Status of MSD subsystem

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FOOT Collaboration Meeting
Bologna, 4-5 dicembre 2017

1) Hardware activities

2) First results from july 2017 LNS beam test on LGAD

3) First results from july 2017 LNS beam test on NON LGAD Microstrips

Hardware activities: LGAD

1) Received in july two structures from N. Cartiglia (1x1 mm) to start learning their response. Used in july beam test @ LNS (more later)

2) Received 6 square structures in september, 5.6x6.3 mm^2, with 30 microstrips each one, 150 μm pitch, 630 μm thickness.

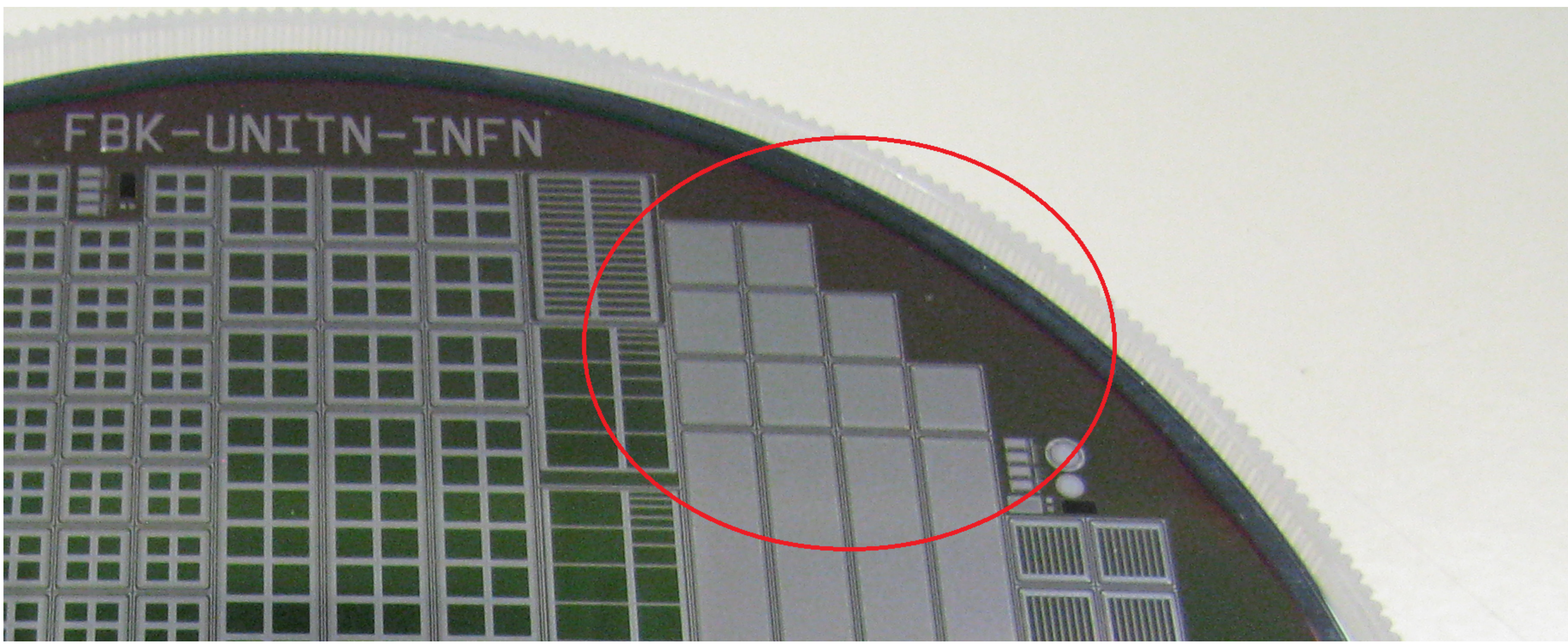
Hardware activities: NON LGAD

3) Received two devices 99 x 96 mm single side sensor, 150 μm thickness from Micron Semiconductor (UK)

4) Discussions going on with Hamamatsu concerning double sided 150 μm thick microstrip sensor.

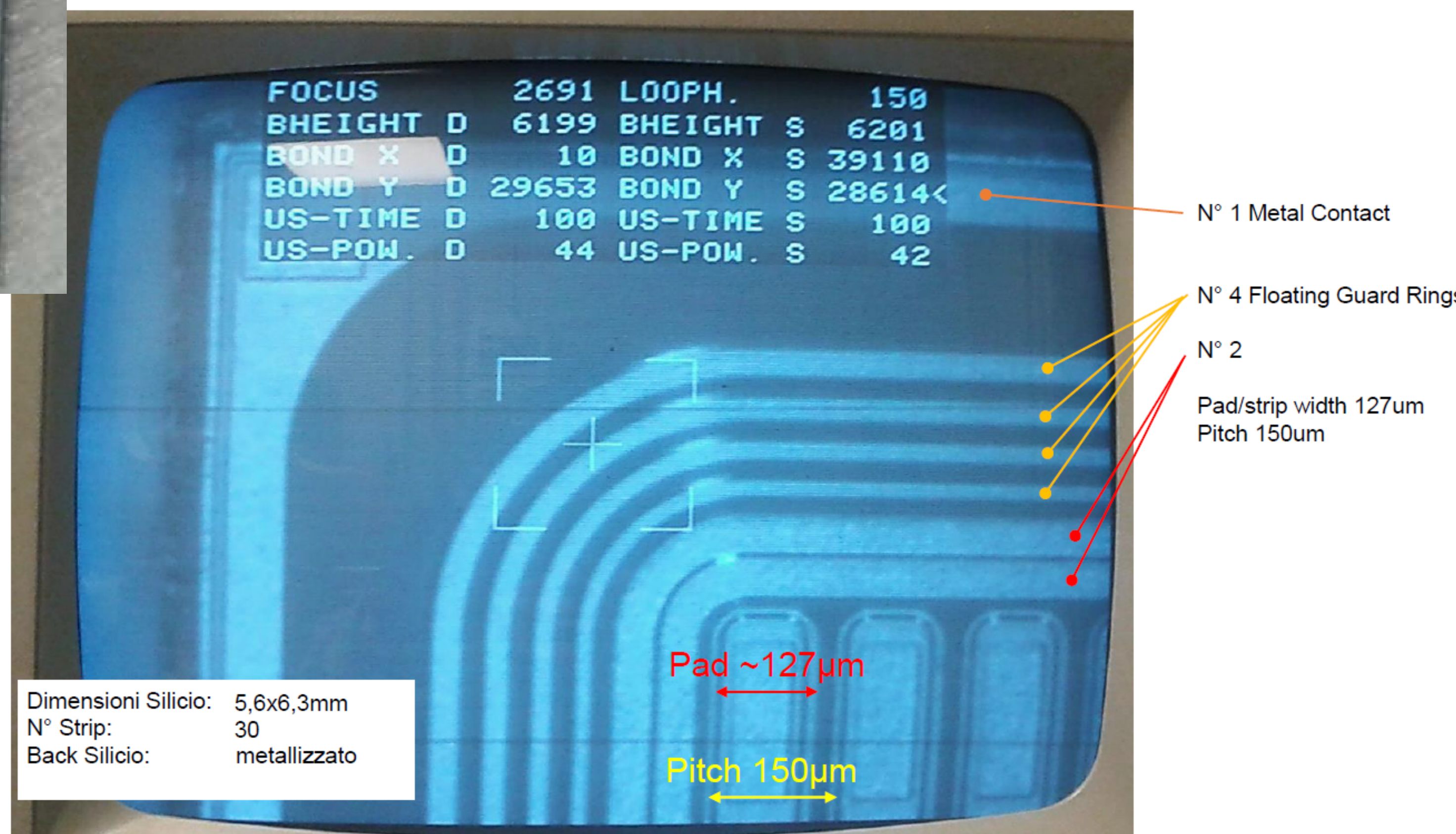
Hardware activities: LGAD

2) Received 6 square structures in september, 5.6x6.3 mm^2, with 30 microstrips each one, 150 μm pitch, 630 μm thickness. Cut from MPW of Nicolò with FBK.



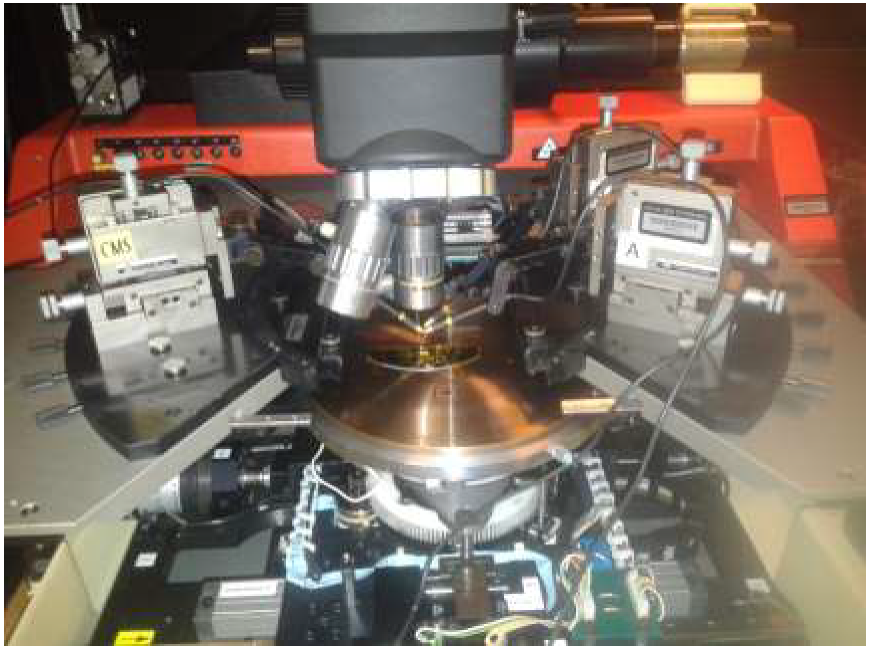
Hardware activities: LGAD

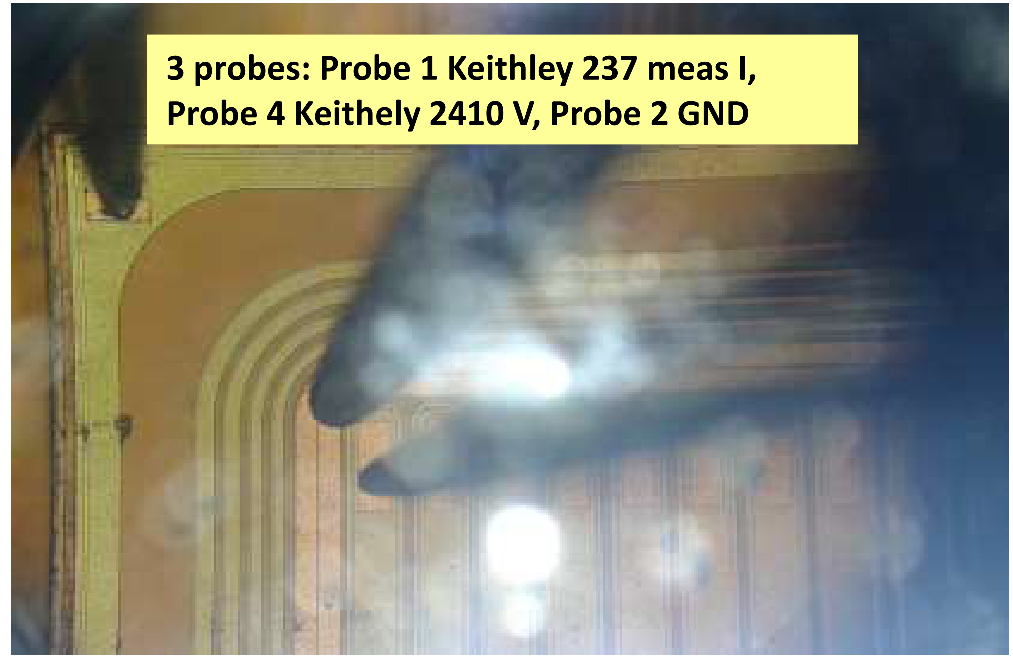
2) Received 6 square structures in september, 5.6x6.3 mm^{2}, with 30 microstrips each one, 150 μm pitch, 630 μm thick.



1 structure (NG) with NO LGAD .

