CALOROC for SiPM readout

EIC calorimetry

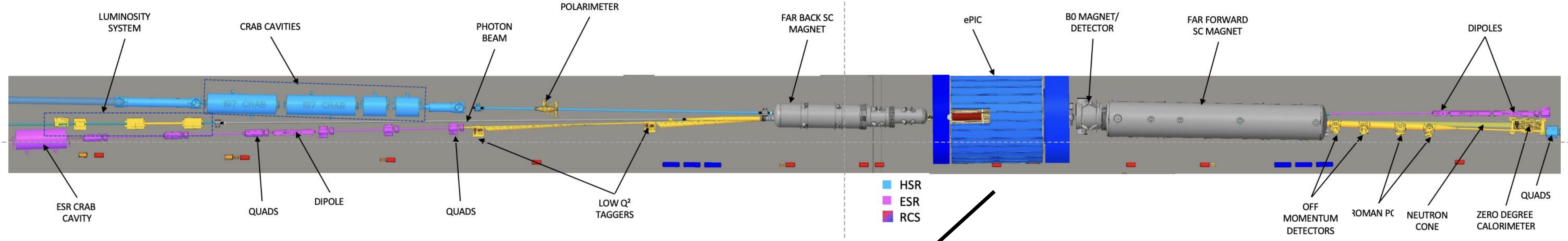
EIC France 2024
9-11 October

Frederic DULUCQ

Organization for Micro-Electronics desiGn and Applications

ePIC detector view

Omega



hadronic calorimeters

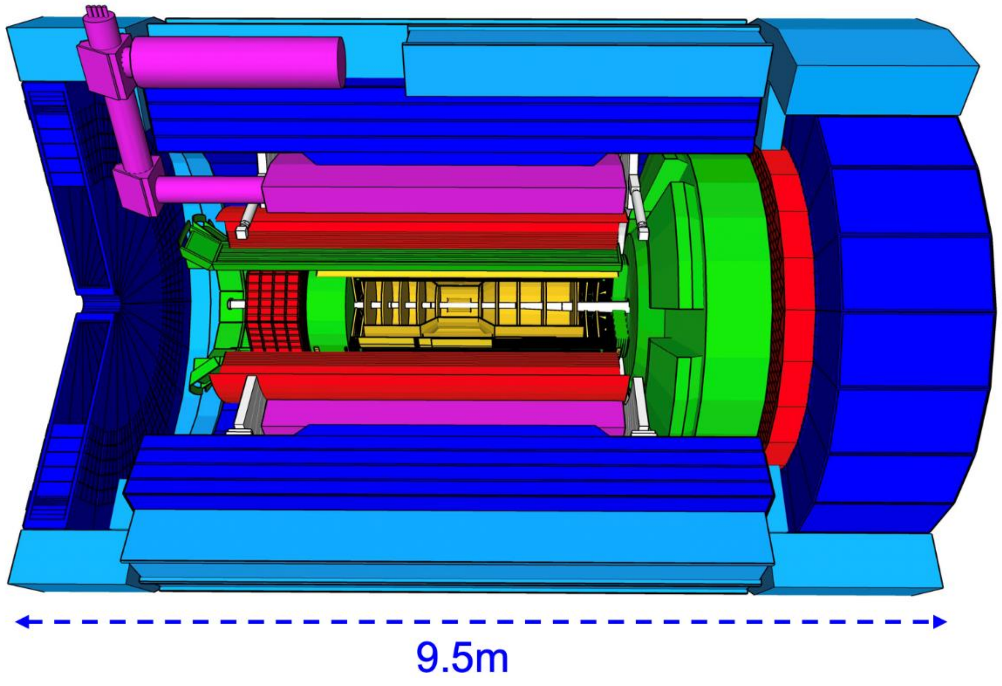
Solenoidal Magnet

e/m calorimeters (ECal)

