SMALL-PAD RESISTIVE MICROMEGAS FOR HIGH RATE ENVIRONMENT: PERFORMANCE OF DIFFERENT RESISTIVE PROTECTION CONCEPTS.

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ON BEHALF OF "PADDY R&D" COMMUNITY:

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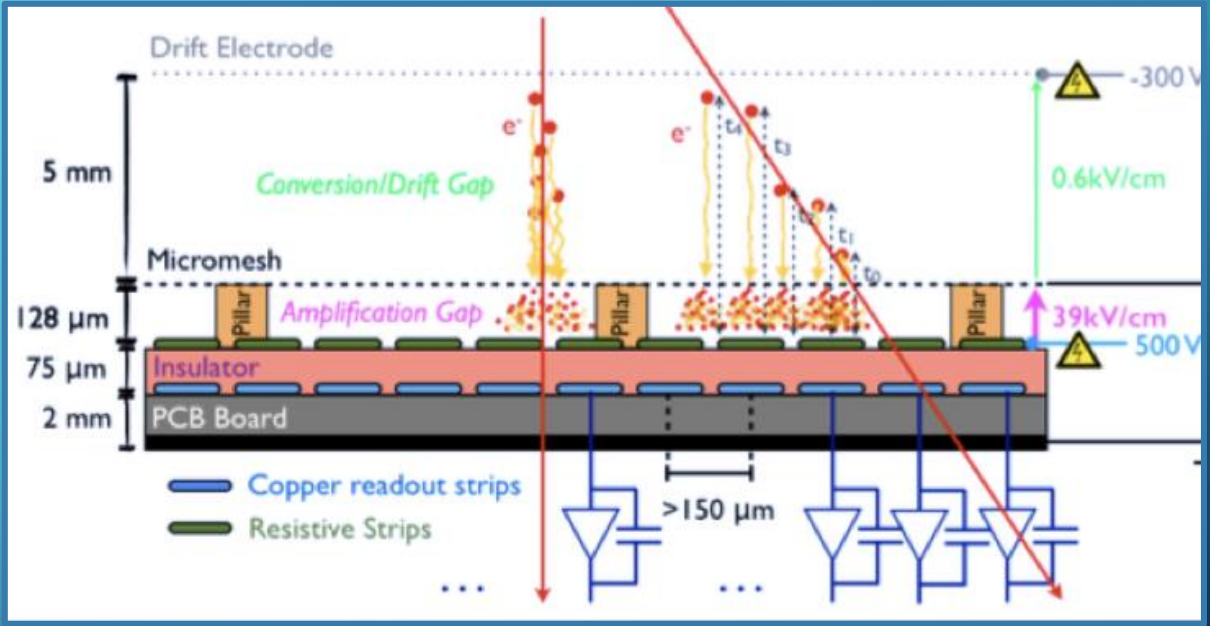
DETECTOR CONCEPT AND MOTIVATION

- Resistive Micromegas belongs to MPGD family:

- A metallic micro mesh separates the drift volume (2-5 mm thick) from the amplification volume (~100 μm thick);
- electrons and ions produced in the amplification volume are collected in 1 ns and ~100 ns respectively;
- spatial resolution < 100 μm independently from the incoming track angle



- Resistive Micromegas have been developed for ATLAS New Small Wheel upgrade
  - add resistive anode strips on the top of the readout strips (with insulator in between) to suppress discharges.

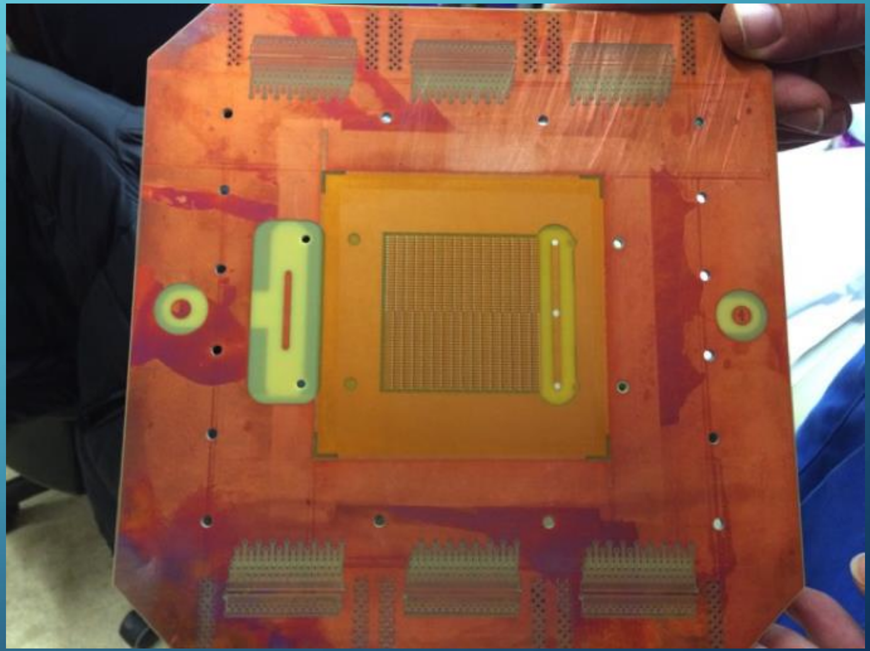
DETECTOR CONCEPT AND MOTIVATION

- The "ATLAS" resistive strip micromegas with a wide surface (about 2 m^2) will operate at a moderate rate of about 20 KHz/cm^2.
- To increase the rate capability and reduce the occupancy you must have a much finer granularity.
- Resistive Micromegas with O(mm^2) pad readout aiming at precision tracking in high rate environment without efficiency loss up to several MHz/cm^2;
- Technical solution inspired by a similar R&D by COMPASS and others within RD51 Collaboration;
- R&D started in 2015 (INFN and University of Napoli and Roma3) in collaboration with CERN and with the CERN PCB Workshop (Rui De Olivera) for prototype construction.

DETECTOR DESCRIPTION: READOUT PADS

- The readout pad segmentation and the routing of the signal to the connectors for the front end electronics is the same for both prototypes

- 48x16 = 768 pads with pitch 1x3 mm^2
- active surface is 48x48 mm^2



Other detector characteristics:

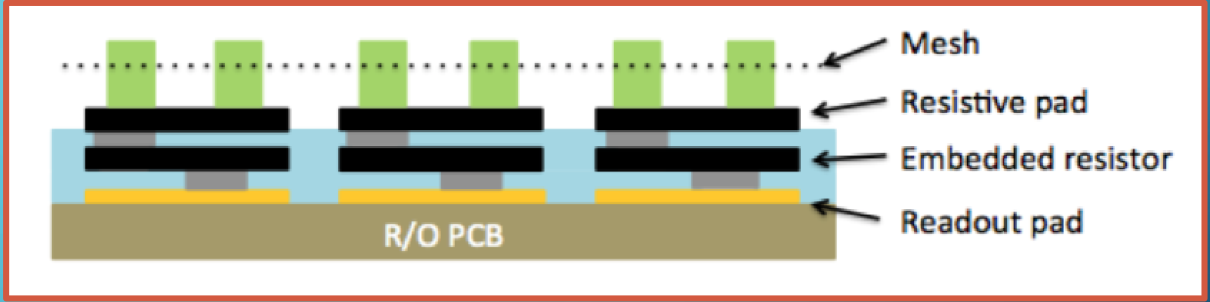
- Mesh added with bulk technique
- Conversion and drift region of 5 mm
- Operating with Ar/CO_2 (93/7) gas mixture

DETECTOR DESCRIPTION: RESISTIVE LAYOUT

- Two different resistive layout have been developed:

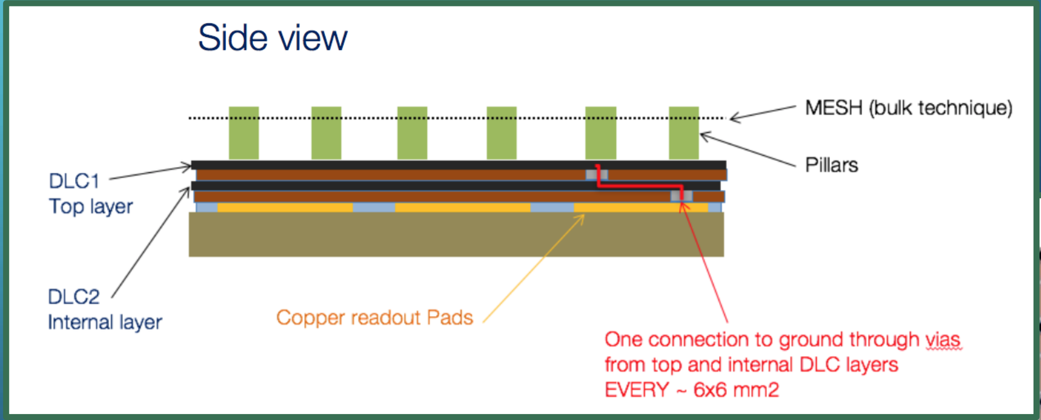
- FIRST SERIES: EMBEDDED RESISTOR:

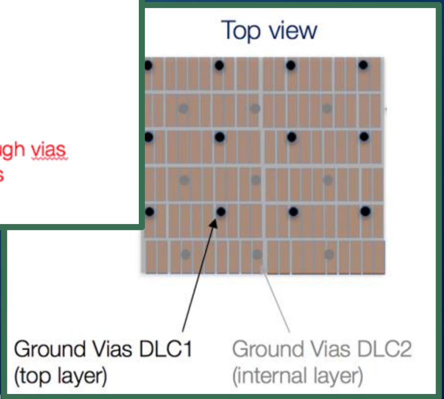
Pad-patterned embedded resistor layout with screen printing (3-7 MΩ) with the same size of readout pads.



- SECOND SERIES: DLC LAYER

Two continuous resistive DLC layers (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



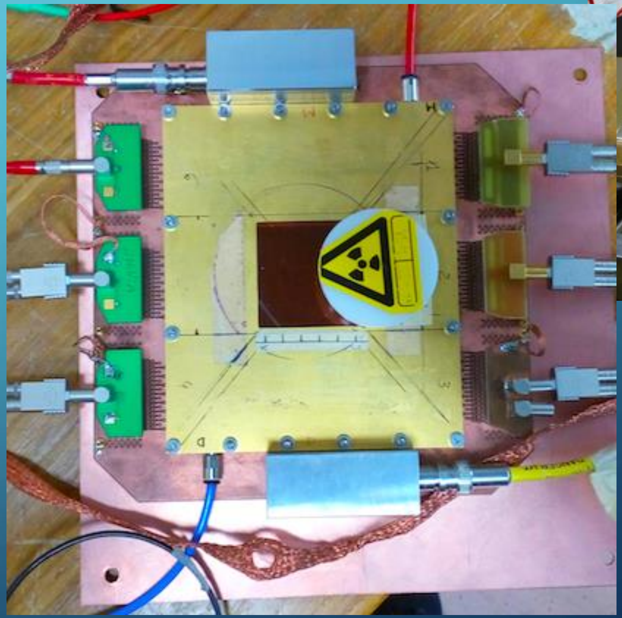


GAIN MEASUREMENTS WITH SOURCES AND XRAYS

- 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

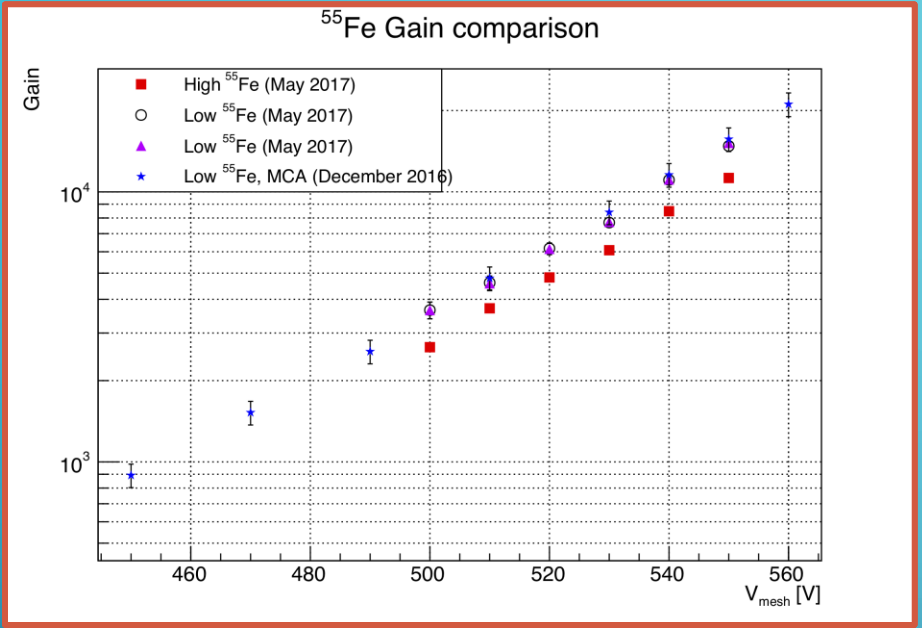
- For both prototypes gain have been measured with two methods:
  - Reading detector current from readout pads with a picoammeter and counting signal rate from the mesh
  - Analysing signals from mesh with an MCA

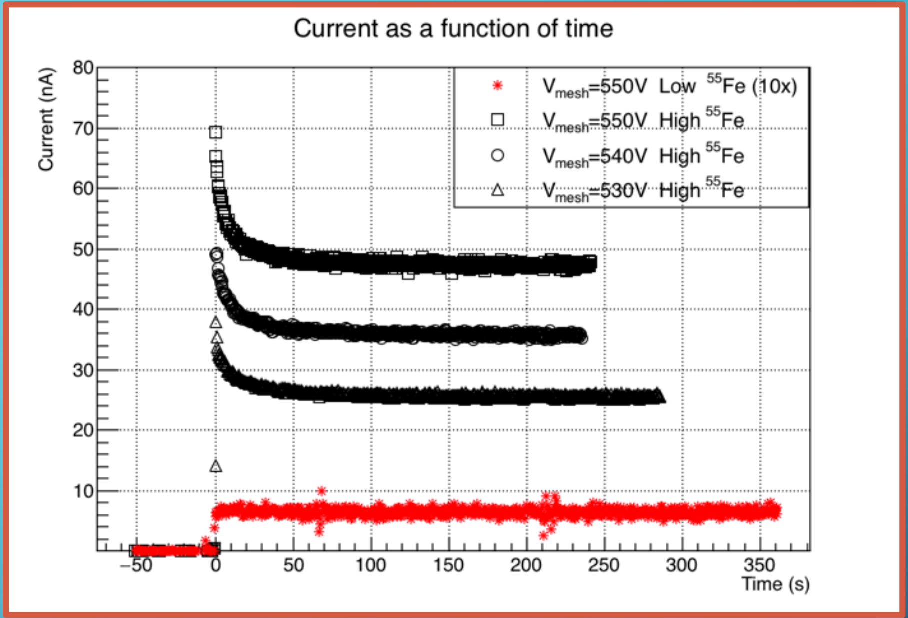
Xrays Gun



^{55}Fe source

EMBEDDED RESISTORS: GAIN AND "CHARGE UP"

