DRAFT - NOT for distribution.

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SPIN AND PARITY OF THE A_1 AND A_2 MESONS

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In the reaction $\pi^+ p \rightarrow p\pi^+\pi^+\pi^-$ (1)

produced by 8 GeV/c positive pions in the Saclay 81cm hydrogen bubble chamber, enhancements in $\pi^+\rho^o$ system have been observed, corresponding to the A_1 and A_2 mesons discovered in experiments at lower energies. Spin and parity determinations have been made, and it is concluded that the most likely assignments are $J^P = 1^+$ for A_1 and 2^+ for A_2.

Out of 8600 four-prong events analyzed using THRESH, GRIND, BAKE, SLICE, SUMX or similar systems, 1711 events were selected corresponding to reaction (1). It has been shown[1] that reaction (1) very often proceeds via formation of resonances, and that, in particular, the N^{*++}_{1238} isobar and the ρ^o-meson are frequently produced. Since the A-mesons have been observed as enhancements in the $\pi\rho$ system, and since the formation of the N^* isobar is competitive with the formation of the A-mesons, a further selection of events is made by requiring that: a) no $p\pi^+$ combination has effective mass in the region of the N^*_{1238} (1.12 to 1.34 GeV) and b) that at least one of the $\pi^+\pi^-$ combination has effective mass in the region of the ρ^o-resonance (0.62 to 0.88 GeV). Both conditions were fulfilled by 543 events. This selection of events could be biased by interference

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effects between the N^{*} and the $\pi\rho$-system. However, the Dalitz plot of Fig. 1 for the reaction $\pi^{+}p \rightarrow p\pi^{+}\rho^{o}$ indicates that the overlap between the N^{*} and the $\pi^{+}\rho^{o}$ bands involves, at this energy, a relatively small number of events, and hence interference effects must be unimportant.

Fig. 2 shows the effective mass distribution of the $\pi^{+}\rho^{o}$ combinations for the events selected. The A_1 and A_2 enhancements are clearly seen. Several mechanisms have been proposed by different authors to explain the A_1 enhancement as a kinematic effect rather than a resonance. This problem is discussed in detail in another paper[2]. Here we will assume that both A_1 and A_2 are resonant states with a definite set of quantum numbers.

The crucial problem for the detailed analysis of the $\pi\rho$ enhancements is the determination of the "background" under the peaks. It has been previously shown that at these energies phase space background, even with corrections to take into account the characteristic steep dependence of high energy processes on the momentum transfer, i.e. the peripheral phase-space, does not represent the physical situation. Here, to compute the background, we shall use a detailed calculation made by Wolf[3] in the framework of the one-pion-exchange model of Ferrari and Selleri. All the main features of reaction (1), at 8 GeV/c, in particular the experimental effective mass distributions for the $(p\pi^{+})$, $(p\pi^{-})$ and $(\pi^{+}\pi^{-})$ systems, are reasonably well reproduced by Wolf's results. One can therefore have confidence that also for the $(\pi^{+}\rho^{o})$ mass distribution (N^{*} excluded) the calculation adequately describes the physical situation in the absence of resonances in the A-meson region.

The experimental distribution of Fig. 2 was fitted with two Breit-Wigner curves modified for threshold effects as suggested by Jackson[4] and with the background shape as calculated by Wolf. The results obtained are

$$\text{Mass}\,(A_1) = 1076 \pm 14 \text{ MeV} \qquad \Gamma(A_1) = 130^{+50}_{-40} \text{ MeV}$$

$$\text{Mass}\,(A_2) = 1280^{+10}_{-8} \text{ MeV} \qquad \Gamma(A_2) = 74 \pm 23 \text{ MeV},$$

with the background represented by the dotted line in Fig. 2, which amounts to about 40°/o in the A_1 and A_2 mass regions. The values for the mass and width of the A_1 and for the width of the A_2 reported here are consistent with those reported in the lower energy experiments; the A_2-mass is somewhat lower than the average reported value of 1324 ± 9 MeV. The cross-sections for the formation

of A_1 and A_2-mesons are 0.24 ± 0.04 mb and 0.23 ± 0.04 mb, respectively, assuming that the isotopic spin of the A-mesons is one, so that $(A \rightarrow \pi^+\rho^0)/(A \rightarrow \pi^0\rho^+) = 1$, which is not inconsistent with our results.

