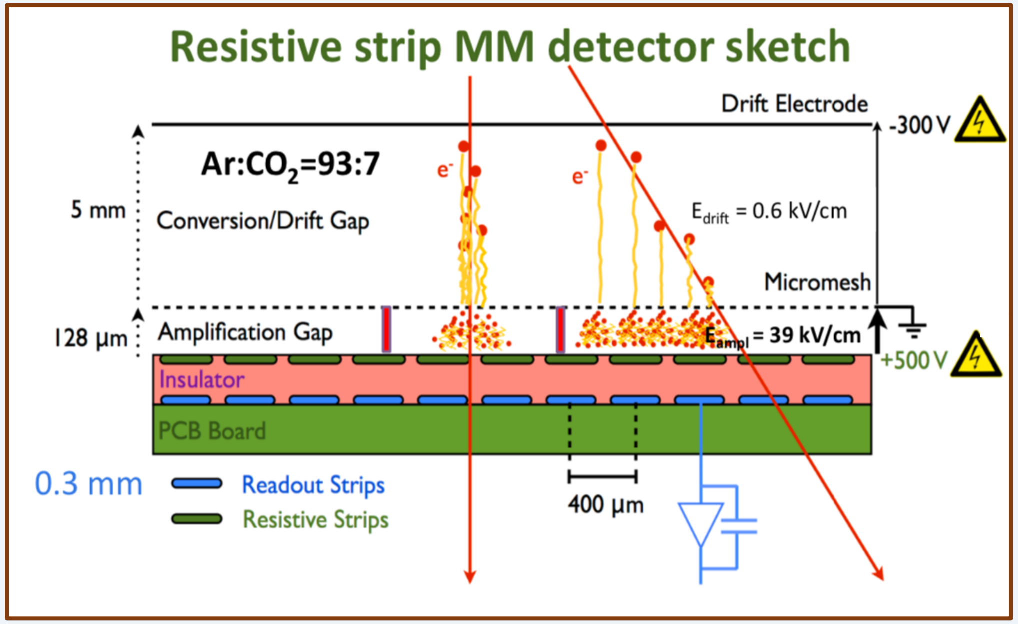
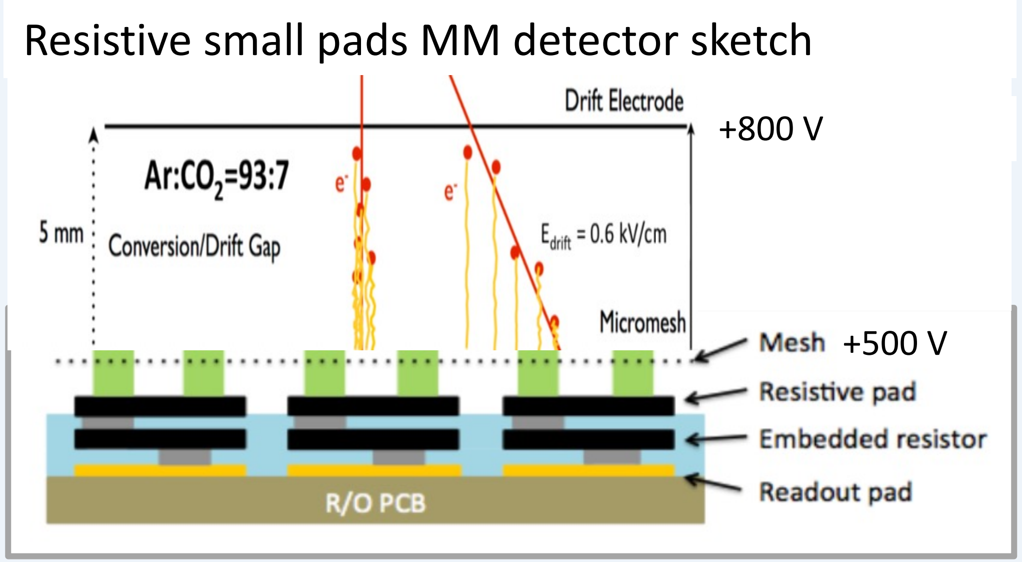
Micromegas a pad resistive

Riunione di Gr1 – 21 dicembre 2021, M.Alviggi

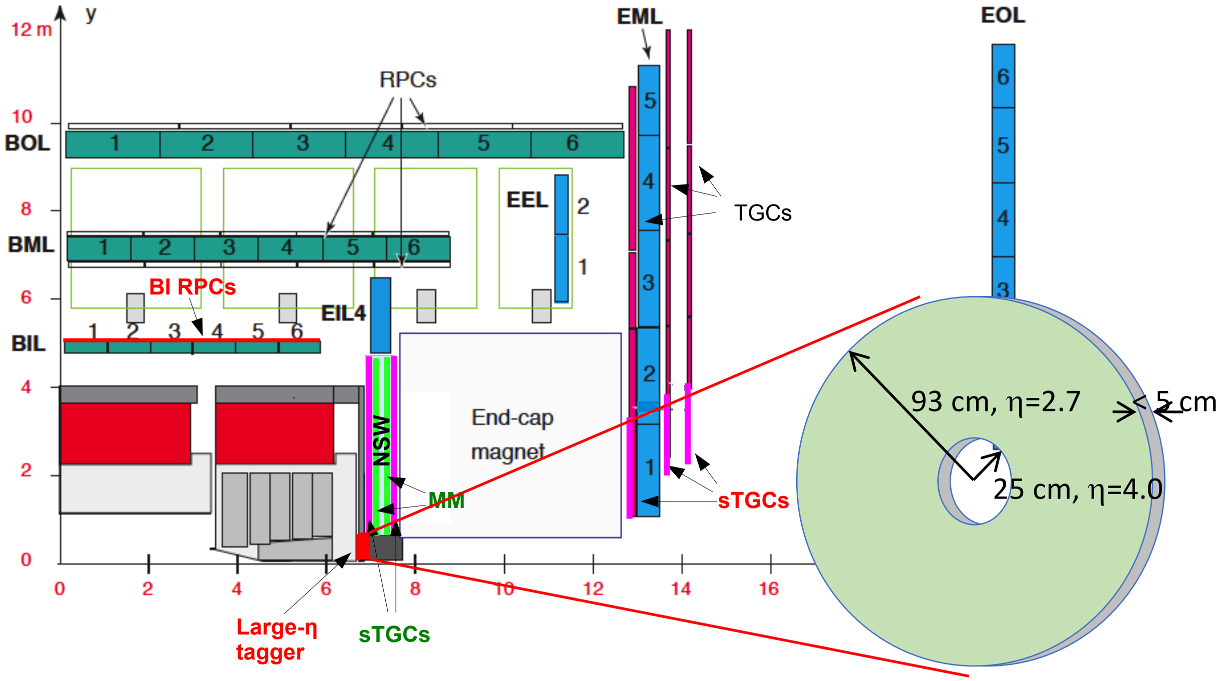




Tracking @ high-rate: ~ several MHz/cm^2

- reduce occupancy using a small (<3mm^2) pad readout
- optimize the spark protection resistive scheme

- **applicazioni:**
  - ATLAS very forward extension of muon tracking (Large eta Muon Tagger as an option for future upgrade),
  - Muon Detectors and TPC at Future Accelerators,
  - Readout for sampling calorimeters.



