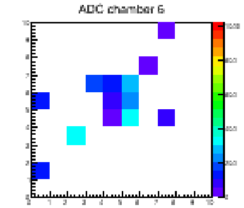
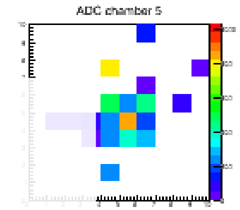
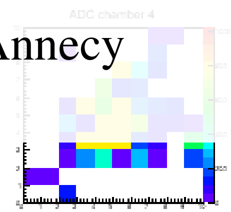
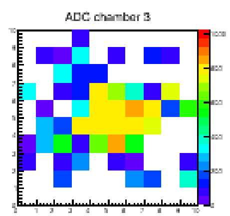




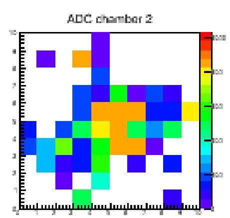
Micromegas status report

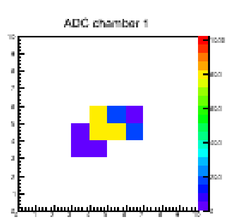
M. Chefdeville, CNRS/IN2P3/LAPP, Annecy





CALICE Collaboration meeting
September 9-11th 2015, Munich





Introduction

- Since 2012 and after the construction and test of 4 large-area prototypes for the SDHCAL, we started an R&D on resistive Micromegas to suppress sparking and remove from the ASU-PCB the passive components (2 diodes/channel) used for front-end ASIC protection.

- In 2013, spark suppression was demonstrated (as expected) thanks to a local charging-up of the resistive elements that quenches the spark at an early stage of development. This charge-up effect induces a current-dependence of the gas gain (Ohmic voltage drop across the amplification gap): gain drops at high rate and in principle also at low rate if the dE/dx is high enough.

- Since 2014, we started a systematic study of resistive prototypes with RC values varying over several orders of magnitude: response linearity & sparking under high rate and high dE/dx.

- First batch of 3 small resistive prototypes produced and beam-tested in 2014.
  Second batch of 3 produced and tested in 2015 during RD51 testbeam in July.

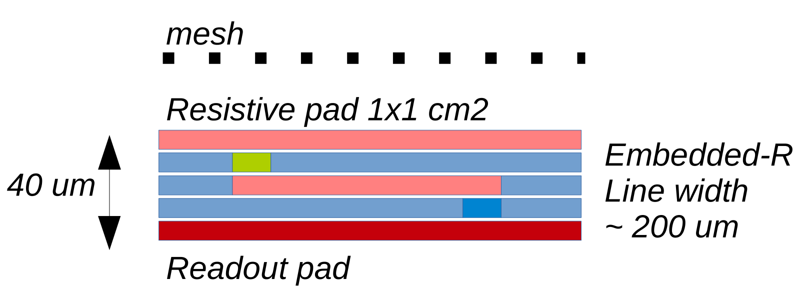
- This work is primarily intended for a LC PF-calorimeter. It is done with colleagues from Demokritos and Saclay (T. Geralis, M. Titov) interested in the CMS/HG-CAL for the backing part.

The resistive prototypes

- Different geometrical configurations can do the job, however, we identified the “buried resistance” as the most promising one because charge is evacuated to ground vertically and not horizontally, which is way faster in case of an anode plane of large area.

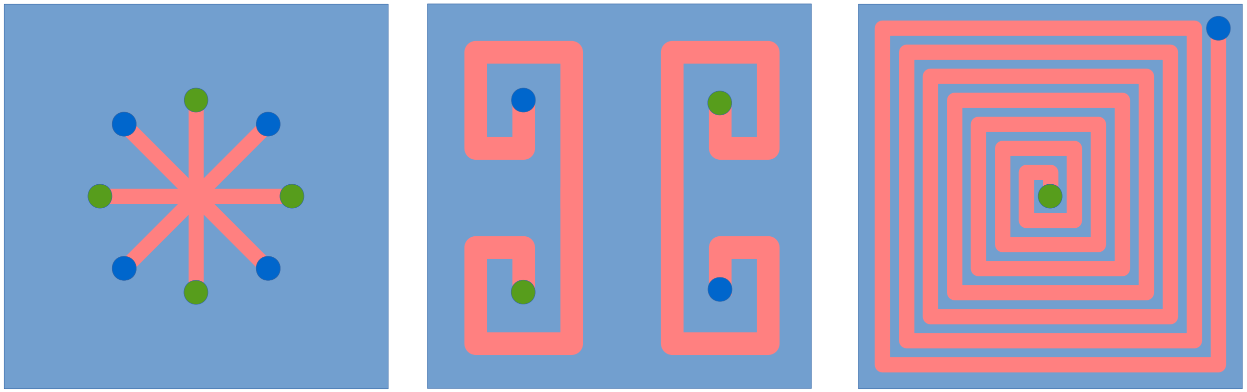
- Also, it gives more freedom in changing the RC compared to parallel-layer structure (like RPCs) because R can be changed independently of C. Reminder, in an RPC:
RC = (rho.d/S).(epsilon.S/d)= rho.epsilon   (d: film thickness, S: avalanche area on film)

- We came up with 3 embedded resistor patterns to change the resistance over 2-3 orders of magnitude. The resistivity of the paste used (for serigraphy) gives another degree of freedom. We tried 100 kOhm/sq. (in 2014) and 1 kOhm/sq. (in 2015).



Green and blue dots are contacts between layers

'Star' pattern | *'Mirror' pattern* | *'Snake' pattern*



R = 400 kOhm @ 100 kOhm/sq | *R = 4 MOhm* | *R = 40 MOhm*

Rate capability

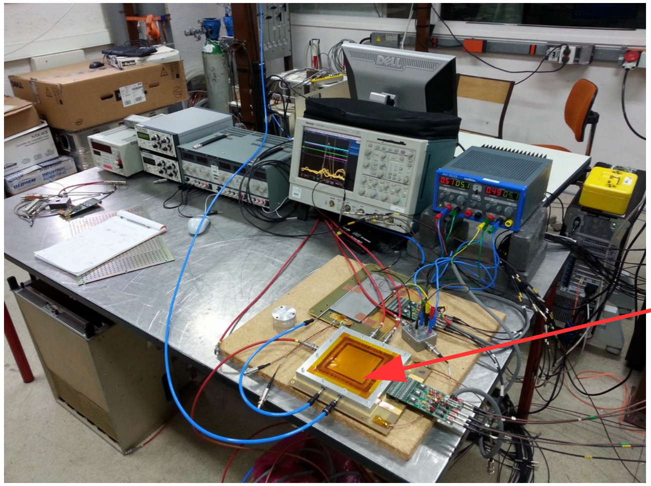
- The 'classic' rate scan performed with an 8 keV X-ray gun: measure the mesh current as a function of X-ray conversion rate. To a good approximation:

  $I(f) = Q_0.f / (1 + B.R.Q_0.f)$

  B is the slope of the gain curve
  R is the resistance
  Q_0 is the total event charge (N_p.G.e)

