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

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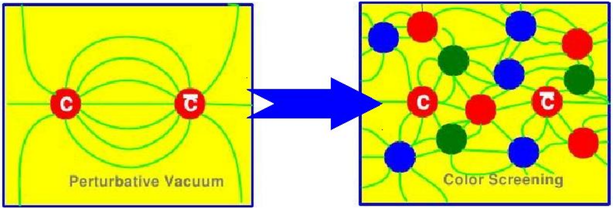
Outline

ALICE and the Muon Trigger

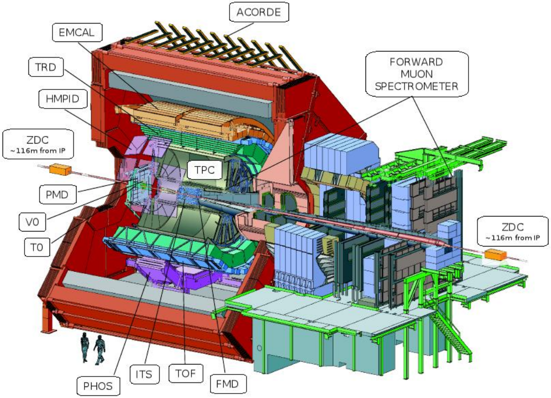
The Quark Gluon Plasma

- QGP is a non-ordinary state of matter in which quarks and gluons are deconfined
- The production of quarkonia and heavy flavours is expected to be modified by the QGP
- In a colored medium, binding forces between partons are screened by other free charges



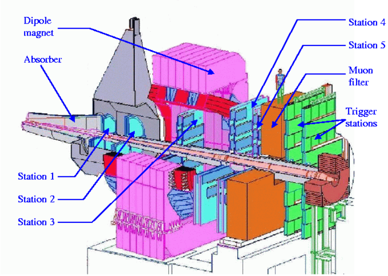
- Ultra-relativistic heavy-ions collisions are the unique tool to produce and to study QGP in laboratory

A Large Ion Collider Experiment



- ALICE is the LHC experiment dedicated to the study of heavy-ions collisions at very high energies
- It participates also to the LHC pp program
- It is composed by a central barrel, a set of forward detectors and a Muon Spectrometer

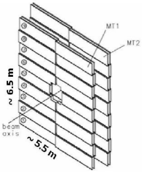
The Muon Spectrometer

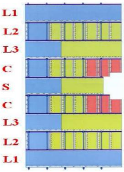


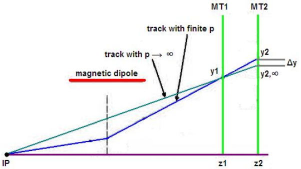
- The goal of the Muon Spectrometer is the detection of J/ψ, Υ and open heavy flavours via their muonic decays
- It is composed by a front absorber, a Muon Tracking system, a magnetic dipole, a muon filter and by a Muon Trigger system
- In order to reject background from π and K decays into muons, a selection performed by the Muon Trigger and based on transverse momentum (p_{T}) is required

The Muon Trigger system

- The Trigger system is composed by four planes of 18 RPCs each (total surface of $\sim$ 140 m^2) operating in *highly saturated avalanche* mode ($\rightarrow$ no need of amplification for electronics)
- The spatial information is used to estimate the p_T via the deviation with respect to a straight track from the I.P.







- Single and dimuon trigger signals above two cuts are delivered:

	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

Analysis conditions

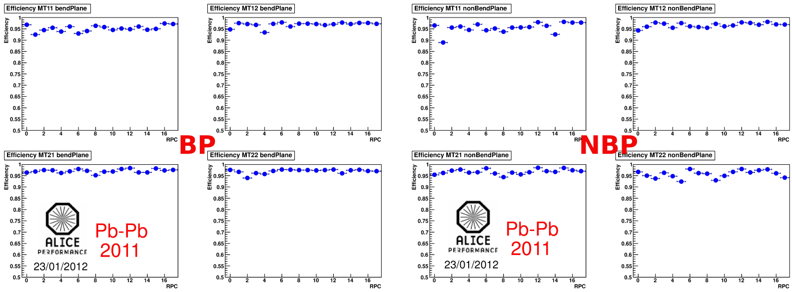
Analysis conditions

- All the statistics collected by the Muon Spectrometer in Pb–Pb collisions ($\sqrt{s_{NN}} = 2.76$ TeV in 2010 and in 2011) has been analyzed
  - $\mathcal{L}_{int}$ 2011 $\sim$144 μb^{-1} (15 times more than 2010)
  - $\mathcal{L}_{max}$ 2011 (2010) = 5 10^{26} (2 10^{25}) Hz/cm^2
  - Max collision rate 2011 $\sim$4 kHz
    $\rightarrow \sim$600 Hz single muon trigger $>$ 1 GeV/c
- Only minimum bias events have been analyzed and will be discussed in the presentation
- Muons have been required to be detected by Muon Trigger and Muon Tracking
- The analysis has been performed for different centrality bins:

0%-10% **10%-20%** **20%-40%** **40%-80%**

RPC efficiency

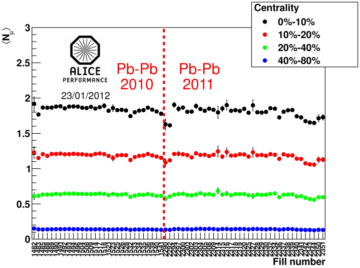
Muon Trigger chamber efficiency



- Efficiency measured during data taking by exploiting the redundancy of the trigger system
- Efficiency for the 72 RPCs (bending and non-bending plane) from 2011 Pb–Pb data
- Typical efficiency is $\sim$ 95% or above (some chambers at 98%)

Multiplicities

Muon multiplicity (vs centrality)

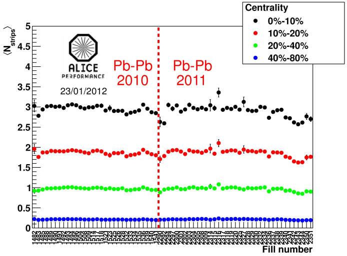


- Average number of muons per event as a function of fill number with the lowest possible p_T cut (0.5 GeV/c)
- As expected multiplicity of muons increases with the centrality

0%-10%	10%-20%	20%-40%	40%-80%
1.8	1.2	0.6	0.1

- The stability over the time is satisfactory

Strip multiplicity (vs centrality)



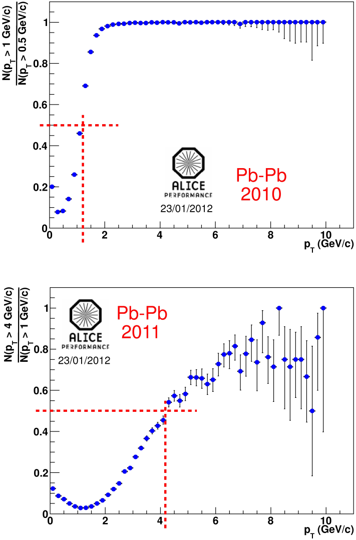
- Average number of hit strips per event as a function of fill number (example of the first trigger plane, bending direction)

0%-10%	10%-20%	20%-40%	40%-80%
2.9	1.9	0.9	0.2

- Soft background is **not** included: only hit strips participating in track recognized by the algorithm are taken into account
- The difference with respect to the mean number of muons per event (previous slide) is due to the cluster size

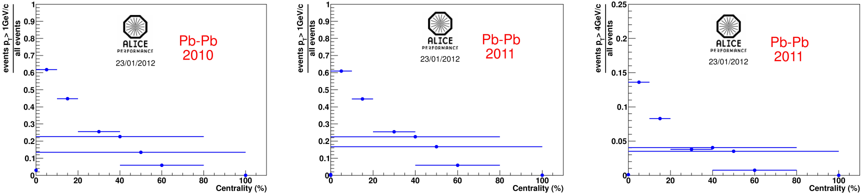
Trigger performance

Ratio $\frac{high\ p_T}{low\ p_T}$ vs p_T



- p_T cuts are determined through simulations
- 2010: high p_T cut = 1 GeV/c
  2011: high p_T cut = 4 GeV/c
- Values of p_T cuts can be checked from data by computing the ratio $\frac{high\ p_T}{low\ p_T}$ vs p_T
- There is a good agreement between p_T cuts determined from simulation and from data

Trigger selectivity

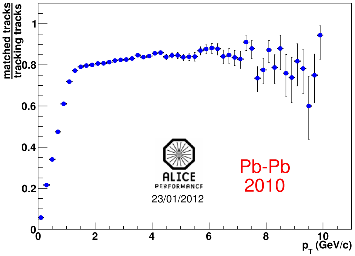


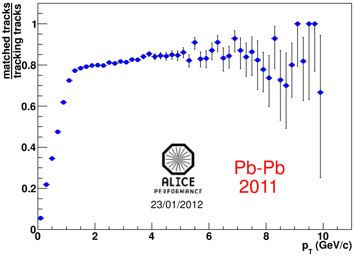
- Ratio between the number of events containing at least one muon with $p_T > p_T$ cut and all the events within a given centrality range
- Horizontal error bars represent the bin width

	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%

- Agreement between 2010 and 2011 ratios with the same p_T cut

Track matching probability between Muon Trigger and Muon Tracking





- In the analysis, tracking and trigger tracks are requested to match
- Same trend and saturation value from 2010 and 2011 data
- Not all the muons detected by Muon Tracking are also detected by Muon Trigger: on top of acceptance $\times$ efficiency effects, hadrons and slow muons are stopped by the muon filter

