The Micromegas SDHCAL project, 2012 testbeam results and 2013 activities

CALICE collaboration meeting
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Overview

- Introduction
  - Large area Micromegas, a reminder
  - Multi-threshold readout, motivations and challenges
- Testbeam results of 4 1x1m2 prototypes
  - RD51 and CALICE setups in SPS/H4 and SPS/H2 lines
  - Settings the detector and using the detector, the results
- On-going R&D on resistive detectors
  - Motivations and simulation results
  - Detector design and schedule
- Future R&D and conclusion

The 1x1 m2 Micromegas prototype, a reminder

Active Sensor Unit (ASU)

PCB of 32x48 pads of 1x1 cm2 + 128 µm Bulk Micromegas + 24 ASIC + diode networks for spark protection

MICROROC ASIC

Low-noise preamp + shaper peaking time of 200 ns + 3 thresholds

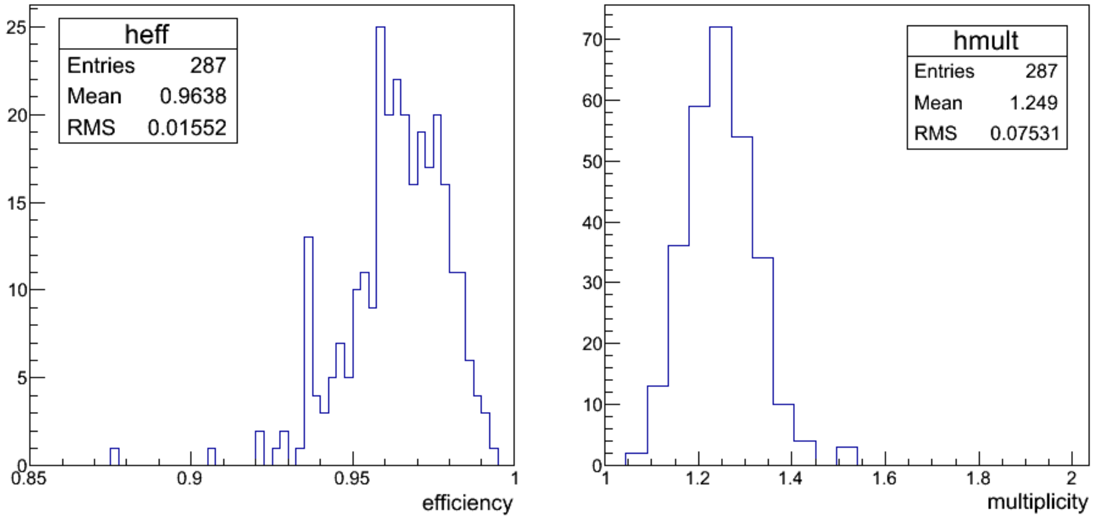
Minimum threshold ~ 1 fC, power consumption 37 mW / per channel @ 3.5 V

1x1 m2 prototype

6 ASU in 1 gas volume, gas thickness = 3 mm, chamber thickness = 9 mm, dead zone ~ 1.5%

MIP efficiency > 95% at low gas gains (~ 1000), hit multiplicity < 1.1 at normal incidence

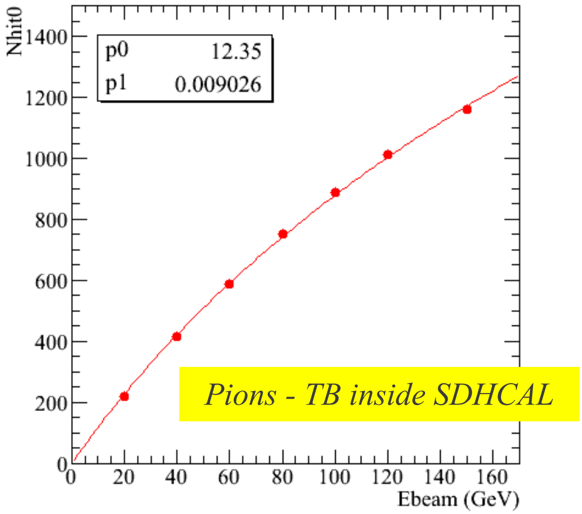
Efficiency and multiplicity – 2 prototypes inside SDHCAL



Readout with 3 thresholds

Motivations *(cf. MC simulation talk in analysis session)*

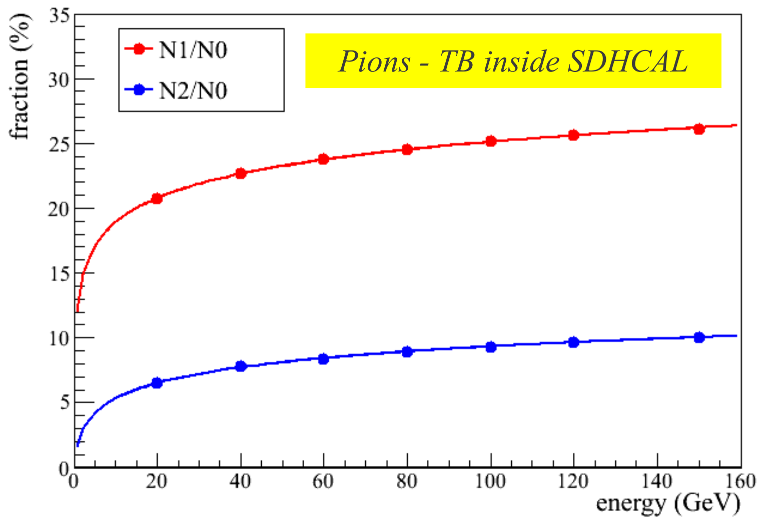
Saturation (EM fraction) in a steel DHCAL expected above 20-30 GeV
→ Resolution gets worse with hadron energy above 20-30 GeV
Promising results of compensation algorithms.



