Un vistazo al sistema de adquisición de datos de los detectores GEM de CMS

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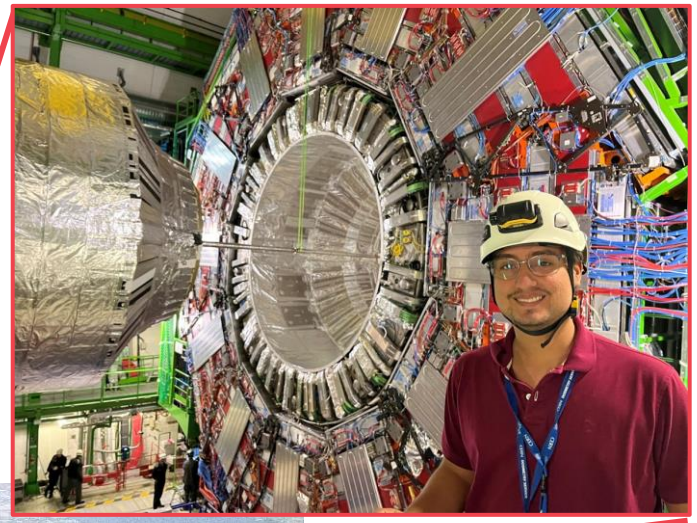
Contenido

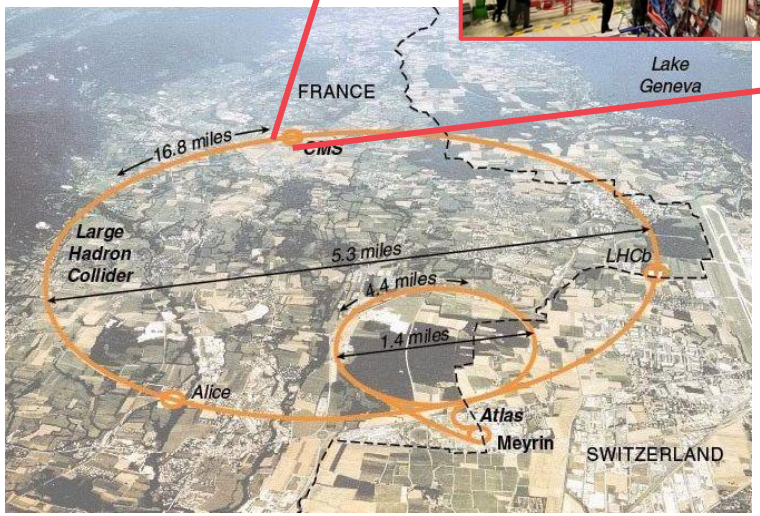
- **Introducción**
  - Experimento CMS y sistema de muones
  - Detectores GEM
  - GE1/1, GE2/1 y ME0
- **Algo de mi trabajo de maestría**
  - GEM-DAQ y un poco sobre las contribuciones al software de análisis.

Introducción

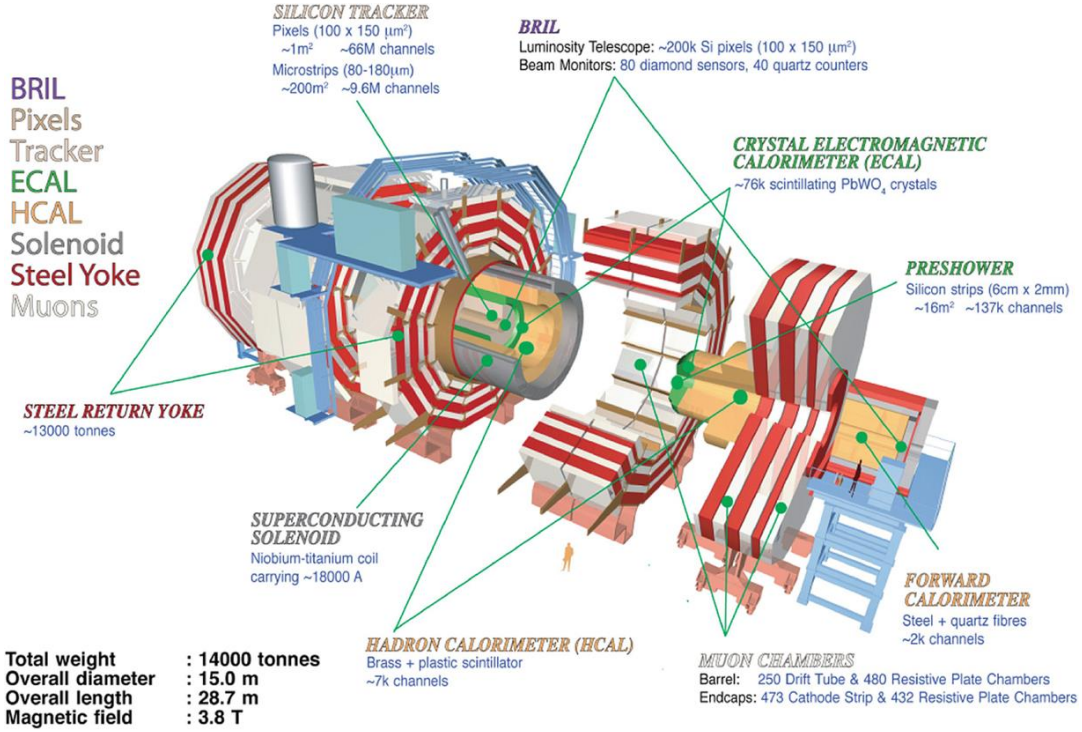
- CMS y sistema de muones
- Detectores GEM
- GE1/1, GE2/1 y ME0

CMS (*Compact Muon Solenoid*)

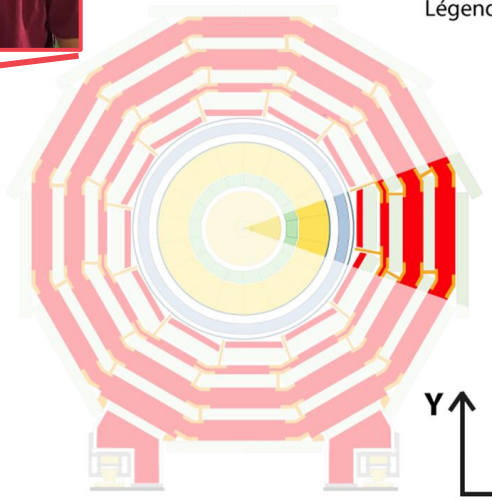


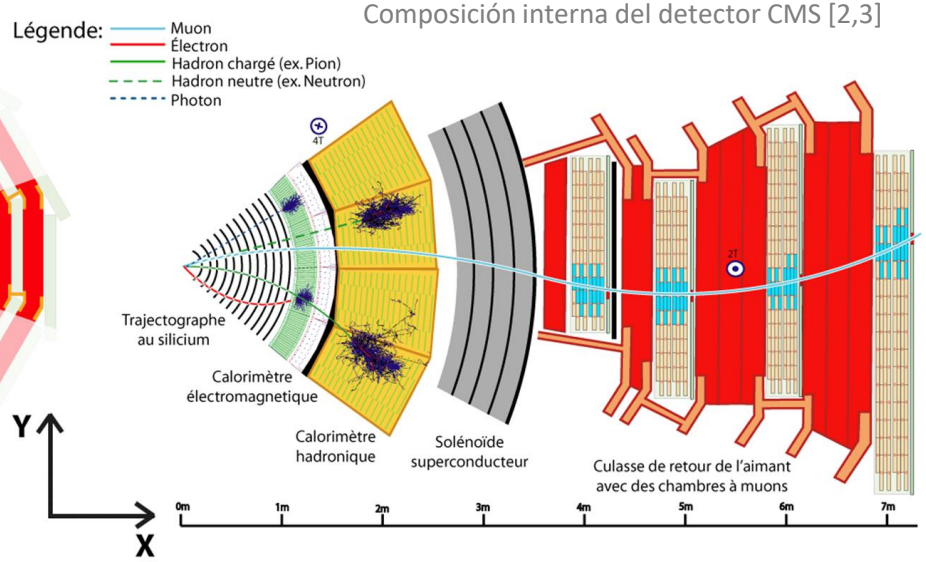


Mapa del LHC, tomada de link



Composición interna del detector CMS [2,3]

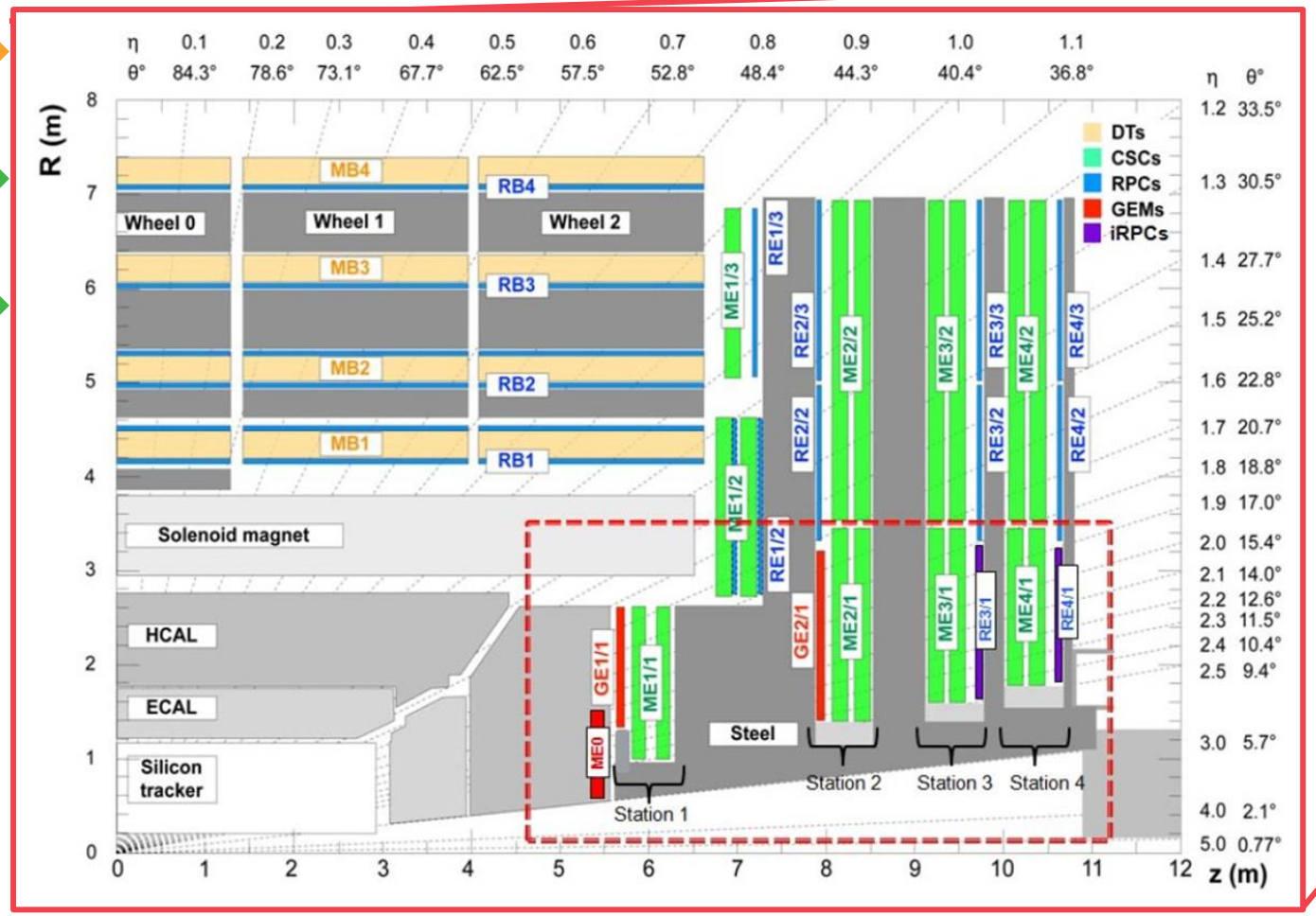


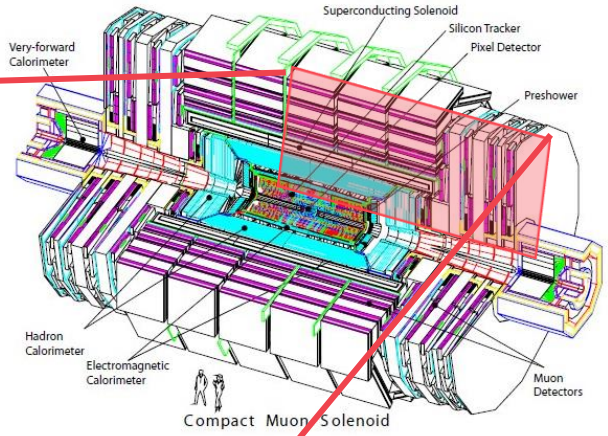


Introducción

- CMS y sistema de muones
- Detectores GEM
- GE1/1, GE2/1 y ME0

Imagen tomada de [3]





Basado en 4 tipos de detectores gaseosos: [2, 3]

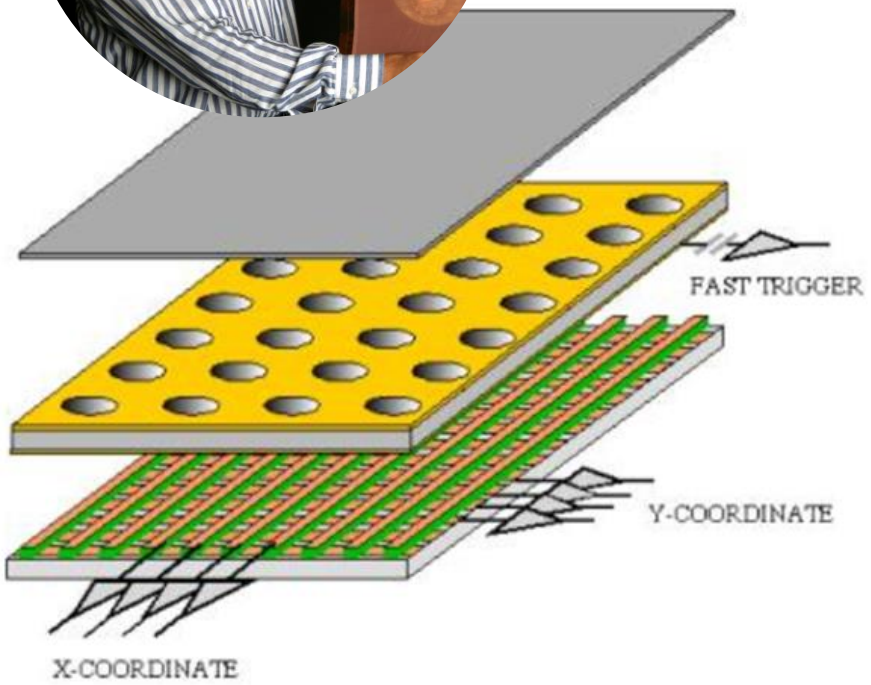
- *Drift Tubes* - **DTs** .
- *Cathode Strip Chambers* – **CSCs.**
- *Resistive plate chambers* **RPCs**.
- ***GEM Detectors*** **GEMs**.

