Environmental study of a Micromegas chamber for hadronic calorimetry at ILC

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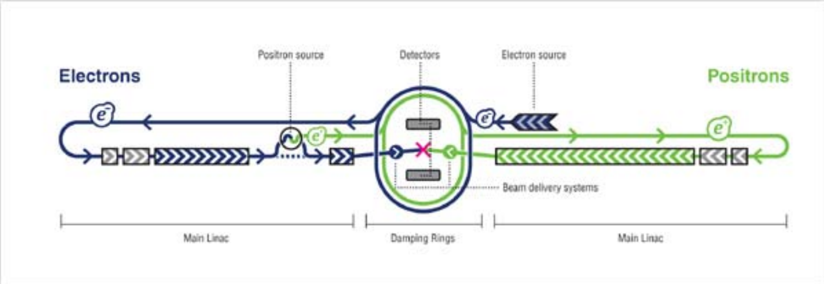
RD51/WG2, CERN, 29/04/2009

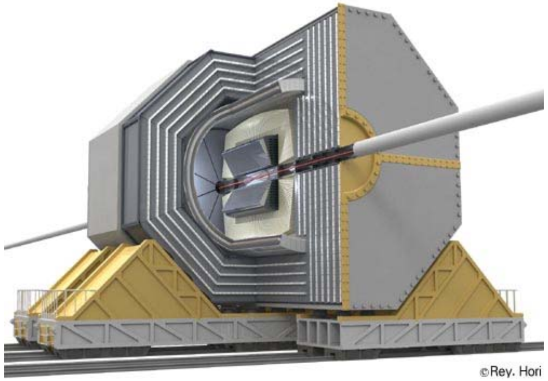
Outlook

- Introduction
  - Hadronic calorimetry at a future linear collider
- DHCAL R&D at LAPP
- Environmental study
  - Experimental setup and gas gain model
  - Basic properties of our Micromegas
  - Gain, gas flow, mixing ratio, pressure, temperature, gap
- Conclusion

Calorimetry at ILC

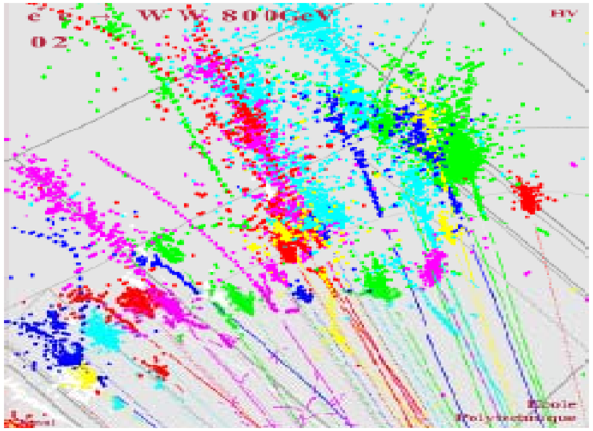


- International Linear Collider
  - e+/e- collisions at 500 GeV, 30 km long
  - Luminosity of 2.10^{34} cm^{-2}s^{-1}
  - 1 ms long bunch trains, 199 ms idle
  - Detailed study of EWSB, Higgs boson properties, SUSY particles, extra-dimension models …



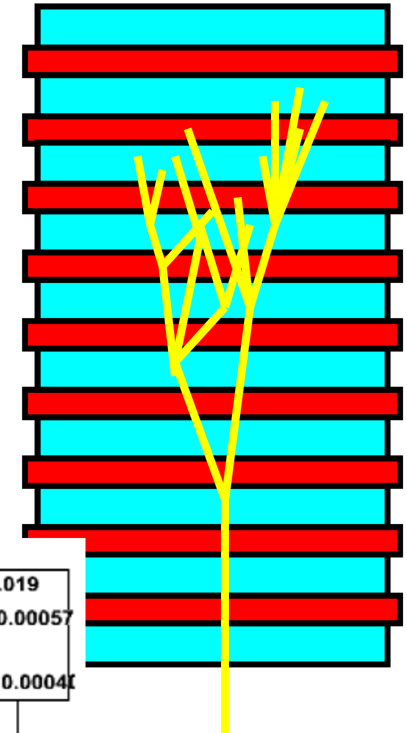
- 3 detector concepts with ≠ tracker and calorimeters
  ILD (TPC) – SiD (Silicon tracker) - 4th (Drift chamber)
  - SiD and ILD based on Particle Flow Approach (PFA)
    - Single particle shower imaging capability
    - Highly segmented and compact calorimeters
    - Resolution goal: 30 %/√E

- Hadronic Calorimeter design
  - Total absorber depth of 4.5 λ, 40 layers, 8 mm gap
  - Small cell sizes (down to 1 cm²!)
  - Thin sensitive layers (solid or gas)