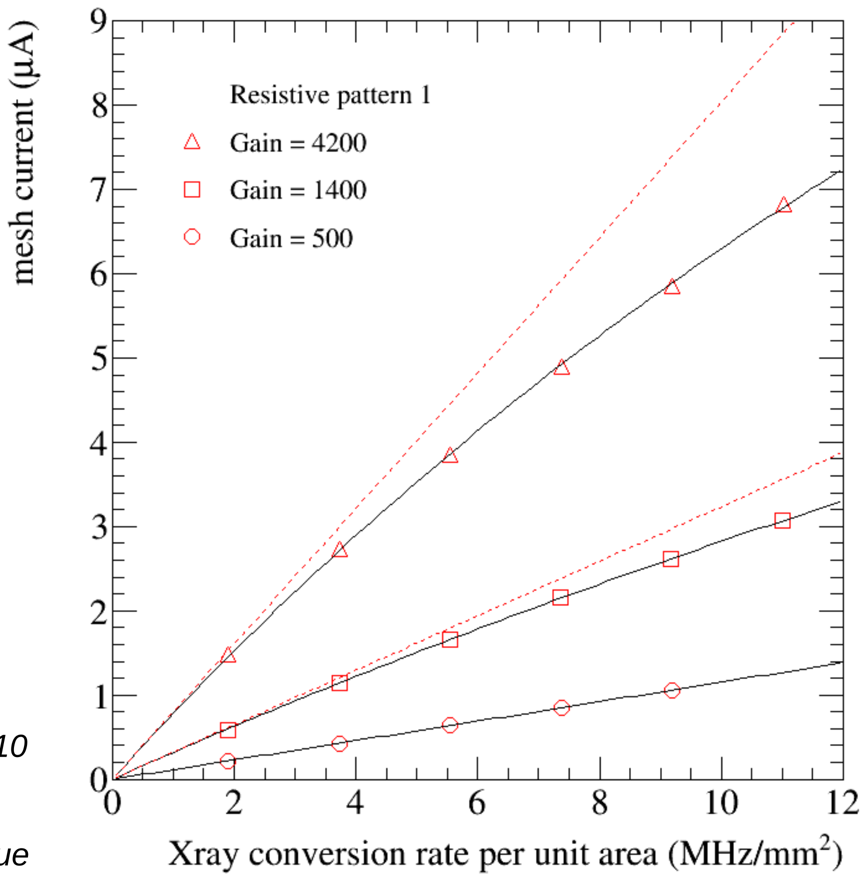
  → R (with Q_0) can be fitted to the data points

- The highest-R prototype response is linear up to rates of 1 MHz/mm² (for 8 keV dE/dx)



Prototypes are 10x10 cm² with 96 pads

Recycle old analogue electronics (Gassiplex)



Testbeam July 2015

RD51 period @ SPS/H4: July 1-15th (participated in the second half only:, July 8-15th)
Run with muons (calibration) and pions (sparks), by the end with electrons (charge-up)

9 prototypes with following design: 10x10 cm^2 pads of 1x1 cm^2

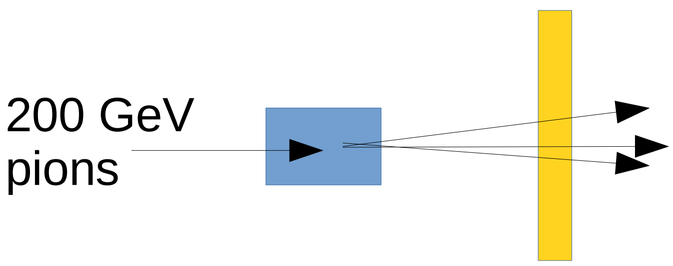
4 old resistive prototypes (star, mirror, snake, spider) @ 100 kOhm/sq.
3 new resistive prototypes (star, mirror, snake) @ 1 kOhm/sq.
2 non-resistive prototypes for comparison purposes

'Old' Analogue RO (no MICROROC): 96 ch. * 6 Gassiplex boards (not more available)
DAQ: C++ software from Demokritos (< 1 kHZ acq. rate)
→ Not all prototypes in DAQ at the same time

<u>Main tests</u>

1. Rate scan in pion shower to assess spark protection capability
2. Energy scan in EM shower to check for charge-up of Rlayer
3. Small 6-layer ECAL for future comparison with Monte Carlo... and to have fun!

Test1, sparking

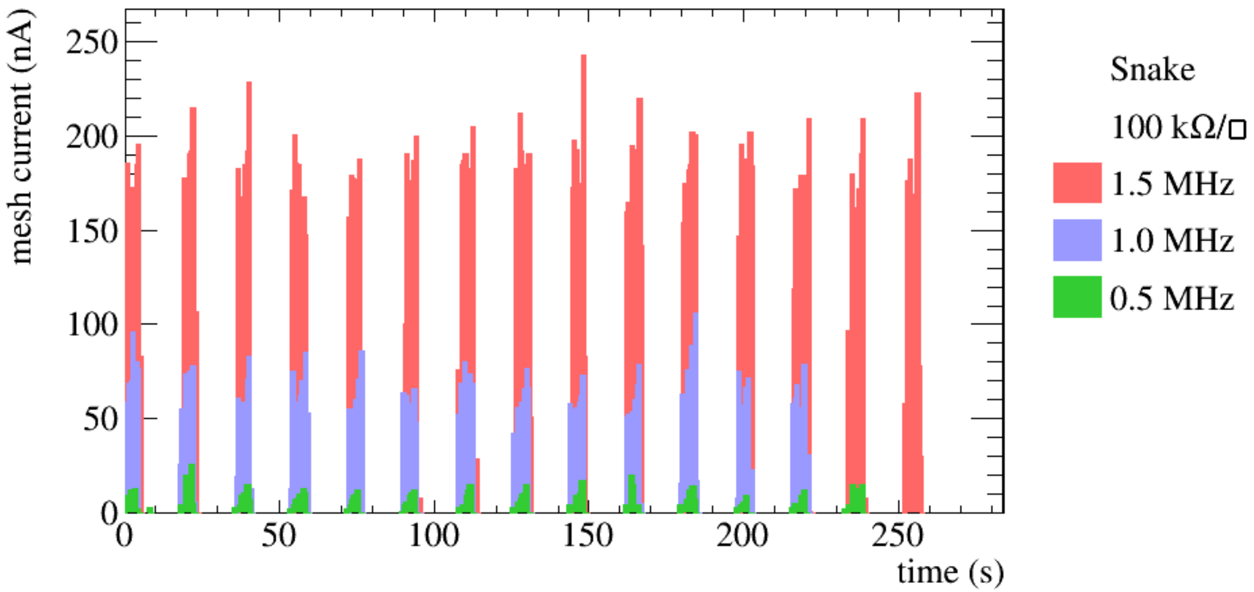


Monitor mesh current and voltage
from CAEN power-supply with RD51 slow-control system

