PROCEEDINGS OF SCIENCE

PoS(RPC2012)008

Performance of the ALICE Muon Trigger system in Pb–Pb collisions

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ALICE is the LHC experiment dedicated to the study of heavy-ion collisions at very high energies. In ALICE quarkonia and open heavy flavors are identified in the forward rapidity region via their muonic decays, by means of a dedicated Muon Spectrometer and a Muon Trigger system selects events with high transverse momentum (p_{T}) muons. The performance of the Muon Trigger in 2010 and 2011 Pb–Pb collisions are presented, with particular regard to multiplicities and trigger algorithm. The stability of the performance throughout the data taking periods is also discussed.

XI workshop on Resistive Plate Chambers and Related Detectors - RCP2012,
February 5-10, 2012
INFN Laboratori Nazionali di Frascati Italy

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1. ALICE and the Muon Trigger system

ALICE [1] (A Large Ion Collider Experiment) is the LHC experiment dedicated to the study of heavy-ion collisions at very high energy density, where the formation of the Quark Gluon Plasma (a state of matter where quarks and gluons are deconfined) is expected. Since March 2010, the experiment has collected data with pp collisions at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 2.76$ TeV, and with Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV. ALICE consists of a central barrel, a set of forward detectors and a Muon Spectrometer [1].

Heavy flavor production is one of the key observables for the study of the QGP [2]. The goal of the Muon Spectrometer ($-4 \leqslant \eta \leqslant -2.5$) is the detection of J/$\psi$, Υ and open heavy flavors via their muonic decays. It is composed (see Figure 1) by a front absorber, a Muon Tracking system, a dipole magnet, a beam shield, a muon filter and a Muon Trigger system that is needed to identify muons and to reduce the background of the low-p_{T} muons coming from π and K decays [3].

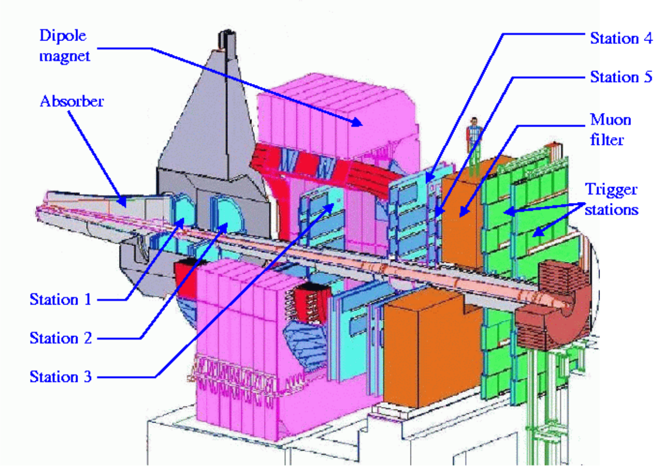


Figure 1: Muon Spectrometer layout

The Muon Trigger is composed of 4 planes of 18 Resistive Plate Chambers (RPCs) [4] each. The RPC gas mixture is optimized for working in a highly saturated avalanche condition, without amplification at the front-end electronics level. The operating voltage of the RPCs is about 10 kV. The signal is picked up inductively by means of orthogonal copper strips of various pitch sizes (1, 2 and 4 cm), which provide the spatial information used to estimate the p_{T} via the relative deviation with respect to a straight track coming from the interaction point.

The first level of the Muon Trigger decision is performed by a set of 234 electronics boards. Single and dimuon trigger signals above two different p_{T} cuts are calculated. For Pb–Pb collisions, the threshold values shown in Table 1 have been set.

2. Multiplicities

2.1 Muon and hit strip multiplicity

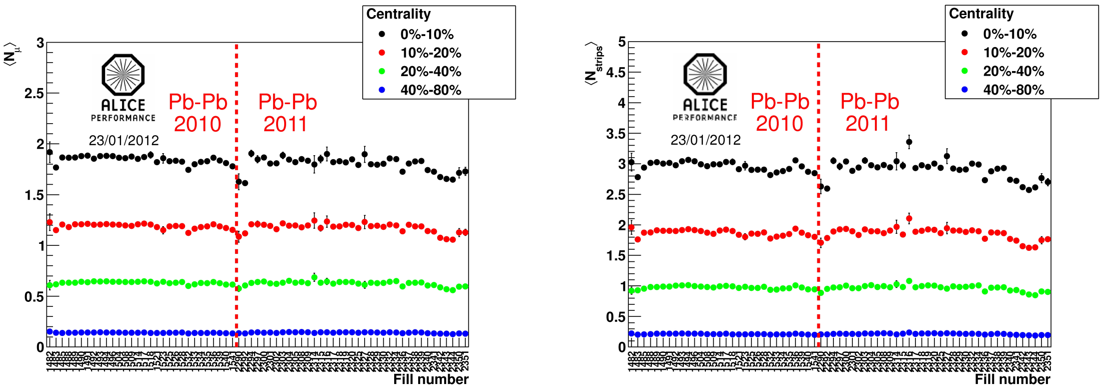
Using minimum bias Pb–Pb events, we study the average number of muons per collision for

	low-p_T cut	**high-p_T cut**
Pb–Pb 2010	0.5 GeV/c	1 GeV/c
Pb–Pb 2011	1 GeV/c	4 GeV/c