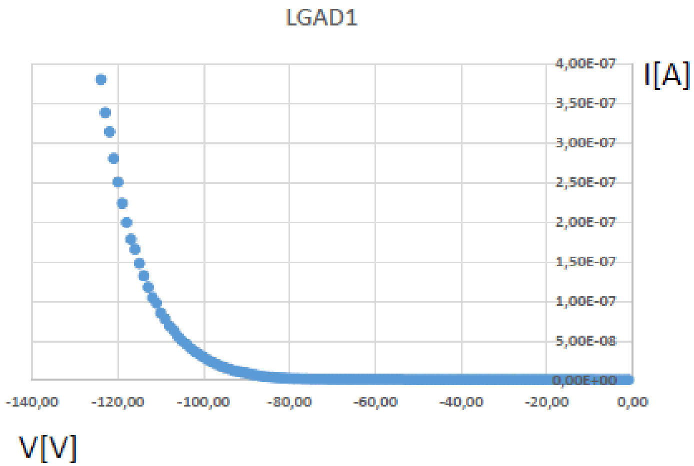
5 structures identical (#1-5) WITH LGAD.

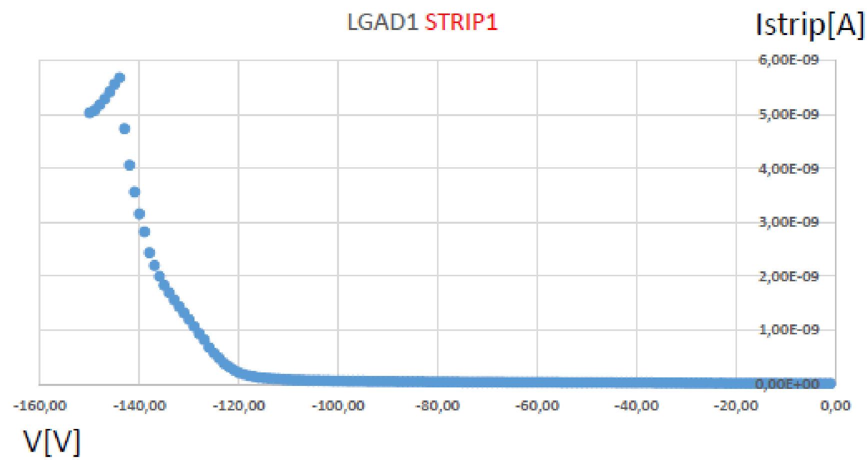


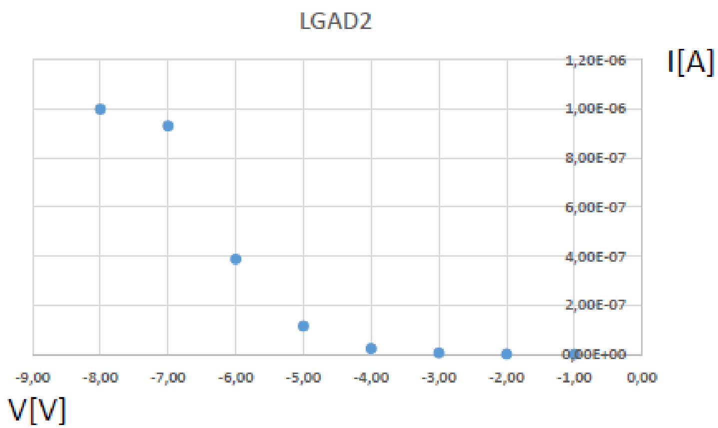


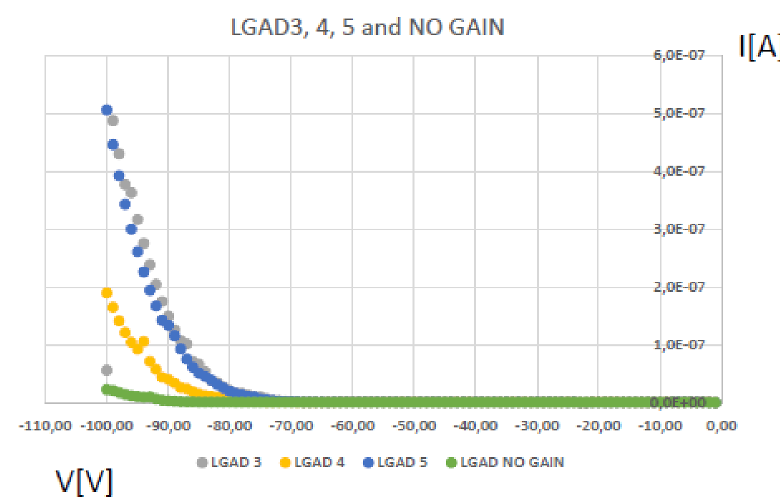
Test with probe station for IV measurement:

- → For the $I_{leak\ total}$ with two probes: Negative bias on external BIAS ring, read current on the innermost guard ring;
- → For the $I_{single\ strip}$ IV with 3 probes: Negative bias on external BIAS ring, GND on the innermost guard ring, read current on the strip.


LGAD1
I[A]
4,00E-07
3,50E-07
3,00E-07
2,50E-07
2,00E-07
1,50E-07
1,00E-07
5,00E-08
0,00E+00
-140,00 -120,00 -100,00 -80,00 -60,00 -40,00 -20,00 0,00
V[V]


LGAD1 STRIP1
Istrip[A]
6,00E-09
5,00E-09
4,00E-09
3,00E-09
2,00E-09
1,00E-09
0,00E+00
-160,00 -140,00 -120,00 -100,00 -80,00 -60,00 -40,00 -20,00 0,00
V[V]


LGAD2
I[A]
1,20E-06
1,00E-06
8,00E-07
6,00E-07
4,00E-07
2,00E-07
0,00E+00
-9,00 -8,00 -7,00 -6,00 -5,00 -4,00 -3,00 -2,00 -1,00 0,00
V[V]

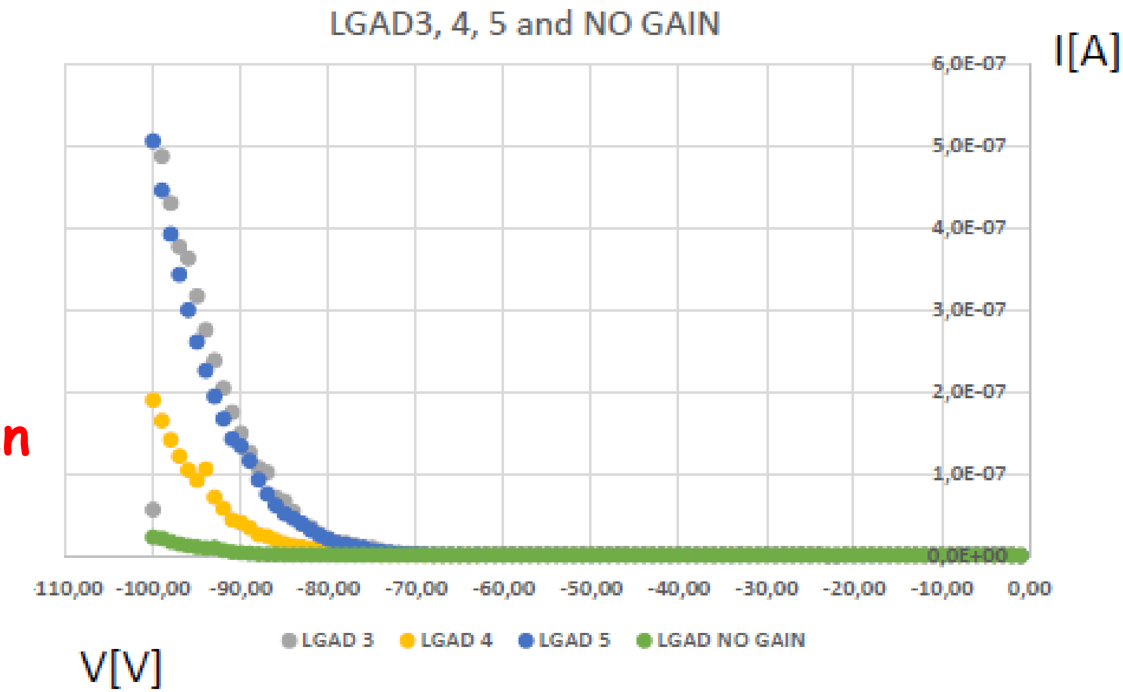

LGAD3, 4, 5 and NO GAIN
I[A]
6,0E-07
5,0E-07
4,0E-07
3,0E-07
2,0E-07
1,0E-07
0,0E+00
-110,00 -100,00 -90,00 -80,00 -70,00 -60,00 -50,00 -40,00 -30,00 -20,00 -10,00 0,00
LGAD 3 LGAD 4 LGAD 5 LGAD NO GAIN
V[V]

Summary:

→ structure #1 low breakdown (80-90 V), problems

→ structure #2 probably broken

→ structure NG : low current expected behavior. Checking the values.



→ structure # 3 and 5: expected behaviour. Good.

→ structure # 4: intermediate current. Checking

Next step LGAD structures:

→ Complete characterization with single strip measurements. Probe card needed and ordered.

→ Bonding the NO LGAD and one between # 3 and # 5 structure to DAMPE readout hybrid (64 channels). We have the substrate; it needs to be populated with components and the chip. Order in progress

→ test the device both in laboratory (β, α) than in a beam with protons, somewhere beginning next year.

→ check possibility to thin structures down to 70 μm. If possible, proceed and then bond to another hybrid two differently thinned structure. Test them.

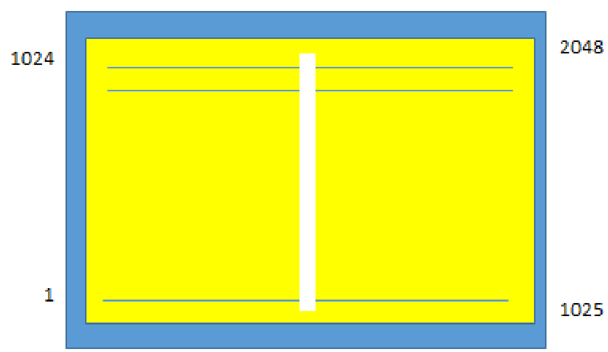
HW activities NON LGAD structures:

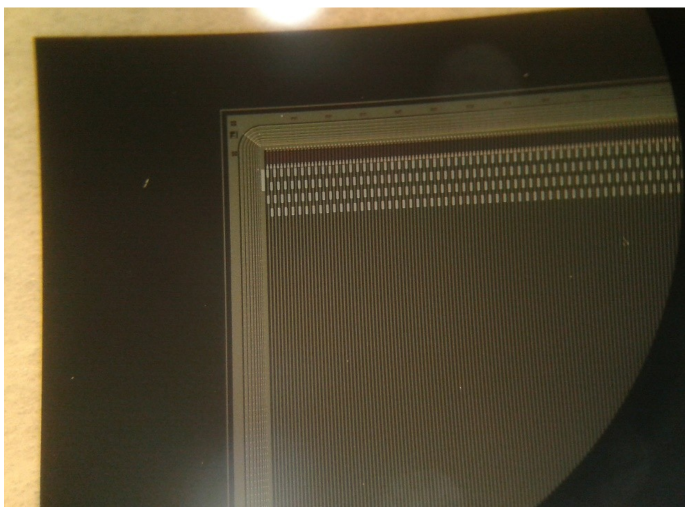
→ We have obtained (no cost) two single sided test structures from Micron Semiconductor (UK).

→ Dimensions: Thickness 150 μm
Area: 99.410 mm x 95.715 mm
Mechanical edges: 4 mm parallel on strips and 2 mm pependicular to strips
Pitch: 94 μm, even (odd) pitch: 185 μm
Nr of strips 1024, divided in 1024 left and 1024 right side.

