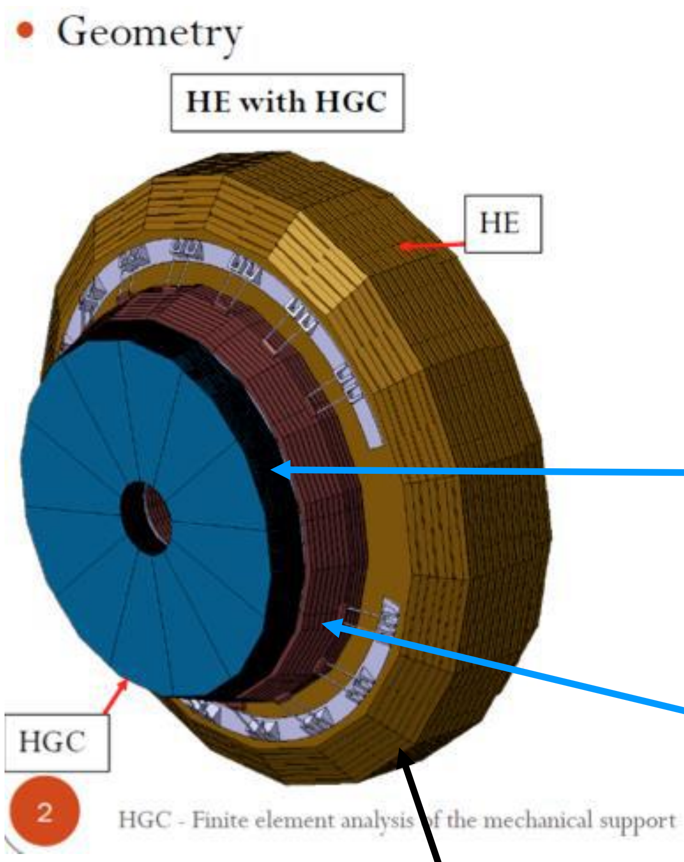
Upgrade Phase II
HGCAL

Christophe Ochando (LLR/Ecole Polytechnique/CNRS)

May 3rd 2016
Visite DAS

The HGCAL Project in a nutshell (1)



High Granular Sampling Si-based Calorimeter
with 4D measurement of showers
(energy, position) !
(possibly 5D with timing)

HGC-ECAL (EE): Si+W/Cu
28 layers, ~26 X_0 (1.5 λ)

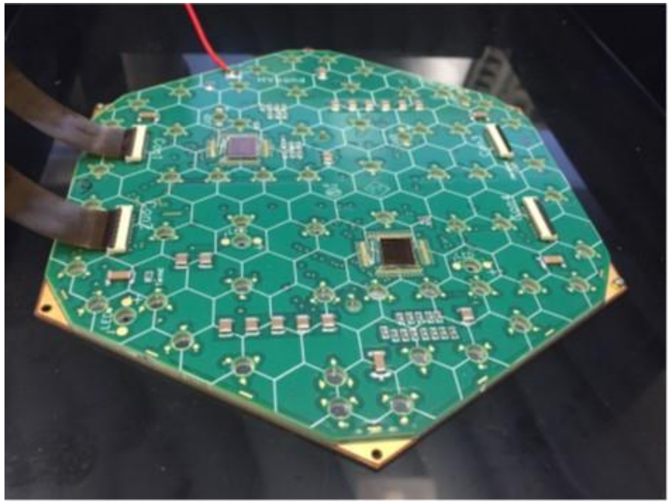
HGC-HCAL (FH): Si+Brass
12 layers, >3.5 λ)

Back-Hadron Calorimeter (BH)
Brass+scintillators
+ >5 λ

Operation at -30° C via CO_2 Cooling
(to mitigate Si leakage current)

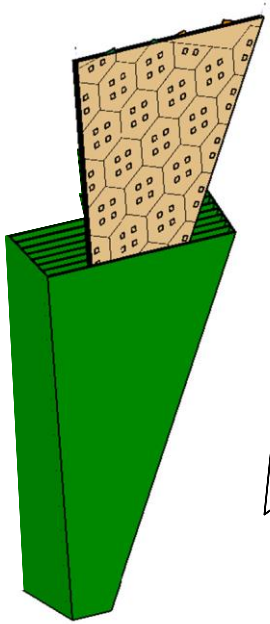
The HGCAL Project in a nutshell (2)

Modules
with 6 or 8" Hexagonal Si sensors, PCB, FE chip



Modules mounted on both sides of **Cu Cooling plate** with embedded pipes == **Cassettes**

double sided (2 layers) Cassettes inserted in **mechanical structure** (containing absorber)



W/C-fiber EE alveolar structure

HGC Project Structure to Q1-17
(making Technical Choices, ..)

IB Chair Drew Baden
Deputy IB Chair: Greg Landsberg

Editorial Board &Conferences
D. Barney and Y. Onel

Technical Coordination
TC: P. Bloch (+ Elect Coord)
DTC: J. Strait (+Engineering)

Project Office
Coordinator: Roger Rusack
Deputy Coord.: M. Gastal
Tasks: schedule, WBS, cost, Databases, ….

Subsystem Manager
SM: T. Virdee
DSM: Marcello Mannelli

Advisory
P. De Barbaro (HCAL), ~~I. Golutvin~~,
D. Petyt (ECAL), Y. Sirois

Resources Coordinator
A. Petrilli

TDR Editor

Engineering
J.Strait, C.Ochando
- EE Structure
- FH/BH Structure
- Services,
- Integration
- Cooling & Environment Cntrl
- Assembly, Installation & Maintenance
- D. Drushkin, H. Gerwig, N. Golubev, A. Levin, T. Pierre-Emile, A. Orlov, P. Rubinov, S. Surkov, …..

Silicon (Active)
J. Incandela
M. Mannelli
- Sensors: T. Bergauer, R. Lipton, M. Mannelli
- Modules: J.Incandela, M. Paulini
- Cassettes: S. Tkaczyk
- Assembly Centres (preparation): Candidates, China, India, Taiwan, US(2+1)

BH (Active)
J Mans, xx
- Optics
- Photosensors
- Assembly Centres (preparation)

Electronics and Electrical Systems
C. De la Taille
A. Marchioro
- fe (ADC, TDC, ..): C. De la Taille
- Links & On Module
- Clock & Control: J-L. Faure
- Power distribution
- Slow Control

TPG/be
P. Dauncey, xx
- TPG: Simulation & Algorithms: J-B Sauvan
- TPG: Front-end Studies: I. Puljak
- TPG architecture design & implementation: P. Dauncey(interim)
- be: DAQ system & Coordn

Test Beams
D. Barney, J. Freeman, R. Rusack
- Beam@FNAL: J. Freeman, R. Rusack
- Beam@CERN: D. Barney
- Analysis

Performance & Simulation
V. Andreev, F. Chlebana, C. Seez
- Simulation: S. Banerjee
- Local Reco: L. Gray
- em Phys Objects
- jets, τ, μ, ..
- Det. Studies: A-M Magnan

Timeline / Milestones

- **27-28 June 2016: First CMS Comprehensive Review,**
  - including external reviewers: L.Serin (ATLAS), Frank Simon (CALICE)

- **End of 2017: Technical Design Report**
  - including key technical choices:

Examples of Milestones for 2016

Subject	Item	Process/Criteria	Internal Milestone	LHCC Milestone
FH & BH Absorber	Brass or SS	Activation and Cost	Jun-16	Q2 2016
EE Mechanical Design	Full disk or phi sectors	Simulation / Performance& Design pros & cons	Oct-16	Q4 2016
FE electronics	Confirm 130 or 65 nm	Irradiation & Test vehicles	Oct-16	Q4 2016
DC-DC converters	Location: local or remote	Irradiation & Prototyping / System implications	Dec-16	Q4 2016
Electrical/optical links	Location: local or remote	Irradiation / System implications	Dec-16	
BH Active Material	Scintillator Type, Megatile Structure	Radiation hardness, ability to operate cold	*Dec-16*	Q4 2016
Cold Volume	Si only or full HGCAL	Integration studies / Performance & System Implications	Dec-16	Q4 2016
Si Sensors	p-in-n or n-in-p	Irradiation / Performance & System	Mar-17	Q1 2017
Si Sensors	6"or 8"	Dialogue with vendors	Mar-17	

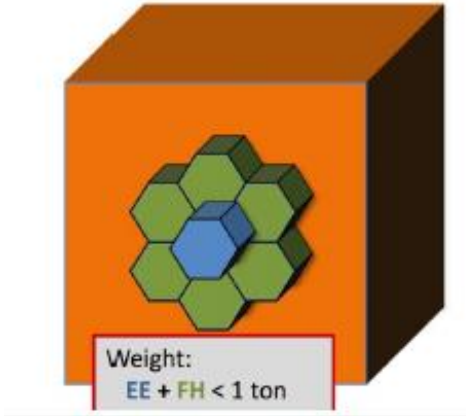
Engineering
Silicon (Active)
BH (Active)
Electronics & Elect. Systems

- **End of 2019: Construction starts…**

R&D is NOW !

