Development of large area MICROMEGAS chambers for digital hadronic calorimetry

Jan Blaha

LAPP, Annecy-le-Vieux

This work was performed within the CALICE collaboration

ALCPG09, Sep. 29 - Oct. 3 2009, Albuquerque, New Mexico

Outline

1 Introduction

2 MICROMEGAS chambers

3 Electronics developments

4 Simulation studies

5 MICROMEGAS development for DHCAL

6 MICROMEGAS prototypes performance

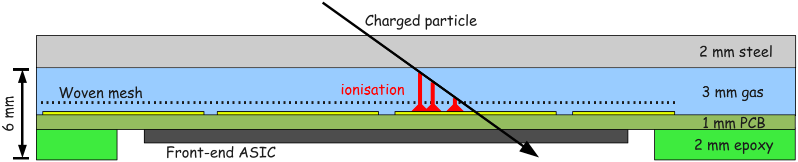
7 $1m^2$ project

8 Conclusions

INTRODUCTION

Introduction

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



- R&D activities at LAPP:
  - fabrication and test of analog readout MICROMEGAS for characterisation
  - fabrication and test of digital readout MICROMEGAS
    - front-end chips used: HARDROC, DIRAC
  - simulation, DAQ (DIF), mechanics (SiD), electronics (DIRAC)

MICROMEGAS specifications

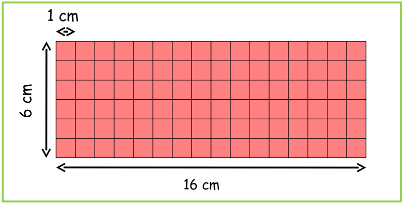
- Requirements on DHCAL
  - High efficiency and low multiplicity detector
  - Very fine granularity (down to 1 cm^2 cell size readout $\rightarrow$ $\sim 30\times10^6$ channels)
  - Very low power consumption

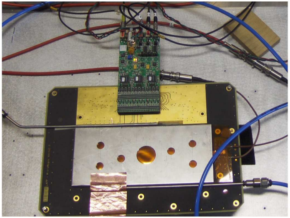
- MICROMAGAS detector
  - Simple and robust
  - Bulk MICROMEGAS - industrial process
  - Low voltage ($< 500\,\mathrm{V}$)
  - 1 cm^2 readout cell size
  - Needs for low noise electronics
  - Needs for reliable sparks protection

MICROMEGAS CHAMBERS

GASSIPLEX readout chambers

- Chamber geometry
  - 6×16 and 12×32 pad anode PCBs (pad size: 1 cm^2)
  - Bulk MICROMEGAS: 128 μm gap mesh laminated on PCB
  - Plastic frame and steal cover define a 3 mm drift gap

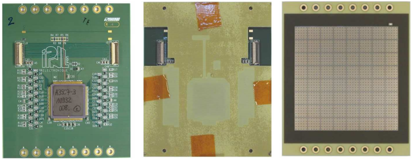




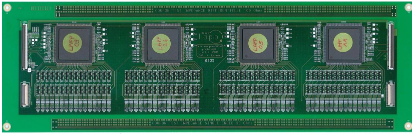
- Analog readout electronics
  - GASSIPLEX chip: 16 channels with preamplifier and shaper
  - 4 boards with 6 chip each, multiplexed output
  - Digitization by 10 bit ADCs connected to a PC
- Ar/iC_4H_{10} 95/5: high gains ($20 \cdot 10^3$) at moderate voltages ($\leq$ 450 V)

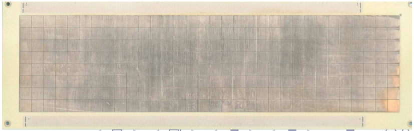
HARDROC and DIRAC readout chambers

- 2 bit digital readout of 64 channels per chip
- VFE electronics embedded below pad PCB
- DIRAC readout:
  - The first protype with ebbeded electronics
  - 1 chamber, 8×8 pads readout by 1 DIRACv.1 chip