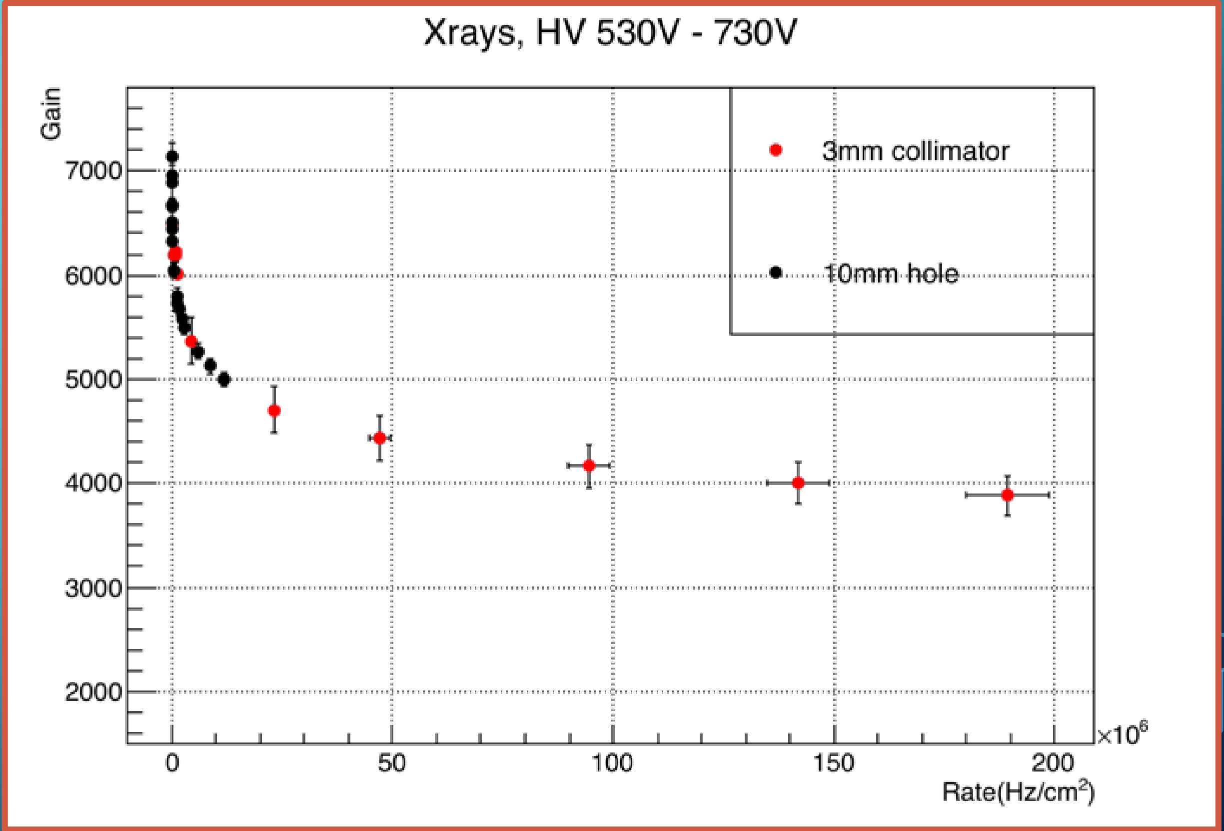




- Measured gain is compatible with resistive strip bulk micromegas
- Observed a 20% gain drop from from Low (1.3kHz) to High (128kHz) intensity ^{55}Fe source
- Observed a current drop of about 20% in current as a function of time with High ^{55}Fe source
- 20% gain reduction is due to the dielectric "charge-up"

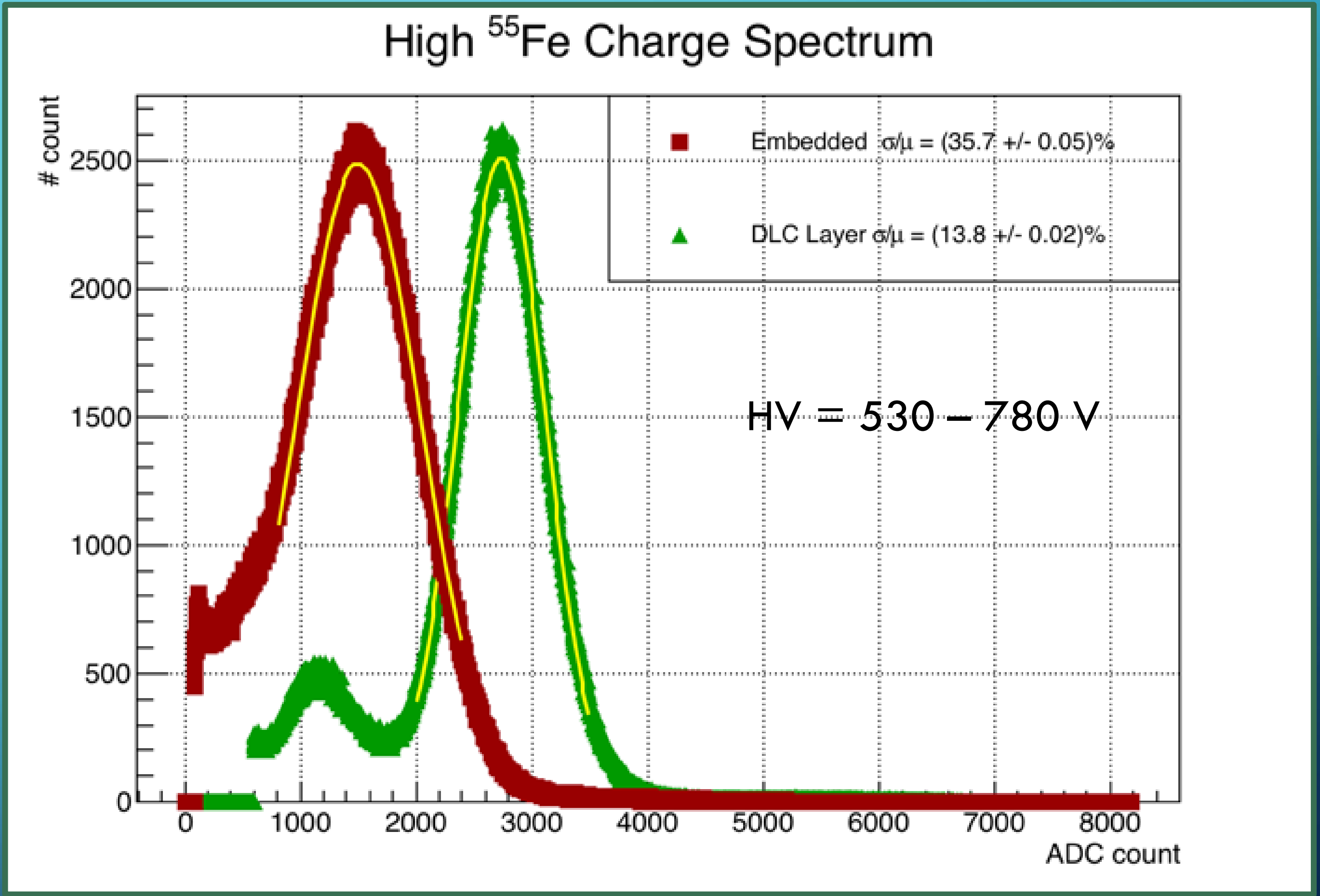
EMBEDDED RESISTOR: GAIN VS RATE

- The gain of the Embedded Resistor prototype has been measured as a function of the rate of the incident radiation.
- 20% gain reduction @ 10 MHz/cm^2 with X-Rays.
- Gain is still about 4000 for rate well above 150 MHz/cm^2, corresponding to a gain reduction of about 40%



