Design and Construction of Precision Tooling for Construction of Micromegas Detectors for the ATLAS Small Wheel Upgrade Project in Germany

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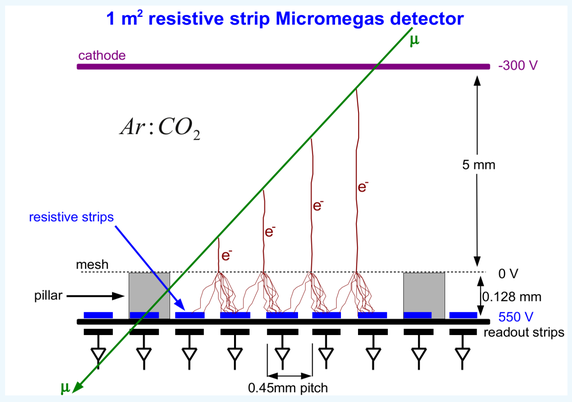
Abstract

Mechanical precision is a key-aspect of the high-rate capable Micromegas detectors for the upgrade of the Small Wheels of the ATLAS muon spectrometer. 32 SM2 quadruplets will be built by four German institutes with cathodes and strip-anodes made of stable honeycomb sandwiches.
To achieve a single plane resolution below $100\mu m$ the deviation from planarity of a single detector plane must not exceed $80\mu m$ over the whole active area and the global position of the readout strips has to be within $30\mu m$ for a single readout-plane of 3 PCB's, as well as between all four planes of a quadruplet.
Precision tooling is used for the correct positioning of readout PCB's and readout sandwich planes. For quality control of the planarity of the sandwich planes a laser distance sensor combined with a coordinate measurement system has been developed. Deviation from planarity below 10 μm can be easily resolved.
We will present key features of the challenging construction procedure to achieve this high level of precision as well as our alignment strategies. This includes the construction and commissioning of a $2.5\ m^2$ lightweight rigid structure (stiffback), which has an overall planarity below $20\ \mu m$ RMS and the measurement of the the blow up of outer planes of a quadruplet due to 2 mbar overpressure of the Ar:CO2 detector gas, the standard situation in ATLAS.

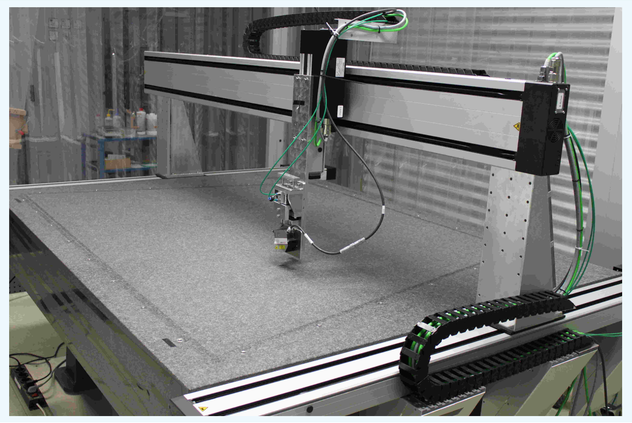
Working Principle of Resistive Strip Micromegas Detectors

- Ionization of $\approx 100\ \frac{e^-}{cm}$ in Ar:CO_2 93:7
- Electron drift velocity $v_{drift} = 47\ \frac{\mu m}{ns}$
- Collection of avalanche charges on resistive strips (anode)
- Capacitive coupling between resistive and copper readout strips
- Pulseheight and timing information, $25\ ns$ sampling
- Strip width $300\ \mu m$, Strip pitch $425 - 450\ \mu m$
- Resistivity of strips $\approx 10 \frac{M\Omega}{cm}$



Coordinate Measurement Machine (CMM)