- HARDROC readout:
  - 4 chambers, 8×32 pads readout by 4 HARDROCv.1 chips
  - 2+4 chambers, 32×48 readout by 24 HARDROCv.2 chips

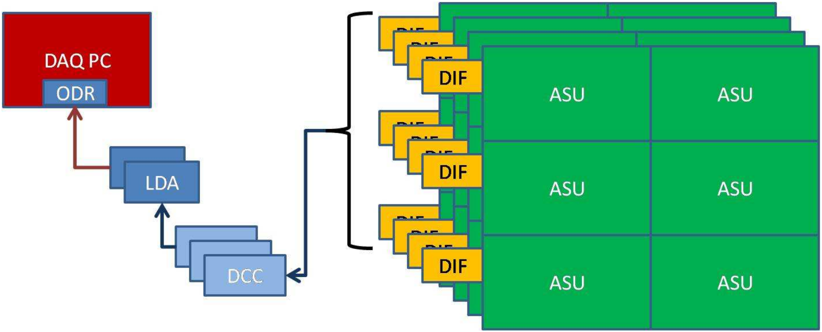




Electronics developments

Detector InterFace (DIF)

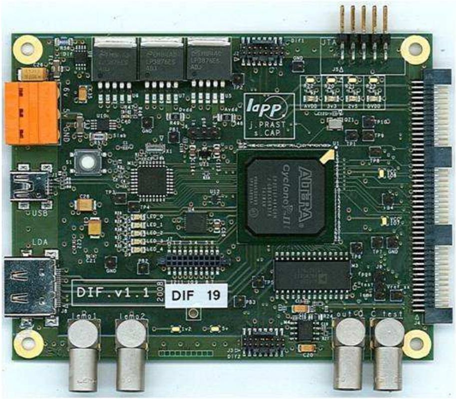
- Calice DAQ Scheme:



- DIF $\Longleftrightarrow$ front-end electronics: data transfer, very front-end chip control
- Compatible with HARDROC, DIRAC, SPIROC, SKYROC

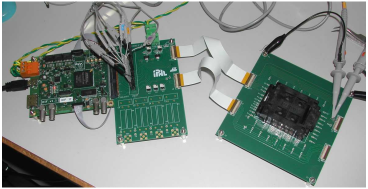
Detector InterFace (DIF)

- Fully designed at LAPP (J. Prast, S. Cap)
- First intermediate board between ASU and DAQ
- Programmable via VHDL code
- The VHDL code implemented at LAPP (G. Vouters)
- Many firmwares available
- Used in 2008 and 2009 Eu-DHCAL beam tests: MICROMEGAS and RPC



DIRAC characterization and development

- DIRACv.2 (IPNL and LAPP)
  - 3 thresholds programmable on 8 bits
  - Dynamic range: 50, 100, 200 fC or 10 pC
  - 10 mW per channel in pulsed mode



- Test results from LAPP
  - Linearity $\pm 2\%$ on 20–200 fC range
  - Noise less than 5 fC at 5σ
  - Very small gain dispersion $\Longrightarrow$ No calibration needed for a DHCAL!
  - Best power pulsing performance (stable at 2.7 $\mu\mathrm{s}$ power-on time)
  - Very low threshold achievable ($<$10 fC)

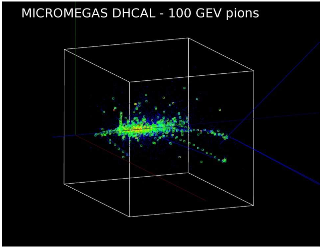
- First digital ASIC embedded on a bulk MICROMEGAS: tested successfully in 2008 beam test

- DIRACv.2 for 1 m^2 foreseen for 2010

Simulation studies

Simulation studies

- Study of DHCAL physics performance
  - Better understanding of digital calorimetry generally
  - The first qualitative view on DHCAL global performance
  - Study of the main calorimeter characteristics
  - Comparison of various absorber materials
  - Comparison of different readouts



