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Heavy Ion Physics with the ATLAS Detector at the LHC

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The heavy-ion program at the LHC will be pursued by three experiments including ATLAS, a multipurpose detector to study p+p collisions. A report on the potential of the ATLAS detector to uncover new physics in Pb+Pb collisions at energies thirty times larger than energy available at RHIC is presented. Key aspects of the heavy-ion program of the ATLAS experiment, with the emphasis on extending measurements from RHIC, are discussed. They include measurement capability of high-p_T hadronic and electromagnetic probes, quarkonia as well as elliptic flow and other bulk phenomena. Measurements by the ATLAS experiment will provide crucial information about the formation of a quark-gluon plasma at the new energy scale accessible at the LHC.

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1. Introduction

An increase in collision energy of heavy nuclei at RHIC has resulted in many unexpected discoveries in heavy ion physics. In particular, a feasible connection between the strongly interacting Quark Gluon Plasma (QGP) and the string theory has emerged. In the coming years, a new regime in physics of heavy ion collisions will be explored by the LHC, reaching a much higher collision energy, up to 5.5 TeV in the nucleon-nucleon center-of-mass system, than RHIC. The first insight into the dynamics of the hot and dense medium created at the LHC will be provided by measurements of global variables like charged particle multiplicity, N_{ch}, total transverse energy, E_{T}, or elliptic flow, v_2. In particular, the global observables will characterize properties of the initial state of nuclear interactions, including the energy and gluon density. Detailed information on the hot and dense medium will be obtained by measurements of high energy photons and jets. It is expected that reconstruction of high energy partonic jets will provide excellent handle on energy loss processes and allow the exploration of the properties of the QGP. Additionally, measurement of quarkonia suppression will test QCD deconfinemet and will allow the study of color screening in the QGP. All these variables and actually many more will be measured by the ATLAS experiment [1].

A unique capability of the ATLAS detector [2] is its full azimuthal acceptance and a large coverage in pseudo-rapidity (η). The tracking detectors measure charged particles, including muons, in about 5 units of pseudo-rapidity. The electromagnetic calorimeter, with the very finely segmented in η ($\sim$0.003) first layer, is particularly useful for photon identification in Pb+Pb collisions [3]. The full calorimeter system covers 10 units in pseudo-rapidity and it is an ideal detector for high-energy jet measurements [4]. At present, the ATLAS detector is fully completed and well prepared for the first p+p collisions at the end of 2009 and for the first Pb+Pb collisions at the end of 2010. In particular, ATLAS gained a lot of experience and showed excellent performance during the Single Beam and Combined Cosmic Runs in 2008 and 2009.

2. Global observables

One of the most important observables in heavy ion physics is the charged particle multiplicity. The extrapolation from AGS, SPS and RHIC data and theoretical predictions are quite divergent at the LHC energy [5]. Therefore, the "day 1" measurement of N_{ch} at the LHC will provide a strong constraint on theoretical models. In one approach to measure N_{ch}, with ATLAS, it is assumed that the particle multiplicity is proportional to the number of silicon hit clusters in the Pixel detector. As one can see in Fig.1, this method provides a good estimate of the event-by-event multiplicity in central Pb+Pb collisions. Additionally, a method was developed to estimate the total transverse energy using signals in all calorimeter cells [6]. This method well reproduces the total transverse energy flow over 10 units of pseudo-rapidity in central Pb+Pb collisions (see Fig.2).

As we learned from RHIC, large azimuthal anisotropy of produced particles is an important signature of the strongly interacting QGP. Based on Monte Carlo studies it was found that ATLAS has an excellent performance to measure v_2 using reconstructed tracks, hits from the inner tracking detector and signals from the first layer of calorimeter detectors. As shown in Fig.3, the input elliptic flow is well reproduced with the reaction plane, two-particle correlation and the Lee-Yang-Zeroes methods [6]. Using different methods of v_2 determination allows for systematic control of non-flow effects which distort elliptic flow measurements in Pb+Pb collisions.

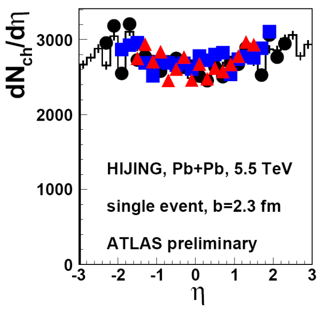

Figure 1: The generated (line) and reconstructed $dN_{\rm ch}/d\eta$ of a single central Pb+Pb event in the 1st (circles), 2nd (squares) and 3rd (triangles) layer of the Pixel detector.

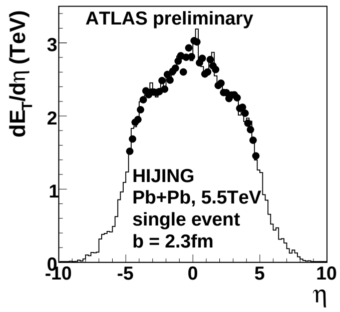

Figure 2: Reconstructed (circles) and generated (line) $dE_{\rm T}/d\eta$ in a single central Pb+Pb collision.

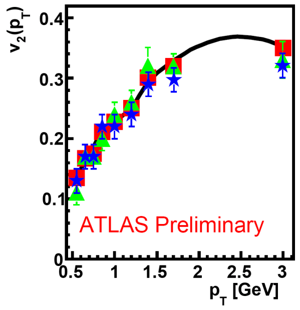

Figure 3: $v_2(p_{\rm T})$ from reaction plane (squares), two-particle correlation (stars) and Lee-Yang-Zeroes (triangles) methods compared to the generated v_2 (line).