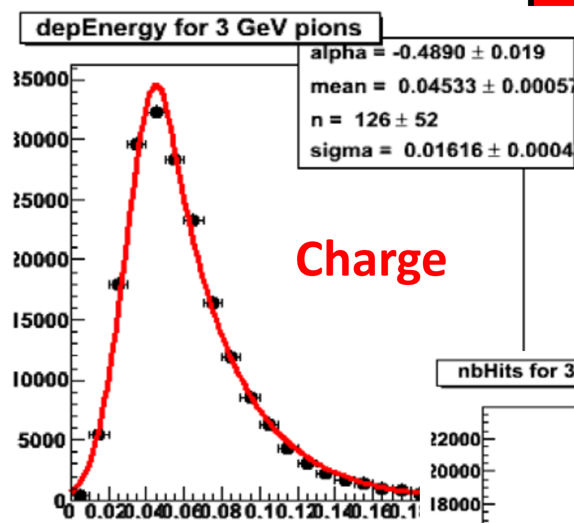


Matching energy deposits in calorimeter with tracks

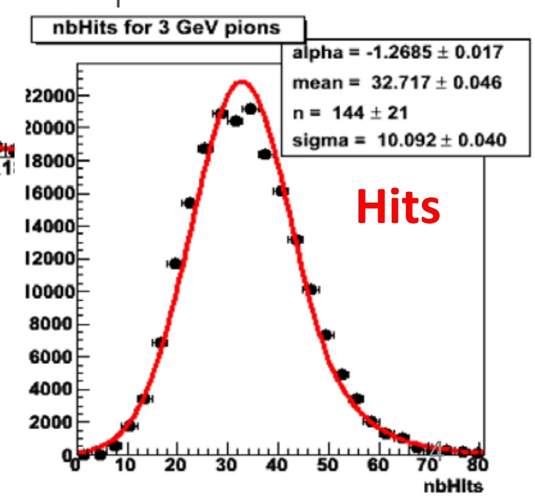
Analog and Digital HCAL



- 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 (HARDROC1/2)
- What is best for energy resolution?
  - Measuring charge or counting hits?
  - Actively simulated (*J. Blaha contribution MPGD, Crete*)

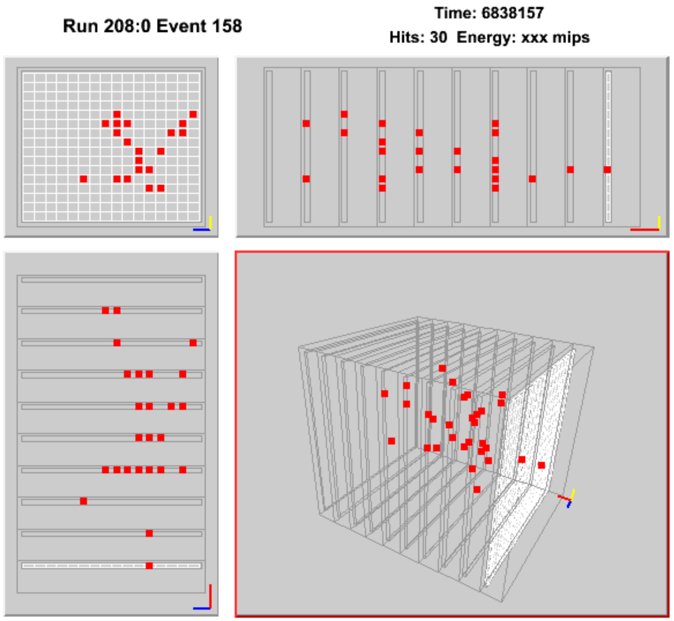


Charge VS Hits



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)

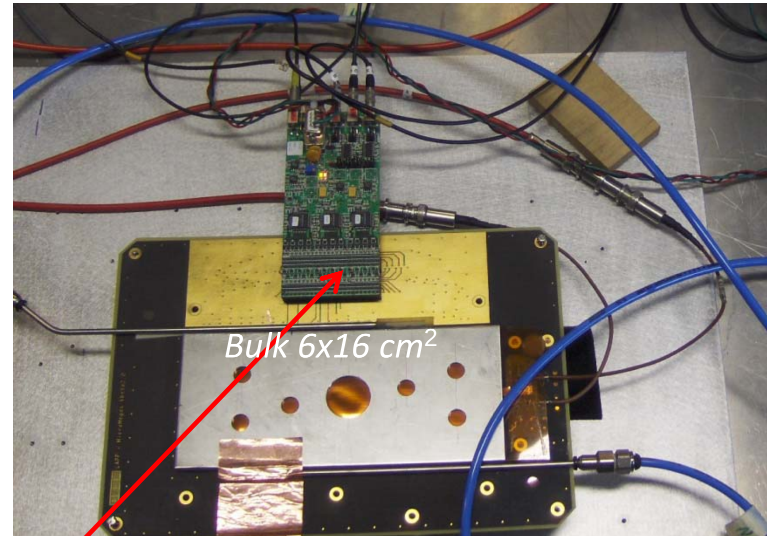


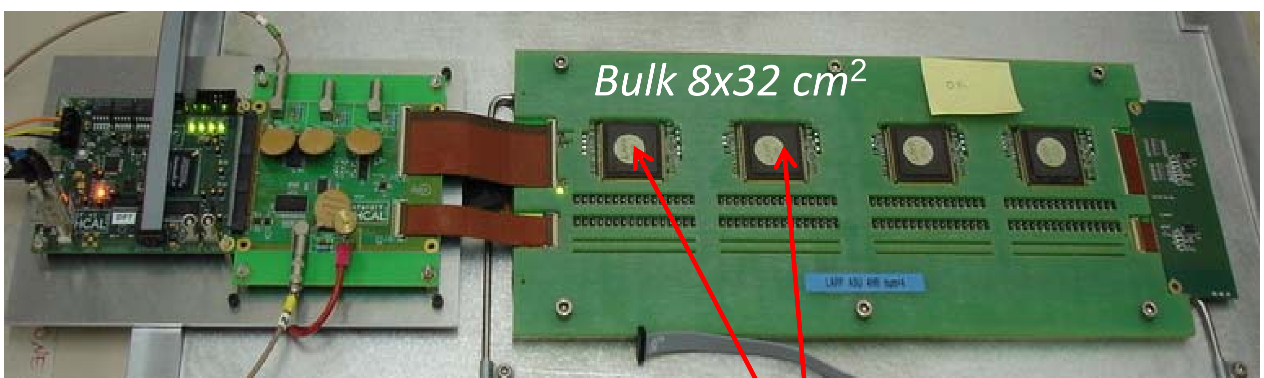
- R&D strategy:
  - –Development of small prototypes and their characterization
  - –Construction and test of 1 m^2 and then 1 m^3 prototypes
  - –Prototype performance comparison → final design for DHCAL

