Large-area Micromegas for sampling calorimetry, an emphasis on mechanics

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Instrumentation Days on Gaseous Detectors,
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Overview

- Introduction
  - (MP)GD for calorimetry
  - The LC case, PFA & detector design rules

- Early prototypes
- Sensor boards
- 1x1 m^2 prototypes
- Performance

- Outlook

(MP)GD for calorimetry

- Lots of fluctuations, non-gaussian distributions
- NTP operation : very low sampling fraction
- Sensitive to Bfield (δ-e^-) and ambiant conditions

- Affordable cost for large-area
- Excellent position resolution (2-γ decays, γ/π^0 ID)

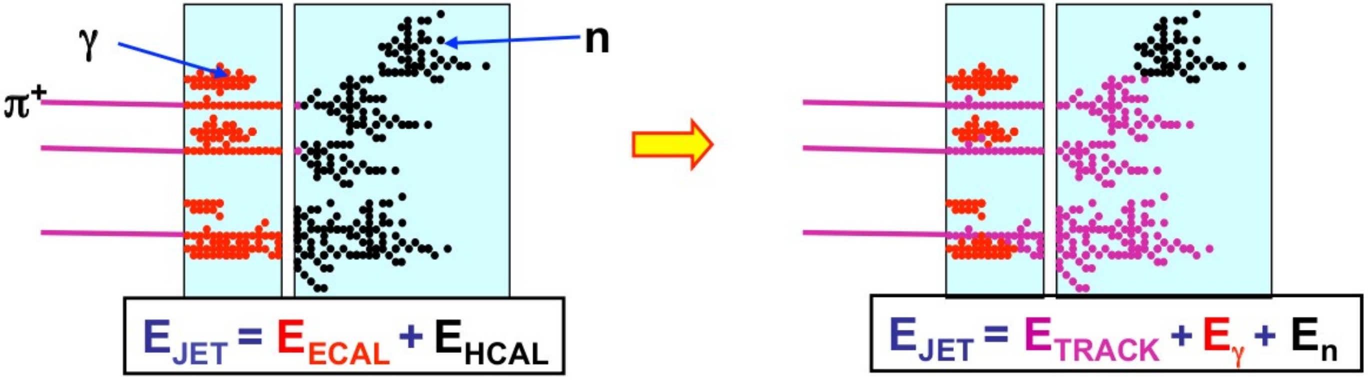
- No rate-dependence almost (pp machines, forward reg.)
- Sustain heavy dose

→ Good choice when energy resolution is not critical.

The Linear Collider case

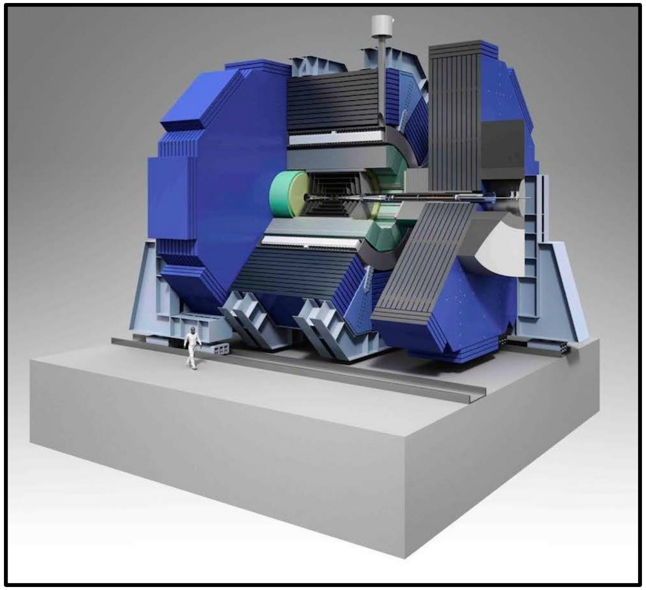
- Higgs spectroscopy with limited lumi. → all decay modes e.g. hadronic modes with jets. Measured with PFA

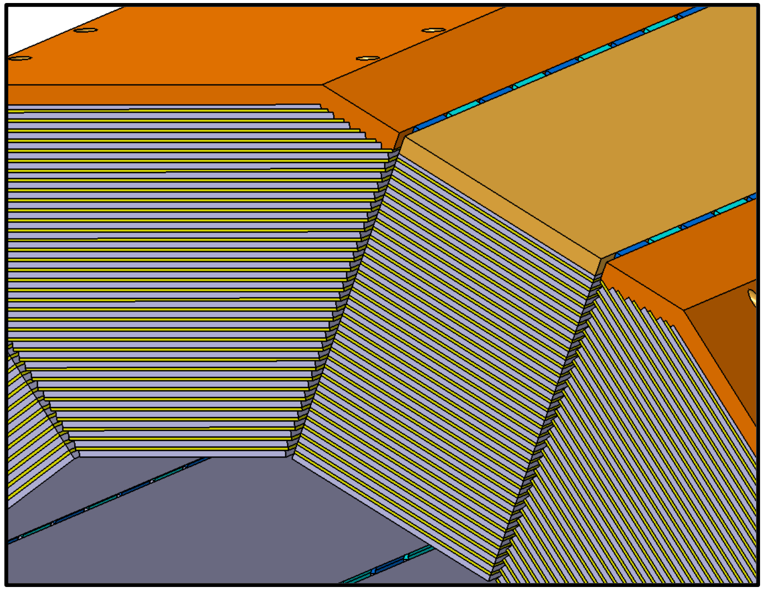
- PFA = smart reco. software + high-segmented detectors
- CALICE R&D : Si/W ECAL, Sc./Fe HCAL and Gas/Fe HCAL (1-2 bit (S)DHCAL) : RPC & Micromegas



Main design rules (HCAL)

- Calorimeters inside solenoid magnet
  → 8 mm between absorbers (4.5 λ_{int}, 40 layers)
- Minimise confusion (separate neighboring showers)
  → 1-10 cm^2 cells (HCAL) with no active cooling (Pw.Pulse)



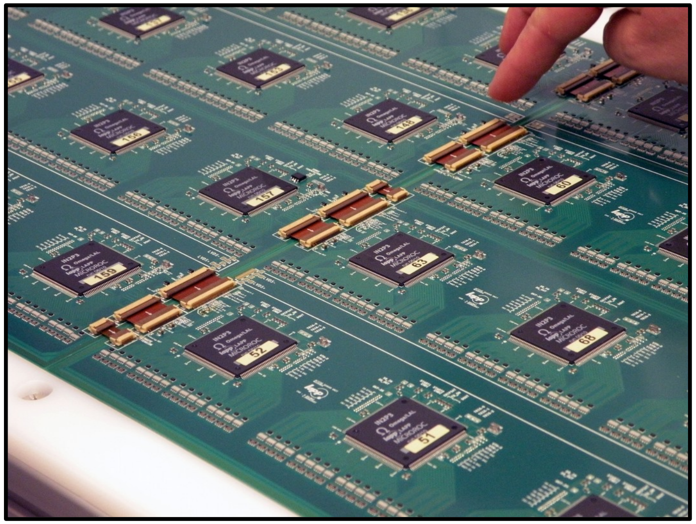


SiD detector concept

Active area : 3000 m^2
Barrel length : 6 m

The Micromegas proposal

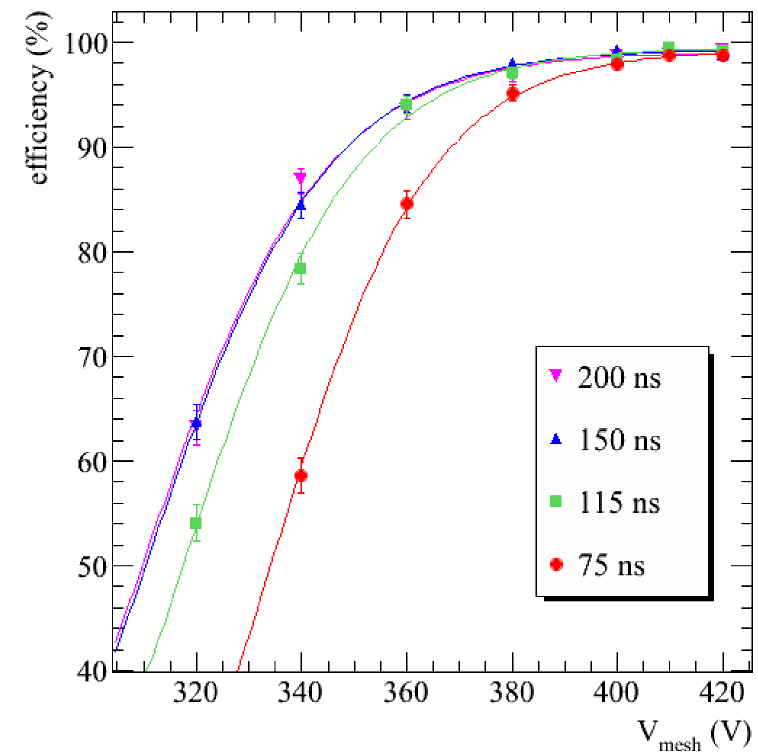
- CALICE paradigm to high granularity
  → VFE inside calo. absorbers (= on sensor boards)
  → [chain boards] + [RO boards at module ends]
- Our sensor boards = PCB(ASIC+diodes+pads+Bulk)
  Achieve large areas by tiling boards



