PROCEEDINGS OF SCIENCE

Heavy Ion Physics with the ATLAS Detector

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ATLAS detector is optimized for studies of high-p_T physics in pp collisions at the LHC collider. Preliminary studies show that it is also capable of working in the high multiplicity environment of heavy ion collisions. Available are early measurements of global observables, such as charged particle multiplicity, transverse energy and particle flow, as well as more complex measurements of jet properties and heavy quarkonia production providing crucial information about the properties of matter created in heavy ion collisions at the LHC.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

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PoS(HEP2005)144

1. Introduction

ATLAS is one of several experiments to be performed at the new LHC accelerator at CERN. The LHC will collide most of the time protons but during one month in a year it will collide also beams of heavy ions at the center of mass energy of 5.5 TeV/n (Pb-Pb collisions). Studies of these collisions will be an important extension of the current studies at RHIC, which lead to unexpected discovery of strongly interacting medium created in AuAu collisions at 200 GeV/n by observations of modified properties of particle production in the high-p_T sector and a strong particle flow. ATLAS detector was originally designed for studies of pp collisions, but it has also excellent properties for measurements of high-p_T particles thanks to its hermetic, high resolution calorimetry and large acceptance Muon Spectrometer [1]. This triggered a full evaluation of ATLAS prospects for doing heavy ion physics and the promising results were presented in the Letter of Intent [2] to the LHC Committee.

In this paper we present a short summary of results from these studies. We analysed PbPb collisions generated in a full range of impact parameters using Hijing program and the GEANT3 detector simulation. The maximum charged particle density, $dN_{ch}/d\eta$ was 3200, which is rather an upper limit of the expected values. At this high particle density, TRT detector can not be used with the standard reconstruction algorithm due to a high occupancy. However even without this detector, track reconstruction in the Inner Detector is still performed with a good efficiency of 70% and low fake rate of the order of 5% [2].

2. Global observables

First runs with heavy ion collisions are expected early in 2008. Measurements of global observables, like charged particle multiplicity (N_{ch}), charged particle density ($dN_{ch}/d\eta$) and transverse energy flow will be possible right from the first days of collisions. They are based on simple properties of detector occupancy and energy deposits from produced particles and accuracy of reconstruction is typically below 3-5% in all except the most peripheral events. Results of the reconstruction of charged particle multiplicity and particle density has been presented in [2].

A very important measure of thermodynamic properties of medium created in heavy ion collisions is collective particle flow. In our reconstruction of the elliptic flow [3] we determine position of the reaction plane from the distribution of signals in the Forward Calorimeter. The value of elliptic flow is then calculated from the position of signal clusters in the first layer of Pixel detector. The result for v_2 as a function of N_{ch} and pseudorapidity η is shown on Fig.1. Compared with MC truth a small, 10% difference is seen which will be accounted for by the final MC correction.

3. Jet studies

In the dense partonic medium created in heavy ion collisions the effect of jet quenching is expected to modify jet properties leading to a broader angular distribution and suppression of high-z ($z=p_{had}/p\,jet$) hadrons from the jet fragmentation [4]. The details of jet quenching will be easier studied at the LHC than at RHIC, due to high rates of jet events, expected at the level of $30*10^6$ per month for jets with transverse energy $E_T > 50$ GeV. Performance of the current, not fully optimized

ATLAS jet reconstruction is shown in Fig. 2. It works from $E_T \geq 40$ GeV, but high efficiency of 95%, low rate of fakes below 5% and good energy resolution of better than 15% is achieved for jets with $E_T > 75$ GeV. Also direct measurements of jet profiles have been studied. It seems feasible to achieve sensitivity of 10% for the fractional energy loss for 100 GeV jets in PbPb collisions.

4. Heavy Quarkonia Suppression

It is predicted that production of heavy quarkonia will be suppressed in the deconfined medium due to the color screening effect [5]. Quarkonia with different binding energies will dissociate at different temperatures so it is important to resolve excited states within Υ and J/Ψ families. In ATLAS we can reconstruct quarkonia via their decays into muon pairs. In order to assure high resolution of muon momentum determination and mass of quarkonia states we match tracks from Muon Spectrometer with tracks reconstructed in the Inner Detector. We use two algorithms, of which first is more selective and accepts only tracks fully traversing muon spectrometer, while the second one works only with track segments, increasing acceptance of reconstruction and extending p_T spectra towards lower values. In the current reconstruction method we use pairs of muons, of which at least one has been found using the first, low background method. In case of Υ reconstruction with muon acceptance limited to $|\eta| < 2$, the obtained mass resolution of 145 Mev is good enough to resolve between Υ and Υ' states. This is illustrated in Fig.3. The expected statistics accumulated during one month is high, $1.5*10^4$ events, when $p_T^\mu > 3$ GeV cut is used. For J/Ψ quarkonia we lower the threshold to $p_T^\mu > 1.5$ GeV. In this way we assure reconstruction of J/Ψ particles in a full range of transverse momenta and the efficiency is increased by a factor of 10, so that 10^5 J/Ψ's per month are expected. The mass resolution is very good at 68 MeV and the signal to background ratio of 0.15 is acceptable, see Fig.4.