HW NON LGAD structures:

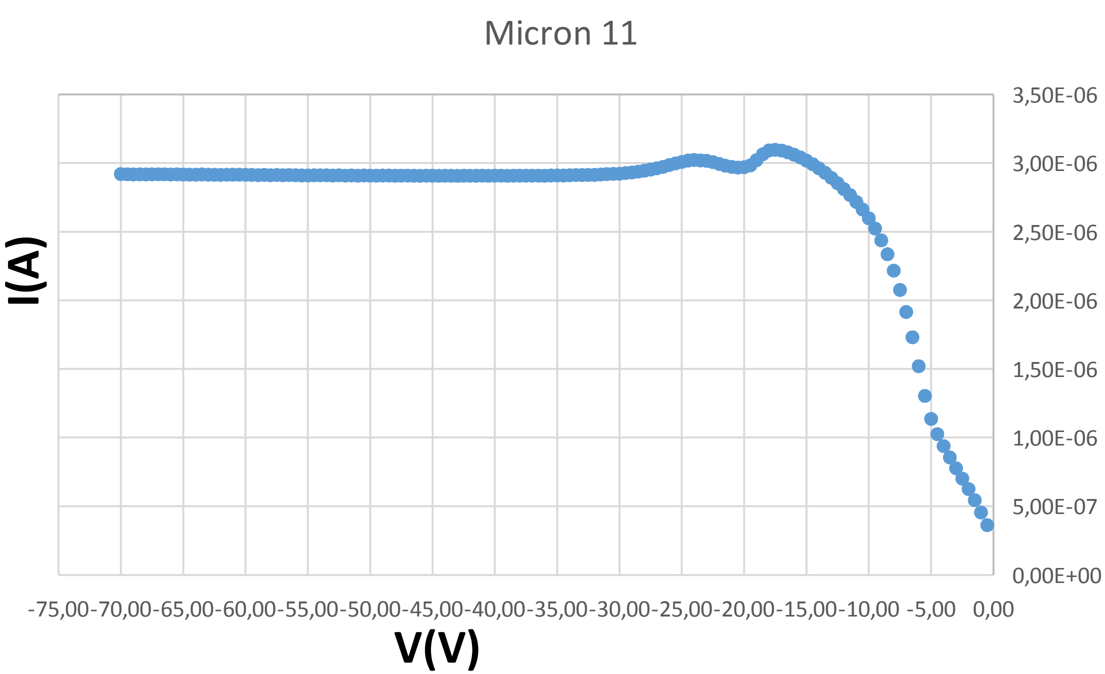
Middle view

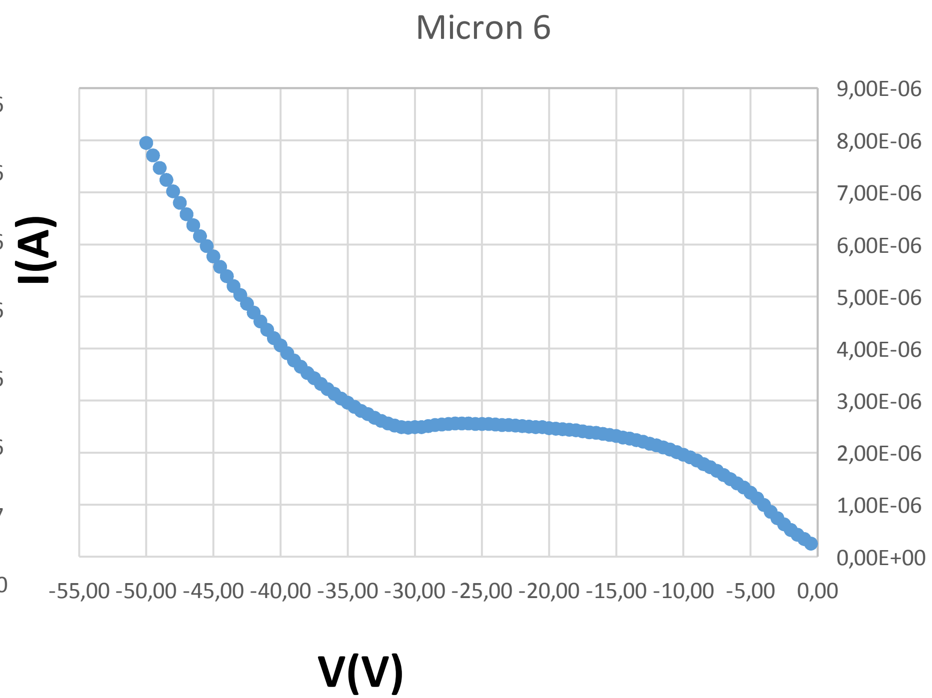




Angle view

HW activities NON LGAD structures:





IV measurement: PA200, 07/11/2017
F. Moscatelli, M. Ionica
Bias NEGATIVE on back , P sensor
Probe on the innermost guard ring

Micron 11 no problem up to 0.5 V/μm

Micron 6 develop breakdown @ 0.25 V/μm

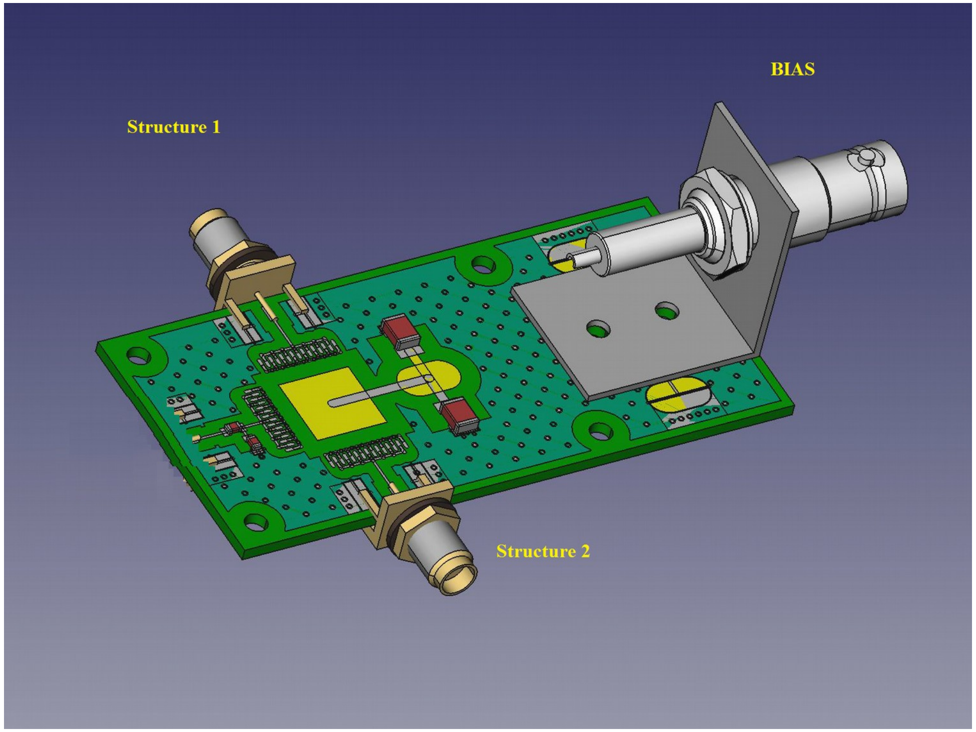
Next step NON LGAD structures:

→ Bonding the Micron 11 sensor to one DAMPE readout hybrid (64 channels). We have the substrate, it needs to be populated with components and the chip. Order in progress

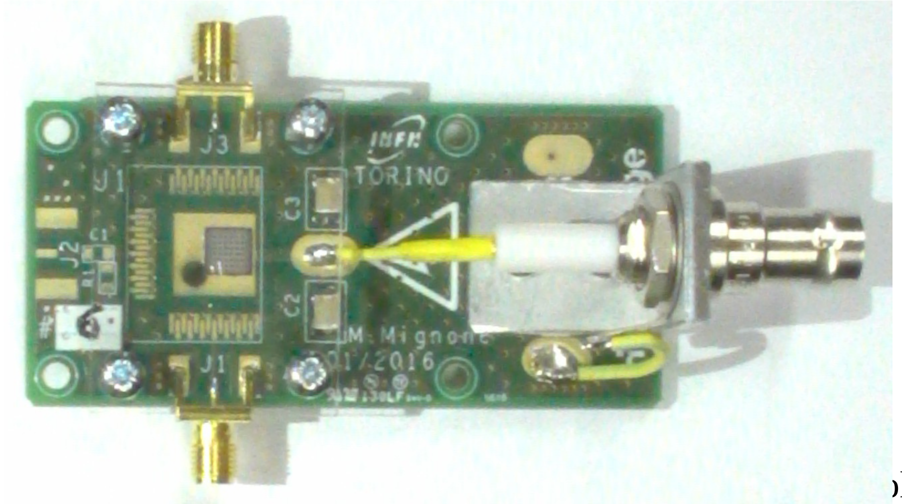
→ test the device both in laboratory (β, α) than in a beam with protons, somewhere beginning next year.

→ check possibility to have double sided sensors, same area.

Analisys activities LGAD structures:



- → We have tested two devices from Nicolò Cartiglia in LNS july ion beam test;
- → each one has two 1x1 mm^2 identical LGAD structures, 300 μm thick.



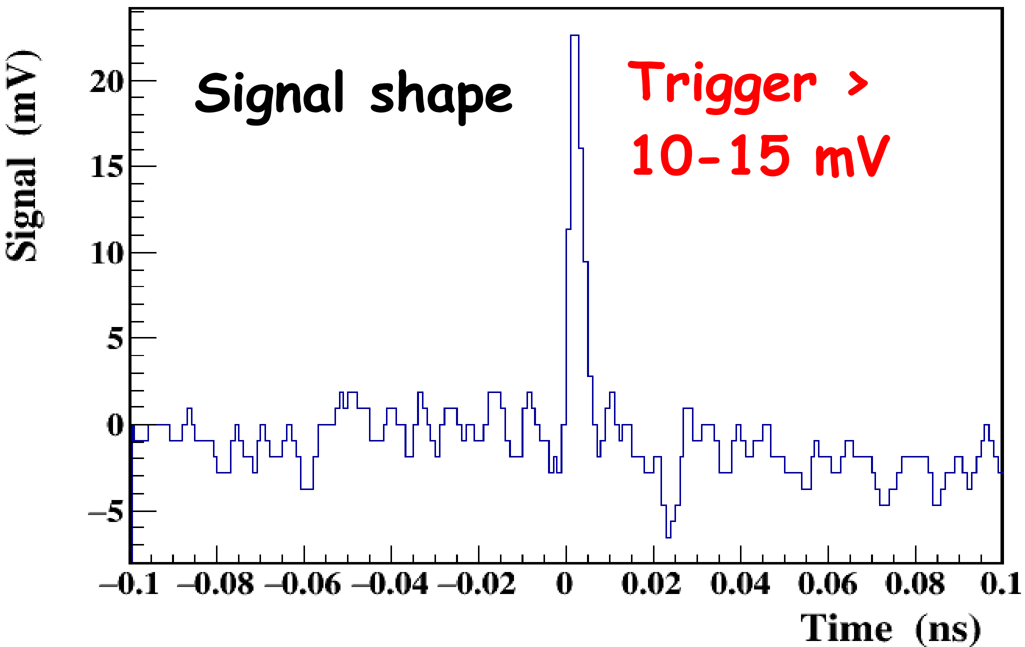
- → goal to understand behaviour when ion beams hit the LGAD.

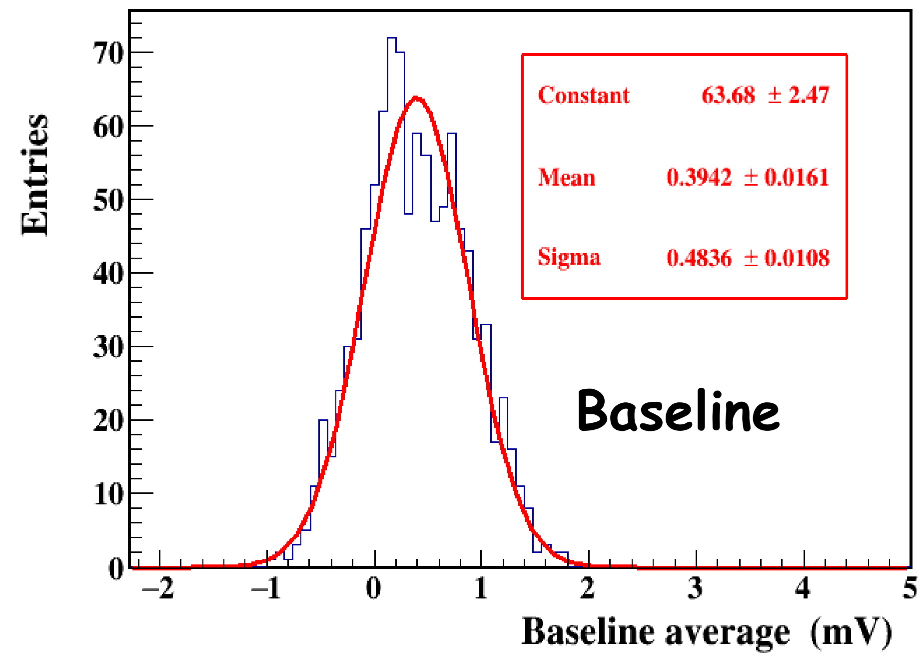
The devices have been exposed to the following ion beams (one structure at a time is read out, after 36 dB amplification by a CAEN wideband A1423 Amplifier, by a PicoQuant Oscilloscope).

