The ATLAS Muon Trigger Performance in pp collisions

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ATLAS EXPERIMENT http://atlas.ch

LHC operation 2011 - 2012

- Main physics subjects at LHC are, for instance, to search for new physics phenomena such as Higgs, and precise measurements on the standard model processes.
- $\sqrt{s}$ = 7 (8) TeV in 2011 (2012) with the increasing peak luminosity and the mean number of interactions per bunch crossing (< μ >) [Fig. 1, 2]
- Delivered integrated luminosity; $\int Ldt$ = 5.6 (6.6) fb^{-1} in 2011 (in 2012 until 19 June)

	2011	2012
$\sqrt{s}$	7 TeV	8 TeV
L (peak)	3.65×10^{33}	6.76×10^{33}
< μ > (peak)	11.6	31.9
$\int Ldt$	5.6 fb^{-1}	6.6 fb^{-1}

Table 1: A summary of LHC operation in 2011 and 2012 (until 19th, June)

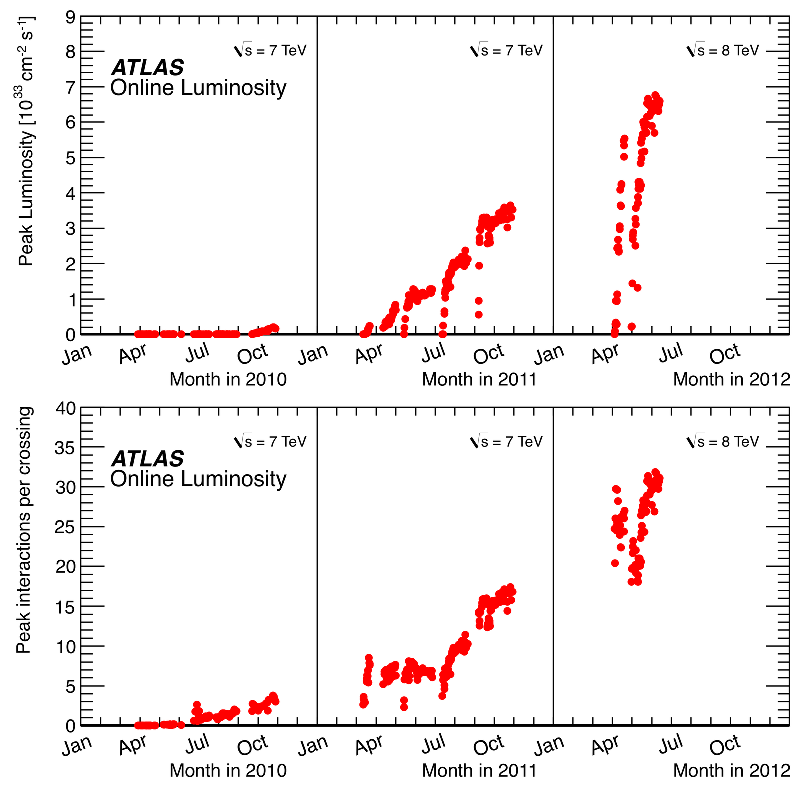

Figure 1: Peak luminosity and < μ >

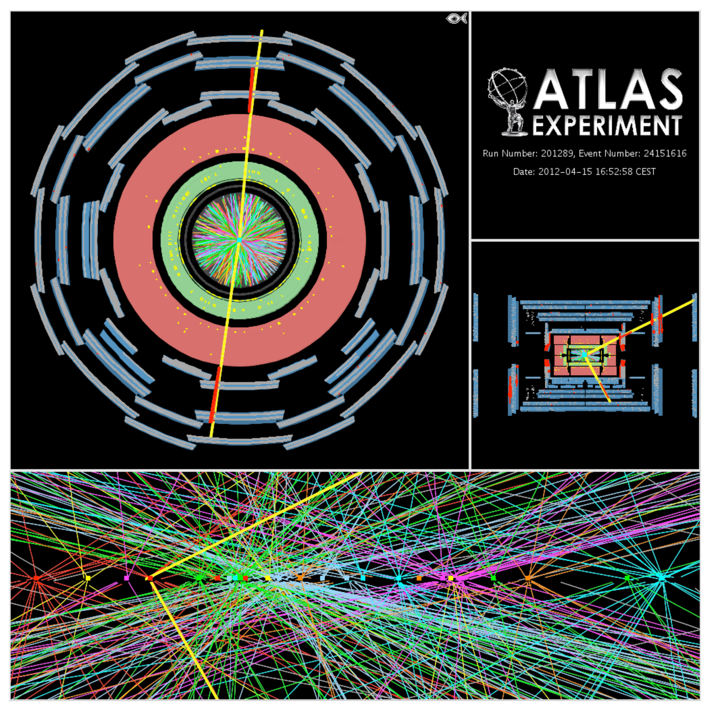

Figure 2: Display of high pile-up Z→μμ event (2012 run; < μ > = 25)

ATLAS muon trigger system

- The ATLAS muon trigger system is designed to select muons in a wide momentum range with a high efficiency filtering events in three sequential steps of increasing complexity and accuracy. Each step is called Level-1 (L1), Level-2 (L2) and Event Filter (EF) respectively.
- The ATLAS muon system utilizes three large air-core superconducting toroidal magnet systems (two endcaps and one barrel) providing an average field of approximately 0.5 T. The deflections of muon trajectories are measured by three stations of precision drift tube (MDT) chambers for tracking. Three layers of resistive plate chambers (RPC) in the barrel and three layers of thin gap chambers (TGC) in the endcaps provide L1 muon trigger. The geometrical coverage of RPC is about 80 % and of TGC is about 99 %. [Fig. 3]
- L2 and EF triggers are performed in a dedicated computer farm. At L2, online-dedicated fast algorithms reconstruct muons in the regions of interest identified by L1 whereas EF deploys algorithms which rely on offline muon reconstruction software and access full event data.

