RD51

Micromegas for sampling calorimetry,

an update on prototyping and simulation studies

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CNRS/IN2P3/LAPP, Annecy

Overview

- Introduction: Micromegas for sampling calorimetry
- *R&D : prototypes and testbeam results*
  - Large area Micromegas for a SDHCAL technological prototype
  - Spark protected resistive Micromegas
- *Monte Carlo : DHCAL compensation & cell size*
  - DHCAL performance with different cell size
  - Compensation based on hit density
- Conclusion and future plans

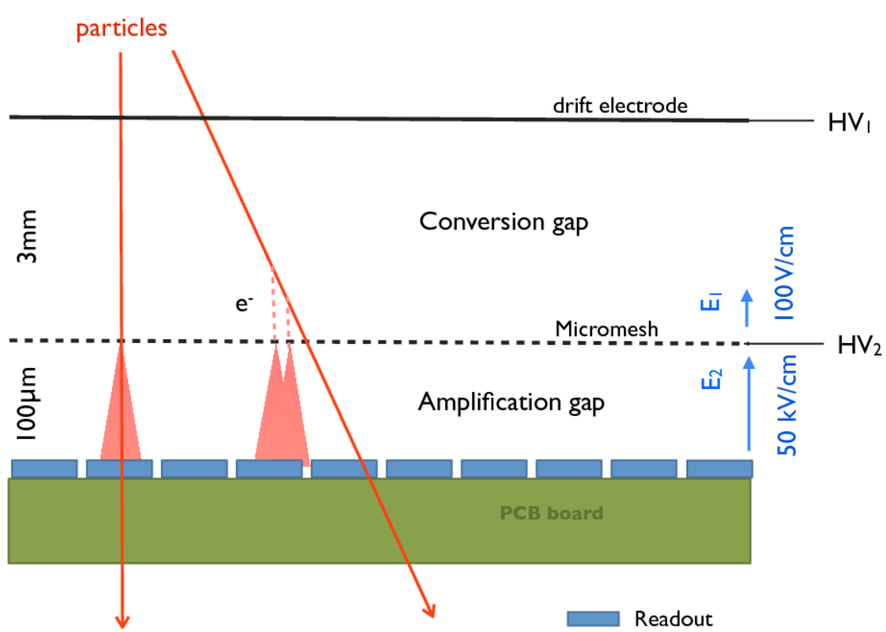
Micromegas for sampling calorimetry

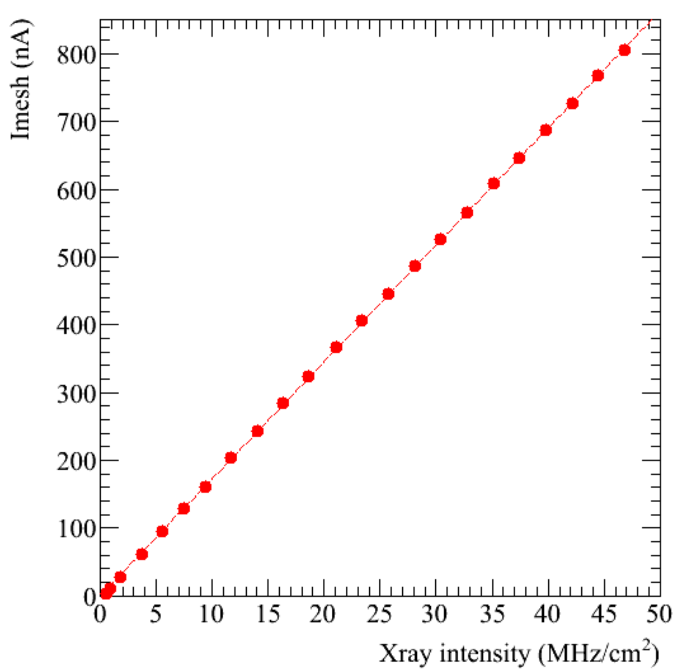
We are studying Micromegas for a digital hadron calorimeter (SDHCAL)

In fact, it is applicable to **sampling calorimetry** in general (ECAL, HCAL, LC, HL-LHC) based on its intrinsic **linear response** that manifests e.g. as a **very high rate capability**

Small avalanches, fast Q collection
Negligible space charge effects

Recent X-ray test
*Mesh current linear (at least) up to **tens of MHz/cm²***



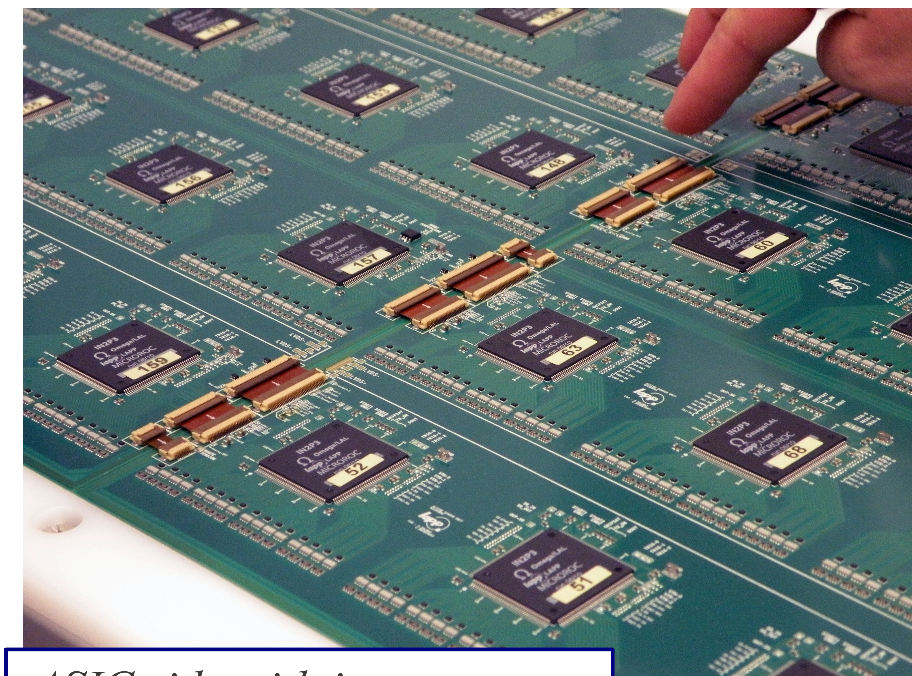


Large area Micromegas (1/3)

Today, we are capable of constructing 1x1 m^2 Micromegas chambers
that fulfil several technical requirements for a technological SDHCAL prototype

*XY-scalability (**board interconnects**), thickness (< 1cm), 1x1 cm^2 anode pads*
*Embedded electronics with 3 readout thresholds, **power-pulsing, self-triggering** (MICROROC)*
Diode protection of ASIC against sparks (works), more elaborate solution with R-coatings studied

