CALOROC
status and plans

DRD6 WP4 meeting
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Organization for Micro-Electronics desiGn and Applications

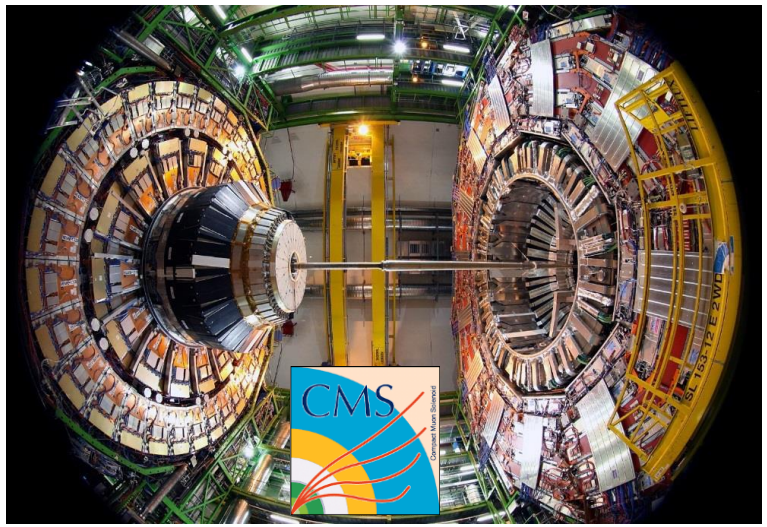
From H2GCROC to CALOROC [F. Dulucq]

H2GCROC for the endcap calorimeter – Phase II

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



CALOROC for EIC

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

Common interfaces

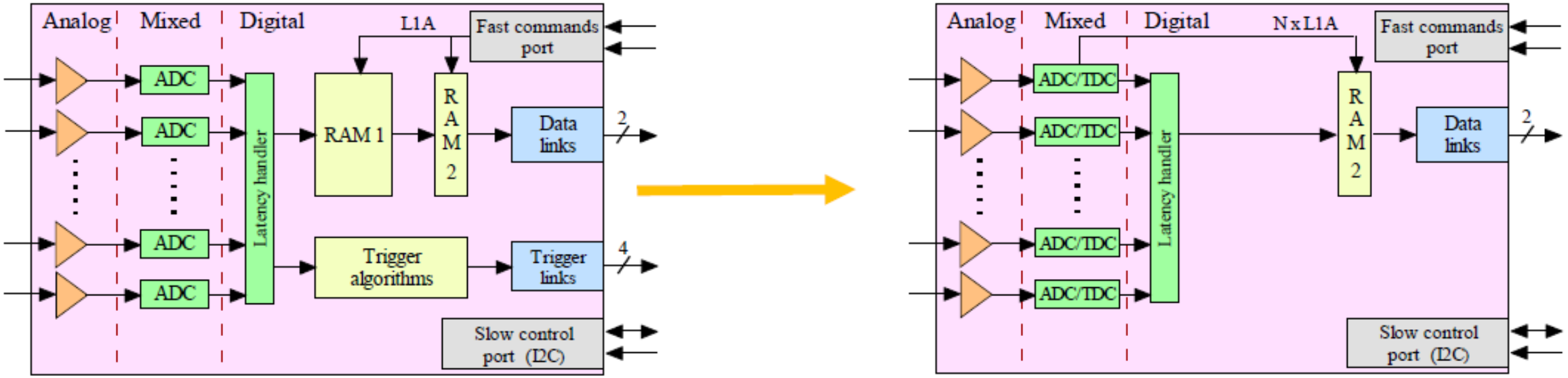
HEP trend => imaging calorimetry

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

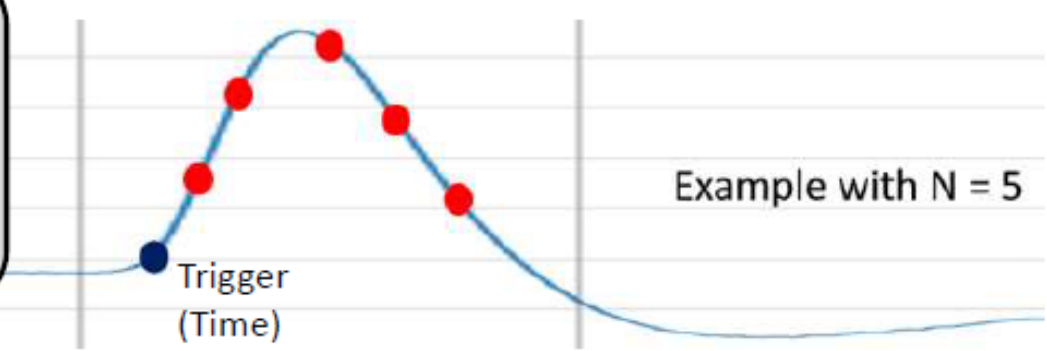
Based on H2GCROC, CALOROC will provide a versatile and low-power solution for SiPM readout

From H2GCROC to CALOROC

- No more LVL1 : data streaming => auto-trigger and zero-suppress
  - very interesting for future DRD6 readout ASICs !



- Each event passing the threshold is readout
- Auto-trigger with N "samples" (1 to 7)
- Can be exercised with present HGCROC (multiple L1A-triggers)

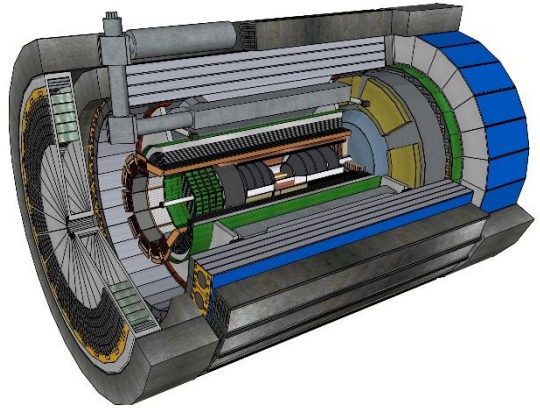


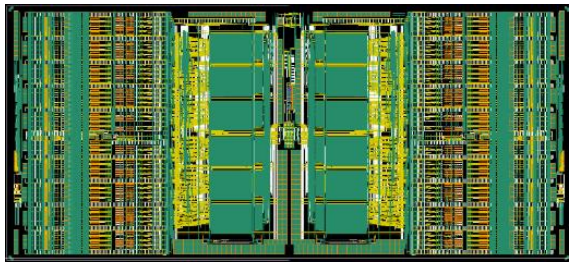
CALOROC : R/O chip for EIC calorimeter (and DRD6)