Micromegas geometry & figures

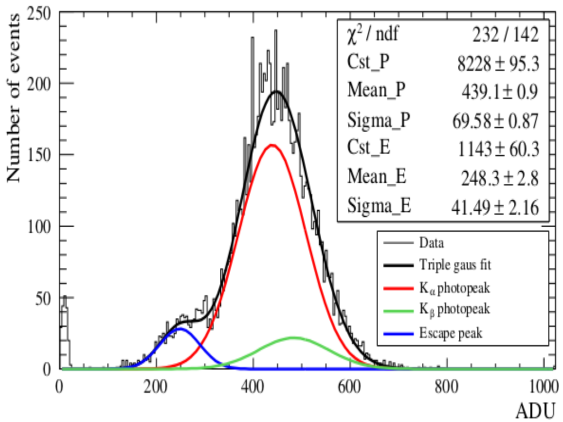
- Drift gap 3 mm (30 e^- / MIP in Ar)
- Ampli. 128 µm (standard Bulk)
- Pad pitch 1 cm
- Inter-pad 100 µm

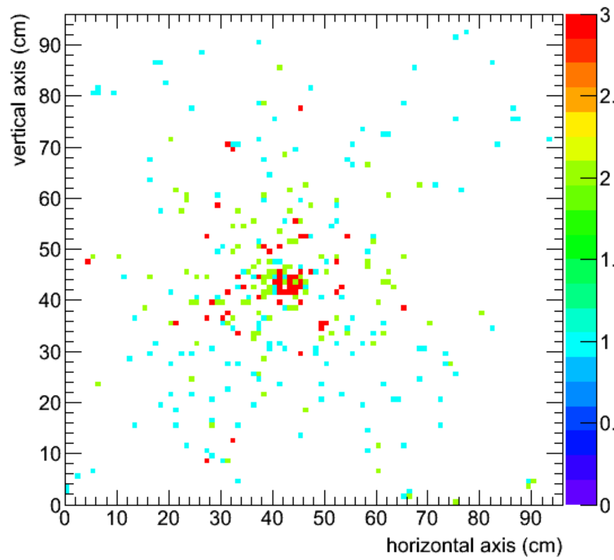
- In Ar/iC_4H_{10} 95/5
  v_{drift}^{max} ~ 4 cm/µs
  t_{drift}^{max} ~ 75 ns
  Ion tail ~ 75 ns
  Within ILC clock (200 ns)
- Typical charge ~ 1-10 fC (MIP)
  Operating gain 2000

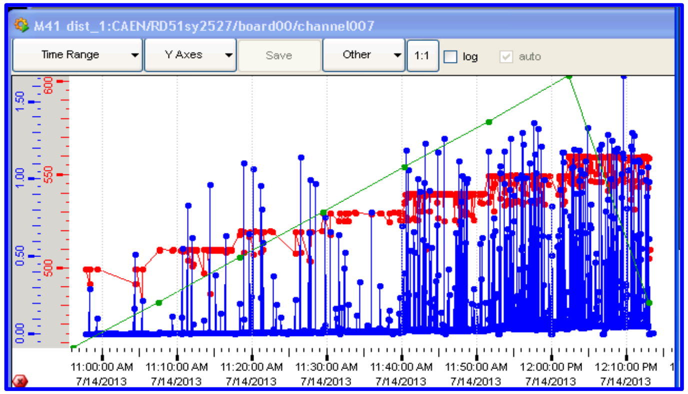


A history of R&D

- 2006-2009 , proof of principle (small proto. Gassiplex)
- 2009-2012 , sensor boards with VFE, 1x1 m^2 proto.
- 2012-… , R&D on (small) resistive prototypes
- 2016-… , resistive sensor boards

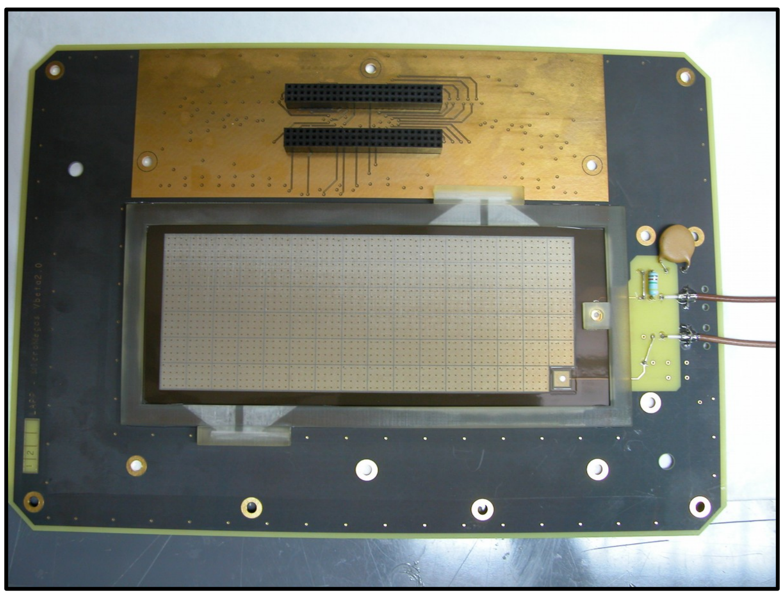


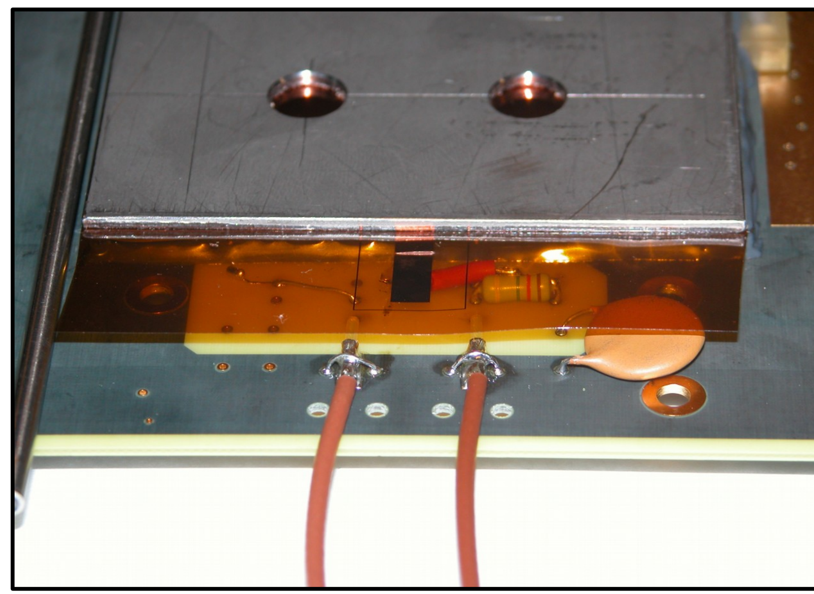




Early prototypes

- Simplest design with 6x16 pads
  Pad board with Gassiplex connectors
  Plastic frames with gas pipes (glued)
  Steel cover with drift foil (glued)





Response uniformity

- 4 prototypes : (6x16 cm^2)x3 + (12x32 cm^2)x1
- With this mechanical design, we achieved :
  ~ 11 % RMS var. of Landau MPV (150 GeV/c^2 muons)
  No edge effects with used track selection.

