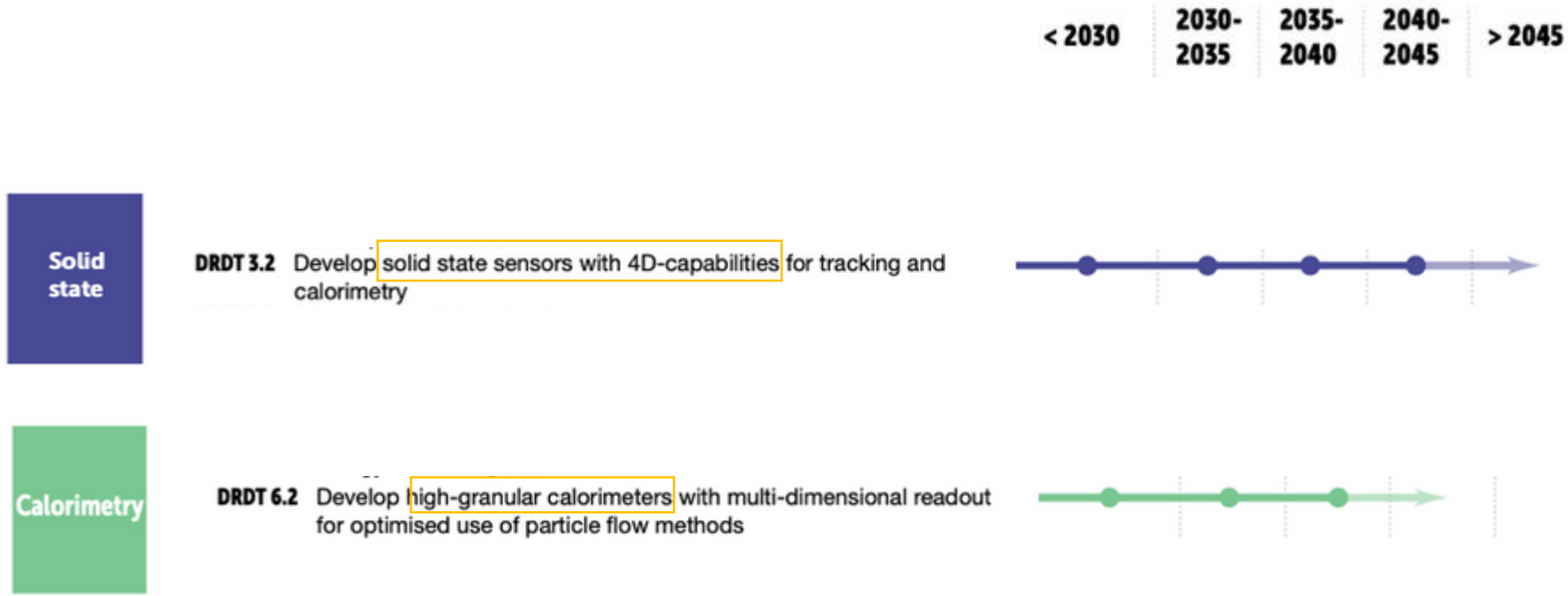
DRD @ LPNHE

Rémi Cornat

28/06/2023

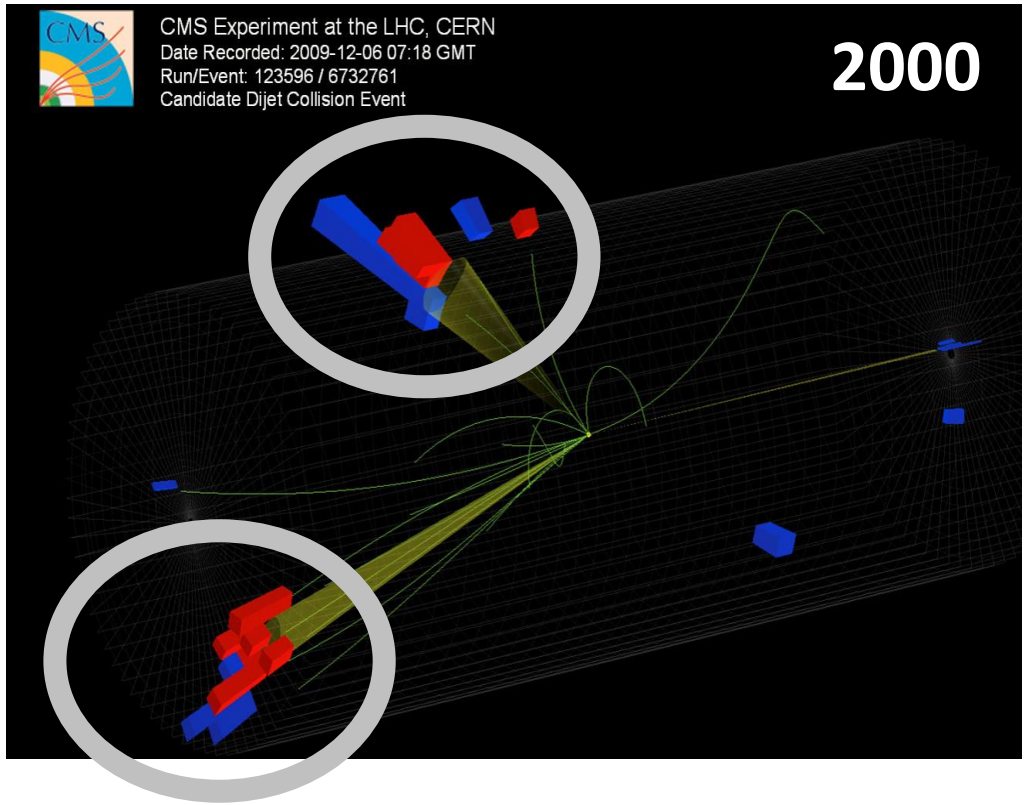
DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

