MICROMEGAS for imaging hadronic calorimetry

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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 ~1cm^2) more important than energy resolution

  → digital option

  - Loss of linearity at high energy (>100 GeV/c)

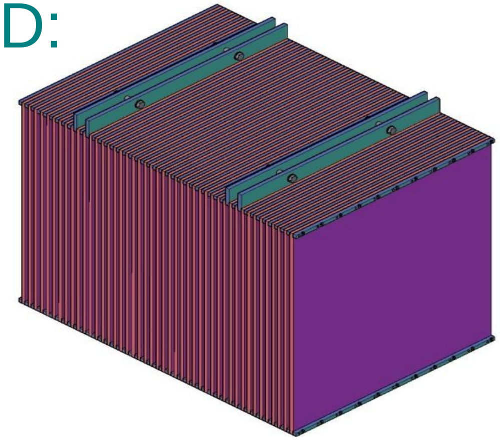
    → 2 bit readout → semi-digital HCAL

1 m^3 semi-DHCAL project in CALICE

- Two technologies under intensive R&D:

  → RPC

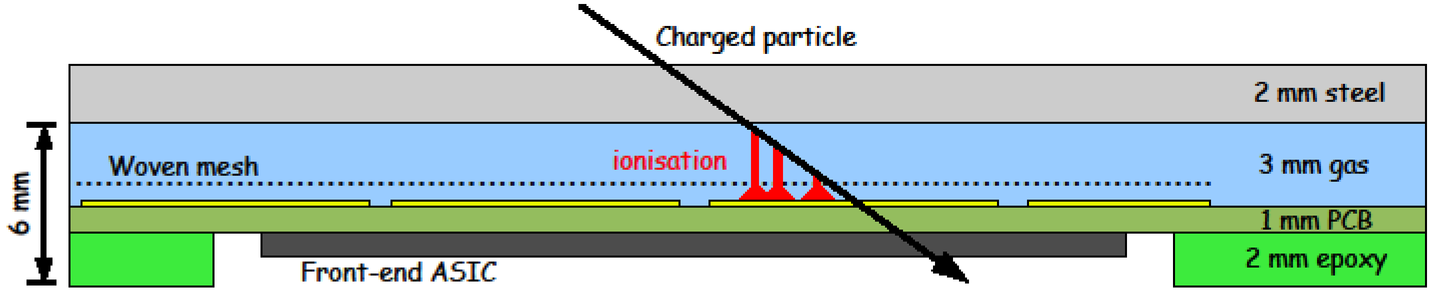
  → MICROMEGAS



MICROMEGAS

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

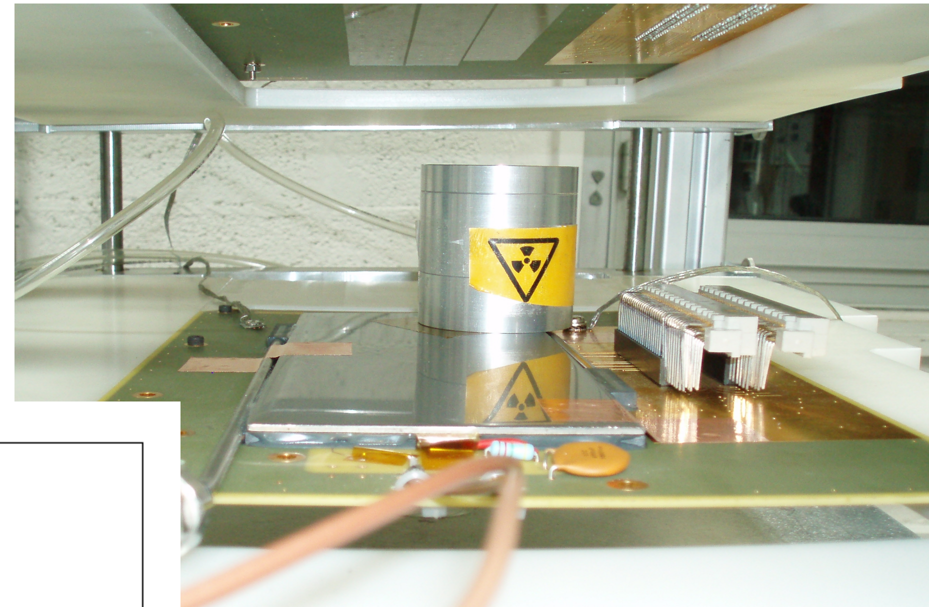
- Sparking
  - Depends on gain & rate
  - Protection exists (RD51)
- Large area
  - Relatively new
  - RD51: MAMMA, SDHCAL

