29th International Cosmic Ray Conference Pune (2005) **9**, 21–24

Asymmetry in charmed hadron production in pp collisions

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We study the hadroproduction asymmetry for charmed particles (D^+, D^-, D^0, $\bar{D}^0$, Λ_c^+, $\bar{\Lambda}_c^-$) in pp collisions as a function of $\sqrt{s}$, x_F and $p_\perp$ in the framework of QGSJET model. QGSJET01 is a Monte-Carlo code developed recently to simulate high energy hadronic interactions based on QGSJET model. Calculations for charmed particles production are done by using this code. It is found that, for all x_F, asymmetry is prominent in the low value of $\sqrt{s}$. There is strong preference for producing Λ_c^+ rather than $\bar{\Lambda}_c^-$ baryons, while that for producing $\bar{D}$ rather than D mesons for this range of $\sqrt{s}$. For low $\sqrt{s}$ range, asymmetry is more with $x_F \geq 0.2$, whereas for higher value of $\sqrt{s}$, it is more pronounced for lower values of x_F. With high value of $p_\perp$ only, asymmetric behavior of charm hadroproduction is considerable for high value of $\sqrt{s}$, but for low value of $\sqrt{s}$, this behavior is effective even for very low value of $p_\perp$. The patterns of asymmetric production of different charmed hadron groups with x_F and $p_\perp$ are approximately same as that with $\sqrt{s}$. we compare our calculations with data from Fermilab experiment E781 (SELEX) for Λ_c^+ and $\bar{\Lambda}_c^-$ production. Agreement is quite good.

1. Introduction

The study of charmed particle production in hadronic collisions is a subject of great interest as it provides a good test of perturbative QCD (pQCD). Charmed quarks are considered to be produced in pQCD processes. To leading order (LO) and next-to-leading order (NLO) these are the gluon-gluon fusion process gg $\rightarrow c\bar{c}$ and the quark-antiquark annihilation process $q\bar{q} \rightarrow c\bar{c}$. There is a wide variety of theoretical models which are more or less satisfactorily applied to description of charmed particle hadroproduction. These models can be divided into three main groups : the models based on pQCD and parton model [1], the models based on Lund string model [2] and the models which incorporate Dual Topological Unitarization Scheme [3]. On the other hand in hadronizaton models charmed particle production is strongly suppressed. The Lund model gives a production probability of different quark flavours as $u\bar{u}$:$d\bar{d}$:$c\bar{c} \approx$ 1:1:0.3:10^{-11}, i.e. charm production in the hadronizaton phase can here be safely neglected, as reported in [4]. The quark-gluon string (QGS) model of the supercritical Pomeron [5] is based on the 1/N expansions in QCD and allows to consider hadron interactions at large distances and small transverse momenta. A close approach to the QGS model is a dual topological unitarization scheme developed in [6]. To solve the problem of proper accounting for semihard processes [5] in QGS model, a most successful model in the field of high energy hadronic interactions, called quark-gluon-string-jet (QGSJET) model [5] is developed. In QGSJET model two contributions are considered into the scattering amplitude. One from the usual soft interaction described by the soft Pomeron exchange and the other from the semihard process. Cross sections of various processes may be obtained as in the usual QGS model if one takes these two contributions into considerations [5]. QGSJET01 is a Monte-Carlo code developed recently based on the QGSJET model. We have used this code to study the charmed hadroproduction in pp collisions and in this brief report we concentrate only on the asymmetry in the charmed hadroproduction in these interactions.

2. Asymmetry in charmed hardoproduction

Theoretically, charm and anticharm production diagrams at quark level show no asymmetry in the LO QCD processes. But NLO introduces very little asymmetry in quark momenta due to interference between contributing amplitudes [7]. However E769 experiment [8] has observed a Λ_c asymmetry for a 250 GeV/c proton beam and in the same experiment has measured D meson asymmetry for a 250 GeV/c pion beam. The WA89 experiment [9] has studied charmed particles produced by a Σ^- 340 GeV/c beam. Considerable production asymmetry between D^+, D^- and Λ_c^+, $\bar{\Lambda}_c^-$ was observed. The WA92 [9] and E791 [10] experiments show D meson asymmetry in 350 GeV/c pion beam and a 500 GeV/c pion beam respectively. The observed asymmetries can be explained as features of the hadronization process [11] or as a manifestation of an intrinsic charm content of the beam hadron [12]. Here we have studied the hadroproduction asymmetry for charmed hadrons D^+, D^-, D^0, $\bar{D}^0$, Λ_c^+, $\bar{\Lambda}_c^-$ in pp collisions as function of $\sqrt{s}$, x_F and $p_\perp$ using QGSJET model. The hadroproduction asymmetry A_s is calculated as [7],

$$A_s = \frac{\sigma_c - \sigma_{\bar{c}}}{\sigma_c + \sigma_{\bar{c}}} \tag{1}$$