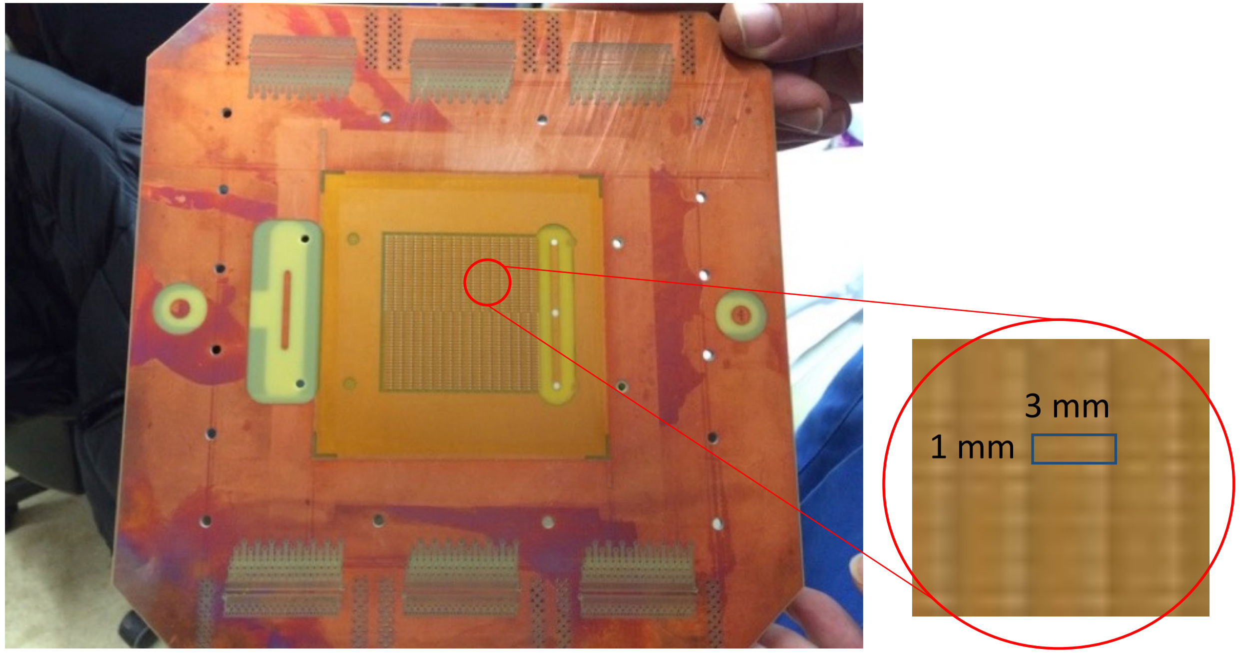
ATLAS NSW @ decine kHz/cm^2

- R&D project (RHUM: Resistive High granUlarity Micromegas)

  (Napoli + Roma3)

Large η tagger requirements:
- Operation at ~1-10 MHz/cm2 at R=25 cm
- Position resolution: few 100 μm
- Angle resolution ~ few 10 mrad
- Requirements (greatly) relaxed at large R

Piano di readout: da strips a pad resistive



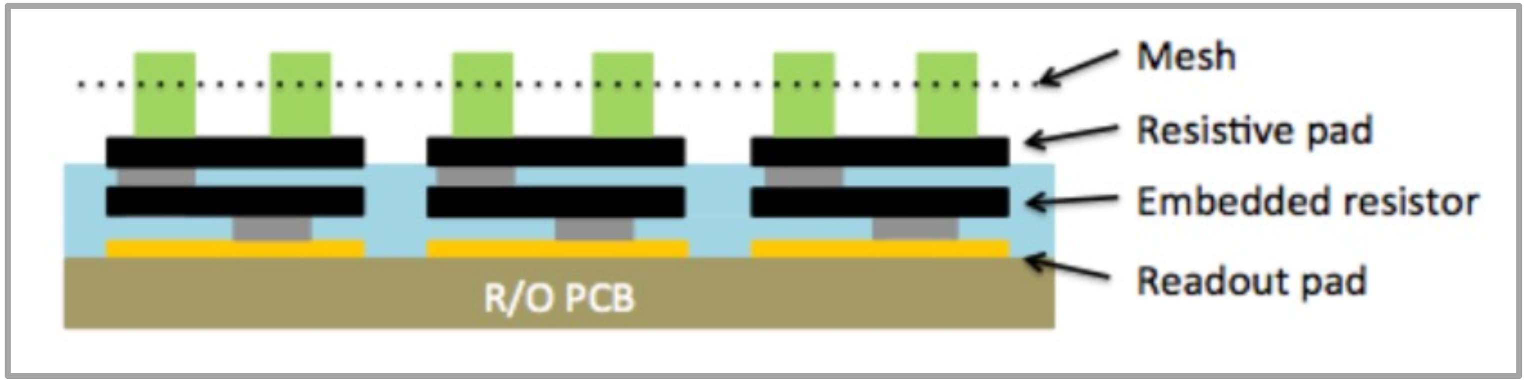
- Segmentato in pads O(mm^2), attuali prototipi:
  - 16 x 48 = 768 readout Pads matrix with (1 mm x 3 mm) covering 4.8 x 4.8 cm^2 active area;
  - Circular pillars with r = 200 μm, height 100-120 μm (bulk technique) and 6 mm pitch;

- Routing delle connessioni alle pad occupa la maggior parte del prototipo → embedded electronics → scaling ad aree maggiori

- Ottimizzazione protezione resistiva degli elettrodi di lettura dalle scariche, sia del layout che del valore/uniformità della resistività:
  - stabilità HV, recupero dopo un segnale, footprint del segnale
  - accoppiamento capacitivo tra le pad
  - stabilità del guadagno al variare del rate/posizione
  - efficienza e risoluzioni
  - ....

