

*Giovanni Maccarrone
INFN – Laboratori Nazionali di Frascati
On behalf of the ATLAS Muon Collaboration*

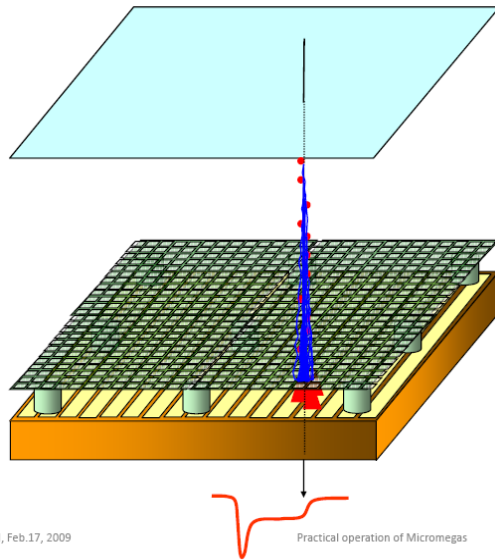
**Large Area Resistive Micromegas
for the Upgrade of the
ATLAS Muon Spectrometer**

*Instrumentation for Colliding Beam Physics (INSTR-17)
Budker Institute of Nuclear Physics (BINP) and
Novosibirsk State University (NSU)
Novosibirsk, Russia
27 February - 03 March, 2017.*

- ◆ The Start of the MicroMegas Detector
- ◆ The MicroMegas Evolution
 - Resistive (principal of operation)
 - Bulk (technical for easier and effective industrial production)
- ◆ The New Small Wheel: The phase-1 upgrade of the forward muon spectrometer
 - The Actual Small Wheel
 - The New Small Wheel
- ◆ The Large Area resistive MM for the NSW in ATLAS
 - Detector Structure
 - RO Boards
 - RO Panels
 - Drift Panels
 - Panels Assembly
- ◆ Final Quadruplet and Tests

Construction and Quality Assurance of Large Area Resistive Strip MicroMegas for the Upgrade of the ATLAS Muon Spectrometer

By Philipp Loesel



I, Feb.17, 2009

Practical operation of Micromegas

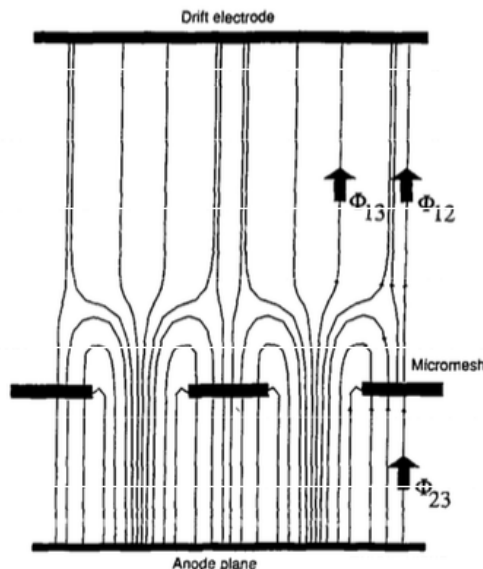


Fig. 11. Electric field configuration and partial flows.

Micromegas (MM): MICRO-MEsh GAseous

Belongs to the family of Micro-Pattern Gas Detector, the detector family born in the 1988 with the Micro-Strip Gas Chamber (A. Oed).

MM are parallel-plate chambers (about 5mm wide) where the amplification (up to 10^5) takes place in a thin gap, separated from the conversion region by a fine metallic micro-mesh, supported by $\sim 100 \mu\text{m}$ high insulating pillars.

Charge is collected on the anode readout board, generally realized with suitable segmented standard PCB.

Funnel field lines



Electron transparency very close to 1

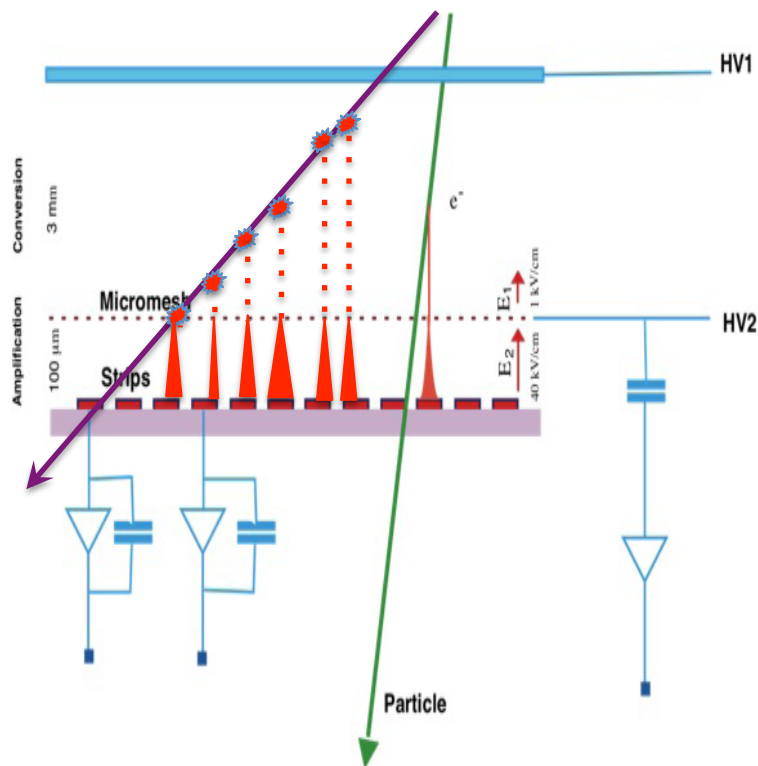
Small gap



Fast evacuation of the positive ions ($\sim 100 \text{ ns}$)

Y.Giomataris et al. NIM A 376 (1996) 29-35

“....our detector combines most of the qualities required for a high-rate position-sensitive particle detector: excellent resolution can be obtained with fine strips printed on a thin G10 substrate or a thin kapton foil.”



Two Different Operation Modes

- By measuring the average of **Charge** collected in few strips for Normal Tracks
- By measuring the signal arrival **Time** in more strips for Inclined Tracks (μ -TPC)

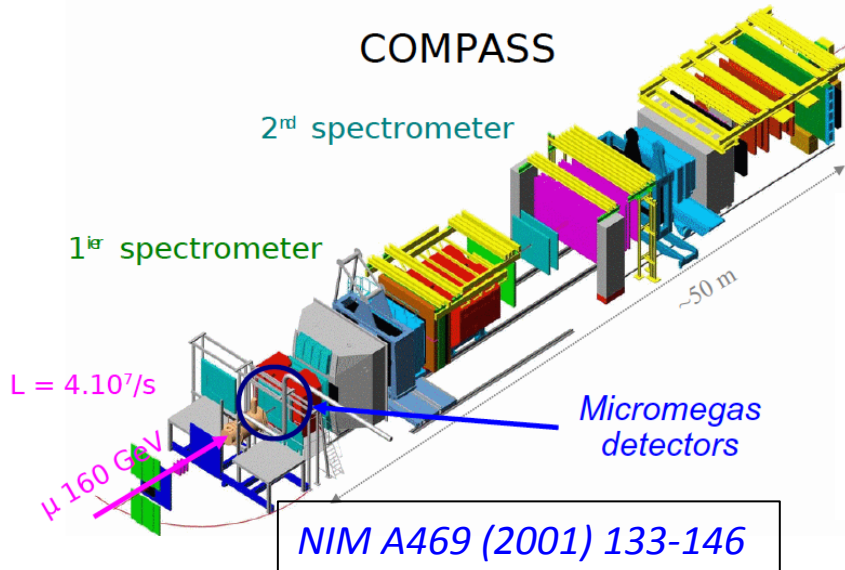
MM Typical Values

- Wide drift region (typically a few mm) with moderate electric field of about **500 V/cm**
- Narrow (**100 μ m**) amplification gap with high electrical field (**40–50 kV/cm**)
- A factor $E_A/E_D \approx 70-100$ is required for full mesh transparency for electrons
- With typical drift velocities of 50 μ m/ns (better if saturated) electrons need 100 ns for a 5 mm gap and Spatial Resolution of about **100 μ m** or better can be achieved.

At this first stage the greatest “enemy” of MMs was the discharges, sparks between mesh and strips, in particular with high flux of ionizing particles.

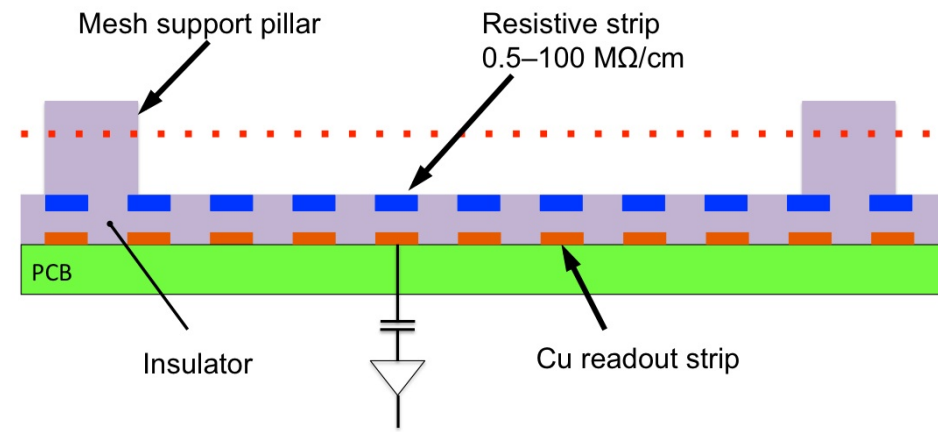
The main limitation for very large diffusion of MicroMegas in the very beginning

Compass Experience with Standard MM



“...The detector is subject to discharges of current which occur at a rate growing as a power function of the gain and proportional to the incident flux of hadrons....for the Ne-C₂H₆-CF₄ mixture (79-11-10), at fully efficiency, the spark probability (per incident particle) is smaller than 10⁻⁶...”

