Laboratoire d'Annecy-le-Vieux de Physique des Particules

UNIVERSITE de SAVOIE CHAMBERY ANNECY

IN2P3 Institut National de Physique Nucléaire et de Physique des Particules

CALICE Calorimeter for ILC

Beam test and X-ray study of a Micromegas DHCAL prototype

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LAPP, Annecy

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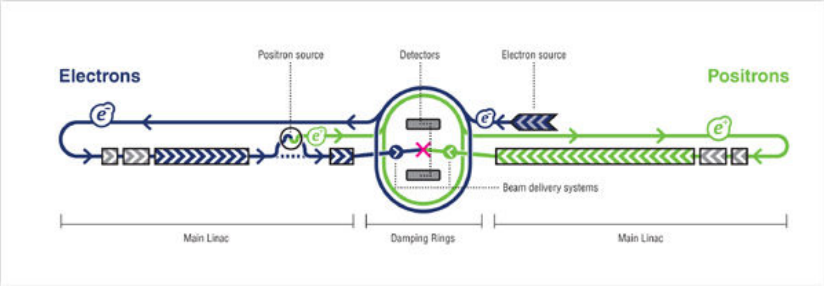
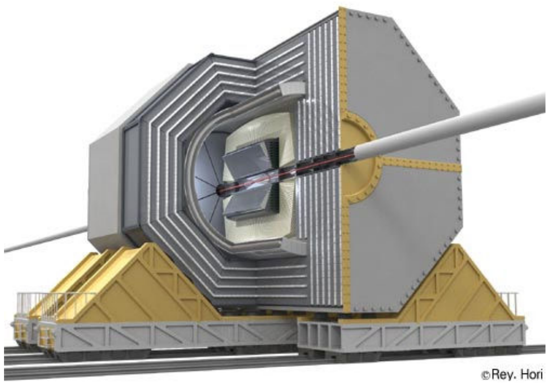
Outlook

- Introduction
  - Hadronic calorimetry at the International Linear Collider
  - DHCAL R&D at LAPP
- Beam test results
  - Efficiency, hit multiplicity, shower profile
- Environmental study with an X-ray source
  - Gain, gas flow, mixing ratio, pressure, temperature, gap
- Conclusion

Calorimetry at ILC

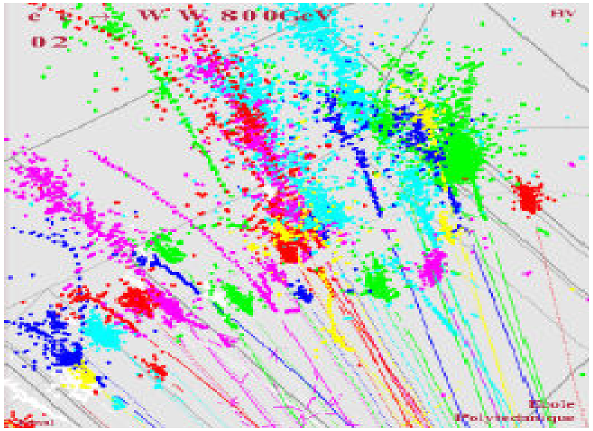


- International Linear Collider
  - e+/e- collisions at 500 GeV, 30 km long
  - Luminosity of 2.10^{34} $cm^{-2}s^{-1}$
  - 1 ms long bunch trains, 199 ms idle
  - Detailed study of EWSB, Higgs boson properties, SUSY particles, extra-dimension models …



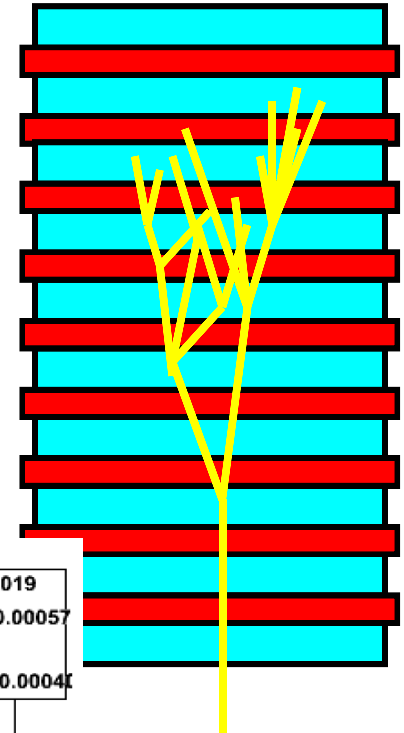
- 3 detector concepts with ≠ tracker and calorimeters
  ILD (TPC) – SiD (Silicon tracker) - 4th (Drift chamber)
  - SiD and ILD based on Particle Flow Approach (PFA)
    - Single particle shower imaging capability
    - Highly segmented and compact calorimeters
    - Resolution goal: 30 %/√E

- Hadronic Calorimeter design
  - Total absorber depth of 4.5 λ, 40 layers, 8 mm gap
  - Small cell sizes (down to 1 cm^2!)
  - Thin sensitive layers (solid or gas)

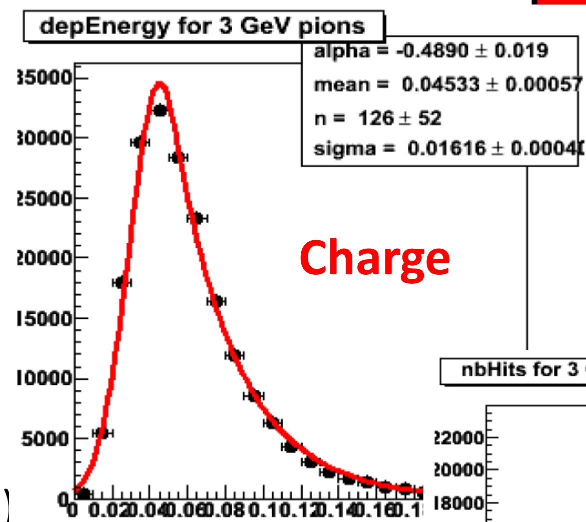


Matching energy deposits in calorimeter with tracks

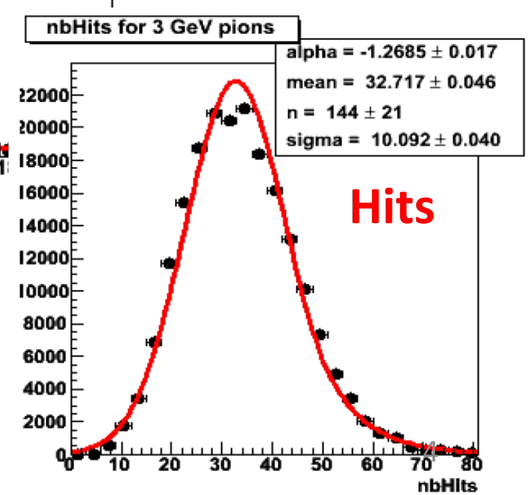
Analog and Digital HCAL



- Total instrumented area of 3000 m^2!
  - Find a compromise between Nchannel and cell size
- Analog HCAL
  - Scintillating tiles of 5-10 cm^2
  - Light readout with SiPM/MPPC
  - 1 m^3 prototype already tested
- Digital HCAL
  - Gas layers with 1 cm^2 pads
  - 1 threshold per pad (single bit info.)
  - GEMs, RPCs, Micromegas
  - ILC oriented ASICs (DIRAC, HARDROC)
- What is best for energy resolution?
  - Measuring charge or counting hits?
  - Actively simulated

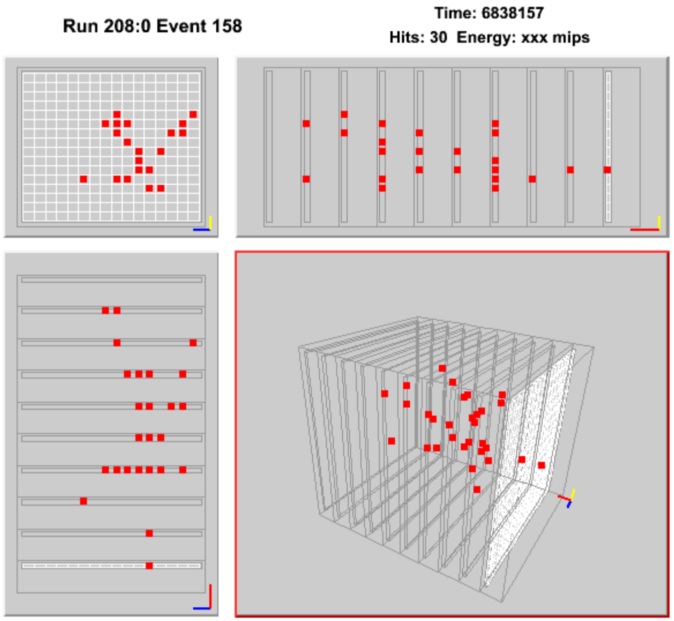


Charge VS Hits



Detectors for a DHCAL

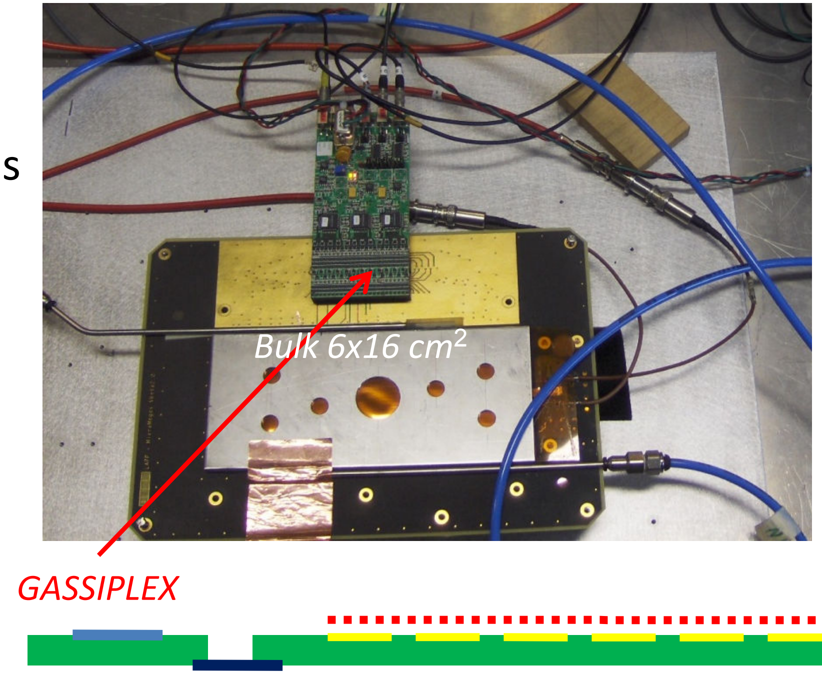
- Different types of gaseous detectors are currently under developments:
  - Glass Resistive Plate Chambers (GRPC):
    - Europe: IPNL (Lyon, France) and IHEP (Protvino, Russia)
    - USA: ANL (Argonne, USA)
  - Gaseous Electron Multiplier:
    - ANL (Argonne, USA)
  - MICRO MEsh GAseous Structure
    - LAPP (Annecy-le-Vieux, France)