Time.of.Flight, DIRC, RICH detectors

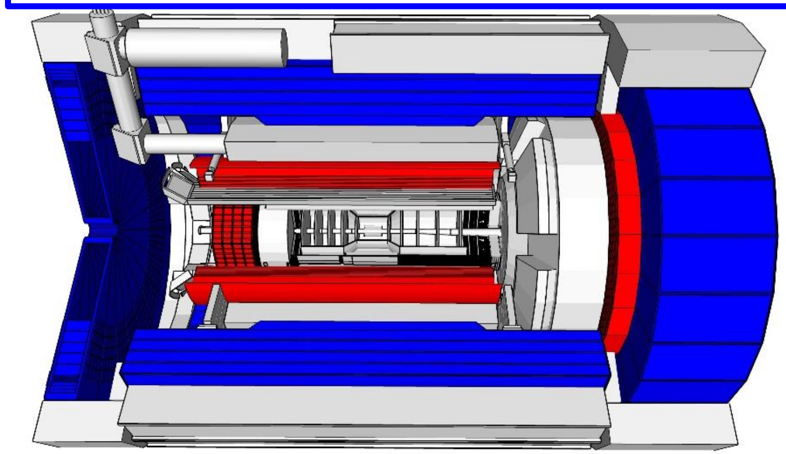
MPGD trackers

MAPS tracker



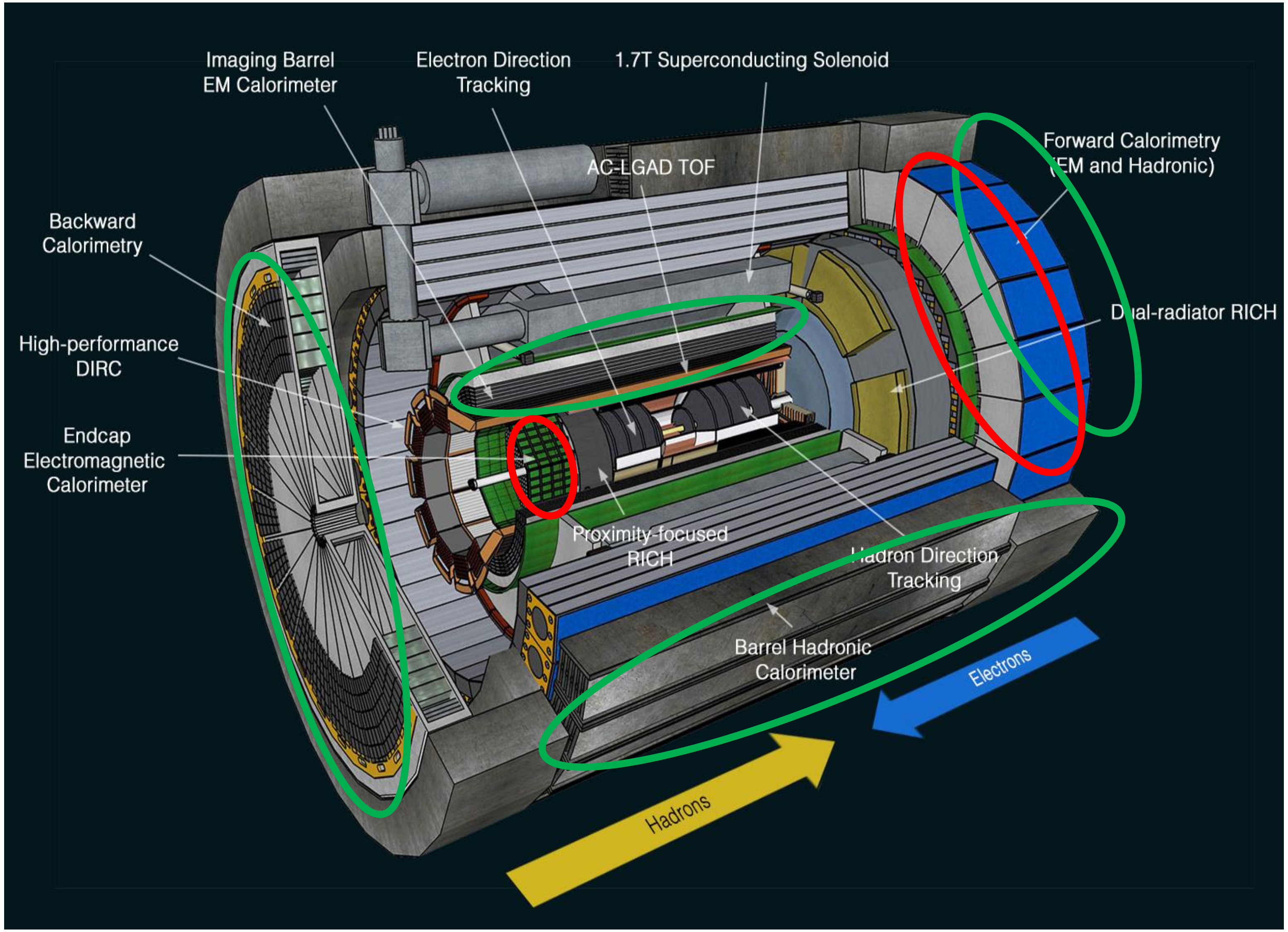
~ 10 ns bunch structure with stream readout

Backward HCAL
Barrel HCAL
Forward HCAL



Backward ECAL
Barrel ECAL
Forward ECAL

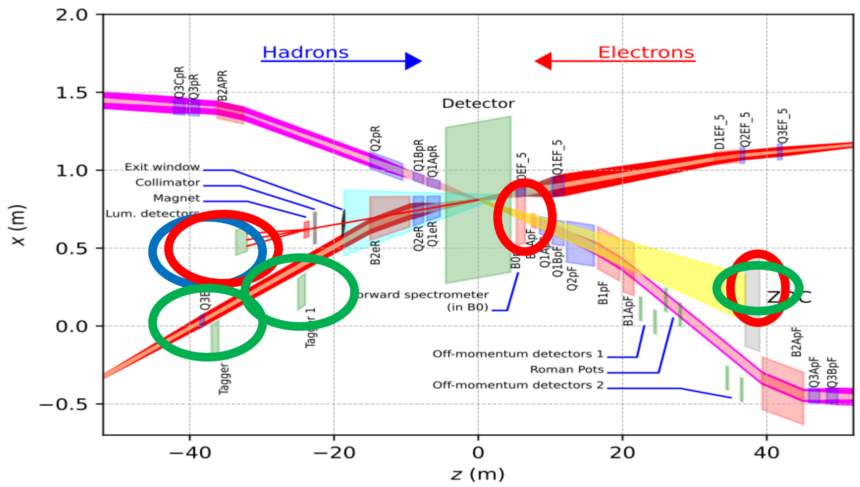
Calorimetry at ePIC



13 Calorimeters:

- 7 x SiPM – CALOROC
- 5 x SiPM – Discrete
- 1 x SiPM – Commercial fADC250

From J. Landgraf (IDR review)



From H2GCROC to CALOROC

Ωmega

H2GCROC for the endcap calorimeter – Phase II

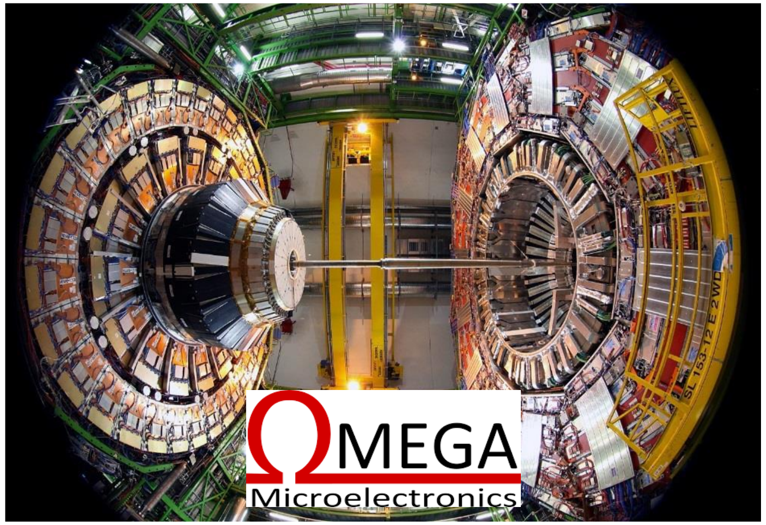
→

CALOROC for EIC

6M of Silicon channels
(+ 240k of SiPM)

Radhard (200 Mrad)
Low Power (15 mW per chn)
Precise timing (25 ps)

