Submitted to Physics Letters B

UCRL-20273
Preprint c. 2

f^0 MASS SPECTRUM IN 7-GeV/c π^+p INTERACTIONS

S. M. Flatté, M. Alston-Garnjost, A. Barbaro-Galtieri,
S. E. Derenzo, J. H. Friedman, G. R. Lynch,
S. D. Protopopescu, M. S. Rabin, and F. T. Solmitz

January 14, 1971

AEC Contract No. W-7405-eng-48

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

f^0 MASS SPECTRUM IN 7-GeV/c π^+p INTERACTIONS*

S. M. Flatté, M. Alston-Garnjost, A. Barbaro-Galtieri,
S. E. Derenzo, J. H. Friedman, G. R. Lynch,
S. D. Protopopescu, M. S. Rabin and F. T. Solmitz

Lawrence Radiation Laboratory
University of California
Berkeley, California 94720

ABSTRACT

Structure in the f^0 [an SU(3) companion of the A_2] is sought in more than 5000 $\pi^+p \rightarrow f^0\Delta^{++}$ events at 7 GeV/c in a hydrogen bubble chamber. The mass spectrum and the moments of the decay angular distribution are studied with a resolution of 7.8 MeV.

The report of structure [1] in the A_2 meson mass distribution has stimulated interest in the possibility of structure in regions near the other 2^+ mesons [$K_N(1420)$, f^0, f'] because of their relationship to the A_2 through SU(3) symmetry. The only published search of the $K_N(1420)$ mass distribution has reported a negative result, [2] and no results are available on the f'. A suggestion of f^0 structure has been reported[3].

We report here on an experiment in which the f^0 is produced in the reaction $\pi^+p \rightarrow f^0\Delta^{++}$ and decays into $\pi^+\pi^-$. No narrow structure is observed in the mass distribution, which is adequately fitted by a Breit-Wigner resonance formula with a linear background. If a narrow resonance ($\Gamma \ll 15$ MeV) contributed incoherently to the mass spectrum in the 1100-1400 MeV mass region with a cross section 4% as large of the f^0 cross section, we would have seen a 6-standard-deviation effect.

We have also searched for structure in the decay of the f^0 by plotting the moments of the spherical harmonics in the $f^0 \rightarrow \pi^+\pi^-$ decay as a function of mass. Again no narrow structure is observed.

Our experiment is a 700 000-picture exposure (≈ 45 events/μb) of the SLAC 82-inch hydrogen bubble chamber to an rf-separated π^+ beam** at 7.1 GeV/c. The f^0 was observed in the reaction

$$\pi^+ p \rightarrow \pi^+ p \pi^+ \pi^- \qquad (65\,000 \text{ events}). \qquad (1)$$

The selection criteria for this reaction have been given in a previous letter [4]. In particular we are reporting only on those events for which the scanner recorded the observation of at least one heavily ionizing positive track (dark track).

Good mass resolution is critical to the observation of any narrow structure. We have previously reported [4] the many checks we have made of our mass resolution. However, we think it useful to show again the check that is most relevant to our f^0 study: the K^0 mass distribution. We have fitted our V-2 prong events of the type $\pi^+ p \rightarrow K^+ p \bar{K}^0$ to the hypothesis $\pi^+ p \rightarrow K^+ p \pi^+ \pi^-$ where the K^0 mass and direction were not constrained. The histogram of the $\pi^+\pi^-$ mass distribution is shown in Fig. 1a. The curve represents the predicted mass resolution calculated when the uncertainties introduced by multiple scattering and measurement errors are propagated by our fitting programs. The curve is centered on the known K^0 mass [5]. By fitting the K^0 mass distribution with the resolution as an unknown parameter, we find the

HWHM of the resolution function to be 3.4 ± 0.2 MeV, whereas 3.5 MeV was expected. The calculated mass resolution (HWHM) of the f^0 mass region is 7.8 MeV.

