THE ANNIHILATION REACTION $p\bar{p} \to 3\pi^+3\pi^-$ WITH AN ISOBARIC AMPLITUDE

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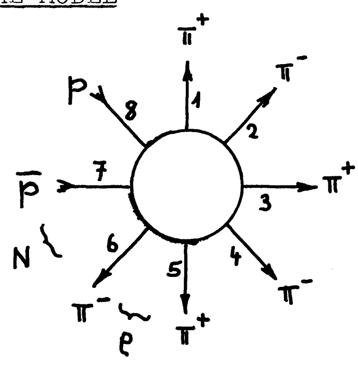
ABSTRACT

A good overall description of the experimental data for the reaction $p\bar{p} \to 3\pi^+3\pi^-$ is achieved with an isobaric amplitude A_8.

1. INTRODUCTION

A successful overall description of annihilation processes has been first obtained by dual amplitudes for reactions at rest, namely for $\bar{p}n \to \pi^+\pi^-\pi^-$ [1], $p\bar{p} \to \pi^+\pi^-\pi^0$ [2], and $p\bar{p} \to 2\pi^+2\pi^-$ [3]. More recent investigations have shown that a similar agreement with the experimental data can also be achieved using simple isobaric amplitudes [4]. The attempt to describe an annihilation reaction in flight with an isobaric amplitude is based on the results of a further study of the process $p\bar{p} \to 2\pi^+2\pi^-$ at rest [5]: The distributions from the dual B_5 computation (Ref.3) can be reproduced almost point by point by a simple isobaric amplitude A_5 with only one resonance pole and irrespective of the use of "kinematical factors". The same holds true for an isobaric A_6. It is therefore suggestive to look for a n-body final state $p\bar{p}$ annihilation in flight dominated by a single resonance, and attempt its description by an A_{n+2} amplitude without caring for the construction of "kinematical factors". Such a candidate is the reaction $p\bar{p} \to 3\pi^+3\pi^-$, as the data show a dominant ρ^0 peak in $M(\pi^+\pi^-)$, a moderate asymmetry in the CM angular distributions of the pions and for the other one-dimensional distributions a rather statistical behaviour.

2. THE MODEL



Starting from the graph shown ($p\bar{p}$ adjacent, no exotic resonances or exchanges) an ansatz for the amplitude is made:

$$A = c \sum_{\text{Perm}\begin{cases}1,3,5\\2,4,6\end{cases}} (-1)^{\text{Perm}} A_8(1,2,3,4,5,6,7,8),$$

where c means a normalization constant. "Perm" stands for the 36 permutations from the symmetrization in the positive and negative pions, respectively. The evaluation of A_8 follows from the required symmetry and factorization properties of the amplitude:

$$A_8 = \frac{1}{x_{12}} A_7(12,3,4,5,6,7,8) + \frac{1}{x_{23}} A_7(\ldots) + \ldots$$

$$= \frac{1}{x_{123}} A_6(123,4,5,6,7,8) + \ldots$$

$$= \frac{1}{x_{1234}} A_5(1234,5,6,7,8) + \ldots$$

The essential term from this expression is:

$$A_8 = \left(\frac{1}{x_{1234}} + \frac{1}{x_{3456}}\right) \cdot \frac{1}{x_{12}} \cdot \frac{1}{x_{34}} \cdot \frac{1}{x_{56}} \cdot \frac{1}{x_{78}} + \left(\frac{1}{x_{2345}} + \frac{1}{x_{4567}}\right) \cdot \frac{1}{x_{23}} \cdot \frac{1}{x_{45}} \cdot \frac{1}{x_{67}} \cdot \frac{1}{x_{81}}$$

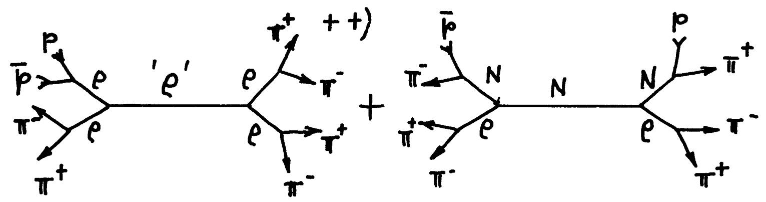
where x_{ijkl} and x_{ij} mean:

$x_{ij} = 1 - \alpha_\rho(s_{ij})$ +) (ρ trajectory in case of a resonance in s_{ij}),

$x_{ij} = \frac{1}{2} - \alpha_N(t_{ij})$ +) (N trajectory in case of an exchange with t_{ij}).