Mesh side

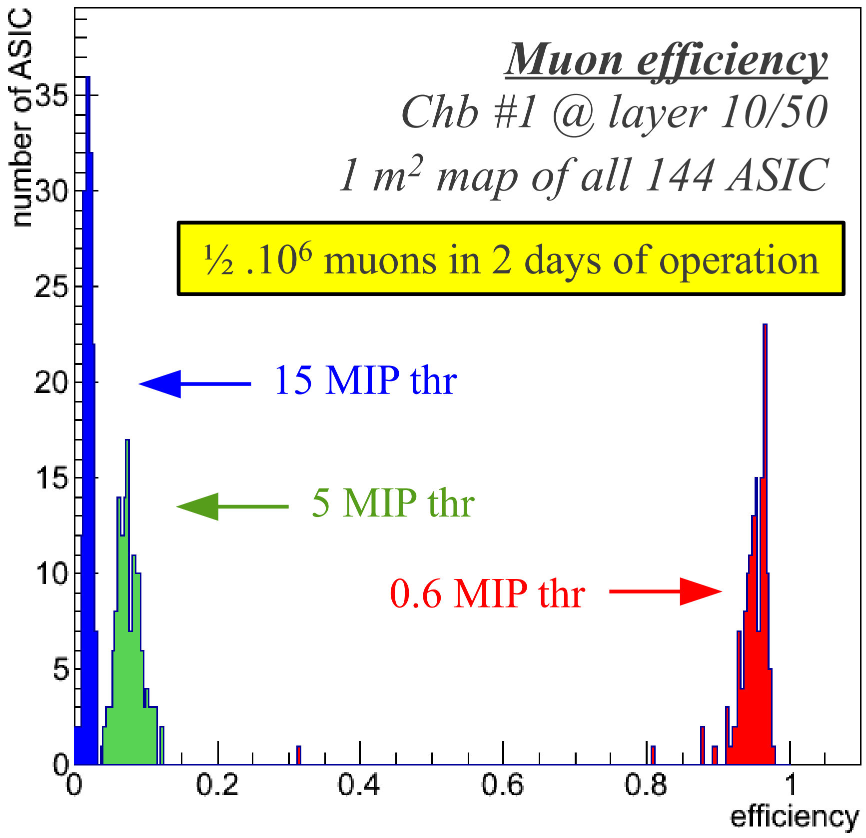


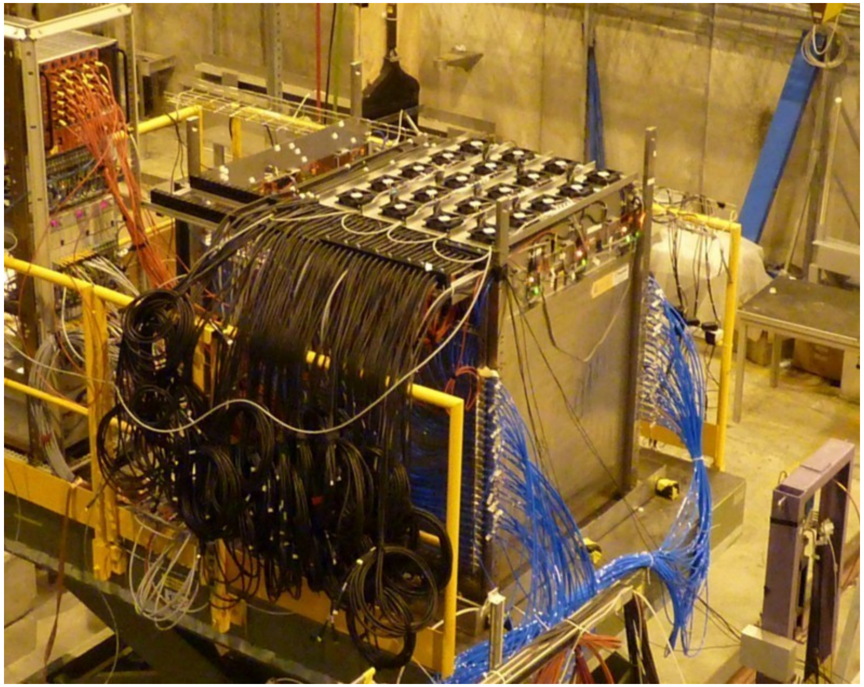
ASIC side with interconnects

Large area Micromegas (2/3)

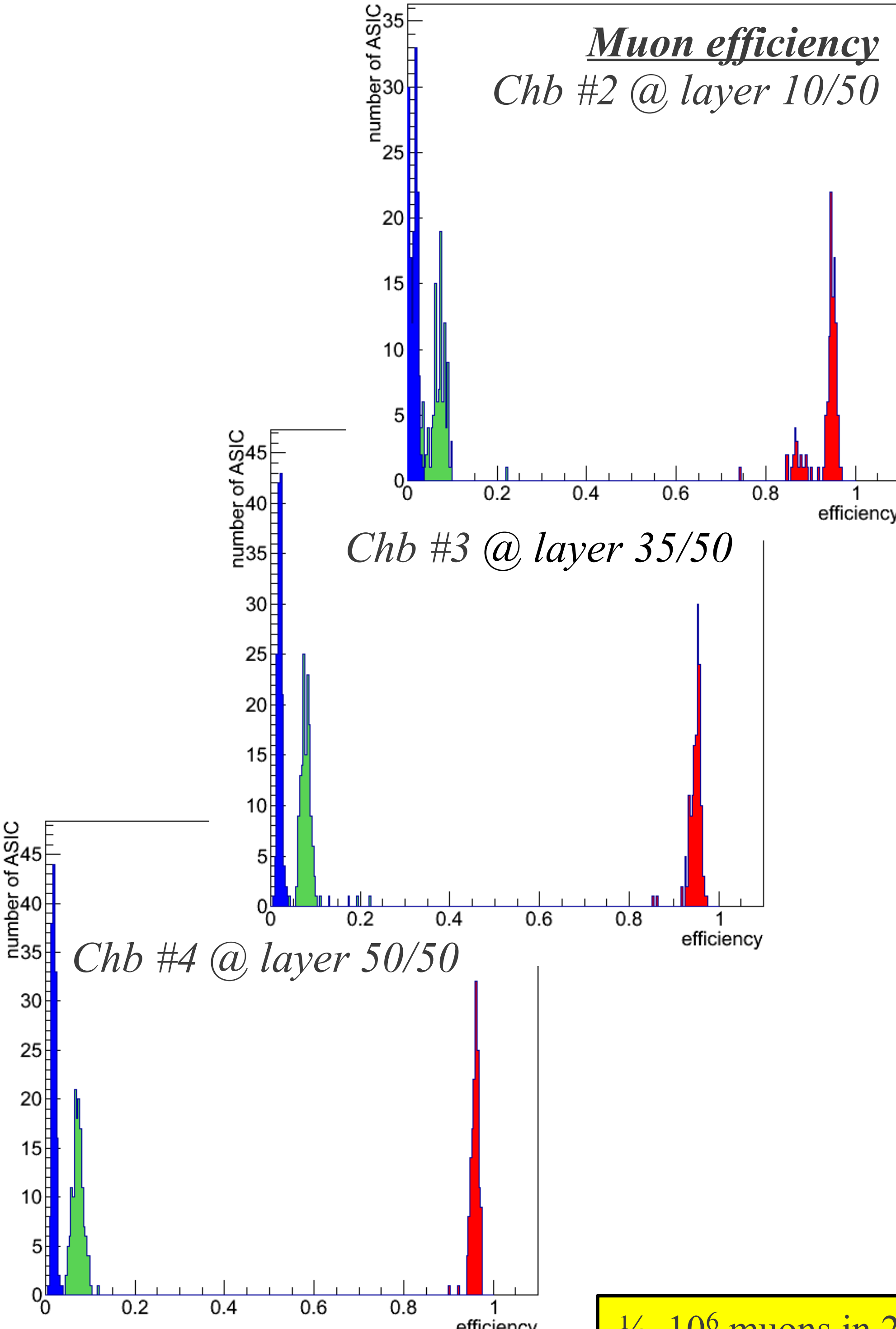
Lot learnt inside the CALICE RPC-SDHCAL: 4 Micromegas + 46 RPC