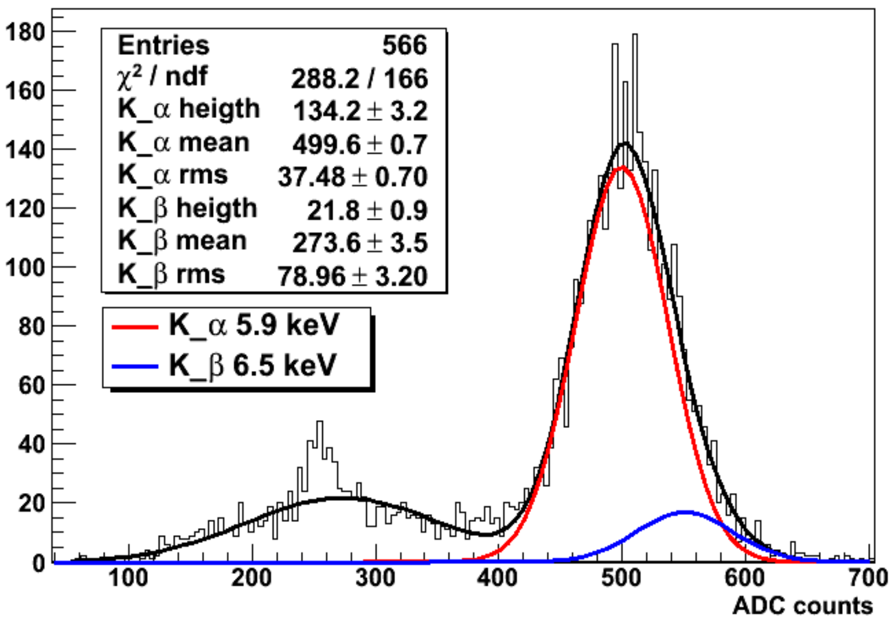


3 mm gas, 1 cm2 pads, thickness < 8mm

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)

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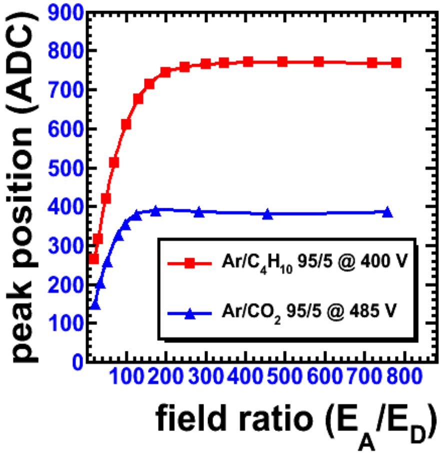
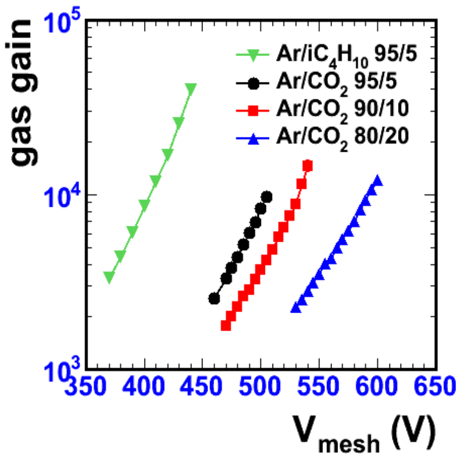
Gas mixtures

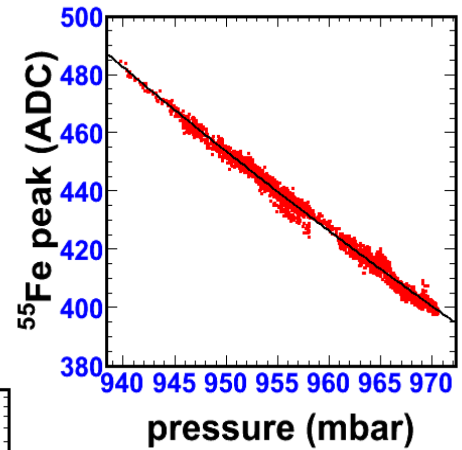
- Collection efficiency
- Gas gain

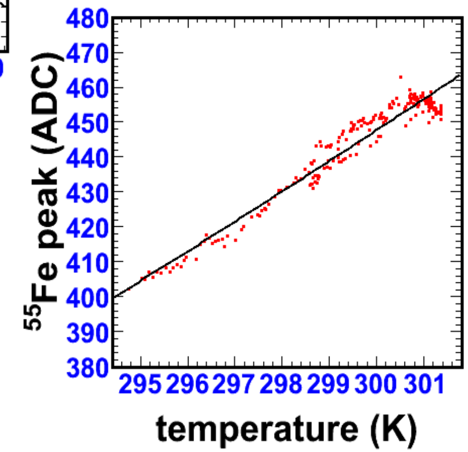
Ambient parameters

- Pressure (-0.6%/mbar)
- Temperature (1.4%/K)



