Beam test of a small MICROMEGAS DHCAL prototype

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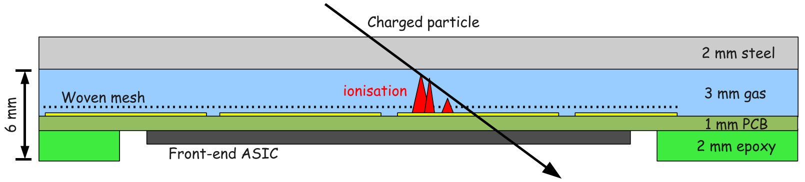
Outline

Introduction

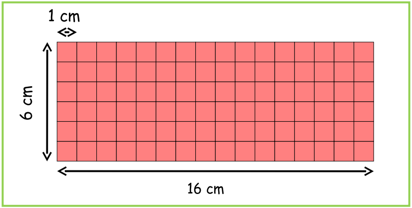
- Micromegas for a DHCAL:
  - fast, radiation hard, good ageing properties, robust, large area, high gas gain, spark proof, standard gas mixture (Ar, iC_4H_{10}, CO_2)
  - small avalanche charge $\rightarrow$ sensitive front-end electronics

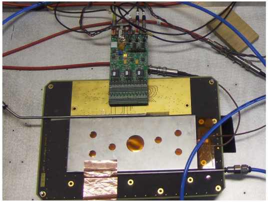


- R&D activities at LAPP:
  - fabrication and test of thin detector of large area (up to 1 m^2)
  - simulation, DAQ (DIF), mechanics (SiD), electronics (DIRAC)

Experimental setup

- Chamber geometry
  - Anode PCB with 1 cm^2 anode pads
  - Bulk MICROMEGAS: 128 μm gap mesh laminated on PCB
  - Plastic frame and steal cover define a 3 mm drift gap

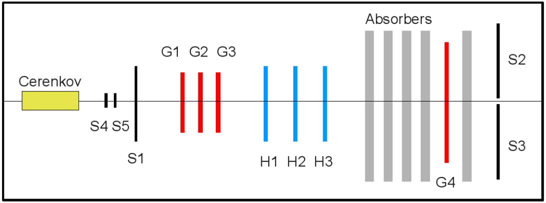




- Readout electronics
  - GASSIPLEX chip: 16 channels with preamplifier and shaper
  - 4 boards with 6 chip each, multiplexed ouput
  - Digitization by 10 bit ADCs connected to a PC
- Ar/iC_4H_{10} 95/5: high gains ($20{\cdot}10^3$) at moderate voltages ($\leq$ 450 V)

Experimental setup

- CERN/PS beam (T10 zone): $e^{\pm}$, $\pi^{\pm}$, $p^{\pm}$ up to 10 GeV
- Chambers
  - 3 6×16 cm^2 chambers with GASSIPLEX readout (G_1–G_3)
  - 1 12×32 cm^2 chamber with GASSIPLEX readout (G_4)



- Trigger
  - 3 8×32 cm^2 scintillators for chamber area scans (S_1–S_3)
  - 2 crossed 2×4 cm^2 sc. for shower profile studies (S_4,S_5)
  - Cerenkov counter to tag 2 GeV electrons/positrons

Energy measurement principle

- The number of ADC counts N measured on a given channel relates to the energy deposited in the gas ϵ above the corresponding pad:

$$N = \frac{q_{\mathrm{e}} G S}{W} \epsilon$$

- Summing over each hit ($t = 3$ fC), the energy deposit is:

$$\xi = \sum_{\mathrm{i}} \epsilon_{\mathrm{i}} = \frac{W}{q_{\mathrm{e}}} \sum_{\mathrm{i}} \frac{N_{\mathrm{i}}}{G_{\mathrm{i}} S_{\mathrm{i}}}$$

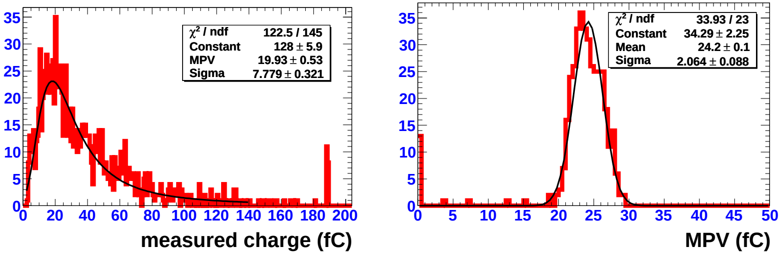
- Using values averaged over all channels:

$$\xi = \frac{W}{q_{\mathrm{e}}} \frac{1}{\overline{G}\ \overline{S}} \sum_{\mathrm{i}} \frac{\overline{G}\ \overline{S}}{\overline{d}} \frac{d_{\mathrm{i}}}{G_{\mathrm{i}} S_{\mathrm{i}}} N_{\mathrm{i}} = \frac{W}{q_{\mathrm{e}}} \frac{1}{\overline{G}\ \overline{S}} \sum_{\mathrm{i}} a_{\mathrm{i}} N_{\mathrm{i}}$$