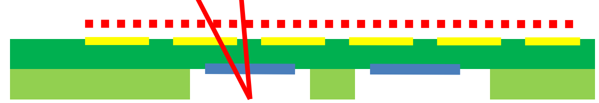
DHCAL R&D at LAPP

- What we are involved in:
  Large area detector (WG1), Bulk Micromegas
  Physics simulation
  ASIC development (DIRAC chip)
  Detector test:
  2 beam tests in 2008, 3 planned 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



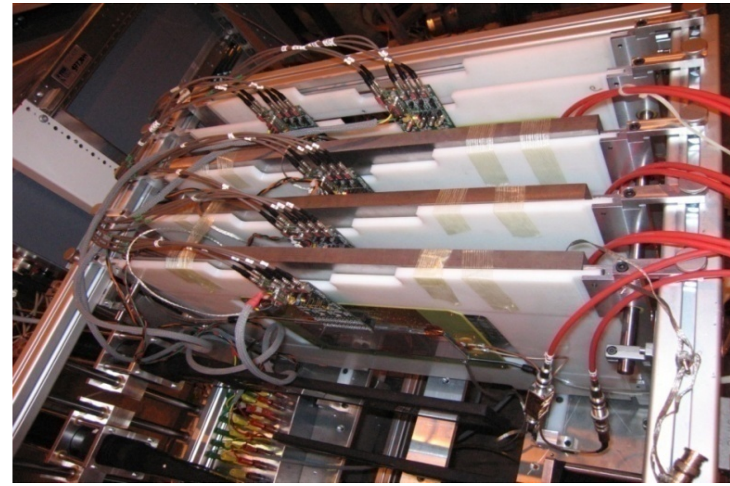




FE Electronics + PCB + Bulk + drift + cover = 8 mm

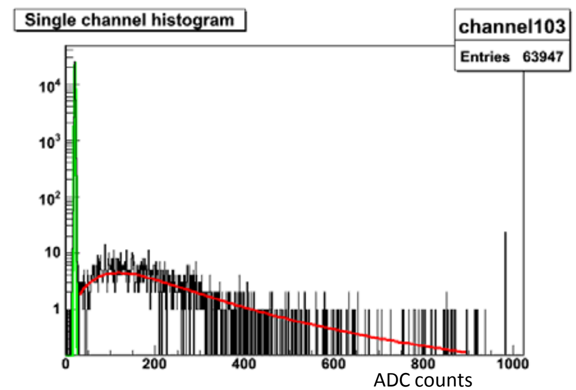
Possibility to chain detectors

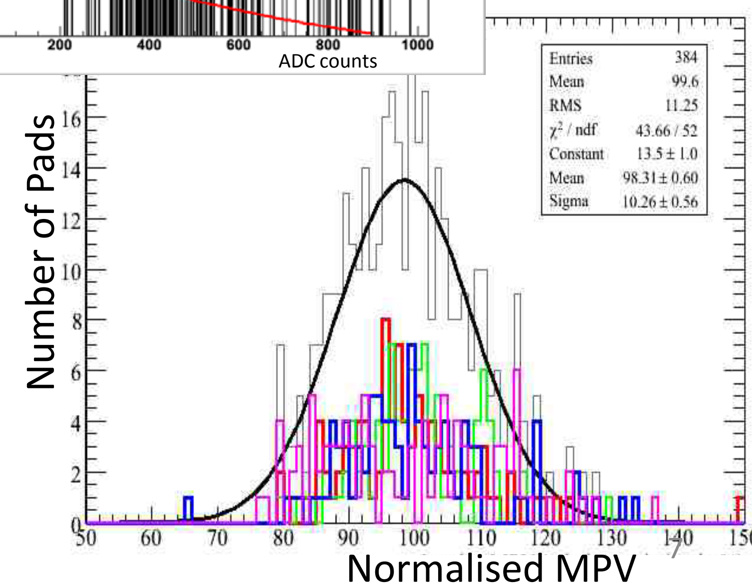
Small HCAL performance

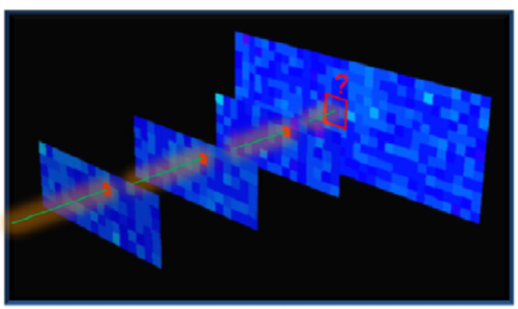


- 4 chamber stack
  - Gas gain ~ 15000
  - Analog readout (pedestal of 3 fC)
  - CERN H2 & T9 beam lines
  - Muons and pions (absorber option)

- Results
  - Most Probable Charge ~ 25 fC
    10 % variation for largest chamber
  - 95 % efficiency to 200 GeV muons
  - Hit multiplicity < 1.1

