Commissioning of SiW ECAL Prototype

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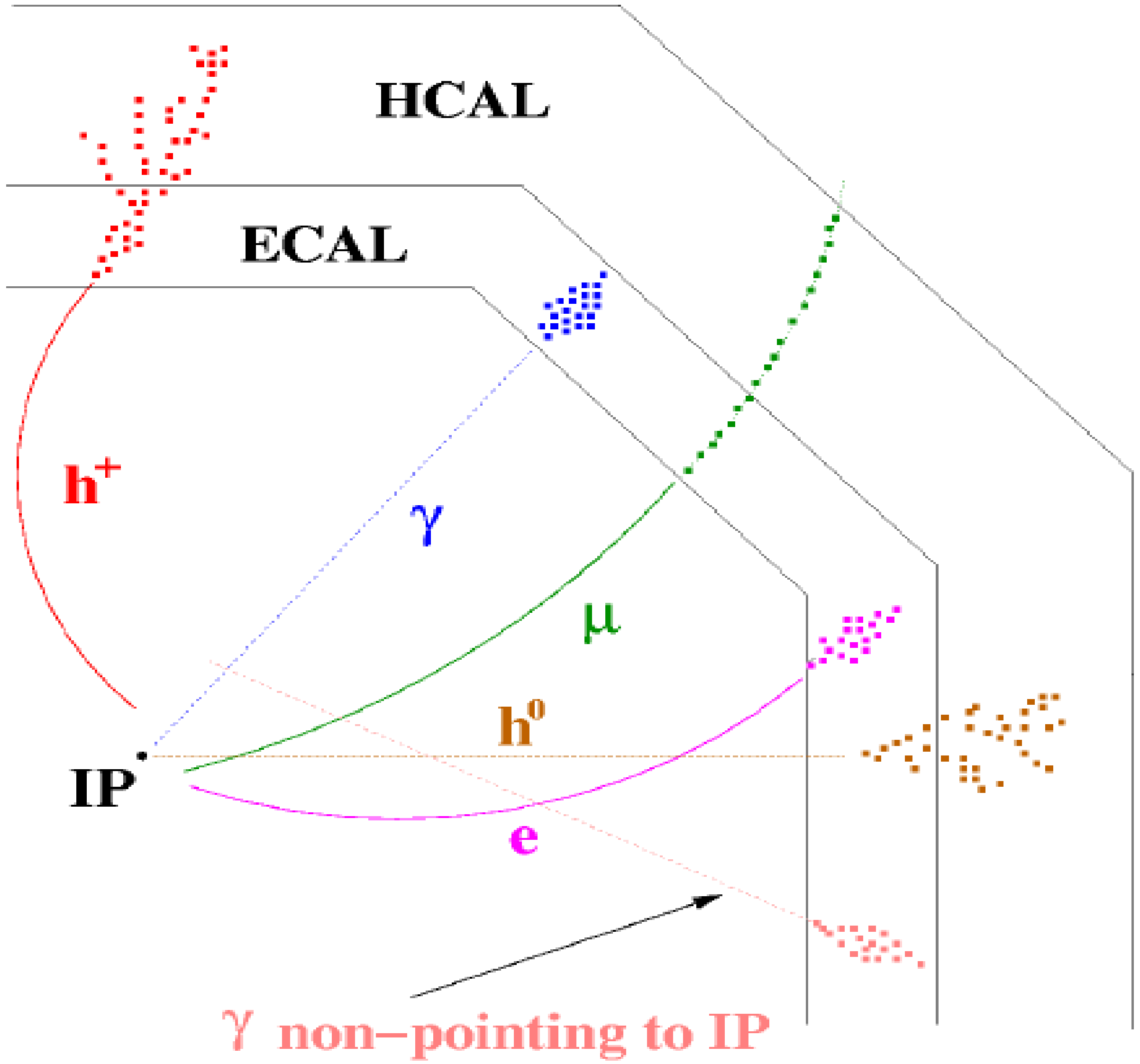
On behalf of the SiW ECAL Groups in CALICE:

CEPC Workshop – May 2022

Particle Flow Calorimetry

Jet energy measurement by measurement of **individual particles**
Maximal exploitation of precise tracking measurement

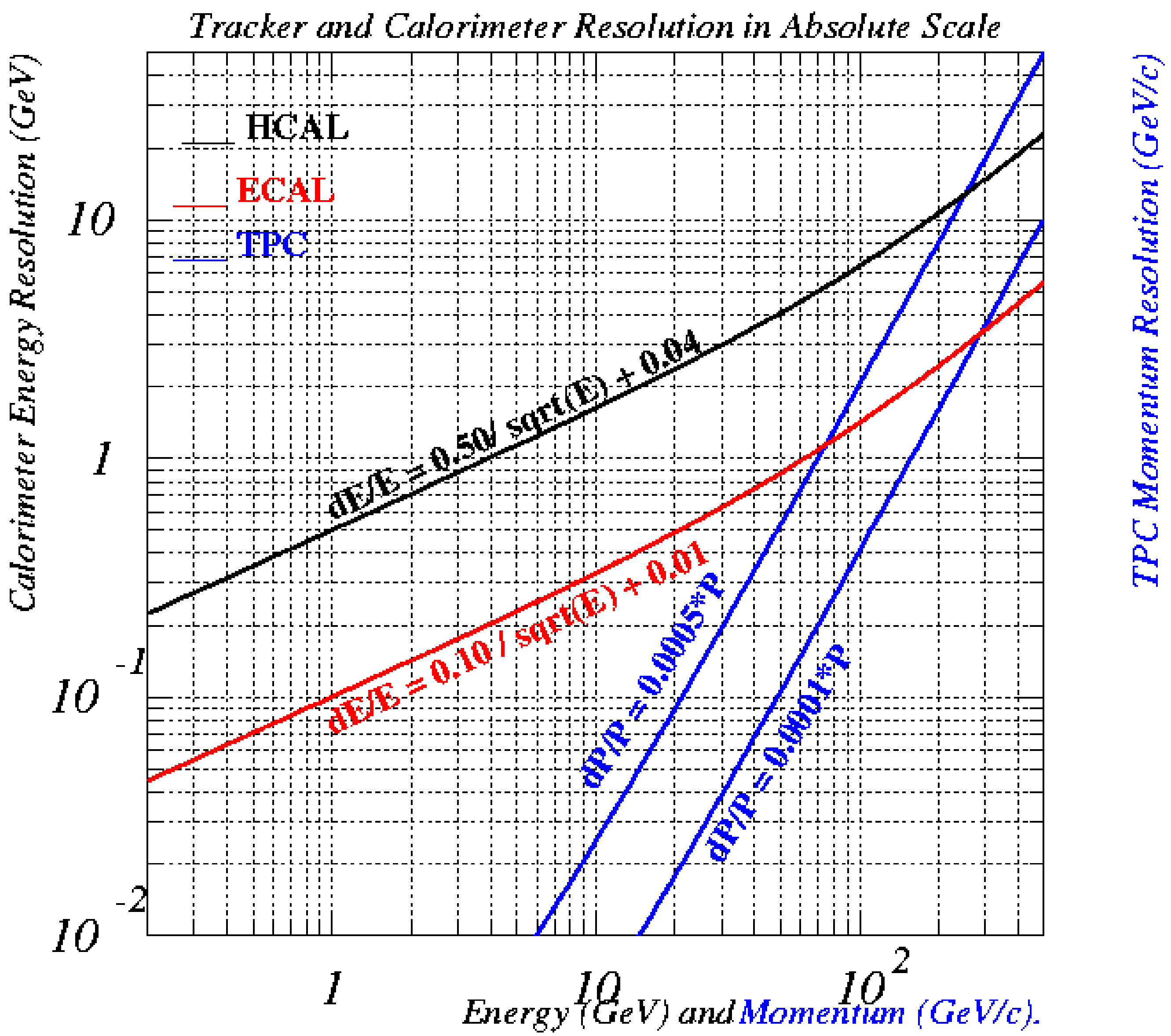
- large radius and length
  - → to separate the particles
- large magnetic field
  - → to sweep out charged tracks
- "no" material in front of calorimeters
  - → stay inside coil
- small Molière radius of calorimeters
  - → to minimize shower overlap
- **high granularity of calorimeters**
  - → to separate overlapping showers



Particle flow as privileged solution for experimental challenges
=> Highly granular calorimeters!!!
Emphasis on tracking capabilities of calorimeters

Jet Energy Resolution

Final state contains high energetic jets from e.g. Z,W decays
Need to reconstruct the jet energy to the utmost precision !
Goal is around dE_{jet}/E_{jet} - 3-4% (e.g. 2x better than ALEPH)



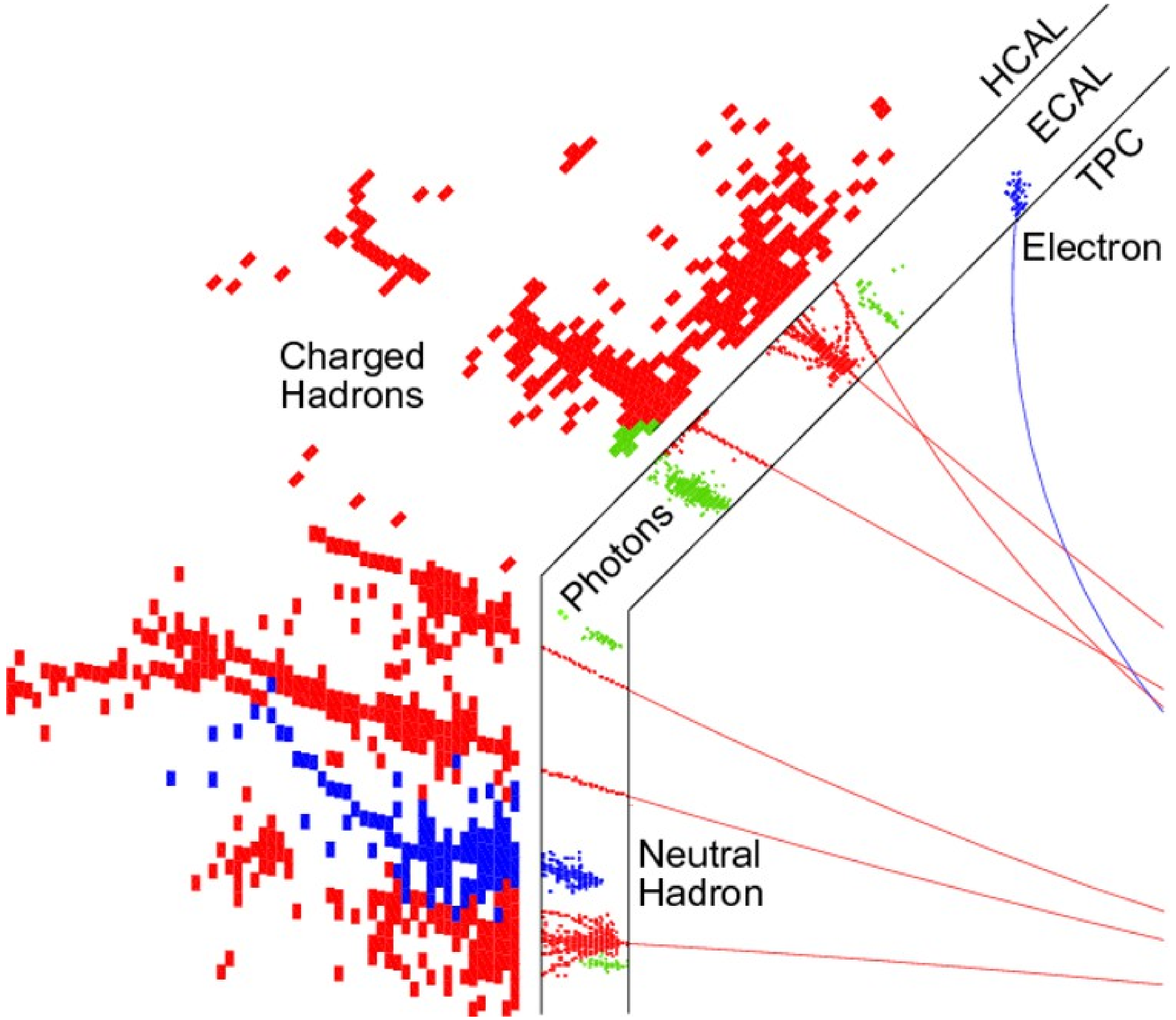
Jet energy carried by …

- Charged particles (e±, h±,μ±65% :((
  Most precise measurement by Tracker
  Up to 100 GeV
- Photons: 25%
  Measurement by Electromagnetic
  Calorimeter (ECAL)
- Neutral Hadrons: 10%
  Measurement by Hadronic
  Calorimeter (HCAL) and ECAL

$$\boxed{\sigma_{Jet} = \sqrt{\sigma^2_{Track} + \sigma^2_{Had.} + \sigma^2_{elm.} + \sigma^2_{Confusion}}}$$

Silicon Tungsten electromagnetic calorimeter

- Base measurement as much as possible on measurement of charged particles in tracking devices
- Separate of signals by charged and neutral particles in calorimeter



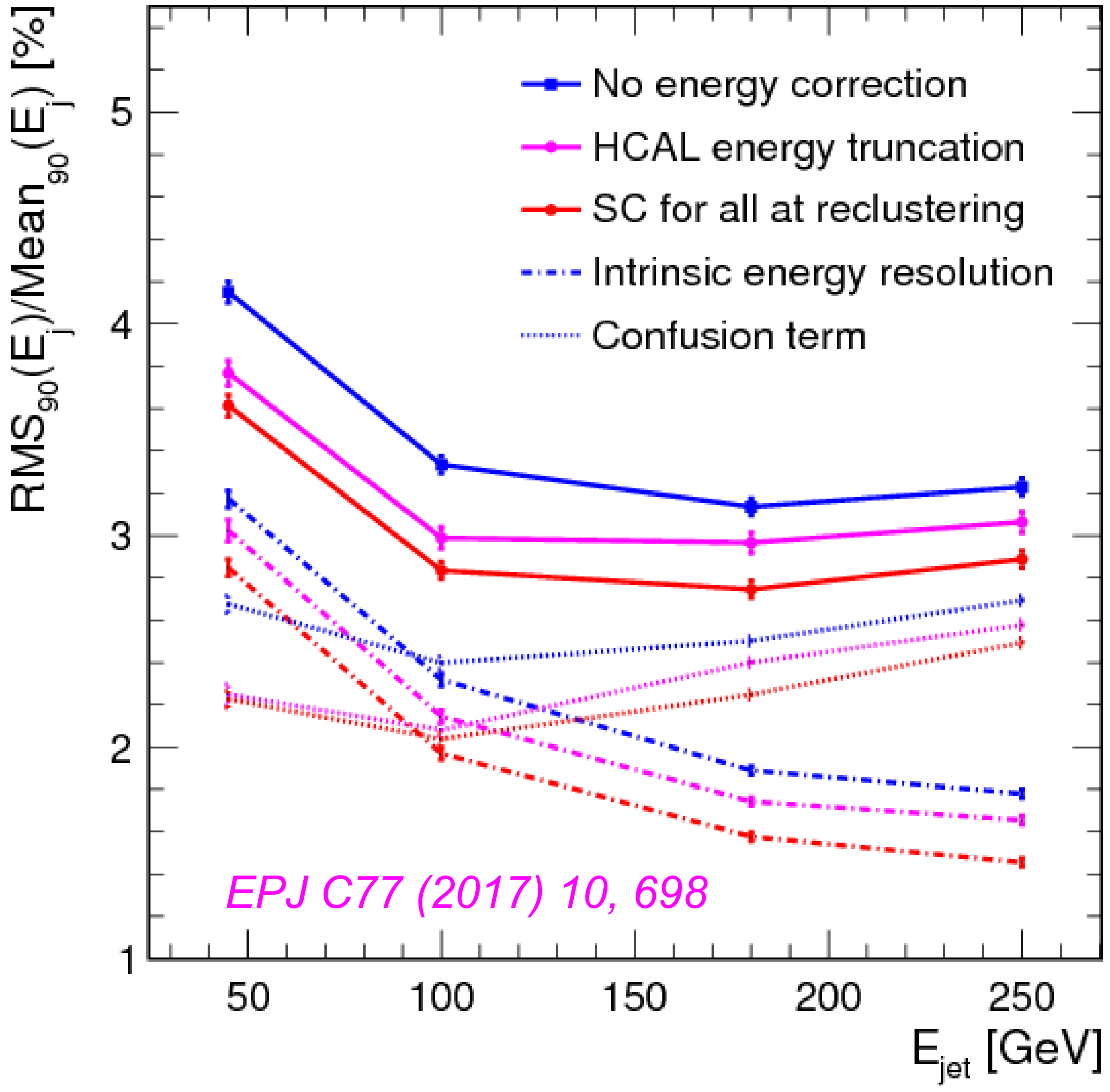
- Complicated topology by (hadronic) showers
- Overlap between showers compromises correct assignment of calo hits

 Confusion Term

Need to minimize the confusion term as much as possible !!!

Jet energy resolution

Pandora PFA jet energy resolution



Study within ILD Concept

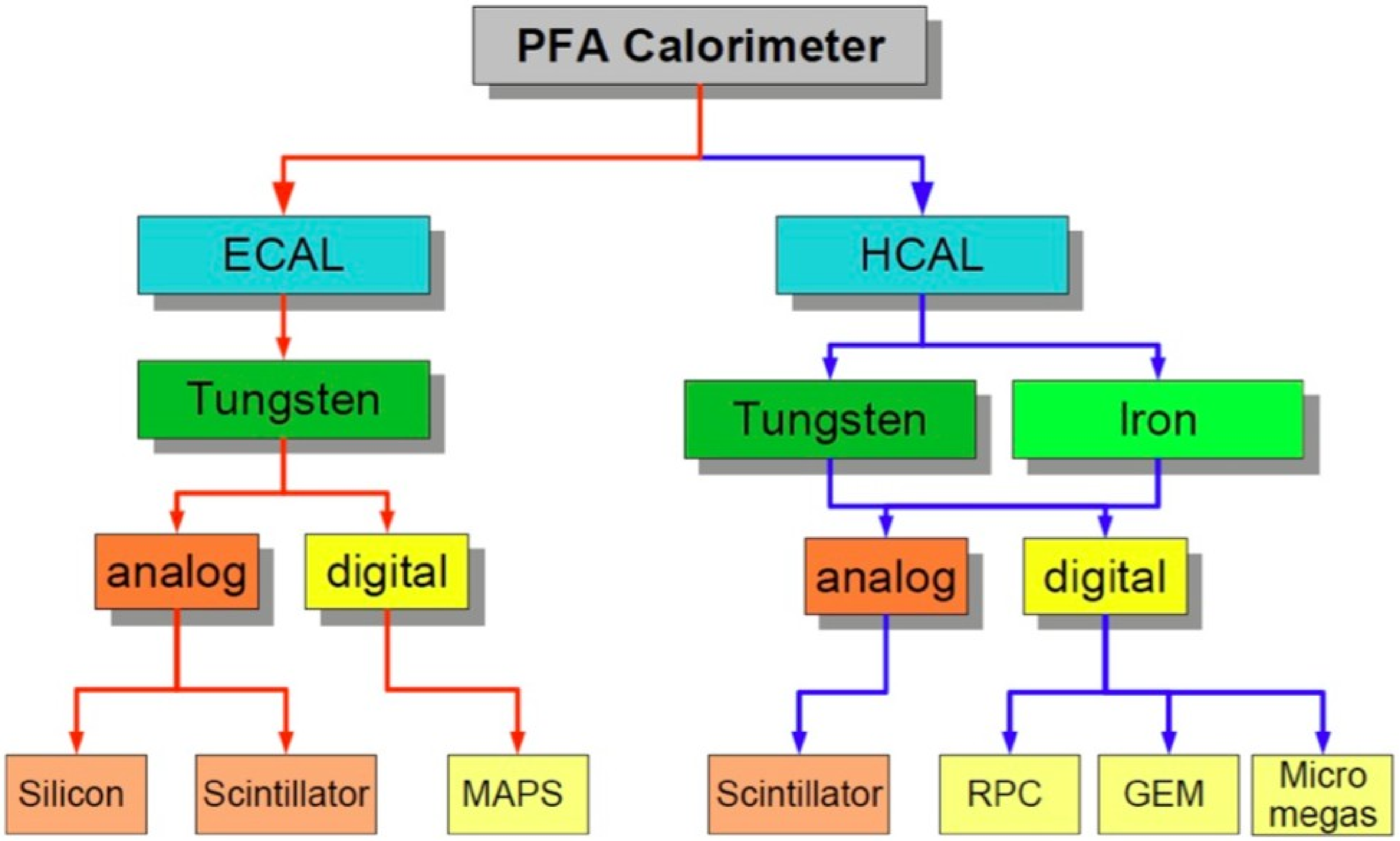
- Design goal: 30%/√E at 100 GeV
  - ~3-4% over entire jet energy range
- At lower energies < 100 GeV resolution is dominated by intrinsic calorimeter resolution
- At higher energies have more particles and higher boost
  - Smaller distance between particles
  - More overlap between calorimeter showers
  - Pattern recognition becomes more challenging

  =>Confusion
- Note particularly the gain by software compensation
  - i.e. exploiting the wealth of information available through high granularity

PFA ARBOR is algorithm of choice for CEPC Detector with similar performance

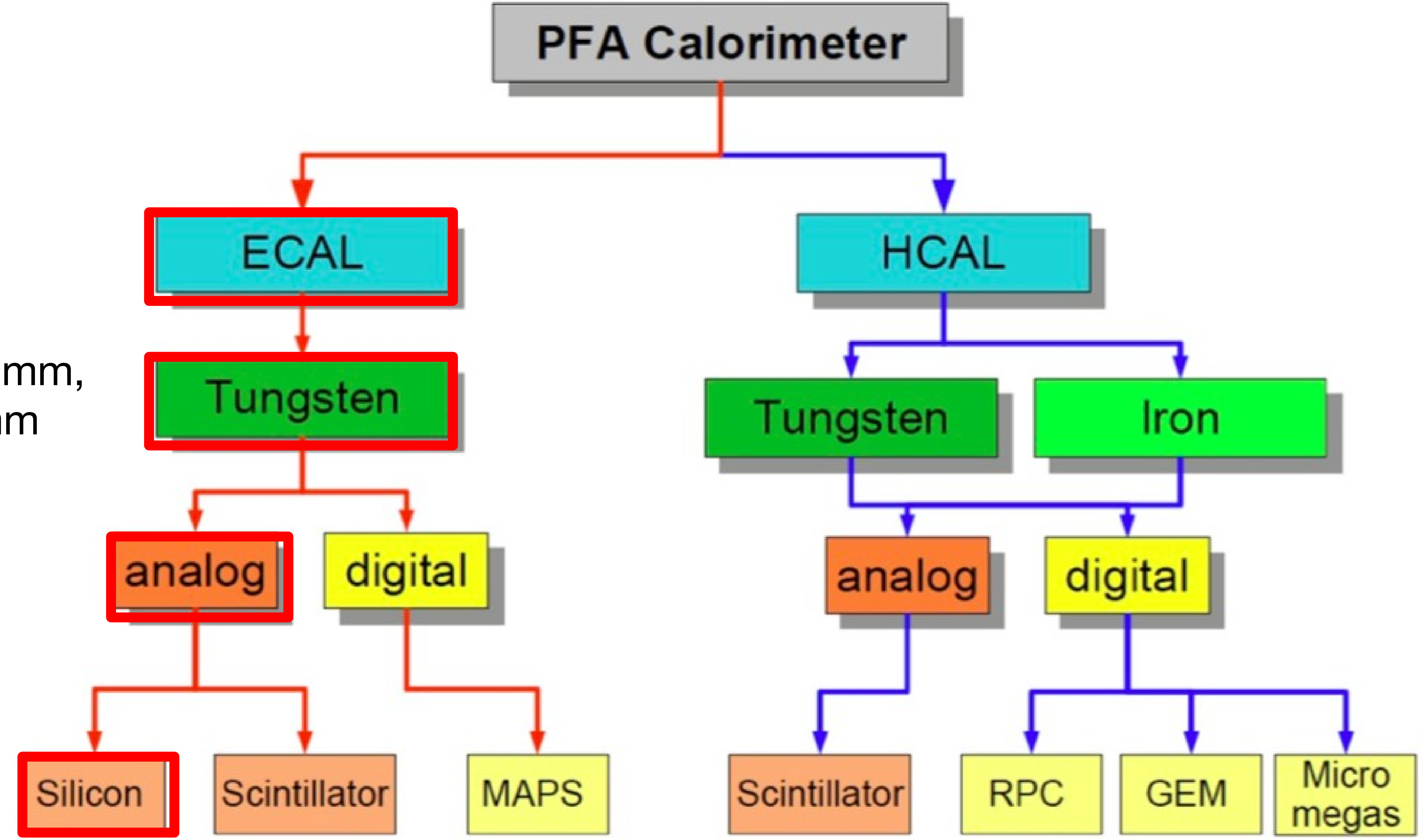
CALICE Collaboration

Mainly organised within the: CALICE Collaboration



CALICE Collaboration

Mainly organised within the: CALICE Collaboration



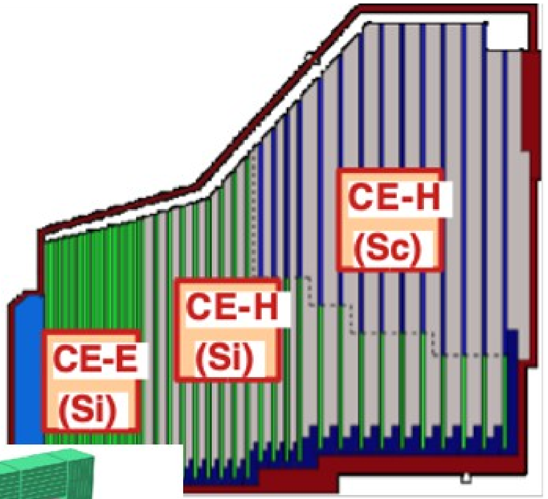
X_0 ~ 3.5 mm,
ρ_M ~ 9 mm

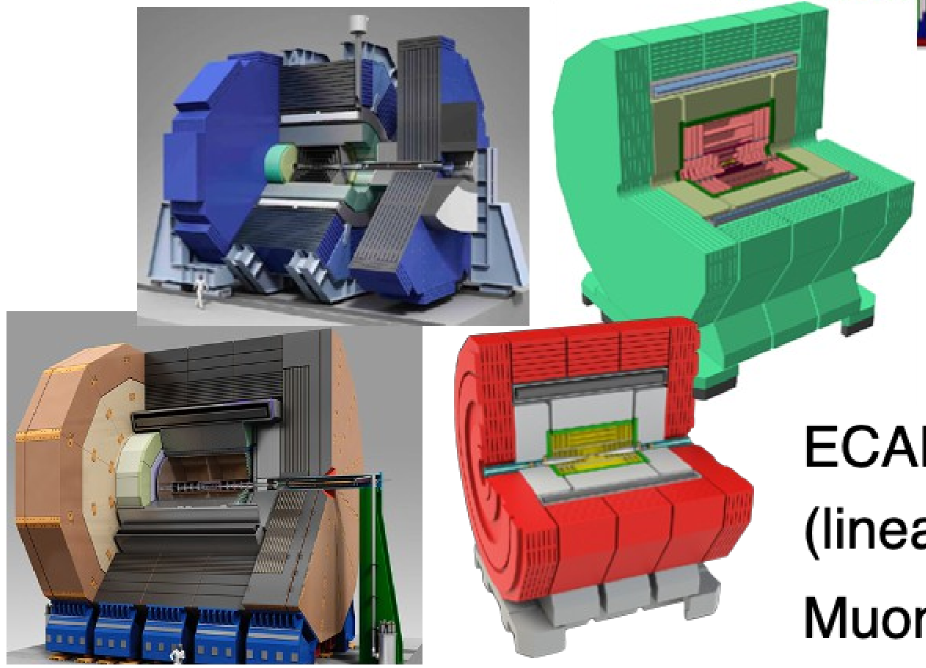
Si Based Calorimeters in Current and Future Experiments

- Grouped into two categories:

Main calorimeters of collider experiments
(barrel and / or endcap)

