Infrastructure for advanced calorimeters

WP14 Final Report

F. Simon, R. Pöschl

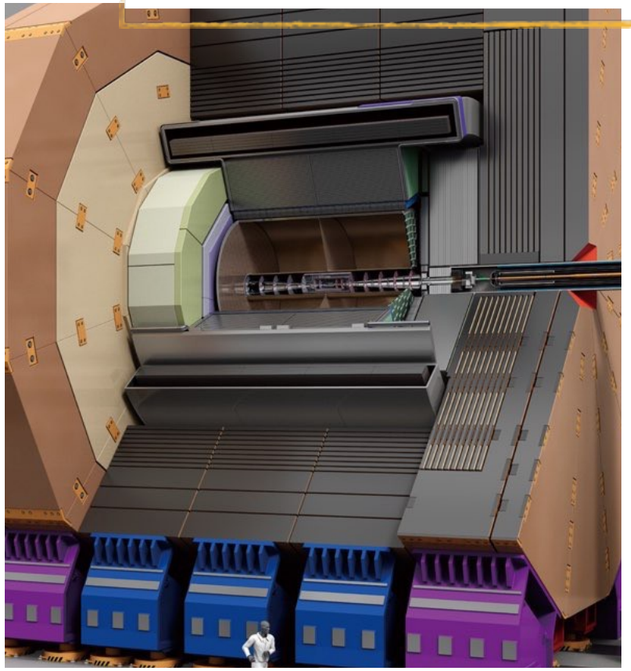
AIDA-2020 Annual Meeting Aprr. 29, 2020

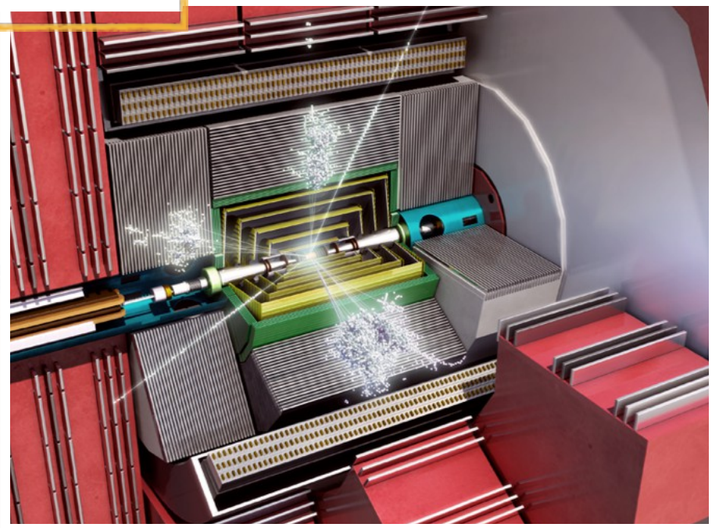
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168.

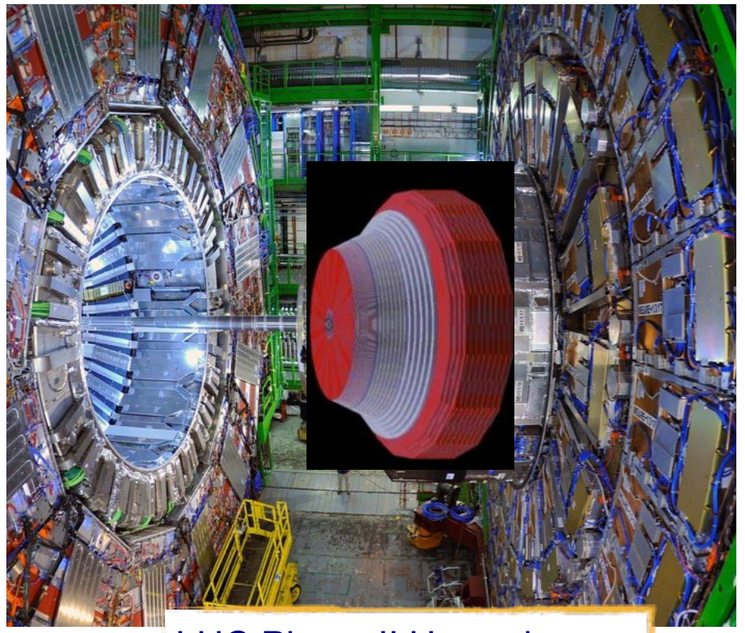
WP14 Introduction

- Calorimeters are key components of HEP detectors - and an area that is currently seeing quite rapid evolution

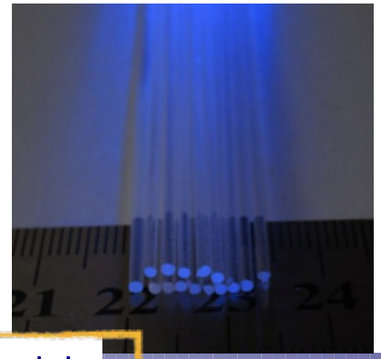
Linear e+e- colliders ILC & CLIC





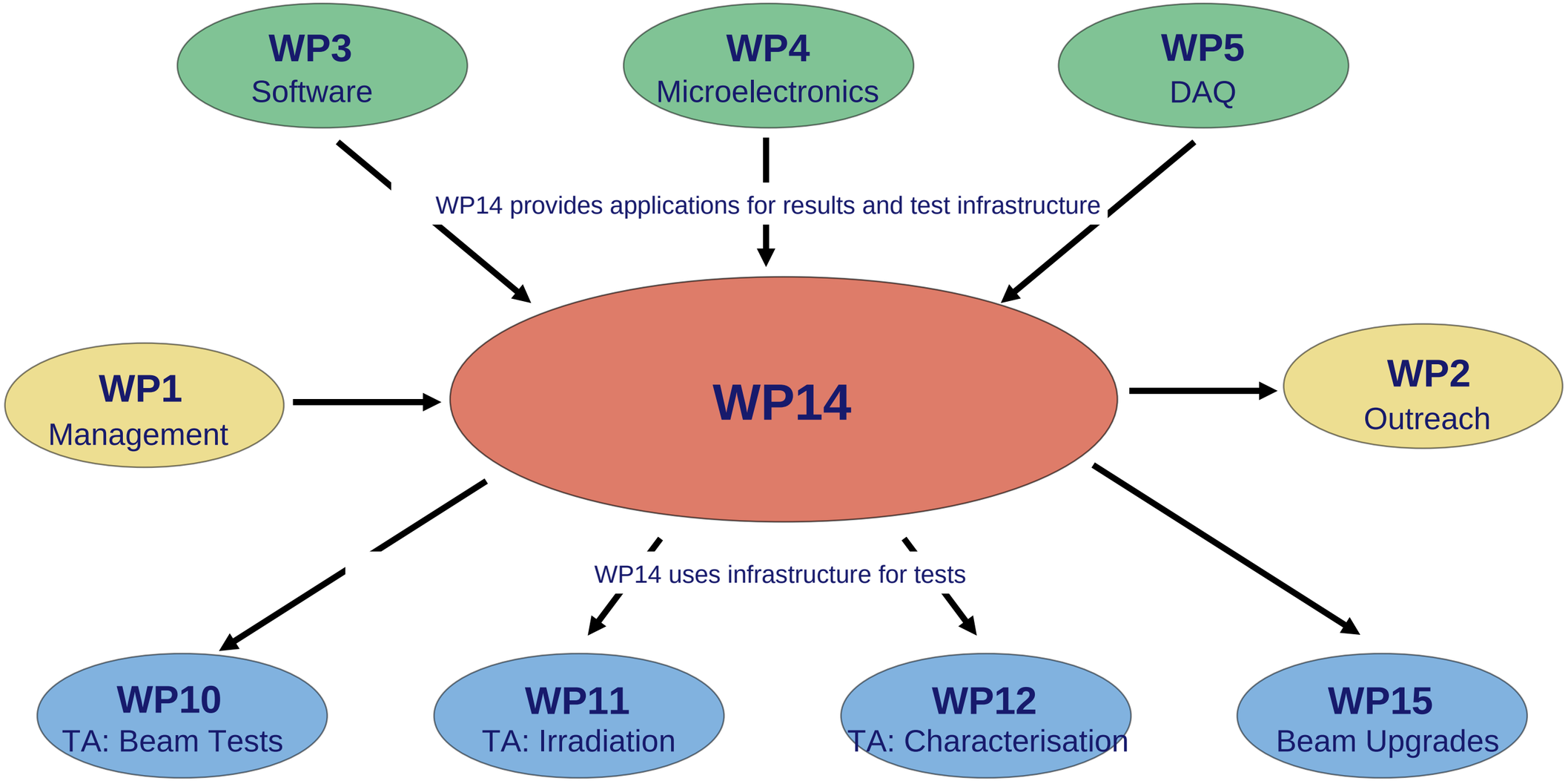


LHC Phase II Upgrades



New Materials

WP14 in AIDA2020



The Tasks/Topics of WP14

- **14.1** Scientific coordination (MPP-MPG, CNRS-LAL)
- **14.2 Test infrastructure for innovative calorimeters with optical readout**
  14.2.1 Test benches for characterisation of organic and inorganic scintillator material (CERN [CERN, RINP, Brunel], INFN [Torino, Roma, MiB, UNIMiB], VU, ETHZ)
  14.2.2 Test benches for the characterisation of highly granular calorimeter elements with scintillator and SiPM readout (JGU, DESY [Uni Heidelberg], MPG-MPP, UiB, IPASCR
- **14.3 Test infrastructure for innovative calorimeters with semiconductor readout**
  14.3.1 Assembly and QA Chain for silicon-based ECALs (CNRS [LLR, LAL, LPNHE], CERN [CERN, Imperial])
  14.3.2 Infrastructure for very compact Tungsten based calorimetry (DESY [Zeuthen], AGH-UST, TAU [Tel Aviv, IFJPAN], Vinca)
- ***14.4* Readout systems for innovative calorimeters**
  14.4.1 LC Calorimetry specific DAQ interfaces (IPASCR, CNRS [IPNL, LLR], DESY [Hamburg])
  14.4.2 Low Power Readout & Monitoring systems (CNRS [LAL, IPNL], DESY [Hamburg, Uni Wuppertal])
- **14.5 Mechanical and thermal tools for innovative calorimeters**
  14.5.1 Precision mechanics for calorimeter structures (CIEMAT [Madrid])
  14.5.2 Infrastructure to evaluate thermal properties of calorimeter structures (CNRS [LPSC], DESY [Hamburg])