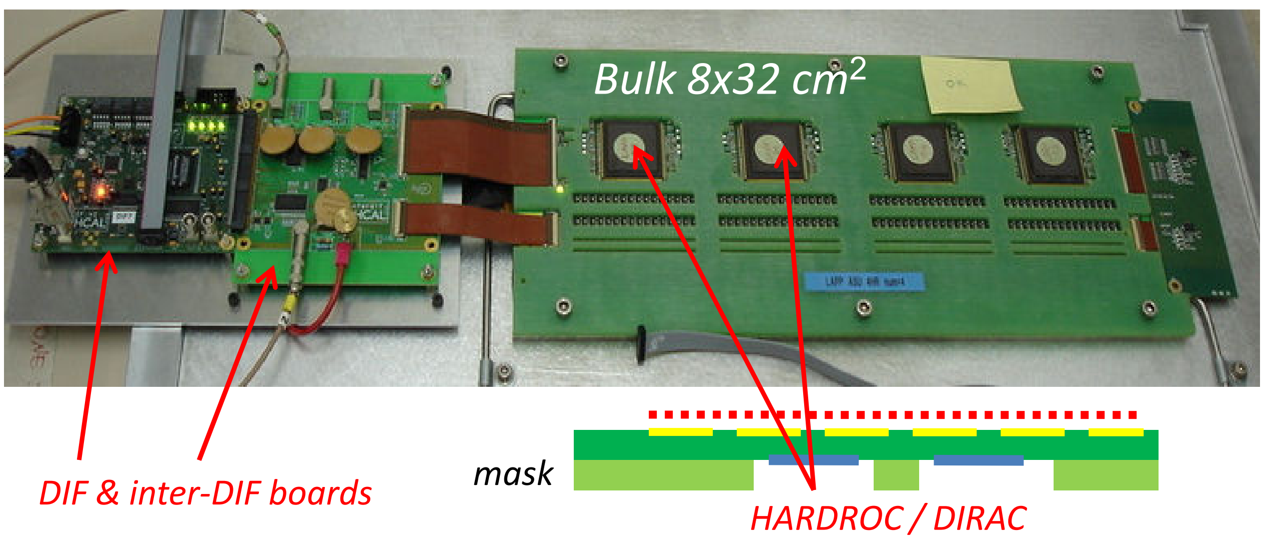
- R&D strategy:
  - Development of small prototypes and their characterization
  - Construction and test of 1 m^2 and then 1 m^3 prototypes
  - Prototype performance comparison → final design for DHCAL

DHCAL R&D at LAPP

- What we are involved in:
  Large area detector (RD51/WG1), Bulk Micromegas
  Physics simulation (see *J. Blaha poster*)
  ASIC development (*see R. Gaglione poster*)
  Detector test:
  3 beam tests since 2008, 2 more this year



- Prototypes: 1 cm^2 pads, 3 mm of Ar/iC_4H_{10} 95/5
  - Analog readout prototypes for characterization (GASSIPLEX chips), 6x16, 12x32 cm^2
  - Digital readout prototypes with embedded electronics (HARDROC/DIRAC chips), 8x32, 32x48 cm^2

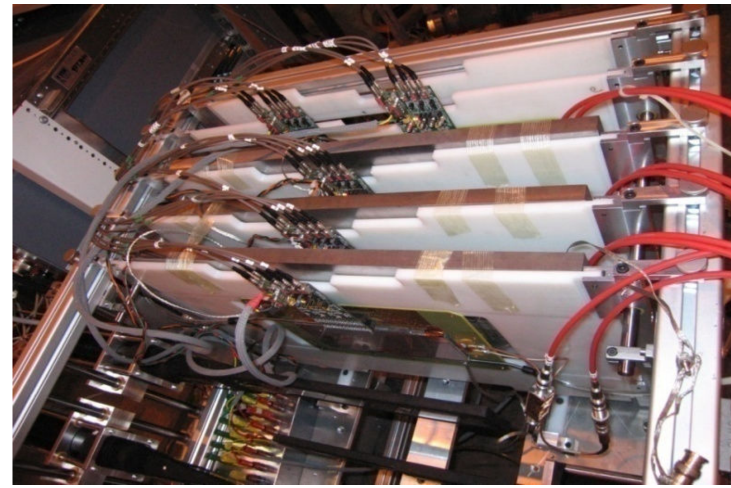


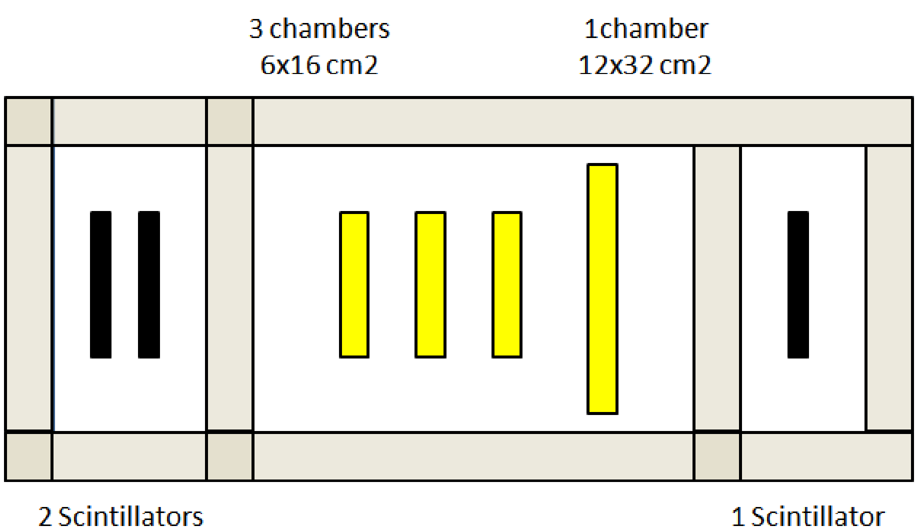
Active Sensor Unit = FE Electronics + PCB + Bulk + drift + cover = 8 mm

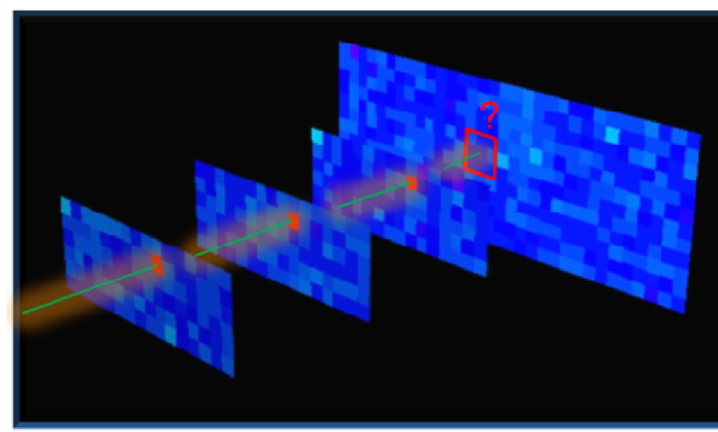
Possibility to chain detectors

Performance of Micromegas chambers

- November 2008 beam test
  - Stack of 4 chambers with 1 cm2 pads
  - Ar/iso 95/5 gas mixture
    Gas gain ~ 10000
  - Bulk with 128 µm amplification gap
  - Gassiplex readout
  - CERN/SPS H2 beam line
    200 GeV muons and pions

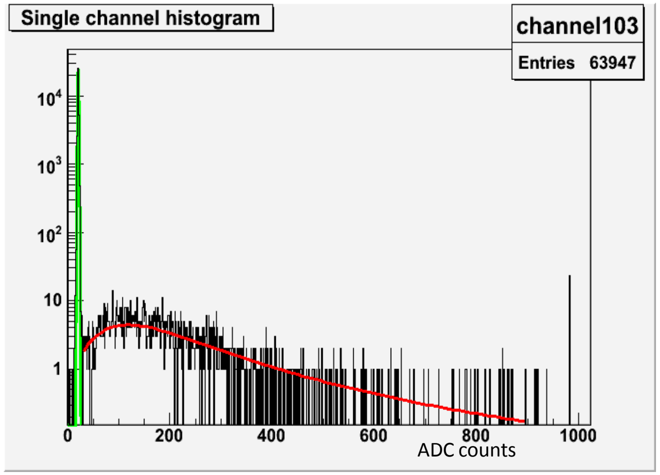






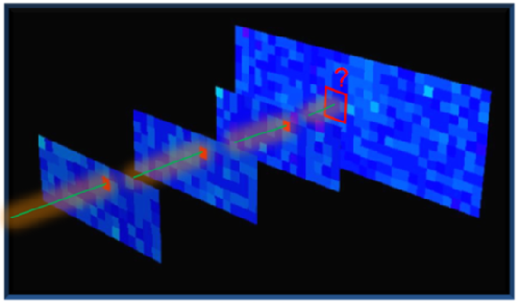
Performance of Micromegas chambers

- Charge distribution on all pads
  - Pedestals at 3 fC
  - MPV of Landau distribution
  - Most Probable Charge ~ 22 fC (110 ADC counts)
  - 10 % variations for largest chamber

