THE MICROMEGAS CONSTRUCTION PROJECT FOR THE ATLAS NEW SMALL WHEEL

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ON BEHALF OF THE ATLAS MUON COLLABORATION
THE ATLAS NEW SMALL WHEEL
Upgrade of the innermost end-cap region of the Muon Spectrometer

Upgrade required to operate the Muon Spectrometer at higher rates

Run III (starting 2021): 2 x design Luminosity
HL-LHC (starting 2026): 5-7 x design Luminosity

Motivations:
- Tracking:
  MDT/CSC performance will drop significantly at HL-LHC rates (expected: up to 15 kHz/cm²)
  → Install detectors which can withstand the rates

- Triggering:
  Current L1 Muon trigger relies mostly on Big Wheel:
  High fake rates on end-cap regions
  → Extend trigger coverage up to |\(\eta| = 2.7
  → More robust trigger to reduce the fake rates

Above 90% trigger fake rates!
THE NEW SMALL WHEEL CONFIGURATION

Two detector types:
- Micromegas (MM): primary tracking
- Strip TGC (sTGC): primary triggering

4 Micromegas (MM) q-plet types

NSW:
- 16 sectors per wheel
  - 8 small, 8 large
Sectors:
- Sandwich of 2 sTGC and 2 MM quadruplets

SM1/LM1 types: 5 PCBs
SM2/LM2 types: 3 PCBs

32 q-lets per type
**MICROMEGAS DETECTOR**

**MM detector characteristics:**
- Good spatial resolution $\sim$100 um independent of incident angle
- Good track separation: 0.4 mm RO granularity
- Rate capability above 15 kHz/cm$^2$

**MM detector requirements:**
- Provide online segments for triggering (1 mrad angular resolution)
- 15% resolution at 1 TeV

**Quadruplet Structure:**
- Two drift panel types
  - Single, Double
- Two readout panel types (back-back configuration)
  - Eta (strips perpendicular to $\eta$ coord.)
  - Stereo (strips inclined by 1.5°)

Gas used: Ar/CO$_2$ (93/7)

Embedding figures and diagrams related to the quadruplet structure and Q-plet construction scheme.
What is a readout panel made of?
- Readout PCBs on both panel sides
  - Etched Cu strips on 0.5 mm glass fiber (FR4) sheets
  - Resistive foils (produced in Japan) for spark reduction
  - Pyralux® pillars to maintain the amplification region height
- Internal structure: Honeycomb, Frames, Cooling bars

Readout panel construction procedure
- PCBs placed on granite table under vacuum
- Internal structure glued on PCBs
  - Stiffback/Vacuum bag method
DRIFT PANEL CONSTRUCTION AND Q-PLET ASSEMBLY

Assembled drift panel (Floating mesh):
- Stretched mesh
- Mesh positioned on transfer frame
- Stretch until reaching 9 N/cm tension (clamps)
- Mesh glued on transfer frame

- Bare drift panel
  - PCBs: Outer skin (FR4-only), Cathode plane (Cu clad)
  - Internal structure: Honeycomb Sheets, Frames

Q-plet assembly

Assembled q-plet
QA/QC AND TESTING

PCB QA/QC @ CERN

PCB/RO panel:
- Visual inspection
- Electrical tests
- Planarity mapping
- PCB/Layer Alignment (C-CCD/2-prong Rasfork)
- Gas leak

Mesh:
- Mesh tension

Drift:
- Planarity
- Electrical insulation
- Gas leak

Panel map (RMS 15-30 um)

Mesh tension

HV tests (air+Ar/CO₂)
- Gas tests
- Planarity
- Panel-panel alignment (4-prong Rasfork)
- Cosmic ray tests

HV instability issues
CLEANING PROCEDURES

Upon panel inspection under microscope residues of “ionic contamination” were observed

Cleaning procedure:
- Wash panel with tap water
- Brush with NGL/CIF (Drift&RO)
- Rinse with tap water & brush
- Spray with high pressure DI water
- Also spray inside drift gap pipes
- Dry panels in drying box
  - Warm air (up to 45°C)
  - Low filtered air flow
  - Dry panels for 2-3 days

Mesh polishing:
Can correct mesh imperfections: sandpaper polishing

After cleaning procedures were adopted by all sites, the HV levels greatly improved
“Ionic contamination” removed
HV STABILITY TESTS

HV test goal: Draw up to O(10 nA) currents in operating voltages

Vmax:
- 1000V in dry air (RH<10%)
- 590-610V in Ar+7%CO₂

Requirements:
- Low current ramp up
- Not long “conditioning”

Stable HV levels above operating point reached

LM2 preliminary results - Voltage vs. Current (nA)

Stability test at 600 V (1 day)
TEST BEAM RESULTS M0

Test Beams:
- SM1 M0: June 2016
- SM2 M0: August 2017 *(Next Talk!)*
- SM2 M1: June/July 2018
- Cosmic ray tests
- Aging tests in GIF++ @CERN
  - No aging after 10y HL-LHC equivalent dose

**Perpendicular track performance @570-580V**

Precision coordinate resolution: 81 um
2nd coordinate resolution: 2.4 mm
Efficiency: ~99%
Alignment: Within max deviation 80um
CONCLUSIONS

The NSW is going to replace the current wheels (MDT+CSC detectors) in order to run at higher rates

- Micromegas detectors: Primary Tracking
  
  Try to install both wheels during Phase I

During q-plet testing, HV instabilities were noticed

- Linked to cleaning standards -> Cleaning procedure defined
- HV results showed great improvement after cleaning

Q-plets were tested in test beams/cosmic stands

- Results within specifications
- New test beam will show the results after applying the cleaning procedure

- More details on Maximilian’s talk
BACK UP
MICROMEGAS REQUIREMENTS

Mechanical accuracies:
- Track accuracy:
  - \( \eta \) coordinate: 30 \( \mu \)m RMS
  - Z coordinate: 80 \( \mu \)m RMS
- Precision coordinate:
  - Strip alignment: 40 \( \mu \)m
  - Layer-layer alignment: 60 \( \mu \)m
  - Panel-panel alignment: 60 \( \mu \)m
- Panel planarity:
  - Max. deviation \( \pm 100 \) \( \mu \)m
  - Max. RMS 37 \( \mu \)m

<table>
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<th>Q-plet assembly</th>
<th>SM1</th>
<th>M1, M2, M3 done, M4 to do</th>
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<td>LM1</td>
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Mesh 250\text{pi} - \approx 30\mu m wires
Kapton\textregistered foil: 50\mu m
Akaflex\textregistered glue: 25\mu m
PCB 500\mu m

Strip pitch: 425\mu m / 450\mu m
Strip width: 300\mu m
Line shaped pillar dimensions: 200\mu m (|| strip) x 1000\mu m (\perp strip)

Pyralux\textregistered pillars height: 128\mu m
carbon resistive strips: <15\mu m
copper readout strips: 17\mu m

Not to scale
MICROMEGAS ASSEMBLY

Sector assembly

The assembly will take place above surface
- Sectors will be mounted on NJD wheel

The wheel will then be transported to ATLAS point 1 and moved down to the shaft

Wheel transportation