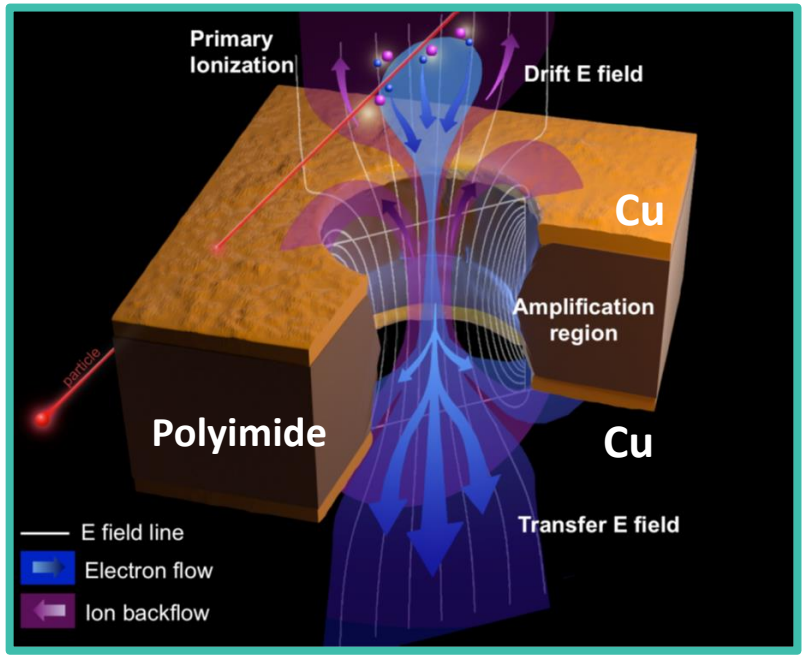
Para reforzar (y ampliar) las regiones $1.6 < |\eta| < 3.0$.
Mejorar la Resolución en momentum y el L1 trigger. [2, 3, 4]

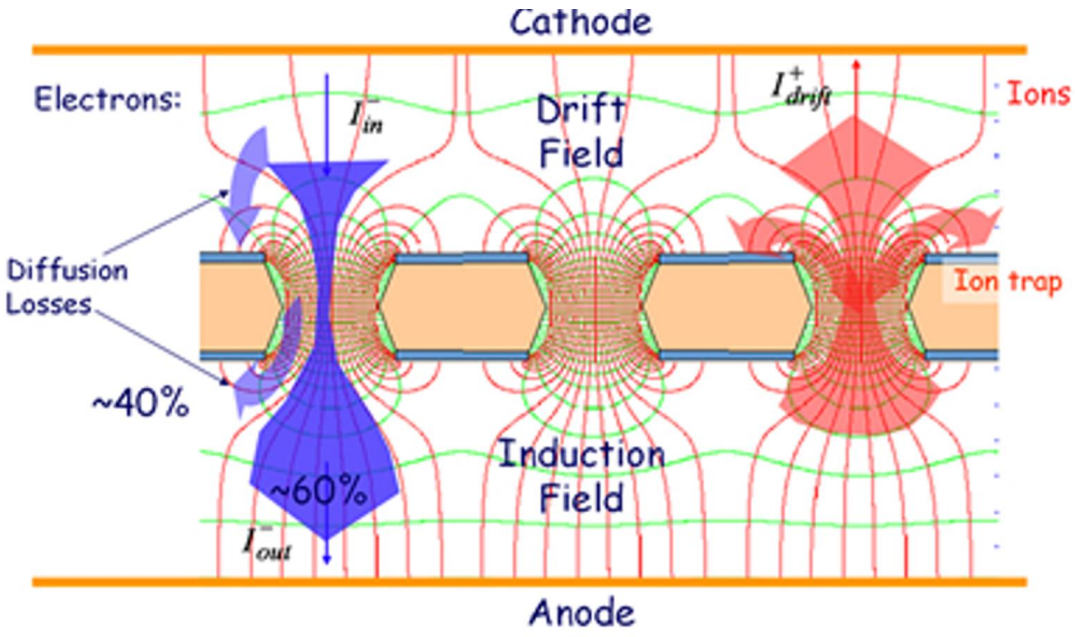
$$\eta = -ln\left(tan\left(\frac{\theta}{2}\right)\right)$$

Detectores GEM
(Gas Electron Multiplier)

Fabio Sauli – Inventor(1997)







Imágenes tomadas de [1, 4, 8]

Introducción

CMS y sistema de muones

Detectores GEM

GE1/1, GE2/1 y ME0

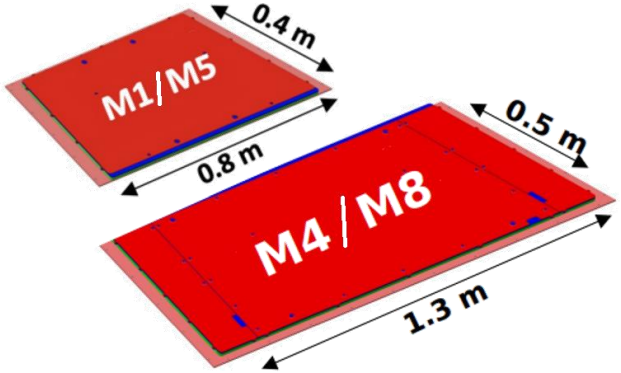
Super cámara

GE1/1 y GE2/1: 2 módulos triple-GEM.

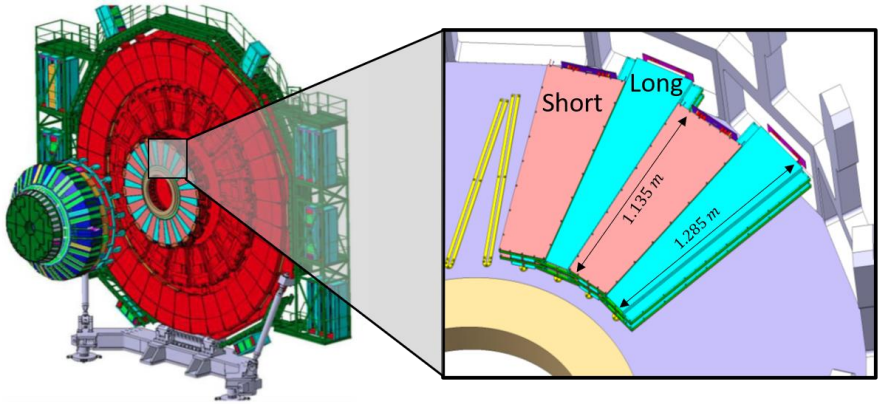
ME0: 6 módulos triple-GEM

Se necesitan (x2 – 1 c/endcap)

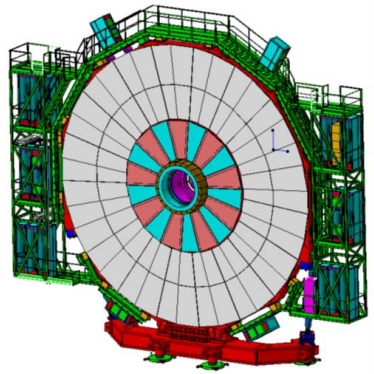
36 GE1/1, **18** GE2/1 y **18** ME0.

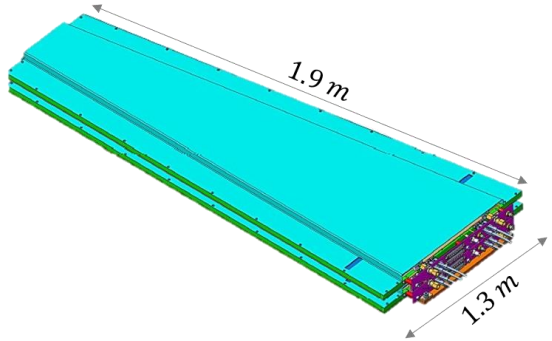


GE1/1

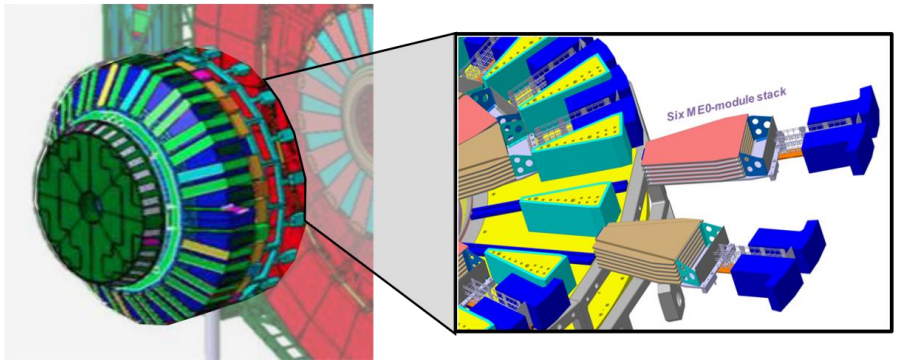


GE2/1





ME0

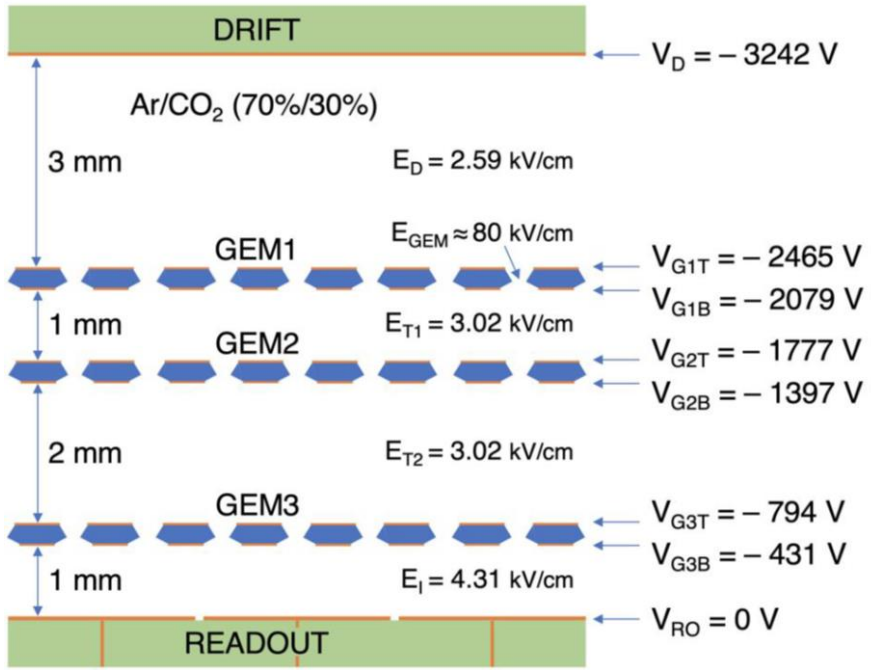


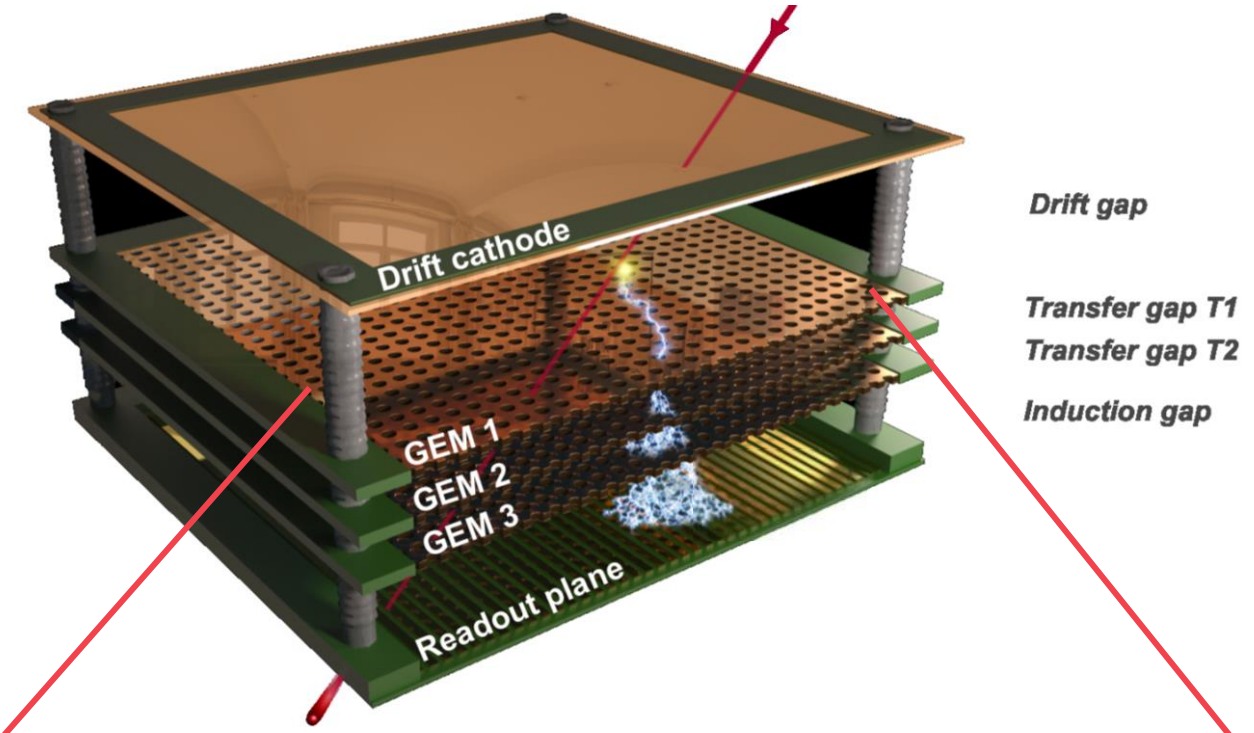
- [x] Instalación de GE1/1 - (2019 – 2020)
- [ ] Instalación de GE2/1 y ME0 – (LS3 -2026)

Introducción

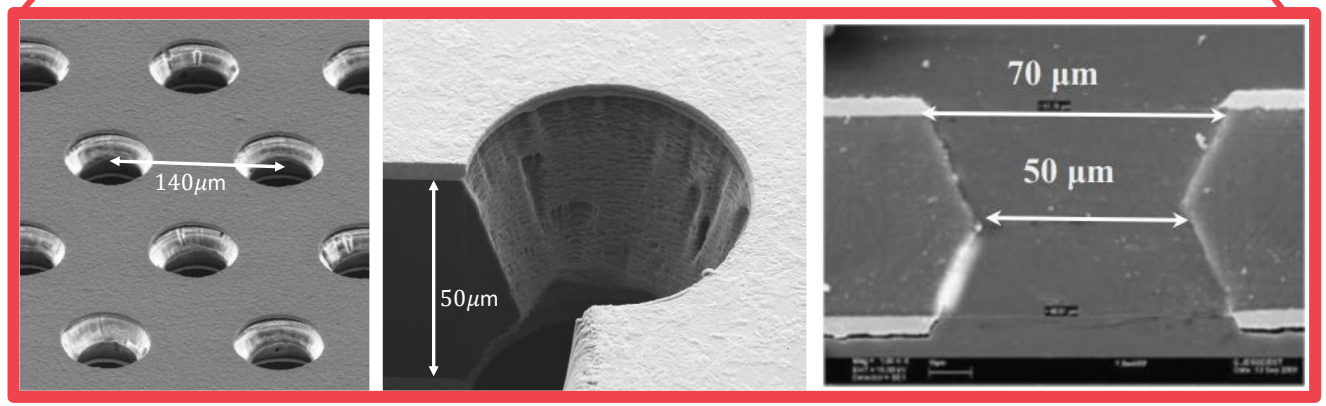
Con esta configuración

Gain $\approx 10^4$





$$n_T = \Delta E\left[\frac{0.7}{W_{Ar}} + \frac{0.3}{W_{CO_2}}\right] \approx 30 \text{ pairs.}$$



Cargas colectadas en los readout-strips

~50 fC

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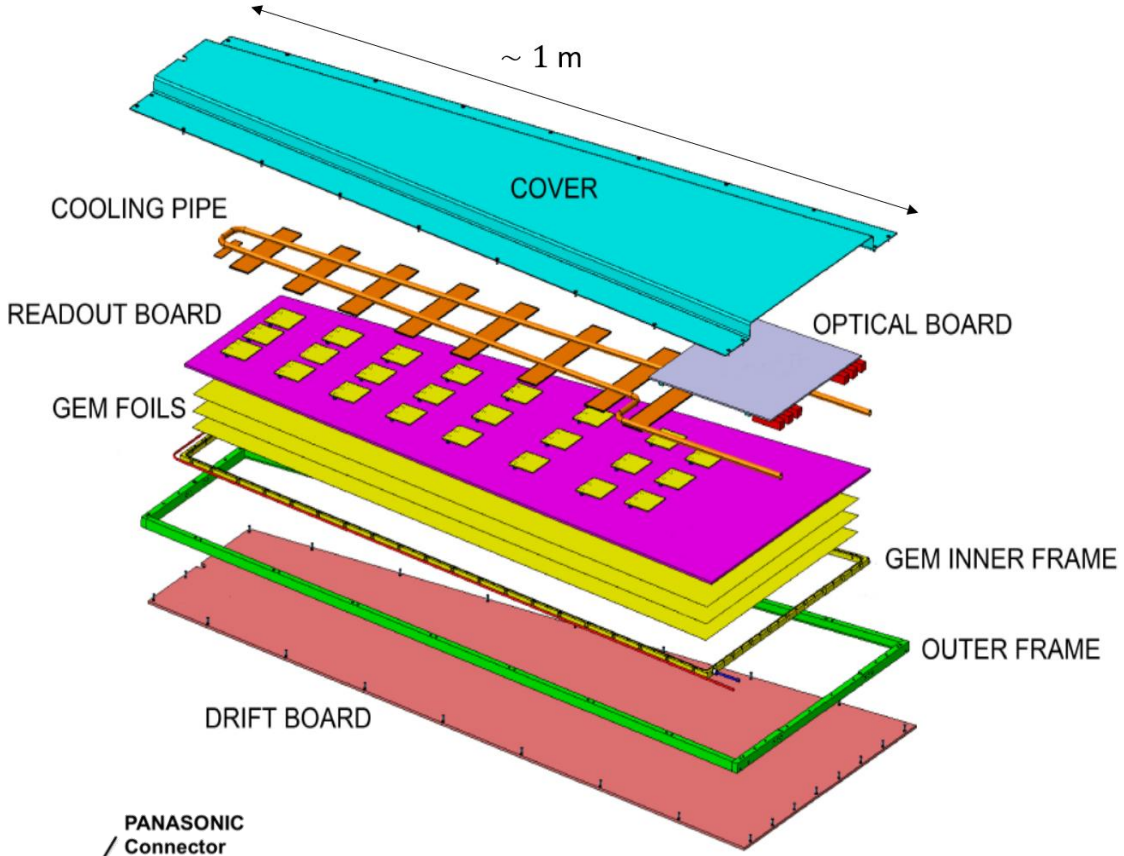
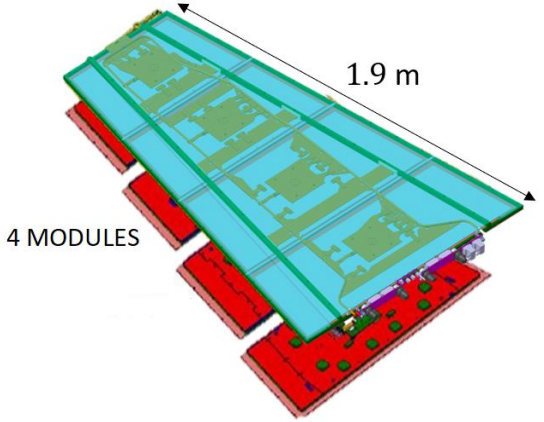
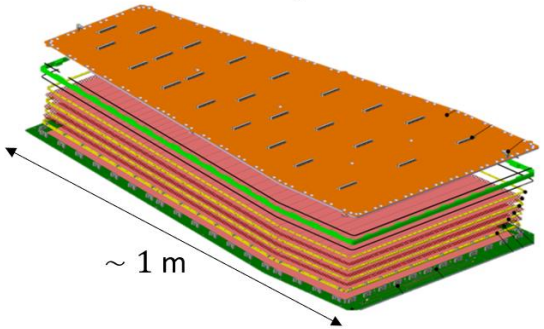
- Estructura
- GEM DAQ



