Development of large area MICROMEGAS chambers for digital hadronic calorimetry

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This work was performed within the CALICE collaboration

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

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3. Electronics developments
4. Simulation studies
5. MICROMEGAS development for DHCAL
6. MICROMEGAS prototypes performance
7. 1m² 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, iC₄H₁₀, CO₂)
  - 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 cm² cell size readout → \(\sim 30 \times 10^6\) channels)
  ■ Very low power consumption

■ MICROMAGAS detector
  ■ Simple and robust
  ■ Bulk MICROMEGAS - industrial process
  ■ Low voltage (< 500 V)
  ■ 1 cm² 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 cm²)
  - 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/iC₄H₁₀ 95/5: high gains (20·10³) at moderate voltages (≤ 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 prototype with embedded electronics
  - 1 chamber, $8 \times 8$ pads readout by 1 DIRACv.1 chip

- HARDROC readout:
  - 4 chambers, $8 \times 32$ pads readout by 4 HARDROCv.1 chips
  - 2 + 4 chambers, $32 \times 48$ readout by 24 HARDROCv.2 chips
Electronics developments
Detector InterFace (DIF)

- Calice DAQ Scheme:

- DIF $\Leftrightarrow$ 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 ±2% on 20–200 fC range
  - Noise less than 5 fC at 5σ
  - Very small gain dispersion → **No calibration needed for a DHCAL!**
  - Best power pulsing performance (stable at 2.7 µs 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 m²** 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

Jan Blaha (LAPP, Annecy-le-Vieux)
- MICROMEGAS Framework $\iff$ user friendly analysis framework
- Works with all type of test beam data, using SVN
Two-week long data acquisition

5.9 keV photons from an $^{55}\text{Fe}$

Dependency of response versus $P$ and $T$

Method for gain correction established:

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

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

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

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

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- 5.9 keV photons from an $^{55}$Fe
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Test beam with analog readout
2008 CERN PS/SPS GASSIPLEX chambers

- Overall gain disparity \(\approx 11\%\) (384 cm\(^2\))
- Efficiency = 97\% at 1.5 fC
- Maximum Multiplicity < 1.1 at 1.5 fC
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- Lateral electron shower profile
- Longitudinal electron shower profile
- Analysis of hadron showers is ongoing
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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
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Raw multiplicity of 1.1
Beam profile observed w and w/o scintillator coincidence

Bad chip configuration  \(\Rightarrow\) data mostly corrupted

Raw efficiency estimated around 60\%
Test beam with digital readout
2008 CERN PS, HARDROCo.1 chambers

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- Bad chip configuration → data mostly corrupted
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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 HARDROCV.1
  - test box with 48 × 32 ASU with HARDROCV.2
  - 6 × 16 and 12 × 32 with GASSIPLEX

- Stack of 8x8 DIRACv.2 MICROMEGAS for efficiency and multiplicity measurements
$1 \text{m}^2$ PROJECT
Engineering design

: Flat Printed Circuit

: ASIC chip (64 channels)

: Hirose connector

: Terminasion component
Engineering design

Top plate

Gaz pipe

DIF & interDIF

Mask

Frame

PCB

Bottom plate
Engineering design

[ Chamber cross section ]

- Stainless steel plate (2mm) + copper foil (5 μm)
- Internal spacer
- PCB + bulk
- Stainless steel plate (2mm)
- Machined mask (Vétronit G11)
- Holes for the cables and electronic devices
Module test box

- Every ASU for 1m² will pass:
  - Electronics verifications
  - Mesh cooking with high voltage
  - Test with an $^{55}\text{Fe}$ 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 cm drift gap

- Clean room available for handling naked mesh ASU
Two $32 \times 48$ 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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1 week needed for assembling a 1m²

1/3 of the 1m² will be equipped at first ⇒ 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*