Small-pad Resistive Micromegas for high rate applications

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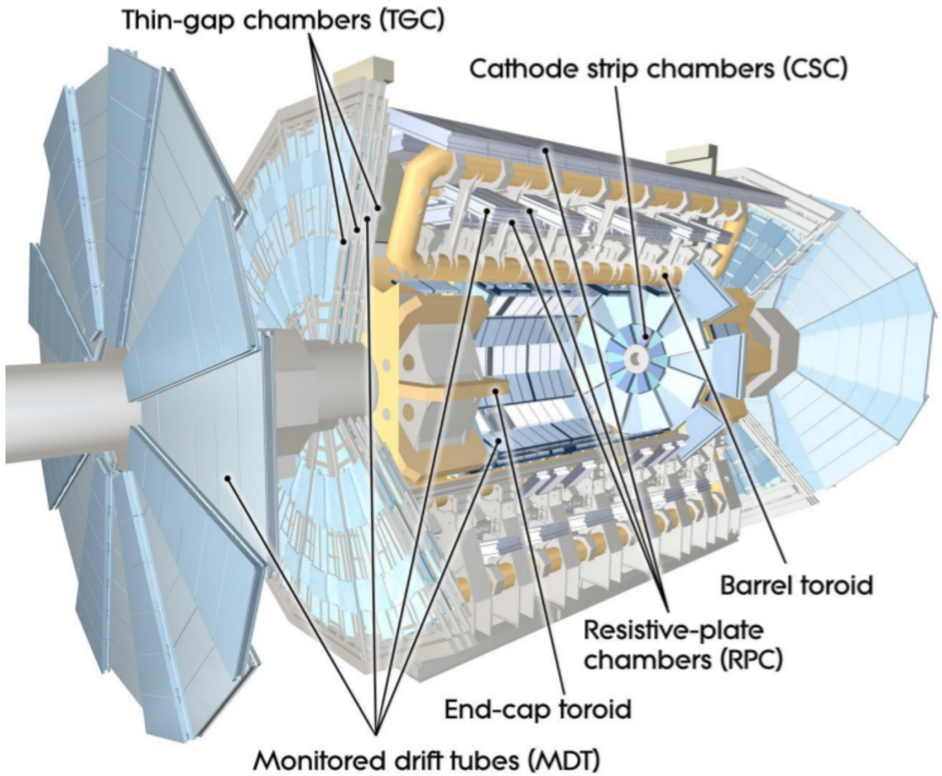
Small-pad Resistive Micromegas for high rate applications

- "High η muon tagger" for the ATLAS experiment at CERN;
- "Small-pad Resistive Micromegas" prototype;
- Gain measurements as function of the amplification field, using ^{55}Fe sources;
- Alternative gain measurements as function of the X-ray rate, using the SRS system;
- Estimates of detector efficiency and spatial resolution from test beam data analysis, using pions.

All measurements have been carried out in the GDD laboratory of the R&D 51 collaboration at CERN

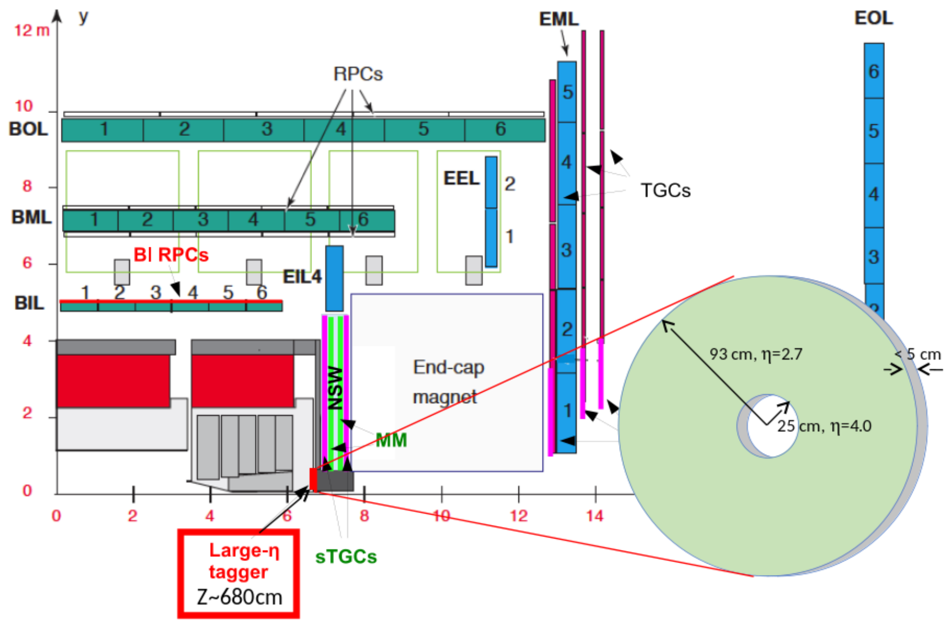
High η muon tagger for ATLAS



ATLAS Phase II Upgrade
(HL-LHC 2024)

Pseudorapidity $\eta = -ln(tan\ \theta/2)$

$\eta = 4 \longrightarrow \theta = 0.5°$
~25cm from the beam line



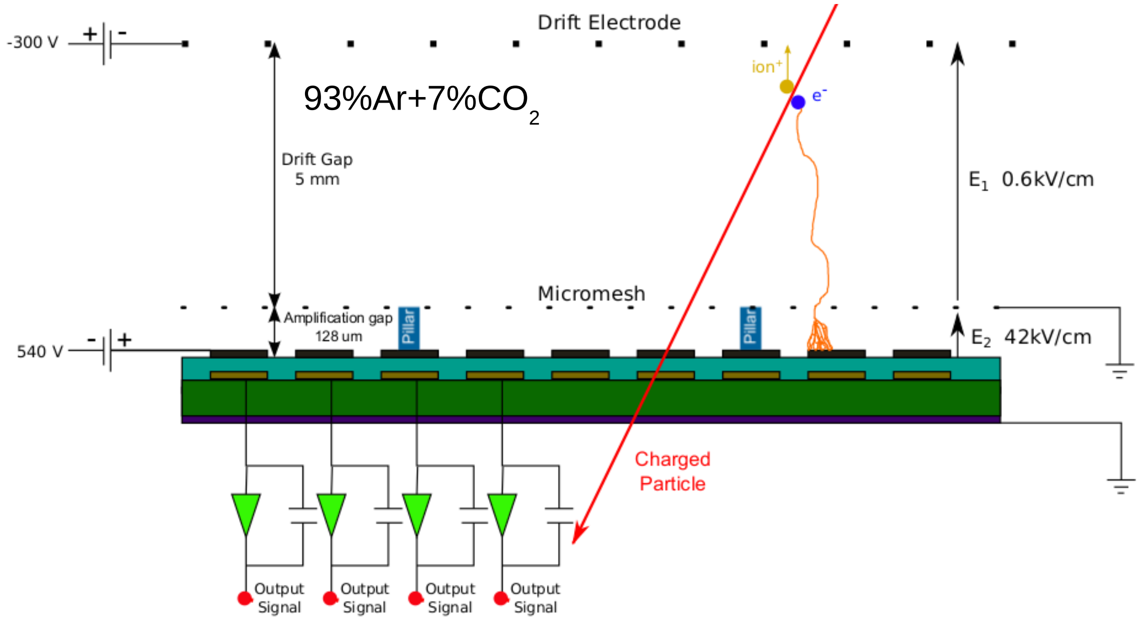
REQUESTED FEATURES:
- high granularity (few mm^2);
- performance at high rate (> 10 MHz/cm^2);
- spatial resolution about 100µm

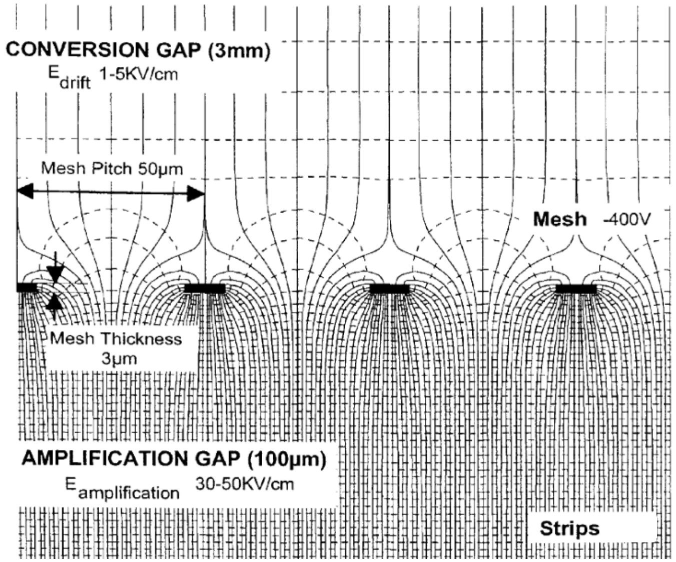
Resistive strip Micromegas

Micro Mesh Gaseous Structure

OPERATION

ELECTRIC FIELD LINES



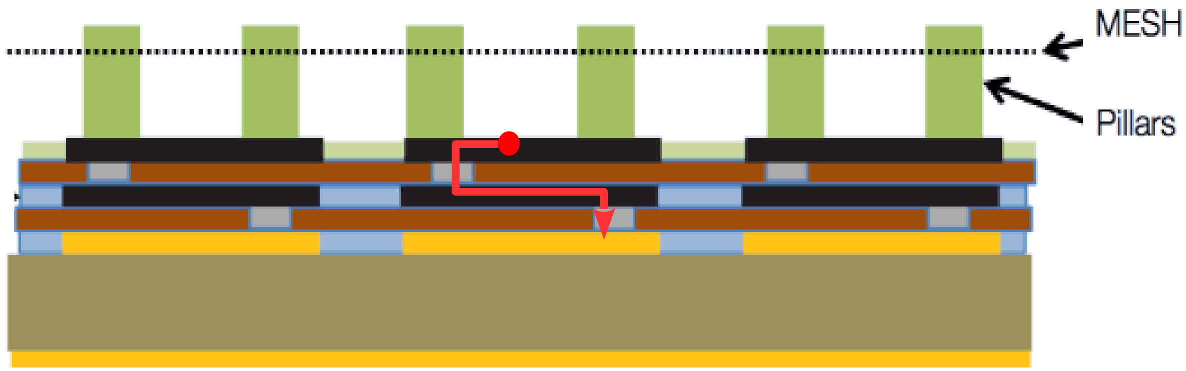


TRANSPARENCY: part of electrons which gets through the mesh plane ($\propto E_{ampl}/E_{drift}$)

GAIN: ratio between the number of avalanche's electrons and the number of primary ionization electrons

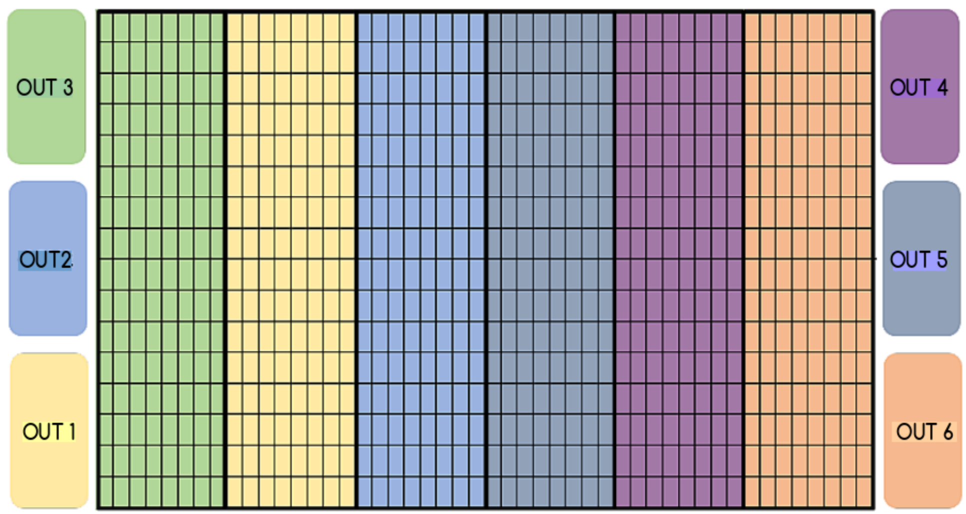
Small-pad Resistive Micromegas

NEW PROTOTYPE:
Small-pad pattern with an embedded resistor between the resistive and the readout pads. It could be part of Phase II upgrade.