- 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} / cm^2 (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 compatib





CALOROC 1A
CMS front end
EIC readout

CALOROC 1B
New front end
EIC readout

CALOROCs will share a common backend
+ pin-pin compatibility

Common: Rates per channel

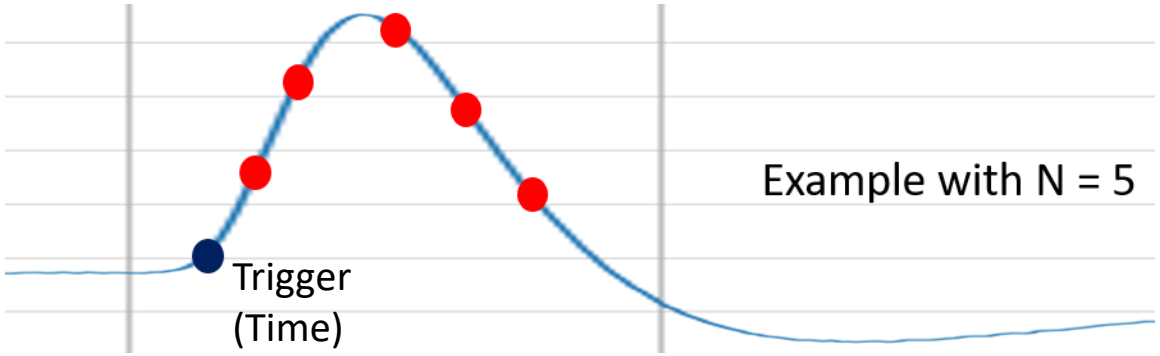
- Present HGCROC rate calculation: 1 serial link for 36 (+2) channels (HGCROC is arranged by 36 channels)

Version	Number of points (N)	Max rate	Remarks
Present HGCROC-36ch	1	976 khz / ASIC	LHC is 1 snapshot
Per channel (1 link/36 ch)	4 or 3	7-9 kHz / chn	Divide by N and by 36 (could be exercised)
CALOROC (1 link/18 ch)	4 or 3	24-32 kHz / chn	
CALOROC with zero suppress	4	55 kHz / chn	With 6 channels triggered (over 18)

Present HGCROC

CALOROC

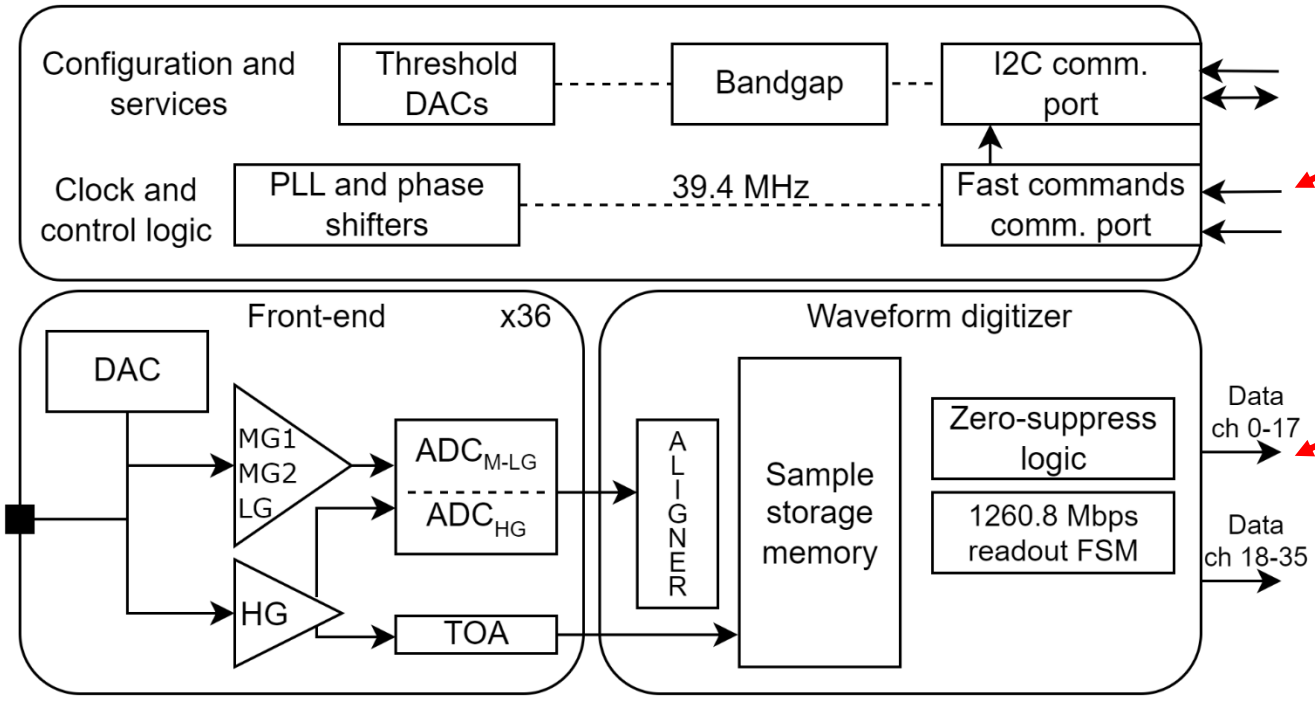
Conclusion: ZS with 2 serial links mandatory



