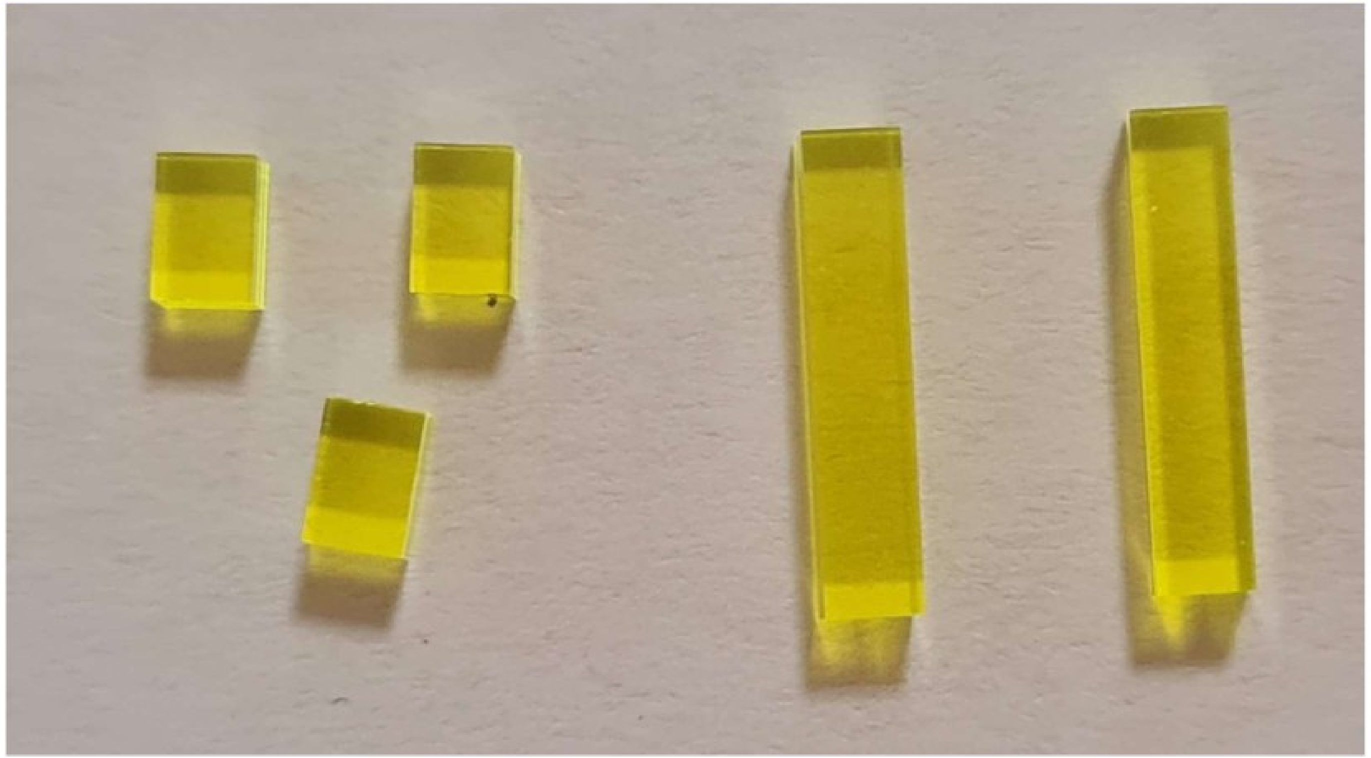
Decay time spectra



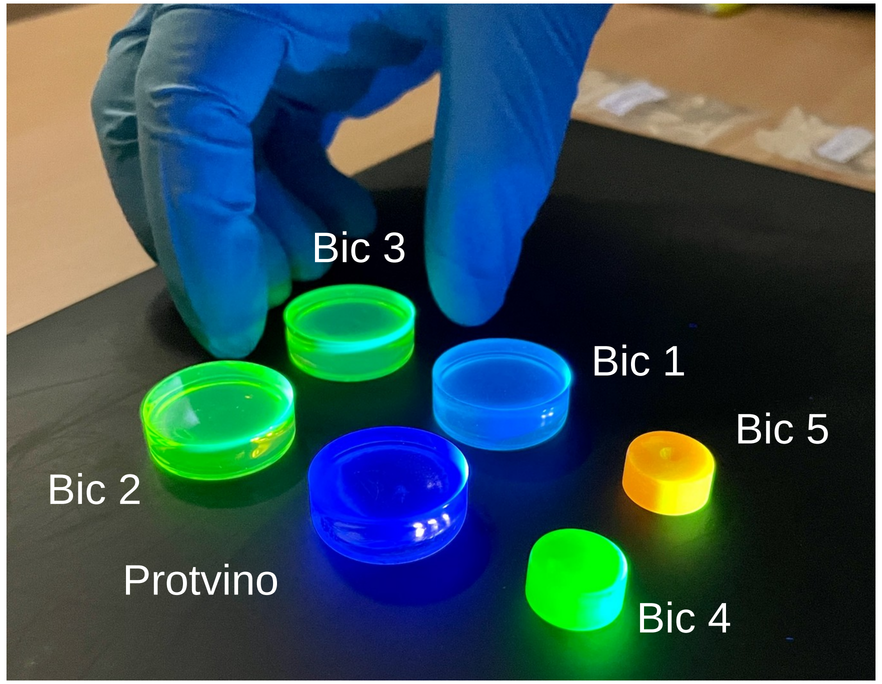


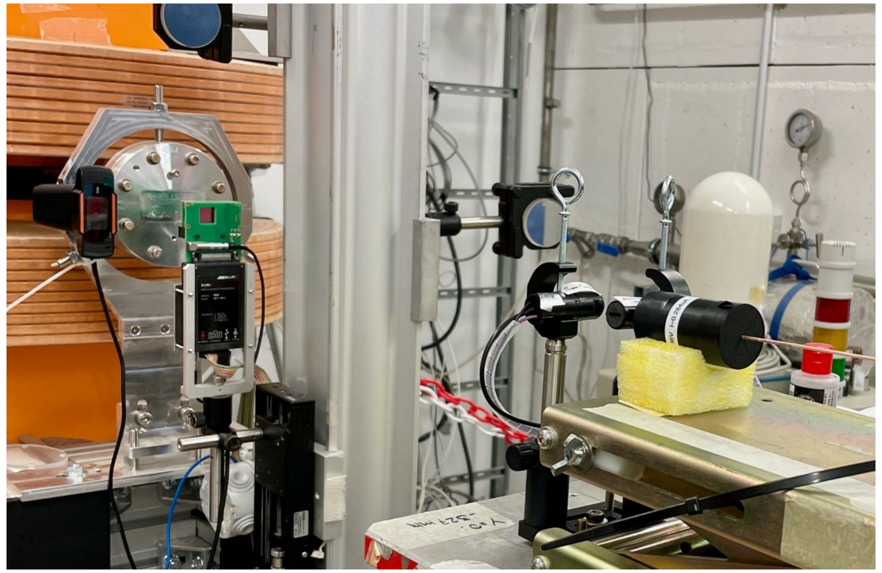
Tech transfer rom FZU to CRYTUR

GAGG Samples produced by CRYTUR