Efficiency > 95% at a low gas gain of 10^3 (= very low spark probability)
Uniformity of a few % over whole chamber area but also from chamber to chamber
<u>→ easy (cell-to-cell & layer-to-layer) calibration in a sampling calorimeter</u>

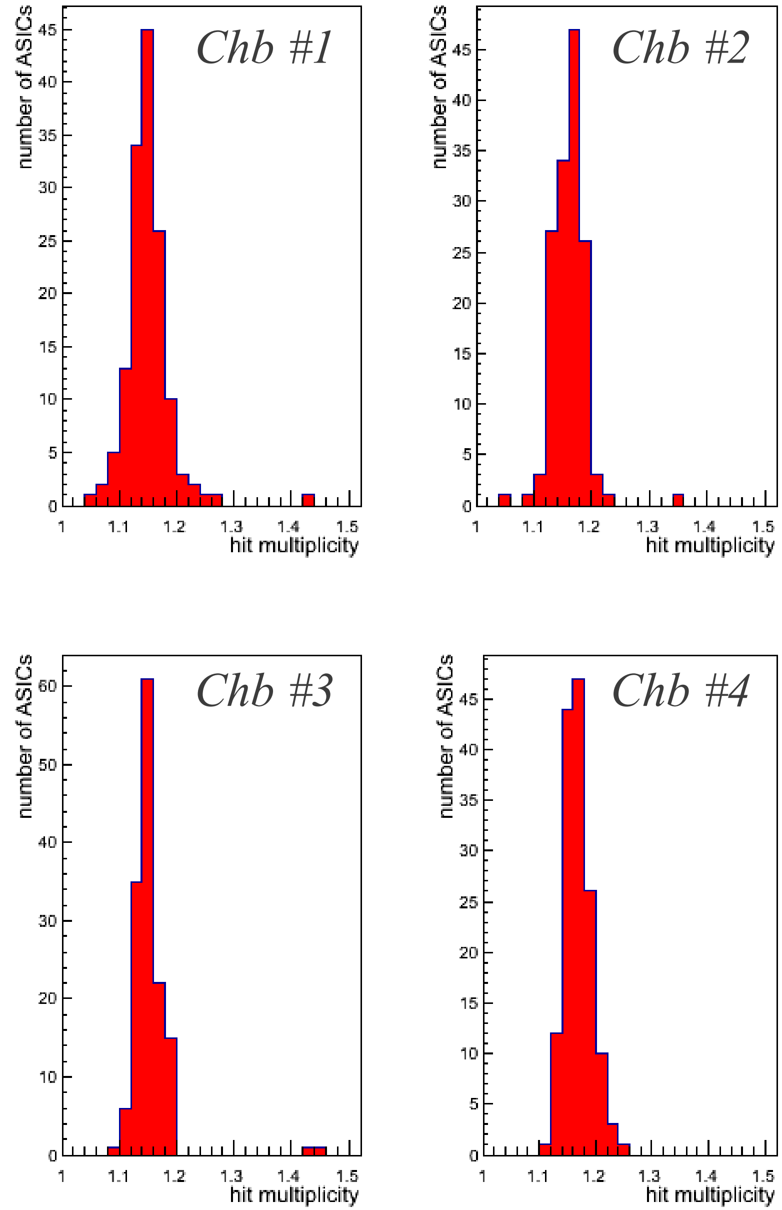




for completeness...



Muon hit multiplicity



½ .10^6 muons in 2 days of operation

Large area Micromegas (3/3)

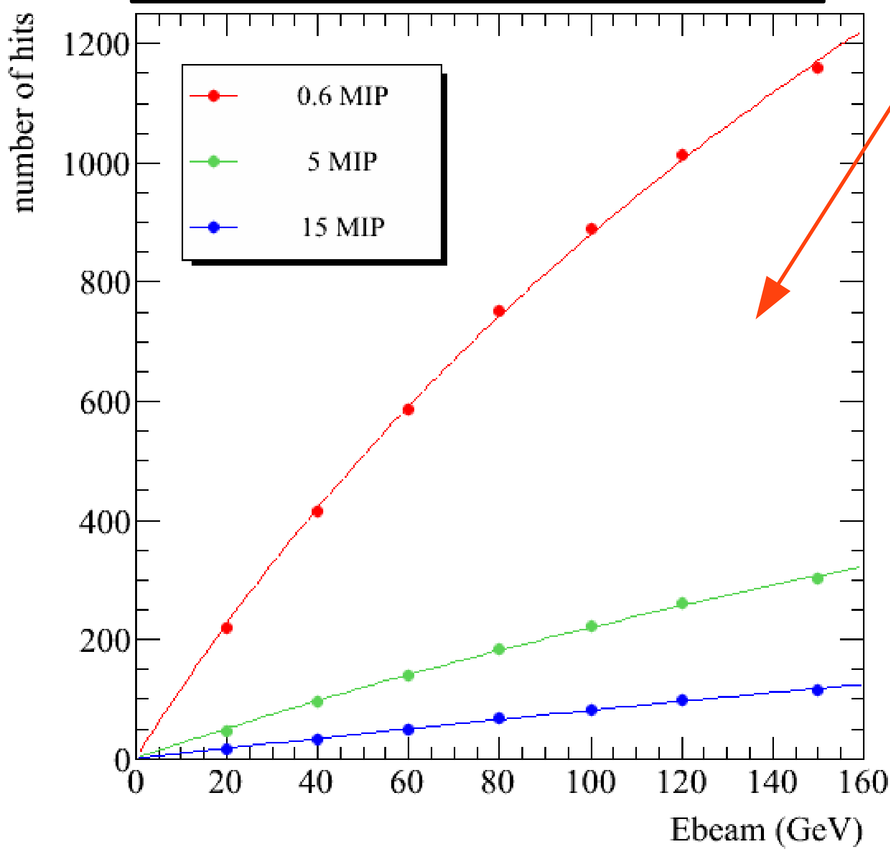
Lot learnt inside the CALICE RPC-SDHCAL: 4 Micromegas + 46 RPC

Measurement of longitudinal pion shower profile in Micromegas chambers

Integral of profile → leakage-corrected pion response of a virtual Micromegas SDHCAL