WP14 Participants

- Beneficiaries
  - AGH-UST
  - CERN
  - CIEMAT
  - CNRS - IPNL, LAL, LLR, LPNHE, LPSC
  - DESY
  - ETHZ
  - INFN - MI, RTV, TO
  - IPASCR
  - JGU
  - MPG-MPP
  - TAU
  - UiB
  - VU

- Associated Partners - receive funding through beneficiaries
  - CERN: Brunel, Imperial, Minsk
  - DESY: U HD, U W
  - INFN: UniMIB
  - TAU: IFJPAN

WP14 Participants

- Two task leaders for each task - to provide expertise in all topics within a task and to represent the full breadth of the WP14 community

- Work package leaders (and Task 14.1):
  Roman Pöschl (CNRS-LAL), Frank Simon (MPG-MPP)
- Task 14.2: Etiennette Auffray (CERN), Lucia Masetti (JGU)
- Task 14.3: Vincent Boudry (CNRS-LLR), Marek Idzik (AGH-UST)
- Task 14.4: Katja Krüger (DESY), Dirk Zerwas (CNRS-LAL)
- Task 14.5: MaryCruz Fouz (CIEMAT), Denis Grondin (CNRS-LPSC)

- Technology Transfer Officer (TTO): Etiennette Auffray (CERN)

WP14 Overall Status

	Title	Lead Ben.	Task	Month
D14.1	Fibre test benches	CERN	14.2.1	47
D14.2	Performance of test infrastructure for highly granular optical readout	MPG-MPP	14.2.2	40
D14.3	Advanced assembly chain for Si calorimeters	CNRS	14.3.1	36
D14.4	Very compact calorimeters	AGH-UST	14.3.2	57
D14.5	Common running of calorimeter prototypes	DESY	14.4.1	36
D14.6	Updated readout system	CNRS	14.4.2	44
D14.7	Electron beam welding demonstrator	CIEMAT	14.5.1	42
D14.8	Large leak-less system, thermal model	DESY	14.5.2	36

- 8/8 of deliverables completed
- Deliverable 14.4 completed on-time at the end of January 2020
- **WP14 Face-to-Face Meeting on 13/2/20 with summaries and outlooks**
  - https://indico.cern.ch/event/881136/

WP 14 – High Level Summary

- 17 Meetings since May 2015
  - Five (annual) Face-to-Face Meetings at CERN
  - … with guest contributions from other workpackages WP 3,4,5
  - Twelve Taskleader Meetings between AIDA2020 Annual Meetings

- Publications

Publication Score Board *

WP	No. of journal publications	No.of conference/ workshop proceedings	Other publications	Total
14	19	16	27 presentations 4 scientific notes 5 poster	**71**

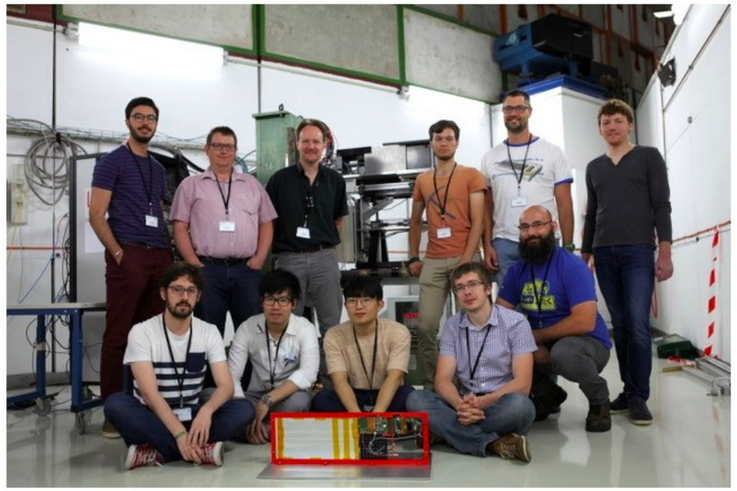
*Own accounting on basis of 'official' scoreboard plus pubs transmitted to management last week

WP 14 – OnTrack Articles

n track
News for the Detector Community

Gearing up to final form

Barbara Warmbein (DESY), 11/12/2017



The SiW-ECAL team at DESY (Image: DESY)

Dec. 2017

n track
News for the Detector Community

New CALICE calorimeter sees beam

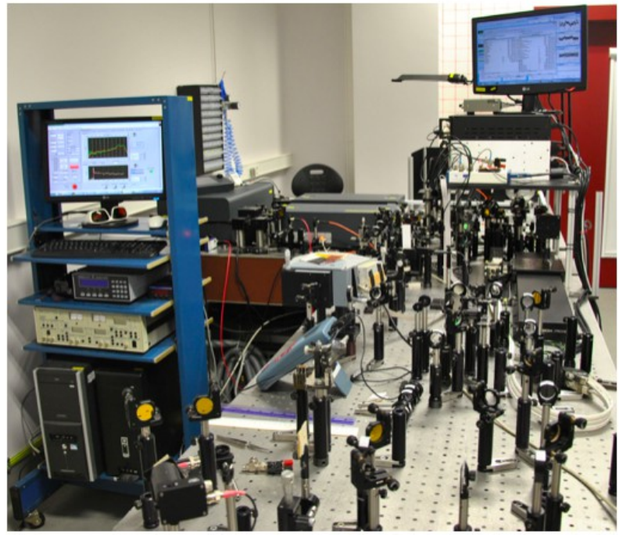
Barbara Warmbein (DESY), 12/07/2018

July 2018

n track
News for the Detector Community

Test benches up and running: tick

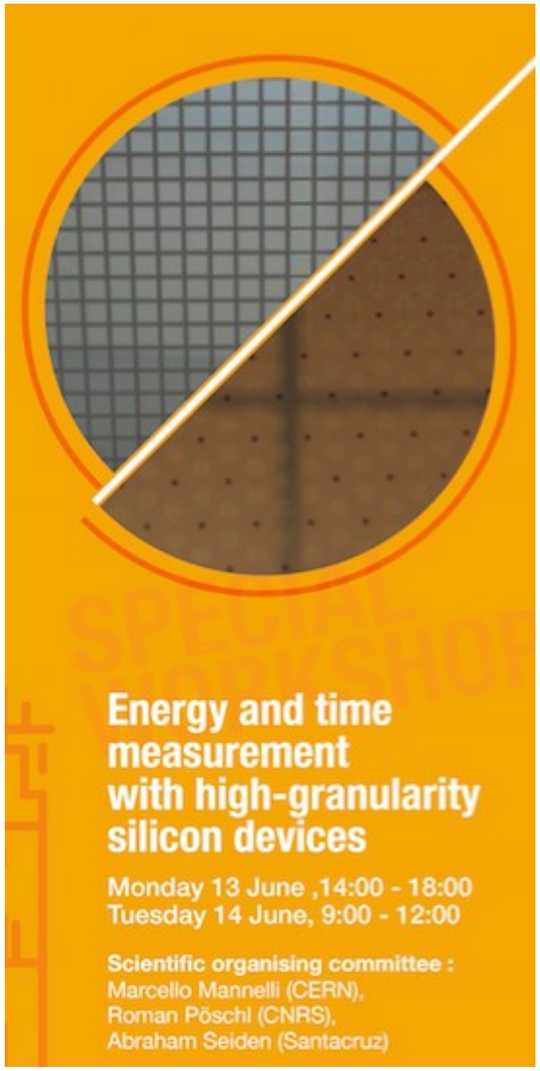
Barbara Warmbein, 25/05/2019



Setup of the pump-and-probe testbench in Vilnius, Lithuania. (Image: AIDA-2020 WP14)

July 2019

WP 14 – Topical Workshop



Workshop on energy and time measurement with silicon devices

13/6/16 – 14/6/16 DESY/Hamburg
during AIDA-2020 Annual Meeting

https://indico.cern.ch/event/468478/overview

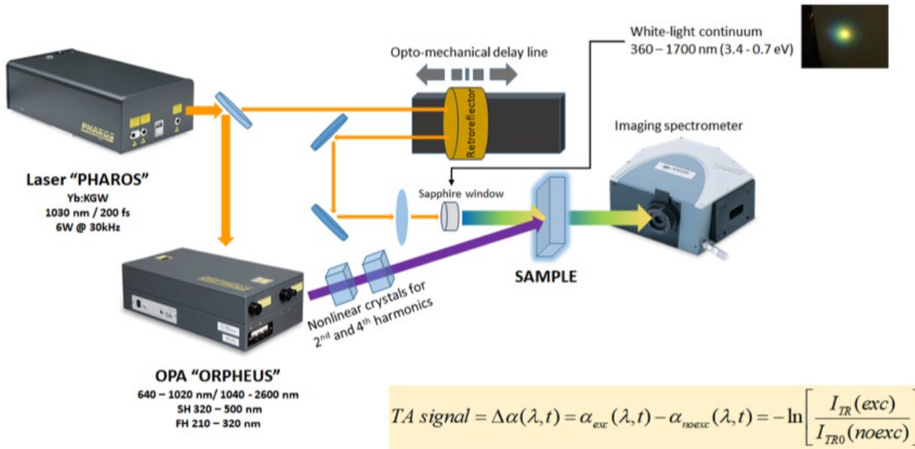
Summary : arxiv:1704.01304, AIDA-2020-NOTE-2017-005

WP 14 – Task 14.2.1

- Deliverable D14.1 “Fiber Test Benches”

A wide range of characterisation tools for f bers:

