A SiPM-based readout system for the CBM's RICH

FAIR next generation scientists - 8th edition workshop
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Bergische Universität Wuppertal
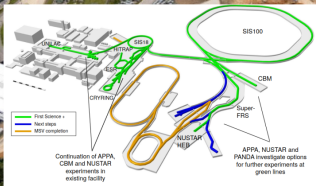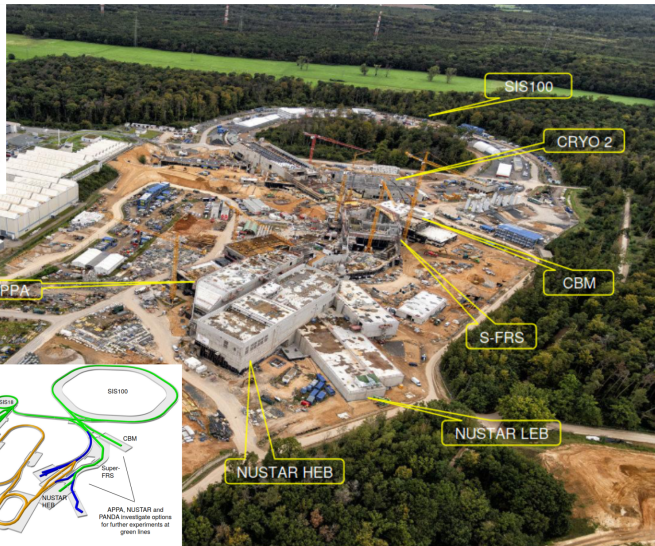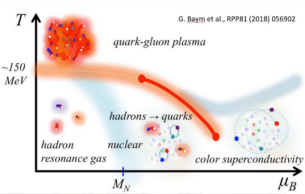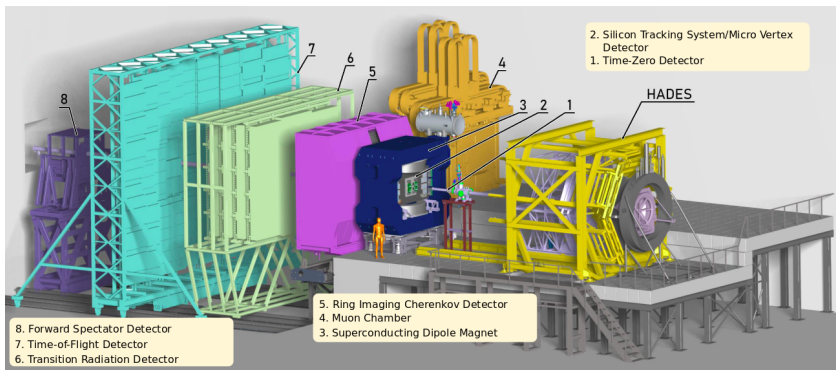Fakultät für Mathematik und Naturwissenschaften
2024

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J. Peña-Rodríguez. CBM's RICH using SiPMs (BUW)

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The CBM's RICH

2. Silicon Tracking System/Micro Vertex Detector
1. Time-Zero Detector

HADES

5. Ring Imaging Cherenkov Detector
4. Muon Chamber
3. Superconducting Dipole Magnet

8. Forward Spectator Detector
7. Time-of-Flight Detector
6. Transition Radiation Detector
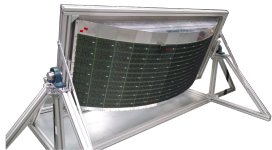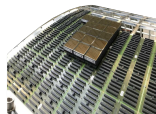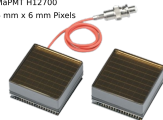
RiCH