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



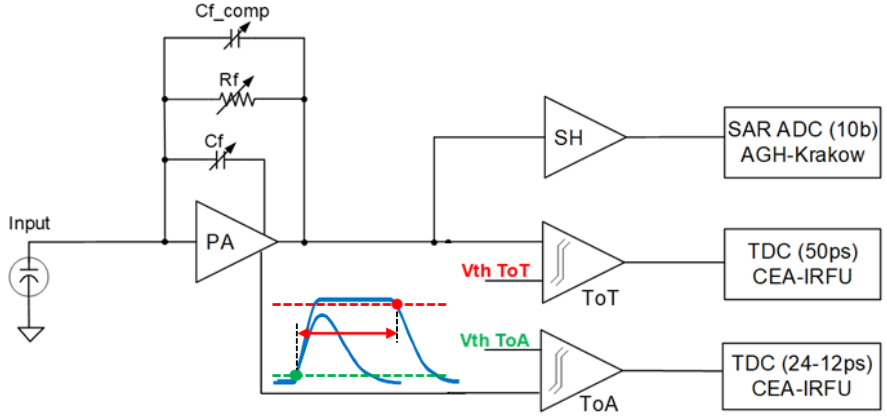
CALOROC1A or 1B

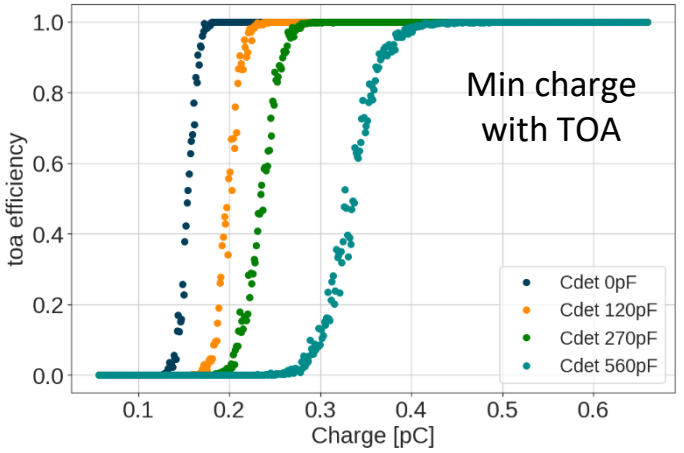
4b-data Header	2b Mode	Dh	24b Timestamp	1
4b-data Header	8b 0	Dh -d	Dh -h	18 channels Hit map
2b Gain	10b ADC$_{-1}$ - HG or 0s	10b ADC 3-gain or 4-gain	10b TOA	
2b Gain	10b ADC$_{-1}$ - HG or 0s	10b ADC 3-gain or 4-gain	10b TOA	
⋮				
2b Gain	10b ADC$_{-1}$ - HG or 0s	10b ADC 3-gain or 4-gain	10b TOA	
CRC				
Idle/Sync Header	28b default IDLE Pattern			

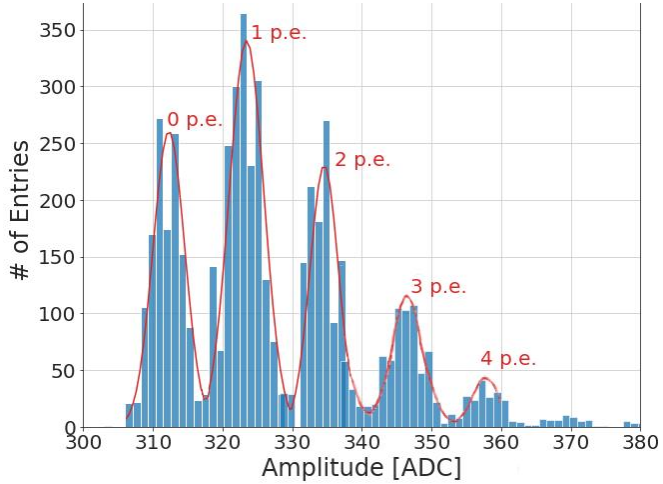
* CERN EDMS ➔ https://edms.cern.ch/document/2954073/1

CALOROC1A (based on H2GCROC)

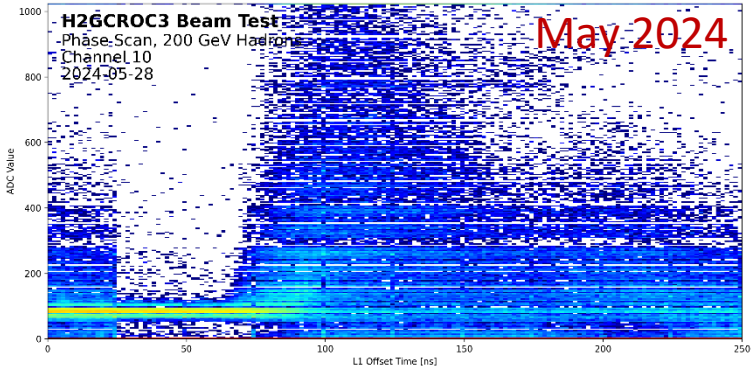
- Reuse of analog front-end based on ADC/TOT and TOA: fully characterized *
  - 15 mW per channel / Radiation performance / SiPM range 100-600 pF

