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UPPER LIMIT ON THE BRANCHING FRACTION $\chi(3554) \to \psi\pi^+\pi^-\pi^0$

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ABSTRACT

An upper limit of 1% is found for the branching fraction $\chi(3554) \to \psi\pi^+\pi^-\pi^0$.

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It has been suggested that the channel $\psi\pi^+\pi^-\pi^0$ could be a significant decay mode of the $J^{PC} = 2^{++}$, $\chi(3554)$ meson[1]. Since this is a strong interaction decay, it might compete favorably with electromagnetic decays even though the $\chi(3554)$ has a mass which is only 43 ± 5 MeV above threshold for this decay channel. [However, there are theoretical arguments which refute this suggestion[2].] In addition, there has been a recent experimental indication that the $\chi(3554) \to \psi\pi^+\pi^-\pi^0$ branching fraction is of the order of 45% ± 15% [3]. The purpose of this letter is to establish an upper limit of 1% for this branching fraction. An important application of this result involves the production of ψ mesons by hadrons[4]. In determining the extent to which hadronically produced ψ mesons come from χ decays, one must examine all χ decay modes involving a ψ, including the known $\chi \to \psi\gamma$.

We have previously investigated the degree to which ψ mesons produced in π^-Be collisions at 190 GeV/c come from $\chi \to \psi\gamma$ decays[5]. Our data were obtained in a large acceptance multiparticle spectrometer which was triggered on ψ mesons decaying into $\mu^+\mu^-$ [6]. Because of our excellent $\psi\gamma$ mass resolution we could resolve the 1^{++} and 2^{++} χ states at masses of 3.507 and 3.554 GeV, respectively. We found that the $\chi(3554)$, through the decay $\chi(3554) \to \psi\gamma$, accounts for 12% ± 4% of ψ production. Since the $\chi(3554) \to \psi\gamma$ branching fraction is known to be 15.4% ± 2.4%, we can measure the $\chi(3554) \to \psi\pi^+\pi^-\pi^0$ branching fraction by determining the percentage of ψ mesons produced by this decay mode[7].

We can observe the decay $\chi(3554) \to \psi\pi^+\pi^-\pi^0$ by examining $\psi\pi^+\pi^-$ masses. Since the ψ and all three pions have small momenta in the $\chi(3554)$ rest frame, the χ should appear as a signal just below the mass of the χ minus the mass of a π^0 [8]. Alternatively, we can look at the effective mass difference between all $\mu^+\mu^-\pi^+\pi^-$ combinations and the corresponding $\mu^+\mu^-$, for those events having $\mu^+\mu^-$ in the ψ mass region. Then it is not necessary to assign the ψ mass to the dimuon. The $\chi(3554)$, if it decays into $\psi\pi^+\pi^-\pi^0$, should appear as a signal just above twice the mass of a charged pion.

From a sample of 42,500 $\mu^+\mu^-$ events in the mass region 2.95 to 3.25 GeV produced with an average beam momentum of 190 GeV/c, we have determined this mass

difference. The data contain 38,000 ψ mesons and 4500 background events. The ψ mass resolution has a σ = 32 MeV. The result is plotted in Fig. 1a. There is no significant $\chi(3554)$ signal at $\sim$ 300 MeV. The prominent $\psi' \to \psi\pi^+\pi^-$ peak at 590 MeV serves as a stringent test of our technique and our mass resolution. Like-sign dipion data are used to determine the background in Fig. 1a. The smooth curve comes from a fit to the effective mass difference between $\mu^+\mu^-\pi^\pm\pi^\pm$ and $\mu^+\mu^-$, allowing for a ψ' resonance. The background-subtracted data are shown in Fig. 1b. A fit to the ψ' signal gives a $\psi' - \psi$ mass difference of 589.7 ± 0.6 MeV, compared to the value of 588.7 ± 0.8 MeV as measured by Lüth et al.[9]. The mass resolution is 5.6 ± 0.7 MeV.

The overall $\pi^+\pi^-$ acceptance, including effects of geometry and pattern recognition, is 58%. Since we have measured the ψ' cross-section from $\psi' \to \mu^+\mu^-$ decays using the same apparatus[6], we have confirmed that the number of ψ' events from $\psi\pi^+\pi^-$ decays, as indicated in Fig. 1, is consistent with our acceptances. Thus the width and height of our ψ' peak verify our ability to detect similar signals.

To indicate the sensitivity of our experiment to $\chi \to \psi\pi^+\pi^-\pi^0$ decays, we show as a dashed curve in Fig. 1b the signal we would expect if 10% of the ψ mesons come from this decay mode. (This would correspond to a $\chi \to \psi\pi^+\pi^-\pi^0$ branching fraction of 13%.) This Monte Carlo study generated χ's having x and p_T distributions equal to those we have measured for the ψ. The χ was allowed to decay isotropically. The total width of the signal is 43 MeV. This is large compared to our mass resolution.

The dashed curve contains 2040 combinations below 325 MeV in Fig. 1b, compared to the 170 combinations that we observe. Most of these 170 combinations are probably due to a contamination of $\psi\gamma$ events in which there is a $\gamma \to e^+e^-$ conversion in the production target and the electrons are assumed (incorrectly) to be pions. Since we cannot determine the extent of this γ conversion effect experimentally, we use these 170 combinations to establish that less than 0.8% ± 0.2% of hadronically produced ψ mesons in 190 GeV/c π^-Be collisions come from $\chi \to \psi\pi^+\pi^-\pi^0$

decays. This corresponds to an upper limit of 1% ± 0.4% on the $\chi \to \psi\pi^+\pi^-\pi^0$ branching fraction. Thus our result is not consistent with suggestions[1,3] that the $\chi \to \psi\pi^+\pi^-\pi^0$ branching fraction is significant.