Total of 150k ASICs needed
Pre-prod this year



Same ASIC structure (floorplan)
Same ADC and TDC
Same readout

Common interfaces

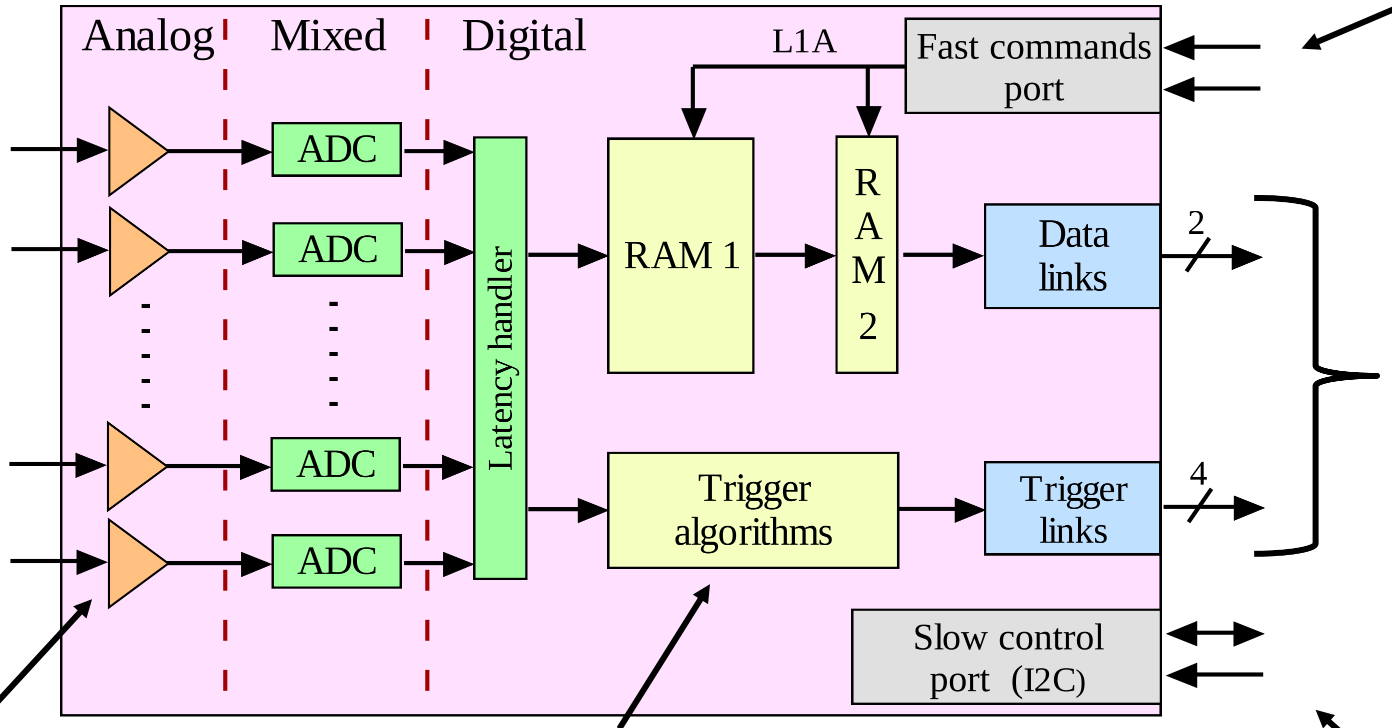
HEP trend => imaging calorimetry

- ❑ High number of channels
- ❑ Charge and precise timing (<100 ps)
- ❑ Low power + System-On-Chip

Based on H2GCROC, CALOROC will provide a versatile and low-power solution for SiPM readout

ROC chips standard structure

- H2GCROC (for SiPM readout) is an HL-LHC colored ASICs (external L1 trigger)
  - Below is an calorimetry structure (but interfaces for CALOROC will similar)



Dedicated fast command interface : calibration pulses, external L1 trigger.

Data and trigger serial links with CLPS signaling (LpGBT @ 1,28 Gbps)

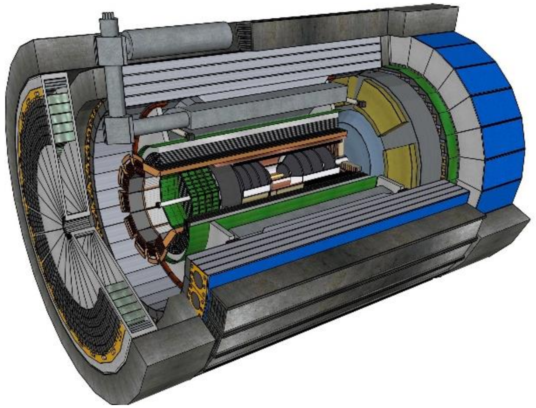
I2C interface to load the ASIC parameters (slow control interface)

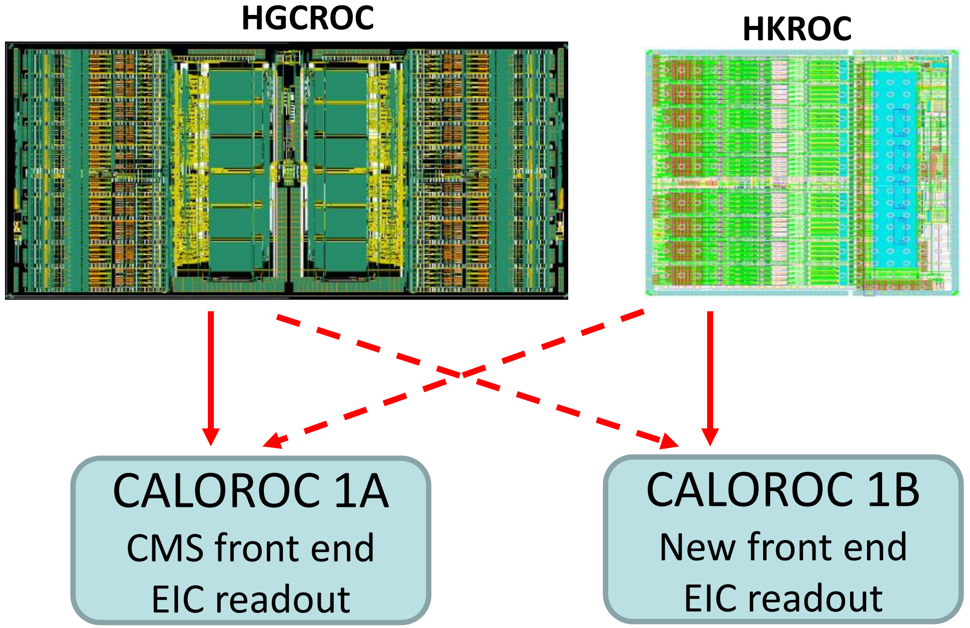
LHC-like structure :
Ram1 for data storage
Ram2 for L1 accepted events

Analog front-end specific to sensor

What is CALOROC ?

- CALOROC will be available in 2 versions for SiPM readout:
  - SiPM range capacitance from 500 pF to 10 nF
  - ~ 10 mW / channel
  - Radiation hardening (HL-LHC levels)
    - 200 Mrad and 10^{16} n_{eq} / cm² (1 MeV equivalent neutrons)
    - SEE hardening on control logic
  - Charge and time measurement
  - Max triggering rate of 50 kHz / chn





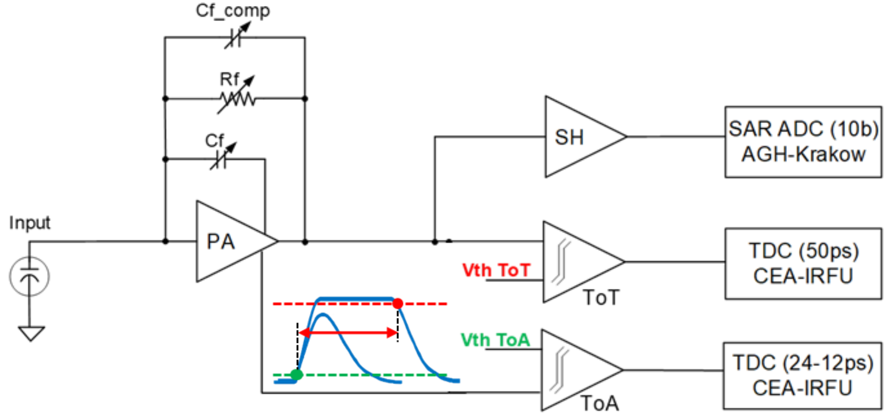
- Conservative CALOROC1A based on CMS H2GCROC:
  - H2GCROC (ADC, TOT) analog/mixed reuse
  - Back-end compatible with EIC + zero-suppress