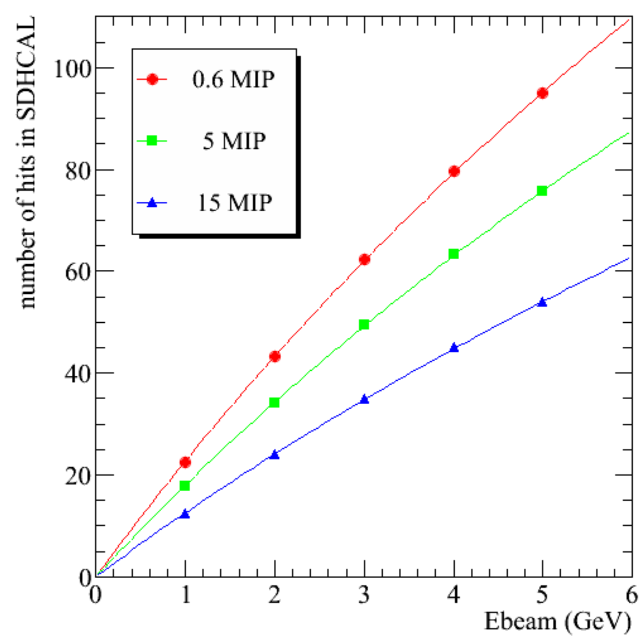
→ "physics" results with a few layers

~10^4 pions / E in 2 days of operation



Similar measurements with electrons

and small prototypes (16x16 cm^2) described in the next slides



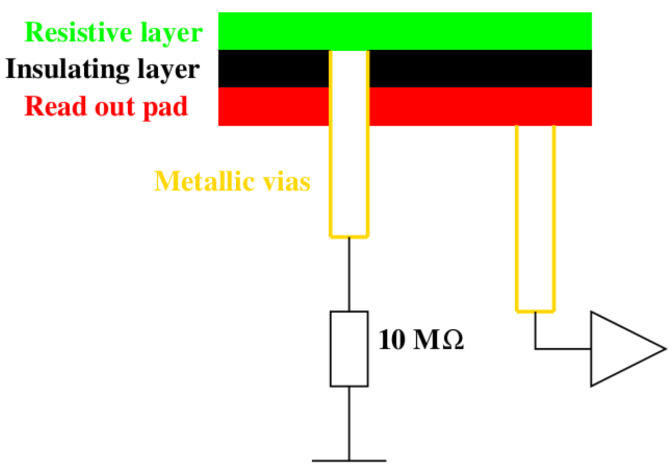
Spark protected Micromegas

Today's protections against sparks are *current*-limiting **diodes on-PCB <u>and</u> in-ASIC**

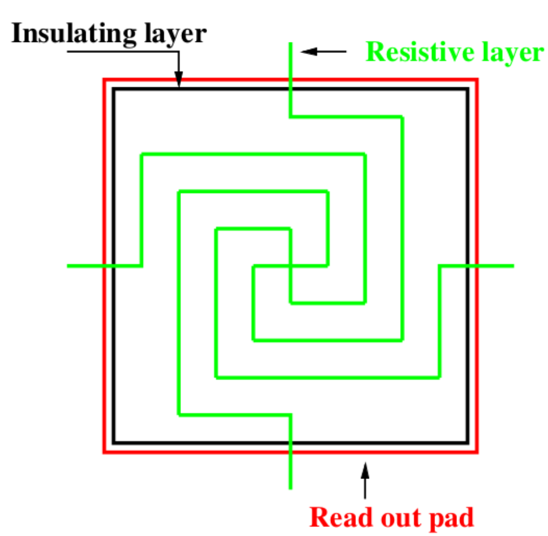
<u>Seems (so far) sufficient to protect the electronics in hadron showers</u>

Sparks, however, are allowed to develop with following consequences
→ all 64 ASIC channels fire (sometimes all 1536 ASU channels) + drop of the HV of the mesh
Wrong energy measurement + dead time in the HV section where the spark occur

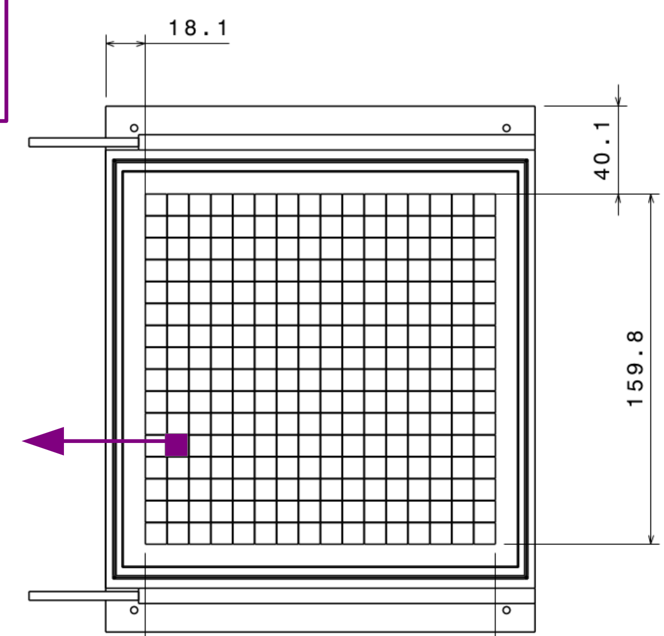
Resistive coatings with capacitive coupling to pads (2 designs)
→ **spark quenching** ($E_{avalanche}$ *competes with* $E_{applied}$)



Design 1



Design 2



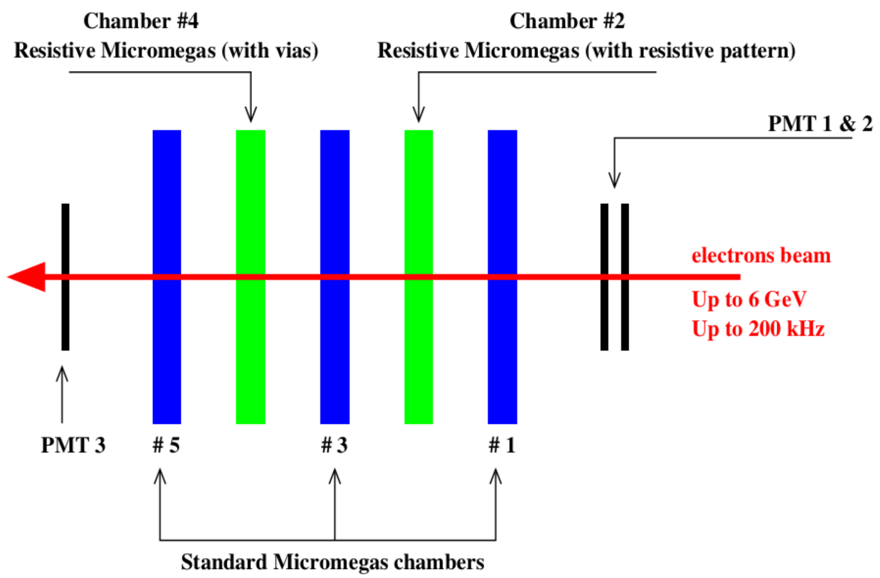
16x16 cm² prototypes

Spark protection effectiveness (1/2)

July 2012 testbeam at DESY (1-5 GeV e^-)

→ *Compare standard and resistive prototypes*

→ *Spot charging-up effects in resistive prototypes*

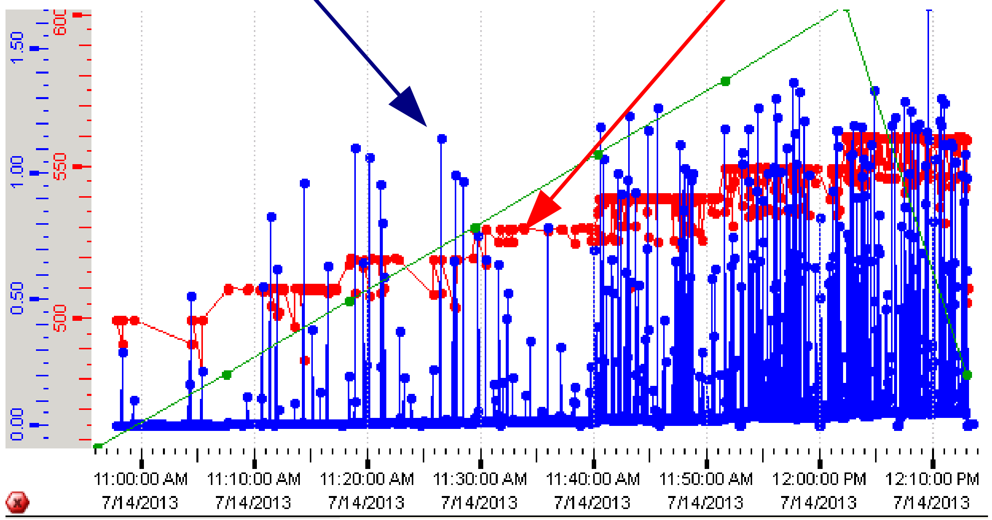


Spark study in Ar/CO_2 90/10

Rate of 1.5 kHz (4 cm^2), *increase V_{mesh} by small steps*

500-560 V → Gas gain from a few 10^3 to a few 10^4

Monitor mesh current



Standard un-coated prototype

Current spikes & voltage drops

At 510 V, during 10 minutes: 11 sparks & ~ 10^6 e^-

Spark probability of ~ 10^{-5} / e^-

Spark protection effectiveness (2/2)