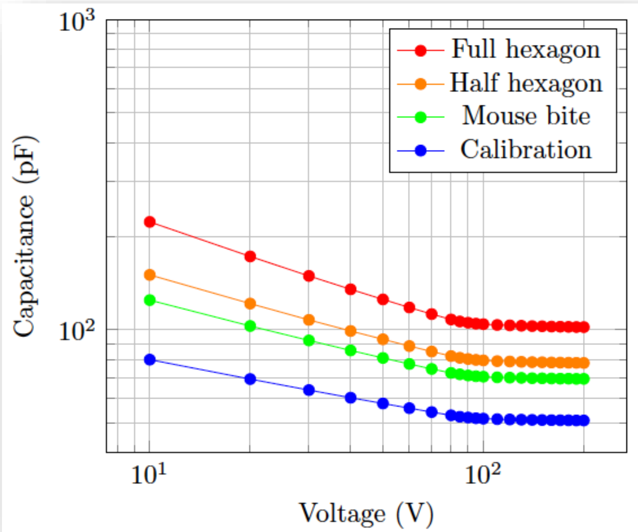
Recent Highlights: Test beams (1)

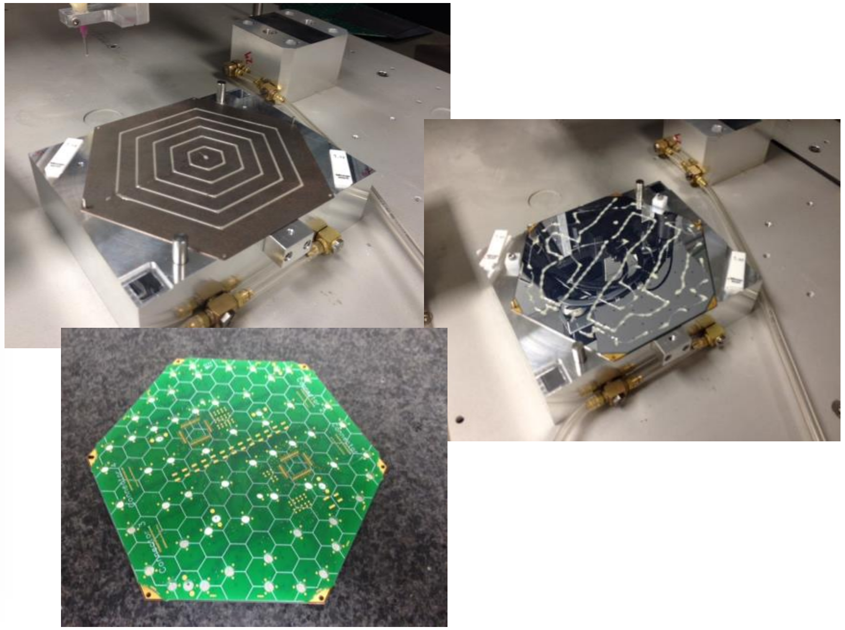
- **Test beams:**
  - 7 periods in 2016 (FNAL & CERN)
  - Study: energy response, resolution, time,… simulation + very fast timing
    - with setups from 1 layer (April)
      to full HGC (28 EE layers + 12 FH layers, November)



- **Test beams at FNAL (April, May):**
  - Very fast progress
  - Driving the design and test of Si sensors, PCB, assembly procedure of modules …

6” HPK 128 ch sensor



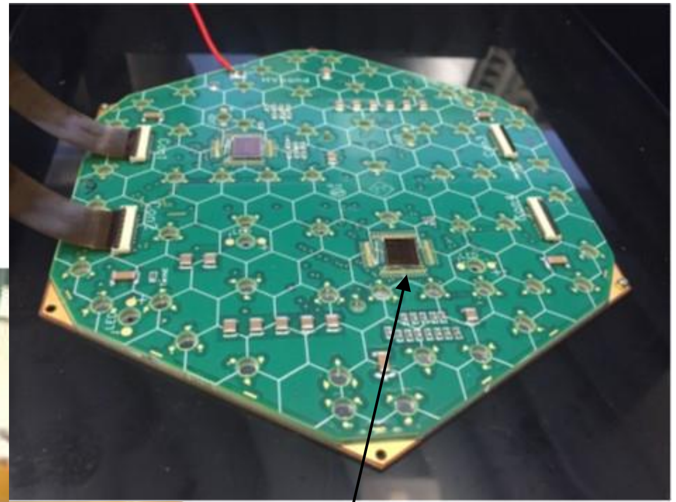


Module assembly (UCSB)

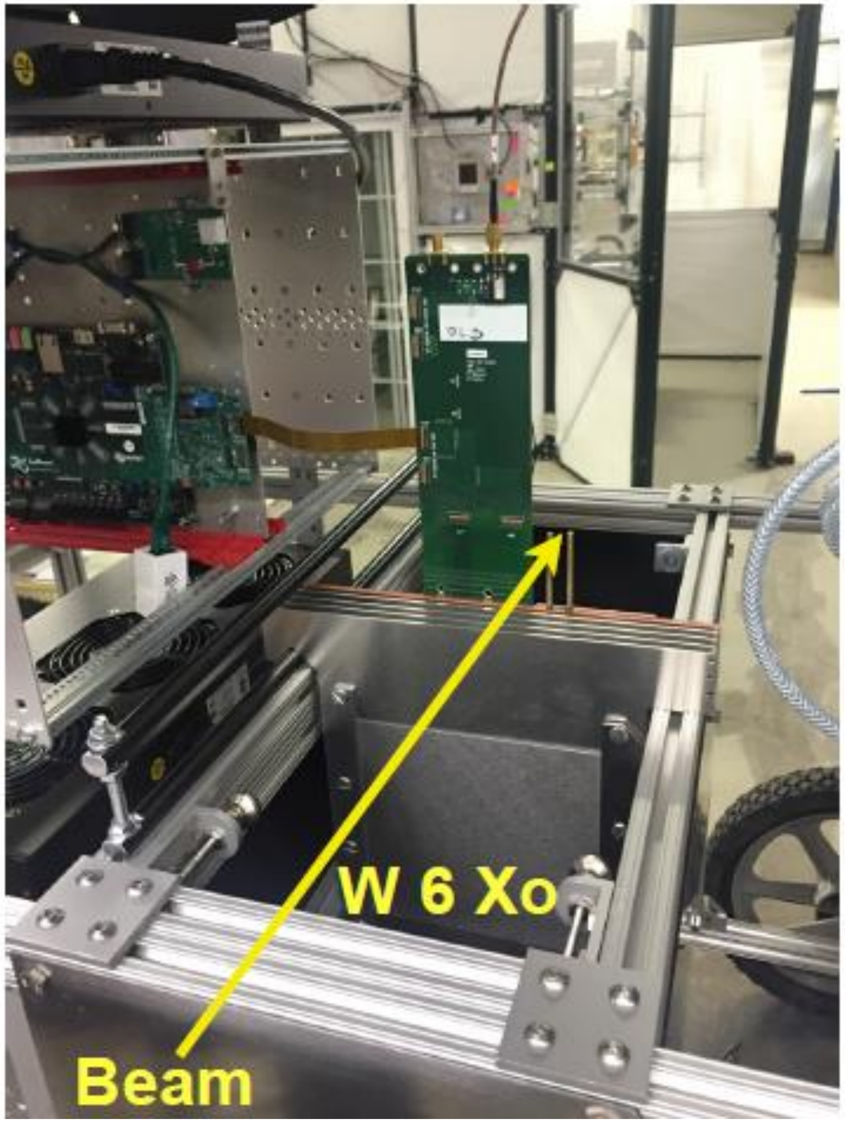
Recent Highlights: Test beams (2)

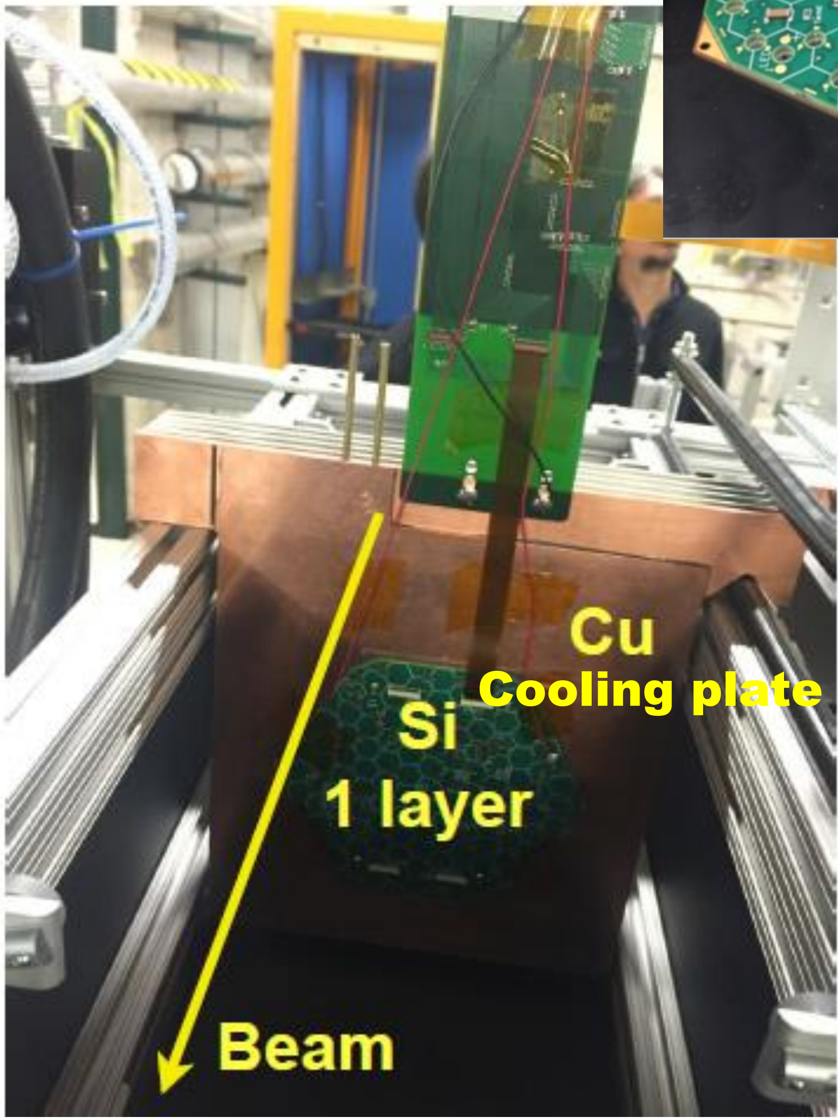
FNAL Setup for April tests:

- proton beam
- 1 module, 6 X_0 before (W, Cu, W/Cu)



SKIROC2

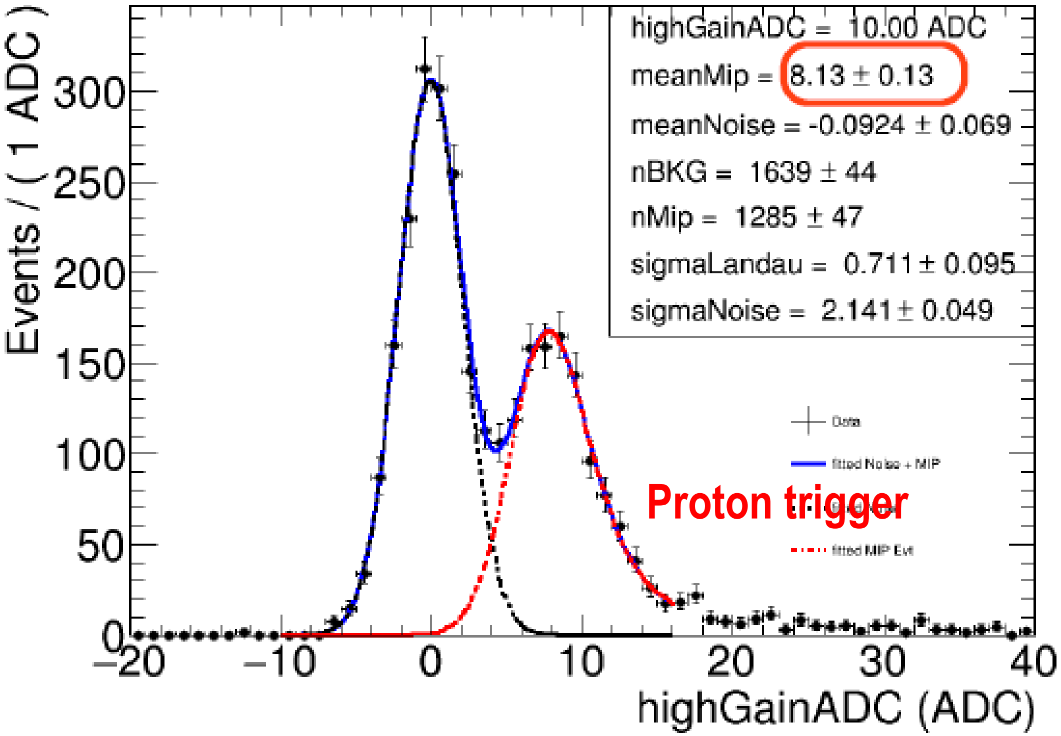




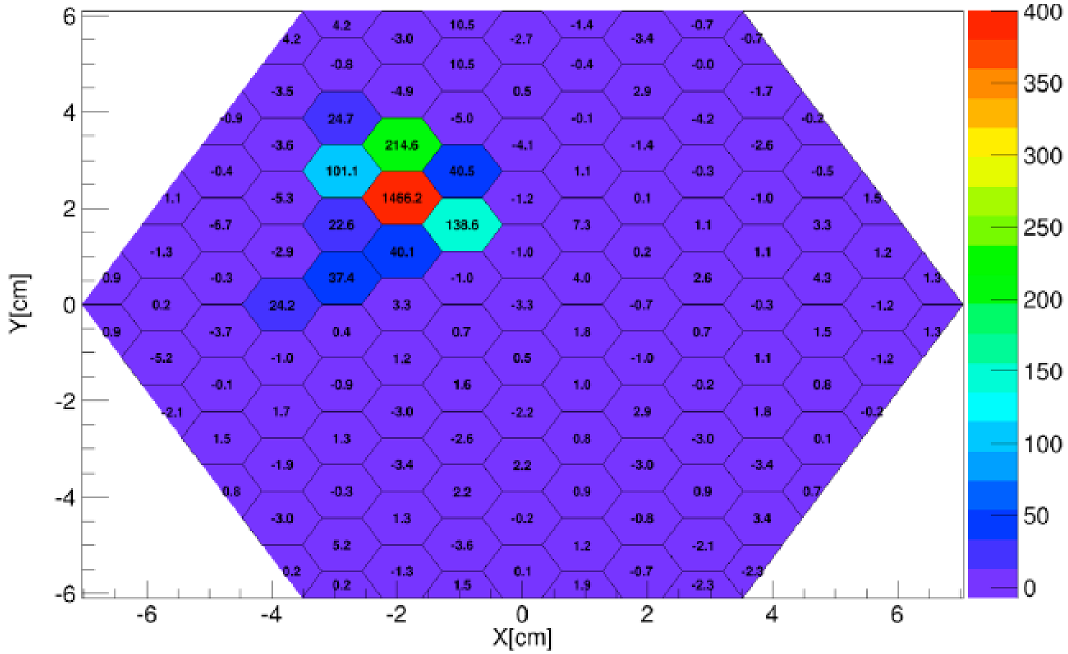
Recent Highlights: Test beams (3)

First results:

120 GeV protons as a proxy for MIP and calibration



32 GeV electron after 6 X0



Size of cluster ~ 2 cm
Pedestals subtracted

Next steps:

- <= 28 layers for tests in May **[SKIROC2]**
- First tests at CERN in August/May (preceded by CALICE tests), then in November **[SKIROC2 or SKIROC2_CMS if validated].**

Recent Highlights: Front End

Ch. De La Taille et al., (Omega)
Test FE pour TPG: Y. Geerebaert

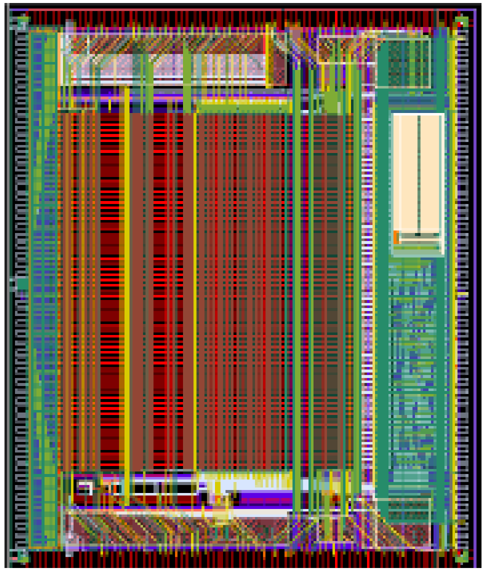
➢ Stringent requirements for Front-End Electronics

- Low power (few mW), low noise (<2000 e-)
- High radiation (200 Mrad, $10^{E}16$ N)
- System on chip (digitization, processing…)
- High speed readout (5-10 Gb/s)
- Timing information to 50ps accuracy

- SKIROC2_CMS expected in June.
- 4-5 boards will be equipped for tests (can start with SKIROC2)