WP8 – Task 8.3.1
Crystal Detectors





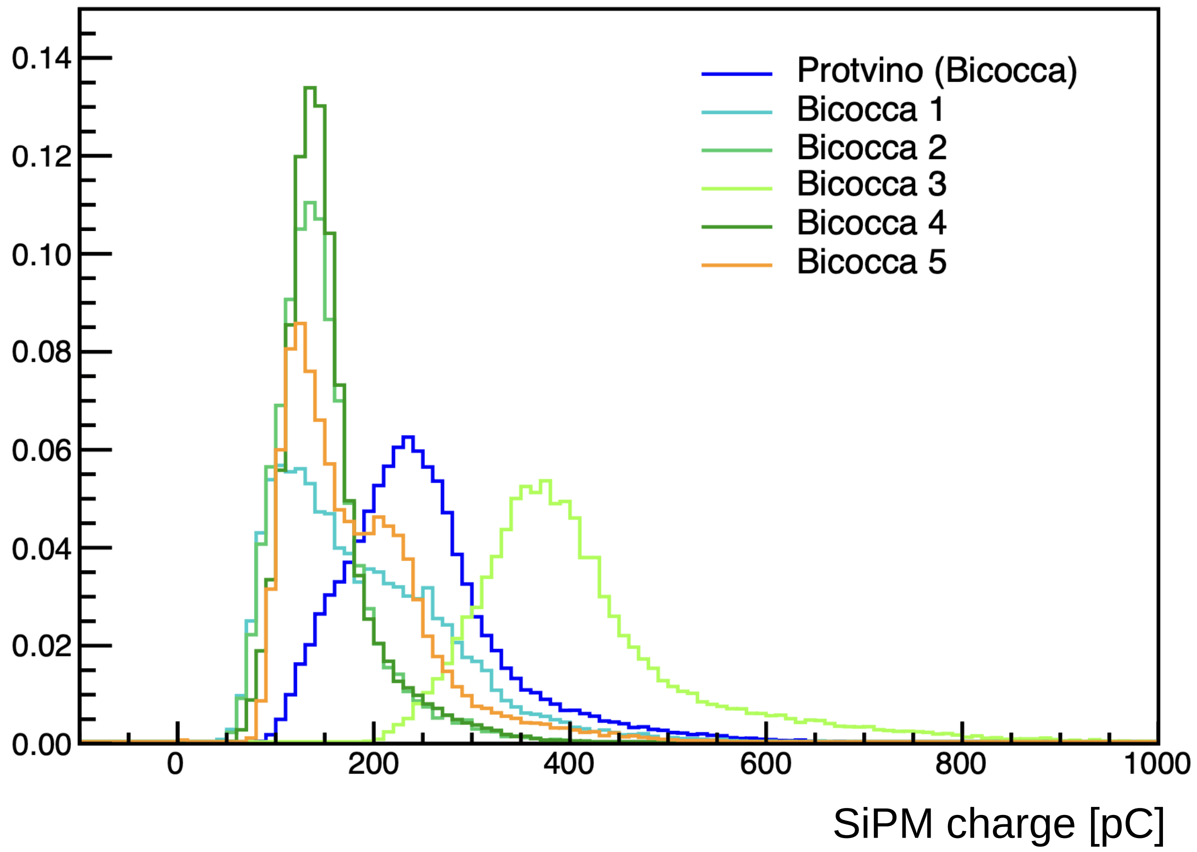
NanoCal

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

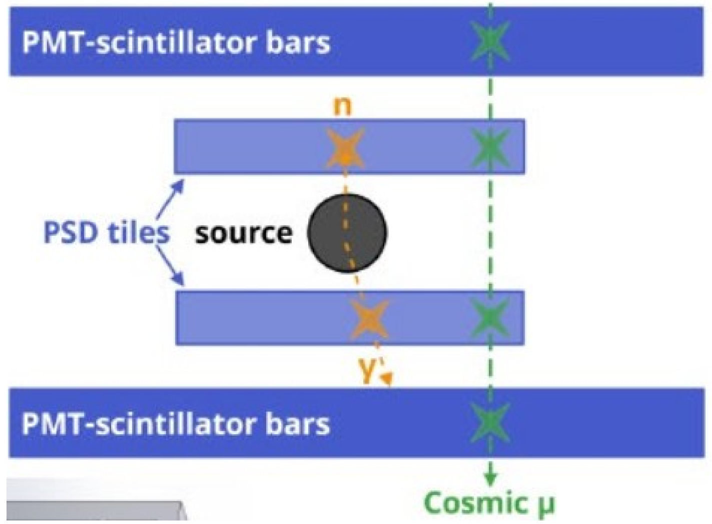
First nanocomposites with good mip response!

