Design and Construction of Large Size Micromegas Chambers for the ATLAS Phase-I upgrade of the Muon Spectrometer

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The Atlas Muon Spectrometer

- The Small Wheel (Innermost Endcap Muon Station) is the region with highest background rates in the ATLAS Muon Spectrometer
- The current system is based on Cathode Strip Chambers (CSCs), Monitored Drift Tubes (MDTs) and TGC for particle tracking and triggering
- Located between endcap calorimeter and endcap toroid

New Small Wheel Motivations

TRIGGER

Foreseen for Phase-I upgrade
in 2018-19

New Small Wheel allows fake tracks
filtering by reconstruction of track direction

→ Extension of LI trigger coverage to
 $\eta = 2.6$ with angular resolution of 1 mrad

TRACKING

At $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ (luminosity of HL-LHC) the maximum
expected rate in the NSW is about
15 kHz/cm² (>1.5 MHz/MDT_tube) (incl. a safety factor of 2)

MDT: Efficiency drops significantly (dead time) and resolution is
degraded (gain loss – space charge)

CSC: Limit reached even earlier (only 4 detection layers)

Detector choice

Combination of **sTGC** and **Micromegas (MM)** multiplets: **4+4+4+4** detector planes

sTGC (small strip TGC)
primary trigger detector

- Bunch iD with good timing resolution
- Good online space resolution for NSW track vector with < 1 mrad angle resolution

Micromegas (MM)
primary precision tracker

- Good Space resolution $\sim 100 \mu\text{m}$, independent of angle
- Good track separation (0.45 mm readout granularity)
- Provide also online segments for trigger

- Conversion gap: 5 mm
- Amplification gap: 128 μm
- Mesh supported by pillars
- Strip pitch ~ 0.45 mm

- Common front-end ASIC: VMM under development at BNL.
- Work together to make a robust detector for the high rate region of very limited access
- The NSW will operate from 2019 until 2032 → **ROBUSTNESS** and **REDUNDANCY**

MM specifications

1200 m ²	Large area detector
Rate up to 15 kHz/cm ²	High rate capability
n, gammas, hadrons background	No aging effect observed
Tracking precision independant from incident angle	Position resolution ~100μm (+μTPC mode)
Trigger capability	Angular resolution (~1 mrad for a multilayer)

Resistive anode (to solve the discharge issue)

voltage drop due to sparking

Neutron flux: 10⁶ Hz/cm²

Mesh attached to the drift panel (large area detectors) and grounded

Position resolution obtained in test beam for different incident angles (impact angle in NSW between 8 and 32°) → see M.Vanadia's talk

The Layout of the NSW

16 Sectors:
8 Small + 8 Large

Large sector

Non-IP side:
Large sectors,
covering area
from
 $r = 92$ to 465 cm

Small sector

IP side:
Small sectors,
covering area
from
 $r = 90$ to 445 cm

Sectors:
sTGC and MM “wedges” + central spacer frame

- 2 Multilayers per sector
- Each ML: 4 MM and 4 sTGC planes

New Small Wheel Sector
and its components

Wedges and Modules

Cross-section view of a module

Construction sites:

- SM1 → Italy/INFN
- SM2 → Germany
- LM1 → France/Saclay
- LM2 → Russia/Dubna – Greece/Thessaloniki (+ Cern)

Inner module: 5 boards
Outer module: 3 boards

Mechanical precision

Requirements for a μ momentum resolution of 15% @ 1 TeV in Atlas

Precision of strip position in Eta (precision coordinate)	30 μm r.m.s.
Precision of strip position in Z (perpendicular to the detection plane)	80 μm r.m.s.

Eta precision

Board positioning

RO panel: side/side alignment

Modules on spacer frame

Z precision

Panel thickness and planarity

Precision of assembly frames

Gas gap height

Thermo-mechanical deformations under control
Monitored and corrected by alignment system

Readout boards

Ladder pattern

PCB + readout strips

50 μ m Kapton
+ resistive strips

2 techniques: sputtering or screen printing

25 μ m solid Glue

High temp Gluing

Pillars creation

Typical resistivity ~ 10-20 M Ω /cm (~300-600 k Ω /□)

10 mm

Zebra footprint

Precision target

512 readout strips per
side
for Zebra connection
(no connector soldered
on the boards)

Panel construction

Board positioning (strip alignment in one side)

- Precision hole in readout board (target)
- Precision washer aligned using rasmasks
- Circle and slot

Positioning precision
10-15 μm

Stiffback method Planarity: min/max 110 μm

(panel thickness/planarity and side/side alignment)

- Vacuum suction of the first boards on granite table (flatness of 1st side)
- Glue distribution
- Positioning of frames, inserts, honeycomb, etc. + curing
- Vacuum suction of first half-panel on the stiffback (flatness)
- Vacuum suction of the second boards on granite table (flatness of 2nd side) + glue
- Positioning of 1st side (stiffback on precision shims) on 2nd side (side-to-side alignment + panel thickness)

Module assembly

- Alignment pin/insert
 - Readout panels alignment
 - Dedicated tool
 - Fixation to spacer frame
- Interconnections
 - Drift gap height
 - Control and monitor deformations with alignment platforms
 - Module stiffness
 - Minimize deformation of outer drift panels due to gas pressure
- Spacer frame
 - module/module alignment

Simulation of a half-panel deformation

LM2 → 7 interconnections

100μm deformation for 2 mbar of gas overpressure

Mechanical prototype

Materials

Aluminum frames

FR4 sheets

Honeycomb (aluminum, nomex)

Each module is heated and deformations are measured on a CMM

B: Static Structural
Directional Deformation_PCB
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1
13/10/2014 10:41

0.025 Max
0.021
0.017
0.013
0.0093
0.0053
0.0012
-0.0028
-0.0069
-0.011 Min

Thermo-mechanical simulations

Measurements

Max deviation
= 55 μ m

Max deviation
= 59 μ m

Max. deviation
= 38 μ m

Max. deviation
= 37 μ m

Alignment system

- Reference alignment bars are fixed and precisely positioned on the NSW structure (taking into account other bars, Big Wheel and Outer wheel)
- Camera + lense define precise alignment lines
- Source platform glued on external drift panels (close to frame or interconnections) using a precise jig and alignment pin for reference
- Measurement of position and global deformation of the modules
- Combined for MM and sTGC

Functional prototypes and mockups

Micromegas SW

2 identical detectors: one for test beams and one installed in Atlas for RUN2

1.2x0.5 m² (upper half of CSC slot)
Configuration close to final module

Operational Multi-layer

X-Y Quadruplet

Tests of alignment with coded masks

Mockup for services integration

2 boards

3 interconnections

Mechanical prototype

Interconnection fixation
Quadruplet assembly

Conclusion

- First time Micromegas detectors will be used on a very large scale to built large area chambers in a particle physics experiment
- The ATLAS NSW Upgrade will enable the Muon Spectrometer to retain its excellent performance
- Design and construction methods have been refined and tested to achieve the Atlas requirements:
 - Alignement of strip and panels
 - Control of deformation
 - Assembly methods
 - Tooling design
- Module-0 construction will start soon
 - First module-0 should be ready in july
 - Second module-0 is foreseen for end 2015
- Transition to series production end 2015/beg 2016
- End of production mid 2017 (2 modules/month/sites)