Study of strongly interacting matter using dimuons produced in Pb+Pb collisions at 2.76 TeV with CMS experiment

Vineet Kumar[1,2*]
[1] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[2] *Homi Bhabha National Institute, Anushaktinagar, Mumbai- 400094, INDIA*

The deconfinement transition and the properties of hot, strongly-interacting matter can be studied experimentally in heavy-ion collisions. A significant part of the extensive experimental heavy-ion program is dedicated to measuring quarkonium yields, since quarkonium suppression could be a direct signal of deconfinement. However, not all of the observed quarkonium suppression in nucleus-nucleus collisions is due to quark gluon plasma formation. In fact, quarkonium suppression was also observed in proton-nucleus collisions, so that part of the nucleus-nucleus suppression is due to cold nuclear matter effects. Therefore it is necessary to disentangle hot and cold medium effects.

This thesis concentrate on production and suppression of $b\bar{b}$ bound states, namely Υ(1S), Υ(2S) and Υ(3S) which are measured in pp, pPb and PbPb collisions at LHC. This is the first time we are able to measure all three Υ states separately with good statistics thanks to the large integrated luminosity and high-tech detectors available at LHC.

Υ measurement in pp and PbPb collisions using CMS detector at LHC

The measurement presented here use the PbPb and pp collision data recorded by the Compact Muon Solenoid (CMS) experiment at $\sqrt{s_{NN}}$ = 2.76 TeV. The integrated luminosity used in this measurement corresponds to 7.28 μb^{-1} for Pb-Pb and 225 nb^{-1} for pp collisions. The quarkonium states are identified through their dimuon decay. Muons are reconstructed by matching tracks in the muon detectors and silicon tracker. The momentum resolution of the CMS detector results in well-resolved peaks in the dimuon mass spectrum. Only muons with a transverse momentum (p_T) higher than 4 GeV/c and $\eta \leq 2.4$ are considered. A simultaneous fit to the pp and Pb-Pb mass spectra gives the double ratio $0.31^{+0.19}_{-0.15}(\text{stat}) \pm 0.03(\text{syst})$ [1].

An update of these measurements is performed, utilizing a PbPb data sample corresponding to an integrated luminosity of 150 μb^{-1} collected in 2011 by CMS, at the same center of mass energy. This larger PbPb data set enables the measurement of the centrality dependence of all three Υ states yields. Absolute suppressions of the individual Υ states and their dependence on the collision centrality are studied using the nuclear modification factor, R_{AA}, defined as the yield per nucleon-nucleon collision in PbPb relative to that in pp. The R_{AA} observable,

$$R_{\mathrm{AA}} = \frac{L_{\mathrm{pp}}}{T_{\mathrm{AA}} N_{\mathrm{MB}}} \frac{\Upsilon(n\mathrm{S})|_{\mathrm{PbPb}}}{\Upsilon(n\mathrm{S})|_{\mathrm{pp}}} \frac{\epsilon_{\mathrm{pp}}}{\epsilon_{\mathrm{PbPb}}}$$

is evaluated from the ratio of total $\Upsilon(n\mathrm{S})$ yields in PbPb and pp collisions corrected for the difference in efficiencies $\epsilon_{\mathrm{pp}}/\epsilon_{\mathrm{PbPb}}$, with the average nuclear overlap function T_{AA}, number of minimum-bias (MB) events sampled by the event selection N_{MB}, and integrated luminosity of the pp data set L_{pp} accounting for the normalization.

The results indicate a significant suppression of the $\Upsilon(n\mathrm{S})$ states in heavy-ion collisions compared to pp collisions at the same per-nucleon-pair energy. The data support the hypothesis of increased suppression of less

*Electronic address: `Vineet.Kumar@cern.ch`

strongly bound states. The Υ(1S) is the least suppressed and the Υ(3S) is the most suppressed of the three states. The Υ(1S) and Υ(2S) suppressions are observed to increase with collision centrality [2].

Υ measurement in pPb collisions

To constrain the cold nuclear matter effects production of Υ(1S), Υ(2S) and Υ(3S) is investigated in pPb and pp collisions at center-of-mass energies per nucleon pair of 5.02 TeV and 2.76 TeV respectively. The datasets correspond to recorded integrated luminosities of about 31 nb^{-1} (pPb) and 5.4 pb^{-1} (pp), collected in 2013 by the CMS experiment at the LHC. Upsilons, are studied as a function of two measures of event activity, namely the charged-particle multiplicity measured in pseudorapidity interval $\eta \leq 2.4$, and the transverse energy deposited at large pseudorapidity, $4.0 \leq |\eta| \leq 5.2$.

The Υ yields normalized by their event average, $\Upsilon(n\mathrm{S})/\langle\Upsilon(n\mathrm{S})\rangle$, rise with both measures of the event activity in pp and pPb. In both datasets, the ratios of the excited to the ground state, Υ(nS)/Υ(1S), decrease with the charged-particle multiplicity. The ratios of excited to ground state production show a smaller variation when measured as a function of the transverse energy. The event-activity integrated double ratios, are also measured and found to be 0.83±0.05(stat.)±0.05(syst.) and 0.71±0.08(stat.)±0.09(syst.) for Υ(2S) and Υ(3S), respectively. These double ratios although less than one, are yet well above the ratios measured in PbPb collisions indicating presence of additional final state effects in PbPb collisions. A global understanding of effects at play in pp, pPb and PbPb collisions calls for more activity related study of Υ yields [3].

Theoretical calculations

With the aim of background estimation in dimuon spectrum, we calculate open charm and bottom production and determine their contributions to the dimuon continuum in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with and without heavy quark energy loss. These rates are then compared with Drell-Yan and thermal dilepton production. The contributions of all these sources are obtained in kinematic regions relevant for the LHC detectors. It is found that dileptons from D$\overline{\mathrm{D}}$ decays dominate over the entire mass range due to the large $c\bar{c}$ production cross sectionBottom pair decays are the next largest contribution followed by Drell-Yan production. Thermal dilepton contribution is very small. It can be concluded that measurement of thermal dileptons will be very challenging for the kinematic range relevant to LHC detectors [4].

To understand contribution of different mechanisms responsible for quarkonia suppression, we estimate the modification of quarkonia yields in the medium produced in PbPb collisions at LHC energy. The quarkonia and heavy flavor cross sections calculated upto NLO are used in the study and shadowing corrections are obtained by EPS09 parameterization. A kinetic model is employed which incorporates quarkonia suppression inside QGP due to gluon dissociation, suppression due to hadronic comovers and regeneration from uncorrelated thermal charm quark pairs. The manifestations of these effects in different kinematic regions in the nuclear modification factors for both J/ψ and Υ has been demonstrated for PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV in comparison with the measurements [5].

References

[1] S. Chatrchyan..,V. Kumar *et al.* [CMS Collaboration], Phys. Rev. Lett. **107**, 052302 (2011), [arXiv:1105.4894 [nucl-ex]].

[2] S. Chatrchyan..,V. Kumar *et al.* [CMS Collaboration], Phys. Rev. Lett. **109**, 222301 (2012) [arXiv:1208.2826 [nucl-ex]].

[3] S. Chatrchyan..,V. Kumar *et al.* [CMS Collaboration], JHEP **1404**, 103 (2014), [arXiv:1312.6300 [nucl-ex]].

[4] V. Kumar, P. Shukla and R. Vogt, Phys. Rev. C **86**, 054907 (2012), [arXiv:1205.3860 [hep-ph]].

[5] V. Kumar, P. Shukla and R. Vogt, completed to be submitted.