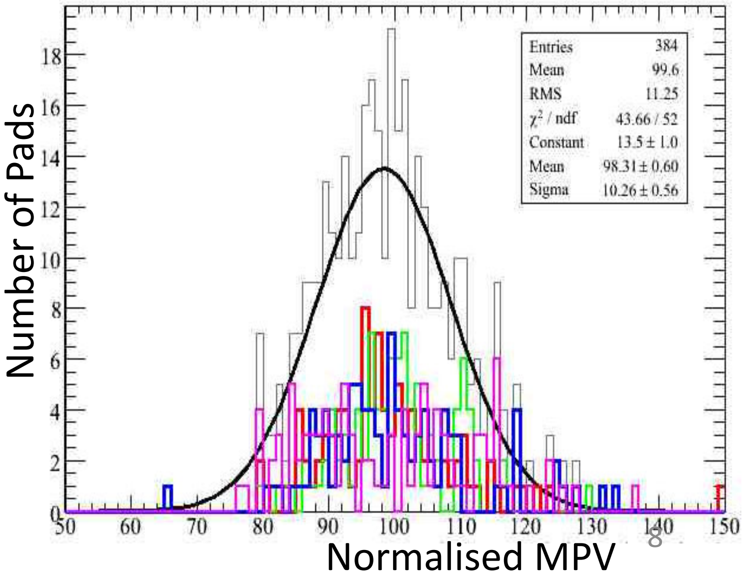


- « Golden events »
  - 93-98 % efficiency to 200 GeV muons

- « Platinum events »
  - Hit multiplicity < 1.1 in all chambers



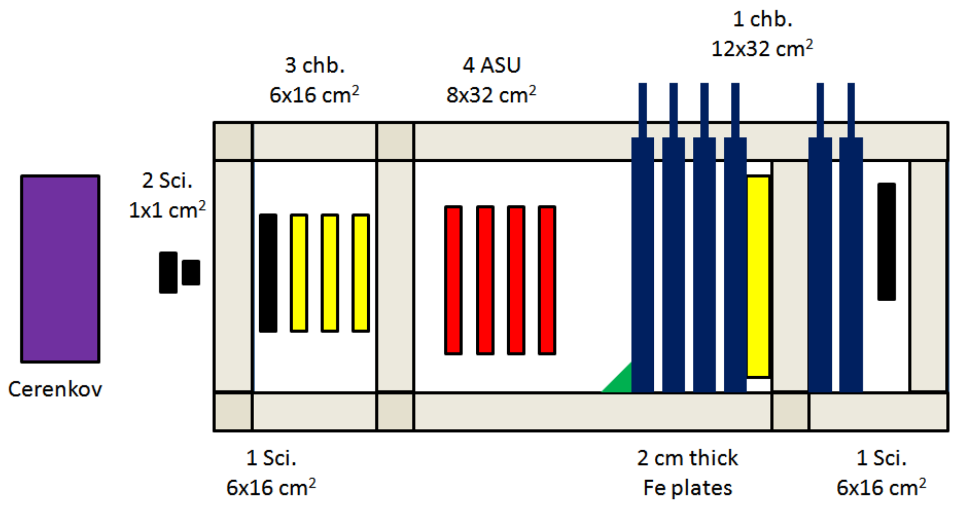
	Efficiency
0	97,05 ± 0,07%
1	98,54 ± 0,05%
Chamber 2	92,99 ± 0,10%
Chamber 3	96,17 ± 0,07%

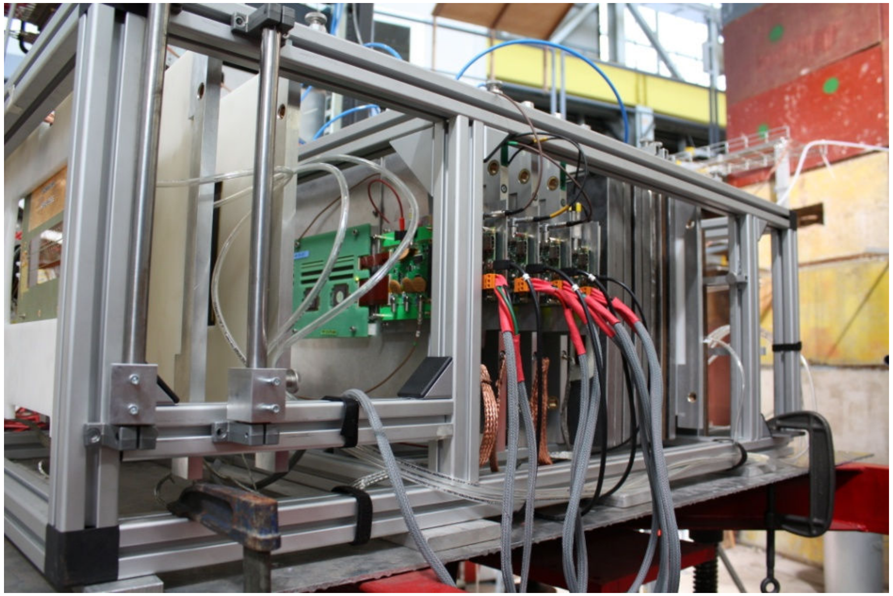


Performance of Micromegas chambers

- May 20th - June 3rd 2009 test beam
  no beam first week, extended till June 10th thanks to ALICE TOF
  - CERN/PS T10 beam line
    - 1-6 GeV electrons, protons and pions
    - Cerenkov counter for electron tagging
    - Small crossed scintillators in front of the chambers OR 2 larger ones

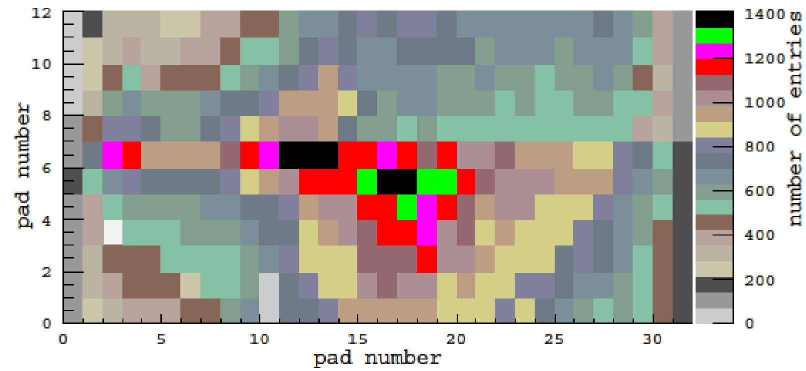
1. Stack of 4 Gassiplex chambers: behaviour in EM showers
   - Shower transverse profiles in largest chamber (12x32 pads)
   - Longitudinal profile by varying the number of absorbers
2. 4 ASU with HARDROC readout: demonstrate proof of working



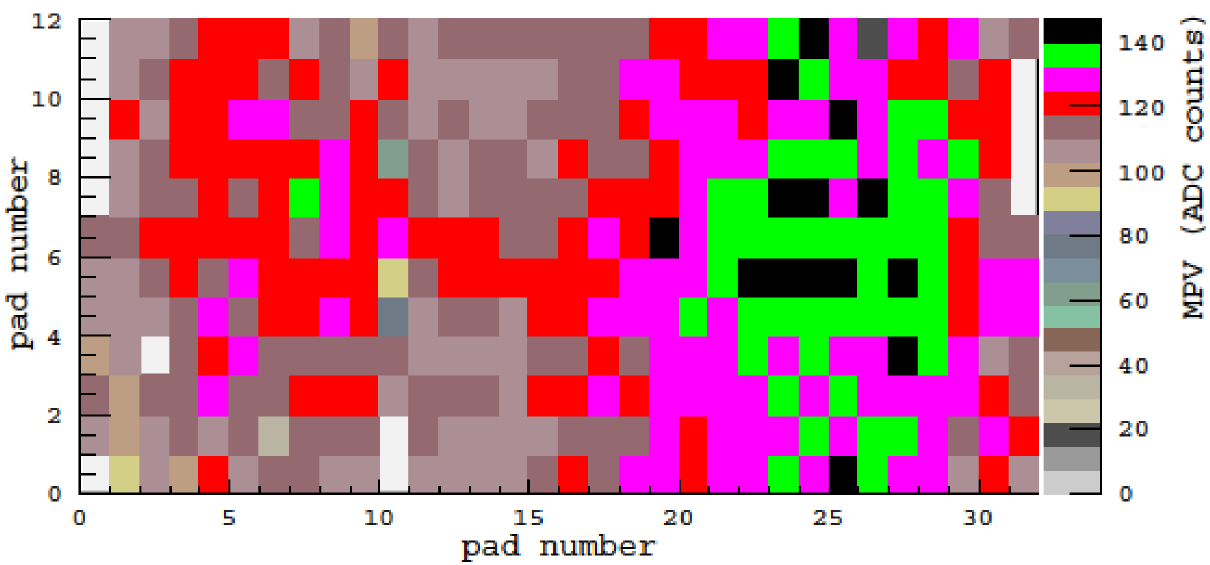


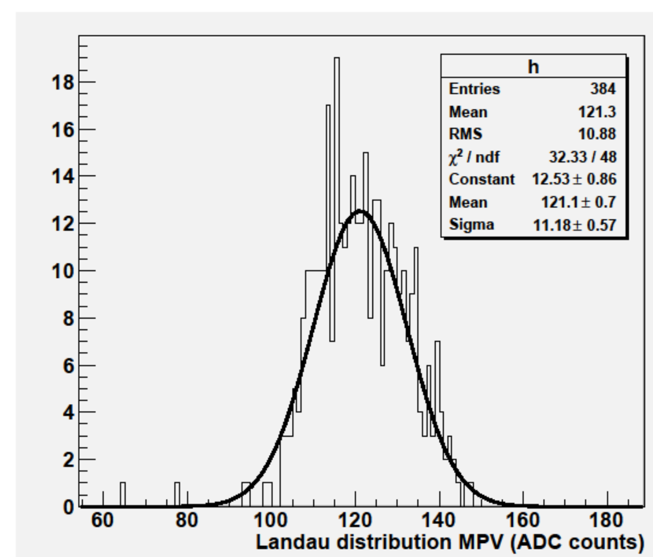
Large chamber response

- Measurement of energy & number of hits in large chamber
  - 4 scans for full chamber
  - Correct for response non-uniformity
  - Measure Landau distribution MPV of single hits (>35 ADC counts) on all pads
  - Trigger from coincidence of large scintillators



