Progress towards a technological prototype for a semi-digital hadron calorimeter based on glass RPCs

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CIEMAT, Gent, IPNL, LAL, LAPP, LLN, LLR, LPC, Protvino, Tsinghua, Tunis
ILD DHCAL – Overall layout of detector planes (‘Videau’ concept)

- Eliminate projective cracks
- Services leave radially – minimize barrel / endcap separation
Detector plane dimensions

- 48 planes / module
- 8 modules / wheel
- 5 wheels total

- Absorber: 20mm SS
- 6mm for GRPCs
  + electronics

Max ~ 3.0m
Min ~ 0.1m
Considerations for a technological prototype

- Build one HCAL module for testing in beams at CERN and/or Fermilab

Simplifications:
- All detectors 1m x 1m
- Only 40 planes

Challenges:
- Detector + electronics thickness < 6mm
- Minimize dead zones
- Homogeneous gain
- Efficiency >90% + minimize multiplicity
- Full electronics with power pulsing
- Realistic support structure for absorbers + RPCs
Chamber performance: key design parameters

- Homogeneity of gain / efficiency
  - Constant gas gap over large areas
  - Efficient gas distribution within chamber
  - No air gaps between readout pads and anode glass

- Optimization of multiplicity
  - Absolute value of coating resistivity
    - Higher values give lower multiplicity
    - Lower values improve rate capability
    - Compromise: 1-10 MΩ/□
  - Uniformity of resistivity over surface
Cross-section of Lyon 1m² glass RPCs

PCB support (FR4 or polycarbonate)

PCB (1.2mm)

Mylar layer (50µ)

Mylar (175µ)

Glass fiber frame (1.2mm)

Cathode glass (1.1mm) + resistive coating

Anode glass (0.7mm) + resistive coating

Ceramic ball spacer (1.2mm)

Gas gap

Readout ASIC (Hardroc2, 1.4mm)

Readout pads (1cm x 1cm)

PCB interconnect

Total thickness: 5.825mm
Ball spacing – FEA study

• Includes glass weight + electrostatic force
• Gas pressure *not* included
• Forces balance for 1 mbar overpressure

Max. deformation: 44µ
Gas distribution

May be an issue for large area, very thin chambers

Plexiglas spacers
Ø = 1.2mm

Gap = 2mm

Capillary 1.2x0.8

20mm
Gas - speed distribution

Boundary conditions:
- Inlet flow = 3.6 l/hr
- Outlet press = 1 atm.

Scale: 0-10 mm/s

Does not include diffusion effects

Scale: 0-1 mm/s

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Gas – ‘Least Mean Age’

Time in seconds for gas to reach a given point in the chamber after entering the volume; *diffusion included*

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## Resistive coating

|                        | Licron | Statguard | Colloidal Graphite type I | Colloidal Graphite type II |
|------------------------|--------|-----------|---------------------------|-----------------------------|
| Surface resistivity (MΩ/□) | ~20    | 1-10      | 1-10                      | Depends on mix ratio; choose 1-2MΩ |
| Best application method | Spray  | Brush     | Silk screen printing      | Silk screen printing        |
| Cost, EUR / kg          | 130    | 40        | 670*                      | 240*                        |
| Delivery time (weeks)   | 3      | <1        | 6                         | 6                           |

*Estimate 20m² (10 chambers) / kg using silk screen printing technique

Licron: fragile coating, problems with HV connections over time
Statguard: long time constant for stable resistivity (~2 weeks), poor homogeneity

Baseline for 1m³ is colloidal graphite type I but type II tests very promising
Colloidal Graphite Type II

- Product designed for Silk Screen Printing
- Drying at high temperature (170°C) required
- Close collaboration with local French company

Mean 1.2 MΩ/□
Ratio MAX/MIN = 1.8
Variation between mix batches
Electronics boards + support

- 144 ASICs, 9216 channels per m²
- 1m³ project: almost 400,000 channels!
- 1m³ project will use Hardroc 2b chip
Protective cassette for RPC + electronics

- SS plates 2mm + 3mm thick
- Contribute to absorber layers (15mm + 5mm)
- PCB supports now in polycarbonate cut with water jet
- PCBs fixed to support using M1.6 screws + ‘Post-It’ glue

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1m$^3$ project – mechanical structure (1)

Enrique Calvo Alamillo (CEIMAT)
Alain Bonnevaux (IPN-Lyon)
1m$^3$ project – mechanical structure (2)

Spring-loaded balls in absorber press cassette plates against RPCs + PCBs

Helps keep PCB pressed flat against anode glass

Cassette insertion test very soon (all elements in hand)

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Thermal modelling

- **Model**
  - 100 mW chips (no power pulsing)
  - No active cooling - thermal dissipation by convection only
  - $T(\text{hall}) = 20^\circ\text{C}$
  - 3 absorbers + 2 detectors (1/4 of 1m$^2$ + symmetry)
  - Cubic grid
  - Modelled in CATIA + EFD

- **Result**
  - $T_{\text{max}} = 25^\circ\text{C}$
  - Conclude: active cooling not necessary
High Voltage

- Cockcroft-Walton voltage multiplier
- Developed in collaboration with ISEG company
- Low profile (<24mm) allows modules to be mounted between HCAL layers
- Low voltage up to detectors minimizes cabling
- Control and monitoring by ethernet link

Characteristics:
- 0-5 V → 0-10 kV
- I <10µA
- I,V monitoring
- Residual noise 50 mV
HV Network

Ethernet Link

Standalone Microcontroller Monitoring System

HV Board ID = 1
HV Board ID = 2
HV Board ID = 39
HV Board ID = 40

RS485 Network
40 Square Meter

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Gas distribution system

- Local French company
- 40+ independent channels
- Individual flow adjustment
- Ensures accurate mixing of gases
- Conforms to CERN safety rules (ATEX zone II)
- Purchase imminent
Conclusions

- Construction of $1m^2$ GRPCs with good detector performance well understood (see talk 164 BELKADHI LLR)
  - Uniform resistive coatings
  - Constant gas gap + optimized gas distribution
- Electronics based on Hardroc 2 chip well advanced
- Cassettes designed
  - Assembly with $1m^2$ RPC + electronics within next 2 weeks
- Mechanical super-structure designed
  - Insertion test (2 absorbers, 1 gap) to follow cassette assembly
  - Thermal analysis completed
- Multi-channel voltage multiplier system well advanced
- 40-channel gas system: tenders received, order imminent
Outlook

☐ Timescale for completion of technological prototype: end 2010
☐ Test in beam in 2011
☐ Timescale is tight, but feasible
☐ Top priority project: will consume most of our resources
☐ Nevertheless, a few parallel developments ongoing:
  ■ Ageing test at CERN GIF (some data already available – being analysed)
  ■ Small prototypes with low resistivity glass
  ■ Multigap chambers