➢ Milestones

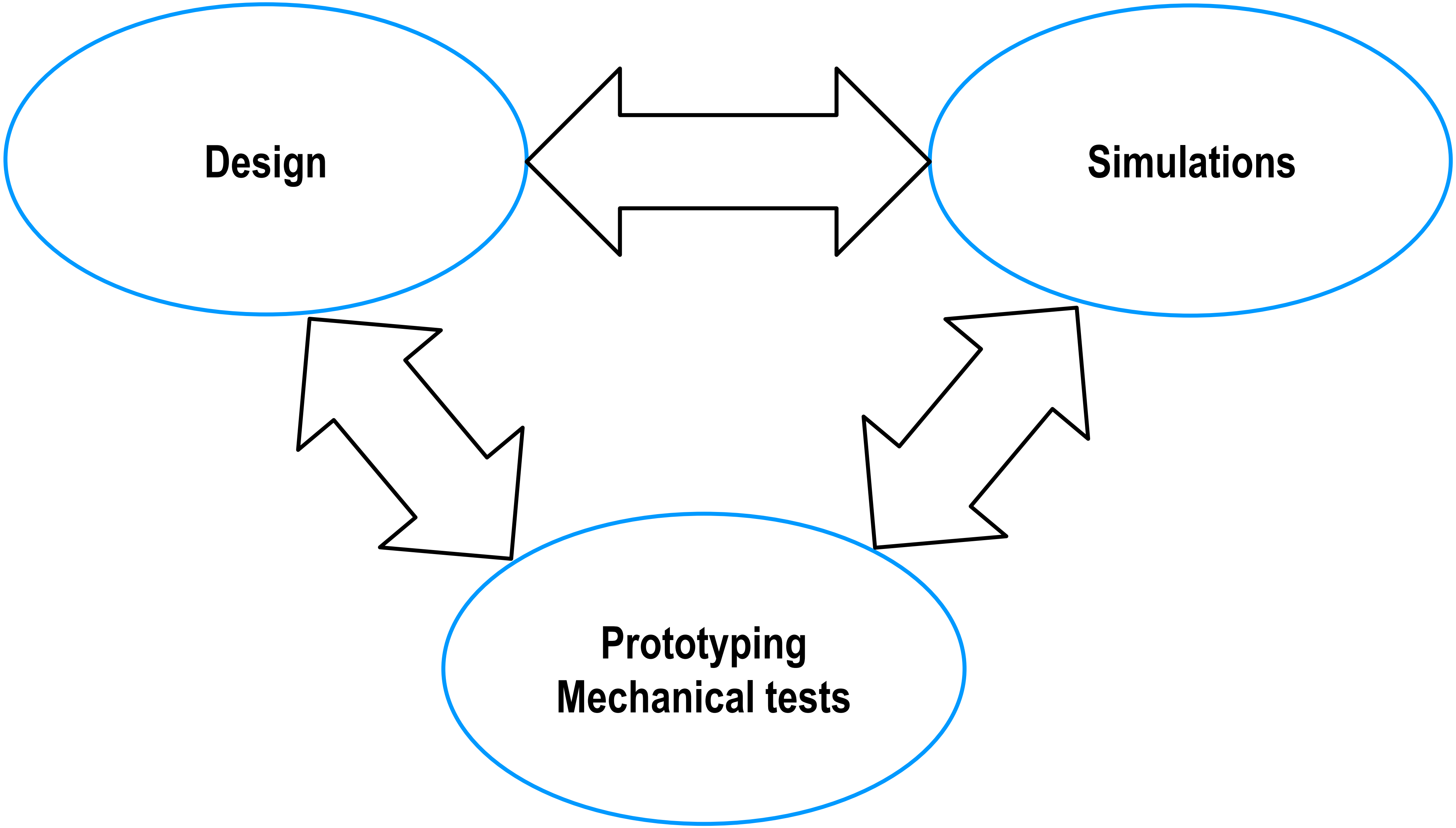
15-Feb-16	Submit v0 fe chip (SKIROC-CMS)	⇒ end january
31-Mar-16	Submit f.e. test vehicles in TSMC130 nm technology	⇒ end april
1-Jun-16	**1st Comprehensive Review**	⇒ 26-27 june
30-Sep-16	1st results from f.e test vehicles	⇒ 2nd test vehicles : full one channel
31-Oct-16	Confirm choice of front-end electronics (130 nm) ?? Under study	
15-Dec-16	Define architecture & specs for LV/HV supply, links and on-module components	
15-Dec-16	Define location of DC-DC converters	
15-Dec-16	Define location of electrical/optical links	
	? Testbeam results of TOT architecture	
31-Mar-17	Submit V1 ASIC	⇒ First 32/64 ch ASIC with full functionnality
31-Mar-17	Choice of Si sensors type: all n-on-p or mixed (i.e. n-on-p and p-on-n)	
1-Jun-17	**2nd Comprehensive Review**	
30-Sep-17	1st results from tests of V1 ASIC	
1-Nov-17	**Submit TDR**	
30-Jun-18	Submit V2 ASIC	



HGCAL at LLR: Mechanics (1)

M. Anduze, M. Frotin, C. Ochando,
T. Pierre-Emile, Y. Sirois

Focus on EE mechanics: W/C-fiber alveolar structure:



HGCAL at LLR: Mechanics (2)

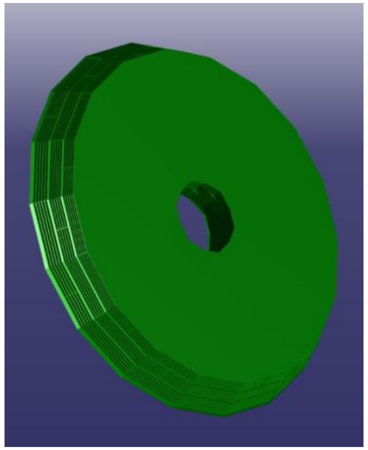
M. Anduze, M. Frotin, C. Ochando,
T. Pierre-Emile, Y. Sirois

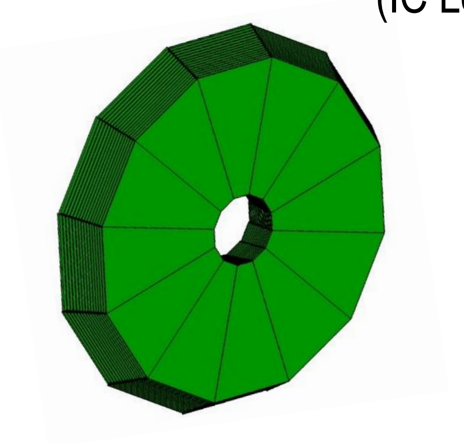
Focus on EE mechanics: W/C-fiber alveolar structure:

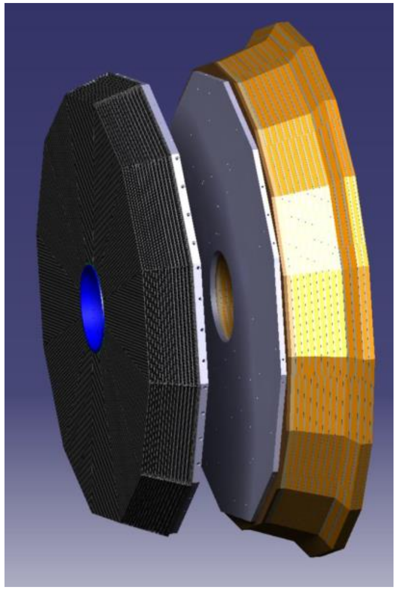
Design

Study of various geometries

Linked with G4 simulations (IC London)

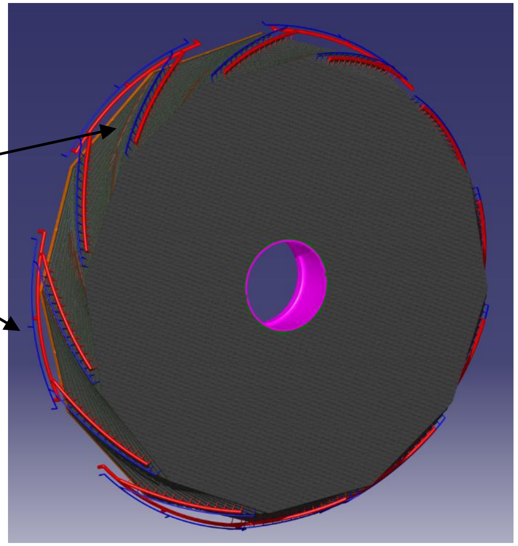


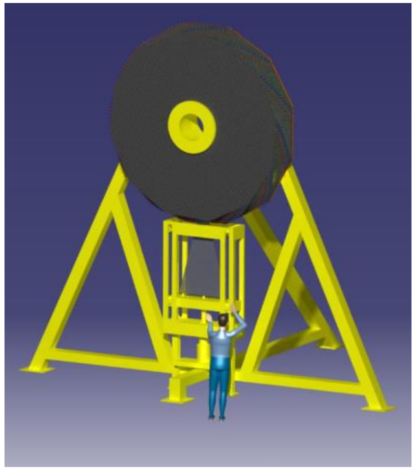




Study of EE/FH interface

Study of Services arrangement, Assembly, Integration (with CERN)





Cassettes insertion

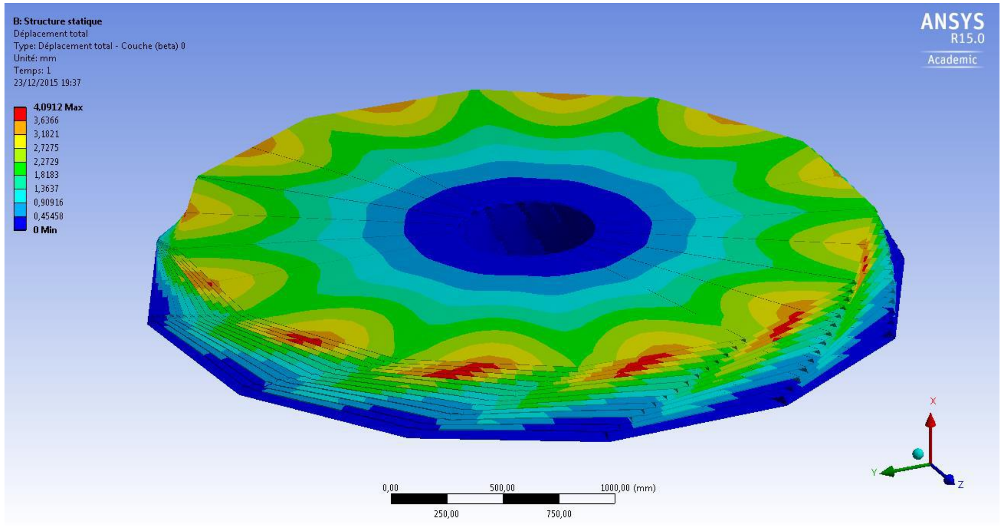
M. Anduze, M. Frotin, C. Ochando,
T. Pierre-Emile, Y. Sirois