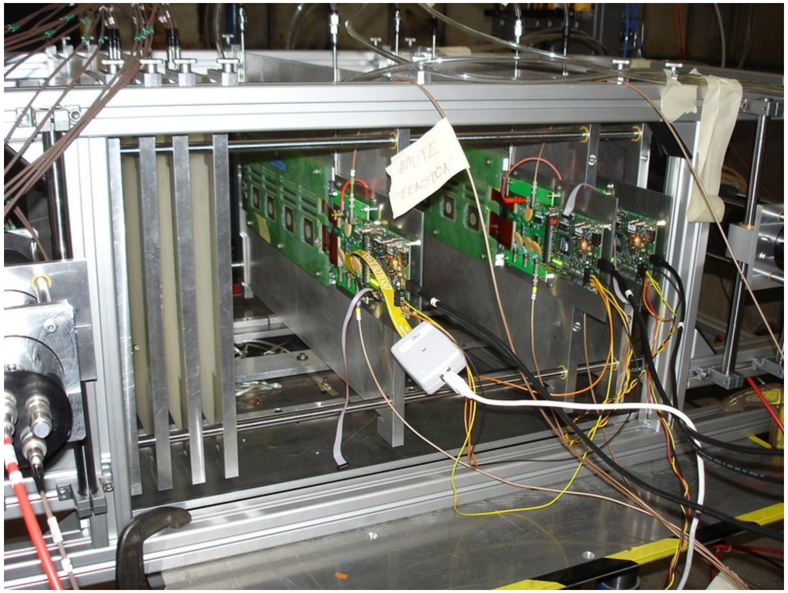


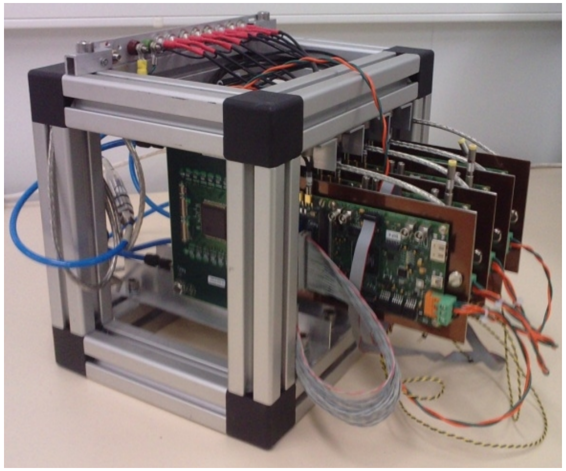


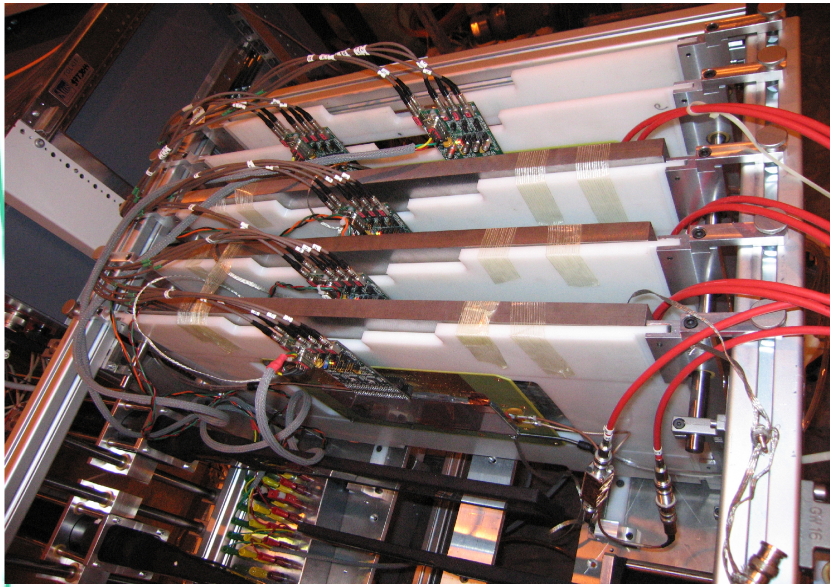


Basic performance (Test beam)

- CERN SPS (2008) and PS (2009) lines
- Analog and digital readouts







Basic performance (Test beam)

