Workpackage 8 - Calorimetry and Particle ID

Roman Pöschl

Roberto Ferrari

Katja Krüger

AIDAinnova Annual Meeting – Valencia April 2023

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004761.

Workpackage 8 – Overview

Task 8.1. Coordination and Communication

Task 8.2. Towards next generation highly granular calorimeters

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

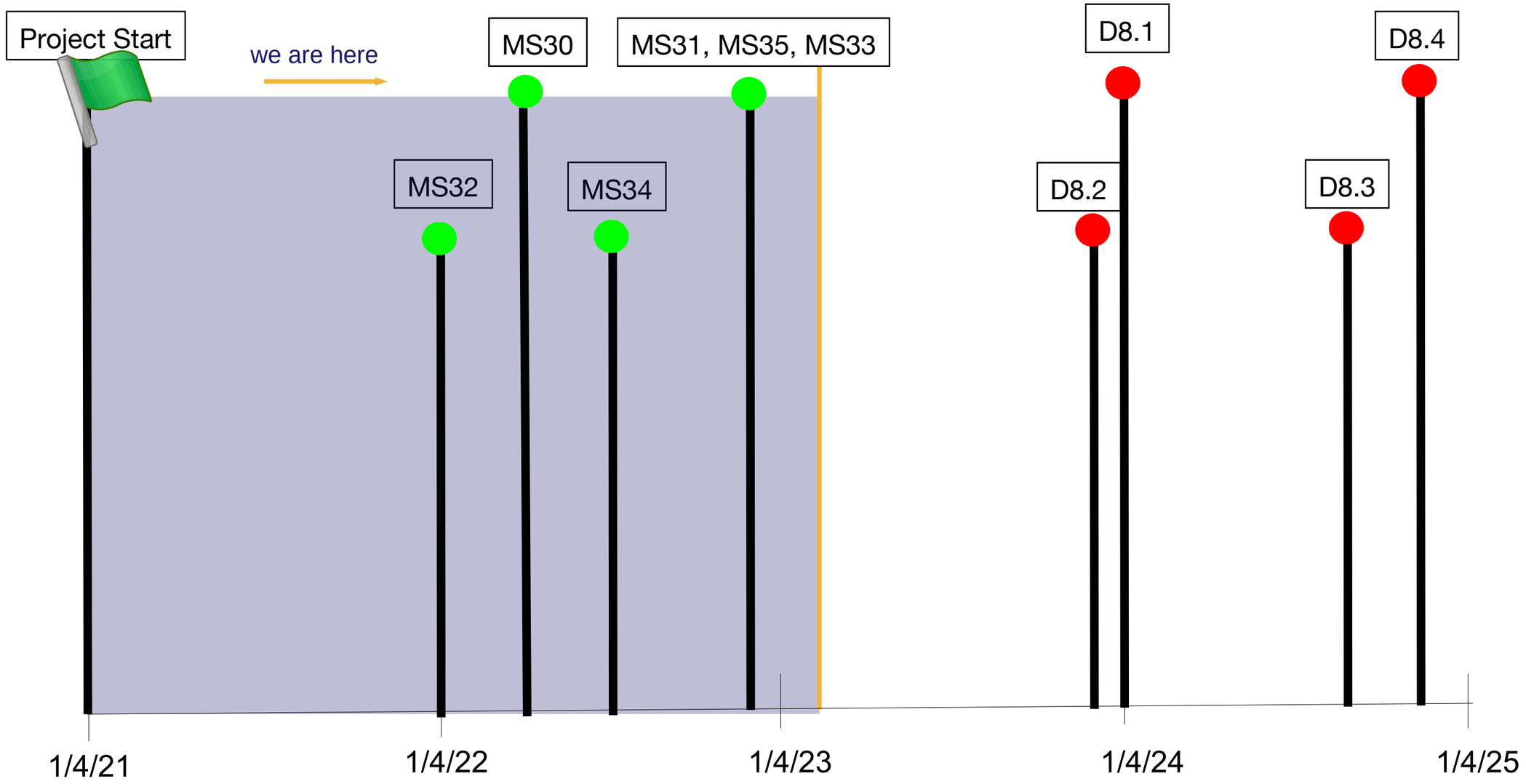
Task 8.3. Innovative calorimeters with optical readout

- 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

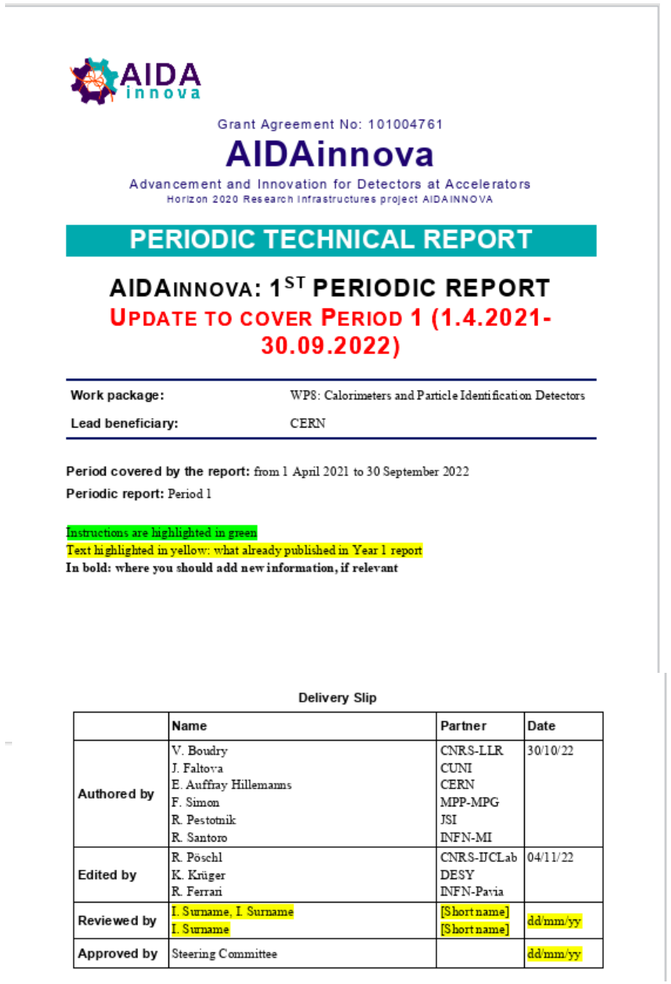
For completeness – WP8 Deliverables

#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

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 11/1/23, CERN 222/R-003
  - https://indico.cern.ch/event/1219756/
- 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 – P1 report



AIDA innova

Grant Agreement No: 101004761

AIDAinnova

Advancement and Innovation for Detectors at Accelerators

Horizon 2020 Research Infrastructures project AIDAINNOVA

PERIODIC TECHNICAL REPORT

AIDAINNOVA: 1ST PERIODIC REPORT

UPDATE TO COVER PERIOD 1 (1.4.2021-30.09.2022)

Work package:	WP8: Calorimeters and Particle Identification Detectors
Lead beneficiary:	CERN

Period covered by the report: from 1 April 2021 to 30 September 2022

Periodic report: Period 1

Instructions are highlighted in green

Text highlighted in yellow: what already published in Year 1 report

In bold: where you should add new information, if relevant

Delivery Slip

	Name	Partner	Date
Authored by	V. Boudry J. Faltova E. Auffray Hillemanns F. Simon R. Pestotnik R. Santoro	CNRS-LLR CUNI CERN MPP-MPG JSI INFN-MI	30/10/22
Edited by	R. Pöschl K. Krüger R. Ferrari	CNRS-IJCLab DESY INFN-Pavia	04/11/22
Reviewed by	I. Surname, I. Surname I. Surname	[Short name] [Short name]	dd/mm/yy
Approved by	Steering Committee		dd/mm/yy

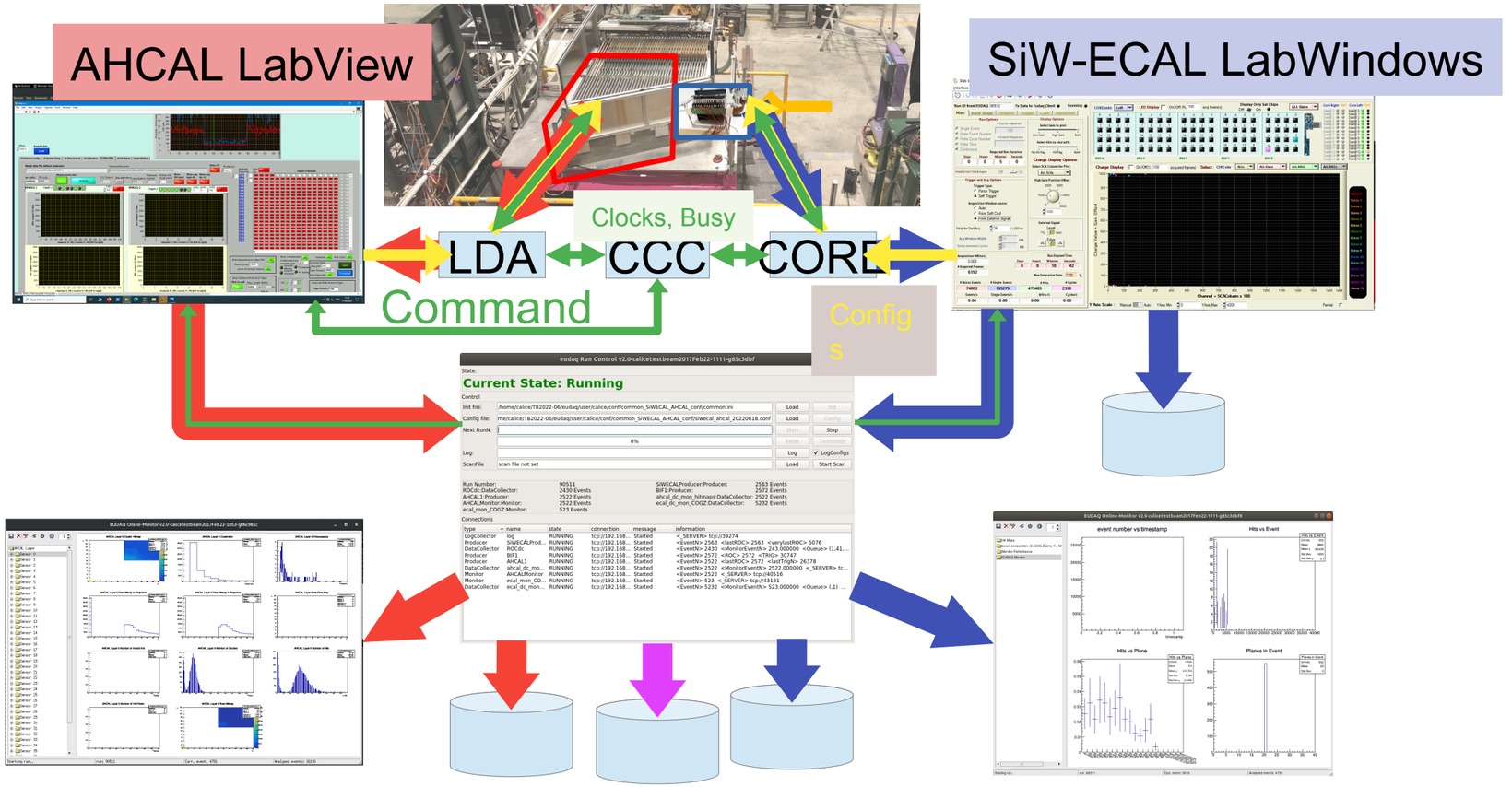
- P1 Report
  - Covers period April 2021 – September 2022 (18 months)
  - Draft was due Oct 24 -> delivered on Nov 10