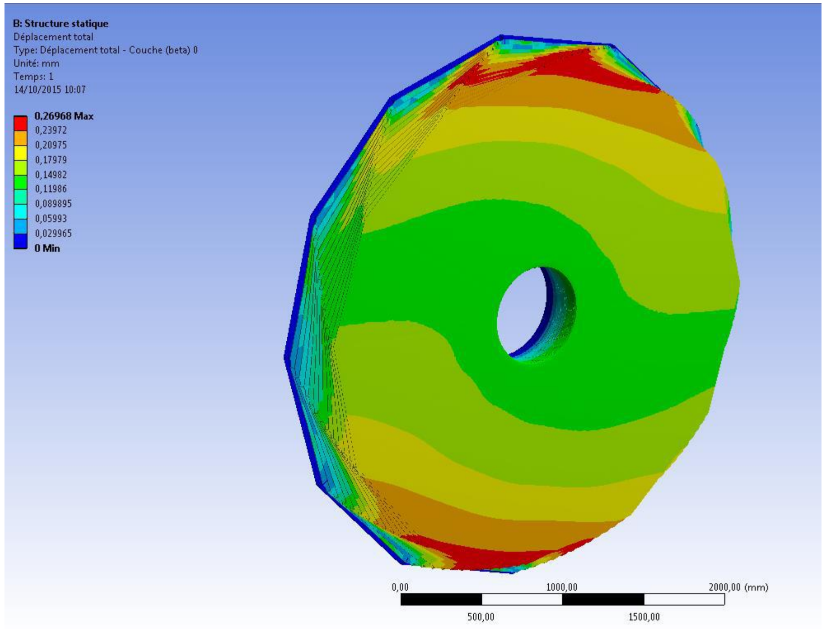
Focus on EE mechanics: W/C-fiber alveolar structure:

Assess Mechanical behavior via FEA simulations:

- in various positions,
- for various material properties,
- stresses from T° cycling
- …

Simulations





HGCAL at LLR: Mechanics (4)

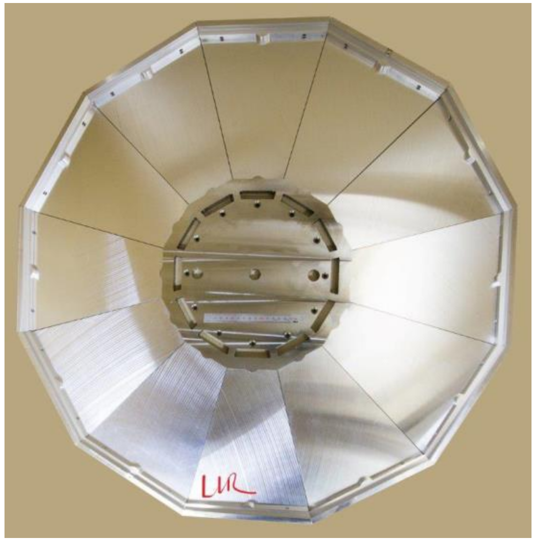
M. Anduze, M. Frotin, C. Ochando,
T. Pierre-Emile, Y. Sirois

Focus on EE mechanics: W/C-fiber alveolar structure:

Mechanical tests on small samples
Before/After irradiation, T° cycling,…

Producing small prototypes
Note: Autoclave not big enough for real size production….

2 C-fiber "petal shape" alveoli



Mold for small disk of alveoli

Prototyping / Mechanical tests

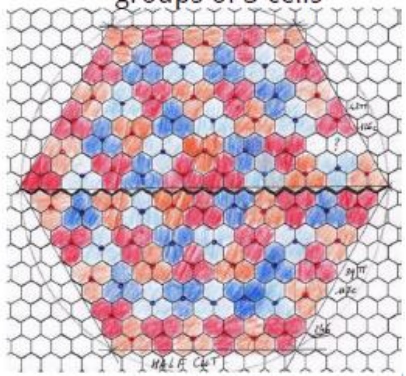
HGCAL at LLR: L1 Trigger

P. Busson, S. Baffioni, *T. Romanteau*, J-B. Sauvan

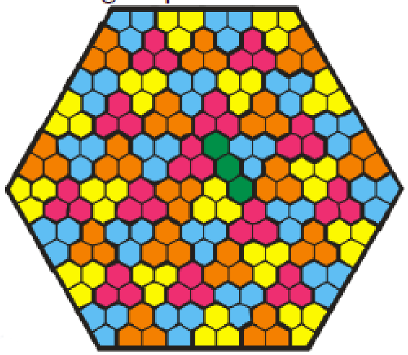
➢ **LLR among the main drivers of the HGCAL L1 Trigger project**
- **Now in strong collaboration with Split & CERN**

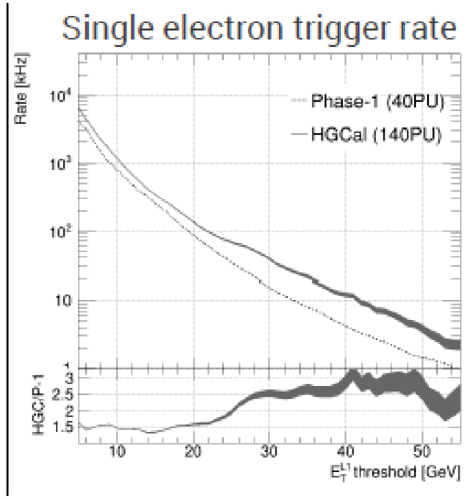
Architecture	Front-End Studies	Simulation & Algorithms
▪ Define baseline architecture for TP	▪ Work on trigger "raw data" (Data reduction, trigger cell geometry, …)	▪ Development of emulator, + standalone tools (digitization, ..)

252 cells with groups of 3 cells



192 cells with groups of 3 cells



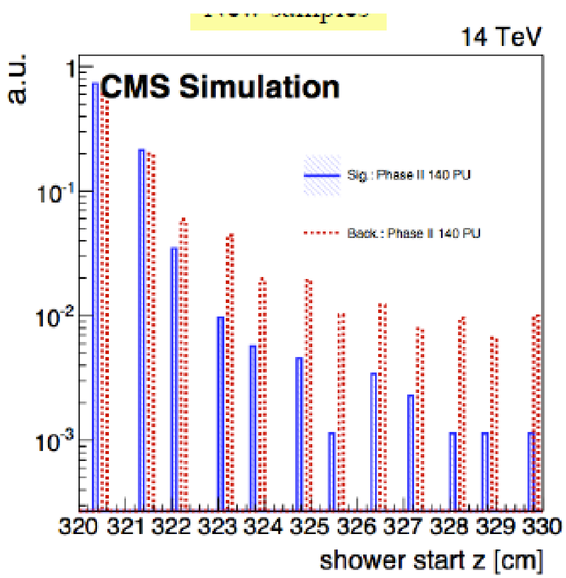


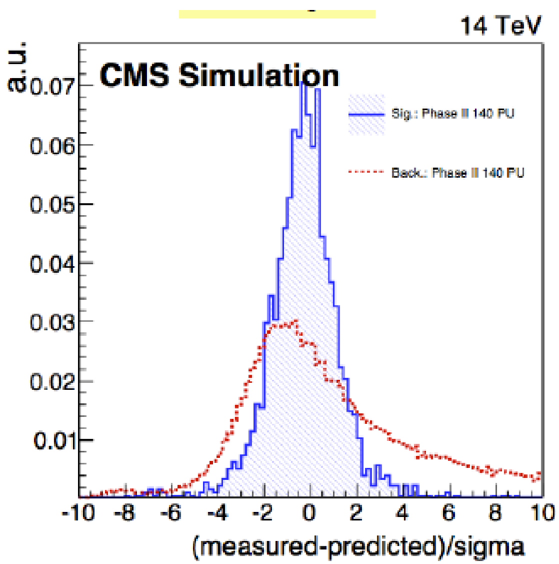
Besoin urgent d'un Test Bench SKIROC-CMS au LLR pour rester dans le jeu côté interface trigger avec le chip de FE

C. Charlot, R. Salerno, Y. Sirois

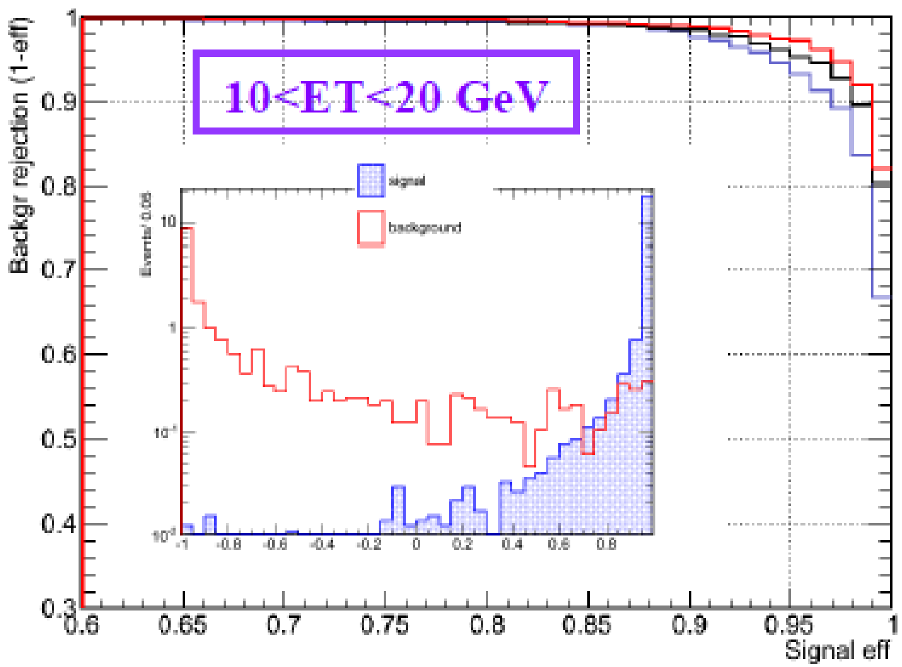
➢ Electrons/Photons (+Taus): Historical expertise of CMS-LLR.