CMS HGCAL
(ECAL, part of HCAL)

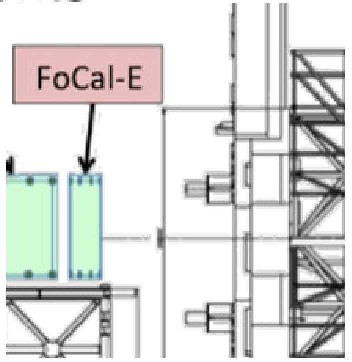


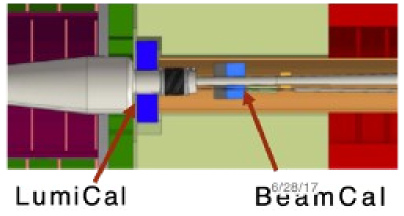


ECALs of Higgs Factory detectors
(linear and circular colliders);
Muon colliders

Smaller, specialized calorimeter systems
in collider and non-collider experiments

Very forward calorimeters: ALICE





Luminosity
measurement at e^+e^-

Non-collider experiments: LUXE, Satellites,
…

Main arguments for adopting silicon:
- Finely segmentable: High granularity
- Robust and stable performance
- Compact design, high density
  - typically combined with W absorbers for maximum compactness, small ρ_M

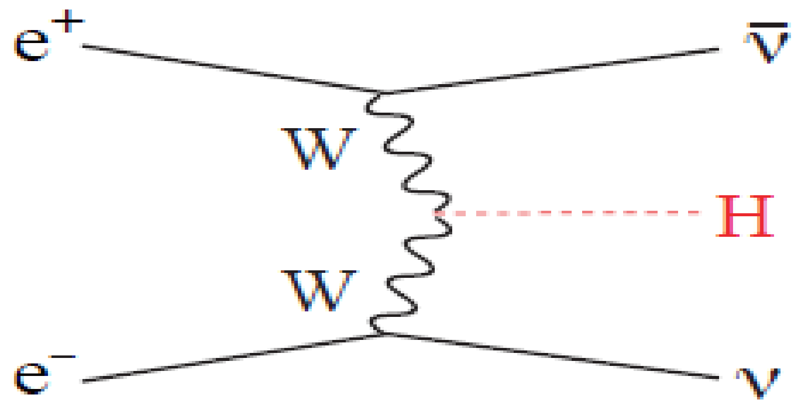
Main challenge: Cost

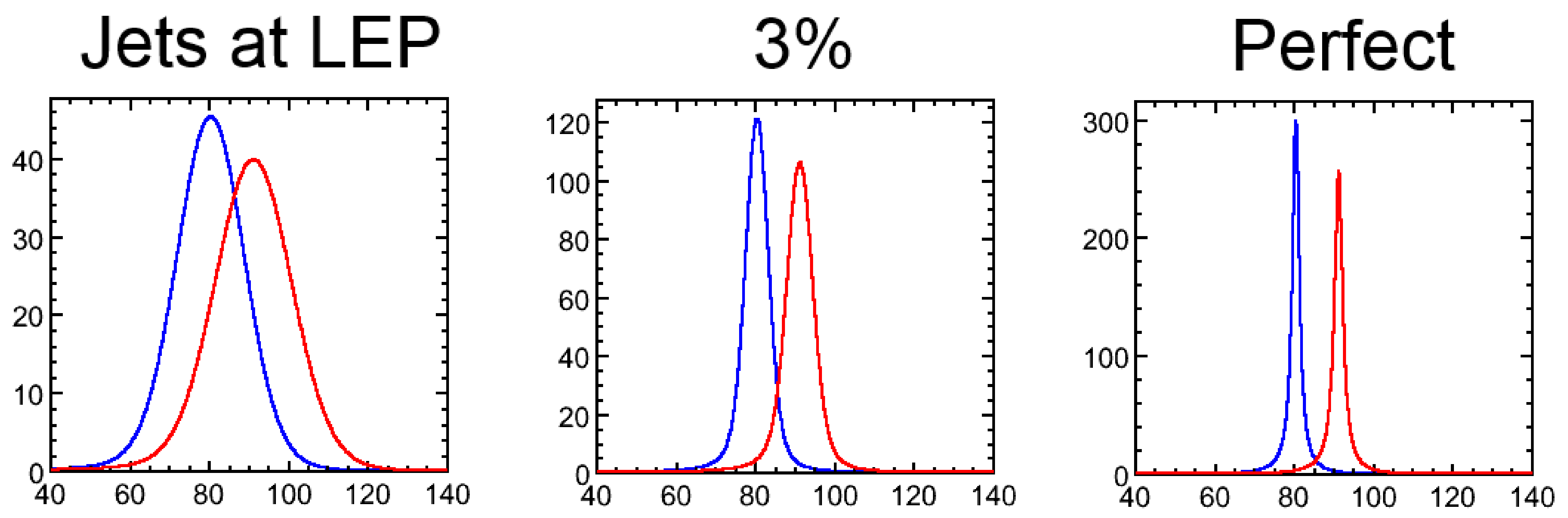
Symposium talk: V. Boudry

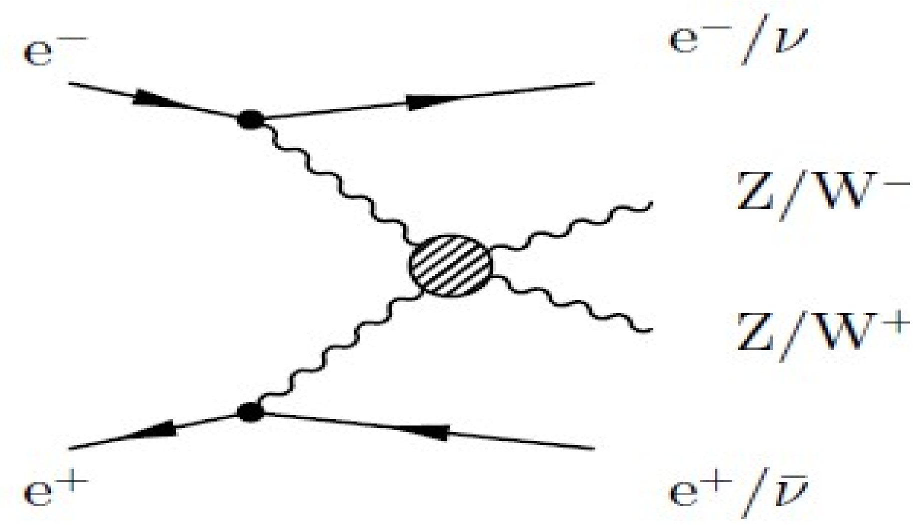
Examples:

- W Fusion with final state neutrinos requires reconstruction of H decays into jets

- Jet energy resolution of ~3% for aclean W/Z separation



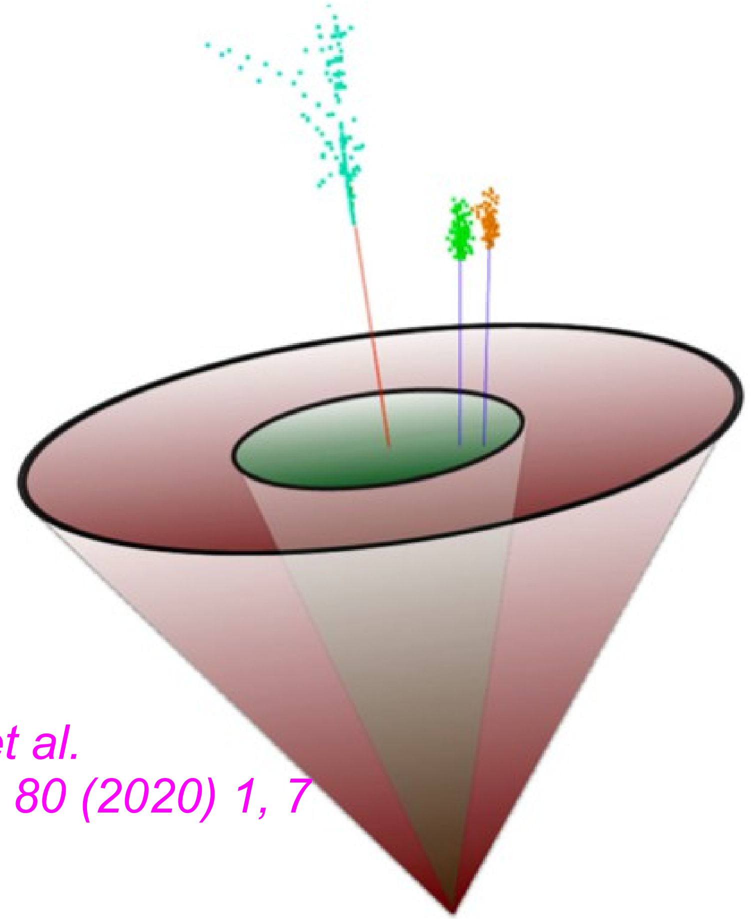




M. Thomson

Slide: F. Richard at International Linear Collider – A worldwide event

Granular calorimeters – Use case II - τ-lepton reconstruction



From D. Yu et al.
Eur.Phys.J.C 80 (2020) 1, 7

Available Tau Finders:

- TAURUS (for CEPC)
- Tau-Finder in ILD Marlin

- Features on τ τ fnal states
  - Small multiplicity
  - => Can cut on small number of Particle Flow objects
- Assets of granular calorimeters
  - High granularity allows for counting of PFO
  - Clean separation of charged pion from photon clusters
  - Spatial resolution of close-by photons (at reasonable energy resolution)

- Prominently used τ decays

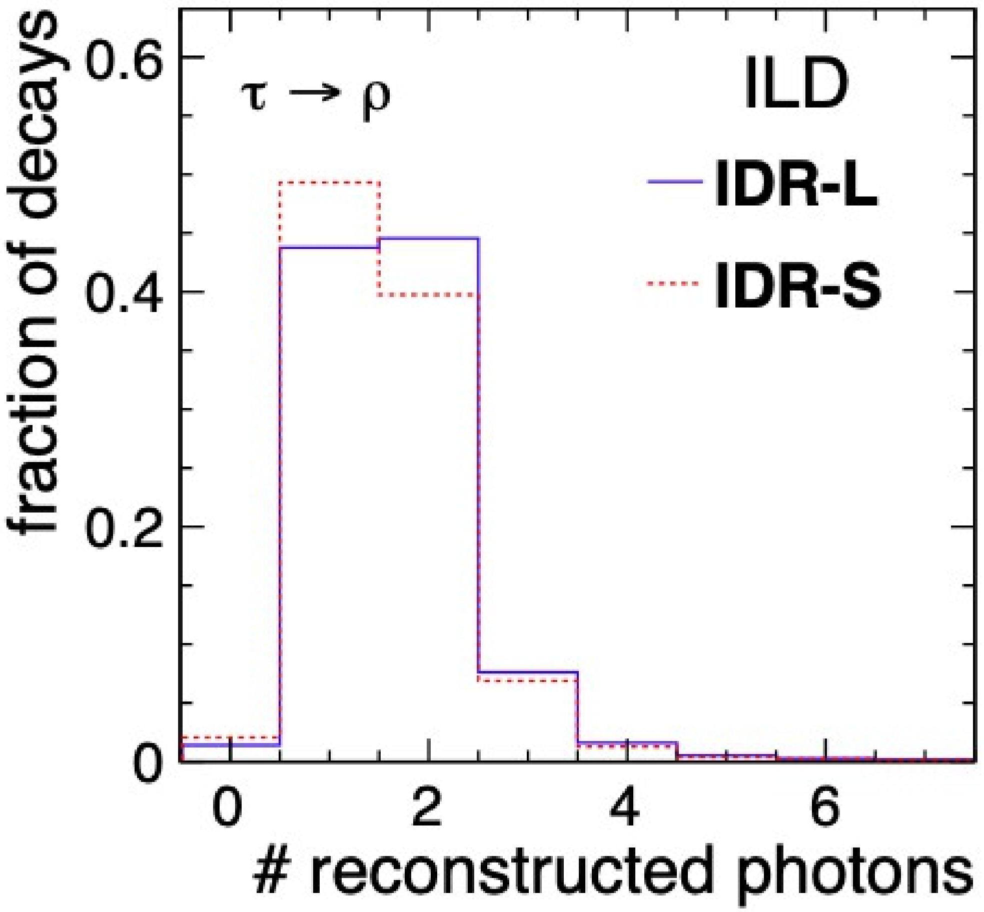
$$\tau^{\pm} \rightarrow \pi^{\pm} + \nu \,(\text{''}\pi\text{''})$$

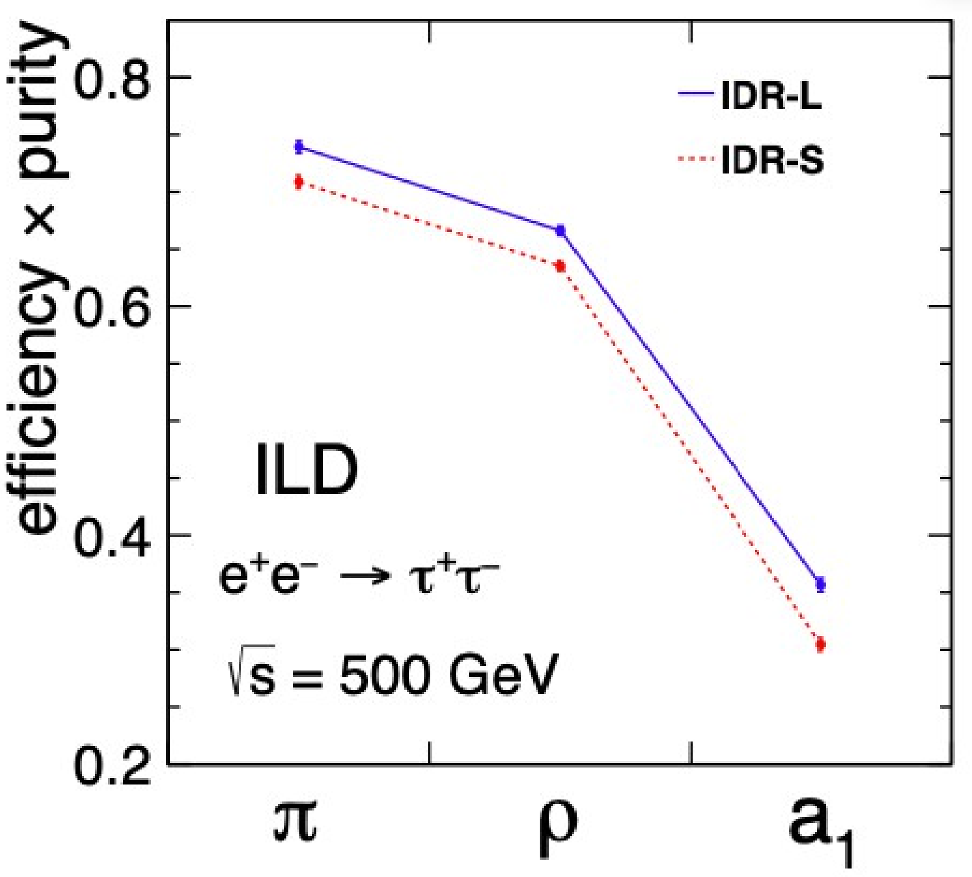
$$\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{0} + \nu \,(\text{''}\rho\text{''})$$

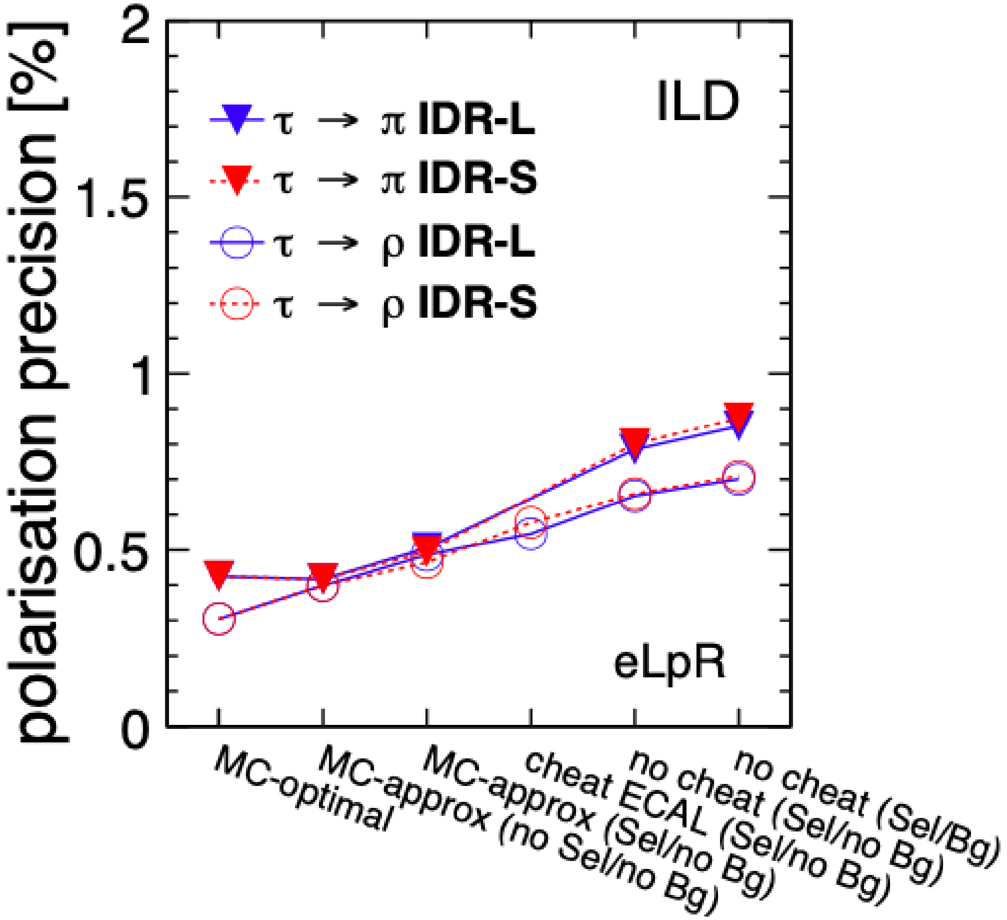
$$\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{0} + \pi^{0} + \nu \,(\text{''}a_1\text{''})$$

Granular calorimeters – Use case II - τ-lepton reconstruction cont'd

$e^+e^- \to \tau^+\tau^-$ Recent study at 500 GeV for ILD IDR







- Photon separation gets involved at high energies
- Still often only one photon reconstructed

- EfficiencyxPurity drops with increasing photon multiplicity

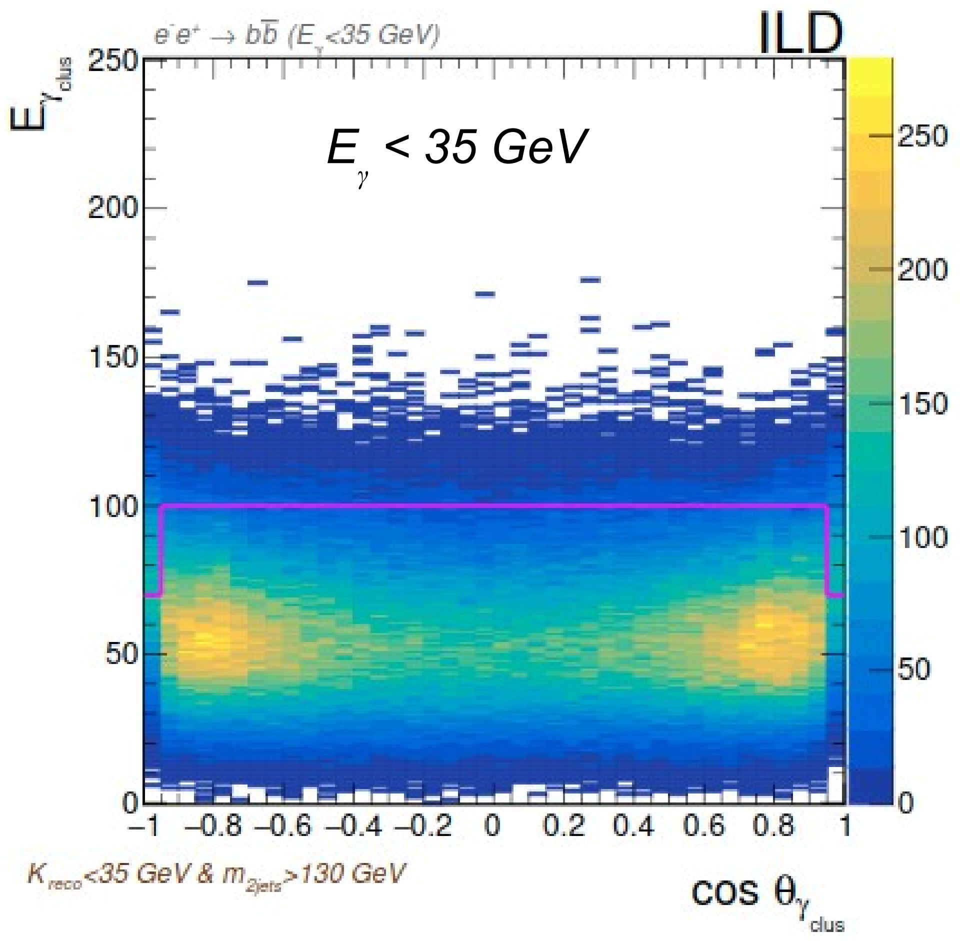
Precision of tau polarisation of order 0.3%-1%

- Close-by photons are challenge for highly granular calorimeters (in particular Ecal) at high-energies
- Ideal benchmark for detector optimisation
- Maybe still room for improvement, better algorithms?

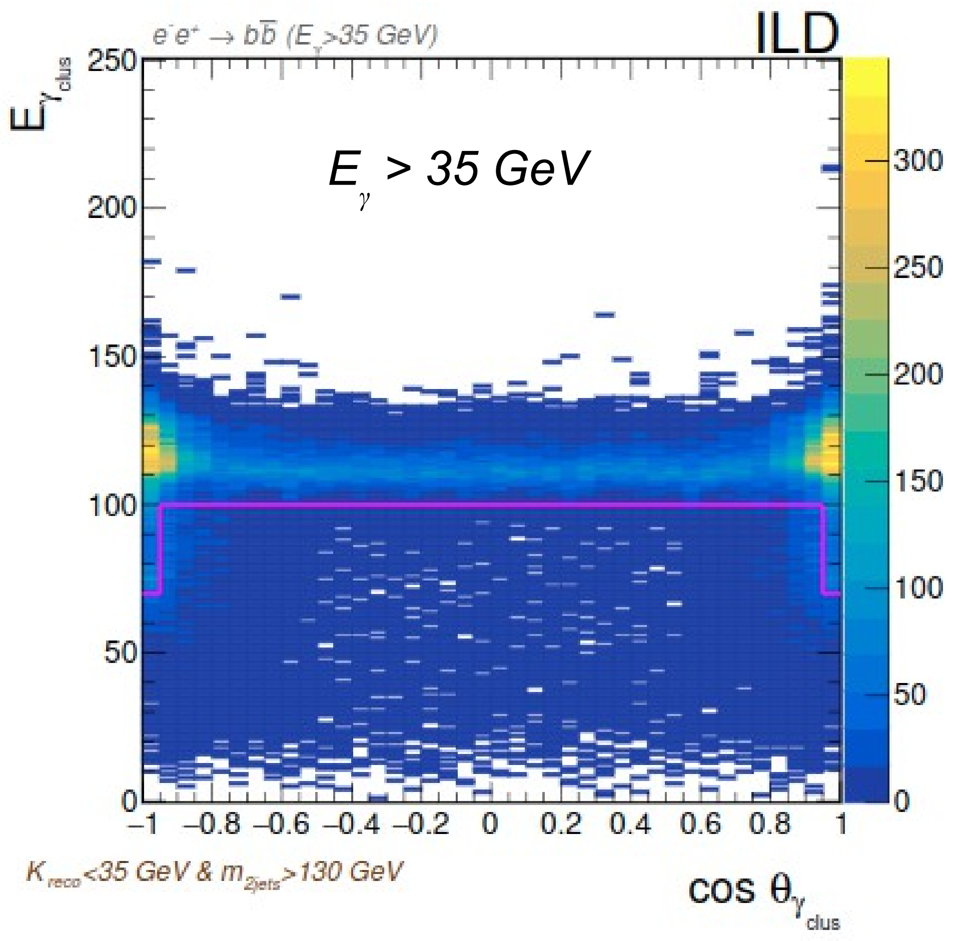
Granular calorimeters – Use case III

- Most ISR Photon are radiated collinearly but lead to a boost -> Check for acolinearity of dijet event
- Method doesn't work when photon is radiated into detector acceptance
  - ... and merged with a jet --> Busy environment

No or mild ISR



“Strong? ISR



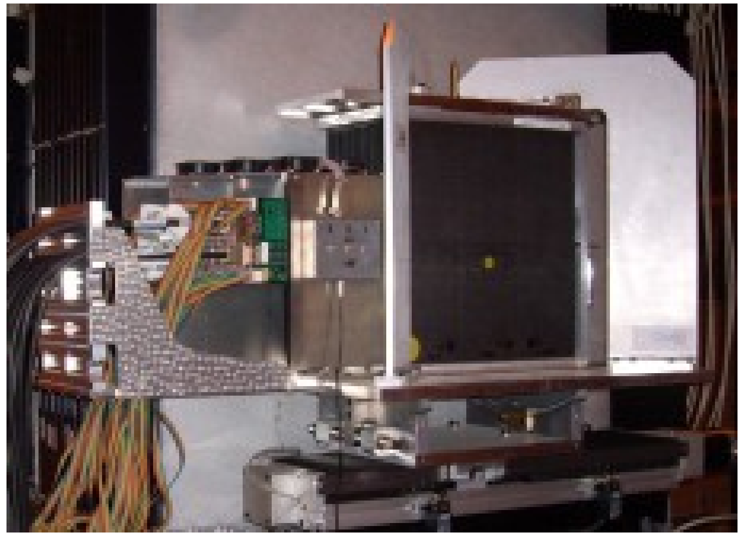
- Excellent photon ID in granular calorimeter is key
- Identification of ISR photon within detector (jet) reduces ISR background by nearly a factor of six
- Would be interesting to carry out this analysis with less granular calorimeters

ILD: Irles, Richard, R.P.

Steps of R&D

Physics Prototype

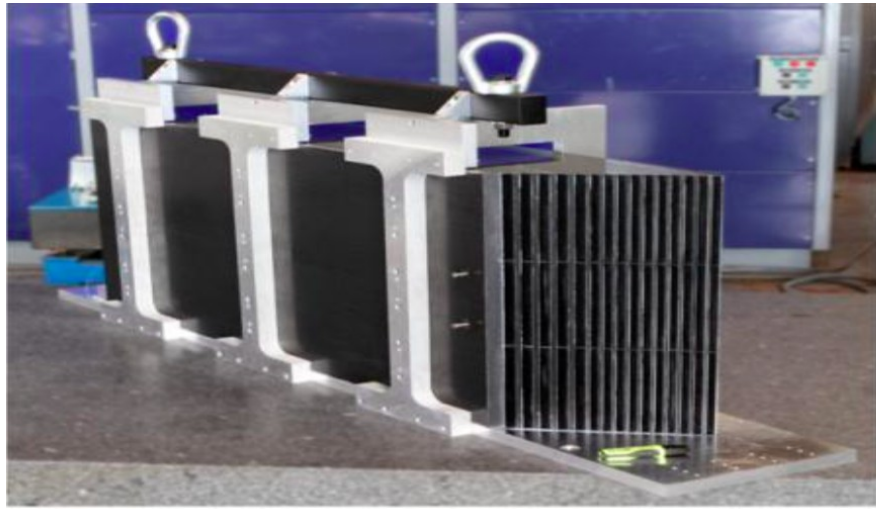
2003 - 2012



- Proof of principle of granular calorimeters
- Large scale combined beam tests

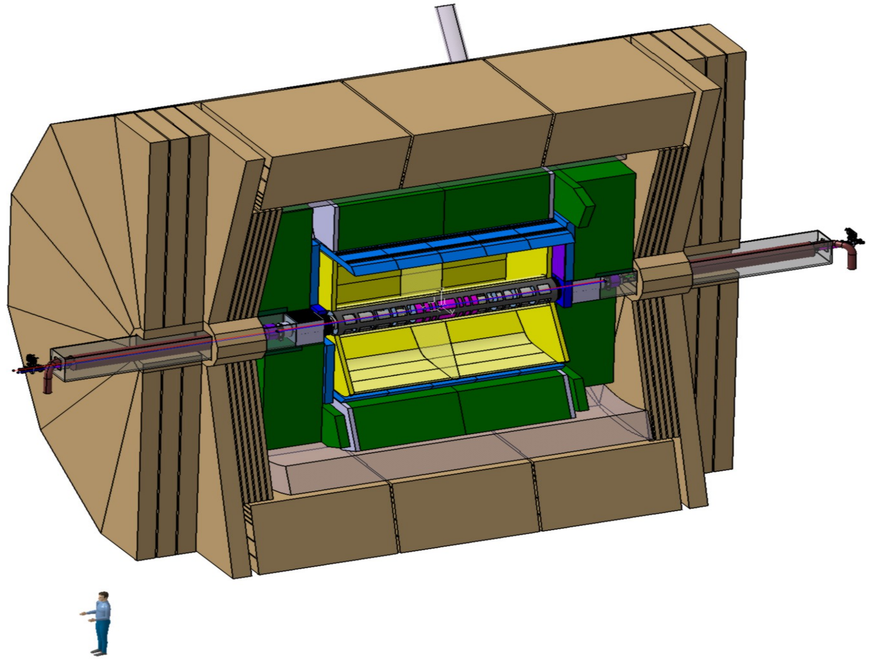
Technological Prototype

2010 - ...



