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M. Bedjidian. $b\bar{b}$ and $c\bar{c}$ resonances detection in Pb-Pb collisions at CMS. International Conference on Physics and Astrophysics of Quark Gluon Plasma (ICPA-QGP) 3, Mar 1997, Jaipur, India. pp.1-658. in2p3-00007474

HAL Id: in2p3-00007474

http://hal.in2p3.fr/in2p3-00007474

Submitted on 3 Nov 1998

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$(b\bar{b})$ and $(c\bar{c})$ resonances detection in Pb-Pb collisions at CMS

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Abstract

The CMS (Compact Muon Solenoid) detector, designed for p-p collisons, is characterized by a very good muon system and a very high quality central tracker. Its use with heavy ion beams is proposed to detect the $(c\bar{c})$ and $(b\bar{b})$ resonant states through their muon decay channel. For this purpose, the advantages of CMS concern the large acceptances and the excellent mass resolution. The efficiencies for tracks reconstruction and vertex finding are estimated. The signal/background ratios are estimated for minimum bias Pb-Pb collisions with the hardest predicted hadronic multiplicity, i.e $dN^{\pm}/dy=8000$. It is shown that these ratios, at least of the order of 1, can be twice higher if the rapidity range detection is restricted to the barrel. The dimuon mass spectra and the expected rates after one month of running time are presented.

III Int. Conf. on Physics and Astrophysics of Quark-Gluon Plasma
Jaipur, India, 17-21 March, 1997

1 - Introduction

At the energies of the future LHC not only J/ψ and ψ' but also the Υ family resonances are accessible to the observation. It is therefore of the greatest interest to study these particles, via their dimuon decays, and look for their possible suppression as it is foreseen[1] if the quark-gluon plasma is formed. The CMS, Compact Muon Solenoid, experimental set-up [2, 3] is optimized for the pp physics goals: a robust muon system which enables the measurement of the particles with a good precision, a performing tracker to reconstruct the muon tracks with an excellent momentum resolution. Figure 1 shows a schematic longitudinal view of the detector.In case of heavy ion collisions, there are some unavoidable constraints:

i- it is necessary to kill the secondary particles, mainly pions and kaons, copiously produced in the collision. They are the main source of background. The multiplicity of charged particles emitted in a central collision and in one unit of rapidity around y=0, which is the principal parameter, is not known at LHC energies but it should range between 3000 and 8000 for a central Pb-Pb collision. In this paper, we consider the highest value which is also the most pessimistic one. In CMS the closest absorber in the barrel region, the electromagnetic calorimeter, is at 1.3m from the vertex. The muon chambers are preceded by $10\lambda_I$ in the barrel, insuring an efficient suppression of the background from the π and kaons decays. However this background suppression is not enough and will be completed by the track reconstruction algorithm.

ii- in order to separate the resonant states and to look for their possible suppression, it is mandatory to obtain a very good dimuon mass resolution. This is in opposition with the presence of an absorber which degrades the resolution by the multiple scattering. This condition is fulfilled by the precise momentum measurement with the inner traker. A σ=40 MeV resolution at Υ mass will be obtained.

iii- Although the Υ production cross-section makes it accessible to the measurement, it is still low. According to some calculations [4] and to the Fermilab results in $p-\bar{p}$ [5] extrapolated to LHC energies and to Pb-Pb collisions, we have assumed an integrated production cross-section for the J/ψ BR$\times\sigma$= 140 mb and $J/\psi/\Psi'$= 1.8 %. For the Υ family we used respectively: Υ:Υ':Υ''= 410:120:41 μb. Therefore a large rapidity range is required. This is the case for CMS which allows to detect the muons in a wide pseudorapidity range, -2.5< η <2.5. This is much larger than other experiments. Even if we limit the detector to the barrel region, about half of the total range is available. Moreover, the 5 units of pseudorapidity around η=0 are well inside the region where the baryon number should cancel, even in the case of a strong stopping power [6].

