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

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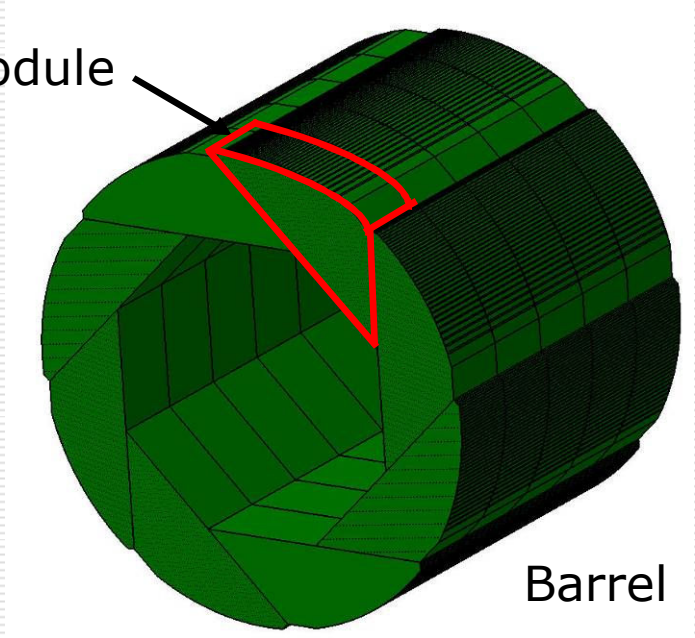
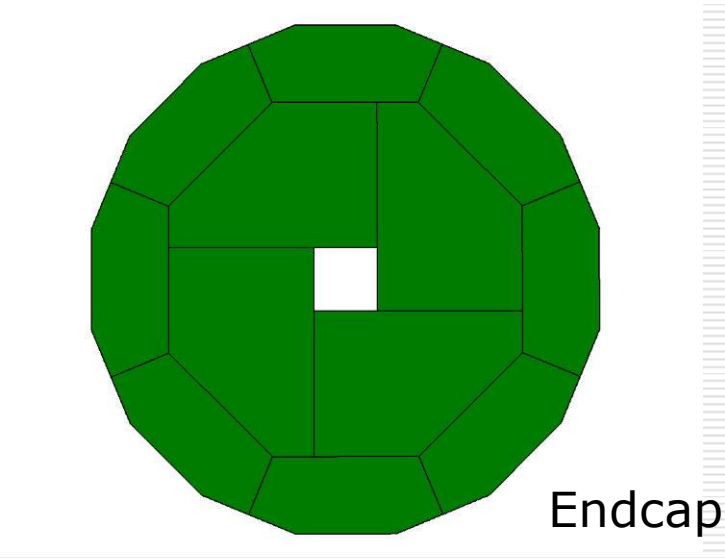
CIEMAT, Gent, IPNL, LAL, LAPP, LLN, LLR, LPC, Protvino,Tsinghua,Tunis

ILD DHCAL – Overall layout of detector planes ('Videau' concept)

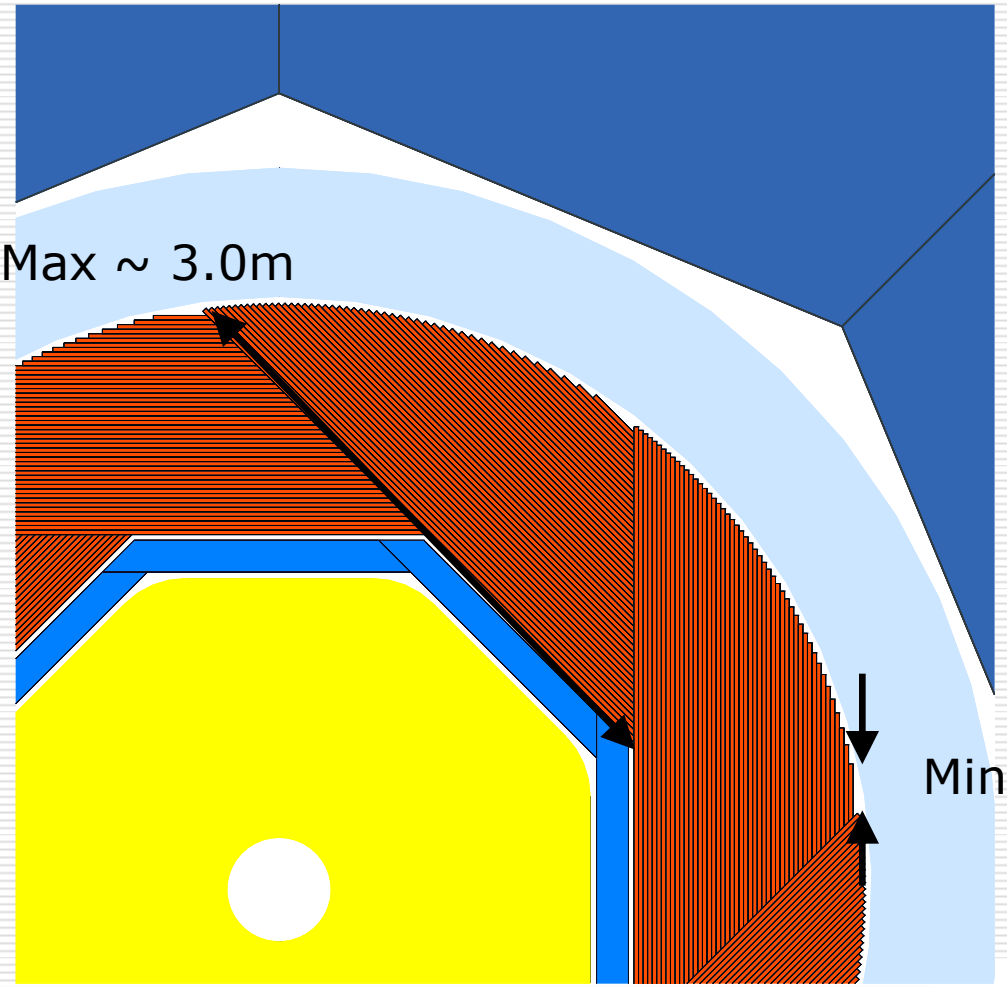




- Eliminate projective cracks
- Services leave radially – minimize barrel / endcap separation