Requirements (fulfilled by Micromegas)

Proportionality between deposited energy and cell signals
→ probability to cross higher thresholds (N1/N0 and N2/N0) increases with hadron energy

Uniform cell response and thresholds to insures that N1 and N2 have the same meaning over all HCAL
→ efficiency to MIP for the 3 thresholds is uniform

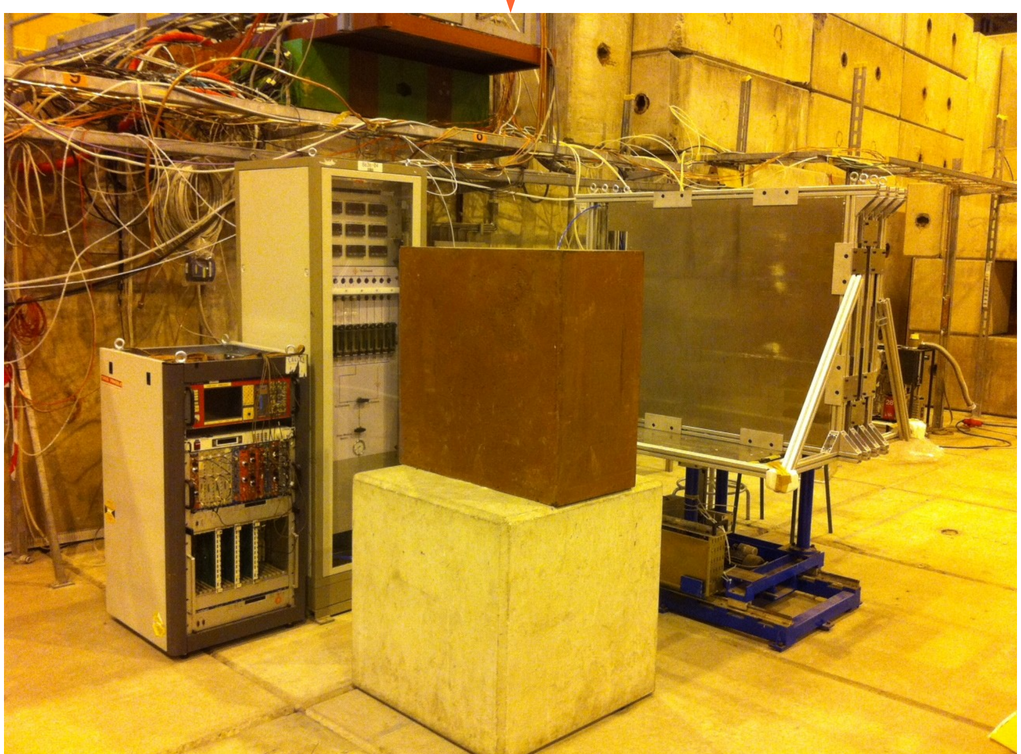


ASU number	1	2	3	4	5	6
ε_0 (%)	97.7	97.5	98.7	98.2	98.2	96.6
m_0 (%)	1.064	1.072	1.079	1.080	1.075	1.079
ε_1 (%)	34.8	36.7	46.4	41.0	38.6	46.0
m_1 (%)	1.033	1.033	1.035	1.035	1.037	1.033
ε_2 (%)	3.7	3.7	4.6	4.0	4.0	4.6
m_2 (%)	1.050	1.057	1.059	1.075	1.052	1.046

Muons – standalone TB

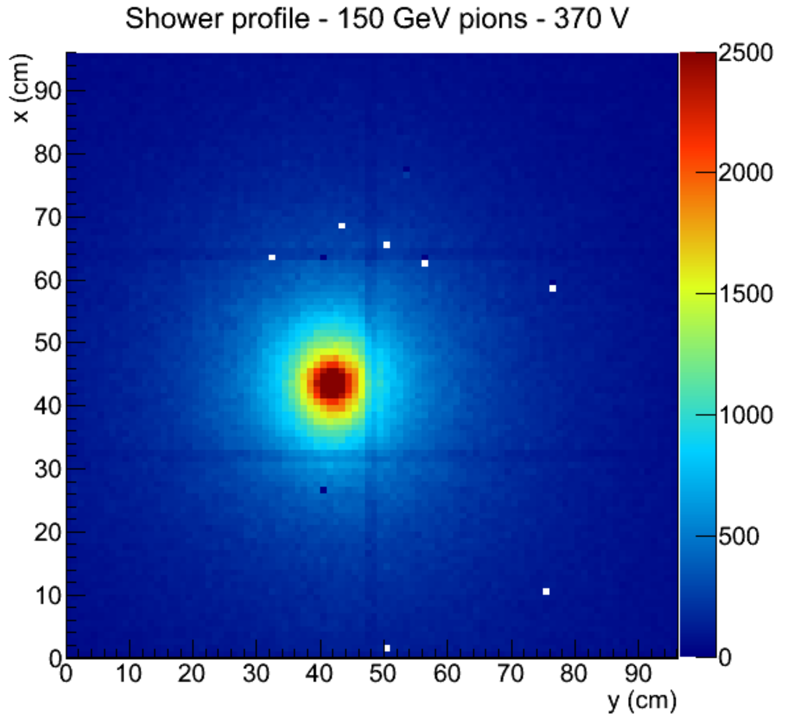
Testbeam activity in 2012

- May: test of 2 Micromegas with 48 RPCs inside SDCHAL with <u>common DAQ</u>!
  (common DAQ = intermediate USB CALICE DAQ developed by IPNL and LAPP)
- November : 3 periods (25 days)
  - RD51 : 4 Micromegas, standalone test in SPS/H2
  - CALICE/GRPC : 4 Micromegas behind GRPC-SDHCAL, acting like a tail catcher
  - CALICE/Micromegas : 4 chambers inside SDHCAL at layers 10, 20, 35, 50 with 46 RPCs



