HADROPRODUCTION OF χ_c STATES IN 530 GeV/c π^- INTERACTIONS WITH NUCLEAR TARGETS

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Abstract

We are studying production of χ_c states in 530 GeV/c π^- interactions with several targets. χ_c mesons are observed in the mode ($\chi \rightarrow J/\psi+\gamma$). Only photons that converted to e^+e^- pairs are used in the reconstruction of the χ_c mesons. Preliminary analysis shows that the fraction of observed J/ψs coming from χ_c radiative decays is 0.44±0.09±0.08, and that the relative production rate of χ_{c1} to χ_{c2} is 1.3 ± 0.6.

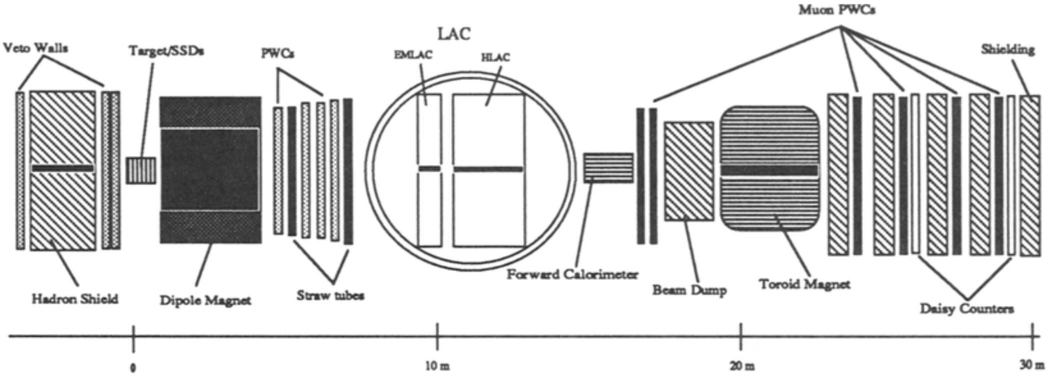

Figure 1. MWEST spectrometer.

INTRODUCTION

Production of the p-wave charmonium states (χ_c) in hadronic collisions provides important information on the QCD subprocesses involved. The p-wave charmonia can couple to two gluons (virtual or on-shell) while the s-wave vector states couplings require at least three gluons. As a result, according to perturbative QCD, the χ_c states are expected to have larger production cross sections than the J/ψ by at least a factor of $1/\alpha_S$ if the contribution from sea-quark fusion is ignored.[1] The χ_{c1} and χ_{c2} are the only p-wave charmonia below the open charm threshold with significant branching ratios for $\chi_c \rightarrow J/\psi + \gamma$. Therefore, we expect a large fraction of observed J/ψs to come from radiative χ_{c1} and χ_{c2} decay.[2] Furthermore, the QCD leading diagram of gluon-gluon fusion suppresses production of χ_{c1} relative to χ_{c2} because of angular momentum conservation and the zero mass of the gluon. Thus, measurement of relative production rate of the two states will help to test the picture of perturbative QCD and the detail of possible nonperturbative effects, such as color evaporation[3], in charmonium production.

APPARATUS

The MWEST spectrometer at Fermilab is designed to simultaneously study productions of dimuon pairs and high p_T direct photons in interactions of protons and pions incident on several targets. The spectrometer is situated in the Meson West beamline. Figure 1 shows a layout of the spectrometer. [4,5]

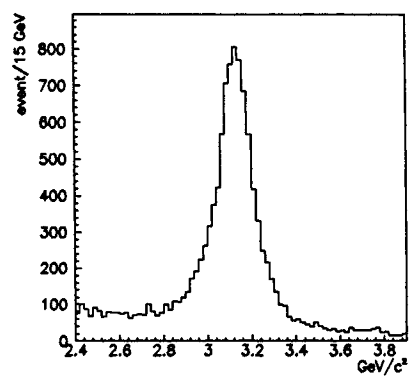

Figure 2. $\mu^+\mu^-$ invariant mass in J/ψ region.

