ATLAS NSW Trigger

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DPF @ Fermilab
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## related talks this week

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introduction
a 20-year plan for the LHC

instantaneous luminosity increasing — experiments must adapt!

ATLAS has suite of upgrades for near-term (Phase 1) and long-term (Phase 2)
the new Small Wheel (NSW)

NSW replaces current SW — under construction now

comprised of eight layers each of two new detectors for ATLAS

Micromegas (MM)

small Thin Gap Chambers (sTGC)
the new Small Wheel (NSW)

offers two major improvements to ATLAS muon spectrometry

rate capacity

detector elements much smaller in NSW than current SW

e.g. MM strip pitch $\approx 0.5$ mm whereas CSC strip pitch $\approx 5$ mm

smaller flux per element @ NSW

latest HL-LHC estimate: $7.5 \times 10^{34}$
the new Small Wheel (NSW)

offers two major improvements to ATLAS muon spectrometry

trigger

NSW adds layer of coincidence for hardware trigger decision

powerful reduction of triggers not originating from muons

emphasis of this talk
the new Small Wheel (NSW)

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emphasis of this talk
sTGC & MM
triggers
sTGC trigger electronics

American institutes building many pieces!

**BNL** for FE chip: VMM

**Michigan** for drivers: TDS and Router

**Illinois** for trigger functions: Trigger anc.
sTGC trigger electronics

- ask for many-layer coincidence with coarse pad triggers
- readout strips within pad trigger tower

There are about 280,000 strips in sTGC. To minimize the amount of transmitted charge information to off-detector Trigger Processors, pad coincidence information is used. The Pad Trigger selects the strips passing through a pad tower made from a coincidence of overlapping pads.

Large data reduction with pad “pre-triggering”
sTGC trigger electronics

120b/116b encoding per packet, one packet per BC

pad trigger data ➔ TDS ASIC × 9

— 8 centroids of strips
— 2 centroids of centroids
— LUT for “track”

Event 1906

layer 4
8.28

layer 3
10.08

layer 2
12.00

layer 1
14.00

Q from Time-Over-Threshold

strip #

-2 0 2 4 6 8 10 12 14 16 18

φ coordinate measured by pad
MM trigger electronics

American institutes building many pieces!

**BNL** for FE chip: VMM

**Arizona** for FE card: MMFE8

**BNL** for driver card: ADDC

**Harvard** for trigger card: MM TP

**Illinois** for trigger functions: Trigger anc.
MM trigger electronics

- only readout *first* strip per VMM
- “ART”: Address in Real Time
- 64 strips per VMM covers ~2.5 cm

*φ* information inferred from stereo planes with $\theta_{\text{strip}} = 1.5^\circ$
MM trigger electronics

all ART strips received at MM TP, then filtered by roads in FPGA

large data reduction with road filtering:
~500 roads per chamber

filtered strips then “fit” for track parameters
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MM trigger electronics

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filtered strips then “fit” for track parameters
performance
simulated performance

simple OR of sTGC and MM decisions

efficient matching
resolution between NSW and existing BW

NSW-BW coincidence
efficiency expected to be 90-95% or better for flagship L1 $p_T(\mu) > 20$ GeV
simulated performance

simple OR of sTGC and MM decisions

muon trigger rates dominated by fakes in the endcaps

substantial rate reduction (≈3x) predicted with NSW

ATLAS Preliminary

Extrapolation to 14 TeV, L=10^{34} cm^{-2}s^{-1}

Muon level-1 trigger rate [Hz]

$p_T$ threshold [GeV]
MM performance in data!

- built 8-layer micromegas mini-chamber at Harvard to measure performance with cosmic ray muons
- chamber equipped with prototype electronics, and recording both trigger and offline data

MMFE8s w/VMM2 | ADDC V1 | MMTP on VC707

VMM | MM “ADDC” | Trigger processor

MM twin-ax | GBT | computer for DAQ and config.

MMFE8 FPGA | ART | fibre

Front end boards | clk/trig. distributor | scintillator trigger

Harvard CRTS
MM cosmic ray test stand

taking offline (full) readout as reference, trigger algorithm fully functioning and performs within spec

RMS: 5.7 mrad

RMS: 0.41 mm

Harvard CRTS

angular resolution

spatial resolution

Events

Road size: ±24 strips

\[ \theta_{\text{MMTP}} - \theta_{\text{MMFE}} \text{ [mrad]} \]

\[ \langle x \rangle_{\text{MMTP}} - \langle x \rangle_{\text{MMFE}} \text{ [mm]} \]
summary
summary

New Small Wheel (NSW) is under construction now, planned to be operational for Run 3 of the LHC and beyond

NSW trigger hardware and algorithms in advanced state, already making triggers with cosmic ray muons
bonus
### Some references

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the current Small Wheel (SW)

innermost layer of ATLAS muon spectrometer endcap

not built to withstand HL-LHC!
collected a few 100k cosmic muons

**with low noise** in May

**Overview at last Muon Week**