- Engineering challenges
- Higher granularity
- Lower noise
- **Today**

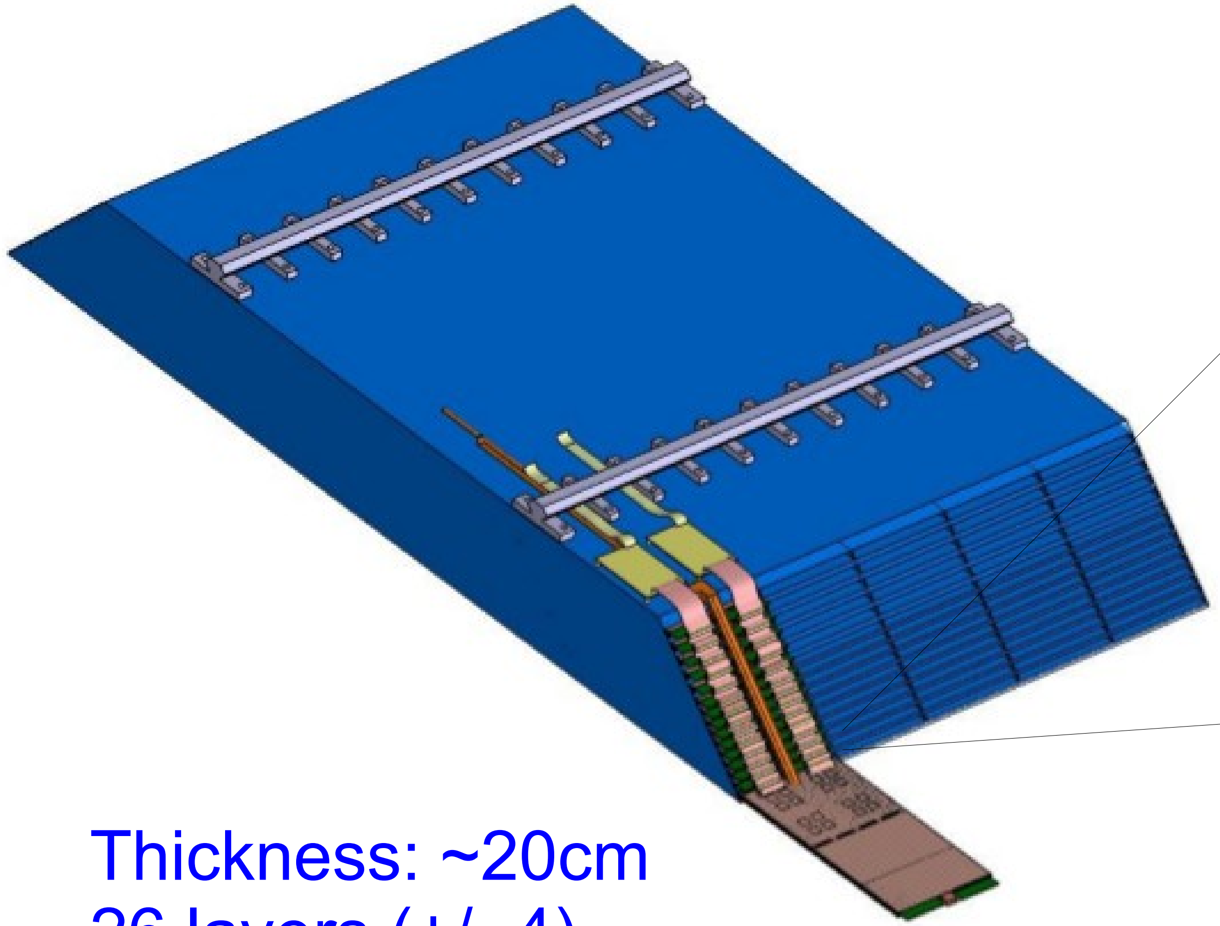
LC detector

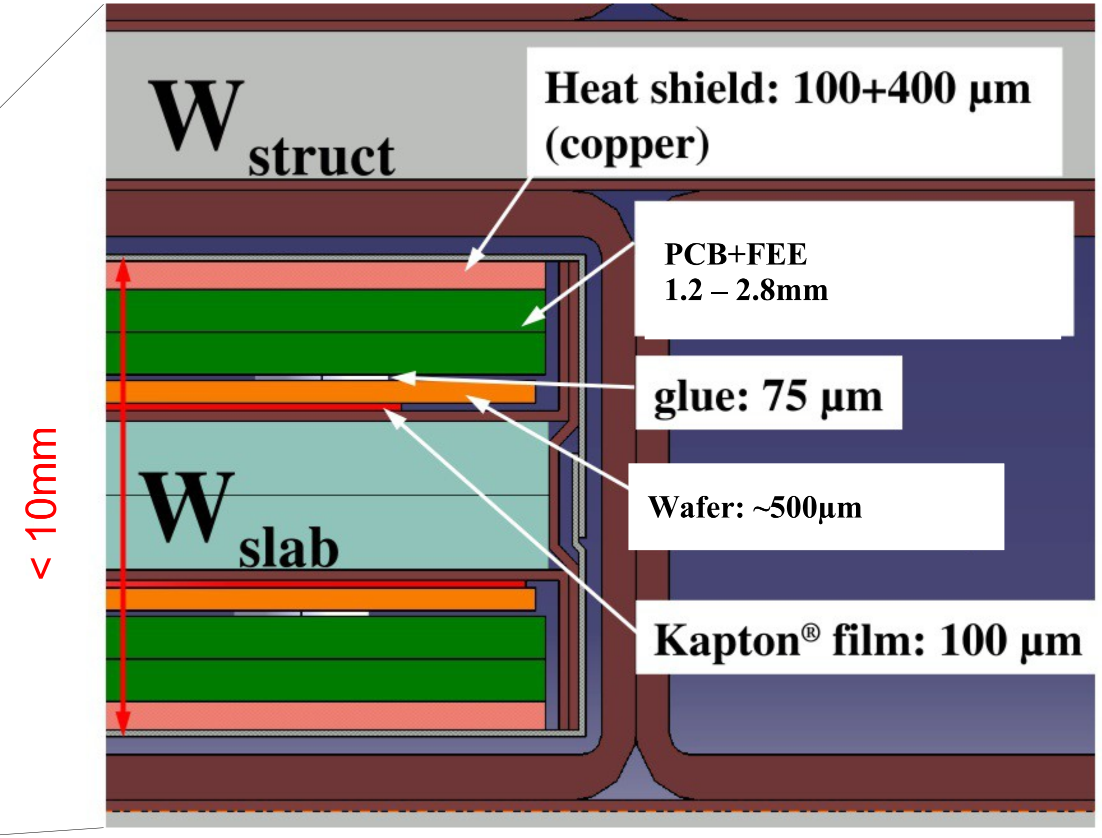


- The goal
  - Typically 10^8 calorimeter cells
- Compare:
  - ATLAS LAr ~10^5 cells
  - CMS HGCAL ~10^7 cells

Silicon Tungsten electromagnetic calorimeter – Example ILD

Ecal alveolar structure



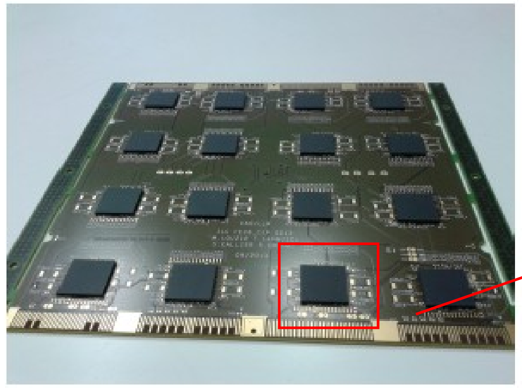


Thickness: ~20cm
26 layers (+/- 4)
24 $X_0/1\lambda_I$
Expected elm. energy resolution 15-20%/√E

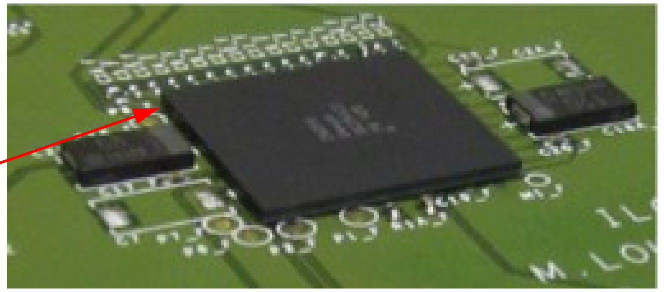
- Sandwich calorimeter
  - Si sensors as active material
  - W as absorber material
- Highly integrated design
  - ASICs in detector volume
  - Compact readout system

SiW Ecal – Elements of (long) layer

ASIC+PCB+SiWafer =ASU
Size 18x18 cm^2
(IJCLab, Kyushu, OMEGA, LLR, SKKU)

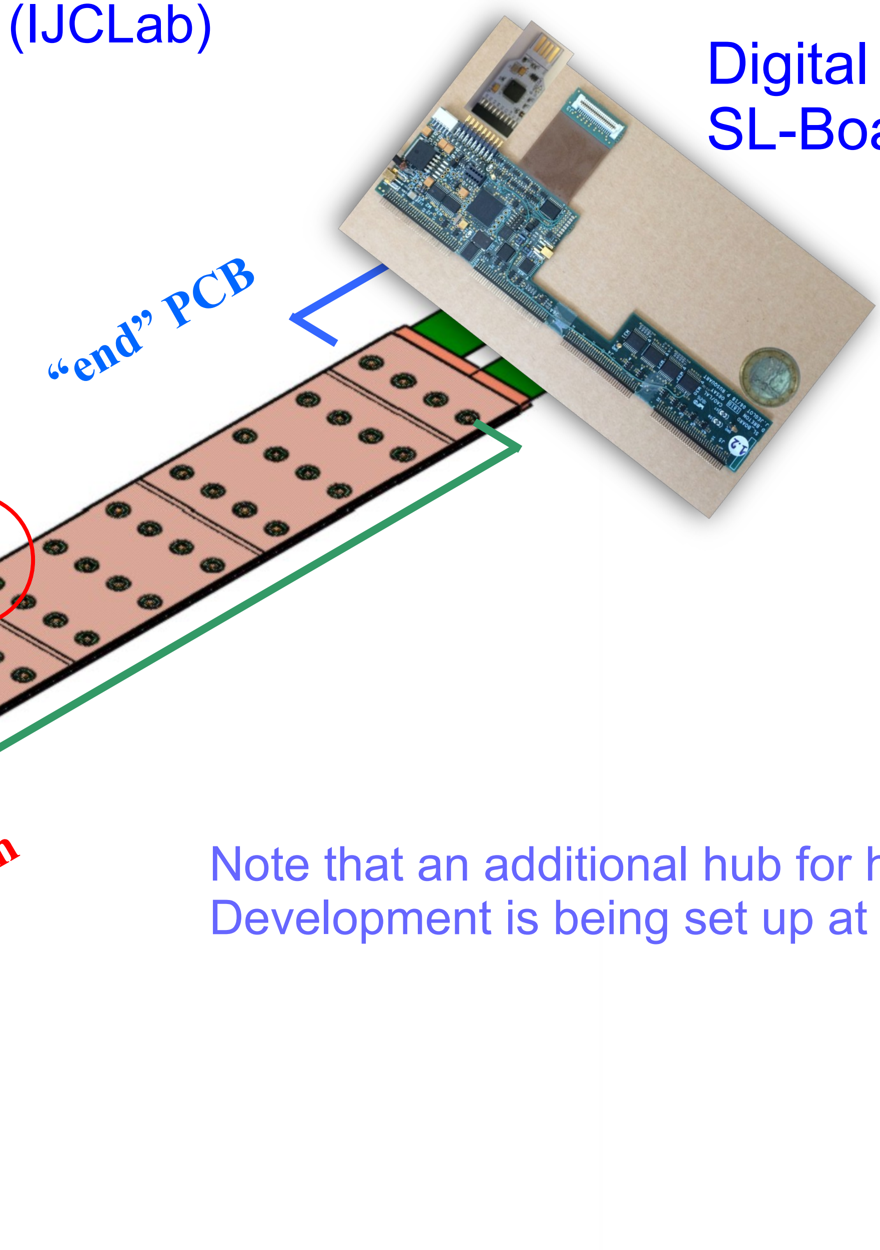
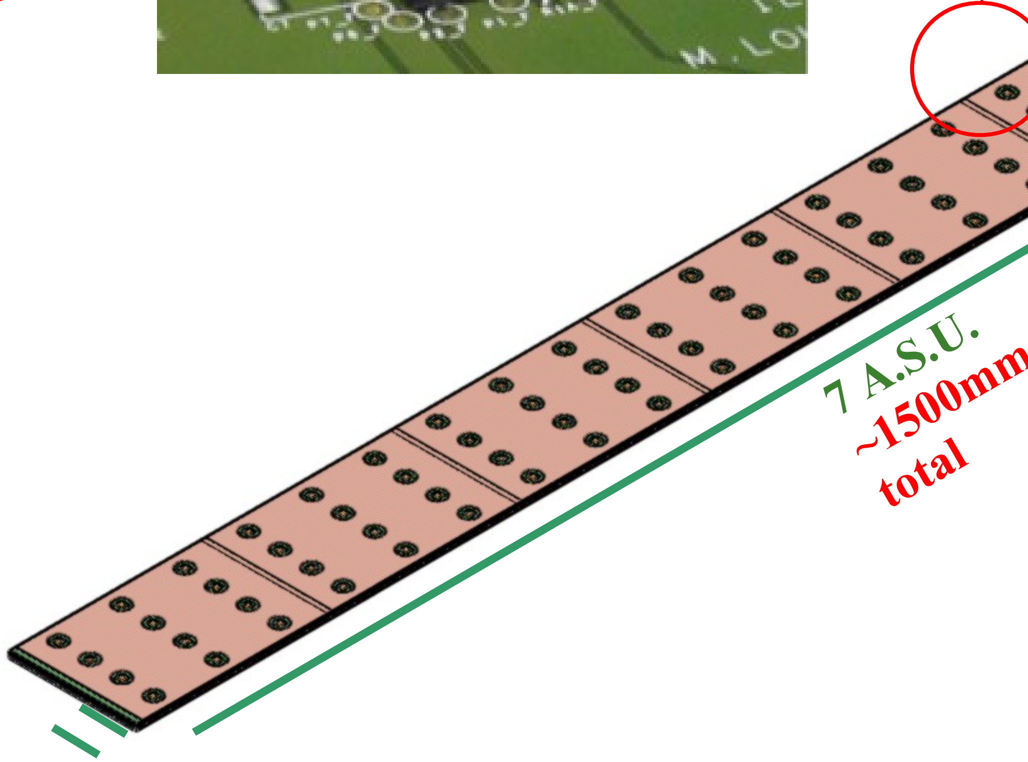


ASIC SKIROC2(a)
(OMEGA)
Wire Bonded or In BGA package
(IJCLab, Kyushu, LLR)

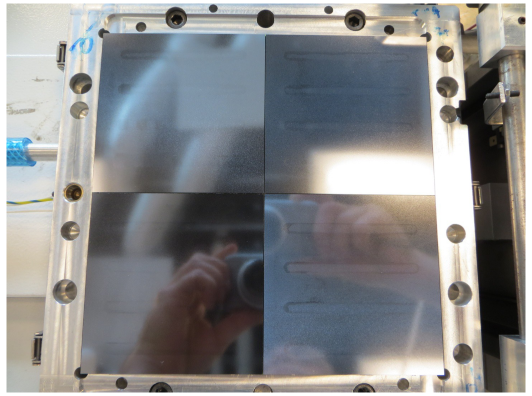


Interconnection
(IJCLab)

Digital readout
SL-Board (IJCLab)

SiWafers glued onto PCB
Pixel size
5.5x5.5 mm^2
(LPNHE)

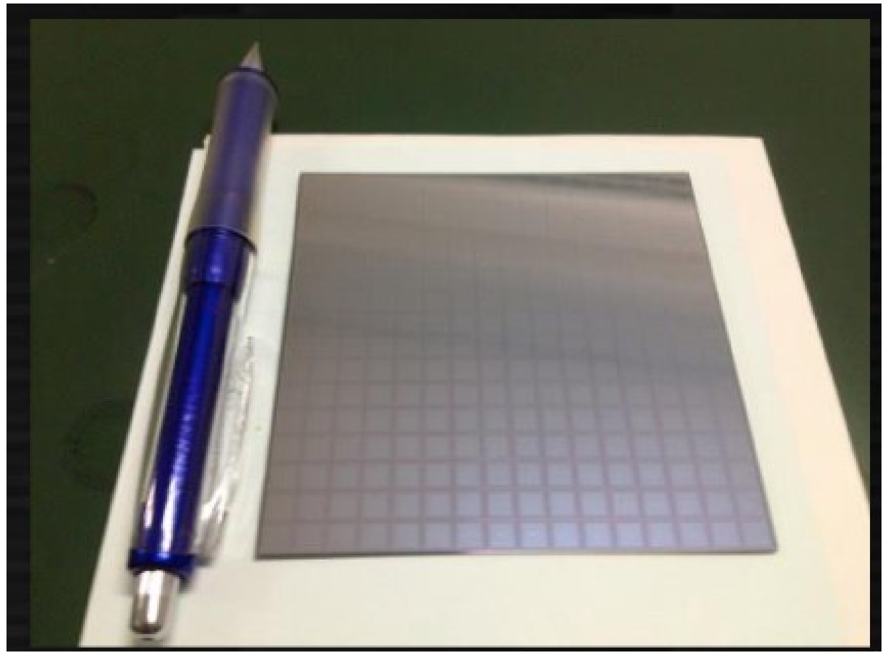


Note that an additional hub for hardware Development is being set up at IFIC/Valencia

- The beam test set up will consist of a **stack of short layers** consisting of one ASU and a readout card each

SiW Ecal – Wafer R&D I

Si Sensor (9x9cm^2 from 6” wafer)



Wafer specs

Tab 1 : Summary of the substrate characteristics			
	Min.	Typ.	Max.
N type silicon	-	-	-
Resistivity (kOhms.cm)	4	5	-
Thickness (µm), option T1	310	320	**330**
Thickness (µm), option T2	490	500	**510**
Width (mm), option S1	89.7	89.8	89.9
Width (mm), option S2	44.7	44.8	44.9

Definition of specifications for different wafer types:
Resisitvity: > 5 kΩxcm

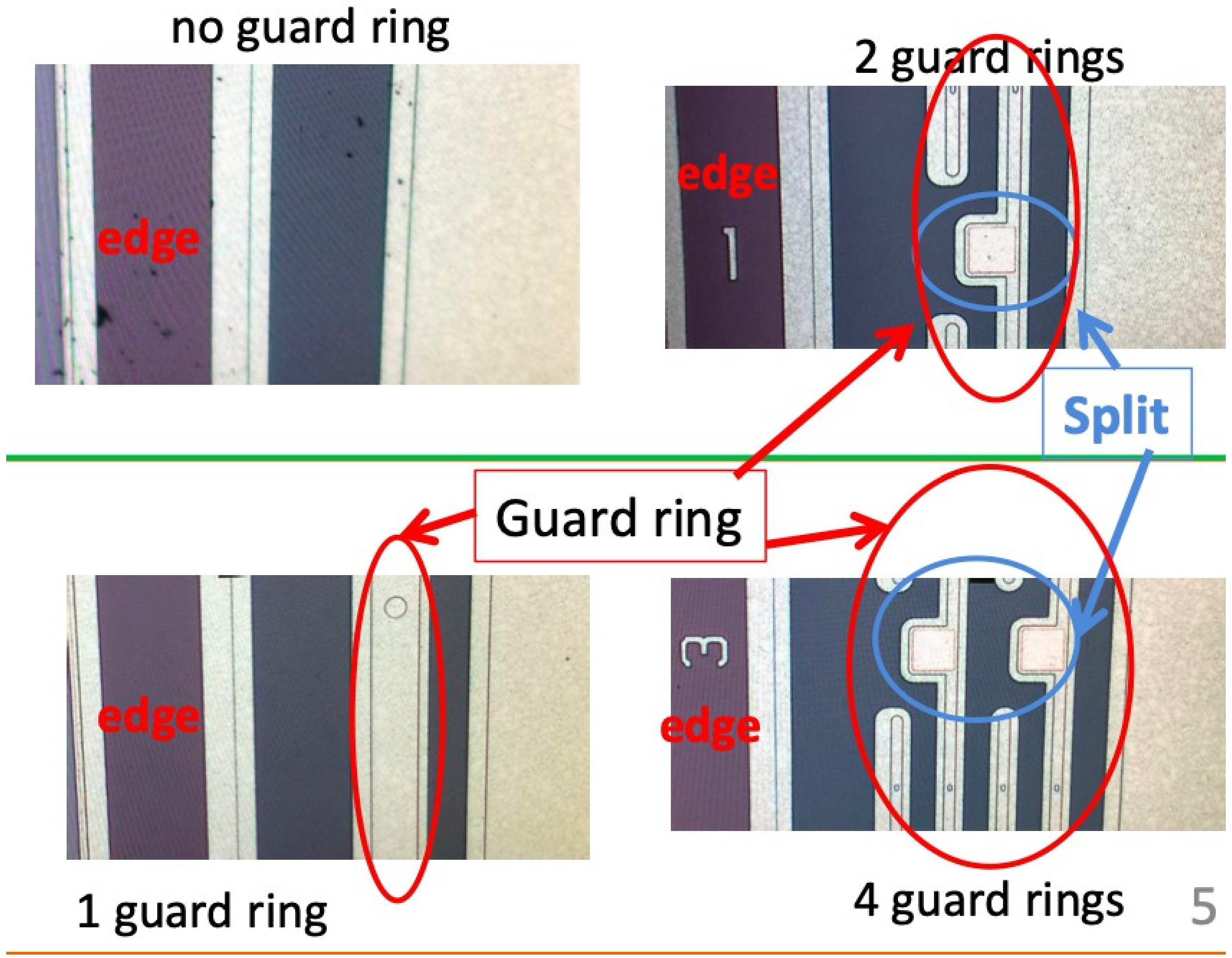
N-type silicon
Crystal Orientation: <100> or <111>

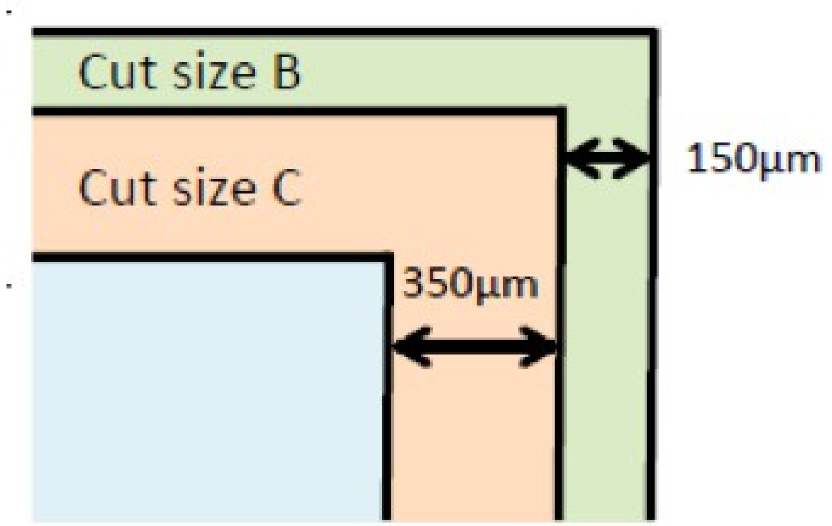
- In addition we require small leakage current:s under full depletion a few nA/pixel but for cost reasons we tolerate a certain fraction of pixels with higher leakage currents

- Vendors: OnSemi (CZ) and Russian company for physics prototype (~2003)
  Hamamatsu for technological prototype (since ~2010)
  Contacts with other vendors (e.g. LFoundry) hibernating mainly for funding reasons

SiW Ecal – Wafer R&D II

We (i.e. Mainly Kyushu) have tested several wafer types in previous years





- Cut size determine the actual sensitive area of a wafer
- Different designs mainly on test samples of “baby wafers”
- The “Hamamatsu” standard is still 0 or 1 full guard ring
  - 0 is “fake 0” guard ring, in fact there is still a small guard ring

Observations in recent years (see also backup for more details)

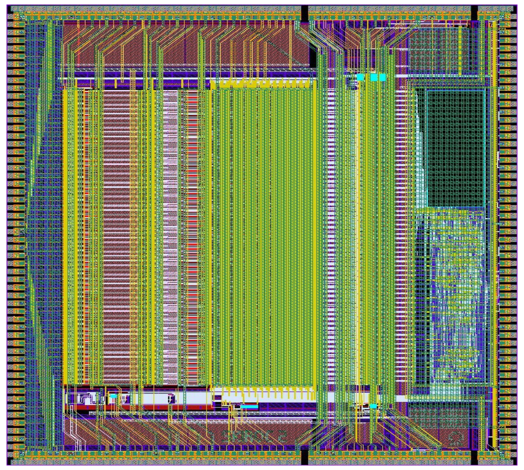
- Split or no guard ring lead to suppression of square events
- In prototype we still use full wafers with 0 or 1 guard ring
- General trend of reduction of bias voltage
- Can operate 500mum wafers at 60-80 V in full depletion