- Develop reconstruction & identification of e/g objects for the TP.
- H→ZZ, $\gamma\gamma$ main benchmarks.
- Will continue towards the TDR.
- Want to exploit the extraordinary potential for physics of this device
  (3D shower reconstruction, layer-by-layer PU subtraction, possibly adding timing, …)





BDT electron identification



Also, wants to play an important role in CERN test beams (shifts, analysis/reconstruction/simulation)

Conclusion

- **LLR: Leading role during the Technical Proposal phase:**
  - mechanics, L1 trigger, performances
  - Project is now in R&D Phase
    - **must remain a key player for the Technical Design Report !**

- **IN2P3 & LLR have a unique expertise in High Granular Calorimeters**
  - we invented & validated the concept
    - **we must be a driving force in this project !**

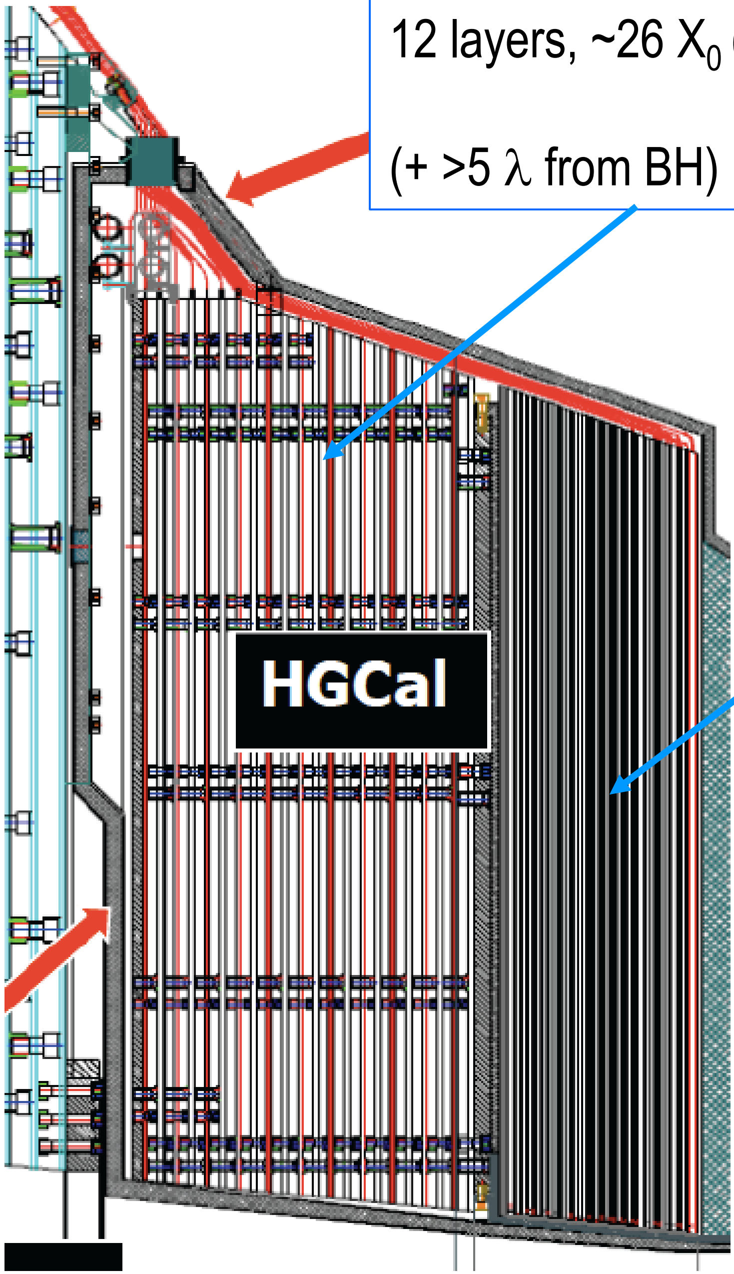
- **Current situation & prospects:**
  - All studies, prototypes, … were done within CMS common budget, previous material from CALICE, LLR internal budget…
  - Important P2IO support for mechanics (+L1) for R&D Phase (HFCFC/"HIGHTEC" Project)
  - … but support for IN2P3 is critical to have a decisive impact.

BACK UP SLIDES

HGCAL Parameters

HGC-HCAL: Si+Brass
12 layers, ~26 X_0 (>3.5 λ)

(+ >5 λ from BH)



Main interest of LLR

HGC-ECAL: Si+W/Cu
28 layers, ~26 X_0 (1.5 λ)
10 x 0.65 X_0 +
10 x 0.88 X_0 +
8 x 1.26 X_0

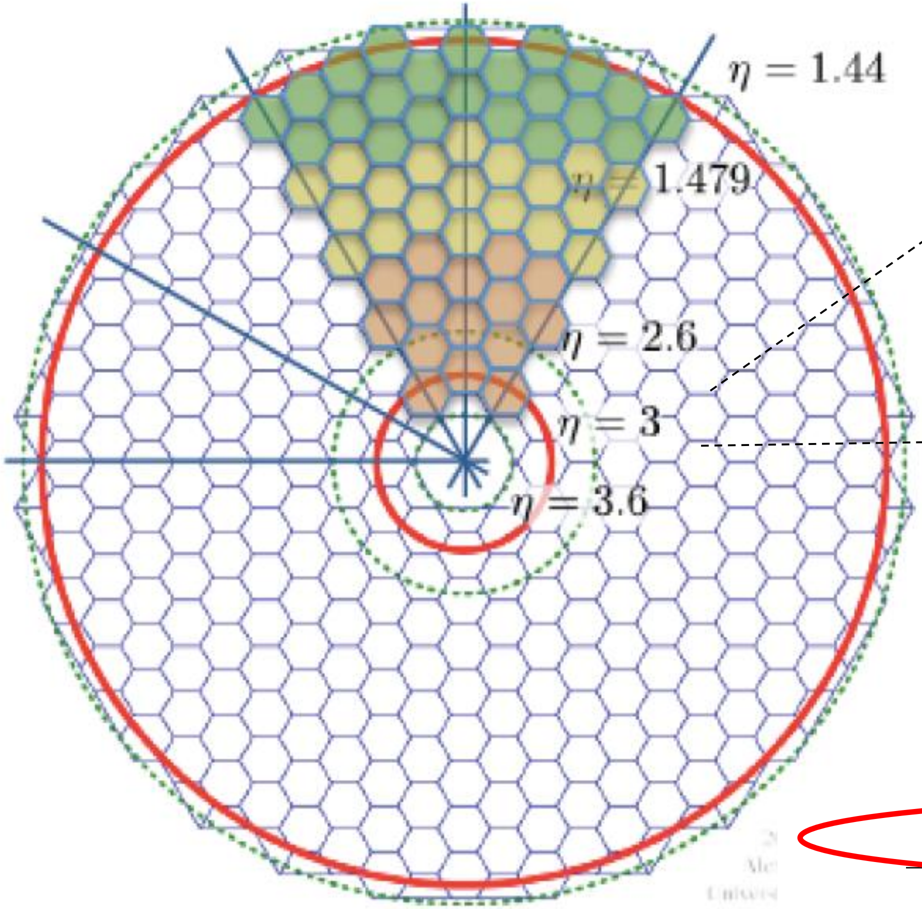
Operation at -30° C via CO_2 Cooling
(to mitigate Si leakage current)

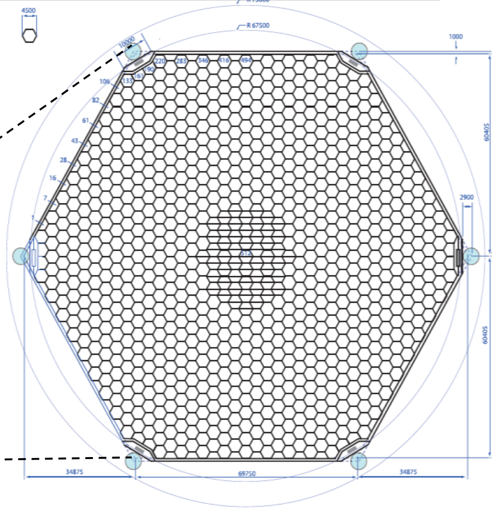
Table 3.2: Parameters of the EE and FH.

