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CERN-PRE-78-169

CM-P00063991

STUDY OF χ PRODUCTION PROPERTIES
AT THE CERN INTERSECTING STORAGE RINGS

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ABSTRACT

The inclusive production of electron pairs with and without additional photons was measured at the CERN Intersecting Storage Rings (ISR). The investigation of J/ψ particles with associated photons indicated that $47 \pm 8\%$ of the J/ψ were produced via the photonic decay of one of the $\chi(3.5)$ states. The upper limit of the production cross-section ratio times the branching ratio into electron pairs of ψ' relative to J/ψ was found to be 2% at centre-of-mass energy of $\sqrt{s} = 62$ GeV.

Geneva - 1 December 1978

(Submitted to Physics Letters)

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 - x) Work supported by the US National Science Foundation.

The observed suppression of the ψ' inclusive production cross-section relative to the J/ψ production in hadronic interaction [1] leads to the proposal that a large fraction of the J/ψ events are produced via the decay of $\chi(3.5) \rightarrow J/\psi + \text{anything}$ [2-5]. The direct production of the χ states is expected to proceed mainly via gluon-gluon interactions, while direct J/ψ and ψ' are expected to be the result of quark interactions. The study of the production properties of the χ states thus should reveal information about the gluonic composition of the nucleons. Earlier results of this experiment, with about 10% of the present data, have already suggested that χ production is indeed an important source of J/ψ production at ISR energies [6]. A recent experiment using a pion beam at FNAL reported a similar observation [7].

In this analysis we find that $47 \pm 8\%$ of the inclusive J/ψ production is the result of the decay of one of the $\chi(3.5)$ states into J/ψ and a photon. The p_T distribution of the χ states shows an exponential behaviour with a slope of 1.5 ± 0.1 GeV and $\langle p_T \rangle = 1.3 \pm 0.1$ GeV. The upper limit at 90% confidence level for the ratio of ψ' to (J/ψ) production cross-section times branching into electron pairs is found to be less than 2% at centre-of-mass energy of $\sqrt{s} = 62$ GeV.

The apparatus used in this experiment was designed to identify electrons of a few GeV with good background rejection and to measure electromagnetic showers with energy larger than several hundred MeV. The apparatus consisted of four modules, each covering a solid angle of approximately 1 sr, 50° to 130° in polar angle and 40° in azimuth. The energies and position of the electromagnetic showers were measured in a segmented lead liquid-argon calorimeter. Discrimination between electrons and hadrons was provided by measurement of shower development in the liquid-argon calorimeters and by two sets of lithium transition radiator and xenon multiwire proportional chamber (MWPC). A more detailed description of the apparatus can be found elsewhere [8-9].

To obtain a sample of electron pairs with relatively small background, offline requirements similar to the ones described in earlier publications [6, 10] were imposed. In Fig. 1 we show the invariant mass distribution of the electron

pairs satisfying these requirements. The observed J/ψ peak dominates the mass distribution, while no enhancement is seen in the 3.7 GeV, ψ' region. Note that our mass acceptance increases by a factor of 1.6 in going from 3.1 to 3.7 GeV. A fit to the electron-pair mass distribution corrected for mass acceptance efficiency resulted in an upper limit of 2% for the cross-sections times branching ratio into electron pairs of the ψ' to J/ψ ratio. If the ψ' excitation function had the same shape as that of the J/ψ the $\psi'/(J/\psi)$ ratio would have been expected to increase from the 2% observed at FNAL energies to 3 to 4% at $\sqrt{s} = 63$ GeV.

To determine the fraction of J/ψ events coming from χ production, the electron pairs in the J/ψ region taken to be from 2.67 to 3.52 GeV, where the background is estimated to be 12%, were selected. The invariant mass of each event was fitted to a mass of 3.098 GeV by fixing the electrons directions and allowing the measured electron energy to vary. In Fig. 2a we show the $(J/\psi, \gamma)$ invariant mass for all events having an associated photon with energy greater than 400 MeV. The photon energy cut was imposed, because at lower energy both the reconstruction efficiency and the measured energy resolution are poorer. A clear low-mass enhancement is observed in the χ region.

