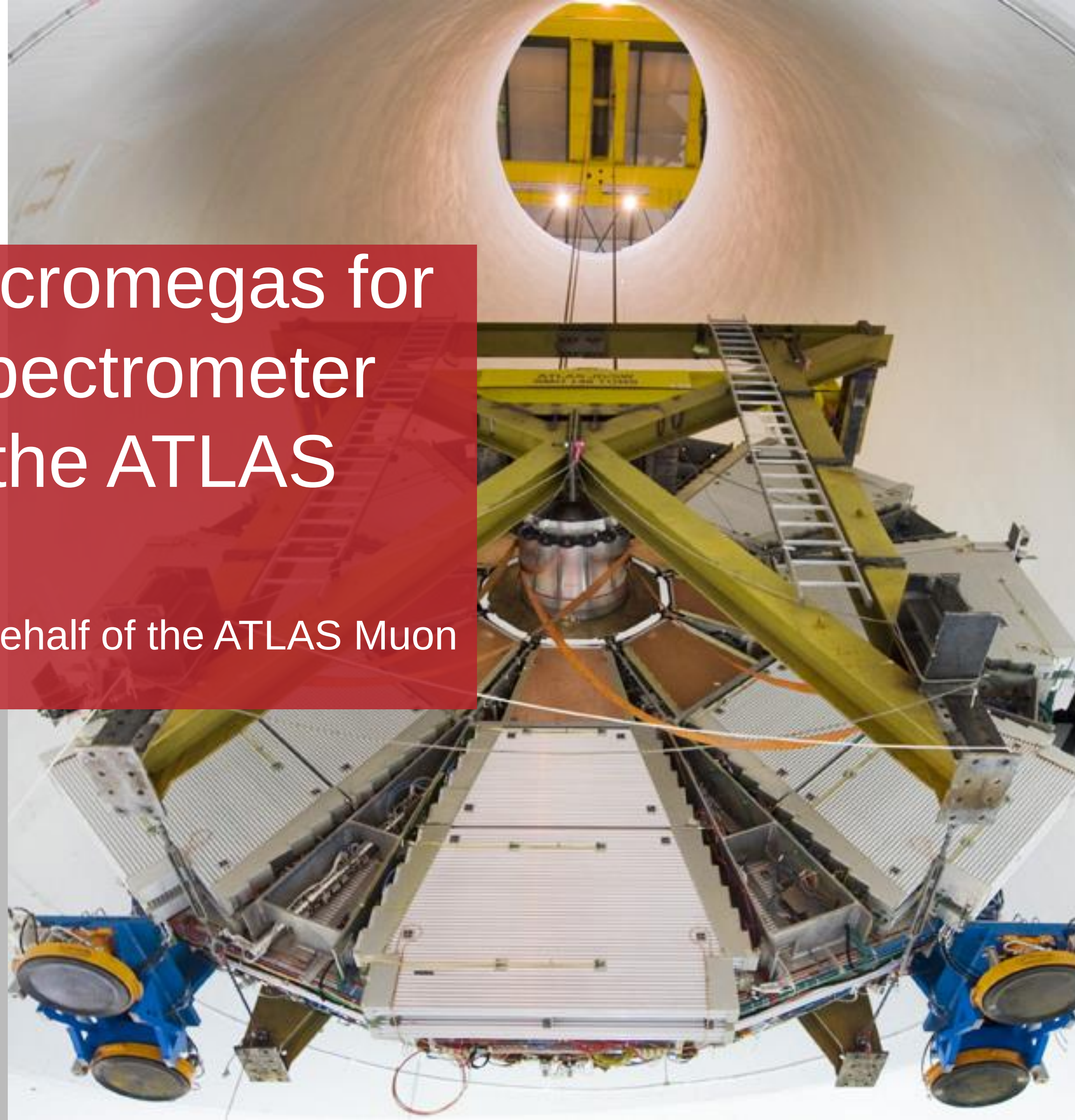
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Resistive Micromegas for the Muon Spectrometer Upgrade of the ATLAS Experiment