Camera

Backpanel

6 MaPMTs per backpanel
2 DiRICHs per MaPMT
Combiner and power module

Multi-Anode Photomultiplier

MaPMT H12700
6 mm x 6 mm Pixels
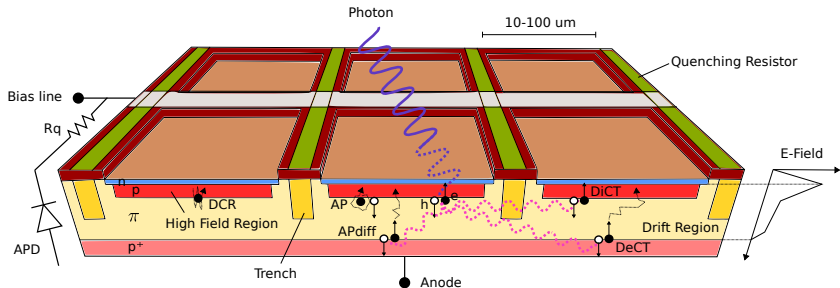
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Cherenkov Ring detection

Detected Cherenkov ring

Cherenkov ring

Cherenkov cone

beam

particle track

mirror

photo detectors

CO_2 radiator
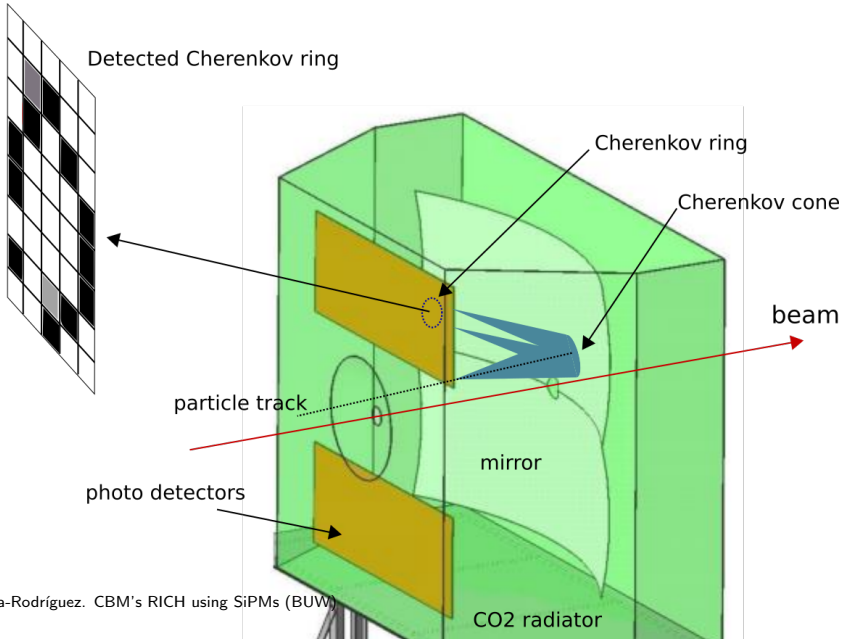
SiPM fundamentals

Uncorrelated noise
DCR, dark count rate
Correlated noise
AP, afterpulsing
APdiff, difusion afterpulse
DiCT, direct crosstalk
DeCT, delayed crosstalk

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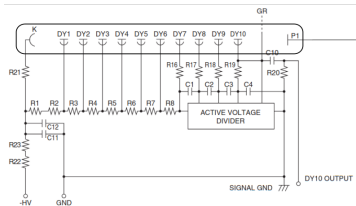
6
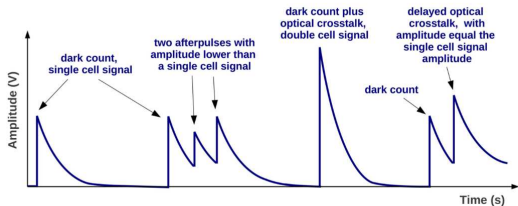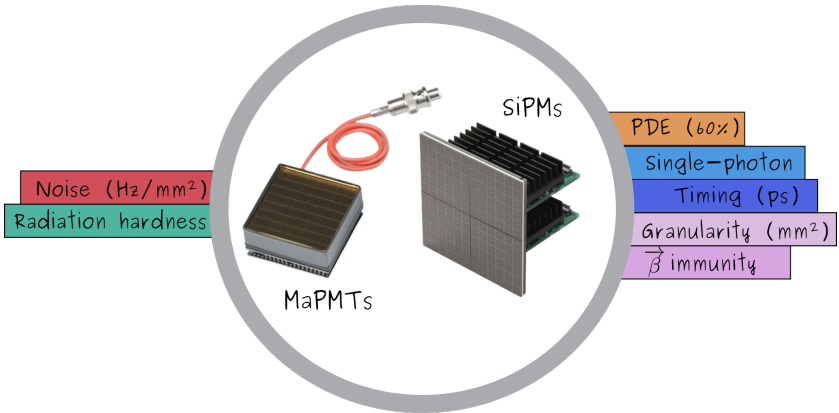
SiPM selection