The mass distribution of $\pi^+\pi^-$ recoiling against a Δ^{++} [$M(p\pi^+)$ < 1.4 GeV] in Reaction (1) is shown in Fig. 1b. The momentum transfer ($t_{p\Delta}$) distribution of the events in the f^0 region (1135 to 1385 MeV) is shown in Fig. 1c. This should not be regarded as the t distribution of $\Delta^{++}f^0$ events, since corrections for the background and the dark-track scanning selection have not been made. From measurements of events without a dark track, we find that if we had included all events without a dark track in this analysis they would have contributed according to the dots in Fig. 1c. By using only dark-track events we have lost 4% of the $f^0\Delta^{++}$ region events with $t_{p\Delta} < 0.4\ GeV^2$, and 17% with $0.4\ GeV^2 < t_{p\Delta} < 1.0\ GeV^2$.

Figure 2 shows the mass distribution in the f^0 region for various momentum-transfer regions. No obvious fine structure is observed in any of these distributions.*** The curve on Fig. 2a is an s-wave Breit-Wigner resonance formula over a linear background. The confidence level of the fit is 23%. The number of f^0 events between 1000 and 1500 MeV is 5300, and the fitted f^0 mass and width are 1277 ± 4 MeV and 183 ± 15 MeV, respectively.

If a narrow resonance ($\Gamma \ll 15$ MeV) contributed incoherently with a cross section 4% as large as the f^0 cross section, it would give a positive contribution that would look like the dashed curve in Fig. 2a. Such a contribution would be a 6-standard-deviation effect. From our data alone, no useful limit can be put on a coherent, narrow contribution without assumptions about the production amplitude of the narrow object.† Thus it should be remembered that it is not possible to make a definite negative conclusion on the existence of structure from an observation of one reaction at one energy.

Structure that is not visible in the mass distribution might manifest itself as a rapid variation in the decay-angle distributions of the f^0. We have looked at the moments of all spherical harmonics $Y_\ell^m(\theta, \phi)$ with $\ell \leqslant 4$, where θ, ϕ are the polar and azimuthal angles of the π^- from the f^0 decay in the f^0 rest frame, the Z axis is the incoming π^+, and the y axis is $p_{in} \times \Delta^{++}$. We have seen no obvious structure. Some of the distributions are shown in Fig. 3. The dark-track scanning selection could result in slightly different moments than if no selection were made, but there is no reason to expect that any narrow structure would be masked by the selection.

In conclusion, with more than 5000 events from the reaction $\pi^+ p \rightarrow f^0 \Delta^{++}$ at 7.1 GeV/c, with a mass resolution of ± 7.8 MeV, no obvious narrow structure in the mass distribution, or the moments as a function of mass, has been seen in the f^0 region.

We thank Joseph J. Murray for his work in beam design and construction. We gratefully acknowledge the assistance of the staff of the Stanford Linear Accelerator and the 82-inch bubble chamber in obtaining the data for this experiment. We also thank the Lawrence Radiation Laboratory Group A Scanning and Measuring Group for their help in data reduction.

Footnotes

*Work done under the auspices of the U. S. Atomic Energy Commision.

**For a description of the beam see S. Flatté, LRL Berkeley Group A Physics Note No. 646, 1968 (unpublished).

***The indication of a dip in the f^0 mass structure reported by reference 3 was between 1230 and 1250 MeV. The statistically insignificant (less than 2 s.d.) dip in the distribution of our Fig. 2a is at 1260 MeV.

†If a narrow resonance contributes in a partially coherent way to a mass spectrum, then although its amplitude may be large, its effect may be small if the average phase of the resonance with respect to background is near $-\pi/2$. See, for example, S. M. Flatté, Phys. Rev. D1 (1970) 1.

References

1. G. E. Chikovani et al., Phys. Letters 25B (1967) 44;
   H. Benz et al., Phys. Letters 28B (1968) 233;
   D. J. Crennell, U. Karshon, K. W. Lai, J. M. Scarr, and I. O. Skillicorn, Phys. Rev. Letters 20 (1968) 1318;
   M. Aguilar-Benitez et al., CERN-Paris (C. d. F.)-Liverpool Collaboration, Phys. Letters 29B (1969) 62;
   R. Baud et al., Phys. Letters 31B (1970) 397;
   K. Böckman et al., Bonn-Durham-Nijmegen-Paris (E.P.)-Torino Collaboration, Nucl. Phys. B16 (1970) 221;
   M. Basile, P. Dalpraz, P. L. Frabetti, T. Massam, F. Navach, F. L. Navarria, M. A. Schneegans, and A. Zichichi, Lettere al Nuovo Cimento 4 (1970) 838.
2. P. J. Davis, S. E. Derenzo, S. M. Flatté, M. A. Garnjost, G. R. Lynch, and F. T. Solmitz, Phys. Rev. Letters 23 (1969) 1071.
3. P. H. Stuntebeck, V. P. Kenney, B. J. Deery, N. N. Biswas, N. N. Cason, A. R. Dzierba, M. S. Farber, J. A. Poirier, and W. D. Shephard, Phys. Letters 32B (1970) 391.
4. M. Alston-Garnjost, A. Barbaro-Galtieri, W. H. Buhl, S. E. Derenzo, L. D. Epperson, S. M. Flatté, J. H. Friedman, G. R. Lynch, R. L. Ott, S. D. Protopopescu, M. S. Rabin, and F. T. Solmitz, Phys. Letters 33B (1970) 607.
5. Particle Data Group, Review of Particle Properties, Phys. Letters 33B (1970) 1.