SECTION VIEW
The layout is composed by:
I black layer: resistive pads;
II black layer: embedded resistors;
Brown layer: kapton foils;
Grey area: conductive silver paste;
Yellow layer: readout pads.
Path of the collected electron

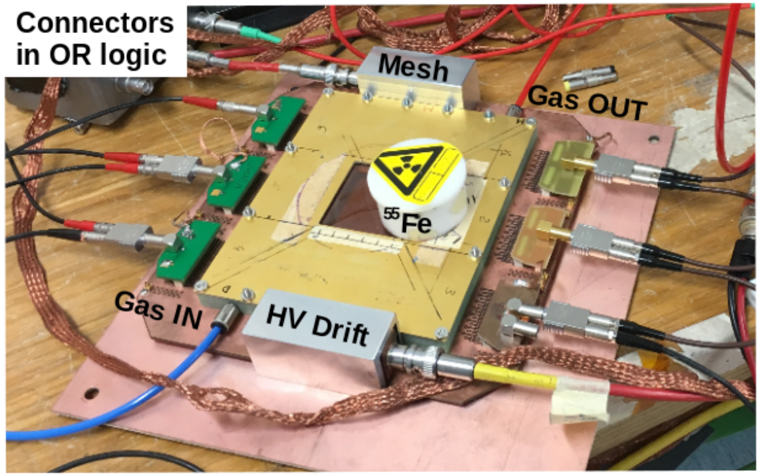
TOP VIEW
Readout channel mapping.
Matrix of 48x16=768 pads
(1x3)mm^2 each one,
(5x5)cm^2 active area.

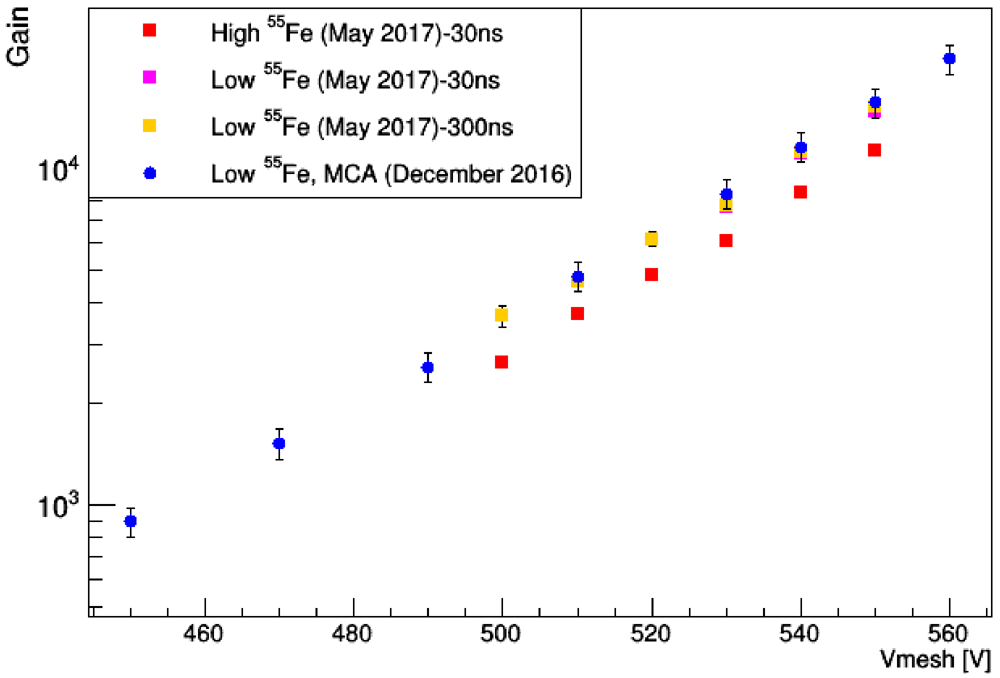


Gain measurement: ^{55}Fe sources

^{55}Fe sources:
- low intensity (3.28MBq in 2011)
- high intensity (1.1GBq in 2012)

$$G = \frac{I[A]}{e \cdot n_p \cdot R[Hz]};$$

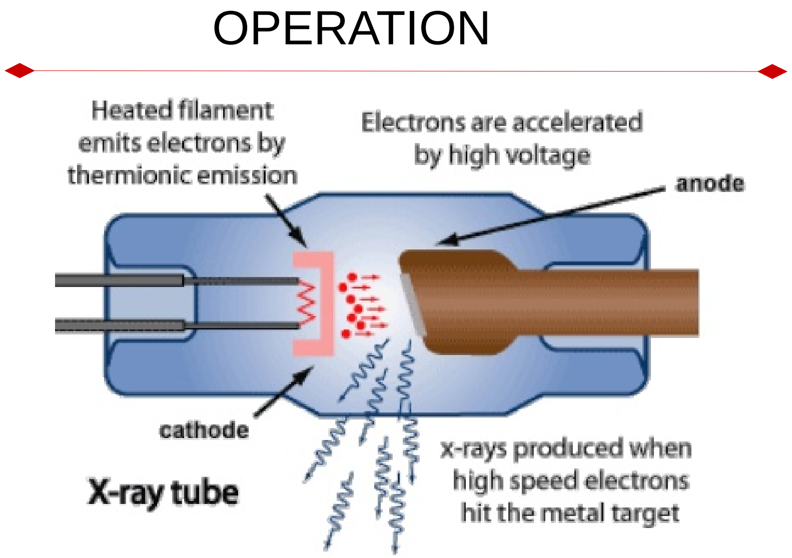




Difference of ~20% between the sources

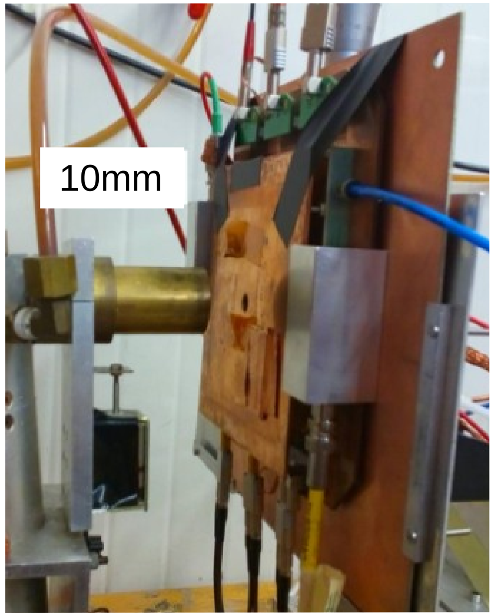
CHARGING UP EFFECT:
Part of the avalanche's electrons is deposited on the dielectric plane between the resistive pads (200µm) and they can't evacuate towards the ground. A localized charge effect is created and the electric field looks less intense.