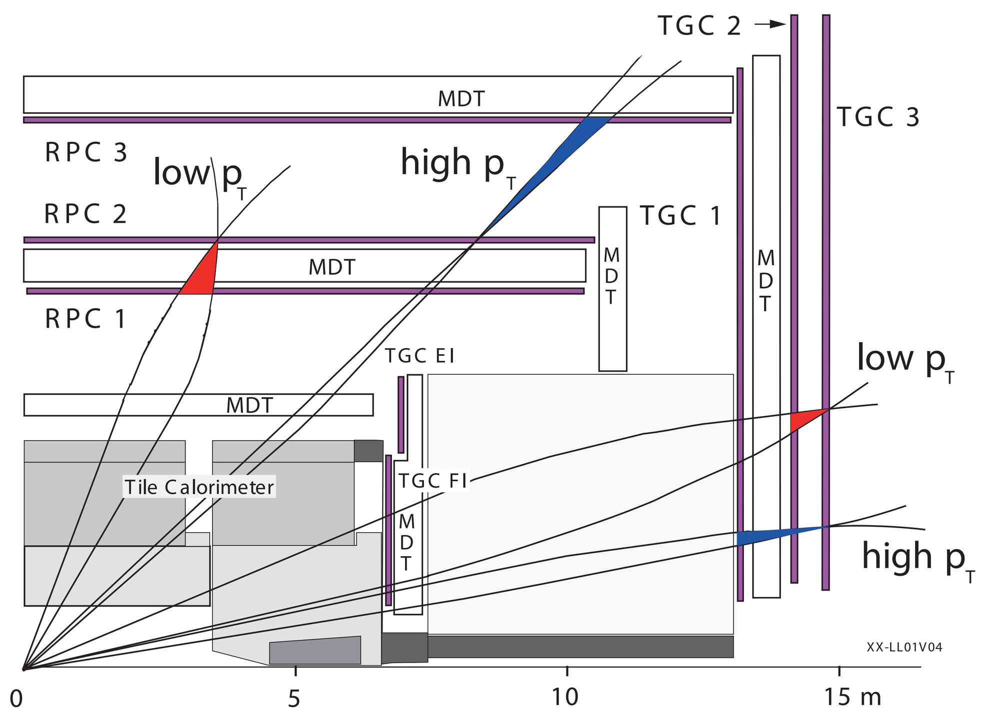

Figure 3: *r - z* view of the ATLAS muon system

Performance in 2011

- The primary single muon trigger in 2011 was seeded from L1_MU11 (3-stations coincidence) and was operated at p_T threshold of 18 GeV ("mu18_medium"). At EF, so called "outside-in" and "inside-out" approaches were used as two independent triggers running in parallel.
- Efficiencies of L1 triggers were measured using the tag-and-probe method with Z→μμ event. [Fig. 4]
- Execution time of the EF triggers in 2011 per each muon candidate processed on the Intel® Core™ 2 Duo CPU E8400 with clock speed of 3.00 GHz running of raw data from the events selected by jet, tau or missing E_T triggers at a luminosity of about 3.1 × 10^{33} cm^{-2} s^{-1}. The mean time of the EF algorithm were 267 (1119) ms for outside-in (inside-out) approach. [Fig. 5]
- L1 and EF trigger rates during the run with a fill of 1332 proton bunches with 50 ns bunch spacing. [Fig. 6] The trigger rates at 3.0 × 10^{33} cm^{-2} s^{-1} for L1_MU11 was 8.2 kHz, and that for mu18_medium was about 110 Hz.

