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TWO-PHOTON PRODUCTION OF $\Lambda\overline{\Lambda}$ BARYON PAIRS

B. Barish,[1] M. Chadha,[1] S. Chan,[1] D.F. Cowen,[1] G. Eigen,[1] J.S. Miller,[1] C. O'Grady,[1] J. Urheim,[1] A.J. Weinstein,[1] F. Würthwein,[1] D.M. Asner,[2] M. Athanas,[2] D.W. Bliss,[2] W.S. Brower,[2] G. Masek,[2] H.P. Paar,[2] M. Sivertz,[2] J. Gronberg,[3] C.M. Korte,[3] R. Kutschke,[3] S. Menary,[3] R.J. Morrison,[3] S. Nakanishi,[3] H.N. Nelson,[3] T.K. Nelson,[3] C. Qiao,[3] J.D. Richman,[3] D. Roberts,[3] A. Ryd,[3] H. Tajima,[3] M.S. Witherell,[3] R. Balest,[4] K. Cho,[4] W.T. Ford,[4] M. Lohner,[4] H. Park,[4] P. Rankin,[4] J.G. Smith,[4] J.P. Alexander,[5] C. Bebek,[5] B.E. Berger,[5] K. Berkelman,[5] K. Bloom,[5] T.E. Browder,[5*] D.G. Cassel,[5] H.A. Cho,[5] D.M. Coffman,[5] D.S. Crowcroft,[5] M. Dickson,[5] P.S. Drell,[5] D.J. Dumas,[5] R. Ehrlich,[5] R. Elia,[5] P. Gaidarev,[5] R.S. Galik,[5] M. Garcia-Sciveres,[5] B. Gittelman,[5] S.W. Gray,[5] D.L. Hartill,[5] B.K. Heltsley,[5] S. Henderson,[5] C.D. Jones,[5] S.L. Jones,[5] J. Kandaswamy,[5] N. Katayama,[5] P.C. Kim,[5] D.L. Kreinick,[5] T. Lee,[5] Y. Liu,[5] G.S. Ludwig,[5] J. Masui,[5] J. Mevissen,[5] N.B. Mistry,[5] C.R. Ng,[5] E. Nordberg,[5] J.R. Patterson,[5] D. Peterson,[5] D. Riley,[5] A. Soffer,[5] P. Avery,[6] A. Freyberger,[6] K. Lingel,[6] C. Prescott,[6] J. Rodriguez,[6] S. Yang,[6] J. Yelton,[6] G. Brandenburg,[7] D. Cinabro,[7] T. Liu,[7] M. Saulnier,[7] R. Wilson,[7] H. Yamamoto,[7] T. Bergfeld,[8] B.I. Eisenstein,[8] J. Ernst,[8] G.E. Gladding,[8] G.D. Gollin,[8] M. Palmer,[8] M. Selen,[8] J.J. Thaler,[8] K.W. Edwards,[9] K.W. McLean,[9] M. Ogg,[9] A. Bellerive,[10] D.I. Britton,[10] E.R.F. Hyatt,[10] R. Janicek,[10] D.B. MacFarlane,[10] P.M. Patel,[10] B. Spaan,[10] A.J. Sadoff,[11] R. Ammar,[12] P. Baringer,[12] A. Bean,[12] D. Besson,[12] D. Coppage,[12] N. Copty,[12] R. Davis,[12] N. Hancock,[12] S. Kotov,[12] I. Kravchenko,[12] N. Kwak,[12] Y. Kubota,[13] M. Lattery,[13] M. Momayezi,[13] J.K. Nelson,[13] S. Patton,[13] R. Poling,[13] V. Savinov,[13] S. Schrenk,[13] R. Wang,[13] M.S. Alam,[14] I.J. Kim,[14]