RD51 period: tuning the prototypes

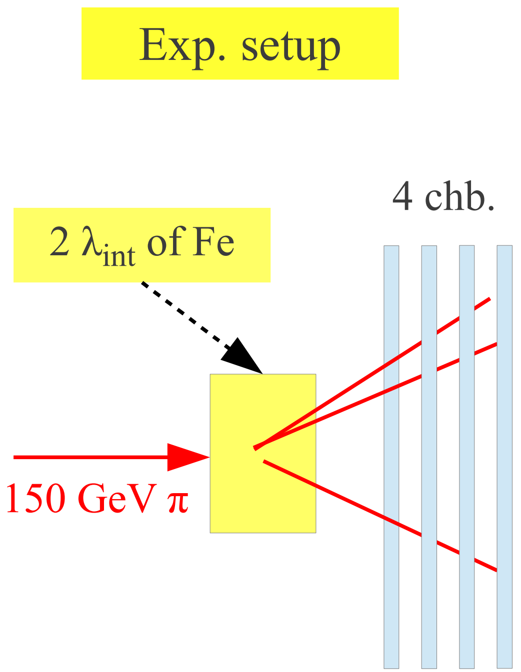
- Questions to answer:
  - At what voltage (or gas gain) to measure showers?
  - How to fix the 3 thresholds in a reliable way?
  - What values for the medium and high thresholds?
  - And some others on stability, rates, sparks etc...

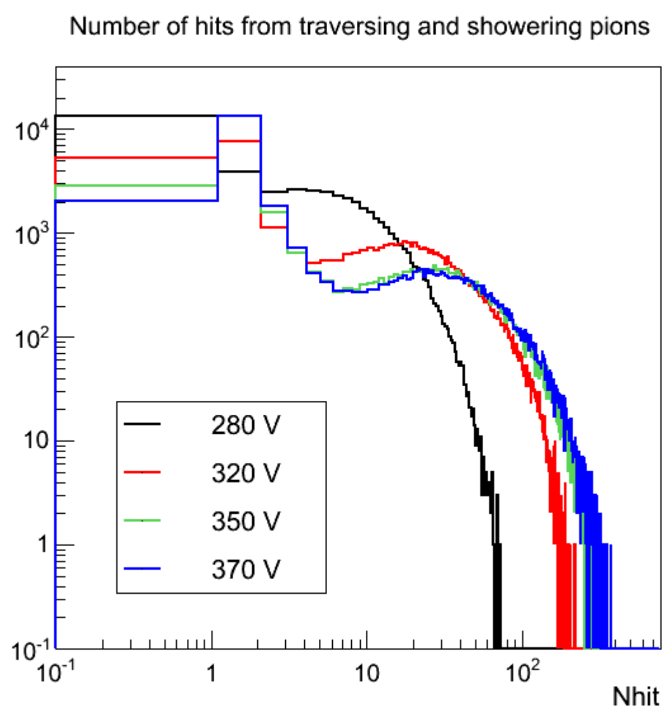


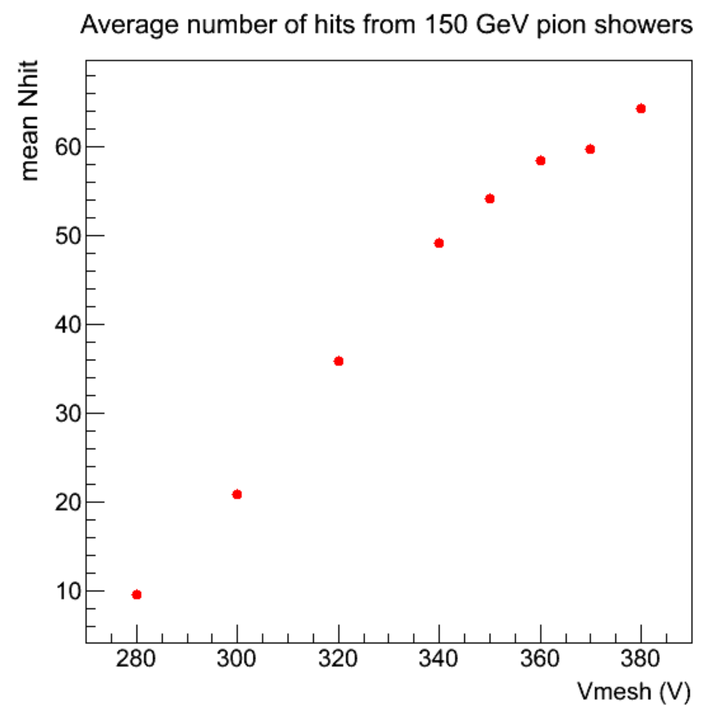
- Detectors: 4 chambers
  Mostly all nicely efficient & noise free
  - #1: all efficient
  - #2: 1 chip missing
  - #3: HV problem on 1 ASU
  - #4: 1 chip missing

- Setup: **PMT - 2 λ_{int} Fe block- 4 chambers**

Necessary gas gain in showers







The number of hits from 150 GeV pions measured after 2 λ_{int} reaches a plateau at 360 V

The penetrating MIPs can be identified with the 4 chambers
They are removed from the average calculation (right plot)

