UNIVERSITÀ DI TORINO

AMBER
Apparatus for Meson and Baryon Experimental Research

INFN
Istituto Nazionale di Fisica Nucleare

A new large-area Micromegas detector and its readout electronics for AMBER experiment at CERN

Amoroso A. on behalf of MM design team

CERN

CERN MPT Workshop

Outline

AMBER experiment at CERN

- Present status and upgrade

New tracking detector development – Large Micromegas

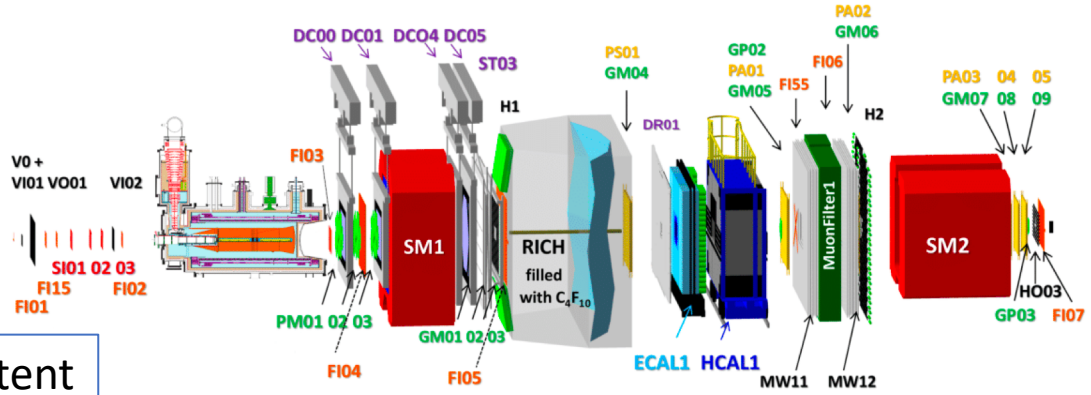
- LMM design
- Prototype production
- Test beam results

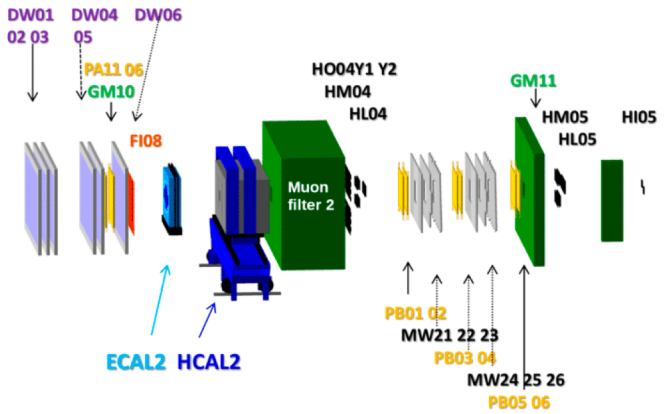
Front-end electronics

- Development of ToRA-based fee

Conclusions

Apparatus for Meson and Baryon Experimental Research (AMBER,NA66)





2018: Letter of intent
arXiv:1808.00848

2019: AMBER Phase1 Proposal
CERN-SPSC-2019-02

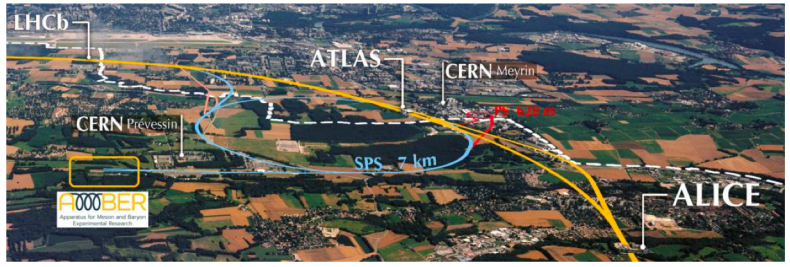
2020: SPSC Recommendation and Research Board approval

2021-2022: Amber Pilot run

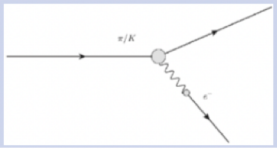
2023: Start of AMBER data taking

Phase-2 proposal in preparation
Post LS4

32 institutes from 14 countries, but there is no Upper limit on the values



Apparatus for Meson and Baryon Experimental Research (AMBER,NA66)

	Beam	Target	Additional hadware
Antiproton production crosse section	50 GeV – 280 GeV protons	LH_2, LHe Done (2023 – 2024)	Liquid He target
Proton radius measurement	100 GeV muons 2025 – 2026	High pressure Hydrogen	Active target TPC, tracking stations (SciFi,Silicon)
Drell-Yan measurement with pions	190 GeV charged pions	Carbon, Tungsten	Vertex detector
Drell-Yan measurement with Kaons	~100 GeV charged Kaons	Carbon, Tungsten Post LS3	Vertex detectors, "active absorber"
Prompt photon measurement	> 100 GeV charged Kaon/pion beams	LH_2, Nickel	hodoscopes
K-induced spectroscopy	50 GeV – 100 GeV charged Kaons	LH_2	Recoil ToF forward PID
Meson radii	50 GeV to 280 GeV charged pions and Kaons		

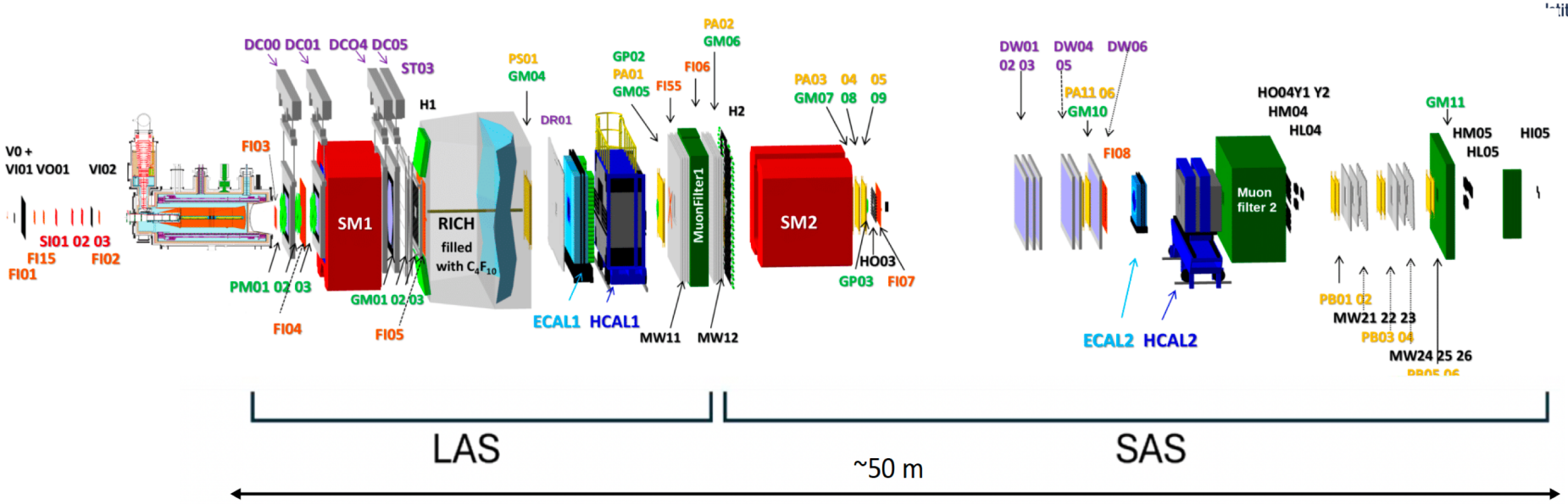
Phase 1 (approved)

2023 -> 2032

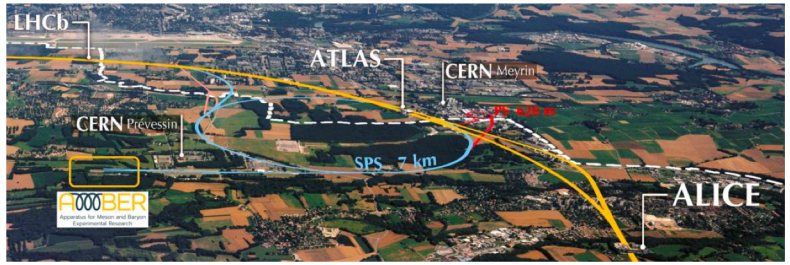
Phase 2 (in preparation)

Beyond LS4

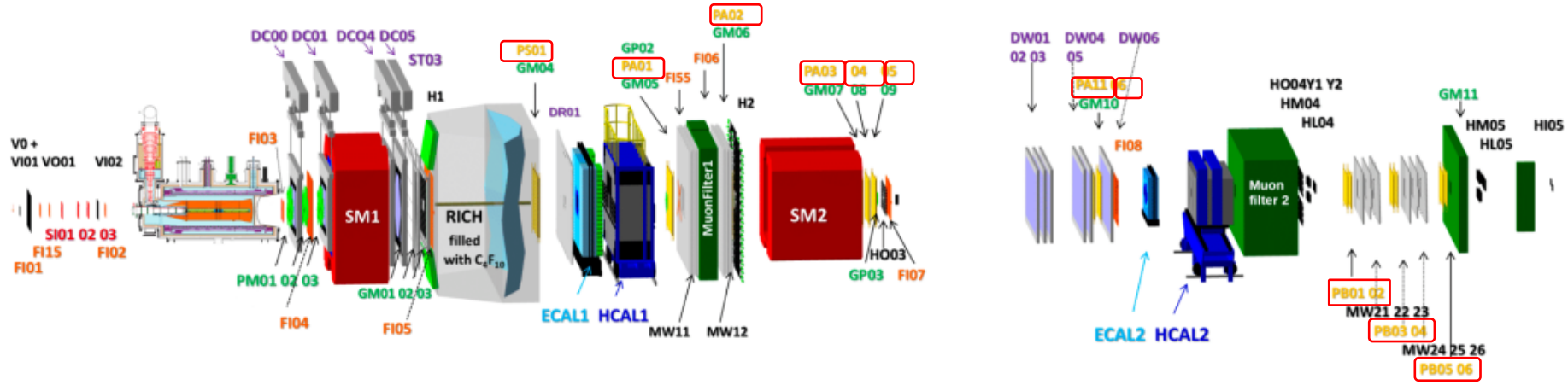
Apparatus for Meson and Baryon Experimental Research (AMBER,NA66)



Torino group is responsible for the Multi-Wire Proportional Chamber (**MWPC**) tracking stations and the **Rich Wall** Mini-Drift Tubes (MDTs) detector. Part of the MWPCs will be substituted by Micro-Pattern Gaseous Detectors (**MPGD**) to face their structural aging.



AMBER Sprectrometer upgrade – Tracker detectors



❖ In the present AMBER setup one of the main tracker are the MWPC stations

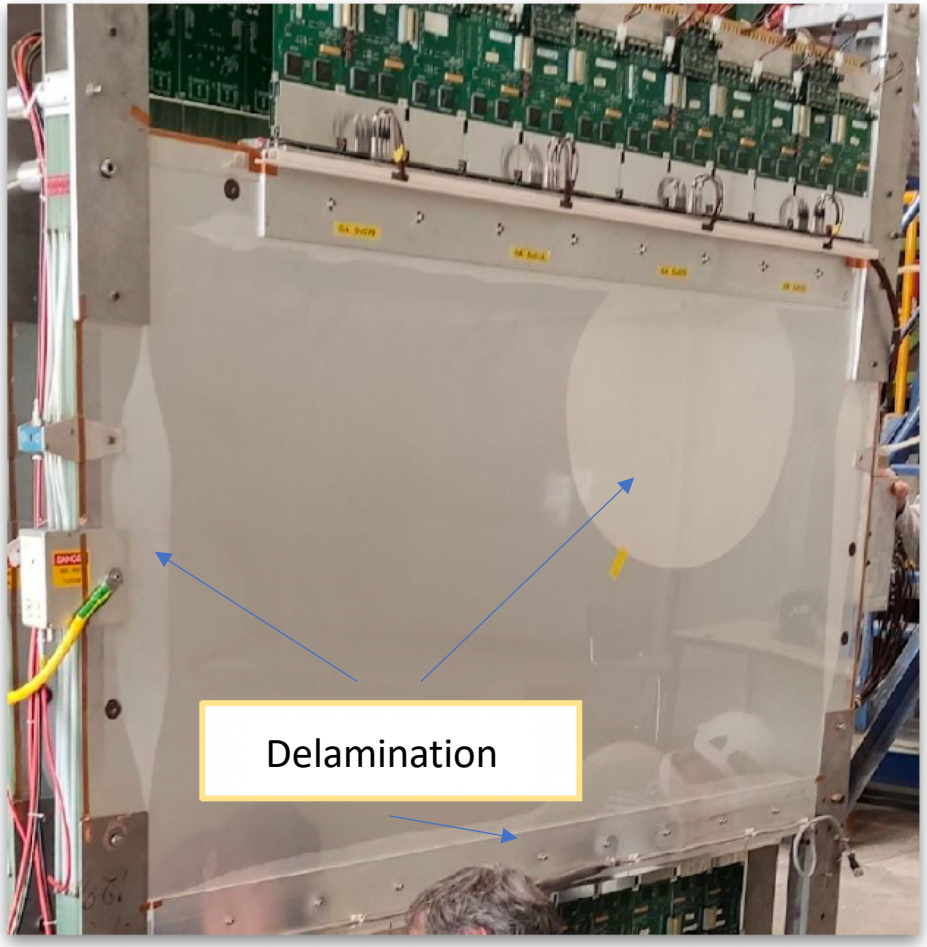
<u>Past situation (23-24)</u>

- ✓ Triggered DAQ
- ✓ Degraded detectors

<u>Present - Future situation (25-….)</u>

- ❑ Trigger less DAQ
- ❑ Maintenance available for a long period of time

Sprectrometer upgrade - Why MM detector



AMBER MWPC stations are **structurally aged**. During last years we carried out a refurbishment campaign for MWPC-PB type.