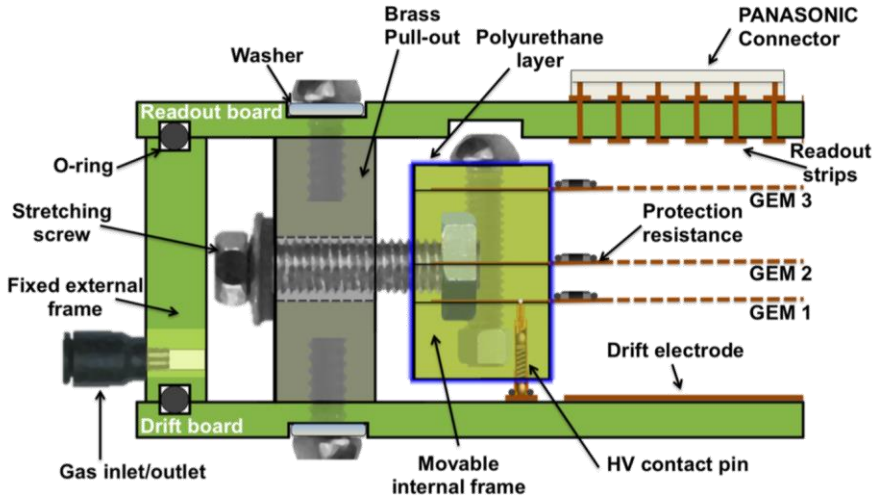
GE1/1



GE2/1

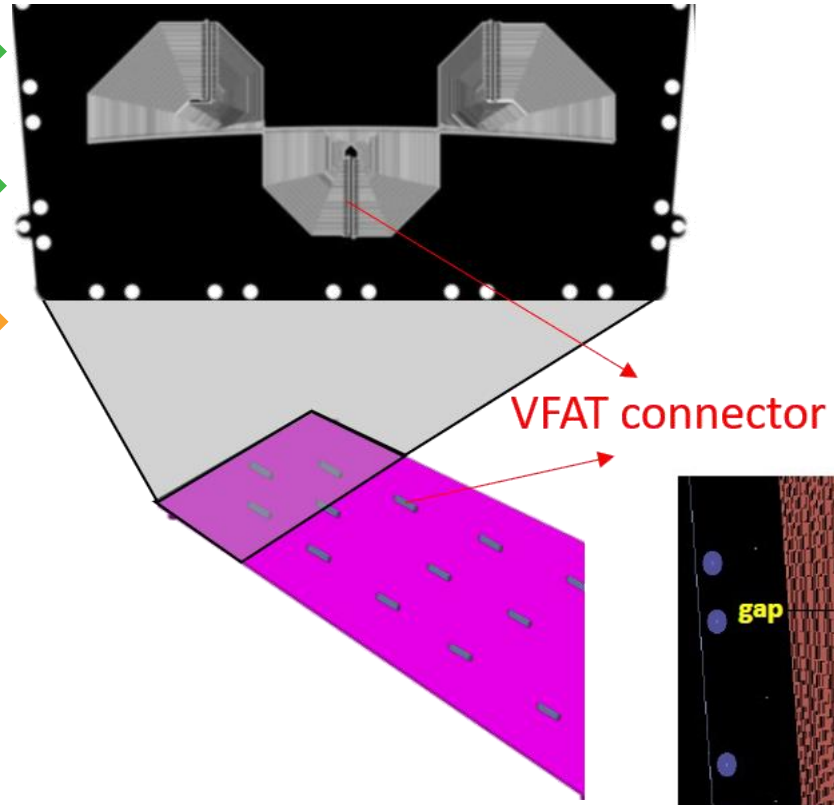


ME0



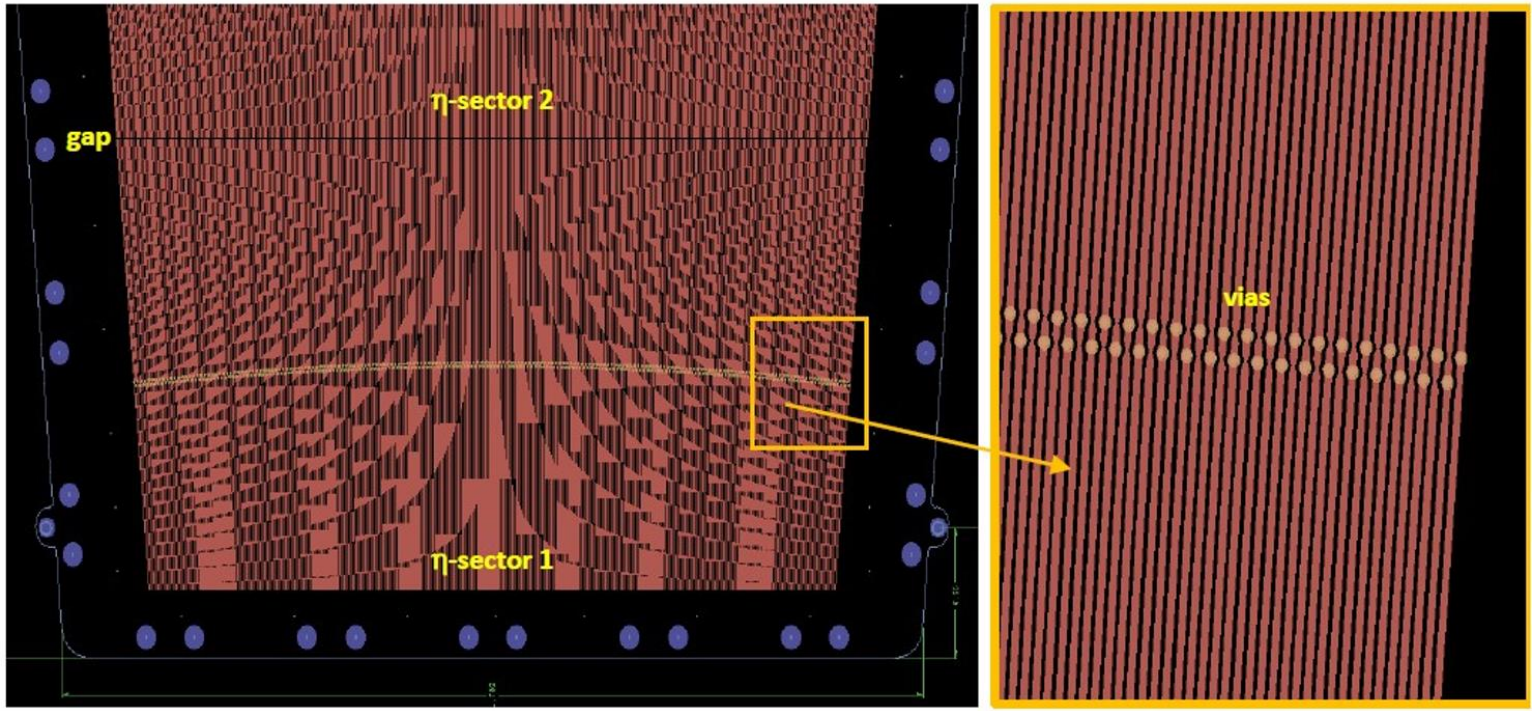
Sistema de adquisición de datos

- CMS y sistema de muones
- Detectores GEM
- GE1/1, GE2/1 y ME0
- Estructura
- GEM DAQ



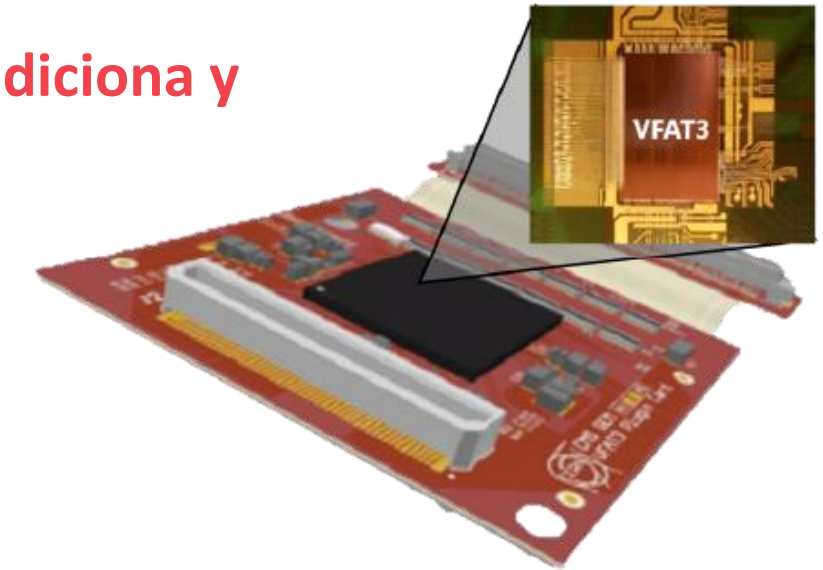
La carga es colectada por los *strips* de la *Read-Out Board*

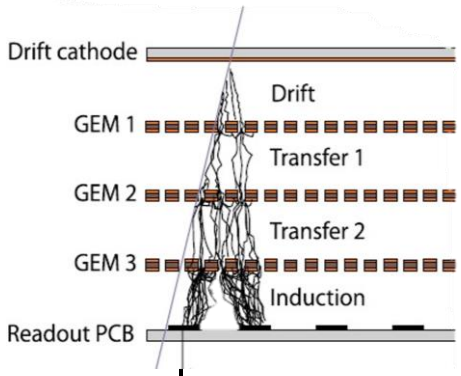
Imagen tomada de [3]



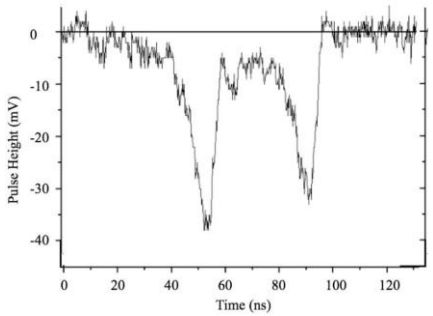
Sistema de adquisición de datos

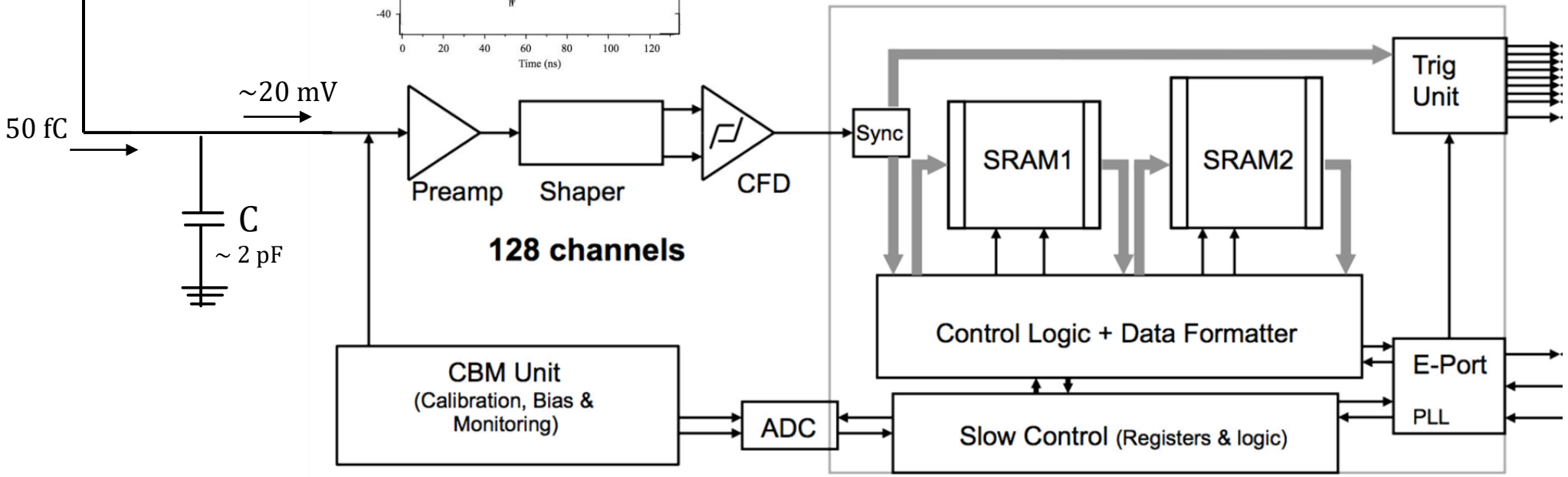
Electrónica especializada que **acondiciona y digitaliza la señal (VFAT)**





Señal típica





Sistema de adquisición de datos

- CMS y sistema de muones
- Detectores GEM
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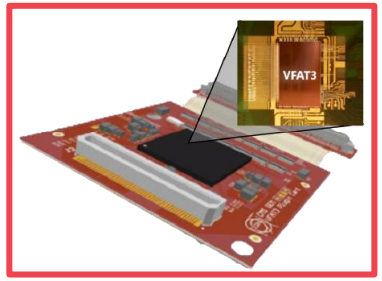
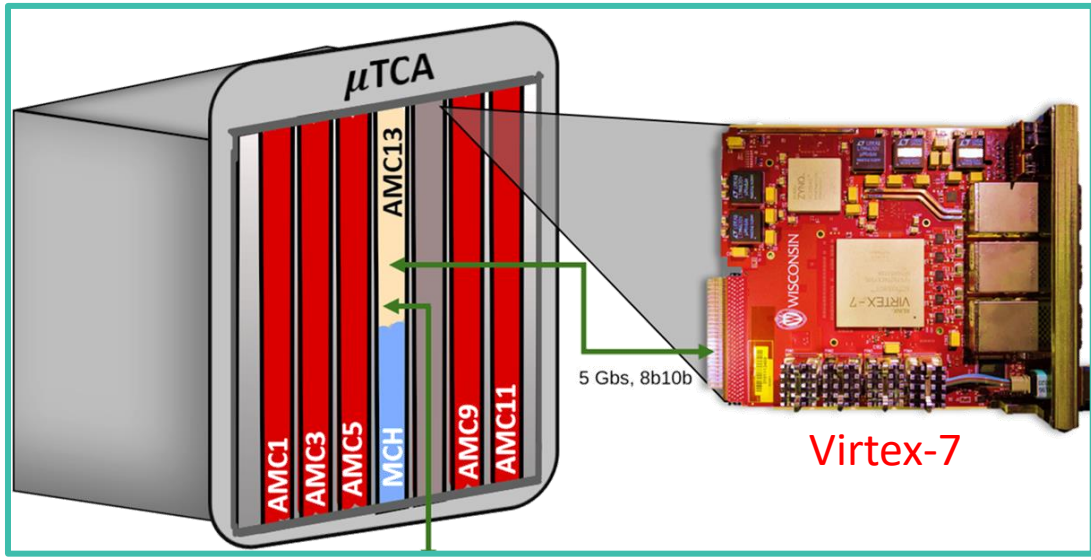
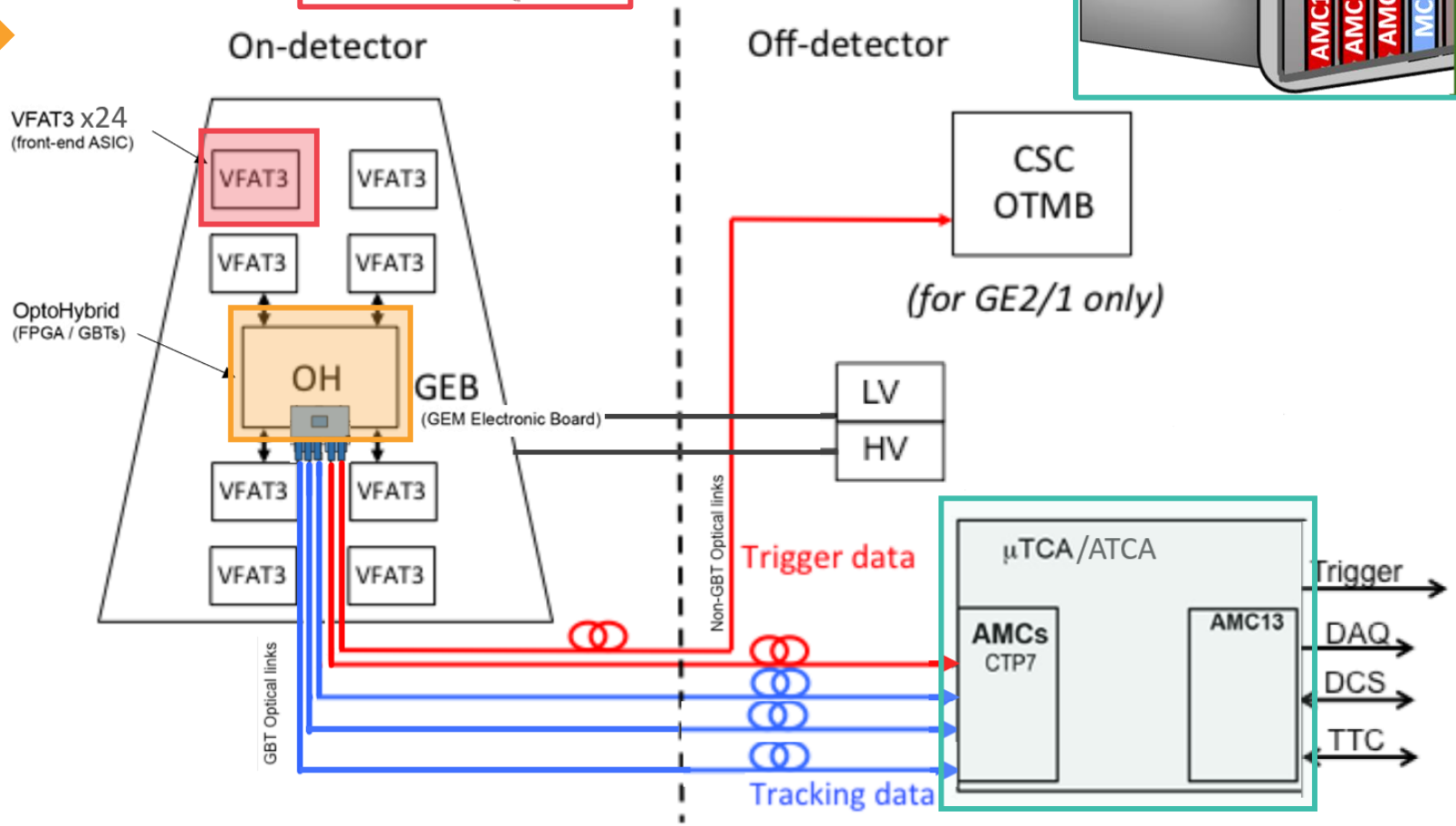
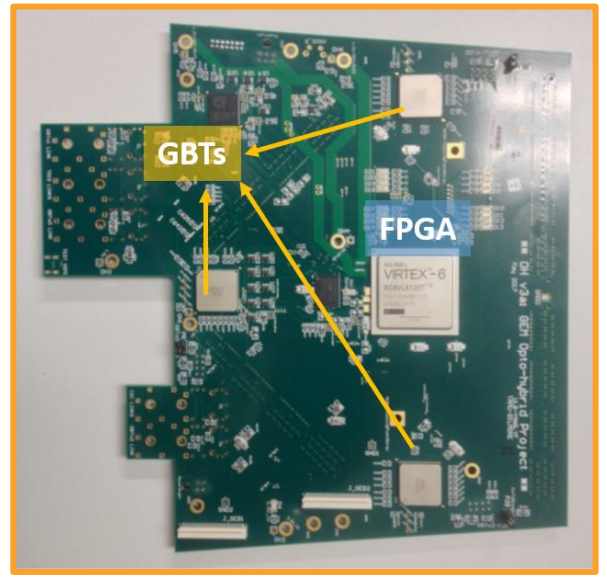
- GEM DAQ