Where $\sigma(\sigma_{\bar{c}})$ is the production cross section for the charmed particle (anti-charmed particle) in study. Fig.1(a) shows the inelastic and different charmed hadrons production cross sections in pp collisions as a function of $\sqrt{s}$. Calculated production cross section for $D/\bar{D}$ is compared with the experimental data from [13]. No data is available with us for comparison with the experiment for other charmed hadron production in study. Although for $D/\bar{D}$ also experimental data is insufficient for comparison, it is observed that calculated production cross section is in close agreement with experiment. Average multiplicity of different charmed hadrons in study that are produced for different value of $\sqrt{s}$ in pp collision is shown in fig.1(b). Experimental data is not available to compare with these results. From the figure it is clear that the average multiplicity is very low for

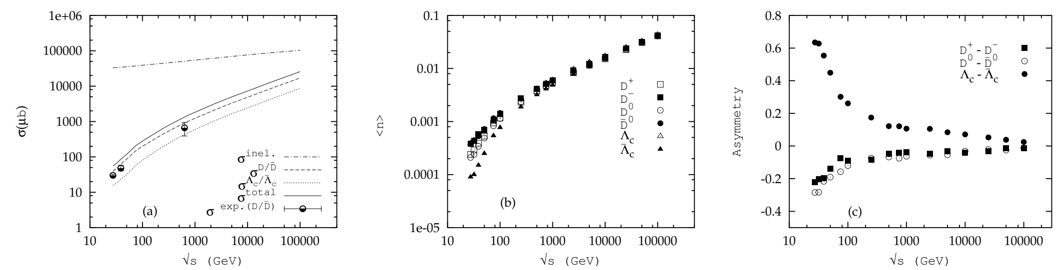

Figure 1. (a) Inelastic and different charmed hadrons production cross sections in pp collisions with the center of mass energy ($\sqrt{s}$). The cross sections are calculated with the QGSJET are compared with the experimental data [13] for $D/\bar{D}$ production. (b) Average multiplicity of different charmed hadrons produced in pp collisions with $\sqrt{s}$. The average multiplicity is calculated with the QGSJET for 10^6 numbers of events. (c) Asymmetry in charmed hadrons production in pp collisions with $\sqrt{s}$.

the whole energy range and the difference in multiplicity of different charmed hadrons decreases considerably with increasing $\sqrt{s}$. Asymmetry in charmed hadrons production in pp collisions as calculated with the QGSJET model as a function of $\sqrt{s}$ is shown in fig.1(c). It is observed that, for all x_F asymmetry is prominent in the low value of $\sqrt{s}$. There is strong preference for producing Λ_c^+ baryon rather than $\bar{\Lambda}_c^-$, while that for producing $\bar{D}$ mesons rather than D mesons for this range of $\sqrt{s}$ ($\leq$ 200 GeV). In this energy range, this tendency is much strong in case of Λ_c baryons than D mesons. As the value of $\sqrt{s}$ increases beyond 200 GeV asymmetric tendency of production of charmed hadrons decreases and at sufficiently high value of $\sqrt{s}$ (>100000 GeV) this tendency vanishes. The study of asymmetry in charmed hadrons production in pp collision at different $\sqrt{s}$ as a function of Feynman x$_F$ is shown in fig.2. It is clear from the figure that for low $\sqrt{s}$ range ($\leq$ 100 GeV)

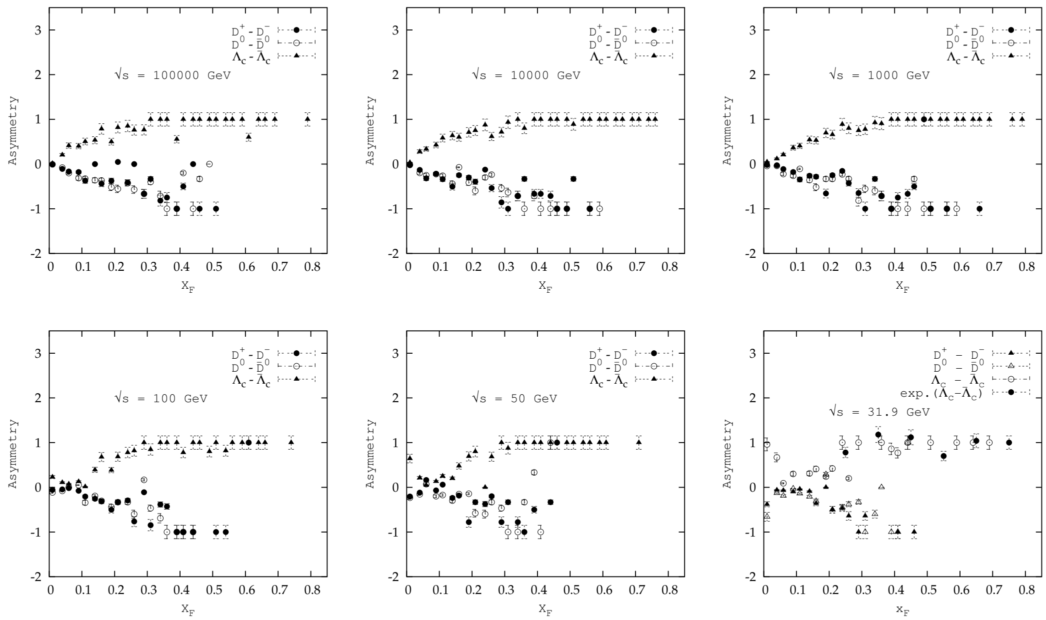

Figure 2. Asymmetry in charmed hadrons production in pp collisions at different $\sqrt{s}$ as function of Feynman x$_F$. Results for Λ_c particles are compared with the experimental data [7] at $\sqrt{s}$ = 31.9 GeV.

