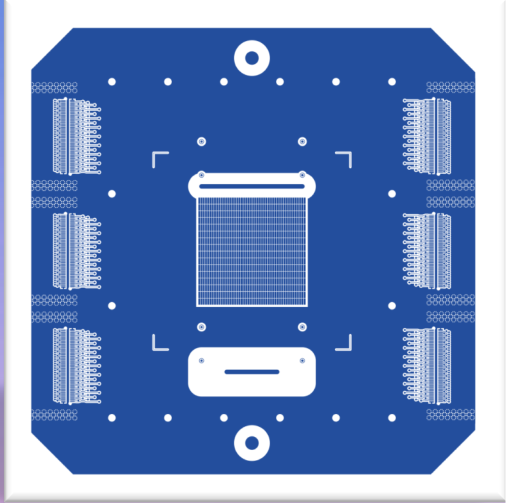
High rate performance of Small-pad Resistive Micromegas. Results of different resistive protection concepts



Mauro Iodice – INFN Roma Tre

for the "Small-pad micromegas" R&D Collaboration

(INFN Italy and CERN)

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ICHEP 2018 Seoul - July 7, 2018

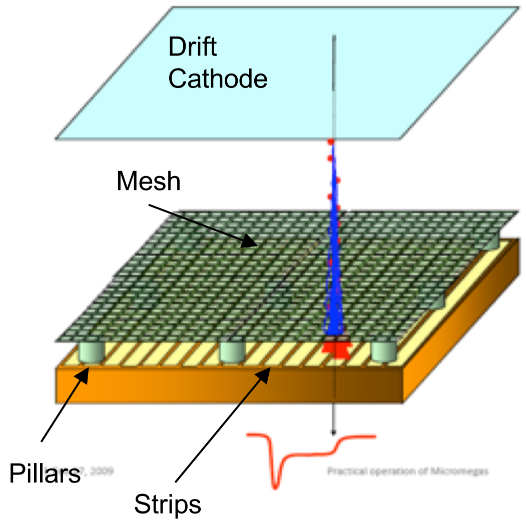
Introduction – Resistive Micromegas detectors

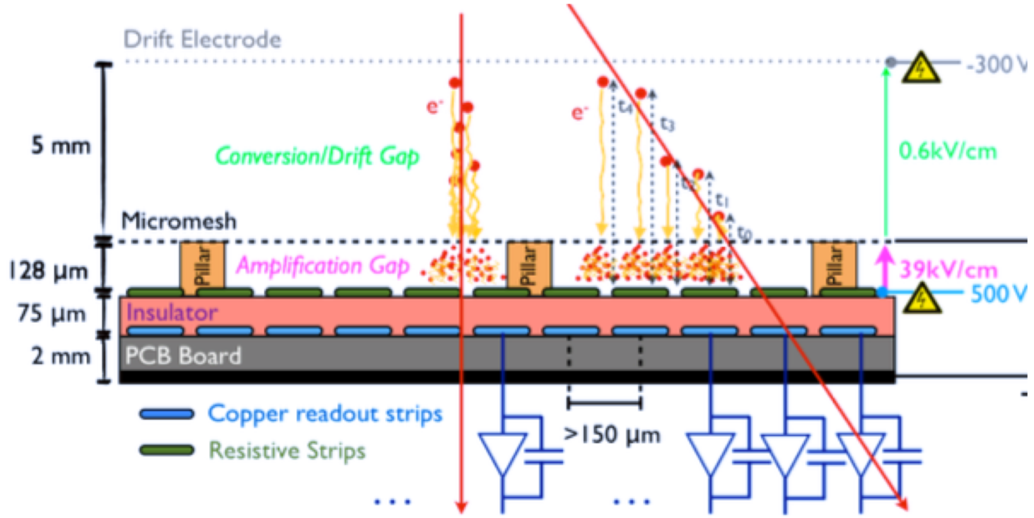
Resistive Micromegas:

Now a mature technology for HEP experiments also taking advantage of the intense phase of R&D for the ATLAS Experiment were resistive strips MM will be employed in the New Small Wheel upgrade of the Muon Spectrometer

(see talks at this Conference by by Athina Kourkoumeli-Charalampidi and Maximilian Herrmann on Thursday July 5th)

- Resistive anode strips → suppress the intensity of discharge
- Large area: total surface of ~1200 m2 of gas volumes
- Operation at moderate hit rate up to ~15 kHz/cm^2 during the phase of High-Luminosity-LHC





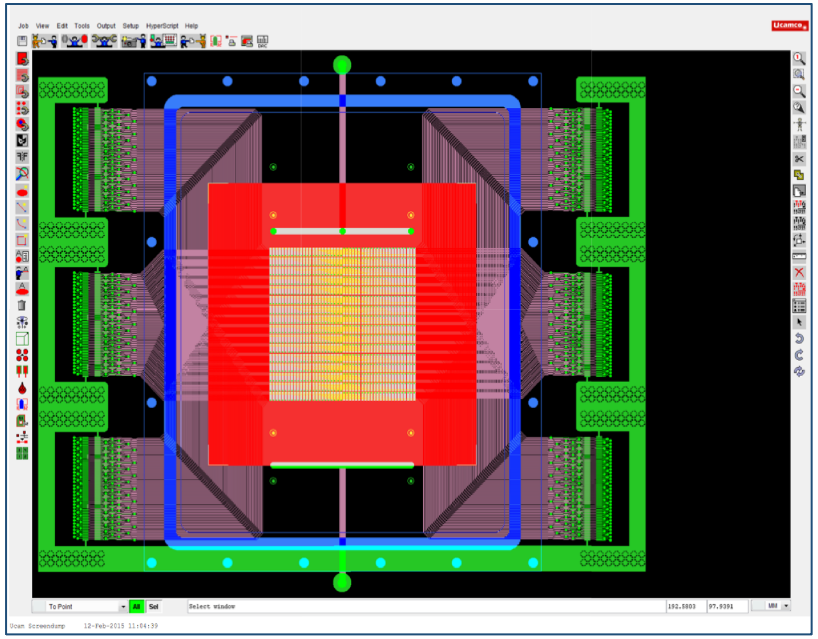
Detector R&D : Small Pads Resistive micromegas

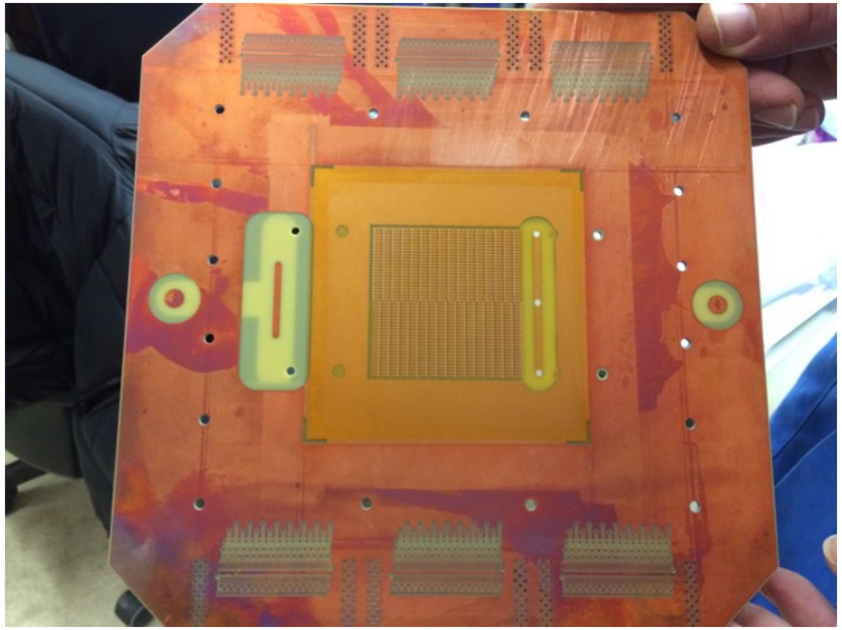
GOAL: Development of Resistive Micromegas detectors, aimed at operation under very high rates (~10 MHz/cm^2)

- R&D BASIC STEPS:
  - **Optimization of the spark protection resistive scheme**
  - **Implementation of Small pad readout** (allows for low occupancy under high irradiation)
- From existing R&D(see acknowledgement) we aim at reducing the pad size from ~1cm^2 to < 3mm^2.
- Possible application: ATLAS very forward extension of muon tracking (Large eta Muon Tagger – option for future upgrade)

Layout of the small size prototypes:

- Matrix of 48x16 pads
- Each pad: 0.8mm x 2.8mm (pitch of 1 and 3 mm in the two coordinates);
- Active surface of 4.8x4.8 cm^2 with a total of 768 channels





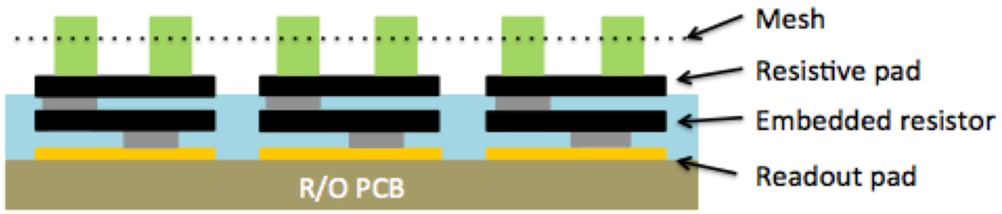
Resistive Layers Configurations

Two series of small pad resistive micromegas prototypes built so far with **pad dimension 3 mm^2**.