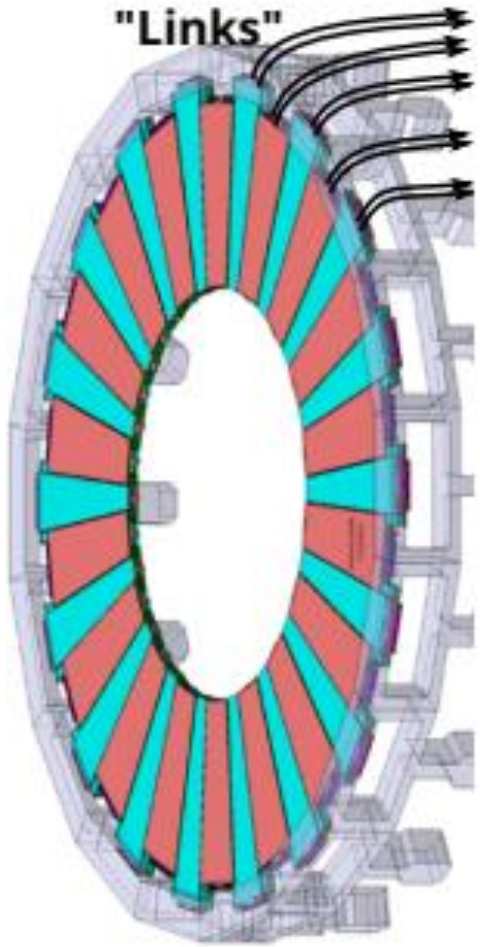








Sistema de adquisición de datos



"fed xxxx- slot xx- oh xx – vfat xx"

Sistema de adquisición de datos

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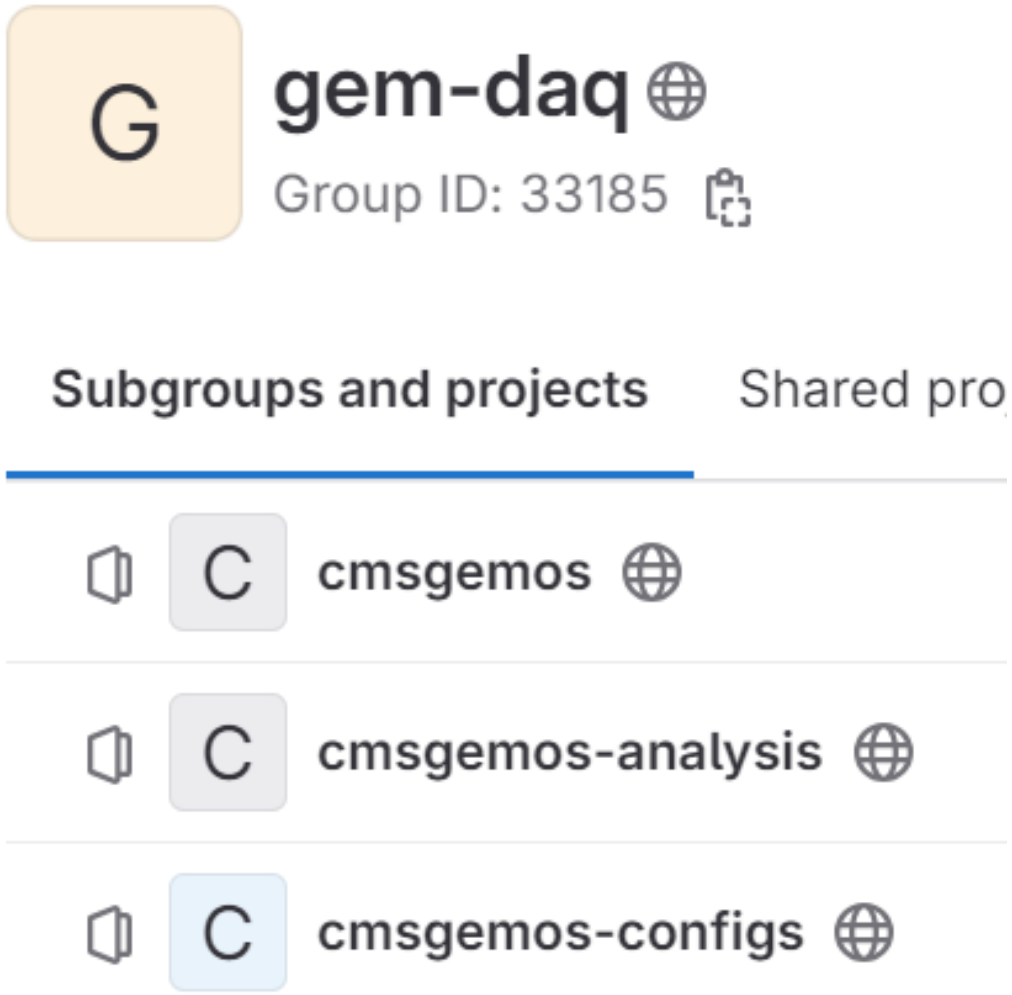


GitLab

Todos los procesos de monitoreo y calibración se hacen a través de firmware y software desarrollado por el equipo de DAQ.

(En construcción)

Sistema de adquisición de datos

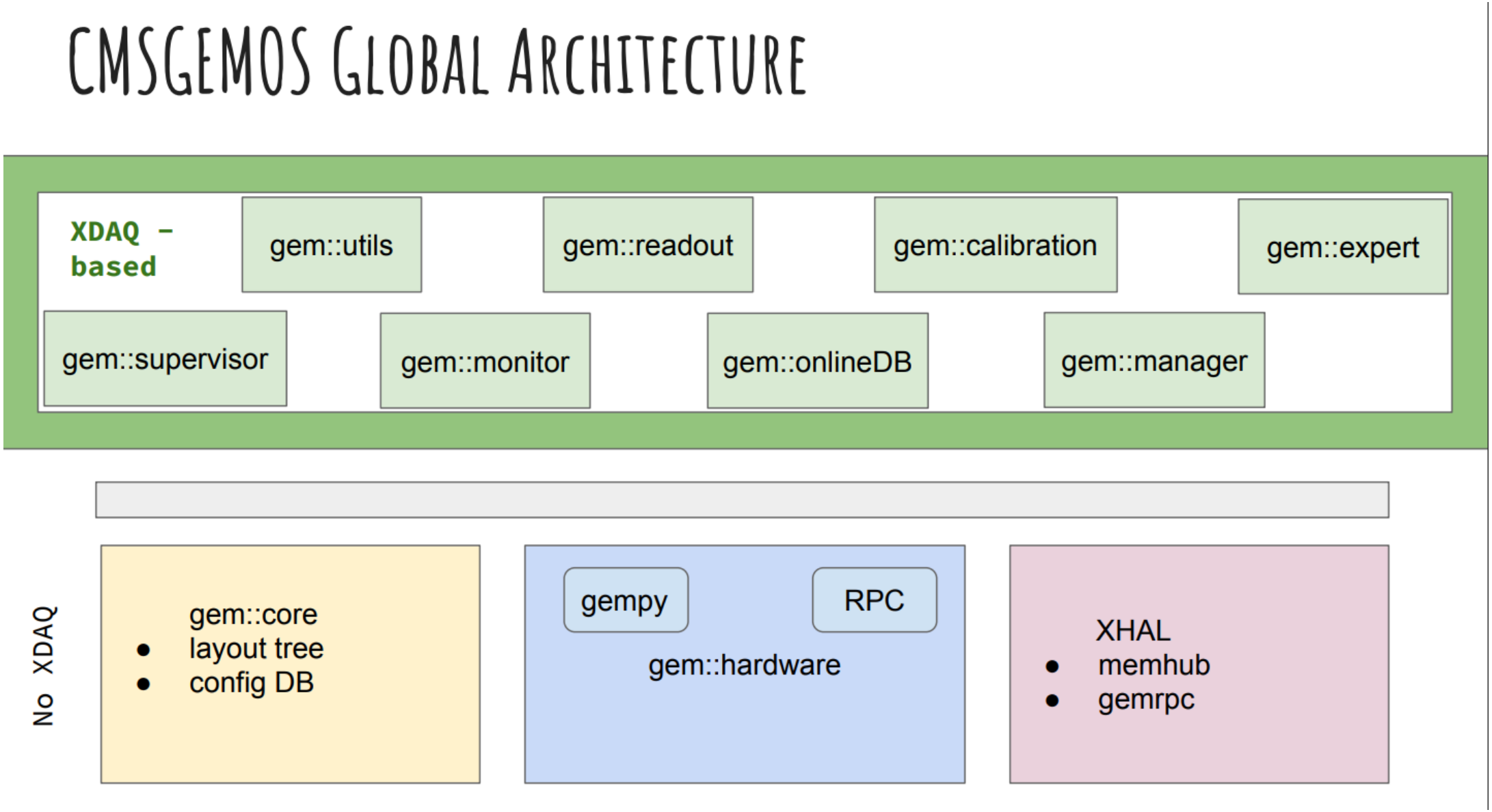


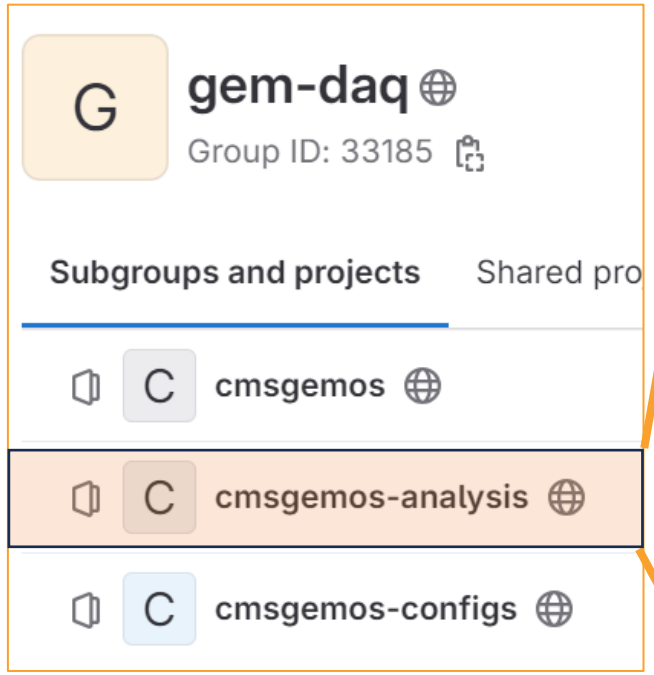
Diagrama tomado de [12]

Software de análisis

- Radiación ionizante
- Detectores gaseosos
- Detectores GEM
- GE1/1, GE2/1 y ME0
- Estructura
- Electrónica
- GEM DAQ
- GEM QC

Sistema de adquisición de datos (DAQ)

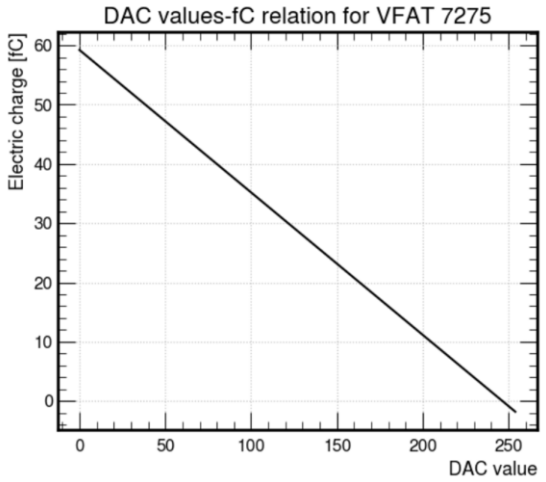
GitLab



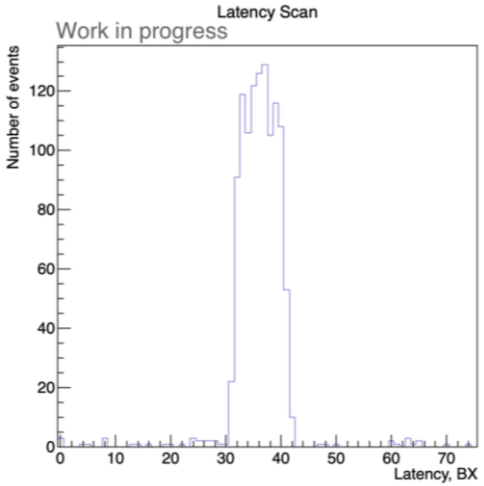
Software y firmware

(En desarrollo)

