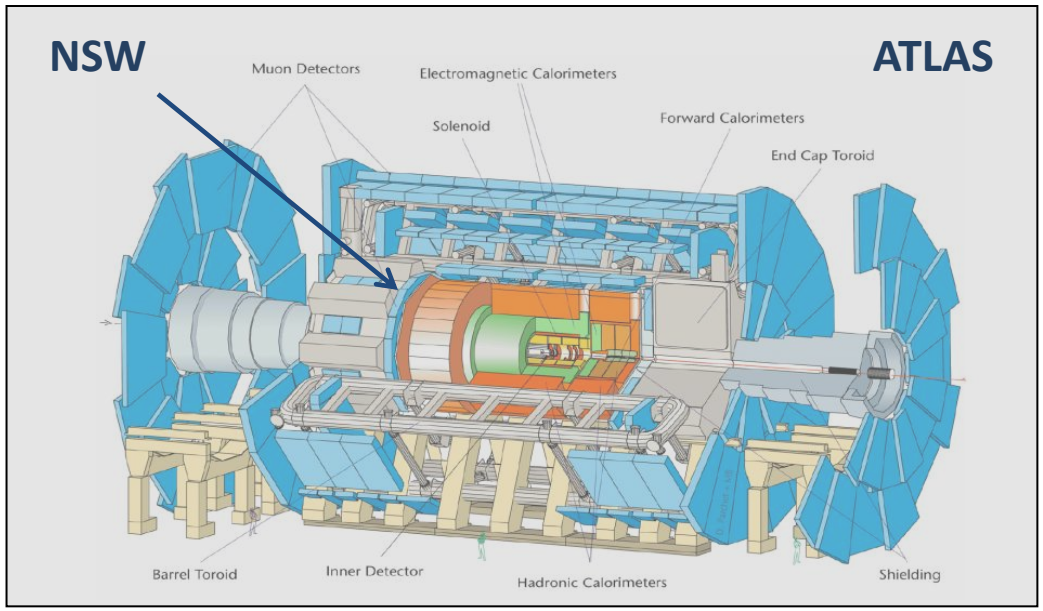
Ageing studies of resistive Micromegas detectors for the HL-LHC

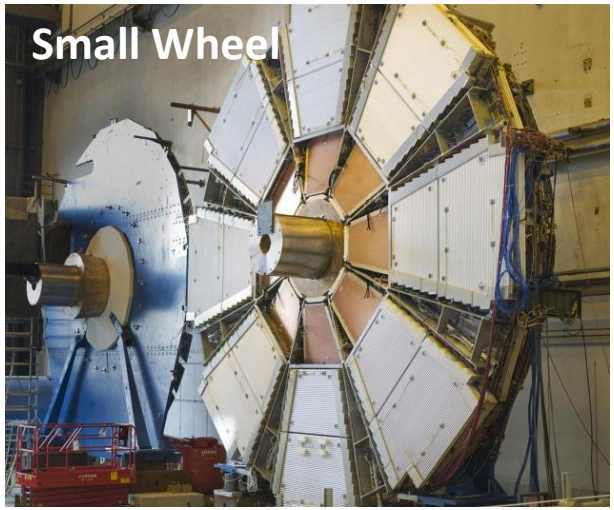
J. Galan
CEA Saclay
for the MAMMA collaboration



Performance requirements

- Rate capability: 10 kHz/cm^2 ✓
- Spatial resolution: 60 μm/track segment ✓
- Angular resolution: 0.3 mrad/segment ✓
- Good double track resolution ✓
- Trigger capability: BCID (angle ≈ 1 mrad) ✓
- Efficiency: 'at least as good as now' ✓
- Radiation resistance: tbd (✓)
- Good ageing properties: tbd (✓)

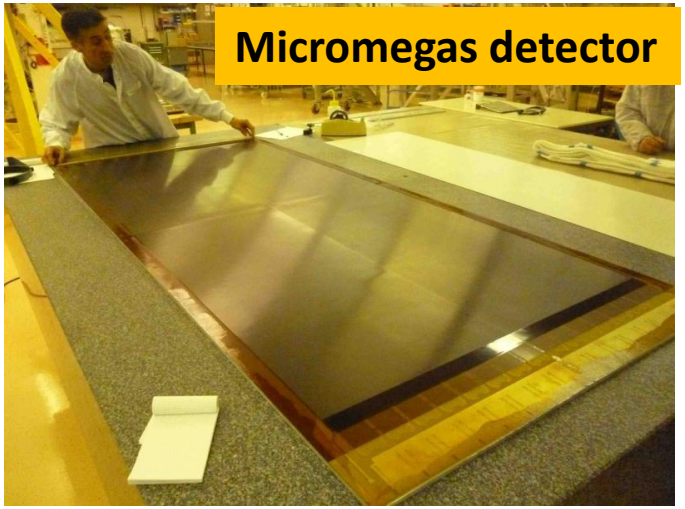
NSW meeting, 06/10/2011 Joerg Wotschack (CERN) 11



Total area of micromegas detectors required

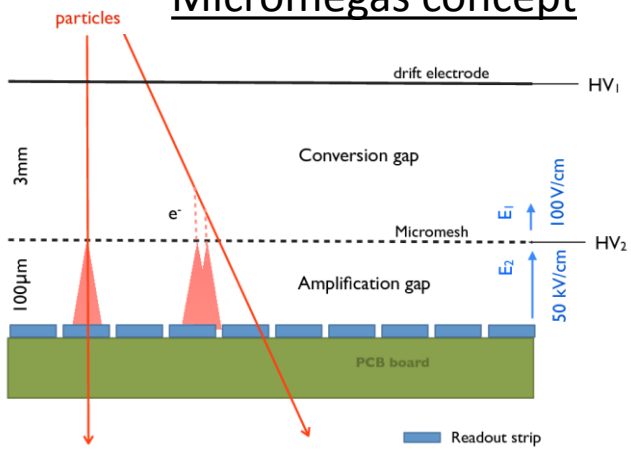
1200m^2

Large area due to multilayer micromegas will be implemented in each sector.