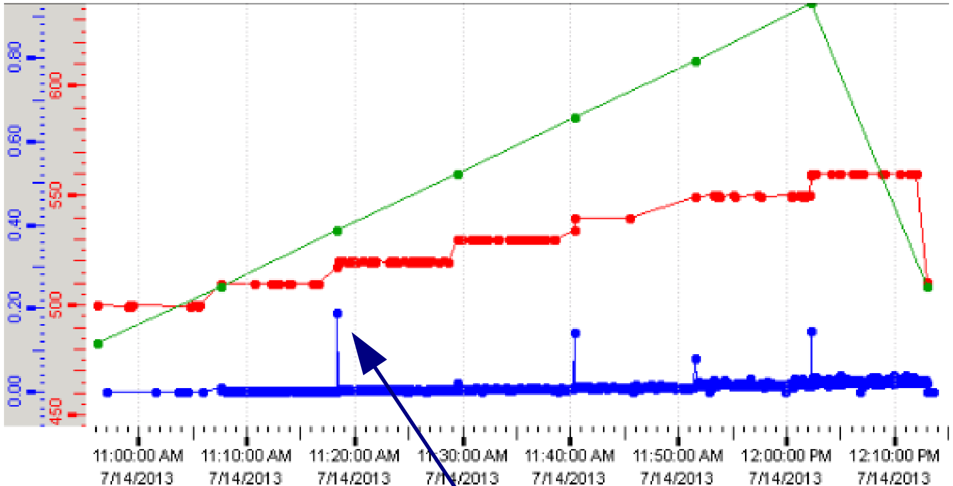
<u>Resistive prototypes</u>

Current spikes & voltage drops disappear as sparks can not develop fully

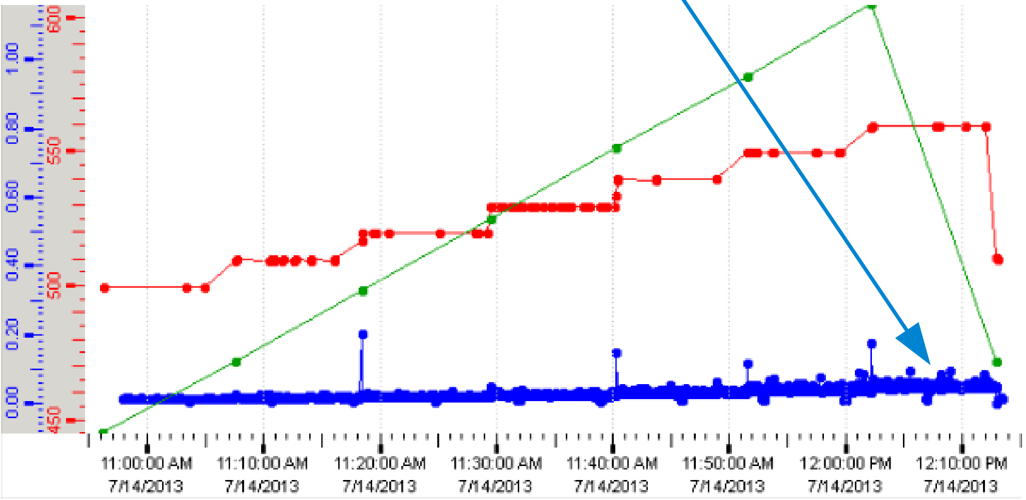
At very high gains (2-3.10^4), a small current activity is noticed

In the region of operation (510 V), spark probability ~ 0

Resistive chamber # 1



Resistive chamber # 2



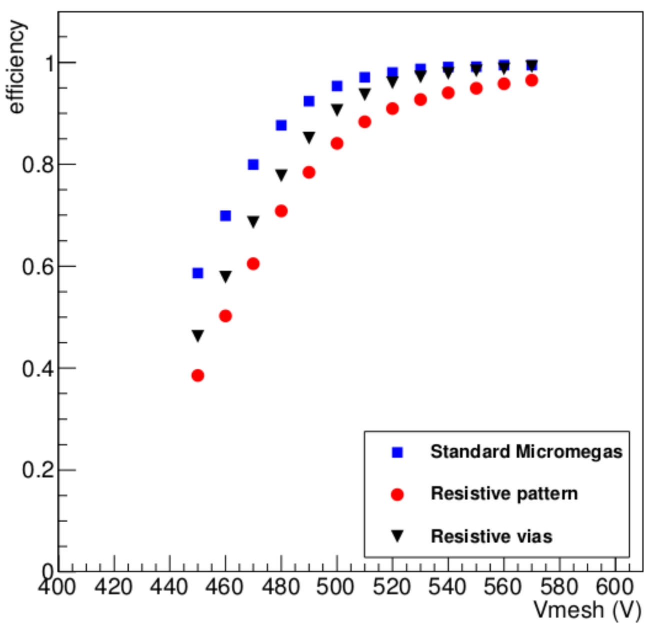
(Current spikes = charge-up current when increasing the voltage)

Comparison standard/resistive prototypes

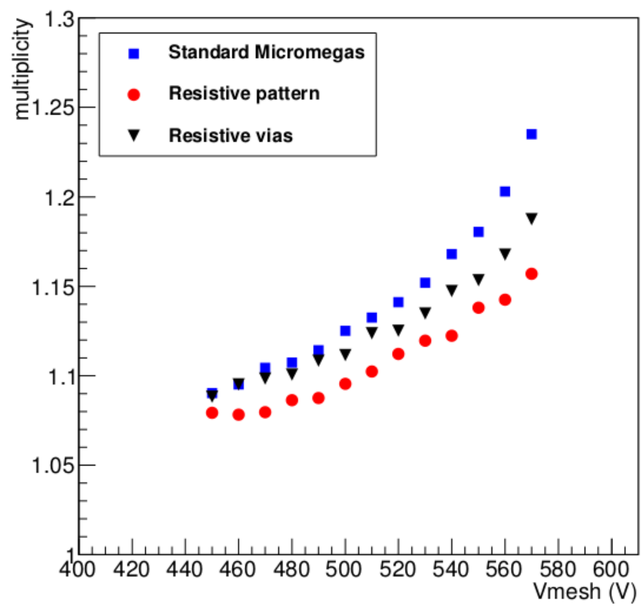
Small signal loss in R-prototypes → lower efficiency at same V_{mesh}

No lateral spread of signals in R-prototypes (as expected from their design)