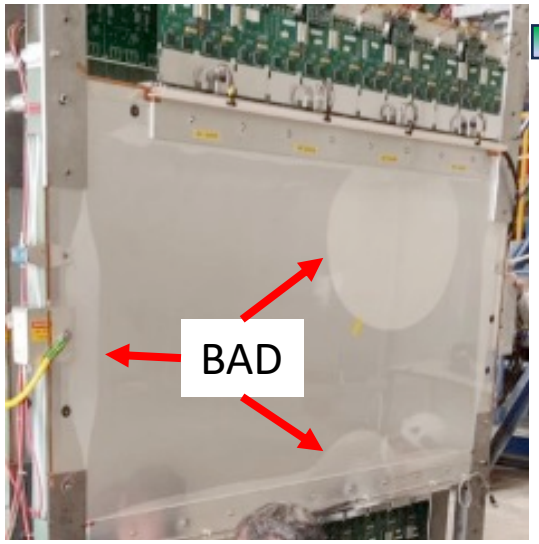
	A-type	A*-type	B-type
# of chambers	7	1	6
Active area (cm^2)	178 × 120	178 × 120	178 × 90
# of layers/chamber	3	4	2
Planes	*X*, *U*, *V*	*X*, *U*, *V*, *Y*	*X*, *U*/*V*
Dead zone ⊘ (cm)	16–20	16	22
Wire pitch (mm)	2	2	2
Anode/cathode gap (mm)	8	8	8
# of wires/plane	752	752 (*X*, *U*, *V*), 512 (*Y*)	752

For AMBER mid and long-term program we decide to substitute a part of the MWPCs (PA-type) with a **micromegas** detector (1,5x1m).

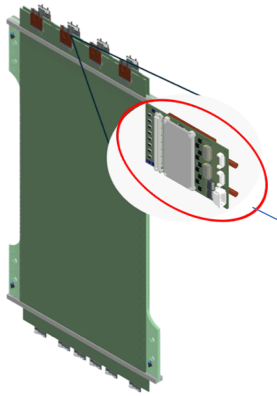
Sprectrometer upgrade - Why MM detector

Till 2024

Existing MWPCs from COMPASS



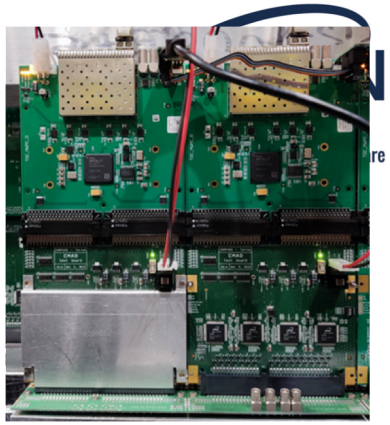
After 2024



New detectors

Trigger less DAQ (2025)

New FE needed

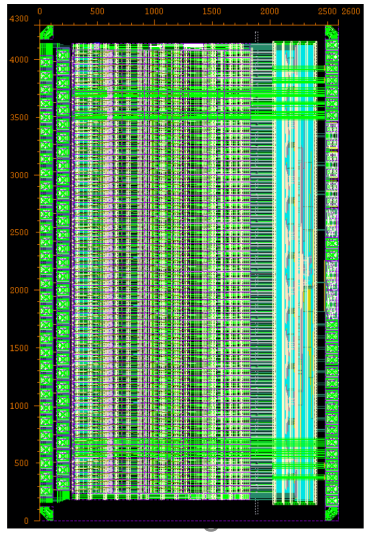


FPGA based

New FE needed

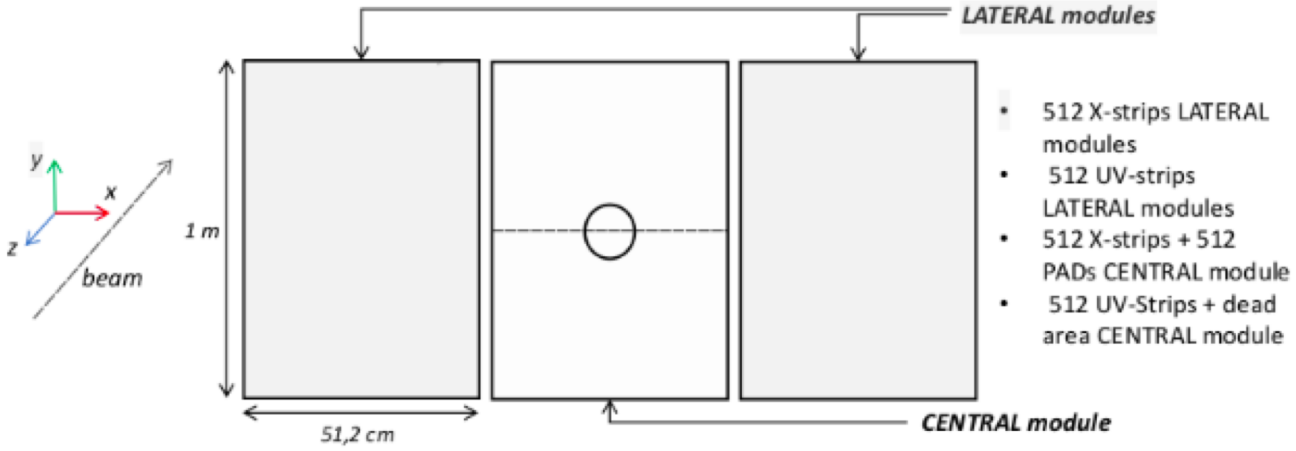
The 2 developments could go together

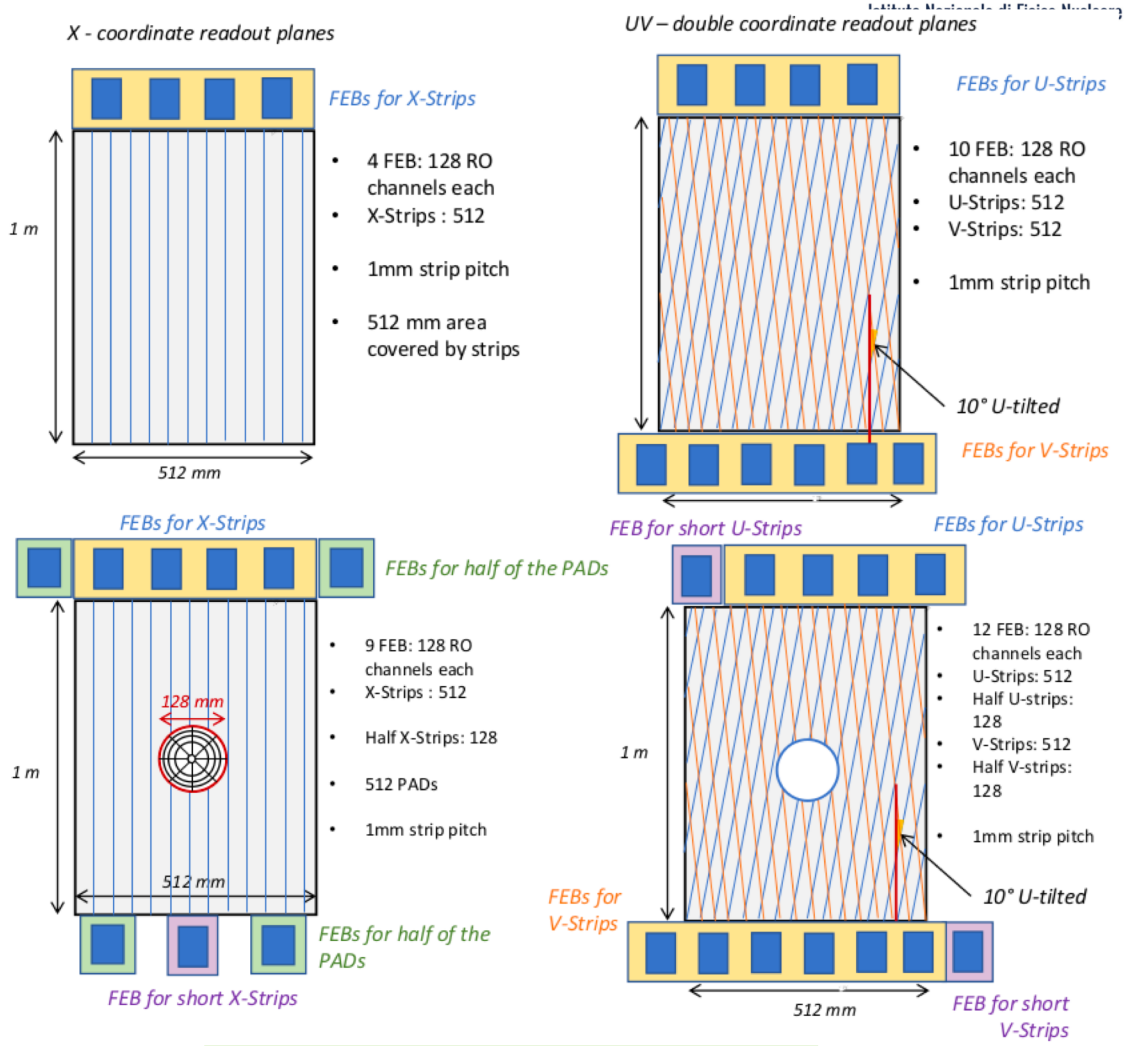
New ASIC - ToRA



Concept Design - 1

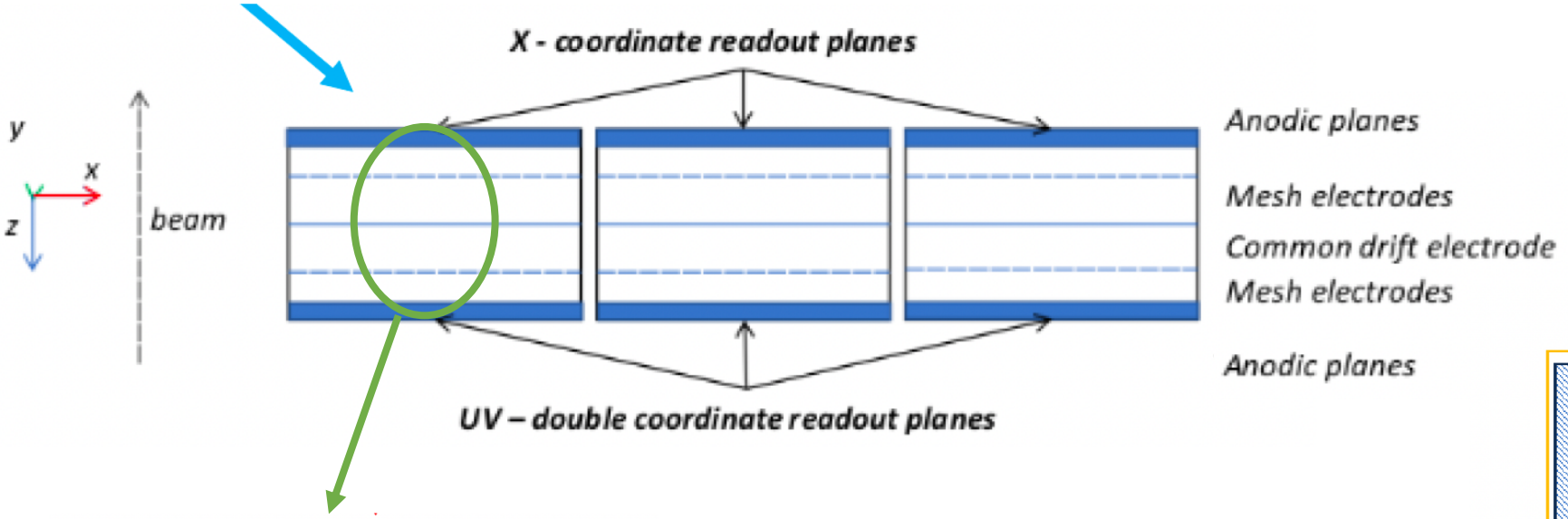
The **large-area MM detector (LMM) for AMBER** will be composed of three different modules covering a total active area of **1.5 m x 1 m**
Each indipendent module will be a **bulk resistive** micromegas in a «**face-to-face**» configuration