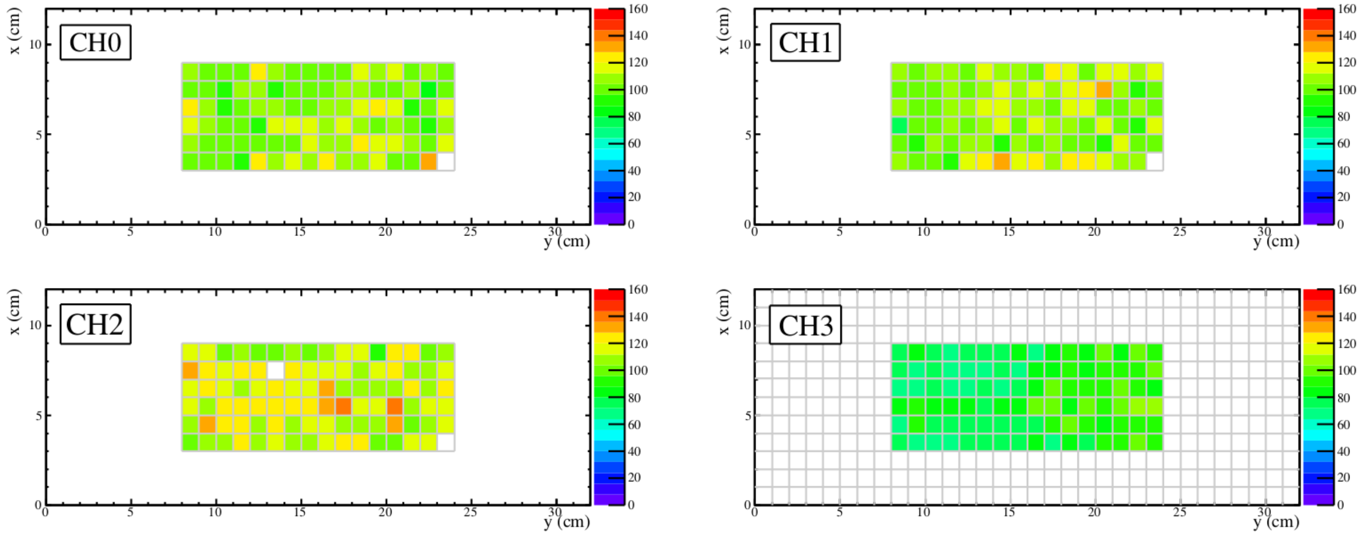
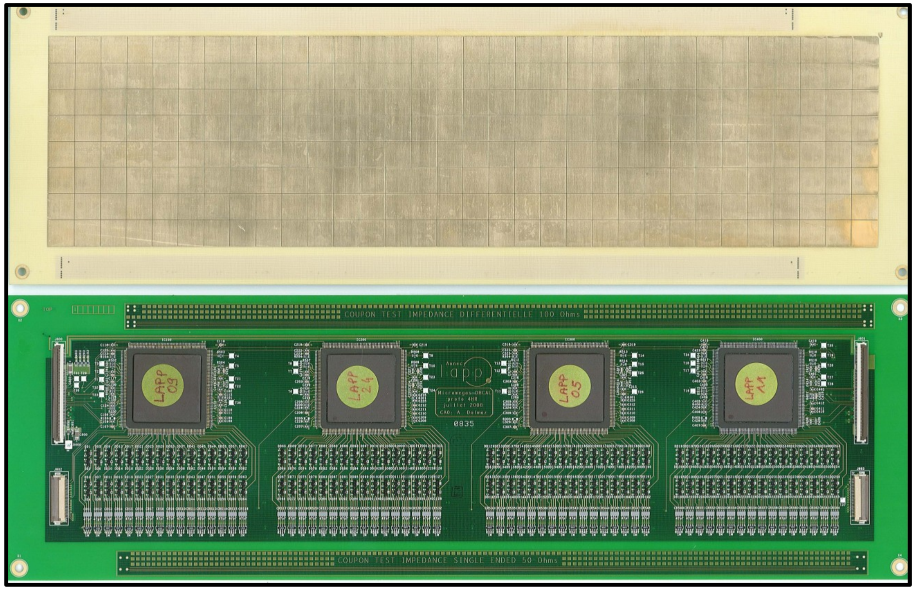


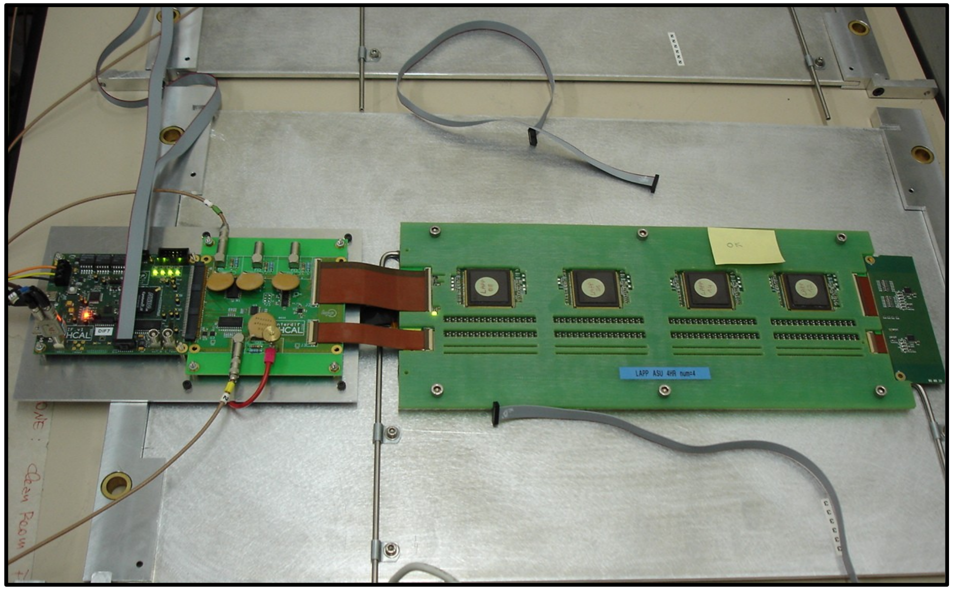
Figure 12. Landau MPV maps of all prototypes (color axis in ADU).

2009 JINST 4 P11023

Sensor boards 1/2

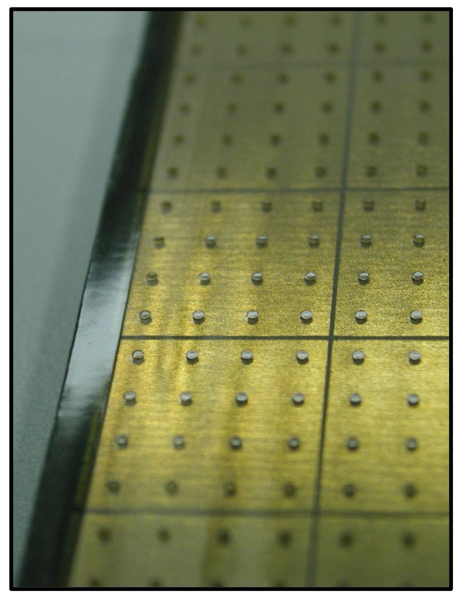
- Boards with ASICs & passives, pads, Bulk, connectors
- Size : 8 layer PCB, 1.2 mm thickness, 8x32 cm^2
- Mask is used for Bulk lamination
- PCB area > mesh area

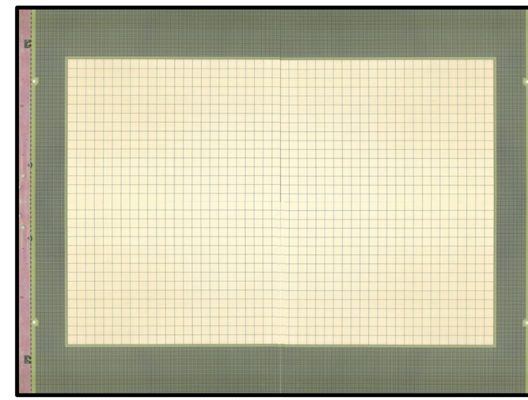


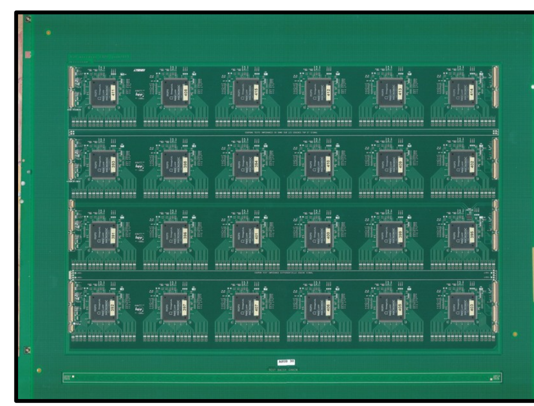


Sensor boards 2/2

- Boards with ASICs & passives, pads, Bulk, connectors
- Size : 8 layer PCB, 1.2 mm thickness, 32x48 cm^2
- Mask is used for Bulk lamination
- PCB area ~ mesh area !