Conclusions

Conclusions

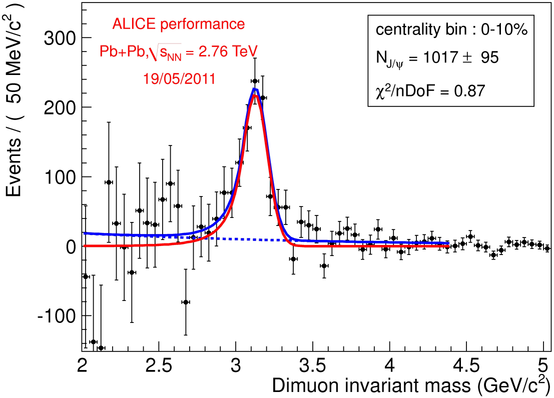
After the analysis of the 2010 and 2011 Muon Trigger data in Pb–Pb collisions it is possible to conclude that:

- Muon Trigger system has shown a very stable behavior
- 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

Also thanks to the Muon Trigger performance, the Muon Spectrometer detected more than 2500 J/ψ in Pb–Pb 2010 and much more in 2011

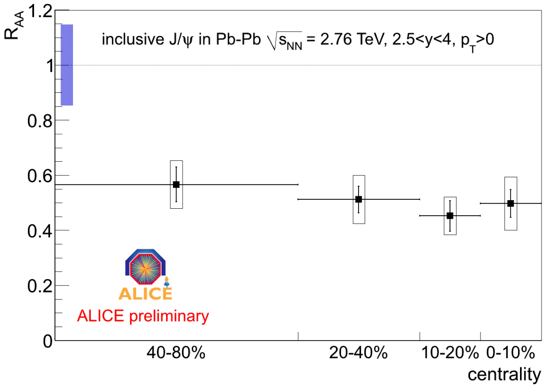
Physics achievements with the Muon Spectrometer in Pb–Pb collisions

$J/\psi \to \mu^+ \mu^-$ invariant mass fit (background subtracted) for 0%-10% most central collisions (2010 Pb–Pb data)



Physics achievements with the Muon Spectrometer in Pb–Pb collisions

Inclusive J/ψ RAA versus the centrality of the collision (2010 Pb–Pb data): RAA $<$ 1 indicates nuclear effects which can be interpreted as a consequence of QGP formation



Backup

RPCs operating conditions

- Working condition: highly saturated avalanche
- Gas mixture: 89.7% $C_2H_2F_4$ 10% i-C_4H_{10} 0.3% SF_6
- Humidity: 37%
- HV: $\sim$ 10 kV
- Threshold: 7 mV
- Bakelite resistivity: $\rho \sim 10^9$ Ω·cm
- Strips width: 1, 2 or 4cm

RPC efficiency evaluation

- N_{tot} is a sample of particles crossing the same chamber in at least 3 planes; ε_i is the efficiency of the RPC in the i-th plane
- The number of reconstructed tracks firing all planes is

$$N_{4/4} = N_{tot} \prod_{1 \leqslant i \leqslant 4} \varepsilon_i$$

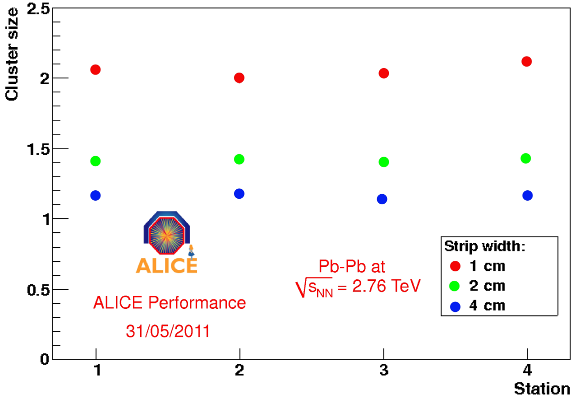
- The number of reconstructed tracks even if the information of the RPC in plane k is not taken into account is

$$N^k_{3/4} = N_{tot} \prod_{\substack{1 \leqslant i \leqslant 4 \\ i \neq k}} \varepsilon_i$$

- And the efficiency for an RPC of plane k is

$$\varepsilon_k = \frac{N_{4/4}}{N^k_{3/4}}$$

Cluster size



1 cm	2 cm	4 cm
1.1	1.4	2.1

Ratio $\frac{high\ p_T}{low\ p_T}$ vs p_T

- Simulation of $\frac{high\ p_T}{low\ p_T}$ vs p_T
- p_T cut = 4 GeV/c