2 lambda steel absorber to generate showers
Pion beam rate from 0.1 till 1.5 MHz

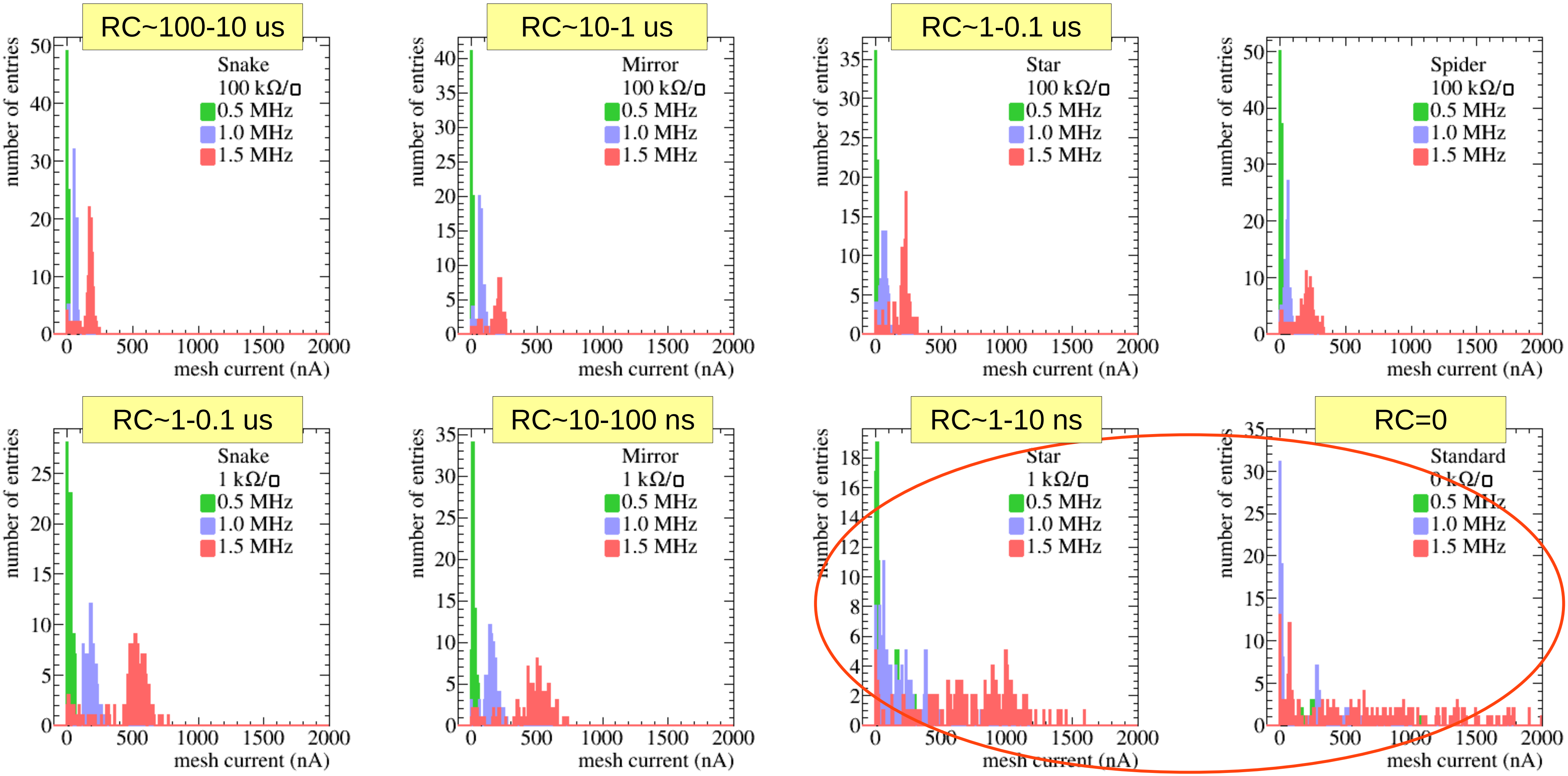
Swap prototypes at each scan (each sees the same activity)

SPS Spill structure (with intensity var.) seen by highest resistivity prototype
Current roughly constant during spill → no sparks



Test1, sparking

Below a certain resistivity, the current shows strong variations during spills.
'Star' pattern with 1 kOhm/sq. behaves as a non-resistive Micromegas.
→ Seems we found the RC-limit (1-10 ns)

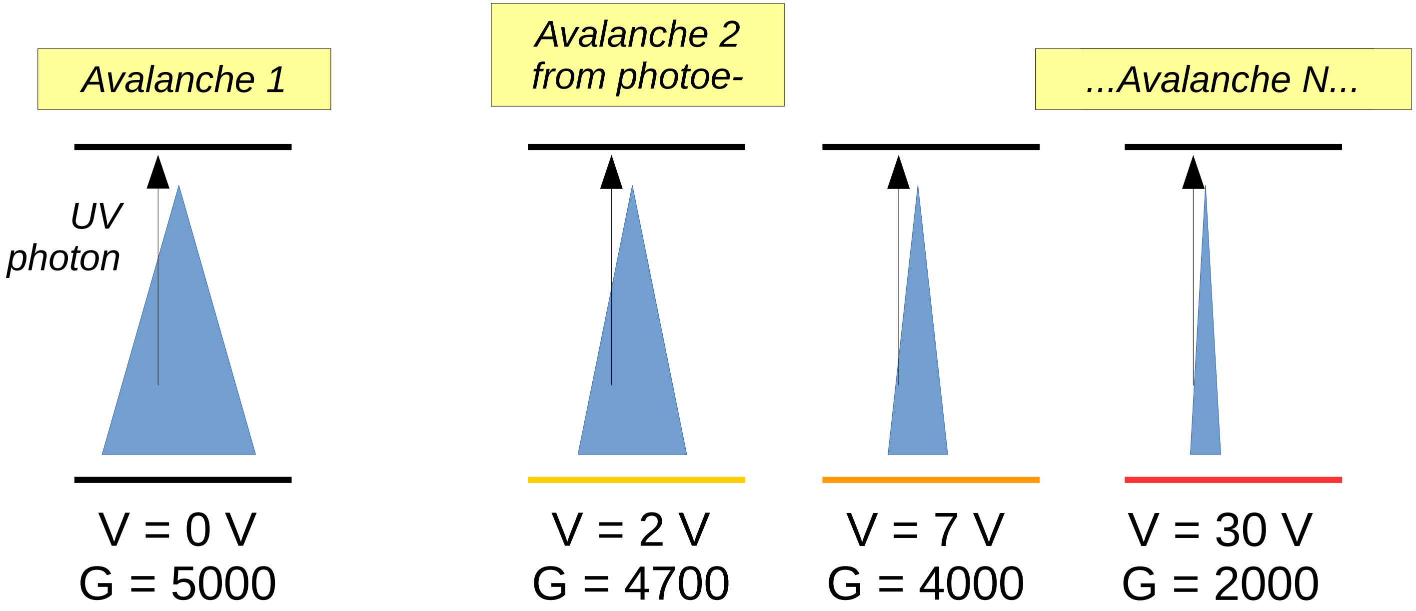


Test1, spark model

→ Seems we found the RC-limit (1-10 ns)
If spark development is driven by photon feedback at the mesh, this makes sense!

Photon feedback: photoelectrons released at the mesh by UV-photon from avalanche.
Diverging process (if the field is constant in time) which yields to spark.

