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The Compact Muon Solenoid Experiment

Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

26 May 2009 (v2, 27 May 2009)

Quarkonium studies in p+p and Pb+Pb collisions with CMS

T. Dahms

Abstract

The collisions of Pb nuclei at the LHC will create strongly interacting matter at unprecedented energy densities, allowing us to probe QCD at extreme temperatures and very low parton momentum fractions. This paper presents the capabilities of the CMS experiment to study the production of quarkonium states in $p + p$ and Pb+Pb collisions. The very good acceptance and excellent dimuon mass resolution will allow us to do with the three Υ states (1S, 2S, 3S) the exciting measurements previously performed with the J/ψ and ψ' states, at the SPS and RHIC.

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Abstract

The collisions of Pb nuclei at the LHC will create strongly interacting matter at unprecedented energy densities, allowing us to probe QCD at extreme temperatures and very low parton momentum fractions. This paper presents the capabilities of the CMS experiment to study the production of quarkonium states in $p + p$ and $\mathrm{Pb} + \mathrm{Pb}$ collisions. The very good acceptance and excellent dimuon mass resolution will allow us to do with the three Υ states (1S, 2S, 3S) the exciting measurements previously performed with the J/ψ and ψ' states, at the SPS and RHIC.

Presented at the *XLVII International Winter Meeting on Nuclear Physics*, Bormio, Italy, January 28, 2009

Preliminary version

1 Introduction

The goal of the SPS, RHIC, and LHC heavy ion programmes is to create a state of deconfined quarks and gluons, the quark-gluon plasma (QGP). In such a state it was predicted [1] that quarkonium production is suppressed by Debye screening of the heavy quark binding potential. Therefore, the observation of such suppression is considered one of the most promising signatures of the creation of the QGP.

In contrast to SPS and RHIC energies, at the LHC the production rates of $b\bar{b}$ bound states such as the $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ are large enough for quantitative measurements and CMS will be able to reconstruct their dimuon decays with a very good acceptance and mass resolution. The corresponding cross section measurements in $p + p$ collisions will not only serve as "references" for heavy ion collisions, but are interesting by themselves as current theoretical models fail to consistently describe all aspects of quarkonium production in hadron collisions. For a review of quarkonium production, see e. g. Ref. [2].

2 Quarkonium measurements with CMS

The Compact Muon Solenoid (CMS) is a general purpose detector with full azimuthal coverage which measures roughly 22 m in length and 15 m in diameter. Closest to the interaction point is located the high-granularity silicon tracker consisting of several layers of pixel and micro-strip detectors with analogue readout, which measure the trajectories of charged particles over the pseudorapidity range $|\eta| < 2.4$, in a magnetic field of 4 T, generated by a superconducting solenoid. Between the tracker and the solenoid, electromagnetic and hadronic calorimeters measure the energies of photons, electrons, and hadrons. The outermost detectors, the muon chambers, are used for muon tracking and triggering, covering a pseudorapidity range of $|\eta| < 2.4$. They comprise drift tube chambers in the barrel and cathode strip chambers in the endcap, in combination with resistive plate chambers interspersed by the iron return yoke. A detailed description of the CMS detector can be found in Ref. [3].

Muons are reconstructed combining information from the muon chambers and the silicon tracker. Tracks reconstructed in the muon chambers are used as seeds to search for tracks in the silicon tracker and for the best match a combined fit of both track segments is performed.

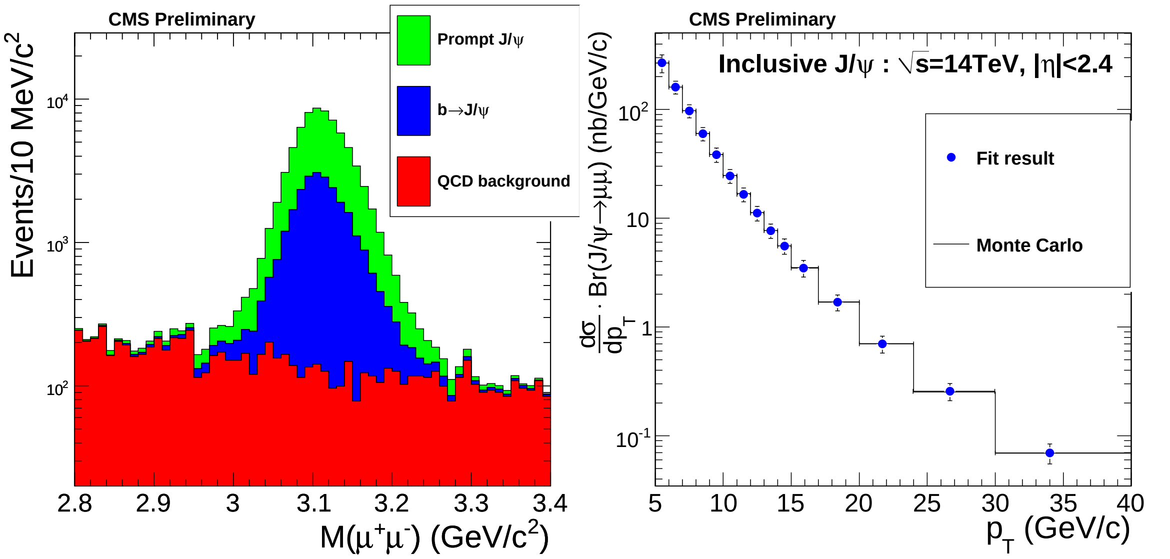
2.1 J/ψ cross section measurements in $p + p$ collisions

J/ψ hadroproduction consists of three contributions: direct J/ψ production, prompt decays of excited states and non-prompt J/ψ's from B hadron decays. CMS will be able to measure prompt and non-prompt contributions to the differential J/ψ cross section, as well as the J/ψ polarization.