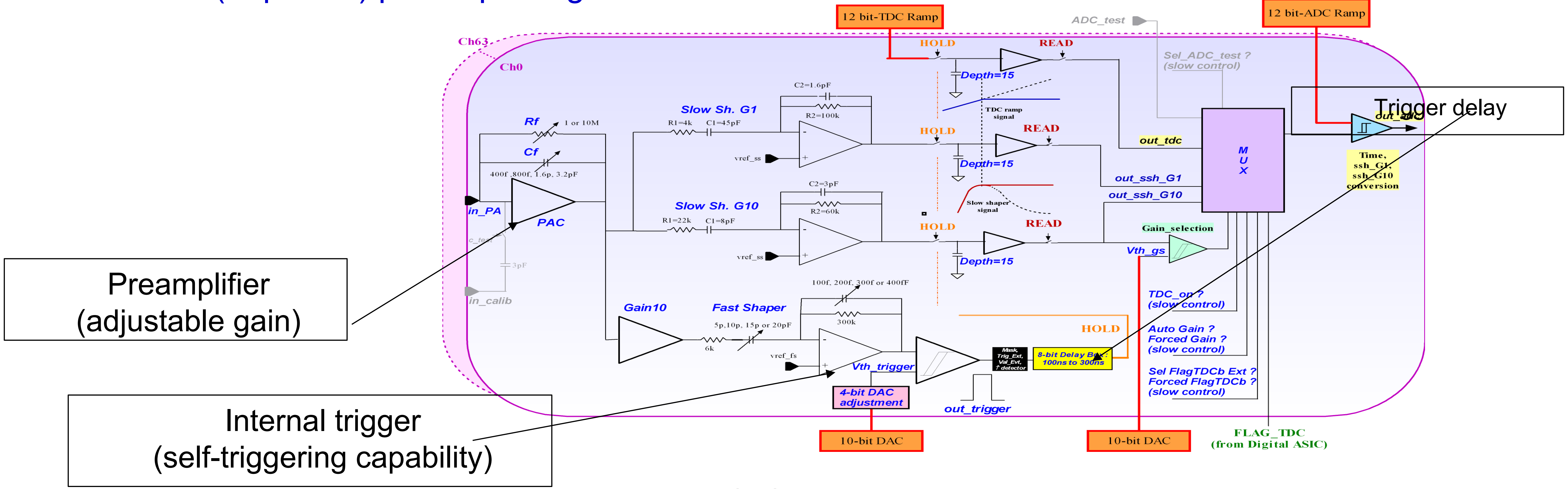
- Towards 8” wafers?
  - General trend (e.g. CMS) is to use 8” wafers
  - Larger surface/wafer =>smaller cost
  - Standard thickness 725mum

SiW Ecal – Front end electronics

SKIROC (Silicon Kalorimeter Integrated Read Out Chip)

- SiGe 0.35µm AMS, Size 7.5 mm x 8.7 mm, 64 channels
- High integration level (variable gain charge amp, 12-bit Wilkinson ADC, digital logic)
- Large dynamic range (~2500 MIPS), low noise (~1/10 of a MIP)
- Auto-trigger at ½ MIP, on chip zero suppression
- Low Power: (25µW/ch) power pulsing





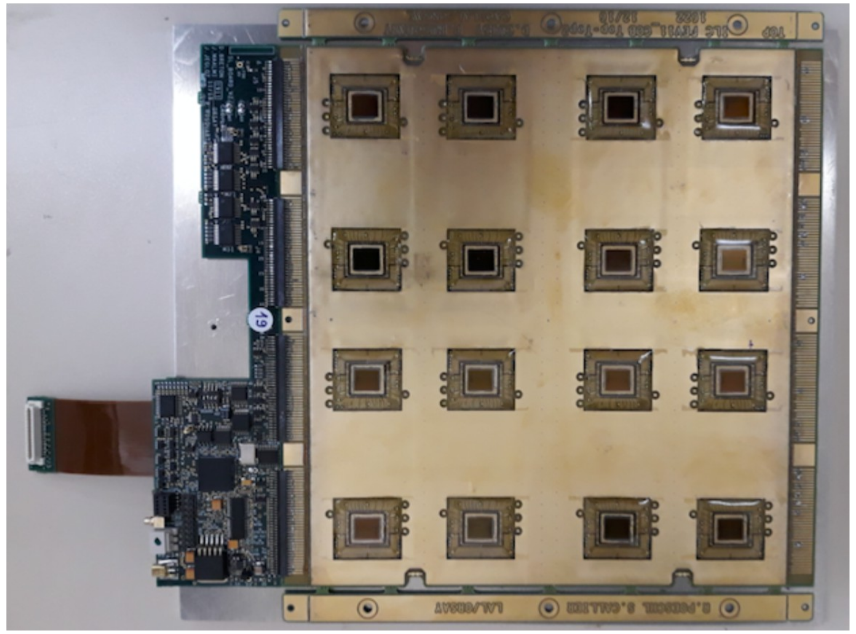
Prologue – “The FEV Zoo”

- In recent years the SiW ECAL has developed and used several PCB variants
  - To make sure that you don't get lost, here comes an introduction

FEV10-12

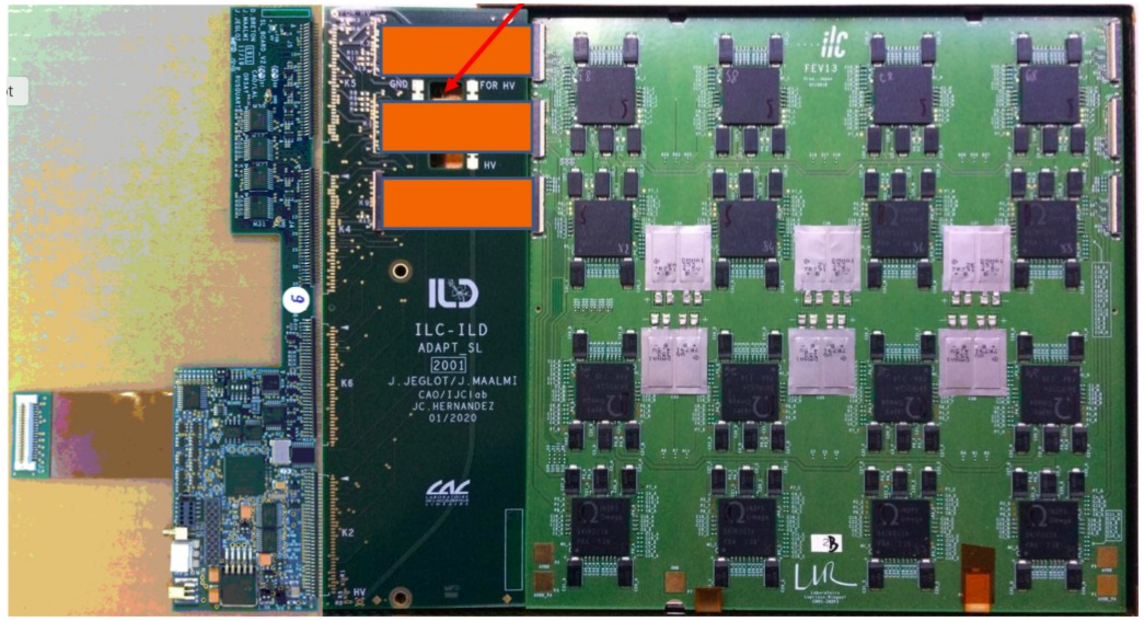
- ASICs in BGA Package
- Incremental modifications From v10 -> v12
- Main “Working horses” since 2014

FEV_COB



- ASICs wirebonded in cavities
  - COB = Chip-On-Board
- Current version FEV11_COB
- Thinner than FEV with BGA
- External connectivity compatible with BGA based FEV10-12

FEV13

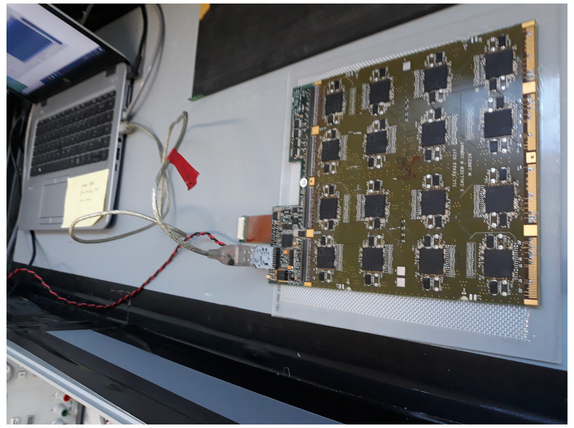


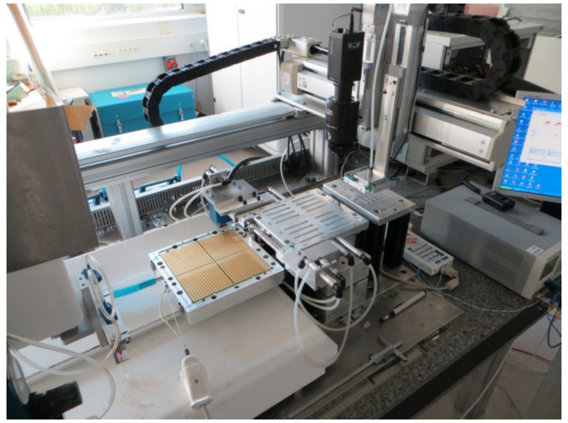
- Also based on BGA packaging
- Different routing than FEV10-12
- Different external connectivity

Current prototype (see later) is equipped with all of these PCBs

SiW Ecal – Assembly and QA Chain

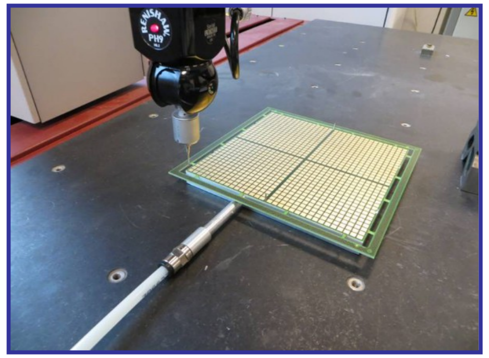
(In house) cabling and
electronics tests with
highly mobile DAQ system



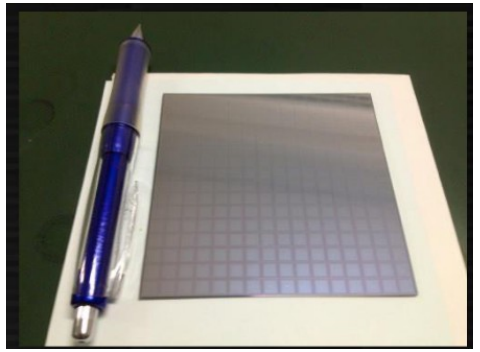


Wafer Gluing
with robot

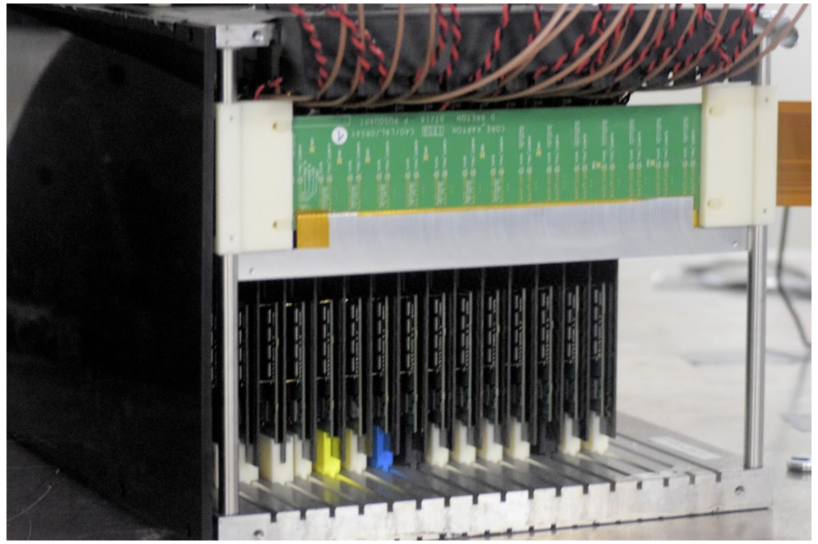
Metrology of
PCBs



Si sensor
tests



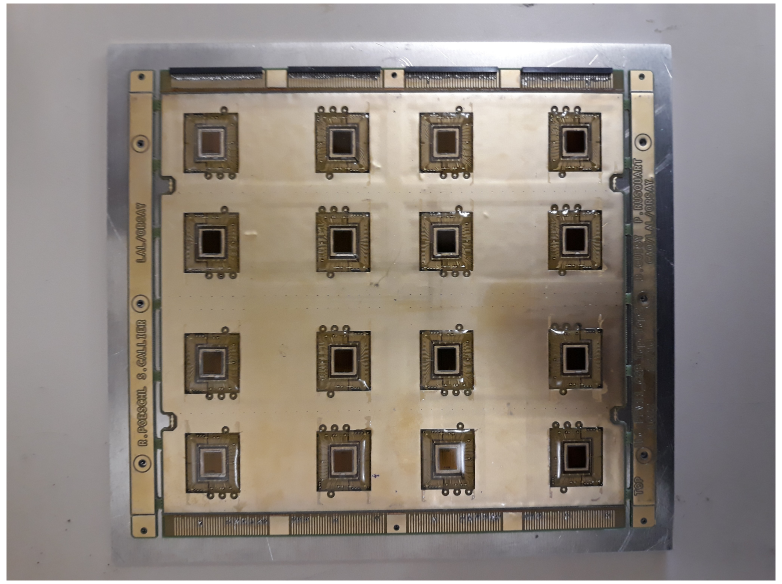
Prototype

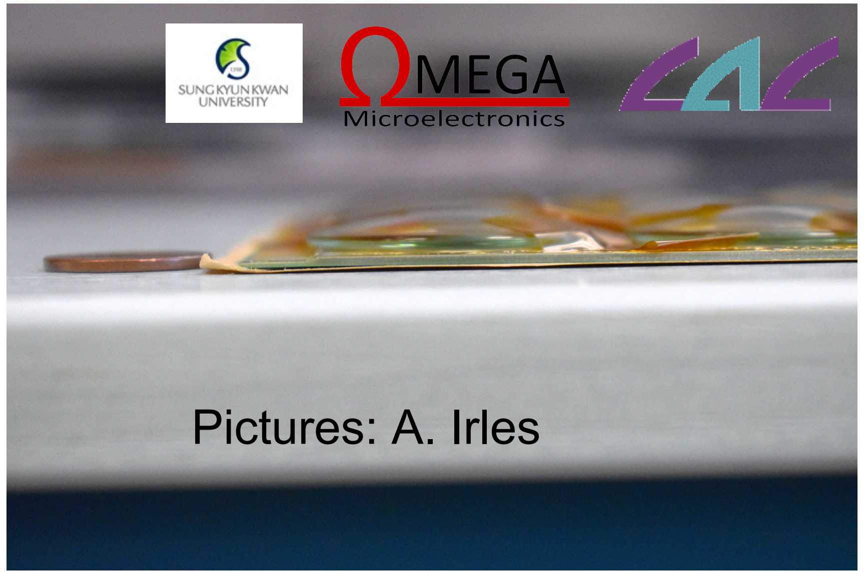


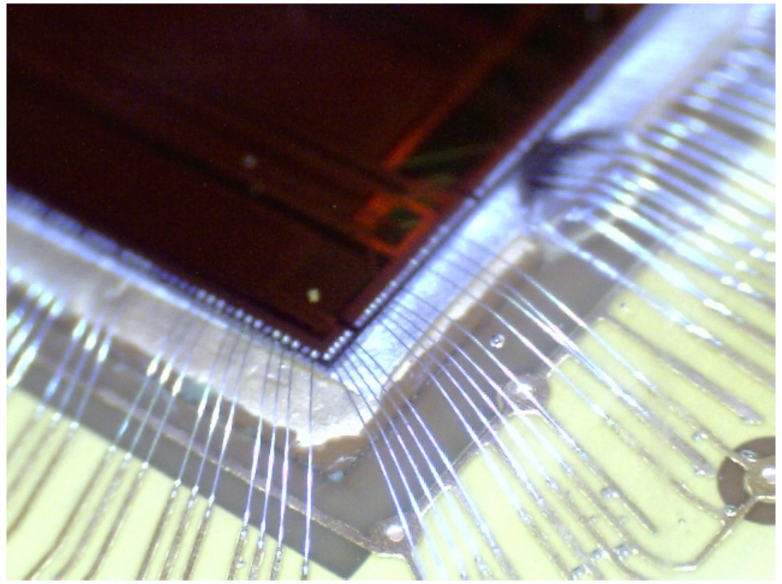
Detector assembly

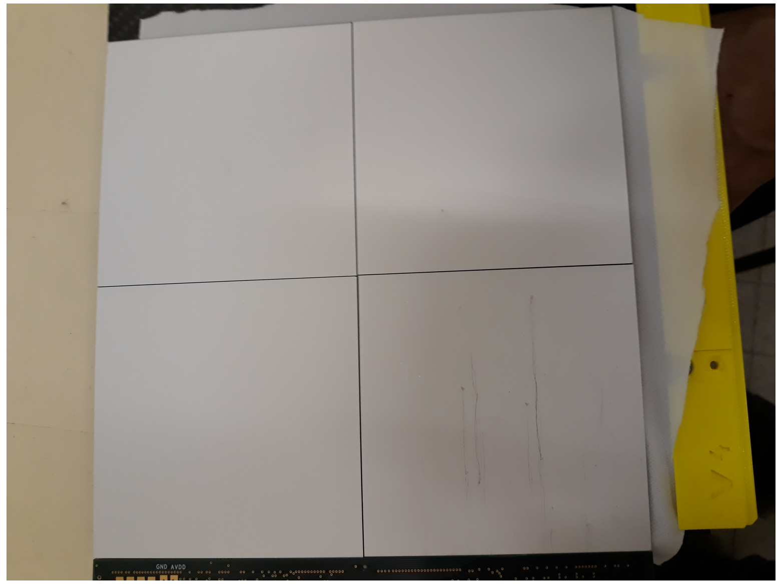
Operational assembly chains in France and Japan

SiW Ecal – Assembly of COB ASU





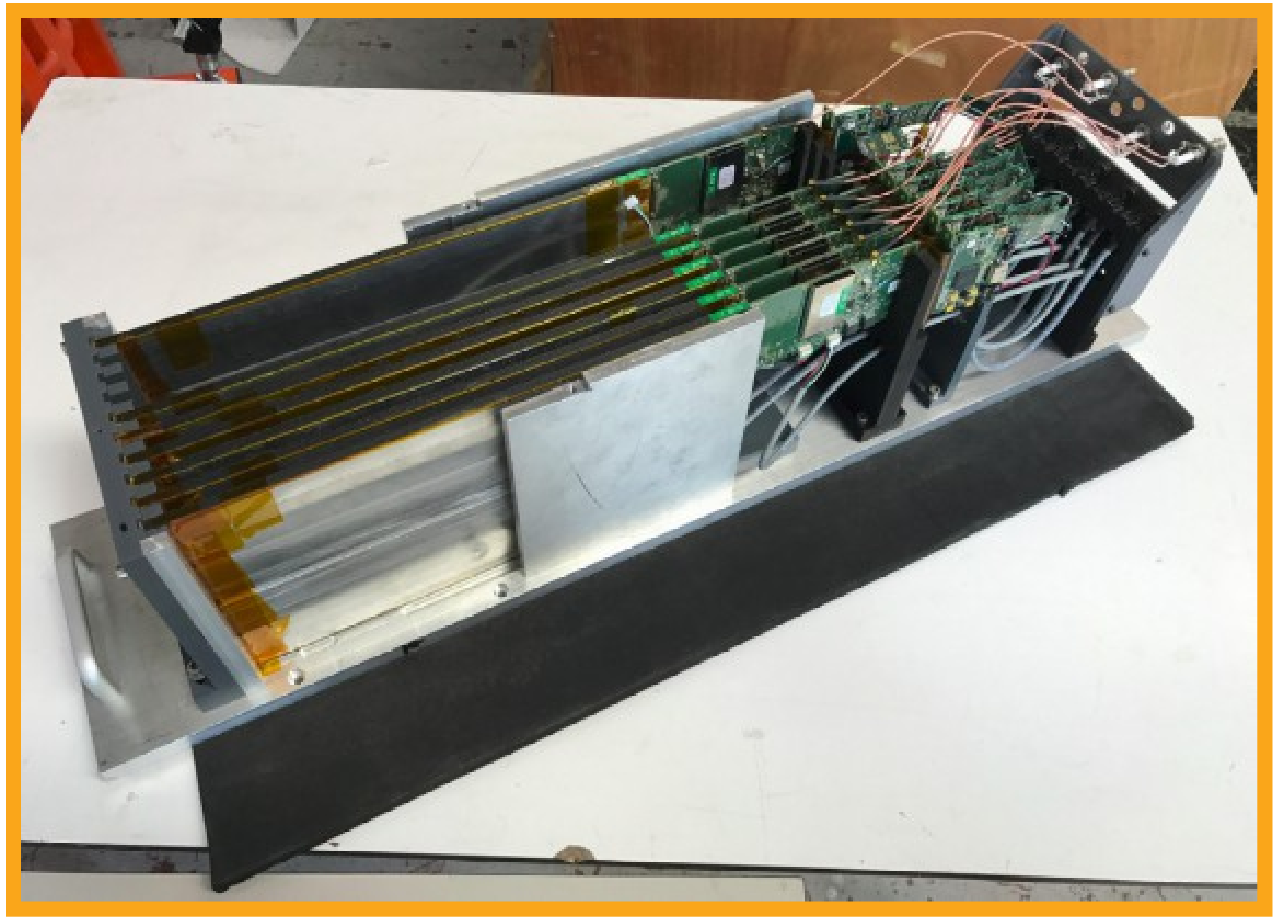




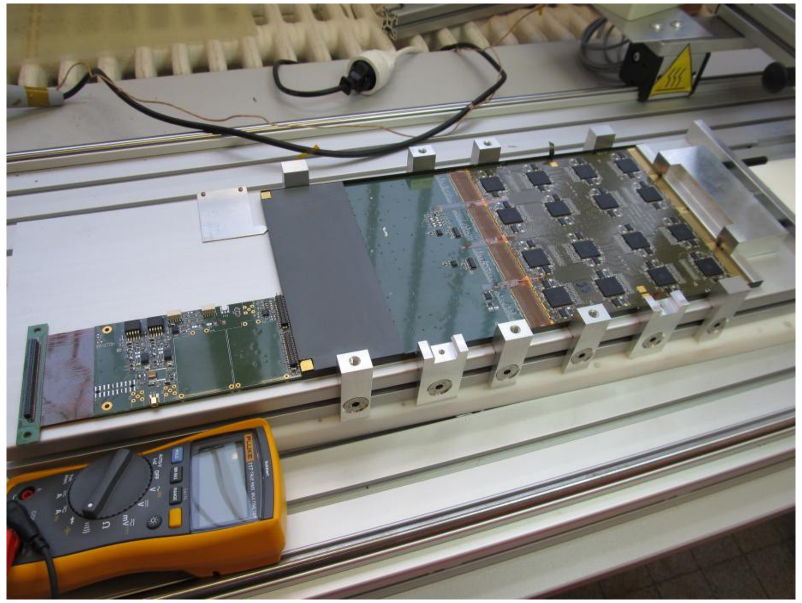
- Height 1.2mm
  - Thin multilayer board => Thermal stress during board production => Planarity was an issue
  - Less than 0.5mm bending after production for 8-% of the board
- ASICs on COB have to be protected
  - Successful “in house” application of Epoxy (Loctite Hysol) on several boards
- Gluing of four sensors onto two boards during winter 2021/22
  - After first test with one sensor in 2019

- First beam test in Summer 2019 with two boards (after many years of development)
- Only one wafer per board
- Full equipement for beam tests 2022

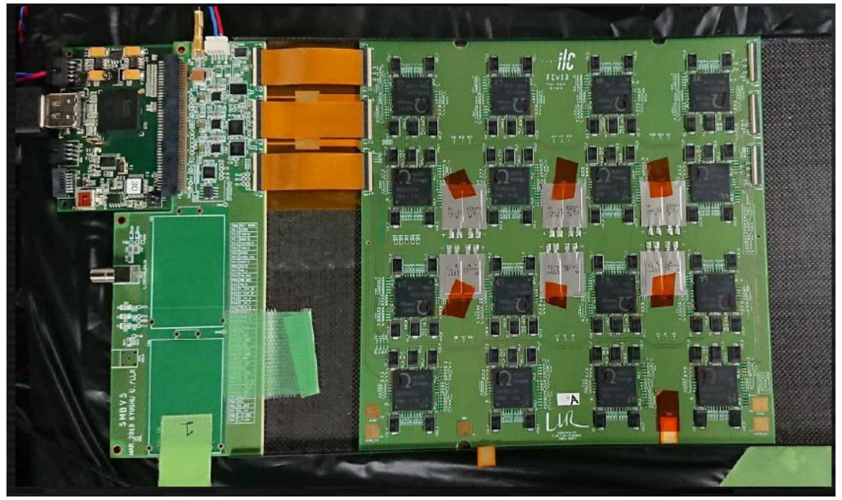
Prototypes until ~2018



- Total ~15 layers constructed
  - Max of ten tested within one stack
- 1024 channels per layer
- Beam tests at DESY and CERN since 2016



