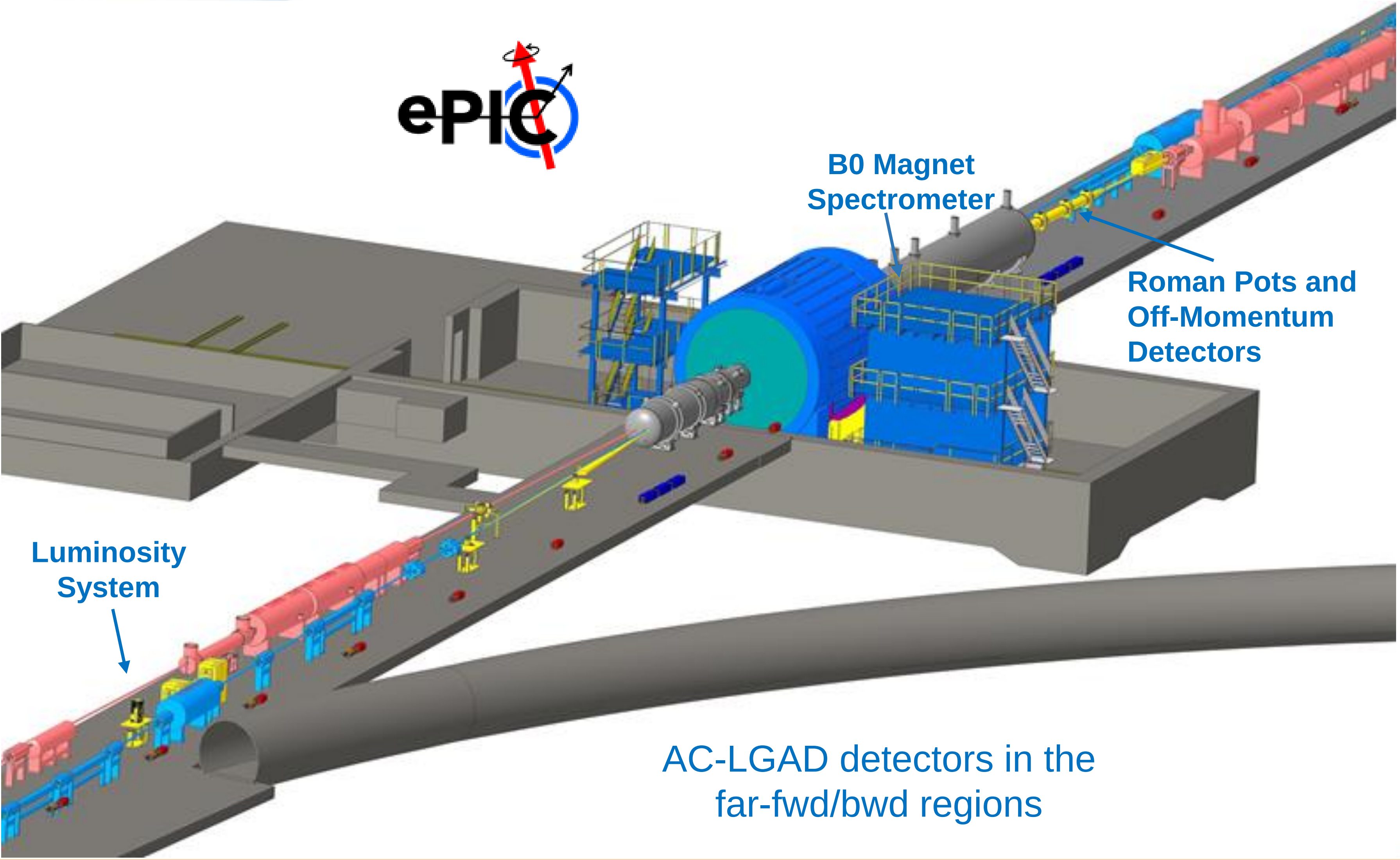
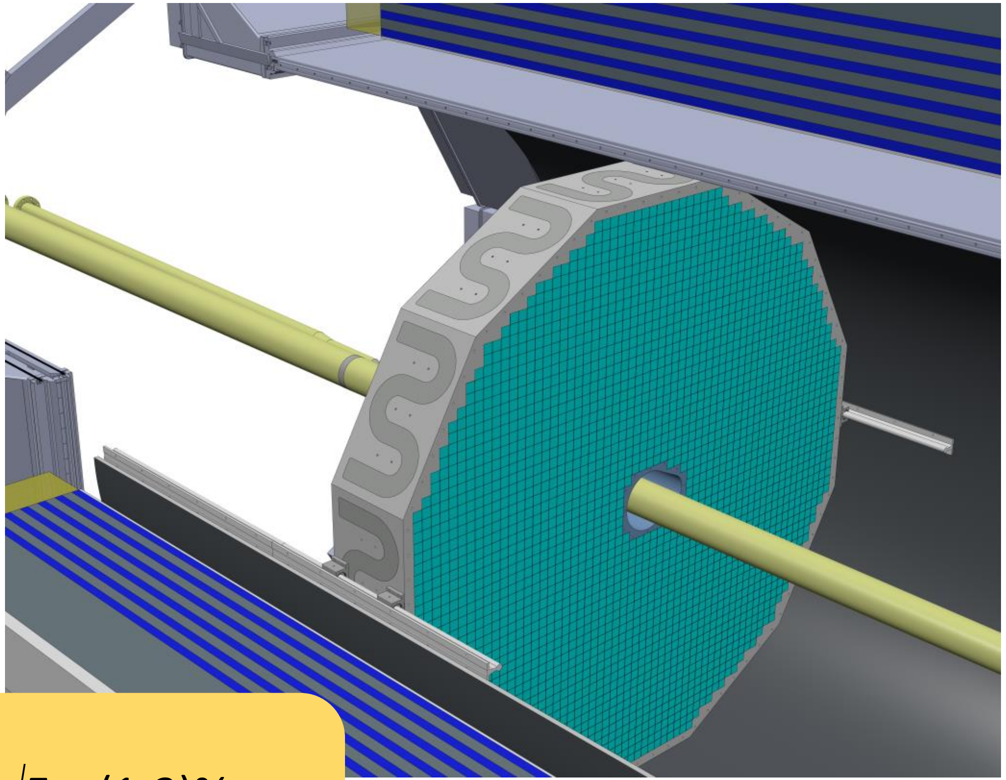


EAP EIC 2024 Backward ECAL

IJCLab
Sep 26, 2025

Backward ECal in ePIC (EIC detector)

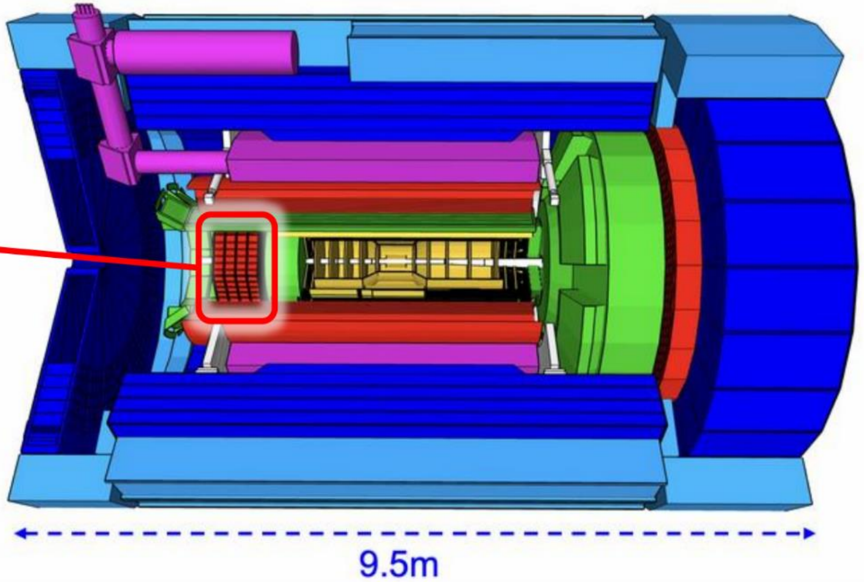
- ~3000 PWO crystals
- SiPM readout
- Cooling
- LED monitoring



High resolution in the forward region (endcap) can only be achieved with homogeneous materials, such as crystals

Requirements:

- Energy resolution: 2%/√E + (1-3)%
- Pion suppression: $1{:}10^4$
- Minimum detection energy: > 50 MeV



Technology choice: PWO crystals (2x2 cm^2) with high density SiPM (16 3x3 mm^2 or 4 6x6 mm^2 per crystal)