Andreas Düdder, on behalf of the ATLAS Muon Collaboration



TIPP 2017

Outline

Detector design

- New Small Wheel Upgrade
- Micromegas Layout and Components

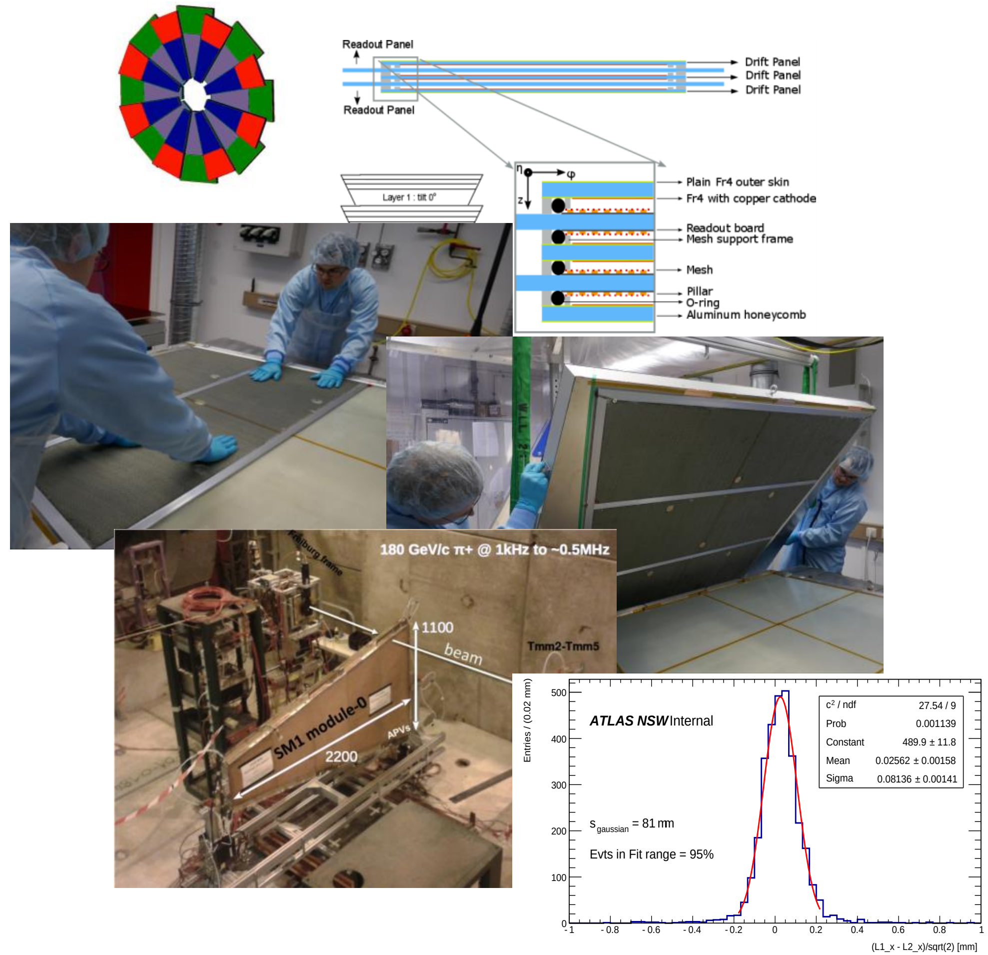
Detector Construction

- Mechanical Tolerances and Quality Control
- Construction principle

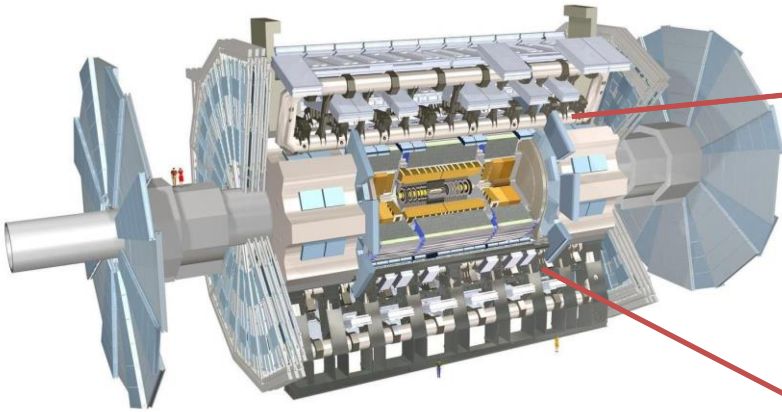
Prototype Performance

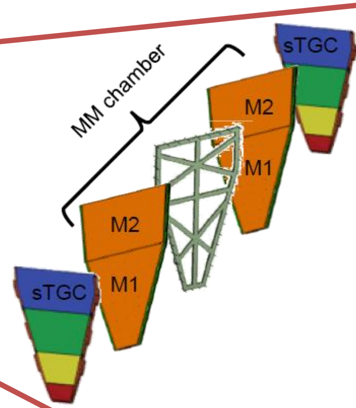
- Small scale prototype
- Real size prototype (Module-0)

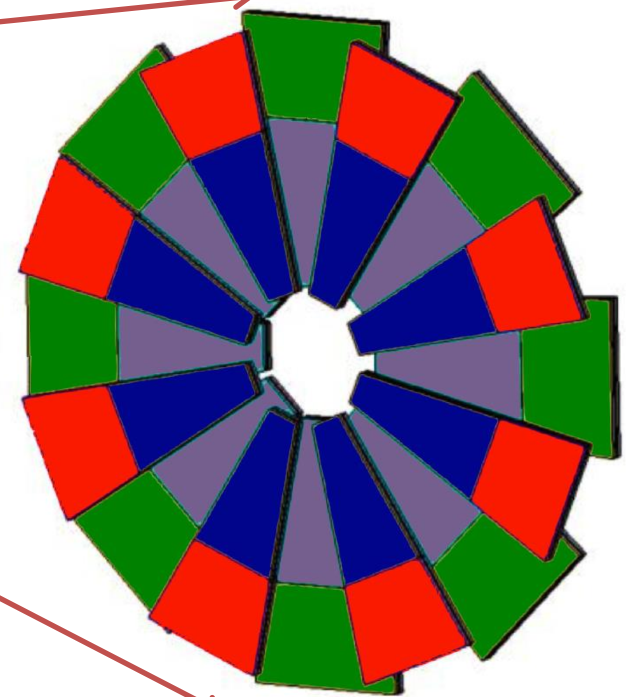
Outlook and Summary

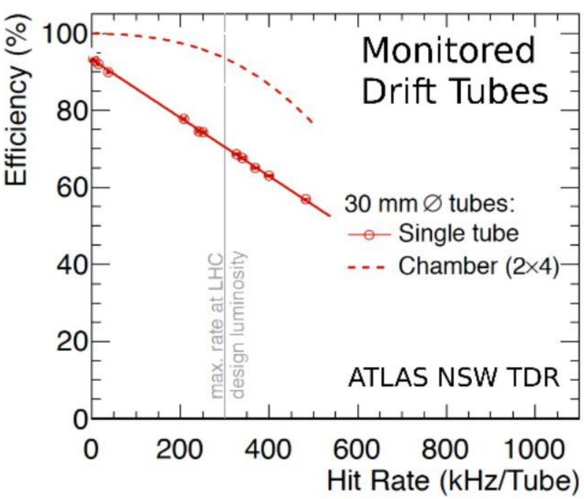


New Small Wheel Upgrade









- HL-LHC
  (L -> 10^{35} $cm^{-2}s^{-1}$,
  15 kHz/cm^2) leads to
  inefficiency in drift tubes
- New Small Wheel Upgrade (Phase-1) with **Micromegas** and small Strip Thin Gap Chamber
- Two quadruplet detectors per wedge