- Results
  - Mean MPV of 24 fC (121 ADC counts)
  - Variations of 8% compatible with previous measurement



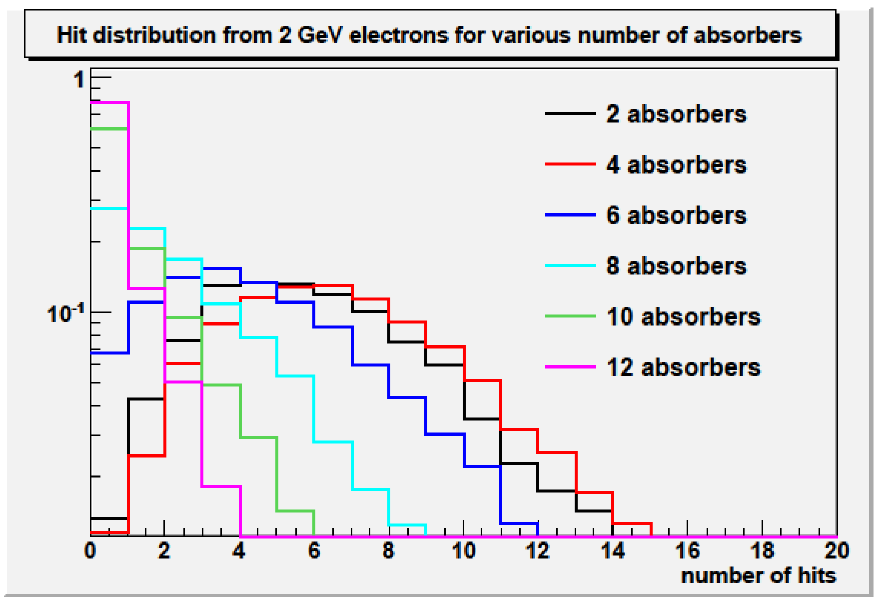


Hit distributions for 2 GeV e-

shower longitudinal profile

- Require at least one hit in 2 of the 3 small chambers (6x16 pads)
- Sum up hits in large chamber
- Take data with varying number of absorber plates

- Longitudinal distribution goes through max. between 2-4 plates
- Qualitative agreement with GEANT4 simulation results (*see J. Blaha poster*)



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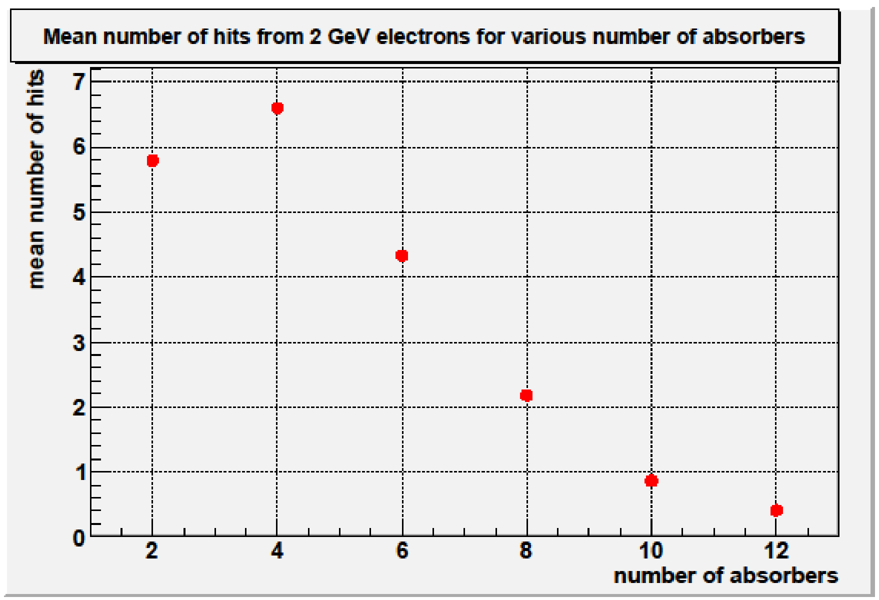


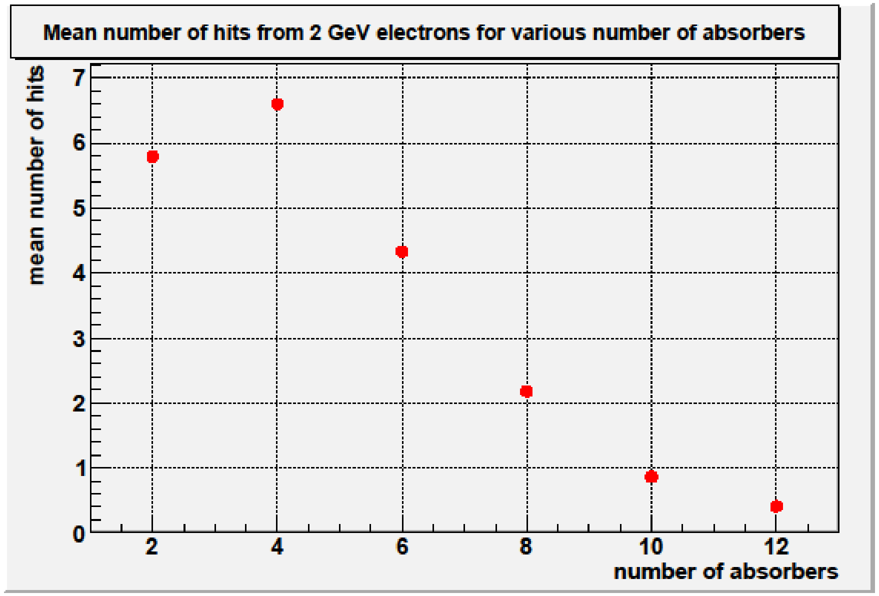
very preliminary

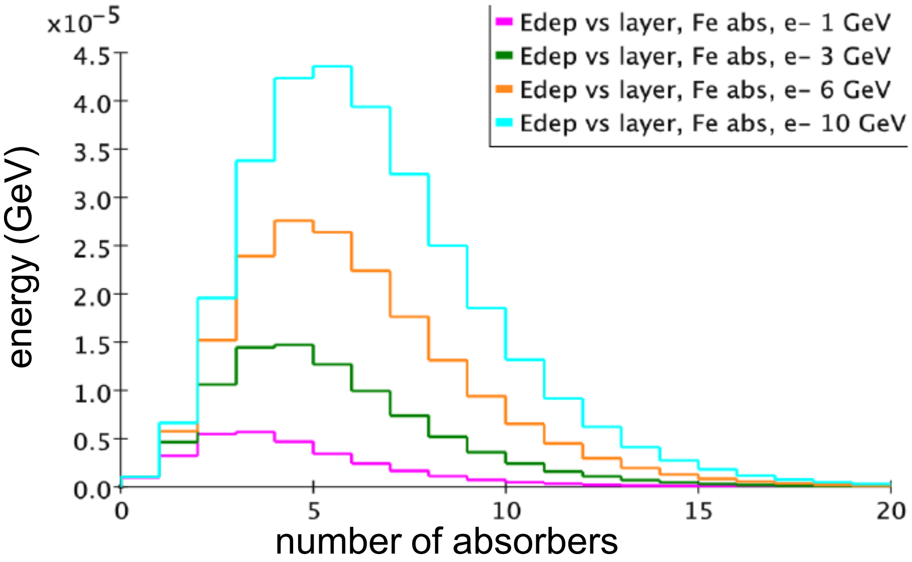
Hit distributions for 2 GeV e-

shower longitudinal profile

- Require at least one hit in three of the small chambers (6x16 pads)
- Sum up hits in large chamber
- Take data with varying number of absorber plates

- Longitudinal distribution goes through max. at 2-4 plates
- Qualitative agreement with GEANT4 simulation results, on-going analysis