- However, G_{i} and d_{i} are not known
  $\longrightarrow$ deduce a_{i} from the signal distribution on each pad

Channel inter-calibration

- Measure signal distribution on each pad:
  - Move chamber across the beam, trigger from large scintillators
  - Insure that all charge is collected on one pad → event with single hit
  - Collect between 200 and 500 events per pad



- Inter-calibration:
  - Adjust Landau function on measured distribution → MPV m_i
  - Coefficient a_i given by $m_i/\overline{m}$
  - Correction applied as: N

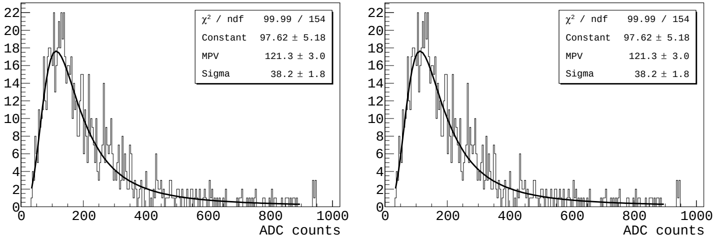
Pressure temperature corrections

- Pressure and temperature variations impact on the gas gain.
  - Writing V the mesh voltage and (A,B) two parameters:

$$G(V) = \exp\left(\frac{APg}{T}\exp(-\frac{BPg}{TV})\right)$$

  - The gain relative sensitivity to P,T variations can be predicted:

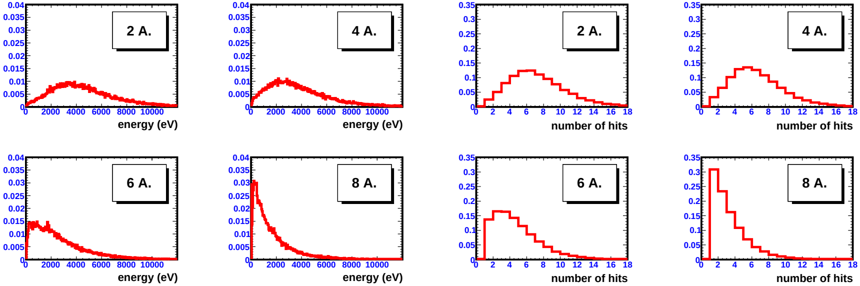
$$C_{P/T} = \left(Ag - \frac{ABPg^2}{TV}\right)\exp\left(-\frac{BPg}{TV}\right)$$



  - The correction is applied as: $N \rightarrow N \cdot (1 - C_{P/T}\,\Delta(P/T))$

Energy and Hit distribution of electron showers

- Check that the high voltage in each chamber is OK
- Insure that a track has traversed the small chambers:
  - request at least one hit in two of the three chambers
  - request aligned hits (centered at the beam profile maximum $\pm$ 1 pad)
- Apply inter-calibration and P, T correction

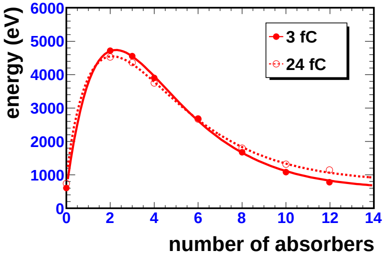


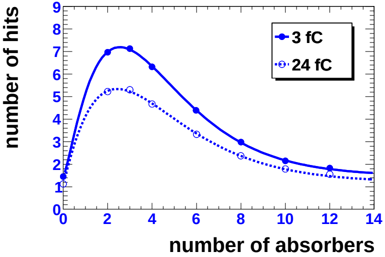
Longitudinal profile of electron showers

- Plot distribution mean versus number of absorber n
  - Adjust 3 parameters on the trend:

$$f(n) = p_0 n^{p_1} \exp(-p_2 n)$$

  - Profile maximum at $n = p_1/p_2$





- Small effect of the threshold:
  - Maximum of $f_{\rm hit}$ reached at a slightly larger depth
  - Most secondaries traverse one pad at the beginning of the shower