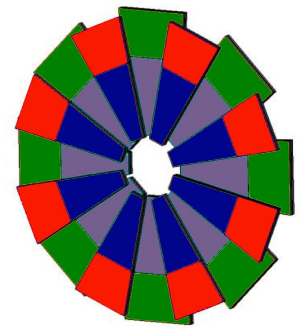
New Small Wheel Micromegas

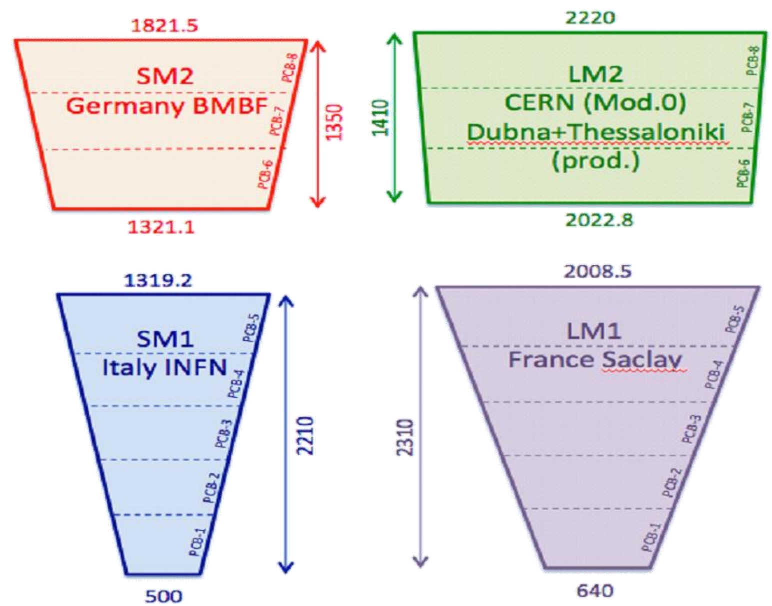
Geometry

- 4 different geometries
- 32 quadruplets of each geometry

► → more than 1200 m^2 active area

► **Largest Micromegas based project**





Requirements

- Maintain 15% p_T resolution at 1TeV
  - ► < 100 µm single plane resolution

- Well defined single muon trigger
  - ► 1 mrad online angular resolution

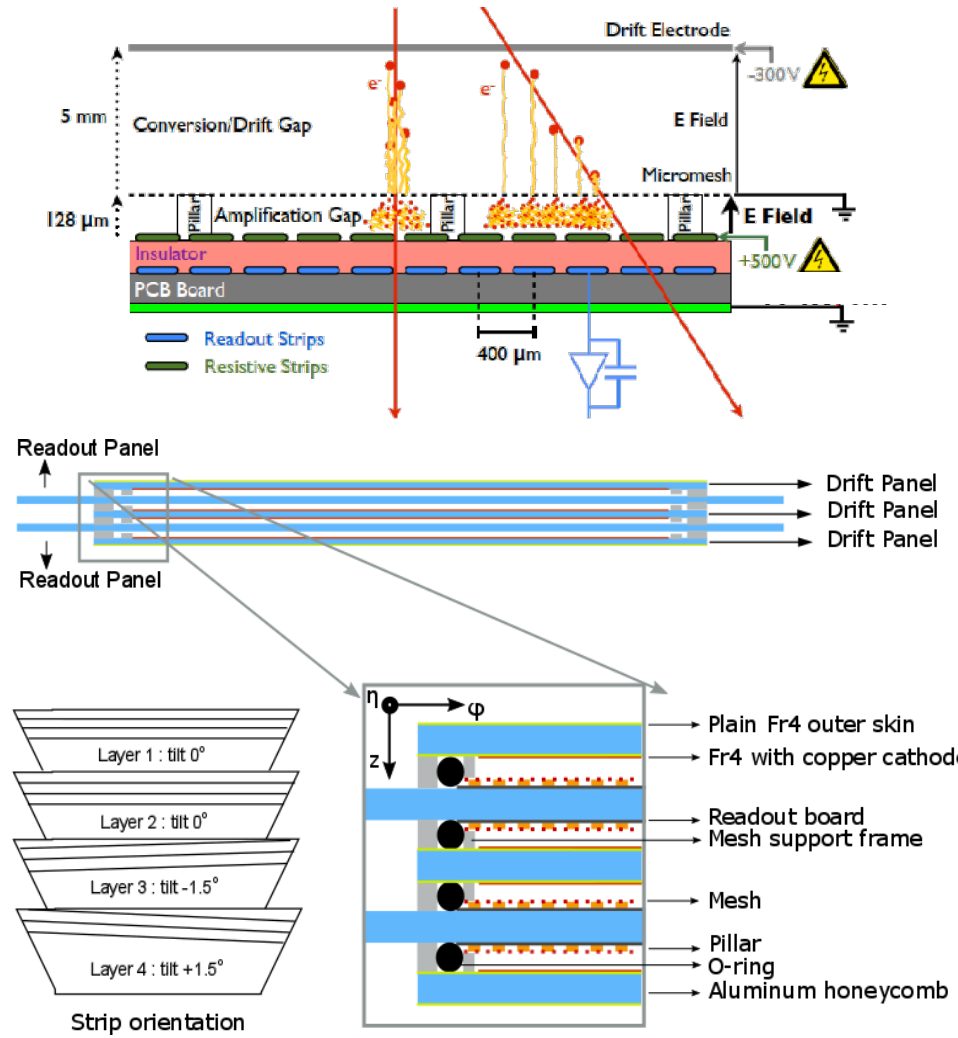
Micromegas Layout

Micromegas

- Conversion/Drift Region for charge generation (5 mm)
- Amplification region with high electric field for charge multiplication in avalance (0.128 mm)
- Regions separated by Micromesh

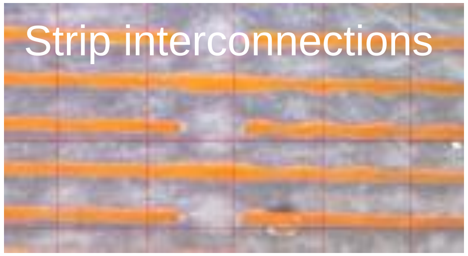
Implementation

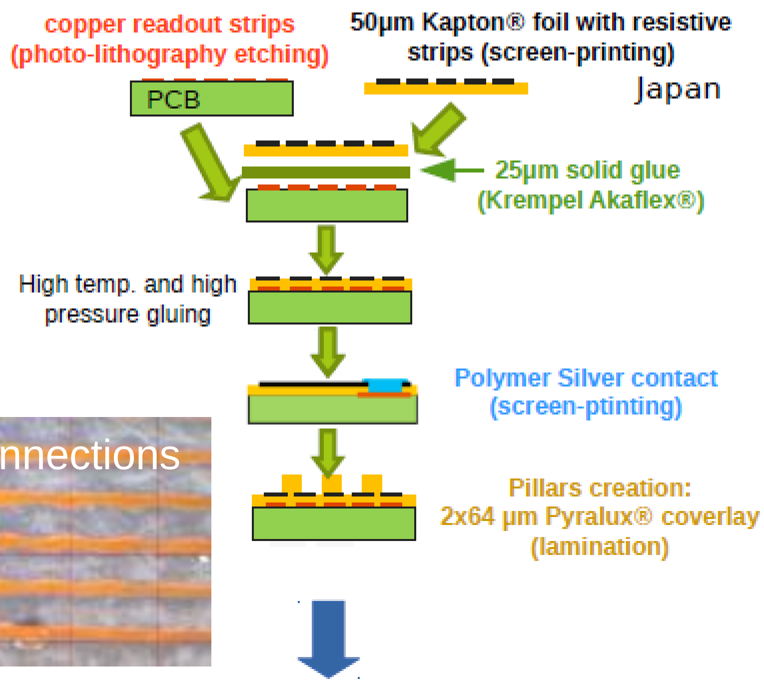
- Quaduplet separated in Drift and Readout Panels
- Two layer with inclined strips (± 1.5°)
- Mesh mechanically floating on support pillars
- Required strip alignment:
  - 30µm RMS in η, 80 µm RMS in z

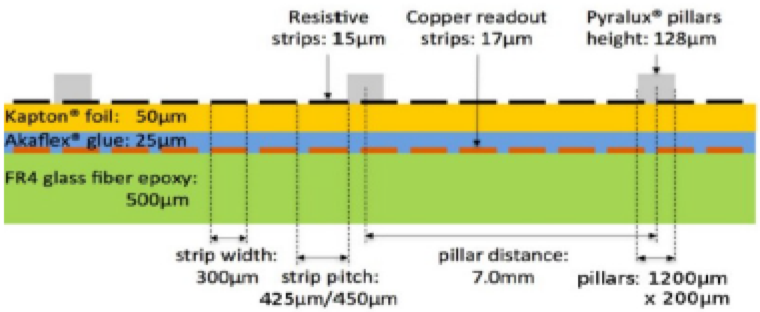


Readout Boards

- Etched copper strips on 0.5 mm FR4 base material
- Resistive Layer (10-20 MΩ/cm) as spark protection
  - Screen printed in Japan
  - Ladder structure to be insensitive to broken strips
- Rasmasks for alignment check
- Board production in industry
  - Scope with large quantity and size (45x30 to 45x220 cm^2)
  - Technology transfer from CERN to industry







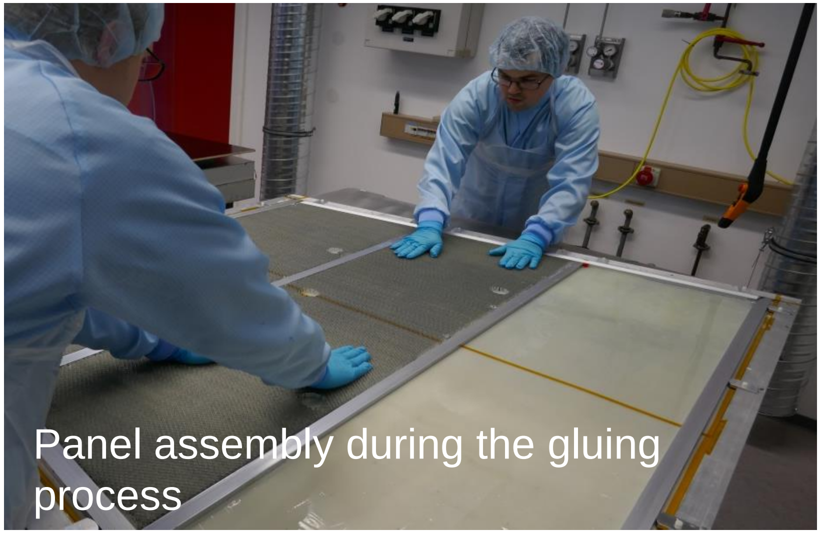
Panel Design

Panel composition

1. FR4 sheet (outer skin, drift board or readout board)
2. Glue (Araldite 2011, ~0.1 mm)
3. Aluminium honeycomb
4. Aluminium frame
5. Glue
6. FR4 sheet