Several possible spin and parity assignments for the A-mesons have been reported by various groups[5]. However, for the A_1 in particular, no firm conclusion had been reached. A peak in the $(K\bar{K})$ effective mass distribution has been observed[6] at about the same mass and with about the same width as the A_2. If this peak corresponds to another decay mode of the A_2-meson, then the simplest assignment for the A_2 is $J^P = 2^+$, others being 4^+, 6^+, etc.

In the following analyses of spin and parity assignments, the events of reaction (1) have been used for which no $p\pi^+$ combination lies in the mass region of the N^*_{1238} isobar. In Figs. 3a and 3d are shown the mass squared Dalitz plots for the $\pi^+\pi^+\pi^-$ system, for mass bands around the A_1 and A_2-mesons, i.e. for $950 \leqslant M(\pi^+\pi^+\pi^-) \leqslant 1125$ MeV and $1220 \leqslant M(\pi^+\pi^+\pi^-) \leqslant 1340$ MeV, respectively. In Figs. 3b and 3c, and in Figs. 3e and 3f, the density of points in the ρ-bands is compared with the theoretical predictions made by Zemach[7] for different assignments of spin and parity to the resonance of which the three-pion system is the final decay product. The theoretical curves are all normalized to the total number of events. It can be seen that all assignments but 1^+ and 2^- are excluded for A_1, while 1^+, 1^-, 2^+ and 2^- are possible for A_2, only 0^- being excluded.

A similar comparison with Zemach's predictions has been made for the radial and axial density distributions of the 6-folded Fabri-Dalitz plots[8] of the same events, and the results are summarized in Fig. 4. In the case of A_1, both 1^+ and 2^- are acceptable on the basis of the distributions of the radial density (Fig. 4a) and of the density along the y-axis (Fig. 4c). However, 1^+ is favoured by the results in Fig. 4b. For A_2, the radial density distribution (Fig. 4d) and the density along the x-axis (Fig. 4e) clearly exclude the possibilities 1^+ and 1^-. Moreover, Fig. 4f also rules out 2^-. So, $J^P = 2^+$ is the only acceptable assignment for the A_2-meson.

Obviously, these analyses, like those by other authors, are hampered by the presence of the background in the A_1 and A_2 bands. Though at 8 GeV/c the ratio of peaks to background is more favourable than at lower energies, the assumption is implicit that the distribution of background points in the Dalitz plots is of such a nature that the characteristics of the A-resonances are preserved. In conclusion, from the analysis of 8 GeV/c π^+p interactions it is deduced that the

best spin and parity assignment for the A_1 and A_2-mesons are $J^P = 1^+$ and 2^+, respectively.

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CAPTIONS FOR FIGURES

Fig. 1 Dalitz plot for the reaction $\pi^+ p \rightarrow p\pi^+\rho^o$, i.e. for those events of the channel $\pi^+ p \rightarrow p\pi^+\pi^+\pi^-$ satisfying the condition that at least one of the $\pi^+\pi^-$ combinations lies in the mass region of the ρ-meson (0.62 to 0.88 GeV).

Fig. 2 Effective mass distribution of the $\pi^+\pi^+\pi^-$ system in the reaction $\pi^+ p \rightarrow p\pi^+\pi^+\pi^-$, for those events satisfying the double condition that no $(p\pi^+)$ combination has a mass in the N^*_{1238} region (1.12 to 1.34 GeV) and at least one of the $\pi^+\pi^-$ combinations lies in the ρ-meson mass region (0.62 to 0.88 GeV). The result of fitting two Breit-Wigner curves to the observed peaks, with the background shape given by an O.P.E. calculation, is shown by the solid line. The background obtained from the fit is the dotted line.

Fig. 3 a) Dalitz plot for the system $\pi^+\pi^+\pi^-$, for those events of reaction $\pi^+ p \rightarrow p\pi^+\pi^+\pi^-$ in which no $p\pi^+$ combination is in the N^*_{1238} mass region and the $(\pi^+\pi^+\pi^-)$ system has an effective mass in the region of the A_1-meson (0.95 to 1.125 GeV).

b) and c) The density distribution of the points lying, in the Dalitz plot of Fig. 3a), inside the ρ-meson band (0.62 to 0.88 GeV) is compared with theoretical predictions for several assignments, J^P, of spin and parity to the A_1-meson.

d), e) and f) are like a), b) and c), respectively, for those $\pi^+\pi^+\pi^-$ combinations whose effective mass is in the A_2-region (1.22 to 1.34 GeV).