(could do better with delivering reports on time)

WP8 – Task 8.2.1

Towards D8.1

Reminder: Common beam test CALICE SiW ECAL and AHCAL – June 2022



- Large scale application of readout tools as e.g. EUDAQ
  - Calorimeter system with 37000 readout cells
- Important input for common development of readout hardware

DESY, CNRS-IJCLab, CNRS-LLR, FZU, JGU + IFIC, MPP-MPG, Kyushu U

WP8 – Task 8.2.1 – Technical Specifications for Common DAQ interfaces

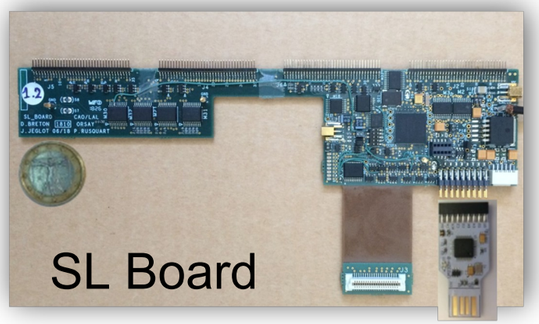
DESY, CNRS-IJCLab, CNRS-LLR, FZU, JGU

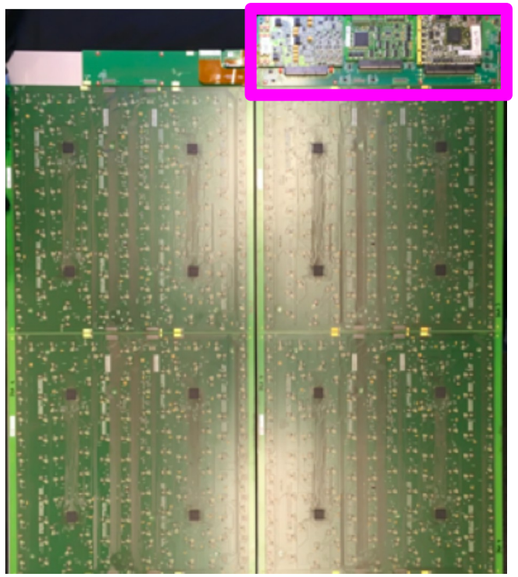
MS32

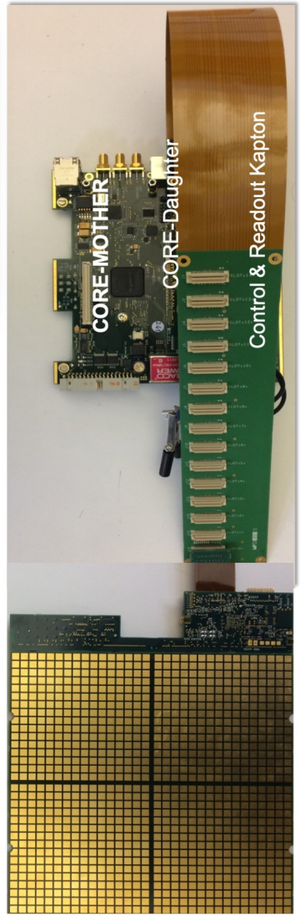
- Based on CALICE SiW ECAL SL Board v2
  - Update of AIDA-2020 Deliverable during AIDAinnova
- Relevant questions for adaptation to CALICE AHCAL
  - identified in 3 meetings, ы 2 physical satellite-meetings @ CALICE

List for AHCAL:

- Central Interface Board for AHCAL has to be shrinked from a lateral size of ~10 cm to a smaller surface
- **Power board** (ASIC, SiPM, LED pulsing) may stay as a mezzanine
  - Important test to do: Can power pulsing be integrated on AHCAL Board ?
- Signal transmission via “CORE Kapton” not feasible (length, and not needed)
- HDMI cables still optimal, also since five differential pairs
- AHCAL may consider combining functionalities in FPGA







WP8 – Task 8.2.1 – Technical Specifications for Common DAQ interfaces

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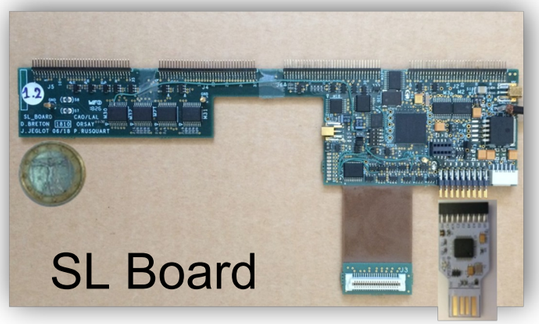

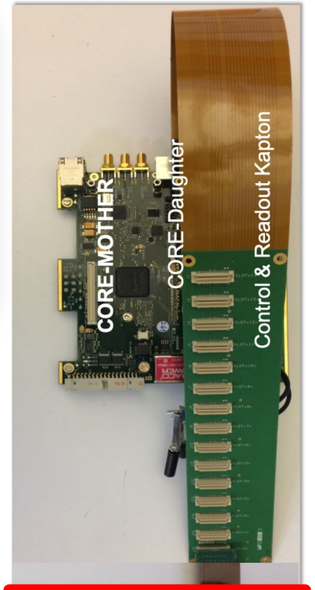

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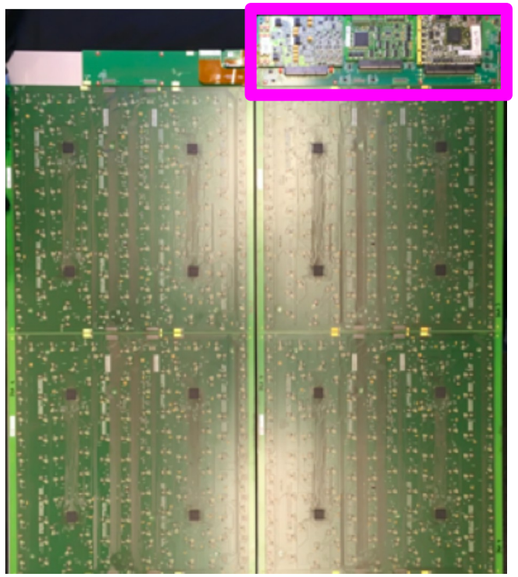
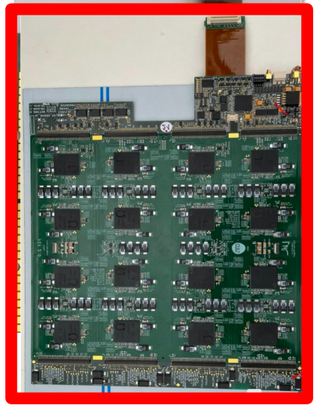
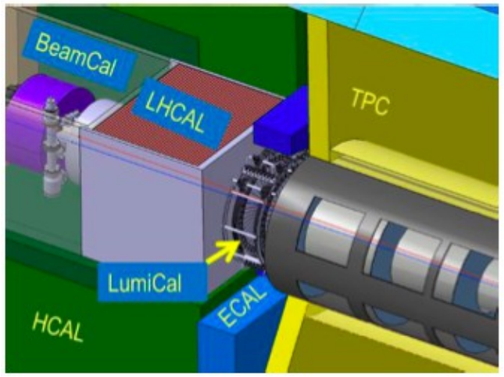


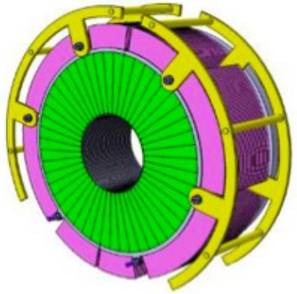


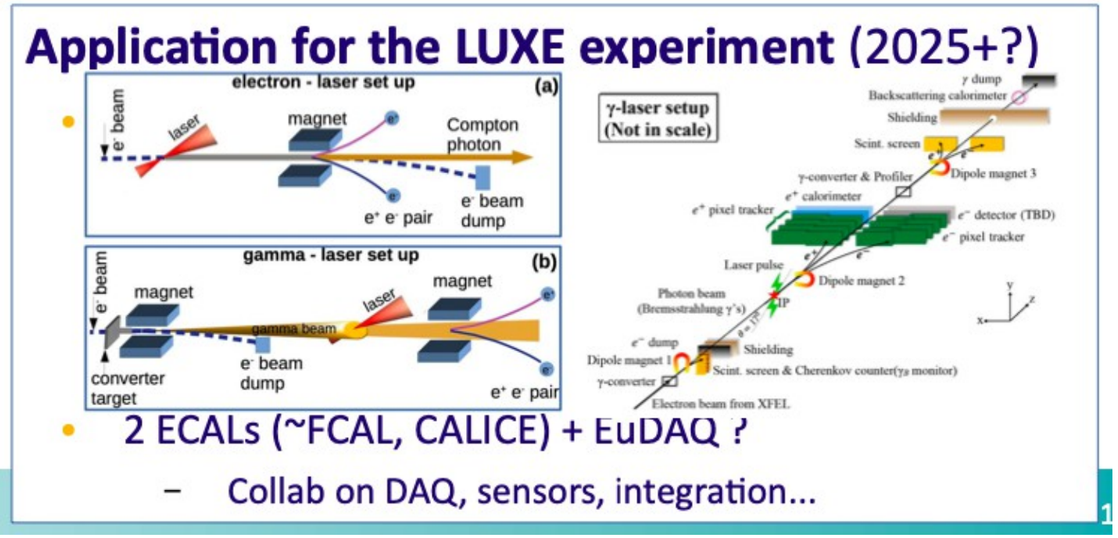
New PCB for SiW-ECAL:

- Improved Layout
- Local Power Supply
- Delivery February 2023 – (Partially) ***funded with AIDAinnova funds***
- Pre-version showed dramatically improved noise
- Current version about to be equipped with components

WP8 – Task 8.2.1 – Compact Calorimetry

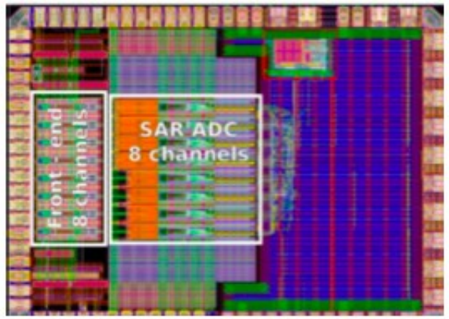






TAU,
CNRS-IJCLab,
CNRS-LLR,
IFIC

FLAME to FLAXE ASIC (WP11)

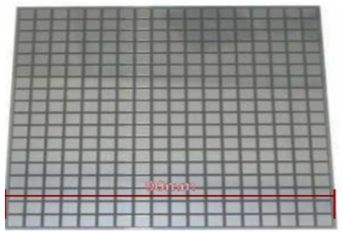


UST Krakow

Sensor R&D

GaAs-Sensor

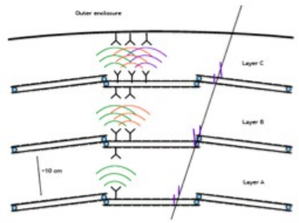
Si-Sensor



Integration of sensors via
Epoxy Gluing, Anistropic Conductive films or ...