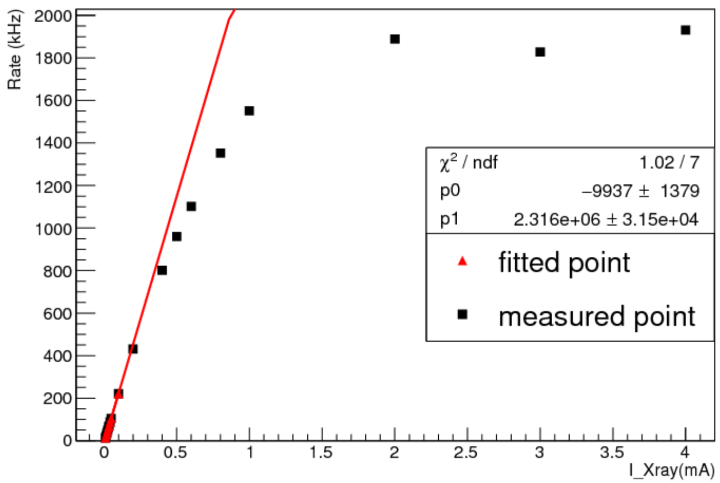
Gain measurements: X rays



The tube provides for X-ray at 8keV

The chamber has been placed orthogonal to the X ray beam

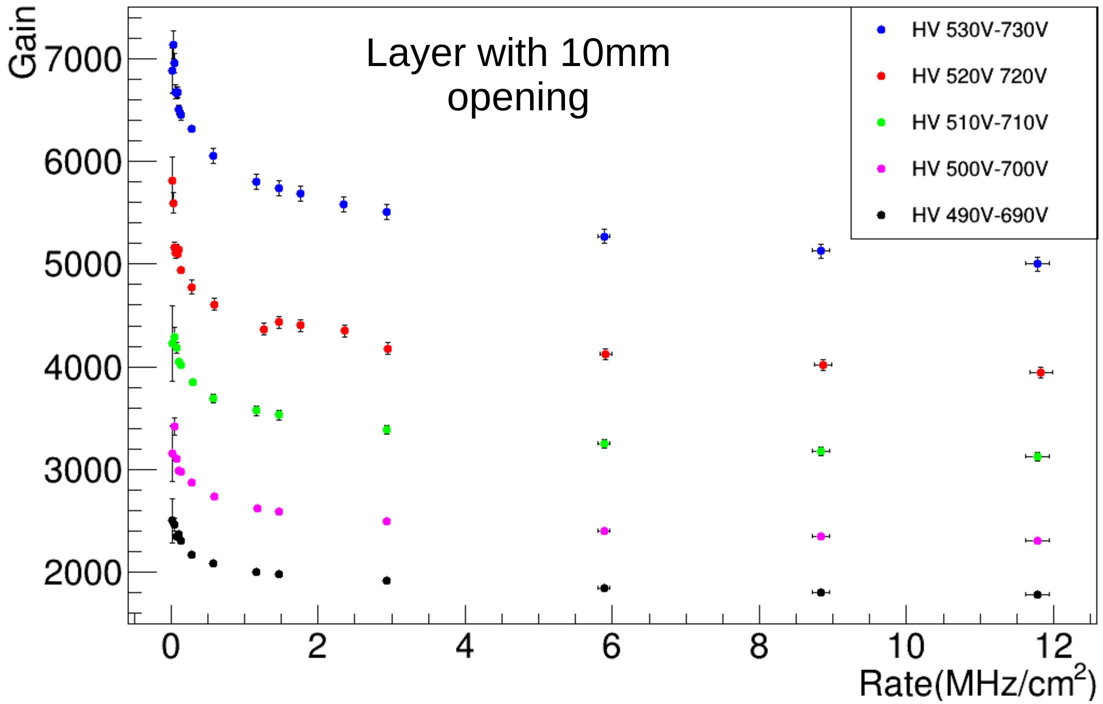


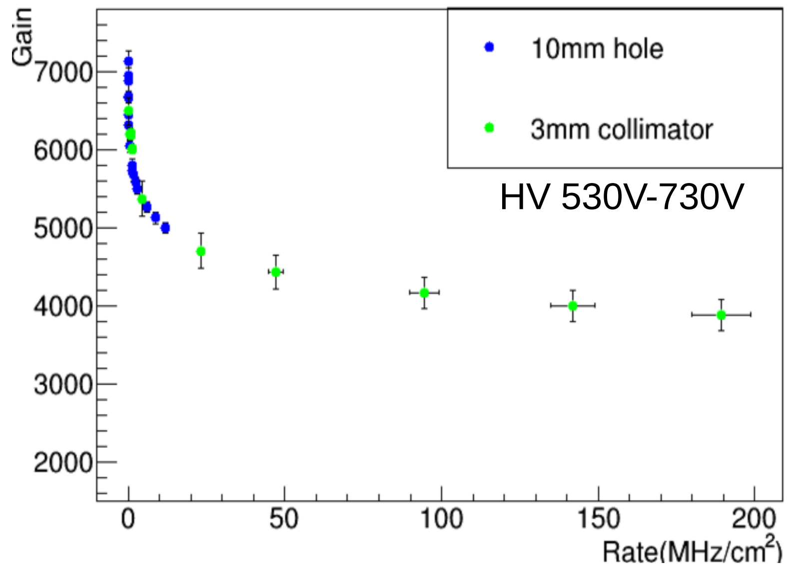


The linear trend is respected only for the first points.
The saturation is due to the dead time of the electronic instruments used in the setup.
The other ones are extrapolated by a linear fit:

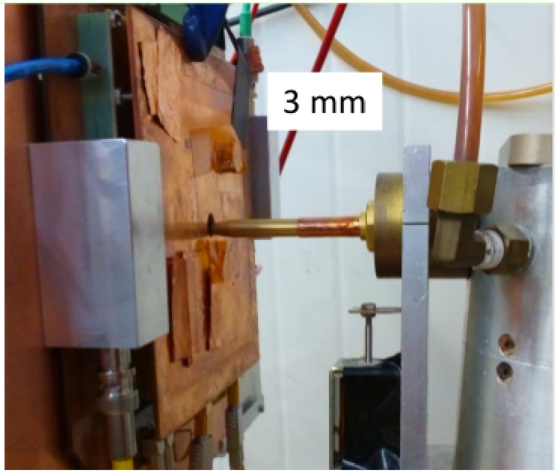
$$Rate = p0 + p1 \cdot I_{Xray}$$

Gain measurements: X rays

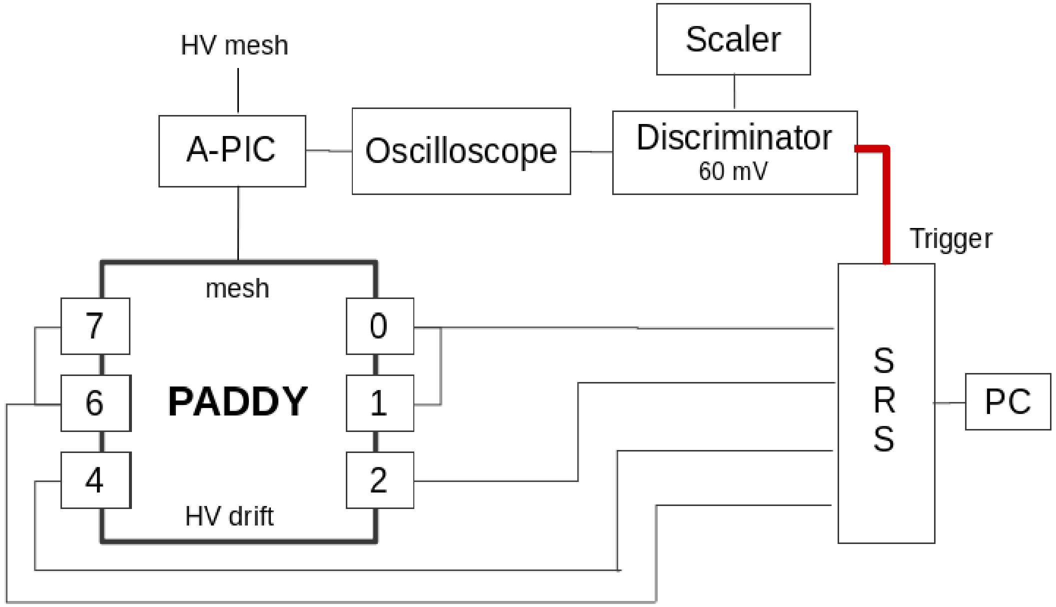


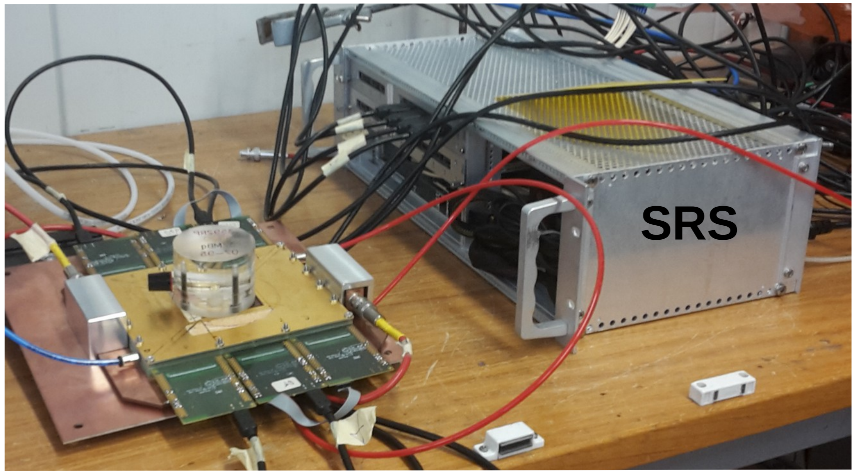


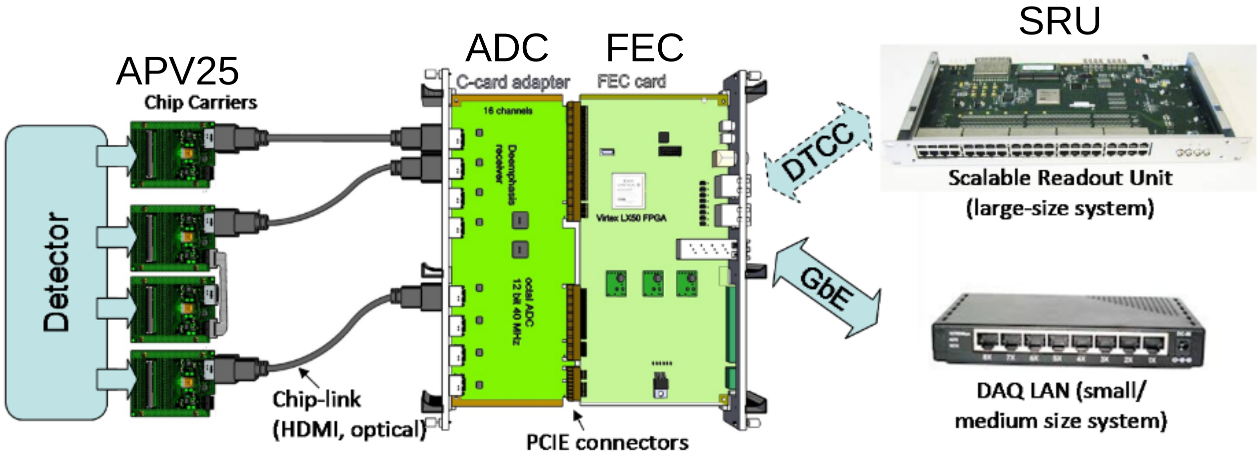
A collimator (3mm) and a layer with 10mm opening have been used in order to change the rate/cm^2 and to vary the hit area.



Scalable Readout System





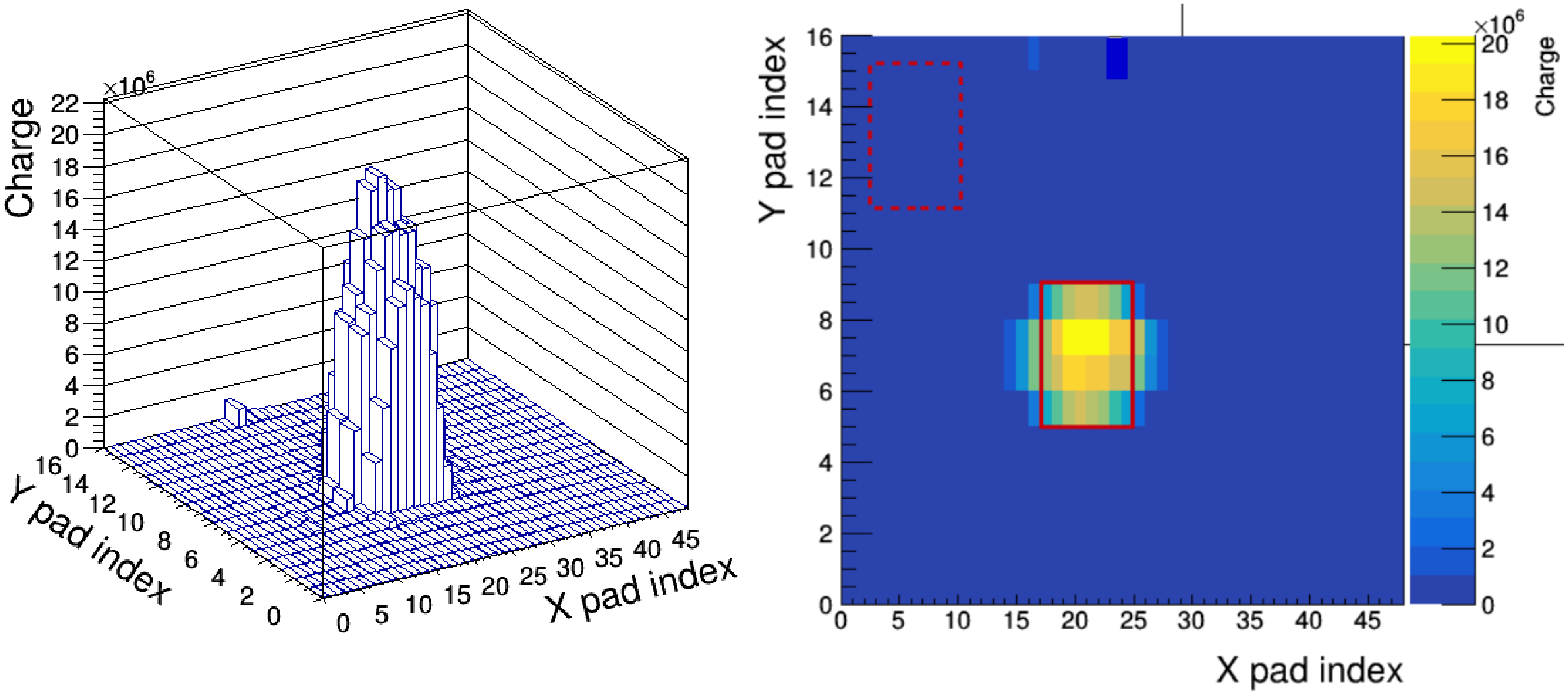


SRS has been used to know the signal (charge, time, position) of each hit pad.