Resistive Strips

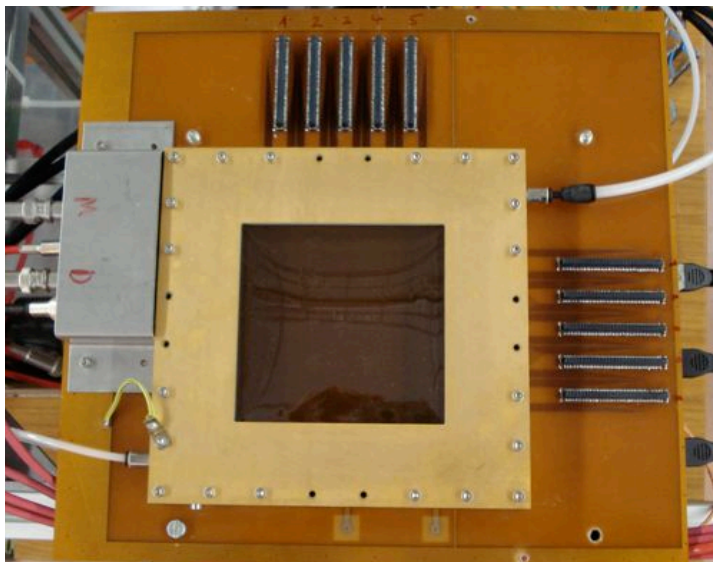


MAMMA Collaboration, NIM A640 (2011) 110

- Sparks dumped by the strips high resistivity, typical value is 1MΩ / Sq.
- Resistive strips at high voltage and mesh at ground is a more safe and easy configuration.
- RO strips are strongly coupled to resistive one and keep all the signal

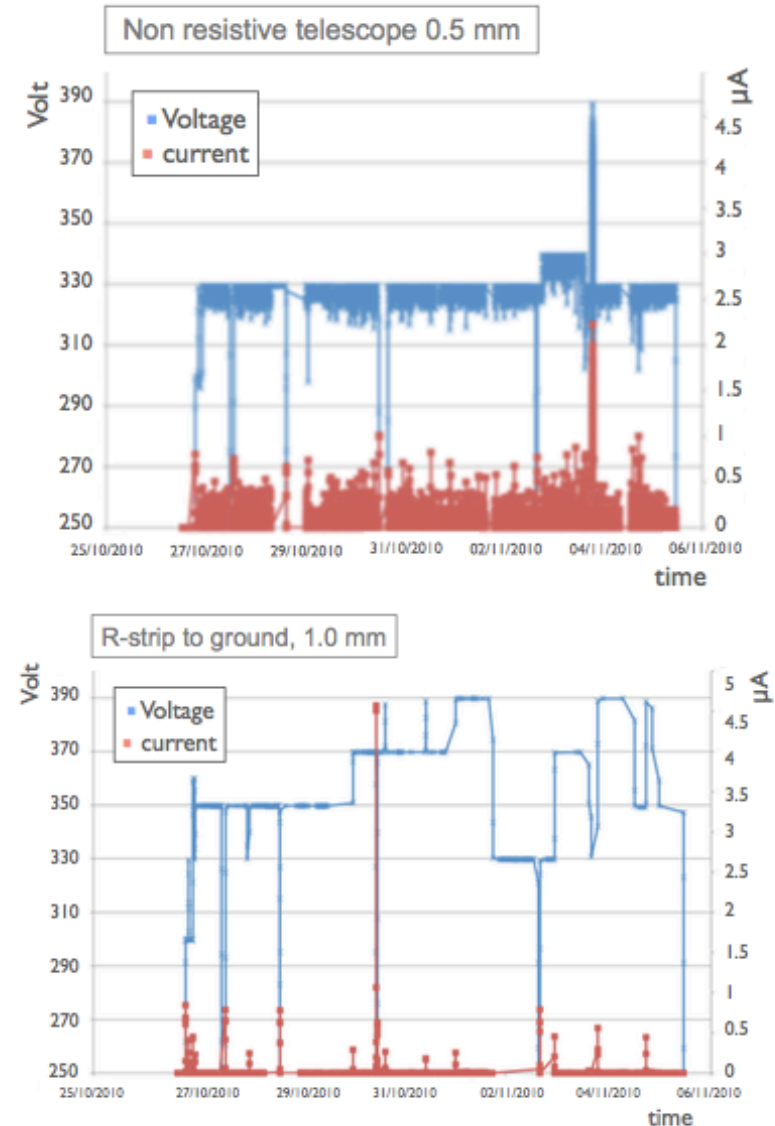
Mamma: Muon Atlas MicroMegas Activity

A synergy of the Atlas Collaboration +
the RD51 Collaboration (MPGD) +
the Cern PCB Laboratory (Rui de Olivera)



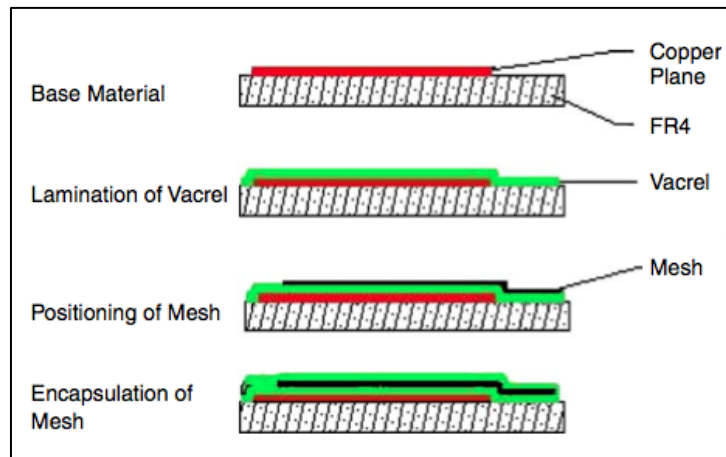
With this new scheme many small MM prototypes
have been produced at Cern and tested in various
test beam for different geometry, gain, gas mixture,
magnetic field effect...

Strong reduction of sparks on Resistive MM

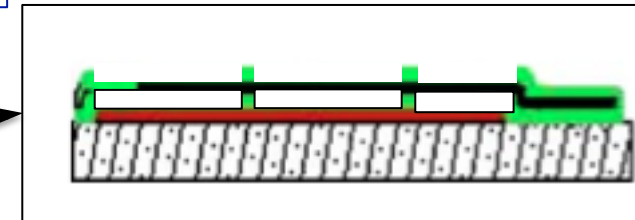


The Bulk MM

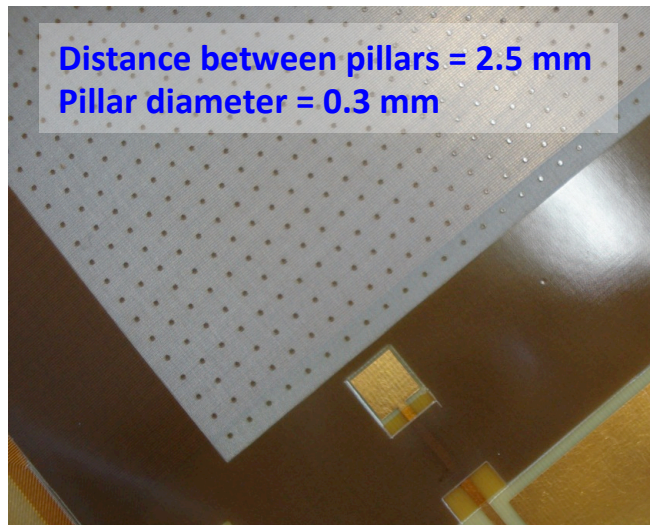
Making a step backward...in 2006 the first Bulk MM was produced at Cern.
In the bulk MM the mesh is embedded in the PCB



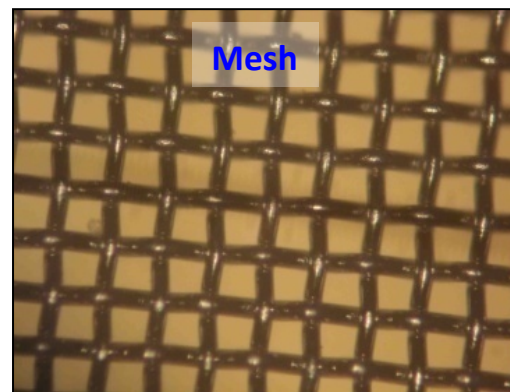
NIM A560 (2006) 405



The Insulator (Vacrel 8100 in this case) is photosensitive and can be removed by etching, creating the pillars.