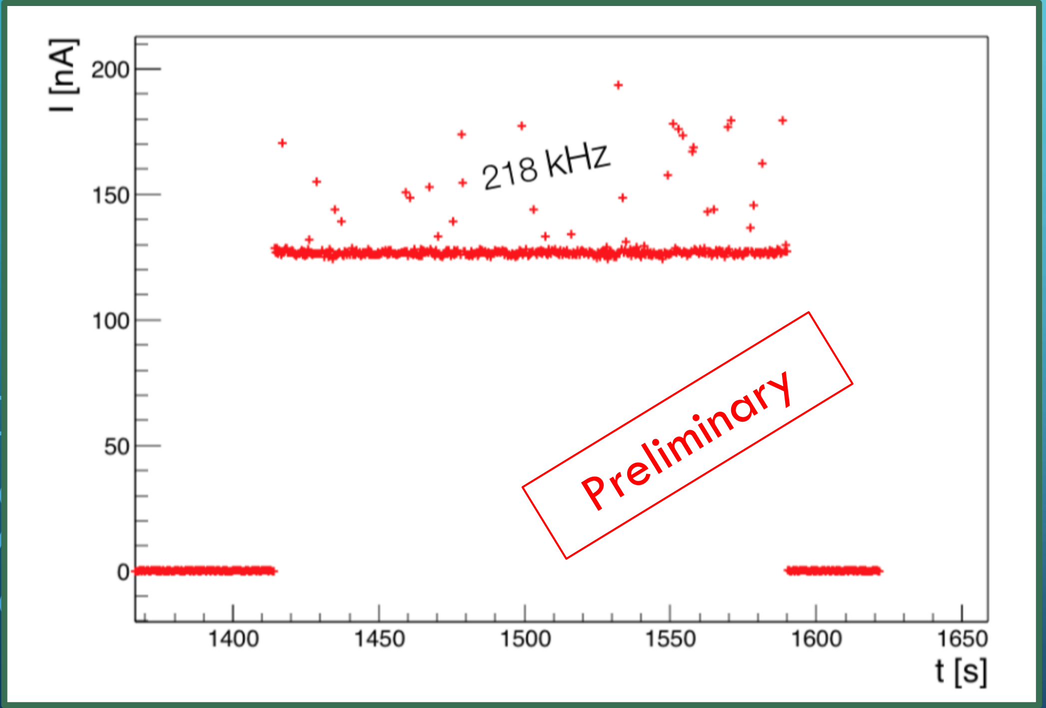
DLC LAYER: CHARGE SPECTRUM

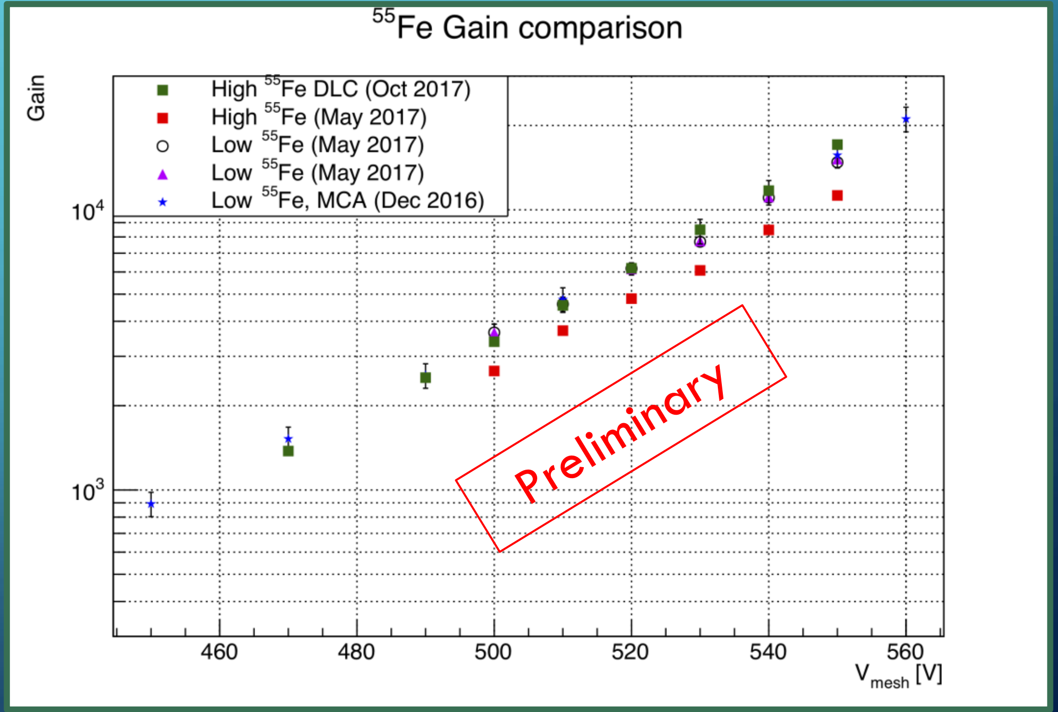
- Comparing the charge spectra measured with MCA for both prototypes is evident that the second series prototype have a better energy resolution and a slightly higher gain



DLC LAYER: GAIN AND CURRENT STABILITY

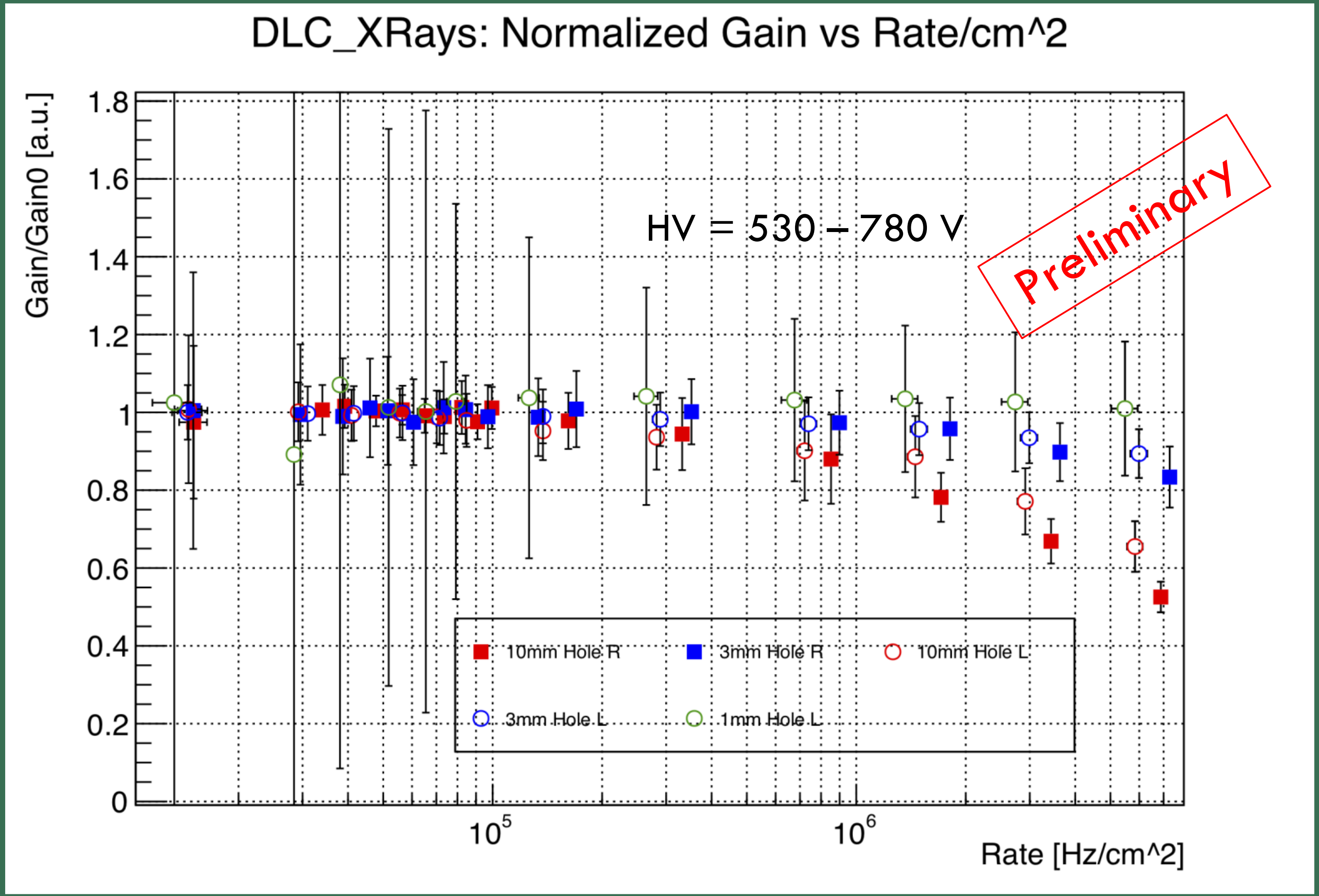
- No current (and gain) reduction as a function of time observed with DLC series
- Gain with "High55Fe" source for DLC is compatible with Embedded resistor gain with "Low 55Fe" source





DLC LAYER: GAIN VS RATE

- 20% gain drop around few MHz/cm² with a resistivity of 50-70 MΩ/□□ with X-Rays
- With 1 mm X-Rays beam spot no gain drop is observed up to several MHz/cm².
- Gain drop depends slightly from the pitch of the conducting vias between the two DLC layers and the readout pads.
    - "Right" means 12 mm pitch
    - "Left" means 6 mm pitch



DETECTOR CHARACTERIZATION: SUMMARY

Embedded resistor:

- Current (and gain) drop of about 20% after few tens seconds of irradiation at 128 kHz
  - Dielectric "charge-up"
- Energy resolution $\frac{\sigma}{<E>} \sim 30\%$
- Rate capability with X-Rays (20% gain reduction) ~ 10 MHz/cm^2

DLC Layer:

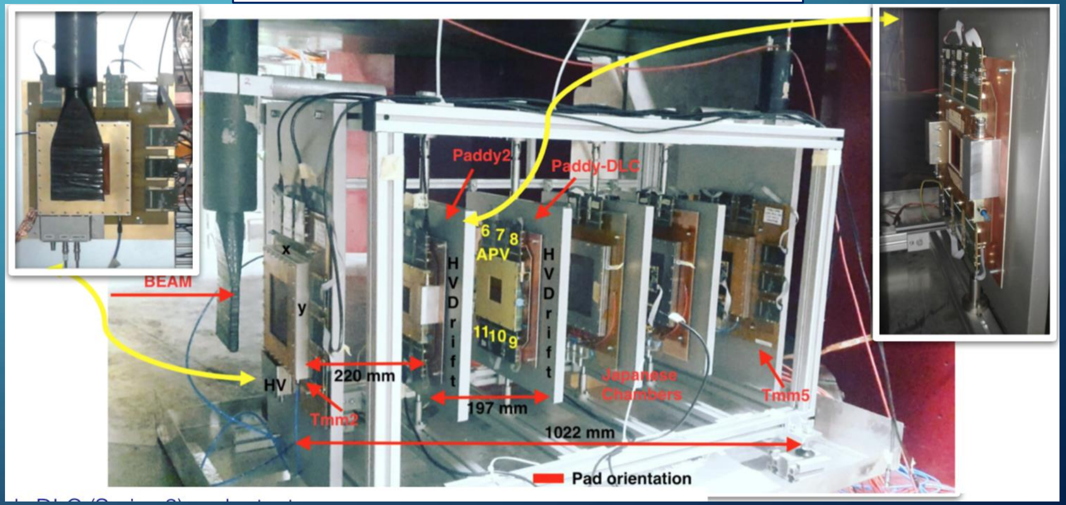
- No current and gain vs time drop shown
- Energy resolution $\frac{\sigma}{<E>} \sim 12\%$
- Rate capability with X-Rays (20% gain reduction) ~ 2 MHz/cm^2

TEST BEAM SETUP

- Both prototypes have been exposed to high energy muons and pions beams at the CERN SPS H4 beam line:
  - During 2016 only Embedded Resistor Prototype
  - During 2017 both Embedded Resistor and DLC Prototypes

- Pad signals have been readout by APV25 chip and SRS system developed by RD51 collaboration.
- Tracking system with two resistive bulk strip MM
- Scintillator hodoscope for trigger

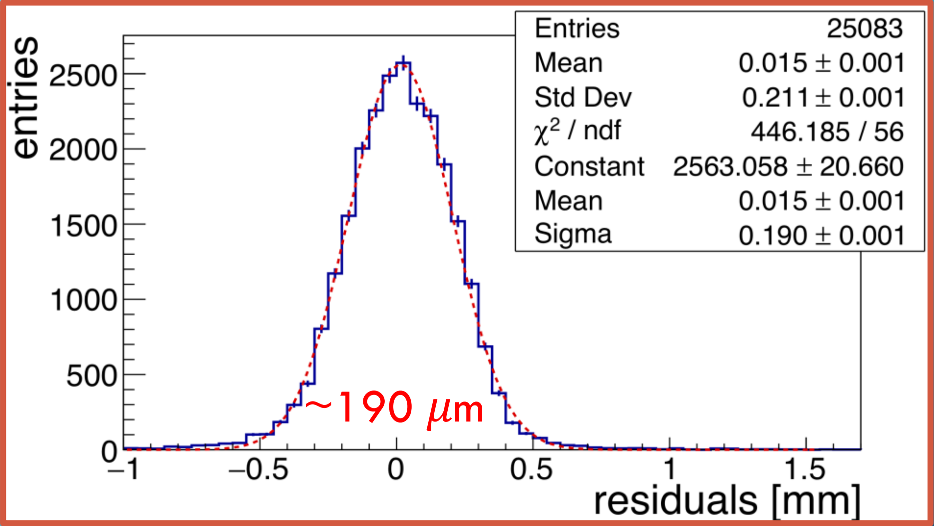
Experimental setup in 2017

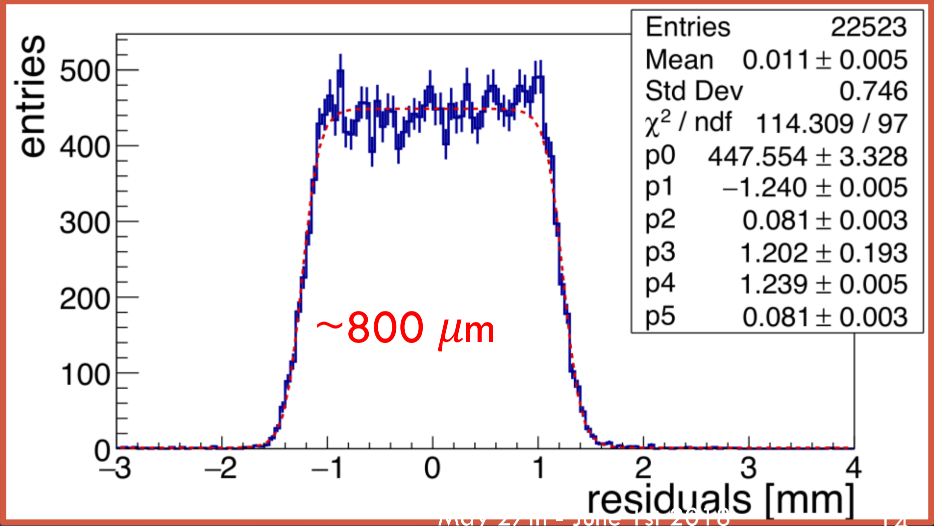


EMBEDDED RESISTOR: SPATIAL RESOLUTION

Results from muon beam (2016)

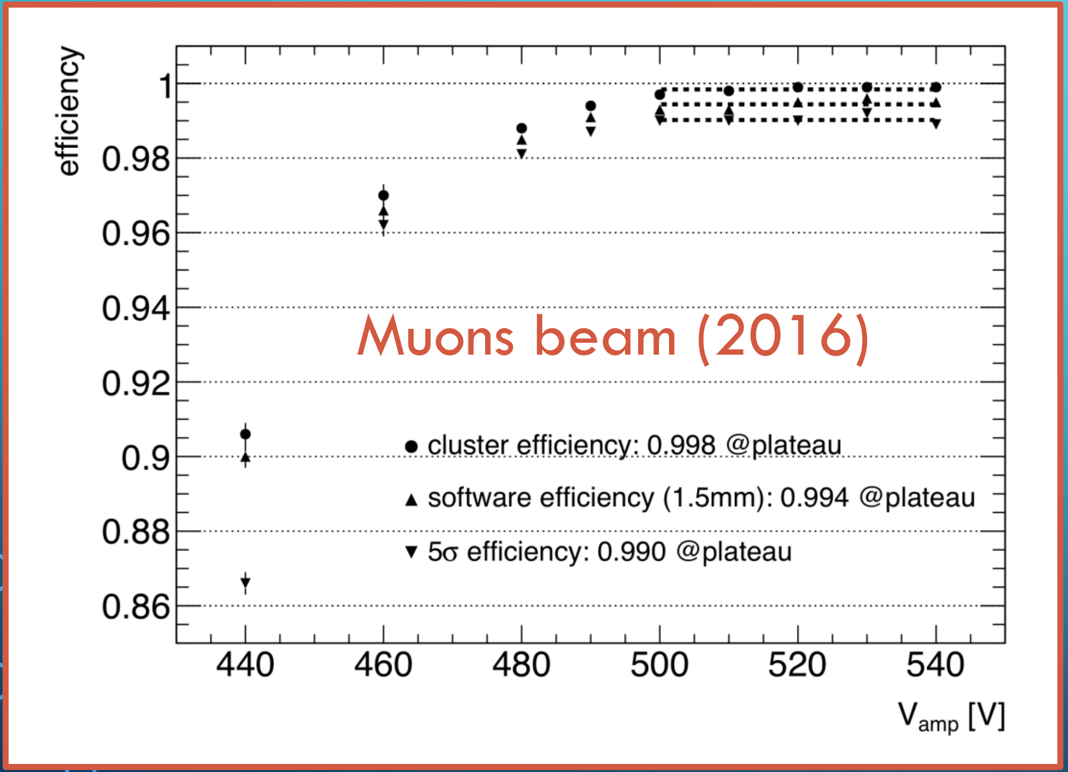
- Resolution in precision coordinate of the order or 190 μm
- Resolution in second coordinate of the order or 800 μm
- Alignment and rotation correction were applied track extrapolation error (~50µm) not subtracted