This result corresponds to the diagram:

$A_8 \equiv$



3. RESULTS AND DISCUSSION

With the above amplitude a good overall description of the reaction $p\bar{p} \to 3\pi^+ 3\pi^-$ at various incoming momenta is obtained. The model reproduces both the asymmetry in the CM production angles of the pions (Fig.1) and the resonance production in $M(\pi^+\pi^-)$, as shown in Fig.2.

Table 1

Cross sections from the isobaric amplitude A_8 (mb) – $\frac{\Delta\sigma}{\sigma} \lesssim 10\%$ –

$\vec{p}$ (GeV/c)	exp	A_8
2.5	0.94 ± 0.06	1.9
3.6	0.92 ± 0.06	0.92
5.7	0.31 ± 0.06	0.34
7.0	0.25 ± 0.03	0.20

+) $\alpha_\rho(s) = 0.48 + 0.9s + i\,0.2(s - s_0)^{\frac{1}{2}}$
$\alpha_N(t) = -0.87 + 0.9t$

++) The (forbidden) $\rho^0\rho^0\rho^0$ coupling is used only for computational purposes. Obviously the exact numerical value of the meson 'ρ' is of minor importance here.

The predicted cross sections, normalized to the 3.6 GeV/c value, are listed in table 1. Detailed references to the various experimental results are given in Ref.6.

We want to stress that in constructing our model no attempt was made to parametrize the data but rather to give an acceptable global description. We found that within the framework of the model, interferences play an essential role. Neglecting the Bose-Einstein symmetrization, or adding the parts of the amplitude incoherently, yields a much poorer agreement with the data. This may be regarded as a hint of the importance of interference phenomena in this kind of interactions.

It is a pleasure for me to acknowledge the excellent collaboration with Dr.J. Boguta throughout this work.

REFERENCES

1) C. Lovelace, Phys.Letters 28B. 264 (1968)
2) R. Jengo and E. Remiddi, Lett.Nuovo Cimento, 1, 637 (1969)
3) J.F.L. Hopkinson and R.G. Roberts, Lett.Nuovo Cimento, 2, 466 (1969)
4) J. Boguta, Nucl.Physics, B13, 537 (1969)
J. Boguta, Lett.Nuovo Cimento , 2, 743 (1971)
J. Boguta, Lett.Nuovo Cimento , 2, 764 (1971)
5) J. Boguta and B. Nellen, $p\bar{p} \to 2\pi^+2\pi^-$ in an isobaric A_6 model (in preparation)
6) B. Nellen, Internal Report, University of Bonn (1971), unpublished.

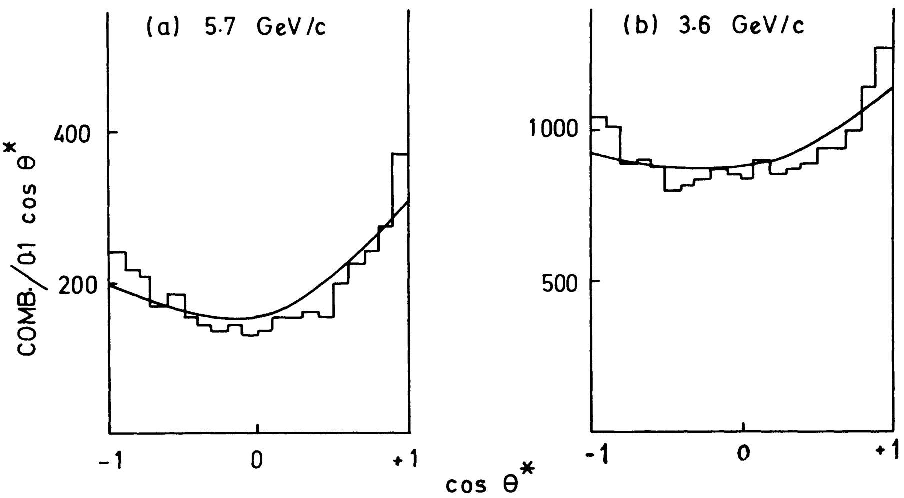


Fig. 1 The c.m. angular distributions of the pions for the reaction $p\bar{p} \to 3\pi^+3\pi^-$ at (a) 5.7 GeV/c and (b) 3.6 GeV/c. The solid curve is from the isobaric model.

