Performance of the discrete element Bulk MicroMegas of the COMPASS RICH-1 and the R&D for the EIC project

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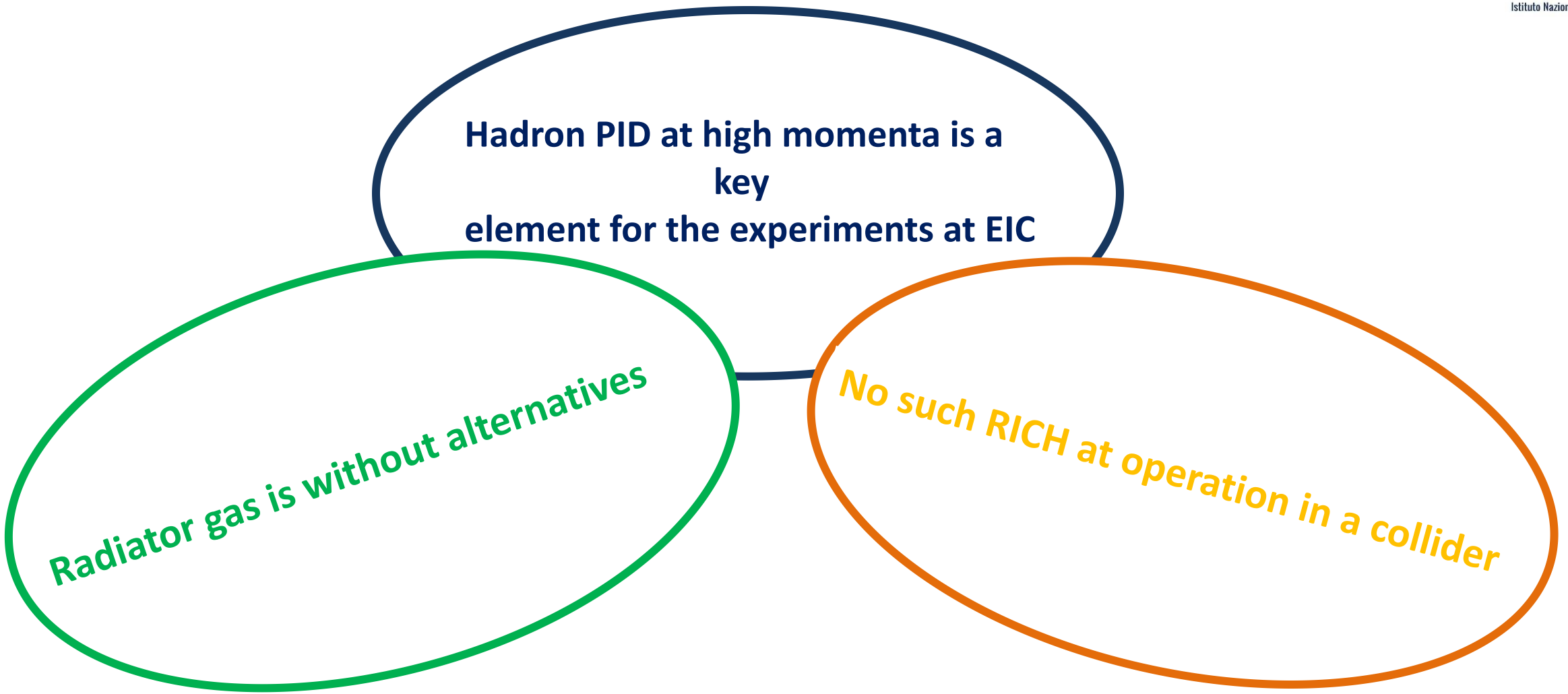
on behalf of the Trieste RICH-1 upgrade group

Hadron PID at high momenta is a key element for the experiments at EIC

Radiator gas is without alternatives

No such RICH at operation in a collider



The Challenge we are attacking

Outlook:

- The photo-detector upgrade of the COMPASS RICH-1: the motivation, our starting point *from witch we capitalize*
- The photon detector architecture: an overview
- The bulk MicroMegas
  - Production technology
  - The signal readout choice
  - Characterization
  - MM Performance
- Ongoing R&D activity for the EIC

The upgrade motivation

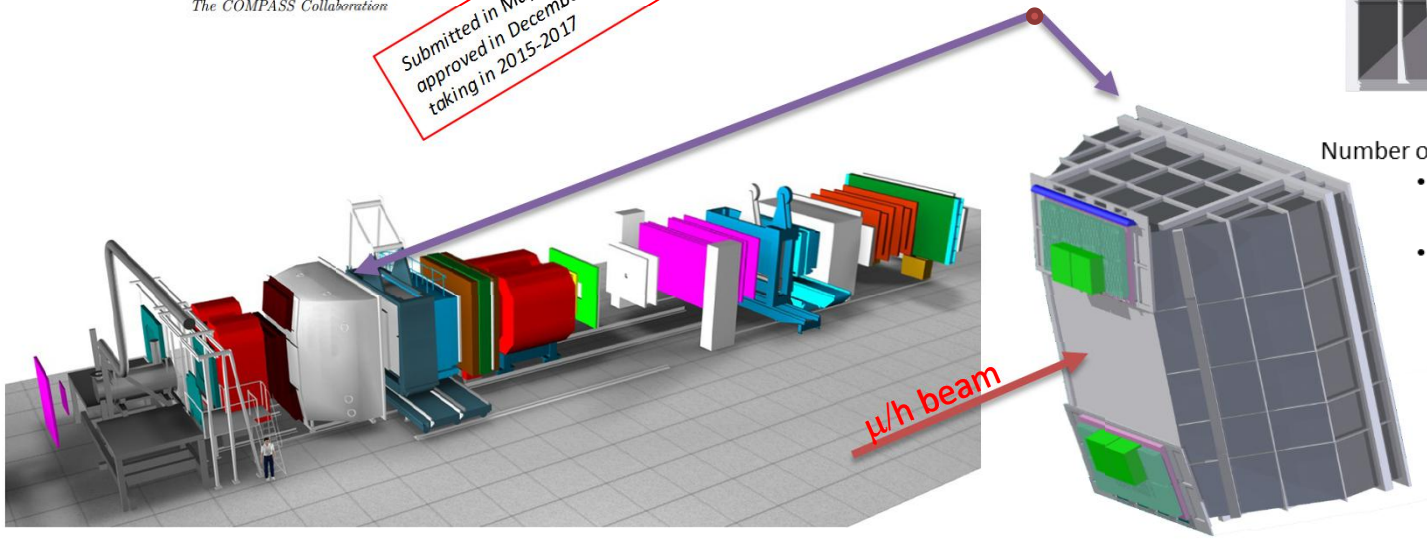
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN–SPSC–2010–014
SPSC-P-340
May 17, 2010

COMPASS-II Proposal

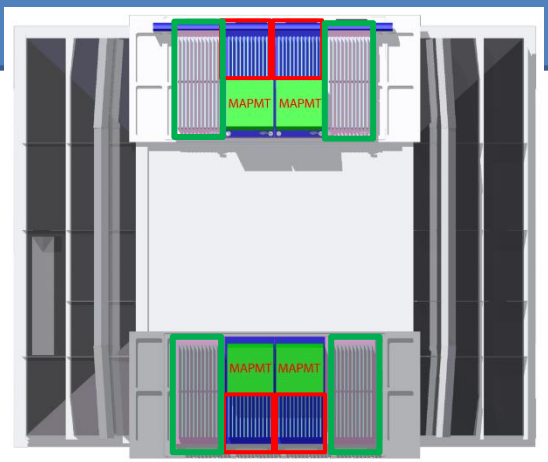
The COMPASS Collaboration

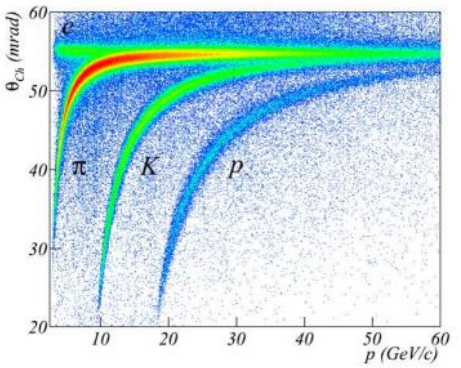
Submitted in May 2010 for 5 yeas data taking (2020)
approved in December 2010 for initially 3 years of data taking in 2015-2017