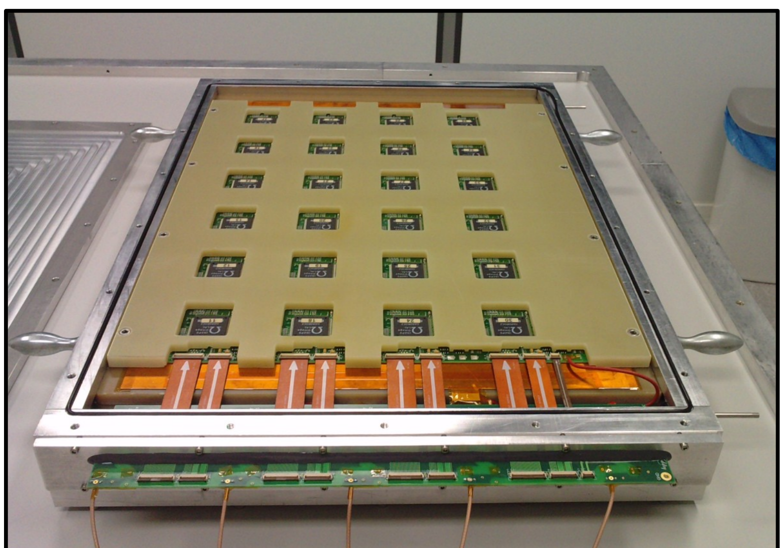


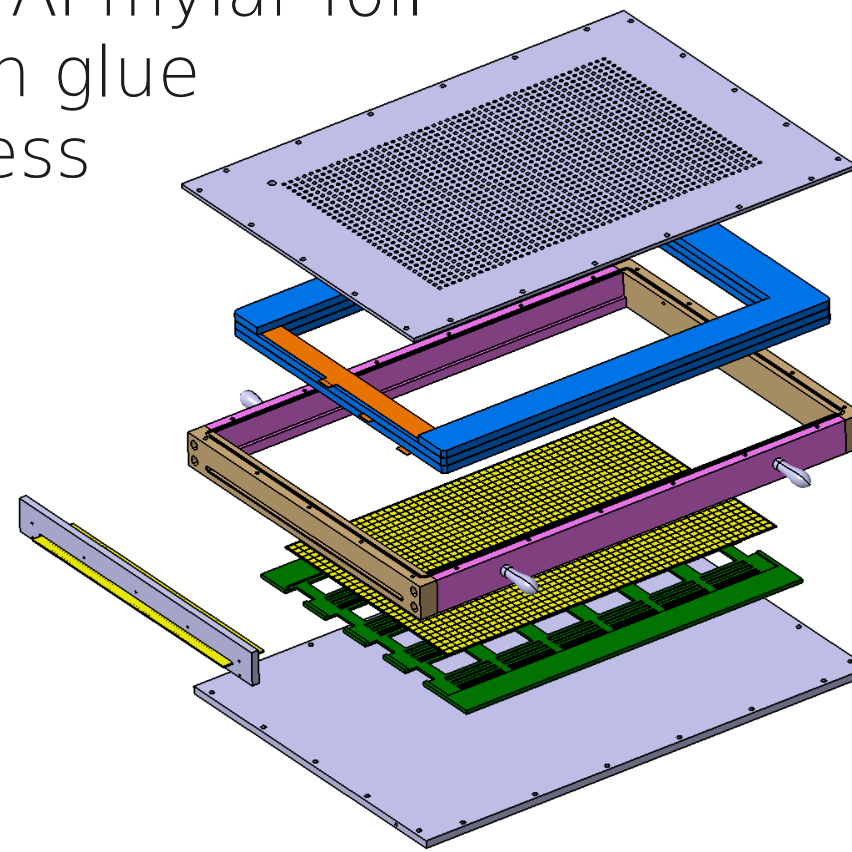




Test chamber - design

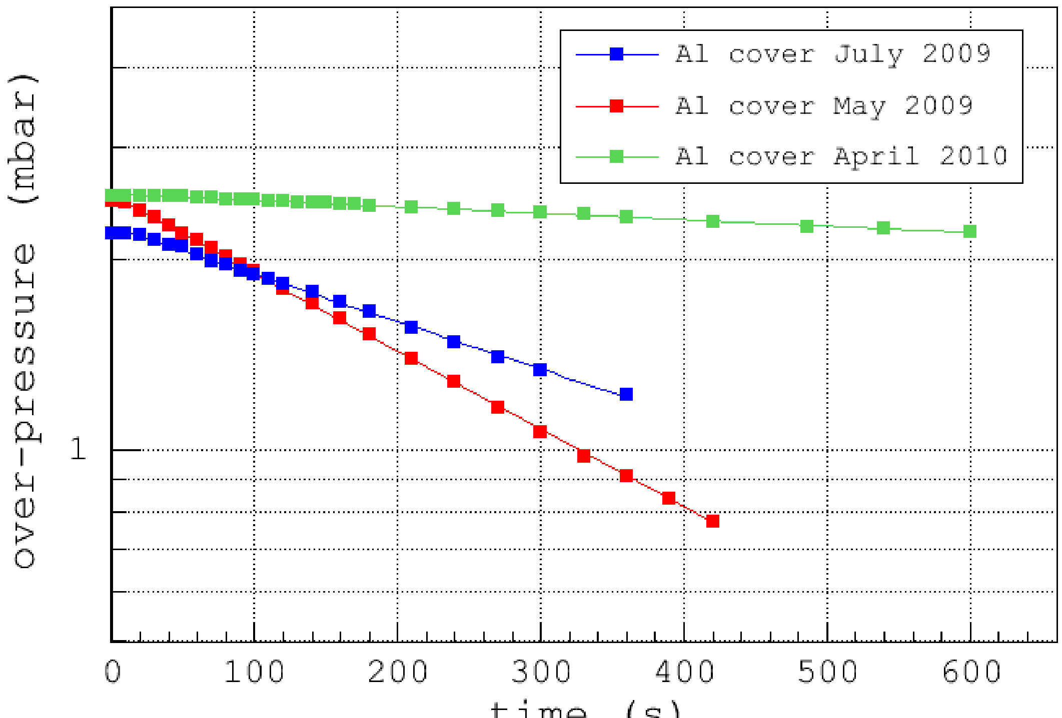
- ^{55}Fe & cosmis tests in dedicated chamber
  - 3 cm drift with 3 guard electrodes & G10 frames
  - Perforated cover + glued thin Al mylar foil
  - Feedthrough (interm. board) in glue
  - Screws & joints for gas tightness





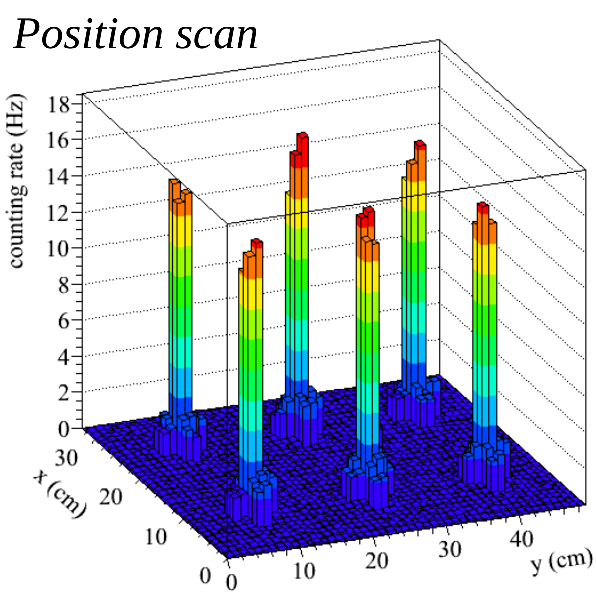
Test chamber – gas tightness

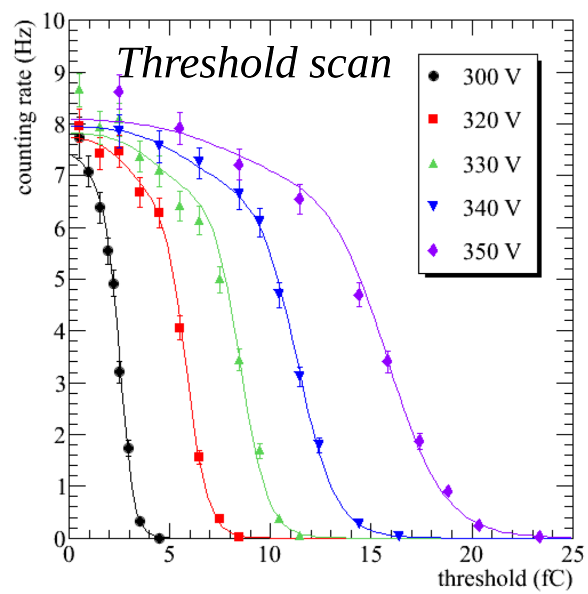
- Critical part was the thin Al mylar foil
  Needed a bit of extra glue to achieve proper tightness