The two series differ for the implementation of the resistive protection system against discharges :

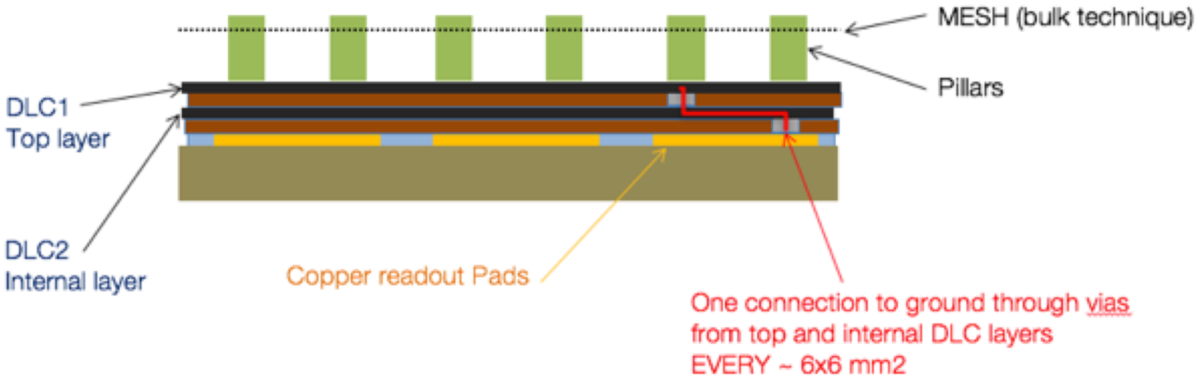
SERIES 1 – EMBEDDED RESISTORS

- Screen printing technique
- **Patterned resistive layer**: separate resistive pads with embedded resistors ~3-7 MΩ

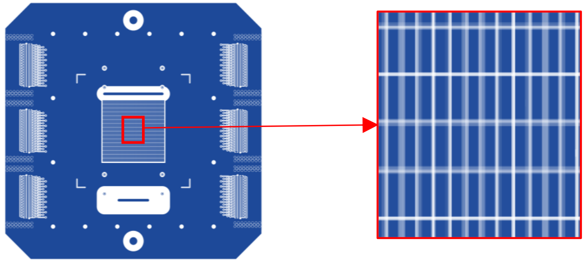


SERIES 2 – DLC (Diamond Like Carbon) LAYER

- Double DLC resistive layer with a resistivity of ~50-70 MΩ/☐
- Connection to ground through resistive vias (few mm apart)
- Design driven by recent developments of μ-RWell detector (see talk by M.Poli-Lener this morning)
- **Uniform resistive layer**



- All prototypes with same anode configuration: Matrix of 48x16 pads
- Pad size 0.8mm x 2.8mm (pitch of 1 and 3 mm in the two coordinates)
- Total # Channels: 768



Characterization of the detectors

Gain Measurements with sources and X-rays

Two radiation sources have been used:

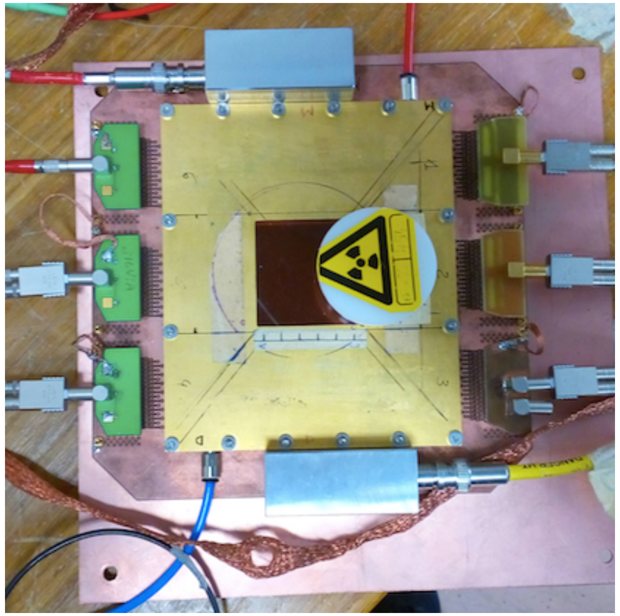
- ^{55}Fe sources with 2 two different activities
  - "Low activity" (total rate of 1.3 kHz)
  - "High activity" (total rate of 128 kHz)
- 8 keV Xrays peak from a Cu target with different intensities varying the gun excitation current

For both prototypes gain has been measured with two methods

- Reading the detector current from readout pads with a picoammeter and counting signal rates from the mesh
- Signals amplitude from a Multi Channel Analyser (MCA)

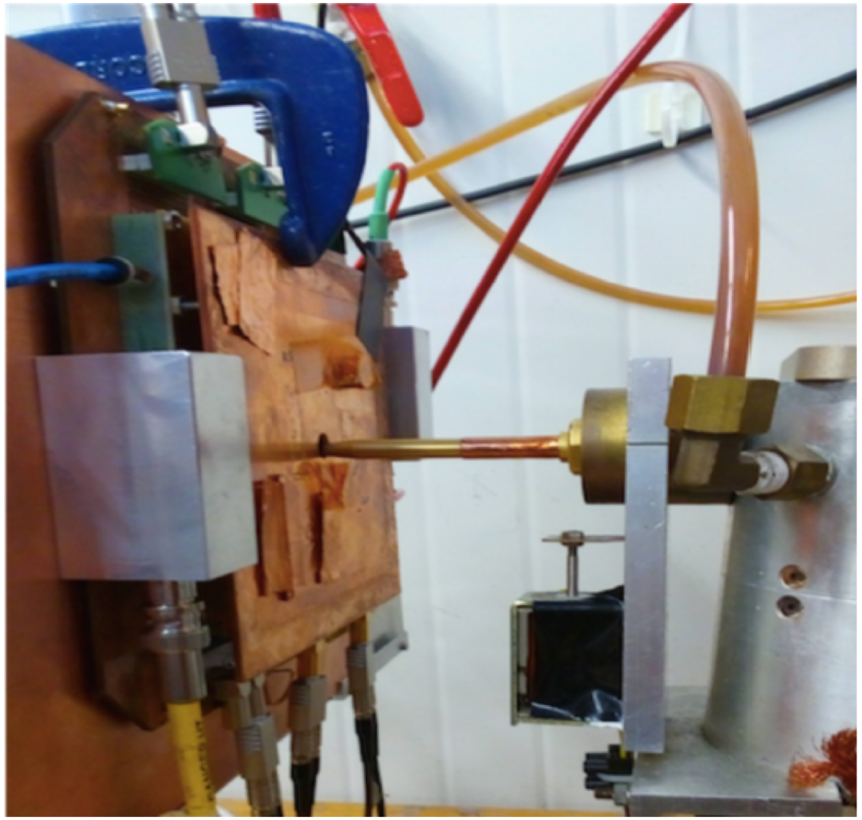
Gas mixture:

Ar:CO_2 93:7

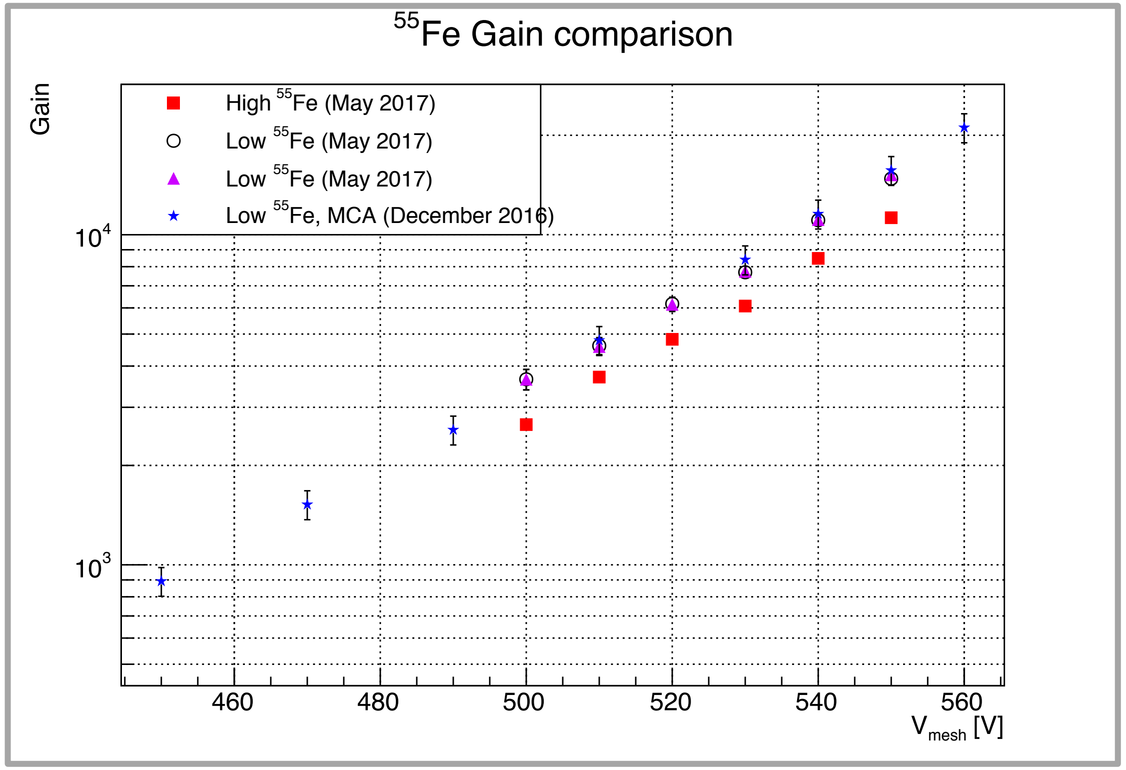


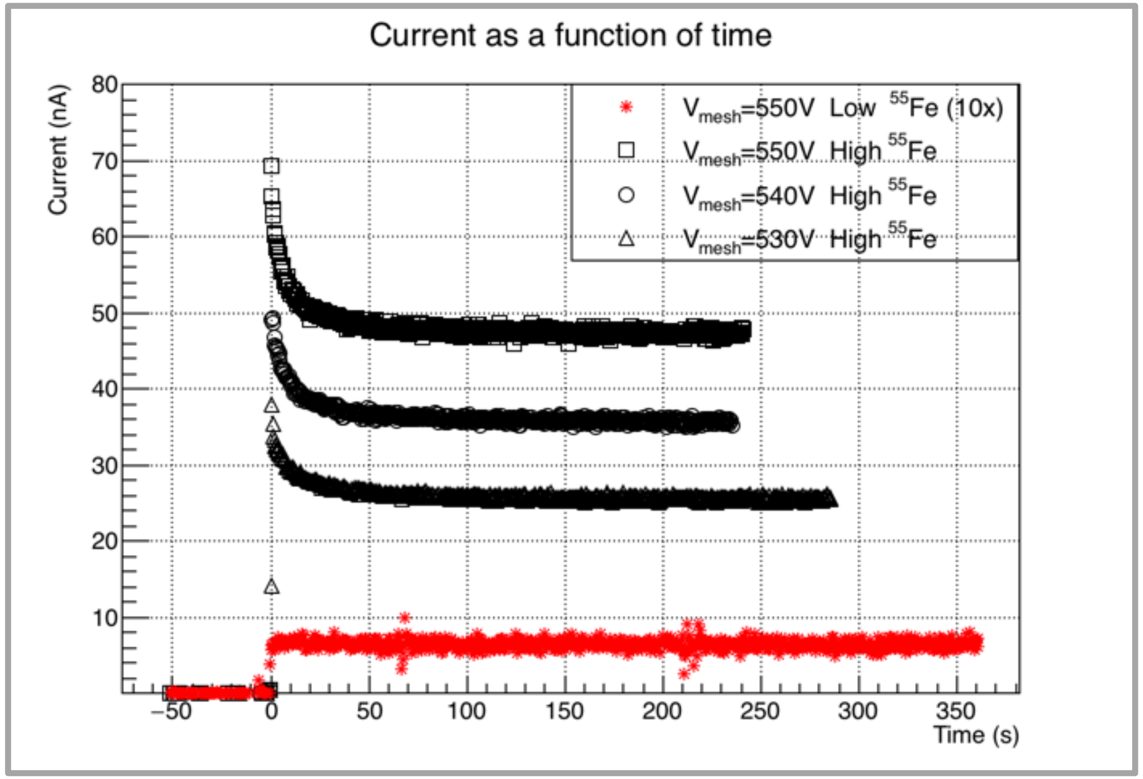
^{55}Fe source

Xrays Gun



Embedded Resistors Prototype - Gain results





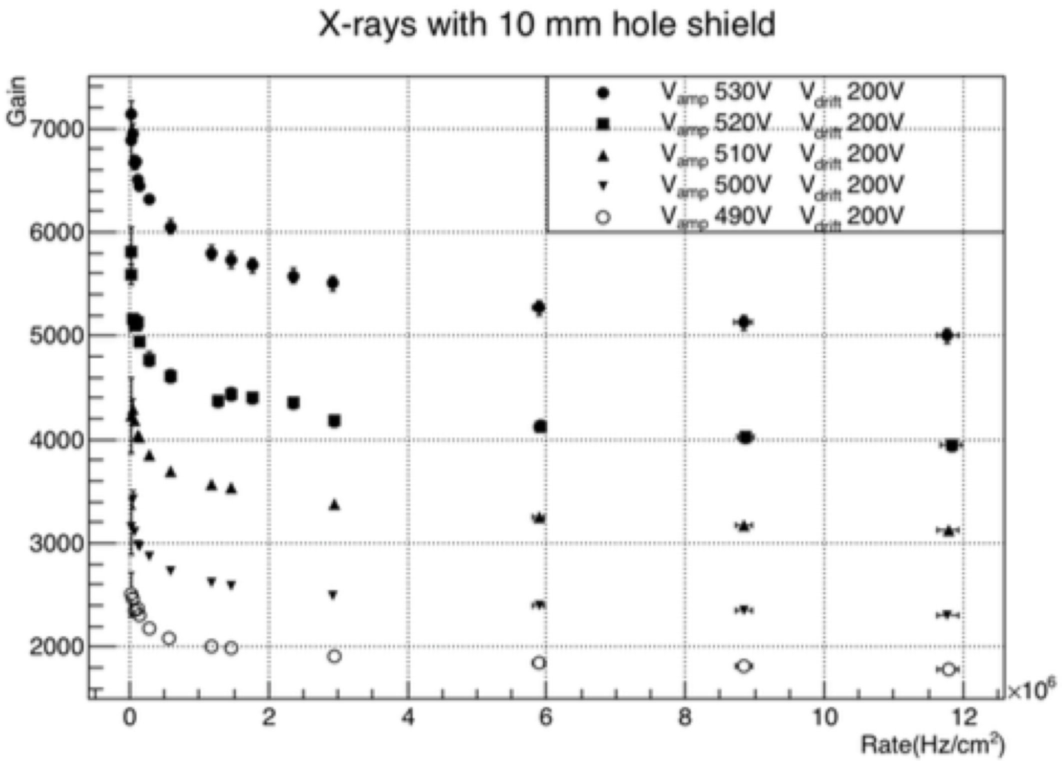
- Gain compatible with resistive strip bulk micromegas
- ∼ 20% gain reduction from Low (1.3kHz) to High (128kHz) intensity ^{55}Fe source

- observed a reduction vs time of the detector current with High intensity ^{55}Fe source
- ~25% gain reduction already observed with different intensities ^{55}Fe sources

Interpretation of the 20-25% reduction: dielectric charge up (exposed kapton between pads)

