Backward Electromagnetic Calorimeter Mechanics and Design

Electron-Endcap Electromagnetic Calorimeter (EEEMCal)

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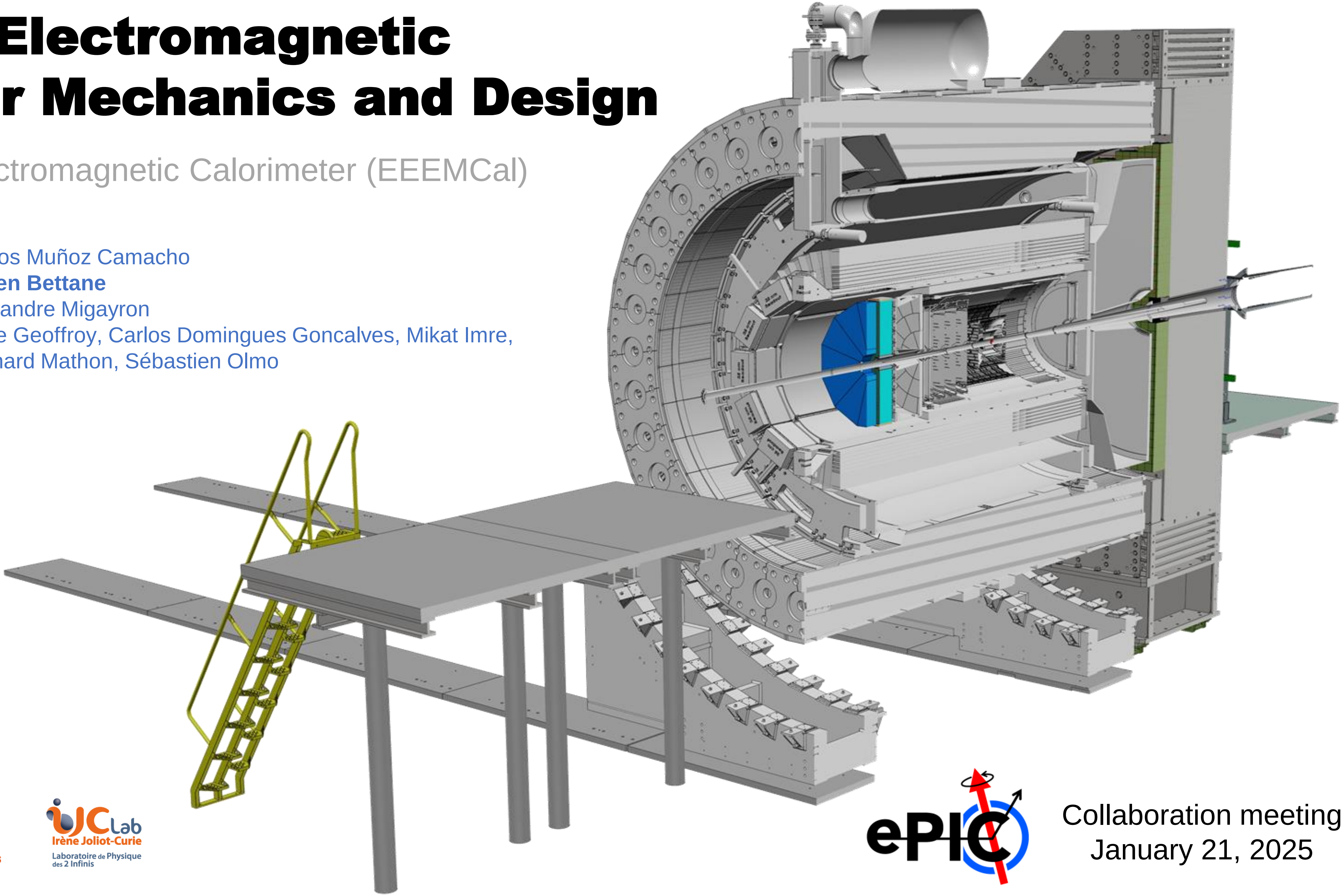
IJCLab (Orsay, CNRS/IN2P3)



Collaboration meeting
January 21, 2025

Outline

- ☐ **Overview**
- ☐ **Readout setup**
- ☐ **Cooling**
- ☐ **Mechanical Design**
- ☐ **Prototype 5x5**
- ☐ **Assembly**
- ☐ **Installation**
- ☐ **Summary**

Overview | Requirements

☐ Physics:

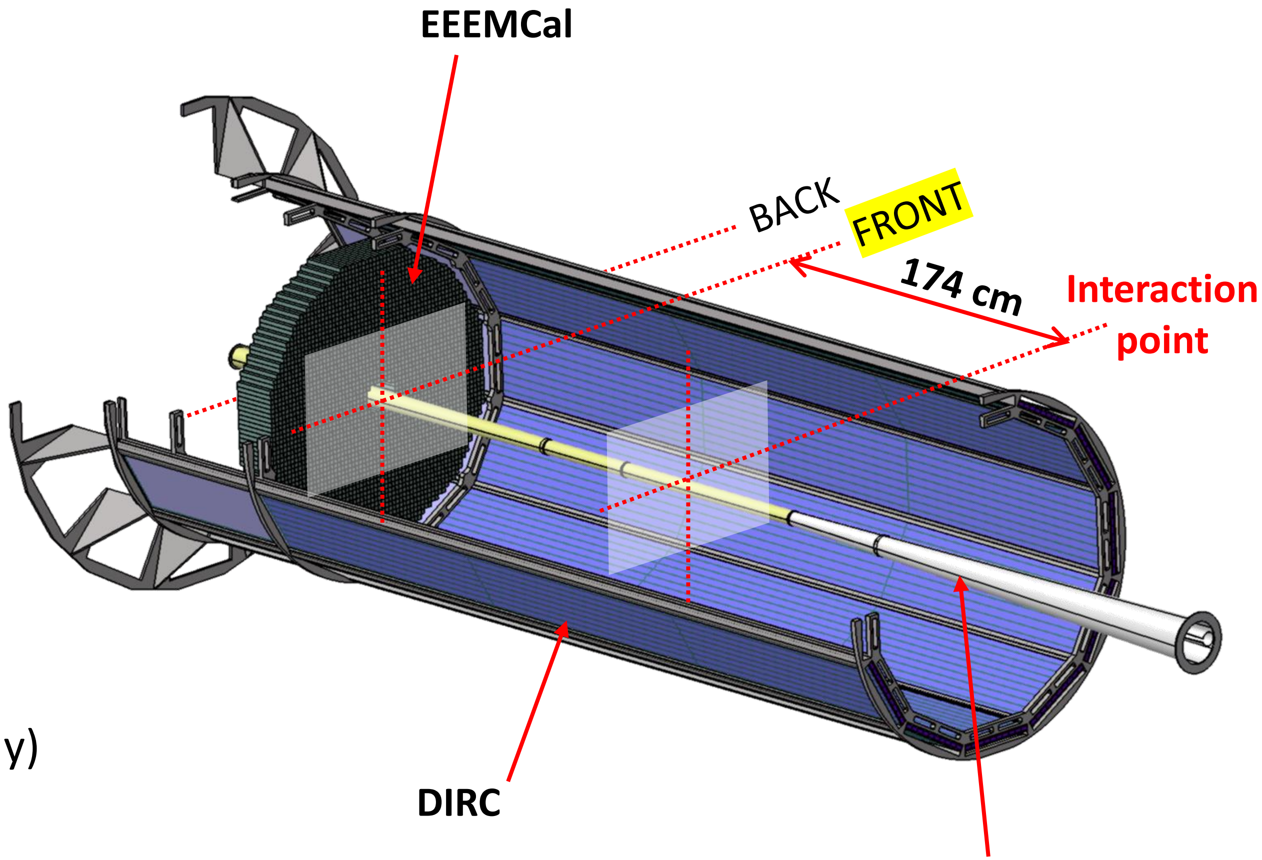
- Distance interaction point/EMCAL = 174 cm
- Minimize the material & space between crystals
- To be as close as possible to the beampipe
- Reduce material in front of the detector

☐ Thermal:

- Good stability of the room temperature at around 23°C
- Temperature stabilty for the crystals to within 0,1°C
- About 1500 W to dissipate

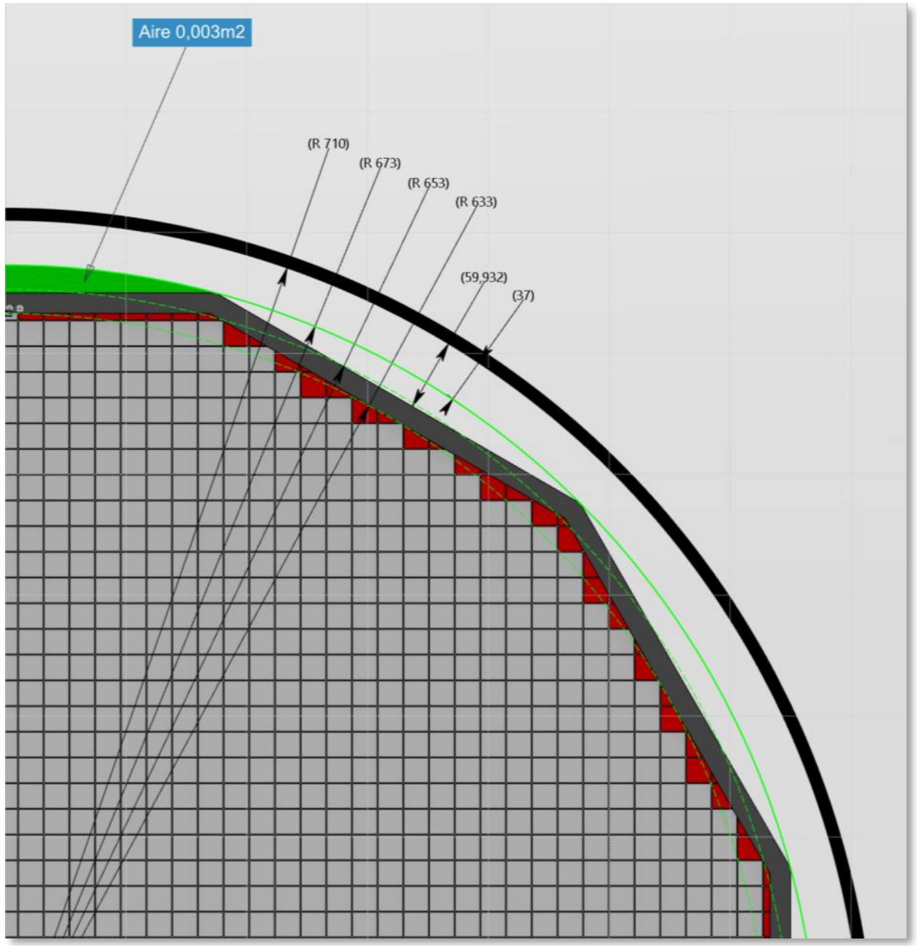
☐ Installation:

- Removing the detector in one block (without disassembly)
- Respect clearance between the beam pipe and the DIRC



Positioning of the EEEMCal

Overview | Clearances (1/2)



Main parameters for the clearances

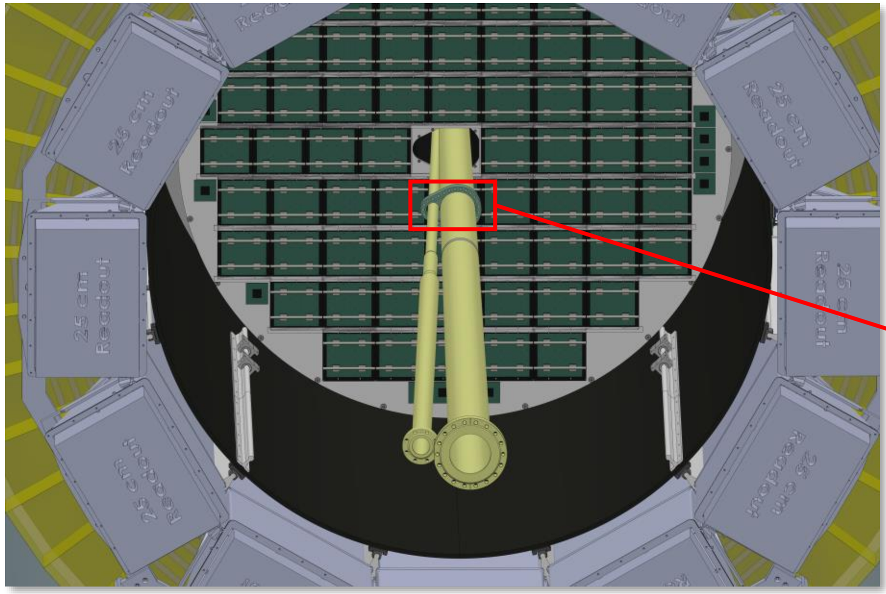
☐ **With the carbon tube:** 37 mm < clearance < 60 mm (mechanical structure and deflection included)

Internal diameter of the carbon tube = 1420 mm
Maximal diameter of the EEEMCal = 1346mm

☐ **Clearance for services:** S = 0,161 + 24x0,003 = 0,233 m^2

☐ **With the pfRICH (in front):** 5 mm (mechanical structure and cables)

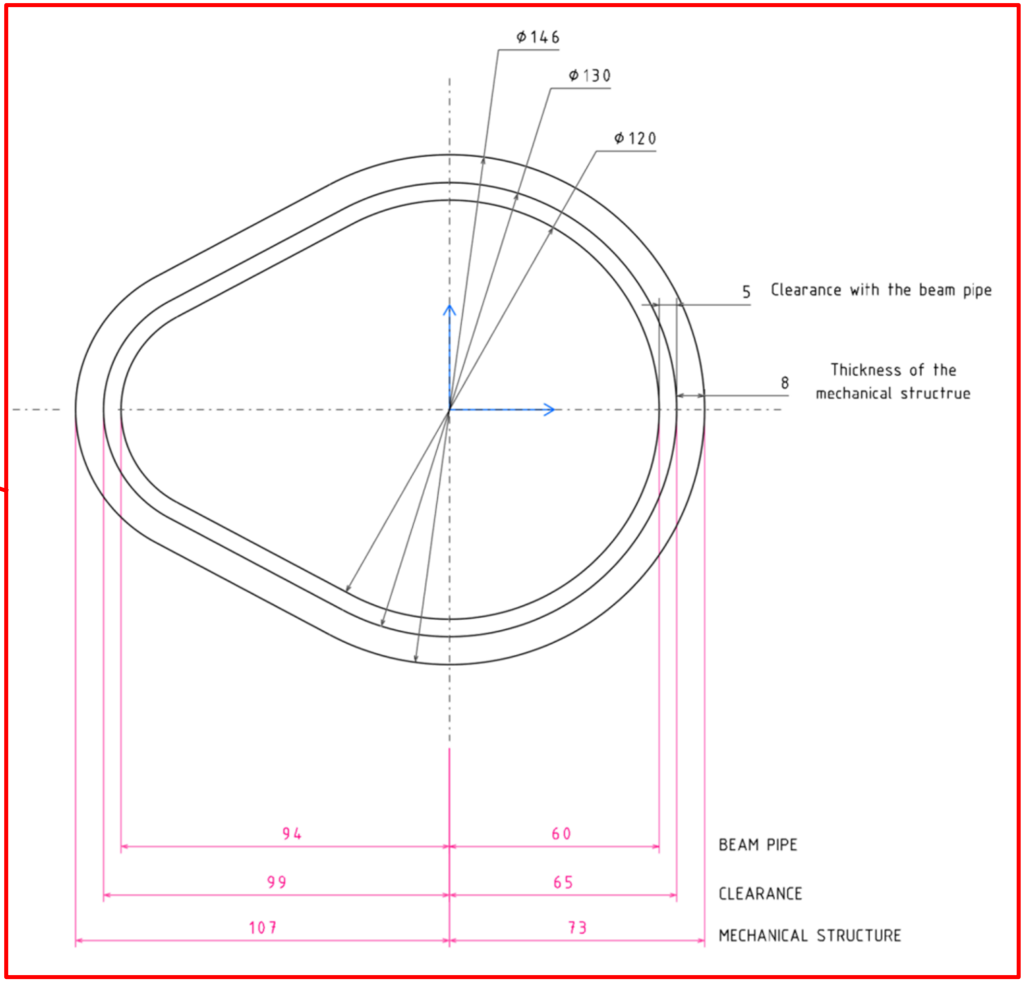
Overview | Clearances (2/2)



Beam pipe (without EEEMCal)

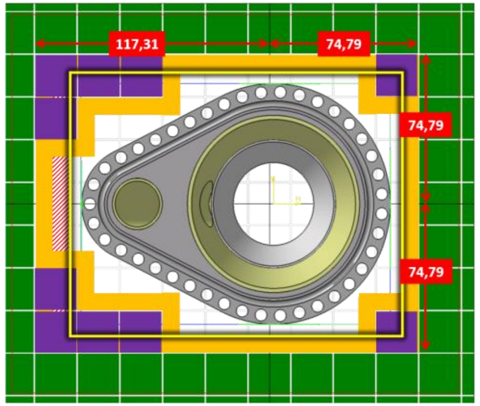
With the beam pipe:
5 mm (mechanical structure and deflection included)

A part of the beam pipe must be removed to perform the installation and the mainteance of the EEEMCal.

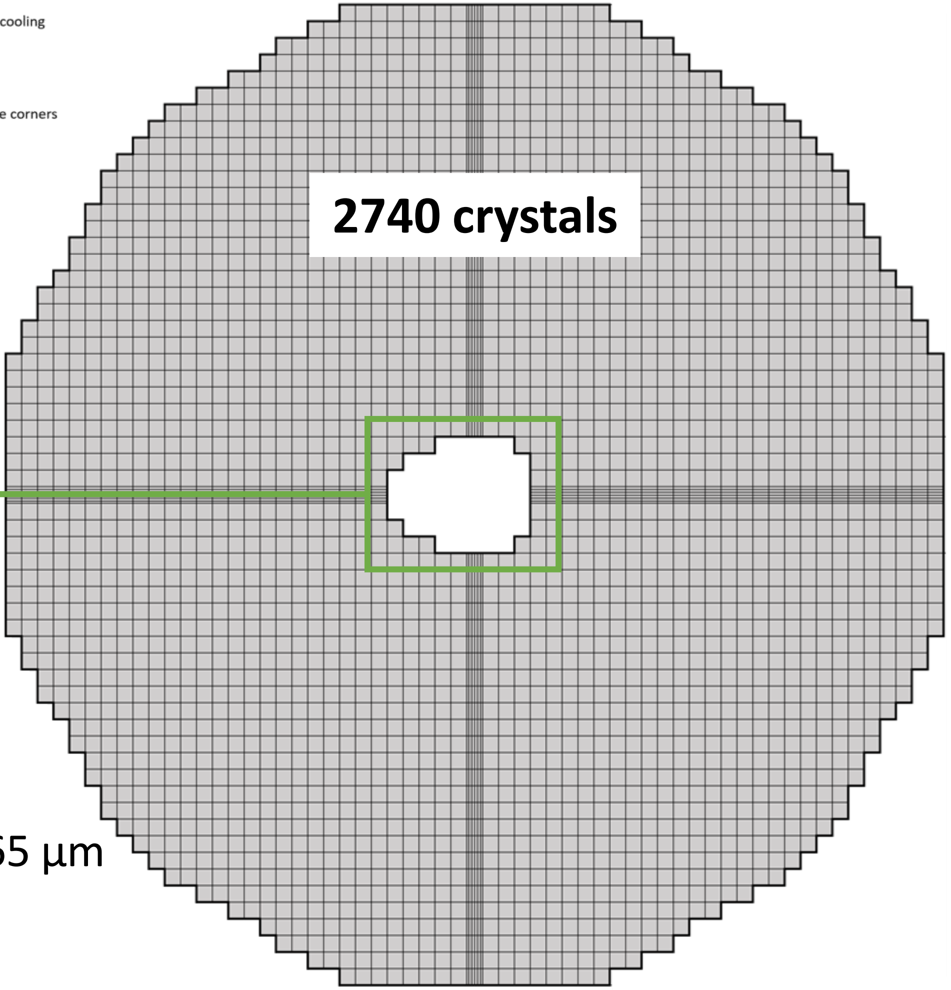


Drawing of the beampipe & clearance

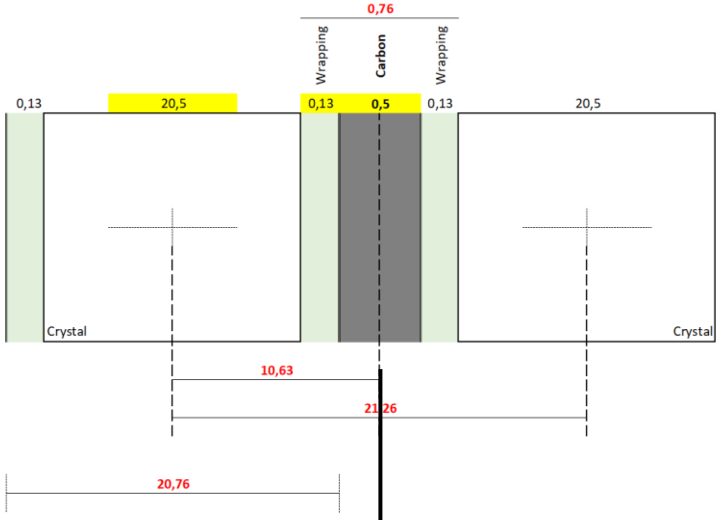
Overview | Crystals configuration

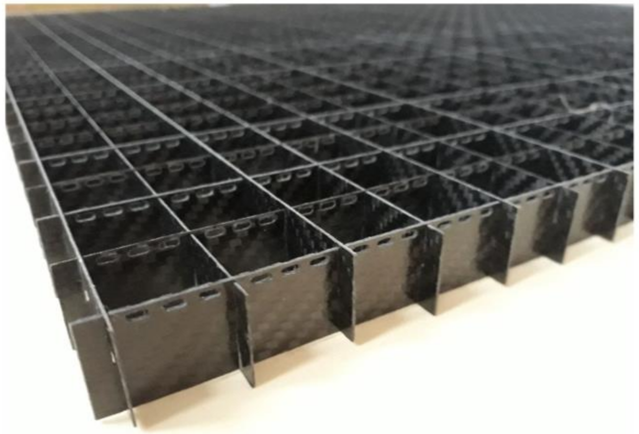


- 🟨 Mechanical structure + cooling
- ▨ Dead area
- 🟪 Additional crystals in the corners
- ☐ Clearance



2740 crystals



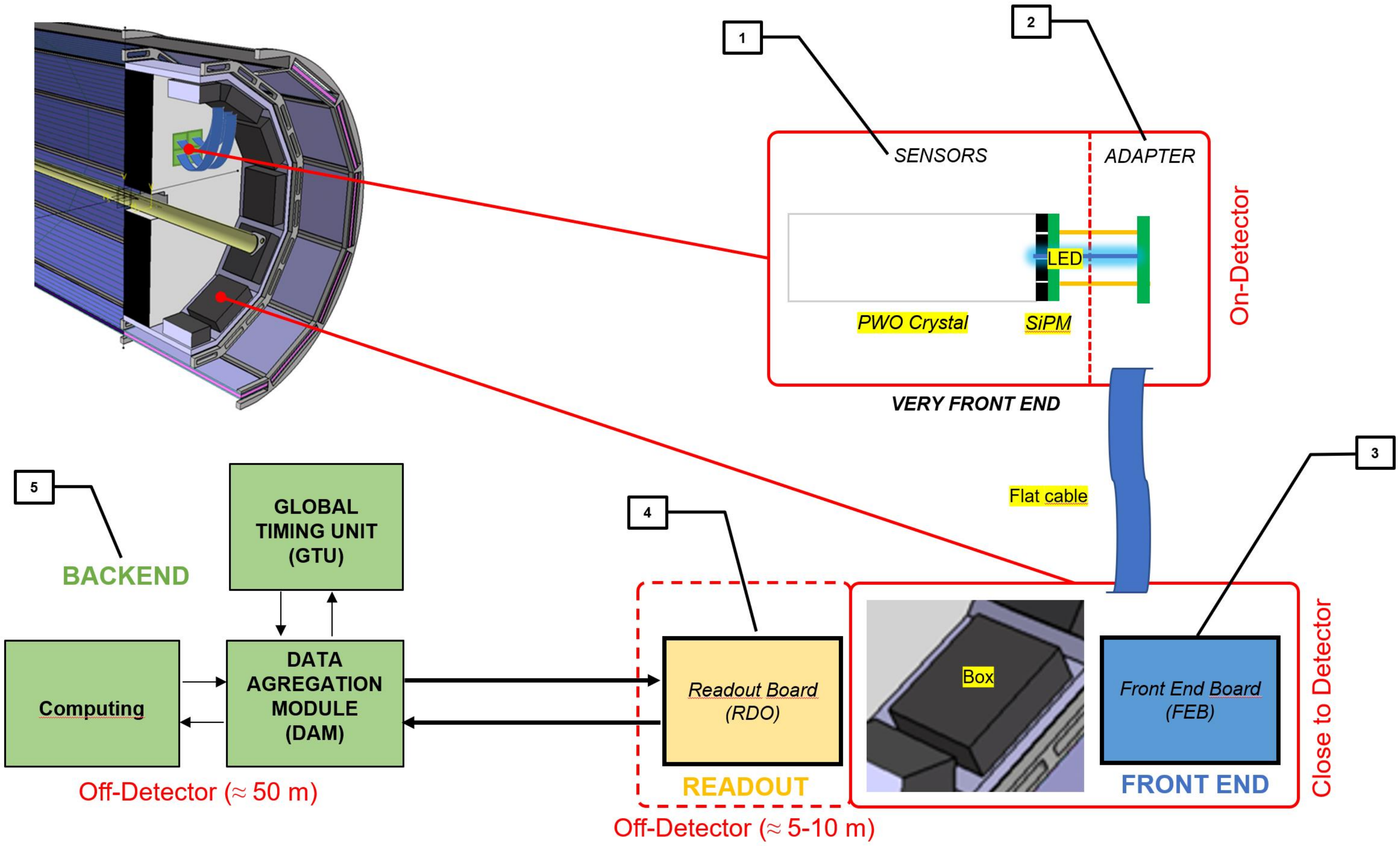


Carbon plate (NPS calorimeter)

Crystals:

- Material: PWO ($PbWO_4$)
- Size= $20.5^{+0-0.5}\times 20.5^{+0-0.5}$x200 mm^3
- Mass= 0,7 Kg (8,28 g.cm^{-3})
- Reflector: ESR® (3M) VM2000 = 0.65 µm
- Light insulation: Tedlar® = 0.65 µm
- Carbon plate= 0.5 mm

Readout setup | DAQ Overview



1

2

SENSORS

ADAPTER

LED

PWO Crystal

SiPM

On-Detector

VERY FRONT END

Flat cable

3

5

BACKEND

GLOBAL TIMING UNIT (GTU)

4

Computing

DATA AGREGATION MODULE (DAM)

Readout Board (RDO)

Box

Front End Board (FEB)

READOUT

FRONT END

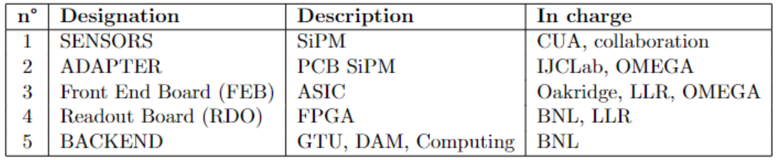
Close to Detector

Off-Detector (≈ 50 m)

Off-Detector (≈ 5-10 m)

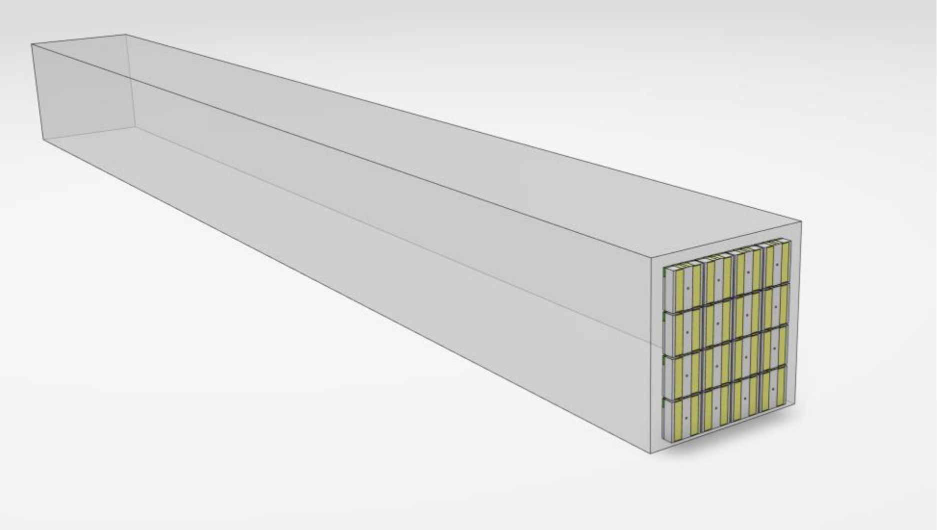
To keep in mind:

- Location of the power: into the FEB & the RDO
- No power on the very front end (+10W for SiPM after one year)
- Current discussion on the design of the FEB



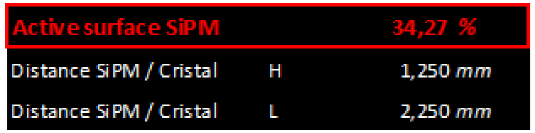
n°	Designation	Description	In charge
1	SENSORS	SiPM	CUA, collaboration
2	ADAPTER	PCB SiPM	IJCLab, OMEGA
3	Front End Board (FEB)	ASIC	Oakridge, LLR, OMEGA
4	Readout Board (RDO)	FPGA	BNL, LLR
5	BACKEND	GTU, DAM, Computing	BNL

Readout setup | SiPM configuration

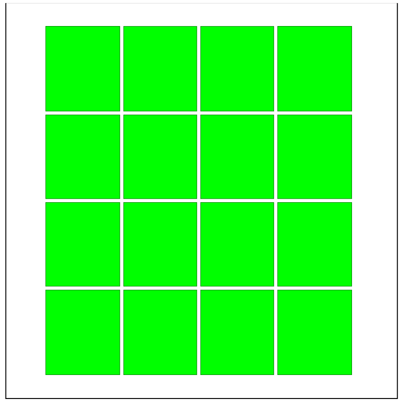


SiPM:

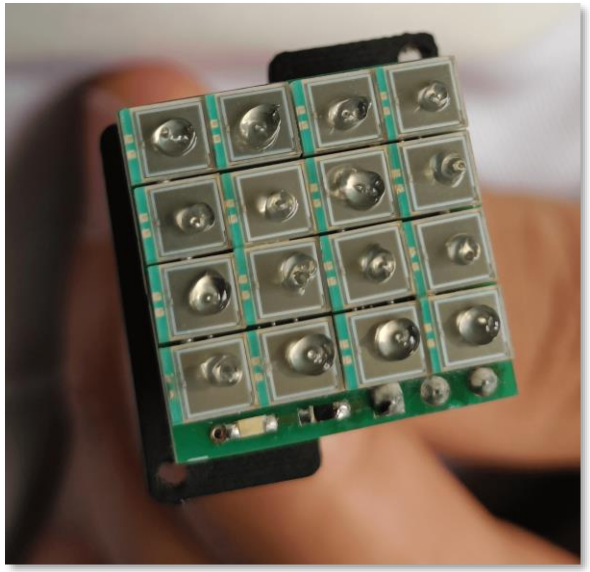
- Current SiPM tested: Active surface= 3x3 mm^2
- External size= 4,35mm x 3,85mm
- Reference: S14160-3015PS
- 16 SiPM per crystal → 43840 SiPM
- Space between SiPM= 0,2 mm
- Surface covered by the SiPM ≈ **34%**
- Option 2x2 SiPM (6x6 mm^2) continue to be considered
- Results of the beam test should help to validate the choice



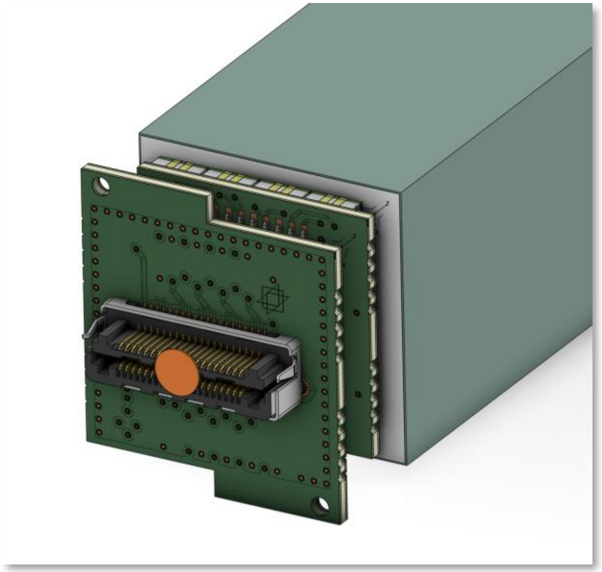
Active surface SiPM		34,27 %
Distance SiPM / Cristal	H	1,250 *mm*
Distance SiPM / Cristal	L	2,250 *mm*



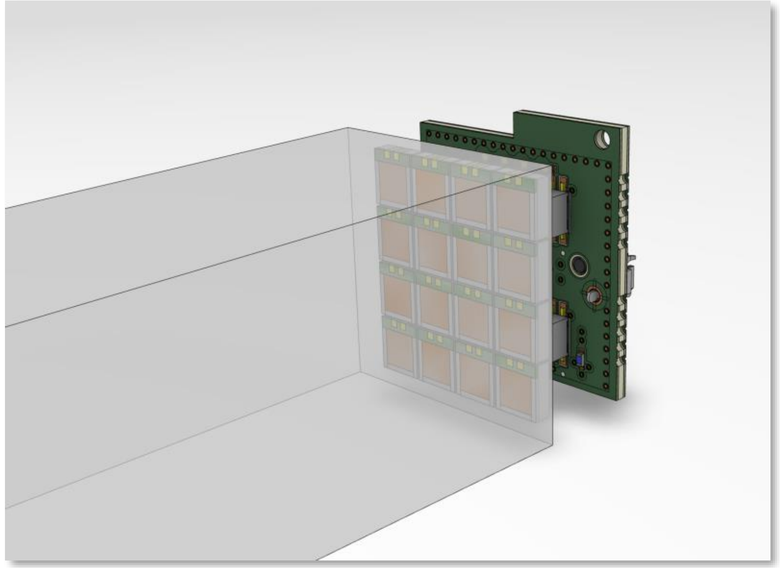
Readout setup | Very Front-End



Optical grease



Daughter board – PCB connectors

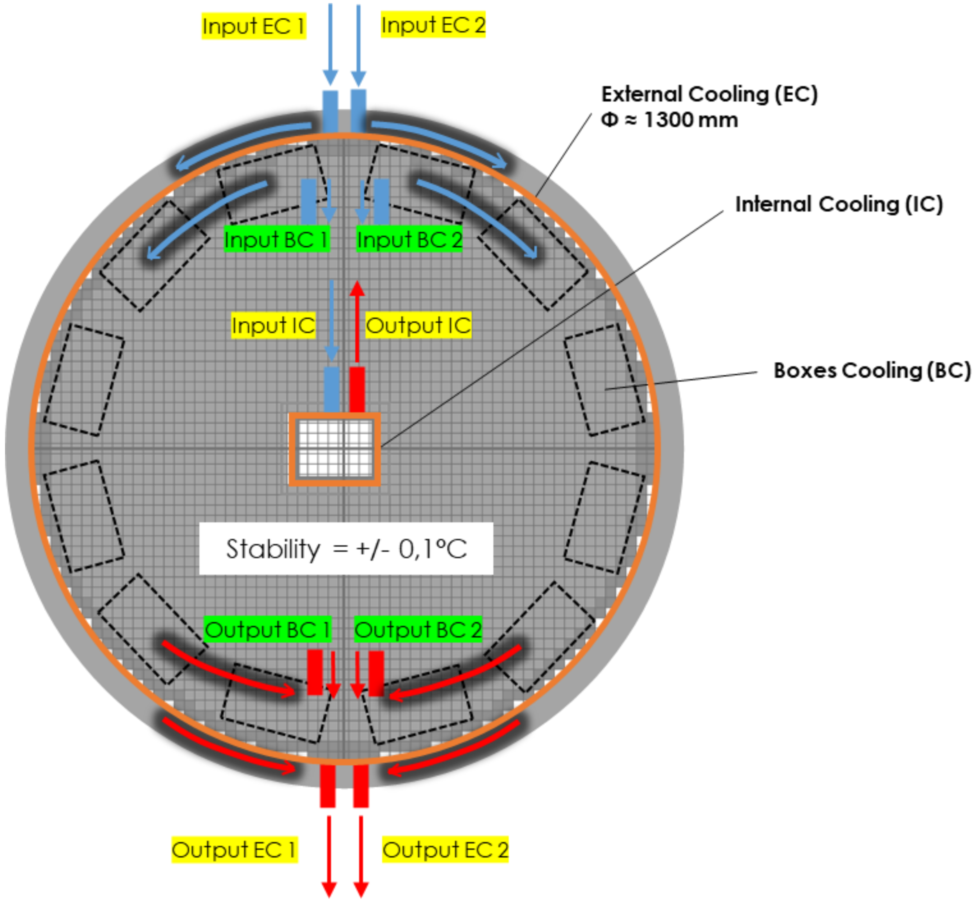


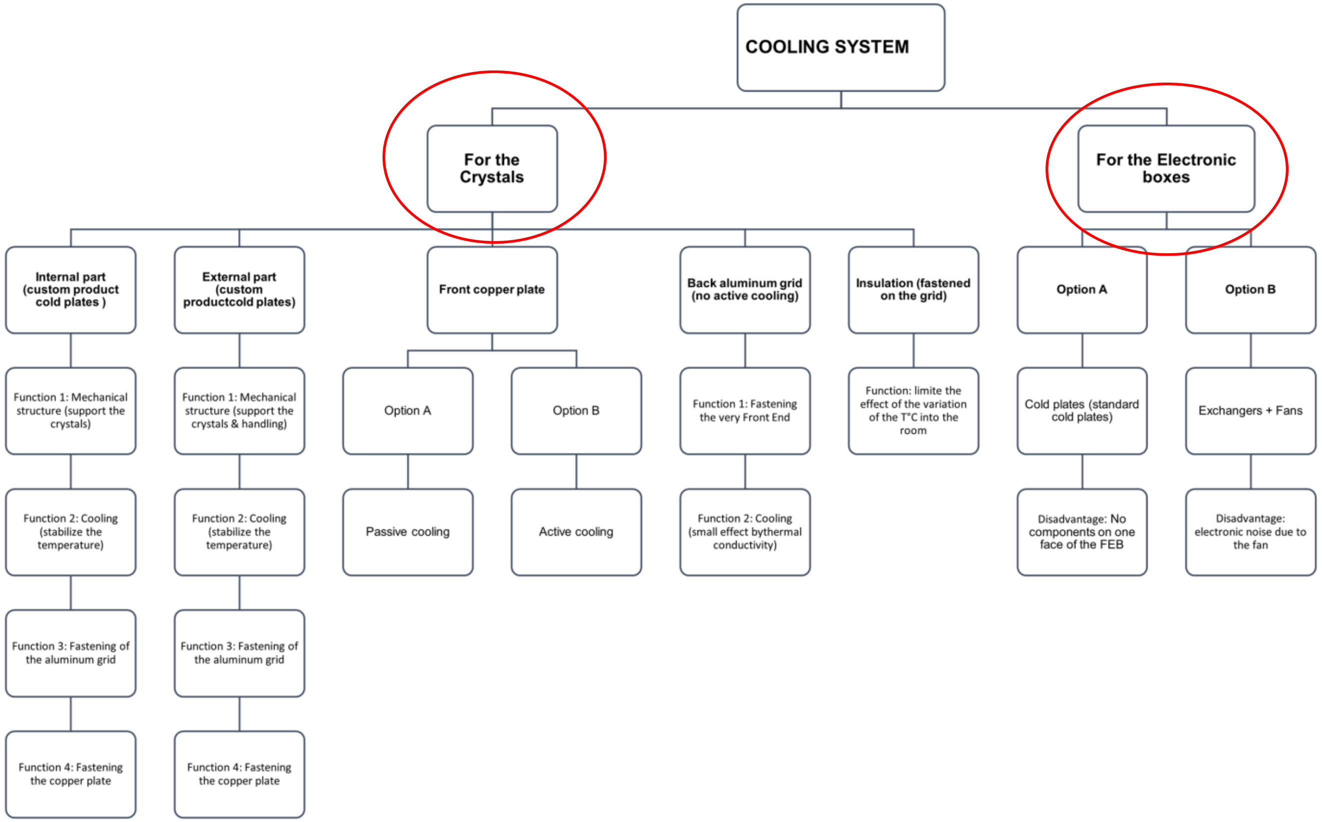
Assembly Crystal + PCB

Components of the very Front-End:

- 4x4 SiPM coupled with optical grease
- 1 PCB with the SiPM welded
- 1 PCB with the output connector pluged on the PCB SiPM
- Several tests (on table & beam test) to validate the reading (// or independant)

Cooling | Overview





- **COOLING SYSTEM**
  - **For the Crystals**
    - **Internal part (custom product cold plates)**
      - Function 1: Mechanical structure (support the crystals)
      - Function 2: Cooling (stabilize the temperature)
      - Function 3: Fastening of the aluminum grid
      - Function 4: Fastening the copper plate
    - **External part (custom productcold plates)**
      - Function 1: Mechanical structure (support the crystals & handling)
      - Function 2: Cooling (stabilize the temperature)
      - Function 3: Fastening of the aluminum grid
      - Function 4: Fastening the copper plate
    - **Front copper plate**
      - Option A
        - Passive cooling
      - Option B
        - Active cooling
    - **Back aluminum grid (no active cooling)**
      - Function 1: Fastening the very Front End
      - Function 2: Cooling (small effect bythermal conductivity)
    - **Insulation (fastened on the grid)**
      - Function: limite the effect of the variation of the T°C into the room
  - **For the Electronic boxes**
    - **Option A**
      - Cold plates (standard cold plates)
      - Disadvantage: No components on one face of the FEB
    - **Option B**
      - Exchangers + Fans
      - Disadvantage: electronic noise due to the fan

2 main objectives:

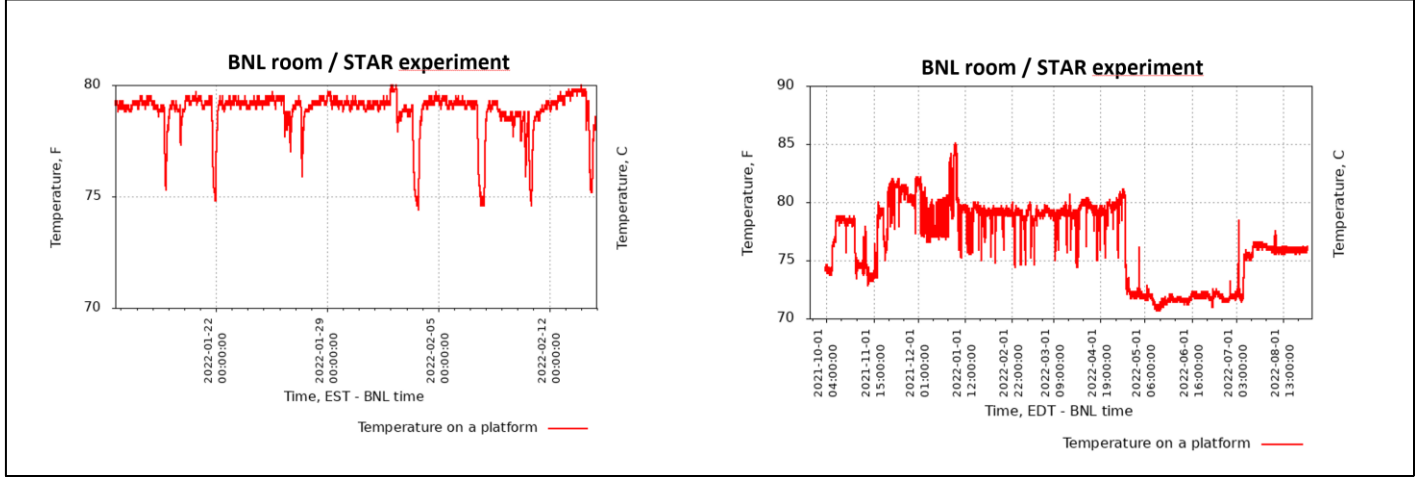
- Stabilize the temperature of the crystals to within 0,1°C
- Dissipate the power of the FEB (& RDO) ≈ 1500 W

Cooling | Specifications

3 main parameters for the sizing:

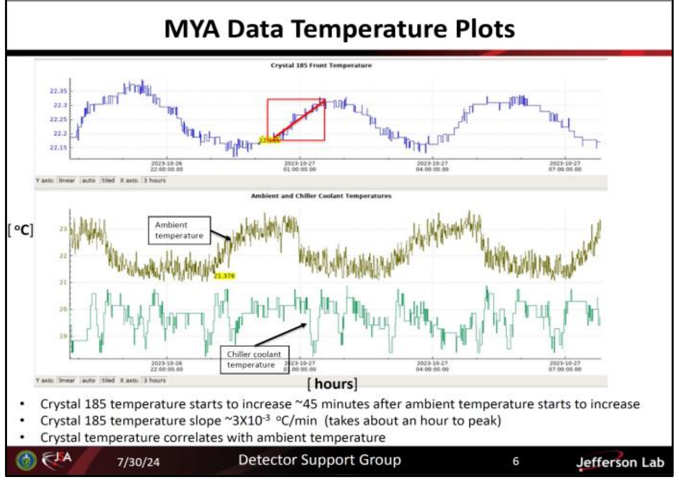
- The amplitude of the temperature variations in the experimental hall → ΔT= 3°C
- The frequency/period of the temperature variations in the experimental hall → 6 hours < T < 12 hours
- The location of the power to dissipate → Power on electronic boxes

RHIC/ STAR experiment data



Temperature evolution | Long period

NPS data



MYA Data Temperature Plots

- Crystal 185 temperature starts to increase ~45 minutes after ambient temperature starts to increase
- Crystal 185 temperature slope ~$3X10^{-3}$ °C/min (takes about an hour to peak)
- Crystal temperature correlates with ambient temperature

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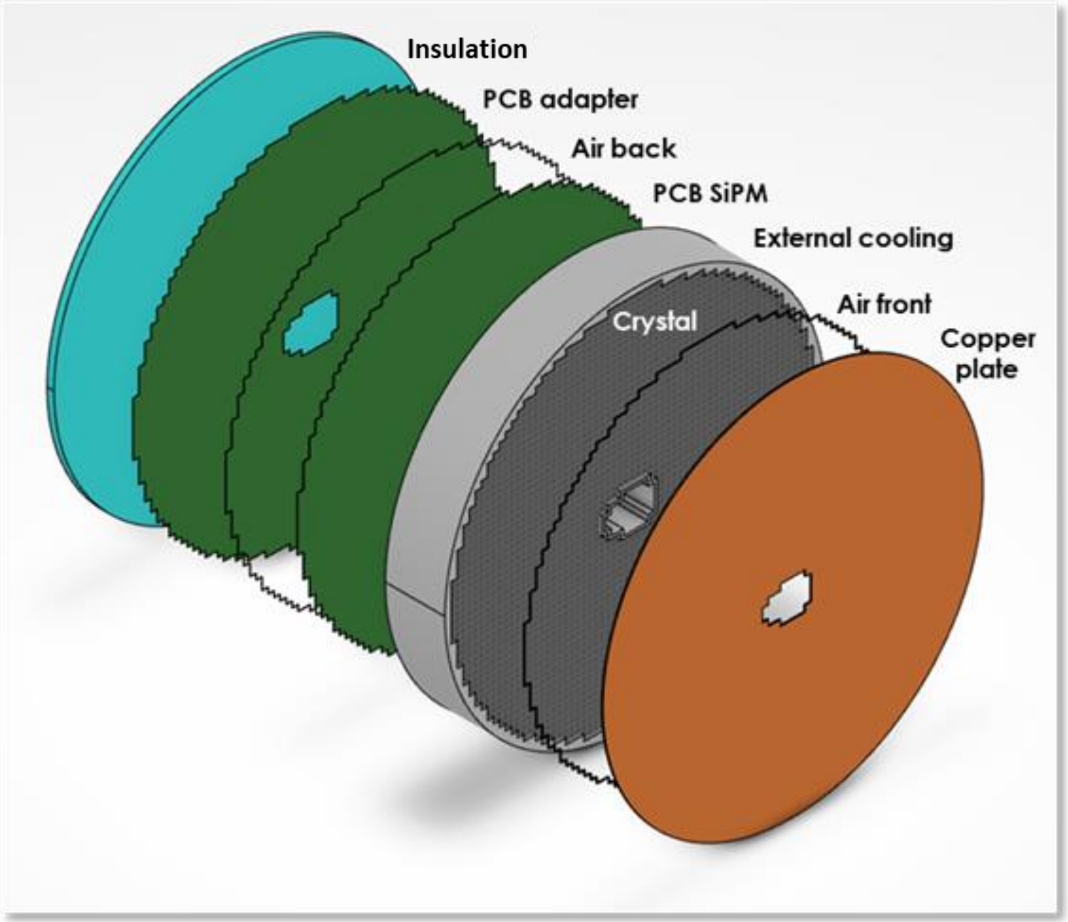
Temperature evolution | Short period

Cooling | Thermal simulation (1/4)

Simplified design for ANSYS thermal analysis

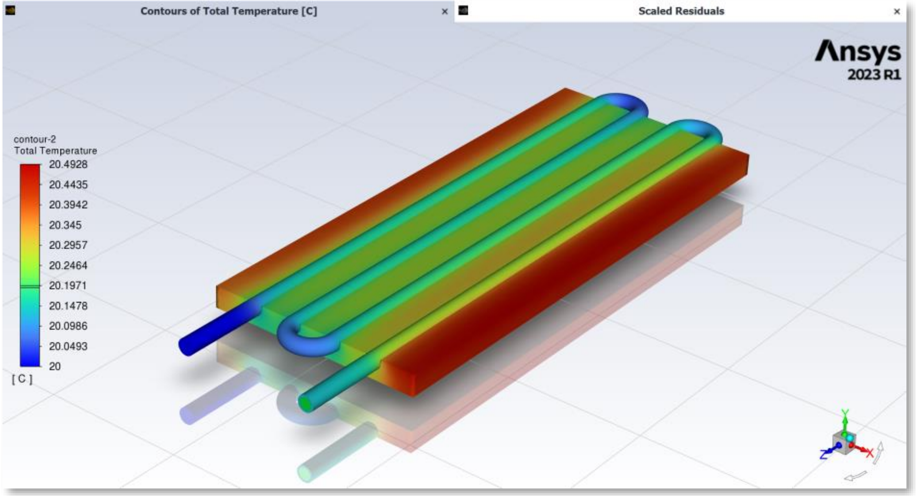


Model:

- To check the effect of the variation of the temperature in the room
- To check the efficiency of the insulation
- Several cases tested to see the efficiency of each parts
- No power near to the crystals

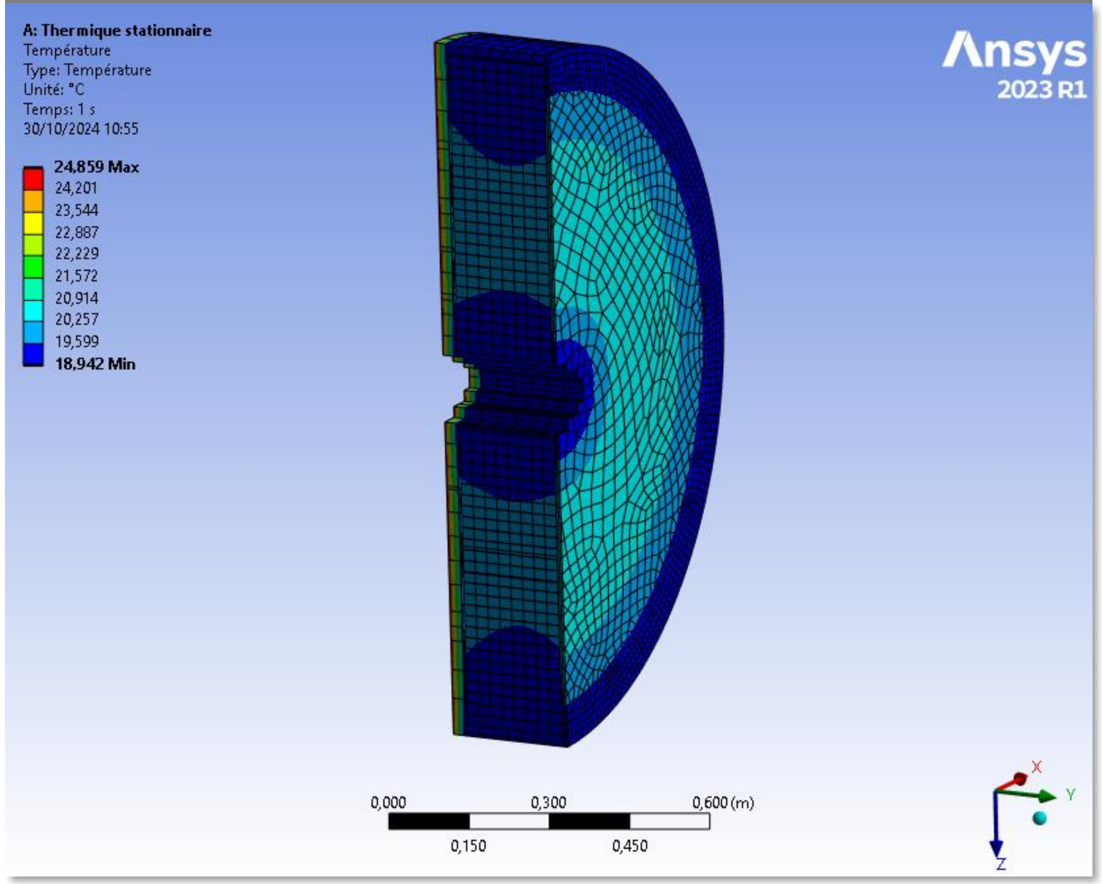
Cooling | Thermal simulation (2/4)

STEADY STATE



Fluent simulation of a cold plate to validate the homogeneity of the cooling

STEADY STATE | Room= 26°C | Cooling= 19°C



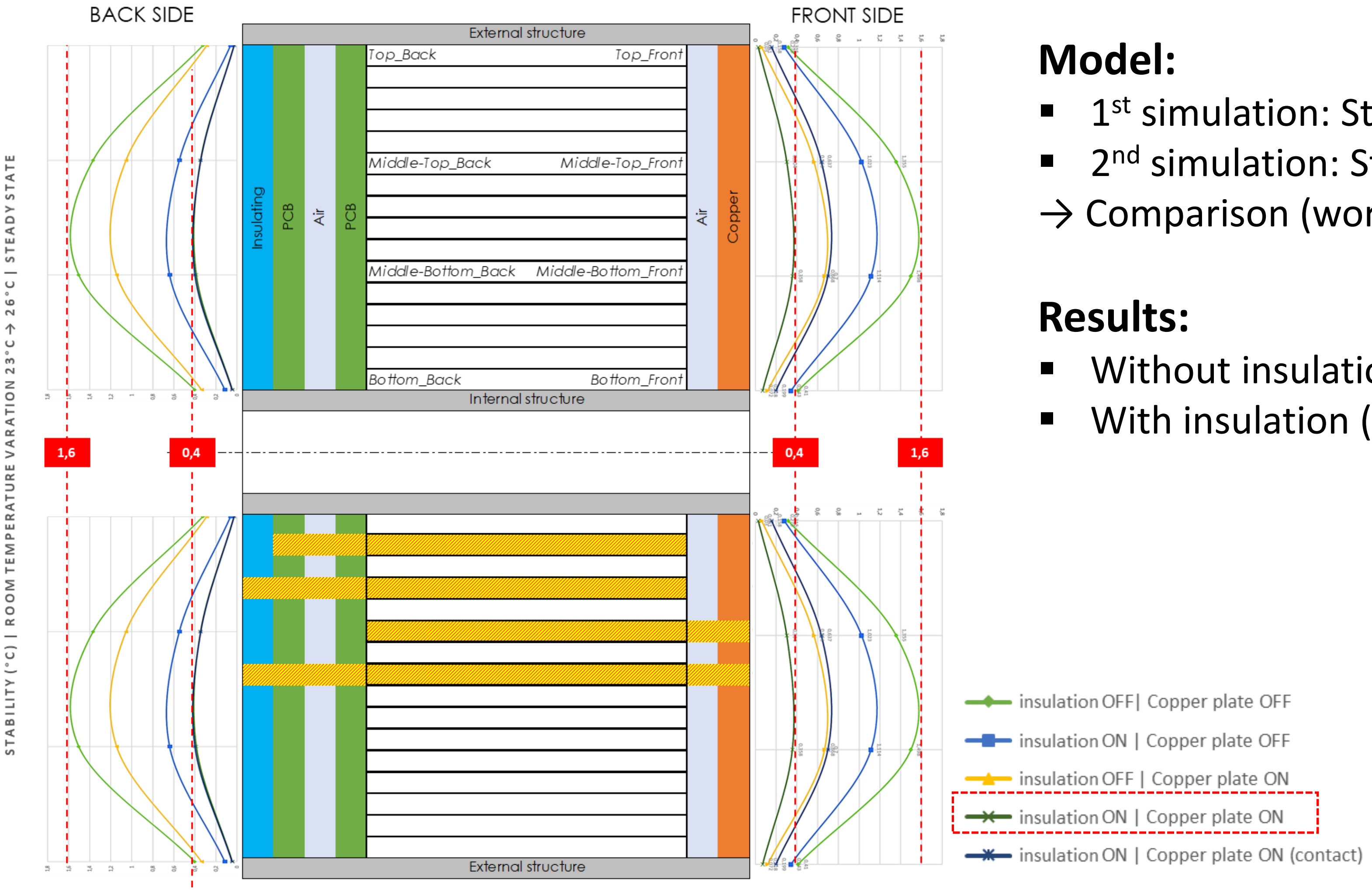
Exemple of results at 26°C
Temperature distribution on the crystals