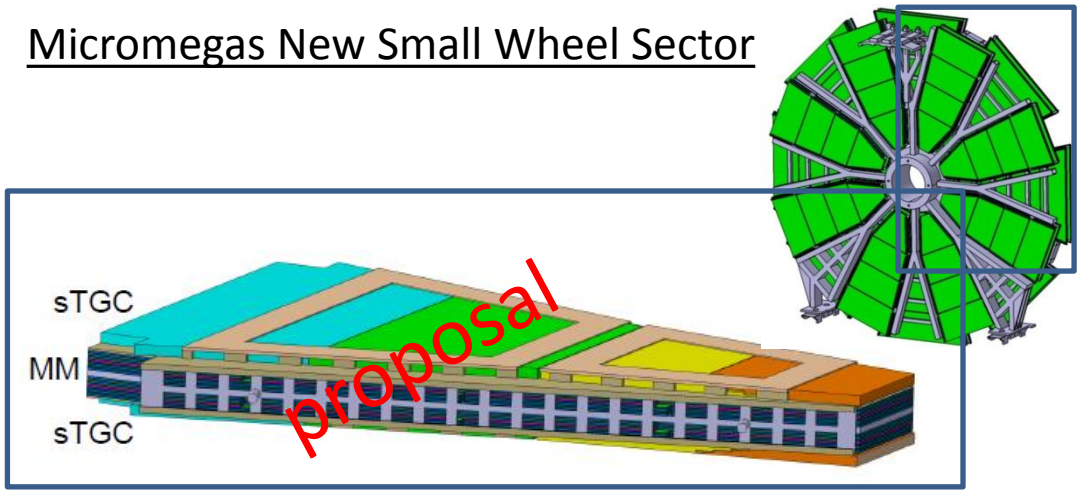


Micromegas detectors for the new small wheel

Micromegas concept

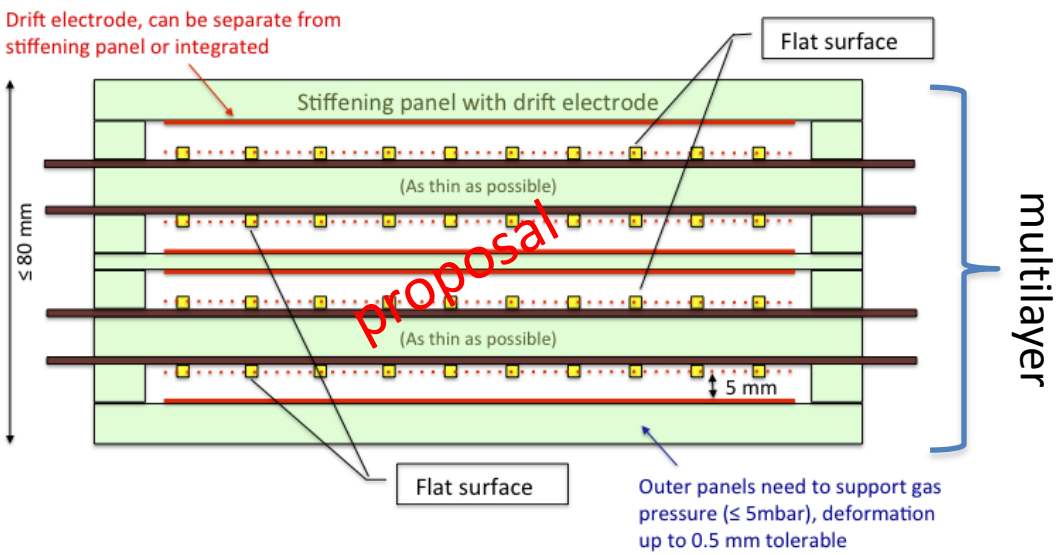


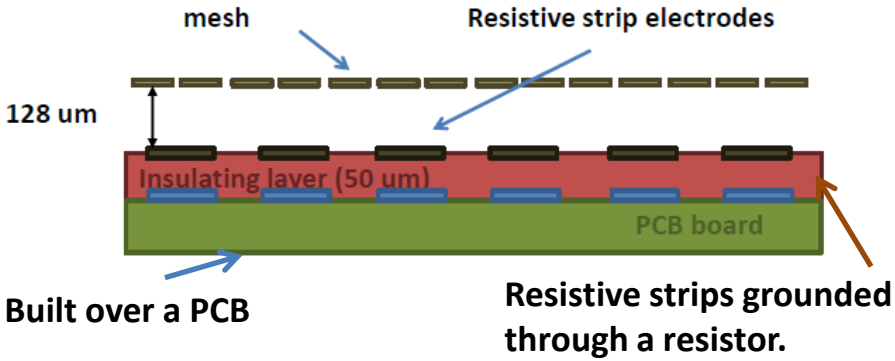
Micromegas New Small Wheel Sector

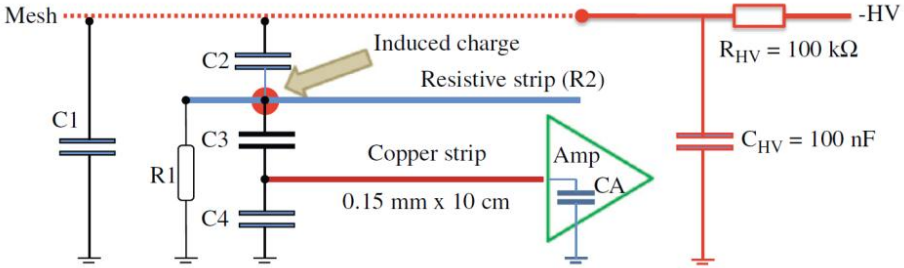


Multilayer description

- Each detector comprises eight active layers, arranged in two multilayers.
- The basic detector unit is an assembly of four layers that form a stiff multilayer.
- The individual layers should be arranged in two doublets in which the Micromegas are mounted back-to-back
- The flat surfaces of all layers should be parallel to within 40–60 µm and the strips in all layers must be parallel with the same precision.







Nuclear Instruments and Methods in Physics Research A 640 (2011) 110–118

A spark-resistant bulk-micromegas chamber for high-rate applications

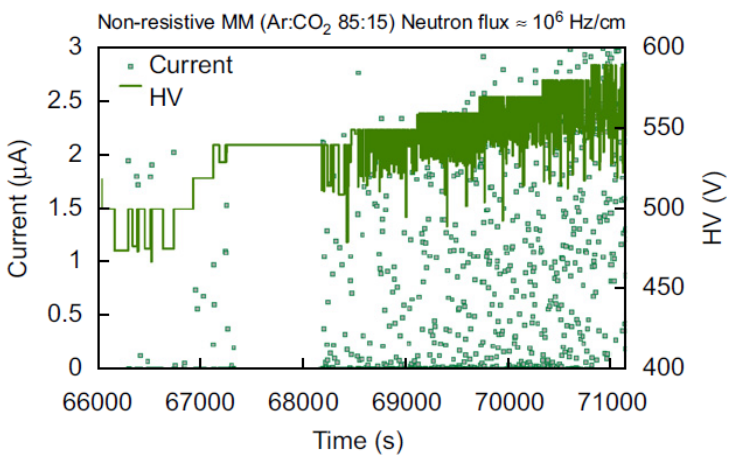
T. Alexopoulos [a], J. Burnens [b], R. de Oliveira [b], G. Glonti [b], O. Pizzirusso [b], V. Polychronakos [c], G. Sekhniaidze [d], G. Tsipolitis [a], J. Wotschack [b,*]

Spark mitigation is achieved by local field loss.

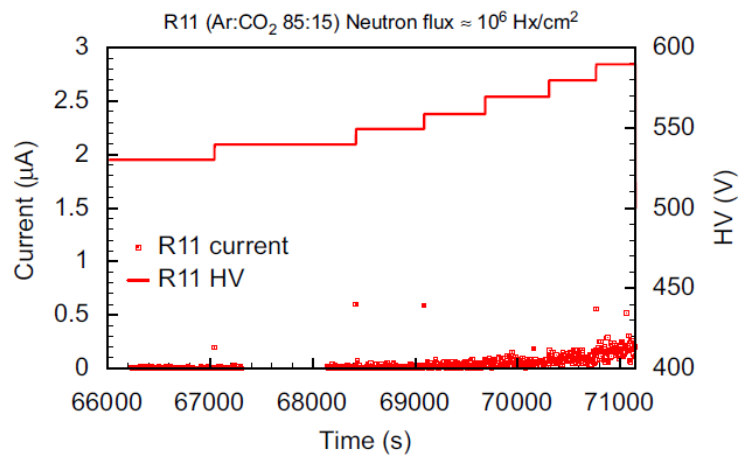
Detector is afected only locally.

No mesh discharge evolves!!

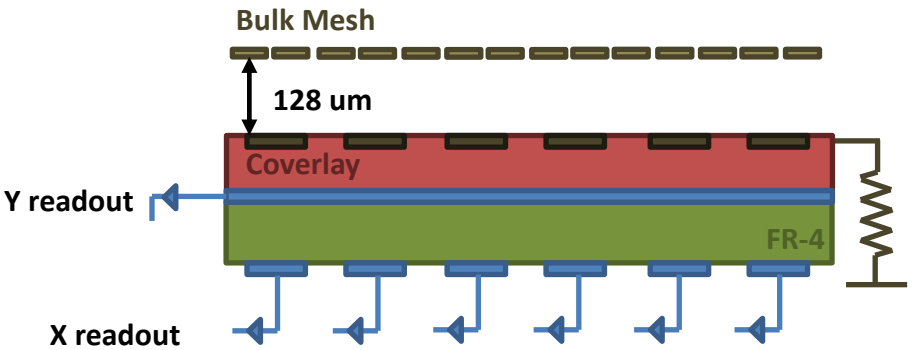
Micromegas technology



Resistive micromegas technology



Resistive prototypes dedicated to fast ageing



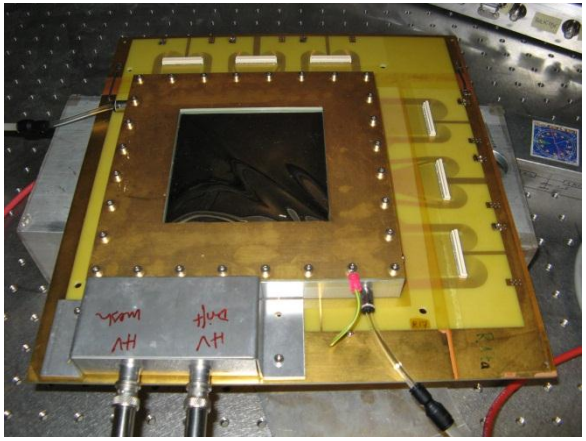
Two resistive prototypes (R17) were sent to Saclay for performing aging tests

17A Resistance to GND: 80-140 MOhm
Resistance along strips: 45-50 MOhm/cm

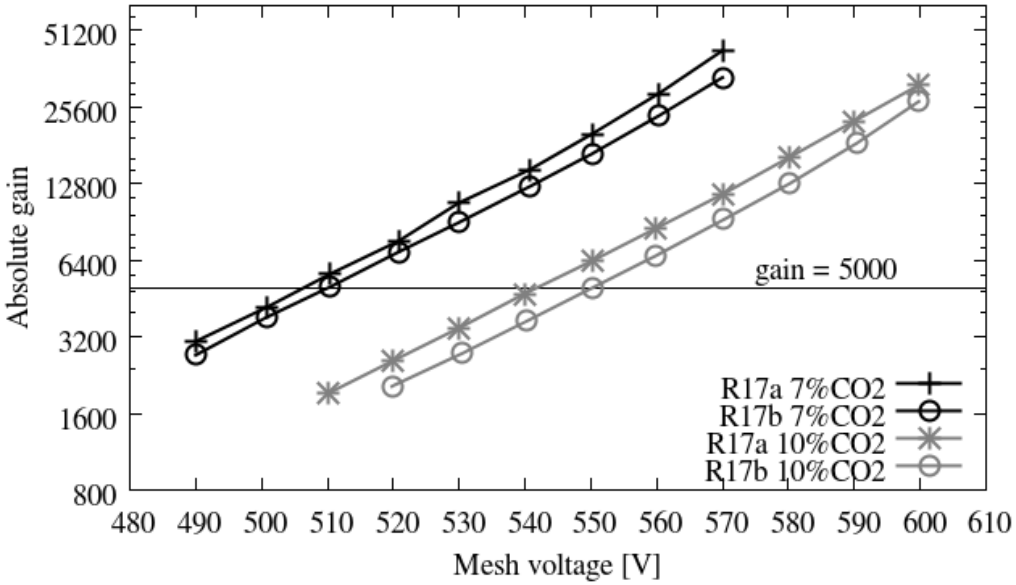
17B Resistance to GND: 60-100 MOhm
Resistance along strips: 35-40 MOhm/cm

Geometrical properties

Strip pitch/width for all: **250 µm/150 µm**
Top layer (Resistive strips): **35 µm thick**
Insulation (coverlay): **60 µm**
Y strips (90 degrees to R strips): **9 µm Cu**
Insulation (FR-4): **75 µm**
X strips (same direction as R strips): **9 µm Cu**



Both detectors show similar gain properties
Re-characterized at CEA for different gas mixtures

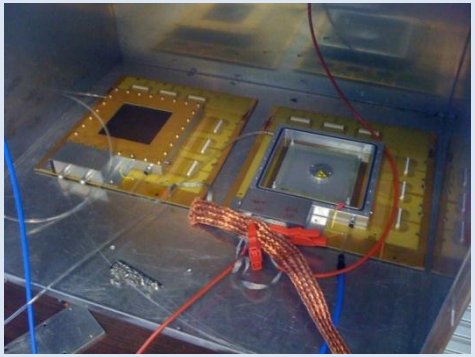


Overview of ageing tests

X-ray beam

Cold neutron beam

Alpha source



Gamma source

R17a detector is exposed to different radiation natures.

