



Performances of anode-resistive Micromegas for HL-LHC¹ environment

J. Manjarrés^b, T. Alexopoulos^a, D. Attié^b, M. Boyer^b, J. Derré^b, G. Fanourakis^c, E. Ferrer-Ribas^b, E. Gazis^a, T. Geralis^c, A. Giganon^b, I. Giomataris^b, S. Herlant^b, F. Jeanneau^b, E. Ntomari^c, Ph. Schune^b, M. Titov^b, G. Tsipolitis^a on behalf of MAMMA² collaboration.

for the following laboratories: (a) National Technical University of Athens Athens, Greece (b) IRFU, CEA - Saclay 91191 Gif-sur-Yvette Cedex, France (c) Inst. of Nuclear Physics, NSCSR Demokritos Athens, Greece.

Workshop IRFU MPGD, CEA-Saclay
6-8 december, 2011

¹ HL-LHC = High Luminosity Large Hadron Collider

² MAMMA = Muon **ATLAS** MicroMegas Activity



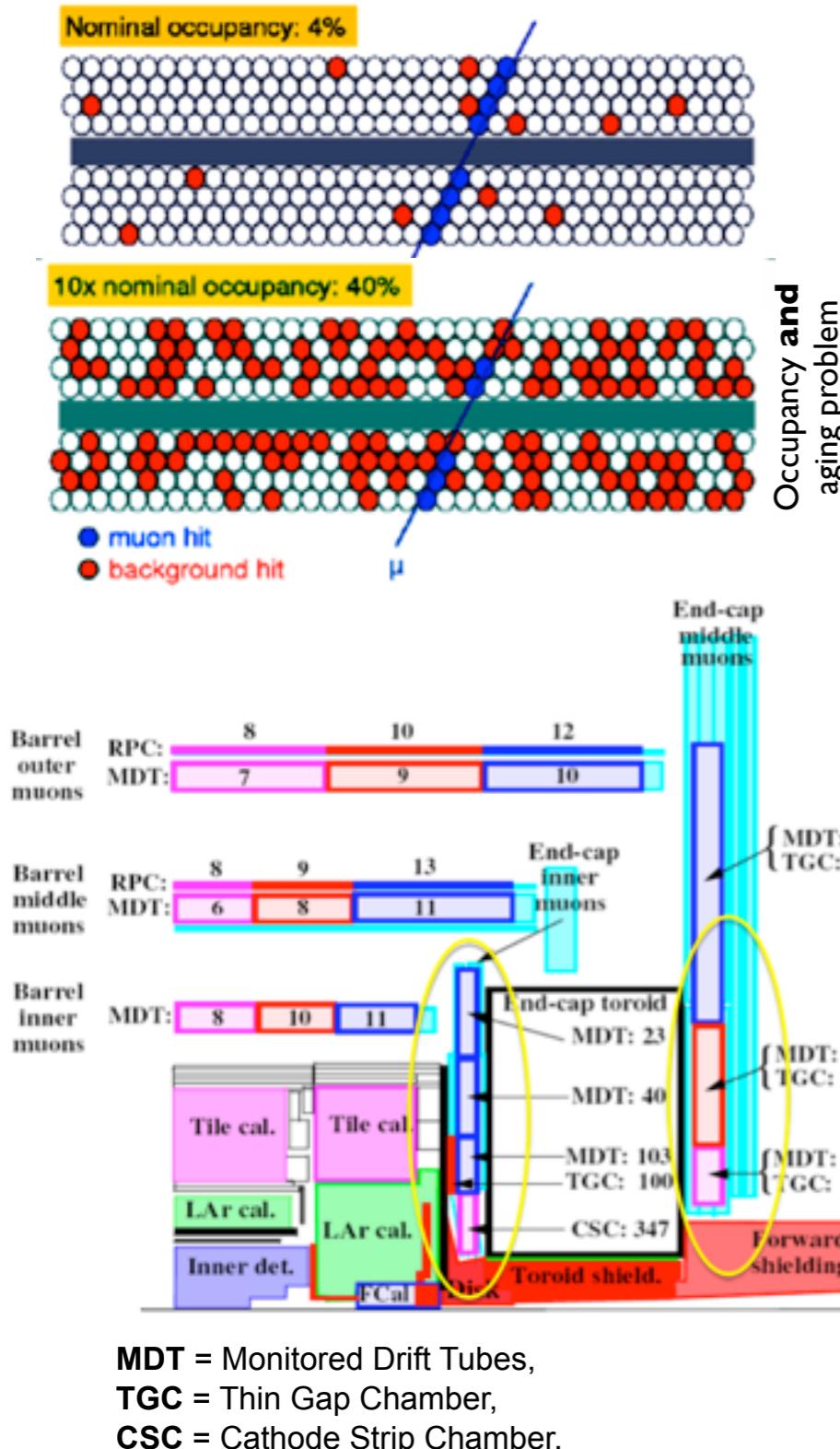
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Outline

- Introduction.
- The Saclay + Athens MAMMA beam test in 2010 at Cern :
 - The beam test setup.
 - Characteristics of the resistive detectors under study.
 - Signal acquisition system.
 - Common mode noise rejection.
- Data Analysis :
 - Clusters and track reconstruction.
 - Track selection.
 - Efficiency and resolution results.
- “Sparks”.
- Conclusion.



Introduction



The LHC¹ Machine plans:

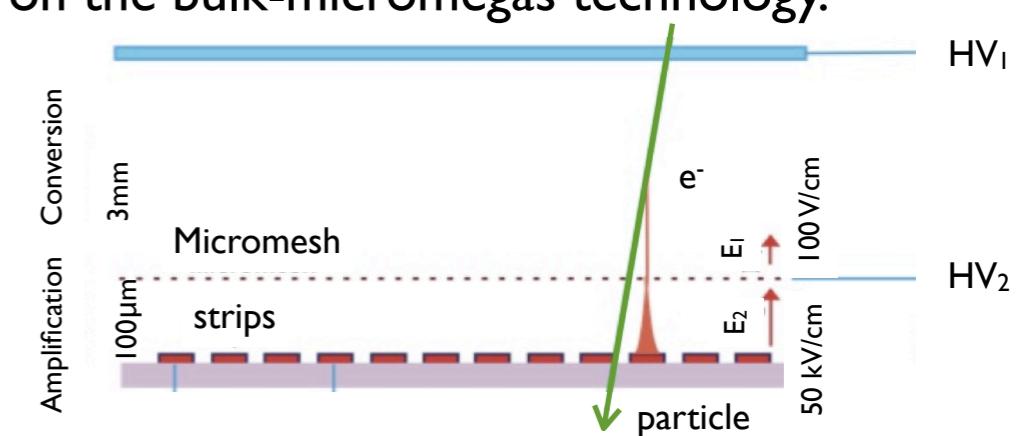
- phase 0: continue to run until 2012 → increasing the energy. Nominal luminosity by 2014?
- phase I: increase to 3 x nom. > 2018? → new small wheel.
- phase II: 10 x nominal in 2020? (HL-LHC).

- Increase on the neutron, photon and hadron background.
- ATLAS² prepares an upgrade of the muon system in, at least, the highest rapidity region.

Requirements:

- High rate capability ($\leq 10 \text{ kHz.cm}^{-2}$)
- Spatial resolution $\sim 100 \mu\text{m}$ ($\theta \leq 45^\circ$)
- Radiation hardness and good aging.
- Time resolution $\sim \text{few ns}$.
- LevelI triggering capability. $\sim 1.8 \mu\text{s}$
- Large surface.

- The MAMMA R&D activity focuses on the development of large-area muon detectors based on the bulk-micromegas technology.





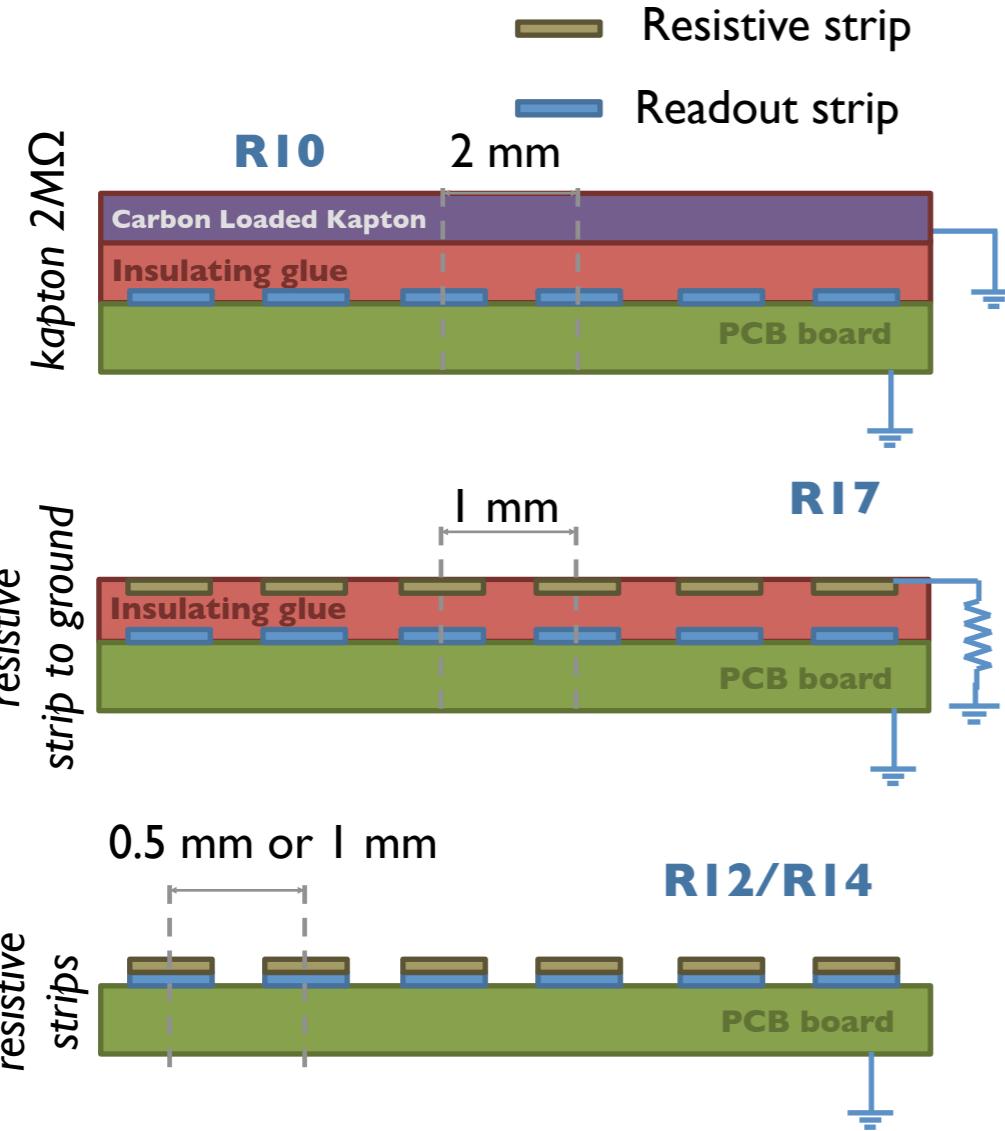
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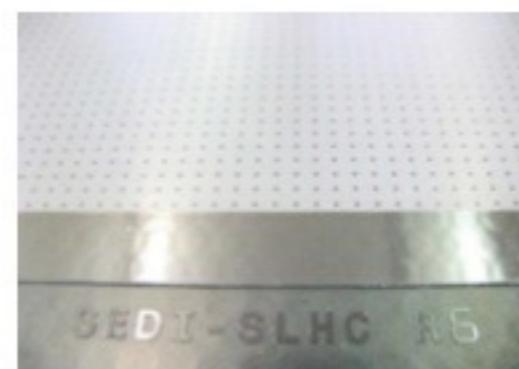
The resistive detectors

- To avoid sparks on micromegas different resistive coating configuration are tested.
- We tested 3 different resistive technologies.

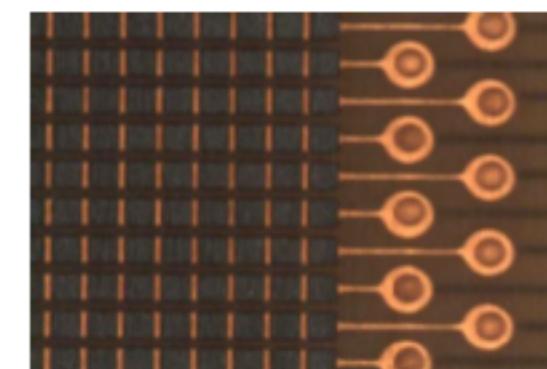


Resistive Bulk detector	pitch	Circuit type	Capacitance	Energy Resolution ^{55}Fe	Gain max
R10	2.0mm	kapton $2\text{M}\Omega/\square$	1.67 nF	22.1% (310V)	7829 (410v)
RI7	1.0mm	resistive strip to ground	943 pF	29.8% (310V)	10236 (410)
RI4	1.0mm	strips $300\text{k}\Omega$	943 pF	36.3% (350V)	10023 (410v)
RI2	0.5mm	strips $300\text{k}\Omega$	637 pF	24.4% (320V)	9835 (410v)

+20V on mesh HV is equivalent to $\sim\times 2$ for the gain



R10



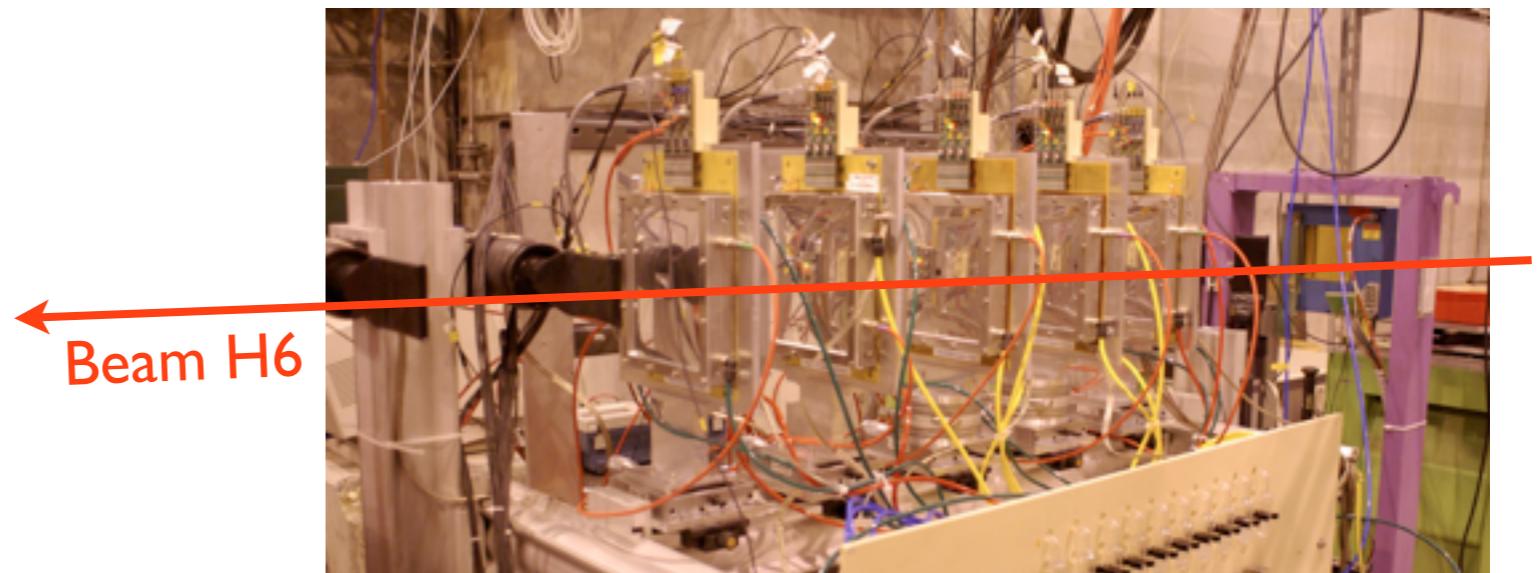
RI2 / RI4

The beam test setup

- Pions of 80 GeV (-) and 120 GeV (+) from CERN H6.