The RC constant should be smaller than the avalanche development time (1-10 ns) so the local R-anode voltage does not decay before the next successor avalanche. In this case, the successor avalanche will feel a reduced field and the probability for photon feedback decreases until feedback stops and spark is avoided.

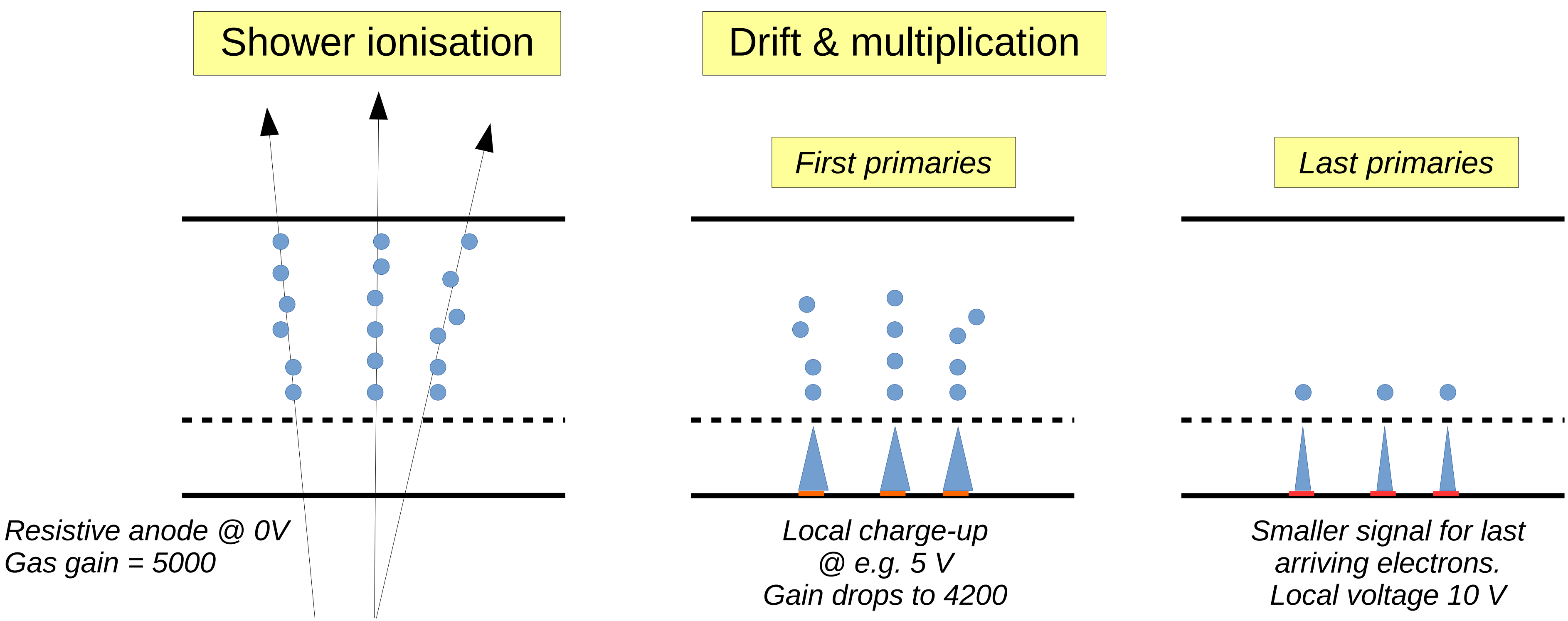


Test2, charge-up (@ low rate)

Can the resistive layer influence the total shower signal during a single event (i.e. @ low rate)?

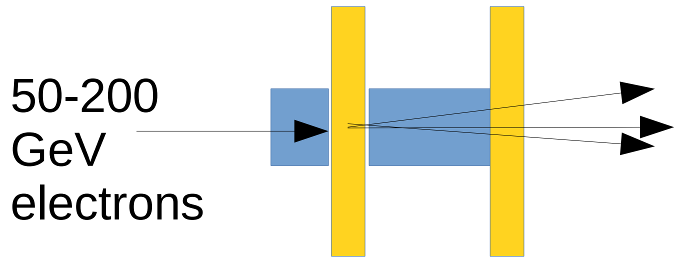
Could be! If the time to collect all primary electrons (~50 ns in out case) is smaller than the RC.
On this timescale, the R-layer acts as an insulator:

→ Multiplication of primary electrons progressively charge-up the R-layer
Last arriving primary electrons feel a reduced E-field due to charge-up from first ones...



PS: in reality there are way many more tracks in the shower core which makes avalanche overlap very likely

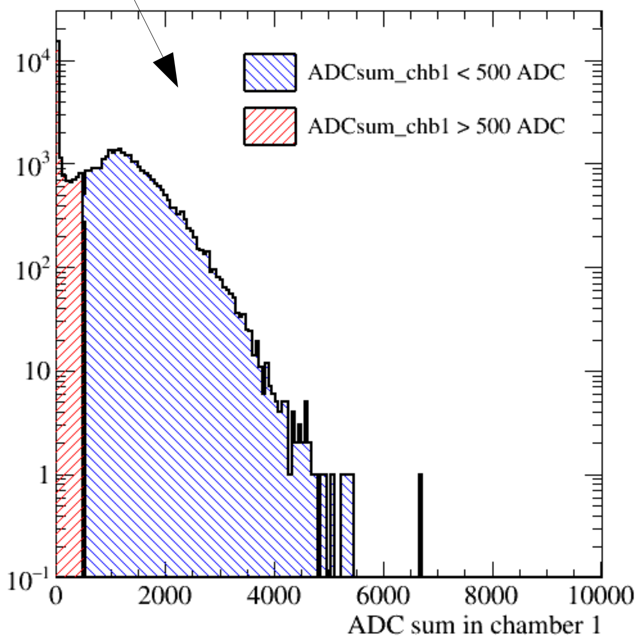
Test2, charge-up (@ low rate)

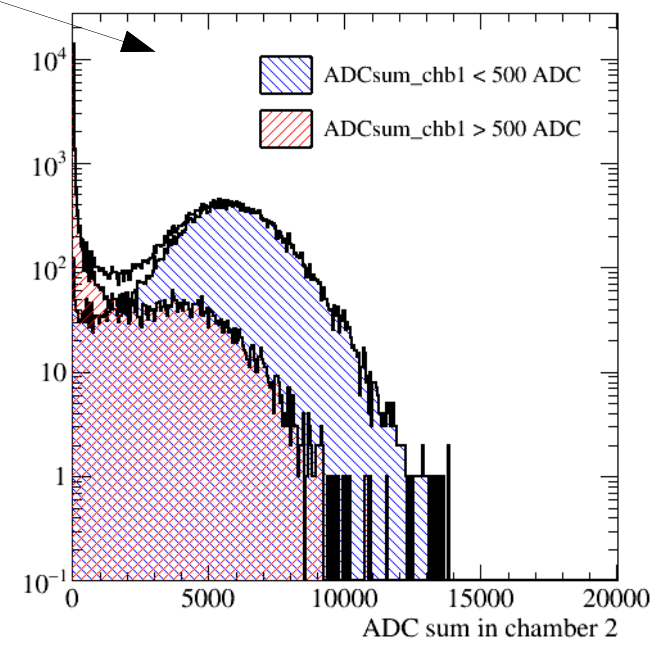


Local charge-up effects could show up as reduced energy distribution.