R17b detector is kept unexposed.

Gain control measurements are performed before and after each exposure.

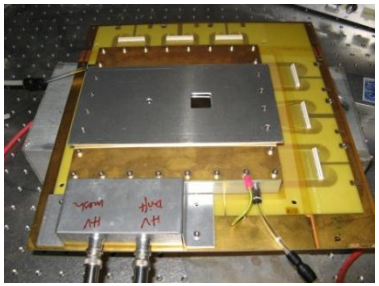
After the ageing both detectors are taken to the H6 CERN-SPS pion beam line.

The goal to accumulate an integrated operation charge equivalent to the one would be obtained at the HL-LHC for 10 years for each type of radiation.

X-ray ageing description. Charge estimation.

Detector operated in nominal data taking conditions

Gas mixture : Argon + 10% CO2
Gas Flow = 0.5 l/h
Gain 3000
HVm = 540V
HVd =790 V



X-ray exposure in a small active area region of 4 cm^2.

Equivalent charge generated during 5 years HL-LHC

Wi (Argon + 10% CO_2) = 26.7 eV
Gain = 5000
MIP deposit in 0.5 cm drift = 1248.5 eV

Charge per iteration = 37.4 fC

Expected rate at the HL-LHC : 10kHz/cm^2

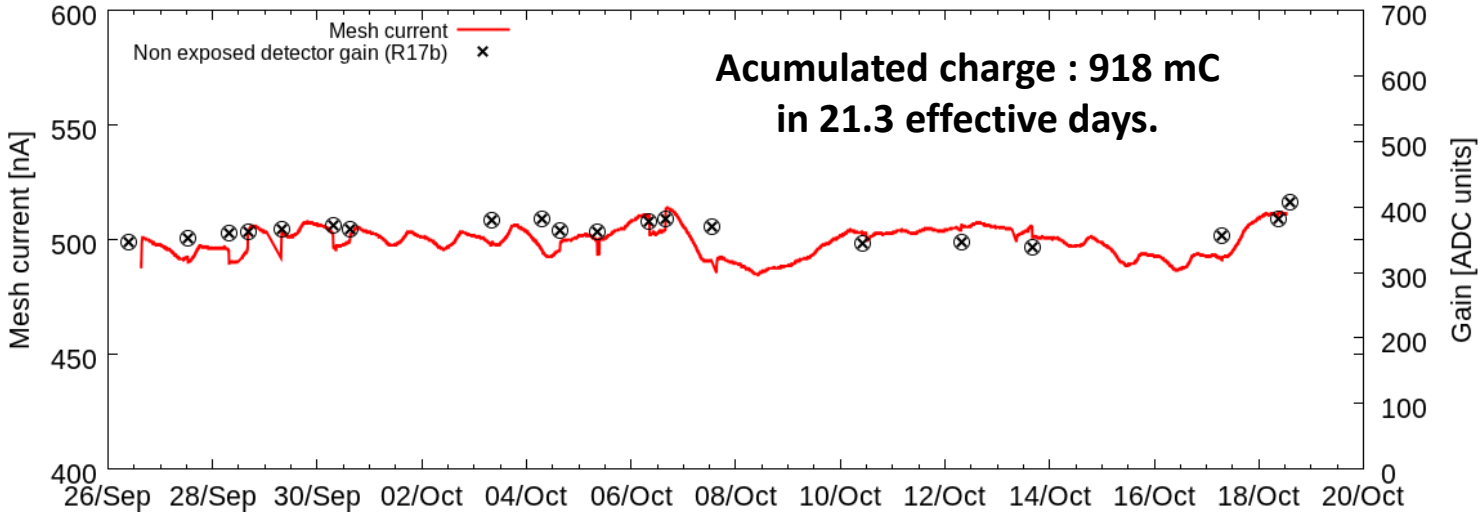
5 years of HL-LHC operation (200days X year)

Total detector charge generated during HL-LHC operation is estimated to be 32.5 mC/cm^2

X-ray generator set-up at 10 kV 5 mA

Generation rate of about 10 MHz/cm^2 in 4 cm^2

X-ray gain evolution history



225 mC/cm2

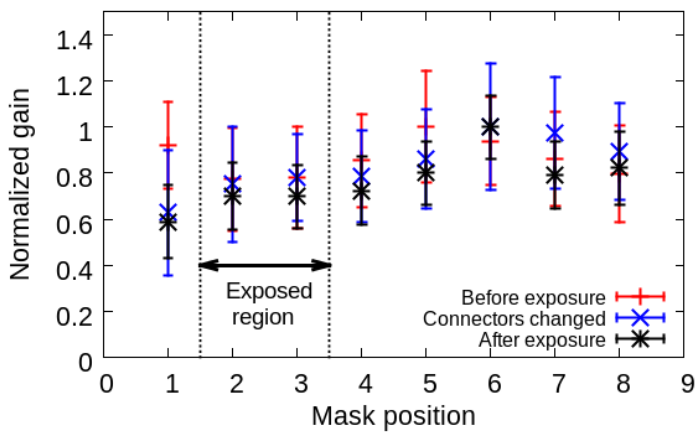
versus

32 mC/cm2

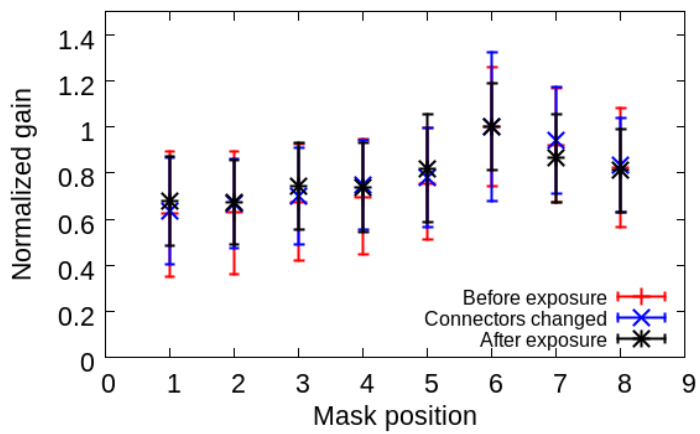
Estimated per HL-LHC year

X-ray gain profile compatibility

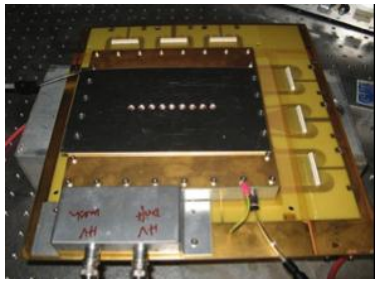
R17a irradiated detector



R17b non-irradiated detector



9-holes mask



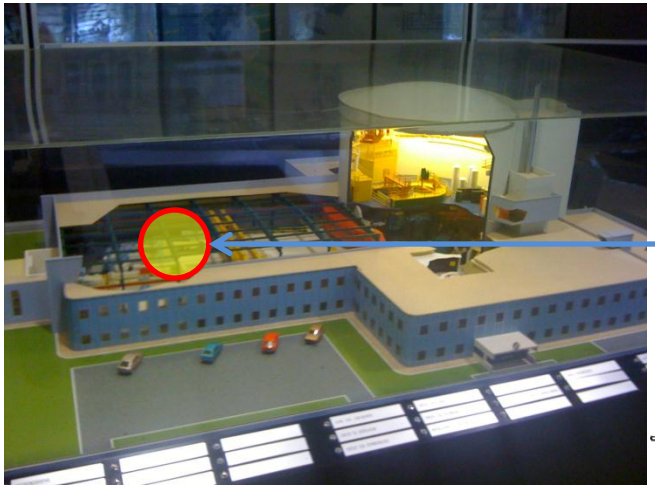
Neutron Irradiation – Orphee reactor

High intensity thermal neutron irradiation had place at C.E.A. Orphee reactor.