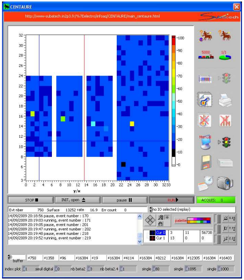
- Simulation of test beam experiments
  - Optimization of the test beam set-up
  - Comparison with measured data
- High energy physics simulation
  - Calorimeter requirements for CLIC detector
  - Physics at 3 TeV

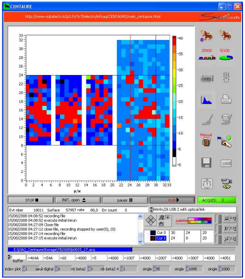
For more see J.Blaha's talk given in the simulation and reconstruction session this Friday morning!

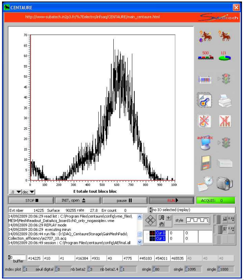
MICROMEGAS DEVELOPMENT FOR DHCAL

Data acquisition for analog readout

- CENTAURE (SUBATECH)
  - Used for analog data acquisition and on-line monitoring
  - GASSIPLEX readout (any number of boards)
  - MICROMEGAS Mesh readout



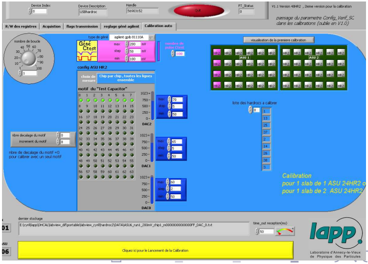




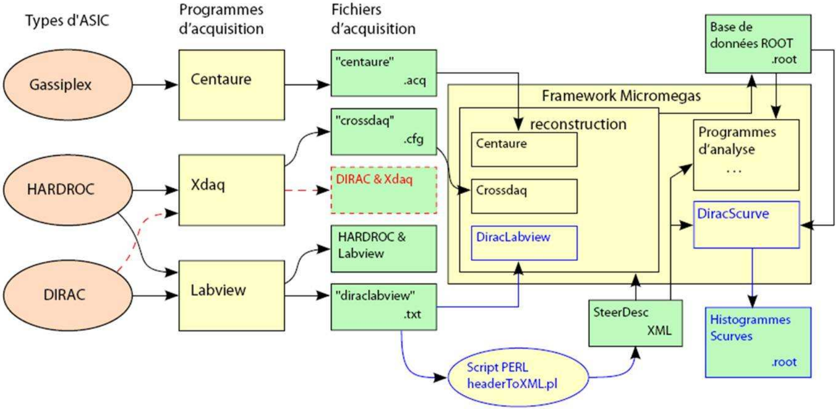
Data acquisition for digital readout

- X-DAQ (IPNL)
  - Used for fast data acquisition
  - Works for HARDROCv.1 and v.2
  - Development for DIRAC is ongoing
  - Fast running
  - html control interface
  - Many annex files (xml, cfg)
  - Need expert on site

- LabView (LAPP)
  - Home made software for calibration
  - Works for HARDROCv.1, HARDROCv.2 and DIRAC chips
  - Development for cosmic data acquisition ongoing



Analysis framework



- MICROMEGAS Framework $\Longleftrightarrow$ user friendly analysis framework
- Works with all type of test beam data, using SVN

MICROMEGAS PROTOTYPES PERFORMANCE

MICROMEGAS environmental study

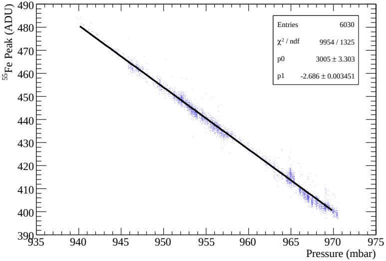
- Two-week long data acquisition
- 5.9 keV photons from an ^{55}Fe
- Dependency of response versus P and T
  - Method for gain correction established:

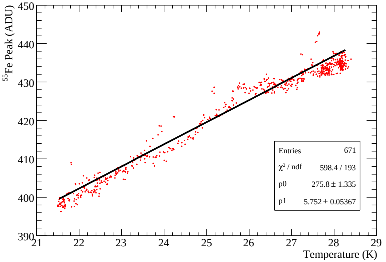
$$f_x = 1 - C_x \cdot \Delta(x)$$

$$C_P = (-0.61 \pm 0.01)\% mbar^{-1}$$

$$C_T = (-1.37 \pm 0.01)\% K^{-1}$$

$$C_{P/T} = (-164 \pm 1)\% Kmbar^{-1}$$





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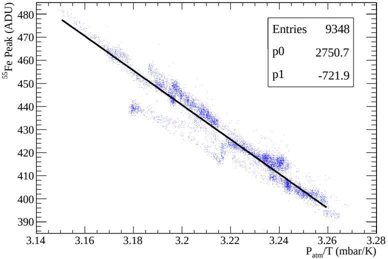
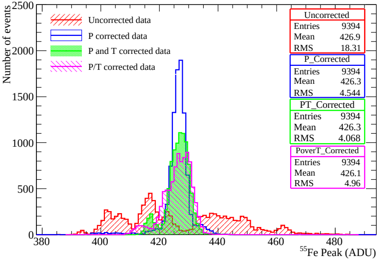
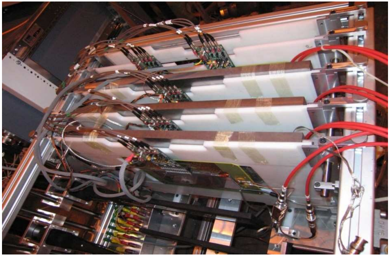
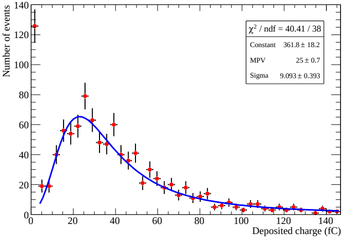




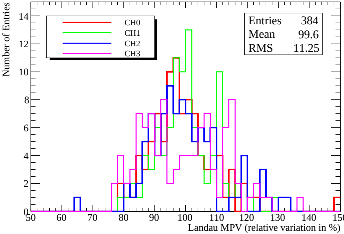
Test beam with analog readout

2008 CERN PS/SPS GASSIPLEX chambers





- Overall gain disparity ≈ 11% (384 cm^2)
- Efficiency = 97% at 1.5 fC
- Maximum Multiplicity < 1.1 at 1.5 fC



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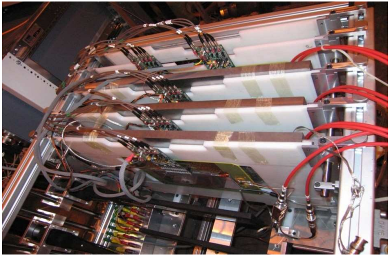

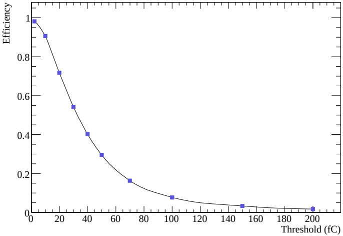

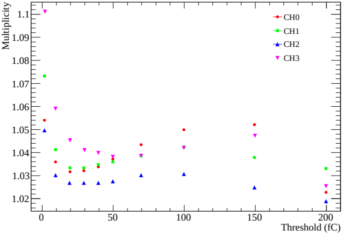

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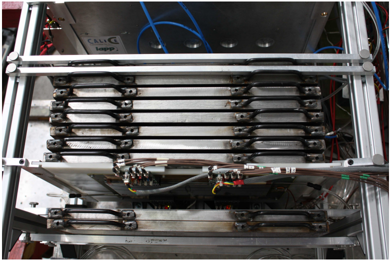