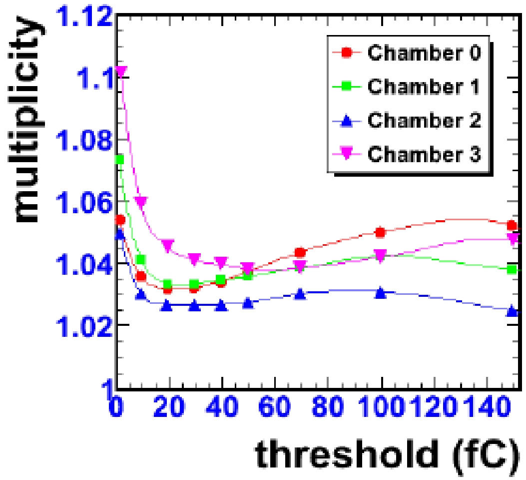
2009 JINST 4 P11023

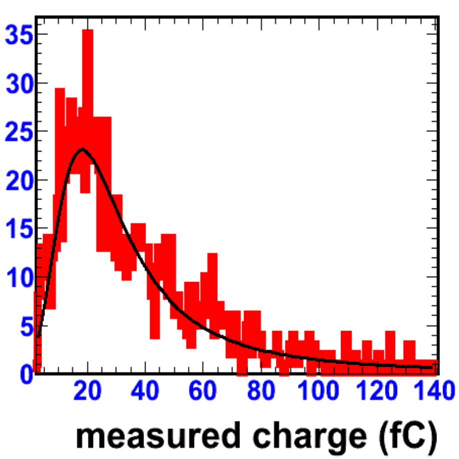
Study with MIPs

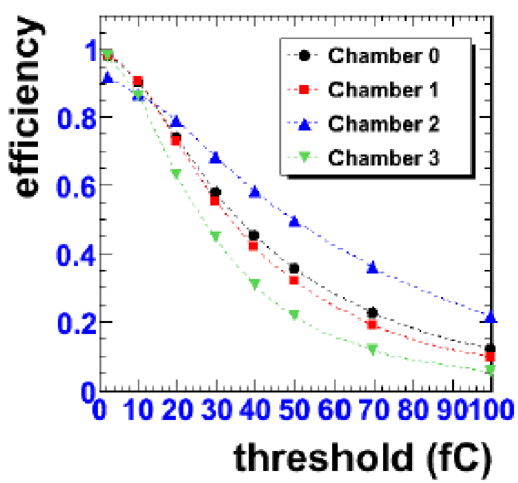
- Efficiency, multiplicity
- Uniformity of efficiency better than 1 % (100 cm²)
- Threshold effect understood

Shower profiles

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







MIP MPV ~20fC with a variations of 11%

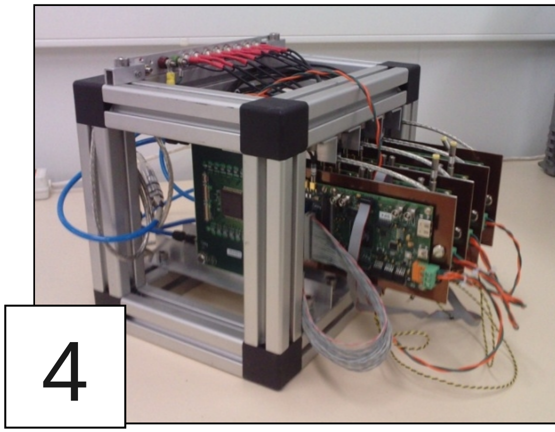
At a threshold of 1.5 fC

- 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



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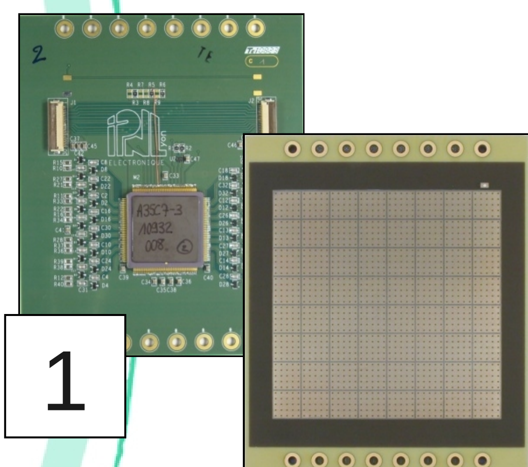
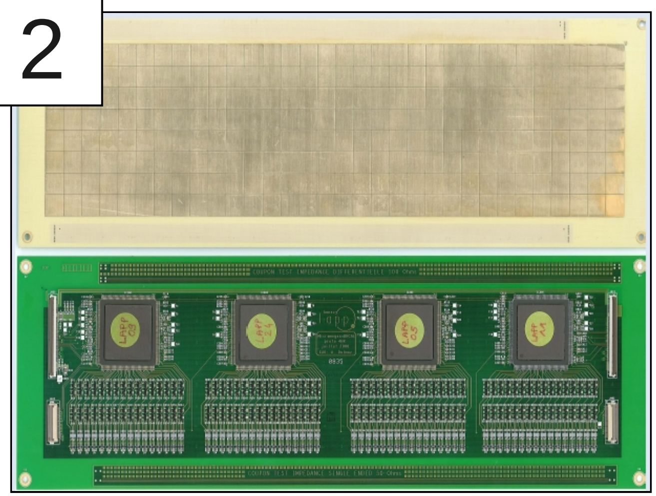