Embedded Resistors – Gain with High rate X-rays

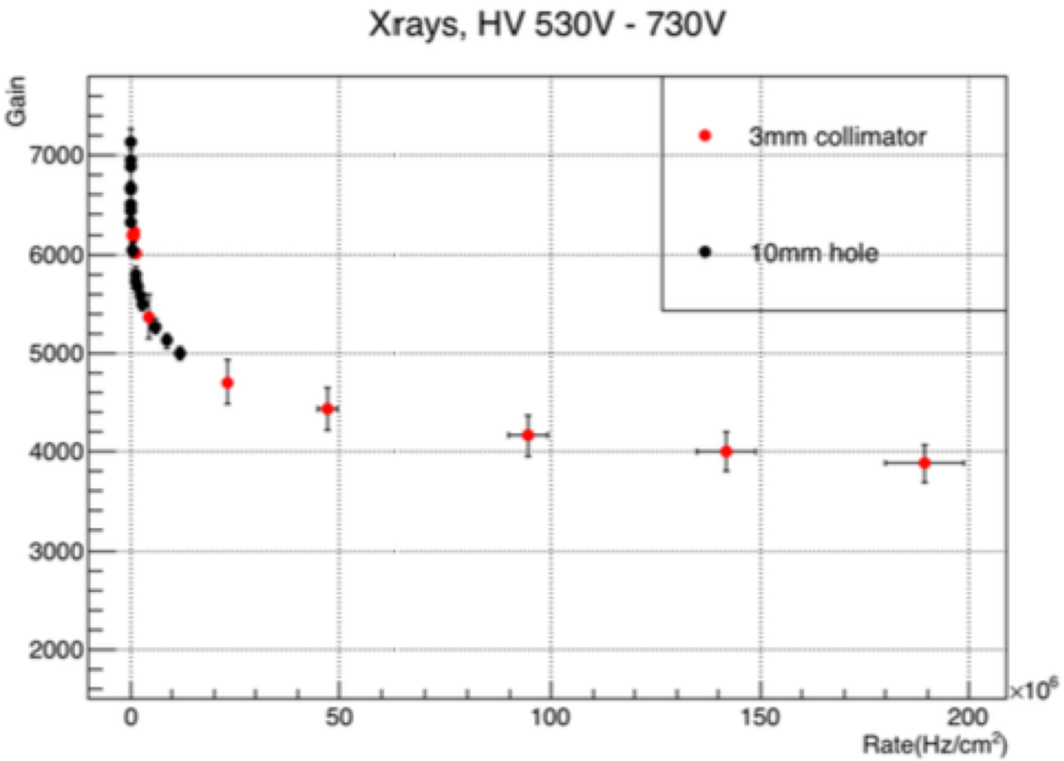
Gain as a function of rate for five different amplification voltages obtained with Cu plate with 10mm diameter hole



Gain reduction ~25% up to 12 MHz/cm^2

same reduction as already observed with 55Fe intense source

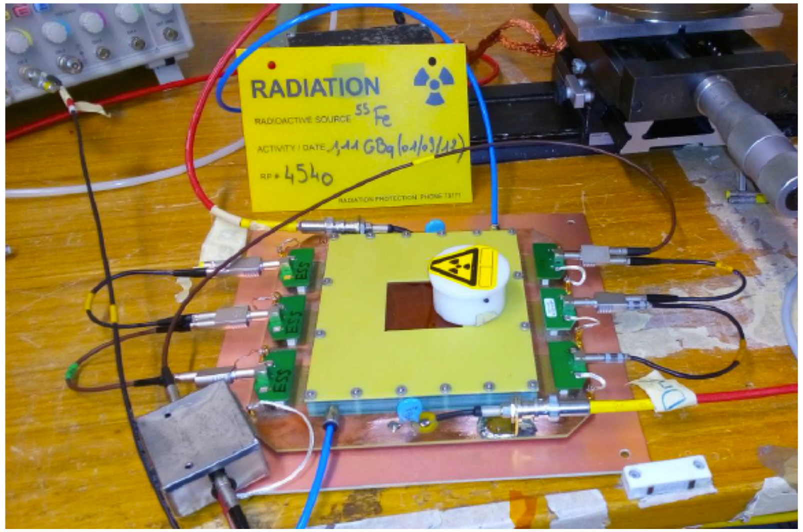
Gain in an extended range of rates obtained with a collimator of 3 mm compared with data with a Cu plate with 10mm diameter hole

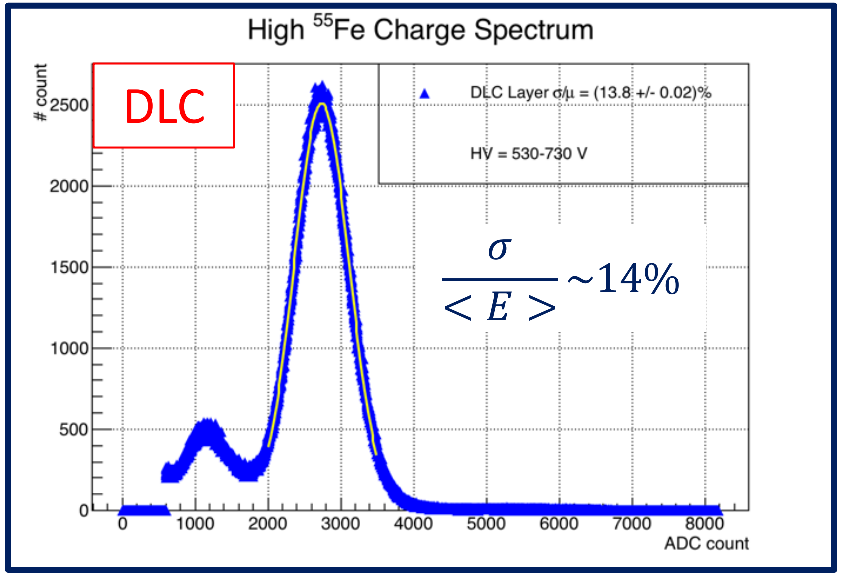


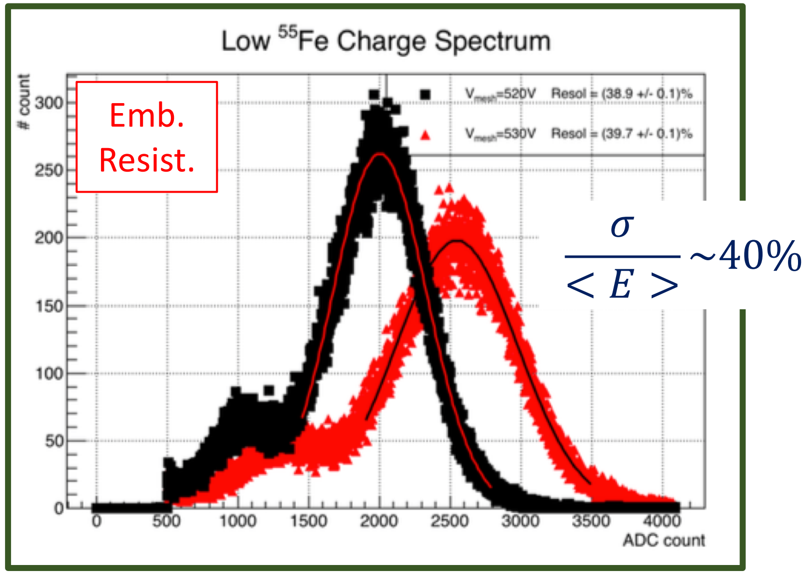
Gain drop increases as rate goes up.

Still able to reach gain of 4x10^3 at a rate of 150 MHz/cm^2 of 8 keV photons

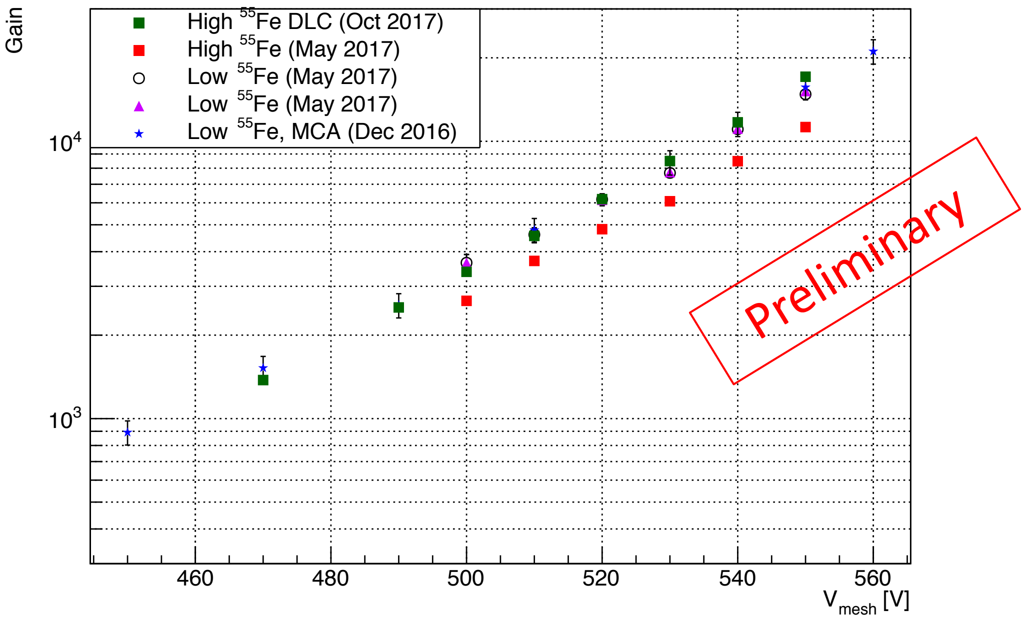
DLC prototype - Charge Spectrum and Gain