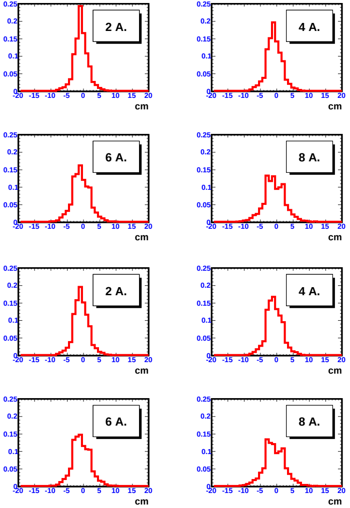

- Lateral electron shower profile
- Longitudinal electron shower profile
- Analysis of hadron showers is ongoing

Test beam with analog readout

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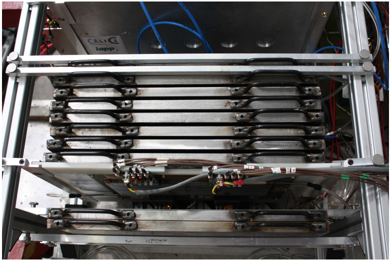

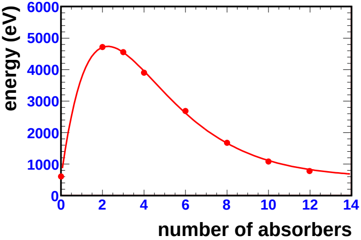

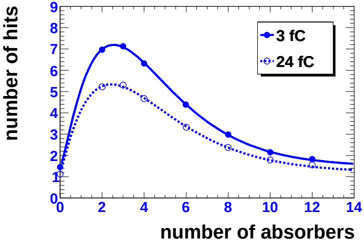

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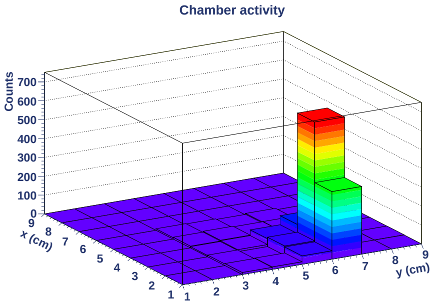
Test beam with digital readout

2008 CERN SPS, DIRAC chamber



- First DIRAC operative test
- Very first test of bulk MICROMEGAS with embedded digital readout
- fully successful
- Raw multiplicity of 1.1

Test beam with digital readout

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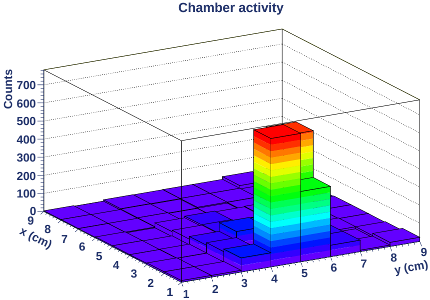

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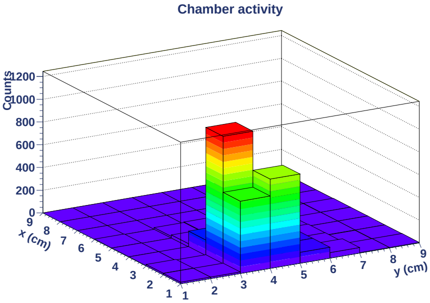

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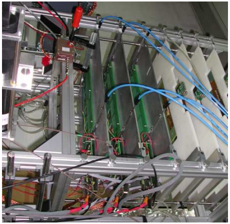
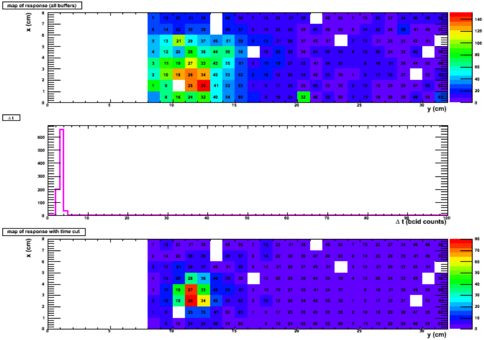
Test beam with digital readout

