EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/EP 87-32
17 February 1987

BARYON ANTIBARYON PRODUCTION IN THE CENTRAL REGION AT 85 GeV/c

WA76 Collaboration

Athens - Bari - Birmingham - CERN

CERN/EP 87-32

T.A. Armstrong ^{1,*}), I.J. Bloodworth ²⁾, J.N. Carney ²⁾, R. Childs ²⁾, B.R. French ¹⁾,
B. Ghidini ³⁾, J.B. Kinson ²⁾, V. Lenti ³⁾, A. Palano ^{1,**}), G. Vassiliadis ⁴⁾,
O. Villalobos Baillie ²⁾, M.F. Votruba ²⁾, G. Zito ³⁾ and R. Zitoun ⁵⁾

Abstract

In a search for glueballs and exotic states decaying into baryons and antibaryons we have investigated the production of baryon antibaryon pairs produced centrally in the reactions $\pi^+/p \rightarrow \pi^+/p (X^0) p$ at 85 GeV/c. In particular channels where X^0 goes to $p \bar{p}$, $p \bar{p} \pi^+ \pi^-$, $p \bar{p} 2\pi^+ 2\pi^-$ and $\Lambda \bar{\Lambda}$ have been observed. No significant new structure is observed in the mass spectra.

Submitted to Zeitschrift für Physik C

-
- 1) CERN, European Organization for Nuclear Research, CH-1211 Geneva 23, Switzerland
  - 2) Physics Department, University of Birmingham, Birmingham, U.K.
  - 3) Dipartimento di Fisica dell'Università and Sezione INFN, Bari, Italy
  - 4) Nuclear Physics Department, Athens University, Athens, Greece
  - 5) LPNHE, Universités de Paris VI et VII, Paris, France

*) Present address: Pennsylvania State University, University Park, USA

**) On leave of absence from the University of Bari, Italy

1. Introduction

Experiment WA76 at CERN aims at studying the centrally produced exclusive final states, and searches for signs of new mesonic states. As the centre of mass energy increases Double Pomeron Exchange (DPE) is one of the production mechanisms which is expected to become more important and, if the Pomeron is composed of multigluons, DPE can be expected to be a source of gluonium states [1].

This paper reports the results of a search for new states whose decays involve baryon antibaryon pairs, and is part of a systematic exploration of the central region in exclusive reactions [2].

The data come from the WA76 experiment performed at CERN using the Ω spectrometer in the H1 beam which contains approximately equal numbers of π^+ and protons at 85 GeV/c. Details of the trigger conditions and the data processing have been given in a previous publication [2a].

2. The $p \bar{p}$ system

The reactions

$$\pi^+ / p \, p \rightarrow \pi^+ / p_f (p \bar{p}) p_s \quad (1)$$

where the subscripts f and s refer to the fastest and slowest positive particles in the laboratory system, have been isolated from the sample of events with four outgoing tracks in the final state. Momentum balancing events were selected by requiring $|\text{missing } P_x| < 4.00 \text{ GeV/c}$, $|\text{missing } P_y| < 0.12 \text{ GeV/c}$ and $|\text{missing } P_z| < 0.10 \text{ GeV/c}$.

We have assumed that the fast forward particle has the same mass as the incident particle, while the slow proton has been identified by using pulse - height information.

In order to isolate the $p \bar{p}$ final state, we have requested that one of the two central particles be identified by the Cherenkov information to be a p ($\bar{p}$) or ambiguous K^+ / p ($K^- / \bar{p}$). The remaining track was required, if reaching the Cherenkov system, to have a mass identification compatible with

the antiproton (proton). Following the method of Ehrlich et al. [3] fig. 1a shows the distribution of the mass squared of the two central particles (assumed to be equal). The peak centred at the square of the proton mass is the signal of the $p \bar{p}$ final state. The reactions have been selected by requiring $0.76 \leq M^2(X) \leq 1.06 \text{ GeV}^2$, and results in a total of 3712 events (71% p beam, 29% π^+ beam).