During 1990, data was taken with 530 GeV/c π^- beam incident on both Cu and Be targets. We collected 5.6 million triggers. About 80% of the data is used in this analysis. Aproximately 9K J/ψs were reconstructed from this sample. The dimuon mass spectrum in the J/ψ region is shown in Fig. 2. The mass resolution of 85 MeV/c^2 is consistent with the Monte Carlo simulation. The x_F range of the reconstructed J/ψs is between 0.1 and 0.8. At this stage of analysis, the data from the straw drift tubes has not been used.

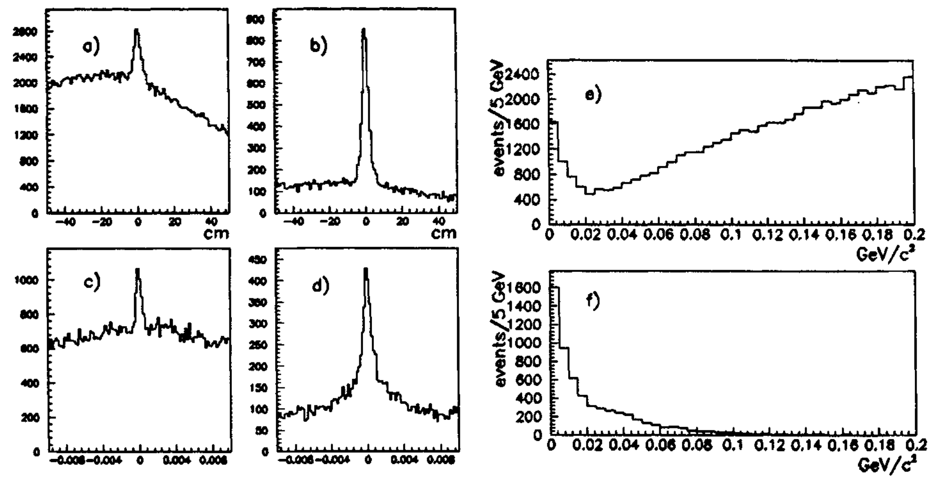

Figure 3.a) z position of the intersection point of two oppositely charged tracks relative to the center of dipole magnet in the x-view without cut; b) same as a) but requiring the difference in the y slopes of the two tracks to be less than 0.003; c) difference in the y slopes without cuts; d) same as c) but requiring the x view intersection point to be at the magnet center within ± 10 cm; e) invariant mass of all oppositely-charged track pairs, assuming they are e^+e^-; f) same as e) but with both of the cuts in b) and in d).

PRODUCTION OF χ_c STATES

In order to achieve the mass resolution required for separating the two χ_c states, we looked for J/ψ events with e^+e^- pairs resulting from photon conversions. An e^+e^- pair appears as a single track in the silicon-strip detector before the dipole magnet, and as two distinct tracks in the PWCs immediately after the magnet (With PWCs we always refer to these PWCs unless stated otherwise). The direction of the magnetic field in the dipole is along the y axis defined as perpendicular to the horizontal plane. Therefore, the electron and positron tracks should nearly overlap in the y view, while in the x view the projection of their downstream segments should intersect near the center of the magnet.

Figure 3 shows the distributions of the y-slope differences and the difference in z between the x view crossing point and the center of the magnet for the oppositely-charged track pairs in the PWCs. The obvious correlation between the peaks in the two distributions indicates that the peaks are due to photon conversion pairs. The e^+e^- pairs also contribute to a clean peak near zero mass in the e^+e^- invariant-mass spectrum shown in Fig. 3e, 3f. In our analysis, a photon conversion pair is defined as a pair of oppositely-charged tracks satisfying the following requirements: a) their invariant mass (assuming they are e^+e^-) is less than 30 MeV/c^2; b) the difference in the y slopes of their PWC segments is less than 0.003 ; c) the x intercept of their PWC segments is within ± 10 cm of the center of the dipole. The $e^+e^-e^+e^-$ invariant mass distribution shown in Fig. 4a exhibits the π^0 peak. The enhancement near zero is due to multiple combinations of tracks.

