MICROMEGAS for imaging hadronic calorimetry

Jan BLAHA

CALOR2010, 9 – 14 May, Beijing, China
Outline

1. Introduction
2. MICROMEGAS basic performance
3. Readout electronics and DAQ
4. $1m^2$ prototype – design and test
5. Simulations
6. Conclusions
Calorimetry at future e⁻e⁺ colliders

Calorimetry is based on Particle Flow Algorithm

- Granularity (down to $\sim 1\text{cm}^2$) more important than energy resolution
  - digital option
- Loss of linearity at high energy ($>100$ GeV/c)
  - 2 bit readout → semi-digital HCAL

1 m³ semi-DHCAL project in CALICE

- Two technologies under intensive R&D:
  - RPC
  - MICROMEGAS
MICROMEGAS

- Proportional mode
- Low working voltage
- Standard gas mixtures
- Robust (Bulk technology)
- High rate capability

- Sparking
  - Depends on gain & rate
  - Protection exists (RD51)
- Large area
  - Relatively new
  - RD51: MAMMA, SDHCAL

3 mm gas, 1 cm² pads, thickness < 8 mm
Basic performance (X-rays)

- $^{55}$Fe source (5.9 keV)
- Analog readout of mesh signal

Energy resolution @ 5.9 keV 
~ 7.5 % (FWHM = 17.6 %)
Basic performance (X-rays)

**Gas mixtures**
- Collection efficiency
- Gas gain

**Ambient parameters**
- Pressure (-0.6%/mbar)
- Temperature (1.4%/K)

---

LAPP-TECH-2009-03

May 2010, Beijing, China
Basic performance (Test beam)

- CERN SPS (2008) and PS (2009) lines
- Analog and digital readouts
Basic performance (Test beam)

Study with MIPs

- Efficiency, multiplicity
- Uniformity of efficiency better than 1 % (100 cm²)
- Threshold effect understood

Shower profiles

- 2 GeV/c electrons
- Hadrons analysis on-going

MIP MPV ~20fC with a variations of 11%
At a threshold of 1.5 fC
- 97% efficiency with variations < 1%
- Hit multiplicity below 1.12
MICROMEGAS with digital readout

Semi-digital readout (2 bit) embedded on one side of PCB

1. DIRAC chip, 8x8 cm², 2008
2. HARDROC1 chip, 32x8 cm², 2008
3. HARDROC2 chip, 48x32 cm², 2009
4. DIRAC2 chip, 8x8 cm², 2009
Readout ASICs and TB results

DIRAC 1 & 2 chip (IPNL/LAPP)

- Synchronous functioning, integrate signals
- Promising results on efficiency
- DIRAC2 not spark-proof, protection tests
  @ LAPP ongoing

HARDROC 1 & 2 (LAL/Omega group)

- Asynchronous functioning, shape signals
- Very low efficiency (5-10 %) due to too short shaping time

Work on a new chip (MICROROC) in collaboration with LAL/Omega
1 m² MICROMEGAS prototype

Features
- 6 ASU of 48x32 cm² (24 ASIC / ASU)
- Dead area < 10 %
- Total thickness of 1.15 cm (incl. steel covers)
- 3 DIF boards

Test of each ASU separately first
Assembly procedure validated on mechanical prototype

1 m² will be tested in a beam in June 2010
HR2 calibration and test of 32x48 ASU

HR2b calibration with test charge

- High efficiency at low threshold (97% @ 1.5 fC) → Align channel gain to lower the threshold
- HR2b successfully debugged (LAL+LAPP)
- Gain distribution spread of 1 % RMS after equalization

ASU test with X-rays

- Test of complete chain (Bulk/HR/DAQ) inside a test box
- Each readout cell is measured individually

![HR2b calibration and test](image)

100 fC inflexion point - chip 18 - asu 12

HR2b
8 % RMS
1 % RMS

![ASU test with X-rays](image)

$^{55}$Fe hits and mesh voltage on ASU 11 - Chip 20 - Channel 14

number of hits

$V_{mesh}$ (V)
First level DAQ electronics

Detector Interface (DIF)

- Board and firmware developed at LAPP
- Provides communication between HARDROCs or DIRACs and DAQ and control systems
- Allows ASIC configuration and performs analog and digital readout
- Also compatible with SPIROC and SKIROC (ECAL and AHCAL)

- CALICE beam tests of RPC and MICROMEGAS (2008-2009)
- Production for m\(^3\) has just started (3 boards per layers, 40 layers)
- DIF firmware for future CALICE DAQ under development at LAPP
Simulations studies 1/2

HCAL physics performance
- Response and linearity
- Energy resolution
- Energy shower shapes

Comparative studies
- Analog vs digital readout with different thresholds
- Several absorber materials (Fe, W, Pb) and detector geometry
- Different particles in a wide energy range → from ILC to CLIC

Longitudinal containment
Simulations studies 2/2

Different prototype setups

- Beam test preparation
  - steel HCAL for SiD detector
  - tungsten HCAL for CLIC detector
- Data comparison and Geant4 validation

HCAL performance for different engineering solutions

- Projective and tilted geometries
- Boundary effects and impact of dead zones

SiD HCAL designed at LAPP
Direct Collaborators

SLAC and Fermilab mechanics groups: SiD HCAL structure
CERN EN-ICE-DEM group: bulk-MICROMEGAS, sparks protections
SUBATECH: Centaure DAQ (analog readout)
CEA-IRFU Saclay: MICROMEGAS support
IPNL: X-DAQ data acquisition program, DIRAC chip design
LAL: HARDROC chip design and support, MICROROC
LLR: future CALICE DAQ
CIEMAT: DHCAL 1m$^3$ steel mechanical structure
CERN PH-LCD group: simulations, W-HCAL prototype

→ Test of scintillator layers + 1 or more MICROMEGAS planes at CERN PS line in November 2010
Conclusions

LAPP is strongly committed to the R&D of a MICROMEGAS DHCAL in various domains from detector fabrication and test, electronics (front-end and DAQ) to simulation and mechanics.

The prototypes realized so far were tested in the laboratory and in CERN particle beams. The basic properties of the detector (gas gain, pressure and temperature effects) as well as the essential performance (efficiency, multiplicity, behaviour in particle showers) have been measured.

These results, together with the possibility of industrial fabrication of large area and thin detectors, demonstrate that MICROMEGAS is an attractive option for a DHCAL.
Acknowledgments

LAPP team:
  Catherine Adloff
  Jan Blaha
  Jean-Jacques Blaising
  Sébastien Cap
  Maximilien Chefdeville
  Alexandre Dalmaz
  Cyril Drancourt
  Ambroise Espargilière
  Laurent Fournier
  Renaud Gaglione
  Nicolas Geffroy
  Jean Jacquemier
  Yannis Karyotakis
  Fabrice Peltier
  Julie Prast
  Guillaume Vouters

Colaborators:
  David Attié
  Enrique Calvo Alamillo
  Paul Colas
  Christophe Combaret
  Mary-Cruz Fouz Iglesias
  Wolfgang Klempt
  Lucie Linsen
  Rui de Oliveira
  Olivier Pizzirusso
  Didier Roy
  Dieter Schlatter
  Nathalie Seguin
  Christophe de la Taille
  Wenxing Wang