Table 1: p_T cuts used in Pb–Pb collisions

different centrality bins (Figure 2a) as a function of the fill number[1]. In this case muons should have a p_T higher than the lowest cut (0.5 GeV/c) and are required to be detected not only by the Muon Trigger, but also by the Muon Tracking.

With the same selection criteria, it is possible to calculate the average number of hit strips per minimum bias event in the same centrality bins. In Figure 2b this is shown for the first trigger plane in the bending direction as a function of fill number.



(a) (b)

Figure 2: average number of detected muons (a) and average number of hit strips for the first trigger plane (b) as a function of the fill number, for various Pb–Pb centrality bins

In both cases one can conclude that the multiplicity of muons and hit strips increases with centrality, as expected. The stability of the detector over the time is satisfactory.

In Tables 2 and 3 the average values of muons and strips for the four centralities are reported.

0%–10%	**10%–20%**	**20%–40%**	**40%–80%**
1.83±0.16	1.18±0.10	0.62±0.07	0.14±0.01

Table 2: average number of muons as a function of centrality

0%–10%	**10%–20%**	**20%–40%**	**40%–80%**
2.93±0.39	1.86±0.24	0.97±0.12	0.21±0.02

Table 3: average number of hit strips as a function of centrality (first trigger plane, bending direction)

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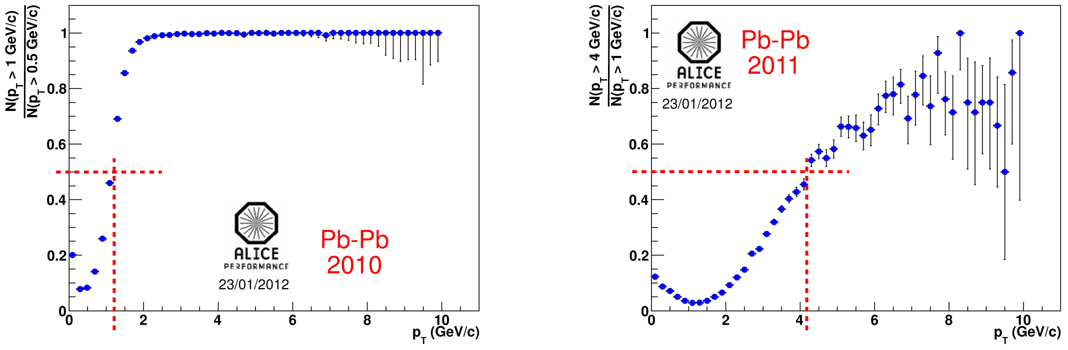
[1] The fill number is assigned directly by the LHC: it is related to the time.

In the analysis of the strip multiplicity soft background is not included: only strips participating in tracks recognized by the algorithm are taken into account. This means that the difference with the average number of muons is mostly due to the cluster size.

3. Trigger algorithm performance

3.1 p_T cuts

The p_T cuts are determined through simulations with muons of known transverse momentum [5]. With real data the only way to check if there is a correspondence between the simulated cuts and the actually applied ones is to compute the ratio between the number of muons with p_T above the high-p_T threshold over the number of muons with a p_T above the low-p_T threshold as a function of p_T (information given by the Tracking system). In Figure 3 such ratios for 2010 and 2011 Pb–Pb collisions are shown.



(a) (b)

Figure 3: number of high-p_T tracks over number of low-p_T tracks as a function of p_T for 2010 (a) and 2011 (b) Pb–Pb collisions

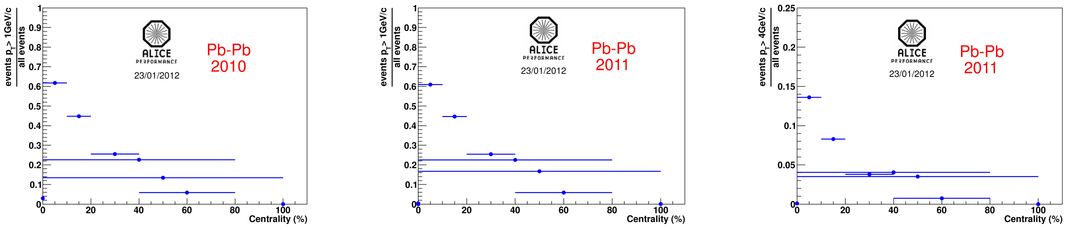
The theoretical shape of these plots should be a step function, with value 0 below and 1 above the high-p_T cut. In reality a plateau with saturation value close to 1 is seen for large p_T, while for very low p_T the ratio is not equal to 0. This is a well known feature, also reproduced in simulations. It is due to the fact that the trajectory of low-p_T muons passing through the muon filter (placed between the two subdetectors, see Figure 1) can be affected by multiple scattering effects and then be flagged as high-p_T tracks by the Trigger system.