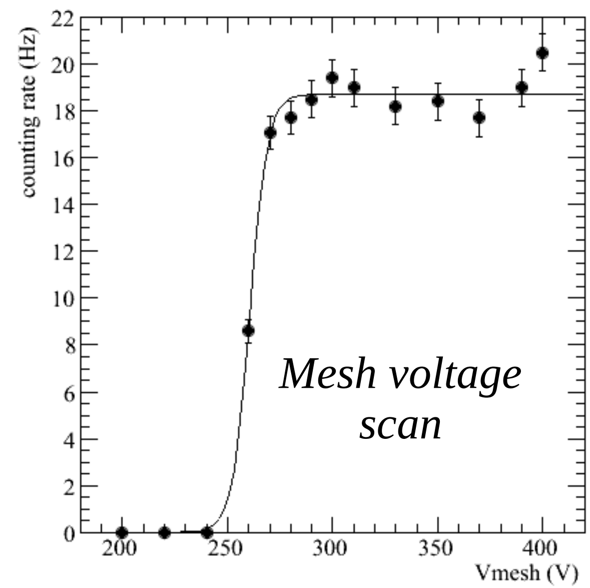


Qualification of sensor boards with ^{55}Fe

- For a given board,
  → response stable w.r.t. position, Bulk OK.
- Threshold & voltage scan
  → absolute electronics calibration in N of primary e$^-$

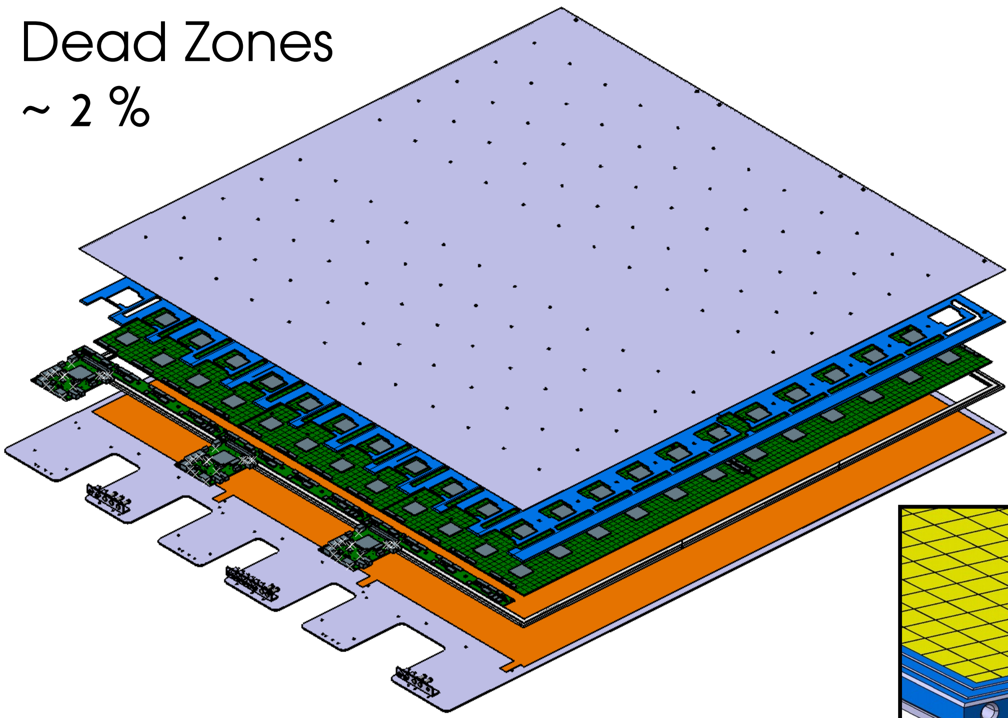


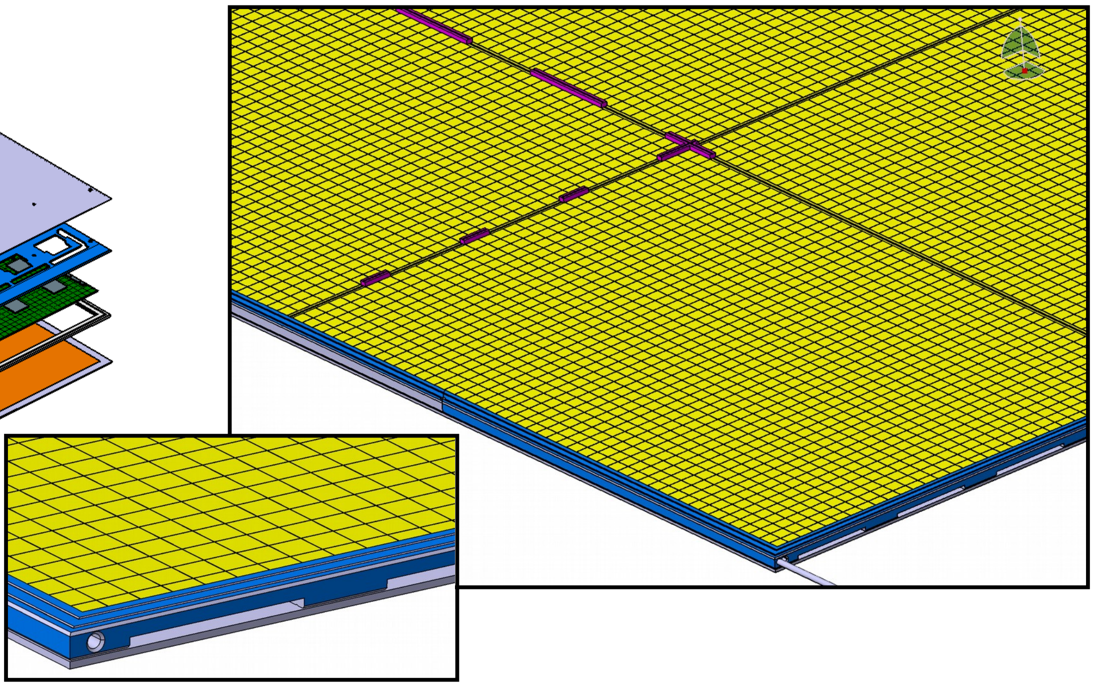




Design of the 1x1 m^2 prototype

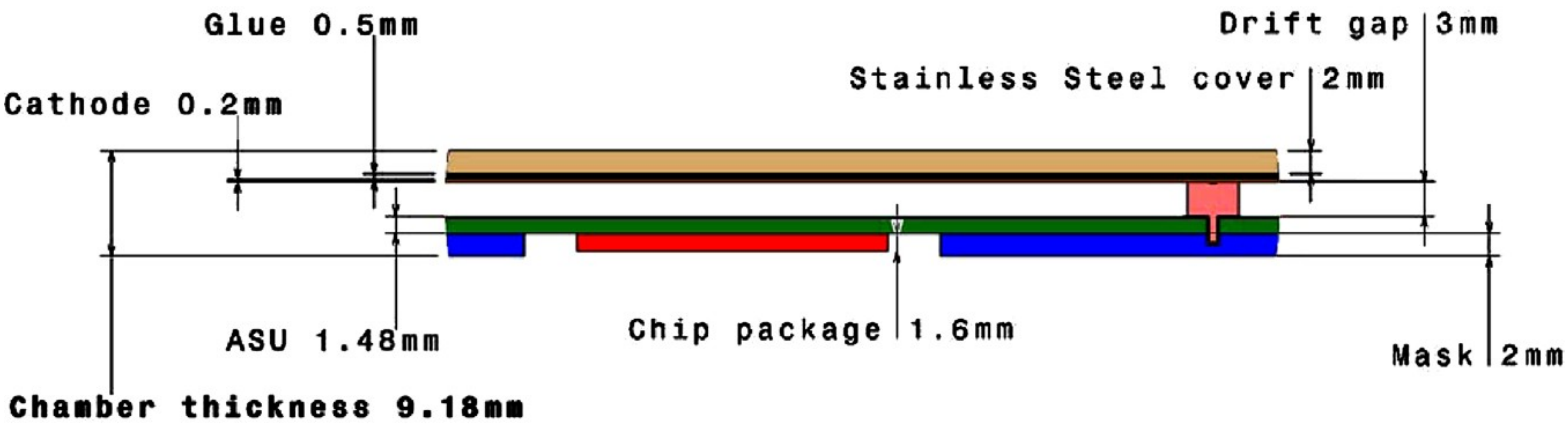
- Paving of 6 boards with minimum dead zones (3 slabs).
- Use gap between boards for spacers
- G10 frames with apperture for flex. cables & gas pipes





