STUDY OF THE REACTION $\bar{p}p \to \bar{n}n$ WITH ANTIPROTON MOMENTUM IN THE RANGE 700-750 MeV/c

Bombay-CERN-Neuchâtel-Tokyo Collaboration

B.S. Chaudhary, S.N. Ganguli, A. Gurtu, P.K. Malhotra, U. Mehtani, R. Raghavan and A. Subramanian; L. Montanet; M. Bogdanski and E. Jeannet; S. Kitamuya, S. Hamada, R. Hamatsu and T. Yamagata; T. Emura, I. Kita, M. Komatsu, K. Takahashi and A. Yamasaki; H. Kohno and S. Matsumoto

(Presented by P.K. Malhotra)

1. INTRODUCTION

Interest in the study of the charge exchange reaction of antiprotons with protons is manifold. Firstly, by combining data on the $\bar{p}p$ charge exchange reaction

$$\bar{p}p \to \bar{n}n \qquad (1)$$

with data on elastic scattering

$$\bar{p}p \to \bar{p}p \qquad (2)$$

one can extract information on the relative importance of I=0 and I=1 amplitudes in $\bar{p}p$ interactions.

Secondly, the $\bar{p}p$ charge exchange reaction (1) is connected to the np charge exchange reaction

$$np \to pn \qquad (3)$$

by line reversal. One may therefore expect a similarity in the $d\sigma/dt$ distributions for reactions (1) and (3). In particular it would be interesting to see if the sharp forward spike found in the d /dt distribution at $|t| < m_\pi^2$ in reaction (3) is also observed in the $\bar{p}p \to \bar{n}n$ reaction. This forward peak for $\bar{p}p \to \bar{n}n$ is predicted in the non-relativistic model of Bryan and Phillips [1] whose potential is a combination of one boson exchange and an imaginary absorption potentials. There exist already some experiments on the $\bar{p}p$ charge exchange reaction [2] but with their limited statistics it has not been possible to determine definitely if a sharp forward spike in $d\sigma/dt$ exists or not. We present here preliminary results based on one-third of our entire data on differential angular distribution of the charge exchange reaction $\bar{p}p \to \bar{n}n$.

2. EXPOSURE DETAILS

(i) Two exposures with antiproton beams of momenta 700 MeV/c (Exposure I) and 750 MeV/c (Exposure II) were made in the Saclay 81 cm hydrogen bubble chamber. The present experiment is based on 234 K pictures at 700 MeV/c and 400 K pictures at 750 MeV/c. The above values of the beam momenta are the average values at the $\bar{p}p$ vertex. A part from each of these exposures has been used here to obtain the preliminary results.

(ii) The contaminations of π^- and μ^- in the antiproton beams are listed in Table 1 for the two exposures.

3. DETECTION OF ANTINEUTRON STARS

(i) The detection of the charge exchange reaction (1) is made by first searching for annihilations of antineutrons with protons giving rise to odd number of charge prongs and then searching for the associated zero prong $\bar{p}p$ annihilations. For antineutron annihilations we select only those events which give rise to 3 or more charge prongs, because it is difficult to identify one prong events from background single tracks. Antineutron annihilation events are not always associated with a zero prong $\bar{p}p$ charge exchange event, because some $\bar{p}$ beam tracks may interact with matter prior to entering the bubble chamber and give rise to antineutrons. Thus we are led to classify antineutron events as (i) associated ones, i.e. where one sees $\bar{p}p$ zero prong event and (ii) unassociated ones where one does not see the $\bar{p}p$ zero prong event. The relative magnitude of these two categories are listed in Table 1.

All the pictures were scanned twice and the scanning efficiencies for the two exposures are given in Table 1.

(ii) Among the antineutron stars giving rise to 3 charged prongs there will be a contamination from πp elastic scattering events. In order to minimise this contamination all the positive tracks were scrutinized on the scanning table to see whether they leave the chamber. A stopping non-decaying positive track was classified as a proton and three prong events with a positive track stopping in the chamber were rejected as they were definitly due to πp scattering. All three prong events with associated fast protons (leaving the chamber), which are therefore candidates for πp scattering, were also recorded. The removal of such πp scattering events is discussed later.

All events of the associated category have been measured and passed through THRESH.