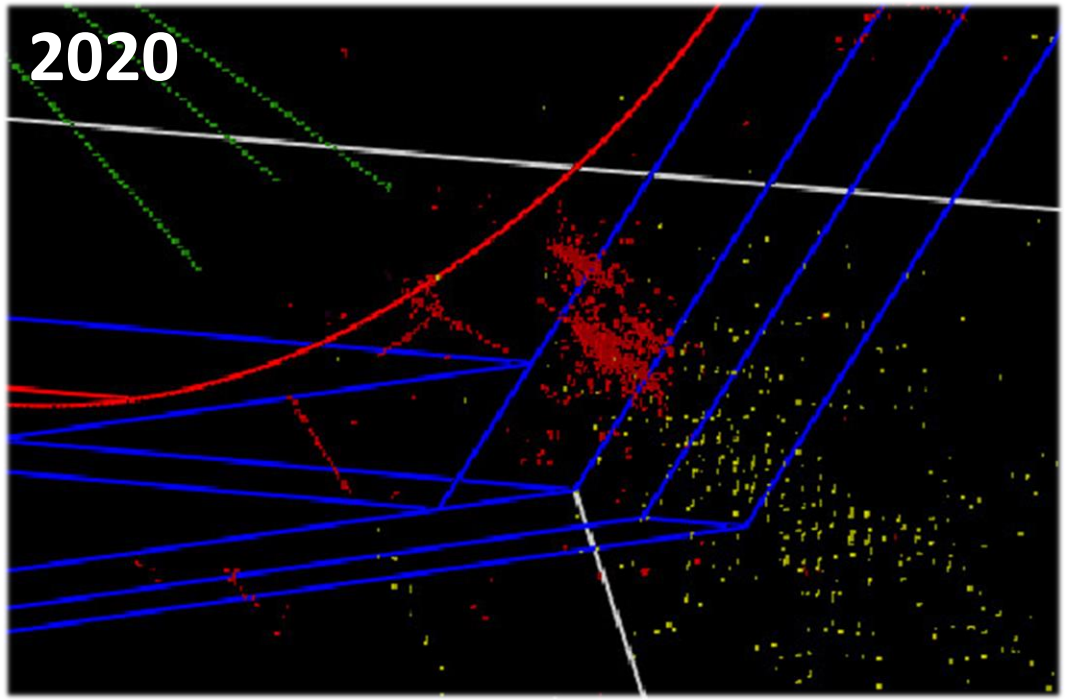


https://aidainnova.web.cern.ch/european-roadmap-detector-rd
https://cds.cern.ch/record/2784893/

Highly granular calorimetry

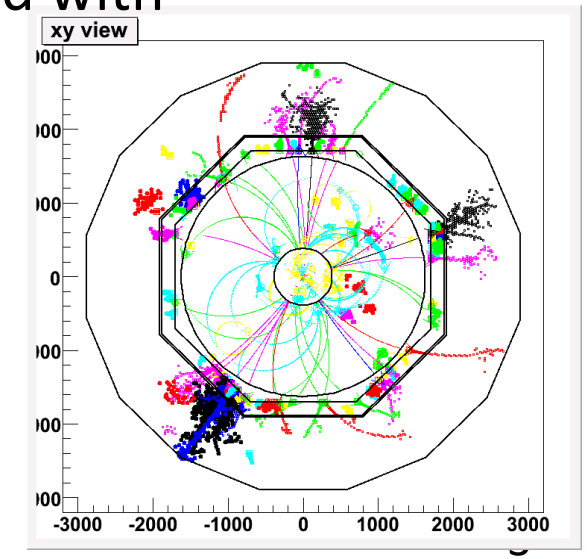
Towards O(10^8) channels detector



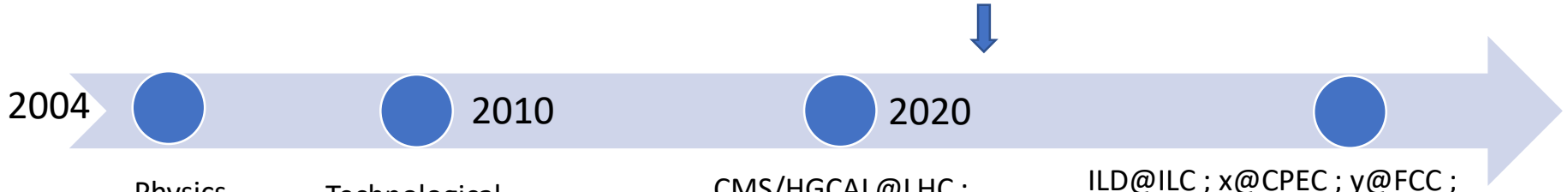


A mix of technologies qualified with prototypes and achieving
5000 “calorimeter grade” channels/dm^3

“Particle Flow” analysis
+ ToF : 5D calo (x,y,z,E,tof)



Silicon-Tungsten ECAL @CALICE



Proof of concept
- Linearity
- Resolution
- Sensors
- Very front-end

1500 channels/dm^3

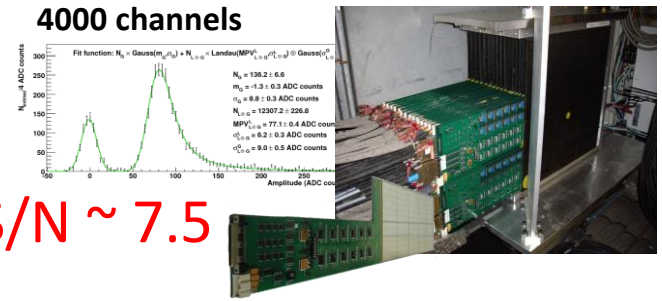
Feasibility of design options
- Compactness
- Granularity
- Front-end
- Power pulsing
- 2m Long SLAB

V1 : 4000 channels/dm^3
V2 : 5000 channels/dm^3

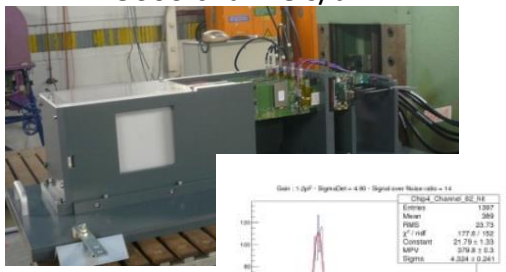
Construction
- Integration
- Environement
- Services
- Industrialization
- Tooling
- Project org.