Z. Ling,[14] A.H. Mahmood,[14] J.J. O'Neill,[14] H. Severini,[14] C.R. Sun,[14] F. Wappler,[14]
G. Crawford,[15] R. Fulton,[15] D. Fujino,[15] K.K. Gan,[15] K. Honscheid,[15] H. Kagan,[15]
R. Kass,[15] J. Lee,[15] M. Sung,[15] C. White,[15] A. Wolf,[15] M.M. Zoeller,[15] X. Fu,[16]
B. Nemati,[16] W.R. Ross,[16] P. Skubic,[16] M. Wood,[16] M. Bishai,[17] J. Fast,[17] E. Gerndt,[17]
J.W. Hinson,[17] T. Miao,[17] D.H. Miller,[17] M. Modesitt,[17] E.I. Shibata,[17] I.P.J. Shipsey,[17]
P.N. Wang,[17] L. Gibbons,[18] S.D. Johnson,[18] Y. Kwon,[18] S. Roberts,[18] E.H. Thorndike,[18]
T.E. Coan,[19] J. Dominick,[19] V. Fadeyev,[19] I. Korolkov,[19] M. Lambrecht,[19] S. Sanghera,[19]
V. Shelkov,[19] T. Skwarnicki,[19] R. Stroynowski,[19] I. Volobouev,[19] G. Wei,[19] M. Artuso,[20]
M. Gao,[20] M. Goldberg,[20] D. He,[20] N. Horwitz,[20] S. Kopp,[20] G.C. Moneti,[20]
R. Mountain,[20] F. Muheim,[20] Y. Mukhin,[20] S. Playfer,[20] S. Stone,[20] X. Xing,[20] J. Bartelt,[21]
S.E. Csorna,[21] V. Jain,[21] S. Marka,[21] D. Gibaut,[22] K. Kinoshita,[22] and P. Pomianowski[22]

(CLEO Collaboration)

[1] *California Institute of Technology, Pasadena, California 91125*

[2] *University of California, San Diego, La Jolla, California 92093*

[3] *University of California, Santa Barbara, California 93106*

[4] *University of Colorado, Boulder, Colorado 80309-0390*

[5] *Cornell University, Ithaca, New York 14853*

[6] *University of Florida, Gainesville, Florida 32611*

[7] *Harvard University, Cambridge, Massachusetts 02138*

[8] *University of Illinois, Champaign-Urbana, Illinois, 61801*

[9] *Carleton University, Ottawa, Ontario K1S 5B6 and the Institute of Particle Physics, Canada*

[10] *McGill University, Montréal, Québec H3A 2T8 and the Institute of Particle Physics, Canada*

[11] *Ithaca College, Ithaca, New York 14850*

[12] *University of Kansas, Lawrence, Kansas 66045*

[13] *University of Minnesota, Minneapolis, Minnesota 55455*

[14] *State University of New York at Albany, Albany, New York 12222*

[15] *Ohio State University, Columbus, Ohio, 43210*

[16] *University of Oklahoma, Norman, Oklahoma 73019*

[17] *Purdue University, West Lafayette, Indiana 47907*

[18] *University of Rochester, Rochester, New York 14627*

[19] *Southern Methodist University, Dallas, Texas 75275*

[20] *Syracuse University, Syracuse, New York 13244*

[21] *Vanderbilt University, Nashville, Tennessee 37235*

[22] *Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 24061*

ABSTRACT

Using the CLEO-II detector, we have studied the two-photon production of $\Lambda\overline{\Lambda}$ baryon pairs. No veto on extraneous energy in the electromagnetic calorimeter was attempted. Thus we report on preliminary measurements of $\Lambda\overline{\Lambda}$ plus neutrals production. The measured cross section appears to be larger than a quark-diquark based model predicts.

1. Introduction

In this paper we present the production of $\Lambda\overline{\Lambda}$ baryon pairs in untagged photon-photon interactions. The reactions are observed in the CLEO-II detector at the Cornell Electron Storage Ring (CESR), a high luminosity e^+e^- collider operating at center of mass energies near 10.5 GeV. This study is a continuation of a program to study the two-photon production of baryon pairs. CLEO results on $\gamma\gamma \to p\overline{p}$ obtained since the 1992 Workshop, have been published[1]. The two-photon production of $p\overline{p}$ was shown to be in agreement with a quark-diquark based model[2,3] whose parameters were adjusted using elastic electron-proton scattering only. The quark-diquark model predicts the cross section for other baryon-antibaryon pairs as well. In particular, the production for $\Lambda\overline{\Lambda}$ is predicted to be a factor 5 to 10 smaller than $p\overline{p}$ production. The $\Lambda\overline{\Lambda}$ channel is detected through the $\Lambda \to p\pi^-$ decay mode.

2. Detector and Data Sample

The measurement described here utilizes data collected with the CLEO-II general purpose magnetic detector. A brief description of the CLEO-II detector[4] and its trigger system[5] can be found in these proceedings[6]. In the present analysis the three cylindrical driftchambers are used for the tracking of charged pions and protons. dE/dx measurements in the central drift chamber and time-of-flight (ToF) measurements with scintillation counters located in the barrel at 1 m radial distance from the beam provide particle identification. The four triggers used are the two-track trigger and the electron trigger discussed already[6] and two multihadron triggers that require that at least two or three tracks have been recognized by their respective tracking processors. The datasample corresponds to an integrated luminosity of approximately 3.0 fb^{-1}.