→ Compare energy response of resistive and non-resistive prototype (at low rates) with electron beam.

Small pion contamination in electron beam
→ Use preshower chamber before chamber under test
2 X0 Fe + PreShw + 6 X0 + Test
→ Test chamber @ shower max

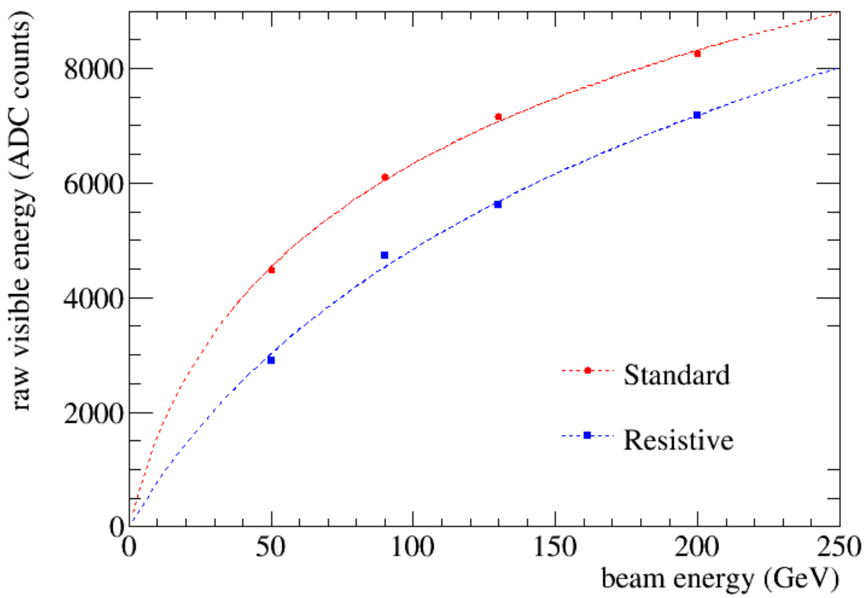


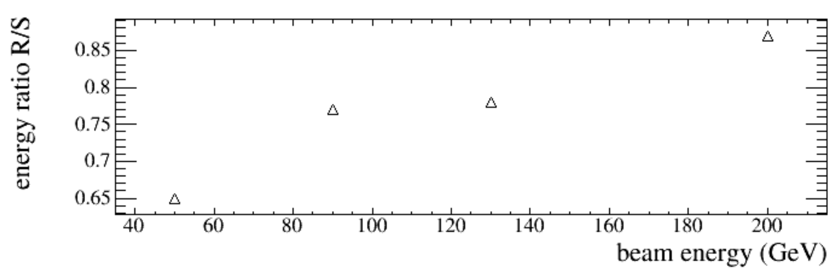


Test2, charge-up (@ low rate)

Local charge-up (i.e. voltage of R-pad) is V=Q/C(S), should depends on:
the charge arriving on the R-layer surface (Q) and also on the area collecting this charge (S).

Runs at EM shower energies, gas gain and different drift field (transverse diffusion).
By comparing the energy distribution between 1 resistive and 1 non-resistive,
we observe small differences.





<u>Ratio of energy sum</u>

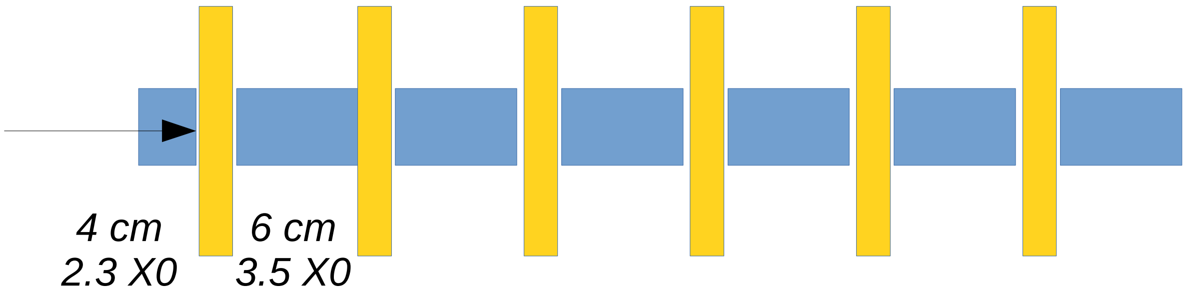
The ratio Resistive/Standard should be constant.
At “low” energy (50 GeV), the R-prototype gives relatively less signal than the S-prototype…

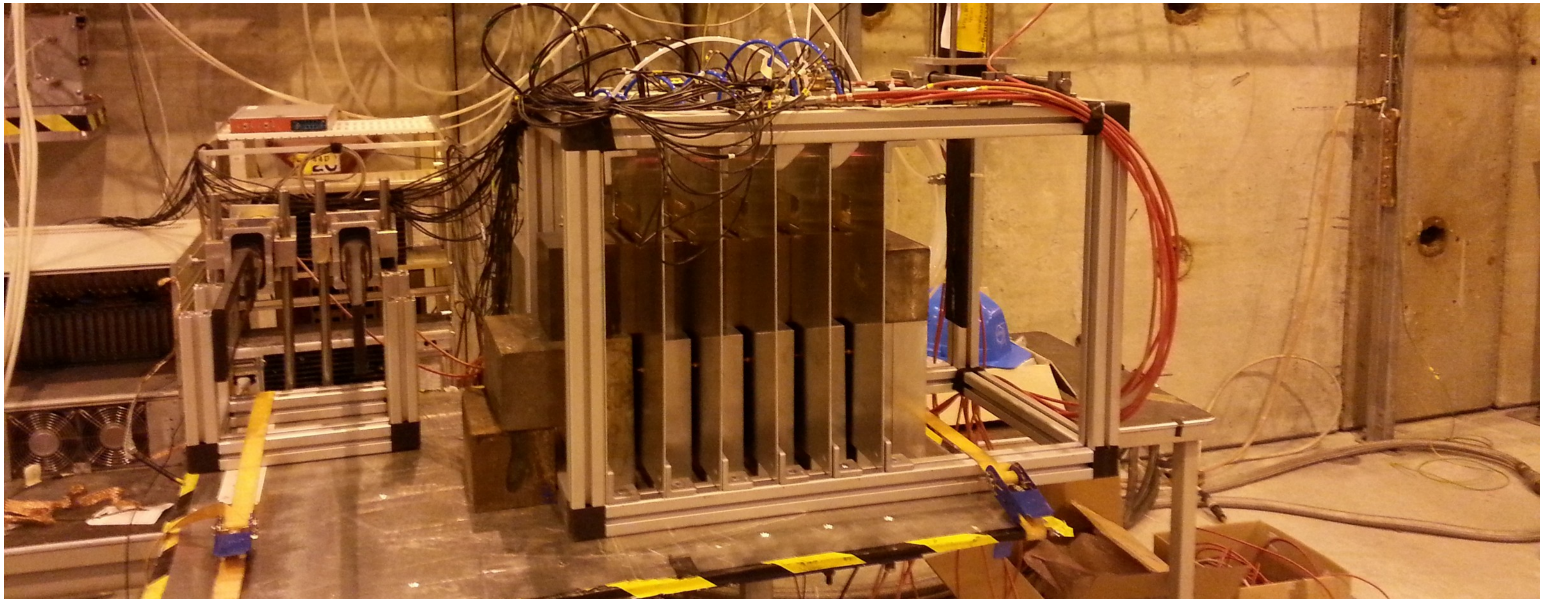
Shower more collimated and higher charge density?

