An overview of the ATLAS NSW Micromegas construction project at Aristotle University

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Outline

Introduction
LHC, HL-LHC, ATLAS detector

ATLAS
detector’s overview and Muon Spectrometer

The New Small Wheel project
motivation
NSW basic description
Micromegas technology

Construction
mechanical challenges
methods adopted
tooling and QA/QC

Summary
Several improvements since the beg. of LHC functioning, and the CERN accelerators chain.
LHC and HL-LHC planning

**LHC / HL-LHC Plan**

**LHC**
- **Run 1**
  - LS1: splice consolidation button collimators R2E project
  - 7 TeV
  - 2011
- **Run 2**
  - EYETS: experiment beam pipes
  - 8 TeV
  - 2012
- **Run 3**
  - LS2: INJECTOR UPGRADE
    - TDIS absorber
    - 11T dipole & collimator
    - Civil Eng. P1-P5
    - 13 TeV
  - 2013-2016
  - ATLAS - CMS upgrade phase 1
  - ALICE - LHCb upgrade
  - 2017-2020
- **Run 4 - 5...**
  - LS3: HL-LHC installation
    - 14 TeV
    - 2021-2026
  - ATLAS - CMS upgrade phase 2
    - 2027-2030
  - 5 to 7 x nominal luminosity

**FP7 Hi-Lumi DESIGN STUDY**
- PDR PREPARATION
  - 2010-2011
- ASSESS & TDR
  - 2012-2015
- MAIN ACCELERATOR COMPONENTS
  - CONSTRUCTION AND TEST
    - 2016-2019
  - INSTALLATION
    - 2020-2026
- PHYSICS
  - 2027-2040

**Integrated luminosity**
- 30 fb⁻¹
- 150 fb⁻¹
- 300 fb⁻¹
- 3000 fb⁻¹

**Nominal luminosity**
- 75% nominal luminosity
- 2 x nom. luminosity
- 2.5 x nominal luminosity
- Radiation damage

**Energy**
- 7 TeV
- 8 TeV

**HL-LHC PROJECT**
ATLAS detector

Three Parts
- Inner detector
- Calorimeter (e/m, h/d)
- Muon Spectrometer

Magnet systems
- Toroid: 0.4T
- Solenoid: 2T
ATLAS Muon spectrometer
ATLAS Muon spectrometer

SW: \(1.3 < |\eta| < 2.7\)

acceptance SW 
Eta \( \sim 1.3 - 2.7\)
(~50%)

muon track

SW position and future NSW
New Small Wheels will replace the present Innermost end-cap station of the Muon Spectrometer
Present end-cap muon L1 trigger **saturated by fake muons** (~5% are real >20GeV muon).

L1 trigger relies only on Big Wheel (fake triggers)
Cannot distinguish cases:
- A (real high-\(p_T\) track)
- B (low-\(p_T\) particle created in toroid)
- C (multiple scattering)

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

Extension of L1 trigger coverage to \(\eta=2.4\) with angular resolution of 1 mrad

**NSW should participate to the trigger decision.**
NSW Motivation II

MDT: Efficiency drops significantly (dead time) and resolution is degraded (gain loss - space charge)
CSC: Limit reached even earlier (only 4 detection layers)

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

- 2 detector technologies for NSW chambers: small strip Thin Gap Chambers (sTGC) and MicroMegas (MM)
- 4 + 4 + 4 + 4 detection planes
NSW configuration II

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

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

- 8 Small + 8 Large
- 10 m

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

Sectors: sTGC and MM “wedges” + central spacer frame.
NSW detector technologies

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

sTGC (small strip TGC)
primary trigger detector

- Good timing resolution
- Good online space resolution for NSW with $<1$ mrad angle resolution

Micromegas (MM)
primary precision tracker

- Good Spatial resolution $\sim 100 \, \mu \text{m}$
- Good track separation (0.4 mm readout granularity)
- Provide also online segments for trigger

sTGC

MicroMegas
Micromegas

NSW MM layout

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total active area</td>
<td>1200 m²</td>
</tr>
<tr>
<td>High rate capability</td>
<td>Up to 15 kHz/cm² in ATLAS</td>
</tr>
<tr>
<td>Ageing</td>
<td>N, gammas, hadrons background</td>
</tr>
<tr>
<td>Tracking precision independent from incident angle</td>
<td>Position resolution ~100μm (+μTPC mode)</td>
</tr>
<tr>
<td>Trigger capability</td>
<td>Angular resolution (~1 mrad for a multilayer)</td>
</tr>
<tr>
<td></td>
<td>Time resolution ~ few ns</td>
</tr>
</tbody>
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Drift gap of ~5mm

Strip pitch 450 μm
NSW modules construction: a shared effort

LM1 – France, Saclay

SM2 – Germany

SM1 – Italy

LM2 – Greece, Russia

Micromegas Wedge Segmentation

Small sector modules

- SM2
- SM1

Large sector modules

- LM2
- LM1

Radial segmentation in 2 chambers per wedge

Construction Sites:
- SM1: Italy/INFN (Pavia, Rome1, Rome3, Frascati, Lecce, Cosenza, Napoli)
- SM2: Germany – Munich, Freiburg, Wurzburg, Mainz
- LM1: Saclay
- LM2: Thessaloniki + Dubna (+ CERN)

Radial segmentation of R/O PCB per plane

- SM1 and LM1: 5 PCBs
- SM2 and LM2: 3 PCBs
NSW mechanical precision requirements

Requirements for a $\mu$ momentum resolution of 15% @ 1TeV in Atlas

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision of strip position in Eta (precision coordinate)</td>
<td>30 $\mu$m r.m.s.</td>
</tr>
<tr>
<td>Precision of strip position in Z (perpendicular to the detection plane)</td>
<td>80 $\mu$m r.m.s.</td>
</tr>
</tbody>
</table>
Micromegas wedge and module
The goals and requirements impose specific mechanical precision on the detectors

NSW modules: very large surface detectors

Challenging engineering solutions to be found and applied (integrate HV, elx connection, cooling, support, screwing, gas in and out etc.)