Spark suppression resistive layout…

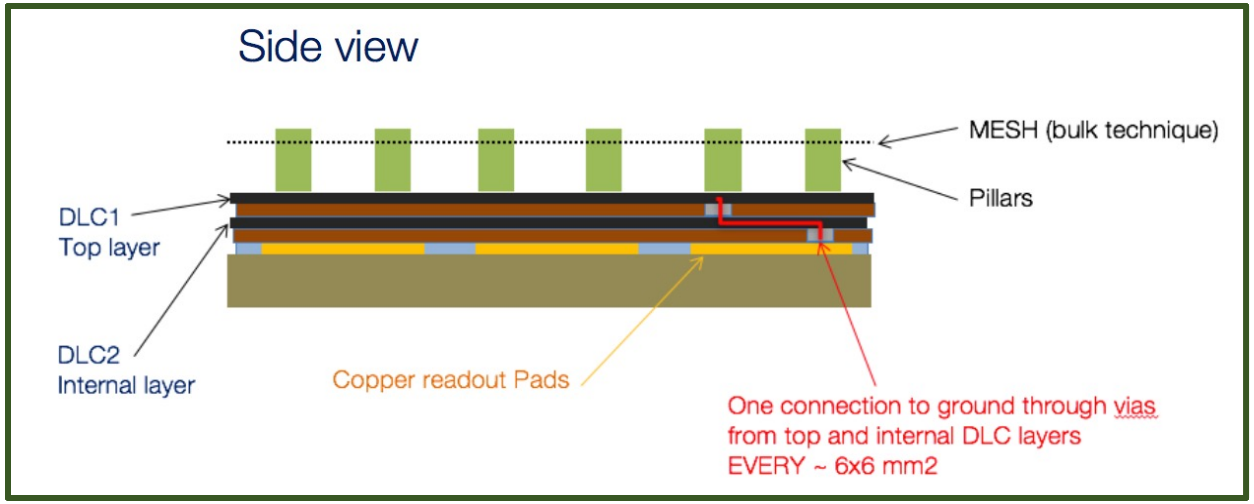
- Scheme 1: PAD-Patterned embedded resistor:
  - Two planes of independent screen printed carbon resistive pads with the same geometry of copper readout pads;
  - The overlapped pads in the different planes are interconnected by silver vias, as shown in the picture.
  - Each pad has an overall impedance ranging within (3 – 7 MΩ) and is completely separated from the neighbours

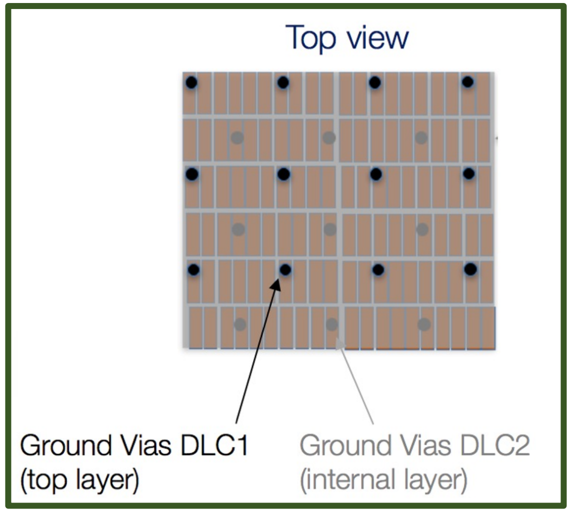


- 'difficoltà' nel realizzare pads con bordi 'regolari' e silver vias 'ben allineate' con i pillars (rischio scariche)

…spark suppression resistive layout…

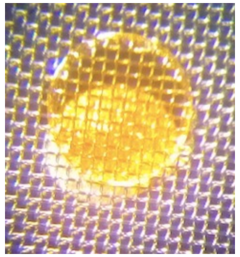
- Scheme 2: Double DLC (Diamond Like Carbon) uniform resistive layer
  - DLC surface treatment consists in sputtering carbon (evaporated from a graphite target) on a kapton foil, obtaining a uniform resistive layer. DLC coatings can be made that at the same time are amorphous, flexible, and yet purely sp^3 bonded "diamond".
  - Two continuous resistive DLC layers (20 - 50 MΩ/□) interconnected between them and to the readout pads with network of conducting links, with the pitch of few mm, to evacuate the charge;



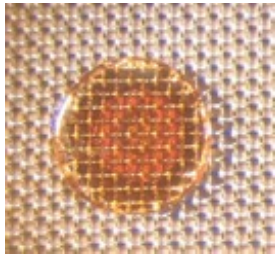


Two prototypes with different surface resistivity:
DLC 20
DLC 50

- An improved production technique have been developed (**SBU sequential built-up**): with copper cladded DLC foils.
- This allows an easier photolithographic construction process improving of the alignment of vias and centering of the pillars



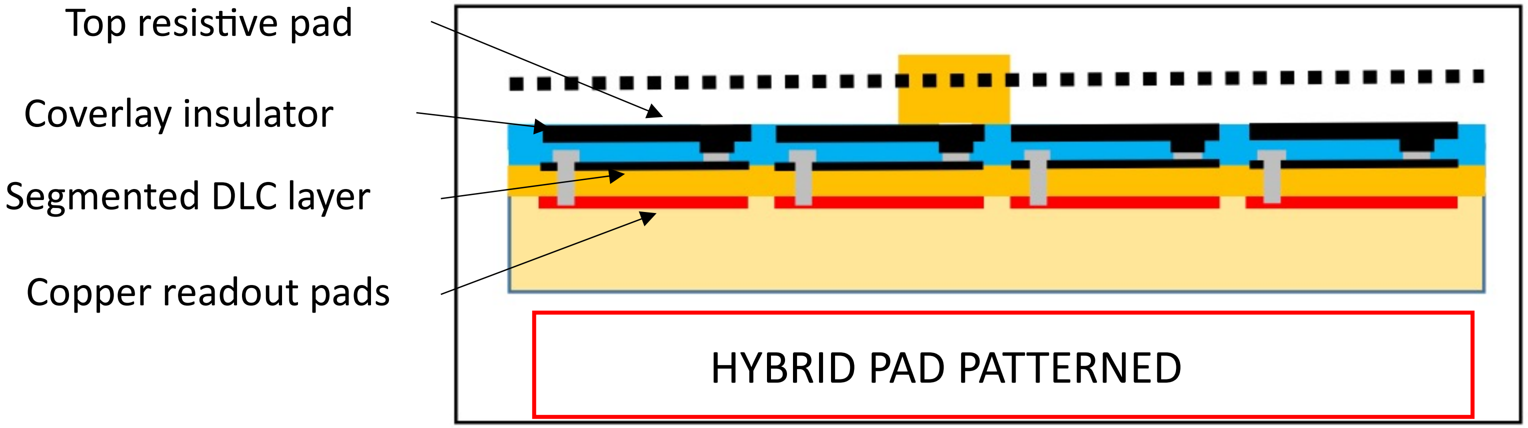
DLC series



SBU series

…spark suppression resistive layout

- Scheme 3: Hybrid PAD Patterned solution
  - le pads resistive verso la gas gap sono screen printed
  - le pad resistive intermedie sono realizzati tramite 'etching' di un foglio DLC



→ indipendenza delle pad resistive + uniformità dell'impedenza vista dalle cariche raccolte