Panel infrastructure

- Readout panel with cooling channel and mount for Frontend boards
- Drift panel with integrated gas manifold



Panel assembly during the gluing process

Construction principle

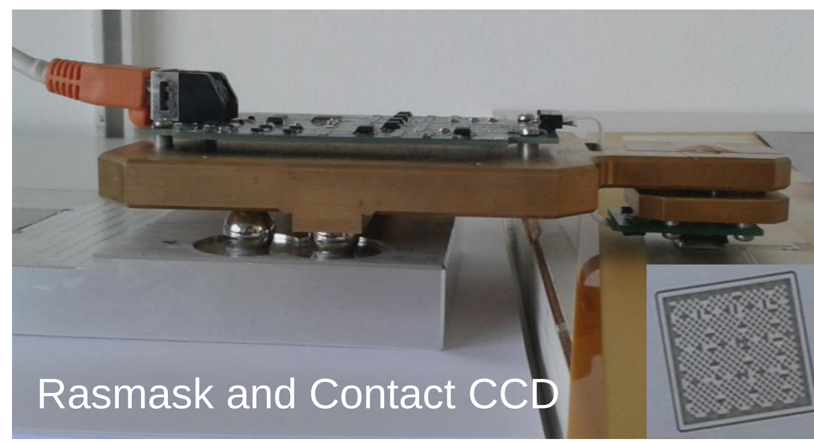
Mechanical Tolerances

- **Alignment** of readout boards on one panel
  - 60 µm maximum deviation
- **Relative alignment** between two readout panels in one quadruplet
  - 60 µm maximum deviation
- **Planarity** of panels
  - Less than 37 µm RMS

Construction Principle

- Construction on precision granite tables or „stiff-back“ (high planarity sandwich structure)
- Horizontal alignment with precision bushes and survailance with optical sensors (Rasmask, contact CCD)

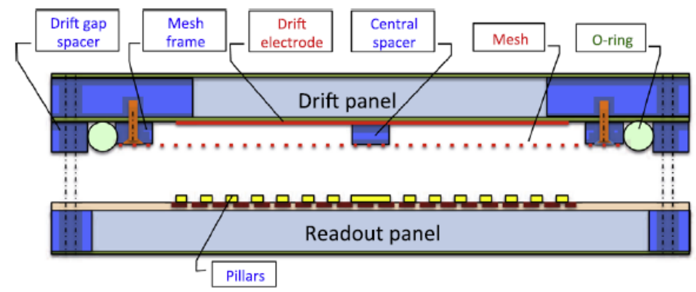
Two sides of a panel sucked to precision tables

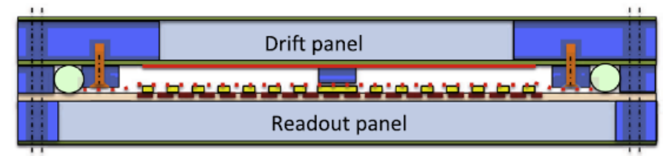


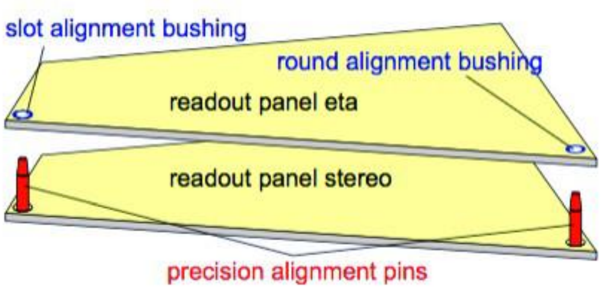
Rasmask and Contact CCD

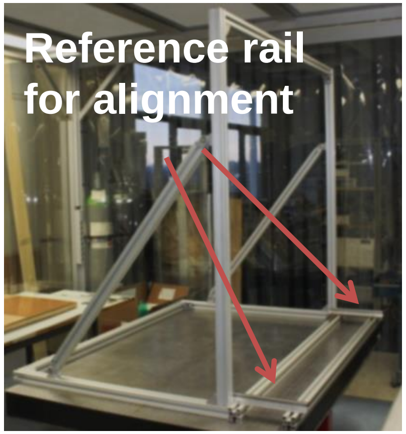
Quadruplet Assembly

- Vertical Assembly in clean room
- Cleaning is crucial, dust between mesh and readout panel leads to sparks
  - Wet cleaning, antistatic roller and compressed nitrogen
- Alignment with holes and pins in panels, or external reference on assembly stand









Quality Control

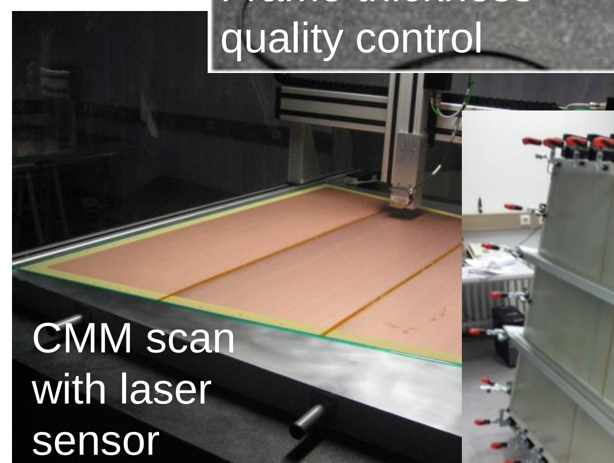
- Extensive Quality Control on raw material, glued panels and quadruplets

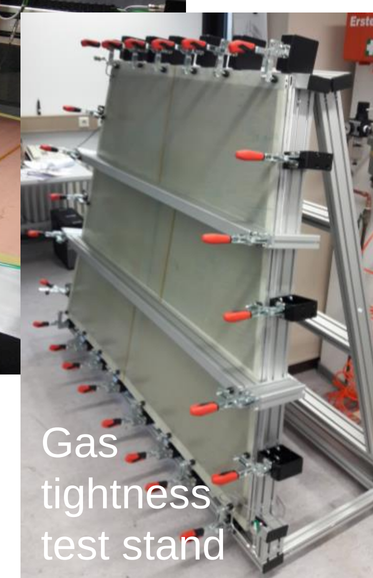
Raw Material:
- QC Lab for Readout Boards at CERN
- Frames, Honeycomb and Drift Board QC at construction site