Distance between pillars = 2.5 mm
Pillar diameter = 0.3 mm

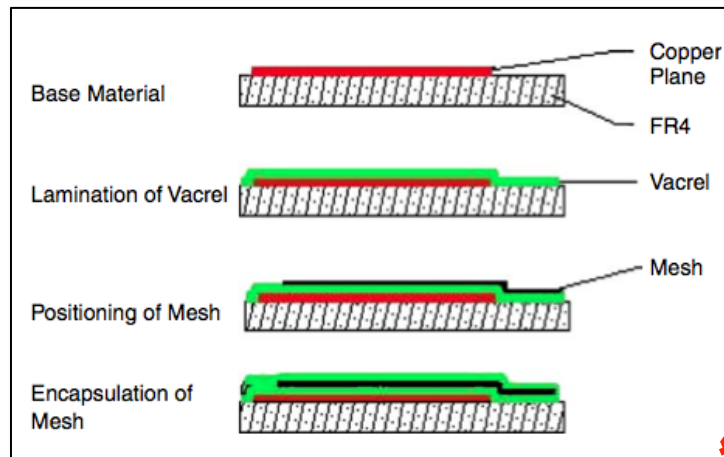


Mesh

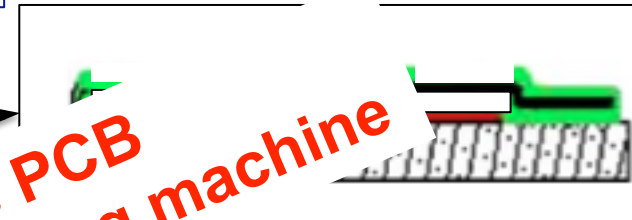
- New mesh used for bulk MM.
- Woven wire mesh, wire diameter about 20-30 μm and about 80% transparency.
- Largely produced for serigraphic application.
- Electroformed micromesh was normally used before.

The Bulk MM

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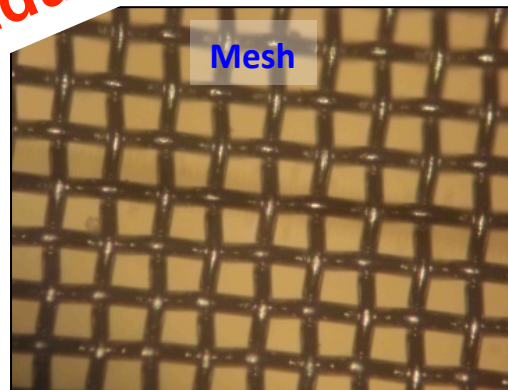
NIM A560 (2006) 405



Limited to less than 60 cm wide PCB
for typical industrial manufacturing machine



Distance between pillars
Pillar diameter = 60 μm

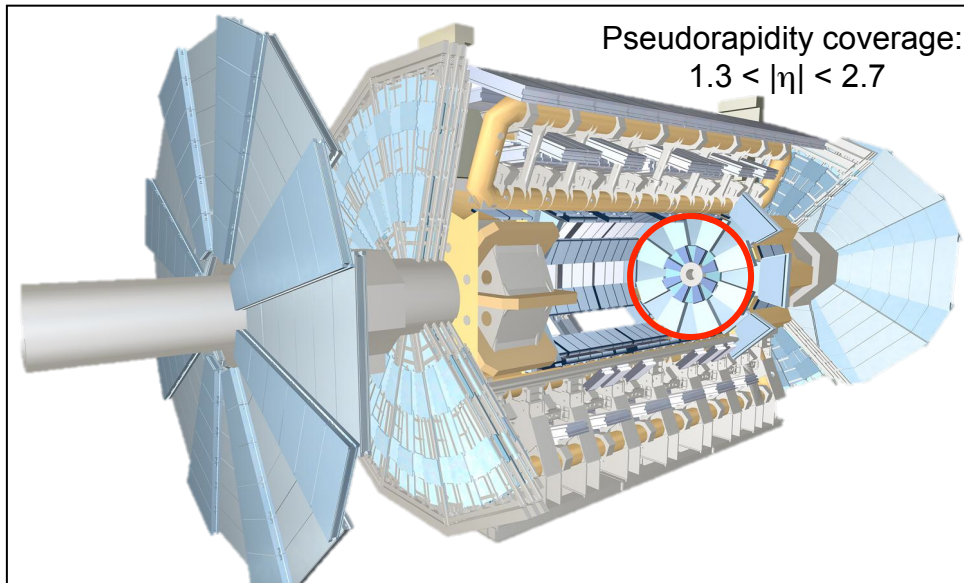


Mesh

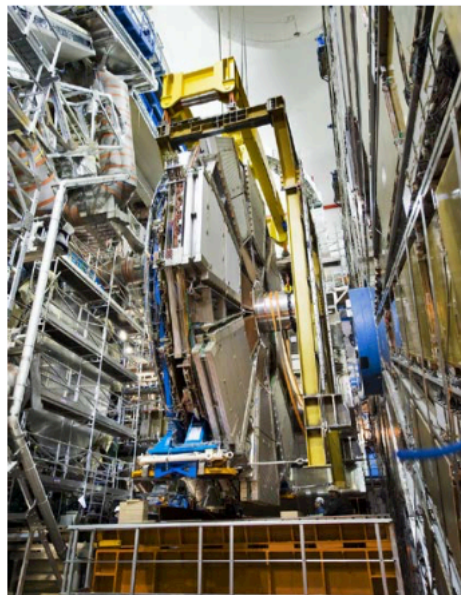
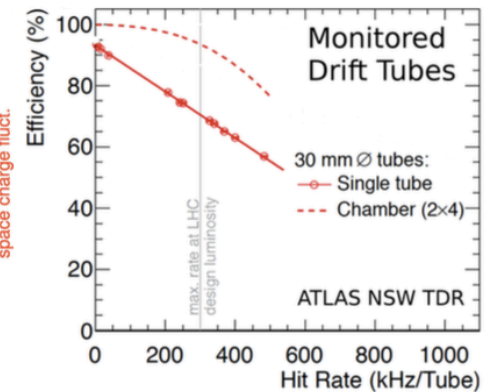
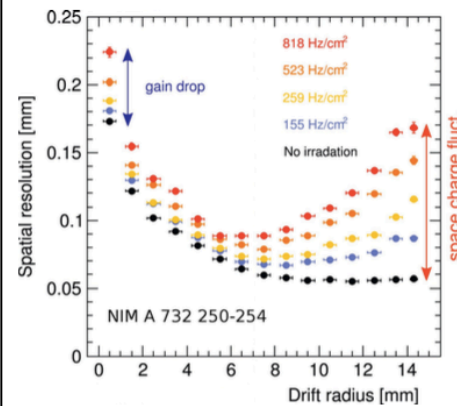
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The NSW: The Actual Small Wheel

1

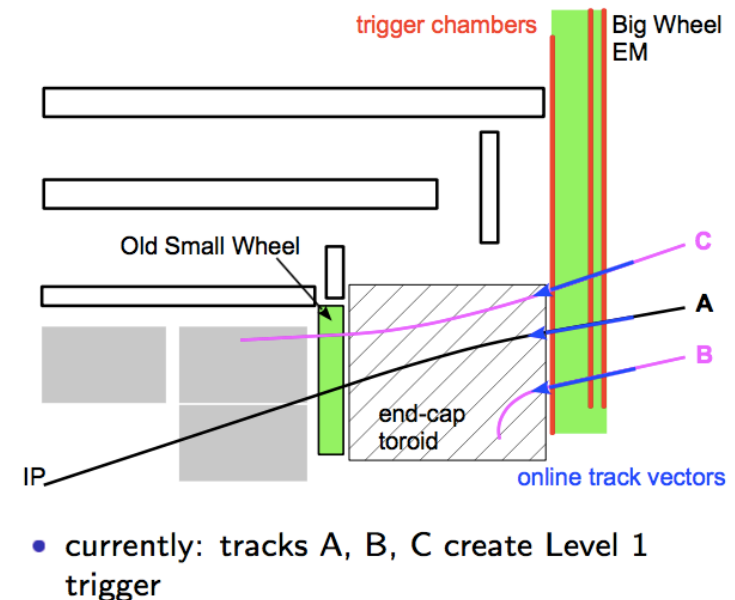


Small Wheel designed for Luminosity up to $10^{34} \text{ cm}^{-2}\text{s}^{-1}$



Small Wheel Detectors:

- Atlas Tubes (MDT) 30mm dia.
- Cathode Strip Chamber (CSC) in the inner part
- TGC for 2nd coordinate

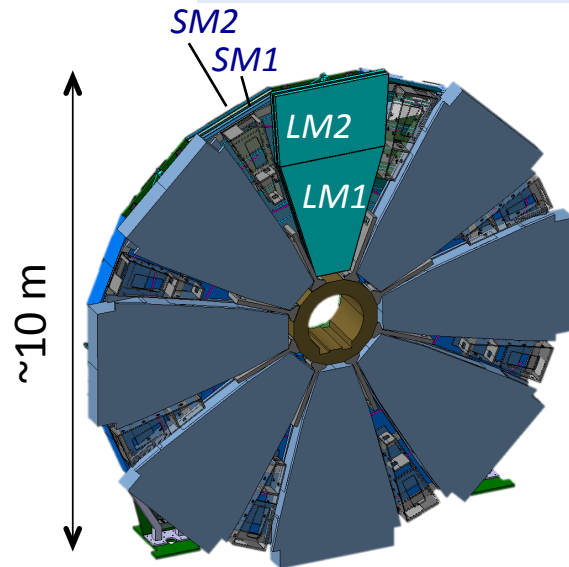


Main ATLAS upgrade during the Long Shutdown 2 (2019/20) (Phase-1)