Spatial resolution and cluster size

- diversi prototipi 'testati' @PSI/CERN con fasci di μ e π

Common setup

- 4 small-pad MM under test
- 2 resistive XY strip MM for trackers
- 2 scintillators for the trigger

Maggiore uniformità nella distribuzione di carica tra le pads →

- DLC hanno risoluzione migliore di PAD-P
- ris. DLC20 < DLC50

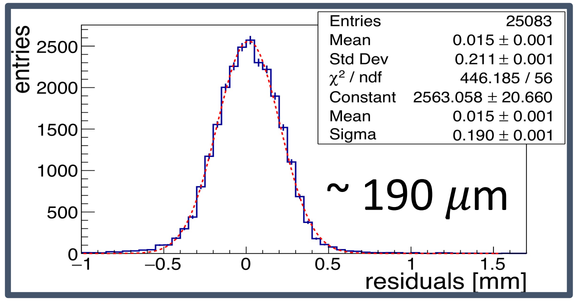
$$\sigma_{resol} = \sqrt{\sigma_{resid}^2 - \sigma_{track}^2}$$

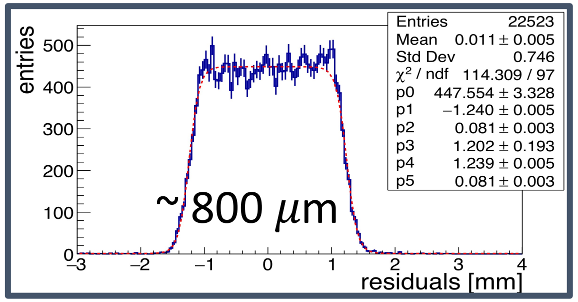
$(\sigma_{track} \simeq 50\ \mu m)$

first coordinate 1 mm pitch

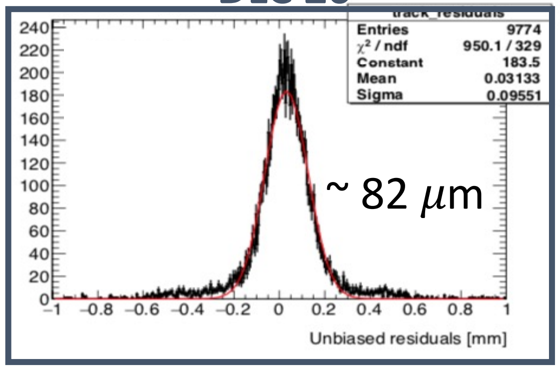
second coordinate 3 mm pitch

PAD Patterned

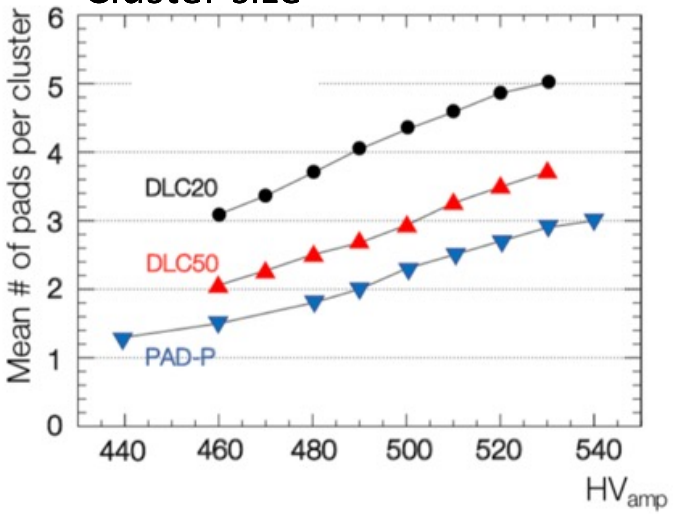




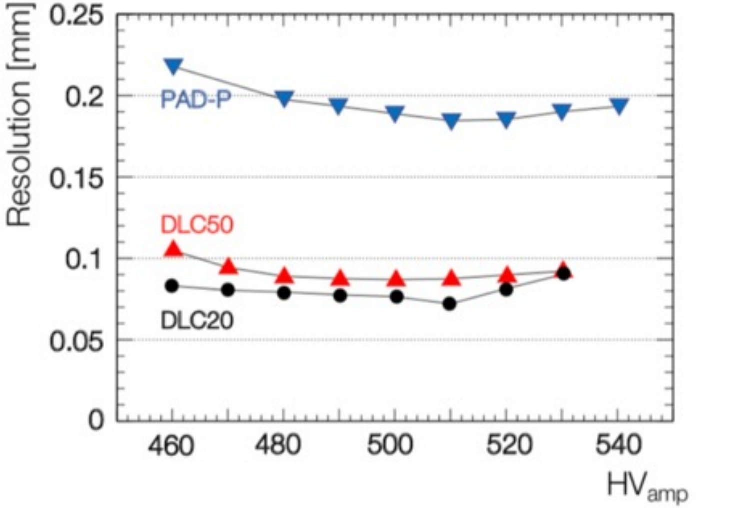
DLC 20



Cluster size

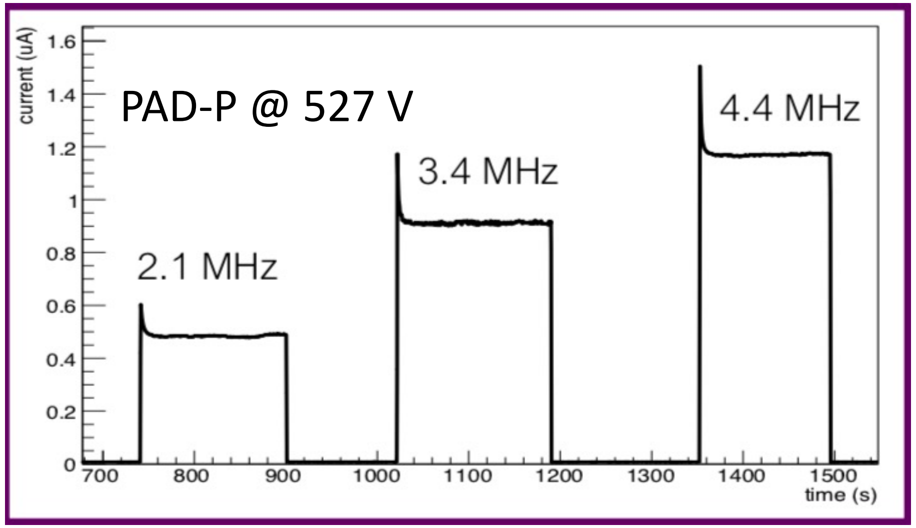


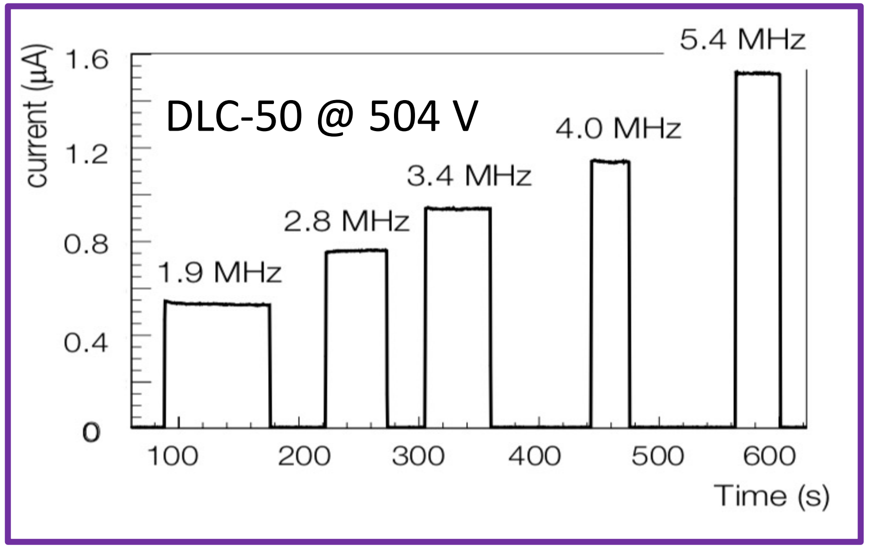
Precision coordinate resolution



