The ALICE Dimuon Spectrometer

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The Dimuon Spectrometer of the ALICE experiment is presented. The different subsystems are detailed with the final detector choices. Some important results of the R&D are shown. The physics performances are also reviewed.

1. Introduction

The main goal of the ALICE Dimuon Spectrometer is the study of the color screening using the heavy quarks resonances J/ψ and Υ. All the resonances of each family will be studied through their decay into dimuons, as a function of the centrality of the collision. The others kinematics variables (p_T, x_F, ...) will be accessible as well. It is important to note that the $c\bar{c}$ and $b\bar{b}$ pairs will be copiously produced at LHC compared to previous heavy ions accelerators (RHIC and SPS). Typically the number of $b\bar{b}$ ($c\bar{c}$) pairs produced in a central collision will be 6 (200) at LHC ($\sqrt{s}_{nn} = 5.5\ TeV$) compared to 0.05 (10) at RHIC ($\sqrt{s}_{nn} = 200\ GeV$).

To study the behavior of each resonance of the Υ family (Υ,Υ',Υ'') $\sim$100 MeV resolution is required for the dimuon invariant mass.

2. Setup

The Dimuon Spectrometer is located in the forward part of the ALICE detector, covering an angular region of $2^o < \theta < 9^o$, corresponding to a pseudo-rapidity of $2.5 < \eta < 4$ [1]. It is mainly composed of several absorbers, a dipole magnet, a trigger system and a tracking system (fig. 1).

2.1. The absorbers

The main goal of the absorbers is to protect the detectors against the flux of hadrons, electrons and γ's. There are 3 absorbers in the Dimuon Spectrometer. The front absorber ($\lambda_I \simeq 10$) located close to the target, the beam shield located around the beam pipe and the muon filter (iron wall of $\lambda_I \simeq 7.2$) located in front of the trigger chambers. Extensive simulations have been done to optimize the final composition of the absorbers using GEANT and Fluka codes. The noise has been simulated with HIJING using $dN_{ch}/dy = 6000$ with an additional security factor of 2. The particles densities in the chambers range from 5 10^{-2} cm^{-2} for the first tracking station, down to 1.5 10^{-3} cm^{-2} for the trigger stations. The design of the absorbers is now final and the start of construction is foreseen for 2003.

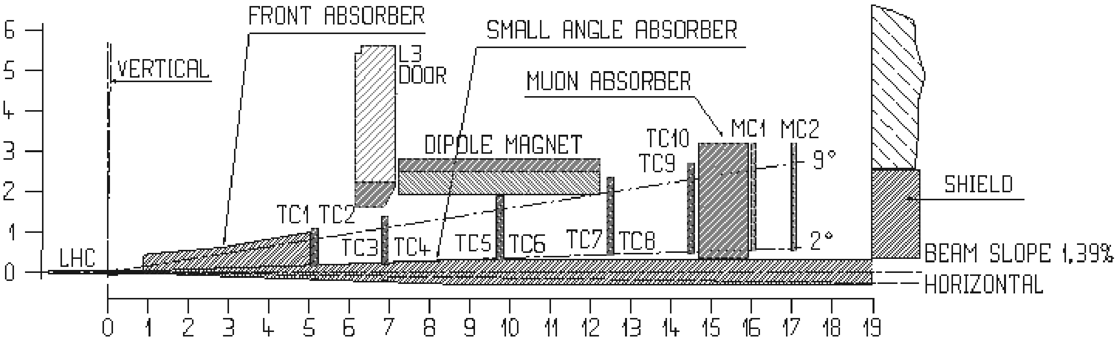

Figure 1. The Dimuon Spectrometer setup.

2.2. The dipole magnet

A warm dipole of 820 Tons is used to measure the muons momenta. The nominal field is 0.7 T and the field integral is $\int Bdl \simeq 3\ Tm$. A water cooling is used to cope with the 3.5 MW dissipated. The iron yoke is under production in Russia. The coils will be produced in the industry in France, where a first pancake assembly (14 turns) was successfully assembled. The final assembly at CERN is foreseen in 2003.

