From test bench to new small wheel – small strip thin gap chamber

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EPS HEP 2013, Stockholm
outline

- LHC plans
- The actual small wheel
- Why a new small wheel?
- Small Thin Gap Chambers
- Test beam and irradiation tests
- The New Small Wheel
- New front end
- Conclusion
LHC plans

- **2009**
  - $\sqrt{s}=7\sim8 \text{ TeV}, \ L=6\times10^{33} \text{ cm}^{-2} \text{ s}^{-1}$, bunch spacing 50 ns
  - **RUN I**

- **2011**
  - $\sqrt{s} = 13\sim14 \text{ TeV}, \ L \sim 1\times10^{34} \text{ cm}^{-2} \text{ s}^{-1}$, bunch spacing 25 ns
  - **ATLAS Upgrade Phase-0**

- **2013**
  - $\sqrt{s} = 14 \text{ TeV}, \ L \sim 2\times10^{34} \text{ cm}^{-2} \text{ s}^{-1}$, bunch spacing 25 ns
  - **RUN II**

- **2015**
  - $\sqrt{s} = 14 \text{ TeV}, \ L = 5\times10^{34} \text{ cm}^{-2} \text{ s}^{-1}$, luminosity levelling
  - **HL-LHC, ATLAS upgrade Phase-II**

- **2017**
  - **RUN III**

- **2019**
  - **RUN IV**

- **2023**
  - **2030?**

**Timeline:**
- **2013:** LS1
- **2018:** LS2
- **2022:** LS3

**Data Rates:**
- **2013:** $\sim20-25 \text{ fb}^{-1}$
- **2017:** $\sim75-100 \text{ fb}^{-1}$
- **2022:** $\sim350 \text{ fb}^{-1}$
- **2023:** $\sim3000 \text{ fb}^{-1}$

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Actual Small wheel

Cathode Strip Chambers

Thin Gap Chambers

Monitored Drift Tubes chambers
Actual Small wheel
Why upgrade?

- Performance of the muon tracking chambers will be degraded with the luminosity increase
- Muon end caps trigger will have too high fake rate

Average luminosity: $9.6 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$

Hit rate: $7/19/13$

Luminosity: $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

Range tube rate: 200-300 kHz

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MDT efficiency

Loss at least 35% at high luminosity

New Small wheel is needed with:
100 μm resolution
Online muon track reconstruction with 1 mrad precision
Small Thin Gap Chamber

### sTGC geometry

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire-carbon gap</td>
<td>1.4 mm</td>
</tr>
<tr>
<td>Wire-wire space</td>
<td>1.8 mm</td>
</tr>
<tr>
<td>Strip pitch</td>
<td>3.2 mm</td>
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<tr>
<td>Inter strip gap</td>
<td>0.5 mm</td>
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<tr>
<td>Gas mixture</td>
<td>CO\textsubscript{2}:n-pentane (55:45)</td>
</tr>
<tr>
<td>Wire potential</td>
<td>2.9 kV</td>
</tr>
</tbody>
</table>

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Quadruplet = 4 sTGCs:
- 4 wires planes
- 4 strips planes
- 4 pads planes
sTGC Front End for the test benches

- From 2008 to mid 2012, the Amplifier Shaper Discriminator (ASD) developed by KEK was used
- Peaking time: 17 ns; Gain 0.8 V/pC
- Provides an analog and digital signal

Muon test beam set up

- Muon test beams at CERN (180 Gev)
- Two quadruplets equipped with ASD, two monitor chambers (small TGC chambers M1 and M2) and two scintillators

Combined test with sMDT

Mechanical system that allows to rotate the TGC with high accuracy
Position resolution

Resolution: difference between expected position from track fit (3 planes) and measured position (4th plane)

Position resolution as a function of the incidence angle for the different layers of a sTGC

Good homogeneity of the quadruplet
Resolution < 100 µm
Angular resolution and pads efficiency

Combined test beam with sMDT chambers in muon beam (180 GeV) at CERN

Good angular resolution < 1 mrad

Efficiency above 99% for all layers above 2.75 kV
Irradiation with neutrons

Test in Demokritos (Greece): Cosmic muons tracking under neutron (5.5-6.5 MeV) irradiation

No drastic degradation of the efficiency: less than 4% at the highest dose rate

No sparks observed

Efficiency rate for $L=10^{35}$ cm$^{-2}$s$^{-1}$
Irradiation with $^{60}$Co source

Tests at Nahal Soreq (IL).