R&D on wireless transmission

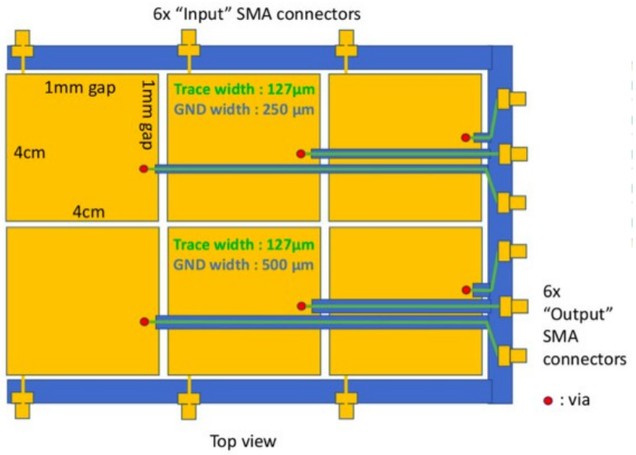
- WADAPT collaboration
  - mockup detetor & transmission chip
  - transmission between layers
- Work :
  - Antennas
  - update existing chips

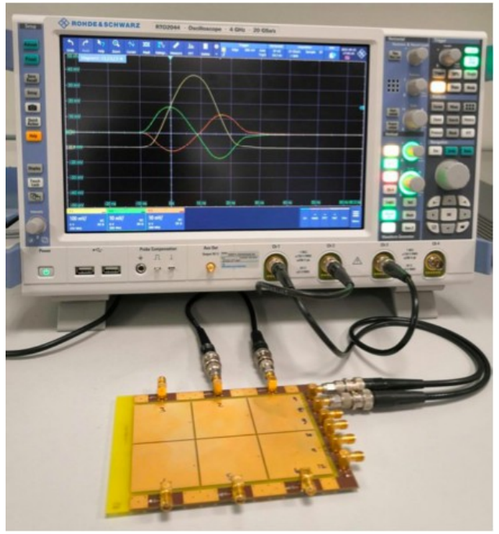


BlueSky:
WP13

WP8 – Task 8.2.2 – Future Noble Liquid Gas Calorimeters – PCB Development

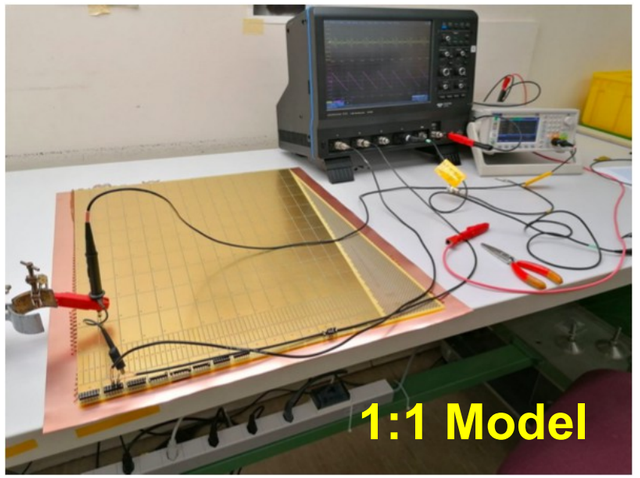
Prototype at CNRS-IJCLab (Even number of layers)





Prototype at CERN (Odd number of layers)

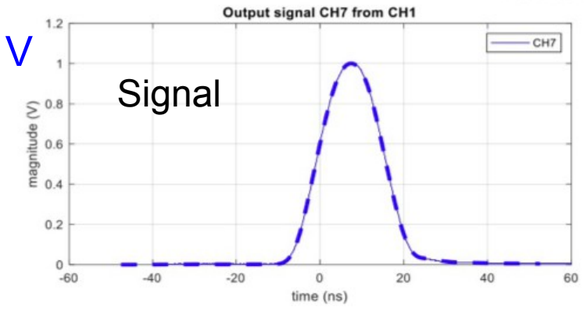
MS31 achieved



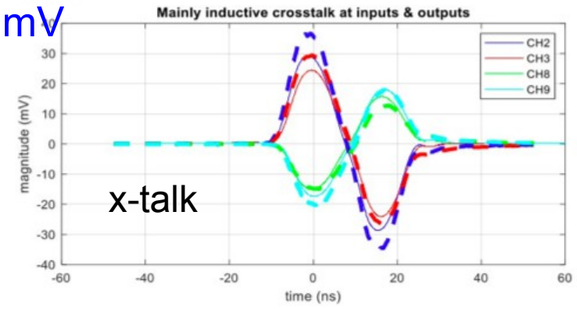
Test bench measurements

Dashed lines: simulation

1V

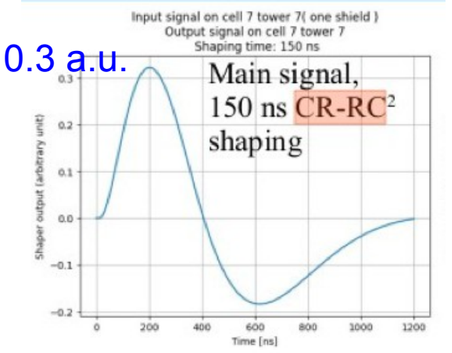


40 mV

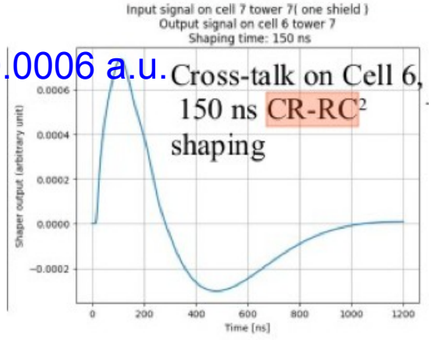


- Small cross talk
- Good agreement between data and simulation

0.3 a.u.



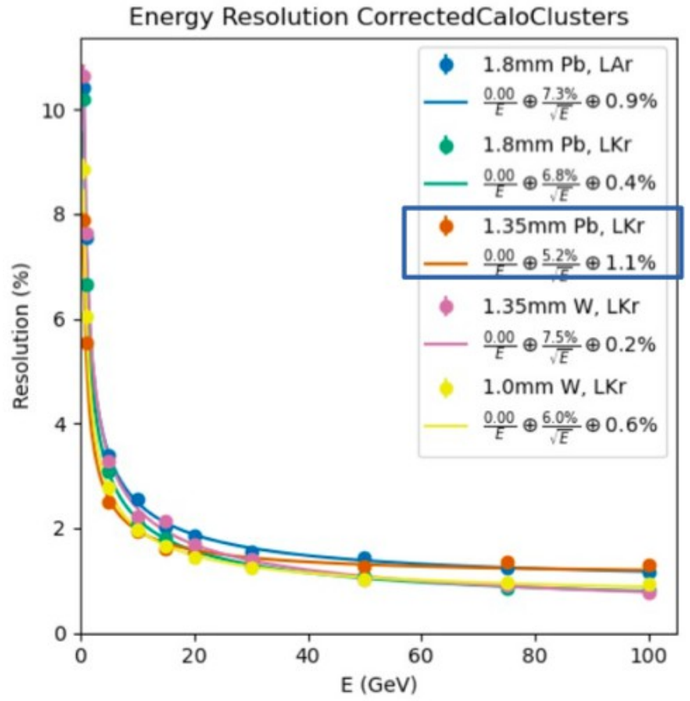
0.0006 a.u.



- Small cross talk
- Only one ground shield (instead of two)

WP8 – Task 8.2.2 – Future Noble Liquid Gas Calorimeters – Software studies

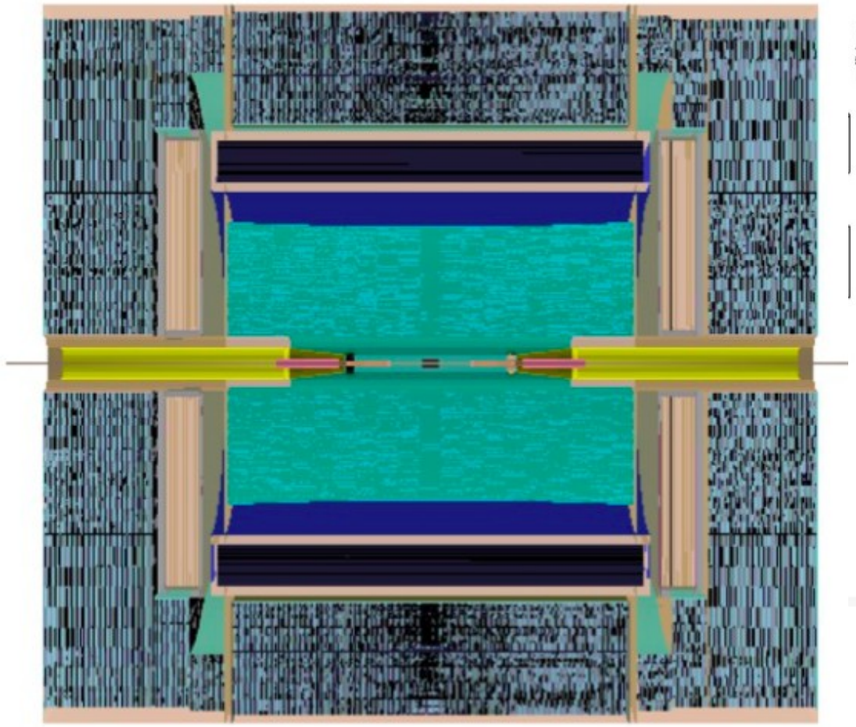
CNRS-IJCLab

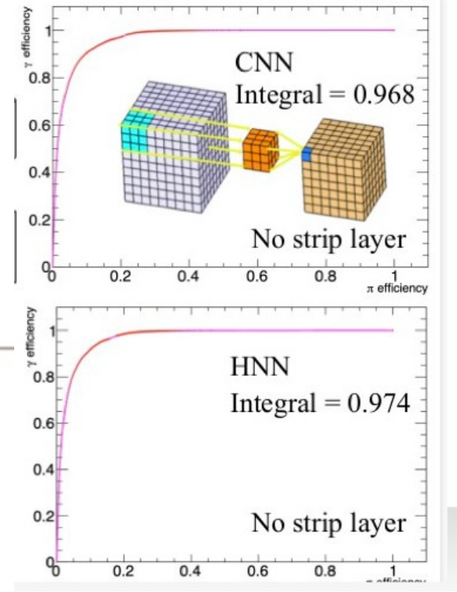


- Simulation studies with different ...
  - ... noble liquids (LAr, LKr)
  - ... absorber materials (Pb, W)

- Best performance with LKr and Pb

CUNI





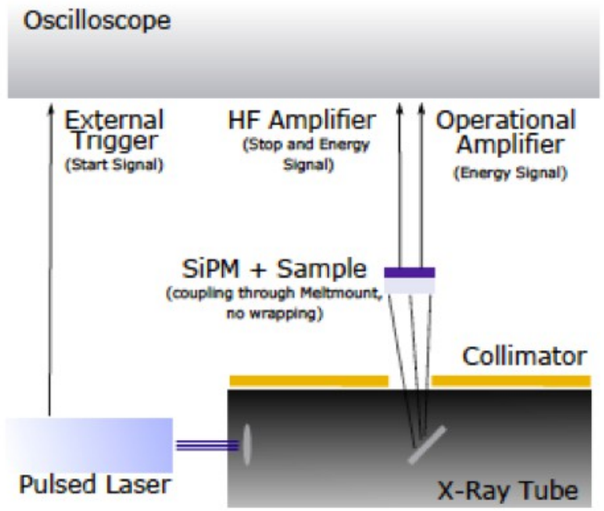
Study of γ/π⁰ separation

- LAr Based Detector DD4Hep
- Full simulation on Key4HEP
- Code ready for performance and physics studies
  - e.g. of γ/π⁰ᶜseparation