PCB FEV10-12
with long adapter card
Wafer thickness
325 µm

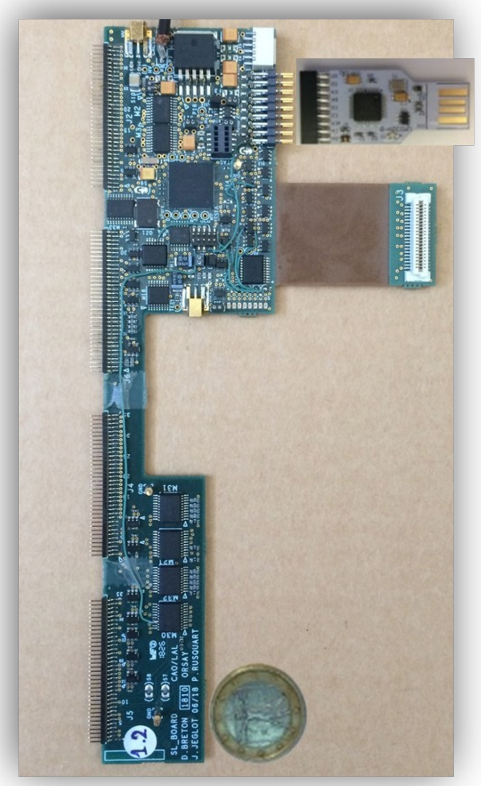


PCB FEV13
with small(er) adapter card
Wafer thickness
650 µm

R&D for thin PCB see backup

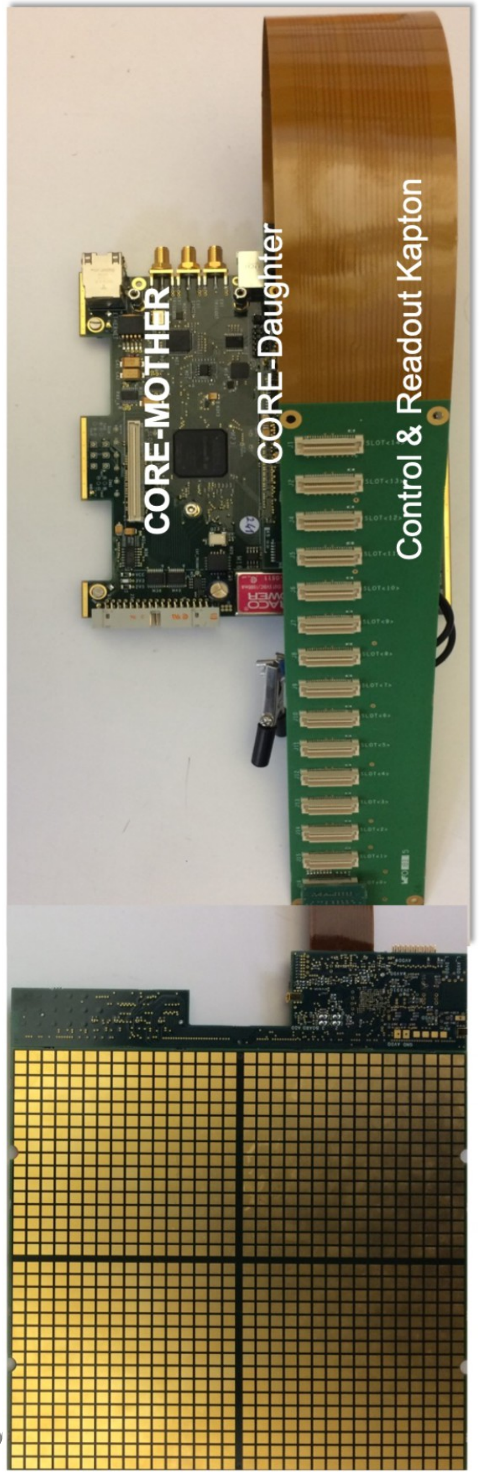
Compact readout

Current detector interface card (SL Board) and zoom into interface region

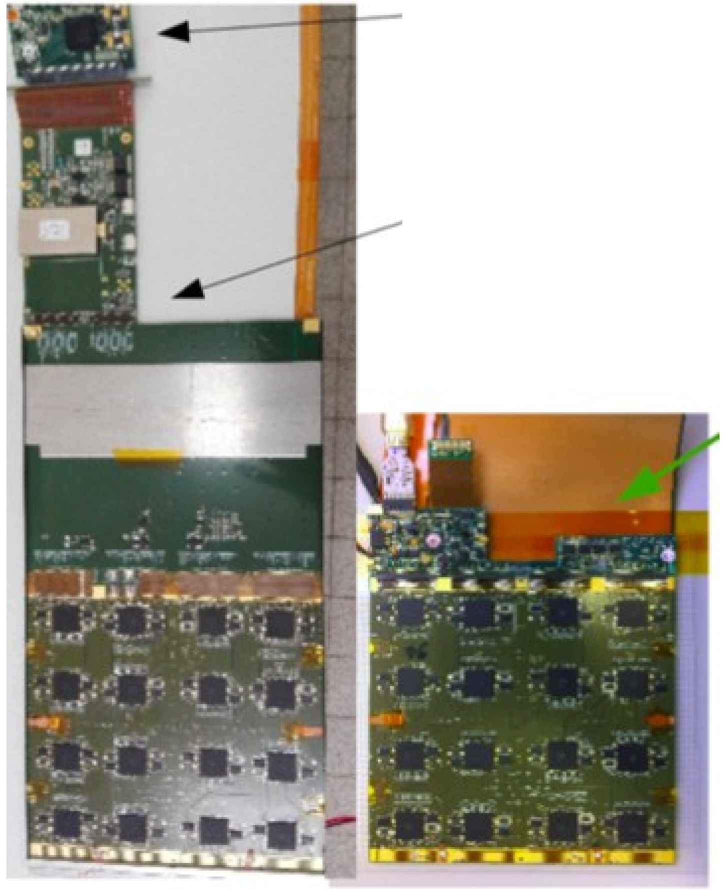


SL Board

Complete readout system

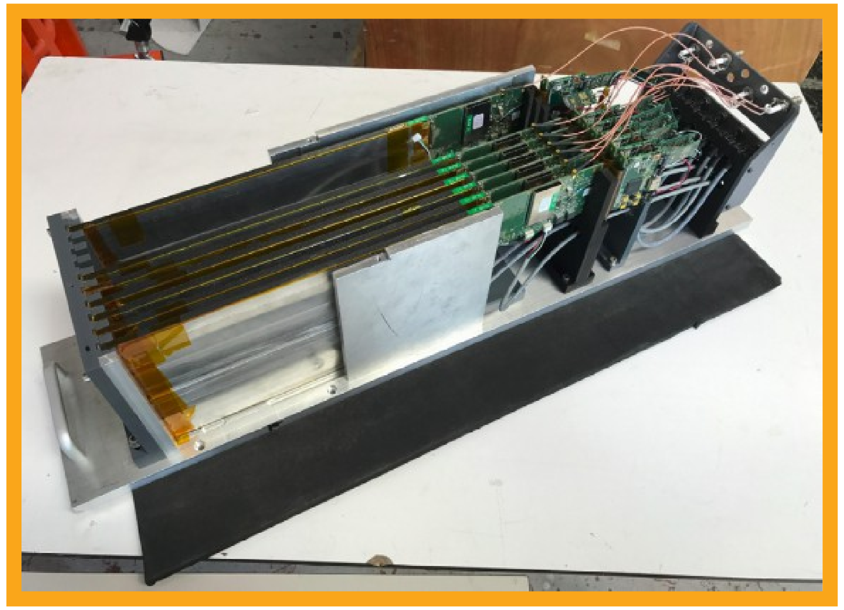


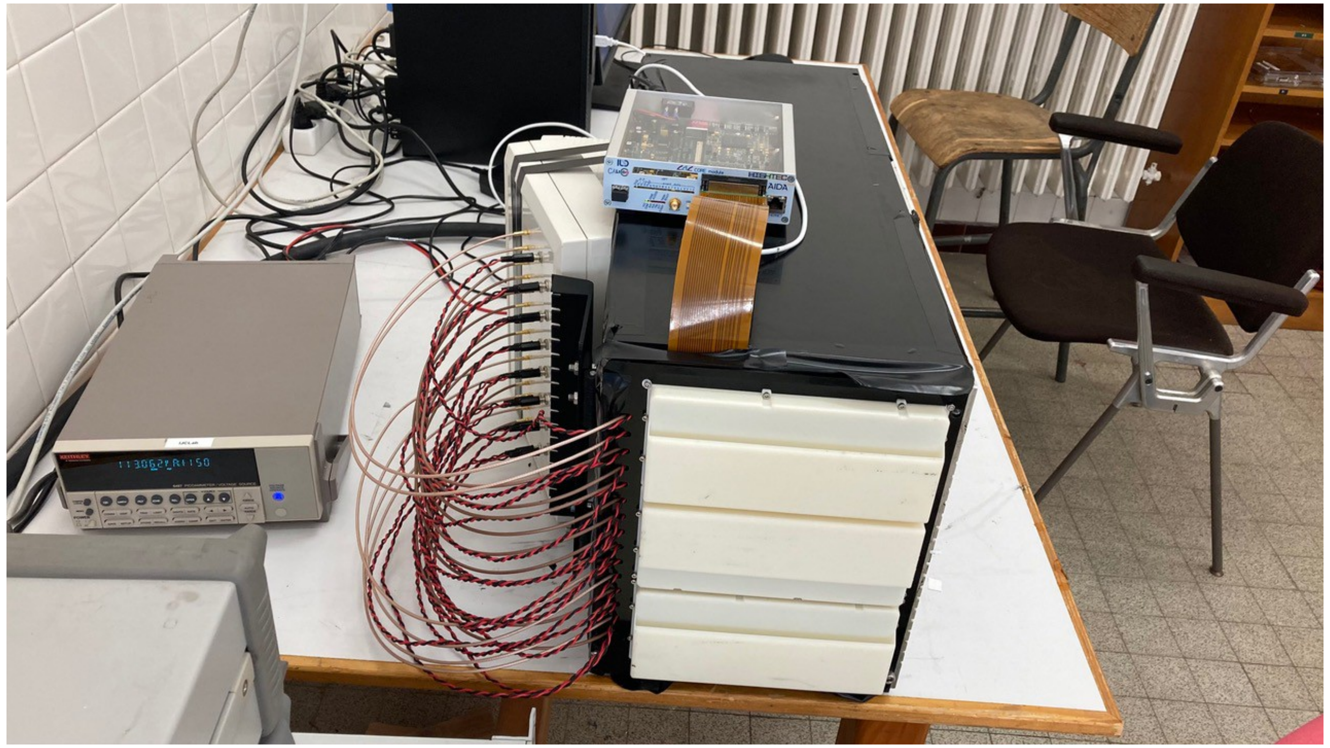
For reference
Comparison old/new r/o system



- “Dead space free” granular calorimeters put tight demands on compactness
  - Current developments in for SiW ECAL meet these requirements
- System allows to read column of 15 layers <-> to be expected in ILD
  - Important that full readout system goes through scrutiny in beam tests

SiW ECAL 2018 -> 2022



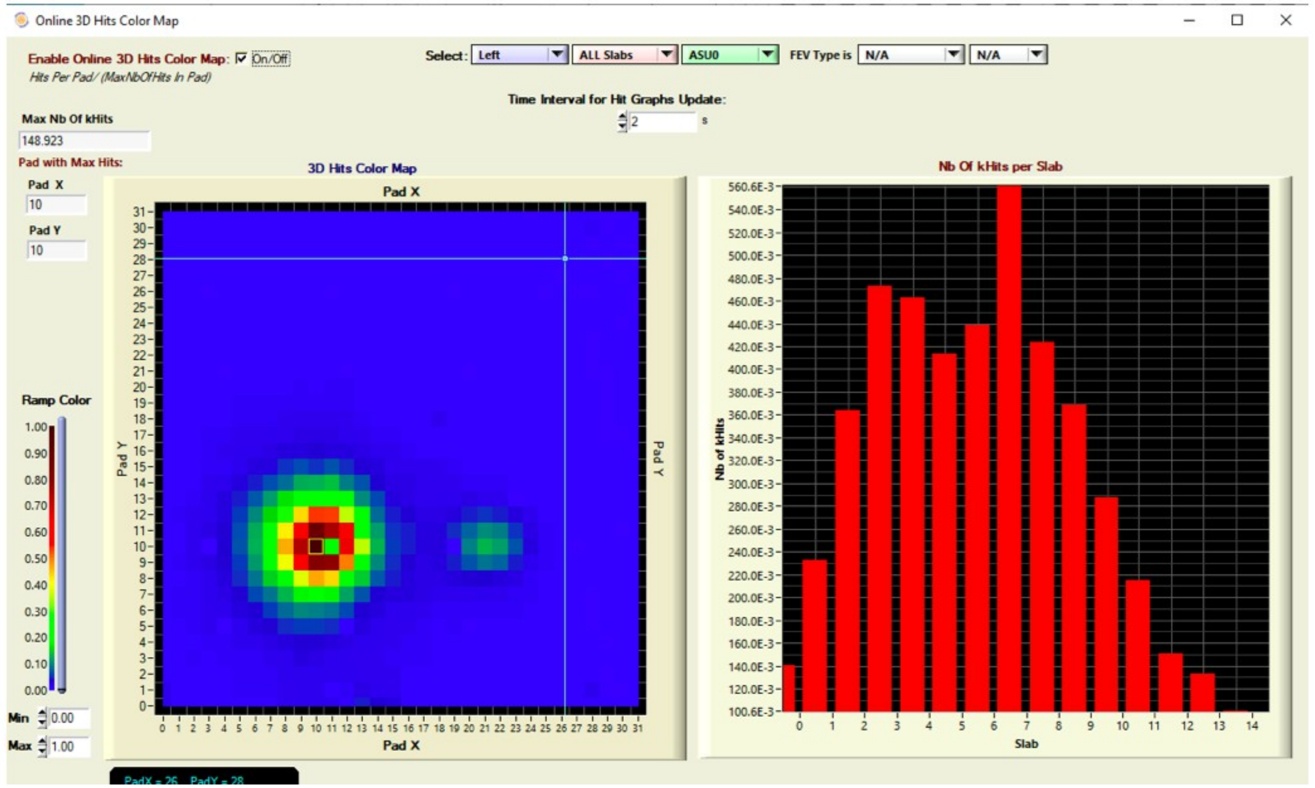


- 7 short layers (18x18x0.5cm^3)
- 1024 channels per layer => 7186 cells
  - Assembly chains in France and Japan
  - Beam tests at DESY and CERN since 2016

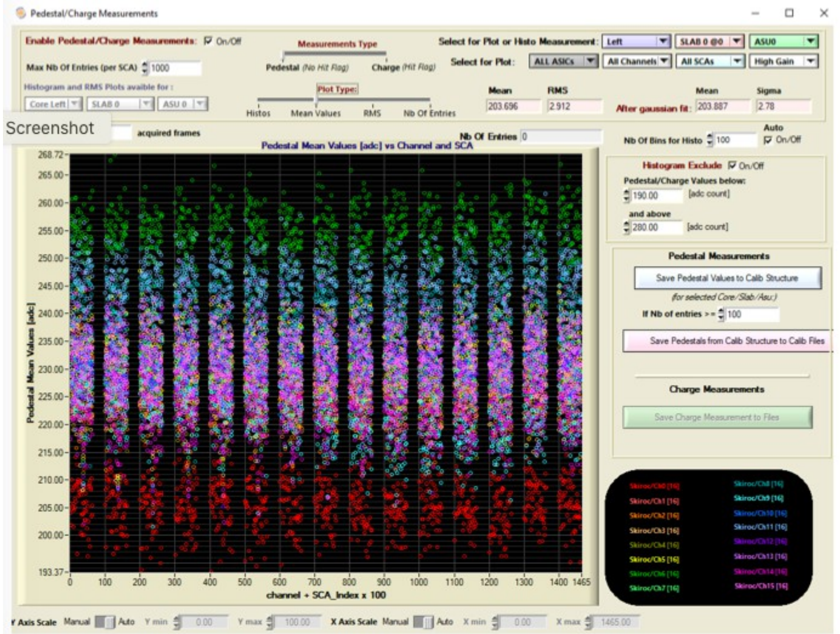
- 15 layers equivalent to 15360 readout cells
- Overall size 640x304x246mm^3
  - Commissioned in 2020 and 2021
  - Testbeams (finally) in November 2021 and March 2022
  - 1.5 years in waiting loop due to pandemic

SiW-ECAL Beam test – Online Monitoring

Jihane Maalmi, CALICE Meeting Valencia



- Online Hit Maps and shower profiles
- Allow for real time beam and detector tuning
  e.g. Adaptation of beam rates or thresholds



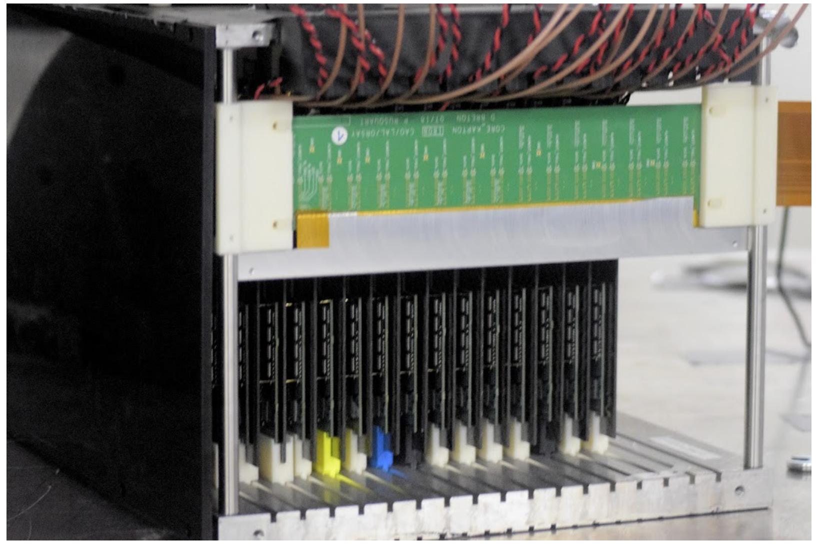
- Further online tools

- Pedestal measurement and subtraction
- Charge measurement and histogramming
- MIP gain correction

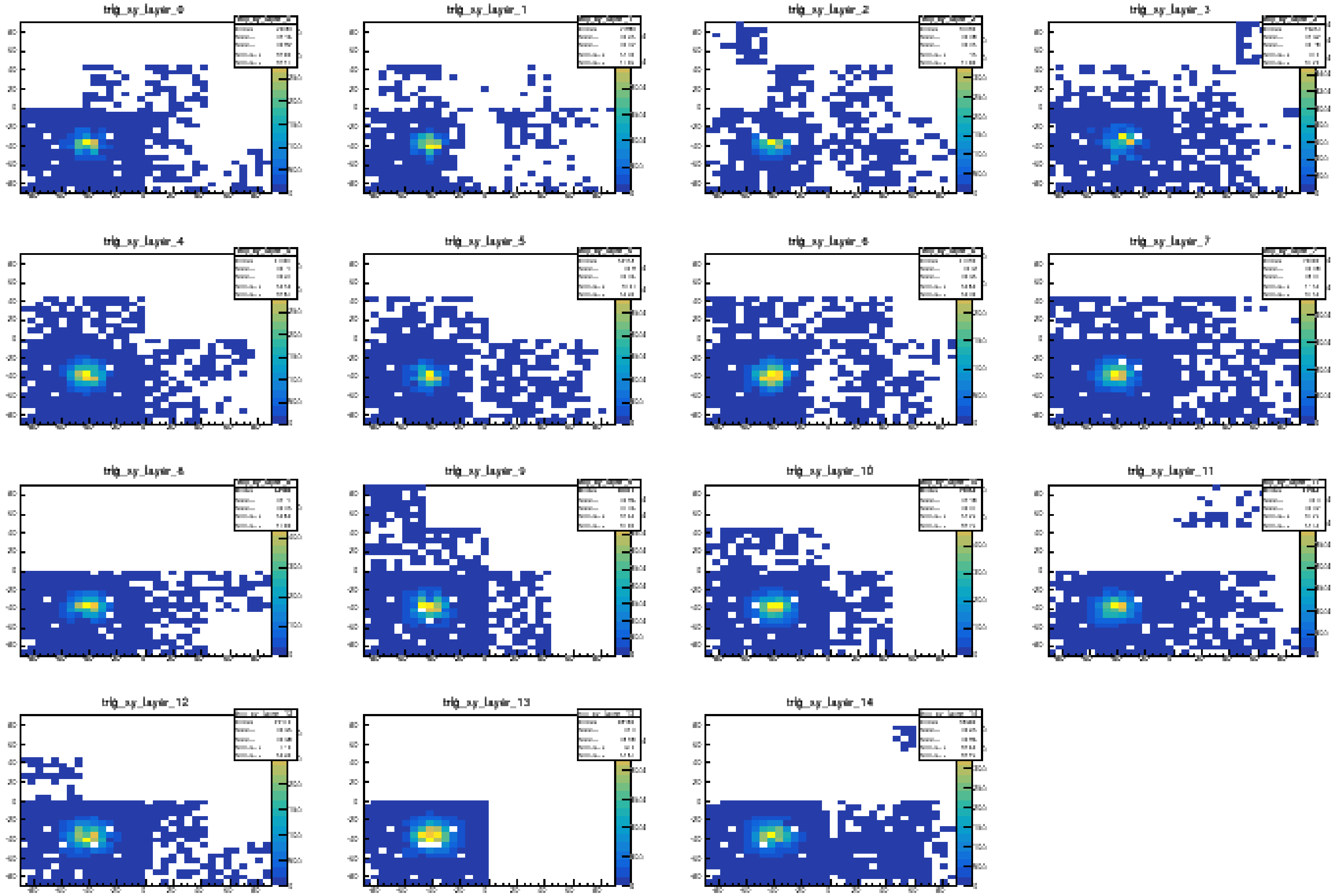
These are just a few examples from the powerful online suite

SiW-ECAL in beam test @ DESY

Detector Setup



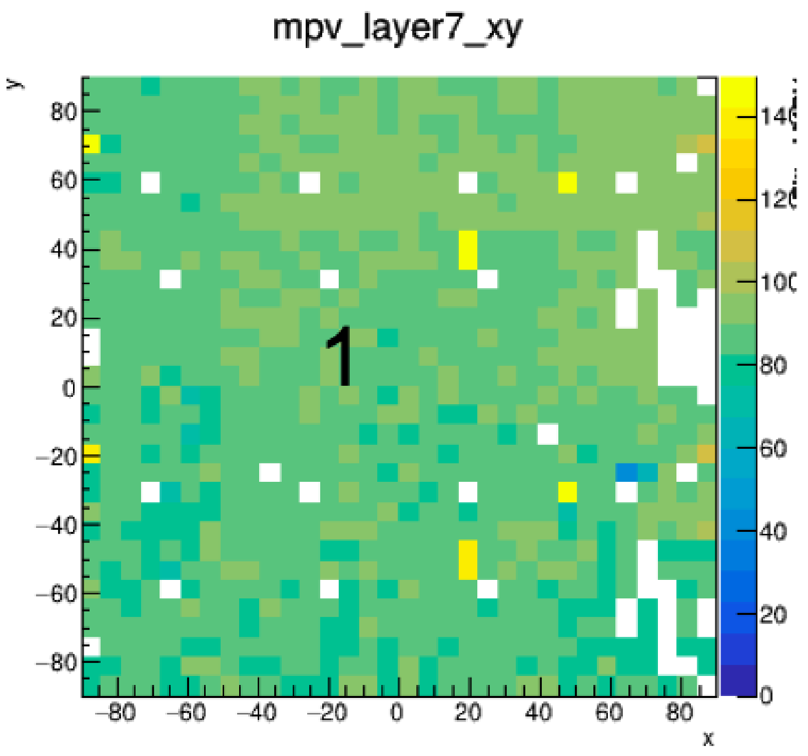
Detector in beam position

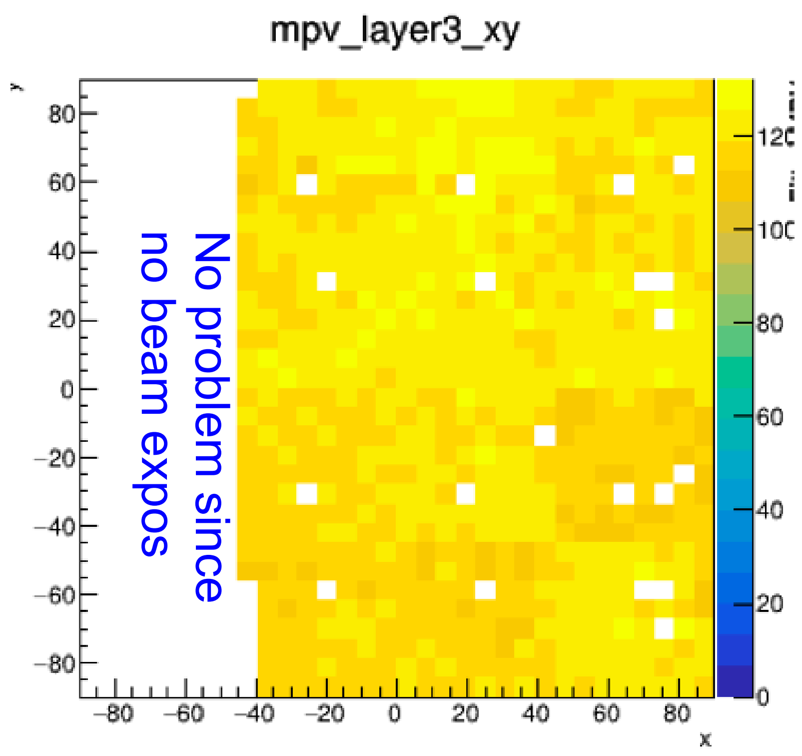


- Stack operational
- Beam spot in 15 layers

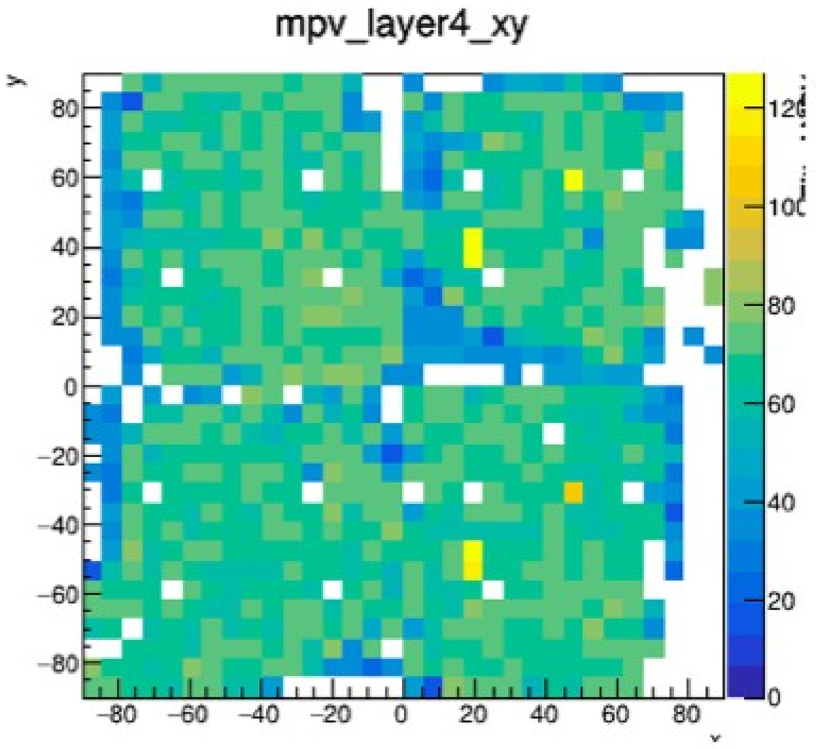
Beam test – First Feedback

Adrian Irles





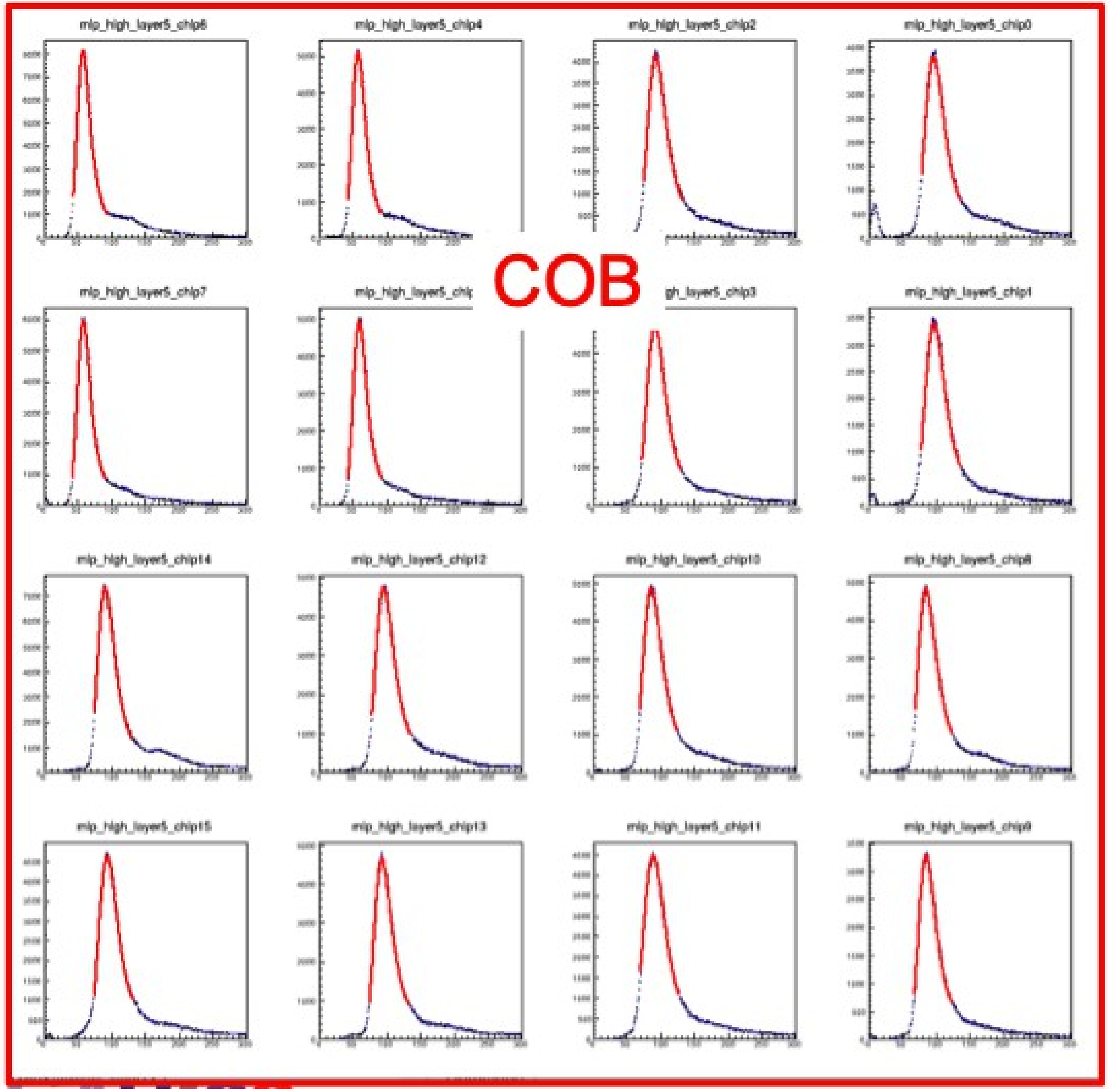
- We have good layers ...
  - Homogeneous response to MIPs over layer surface
  - Here white cells are masked cells due to PCB routing
    - Understood and will be corrected

