HGCFC: High Granularity Calorimetry for Future Collider Experiments in High Energy Physics

A. Irles (LAL-IN2P3/CNRS) on behalf of HIGHTEC colleagues

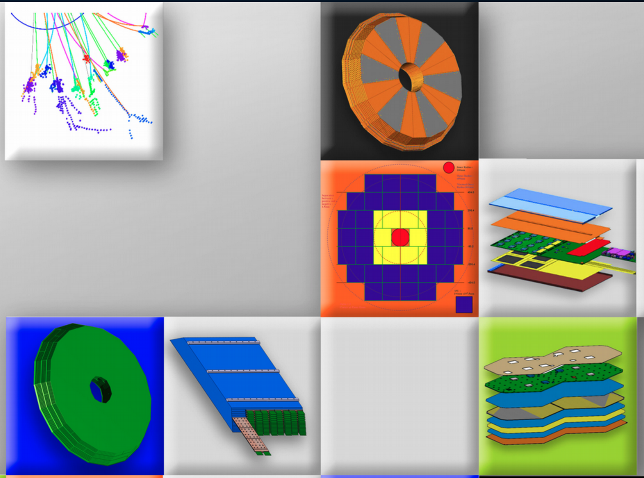
15th November 2018

Physique des 2 Infinis et des Origines

Journée 2018 du Labex P2IO

HIGHTEC

HIgh Granularity Hybrid Timing and Energy Calorimetry



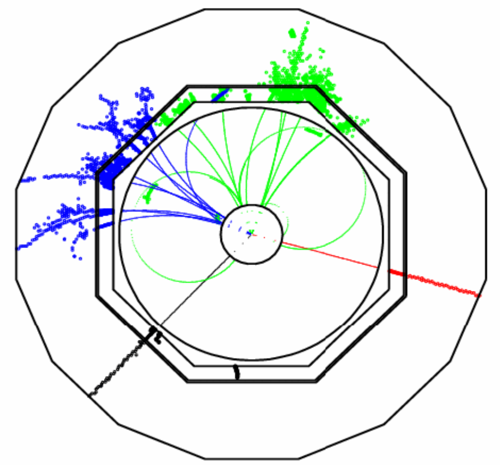
a P2IO project by LLR, LAL and IRFU

Bruno Mazoyer - LAL Orsay

Experimental Tool – Particle Flow at Colliders

ILC

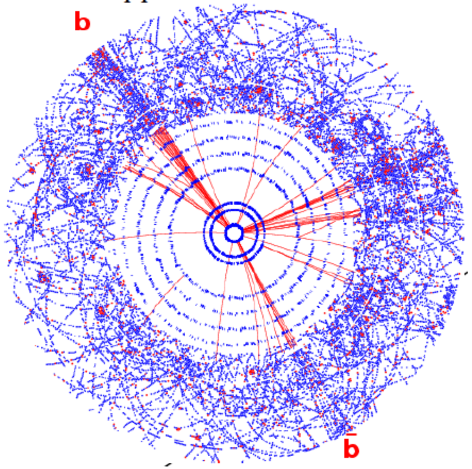
e+e- 2> H + Z; H 2> bb; Z -> μμ



- Clean, low repetition rates
- Pulsed electronics
- No trigger / data reduction
- Reconstruct full particle patterns

LHC

pp 2> H + X; H 2> bb



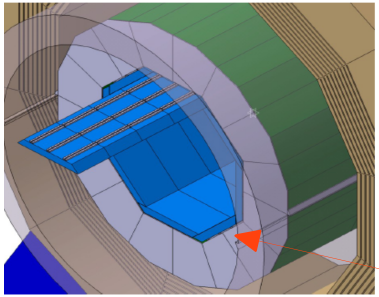
- Messy, High rates (40 Mhz)
- Continuous readout
- Data reduction/trigger challenge
- Reconstruct constrained patterns

Particle Flow Technique require highly granular calorimeters
P2IO Groups do pioneer this technology

4

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

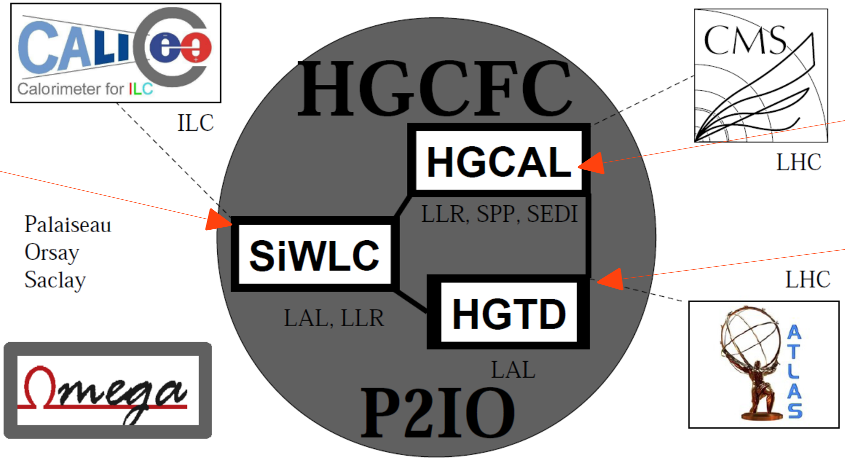
Introduction

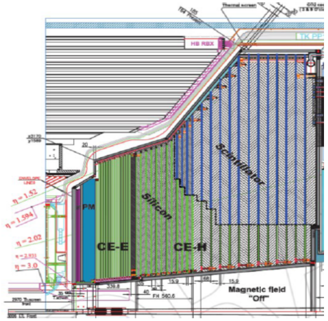


LC Calorimeter:

Full size calorimeter
Barrel and Endcaps
10^8 cells
130 t

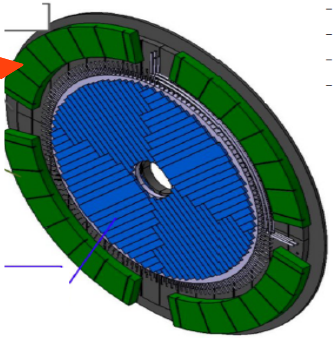
High Granularity Hybrid Time-Energy Calorimetry©
HIGHTEC





CMS-HGCAL =
EE+FH Highly granular

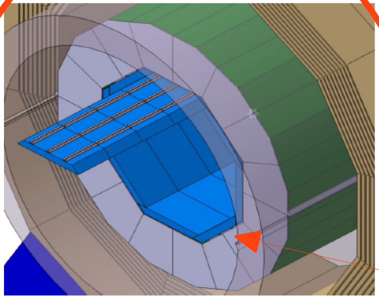
- **312** Cassettes,
- **44k Si** Wafers
- **100k** FE ASICS,
- **6M** Channels



ATLAS-HGTD:

Pseudorapidty
Coverage
$2.4 < |\eta| < 4$
Up to 4 layers
$1.3x1,3mm^2$ cell size

Introduction



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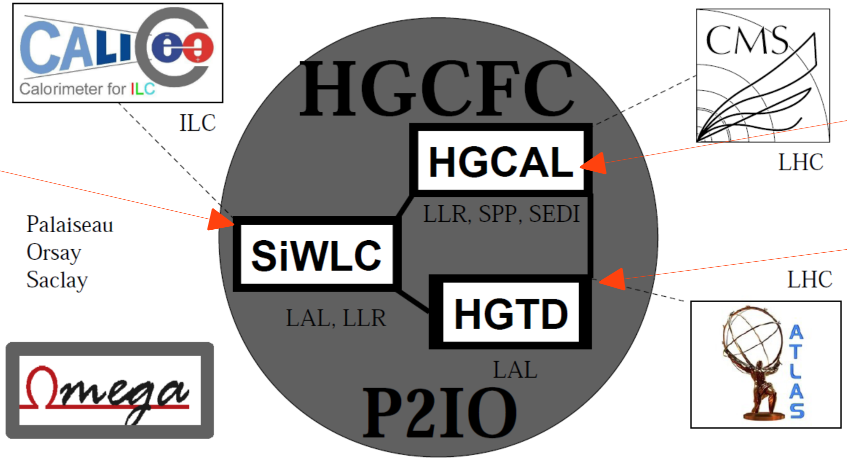

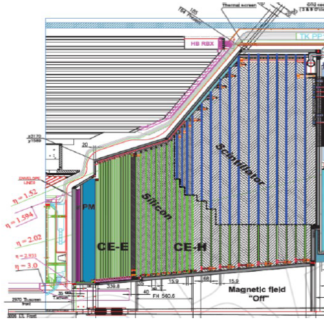

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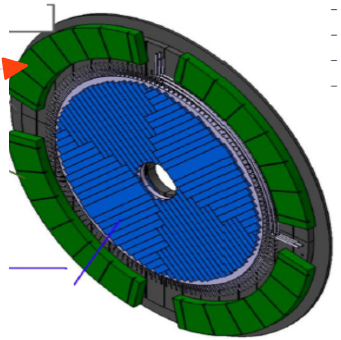

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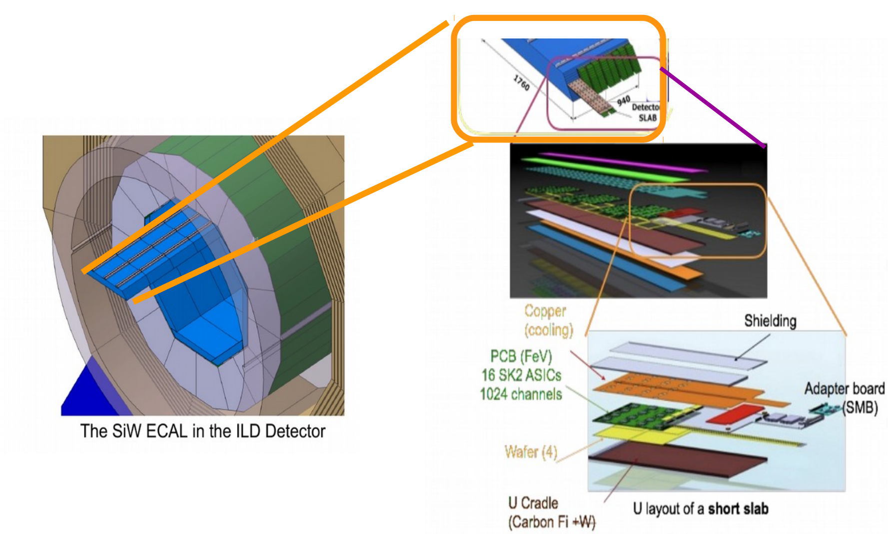
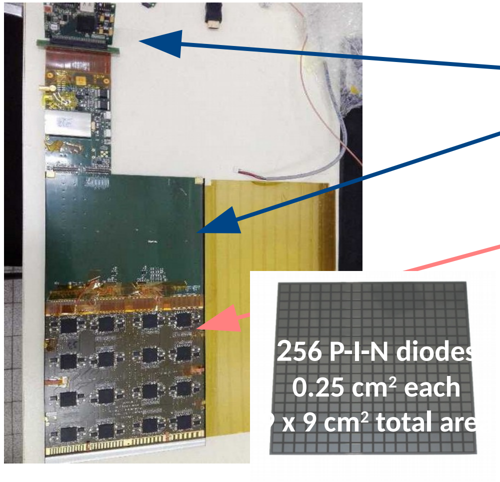


The SiW ECAL in the ILD Detector



Detector Interface + adapter board

Active Sensor Unit

equipped with 4 Si-wafers

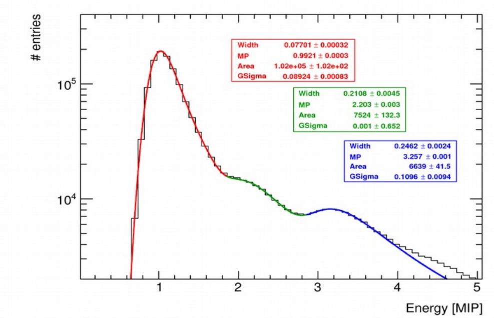
2017 status of the technological prototype modules.