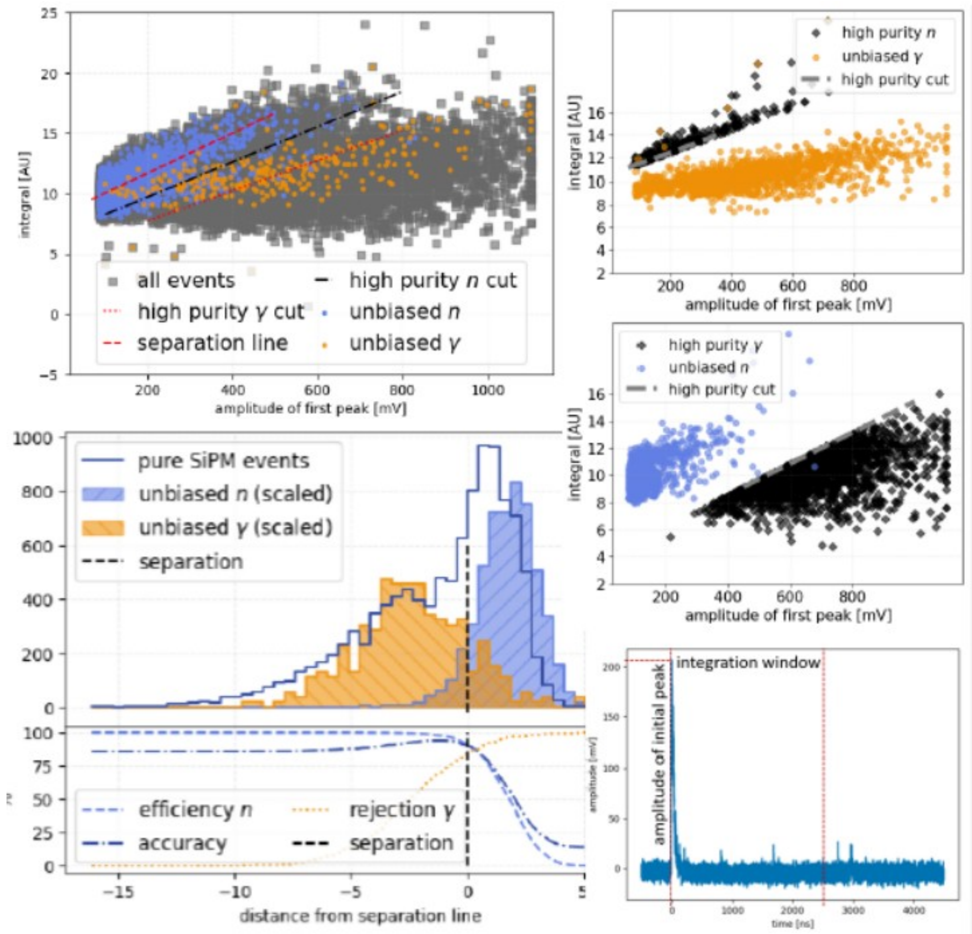
- Bicocca 3: Coumarin-6 (green) scintillator with ~160% light yield of ref. sample