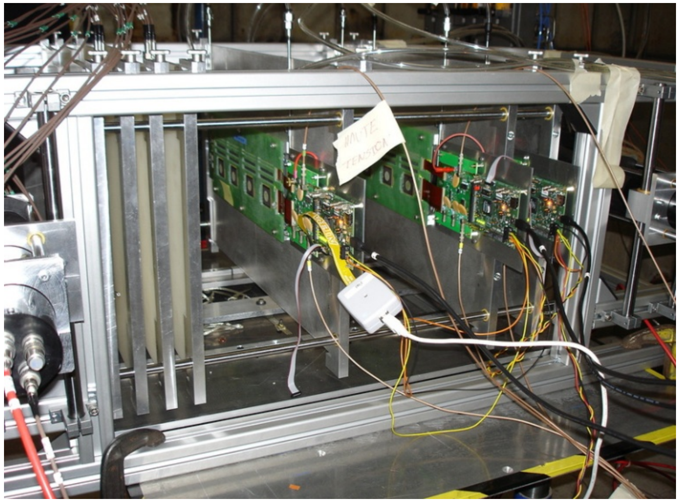




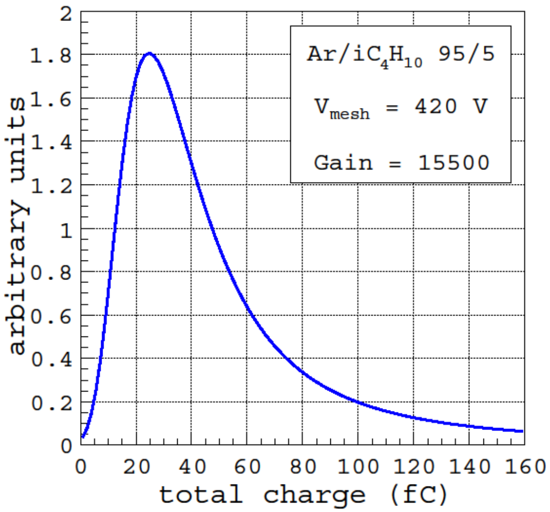


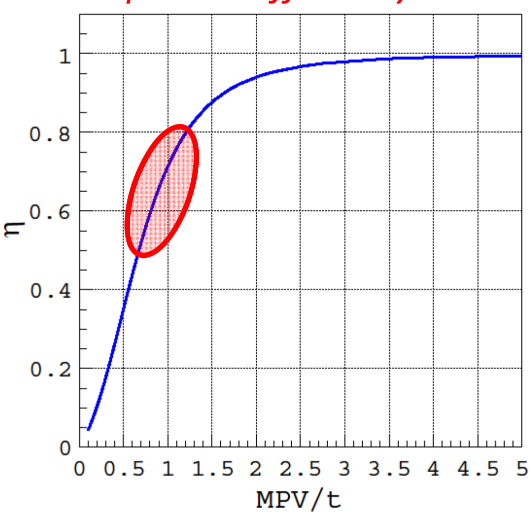
	Efficiency
0	97,05 ± 0,07%
1	98,54 ± 0,05%
Chamber 2	92,99 ± 0,10%
Chamber 3	96,17 ± 0,07%

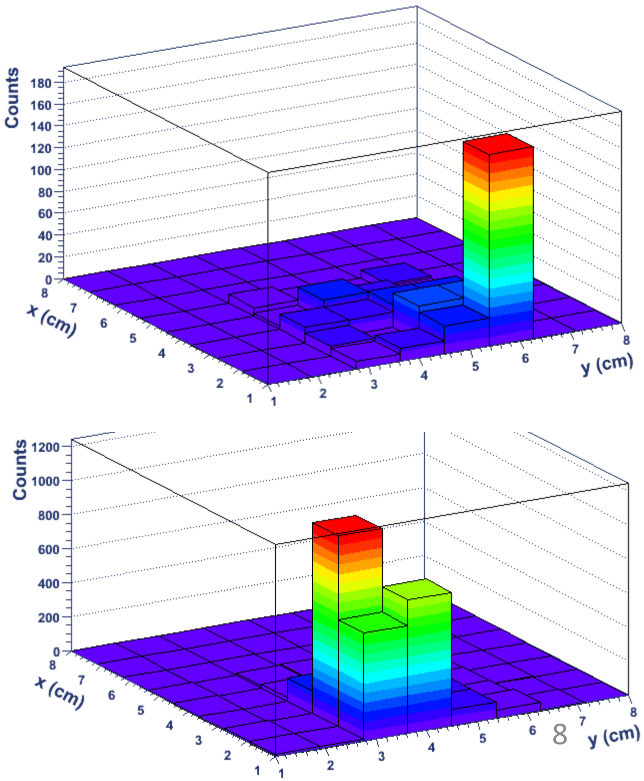
Tests with digital readout



- Not much done sofar
- Problems with HV, DAQ software
- Still, predictions can be made from tests with analog readout prototypes







Efficiency for a 20 fC threshold is rather low (70 %)

Efficiency sensitivity to changes in various parameters should be known.