2008 CERN PS, HARDROCv.1 chambers





- Beam profile observed w and w/o scintillator coincidence
- Bad chip configuration $\Longrightarrow$ data mostly corrupted
- Raw efficiency estimated around 60%

Test beam with digital readout

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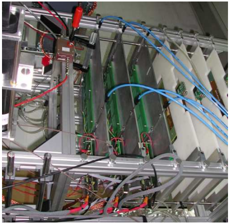

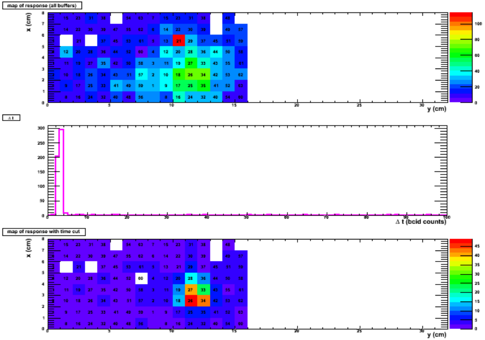

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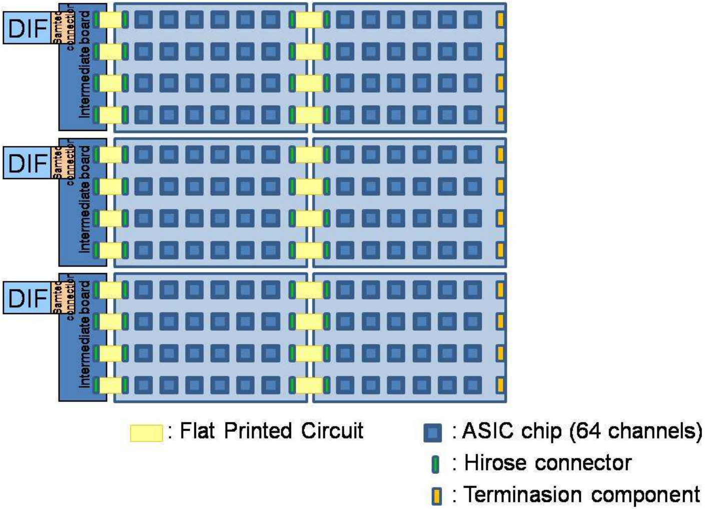
Test beam with digital readout

Ongoing tests

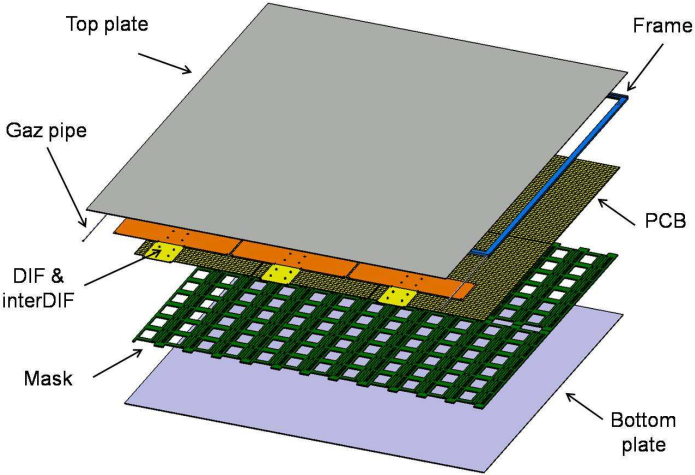
- Calibration
  - LabView software
  - All S-curves processed (calibration constants almost ready)
  - HARDROCv.1 with optimal calibration is ready
- 2009 Sep. test beam
  - X-DAQ is up to date
  - Scintillator trigger
  - High rate
  - Calibration applied
  - Chambers in bean
    - 32×8 chambers with HARDROC.v1
    - test box with 48×32 ASU with HARDROC.v2
    - 6×16 and 12×32 with GASSIPLEX
- Stack of 8x8 DIRACv.2 MICROMEGAS for efficiency and multiplicity measurements