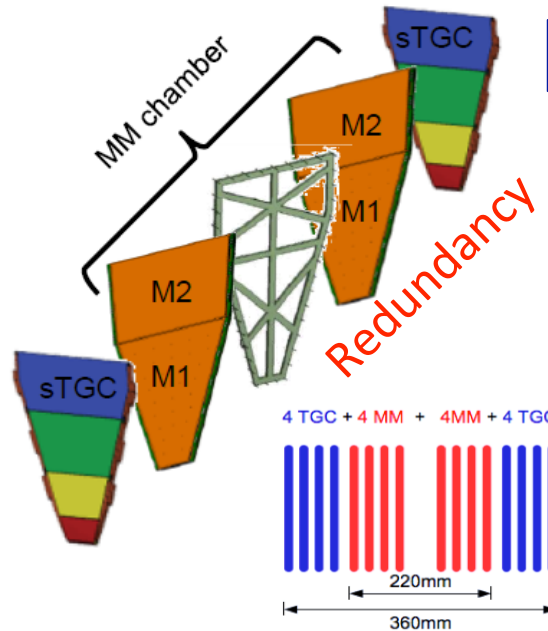
CERN-LHCC-2013-006 ATLAS-TDR-020

Two different technology:

- MM (main role tracking)
- sTGC (main role trigger)



Each NSW has 16 sectors
8 Large + 8 Small



NSW Requirements

- 15% P_T resolution at 1 TeV
- $\sim 100 \mu\text{m}$ resolution per plane
- Keep single muon trigger under control
- 1 mrad **online** angular resolution

About 15kHz / cm^2 at $L \approx 5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$

S/L M1 : 5PCB

S/L M2 : 3PCB

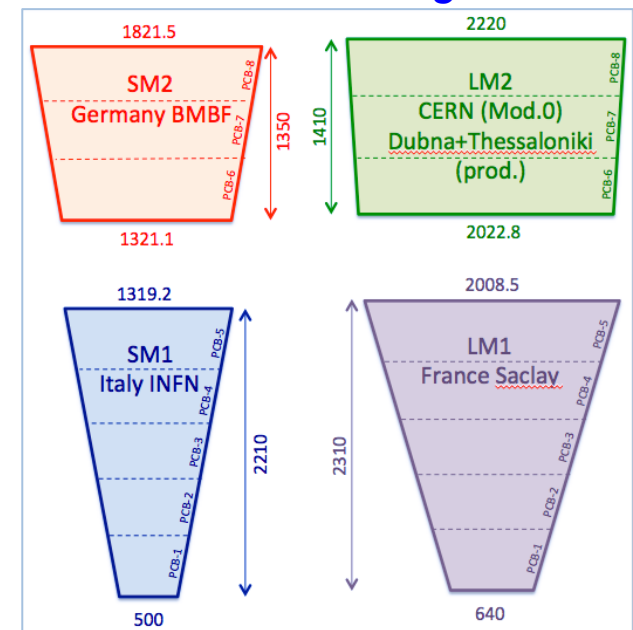
PCB:

$\sim 420\text{mm}$ wide

1024 Strips

MM Sharing

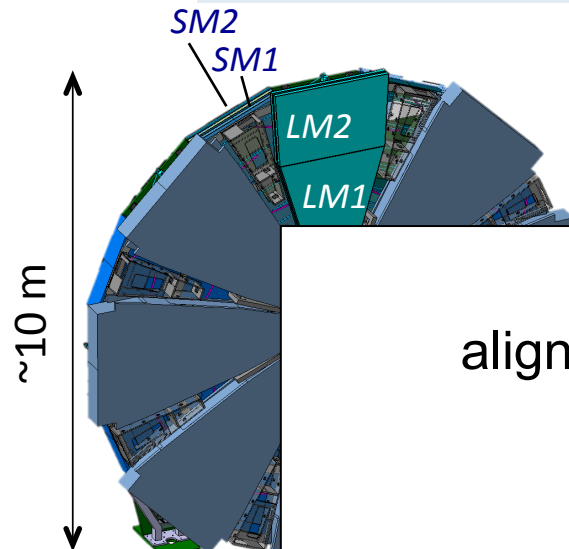
32 Quadruplet / Site



Main ATLAS upgrade during the Long Shutdown 2 (2019/20) (Phase-1)

CERN-LHCC-2013-006 ATLAS-TDR-020

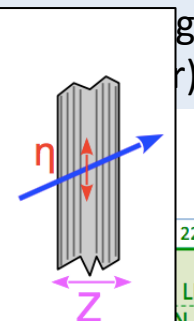
Two different technology:



Challenge in MM construction:
alignment of the strips on each detection layer

30 μm RMS in η

80 μm RMS in z



Each NSW has 16 sectors
8 Large + 8 Small

MM Requirements

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S/L M1 : 5PCB

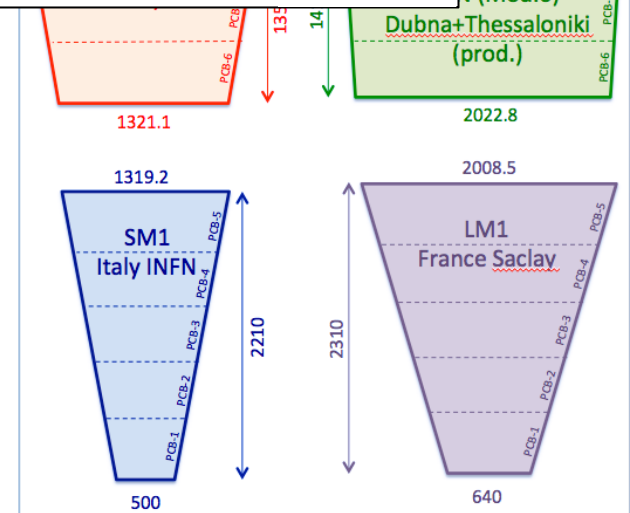
S/L M2 : 3PCB

PCB:

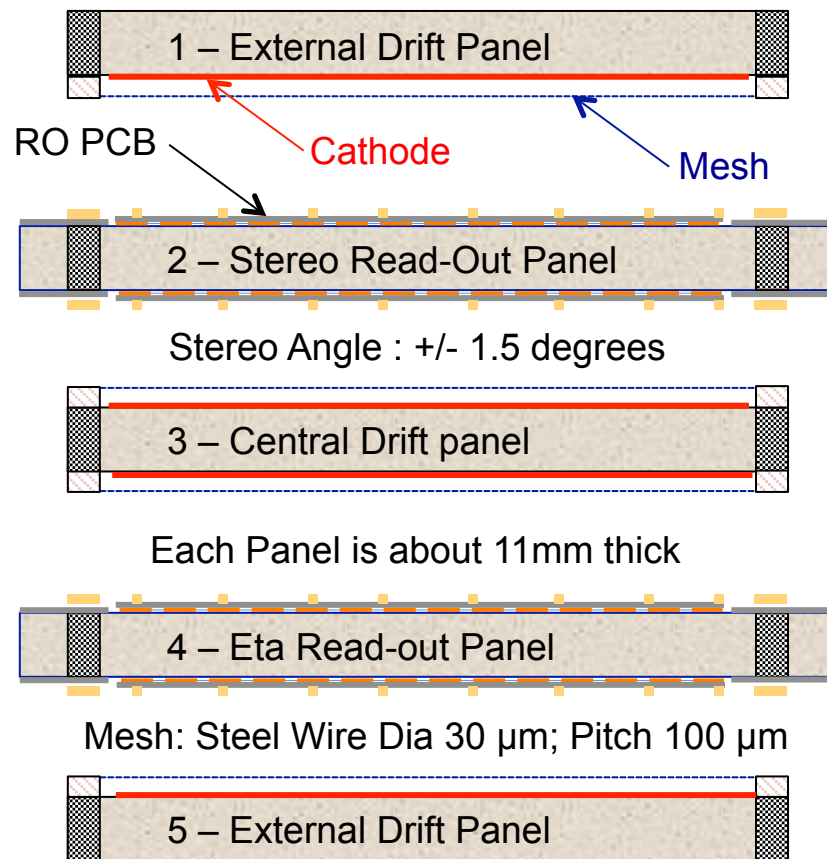
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32 Quadruplet / Site



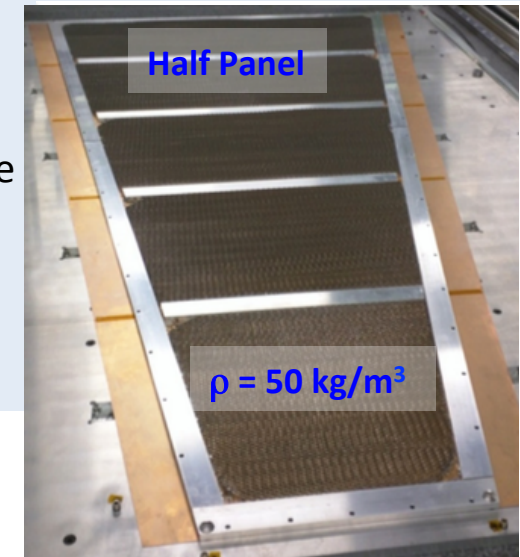
MM Quadruplet Exploded View

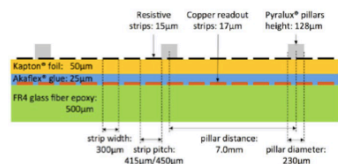


Five panels joined to make a detector unit (Quadruplet) with 4 gas layers.