COMPASS RICH-1

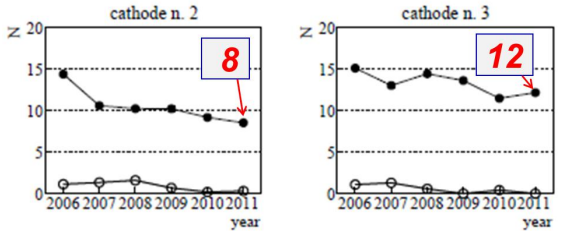
Already upgraded in **2006** with **MAPMT** in the most inner central region



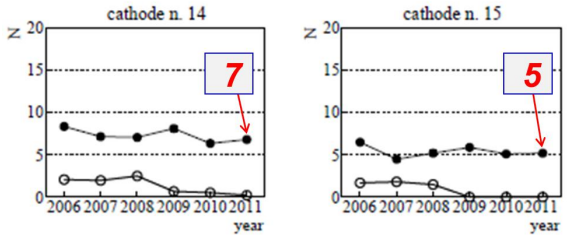


Number of photons for central 60x60 cm ^{2}MWPC:

- On average lower than the other PC $\langle N_{ph} \rangle = 13$
- Slow decreasing trend $\langle N_{ph} \rangle$ vs year



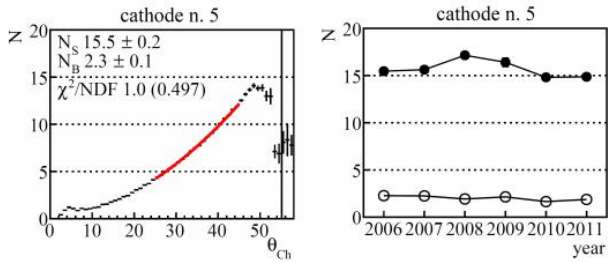
Central Cathodes



- ✓ **Generalized parton distribution (GPD)**
- ✓ **Flavour separation and fragmentation in SIDIS**
- ✓ **Transverse momentum dependent distributions (TMD)**
- ✓ **QCD at very low momentum transfers**

Improved / challenging performance for the COMPASS spectrometer detectors

- **In our case a *"improved PID performance"***
  - ***Faster and higher gain***



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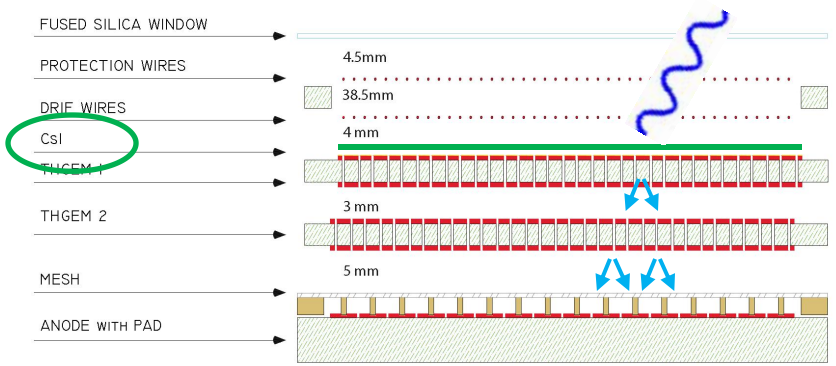
The Hybrid detector concept and the building blocks: the THGEM the Bulk MicroMegas and the FE

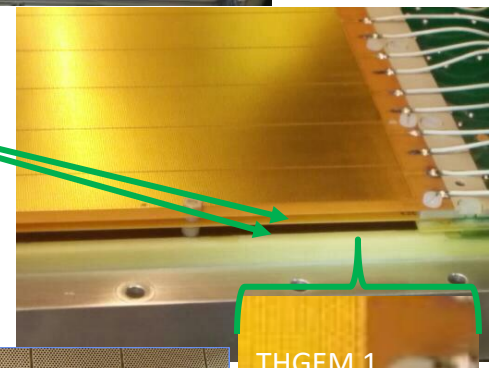


IBF reduction: approx. 3%
Charge splitting processes → Larger Gas Gain

Hybrid detector concept

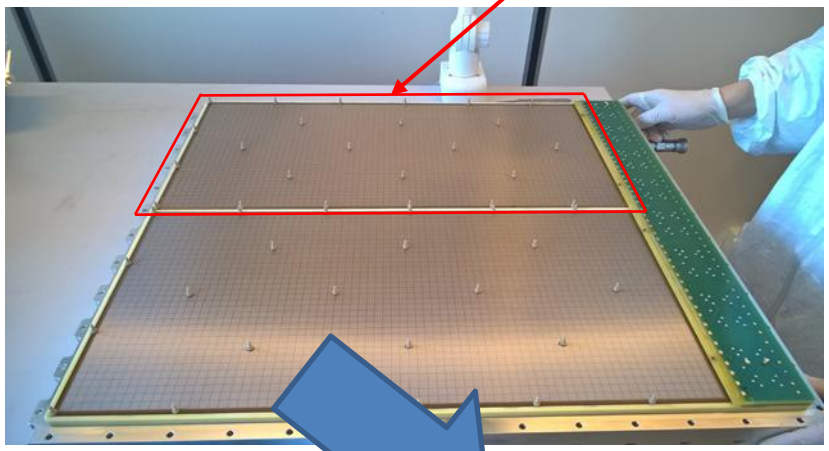
To simplify the construction requirements a modular architecture has been adopted where one "*module*" consists of:

- **One 300 mm x 600 mm Bulk Micromegas detector**
- **Two layers of THGEMs (300 mm x 600 mm) in *staggered* configuration**

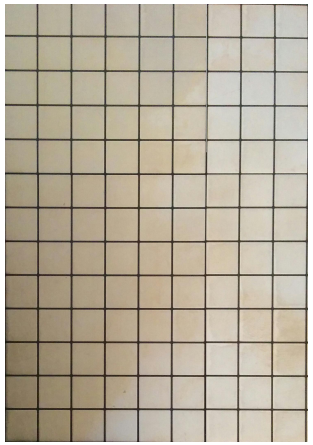


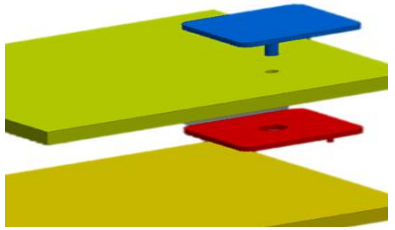
Operational gas mixture : Ar/CH_4 50/50

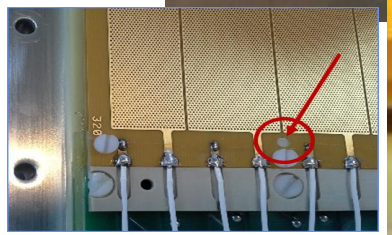
Two modules are put side by side to build a 600 mm x 600 mm detector