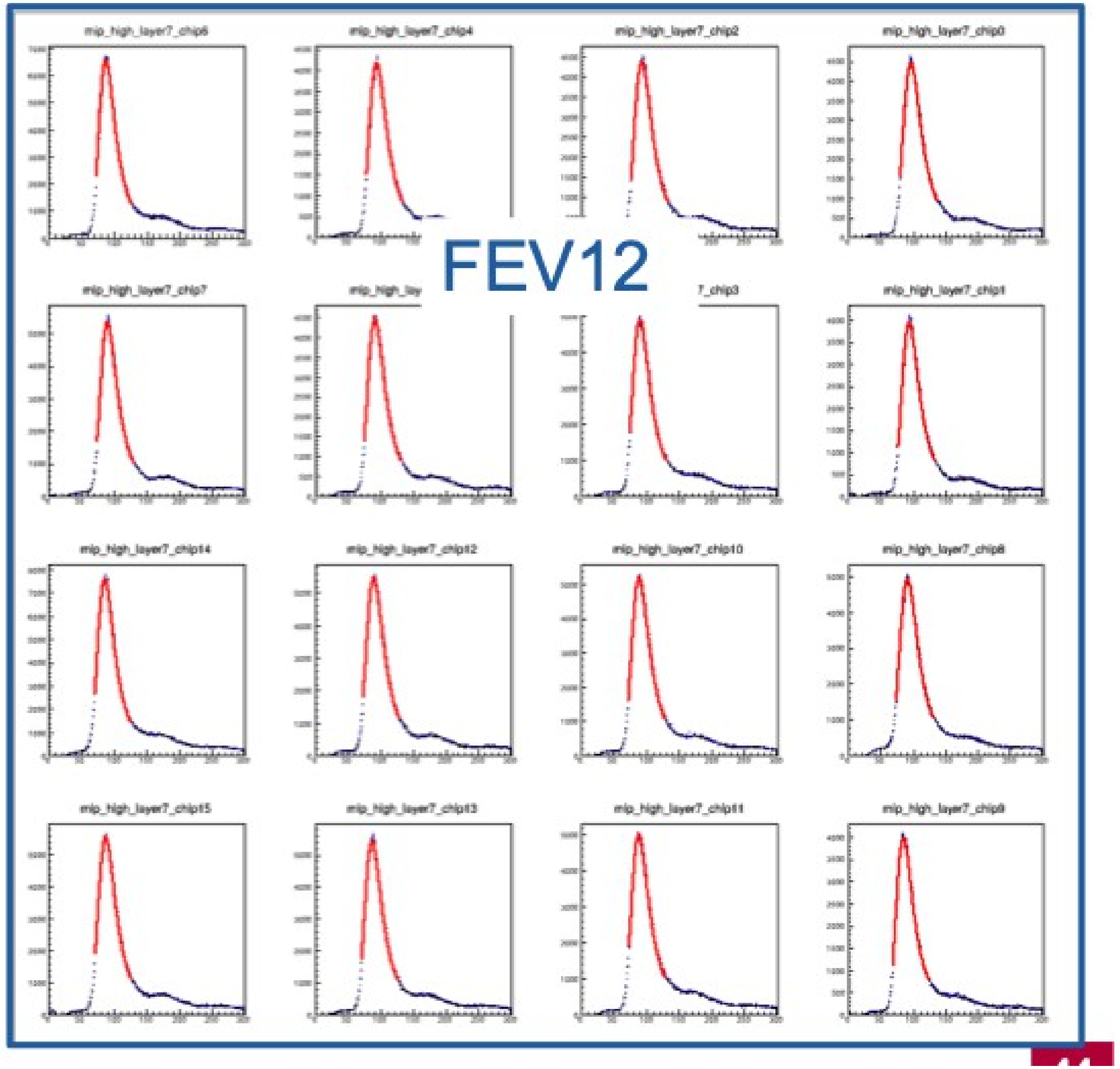


... and not so good layers

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

MIP Signals

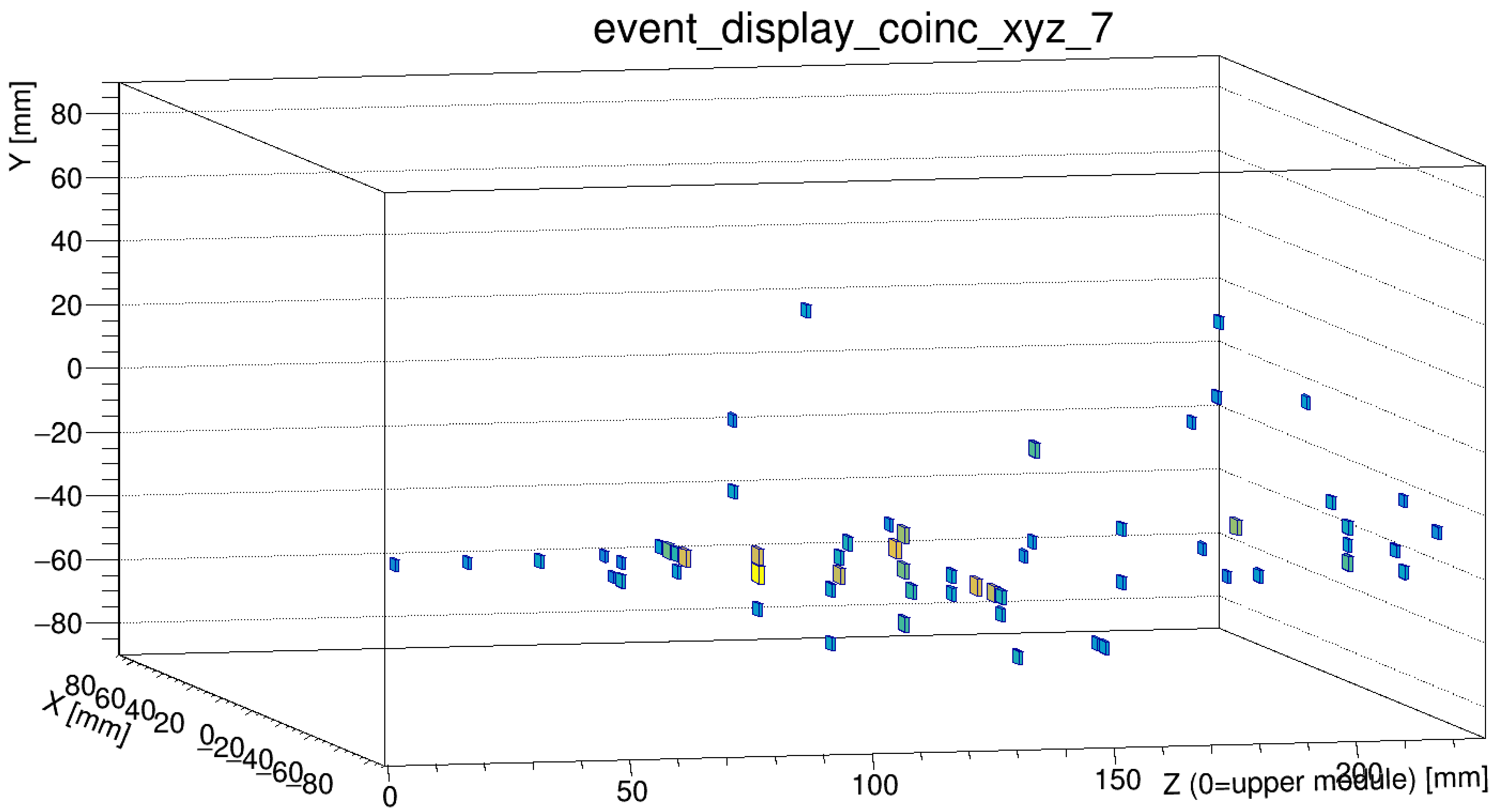




- Quality of MIP signals comparable between COB and BGA variants of PCB

SiW-ECAL Beam test – Onlline/Offline Event Displays

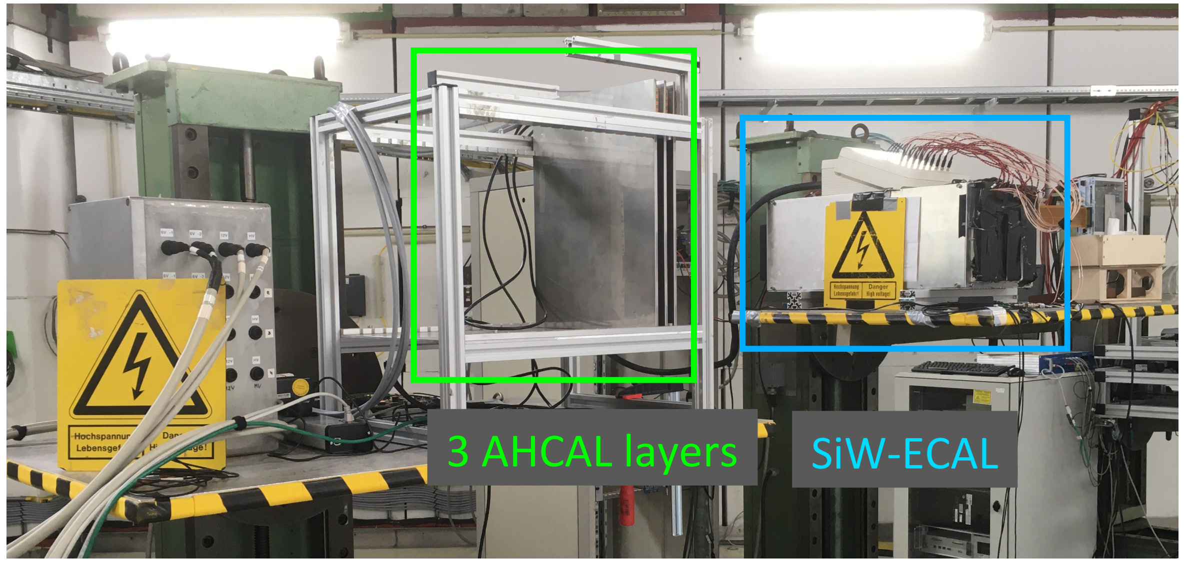
Jonas Kunath



- Clear showers measured during beam test campaigns
- Require full event reconstruction
- These (and more) “high level” views are available already while a run is going on

Common testbeams

Preparation for common SiW-ECAL AHCAL beam test



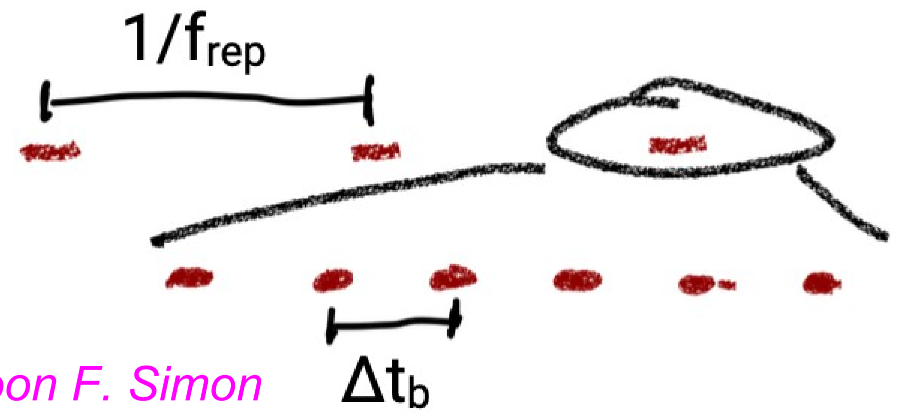
SiW-ECAL + AHCAL DAQ test @ DESY in March 2022

- Successful synchronisation of data recorded with SIW-ECAL and AHCAL
- Common running makes full use of EUDAQ tools (developed within European projects)

Gearing up for common beam test at CERN in June

Reminder power pulsing

- Linear Colliders operate in bunch trains



Cartoon F. Simon

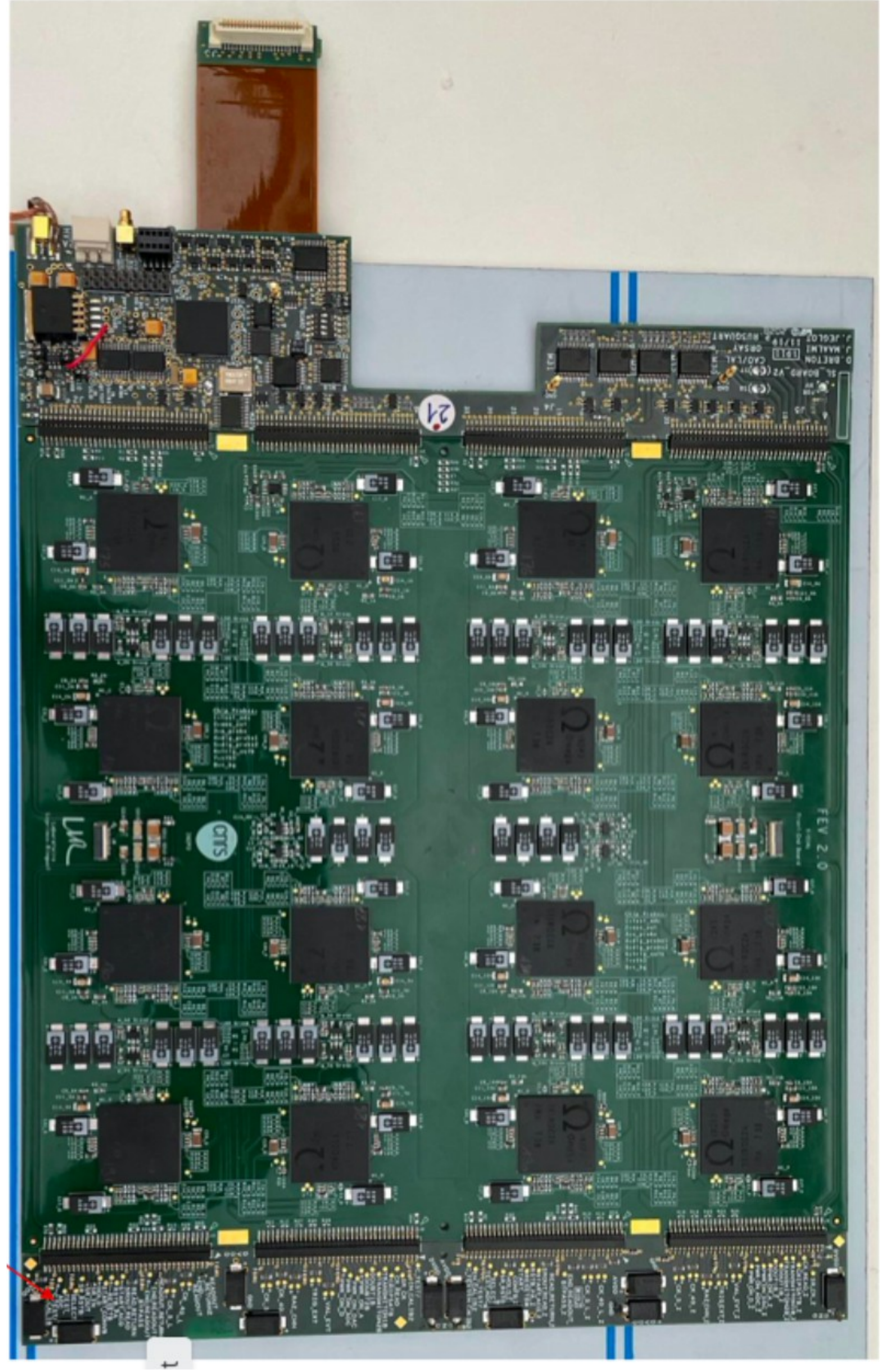
CLIC: Δt_b ~ 0.5ns, frep = 50Hz
ILC: Δt_b ~550ns, frep = 5 Hz (base line)

- Power Pulsing reduces dramatically the power consumption of detectors
  - e.g. ILD SiECAL: Total average power consumption 20 kW for a calorimeter system with 10^8 cells
- Power Pulsing has considerable consequences for detector design
  - Little to no active cooling
  - => Support compact detector design
- Have to avoid large peak currents
- Have to ensure stable operation in pulsed mode

- Upshot: Pulsed detectors face other R&D challenges than those that will be operated in “continuous” mode

New PCB – FEV2.x

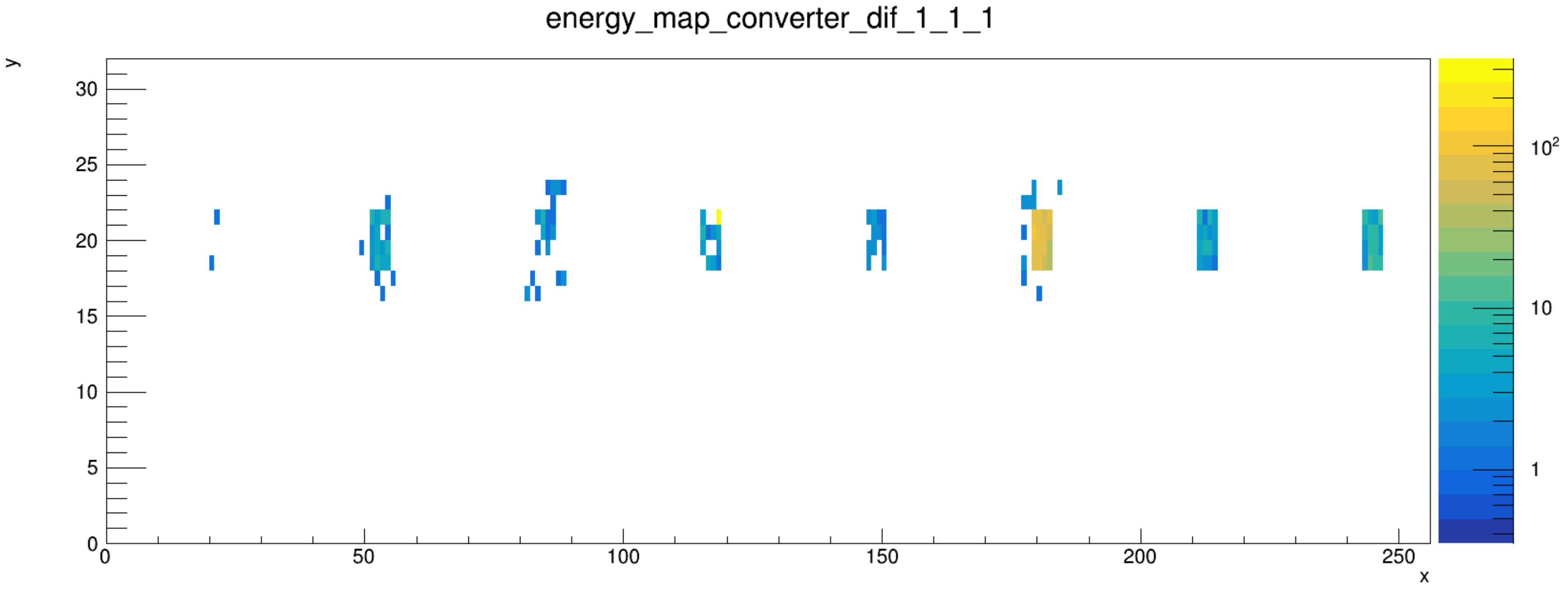
LLR, IJCLab, LPNHE, OMEGA



- Improved Layout
  - Better shielding of AVDD and AVDD PA plans and minimisation of cross-talk between inputs and digital signals.
- Power Pulsing Mode: new philosophy
  - limiting the current through the Slab (current limiter present on the SL Board) to:
    - avoid driving high currents through the connectors and makes the current peaks **local** around the SKIROCs chips
    - avoid voltage drop along the slab
    - ensure temperature uniformity
  - We add large capacitors with low ESR for **local** energy storage (around each SKIROC chip)
  - Generate **local** power supply with LDO (Low Drop Out) to avod voltage variations
- Clean clock distribution all over the slab
  - for Slow Control and Readout Clocks
- Parallel configuration and readout over 2 partitions.
- Driving high voltage up to 350V for 750µm wafer (via the ASU connectors)
  - Adding a filter for each wafer HV and limit the current in case of wafer failure

Reminder – Electrical long slab

Chain of
8 detection elements
~3m



- Very encouraging results in first beam test in 2018
  - Credibility for concept as foreseen for e.g. ILD
  - Issues with signal drop towards extremities
- Long slab studies will be resumed with new FEV
  - Adapted for power pulsing, will avoid voltage drop, etc ...

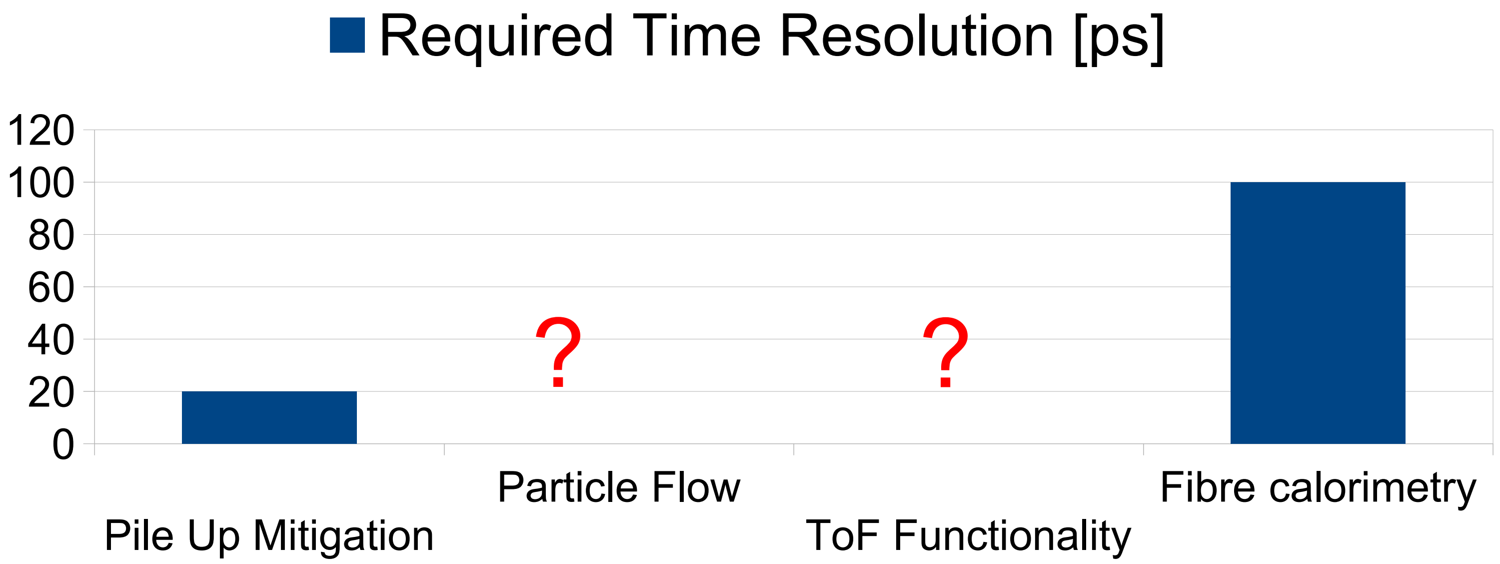
(Non exhaustive) “To do list” (for LC Detector)

	Today	LC Detector
#cells*	15360	10^8
Sensor surface/m^2	0.5	2000-2500
Sensor type	9x9cm^2 based on 6” wafers	Size ? Based on 8” wafers?
Real size slabs	1 “electrical” long layer	~10000 detector slabs (5000 double layers)
Front end ASICs	SKIROC2, ns timing	SKIROC3, ps timing? Need 1.2-1.5M
Digital electronics	SL-Boardv2 (already quite close)	New versions,need 9k
DAQ	Highly performant system for prototype	Scaling to full detector
PCB	FEV2.x (already quite close)	Integration of new FE electronics, need ~75k
Slow control	Integrated in SL Board	Solution for full detector?
Mechanical Structures	1 barrel alveaola structure (EUDET 2010)	40 barrel modules + **endcaps**
Carrier Boards	Simple carbon plates	“H Boards” with wrapped W (Studies date back to 2010-2016)
Cooling	Advanced studies (AIDA-2020)	Full detector integration Continous powering woulf be anew world
Engineering (electrical and mechanics)	Advanced studies (for ILD IDR)	Require full revision and consolidation
Software	**Few** skillful people	Needs consolidation and person power

- A lot has been achieved
  - ... but the way is still long, as of today the team is too small and the funding is very (too) volatile
  - We are good in engineering but too few (young) physicists

Timing ?