Many new samples to be tested in next BTF run

WP8 – Task 8.3.2
Large-area scintillation detectors

JGU update

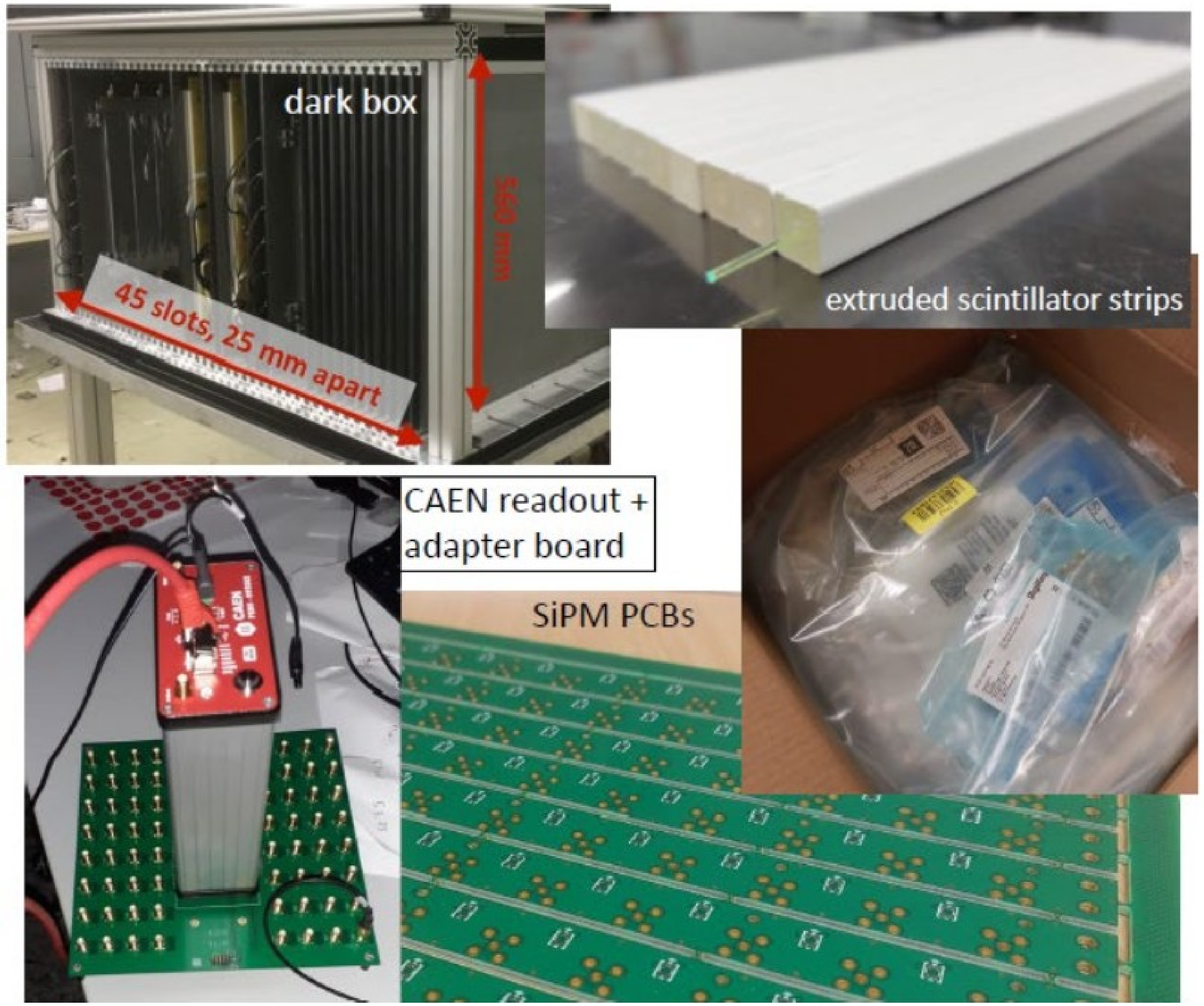




87% accuracy achievable w/ integrating readout

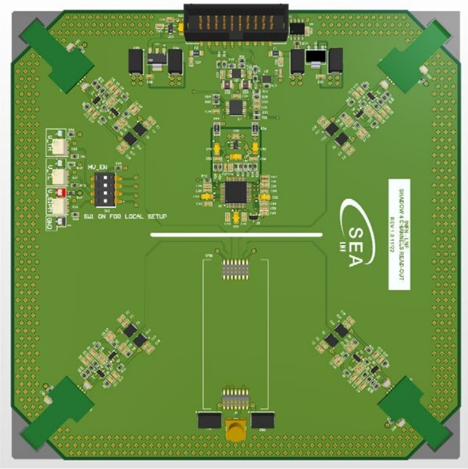
n/γ separation w/ PSD

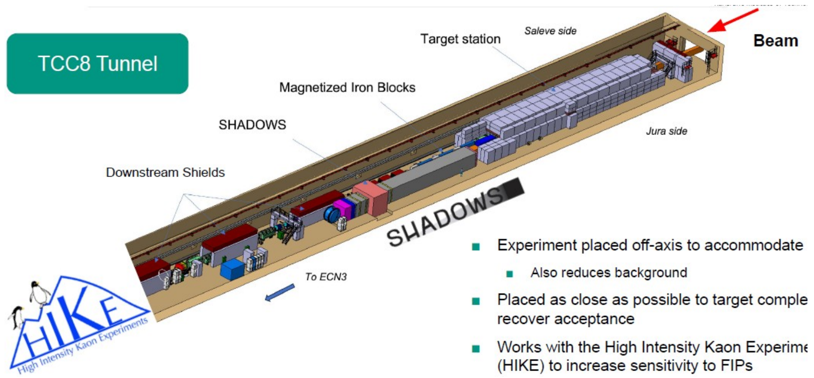
SHADOW Fe/Scint ECAL prototype



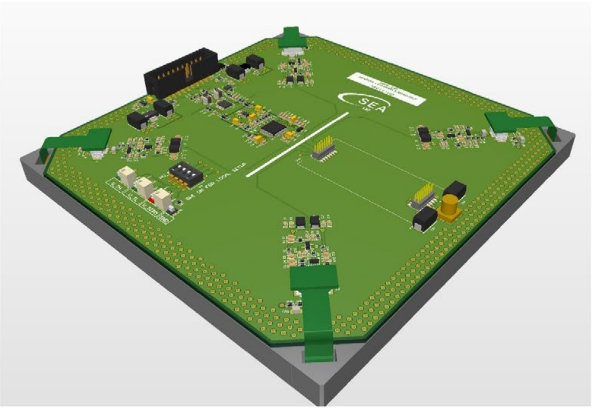
WP8 – Task 8.3.2
Large-area scintillation detectors