...10000 channels/dm^3

2004-2008
30 layers
4000 channels

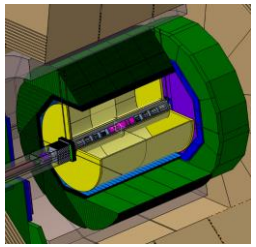


S/N ~ 7.5

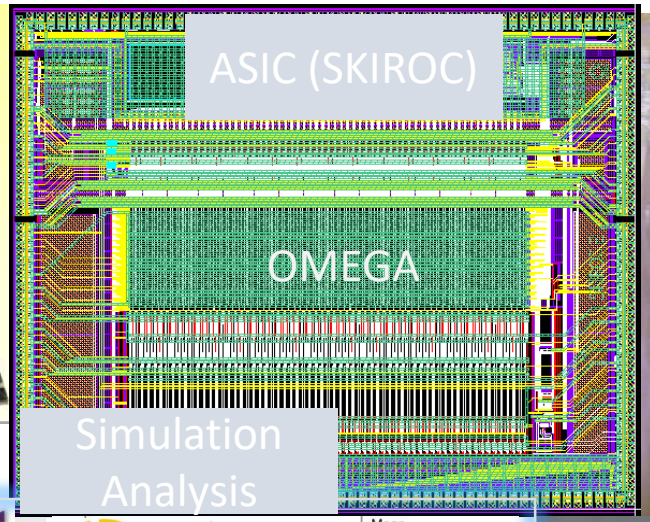


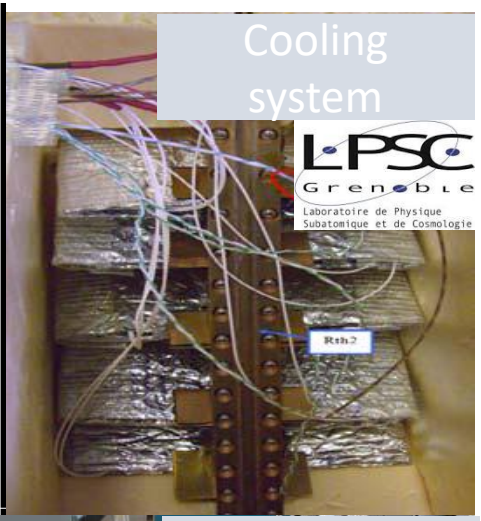
S/N ~ 15

~24 X0, 20 cm thick
~2500 m^2 active detectors
~100M readout channels



Si-W collaboration @CALICE

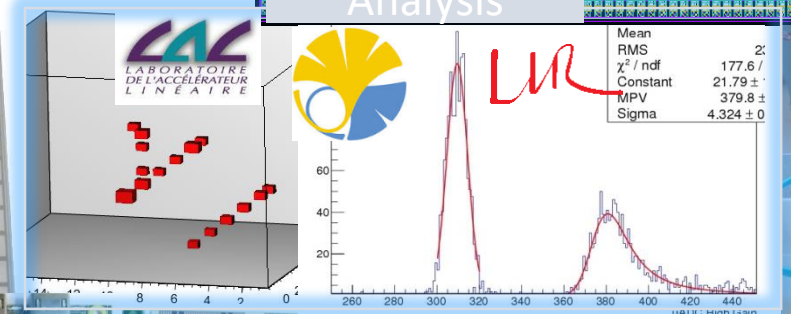


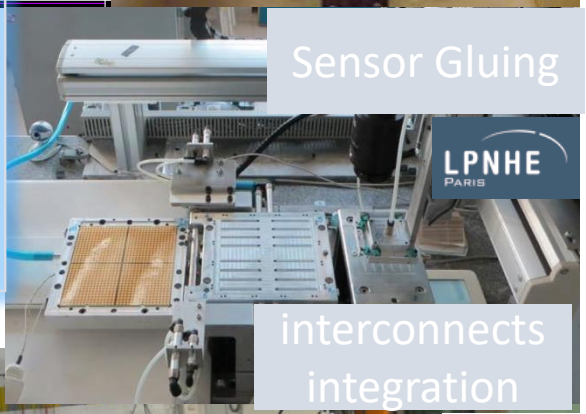


Simulation Analysis

PIN diodes

KYUSHU UNIVERSITY

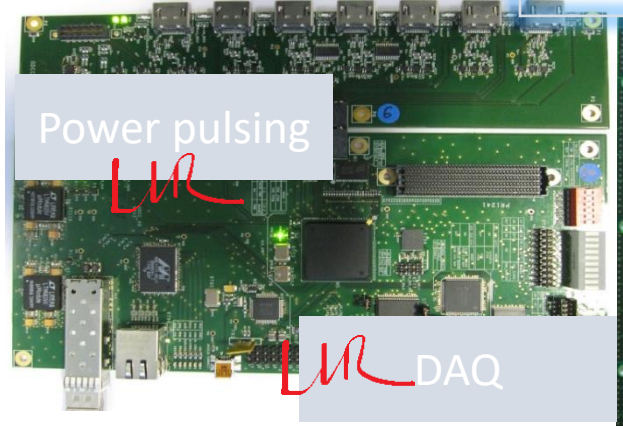




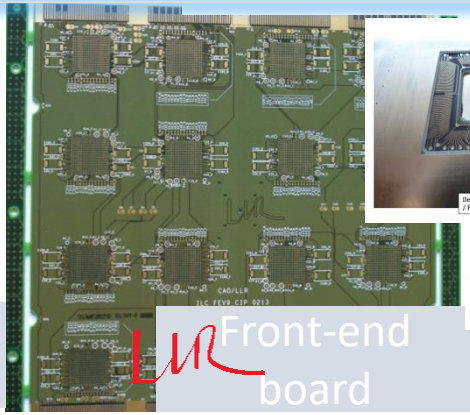
Sensor Gluing

