Small-pads Resistive MicroMegas for operation at Very High Rates

M. Alviggi on behalf of the Small-pads Micromegas Group:

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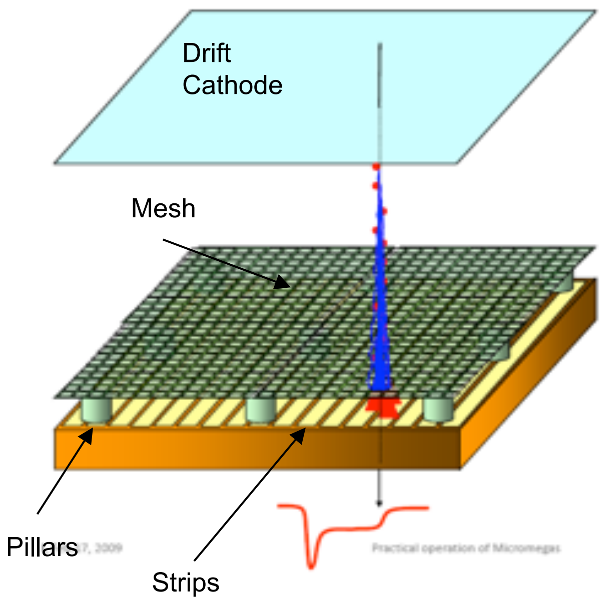
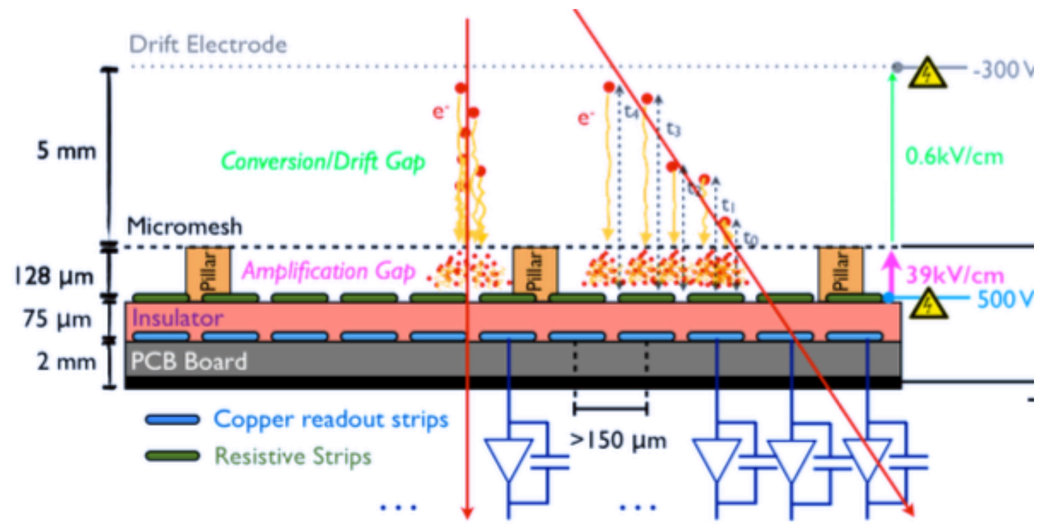
Resistive MicroMeGas



Resistive MicroMeGas technology consists in adding **resistive anode strips** on the top of the readout strips (with insulator in between) to suppress discharges



It has been developed for the Muon Spectrometer Upgrade of the ATLAS experiment, were we needed:

- High efficiency
- Operation at a rate up to ~15 kHz/cm^2 during the phase of High-Luminosity-LHC
- Large area: total surface of ~1200 m^2 of gas volumes

…from strips to small pads readout…

- **fine granularity to reduce Occupancy/increase the Rate Capability**
- R&D started in 2015 (INFN and University of Roma3 and Napoli) in collaboration with CERN and with the CERN PCB Workshop (Rui De Olivera) for prototype construction

Main topics:

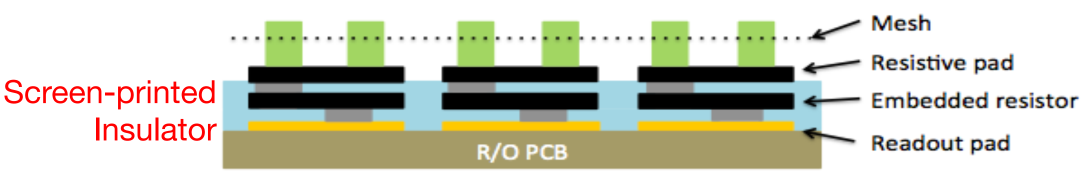
1. **R&D on the detector itself…**
   - resistive/readout pads pattern,
   - resistivity value,
   - amplification and drift gap size, …

2. **EMBED the READOUT electronics into the detector:**
   - bond the readout chips on the back of the MM PCB -> signal routing, chip mounting, wire bonding, …

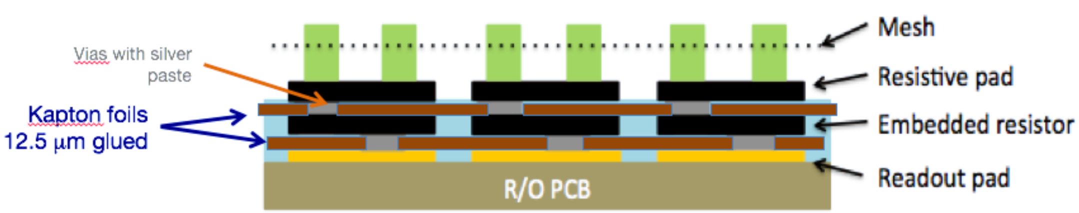
Small Pads Resistive MicroMeGas

TWO Prototypes built so far (Paddy1 and Paddy2)

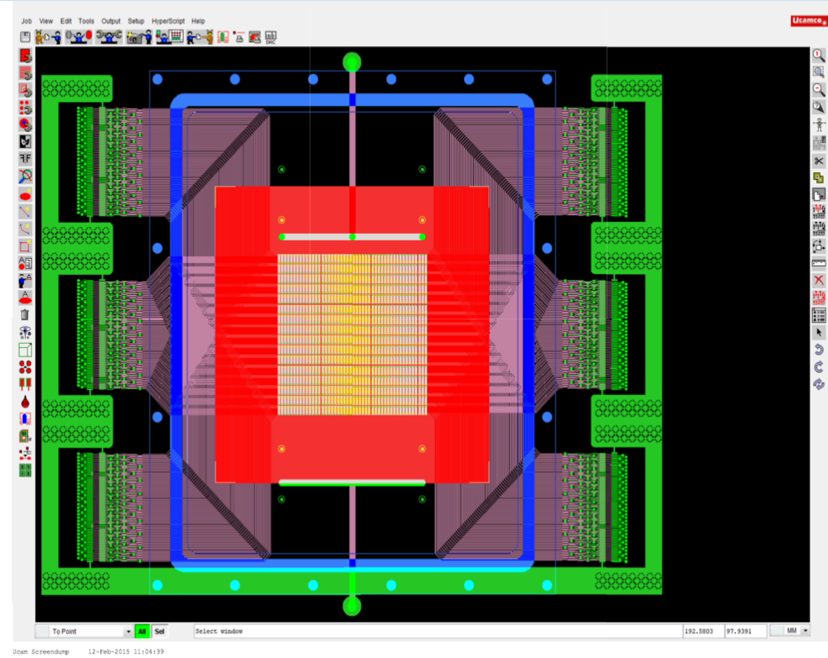
- Matrix 48x16 – 1x3 mm^2 pads – 768 channels
- The construction technique makes use of EMBEDDED resistors :
  1. Full screen printing: stack of all layers, including the insulator, all deposited by screen-printing (new technique by R. De Oliveira and A. Teixeira). A simple, cost effective technique but subject to HV instabilities

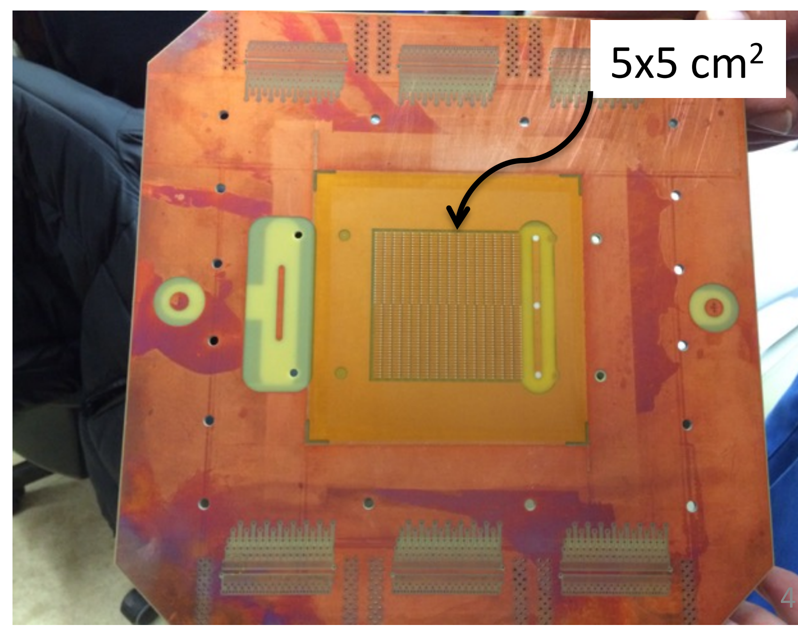


  2. "standard kapton insulating foils". Tested without any problem of HV instabilities.