	EE	FH	Total
Area of silicon (m^2)	380	209	589
Channels	4.3M	1.8M	6.1M
Detector modules	13.9k	7.6k	21.5k
Weight (one endcap) (tonnes)	16.2	36.5	52.7
Number of Si planes	28	12	40

HGCAL Cells Geometry

Hexagonal 6” Si wafer (256 or 512 channels





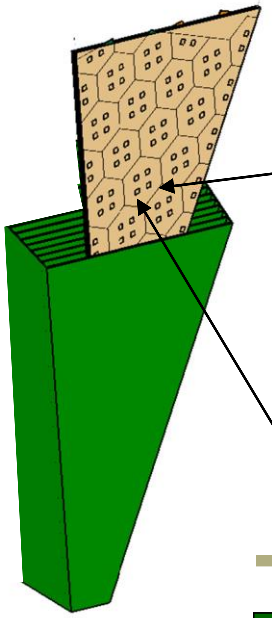
To cope the irradiation / PU:

- η-dependent depletion of Si
- η-dependent cell size

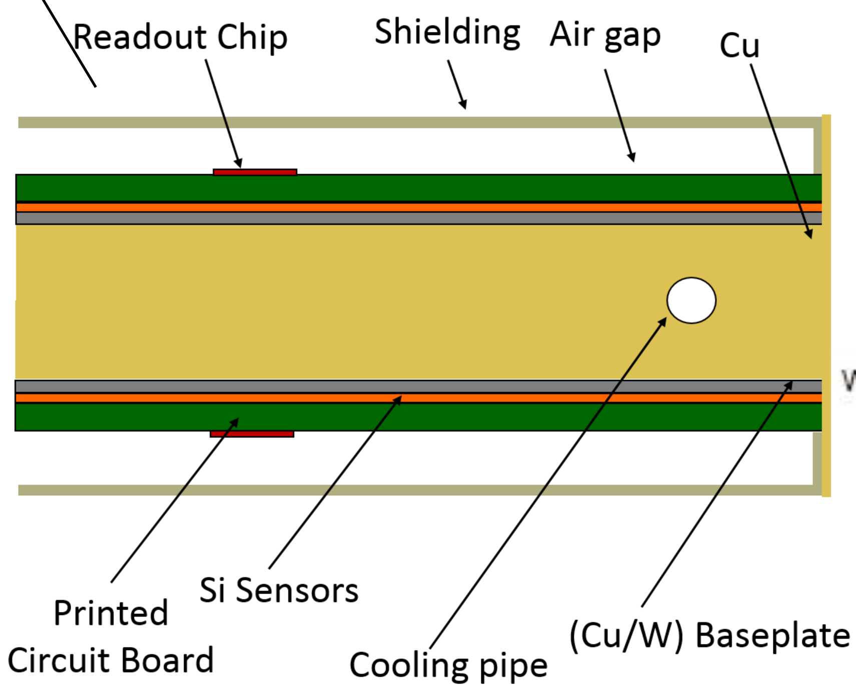
Thickness	300 μm	200 μm	100 μm
Maximum dose (Mrad)	3	20	100
Maximum n fluence (cm^{-2})	6×10^{14}	2.5×10^{15}	1×10^{16}
EE region	$R > 120$ cm	$120 > R > 75$ cm	$R < 75$ cm
FH region	$R > 100$ cm	$100 > R > 60$ cm	$R < 60$ cm
Si wafer area (m^2)	290	203	96
Cell size (cm^2)	1.05	1.05	0.53
Cell capacitance (pF)	40	60	60
Initial S/N for MIP	13.7	7.0	3.5
S/N after 3000 fb^{-1}	6.5	2.7	1.7

ECAL, Cassettes & Modules

double sided (2 layers) **Cassettes**
(with Si active element, FE, Cooling plates==**Modules**)
inserted in alveoli.

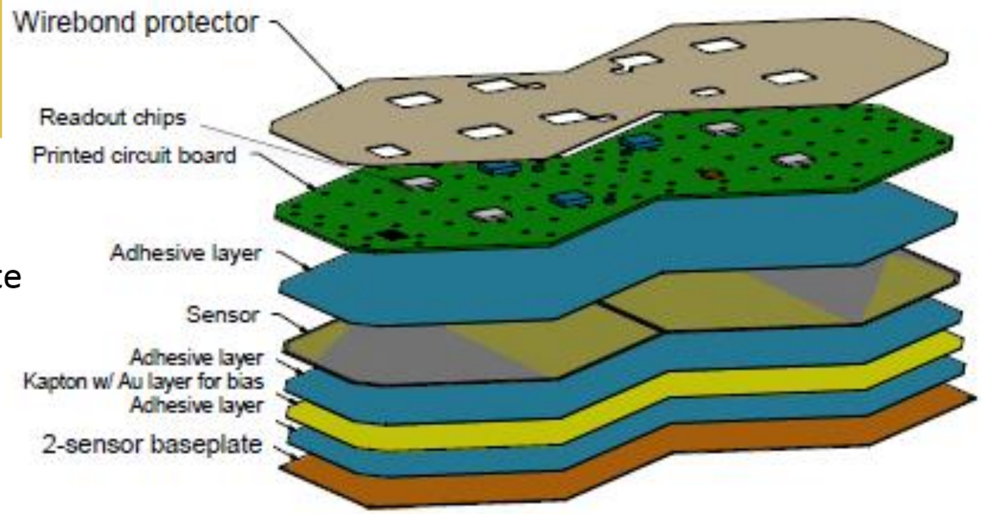


C-fiber/W alveolar structure

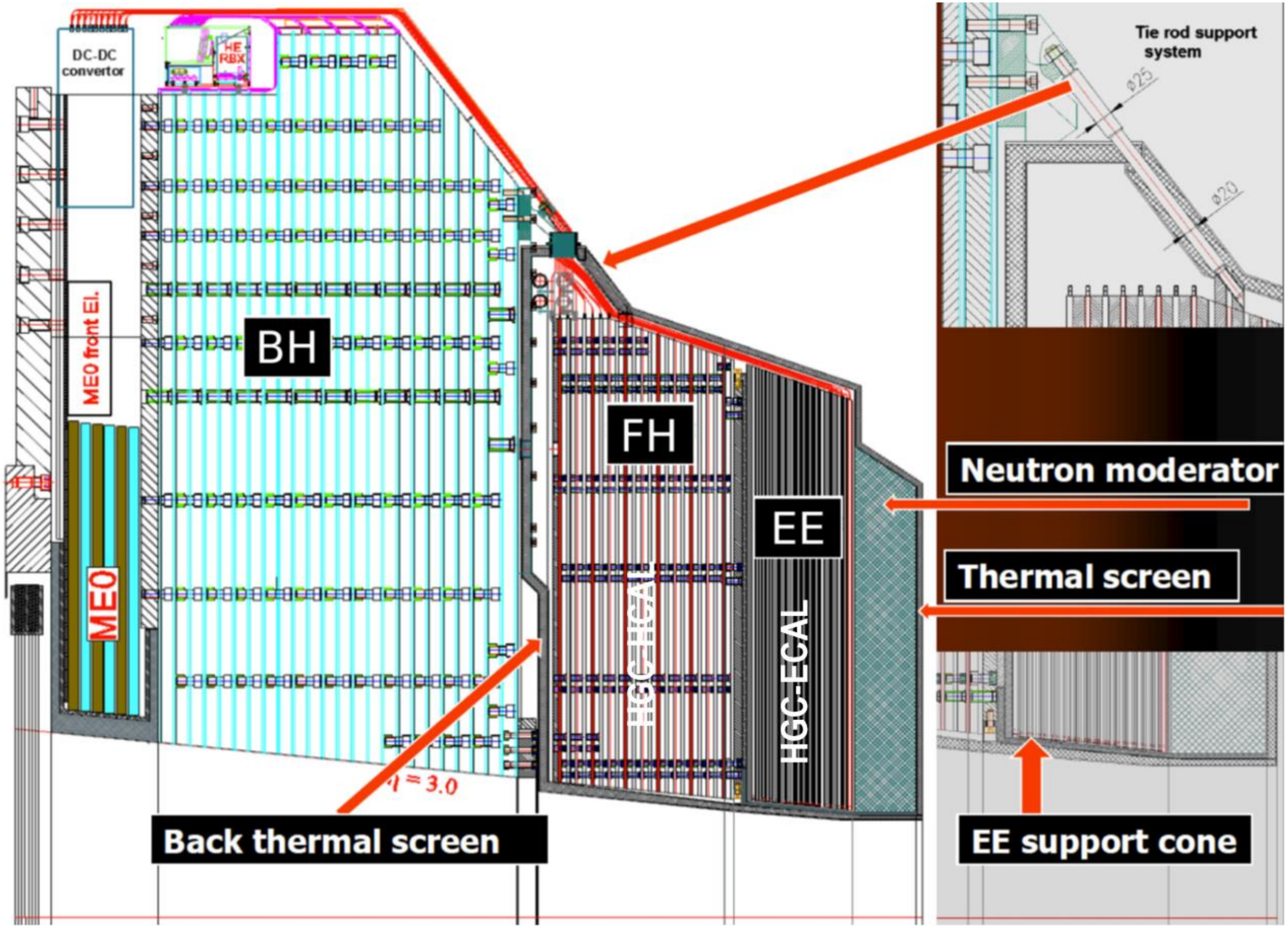


Modules mounted on both sides of **Cu Cooling plate** (pipes embedded)