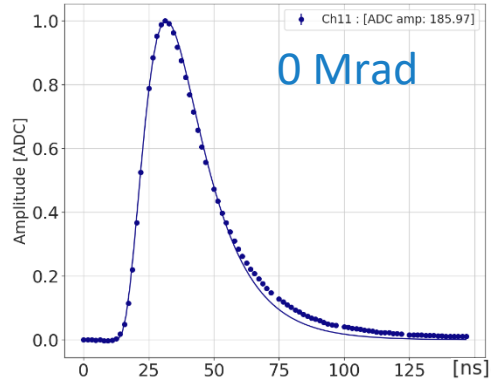


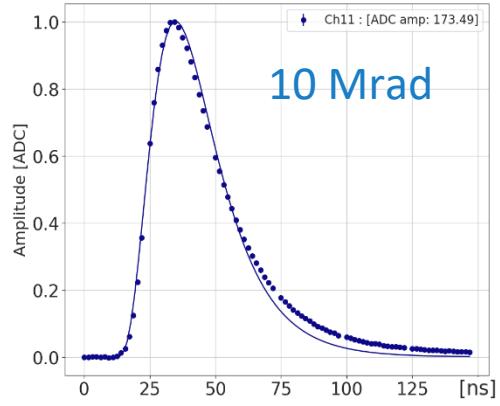




- H2GCROC already evaluated by ORNL for EIC calorimetry





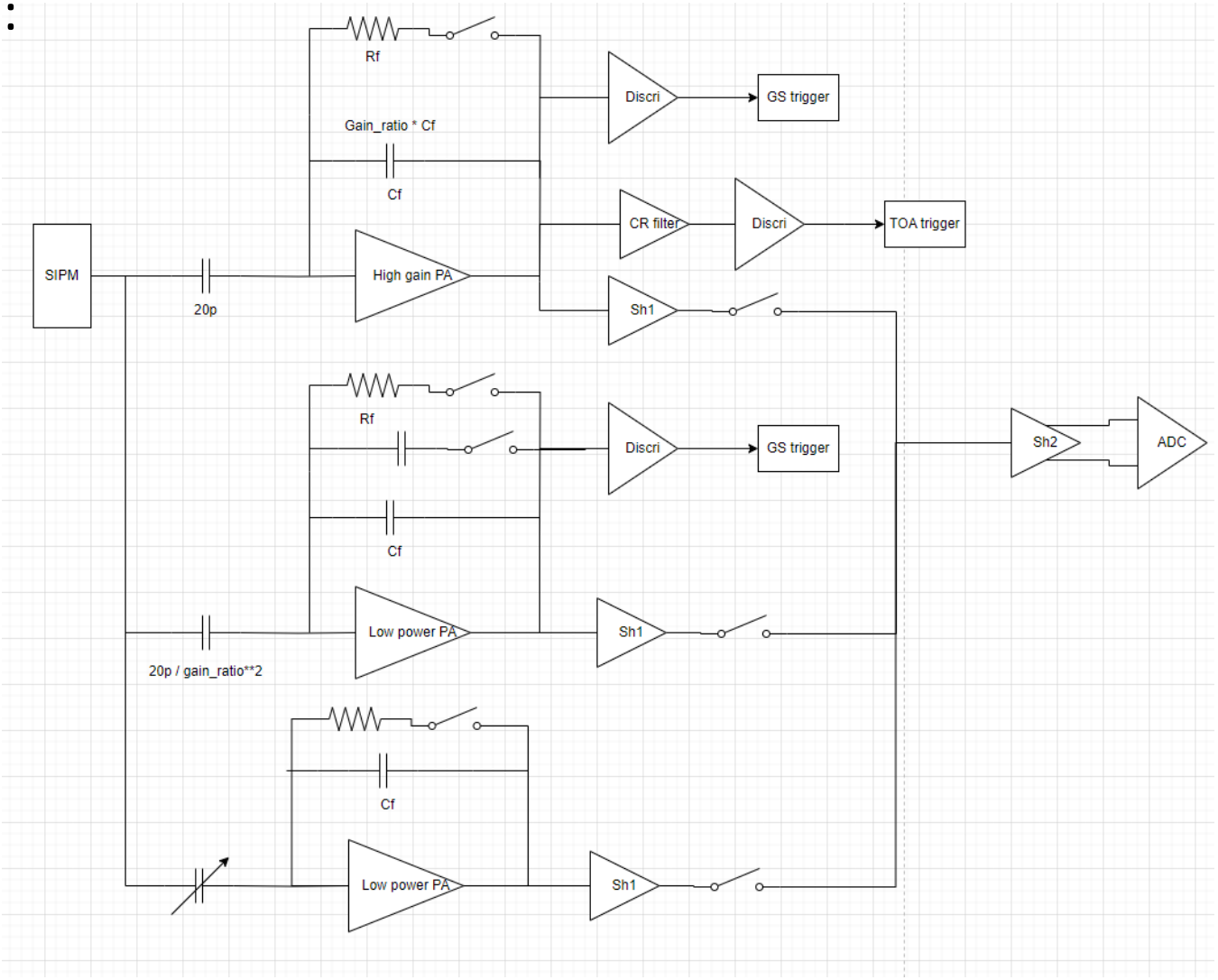


- CALOROC1A will only update its back-end to be EIC compatible

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

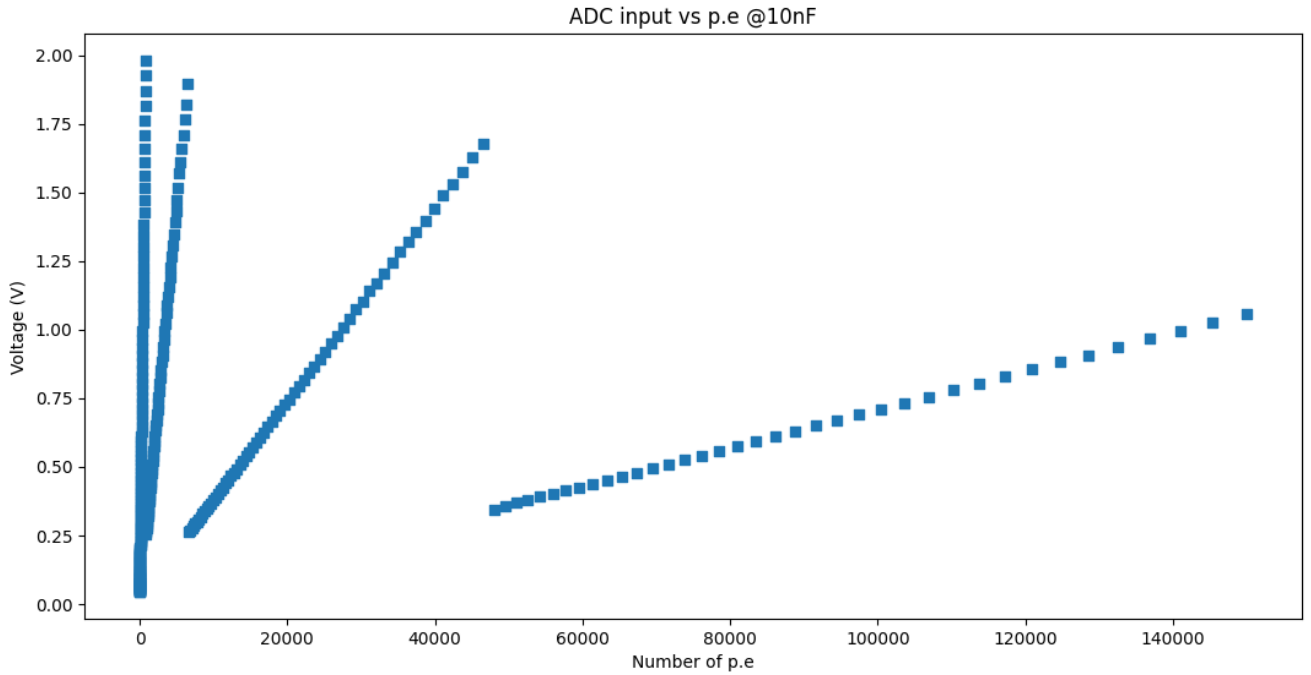
CALOROC1B: new architecture [P. Dumas]