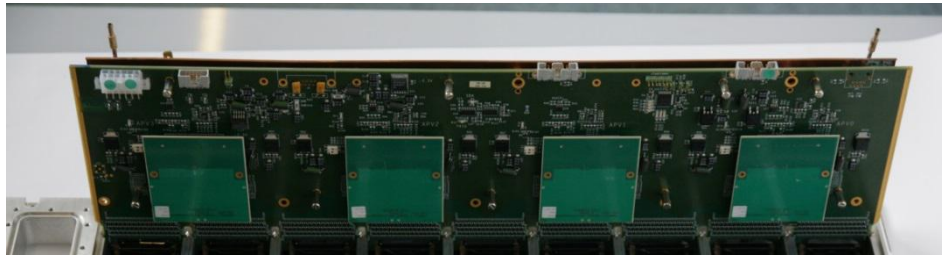


Signal read out via capacitive coupling pad readout and APV25 F/E boards









The main topic of this talk

8mmx8mm pad size
0.5 mm pad spacing

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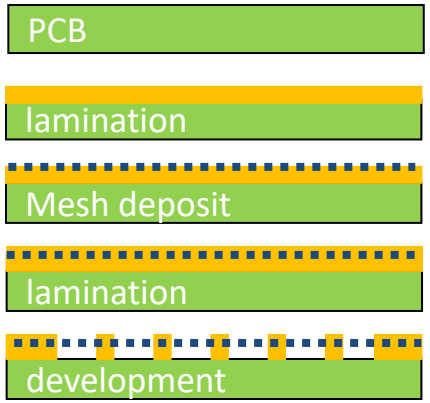
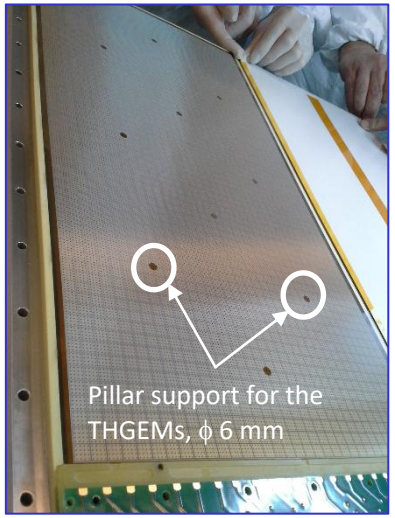
BULK Technology

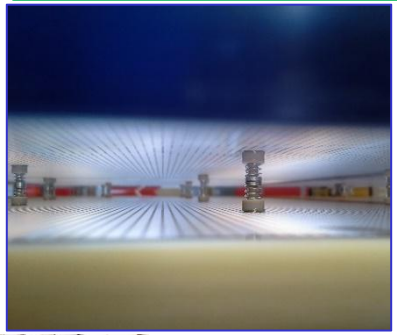
DUPONT PC 1025 coverlay
BOPP Meshes
SERITEC stretching

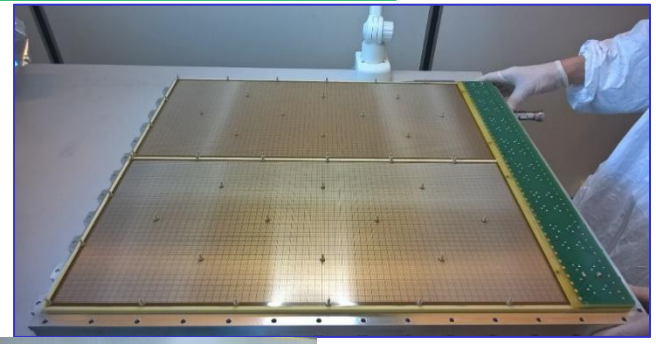


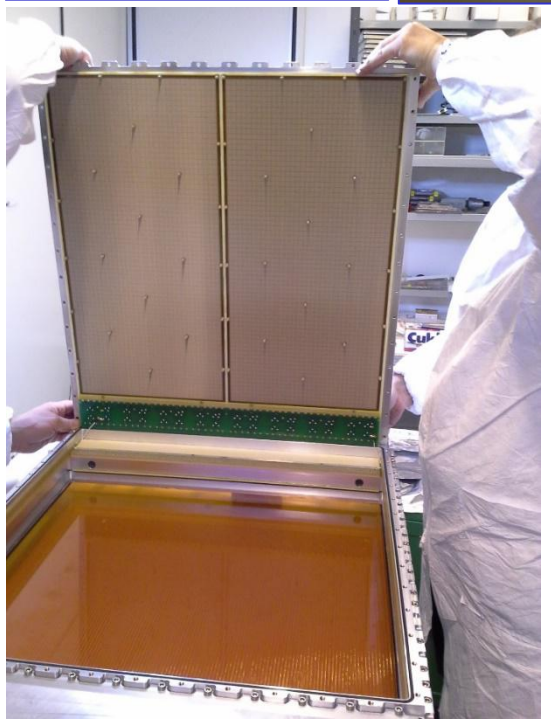
2 x 64 μm layer coverlay

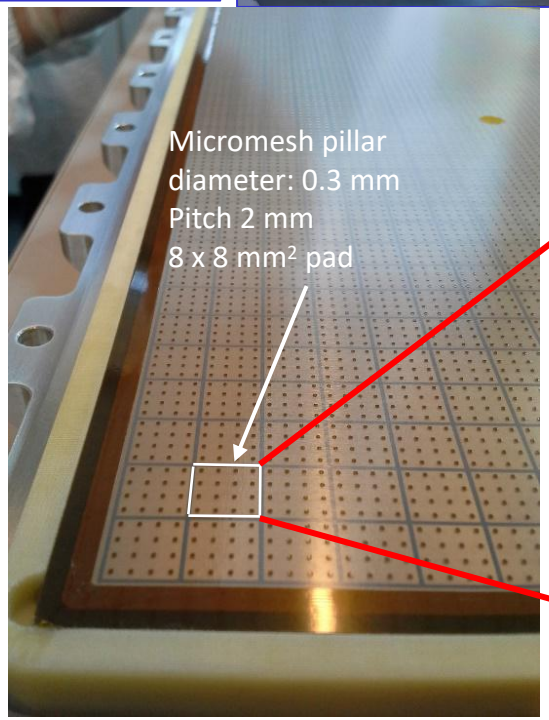


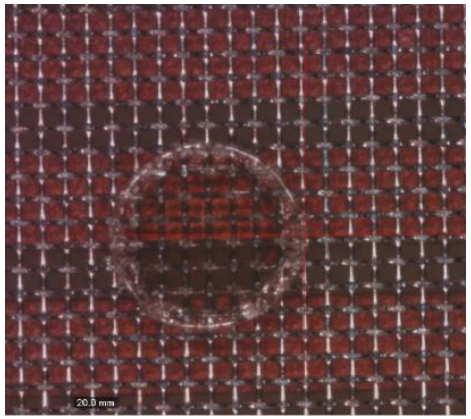
Bulk Micromegas (CERN) active area: 581 mm x 287 mm
- 128 μm mesh pad distance
- 18μm woven wires 45 μm pitch
- pad segmented (8x8 mm²) 2380 pads/module