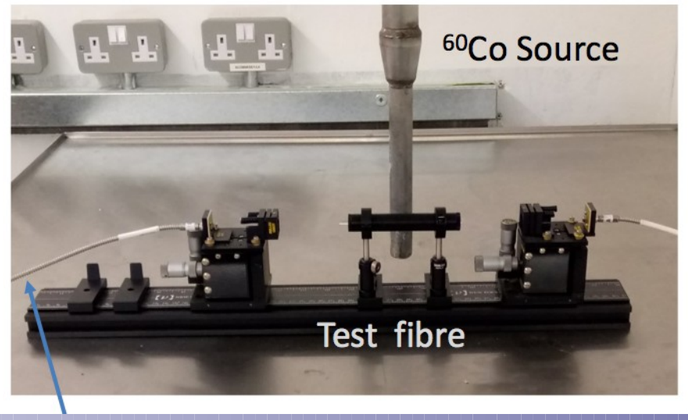
Test benches



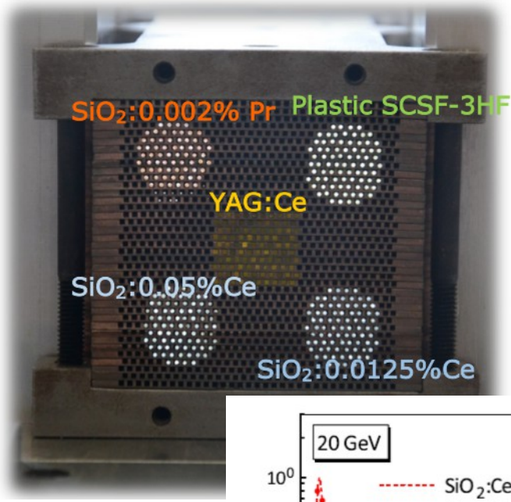
$$TA\ signal = \Delta\alpha(\lambda,t) = \alpha_{exc}(\lambda,t) - \alpha_{noexc}(\lambda,t) = -\ln\left[\frac{I_{TR}(exc)}{I_{TR0}(noexc)}\right]$$

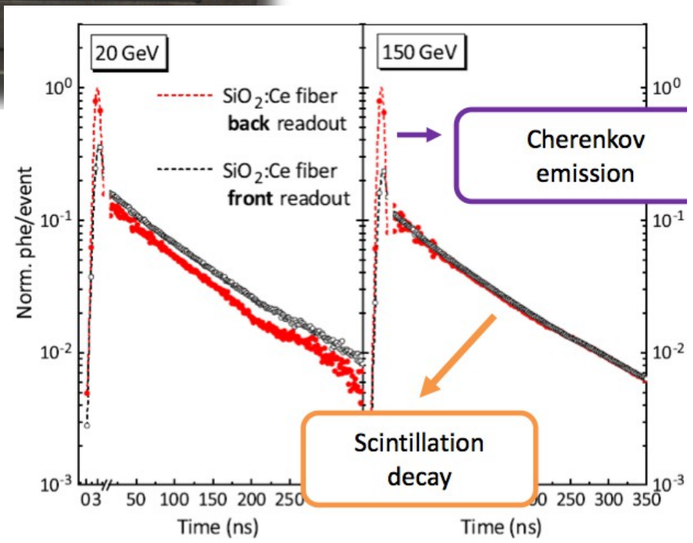
Timing response

transparency & absorption
radiation hardness…
…

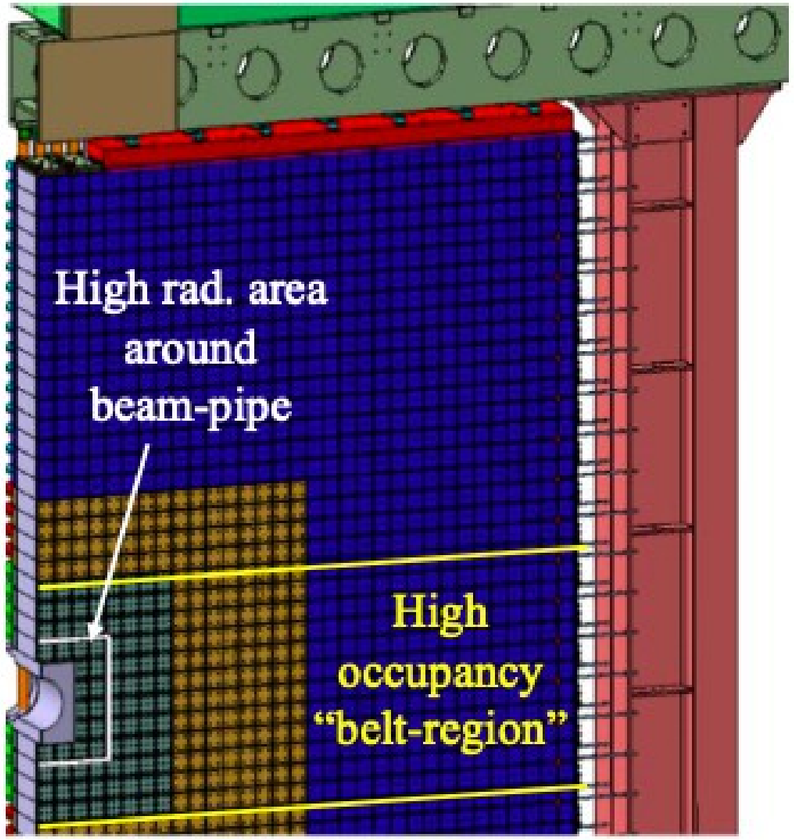


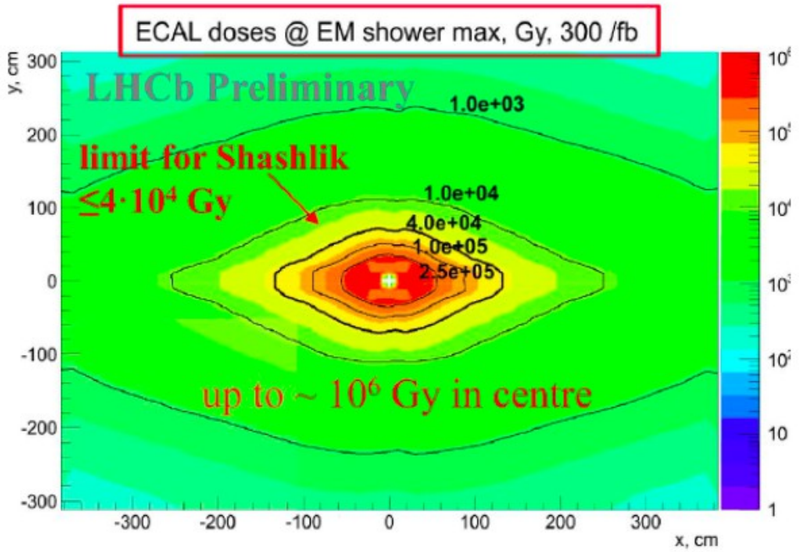
Test beam infrastructure



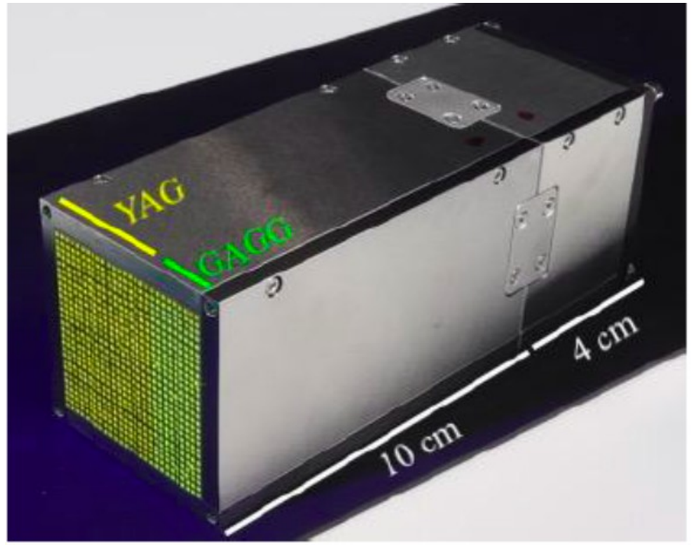


14.2.1 – Potential future project – LHCb Upgrade Phase II





- Detector requirements :
  - Radiation hardness
  - Smaller cell size and Moliere Radius
  - Timing resolution ~10ps
  - Good energy resolution
- Crystal fibres could be a solution



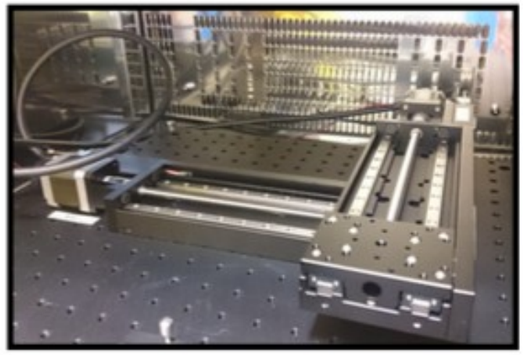
- New compact prototype with pure tungsten
  - Fabricated by Crytur
- 9 cells 1.5x1.5cm^2 made of 1x1mm^2 fibres with long. Segmentaion of 4+10cm
- Crystal fibres :
  - 3 GAGG cells from FOMOS
  - 6 YAGG cells from CRYTUR