- Non resistive telescope:

- 3 X-Y detectors
 - Gas Ar + 2% C₄H₁₀
 - pitch 0.5mm, 0.25mm



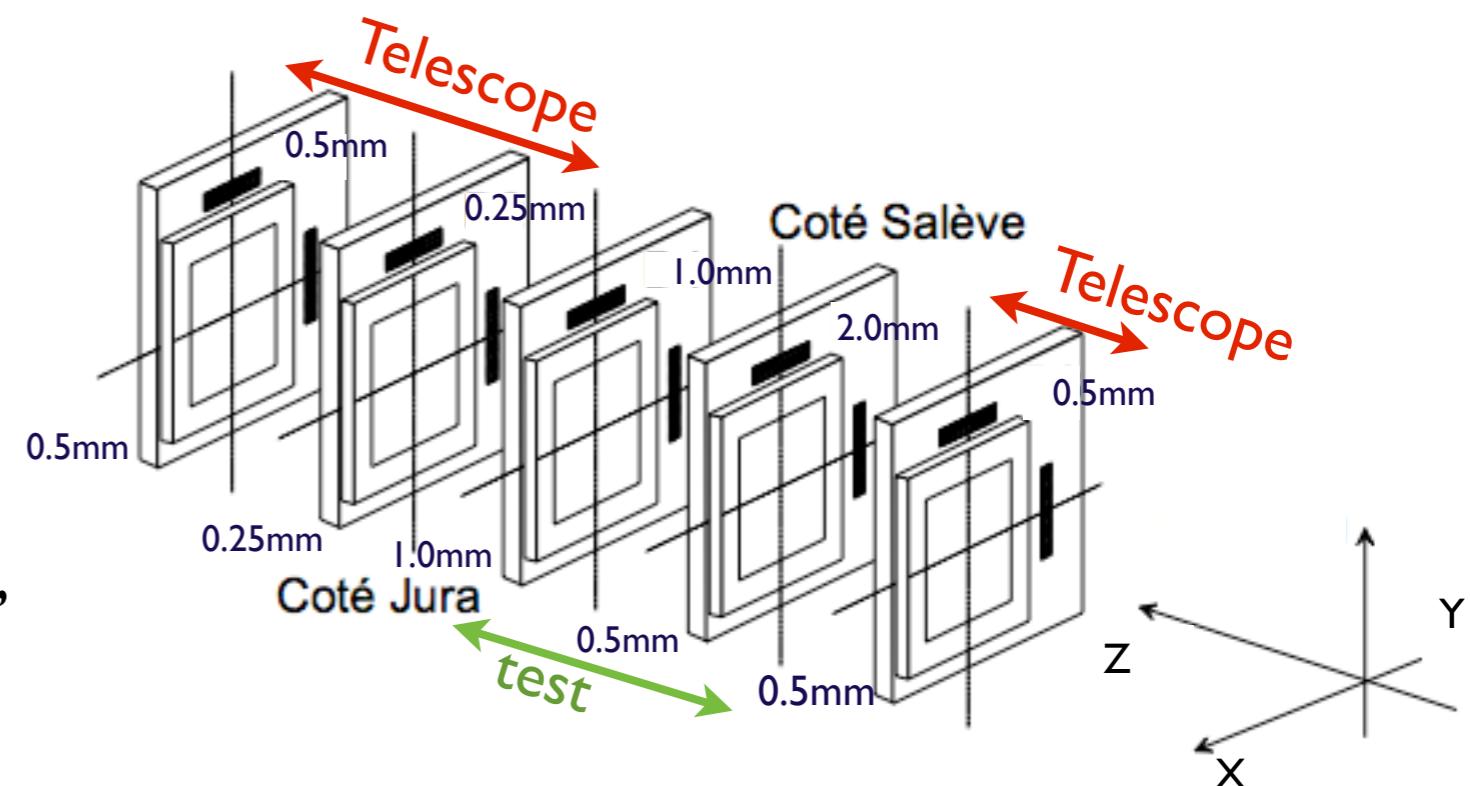
- Resistive chambers tested:

- 2 X - Y detectors
 - Gas Ar + 2% C₄H₁₀ + 3% CF₄
 - pitch 0.5mm, 1.0mm, 2.0mm

- Trigger: 3 PM.

- Electronics: Gassiplex 96 channels, Gassiplex picking time 1.2μs

- DAQ: based on labview.



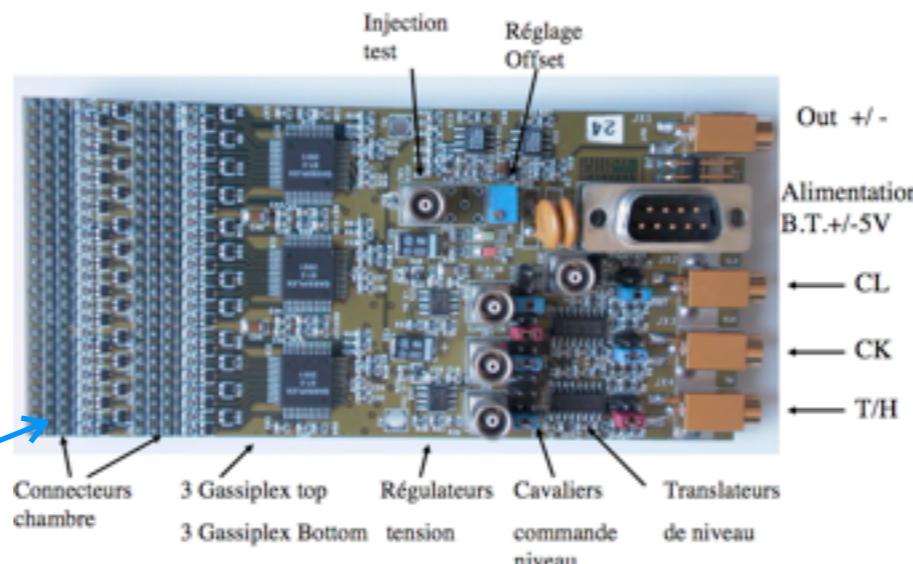
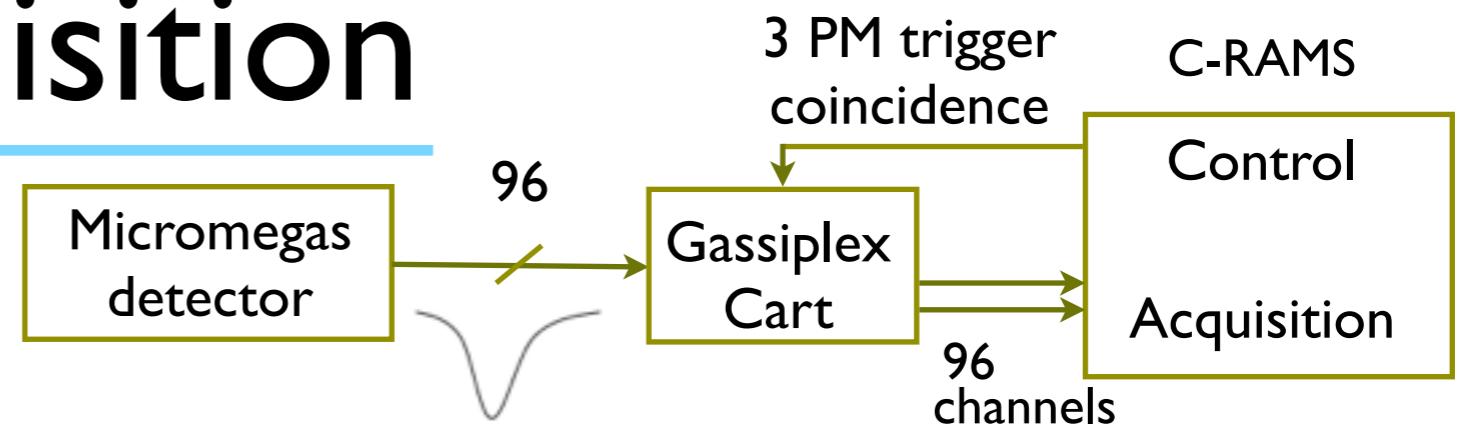
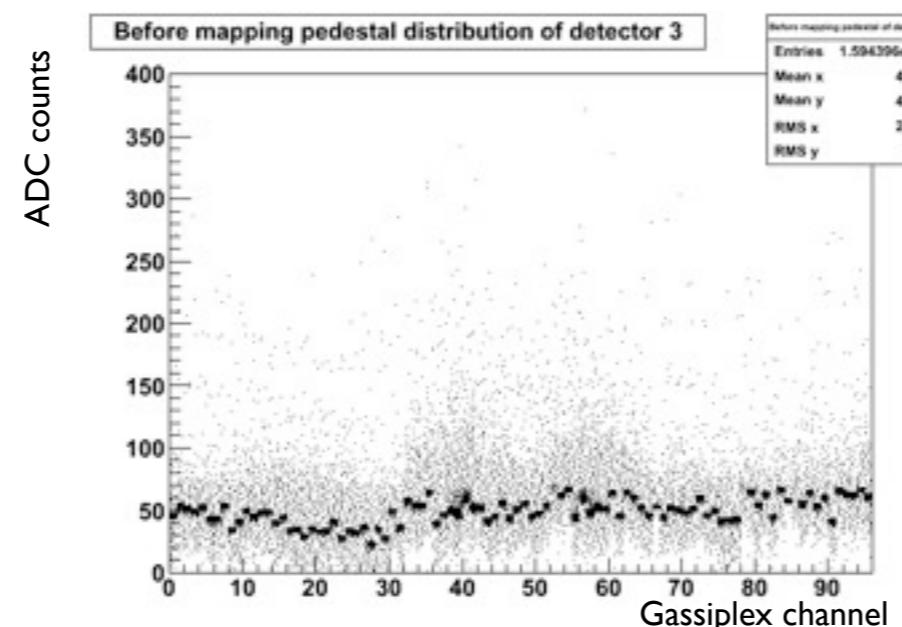


Signal acquisition

- Trigger 3 PM coincidence.
- Gassiplex card integrates de charge (peacking time 1.2 μ s, 96 channels)
- CAEN sequencer with four CRAM modules.
- LabView software to data acquisition and detector monitoring



- A normal run with beam before pedestal adjustment



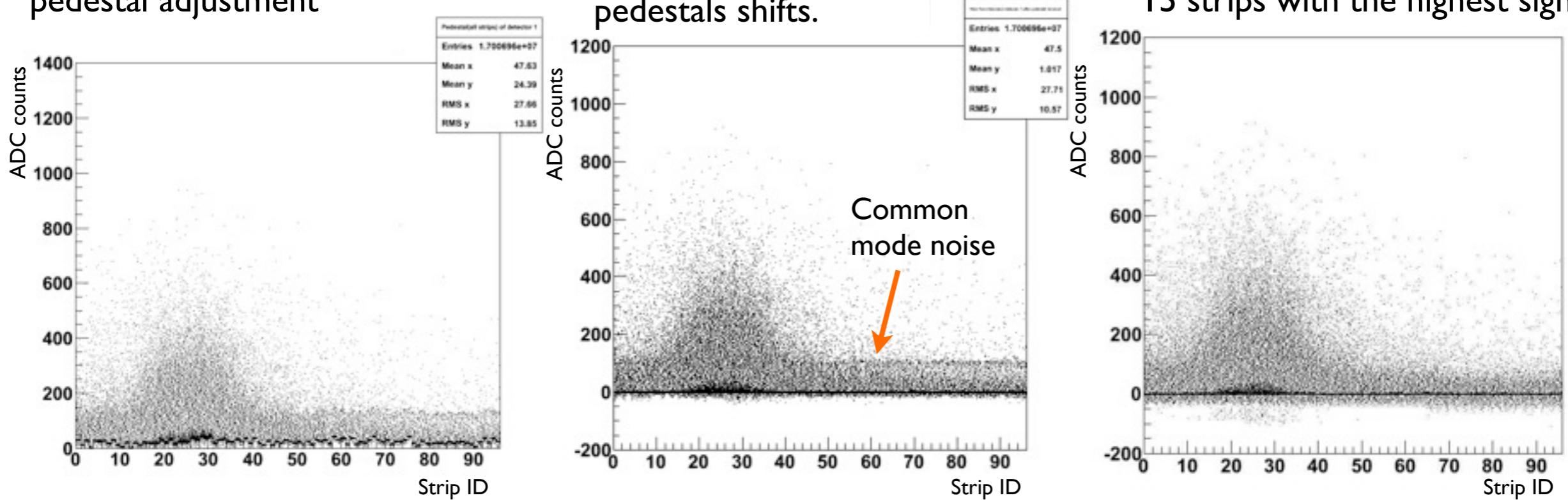
Runs summary

- High rate exposures:
Pions of 80 GeV (-) and 120 GeV (+)
Rates: 25–250 kHz/cm²
- High Voltage scan.
- Track angles w.r.t the beam:
0°, 20°, 30°.

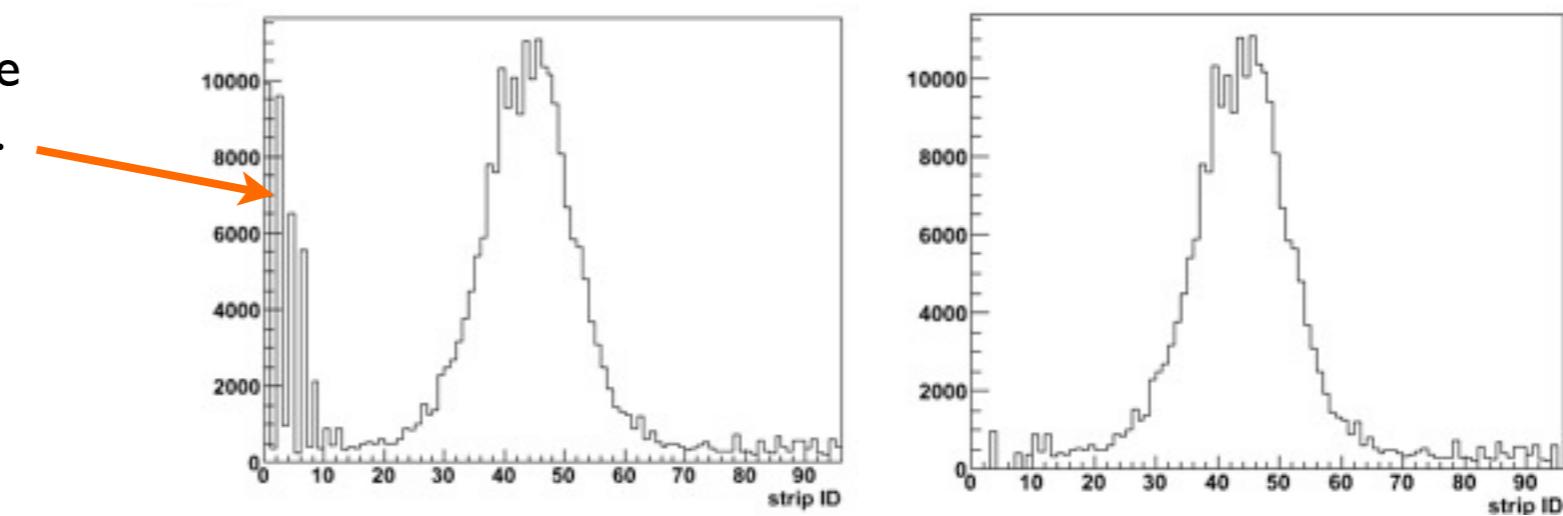


Common mode noise rejection

- We do gaussian fit channel by channel and we bring the mean value to zero.
- A normal run with beam before pedestal adjustment
- We can clearly see some pedestals shifts.
- The mean value of the event is calculated and subtracted, without taking in account the 15 strips with the highest signal.



- The noisy channels are identified and masked.





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- Data Analysis :
 - Clusters and track reconstruction.
 - Impact point estimation.
 - Impact point estimation: A different approach.
 - Track selection.
 - Efficiency and resolution results.
 - “Sparks”.
 - Conclusion.