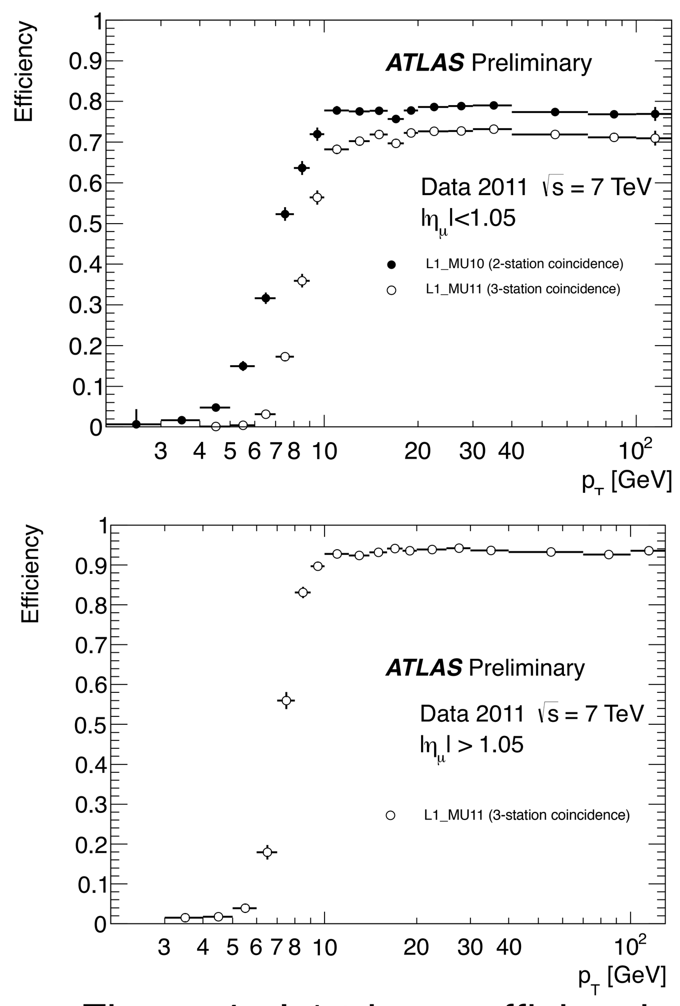

Figure 4: L1 trigger efficiencies

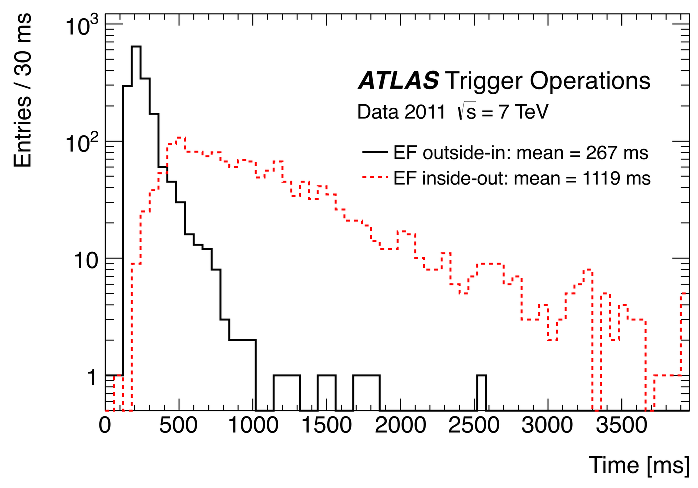

Figure 5: Processing time for EF

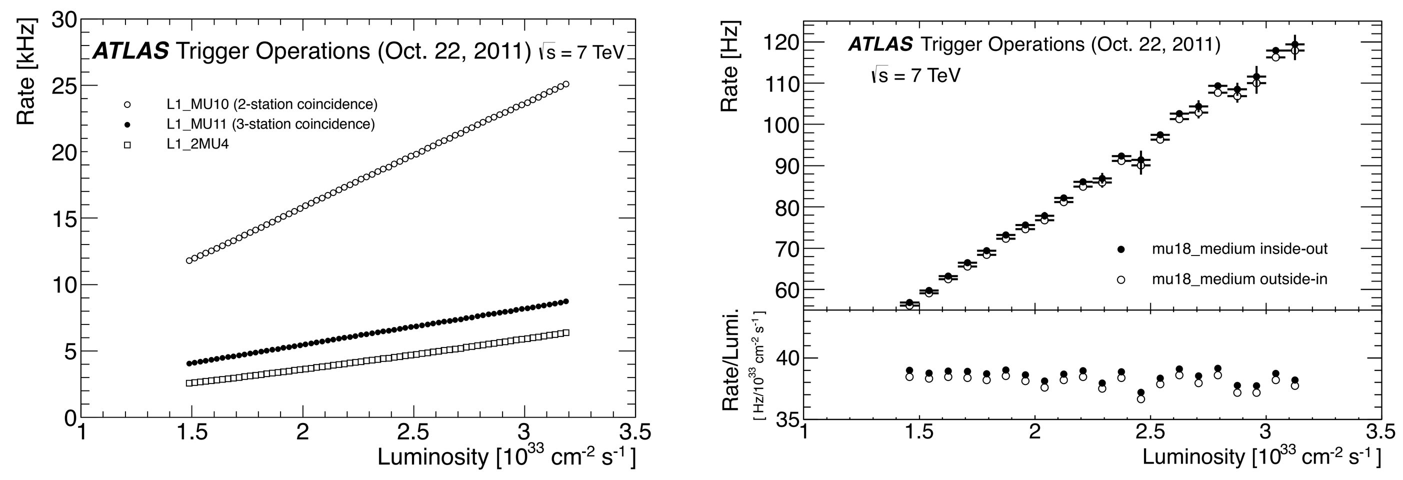

Figure 6: Trigger rate for L1 (left) and EF (right)

2012 primary trigger performance

- **Merged EF algorithm:** The EF inside-out and outside-in approaches have been merged into a single algorithm resulting in a more efficient trigger. The inside-out algorithm is executed only if the outside-in algorithm couldn't find a muon candidate in the merged algorithm. [Fig. 7]
- **Isolation requirement:** An isolation requirement in terms of the tracking activities around the muon candidate is firstly applied for single muon trigger. The isolation working point has been set at relative isolation, ($\sum p_T/p_T^{\mu}$) < 0.12, where $\sum p_T$ is the sum of p_T of the tracks surrounding the muon in the cone of ΔR < 0.2. p_T of the tracks should be > 1 GeV and $|z_0(\text{track}) - z_0(\text{muon})|$ < 6 mm. This variable is stable against < μ >. [Fig.8]