1



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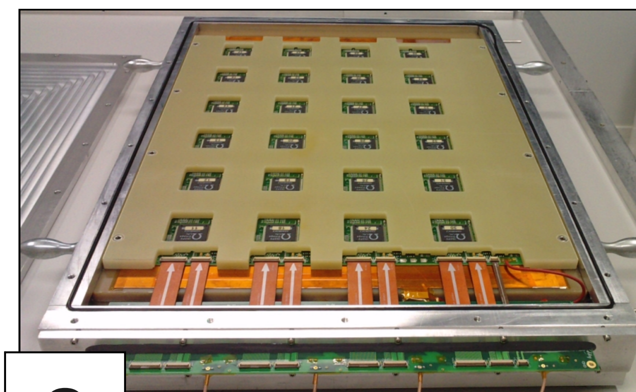


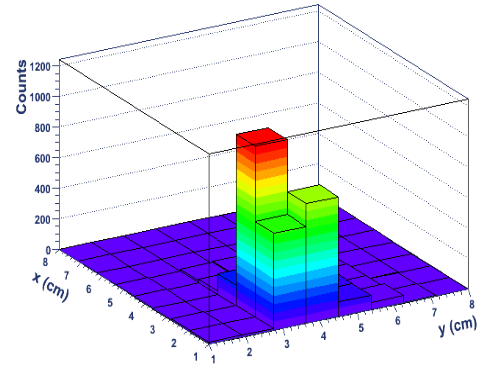
3

Readout ASICs and TB results

[2009 JINST 4 P11011]

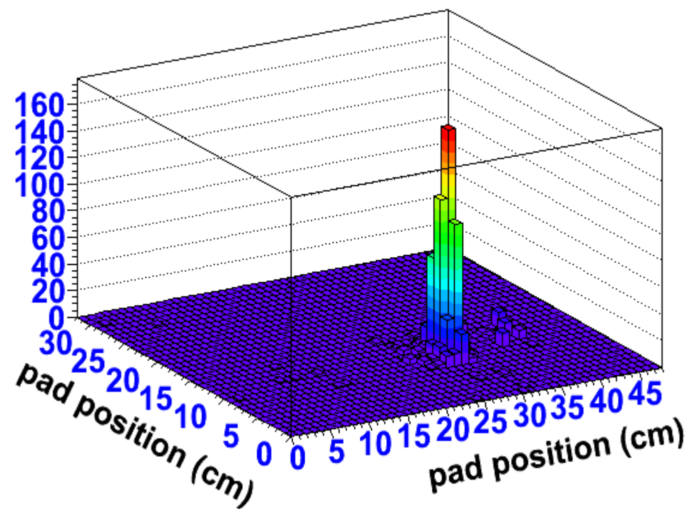
DIRAC 1 & 2 chip (IPNL/LAPP)