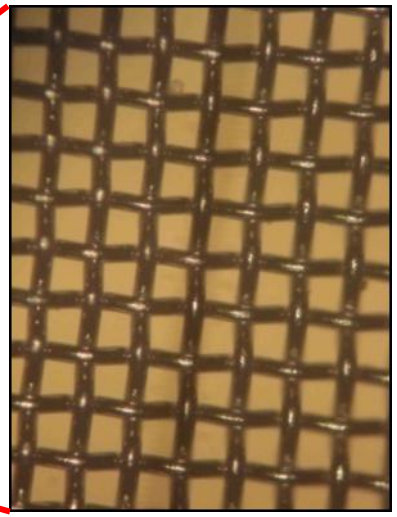






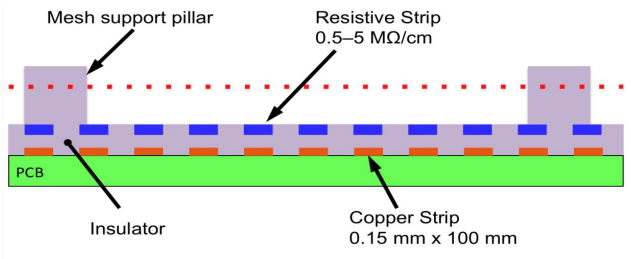


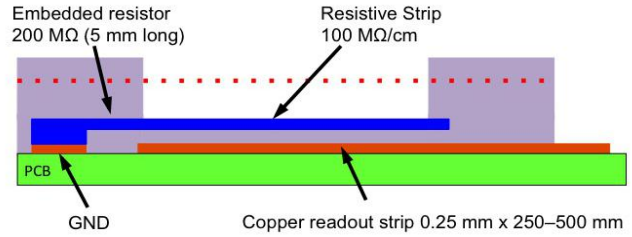


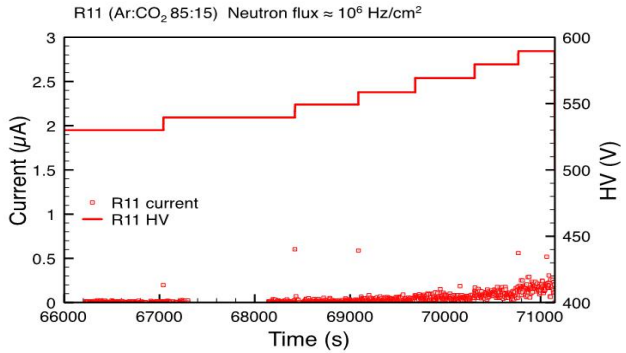


The discrete element approach: a different choice than ATLAS MAMMA project

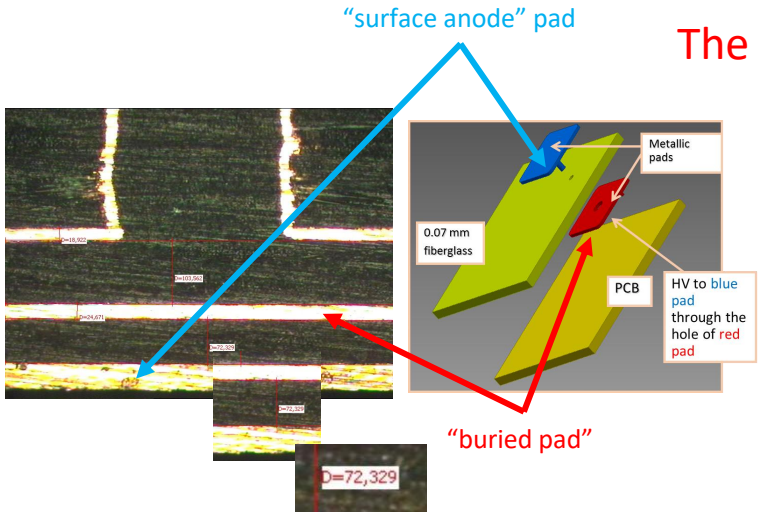
The ATLAS MAMMA approach:
NOT our choice: resistive layer deposit technology readiness not mature when the RICH-1 upgrade decisions was taken (2015)







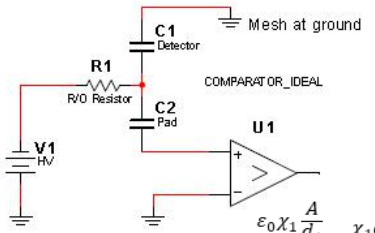
The COMPASS RICH-1 approach



1 Single pad scheme:

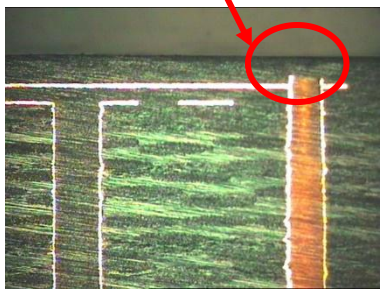
Blue pad at HV via individual pad resistor at the PCB rear surface

Red pad: signal induced by RC coupling

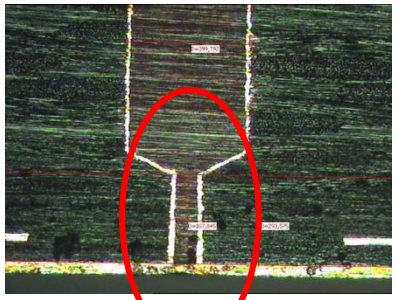


$$\delta = \frac{\varepsilon_0 \chi_1 \frac{A}{d_1}}{\varepsilon_0 \chi_2 \frac{A}{d_2}} = \frac{\chi_1 d_2}{\chi_2 d_1} \sim 8\%$$

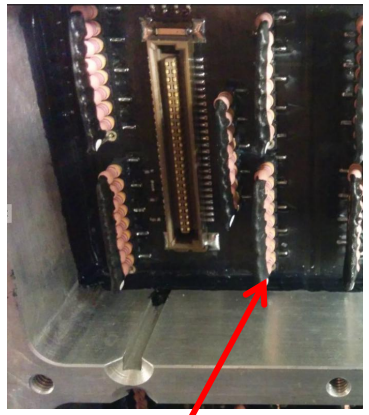
"Via closure" → leakage issue



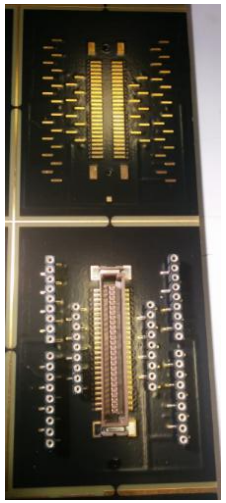
MMesh at Ground
Pads HV segmentation



"Z drilling controlled via" → planarity issue

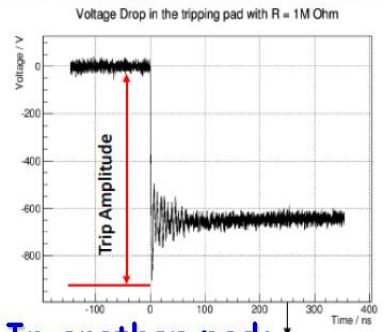


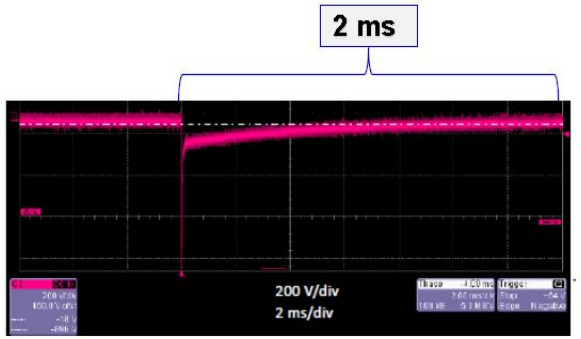
Resistor arrays
Connector 8+1 pin



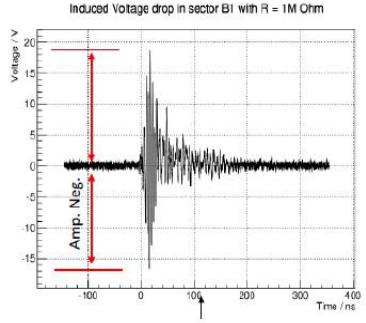
Test of the (4 x 2) 30 x 60 cm² MMs
[in total: 1.4 m², 19040 pads]:
-2 pads with shorts
-1 pad: no read-out connection
→ 3 bad pads out of 19040 before installation

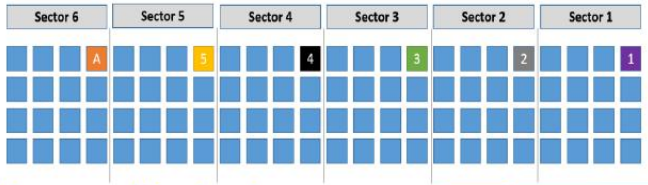
Discharge in Pad A (720 V)



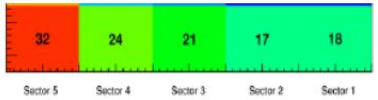


In another pad:

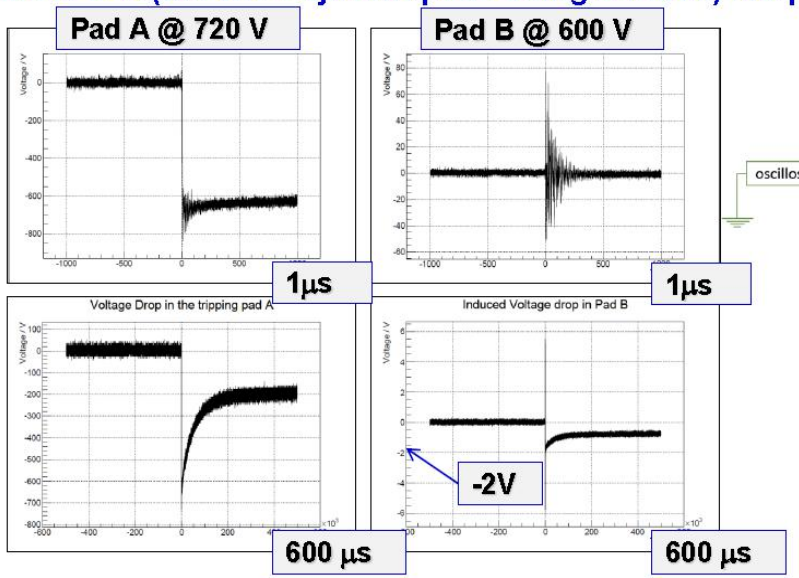


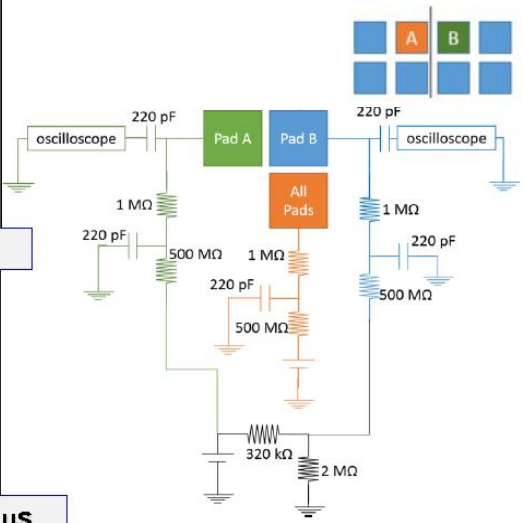


the amplitude decreases with the distance



Pads A & B (the two adjacent pads being studied) are powered by the same PS



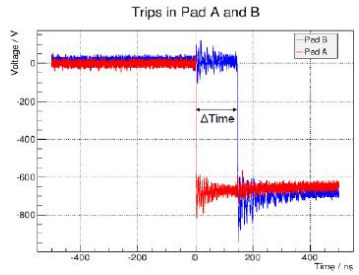


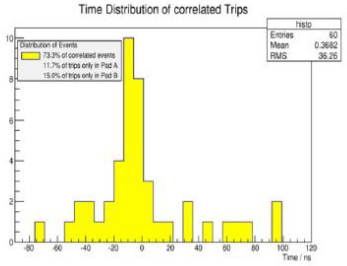
The HV of the non tripping pad is very limited affected:

2V drop → ~4% drop in G

R ~ 0.5 GΩ is preserving the non-tripping pads efficient all the time !

Two adjacent pads kept at anomalous high voltage (720 V) to enhance trip frequency (~ 0.1-0.2 Hz)

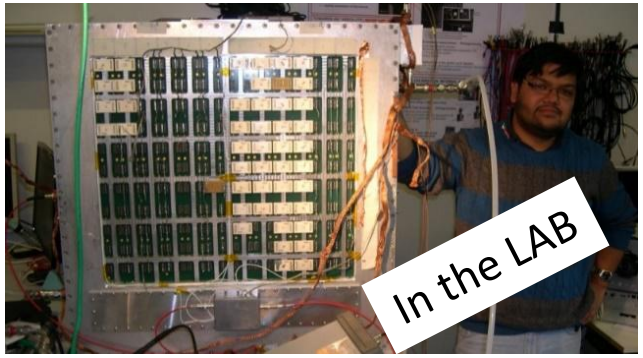


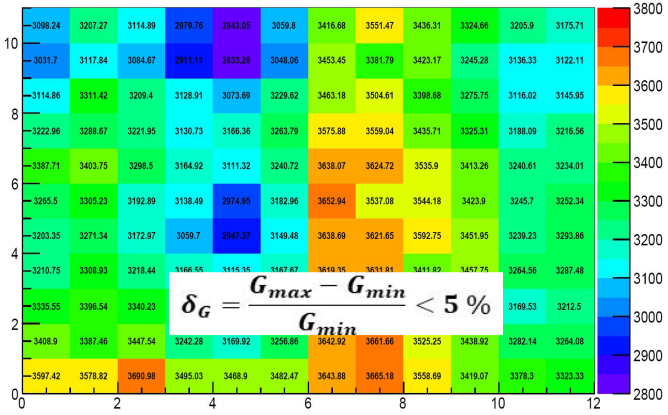


Coupled pads	V(A)	V(B)	% correlated events	% only in A	% only in B
AB	720	720	73.3	11.7	15
AB	735	720	90	8.3	1.7
AB	720	735	70.5	1.6	27.9
AB	730	600	0	100	0
AB	600	730	0	0	100

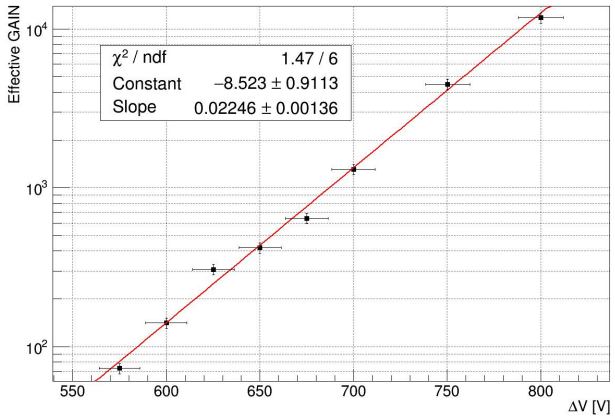
One of the two pads at standard voltage no trip is observed!

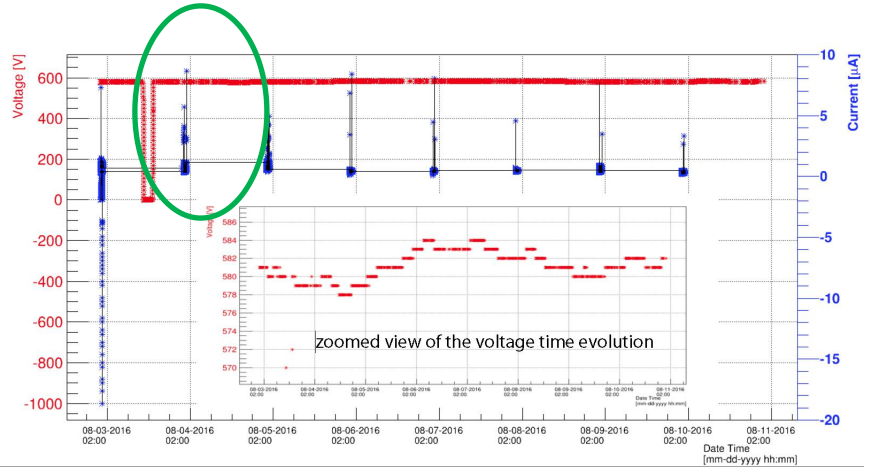
The MicroMegas performance, and the proof the discrete element approach is working

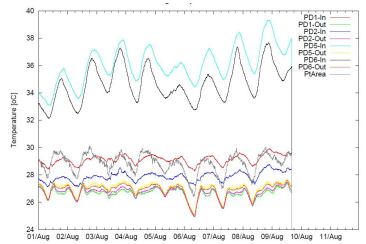


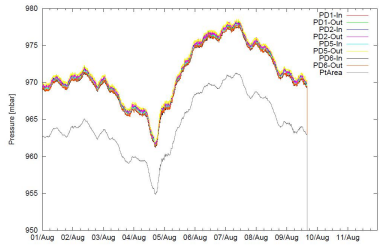


Effective GAIN scan Ar:CH_4 40:60









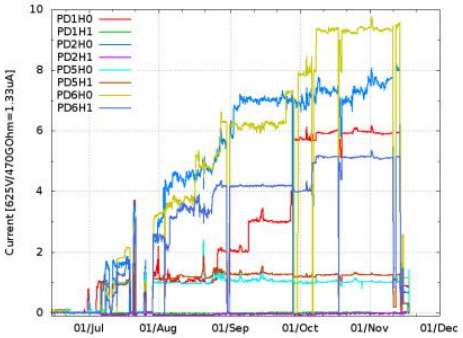
1% of P/T variation corresponds to 40% total gain variation: THGEM 15% (x 2) and MM 12% Need for P/T correction; residual variation ~10 %

Shorts have appeared during operation:

- Investigation of the possible source non trivial.