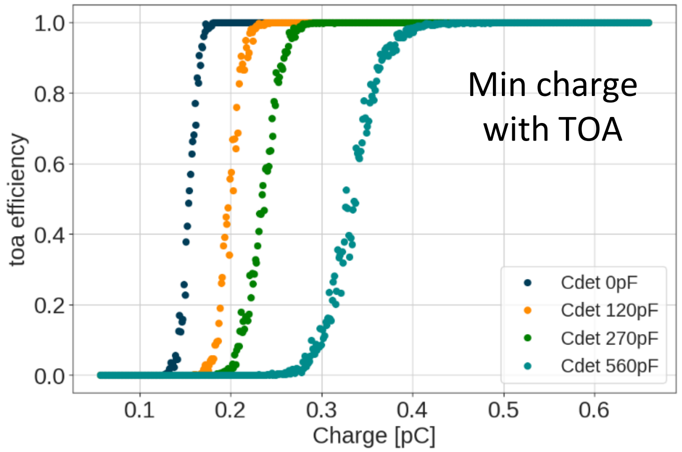
- New CALOROC1B based on gain switching:
  - New analog part without TOT (dynamic gain switching)
  - Backend « à la HKROC »: auto-trigger, zero-suppress – EIC compatible

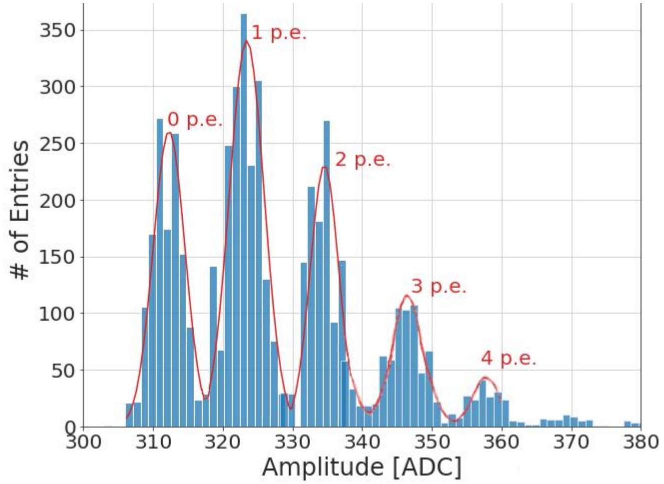
CALOROCs will share a common backend
+ pin-pin compatibility

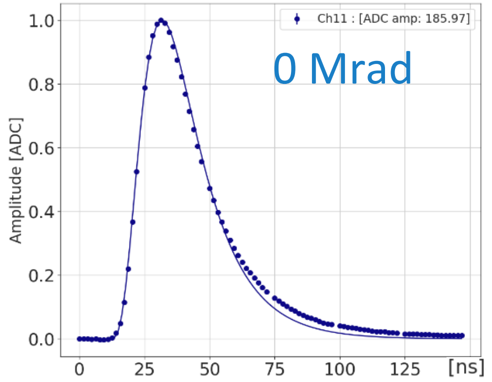
CALOROC1A (based on H2GCROC)

- ❑ Reuse of analog front-end based on ADC/TOT and TOA: fully characterized *
  - ❑ 15 mW per channel / Radiation performance / SiPM range 100-600 pF