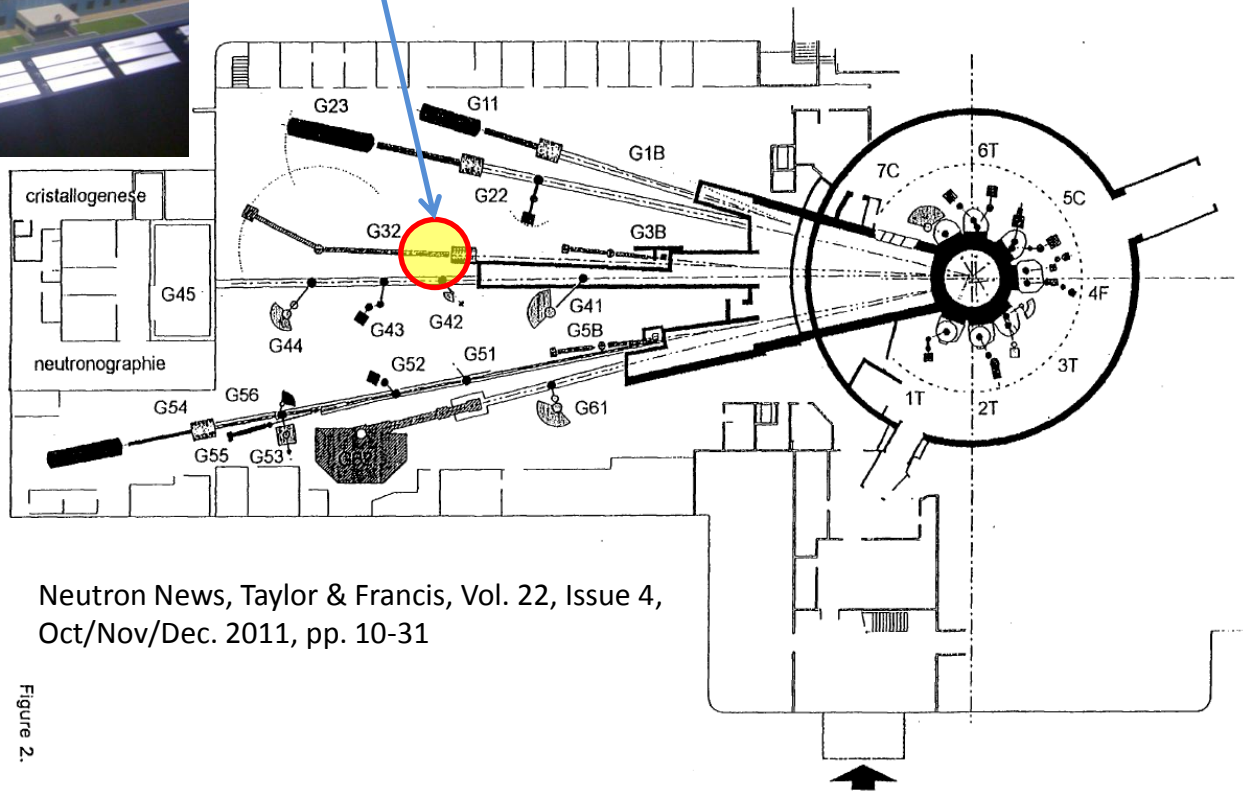
Several neutron research lines available.

Neutron flux : ~8.10^8 n/cm2/sec

Neutron energy : 5 to 10 meV



Detector emplacement at Orphee reactor Neutron guide



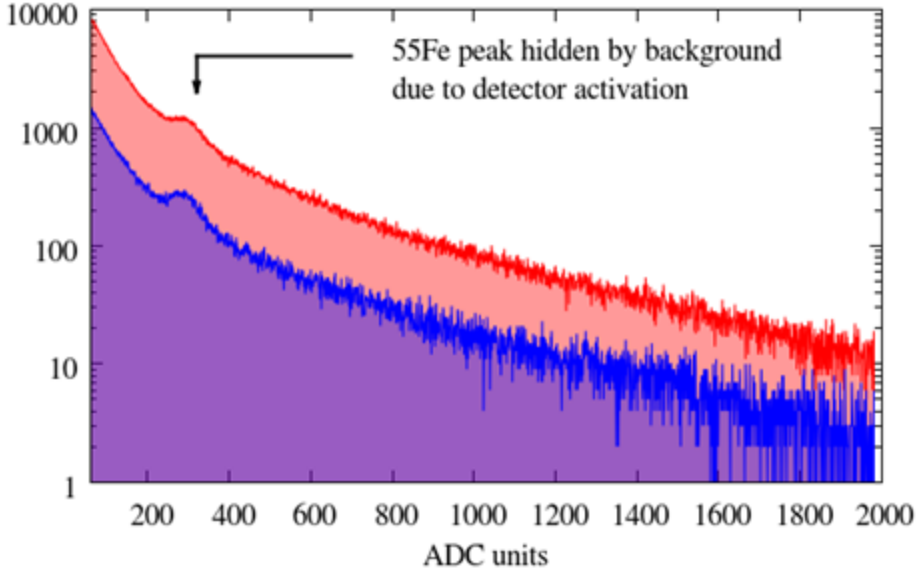
Neutron News, Taylor & Francis, Vol. 22, Issue 4, Oct/Nov/Dec. 2011, pp. 10-31

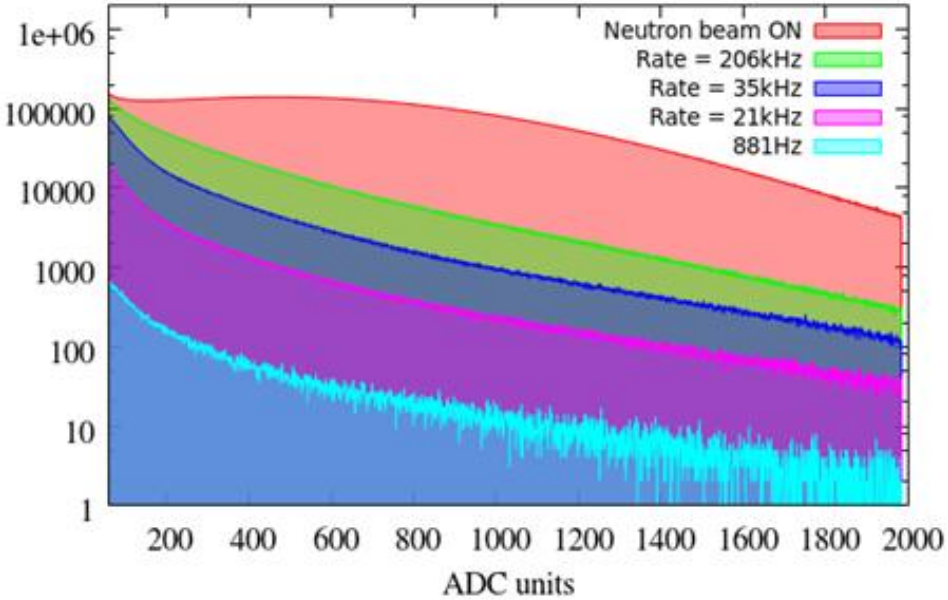
Figure 2.

Neutron irradiation – First exposure

After a short irradiation period the detector is quickly activated and takes long time to deactivate.

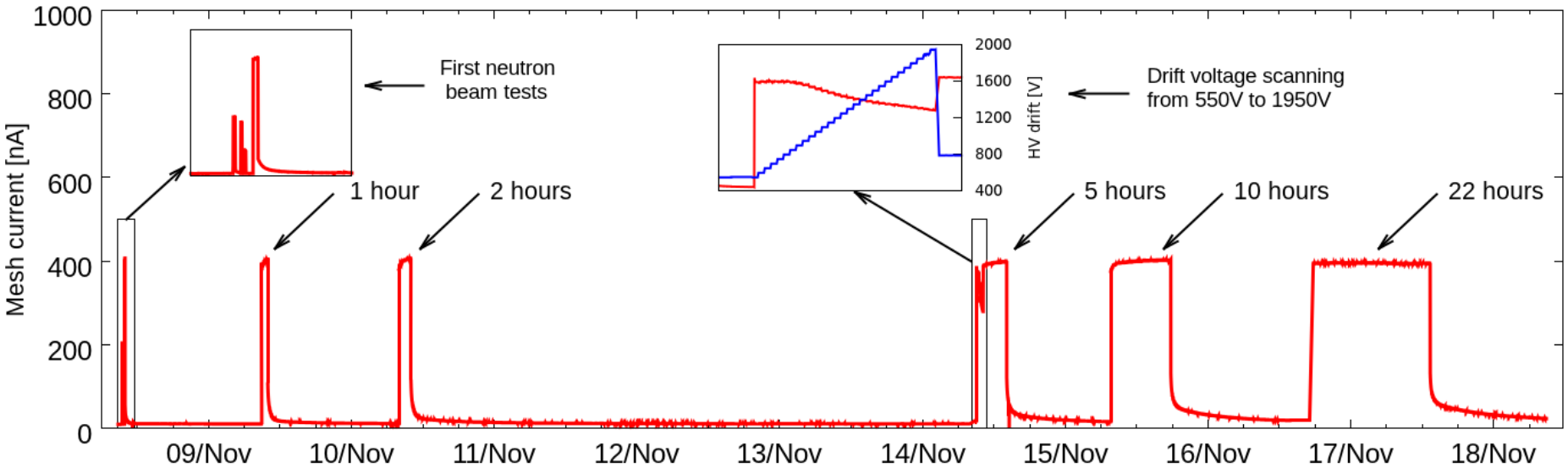
The activation rate measured saturates and reaches a limit of about 250kHz which does not increase with exposures longer than 2 hours.