Figure Captions

1. a) K^0 mass distribution for V-2 prong events fitted to the reaction $\pi^+ p \rightarrow K^+ p \pi^+ \pi^-$ without constraining the K^0 mass or direction. The curve is the calculated resolution function centered on the known K^0 mass.

   b) Histogram of $\pi^+\pi^-$ mass in reaction (1) for events in which the other π^+ and the proton form a Δ^{++} ($M(p\,\pi^+) < 1.4$ GeV).

   c) Momentum transfer distribution of events in the f^0 ($1.135 < M(\pi^+\pi^-) < 1.385$ GeV) and Δ^{++} regions. The open circles are an estimate of what has been missed due to a dark proton scanning selection.

2. Mass plots in the f^0 region. A Δ^{++} is always required. The solid curve is a fit with a Breit-Wigner s-wave resonance formula plus a linear background. The dashed curve is our resolution function normalized to 4% of the number of f^0 resonance events found in the fit.

3. Some moments of the decay-angle distribution in the f^0 region as a function of mass. A Δ^{++} is always required. The Z axis is the incoming π^+; the y axis is $p_{in} \times \Delta^{++}$. $\langle \mathrm{Im}\, Y_2^m \rangle$ are examples of parity-violating moments, and are thus expected to be equal to zero.

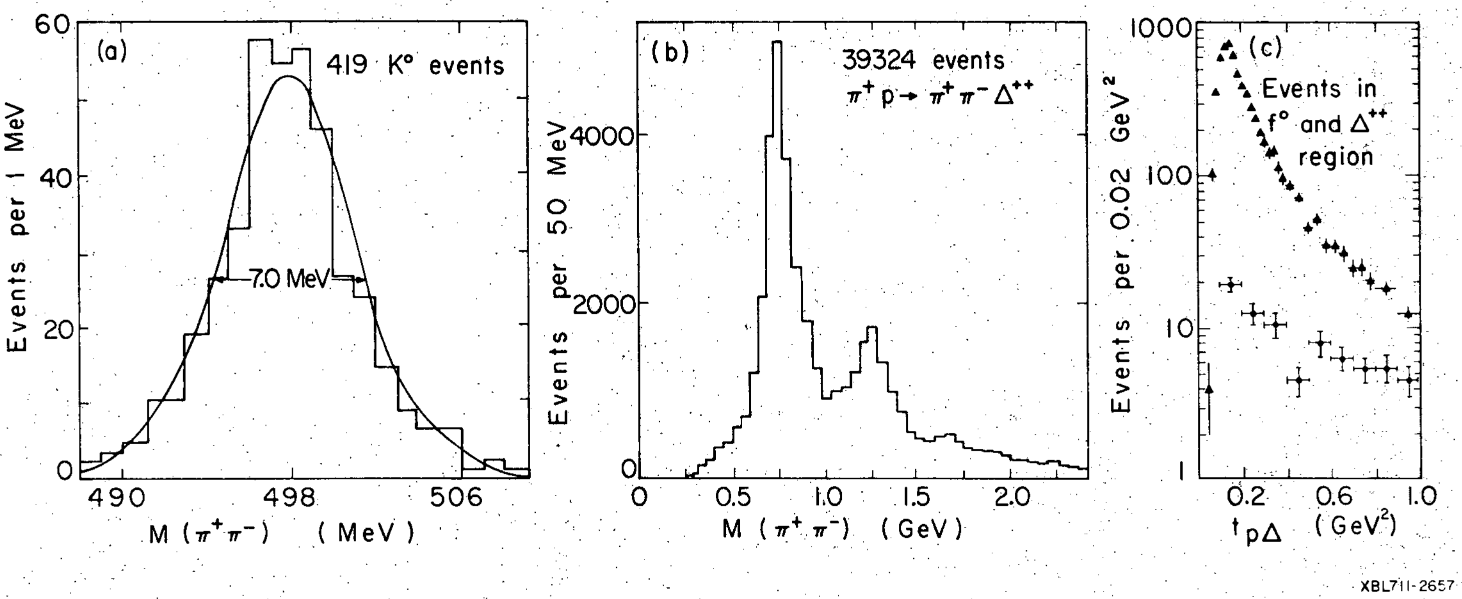
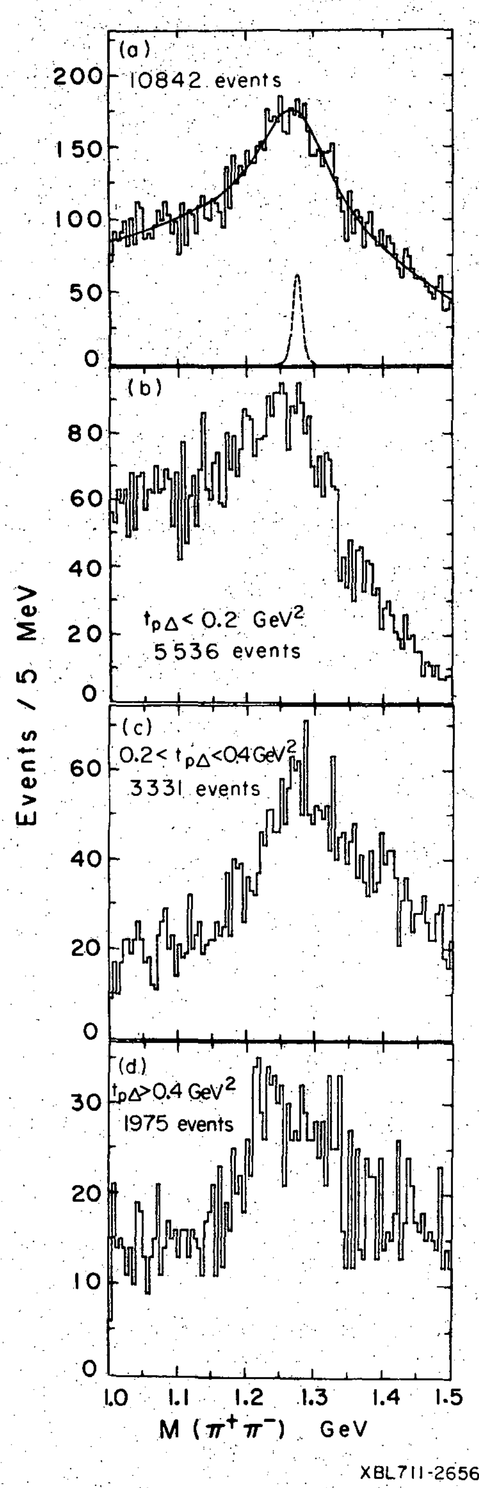

(a)
419 K° events
7.0 MeV
Events per 1 MeV
M ($\pi^+\pi^-$) (MeV)
(b)
39324 events
$\pi^+ p \to \pi^+\pi^-\Delta^{++}$
Events per 50 MeV
M ($\pi^+\pi^-$) (GeV)
(c)
Events in f° and Δ^{++} region
Events per 0.02 GeV²
$t_{p\Delta}$ (GeV²)
XBL711-2657

Fig. 1



(a)
10842 events
(b)
$t_{p\Delta}$ < 0.2 GeV^2
5536 events
(c)
0.2 < $t_{p\Delta}$ < 0.4 GeV^2
3331 events
(d)
$t_{p\Delta}$ > 0.4 GeV^2
1975 events
Events / 5 MeV
M ($\pi^+\pi^-$) GeV
XBL711-2656