very preliminary

Hit distributions for 2 GeV e-

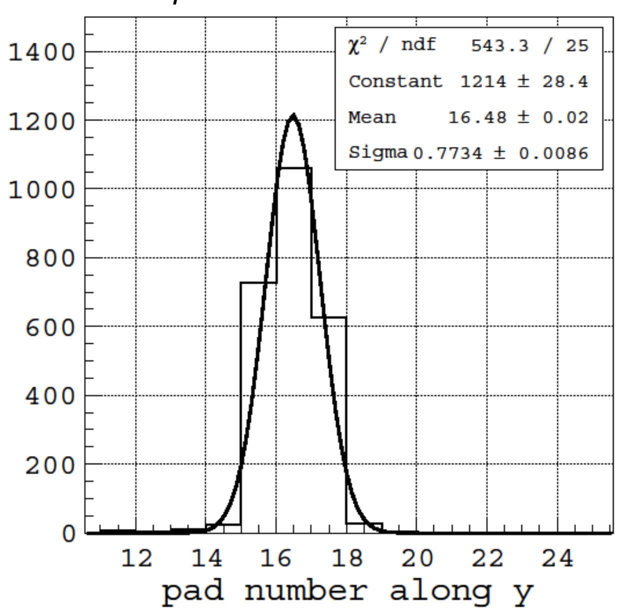
shower radial profile

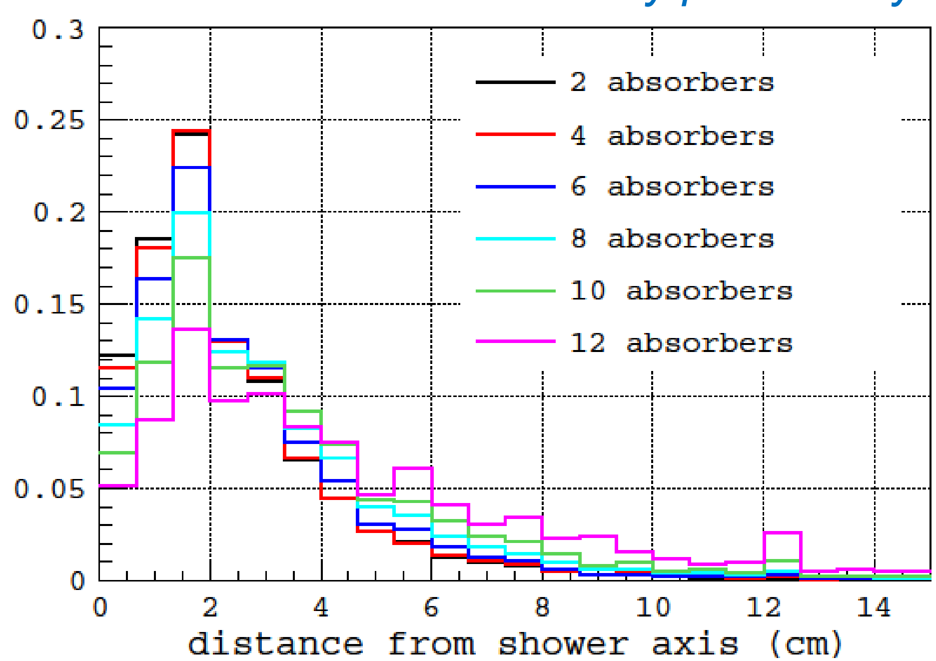
- Measure the hit profile in the large chamber without absorber to determine the shower axis
- Require at least one hit in three of the small chambers (6x16 pads)
- Calculate the distance from the profile center to each hit in the large chamber

- Radial distribution similar in all planes, with a mean radius of 1-2 cm
- Comparison with GEANT4 simulation results is on-going

very preliminary

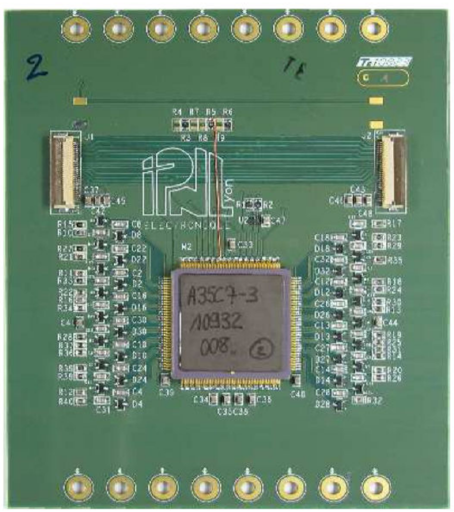
Beam profile in one direction

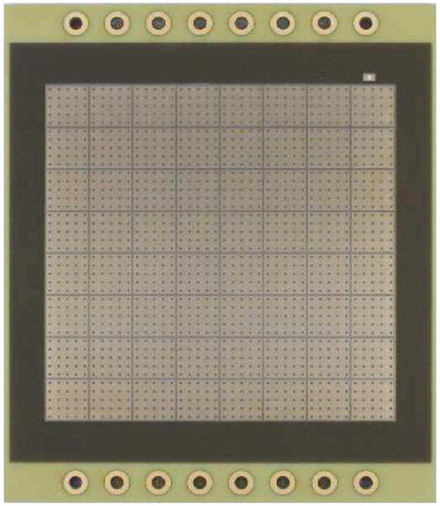


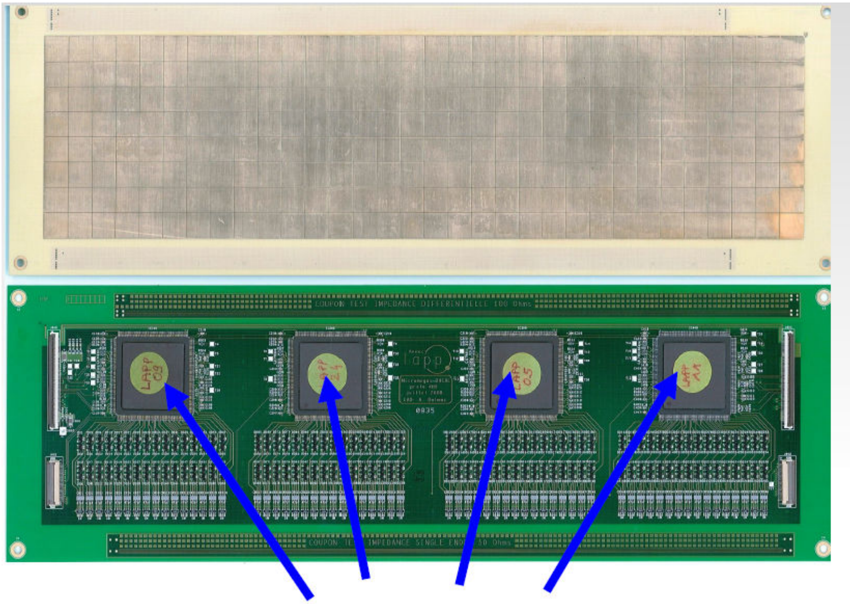


Detectors with digital readout

- DIRAC (*see R.Gaglione poster*)
  - Developed at IPNL, Lyon & LAPP, Annecy
  - 64 channels
  - Self-triggered
  - 3 thresholds
- HARDROC
  - Developed at LAL, Orsay
  - 64 channels, 4 HR / ASU
  - Self-triggered
  - 2 thresholds







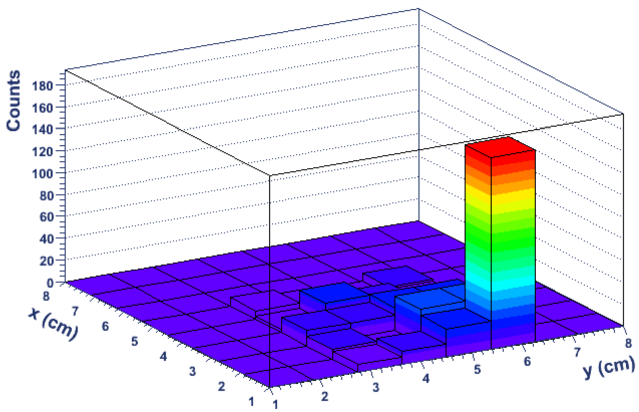
4 HARDROC for 8x32 pads

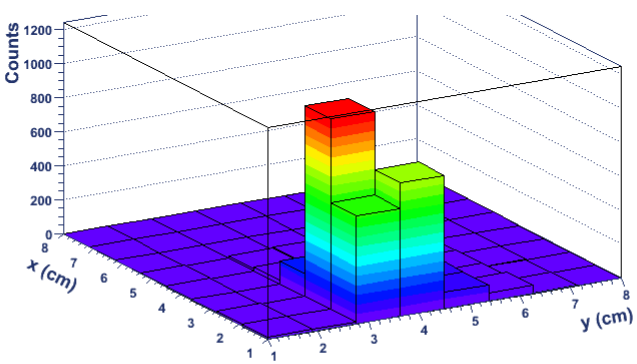
What is best for a Micromegas DHCAL?
Measure performance (efficiency, multiplicity…) first

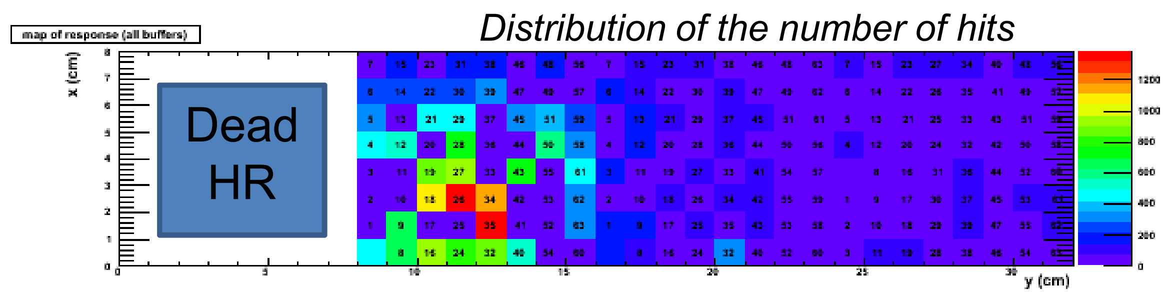
First tests in a beam

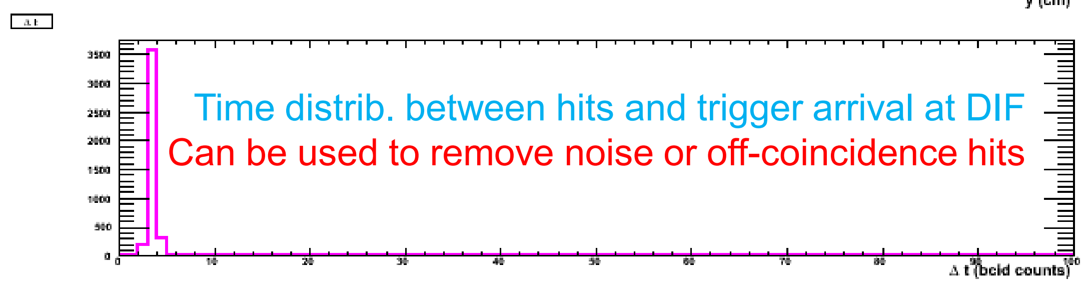
- Nov. 08: DIRAC
  - Profile of a 200 GeV pion beam
  - One prototype built so far
  - Need more to assess performances