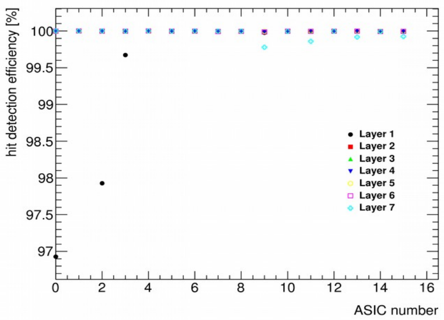
The **objectives** pursued by the SiW LC ECAL at the **HIGHTEC project are**

- The construction and test of a **long slab**
- The **compactification** of the system
- Test and **characterization** of **silicon** sensors
- **Beam test activities** as a tool for feedback for the R&D and short term objective itself
  - 3 tests during last two years: DESY@2017, DESY@2018 and CERN@2018

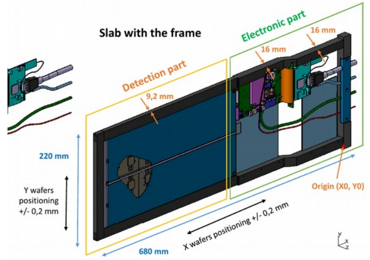
Setup : 7 FEV11 each equipped with 4 325um Si wafers and 16 Skiroc2, first beam test with ASICS fully operated in power pulsing
Commissioning used for DESY 2017 & 2018 and optimized for CERN@2018
Masked channels = 7-8%: (very conservative approach)

SiECAL w/o W and 3GeV e+

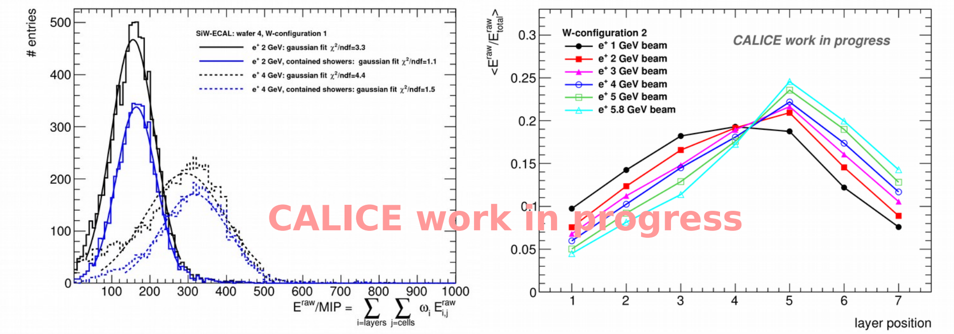




- MIP: We **fit** the **98%** of available channels → **MPV** = 62.2 ADC, **(dispersion of 5.1 %)**
- Hit detection efficiency of ~100%



SiWECAL electromagnetic showers

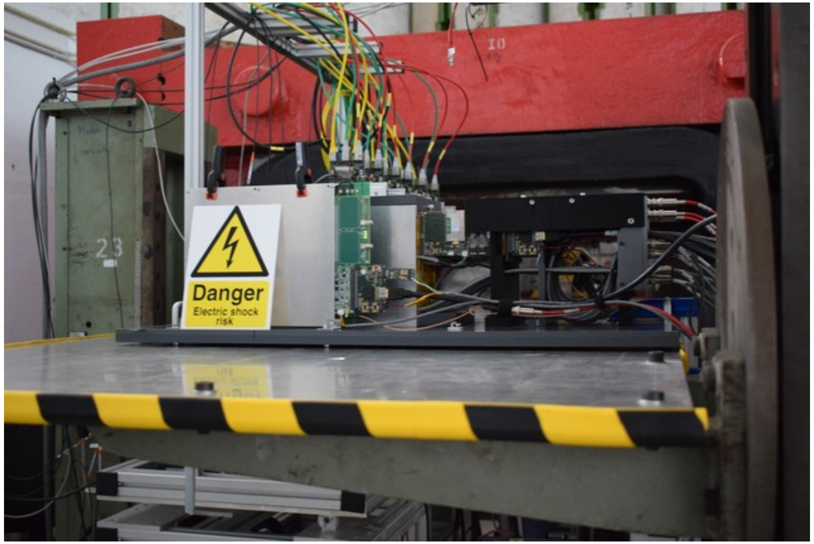


- Conferences: **CHEF2017, IEEE2017, LCWS2017 & 18**
- **Paper**: arXiv:1810.05133 to be submitted (shorter version) to Nucl.Instrum.Meth. A7

First beam test results for MIPs and showers with fully assembled detector elements (7 of 10000 needed for ILD) with power pulsing. Good performance in 1T field.

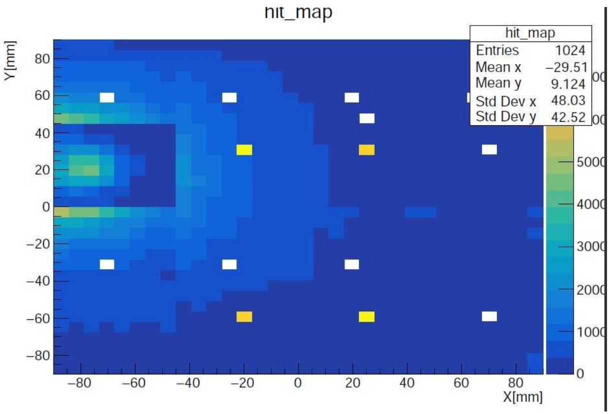
- Successful **operation in 1T field** without any loss of performance

DESY@2018 (TB21&24) Short slabs



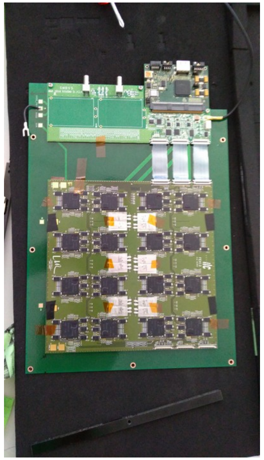
- Same configuration than in 2017 for all FEV11.
- New all plastic structure to avoid grounding loops
- 6FeV11 + 1 FEV13-Jp

- New FEV13-JP + SMBv5 (LLR+Kyushu collab.)
  - Aim of noise level improvement by separating PCB analogue and digital power layers + specific re-design of pad-channel routing
- Integration in the DAQ worked out-of-the-box.



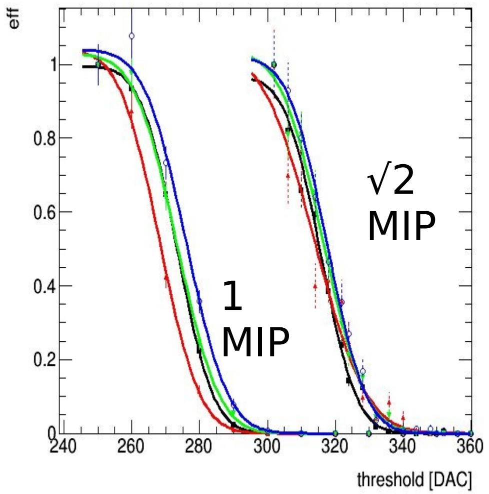
Example of FEV13-JP hit map

(still some systematically noisy channels)



DESY@2018 S/N in the trigger line

- For autotrigger data taking, a S/N is to be defined by the study of the trigger line (fast shaper in Skiroc) → threshold scans with different signals
  - The threshold scan curve is interpreted as the integral of the gaussian distribution of the noise.

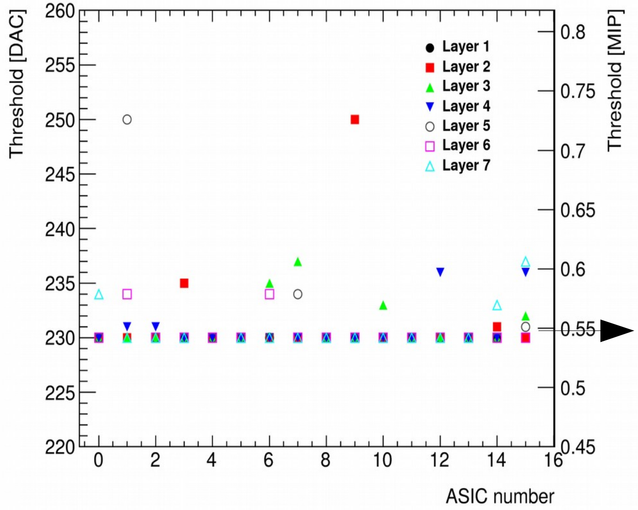


Slab **17**, **18**, **19**, **20** **(FEV11)**

These curves are used for trigger calibration

and S/N calculation

Trigger thresholds used in DESY@2017&2018



230DAC ≈ 5σ distance of the MIP

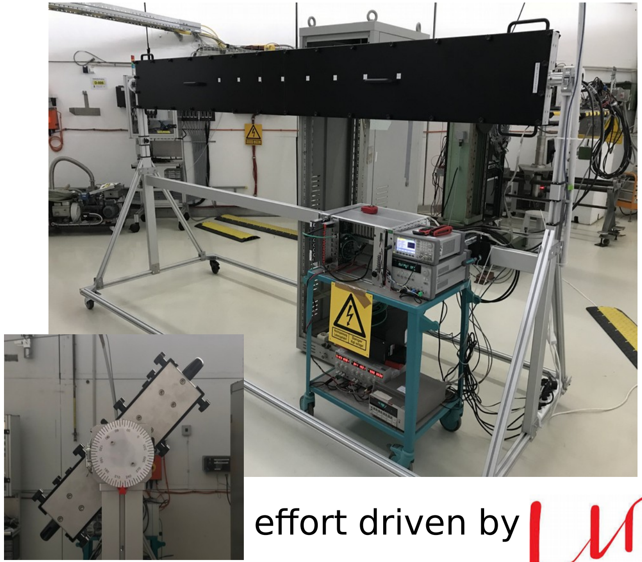
S/N = 11.6 ± 0.7 (ILD baseline requirements: S/N=10)

Trigger threshold at ~0.5 MIP

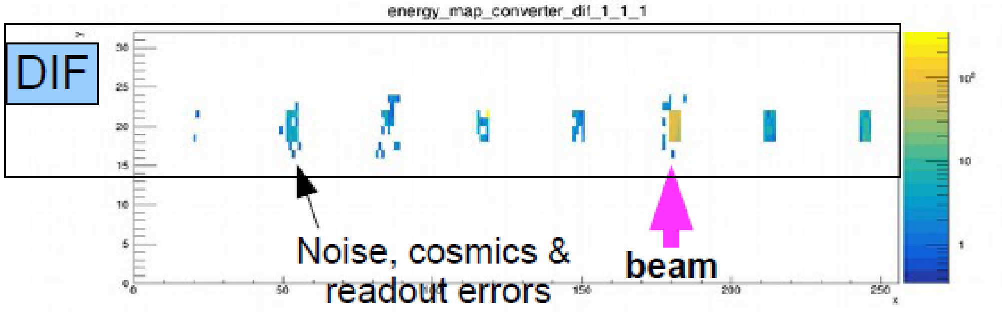
First S/N (trigger) measurements in beam test.

