The Muon Spectrometer of the ALICE

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Abstract. The Muon Spectrometer of the ALICE experiment is a unique tool to study of the heavy quarks in pp, pA and AA collisions at LHC energies, via the muonic channel. The spectrometer consists of different absorbers, a dipole, five tracking stations and two trigger stations.

1. Introduction
The future Large Hadron Collider (LHC) at CERN will provide beam energies of 14TeV for p-p and 5.5TeV for Pb-Pb collisions. The ALICE experiment will be the only experiment at LHC dedicated to the heavy ion physics. The goal of the Muon spectrometer of ALICE is to study the open heavy flavor production and the quarkonia production (J/ψ, ψ′ and Υ(1S), Υ(2S) and Υ(3S)) via the muonic channel.

The muon spectrometer will be able to measure the quarkonia production in central Pb-Pb collisions at LHC energies, down to very low p_{T}, since low p_{T} quarkonia will be sensitive to medium effects like heavy-quark potential screening and/or statistical recombination. Since muons are passively identified by the absorber technique, a Lorentz boost is needed to be able to measure quarkonia at low p_{T}. The muon spectrometer will be a unique apparatus at LHC to measure charmonia production at p_{T} ∼ 0 with a large rapidity range −4.0 < η < −2.5 [1].

The muon spectrometer consists of absorbers, a muon magnet, a muon filter (iron wall), a trigger system and a tracking system. The layout of the muon spectrometer is presented on Fig. 1 [2].

2. Absorbers
Absorbers reduce the initial flux of primary hadrons from nucleus-nucleus collisions by a factor 100, and they reduce the low energy particles flow produced in secondary interactions (mainly low energy electrons). The front absorber is the most critical component and it has been designed for minimizing the invariant mass resolution deterioration of the spectrometer due to straggling and multi-scattering. This imposes an upper limit of the amount of material (λ_I ∼ 10), and requires that components with low Z are located close to the interaction point (IP), whereas high Z components are placed close to the spectrometer. Moreover, muons from hadronic weak decay are optimally suppressed by placing the front absorber as close as possible to the interaction point. The distance from the IP is, however, limited to 90 cm since physics performances of the ALICE central barrel should not be deteriorated by the presence of any absorber. The front absorber is the main contributor to the invariant mass resolution of the spectrometer in
the $\Upsilon$ region, with a quadratic contribution equal to about 80 MeV/$c^2$. The absorber (shield) around the beam pipe is crucial to reduce the low energy background in the tracking and trigger chambers due to secondary interactions along the pipe. Finally, an 120 cm thick iron wall is located between the tracking stations (stations 1-5 in fig. 1) and the trigger stations (stations 6 and 7 in fig. 1) allows for reducing the low energy particle background in the trigger chambers. At present, the absorbers are under construction at CERN.

3. Muon Dipole Magnet
Muon momenta are determined by muon tracking in a magnetic field generated by a warm dipole of 820 tons, the largest warm dipole in the world with a nominal field of 0.7 T and a field integral along beam axis $\int |B|dz \sim 3$ Tm. The yoke was provided by the Dubna collaboration whereas the two coils were manufactured by SigmaPhi company at Vannes (France). The magnetic field is directed in the horizontal plane perpendicular to the beam direction (x axis) defining a bending plane (zy plane) and a non bending plane (xz plane). The muon magnet has been assembled and has been tested in the cavern (point 2). It’s presently dismounted and is being mounted in its nominal position. The procedure will last until end of June 2005. During summer the field’s mapping will be performed.

4. Trigger system
Muon detection based on absorption technique allows for a very efficient triggering on high $p_T$ muons. This is crucial in order to take advantage of the full luminosity of the heavy ion beams at LHC, taking into account that muon acquisition system is limited to an event rate of 1kHz. The trigger system (stations 6 and 7 in fig.1) consists of 4 planes of 18 Resistive Plate Chambers (RPC) each, located between 16 m and 17 m from the IP (just behind the iron wall) and operating in the streamer mode with a gas mixture of Ar, CH$_2$F$_4$, C$_4$H$_{10}$ and SF$_6$ [3]. Signals in individual strips of the RPC are treated by a dual threshold discriminator (ADULT) [4]. The time resolution of the 2 mm gap RPC equipped with the ADULT chip is in the order of 1 ns. Information from the 21,000 strips are locally processed by the so-called local cards [5].