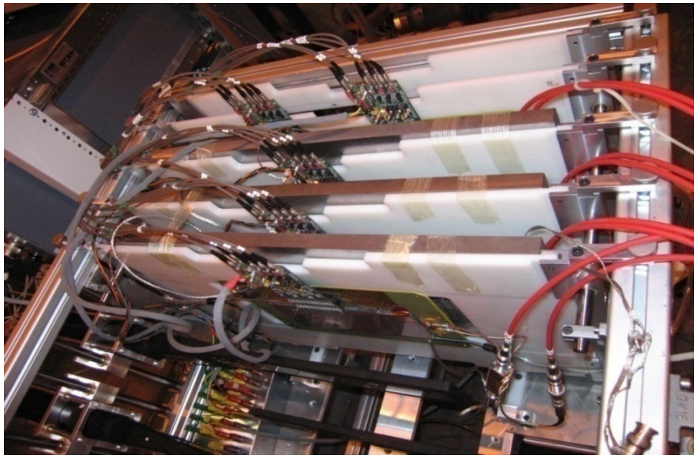
Our study

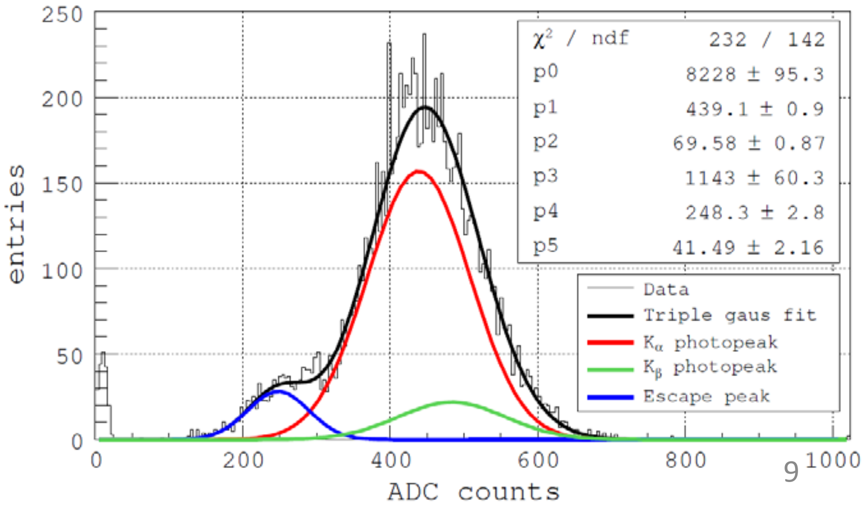
- Study effect of various variables on gain
  - Gas variables: gas flow, mixing ratio
  - Ambient variables: pressure, temperature
  - Amplification gap

- 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

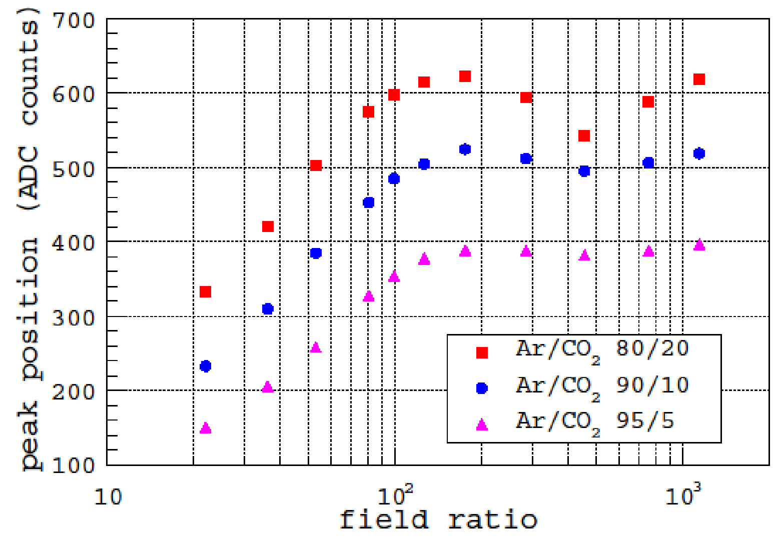
One chamber of the stack is used

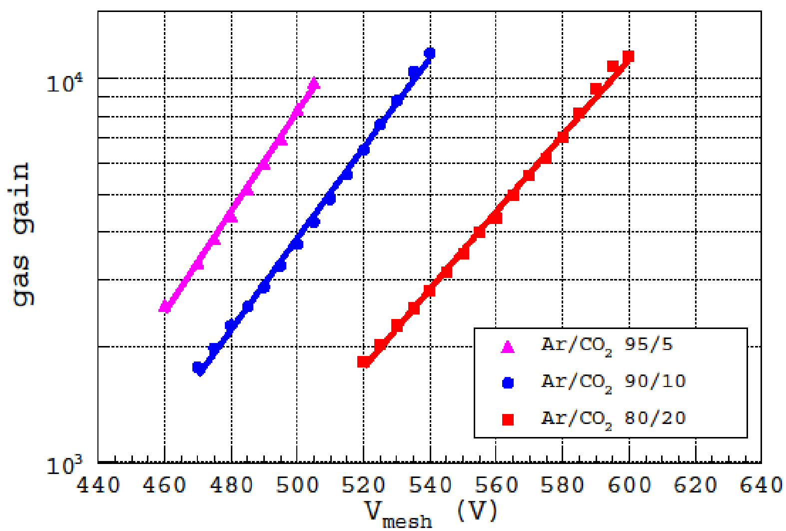


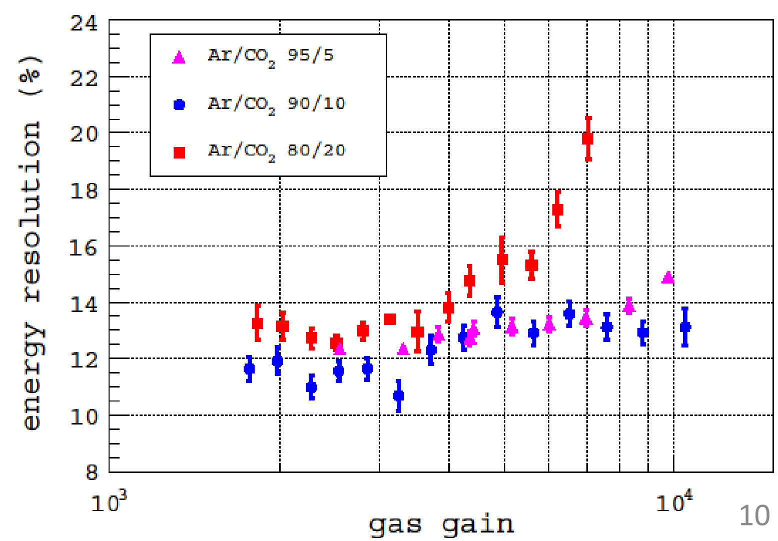


Amplification properties

- Electron collection efficiency
  - Probably some electron attachment
- Gas gain
  - Maximum gain of 10^4
- Energy resolution
  - Twice larger than theoretical limit