Detector current vs time: charging up

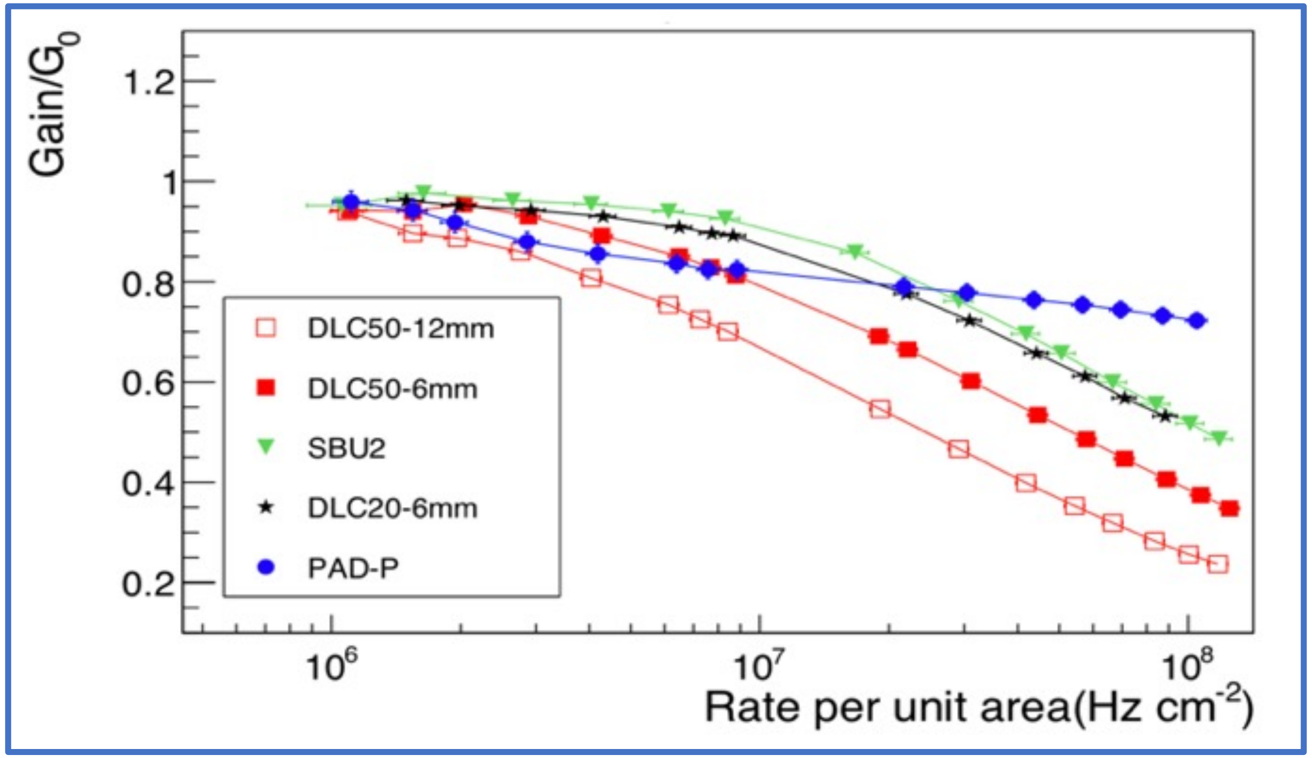
- All prototypes with Pad-Patterned resistive layout shows sizeable effects of charging-up (gain reduction by ~20%) in **current as function of time**.
  - a possible explanation is due to dielectric charging-up of exposed Kapton surroundings the resistive pads. **Still under investigation.**
- DLC detectors do NOT show any sizeable charging-up effects (less than few %)
  - expected from the uniformity of the resistive layer and from the absence of exposed dielectric, with the exception of the pillars.
  - Very stable on short time scale (several minutes). we also observed a slow increase of gain over long time - few percent - still under investigation





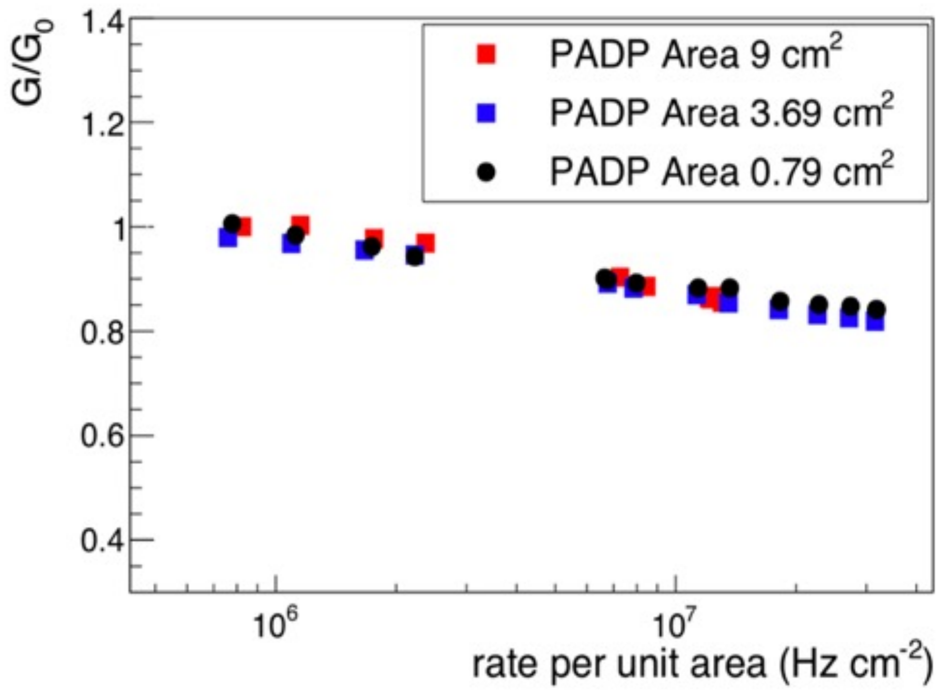
Current measurement Vs Time during cycles of X-Rays irradiation