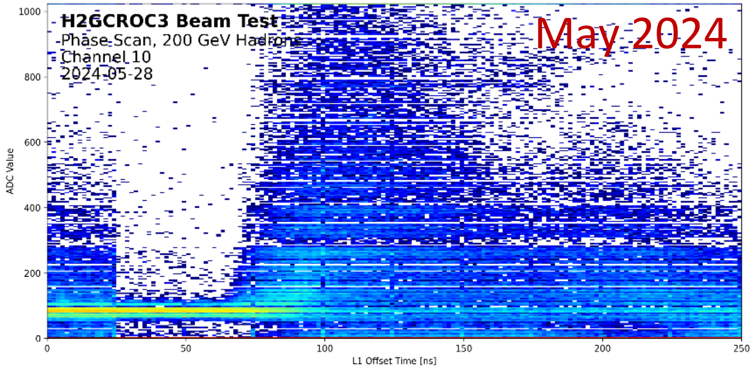


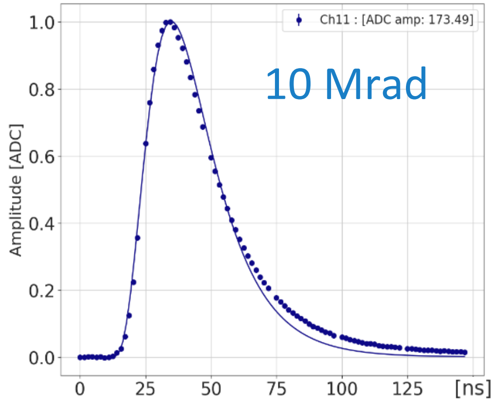






- ❑ H2GCROC already evaluated by ORNL for EIC calorimetry





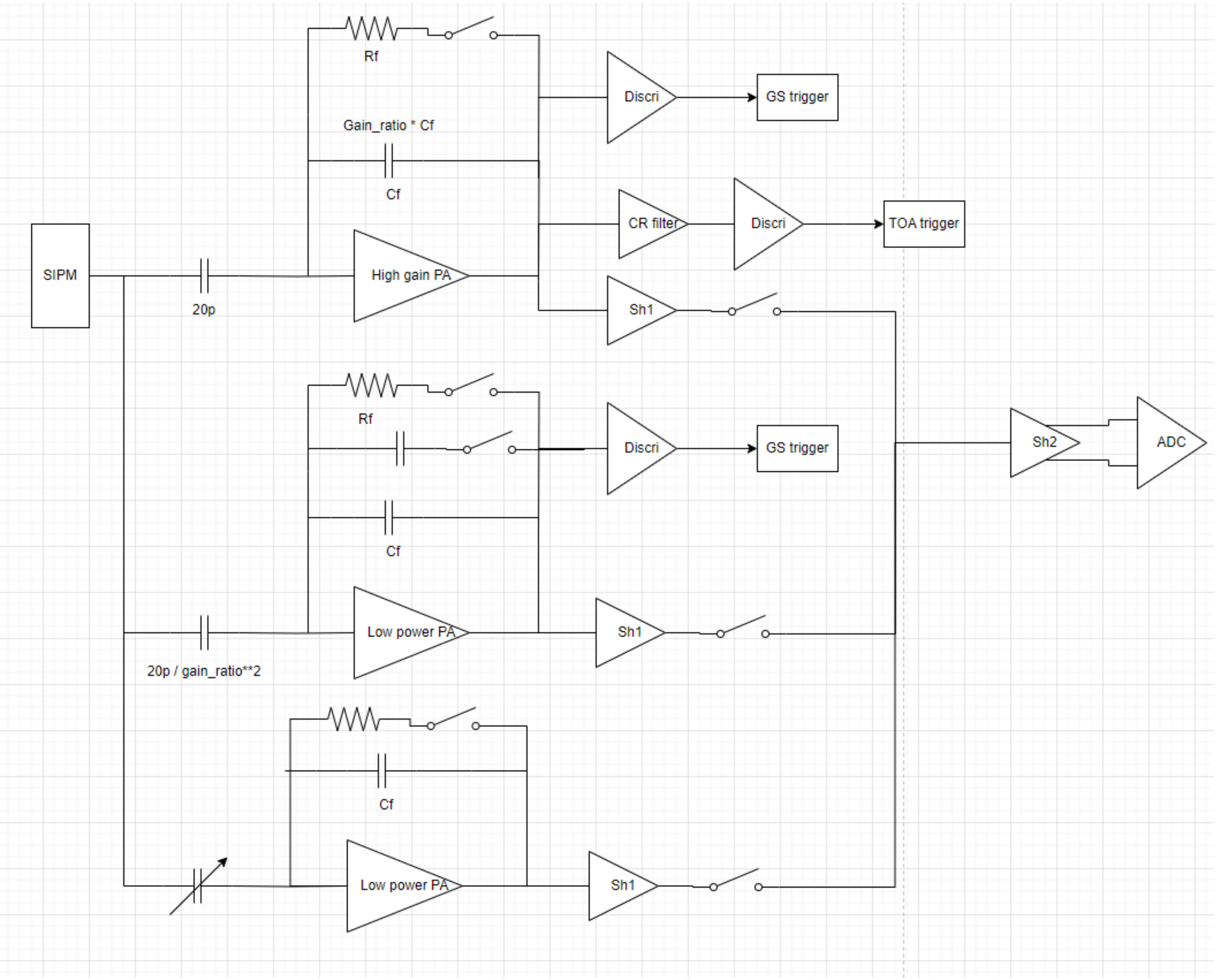
- ❑ CALOROC1A will only update its back-end to be EIC compatible

* TWEPP 2023 ➔ https://doi.org/10.1088/1748-0221/19/04/C04005

CALOROC1B: Chosen architecture [P. Dumas]