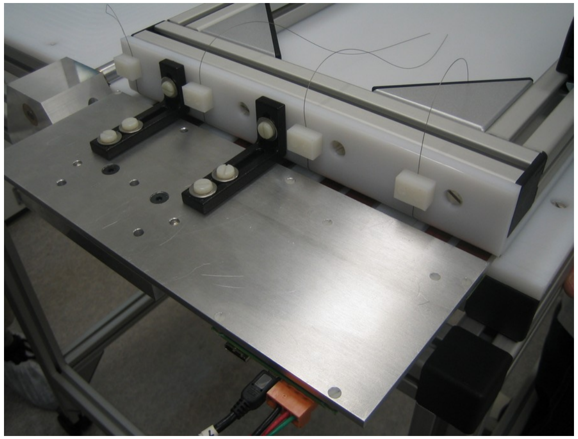
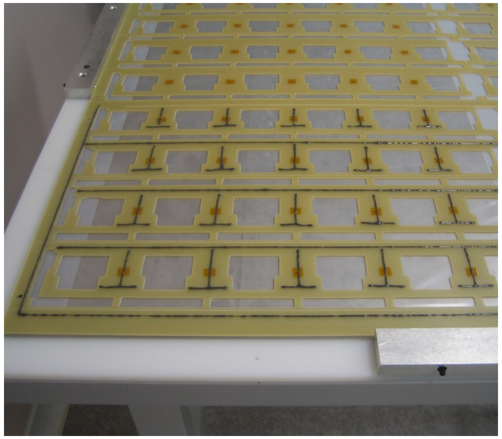
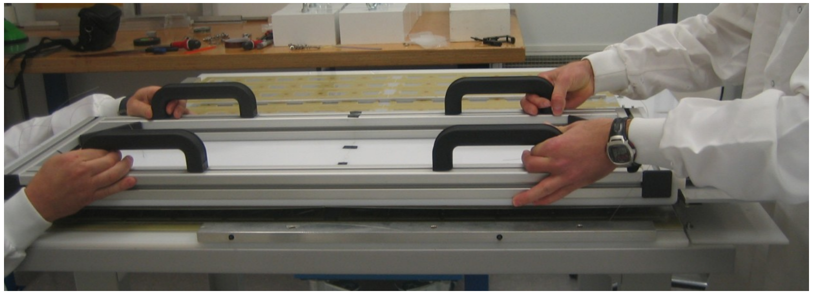
Thickness budget

Cover+glue+drift electrode = 2.7 mm
Gas = 3 mm
ASU+mask = 3.5 mm
→ ~ 9.2 mm which includes 2 mm of steel (=absorber)



Assembly

- Start with connecting 1 slab & testing RO
- Flip slab upside-down (mesh side up)
- Transport it on the pre-glued mask (with the RO board)

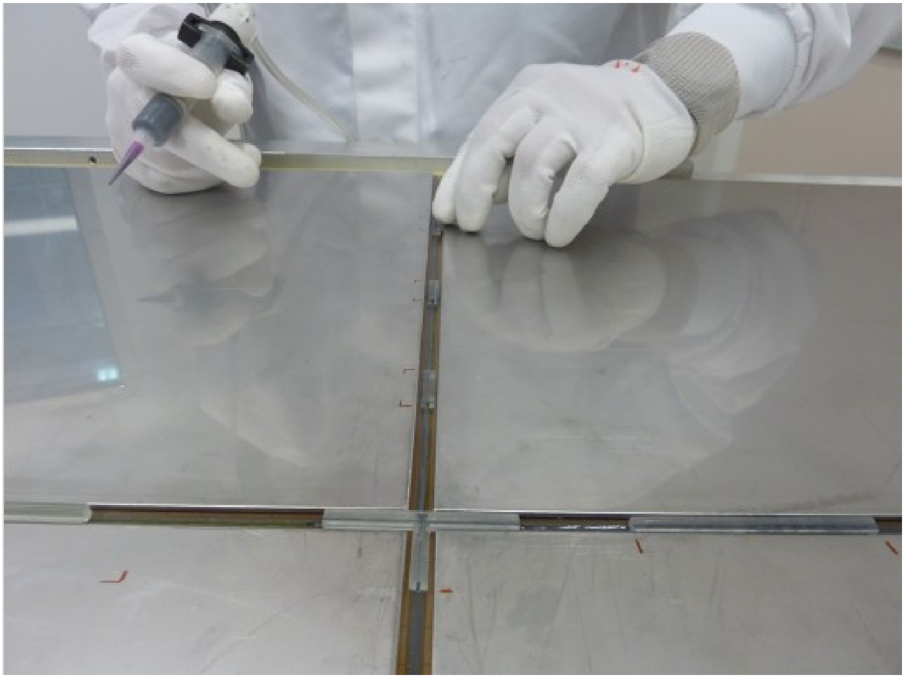
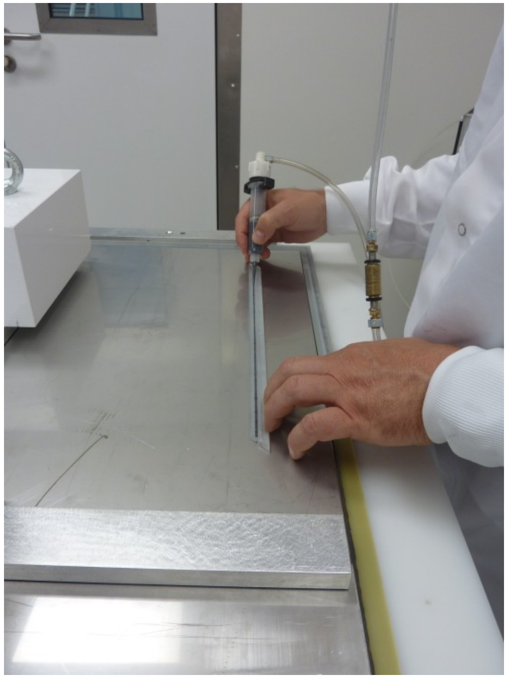
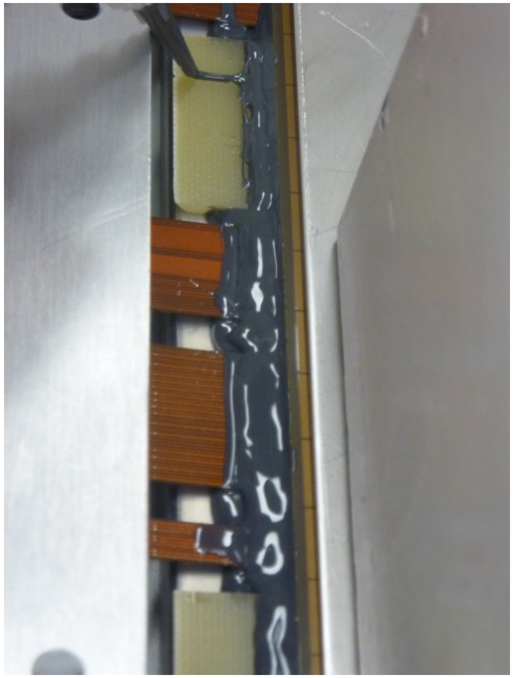
Assembly

- Re-test RO and remove support lines
- Insert spacers between boards
- Place steel plates & weights

Repeat for 2 other slabs

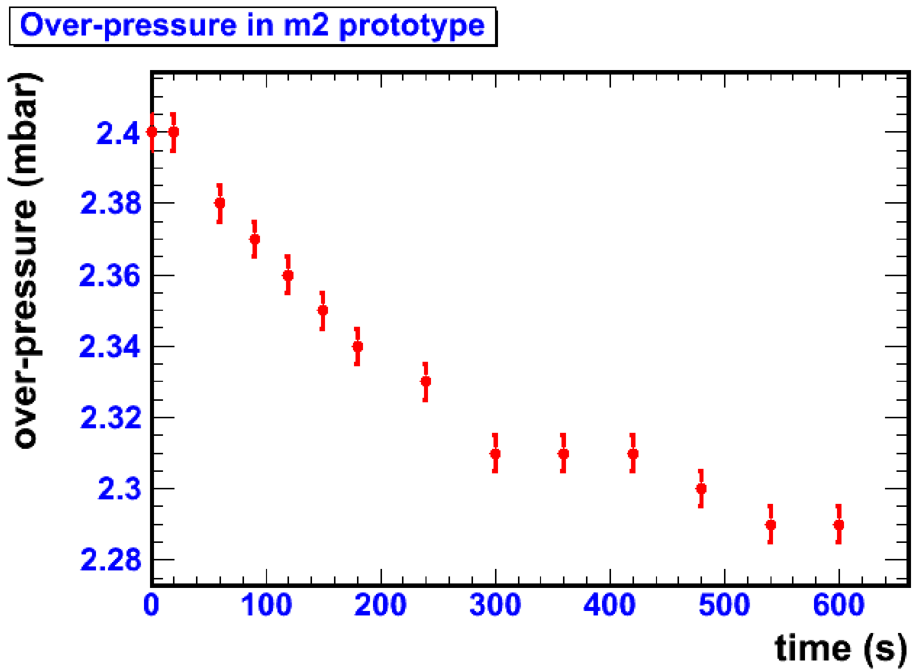
Assembly

- Fill with glue :
  between boards, frame segments, edges of boards & around flexible cables