Panels:
- Thickness, Surface Planarity, Gas tightness and electrical integrity

Quadruplet:
- Readout Board Alignment, Gas tightness and HV stability

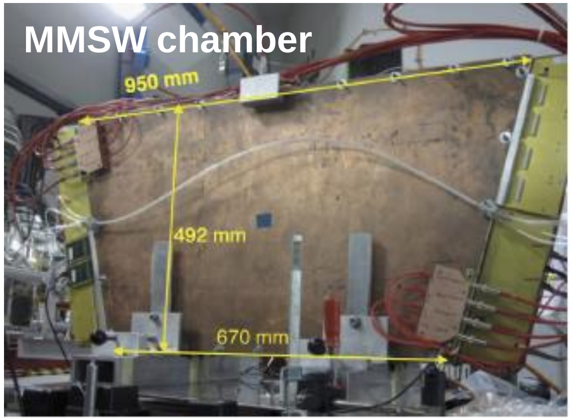

Frame thickness quality control


CMM scan with laser sensor


Gas tightness test stand

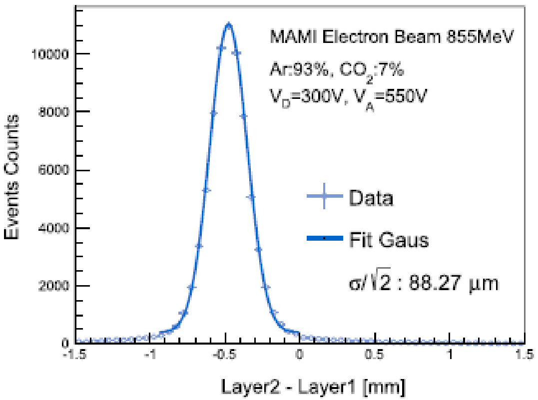
Small scale prototype (MMSW)

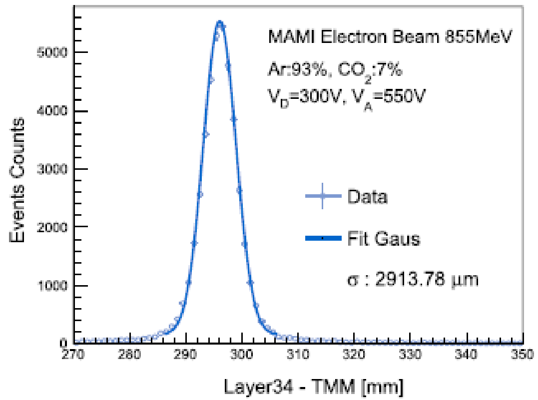
- Detector constructed in 2014 and extensively tested at CERN and JGU Mainz
- Same geometry, but smaller size than series detectors

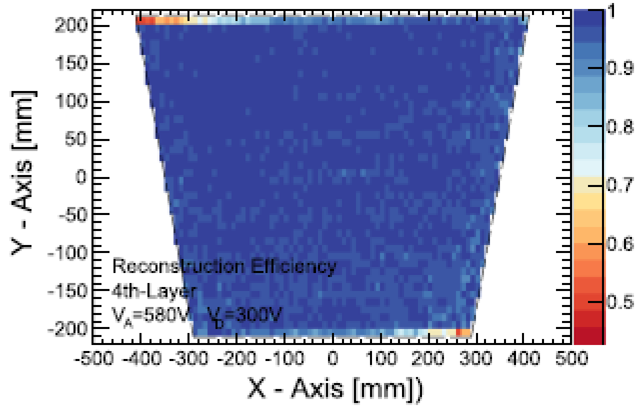


Perfomance:

- Resolution precision coordinate < 90µm
- Resolution second coordinate < 3 mm
- Efficiency > 95%

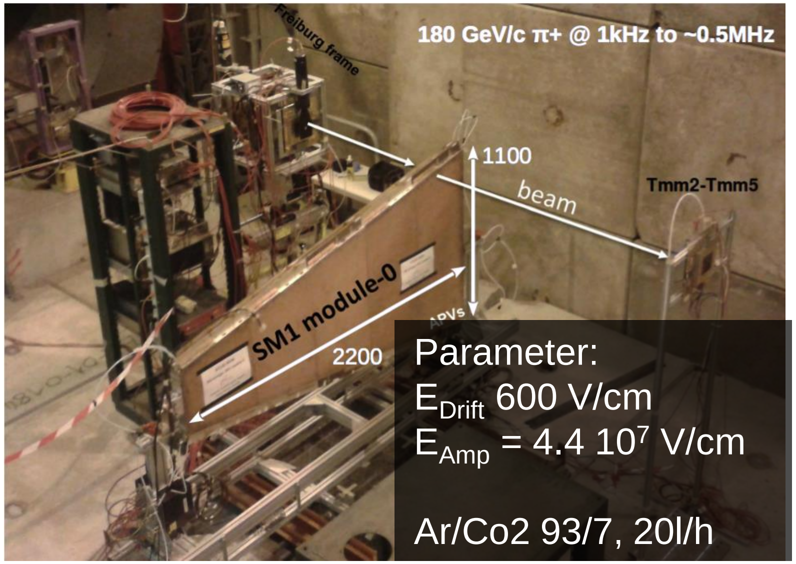


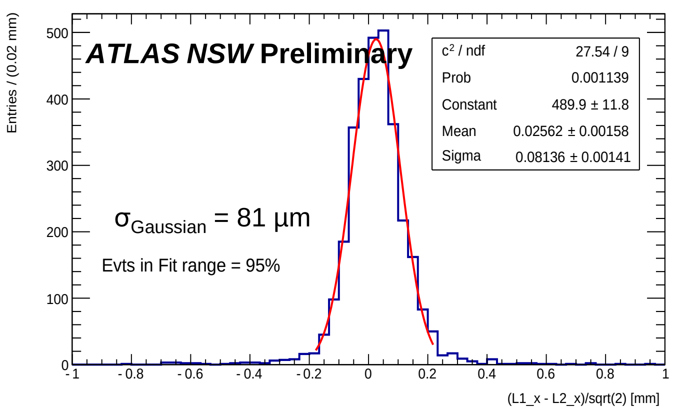


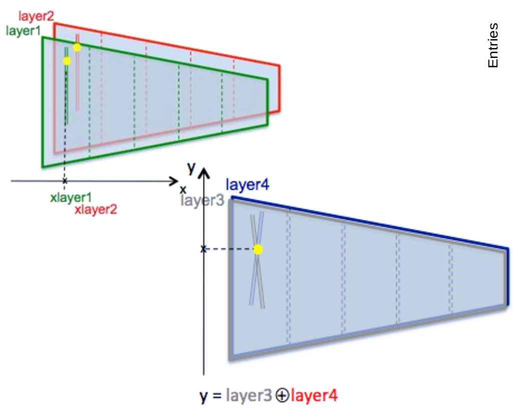


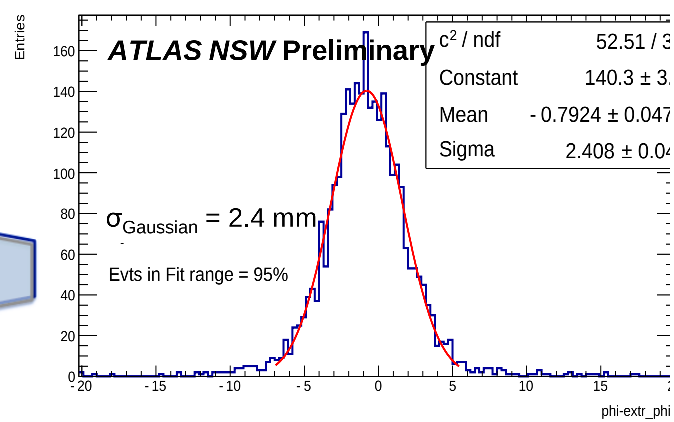
Full size prototype (SM1, Preliminary)

- First real size prototype (SM1) finished and tested in June 2016
- 180 GeV pion beam
- Scintillator trigger with beam spot trigger
- 5 small Micromegas reference chambers with 2D readout for tracking
- Readout via RD51 APV25 and SRS (not the final NSW electronics)