- 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 dynamic range

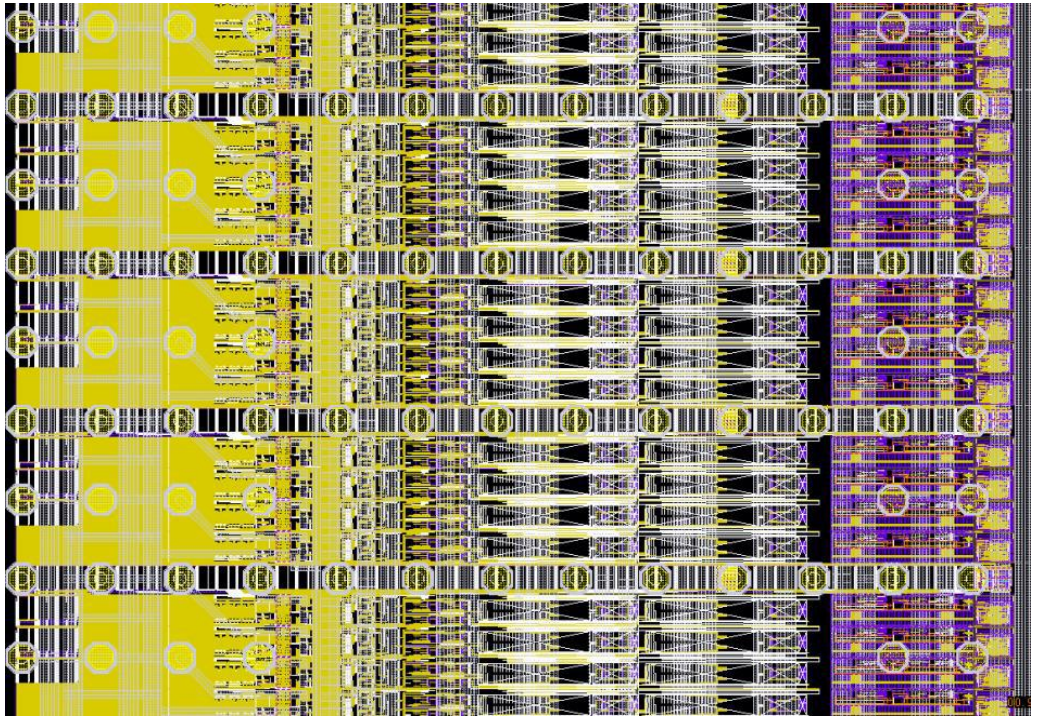
- DR ~1^E5
- S/N depends on sensor capacitance
- Linearity : all residuals within +/- 1%



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

CALOROC1A/1B : status

- Layout complete for analog part
- CALOROC1A and 1B now waiting for the completion of digital part
- Will fit in HKROC footprint => re-use BGA substrate