Model:

- We consider the external & internal cooling are considered at the same temperature (19°C)
- Low gradient along the crystal (ΔT < 2°C)

Cooling | Thermal simulation (3/4)

STEADY STATE



Two steady states comparison

Model:

- 1st simulation: Steady state with temperature room= 23°C
- 2nd simulation: Steady state with temperature room= 26°C

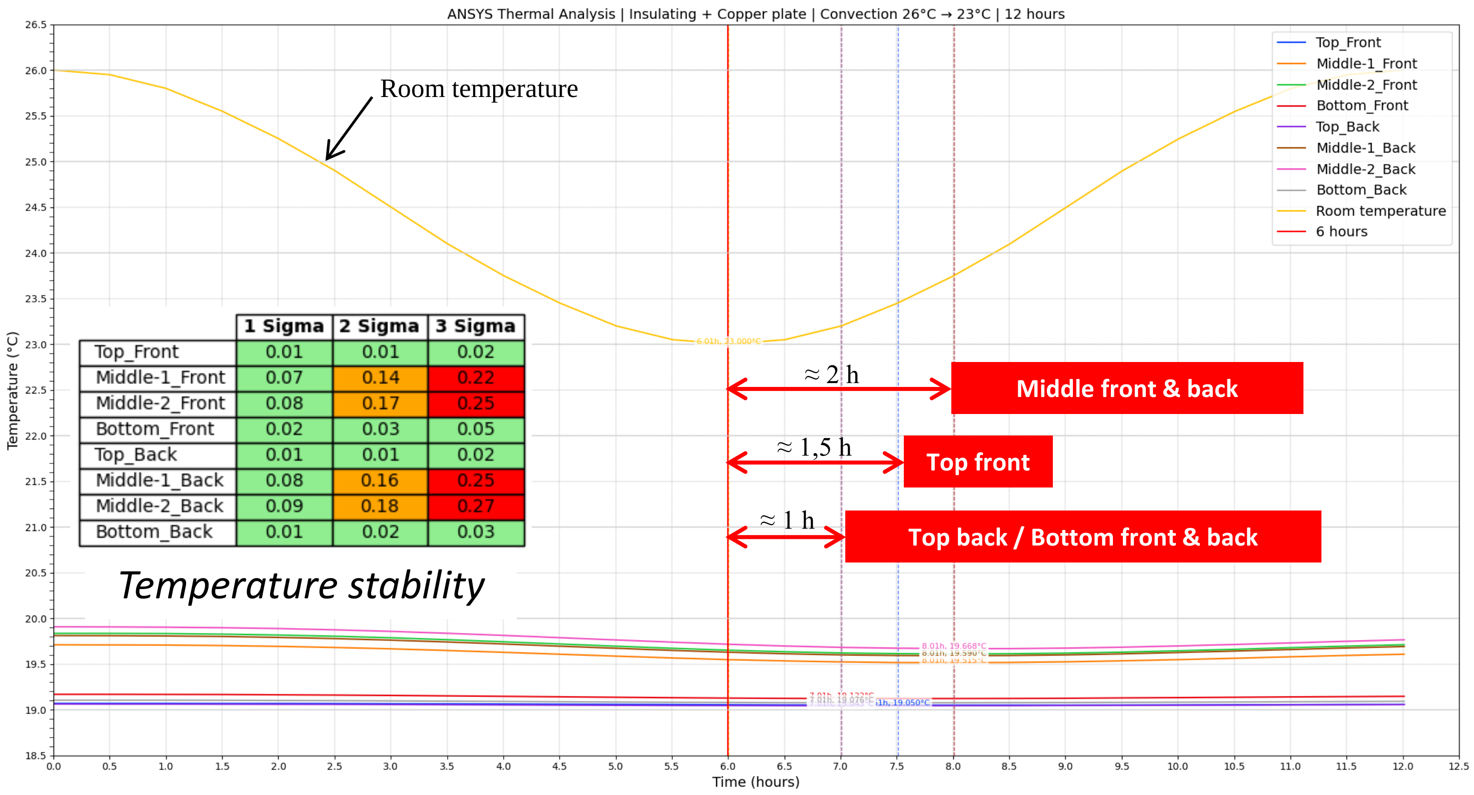
→ Comparison (worst case)

Results:

- Without insulation: ΔT (stabilty) = **1,6°C**
- With insulation (foam, air and copper): ΔT (stability) = **0,4°C**

Cooling | Thermal simulation (4/4)

TRANSIENT STATE



	1 Sigma	2 Sigma	3 Sigma
Top_Front	0.01	0.01	0.02
Middle-1_Front	0.07	0.14	0.22
Middle-2_Front	0.08	0.17	0.25
Bottom_Front	0.02	0.03	0.05
Top_Back	0.01	0.01	0.02
Middle-1_Back	0.08	0.16	0.25
Middle-2_Back	0.09	0.18	0.27
Bottom_Back	0.01	0.02	0.03

Temperature stability

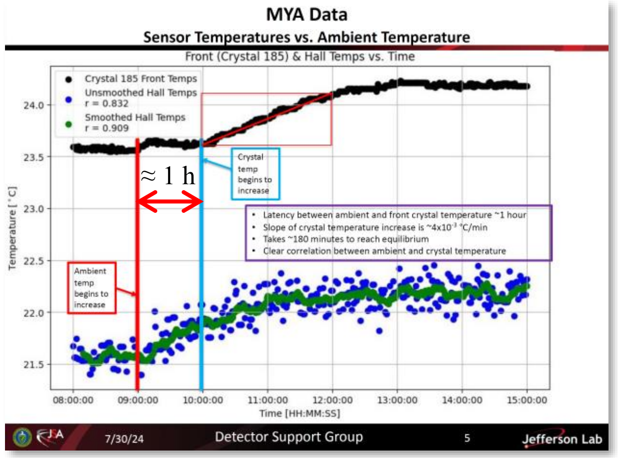
Evolution of the temperature for a variation of the room temperature from 26°C to 23°C in 6 hours and 23°C to 26°C in 6 hours

Model:

- 26°C → 23°C in 6 hours
- T= 12 hours
- Start from the steady state at room= 26°C

Results:

- ΔT (stabilty) < **0,1°C**
- 1 hour < Shift (inertia) < 2 hours
- In accordance with the NPS data



MYA Data

Sensor Temperatures vs. Ambient Temperature

- Latency between ambient and front crystal temperature ~1 hour
- Slope of crystal temperature increase is ~4x10^{-3} °C/min
- Takes ~180 minutes to reach equilibrium
- Clear correlation between ambient and crystal temperature

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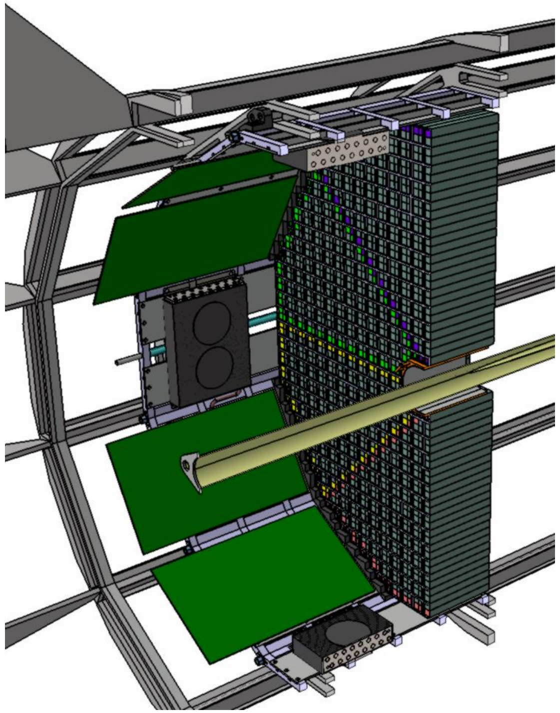
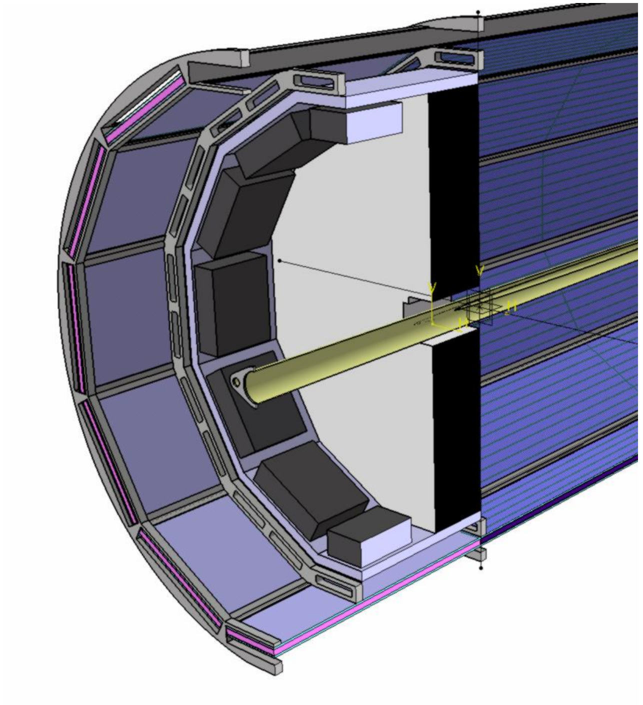
NPS experiment, temperature data

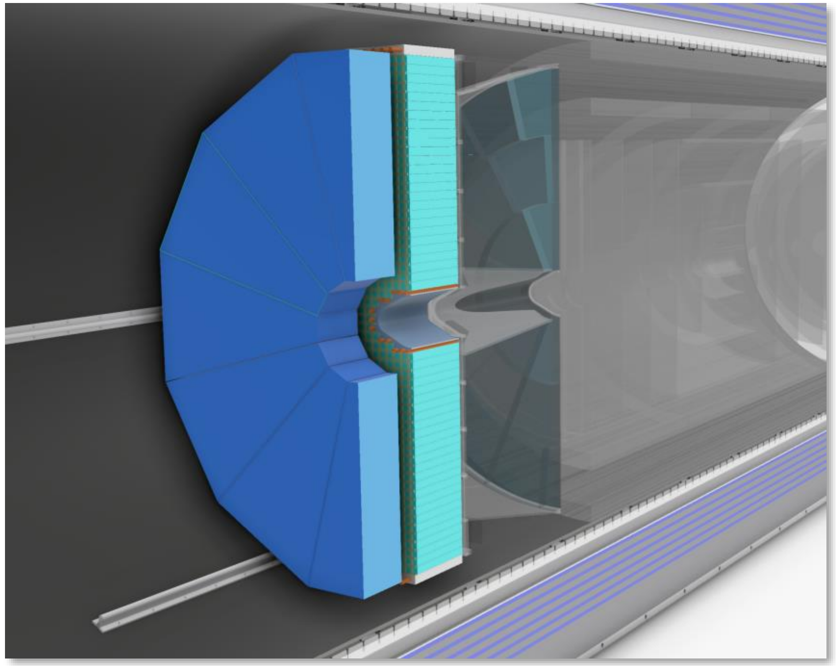
Mechanical design | Overview



2022



2023



2024

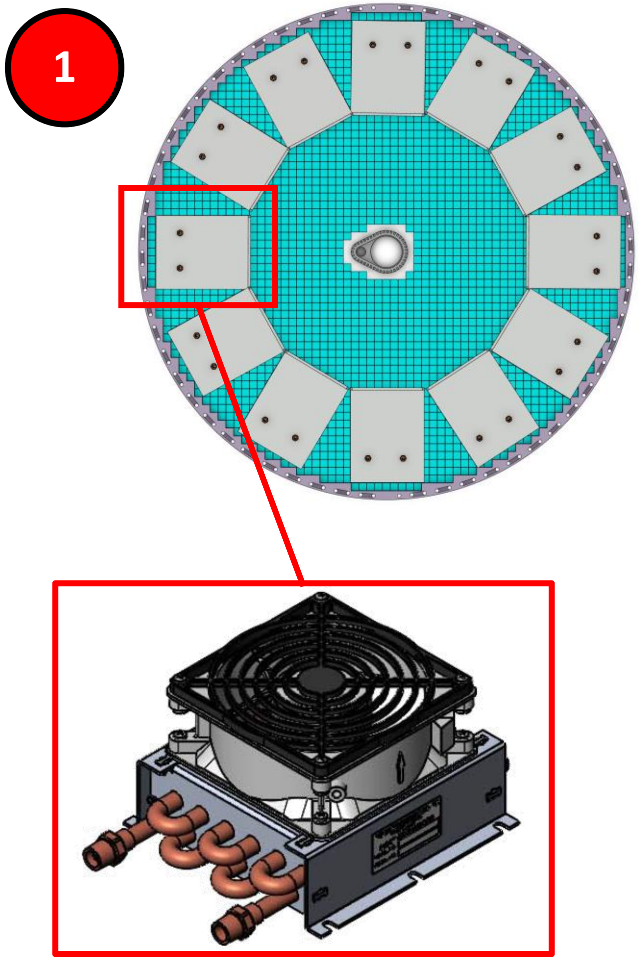
The design evolved along with the design of the FEB

Mechanical depends on :

- The physics performances
- The clearances with other detectors and beam pipe
- The positioning of the FEB & RDO → The power to dissipate & the cooling

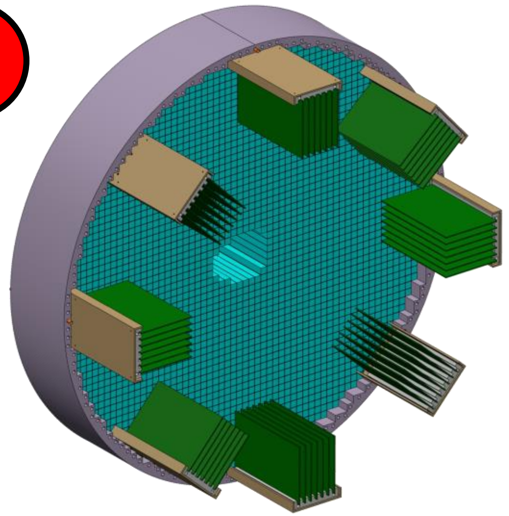
Mechanical design | Current design studied

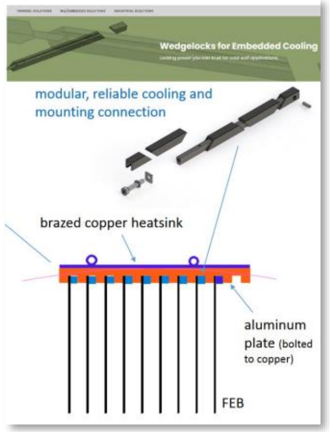
1



Fan + Exchanger

2





Wedgelocks for Embedded Cooling

modular, reliable cooling and mounting connection

brazed copper heatsink

aluminum plate (bolted to copper)

FEB

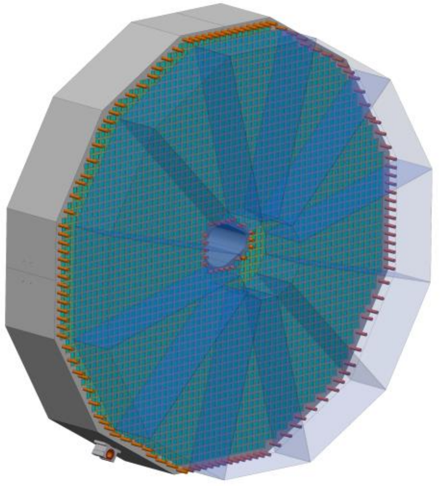
426C7 GENERAL DIMENSIONS

'C' STYLE WEDGELOCKS

14

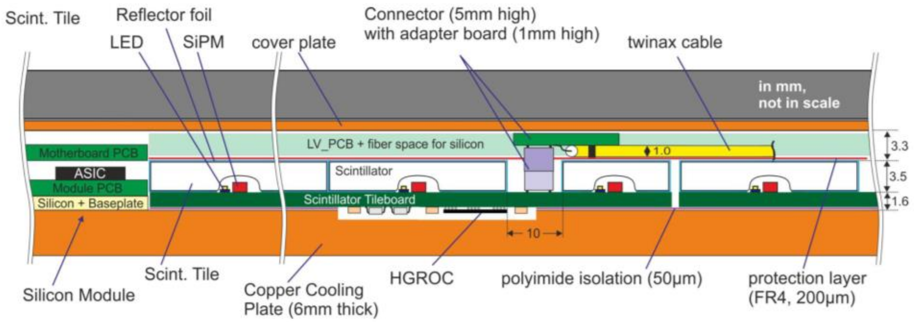
Racks with cold plates

3

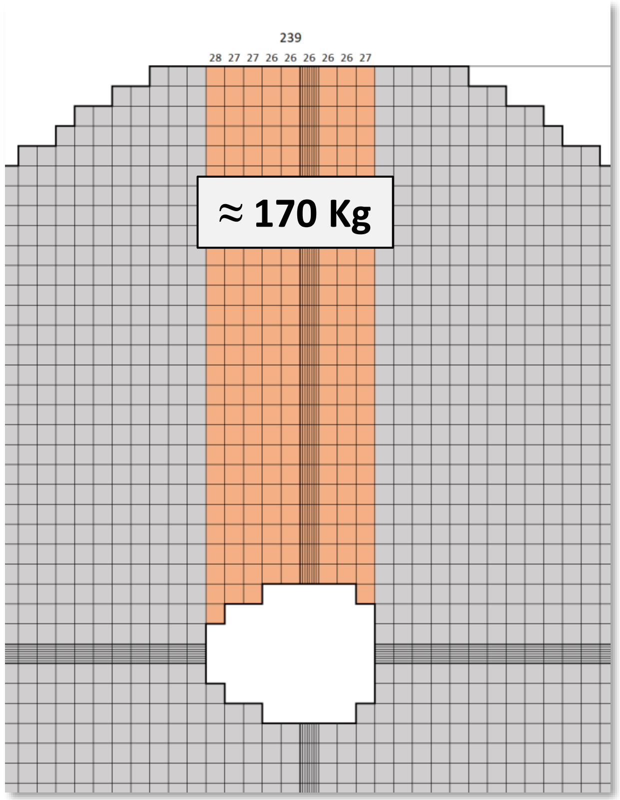


Boxes in front of the SiPM

- With cables → Fan +Exchanger
- Without cables → Cold plates (Like CMS HGCAL)

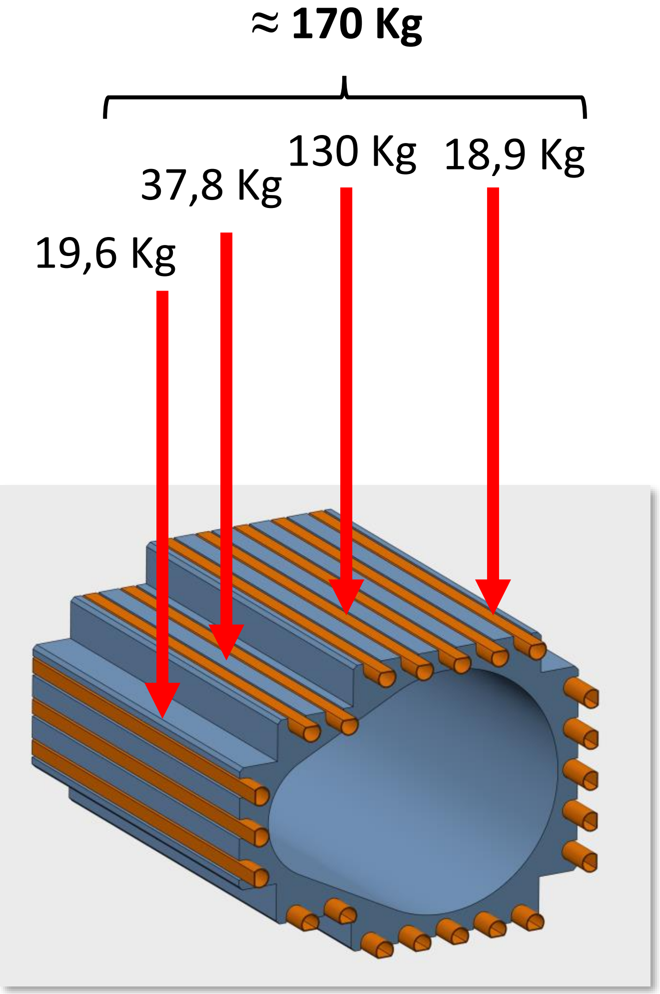


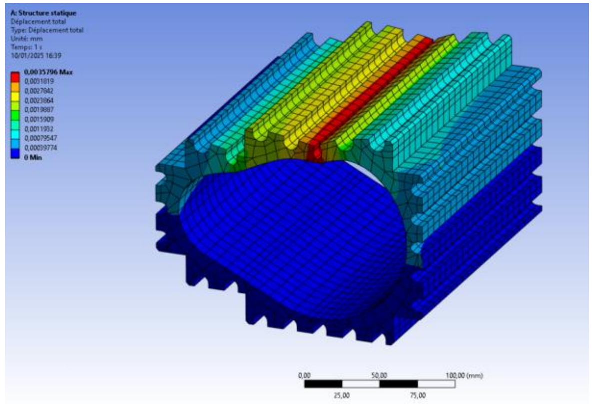
Mechanical design | Internal structure



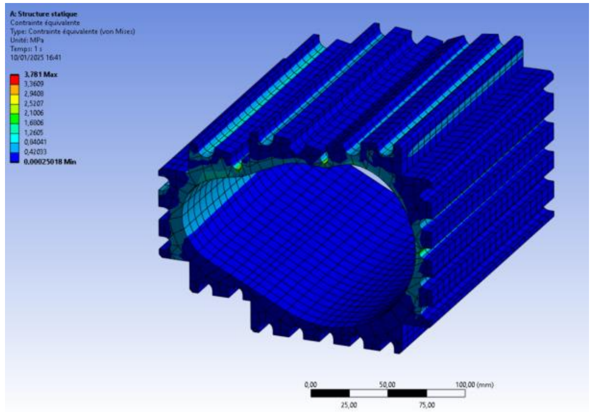
FEA (Finite Element Analysis) Model:

- 239 crystals stacked on the internal structure
- Without copper tubes for the FEA



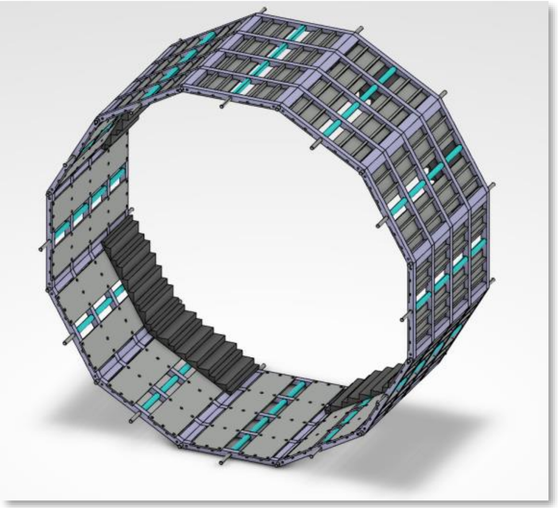


Displacement < 0,01 mm



Stress < 3 Mpa

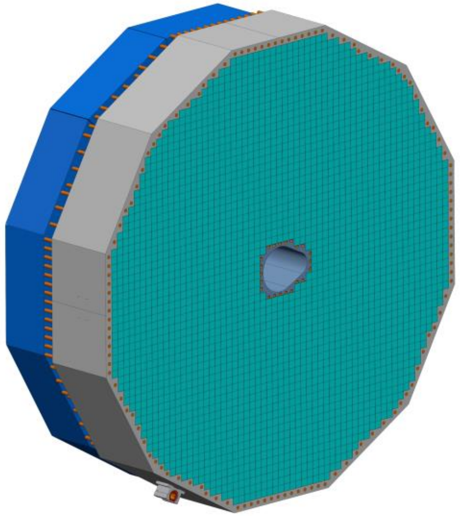
Mechanical design | External structure (1/4)



2022

Assembly of rings and plates

-	+
Assembly	**Cheap**
Cooling	
Stress & Deflection	



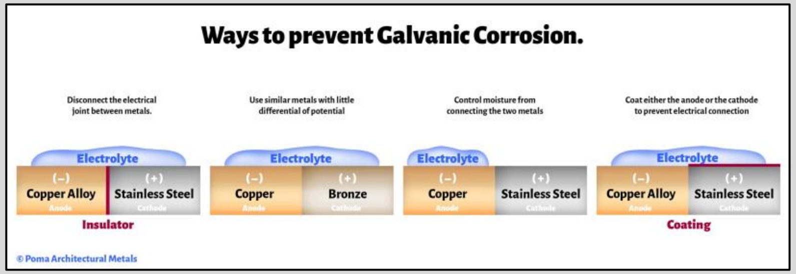
2024

Monobloc

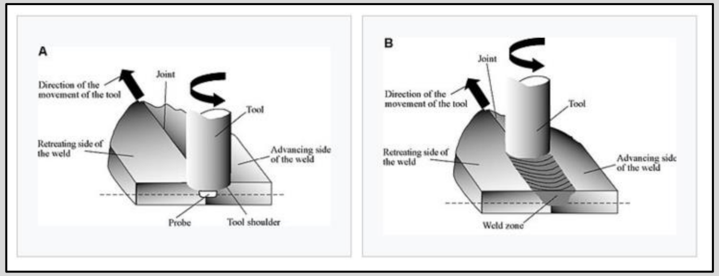
-	+
Expensive	**Cooling**
Production	**Stress & Deflection**
Corrosion	**No assembly**

R&D IN PROGRESS

Foundry vs Machining ?