Work continues in frame of LHCb upgrade, Crystal Clear and EP-RD WG3

14.2.2 – Granular calorimeters with Scintillator and SiPM

AIDA-2020 Infrastructure

SiPM/Scint. Scanner - MPP

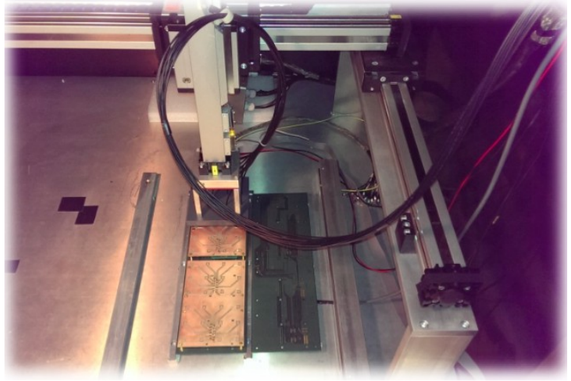


15 cm range translation stages inside the climate chamber

SiPM Gain Stability – UB, Prague

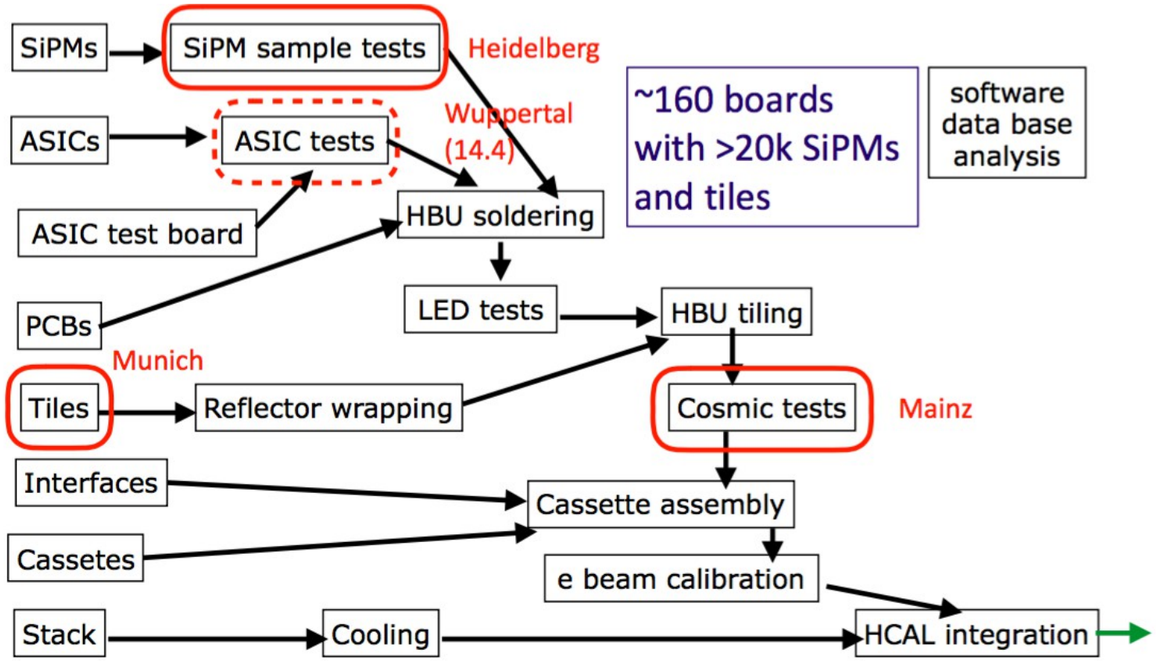
Cosmic Test Bench - JGU

SiPM Characterisation – UHEID



User

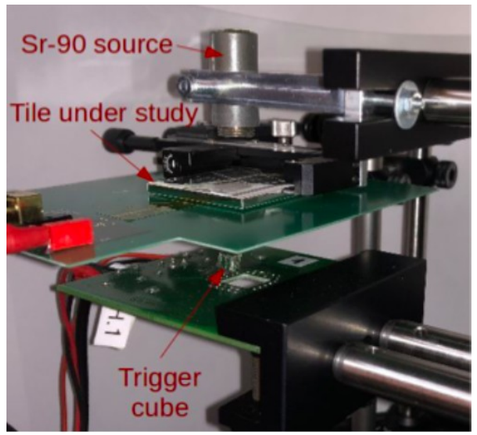
CALICE Scintillator/SiPM hadron calorimeter

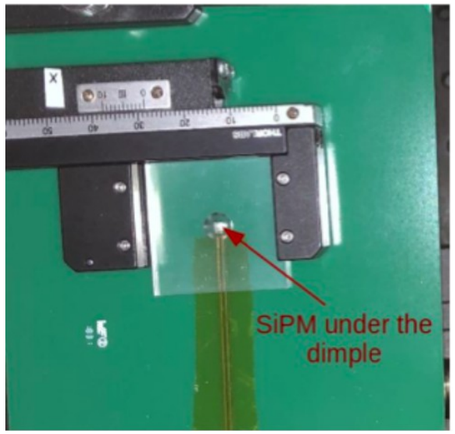


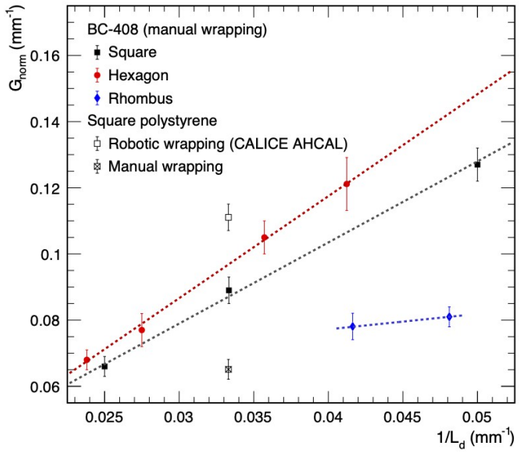
Application to e.g. DUNE ND under study

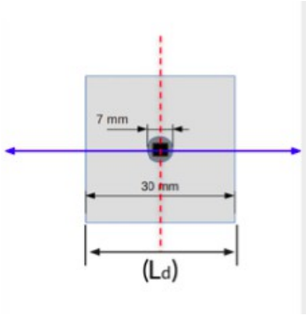
Task 14.2.2 – Use cases

Tile misalignment studies (position of dimple)





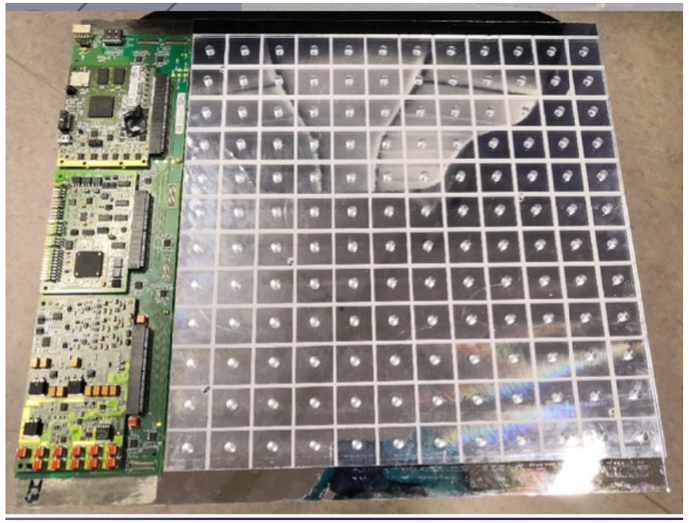




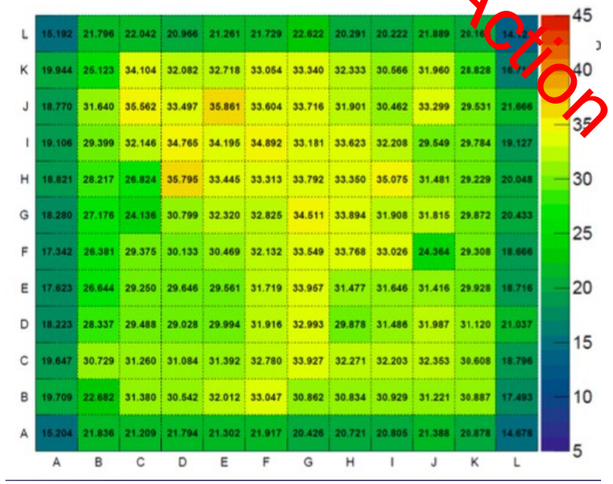
Measurement of light yield asymmetry

Evaluating the Megatile Concept

Year 5 Action



Light uniformity map

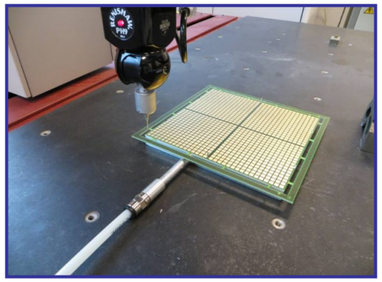


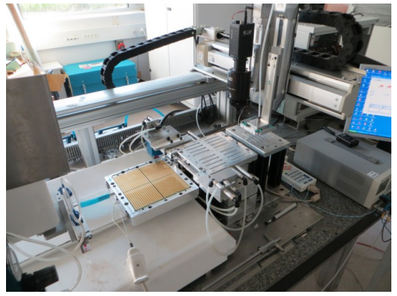
- AIDA2020 enabled these tests that are central for future detectors with large area scintillation detectors

Task 14.3.1 – Assembly and QA Chain for silicon-based ECALs

Assembly of current SiW Ecal prototype

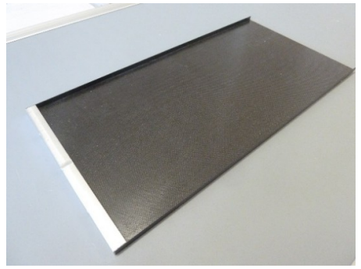
Metrology



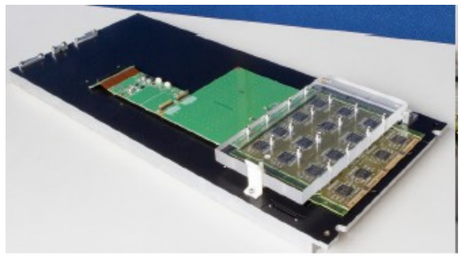


Gluing
(CALICE, ATLAS)

