L1-muon / RPC for Phase-2

D.Boscherini
on behalf of the RPC/LVL1 group

ATLAS Italia - Bologna, 15/05/2015
Current L1 Muon Barrel Trigger Scheme

**High-\(p_T\)**
- Low-\(pt\) \&\& \(>=1\) hit on RPC3

**Low-\(p_T\)**
- 3/4 hits on RPC1, RPC2
**L1 Muon Barrel trigger rates in Run-1**

**Low-\(p_T\)** (3/4 hits on RPC1, RPC2)
- e.g. MU10
  - \(\sim 70\%\) fake muons
  - used for multi-object triggers
  - \(\epsilon A = 79\%\)

**High-\(p_T\)** (Low-\(p_T\) && \(\geq 1\) hit on RPC3)
- e.g. MU11, MU15, MU20
  - Low fake contamination
  - used as single muon triggers
  - \(\epsilon A = 73\%\)

Rate scales linearly with luminosity in the measured range.
TDAQ upgrade

Trigger scheme change: $L_1 \rightarrow L_0/L_1$

Current scheme
$L_1$ max rate: 100 kHz
$L_1$ latency: 3 $\mu$s

Phase-2 scheme
$L_0/L_1$ max rate: 1000/400 kHz
$L_0/L_1$ latency: 10/60 $\mu$s

→ need to replace RPC trigger electronics

Muon trigger requirements

Max $L_1$ trigger rate of 20 kHz for 15-20 GeV single muons in phase-0/1,
~50 kHz in phase-2
L1 Barrel Muon Trigger Phase-2 Upgrade

- The current barrel trigger system is **not compatible** with the Phase-2 requests (latency and rates)

- The current on-detector electronics will be replaced with the new boxes (*Data Collector Transmitter*, about 800 in total)
  - Use of **FPGAs** instead of **ASICs** for the on-detector electronics
  - The DCT box will collect RPC front-end data, and perform some **simple logic** before sending the data off-detector

- Most of the trigger logic will be located in the **off-detector** new Sector Logic boards (64 in total):
  - provide **seed for MDT-based** trigger
  - increased algorithm **flexibility**, easier operations and maintenance, **no radiation**
  - increased **trigger coverage** could be feasible by changing the trigger algorithm (and possibly by adding **new RPCs in the inner barrel layer**)
  - increased **steepness of the trigger turn-on curve** could be feasible thanks to the improved spatial resolution
  - possibility to use **Time-over-Threshold** to increase RPC spatial resolution (under study)
  - **muon charge** info could be added to the trigger data
  - **trigger thresholds** could be fully programmable and more flexible (possibly > 6)
Phase-2 L0 Muon Barrel Trigger System

 Trigger logic moved from detector to counting room (USA-15)
Costs & Manpower

• Interest in the project expressed by the INFN groups:
  - Bologna, Napoli, Roma, Roma Tor Vergata

• Costs of new LVL1 trigger electronics:
  - 4.2 MCHF (RPCs)
  - 5.1 MCHF (RPCs + new RPCs in BI 4-6)
  - 5.9 MCHF (RPCs + new RPCs in BI)

Money for evaluation boards (FPGA based, to test possible algorithms and performances) have been asked to INFN referees
### RPC rate extrapolation

RPC BM rates (Hz/cm²) at L=7×10^{34} cm⁻² s⁻¹

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Average: 214 208 218 156 111 94 90 82 52 49 48 52 80 90 96 111 160 224 206 206 128

Rate limit of 100 Hz/cm² assumed in ageing tests

Safe value exceeded in many chambers.
Safe operation of current RPCs

- Safe rate limit 100 Hz/cm² with nominal HV, exceeded in many chambers

- Plan to reduce HV to keep gap currents within the safety level

- Hit efficiency reduction with increasing eta, down to 65-75% in BML5-6 stations
Acceptance of present L1 barrel trigger

- High-Pt requirement: 3 out of 3 stations, hole in one station => no trigger

- Holes in “small sectors” BM due to toroid coils and supports

- Run-1 eff x Acceptance ~73%
Benefits from new RPCs on BI stations

Using 3/4 station majority instead of 3/3:
- recover RPC inefficiency (lower HV operation)
- recover holes on BM stations => acceptance ~88%
- using also (locally) BI-BO coincidences => acceptance ~95%
New RPCs in BI stations

Main requirements:
1. Expected max rate in new inner layer $\sim 600 \text{ Hz/cm}^2$: need to improve the long term RPC rate capability to sustain the HL-LHC

2. Limited space available for the installation in the inner layer: $\sim 5\text{ cm}$

Reduced gas gain:
- increased Signal/Noise in front-end electronics
- thinner gap $2 \rightarrow 1\text{ mm}$
- thinner electrodes (improved ratio prompt/total charge) $1.8 \rightarrow 1.2\text{ mm}$

Improved spatial and time resolution:
- timing is improved by reducing the gap thickness
- improve spatial resolution through charge centroid by exploiting electronics sensitivity

Reduced detector thickness
- higher-quality mechanical structures is required
- thinner electrodes and gas gaps
ATLAS RPC phase-2 proposal

Completion of the detector for the barrel muon trigger via the installation of new trigger stations in the inner layer of the spectrometer (currently equipped only with MDTs)

- Increase the number of measurement stations from 2 → 3
- Increase the number of independent layers from 6 → 9

Cost (very preliminary): 3 MCHF(detector+FE elx) + 1.7 MCHF trigger elx
RPC + MDT trigger at L0

First studies with MDT L0 trigger, to be further investigated
Not included in the draft document for LHCC

