第23卷 第8期 高能物理与核物理 Vol.23, No.8
1999 年8月 HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS Aug., 1999

Direct Hard Photoproduction of J/ψ and ϒ in High Energy Pb–Pb and Ca–Ca Collisions at LHC

Li Yunde[1)]

(*Department of Physics, Yunnan University, Kunming* 650091)

Xu Xiaomei

(*Department of Physics, Yunnan Normal University, Kunming* 650092)

Liu Lianshou

(*Institute of Particle Physics, Huazhong Normal University, Wuhan* 430070)

Abstract Direct hard photoproduction of J/ψ and ϒ at LHC Pb–Pb collisions with CMS energy 5.5ATeV, and Ca–Ca collisions with CMS energy 7ATeV, are discussed in the process: A + A→A + J/ψ (ϒ) + X. It turns out that the processes can be used to testing the gluon distribution in the nucleus, as well as to studying the mechanism of large P_t gluon and heavy quark fragmentation of J/ψ.

Key words photoproduction process, equivalent photon spectrum, *J/ψ* and ϒ production

1 Introduction

Photoproduction physics is one of the main program of the Large Hadron Collider (LHC) Collaborations[1—3]. The intense heavy-ion beams represent a prolific source of quasireal photons. Hence it is enable an extensive studies of the photoproduction physics. Similar to what is done at the Hadron- Electron Ring Accelerator(HERA), hard hotoproduction of J/ψ and ϒ at LHC Pb–Pb with CMS energy 5.5ATeV, and Ca–Ca with CMS energy 7 ATeV collision process, A + A→A + J/ψ (ϒ) + X can be performed at high CMS γ–Pb energies. The direct photon–gluon collision process allow the study of the gluon distributions in ions.

In the calculations of J/ψ production in hadronic collisions[4] it has been assumed that the dominant contribution to the cross section comes from leading order diagrams with gg fusion into a charmonium state and a recoiling gluon and $b\bar{b}$ pair production followed by b→J/ψ decay, These calculations, however, did not explain all the observed rates at hadron colliders[5,6]. An ansatz for the problem was suggested recently that the dominant mechanism for charmonium production at large transverse momentum P_t is

Received 23 February 1999

1) Present address: Institut für Theoretische Physik, FU Berlin, 14195 Berlin, Germany

fragmentation[7,8], which is the production of a high P_t gluon or charm quark which subsequently fragments into charmonium states, such as J/ψ, χ_c. If it is true this may be the important progress in understanding hadronization from first principles. For it is possible to calculate the fragmentation functions which specify the probability for heavy quarks and gluons to hadronize into quarkonium bound states starting from perturbative QCD. It is necessary to test this important problem in further experiments. Our results show that the photoproduction process at LHC may be used for the purpose.

It is the purpose of this paper to discuss all the above problems. We will show that the photoproduction of J/ψ and Υ at LHC Pb–Pb, Ca–Ca processes may be a useful tool of testing these problems.

2 Theoretical Imput and Results

There are several expressions of equivalent photon spectrum function, in the paper we use the following types of the functions to calculate J/ψ and Υ cross section so as to compare the difference caused by equivalent photon spectrum functions.

The equivalent photon spectrum can be obtained from a semiclassical description of high-energy electromagnetic collisions. A relativistic heavy-ion with Z times the electronic charge moving with a relativistic factor $\gamma \gg 1$ with respect to some observer develops an equally strong magnetic field component so it resembles a beam of real photons, where the number of photons is given by[9]

$$n(\omega) \simeq \frac{2Z^2\alpha}{\pi\omega} \ln\left(\frac{\gamma}{R\omega}\right), \tag{1}$$

where ω is the energy of photon $R = b_{\min}$ ($b_{\min}$ is the cut-off of impact).

The production cross section of a photon fusion a parton in the nucleus in the collision of heavy-ion N is given by

$$\sigma(\mathrm{NN}\to\mathrm{NX}) = \int \mathrm{d}x f_{\gamma/\mathrm{N}}(x)\,\sigma(\gamma\,\mathrm{g}\to\mathrm{X}) \tag{2}$$

The direct photoproduction cross section of the subprocess $\gamma g\to J/\psi + g$ and $\gamma g\to\Upsilon + g$ can be found in[10,11]. The fragmentation contribution subprocess is dominated by the following process:

$$\gamma + g\to Q_{c(b)} + \bar{Q}_{c(b)};\ Q_{c(b)}\to J/\psi;$$
$$\gamma + q\to g + q,\ \gamma + g\to g + g;\ g\to J/\psi.$$

In our calculation the impact parameter is approximately equal to the radius of the nuclei. The parton distribution in nucleus can be obtained by using the simple parton model.

Fig. 1 shows the transverse momentum distribution J/ψ cross-section of the following subprocesses, the solid line in the figure gives out the contribution of the subprocess: $\gamma g\to J/\psi + g$. The dotted line shows the total contributions of large P_t gluon fragmentation in the two subprocesses: $\gamma + q\to g + q$; $\gamma + g\to g + g$; $g\to J/\psi$. The dashed line turns out the total contributions of large P_t heavy fragmentation in the two subprocesses: $\gamma + g\to Q_c + \bar{Q}_c$; $Q_c\to J/\psi$, $\gamma + g\to Q_b + \bar{Q}_b$; $Q_b\to J/\psi$.