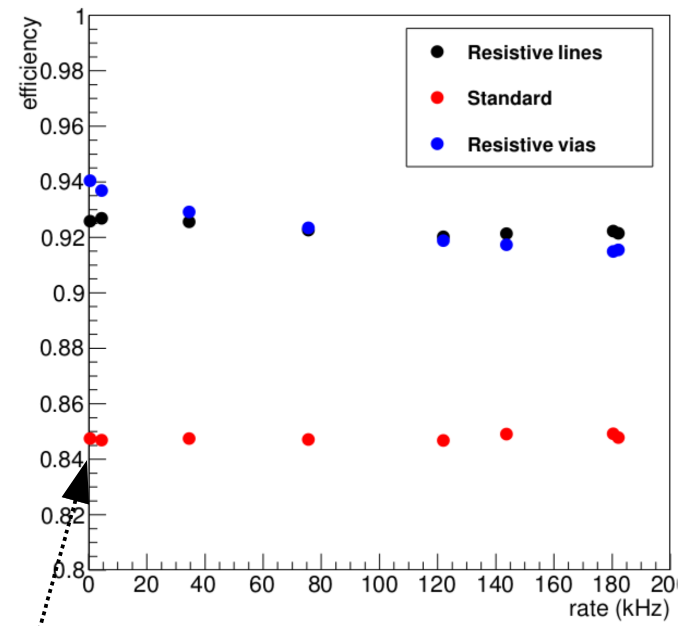
1-2% loss of efficiency from 0.25 to 50 kHz/cm^2 beam intensity in 1 R-prototype



Efficiency VS V_{mesh}



Hit multiplicity VS V_{mesh}



Efficiency VS Rate / 4 cm^2

(standard prototype HV lowered to avoid sparks at high rate; sparks can disturb the DAQ)

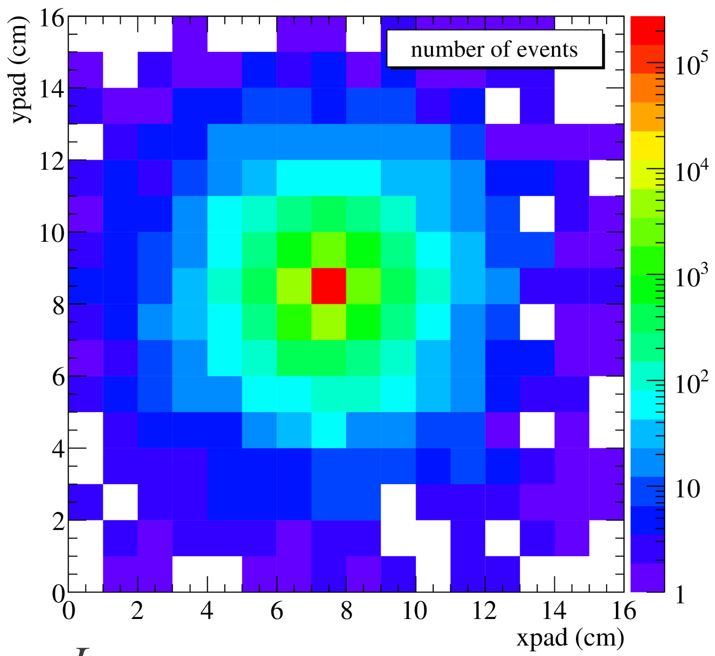
On-going study of charging-up effect (1/2)

RD51 lab. at CERN: X-ray gun (Cu target 8 keV line)

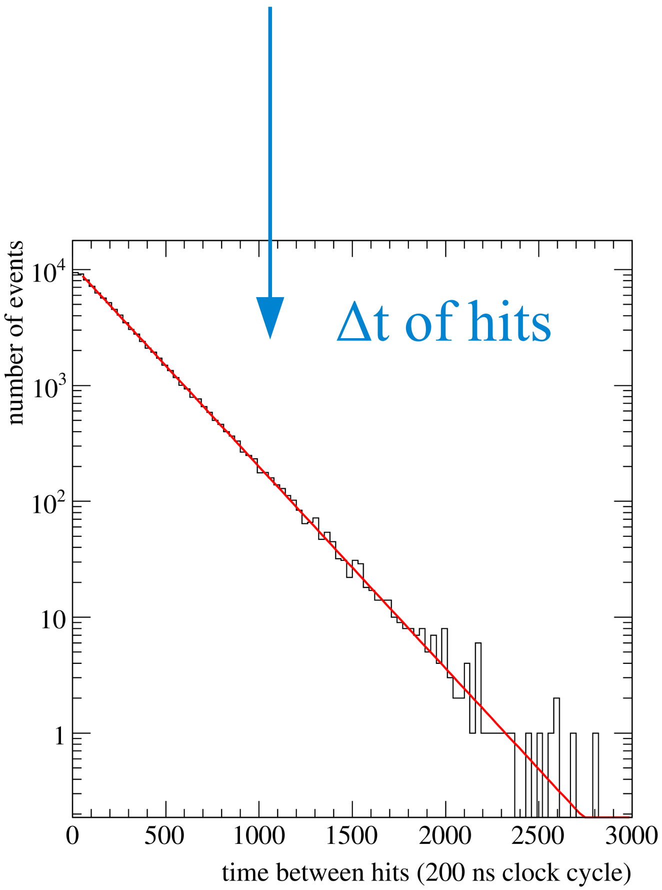
Beam collimated to 3 mm diameter (~ 7 mm^2) → one pad
X-gun calibration performed with standard detector (*Igun → X-rate*)

Readout1 at low rate (< 1 MHz)
Counting hits (~ quanta conversion) in trigger-less mode with MICROROC

Readout2 at high rate (> 1 MHz)
Measure mesh current on power-supply



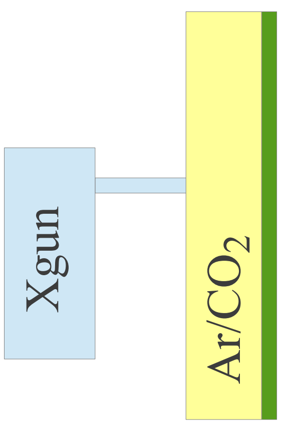
Log_z



Modified chambers

Thin kapton window

5 mm gap



On-going study of charging-up effect (2/2)

Only “resistive via” prototype tested so far (preliminary results, methodology not yet fully defined)

Current mode

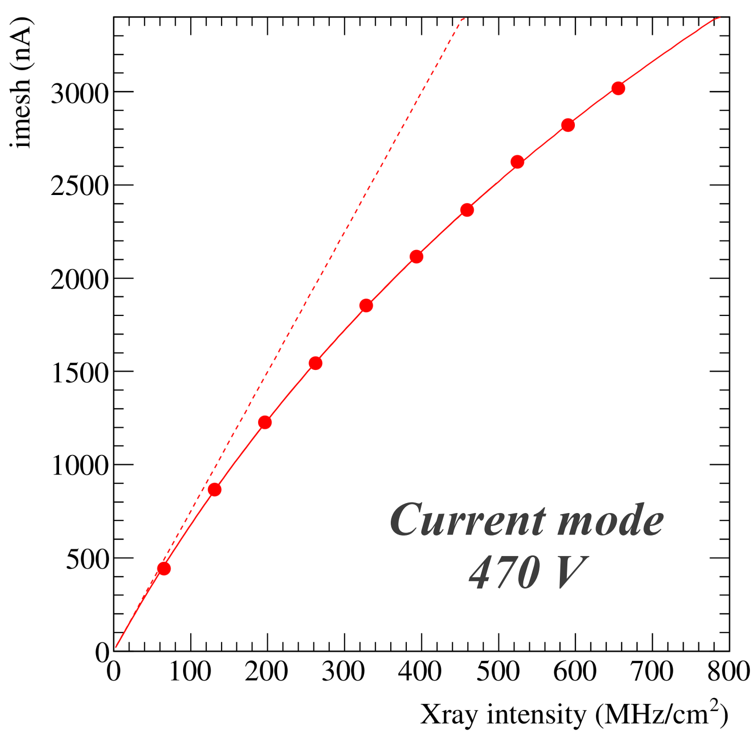
→ resistive prototype works at least up to 700 MHz/cm^2 but with a saturated response