To be understood...

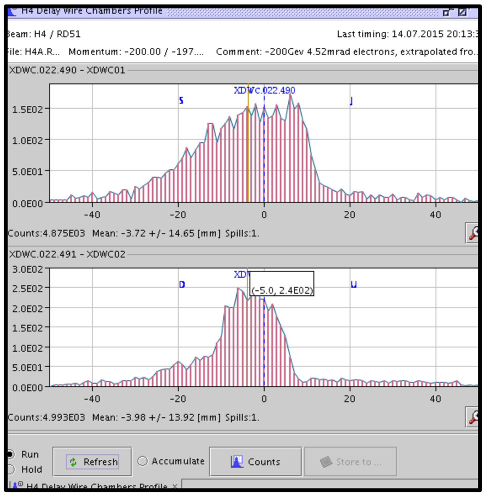
Test3, Micromegas ECAL

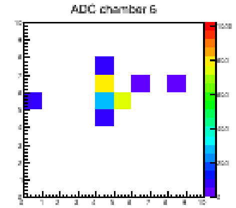
9 prototypes but only 6 Gassiplex boards → 6 R-layers with in total 34 cm of steel (~20 X0)
Electron beam energy from 30 to 200 GeV with 6 energy points, 2 gas gain values (1500-3000)
As before, we use the energy in first chamber to reduce the pion contamination

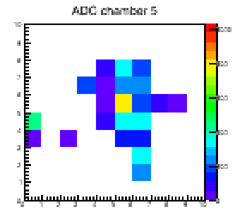


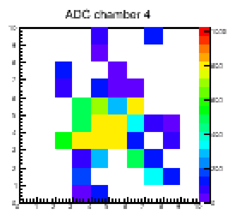


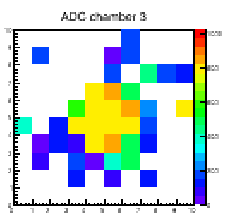
200 GeV EM showers
Low rate (~1 kHz)
Beam spot ~ 1 cm2
Ar/CO2 gas mix.
(chb. flushed in series)
G = 3000

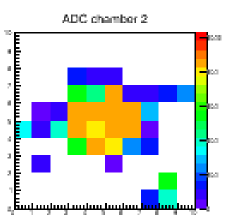


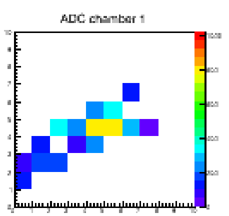












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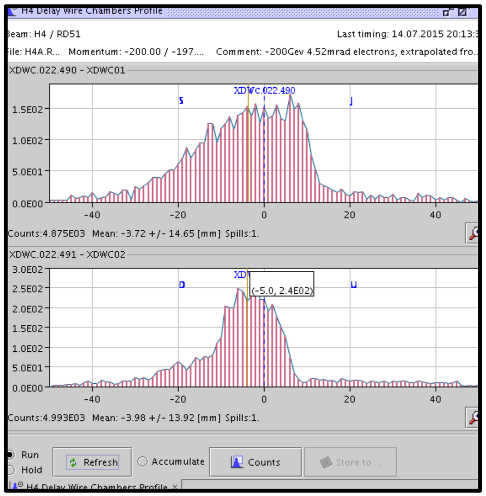

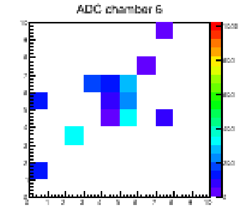

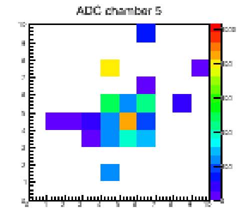

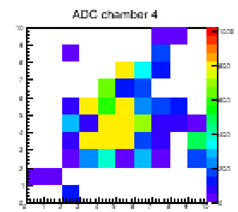

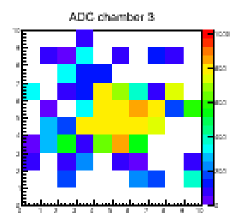

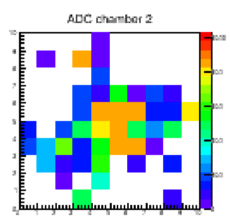

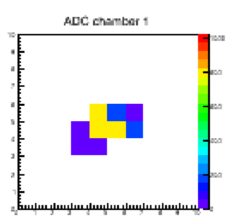

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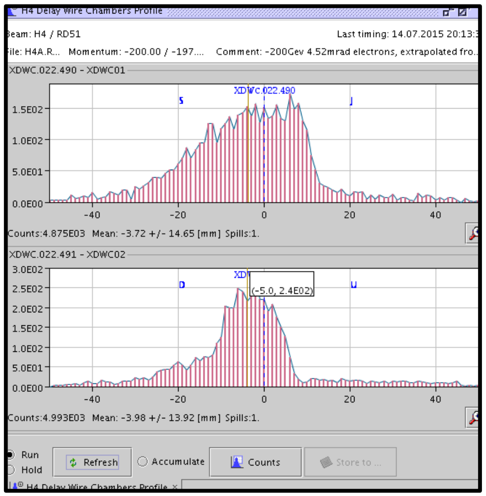
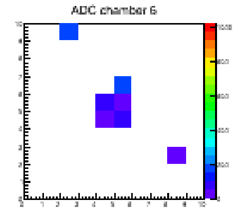
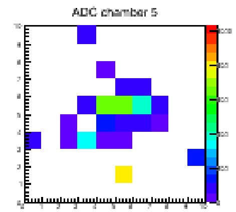
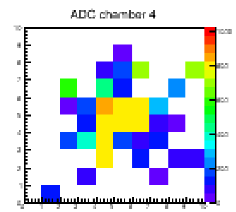
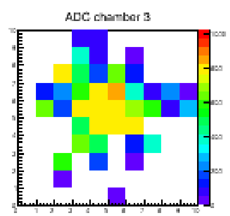
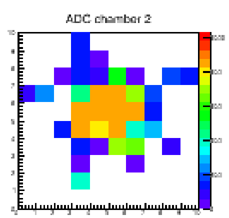