Modules with two 6" sensors



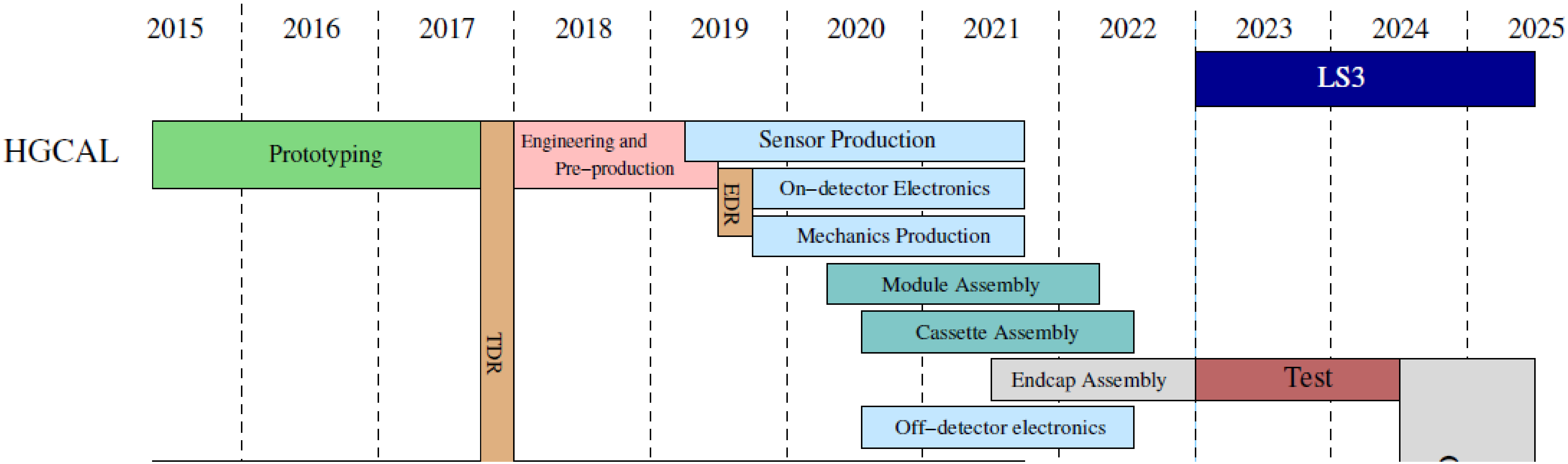
HGCAL General Layout



Back Hadron Calorimeter
(Brass+Scintillators)

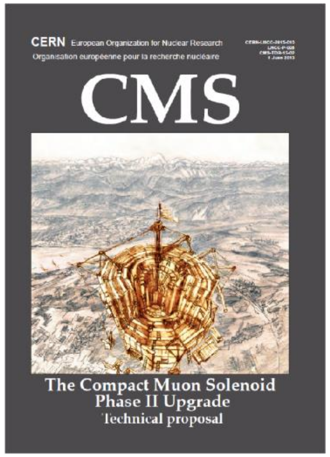
HGCAL

Timeline



- Technical Proposal published in Summer 2015

  (since then, many things have changed…)



- Technical Design Report for end of 2017 – beginning of 2018.

- Installation during LS3

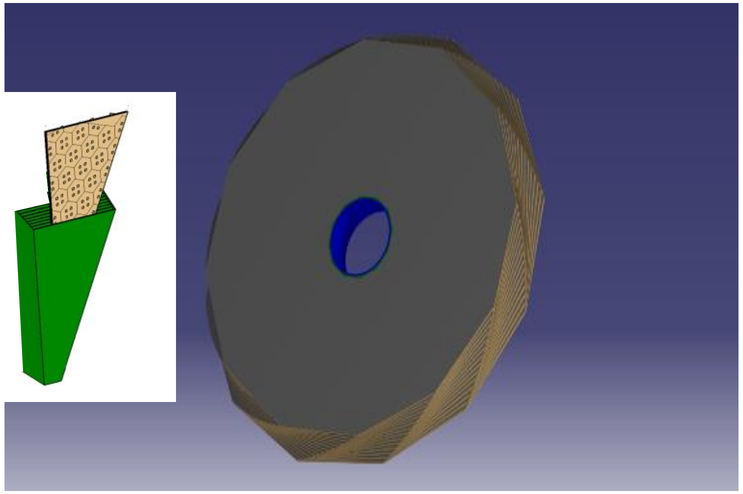
Test Beam Plans and Goals

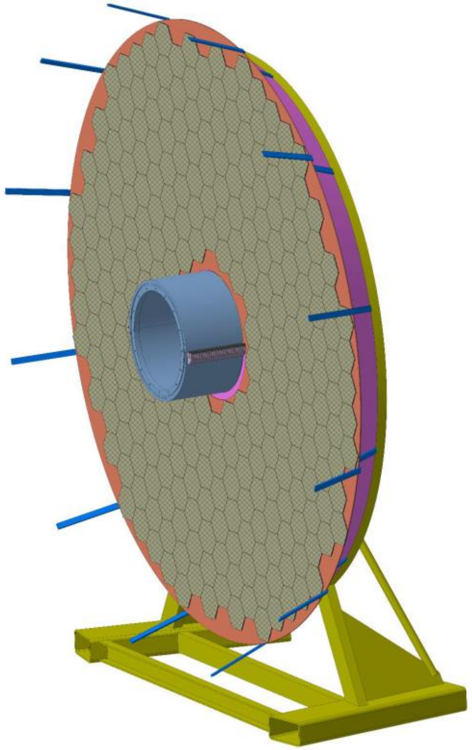
FNAL	Single module with ≤6 X_0 absorber	March 25 – April 5	Complete **Construction and first results are shown today**
H2 (SPS)	Fast timing of irradiated diodes and a full hexagonal sensor	18-27 April	Now sharing a period in H2 for several fast-timing devices
FNAL	Full 28-layer EE (tbd)	May 18 - 31	
H2 (SPS)	Fast timing, as above	1-8 June	Extra period requested due to late arrival of SPS beam
T9 (PS)	Possibly a few full modules (tbd)	15-22 June	
H2 (SPS)	Full 28-layer EE (tbd)	31 Aug – 7 Sept	Moved as late as possible. Preceded by CALICE tests.
H2 (SPS)	28-layer EE + 12-layer FH (tbd)	9-14 Nov	Beam area will be available ~2 months before our tests. Cosmics?

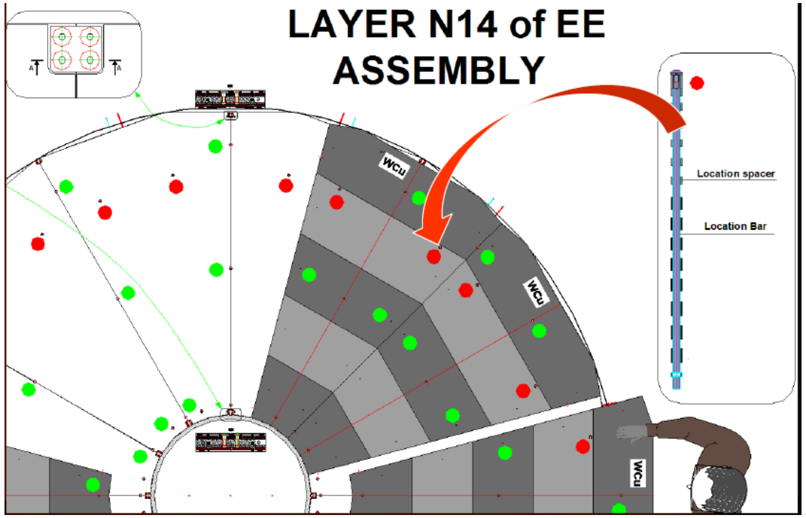
Goals: measure energy response, time and position resolutions, compare to simulation

EE mechanical structure options

3 different designs under study
(with different level of maturity)







(A) W/C-fiber Alveolar Structure

- phi-sector Disks,
- WITH INSERTABLE cassettes

(B) Full Disk

- Inspired from PreShower experience

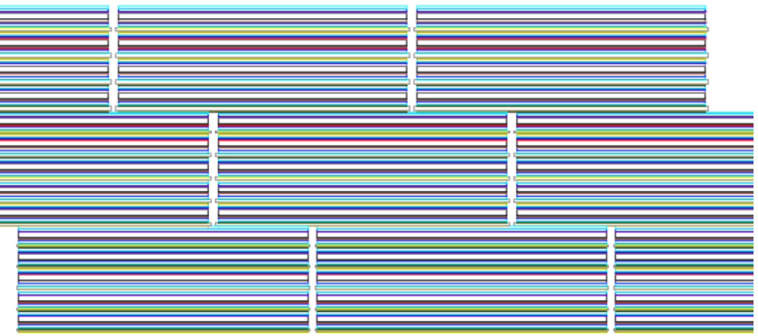
(C) "Tie-rods" design

- Variant of "full disk"
- Made from 30° cassettes, connected in inner/outer periphery +tie-rods + spacers

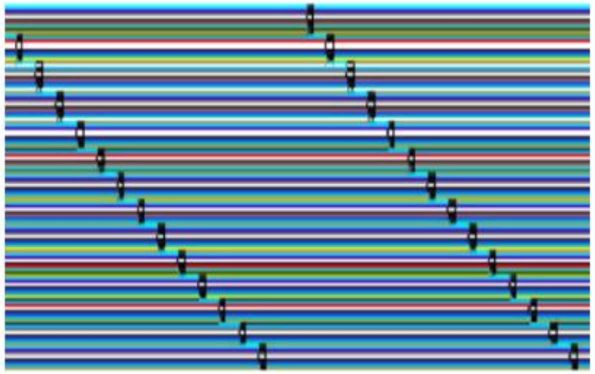
Physics (2)

- **(A) Phi-sector Disks**
  - Various configurations simulated

(1) “TP design”
3 blocks (8-10) layers rotated
by 10°



(2) Disks rotated every 2°
layer by layer
(or every 2 layers==1 cassette)



Continuous W

(3) Disks with staggered layers
(ever 2nd or 3rd)

Continuous W

- Active-to-active gap: mainly created by C-fiber alveoli (+ Si guard ring, mechanical tolerance): 0.5 – <1cm