2 - J/ψ and Υ acceptances

The resonances are generated in (P_T, η) space. The shapes of the distributions are similar to those given by PYTHIA generator except for the P_T of Υ's which are fitted from the CDF experimental result [5]. The accepted events are the resonances for which both muons cross any muon station. We have distinguished two rapidity regions: the barrel with $|\eta| \leq 1.3$, and the full detector, barrel plus the endcaps. Figure 2 shows the acceptance as a function of P_T for J/ψ and Υ in the two rapidity regions. In the case of Υ this dependence is rather flat in both regions. The situation is completely different for the J/ψ which shows a strong suppression in the barrel for the low P_T, below 6 GeV/c. This discrepancy between J/ψ and Υ comes from their rest mass difference. The muons from J/ψ decay have not a sufficiently high P_T to reach

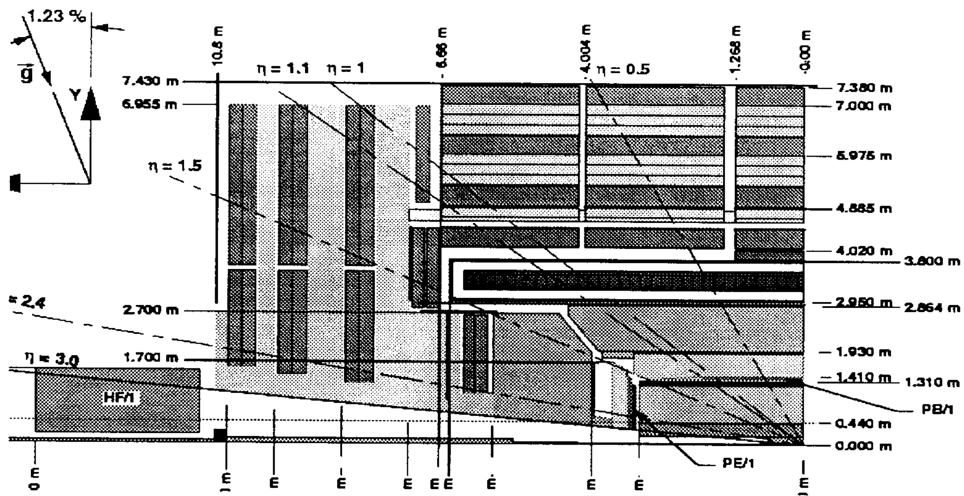

Figure 1: Schematic longitudinal view of CMS

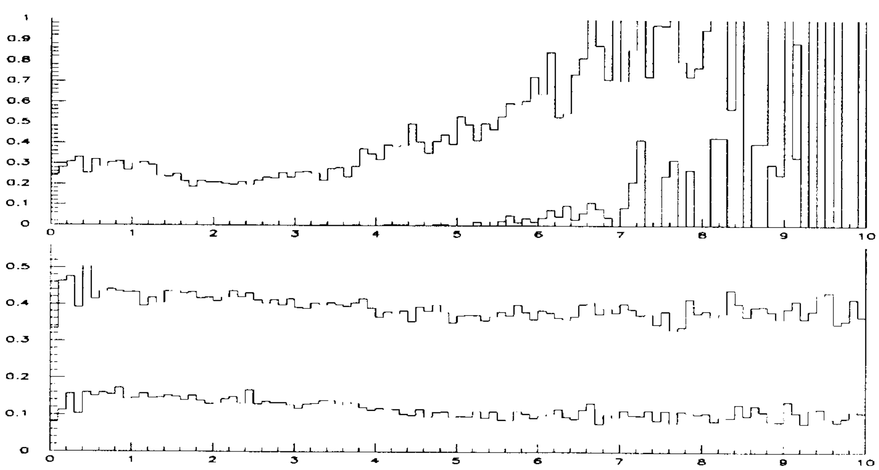

Figure 2: Acceptance as a function of P_T for J/ψ (up) and Υ (down), in the full detector (upper curve) and in the barrel (lower curve).

Table 2. Efficiencies and purities for different sets of background multiplicity and for dimuons originating from Υ and π/K

$dN^{\pm}/dy$	8000		2500	
Dimuon origin	Υ	π/K	Υ	π/K
efficiency (%)	66	11	88	16
purity (%)	97		99	

Table 1. Integrated acceptances

	J/ψ	Υ
full detector	7 %	39 %
barrel region	0.07 %	12 %

the muon stations. The P_T threshold at η=0 is ≈3 GeV/c. The analysis of the low P_T J/ψ will be possible only in the endcaps parts. Table 1 gives the integrated acceptance values.