Detector plane dimensions

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



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

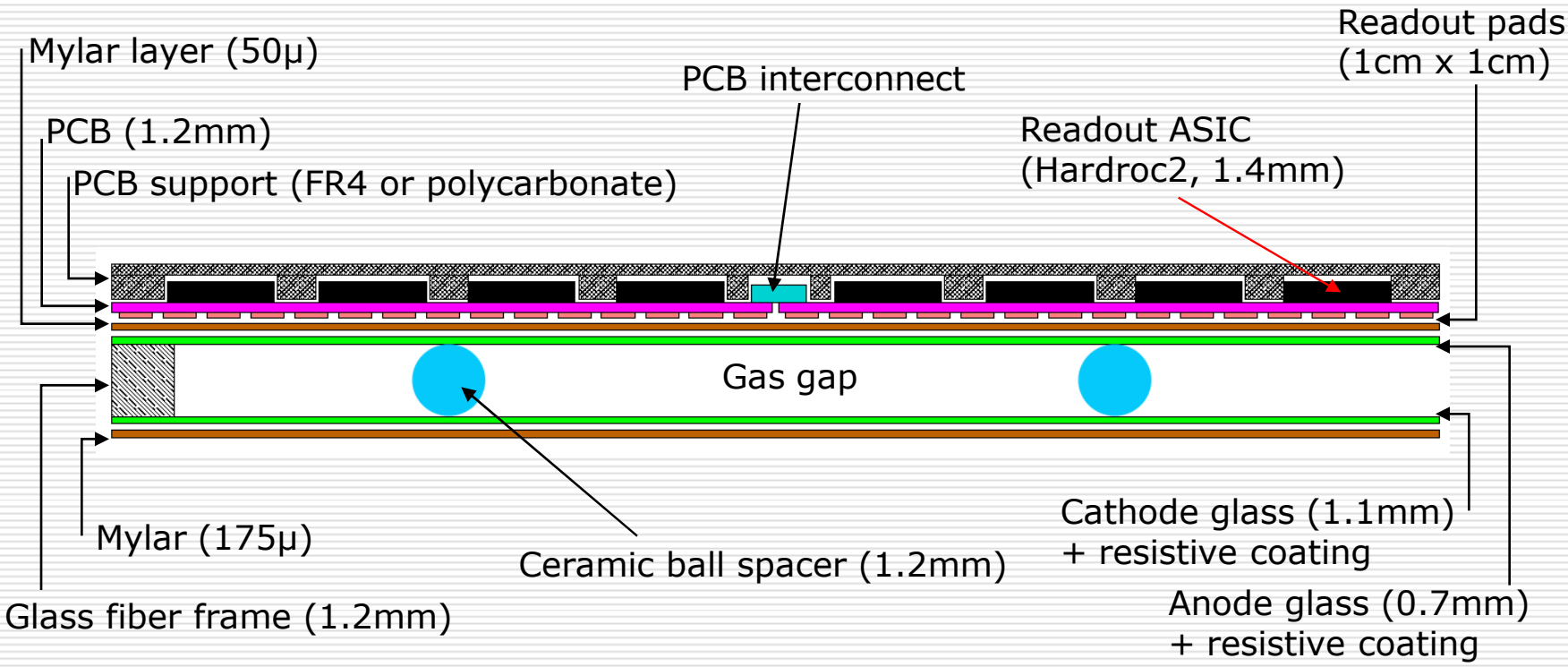
Considerations for a technological prototype

- 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

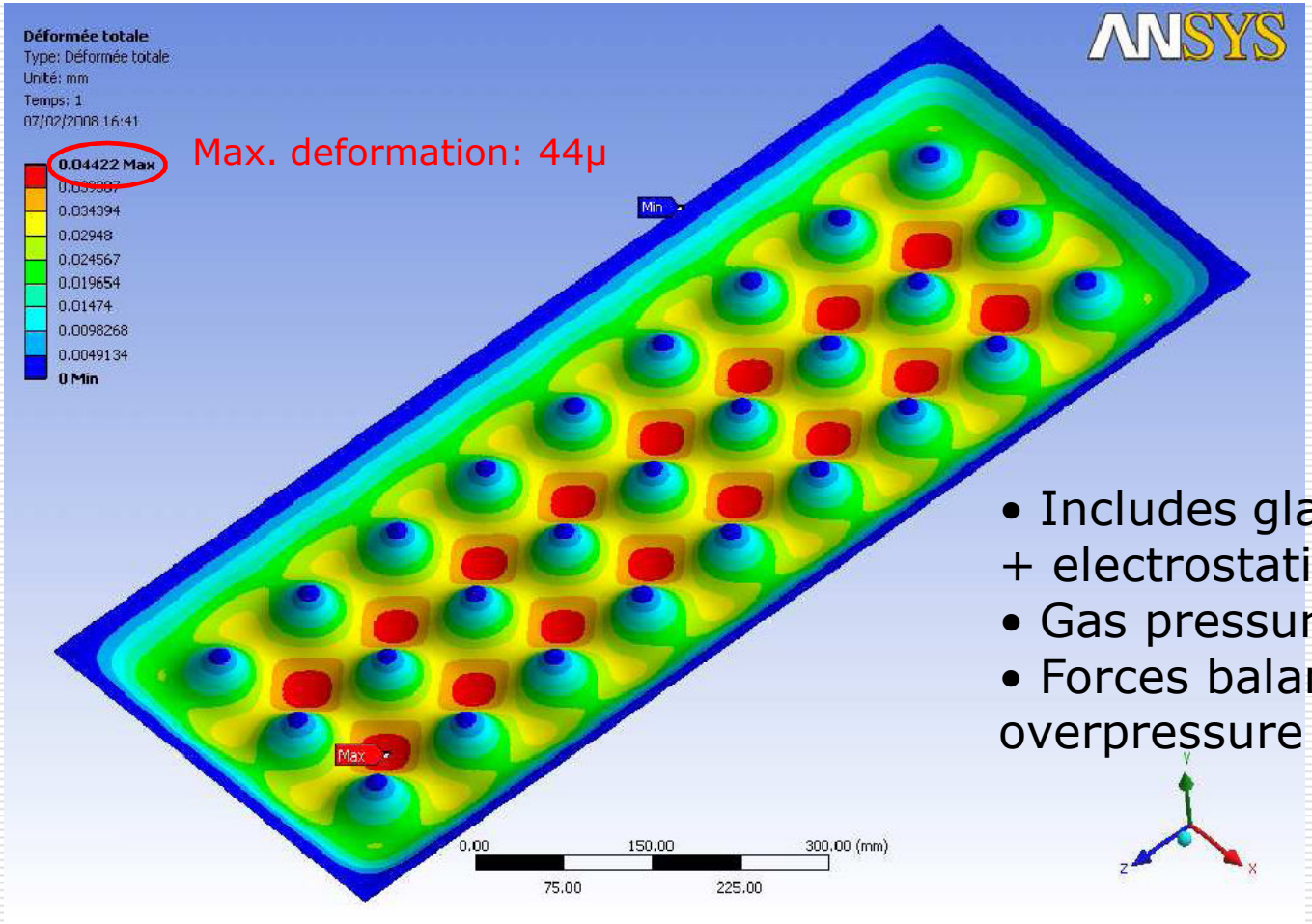
- Homogeneity of gain / efficiency
  - Constant gas gap over large areas
  - Efficient gas distribution within chamber
  - No air gaps between readout pads and anode glass
- Optimization of multiplicity
  - Absolute value of coating resistivity
    - Higher values give lower multiplicity
    - Lower values improve rate capability
    - Compromise: 1-10 MΩ/□
  - Uniformity of resistivity over surface