The SRS trigger is provided by a discriminated signal from the mesh plane. Collected signals are *correlated* with the trigger.

Beam profile

Pads hit by the X-ray beam, using layer with 10mm opening, 3D and 2D views



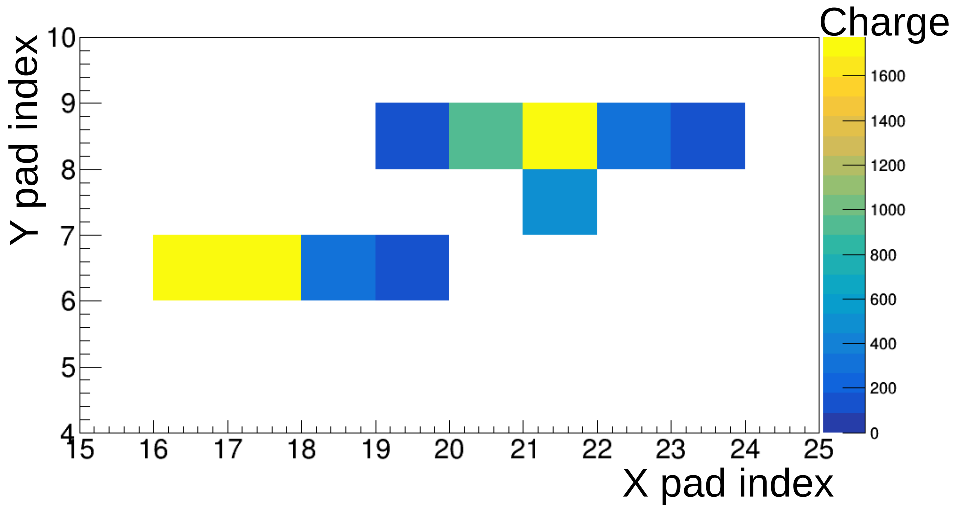
Cluster algorithm

REQUESTS

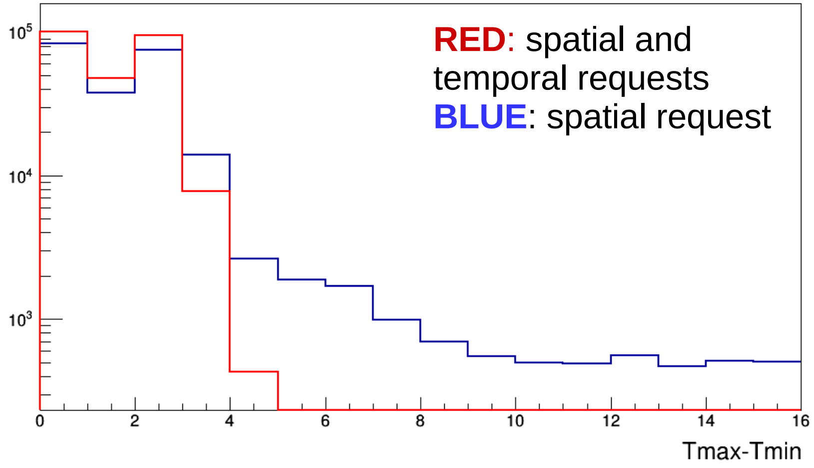
SPATIAL ONE: starting from the most energetic hit pad, eight closest pads to it are controlled;

TEMPORAL ONE: the time of the pad is distant or less of 50ns from the cluster mean time, or less of 25ns from the next pad.

Example of clusters built in the same event



T_{max} - T_{min} distribution for each cluster



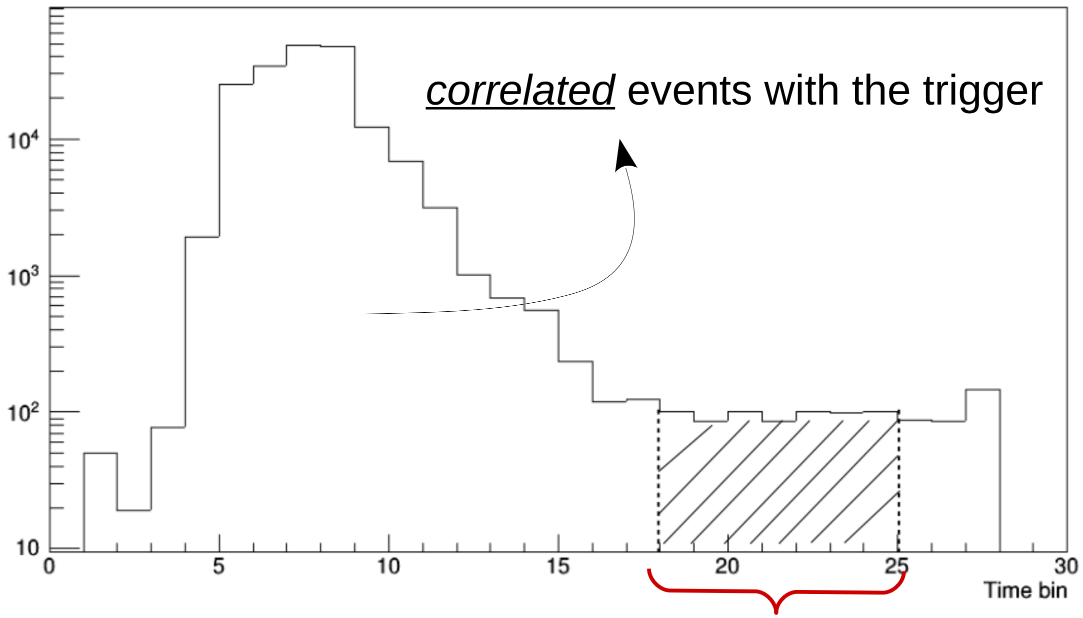
100ns: drift time in 5mm

High rate calculation with X rays

Alternative method to calculate the rate → Distribution of the cluster mean time, weighted to the charge

$$R = \frac{A}{25ns \cdot nbins \cdot T}$$

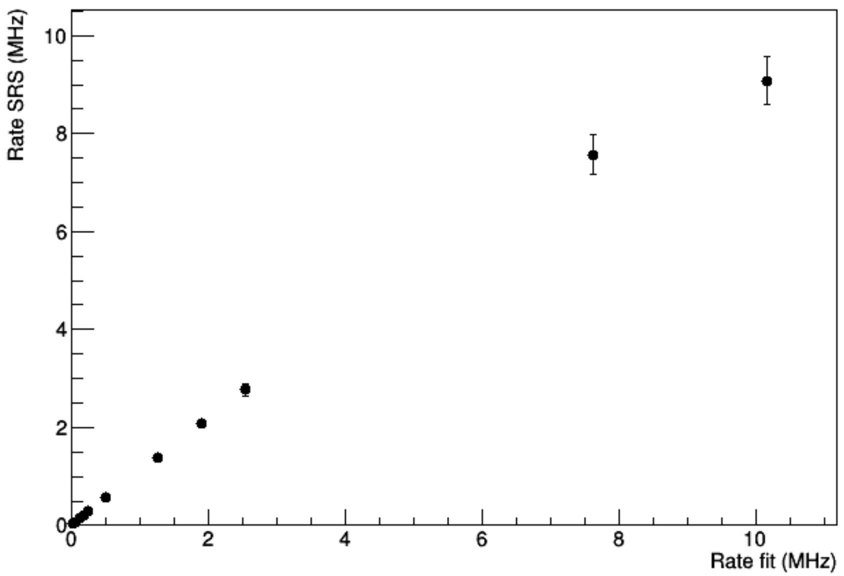
A: entries in the selected area;
25ns: temporal size of each bin;
Nbins: bin number included in the range;
T: trigger number in all the run (number of events)



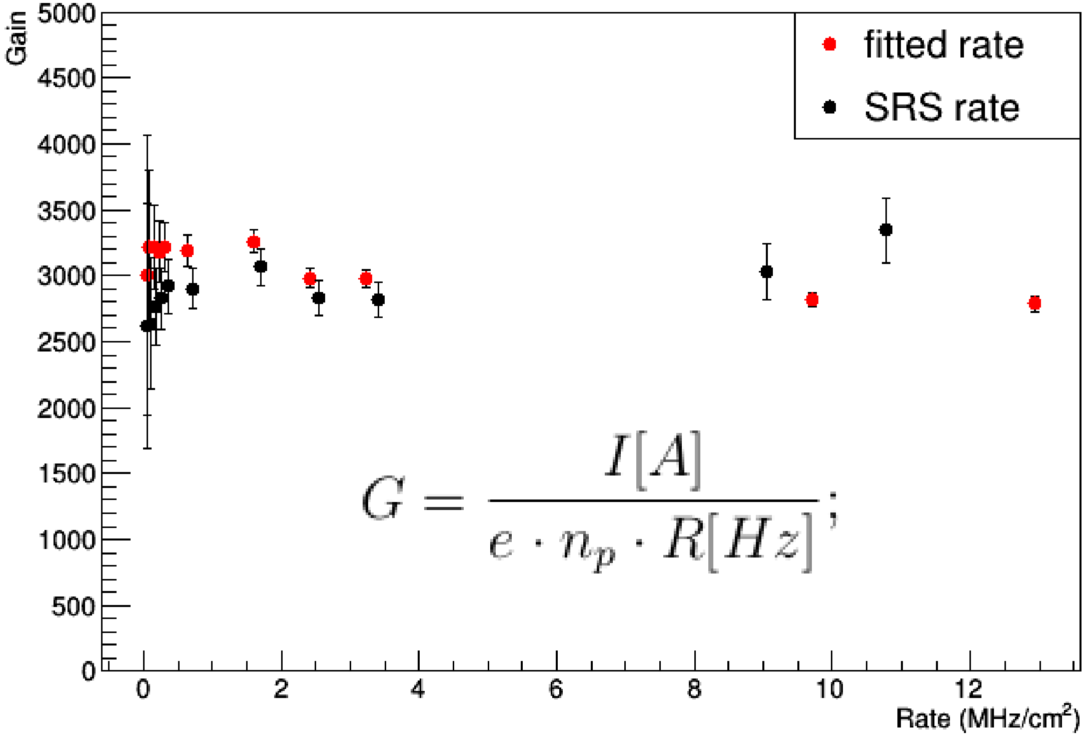
The range has been chosen into the histogram tail to analyse only *uncorrelated* signals with the trigger