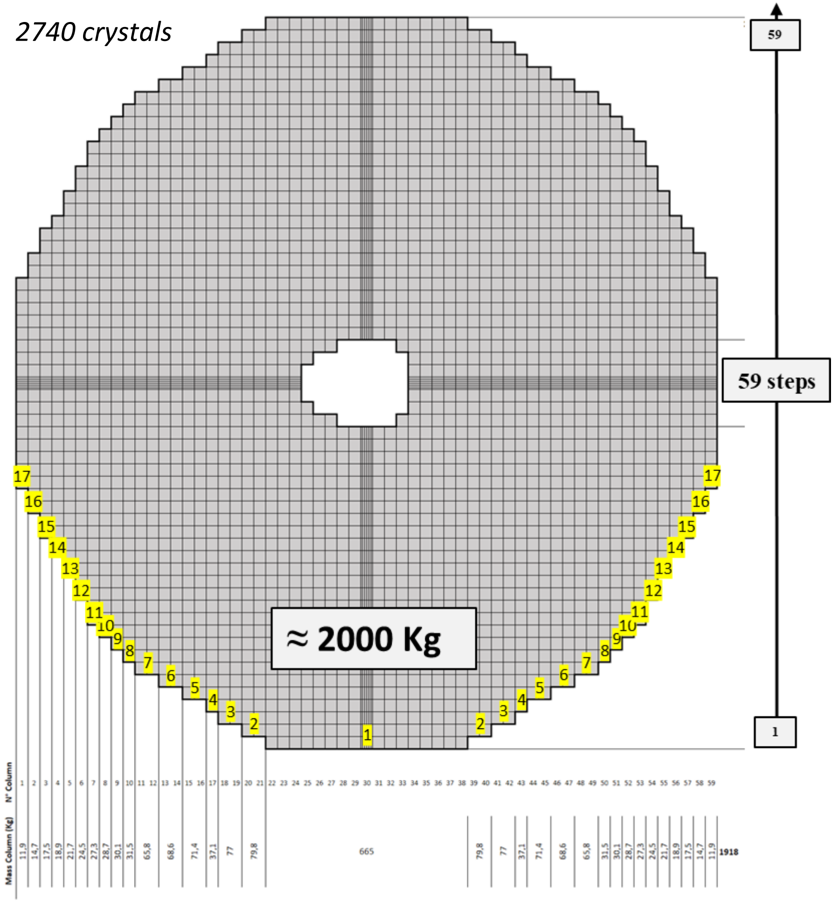


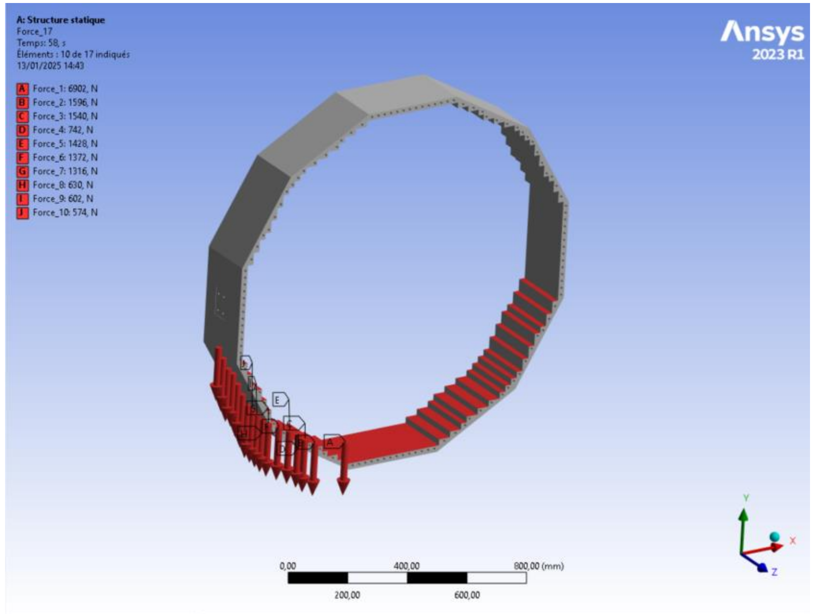
Careful to the galvanic corrosion in the case without copper tubes



Innovating solution with FSW technologie process (Friction Stir Welding)

Mechanical design | External structure (2/4)





A: Structure statique
Force_17
Temps: 58, s
Éléments : 10 de 17 indiqués
13/01/2025 14:43

- A Force_1: 6902, N
- B Force_2: 1596, N
- C Force_3: 1540, N
- D Force_4: 742, N
- E Force_5: 1428, N
- F Force_6: 1372, N
- G Force_7: 1316, N
- H Force_8: 630, N
- I Force_9: 602, N
- J Force_10: 574, N

FEA Model:

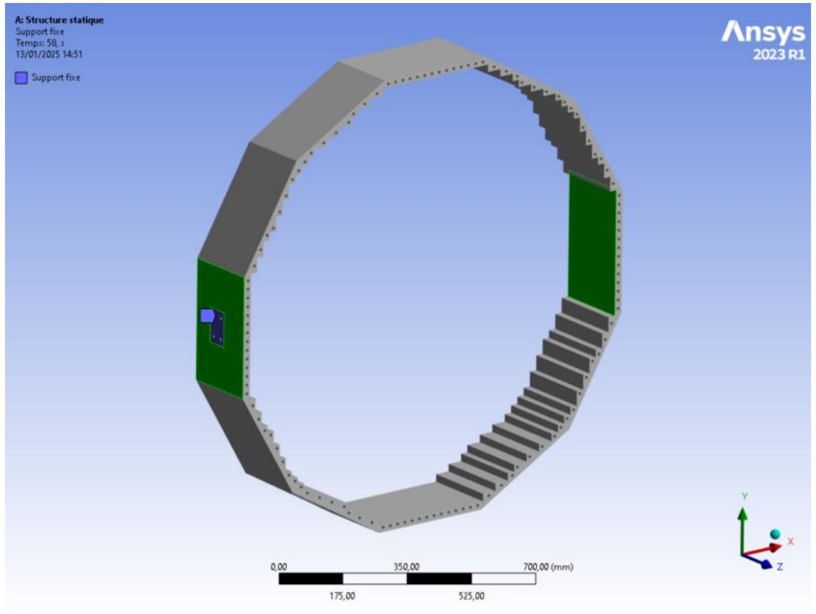
- 1 face at the center

→ 665 Kg

- 16 other faces on both sides

→ 626,5 Kg x2 (11,9 kg to 79,8 Kg)

- 59 steps to check the deflection during the assembly



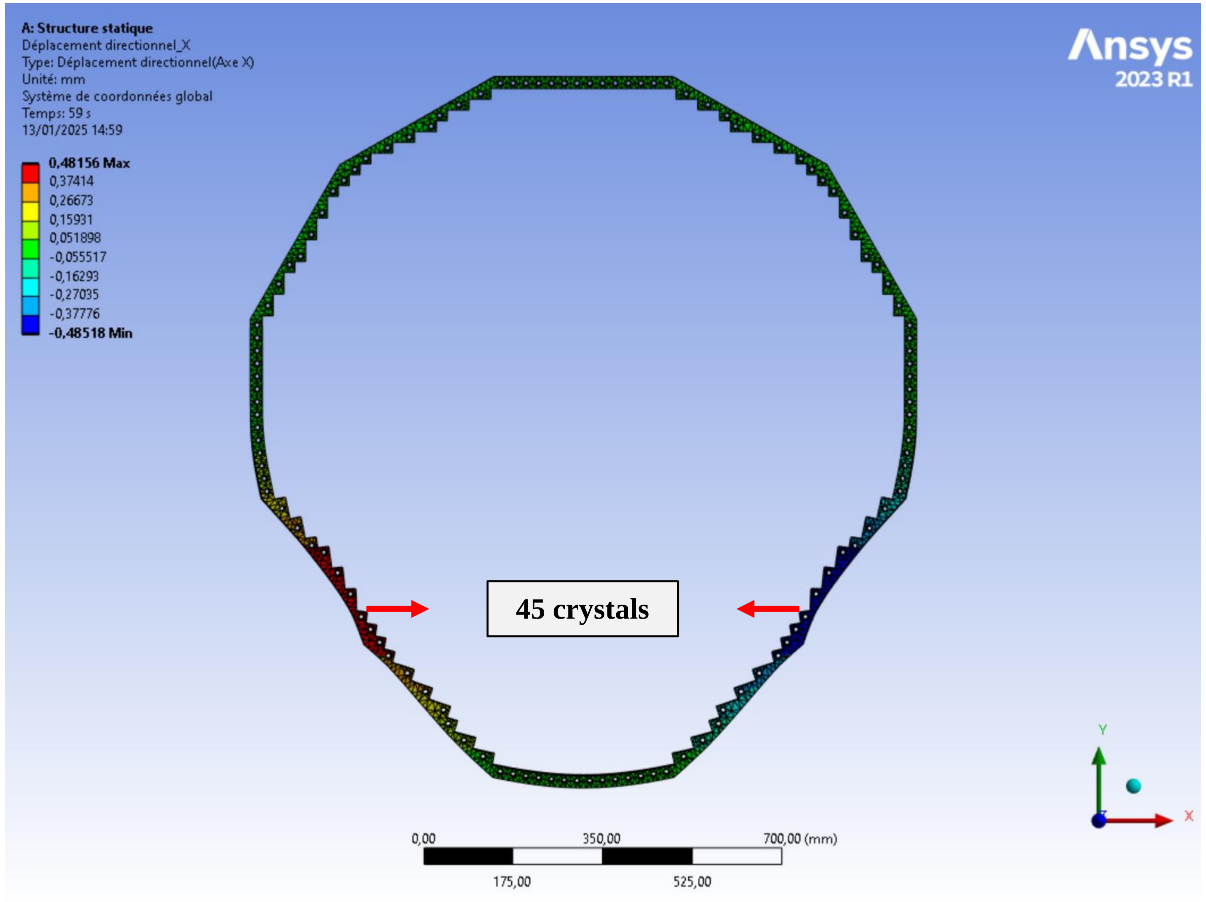
A: Structure statique
Support fixe
Temps: 58, s
13/01/2025 14:51

- 🟦 Support fixe

FEA Model:

- Worst case: fastened at 3 and 9 o'clock
- The way to fasten the structure increase the results in terms of stress

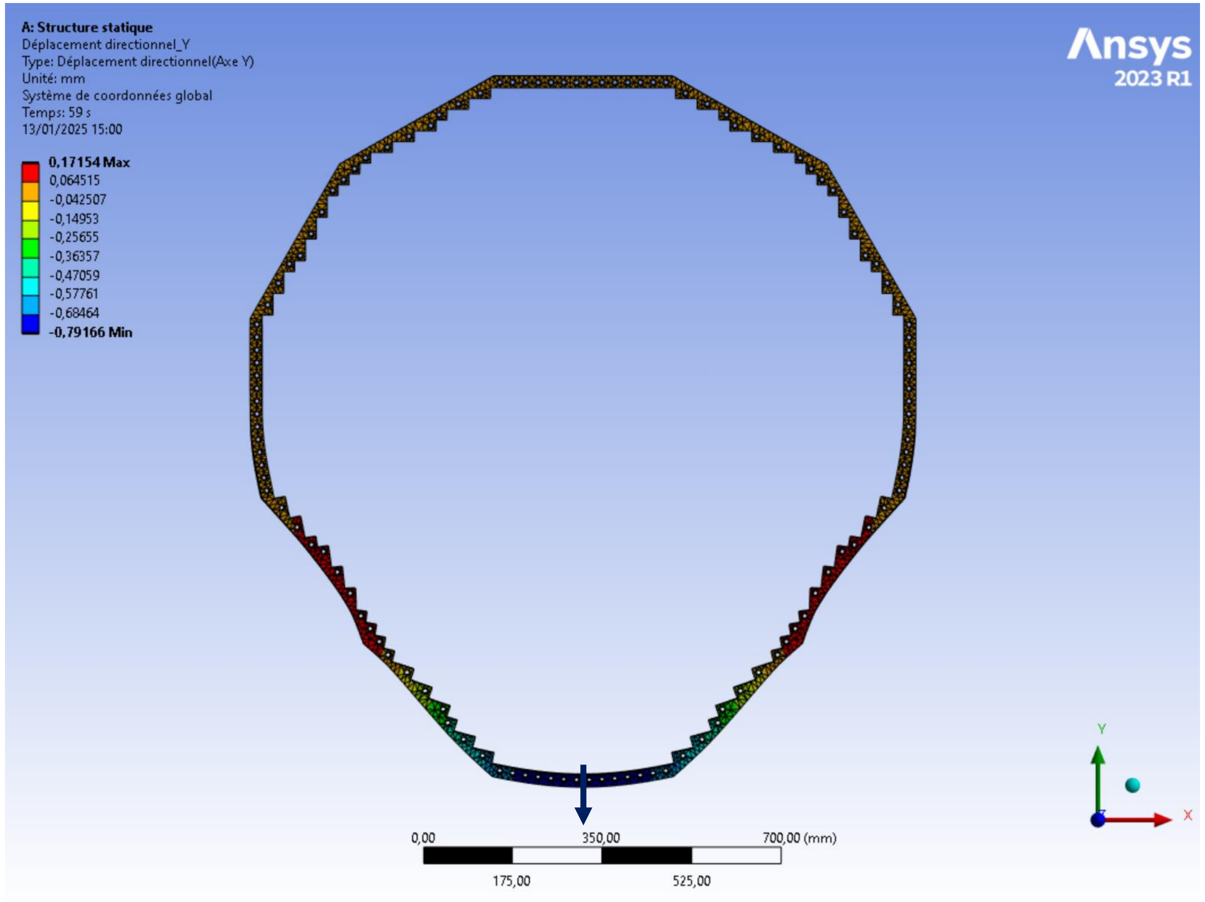
Mechanical design | External structure (3/4)



A: Structure statique
Déplacement directionnel_X
Type: Déplacement directionnel(Axe X)
Unité: mm
Système de coordonnées global
Temps: 59 s
13/01/2025 14:59

45 crystals

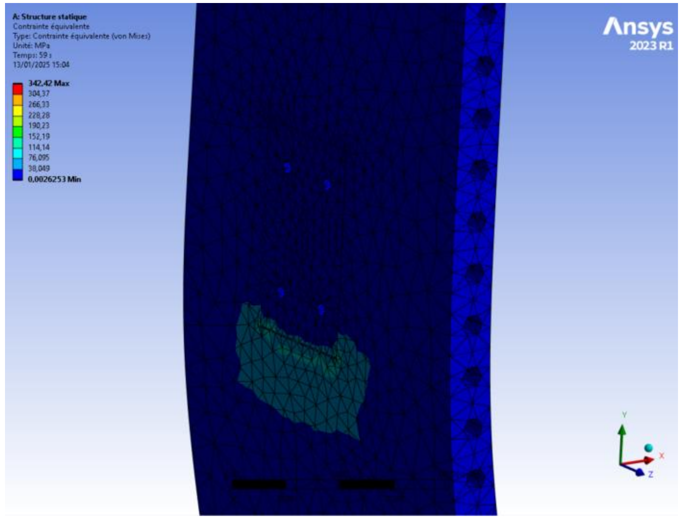
Displacement X < 0,5 mm



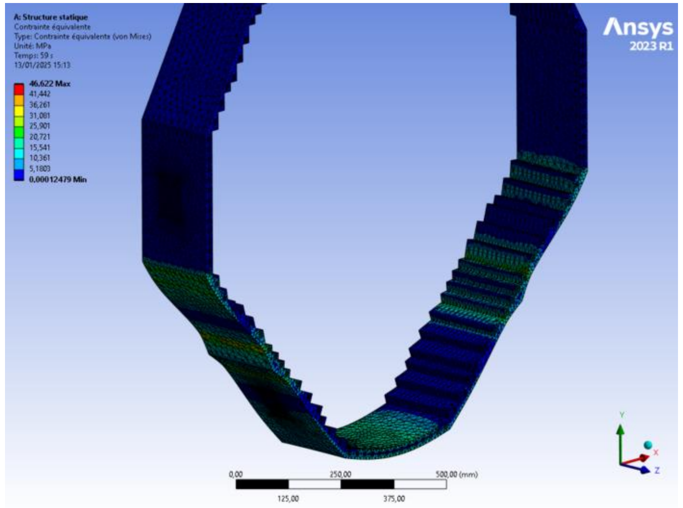
A: Structure statique
Déplacement directionnel_Y
Type: Déplacement directionnel(Axe Y)
Unité: mm
Système de coordonnées global
Temps: 59 s
13/01/2025 15:00

Displacement Y < 0,8 mm

Mechanical design | External structure (4/4)



Small surface
→ Stress= 342 MPa



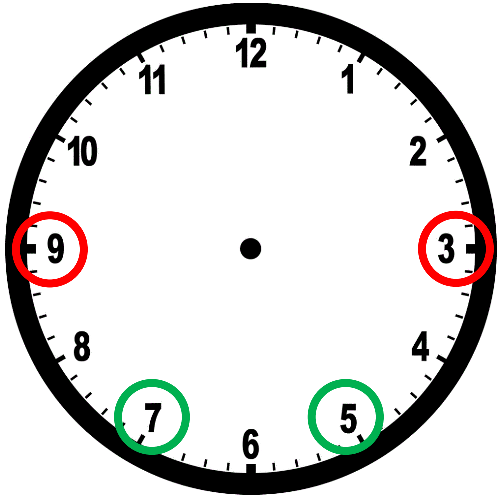
Large surface
→ Stress= 47 MPa

Results:

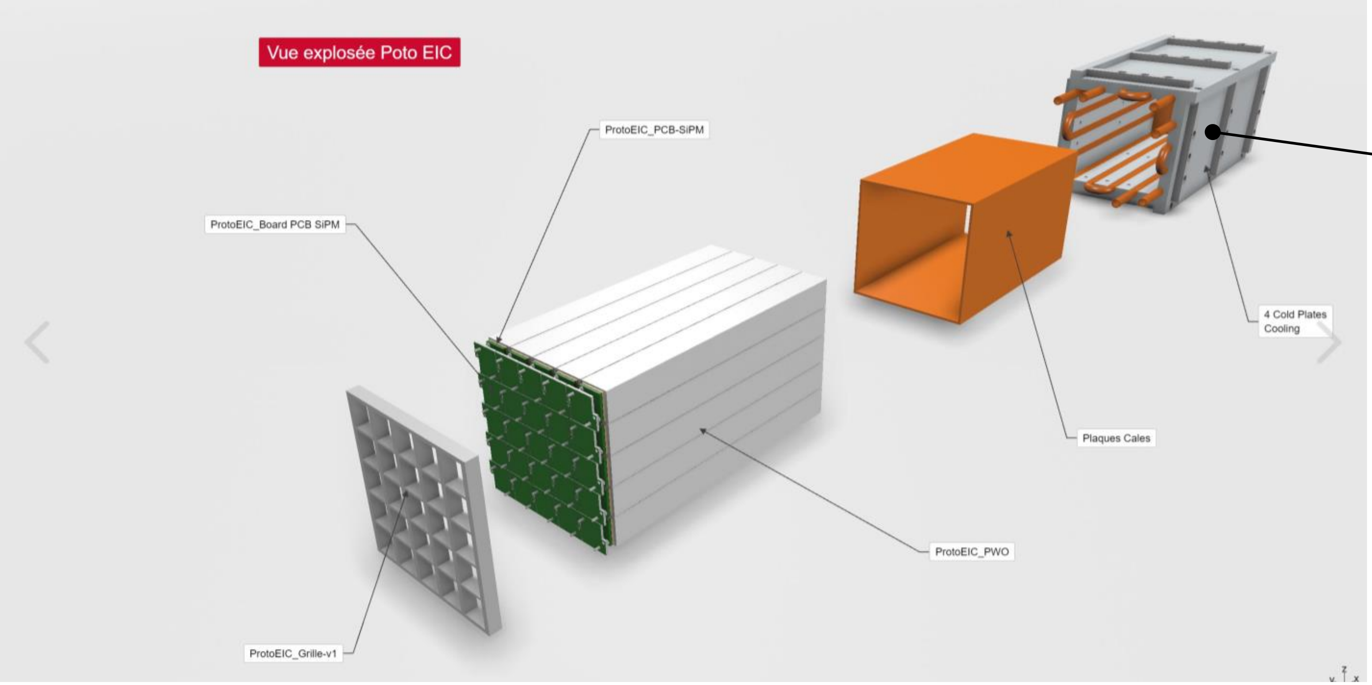
- Displacement X < 0,5 mm → No stress on the crystals (45 crystals +0,025)
- Displacement Y < 0,8 mm for the worst case
- Displacement Y = 0,36 mm for step 26 (just before the assembly of the internal structure)
- Stress: Optimization required

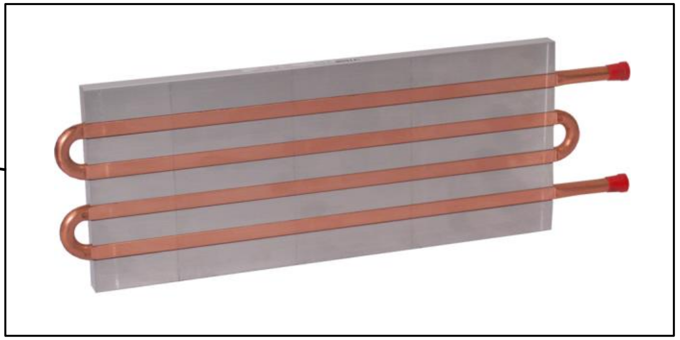
Enhancement:

- Improve the way to fasten the mechanical structure
- Use a large surface reduce the stress and the deflection (almost a factor 2)
- Put the calorimeter on rail at **5 and 7 o'clock** to reduce displacement and stress
- Perform another FEA on the mechanical structure with structure composed by rings and plates

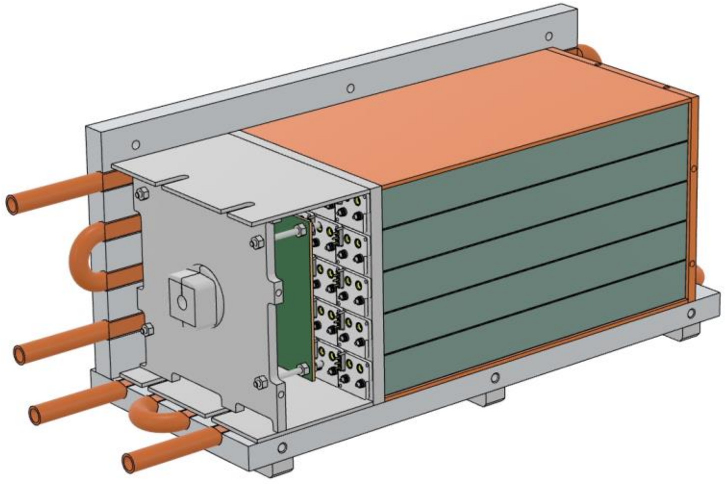


Prototype 5x5 | Mechanical design





4 standard cold plates

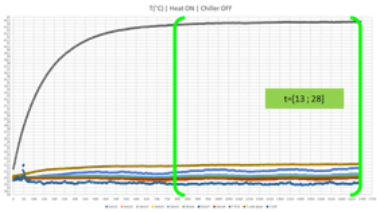


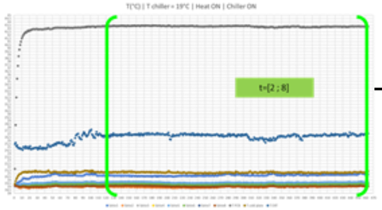
Possibilty to put 25 crystals

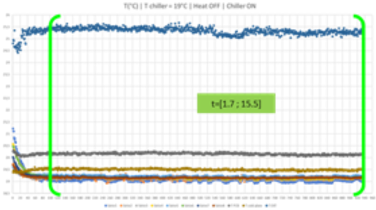
Objectives:

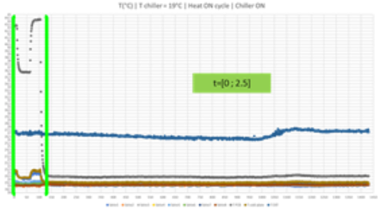
- Test the mechanical assembly
- Test the efficiency of the cooling
- Perfom beam tests
- Tests several configurations of the daughter board

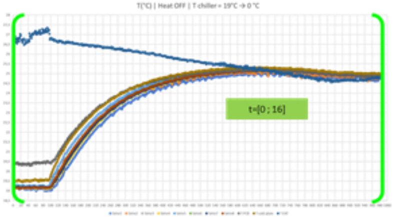
Prototype 5x5 | Room test | Thermal tests

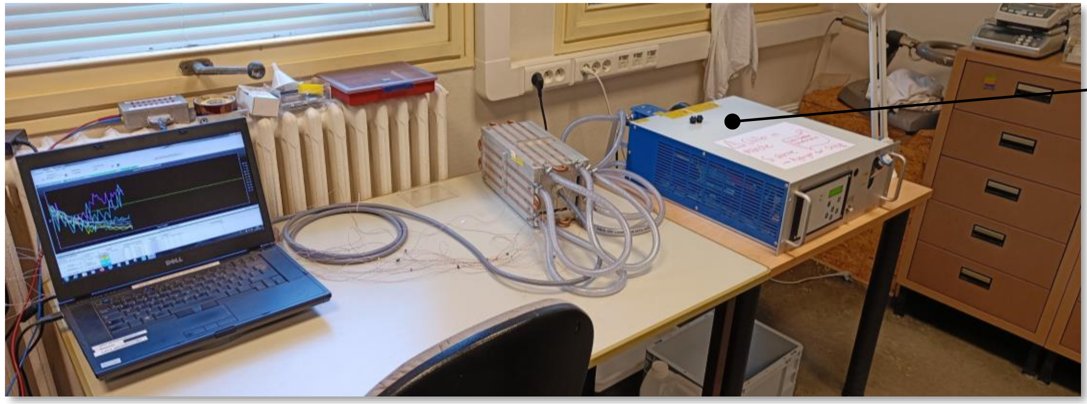












Chiller
Stability = +/- 0,1°C

Setup of the thermal with prototype 5x5 (with cooling)

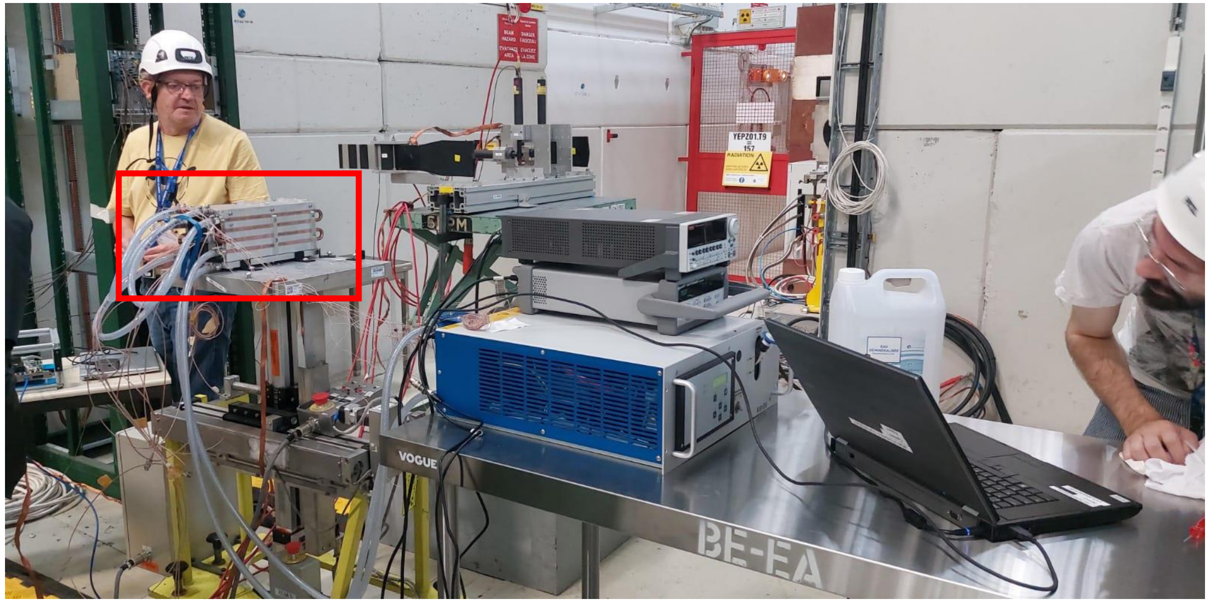
Without cooling
Stability = +/- 0,5°C

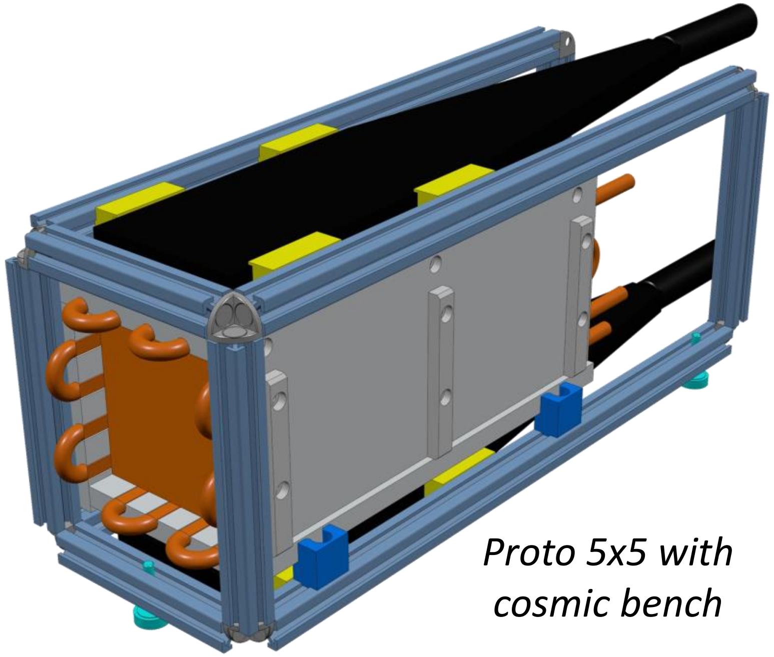
With cooling
Stability = +/- 0,1°C

Room= 19°C – 27°C | PCB= ON, OFF & Cycle | Cooling= ON & OFF

	Standard deviation 1 σ										
Results	**101 (C)**	**102 (C)**	**103 (C)**	**104 (C)**	**105 (C)**	**106 (C)**	**107 (C)**	**108 (C)**	**T° pcb**	**T° plate**	**T° ext**
Heat ON - Chiller OFF	0,15	0,11	0,11	0,09	0,09	0,08	0,04	0,04	0,12	0,07	0,09
Heat ON - Chiller ON	0,11	0,08	0,07	0,07	0,06	0,06	0,05	0,05	0,08	0,07	0,26
Heat OFF - Chiller ON	0,05	0,06	0,04	0,04	0,03	0,03	0,02	0,02	0,04	0,03	0,12
Heat ON cycle - Chiller ON	0,57	0,09	0,06	0,07	0,13	0,06	0,08	0,07	8,83	0,65	0,14
Heat OFF - T chiller = 19°C → 0°C	2,05	1,99	1,99	2,06	1,99	2,06	2,04	2,03	1,62	1,90	0,76

Prototype 5x5 | Beam test | Setup





Proto 5x5 with cosmic bench

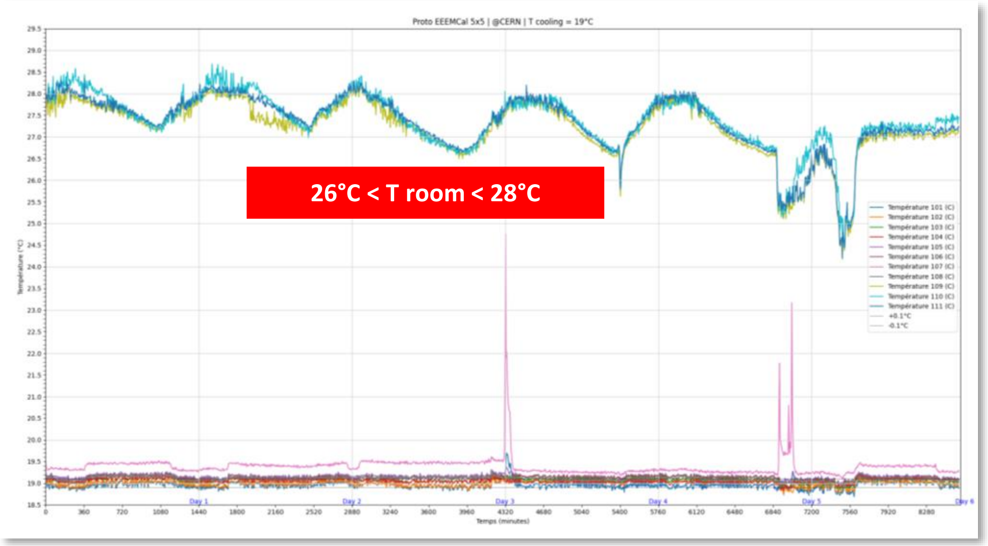
Beam tests performed and planed:

- @ CERN | August 2024
- @ DESY | November 2024 (problem, fire in the accelerator part)
- @ DESY | February 2025

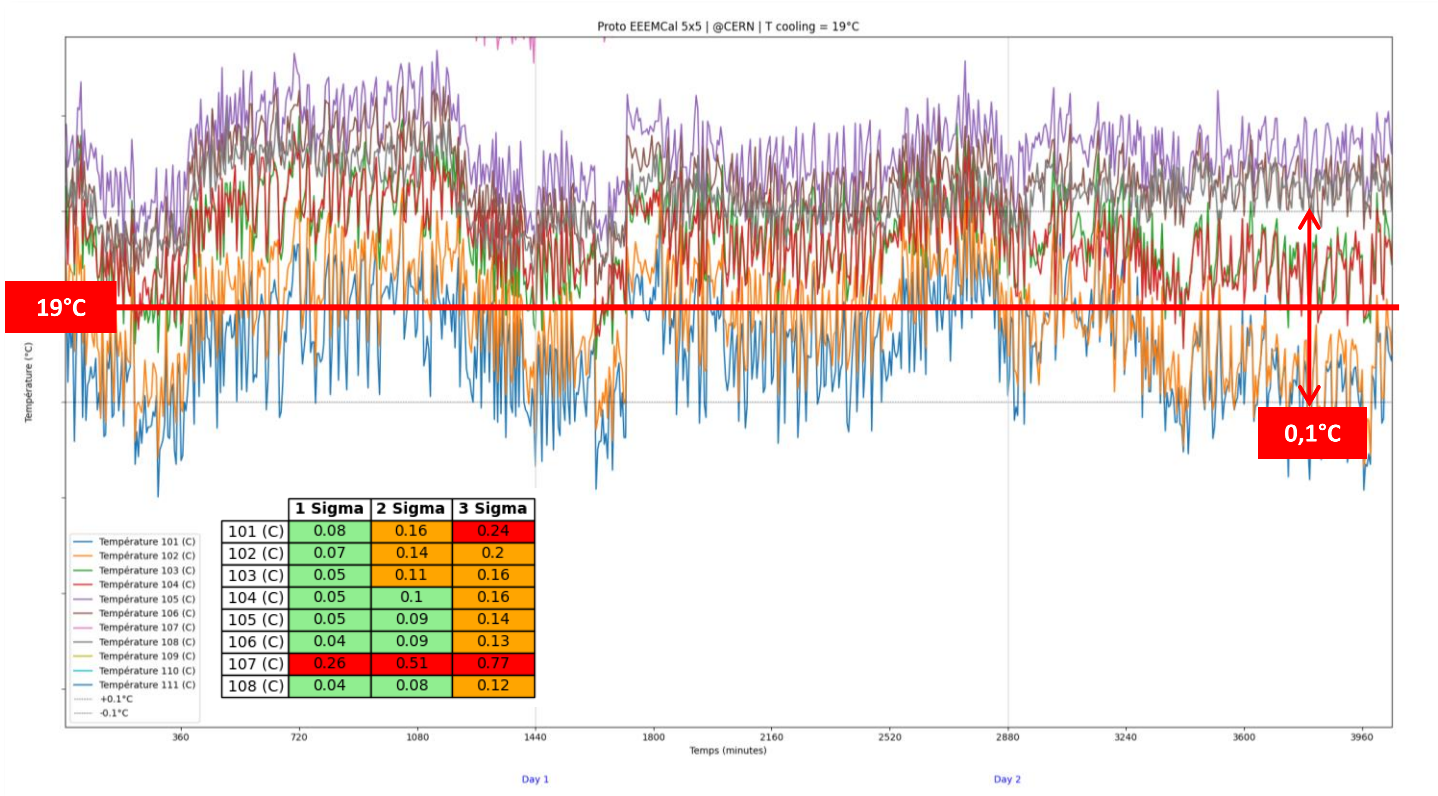
Main objectives:

- Take physics data and validate reading by SiPM
- Tests several configurations of the daughter board

Prototype 5x5 | Beam test | Thermal analysis



Room= 26°C – 28°C | T= 3 days | Cooling= 19°C



	1 Sigma	2 Sigma	3 Sigma
101 (C)	0.08	0.16	0.24
102 (C)	0.07	0.14	0.2
103 (C)	0.05	0.11	0.16
104 (C)	0.05	0.1	0.16
105 (C)	0.05	0.09	0.14
106 (C)	0.04	0.09	0.13
107 (C)	0.26	0.51	0.77
108 (C)	0.04	0.08	0.12

Evolution of the temperature of the crystals during the beam test at CERN

Beam test @ CERN:

- Temperature stability under +/- 0,1°C
- Problem on one sensor (107, out of use)

Assembly (1/2)

List of materials to install:

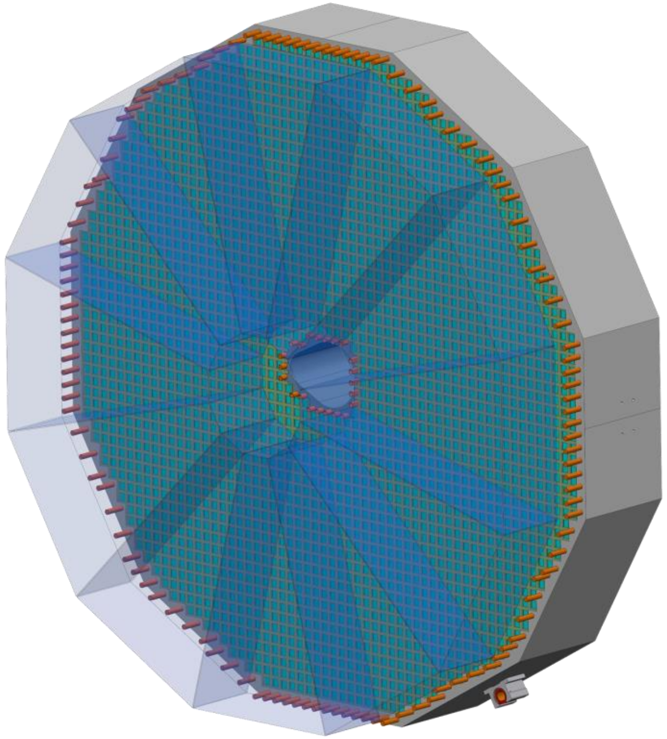
- Crystals
- Mechanical structures (internal & external)
- Grid (fastening of the PCB)
- Copper plate, Insulation
- Cooling
- Electronic boxes, Cables

Geographical location:

- Crystals → USA
- Mechanics, cooling → France
- Electronics, cables → France (a priori)
- Transport by plane in flight-cases

Options considered for the assembly:

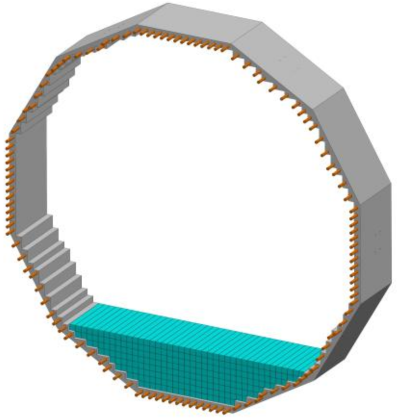
- Pre assembly without crystals @IJCLab (Orsay, France)
- Assembly @Jlab or/and @BNL



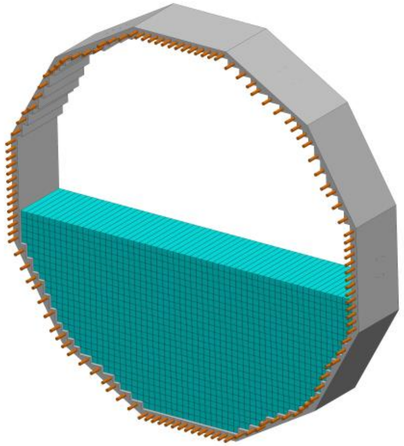
Resources required:

- To be discussed with the collaboration
- Wrapping task performed in parallel

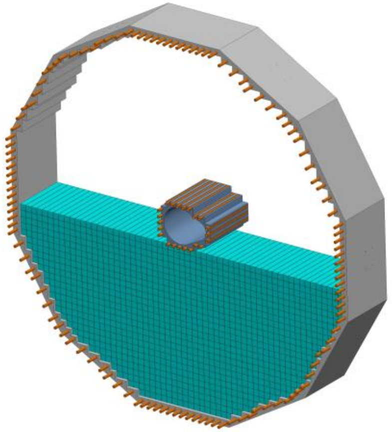
Assembly (2/2)



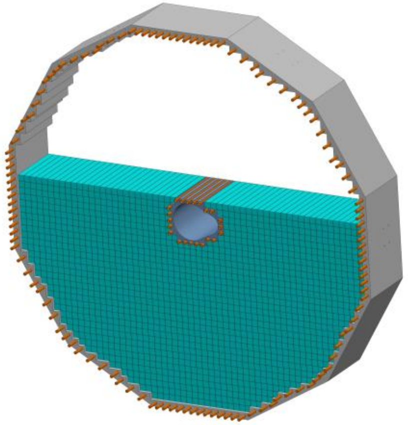
Start of the assembly
of the crystals



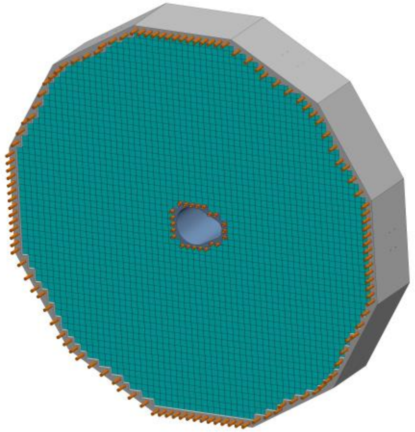
Control before the assembly
of the internal structure



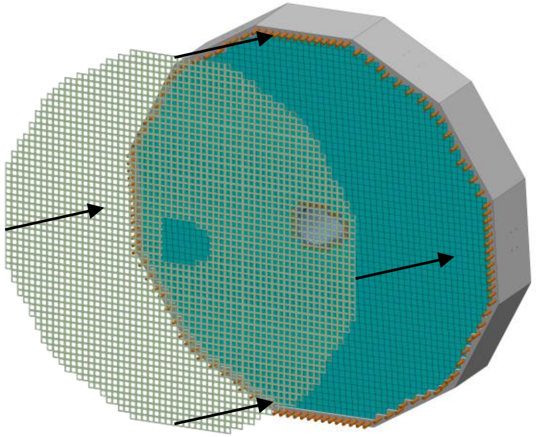
Positioning of the
internal structure



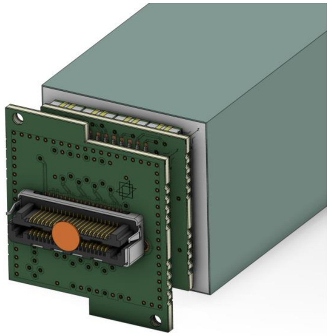
Control after the assembly
of the internal structure



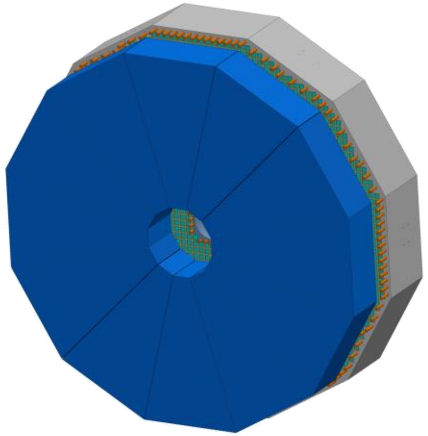
End of the assembly
of the crystals



Fastening of the grid



Optical coupling between the SiPM PCB
and the crystal.
Quality control by the other side (front)

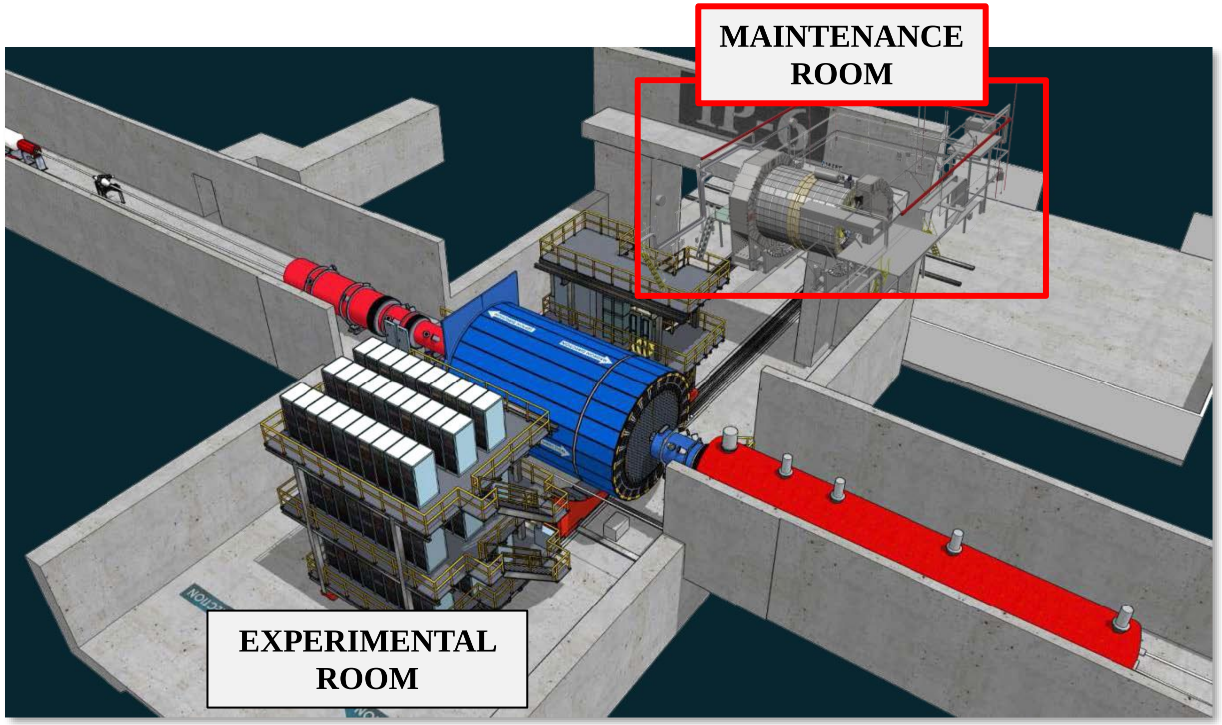


Assembly of the electronic boxes +
insulation (back) and copper plate (front)

⇨

<u>Ready to:</u>
Cabling, tubing
INTEGRATION

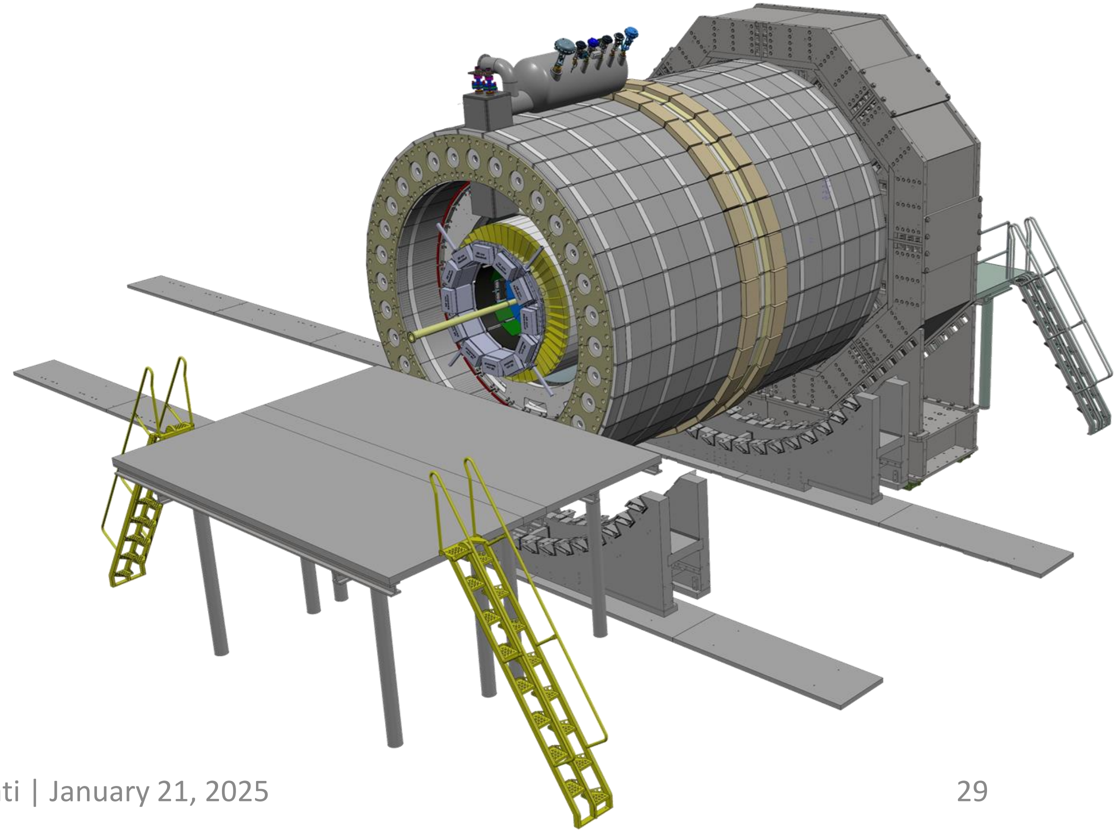
Installation (1/2)



Overview of the experimental and maintenance rooms

Requirements:

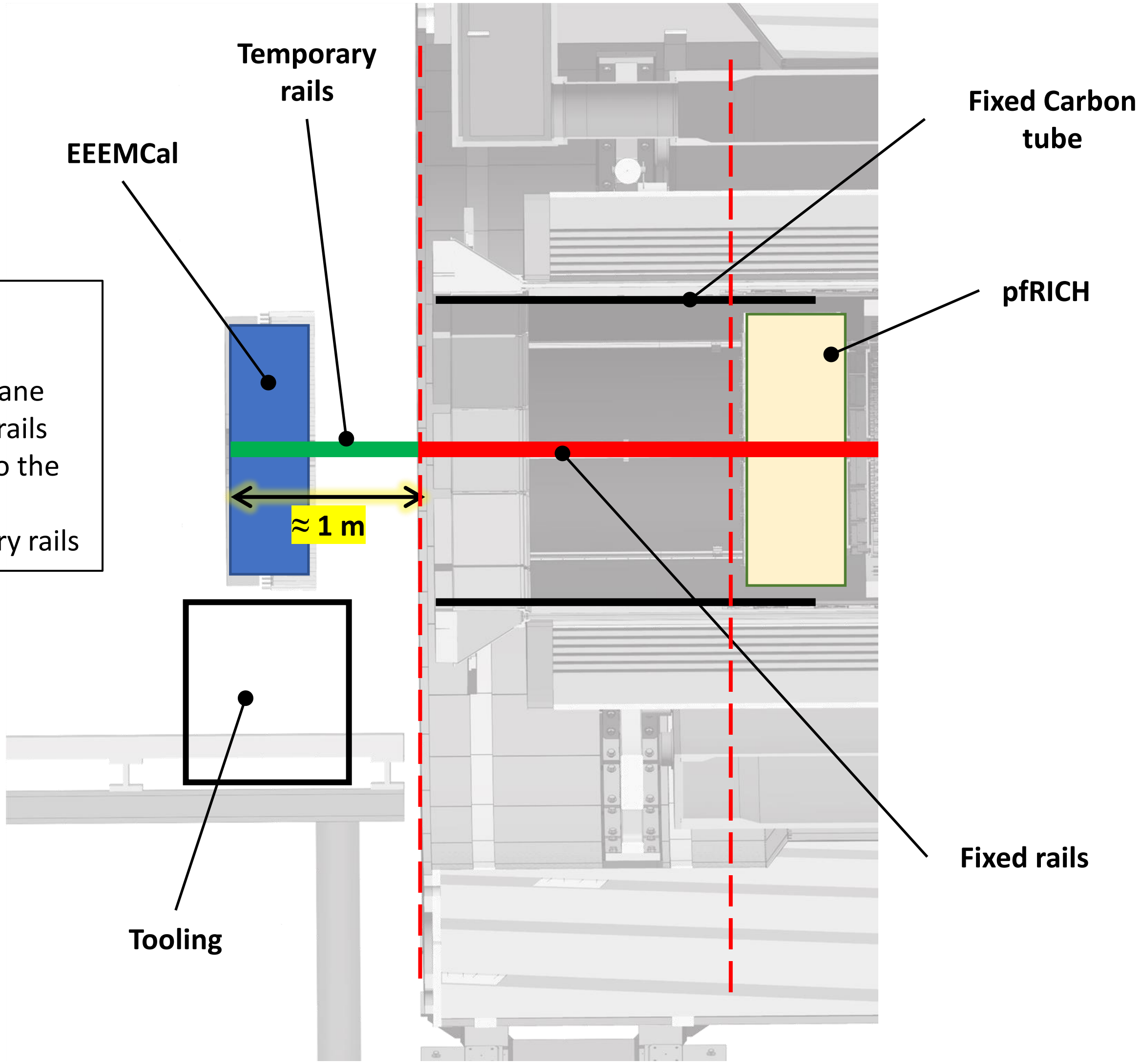
- Work in the maintenance room
- Disconnect the beam pipe
- Work plateform
- Special tooling assembly & Bridge crane

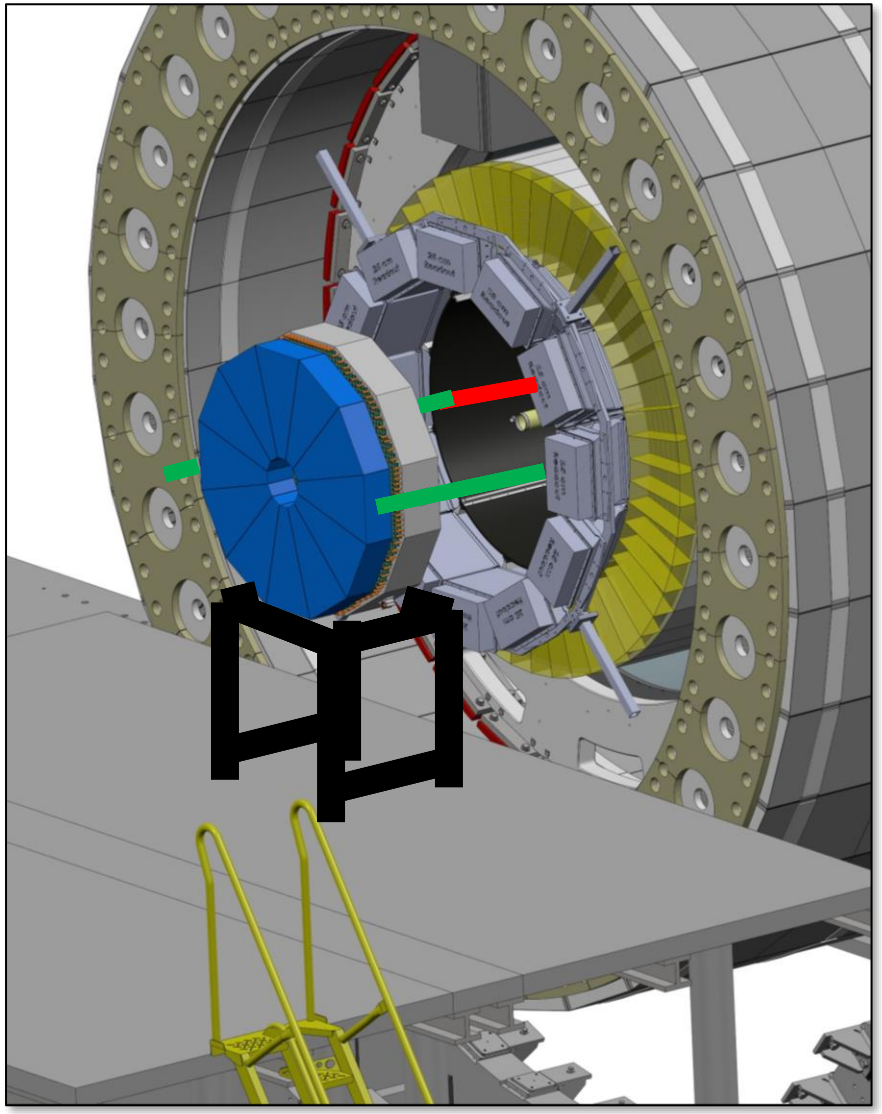


Installation (2/2)

Steps:

- Put the detector on a tooling with bridge crane
- Fasten the temporay rails
- Slide the detector into the carbon tube
- Remove the temporary rails





Summary

Requirements, Clearances and Crystals

- The requirements for the physics of the EEEMCal are defined
- The main clearances are defined
- The crystals configuration is defined

Electronic Readout

- There is a significant work on the FEB and RDO
- The location of the power depends on the FEB
- The choice of the SiPM is done (pratically)

Cooling

- The environment is correctly known
- The results of the simulations are OK
- Thermal simulation (mechanical, Fluent) with advanced design

Mechanical design

- We have to choose the means of production for the structures (machining or foundry)
- The results of the FEA are encouraging
- Perform FEA simulation with advanced design

Prototype 5x5

- The prototype with 25 crystals is operational
- The measure of the stabilty is OK
- There is a beam test @DESY in february 2025
- Instrumental tests planed

Assembly

- The procedure is on going
- It depends on the very Front-End and the FEB
- Assembly test @ICLab
- Final assembly @Jlab or @BNL

Installation

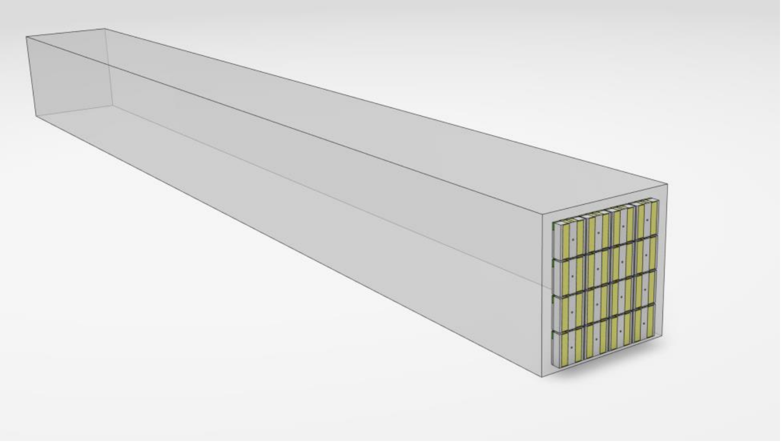
- The positioning of the rails for the inserting has to be defined
- The handling of the detector has to be studied
- The services depends on the FEB and the cooling

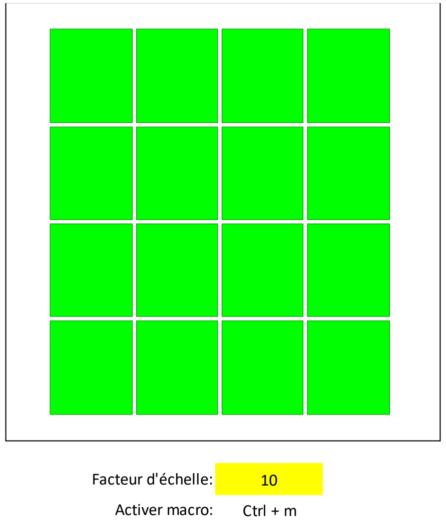
2025

- Design of the FEB
- Validation: SiPM, readout
- Results of the beam tests
- End of the R&D on the structures
- Mechanical prototype(s)
- TDR

Backup slides

Readout setup | SiPM configuration





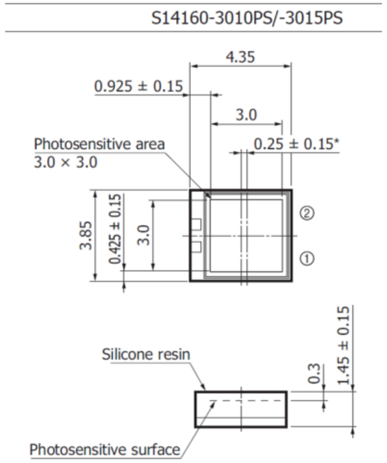
Facteur d'échelle: 10

Activer macro: Ctrl + m

a	Transverse x size of the crystal	20,5	*mm*	
	Matrix crystals	1	*x*	1
d	Space between crystals (carbon+wrapping)	0,76	*mm*	
	Transverse y size of the crystal	20,5	*mm*	
h	SiPM	4,35	*mm*	
l	SiPM	3,85	*mm*	
h x l	Matrix SiPM	4	*x*	4
e	Space between SiPM	0,2	*mm*	
H	Matrix SiPM	18	*mm*	
L	Matrix SiPM	16	*mm*	