- Laser triangulation sensor on a XYZ translator (CMM)
- Dimensions of the CMM: $X = 2270\ mm;\ Y = 1680\ mm;\ Z = 120\ mm$
- Resolution of translation: $\sigma_{trans} = 10\ \mu m$
- Measurement accuracy: $< 10\ \mu m$
- topology = object surface scan - granite table surface scan



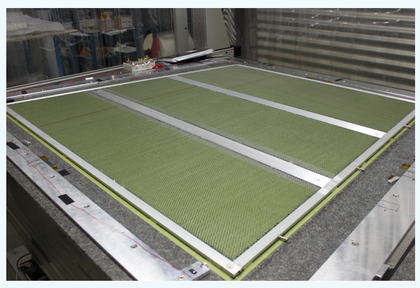
Panel Construction Using a Stiffback in a Two Step Gluing Process

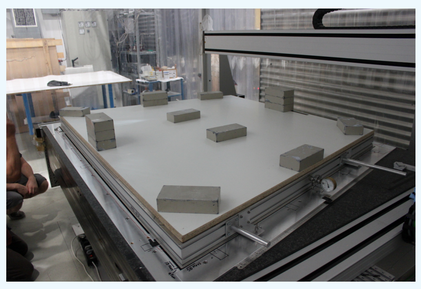
First step:

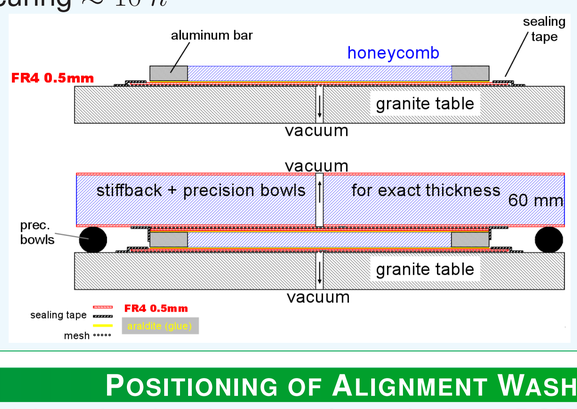
- Alignment of three FR4 PCB sheets relative to each other and to granite table
- Fixation with vacuum and tape
- Adaption of precise and flat granite table surface
- Adjustment of aluminum bars and honey
- Glue curing $\approx 10\ h$

Second step:

- Suction of first half-panel to stiffback
- Alignment of second set of PCB
- Alignment of first half panel relative to second side
- Parallelism ensured by precise distance balls
- Glue curing $\approx 10\ h$







Laser Triangulation

1. Laser beam hits the surface perpendicularly
   - Diffuse reflection of laser light with known constants: $a,\ a', \delta$
   - Calculated values

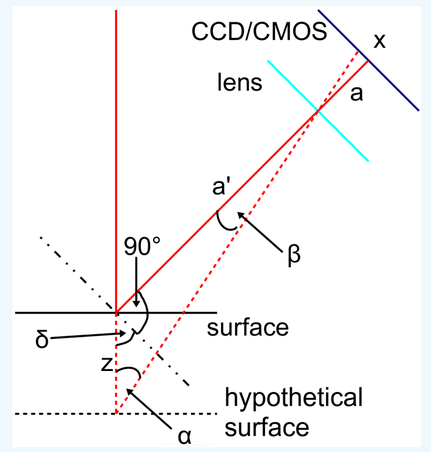
$$\alpha = 90° - \delta - \beta \equiv \delta' - \beta \quad (1)$$

$$\tan\beta = \frac{x}{a};\ \ \frac{\sin\alpha}{a'} = \frac{\sin\beta}{z} \quad (2)$$