DESY@2018 – Electrical prototype of Long Slab

- Daisy chain of 8 ASU (extendable to 12)
  - Corresponding to typical barrel length
  - Based on FEV12 ASU & SMBv4 (adiabatic modification of FEV11, in stock)
  - Adaptation of impedance of any lines (simulations)
  - DAQ resizing to cope with chips multiplicity
- No ILC geometrical constraint
- 1 Baby-wafer 4x4 px (2x2cm) on each ASU
- HV filtered by RC circuits to reduce noise

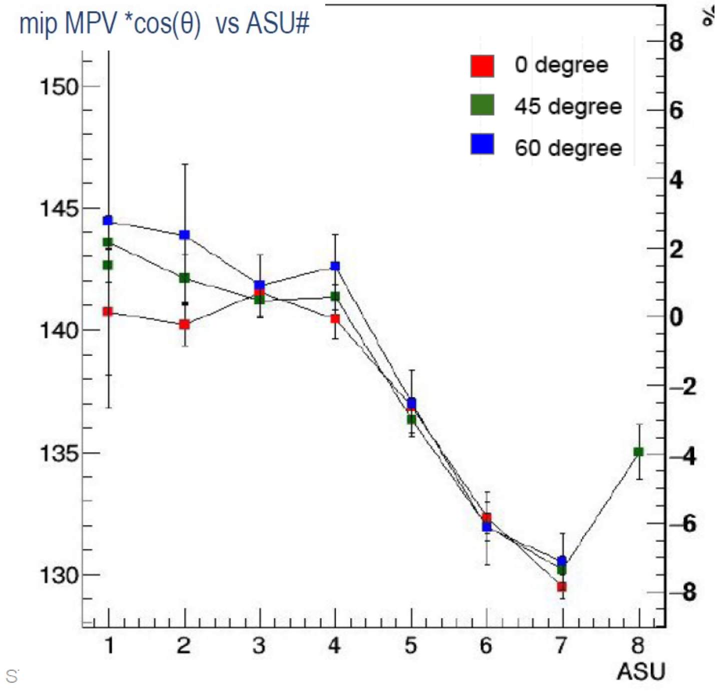


effort driven by LLR



- Mechanical structure with mono-directionnal wheels for precise positionning
- Calibrated wheel for angular scans
- Compact DAQ on a wheel table
- 3224mm long

DESY@2018 – Electrical prototype of Long Slab

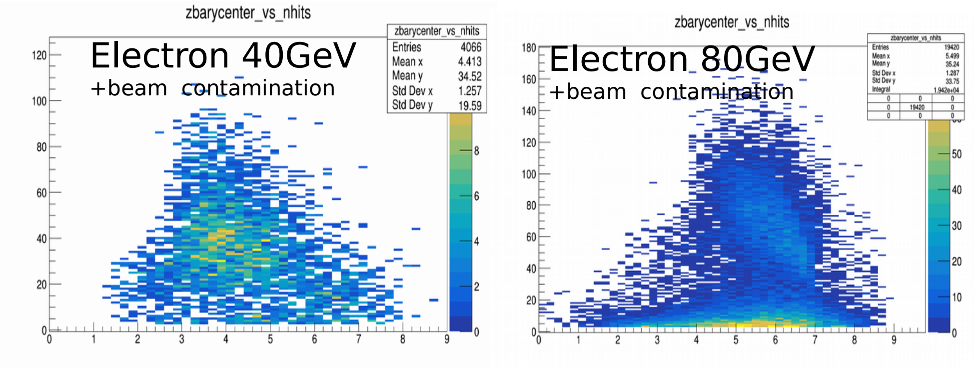


- All ASUs responding and calibrated.
- Lower MIP values than expected observed at the end of the slab
  - 2%/ASU drop for the second half of the slab.
  - Similar drop in the width of the pedestal.
  - Voltage & cain drop ? Under study.
- Lots of inputs for a the next prototype:
  - Adjustemt of HV/LV distribution, clock distribution, mechanical support, etc

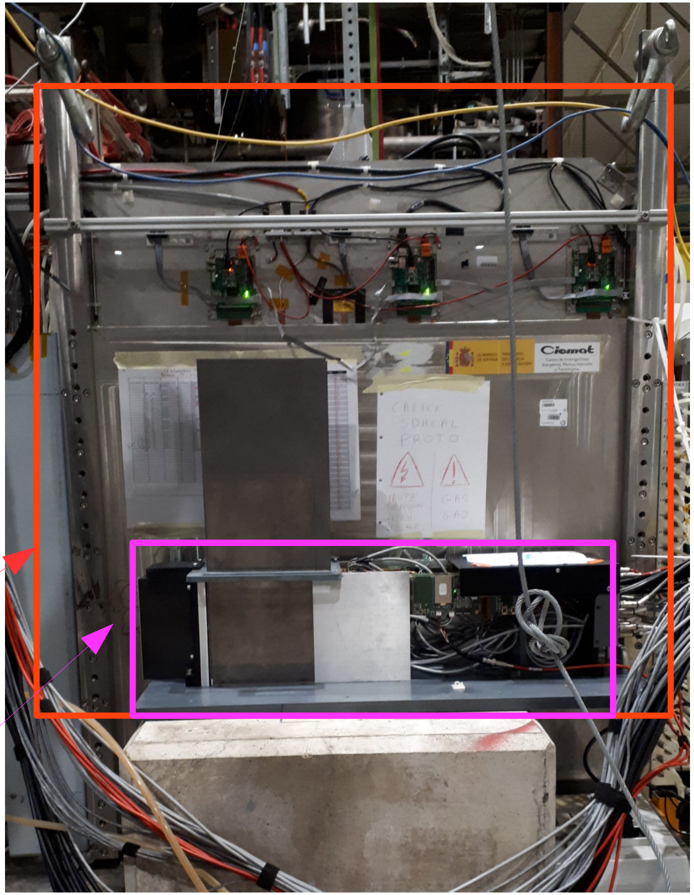
First Long Slab Prototype tested with particle beam

CERN@2018 SiW-ECAL and SDHCAL

- Two weeks from the 26/09 to 3/10 at CERN
  - 10 ECAL slabs in the stack: 6 FeV11 + 4 FeV13-Jp
- ~1 week of standalone runs with different number of layers (between 7 and 10)
  - Muons and "low energy" electrons



6 FEV11 + 1FEV13-Jp

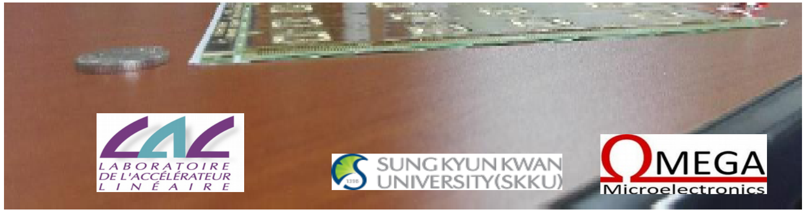


- Common running for the last ~ week.
  - High energetic electrons, muons and pions. Data analysis ongoing.

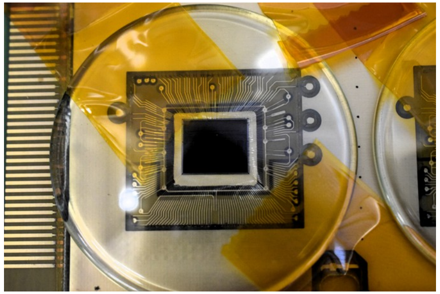
Road towards CALICE technological prototypes common beam tests

Electronics compactification

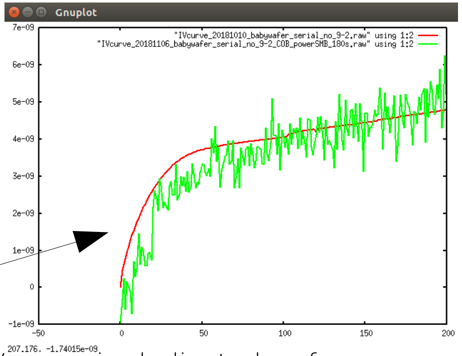
- **Investigating ultra thin PCB, with chip on board COB:**
  - Baseline design Maximum Height for Electronics (i.e. PCB+ASICS) ≤2mm



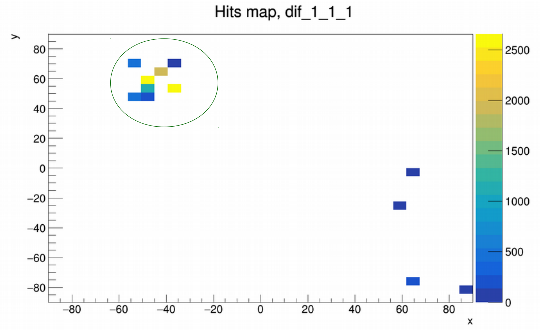
- LAL/OMEGA collaboration with Corean Group of SKKU (EOS company for the PCB)
  - FEV11_COB: 10 boards of 1.2mm, good planarity and good electrical response).
  - SK2a wirebonded at CERN (Contact with P2IO Platform CAPTINNOV)



- Successful debugging w/o sensors: (3-4% of noisy channels, good response to injected signals)
- Debugging with sensors (baby wafers 3x3 px)
  - Last minute wafer gluing for DESY@2018 didn't succeed.
  - New wafer testbench setup in LAL with support of LPNHE
  - Recent (and very quick) tests with Cs137 source signals for first times
  - Further studies ongoing at LAL

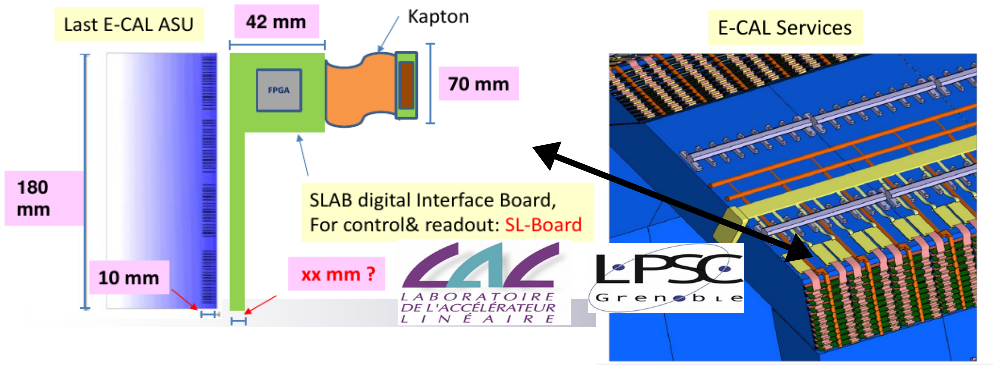


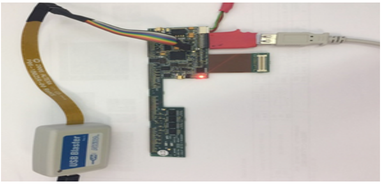
IV curve in dedicated wafer testbench from LPNHE (red) vs glued to the board (green)



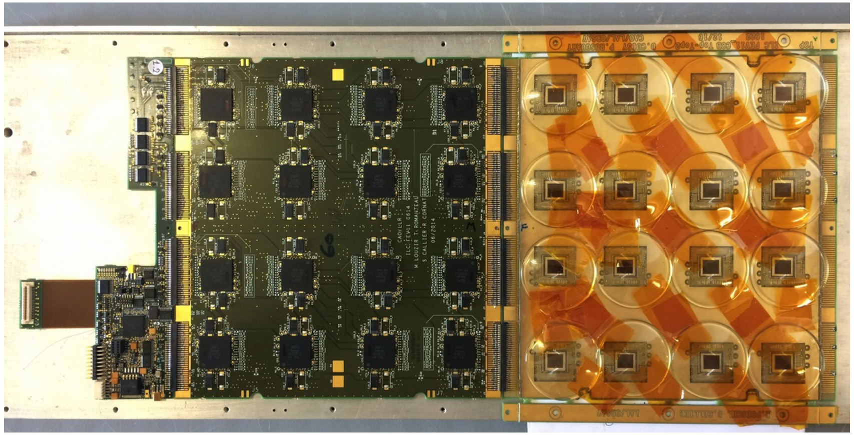
Electronics compactification

- **Spatial constraints**: limited space between layers and between ECAL and AHCAL





Script TCL test **ok**
USB communication **ok**
Jtag programming **ok**
Test ADC Vref Extern **ok**
Test interconnection **ok**
test ADC hard IP Bloc in FPGA with generator and QSYS **ok**

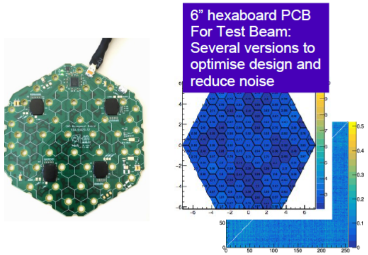


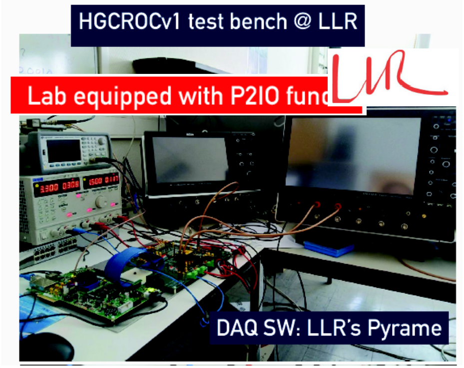
- Communication with SKIROC ASIC established
- Test series with Active Sensor Units envisaged until ~Xmass/early 2019
- Set up will be made flexible enough to allow for short layer and long layer tests

Develop and test of the HGCAL (silicon).