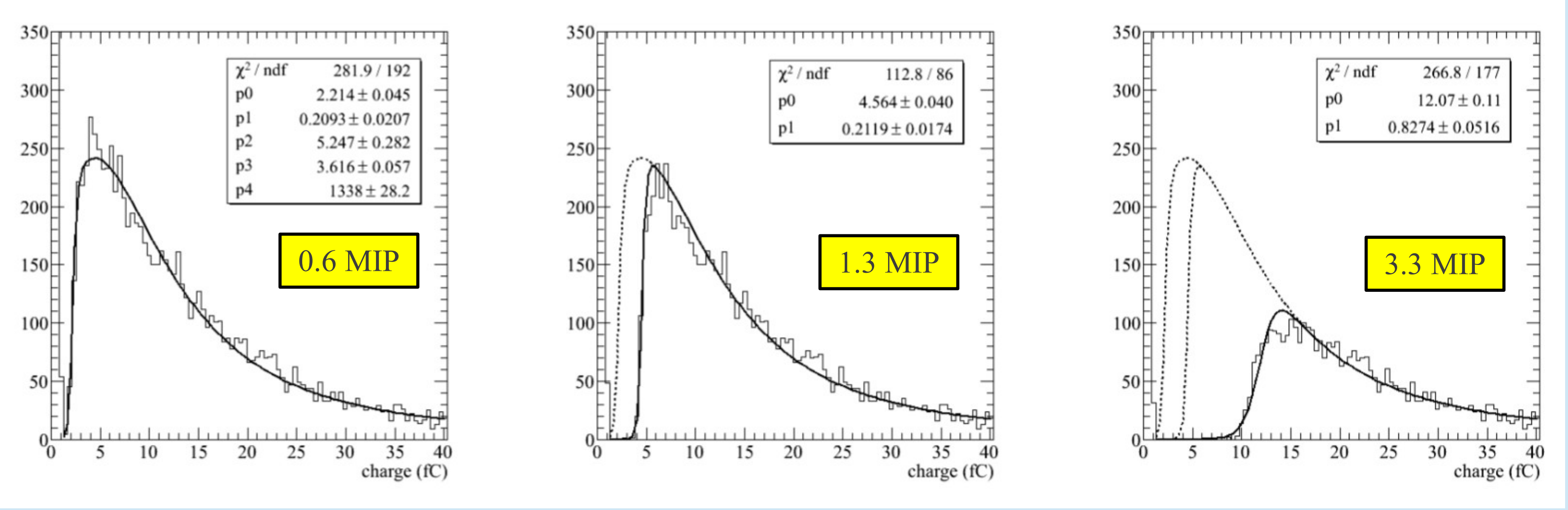
We chose 370 V. Above, the average increases due to the increased hit multiplicity (checked with MIPs too).

A method to set the 3 thresholds

Make use of the analogue readout to set the thresholds directly in terms of the MIP value.

No knowledge of gas gain or electronic gain involved!

Landau distribution with cuts on the passed thresholds



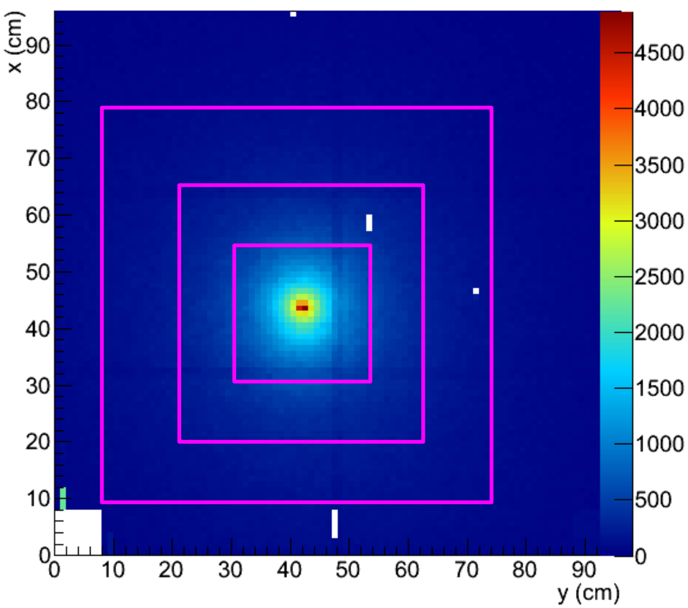
Thresholds can be set in unit of MIP which is the natural energy unit for the HCAL.

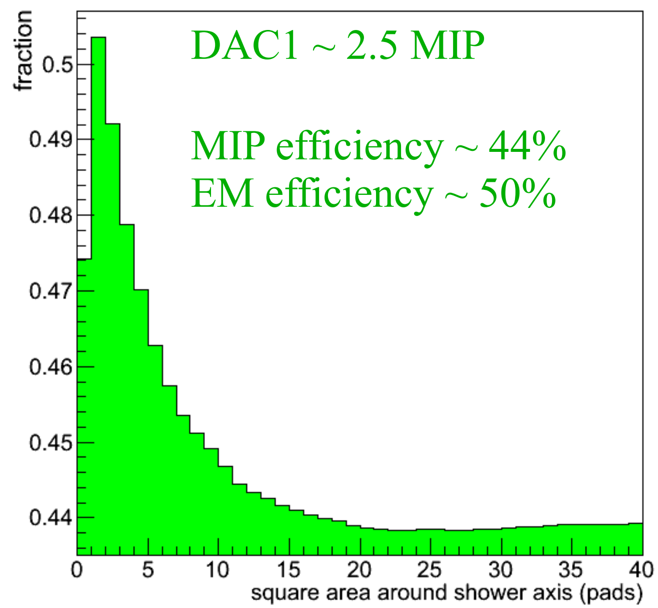
We measured the MIP @ various Vmesh and can set the medium and high threshold at will.