WP8 – Task 8.3.1 – Testbenches for characterisation of crystals

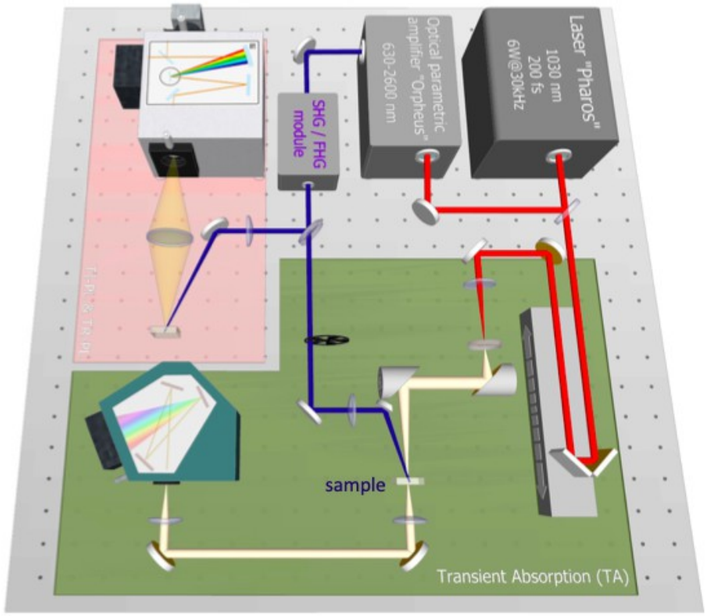
MS30

Testbench at CERN



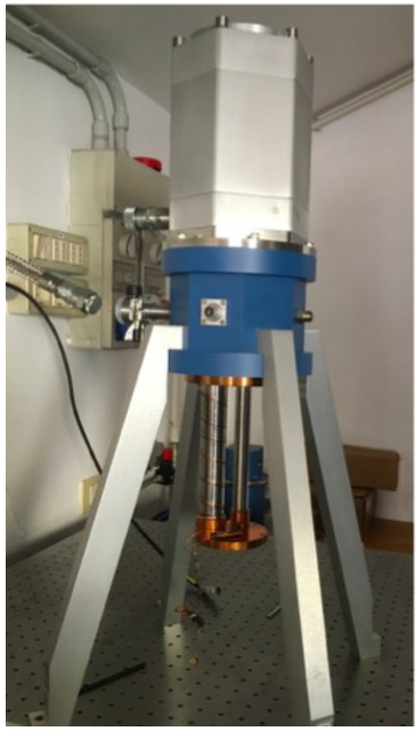
Light output and detector time resolution for low density material

Testbench at Vilnius



Material characterisation by Transient Absorption

Testbench at Perugia



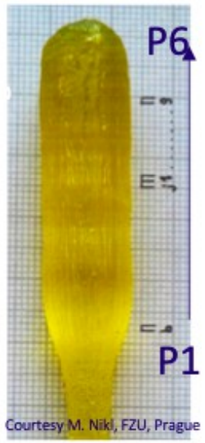
Light output at low Temperatures
(LHe [4K] ou LN [77K])

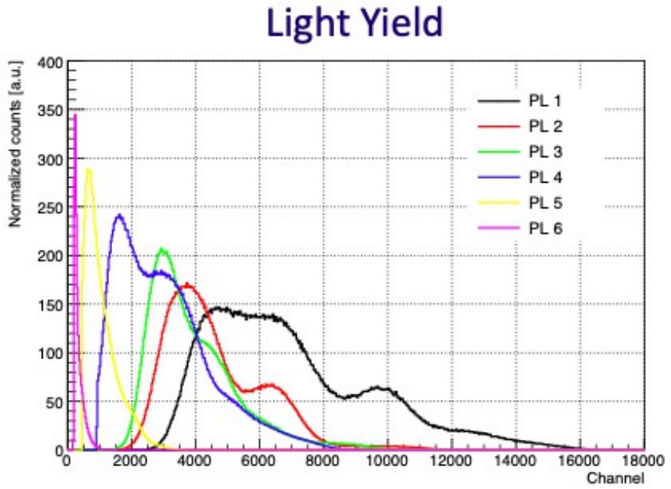
WP8 – Task 8.3.1 – Crystal characterisation

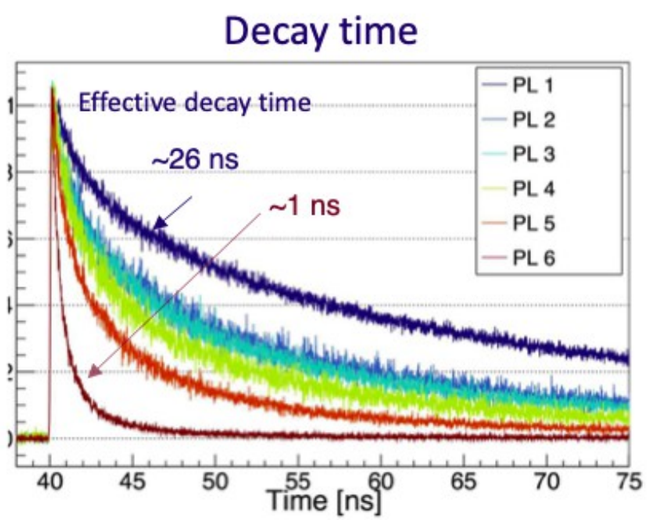
MS30

GAGG:Ce Xtal doped with Ce/Mg

Increased concentration

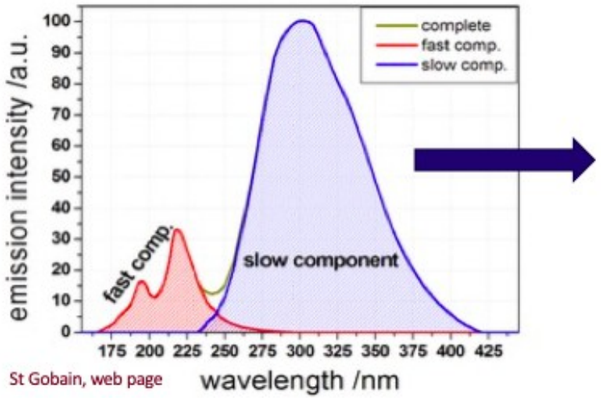


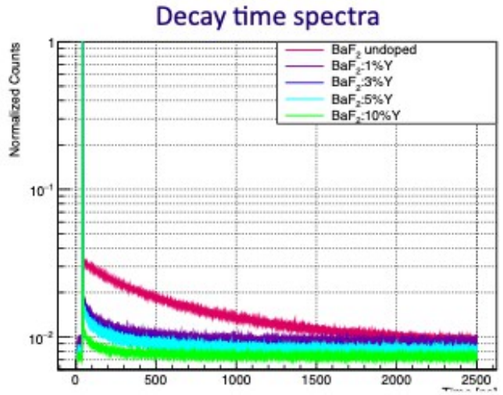


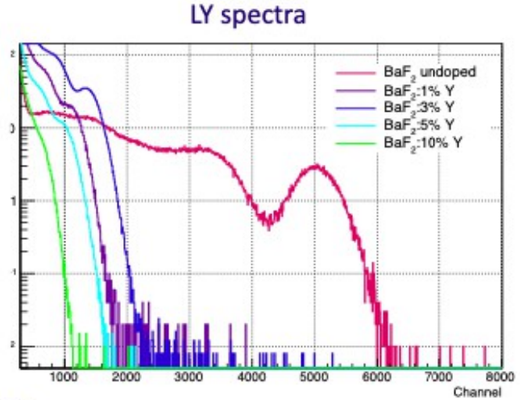


Decrease of decay time with increased doping
(Lower light output has no influence on time resolution)

BaF2 with Y





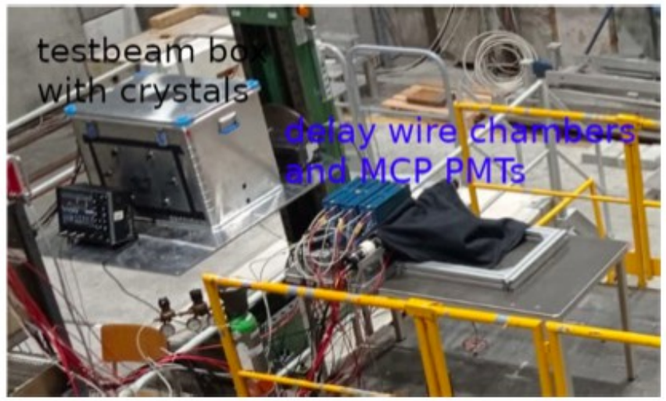


CTR

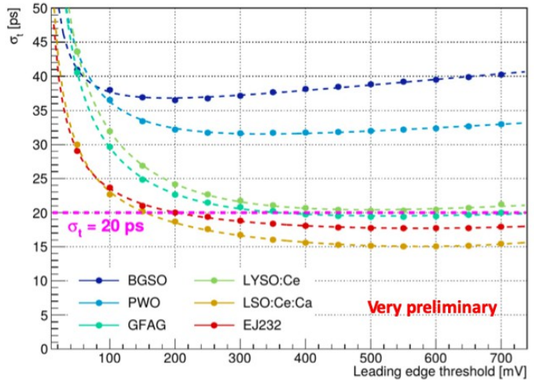
Suppression of slow component of BaF2

WP8 – Task 8.3.1 – Testbeams

Testbeam to study time resolution of crystals



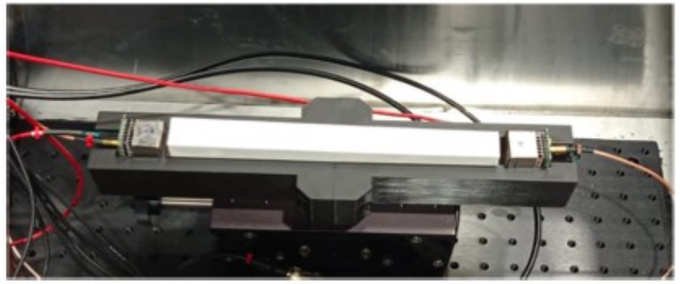
Crystal r/o with SiPM and High frequency amplifier