1M^2 PROJECT

Engineering design

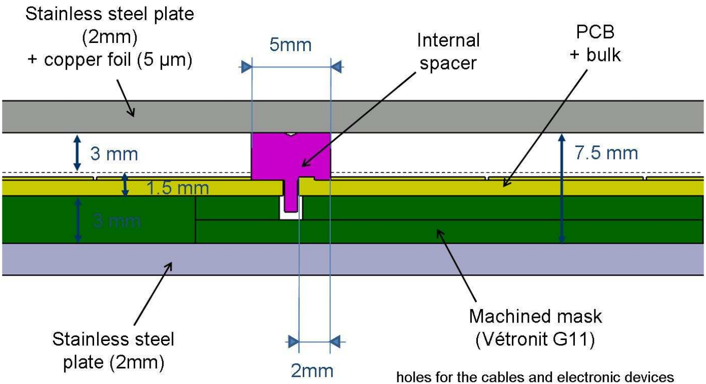


Engineering design



Engineering design

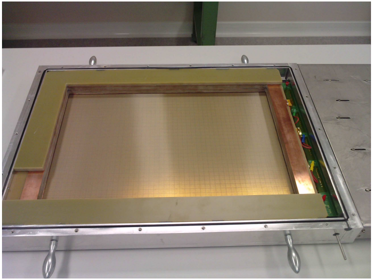
[Chamber cross section]

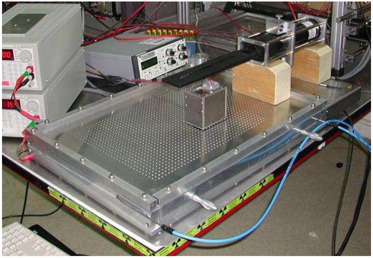


holes for the cables and electronic devices

Module test box

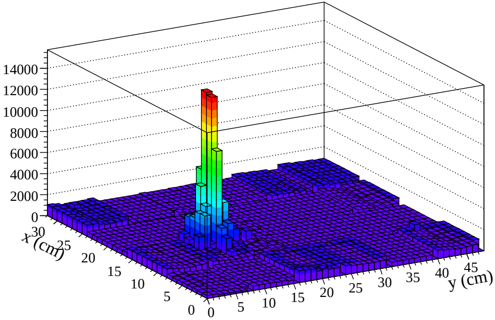
- Every ASU for $1m^2$ will pass:
  - Electronics verifications
  - Mesh cooking with high voltage
  - Test with an ^{55}Fe source and/or cosmics)
- Module test box:
  - Plexiglass lid for mesh cooking
  - Aluminum lid for X-rays injection
  - Drift cathode on the aluminum lid $\Rightarrow$ MICROMEGAS with a $3\,\mathrm{cm}$ drift gap
- Clean room available for handling naked mesh ASU





First tests of the MICROMEGAS HARDROCv.2 at LAPP

- Two $32\times48\,\mathrm{pad}$ ASUs tested with an ^{55}Fe source
- Each ASU has 24 HARDROCv.2 (1/6 m^2 physics prototype)



Mechanical prototype

- Test and establish an assembly process
- Training of assembly procedure
- Perform mechanical tests
- Verify gas tightness

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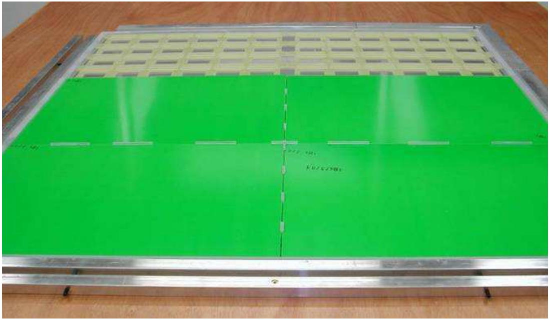