interconnects integration

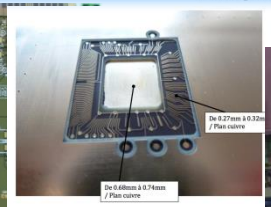
Power pulsing

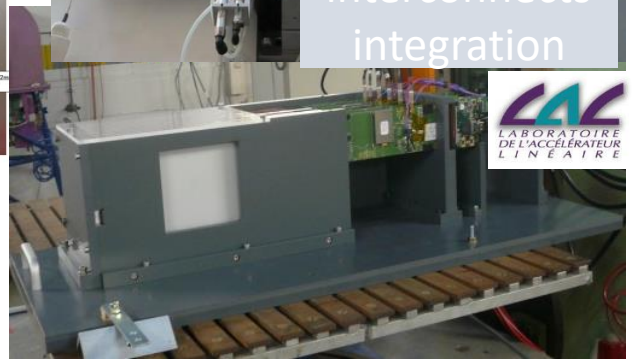


DAQ

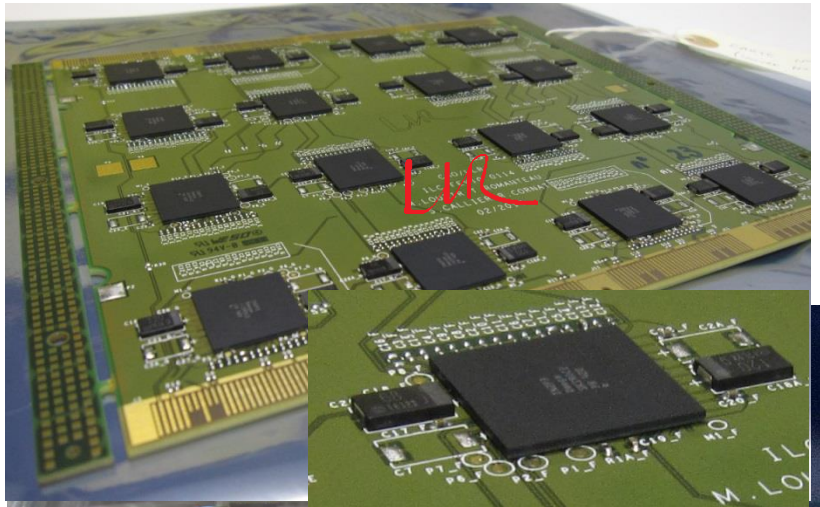


Front-end board

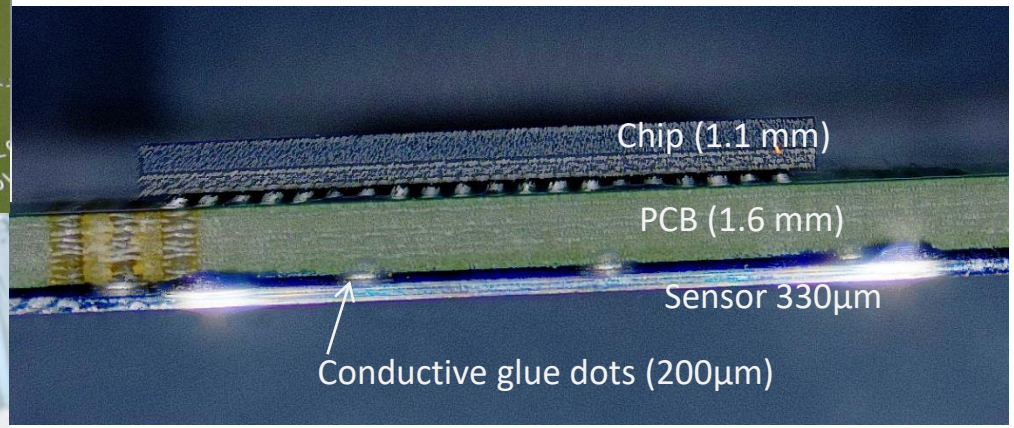


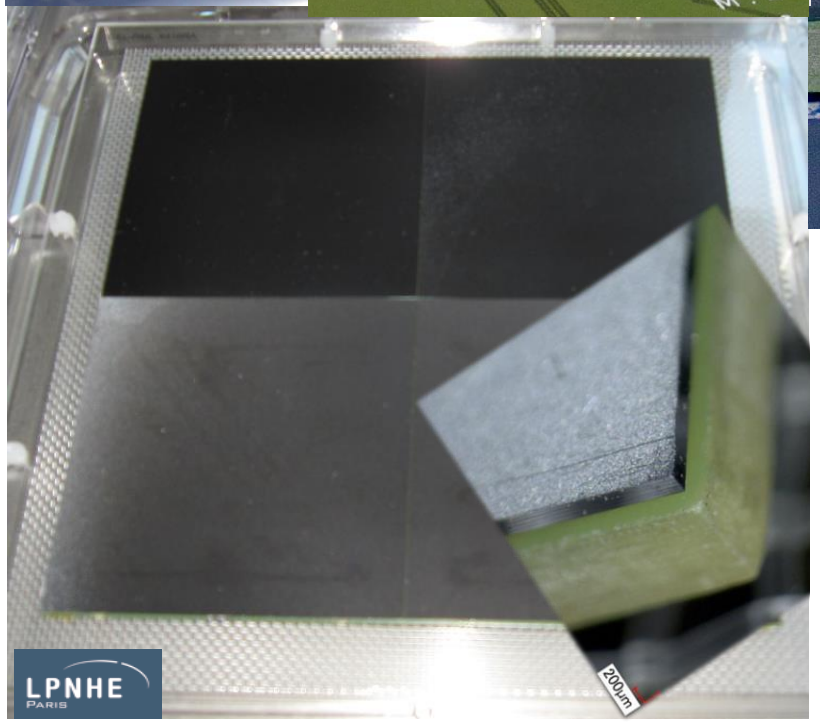


1024 channels module



Front-end board features 16 SKIROC2 ASICS
Each channel is individually shielded

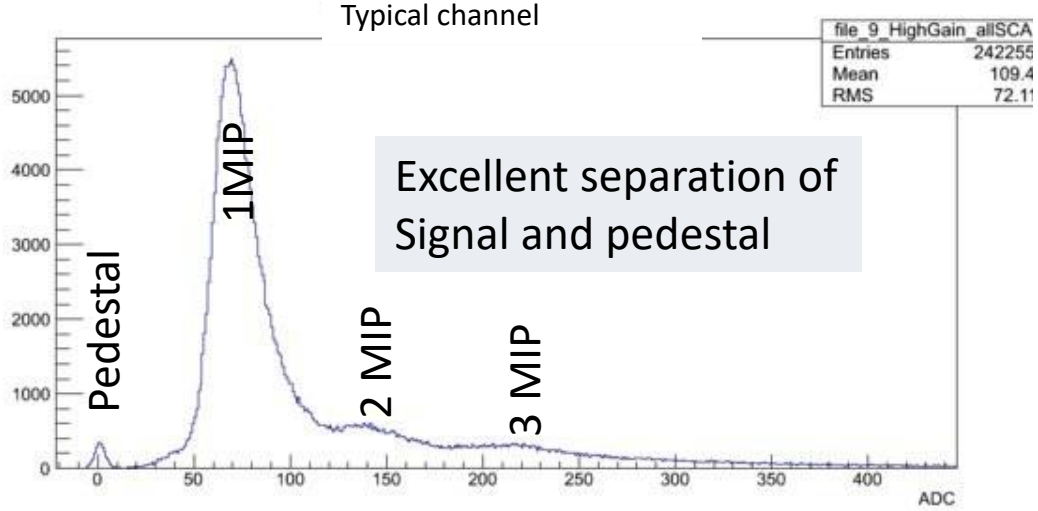




The 18cm x 18cm wide board is fully instrumented with minimal dead space (100 µm at the edges of the sensor)