Fig. 2

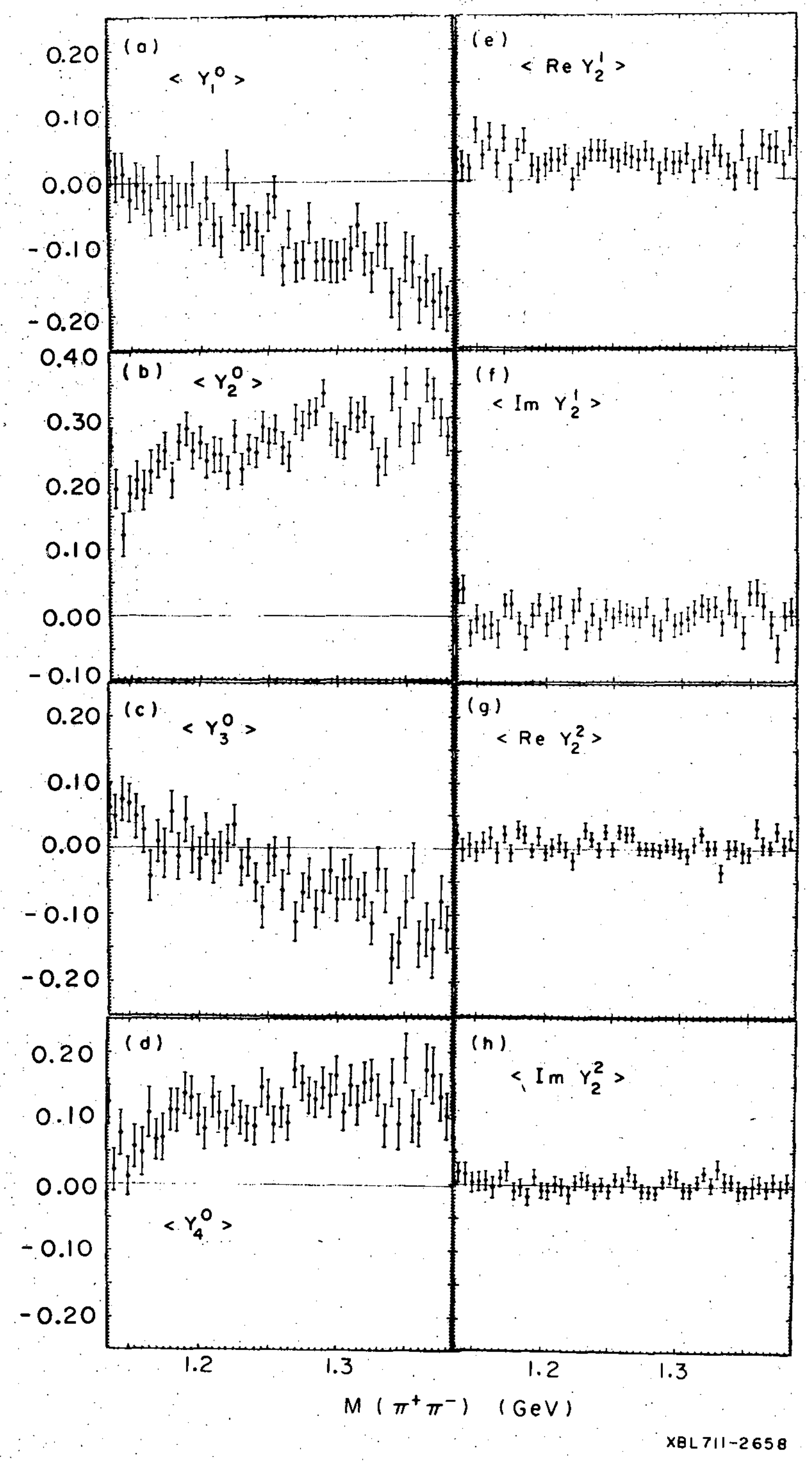

(a)
< Y_1^0 >
(b)
< Y_2^0 >
(c)
< Y_3^0 >
(d)
< Y_4^0 >
(e)
< Re Y_2^1 >
(f)
< Im Y_2^1 >
(g)
< Re Y_2^2 >
(h)
< Im Y_2^2 >
0.20
0.10
0.00
-0.10
-0.20
0.40
0.30
1.2
1.3
M ($\pi^+\pi^-$) (GeV)
XBL 711-2658

Fig. 3

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720