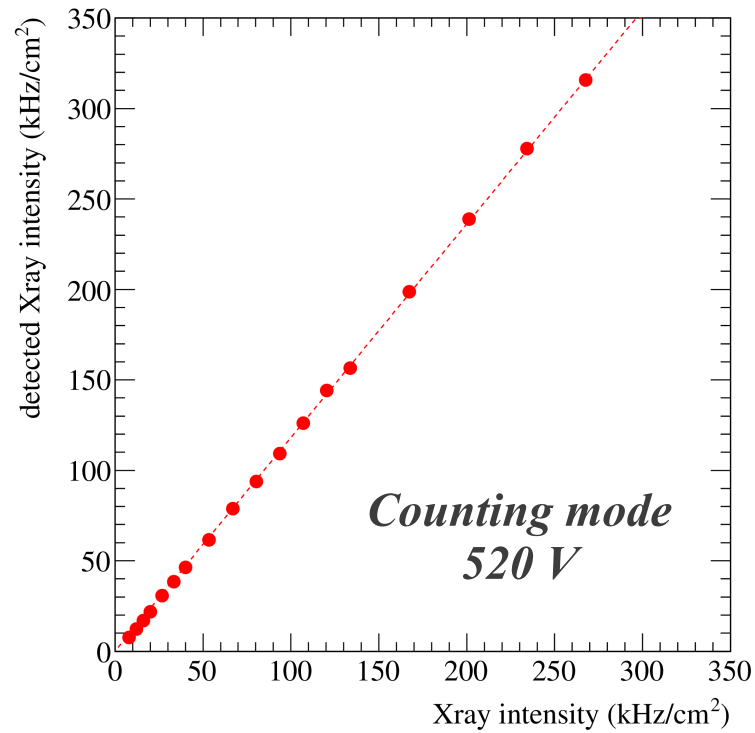
→ linear region suggested below 50 MHz/cm^2

Counting mode

→ linear region extends at least up to 300 kHz/cm^2

Linearity limit between 0.3 & 50 MHz/cm^2
To be continued...





MC simulation: DHCAL pion response & cell size

We don't have a Micromegas calorimeter but we have a model of it

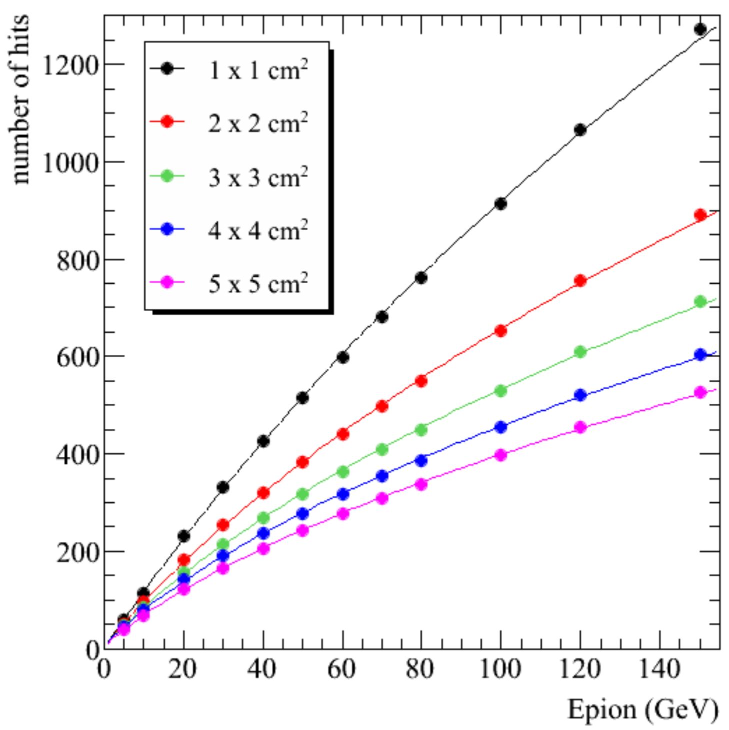
Model: 100 layers of 1x1 m^2 with 1x1 cm^2 pads and steel absorbers (10k pions/E, QGSP_BERT)

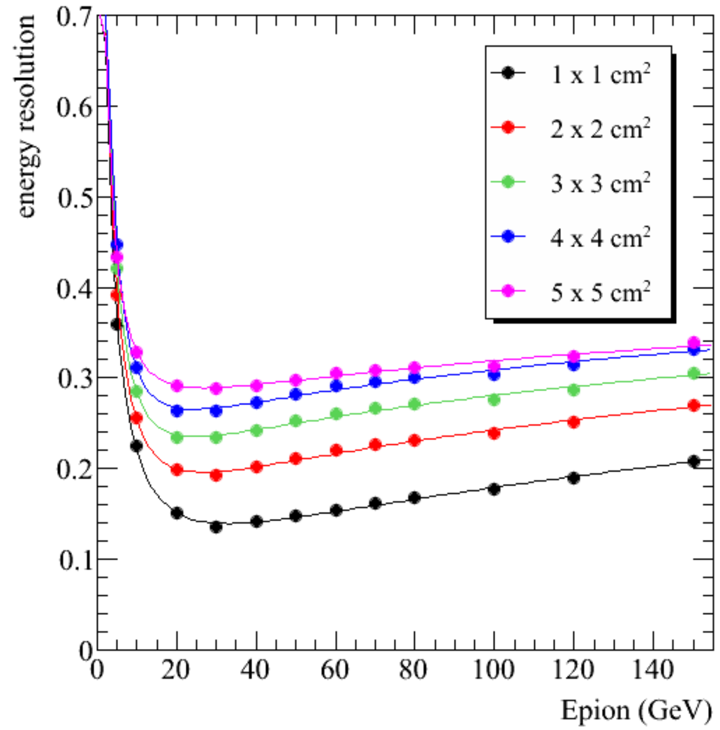
(Pion response with 1x1 cm^2 compares well with testbeam data, so far only check)

Old DHCAL response & resolution, multi-threshold compensation with SDHCAL

New Effect of cell size + hit density compensation

Performance quickly degrades with cell size (as geometric saturation gets worse)





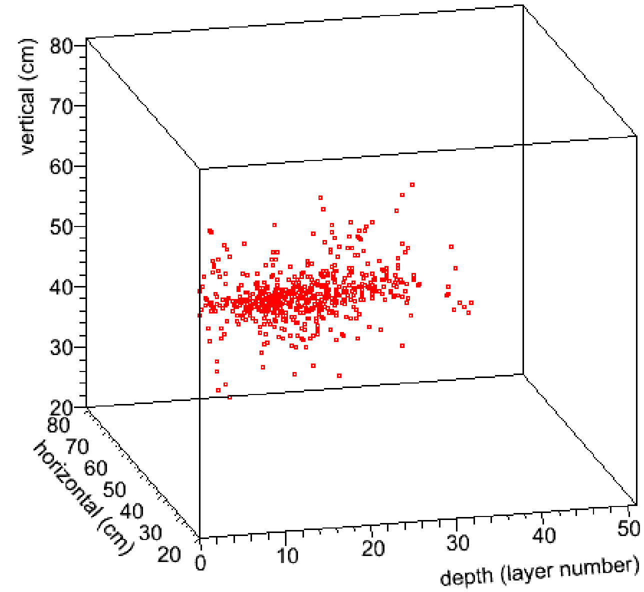
Hit density compensation of DHCAL response (1/2)