(iii) From the frequency of unassociated antineutron stars and the frequency of zero prong $\bar{p}p$ annihilations, the contamination in the associated antineutron stars due to the coincidence of unassociated antineutron stars with zero prong $\bar{p}p$ is calculated and the values for the two exposures are given in Table 1.

(iv) Coplanarity test was made from THRESH output to remove the πp elastic scattering events where protons did not stop in the chamber. We define COPL as

$$\mathrm{COPL} = \vec{i} \cdot (\vec{j} \times \vec{k})$$

where, $\vec{i}$, $\vec{j}$ and $\vec{k}$ are unit momentum vectors along the direction of the three charged particles. The distribution of COPL shows a sharp peak at $\lesssim 0.03$ superimposed on a uniform distribution pertaining to genuine $\bar{n}p$ events. The peak is due to πp elastic events. The contribution of πp elastic events among the three prong events for the two exposures are given in Table 1..

4. EXPERIMENTAL RESULTS

(i) To obtain the differential cross section we have weighted each event by the inverse of the probability of detection of $\bar{n}$ annihilation stars. The probability is given by

$$P(T) = [1 - \exp(-N\rho L\sigma_{tot}(T))] \, \sigma_{anh}(T)/\sigma_{tot}(T)$$

where N is Avogadro's number, ρ the density of hydrogen, L is the potential length of $\bar{n}$ and $\sigma_{anh}(T)$ is the annihilation cross section of $\bar{n}$ of kinetic energy T in MeV, to give rise to ≥ 3 charge prongs. The latter has been taken to be [2]:

$$\sigma_{anh}(T) = 722/\sqrt{T} \text{ , in mb.}$$

Because of the mass difference between neutron and proton, there are two values of momentum of $\bar{n}$ even though we know the laboratory angle of emission of $\bar{n}$. It has been discussed in detail by several workers [2] that it is more appropriate to choose the higher momentum solution for $\bar{n}$ and so we have also used the higher momentum solution of $\bar{n}$. However, this assumption implies that our data for the very backward direction, $\cos\theta^* \lesssim (-0.95)$ may not be very reliable.

Fig. 1 shows our results on differential cross section of the reaction $\bar{p}p \rightarrow \bar{n}n$ based on 1827 events.

The salient features of this figure are:

(i) there seems to be a sharp forward peak and

(ii) there is a clear secondary maximum.

The curves shown are the predictions of Bryan and Phillips [1] model (solid curve) and Frahn and Venter model (dotted curve) modified by Daum at al. [3] for $\bar{N}N$ scattering.

Bryan and Phillips use one boson exchange potentials (OBE) which are real and a phenomenological imaginary potential (independent of spin and isospin) of the Woods-Saxon shape to take care of the strong absorption in $\bar{N}N$ case. The OBE potentials are obtained by fitting the NN data and are used for $\bar{N}N$ case after changing the sign of contributions from mesons of odd G-parity. It is clear from fig. 1 that the present data is in reasonable agreement with the predictions of Bryan and Phillips model. However, as pointed out by Ohsugi et al., [4] the predictions of this model for polarization in $\bar{p}p$ elastic scattering disagree with their data.

The other model with which we compare our results is a diffraction model developed by Daum et al., from an earlier model of Frahn and Venter [3].

The model contains five parameters: radius R, skin thickness r, transparency ε and two parameters $\mu^{\pm}$ which describe contributions from the parallel and antiparallel spin states to the real part of the scattering amplitude. The model neglects spin-spin interactions compared to spin-orbit interactions. We have carried out a simultaneous fit to the data of fig. 1 as well as the differential cross section and polarization data of Kohno et al. [5] and Ohsugi et al. [4] respectively, for $\bar{p}p \rightarrow \bar{p}p$ elastic scattering. The overall fit is quite good for all the three types of data and the values of the parameters obtained are $R = 1.47$ fm, $r = 0.28$ fm, $\mu^+ = 1.16$, $\mu^- = -0.47$ and $\varepsilon = 0$. The fit corresponding to the charge exchange data is shown (dashed) in fig. 1.

The conclusions arrived in this preliminary investigation may be summarised as follows:

(a) The differential angular distribution for the charge exchange reaction $\bar{p}p \rightarrow \bar{n}n$ at 700-750 MeV/c seems to exhibit a sharp peak in the forward direction and a secondary maximum.