  Inside the detector's gas volume or in the PCB material, close to discrete steps in currents ~= 625V / 470MΩ

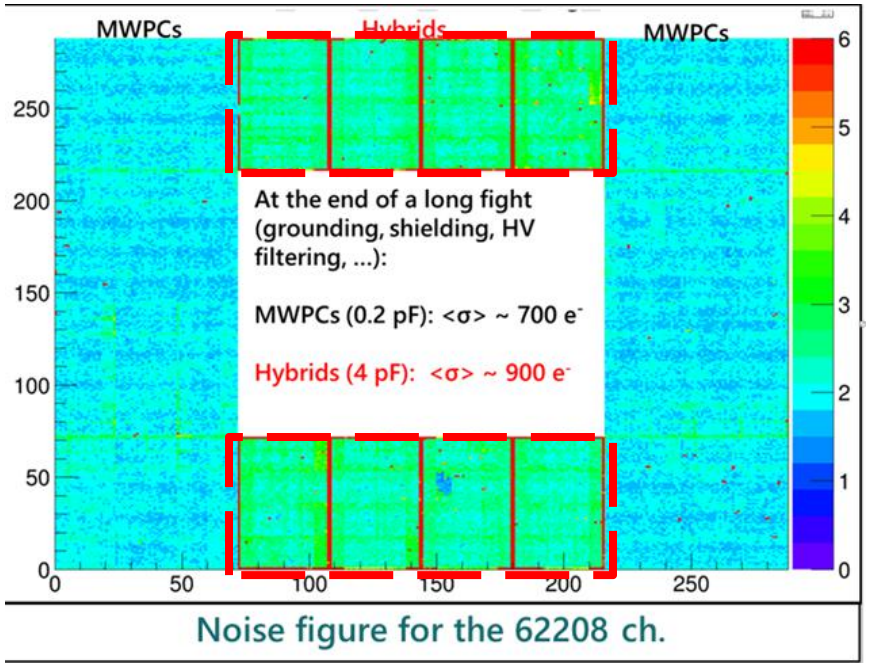
-**MM is still usable**, with constant current(flowing to the shorted pad) no extra noise introduced



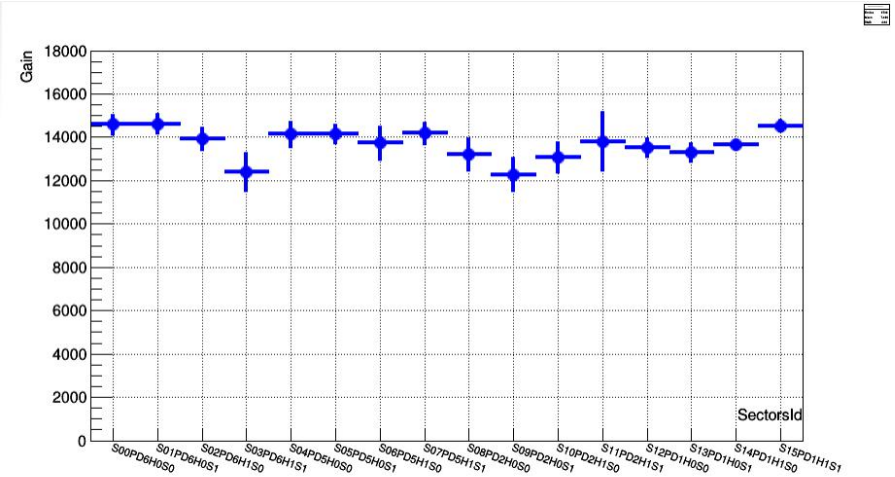
- Part of them fixed during the winter shutdown (reverse bias voltage applied) to the problematic pad(s), most non recoverable→ removed the external resistor array pin, anyhow few pads affected (less than per mill), shorts have stopped to appear.

- Discharge rate below 1/h per detector

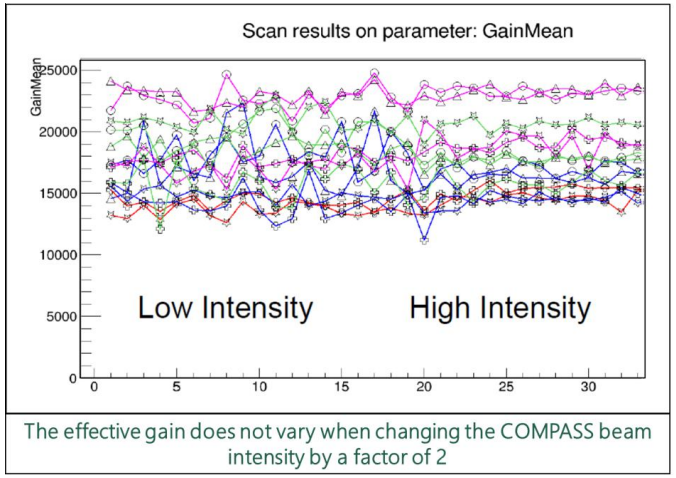
FE noise well under control despite the “large” C_{det}~35 pF



Gain uniformity can be kept via tuning the Micromegas stage:
Robust and reliable operation
(up to 50 Volt difference in different MM sectors)



The hybrid detector shows good stability despite beam intensity variation (not only MM)



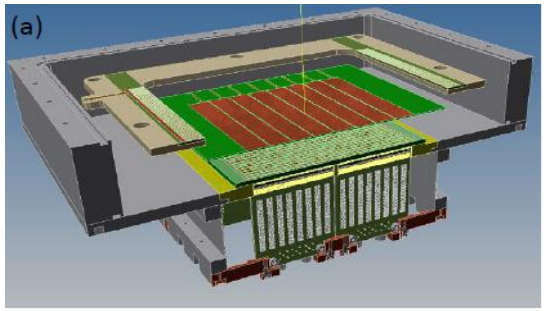
Outlook:

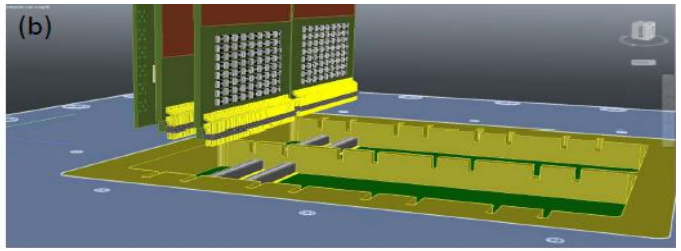
- The photo-detector upgrade of the COMPASS RICH-1: the motivation, our starting point *from witch we capitalize*
- The photon detector architecture: an overview
- The bulk MicroMegas
  - Production technology
  - The signal readout choice
  - Characterization
  - MM Performance
- Ongoing R&D activity for the EIC