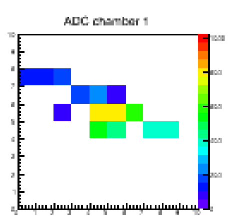








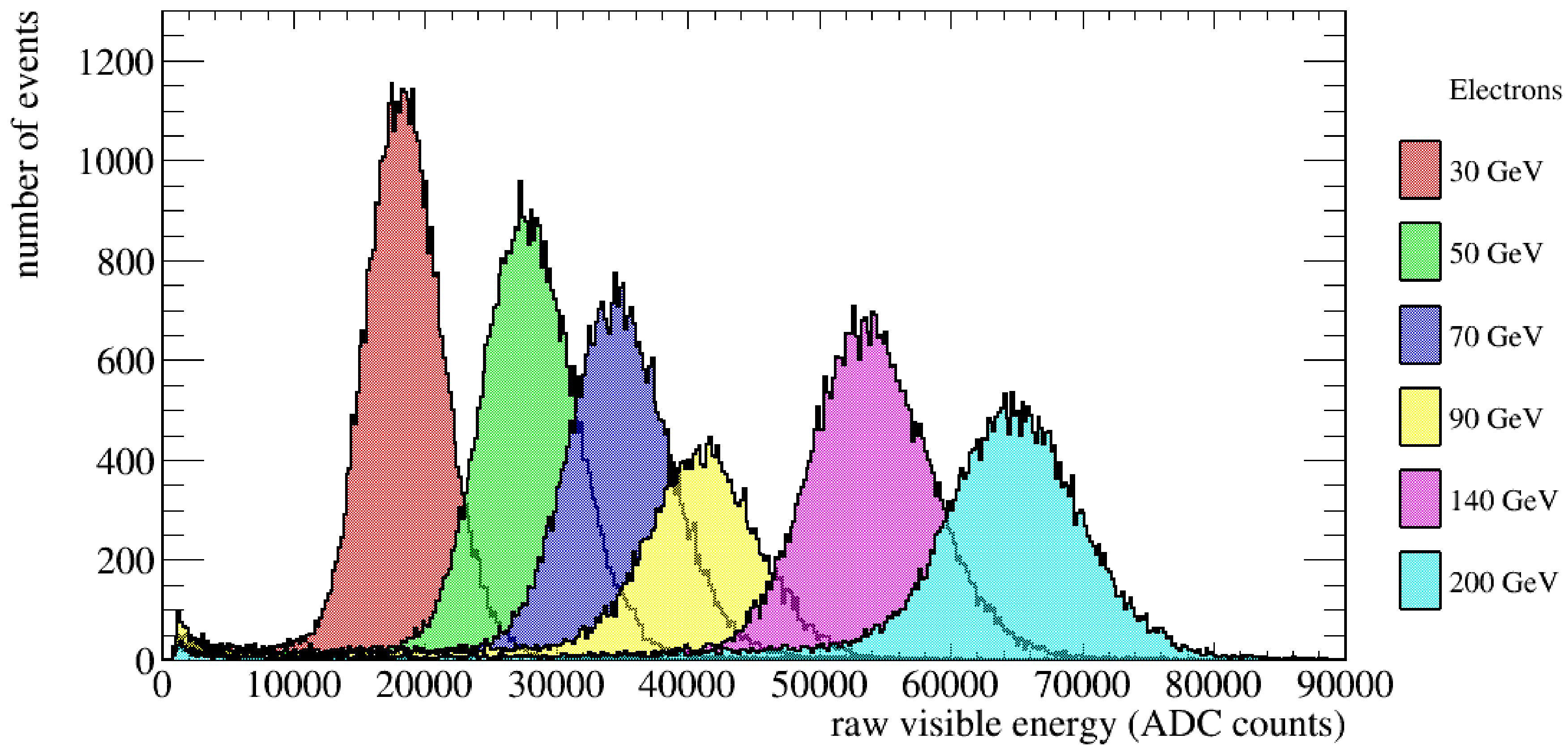




Test3, Micromegas ECAL

<u>Energy sum (no MIP and electronic calibration yet)</u>

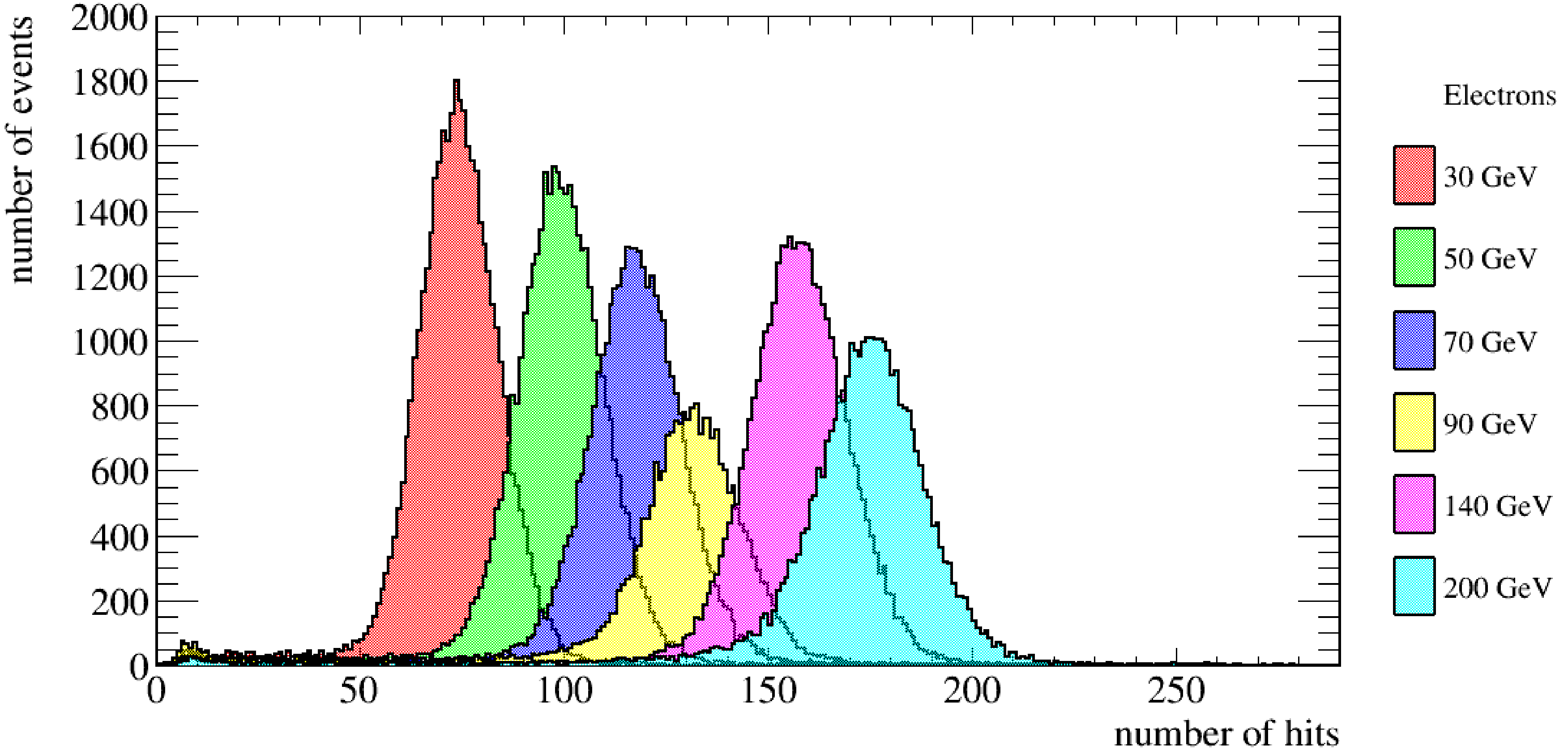
Pion contamination was higher @ 90 GeV → lower statistics