5. Conclusion

ATLAS detector is optimized for studies of pp collisions but its performances are not significantly deteriorated in heavy ion runs. A variety of global event measurements is possible on small collision samples which will be available soon after the beginning of the LHC heavy ion operations. Jet reconstruction is possible even at relatively low jet transverse energy, but high efficiency and low rate of fake jets is achievable only at $E_T > 75$ GeV. Reconstruction of both Υ and J/Ψ quarkonia is possible with good precision and high statistics and their excited states can be separated. This proves that ATLAS has a good potential for making a valuable and significant contribution to the LHC heavy-ion physics programme.

References

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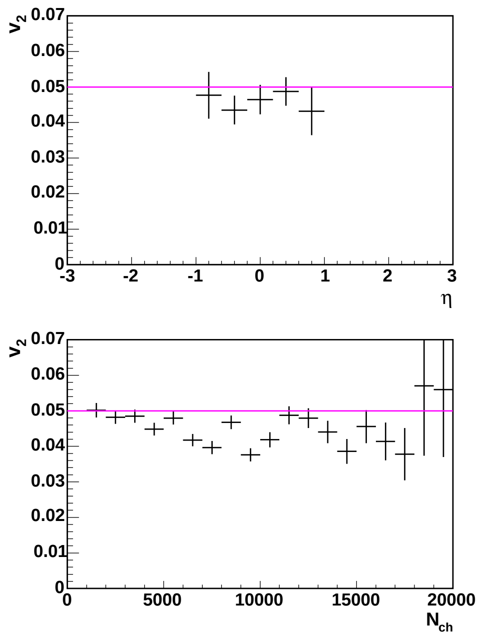

Figure 1: Reconstructed elliptic flow v_2 as a function of pseudorapidity, η (top panel) and charged particle multiplicity, N_{ch} (bottom panel). The lines correspond to generated values.

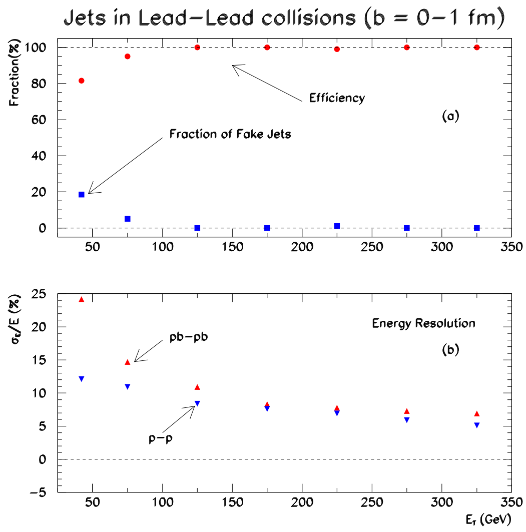

Figure 2: Reconstruction effi ciency and percentage of fake jets (top panel) and energy resolution (bottom panel) as a function of jet transverse energy, E_T.

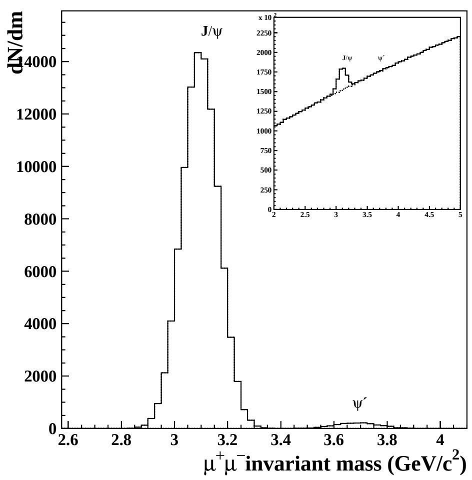

Figure 3: Reconstructed $\mu^+\mu^-$ invariant mass distribution in the region of J/Ψ state, with background (in the inset) and without background.

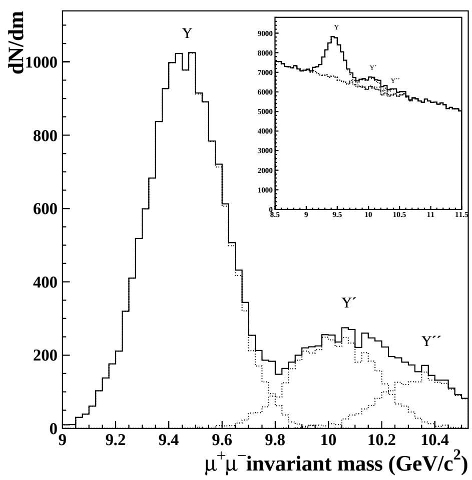

Figure 4: Reconstructed $\mu^+\mu^-$ invariant mass distribution in the region of ϒ state, with background (in the inset) and without background.