High rate calculation with X rays

HV= 490V - 690V – layer with 10mm opening



Rate (calculated with SRS) versus
Rate (from the linear fit)



$$G = \frac{I[A]}{e \cdot n_p \cdot R[Hz]};$$

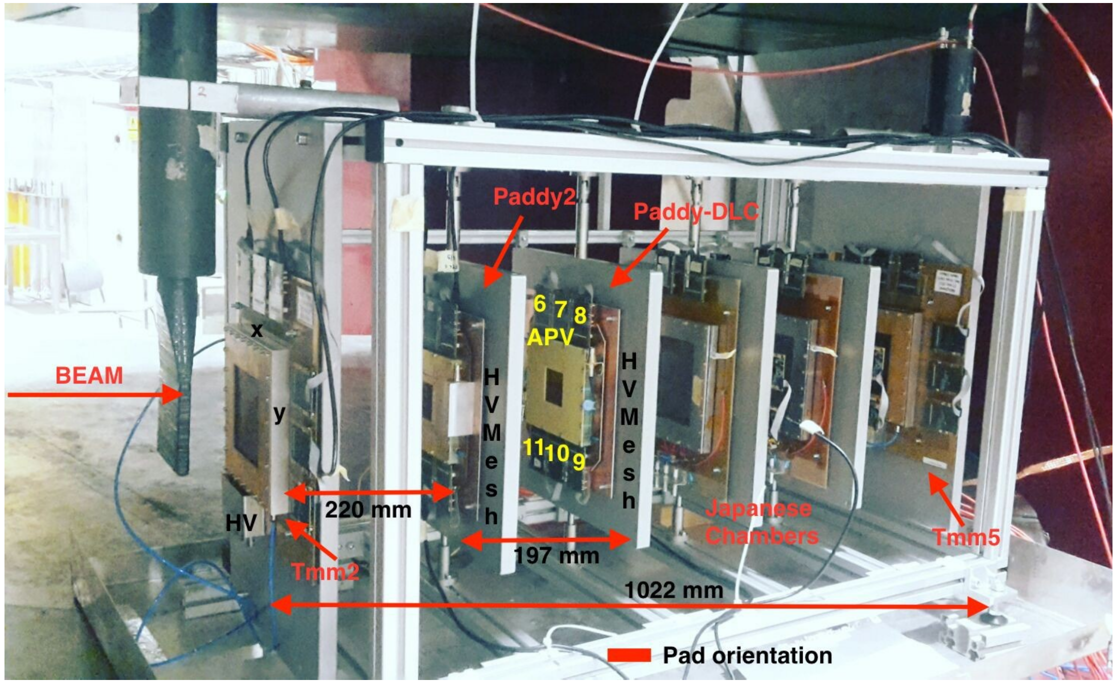
SYSTEMATIC ERROR AT THE R_{SRS}

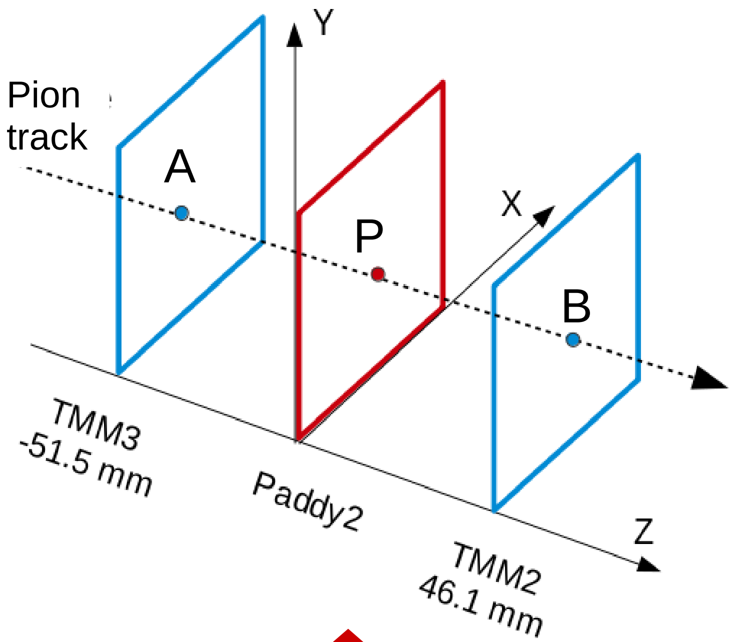
Introduced by the choice of the temporal request in the cluster algorithm

Gain versus Rate/cm^2

Test beam: resolution and efficiency

Pions at 500GeV provided by the SPS@CERN





SETUP USED FOR THE MEASUREMENTS:

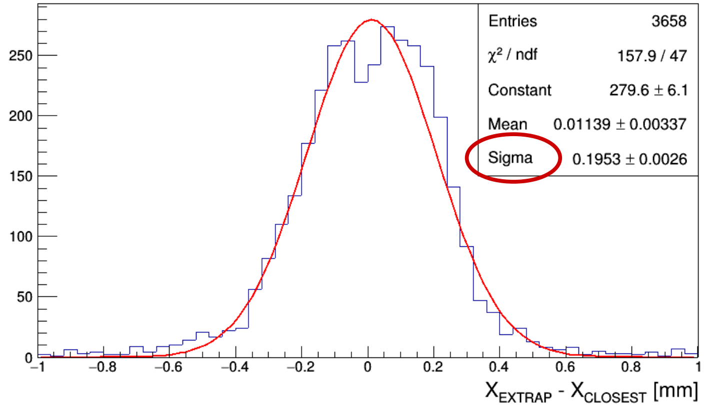
- two scintillators which provide the trigger signal;
- two strip Micromegas (TMM) used as external trackers;
- Paddy was placed in the middle.

LINEAR EXTRAPOLATION PROCESS IN 3D SPACE

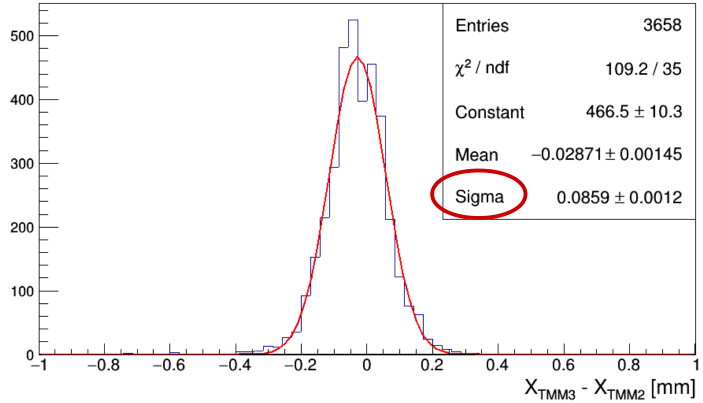
Spatial resolution results

$$\sigma_X = (\sigma^2_{X residual} - \sigma^2_{X extrapolated})^{1/2}$$

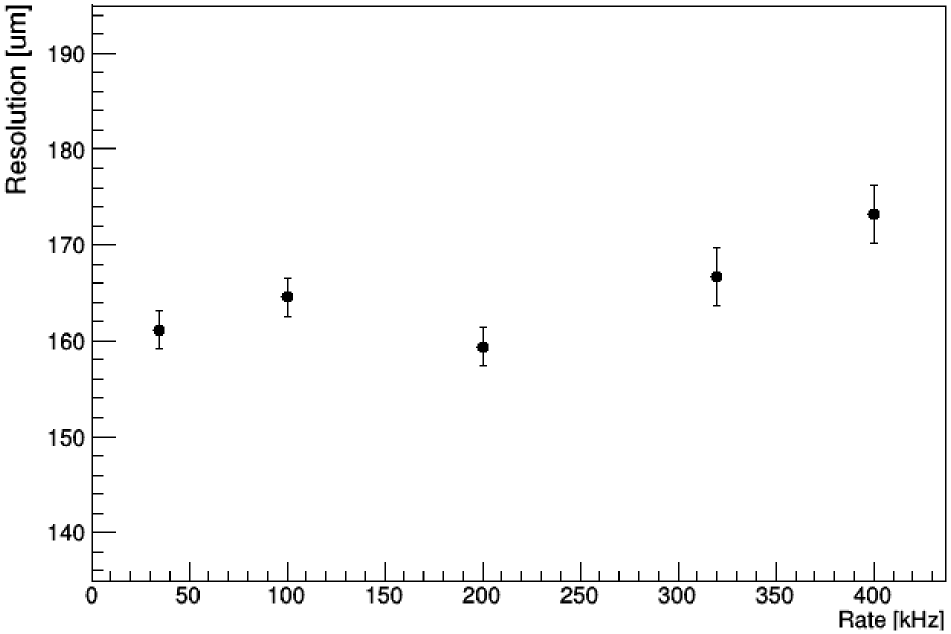
Residual between the extrapolated point and the cluster in Paddy



Residual between the TMM cluster



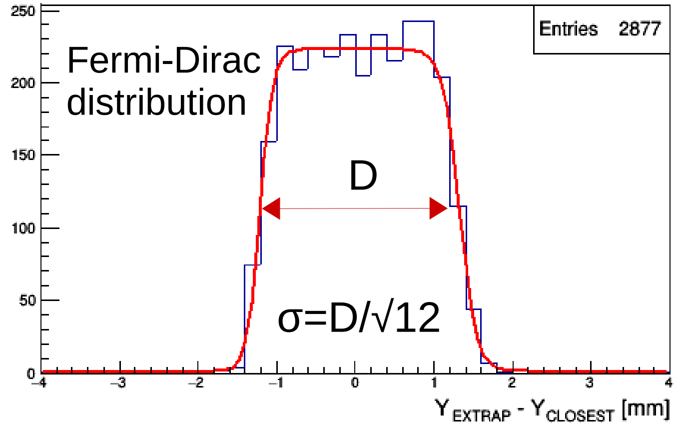
Resolution in X view ~ 170μm (precision coordinate)



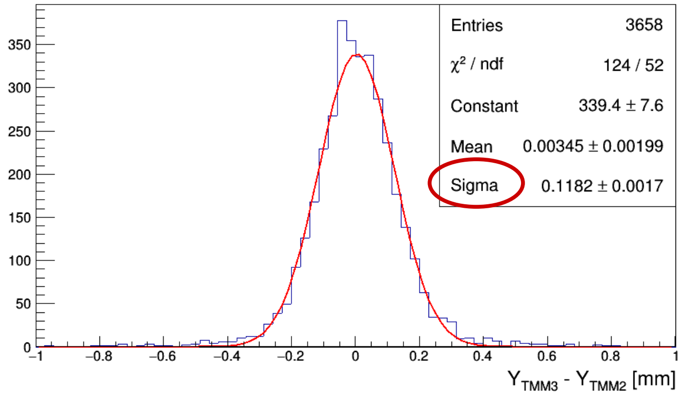
Spatial resolution results

$$\sigma_Y = (\sigma^2_{Y residual} - \sigma^2_{Y extrapolated})^{1/2}$$

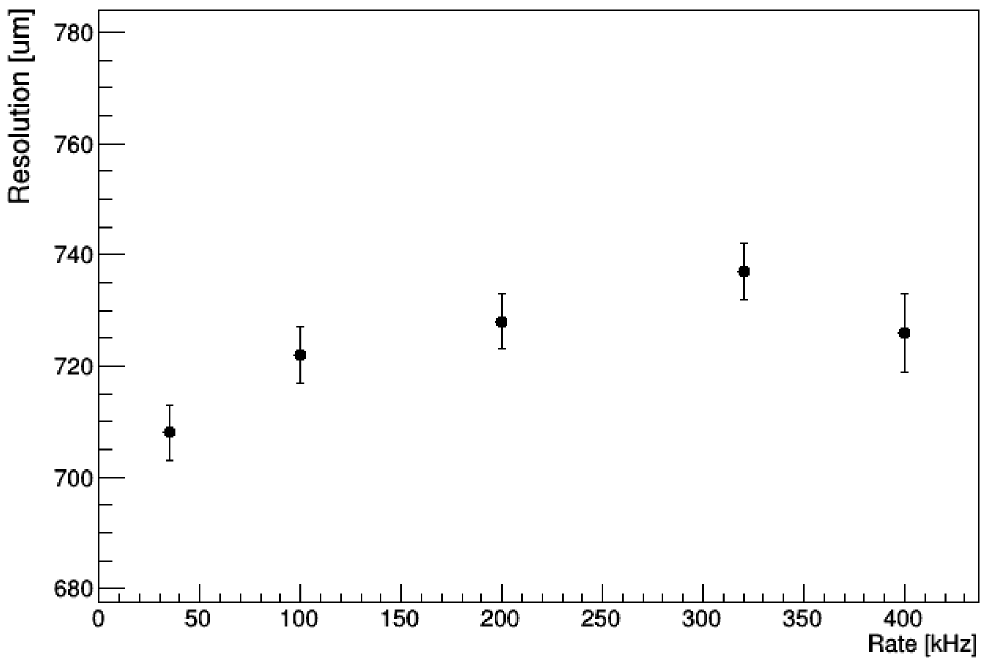
Residual between the extrapolated point and the cluster in Paddy