REFERENCES AND FOOTNOTES

1) R. Raja, Fermilab-PUB-81/32-exp (1981), submitted to Physical Review.

2) C. Flory and I. Hinchliffe, LBL-12703 (1981) preprint; E. Berger and C. Sorensen, Argonne preprint ANL-HEP-PR-81-28 (1981).

3) S. Pordes, Bull. Am. Phys. Soc. 26, 586 (1981).

4) E. Reya, Perturbative quantum chromodynamics, preprint DESY 79/88 (1979), DO TH 79/20 (1979).

5) See p. 197 in Proc. Int. Conf. on High-Energy Physics, Madison, 1980 (Amer. Inst. Phys., New York, 1981).

6) The experimental apparatus is described in M. Abolins et al., Phys. Lett. 82B, 145 (1979).

7) Particle Data Group, Rev. Mod. Phys. 52 (1980).

8) For the remainder of the article, the symbol χ refers to the $\chi(3554)$ state.

9) V. Lüth et al., Phys. Rev. Lett. 35, 1124 (1975).

Figure caption

Fig. 1 : For each $\mu^+\mu^-\pi^+\pi^-$ combination with a $\mu^+\mu^-$ mass between 2.95 and 3.25 GeV, the difference between the $\mu^+\mu^-\pi^+\pi^-$ and $\mu^+\mu^-$ effective masses is plotted. Figure 1a contains the number of combinations for each 5 MeV bin for this mass difference. Figure 1b shows these data after a background subtraction. The smooth curves, background determination, and dashed histogram are explained in the text.

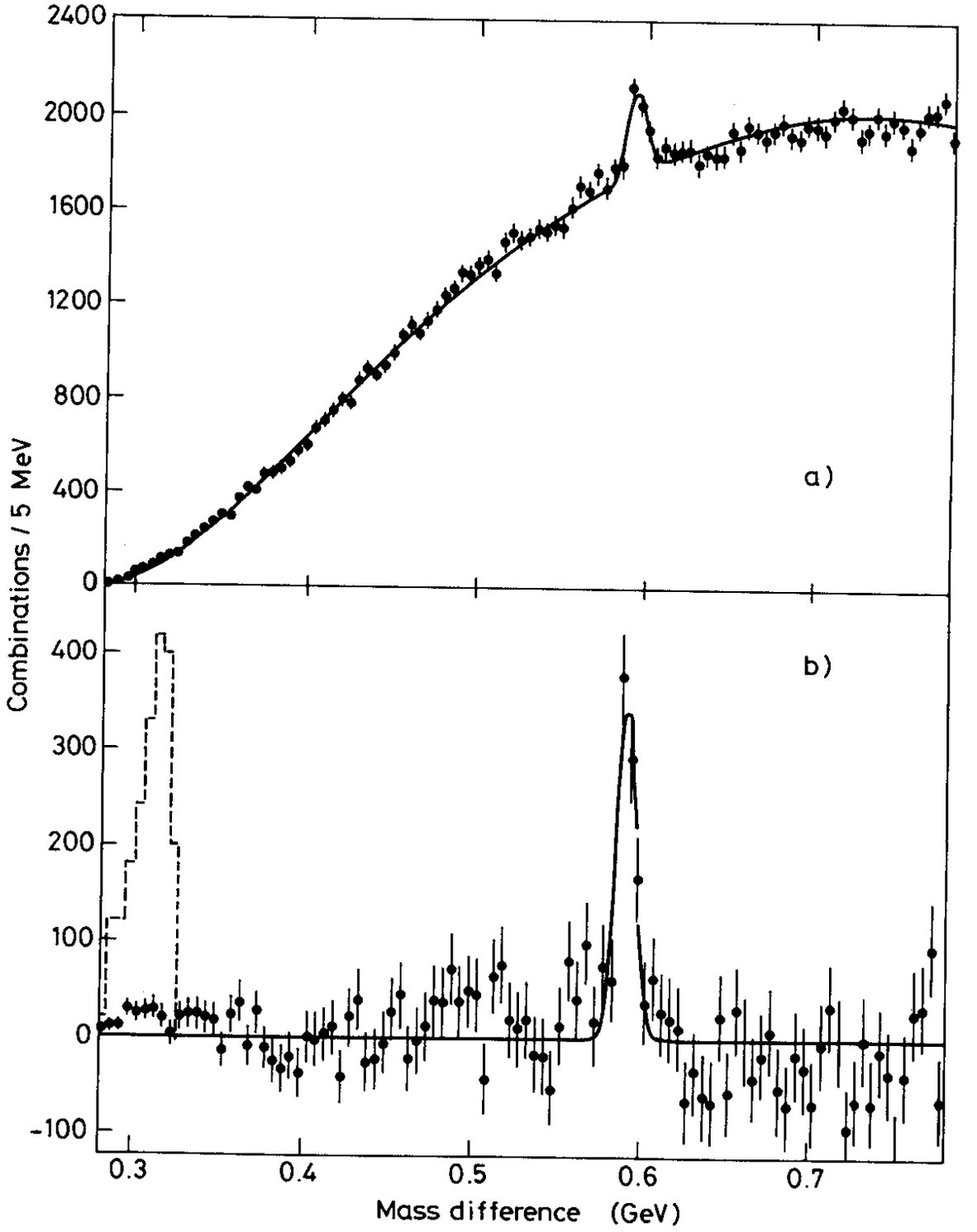
2400
2000
1600
1200
800
400
0
a)
400
300
200
100
0
-100
b)
Combinations / 5 MeV
0.3
0.4
0.5
0.6
0.7
Mass difference (GeV)

Fig. 1