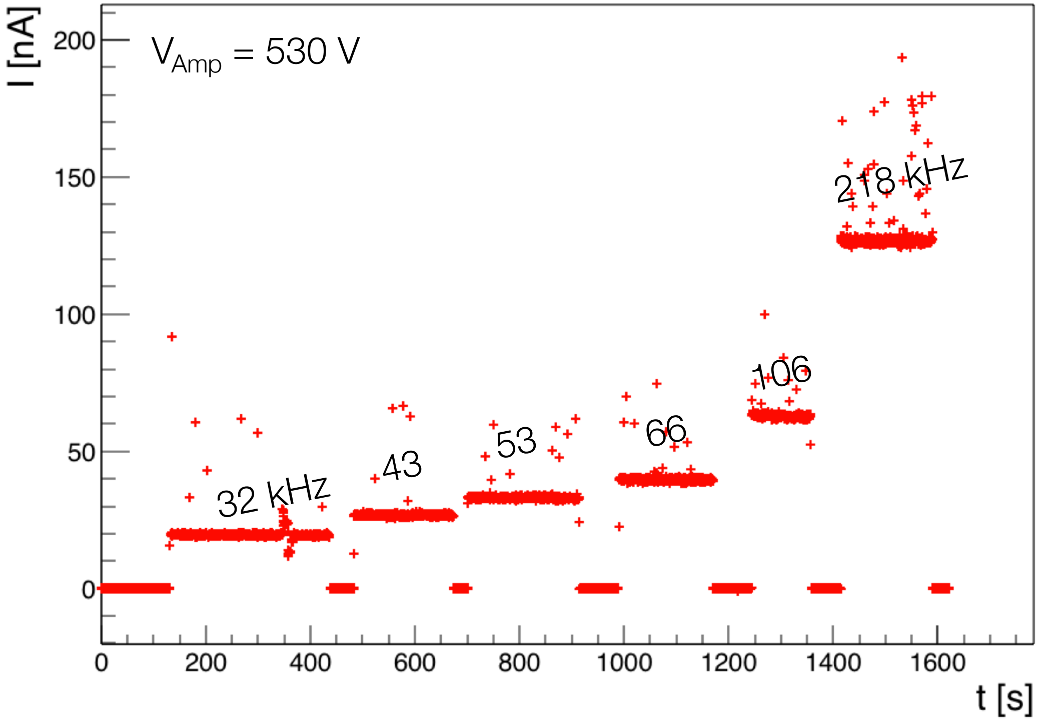
^{55}Fe Gain comparison

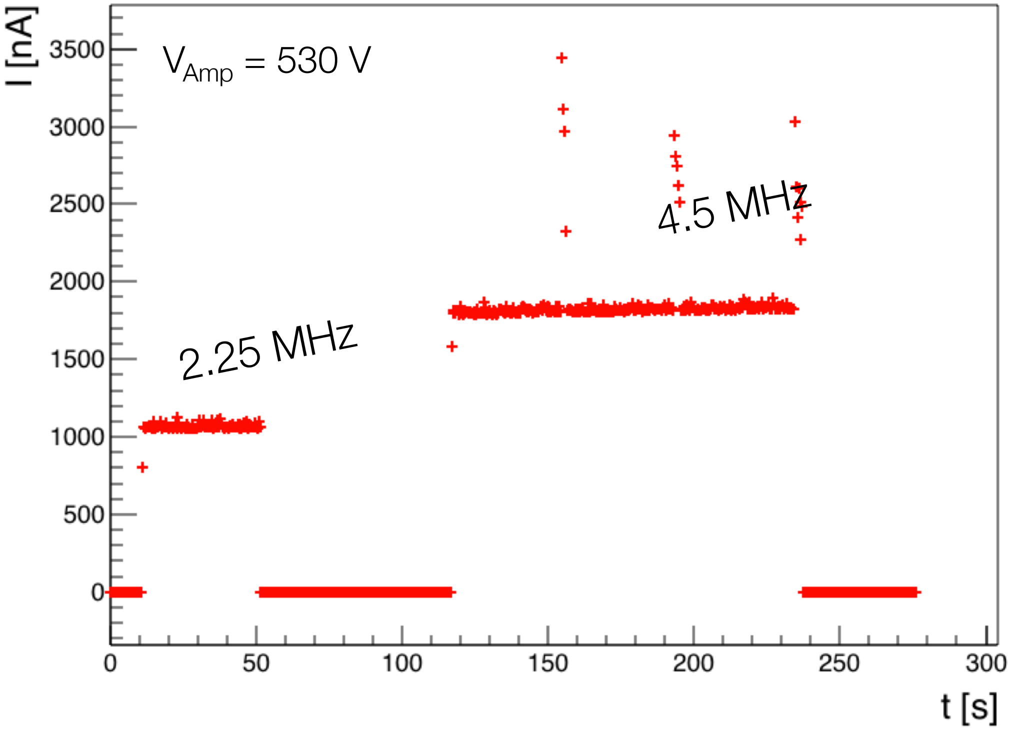


- DLC Prototype (Series 2) has much better energy resolution:
  - $\frac{\sigma}{<E>}$ ~14% Vs ~40% of Embedded Resistor
- No gain reduction observed with DLC series with high intensity ^{55}Fe source (~ 128 kHz) [first indication that there is no charge-up effect]

DLC proto - Current Stability

- Paddy_DLC Current measurement Vs Time with X-Rays on/off and increasing rate (X-Ray current) at each step
  - NO charging-up effects
  - Some instabilities (discharges) to be further investigated (a single defect? more general issue?)