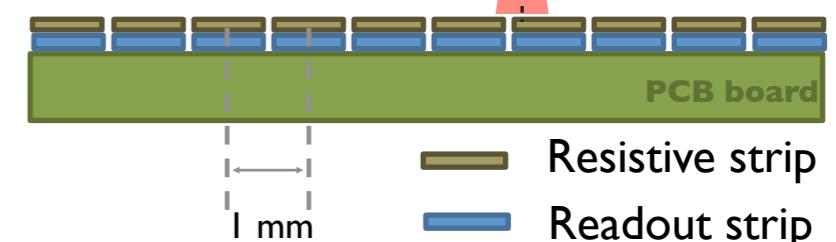
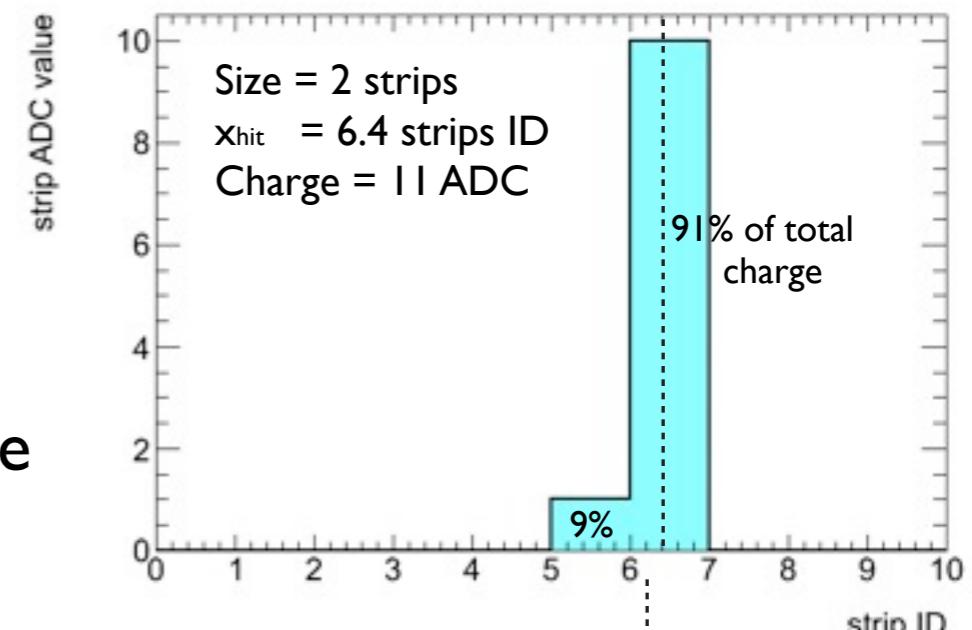
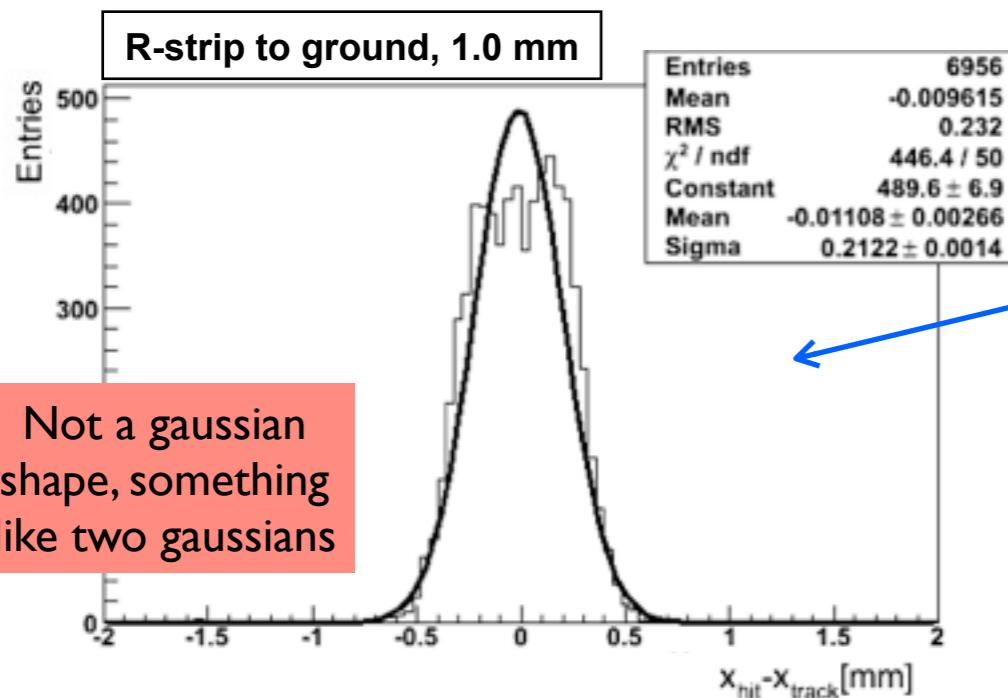
Impact point calculation (I)

A Cluster is a group of fired strips with charge above threshold. The threshold is defined by 3.5 sigma of electronics noise (usually $\sim 2\text{-}3$ ADC counts).

- We use the Center Of Gravity, to calculate the impact point :

$$x_{hit} = \frac{\sum_i w_i \cdot x_i}{\sum_i w_i}$$

w_i = Charge on strip.
 x_i = coordinate of strip in cluster.
 x_{hit} = coordinate of cluster COG.

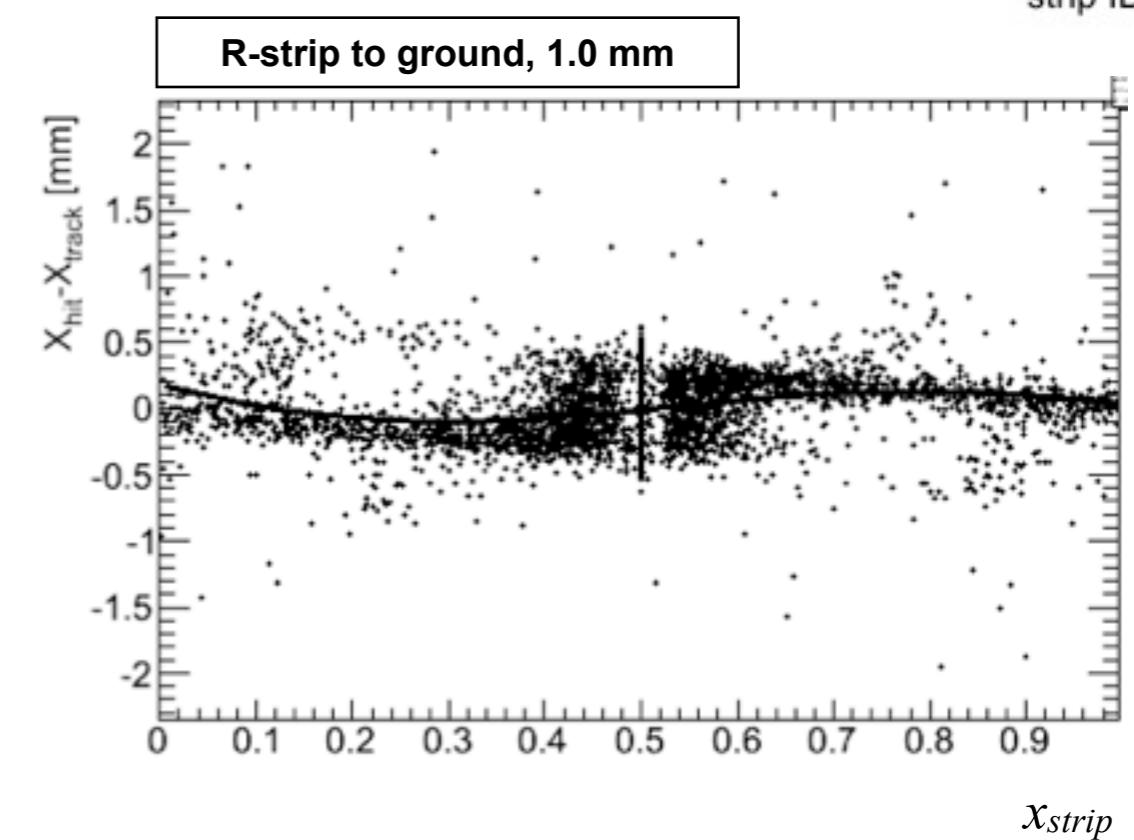
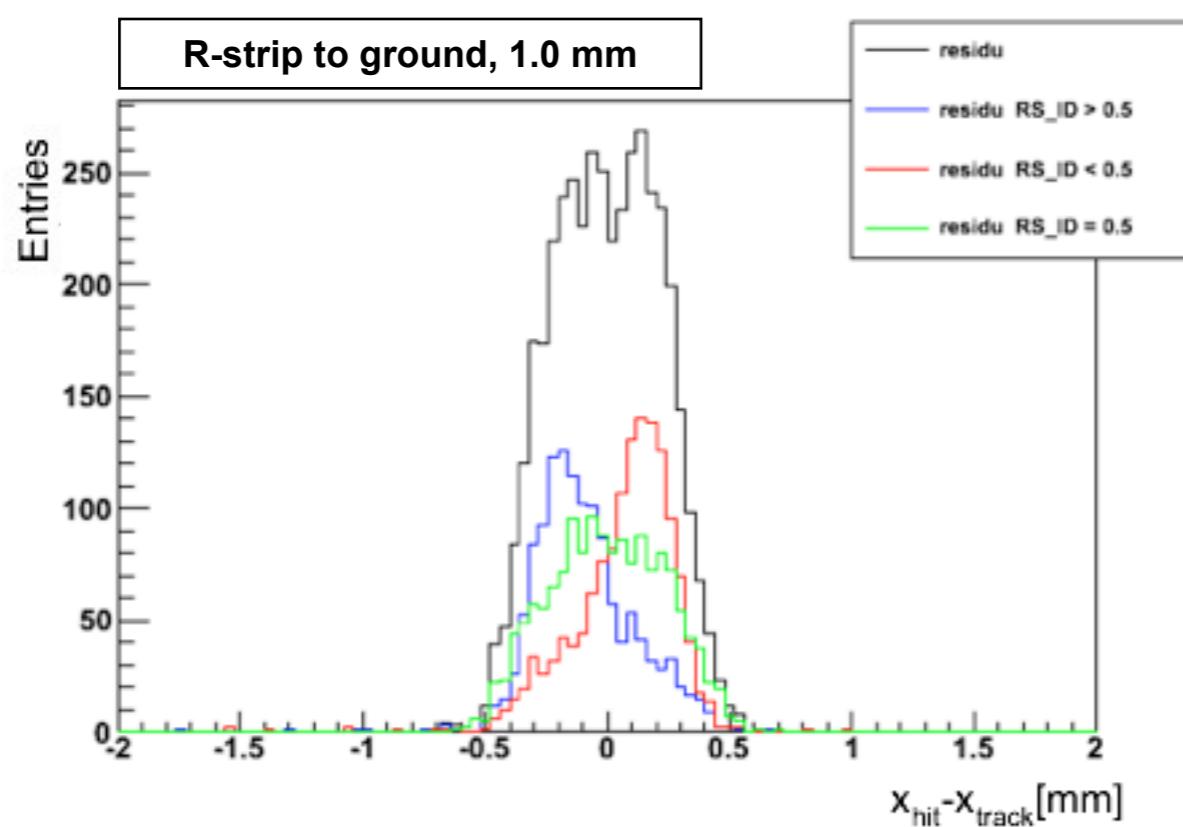
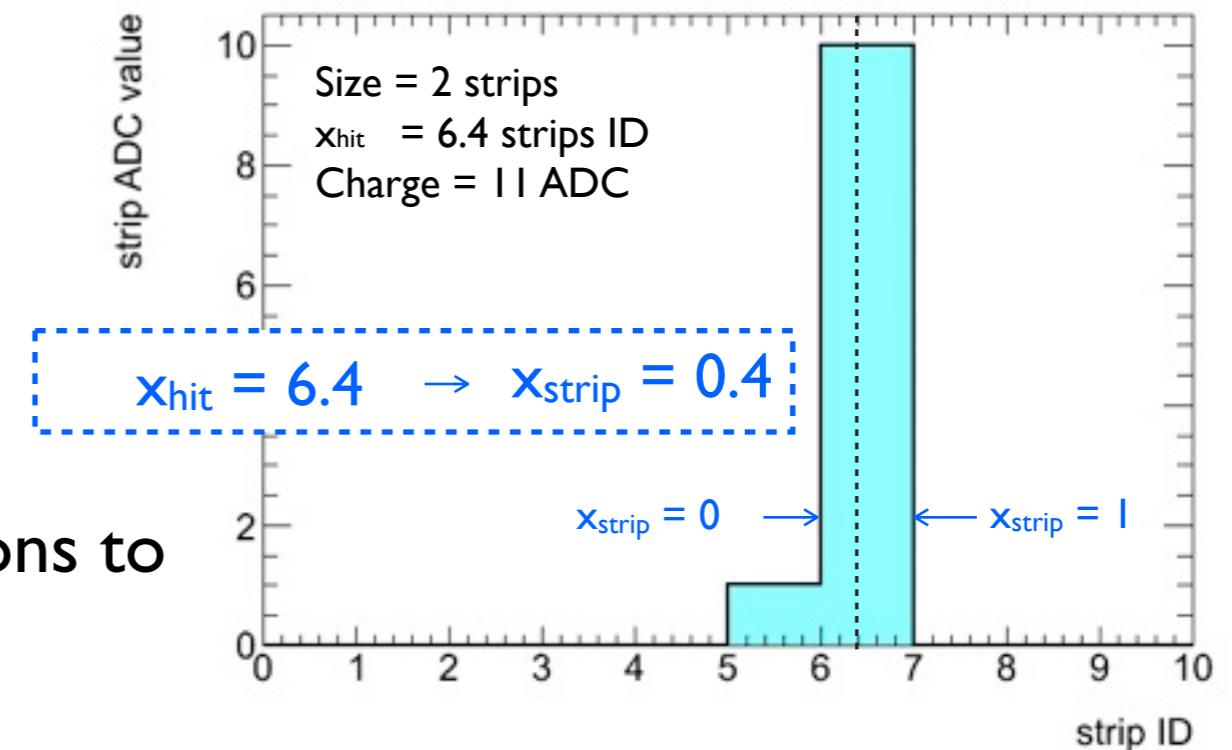


If we look at the residuals distribution, which are the difference of the COG position (x_{hit}) and extrapolated track from telescope (x_{track}).

- Large strips pitch discretization introduces systematic errors.

Impact point calculation (2)

- Let's look the residual distribution as a function of the position of the impact point w.r.t the central strip (x_{strip}).
- We can clearly see the two contributions to the residual distribution.



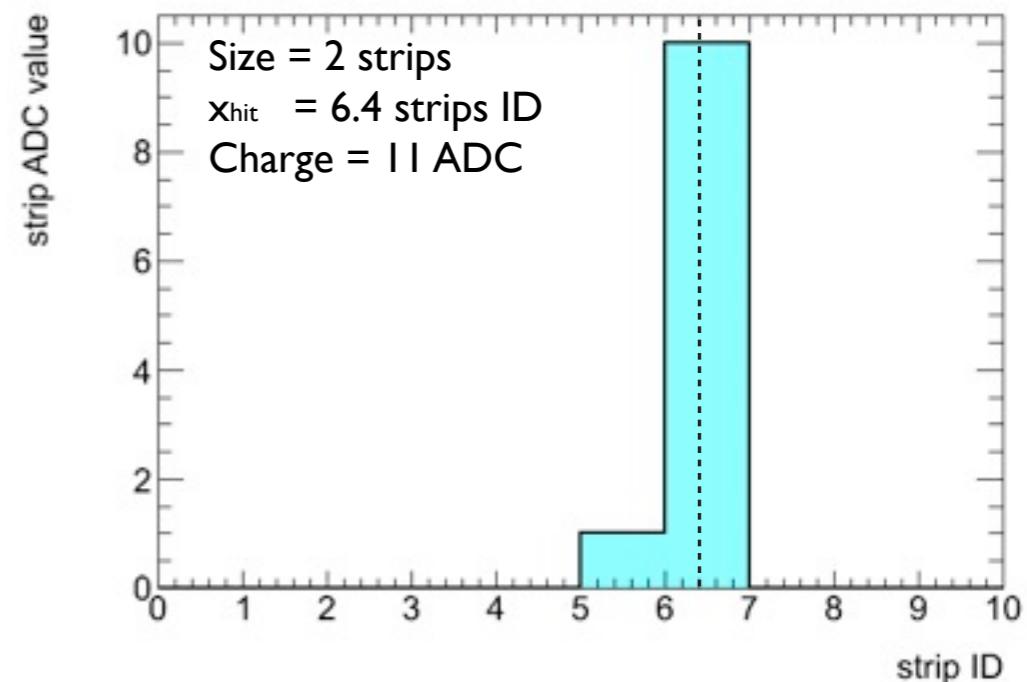
Impact point calculation : A different approach* (I)

- The new idea is to calculate the position of the cluster like a center of gravity but with logarithmic weights.