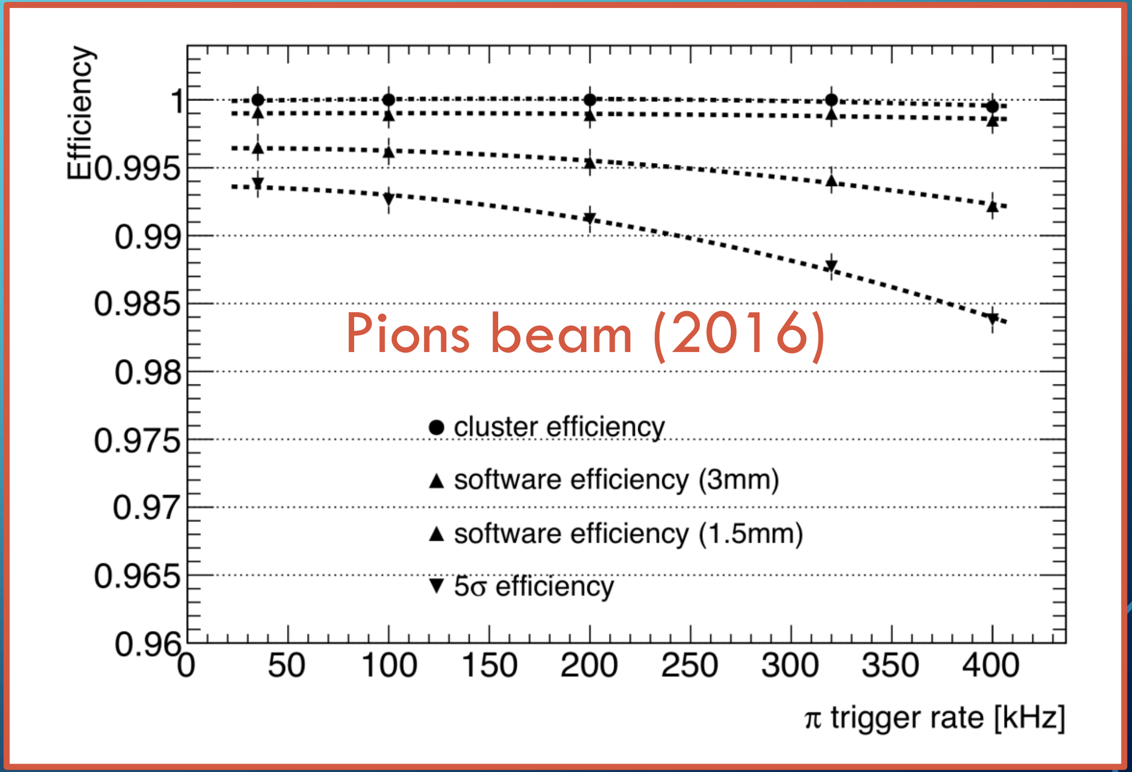




EMBEDDED RESISTOR: EFFICIENCY

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

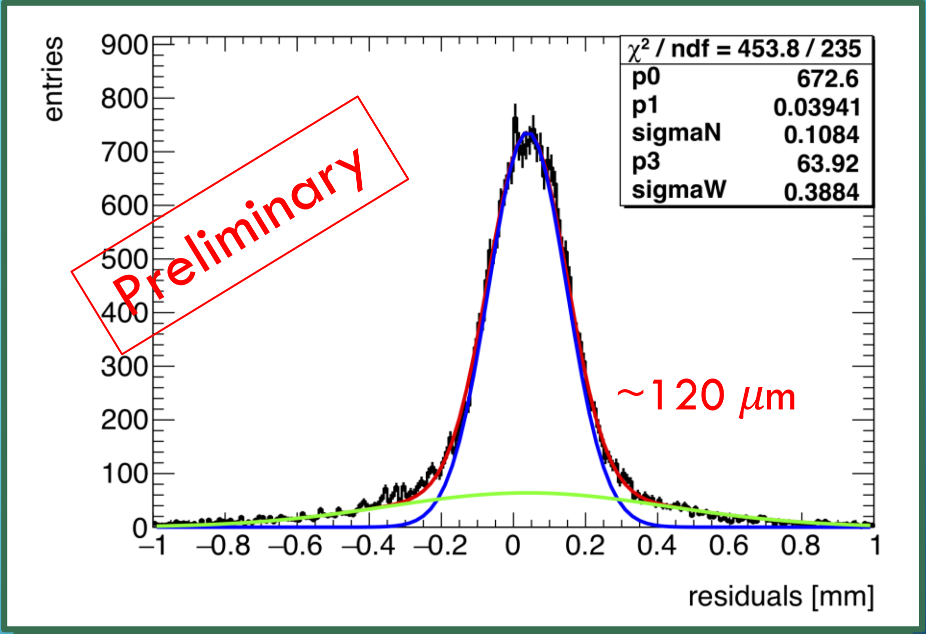


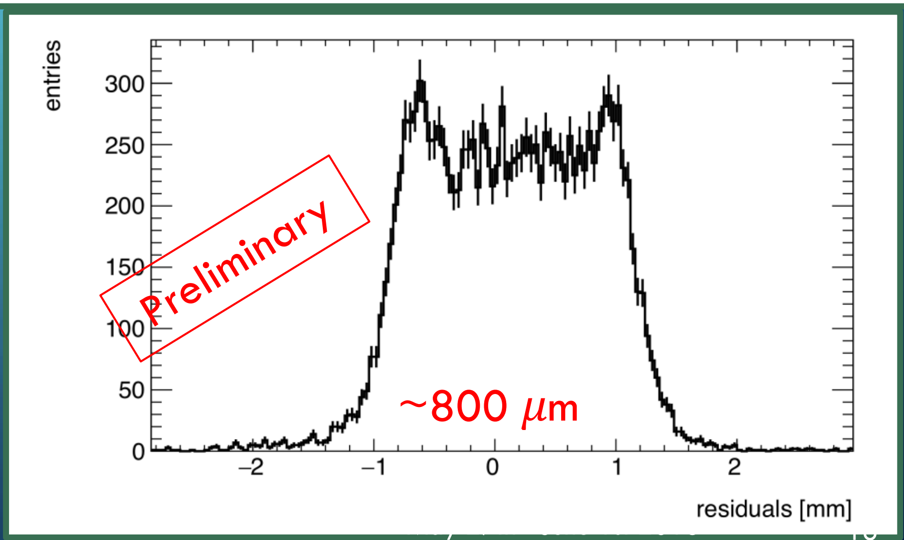


DLC LAYER: SPATIAL RESOLUTION

Results from muon beam (2017)

- Resolution in precision coordinate of the order or 120 μm
- Resolution in second coordinate of the order or 800 μm
- Alignment and rotation correction were applied track extrapolation error (~50µm) not subtracted





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/cm^2
  - 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