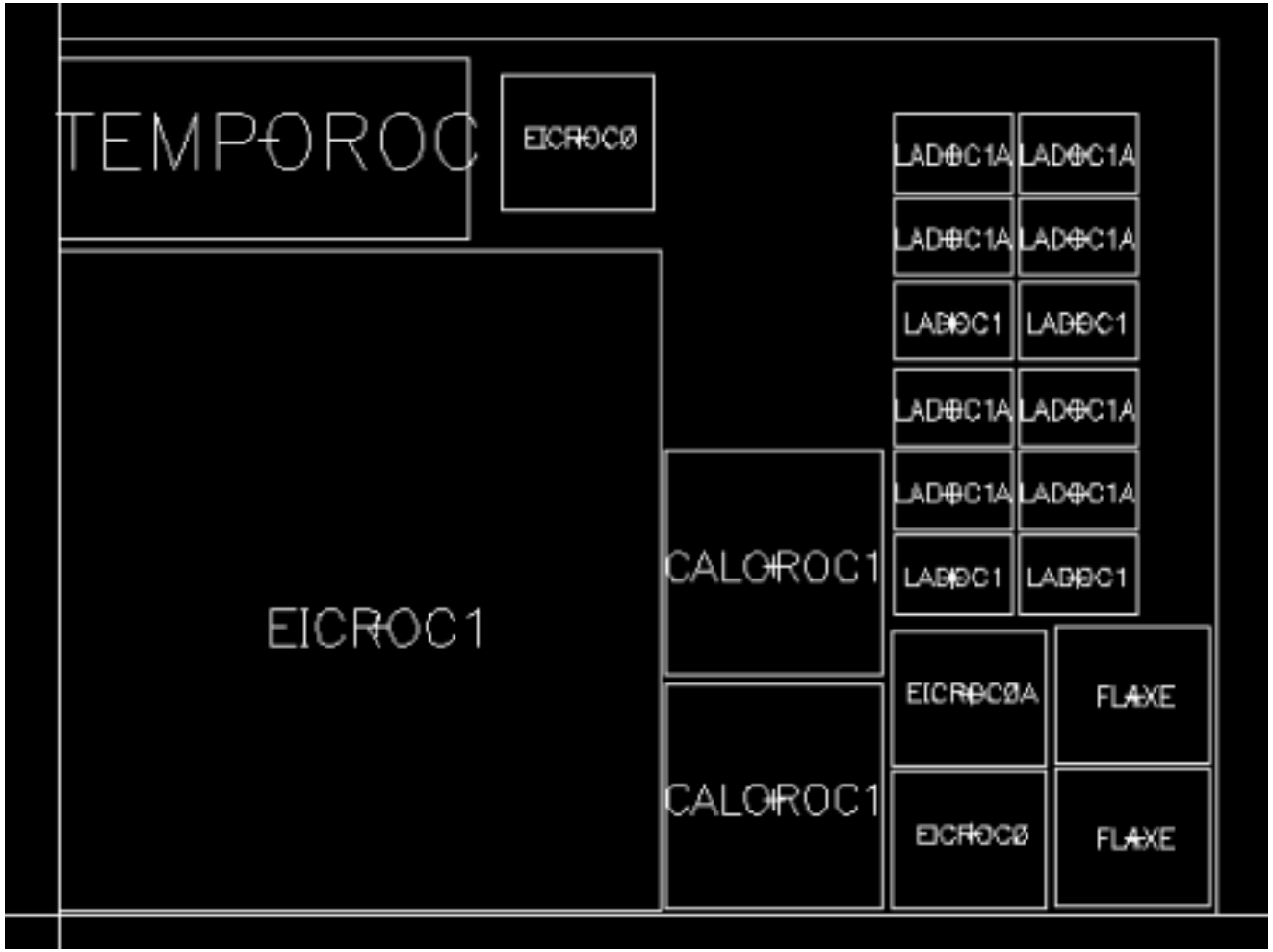
HKROC

EIC reticle 2024

- TSMC now requires to fully populate the reticle of 24x32
  - Cost ~300 k€

- For EIC we would have
  - EICROC1
  - 2 or 3 EICROC0/A/B
  - 2 CALOROC1A/1B
  - ~60% of reticle area

- Possible additionnal partners
  - ~20% of reticle area
  - Still space available (if ready in time !)



Conclusion

- CALOROC is a 36 chip to readout SiPMs for EIC calorimetry
  - Streaming readout
  - will pave the way for DRD6

- 2 variants
  - CALOROC1A : conservative « à la H2GCROC » (SiPM)
  - CALOROC1B : innovative « à la SPIROC » with auto-gain

- Study of a possible variant « à la HGCROC » for Si and LAr

- R&D proposal by ADRIANO3 collaboration to develop R/O with CALOROC and FPGA concentrator (to be followed up)

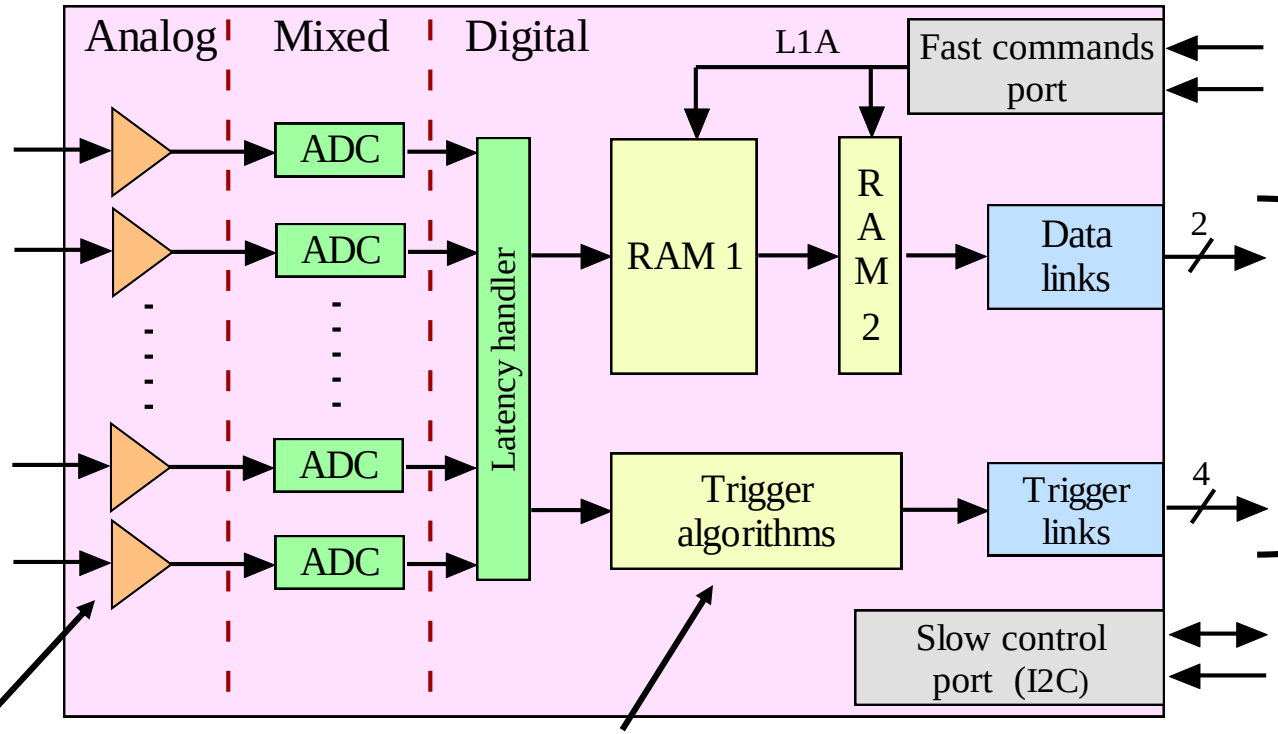
WP4 discussion

- Common R/O ASICs development already started thanks to EIC R&D
  - Streaming readout !
  - SiPM sensors, hopefully also Si and Lar
  - Pinout confirmed soon => Front End boards design can be initiated
- Inputs welcome from WP1-2-3 welcome to check matching of their requirements
- Still room for other groups to join or start their own developments
  - Trying to re-use some common features (40MHz clock, fast commands, data format…)
- Need to gather groups interested in common DAQ development !
  - These chips are not so easy to operate (high speed links, low jitter clock distribution…)

backup

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)