3. Event Selection

The event selection identifies $\Lambda\overline{\Lambda}$ pairs through the $\Lambda \to p\pi^-$ (and charge-conjugate) decay channel. Events are required to have four tracks with total charge equal zero. Two-photon produced events are selected by requiring that the visible energy be less than 6 GeV

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*Permanent address: University of Hawaii at Manoa

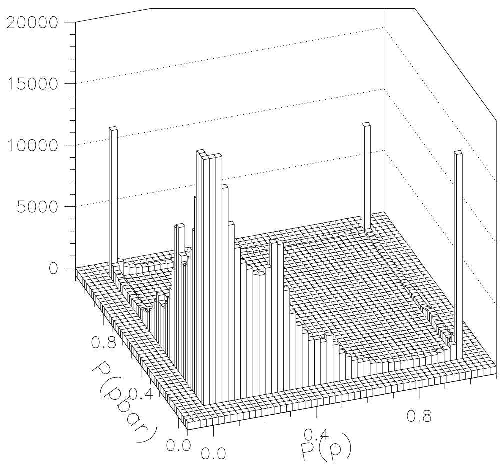

Fig. 1. Scatterplot of the probabilities P_p and $P_{\overline{p}}$ for four possible assigments of $p\,\pi^-\overline{p}\,\pi^+$.

(out of a maximum of 10.5 GeV). Because of the finite lifetime of the Λ the track quality can not be ensured by standard vertex cuts. Here we require that for each of the four tracks the component of the impact parameter parallel to the beam direction be less than 5.0 cm. The events are required to be triggered by at least one of the four triggers mentioned in Sec. 2.

Particle identification of the p and $\overline{p}$ is obtained by the use of the dE/dx and ToF information. Energy loss and time information from these devices are converted into a χ_i^2, one for each of five particle species $i = e, \mu, \pi, K, p$ and separately for dE/dx and ToF. The χ^2 are defined such that they are approximately gaussian distributed with zero mean and unit variance for a correct assignment of particle species so that $\exp(-\chi^2/2)$ is the probability distribution. Probabilities P_p ($P_{\overline{p}}$) that a particle species is a proton (antiproton) are equal to

$$\frac{e^{-\frac{\chi^2_{p,dE/dx}}{2}-\frac{\chi^2_{p,ToF}}{2}}}{\sum_i e^{\frac{\chi^2_{i,dE/dx}}{2}-\frac{\chi^2_{i,ToF}}{2}}}$$

for positive (negative) particles. No attempt is made to apply this procedure for pion identification as pion assignments to tracks are often ambiguous with another particle species' assignment. There are four possible ways to assign a $p\,\pi^-\overline{p}\,\pi^+$ combination to each event. Fig. 1 is a scatterplot of the probabilities P_p versus $P_{\overline{p}}$ with four entries per event. The accumulation of entries in the far corner corresponds to the presence of a $p\,\overline{p}$ pair in the event. The entries with large P_p ($P_{\overline{p}}$) correspond to pairings of protons (antiprotons) with other particle species. An excess of such pairings with a proton over an antiproton is evident and is due to beam-gas interactions and secondary interactions in material surrounding the interaction region. The $p\,\overline{p}$ entries are selected by requiring that they are within a circle of radius 0.1, centered on the point $P_p = P_{\overline{p}} = 1.0$.

Annihilation of antiprotons in the electromagnetic calorimeter causes large energy de-

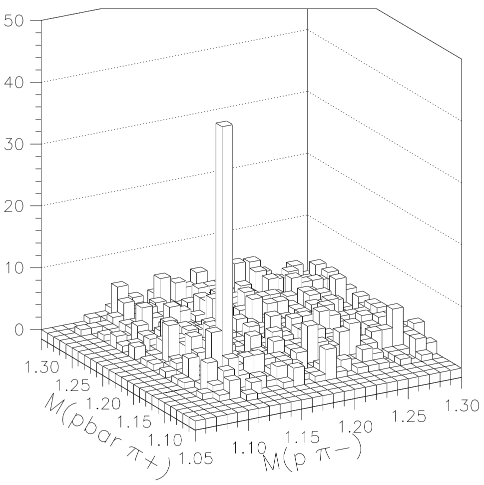

Fig. 2. Scatterplot of the effective mass $m(p\,\pi^-)$ versus $m(\overline{p}\,\pi^+)$.

posits equivalent to at least two proton masses. These deposits can be spread laterally over a large volume. We therefore do not veto events that have extra energy deposits in the calorimeter. The $\Lambda\overline{\Lambda}$ are therefore not necessarily produced exclusively. In particular, feeddown from other produced baryons that decay in a Λ and neutrals may contribute to the observed yield of $\Lambda\overline{\Lambda}$.