Time	Rate
11h08	206 kHz
14h04	35 kHz
16h03	26 kHz
18h16	21 kHz
8h52*	881 Hz

Neutron Irradiation – Mesh current history

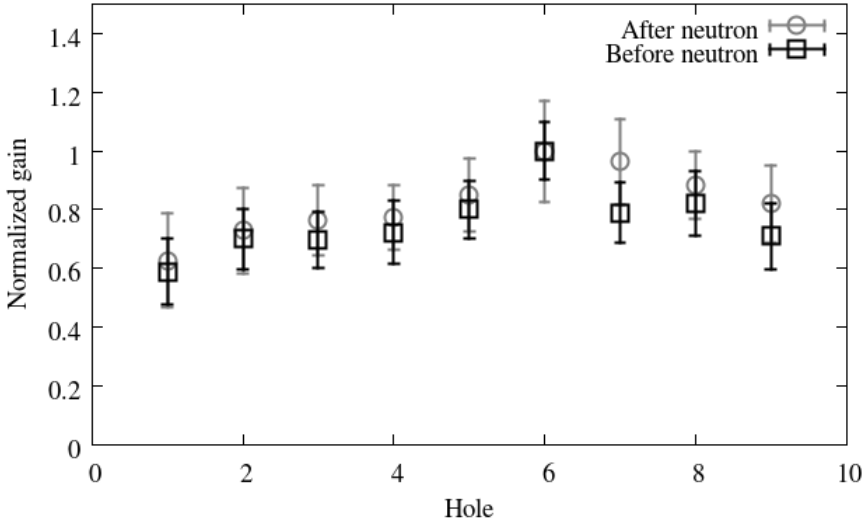


Neutron flux at the level of CSC in ATLAS ~3.10^4 neutrons/cm2/s

10 years at HL-LHC (=> x10.10^7 sec) with a security factor : x3

At the HL-LHC, we will accumulate 1,5.10^{13} n/cm2

At Orphee we have ~8.10^8 n/cm2/sec so in 1 hour we have : 8.10^8 x 3600 ~ 3.10^{12} n/cm2/hour which is about 2 HL-LHC years (200 days year).



COCASE facility and equivalent gamma charge.

LHC -nominal condition- prediction (from Background task force, CERN-ATL-GEN-2005-001) http://inspirehep.net/record/1196420

Position	Fluences (kHz/cm^2)				Currents (Hz/cm^2)			
	Neutrons			Photons	Ch.hads	Protons	μ^{+-}	e^{+-}
	Total	>100keV	>10MeV	>30keV	>10MeV	>10MeV	>10MeV	>0.5MeV
Barrel								
1st,low-z	5.08	1.47	0.10	1.81	2.79	1.89	1.89	9.30
1st,high-z	5.25	1.47	0.07	1.88	2.24	1.86	2.55	13.29
2nd,low-z	4.97	1.20	0.10	2.19	0.69	0.64	0.37	7.00
2nd,high-z	6.28	1.72	0.30	4.14	1.88	1.81	0.77	11.81
3rd,low-z	4.45	0.86	0.08	1.90	0.32	0.31	0.09	5.96
3rd,high-z	4.87	1.02	0.18	2.71	0.98	0.97	0.39	8.10
Forward								
1st,low-eta	14.23	4.80	0.66	4.93	4.89	4.38	3.60	33.57
1st,mid-eta	39.33	14.38	1.63	11.64	9.83	8.58	15.03	64.30
1st,high-eta	81.72	34.23	5.72	17.51	40.46	35.10	91.38	162.67
2nd,low-eta	5.55	1.51	0.25	3.18	1.98	1.93	0.25	11.91
2nd,mid-eta	8.36	2.61	0.49	4.43	6.45	6.20	1.20	23.58
2nd,high-eta	16.70	5.83	1.23	8.11	19.55	17.63	4.05	57.90
3rd,low-eta	3.16	0.48	0.06	1.40	1.53	1.47	0.27	7.41
3rd,mid-eta	3.09	0.47	0.05	1.31	1.25	1.21	0.32	6.41
3rd,high-eta	2.95	0.48	0.05	1.21	1.06	0.97	0.46	7.32

Table 5.10 Neutron and photon fluences and charged particles currents predicted by FLUKA for the AV16 geometry layout. Scoring surfaces used are shown in Figure 5.16.

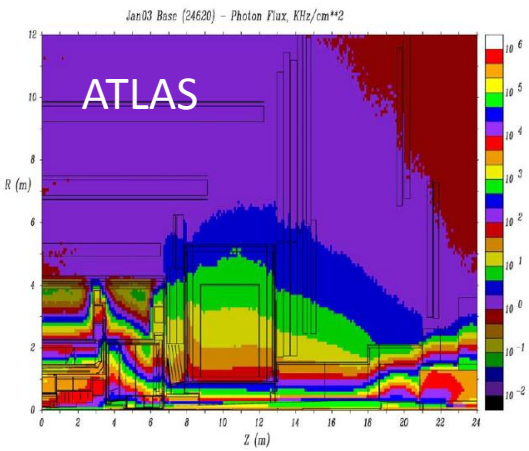


Figure 5.13 Photon flux in a full Atlas quadrant (GCALOR – Jan03).

For LHC (L = 10^{34} cm^{-2} s^{-1}):
Hottest region for gamma (E> 30 keV) in muon spectrometer is in forward CSC region:

18 kHz/cm^2

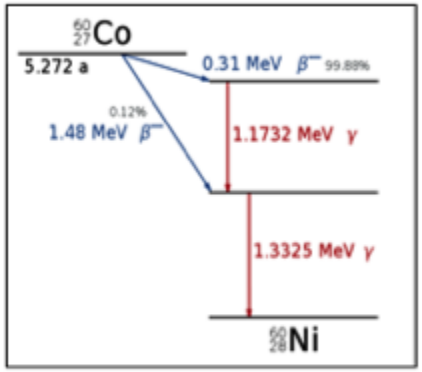
For 10 years of HL-LHC (assuming 1 y = 10^7 s):

x5 luminosity increase
x3 security factor
x10 year

⇒ Total of time equivalent: 1.5 10^9 sec

⇒ during 10 years of HL-LHC exposure

In hottest region we accumulate 2.7 10^{13} gamma / cm^2



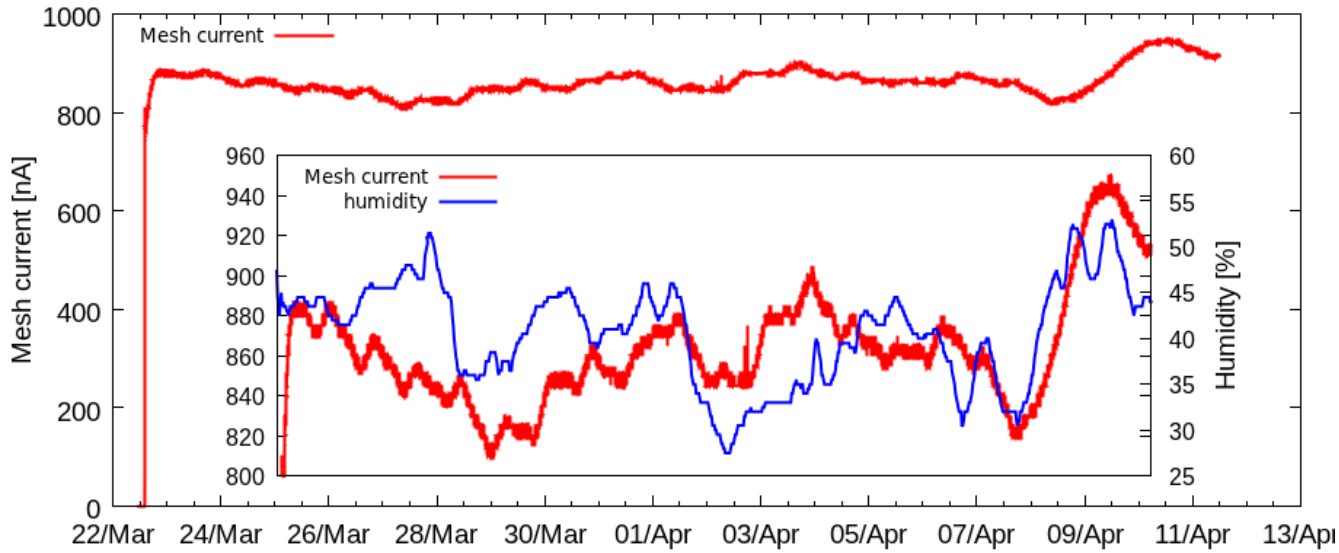
Gamma irradiation - Mesh current history and control measurements

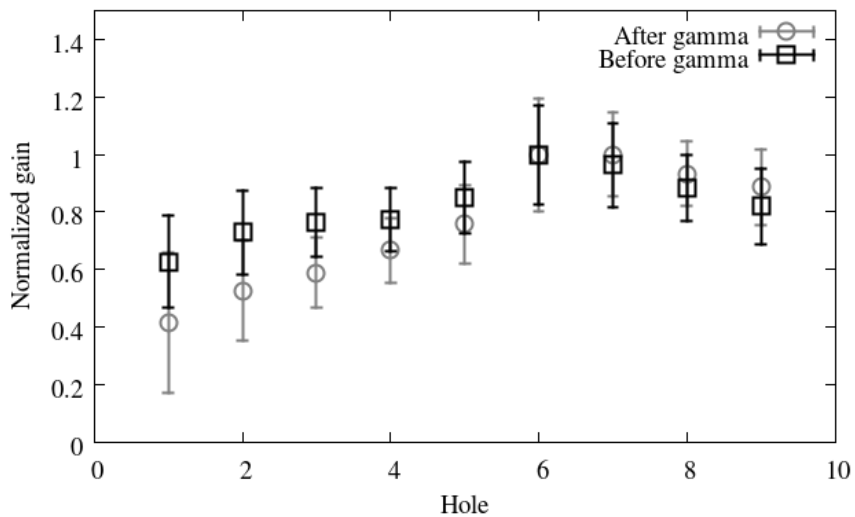
Gamma exposure between 22nd of March and 11th of April (2012).