Residual between the TMM clusters

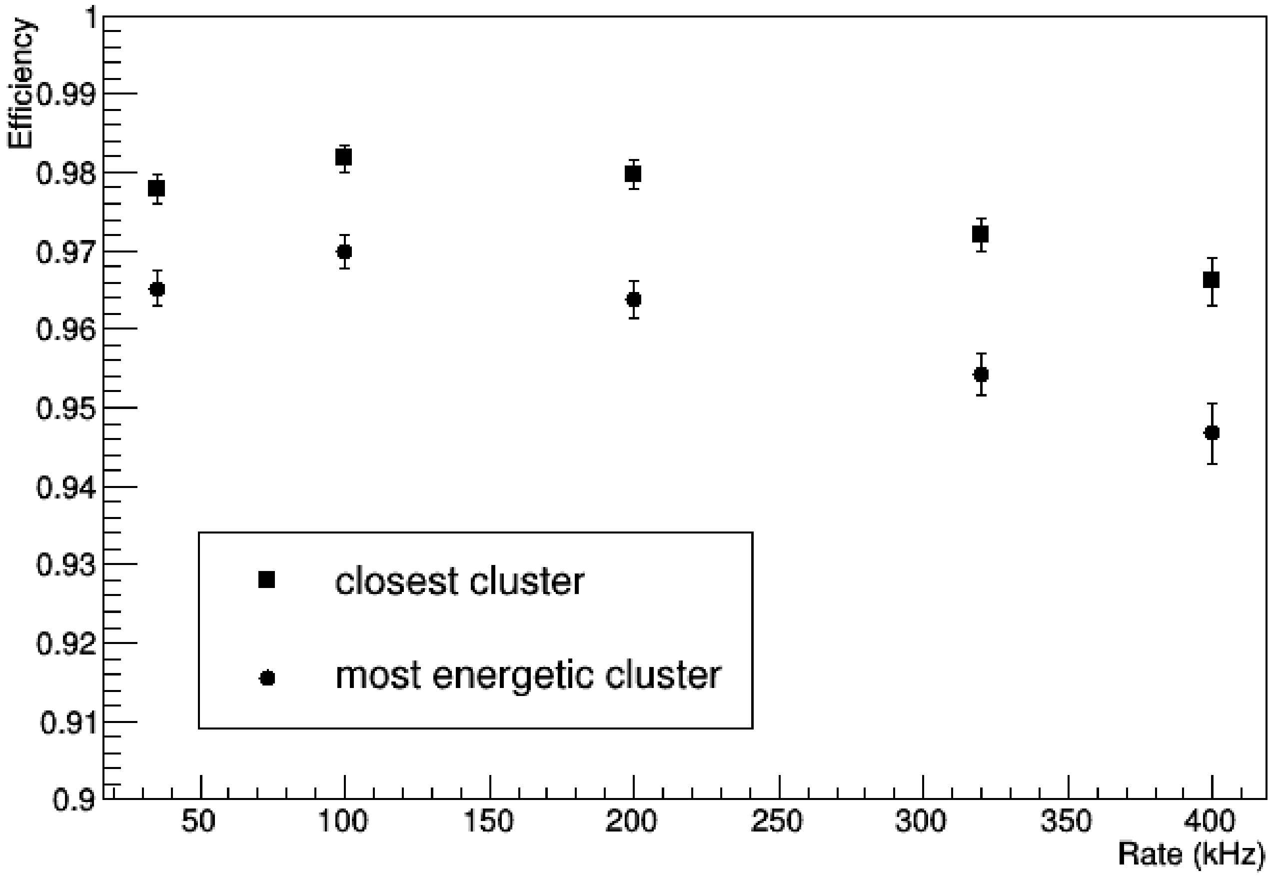


Resolution in Y view ~ 730μm



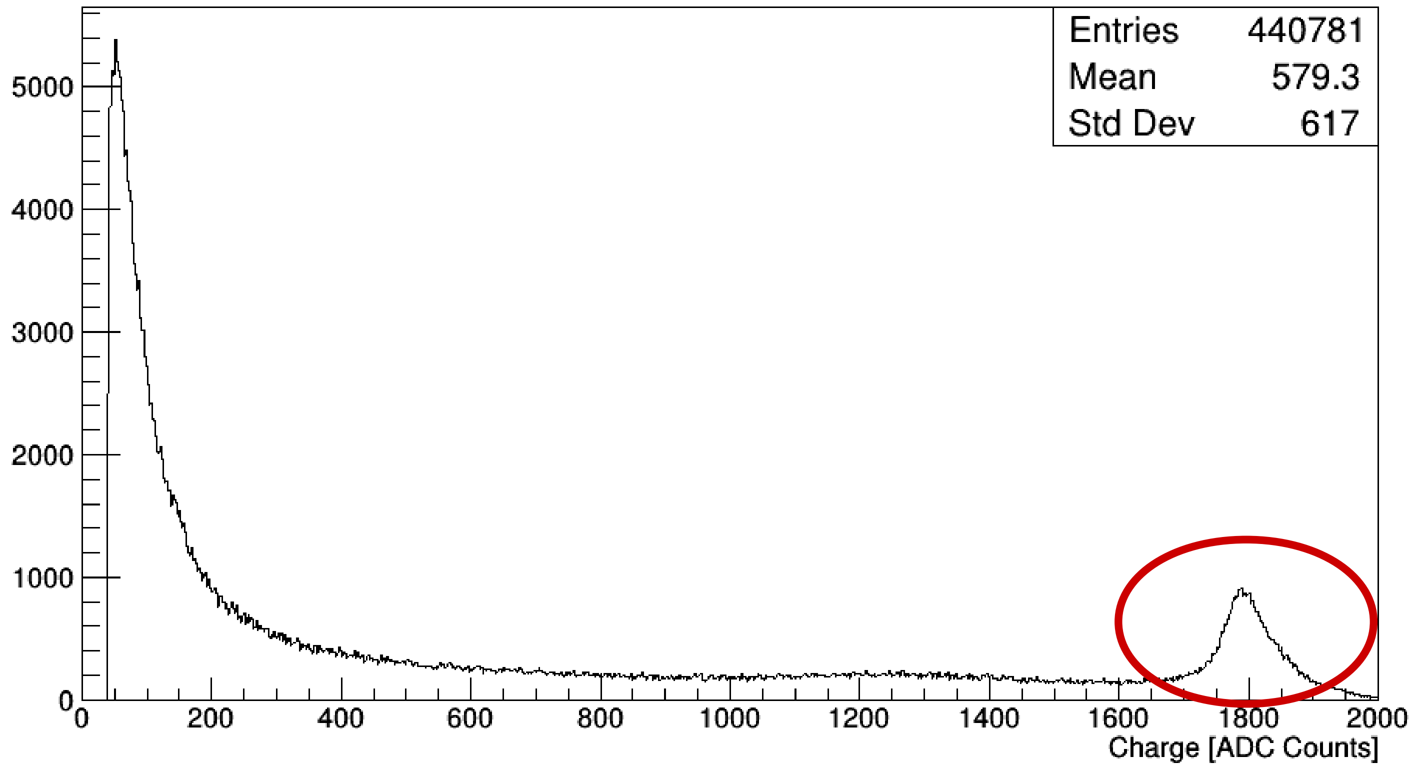
Detector efficiency

EFFICIENCY in 3σ from the extrapolated point



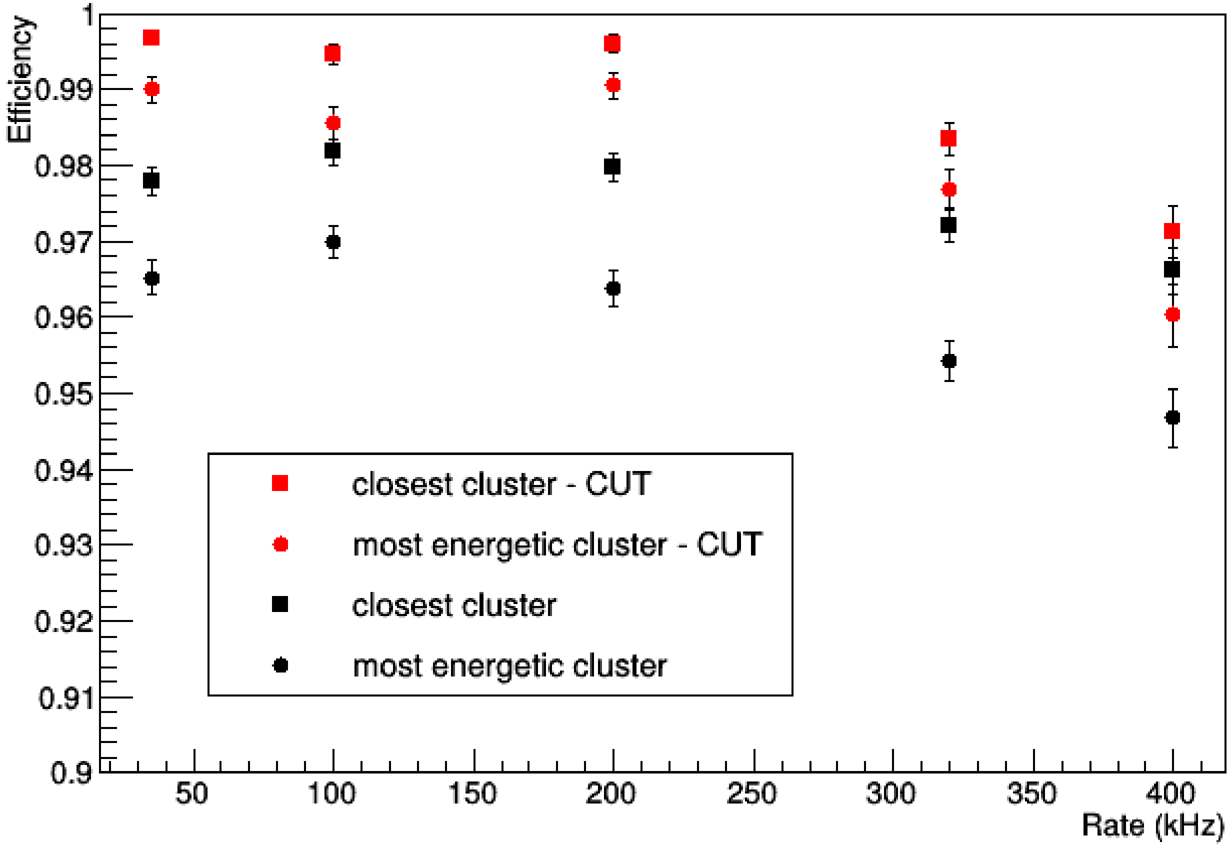
Saturation cut

Charge distribution of the single hit pad → Cut at 1650 ADC counts because of the ADC saturation peak