Cosmic muons detection under gamma ($\sim 50$ Ci $^{60}$Co source) irradiation. sTGC is 120x70cm$^2$ was totally irradiated.

Position resolution and efficiency measurements with large scale Thin Gap Chambers for the super LHC, arXiv:1006.0135 [physics.ins-det]

No efficiency deterioration observed for a flux of $2.10^4$ Hz/cm$^2$
New Small Wheel

- Decision to build the NSW with 2 chamber technologies:
  - sTGC devoted to the level 1 trigger
  - Micro mesh gaseous structure or Micromegas (MM) dedicated to precision tracking

- The sTGC-MM is a fully redundant system:
  - sTGC can measure muon track with high precision
  - MM can confirm the muon track existence
New FE ASIC for the NSW : VMM

- New ASIC common for MM and sTGC designed in 2011. we received it in 2012

- Front end provides
  - 64 channels
  - Time to peak
  - Time over threshold
  - Adjustable gain : from 0.5 to 9 V/pC
  - Adjustable peaking time : from 25 to 200 ns
  - Threshold per channel

Result sTGC strip + VMM1

In last test beam, strip readout was realized with ASD and VMM

ASD analog output (HV=2.85 kV)

VMM 3mV/fC (HV=2.85kV)

VMM 9mV/fC (HV=2.7kV)

Except for a few minor problems, all VMM features are working
Conclusion

- sTGC are able to support high flux radiation without loss of trigger efficiency and position resolution.
- Sandwich with micromegas: MM for tracking purpose and sTGC for trigger (fully redundant).
- First prototype of a new front end designed for MM and sTGC gave good results.
- NSW will be able to provide muon level 1 information and good tracking system at luminosities up to $10^{35}\text{cm}^{-2}\text{s}^{-1}$. 

7/19/13

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Strips pitch

Average position resolution for two different incident angles (0-10°, circles) and (20-30°, squares) using charge division between strips. The values shown have been averaged over different HV settings.
Comparison of simulated earliest cluster arrival time distributions for normal incident muon tracks with and without magnetic fields.

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### Track fit

#### Table

<table>
<thead>
<tr>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
<th>$\chi^2$/ndf</th>
<th>Constant</th>
<th>Mean</th>
<th>Sigma</th>
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</thead>
<tbody>
<tr>
<td>16</td>
<td>11.09</td>
<td>2.292</td>
<td>7.413 / 2</td>
<td>207.1 ± 12.1</td>
<td>12.42 ± 0.95</td>
<td>1.034 ± 0.044</td>
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<td>16</td>
<td>10.15</td>
<td>2.391</td>
<td>7.688 / 2</td>
<td>90.58 ± 8.47</td>
<td>10.63 ± 0.08</td>
<td>1.075 ± 0.079</td>
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<tr>
<td>16</td>
<td>9.045</td>
<td>2.614</td>
<td>1.654 / 2</td>
<td>55 ± 6.3</td>
<td>9.671 ± 0.004</td>
<td>1.052 ± 0.001</td>
</tr>
<tr>
<td>16</td>
<td>7.097</td>
<td>2.514</td>
<td>17.55 / 2</td>
<td>533.1 ± 19.6</td>
<td>7.763 ± 0.030</td>
<td>1.047 ± 0.030</td>
</tr>
</tbody>
</table>

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7/19/13
Cosmic muon under irradiation
Muons test beam at CERN - combined test with sMDT

Test setup, typical event

The combined angle residual distribution

σ of the combined angle residual versus impact angle

The combined angular correlation
TGC detector

Gas gap: 2.8 mm
Anode wire pitch: 1.8 mm
HV: 3.0 KV
Gas gain: $10^6$
Gas mixture: $\text{CO}_2 / n\text{-C}_5\text{H}_{12} (55\%/45\%)$

Read-out:

- wires
  (read out in group of 4 - 20)
- strips
  (pitch: 15mm - 49mm)

Efficiency: > 99% for 25 ns gate