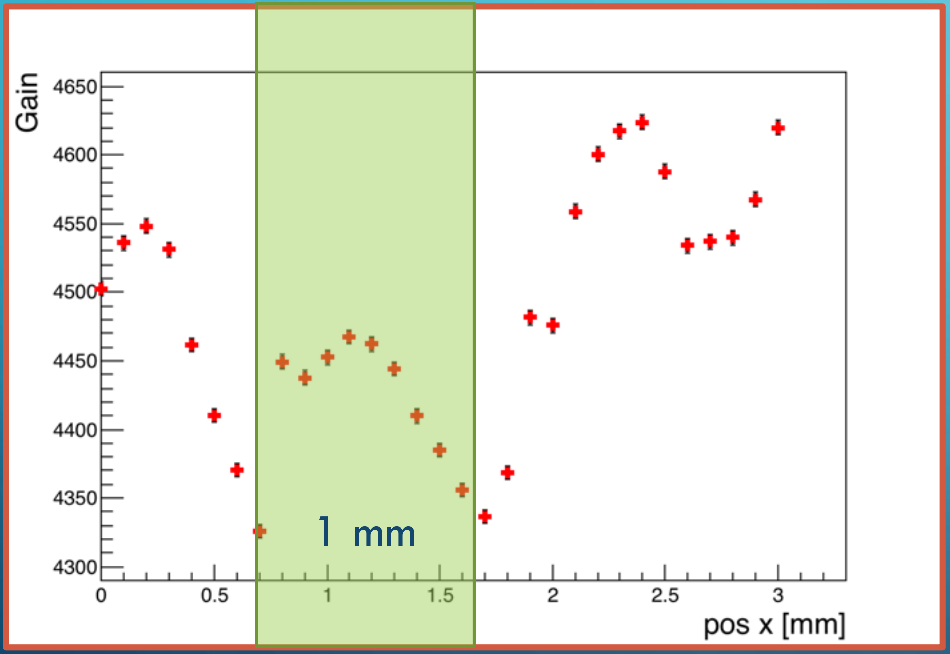
SUMMARY

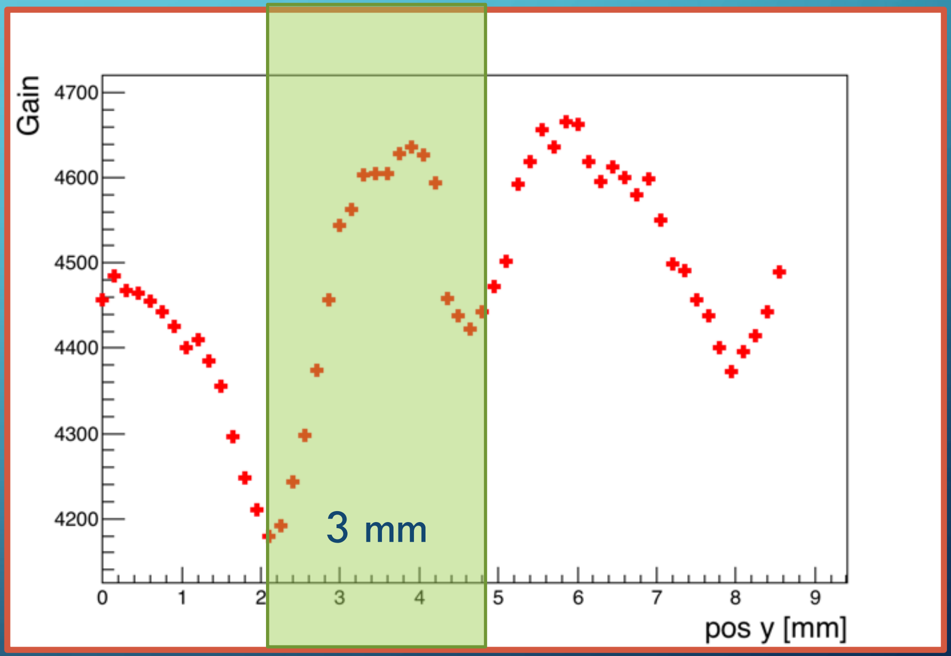
- Two small-pad resistive micromegas, with different concepts of the spark protection resistive system, have been tested and compared :
- Series-1 with patterned resistive layer shows
  - a very good performance under high rate (operate with a gain of 4000 at 150 MHz/cm2 with X-rays);
  - moderate energy resolution ($\frac{\sigma}{<E>} \sim 30\%$) (not critical for us);
  - good position resolution (~200 µm);
  - evidence of dielectric charge-up effects (reduction of ~20% in gain and then saturate)
- Series-2 with uniform DLC resistive layer PRELIMINARY results show:
  - Gain drop vs rate with X-rays is small (20% @ 2 MHz) even with a too high DLC layer sheet resistivity (50 MΩ/□□).
  - Much better energy resolution ($\frac{\sigma}{<E>} \sim 10\%$) (expected – more uniform electric field – no pad border effects);
  - no evidence of significant charge-up effects;
  - very good position resolution (~120 µm however with larger tails);
- Prototypes with embedded electronics will be tested very soon

ADDITIONAL RESULTS

EMBEDDED RESISTOR: DIELECTRIC CHARGE-UP

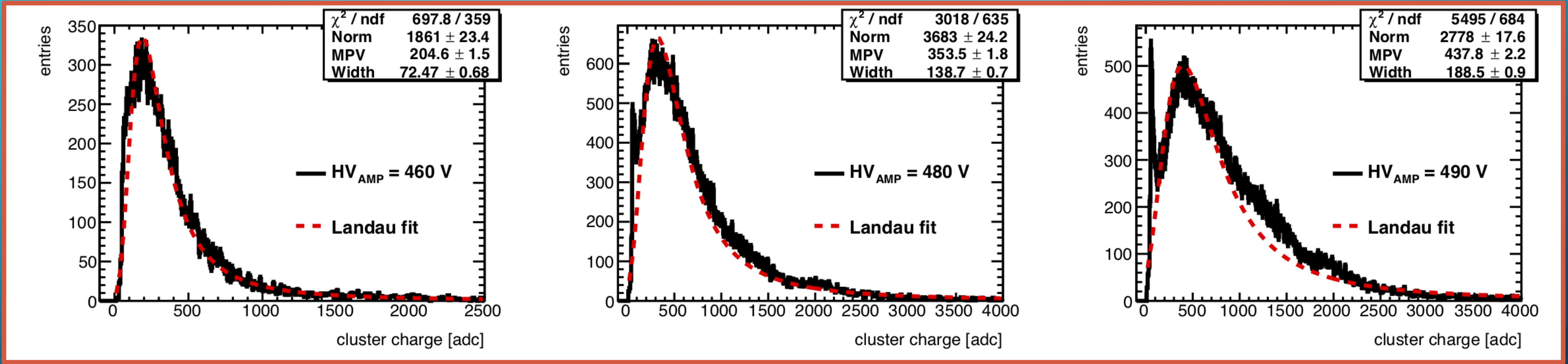
Gain has been measured moving the 1mm collimator Xrays beam along x and y direction with 0.1 mm steps
Modulation is compatible with pads dimensions