Rate capability with X-Ray gun@CERN

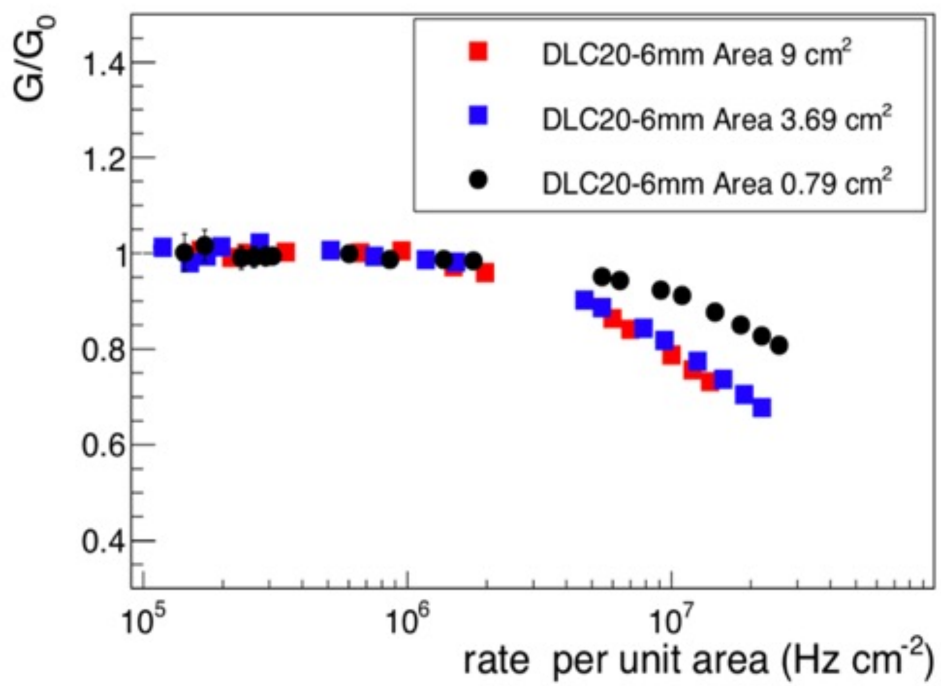


- PAD-P: gain drop iniziale dovuto al charging-up, poi scende 'lentamente' poichè ogni pad si comporta come un elemento resistivo indipendente verso massa
- Comportamento di DLC20 e SBU simile (up to ~100 MHz/cm^2):
  - mean values of the resistance between first and second DLC protection foils are almost the same
  - for rates greater than 20-30 MHz/cm^2 they shown a higher gain drop w.r.t. PAD-P
- DLC20 e SBU si comportano meglio di DLC50, a causa della minore resistività
- Chiara differenza tra le zone con 6mm and 12 mm di pitch tra le grounding vias (the larger the vias pitch the greater the impedance to ground seen by the collected charge)

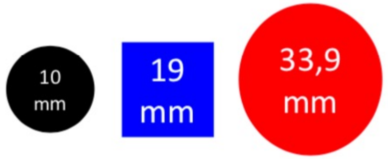
Rate capability dependence on irradiated area



PAD-P



DLC20-6mm



- Thanks to independent pads there is no dependence on the exposed area.

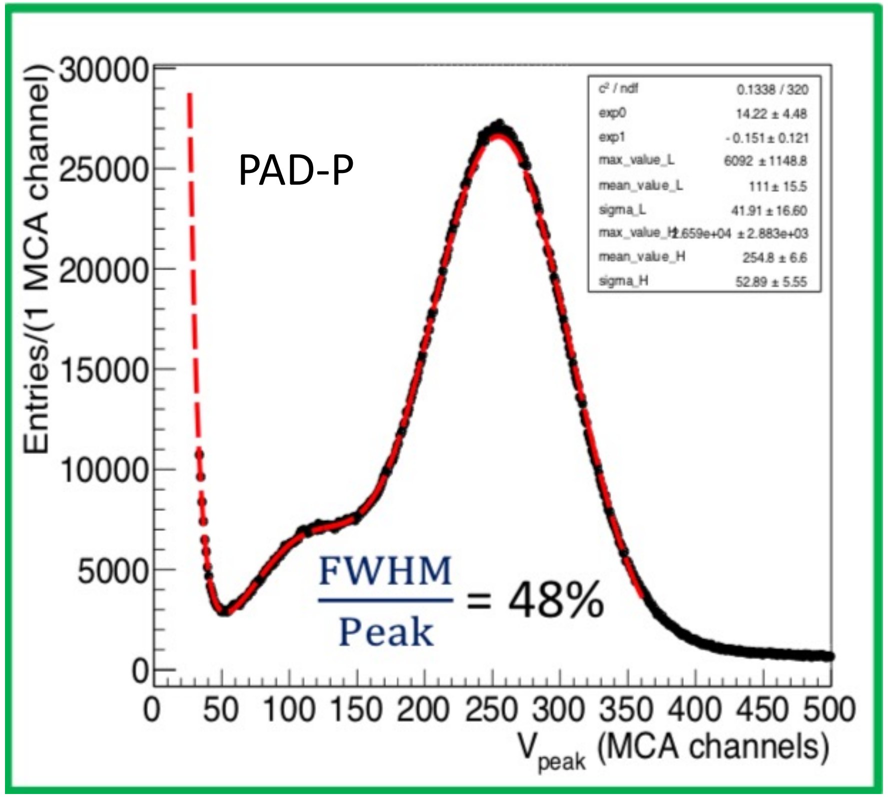
- For rates greater than 5 MHz/cm2 a dependence of the gain drop from exposed area is measured.
- For irradiated surface bigger than ~3.7 cm^2 (~10 times the grounding vias (0.6 x 0.6) cm^2 cell) gain drop does not scales with the area.