Energy and Hit distribution of hadrons

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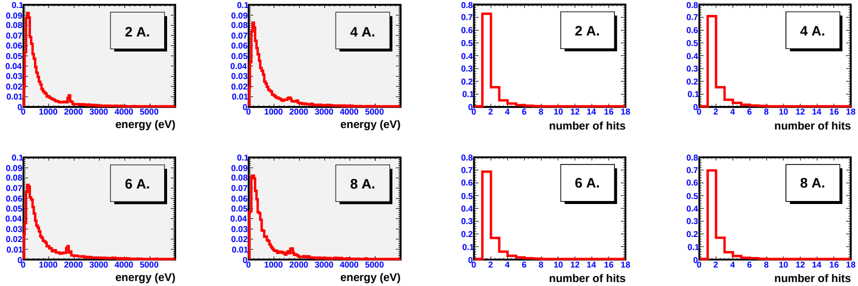

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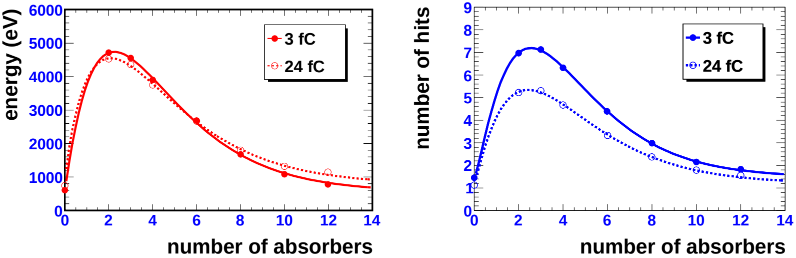
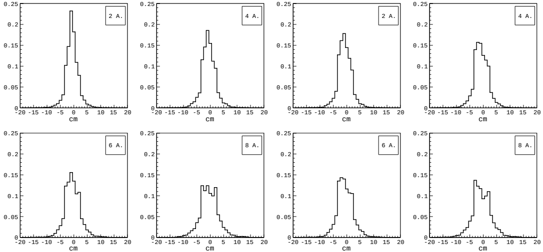


- Comparison with electron showers:
    - Flatter profile, maximum reached at similar depth
    - Small saturation effect

Energy and hit distribution of electrons

- Insure that a track has traversed the small chambers:
  - request at least one hit in two of the three chambers
  - request aligned hits (centered at the beam profile maximum)
- Calculate the distance between hit pad i and shower axis
  - use coordinates (x_0, y_0) of beam profile maximum in large chamber

$$r_i = \pm \sqrt{(x_0 - x_i)^2 + (y_0 - y_i)^2}$$



- Small effect of the threshold:
  - Energy distribution slightly more peaked with a smaller RMS

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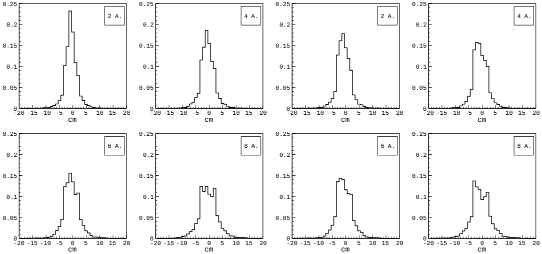

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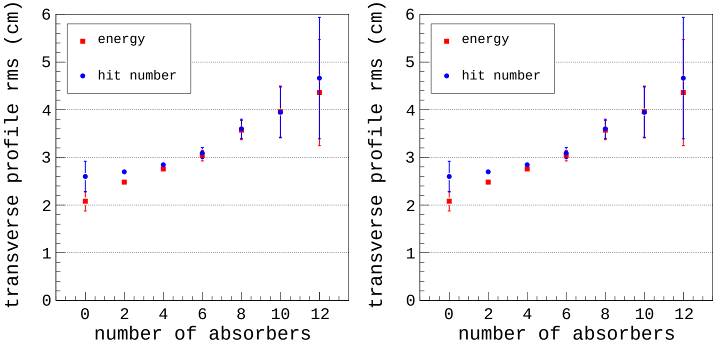
Transverse profile of electrons and hadrons

- Difference between energy and hit profile
  - Hit distribution is flatter at the beginning of the shower
  - Can be seen as a larger RMS
  - Applies for electron and hadron showers



Conclusion

- Micromegas behaviour in 2 GeV electron and hadron showers
  - Stable and high gain during test period (a few HV trips over 12 days)
  - P, T variations can be corrected for, or HV adjusted accordingly
- Electron and hadron shower profile
  - Longitudinal profile of electrons shows more variations
  - Transverse profile is similar
- Energy and number of hit distributions
  - Show a similar trend with the number of absorber
  - Longitudinal distribution maximum shifts deeper at larger threshold
  - Larger transverse distribution RMS for hits at the beginning of the shower