The observed Feynman x_F distributions for the slow, fast and central system are displayed in fig. 1b; the $p \bar{p}$ system is mainly concentrated at $|x_F| < 0.25$.

The $p \bar{p}$ mass spectrum is shown in fig. 2a for π^+ incident and in fig. 2b for p incident. The two spectra are similar and their sum is shown in fig. 2c. This distribution has been fitted by a curve of the form $dN/dm = (m - m_{th})^\alpha e^{-\beta m}$, where m_{th} is the threshold mass of the $p \bar{p}$ system.

The fitted function is superimposed on the data in fig. 2c while fig. 2d shows what remains after the background subtraction. The fit gives a $\chi^2/\text{NDF} = 105/88$ and no structure exceeding the 3σ level is seen. Recently a new state (the $\xi(2220)$) has been suggested in this mass region in the radiative J/ψ decay $J/\psi \rightarrow \gamma \xi$, $\xi \rightarrow K^+ K^-$ and $K^0 \bar{K}^0$ [4]. Attempts to observe this state in $p\bar{p} \rightarrow K^+ K^-$ [5] have given negative results. We have estimated our experimental resolution in the 2.22 GeV mass region to be ± 5 MeV. We find upper limits for the production of a 3σ (30 MeV wide) effect at 2.22 GeV, after correction for acceptance, losses and inefficiencies, of 1 nb (π^+ incident) and of 2.5 nb (p incident).

3. The $p \bar{p} \pi^+ \pi^-$ system

The reactions

$$\pi^+ / p \ p \rightarrow \pi^+ / p_f (p \bar{p} \pi^+ \pi^-) p_s \quad (2)$$

have been isolated from the sample of events with six outgoing tracks in the final state.

The mass identification for this channel was achieved by assuming the fast particle to be of the same nature as the incident beam and by identifying the slow proton by the pulse – height momentum correlation. The baryon antibaryon pair was identified by using the information from the two Cheren-

kov counters C1 and C2, i.e. requiring one positive particle to be identified as a p or K/p and one negative particle to be identified as a $\bar{p}$ or $K^-/\bar{p}$. The two remaining tracks were required, if reaching the Cherenkov system, to have a mass assignment compatible with the pion.

Momentum balancing events were selected by requiring $|\text{missing } P_x| < 3.00 \text{ GeV/c}$, $|\text{missing } P_y| < 0.10 \text{ GeV/c}$ and $|\text{missing } P_z| < 0.08 \text{ GeV/c}$.

The Cherenkov information antiselects all the competing channels except the $K^+ K^- \pi^+ \pi^-$ final state. In order to separate this contribution we have plotted in fig. 3a the Δ function defined as

$$\Delta = MM^2(\pi^+ f/P_f P_s) - M^2(p \bar{p} \pi^+ \pi^-)$$

The plot shows a signal around zero corresponding to reactions (2) with little background. The final selection of the $p \bar{p} \pi^+ \pi^-$ channel has been achieved by requiring $|\Delta| < 2.0 \text{ GeV}^2$ resulting in 1257 events (71% belonging to the p beam and 29% to the π^+ beam).

The Feynman x_F distributions for the slow, the fast and the $p \bar{p} \pi^+ \pi^-$ system are shown in fig. 3b. The x_F distribution of the $p \bar{p} \pi^+ \pi^-$ system is shifted towards positive values due mainly to the requirement of Cherenkov identification of the baryon antibaryon pair which requires their momenta be greater than 3.0 GeV/c. Selected mass spectra involving central particles are shown in fig. 4. No structure is observed except $\Delta^{++} (\bar{\Delta}^{--})$ in the $p \pi^+ (\bar{p} \pi^-)$ mass distribution. We have investigated the possibility of associated $\Delta^{++} \bar{\Delta}^{--}$ production and fig. 5 shows the scatter diagram $M(p \pi^+)$ vs $M(\bar{p} \pi^-)$. Problems are encountered due to the correlation between the Δ and phase space and an attempt to fit the whole channel by the channel likelihood fit method [6] gives inconclusive results. The analysis, however, shows that the data are consistent with incoherent production of Δ^{++} and $\bar{\Delta}^{--}$.