Surface crystal		420,25	*mm2*
Surface SiPM		16,75	*mm2*
Detection active SiPM		3,00	*mm*
Surface active SiPM		9,00	*mm2*
Total active SiPM		144,00	*mm2*
Active surface SiPM		**34,27**	**%**
Distance SiPM / Cristal	H	1,250	*mm*
Distance SiPM / Cristal	L	2,250	*mm*

Hamamatsu S14160 6010 (10µm)	*H 7,35* *L 6,85* *6 mm* *Active 6x6*
Hamamatsu S14160 3010 (10µm)	*H 4,35* *L 3,85* *3 mm* *Active 3x3*



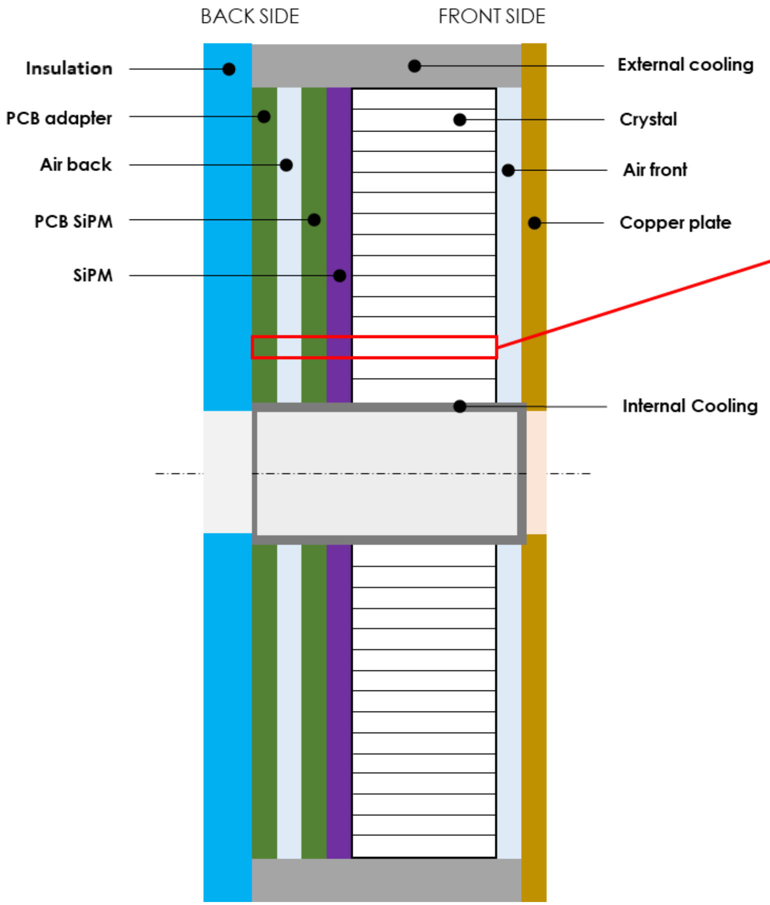
SiPM:

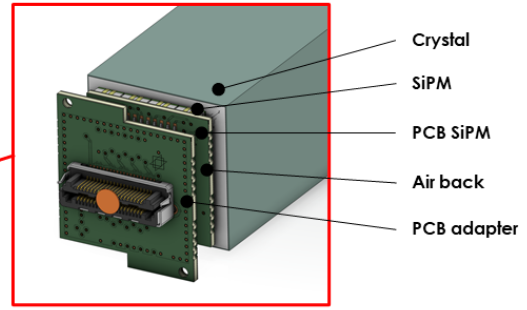
- Reference: S14160-3015PS
- 4x4 SiPM per crystal → 43840 SiPM
- Surface covered by the SiPM ≈ **34%**
- Current discussion on the design of the FEB

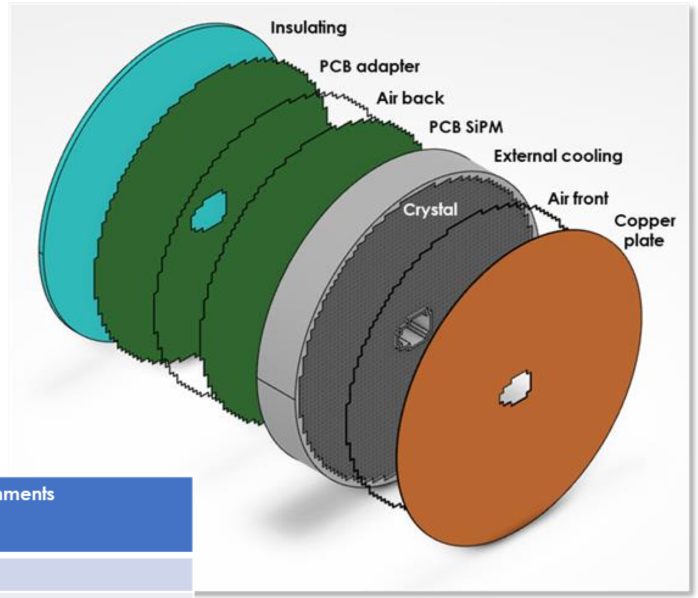
Option 2x2 SiPM (6x6 mm2) continue to be considered

Cooling | Thermal simulation (1/4)

Simplified design for ANSYS thermal analysis







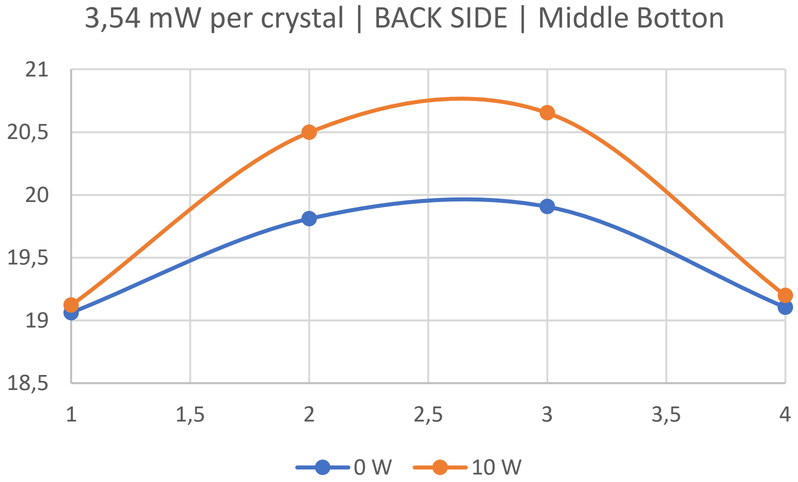
Designation	Material	Thickness (mm)	Thermal conductivity ($W.m^{-1}.K^{-1}$)		Comments
External cooling	Aluminum	20 - 30	237		
Crystal	PWO	20,5 x 20,5	2-2,4		L= 200 mm
Air front	Air	5	0,026		
Copper plate	Copper	5	390		
Internal cooling	Aluminum	10	237		
Insulating		25	0,029		ROOFMATE
PCB adapter	Epoxy	1	0,25		
Air back	Air	2	0,026		Between PCBs
PCB SiPM	Epoxy	1	0,25		
SiPM	Epoxy	1,45	0,25		0,3 mm Silicon resin + 15 µm + Epoxy

Model:

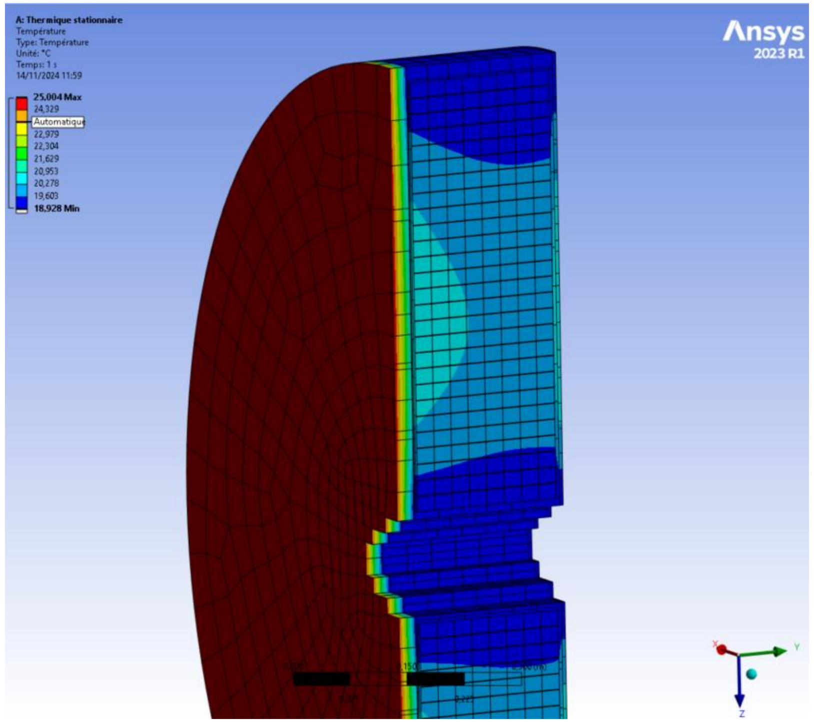
- To check the efficiency of the insulation
- No power near to the crystals

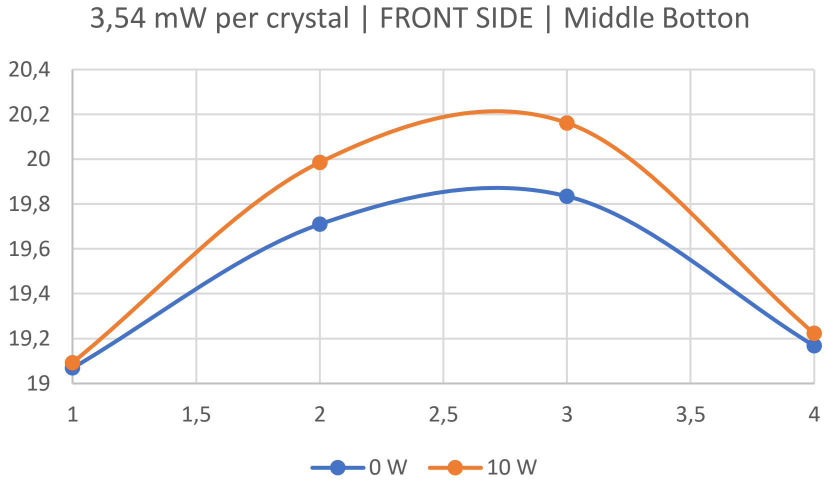
Cooling | Thermal Simulation

STEADY STATE | Room temperature 26°C | Cooling= 19°C | SiPM irradiation | 0W → 10W (total) in one year



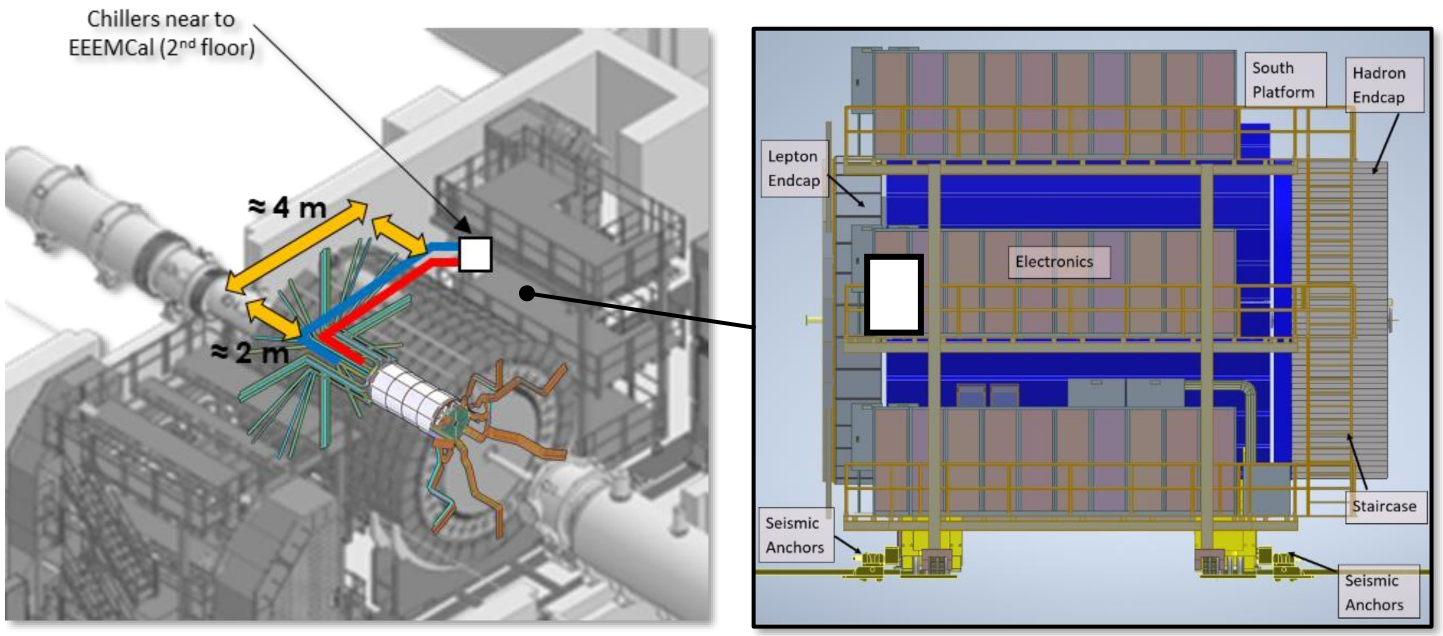
3,54 mW per crystal | BACK SIDE | Middle Botton

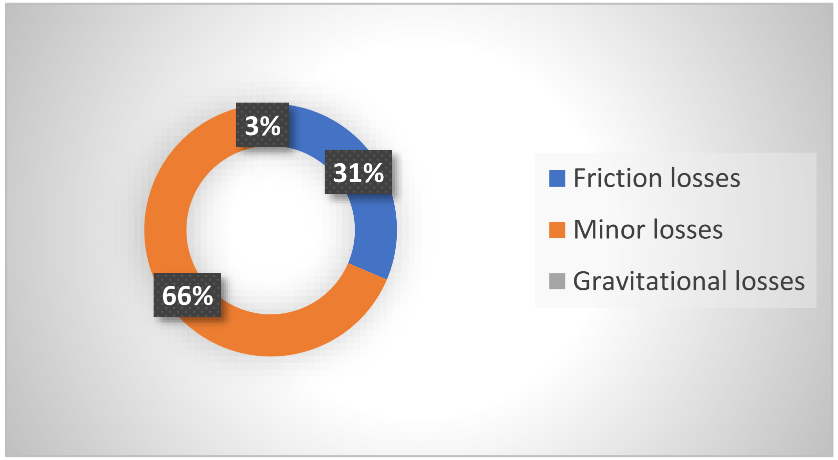


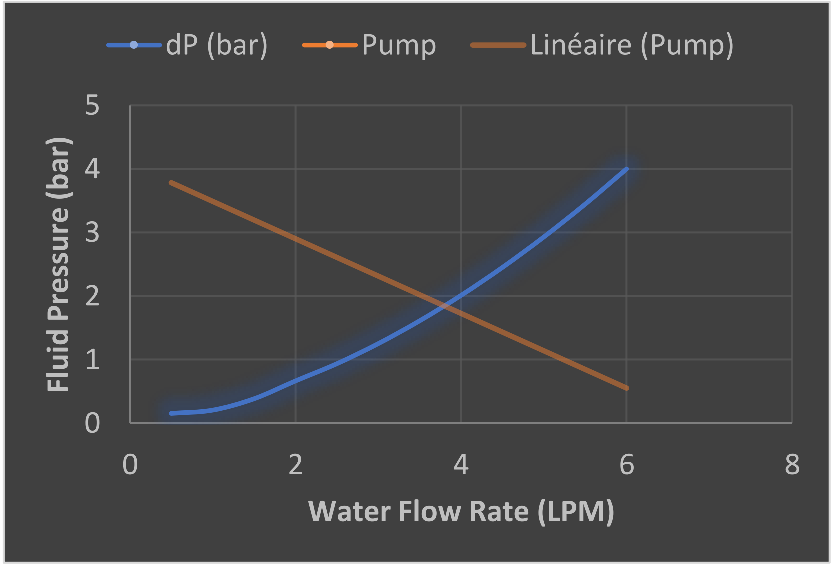


3,54 mW per crystal | FRONT SIDE | Middle Botton

Cooling | Chillers / Pressure drop



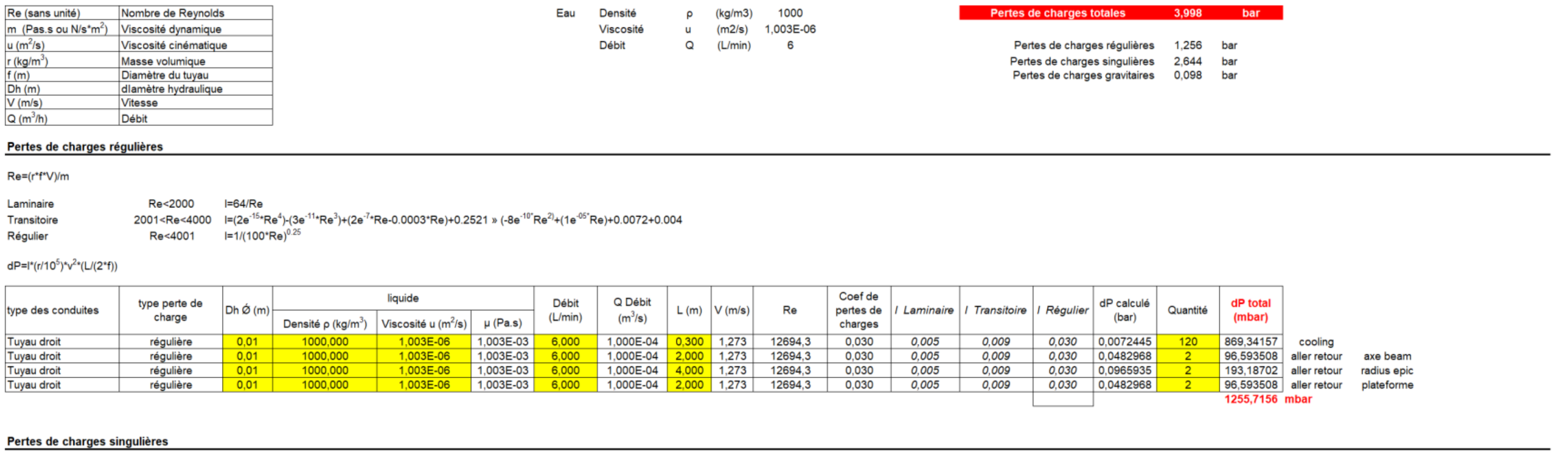




To be considered:

- The location of the chillers
- The entire network of tubes for the cooling
- The power of the pump of the chiller

Cooling | Chillers / Pressure drop



Re (sans unité)	Nombre de Reynolds
m (Pas.s ou N/s*m^2)	Viscosité dynamique
u (m^2/s)	Viscosité cinématique
r (kg/m^3)	Masse volumique
f (m)	Diamètre du tuyau
Dh (m)	dIamètre hydraulique
V (m/s)	Vitesse
Q (m^3/h)	Débit

Eau	Densité	ρ	(kg/m3)	1000
	Viscosité	u	(m2/s)	1,003E-06
	Débit	Q	(L/min)	6

Pertes de charges totales	**3,998**	**bar**
Pertes de charges régulières	1,256	bar
Pertes de charges singulières	2,644	bar
Pertes de charges gravitaires	0,098	bar

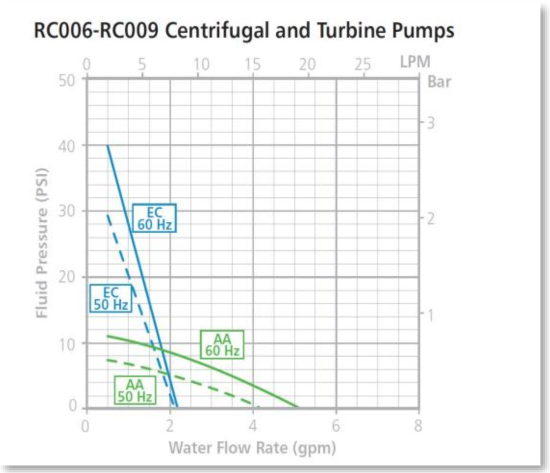
Pertes de charges régulières

Re=(r*f*V)/m

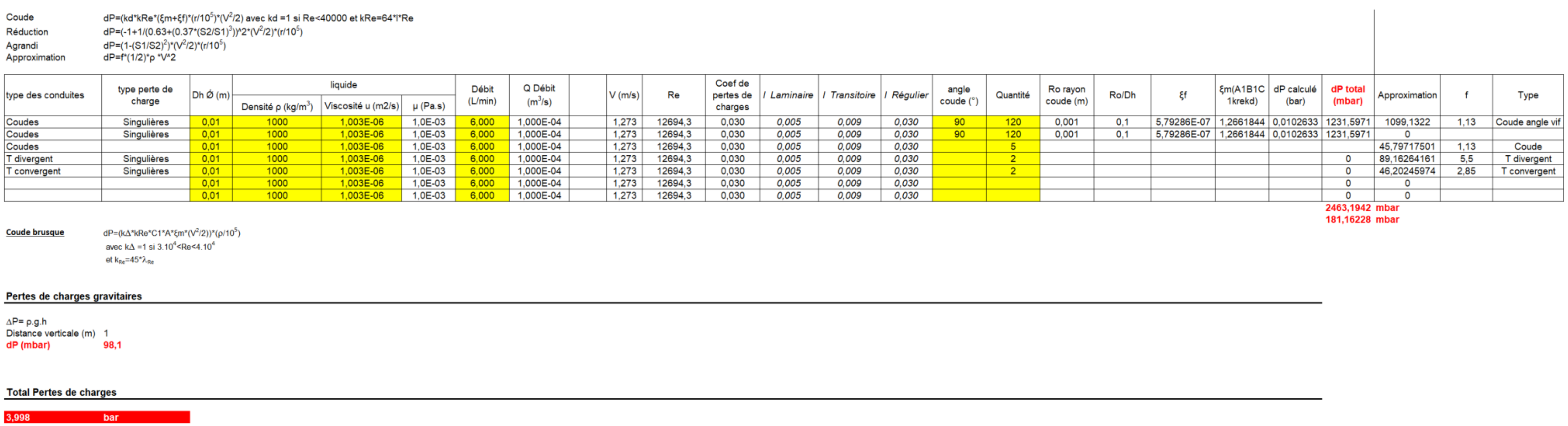
Laminaire	Re<2000	I=64/Re
Transitoire	2001<Re<4000	I=(2e^{-15}*Re^4)-(3e^{-11}*Re^3)+(2e^{-7}*Re-0.0003*Re)+0.2521 » (-8e^{-10}*Re$^{2)}$+(1e^{-05}*Re)+0.0072+0.004
Régulier	Re<4001	I=1/(100*Re)$^{0.25}$

dP=I*(r/10^5)*v^2*(L/(2*f))

type des conduites	type perte de charge	Dh Ø (m)	liquide			Débit (L/min)	Q Débit (m^3/s)	L (m)	V (m/s)	Re	Coef de pertes de charges	*l Laminaire*	*l Transitoire*	*l Régulier*	dP calculé (bar)	Quantité	dP total (mbar)		
			Densité ρ (kg/m^3)	Viscosité u (m^2/s)	μ (Pa.s)														
Tuyau droit	régulière	0,01	1000,000	1,003E-06	1,003E-03	6,000	1,000E-04	0,300	1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*	0,0072445	120	869,34157	cooling	
Tuyau droit	régulière	0,01	1000,000	1,003E-06	1,003E-03	6,000	1,000E-04	2,000	1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*	0,0482968	2	96,593508	aller retour	axe beam
Tuyau droit	régulière	0,01	1000,000	1,003E-06	1,003E-03	6,000	1,000E-04	4,000	1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*	0,0965935	2	193,18702	aller retour	radius epic
Tuyau droit	régulière	0,01	1000,000	1,003E-06	1,003E-03	6,000	1,000E-04	2,000	1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*	0,0482968	2	96,593508	aller retour	plateforme
																	1255,7156 mbar		



RC006-RC009 Centrifugal and Turbine Pumps



Pertes de charges singulières

Coude	dP=(kd*kRe*(ξm+ξf)*(r/10^5)*(V^2/2) avec kd =1 si Re<40000 et kRe=64*I*Re
Réduction	dP=(-1+1/(0.63+(0.37*(S2/S1)^3))^2*(V^2/2)*(r/10^5)
Agrandi	dP=(1-(S1/S2)^2)*(V^2/2)*(r/10^5)
Approximation	dP=f*(1/2)*ρ *V^2

type des conduites	type perte de charge	Dh Ø (m)	liquide			Débit (L/min)	Q Débit (m^3/s)		V (m/s)	Re	Coef de pertes de charges	*l Laminaire*	*l Transitoire*	*l Régulier*	angle coude (°)	Quantité	Ro rayon coude (m)	Ro/Dh	ξf	ξm(A1B1C 1krekd)	dP calculé (bar)	dP total (mbar)	Approximation	f	Type
			Densité ρ (kg/m^3)	Viscosité u (m2/s)	μ (Pa.s)																				
Coudes	Singulières	0,01	1000	1,003E-06	1,0E-03	6,000	1,000E-04		1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*	90	120	0,001	0,1	5,79286E-07	1,2661844	0,0102633	1231,5971	1099,1322	1,13	Coude angle vif
Coudes	Singulières	0,01	1000	1,003E-06	1,0E-03	6,000	1,000E-04		1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*	90	120	0,001	0,1	5,79286E-07	1,2661844	0,0102633	1231,5971	0		
Coudes		0,01	1000	1,003E-06	1,0E-03	6,000	1,000E-04		1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*		5							45,79717501	1,13	Coude
T divergent	Singulières	0,01	1000	1,003E-06	1,0E-03	6,000	1,000E-04		1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*		2						0	89,16264161	5,5	T divergent
T convergent	Singulières	0,01	1000	1,003E-06	1,0E-03	6,000	1,000E-04		1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*		2						0	46,20245974	2,85	T convergent
		0,01	1000	1,003E-06	1,0E-03	6,000	1,000E-04		1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*								0	0		
		0,01	1000	1,003E-06	1,0E-03	6,000	1,000E-04		1,273	12694,3	0,030	*0,005*	*0,009*	*0,030*								0	0		
																						2463,1942	**mbar**		
																						181,16228	**mbar**		