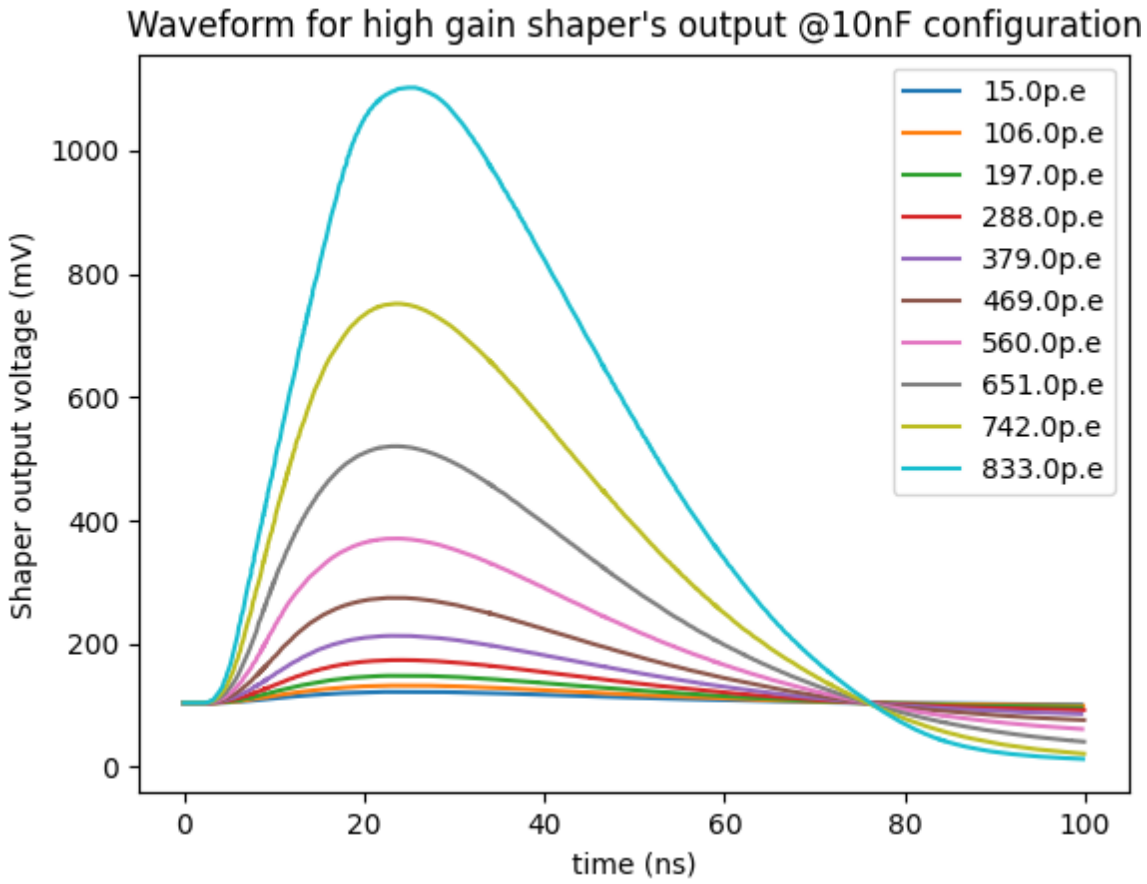
Analog front-end specific to sensor

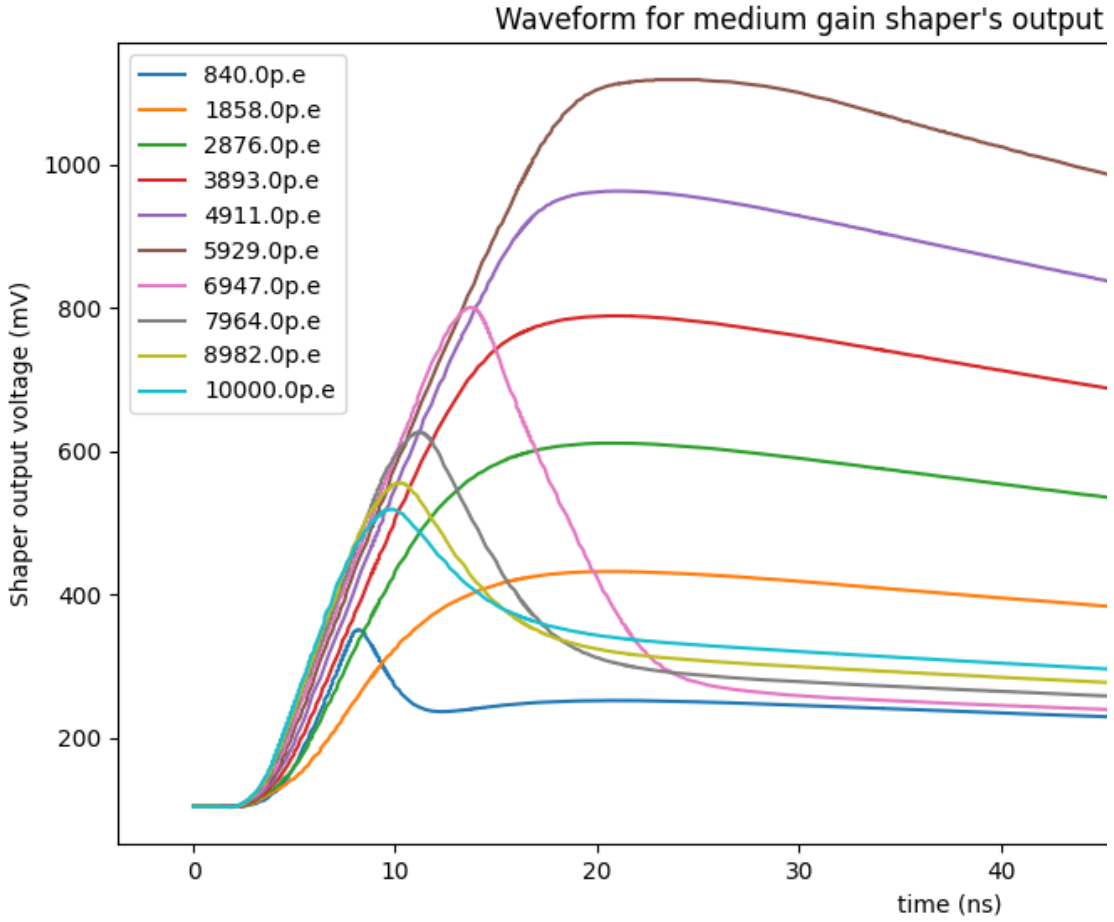
LHC-like structure :
Ram1 for data storage
Ram2 for L1 accepted events