ASICs

7 Calorimeters
(5 in central detector + 3 far-fwd/bwd region)
currently planning to use **CALOROC**

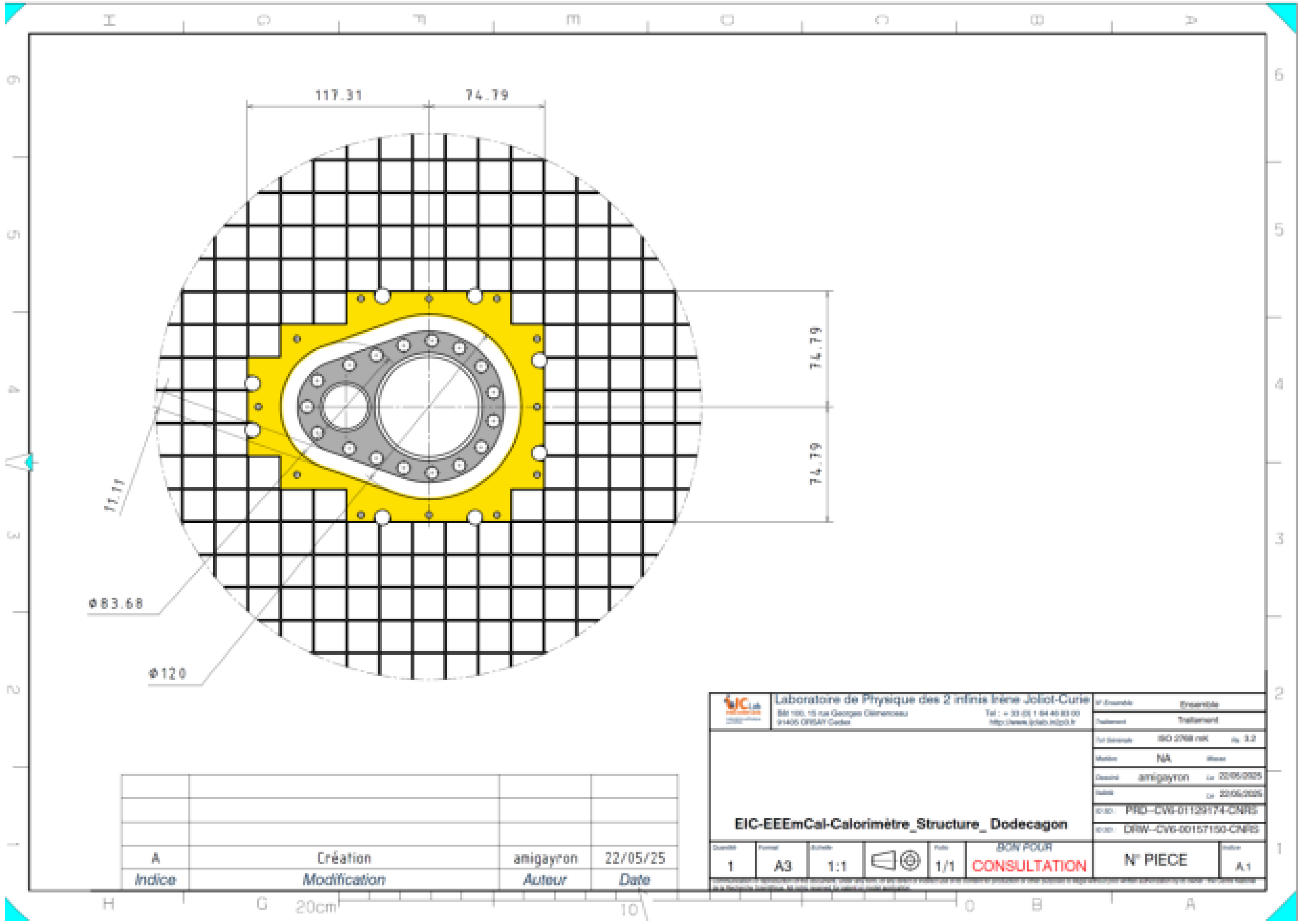
If CALOROC is proven feasible for the backward ECAL, then 3 additional calorimeters will use it (bwd ECal, ZDC, B0)

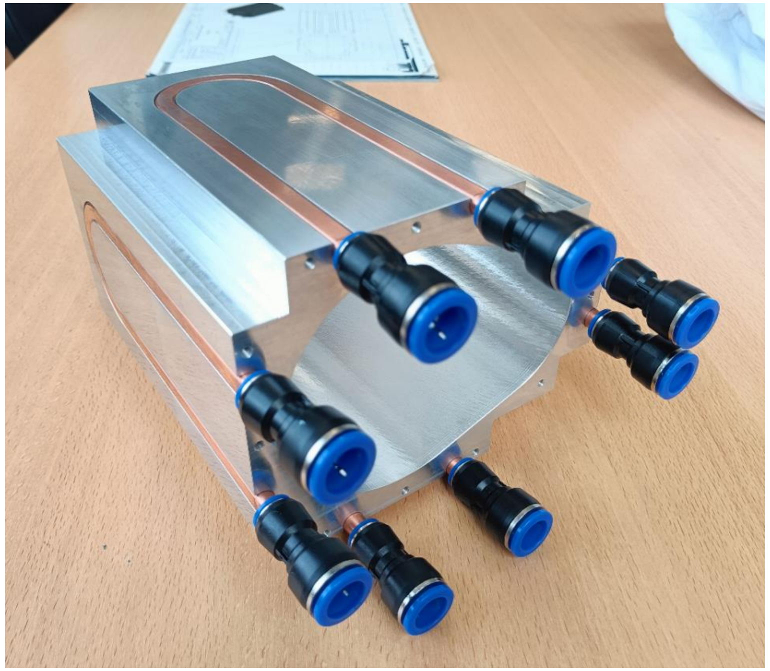
A total of **10 calorimeter systems** (hadronic and electromagnetic)

EICROC planned for 3 far-fwd trackers (B0, RP & OMD) + fwd-TOF:
4 AC-LGAD detector systems

Detector System		Channels	SensorTechnology	Redout Technology
Si Tracking				
	3 vertex layers	7 m^2	MAPS	lpGBT, VTRX+
	2 sagitta layers	368 pixels	MAPS	lpGBT, VTRX+
	5 backward disks	5,200 MAPS sensors	MAPS	lpGBT, VTRX+
	5 forward disks		MAPS	lpGBT, VTRX+
MPGD Tracking				
	Barrel, e & H Endcaps	202 k	uRWELL, MicroMegas	SALSA
Forward Calorimeters				
	LFHCAL	63,280	SiPM	CALOROC
	HCAL Insert	8 k	SiPM	CALOROC
	pECAL W/SciFi	16,000	SiPM	Discrete
Barrel Calorimeters				
	HCAL	7,680	SiPM	CALOROC
	ECAL SciFi/Pb	5,760	SiPM	CALOROC
	ECAL Imaging Si ASTROPIX	500 M pixels	Astropix	
Backward Calorimeters				
	nHCAL	3,256	SiPM	CALOROC
	ECAL (PWO)	2,852	SiPM	Discrete
Far Forward				
	B0: 3 Crystal Calorimeter	135	SiPM/APD	Discrete
	B0: 4 AC-LGAD layers	688,128	AC-LGAD Pixel	EICROC
	2 Roman Pots (RP)	524,288	AC-LGAD Pixel	EICROC
	2 Off Momentum (OMD)	294,912	AC-LGAD Pixel	EICROC
	ZDC: Crystal Calorimeter	900	SiPM/APD	Discrete
	ZDC: HCAL	9,216	SiPM	CALOROC
Far Backward				
	Low Q Tagger 1	33,030,144	Timepix4	
	Low Q Tagger 2	33,030,144	Timepix4	
	Low Q Tagger 1+2 Cal	420 (2x210)	SiPM	CALOROC
	2 Lumi PS Calorimeter	3,360 (2x1680)	SiPM	Discrete
	2 Lumi PS Tracker	128,000 (2x64,000)	AC-LGAD Strip	FCFD
	Lumi Direct Photon Calorimeter	100	SiPM	Flash250
PID-TOF				
	Barrel bTOF	2,359,296	AC-LGAD Strip	FCFD
	Hadron Endcap fTOF	3,719,168	AC-LGAD Pixel	EICROC
PID-Cherenkov				
	dRICH	317,952	SiPM	ALCOR, VTRX+
	pfRICH	69,632	HRPPD	FCFD
	hpDIRC	73,728	MCP-PMT or HRPPD	FCFD