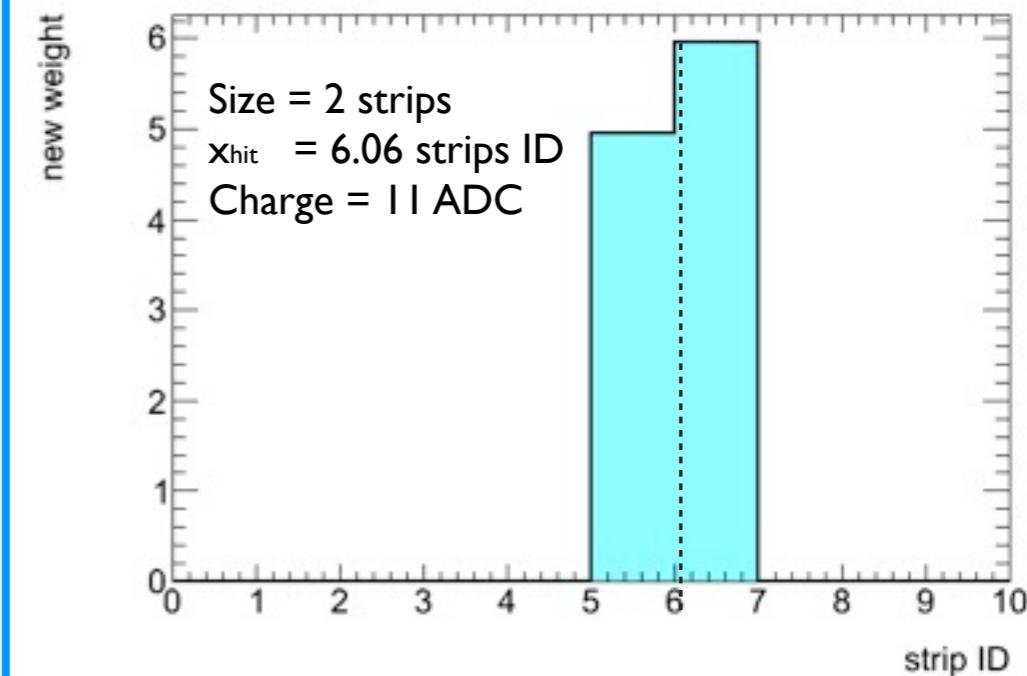
$$w_i = w_0 + \log\left(\frac{Q_i}{\sum_j Q_j}\right)$$

$$w_0 = -\log \frac{Q_{min}}{Q_{tot}} \rightarrow w_0 > 0$$

- The weight is constrained to be positive, or is otherwise set to zero.
- So w_0 is threshold on the charge to decide which cell will be taken into calculation of gravity-center

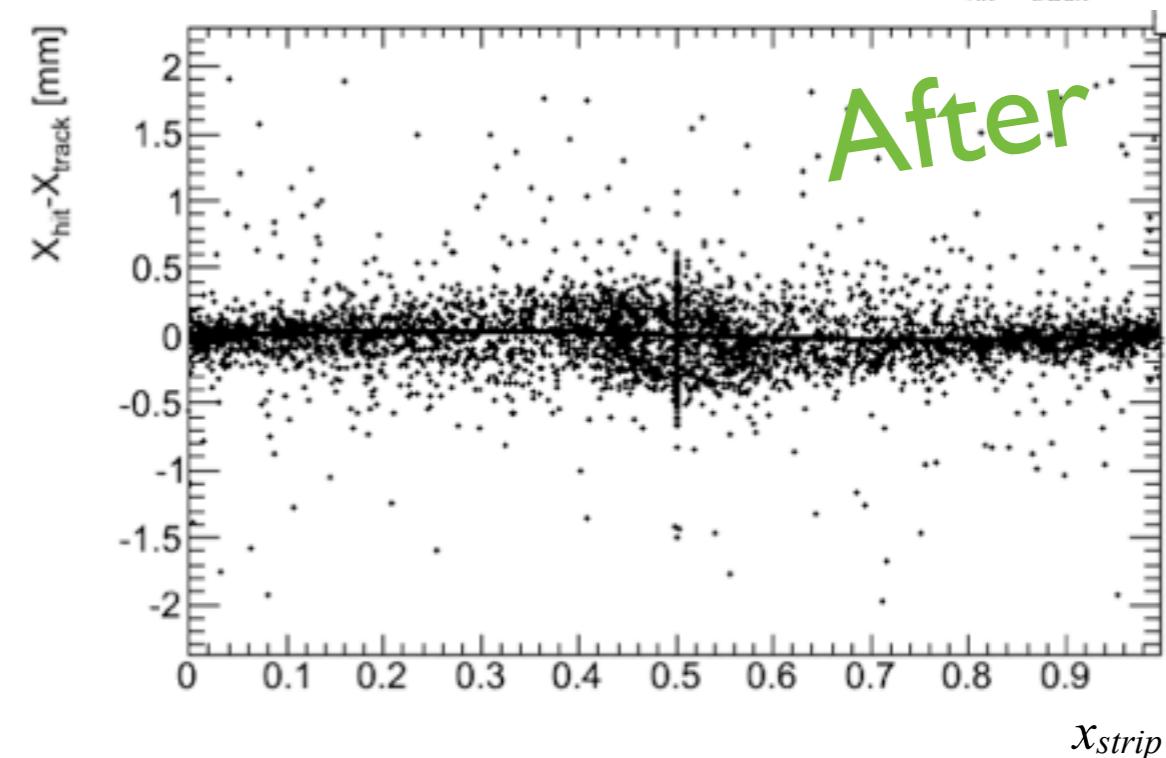
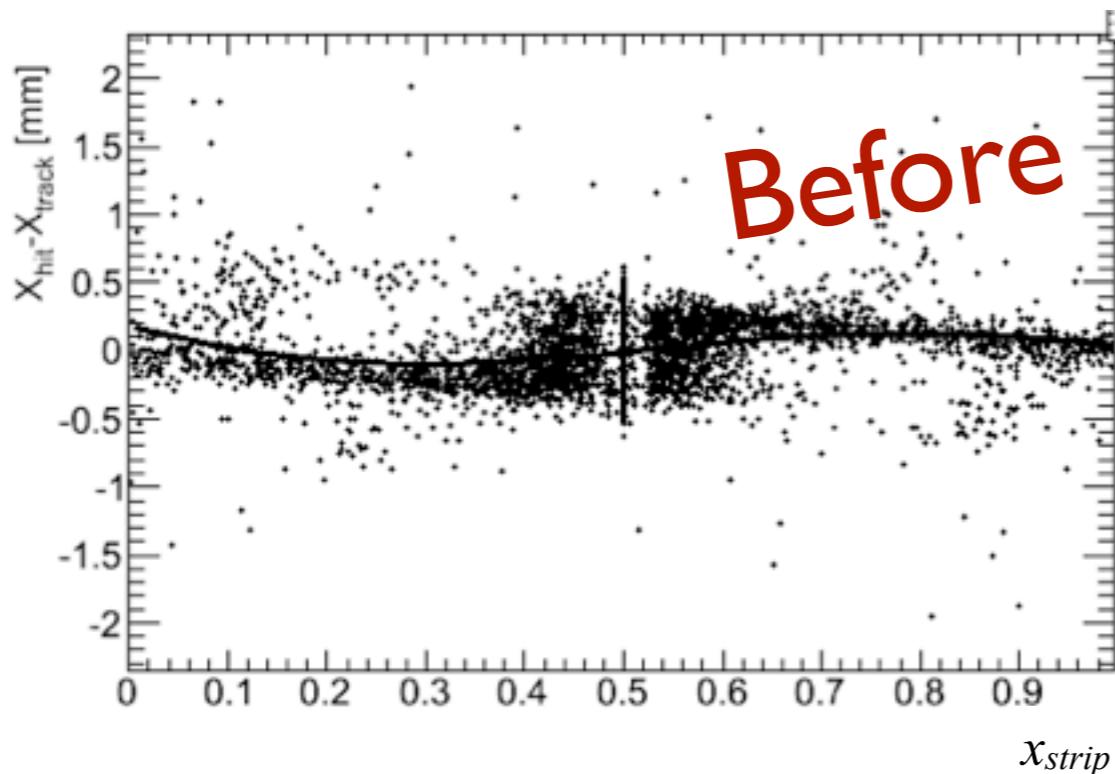
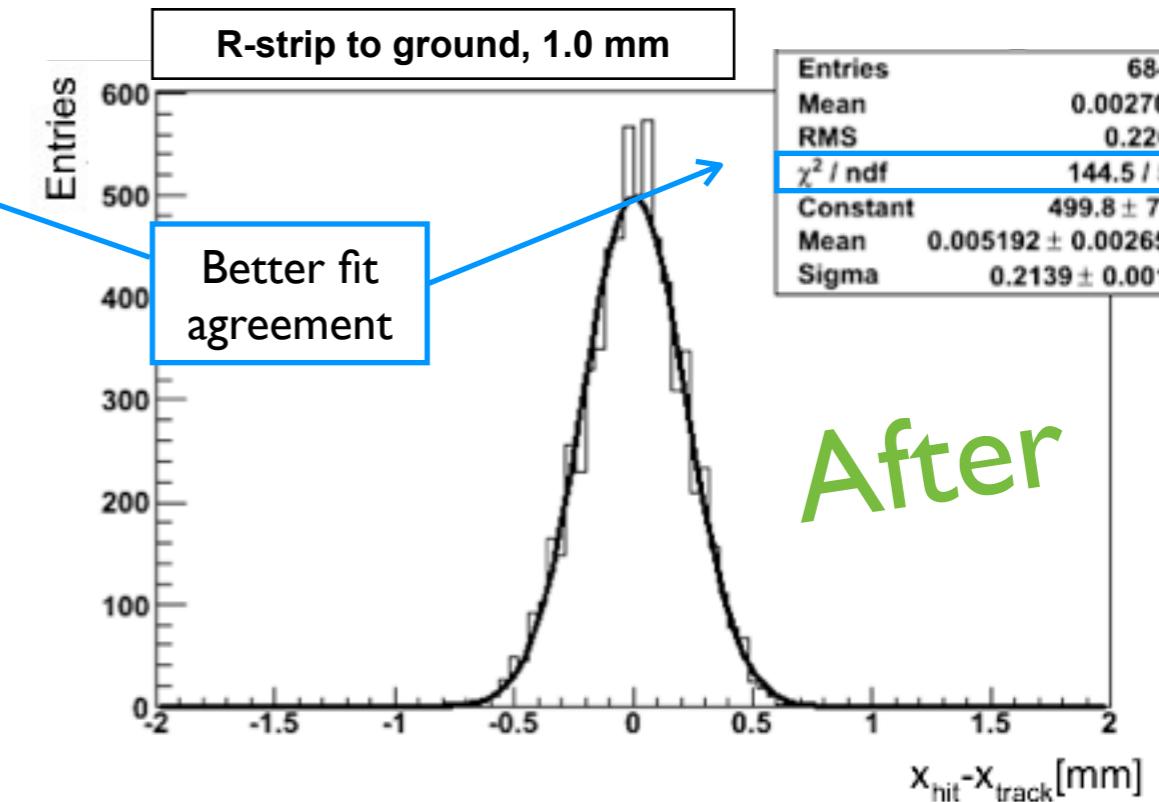
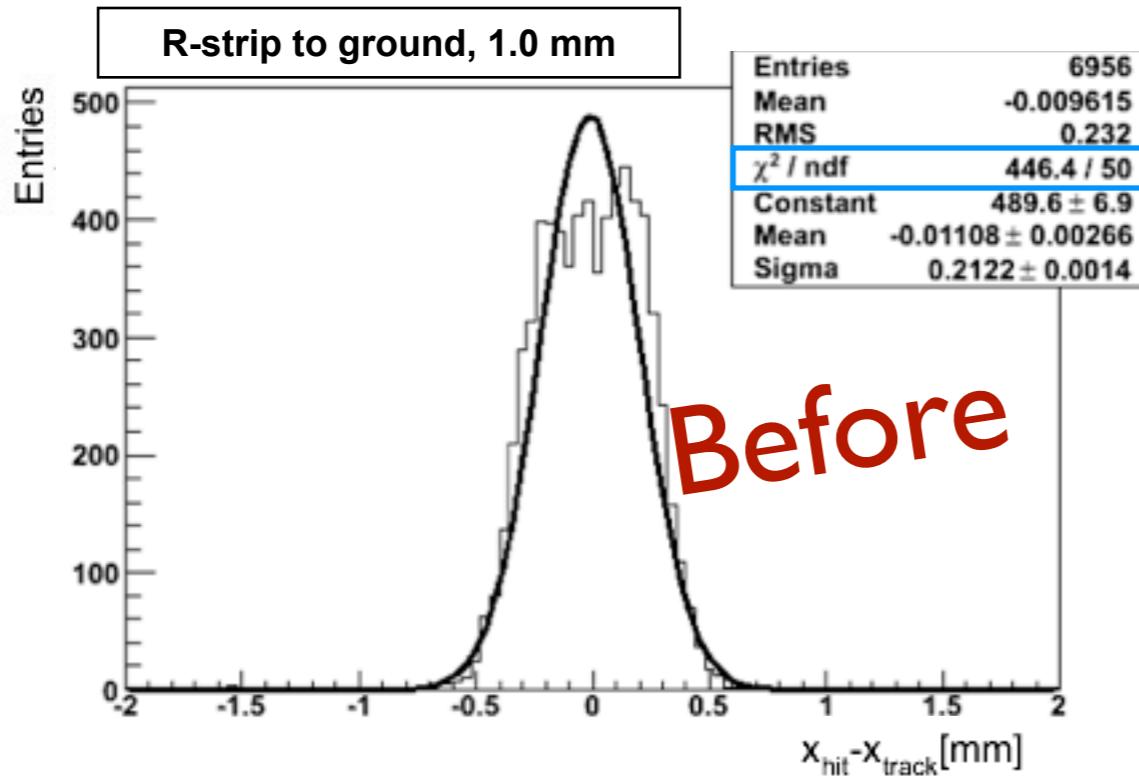


Using the log weighted technique with $w_0 = 6$





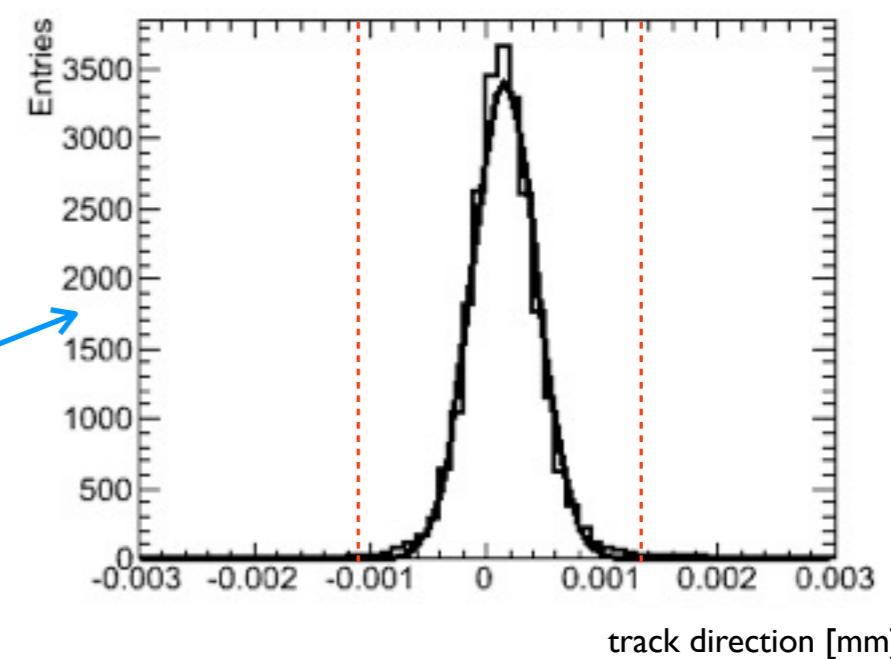
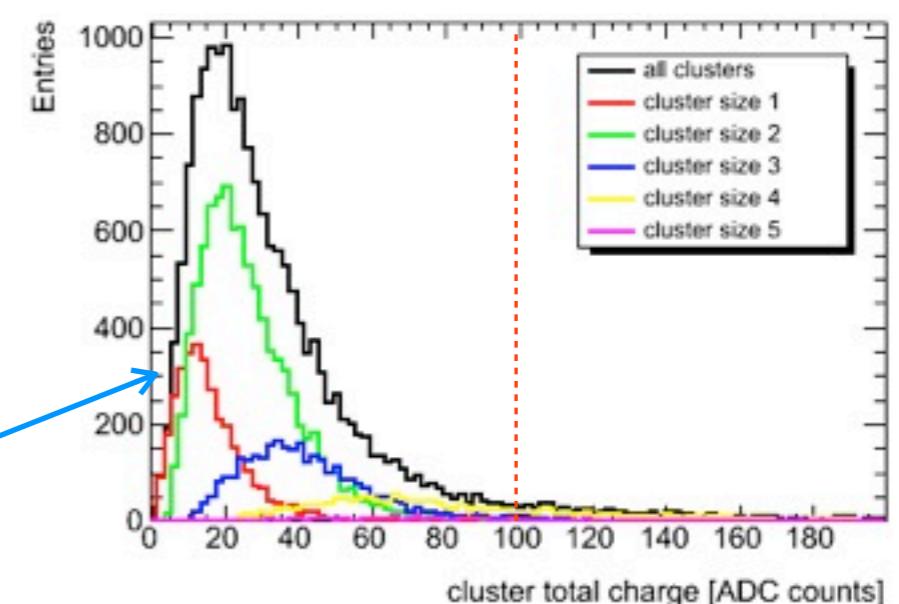
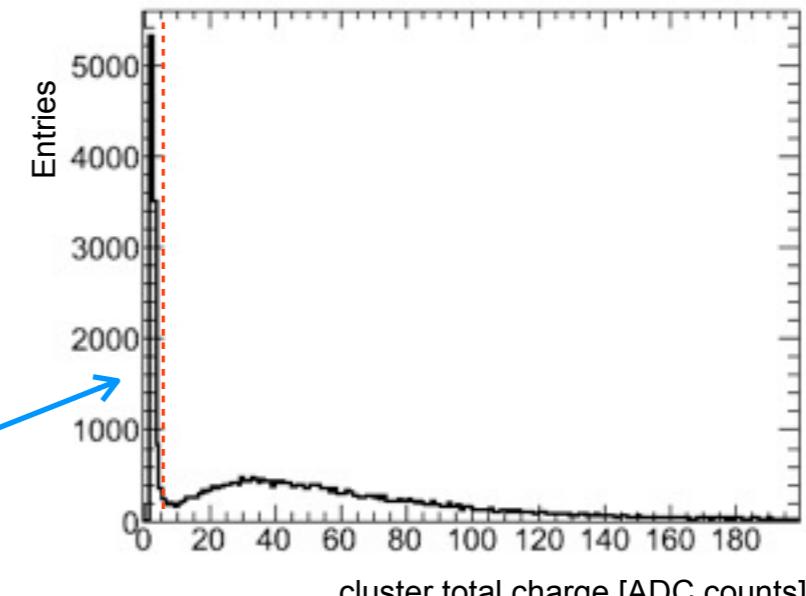
Impact point calculation : A different approach (2)