	MICROFJ-60035	S14160-6050CS	AFBR-S4N66P024
Vendor	OnSemi	Hamamatsu	Broadcom
A. area (mm^2)	6×6	6×6	6×6
Pixel pitch (μm)	35	50	40
V. operating (V)	30	40	45
PDE (%)	50	50	63
Wav. peak (nm)	420	450	420
Gain ($\times 10^6$)	6.3	2.5	7.3
DCR (kHz/mm^2)	150	100	125
Crosstalk (%)	25	7	23
Afterpulsing (%)	5	-	1
Price/Pixel (€)	41	86.2	37

Design requirements

MaPMT channel

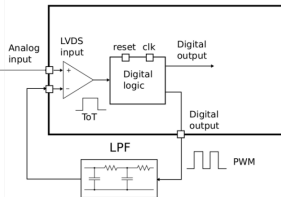Requeriments
~ mV amplitude
~ ns FWHM
± polarity

DIRICH channel

SiPM
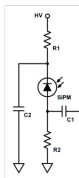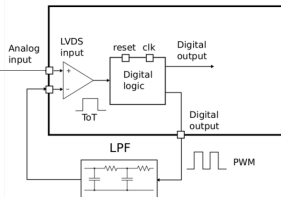
Signal conditioning
* Shaping
* Filtering
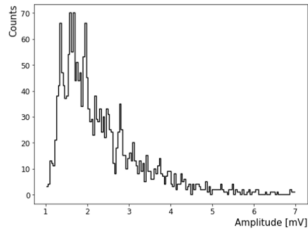* Amplification ...

DIRICH channel

Signal shortening

Raw signal
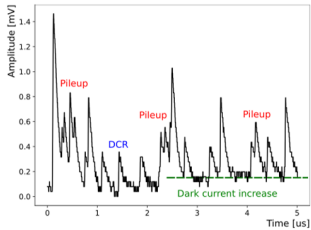
Shortening

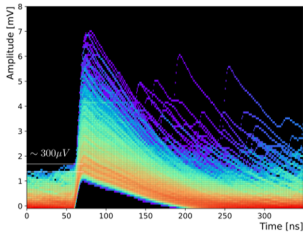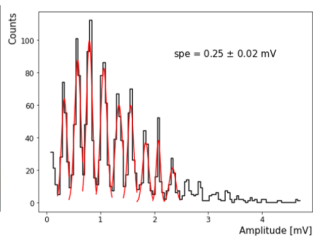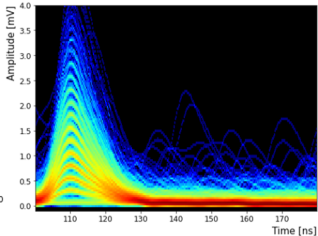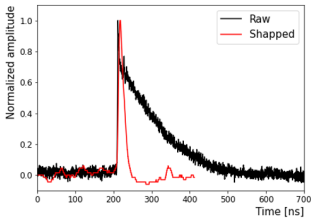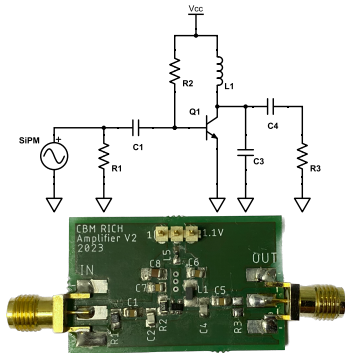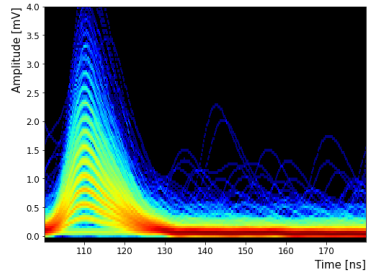# Signal amplification
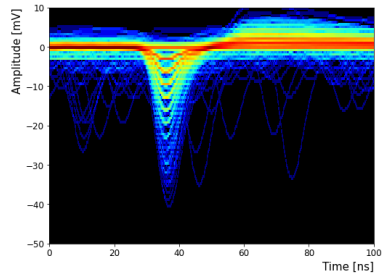
BFU760F RF transistor
Low noise
High linearity
Transition frequency 45 GHz
1.1V/12mA per channel