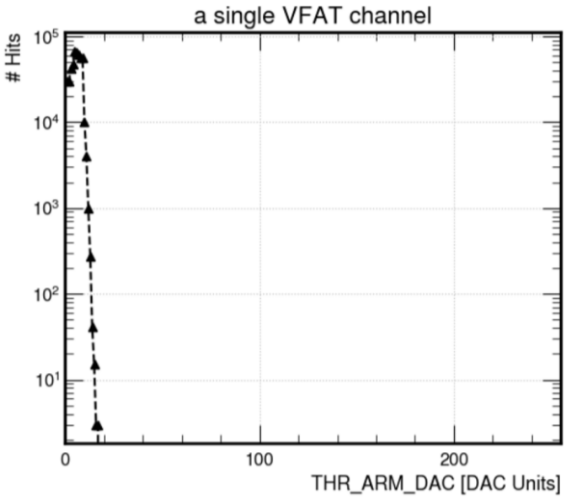
ADC – DAC *scans*



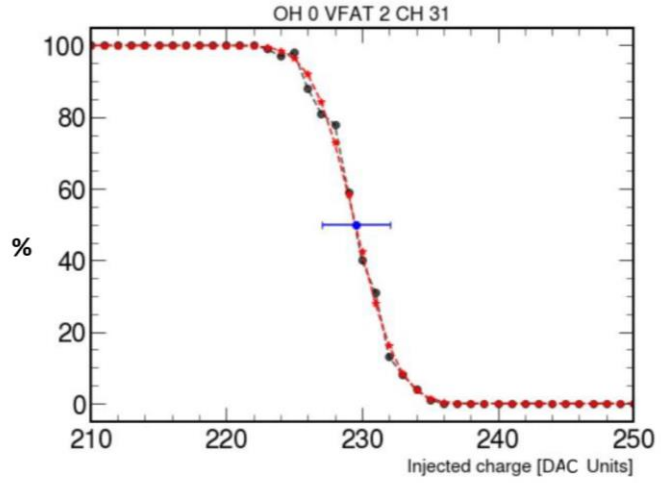
Latency scan



Threshold scan

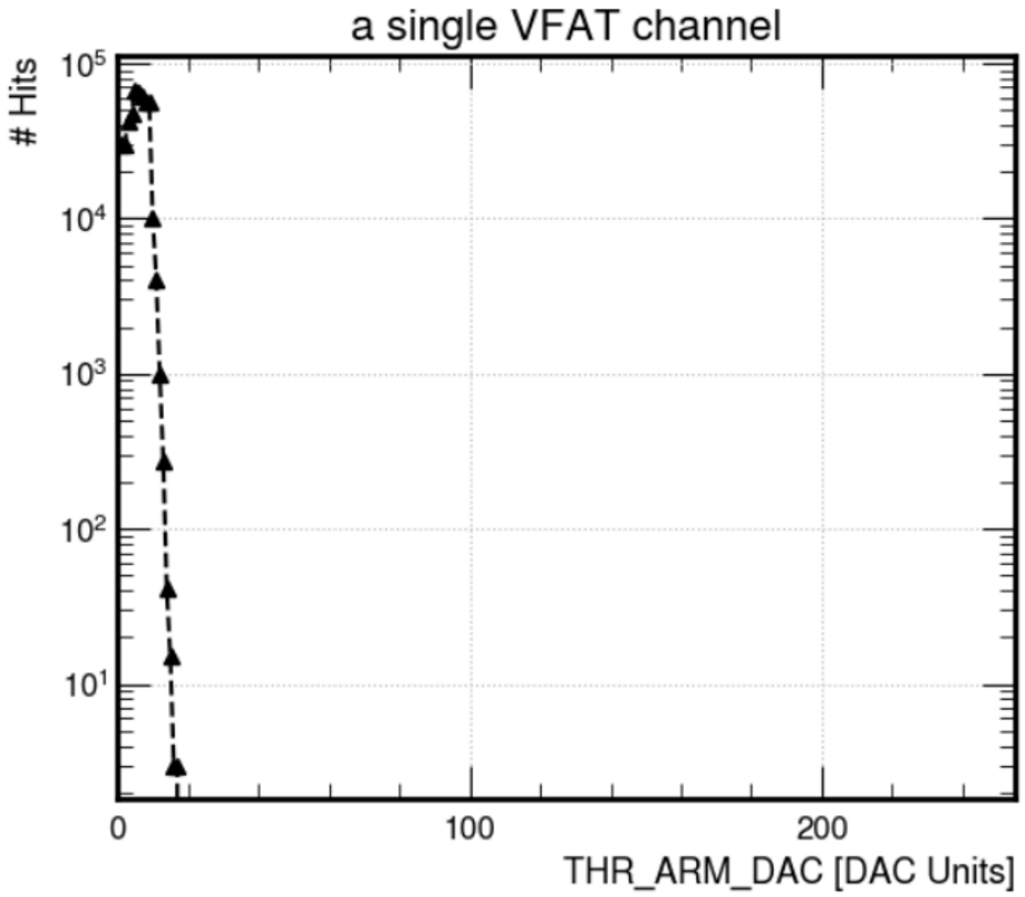


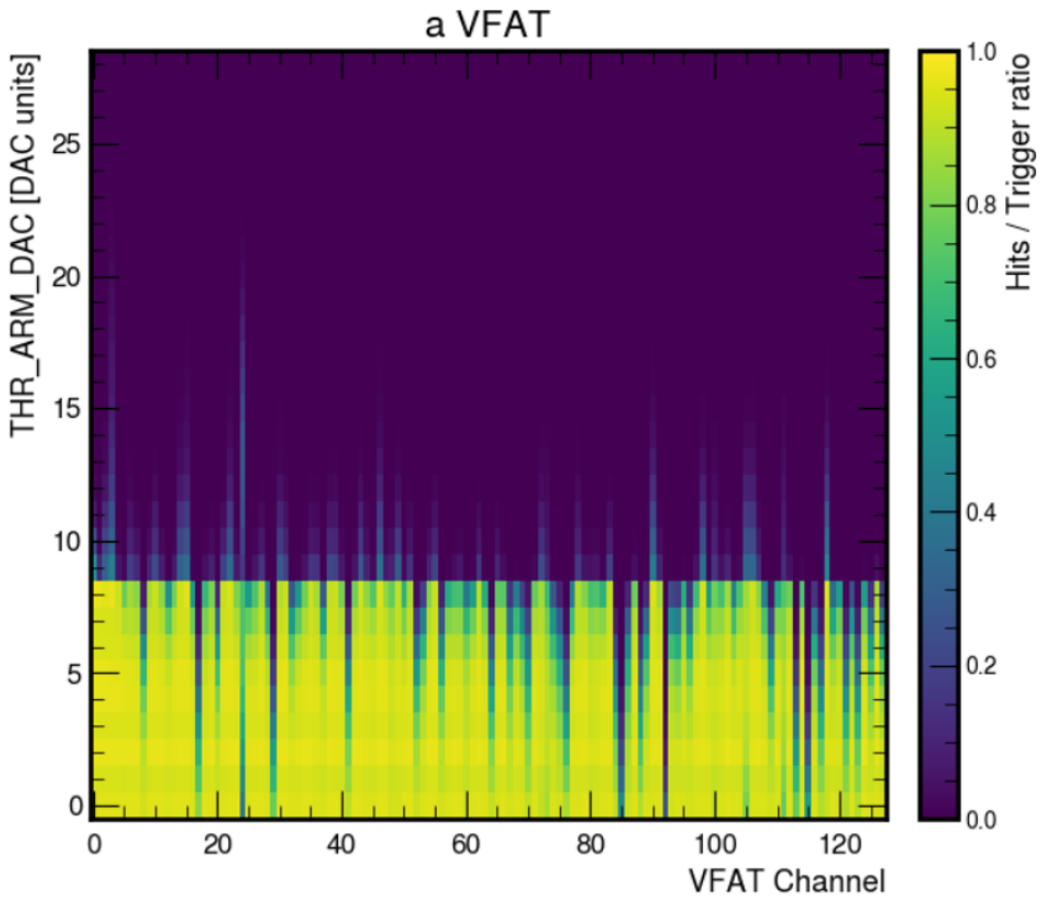
S-curve Analysis



Resultados

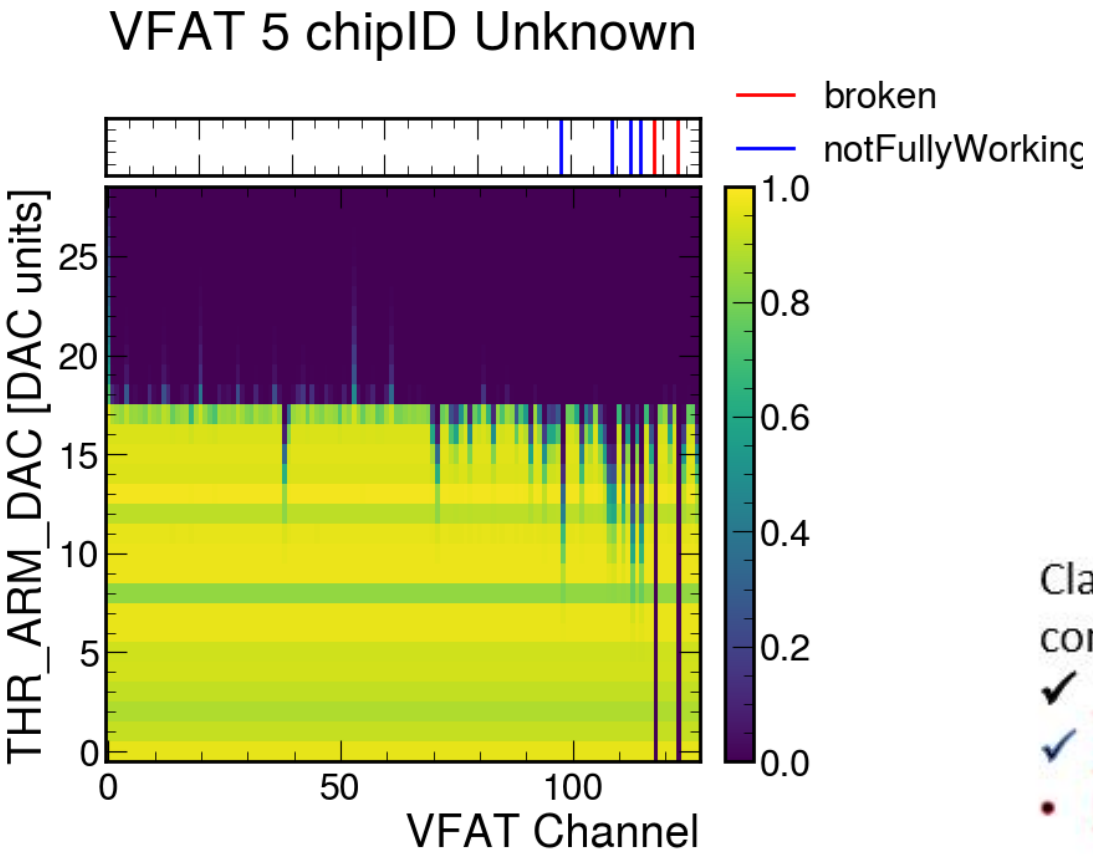
Threshold Scan

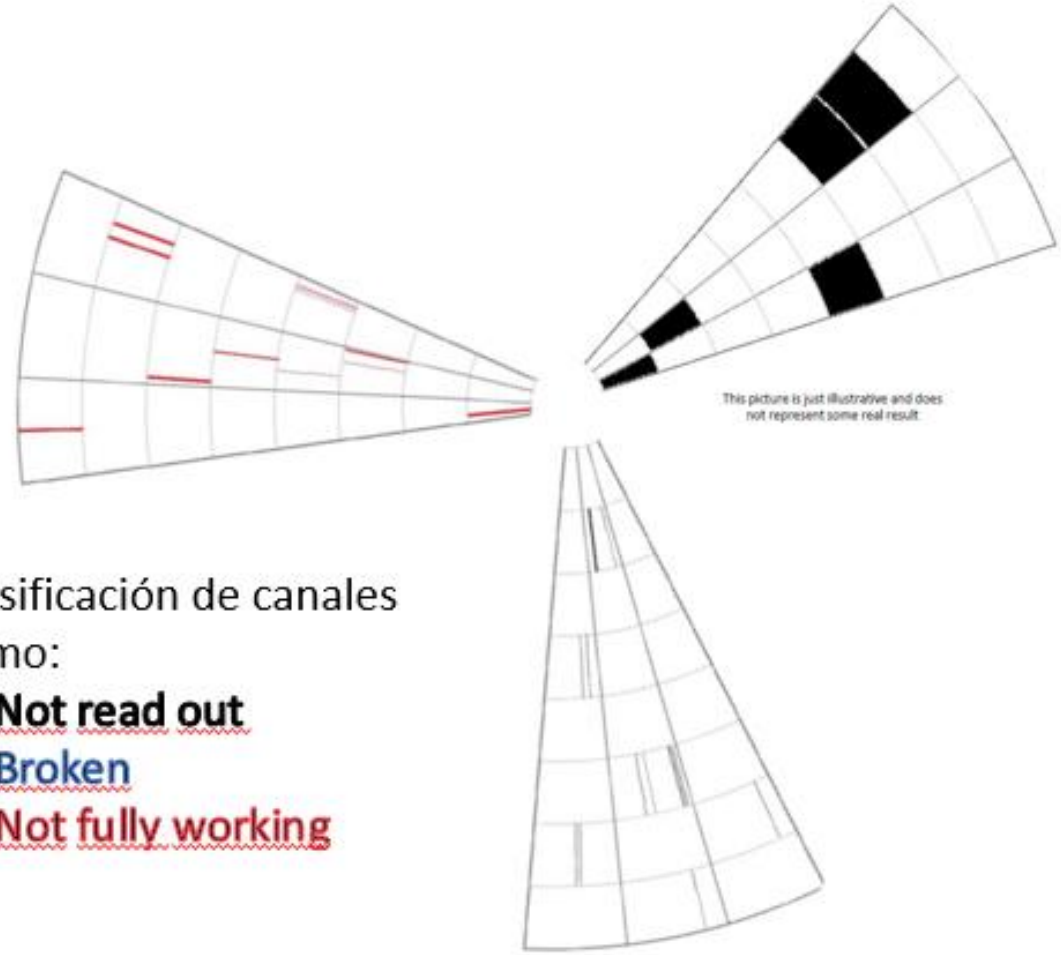




Resultados

Se desarrolló un código para la **clasificación de canales** a partir de los datos del ***Threshold Scan***

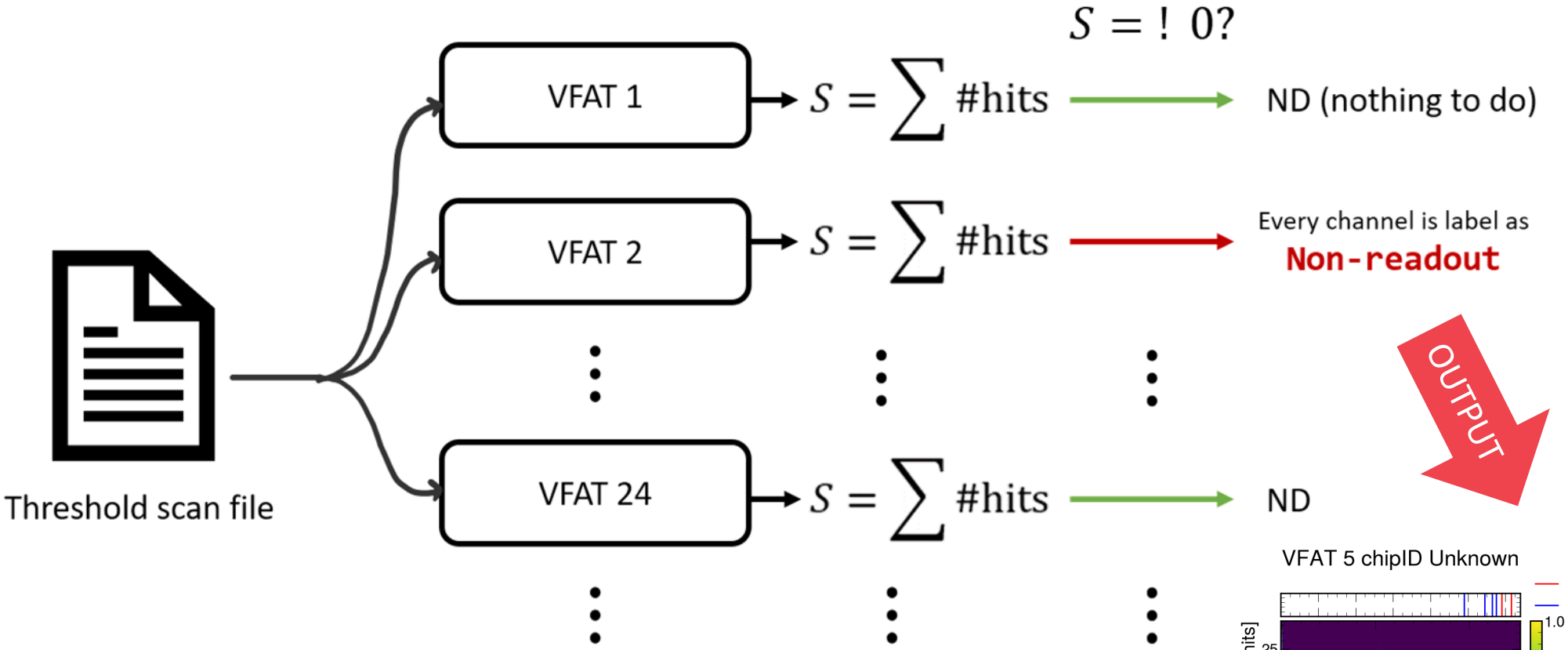


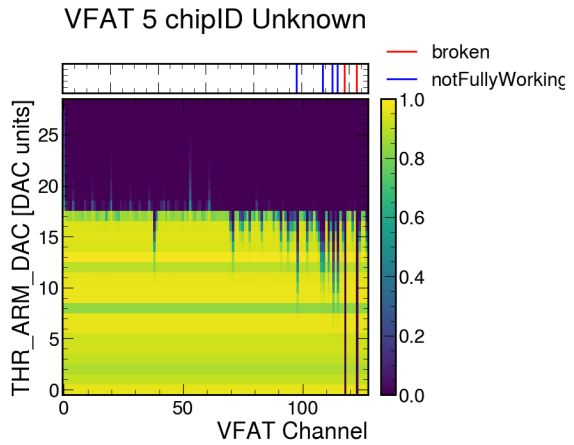


Clasificación de canales como:

- ✓ **Not read out**
- ✓ Broken
- • Not fully working

Este análisis sigue un **algoritmo** sencillo que corre en paralelo



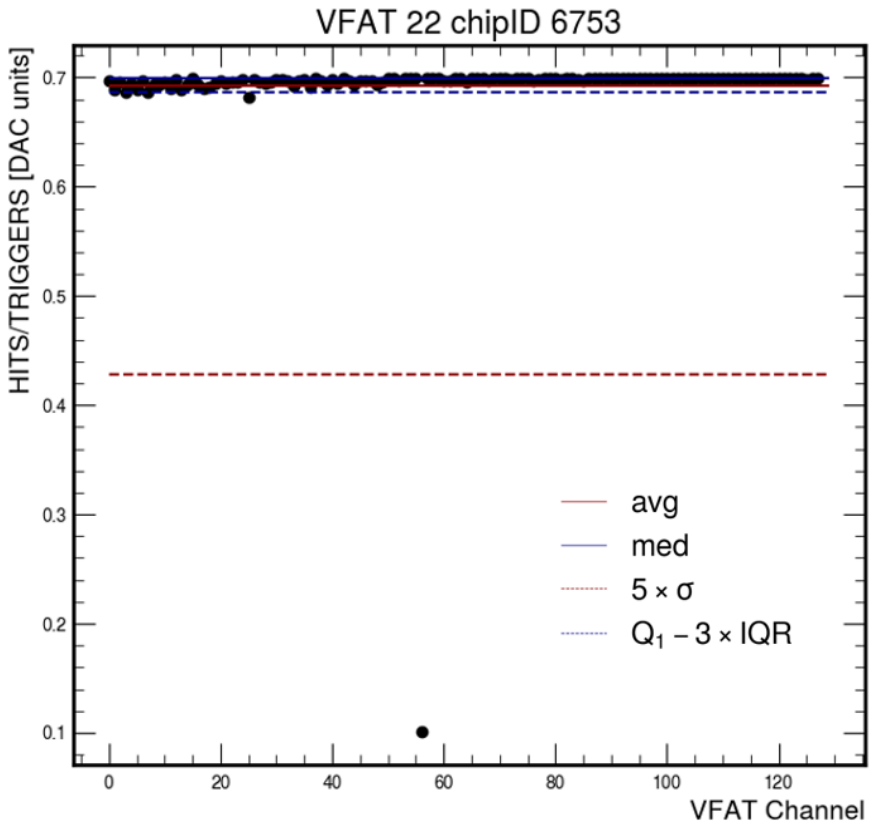


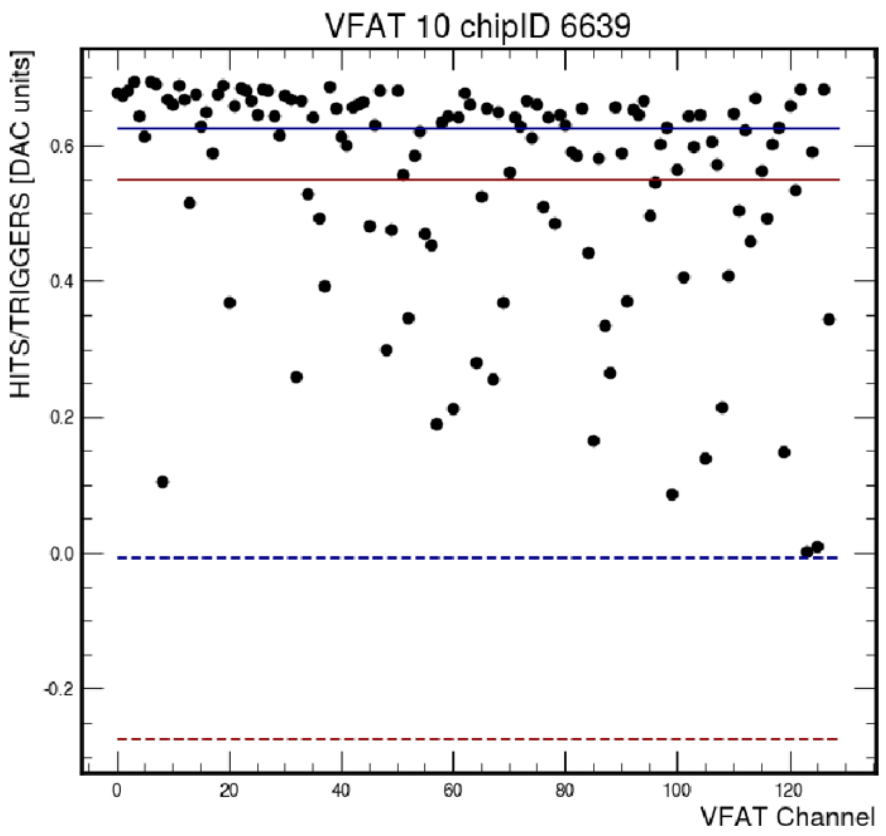
Basado en Python:

Input File (.txt) → Procesa con Pandas y Multiprocessing

Código disponible en: https://gitlab.cern.ch/cmsgemonline/gem-daq/cmsgemos-analysis/-/blob/main/gemos/analysis/threshold_scan_analysis.py?ref_type=heads

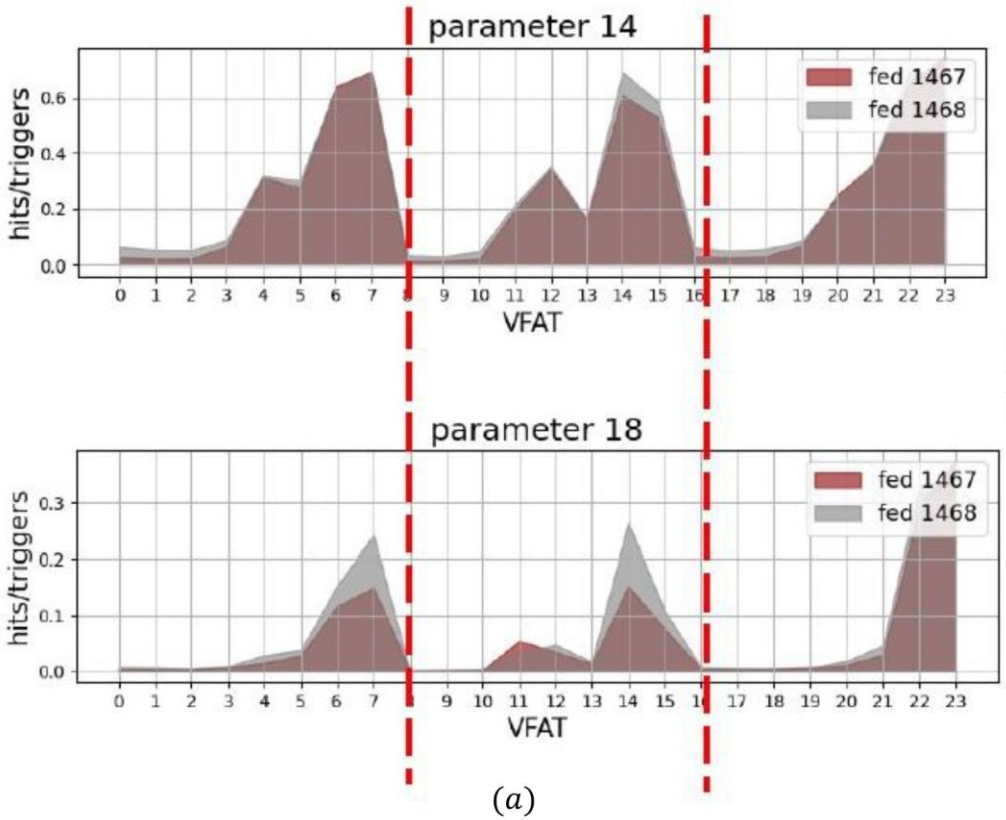
Las dinámicas entre canales difieren mucho por diversos factores



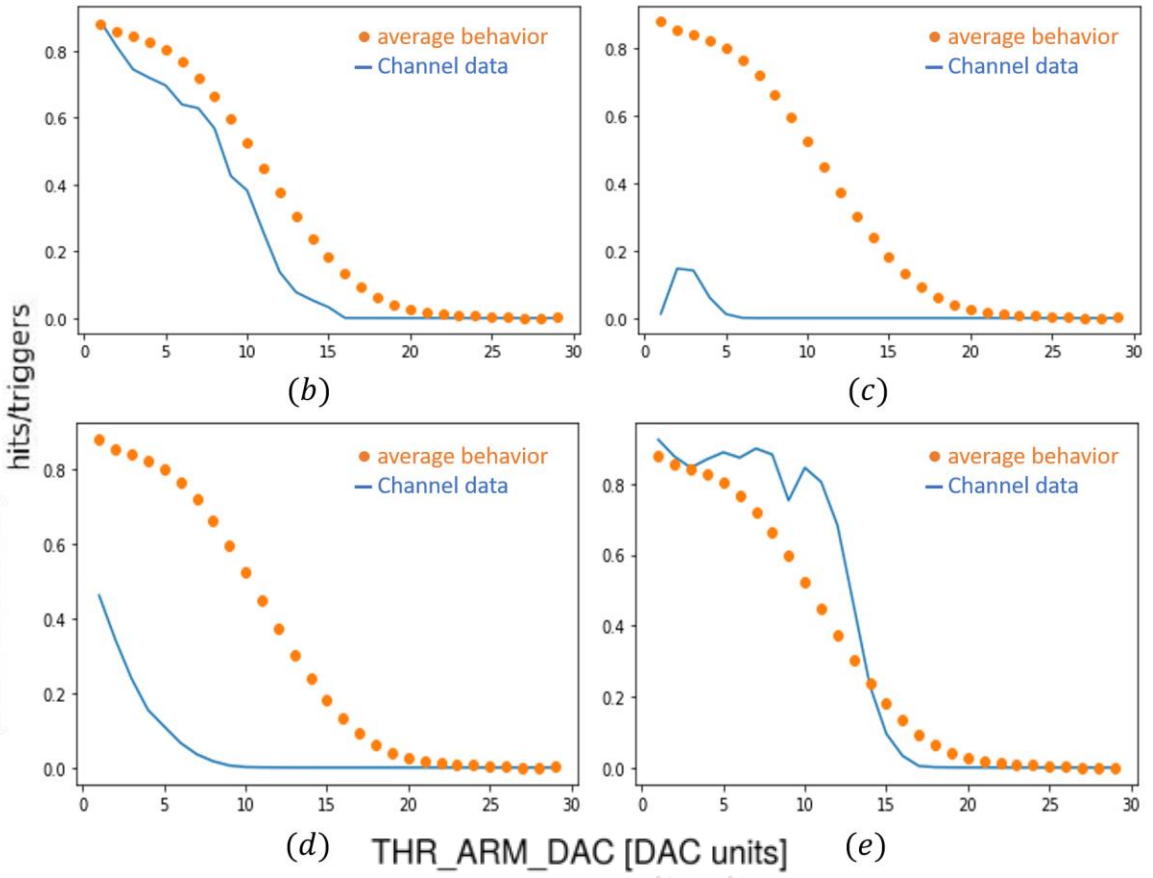


Resultados

Las dinámicas entre canales difieren mucho por diversos factores

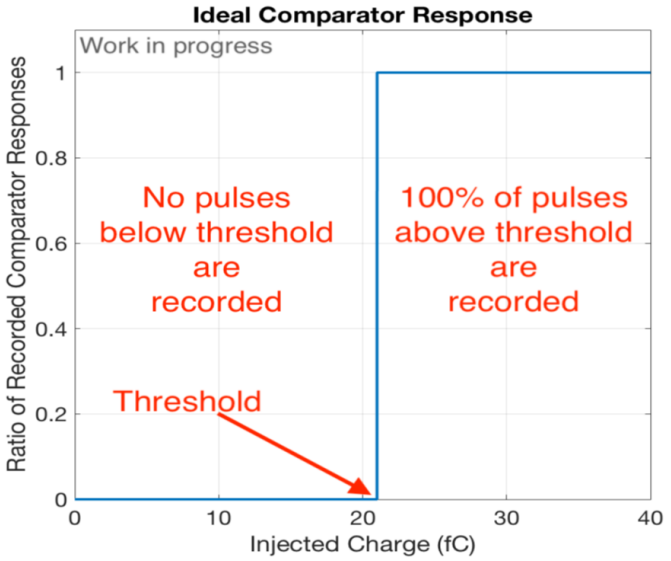


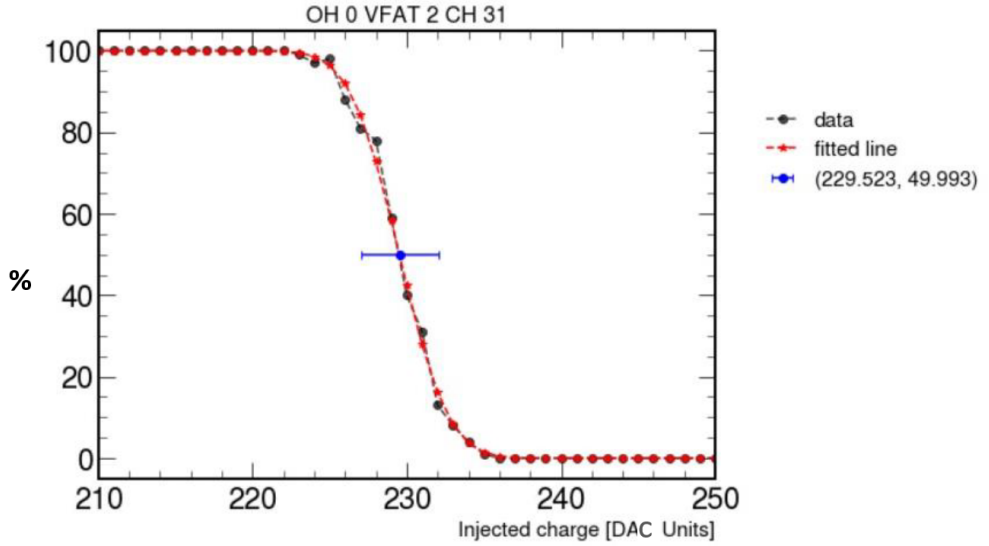
(a)

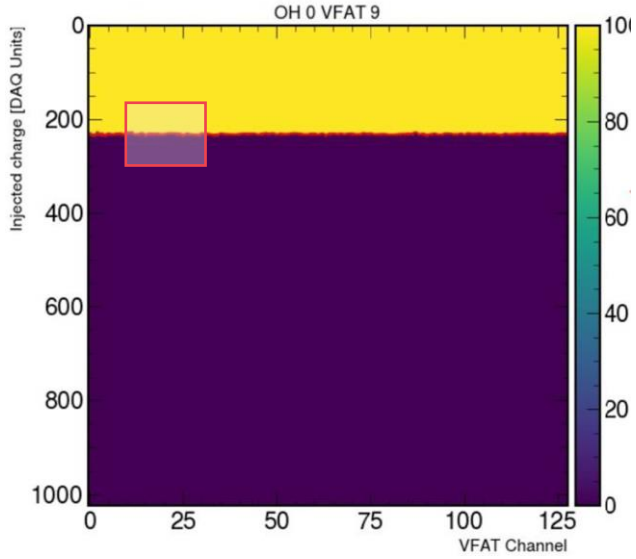


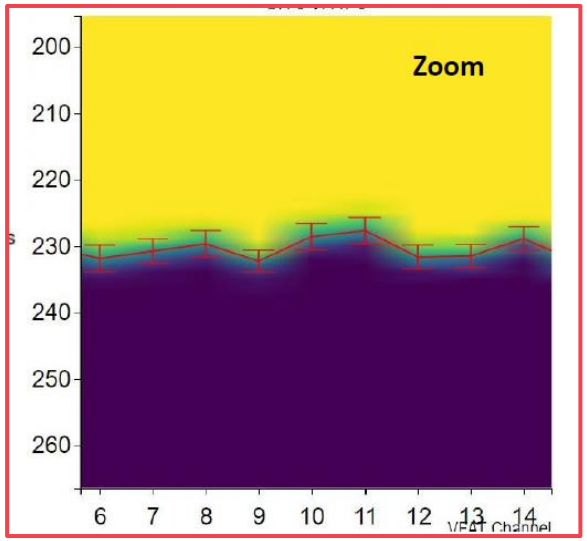
La clasificación de canales que "no funcionan del todo bien" NO FUE POSIBLE…