INFN – Tile demonstrator for SHADOW μ detector

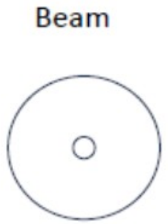


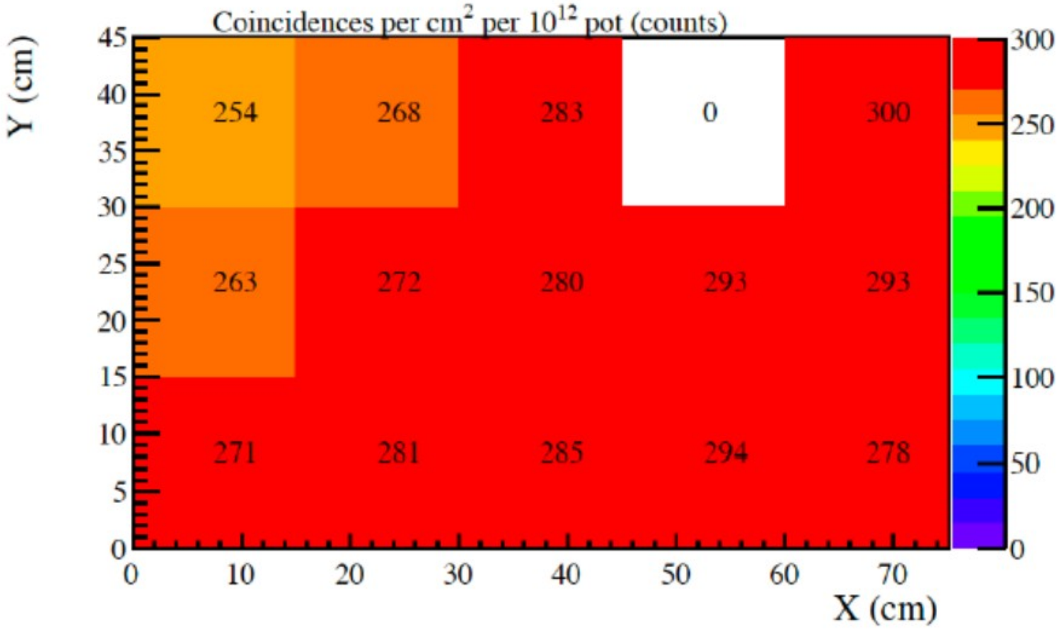


μ flux measurement in the foreseen location for SHADOWS (preview)