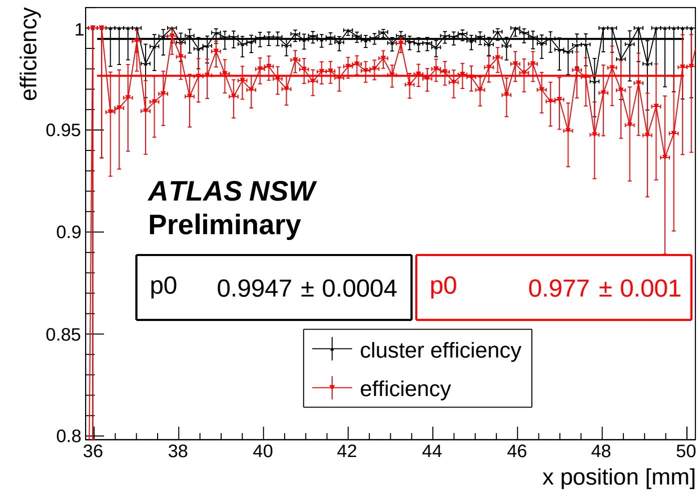




Full size prototype (SM1, Preliminary)

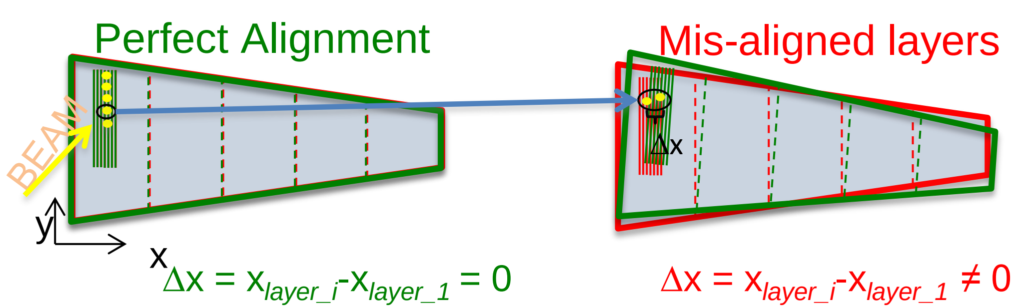
Efficiency:

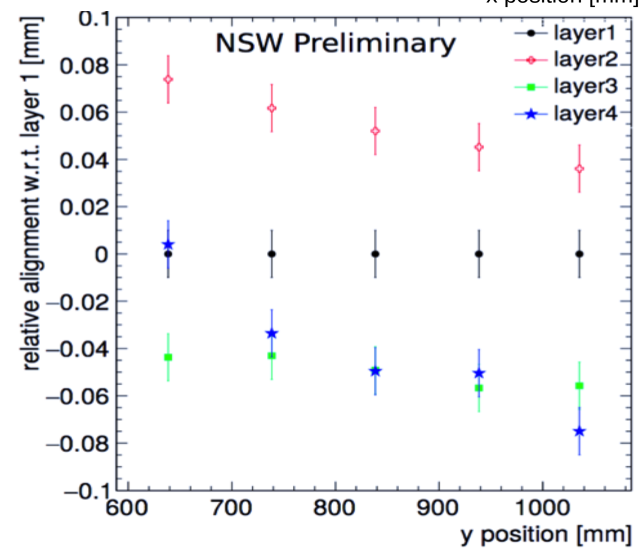
- Cluster efficiency
  - Any cluster for given reference track
- Track based effiency
  - Cluster in given distance to hit position of reference track
  - 2% inefficiency due to delta rays



Alignment

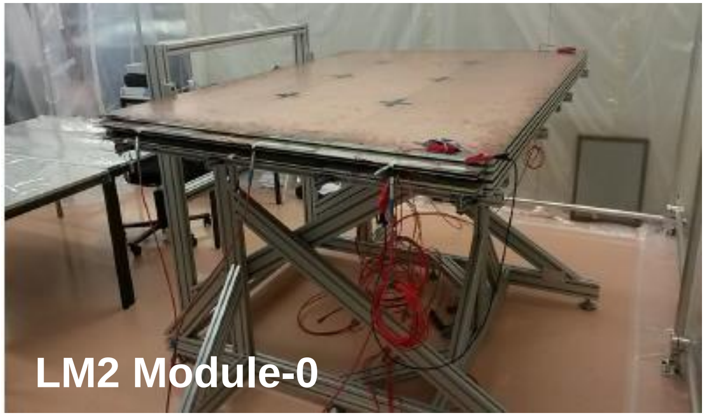
- Beam residual at different y postitions measured relative to layer 1
- Maximum deviation of 60 µm in mostly fulfilled