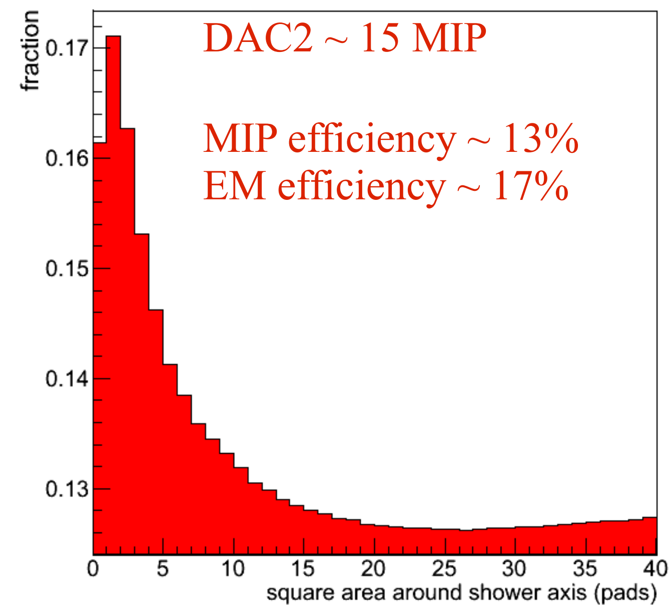
What values for the thresholds?

No definitive answer yet... simulation is catching up... but some ideas

Shower hit profile – 1 chamber | *Ratio N1 / N0 inside square area* | *Ratio N2 / N0 inside square area*







Records profile from 150 GeV pion showers

Sum up hits in a square window and look at fraction of hits N1/N0, N2/N0 → EM & MIP parts

Want large difference between EM & MIP fractions but still some efficiency to EM core

Trade-off: we chose 5 MIP and 15 MIP finally.

CALICE period: measure the Micromegas pion response

- Measure response of a virtual 50 layers Micromegas SDHCAL
  from the longitudinal profile of hadron showers at various energies (20-150 GeV)
  - *This measurement is possible with a limited number of chambers, e.g. 4*
    → Proof-of-principle: Micromegas talk in Cambridge C.M.

- Running
  - Manpower from LAPP, CIEMAT, UCL, CERN, LLR
  - Remote support on Xdaq from IPNL (essential)
  - **Severe beam loss** (~ 50%)
  - Power-pulsing MICROROC configuration partly understood
    → Micromegas was running **without PP**

Event rate ~ 100 pions / spill

- low intensity pion beam (<50 Hz) in H2
Difficult without an important muon contamination

- SDHCAL is self-triggered.
At low beam rate, 50% of reconstructed events are cosmics.

About 5-15 % of the reconstructed events are pions.

Pion E(GeV)	Nshower
20	21580
30	21049
40	20149
60	20433
80	20750
100	17500
120	16000
150	12500

From longitudinal profiles to the pion response

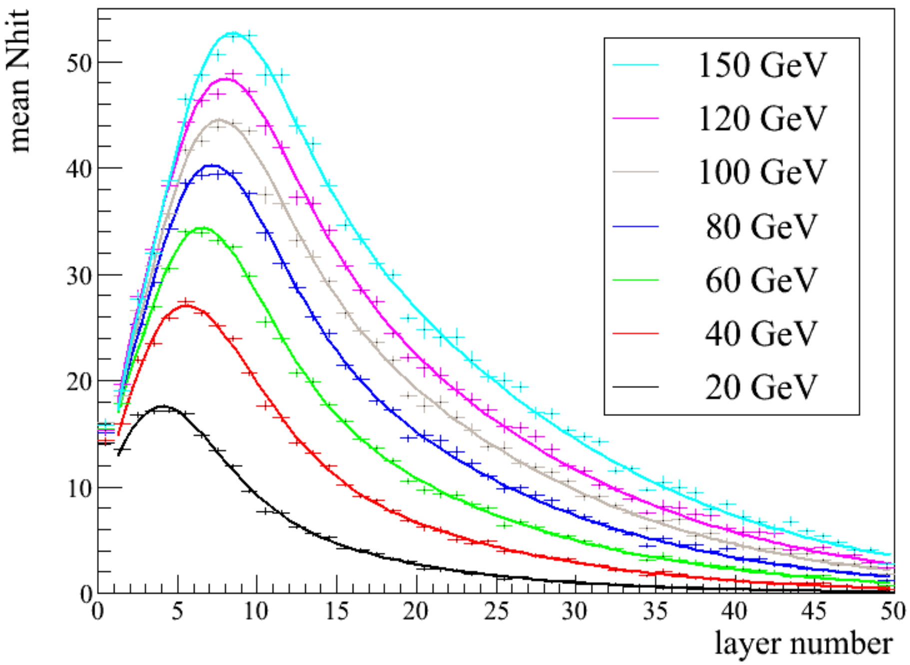
Analysis

Simple algorithm to find shower start (to be optimised with MC)