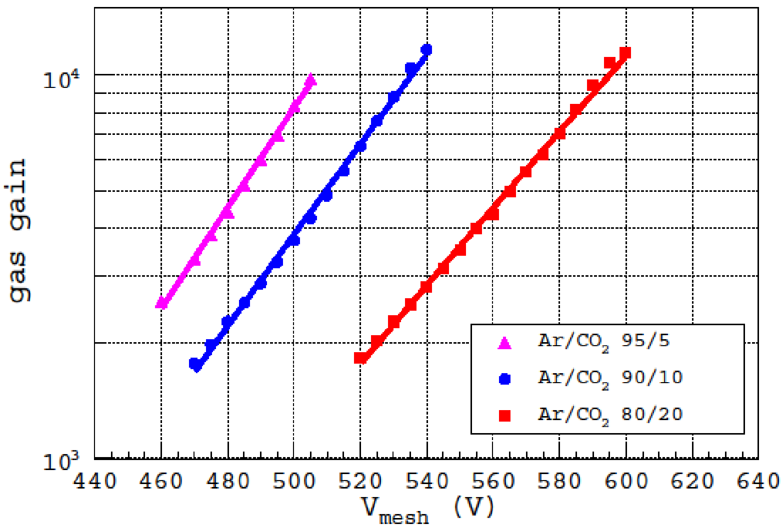


Gas gain model & gain curve fit

- Using Rose and Korff parametrization of the Townsend coefficient:

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

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



- Gain sensitivity to P, T and g variations:

$$\frac{\Delta G}{G} = C_\mathrm{P}\Delta P + C_\mathrm{T}\Delta T + C_\mathrm{g}\Delta g$$

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

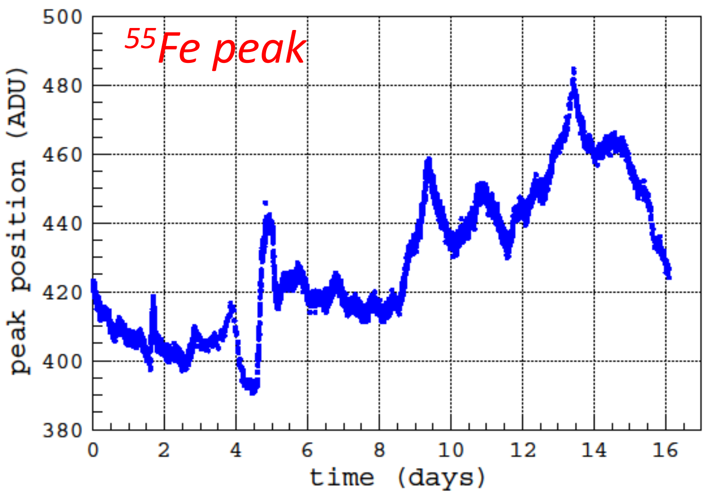
$$C_\mathrm{T} = \frac{1}{G}\cdot\frac{\partial G}{\partial T} = \exp(-\frac{BPg}{TV})\cdot(\frac{APg}{T^2} - \frac{ABP^2g^2}{T^3V})$$

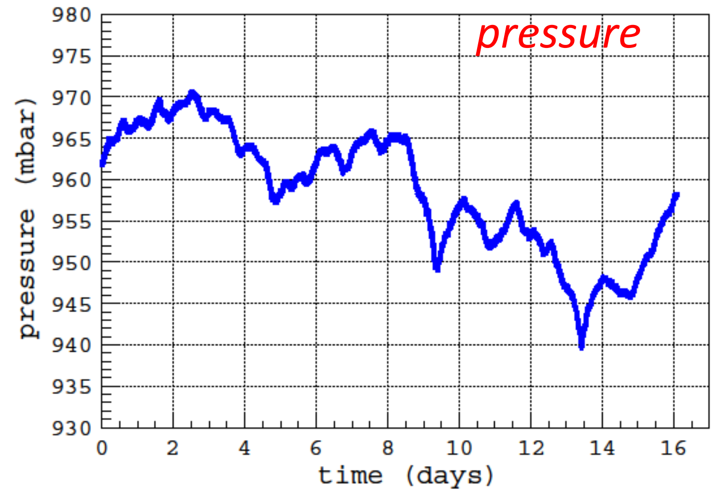
$$C_\mathrm{g} = \frac{1}{G}\cdot\frac{\partial G}{\partial g} = \exp(-\frac{BPg}{TV})\cdot(\frac{AP}{T} - \frac{ABgP^2}{T^2V})$$