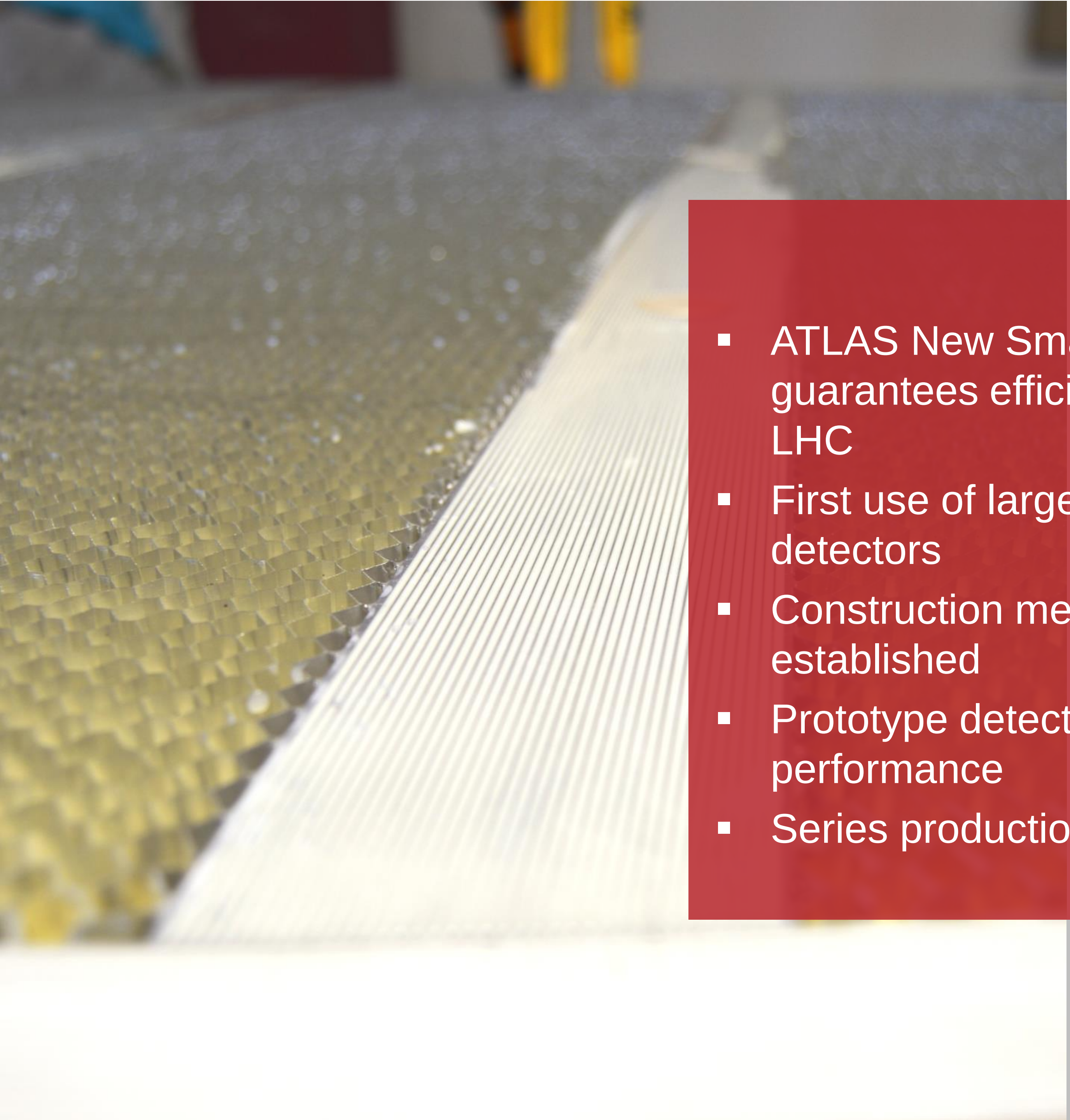




Outlook

- LM2 Module-0 finished in November 2016
- Design and construction principle validated with Module-0 quadruplets
- First batches of industrial parts received and quality approved
- Series production started in several construction sites
- Despite initial delays, the integration in ATLAS can be reached in the envisioned time frame





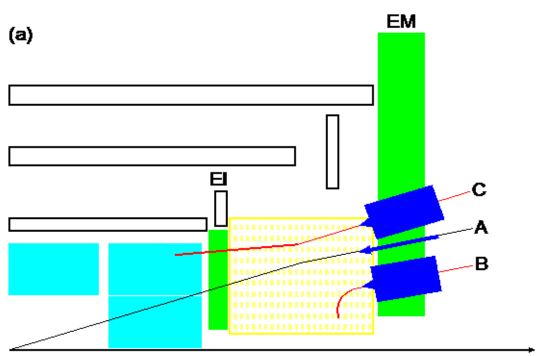
Summary

- ATLAS New Small Wheel Upgrade guarantees efficient operation for HL-LHC
- First use of large scale Micromegas detectors
- Construction methods are established
- Prototype detectors show expected performance
- Series production started

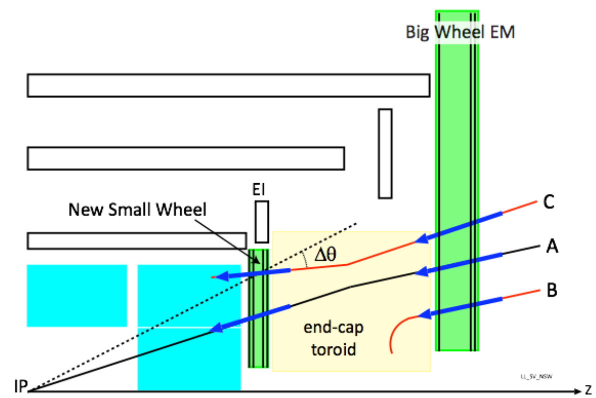
Backup

Trigger Improvements

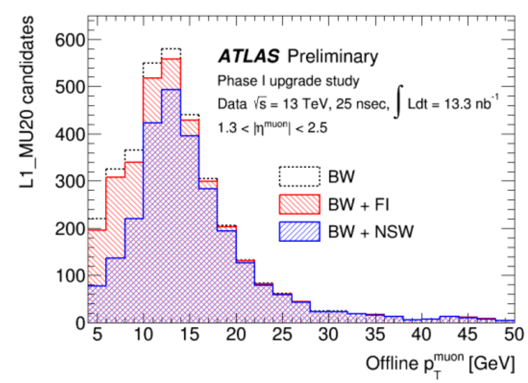
- At a 3 x 10^{34} $cm^{-2}s^{-1}$ L1MU20 (p_T>20 GeV) rate is estimated ~60 kHz, exceeding the available bandwidth (~15kHz for muons)
- Fake trigger rate for low p_T or multiple scattering events reduced by implementation of NSW
- Currently alread TGC Forward inner station included in Trigger, but larger improvement with NSW