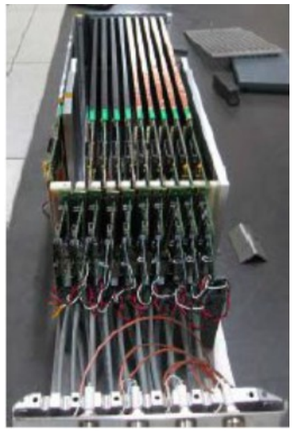
CNRS-LPNHE



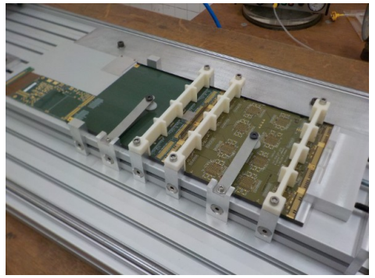
CNRS-LLR



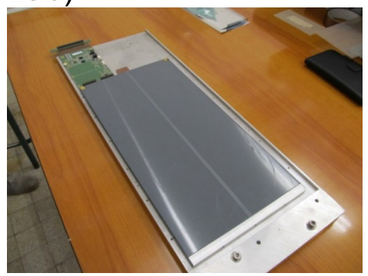
Housing and electronics tests



Prototype



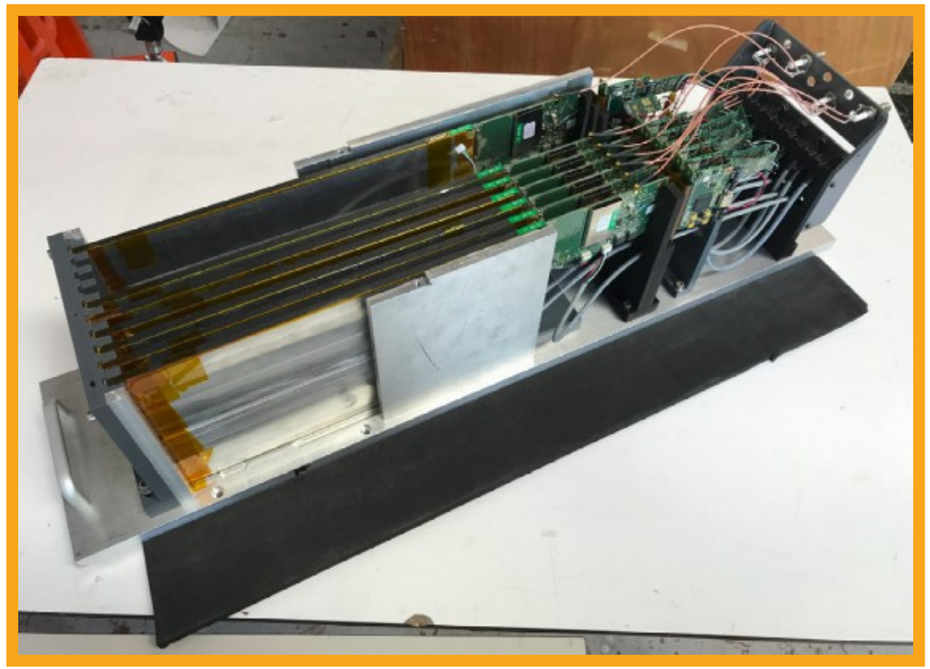
CNRS-LAL (IJCLab)

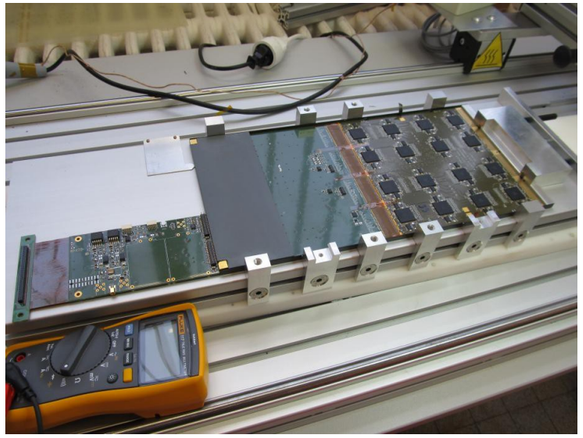


Detector assembly

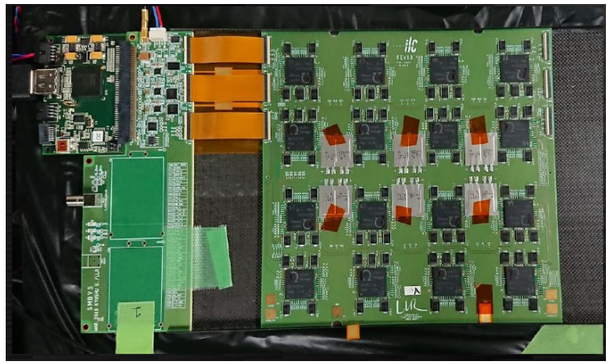
Deliverable 14.3

Task 14.3.1 – Prototype construction





PCB FEV12
with long adapter card
Wafer thickness
325 µm



PCB FEV13
with small adapter card
Wafer thickness
650 µm

Assembled in Japan following technique developed within AIDA2020

- Total ~15 layers constructed
- 1024 channels per layer
- Beam tests at DESY and CERN since 2016
  - *Nucl.Instrum.Meth.A* 950 (2020) 162969 • e-Print: 1902.00110 [physics.ins-det]

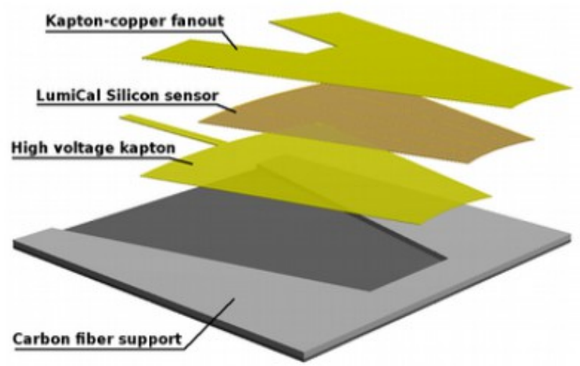
Task 14.3.2 – Compact caloimetry

- Task : Infrastructure for very compact tungsten-based calorimeters
- Deliverable D14.4: Very compact calorimeters
- Elements of Deliverable:
  - Thin sensor planes and precise tungsten plates
  - FLAME readout ASIC
  - Beam test results
- D14.4 has been postponed from M48 to M57 due to problems with ASIC foundry
  - Achieved on time in M57

Task 14.3.2 – Compact caloimetry

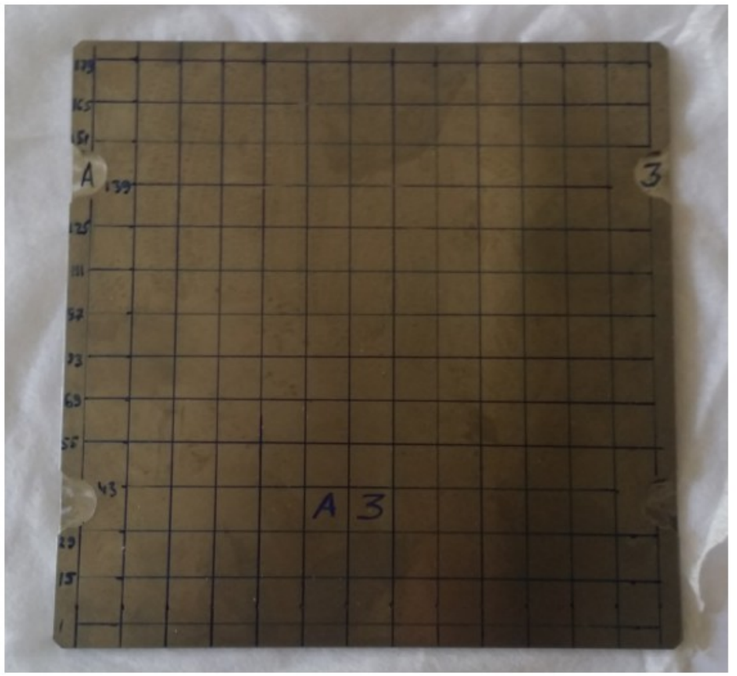
Year 5 Action

Exploded view of
650um thick sensor plane



Mounted sensor plane

Tungsten plate

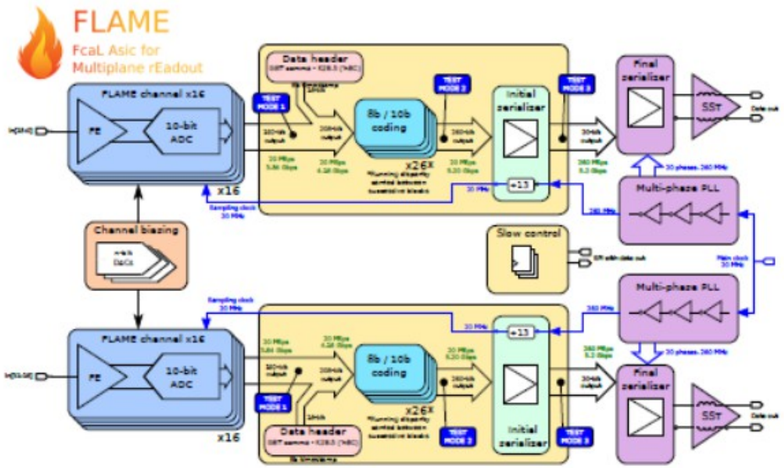


- Precise tungsten plates of 140x140x3.5 mm^3 and flatness of ~50mum have been developed and produced (more than 30 plates available)

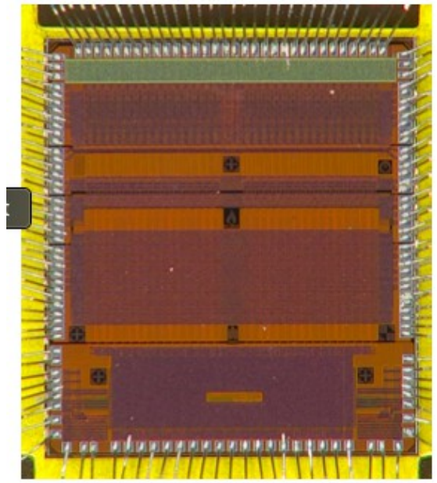
Task 14.3.2 – Compact calorimetry – FLAME ASIC

Year 5 Action

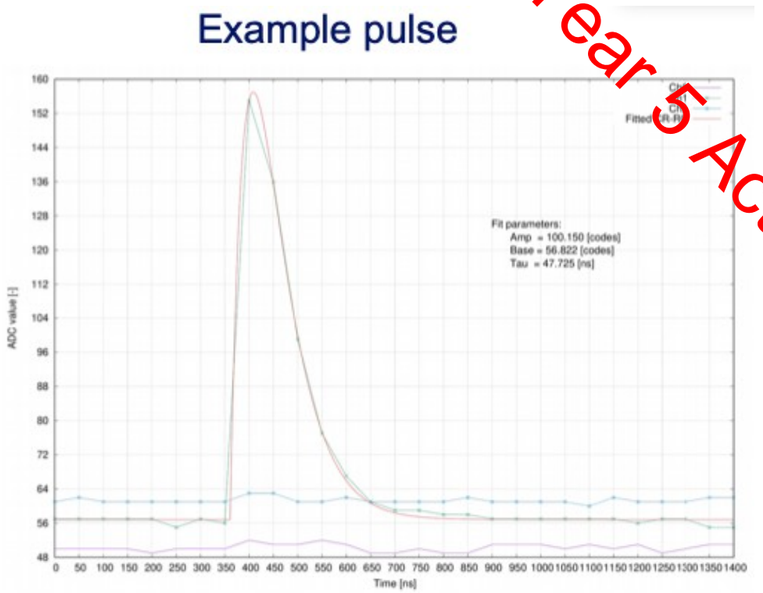
FLAME Block Diagram



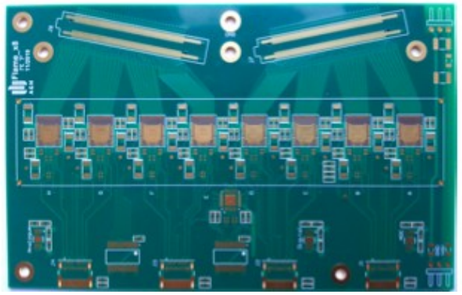
Photograph of bonded FLAME



Example pulse



PCB for 8 FLAMEs (256 channels)