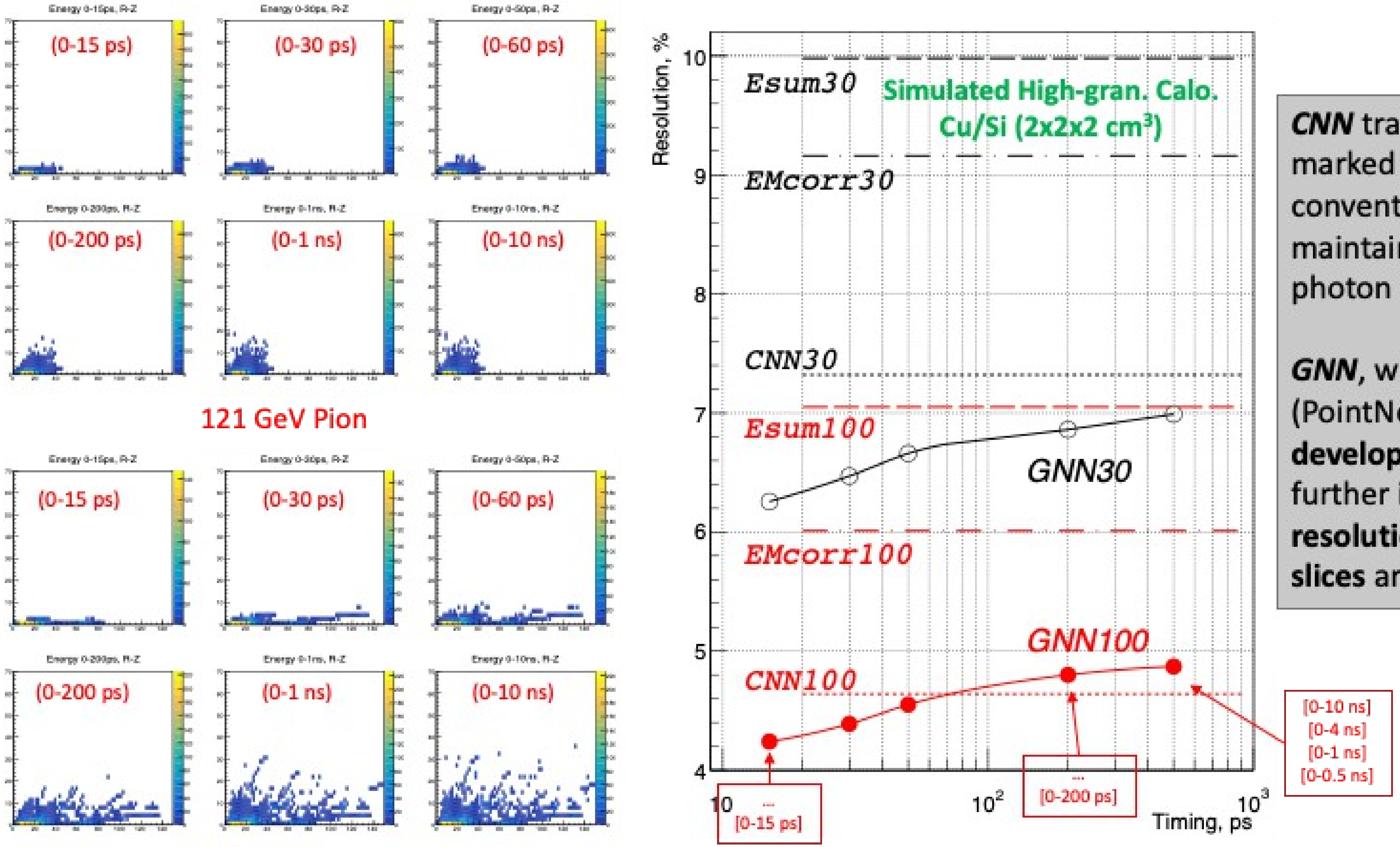
- Timing is a wide field
- A look to 2030 make resolutions between 20ps and 100ps at system level realistic assumptions
- At which level: 1 MIP or Multi-MIP?
- For which purpose ?
  - Mitigation of pile-up (basically all high rate experiments)
  - Support of PFA – unchartered territory
  - Calorimeters with ToF functionality in first layers?
    - Might be needed if no other PiD detectors are available (rate, technology or space requirements)
    - In this case 20ps (at MIP level) would be maybe not enough
  - Longitudinally unsegmented fibre calorimeters



- A topic on which calorimetry has to make up it's mind
  - Remember also that time resolution comes at a price -> High(er) power consumption and (maybe) higher noise levels

Timing in calorimeters

Features that emerge in the time domain can help distinguish particle types and, with GNNs, enhance σ(E)/E



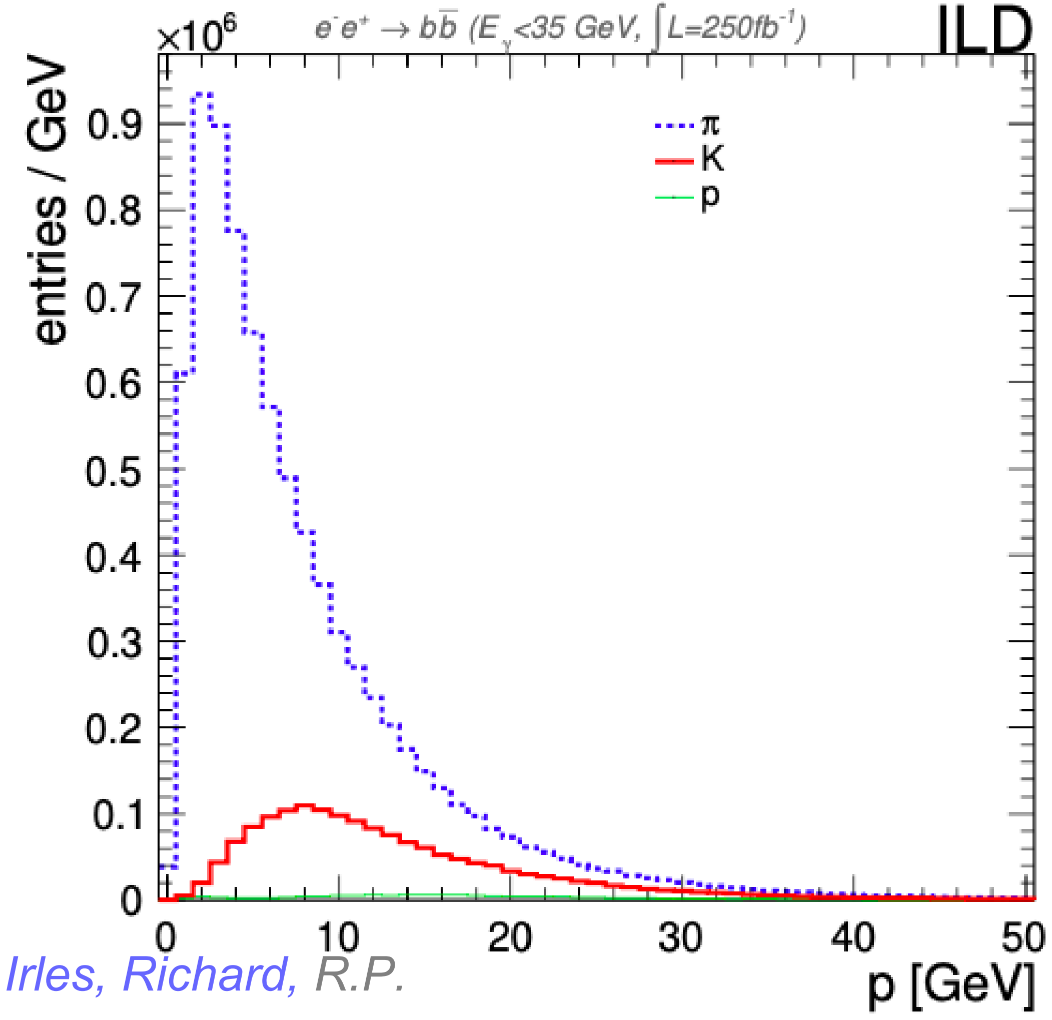
CNN trained on pions achieves marked improvement over the conventional approache while maintaining performance for photon reconstruction

GNN, with edge convolution (PointNet), **with shower development timing information** further **improves energy resolution** when **shorter time slices** are included

arxiv:2108.10963

Calorimeters with ToF Functionality?

Momenta and abundance of pi/K/p in ee->bb @ 250 GeV



ILD: Irles, Richard, R.P.

Available time resolution with calos

Available "now"

Doable with Intensive R&D in 5-10 years

Requires a new breakthrough

Difference in ToA at ILD Calos

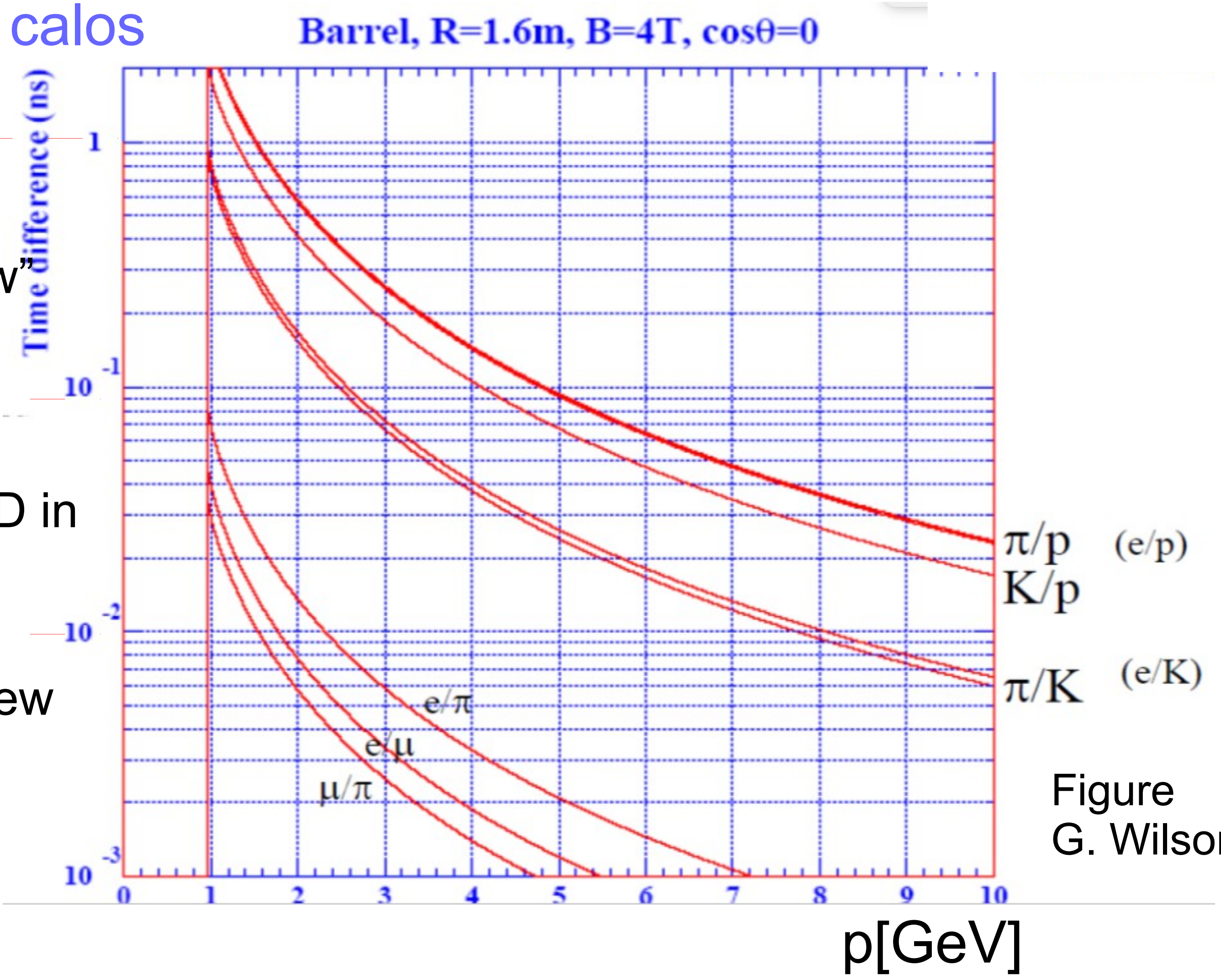


Figure G. Wilson

- Particle momenta (at 250 GeV) have peak below 10 GeV but long tail to higher energies
- Realistically ToF measurements will be (in foreseeable future) limited to particles below 10 GeV
  - Note that, apart from power consumption, in a final experiment one needs to control full system
- Momenta above 10 GeV require a real breakthrough and maybe even radically new approaches
  - Mandatory if ToF should work at and well above 250 GeV i.e. at Linear Collider energies

Summary and outlook

- Successful operation of a fifteen layer stack in two beam tests at DESY
  - Major milestone for technological prototype
  - Demonstration of performance of compact DAQ
  - Rich set of data to study detector performance
  - Have already precious feedback on strong points but also of weak spots
    - The inhomogeneity in the layer response is a matter of concern
    - Debugging has started

- Powerful infrastructure to conduct conclusive system tests now and in coming years

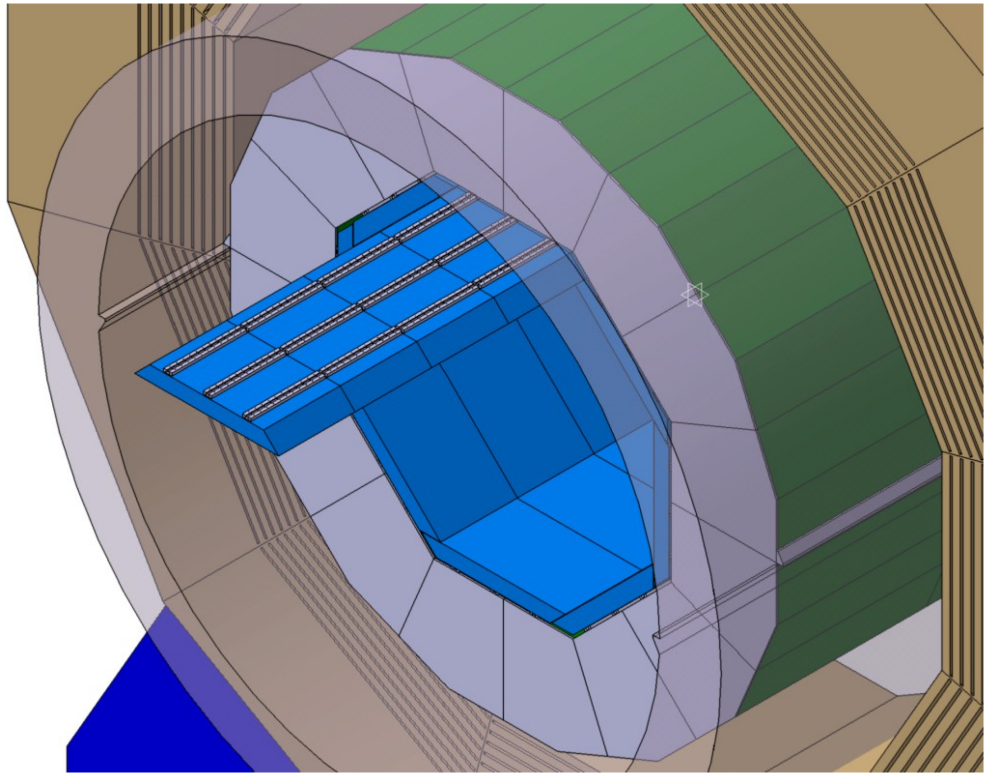
- New type of PCBs will allow for finalising the R&D in terms of power pulsing
  and for bringing us to the "eve" of an engineering prototype in the next around two years
  - Sufficient support provided ... the team is working at the limit
  - We need in particular more people for data analysis

- Have to make up our minds on the requirements for timing in PFA calorimeters

Backup

Silicon Tungsten electromagnetic calorimeter

- Optimized for Particle Flow: Jet energy resolution 3-4%, Excellent photon-hadron separation



The SiW ECAL in the ILD Detector

- O(10^8) cells
- "No space"
=> Large integration effort

Basic Requirements:

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

Basic Choices:

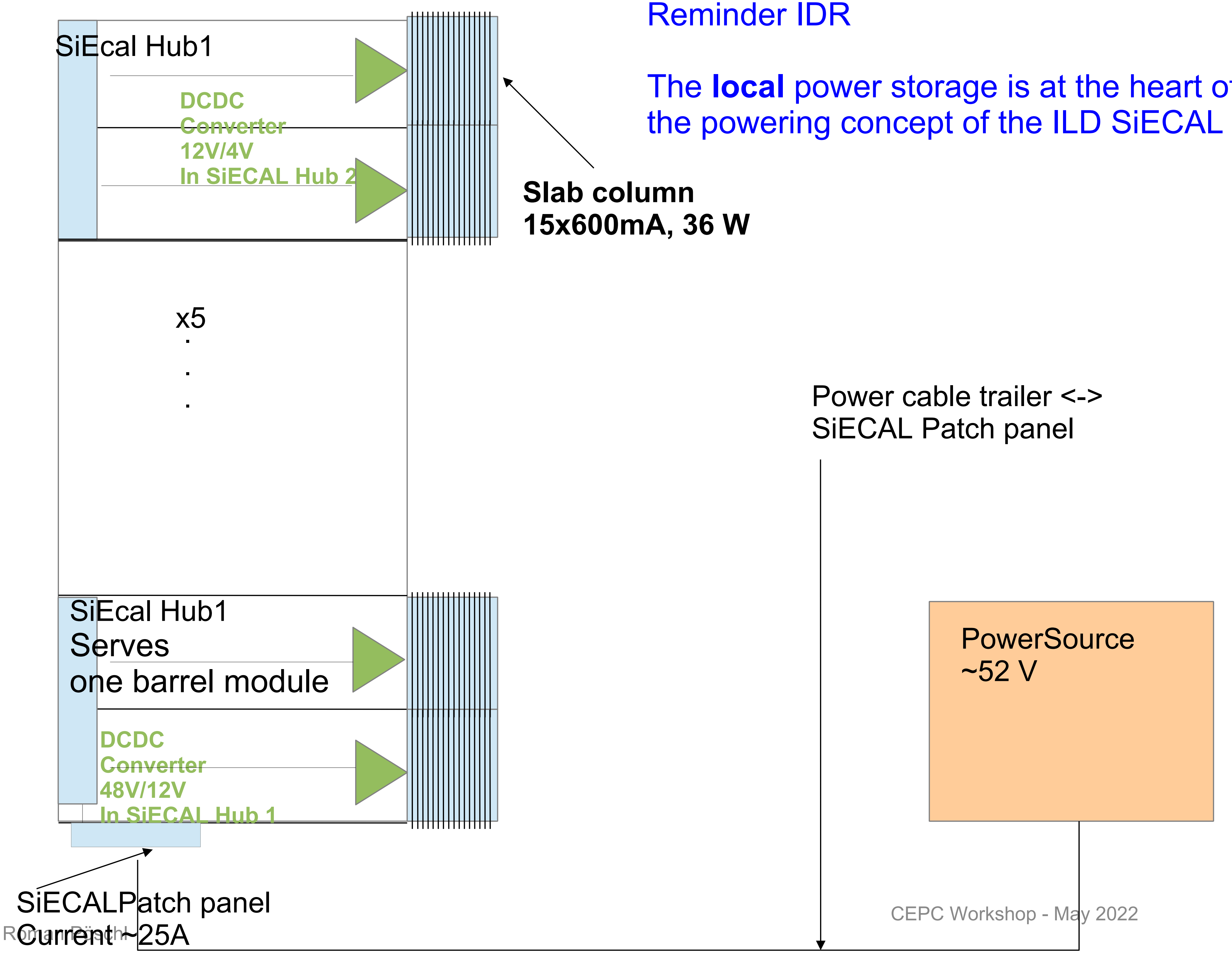
- Tungsten as absorber material
  - X_0=3.5mm, R_M=9mm, λ_I=96mm
  - Narrow showers
  - Assures compact design
- Silicon as active material
  - Support compact design
  - Allows for pixelisationRobust technology
  - Excellent signal/noise ratio: 10 as design value

- All future e+e- collider projects feature at least one detector concept with this technology
  - Decision for CMS HGCAL based on CALICE/ILD prototypes

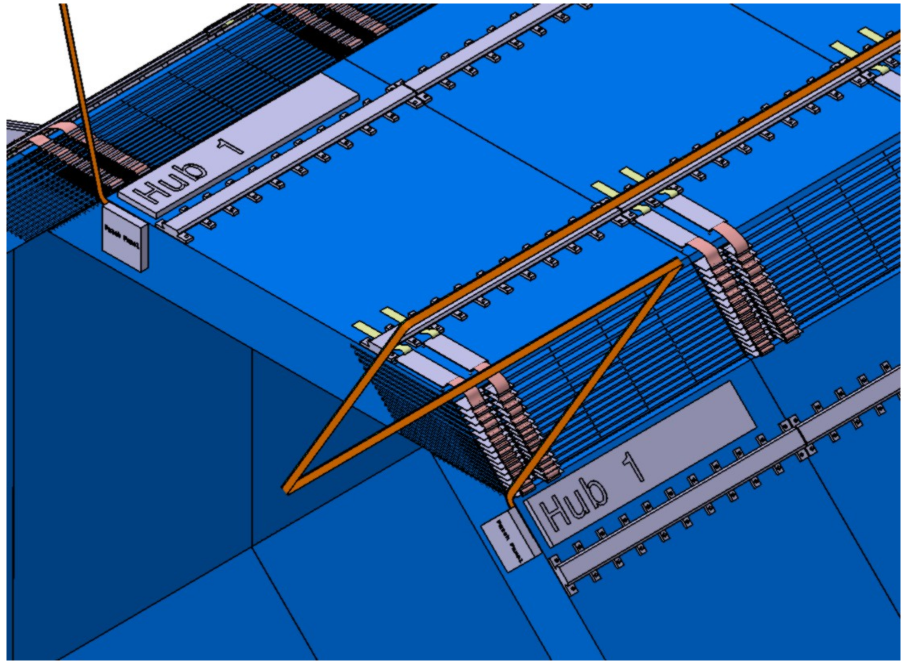
Powering concept/management – ILD SiECAL

Reminder IDR

The **local** power storage is at the heart of the powering concept of the ILD SiECAL



Zoom into ILD Ecal barrel



- Total average power consumption **20 kW** for a calorimeter system with 10^8 cells*
  - Only possible through PP
- The art is to store the power very locally
- Issue for upcoming R&D

*Compare with 140 kW for CMS HGCAL FEE 6×10^6 cells

Next generation ASICS?

Ch. de la Taille
CALICE Meeting, Valencia

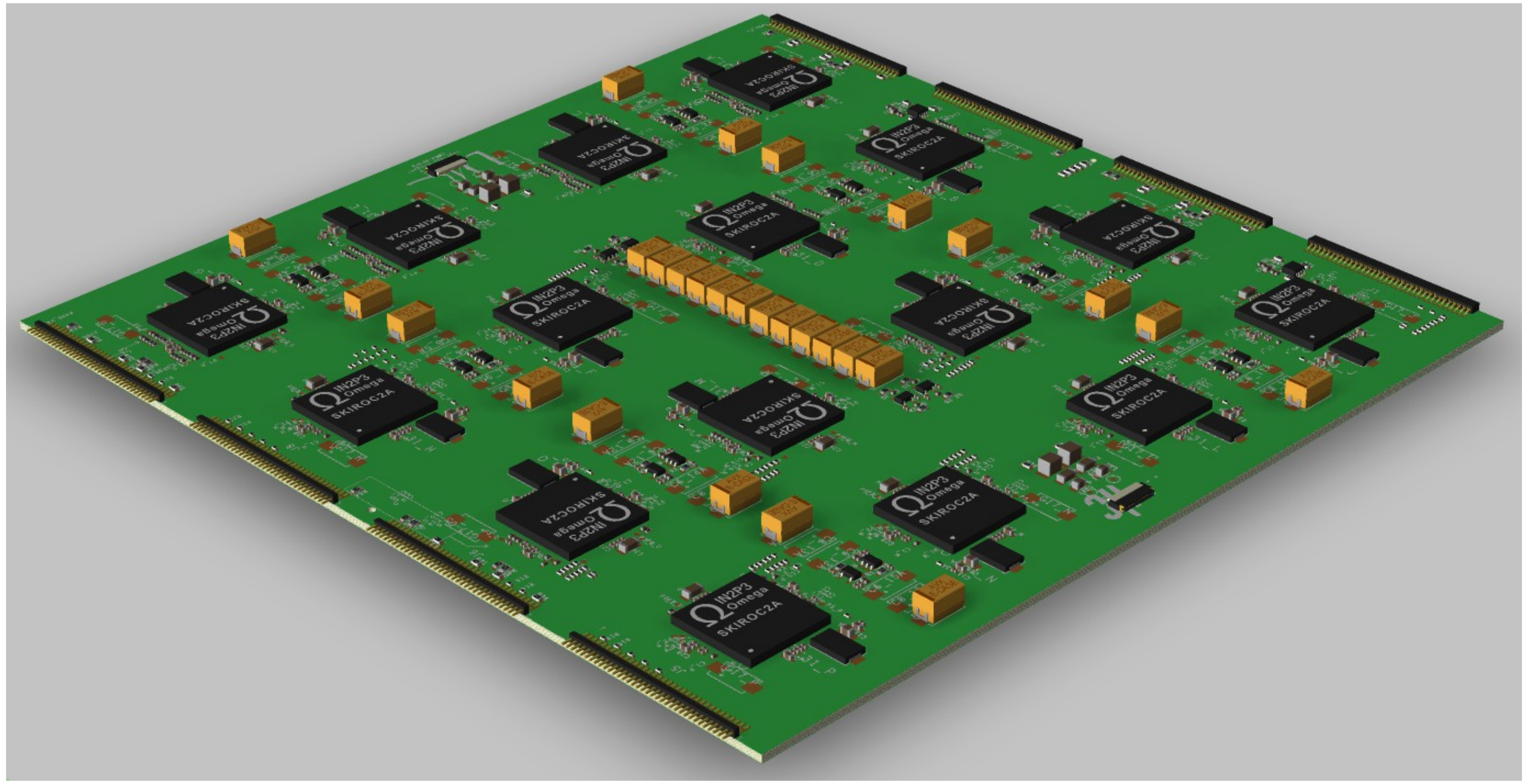
- Dynamic gain preamp or TOT ?
- 200 ns shaping, 10 MHz ADC, several samples on the waveform
- Timing capability ? Auto-trigger and zero suppression
- Target ~1 mW power/ch and possible power pulsing
- I²C slow control ? New readout protocol ?
- Include 2.5V LDO inside VFE ?
- Compatible with FCC LAr. SiPM/RPC tbd

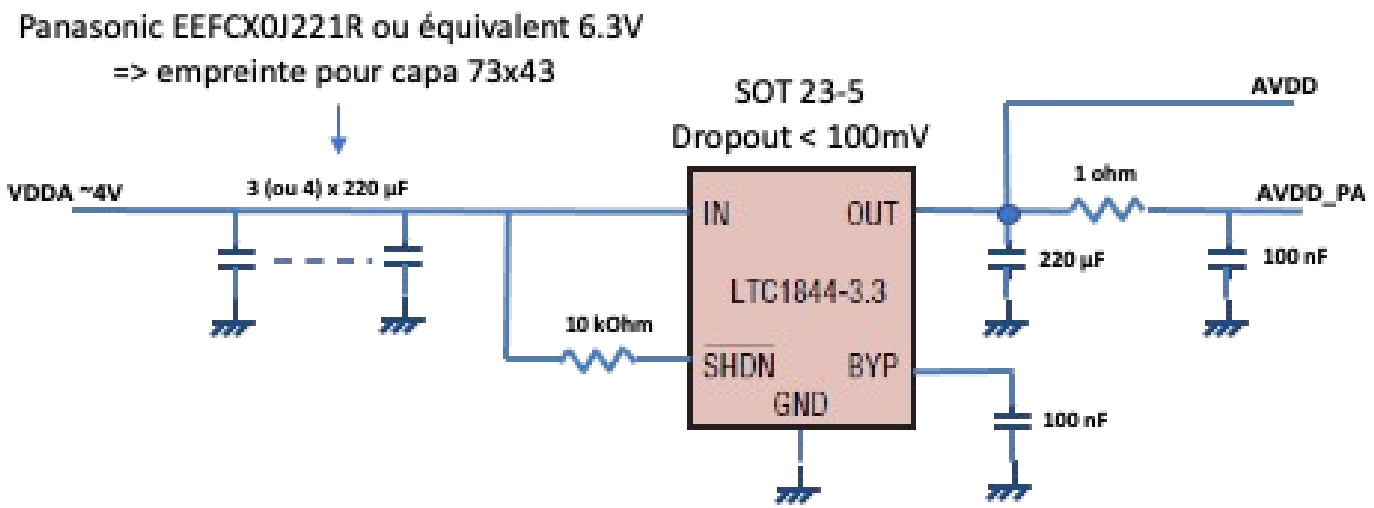
	experiment	Sensor	capacitance	shaping	power	data	techno	Vdd	slow control
SKIROC2	CALICE	Si	30 pF	300 ns	5 mW/ch	5 MHz	SiGe 350n	3.3 V	SPI
HGCROC	CMS	Si	50 pF	20 ns	20 mW/ch	1.2 Gb/s	TSMC 130n	1.2 V	I²C
FCC	LAR	Lar	50-200 pF	200 ns	<1 mW	Gb/s	TSMC 130n	1.2 V	I²C
SKIROC3	CALICE	Si	50 pF	200 ns	<1 mW	Mb/S	TSMC 130n	1.2 V	?

CdLT CALICE meeting 20 apr 2022

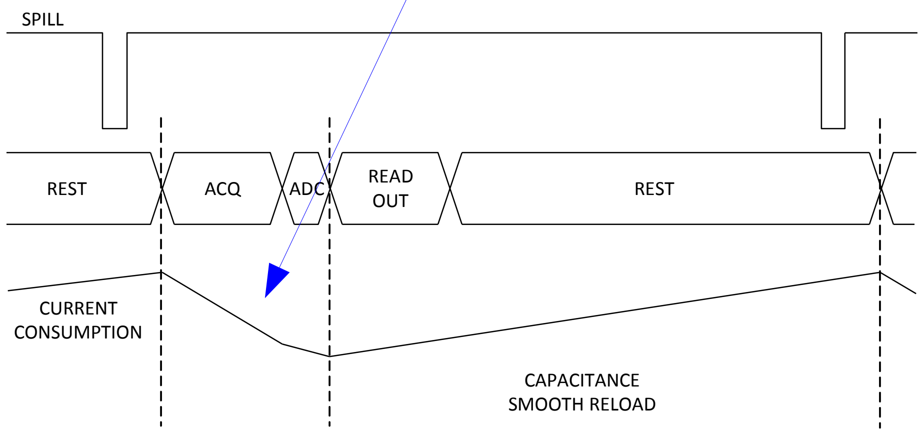
New FEV2.0 et al.

Status after regular discussions between engineers of LLR, IJCLab, LPNHE and OMEGA





With 600 µF, we ensure 100mA during 3ms with a voltage drop of 0.5V ($\Delta V = I.t/C$).