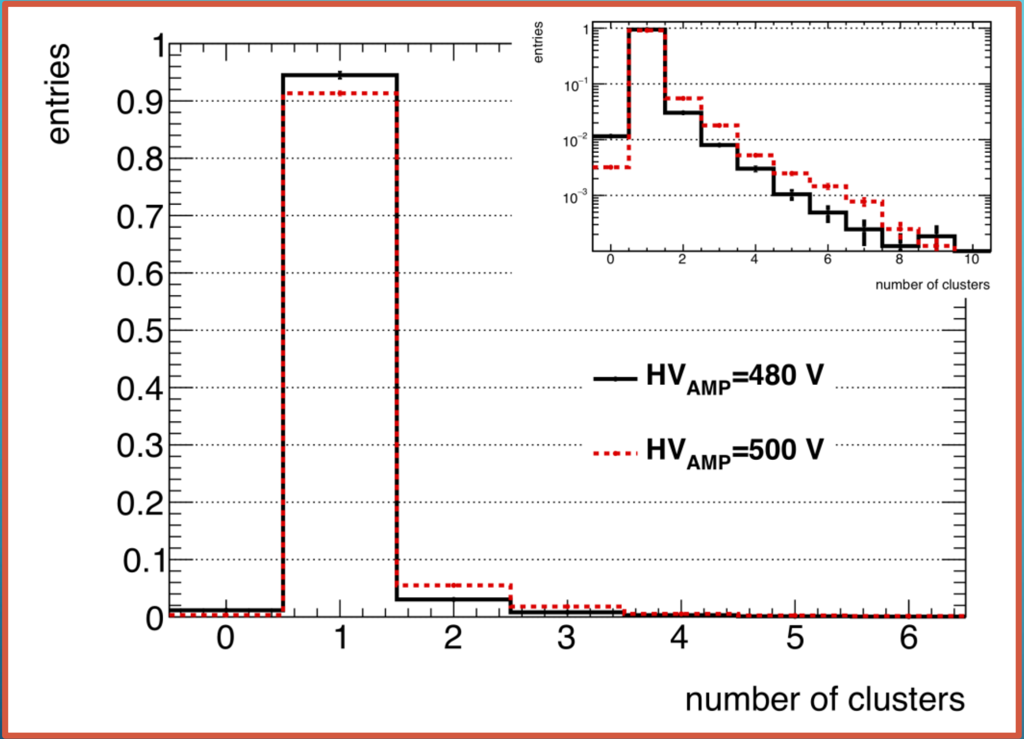


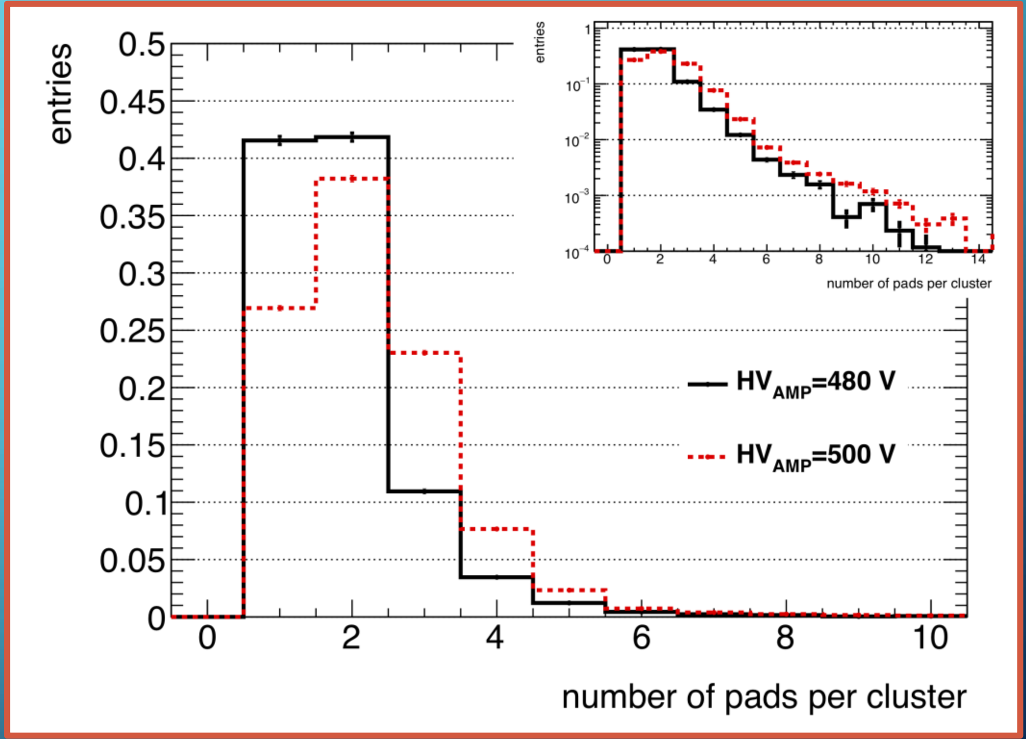
EMBEDDED RESISTOR: CLUSTER CHARGE

- Landau fit to cluster charge distribution. At higher amplification voltage the distortion of the spectrum is due to saturation of the APV25 ADC counter

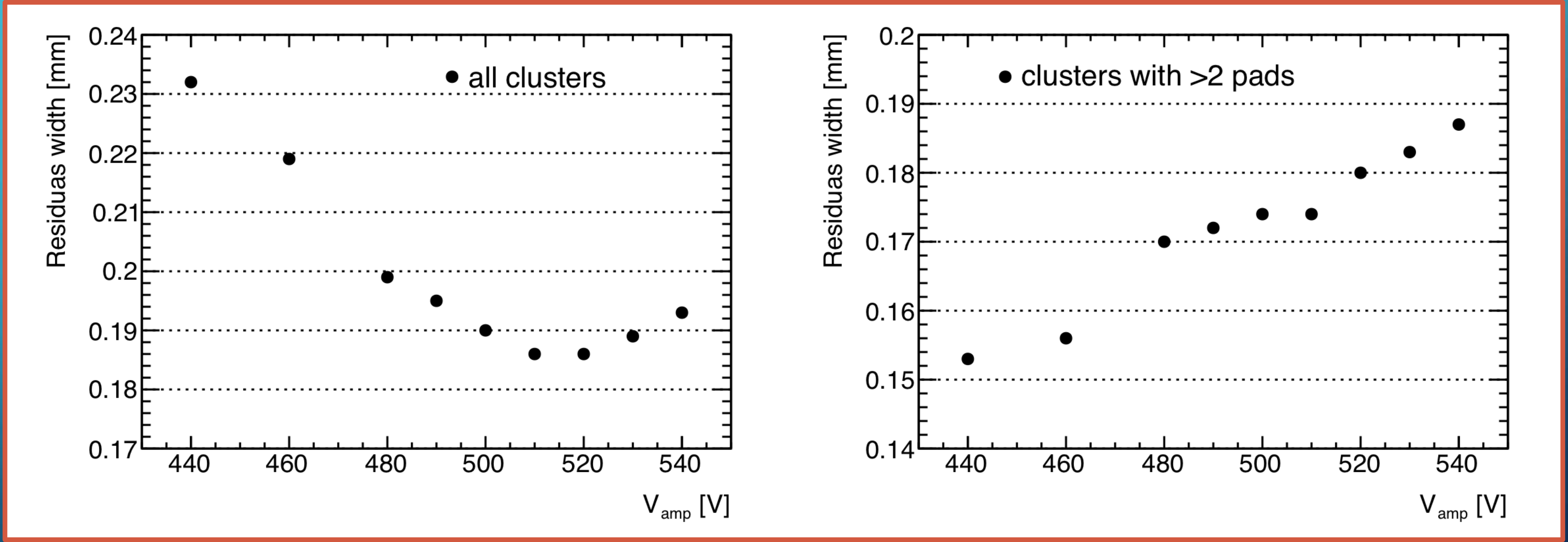


EMBEDDED RESISTOR: CLUSTER MULTIPLICITY AND SIZE

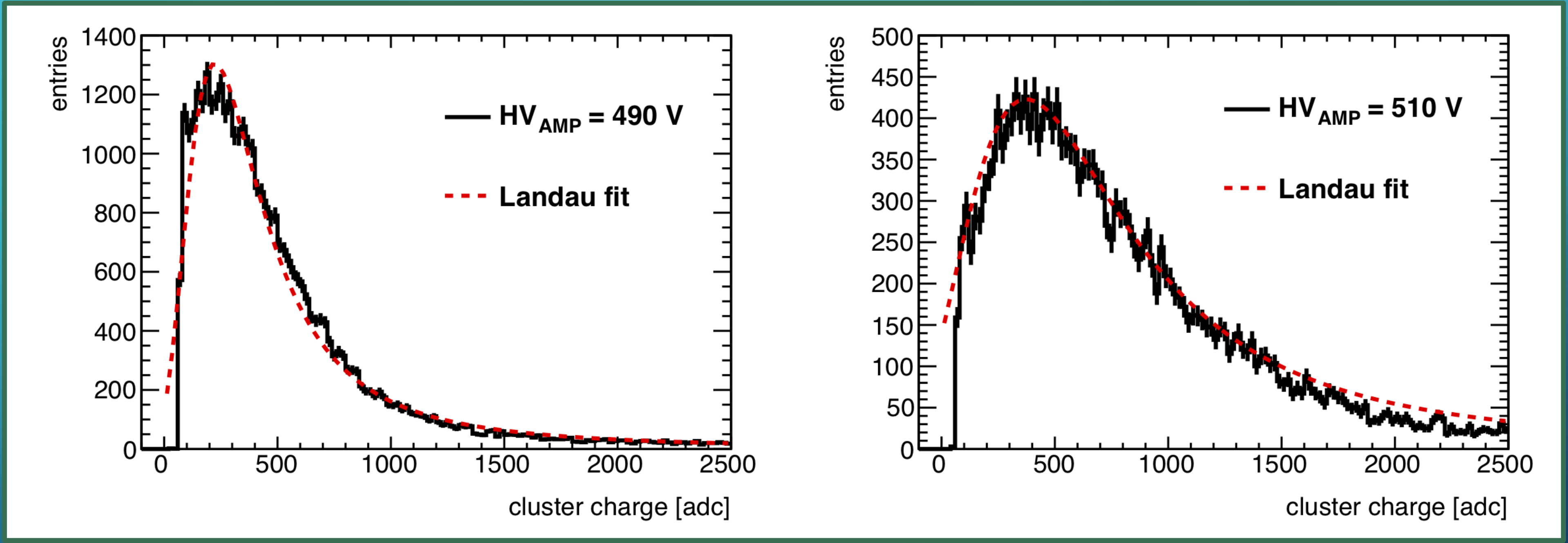




EMBEDDED RESISTOR:



DLC LAYER: CLUSTER CHARGE



DLC LAYER: CLUSTER MULTIPLICITY AND SIZE