It is easy to find from the figure that when $P_t < 4\mathrm{GeV}$ the J/ψ production is

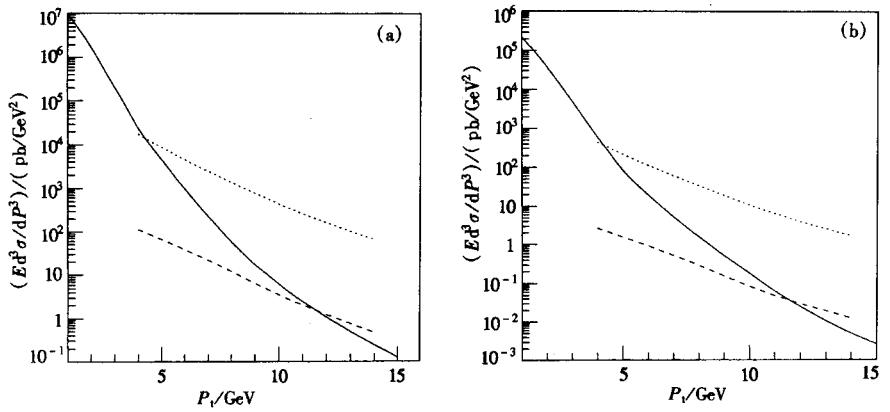

Fig.1. Cross section of J/ψ photoproduction
((a) for Pb-Pb and (b) for Ca-Ca) in several subprocesses
Solid line for the direct production, Doted line for the g→J/ψ contributions,
Dashed line for q→J/ψ contributions.

dominated by the direct production process: $\gamma g \rightarrow J/\psi + g$. So it is possible to test the gluon distribution in nucleus in this P_t range. When $P_t > 4$GeV, the contribution of subprocesses $\gamma + q \rightarrow g + q$, $\gamma + g \rightarrow g + g$; $g \rightarrow J/\psi$, are much larger than the other three subprocesses. In the situation the mechanism of large P_t gluon to fragmentate into J/ψ may be tested directly. While $P_t > 10$GeV the contribution from the fragmentation of large P_t heavy also becomes important and may be observed.

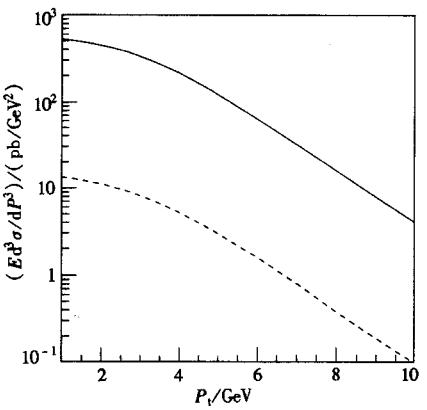

Fig.2. Cross section of Υ photoproduction
Solid line for γ Pb, Doted line for γ Ca process.

Fig. 2 shows the direct Υ photoproduction of Pb-Pb and Ca-Ca collisions respectively. From calculation we have found that in leading order the Υ photoproduction is dominated by the subprocess $\gamma g \rightarrow \Upsilon + g$. Other subprocesses such as $\gamma + g \rightarrow Q_c + \bar{Q}_c$, $Q_c \rightarrow \Upsilon$, $\gamma + g \rightarrow Q_b + \bar{Q}_b$, $Q_b \rightarrow \Upsilon$, and $\gamma + q \rightarrow g + q$, $g \rightarrow \Upsilon$ are suppressed by the mass of Υ, so the contributions come from both the gluon and the heavy quark fragmentation can be ignored. Hence the Υ photoproduction process can be mainly used to test the gluon distribution in the nucleus.

We are grateful to Prof. Dr. T. Meng for his help.

References

1 ALICE Collab. CERN/LHCC/95-01; Eggert K et al. CERN/LHCC 97-45, LHCC/110, 1997
2 Baur G. hep-h/9804348
3 Sadovsky S A. ALICE/95-30
4 Baier R, Rückl R. Z. Phys., 1983, **C19**:251
5 UA1 Collab, Albajar C et al. Phys. Lett, 1991, **B256**:112
6 CDF Collab, Abe F et al. Phys. Rev. Lett., 1992, **69**:3704
7 Braaten E, Yuan T C. Phys. Rev. Lett., 1993, **71**:1673
8 E Braaten, K Cheung, Yuan T C. Phys. Rev. 1993, **D48**:5049
9 Papageorgiu E. Phys. Lett., 1990, **B250**:155; Phys. Lett., 1989, **B223**:454
10 Bazizi K A. FERMILAB-Conf-95/238-E
11 Kunszt Z. Phys. Lett., 1988, **B207**:103

LHC 高能 Pb-Pb和 Ca-Ca 碰撞中的直接硬光生 J/ψ及Υ

李 云 德[1)]

(云南大学物理系 昆明 650091)

徐 晓 梅

(云南师范大学物理系 昆明 650092)

刘 连 寿

(华中师范大学粒子物理研究所 武汉 430070)

摘要 研究了 LHC 中，Pb-Pb以质心系能量 5.5ATeV 以及 Ca-Ca以质心系能量 7ATeV 碰撞过程中的硬直接光生 J/ψ和Υ过程：$A+A\to A+J/\psi(\Upsilon)+X$.结果表明该过程不仅可用于测量原子核中的胶子分布，还可以用以研究大 P_t胶子以及重夸克的 J/ψ碎裂机制.

关键词 光生过程 等效光子谱 J/ψ及Υ产生

1999-02-23收稿

1) 目前所在地址：柏林自由大学，理论物理研究所，14195柏林，德国