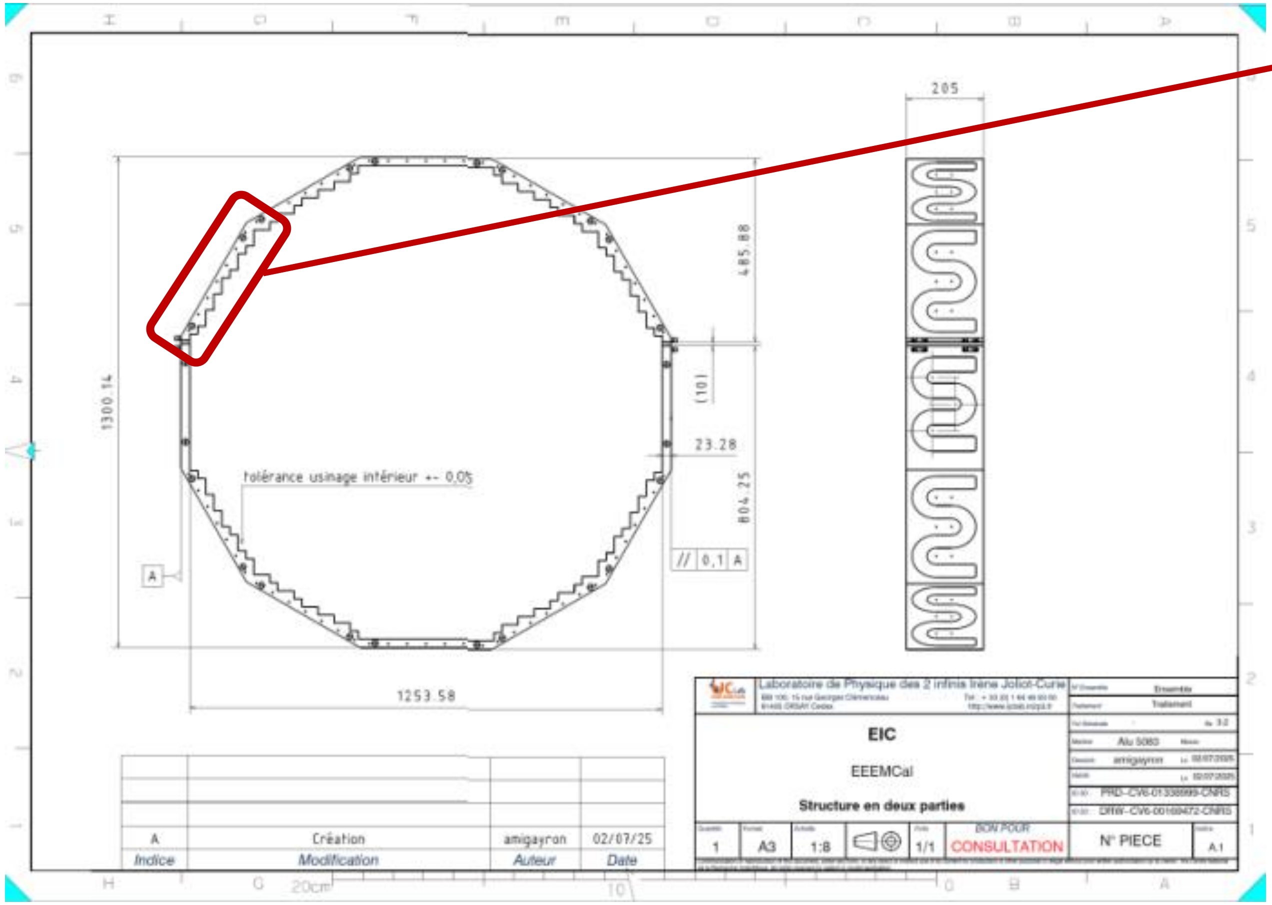
- Design and fabrication completed
- Part received and under tests (if successful, part will be final)

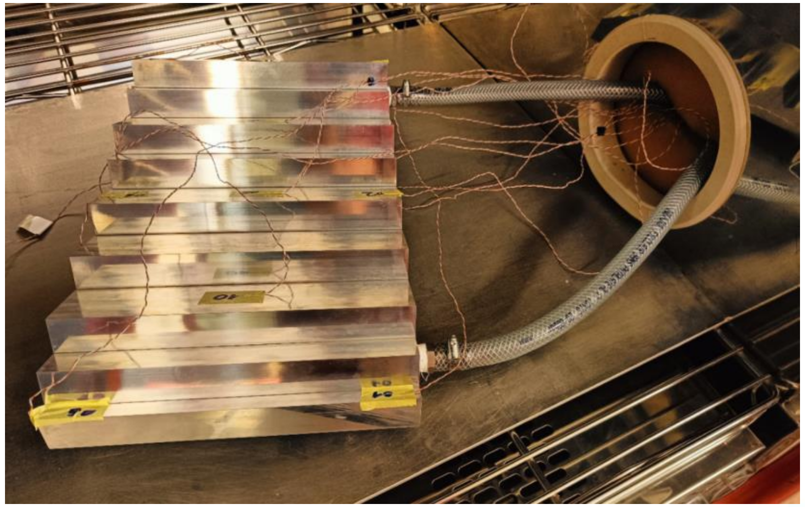




Mechanics: external structure

- Set of 12 cooling plates made by Friction Stir Welding (FSW)
- One plate (prototype) received and under tests





Thermal tests ongoing…

Readout electronics: CALOROC

Readout solution we propose for the backward ECal (EEEMCal) : CALOROC

- Based on HGCROC developped for a SiPM calorimetry
- Low power comsumption (easier cooling)
- Cost efficient

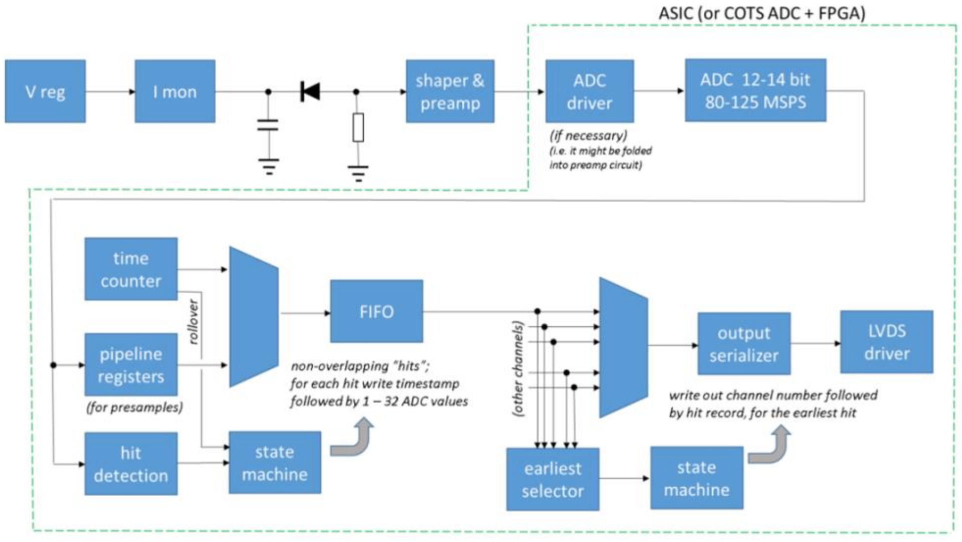
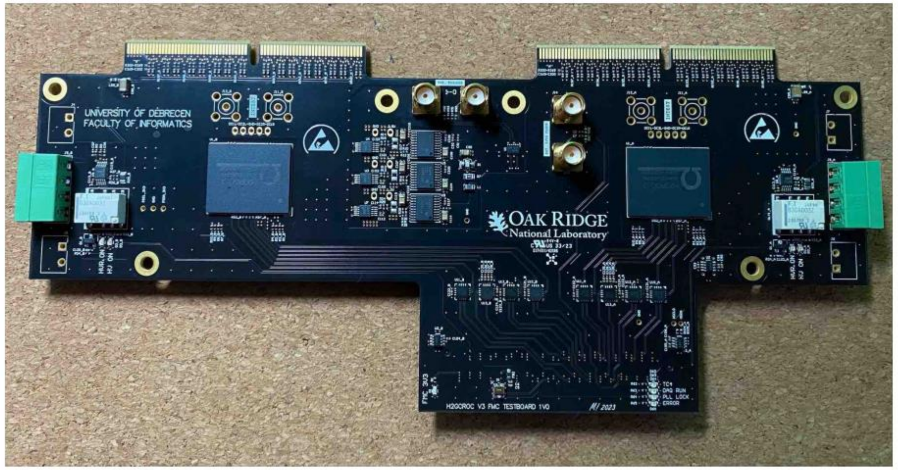


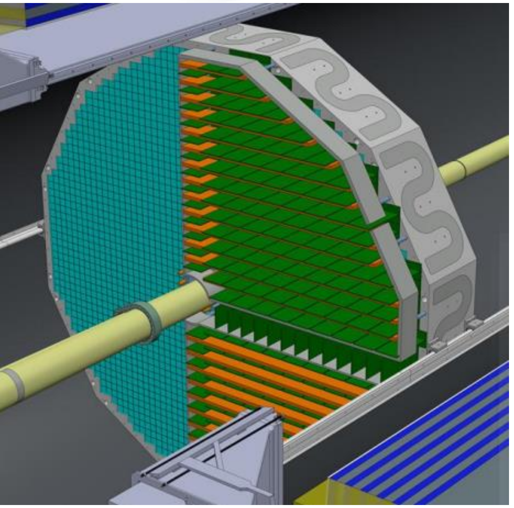
Figure 11: Signal path block diagram of the proposed front-end.