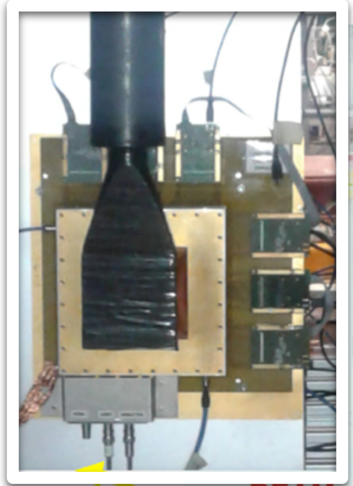
Test Beam SPS H4 at CERN

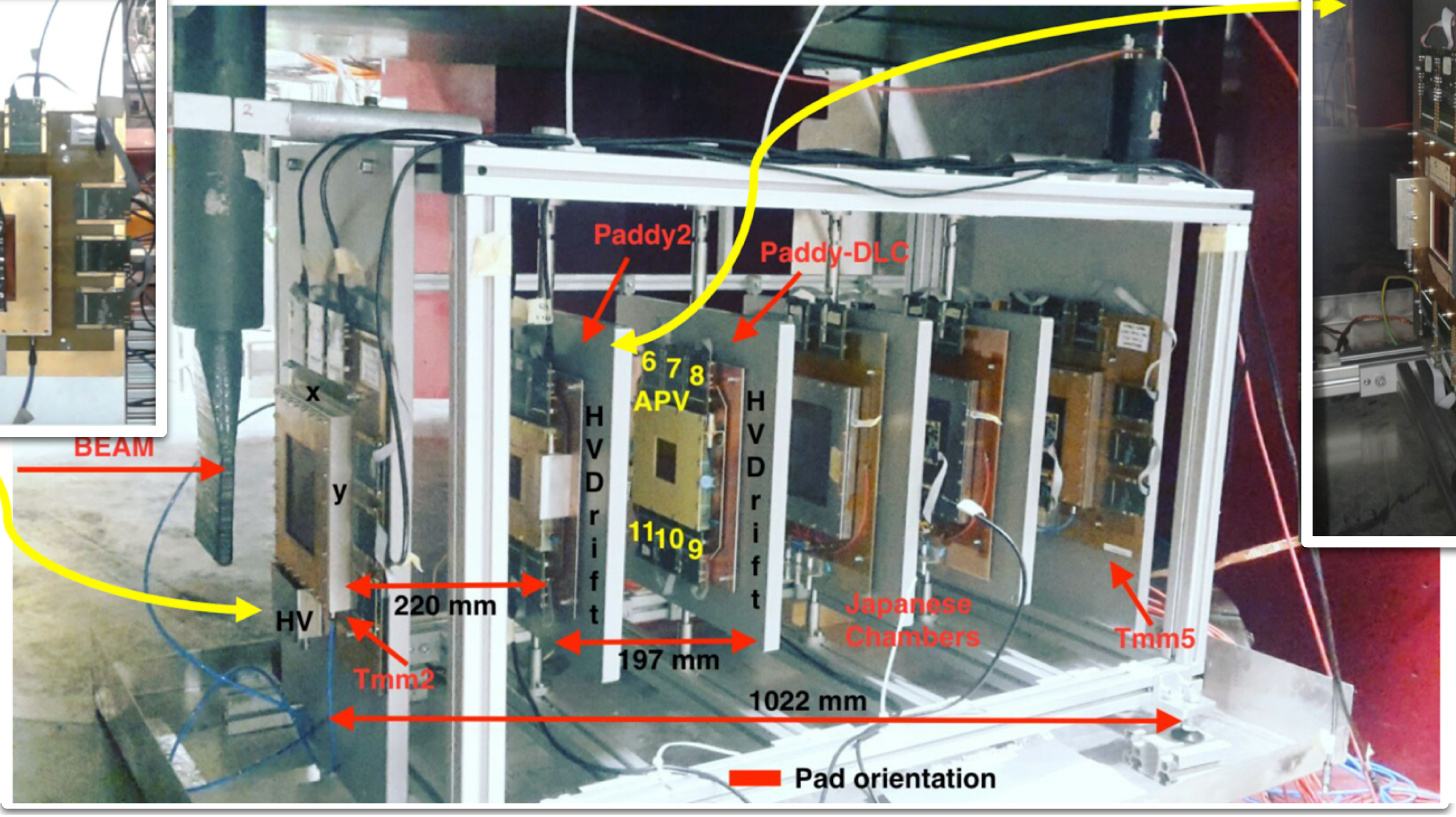
SPS H4 CERN
OCTOBER 2017

Beam:

high energy muons/pions

Both prototypes have been exposed to high energy muons and pions beams at the CERN SPS H4 beam line





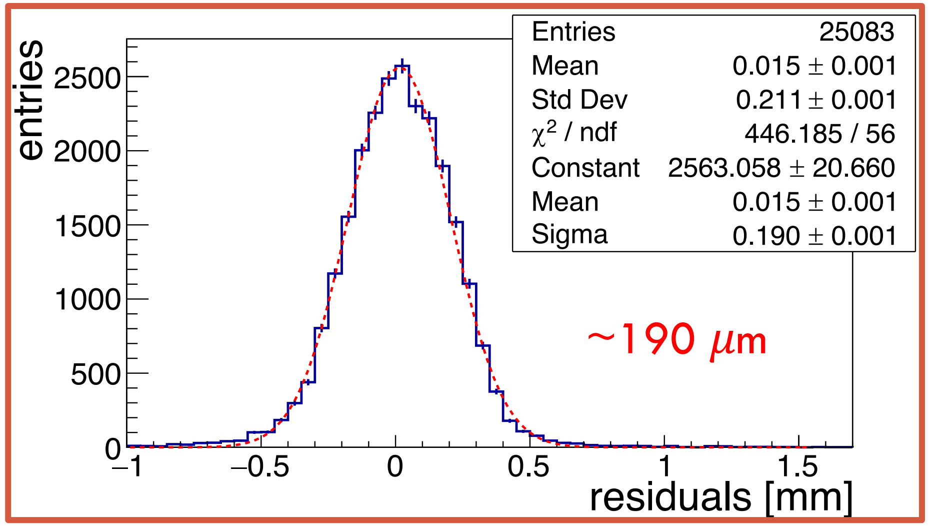
Setup:

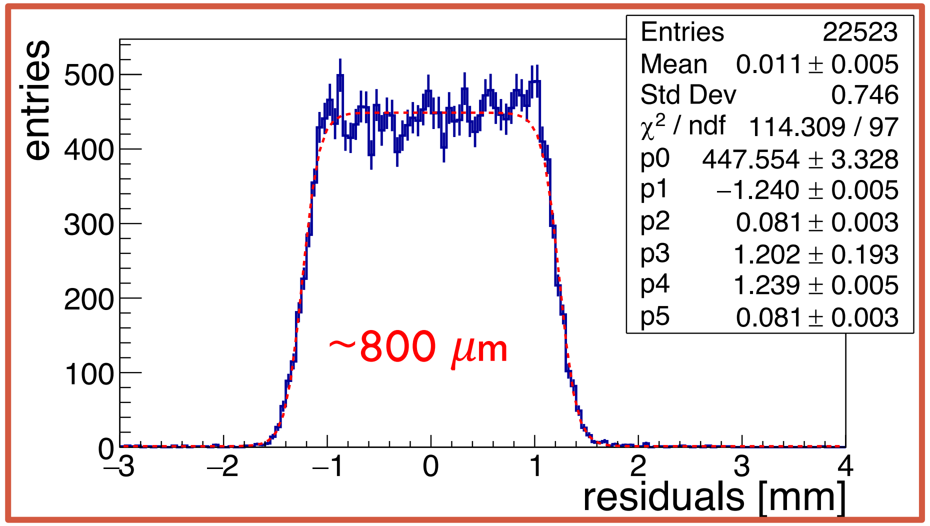
- **Embedded Resistor** and **DLC** Prototypes under test
- Tracking system: 2 Tmm strips micromegas (x-y readout) for external tracking
- Gas: Ar:CO2 93:7
- Scintillators for triggering
- DAQ: SRS + APV25 with custom DAQ

Spatial Resolution – Embedded resistors Vs DLC

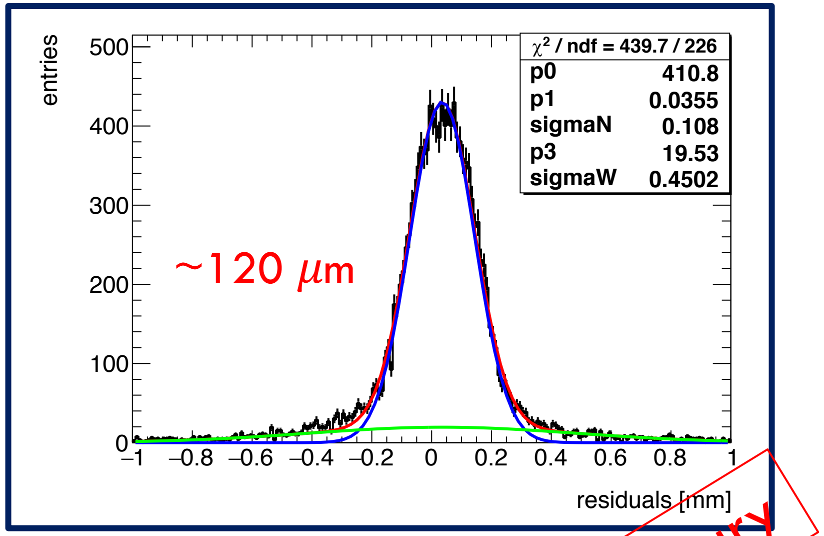
Position resolution: difference between the cluster position on prototype and extrapolated position from external tracking chambers.

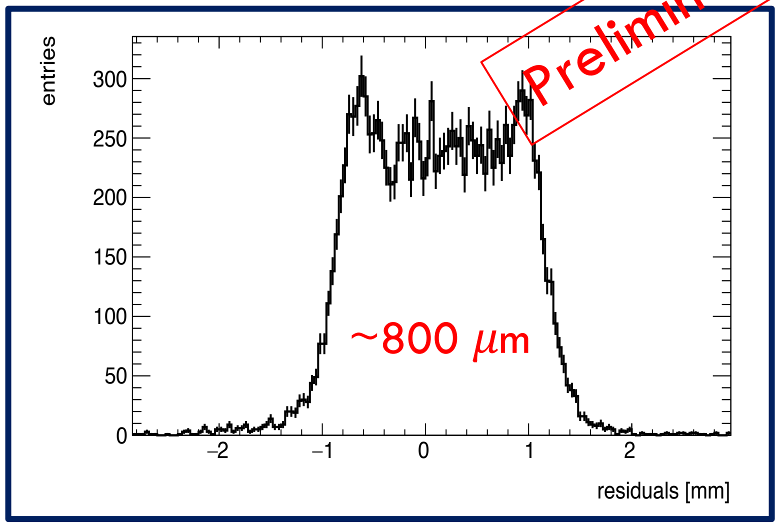
Embedded Resistors





DLC





Precision coordinate (pad pitch 1 mm)

Significant improvement of spatial resolution (pad charge weighted centroid) on the DLC prototype

More uniform charge distribution among pads in the cluster

Second coordinate (pad pitch 3 mm)

Similar resolution.