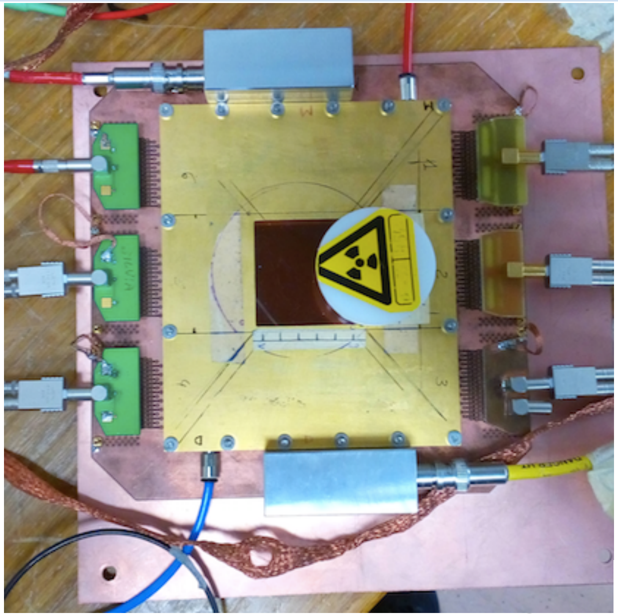


In the pressing procedure the resistivity increases
→ used "low resistivity" paste 100 kΩ/sq

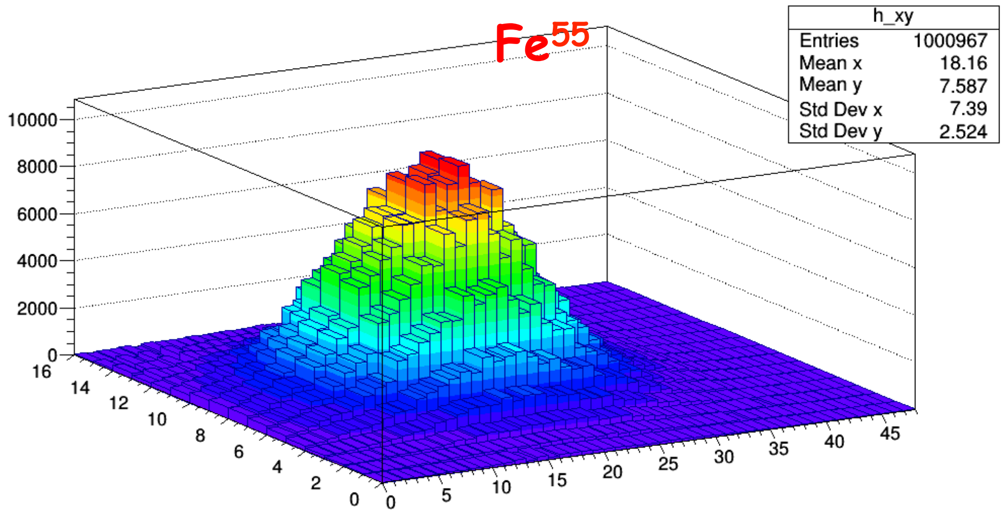




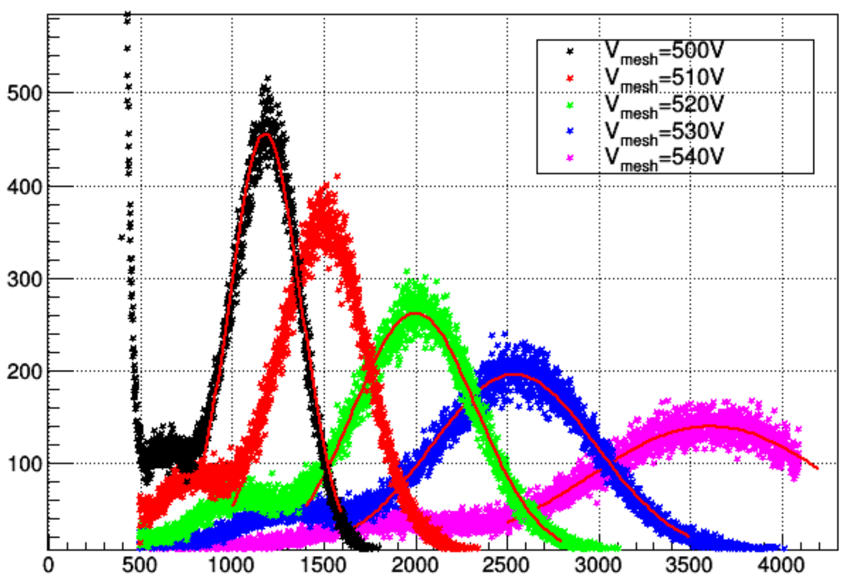
Tests with ^{55}Fe



gas mixture: Ar/CO2=93/7



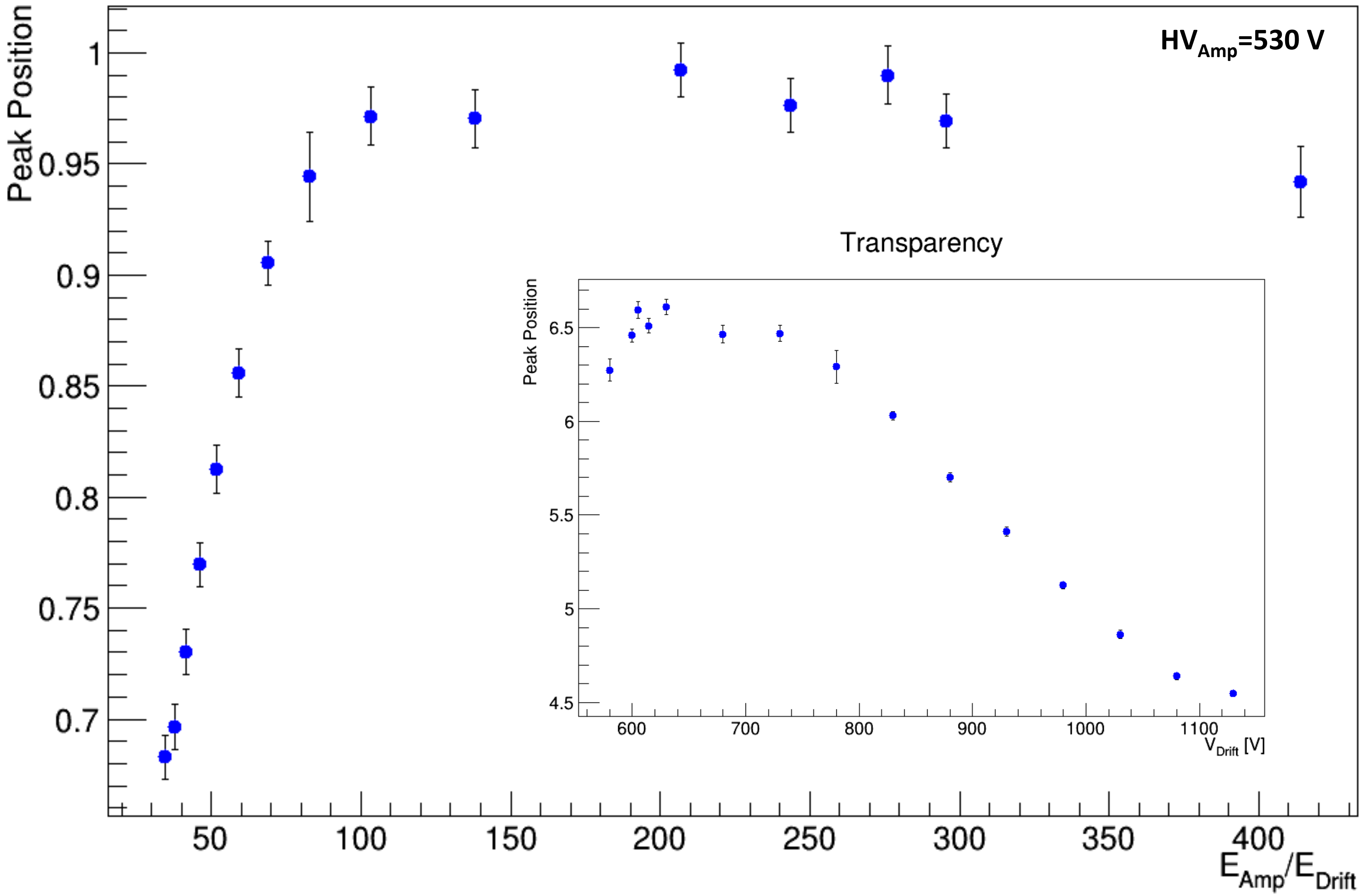
3D image of the ^{55}Fe source



not a great energy resolution (not relevant in our application), probably due to field disuniformity near the pads edges/corners

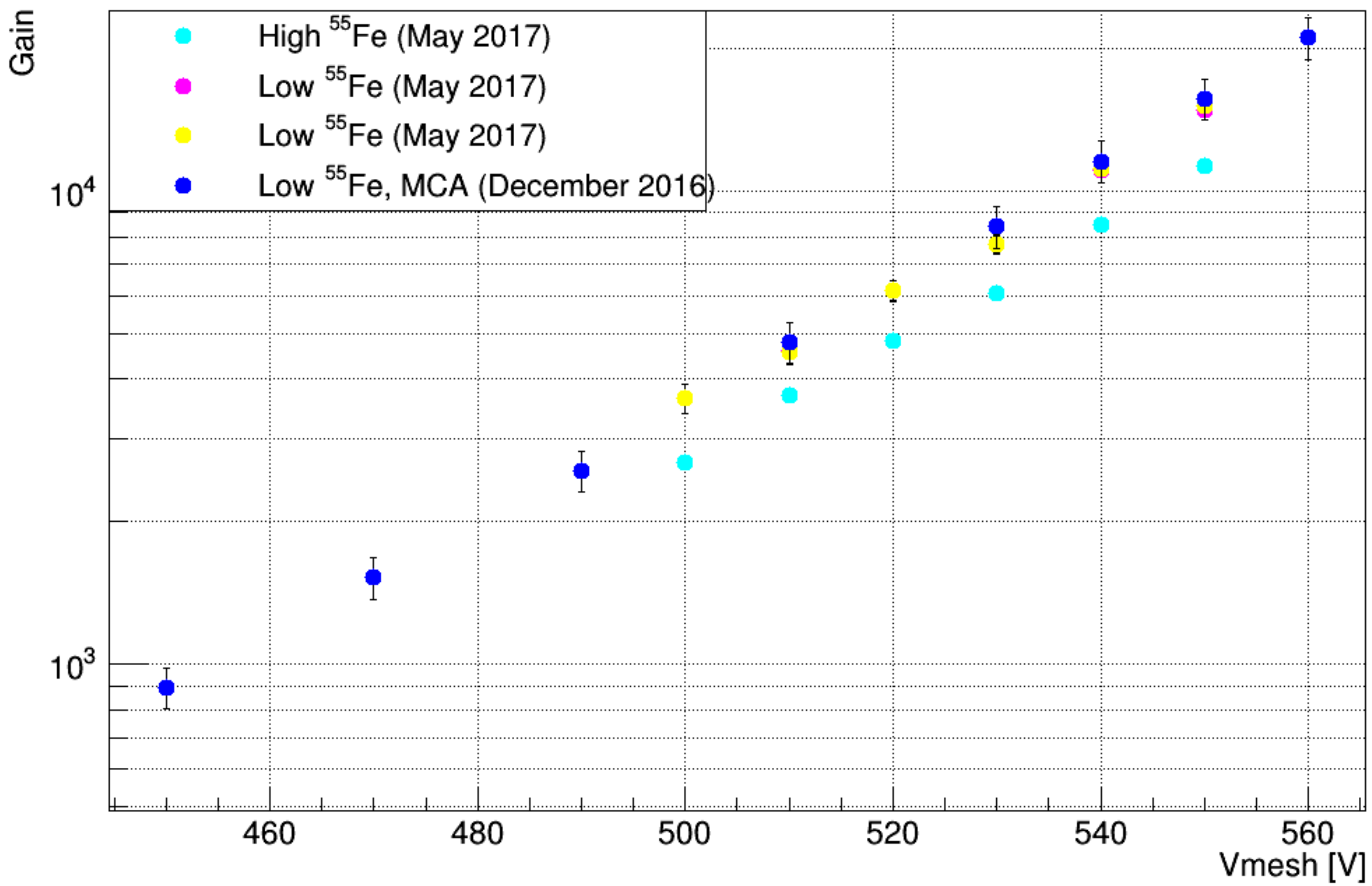
Tests with ^{55}Fe: *Transparency Measurement*