MC calculations yield a value of the ratios of 0.5, in correspondence with the required high-p_T cuts (reported in Table 1). This confirms that the p_T thresholds have been properly set.

3.2 Global trigger

The ratios (called Trigger selectivity hereafter) between the number of minimum bias events containing at least one muon with $p_T > p_T$ cut (global trigger) and all the events within a given centrality range are reported in Figure 4 for different p_T cuts as a function of the centrality.

The centrality dependence is very clear. In the Table 4 the Trigger selectivity for two centrality bins are reported. The agreement between the 2010 and 2011 ratios with the same cut (in red) is evident.



(a) (b) (c)

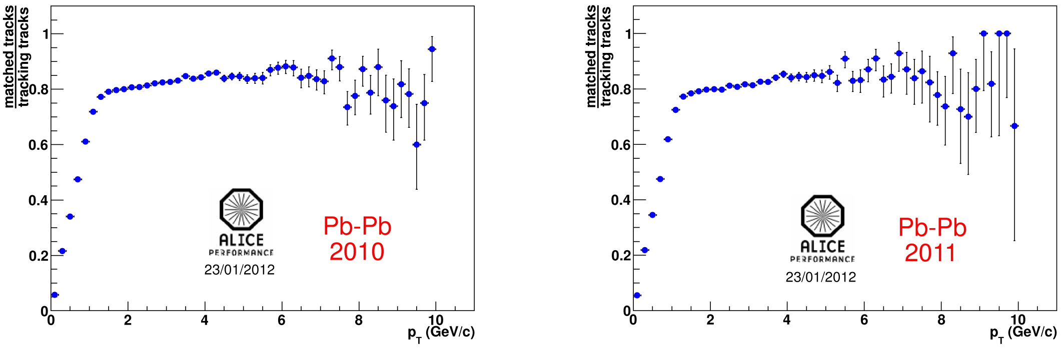
Figure 4: Global trigger ratios for 2010 (high-p_T (a)) and for 2011 (low-p_T (b) and high-p_T (c)) Pb–Pb collisions. Horizontal error bars represent the bin width.

	2010 $p_T > 1$ **GeV/c**	**2011** $p_T > 1$ **GeV/c**	**2011** $p_T > 4$ **GeV/c**
0%-10%	61.8%	60.9%	13.6%
40%-80%	5.8%	5.9%	0.7%

Table 4: Trigger selectivity for two centrality ranges and different cuts

3.3 Tracking-Trigger matching

In the two plots of Figure 5 the ratios between the number of tracks detected by both the Muon Tracking and the Muon Trigger (so called matched tracks) and the number of tracks detected at least by the Muon Tracking are shown as a function of p_T.



(a) (b)

Figure 5: number of matched tracks over the number of tracks detected at least by the Muon Tracking as a function of p_T for 2010 (a) and 2011 (b) Pb–Pb collisions

One can see the same trend for both years. This is a further confirmation of the stability of the Muon Spectrometer system. Another important point is the saturation value (about 0.85, common to 2010 and 2011) of the plateau which doesn't reach the value of 100% also for very high values of p_T. This means that not all the particles detected by the Muon Tracking system are also detected by the Muon Trigger: hadrons (up to quite high p_T) and slow muons are stopped by the muon filter between the two systems or rejected by the trigger algorithm.

4. Conclusions

After the analysis of the 2010 and 2011 Muon Trigger data in Pb–Pb collisions it is possible to conclude that:

- the Muon Trigger system has shown a very stable behavior;
- the RPCs are operating with a high level of performance;
- the trigger decision algorithm is efficient and selective;
- the Muon Trigger allows to reject hadrons and low-p_{T} muons which are detected by the Muon Tracking. It actually acts as a muon identifier.

During 2011 Pb–Pb collisions ALICE collected an integrated luminosity of $\sim$144 μb^{-1} (15 times more than in 2010) with $\mathscr{L}_{max}$ = 5 10^{26} Hz/cm^2 (an order of magnitude higher with respect to 2010). The maximum collision rate in 2011 was of $\sim$4 kHz corresponding to $\sim$600 Hz of single muon trigger above 1 GeV/c. With these numbers and also thanks to the good Muon Trigger performance, the Muon Spectrometer reconstructed in Pb–Pb 2010 more than 2500 J/ψ [6] and in Pb–Pb 2011 about 40000 J/ψ and more than 100 Υ are foreseen.

References

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