Coude brusque dP=(kΔ*kRe*C1*A*ξm*(V^2/2))*(ρ/10^5)

avec kΔ =1 si 3.10^4<Re<4.10^4

et k$_{Re}$=45*λ$_{Re}$

Pertes de charges gravitaires

ΔP= ρ.g.h

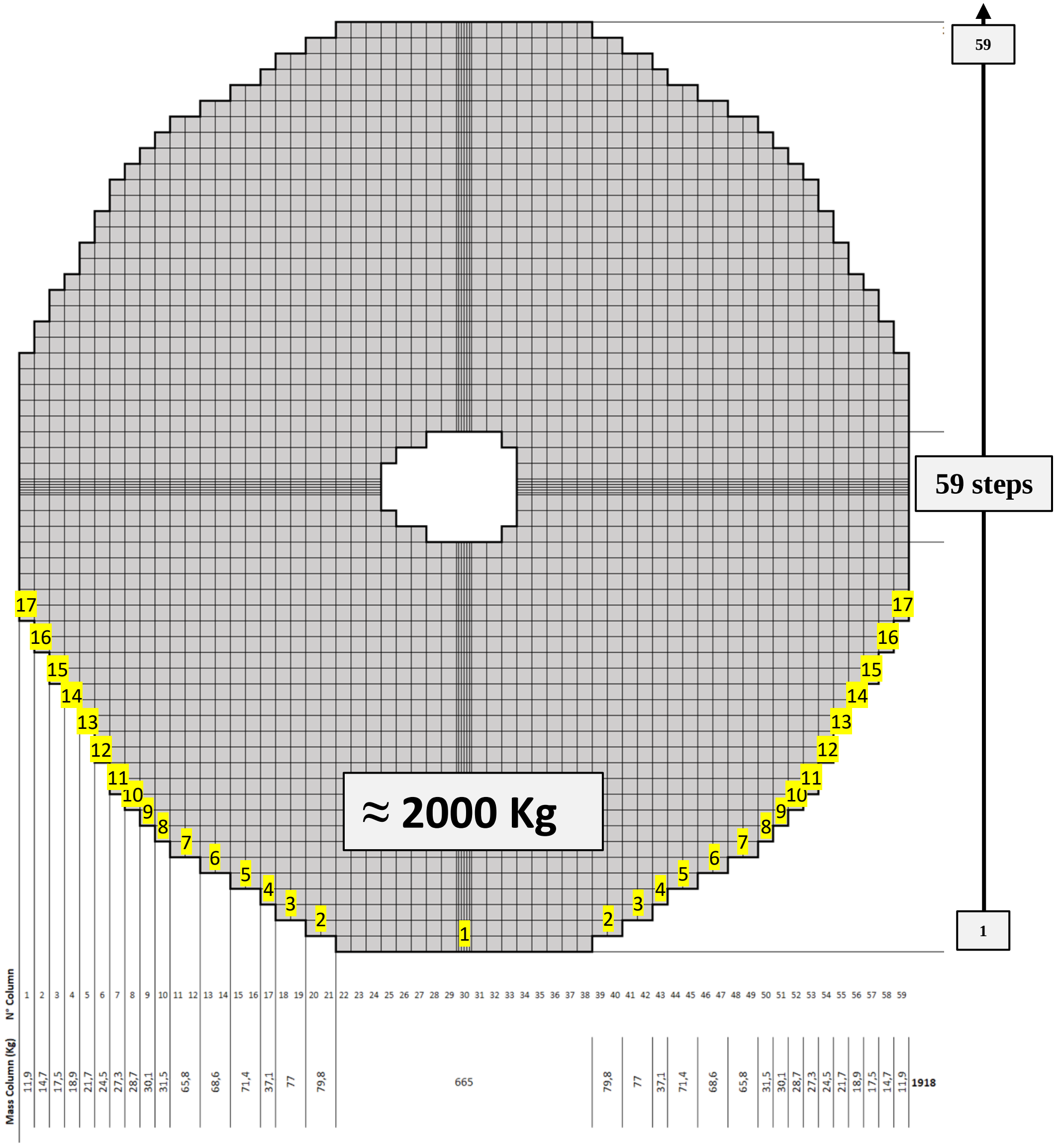
Distance verticale (m)	1
dP (mbar)	**98,1**

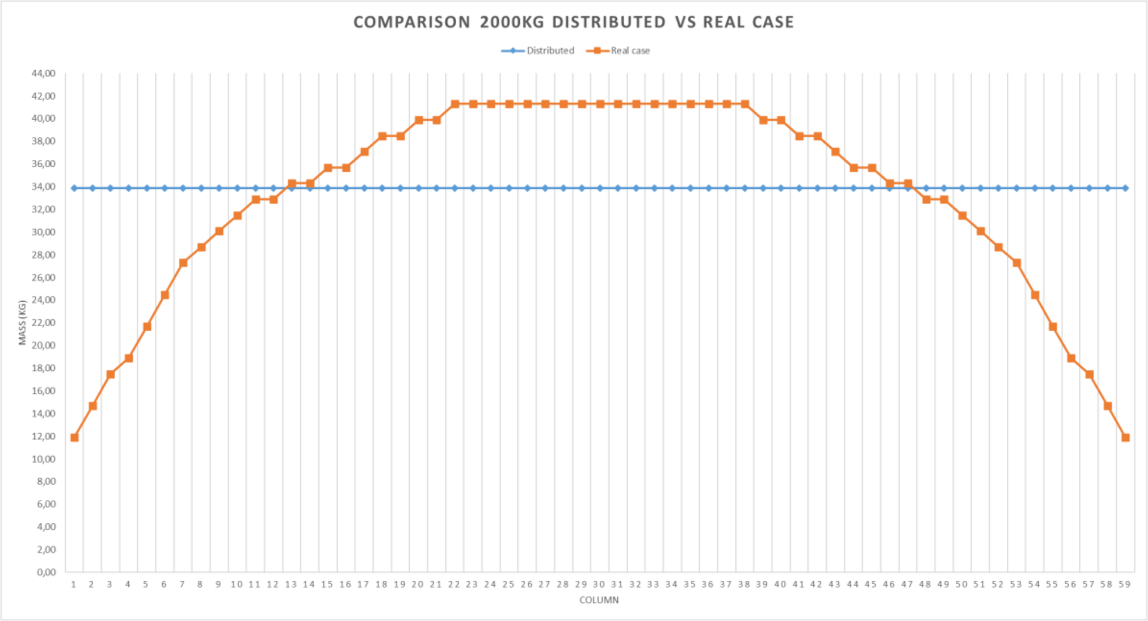
Total Pertes de charges

3,998 bar

Mechanical design | External structure

Nb Crystals	Mass layer (Kg)	N° layer
17	11,9	59
21	14,7	58
25	17,5	57
27	18,9	56
31	21,7	55
35	24,5	54
39	27,3	53
41	28,7	52
43	30,1	51
45	31,5	50
47	32,9	49
47	32,9	48
49	34,3	47
49	34,3	46
51	35,7	45
51	35,7	44
53	37,1	43
55	38,5	42
55	38,5	41
57	39,9	40
57	39,9	39
59	41,3	38
59	41,3	37
59	41,3	36
59	41,3	35
59	41,3	34
54	37,8	33
51	35,7	32
50	35	31
50	35	30
50	35	29
51	35,7	28
54	37,8	27
59	41,3	26
59	41,3	25
59	41,3	24
59	41,3	23
59	41,3	22
57	39,9	21
57	39,9	20
55	38,5	19
55	38,5	18
53	37,1	17
51	35,7	16
51	35,7	15
49	34,3	14
49	34,3	13
47	32,9	12
47	32,9	11
45	31,5	10
43	30,1	9
41	28,7	8
39	27,3	7
35	24,5	6
31	21,7	5
27	18,9	4
25	17,5	3
21	14,7	2
17	11,9	1
2740	**1918**	

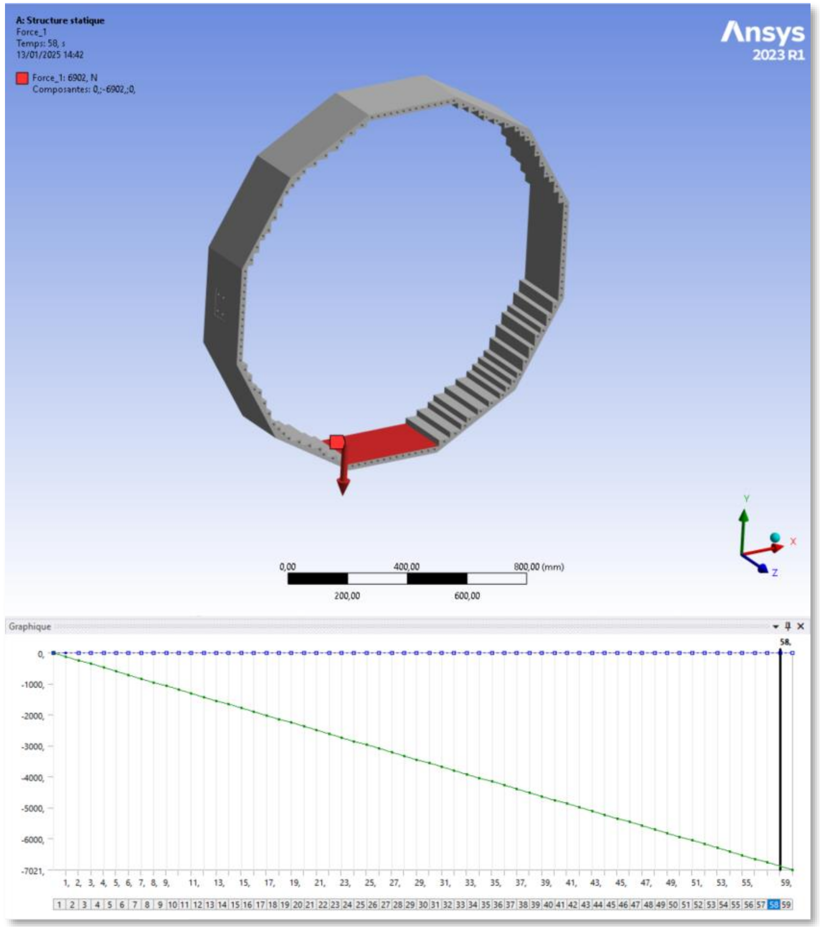




FEA Model:

- 2740 crystals
- About 2 Tons on the mechanical structure
- 1 face at the center → 665 Kg
- 16 other faces on both sides → 626,5 Kg x2 (11,9 kg to 79,8 Kg)
- Real case used for the FEA

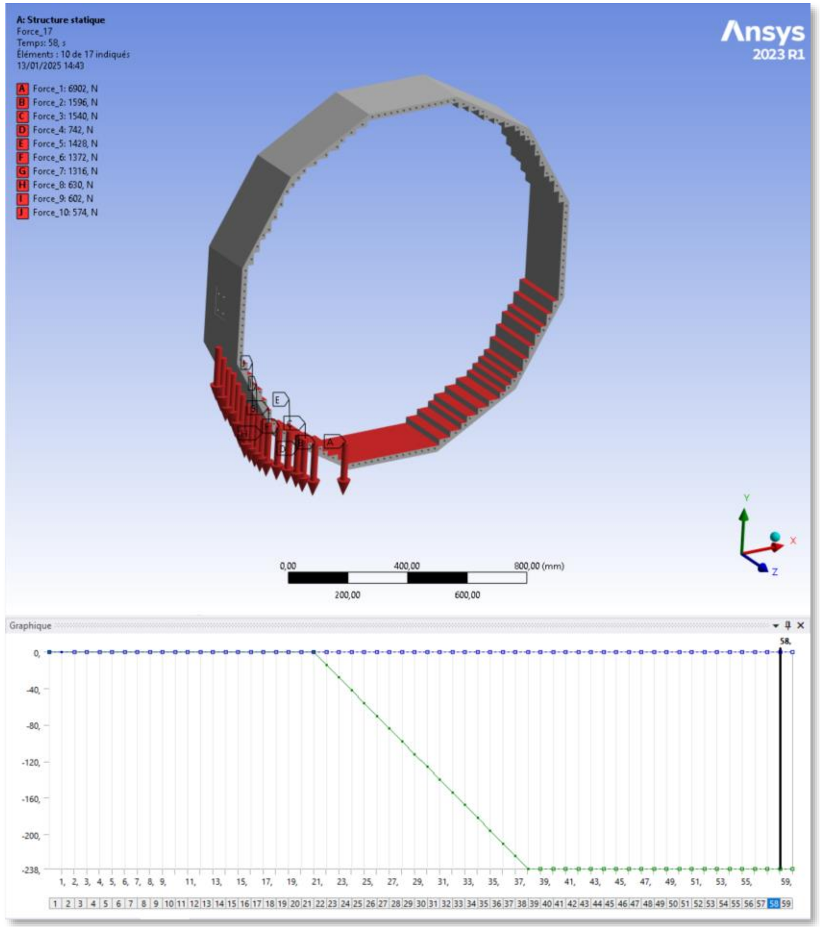
Mechanical design | External structure



A: Structure statique
Force_1
Temps: 58, s
13/01/2025 14:42

🟥 Force_1: 6902, N
Composantes: 0,;-6902,;0,

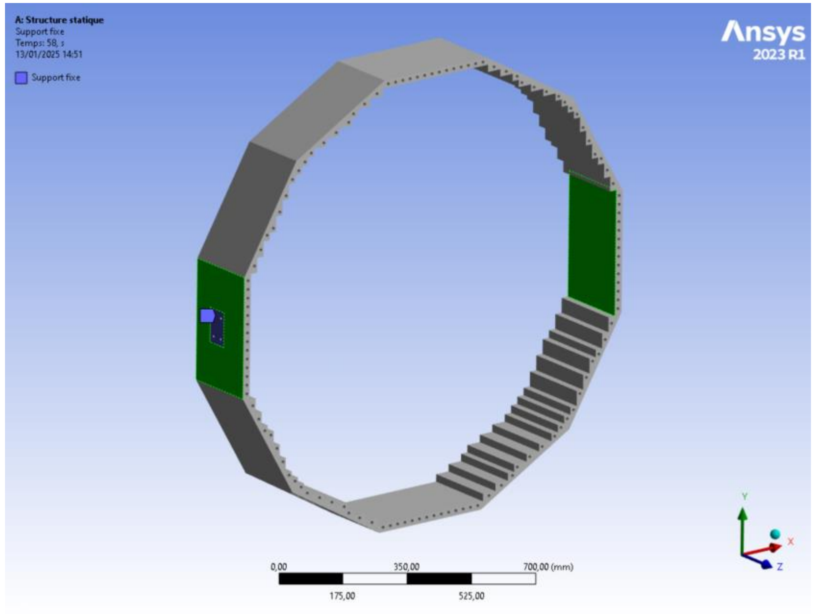
Progression of the force on face 1



A: Structure statique
Force_17
Temps: 58, s
Éléments : 10 de 17 indiqués
13/01/2025 14:43

- A Force_1: 6902, N
- B Force_2: 1596, N
- C Force_3: 1540, N
- D Force_4: 742, N
- E Force_5: 1428, N
- F Force_6: 1372, N
- G Force_7: 1316, N
- H Force_8: 630, N
- I Force_9: 602, N
- J Force_10: 574, N

Forces on all faces



A: Structure statique
Support fixe
Temps: 58, s
13/01/2025 14:51

🟦 Support fixe

FEA Model:

- Worst case: fastened at 3 and 9 o'clock
- The way to fasten the structure increase the results in terms of stress

Mechanical design | External structure

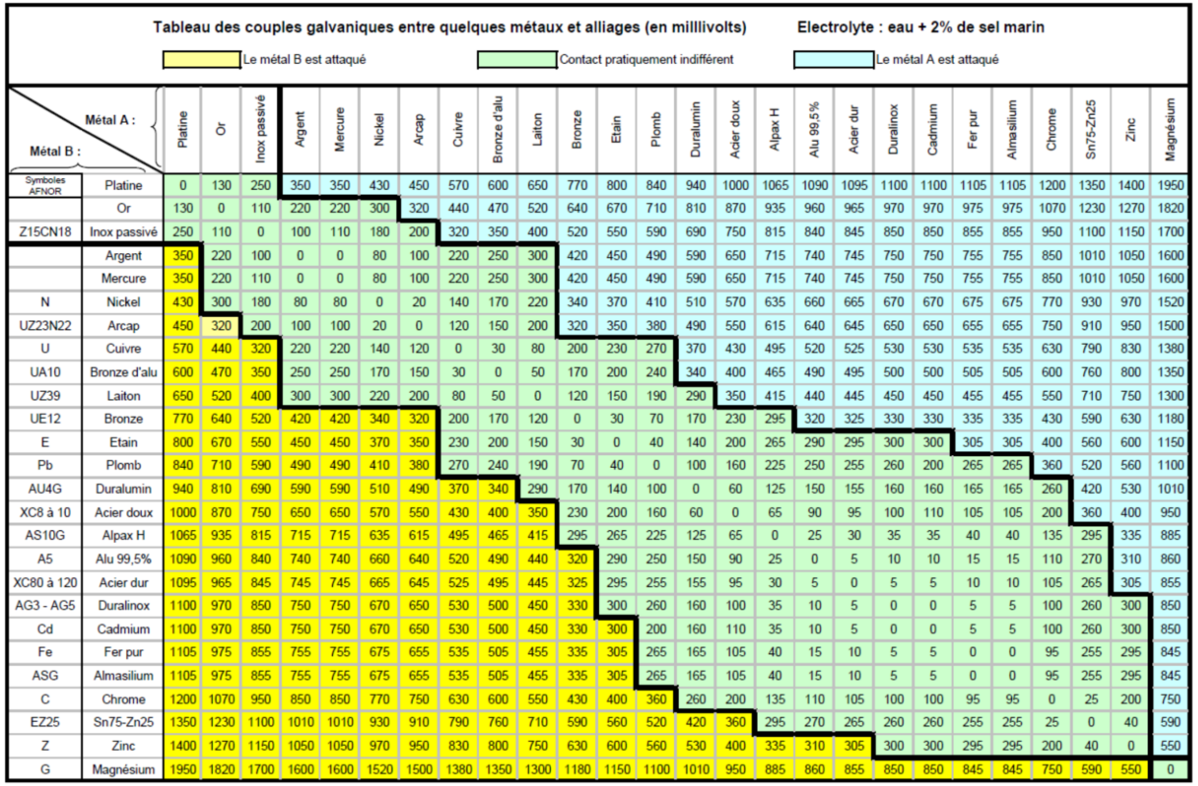
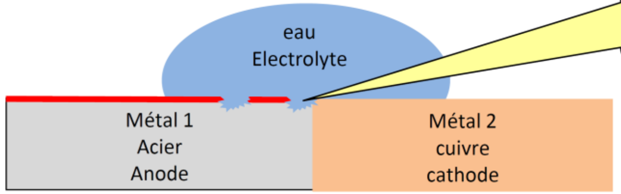


Tableau des couples galvaniques entre quelques métaux et alliages (en milllivolts) **Electrolyte : eau + 2% de sel marin**

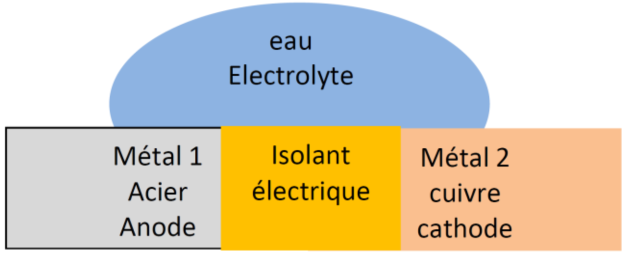
🟨 Le métal B est attaqué 🟩 Contact pratiquement indifférent 🟦 Le métal A est attaqué

	Métal A : Métal B :	Platine	Or	Inox passivé	Argent	Mercure	Nickel	Arcap	Cuivre	Bronze d'alu	Laiton	Bronze	Etain	Plomb	Duralumin	Acier doux	Alpax H	Alu 99,5%	Acier dur	Duralinox	Cadmium	Fer pur	Almasilium	Chrome	Sn75-Zn25	Zinc	Magnésium
Symboles AFNOR	Platine	0	130	250	350	350	430	450	570	600	650	770	800	840	940	1000	1065	1090	1095	1100	1100	1105	1105	1200	1350	1400	1950
	Or	130	0	110	220	220	300	320	440	470	520	640	670	710	810	870	935	960	965	970	970	975	975	1070	1230	1270	1820
Z15CN18	Inox passivé	250	110	0	100	110	180	200	320	350	400	520	550	590	690	750	815	840	845	850	850	855	855	950	1100	1150	1700
	Argent	350	220	100	0	0	80	100	220	250	300	420	450	490	590	650	715	740	745	750	750	755	755	850	1010	1050	1600
	Mercure	350	220	110	0	0	80	100	220	250	300	420	450	490	590	650	715	740	745	750	750	755	755	850	1010	1050	1600
N	Nickel	430	300	180	80	80	0	20	140	170	220	340	370	410	510	570	635	660	665	670	670	675	675	770	930	970	1520
UZ23N22	Arcap	450	320	200	100	100	20	0	120	150	200	320	350	380	490	550	615	640	645	650	650	655	655	750	910	950	1500
U	Cuivre	570	440	320	220	220	140	120	0	30	80	200	230	270	370	430	495	520	525	530	530	535	535	630	790	830	1380
UA10	Bronze d'alu	600	470	350	250	250	170	150	30	0	50	170	200	240	340	400	465	490	495	500	500	505	505	600	760	800	1350
UZ39	Laiton	650	520	400	300	300	220	200	80	50	0	120	150	190	290	350	415	440	445	450	450	455	455	550	710	750	1300
UE12	Bronze	770	640	520	420	420	340	320	200	170	120	0	30	70	170	230	295	320	325	330	330	335	335	430	590	630	1180
E	Etain	800	670	550	450	450	370	350	230	200	150	30	0	40	140	200	265	290	295	300	300	305	305	400	560	600	1150
Pb	Plomb	840	710	590	490	490	410	380	270	240	190	70	40	0	100	160	225	250	255	260	200	265	265	360	520	560	1100
AU4G	Duralumin	940	810	690	590	590	510	490	370	340	290	170	140	100	0	60	125	150	155	160	160	165	165	260	420	530	1010
XC8 à 10	Acier doux	1000	870	750	650	650	570	550	430	400	350	230	200	160	60	0	65	90	95	100	110	105	105	200	360	400	950
AS10G	Alpax H	1065	935	815	715	715	635	615	495	465	415	295	265	225	125	65	0	25	30	35	35	40	40	135	295	335	885
A5	Alu 99,5%	1090	960	840	740	740	660	640	520	490	440	320	290	250	150	90	25	0	5	10	10	15	15	110	270	310	860
XC80 à 120	Acier dur	1095	965	845	745	745	665	645	525	495	445	325	295	255	155	95	30	5	0	5	5	10	10	105	265	305	855
AG3 - AG5	Duralinox	1100	970	850	750	750	670	650	530	500	450	330	300	260	160	100	35	10	5	0	0	5	5	100	260	300	850
Cd	Cadmium	1100	970	850	750	750	670	650	530	500	450	330	300	200	160	110	35	10	5	0	0	5	5	100	260	300	850
Fe	Fer pur	1105	975	855	755	755	675	655	535	505	455	335	305	265	165	105	40	15	10	5	5	0	0	95	255	295	845
ASG	Almasilium	1105	975	855	755	755	675	655	535	505	455	335	305	265	165	105	40	15	10	5	5	0	0	95	255	295	845
C	Chrome	1200	1070	950	850	850	770	750	630	600	550	430	400	360	260	200	135	110	105	100	100	95	95	0	25	200	750
EZ25	Sn75-Zn25	1350	1230	1100	1010	1010	930	910	790	760	710	590	560	520	420	360	295	270	265	260	260	255	255	25	0	40	590
Z	Zinc	1400	1270	1150	1050	1050	970	950	830	800	750	630	600	560	530	400	335	310	305	300	300	295	295	200	40	0	550
G	Magnésium	1950	1820	1700	1600	1600	1520	1500	1380	1350	1300	1180	1150	1100	1010	950	885	860	855	850	850	845	845	750	590	550	0

vitrification de la surface qui isole l'acier de la cuve. On protège de l'eau par isolement galvanique entre le métal et l'électrolyte.



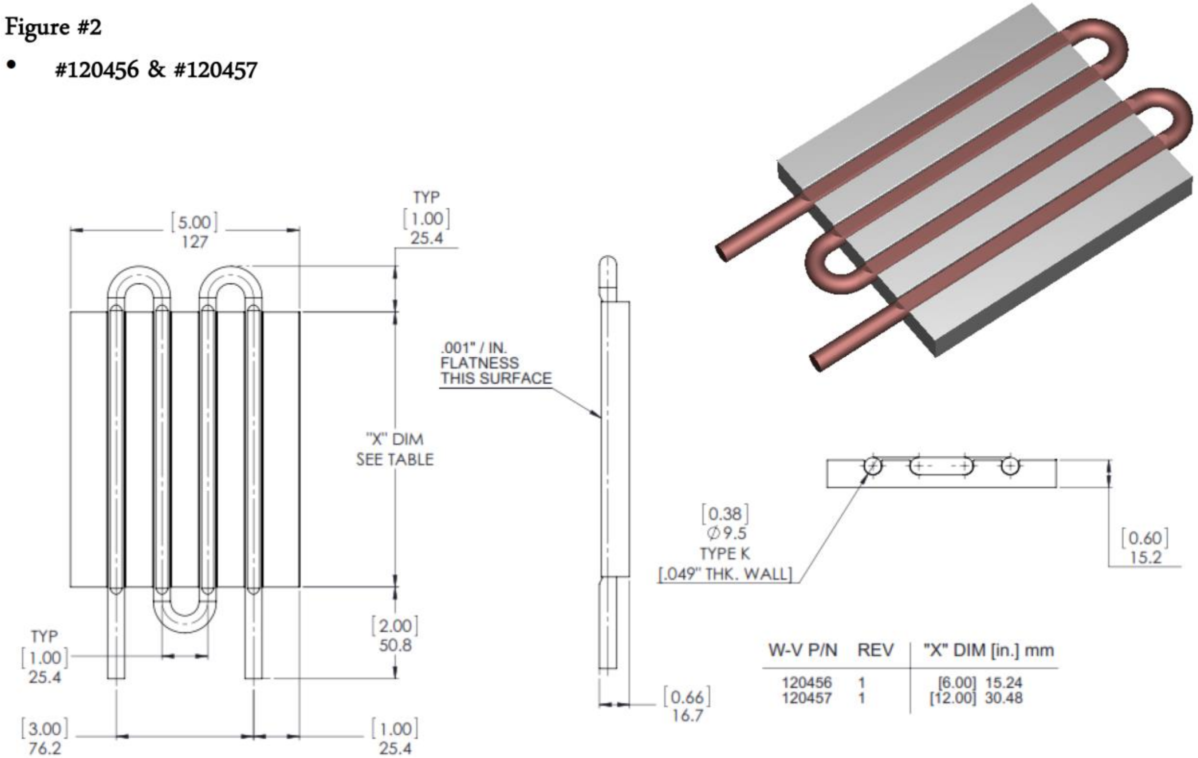
Ne perdons pas de vue que l'émaillage n'est jamais homogène à 100 % : il peut demeurer des zones non couvertes qui seront le siège de corrosion par piquage !