Cross-section of Lyon 1m^2 glass RPCs



Total thickness: 5.825mm

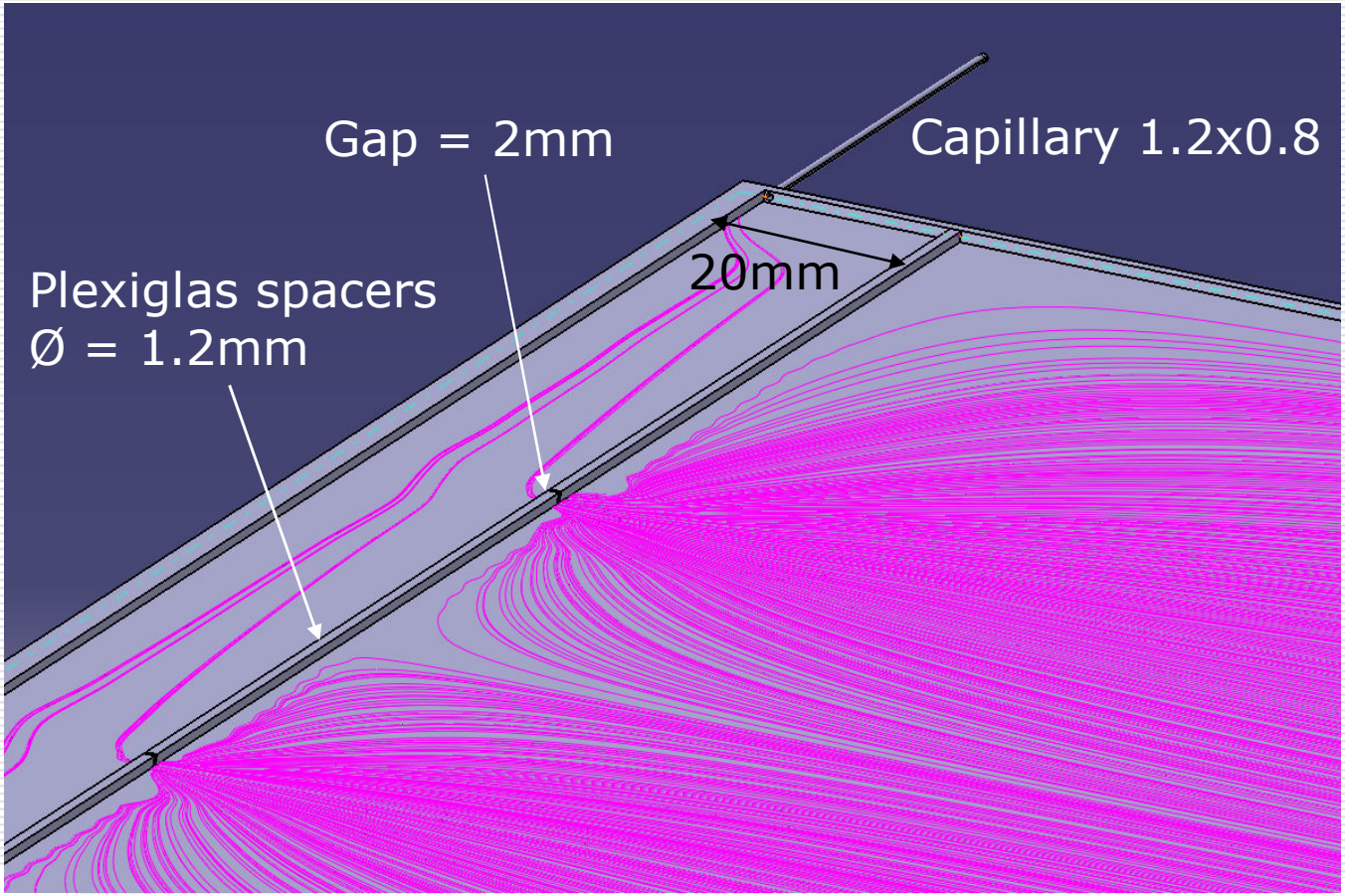
Ball spacing – FEA study



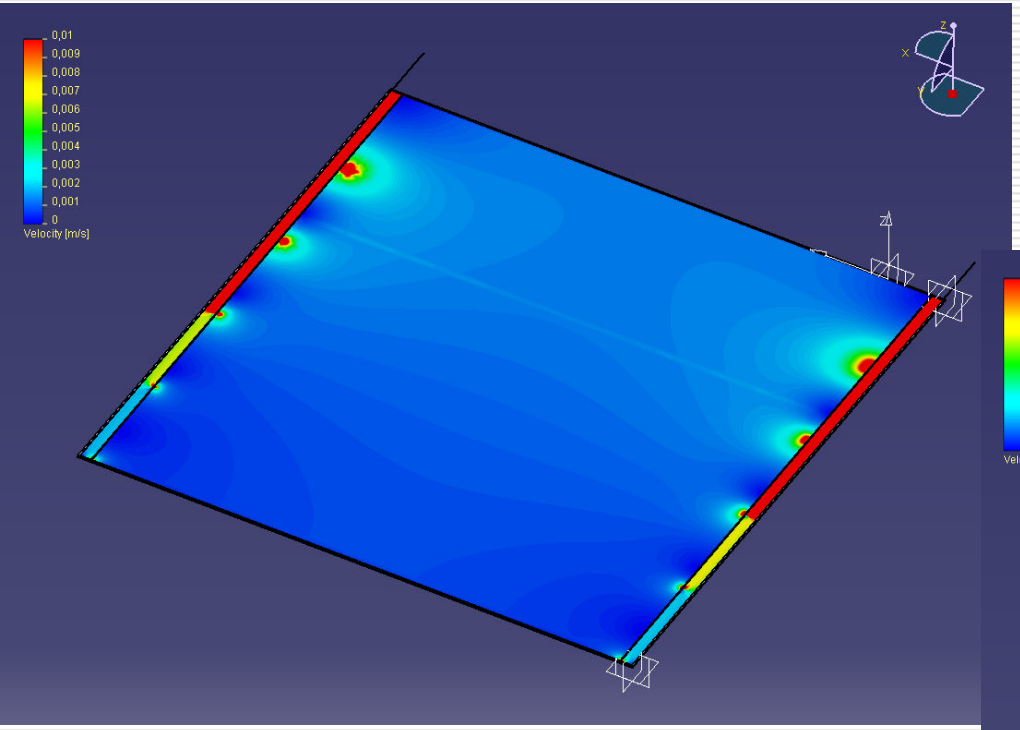
- Includes glass weight + electrostatic force
- Gas pressure *not* included
- Forces balance for 1mbar overpressure

Gas distribution

May be an issue for large area, very thin chambers

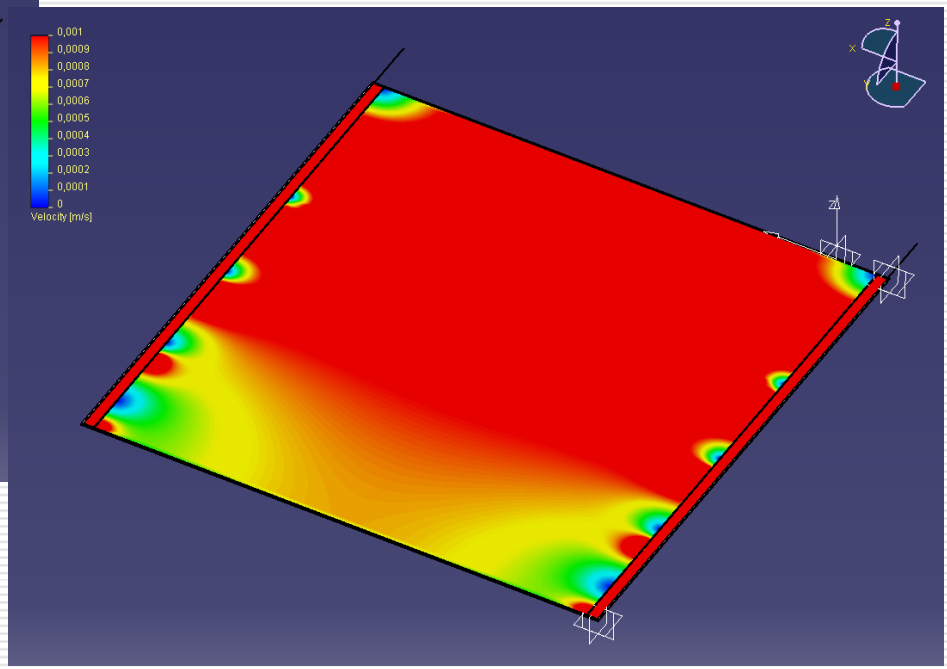


Gas - speed distribution



Boundary conditions:

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



Scale: 0-10 mm/s

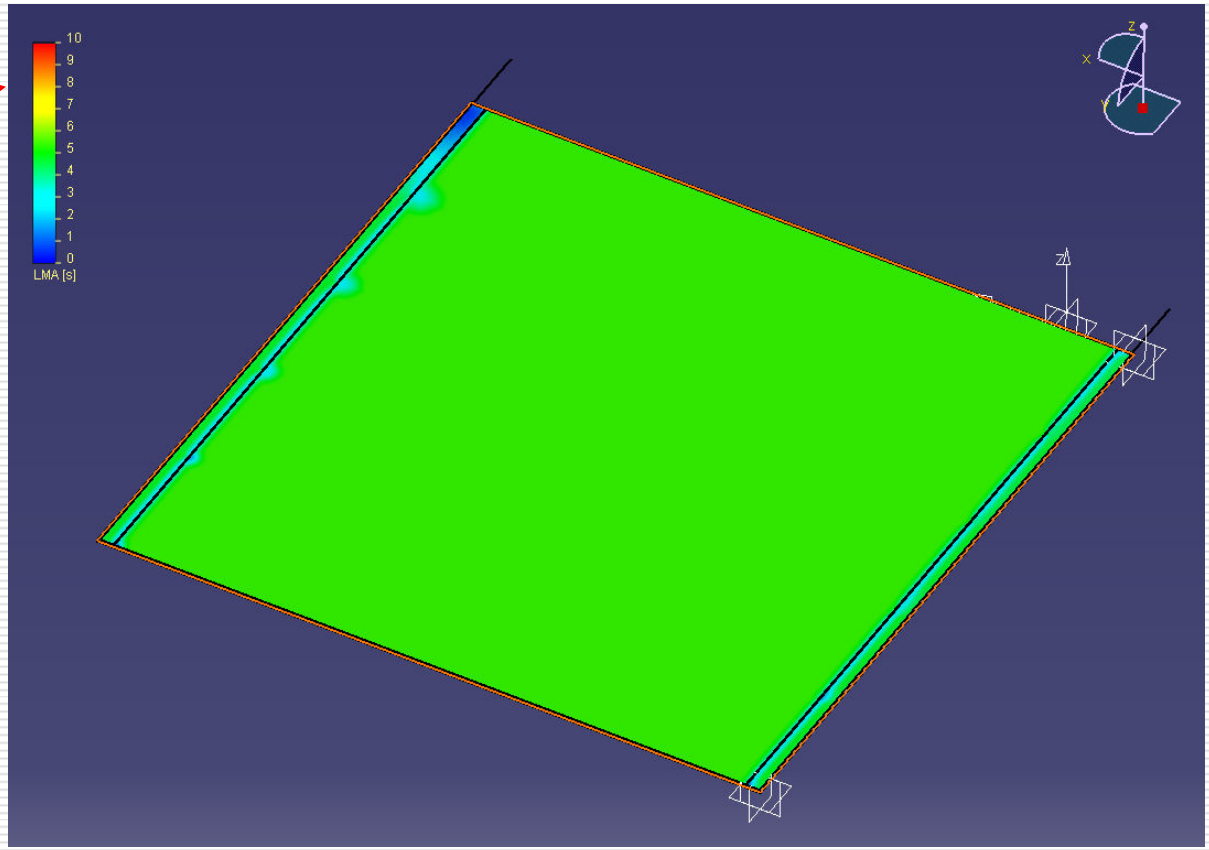
Does not include diffusion effects

Scale: 0-1 mm/s

Gas – 'Least Mean Age'

0-10s

Green ~5s



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

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

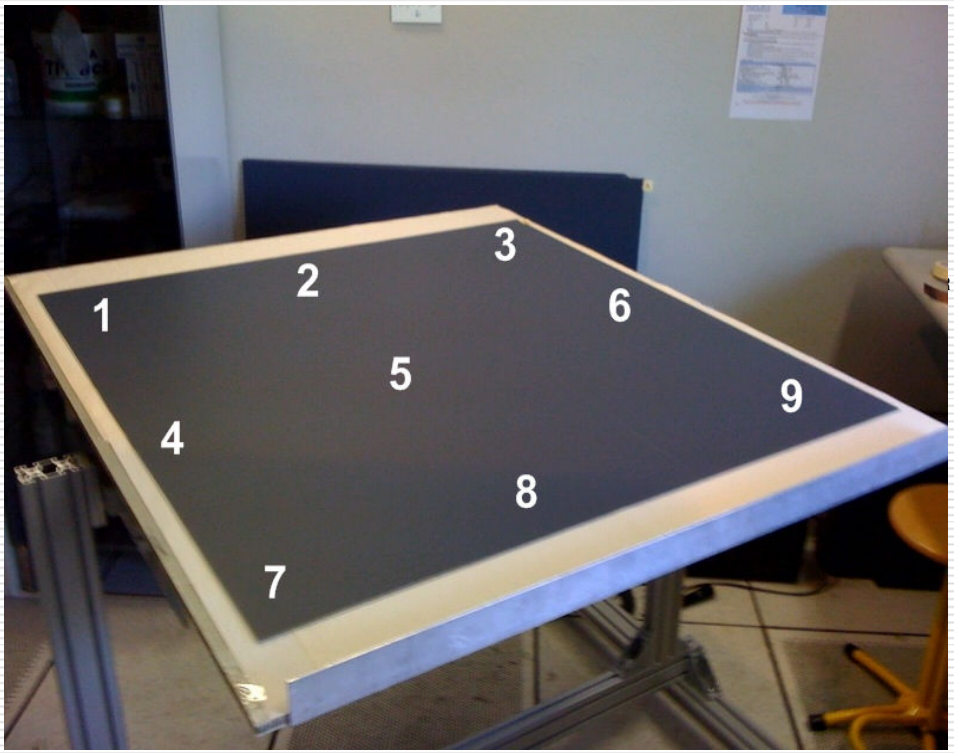
*Estimate 20m^2 (10 chambers) / kg using silk screen printing technique