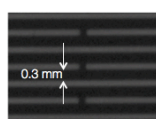
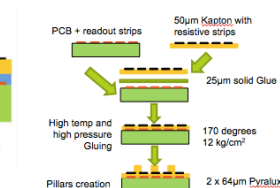
Building Large Area MM

- Panel is a sandwich of 0.5 mm PCB skin with honeycomb in the middle and frames in the perimeter and in the joint of two adjacent PCB. Honeycomb and frames are in Al.
- Different Panels are needed for a Quadruplet
 - RO Panels (Eta and Stereo)
 - N.2 External Drift Panels
 - One Central Drift Panel
- For each gas layer a unique Mesh is glued on the drift panel, using a custom frame that define the 5 mm height.
- Slow bi-component epoxy is used as glue.

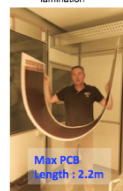




- All production steps of the PCB construction procedure are industrially well known.
- The collaboration is directly taking care of the production of the Resistive Strips on Kapton. Screen Printing technology is used.
- "Ladder pattern" (join every 10mm) used for homogeneous resistivity and insensitivity to broken lines.



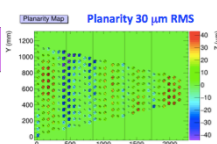
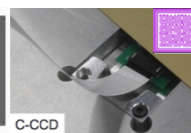
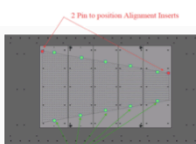
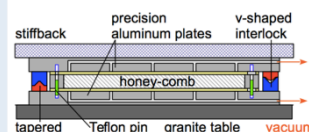
Typical Resistivity
~800 kΩ/□



...RO PCB...

Stiffback Construction Method

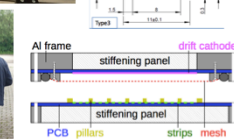
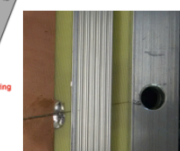
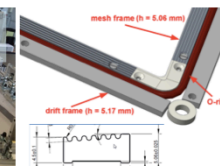
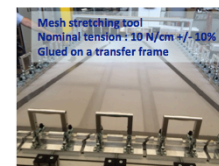
- Challenge in MM construction: strips alignment
 - 30 μm RMS in η
 - 80 μm RMS in z
- Precision Panel construction is guaranteed by high precision hole/slot on PCB and by the external tooling.
- Position check is done reading masks etched on the PCB, using optical sensors
- Glue compensate for non-precise components.



...RO Panels...

Drift Panels are build using different techniques in different sites. Stiffback, like RO Panels, or Vacuum bag. Results are similar.

The floating mesh is attached to the drift panels



...Drift Panels...

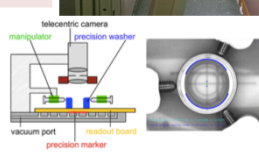
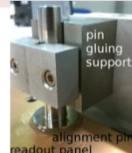
Vertical Panel Assembly

- Cleanliness
- No panel deformation under its own weight
- Panel deformation because of the mesh

External drift panel, because of the mesh tension, is deformed, with a sagitta of about few mm, when put in vertical.

During the assembly a support structure called stiff-frame is used and visible on the left part of the picture (fixed part); RO (stereo) panel on the right (movable part)

Precise pins/slot are glued on the RO panels for relative alignment

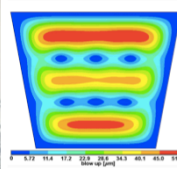


...Panels Assembly...

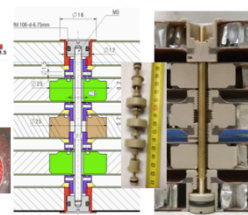


The two external surfaces are deformed by the overpressure due to gas flowing in the detector.

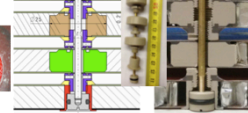
Simulations show many hundreds of microns largest deviation.



Simulation with 6 interconnections for 2 mbar overpressure, the largest deformation is now 50 μm . The final number of interconnections range from 4 to 7.



Need to make holes in the mesh !

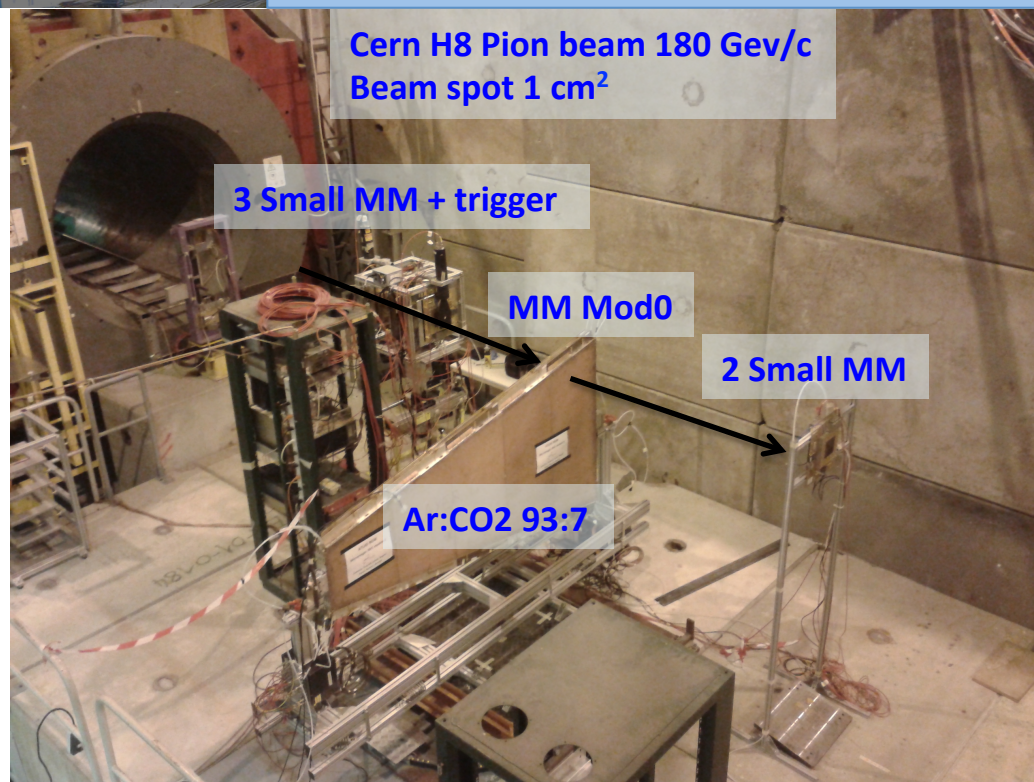


...*Quadruplet* !

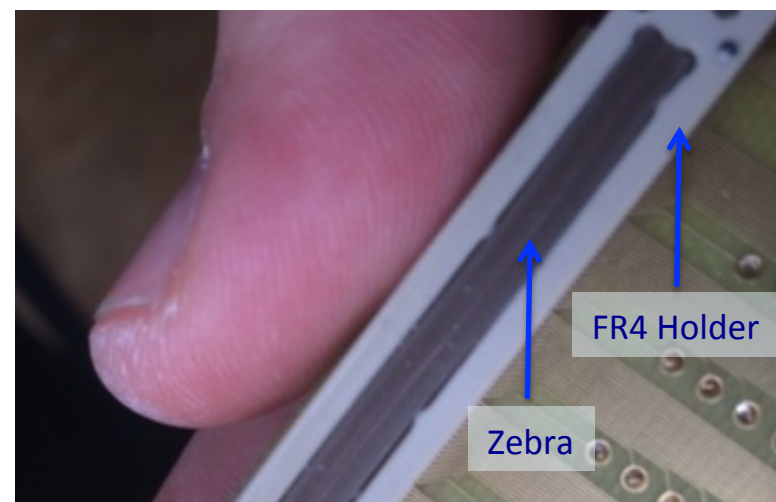
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MicroMegas Test Beam at Cern H8

1



Used final Zebra connectors to Read-Out the strips with some adapter boards to use the APV25 being the final electronic not jet available.



Zebra connector is a rubber strips with high contacts density inside (typical pitch 50-100 μm).
The Read-Out card has the identical footprint of the PCB and the zebra get connection.
Zebra needs to be pressed in order to get contact, this is done via a compression bar.