Idea: EM core hits have more neighbours than "hadronic" tracks

→ can be identified and weighted accordingly in the energy reconstruction

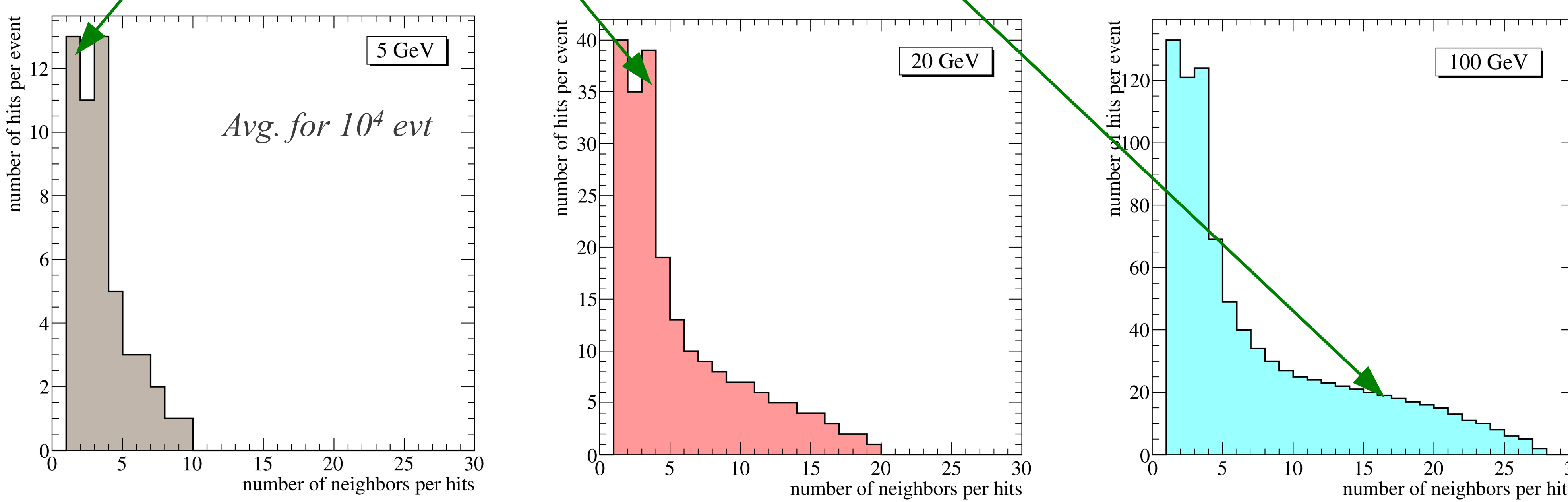
First try: determine weighs of each hit as its number of neighbours

Look at correlation of the sum of the number of neighbours VS pion energy



Neighbours are searched in a 3x3x3 3D cell around each hit

Isolated hits (γ,n) → 1 MIP track → 3 Em core → up to 27



Hit density compensation of DHCAL response (2/2)

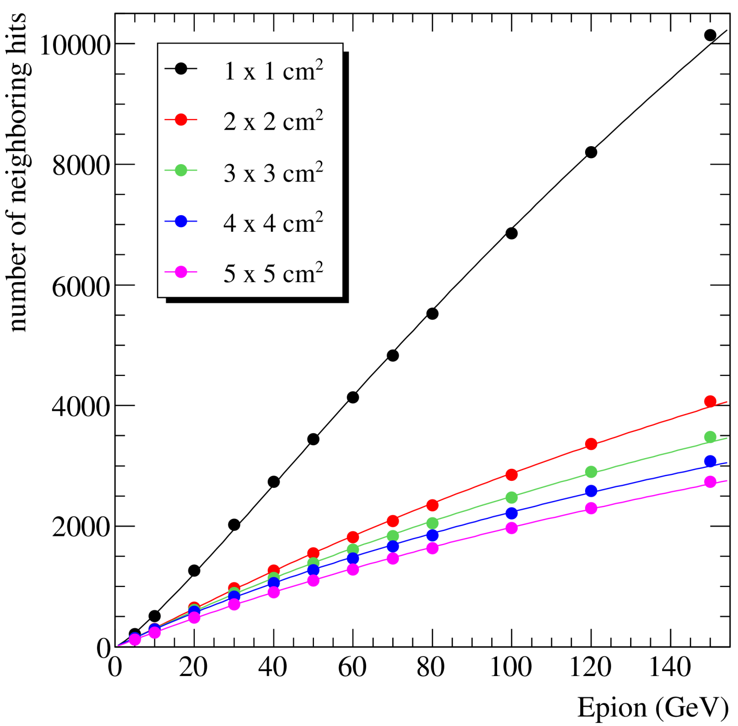
With 1x1 cm^2 cells, the "total number of neighbouring hit" response is only slightly saturated

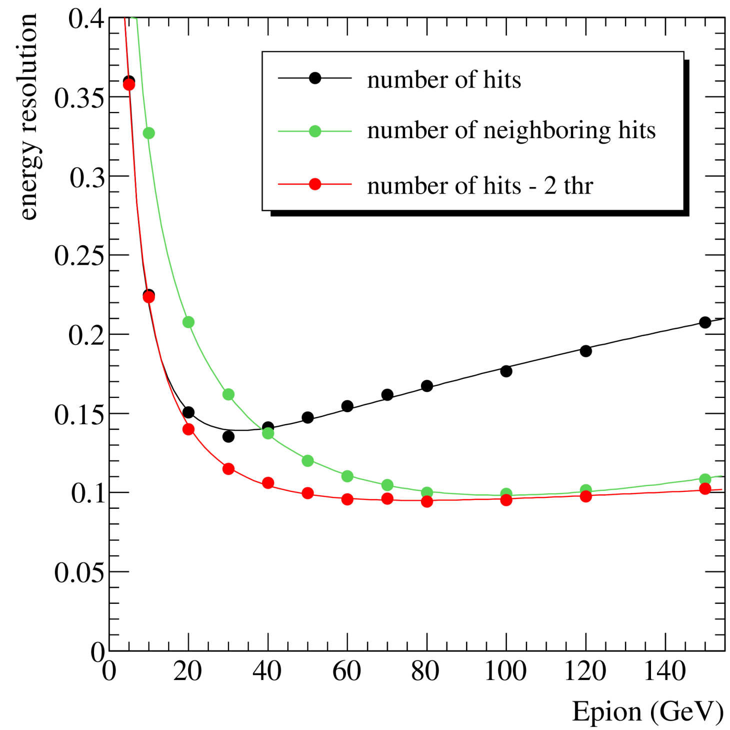
Using a logarithmic parametrisation, the energy can be reconstructed (non-linearity < 5%)

Above 30 GeV, energy resolution improved w.r.t. simple counting approach (sum of hits)

Above 80 GeV, compensation as effective as the one based on multi-thresholds

→ Worth testing on testbeam data (DHCAL, SDHCAL)





Future & conclusion

Large area Micromegas chambers can be built with high and uniform performance

Still, they are rooms for improvement such as *integrating resistive spark protections* inside the chamber during the *ASU* manufacturing process
(instead of soldering 1 diode / channel on PCB)

Immediate step: understand charge-up effect of small resistive prototypes
Next step: construct and test a *large area resistive prototype*

What we would like to do on the longer term: measure instead of simulate
→ *Micromegas HCAL prototype*
→ Proposal submitted to French funding agency, answer in 2014