   - Using (1) and (2) one obtains

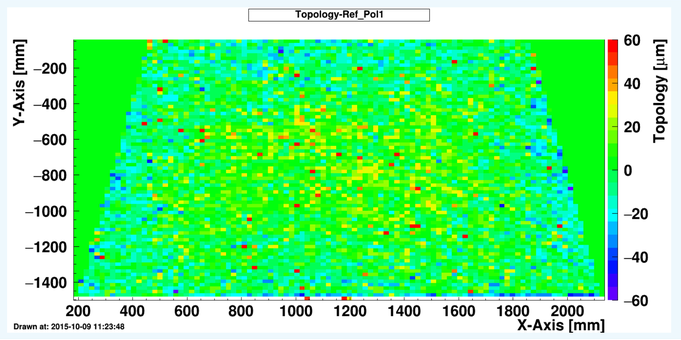
$$z = \frac{a'}{\frac{a}{x}\cos\delta - \sin\delta} \quad (3)$$

2. Specular reflection using inclined beam. Less penetration of semitransparent surfaces



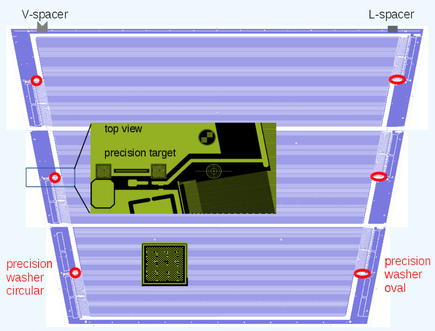
Topology Measurement of Stiffback

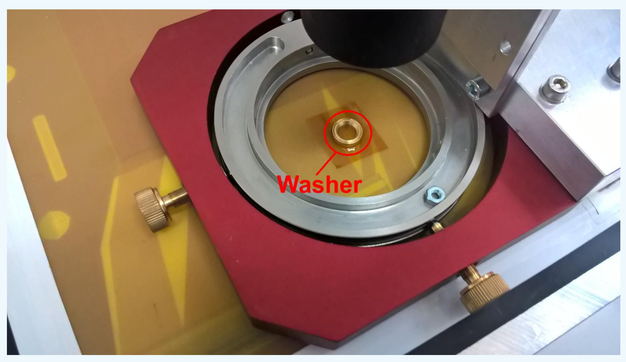
- Measurement of a trapezoidal plane of $2\ m^2$ in $1{:}45\ h$ with a modularity of $\approx 1.5\ cm$, 7000 data points
- Accuracy of repeated measurement: $< 10\ \mu m$
- Deviation from a measurement with a tactile sensor: $\sigma_{laser-tactile} = 15\ \mu m$

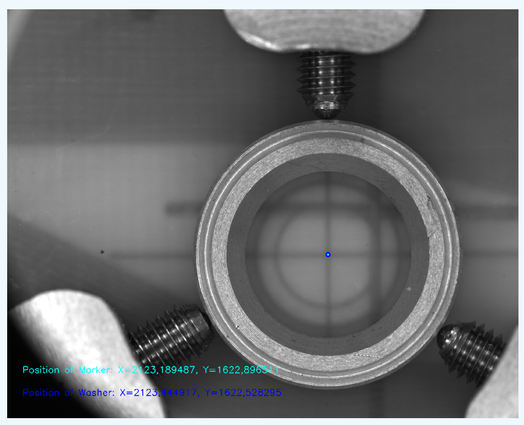


Positioning of Alignment Washers on Readout PCBs

- Subdivision of active detector planes in three PCBs
- Need of a precise alignment between readout PCBs Parallelism requirement: $\frac{30\ \mu m}{2\ m} \approx 10^{-5}$
- Positioning of two washers per PCB on to precision markers on PCB
- Using of telecentric camera to locate marker through PCB
- Washer positioning accuracy $< 5\ \mu m$
- Alignment of PCBs with an alignment frame having pins fitting into the washers