- 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

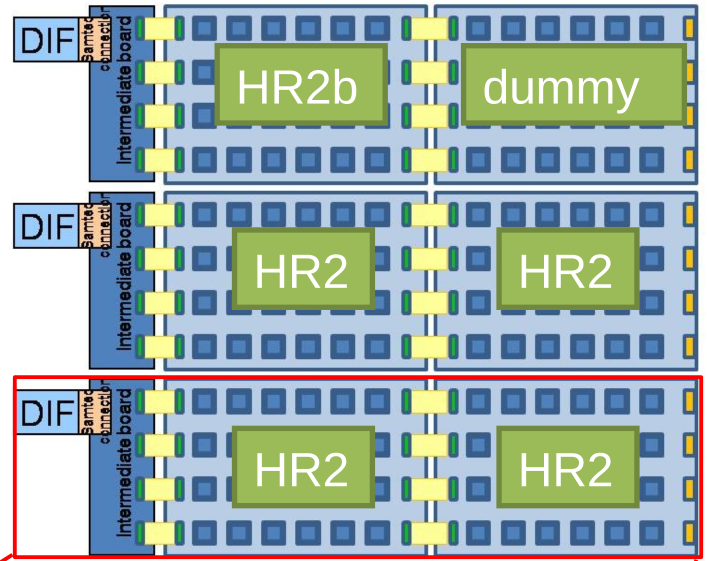
1 m^2 MICROMEGAS prototype

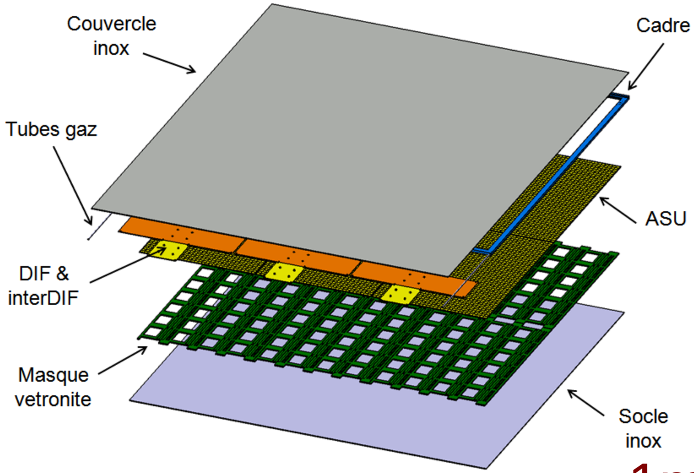
Features

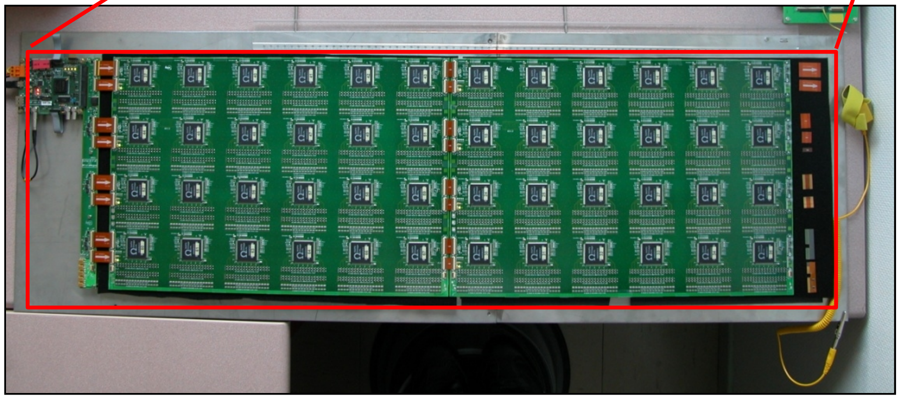
- 6 ASU of 48x32 cm^2 (24 ASIC / ASU)
- Dead area < 10 %
- Total thickness of 1.15 cm (incl. steel covers)
- 3 DIF boards

