EPJ Web of Conferences **37**, 09023 (2012)
DOI: 10.1051/epjconf/20123709023

Exclusive $D\bar{D}$ meson pair production in peripheral ultrarelativistic heavy ion collisions

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Abstract. The cross sections for exclusive D^+D^- and $D^0\bar{D}^0$ meson pair production in peripheral nucleus - nucleus collisions are calculated and several differential distributions are presented. The calculation of the elementary $\gamma\gamma \to D\bar{D}$ cross section is done within the heavy-quark approximation and in the Brodsky- Lapage formalism with distribution amplitudes describing recent CLEO data on leptonic D^+ decay. Absorption effects are discussed and quantified. The cross sections of a few nb are predicted for RHIC and of a few hundreds of nb for LHC with details depending on the approximation made in calculating elementary $\gamma\gamma \to D\bar{D}$ cross sections.

1 Introduction

Heavy quark meson pair production was studied theoretically only in Ref.[1] where formulas have been derived in the heavy quark approximation with Dirac delta-like distribution amplitudes. On the other hand both lattice QCD and the CLEO collaboration extracted the D-meson distribution amplitude which turned out to differ considerably from the delta-like distribution amplitude assumed in heavy quark approximation. In the present studies we will use also the more realistic distribution amplitudes.

In Fig. 1 we show the basic QED mechanism of the exclusive production of $D\bar{D}$ pairs in the peripheral heavy-ion collisions. We consider both D^+D^- and $D^0\bar{D}^0$ production.

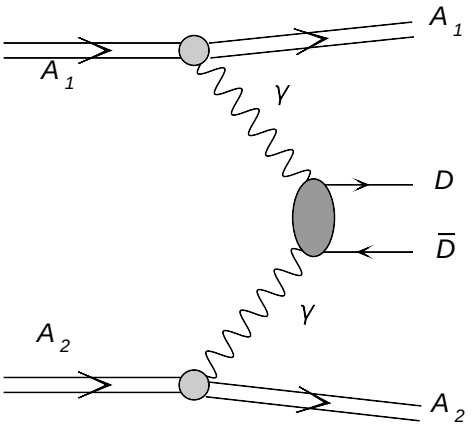

Fig. 1.

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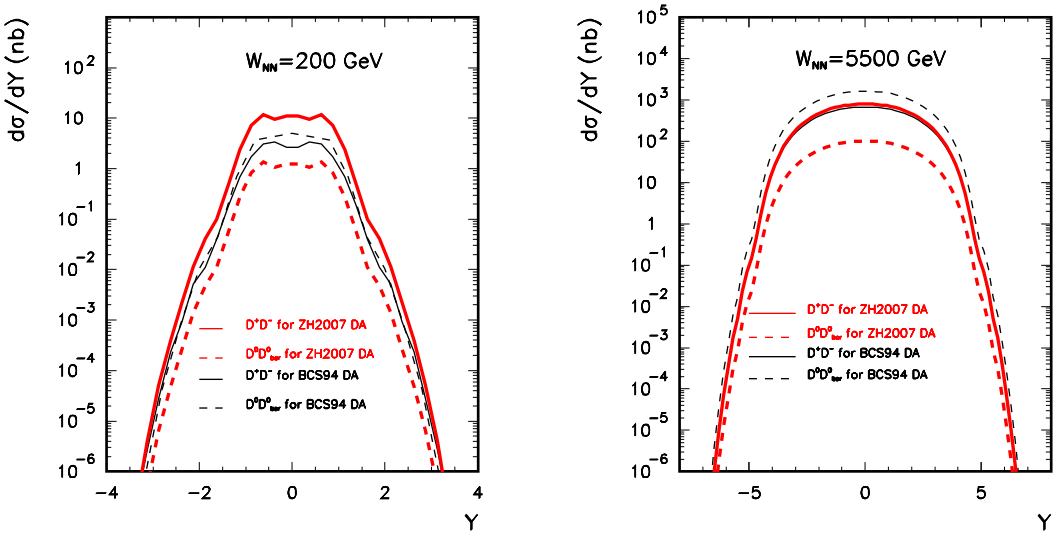

Fig. 2. The cross section as a function of the meson pair rapidity for D^+D^- and $D^0\bar{D}^0$ for the BCS94 DA [1] (black) and for the ZH2007 DA [3] (red) for RHIC and LHC energies.

2 Heavy meson pair production via photon- photon subprocess

In the two- photon case there are 20 Feynman diagrams in the leading order of α_s [1]. The diagrams can be classified into three parts. Six diagrams of first part represent the heavier- quark pair production by two- photon collisions followed by one virtual gluon emission to allow the produced heavier quarks to hadronize into heavy mesons. The second part of that diagrams are obtained by exchanging heavier quark lines with lighter antiquark line. The last part consists of eight diagrams where one photon produces a pair of heavier quarks and the other photon produces a pair of lighter quarks.

The resulting pseudoscalar- pseudoscalar production amplitude $M_{PP}^{\gamma\gamma}(\lambda, \lambda')$ can be found in [1]. The equivalent photon approximation is the standard semi–classical alternative to the Feynman rules for calculating cross sections of electromagnetic interactions. Here we follow an impact parameter space method presented in [2]. It allows for convenient inclusion of absorption effects. The details were explained elsewhere [4].

3 Results

We present results for gold-gold collisions at RHIC ($W_{NN} = 200$ GeV) and lead-lead collisions at LHC ($W_{NN} = 5.5$ TeV). In all the calculations presented here and in Ref. [4] we use realistic charge form factor being a Fourier transform of the realistic charge densities. Both D^+D^- and $D^0\bar{D}^0$ channels are discussed. Below we present the distributions which can be directly measured. In Fig.2 we show the distribution in the D^+D^- and $D^0\bar{D}^0$ pair rapidity being $Y \approx \frac{1}{2}(y_D + y_{\bar{D}})$. The visible irregularities at larger $|Y|$ are caused by the oscillating nuclear form factor. The larger meson pair rapidity the larger four-momentum squared of the exchanged photon (which is the argument of the charge form factor). The irregularities correspond to the four-momentum squared when the charge form factor changes its sign, i.e. when $|F|^2$ is close to zero. A more elaborate discussion on the role of the nuclear form factor can be found in Ref. [2].

4 Conclusions

We have calculated for the first time in the literature total and differential cross sections for $AA \to AA\bar{D}D$ reactions assuming that the reaction is driven by the $\gamma\gamma \to D\bar{D}$ subproceess. The elementary cross section were calculated in the heavy - quark approach as well as in the Brodsky- Lapage formalism with distribution amplitude describing recent CLEO data on leptonic D^+ decay. Rather small cross sections have been found. The cross section for exclusive $D\bar{D}$ production is much smaller than the cross section for the exclusive or semi-exclusive production of $c\bar{c}$ calculated recently. In our calculations absorption effects were included in the impact parameter Equivalent Photon Approximation. Whether the process can be measured requires further dedicated studies including detector simulations. We belive that our evaluation will be a useful starting point for such future studies. Since the cross section strongly depends on theoretical details experimental verification would be very helpful.

References

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