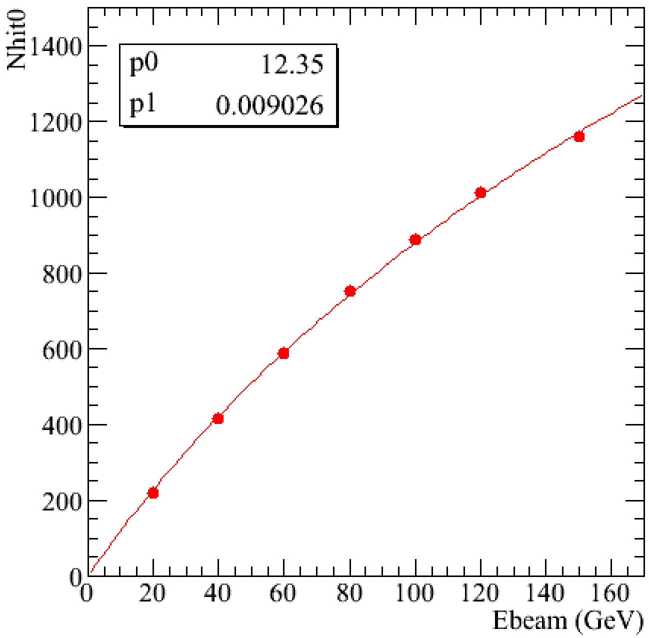
Average Nhit obtained by integration of the profile up to 100 layers (leakage correction!)

Response of a virtual Micromegas SDHCAL well described by a logarithmic function up to 150 GeV

Longitudinal profile of pions showers (low thr.)



N = A/B . log (1 + B.E)



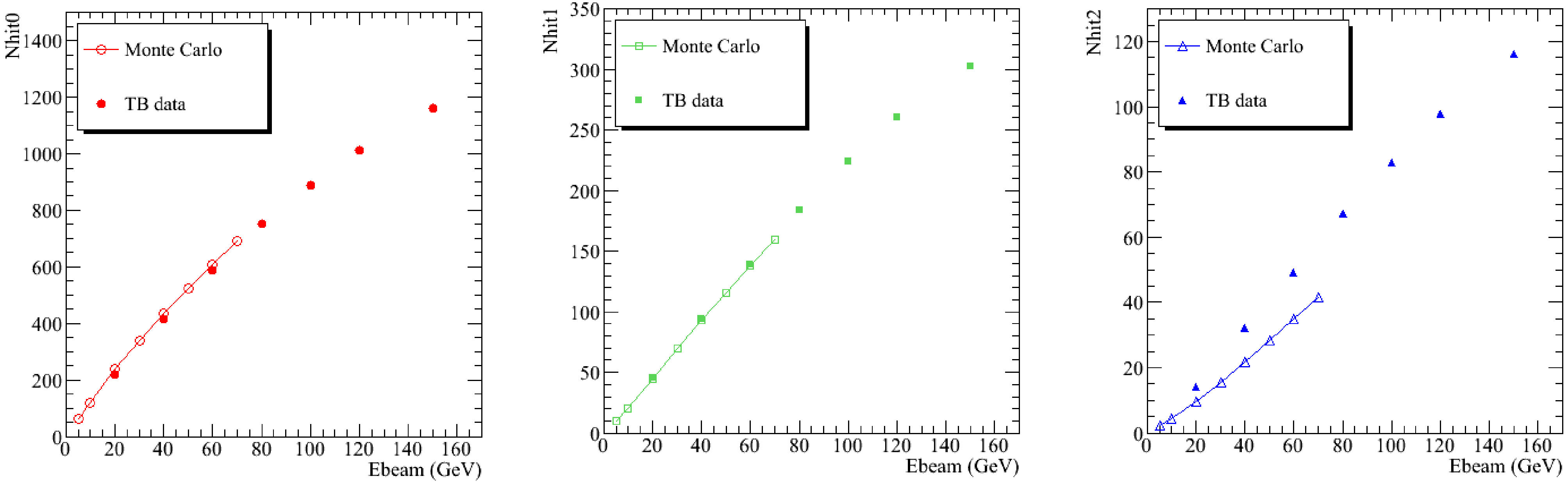
Comparison of threshold trends to Monte Carlo

<u>Monte Carlo simulation of a 100 layers Micromegas SDHCAL</u>

thr0 ~ 0 thr1 = 5MIP thr2 = 15 MIP

Average Nhit taken as the mean of Nhit distribution (not from the shower profile)

Low threshold *Medium threshold* *High threshold*



Very good agreement for low and medium thresholds

High threshold harder to reproduce (Landau tail → treatment of delta rays in Geant4?)

On-going R&D on resistive detectors

Micromegas prototypes perform very well and may be best suited for a SDHCAL

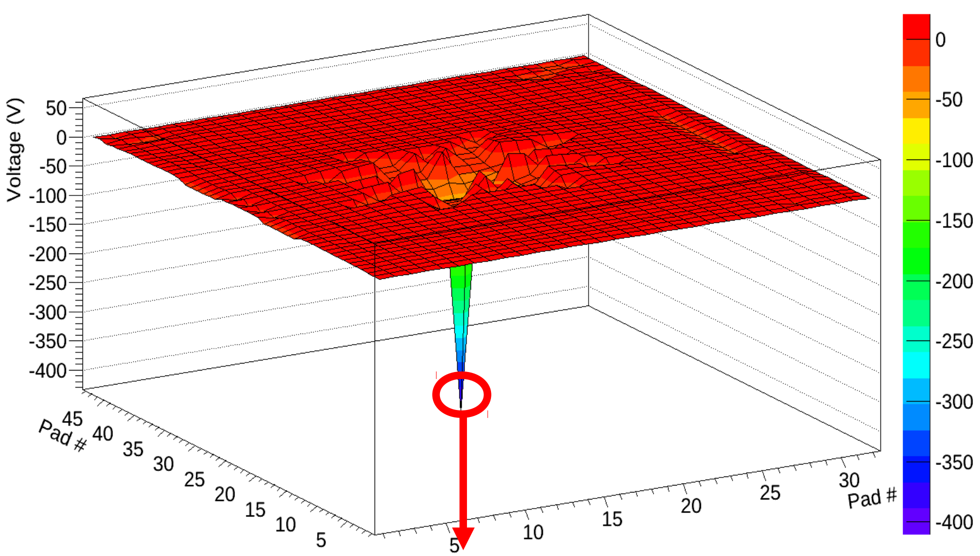
But they are more expensive: <u>6 meshes / m2 + lot of passive components for spark protections</u>