S-curve Analysis



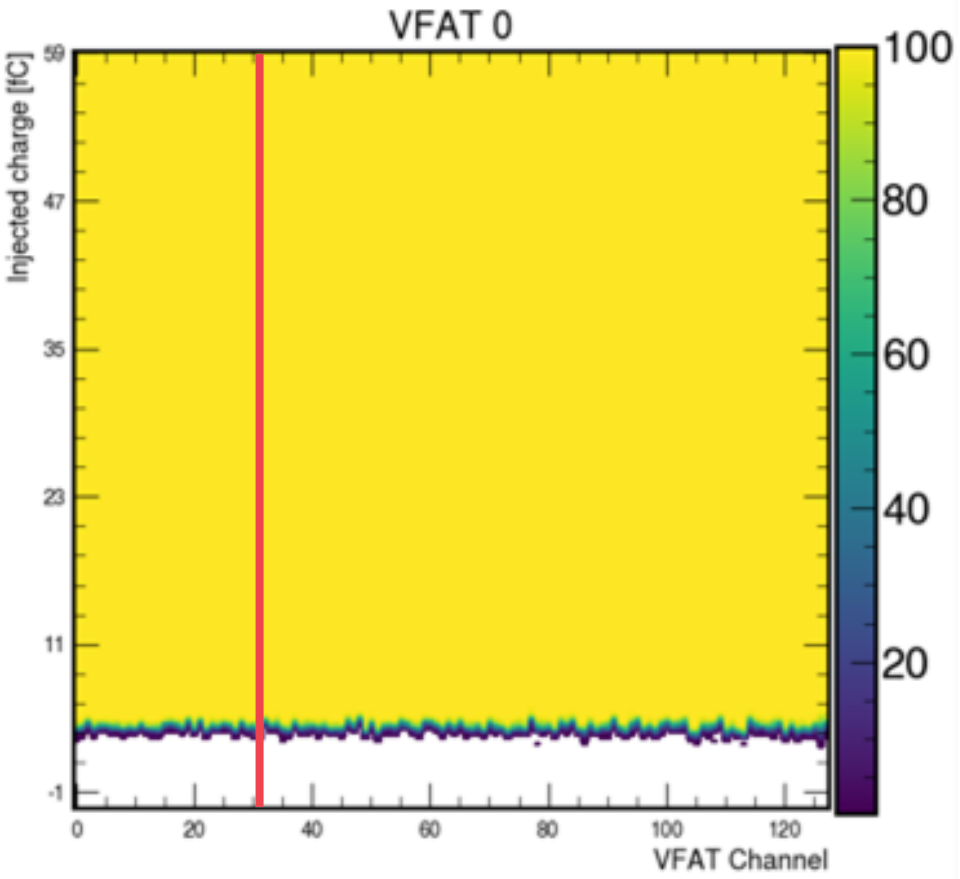




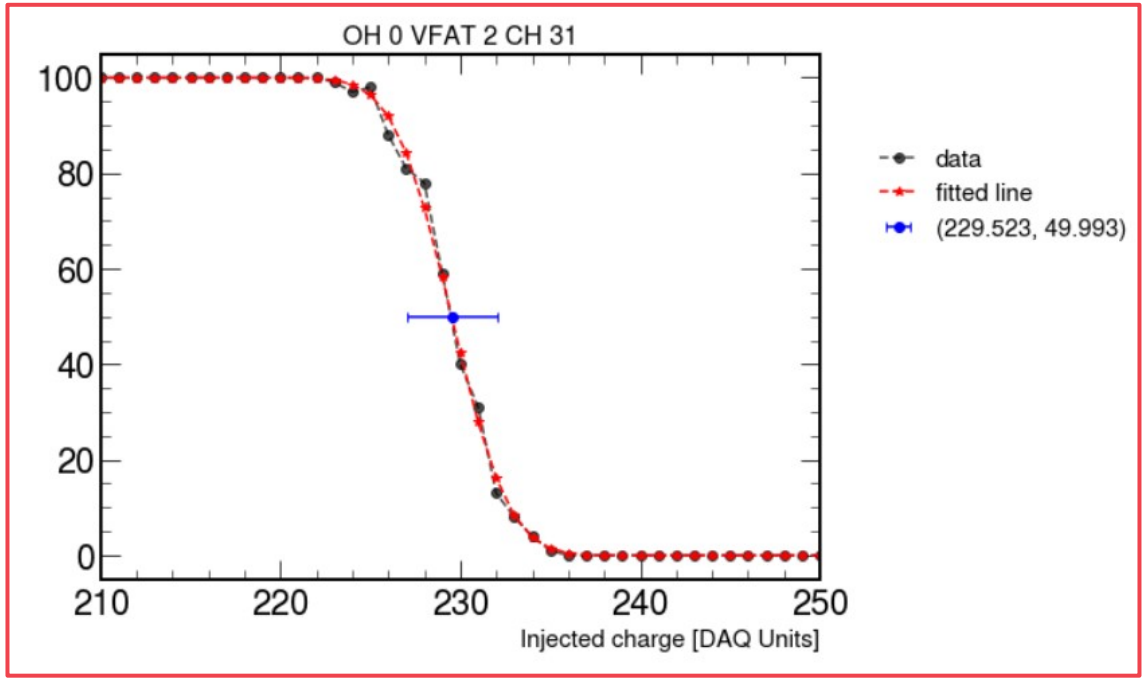


Resultados

Se implementó un código para la ejecución del análisis de las **S-curves**

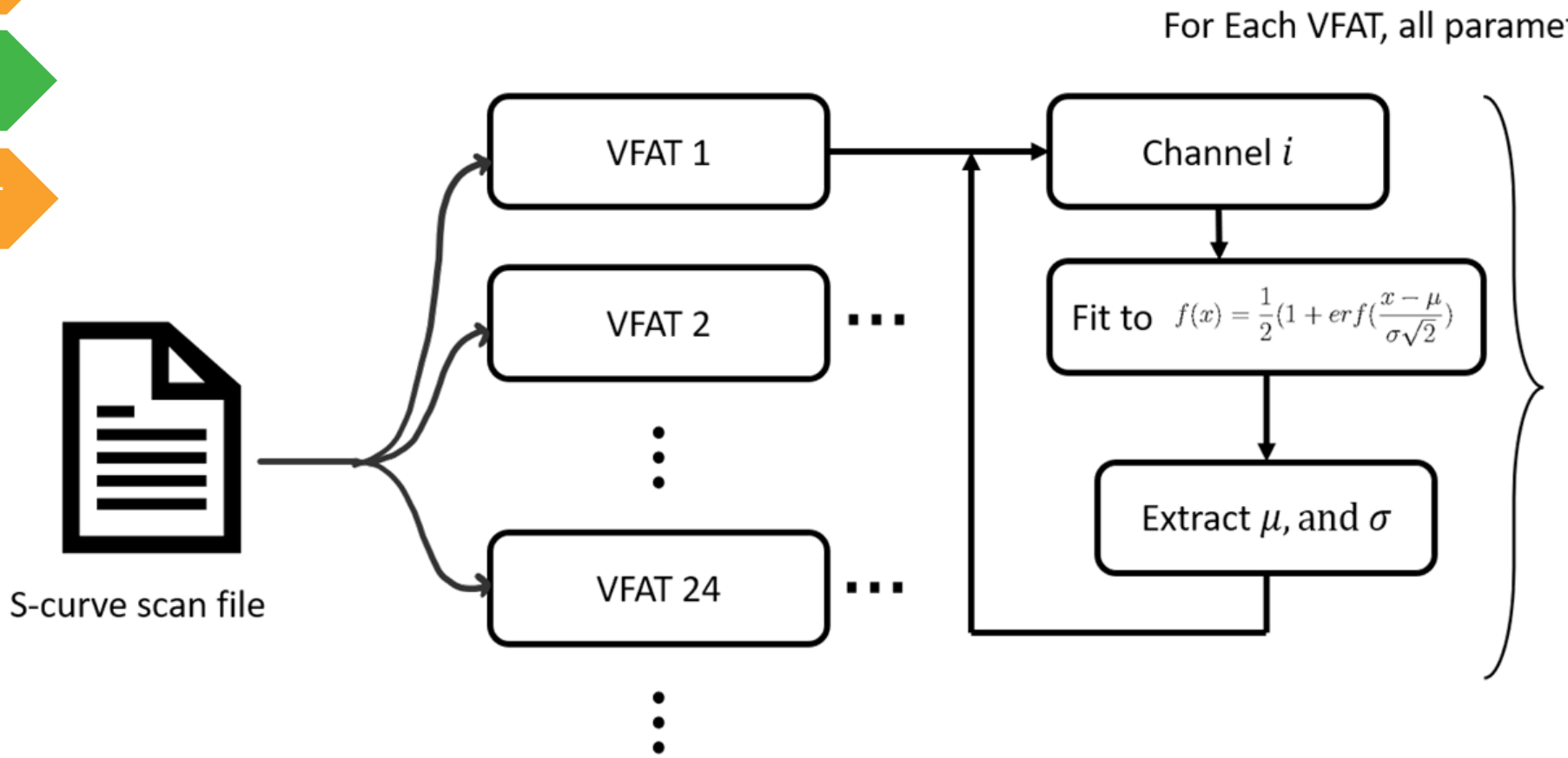


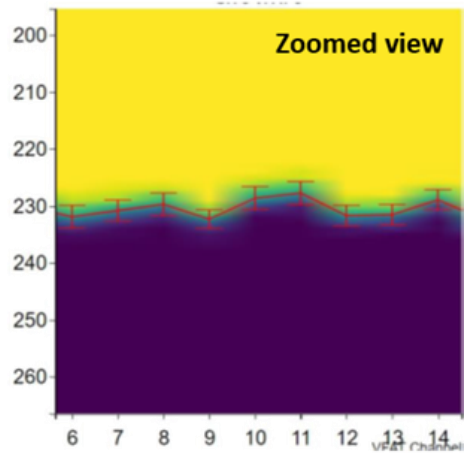
$$y = b + b * erf\left(\frac{-(x-\mu)}{\sqrt{2\sigma}}\right)$$



Analizar esta curva permite determinar el ruido y el umbral de activación de cada canal.

Este análisis sigue un **algoritmo** recursivo de ajuste de curvas que corre en paralelo sobre los VFAT





Basado en Python:

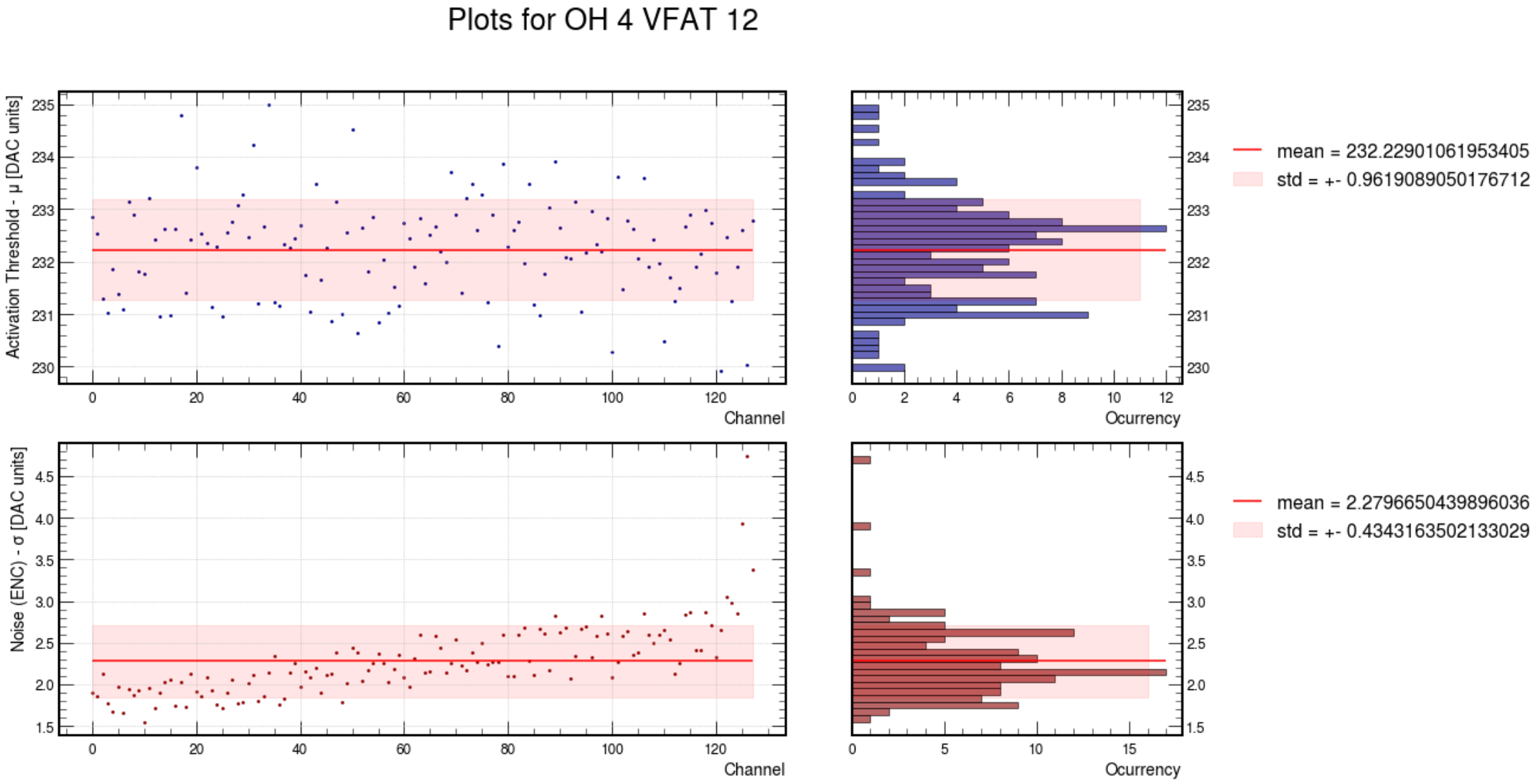
Input File (.root) → Procesa con uproot, Pandas y Multiprocessing

OUTPUT

Código disponible en: https://gitlab.cern.ch/cmsgemonline/gem-daq/cmsgemos-analysis/-/blob/main/gemos/analysis/scurve_analysis.py?ref_type=heads

Resultados

- CMS y sistema de muones
- Detectores GEM
- GE1/1, GE2/1 y ME0
- Estructura
- GEM DAQ