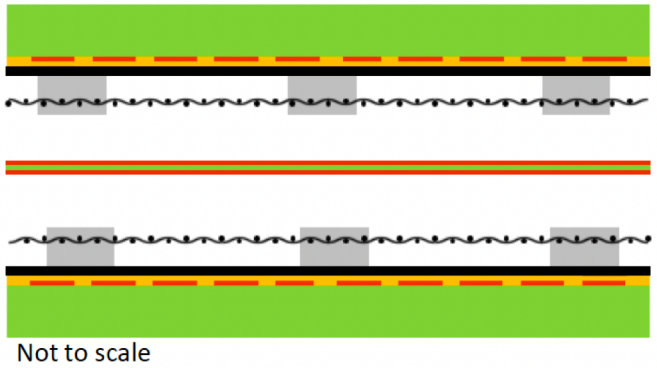




Dead area covered with GEM

Concept Design - 2



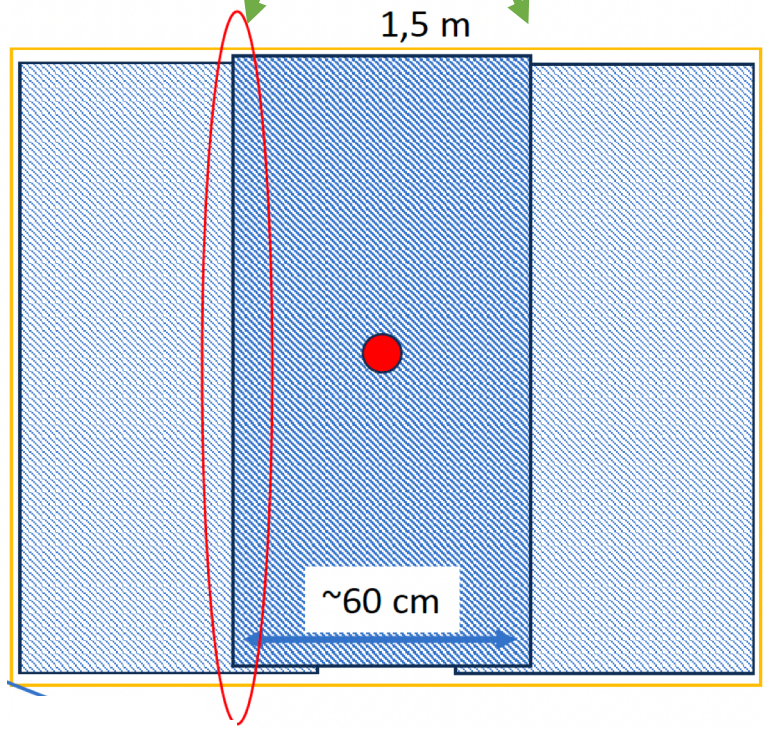


Face-to-face configuration

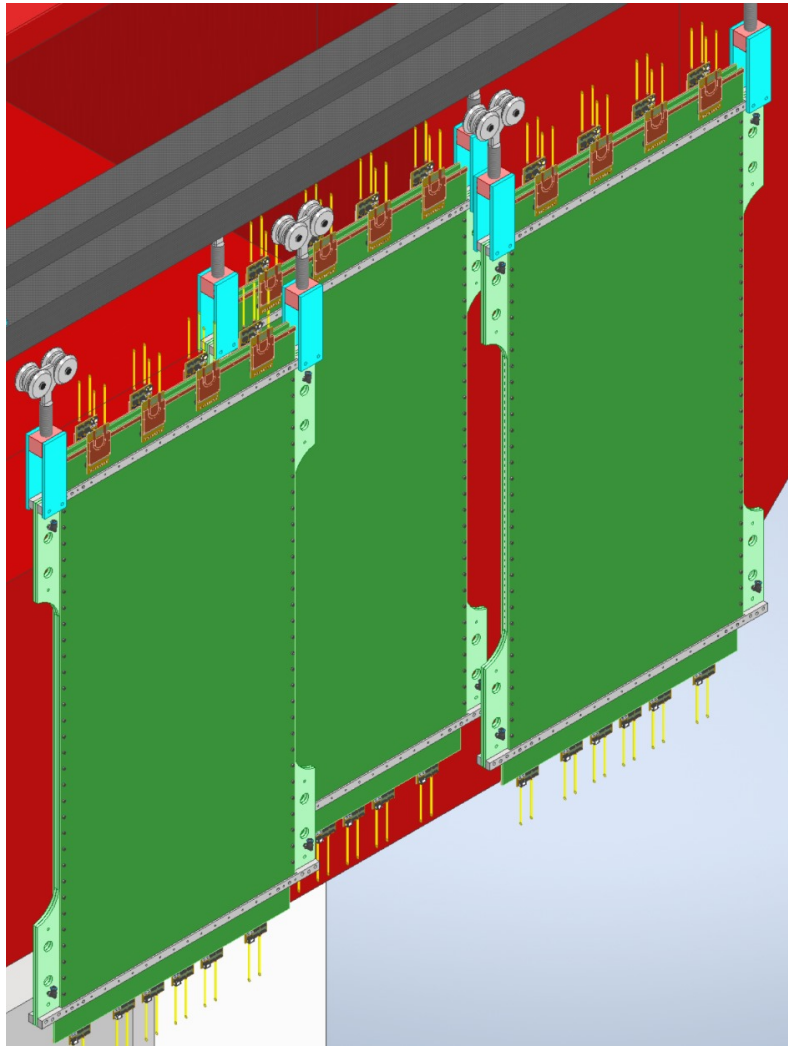
No thick frame allowed in the acceptance

Common cathode configuration to reduce material budget

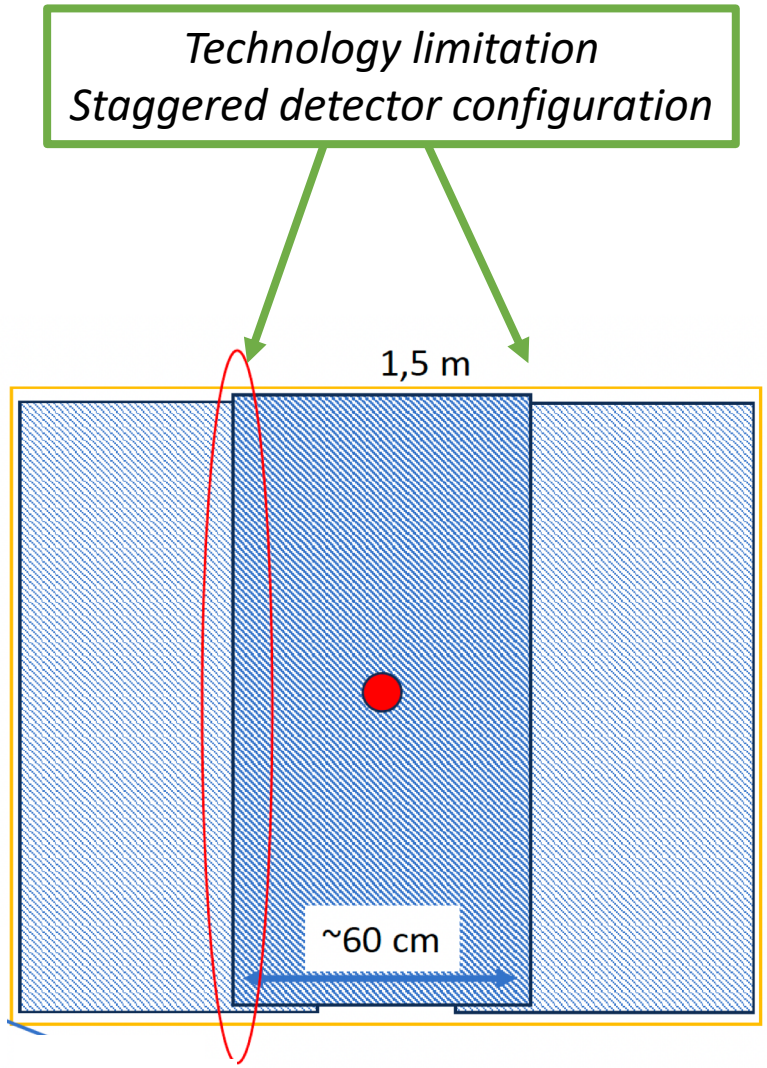
Technology limitation
Staggered detector configuration