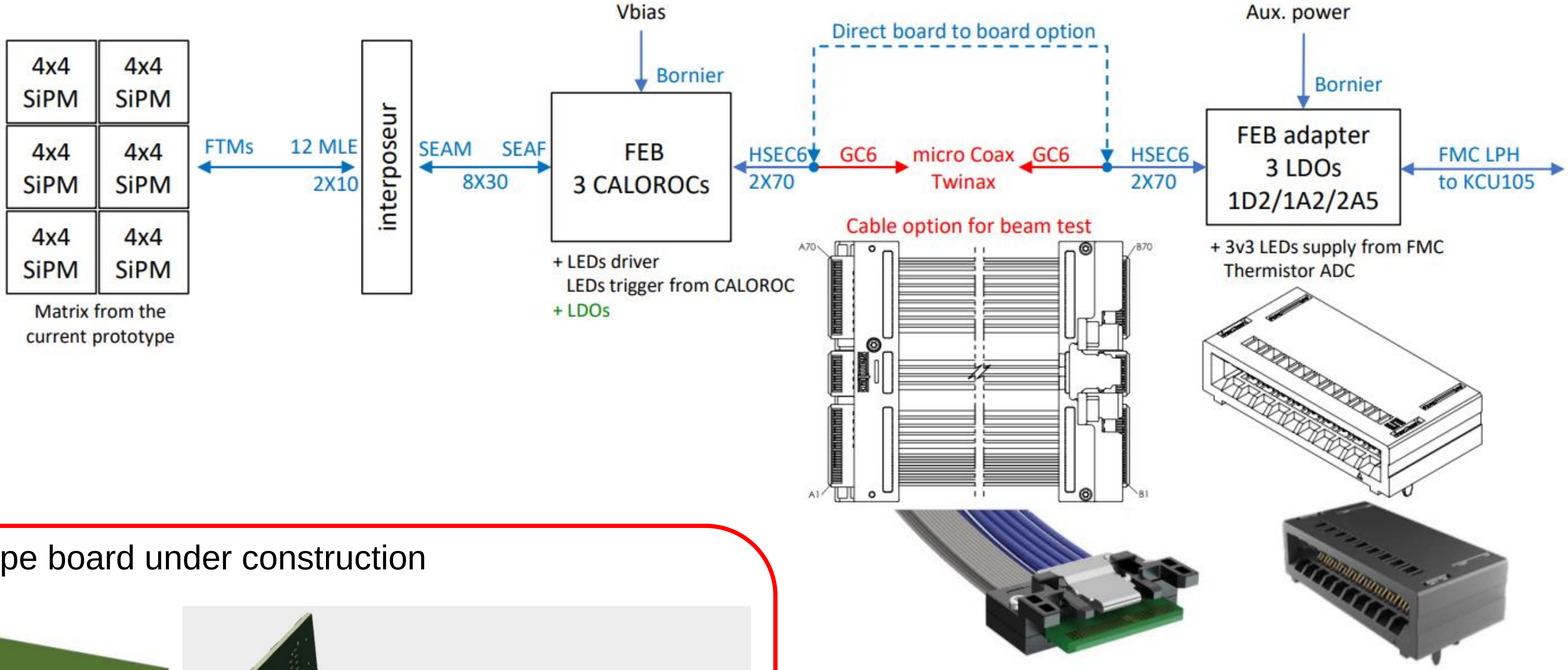


Protoboard designed by forward HCAL team to read HGCROC

NB: An alternative solution based on commercial flashADC is also being considered for EEEMCal

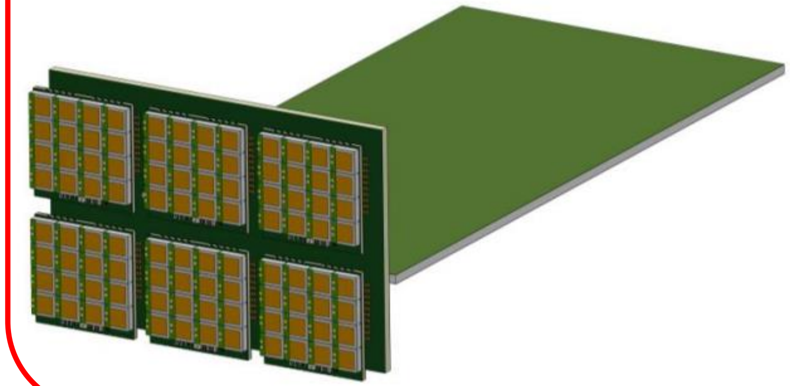
Front-end electronics: design concept

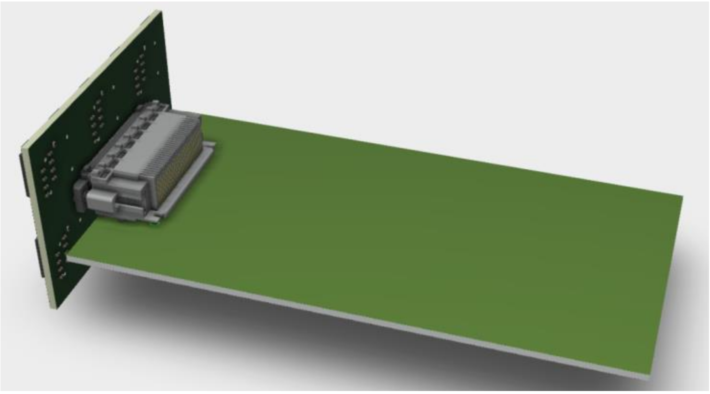




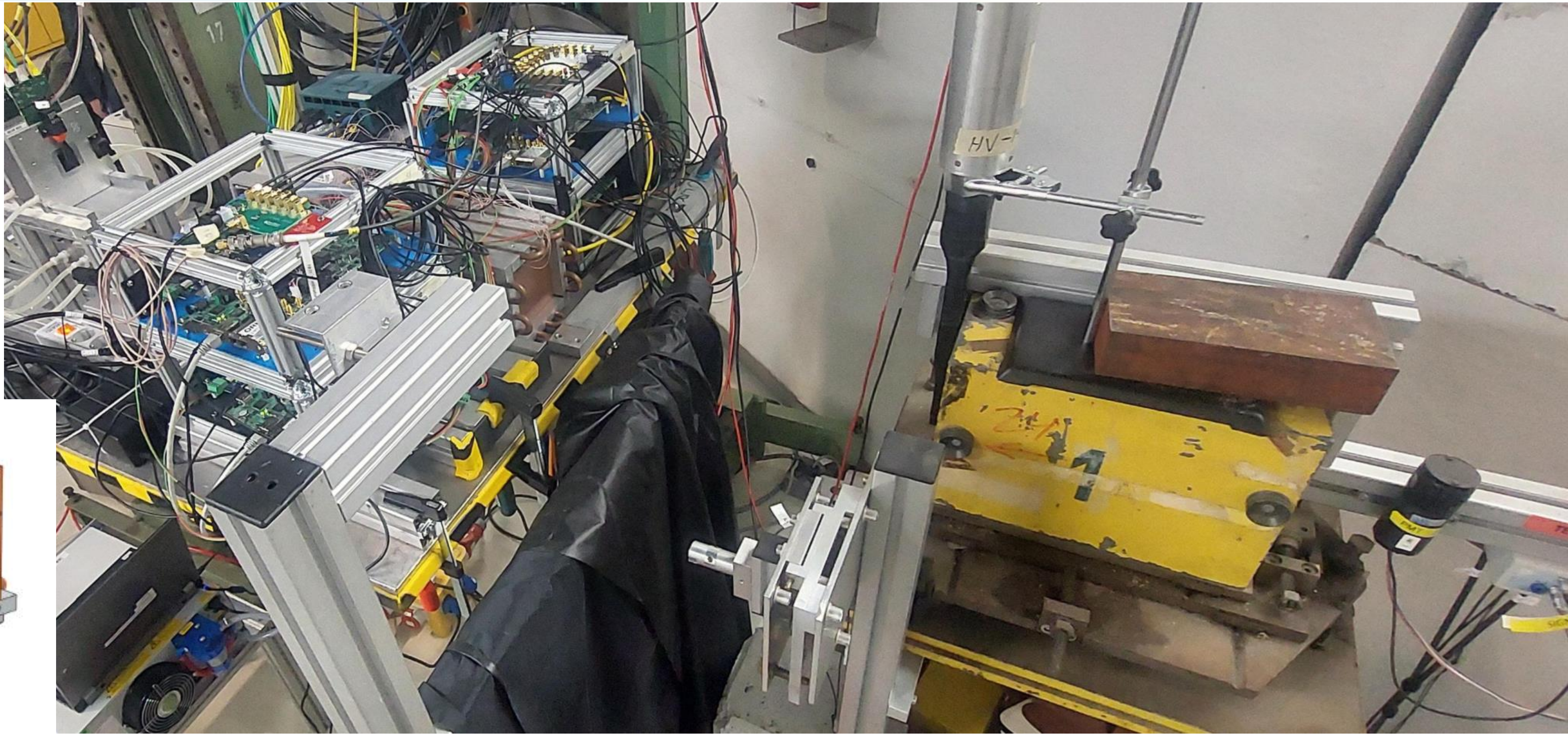
GC6 cable 70 pins/row, HSEC6 right angle

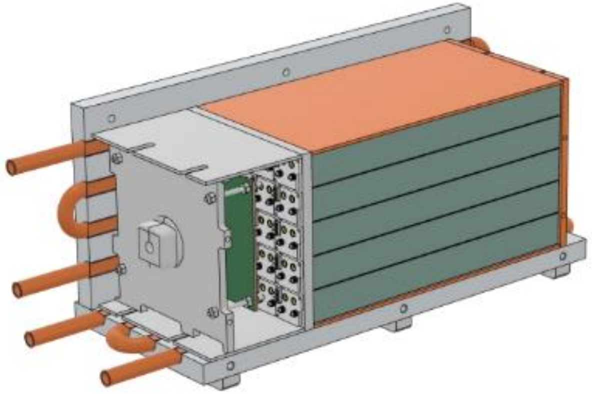
Prototype board under construction





Beam test at DESY (Feb 2025)