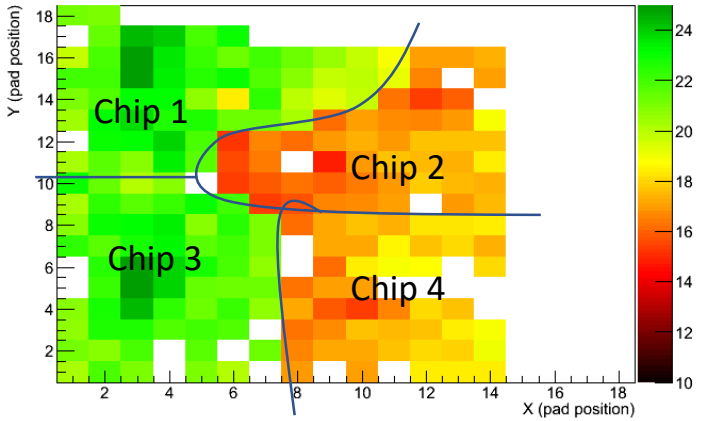
Experimental data

Typical channel



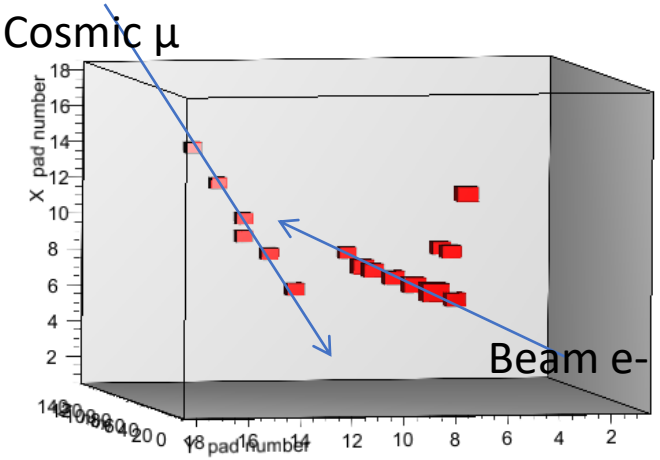
Excellent separation of Signal and pedestal

S/N map

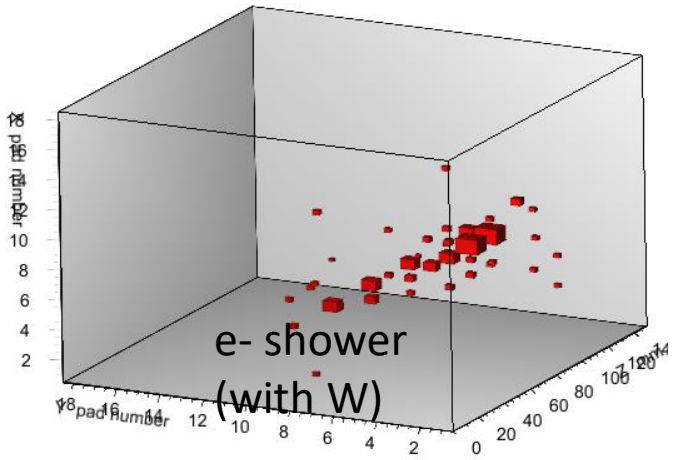


S/N better than the target (10), non uniformity understood (pixel-pcb capacitance)
EMI (chip 2 and 4 close to digital lines) and PSRR can be optimized (multi-trigger events)

Cosmic μ

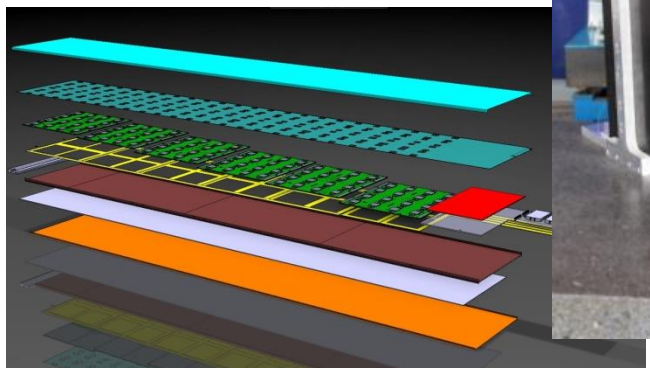


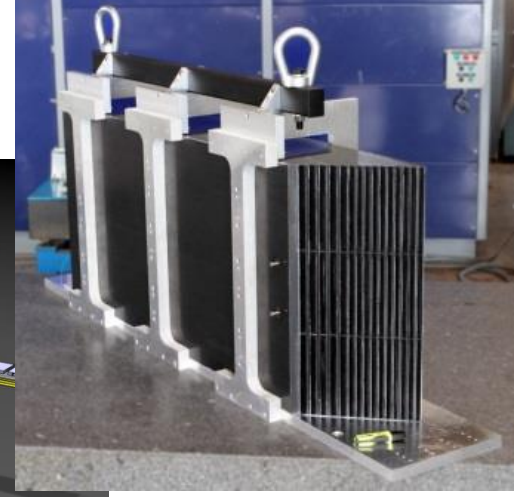
6 detector SLABS
1278 channels
10% off due to out-of-range calib.