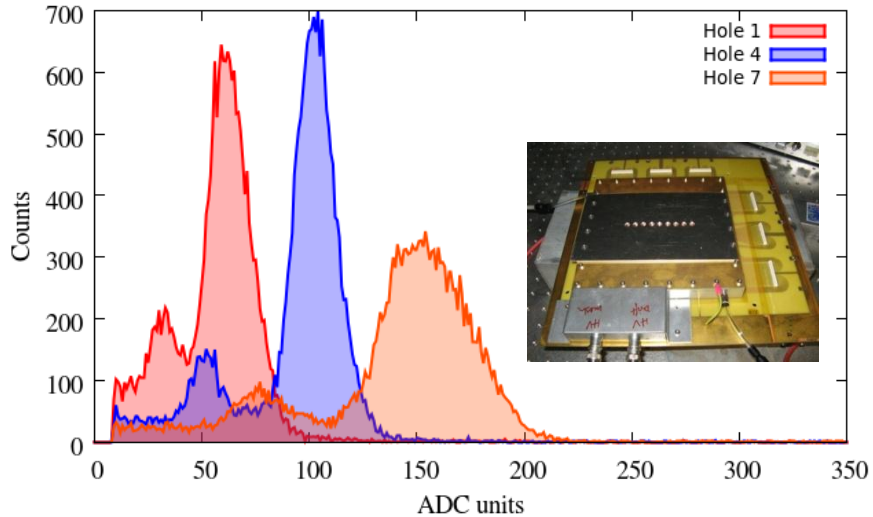
Total exposure time : 480 hours

Total integrated charge : 1484 mC

Mean mesh current : 858.4 nA



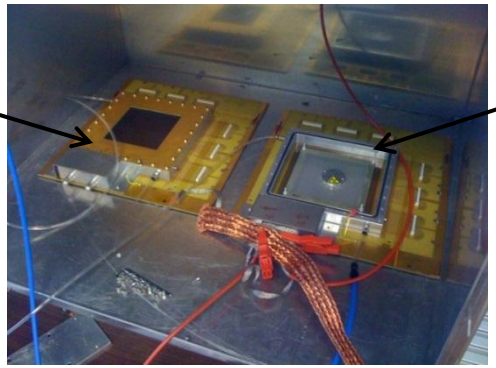




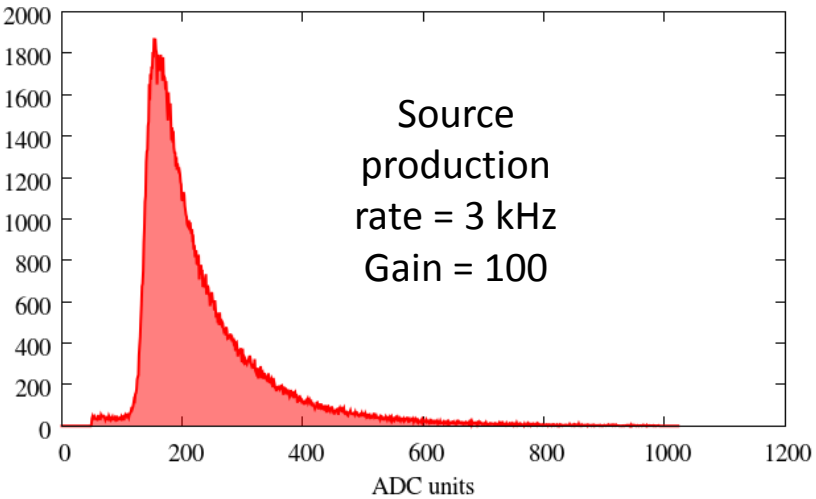
Alpha irradiation. ^{241}Am source.

About 30000 primaries are produced by an alpha in 0.5cm conversion region

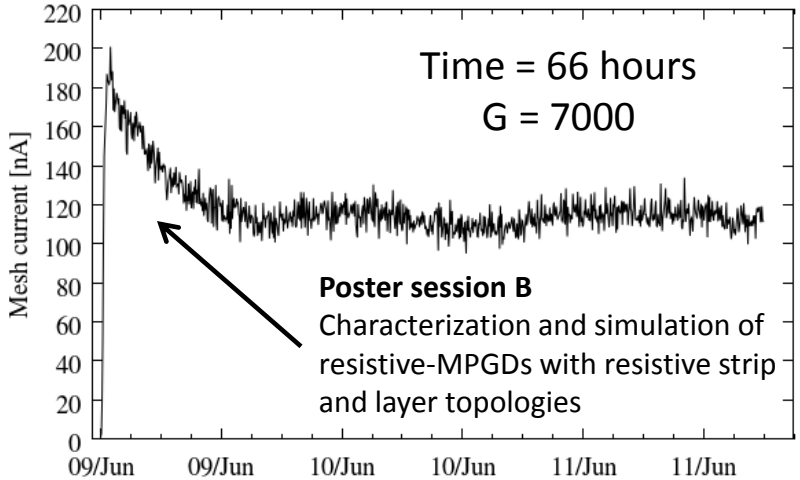
R17b



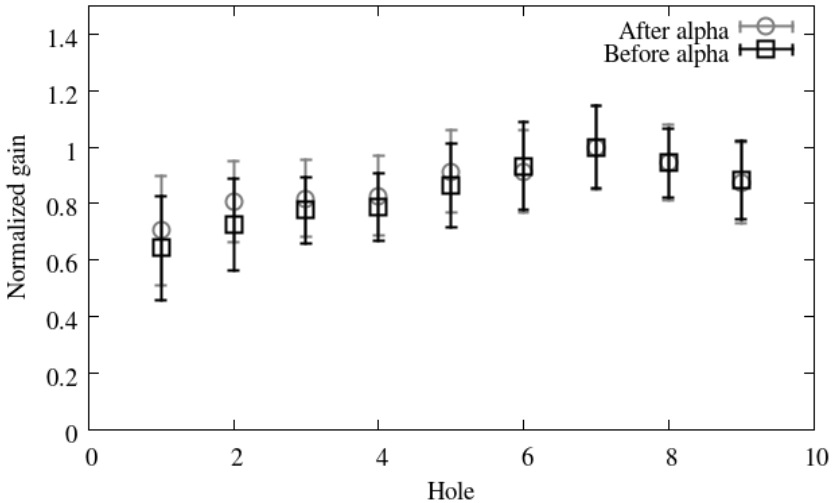
R17a with alpha source



In standard conditions, gains higher than 100 produce a spark on every alpha (Raether's)



Poster session B
Characterization and simulation of resistive-MPGDs with resistive strip and layer topologies



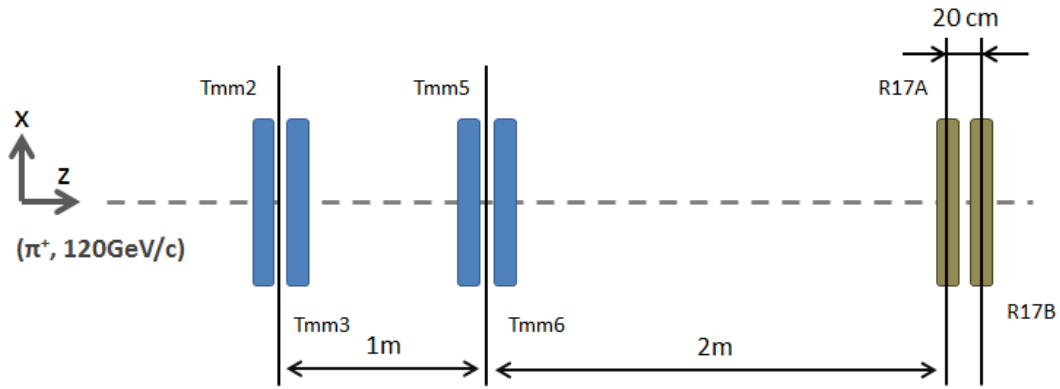
R17 ageing detector prototypes beam set-up

The two R17 prototypes were taken to the H6 SPS CERN pion beam to perform a **comparative study between both prototypes**, **irradiated** and **non-irradiated** one.

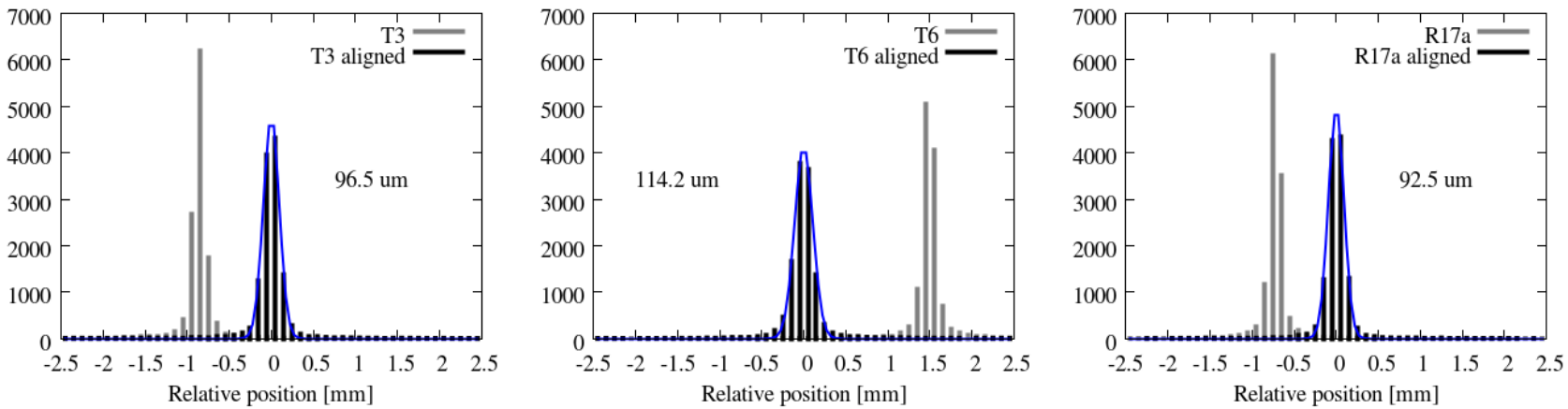
The performance was evaluated in terms of spatial resolution (SR) and efficiency.