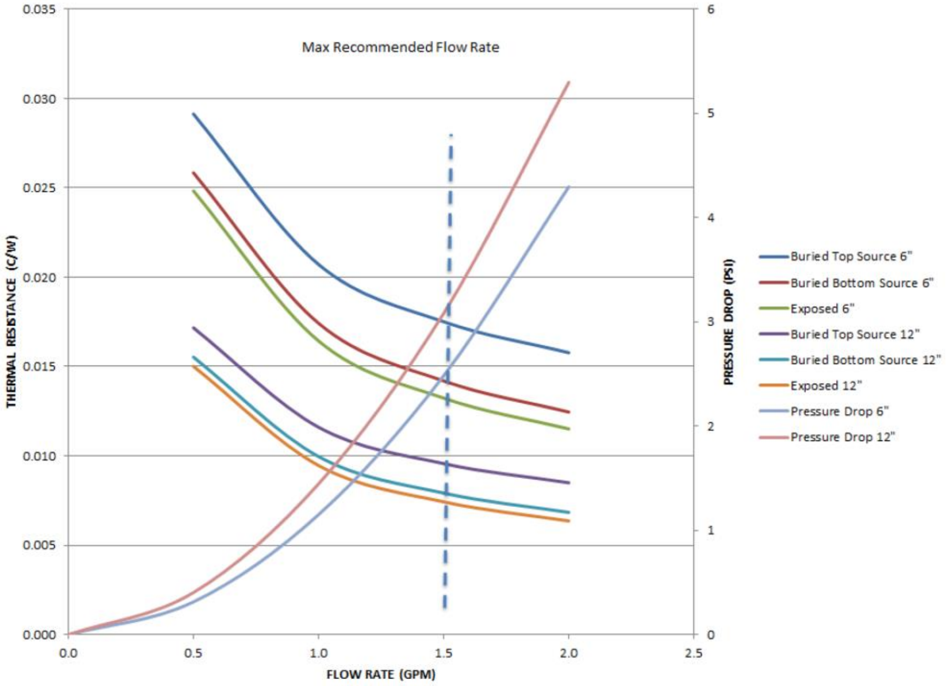
Prototype 5x5 | Mechanical design

Figure #2

- #120456 & #120457

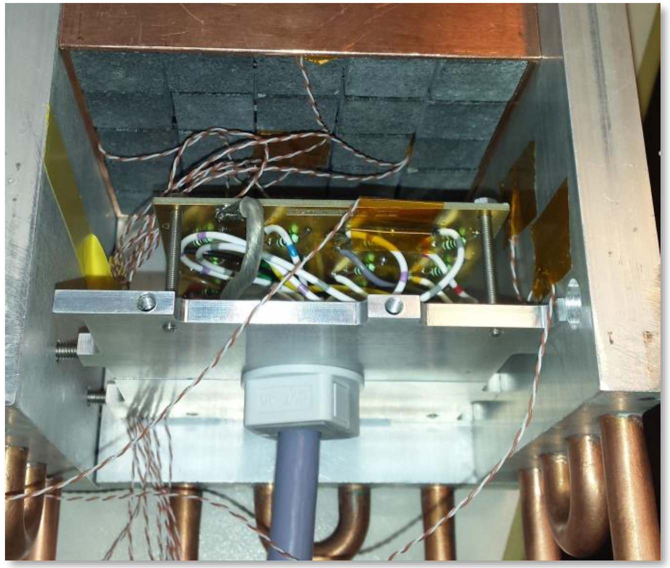


W-V P/N	REV	"X" DIM [in.] mm
120456	1	[6.00] 15.24
120457	1	[12.00] 30.48



Prototype 5x5 | Room test | Thermal tests

Setup of the thermal with prototype 5x5 (without cooling)

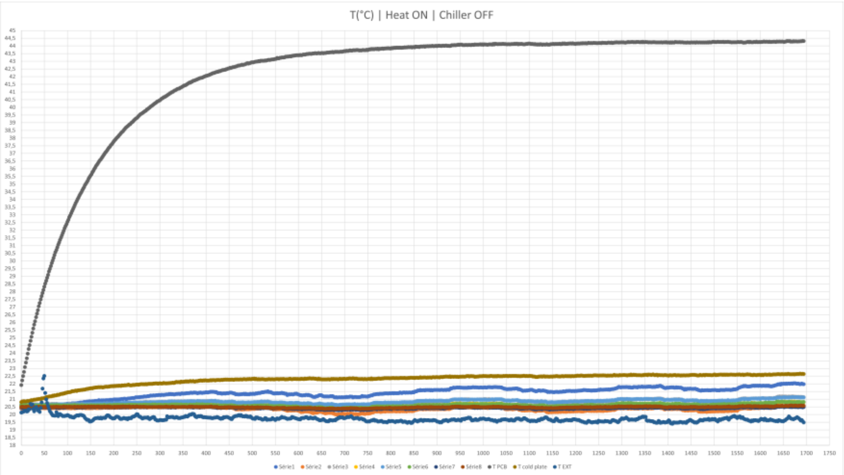


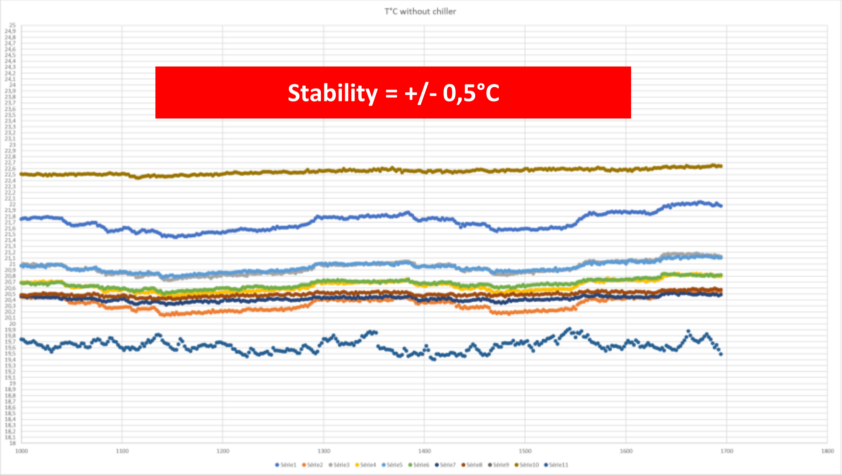
Thermal test with:

- 25 « fake » crystals in stone (marble)
- Heat PCB in front of the crystals (max 4W)

(thermal conductivity near to the PWO 2,08 à 2,94 $W.m^{-1}.K^{-1}$*)*

Room= 20°C | PCB= 45°C | Cooling= OFF



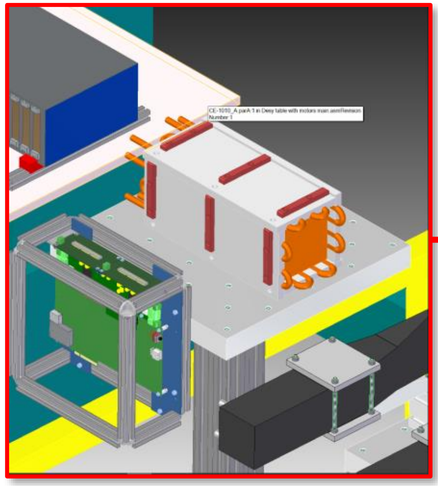


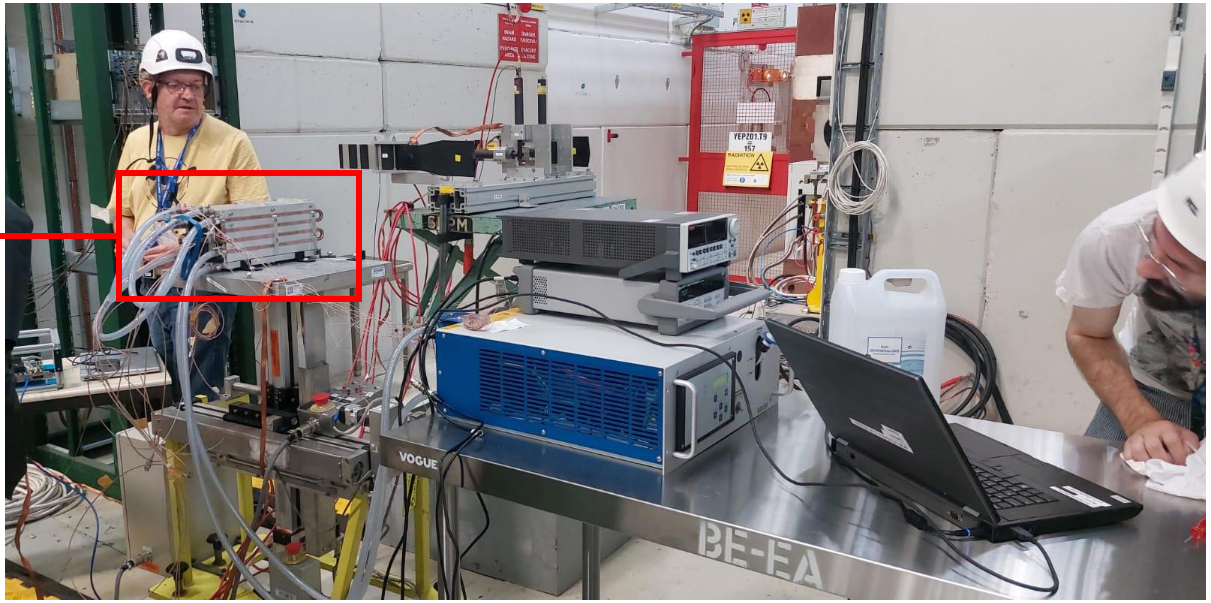
Stability = +/- 0,5°C

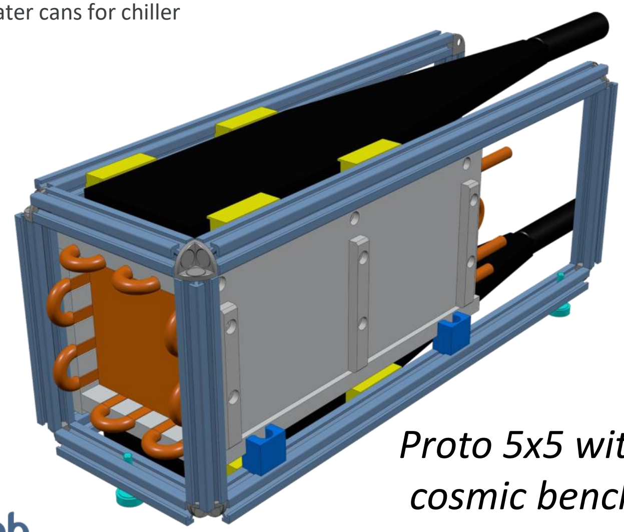
Prototype 5x5 | Beam test | Setup

List of material for the beam test:

- Beam test equipment
- Prototype
- 25 crystals packaged separately
- Chiller
- 4 electronic boxes
- PC thermal probes
- Thermal probes + cables
- PC acquisition
- Thermal probe reading box
- Power supply
- Oscilloscope
- Pulse generator
- SiPM cards and daughter cards (100 small cards in total)
- Small optical coupling equipment (grease, syringe, cotton swab, cloths, etc.)
- Various electrical equipment (approximately 50x50x40cm3): power strips, cables, PC and electronic chargers, various power cables.
- Mechanical tools (key, screws, etc.)
- Optional: water cans for chiller







Proto 5x5 with cosmic bench

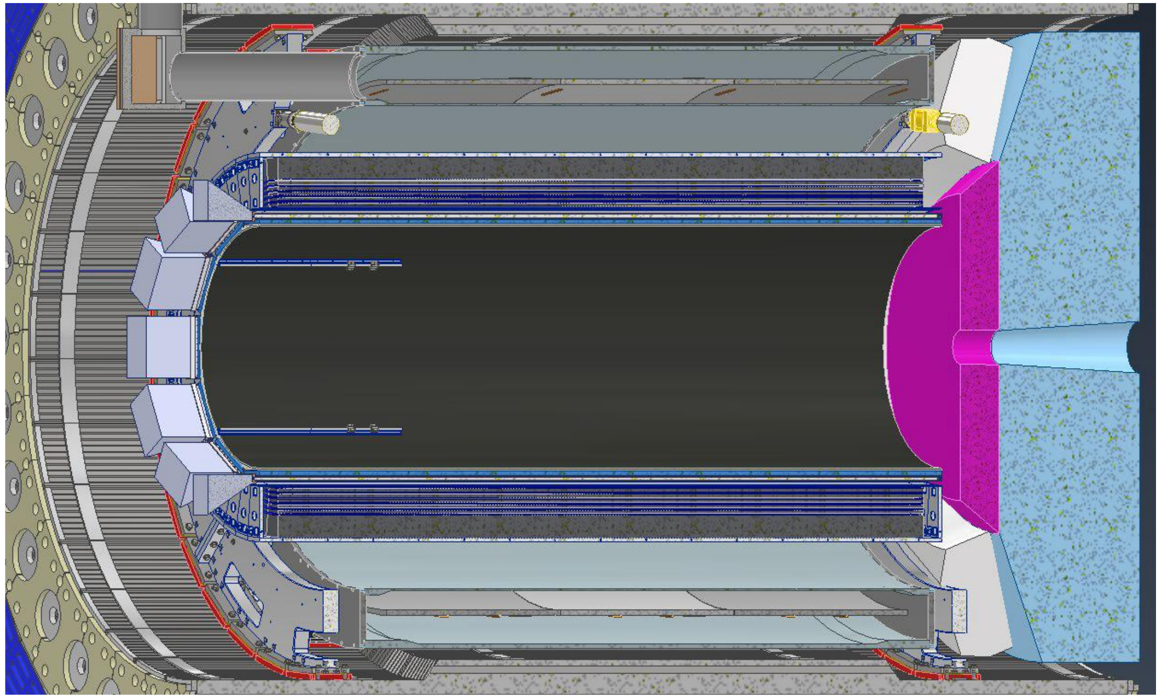
Beam tests performed and planed:

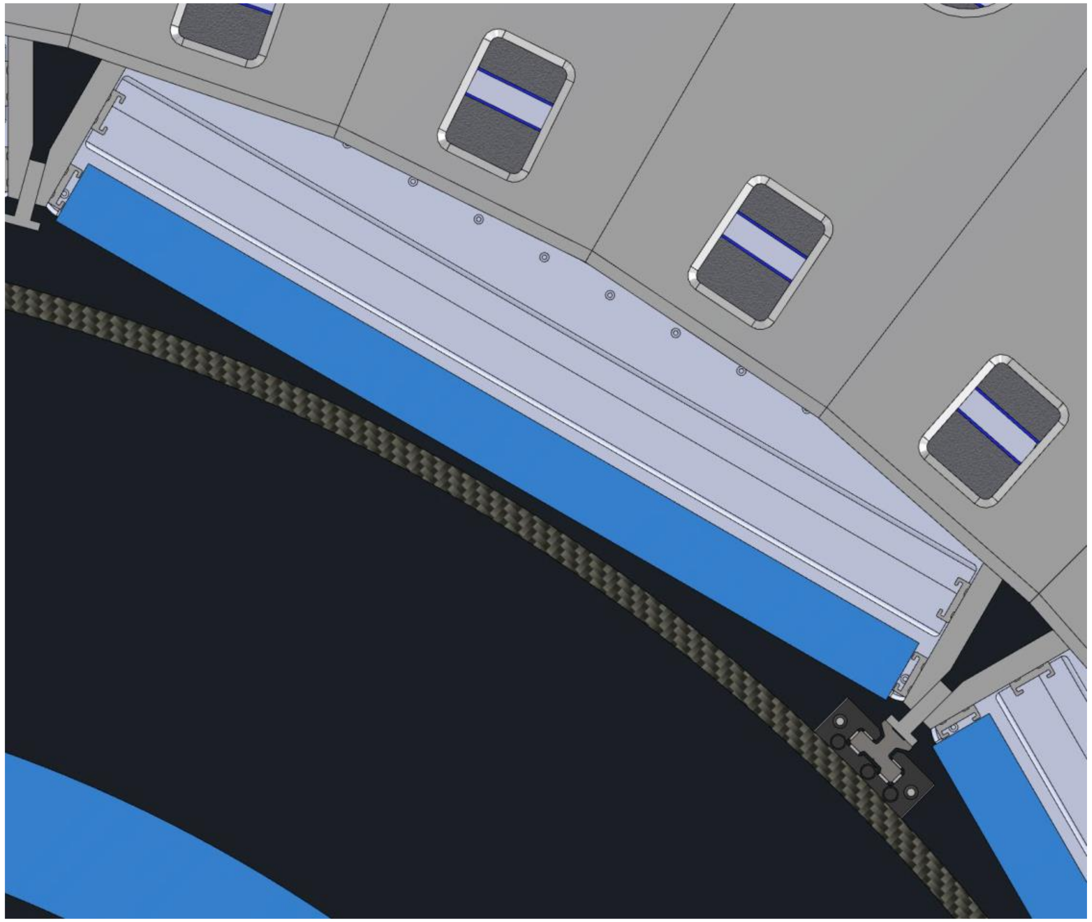
- @ CERN | August 2024
- @ DESY | November 2024 (problem, fire in the accelerator part)
- @ DESY | February 2024

Main objectives:

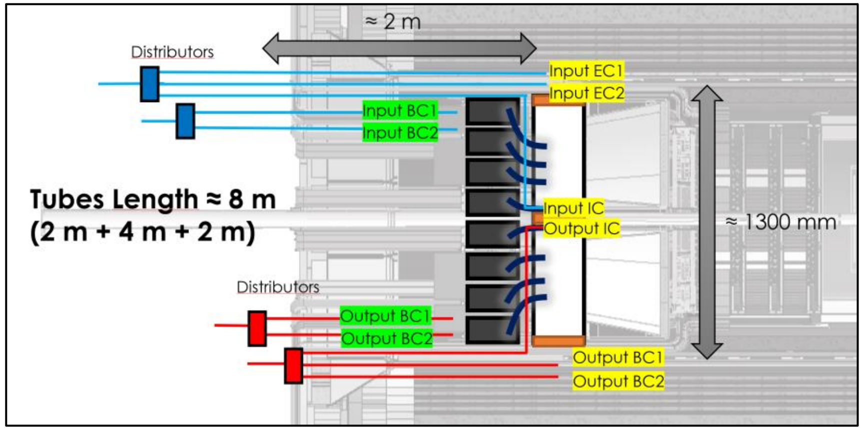
- Take physics data and validate reading by SiPM
- Tests several configurations of the daughter board

Installation



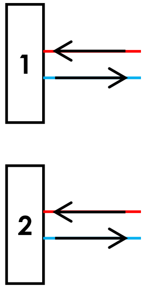


Services



Tubing drawing of the cooling

Chillers

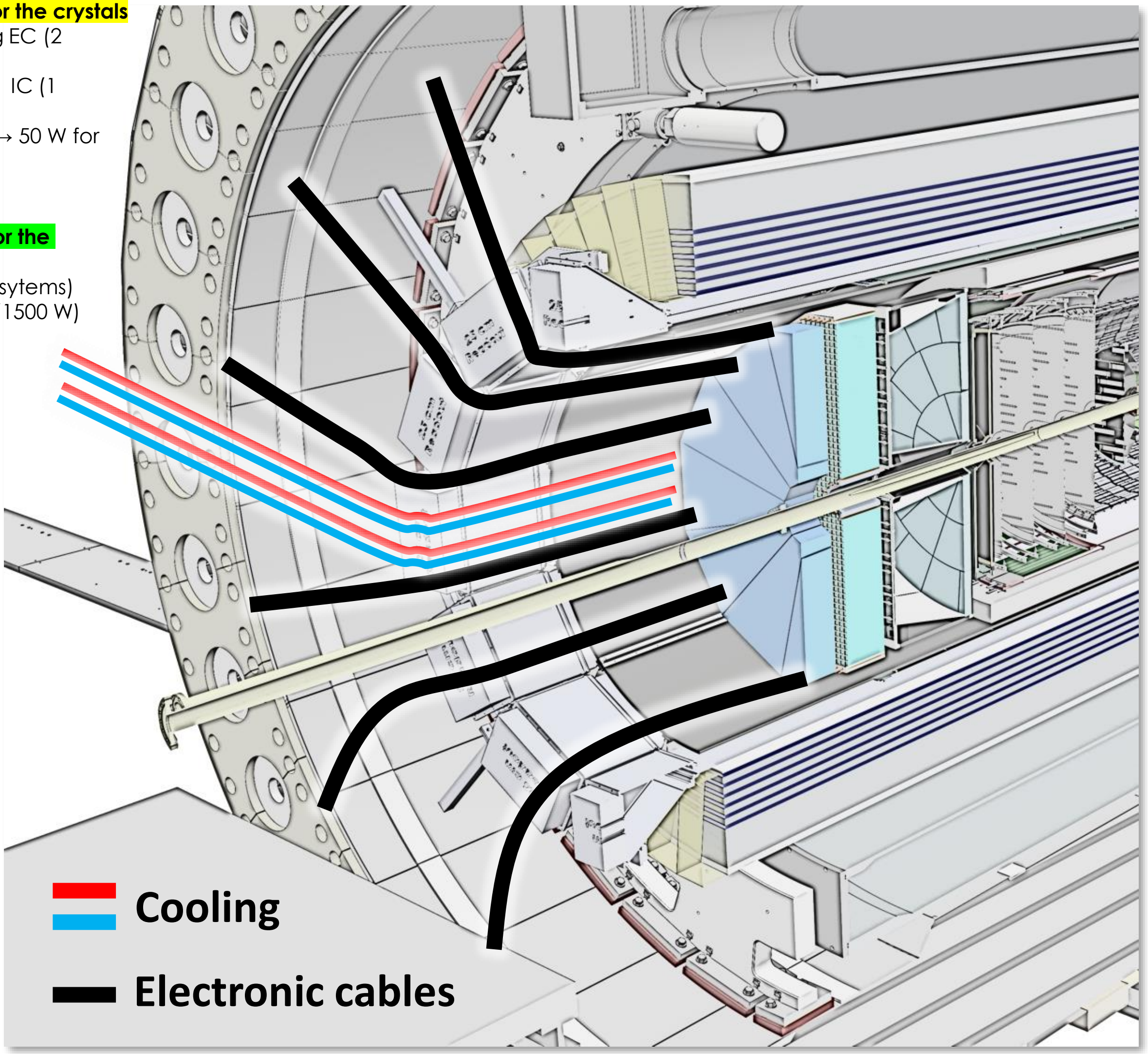


Chiller 1: Cooling for the crystals

- External cooling EC (2 systems)
- Internal cooling IC (1 sytem)
- ΔT room = 3°C → 50 W for the crystals

Chiller 2: Cooling for the electronics

- 12 boxes BC (2 sytems)
- 120 W per box (1500 W)

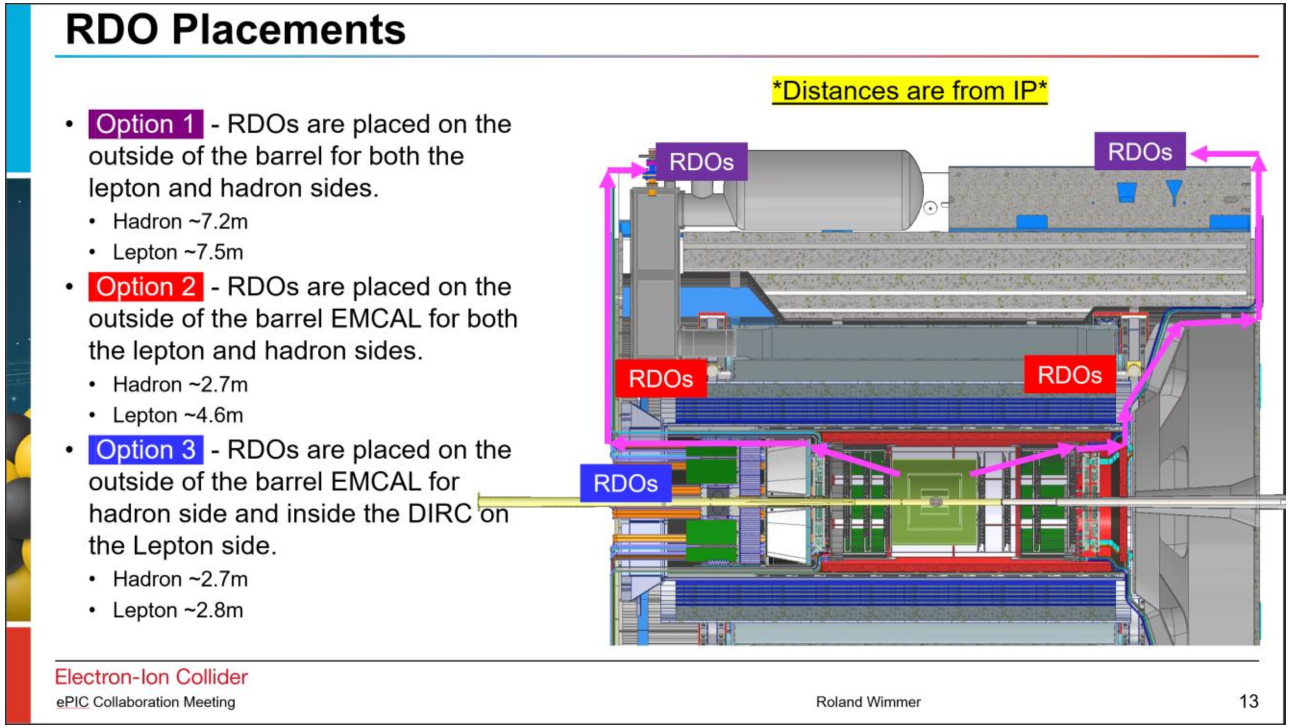


Cables:

- LED (1 LED per crystal → controled by the FEB)
- Thermal sensors (10% of the crystals x2 → 600 cables)
- Signal cables (Depend on the regroupment, reading with 16 SiPM vs 4 SiPM)
- Power supply cables

STUDY IN PROGRESS

Services



RDO Placements

Distances are from IP

- Option 1 - RDOs are placed on the outside of the barrel for both the lepton and hadron sides.
  - Hadron ~7.2m
  - Lepton ~7.5m
- Option 2 - RDOs are placed on the outside of the barrel EMCAL for both the lepton and hadron sides.
  - Hadron ~2.7m
  - Lepton ~4.6m
- Option 3 - RDOs are placed on the outside of the barrel EMCAL for hadron side and inside the DIRC on the Lepton side.
  - Hadron ~2.7m
  - Lepton ~2.8m

Electron-Ion Collider

ePIC Collaboration Meeting

Roland Wimmer

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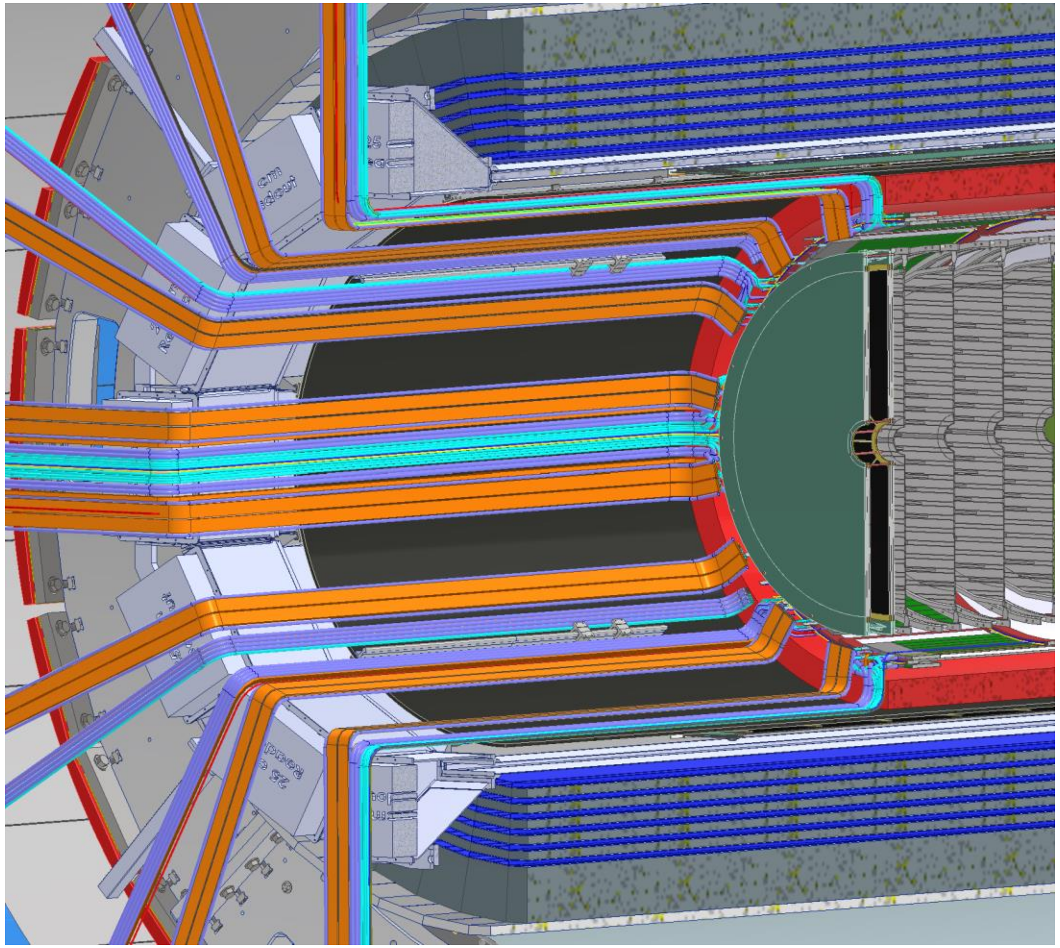
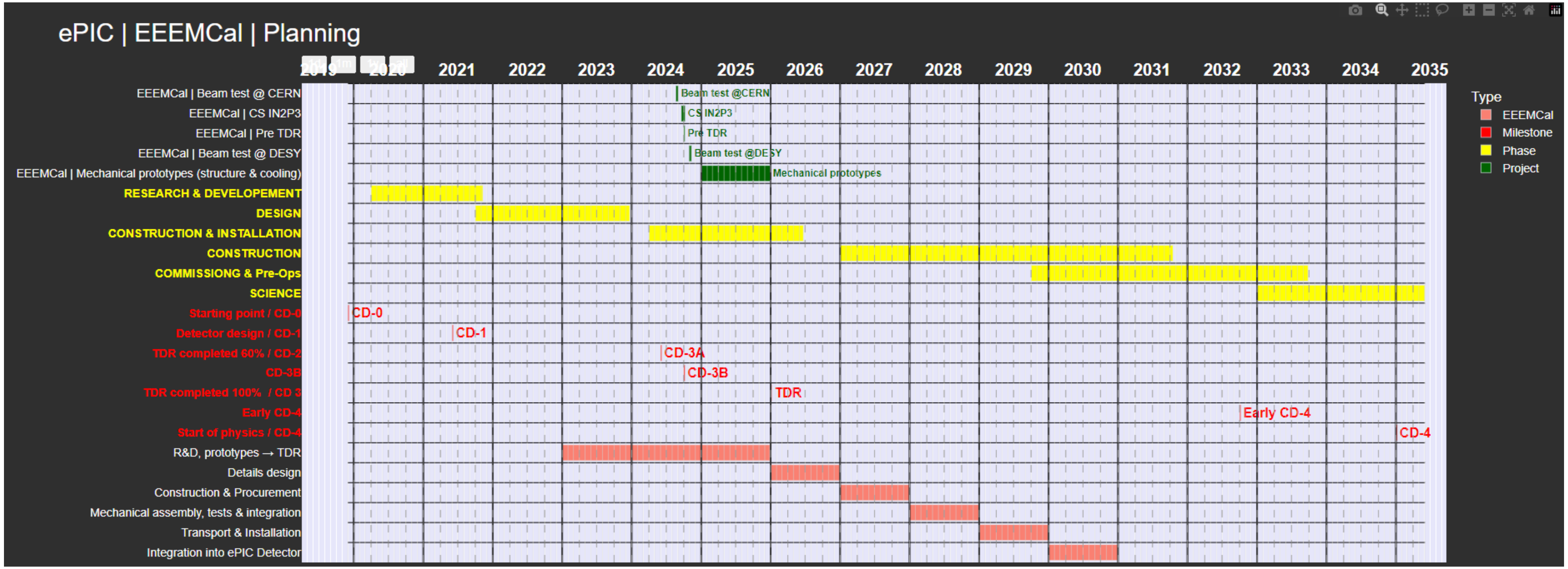


Development plan



Front-End Board (FEB)

→ Location of the power to dissipate
→ Better estimation of the cables needed
→ Design of the FEB

Mechanical design:

→ Internal structure + cooling
→ External structure + cooling
→ FEA simulation with advanced design
→ Thermal simulation with advanced design

Installation requirements

→ Clearances
→ Location of the rails for the assembly
→ Services