Track selection

- 1) The charge must be bigger than $3.5 \sigma_{\text{pedestal}}$.
- 2) The detectors were aligned using a minuit minimization, with the extreme detectors as reference.
- 3) Selection of tracks :
 - For the telescope :
 - The Event must be in all telescope detectors.
 - The total charge of the cluster for the telescope should be inside de landau shape.
 - The cluster size for the telescope events must not be $> 3\text{mm}$.
 - If multitrack, several clusters were in one detector the bisecting line criteria was used to choose.
- 4) The track direction must be within 3σ of the mean beam direction on x and y





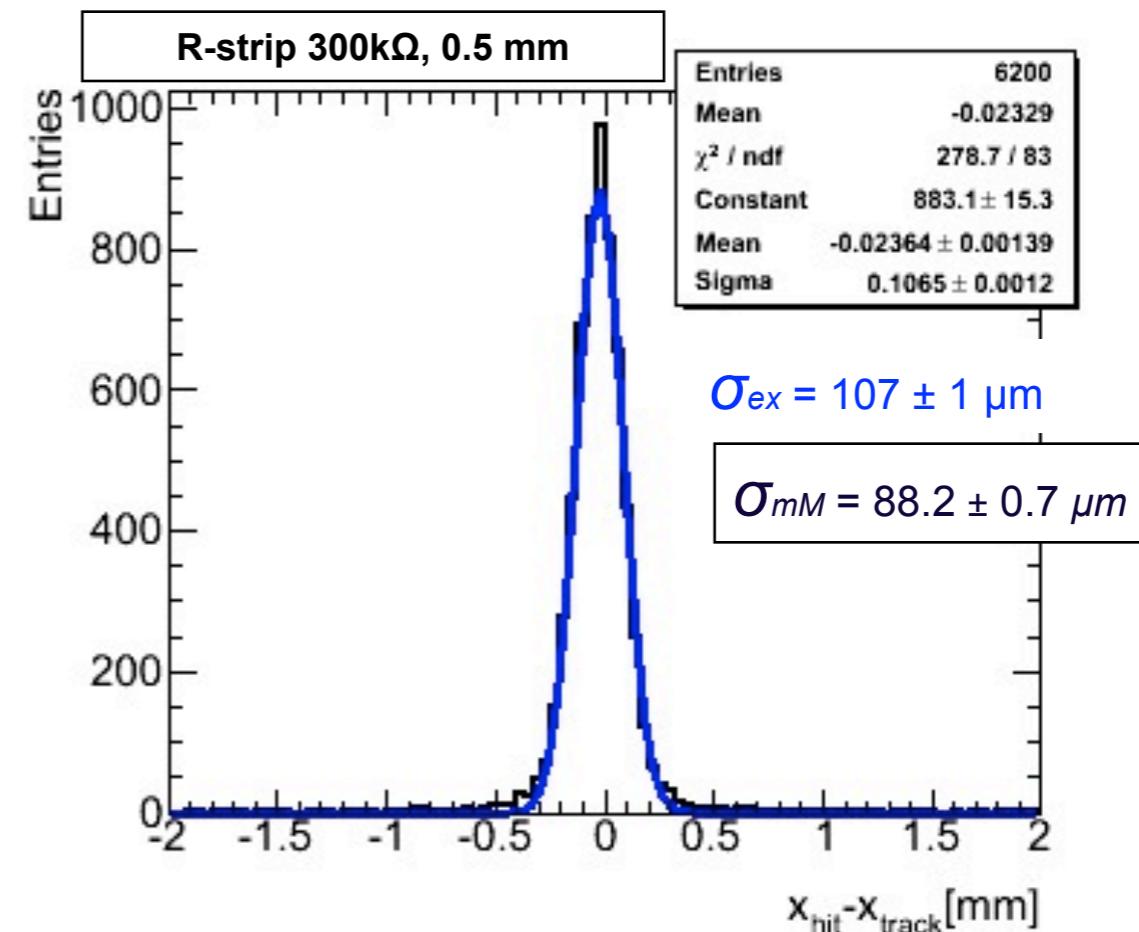
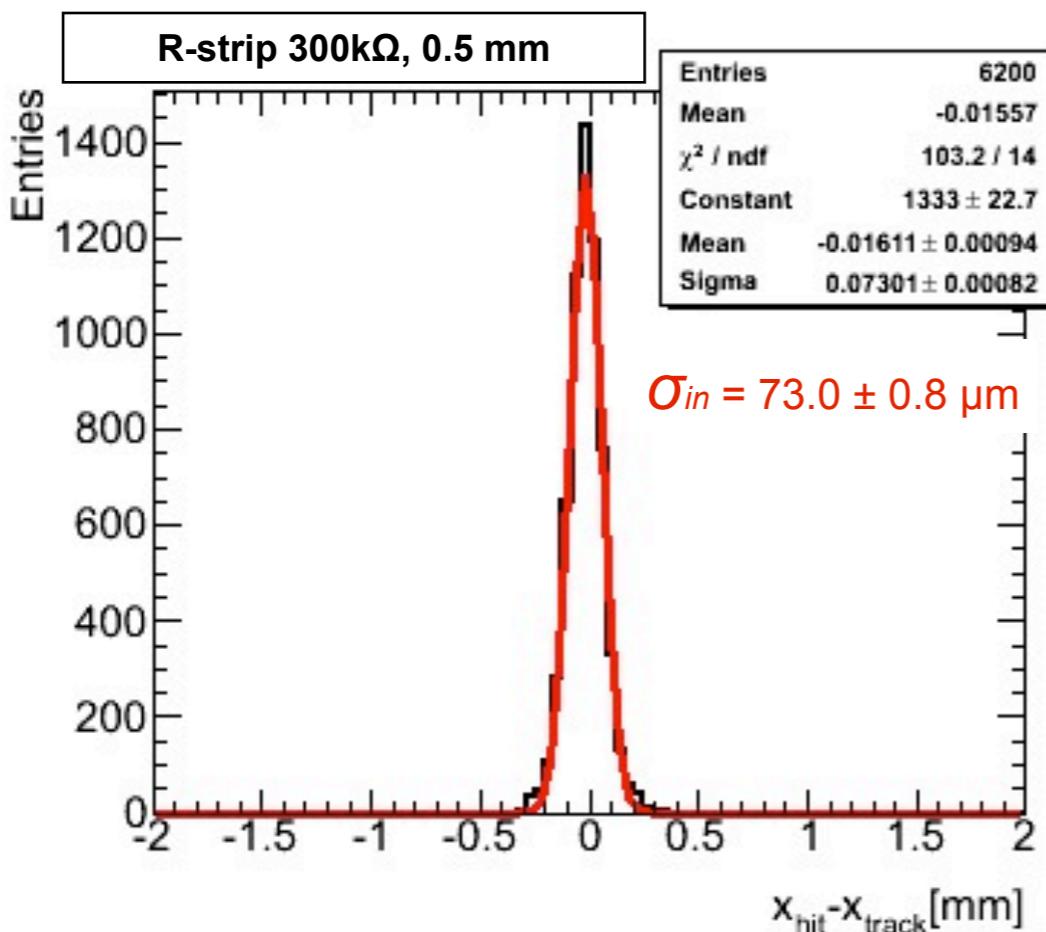
Spatial Resolution

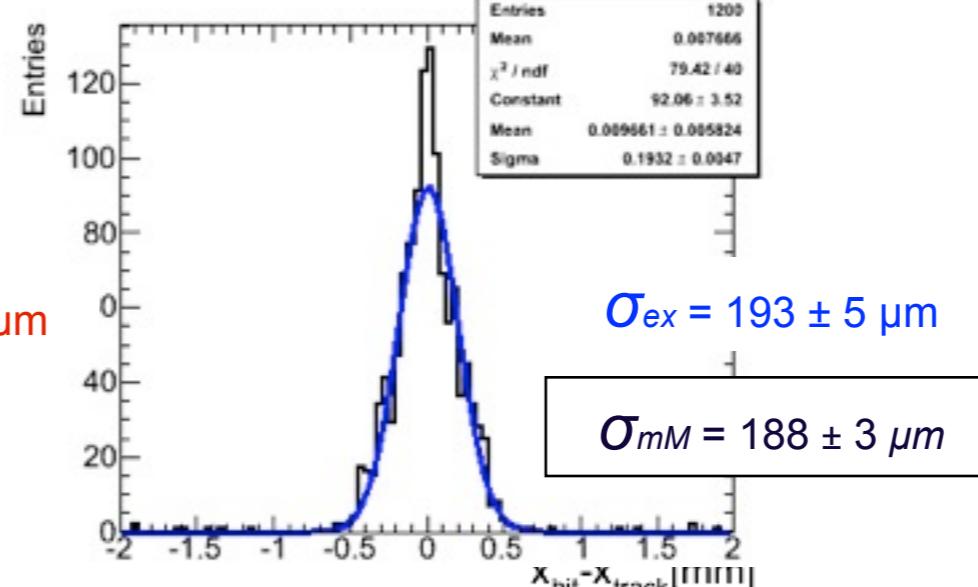
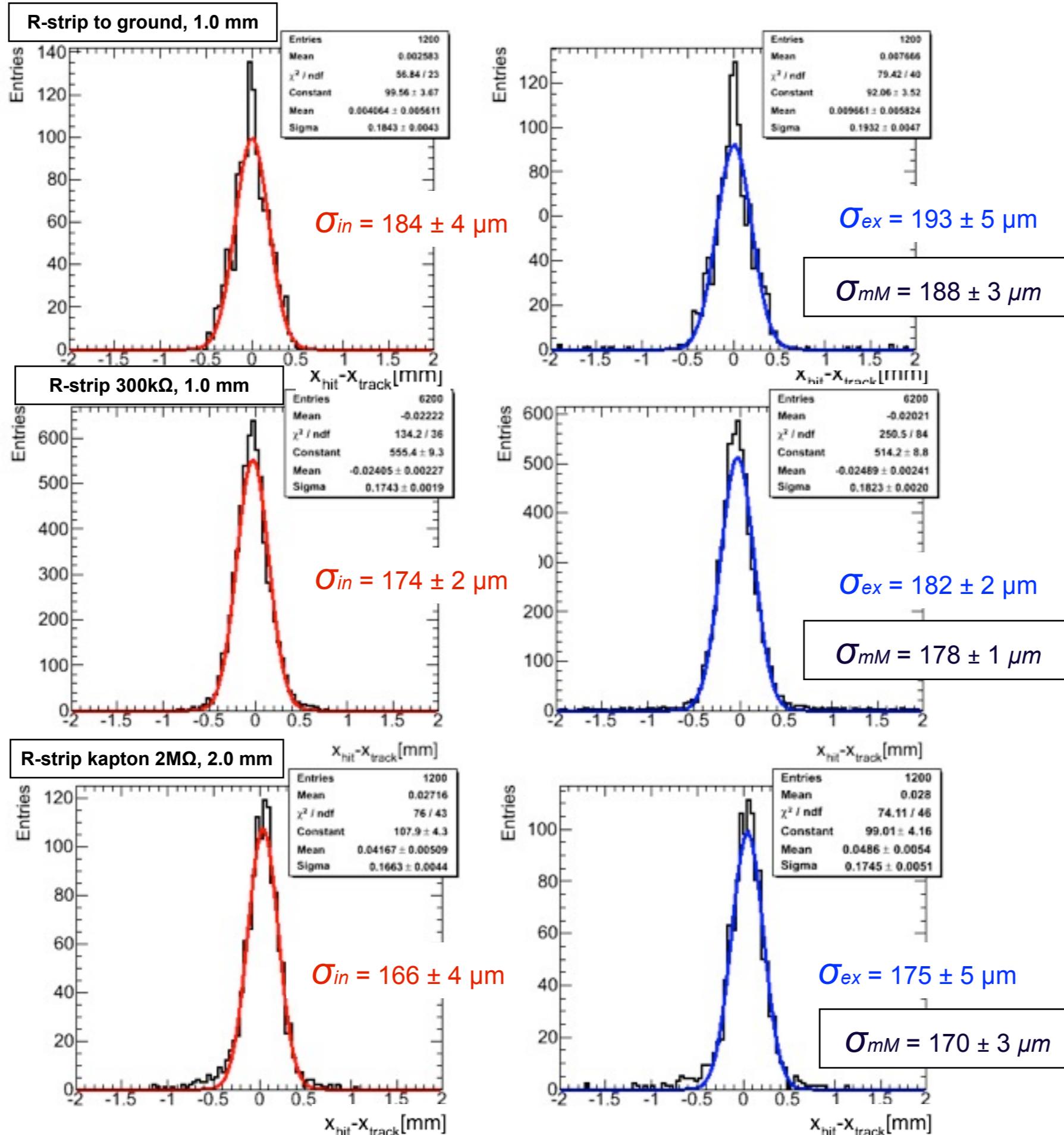
- σ_{in} and σ_{ex} : are obtained by computing the track resolution by including, respectively, excluding the chamber of interest from the track fit.
- σ_{mM} : is a geometric-mean recipe between the two distributions, proposed by R. K. Carnegie.*

$$\sigma_{mM} = \sqrt{\sigma_{in}\sigma_{ex}}$$

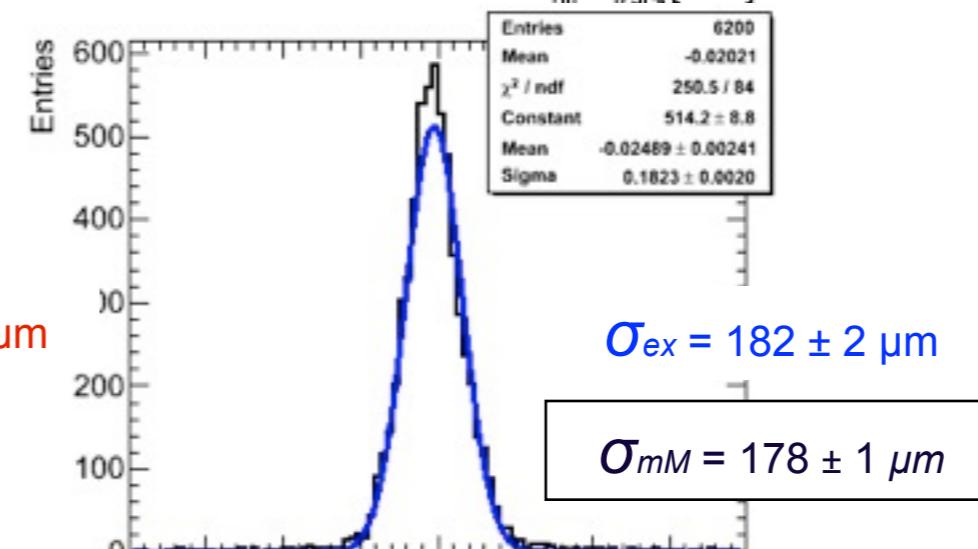
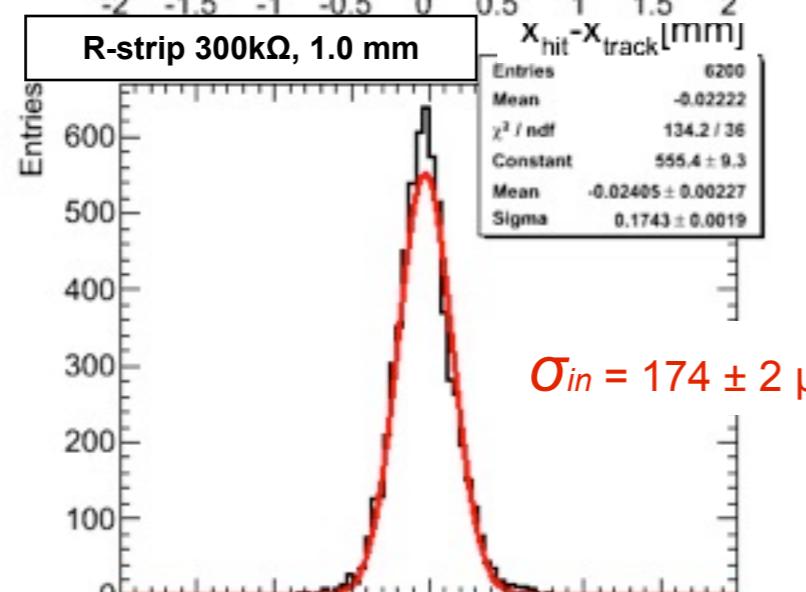
Non resistive telescope :

pitch	σ_{mM}
0.5 mm	$90 \pm 1 \mu\text{m}$
0.5 mm	$72 \pm 2 \mu\text{m}$
0.5 mm	$78 \pm 1 \mu\text{m}$
.25 mm	$59.5 \pm 0.8 \mu\text{m}$
.25 mm	$60.6 \pm 0.7 \mu\text{m}$