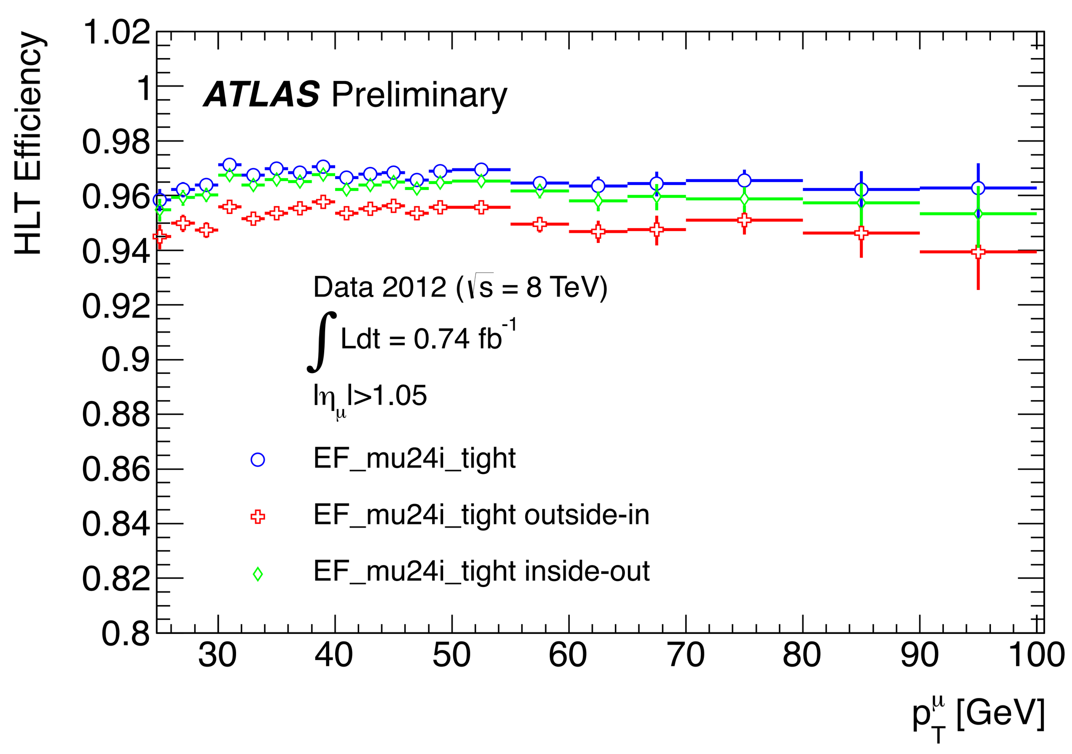

Figure 7: Efficiencies for the triggers in endcap with respect to the L1 trigger

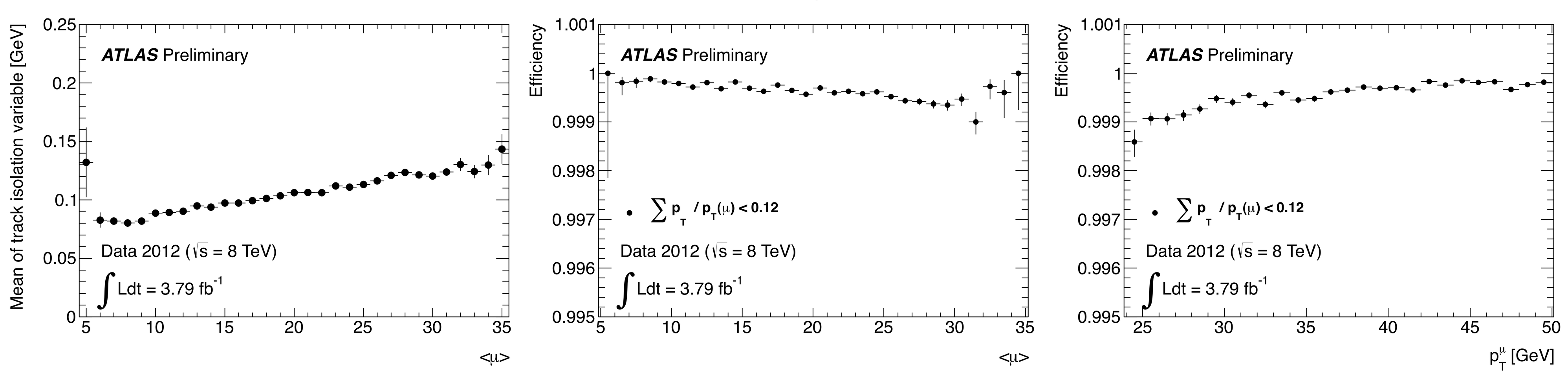

Figure 8: Mean of the isolation variable and the efficiency of the isolation requirement in 2012 as a function of < μ > and p_T

- The primary single muon trigger in 2012 has the p_T threshold of 24 GeV with the isolation requirement ("mu24i_tight"). The efficiency of mu24i_tight with respect to offline isolated muons is about 70 % in barrel and 90 % in endcap including the geometrical acceptance losses. [Fig. 9]