Simplified beam set-up with R17 detectors

Detectors long offset produces systematics due to pion scattering. Resistive detectors were considered for track reconstruction. Non final set-up for intrinsic SR determination.



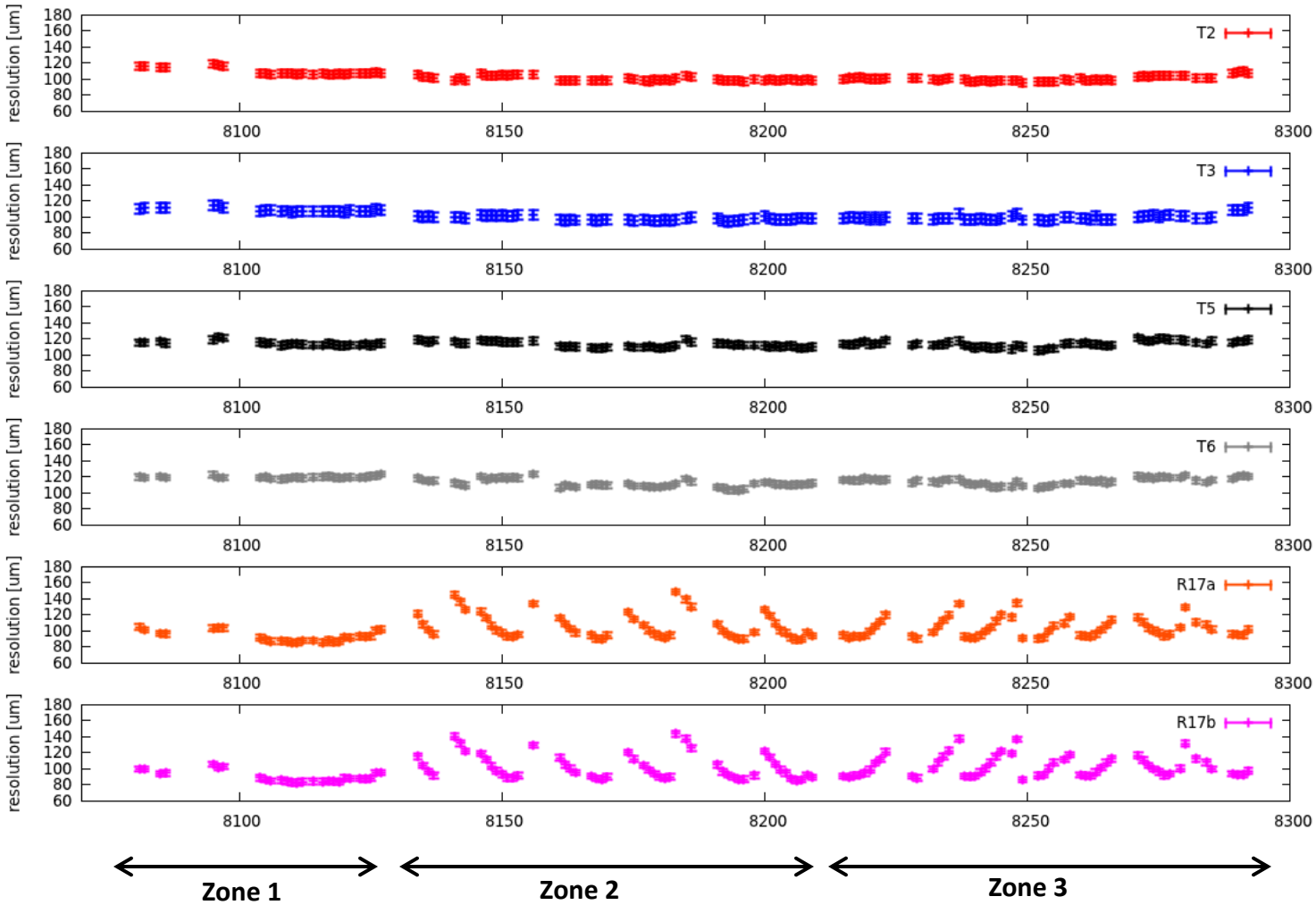
Residual distribution and alignment of resistive R17 prototypes to reference chambers



R17 ageing detector prototypes beam tests history

Beam tests took place at the end of October 2012. During two weeks R17 detectors took data. Three different zones were irradiated. And different settings were taken at each of these beam exposed regions.

Spatial resolution history for the different runs taken during this period.

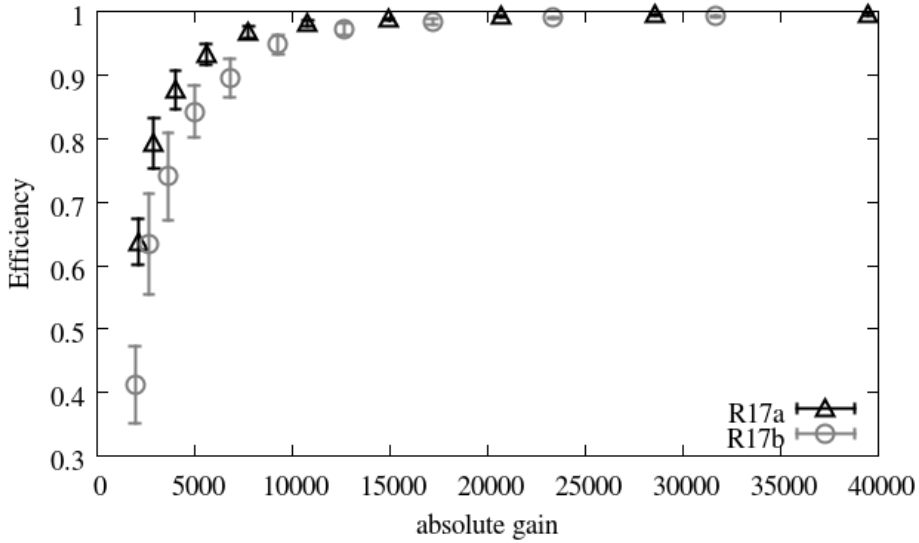


R17 prototypes efficiency

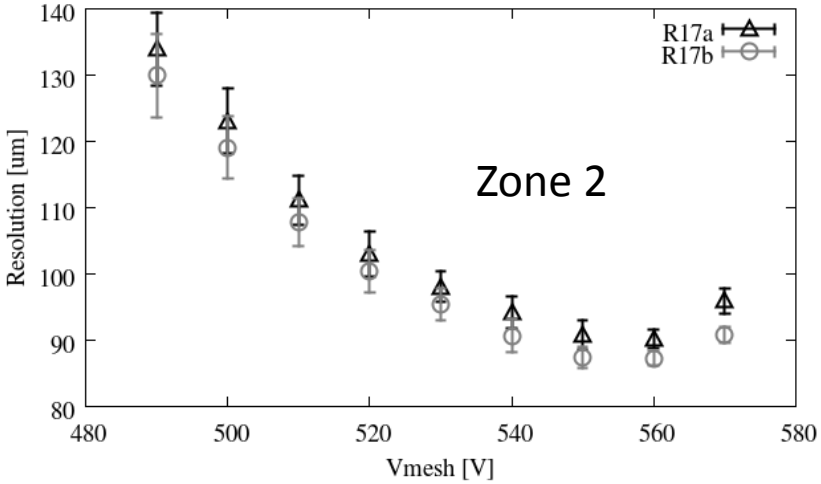
The **different scans are combined** as a function of the Vmesh and equivalent absolute gain.

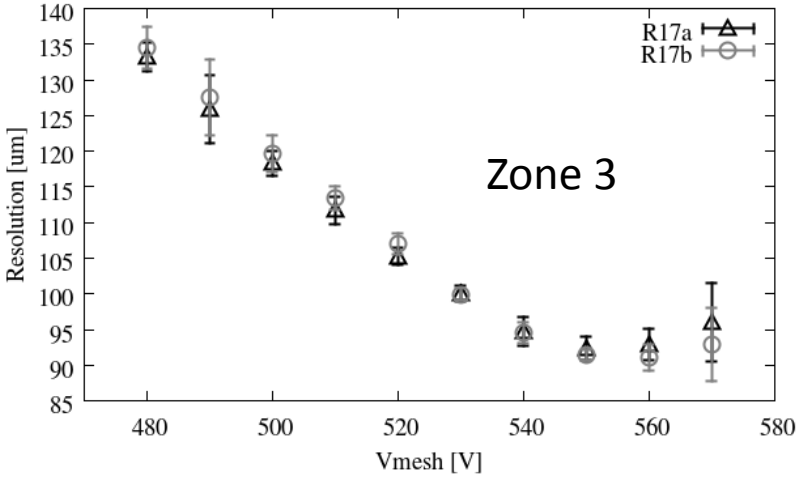
The efficiency of both detectors behaves good. In fact R17a detector efficiency grows faster. The gain curve of this detector was also growing faster and somehow is coherent with previous results.

Two different zones of R17a and R17b detector show same performance in terms of SR and efficiency!!



R17 prototypes spatial resolution





Summary and conclusions

Mechanical design concept is ready and PCB strips within required precision.