2 full-size modules



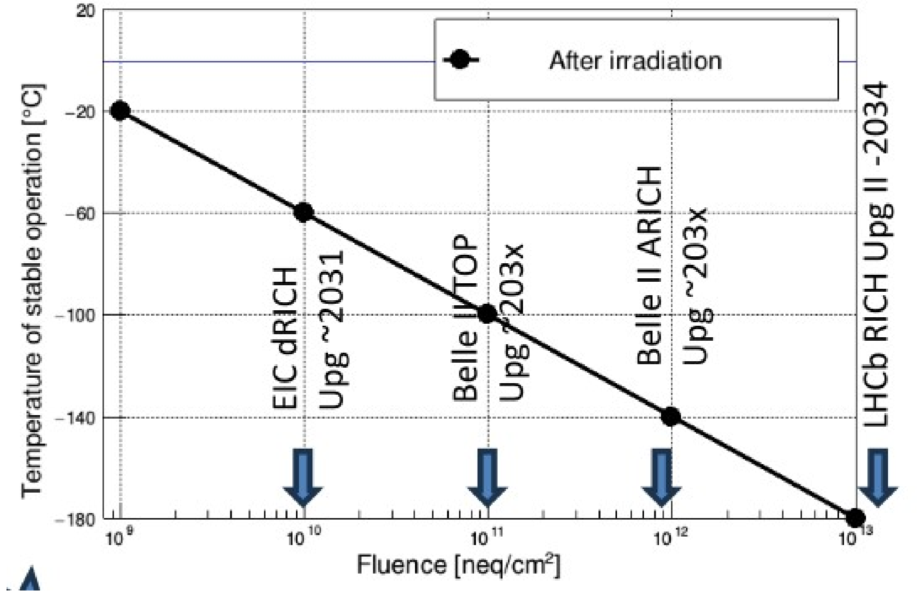


measured rate: 250-300 cts/cm^2/spill increasing w/ distance

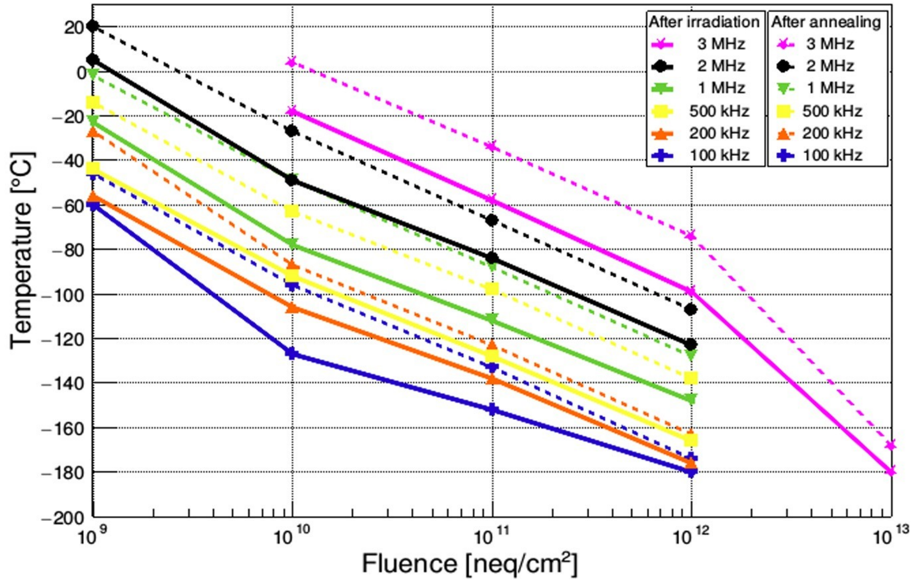
WP8 – Task 8.4.1
Innovative SiPMs

Neutron irradiation @ JSI of FBK NUV SiPMs

single p.e. peak visible @ 9V OV

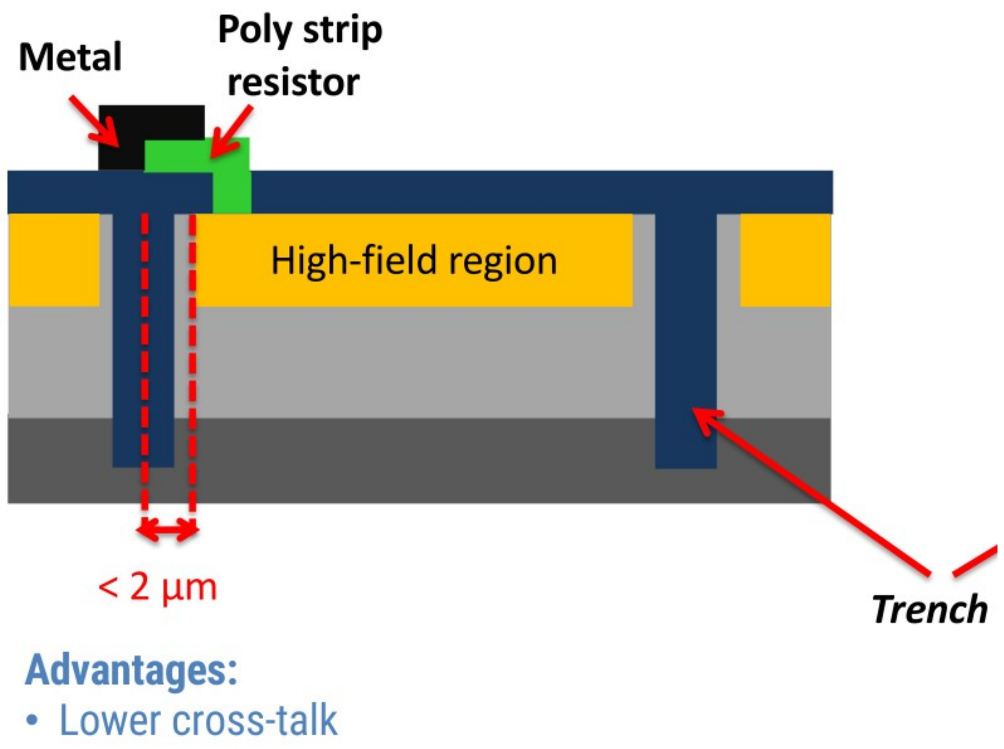


D.C. rate w/ irradiation and w/ annealing

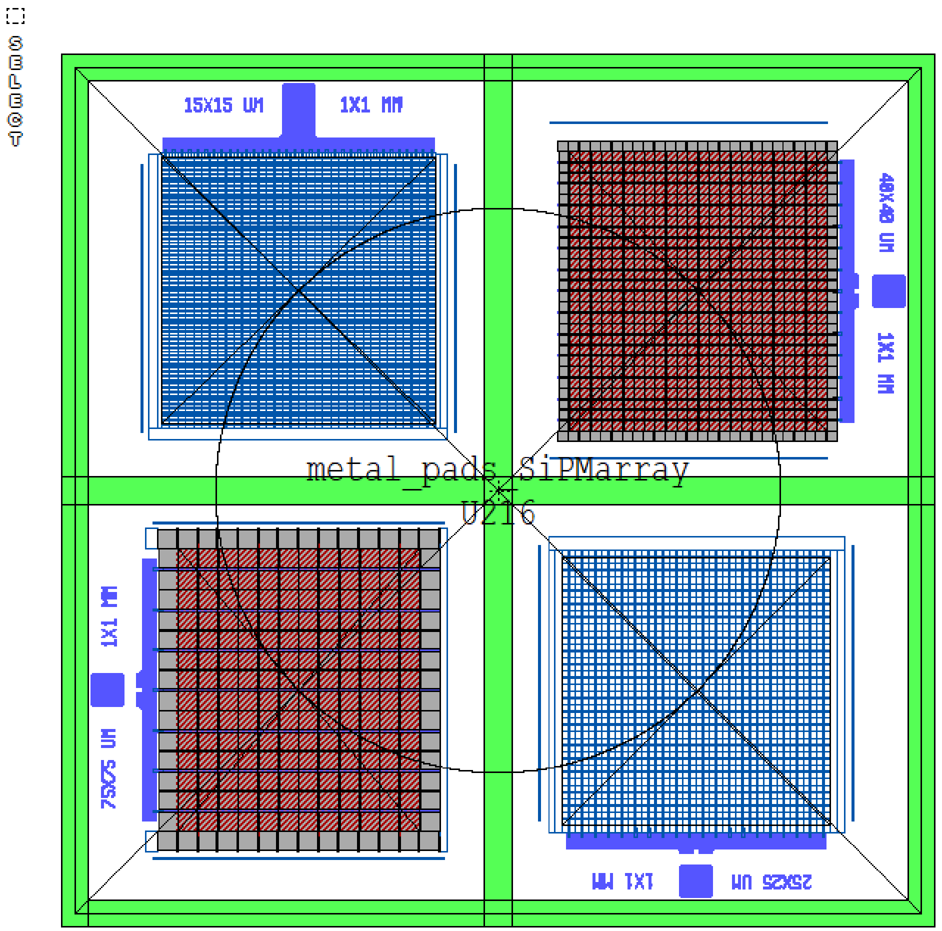


NUV-HD for AIDAInnova

Design of new rad-hard design with low field under way
Production start: Q1 2024, end Aug. 2024