Fig. 4 a) Radial density, b) density along the x-axis and c) density along the y-axis of the points contained in the 6-folded Fabri-Dalitz plot for the $\pi^+\pi^+\pi^-$ system of reaction $\pi^+ p \rightarrow p\pi^+\pi^+\pi^-$, for which no $p\pi^+$ combination lies in the N^*_{1238} region and for which the effective mass of the $(\pi^+\pi^+\pi^-)$ system lies in the A_1-region (0.95 to 1.125 GeV).

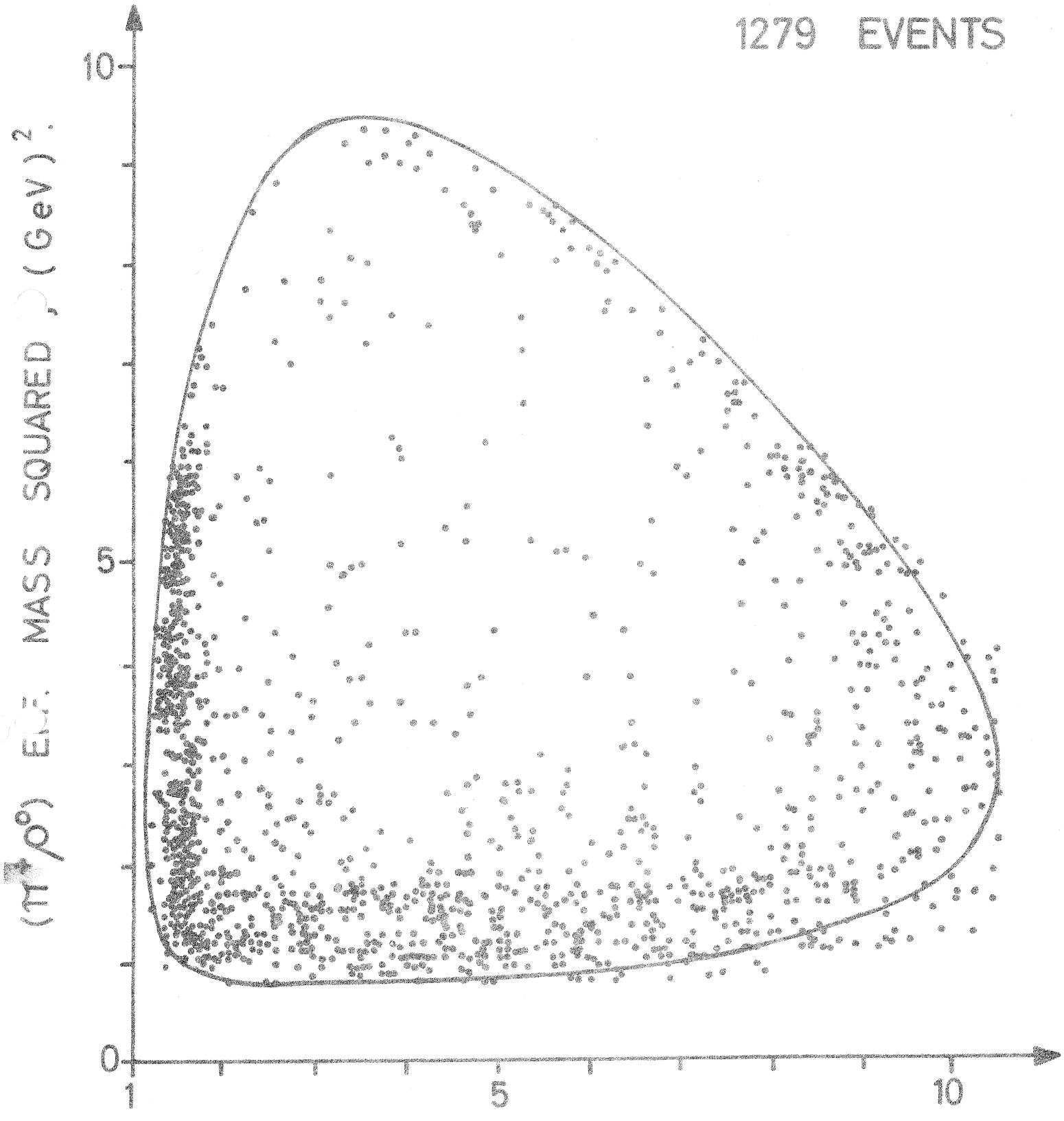
d), e) and f) are like a), b) and c), respectively, for the $\pi^+\pi^+\pi^-$ combinations with effective mass in the A_2-region (1.22 to 1.34 GeV).