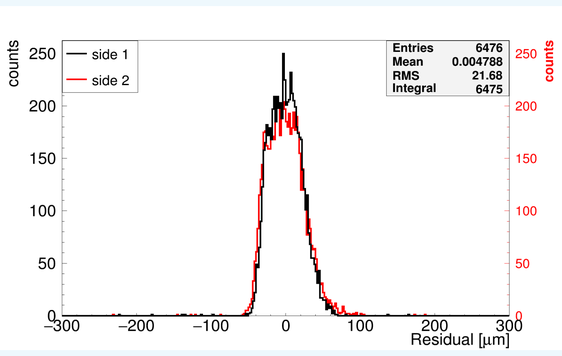


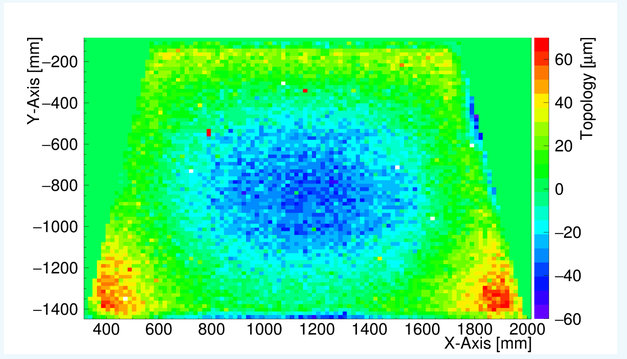


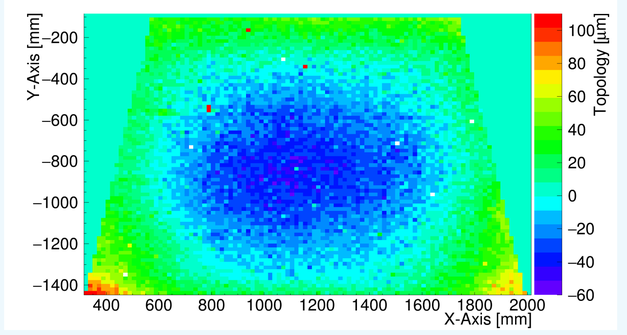


Topology of Testpanel

- Panel sucked to granite table during measurement
- Side 1: RMS $21.7\ \mu m$, $\Delta_{Min-Max} = 130$ µm
- Side 2: RMS $24.8\ \mu m$, $\Delta_{Min-Max} = 160\ \mu m$
- Correction of systematic effect in future

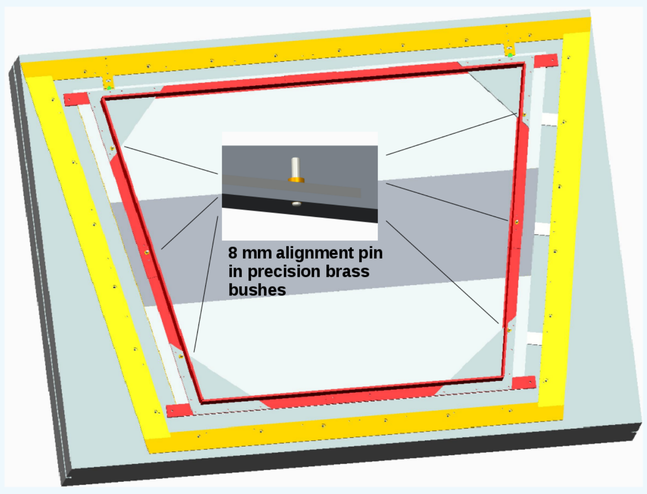






Alignment Frame for Precise Relative and Global Positioning of Three PCBs

- Aluminum frame with inserts for precision pins
- Machining of all inserts in a single step (eight inserts)
  ⇒ Precise positions
- Aligning PCBs by attaching pins in frame to washers on PCBs



Interconnects

- Overpresure of detector gas inside Micromegas $2 - 3\ mbar$
- Blow up of Micromegas
  ⇒ Need of fixation to keep surfaces flat
- Six interconnects at dedicated positions to minimise blow up
- ANSYS simulation shows $\approx 50\ \mu m$ blow up