3 - Reconstruction and background suppression

The $10\lambda_I$ material before the muon chambers in the barrel region prevents the low P_T tracks to reach the chambers. The threshold is ≈3 GeV/c. In our simulations we considered the secondaries as only made of pions and kaons, in the proportion K/π= 20% independently to the strength of the collision, with P_T distributions given by SHAKER [7] based on the results of CDF [8]. The average generated P_T values are:

$$< P_T^{\pi} >= 460 MeV/c \quad and \quad < P_T^{K} >= 660 MeV/c$$

The probability that a pion with $P_T > 3$ GeV/c decay into a detected muon is of the order of 10^{-4}. This rejection factor is not enough to limit the background level under the resonances. An additional rejection is obtained by the algorithm of reconstruction of the dimuon. This algorithm [9] has been built using GEANT to track the hadrons in the inner tracker of CMS. For this study, limited for the moment to the rapidity region $|\eta <|0.8$, we supposed that only 6 points of measurement can be used together with 2 muon chambers informations: 1 hit in each pixel plane and 4 in the outermost MSGC. The signal dimuon is superimposed to the background tracks. Several sets of hadronic multiplicity and type of dimuon were used. A set corresponding to a central Pb-Pb collision with 8000 charged particles per unit of rapidity, and a set corresponding to an average collision, i.e. "min. bias" Pb-Pb collision with 2500 particles/Δy=1. After digitization and clusterization, the tracks are chosen within $(\Delta\Phi, \Delta P_T)$ roads and submitted to helix fit. At the end of the process a vertex constraint is applied to the pair of candidate tracks. This last selection rejects mostly background pairs. The corresponding efficiencies and purities are summerized in table2. Whatever is the hadronic multiplicity there is a factor 6 in the efficiencies to reconstruct the Υ relatively to an opposite sign background pair.

4 - Dimuon mass spectra

We have studied Pb-Pb collisions at various impact parameters. We have also distinguished two possibilities for the CMS geometry: the barrel region alone and the total CMS detector

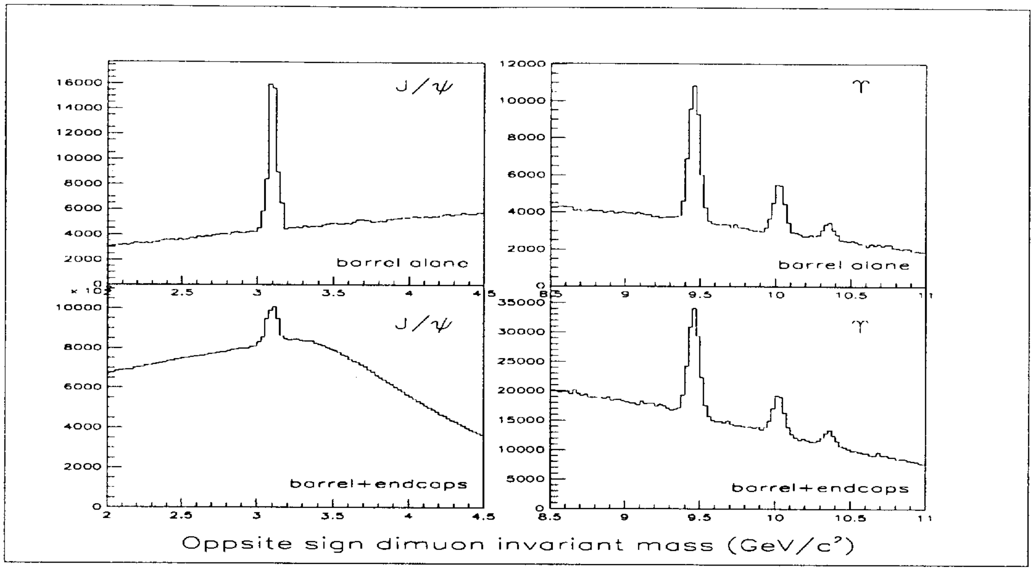

Figure 3: Pb-Pb min.bias collisions: the invariant dimuon mass spectra after one month run. On the left for the J/ψ mass region and detection in the barrel (up) and in full detector (down), On the right for the Υ mass region