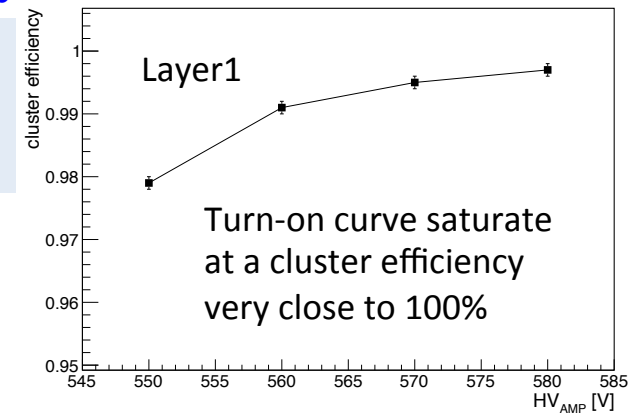


Track-based efficiency

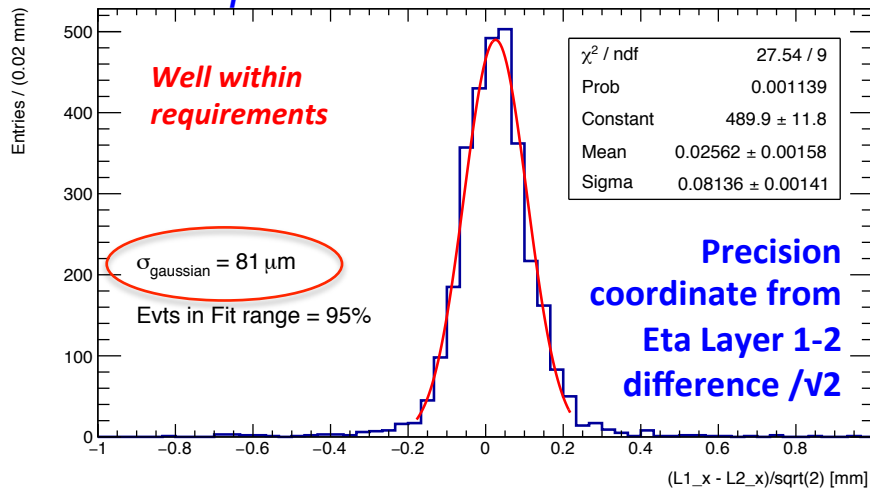
One cluster within
given distance from the
reference track impact.

Normal Incidence

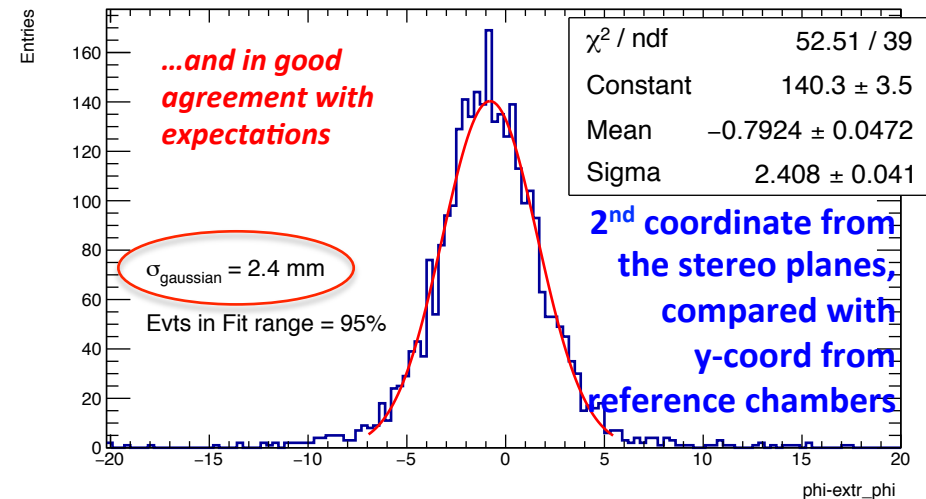
Cluster efficiency Vs Amplification HV



Preliminary result: Spatial Resolution of the precision coordinate



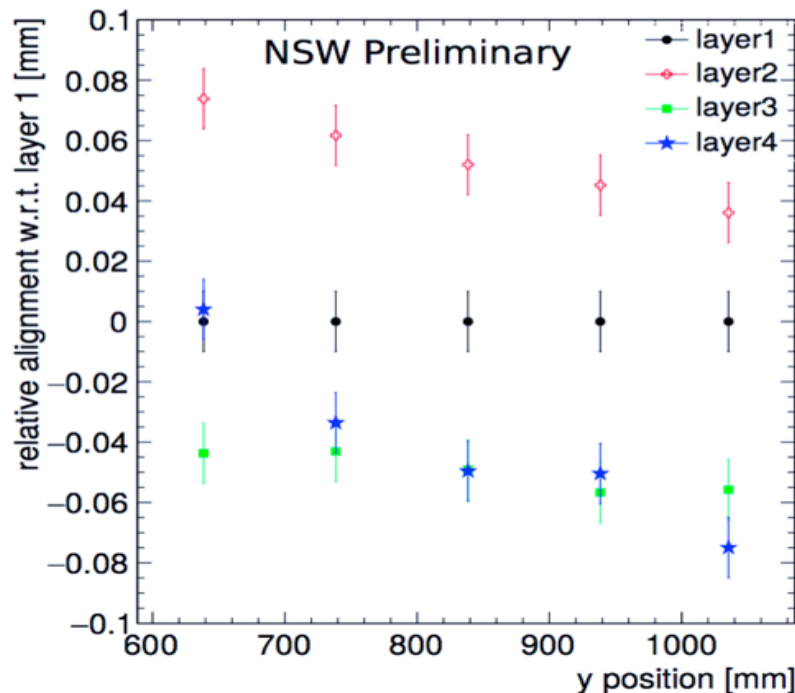
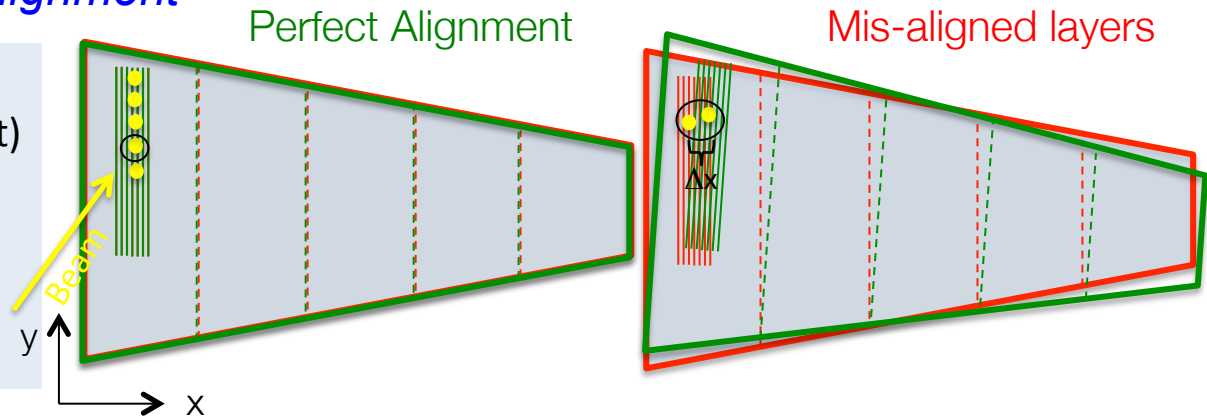
Preliminary result: Spatial Resolution of the second coordinate.



Evaluation of Layers Relative Alignment

Measurements at different vertical positions, along the strips. (yellow spot)

For each y-position measure Δx between $layer_i$ and $layer_{-1}$ using reference tracks defined by the small bulk MM in the beam setup



$$\Delta x = x_{layer_i} - x_{layer_1} = 0$$

$$\Delta x = x_{layer_i} - x_{layer_1} \neq 0$$

Relative Alignment wrt Layer_1 :

- Measured a maximum deviation of +/- 80 μm
- The effects are both shifts and rotation
- Under investigation at the construction site
- Before production start a second Mod0 (called 0.5) will be built using the control system based on C-CCD.

The Large Eta zone in the LHC experiments will be, in the next future, very challenging because of high background rates.