→ replace diodes by a resistive layer

Simulation to compare standard and resistive configurations in a 32x48 cm2 ASU geometry

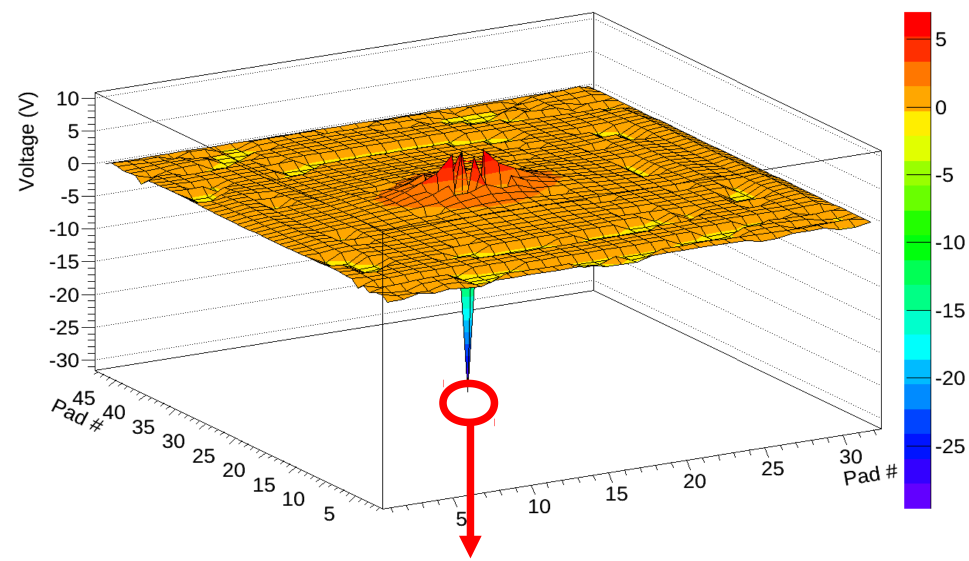
→ Voltage drop on readout pads

Standard configuration
($C_{pad/gnd}$ = 40 pF)



Discharge pad @ -410 V, neighbors @ -60 V

Resistive configuration
ρ = 1 MΩ/□ & $C_{resist/pad}$ = 2,2 pF)



Discharge pad @ -30 V, neighbors @ -6 V

On-going R&D on resistive detectors

Other issues related to resistive detectors

Space charge

Loss of proportionality: yes but at very high gas gains

Loss of rate capability: yes but at very high rates

→ Not an issue in the case of a Micromegas SDHCAL

Charge spread

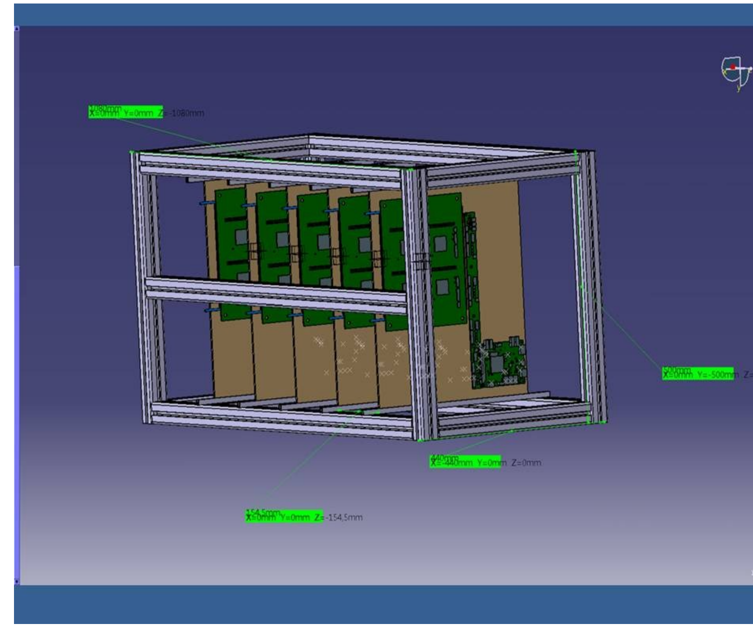
Increase of hit multiplicity

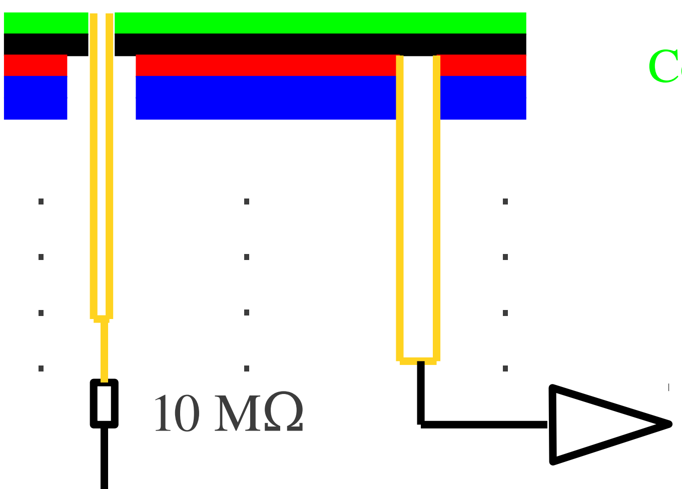
Depends on the kind of resistive configurations