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

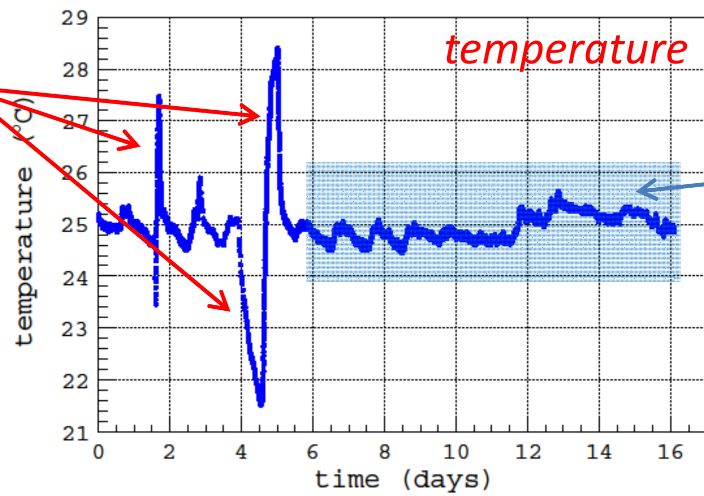
Environmental study

- Gain, pressure and temperature as a function of time





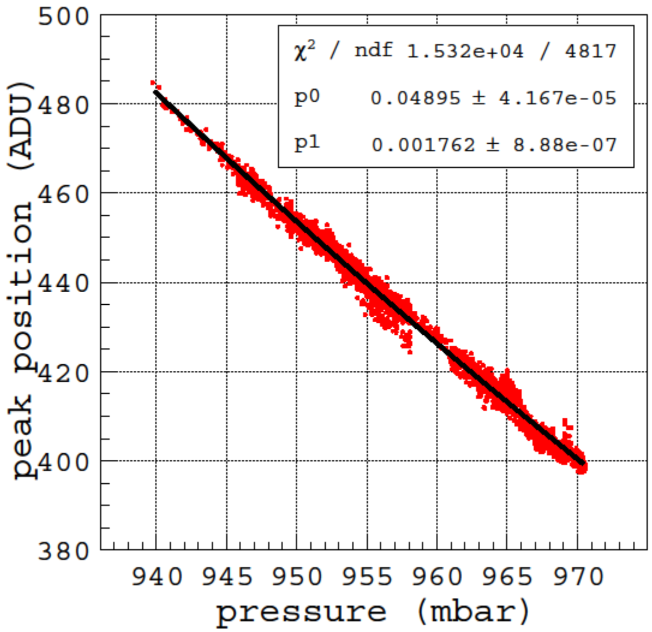
Voluntary changes of room temperature
Time period for G(T) study