J/ψs are defined as the dimuons with invariant mass 2.9 GeV/c^2 $\leq M_{\mu^+\mu^-} \leq$ 3.3 GeV/c^2. With the constraint that the $\mu^+\mu^-$ invariant mass is 3.097, an χ^2-fit is done for each J/ψ to improve the momentum accuracy. In a Monte Carlo study, we calculated the detection efficiencies of J/ψ and the e^+e^- pairs from χ_{c1} state, assuming the initial x_F and p_T distribution for χ_{c1} is the same as we measured for J/ψs. Decay of χ_c was assumed to be isotropic. GEANT3 package was used in the Monte Carlo simulation. All the known

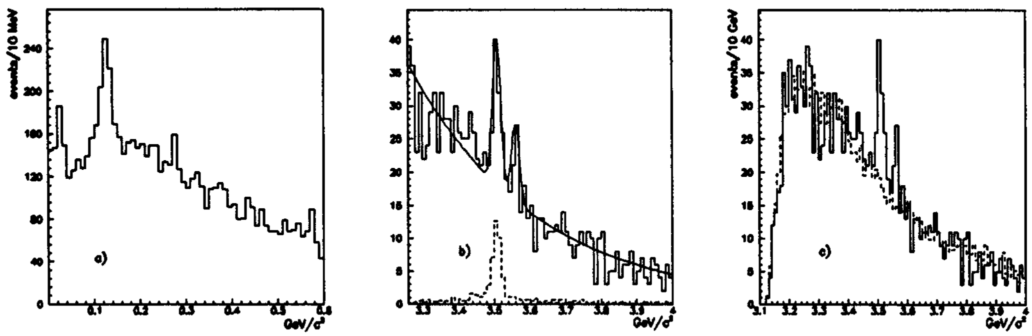

Figure 4. a) $e^+e^-e^+e^-$ mass distribution. b) e^+e^- J/ψ mass distribution with fit. The dashed line is the mass distribution calculated from Monte Carlo χ_{c1} events. c) Calculated background (dashed line) overlapped with the mass distribution.

materials in front of the dipole magnet were included in the simulation in order to get the proper photon conversion probabilities. The ratio of global detection efficiencies for the χ_cs relative to J/ψs was found to be 0.018±0.003. The errors are mainly due to uncertainties in χ_c and J/ψ initial distributions and in the photon reconstruction efficiencies. The Monte Carlo estimated χ_c mass resolution is 11±2 MeV/c^2.

The e^+e^-J/ψ mass distribution is shown in Fig 4b. Two peaks corresponding to χ_{c1} and χ_{c2} are clearly visible. The background was determined by mixing e^+e^- pairs and J/ψs from different events and was normalized to the number of events in the region $M(\gamma J/\psi) \leq 3.4 GeV/c^2$. In figure 4c, the calculated background (dashed line) is shown with the complete mass spectrum. A fit to the background shape plus two Gaussians, with fixed widths of 11 MeV/c^2, gives 51±11 and 19±9 χ_{c1} and χ_{c2} events, respectively. The measured χ_{c1} and χ_{c2} mass was 3.509±0.003 GeV/c^2 and 3.560±0.004 GeV/c^2, respectively. Using the relative acceptance mentioned above and the total number of J/ψs and χ_cs observed, we find that 44±9±8% of the observed J/ψ production cross section are due to χ_c productions and decays. The first uncertainty is statistical and second systematic. Assuming that the acceptance for the two χ_c states is the same and taking into account the different branching ratios[6], we determine the relative production $\sigma(\chi_{c1})/\sigma(\chi_{c2})$ to be 1.3 ± 0.6. The uncertainty here is statistical. These results are consistent with previous measurements made at lower energies.[7]

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