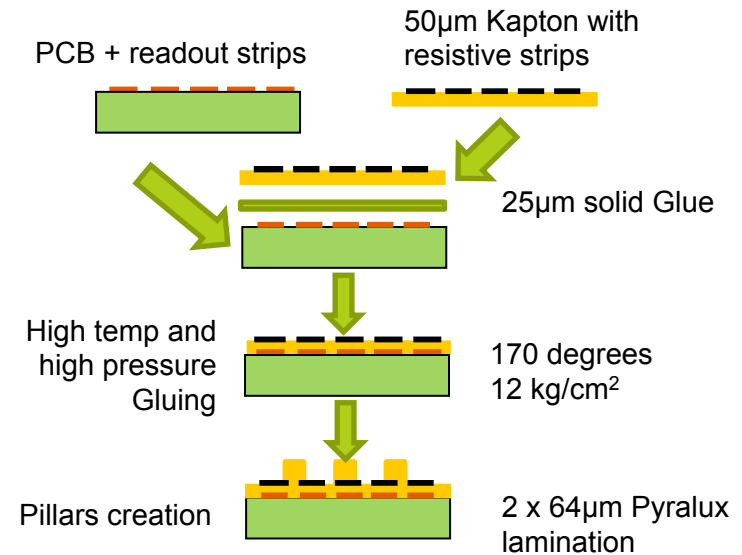
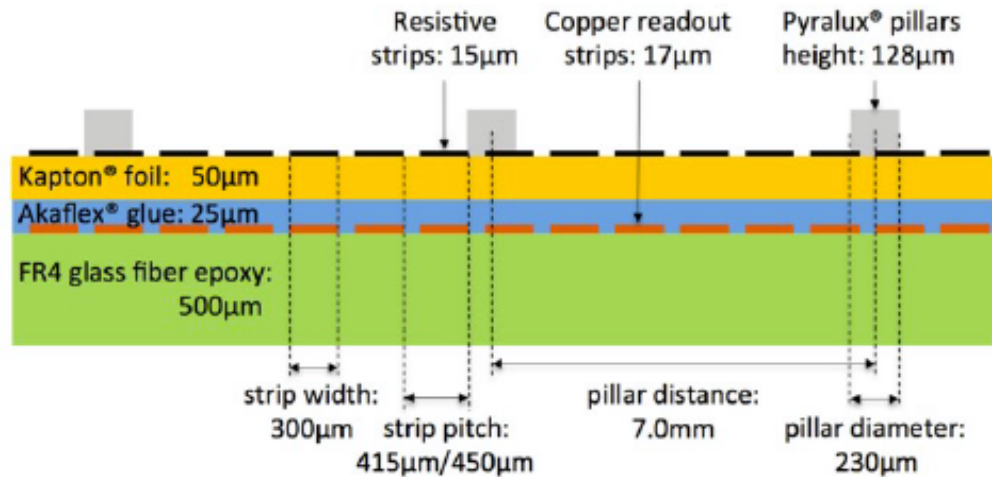
Conclusions:

Large Area Resistive MicroMegas is a suitable technology to upgrade the ATLAS forward muon spectrometer.

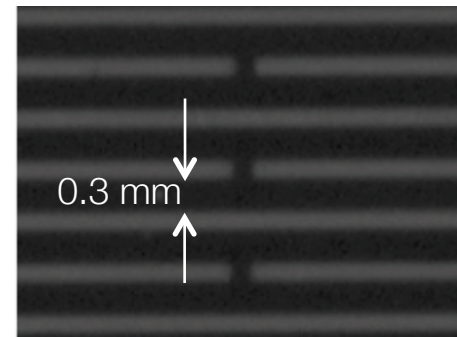
The MM Collaboration, inside the ATLAS-NSW project, is now starting the detectors production and, despite a very tight schedule, will be ready for the Long Shutdown 2 *RendezVous*

Thanks for Your Attention

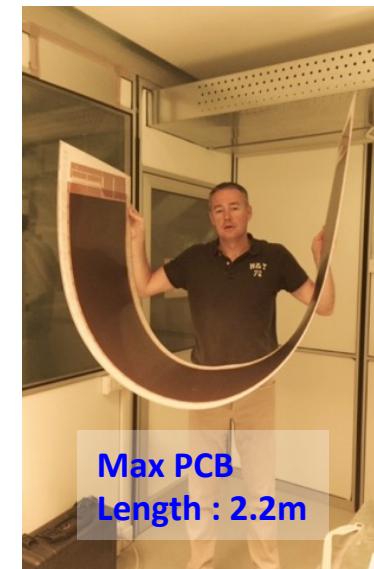
Backup Slides



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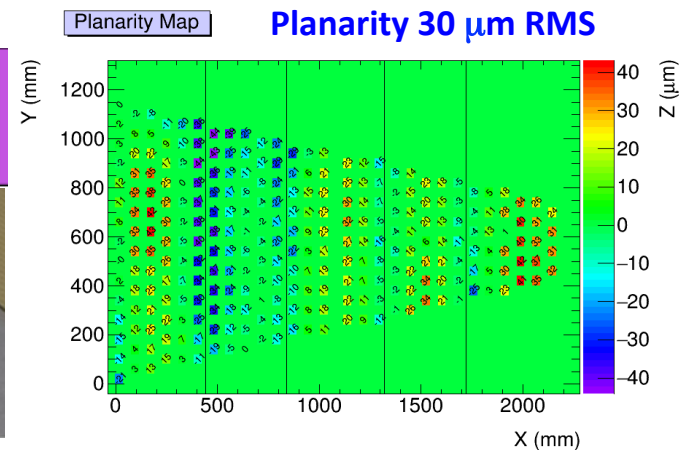
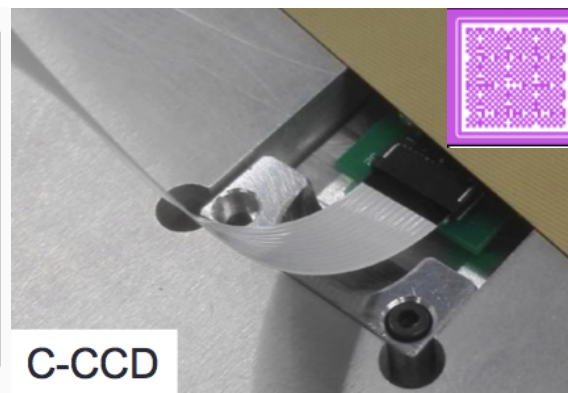
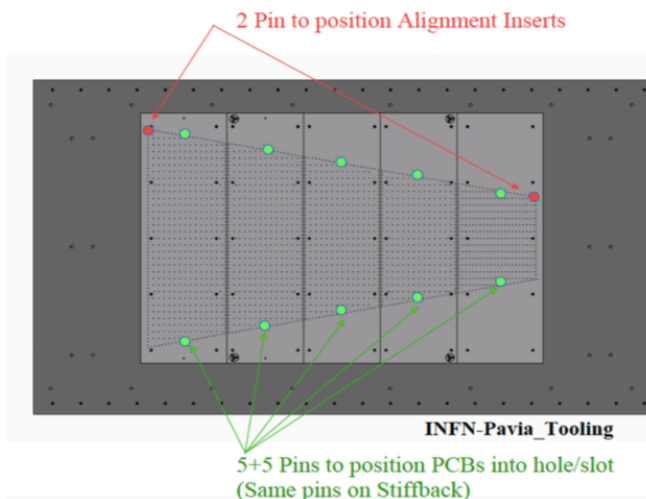
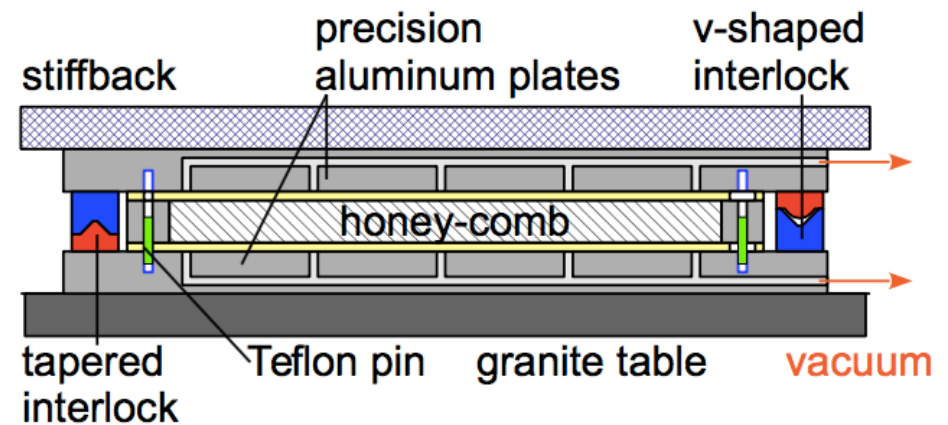