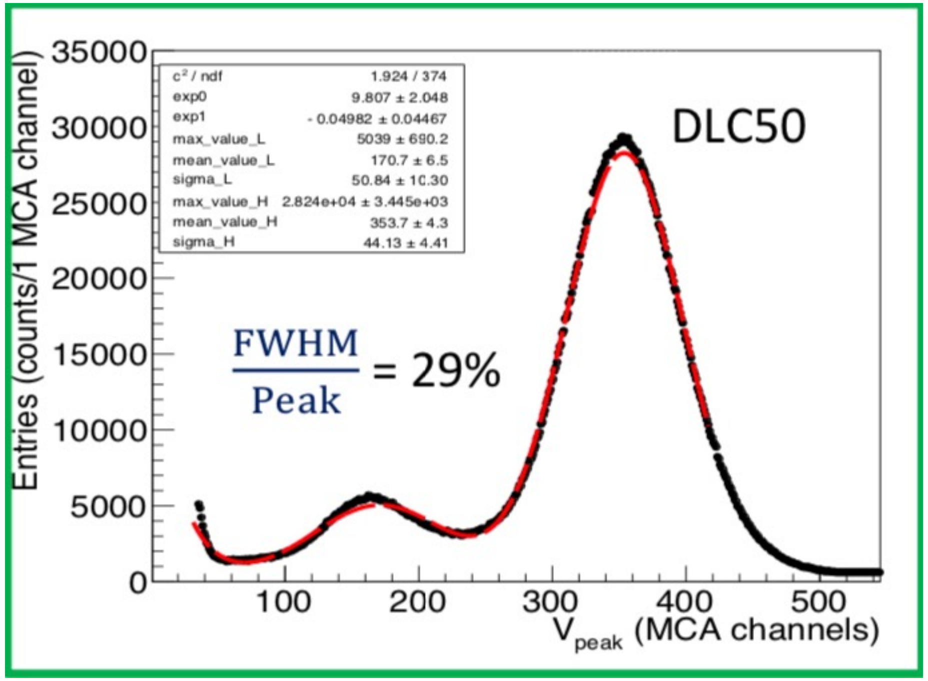
Energy resolution

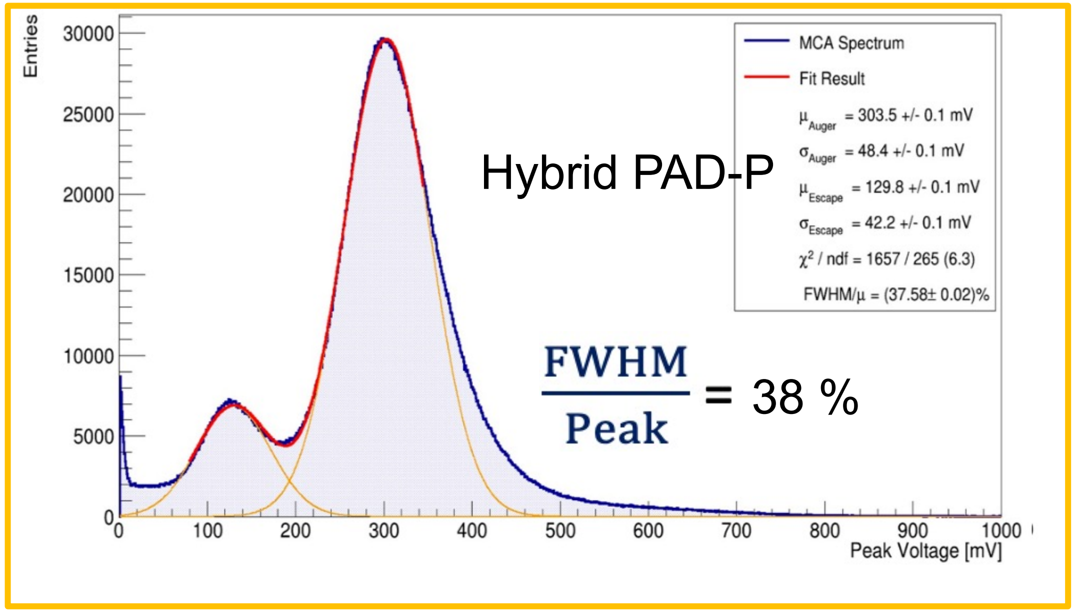
measured looking at the ^{55}Fe spectrum

The DLC resistive protection scheme shows a better energy resolution with respect to the "PAD-P" and "Hybrid PAD-P" schema due to:

- more uniform electric field
- no pad border effects

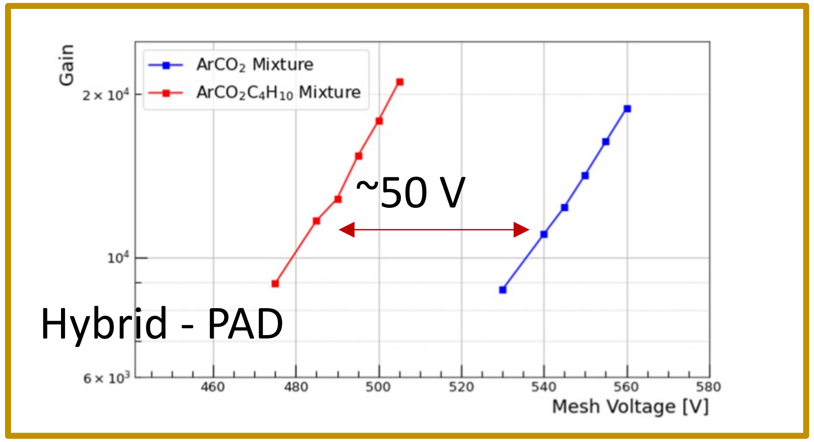


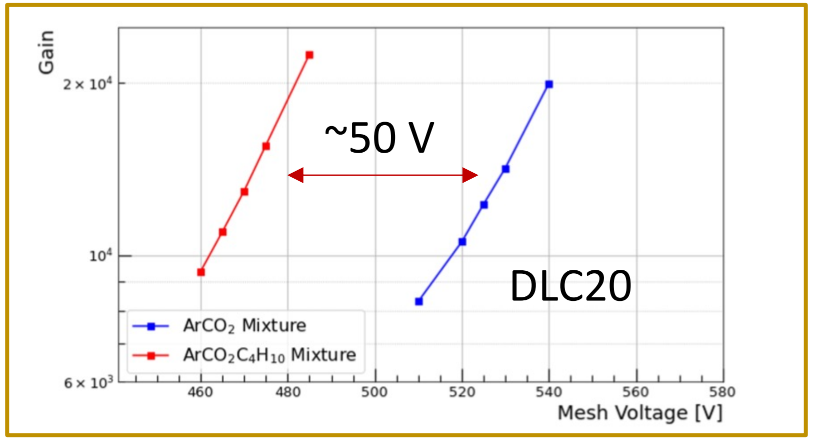




Studies with different gas mixture

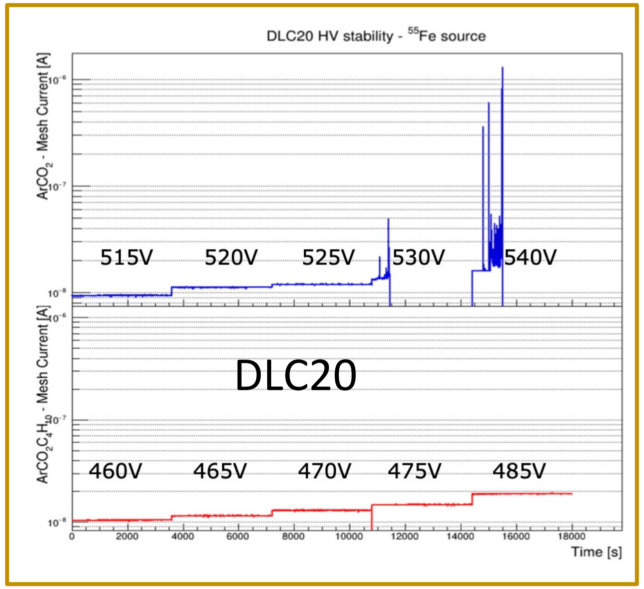
- Added 2% of Isobutane to our standard gas mixture in order to improve the detector stability
  - From $Ar:CO_2$ 93:7 to $Ar:CO_2:iC_4H_{10}$ 93:5:2
- Very high gain reachable in very stable conditions (^{55}Fe sources)