The $J/\psi \to \mu^+\mu^-$ decay channel will be the preferred channel for the J/ψ reconstruction in CMS. Figure 1a shows the expected dimuon invariant mass distribution around the J/ψ resonance peak from the contributions of prompt and non-prompt J/ψ and QCD background to the dimuon spectrum [4]. The J/ψ width increases from ~ 15 MeV/c^2 at midrapidity to ~ 40 Mev/c^2 at forward rapidity due to the rapidity dependent momentum resolution of single muons. The differential cross section of inclusive J/ψ production is obtained fitting the dimuon mass spectrum with a double Gaussian for the signal and a linear function for the background. The simulated result is shown in Figure 1b for an integrated luminosity of 3 pb^{-1}, when 75 000 J/ψ should have been reconstructed [4]. The non-prompt contribution to the inclusive J/ψ cross section can be separated via the measurement of the secondary vertex. Feed-down contributions from higher states contributing to the prompt J/ψ signal should be subtracted using direct measurements (for instance, the χ_c should be seen via its radiative decay $\chi_c \to J/\psi\gamma$).

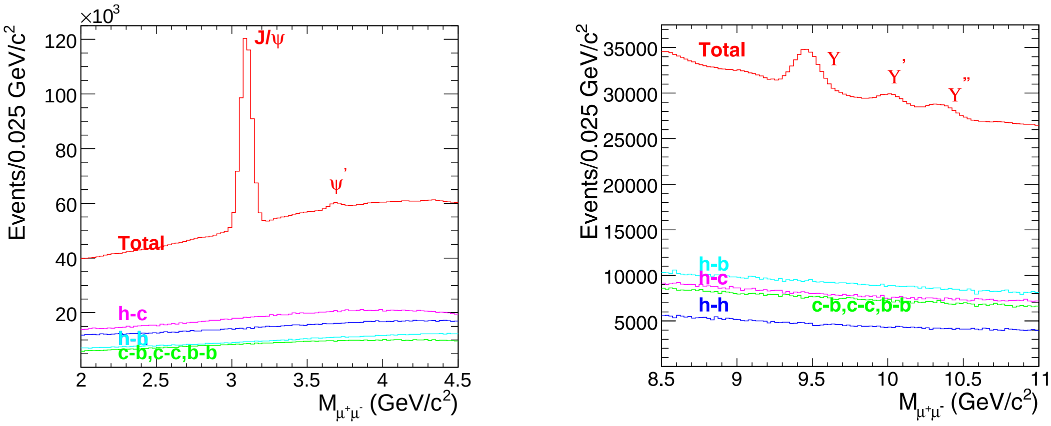
2.2 Quarkonium measurements in heavy ion collisions

CMS has also studied the reconstruction of quarkonia in $\mathrm{Pb} + \mathrm{Pb}$ collisions at $\sqrt{s_{NN}} = 5.5$ TeV [5]. The expected dimuon invariant mass spectra around the J/ψ and Υ mass ranges are shown in Figure 2 for an integrated luminosity of 0.5 nb^{-1} and a charged particle density of $dN_{\mathrm{ch}}/d\eta\big|_{\eta=0} = 2500$. The very good mass resolution of ~ 90 MeV at $m_{\mu\mu} \sim 10$ GeV over the full pseudorapidity range of $\eta < 2.4$ will allow us to individually measure the bottomonium states $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$. This should allow us to observe successive suppression patterns of the three Υ states, with increasing centrality, as expected if a QGP is formed.



(a) (b)

Figure 1: Left: Dimuon mass distribution for $p + p$ collisions at $\sqrt{s} = 14$ TeV, normalized to an integrated luminosity of 3 pb^{-1}. Separated are the contributions of prompt *(green)* and non-prompt *(blue)* J/ψ decays, as well as the QCD background *(red)*. Right: The corresponding inclusive J/ψ cross section as function of p_T.



(a) (b)

Figure 2: Dimuon mass distribution in the J/ψ (left) and Υ (right) mass regions, for $\mathrm{Pb}+\mathrm{Pb}$ collisions at $\sqrt{s} = 5.5$ TeV, normalized to an integrated luminosity of 0.5 nb^{-1}, for an expected charged particle density of $dN_{\mathrm{ch}}/d\eta|_{\eta=0} = 2500$.

3 Summary

In this paper we presented a very brief summary of quarkonium production studies which CMS will be able to perform during early $p + p$ and $\mathrm{Pb}+\mathrm{Pb}$ collisions at the LHC. More of these studies are ongoing and first collisions at the LHC are eagerly awaited in late 2009.

References

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