Detector efficiency results

EFFICIENCY in 3σ from the extrapolated point



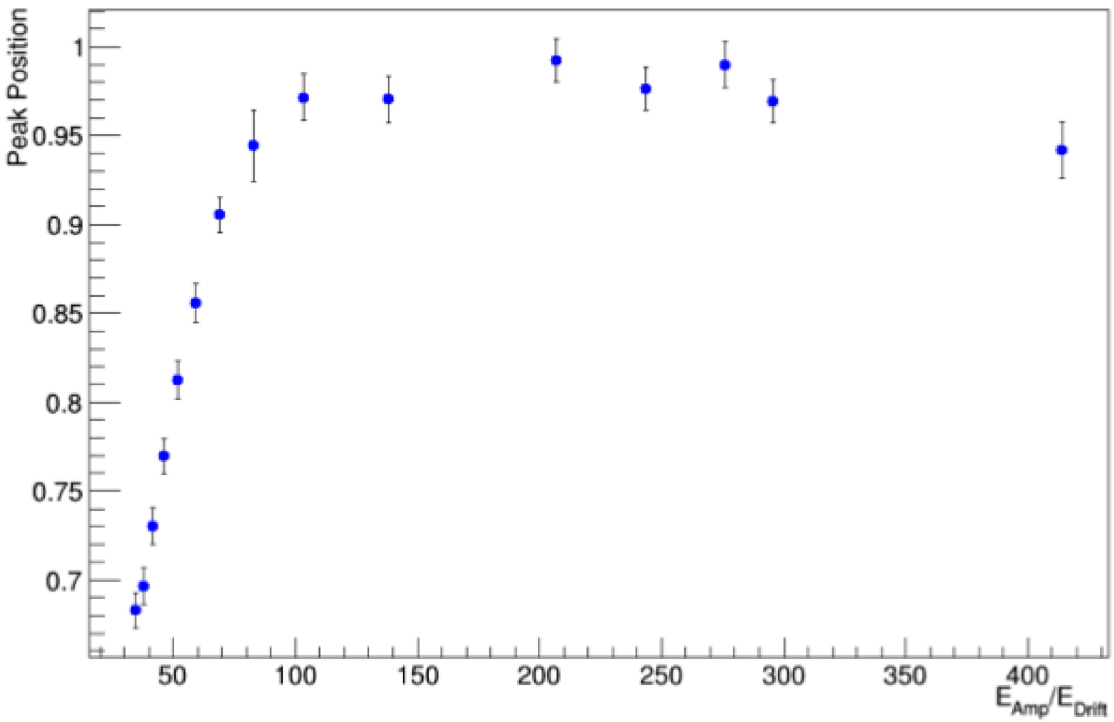
Studying a different criteria to analyze the saturated pad, without deleting the event

Conclusions

- Gain versus HV using ^{55}Fe sources; stable values, about $10^3 \div 10^4$, are obtained.
- Gain versus rate/cm^2 using X ray beam and varying the hit area. Values about 10^3 at ~150 MHz/cm^2 are obtained;
- Good agreement between the R_{SRS} and R_{fit}, calculated by different ways, has been verified;
- The spatial resolution in x view is ~170μm, in agreement with the precision coordinate requested in the "High η muon tagger" project;
- The spatial resolution in y view is ~730μm, because of the bigger size of the pad;
- The detector is efficient at 97% with a π rate of 400kHz/cm^2.

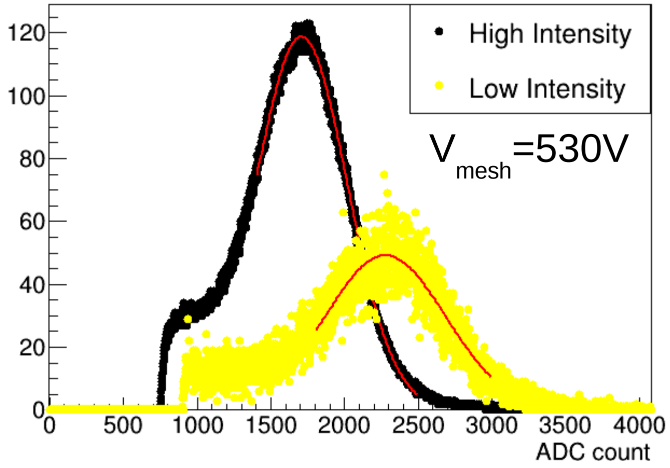
BACKUP

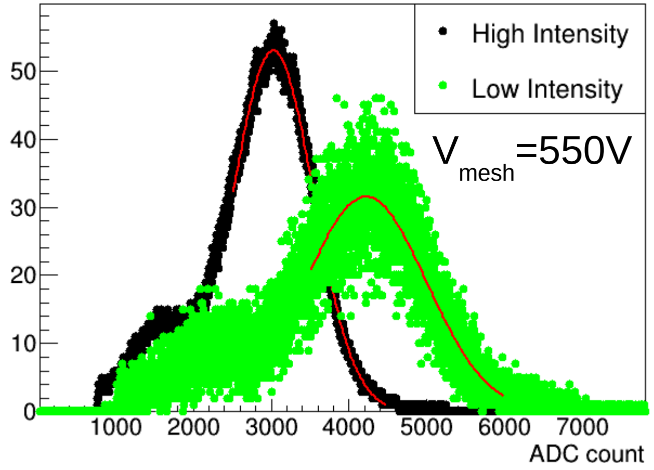
Paddy transparency



Charging up effect

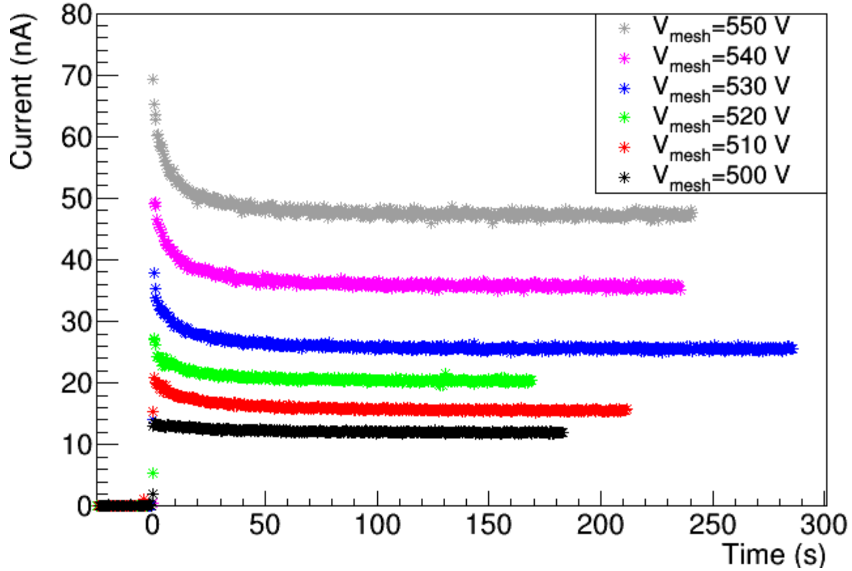
From the MCA files:
~20% shift of the low source peak towards the right





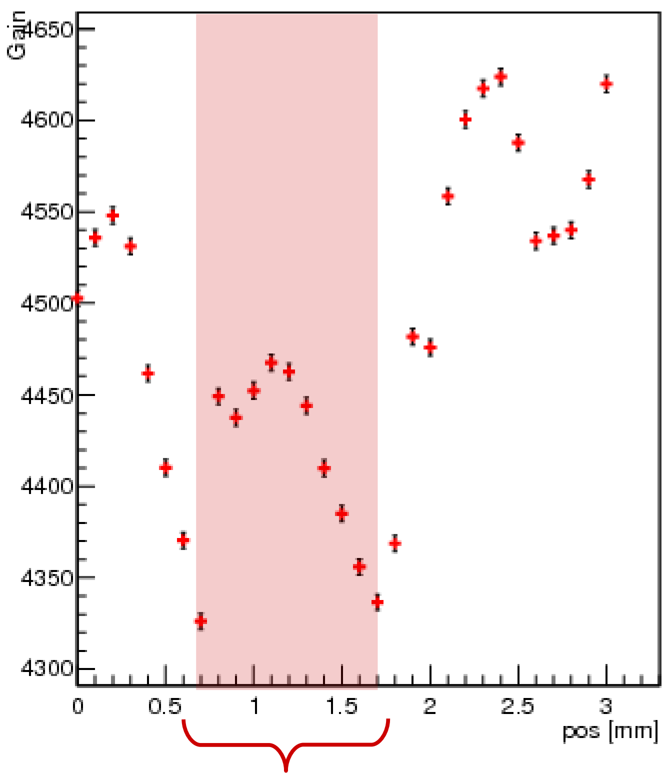
From the picoammeter files:
Current reduction in about 20s

CHARGE UP:
Part of the avalanche's electrons is deposited on the dielectric plane between the resistive pads (200µm) and they can't evacuate towards the ground. A localized charge effect is created and the electric field looks less intense.