2.3. The trigger system

The trigger requirements are : rate capability of 3, 10 and 40 Hz/cm^2 for Pb-Pb, p-p and Ca-Ca, a time resolution of few ns, a small cluster size (close to 1 to limit the occupancy and increase the selectivity). We have to be able to strobe the LHC clock signals in a 20 ns time window.

The final detector choice is the Resistive Plate Chambers (RPC) operated in the streamer mode with a low resistivity electrodes ($\rho \simeq 10^9\ \Omega cm$). A total of 4 planes of 18 single gaps RPC's will be used to cover the acceptance. A gas mixture of Ar, $C_2H_2F_4$, C_4H_{10}, SF_6 will be used. The electronics is based on a dual threshold discriminator called ADULT which allows a time resolution below 2 ns. The total decision time is < 700 ns. Different types of triggers are possible : low (1 GeV)/high (2 GeV) p_T, like/unlike sign, single muon.

An important R&D program has been setup to test and control the aging of the RPC's [2]. Several parameters have been tested so far : gas composition, electrodes resistivity, oil coating, etc. One of the most important results obtained at GIF (^{137}Cs source) at CERN is the stability of the dark current as a function of time (fig. 2) which guarantee a good detector response for more than 30 years of LHC operation. It appears also that the double linseed oil coating is better than the single one. The detector production will begin in 2003.

2.4. The tracking system

The tracking system is made of 5 stations of 2 Cathode Pad Chambers (CPC) each (fig. 1). A spatial resolution of 100 μm is required in the bending plane (vertical) to achieve the mass resolution of 100 MeV for the Υ family, while in the non-bending plane (horizontal)

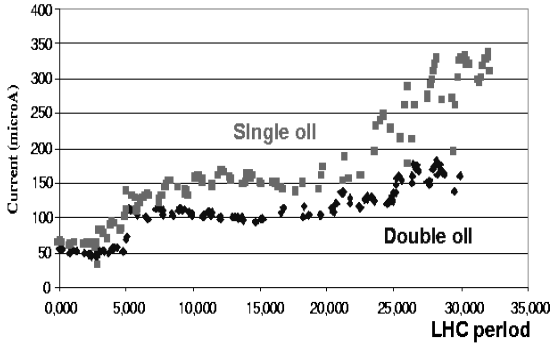

Figure 2. Current as a function of the number of years of operation. Double coated oil and single coated oil are shown.

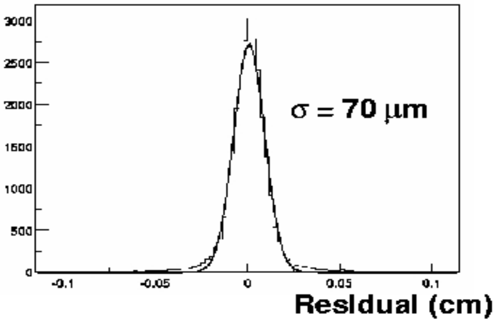

Figure 3. Typical CPC residual spectrum showing a spatial resolution of 70 μm.

$\simeq$ 1 mm is good enough. The thickness of each chamber is required to be below 3% of radiation length. The particles coming from the hadronic noise, which reach a maximun of 5 10^{-2} particles/cm^2 for the inner part of the Station 1, varies with the distance to the beam pipe (higher for low radius) requiring an adequate pad segmentation of each chamber. A maximun of 5% pad occupancy in each tracking plane is then obtained.

The first 2 stations have a modest size (radius $\sim$ 1m) with a high granularity then a quadrant design has been adopted. On the contrary, the stations 3 to 5 are larger (up to 5 m high) with a modest granularity which requires a modular design. In the last case, each chamber is made of horizontal modules, called *slats*, of different sizes, that are precisely positioned on a common support. The pad size ranges from 4x6 mm^2 for the smallest pads of the Station 1 up to 5x100 mm^2 for the largest pads of the Stations 3, 4 and 5. The chamber gap is 5 mm except for the Station 1 (4 mm). The wire pitch is equal to the half gap for all the stations and the gas used is an Ar (80%) CO_2 (20%) mixture.