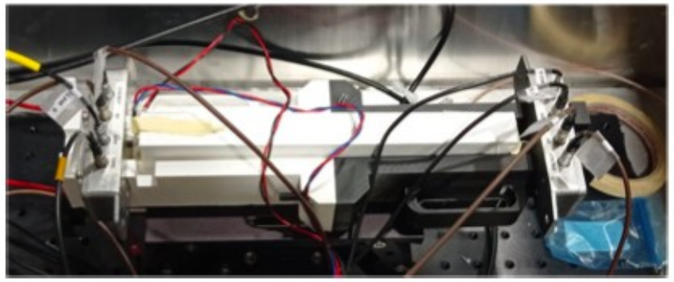
Time resolution at MIP level

Testbeam to study dual readout of PWO

PWO + filters + PMTs

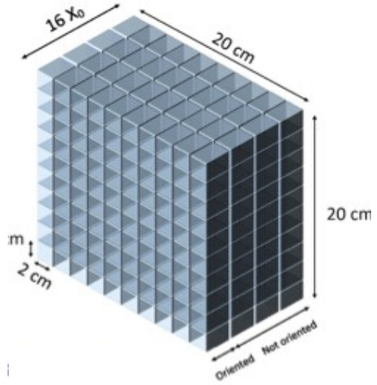


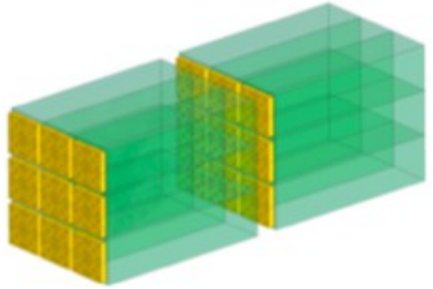
PWO + filters + SiPMs



Testbeam to study highly granular crystal calorimeters

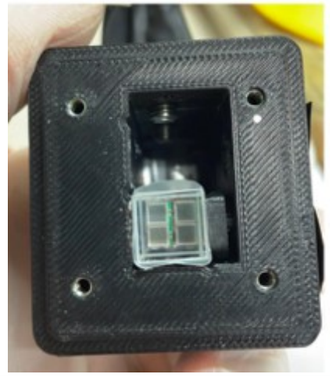
Klever: Concept for Small Angle Calo





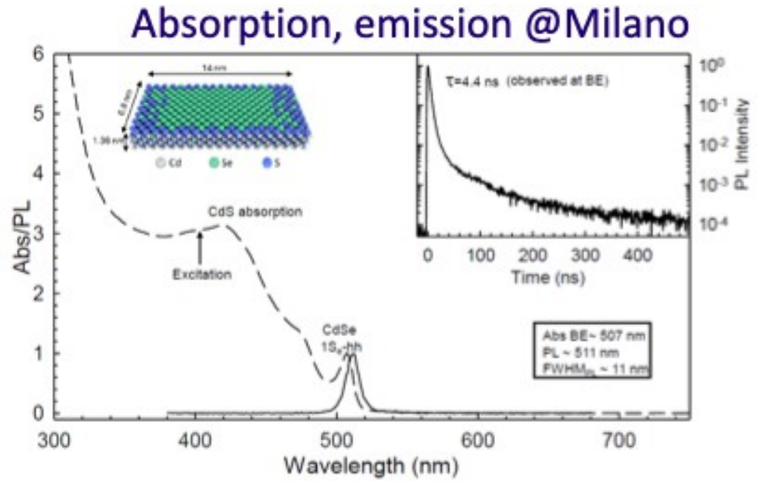
CRILIN Concept (mu collider)

Testbeam at CERN with single crystals



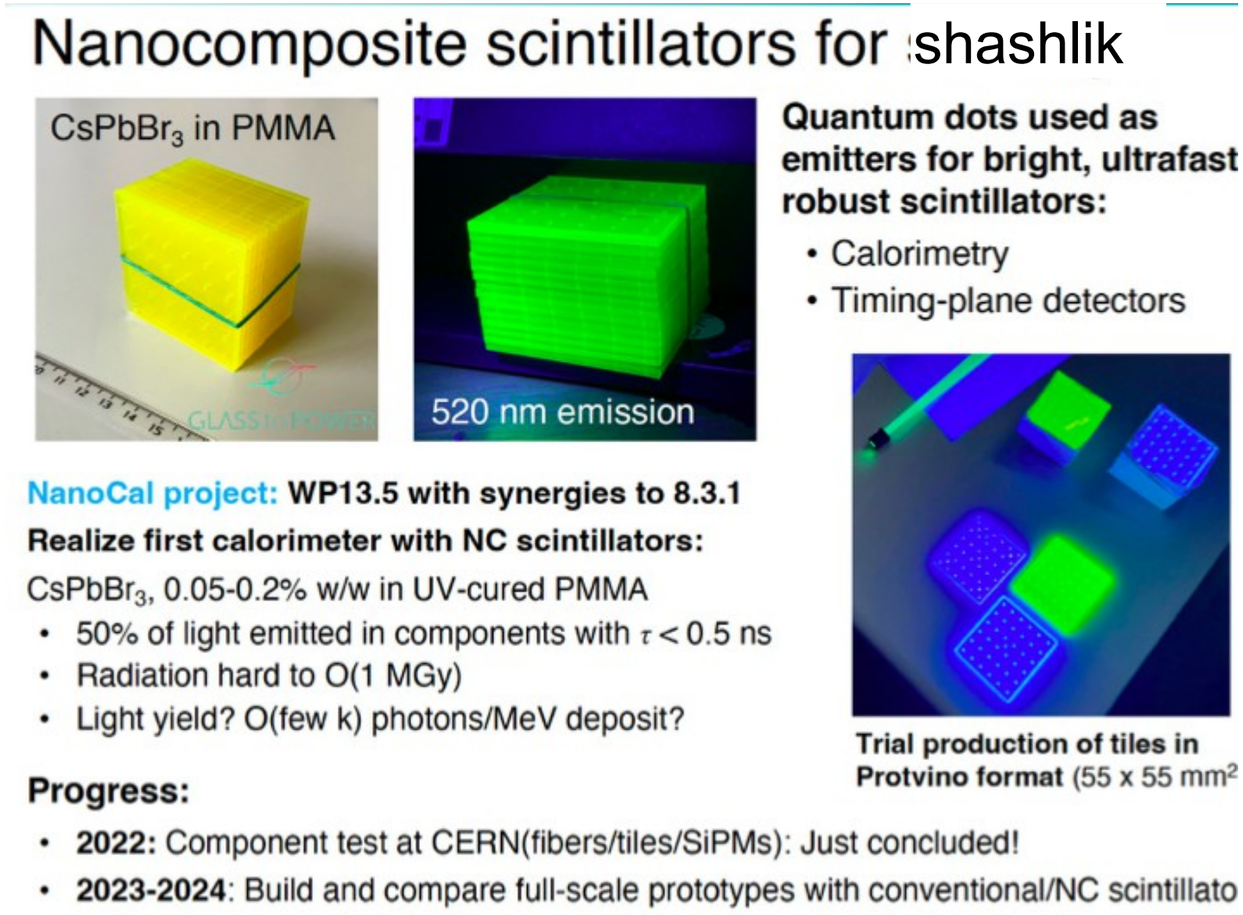
WP8 – Task 8.3.1 – Blue Sky R&D - Nanomaterials

Test of encapsulation of nano materials (Glass2Power)



Absorption and emission spectra demonstrate
Successful encapsulation of nano materials

Toward a calorimeter using nano materials



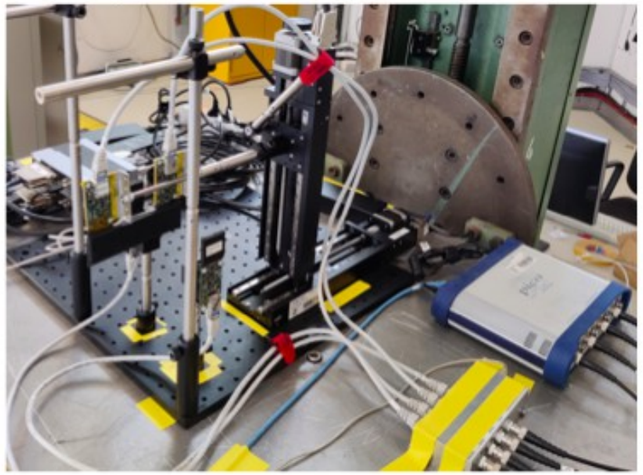
WP8 – Task 8.3.2 – Large area scintillators - 1

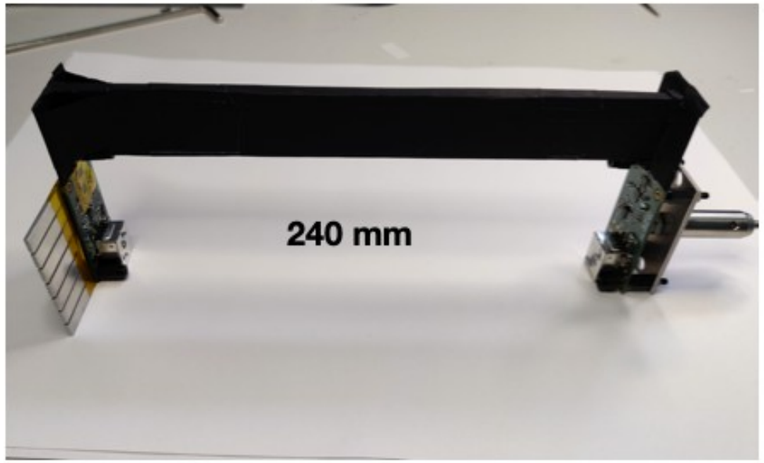
The "DUNE Side"

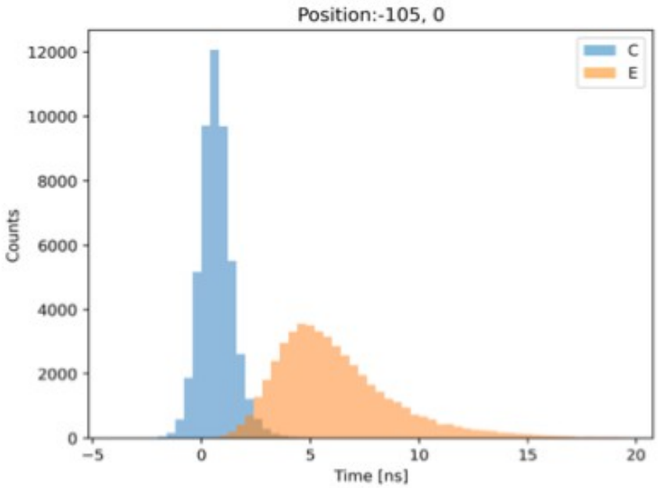
JGU, MPG-MPP

MS33 achieved

- For the investigation of scintillator materials for near-detector calorimeters, test infrastructure has been built up both at JGU and MPG-MPP.
- Scintillator bar prototypes have been tested at MPG-MPP and in the DESY test beam using a test system with double-sided SiPM readout, coincidence trigger system and a translation stage enabling automatic scanning sequences across the scintillator bar surface. Setup and first results on Timing:





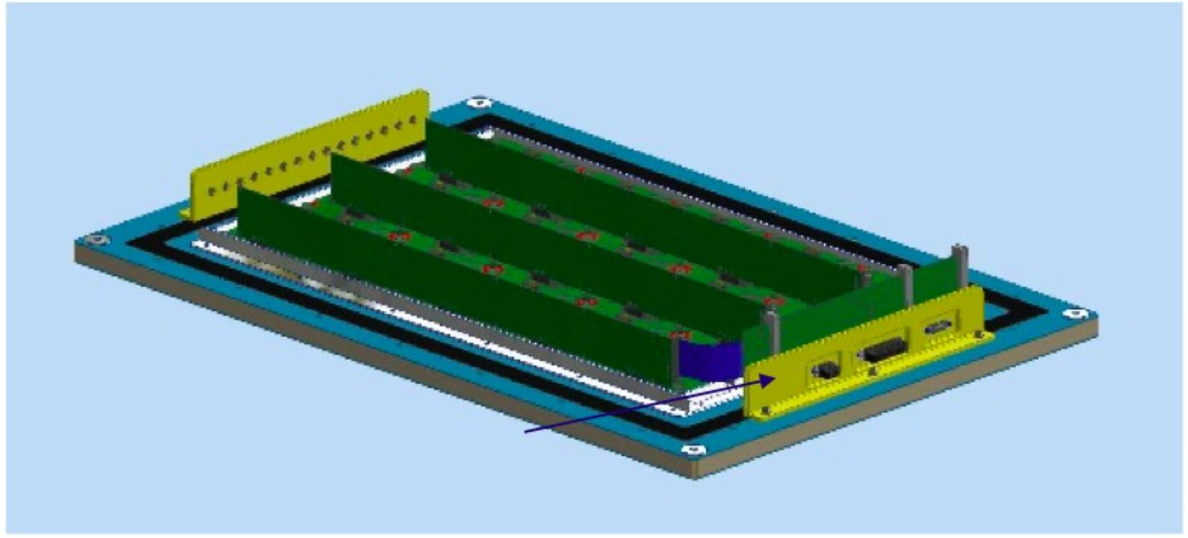


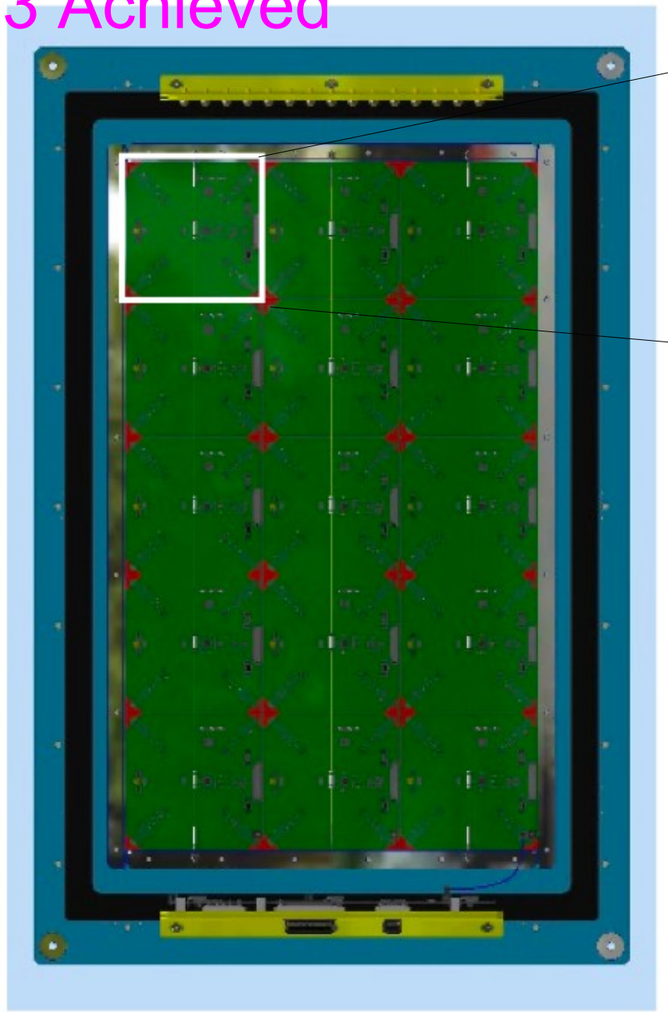
- At JGU, the development of test systems characterising the response of different scintillator materials to neutrons and photons has progressed further.

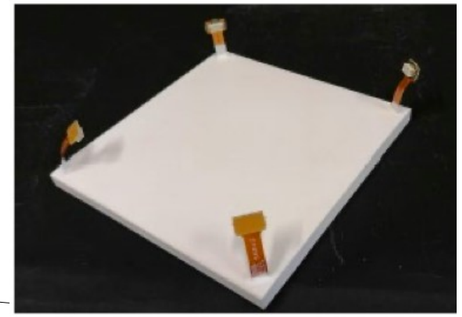
WP8 – Task 8.3.2 – Large area scintillators for e.g. SHiP

MS33 Achieved

- New prototype: 3x5 tile matrix
  - 15 instrumented tiles
  - I2C control lines to set bias voltages, fast comparator thresholds
  - Summed analog output for each tile
  - Digital output from comparators

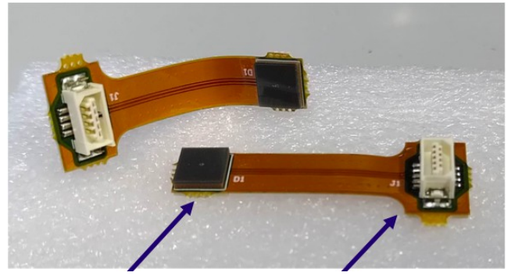






15x15x1 cm^3

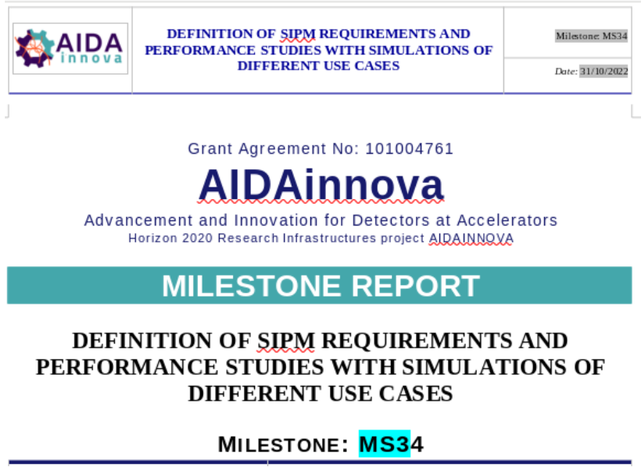
- Choice of scintillator type EJ 200
- Readout at corners by



Hamamatsu SiPM Model S14160-6050HS0

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

MS 34 achieved in M21 – Lead JSI



AIDA innova

DEFINITION OF SIPM REQUIREMENTS AND PERFORMANCE STUDIES WITH SIMULATIONS OF DIFFERENT USE CASES

Milestone: MS34

Date: 31/10/2022

Grant Agreement No: 101004761

AIDAinnova

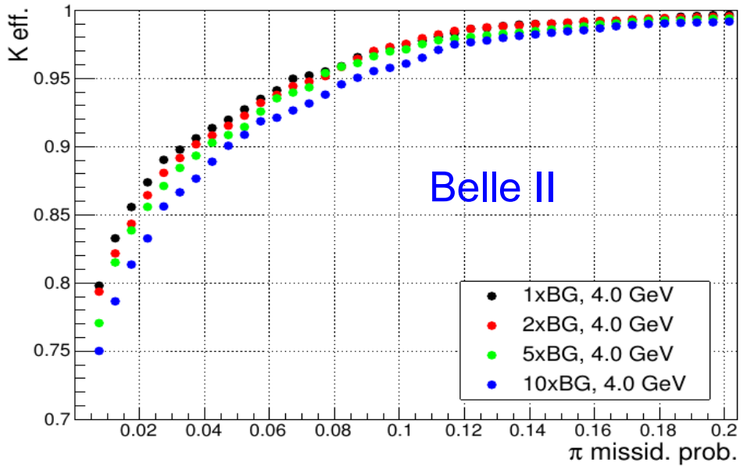
Advancement and Innovation for Detectors at Accelerators

Horizon 2020 Research Infrastructures project AIDAINNOVA

MILESTONE REPORT

DEFINITION OF SIPM REQUIREMENTS AND PERFORMANCE STUDIES WITH SIMULATIONS OF DIFFERENT USE CASES

MILESTONE: MS34

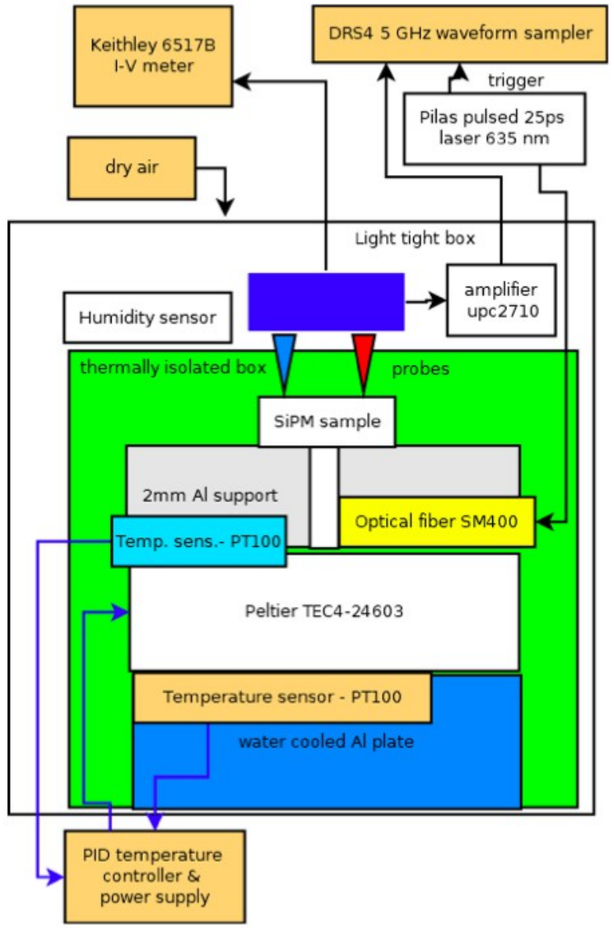


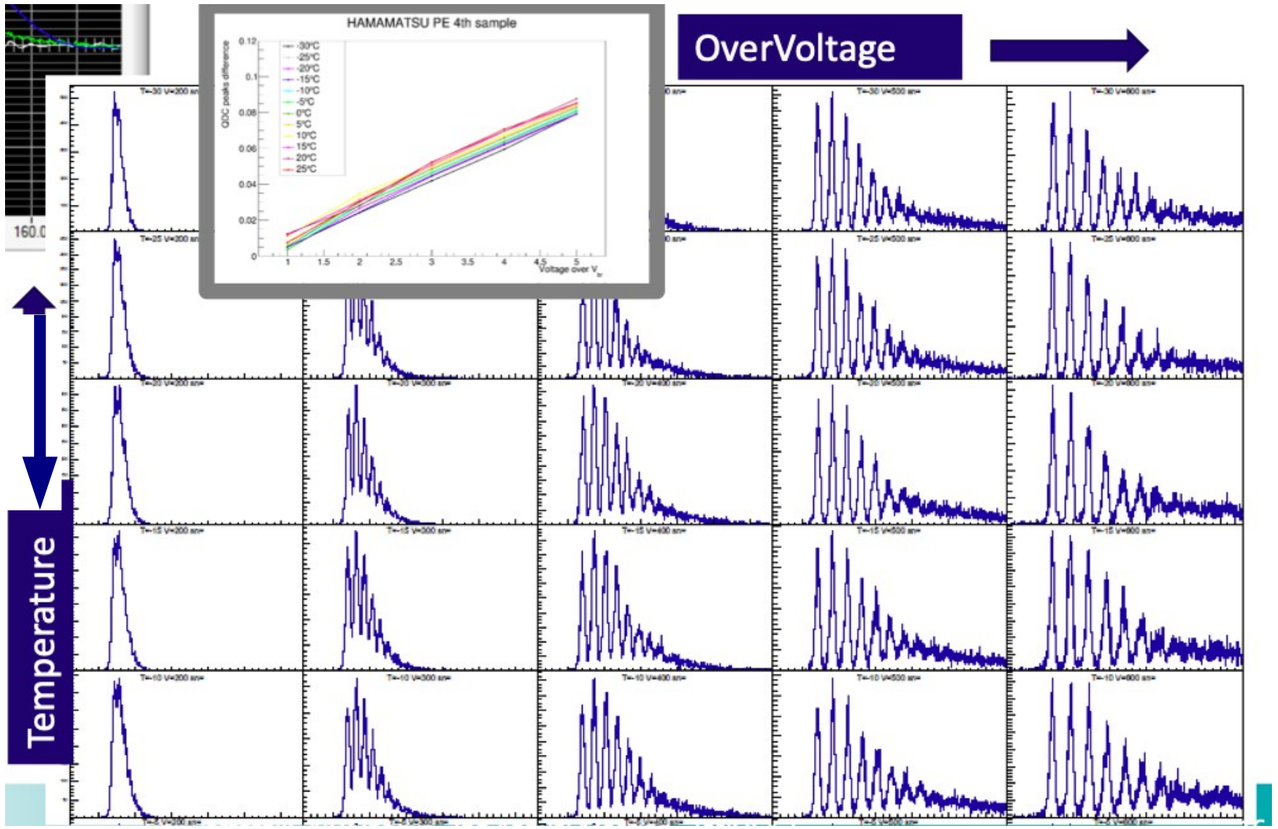
Single Photon Applications

Application	ARICH@BelleII	TOP@BelleII	RICH@LHCb
Sensor size	5 mm	6 mm	1 / 3 mm
Single photon sensitivity	+	+	+
Low DCR	+	+	+
Peak PDE	Blue	Green	Green
SPTR (ps)	50	50	100
Operating T(deg. C)	-20 .. 20	20 (in contact with quartz bars)	-100 (Gas vessel @ 20 deg. C)
Light focusing	+	-	+
Area to cover	4.5 m2	0.4m2	1m2/9m2
Fluence neq/cm²	**10^{12}**	**10^{11}**	**$3x10^{13}$**
Trigger rate	30 kHz	30 kHz	40 MHz
Phot. incident angle deg	0-30	0-90	0-10
Start	**2035**	**2028**	**2033**