Test of each ASU separately first

Assembly procedure validated on mechanical prototype





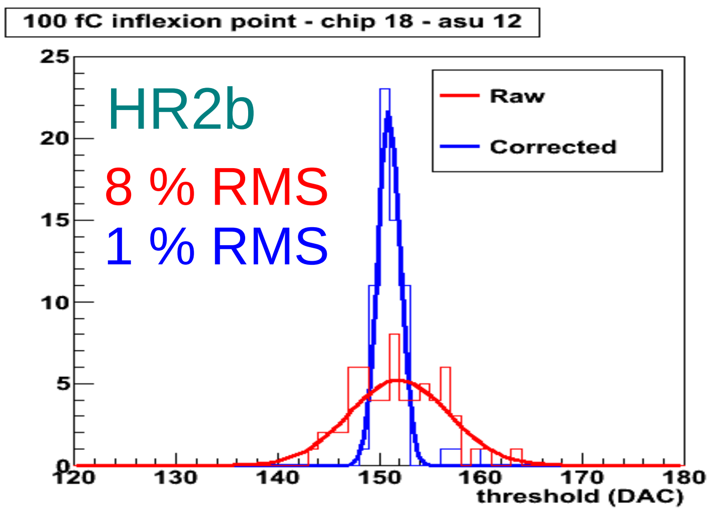


1m^2 will be tested in a beam in June 2010

HR2 calibration and test of 32x48 ASU

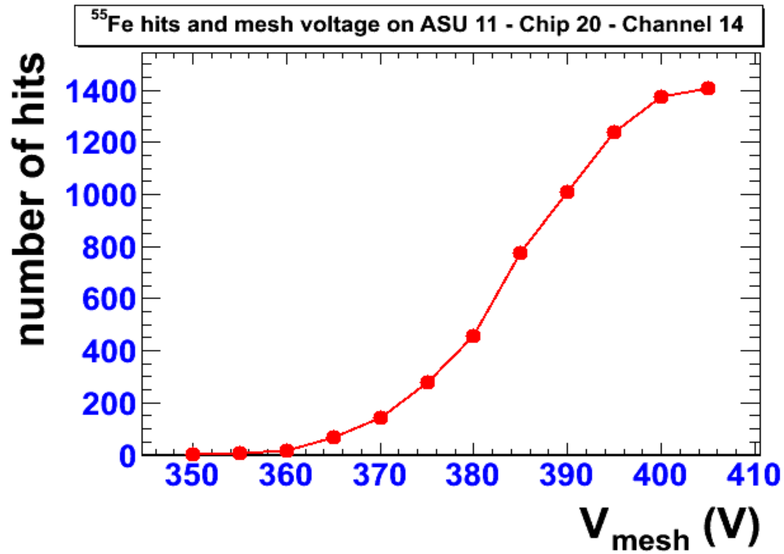
HR2b calibration with test charge

- 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

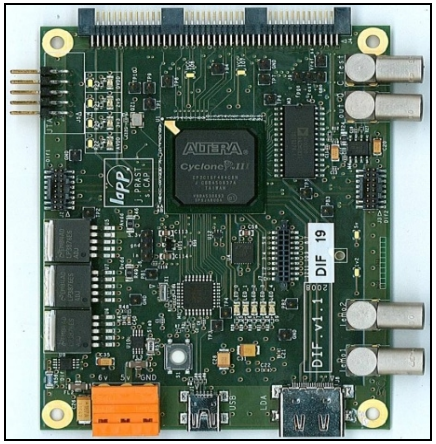
- Test of complete chain (Bulk/HR/DAQ) inside a test box
- Each readout cell is measured individually

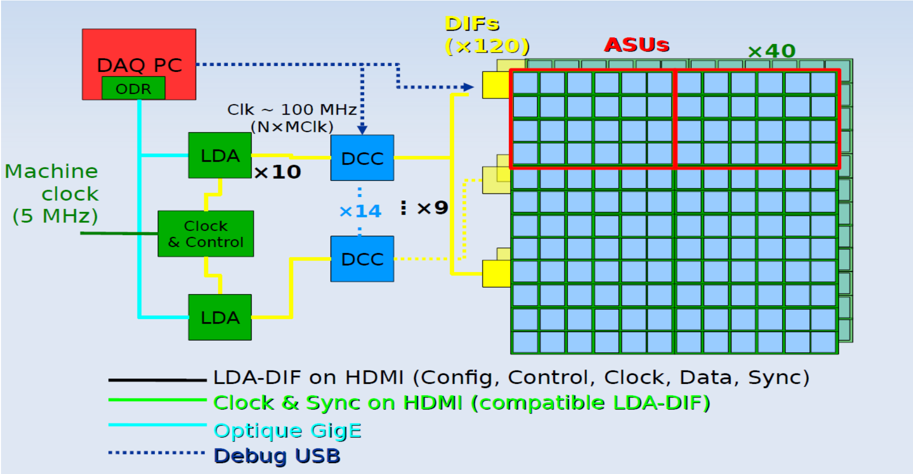


First level DAQ electronics

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)





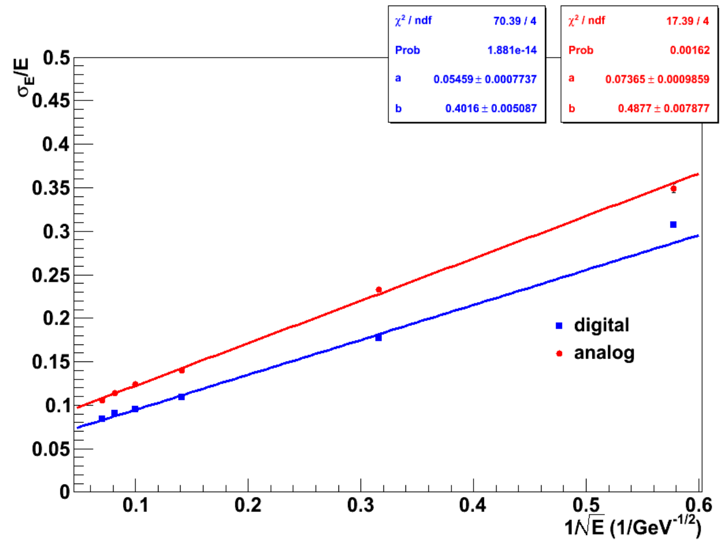
- CALICE beam tests of RPC and MICROMEGAS (2008-2009)
- Production for m^3 has just started (3 boards per layers, 40 layers)
- DIF firmware for future CALICE DAQ under development at LAPP