4. Signal Extraction

We show in Fig. 2 a scatterplot of the effective mass $m(p\,\pi^-)$ versus $m(\overline{p}\,\pi^+)$. A clear enhancement of 37 events is visible at the $\Lambda\overline{\Lambda}$ crossover point. There do not appear to be contributions from $(\overline{p}\,\pi^+)\,\Lambda$ or its charge conjugate ($\overline{p}\,\pi^+$ means non-resonant). To measure the $\Lambda\overline{\Lambda}$ signal, the same new method[7] is used as in the study of the $\omega\,\omega$ final state. The average of $m(p\,\pi^-)$ and $m(\overline{p}\,\pi^+)$ is formed and plotted in Fig. 3. A clear enhancement at the Λ mass is seen. It was shown[7] that such an enhancement in the average mass plot can only come from $\Lambda\overline{\Lambda}$ and that there is no contribution from $(\overline{p}\,\pi^+)\,\Lambda$ or its charge conjugate or from $(p\,\pi^-)(\overline{p}\,\pi^+)$.

We plot the visible energy of the events selected to be within 6 MeV of the $\Lambda\overline{\Lambda}$ average mass. For this plot the 6 GeV cut on the visible energy has been removed. The result is shown in Fig. 4. There is a clear evidence for events with large missing energy as expected for two-photon produced events.

5. Event Simulation and Cross Section

The event simulation consists of two parts: event generation and detector simulation.

Two-photon events are generated using the BGMS formalism as in Ref. [7]. The state X corresponds to the $\Lambda\overline{\Lambda}$ final state where the Λ are produced isotropically in the $\gamma\gamma$-CM

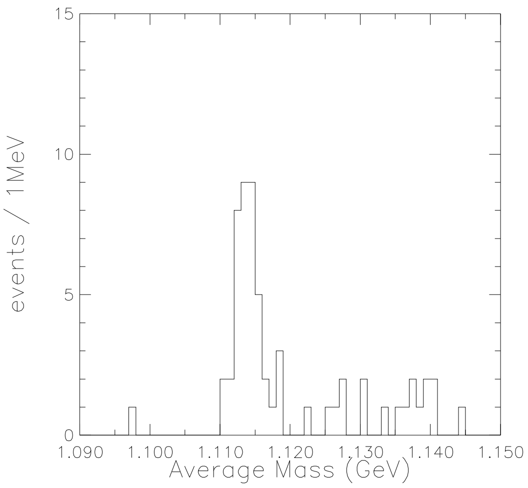

Fig. 3. Average mass.

according to

$$\sigma(\gamma\gamma \to \Lambda\overline{\Lambda}) = \frac{\text{const}}{W^{12}}\sqrt{1-\frac{4M_\Lambda^2}{W^2}}$$

Here W is the $\Lambda\overline{\Lambda}$ effective mass. The $\Lambda \to p\,\pi^-$ decay is generated isotropically in the Λ centre-of-mass.

The CLEO-II detector response, including the trigger, is simulated with CLEOG, a GEANT based package that generates raw data for each detector element in the same format as the real data. The data from the simulated events is processed through the same event reconstruction software and analyzed by the same analysis program as the real data. The resulting two-photon cross section $\sigma(\gamma\gamma \to \Lambda\overline{\Lambda})$ is plotted in Fig. 5 as function of W. The uncorrected angular distribution of the Λ in the $\Lambda\overline{\Lambda}$ centre-of-mass is shown in Fig. 5 together with the event simulation, normalized to the same number of events. The errors shown are statistical only.

A major source of systematic error is the current uncertainty in the track reconstruction efficiency for tracks below about 130 MeV. While that error is 5% per track for tracks over 130 MeV it could be a multiple of that for energies below 130 MeV. As both π momenta are often below 130 MeV we conservatively assign a 50% uncertainty to the cross section from this source. All other sources of systematic uncertainty lead to errors that are negligible relative to this one and need not be discussed at this preliminary stage of the analysis.

The $\Lambda\overline{\Lambda}$ cross section is seen to be about a factor two to three larger than the $p\,\overline{p}$ cross section. The quark-diquark model[2,3] on the other hand predicts that the $\Lambda\overline{\Lambda}$ cross section should be smaller than the $p\,\overline{p}$ cross section by a factor ranging from about 10 at low values of W to about three at $W = 3.5$ GeV. As already noted, the quark-diquark model is in good agreement with the measured[1] $p\overline{p}$ cross section at larger values of W.