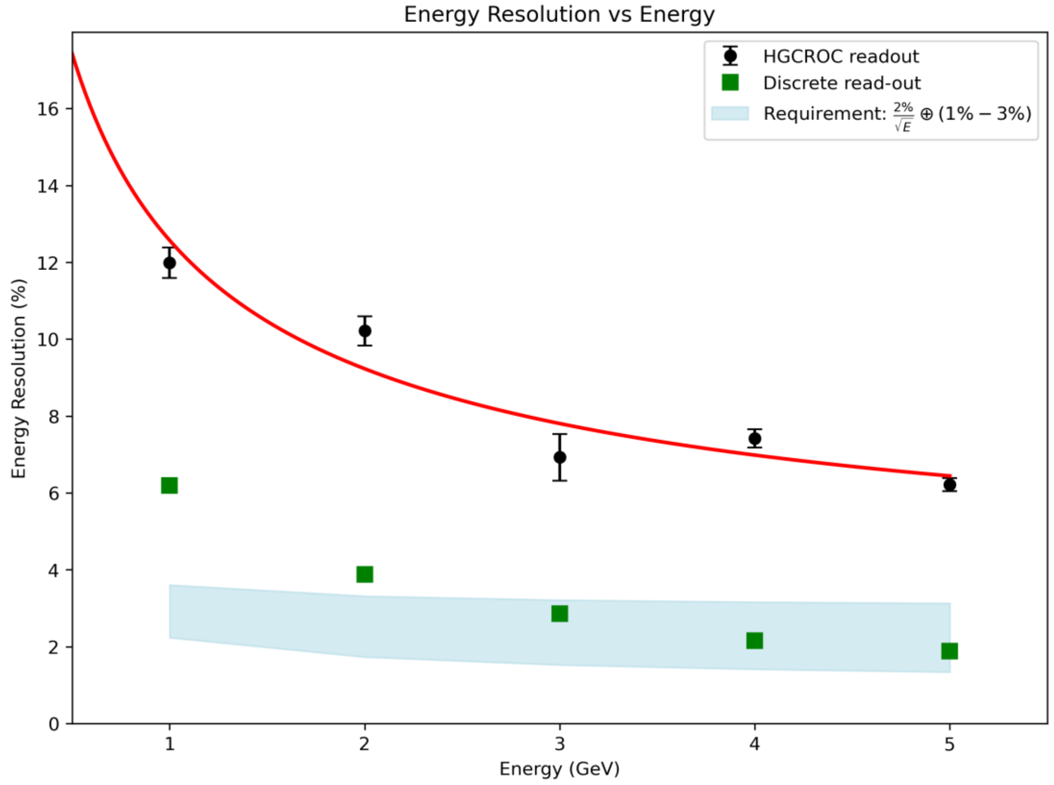




- 1 – 5 GeV electron beam through a 2x2 mm^2 collimator
- Triggered by 2 scintillators
- Typical DAQ rates: ~50-100 Hz
- Prototype on a X-Y table with 0.1 mm position accuracy

Beam test results

- Successful readout of the full 400-channel prototype using HGCROC
- Full check-out of the electronic chain in realistic conditions
- Energy and position reconstruction of showers
- Good dynamic range confirmed
- Reasonable linearity of the readout



Several issues encountered:

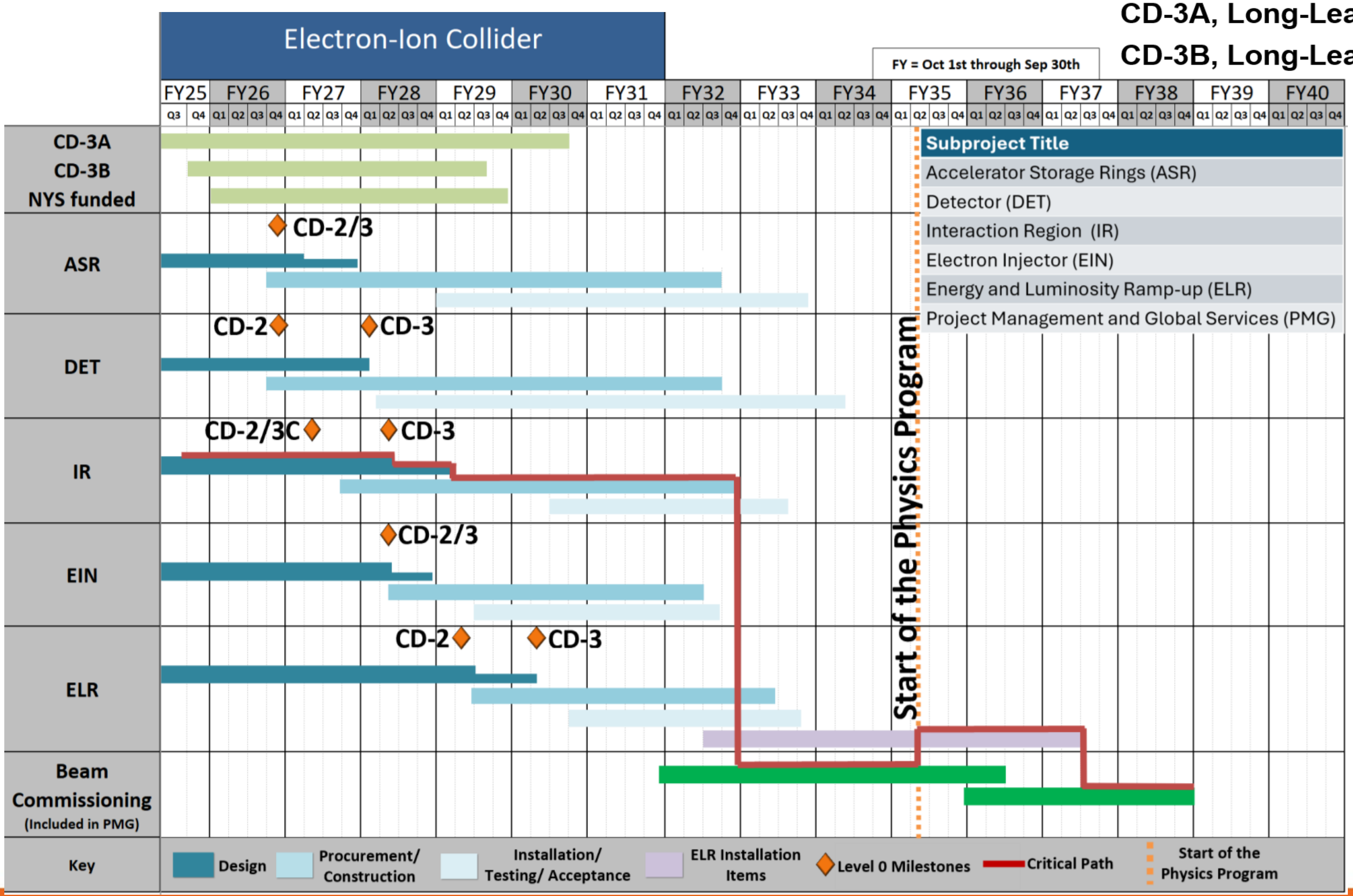
- Power supply instability
- Some connectors not grounded properly
- Electronic noise not yet understood (bad grounding, bad cable isolation…)

Energy resolution measured was far from the needed goal

Issue not likely related to the readout chip (HGCROC) but to the setup

EIC reference schedule

CD-0, Mission Need Approved	December 2019
DOE Site Selection Announced	January 2020
CD-1, Alternative Selection and Cost Range Approved	June 2021
CD-3A, Long-Lead Procurement Approved	**March 2024**
CD-3B, Long-Lead Procurement Planned Approval	**March 2025**



EIC detector milestones

- *Currently: Finalizing detector design*
- 2026: TDR completed (CD-2/3)
- 2027: Detector construction
- 2033/4: Installation/commissioning
- 2035: Start of physics program

DOE project phases:

- CD-0: Approve mission need
- CD-1: Approve Alternative Selection and Cost Range
- CD-2: Approve performance Baseline
- CD-3: Approve Start of Construction
- CD-4: Approve Start of Operations