Table 3. Signal/background ratios and significances together with the available statistics in 1 month with Pb beam in full CMS (left table) and in barrel (right table)

full CMS	J/ψ	Υ	Υ'
statistics	580000	55000	20000
S/B	0.17	0.8	
$S/\sqrt{(S+B)}$	290	150	

barrel region	J/ψ	Υ	Υ'
statistics	31000	23000	8300
S/B	1.8	1.6	
$S/\sqrt{(S+B)}$	140	120	

including the endcaps. The efficiencies used at this moment were different to those shown in table 2: instead of 88 % for a min. bias collision we used 60 %. In addition to the hadronic particles we have also considered the contributions to the background generated by $c\bar{c}$ and $b\bar{b}$ pairs production. The results are shown in the figure 3 for the J/ψ and Υs, and for both rapidity regions, barrel and full detector. The S/B ratios under the resonances are indicated in table 3 together with the expected statistics available in one month run (1.3 10^6 s) with a luminosity of 10^{27}cm^{-2}s^{-1} and the production cross-sections given above. The main contributions to the background under the Υ are uncorrelated muon pairs coming first from π/K decay, 30 % of the total $\mu^+\mu^-$ pairs under the Υ for a detection in the barrel alone, and second from mixed origin, one muon from hadron decay and the second from $b\bar{b}$ production, 6%. As the background is essentially made of uncorrelated dimuons it will be possible to sustract it from the like-sign muon pairs spectra.

5 - Conclusions

The possibility to detect in CMS the dimuons from ($c\bar{c}$) and ($b\bar{b}$) resonances produced in Pb-Pb collisions have been investigated. The number of secondary charged particle has been fixed to 8000/Δy at y=0 for one central Pb-Pb collision.

The uncorrelated muon pairs from the hadronic background are suppressed, in one hand, by the natural P_T threshold, $\approx$ 3 GeV/c in the barrel region, minimum value to reach the first muon station, and in other hand by the dimuon tracks reconstruction. With a such high level of background, the occupation rates forbid the use of the complete inner tracker. Only the two pixel planes and the four outermost MSGC are used in the algorithm to match the tracker hits with those of the muon chambers. The efficiency to reconstruct a dimuon from Υ decay is 66 % in the case of a central Pb-Pb collision, increasing to 88 % for an average collision with 2500 π,K/Δy. In both cases the purity is larger than 95 %. For a dimuon coming from the background the efficiencies are respectively 11 % and 16 %. This study was achieved for a part of the barrel region only and the results were assumed to hold in the whole detector. The resulting dimuon mass resolution amounts to σ= 40 MeV/c^2 at the Υ mass.

The result of the simulations shows that the acceptance for J/ψ is concentrated in the endcaps where the background is the worse leading to a S/B ratio rather low, S/B= 0.17. Therefore its study would be limited to the barrel part with S/B= 1.8 with a very weak acceptance value possibly counterbalanced by a high production cross-section. Then the major inconvenient comes from the P_T distorded distribution. Only J/ψ with $P_T >$ 5 could be detected.

Concerning the Υ the large acceptance and the very good resolution make CMS one of the best detector to study its production rate in function of the centrality of the collision. The S/B ratio ranges from 0.8 in the whole detector to 1.6 if we restrict to the barrel. The expected statistics, above 20000 per month for the barrel, would able correlation studies, $(M_{\mu\mu}, P_T)$, $(M_{\mu\mu}, E_T)$.

References

[1] T.Matsui and H.Satz, Phys. Lett. B178 (1986) 416.

[2] CMS Letter of Intent, CERN/LHCC 92-3, LHCC/I1, 1 October 1992.

[3] CMS Technical Proposal, CERN/LHCC 94-38, LHCC/P1, 15 December 1994.

[4] R.Gavai et al, CERN-TH.7526/94 and BI-TP 63/94.

[5] F.Abe et al, CDF Collaboration, Fermilab-Pub-95/271-E.

[6] H.Satz, Lepton/Photon Symp. 2(1991)271, CERN-TH 6216/91.

[7] F.Antinori, Internal Note, ALICE/MC, 93-09 (1993).

[8] F.Abe et al, CDF Collaboration, Phys. Rev. Lett. 61 (1988) 1819.

[9] O.Kodolova and M.Bedjidian, CMS-TN/95-124 (1995).