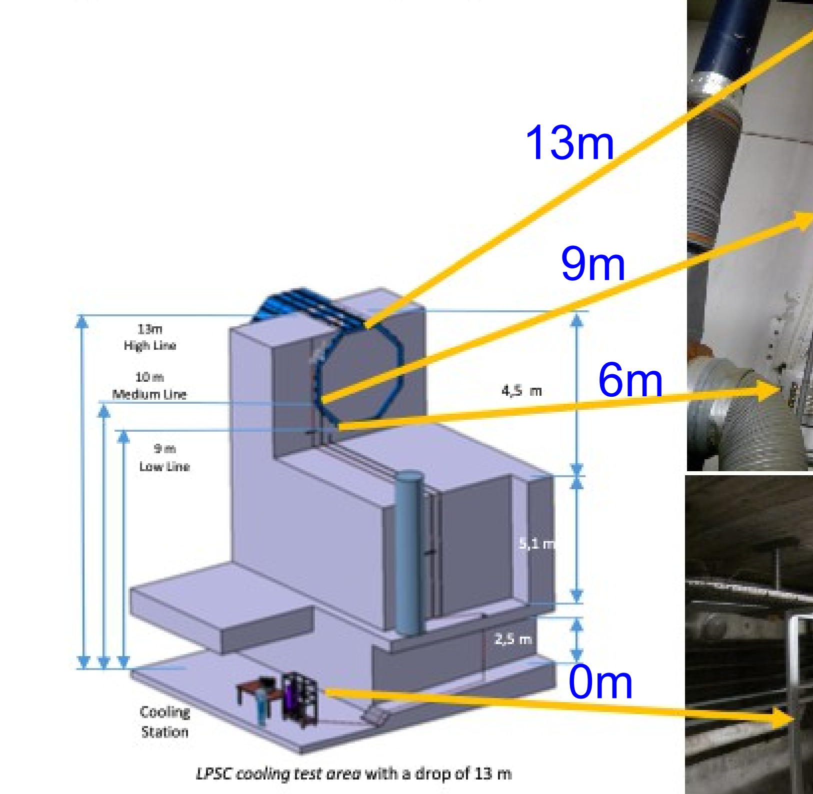


- New board for next step of technical realisation of power pulsed Ecal layers
  - Capacitances and LDO close to ASICs
- Last month progress in design
  - Stacking of PCB
  - Choice of components
- Another important feature is that HV will be transported via connectors (i.e. On top of board
  - Wafer supply from bottom of board via plies (copper/kapton)
  - These plies are a delicate piece
  - Risk of shortcuts and wafer damage (the design of the kapton that goes below the board requires another design round)
- Expect production either shortly before or shortly after the summer break (not in a hurry, carefulness comes before speed)
- The setup will be completed by a “Termination card” that will allow for flexible chaining of cards (i.e. No soldering of terminations)
- and for flexible adding of decoupling capacitances (to study noise behaviour of COBs)

Demonstrator of large leakless loop for CALICE/ILD ECAL

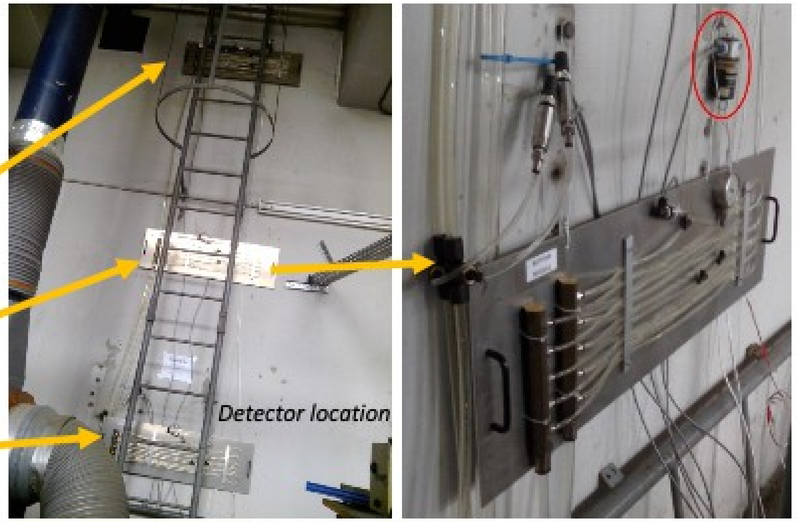
- Thermal model as milestone
- Probes at different heights to establsih full model of Cooling system for large detectors

a large leak-less cooling-loop



LPSC cooling test area with a drop of 13 m

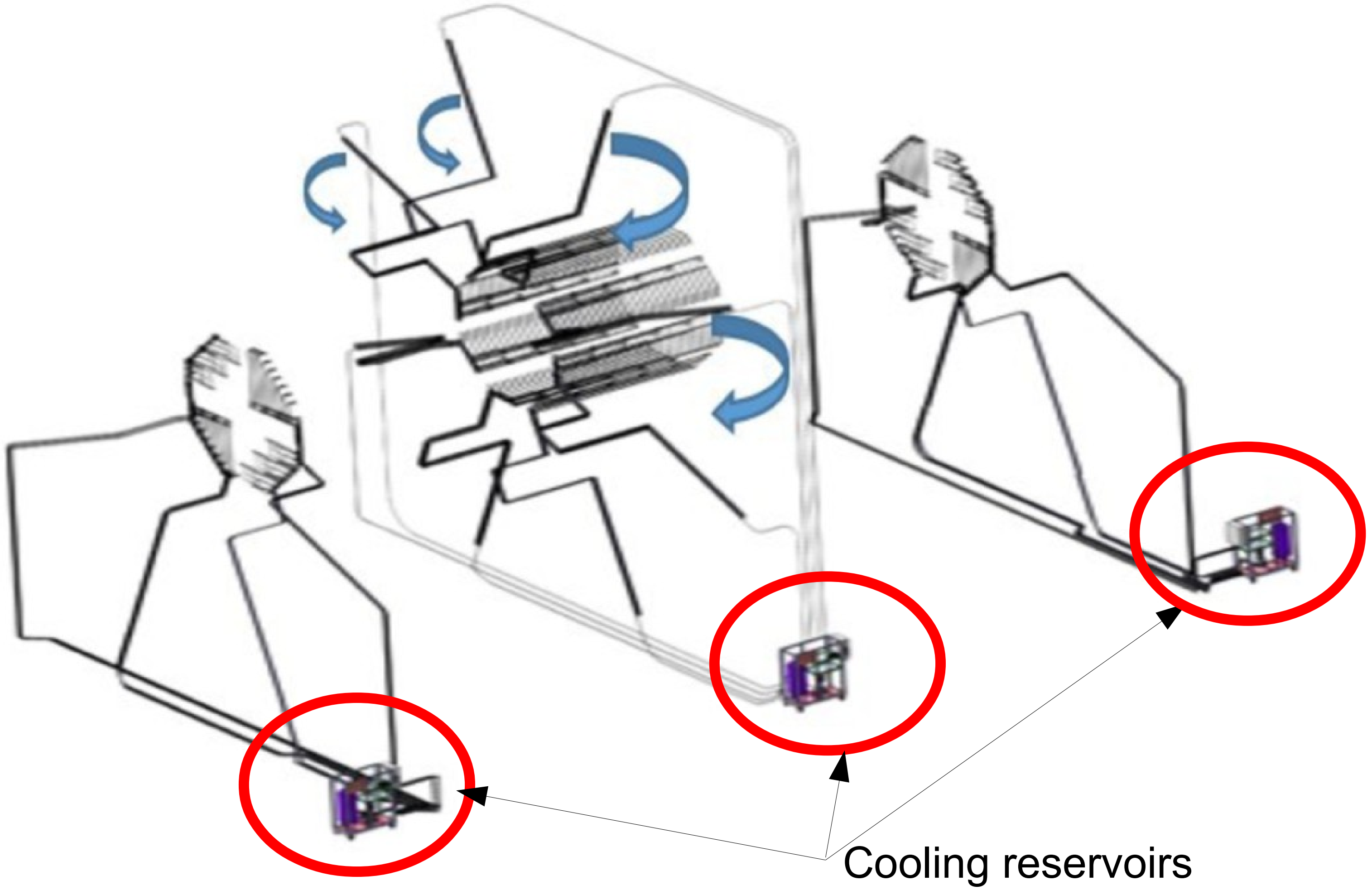
Upper part of the experiment



Julien Giraud

Studies for efficient leak detection Ongoing (Polarographic probe)

LPSC



Final considerations: Powering needs for different running schemes

Power pulsed systems

Numbers from Vincent

All faults are mine

ILC "Standard"

T_{Bunch} ~ 1ms
f_{rep} ~ 5Hz
=> ΔT_{Bunch}=200ms

HL-ILC:

- $\mathscr{L} \times 4\,(6)$
- $N_{bunches} \times 2: \ \tau_{Train:}\ 1 \rightarrow 2\ \mathrm{ms}$
- $f_{rep}\ \times 2\,(3): 5 \rightarrow 15\ \mathrm{Hz}$

=> $\Delta T_{Bunch,min}$=66ms

HL-CLIC:

- $\mathscr{L} \times 2$
- $N_{bunches} \rightarrow : \ \tau_{Train:}\ 176\ \mathrm{ns}$
- $f_{rep}\ \times 2 : 50 \rightarrow 100\ \mathrm{Hz}$

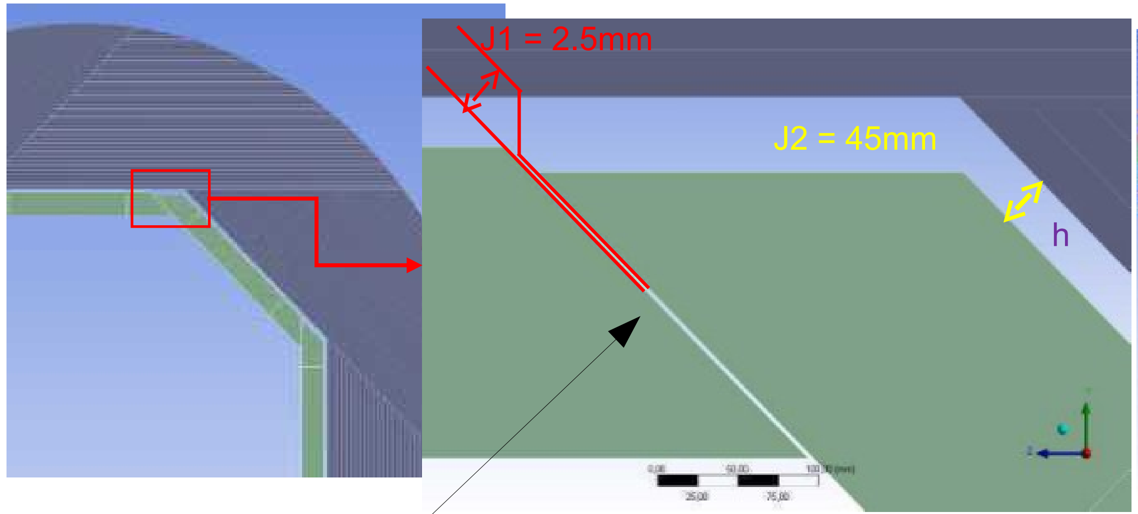
=> $\Delta T_{Bunch,min}$~10ms

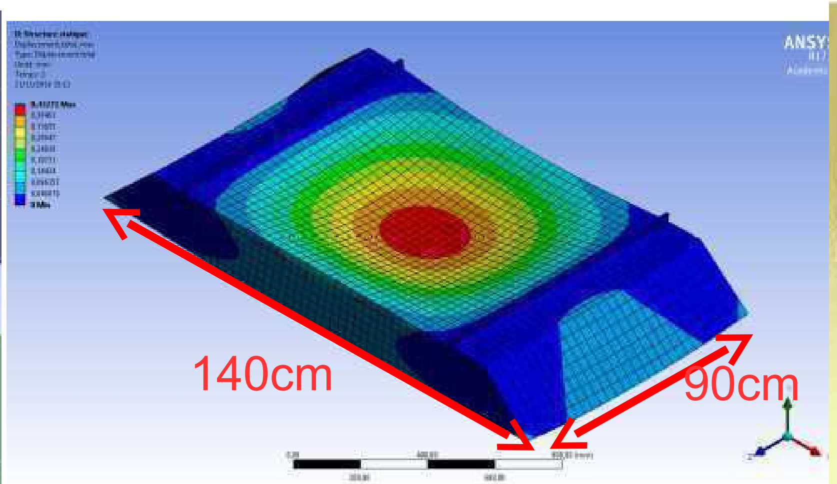
- In the (local) powering scheme the power is reloaded between the bunch trains with a small constant charging current
- As long as one manages to charge the capacitances between the bunch trains, the overall power consumption will not increase with increasing luminosity
  - The step from ILC Standard to HL-ILC doesn't look too big, CLIC may require a further look
  - Of course, the front-end electronics will still dissipate heat, passive cooling should still work

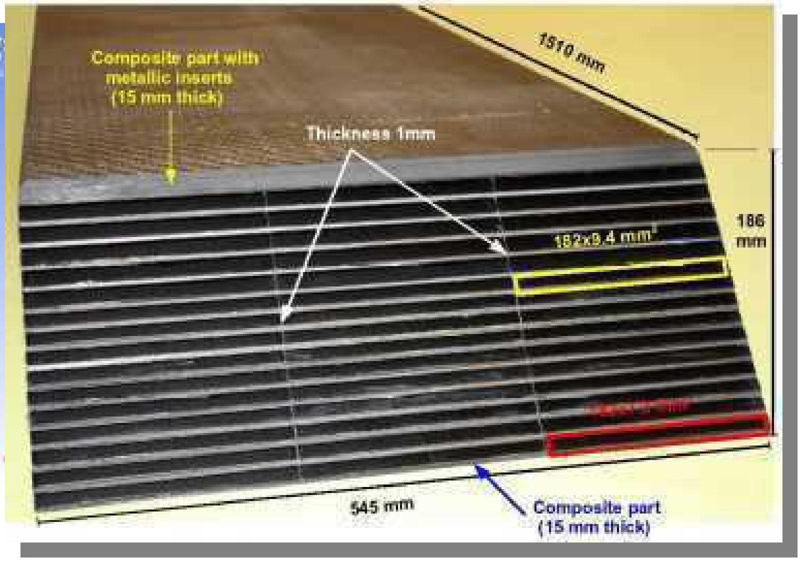
Continuously powered systems:

- Typical consumption of FEE (as of today) 5-10mW/channel
  - CMS HGCROC has 20mW/channel due to sophisticated digital part
- This translates directly into power consumption of detector
- 5mW: For 10^8 channels this leads to 500 kW power consumption of full detector
  - This is the pure consumption of the front-end electronics (e.g. no ohmic losses in power transfer etc. U=RI and I would be high)
  - => Active cooling

ILD SiECAL – Mechanical structures and studies



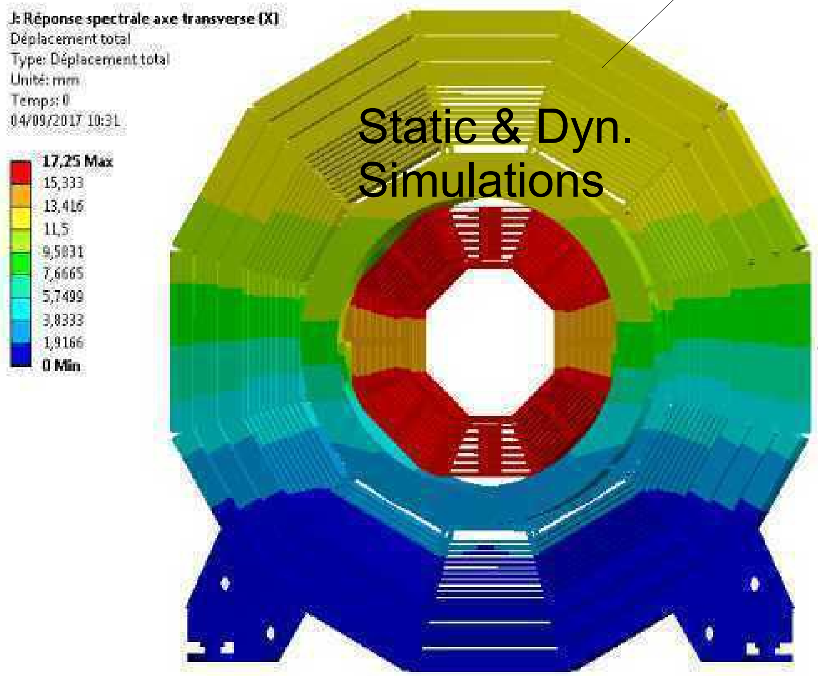


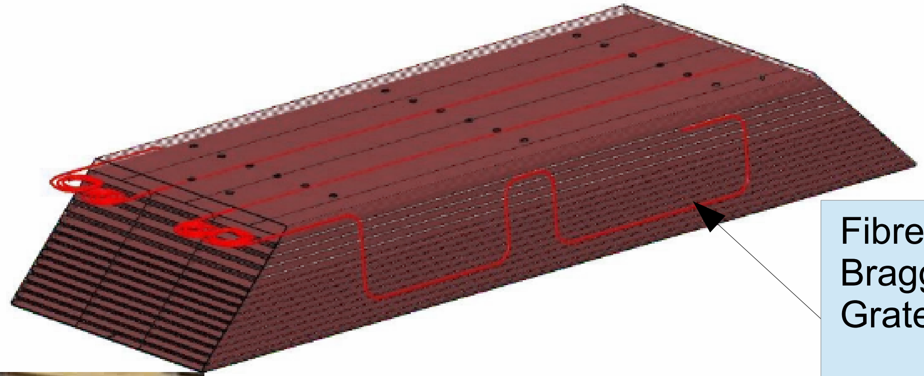


J1 = clearance between modules for the ECAL

J2 = Clearance at ECAL edges between ECAL and HCAL

h = height of the rails 30mm





Fibre Bragg-Grated

measurements still to be done...

Shower development in CALICE Type Calorimeters

LLR

Shower reconstruction

ILD

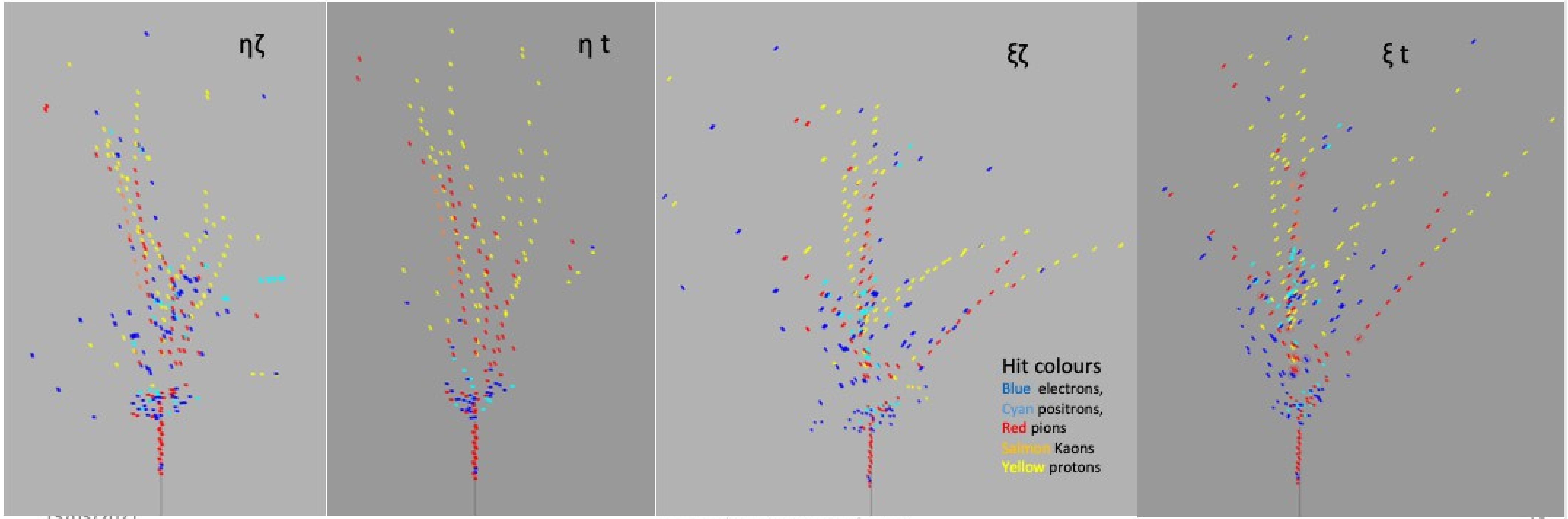
It is known that the more dimensions, the easiest to reconstruct patterns

Using the time-space

To figure out the pattern of a shower developed by a charged track or a neutral
We assume that the main direction of the shower, called ζ, is
- along the flight line from interaction to the earliest hit in the Ecal (or globally) for a neutral
- along the track direction at the position of the earliest hit for a charged track

Two perpendicular coordinates, ξ and η, are chosen to optimise the match with the detector axes, mostly for visualisation.
Then t which is much correlated to ζ.

You see immediately
the role of the β
and how the protons slow down
when the pions do not



15/03/2021 Henri Videau LCWS March 2021 12

H.Videau et al., LCWS2021

arxiv:2108.10963

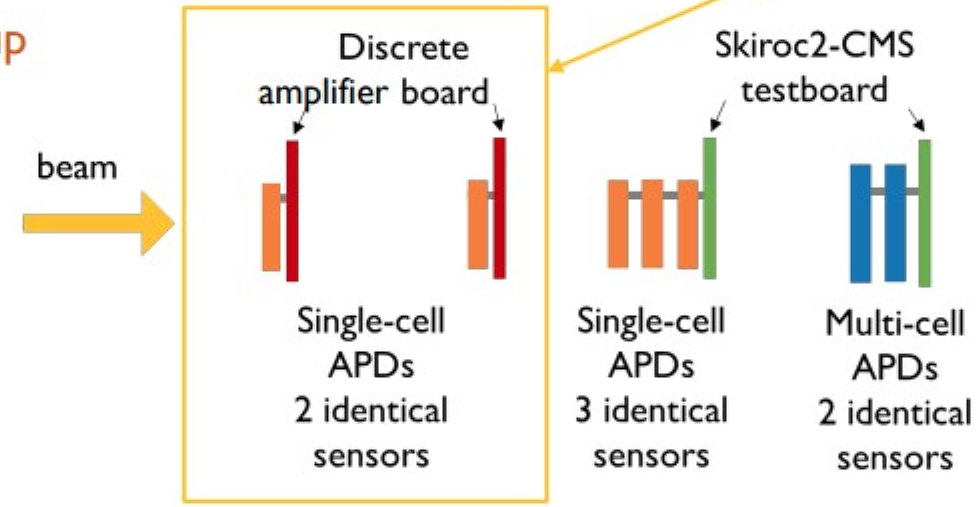
Timing devices – Hardware Studies

T. Suehara
CALICE Meeting, Valencia

6-8 Oct. 2021 at ELPH, Tohoku University

- 3 days ✕ 12 hours positron beam: ~770 MeV

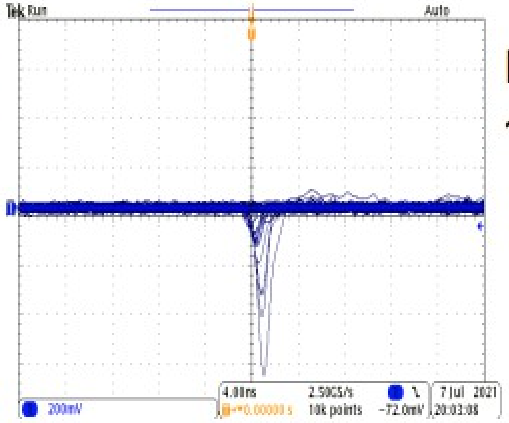
Setup



amplifier board

2 stages

Waveform output from the amp. board



Rising time ~1 nsec

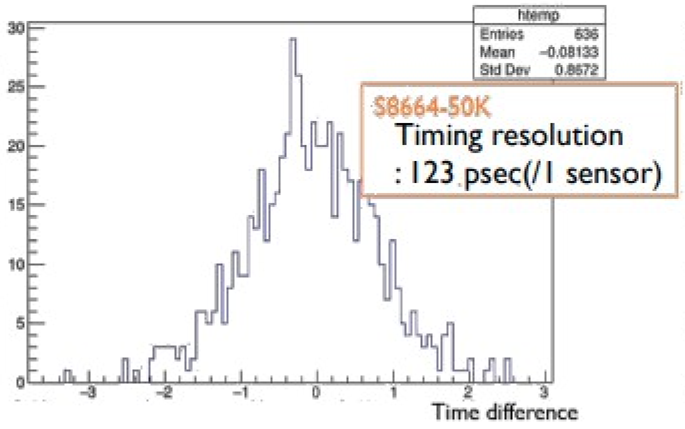
Amplifier chip

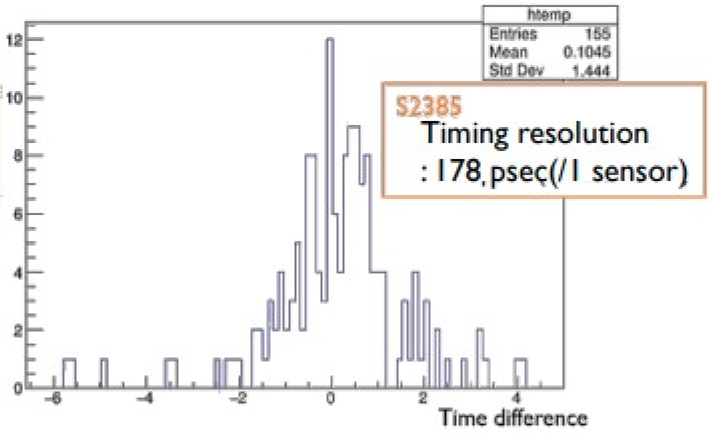
- GALI-S66+ (Mini-circuit)
- Gain: 20 dB
- Wide bandwidth 3GHz

APD

APD sensor	Cut of charge	Timing resolution
S8664-50K (Inverse type)	> 18 fC	123 ps
	> 36 fC	63 ps
S2385 (reach through type)	> 18 fC	178 ps
	> 36 fC	89 ps

Time difference between the two APDs (charge > 18 fC)



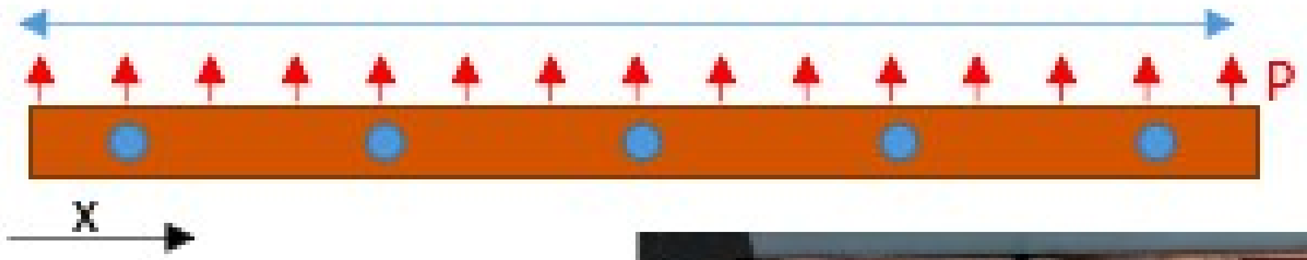


- Timing resolution of S8664-50K is better

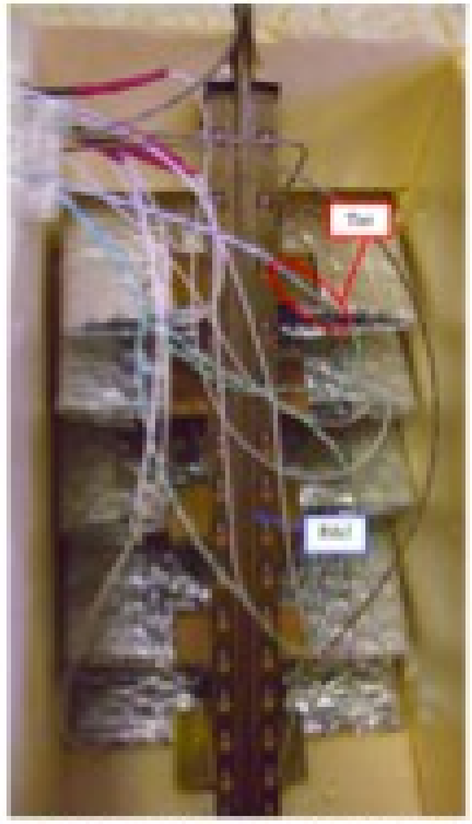
→ Difference in capacitance related to signal rising time (S8664-50K: 55 pF S2385: 95 pF)

Passive cooling

Active cooling




Passive cooling ramp example


Passive cooling ramp set up test


Active cooling set up test with water at room temperature


Active cooling test layout (400mm x 300mm x 3mm thick copper plate with 1,800 pipes embedded)