Physics prototype: performance of EM/hadronic showers for wide E range (20-300GeV) including **timing (~50ps)**

- **Develop of thin detector modules (<6mm).**

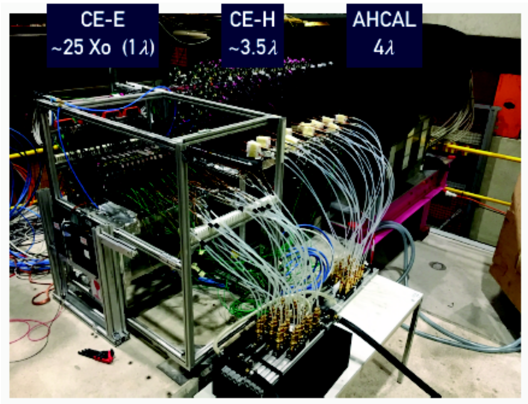


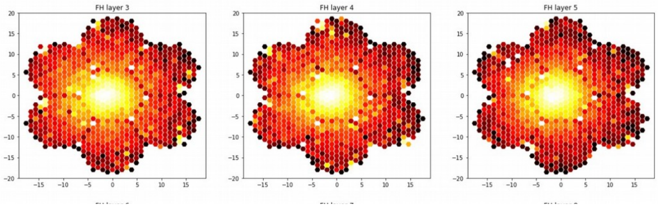


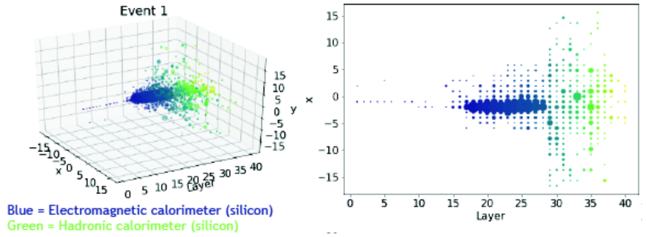
- **Test of HGCROC** – the main readout ASIC for HGCAL developed by Omega, CEA Saclay and Imperial College

- **Intense Beam Test activities** in 2018

  - March (DESY) single mode tests. Study MIPs & showers using precise tracking from beam telescope.
  - June (CERN) "full" ECAL with 28 modules, cooling and detector control system (T/RH readout).
  - October (CERN) HGCAL: silicon CE-ECAL and CE-HCAL with 94 modules (40 layers) + AHCAL (CALICE/ILC) as tile catcher



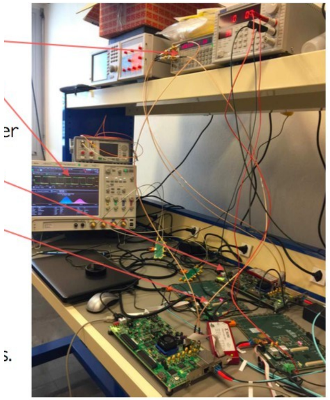




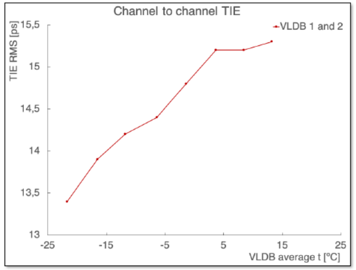
- One of the HGCAL goals is to reach the highest possible precision for experiment's timing measurements.
  - Each component in the clock distribution path may add jitter to the reference clock on which all timing measurements are based and must be synchronous to.
  - If not properly studied and organized, the clock distribution may significantly mitigate the aimed performance of our cutting-edge upgraded detectors.

P.-A. Bausson et al

Phase I microTCA-based clock chain performances



Temperature effects measurement on clock jitter .

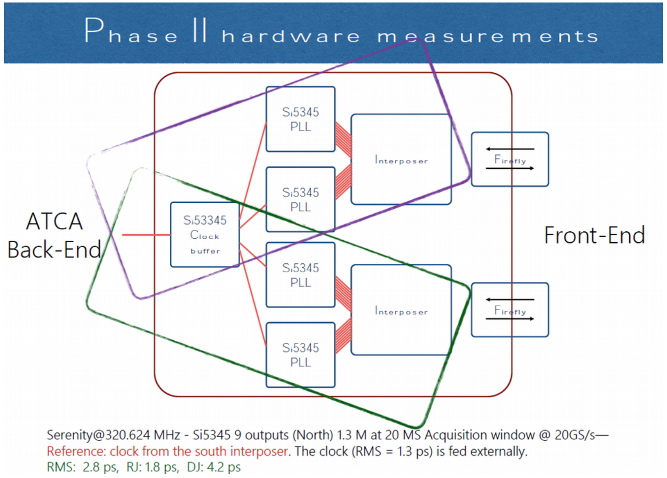


Performance under specs. Results on temperature effects are encouraging.

Phase II: hardware ATCA-based clock measurements (final clock chain)

Most phase II are still under design or manufacturaing. Expected during 2019

Phase II baseline full clock chain tests will follow during 2019.



Presentations at PM2018, TWEPP and ISPCS conferences. A CMS note is also in preparation.

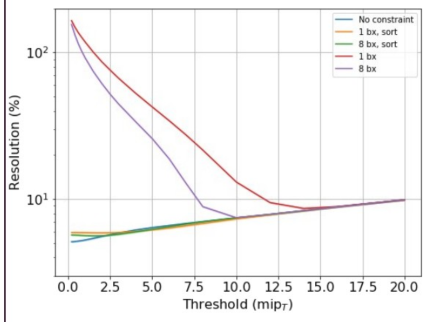
Simulation and performance studies

E. Becheva
M. Prvan
J.-B. Sauvan

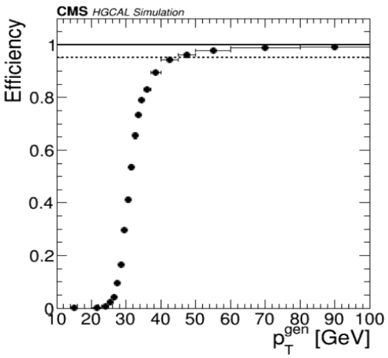
- **Development & responsibility** of the official HGCAL trigger simulation framework.
- Development of the **HGCAL trigger validation framework**.

algorithms based on compression and sorting sorting.

Impact of selection on EM resolution



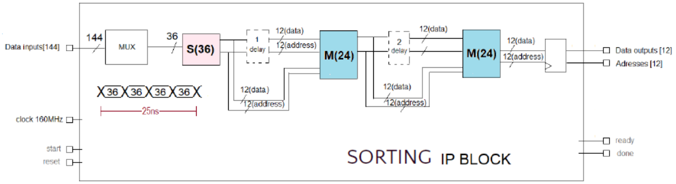
Electron trigger efficiency (TDR)



Firmware and hardware architecture developments

- Implementation and study of cell selection algorithm based on sorting.
- Starting studies of deep learning models

L. Pacheco
T. Romanteau
F. Thiant

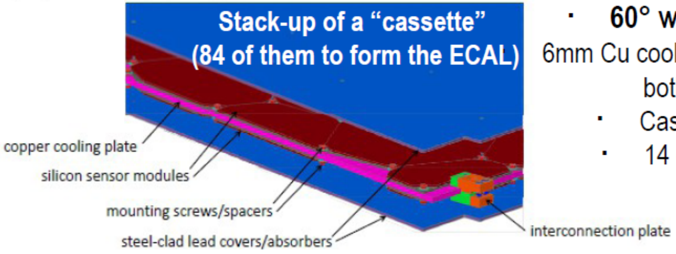


- Possible thanks to P2IO support
  - New server
  - FPGA board

Responsibilities and impact on the design and development of the trigger model for the coming LHC detectors upgrade.

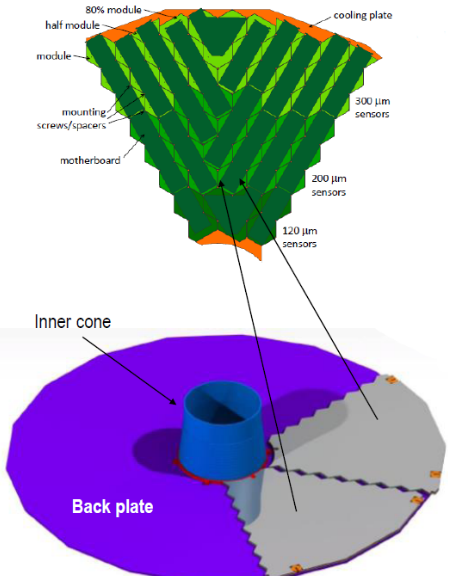
HCAL mechanics

LLR co-responsible (with CERN) for the CE-E mechanical structure design



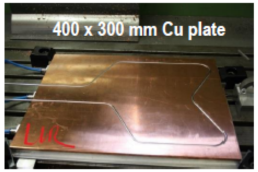
- **60° wide wedge-shaped cassettes:**
  6mm Cu cooling plate with Silicon sensors modules or both sides + Pb/SS absorber cover
- Cassettes assembled to form disks.
- 14 disks stacked-up to form ECAL.

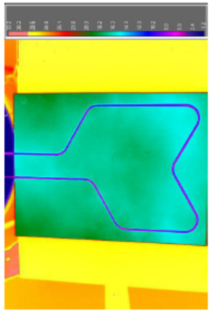
- **Significant progresses made on all fronts**, not possible without **P2IO support**.