Concept Design - 3

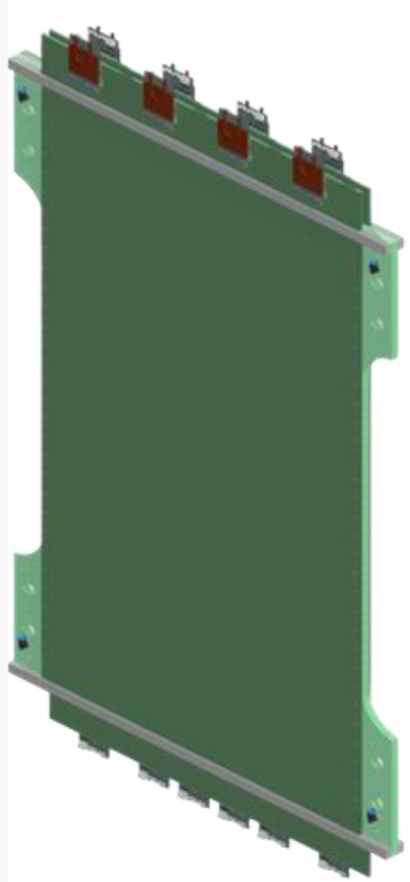


No thick frame allowed in the acceptance



Lateral module prototype production

Layout and production – CERN MPT Workshop



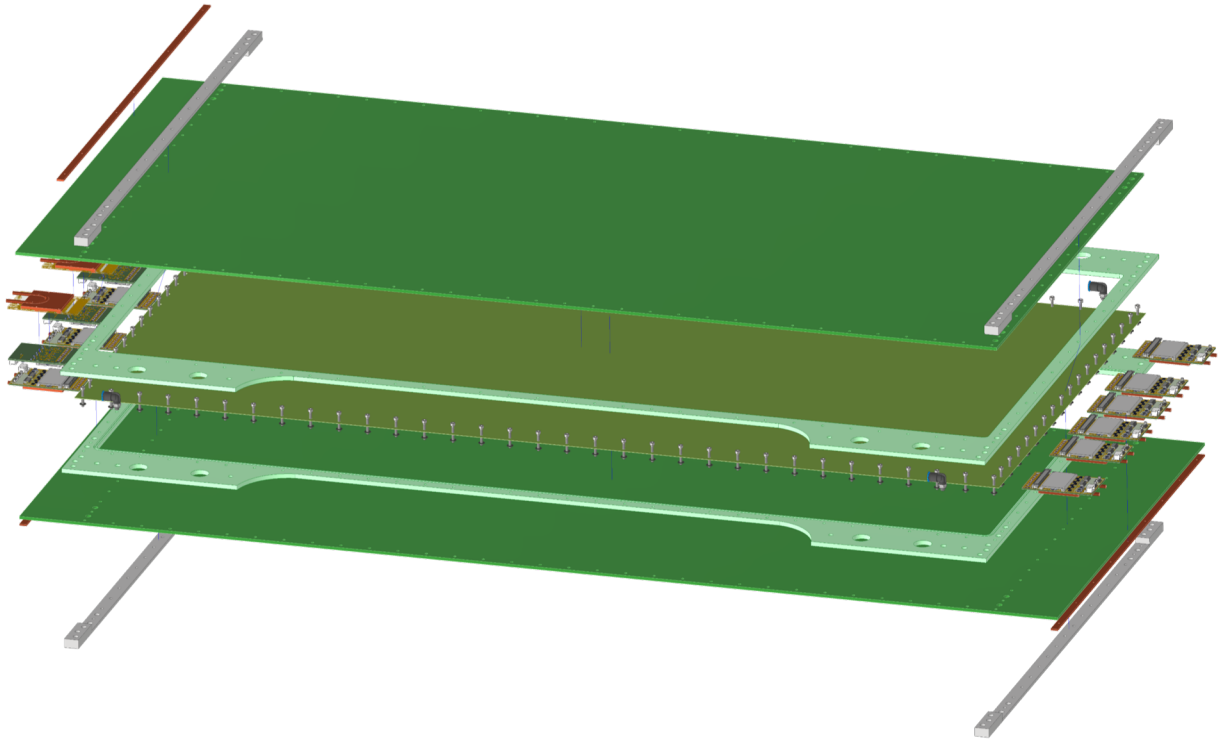
X-coordinate R/O plane

FR_4 gas vessel frame

Cathode PCB - drift electrode

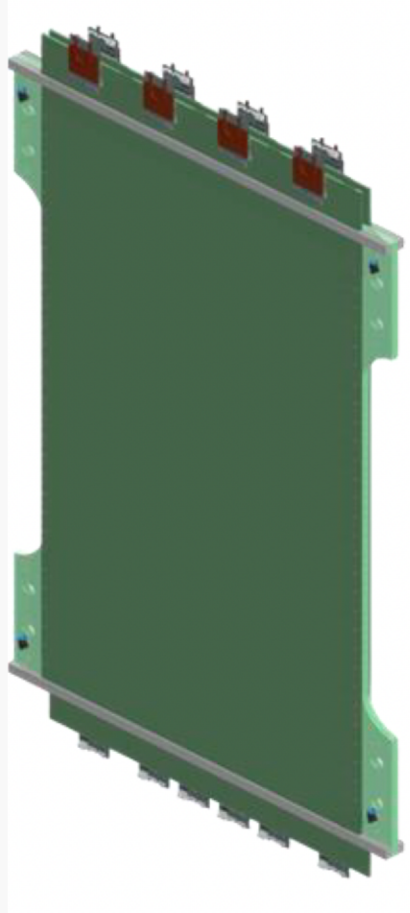
FR_4 gas vessel frame

UV-coordinates R/O plane



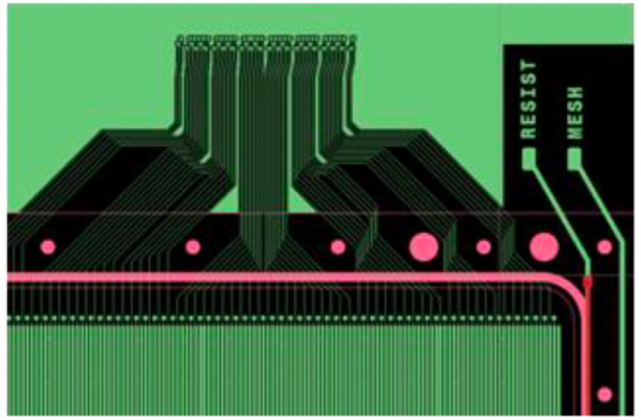
Lateral module prototype production

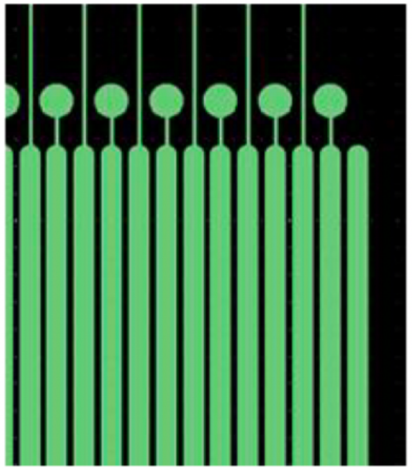
Layout and production – CERN MPT Workshop



- 512 strips
- 1mm pitch
- 750 um width
- 4 FEBs: 512 fe channels

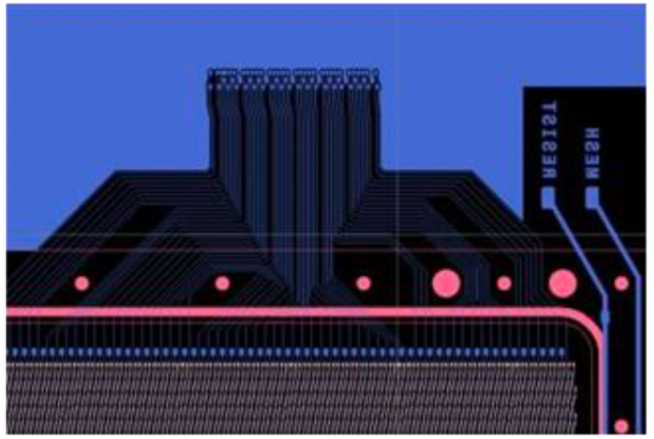
X-coordinate R/O plane

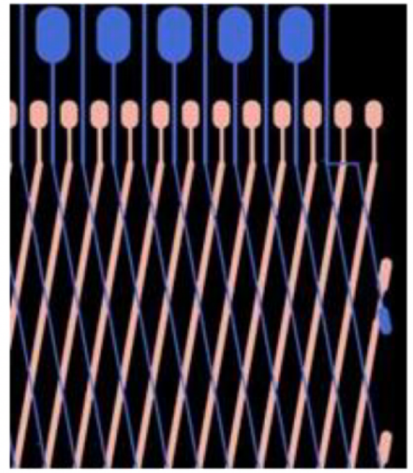




UV-coordinate R/O plane

- 1280 strips
- 1mm pitch
- 250 um U strips width
- 150 um V strips width
- 10 FEBs: 1280 fe channels





Lateral module prototype production

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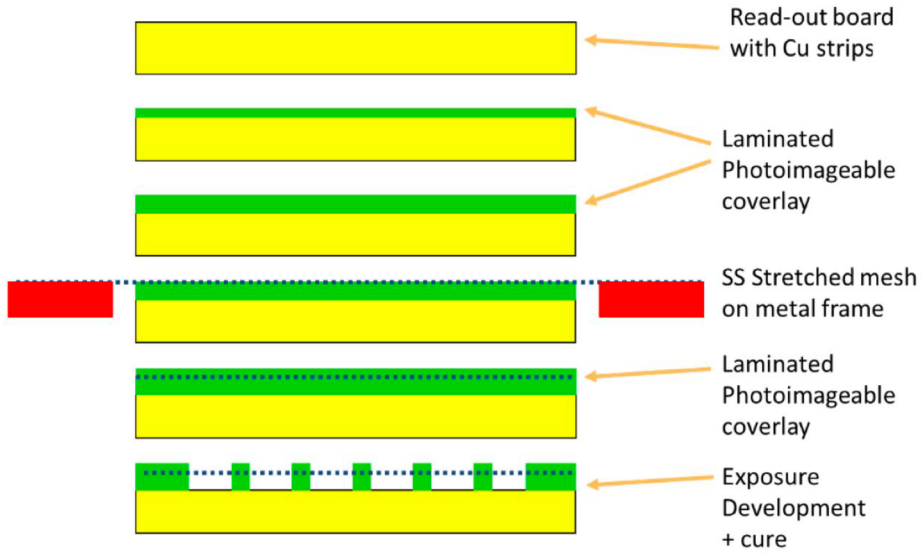
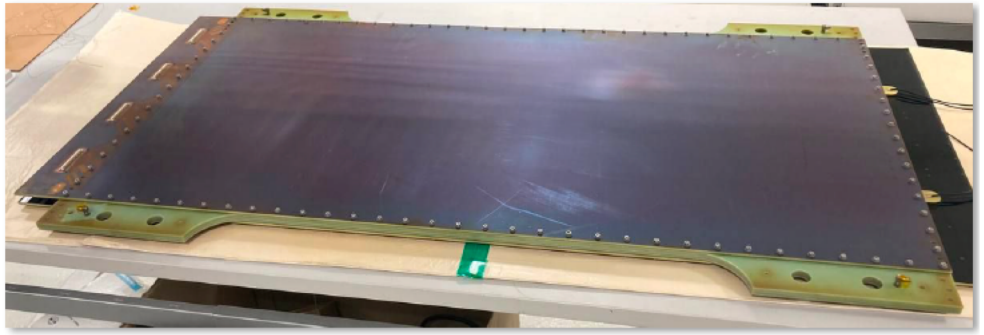


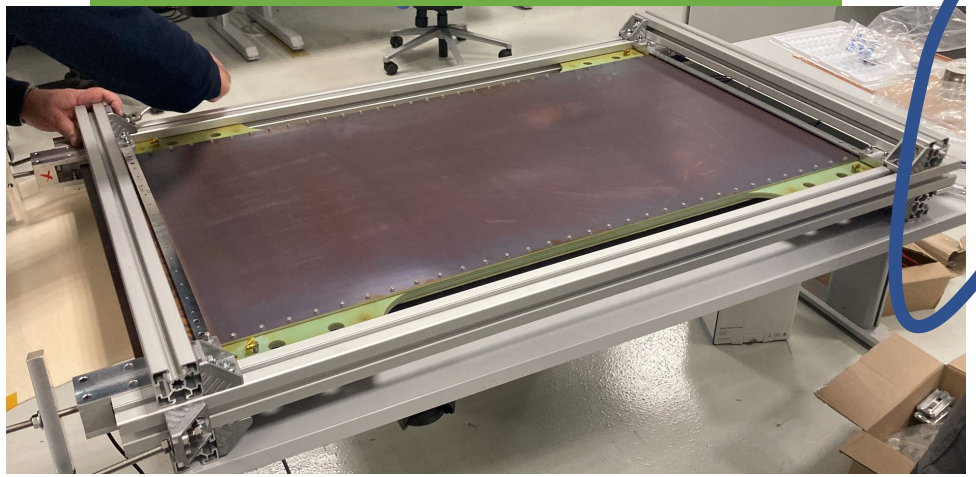
Manifacturing techniques – RD51 school lecture by Rui De Oliveira



Lateral module prototype testing

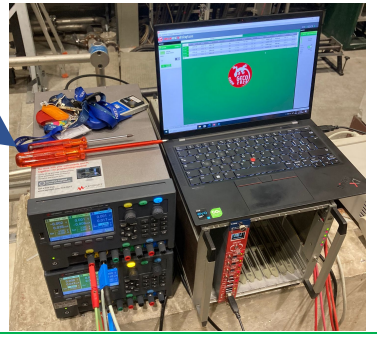
Delivered on 11.10.24

Mechanics for transport and suspension on 11.10.24



Prototype installation 12.10.24

HV stability verified by MPT workshop experts 17.10.24



- 450V resistive layers
- 325V cathodes planes
- resistive UV ~5nA
- resistive X ~7nA
- drift UV ~1,5nA
- drift X ~3nA

Thanks to MPT and GDD labs colleagues

MM prototype 2024 test beam FEE

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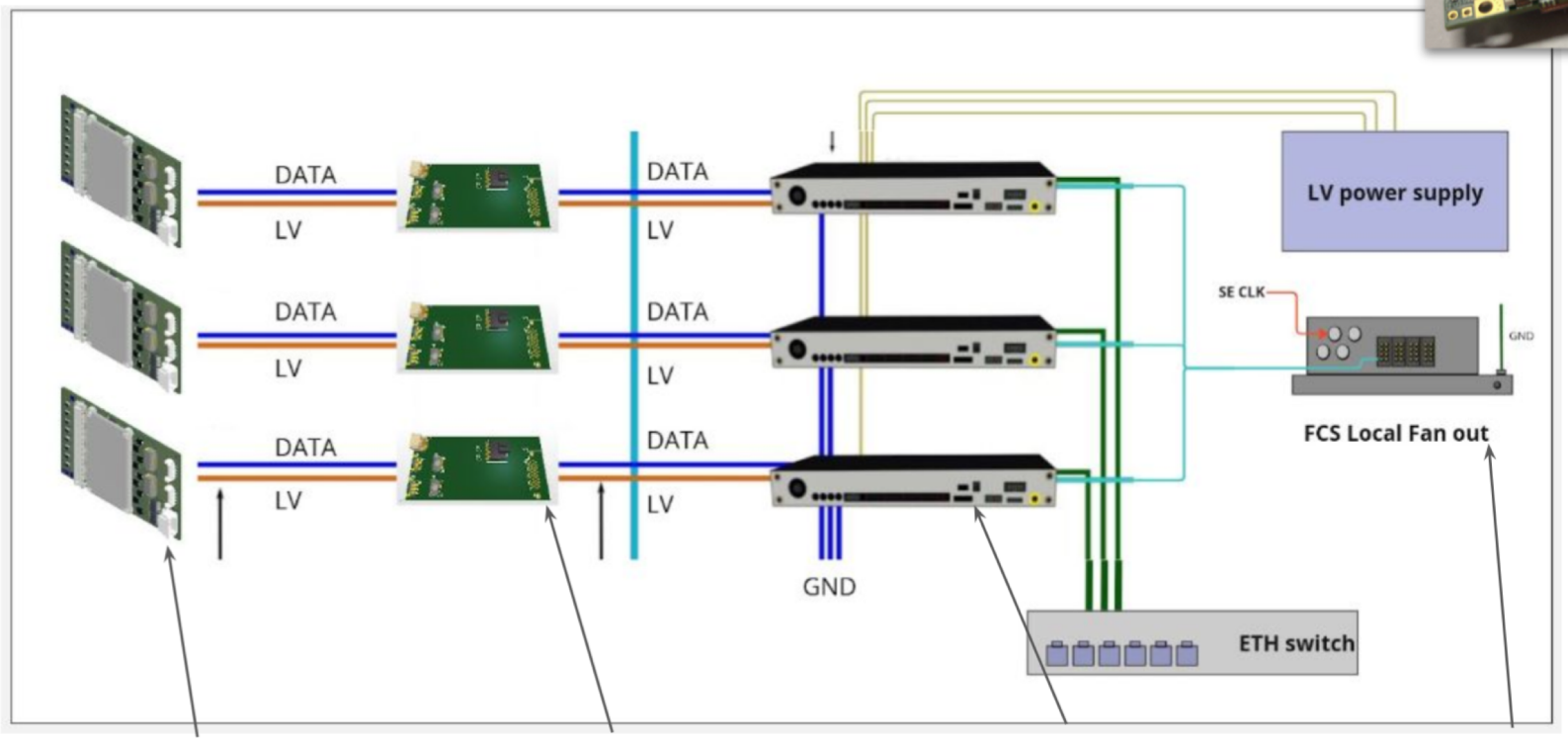
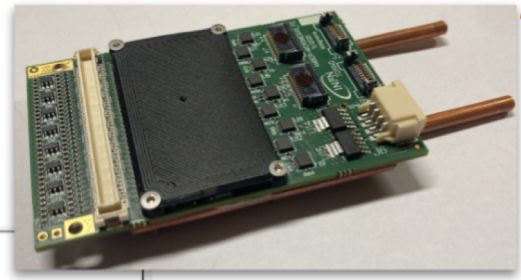
AMBER TIGER-based readout chain:





6 TIGER-febs available:

- 768/1280 UV
- 512/512 X+ 256/1280 UV connected (from shorter strips)

AMBER-micromegas_FE
designed at INFN To

TIGER-based front-end board

Data and Low Voltage Patch Card - DLVPC
designed at JINR

adapter for data and LV

GEMROC modules
designed at INFN Fe

Configuration and control signal distribution
Data concentration

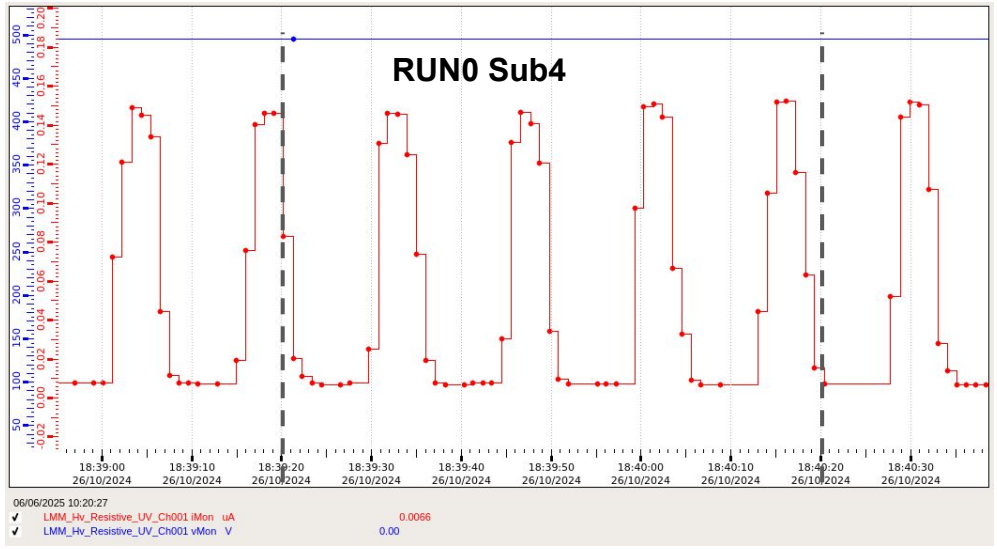
Local FAN OUT
designed at INFN Fe

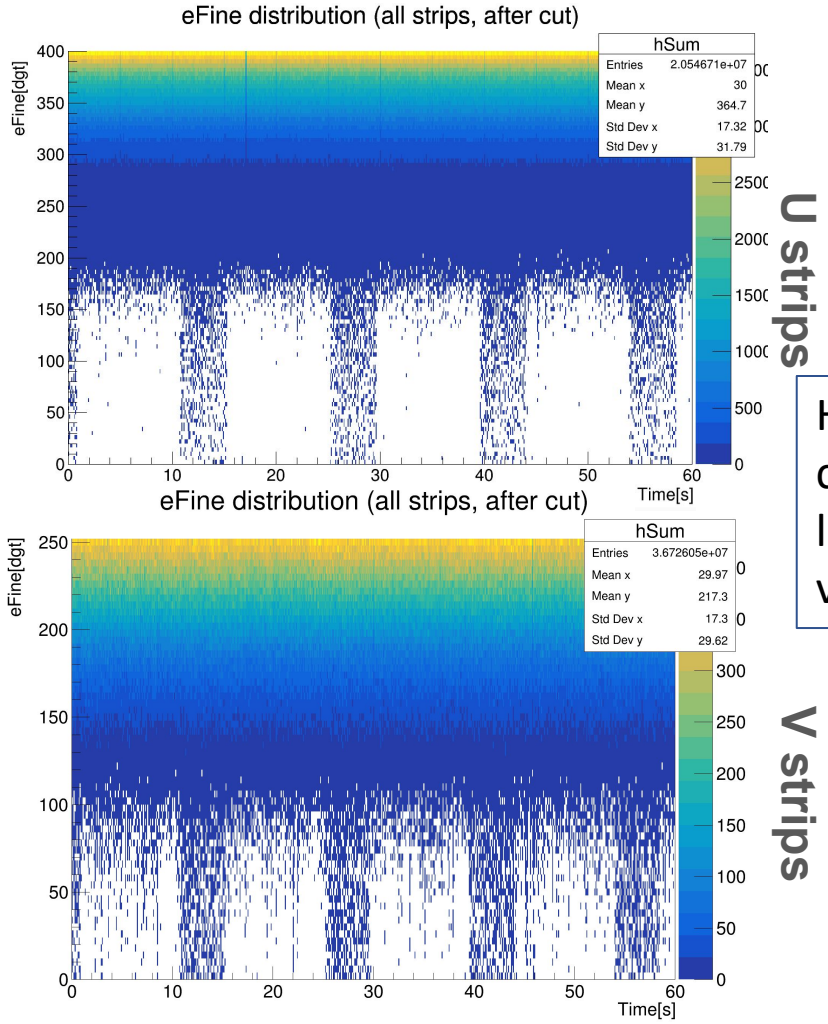
Trigger and clock distribution

Analysis tools: charge distribution

	HV set	450V	475V	480V	490V	493V	495V
GAS mixture	Ar-CO2 93/7	RUN0 Sub0	RUN 0 Sub1	RUN0 Sub2	RUN0 Sub3	RUN1 Sub0	**RUN0 Sub4**
	Ar-CO2-iC 4H10 93/5/2		RUN4 Sub0	RUN5 Sub0	RUN2 Sub0	RUN3 Sub0	

Cumulative distribution of eFine values registered on UV strips during the data acquisition time.





Higher charge correspond to lower eFine values.

Analysis tools: charge distribution

	HV set	450V	475V	480V	490V	493V	495V
GAS mixture	Ar-CO2 93/7	RUN0 Sub0	RUN 0 Sub1	RUN0 Sub2	RUN0 Sub3	RUN1 Sub0	**RUN0 Sub4**
	Ar-CO2-iC 4H10 93/5/2		RUN4 Sub0	RUN5 Sub0	RUN2 Sub0	RUN3 Sub0	

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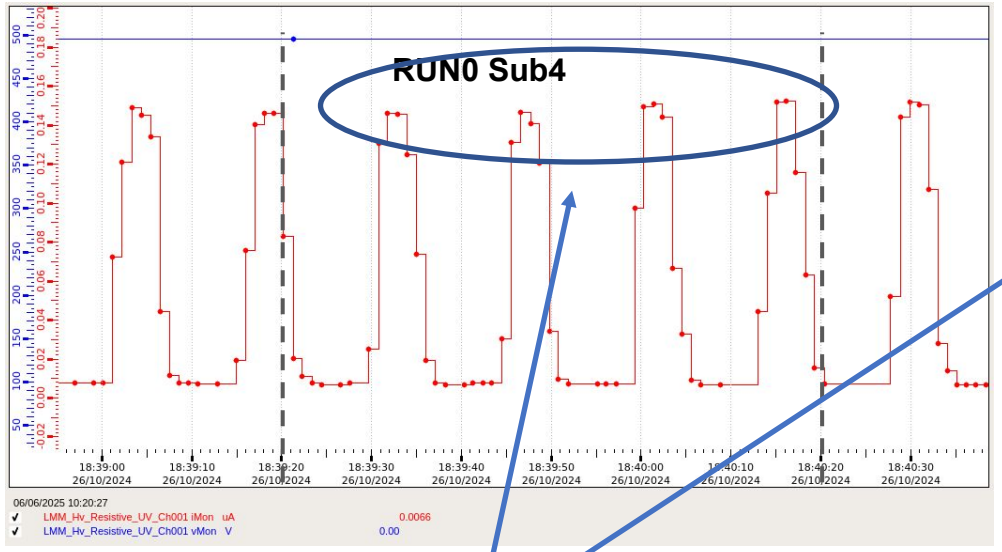
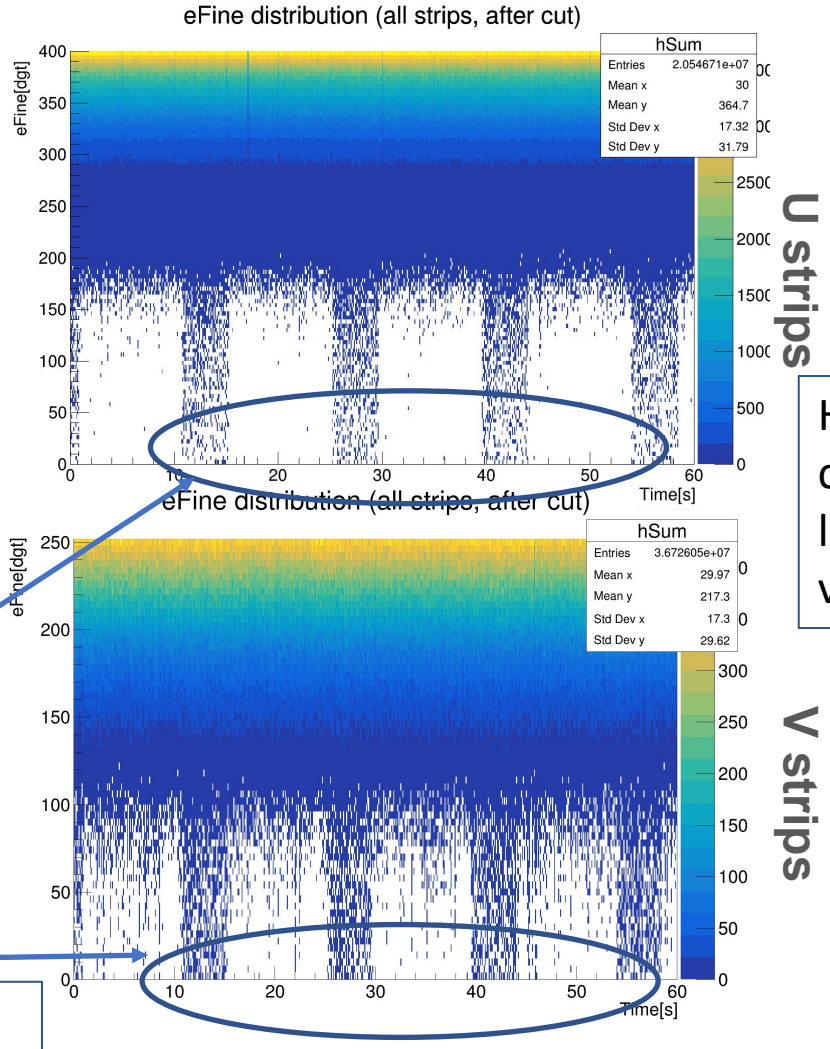