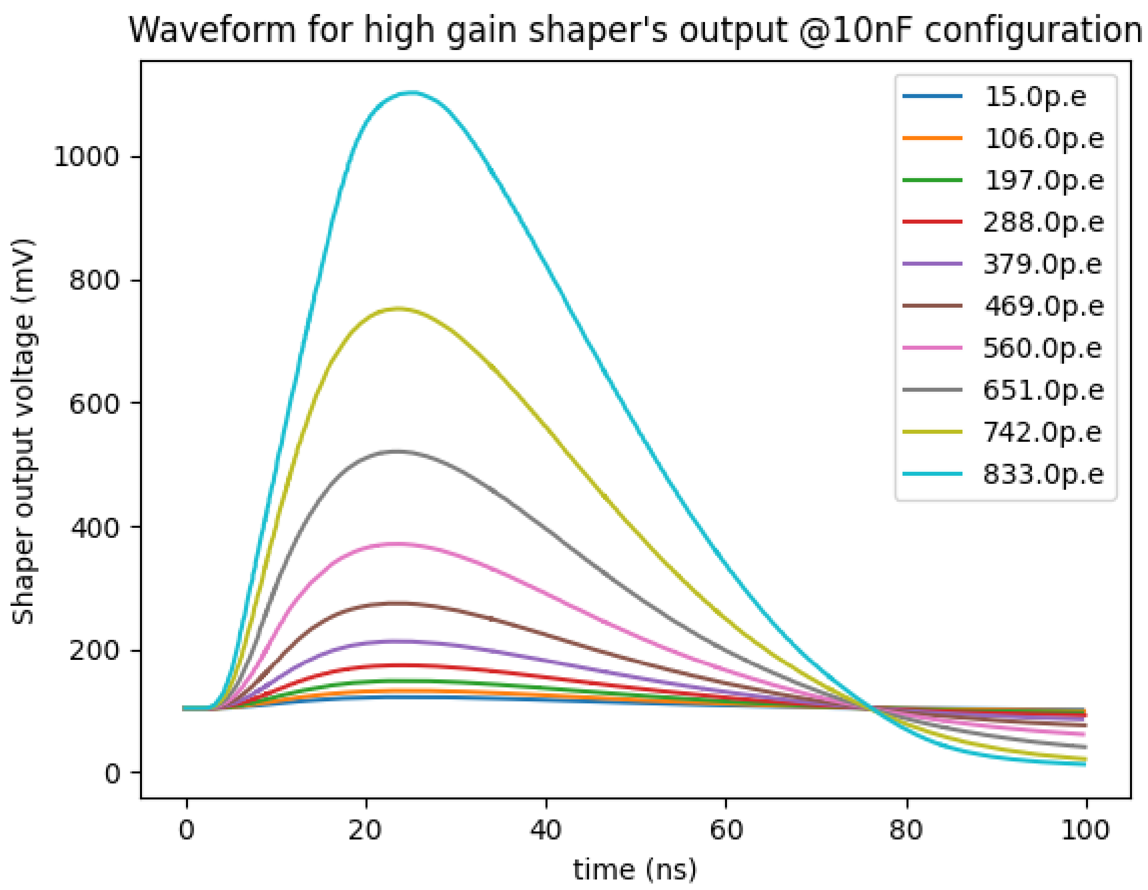
Omega

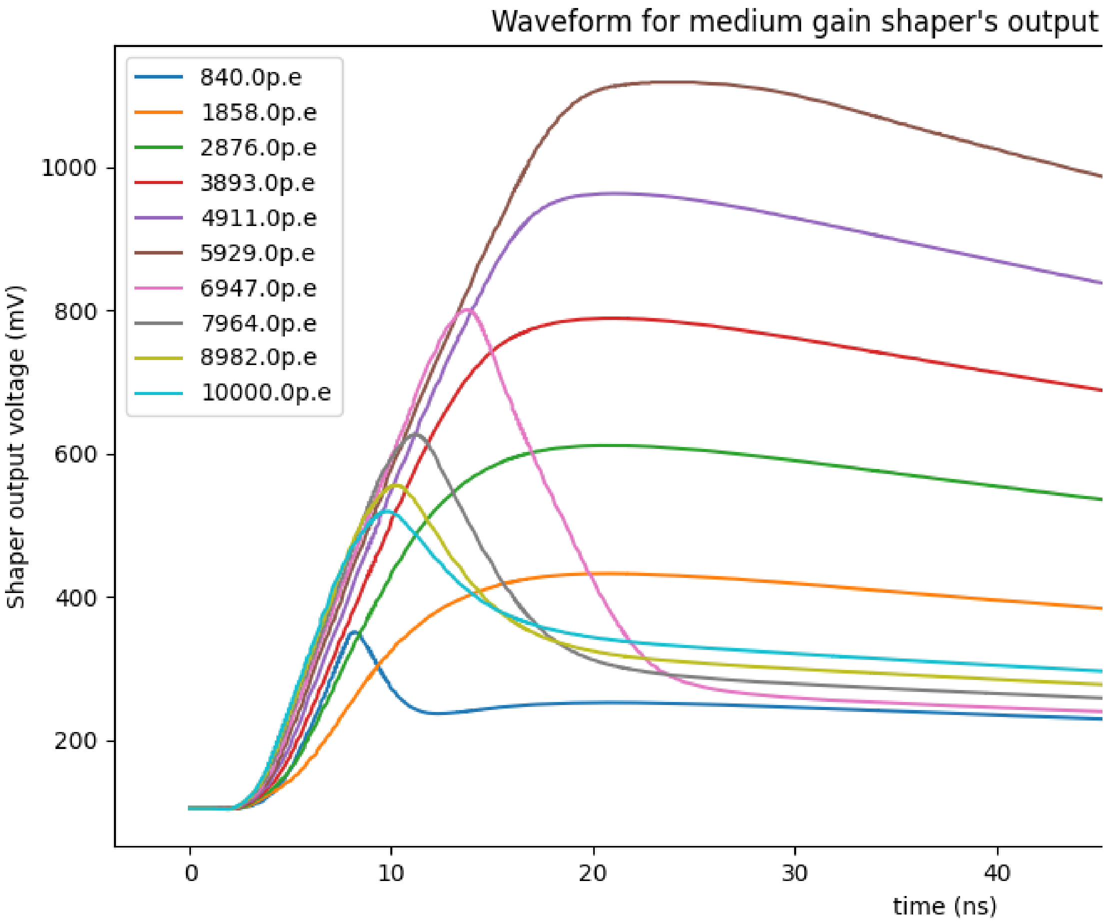
- New dynamic frontend with switched gain:
  - High gain
  - 2x medium gain
  - Low Gain
- Reuse CMS-H2GCROC ADCs and TDCs:
  - 10-bit 40 MHz ADC (Krakow)
  - 25 ps TDC (Saclay)
- Shared CALOROCs backend
- Common specifications:
  - SiPM from 500 pF to 2.5 - 10 nF
  - ~ 10 mW/channel
  - CMS HL-LHC Radiation level 200 Mrad



CALOROC1B: Charge and time simulations

- Waveform for HG on the left + gain switching on the right:
  - Example with Cd of 10 nF