The ePIC collaboration

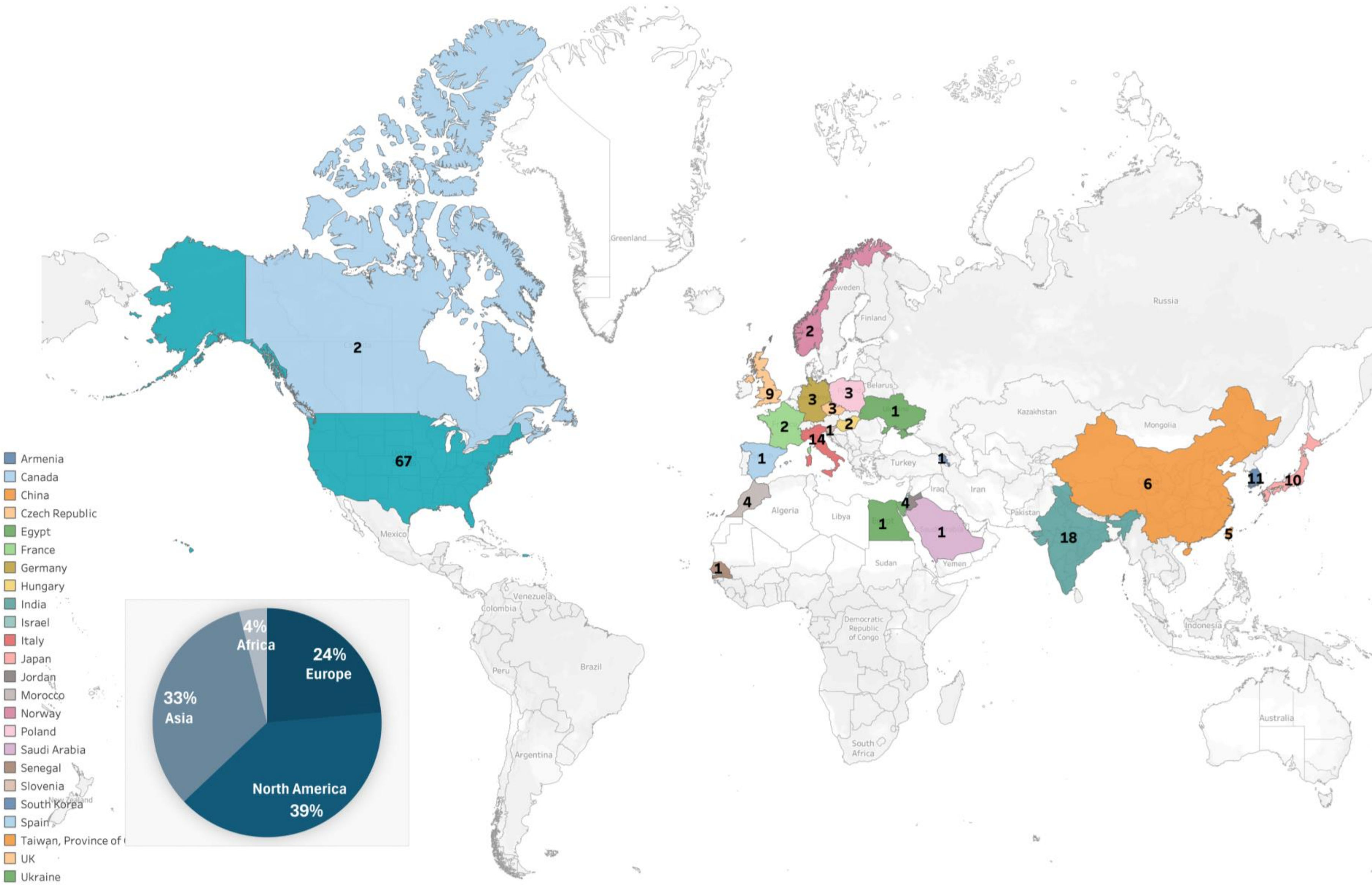
ePIC Collaboration

https://www.epic-eic.org

Formed in 2022 → Now

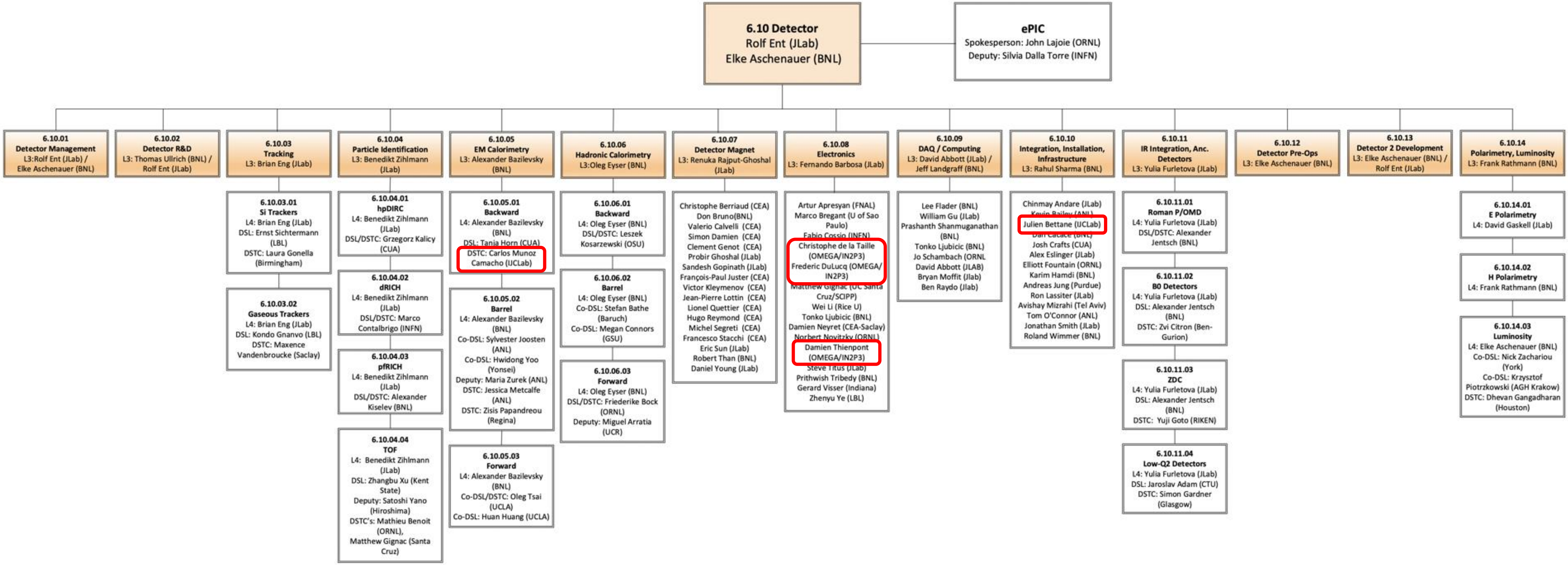
~1050 collaborators, 25 countries,
182 institutions

US: 8 National Labs + 59 Universities



EIC detector work organization

Integration of ePIC Collaboration in EIC Project WBS:



Project organization

WP | EEEmCAL

Responsable Scientifique: Carlos Muñoz Camacho (IJCLab)

Responsable Technique: Julien Bettane (IJCLab)

WP - EM Calorimetry

(ePIC → 6.10.05.01)

- **WP 1 - Detector** Clément Delafosse (IJCLab)
  - **WP 1.1 - Specifications & validation** Clément Delafosse (IJCLab)
  - **WP 1.2 - Detector Tests** Vincent Chaumat (IJCLab), Clément Delafosse (IJCLab), Lorena Bucuru (IJCLab), Chun-Ting Kuan (IJCLab)
- **WP 2 - Electronic** Olivier Le Dortz* (LLR)
  - **WP 2.1 - Front-end & Readout boards** Olivier Le Dortz (LLR), Yoann Le Roux
  - **WP 2.2 - Very front-end (adpter)** Pierrick Dinaucourt (OMEGA)
- **WP 3 - Micro Electronic** Frédéric Dulucq (OMEGA)
  - **WP 3.1 - Developement ASIC (CALOROC)** Frédéric Dulucq (OMEGA), Damien Thienpont (OMEGA), Pedro Dumas (OMEGA)
  - **WP 3.2 ASIC caracterisation & tests** Olivier Le Dortz (LLR), Stepan Obraztsov (LLR), Clément Delafosse (IJCLab)
- **WP 4 - Mechanic** Julien Bettane (IJCLab)
  - **WP 4.1 - Design** Alexandre Migayron (IJCLab)
  - **WP 4.2 - Thermal analysis** Julien Bettane (IJCLab)
  - **WP 4.3 - Production follow-up** Alexandre Migayron (IJCLab)
  - **WP 4.4 - Construction** Atelier (IJCLab)
  - **WP 4.5 - Integration & Tests** Julien Bettane (IJCLab)
  - **WP 4.6 - Installation** Atelier (IJCLab)
- **WP 5 - Simulation & Software** Matthew Nguyen (LLR)
  - **WP 5.1 - Detector geometry** Dmitry Kalinkin (Kentucky), Mostafa Hoballah (IJCLab)
  - **WP 5.2 - Reconstruction algorithms** Matthew Nguyen (LLR), Afnan Shatat (LLR)
  - **WP 5.3 - Physics analysis** Lorena Bucuru (IJCLab), Carlos Muñoz Camacho (IJCLab)
- **WP 6 - Management** Julien Bettane (IJCLab)
  - **WP 6.1 - Review preparation**
  - **WP 6.2 - Meeting organisation**
  - **WP 6.3 - Reviews**
  - **WP 6.4 - Risk Analysis**
  - **WP 6.5 - Scheduling**