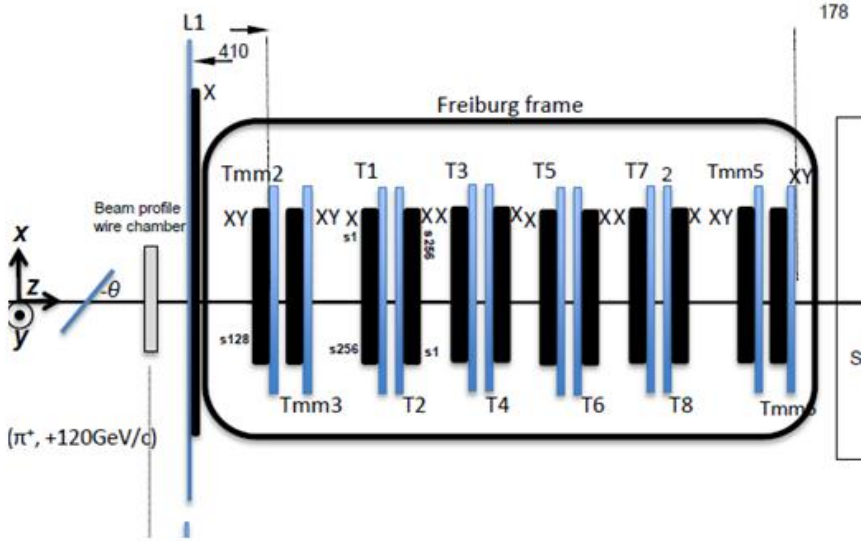
Resistive technology shows robustness and it is a mature technology now.

Different nature irradiation processes (X-ray, neutron, gamma and alpha) took place in one of these resistive prototypes.

During the different ageing periods the irradiated detector response does not show performance decrease and its performance is comparable to that performance achieved with a similar non-irradiated detector.

Several additional tests have proven the capability of Micromegas chambers to reconstruct the track and determine the spatial resolution of this track within the required precision.

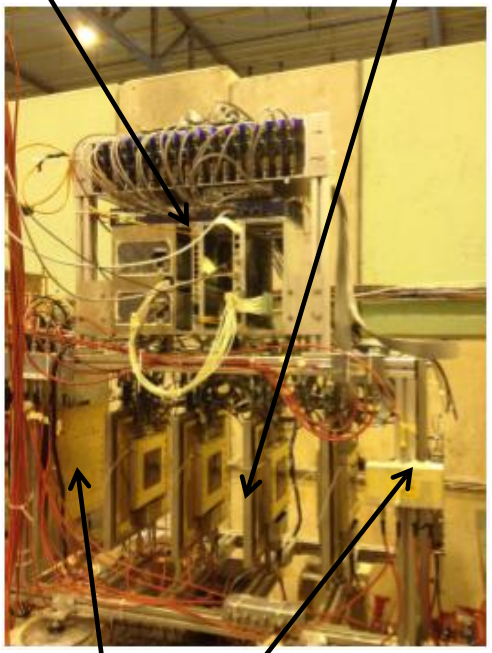
Additional micromegas studies which had place in parallel to these tests.



- 4 Doubles of X-precision chambers (0.4mm strip pitch – 5mm drift gap)
- 2 Doubles of XY reference chambers (0.25mm strip pitch – 5mm drift gap)
- Gas mixture : Ar + 7% CO2
- APV25 electronics – read-out with the SRS

SRS + APV daq

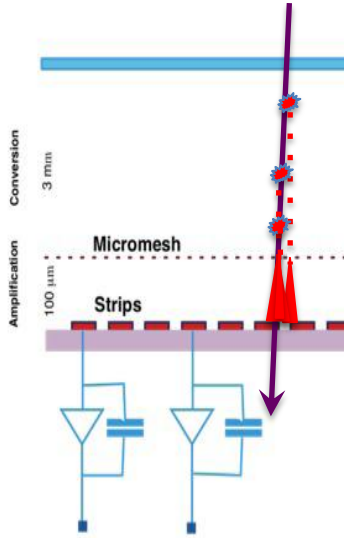
Detectors under test



Reference detectors mentioned previously

STRAIGHT TRACKS

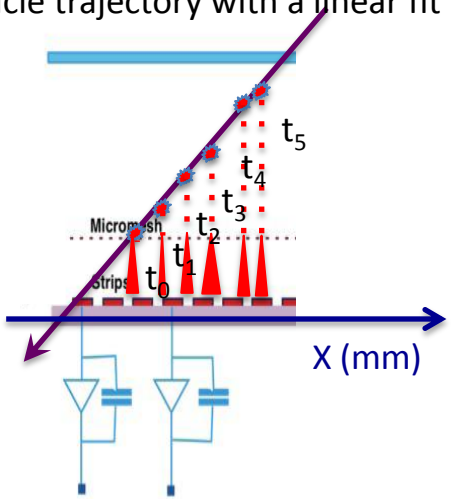
Particle position via Centroid calculation

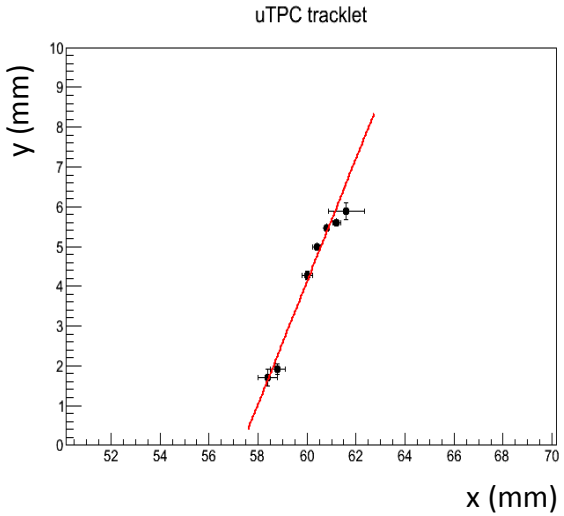


$$x_c = \frac{\sum_i q_i x_i}{\sum_i q_i}$$

INCLINED TRACKS

Measuring the arrival times of charges on single strips it is possible to determine the particle trajectory with a linear fit



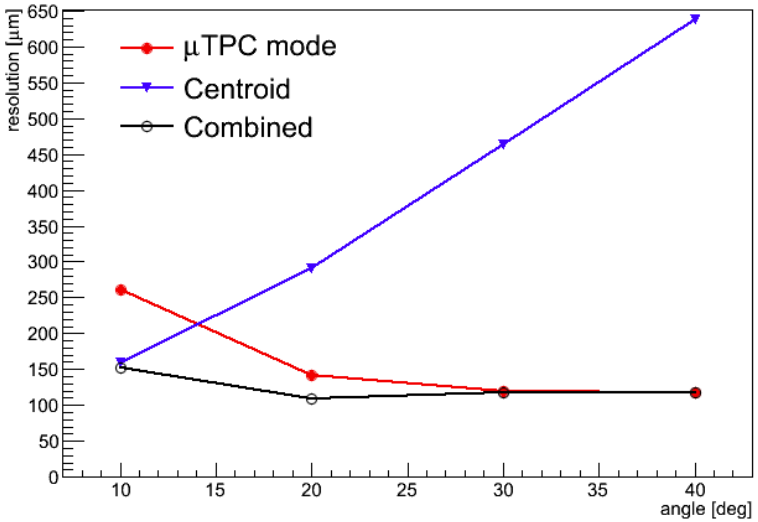


Optimum spatial resolution is achieved by combining both methods

$$w_c = \left(\frac{N_{cut}}{N_{strip}}\right)^2$$

$$w_\mu = \left(\frac{N_{strip}}{N_{cut}}\right)^2$$

$$x_{comb} = \frac{w_\mu x_\mu + w_c x_c}{w_\mu + w_c}$$

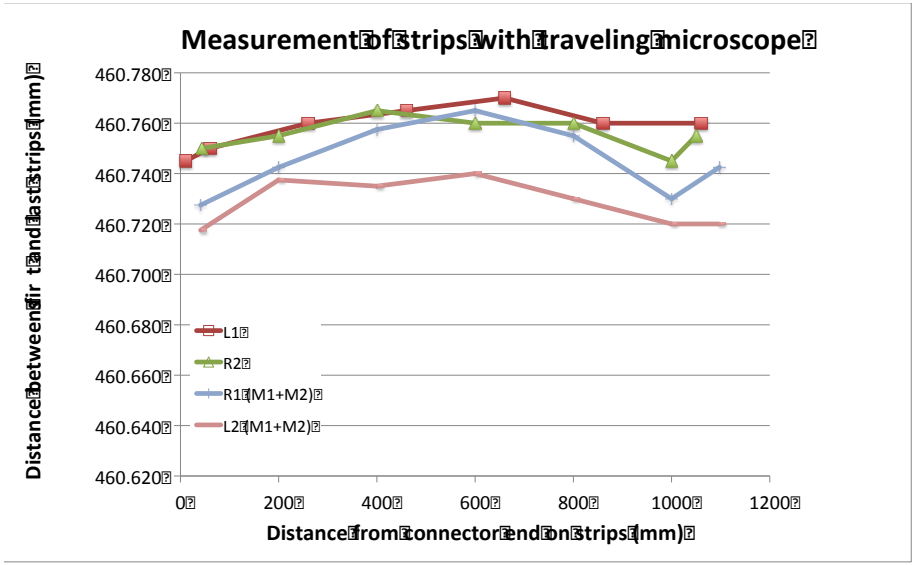


Backup. Micromegas detectors pattern precision

✓Precision of readout strips ≤ 10 µm (rms), measurements of made in CERN boards, within specs.

✓Flatness of r/o panels almost, OK, glueing of panels needs to be improved.

✓Alignment of boards with respect to each other seems to be easy, final method to be decided



Backup. Micromegas detectors assembly. Non-bulked Micromegas.

It uses pillars to keep the mesh at a defined distance from the board.

The mesh is not fixed but integrated with the drift-electrode panel.

Placed on the pillars when the chamber is closed.