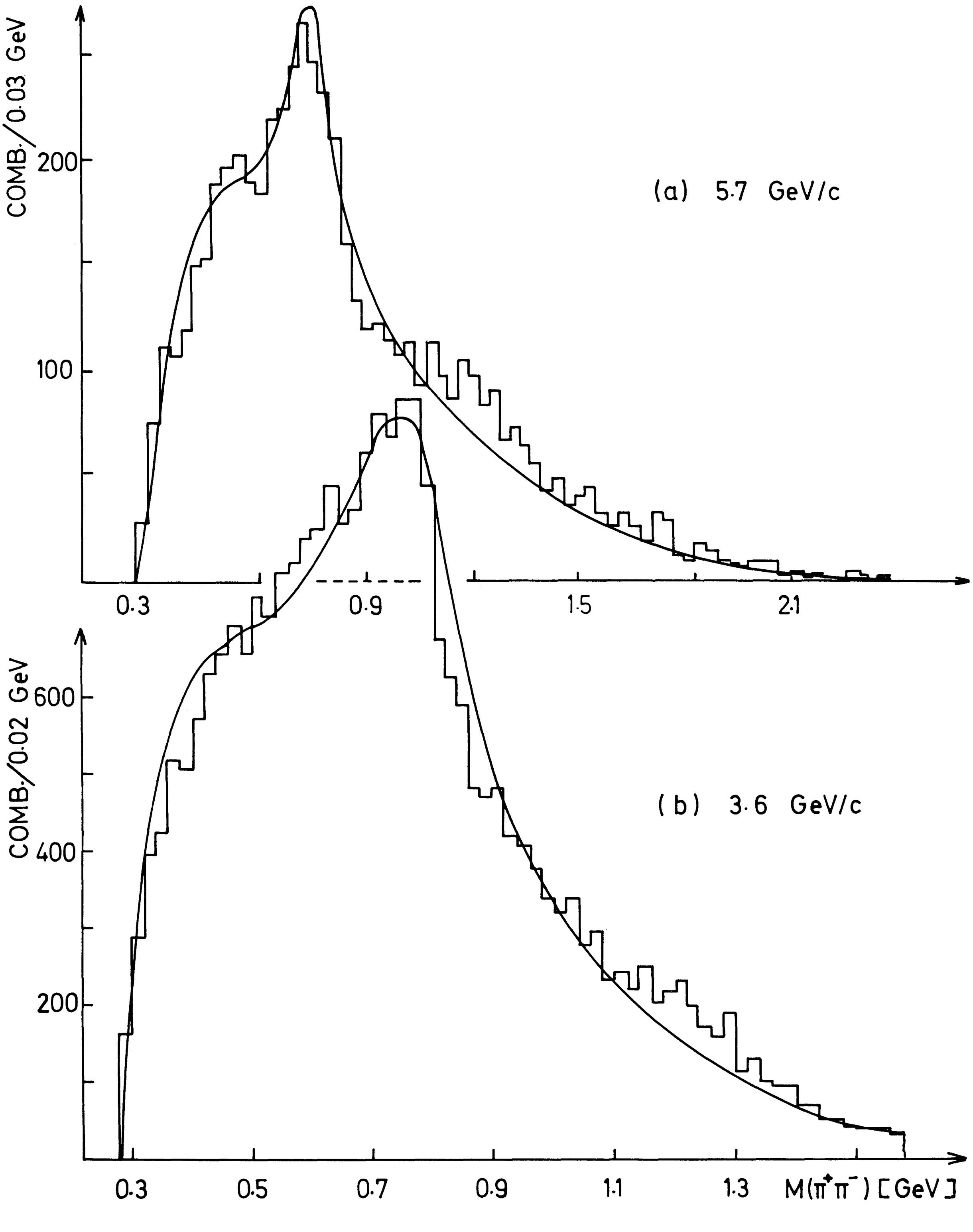


Fig. 2 $M(\pi^+\pi^-)$ for the reaction $\bar{p}p \rightarrow 3\pi^+3\pi^-$ at (a) 5.7 GeV/c and (b) 3.6 GeV/c. The solid curve is from the isobaric model.

DISCUSSION AND COMMENTS

Mr. Bettini : I think that the theoretical models, when put out, should be tested against all the published data relevant for the model itself. The Hopkinson and Roberts work for example tests the B5 model only against the $\bar{p}p \rightarrow 4\pi$ annihilation at rest and not against the published data on $\bar{p}n \rightarrow 2\ (\pi^- \pi^+)\pi^o$ at rest; in this case there are more different mass distributions, whose behaviour must be predicted by the model, and hence the test would be more stringent e.g. (experimentally ρ^o, ρ^+ and ρ^- are produced with different intensities).

Also the model just presented by Nellen is not tested against these data.

Mr. Lillestøl : Sorry for Nellen's statement about the fair agreement between the model and the experimental data. At least concerning the application of B_5 to the data of $\bar{p}p$ at rest into 4π, my personal opinion is that the disagreement is so large that one should rather conclude that it is complete!

Mr. Nellen : My main concern in discussing the dual approach to the reaction $\bar{p}p/_{rest} \rightarrow 2\pi^+ 2\pi^-$ was to show that it can be simplified (drop of kinematical factor). This simplification then motivated our isobaric A_8-Ansatz.