\footnote{For the pp runs, an avalanche operating mode is being investigated to reduce the aging effect of RPC’s}
(234 cards), determining roughly the transverse momentum of the muon track (see fig 2). The 234 local cards are dispatched in 16 crates, each equipped by a controller (called regional card). The global cards collect the full information from regional boards and determine the trigger condition of the event in less than 700 ns. The data from the regional crates and from the global card are steered to the readout card (Dimuon Arm Readout Controller). Different trigger types are possible: low \( p_T \) pairs (above 1 GeV/c for \( J/\psi \) studies), high \( p_T \) pairs (above 2 GeV/c for \( \Upsilon \) studies), like sign muon pairs, single muons, etc... The muon trigger delivers information to the central trigger processor for the generation of the ALICE level 0 trigger. A full test of the RPC equipped with the front-end electronics and with the local boards has been performed at GIF in 2002 [6]. Reconstruction track efficiency was found to be higher than 98 % (see Fig. 3 [7]).

5. Tracking system
Muon transverse momenta in the bending plane (\( |p_{zy}| \)) are determined by tracking muons along the magnetic field. A momentum resolution of about 1% is needed to achieve the required resolution in the \( \Upsilon \) invariant mass region (\( \sim 100 \) MeV/c\(^2\)). The tracking system is made of 5 stations with two detection planes consisting of 5 mm gas gap drift multi-wire proportional chambers with segmented cathode plane (cathode pad chambers, CPC). The thickness of each chamber is below 3% radiation length. The first two stations are placed in front of the muon magnet at a distance of \( \sim 5.4 \) m and \( \sim 6.8 \) m respectively from the IP. They consist of four detection planes made of four CPC’s each with a quadrant design. Stations 3, 4 and 5 are placed at a distance of \( \sim 9.7 \) m (inside the muon magnet), \( \sim 12.6 \) m and \( \sim 14.2 \) m from the IP. A modular design was chosen for these stations, consisting of rectangular CPC called slat (36, 52 and 52 slats for stations 3, 4 and 5 respectively). Different pad densities are present in the CPC depending on the station and pseudo-rapidity positions, ranging from \( 4 \times 6 \) mm\(^2\) for pads closest to the beam-pipe in station 1, to \( 5 \times 100 \) mm\(^2\) for stations 3, 4 and 5 in the bending plane. An initial direction of the muon is determined from the track parameters of the muon and from the position of the IP, taking into account the multi-scattering in the absorber. In order to keep the invariant mass resolution in the \( \Upsilon \) region below 100 MeV/c\(^2\), a spatial resolution of 1 mm is required in the non-bending plane (x direction) and a resolution below 100 \( \mu \)m is required for the bending plane (y direction). Several campaigns of testbeam were performed at the PS and the SPS facilities (CERN), the spatial resolution in the bending plane of the tracking chamber is better than the required value (see Fig. 4), with an efficiency of 98% [8].

The muon tracking system consists of \( 10^6 \) channels. The front-end card, so-called MANU
board (64 channels) [9] consist of 4 MANAS chips (pre-amplifier and shaper chip [10]), several ADC’s and the controller chip (Muon Arm Readout Controller) [9]. The latter takes in charge the zero suppression and the communication at the DSP level. The noise level of the full electronics chain is around one thousand electrons. The data flow is gathered with the help of 100 front-end CROCUS board placed in 20 crates. Each crate has its concentrator board CROCUS [9] which communicates with the Alice - DAQ [11].

6. Conclusions and Perspectives
In summary, the muon spectrometer has entered in its construction phase. The passive elements are presently under installation (absorber and dipole). Most of the active elements are under production (RPC, CPC, front-end chips, controller boards) or under final design and/or test (readout boards). And the muon spectrometer should be ready in 2007 at the interaction point 2 of LHC for the first data taking.

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