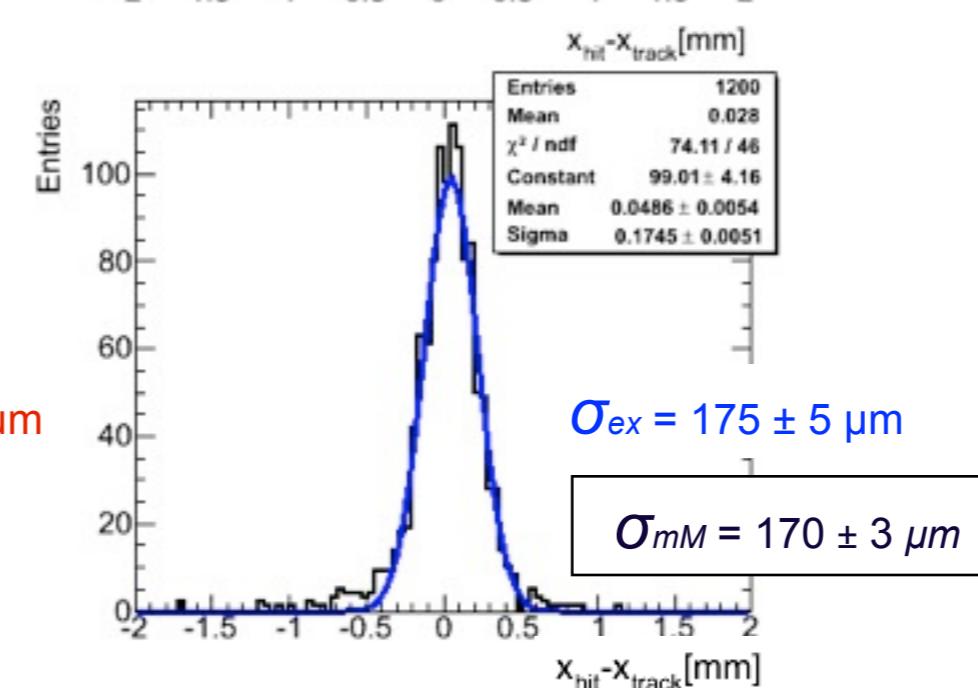
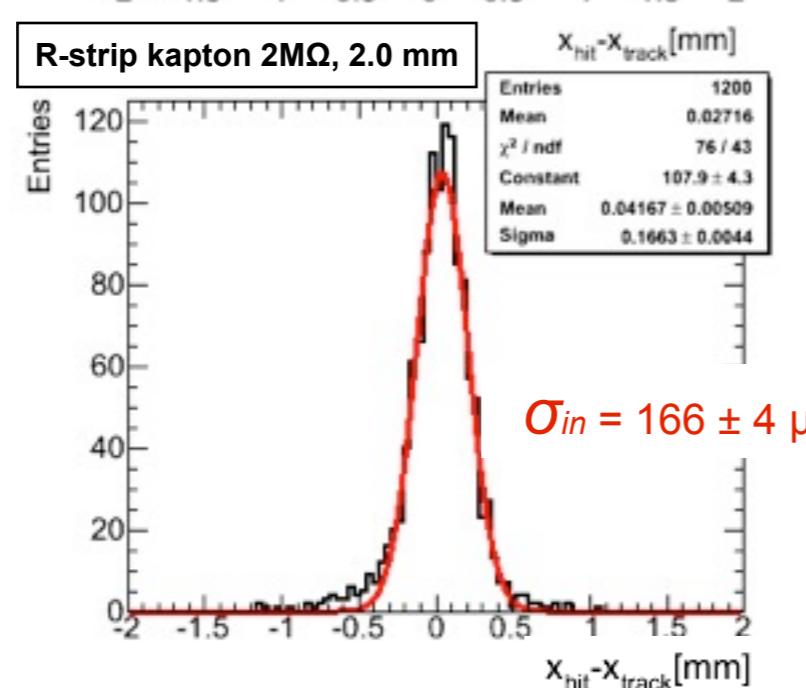




$$\sigma_{mM} = 188 \pm 3 \mu\text{m}$$



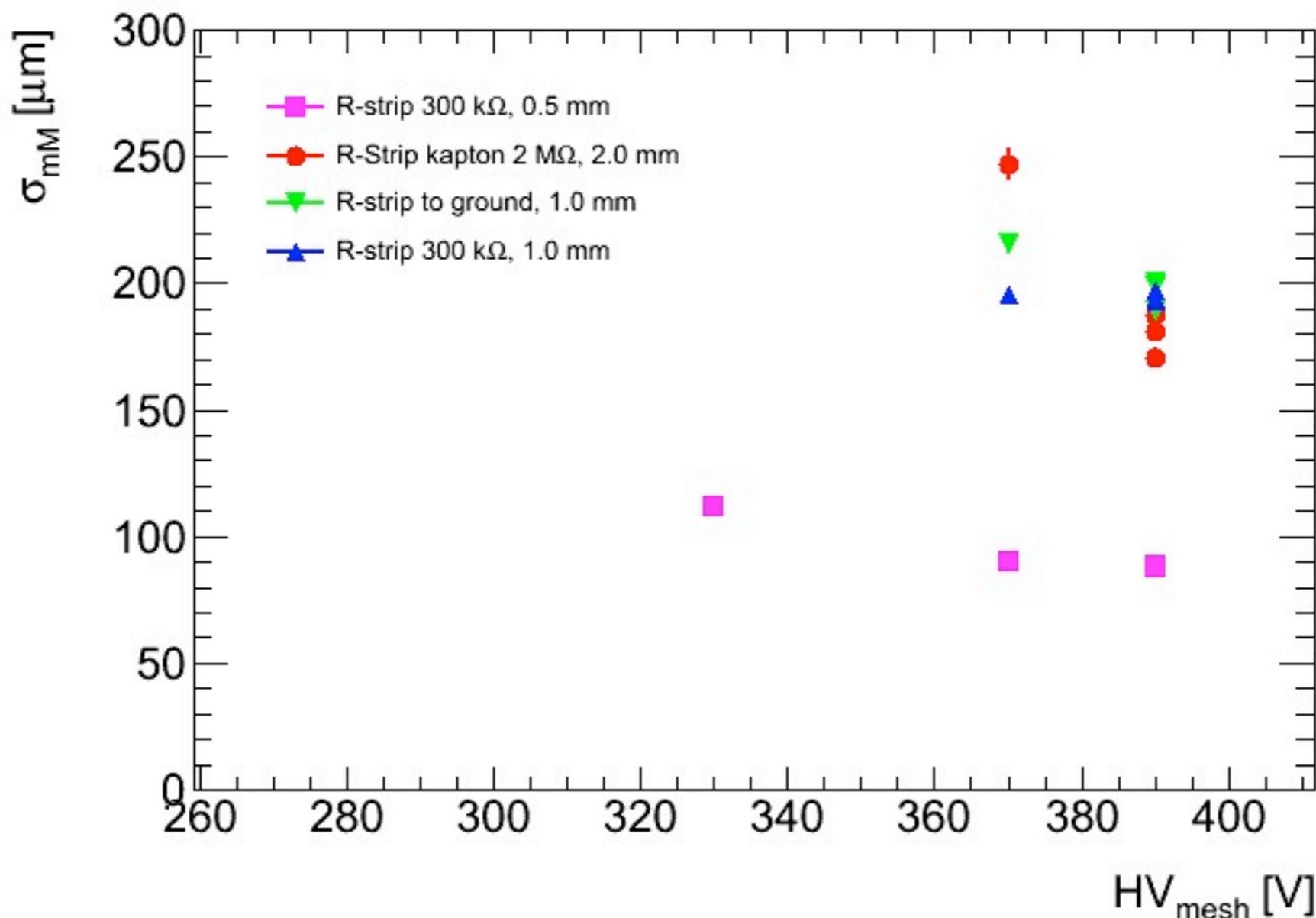
$$\sigma_{mM} = 178 \pm 1 \mu\text{m}$$



$$\sigma_{mM} = 170 \pm 3 \mu\text{m}$$

Spatial Resolution

- We do a scan in HV and we get :



- So for smaller strip pitch and higher HV_{mesh} better is the resolution.



Efficiency

- $\Delta Y_{\text{acceptance}}$: is the size of the acceptance window around the expected point.
- For each $\Delta Y_{\text{acceptance}}$ we calculated the efficiency using * :

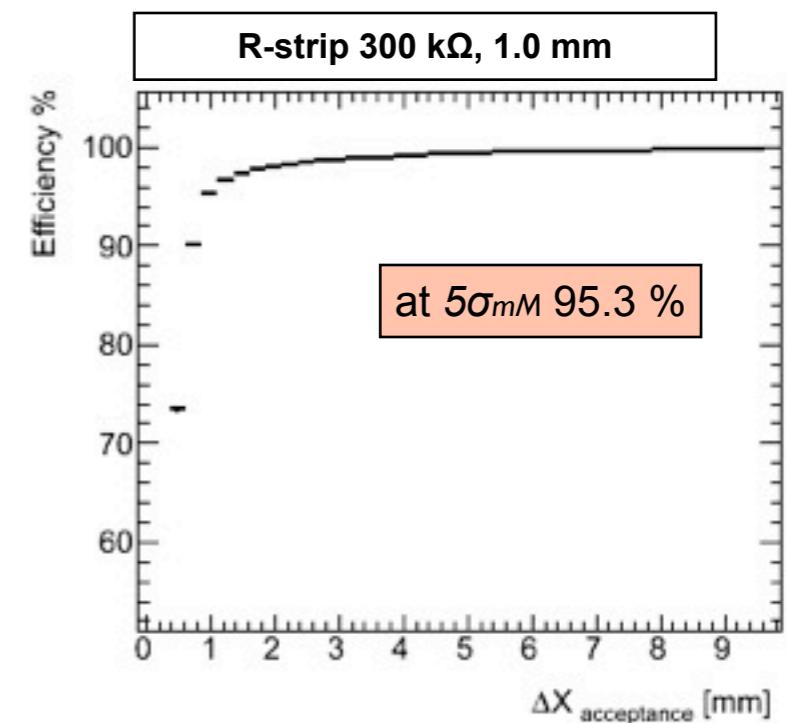
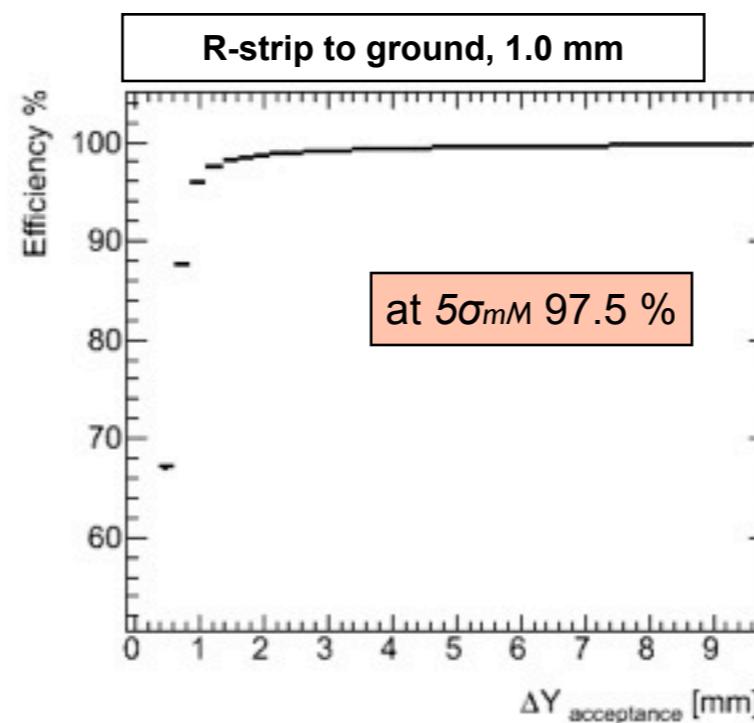
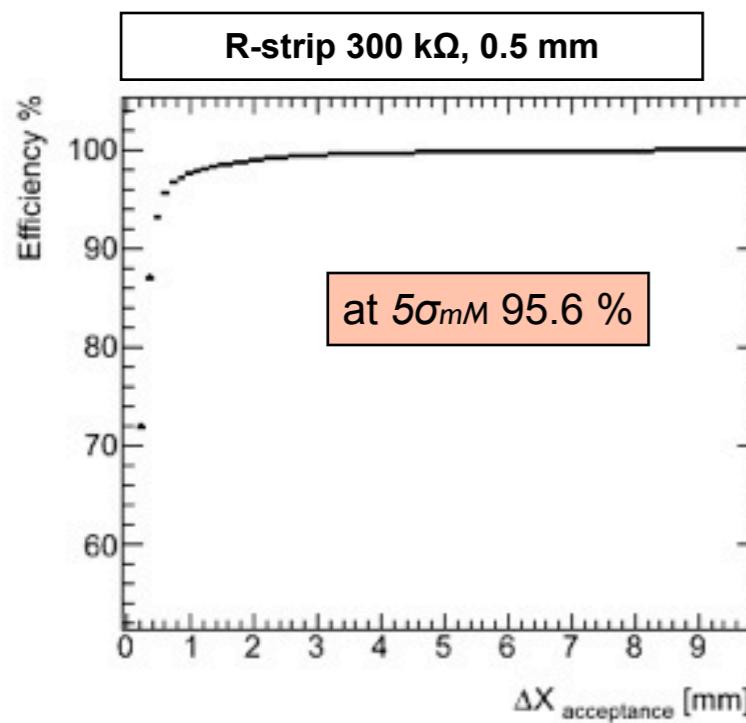
$$\epsilon = \frac{n_+}{n}$$

$$\delta\epsilon = \sqrt{\frac{n_+ n_-}{n^3}} = \sqrt{\frac{\epsilon(1-\epsilon)}{n}}$$

n number of telescope events.

n_+ number of events on the tested detector.