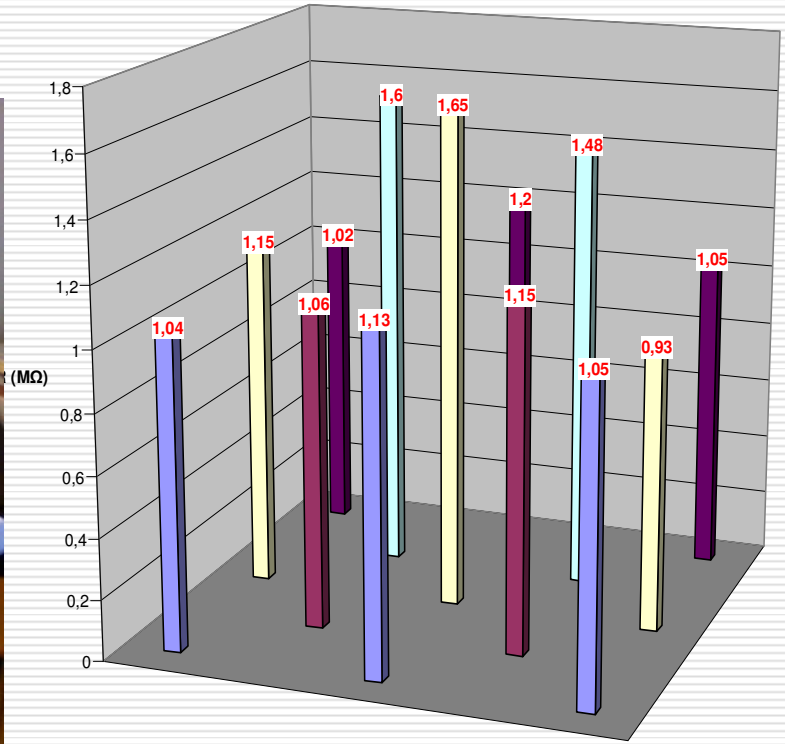
Licron: fragile coating, problems with HV connections over time
Statguard: long time constant for stable resistivity (~2 weeks), poor homogeneity

Baseline for 1m^3 is colloidal graphite type I but type II tests very promising

Colloidal Graphite Type II

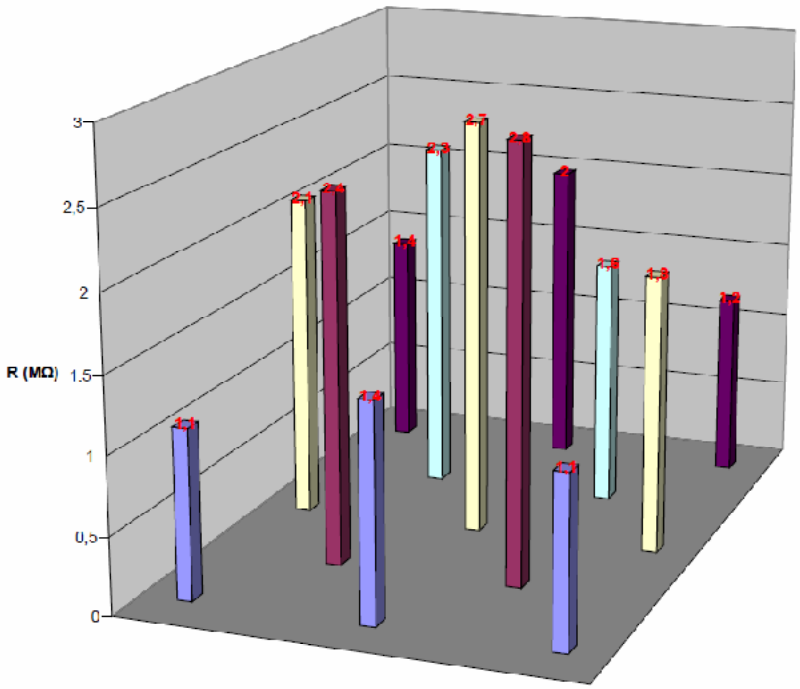
- Product designed for Silk Screen Printing
- Drying at high temperature (170°C) required
- Close collaboration with local French company