Test3, Micromegas ECAL

<u>Nhit distribution</u>

Pion contamination was higher @ 90 GeV → lower statistics

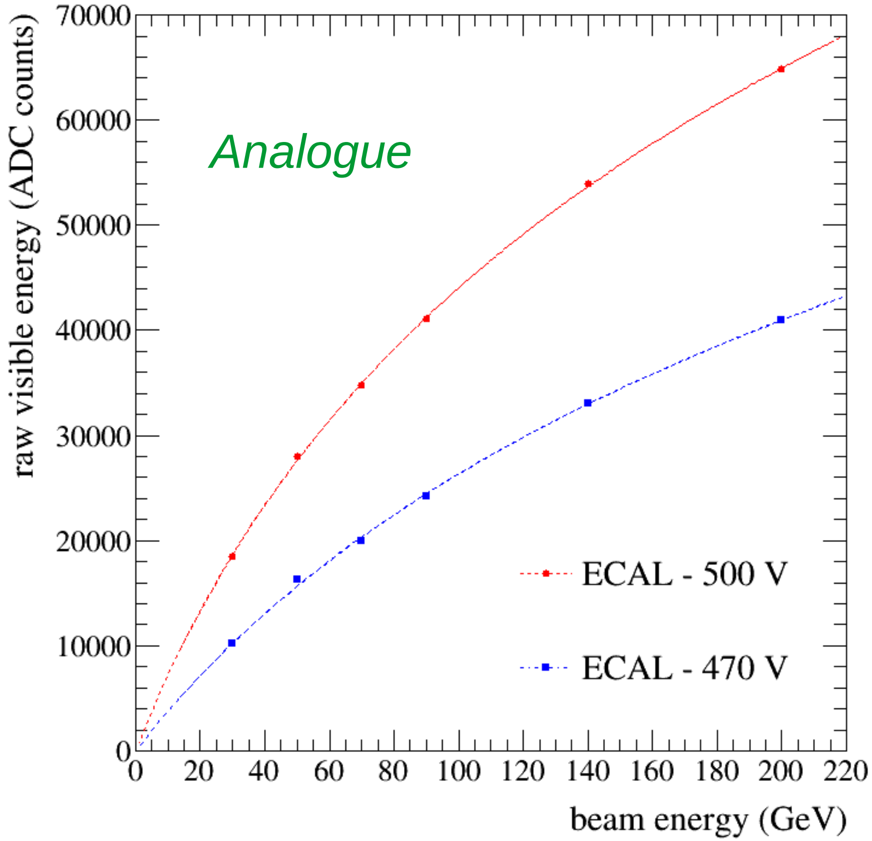


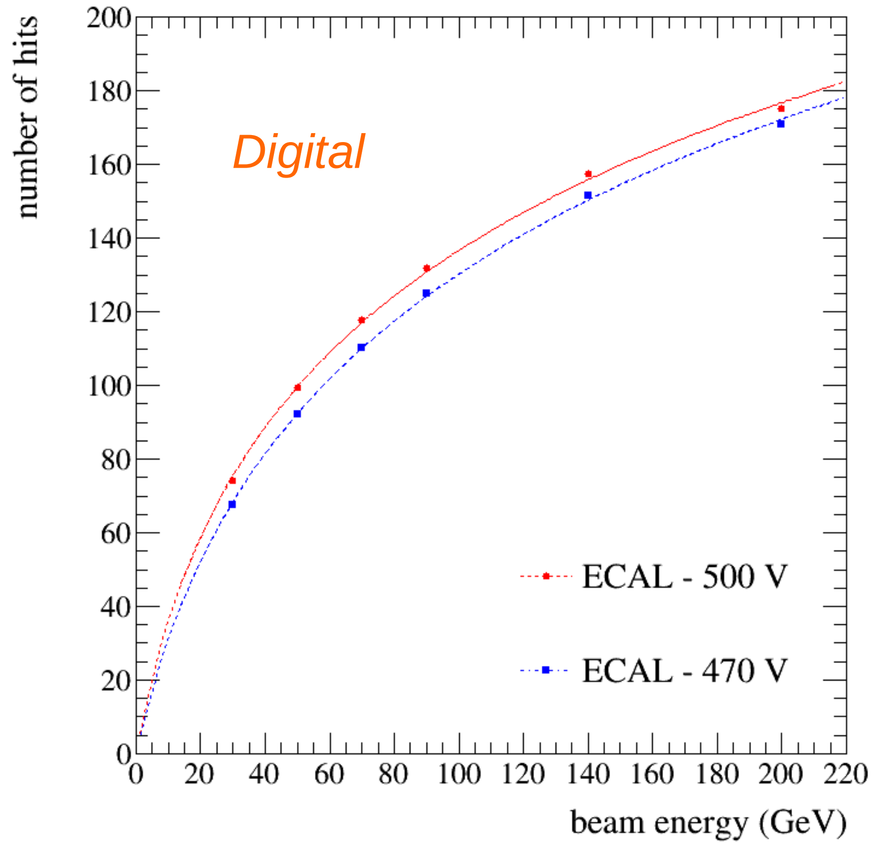
Test3, Micromegas ECAL

<u>Response</u> (from gaus+pol1 fit)

Digital response saturated (we are used to it!)

Analogue as well… very coarse sampling (3.5 X0/layer) + side leakage





Summary

- The necessary RC to quench sparks is of the order of the avalanche time development (1-10 ns). This makes sense, if one accepts that spark development proceeds through photon feedback.
- Charge-up at high rate can be minimized by choosing a low resistivity, rate capability beyond 1 MHz/mm^2 possible for X-rays (and therefore MIPs but lower for showers).
- Response of R and non-R prototypes to EM showers is similar, i.e. single-event charge-up under high dE/dx seems negligible (good point for calorimetry!).

- Future plans: make resistive ASUs with MICROROC
  ~ 150 MICROROC chips left from first batch
  + received new 288 chips (second batch)

  Have to decide on ASU size:
  * 48x48 cm^2, for small HCAL, 36 ASIC/layer (→ 12 layers feasible)
  * 24x24 cm^2, for ECAL, 9 ASIC/layer (→ 40 layers feasible)

  An ECAL (physics) prototype would use the analogue readout of the MICROROC ASIC rather than the 3 thresholds (SDHCAL).
  Interesting to understand the calibration, energy reconstruction, temperature effects ...
  Few years long project; carried out with our MPGD partners (Demokritos, Saclay, Weizmann).
  Simulation studies on-going (see back-up slide) as well as cost estimation.

Micromegas ECAL sim. studies

- Cost effective: steel absorber (part of chamber cathode)
- Sampling of 1 X0/layer (absorber of 18 mm, gas gap of 3 mm)
- Target tests at the PS, 15 layers sufficient to have good linearity