(b) Considering the data on $\bar{p}p \rightarrow \bar{n}n$, $\bar{p}p \rightarrow \bar{p}p$ and the polarisation in totality we find that the diffraction model of Frahn and Venter as modified by Daum et al., seems to fit the data better than the model of Bryan and Phillips.

Finally, we would like to mention that the preliminary results presented here are based on only one-third of our data. We hope to be able soon to draw quantitatively more definite conclusions from the analysis of our entire data.

REFERENCES

[1] R.A. Bryan and R.J.N. Phillips, Nucl. Phys. B5 (1968) 201.

[2] R. Bizzarri et al., Nuovo Cimento 54A (1968) 456;
H. Kohno et al., Nucl. Phys. B41 (1972) 485;
A. Colebourne et al., (Liverpool-Neuchâtel-Lausanne Collaboration), Nucl. Phys. B70 (1974) 205.

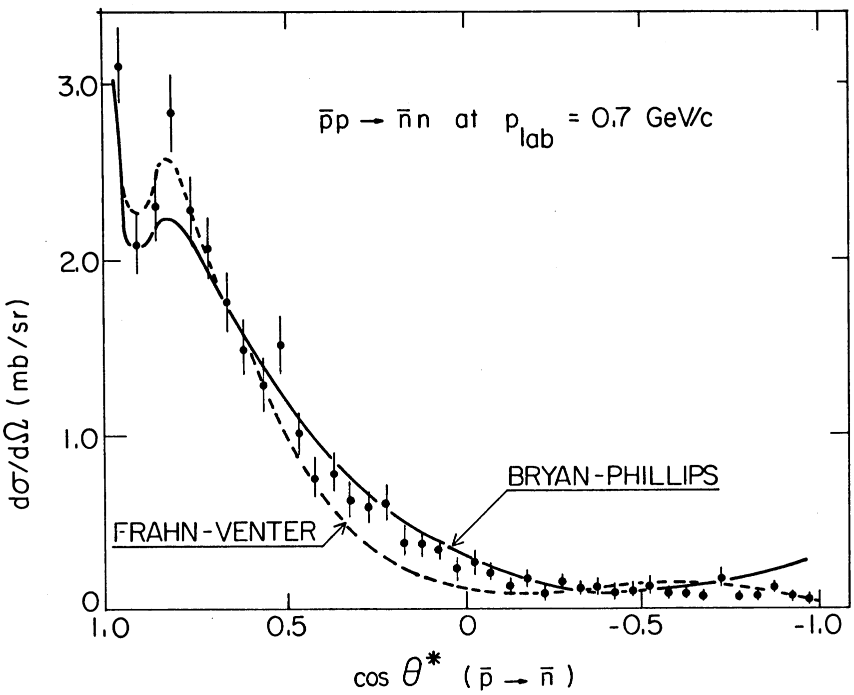
[3] W.E. Frahn and R.H. Venter, Ann. of Phys. 27 (1964) 135, 385, 401.
C. Daum et al., Nucl. Phys. B6 (1968) 617.

[4] T. Ohsugi et al., Nuovo Cimento 17A (1973) 456.

[5] H. Kohno, Journ. of Sciences of the Hiroshima University, 37A No. 2, 1967.

TABLE 1

Exposure	π^-, μ^- contamination	(Associated)/(unassociated)	Scanning Efficiency	Coplanar events among 3 prongs	Contamination in associated $\bar{n}$ stars from coincidence
I	9%	1.0	97%	15%	10%
II	10%	1.9	96%	13%	6%



$\bar{p}p \to \bar{n}n$ at p_{lab} = 0.7 GeV/c
3.0
2.0
1.0
0
dσ/dΩ (mb/sr)
BRYAN-PHILLIPS
FRAHN-VENTER
1.0
0.5
0
-0.5
-1.0
cos θ* ($\bar{p} \to \bar{n}$)

Fig. 1

D I S C U S S I O N

- *Moebes:*

  How many events do you have?

- *Malhotra:*

  1827, and we should very soon have three times that.

- *Kalogeropoulos:*

  What is the efficiency for detecting an $\bar{n}$? and how much does it change for various angles?

- *Malhotra:*

  The average weight factor is 24.5.