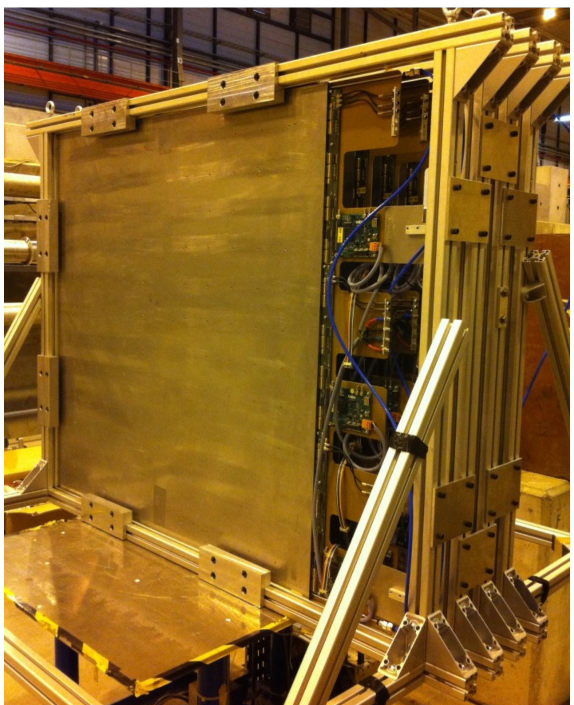
Gas tighness

- Comparable with what was achieved.
- 4 prototypes were assembled in 2012.
  Some glue corrections were sometimes necessary



Services & mechanical support

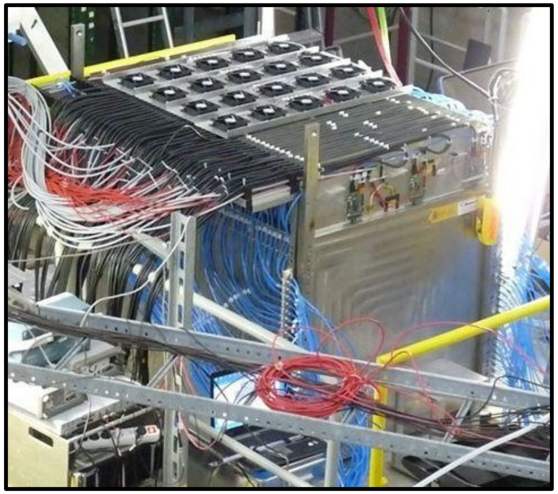
Bias individual meshes + 1 drift electrode = 7 lemo-HV
RO boards = 3 HDMI-clock-trigger & 3 data-USB
LV for electronics = 4 cables

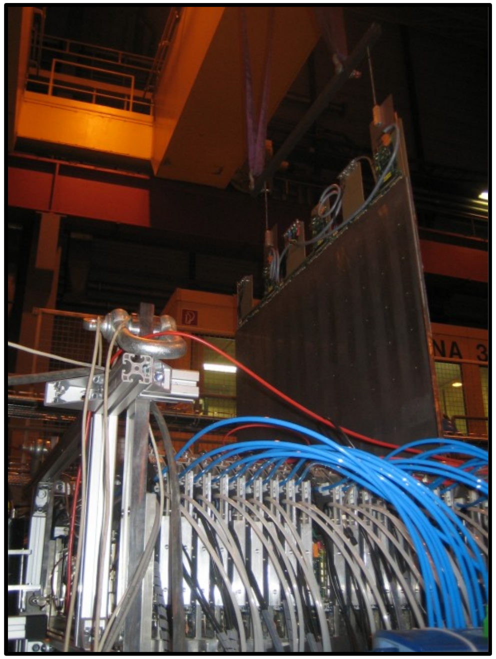


Support structure
Made of ELCOM elements
TestBeam & Cosmics positions

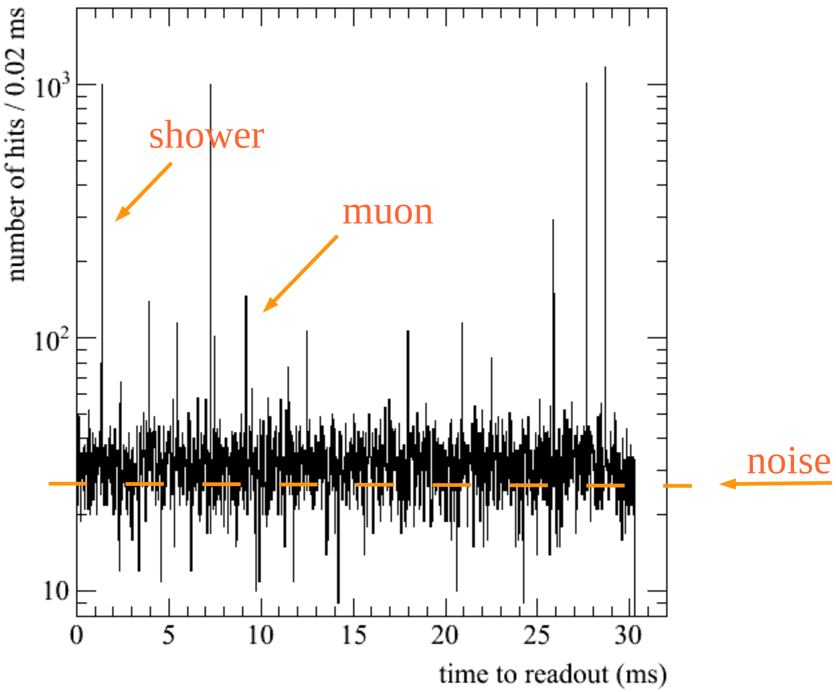
Test in CALICE SDHCAL

SDHCAL with 46 RPC & 4 Micromegas ($\sim 5.5\ \lambda_{int}$)
Similar geometry & common RO system
Self-trigger → events = peaks in time distribution