Time period for G(P) study

Pressure and temperature

- Peak and pressure allow for ΔT of 1 K

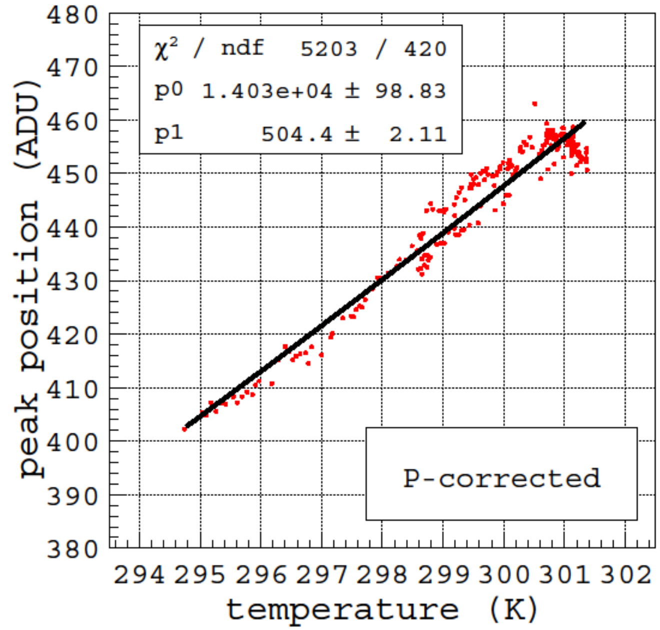


$$G(P) = \exp(A_1 P \exp(-B_1 P))$$

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

Compatible with gain curve: -0.46 %/mbar

- Pressure corrected peak and temperature



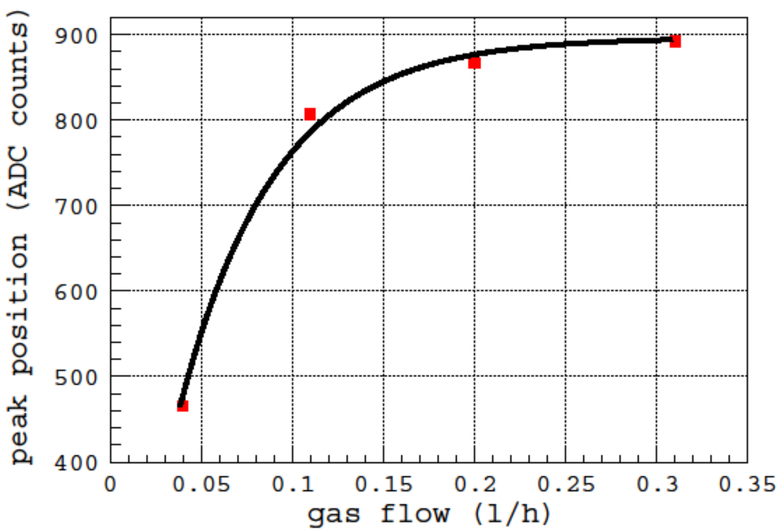
$$G(T) = \exp(A_2/T \exp(-B_2/T))$$

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

Compatible with gain curve: 1.50 %/K

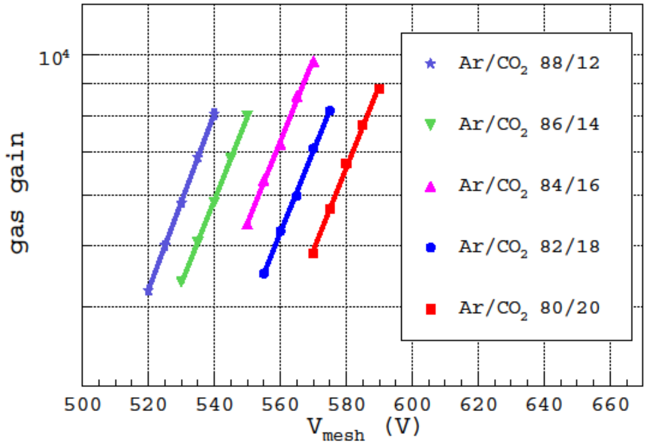
Gas parameters

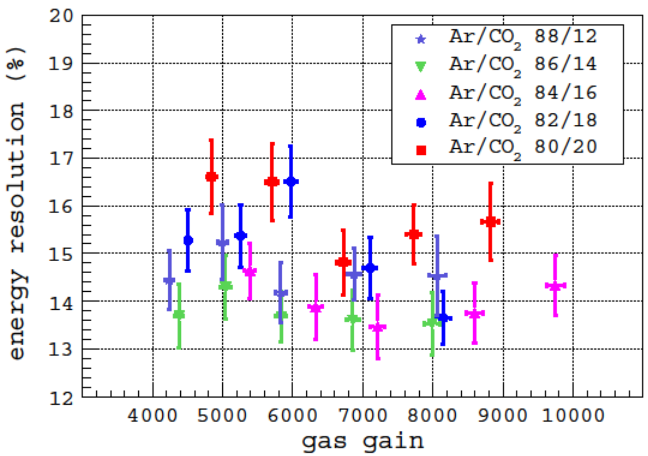
- Effect of gas flow
  - four chambers in parallel
  - Total volume of 0.2 l
- Saturation for flow > 0.2 l/h
  - = 1 chamber volume / hour
  - Probably e- attachment
  - Should improve gas tightness



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)





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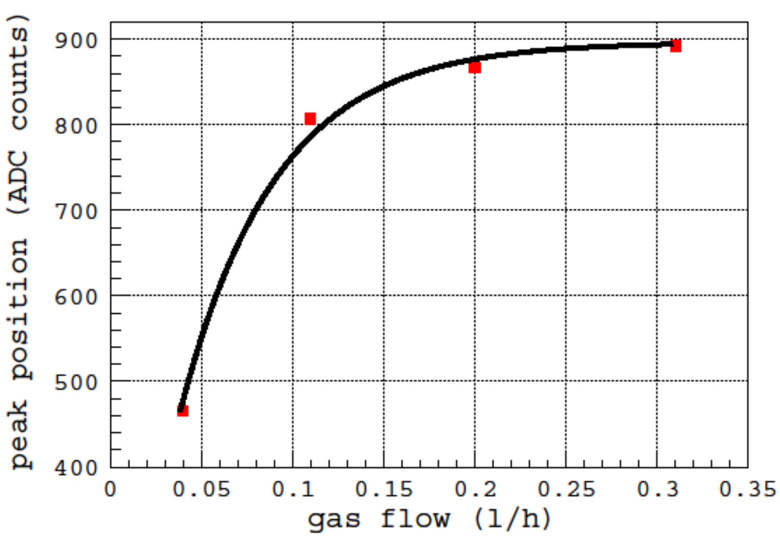
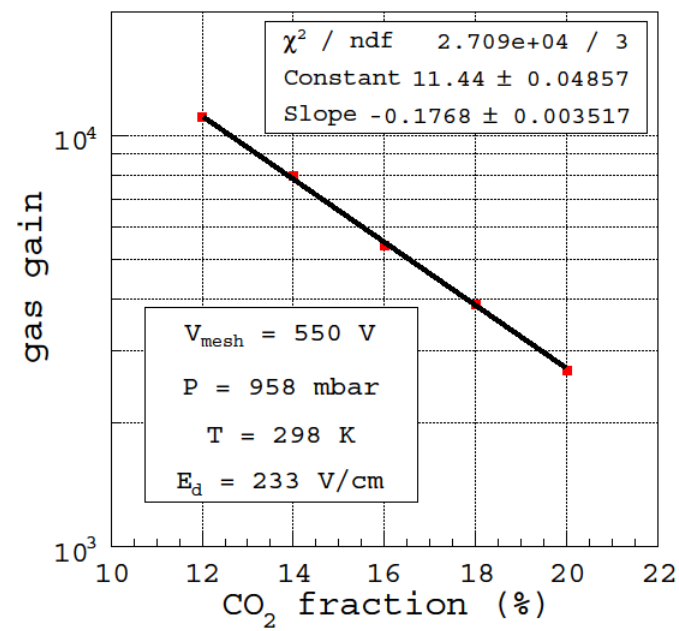


Previous measurements performed at flows > 0.5 l/h

- 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

- To summarize:

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

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

these findings are applicable to other MPGDs

- Expected efficiency drop for $G=10^4$ and t=20 fC is mild

t (fC)	MPV/t	η	η(+10 mbar)	η(-5 K)	η(+5 μm)	η(+0.5 % CO_2)
20	0.95	0.69	0.65	0.63	0.58	0.64

- More details on that study can be found at:

http://lappweb.in2p3.fr/~chefdevi/Work_LAPP/environmental_study.pdf

- Acknowledgements: Catherine Adloff, Jan Blaha, Sébastien Cap, Alexandre Dalmaz, Cyril Drancourt, Ambroise Espagilière, Renaud Gaglione, Raphael Gallet, Nicolas Geffroy, Claude Girard, Jean Jacquemier, Yannis Karyotakis , Nicolas Lafaye, Fabrice Peltier, Julie Prast, Jean Tassan, Guillaume Vouters