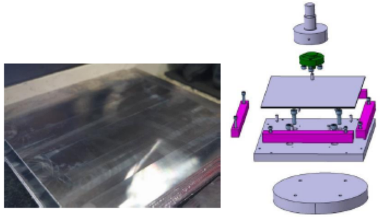
Cooling pipe shaping & insertion in 6mm Cu plate

Cooling tests (optimization of Cu & tube thermal contact)

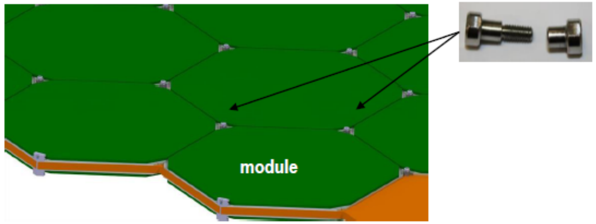




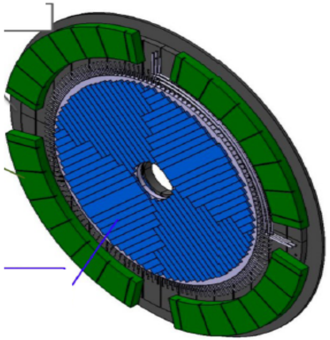
Pb/SS Mechanical tests

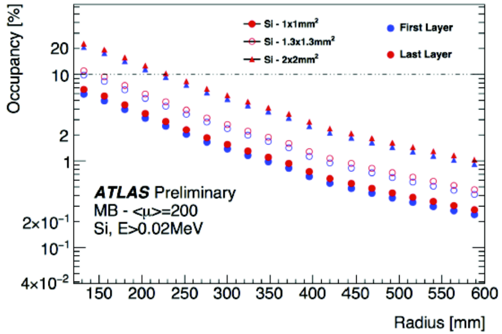


Design & Mechanical tests of "spacers"



- **Goal**: time resolution of less than 30ps per track and occupancy less than 10%





ATLAS-HGTD:

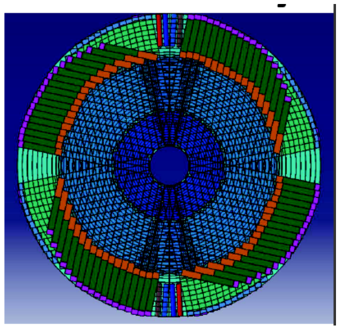
Pseudorapidty Coverage
$2.4 < |\eta| < 4$
Up to 4 layers
1.3x1,3mm² cell size

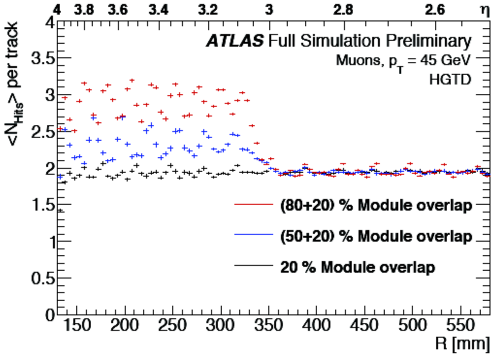
$$\sigma_t(Track) = \frac{\sigma_t(Hit)}{\sqrt{N_{Hits}}}$$

$$\sigma_t^2(Hit) = \sigma_t^2(Sensor) + \sigma_t^2(Electronic) + \sigma_t^2(Clock)$$

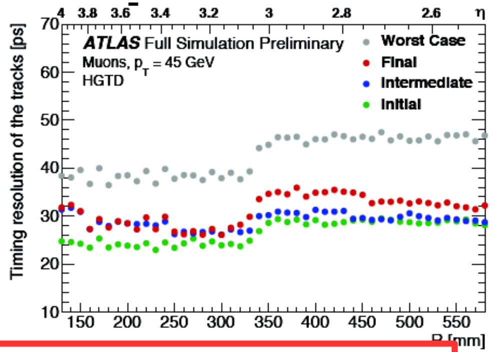
Increased by the sensor irradiation (stronger for low R)
Timing resolution of the electronic of the order of 25 ps (measured on test bench)
The clock contribution should be kept below 10 ps

- **LAL: driving force** behind detector optimization
  - Additional hits per track are obtained by overlapping sensors in the layer.





- Timing resolution ≤30ps/MIP
- Efficiency of the track matching between the HGTD and Tracker (>95% for a pt>20 GeV)
- Isolation of the Electrons (performance independent of the vertex density)



Important contribution to the LOI and TP approved by the LHCC CERN-LHCC-2018-023 http://cdsweb.cern.ch/record/2623663

Summary

- The support of the emblematic HIGHTEC project of P2IO makes a tangible difference in the R&D of the three projects
- Strong synergies created and exploited.
- Lots of results delivered this year and more to come next:
  - Major step on the long slab for SiWECAL and also good progresses on the compactification of electronics for the SIWECAL
  - Influence on detector designs: HGCAL mechanics, detector optimization, trigger and timing simulation and studies
  - Influence on detector designs: driving force on HGTD design optimization.
- HIGHTEC enters 2019 well on track.
- Large presence of P2IO on international forums
  - Summary of talks in international conferences in the backup

Back-up

HIGHTEC conferences (I)

References

[1] **"Precision Clock Distribution studies for timing in phase II upgrade of the CMS experiment"**,
Pierre-Anne Bausson, Talk at the TWEPP 2018 Topical Workshop on Electrronics for Particle Physics, 17 - 21 septembre 2018.
PrecisionClockDistributionstudiesfortiminginphaseIIupgradeoftheCM

[2] **"The CMS HGCAL detector for HL-LHC upgrade"**,
Artur Lobanov, Talk at the ICHEP2018: 39th International Conference on High Energy Physics, Seoul, Republic of Korea, 4-11 Juillet 2018; *with proceedings.*
https://indico.cern.ch/event/686555/contributions/2972180/attachments/1680810/2700302/ALobanov_HGCAL_ICHEP2018.pdf

[3] **"Status of ATLAS and CMS upgrades on calorimetry and timing and future prospects"**,
Jean-Baptiste Sauvan, Talk at The Sixth Annual Large Hadron Collider Physics conference LHCP 2018, 3-9 juin 2018.
https://indico.cern.ch/event/681549/contributions/2849756/attachments/1664942/2668682/180609_LHCP_sauvan_calo.timing_v6.pdf

[4] **"Precision Clock Distribution for CMS at the HL-LHC"**,
Mehmet Ozgur Sahin, Talk at the PM2018 - 14th Pisa Meeting on Advanced Detectors, 27 mai - 2 juin 2018.
https://agenda.infn.it/materialDisplay.py?contribId=393&sessionId=10&materialId=slides&confId=13450

[5] **"The ATLAS High-Granularity Timing Detector"**,
S. sacerdoti, Talk at the 11th workshop on picosecond timing detectors, electronics and applications, Mai 2018, Turin (Italie); https://agenda.infn.it/contributionDisplay.py?contribId=15&sessionId=1&confId=15031

[6] **"A High-Granularity Timing Detector (HGTD) in ATLAS: Performance at the HL-LHC"**,
C. Allaire, Poster at the CHEF2017 11th International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors (HSTD11), Decembre 2017, Okinawa (Japon); *with proceedings.*
https://indico.cern.ch/event/577879/contributions/2740068/

[7] **"The High Granularity Timing Detector for ATLAS: Motivation and Performance"**,
D. Zerwas, Talk at the LHCC, 1 Dcembre, CERN;

[8] **"The High Granularity Timing Detector for ATLAS: HGTD Detector"**,
L. Serin, Talk at the LHCC, 1 Dcembre, CERN;

[9] **"A High Granularity Timing Detector for the Phase-II Upgrade of the ATLAS detector system"**,
C. Agapopoulou, Talk at the 2017 Nuclear Science Symposium and Medical Imaging Conference, Octobre 2017, Atlanta (tats-Unis); *with proceedings.*
https://www.eventclass.org/contxt_ieee2017/online-program/session?s=N-34#2164

[10] **"The CMS HGCAL detector for HL-LHC upgrade"**,
J.B. Sauvan, Talk at the CHEF2017 Calorimetry for the High Energy Frontier, Octobre 2017, Lyon (France); *with proceedings.*
https://indico.cern.ch/event/629521/contributions/2702989/attachments/1533813/2401883/171003_CHEF_sauvan_HGCal_v4.pdf

[11] **"Electronics and triggering challenges for the CMS High Granularity Calorimeter"**,
A. Lobanov, Talk at the CHEF2017 Calorimetry for the High Energy Frontier, Octobre 2017, Lyon (France); *with proceedings.*
https://indico.cern.ch/event/629521/contributions/2703016/attachments/1533975/2403800/ALobanov_HGCAL_CHEF2017.pdf

[12] **"HGCAL: A High-Granularity Calorimeter for the Endcaps of CMS at HL-LHC**
C. Ochando, Talk at the 17th International Conference on Calorimetry in Particle Physics (CALOR2016), 15-20 May 2016, Kyungpook National University , Daegu (Republic of Korea); *with proceedings.*
https://indico.cern.ch/event/472938/contributions/1150701/attachments/1274520/1890377/ochando_hgcalCMS_18Mayt16_v2.pdf

[13] **"Concepts and design of the CMS High Granularity Calorimeter Level 1 Trigger**
J.B. Sauvan, Talk at the 17th International Conference on Calorimetry in Particle Physics (CALOR2016), 15-20 May 2016, Kyungpook National University , Daegu (Republic of Korea); *with proceedings*
https://indico.cern.ch/event/472938/contributions/1150702/attachments/1274512/1890362/calor2016_hgcal.l1.trigger_sauvan.pdf

[14] **"Latest R&D news and beam test performance of the highly granular SiW-ECAL technological prototype for the ILC"**,
A. Irles [CALICE Collaboration], Talk at the CHEF2017 Calorimetry for the High Energy Frontier, Octobre 2017, Lyon (France),
https://indico.cern.ch/event/629521/contributions/2703010/
JINST **13** (2018) no.02, C02038 doi:10.1088/1748-0221/13/02/C02038 [arXiv:1802.08806 [physics.ins-det]].

[15] **"Latest developments on the highly granular Silicon-Tungsten Electromagnetic Calorimeter technological prototype for the International Large Detector"**,
A. Irles [CALICE Collaboration], Talk at the IEEE NSS/MIC Symposium 2017, Atlanta (US, Georgia).
arXiv:1801.10407 [physics.ins-det].

HIGHTEC conferences (II)

[16] **"Pyrame 3, an online framework for Calice SiW-Ecal",**
F. Magniette *et al.* [CALICE Collaboration], Talk at the CHEF2017 Calorimetry for the High Energy Frontier, Octobre 2017, Lyon (France),
https://indico.cern.ch/event/629521/contributions/2703025/,
JINST **13** (2018) no.03, C03009. doi:10.1088/1748-0221/13/03/C03009

[17] **"SiW ECAL for future e^+e^- collider",**
V. Balagura, K. Shpak *et al.*, Talk at ICHEP 2016, Juillet 2016 Chicago (US, Illinois),
https://indico.cern.ch/event/432527/contributions/1071765/,
JINST **12** (2017) no.07, C07013 doi:10.1088/1748-0221/12/07/C07013 [arXiv:1705.10838 [physics.ins-det]].

[18] **"Technical instrumentation R&D for ILD SiW ECAL large scale device",**
V. Balagura [SiW ECAL ILD Collaboration], Talk at the CHEF2017 Calorimetry for the High Energy Frontier, Octobre 2017, Lyon (France),
https://indico.cern.ch/event/629521/contributions/2702984/,
JINST **13** (2018) no.03, C03047 doi:10.1088/1748-0221/13/03/C03047 [arXiv:1712.05680 [physics.ins-det]].

[19] **"SiW ECAL for future e^+e^- collider",**
V. Balagura *et al.*, Talk at International Conference on Instrumentation for Colliding Beam Physics (INSTR17), Février/Mars 2017 Novosibirsk (Russia),
https://indico.inp.nsk.su/event/8/session/5/contribution/132
JINST **12** (2017) no.07, C07013 doi:10.1088/1748-0221/12/07/C07013 [arXiv:1705.10838 [physics.ins-det]].

Hightec postdocs & PhD

Post-doc: HIGHTEC Test Beams SiWLC/CMS LLR

ARTUR LOBANOV

2013 – 2016: PhD in Particle Physics, *University of Hamburg*, Hamburg, Germany.
Search for gluino production in final states with an isolated lepton and b-tagged jets using 13 TeV collisions at CMS

- Research Assistant at Deutsches Elektronen-Synchrotron (DESY)
- Member of the PIER Helmholtz Graduate School

2007–2013 Specialist degree in Physics (equivalent of MSc),
Moscow State University, Moscow, Russia, *Degree with Honours*.