Raw signal

Amplified signal

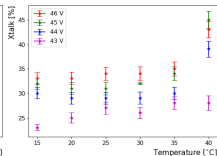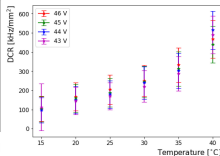J. Peña-Rodríguez. CBM's RICH using SiPMs (BUW)

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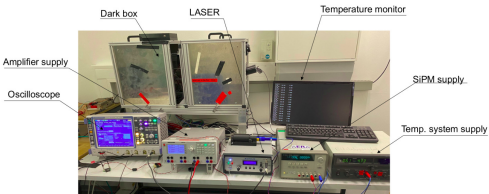
Signal conditioning chain
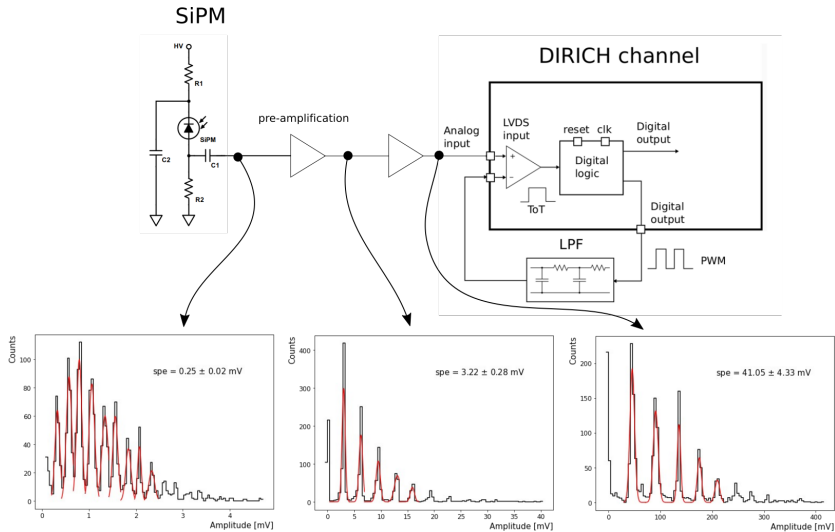
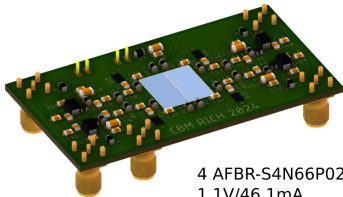# SiPM characterization (Jan's bachelor thesis)
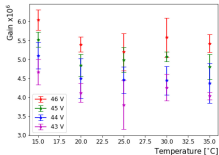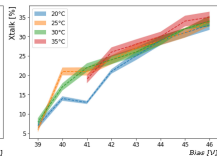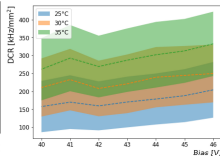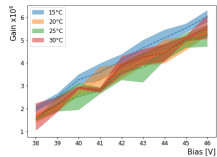
Jan Lietz bachelor thesis
Bergische Universität Wuppertal