- Mesh Transparency compatible with resistive strip bulk micromegas



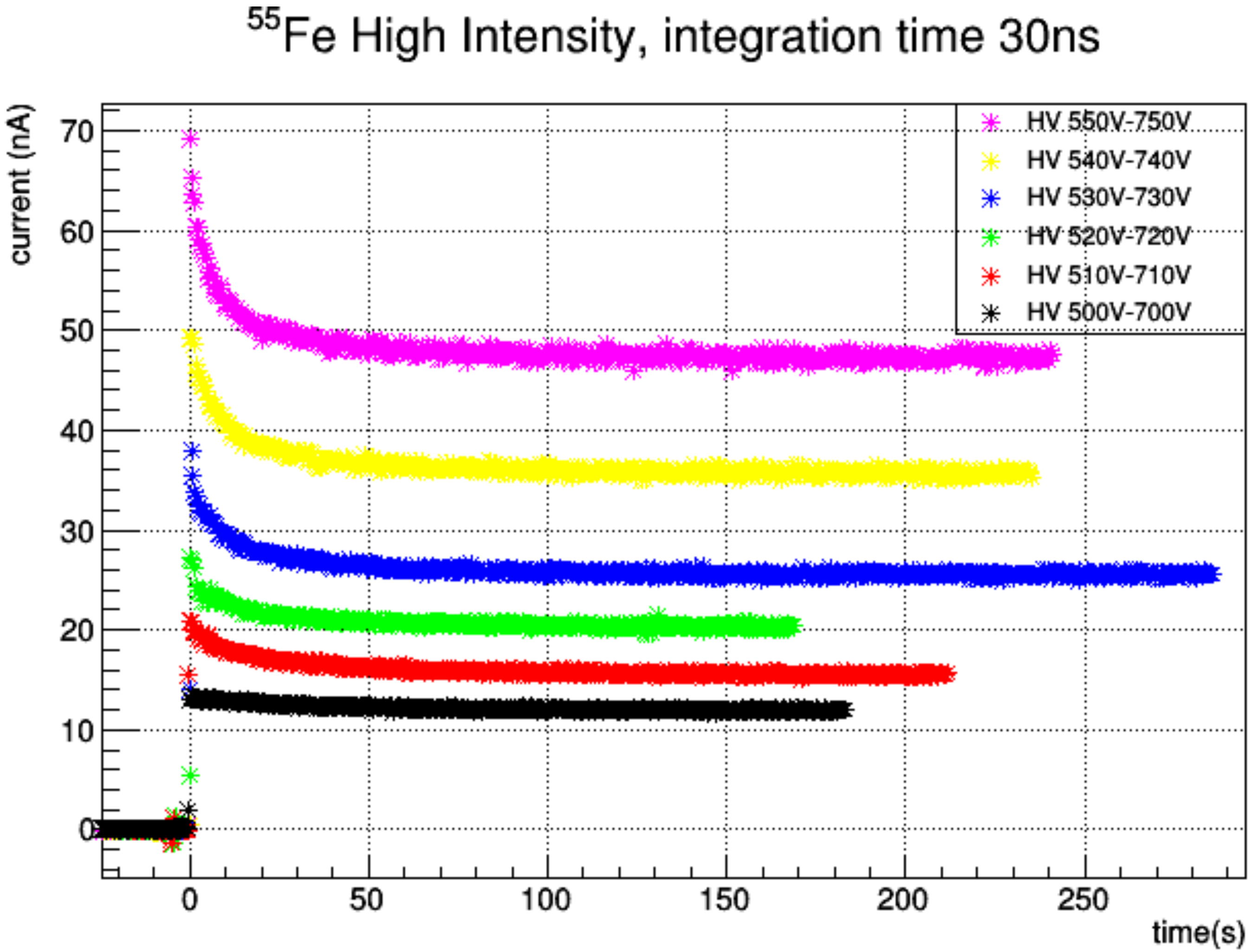
Tests with ^{55}Fe: *Gain Measurement*

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



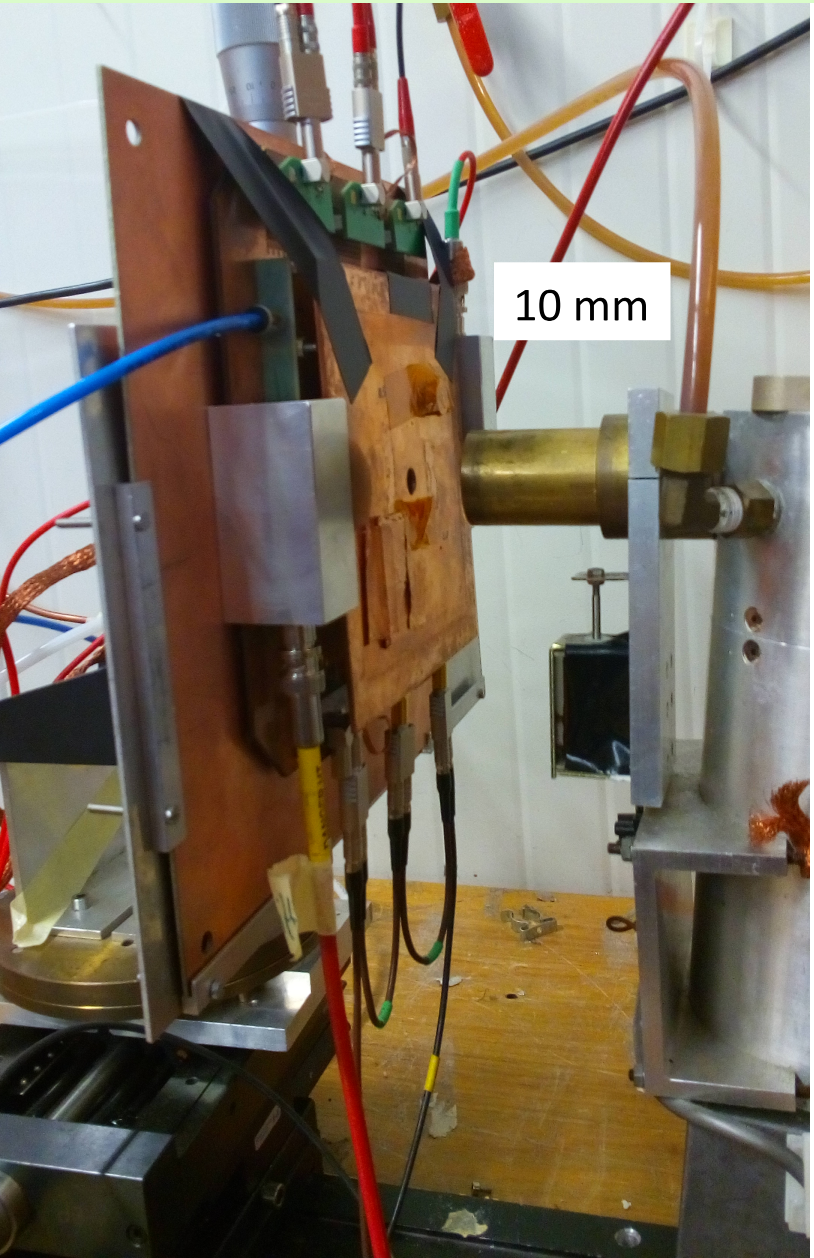
Tests with ^{55}Fe: *'High intensity source'*

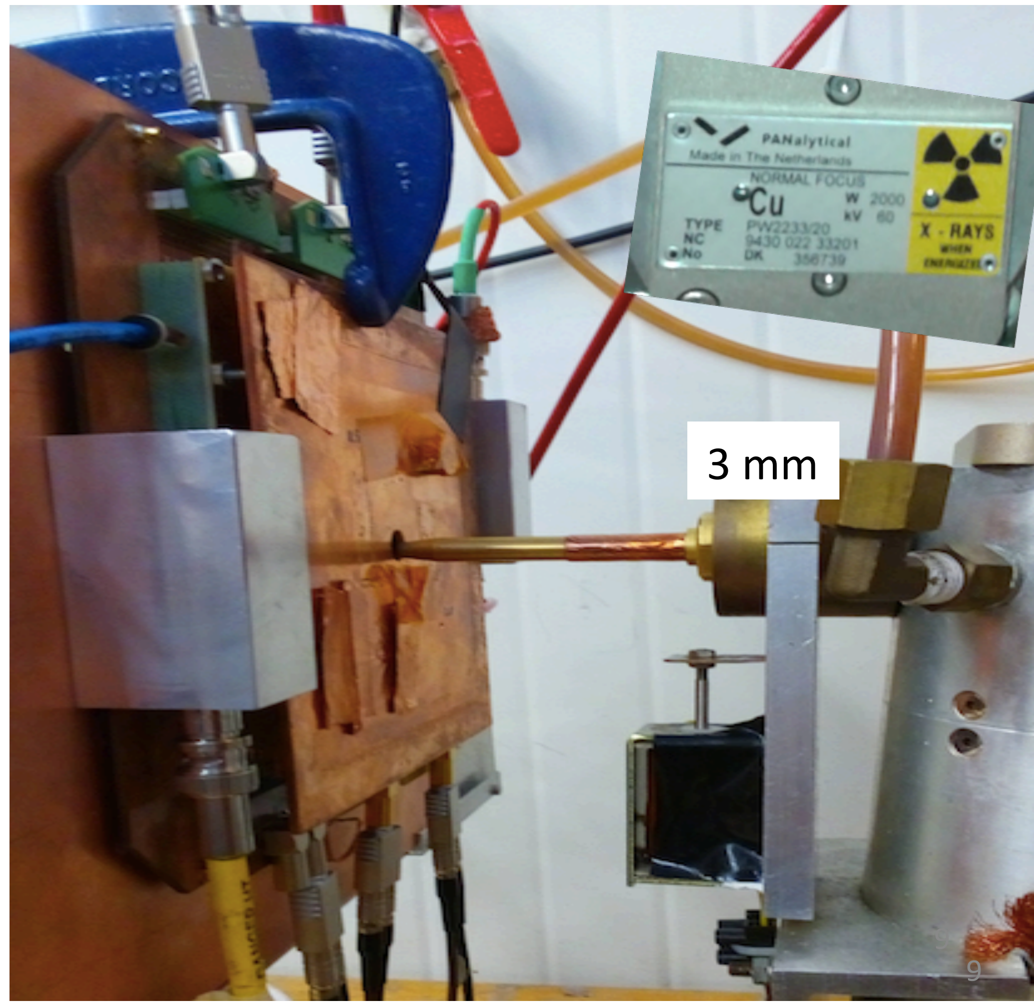
- observed a reduction vs time of the detector current (with ^{55}Fe High intensity source)
- ~ 20%, same as in Gain …
- possible explanation: dielectric charge up …