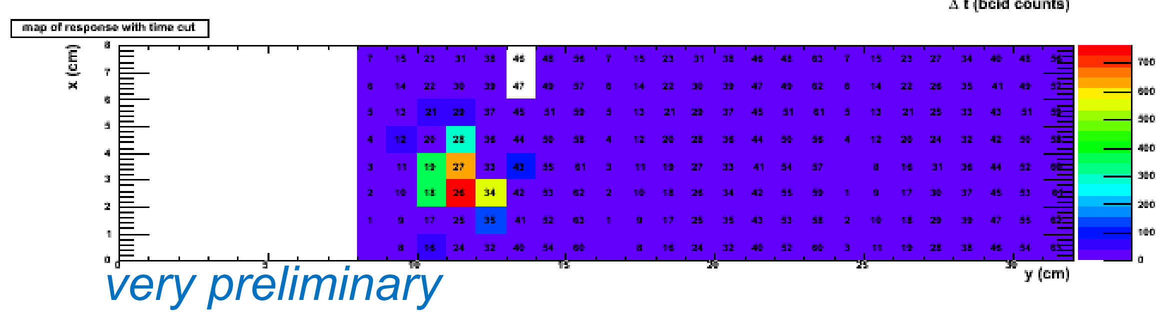
- May-June 09: HARDROC
  - 4 ASU with various number of working HRs
  - Exposed to 2 GeV electrons and hadrons
  - Trigger signal from X-Scintillators delayed by 1 μs





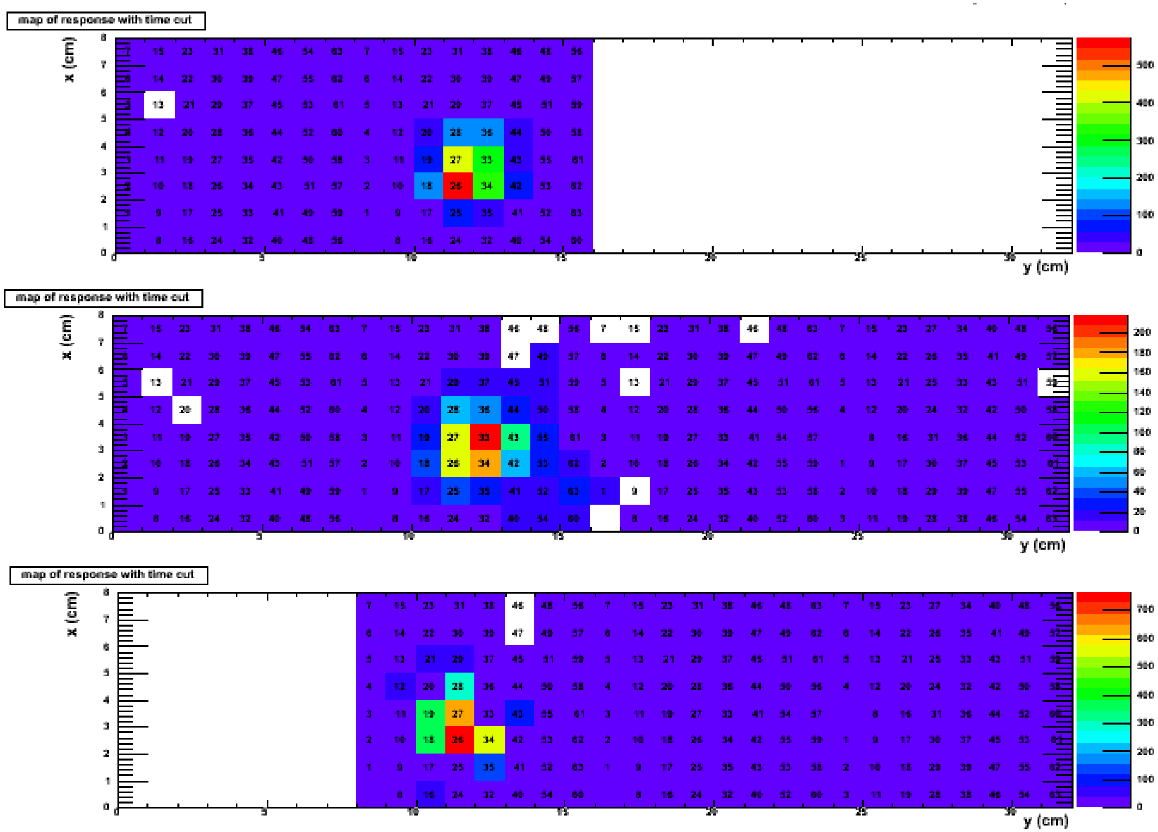


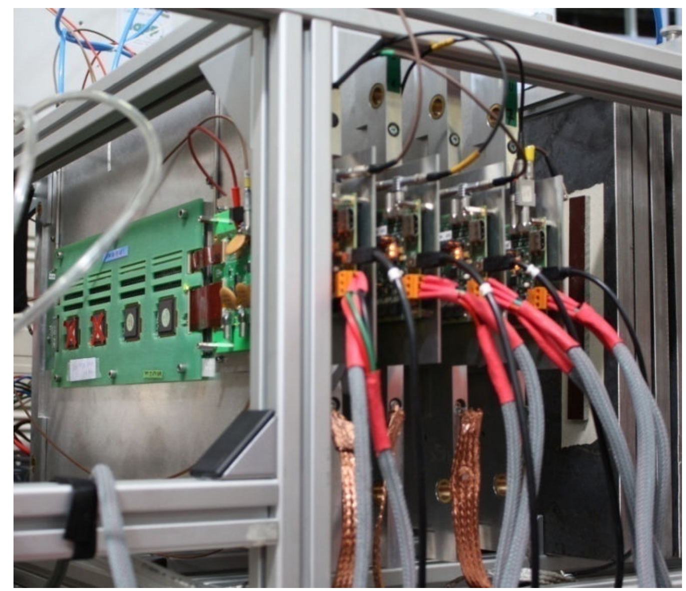




First tests in a beam

- Results
  - 3 of the 4 ASU worked
  - Each hit has a time stamp that will be used for event reconstruction
  - Analysis is on-going: look for “golden” and “platinum” events and determine efficiency and multiplicity



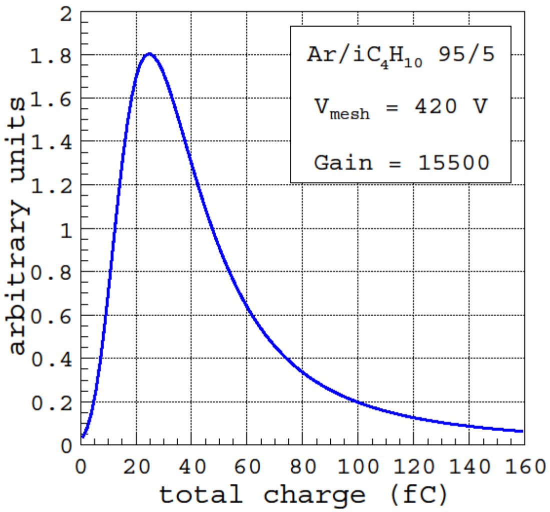


very preliminary

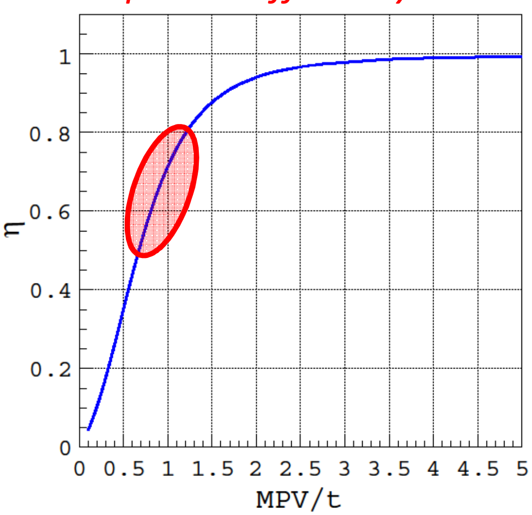
Environmental study

- Digital readout ASIC have a threshold of about 20 fC which is about the most probable charge arriving at a pad
- Efficiency should be rather low (70 %) and could change with time (as gas gain changes) which could degrade the calorimeter performance

Landau 200 GeV muons



Expected efficiency

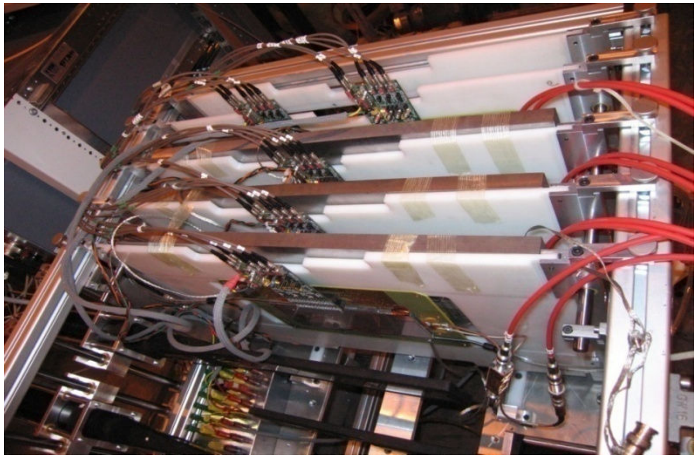


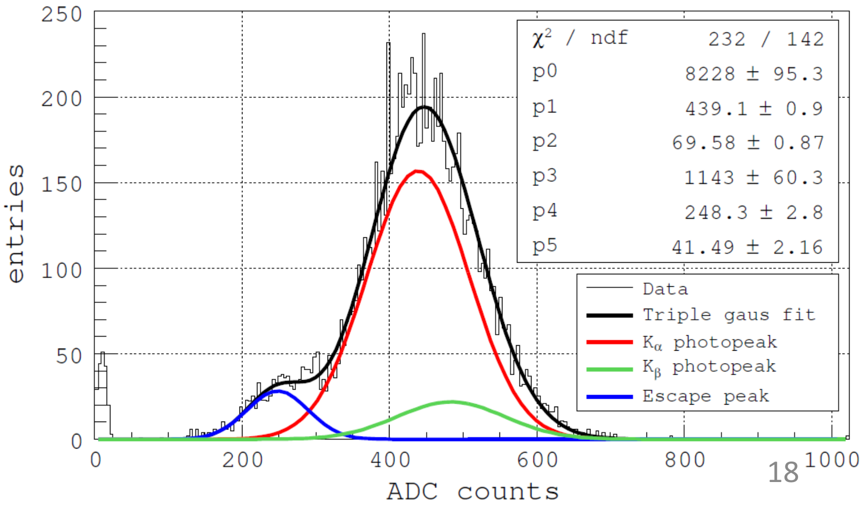
Efficiency sensitivity to changes in various parameters should be known