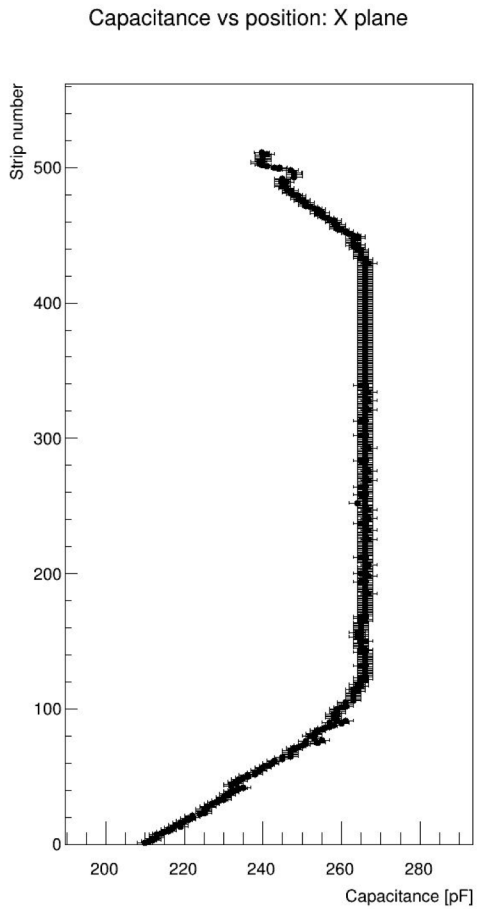


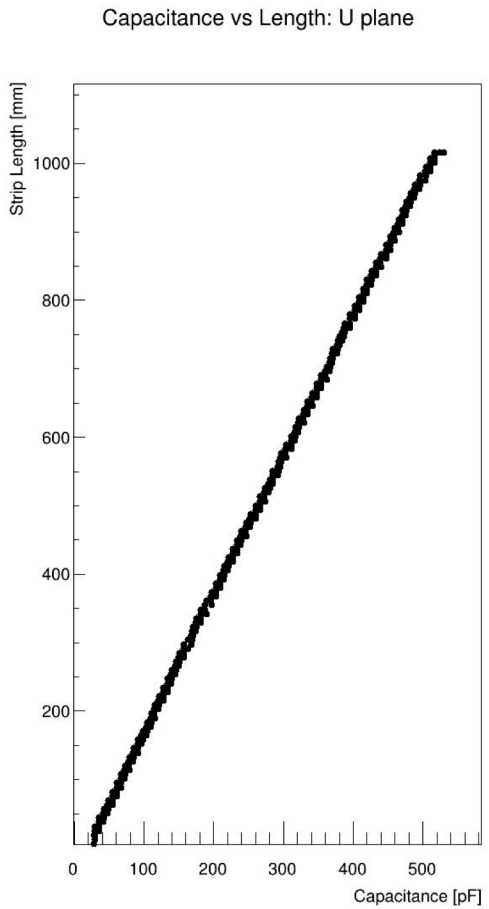
Higher charge correspond to lower eFine values.

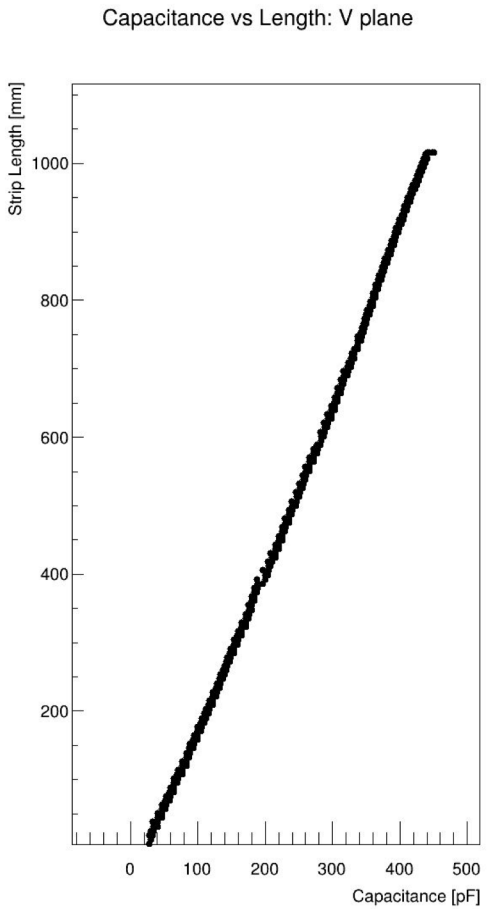
The spill structure is visible in both planes at the same time in which is visible in the current drawn by the resistive electrodes

Strips capacitance measured in Torino

- X strip range: 210-250 pF
- U strip range: 30-530 pF
- V strip range: 28-450 pF







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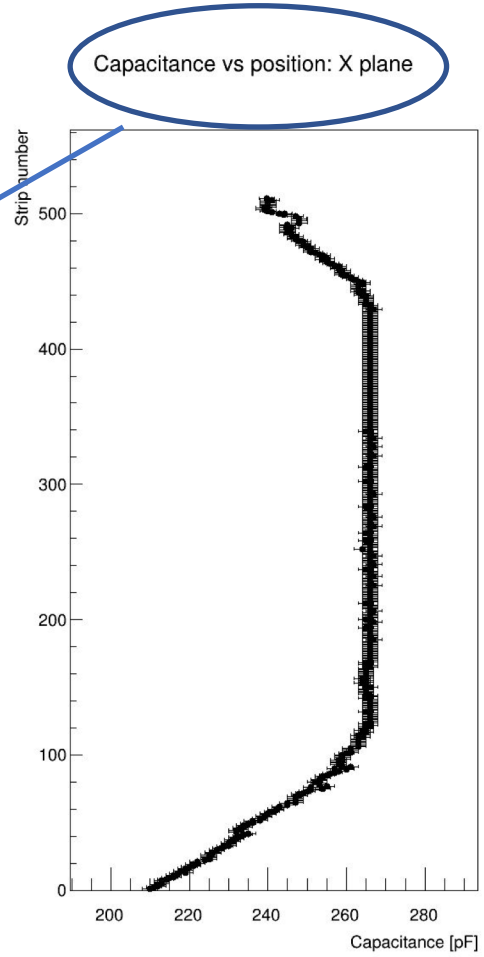

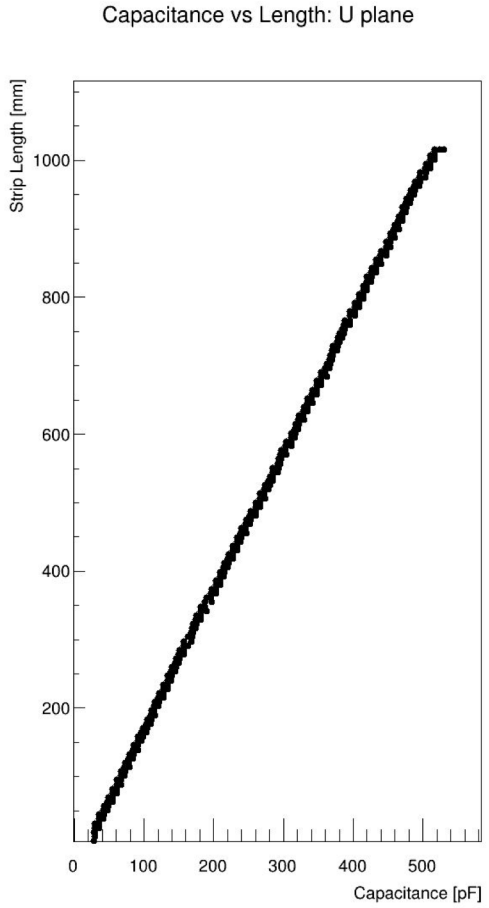

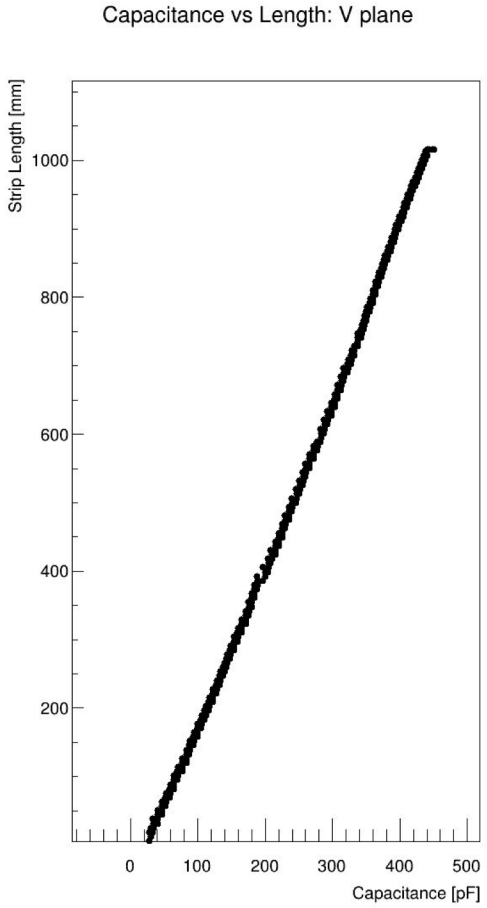

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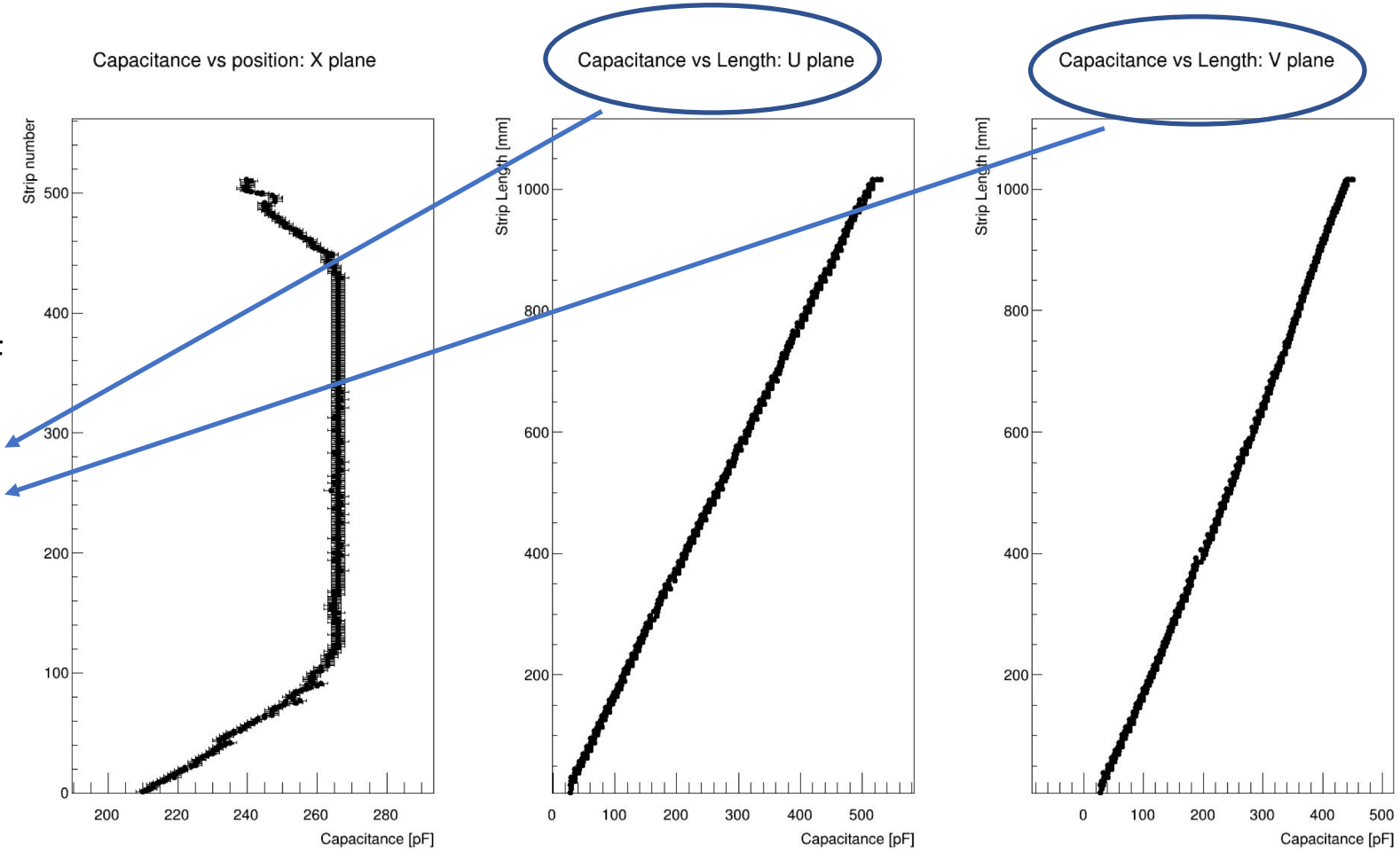
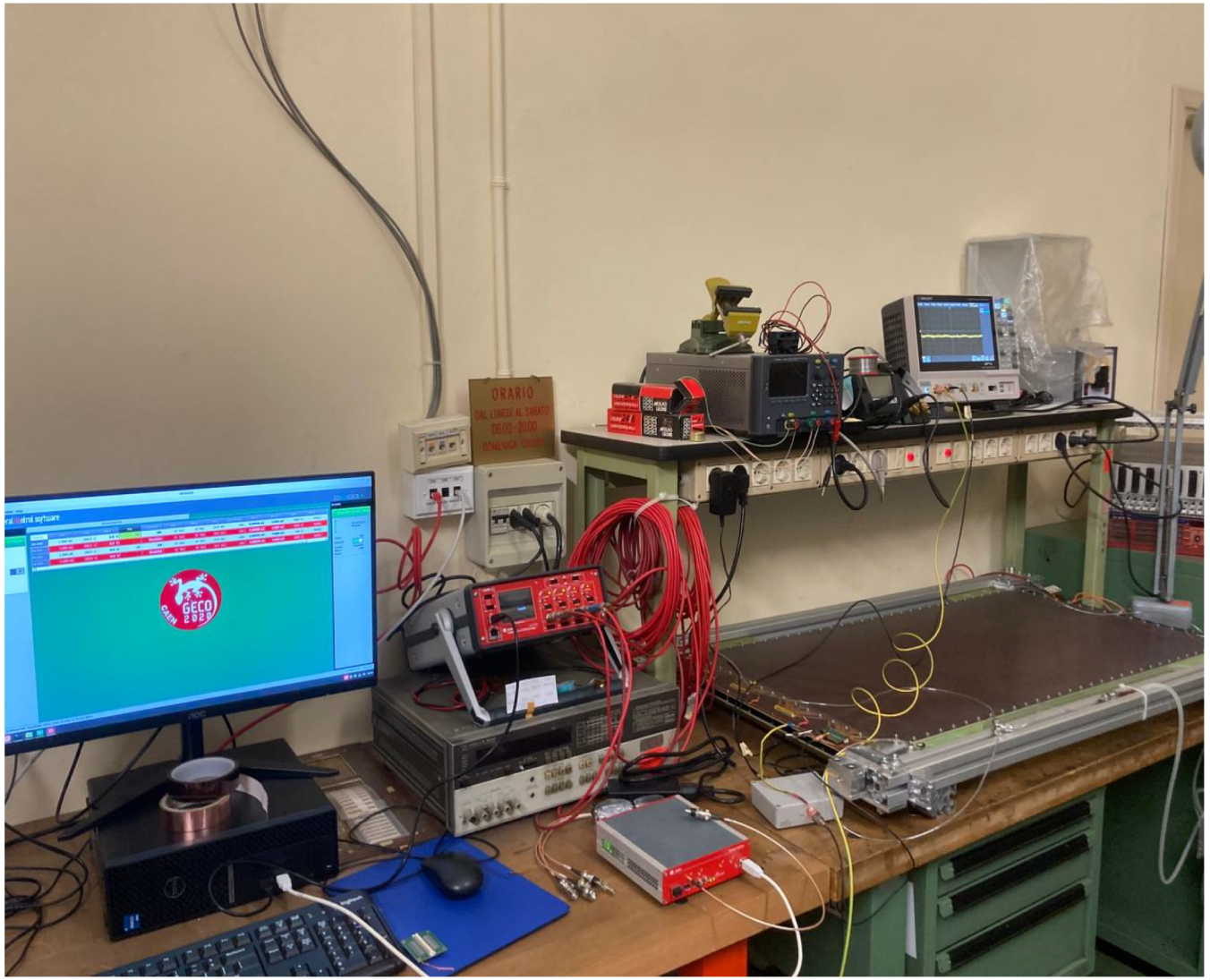