- **Search for supersymmetry at the LHC (PhD Thesis)**
  - Study of prospects of a future search for non-simplified SUSY models at 14 TeV
  - Developed a framework for a SUSY search in the single lepton final state
  - Data-driven background estimation for a multi-bin counting experiment
  - Trigger development and measurement
- **Upgrade and commissioning of the HCAL Outer (HO) detector of CMS (Phd Thesis)**
  - **Key participant** in the installation of the new readout electronics of the HO
  - Performance measurements and cosmic muon calibration of the SiPMs
  - Commissioning of the new HO hardware within CMS
- **Nucleon experiment ECAL (Diploma Thesis)**
  - Development of electron/hadron separation algorithm
  - readout electronics performance studies (test-stand, beam test, development of DAQ and DQM systems,…)

Christophe Ochando, Vincent Boudry IN2P3-X LLR

Post-doc : HIGHTEC SiWLC LAL

ADRIAN IRLES QUILES

2010-12/2014: PhD in particle physics by the University of Valencia.
Thesis title: "Top-quark mass measurement in the ATLAS detector at the LHC using jet rates"
http://inspirehep.net/record/1339742?ln=es

2009 Master en Fi sica Avanzada
Especialidad Fi sica Nuclear y de Parti culas. Universidad de Valencia.
Thesis title: "Estudio introductorio a la topologi a de sucesos tt+g en el Gran Colisionador Hadro nico (LHC)".

- PhD
- The theoretical proposal, study and development of a new method to measure the top-quark pole mass with high in an unambiguously def ined mass scheme.
Refs:: http://inspirehep.net/record/1225522/ and http://inspirehep.net/record/1381766

- DESY Fellow at DESY Hamburg (1/2015 – 10/2016)
- Commissioning of a power-cycled operation mode for the CALICE analogue hadron calorimeter (AHCAL) read-out electronics, and the integration of its data acquisition (DAQ) into the higher level EUDAQ framework with the goal to enable the combination of different detector types in a common test beam set-up.
Workpackage leader on « *Common Data Acquisition and Common Testbeams* » of AIDA-2020 WP5

Roman Pöschl, IN2P3-LAL

Hightec postdocs & PhD

CEA - Saclay

Post-doc: HIGHTEC HGCAL-Timing IRFU/SPP

MEHMET ÖZGÜR ŞAHİN

2012 - 2016: DESY Hamburg/GERMANY
Ph.D., Physics, Magna Cum Laude, Joachim Herz Fellow,
University of Hamburg, and PIER Helmholtz Graduate School

2005 - 2012: Middle East Technical University (METU) Ankara/TURKEY
MSc, BSc Physics (Special Undergraduate Program - Advanced Physics)

- **2016 - Present (CERN/DESY)**
  Upgrade of the CMS Outer Hadronic Calorimeter (HO) and Muon System trigger link
  - re-design of detector readout system of the upgraded HO to handle higher data transfer rates with improved reliability
  - FPGA design of the readout system to establish a trigger link for the first time between the muon system and HO
- **2012 - Present (DESY)**
  Design of the next generation Front-End Controller (ngFEC) of the CMS Had.Calorimeter (Ph.D.)
  - development of a new front-end readout control system for the CMS HCAL detector, using high speed (4.8Gbps) duplex links with RS error correction, redundant paths for slow controls and monitoring
  - lead designer for a new firmware for the Kintex-7 FPGA of the ngFEC motherboard (FC7 board)
- **2012 - Present (DESY)**
  Search for Pair Production of Supersymmetric Top-Quark Partners in Events with a Single Lepton using Support Vector Machines at CMS (Ph.D.)

Marc Besançon, IRFU-SPP

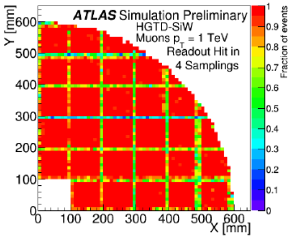
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

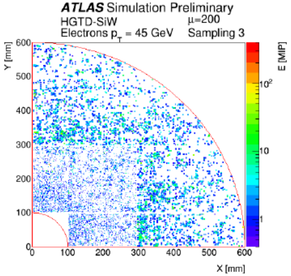
PhD Student: HIGHTEC HGTD/ATLAS LAL

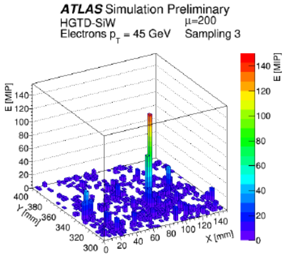
CORENTIN ALLAIRE

Master (NPAC):

- Study of muons in simulation:
  uninstrumented zones lead to only 1% inefficiency
- Electron properties in HGTD:
  separate electron cluster from pile-up
- Testbeam analysis and simulation of timing performance
  ECFA workshop HL-LHC (Oct 2016):
  27 Simulation figures made public (20 provided by LAL)
  13 figures provided by Corentin







LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

SiW-ECAL for the ILC

Basic requirements of a **PF calorimeter** for future linear colliders

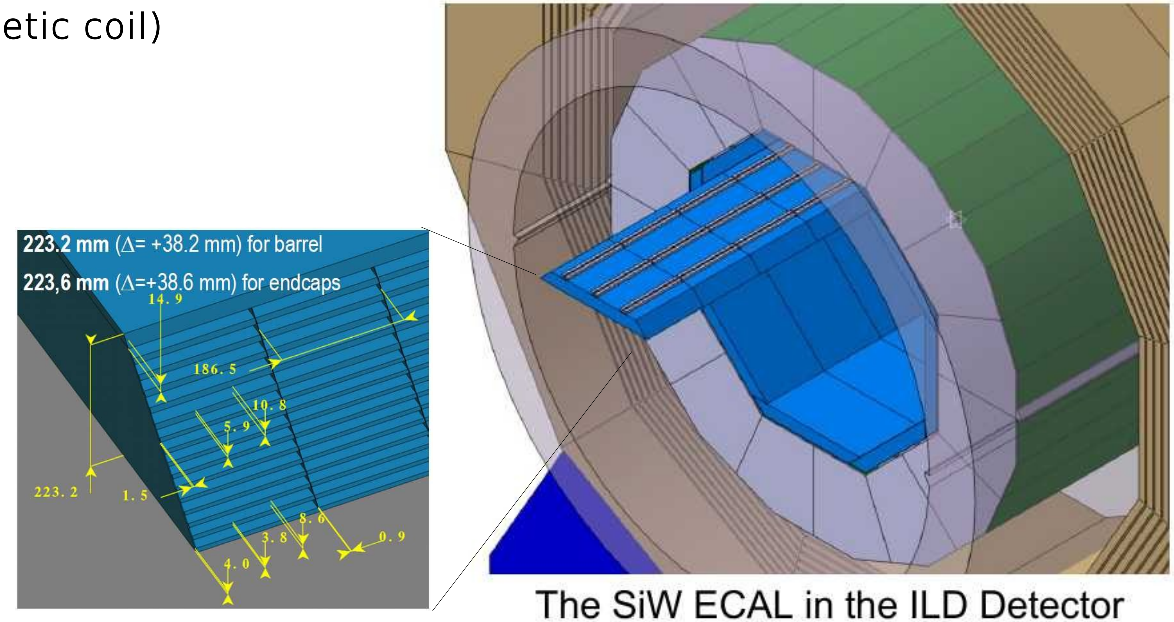
- Extreme high granularity
- Compact and hermetic (inside magnetic coil)

Tungsten as absorber material

- Narrow showers
- Assures compact design
- Low radiation levels foreseen at LC
- X_0=3.5 mm, R_M=9mm, I_L=96mm

Silicon as active material

- Support compact designs
- Allows pixelisation
- Robust technology
- Excellent signal/noise ratio

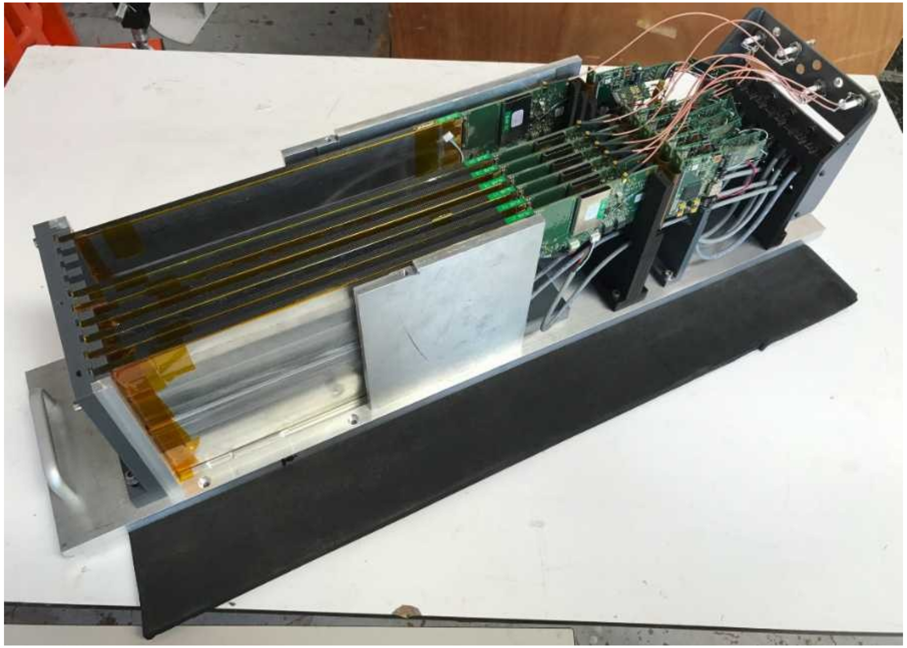


The SiW ECAL in the ILD Detector

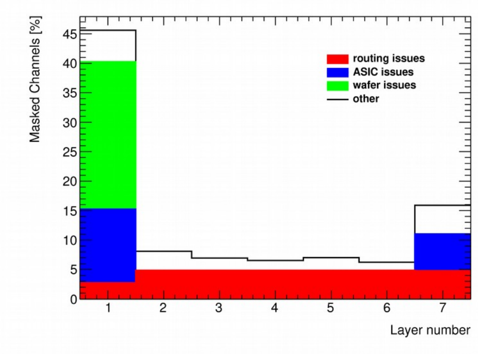
The **SiW ECAL R&D** is tailored to meet the specifications for the **ILD** ECAL proposal

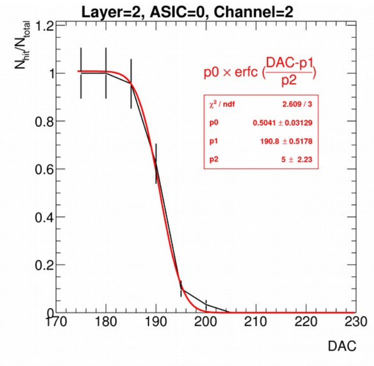
Commissioning & Passport delivery

- **Setup** :
  - 7 FEV11 each equipped with 4 325um Si wafers and 16 Skiroc2
  - Power pulsing and ILC mode (emulated ILC spill conditions)



- **Noise control → noisy channels: 7-8%**: very conservative approach.
  - Found a pattern on the spatial distribution of the noisy channels (3% of the total)
- **Autotrigger** optimization
  - Threshold scans made for all channels → one optimal threshold found for each ASIC

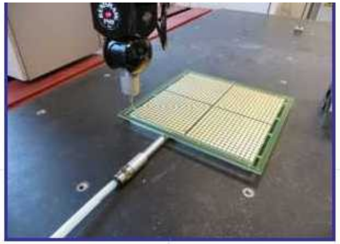




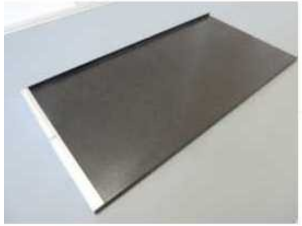
Commissioning used for DESY 2017 & 2018 and optimized for CERN@2018

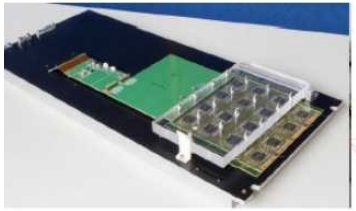
https://twiki.cern.ch/twiki/bin/view/CALICE/SiWDESY201706