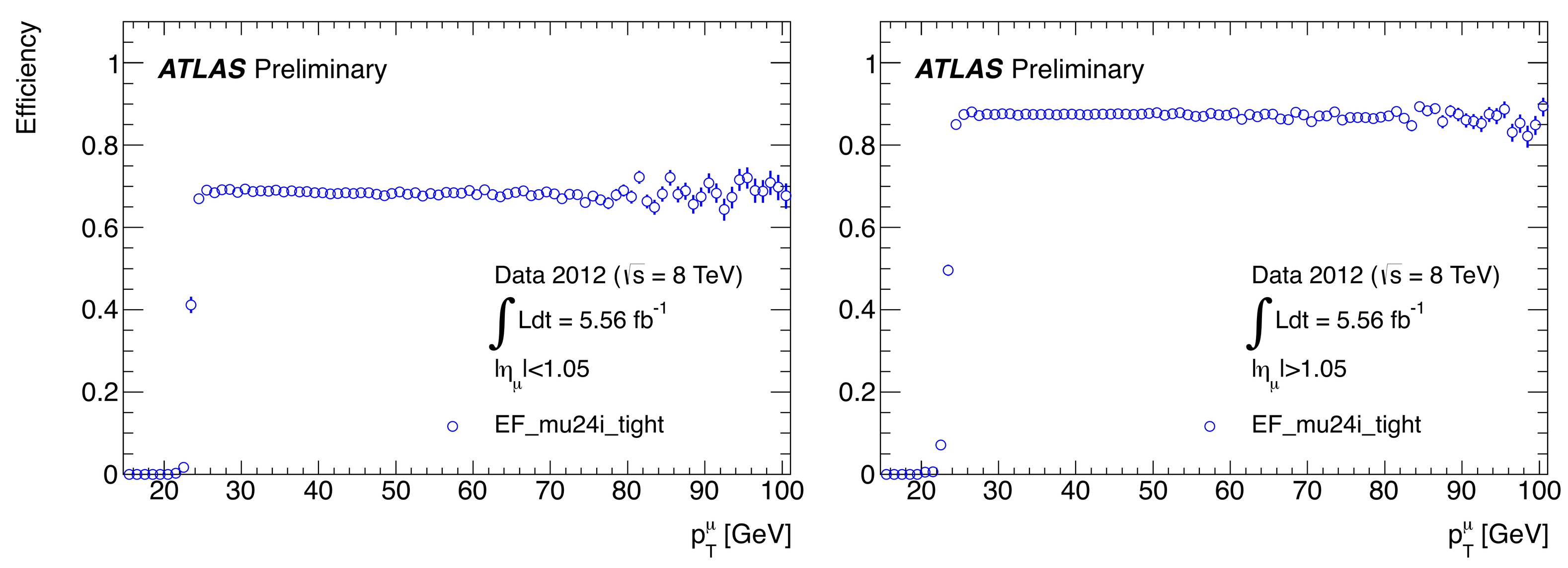

Figure 9: Efficiencies of mu24i_tight as a function of pT in barrel and endcap

Conclusion

- At LHC, muon trigger with a high rejection power against large backgrounds while maintaining a high efficiency for rare signal events is important in searches of new physics phenomena and precise measurements on the standard model processes.
- The peak luminosity and the mean number of interactions per bunch crossing have been rising resulting in a harsh environment for the ATLAS muon trigger system.
- In 2011 run, the p_T threshold was kept at 18 GeV at the EF. Event rate of the L1_MU11 trigger was about 8.2 kHz and of the primary EF single muon triggers are about 110 Hz at 3.3 × 10^{33} cm^{-2} s^{-1} of the luminosity.
- In 2012 run, an additional requirement of isolation in terms of the tracking activities around the muons are imposed on the primary single muon trigger as well as the introduction of the merged algorithm of the outside-in and inside-out approaches. The ATLAS muon trigger has been keeping the p_T threshold at 24 GeV with a comparable trigger efficiency on the plateau to the primary EF trigger in 2011 run.
- The muon trigger has been used for many physics analyses starting from ones which have been reported in the ICHEP 2012.

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