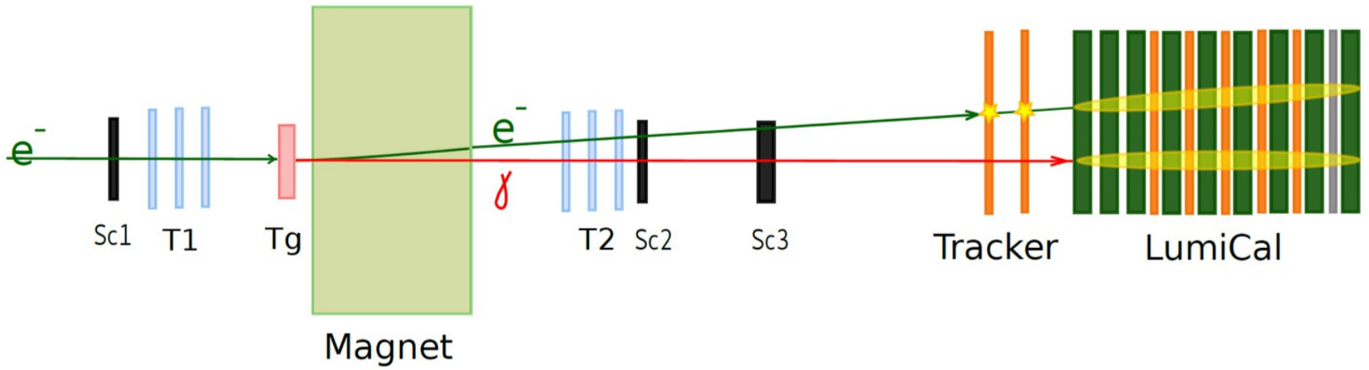


- 32 channel r/o ASIC in CMOS 130nm
- Frontend and ADC in each channel
- Fast serialisation and data transmission
- Arounf 80 ASICs are available

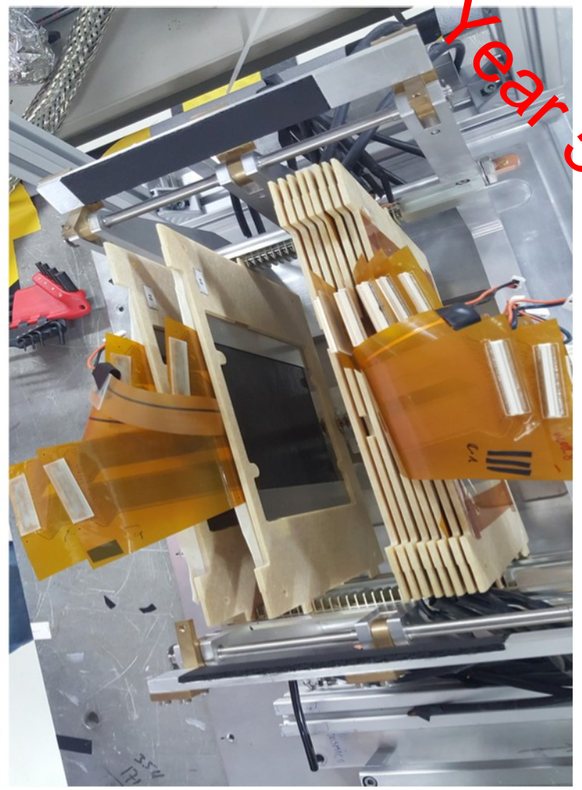
FLAME was succesfully tested. PCB readout board to read the whole sensor tile (256 channels) with 8 FLAME chips was designed and produced.

FLAME also used for CMS HGROC and MDC readout of CMS Experiment

Task 14.3.2 – Compact calorimetry – Beam test in 2016

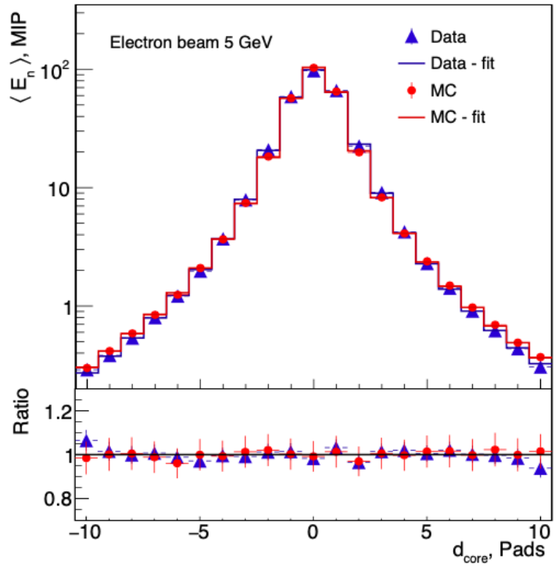


- External electronics (No FLAME ASIC yet)
- EUDET Telescope for precise beam position on calorimeter surface



Year 5 Action

(Main) result :



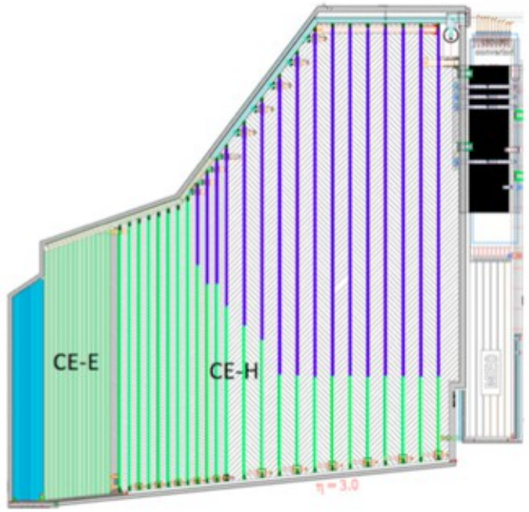
Effective Molière Radius as measure for compact design

Task 14.4 – Common beam tests

SiW ECAL/SDHCAL (2018)

CALICE meets CMS

Common beam tests since 2017



- Benefitted from networking activities such as EUDAQ2 of AIDA2020
- More common beam tests to come after CERN shutdown
- Remark : First common data taking SiW ECAL/AHCAL at DESY had to be postponed due to Corona-Crisis

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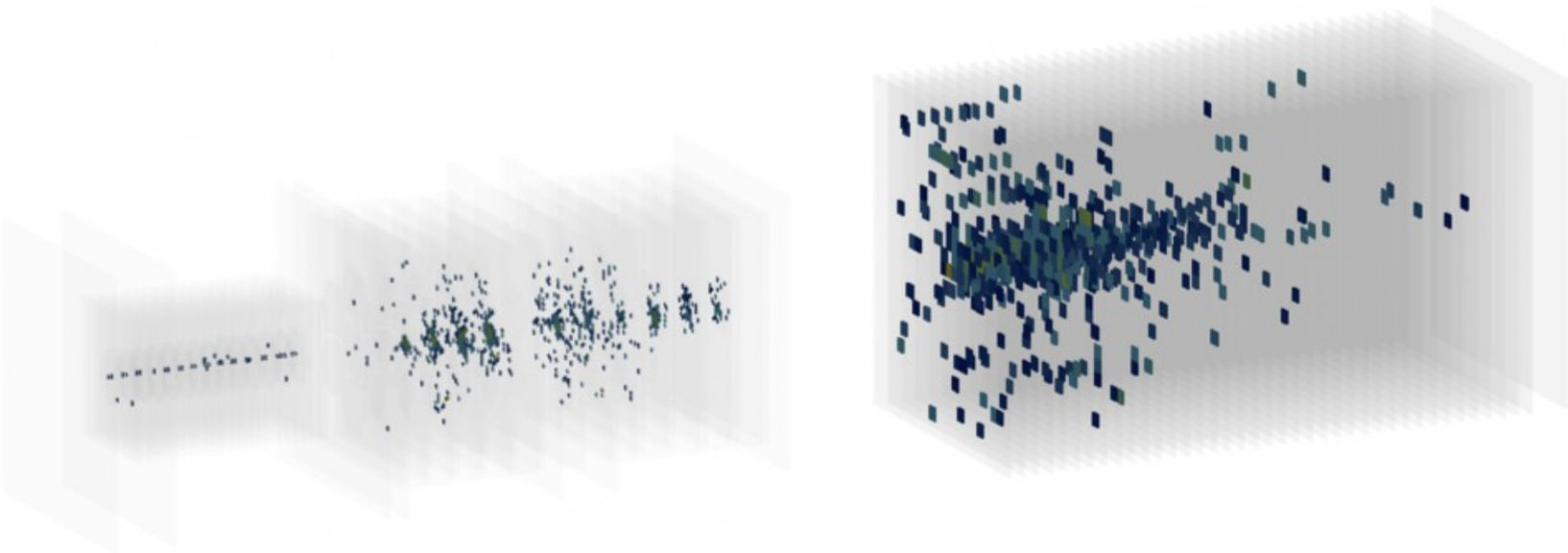