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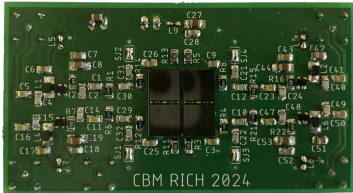
4 AFBR-S4N66P024M
1.1V/46.1mA
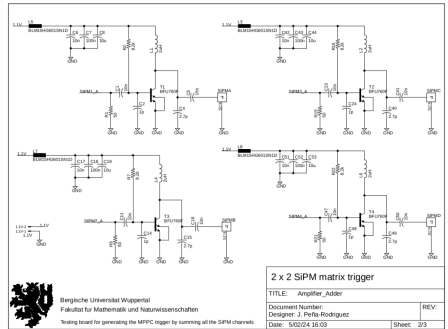
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Toy prototype: Measuring setup

2x2 SiPM array
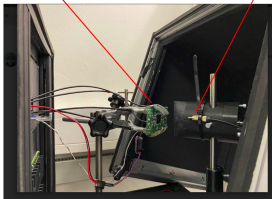
Laser

Power module   DIRICHes   Combiner

Backpanel   Connecting board
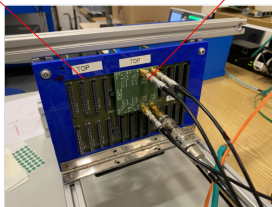
Channel A

Channel B

Channel C

Channel D

10 mV

5 ns

2D Rate vs. Threshold of 1202

channels 16, 22, 26 & 30

Rate graph over baseline of dirich 0x1202's ichannel 30

1 pe
2 pe
3 pe
4 pe
5 pe
6 pe
7 pe
8 pe
9 pe
10 pe
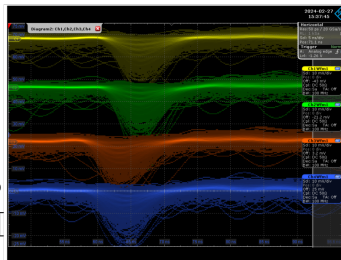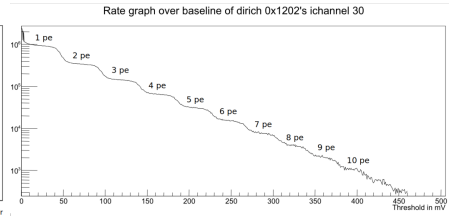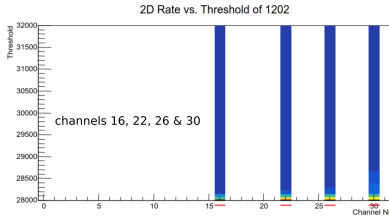
Differentiated rate graph over baseline of dirich 0x1202's ichannel 16

0 pe
1 pe
2 pe
3 pe
4 pe
5 pe

Analysis
* Inter-channel crosstalk
* Noise rate vs. threshold
* Photo-electron spectrum
* Gain vs. bias