X Rays

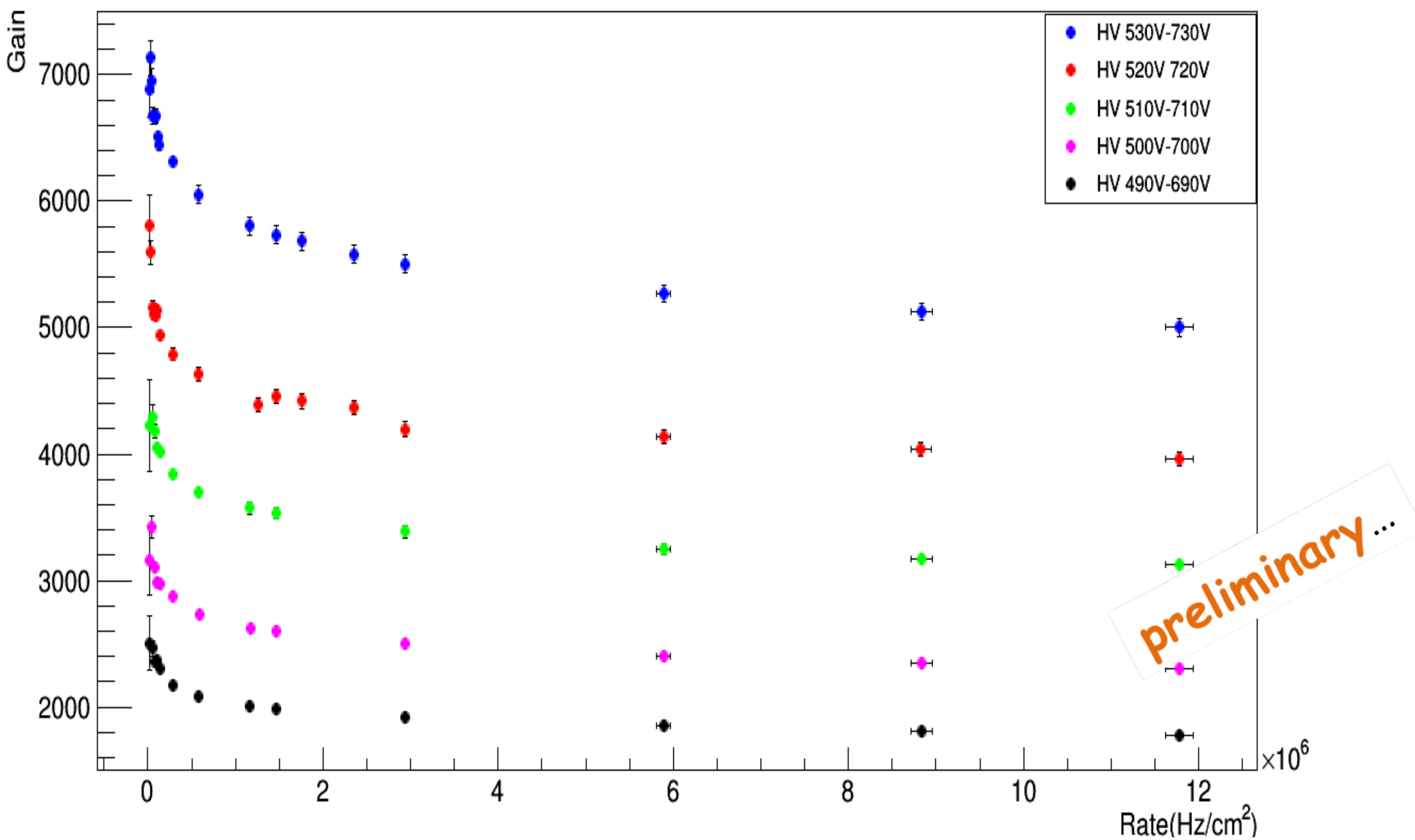
- test detector response with increasing X-rays rate
- 8KeV photons from Cu anode X-Ray generator
- measurements with a ϕ = 10mm hole on a Cu screen or with a ϕ = 1 or 3mm collimator





Tests with X Rays: *Gain measurement*

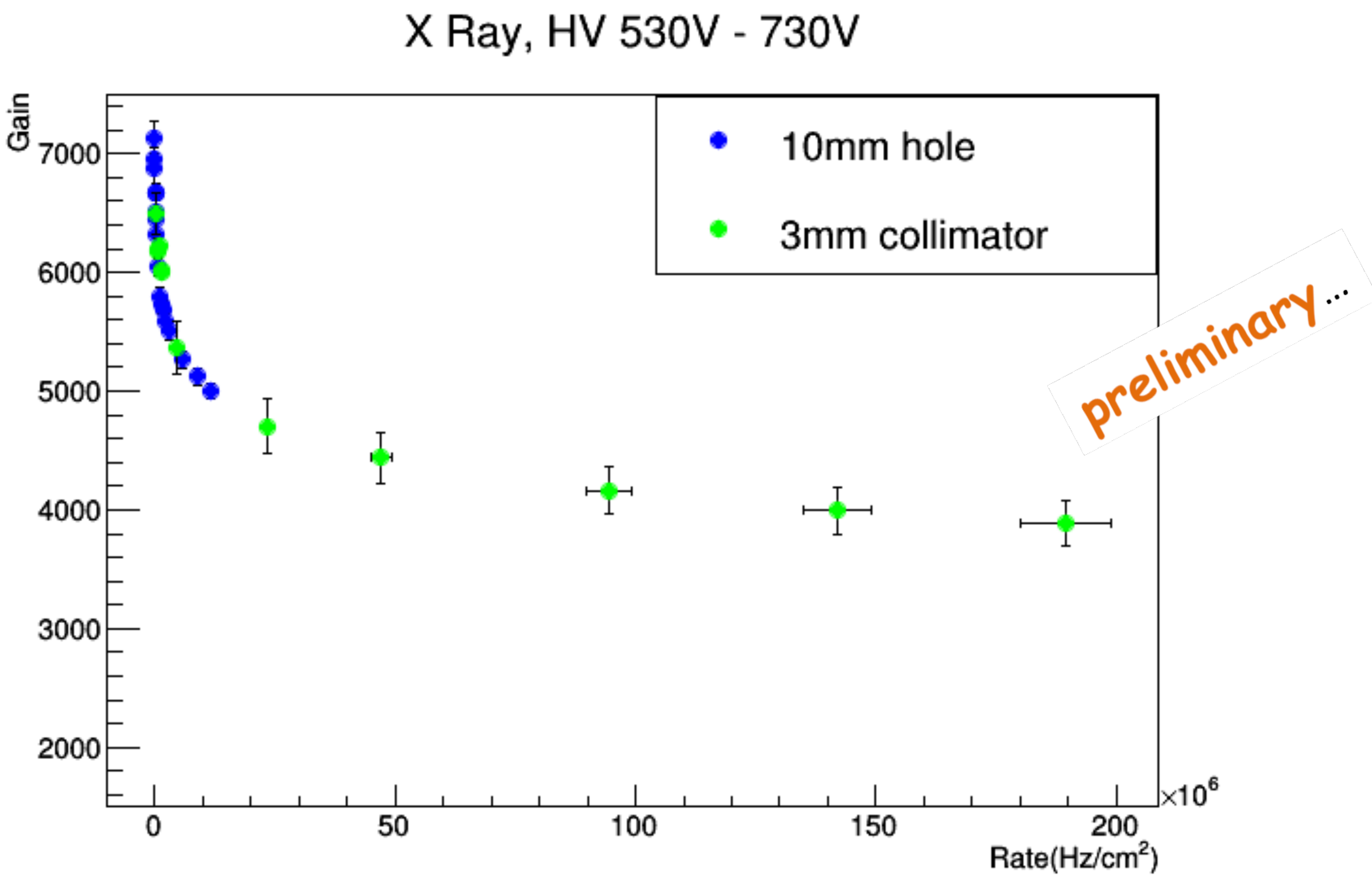
Gain vs Rate/cm², ϕ = 10 mm hole , 70μm Cu attenuator



- gain reduction of ~ 27%
- few % could be due to voltage drop on the pad resistors…
- Rate, measured up to 300 kHz/cm² , shows linear behaviour with the X-Ray current; after that value the rate has been linearly extrapolated from the X-Ray current