- How do we build the drift and readout “planes”?
- How do we align the panels?
- How do we restrict deformation due to gas pressure?
- How the mesh is stretched and positioned?
- HV related cleanliness issues?
- Pillars height, diameter and spacing role on HV performance?
- Is it robust enough?
- Costs?
NSW single panel construction basics

- Panel is a sandwich of two skins glued on a stiff plane without mechanical constraints
- It consists of two PCBs (500μm) with aluminum made honeycomb and frame in between

- Super – flat surfaces are required as reference planes
- Granite + Stiff – back or Double Vacuum tables methods applied
- Single or dual step processes

Glass fibre skin | Aluminium frame
---|---
Aluminium honeycomb | Glass fibre skin
0.25mm gap for glue

stiff – back  |  vacuum tables
NSW drift panels construction @ AUTh

KEDEK center

Facilities layout

Clean room & rooms for complementary works
LM2 Drift panel construction clip

The LM2 Micromegas Project
for the ATLAS New Small Wheel Upgrade
construction of particle detectors
Drift panel completion actions

- Sealing
- Mesh frame gluing
- Gas distribution pipes - Soldering
- Cutting and cleaning
- Interconnection spacers gluing
Mesh stretching and gluing

- Custom made stretching device
- Mesh transfer frames
- Passivation process and punching
- Washing and cleaning
- Final gluing on drift panel
QA/QC measurements I

Panel thickness and planarity control

Mesh frame/interconnections height measurements and panel edge control
QA/QC measurements II

Mesh tension control (specs: 7 - 10N/cm)

Gas leak measurement: pressure drop and/or mass flow
### LM2 Quality Assessment Just Before Shipment

#### Dispatched Items

- Number of tripes in transport box: 0
- Number of central panels: 0
- Number of external panels: 0

**Passage: Oct 2019**

#### Components Contributing to Global MM Quadruplet Quality

<table>
<thead>
<tr>
<th>Side</th>
<th>Drift Label</th>
<th>Remarks/Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Side</td>
<td></td>
<td></td>
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<tr>
<td>Mask (Step 1)</td>
<td></td>
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</tbody>
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**1. Check Points**

- Mesh Tension: measured flat on table (or on shims for interconnections - flatness;
- quality of hole alignment, mesh frame - O-ring groove; quick control of mesh frame;
- Mesh Quality: Thorough visual inspection to trace marks;
- Deformation: Trace deformation spots/lines;
- HV connectors: control placement and pin;
- Gas lines: check and block using Scotch tape;
- Compression bars: proper mounting of all components;
- Barcodes: mount stickers on side panel frames according.

**AVG: 7.9 N/cm Uniformity: 0.06**

- OK
- Small scratch was sanded with 2500 sandpaper.
- Small mark near interconnection #1 towards cathode (not sanded).
- OK
- Checked mounting and HV pin orientation.
- Checked and scotched using no tape to protect.
- #2 was hard to screw in & #4 & #6 long pins were not used due to misalignment of the small holes.
- Stickers glued on the side frames of panel.

**2. DB stored information**

- Thickness
- Planarity
- Mesh Frame/Interconnections Height
- Gas Tightness
- HV performance

**3. Additional Information/Comments**

- If yes, please write below.

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**Map:**
- Thessaloniki
- Geneve, CERN
- Dubna

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**ATLAS – AUTh group**

**ICNFP2019 – Crete 26/08/2019**
LM2 drift panels production status

‘Bare’
- External 70
- Central 35
  total 105

Completed
- External 56
- Central 24
  total 80

All panels constructed
Mesh gluing on few panels pending
TwinAX cables for NSW

Connection between FEC:
MMFE8-ADDC, MMFE8-L1DDC, ADDC-L1DC
Twinax, from 3M (ref.: SL8801/12) Thickness ~1.8 mm

Issue
Due to the way they are manufactured they can loose their insulation where they are bent.

Solution
wrap the TwinAx cables in Kapton

5400 cables, 3m length delivered to AUTH for ‘kaptonization’

Work finished
Team of more than 10: professor(s), postdoctoral, graduate and undergraduate students, engineer(s), technician(s)
NSW project @ AUTH: multiple benefits

• A new lab was established and equipped with dedicated tooling
• Proven ability to construct and technical competencies acquired for detectors R&D
• Six Qualification tasks fulfilled
• 11 persons trained and worked for ~ 2 years to this demanding project
  2 postDocs, 4 PhD students, 2 Physicists, 1 engineer, 2 technicians
  2 student internships (from Ioannina and Aegean Univ.)
• 3 Diploma thesis, 1 Master thesis
• Continuous collaboration with Greek industry/private sector
• Enhancement of collaborations within the NSW community
• AUTH/KEDEK public awareness and visibility
Summary

The New Small Wheel is the largest ATLAS upgrade project for LHC Long Shutdown 2

Challenging project:
   Unprecedented use of Micromegas detector
   Complex mechanics
   Tight schedule

Shared effort between all construction sites:
SM1: Italy/INFN
SM2: Germany
LM1: France/Saclay
LM2: Russia/Dubna – Greece/Thessaloniki (+CERN)

The construction of the LM2 drift panels is coming successfully to the end
Acknowledgements

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Thank you!