4. The $p \bar{p} 2\pi^+ 2\pi^-$ system

We have selected the reactions

$$\pi^+/\bar{p} p \rightarrow \pi^+ f/P_f (p \bar{p} 2\pi^+ 2\pi^-) P_s \quad (3)$$

using the technique described in sect. 3. The channels were selected from the sample of events with eight tracks in the final state and two particles were required to be identified as p ($\bar{p}$) or ambiguous K^+/p ($K^-/\bar{p}$). Momentum balancing events were selected by requiring $|\text{missing } P_x| < 4.00 \text{ GeV}/c$, $|\text{missing } P_y| < 0.20 \text{ GeV}/c$ and $|\text{missing } P_z| < 0.15 \text{ GeV}/c$. The final selection of the channel was achieved by requiring the Δ function (fig. 6a) defined as

$$\Delta = MM^2(\pi^+ f/p_f p_s) - M^2(p \bar{p} 2\pi^+ 2\pi^-)$$

to satisfy $|\Delta| < 2.0 \text{ GeV}^2$.

The final sample consists of 294 events (62% belonging to the p beam and 38% to the π^+ beam). The Feynman x_F distributions for the slow proton, the central system and the fast track are shown in fig. 6b. Some relevant mass distributions are shown in fig. 7. Production of Δ^{++} and $\bar{\Delta}^{--}$ can be observed in the combined $p \pi^+$ and $\bar{p} \pi^-$ mass spectrum. No structure is observed in the $p \pi^+ \pi^+$ or $\bar{p} \pi^- \pi^-$ mass spectra where exotic states have been predicted [7].

5. The $\Lambda \bar{\Lambda}$ system

The reactions

$$\pi^+/p \rightarrow \pi^+ f/p_f (\Lambda \bar{\Lambda}) p_s \quad (4)$$

have been isolated from the sample of events with two outgoing tracks and two reconstructed V^0 's. Momentum balancing events were selected by requiring $|\text{missing } P_x| < 4.00 \text{ GeV}/c$, $|\text{missing } P_y| < 0.15 \text{ GeV}/c$ and $|\text{missing } P_z| < 0.12 \text{ GeV}/c$. In order to separate Λ from γ and K^0 we required one of the two V^0 to have the baryon (antibaryon) identified as a p ($\bar{p}$) or ambiguous K^+/p ($K^-/\bar{p}$). The remaining tracks were required to have a mass assignment, if any, compatible with the $\Lambda \bar{\Lambda}$ assignment. Energy balance was achieved by requiring the Δ function (shown in fig. 8a) defined as

$$\Delta = MM^2(\pi^+ f/p_f p_s) - M^2(\Lambda \bar{\Lambda})$$

to satisfy $|\Delta| < 2.0 \text{ GeV}^2$. The $p \pi^- (\bar{p} \pi^+)$ effective mass after this selection is shown in fig. 9a where a clear $\Lambda (\bar{\Lambda})$ signal can be seen over little background. The Λ and $\bar{\Lambda}$ signals were selected by requiring $M(p \pi^-)$ and $M(\bar{p} \pi^+) < 1.15 \text{ GeV}$.

The final sample consists of 59 events (63% belonging to the p beam and 37% to the π^+ beam). The Feynman x_F distribution for the slow, the central $\Lambda \bar{\Lambda}$ system and the fast particle are shown in fig. 8b. The effective mass distribution $\Lambda \bar{\Lambda}$ is shown in fig. 9b. The majority of the events are concentrated in the threshold region.

6. Conclusions

We have studied the production of baryon antibaryon systems in the central region at 85 GeV/c incident momentum by p and π^+ in a search for glueballs and exotic states. The channels show little resonance production with the exception of Δ^{++} and $\bar{\Delta}^{--}$ states. Upper limits of 1 nb (π^+ incident) and 2.5 nb (p incident) have been calculated for the production of $\xi(2220)$ decaying to $p \bar{p}$ in the range $|x_F| < 0.25$.