Dominated by single pad cluster (in this coordinate)
→ 3 mm/√(12) = 0.866 mm

Summary

- Two small-pad resistive micromegas, with different concepts of the spark protection resistive system, have been tested and compared :
- Series-1 Embedded Resistor type with patterned resistive layer shows
  - a very good performance under high rate (operate with a gain of 4000 at 150 MHz/cm2 with X-rays);
  - moderate energy resolution ($\frac{\sigma}{<E>} \sim 40\%$) (not critical for us);
  - good position resolution (190 μm);
  - evidence of dielectric charge-up effects (reduction of ~25% in gain and then saturate)
- Series-2 with uniform DLC resistive layer PRELIMINARY results show:
  - Much better energy resolution ($\frac{\sigma}{<E>} \sim 10\%$) (expected – more uniform electric field – no pad border effects);
  - Good performance under high rates up to several MHz/cm^2
  - no charge-up effects;
  - very good position resolution (~120 μm);

THANK YOU!

ACKNOWLEDGEMENT

CERN RD51 Collaboration for the continuous support and the CERN GDD Lab for MPGD tests.

Rui De Oliveira and Antonio Teixeira (CERN EP-DT)

R&D based on previous developments of Pad micromegas for COMPASS and for sampling calorimetry :

- C. Adloff et al., Construction and test of a 1x1 m^2 Micromegas chamber for sampling hadron calorimetry at future lepton colliders NIMA 729 (2013) 90–101.
- M. Chefdeville et al. Resistive Micromegas for sampling calorimetry, a study of charge-up effects, Nucl. Inst. Meth. A 824 (2016) 510.
- F. Thibaud at al., Performance of large pixelised Micromegas detectors in the COMPASS environment, JINST 9 (2014) C02005.

DLC double resistive layer configuration re-arranged from microResistive Well R&D:

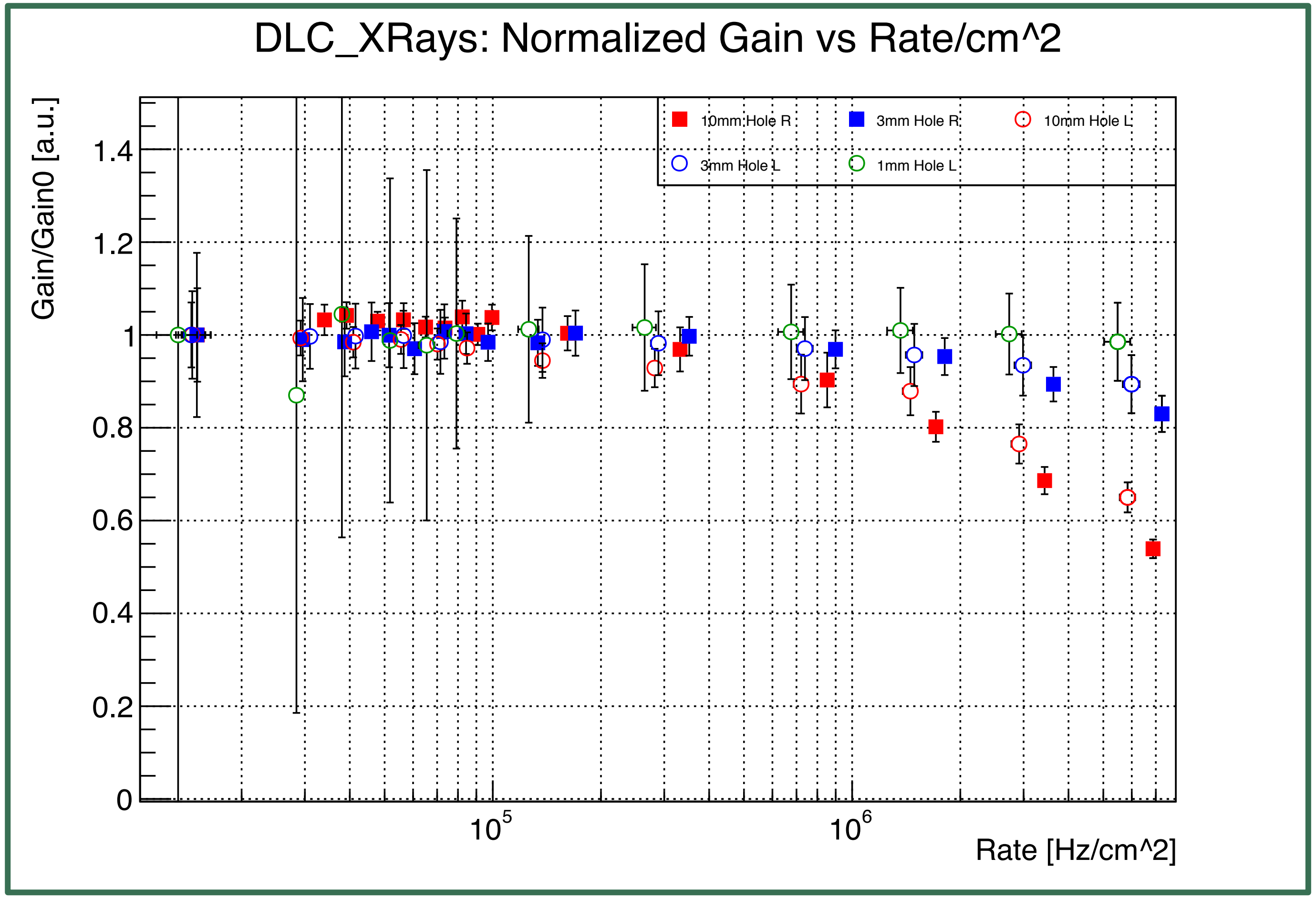
- G. Bencivenni et al., “The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD” 2015_JINST_10_P02008
- M. Poli-Lener “The μ-RWELL detector for the the phase 2 upgrade of the LHCb Muon System Upgrade” TALK this morning

BACKUP

DLC proto - Gain Vs rate

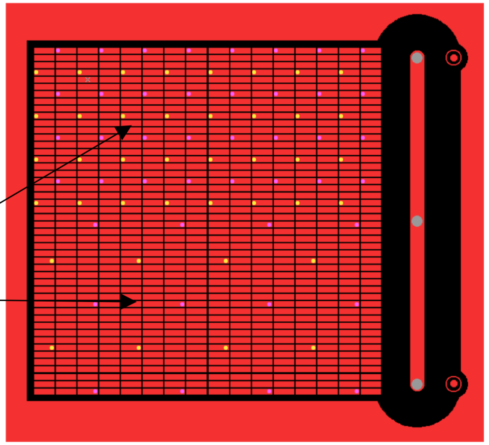
Gain drop as a function of X-rays rate, spot size and impact position (different distance of grounding vias)

- Gain drop of about 20% at few MHz/cm^2 with a sheet resistivity of the DLC layer of **70 MΩ/sq**
- With 1 mm wide photon spot no gain drop is observed up to several MHz/cm^2
- Gain drop slightly depends from the pitch of the conducting vias between the two DLC layers and the readout pads.



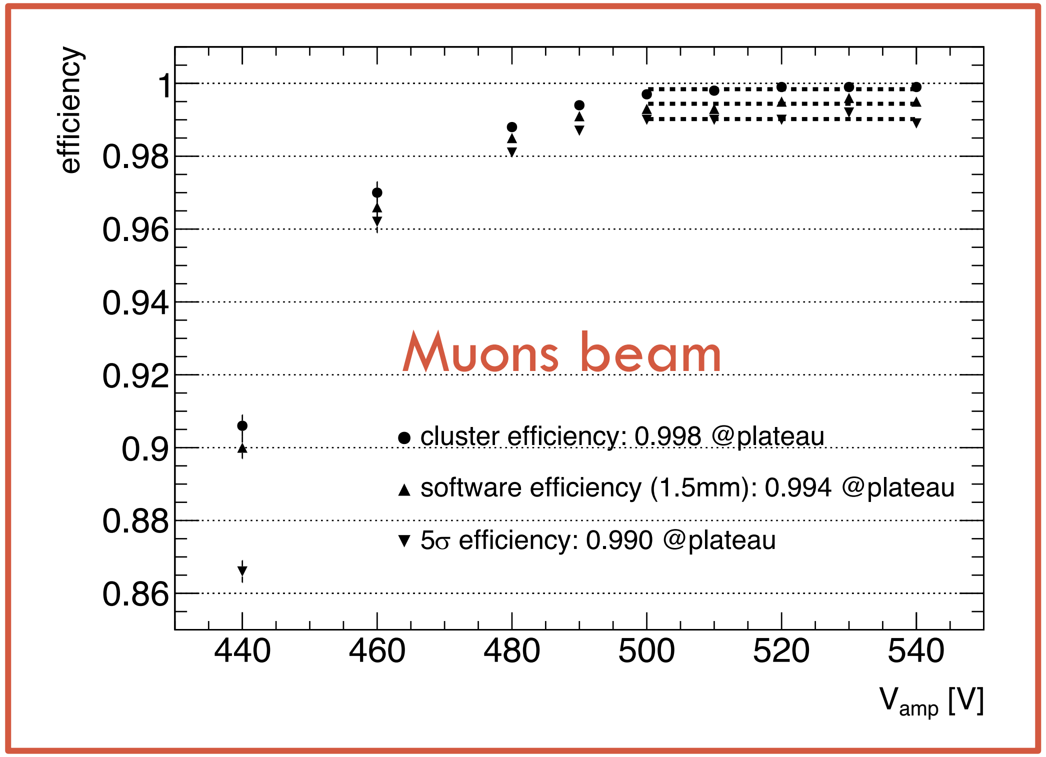
Two regions with different pitch of the grounding vias