Toward a full length module : R&D

up to 2m long detector SLAB, most of signals in bus





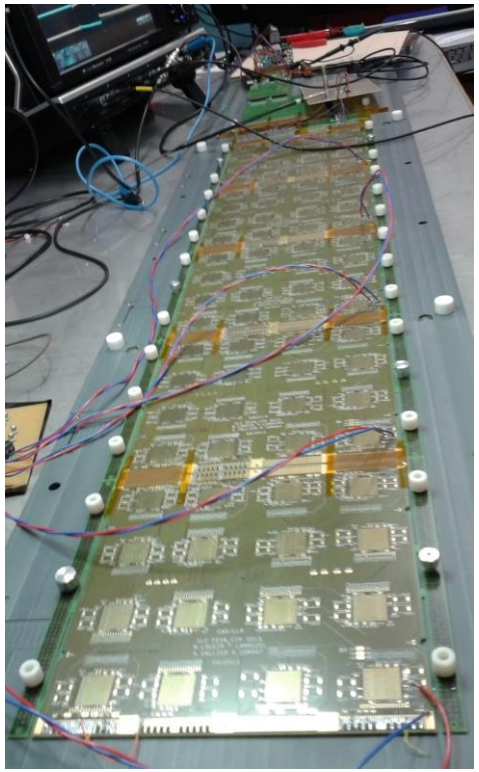
large C-W structure exists

Issue 1 : clock distribution (5 & 50 MHz)

Issue 2 : Power distribution

Issue 3 : Integration of services (cooling, according to experiment)

Issue 4 : Mechanical integration

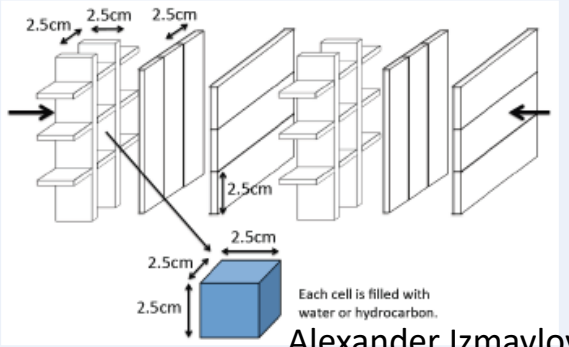


And optimization of geometry wrt. Physics : pixel density, dead area, layers…

Application to other projects

WAGASCI detector for T2K experiment

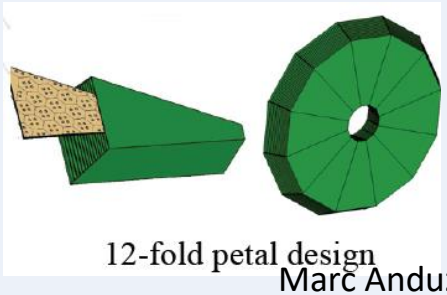
Scintillator + MPPC based detector, both water and plastic “absorber”.
Can keep same concept changing chip from SKIROC to SPIROC : same DAQ, similar FE.

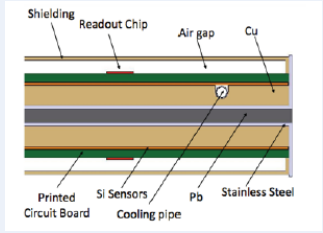


Alexander Izmaylov

Upgrade of the CMS ECAL end-caps

Completely different electronics but similar sensors (large PIN diodes matrix) & very similar mechanical structure build on carbon fiber composite





Marc Anduze, LLR

An ECAL for ILC, CEPC, FCC…
may also be based on similar concepts

DRD6 proposal
IN2P3 (IJClab, LLR, OMEGA) + KEK + Kyushu + IFIC

Adaptation from CALICE to FCC

- Continuous powering + cooling
- Optimized granularity
- Power efficient electronics
- REAL mechanical structure
- ToF O(10ps)

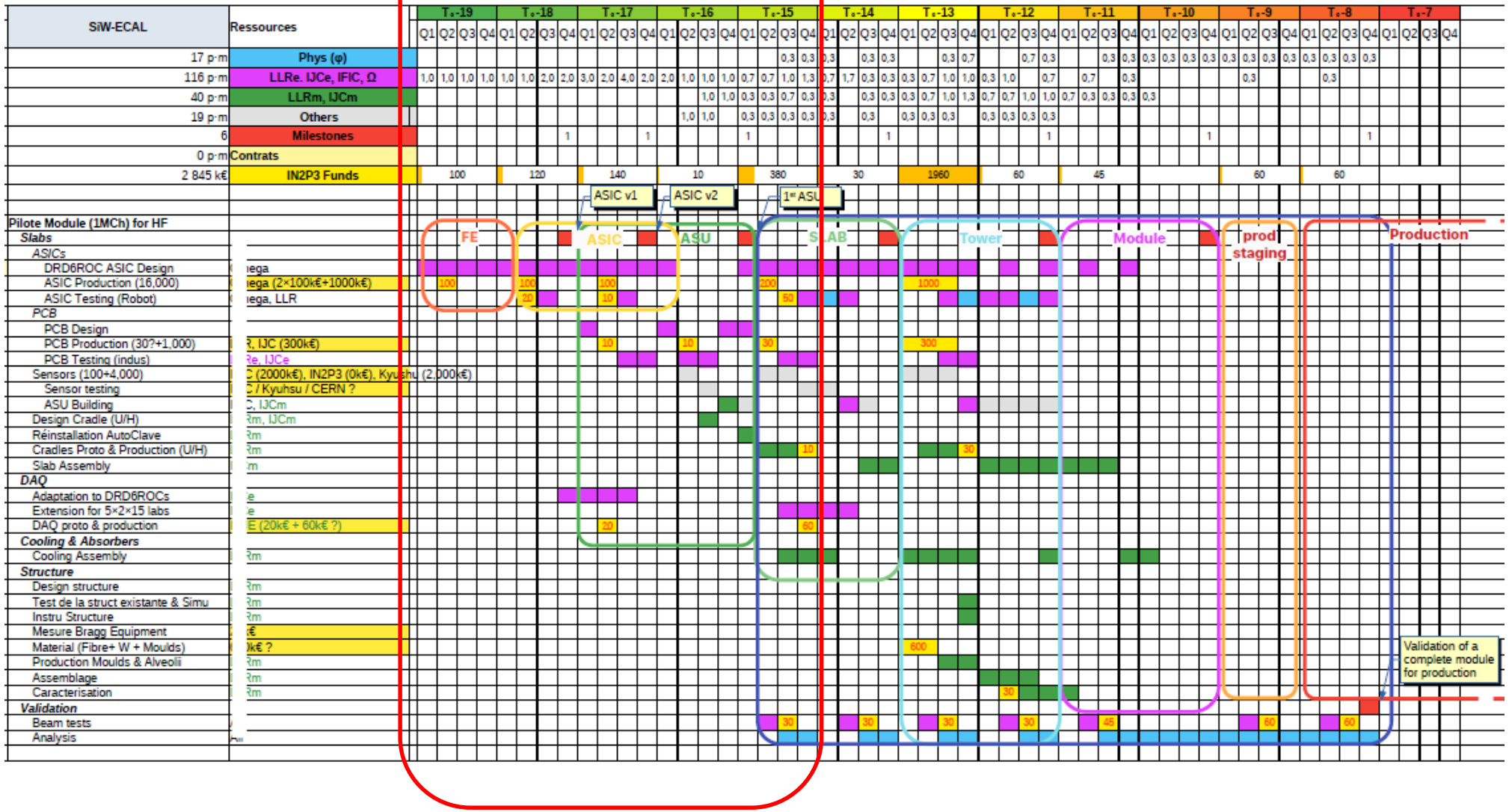
Proposal schedule allowing to compete for CEPC