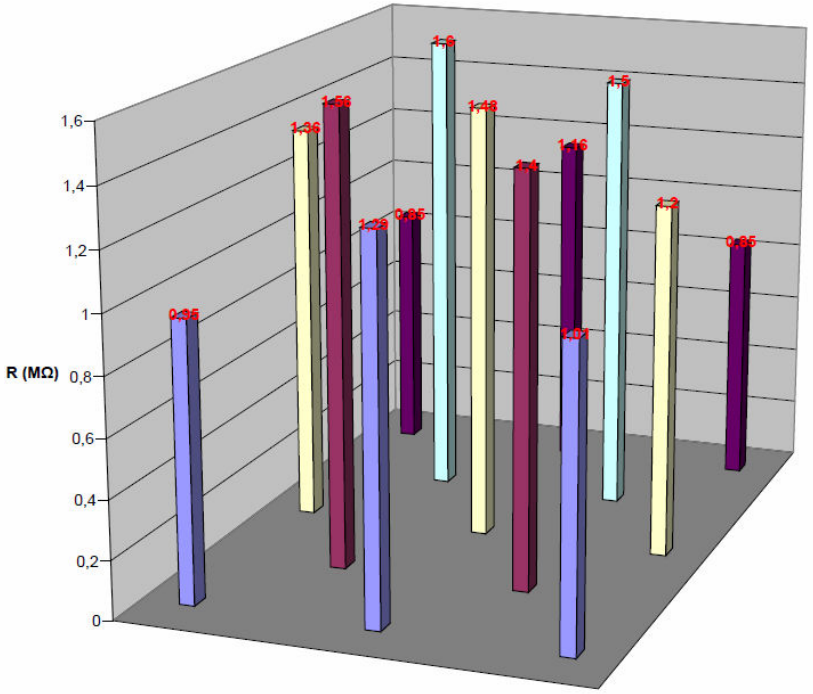
Mean 1.2 MΩ/□
Ratio MAX/MIN = 1.8

Variation between mix batches



Résistivité après cuisson 170°C pendant 20mn

Min (MΩ)	1,1
Max (MΩ)	2,8
Moy (MΩ)	1,84
Rapport min/max	2,55

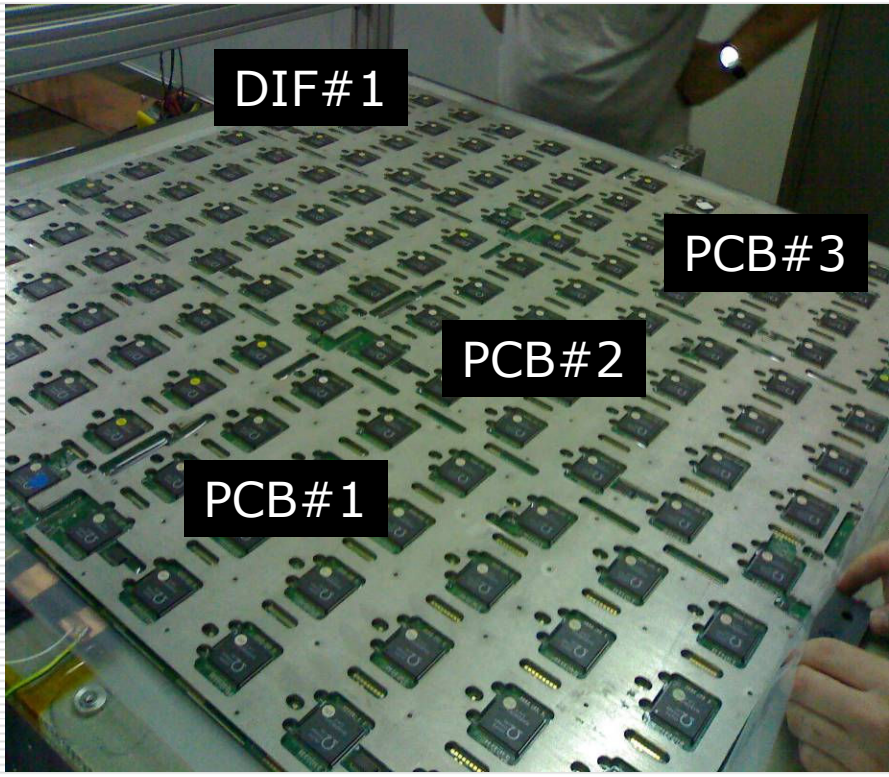


Résistivité après cuisson 170°C pendant 20mn

Min (MΩ)	0,85
Max (MΩ)	1,6
Moy (MΩ)	1,25
Rapport min/max	1,88

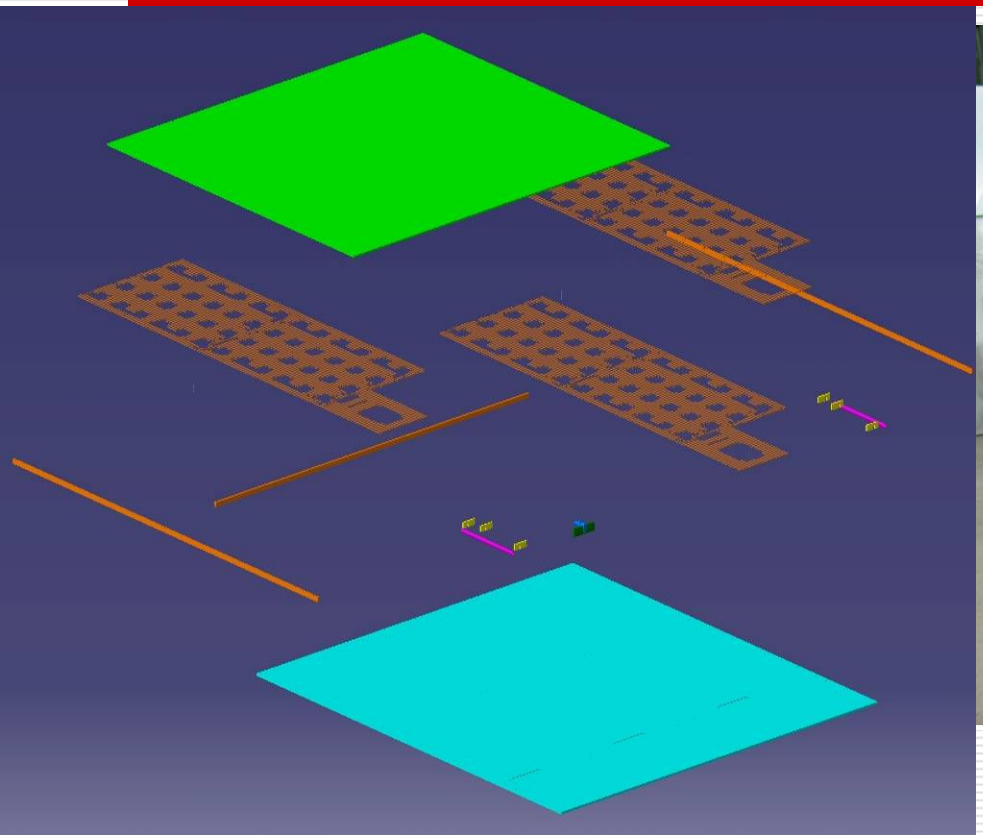
Average

Electronics boards + support



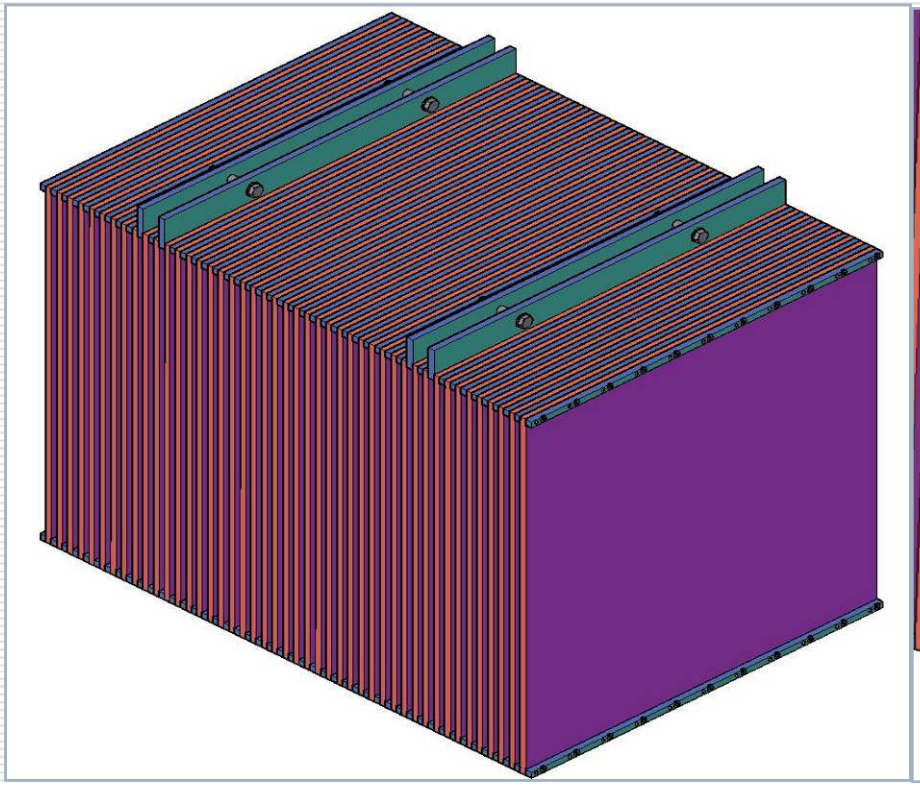
- 144 ASICs, 9216 channels per m^2
- $1m^3$ project: almost 400,000 channels!
- $1m^3$ project will use Hardroc 2b chip

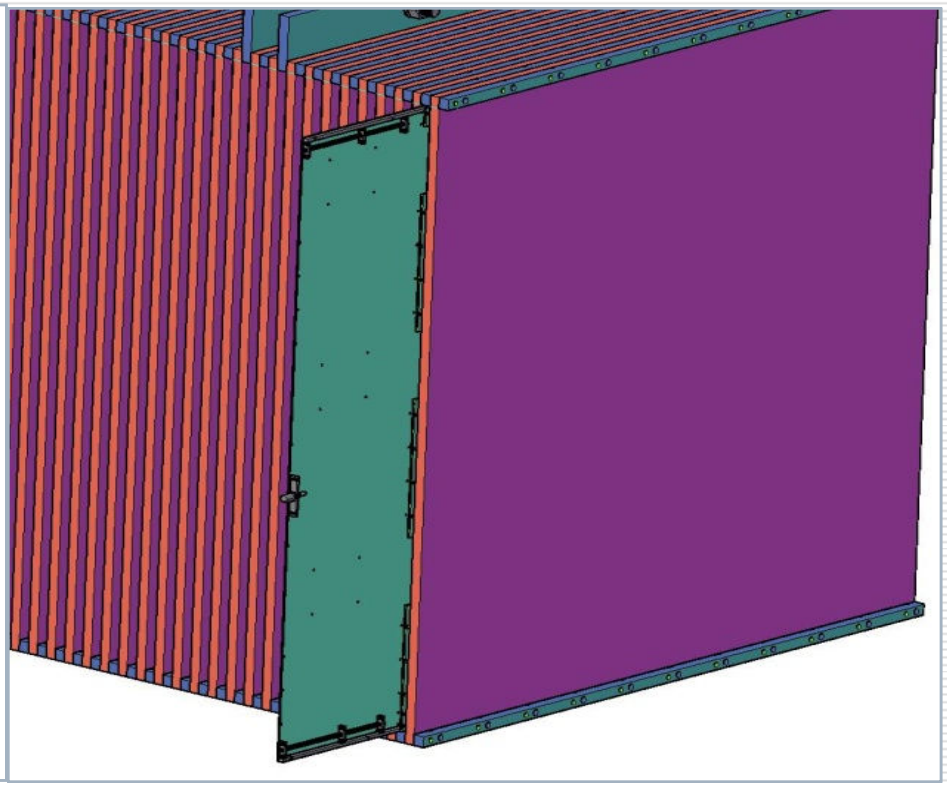
Protective cassette for RPC + electronics