7. References

- [1] D. Robson, Nucl. Phys. B130 (1977) 328.
- [2] a) T.A. Armstrong et al., Phys. Lett. 146B (1984) 273.
b) T.A. Armstrong et al., Phys. Lett. 166B (1986) 245.
c) T.A. Armstrong et al., Phys. Lett. 167B (1986) 133.
d) T.A. Armstrong et al., CERN/EP 86-138, 26 September 1986
e) T.A. Armstrong et al., CERN/EP 86-139, 26 September 1986
- [3] R. Ehrlich et al., Phys. Rev. Lett. 20 (1968) 686.
- [4] R.M. Baltrusaitis et al., Phys. Rev. Lett. 56 (1986) 107.
- [5] J. Sculli et al., XXIII Int'l. Conf. on High Energy Physics, Berkeley, USA (1986).
- [6] P.E. Condon and P. Cowell, Phys. Rev. D9 (1974) 2258.
- [7] L.S. Bagdasaryan et al., Preprint YPI-812(39)-85.

8. Figure captions

- Fig. 1   a) Mass squared of the central particles in the four body final state after having required one particle to be identified as K or ambiguous K/p. The three peaks correspond to the signals of the reactions with $\pi^+ \pi^-$, $K^+ K^-$ or $p \bar{p}$ in the final state.
              b) Feynman x_F distribution for the slow proton, the $p \bar{p}$ system and the fast particle.
- Fig. 2   a) Effective $p \bar{p}$ mass spectrum for incident π^+ .
              b) Effective $p \bar{p}$ mass spectrum for incident p;
              c) Effective $p \bar{p}$ mass spectrum for the combined reactions. The line is the result of the fit described in the text.
              d) Fit residuals.
- Fig. 3   a) Δ function for centrally produced $p \bar{p} \pi^+ \pi^-$ candidates.
              b) Feynman x_F distribution for the slow proton, the $p \bar{p} \pi^+ \pi^-$ system and the fast particle.
- Fig. 4   Effective mass distributions for the $p \bar{p} \pi^+ \pi^-$ channel.
              a) Effective mass $p \bar{p} \pi^+ \pi^-$.
              b) Effective mass $p \pi^+$ and $\bar{p} \pi^-$.
              c) Effective mass $p \bar{p}$.
              d) Effective mass $\pi^+ \pi^-$.
- Fig. 5   Scatter diagram $M(p \pi^+) vs M(\bar{p} \pi^-)$ for the centrally produced $p \bar{p} \pi^+ \pi^-$ final state.
- Fig. 6   a) Δ function for centrally produced $p \bar{p} 2\pi^+ 2\pi^-$ candidates.
              b) Feynman x_F distribution for the slow proton, the central $p \bar{p} 2\pi^+ 2\pi^-$ system and the fast particle.
- Fig. 7   Effective mass distributions for the reactions having a centrally produced $p \bar{p} 2\pi^+ 2\pi^-$ final state.
              a) Effective mass $p \bar{p} 2\pi^+ 2\pi^-$.

- b) Effective mass $2\pi^+ 2\pi^-$.
- c) Effective mass $p \pi^+$ and $\bar{p} \pi^-$.
- d) Effective mass $p \pi^+ \pi^+$ and $\bar{p} \pi^- \pi^-$.

Fig. 8 a) Δ function for events which are candidates for belonging to the reaction containing a centrally produced $\Lambda \bar{\Lambda}$ system.

b) Feynman x_F distribution for the slow proton, the $\Lambda \bar{\Lambda}$ system and the fast particle.

Fig. 9 a) Effective mass $p \pi^-$ and $\bar{p} \pi^+$ at the V^0 vertices.

b) Effective mass $\Lambda \bar{\Lambda}$.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9