Old situation



Situation with NSW

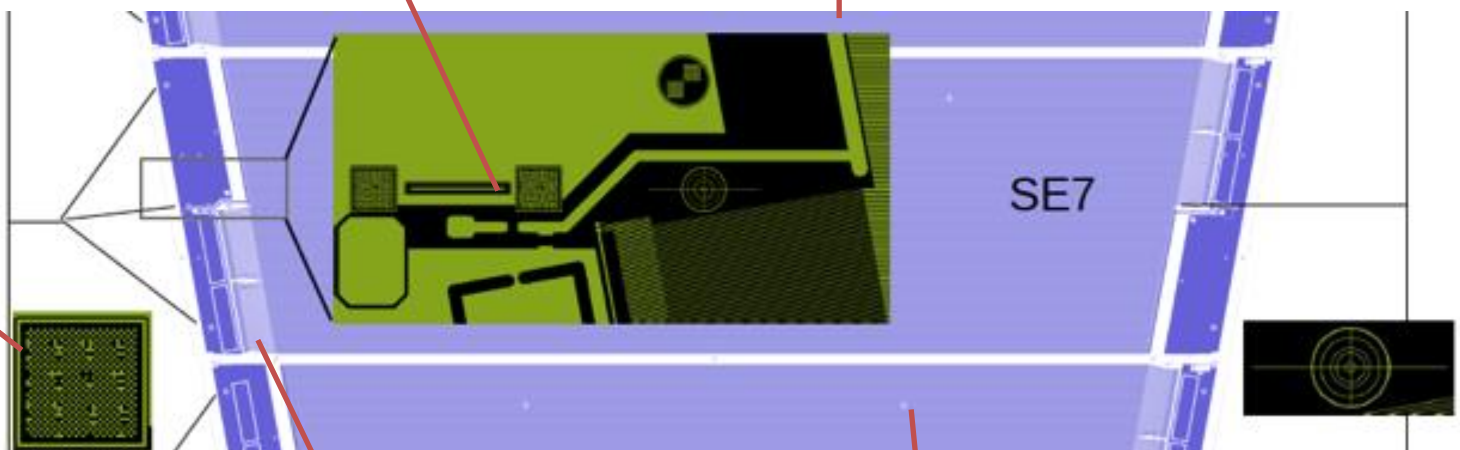


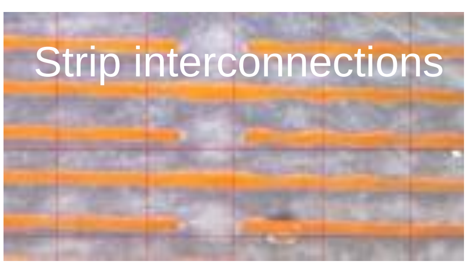
Readout Boards

HV contact for resistive layer

HV filter

Rasmask



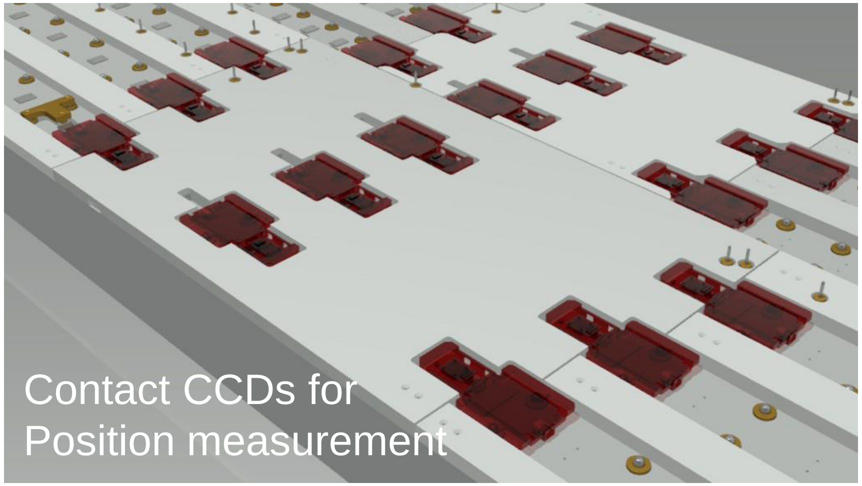


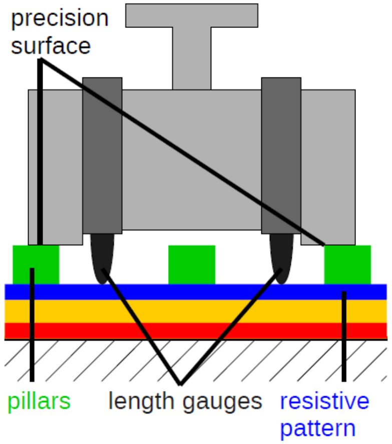
Footprint for
Zebra connector

Passivation for Interconnection

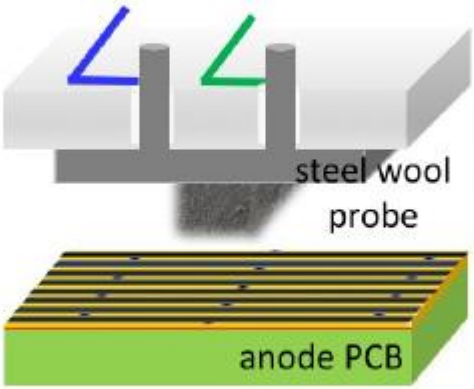
Readout Board Quality control

- Quality control lab at CERN
- Visual inspection
  - Top light and backlight for etching quality and alignment of the different layers
- Electrical tests
  - Insulation tests
  - Resistivity mapping
  - Strip capacity measurement
- Mechanical dimensions
  - Pillar height measurement
  - Rasmask table for board dimension





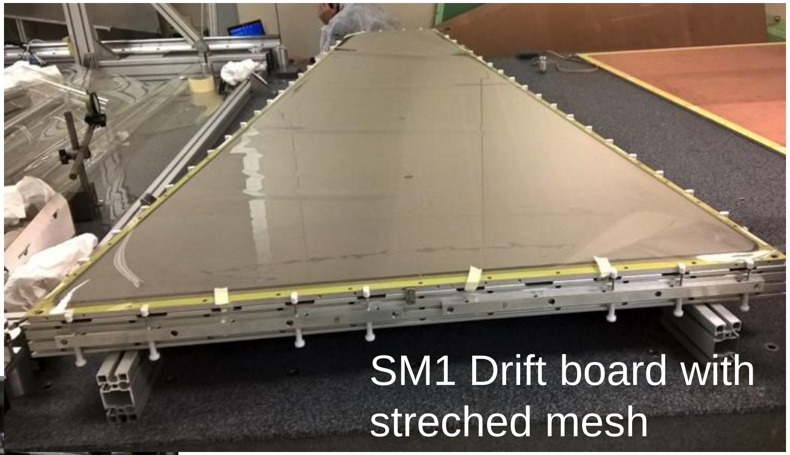
Pillar height check



Probe for resistivity test

Mesh stretching

- Pneumatic stretching clamps
- Tension ~12 N/cm^2
- Prestretching on transfer frame
- Gluing to frames mounted on drift panel

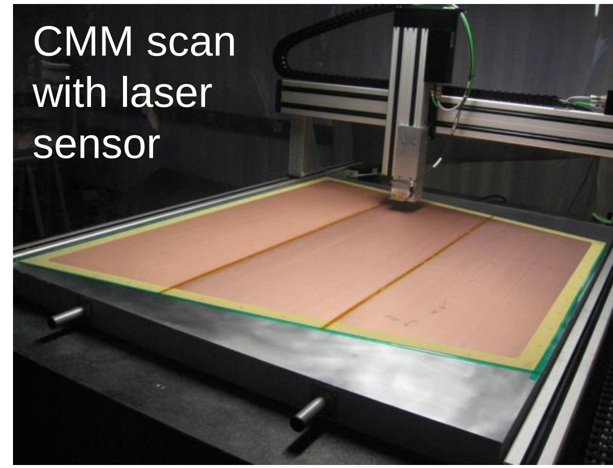


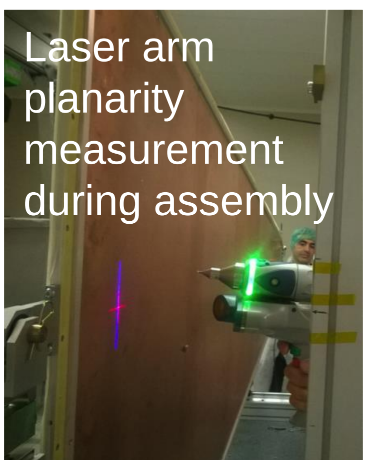
SM1 Drift board with streched mesh

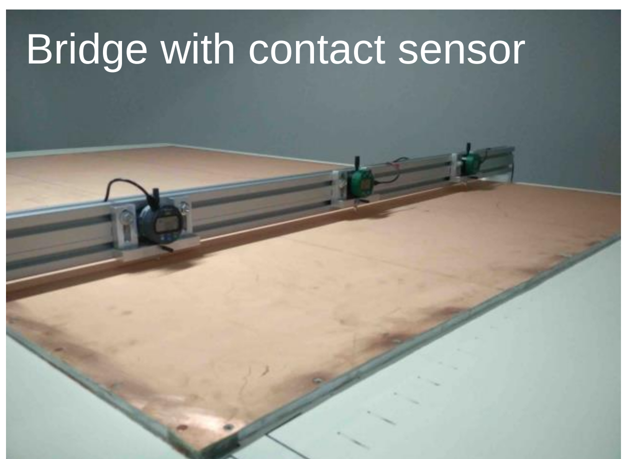
Mesh stretching frame

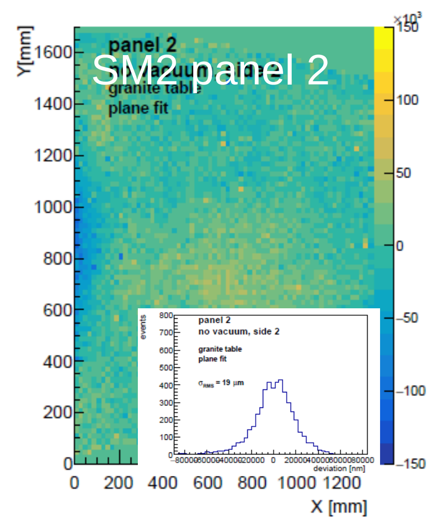
Planarity Measurements

- Scan with laser triangulation sensor on CMM
- Measurement with Laser arm
- Measurement with contact sensors on bridge









Strip Alignment Test

- Cosmic muon measurement with reference tracking system
  - Residuals from reference track at different positions allow a reconstruction of the misalignment
- Measurement of the Rasmask position on both sides of the finished panel or of all panels
  - Direct measurment of the misalignment