Construction and Performance of the sTGC and MicroMegs chambers for ATLAS NSW Upgrade

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Outline

- Motivation for ATLAS New Small Wheel upgrade
- Detector technologies and New Small Wheel layout
- sTGC:
 - Detector structure and construction
 - Module-0 construction
 - Test beam results at FermiLab and CERN
- MicroMegas:
 - MicroMegas design and challenges
 - Module-0 construction
 - Test beam results at CERN

Motivation

The instantaneous luminosity of the Large Hadron Collider at CERN will be increased up to a factor of five to seven with respect to the design value by undergoing an extensive upgrade program over the coming decade.

Add triggering capabilities to full New Small Wheel area and make it cope with beyond design luminosity rates, up to 15 kHz/cm^2

Will replace the present Small Wheel, not designed to exceed $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

Will operate up to HL-LHC luminosity (Phase-2)

Need fast, precise, and high radiation resistant detectors

New Small Wheel detector technologies

Combination of **sTGC** and **MicroMegas** detector planes

Small Strips TGC (sTGC)

primary trigger detector

- Bunch ID with good timing resolution
- Online track vector
with <1 mrad angle resolution
- pads: region of interest
- strips: track info (strip pitch 3.2 mm)
- wire groups: coarse azimuthal coordinate

MicroMegas (MM)

primary precision tracker

- Good Spatial resolution $< 100 \mu\text{m}$
- Good track separation (0.4 mm readout granularity)
- Resistive anode strips $\rightarrow$ suppress discharge influence on efficiency
- Provide also online segments for trigger

- Common front-end ASIC: VMM second prototype under tests

New Small Wheel layout

Each NSW has 16 sectors
8 Large + 8 Small

Each Sector is a sandwich of
sTGC and MM quadruplets

sTGC construction sites

sTGC structure

- The basic sTGC structure consists of a grid of gold-plated tungsten wires sandwiched between two resistive cathode planes at a distance of 1.4mm from the wire plane
- The precision cathode plane has strips with a 3.2mm pitch for precision readout relative to a precision brass insert outside the chamber, and the cathode plane on the other side has the pads for triggering
- The gap is provided using $1.4\text{mm} \pm 20\mu\text{m}$ precision frames glued to the cathode boards

sTGC structure

- Pad readout provide fast pre-trigger to determine the strip to be read
- Precision strips for precision muon tracking reconstruction at level of $100\mu\text{m}$
- High efficiency at high background rate

sTGC working conditions

- sTGC chambers are working on n-Pentane/CO₂ (45% / 55%) gas mixture
- This mixture has three main properties:
 - High gain
 - Quenching of photons
 - Clean the chamber
- Nominal operational voltage – 2800V
- The cathode plane is made by the resistive layer of graphite with a surface resistivity of $\sim 100\text{k}\Omega/\square$ ($200\text{k}\Omega/\square$ for outer chambers)
- All quadruplets have trapezoidal shapes with surface area up to 2m^2

Module-0s

Gain uniformity test

Gain uniformity test has been performed using Mini-Xray gun by the scanning of whole surface of the chamber

Measurements

Position resolution measurement at Fermilab

- Position resolution was measured using 32 GeV pion beam at Fermilab
- The results shown a position resolution to be better than $\pm 50\mu\text{m}$ comparing to an external pixel telescope for different position scan in X-Y (A,B,C,D,E,F) in all four layers

MicroMegas construction sites

MicroMegas construction: Read-out boards and resistive strips

- Resistive strips on kapton by screen-printing
- “Ladder pattern” (connections every 20 mm):
 - Homogeneous resistivity (independent from distance)
 - Insensitivity to broken lines

Typical resistivity:

~ 10-20 MΩ/cm
(~800 kΩ/□)

- Board dimensions:
from 45x30 up to 45x220 cm²
- 1022 strips/boards
- Readout strips pitch:
425 or 450 mm
- Pillars height: 128 µm
- Several types of alignment masks