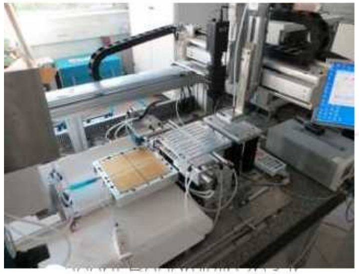
Assembly chain

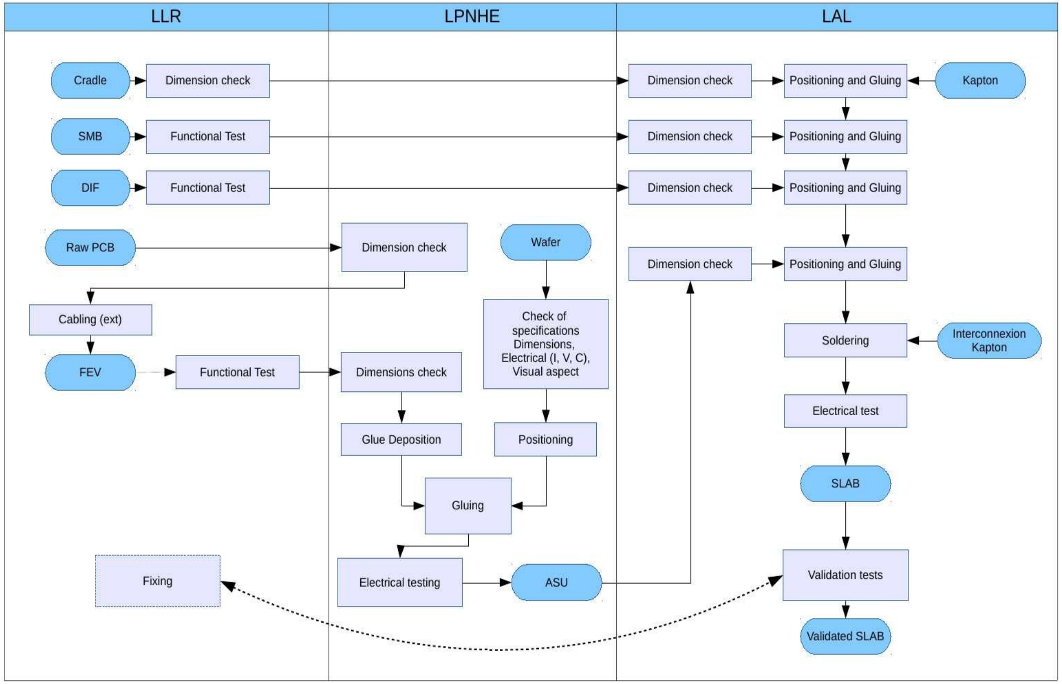


‘Simplified view’



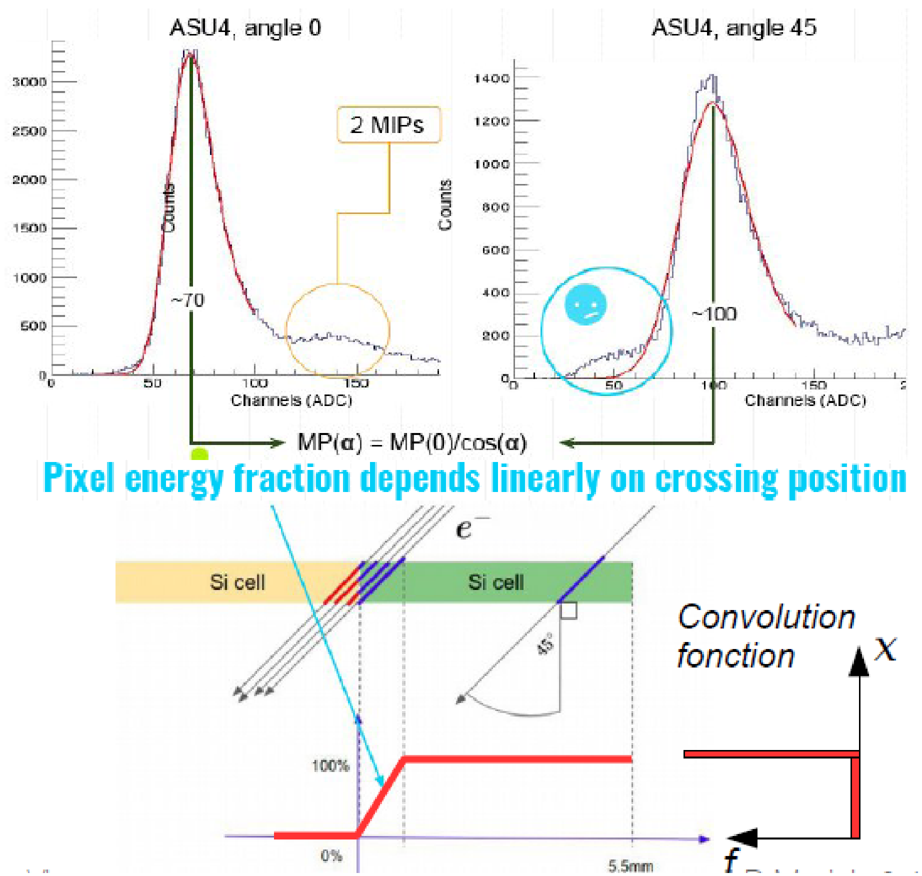


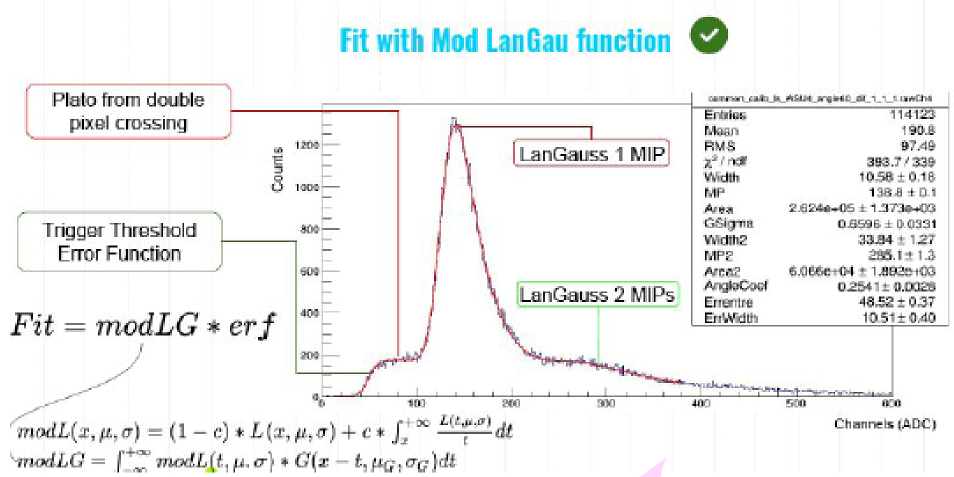




“Assembly and QA chain demonstrator report” on https://cds.cern.ch/record/2166513

4/30





- The mechanical strucutre of the long slab allowed for dedicated studies of MIP-like beam particle bombarding the ASUs at different angles.
- Allows for threshold calibration
  - Values at the expected position ~0.6-0.7MIP

O. Korostyshevskiy

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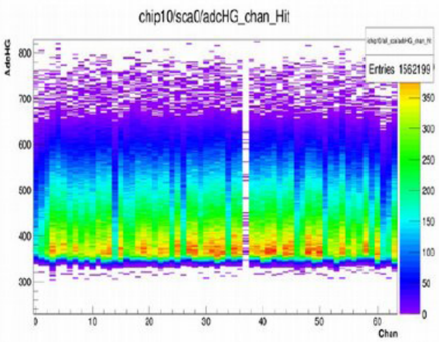
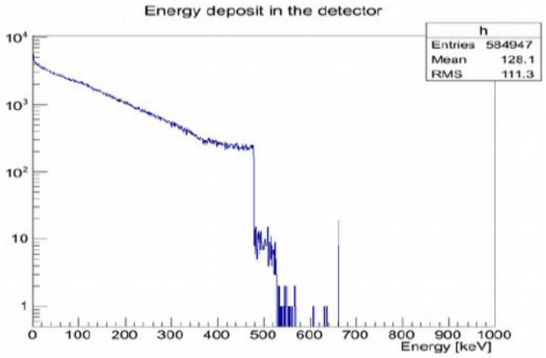
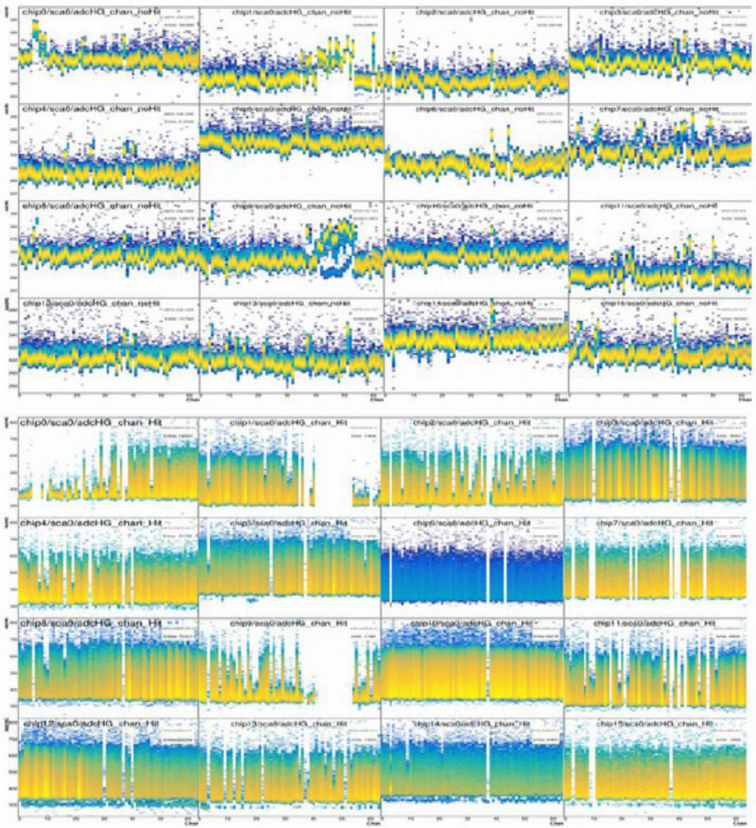
Full Stack & longs Slab irradiation with 137Cs sources



- Source 137Cs, 37MBq
- D~10 cm
- Acquisition time = 60000 s
- Threshold 240

Analysis on-going



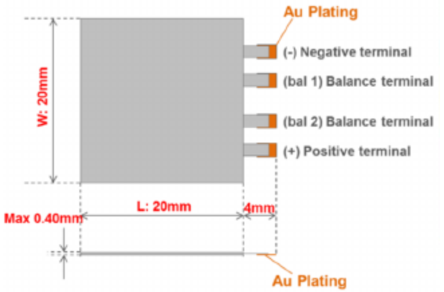


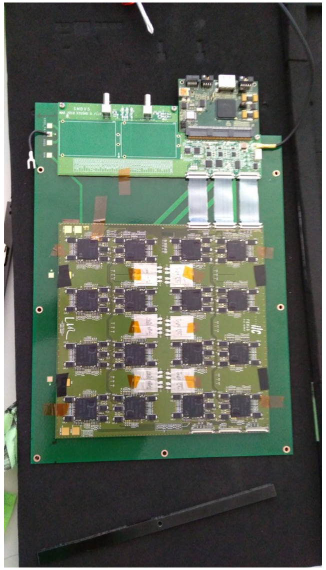
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

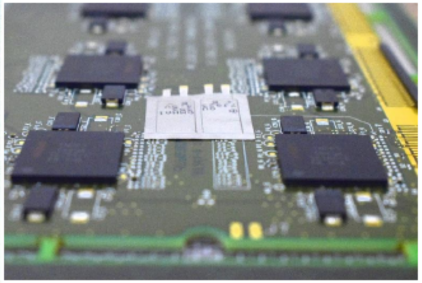
Compactification of the passive components of the ASU

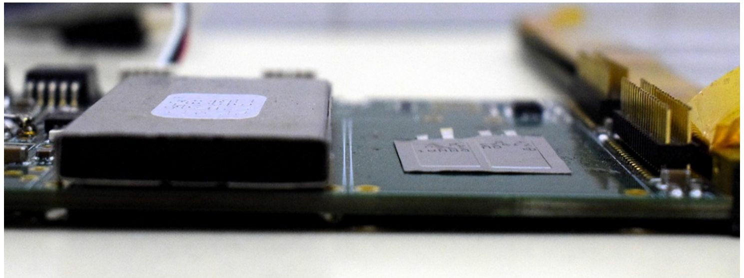
- Proposal to use new ultra-flat capacitors to distribute over the ASUs. This will permit:
  - Peak current reduction: especially through the connectors
  - No more voltage drop along the slab
  - Homogeneous peak power dissipation during power pulsing.
- We go from the 400 mF capacitor/ 12A (peak Current) for the whole SLAB to 140 mF / 1.2 A per ASU.