RPC + MDT “tube count” trigger
- “loose” RPC trigger (2/3 stations) and MDT tube segments in BM, BO
- ”tube segments” made in a road defined by the RPCs

Num of hits in “tube segments” data overlays with $\mu=140$

See https://indico.cern.ch/event/355902/contribution/0/material/slides/0.pdf
Studies of RPC trigger performance

Evaluate efficiency and rates for:

- RPCs
- RPCs + new-RPCs on BI 4-6
- RPCs + new-RPCs on BI
- RPCs + MDT L0 (2 st.)
- RPCs + new-RPCs on BI + MDT L0 (3 st.)
- RPCs + new-RPCs on BI 4-6 + MDT L0 (3 st.)
Two scenarios considered (G. Aielli):

- constant RPC hit efficiencies at 80% everywhere
- variable RPC hit efficiency to keep rate current below equivalent of 100 kHz/cm2

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<td>BMS</td>
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Note: present average efficiency ~95% (peak at 98%)

Two MC single muon samples:
- constant RPC efficiency
- variable RPC efficiency (chamber-by-chamber)
Efficiency based on dedicated single-muon samples

Similar results obtained with the two RPC hit simulations

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<th>RPC hit eff. 56-90%</th>
<th>RPC hit eff. 80%</th>
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<tr>
<td>+Bl RPCs (fullII)</td>
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<tr>
<td>RPCs + MDT BM-BO</td>
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<tr>
<td>+Bl RPCs (stations 4-6)</td>
<td>0.89</td>
<td>0.88</td>
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<tr>
<td>+Bl RPCs (full)</td>
<td>0.95</td>
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Table 2. Efficiency of the L0 trigger in the range $|\eta| < 1.05$, calculated with respect to offline reconstructed muons, for different trigger options and for different assumptions of the hit efficiency of the old RPCs.
1) RPCs 3/3 stations \([majority: 3/4 (rpc1+rpc2) * 1/2 (rpc3)]\)

2) (RPCs 2/3 stations \([majority 3/6 layers]\) + MDT “tube segments” on BM [maj. 5/6] + BO [maj. 5/6] ) OR (1)

3) (BI RPCs + RPCs 3/4 stations \([majority: 2/3 BI, 3/6 old RPCs]\) ) OR (RPC BI * RPC BO) OR (1)

Trigger efficiency vs eta

Covered by BI 1,2,3

RPCs: 80% hit efficiency
Rate estimation

Rate estimated with data overlays at ntuple level (*work in progress*):

Mix zero-bias events from filled and empty bunches to emulate HL-LHC conditions
Start from run at 25 ns (no correction for energy and different layouts)

Results for $\mu=140$ (*to be recalculated for $\mu=200$ as from ATLAS requirements*)

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<th>Barrel Trigger configuration</th>
<th>Rate (kHz)</th>
<th>Comments</th>
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<td>RPCs + BI RPCs (3/4 layers)</td>
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No BI RPC in data $\rightarrow$ BI rate difficult to estimate

Simple emulation with MDTs largely overestimates the rate
(no phi, long time window)
Studies of BI project feasibility

Actions to be performed:
- Replacement of BI layer MDT front end electronics
- RPC installation in BI layer of chambers

Two options considered (preliminary):
1. Moving BI chambers to surface
2. Without BI chambers removal to surface
Estimates for BI project

Already advanced for MDTs ...

**Option 1:**

Detailed estimation of number of days for removal and re-installation of BIL, BIS chambers, replacement of electronics and tests in BB5 for sides A and C

**Option 2:**

Electronics accessible by sliding BIL chambers by ~60 cm
Need judgement from MDT electronics experts about replacement operation
Additional RPC in the BI region

Following variants can be proposed for the investigation:

For BIS:
- To insert RPC on the inner side between BIS and calorimeter surface
- To replace BIS chambers by sMDT with RPC attached to it taking together the same envelope as the existing MDT

For BIL:
- To install RPC on the MDT inner side
- To install RPC on the MDT outer side

No time nor manpower estimation yet
Work is in progress
Scoping document scenarios

Draft version to be presented at LHCC in June 2-4

Three options: 200 (Low), 235 (Medium), 275 (High) MCHF defined by ATLAS management/USC/project leaders

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<td>High-Eta tagger</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Power system</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
Muon working group for the scoping document

Muon costing group:
- Oliver Kortner (MDT electronics and trigger, sMDT chambers)
- Tatsuo Kawamoto (High-eta options)
- Agostino Lanza (Power System)
- Giulio Aielli (RPC chambers)
- Riccardo Vari (RPC trigger & chair)
- Osamu Sasaki (TGC trigger)

Cost estimates status:
- MDT: complete estimate for the three scenarios
- RPC: complete estimate for the three scenarios
- TGC: a few numbers missing
- High-eta tagger: estimate to be completed
- Power System: some initial discussions with CAEN planned for coming months, but do not expect a solid estimate on the time scale of the scoping document
- Cost detail in last Muon Week - Upgrade Cost session: https://indico.cern.ch/event/376177

Next steps:
- complete all the cost estimates, clearly separate TDAQ/Muon contributions
- compare assumptions between different areas and make them consistent, then systematic comparisons and scrutiny
Trigger electronics has to be replaced

Barrel trigger options are the main addition to LoI:
- “efficiency loss scenario” for RPCs defined
- RPC efficiency consistently re-evaluated
- rate estimates in progress

Project feasibility studies ongoing (accessibility/installation issues)

Costing group finalizing the cost estimates