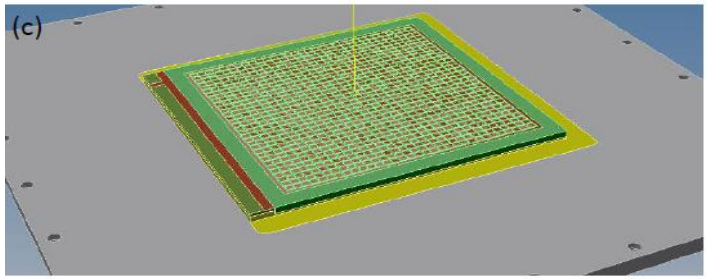
- Design of a <u>prototype</u> of the resistive MM by discrete elements with **miniaturized pad-size 3x3 mm² completed**, construction starting

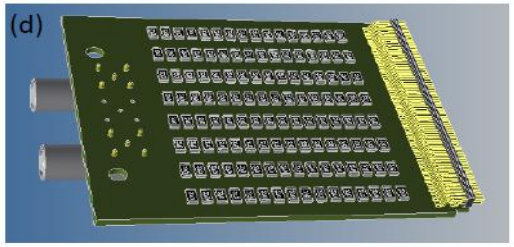
The EIC design requires short radiator length (~1m) therefore shorter lever arm → smaller pad size

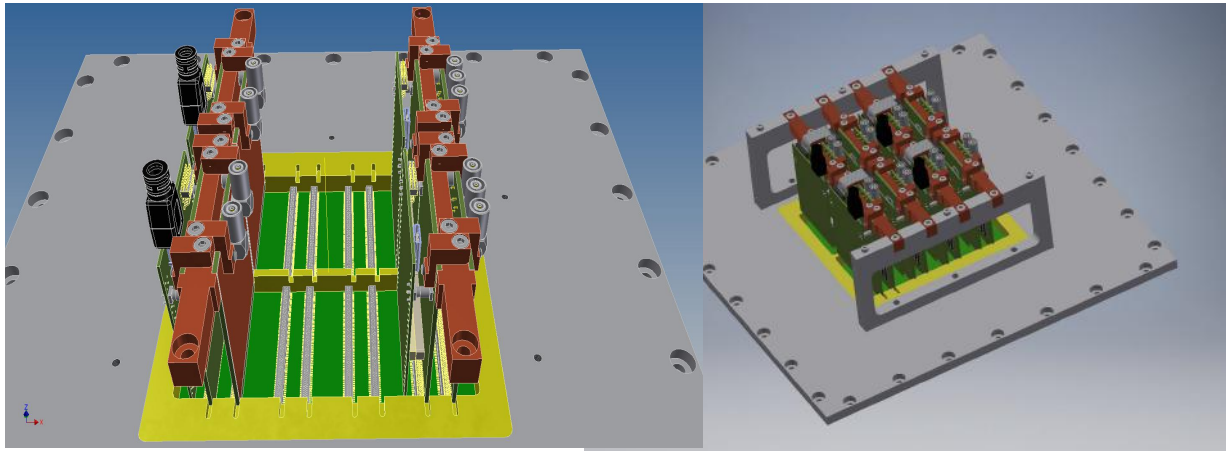
- Preparing the DAQ to characterize the prototype (SRS plus APV25 FE chip) new DataDecodingLibrary on its way (pad oriented,multicore)