Simulations studies 1/2

2009 JINST 4 P11009

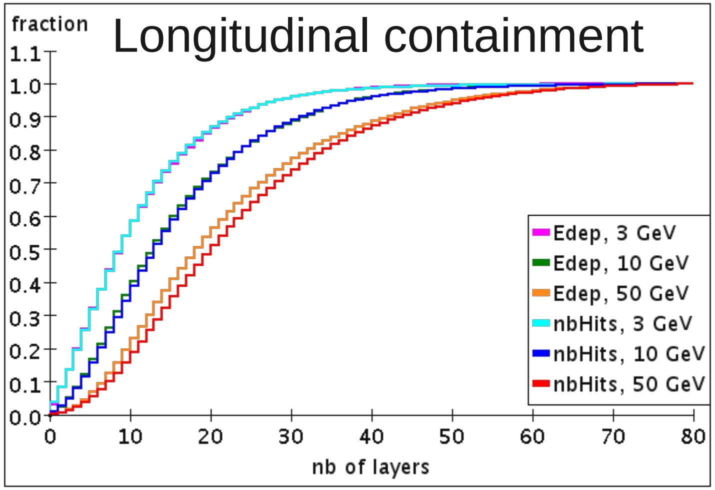
HCAL physics performance

- 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



Simulations studies 2/2

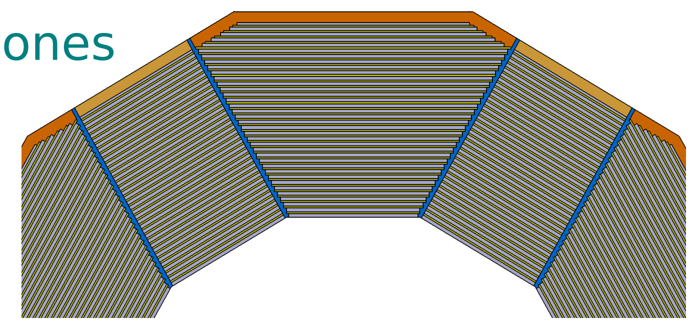
Different prototype setups

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

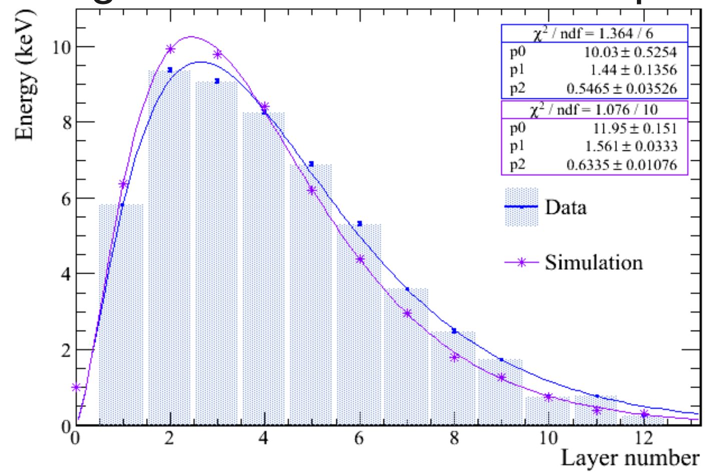
HCAL performance for different engineering solutions

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

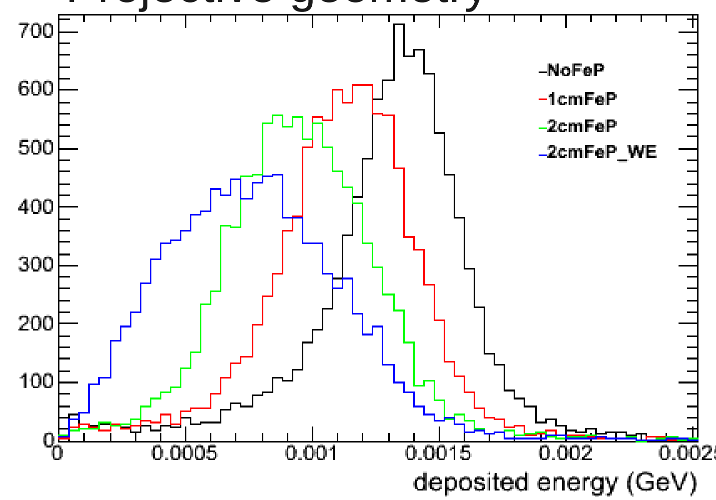
SiD HCAL designed at LAPP



Longitudinal electron shower profile



Projective geometry



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
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- Didier Roy
- Dieter Schlatter
- Nathalie Seguin
- Christophe de la Taille
- Wenxing Wang