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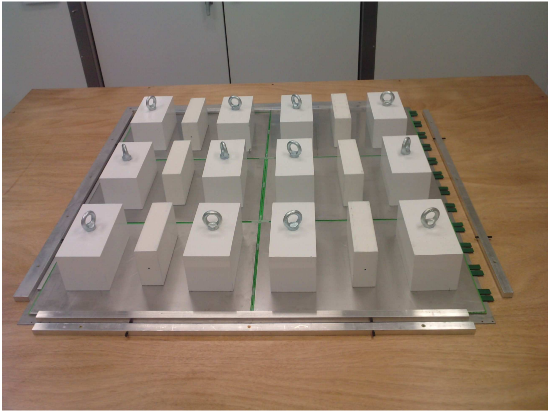

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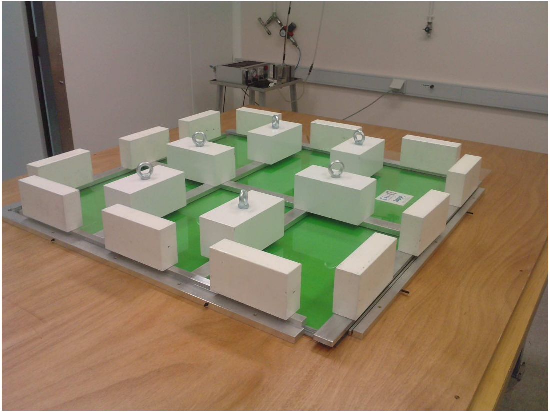

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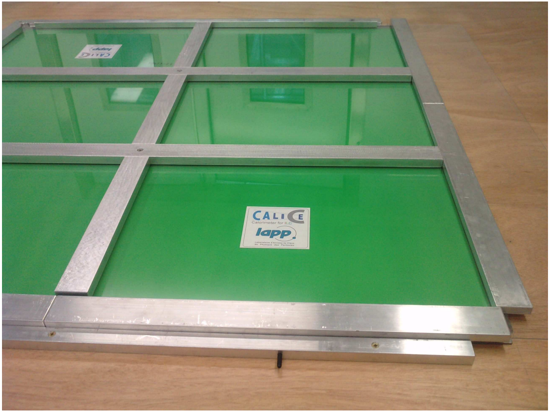

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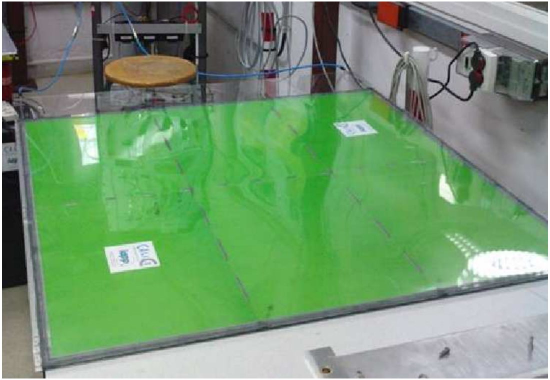

Physics prototype

- 1 week needed for assembling a 1m^2
- 1/3 of the 1m^2 will be equipped at first
  $\Rightarrow$ will hold only two ASUs
- Physics prototype equipped with 2 ASU will be tested during next test beam

CONCLUSIONS

Conclusion

- MICROMEGAS performance is in agreement with the DHCAL requirements
- Digital front-end electronics is ready
- MICROMEGAS related collaborators: CERN (bulk MICROMEGAS) and Saclay (test beams)
- Eu-DHCAL collaborators: CIEMAT, IPNL, LAL, LLR
- Very good progress toward a technological prototype (Eu-DHCAL 1m^3)

C. Adloff et al.:*MICROMEGAS chambers for hadronic calorimetry at a future linear collider, arXiv:0909.3197v1, submitted to JINST, 2009*