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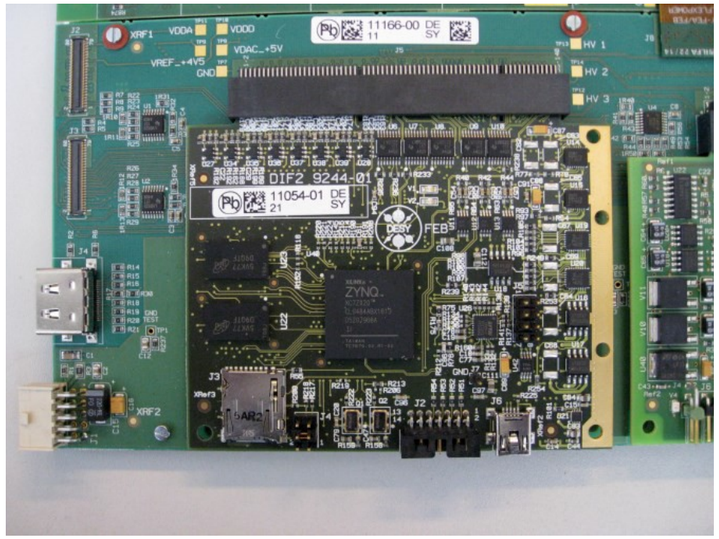
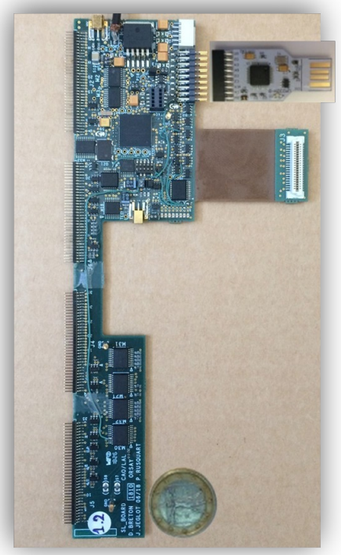
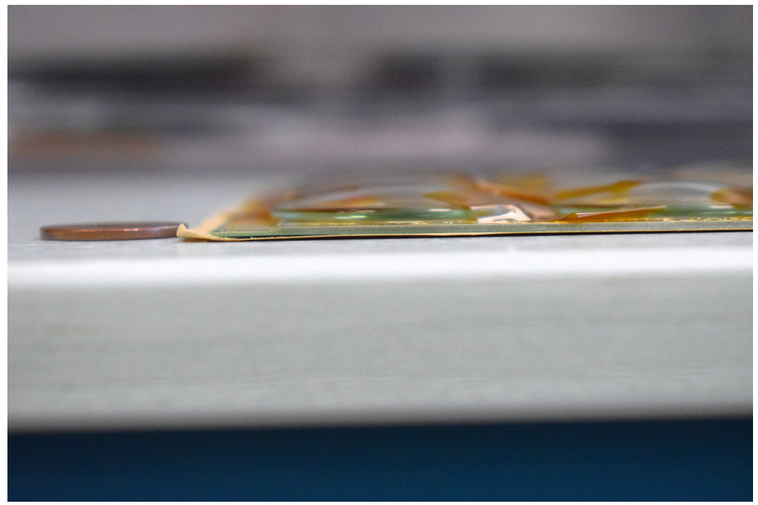
WP 14.4 – Common beam tests

Current detector interface card - AHCAL

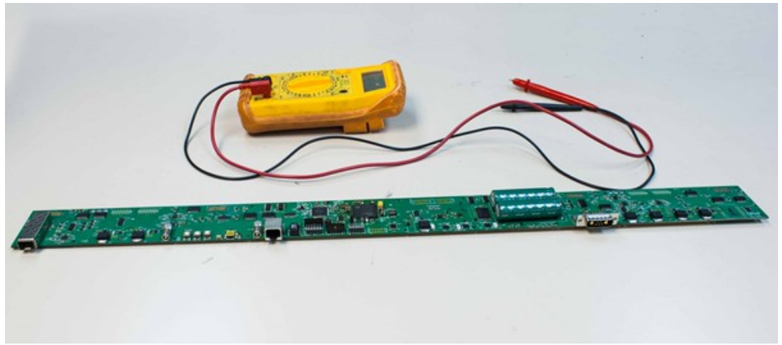


Current detector interface card and thin detection unit – SiW Ecal





Current detector interface card - SDHCAL

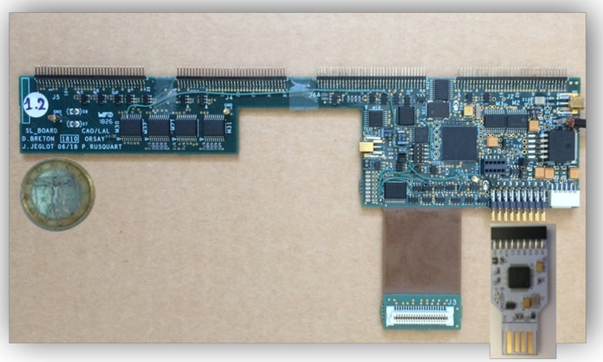


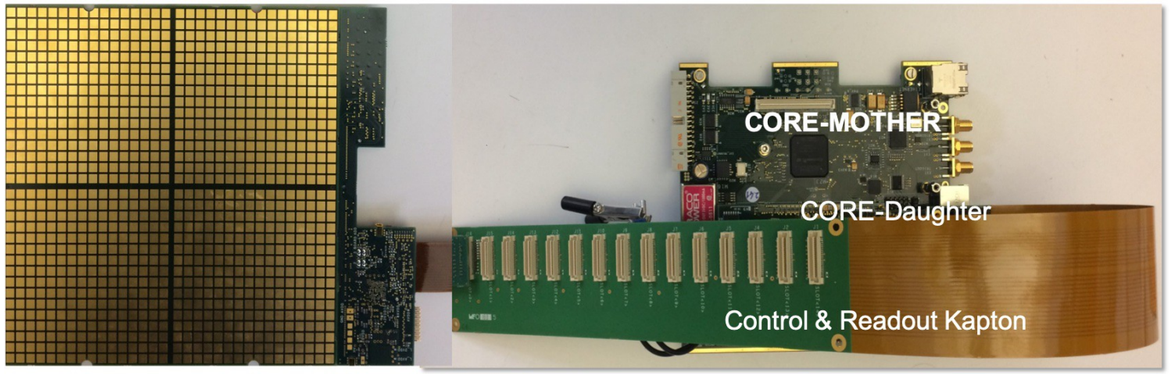
- “Dead space free” granular calorimeters put tight demands on compactness
- **Common development and detailed system integration studies in coming years**

Task 14.4 – SiW ECAL compact r/o in beam test

SL-Board for up to 10000 cells and connection to concentrator unit via flat kapton cable

Year 5 Action

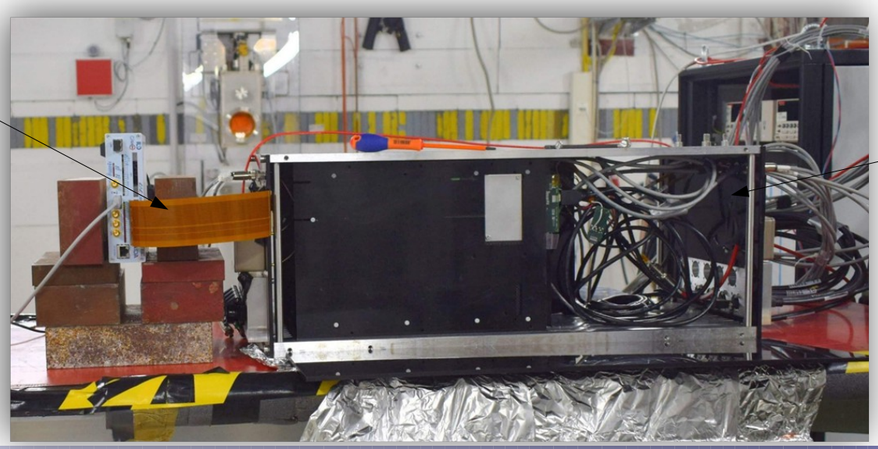




Service for up to 15 layers

Elegant space economic solution
Seamless operation in DESY beam test 2019

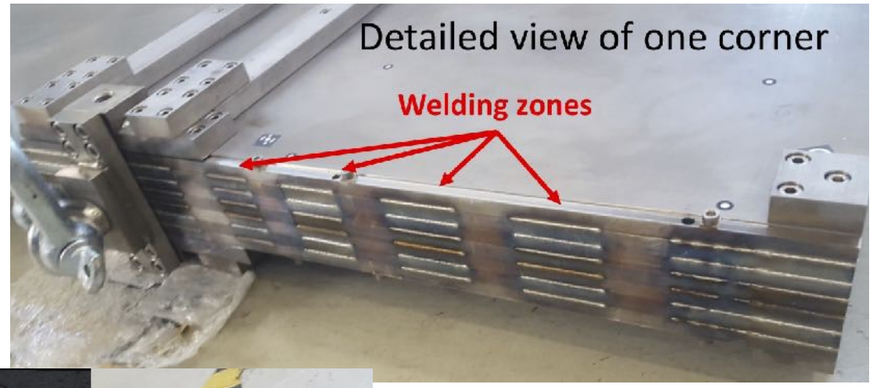
2019:
One flat cable leaving the detector

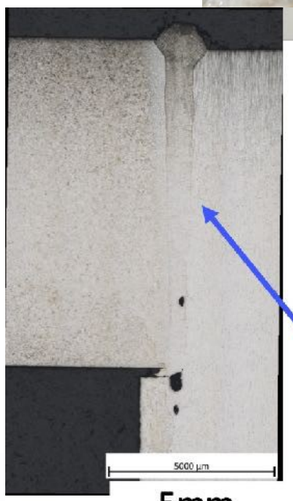


< 2019:
“Jungle” of bulky cables

14.5.1 – Precision mechanics for calorimeter structures

- Successful demonstration of electron beam welding for the construction of compact calorimeter absorber structures
  - Detailed studies on welding sequence to establish procedure resulting in minimal deformations





Detail of welding (transversal cut zoomed)

5mm

- Ongoing construction of 2 x 1 m2 GRPCs for insertion into structure, tests in beam
  - Potential future extension to 3 x 1 m^2 to fully exploit size of absorber

Observation: With the prototype, the size limitations of EBW infrastructure in research institutions is reached -

- Larger machines are available in specialized companies
- More smaller units are also an option under study