FIG. 1

$\pi^+ p \rightarrow p\pi^+\rho^0 \rightarrow p\pi^+\pi^+\pi^-$ AT 8 GeV/c.

DALITZ PLOT FOR $p\pi^+\rho^0$

1279 EVENTS



$\pi^+ p \rightarrow p\,\pi^+\rho^0 \rightarrow p\,\pi^+\pi^+\pi^-$ AT 8 GeV/c.

N^{*++} EXCLUDED

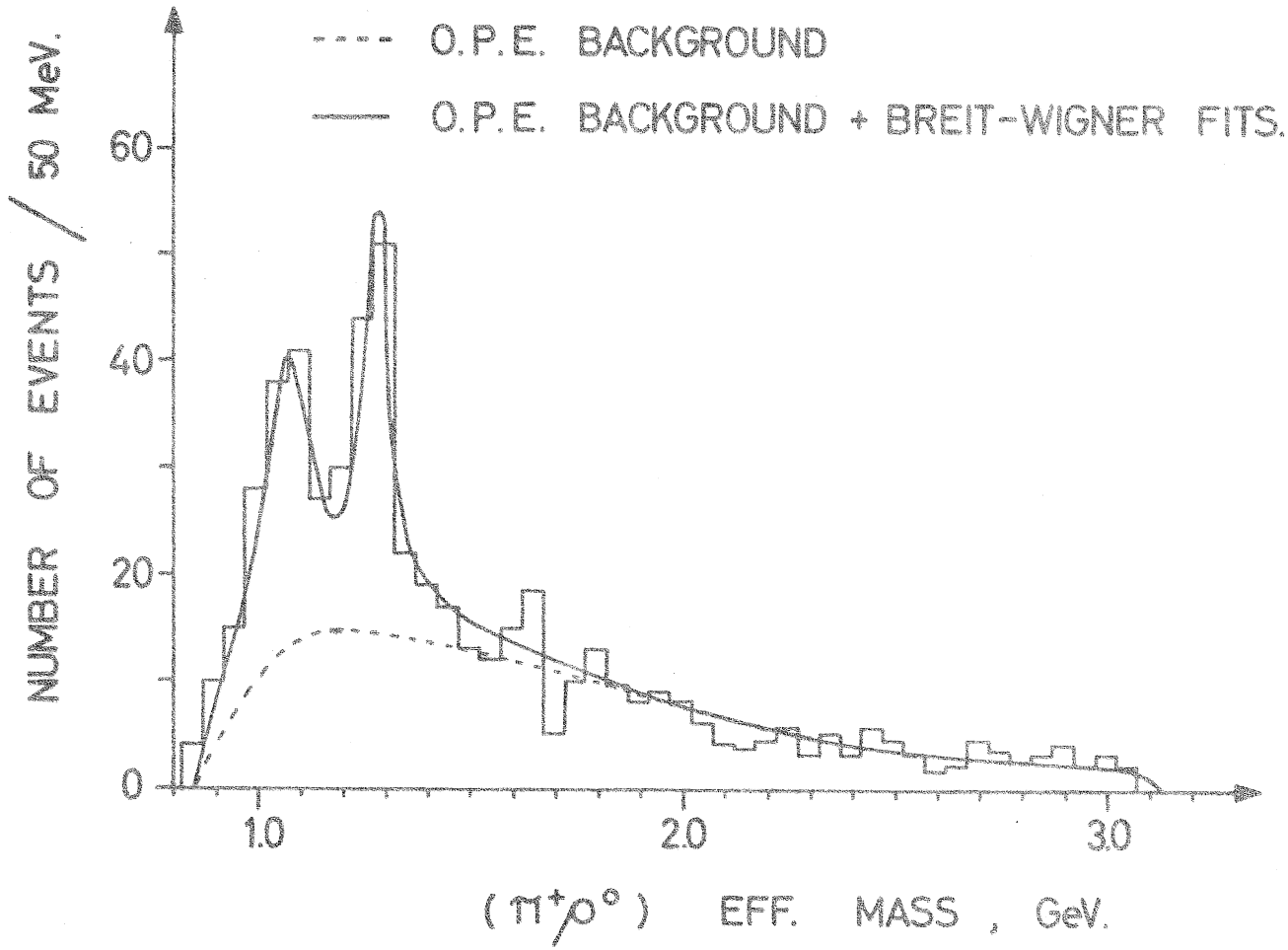
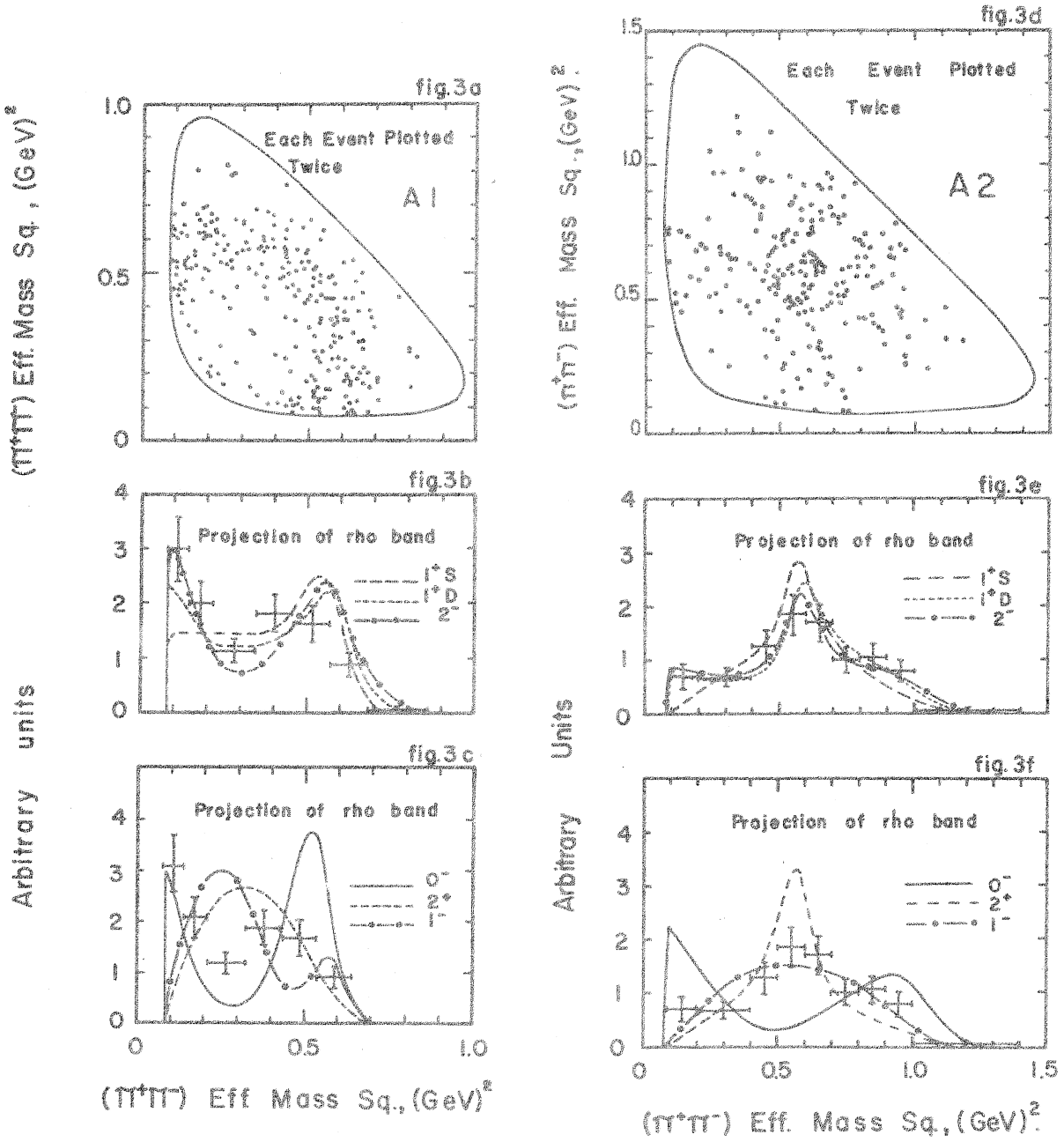


FIG. 2

FIG. 3



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