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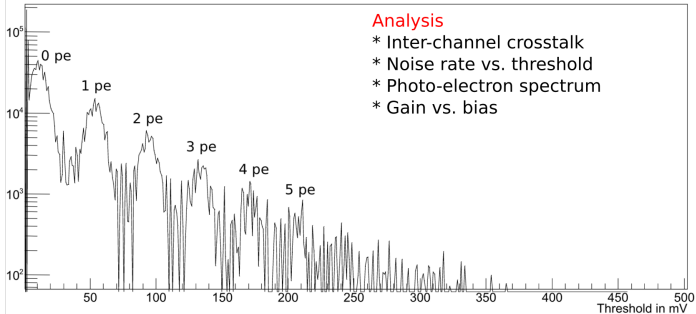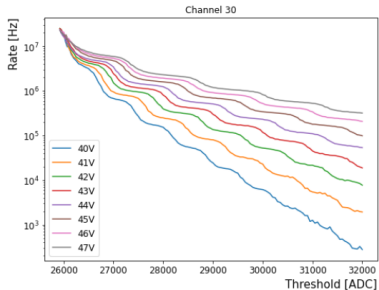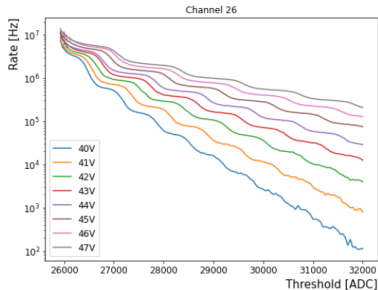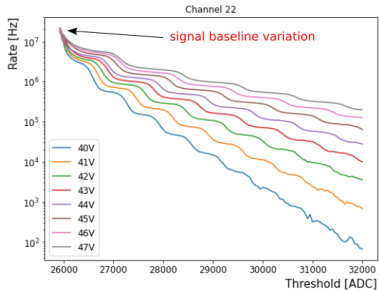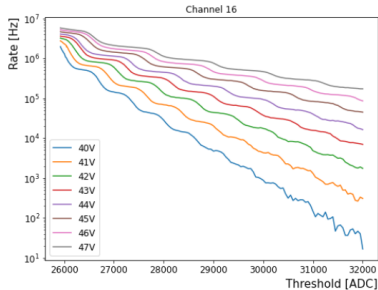
4 SiPMs set at $45\,\mathrm{V}/25^\circ\mathrm{C}$

A baseline shifting is observed (sol. DiRICH baseline calibration), however the channel gain seems to be similar.

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Top view

Bottom view

5.5 cm

5.5 cm

CBM RICH 2024
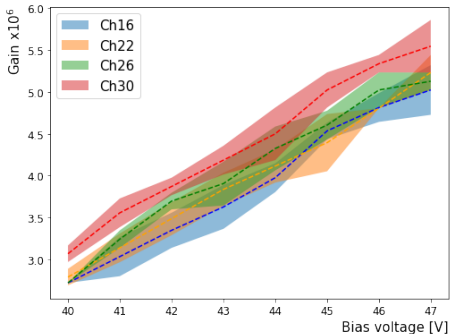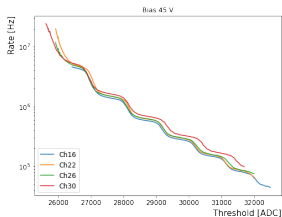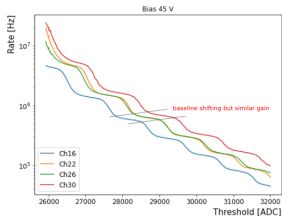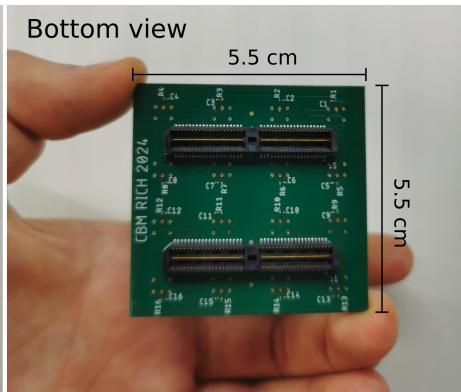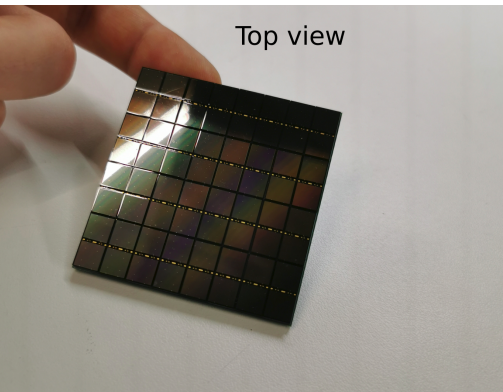
Thanks to GSI (M. Traxler's team) for PCB soldering!