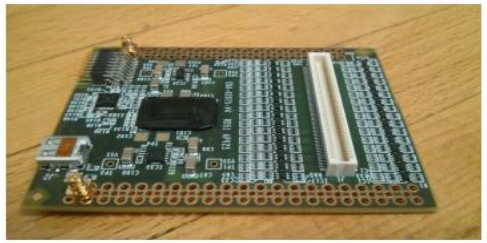


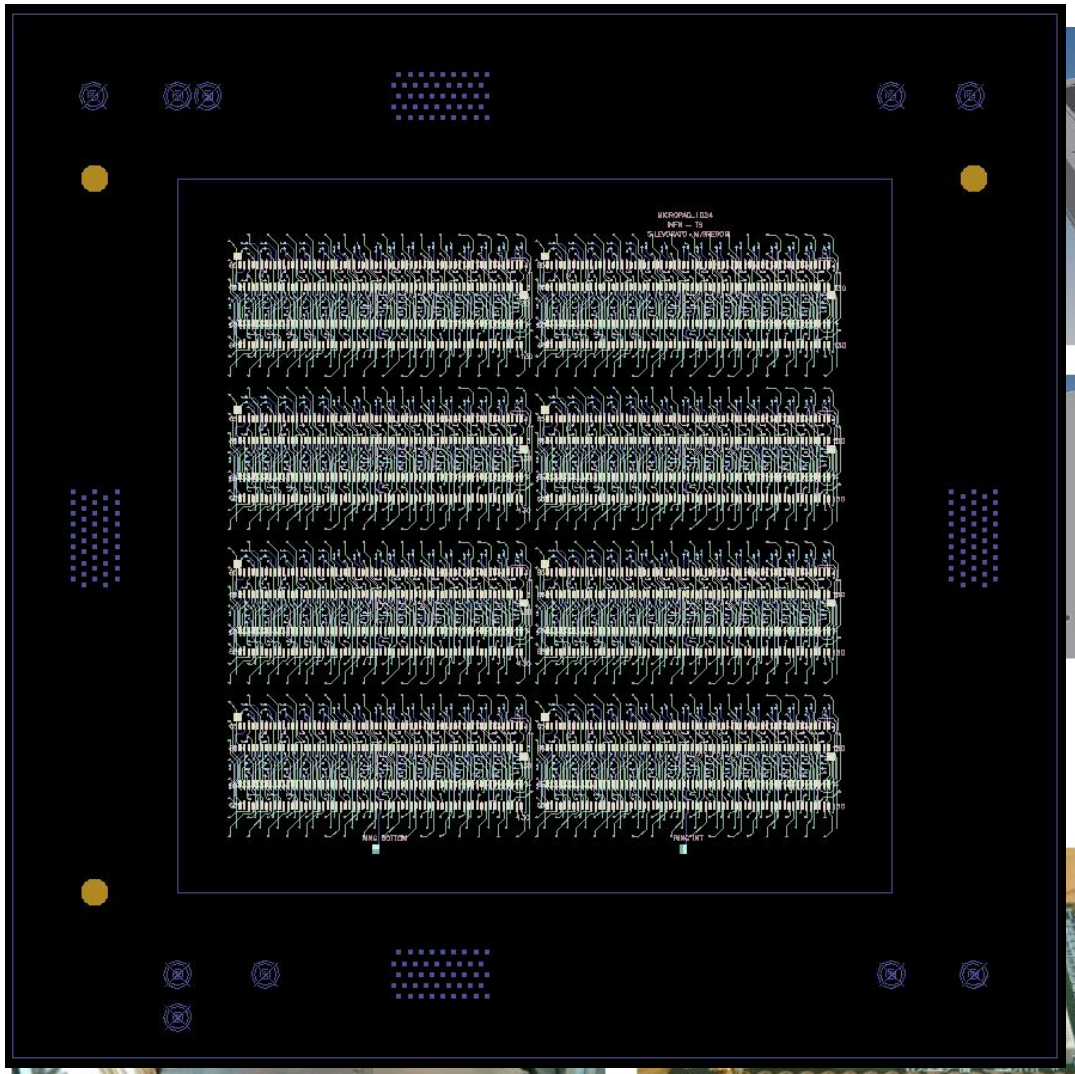


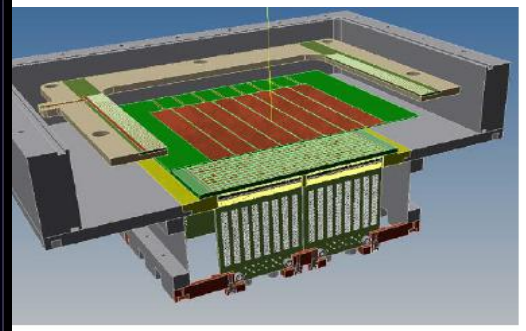


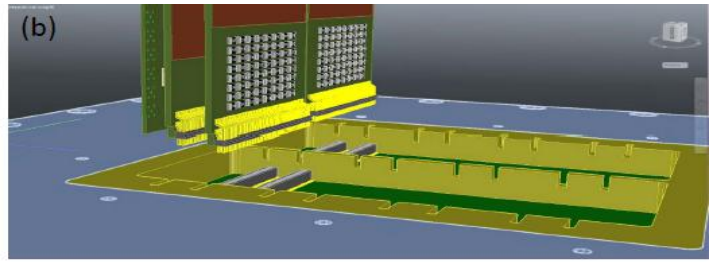


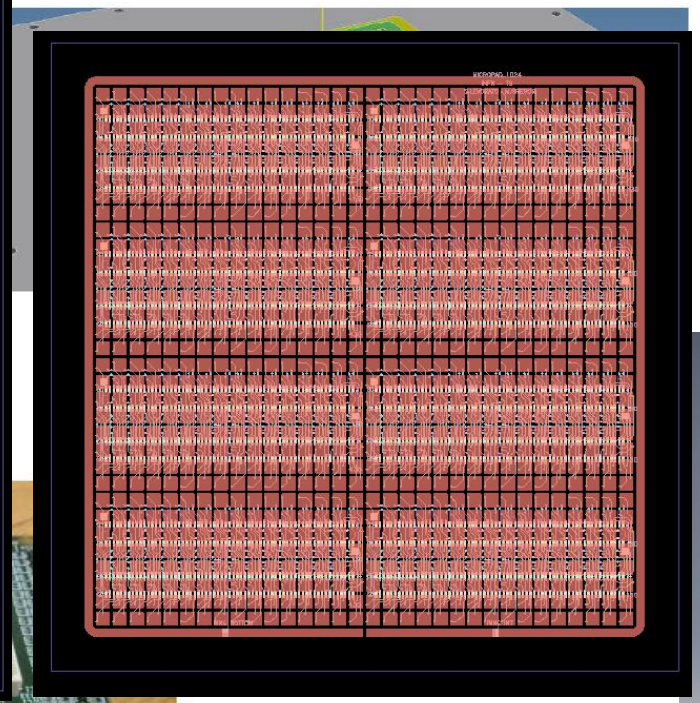


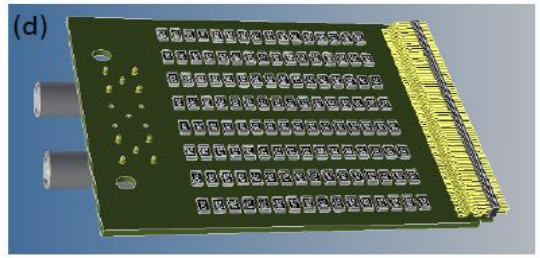


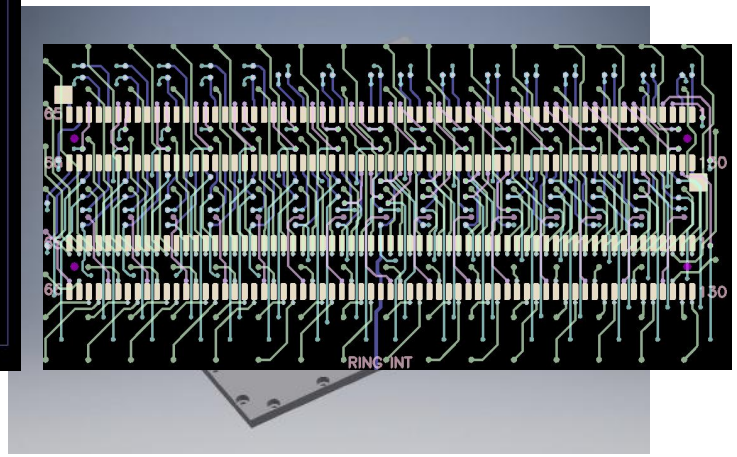





(b)




(d)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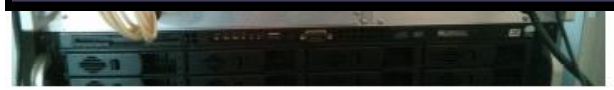
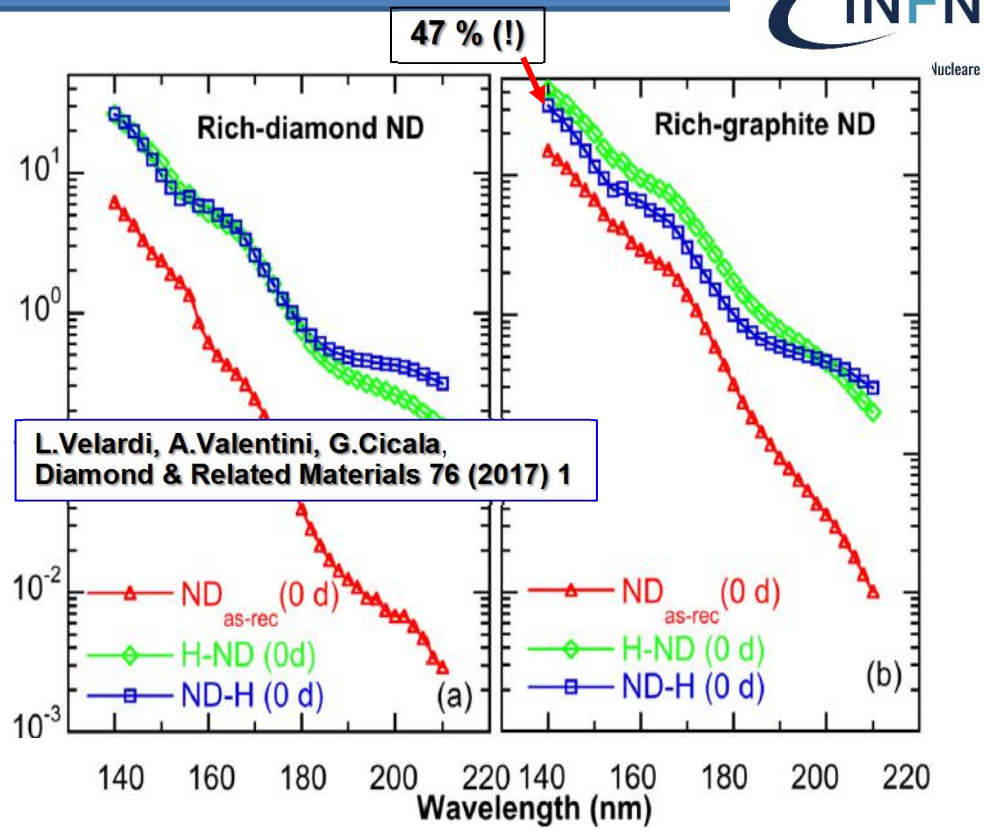


CsI, the only standard photo converter compatible with gaseous atmospheres, has problematic issues, main ones:
It does not tolerate exposure to air (water vapour, O_2)
Ageing by ion bombardment

From Antonio Valentini – INFN - Bari
Italian patent application n. 102015000053374
Photocatodes: hydrogenated diamond film obtained with
Spray* Technique making use of *NC powder
Spray technique: T ~ 120° (instead of > 800° as in standard techniques)



2018: Coupling of ND photoconverter and MPGDs
answering a first set of basic questions
QE: gas vs vacuum?
Characterize a prototype
Ageing ?

The Hybrid detector for single photons is currently in operation for the COMPASS RICH-1 detector

After 2016 year commissioning it is now stable operating

MicroMegas detectors, built using standard bulk technology, are a key ingredient of this success

Micromegas has proven to reliable operate (only few pads has showed or developed defects in a initial stage) and Allow for THGEM gain compensation for a uniform detector response

The experience gained in the COMPASS RICH-1 upgrade is now beneficial for the EIC R&D activity (both for RICH application or TPC development)

The small size prototype, and its modular approach are well progressing.

THANK YOU