Different requirements for e.g. LHCb and Belle II

WP8 – Task 8.4.1 – SiPM characterisation at different temperatures





- e.g. LHCb requires cryogenic environment
  - Here setup for temperatures between -35 and 25°C
  - Setups to measure -196 and -20°C well advanced
- Room temperature measurements for Belle II see talk by E. Torassa

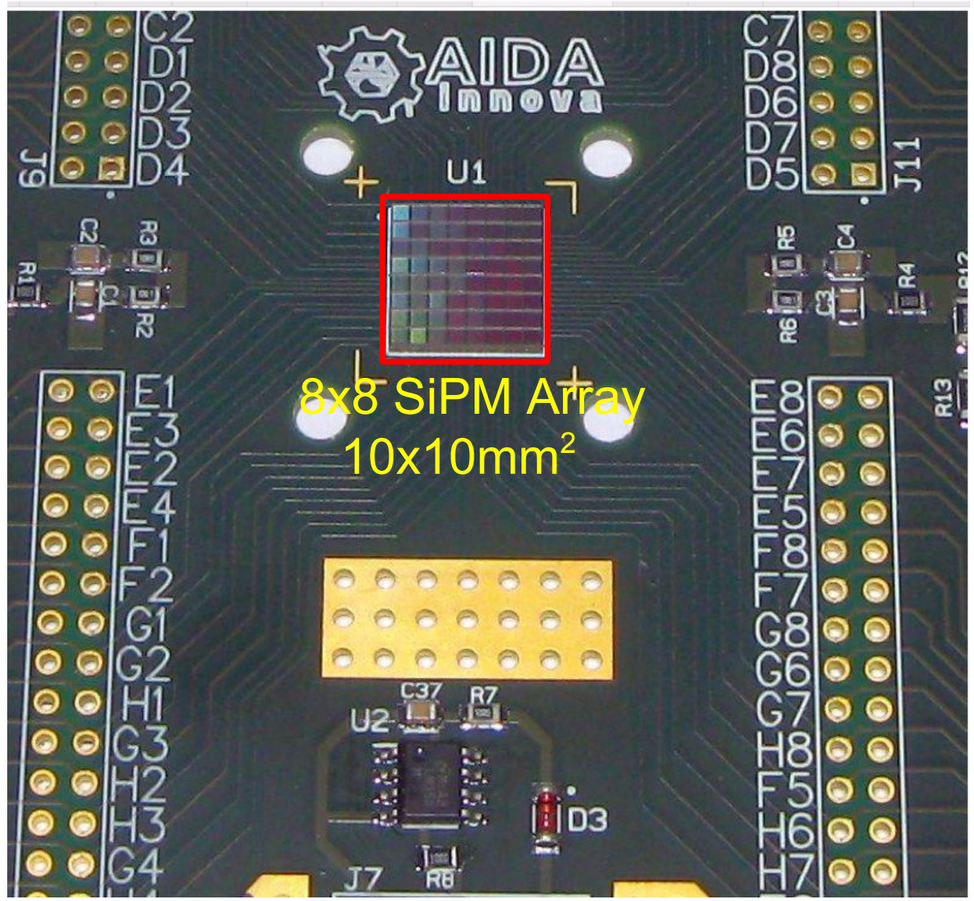
WP8 – Task 8.4.1 – FBK Activities

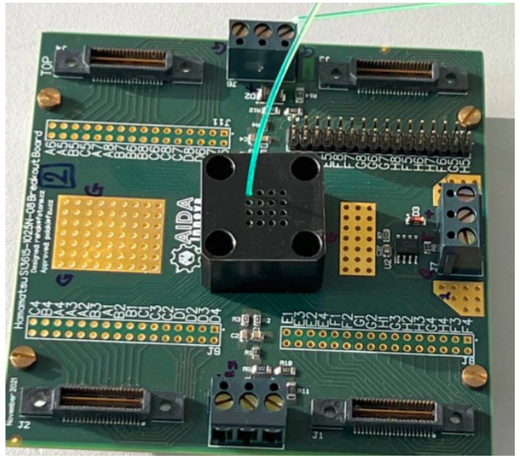
- *Current work:*
  - *Analysis and review of the data on currently available FBK SiPM* technologies, including NUV-HD-RH and new variantsDefine *suitable testing procedures* for future measurements in collaboration with AIDAinnova partners
- *Plan:*
  - Study / modeling of the effects of radiation damage on SiPM characteristics, under different sources of radiation.
  - *Design an optimized SiPM run*
  - *Fabricate SiPMs in FBK clean-room – in Q3/Q4 2023.*
  - Characterize the newly produced SiPMs.

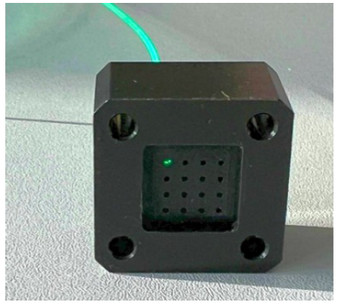
WP8 – Task 8.4.1 – SiPM array for TileCal Application

One Photon --> Many Photons *FZU, U Bergen/U Göttingen,* ***FOTON***

Industrial Beneficiary

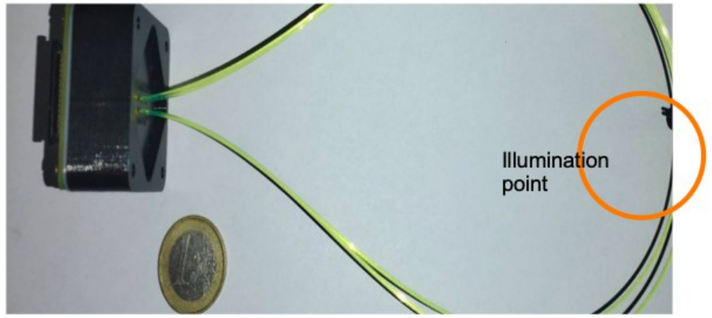


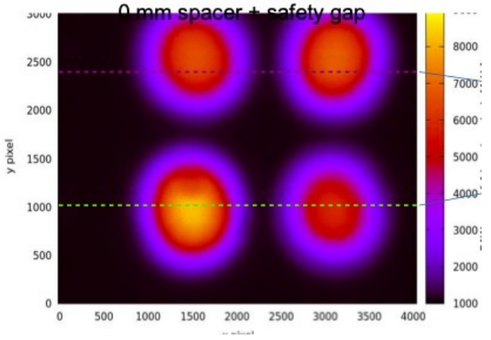




SiPM Array woth flange to illuminate 4x4 SiPM with fibres

Control light output of optical fibres

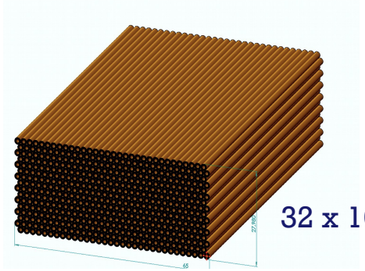




Next steps: Integration of pre-amplifiers and adaptive power supply

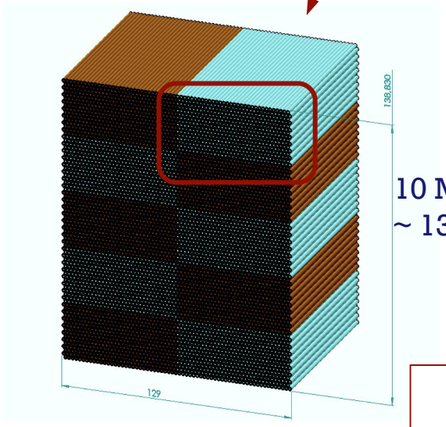
WP8 – Task 8.4.2 – Development of highly granular dual-readout fibre-sampling calorimeter

The Mini-Module

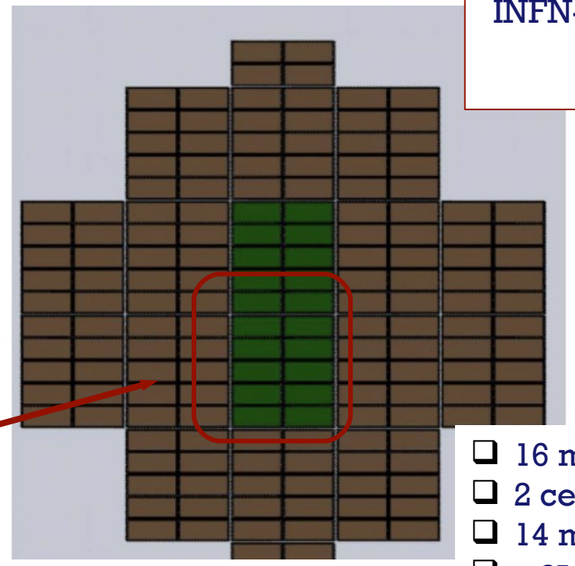


32 x 16 capillaries

The Module



10 Mini-modules
~ 13 x 13 x 250 cm^3



INFN-funded R&D project

- 16 modules in total
- 2 central modules equipped with SiPMs
- 14 modules equipped with PMTs
- ~ 65 x 65 x 250 cm^3

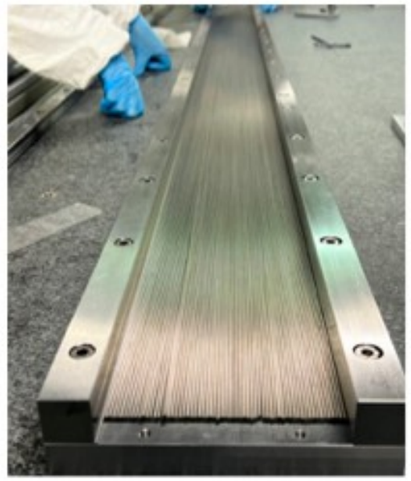
The challenge:

We have 10240 SiPMs, fitting the back side of the detector

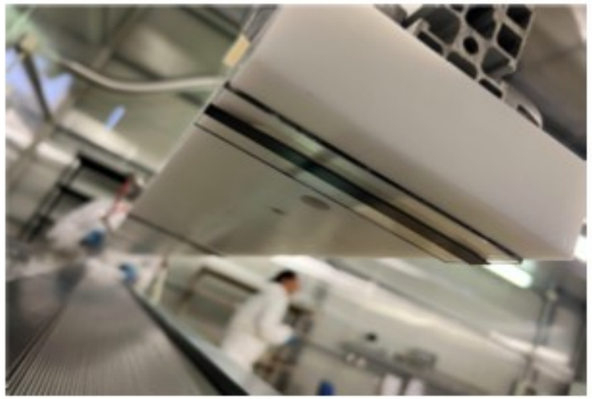
Beneficiaries:
*INFN (PV, MI, PI, BO, CT and RM1), U Sussex, **CAEN***
Collaborators:
South Korea (KNU, KU)
US (U Iowa)