MicroMegas construction: read-out panel

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Double Side Readout panel built with 5+5 Readout boards – strips alignment $< 40 \mu\text{m}$

Planarity Requirements: $< 37 \mu\text{m}$ RMS

Measured:

- Eta panel $22 \mu\text{m}$
- Stereo panel $26 \mu\text{m}$

Sandwich: 5 PCB boards on side1 – Honeycomb and structural Frames – 5 PCB boards on side2

- Readout boards positioning
 - Mechanical: Precision pin-holes
- Stiff-back technique:
first layer on the granite table – second layer on a separate stiff-back

MicroMegas construction: drift panel

Similar construction Concept as for the readout panels

- Same planarity requirements as RO panels
- Mesh tension ~ 10 N/cm – uniformity 10%

SM1 Module-0 quadruplet assembly

Crucial: Alignment of the two readout panels at < 60 mm precision

Vertical Assembly

Alignment of eta Vs Stereo Readout Panel ensured by alignment pins

Laser arm planarity measurements during assembly

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- Assembly completed in mid-May, then shipped to CERN for Test-Beam early June
→ superb achievement !

Test beam results at CERN

- 180 GeV/c pion beam
- Scintillators trigger
- Beam spot+trigger $\sim 1 \times 1 \text{ cm}^2$
- 5 small MicroMegas chambers with x-y readout (Tmm) used as reference
- SM1 Module-0 on a x-y scanning table
- Ar:CO₂ gas mixture (93:7)
- APV25+SRS readout (from RD51) [NOT FINAL NSW electronics]

SM1 quadruplet:

- 425 μm strip pitch
- L1 & L2 vertical strips (eta),
- L3 & L4 $\pm 1.5^\circ$ w.r.t. vertical axis (stereo)

Test beam results at CERN

- Perpendicular incident beam on PCB5 = longest strips
- Nominal High voltage settings:
 $HV_ampl = 570 \text{ V}$ ($E = 44 \text{ kV/cm}$)
 $HV_drift = 300 \text{ V}$ ($E = 600 \text{ V/cm}$)
- Ar/CO₂ 93/7 @ 20 l/hour

Preliminary result: Spatial Resolution of the precision coordinate

ATLAS NSW Preliminary

Preliminary result: Spatial Resolution of the second coordinate.

ATLAS NSW Preliminary

Test beam results at CERN

Cluster efficiency Vs Amplification HV for Layer1

- Cluster efficiency: presence of a cluster for any reference track
- Track-based efficiency: one cluster within given distance from the reference track impact on SM1
- Turn-on curve saturate at a cluster efficiency very close to 100%

Conclusions

- The ATLAS NSW Upgrade will enable the Muon Spectrometer to retain its excellent performance also beyond design luminosity and for the HL-LHC phase
- Large size resistive MicroMegas will be employed for the first time in HEP experiments

Thanks to great effort from all collaboration groups from different universities and institutes from different countries

- sTGC:
Canada, Chile, China, Israel, Russia
- MicroMegas:
France, Germany, Greece, Italy, Russia

the project is well advanced and will be ready for LS-2

Back-up slides

LHC / HL-LHC Plan

To benefit from the high luminosity at LHC after LS2 and LS3 the forward region of the ATLAS Muon spectrometer will be upgrade.

ATLAS New Small Wheel

- Help rejecting background in the forward region, allowing to keep low p_T thresholds in the trigger at high luminosities, to study interesting physics processes with low p_T muons (for instance 125 GeV Higgs)
- The current SW can't cope with rates up to 15 kHz/cm²; degradation in tracking efficiency and resolution.

Test beam results at CERN

- Efficiency was measured at CERN SPS H8 channel using 130 GeV muon beam about 8cm diameter
- It was determined that the detector efficiency is ~100%
- When particle cross is between two adjacent pads, charge is shared between them