asymmetry is appreciable only with x$_F \geq 0.2$, whereas for higher value of $\sqrt{s}$, it is more pronounced even for much lower values of x$_F$. The patterns of production of different charmed hadron groups as a function x$_F$ are that, more number of Λ_c^+ baryons are produced than that of $\bar{\Lambda}_c^-$ baryons, whereas the reverse is the case for D mesons for all values $\sqrt{s}$. This behaviour of production of charmed hadrons is similar that with $\sqrt{s}$ for all values of x$_F$. We have compared the results of Λ_c particles at $\sqrt{s}$ = 31.9 GeV with the experimental data from [7]. It is observed that agreement is quite satisfactory. The asymmetric behaviour of charmed hadroproduction as a function of p$_\perp$ is complex in nature. Fig.3 shows this nature of charmed hadroproduction as function of p$_\perp$ for different value of $\sqrt{s}$. Here we can infer that for high value of $\sqrt{s}$, asymmetry is considerable only with comparatively high value of $p_\perp$, but for low value of $\sqrt{s}$ it is more effective even for vary low value of $p_\perp$. The pattern of asymmetric production of charmed hadrons with $p_\perp$ is approximately same as that with $\sqrt{s}$ and x_F.

3. Summary

We have used successfully the QGSJET model to study the charmed hadroproduction in pp collision. Asymmetric behaviour of charmed hadroproduction in these collisons as a function of$\sqrt{s}$, x$_F$ and p$_\perp$ are interesting and needs more attention in this regard to understand QCD processes. There is a strong enhancement of the production charmed baryons over antibaryons, while that for charmed antimesons over mesons. In this connection more experimental data over a wide range is an urgent need.

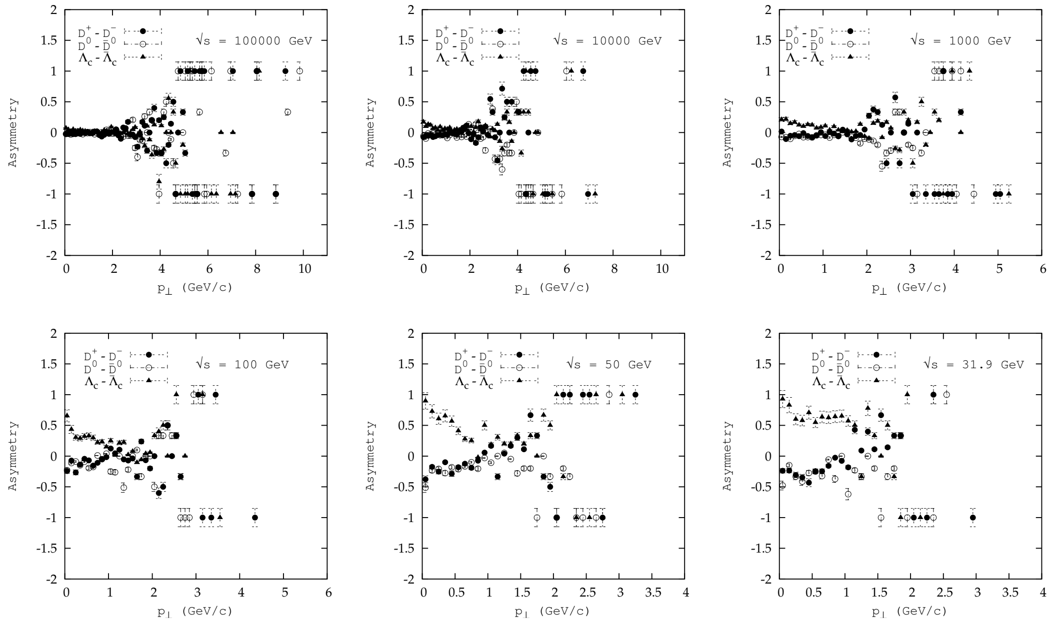

Figure 3. Asymmetry in charmed hadrons production in pp collisions at different $\sqrt{s}$ as function of transverse momentum $p_\perp$.

4. Acknowledgment

First author is indebted to Dr. Ralph Engel of Institut für Kernphysik, Forchunszentrum Karlsruhe, Karlsruhe, Germany for his initiating guidance. He would like to thank the Institut für Kernphysik of Forchunszentrum Karlsruhe for kind hospitality during his visit to that Institute where this work was initiated.

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