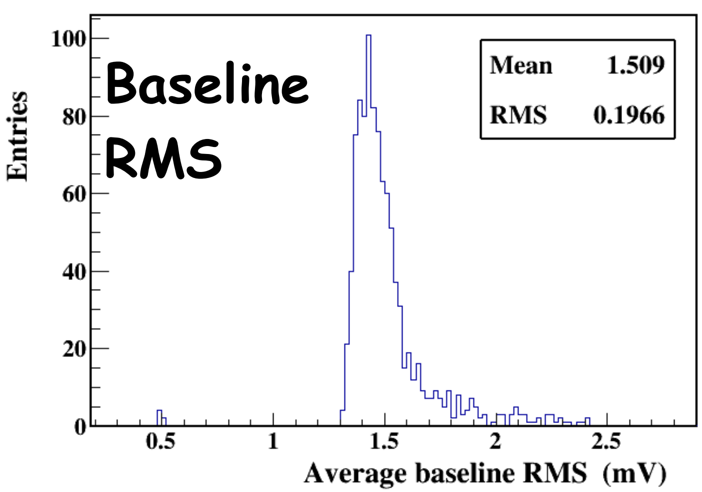
$1\ mV * 1\ ns / 50\ \Omega / 63 = 0.317\ fC = 1671\ e^-$

→ protons	@ 77 MeV	(Device A, structures 1 e 2)	
→ Helium	@ 80 MeV	(Device B, structures 3 e 4)	
→ Carbon	@ 80 MeV	(Device B, structures 3 e 4)	(Problems!)
→ Deuterium	@ 80 MeV	(Device B, structures 3 e 4)	

For each ion beam a bias scan has been done, [-100 V,-800 V]. For each scan point 1000 triggers have been acquisred (threshold varying from 10 to 15 mV).





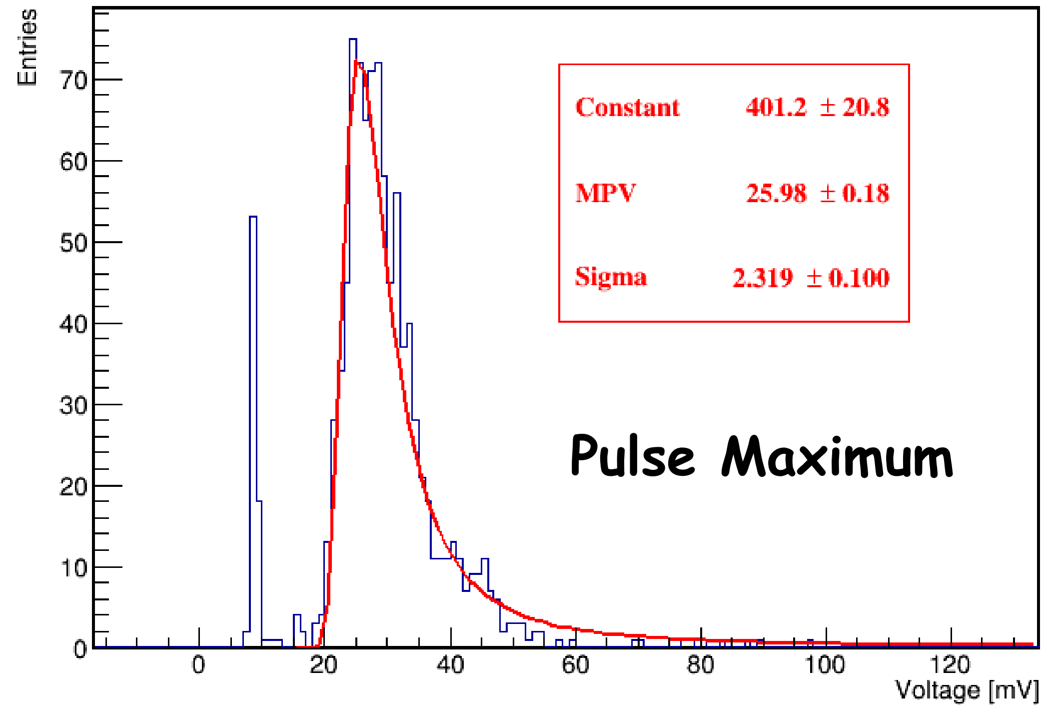


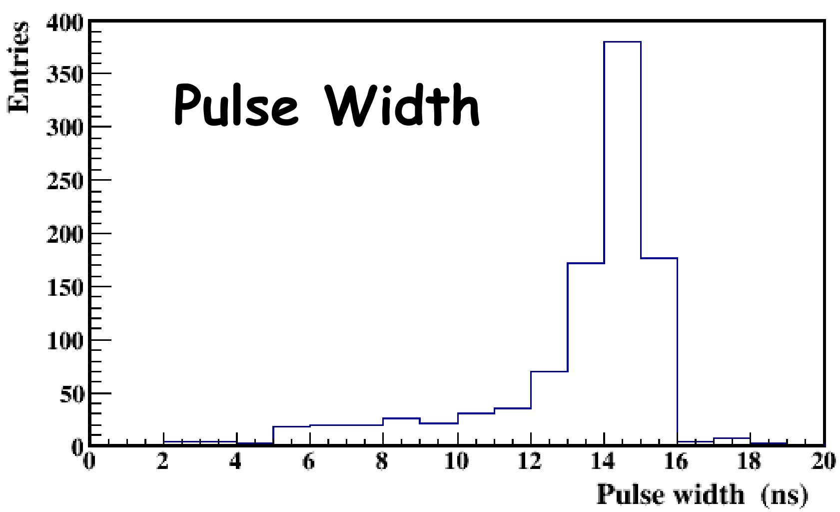
Baseline fluctuations (computed over the time segment preceding the trigger) are below 2 mV.

In analisys baseline subtracted from signal on event by event basis.

Variables to be measured:

- → Pulse maximum;
- → Pulse width;
- → Pulse integral;
- → Signal shape;

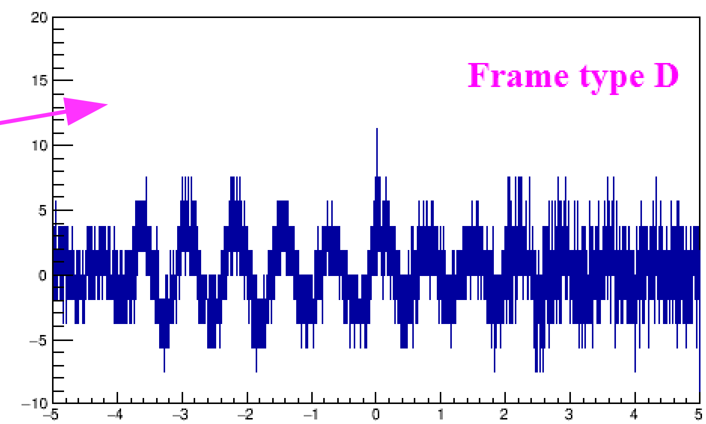




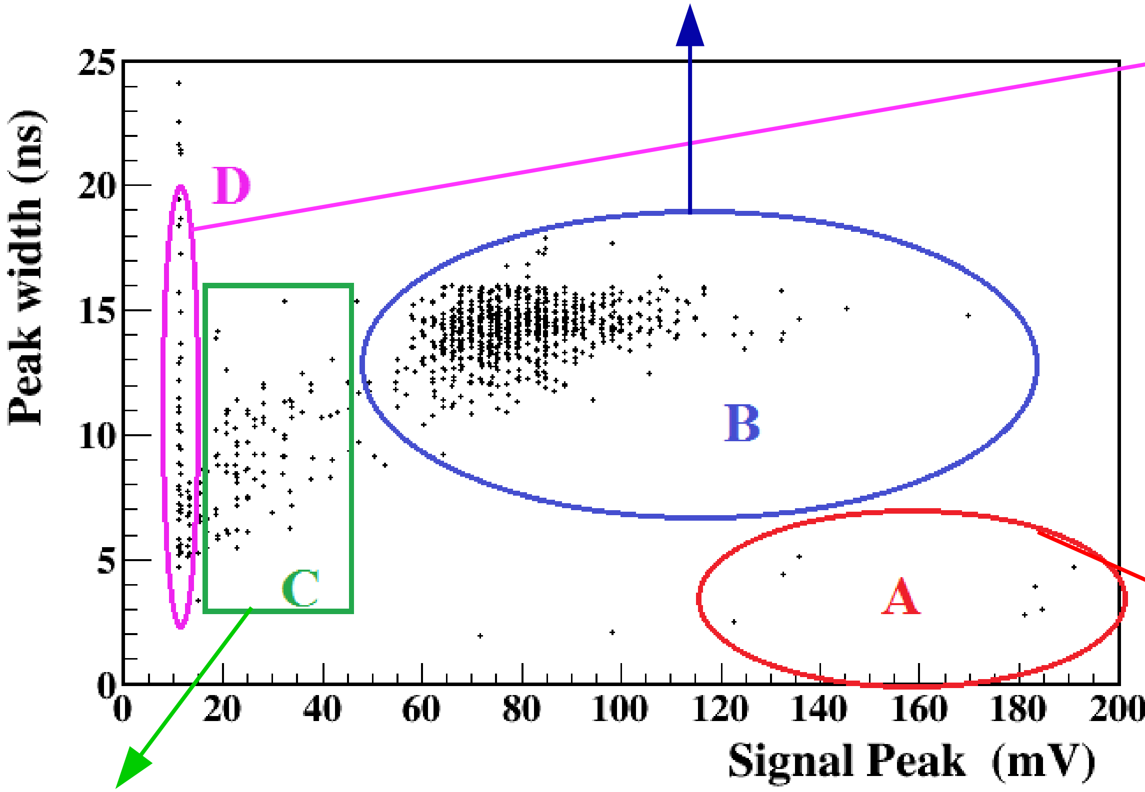
There are some queues for both distributions toward low values. We studied the correlation.

Several correlation regions:

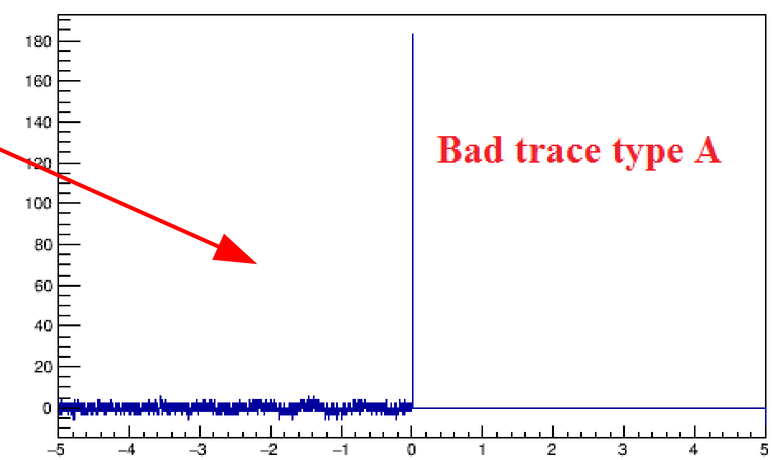
Near threshold frame:



Normal signal frame:



Low width frame:

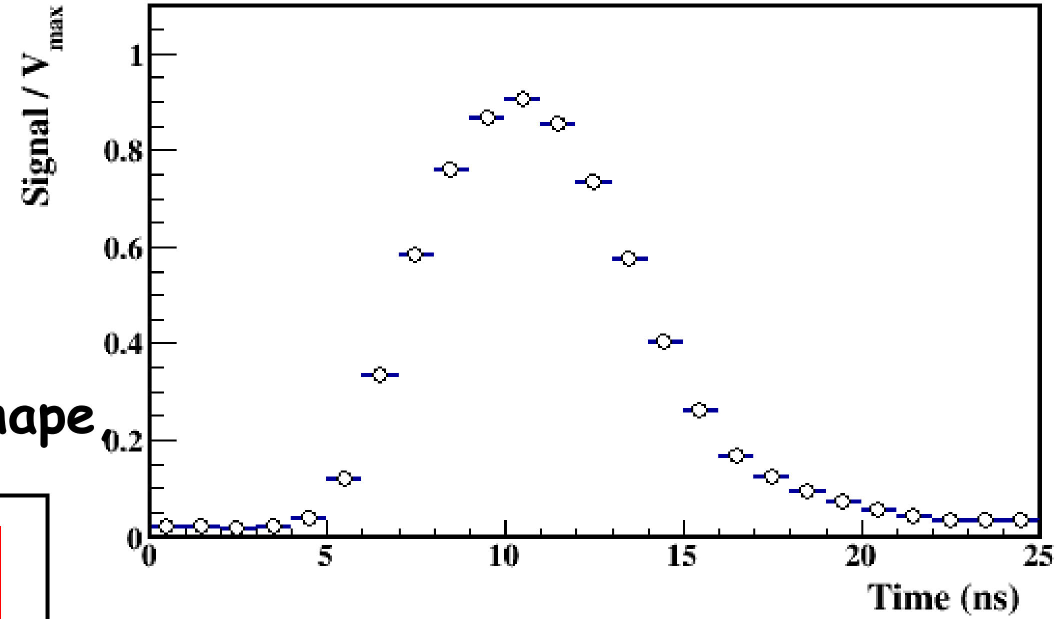


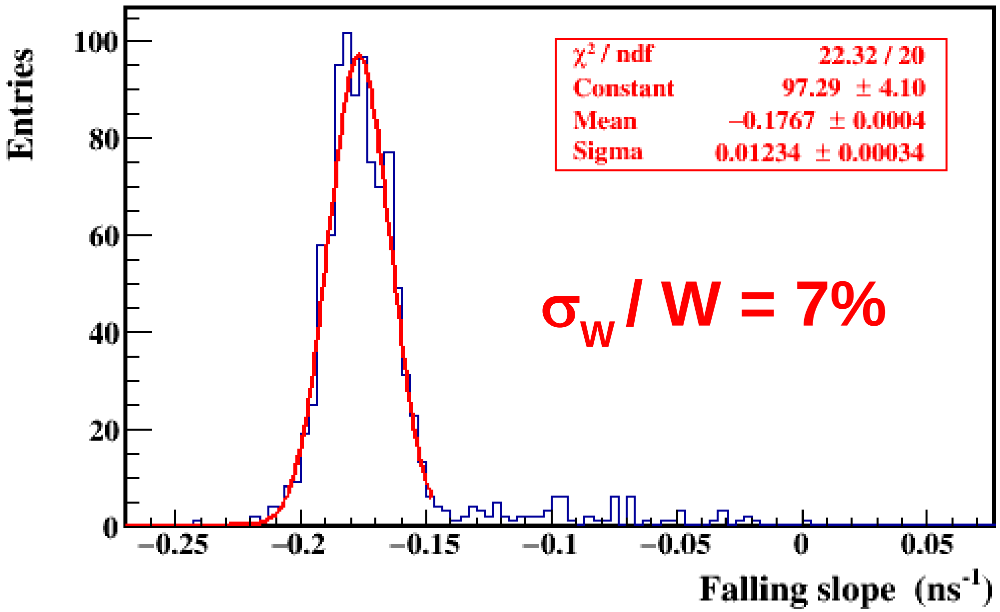
Low peak values: incomplete charge generation?

Signal shape:

→ Normalization to maximum signal value;

→ Profile histogram: well defined shape



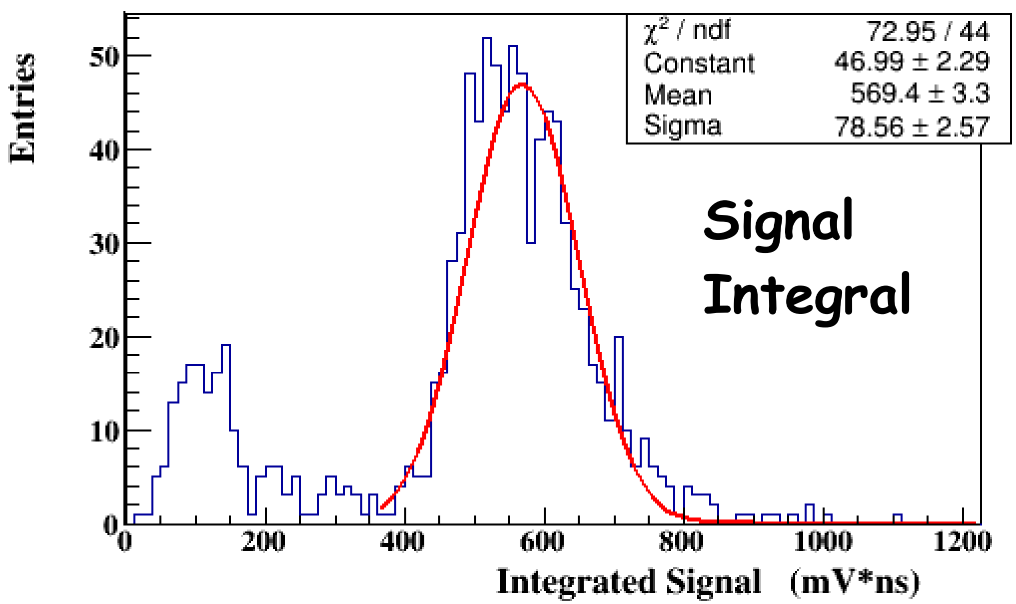


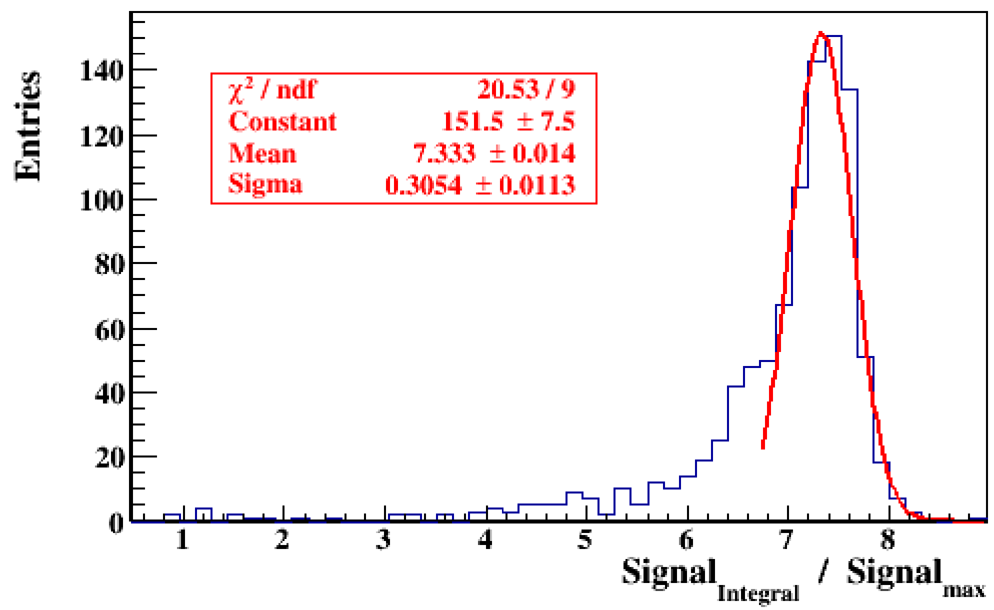
Both rising and falling times, due to filters on device board, are well defined. For example, falling part, computed for each frame, has a narrow distribution:

$Slope^+ = -0.181 \pm 0.012$ mV/ns

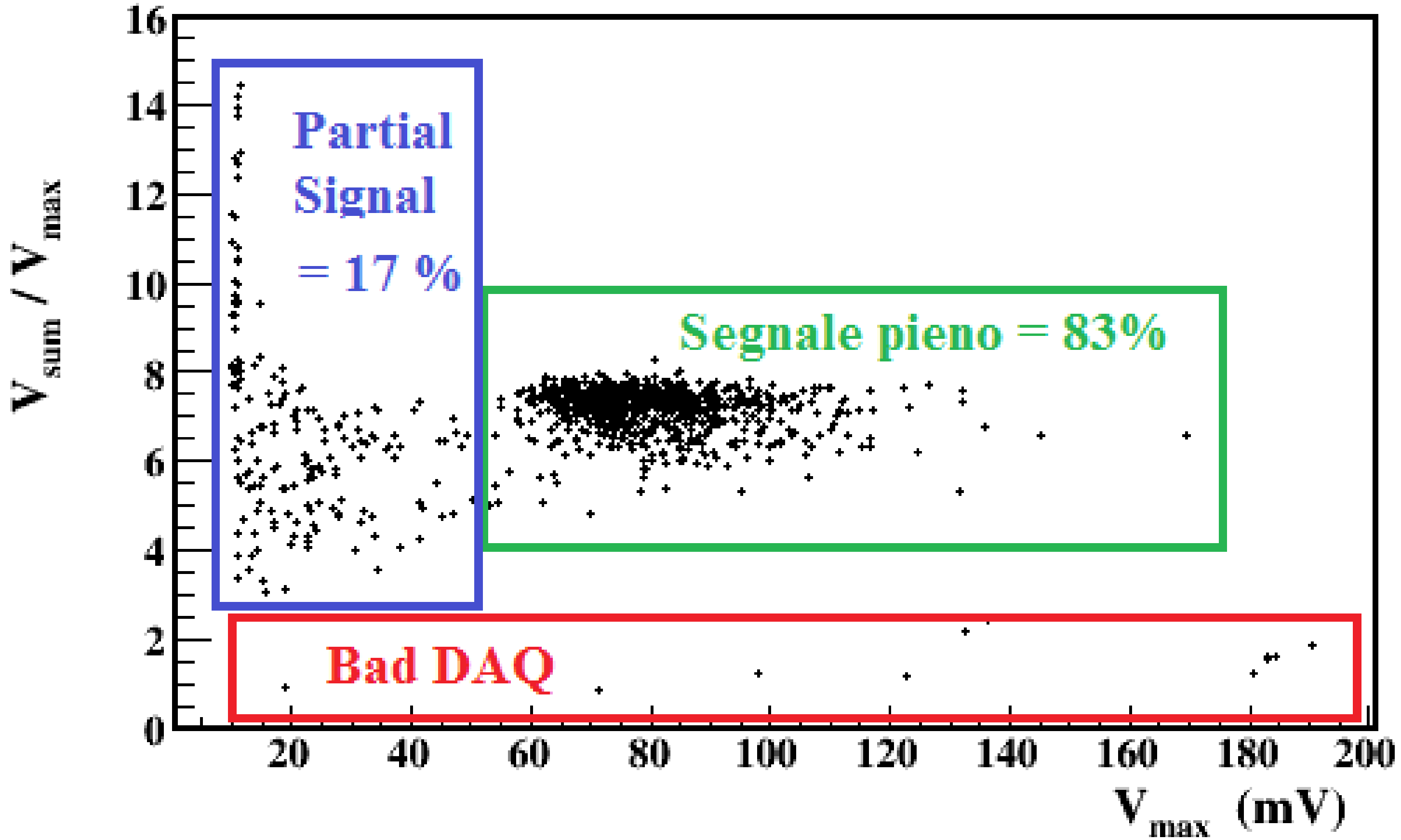
$Slope^- = -0.177 \pm 0.012$ mV/ns

The pulse integral ($Signal_{Integral}$) is defined as the area integrated over time when signal > threshold. As threshold we have chosen 5 mV. Given the narrow distribution of both $Signal_{Max}$ and $Signal_{width}$, we do expect also a narrow distribution of this variable, and of rate with $Signal_{Max}$:



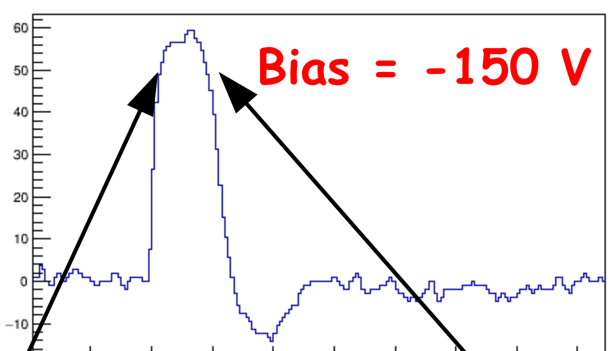


Finally, using the correlation plot between V_{max} and rate, the fraction of "good events", meaning with full charge collection is of the order of 80%