Several years of test beam have been done to validate the design of all the chambers. Among all the results obtained (see for instance [3] [4]) we can show some of the most significant ones. For instance fig. 3 shows a residual spectrum obtained for a 2.4 m long slat in a test-beam in 2001, while fig. 4 shows the efficiency and the resolution as a function of the high voltage for a prototype of the Station 1 tested in 2000. The final validation of the design of all the chambers will be done by the end of 2002 and the beginning of the production is foreseen in 2003.

3. Physics performances

A set of different colliding system will be covered by the LHC: Pb-Pb, Ca-Ca, p-p and p-N, giving access to a complete study of the collision dynamics for the different signals. The expected statistics obtained for the resonances in the most central (10%) Pb-Pb collisions per year can be evaluated using a luminosity of $L = 5\ 10^{26}\ cm^2 s^{-1}$ (half of the nominal), a 10^6 s running time (1 month data taking) and one sigma cut in the

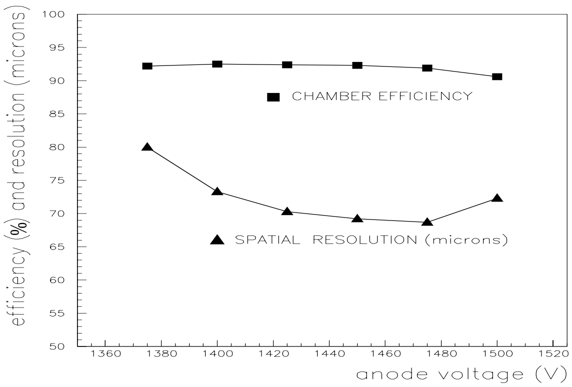

Figure 4. Efficiency and resolution plateau for a Station 1 prototype.

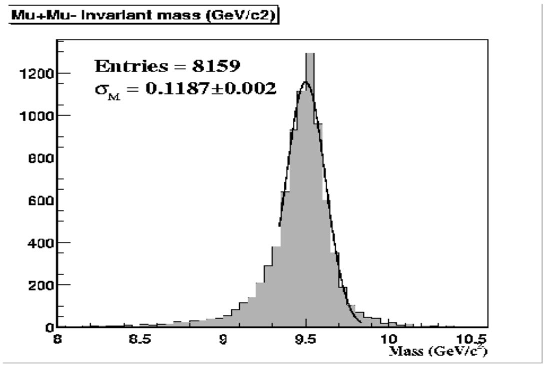

Figure 5. Υ mass resolution. A single Gaussian fit is done in the mass interval [9.2 , 9.8] GeV/c^2.

mass spectra. We obtained $\sim 230000 J/\psi$ and $\sim 2000\Upsilon$ with a signal over background ratio of 0.7 and 7.1 respectively. The statistics will be significantly higher for the Ca-Ca collisions, since the luminosity expected is bigger by 2 orders of magnitude.

The Dimuon Arm performance has been evaluated using the general ALICE simulation program AliRoot, an object oriented ROOT based program coded in C++. The reconstruction efficiency obtained for the Υ is 71% and the invariant mass resolution $\simeq 118$ MeV/c^2. The tail on the left of the mass spectrum is due to the energy loss straggling in the front absorber. It is important to note that these results are obtained using a high noise level with a security factor of 2 (see. 2.1) which is very pessimistic in the light of the last RHIC results on the particle production [5]. The efficiency and the resolution on the Υ without noise are 80% and 95 MeV/c^2. The optimization of the reconstruction is still in progress to improve these numbers, in particular the cluster fit in the CPC's.

4. Conclusion

A Physics Performance Report (PRR) is under preparation where all the physics topics and the performances will be reviewed in detail. The Dimuon Spectrometer is moving now to the detector production phase.

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