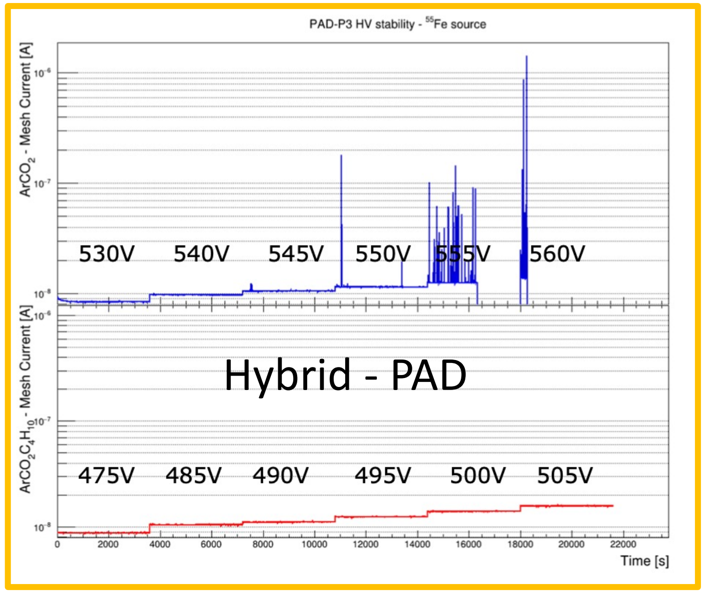




Without isobutane: Instability for Gain > ~15k

With isobutane: Stable operation up to Gain >20k

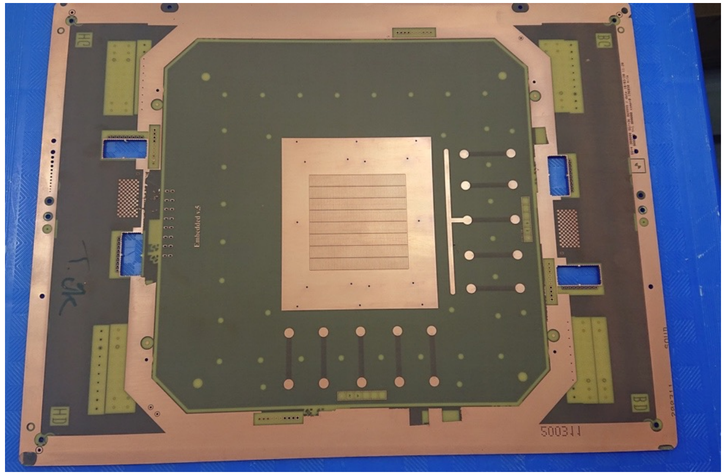




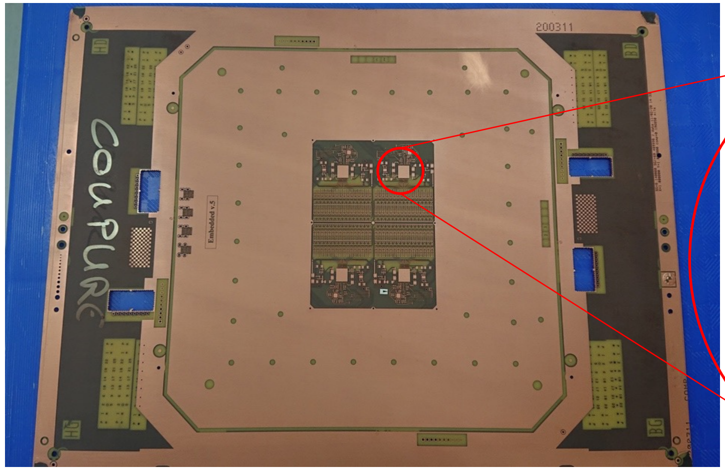
Larger surface and integrated Electronics

- A larger area (20 x 20 cm^2) detector is under construction:
  - SBU resistive layout; 4800 readout pads (1x8 mm^2) only partially instrumented
- In order to solve the problem of the signal routing when scaling to larger surface a small prototype (64 x 64 mm^2) with integrated electronics on the back-end of the anode PCB has been built.
- APV25 FE chip used for the proof-of-concept: looking for alternative and more suitable solutions

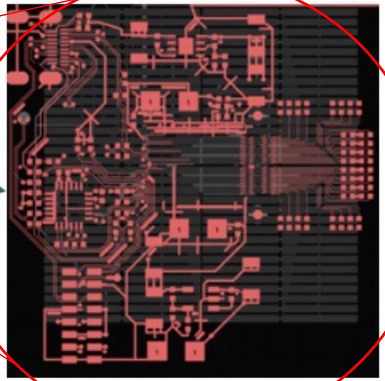
FRONT VIEW



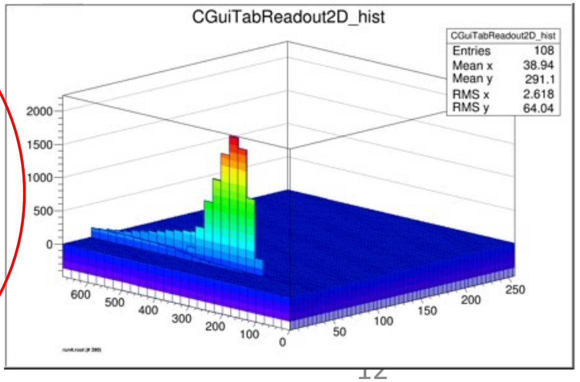
BACK VIEW



APV25 layout



Signal from 55Fe



Prossimamente…

Continuare i test per ottimizzare

- il layout resistive
- la miscela di gas
- anche con simulazione…

Test del prototipo con embedded electronics

- Valutare anche FE chips alternative agli APV25
- prototipo 20x20 cm^2 with embedded electronics

Studi di ageing (iniziati a GIF++)

THE END