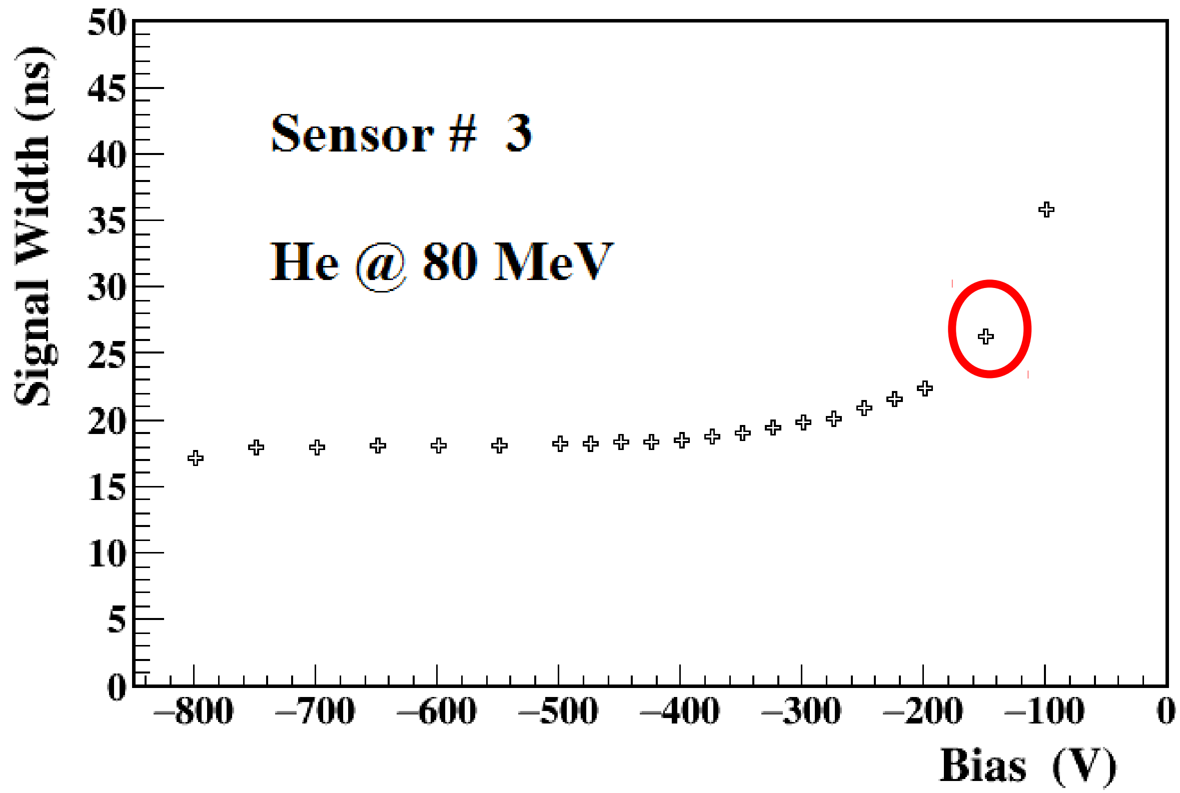


Width depends weakly on bias for most of the bias scan interval.

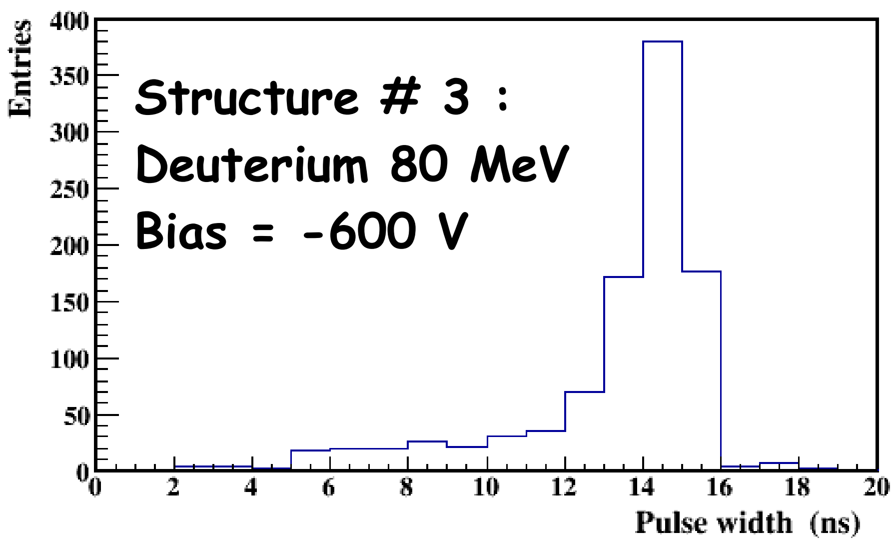
Only at low bias values there is a sizeable increase of the width:



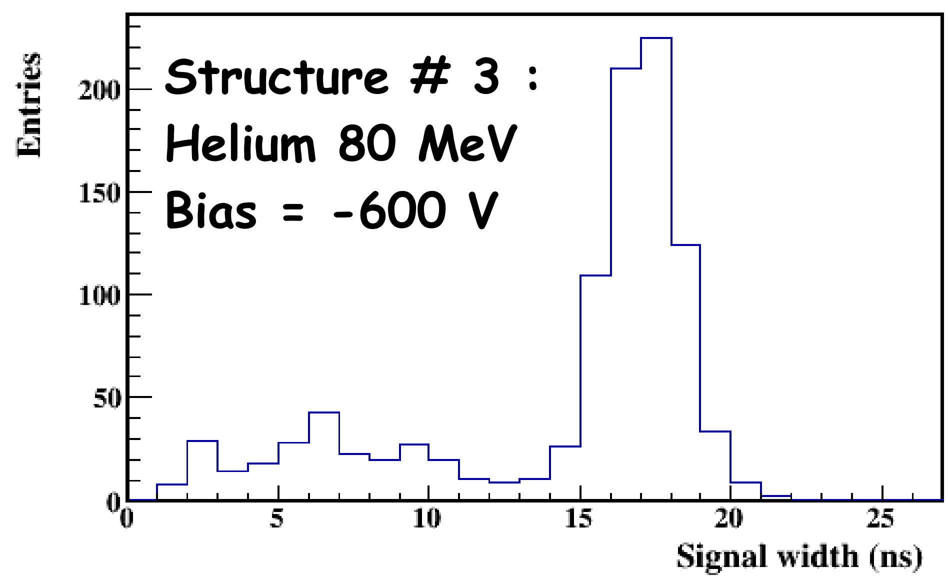
There is a kind of double peak.



Width depends weakly on ion species because of higher ionization → longer time to fall below fixed threshold.



$\langle Width \rangle_D = 14 \pm 1$ ns

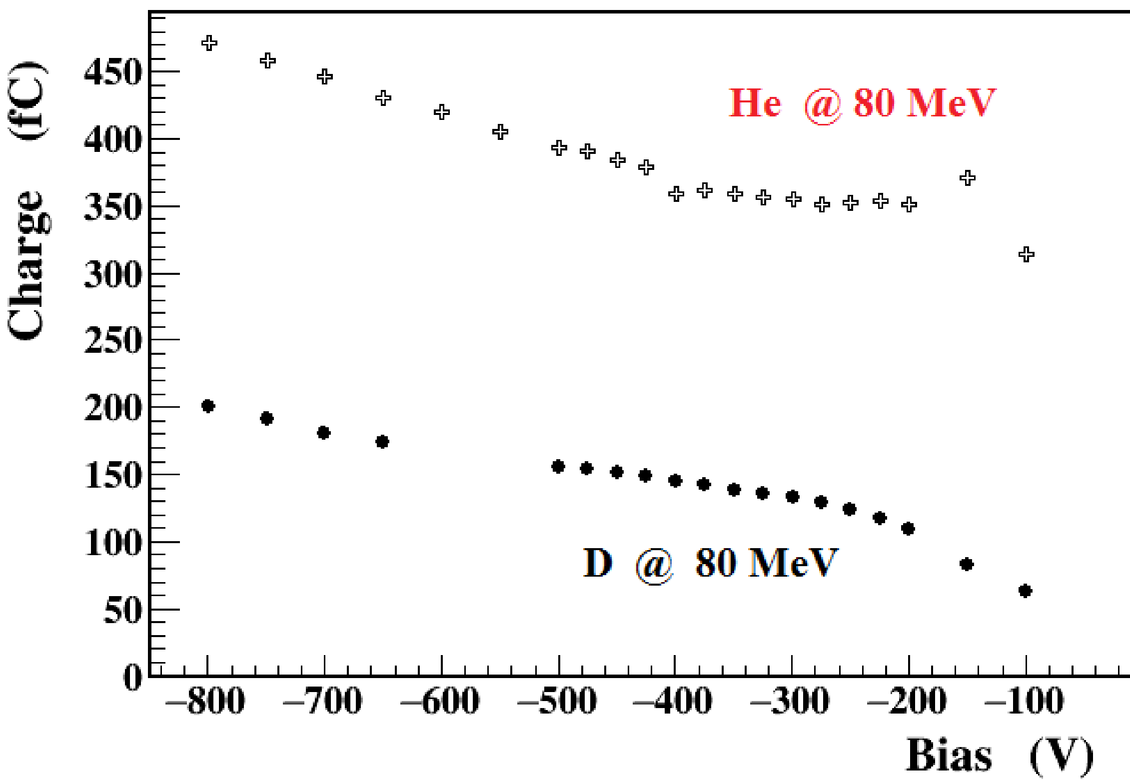


$\langle Width \rangle_{He} = 16.5 \pm 1.5$ ns

Integrated signal (charge) depends on bias.

It increases quite linearly after -400 V.

Comparing with the signal f an 80 MeV proton in 300 μ thick silicon sensor at fully depleted bias



300 μm * 1600 eV /μm / 3.6 eV * 1.9 10^{-19} C = 24000 e^- ~ 25 fC

Hence a gain @ -650 V : 173 fC / 25 fC = 6.9

Analisys still going on…

→ ratio between He and Deuterium charge is not 4 (actually < 3) [saturation? Non-linearity in charge multiplication mechanism?]

→ shape of signal when bias is changing (more accurate description)

→ dependence of results from 5 mV threshold choice.

→ uniformity among several structures

Further measurement in lab with electrons and alfa sources.

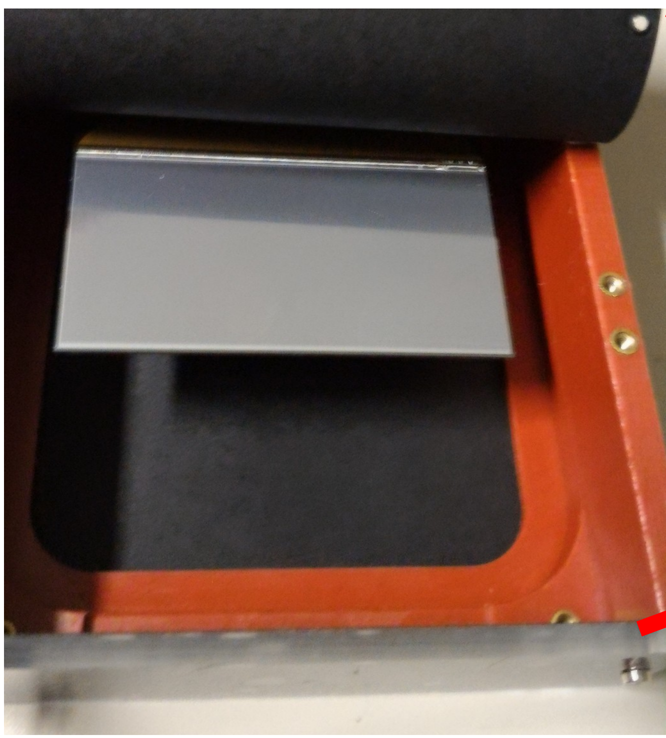
Measurements with monochromatic fluorescence photons.

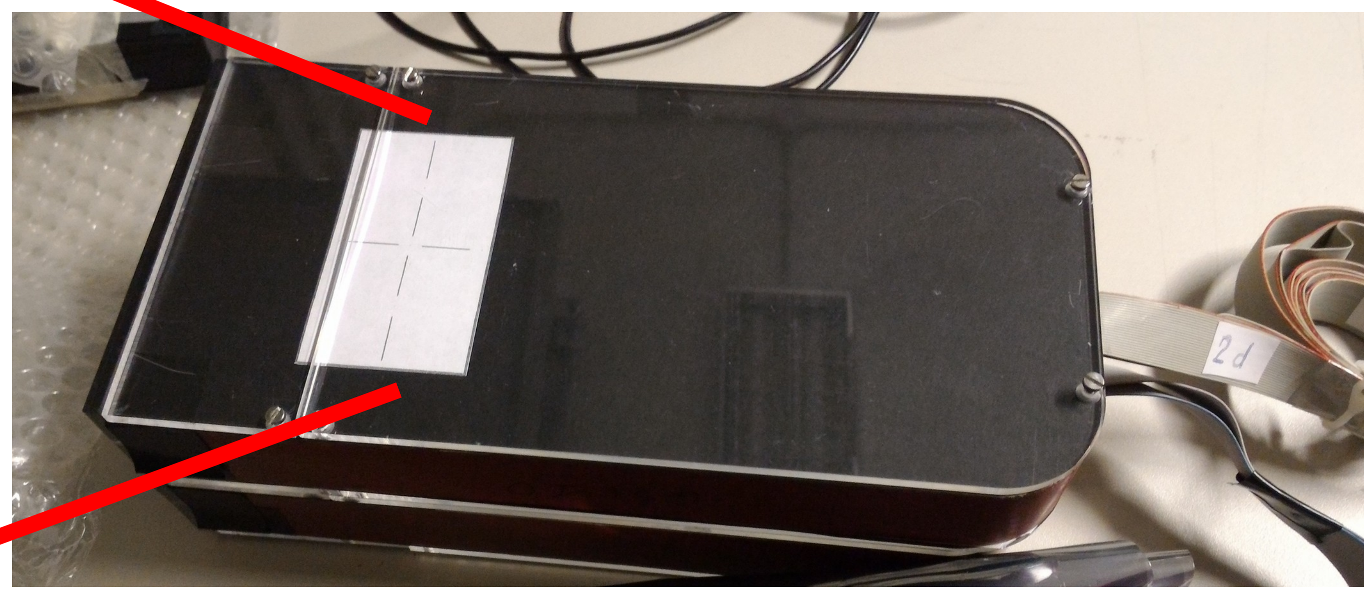
Analisys activities Microstrip @ LNS:

We have put on beam an AMS-like double sided detector:

→ with 320 μm thickness, 110 μm S-side, 107 μm K-side strip pitch.