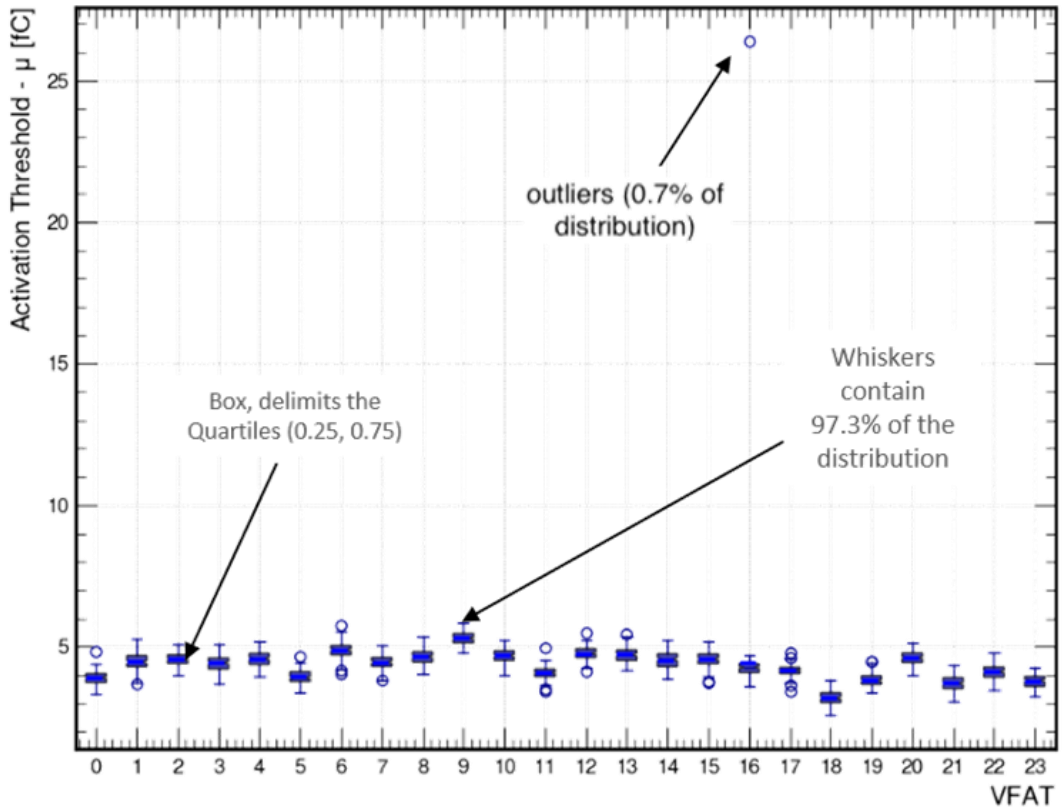
Resultados

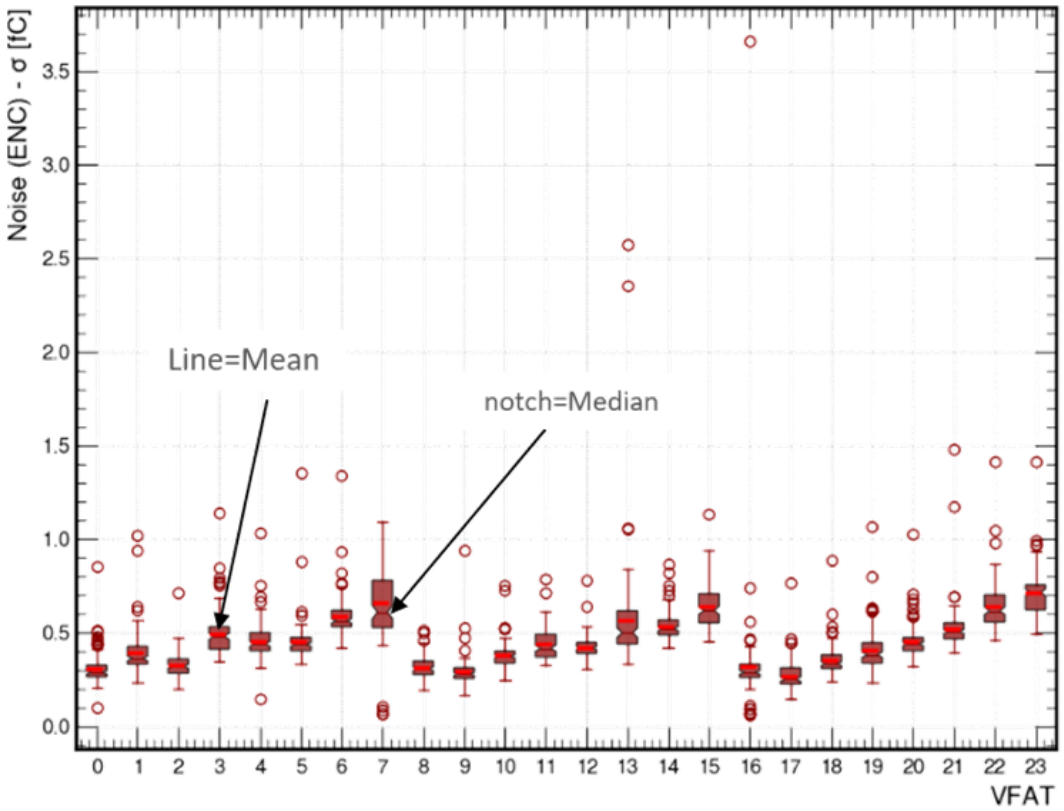
Procesos de QC

GEM-DAQ

Threshold Scan Analysis

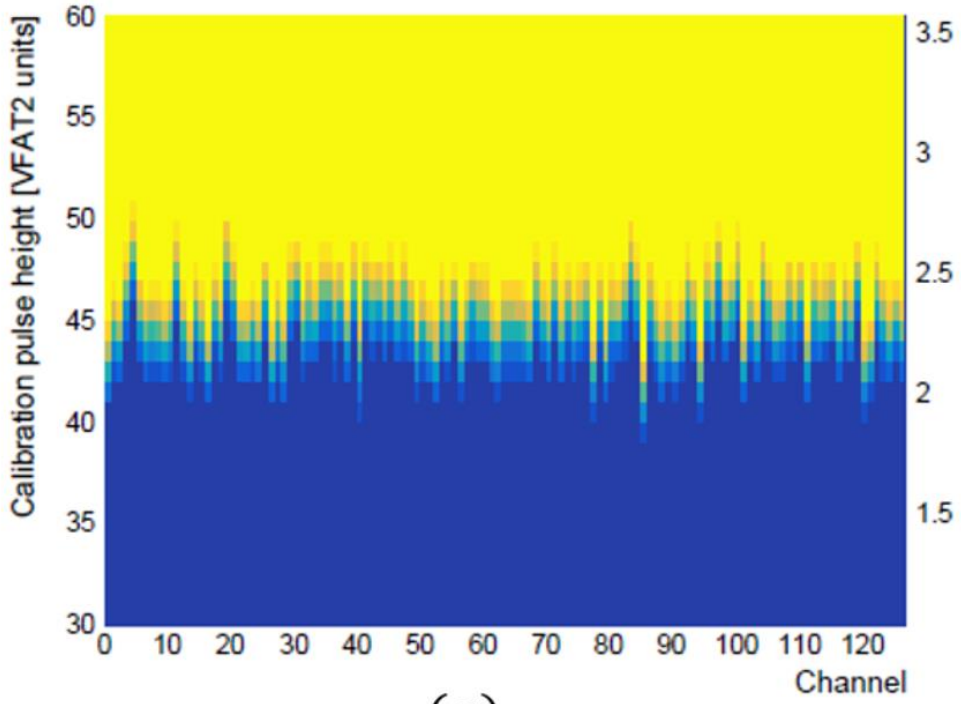
S-curve Analysis



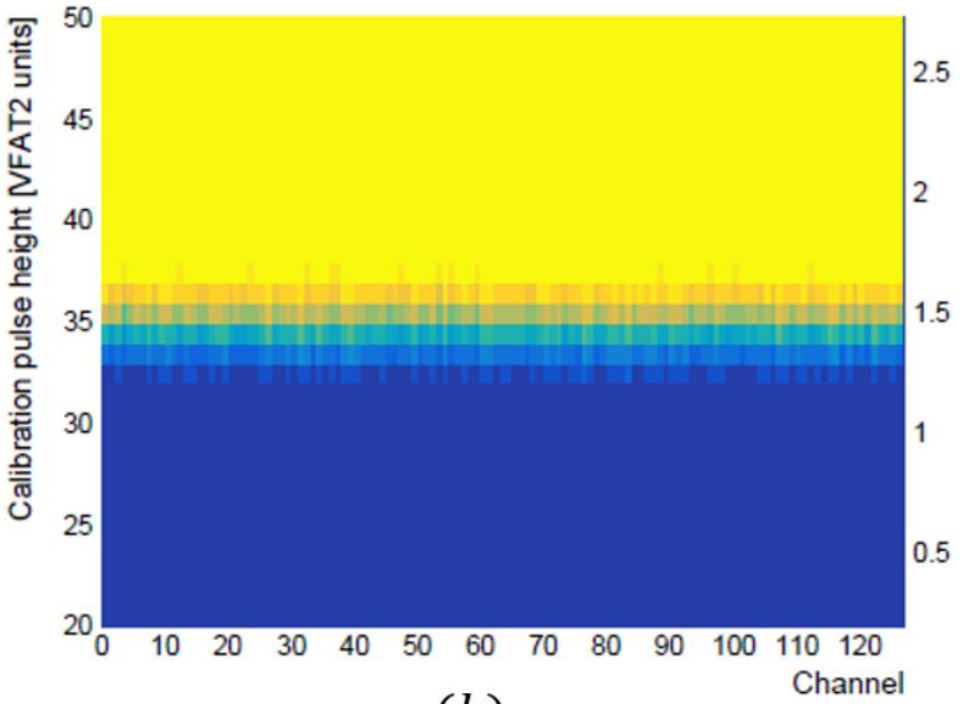


Resultados

Esta información se usa para identificar casos fuera de la media y para calibrar la electrónica homogeneizando la respuesta de todo el detector



(a)



(b)

Gracias

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Andrey Marinov. Overview of Production for CMS GE1/1, Slide from CERN PH Seminar. 2013

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[9] Sauli, F. "*Gas Detectors Physics 1*". RD51 MPGD School November 27, 2023 CERN.

[10] Sandoval, C. "*MEASUREMENTS AND DISCOVERIES AT THE LHC". 1st* CONHEP School, Universidad del Tolima, Dic. 1, 2023.

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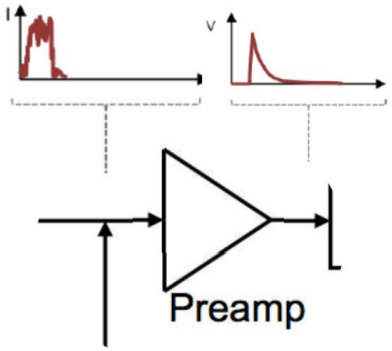
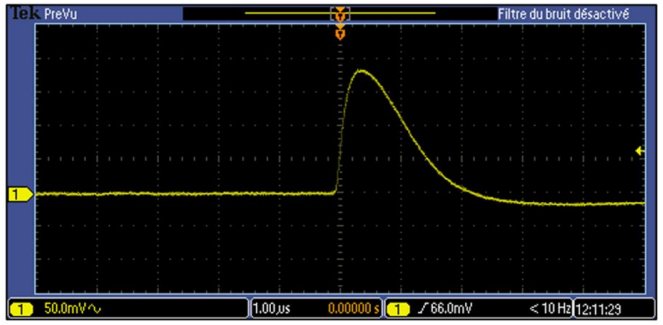
Backup

Electrónica on-detector

Preamplification stage

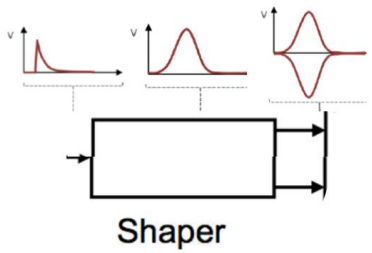
(a)

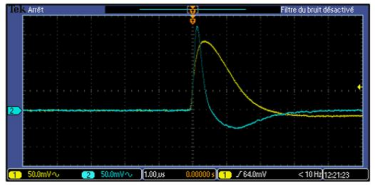


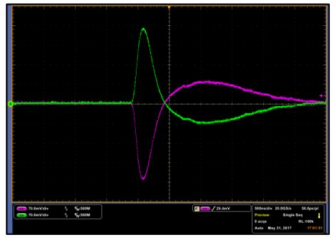


Shaper and single-to-differential stage

(b)

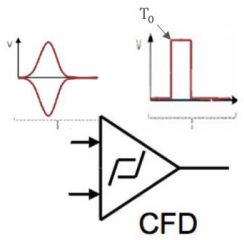


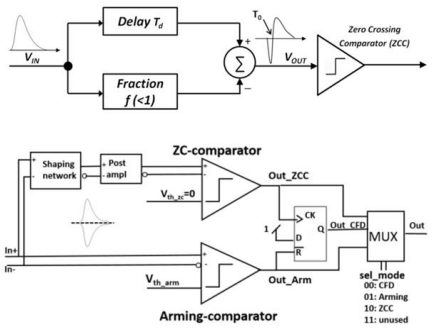


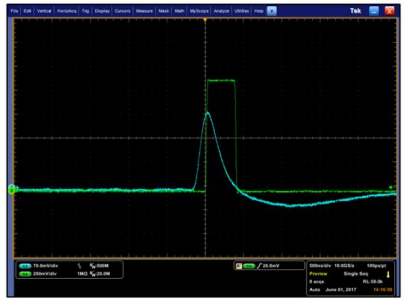


Shaper and single-to-differential stage

(c)

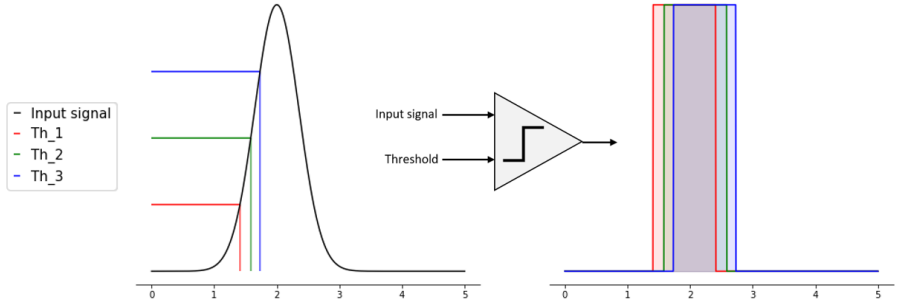






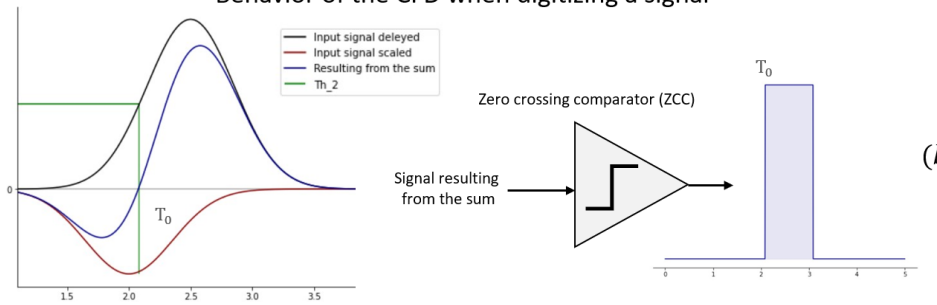
Behavior of the simple comparator when digitizing a signal

(a)

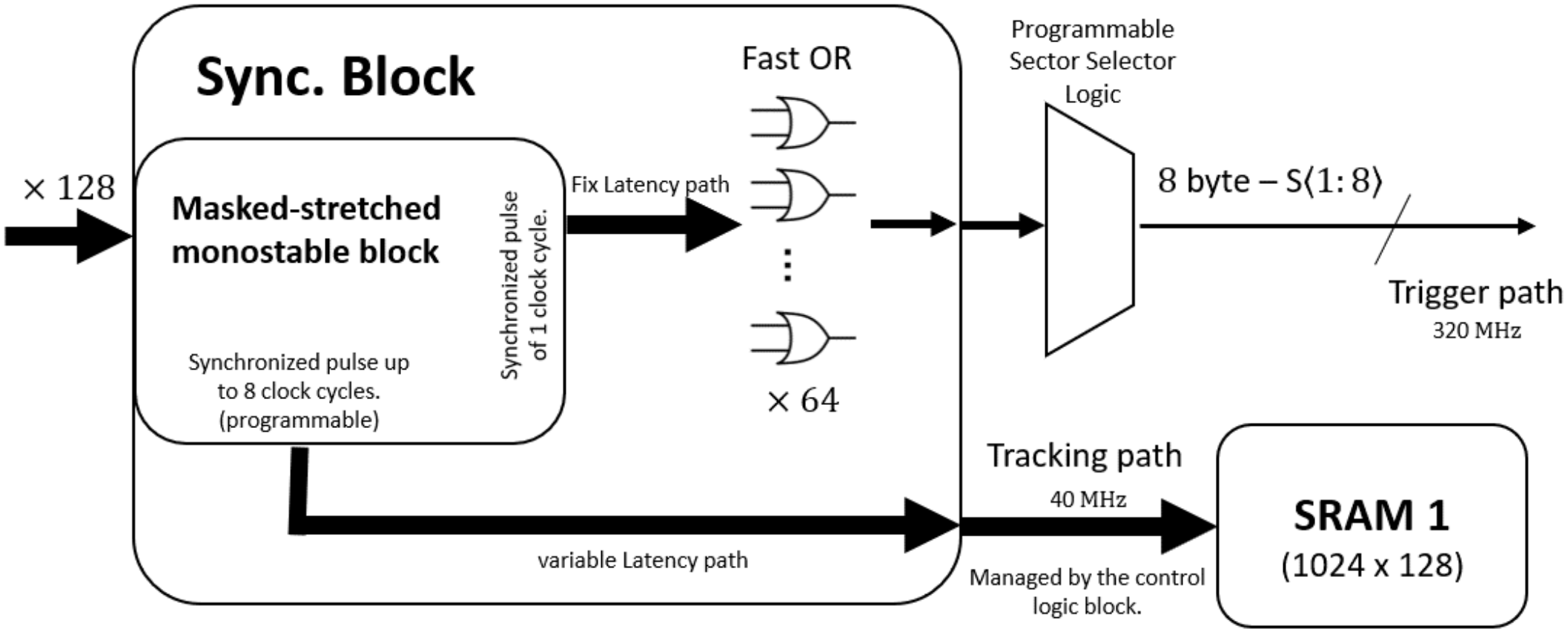


Behavior of the CFD when digitizing a signal

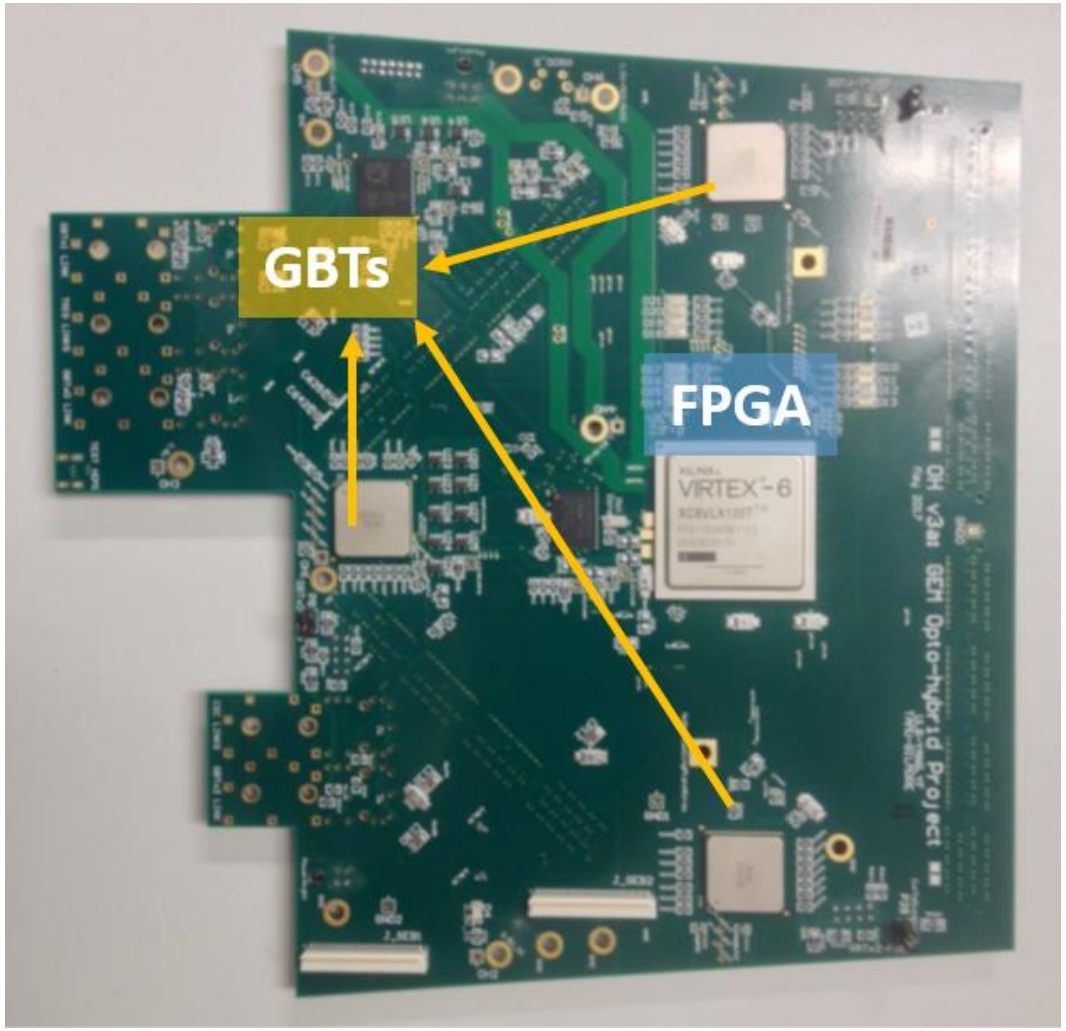
(b)



Electrónica on-detector



Electrónica on-detector



Xilinx Virtex-6

Electrónica Off-Detector