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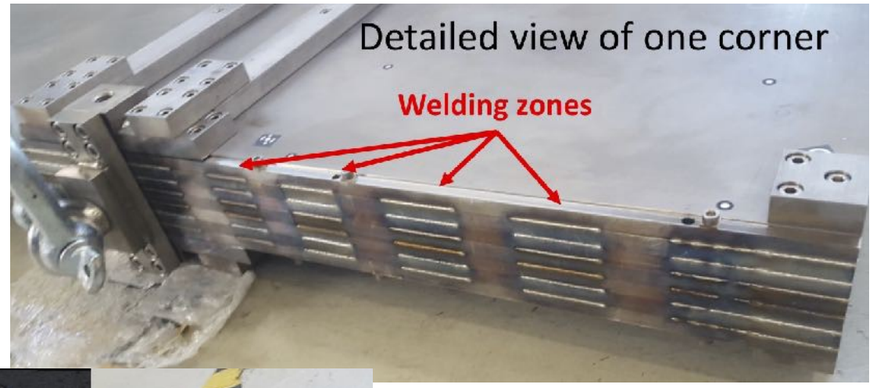

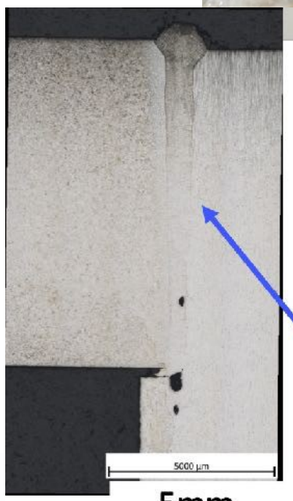

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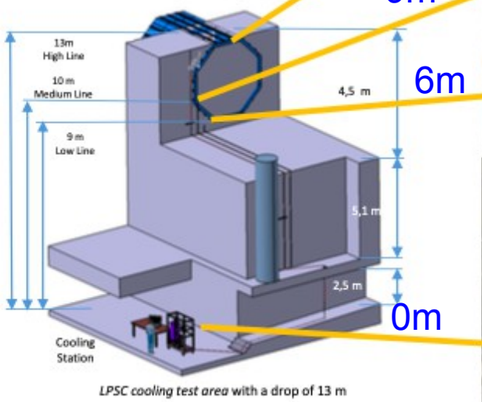
14.5.2 –Infrastructure to evaluate thermal properties of calorimeter structures

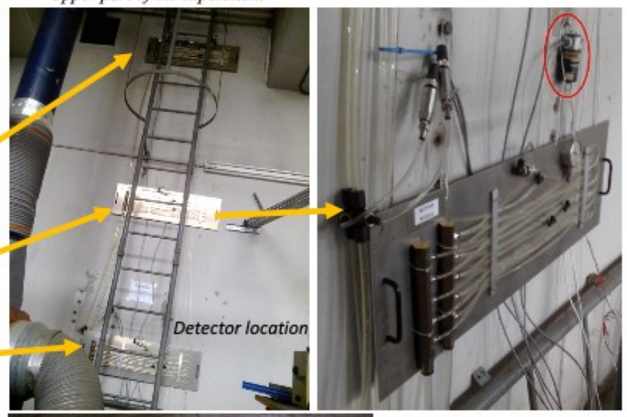
Demonstrator of large leakless loop for CALICE/ILD ECAL

- Thermal model as milestone
- Probes at different heights to establsih full model of Cooling system for large detectors



LPSC cooling test area with a drop of 13 m

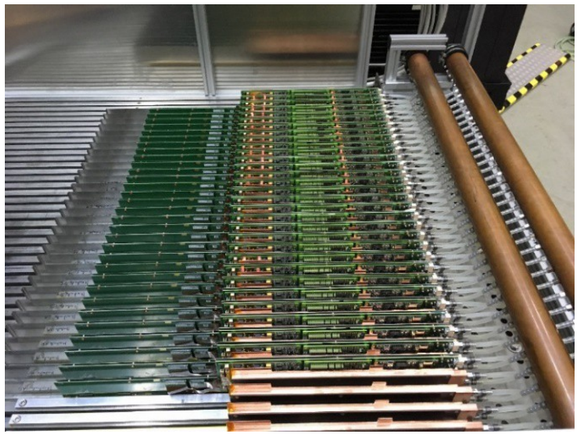
Upper part of the experiment

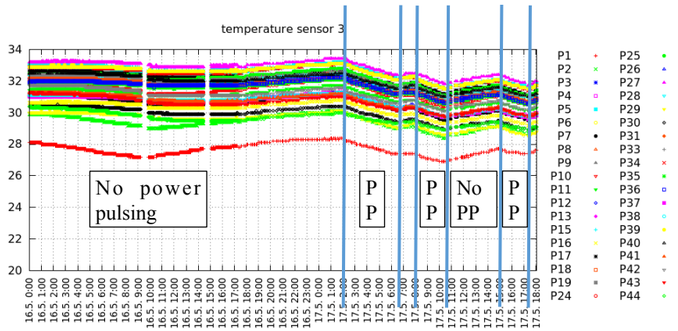


Julien Giraud

Studies for efficient leak detection Ongoing (Polarographic probe)

Cooling system for CALICE AHCAL Prototype





- Stack of 38 layers equipped
- Reliable operation during several beam tests in 2018/19
  - …. including power plused operation
- Operation with overpressure but leakless option foreseen

- Experience with large cooling system established during AIDA2020
- Next major step is full integration with readout electronics at detector extremities (e.g. SL-Boards)

AIDA2020 WP14 – Summary and outlook

- We are (almost) done …

- WP14 has contributed to laying the foundation for ambitious calorimeter projects in the next decades
  - Calorimeters with optical and semiconductor readout
  - Infrastructure for testing and construction
  - WP14 has established new connections between LHC and non-LHC communities that have proven to be highly succesful

- Lots of scientific results obtained in beam tests
  - Thanks to AIDA-2020 TA and the beam test operators and DESY and CERN
  - Operational prototypes will increase the harvest of this workpackage with future (common) beam tests

- Technological progress at many fronts
  - Precise mechanics (e.g. Beam welding and cooling systems)
  - Highly compact readout electronics

- It has been a pleasure to lead this workpackage
  - Thanks to the members of WP14 (physicists, engineers and technicians)
  - … and to the AIDA-2020 management for confidence and guidance
  - … and to the AIDA-2020 secretaries Livia and Sabrina for having been always helpful and patient

Backup

- Optical testbenches (Task 2.1) as basis for investigation of new materials with sub 10ps timing
- Optical testbenches (Task 2.2) for development of large area scintillator detectors with SiPM
- Assembly chain for semi-conductor (Task 3.1) r/o as basis for construction of larger prototypes
  - Climate chamber (Task 3.1) in use for construction of CMS HGCAL
- Towards detector integration of compact calorimeters (Task 3.2)
- Continuation of common beam tests
  - e.g. First common data taking CALICE SiW ECAL and CALICE AHCAL was envisaged for this week but got cancelled due to Corona Crisis
- Compact readout (Task 4.1) as basis for advanced prototypes of granular calorimeters and detector integration
  - V2 of compact r/o developed and produced during Winter 2019/20
- Beam welded mechanical structures (Task 5.1) validate mechanical concept of ILD SDHCAL
- Further integration of cooling systems (Task 5.2) into advanced prototypes of granular calorimeters

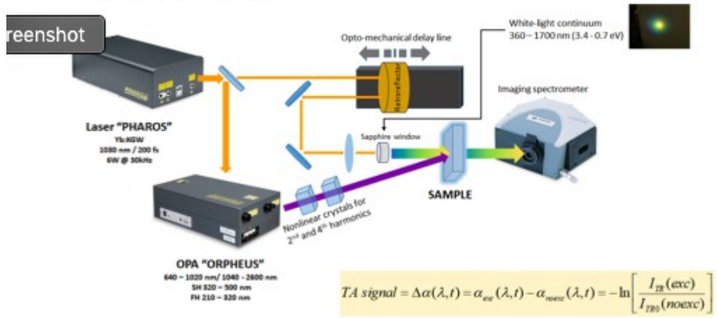
Further Highlight(s) of Year 5 – SiW ECAL compact r/o in beam test

Publication Score Board

WP	No. of journal publications	No.of conference/ workshop proceedings	Other publications	Total

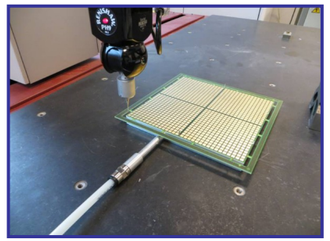
WP 14 – What has been achieved ?

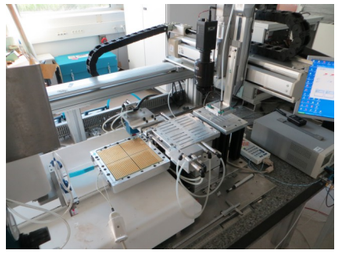
Test benches



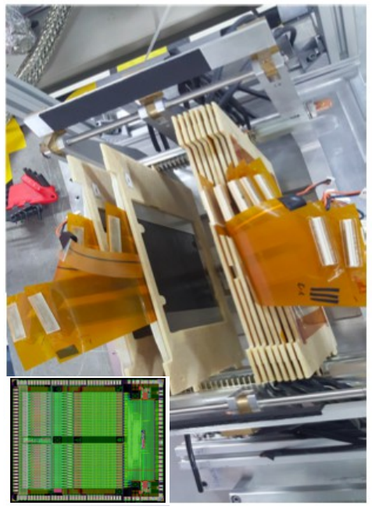
Cosmic and tile teststands

Detector assembly tools

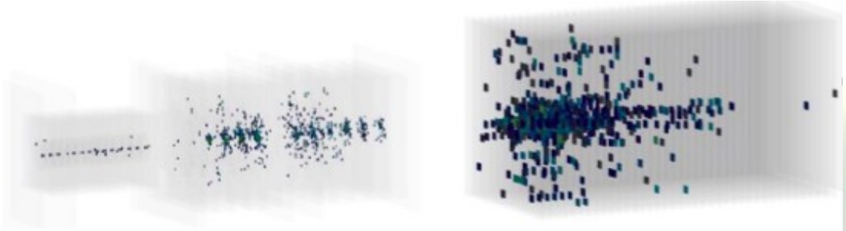




Compact calorimetry



Common beam tests



Compact r/o

Electron beam welding

Cooling system(s)