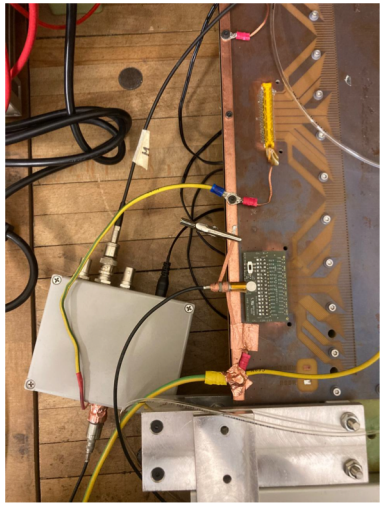
Test setup



HV PS: CAEN DT1471HET

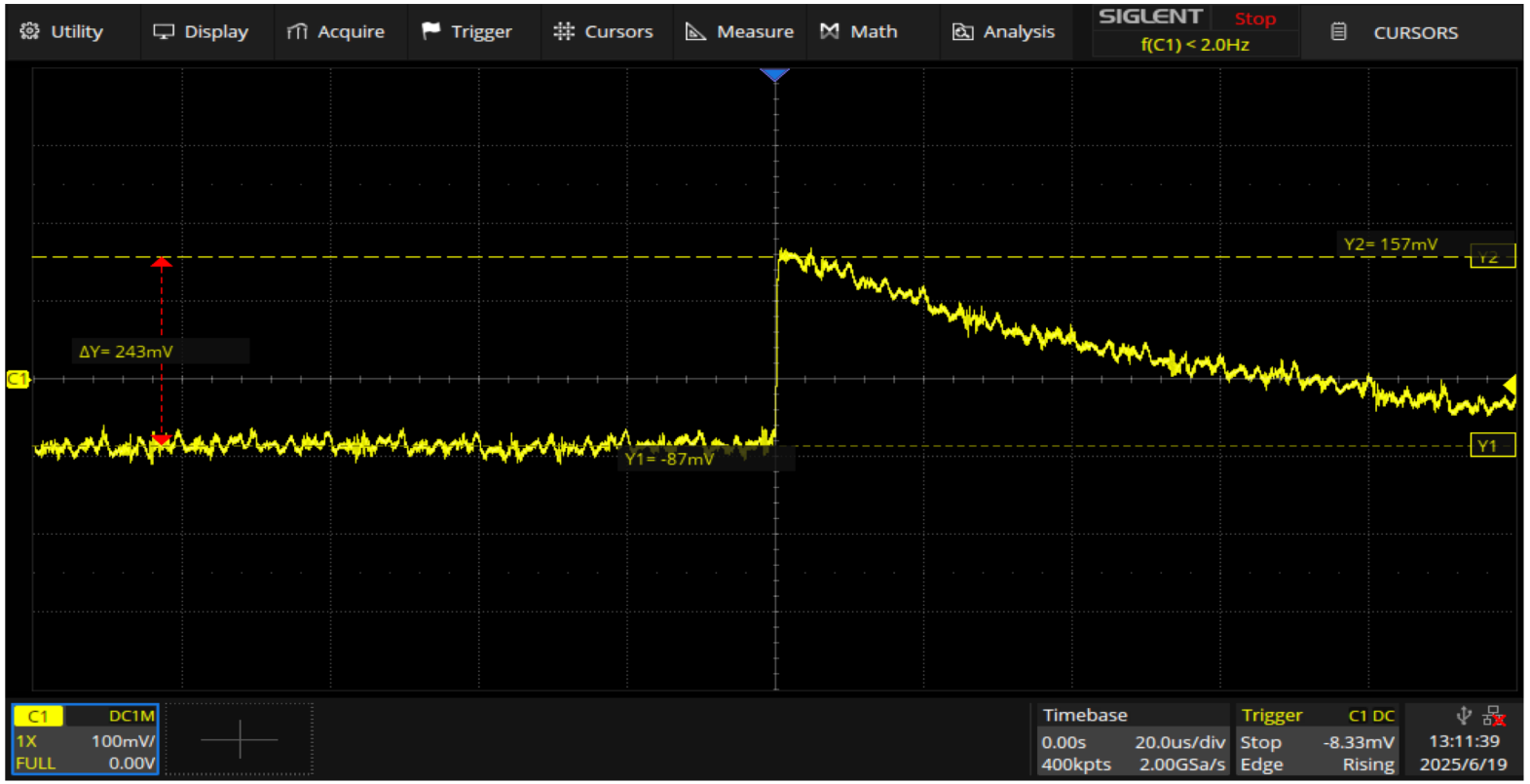
Amplifier: Cremat CR-110

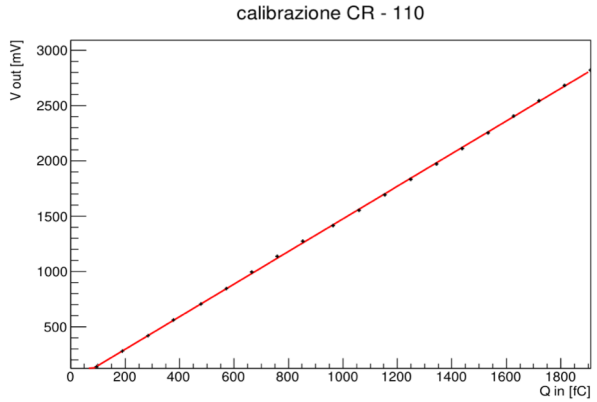
Scope: Siglent



Test with cosmic

First cosmics signals with CREMAT CSA:



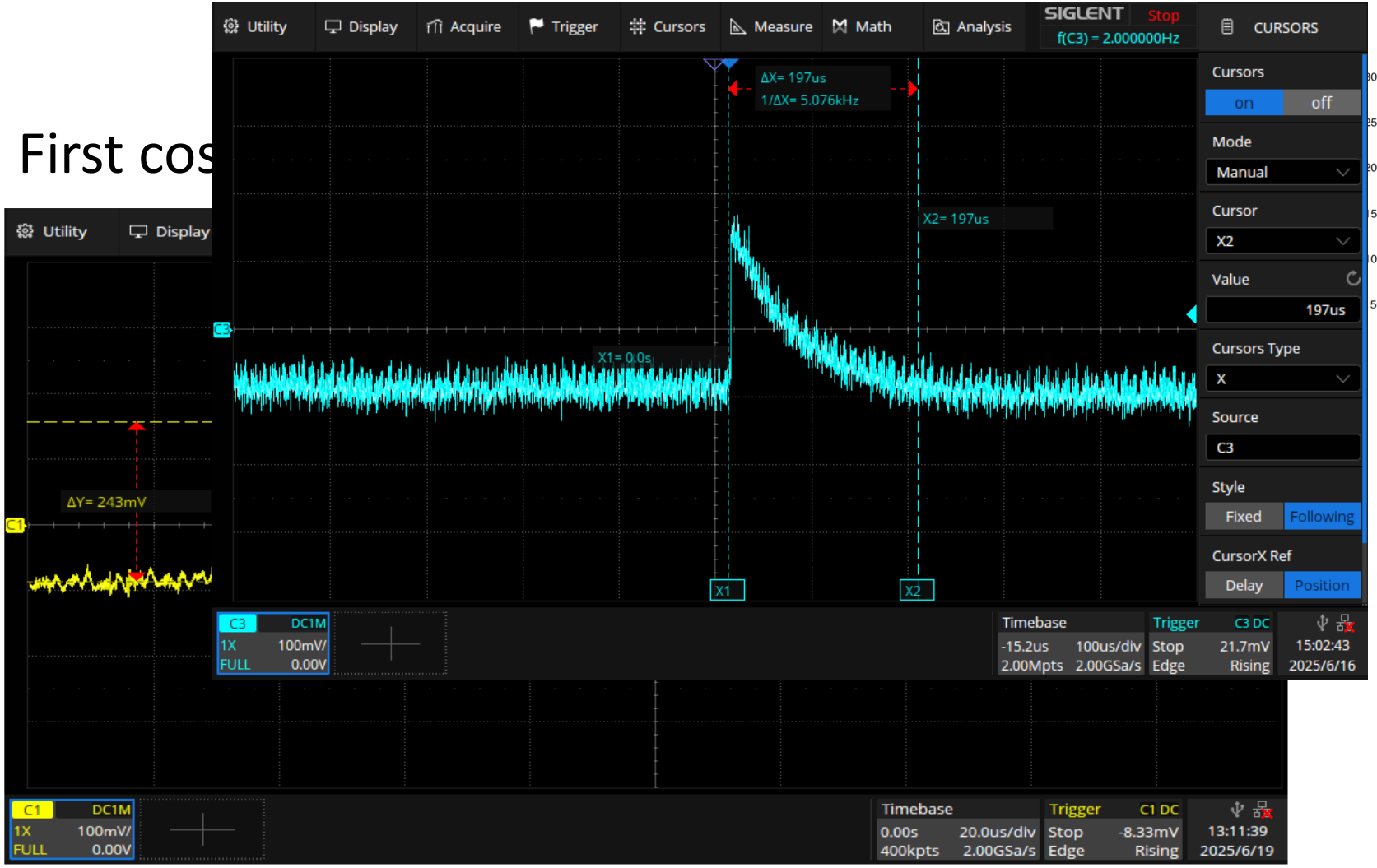


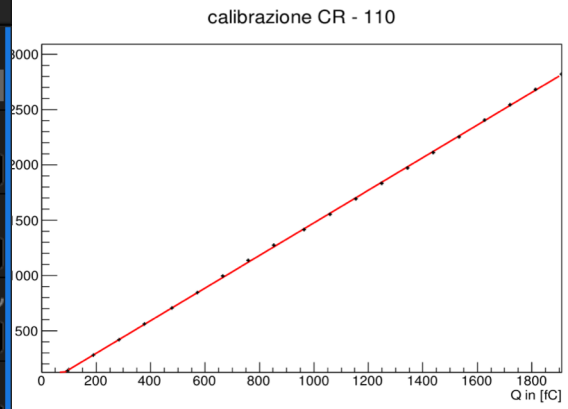
CSA gain is (1.4743 ± 0.0009) mV/fC

Peak height depeds on the detector volume crossed

Test with cosmic

First cos





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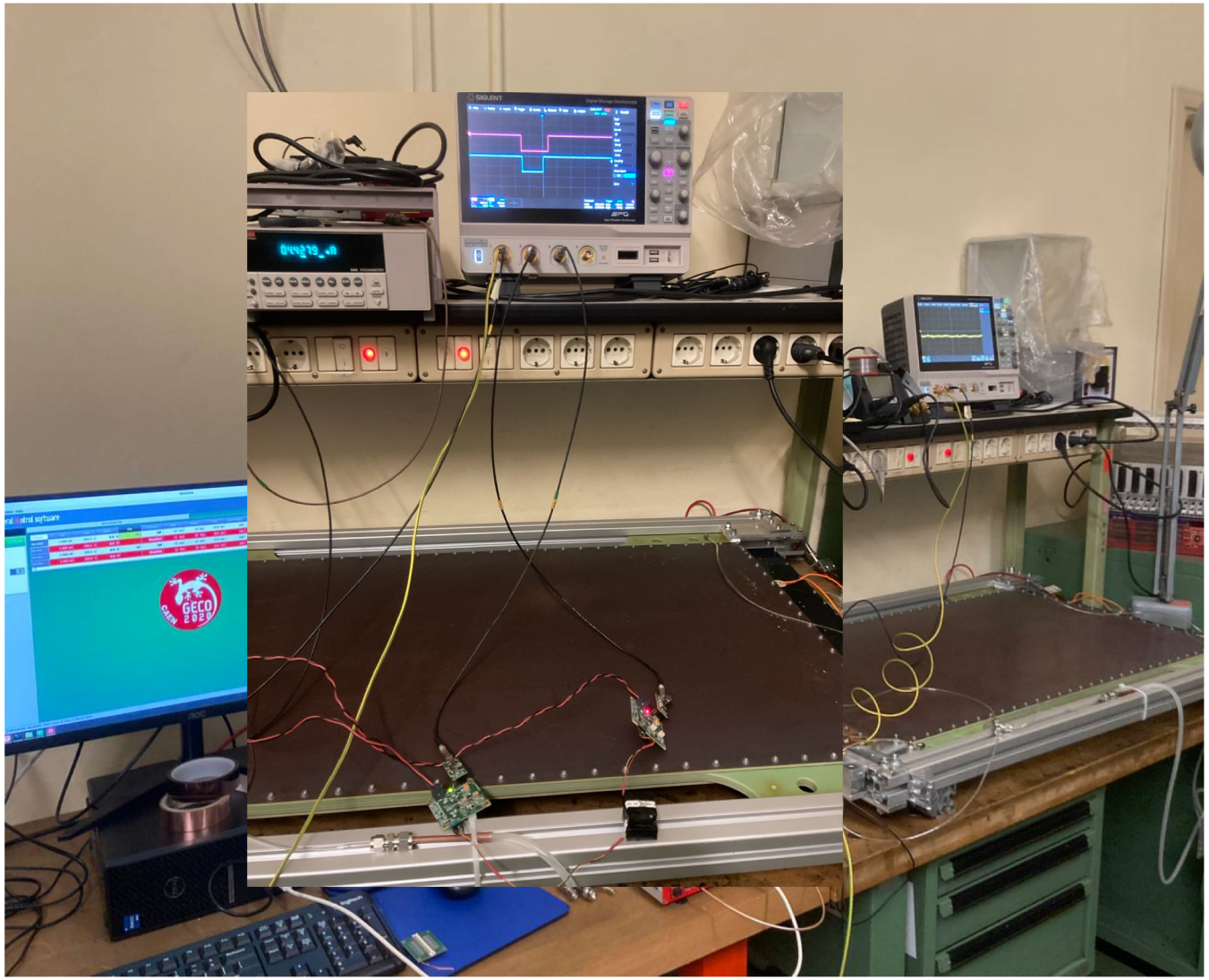
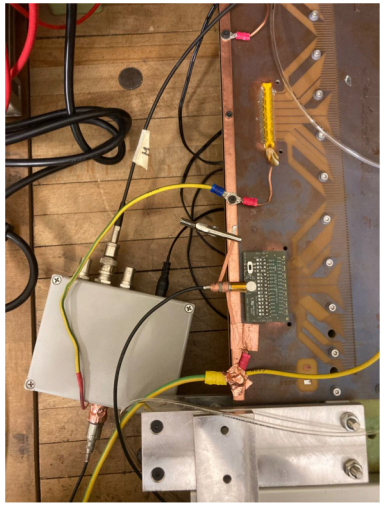
Test setup – next step – efficiency study



Cosmics rate measurement with scintillators 3x3cm^2



Test with source

Gain measurements with:

V Am241 → main peak at 60keV
V cs137 → second peak at 600keV

Front-end electronics: ToRA-based FEE (Torino Readout (for) AMBER)

2 step design plans

v1(2025-2026)

- Base version aimed at MM (GEM) & STRAW/MWPCs
- Would be sufficient for the AMBER environment
- 4 Gains
- 4 shaping times
- Trigger less
- 1 or 2 revisions depending on performance & testing

Submitted 05.25

v2 (2026-2028)

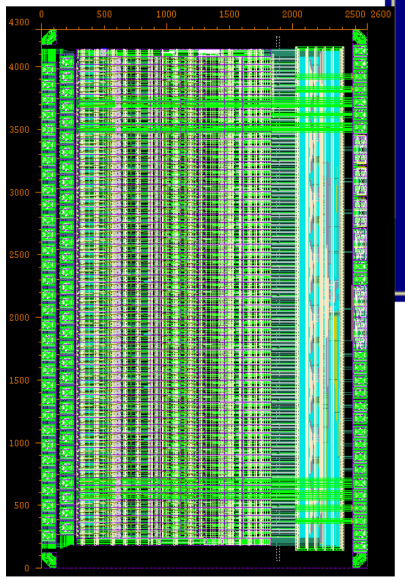
- Actions on the inter-channel analog architecture
- Minor tuning of the channels & Backend

We have a pipeline for 2 submissions… depending on the v1_a performance

Torino Readout (for) AMBER ASIC

- MPGD and Wire detectors compatible
- Target specific application
- Limited complexity
- Reuse existing solutions (ToASt)
- 65nm
- Two step features design v1, v2
- Final 4300x2600 µm

Detector	MM	Straw	
Channels/ASIC	64	64	
Power/channel	≤ **25**	≤10	mW
Input capacitance	≤550	20-100	pF
Input charge	1-100	1-1000	fC
Input impedance	≤50 Ω	*tbd*	Ω
Max rate	≤ **0.5**	≤0.18	MHz
Peaking time	**150-500**	**25-150**	ns
Time resolution	1-2	≤1	ns
Charge resolution	8	10	bits
Gain	**10-20**	2	mV/fC
Clock frequency	200	200	MHz



Lateral module prototype testing
Past and Future operations

2024

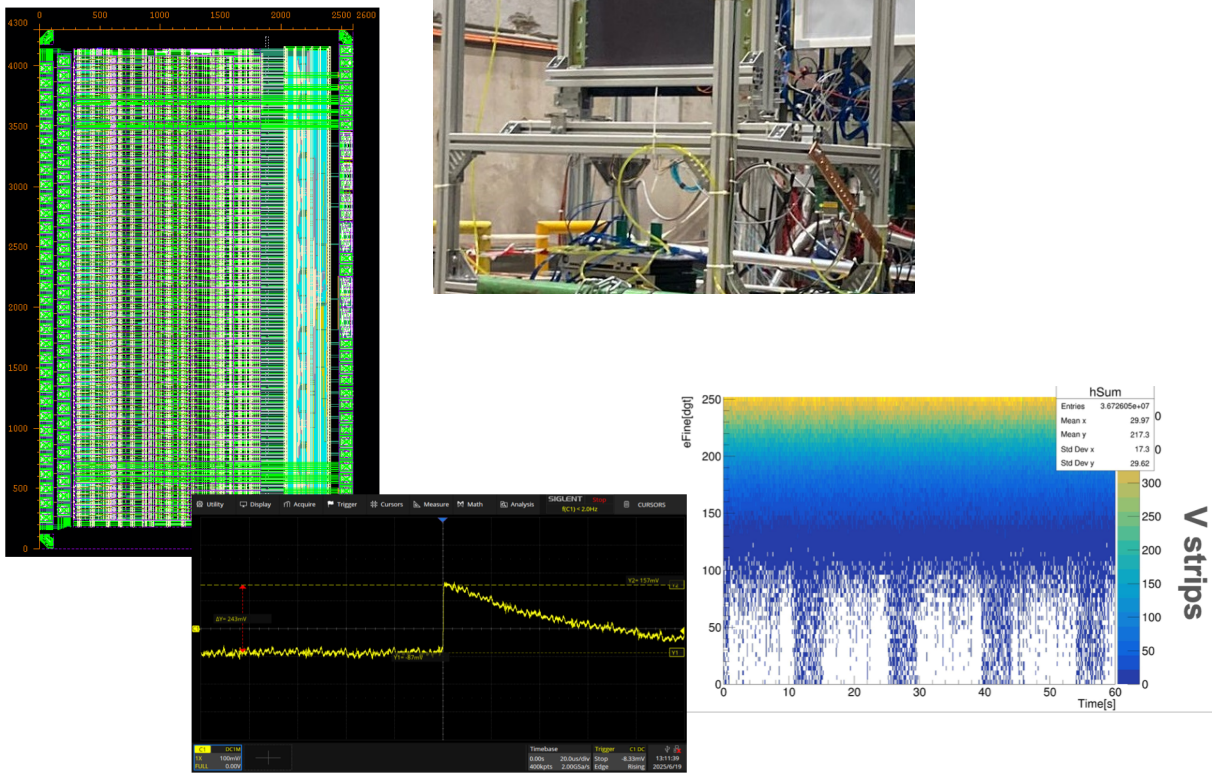
- High Voltage stability
- Noise performance & shielding optimisation
- First data (beam)
- Compare $ArCO_2$ (93/7) and $ArCO_2$Iso(93/5/2)

2025

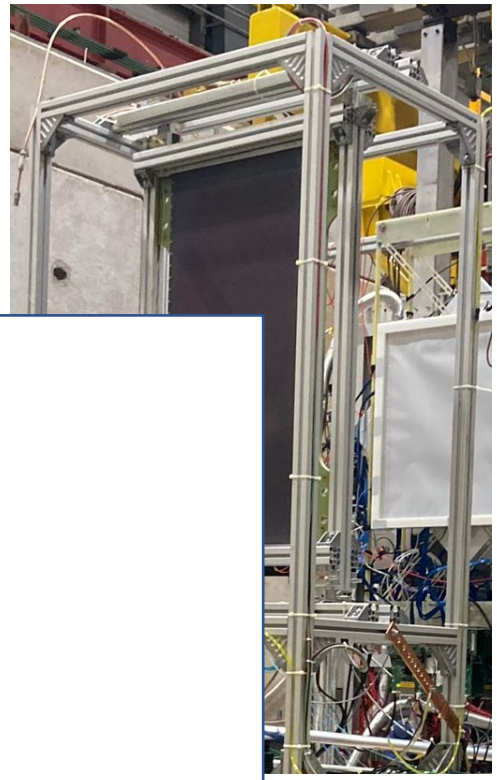
- Test with sources
- We will have our parasitic setup in the AMBER spectrometer for the whole beam period (Sept-Nov)
- We need to achieve a stable operation/understand the problems before starting the layout of the Central module
- First test with the ToRA ASIC

Conclusions

- First successful powering achieved
- Detector prototype is under test
- ToRA v1 ASIC design is optimised on the base of first detector tests and submitted
- Signal propagation studies to optimize detector and frontend design is ongoing



Conclusions



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Thank you

Merci