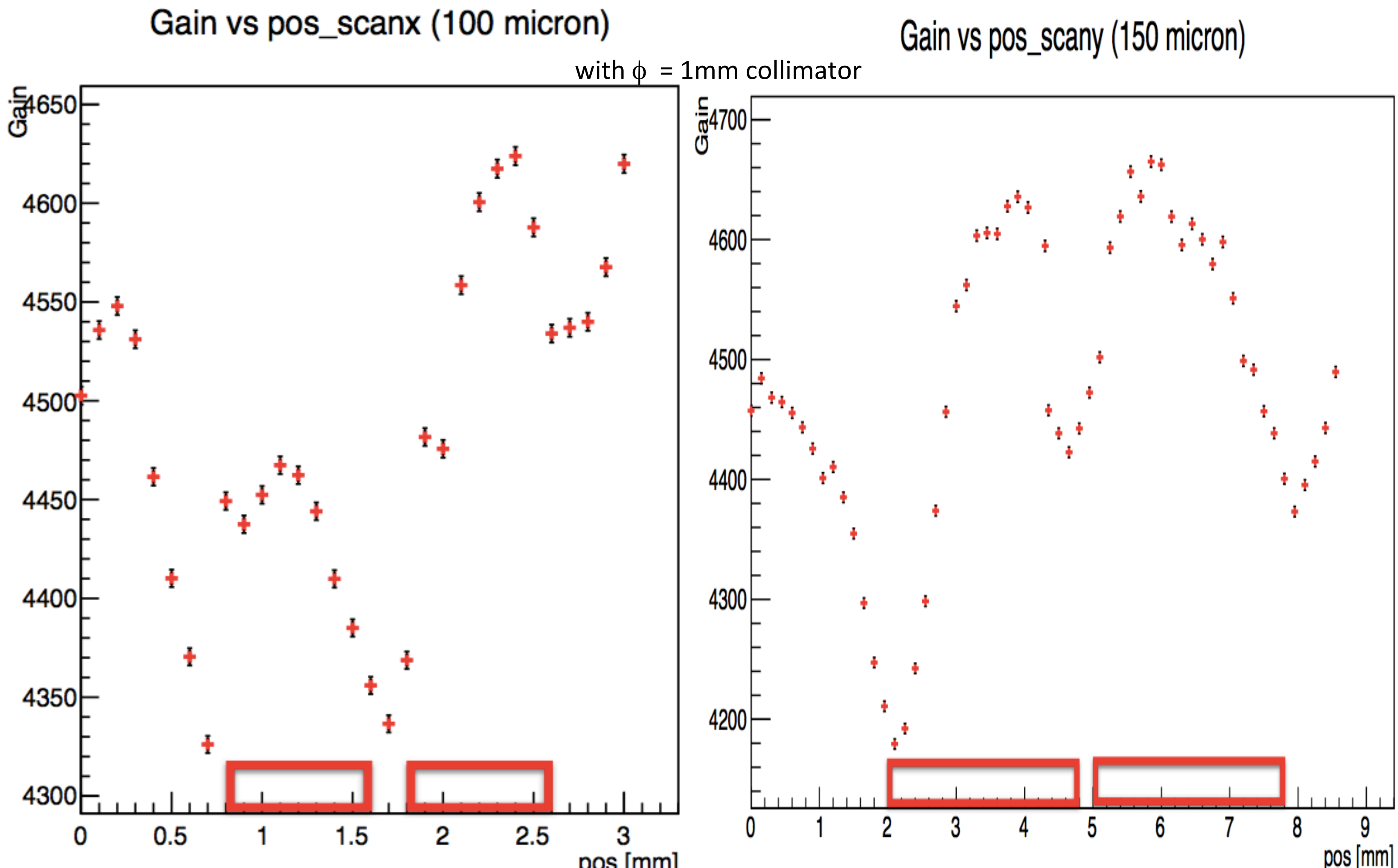
Tests with X Rays: *Gain measurement*

Gain vs Rate/cm^2, comparison between ϕ = 10 and 3 mm collimator



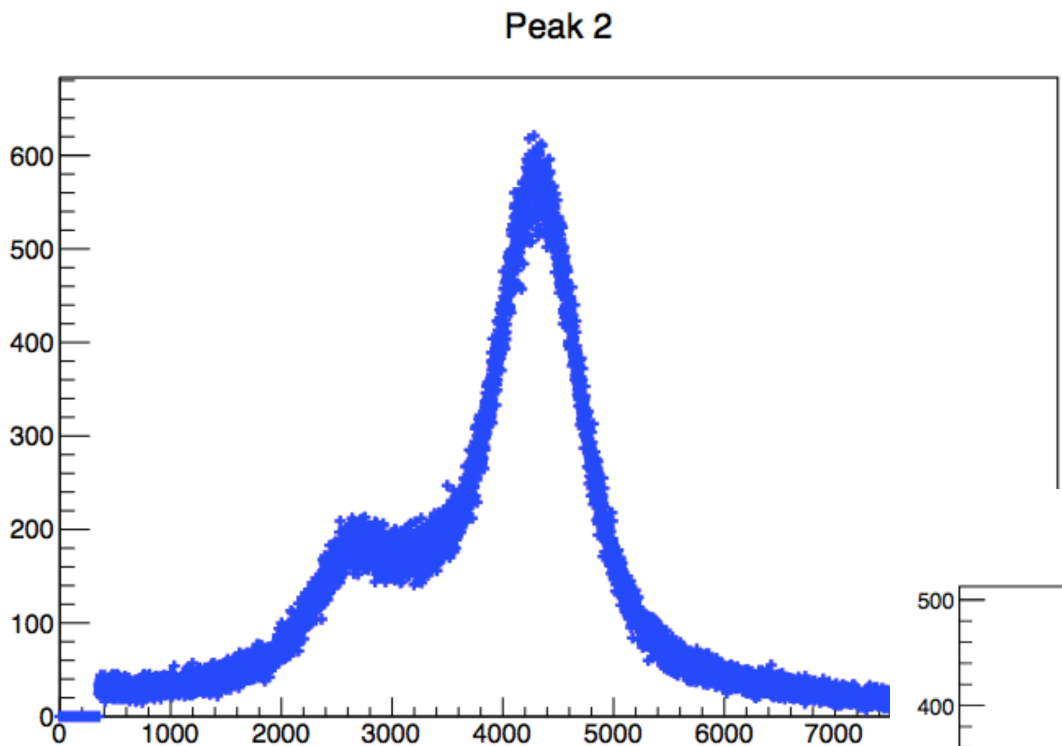
- the use of collimator (without Cu absorber) allows to increase even more the rate/cm^2 …
- higher drop in gain but detector still works with Gain= 4x10^3 @more then 150MHZ!

Tests with X Rays: *Gain scan through pads*

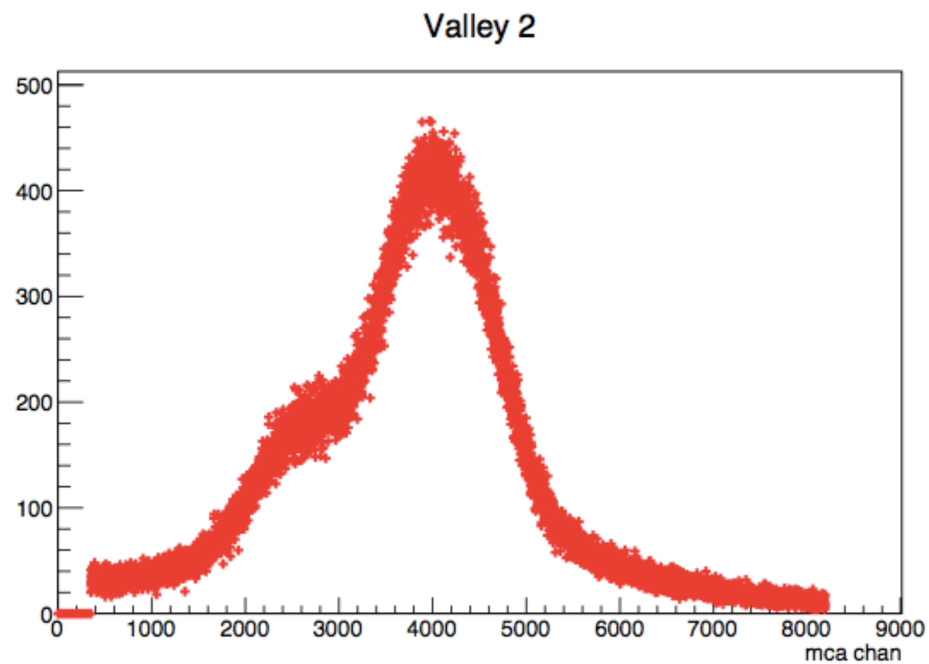


- few (5 to 10) % variation from center of the pad to edges…..

Tests with X Rays: *Gain scan through pads*

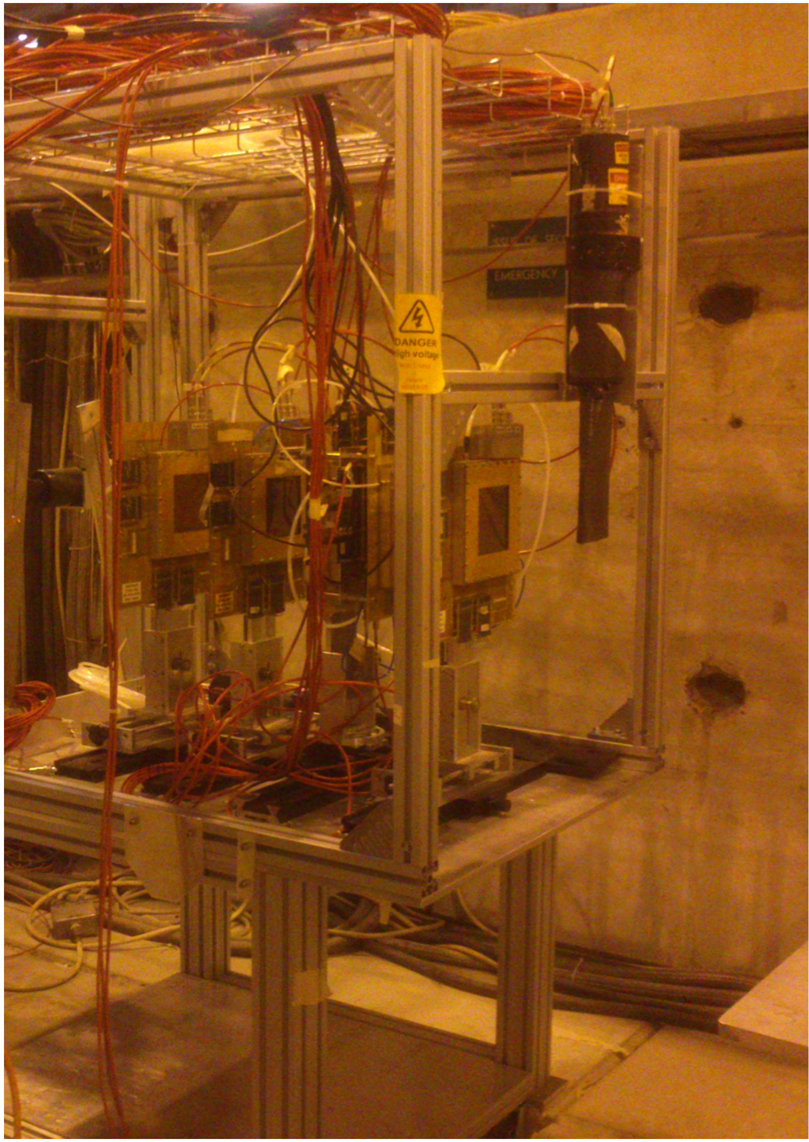


- better energy resolution on 'peaks' with respect to 'valleys'....



Test Beam @ CERN

- @ SPS H4 CERN Experimental area
- Beam: high energy muons/pions
- Test Setup:
  - Two small scintillators for triggering
  - Two double coordinate (xy) bulk strips micromegas (10 x 10 cm^2) for tracking
  - Small-pads MM (Paddy2) in between
  - gas mixture: Ar/CO_2=93/7 pre-mixed
  - DAQ: SRS+APV25



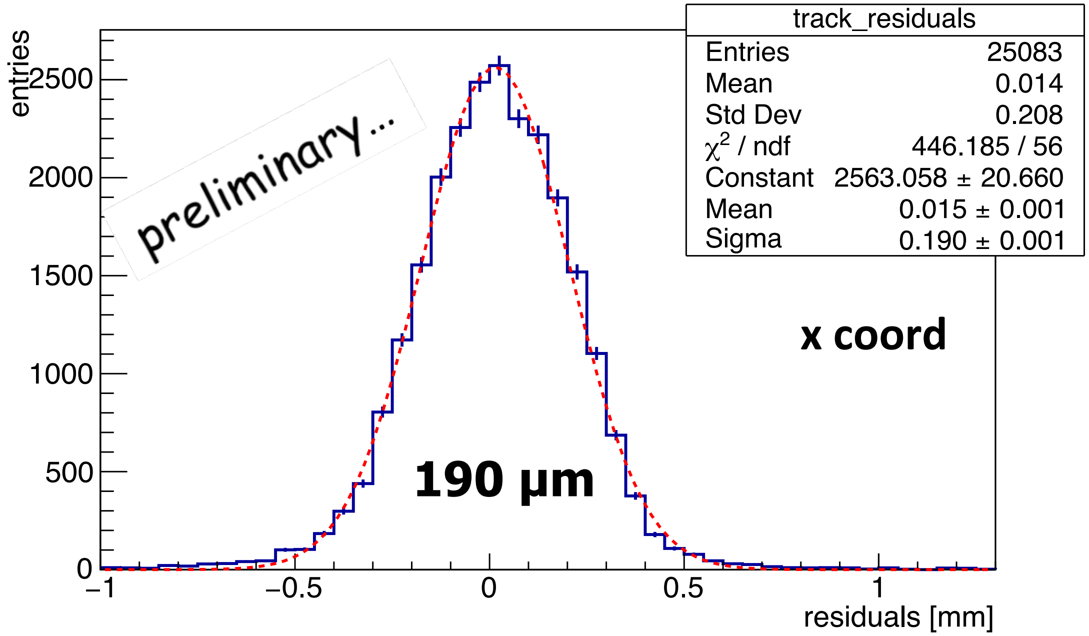
Data taken to study:

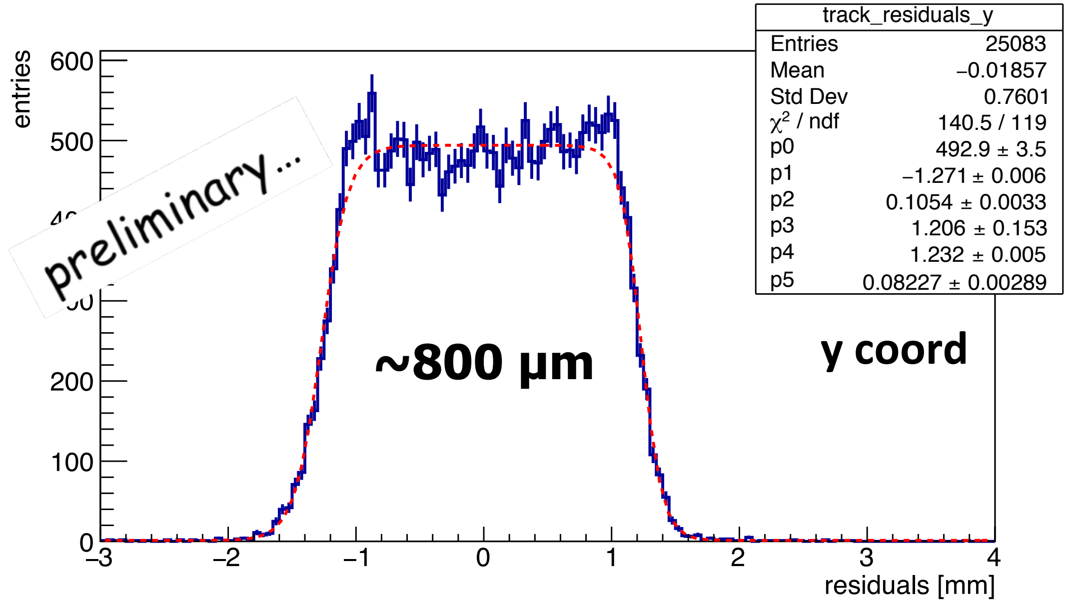
- Efficiency
- Spatial resolution

and how they change with:

- Mesh/Drift HV
- Inclined tracks
- Low/high intensity beam → rate capability

Test Beam Results: *Position resolution*



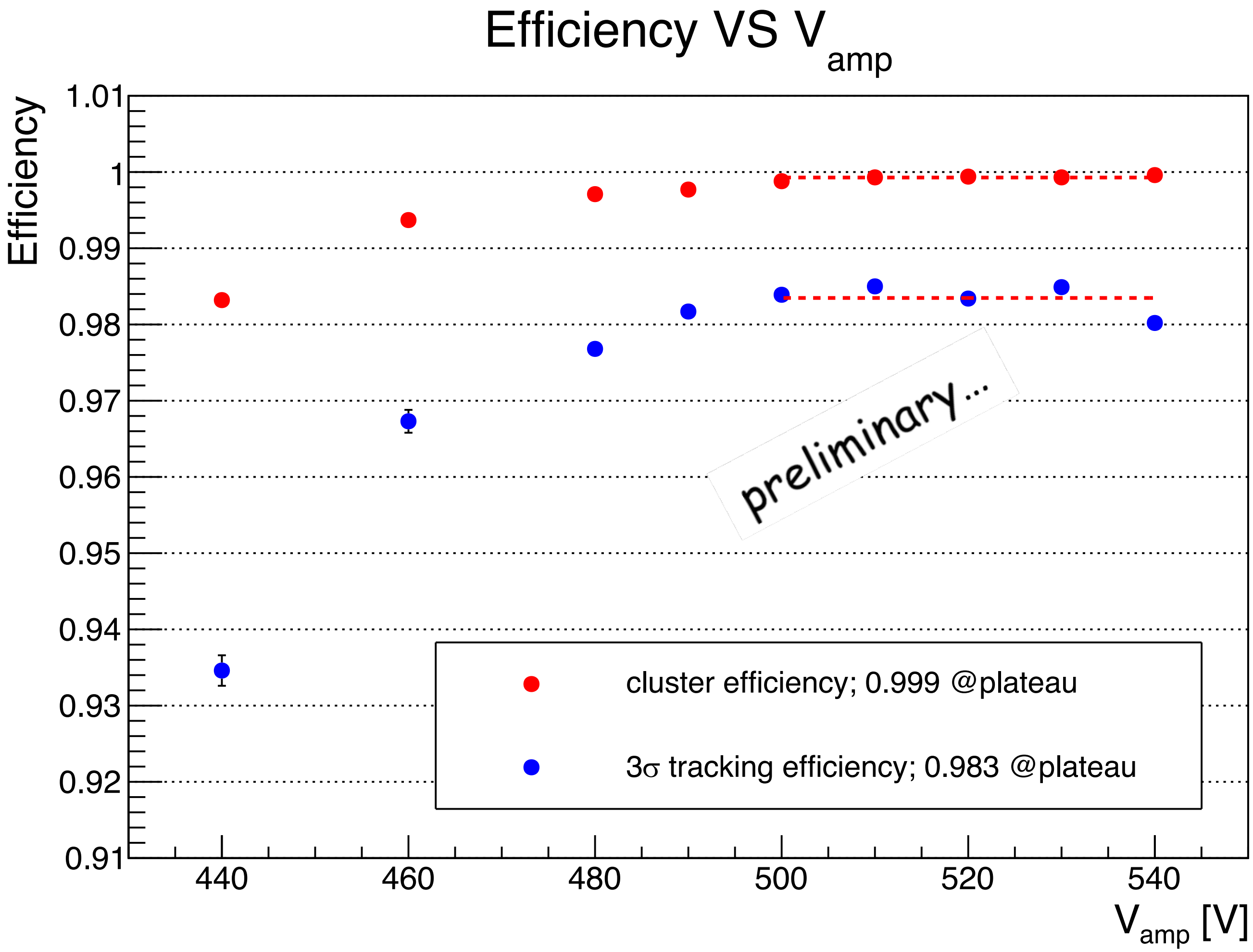


- double coordinate strips MM used as tracking detector (x-y, orthogonal to the beam direction)
- tracks are extrapolated at the z coordinate of the Small-pads MM

Position resolution is obtained by the difference between the position measured from Paddy2 and the one extrapolated by the tracks.

- Alignment and rotation correction were applied
- track extrapolation error (~50μm) not subtracted

Test Beam Results: *Efficiency*

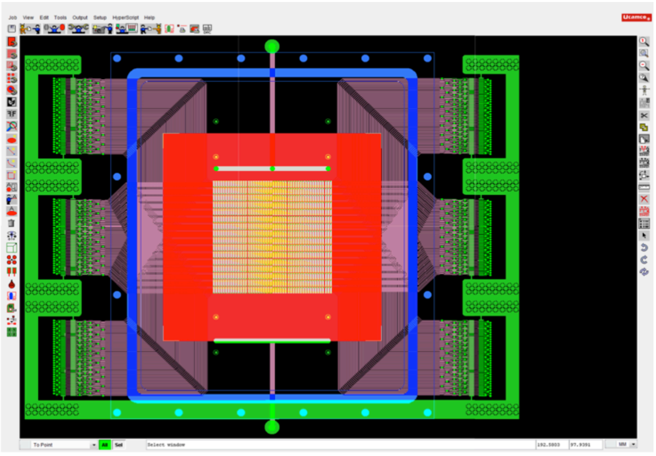


Still to do:

- analyze data with inclined tracks and high rate pion beam

Toward Larger Size prototype…

Layout not scalable for large dimensions (very dense routing)



New R&D on MM mini-pad Detectors WITH **EMBEDDED** (back wire-bonded) electronics.

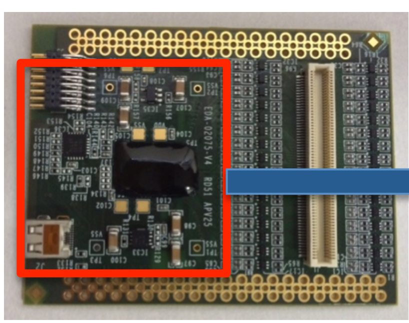
DESIGN OF A FIRST PROTOTYPE :

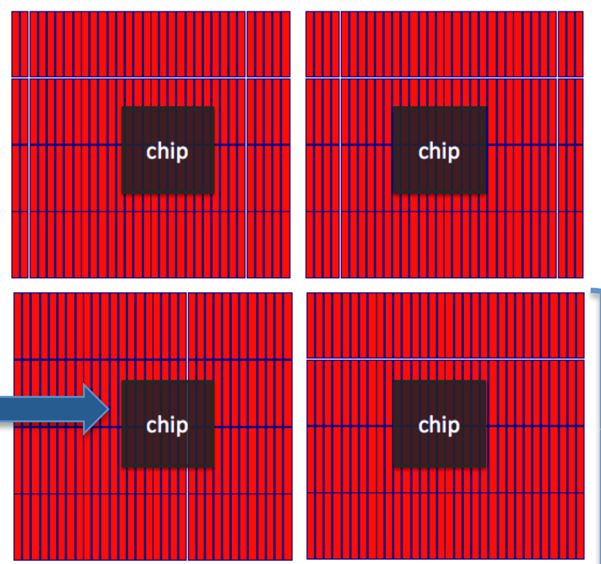
- 3 regions with 32x4 mini-pad, pitch 1x8 mm^2
- 1 region with 16x8 mini-pad, pitch 1x3 mm^2
- Each region can be readout by a back embedded APV25 chip with associated Front-end electronic reassembled on the detector board