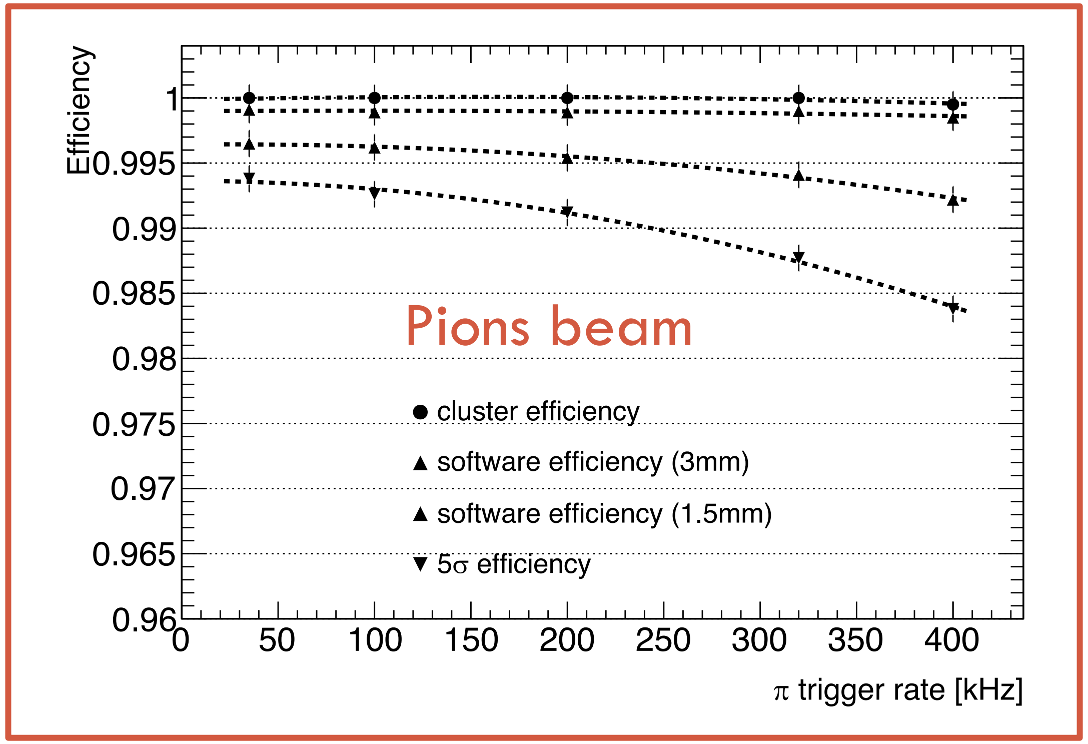
- One region with vias on the two layers **every 6 mm.**
- The other **every 12 mm**



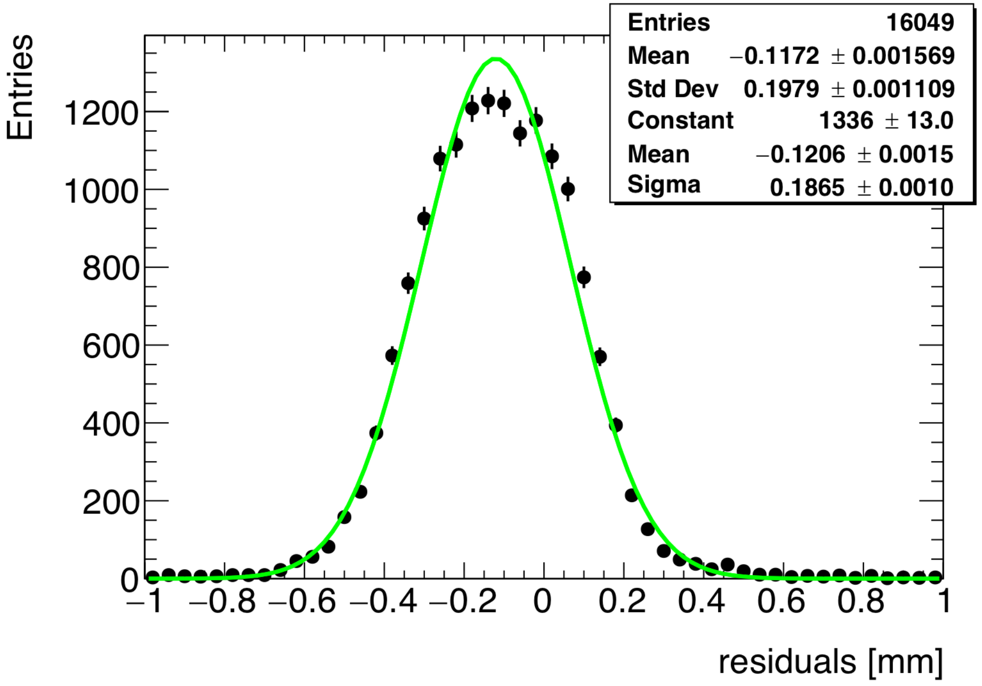
Embedded Resistors EFFICIENCY

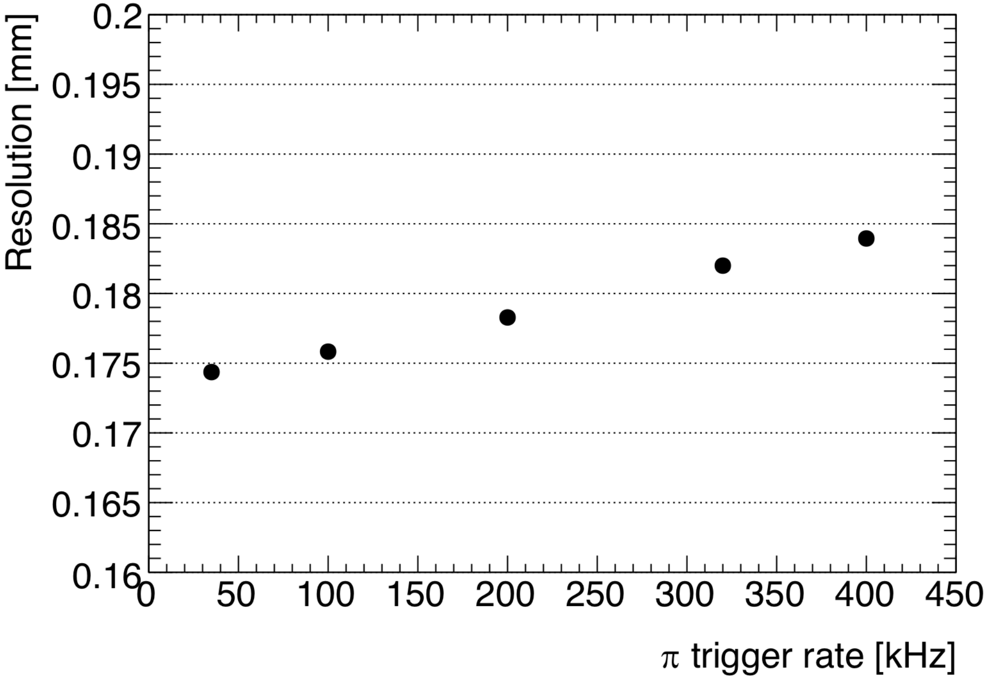
- Efficiency greater than 99% for muons and still above 98% for high energy pions up to a trigger rate of 400 kHz, corresponding to a pion rate of few MHz/cm2 in the middle of the pion beam spot





Embedded resistor - muon and high rate pion spatial resolution





Next Steps and Outlook

- Next steps are following two parallel paths:
  - Optimizing sheet resistivity and pitch of the conducting vias pattern in DLC double layer prototype to cope with the requirement of a full operation beyond tens of MHz/cm2
  - A first version of a prototype with embedded electronics on the back-end of the anode PCB have been built to solve the problem of the signal routing when scaling to larger surface
  - Unfortunately the first prototype showed many electrical problems.
  - After the debug a second version is under production