Typical Resistivity
~800 k Ω /□



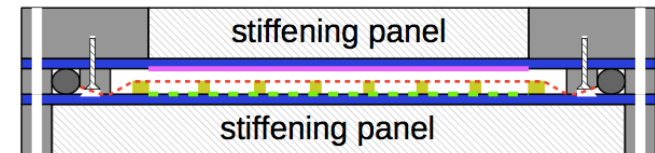
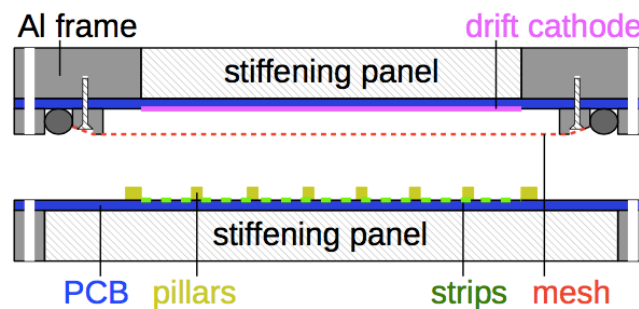
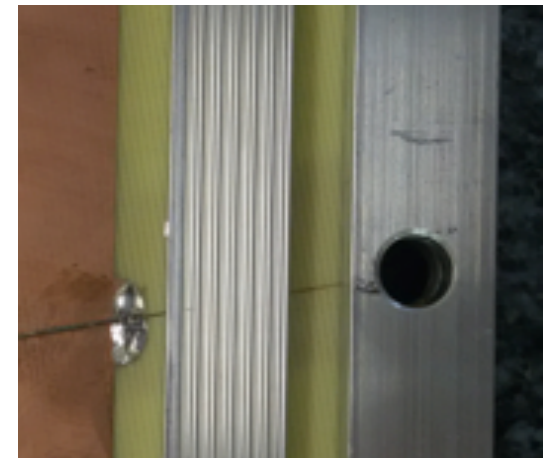
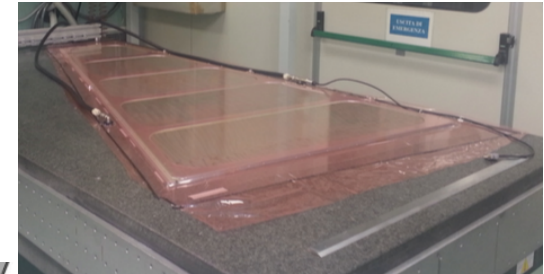
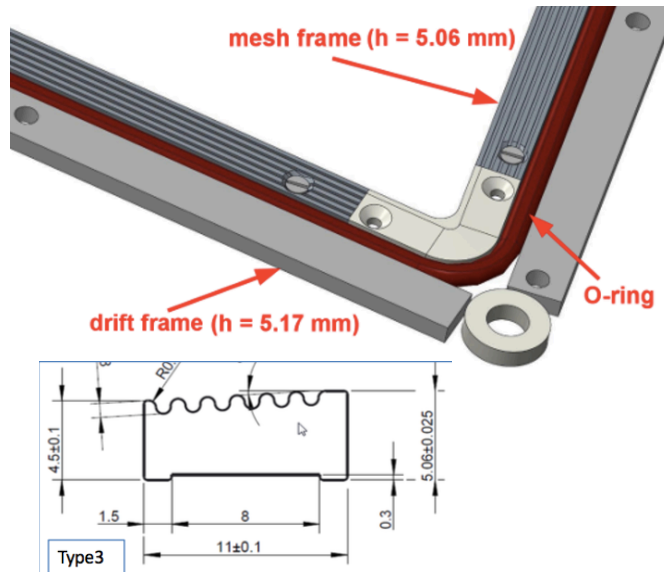
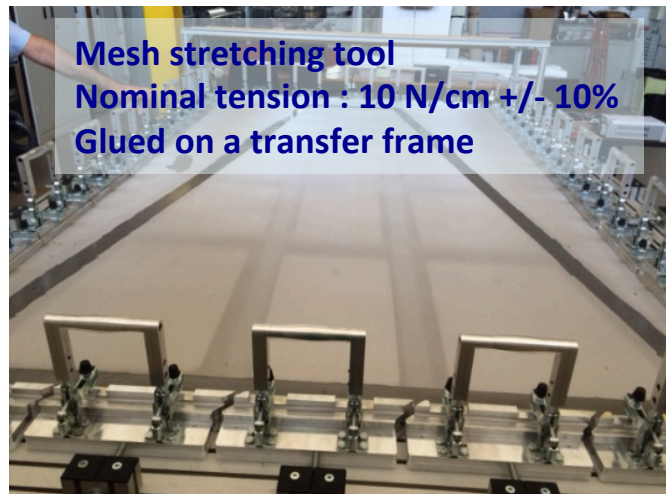
- Challenge in MM construction: strips alignment
 - 30 μm RMS in η
 - 80 μm RMS in z
- Precision Panel construction is guaranteed by high precision hole/slot on PCB and by the external tooling.
- Position check is done reading masks etched on the PCB, using optical sensors
- Glue compensate for non-precise components.

Stiffback Construction Method



Drift Panels are build using different techniques in different sites.
Stiffback, like RO Panels, or Vacuum bag. Results are similar.

The floating mesh is attached to the drift panels



Vertical Panel Assembly

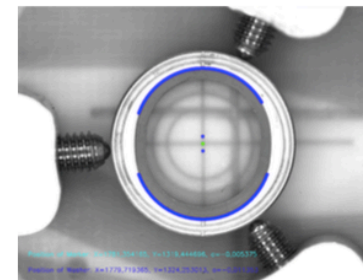
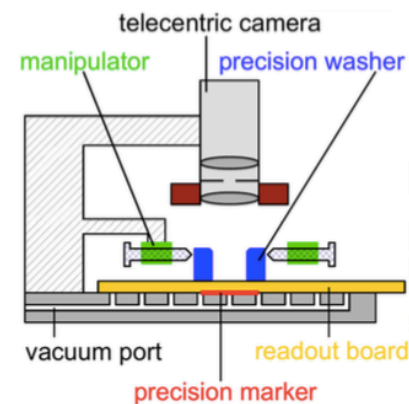
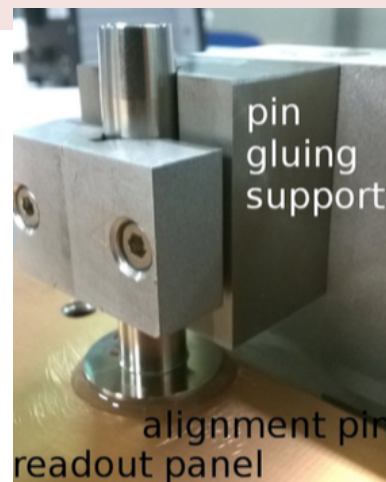
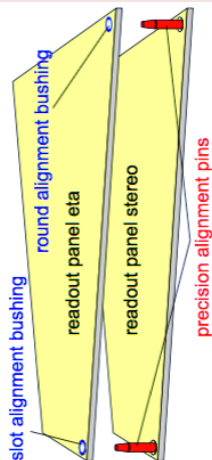
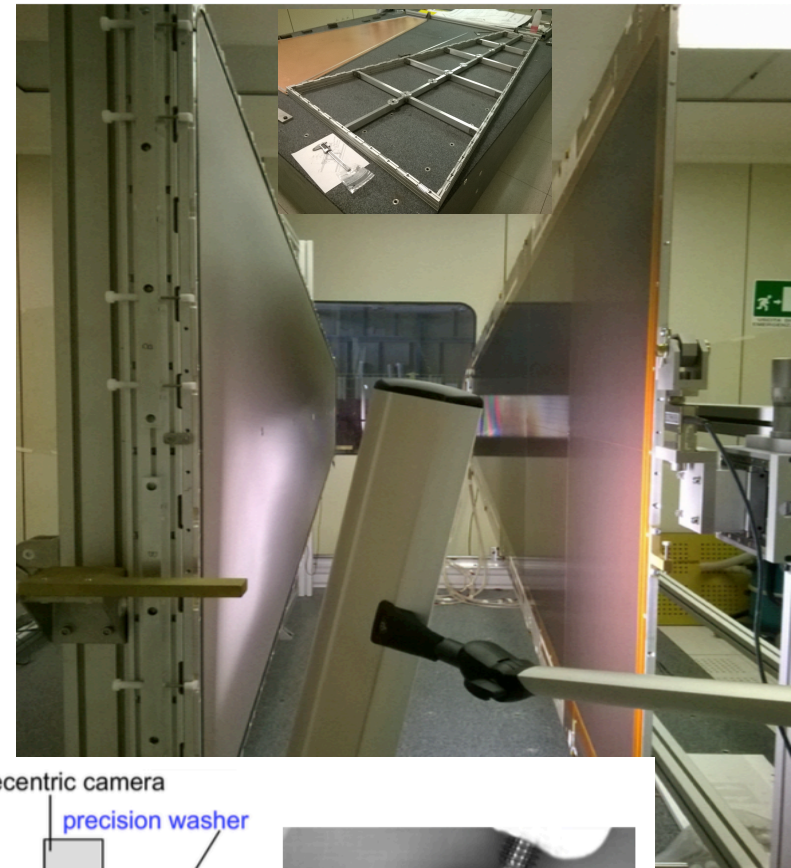
- Cleanliness
- No panel deformation under its own weight
- Panel deformation because of the mesh

External drift panel, because of the mesh tension, is deformed, with a sagitta of about few mm, when put in vertical.

During the assembly a support structure called stiff-frame is used and visible on the left part of the picture (fixed part);

RO (stereo) panel on the right (movable part)

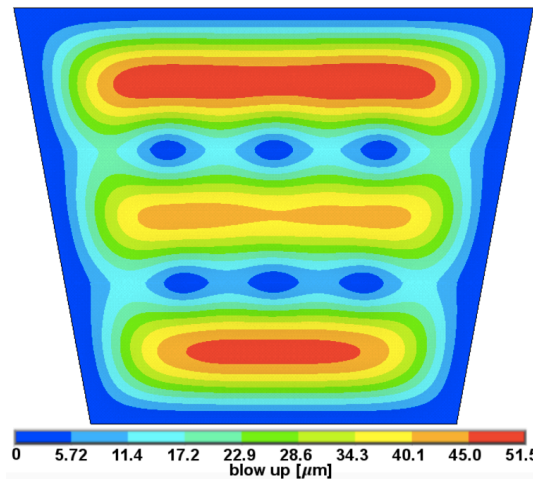
Precise pins/slot are glued on the RO panels for relative alignment





The two external surfaces are deformed by the overpressure due to gas flowing in the detector.

Simulations show many hundreds of microns largest deviation.



Simulation with 6 interconnections for 2 mbar overpressure, the largest deformation is now 50 μm .
The final number of interconnections range from 4 to 7.

Need to make holes in the mesh !