One of the firsts MPGD with Embedded Electronics

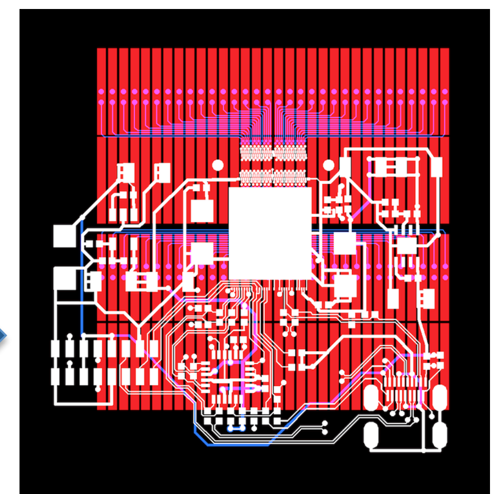
- Pad readout
- Fully scalable

The RD51 front-end board with APV25



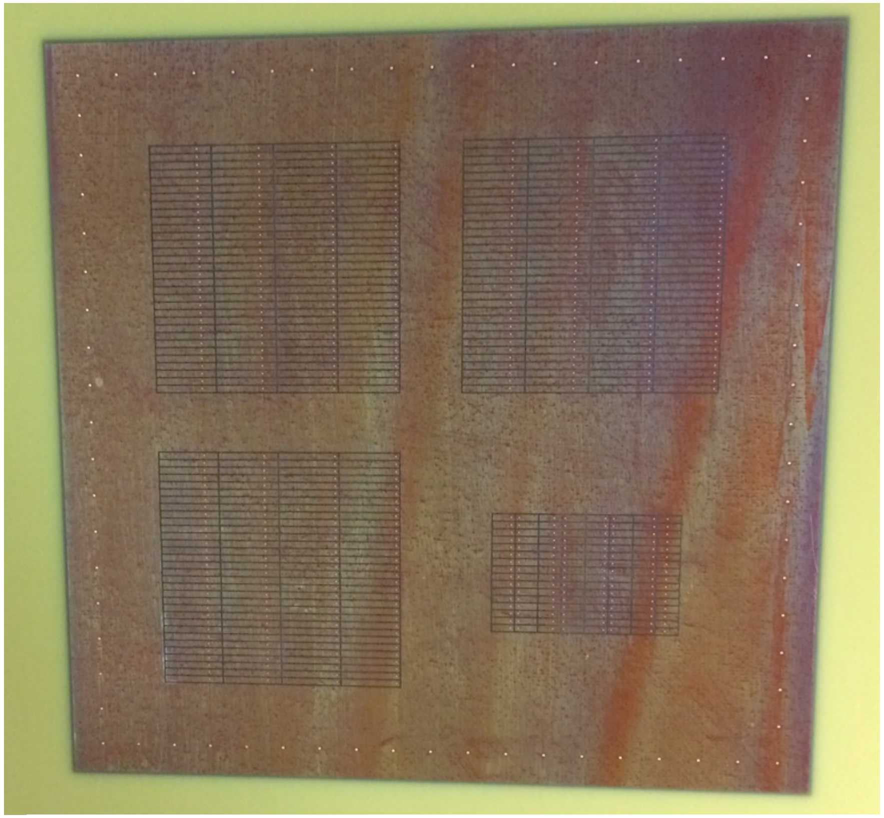


Here a single region. It will be repeated x 4

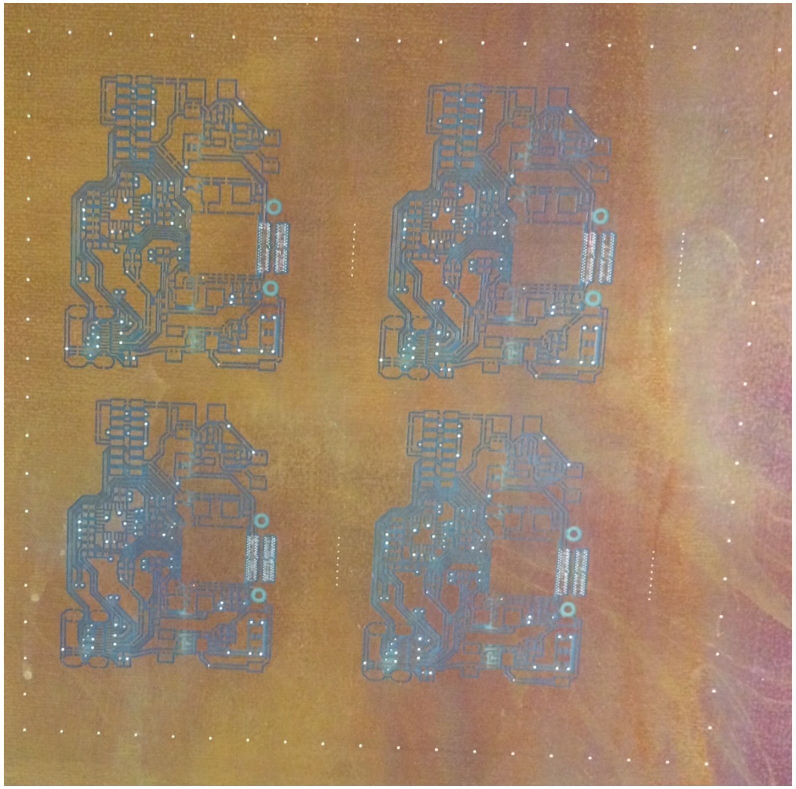


Construction of Small-Pads MM with embedded ELX

Prototype under construction (at CERN – Rui De Oliveira's Workshop)
- Assembly of Electronics components done (including APV)
- First on this "bare board" —> Check functionality wth APV pedestals measurements - Then (if everything is ok) move on with resistive layers, bulk mesh, … —> complete detector



Front view: 4 zones with different pads pitch (8x1 mm, 3x1 mm=same as previous prototypes)



Back view:
Layout of the 4 regions with APV25

Construction of Small-Pads MM with embedded ELX

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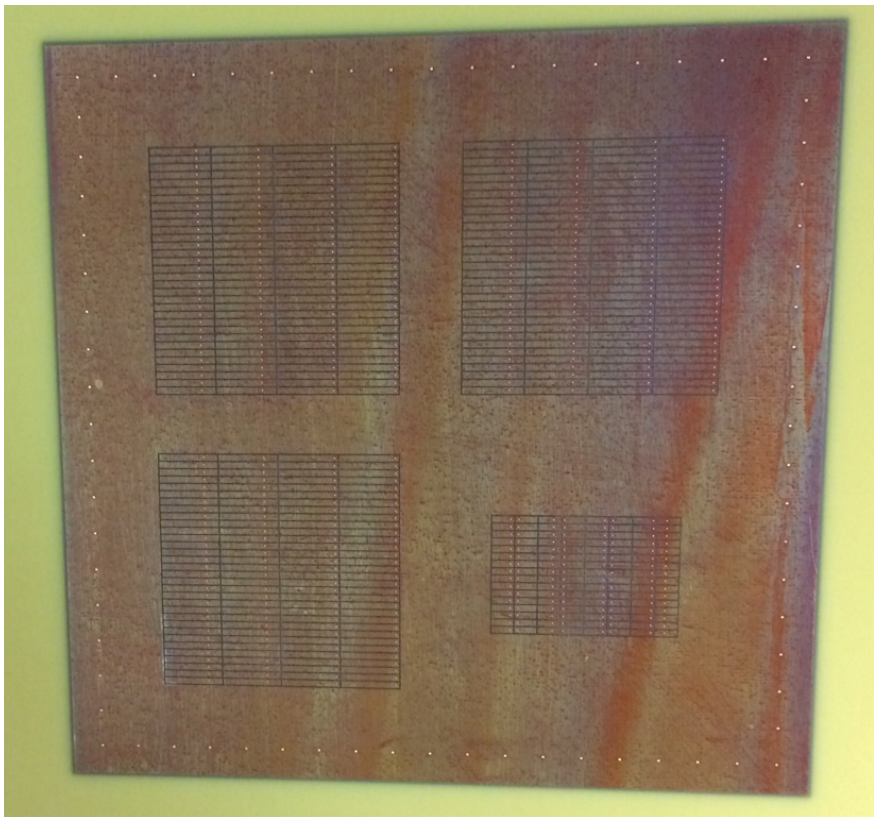
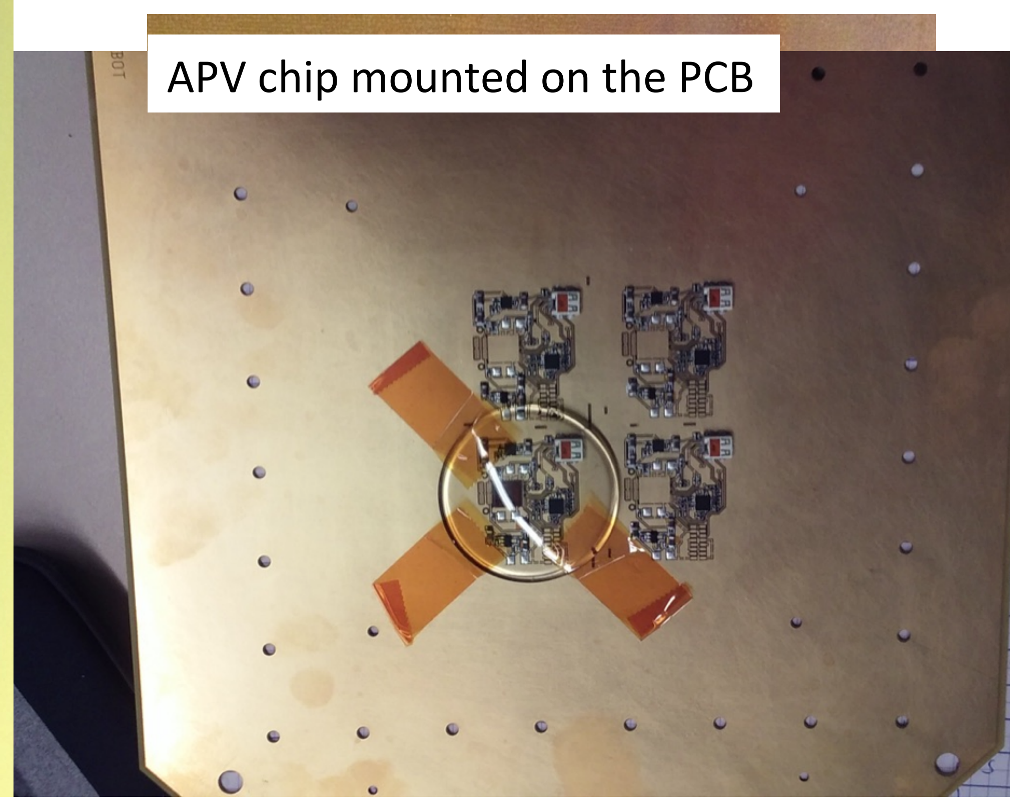


Front view: 4 zones with different pads pitch (8x1 mm, 3x1 mm=same as previous prototypes)