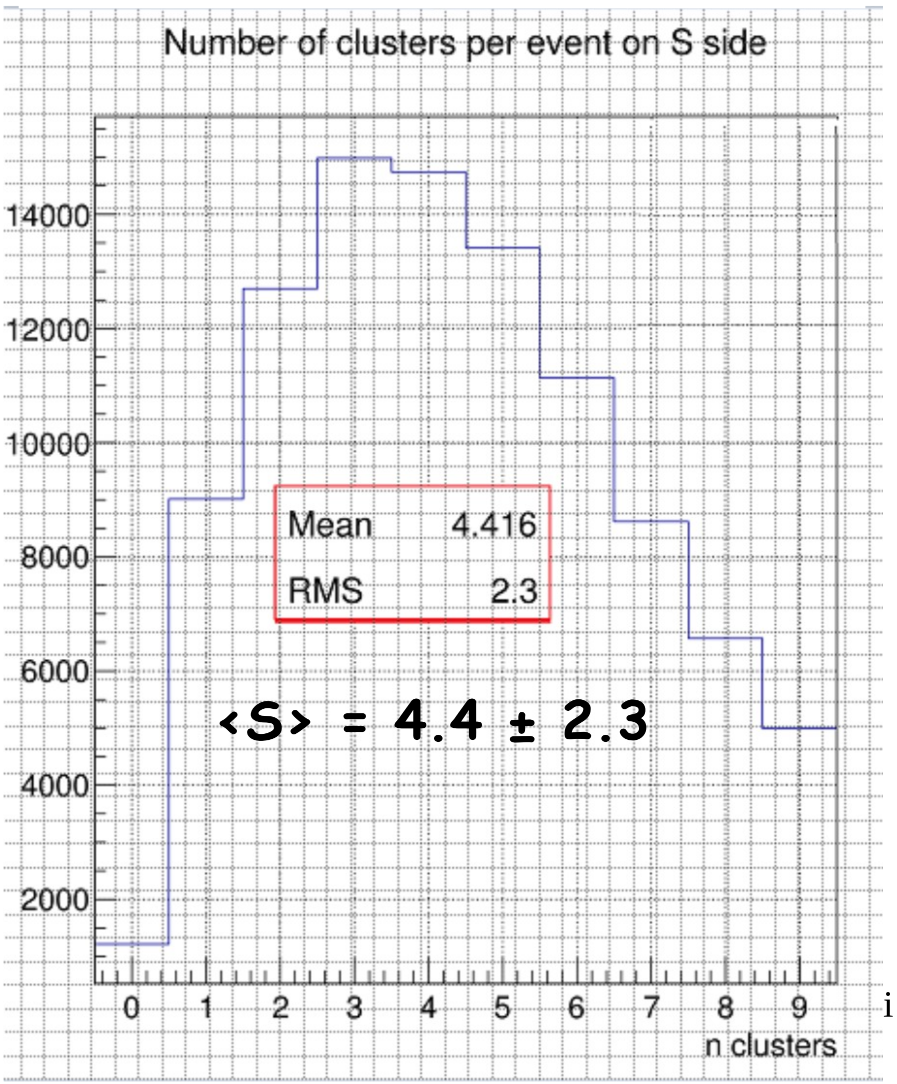
→ dimensions: (640x110 μm) x (384*107 μm) = 70.4 x 41.1 mm;

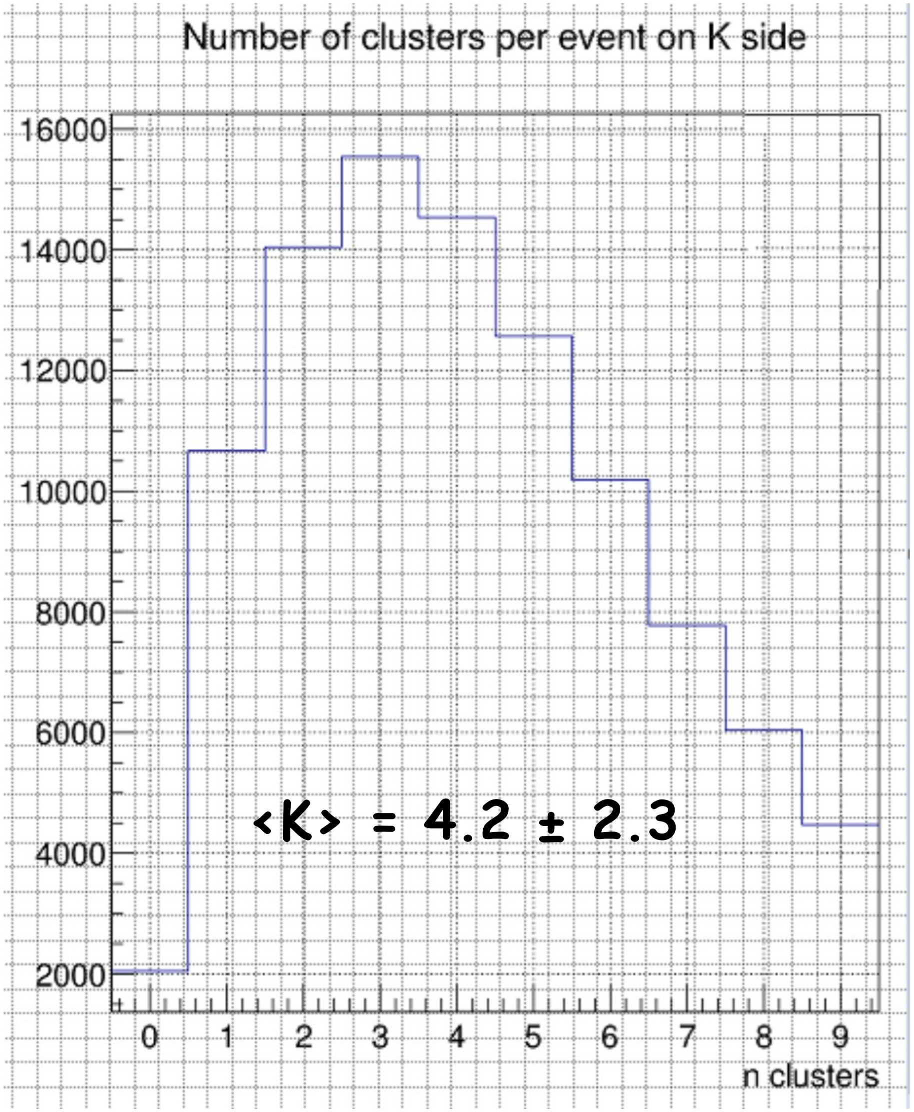




Preliminary Results

Deuterium @ 80

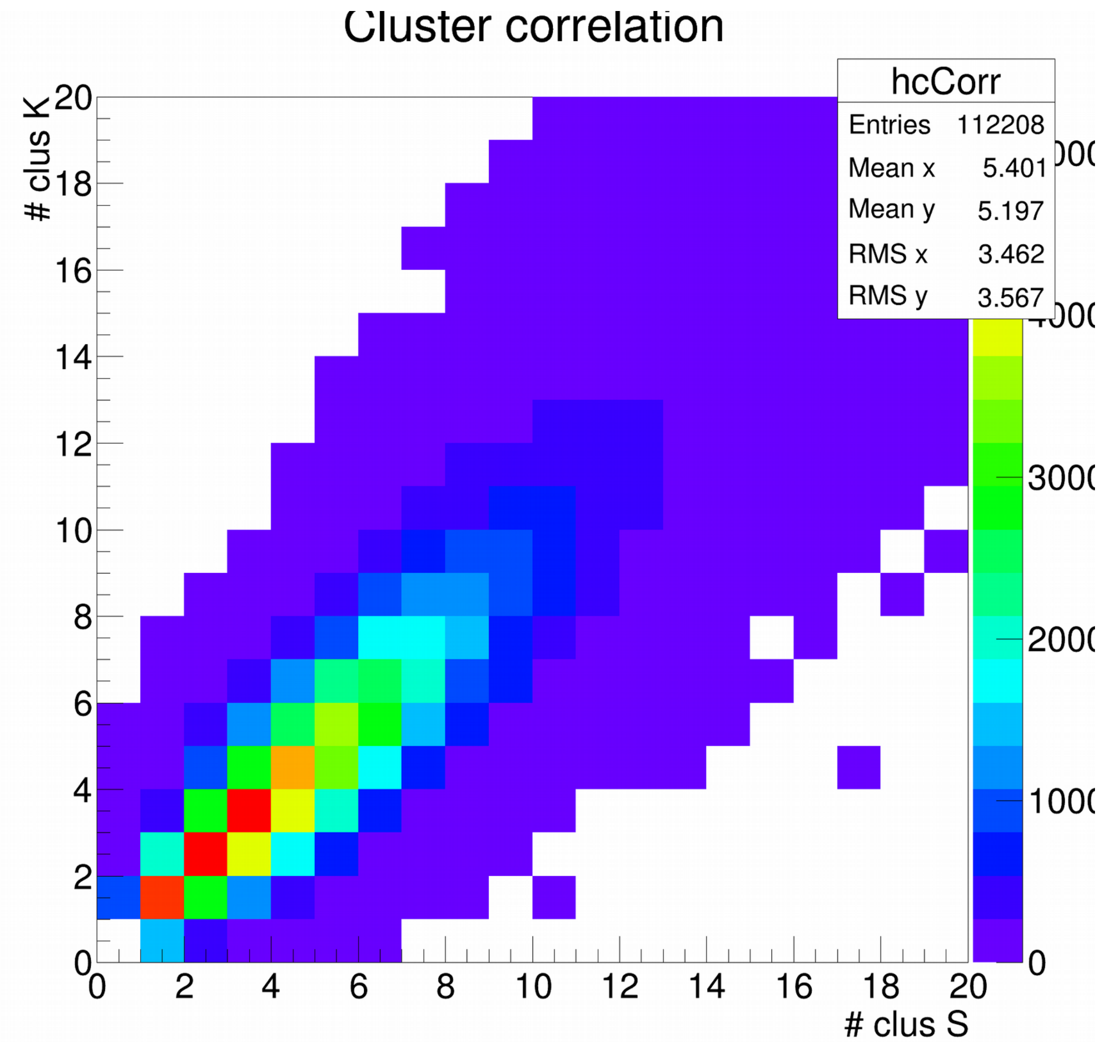




Number of clusters seen on both sides is closely correlated, even if there is a wide distribution around the correlation line.

Most likely due to inefficiencies on one or the other side, like dead or noisy strips.

Ongoing investigation .....