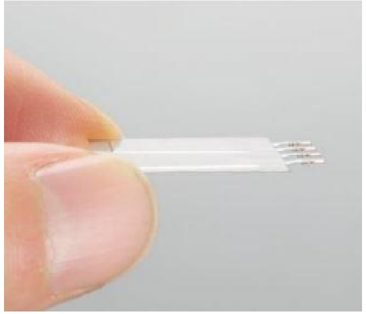
Brand new product, appeared few months ago



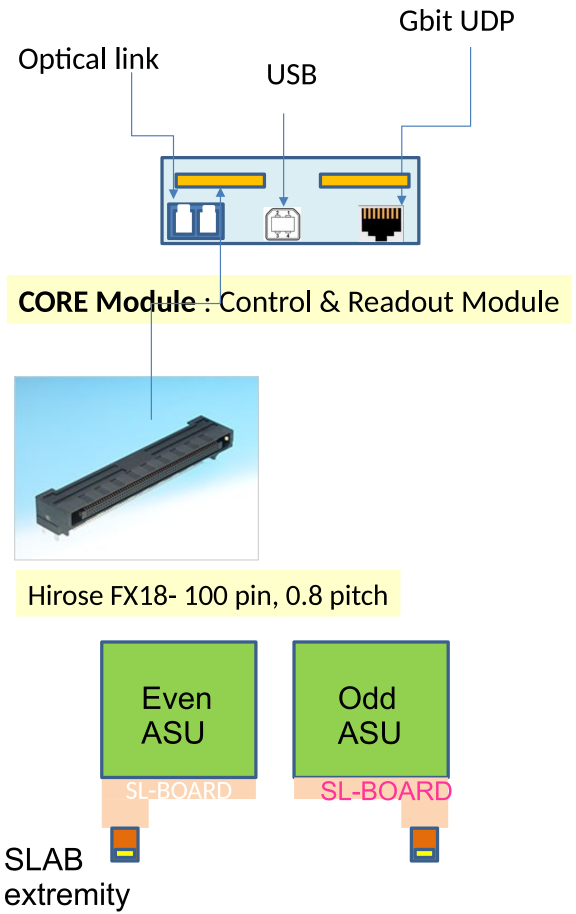


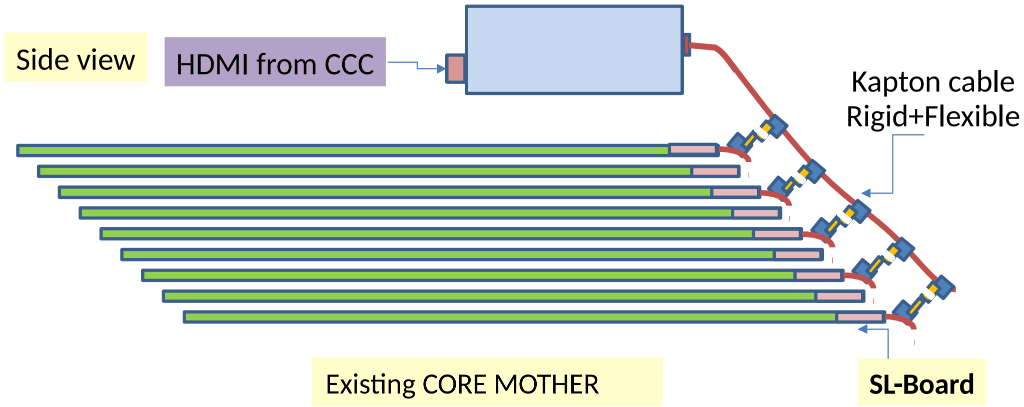




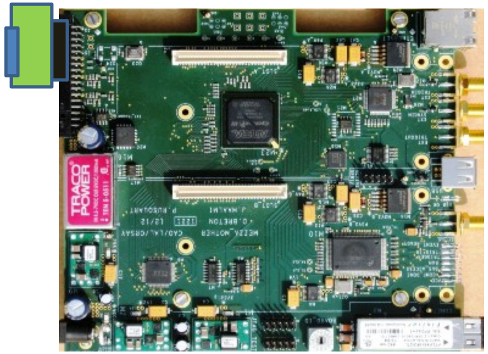


Digital readout – The CORE Module



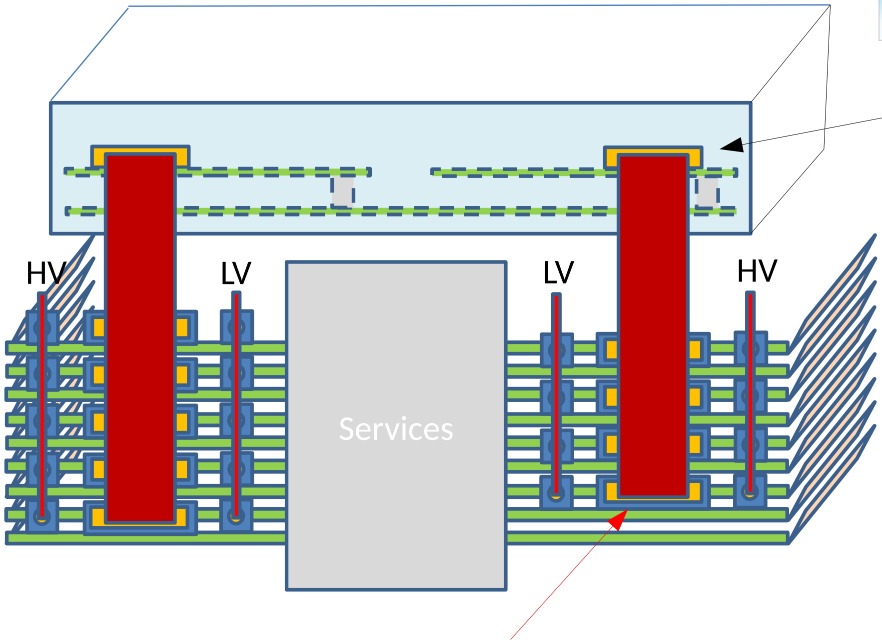


Existing CORE MOTHER



Towards global architecture I

Services separated between odd/even layers



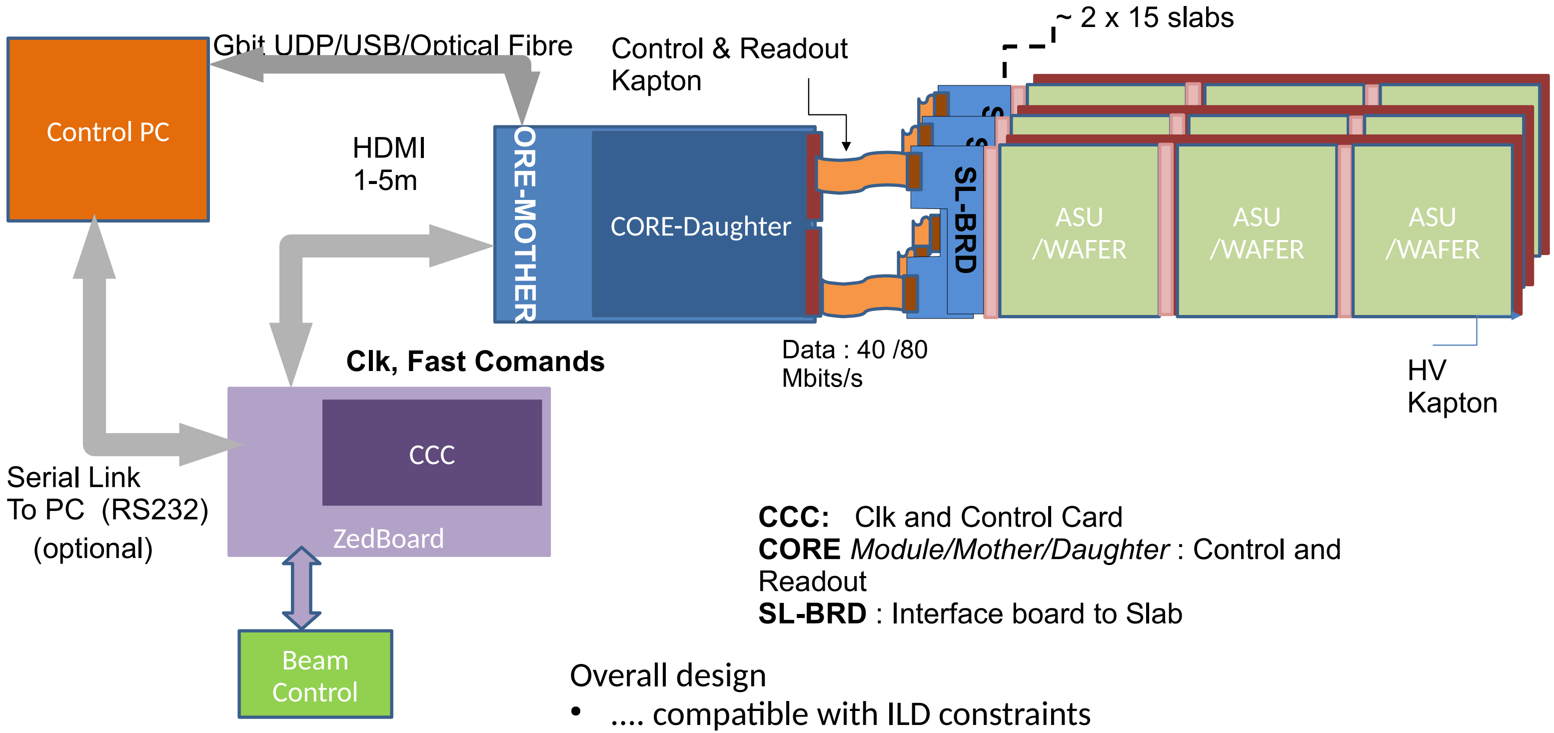
SL-Board Connector
7 differential pairs for sensitive signals, 2 individual pairs for control and readout, 14 common lines, GND

Core Module connector:
7 common differential pairs for sensitive signals, *30 individual pairs* for control and readout, 14 common lines, GND

	Signals
	Clk
	Trigger
	Start/Stop
	Busy
	Irq
JTAG	TCK
JTAG	TMS
JTAG	TDI
JTAG	TDO
SPI	SCK
SPI	SDI
SPI	SDO

Signals
Rx_i
Tx_i
ADD[0]
ADD[1]
ADD[2]
ADD[3]
Spare …
GND …

Towards global architecture II



CCC: Clk and Control Card
CORE *Module/Mother/Daughter* : Control and Readout
SL-BRD : Interface board to Slab

Overall design
- .... compatible with ILD constraints
  - Little space consumption for connection between slabs and CORE Modules
  - CORE Mother can be placed at the forefront of barrel, Daughter between Ecal and Hcal
- ... assures compatibility with other AIDA2020 developments
  => Paves way for combined beam tests (other calos, trackers etc.)
- Expect first version of system to be in place for summer 2018
- SL-Board is delivery for AIDA2020 and P2IO/HIGHTEC