Back view:
Layout of the 4 regions with APV25

Next steps for detector R&D

- Test other readout configurations and resistivity values/layout

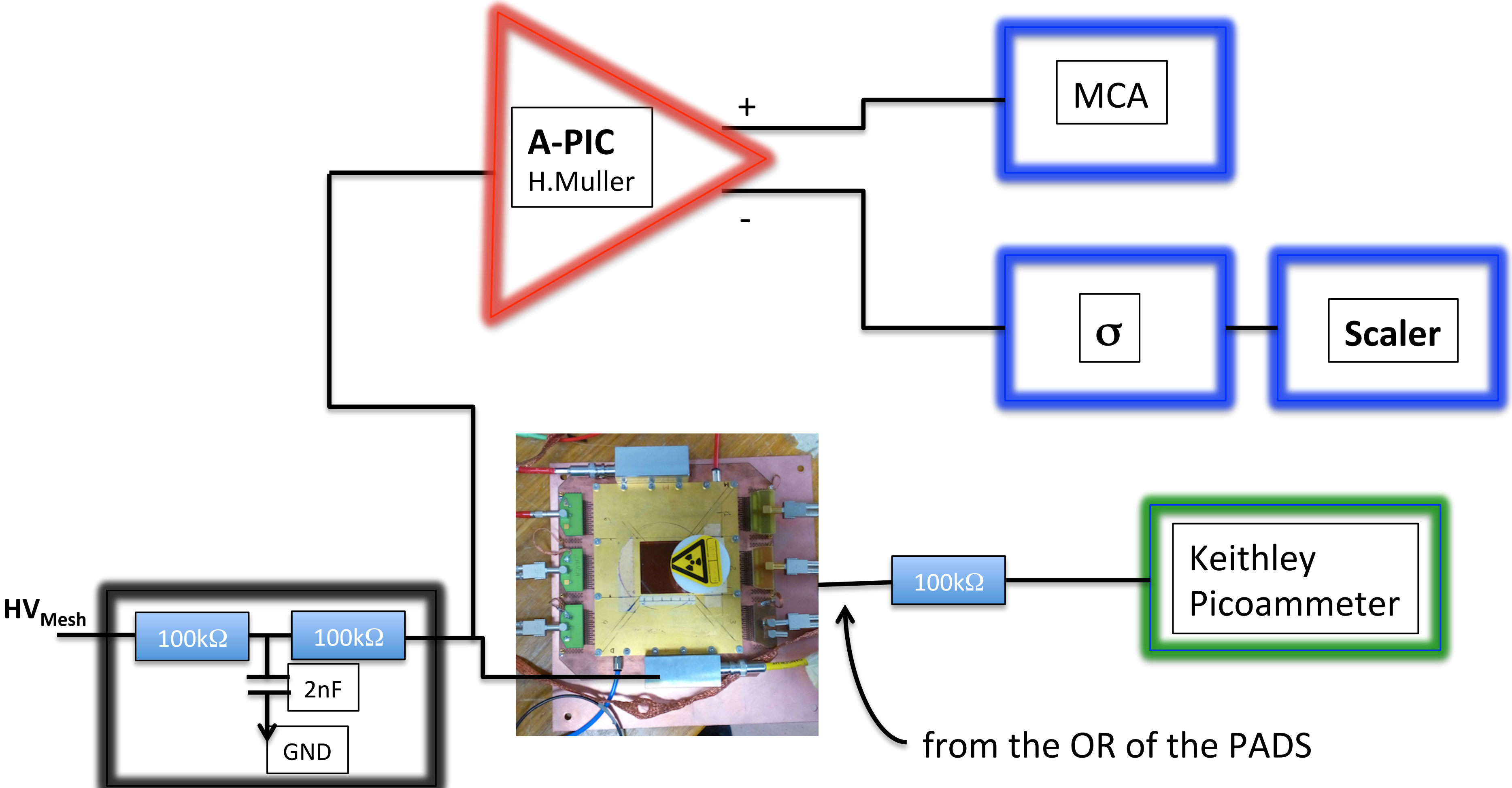
- Embedded electronics, first tests with APVs coming soon…
- Move to the larger size detector
- Selection of large channels density, rad hard (APV25, ATLAS SCT CHIP,..) and low power chips

- Cooling: embedded tubes in the PCB with CO_2 Cooling

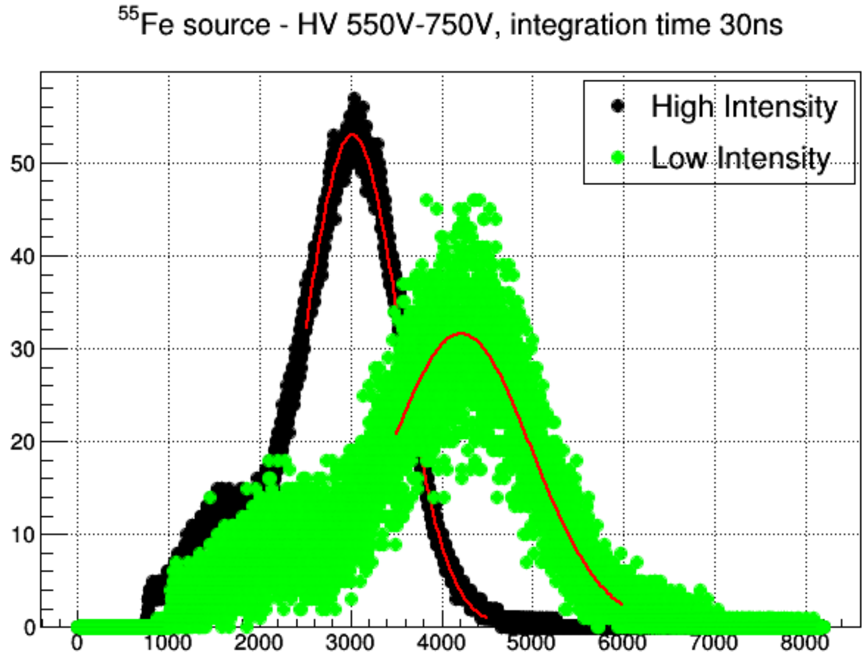
Acknowledgements: to the CERN MPT workshop (in particular R.De Oliveira and A. Teixeira for ideas, discussions, construction of the detectors) and RD51 Collaboration for support with the tests at the Gas Detector Development (GDD) Laboratory at CERN and at CERN H4 test beam.

Backup slides

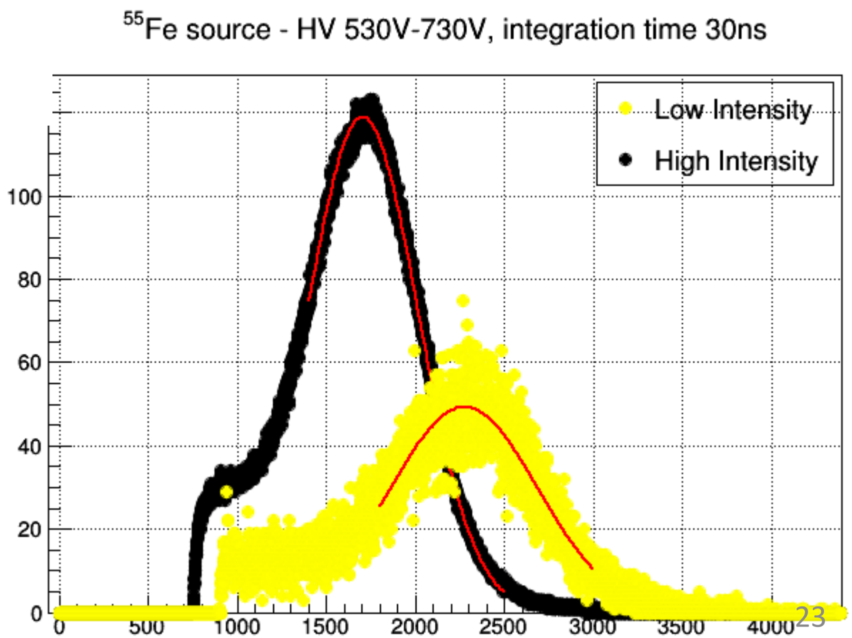
Read Out electronic chain



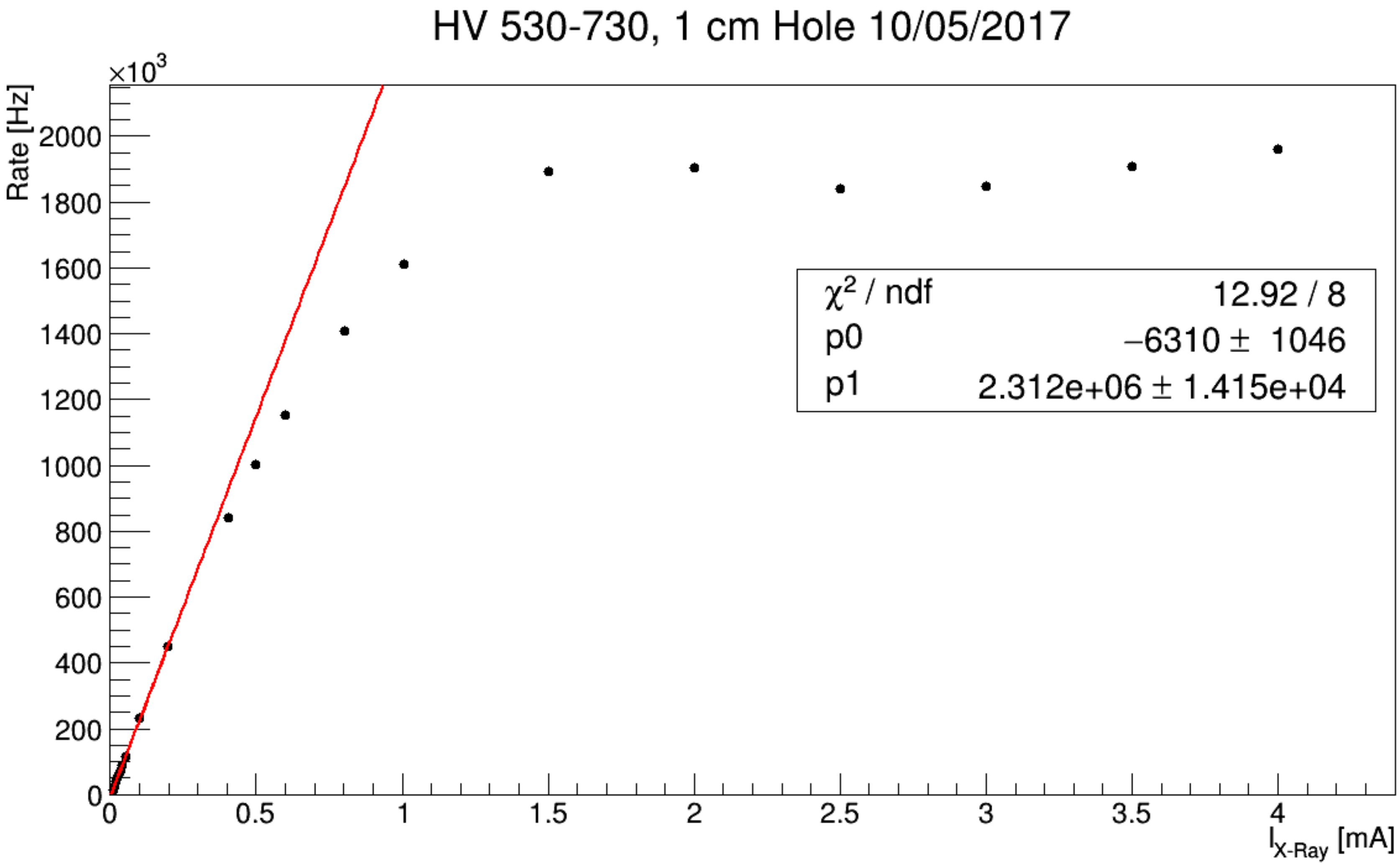
Fe55 Low/High intensity



Peak displacement between the High/Low intensity ^{55}Fe sources spectra



X Rays



HV 530-730, 1 cm Hole 10/05/2017
×10^3
Rate [Hz]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
0.5
1
1.5
2
2.5
3
3.5
4
I_X-Ray [mA]
χ^2 / ndf 12.92 / 8
p0 −6310 ± 1046
p1 2.312e+06 ± 1.415e+04