The quark-diquark model has predictions for the production of other baryon-antibaryon pairs. For example, $\Sigma^0\overline{\Sigma^0}$ is predicted to have a cross section larger than the $\Lambda\overline{\Lambda}$ cross section

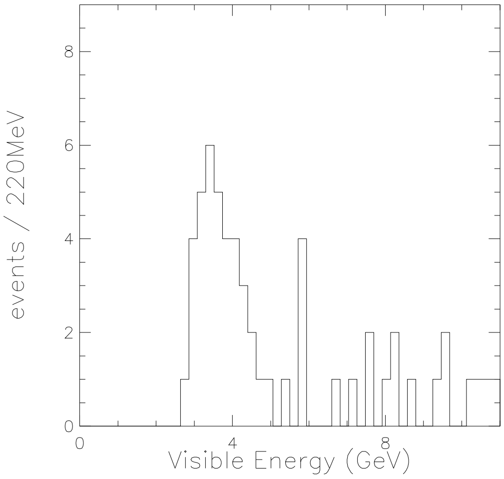

Fig. 4. Visible energy.

by a factor ranging from about two at low values of W to about three at $W = 3.5\,\mathrm{GeV}$. This process has feeddown into $\Lambda\overline{\Lambda}$ pairs through the decay $\Sigma^0 \rightarrow \Lambda\gamma$. As we have not rejected events with unmatched energy in the electromagnetic calorimeter a possible Σ^0 contribution is not vetoed. A study of higher mass baryon-antibaryon production and its feeddown to $\Lambda\overline{\Lambda}$ are in progress.

6. Conclusions

We report preliminary results of a study of two-photon production of $\Lambda\overline{\Lambda}$ baryon pairs with the CLEO-II detector at CESR. Due to annihilation of antiprotons in the electromagnetic calorimeter we do not veto on unmatched electromagnetic energy so the $\Lambda\overline{\Lambda}$ may be accompanied by neutral particles. The dataset corresponds to $3.0\,\mathrm{fb}^{-1}$, 37 events have been observed in the W range from 2.2 to 3.5 GeV.

The yield appears to be in conflict with the quark-diquark model but firm conclusions must await a reduction of the systematic error due to track reconstruction efficiency and the results of the study of feeddown from other baryon-antibaryon pairs.

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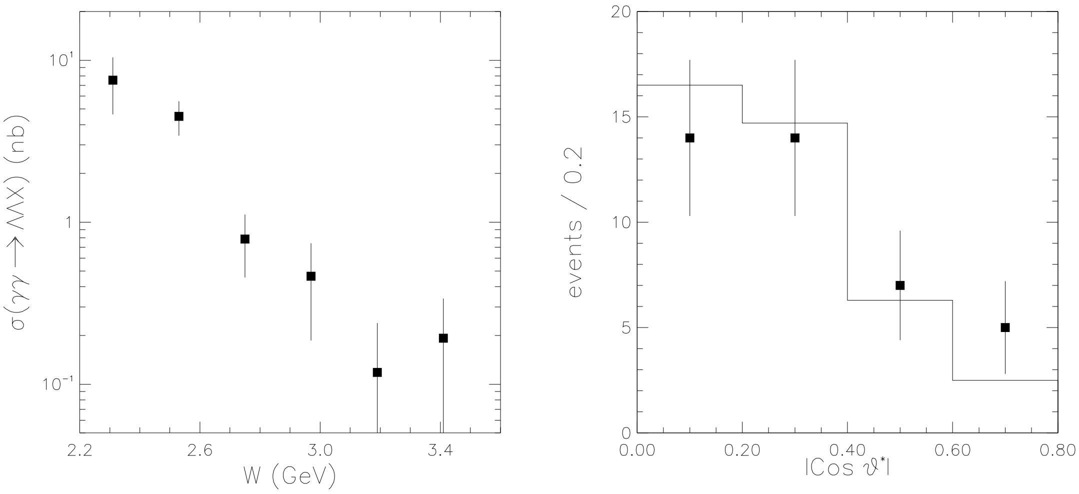

Fig. 5. Cross section for $\sigma(\gamma\gamma \to \Lambda\overline{\Lambda})$ as function of W and the uncorrected angular distribution of the Λ in the $\Lambda\overline{\Lambda}$ centre-of-mass. The histogram is the event simulation. The errors shown are statistical only.