The background curve (dotted line) was calculated from the invariant mass distribution of all the J/ψ events, combined with photons from other events having a trigger similar to that of the J/ψ events. The background distribution was then normalized to the number of events above 3.9 GeV. In Fig. 2b we show the invariant mass distribution for events with a forward photon in the $(J/\psi, \gamma)$ centre-of-mass system. The background curve was calculated with the additional cut imposed. A clear excess of events is observed in the χ region with the expected relative signals observed in Figs. 2a and b. The subtracted histograms are shown in Figs. 3a and b. Similar results are obtained when an analysis is performed using only events where the photon and electrons were found in separate modules. Note that this result might be attributed to a dynamical effect which could be caused only if the photon spectrum of the J/ψ events are different from the background sample. The natural interpretation of this enhancement is its attribution to χ production.

Because of the mass resolution it is not possible to separate the $\chi(3.5)$ and $\chi(3.55)$ states produced in this experiment. No evidence is seen for $\chi(3.4)$ production, but note that the E_γ cut imposed, as well as the relatively low branching ratio of the $\chi(3.4)$ into $J/\psi + \gamma$, would prevent detecting it unless its production cross-section was much larger than the other $\chi(3.5)$ states.

The χ signal observed in Fig. 2b was used to calculate the p_T distribution. The p_T acceptance for the χ states is relatively flat for the p_T range 0 to 5 GeV (Fig. 3a). After acceptance correction, the resulting $(1/p_T)/(dN/dp_T)$ distribution for the χ states is shown in Fig. 3b. The distribution exhibits an exponential behaviour with a slope of $1.5 \pm 0.1 \text{ (GeV)}^{-1}$ and $\langle p_T \rangle = 1.3 \pm 0.1 \text{ GeV}$.

The observed p_T behaviour together with geometrical configuration, trigger requirements, etc., were used in a Monte Carlo calculation of the experimental acceptance of the χ states relative to the J/ψ . After the appropriate corrections, $47 \pm 8\%$ of the J/ψ were found to come from a photonic decay of a χ state. Since the χ -decay modes are not completely known, it may be that the χ states can produce J/ψ via another decay mode, and the total number of J/ψ originating from a χ state could be larger.

The $\chi(3.5)$ and $\chi(3.55)$ have a 23.4% and 16% branching ratio into $(J/\psi, \gamma)$, respectively. Assuming the relative amount of $\chi(3.5)$ and $\chi(3.55)$ produced to be equal, one can calculate the ratio of each of the χ states to J/ψ inclusive production ratio to be 2.35 ± 0.5 . Using the results obtained above, one can also calculate the lower limit on the ratio of direct χ states to J/ψ production to be 4.7 ± 1 . This indicates that the χ states are indeed produced more abundantly in hadronic interactions. The measured p_T distribution for the χ states is similar to that obtained for J/ψ production at ISR energies [10,11]. The upper limit on the ψ' cross-section suggests that its energy dependence might be different from that of the total J/ψ , but perhaps consistent with direct J/ψ production.

REFERENCES

- [1] B.C. Brown et al., Fermilab 77-54 Exp (1977).
- [2] C.E. Carlson and R. Suaya, Phys. Rev. D15 (1977) 1416.
- [3] A. Donnachie and P.V. Landshoff, Nuclear Phys. B112 (1976) 233.
- [4] S.D. Ellis, M.B. Einhorn and C. Quigg, Phys. Rev. Letters 36 (1976) 1263.
- [5] S. Nandi and H.R. Schneider, Bonn-He-78-1 (1978).
M. Gluck and E. Reya, DESY 78/41 (1978).
- [6] J.H. Cobb et al., Phys. Letters 72B (1978) 497.
- [7] L. Holloway et al., paper submitted to 19th Internat. Conf. on High-Energy Physics, Tokyo, August 1978.
- [8] C. Kourkouvelis, CERN 77-06 (1977).
- [9] A.J. Lankford, CERN EP Internal Report 78-3 (1978).
- [10] J.H. Cobb et al., Phys. Letters 65B (1977) 101.
- [11] C. Kourkouvelis et al., paper submitted to 19th Internat. Conf. on High Energy Physics, Tokyo, August 1978.

Figure captions

Fig. 1 : Invariant mass of electron pairs.

Fig. 2 : The invariant mass distribution for J/ψ with γ
a) for all events with $E_\gamma > 0.4$ GeV,
b) for all events with forward γ in the $(J/\psi, \gamma)$ centre of mass.
Dotted curves are calculated background.

Fig. 3 : The invariant mass distribution of J/ψ with γ after background subtraction. a) and b) same as in Fig. 2.

Fig. 4 : a) p_T acceptance for χ states.
b) $(1/p_T)/(dN/dp_T)$ distribution for events in the χ states. The line is an exponential fit with $b = 1.5$.

Fig. 1

Fig. 2

Fig. 3

Fig. 4