Optional fully digital calorimeter (no more E measurement in cells)

M/D	Description	Date
M2.1a	Give the 1st specifications for the electronics and dimensioning of an SiW-ECAL near continuous collider (2024)	2024-01
D2.1a	Full performances studies for Physics channels	2025-01
M2.1c	Design of active cooling prototype	2024-07
D2.1c	Report on active cooling	2025-07
D2.1	EoI for the FCC	2025-09
M2.3	Design and specifications of the electronics for a timing layer based on LGADs (2025)	2025
D2.2	Blueprint for a pilote module following the specifications of a Higgs factory (2025)	2025
M2.4a	Construct a homogeneous prototype of 1 Tower 15 single-ASU layers	2024-03
D2.4a	Publish the performance in beam and release the G4 sample of the 1T 15 layer prototype	2025
M2.4b	Construct the prototype of 2 Towers. 7–12 layers	2024-09
M2.4b	Use the prototype in one or several fixed target experiments (2025)	2025-12

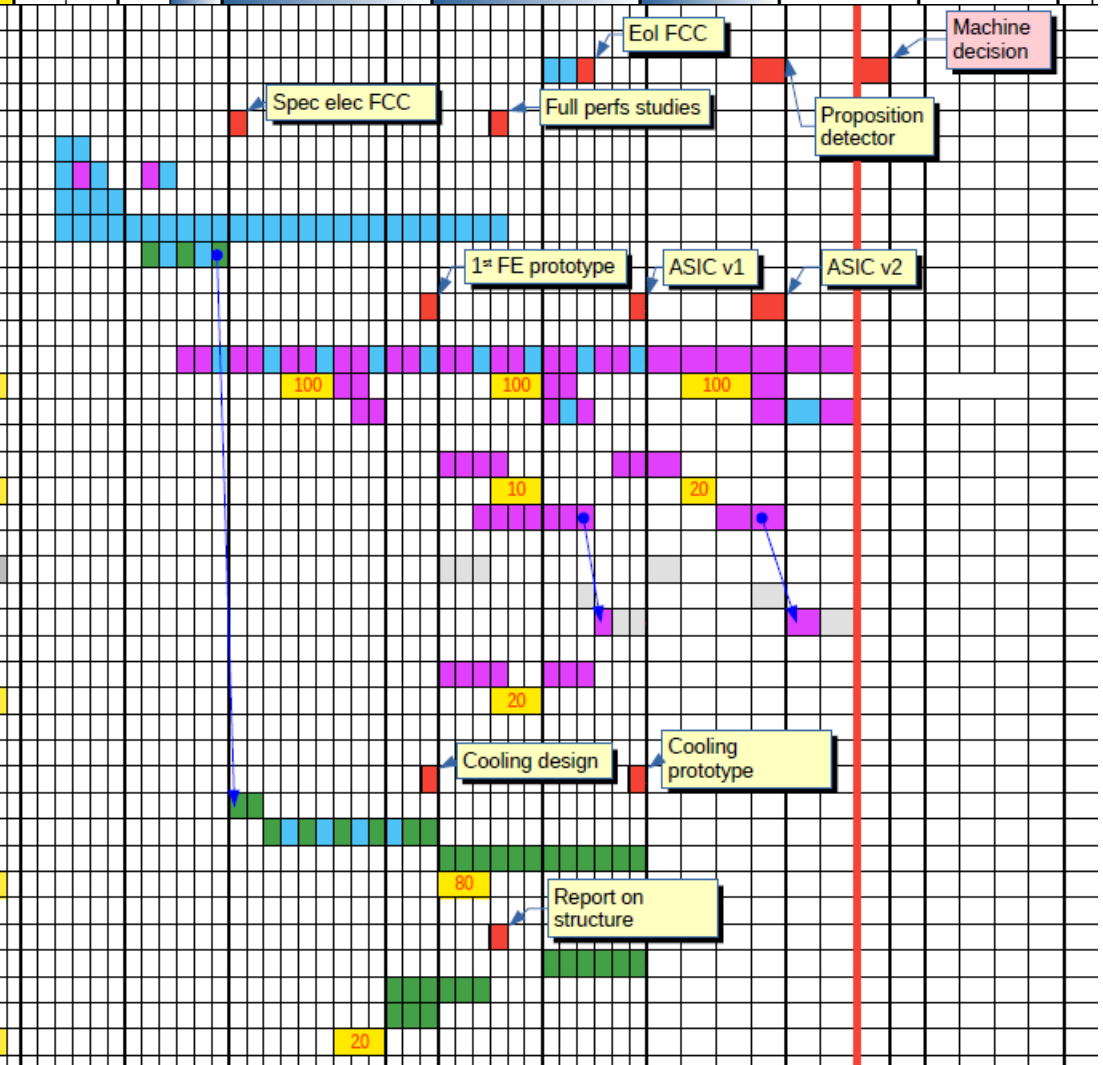
DRD

2024 2028 2037



SiW-ECAL	Ressources	2023				2024				2025				2026				2027				2028				
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
173 p·m	Phys (φ)	1,3	3,7	3,3	4,3	3,3	6,3	5,0	5,7	3,7	3,0	3,7	3,7	1,0	2,0	3,0	3,0	0,7	0,3	0,3	0,3					
101 p·m	LLRe. IJCe, IFIC, Ω	0,3	1,3	1,3	0,7	0,7	1,0	2,3	1,7	3,7	3,0	4,3	2,0	3,0	1,0	2,0	4,0	0,7	0,7							
45 p·m	LLRm, IJCm			1,3	1,7	1,0	0,3	0,7	3,0	2,0	1,0	2,0	2,0													
82 p·m	Others			1,0	1,0	3,0	2,3	2,3	2,7	4,0	3,0	2,7	3,0	1,0			1,0		0,3							
15	Milestones					2		1	2		3	1	3				2			1						
148 p·m	Contrats	1	1	1	1	3	3	3	3	4	3	3	3	3	3	3	3	2	2	2	2					
560 k€	IN2P3 Funds				20	170				250				120												

EoI for FCC	All
Low occupacy & High-rate ECAL	
Simulation of ILD4FCC/CLD	
ASICs scaling functions	LLRe,Ω
1st estimation of fluxes	LLRφ
PFA performances	LLR, IP2I, IJClab
2nd est. of fluxes & implications	LLRm
Electronics	
ASICs	
DRD6ROC ASIC Design	Omega
ASIC Production (16,000)	Omega (3×100k€)
ASIC Testing (Robot)	Omega, LLR
PCB	
PCB Design	
PCB Production (10+20)	LLR, IJC (30k€)
PCB Testing (indus)	LLRe, IJCe
Sensors	
Sensor design (if 8'') & purchase	IFIC (20k€), Kyushu (20k€)
Sensor testing	IFIC / Kyuhsu / CERN ?
ASU Building (4+	IFIC, IJCm
DAQ	
Adaptation to DRD6ROCs	IJCe
DAQ proto & production	ICJE (20k€ + 60k€ ?)
Cooling R&D (if needed)	LLRm
Dimensionning	LLRm
Design	LLRm, VB
Prototyping	LLRm
C02 cooler	80k€ ?
Structure	
Design structure	LLRm
Test de la struct existante & Simu	LLRm
Instru Structure	LLRm
Mesure Bragg Equipment	20k€



SiW-ECAL	Ressources	2023				2024				2025				2026				2027				2028				
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