- 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

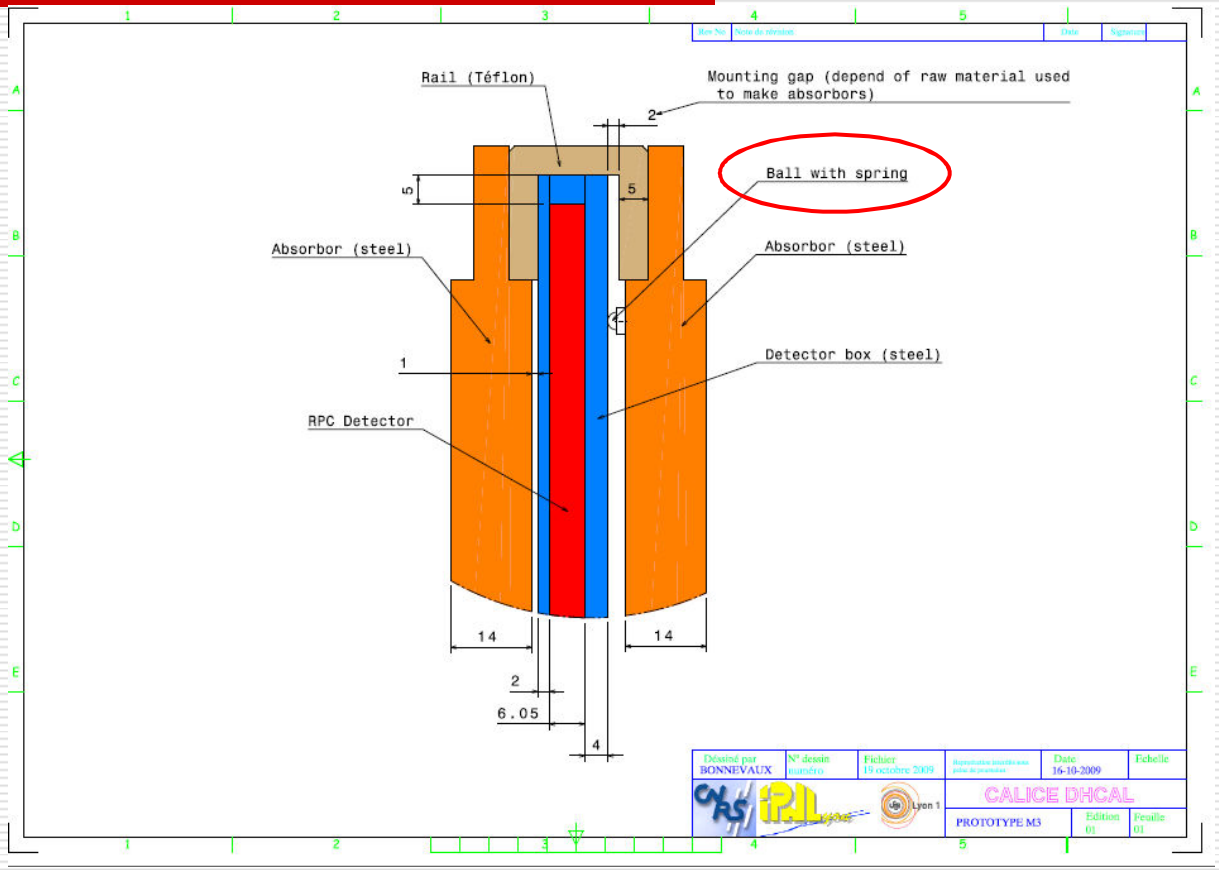
1m^3 project – mechanical structure (1)





Enrique Calvo Alamillo (CEIMAT)
Alain Bonnevaux (IPN-Lyon)

1m^3 project – mechanical structure (2)



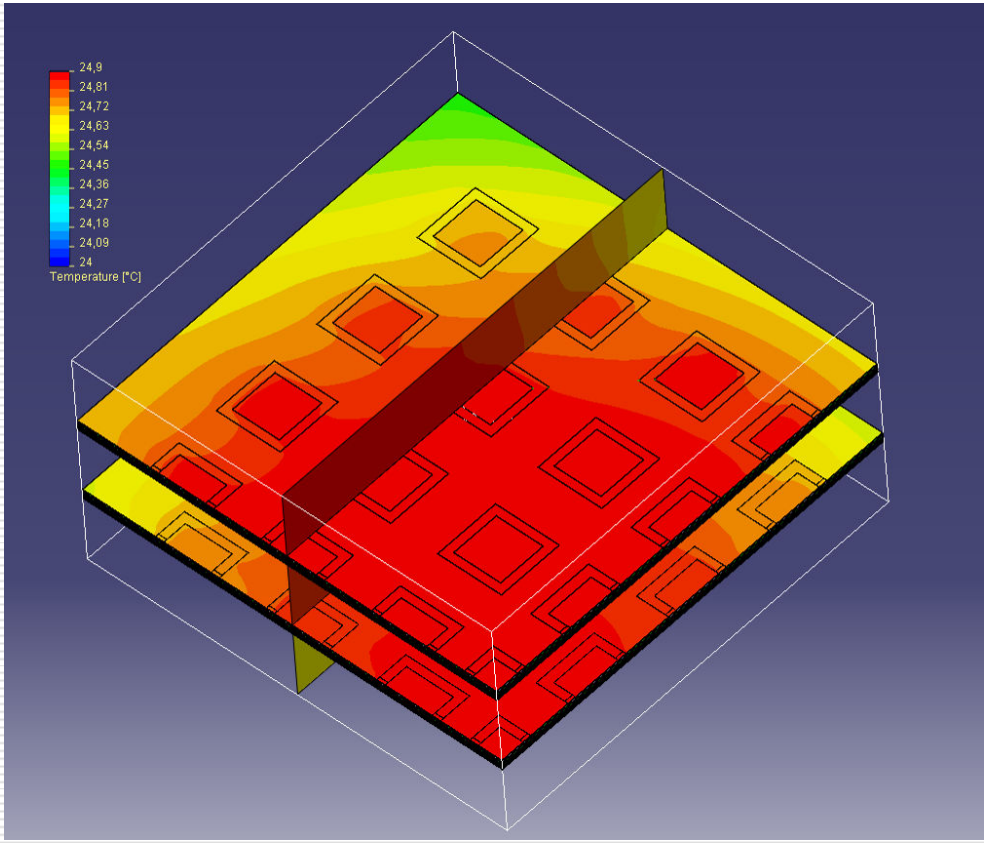
Spring-loaded balls in absorber press cassette plates against RPCs + PCBs