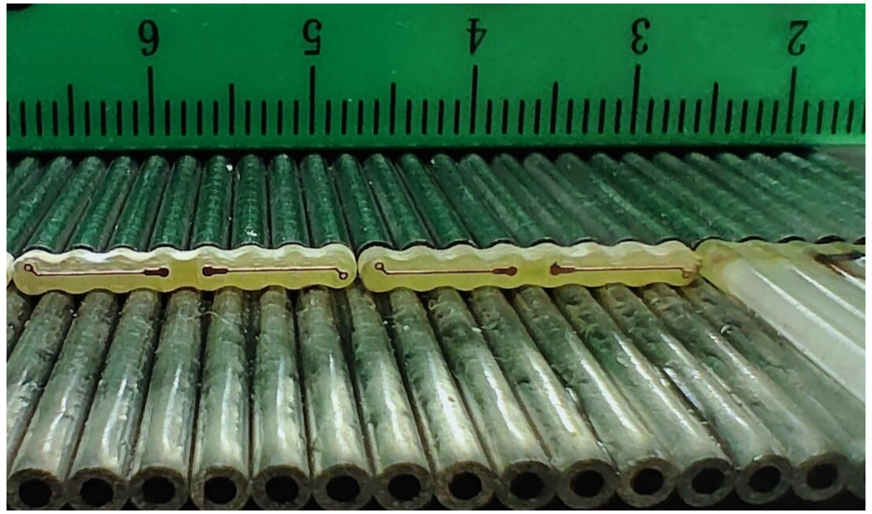
Several different SiPM and pixel sizes

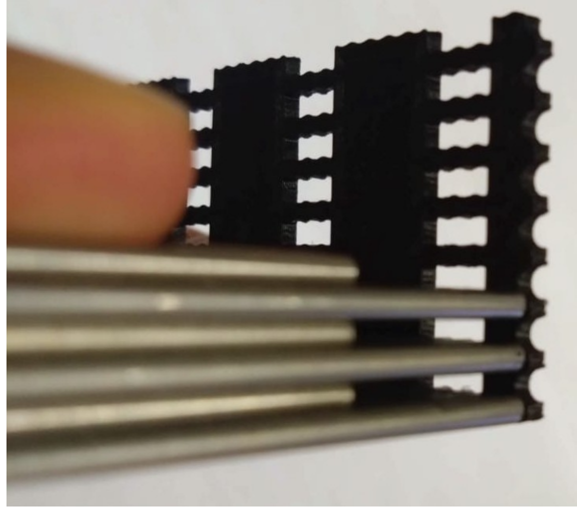


WP8 – Task 8.4.2
Highly granular dual-readout calorimeter

- Started series production ...
- 18 MiniModules (MMs) completed
  - ~5-10% rejection for both sci-fibres and capillary tubes
- Estimated production rate: ~ 2 MMs / week

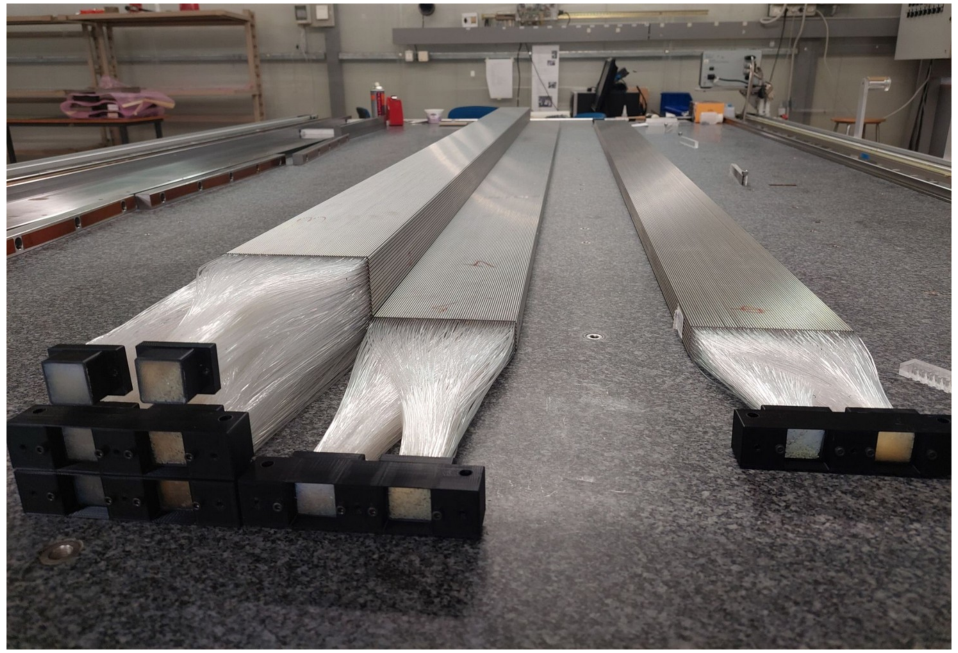
- SiPM readout: Integration tests w/ dummy components:

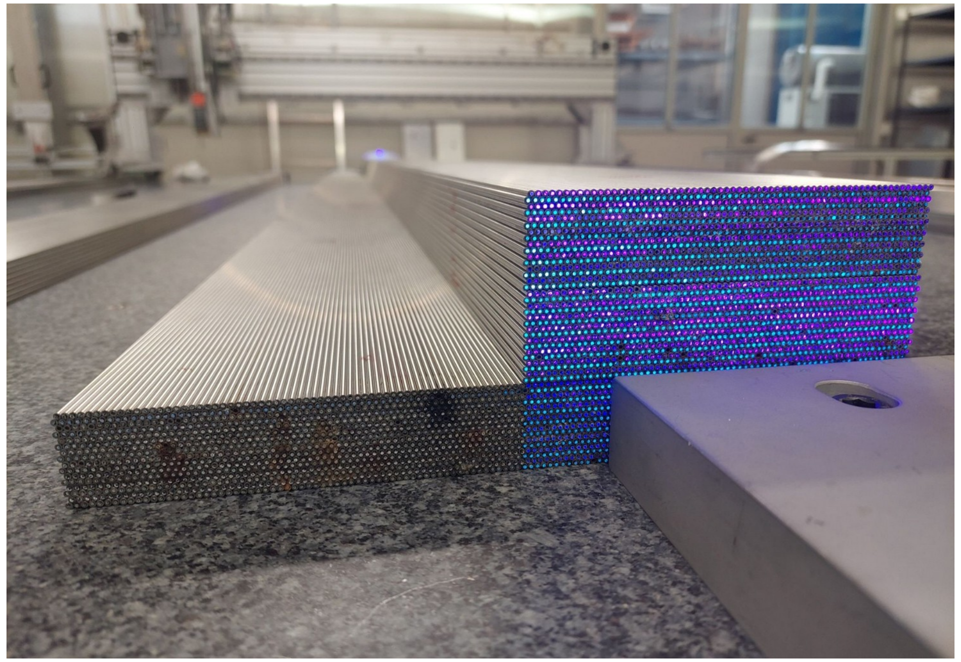




- Waiting for (hopefully) final pieces

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





WP8 – Task 8.4.2
Highly granular dual-readout calorimeter

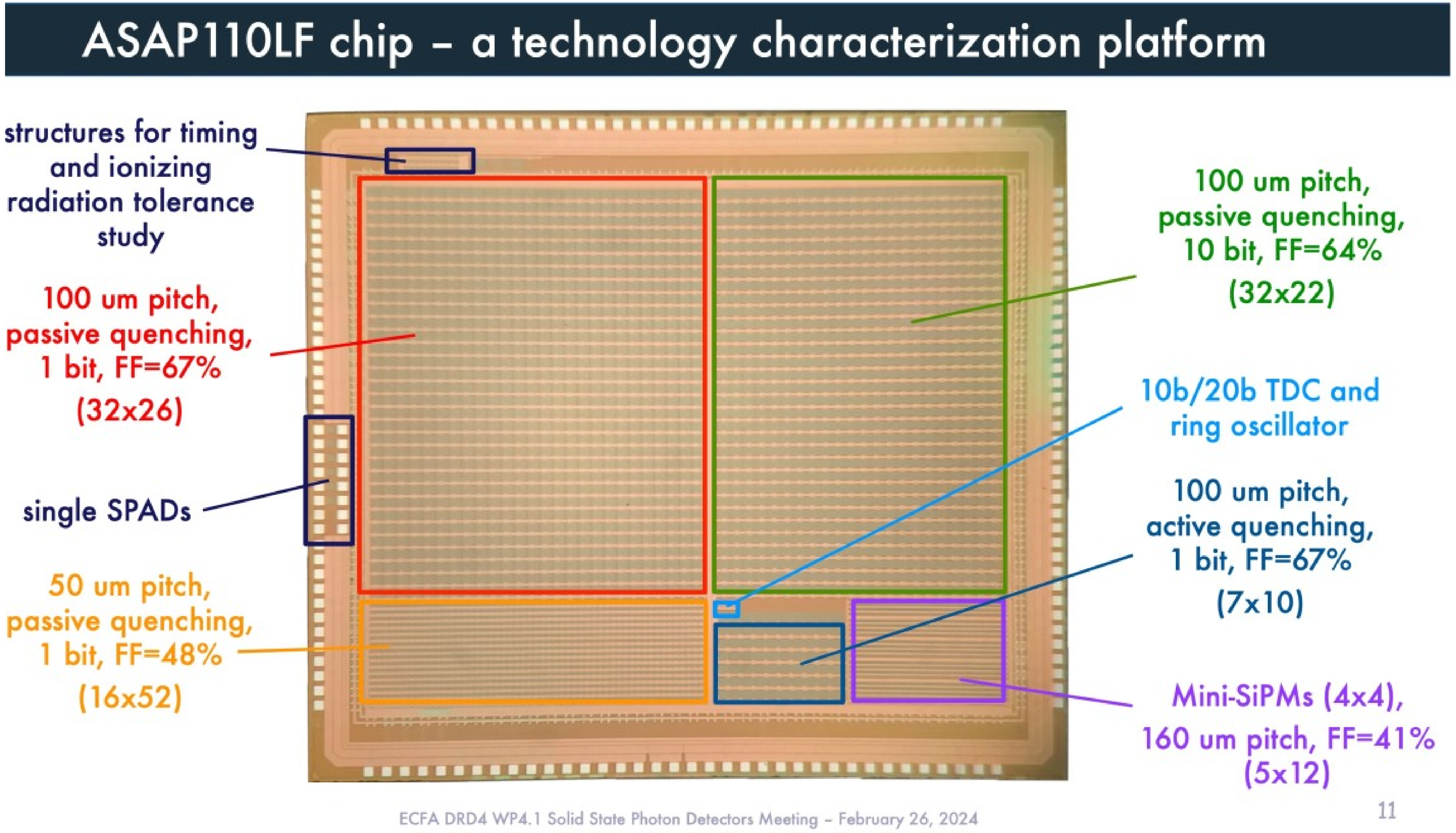
New:

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



Conclusions

All WP8 activities quickly progressing

→ few delay-causing issues promptly tackled

Just a subset presented here

→ too many to be summarised here: apologies for that!

Several sub-tasks already satisfied their committments

→ only 3 deliverables missing

Significant impact of WP8 on DRD-on-Calorimetry (DRD6)

→ need to clarify interplay

→ DRDs must boost AIDAinnova activities and viceversa

Backup