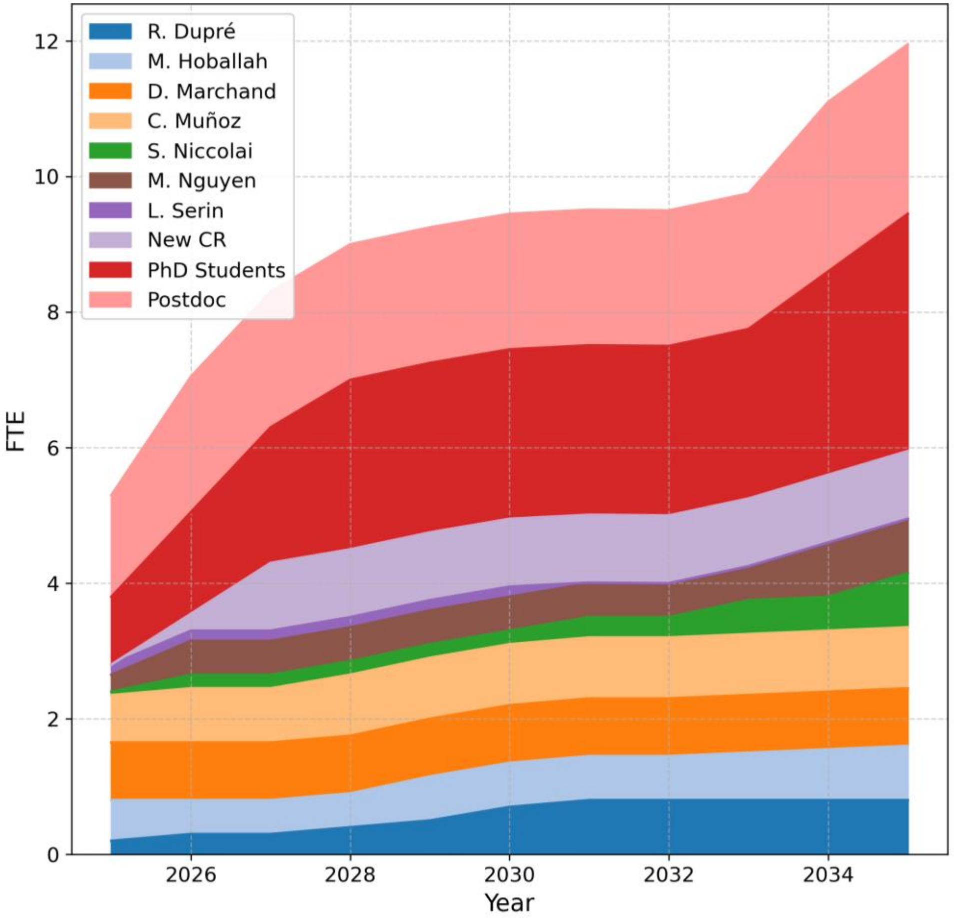
* Preliminary name attribution

WBS

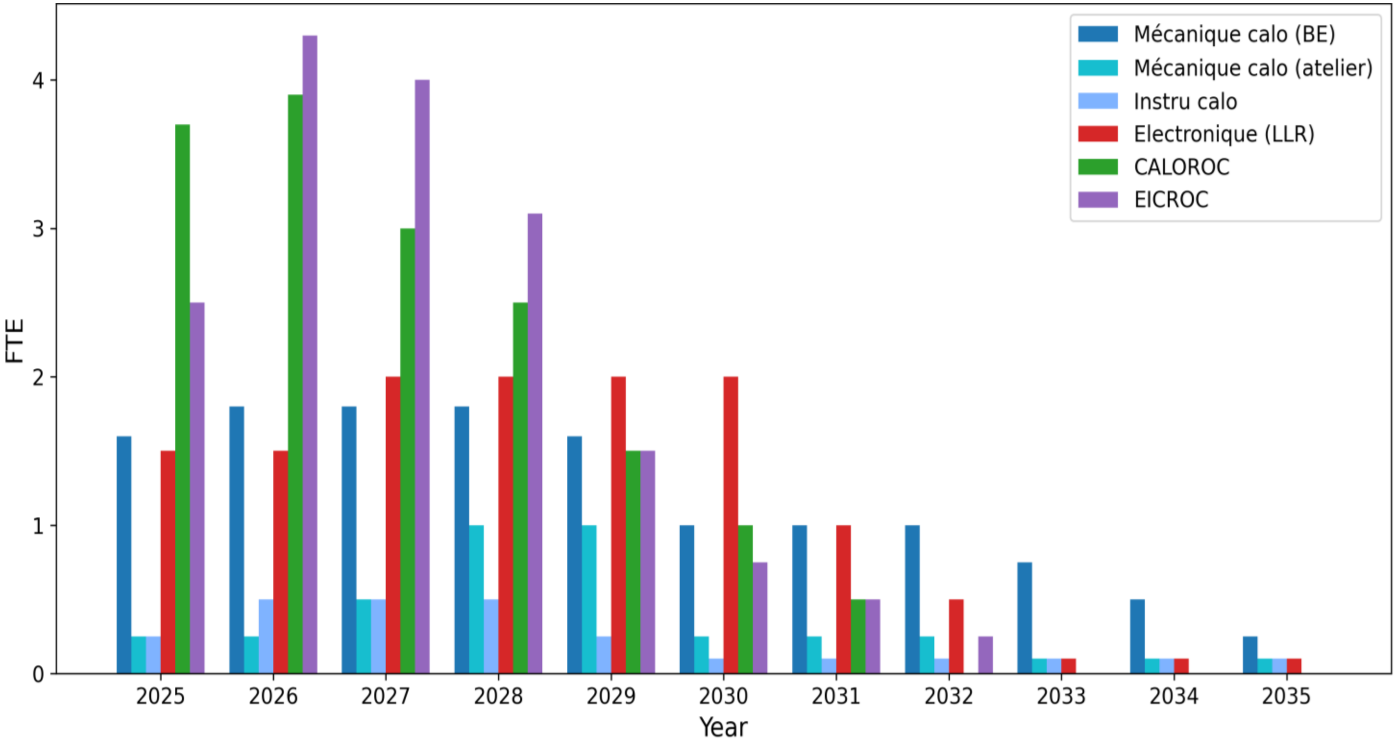
WBS	Niveau 1	Niveau 2	Niveau 3	Niveau 4
1	Gestion du Projet	Planification & coordination	Suivi budgets & ressources	
			Gestion risques & changements	
			Documentation & rapports	
			Coordination parties prenantes	
2	Conception Mécanique	Spécifications mécaniques	Exigences d'intégration	
		Structure du calorimètre	Supports des cristaux	Conception & fabrication supports carbone (PWO)
			Structure globale	Assemblage de la structure externe
		Assemblage mécanique	Intégration sous-ensembles	Compatibilité avec électronique & câblage
3	Conception Électronique	Spécifications électroniques	Communication & contrôle (SiPM, LED, FEB)	
		Cartes Front-End (FEB)	Design PCB	Conception cartes (SiPM + LED)
			Développement firmware	Gestion signaux SiPM & LED
			Intégration LED & SiPM	Assemblage & tests pour calibration
		Systèmes de lecture (RDO)	Design & fabrication	Conception cartes RDO (transmission données)
			Tests cartes RDO	Validation performance & compatibilité
		Calibration & monitoring	LED de calibration	Implantation PCB, liaison SiPM
			Algorithmes de calibration	Développement corrections & auto-calibration via LED
4	Câblage & Connectique	Conception système câblage	SiPM, LED, FEB, RDO	
		Câblage Very Front-End	Liaisons SiPM/LED → lecture	
		Connectique backend	RDO ↔ backend haute performance	
5	Refroidissement & Alimentation	Spécifications thermiques	Besoins cristaux & électronique	
		Systèmes de refroidissement	Conception	Plaques froides, échangeurs, etc.
			Installation	Solutions thermiques, ventilateurs
		Systèmes d'alimentation	Conception circuits	Alimentation SiPM, LED, FEB, RDO
			Distribution d'énergie	Installation & mise en service
6	Intégration du Système	Intégration mécanique	Compatibilité supports, structure, etc.	
		Intégration électronique	Interfaces SiPM, LED, FEB, RDO	
		Intégration backend	Cartes RDO ↔ backend (transfert données)	
7	Tests & Validation	Tests composants	SiPM	Sensibilité
			LED	Efficacité calibration & stabilité
			FEB & RDO	Vérification fonctionnement
		Tests d'intégration	Interopérabilité	Fonctionnement conjoint & interférences
			Performance système	Temps de réponse & qualité signaux
		Validation en conditions réelles	Tests de calibration	Précision globale système LED
			Validation des résultats	Critères d'acceptation / physique