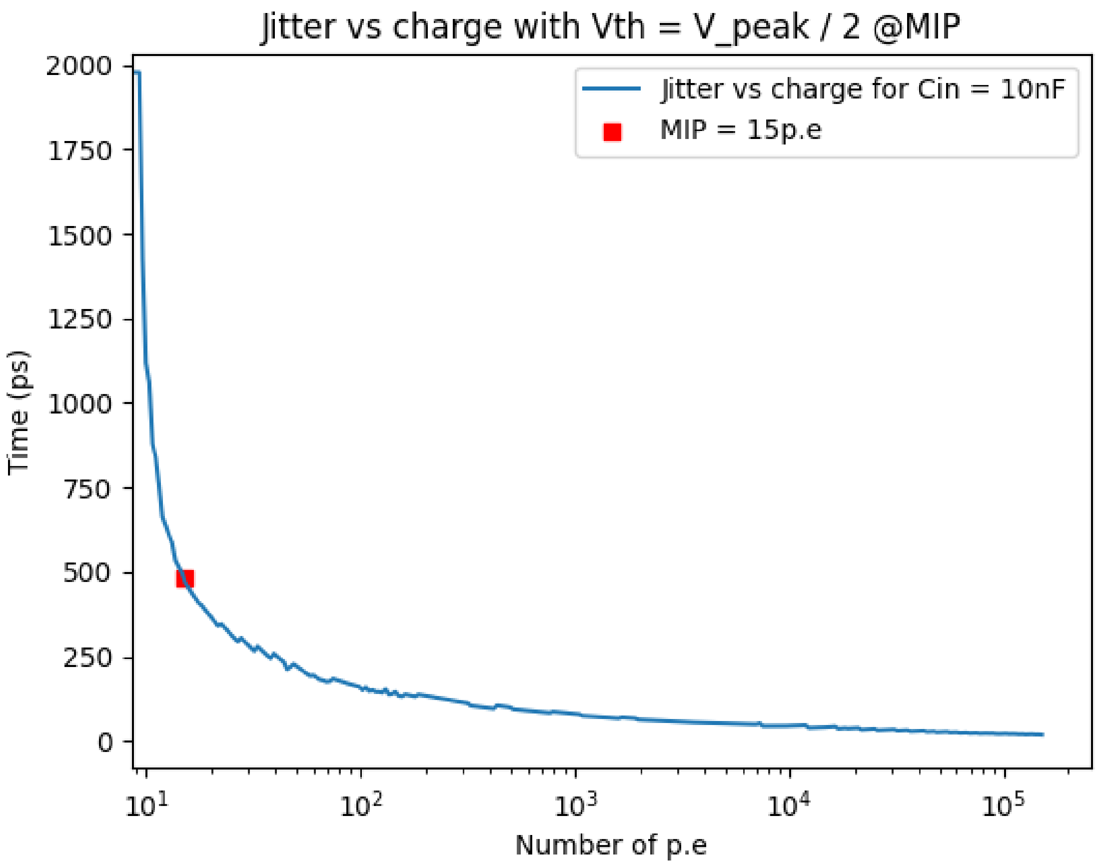


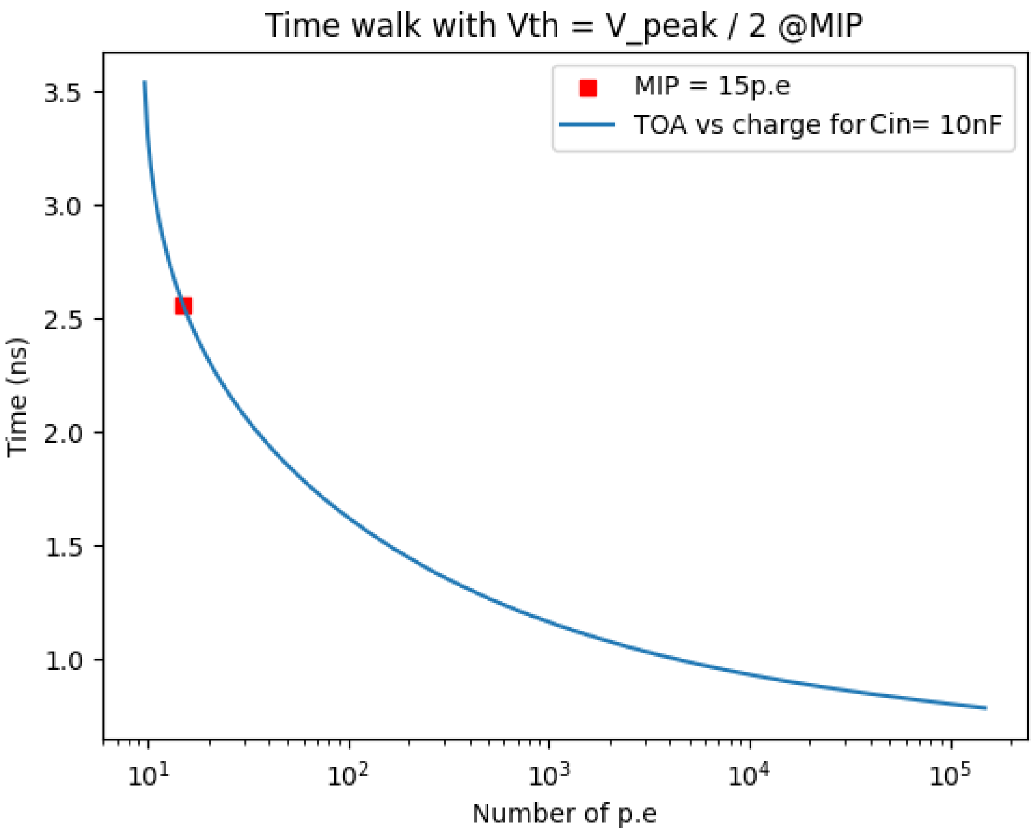


CALOROC1B: Timing precision

- Simulated time jitter goes down to 20 ps with < 500 ps for the MIP

- Time walk is below ~2,5 ns (equivalent to the value of CMS H2GCROC)





CALOROC1B: SiPM vs SNR

- The SiPM configuration has a direct impact on the SNR
  - SNR for 1p.e is proportional to Q/C (larger SiPM cap decrease SNR)
  - Gain of 1.8e5 electrons per p.e (table below)

- CALOROC1b will be able to readout SiPM in the range ~ 500 pF to 10 nF
  - Timing measurements will focus on the MIP (~15pe)

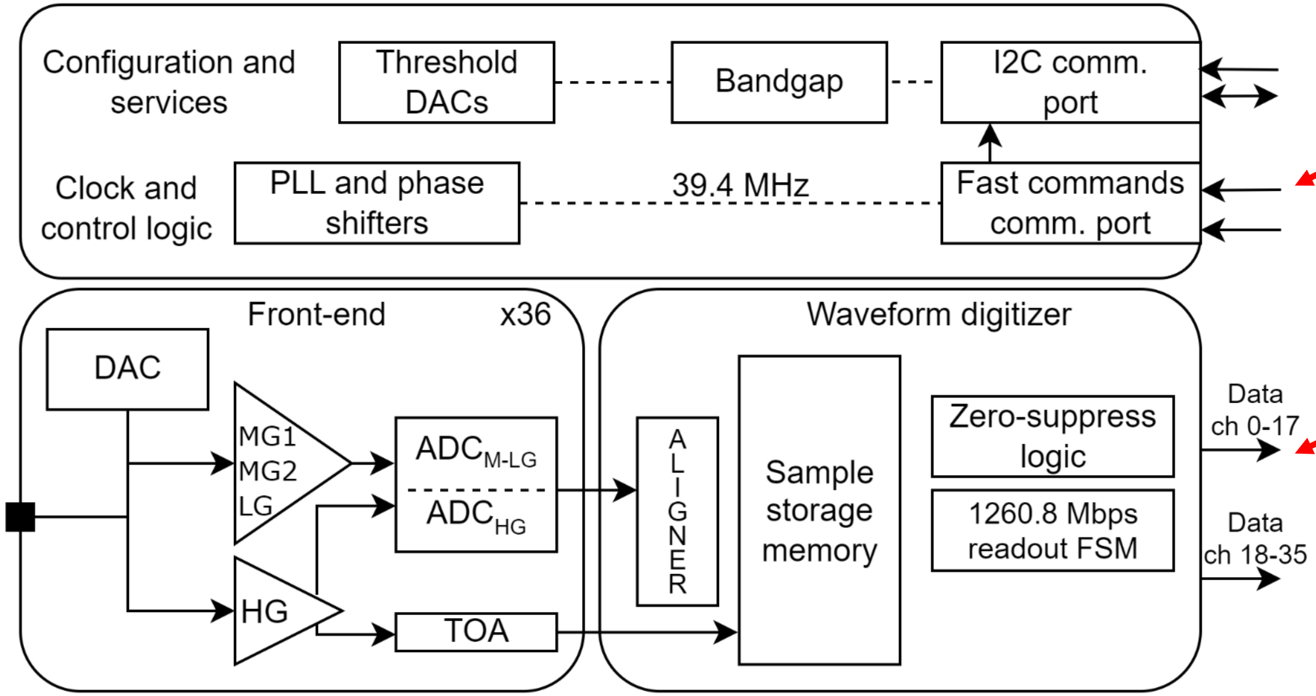
Operation modes	1 SiPM of 530pF	1 SiPM of 2.5nF	4 SiPM of 2.5nF
Cin	530pF	2.5nF	10nF
SiPM config gain (μV/p.e or Q/C)	13.58μV	11.52μV	2.88μV
Dynamic range (in p.e)	22.79k	107.5k	430k
Dynamic range (Charge)	656pC	3.1 nC	12.3nC
Jitter @ 1p.e	390ps	Not measurable	Not measurable
SNR @ 1p.e	10	2.13	0.53

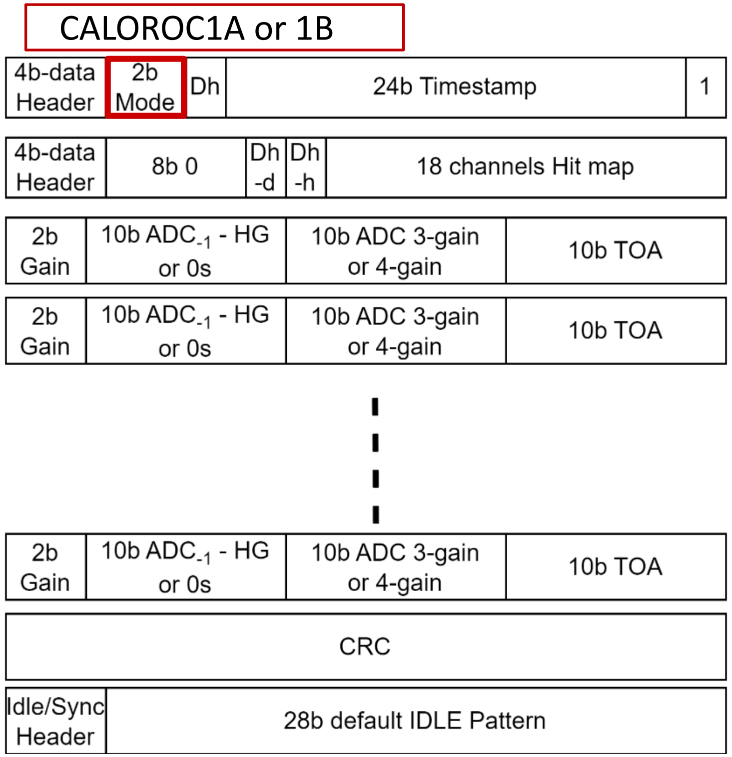
SiPM: S14160-3010PS 3x3mm (530pF) / S14160-6010PS 6x6mm (2.5nF)