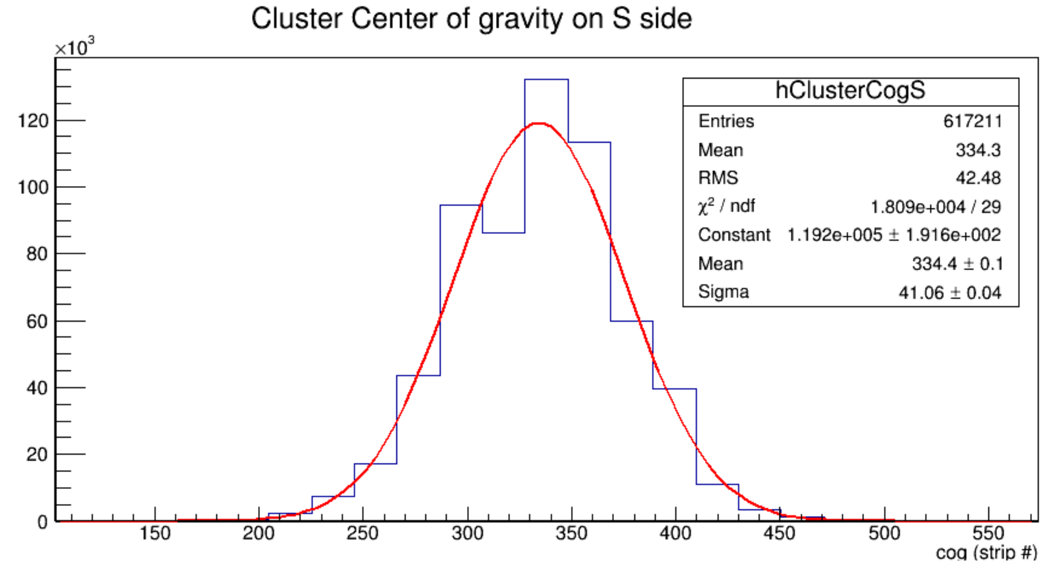


Beam profile:

Side S:

σ = 41 strip = 4.5 mm

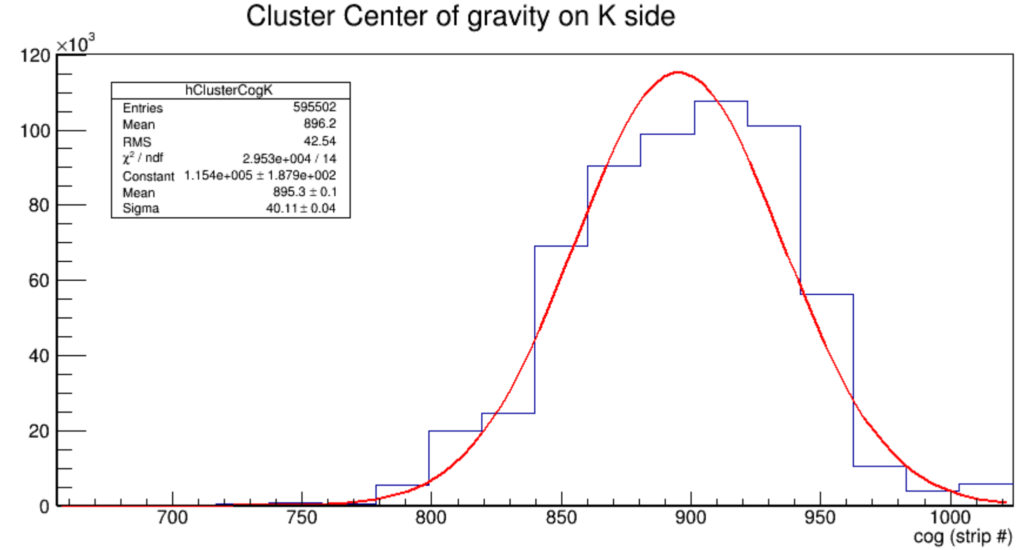
FWHM = 2,56 * σ = 11.5 mm



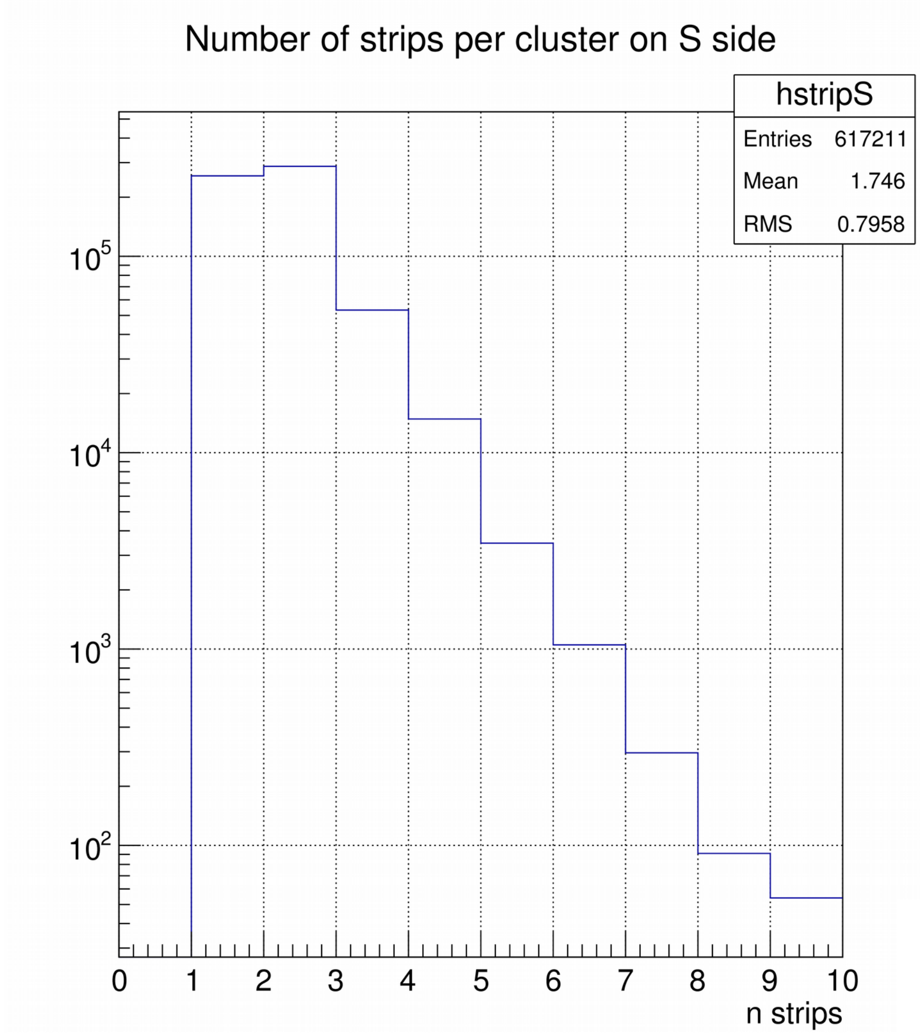
Side K:

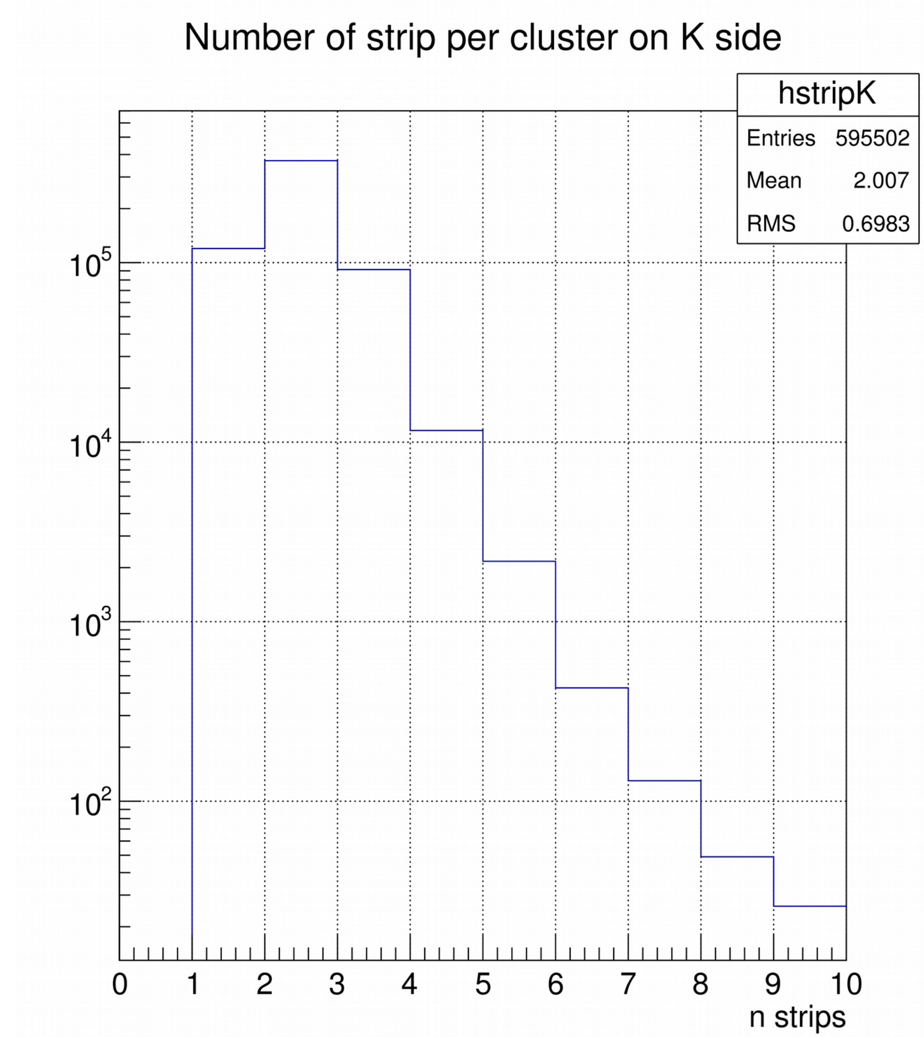
σ = 40 strip = 4.3 mm

FWHM = 2,56 * σ = 11.0 mm



Number of strips in a cluster: very similar…. <S> = 1.75; <K> = 2.01;

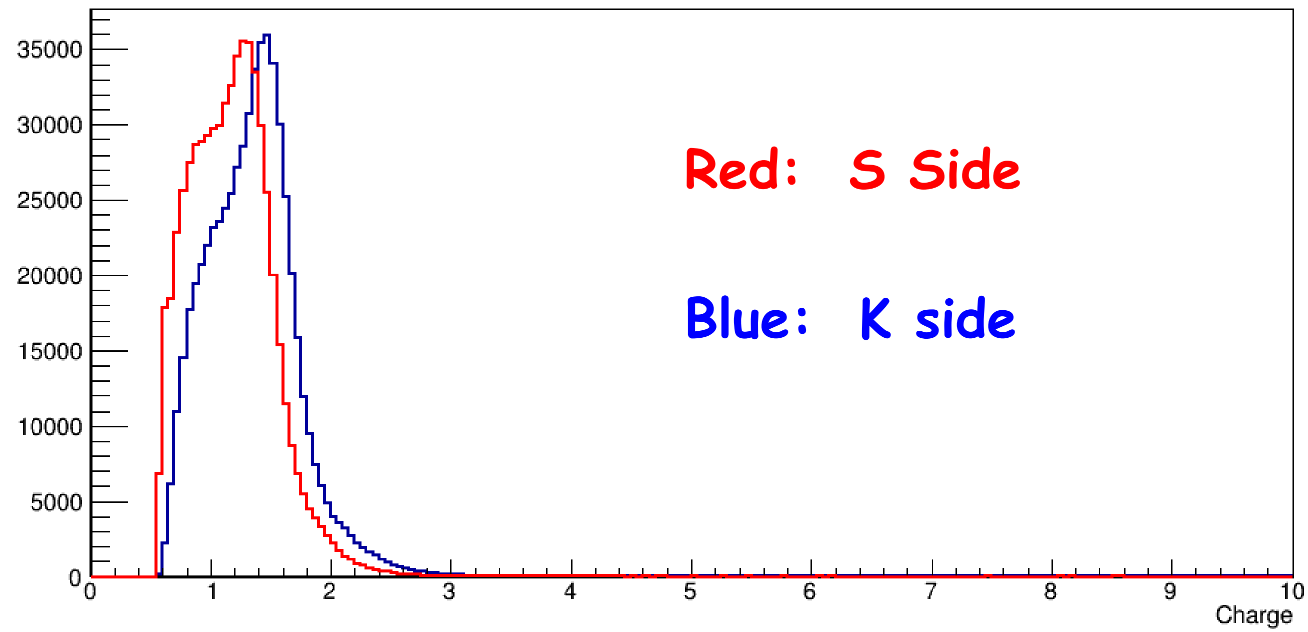




Cluster charge normalized to 1 MIP:

1 MIP = 320 μm * 80 e-h/μm = 4.86 fC

Cluster charge ~ 7 fC



Seed charge / cluster charge = 65% ~ 4.5 fC.

If for higher Z, signal scales as expected with Z^2 , for ^{16}O we should hence expect, rescaling for thickness: 64 * 4.5 * 150/320 = 135 fC

Cluster charge correlation between S an K side:

Only avents with 1 cluster in S and 1 in K have been selected.
A very good correlation is observed

The same amount of e-h is seen by both sides.

This could be used to reject fake hits and reduce combinatorial in position reconstruction.