Helps keep PCB pressed flat against anode glass

Cassette insertion test very soon (all elements in hand)

Thermal modelling

- Model
  - 100 mW chips (no power pulsing)
  - No active cooling - thermal dissipation by convection only
  - T(hall) = 20°C
  - 3 absorbers + 2 detectors (1/4 of $1m^2$ + symmetry)
  - Cubic grid
  - Modelled in CATIA + EFD
- Result
  - T_{max} = 25°C
  - Conclude: active cooling not necessary



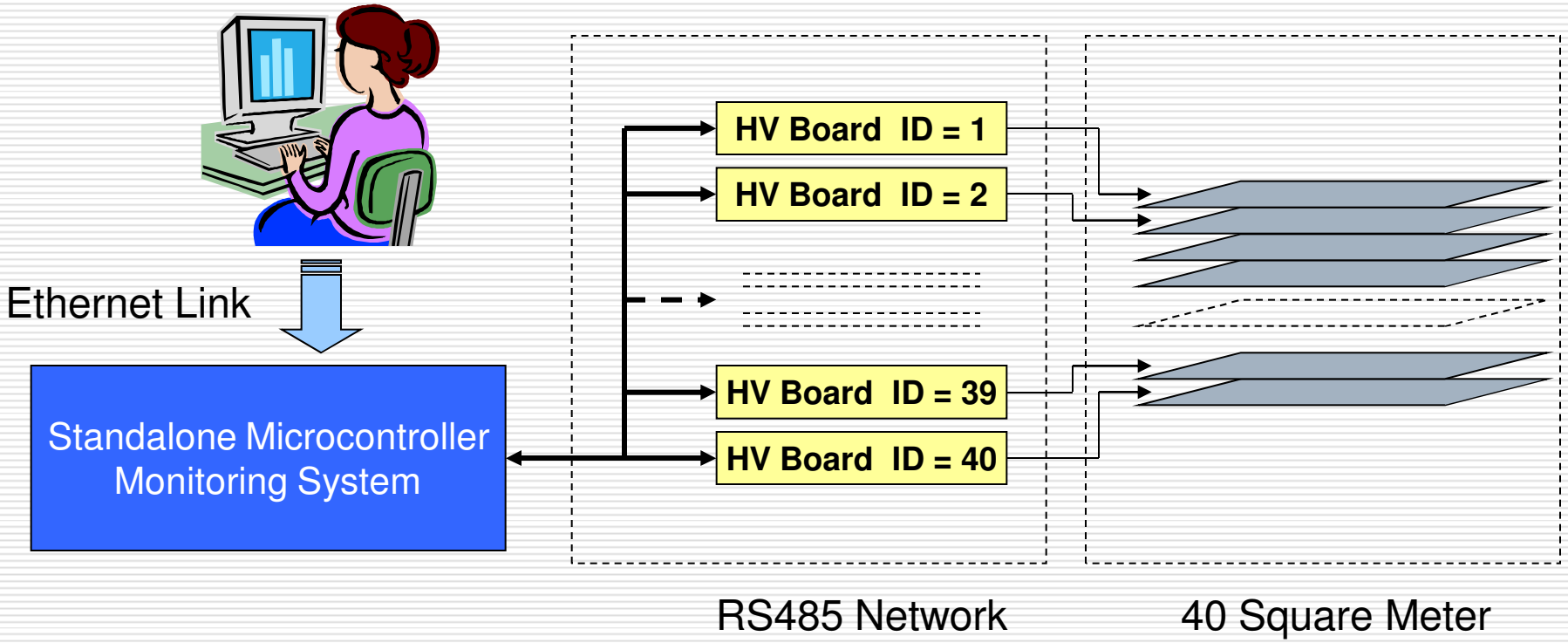
High Voltage

- 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

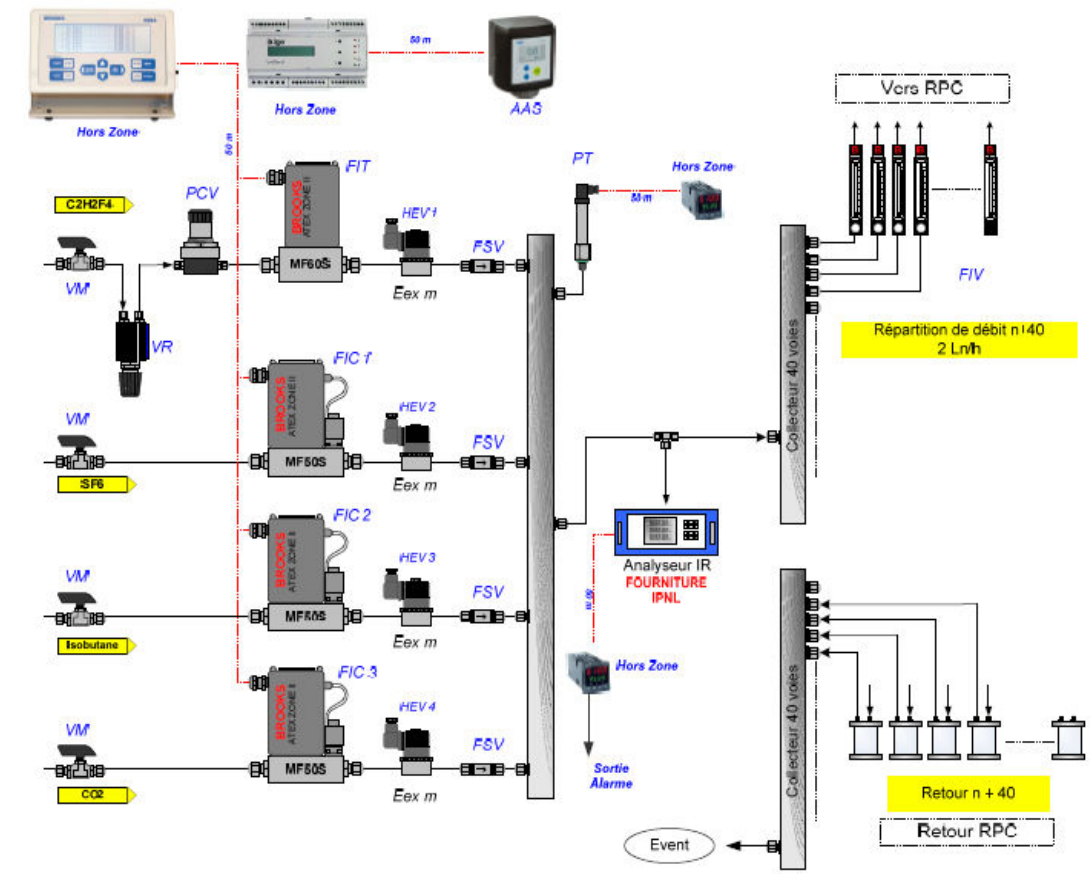
Characteristics:

- 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

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