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Amplification board

- 64 amplification channels
- $5.5 \times 5.5 \, cm^2$ PCB
- 2 high-density SAMTEC connectors (QSE-040-01-F-D-A)
- ~ 700 components
- $0.77 \, A / 1.1 \, V \sim 0.84 \, W$
- 5 W per panel (6 SiPM arrays)

Top view

SiPM bias line

1.1V line

Bottom view

5.5 cm

SiPM array connector

Amplification block

DiRICH connector

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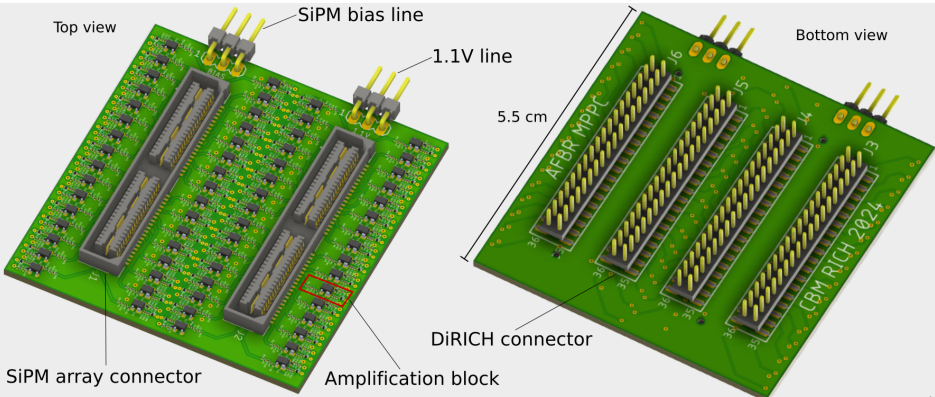
MAPMT FPGA Architecture
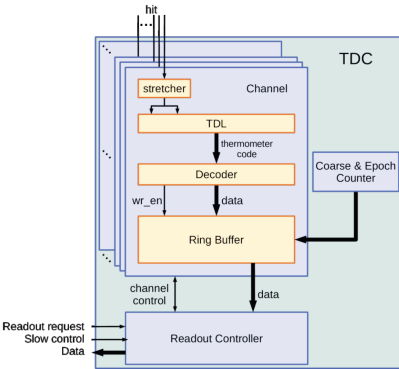
SiPM FPGA Architecture

Summary: Hardware

- Complete characterization of SiPM's performance depending on temperature and over-voltage
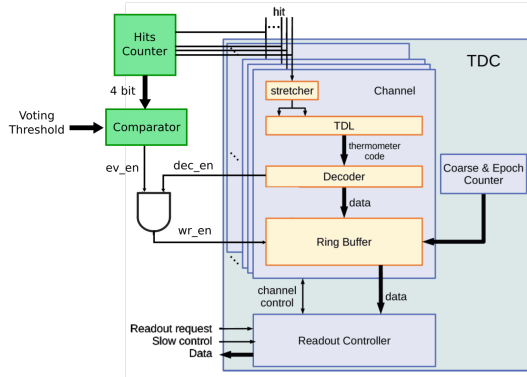- Design of the SiPM signal conditioning (shortening & amplification) warranting linearity, photo-electron resolution, low power consumption, and scalability.
- 2×2 SiPM array designed and tested (threshold scanning, photo-electron resolution, no inter-channel crosstalk)
- Design of an 8×8 SiPM array. PCB under assembly and soldering!
- Design of the amplification board for 64 SiPM channels

Outlook

- 8×8 SiPM array characterization (temperature, bias voltage, radiation damage)
- Ring signal detection under synchronized conditions
- FPGA triggering modification for free-streaming detection

Thanks!

Backup