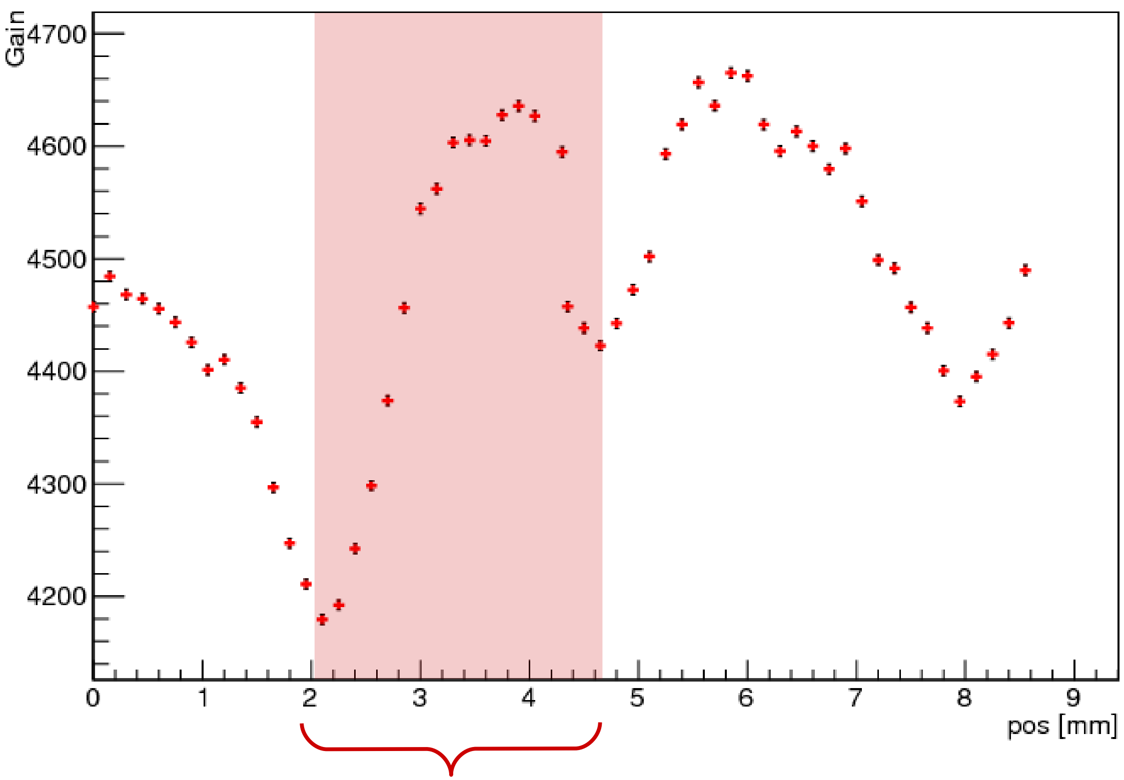


Charging up effect

Scan in the x way using X ray



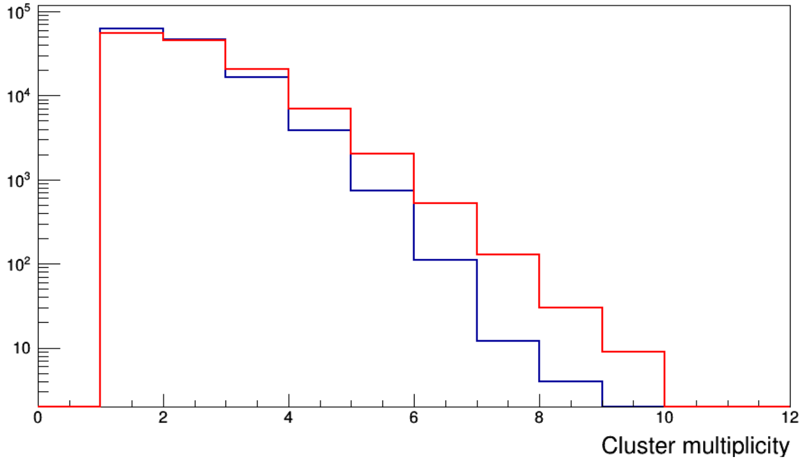
Scan in the y way using X ray



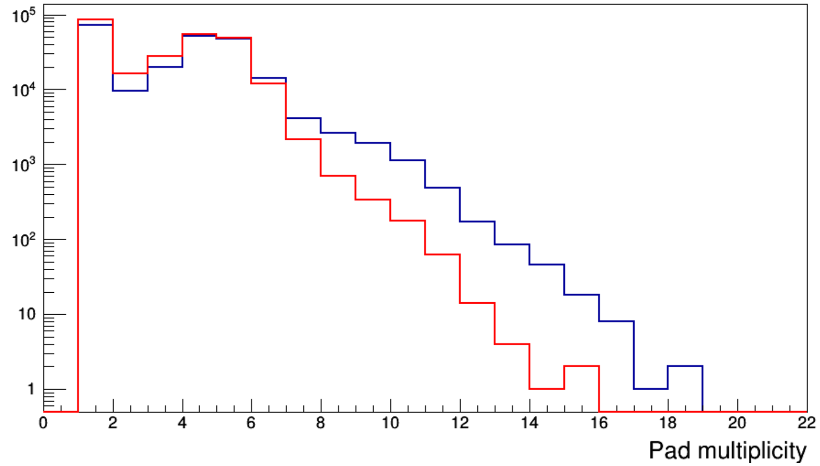
~1mm → The width matches the pad size ← ~3mm

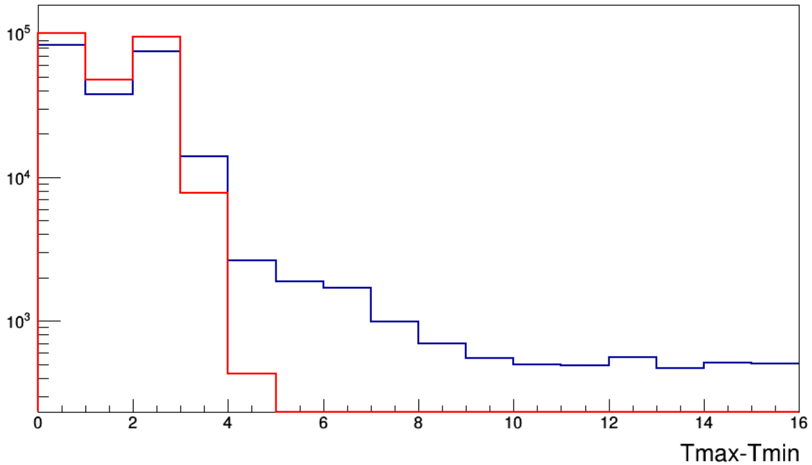
Cluster algorithm

Number of clusters built for each event



Number of pad for each cluster





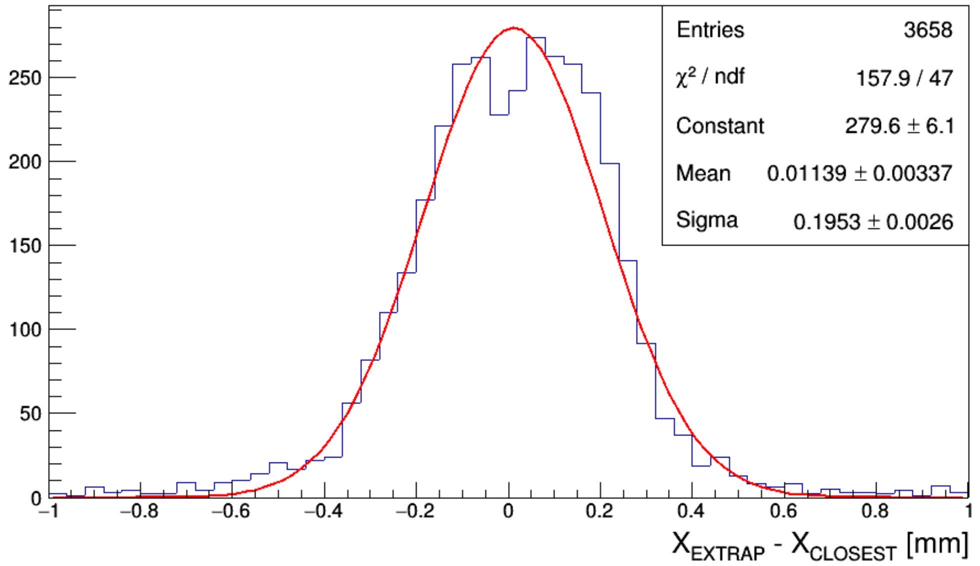
T_{max} - T_{min} distribution for each cluster

RED: spatial and temporal requests
BLUE: spatial request

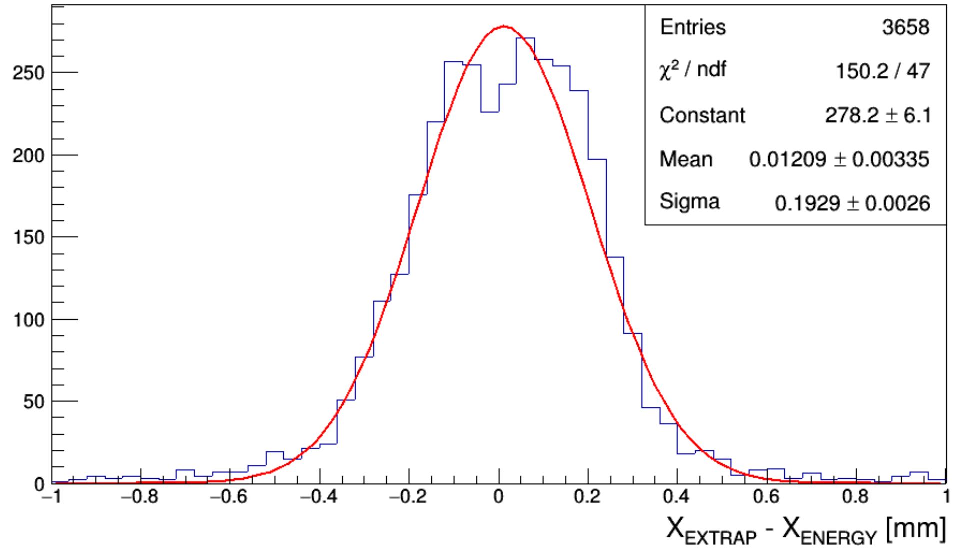
Detector efficiency

Residual in X view in Paddy

Closest cluster



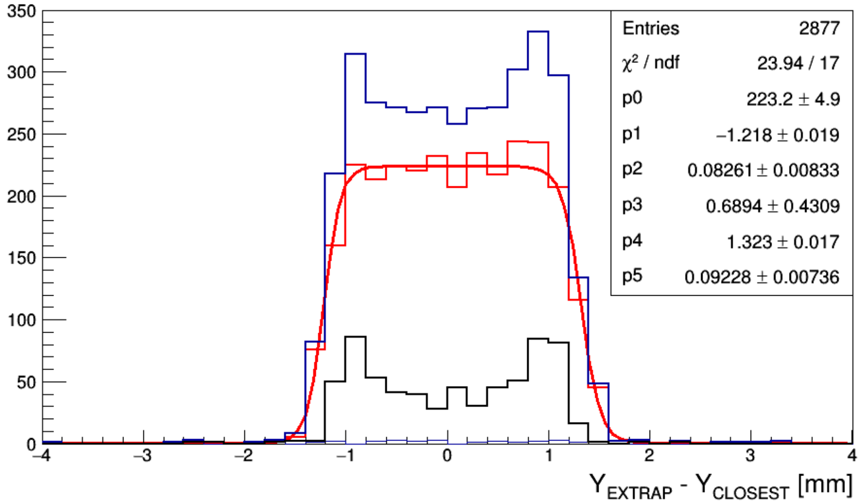
Most energetic cluster



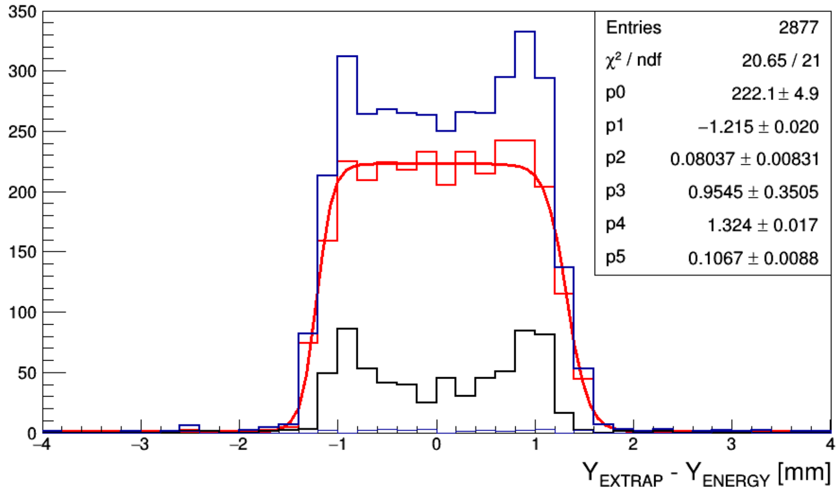
Detector efficiency

Residual in Y view in Paddy

Closest cluster



Most energetic cluster



Fermi-Dirac function on the rising and falling side:

$$f = (f_u \cdot f_d) + p_3 = \left(\frac{p_0}{1 + e^{-(x-p_1)/p_2}} \cdot \frac{1}{1 + e^{(x-p_4)/p_5}} \right) + p_3$$

$\sigma = (p_4 - p_1)/\sqrt{12}$

- p_0 normalization parameter
- p_1 e p_4 inflection point
- p_2 e p_5 from 10% to 90% for each side
- p_3 baseline

DLC prototype