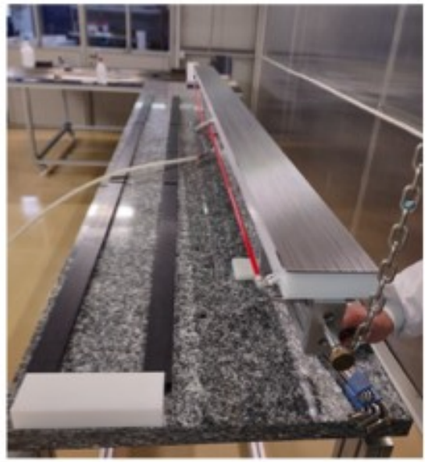
Prototype with hadronic containment: HiDRa

WP8 – Task 8.4.2 – Development of highly granular dual-readout fibre-sampling calorimeter – Module assembly

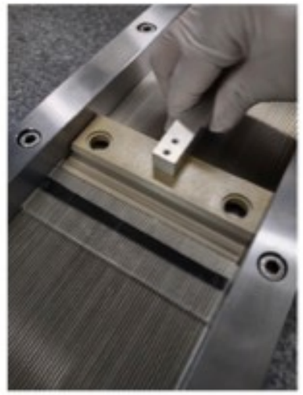


Assembly reference structure anchored to the granite table with the 1st layer of tubes in place



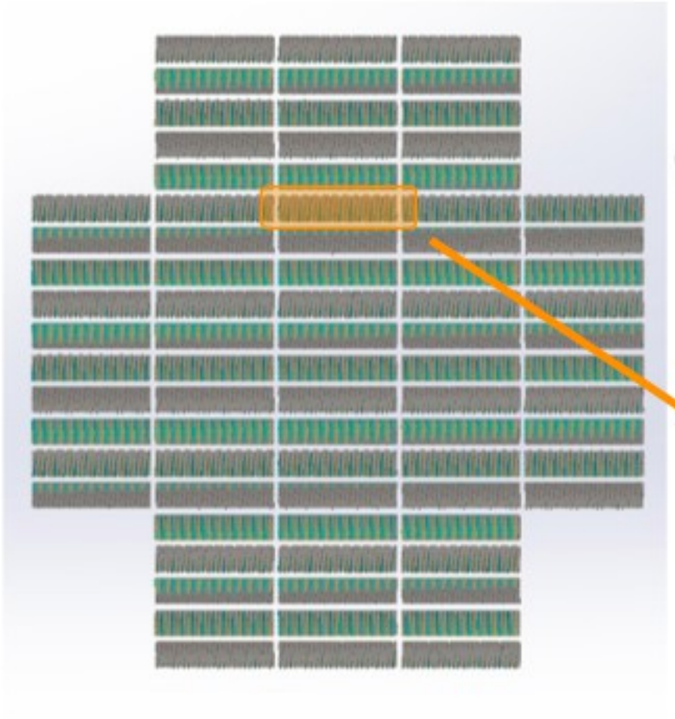


Vacuum + double-sided tape for tube handling



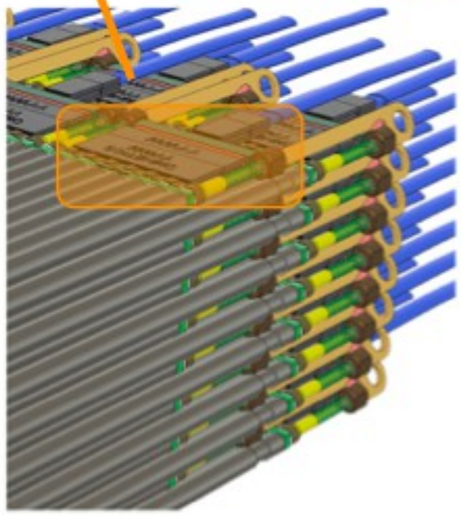
Glue dispensing and tube alignment and positioning

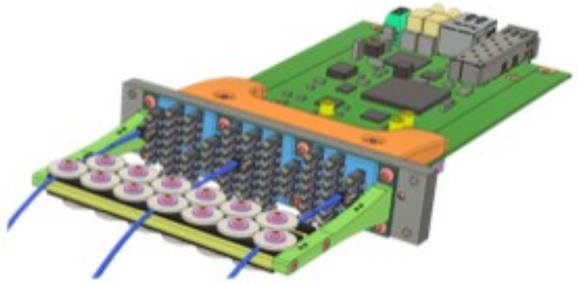
WP8 – Task 8.4.2 – Development of highly granular dual-readout fibre-sampling calorimeter – Module assembly



The front-end board with signal grouping

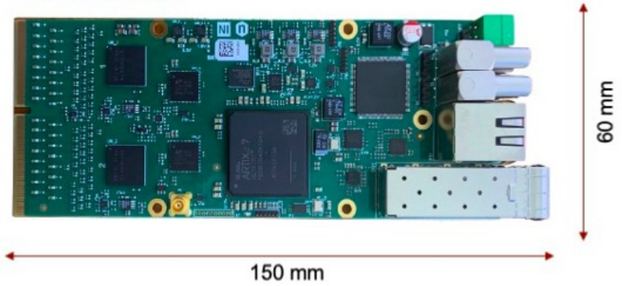
The mini-module





1 readout board serves 64 front-end boards with grouping: half mini-module

FERS: A5202



... in cooperation With CAEN

WP8 – Summary and outlook

- WP8 on track
  - Already rich set of results
  - All milestones achieved
  - Active participation of industrial partners

- Face-to-Face Meeting in January 2023
  - Will allow for seeing more facettes of workpackage

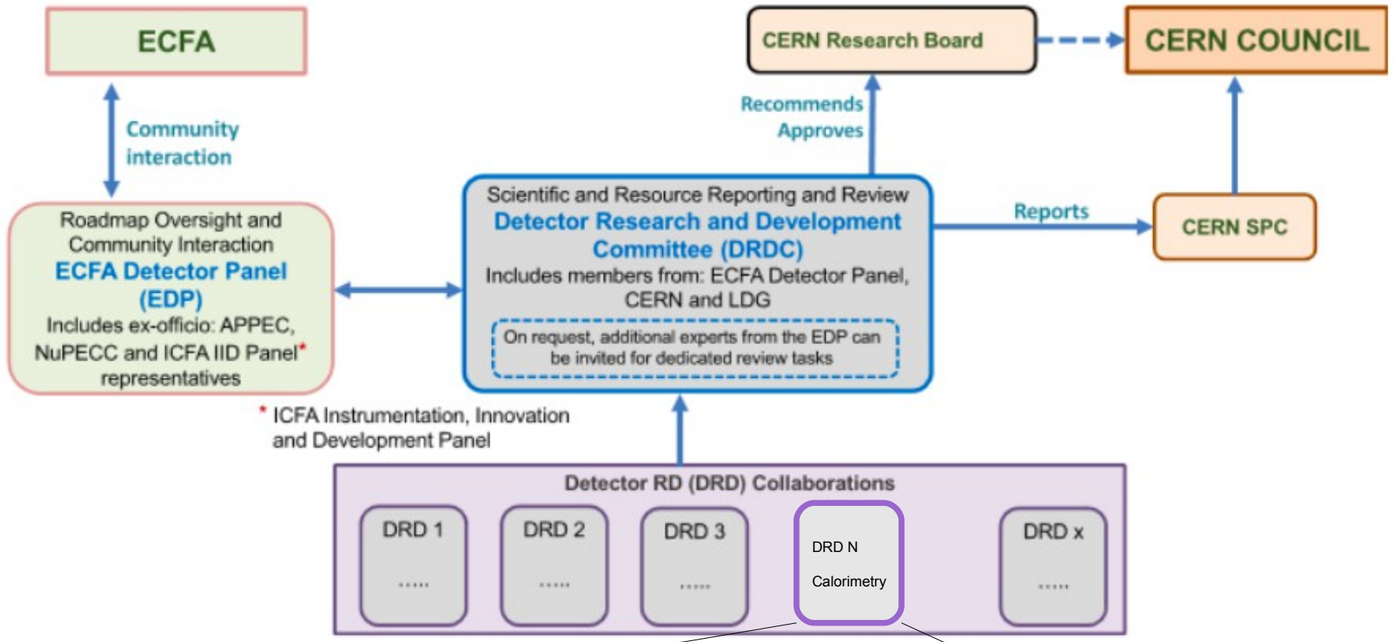
- Will put from now on also emphasis on publication record

- WP8 is also “nucleus” for DRD Calorimetry and a forum to connect planning level with working level at an early stage
  - Improves mutual understanding right from the beginning
  - Forum for identification of synergies
  - Might be necessary to clarify the role of the WP when DRD gets going in 2024
  - Initially AIDAinnova may be one of the few sources for dedicated funding

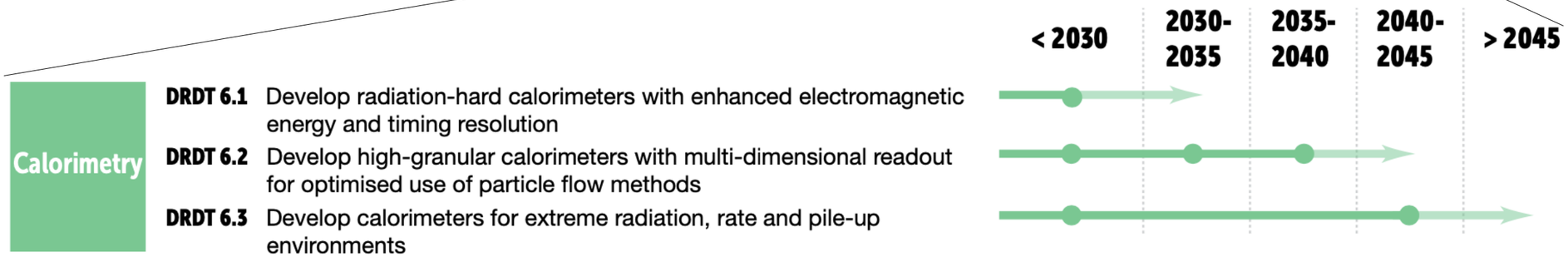
Towards DRD on Calorimetry

Proposed organisation scheme :

Endorsed by CERN Council in Sept. 2022



Research themes calorimetry:



110 Institutes from four continents have declared interest to join DRD on Calorimetry

Towards DRD on Calorimetry

Management: Gouvernmental and executive bodies including Speakers Bureau (→ Dissemination)

Work Areas: Will deliver monitorable results and enable R&D with shared interest

- Technologies will emerge from input-proposals
  - Maybe after some minor regrouping

Full integrated sampling Calorimeters ~Track 1	Liquified Noble Gas Calorimeters ~Track 2	Optical Calorimeters ~Track 3
· Technology 1 · Technology 2 · ….		· Technology 1 · Technology 2 · ….

Network established by existing collaborations and European Projects as **AIDA-2020, AIDAinnova** etc. is instrumental to set up the DRD

Transversal Activitites (common collaboration interests):

- Materials
- Photodetectors, Electronics and DAQ
- Testbeam Facilities snd Infrastructure
- Detector Physics, simulation, algorithms and s/w tools
- Industrial connection + technological transfer

- Transversal Activities are vital for the success of the collaboration
- Transversal Activities will also ensure relations with other DRD

Backup

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