→ Find the optimal configuration

→ Prototypes of 16x16 cm2, expected in May

→ Testbeam at DESY in July





With PCB vias

Couche resistive

Isolant

Pad

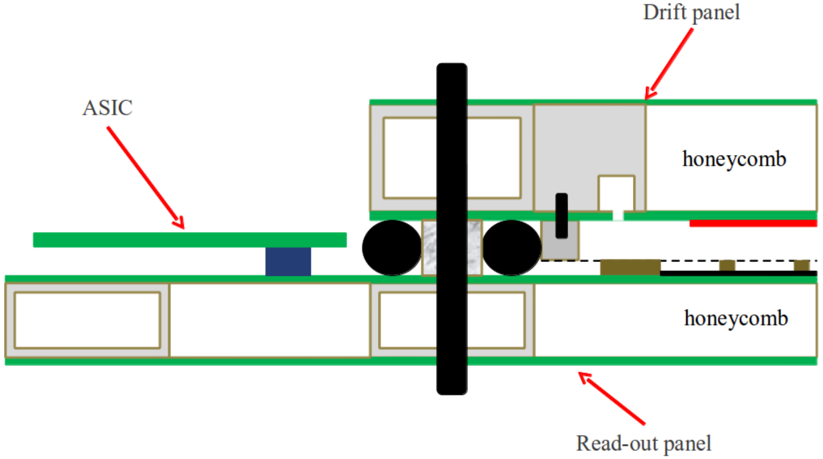
PCB

With buried resistor

Longer-term R&D: single mesh detectors

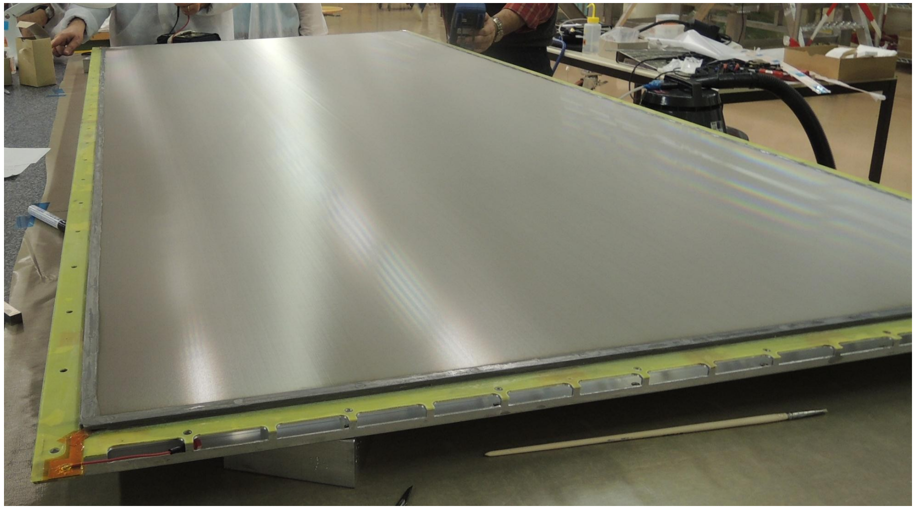
- Important level-harm to reduce cost but very challenging!
  - The mesh is not part of the PCB anymore
  - Requires a radically different mechanical design

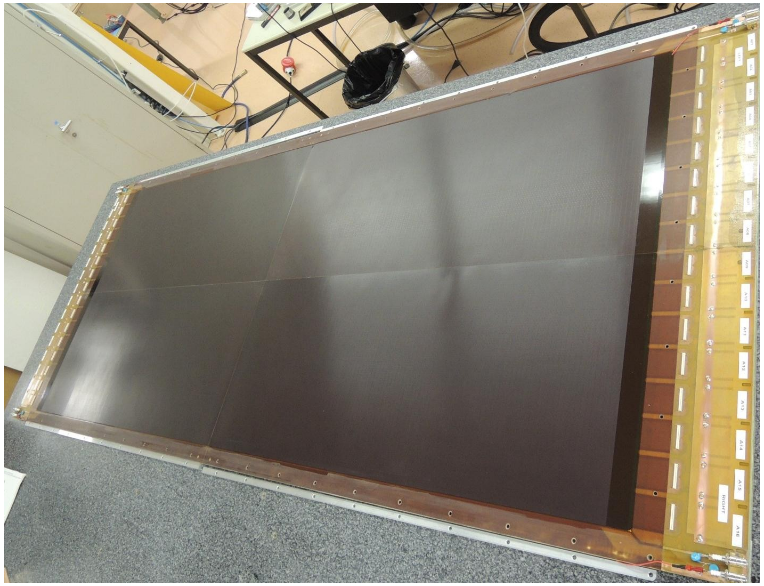
- Get inspiration from the ATLAS upgrade Micromegas group
  - Muon chambers: no thickness constraints but interesting ideas
    - Decoupling of anode plane & readout plane
    - Polarise readout pads and keep mesh @ ground
    - Single mesh prototype of 1x2 m2 works



Readout plane with resistive strips

Mesh is part of the drift plane





Conclusions

- Four 1x1 m2 Micromegas prototypes have been built and tested
  - Performance compatible with requirements for a SDHCAL
  - Calorimetry measurement inside CALICE SDHCAL!
  - Analyse and publish results this year

- Simulation activities emphasized in analysis session
  - Understand the performance of (S)DHCAL
  - Compensation algorithms

- Focus now on ways to reduce costs
  - Resistive detectors to be tested in beam this summer
  - Single mesh detector: come up with a new design next year, maybe a prototype