Experimental set-up

- Study effect of various variables on gain
  - Gas variables: gas flow, mixing ratio
  - Ambient variables: pressure, temperature
  - Amplification gap
- Two studies:
  - Environmental study: G(t), P(t), T(t)
  - G(V), lot to be learnt from gain curve too!
- Experimental setup:
  - Gas system:
    2 bottles of Ar and CO_2
    mass flow controllers (1% accuracy)
    rotameters, chamber stack and bubblers
  - Readout of mesh (^{55}Fe) signals:
    ORTEC preamplifier + ampli/shaper
    12 bits ADC
  - Slow control:
    Pressure and temperature gauges

One chamber of the stack is used



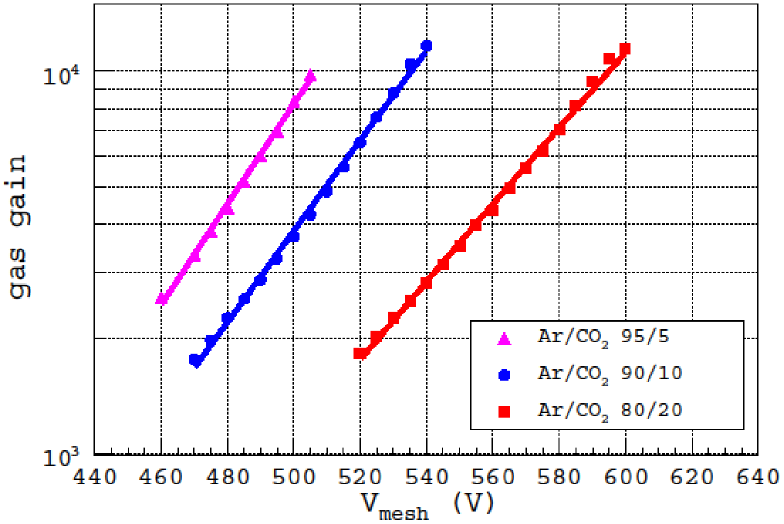


Gas gain model & gain curve fit

- Using Rose and Korff parametrization of the Townsend coefficient:

$$\alpha/n = A_0 \exp(-B_0 n/E) \qquad n = \frac{N_A P}{RT}$$

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



- Gain sensitivity to P, T and g variations:

$$\frac{\Delta G}{G} = C_P \Delta P + C_T \Delta T + C_g \Delta g$$

$$C_P = \frac{1}{G}\cdot\frac{\partial G}{\partial P} = \exp(-\frac{BPg}{TV})\cdot(\frac{Ag}{T} - \frac{ABPg^2}{T^2V})$$

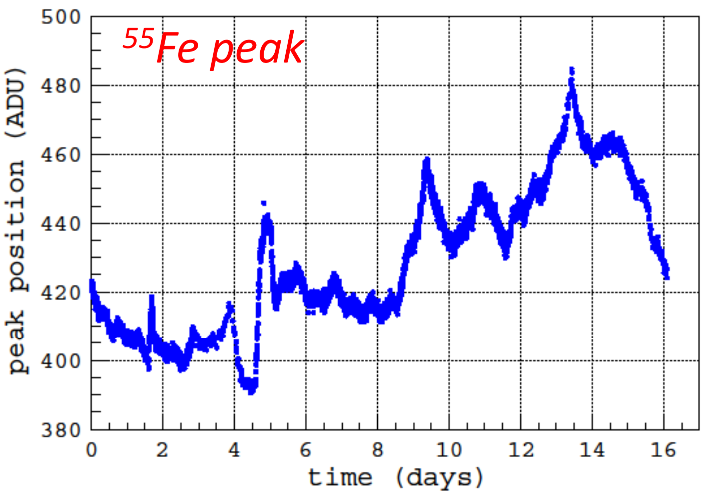
$$C_T = \frac{1}{G}\cdot\frac{\partial G}{\partial T} = \exp(-\frac{BPg}{TV})\cdot(\frac{APg}{T^2} - \frac{ABP^2g^2}{T^3V})$$

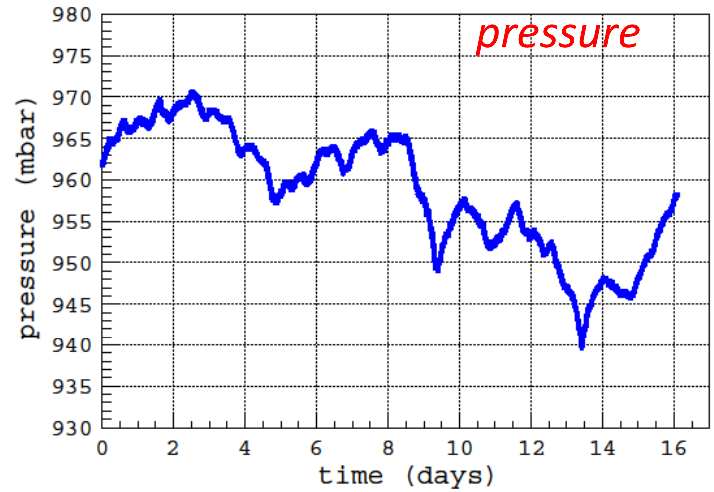
$$C_g = \frac{1}{G}\cdot\frac{\partial G}{\partial g} = \exp(-\frac{BPg}{TV})\cdot(\frac{AP}{T} - \frac{ABgP^2}{T^2V})$$

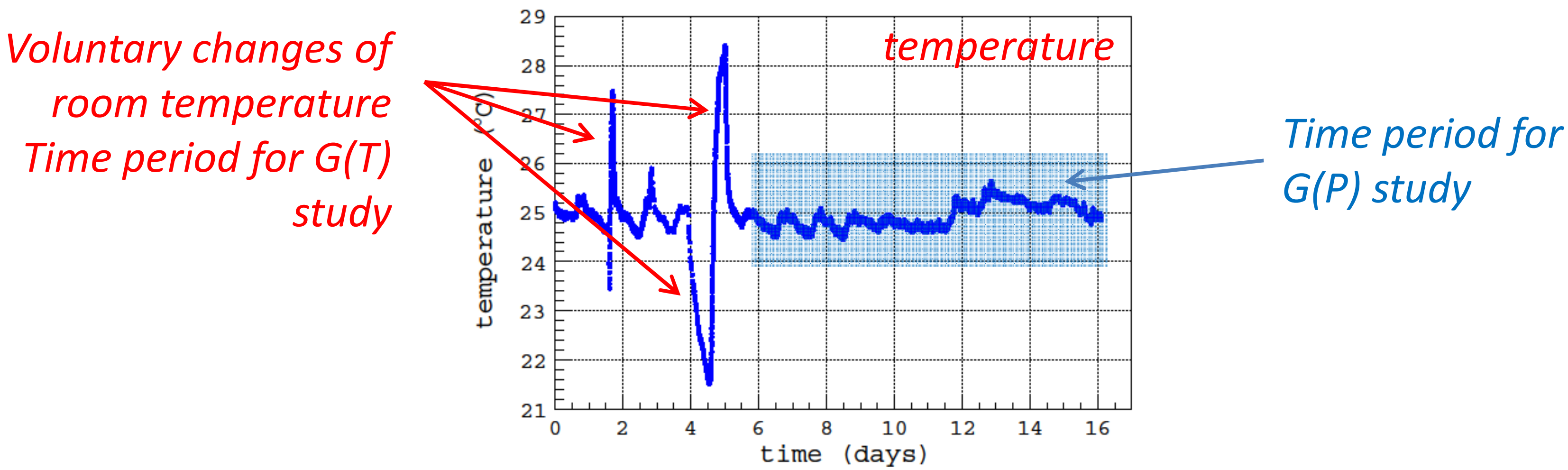
Mixing ratio	C_P (1/mbar)	C_T (1/K)	C_g (1/μm)
80/20	-0.46	1.50	-3.49
90/10	-0.59	1.91	-4.44
95/5	-0.68	2.18	-5.08