FTE

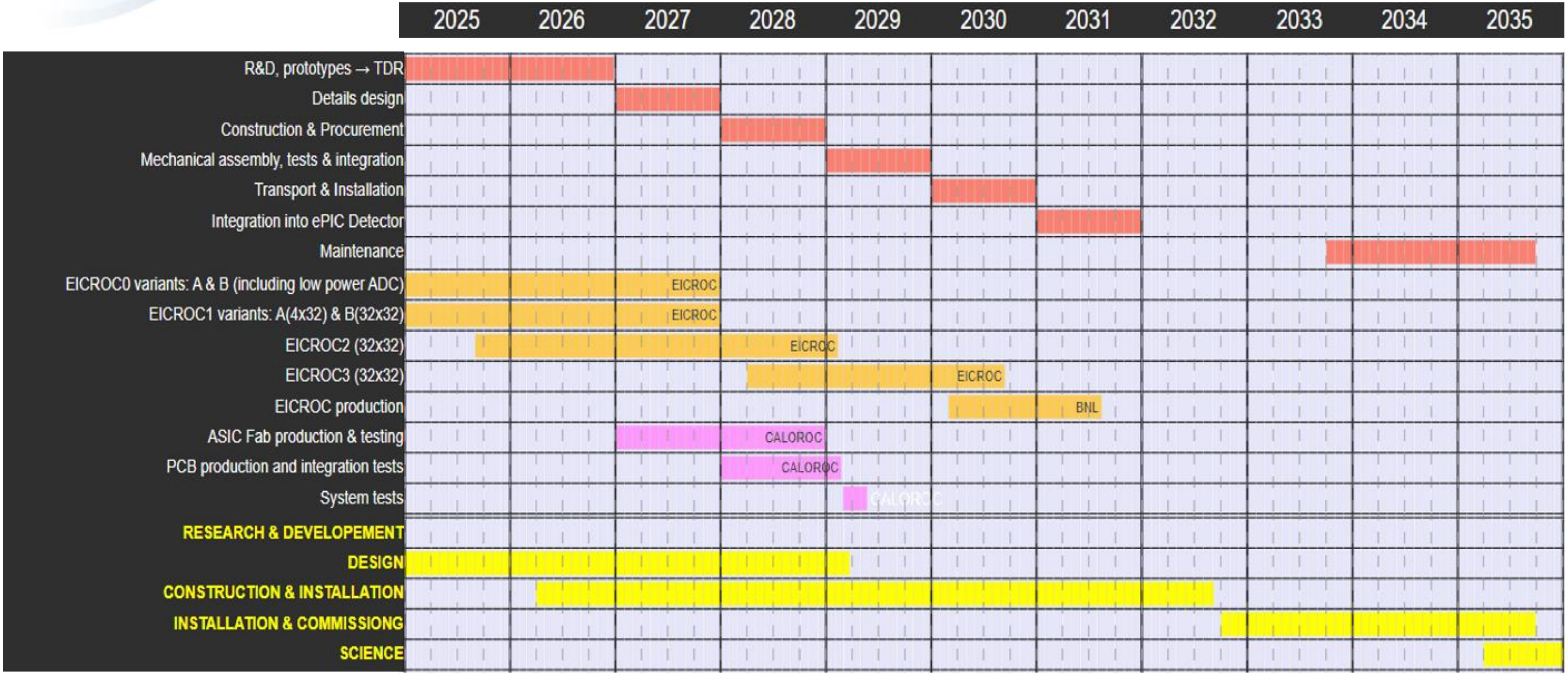
FTE chercheurs (EICCalo & RP combined)



IT needs/request



Timeline



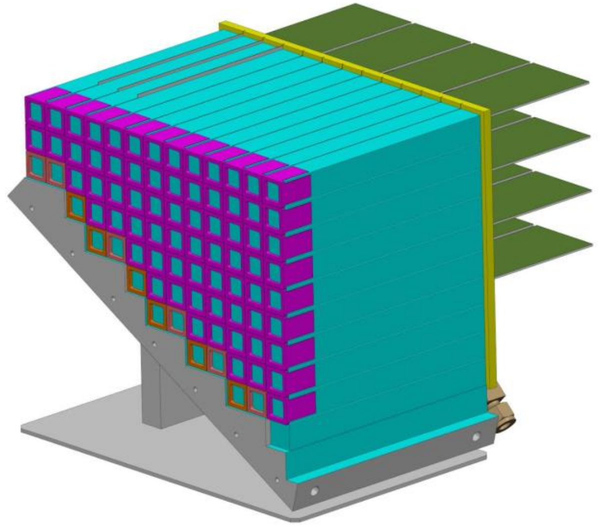
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
R&D, prototypes → TDR
Details design
Construction & Procurement
Mechanical assembly, tests & integration
Transport & Installation
Integration into ePIC Detector
Maintenance
EICROC0 variants: A & B (including low power ADC)
EICROC
EICROC1 variants: A(4x32) & B(32x32)
EICROC
EICROC2 (32x32)
EICROC
EICROC3 (32x32)
EICROC
EICROC production
BNL
ASIC Fab production & testing
CALOROC
PCB production and integration tests
CALOROC
System tests
RESEARCH & DEVELOPEMENT
DESIGN
CONSTRUCTION & INSTALLATION
INSTALLATION & COMMISSIONG
SCIENCE

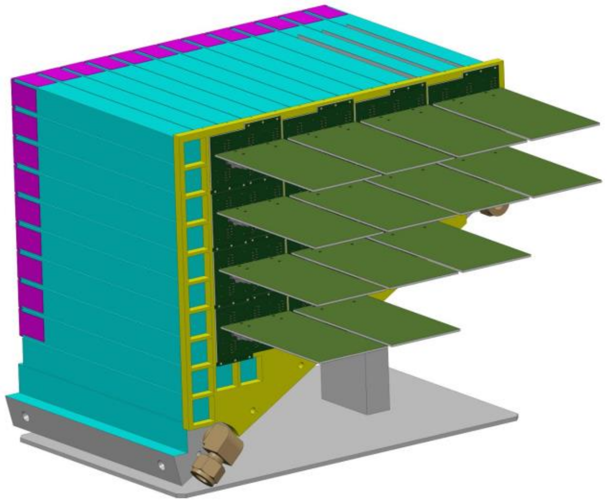
Request of resources for 2026

	EIC-Calo		RP/EICROC		Total
	Description	Montant	Description	Montant	
IJCLab	Mécanique détecteur	10	Proto cooling	7	
	Proto "6x6":		Banc test IR	6	
	SiPM	8	Missions	18	
	Mécanique proto	3			
	Missions	15			
	Total	**36**	**Total**	**31**	**67**
LLR	Proto "6x6":				
	Front-end boards	8			
	Cartes SiPM	8			
	Missions	15			
	Total	**31**	**Total**	**0**	**31**
OMEGA	Cartes et composants	10			
	Missions	12	Missions	12	
	Total	**22**	**Total**	**12**	**34**
LPC			Banc test	5	
			Missions	3	
	Total	**0**	**Total**	**8**	**8**
TOTAL		**89**		**51**	**140**

Plans for 2026: EIC-Calo

- Detector frame (IJCLab: 10kE)
- Larger prototype for mechanical (cooling, stress…) studies (IJCLab: 11kE)
- Test boards for CALOROC (OMEGA: 10kE)
- Production of front-end boards with CALOROC chips (LLR: 16kE)
- Travel (IJCLab, OMEGA, LLR: 42kE)





New beam test at DESY requested in June 2026

Back-up

Demande AP EIC 2026 (20/05/2025): argumentaire

Aucune soumission d'ASIC n'est prévue pour l'année 2026. La prochaine itération est envisagée au début de l'année 2027.
Le personnel actuellement impliqué dans les différents projets s'élève à 25 personnes, réparties comme suit :

- EIC-Calo IJCLab : 5
- EIC-Calo LLR : 5
- EIC-Calo OMEGA : 4
- RP/EICROC IJCLab : 6
- RP/EICROC OMEGA : 4
- RP LPC : 1

Projet EIC-Calo

- Poursuite du développement de la structure mécanique du détecteur.
- Construction d'un prototype correspondant à un quadrant complet du calorimètre, destiné à tester :
  - La rigidité mécanique (contrainte, déformation)
  - Les performances du système de refroidissement
- Réalisation d'un prototype intégrant une première version des cartes front-end avec les circuits CALOROC.

Projet RP / EICROC

- Poursuite de la caractérisation des circuits EICROC (itérations 0 et 1).
- Développement d'un banc de test infrarouge.
- Implication récente de l'équipe technique du LPC Clermont dans le développement de la puce.
- Conception d'un système de refroidissement et essais sur un prototype.

Missions

Un budget de 3 k€ par personne impliquée dans les projets est demandé (réunions de travail, collaborations, etc.).

<u>En cas de financement supplémentaire (IR / IR*)</u>

- Tests de différents modèles de SiPM dans le prototype calorimètre : +25–50 k€
- Acquisition d'électronique actuellement prêtée par des collaborateurs (protoboards, cartes KCU, etc.) : +20–30 k€
- Anticipation d'achats d'équipements lourds (chillers, etc.) : +30–40 k€
- Fabrication de prototypes supplémentaires pour le projet RP : +7–14 k€
- Recrutement d'un post-doctorant : +50 k€
- Anticipation des coûts de soumission de la prochaine puce ASIC (2027) : +350–400 k€

Synthèse budgétaire

- Budget de base demandé : 140 k€
- Si financement additionnel (option IR/IR*) : +584 k€
- Budget total potentiel : 724 k€