3. High energy jets and photons

Detailed properties of the hot and dense medium are provided by measurements of particles with high transverse momenta. At RHIC, jet quenching is mostly studied by leading particle measurements. At the LHC, with the $p_{\rm T}$ reach extended by an order of magnitude, high energy jets will be the ideal probe to study parton energy loss processes ($\sim$20 million jets with $E_{\rm T} > 80$ GeV is expected to be measured in one month of Pb+Pb running [7]). ATLAS capability to measure jet spectrum in central Pb+Pb collisions was studied previously [4]. A comparison of input and reconstructed cone (R=0.4) jet spectra for Pb+Pb events with $dN_{\rm ch}/d\eta = 2650$ is shown in Fig.4. As one can see, even without correcting the spectra for efficiency and energy resolution, the reconstructed jet spectrum matches the input yield quite well at $E_{\rm T} > 70$ GeV.

Another interesting tool to study in-medium parton energy loss processes is provided by measurement of prompt photons. Fig.5 shows the ATLAS performance to measure the direct photon spectrum for central Pb+Pb collisions after subtracting the hadronic decay background, for data collected in one month of Pb+Pb running at the nominal luminosity (0.5 nb^{-1}, $\sim$200k direct photons of $E_{\rm T} > 30$ GeV is expected to be measured) [3].

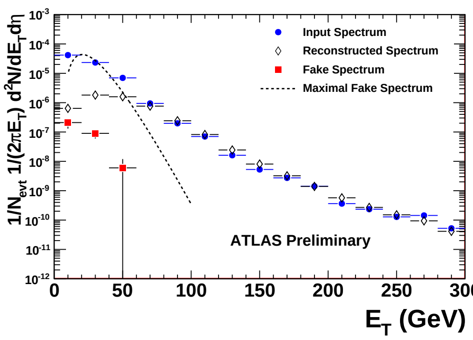

Figure 4: Input (filled circles) and reconstructed (diamonds) spectra for cone jets in central ($dN_{\rm ch}/d\eta = 2650$) Pb+Pb collisions. Squares and dashed line illustrate fake jet spectra with and without fake rejection cut applied.

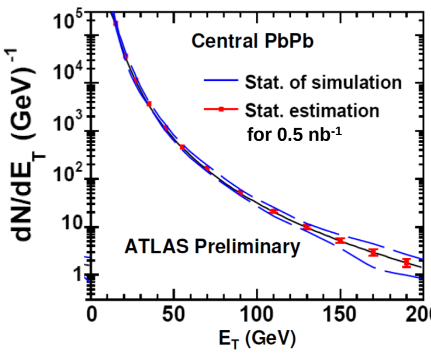

Figure 5: Reconstructed direct photon spectrum for central Pb+Pb collisions. Statistical errors correspond to one month of Pb+Pb running at nominal luminosity. The dashed lines show the statistical uncertainty due to the simulation [3].

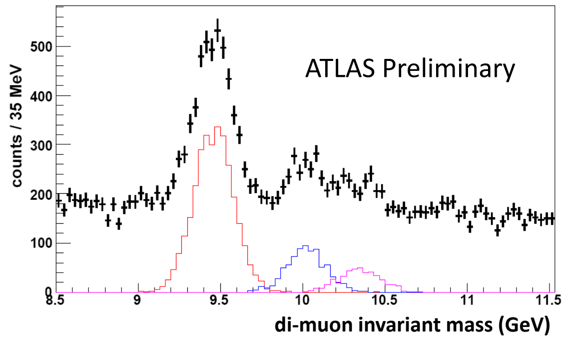

Figure 6: Di-muon invariant mass distribution as expected for one month of Pb+Pb running, taking into account acceptance, efficiency and background contribution, for decay muons in the barrel region only ($|\eta| < 1$). Error bars show statistical errors only. Solid color histograms illustrate expected yields from Υ, Υ' and Υ'' states, and points show the sum of signal and background.

4. Quarkonia

Quarkonia suppression is an important signature of the QGP because it is expected that color screening in the QGP prevents formation of various quarkonia states. Particularly interesting is the Υ family whose states have different dissociation temperatures. Thus, it is very important to have a good capability to measure Υ and Υ' separately in Pb+Pb collisions [8]. Fig.6 shows the ATLAS performance to measure di-muon invariant mass distribution for Υ family states expected for one month of Pb+Pb running at nominal luminosity. Different sources of background including muons from open charm and beauty, muons from hadron decays, as well as calorimeter punch-through hadrons are taken into account. As one can see, the obtained mass resolution of 120 MeV is sufficient to separate Υ and Υ' states.

5. Summary

Detailed studies have shown that the ATLAS detector, primarily designed to measure p+p interactions, has also a high potential to uncover new physics in heavy ion collisions. In particular. ATLAS has excellent capability to measure bulk properties, inclusive jet and direct photon spectra and quarkonia suppression. The p+p data, which comes first, will not only allow for detailed testing of different methods used to analyze “day 1” heavy ion collisions but also will serve as a valuable reference for Pb+Pb results.

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References

[1] The ATLAS Collaboration. *Heavy Ion Physics with the ATLAS Detector*, LHCC 2004-009/1-013.

[2] The ATLAS Collaboration, G. Aad *et al*, *JINST* **3** (2008) S08003.

[3] The ATLAS Collaboration, M. Baker *et al*, ATL-PHYS-PROC-2009-059.

[4] The ATLAS Collaboration, N. Grau *et al*, ATL-PHYS-PROC-2008-055.

[5] P. Steinberg, Nucl. Phys. **A827** (2009) 128c.

[6] The ATLAS Collaboration, A. Trzupek *et al*, ATL-PHYS-PROC-2009-021.

[7] A. Accardi *et al*, CERN Yellow Report CERN-2004-009, [hep-th/200310274].

[8] The ATLAS Collaboration, L. Rosselet *et al*, J. of Phys.: Conference Series **110** (2008) 032015.