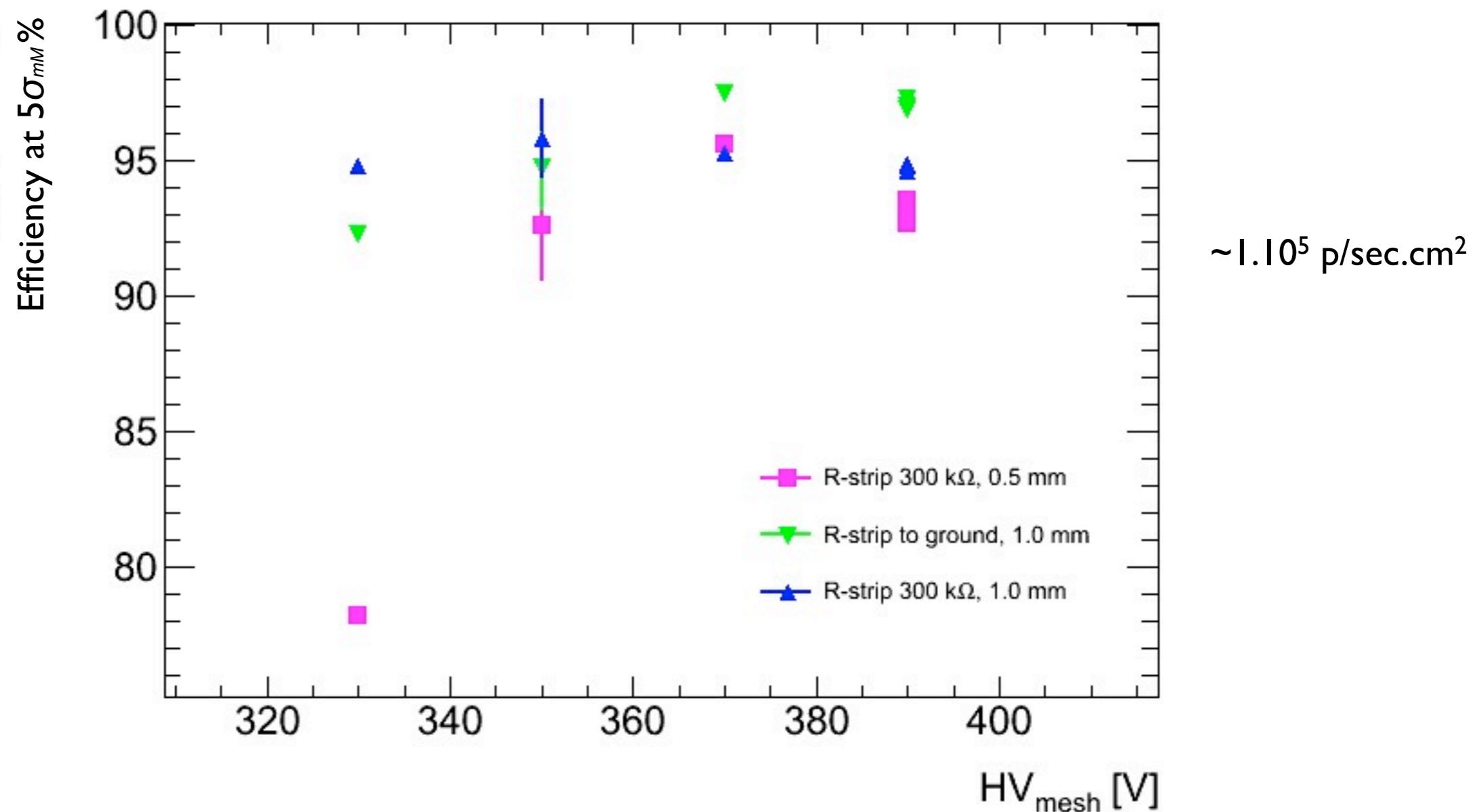
n_- number of missing events on the tested detector.



Efficiency

Efficiencies using a cut
in $\Delta Y_{\text{acceptance}}$ of $5\sigma_{mM}$.

- Efficiencies using a cut in $\Delta Y_{\text{acceptance}}$ of $5\sigma_{mM}$.
- We do a scan in HV and we get :

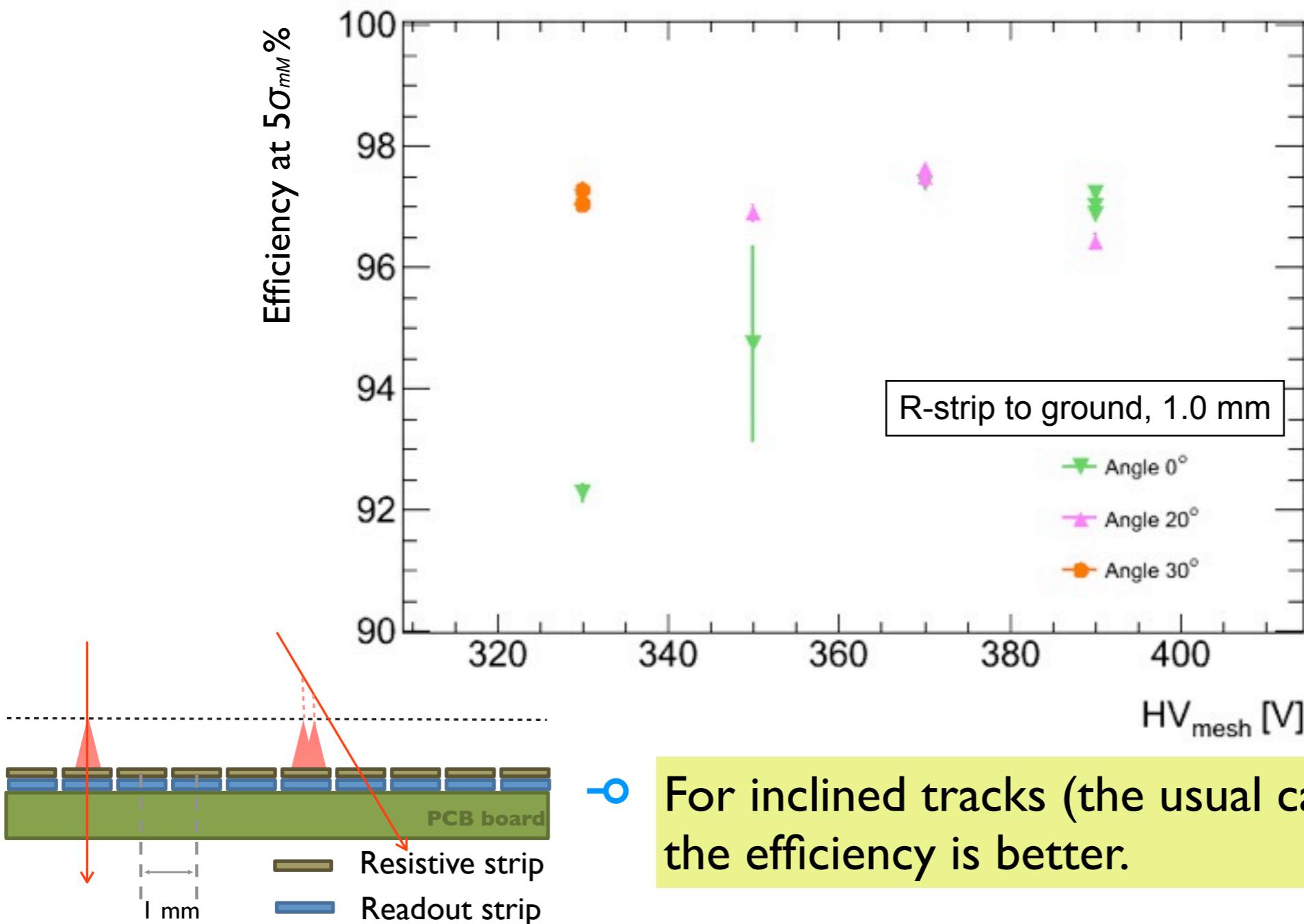


- So the best efficiency is for the R-strip to ground.

Efficiency vs Angle

Efficiencies using a cut
in $\Delta Y_{\text{acceptance}}$ of $5\sigma_{mM}$.

- Efficiencies using a cut in $\Delta Y_{\text{acceptance}}$ of $5\sigma_{mM}$.
- We do a scan in HV and at 3 different incidence angle and we get :



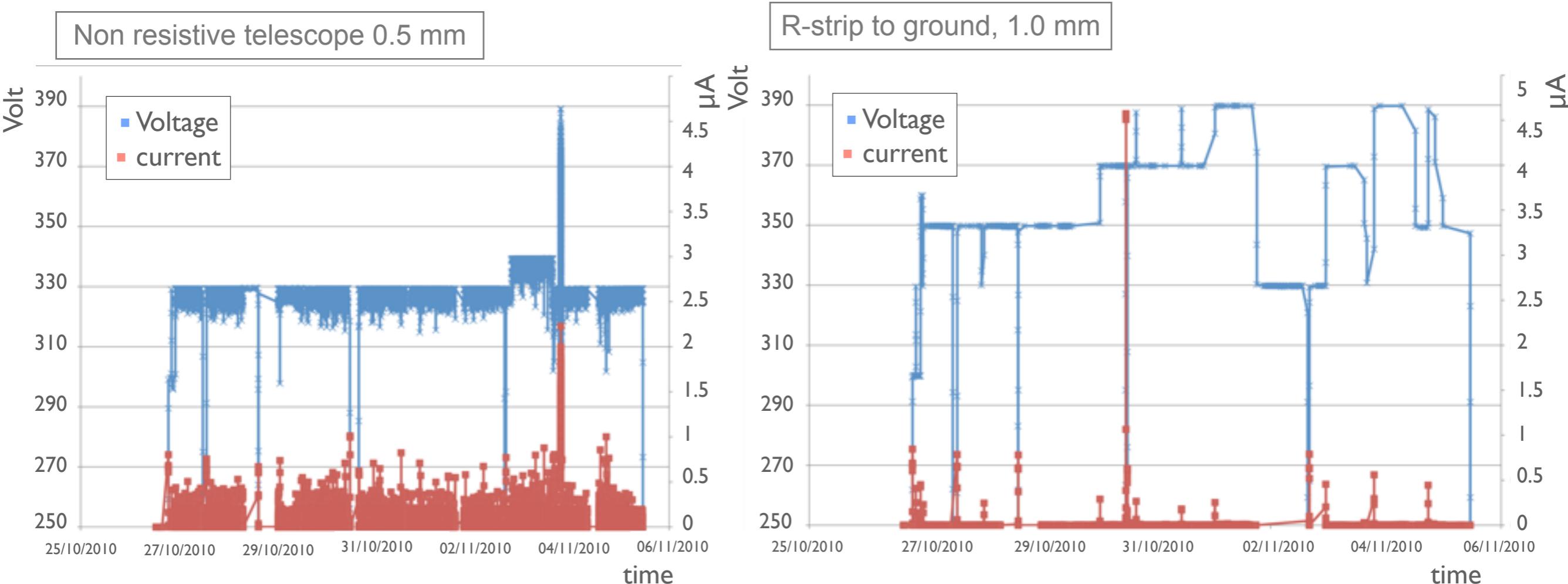
- For inclined tracks (the usual case in ATLAS) the efficiency is better.

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“Spark”

A spark is a electric arc between the mesh and the anode at ground potential, be it resistive strips or metallic readout strips.

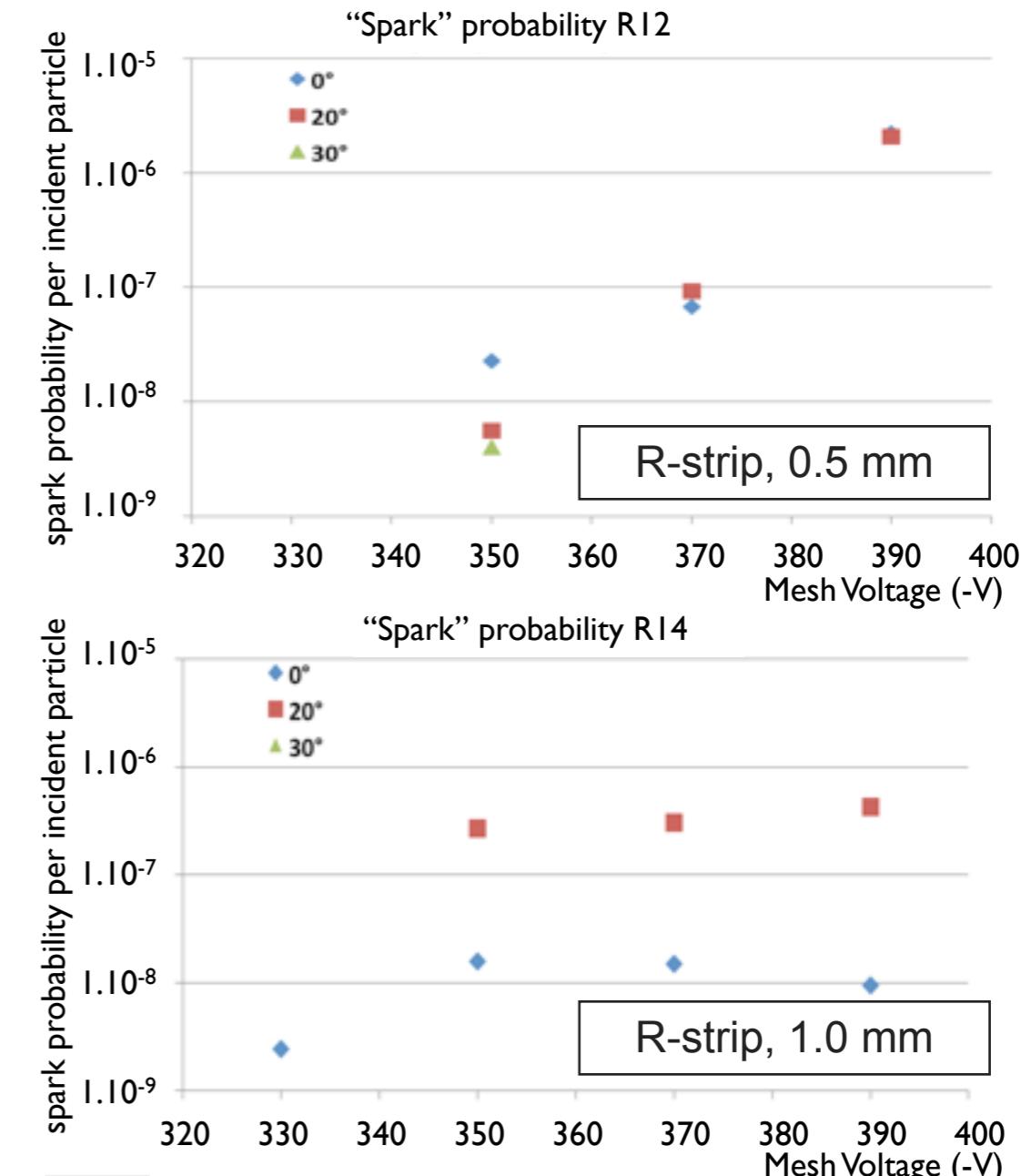
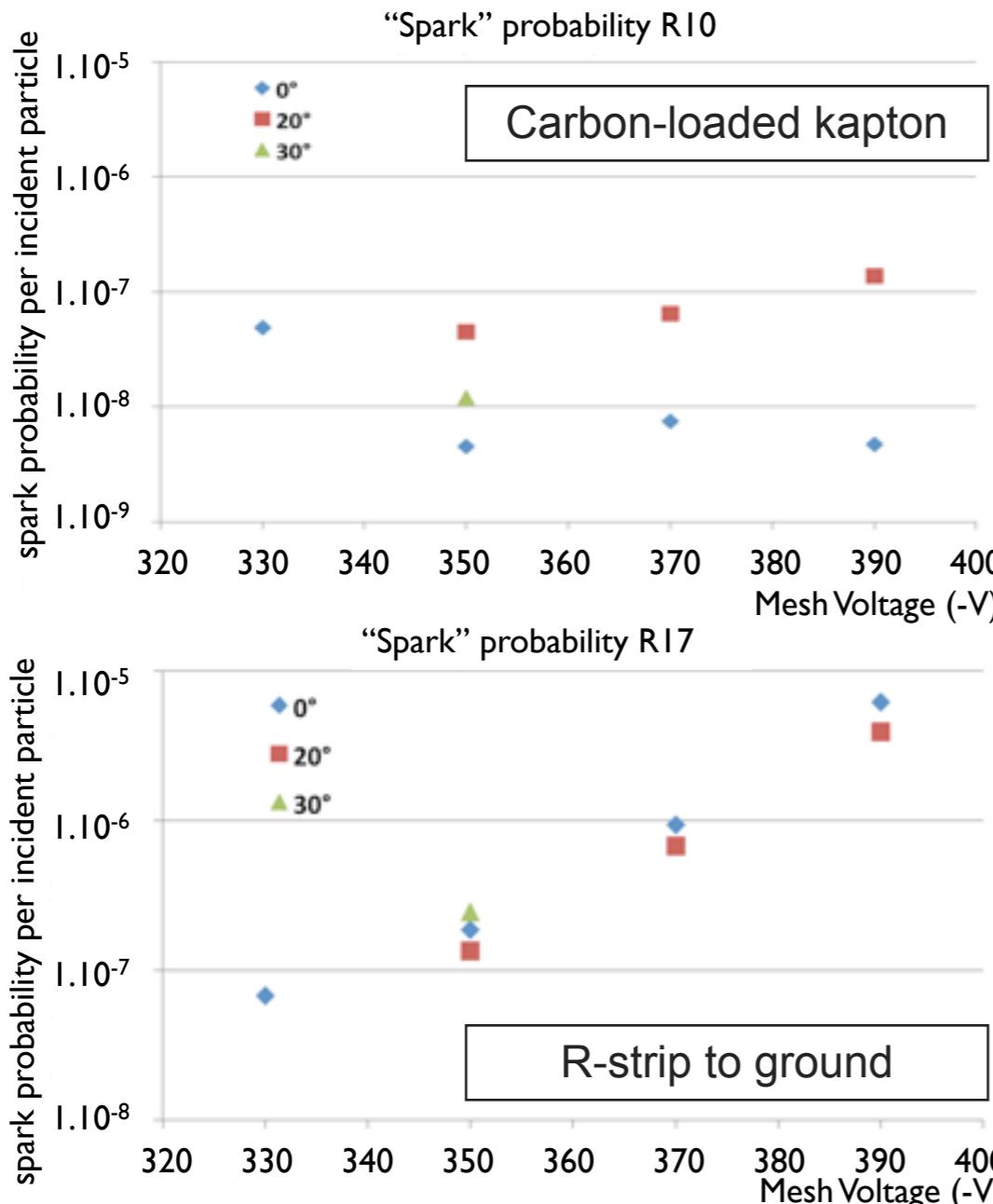


- The non resistive chamber suffered from HV breakdowns while the resistive chambers operate stably.