173 p·m	Phys (φ)	1,3	3,7	3,3	4,3	3,3	6,3	5,0	5,7	3,7	3,0	3,7	3,7	1,0	2,0	3,0	3,0	0,7	0,3	0,3	0,3					
101 p·m	LLRe. IJCe, IFIC, Ω	0,3	1,3	1,3	0,7	0,7	1,0	2,3	1,7	3,7	3,0	4,3	2,0	3,0	1,0	2,0	4,0	0,7	0,7							
45 p·m	LLRm, IJCm			1,3	1,7	1,0	0,3	0,7	3,0	2,0	1,0	2,0	2,0													
82 p·m	Others			1,0	1,0	3,0	2,3	2,3	2,7	4,0	3,0	2,7	3,0	1,0			1,0		0,3							
15	Milestones					2		1	2		3	1	3				2			1						
148 p·m	Contrats	1	1	1	1	3	3	3	3	4	3	3	3	3	3	3	3	2	2	2	2					
560 k€	IN2P3 Funds				20	170				250				120												

Timing	LLR, IJC, IP2I	
Timing in PFA	LLR, IJC, IP2I	
ANR PRCI ?	CDD + PhD/2	
ANR PRC ?	CDD	
Optimisation	LLR, IJC + KIT ...	
Dedicated Timing layer (Kyushu)	KIT ?	
Dedicated Timing layer (KIT ?)	Kyushu ?	
Proto 1 Tower 15 layers		
ASIC testing	LLRe	
Building ASU (15)	IJC, IFIC	
ASU Commisionning	ICJ, IFIC, Kyushu	
DAQ adpatation	IJCe, IFIC	
Slab & Casing design	LLRm, IJCm	
Buiding casing	IJCm (10k€?)	10
Assembly & Commissioning	ICJlab, IFIC	
BT & analyse	IJCe, IJCe, IFIC, IJC, Kyushu	
	PD analyse	
Travel	LLR, IJC (20k) + Eurolabs (20k€?)	20 20
AIDAinnova		
LUXE Proto 2 Towers 7–12 layers		
Wafer purchase (IFIC/IN2P3?)	IFIC (20k€), IN2P3 (20k€), Kyushu (??)	20
Buidling ASUs (10)	IFIC	
Assembly & Commissioning	IJC, IFIC	
BT & analyse	All	
	PD analyse	
Travel	All, **DMLab ?**	20 20
LUXE Proto 3Towers 7–12 layers		
Funding		
Wafer & W purchase	LLRm, IFIC, PCB (300k€ ?)	
Buidling ASUs (10)		
Assembly & Commissioning		
BT & Analyse		
ANR LUXE ?		
	PD analyse	

Check with Taikan Gantt

Proto ready

Publication and data sample

Proto ready

Publication

Short term spin-off

The prototypes can have some direct usage for several fixed target experiments.

The LUXE experiment near XFEL at DESY aims at measuring non-linear QED Compton and pair production starting in 2025. The beam conditions comparable to ILC's would be a perfect fit for the current electronics.

Then, various small-scale experiments looking for dark photons (LUXE at XFEL, EBES at KEK, Lohengrin at ELSA) could also almost directly use the SiW-ECAL prototype.

Beside their intrinsic physical interest, running the device in such experiments during couples of months will bring invaluable instrumental experience with composed slabs.

LPNHE ?

Sensors : Semiconductor simulation & qualification @CLAP

Integration : mechanical constraints, cooling

PCB design : dense & delicate

System design : timing, powering, signaling, dual phase CO2 cooling...

Test & measurements : functionnal (asic, daq) , physics + automation + source (X, ...)

Computing & IA : clustering, pattern recognition, smart calibration, etc.

+ Physics