CALOROCs: block diagram and interfaces

- CALOROCs will have the same interfaces (comparable to CMS H2GCROC *):
  - Fast command to dynamically control the ASIC
  - I2C to set the parameters
  - High speed serial links (**C**ern**L**ow**P**ower**S**ignal compatible)

Fast commands	Value
Idle	00011
External trigger	01101
ChipSync	01110
BCR	10101
EBR	11001
Link-sync-ROC or Link-reset-ROC	10110
Calibration int or ext	11010

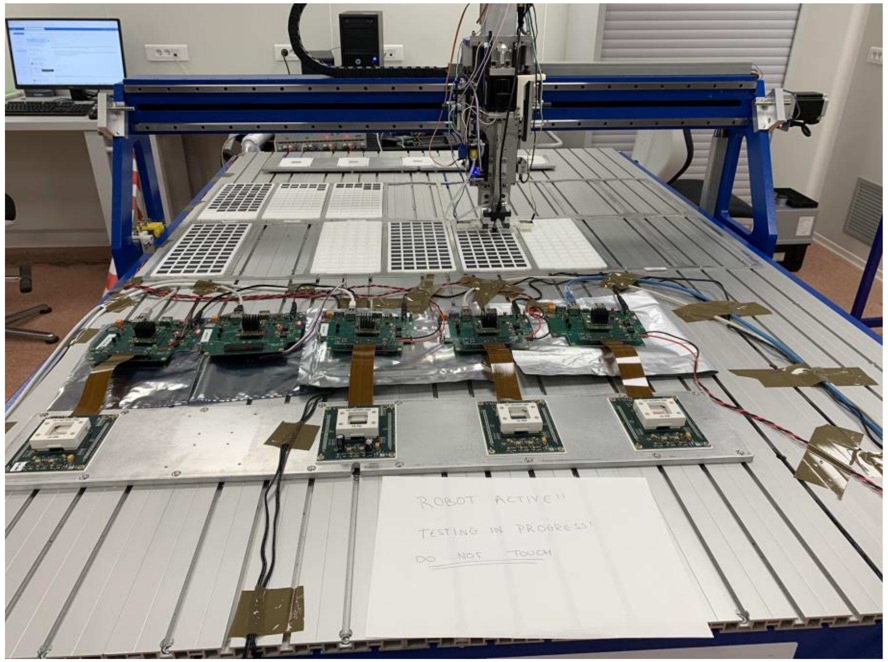




* CERN EDMS → https://edms.cern.ch/document/2954073/1

Quality assurance and timeline

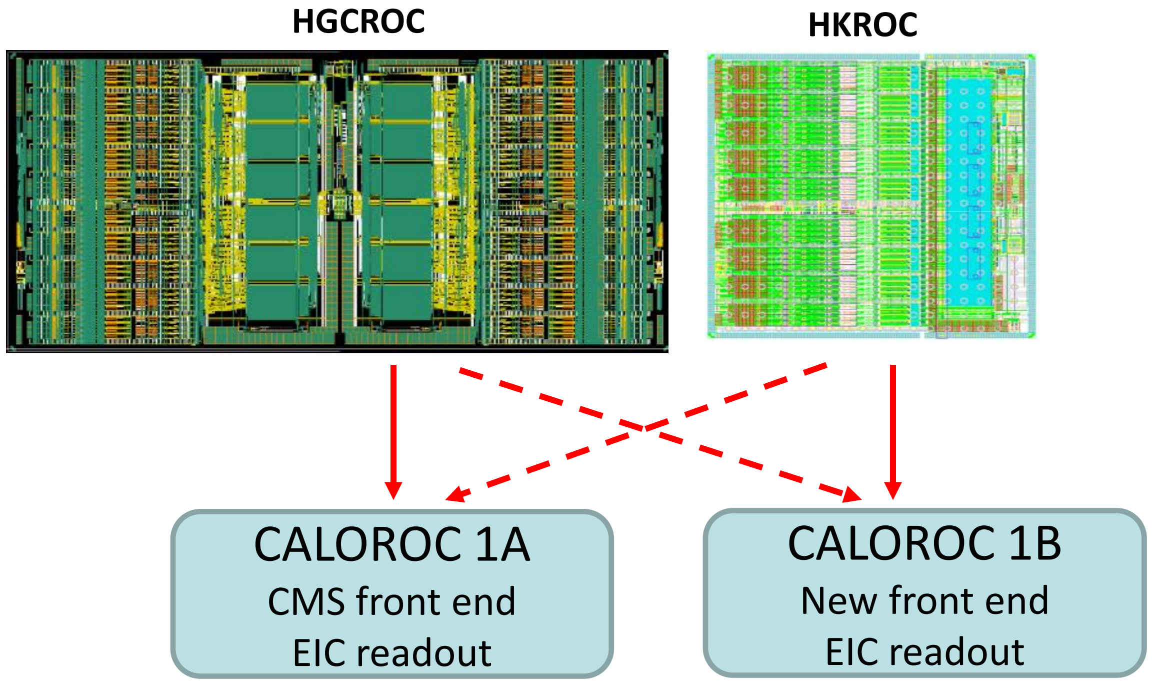
- Expertise in radiation-hardened front-end ASICs for HEP
  - HL-LHC ASICs: ATLAS HGTD and CMS HGCAL (10^5 ASICs)
- Expertise in irradiation testing (dose and displacement)
  - HL-LHC levels 200 Mrad and 10^{16} n_{eq} / cm² (1 MeV equivalent neutrons)
- Standard interfaces ensures a full compatibility with our robot
  - 2x 50 ASICs tested per hour (H2GCROC) with QR code scan



- CALOROC timeline – 2024 to 2027
  - End 2024, CALOROC1A **and** B submission (Eng. Run)
  - 2025, packaging, performance tests and DAQ validation
  - 2025-2026, irradiation tests and CALOROC2A **or** B preproduction (final ASIC/package)
  - (If chosen, possible CALOROC3B extra submission end 2026)
  - Q1 (Roc1A) or Q3 (Roc1B) 2027 production and robot tests

Conclusion

- ❑ Both CALOROC will be submitted by the end of 2024 (common fabrication run)
- ❑ 2 new designers joined OMEGA for CALOROC
  - ❑ 1 PhD in 2023 + backend designer in March 2024
- ❑ Conservative **CALOROC1A**: analog and mixed part finished
  - ❑ Shared CALOROCs backend under simulation
- ❑ New **CALOROC1B**: Analog and mixed architecture frozen
  - ❑ Analog and mixed part finished
  - ❑ Shared CALOROCs backend under simulation
- ❑ CALOROCs will be compatible with CMS test robots



CALOROCs are targeted to include all features + radiation hardness on the first submission