“Spark” rate

- Sparks measured with a capacitor (50 pF) on the mesh
- Signal too small → pre-amplification (I42B)

- Threshold to discriminate: 1 Volt (250 mV in)
- Equivalent charge: 12.5 pC → $8 \cdot 10^7 e^-$ (at least 200 pC → $1.25 \cdot 10^9 e^-$ for standard detectors)



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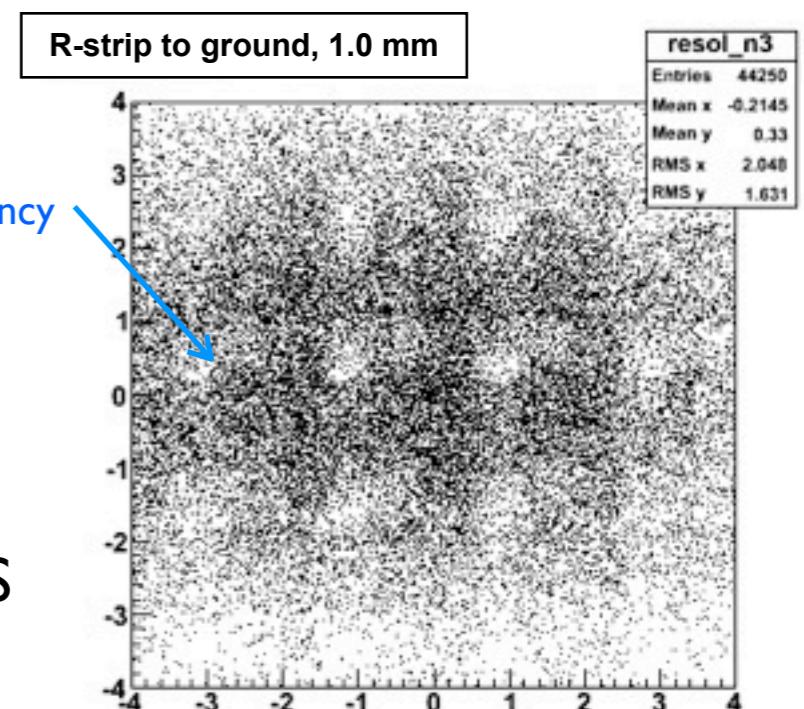
Data Analysis : ✓

- Clusters and track reconstruction. ✓
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→ Conclusion.

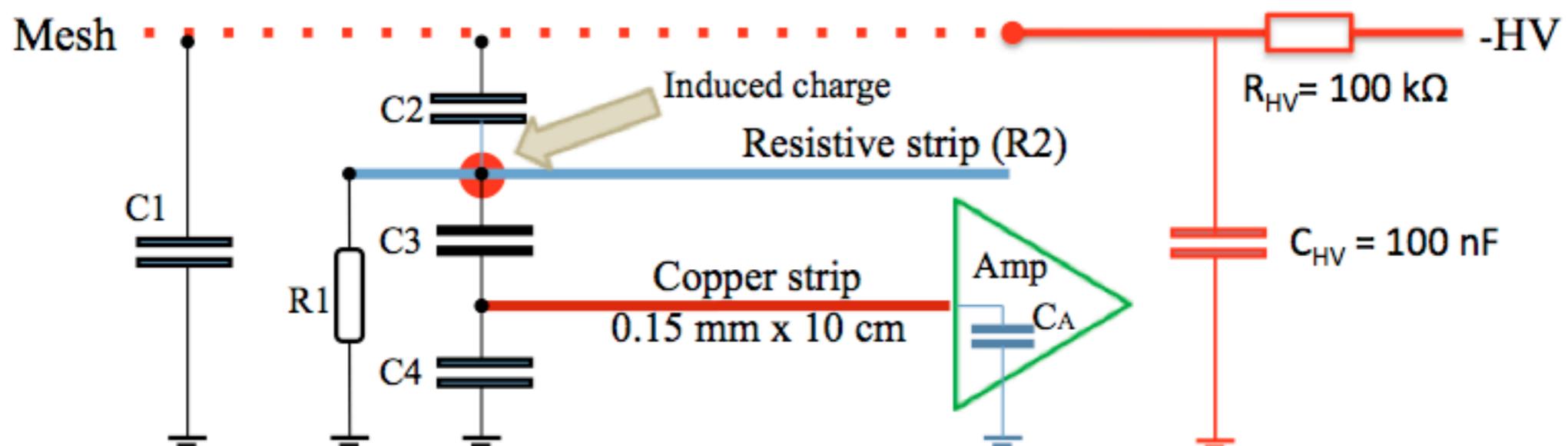
Conclusion

- Three different resistive technologies were tested, we don't see any degradation on the efficiency or the resolution w.r.t the standard micromegas.
- The resistive coating is able to contain or even suppress the spark signal.
- The detector “R-strip to ground” is the one with the best efficiency results $\sim 98\%$ at $5\sigma_{mM}$, and the chosen one for ATLAS upgrade.
- In order to improve resolution we need to optimize:
 - 1) the strip pitch \rightarrow electron diffusion on the drift region gas mixture \rightarrow electric field;
 - 2) charge spreading along the resistive strips \rightarrow readout lecture on 2 or 3 direction;
 - 3) the impact angle of the track \rightarrow integration of Micromegas in ATLAS;
 - 4) a impact point reconstruction “optimized” with small or none bias;
- Resistive micromegas are currently under other studies like aging (J. Galan poster), larger surface construction (J.Wotschack presentation), etc.



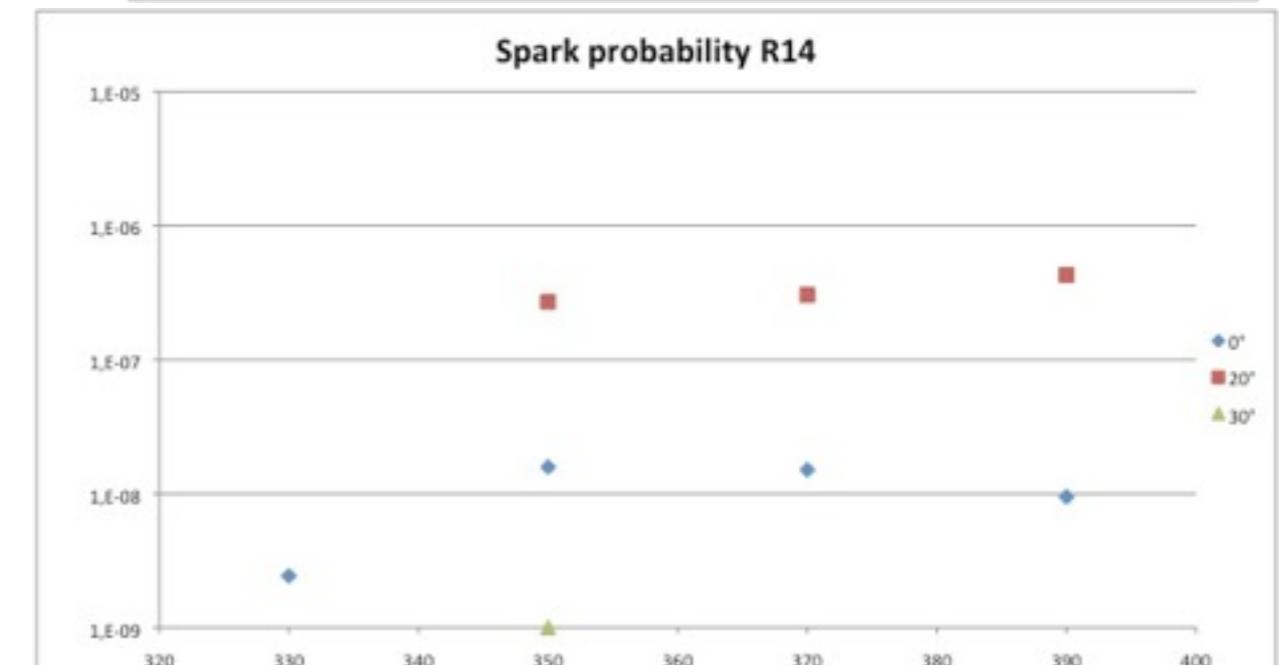
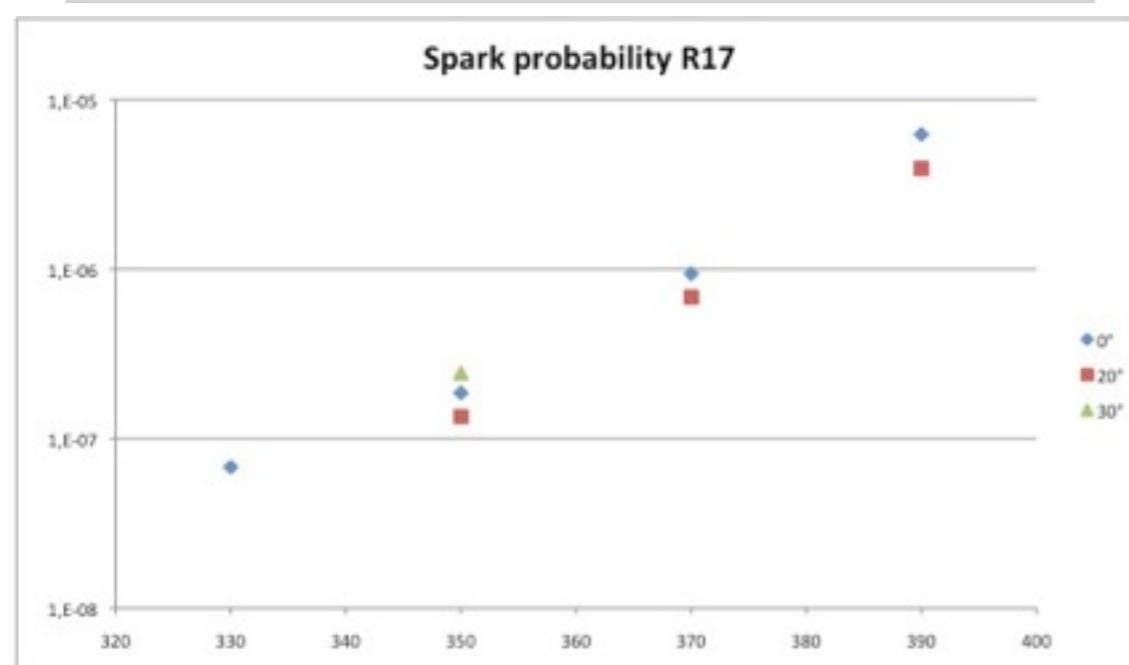
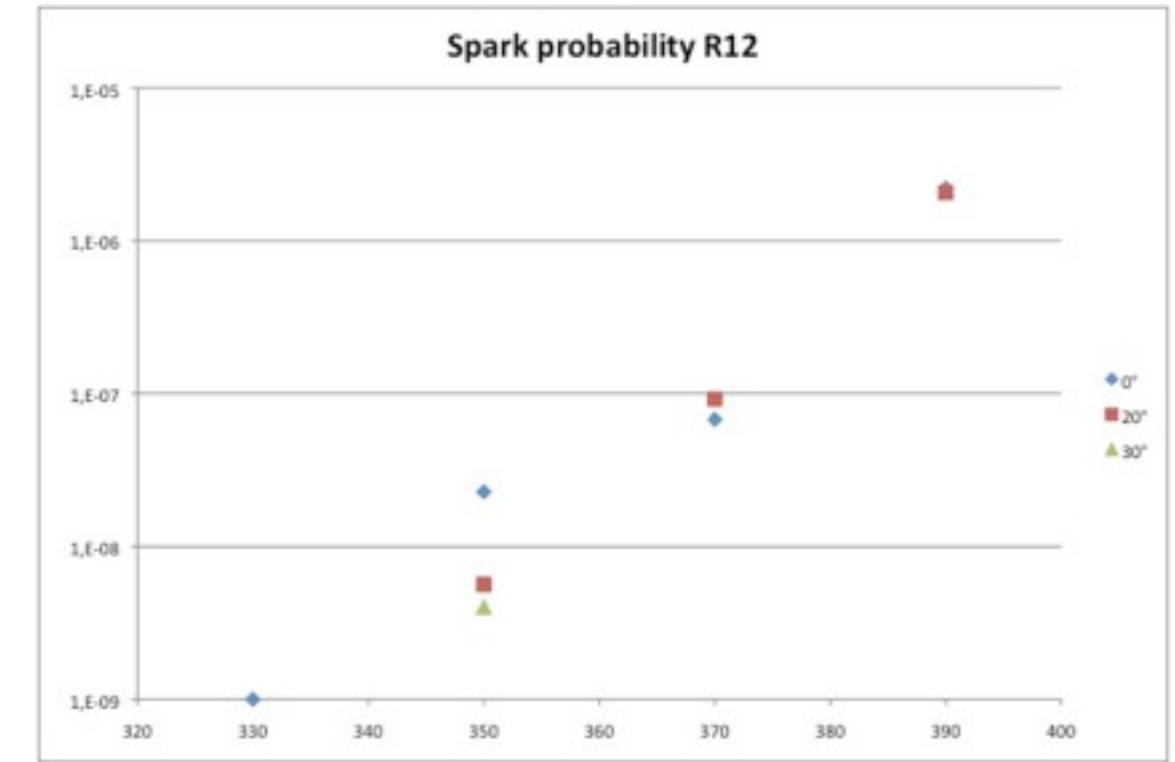
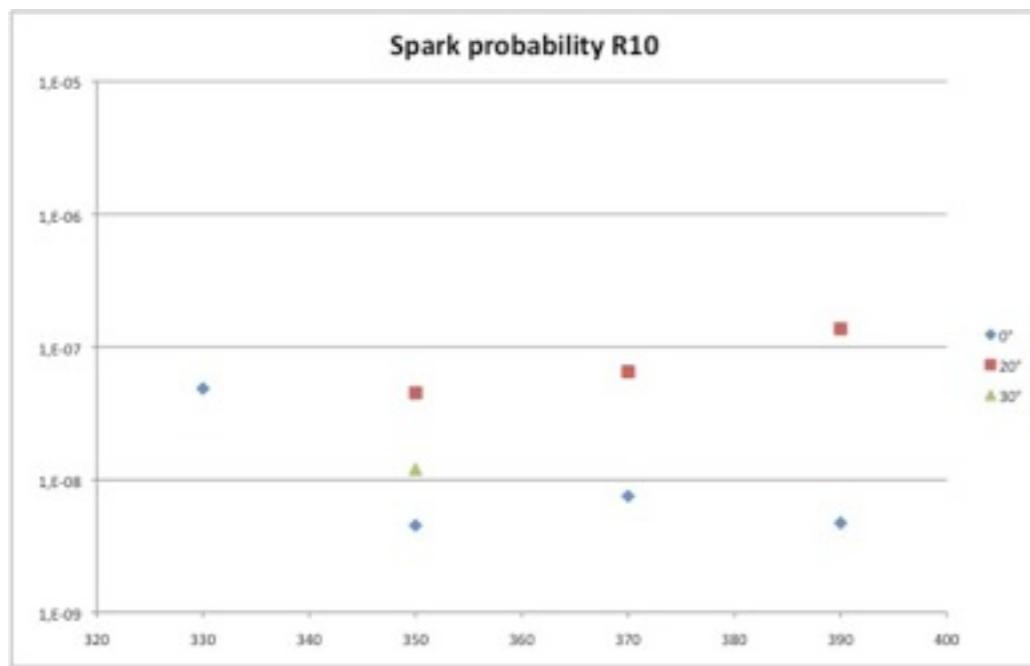
Back-up

Sketch of the equivalent electric circuit of the chamber with resistive strips connected to the ground



“Spark” rate

Definition of spark: A spark is a electric arc between the mesh and the anode at ground potential, be it resistive strips or metallic readout strips.



◆ R14 ■ R10 ▲ R12 × R17

Gain curves in Ar+2%C4H10+3%CF4