Measurements

- Gain, pressure and temperature as a function of time

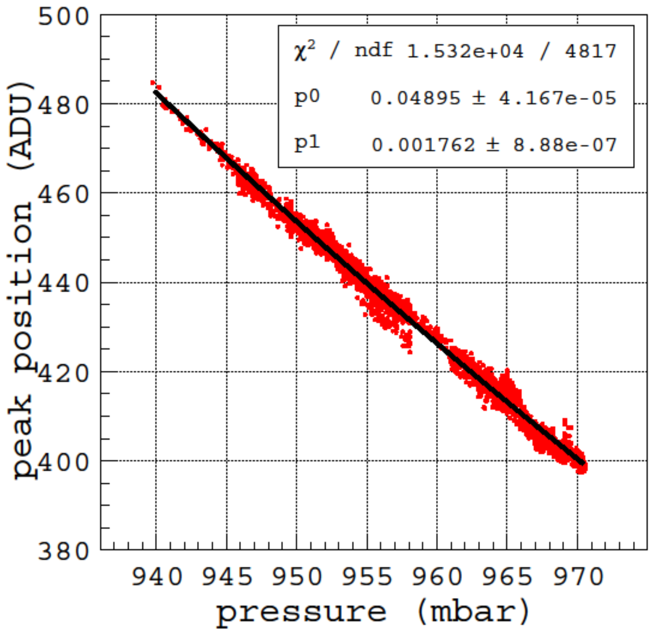






Pressure and temperature

- Peak and pressure allow for ΔT of 1 K

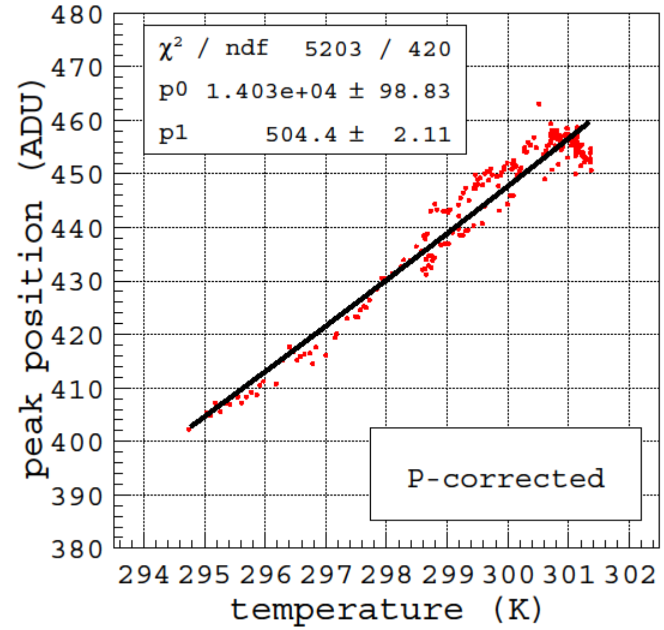


$$G(P) = \exp(A_1 P \exp(-B_1 P))$$

$$C_\mathrm{P} = \text{-}0.63\ \%/\mathrm{mbar}$$

Compatible with gain curve: -0.46 %/mbar

- Pressure corrected peak and temperature



$$G(T) = \exp(A_2/T \exp(-B_2/T))$$

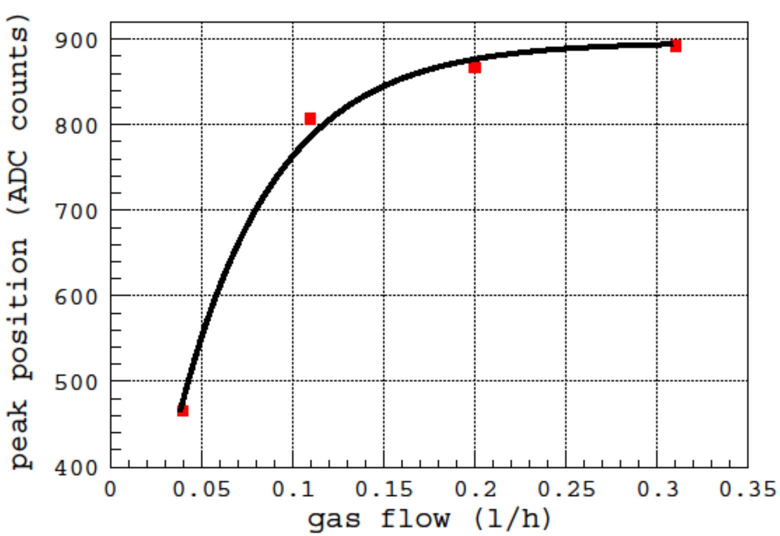
$$C_\mathrm{T} = 2.01\ \%/\mathrm{K}$$

Compatible with gain curve: 1.50 %/K

Gas parameters

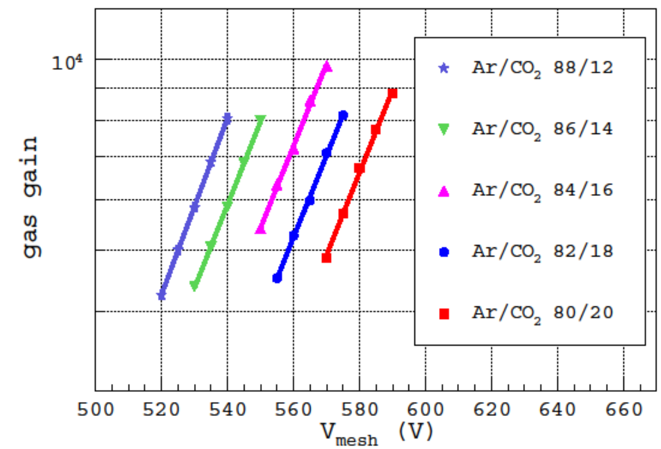
- Effect of gas flow
  - four chambers in parallel
  - Total volume of 0.2 l

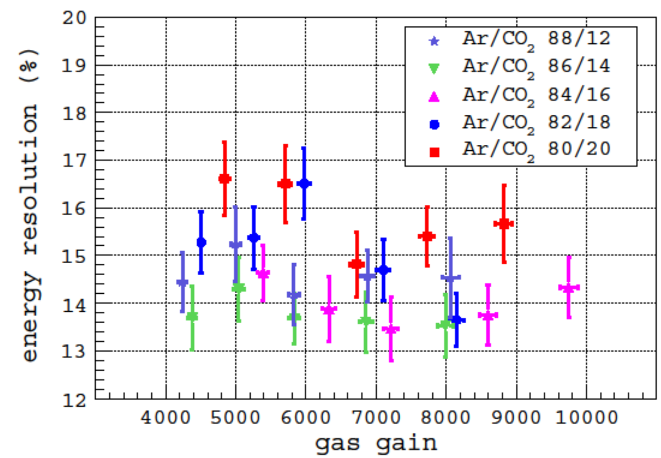
- Saturation for flow > 0.2 l/h
  - = 1 chamber volume / hour
  - Probably e- attachment
  - Should improve gas tightness



Previous measurements performed at flows > 0.5 l/h

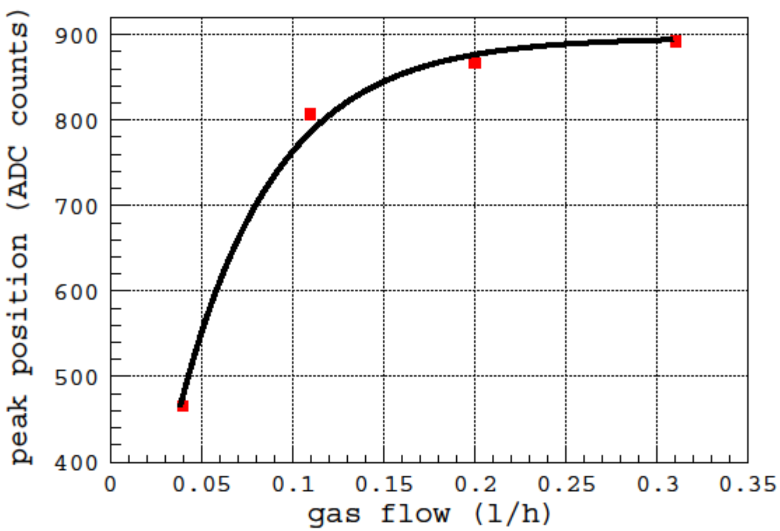
- Ar/CO_2 mixing ratio
  - Gain decreases with CO_2 fraction
  - Gain curves at various concentrations (Get energy resolution for free)





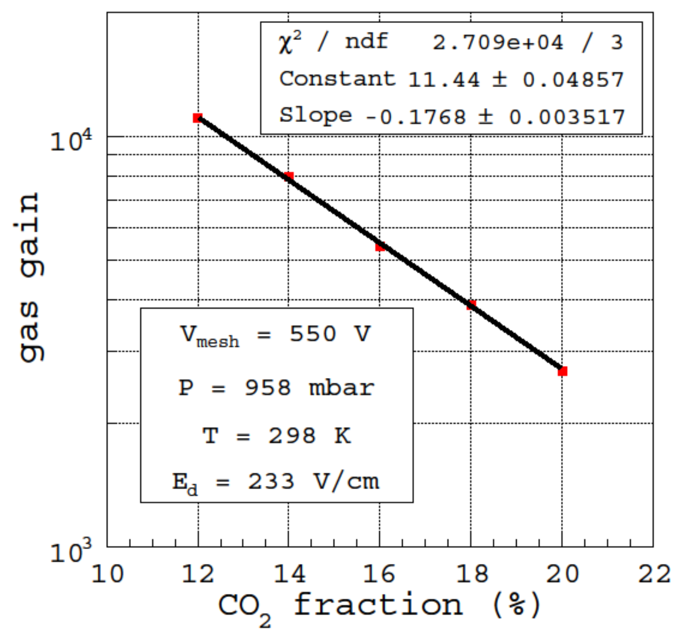
Gas parameters

- Effect of gas flow
  - four chambers in parallel
  - Total volume of 0.2 l
- Saturation for flow > 0.2 l/h
  - = 1 chamber volume / hour
  - Probably e- attachment
  - Should improve gas tightness



Previous measurements performed at flows > 0.5 l/h

- Ar/CO_2 mixing ratio
  - Gain decreases with CO_2 fraction
  - Gain curves at various concentrations (Get energy resolution for free)
- Look at gain at given mesh voltage



$$\frac{\Delta G}{G} = -0.177 \Delta f$$

Conclusion

- R&D on Micromegas DHCAL very active
  - Performance with analog prototypes promising
  - First results with digital prototypes encouraging
  - Also produce some results useful for other MPGDs:

$$\frac{\Delta G}{G} \sim -(0.5-0.6)\ \%\ \Delta P + (1.5-2.0)\ \%\ \Delta T - 3.5\ \%\ \Delta g - 17.7\ \%\ \Delta f$$

ΔP in mbar, ΔT in K, Δg in µm and Δf in % of CO_2

- Future plans:
  - Construction and test of larger area detectors
    - 2009: 32x48 cm^2 ASU with DIRAC or HARDROC
    - 2010: 1 m^2 prototype from 6 ASUs

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