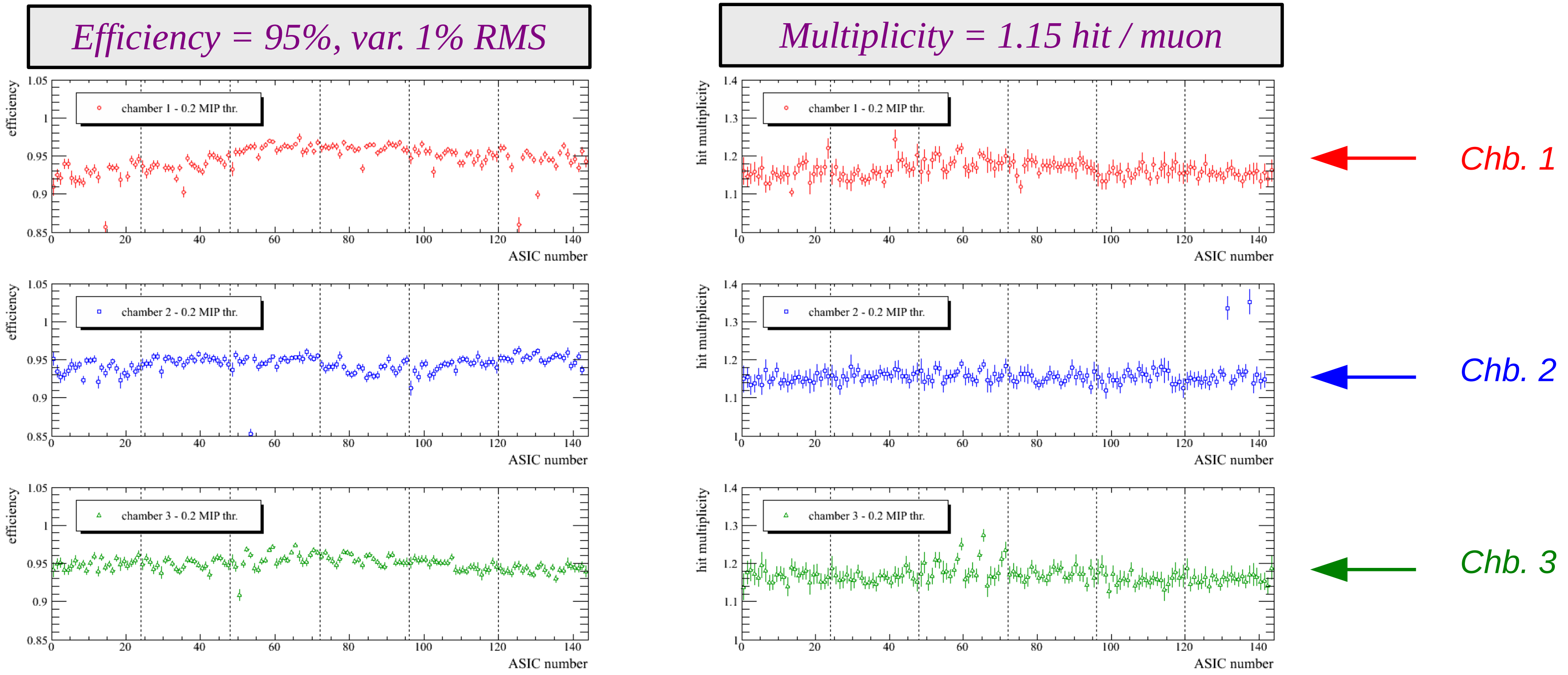


Time spectrum of hits in RPC-SDHCAL



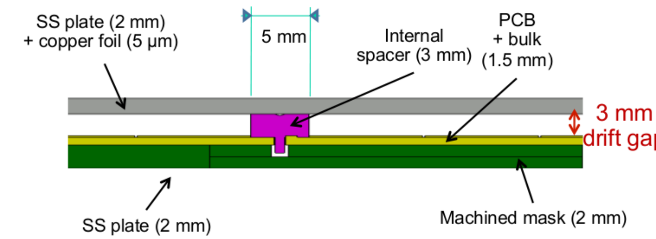
Response uniformity

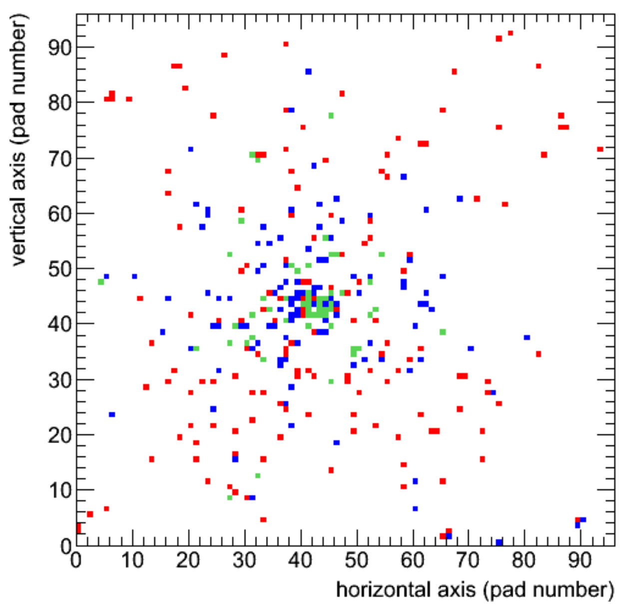
Inside SDHCAL, search for muon tracks with RPCs
→ test Micromegas chambers ASIC per ASIC (8x8 cm^2)

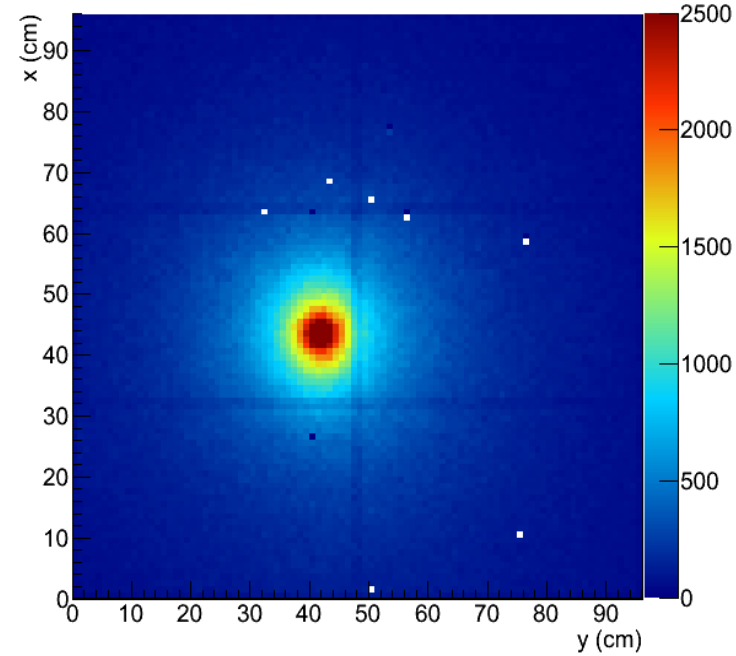


Dead zones

Hit map from pion showers
→ loss of charge for bondaries pads
Field uniformity questionable.







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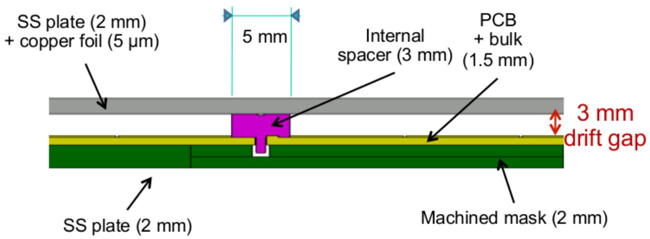

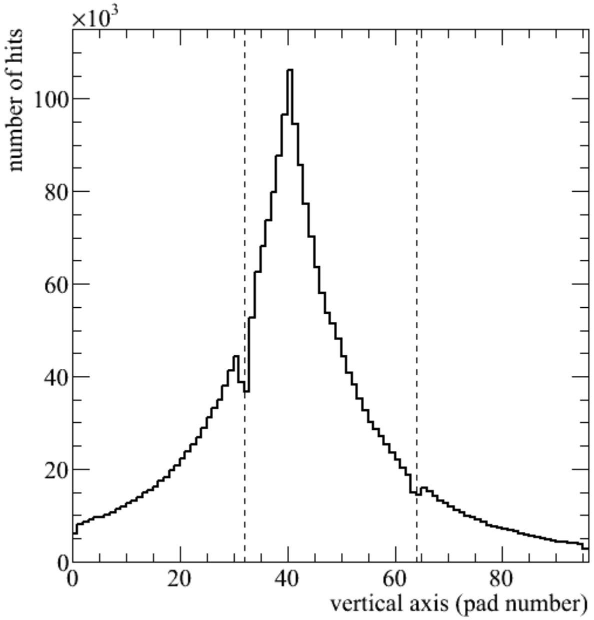

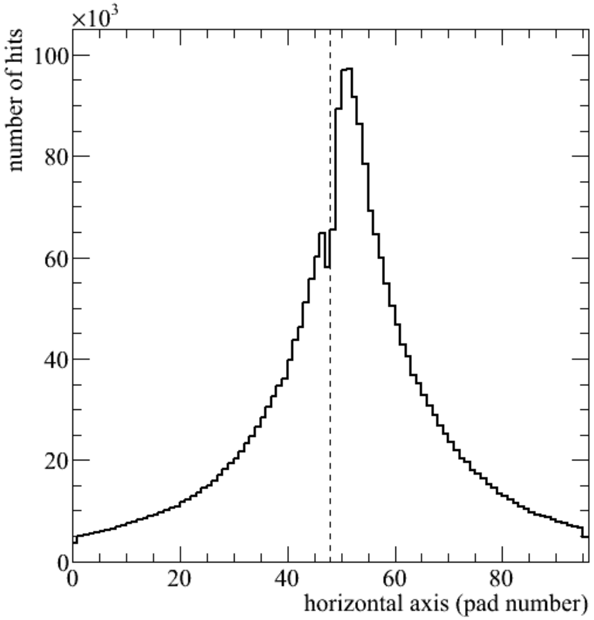

Outlook

The Micromegas project, achievements :

- VFE integration on Bulk board
  → modular approach necessary

- Thickness below 1 cm over m^2 area
  → gluing necessary to guarantee gas tightness
  but complicated when it comes to debug HV problems.
  Chambers can not be opened, only access to ASIC side.

  → How to make thin chambers without glue ?