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

CALOROC1B: Charge and time simulations

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

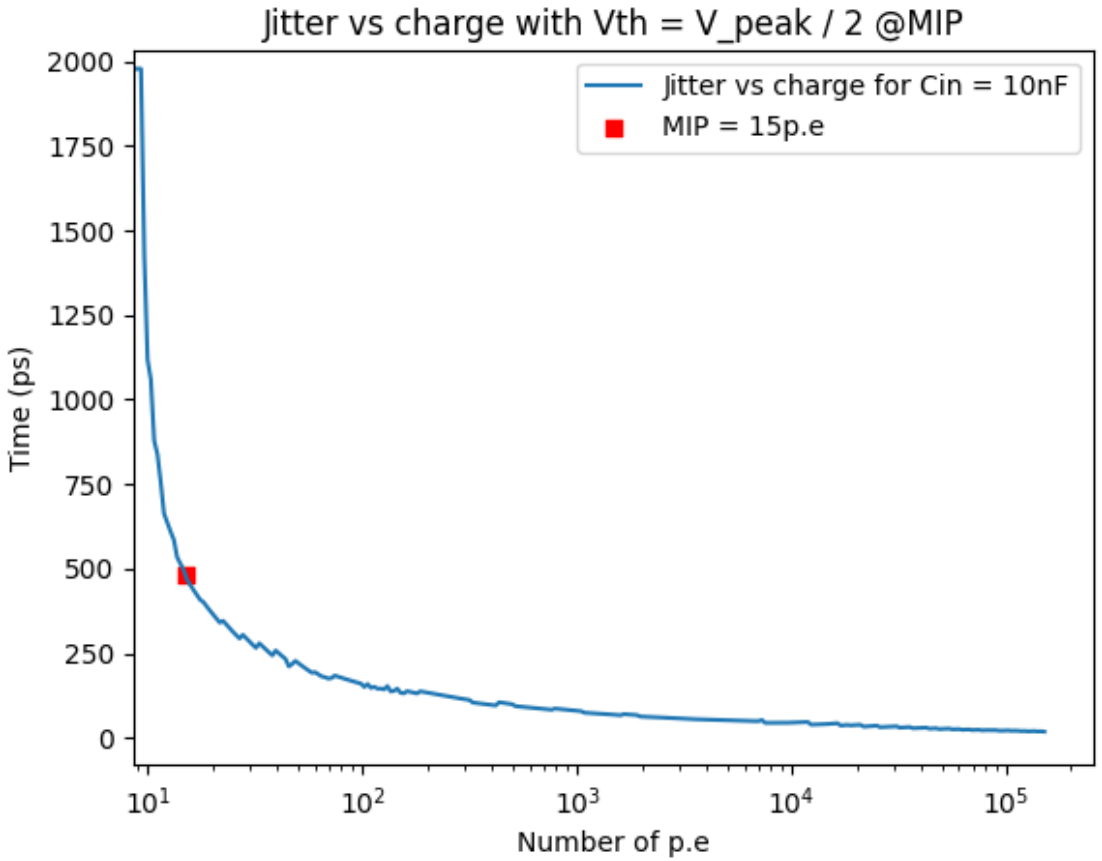


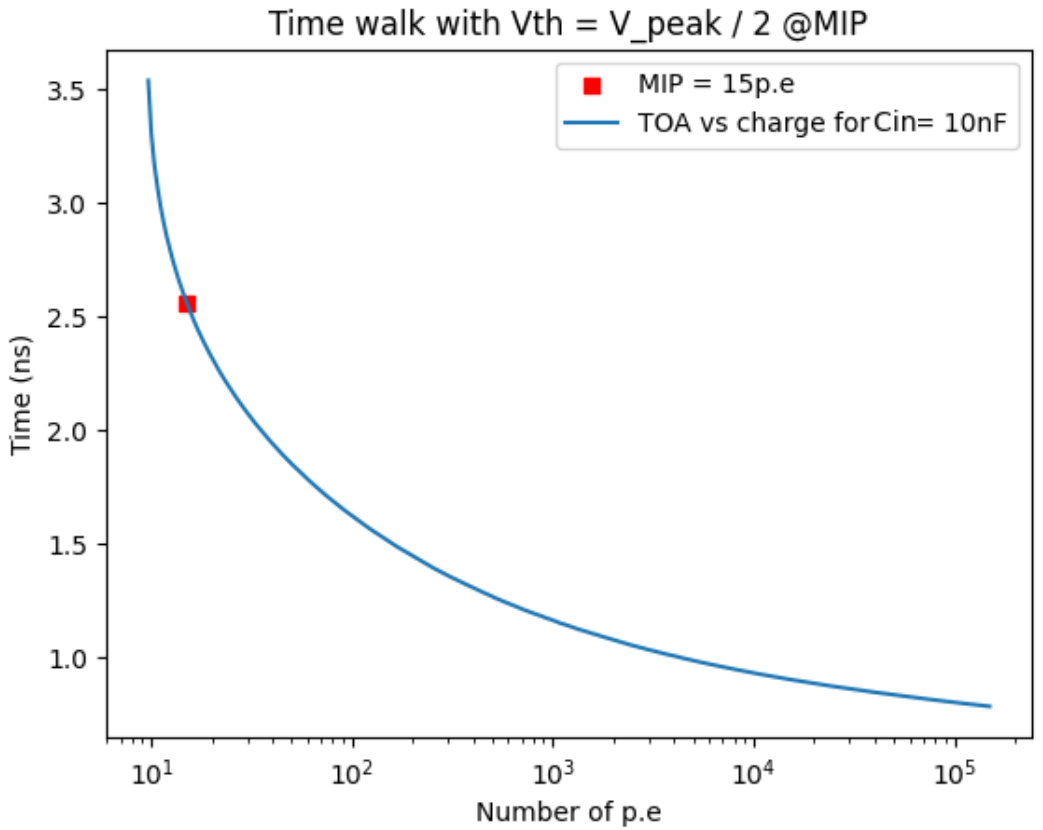


CALOROC1B: Timing precision

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

Calorimetry : experience from CMS (HGCROC/H2GCROC)

- H2GCROC developed for CMS HGCAL is a good candidate to provide charge and time on a large dynamic range

- H2GCROC provides 72 channels with (see backup)
  - Charge measurement from 30 fC (noise) to 300 pC (MIP ~0.5 pC)
  - ToA measurement down to 15 ps
  - Optimized for Cd=500 pF
  - 15 mW/ch. Radiation hard, TMR.