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Search for More J Particles

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We report here on an experiment done at the 30-GeV proton synchrotron at Brookhaven National Laboratory using a large-acceptance ($\Delta m = 1$ GeV) pair spectrometer with a mass resolution of ± 5 MeV, to search for additional long-lived particles which decay into $K^-\pi^+$, $K^+\pi^-$, $\bar{p}p$, K^+K^-, $\pi^+\pi^-$, K^-p, π^-p, $K^+\bar{p}$, or $\pi^+\bar{p}$. The result, based on 2×10^7 events, shows that, to a sensitivity comparable to or lower than the production of J particles [(production) $\times$ (decay branching ratio) $\approx 10^{-34}$ cm^2], no additional states were found.

We report here the results of an experiment done at the 30-GeV alternating-gradient proton synchrotron at Brookhaven National Laboratory. The purpose of this experiment is to search for additional narrow resonances. Their existence may give a clue to the understanding of the recently discovered J particles.[1-3] In this Letter we will present the results of a systematic search for new particles from reactions

$$p + \mathrm{Be} \to \begin{pmatrix} K^-\pi^+ \\ K^+\pi^- \\ \bar{p}p \\ K^+K^- \\ \pi^+\pi^- \\ K^-p \\ K^+\bar{p} \\ \pi^-p \\ \pi^+\bar{p} \end{pmatrix} + X$$

by measuring the pairs directly.

Data also exist on $p + N \to p + p + J'$, by measuring the two protons and studying the missing-mass structure, and

$$p + \mathrm{Be} \to \begin{pmatrix} K^-K^- \\ K^-\pi^- \\ \bar{p}\bar{p} \\ \pi^-\pi^- \end{pmatrix} + \ldots$$

to search for multibody decays. These data will be presented later.[4]

This experiment used a pair spectrometer described previously for the discovery of the J particle.[1] The spectrometer measures a pair of 90° decay particles from a resonance produced at rest in the p-p center-of-mass system.

The 8000-wire proportional-chamber system provides a mass resolution of ± 5 MeV. There are eleven planes of chambers in each arm rotated 20° with respect to each other so as to be able to sort out up to eight tracks per arm. Timing is provided by thin two-dimensional hodoscopes behind the chambers.

For the hadron-pair runs three modifications were made on the original setup:

(a) In order to reduce the random accidentals to a minimum we put in a new target system which consists of five pieces of 4 mm×4 mm×4 mm Be target separated from each other by 6 in. The targets are supported by thin piano wires and the whole system is mounted inside a helium bag. This arrangement enables us to know the location of the interaction and to reduce the accidentals by requiring that the particles in each arm of the spectrometer trace back to the same point of interaction. Figure 1(a) shows a typical target reconstruction distribution for this experiment. As seen, there are very few random accidentals. Occasionally, sapphire targets (fluorescent Al_2O_3 of the same dimensions) were used and viewed by closed-circuit television to ensure that the beam was centered on the targets.

(b) To further reduce the accidentals we installed additional scintillation counters at the end

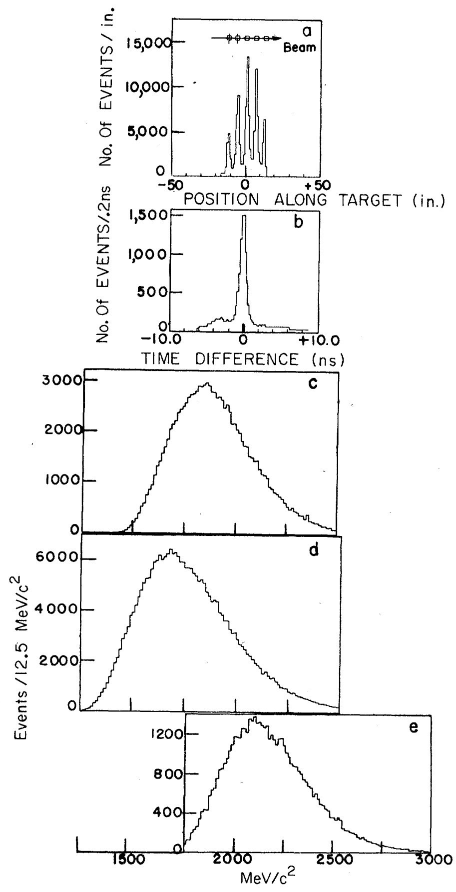

FIG. 1. (a) Reconstruction of the pair vertex at the target, using information from the proportional chambers. The five pieces of beryllium are seen clearly. (b) Time difference between the additional scintillation counters at the back ends of the left and right arms. The resolution obtained is 0.9 nsec and little background is present. (c)–(e) Mass spectra at the lowest mass setting for $K^+\pi^-$, $\pi^-\pi^+$, and π^+K^-, respectively.

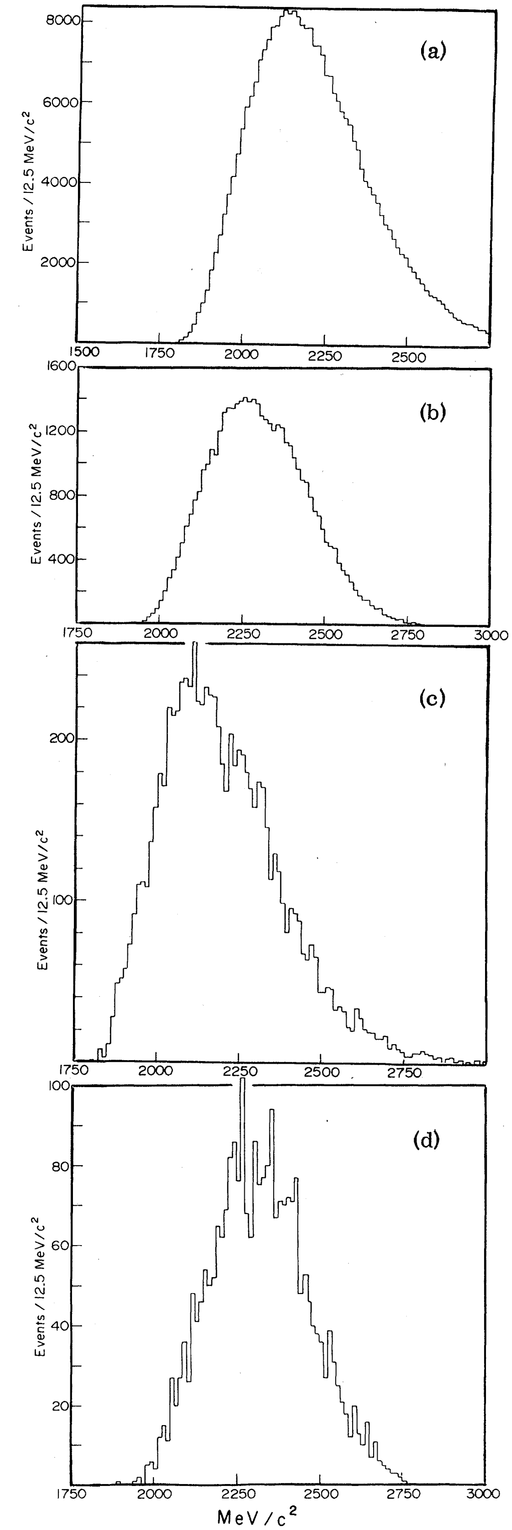

FIG. 2. (a)–(d) Mass spectra for the lowest mass setting for π^-p, K^-p, $\pi^+\bar{p}$, and $K^+\bar{p}$, respectively.

of the spectrometer. These counters had tubes at both ends to measure the mean time of the particles. Typical left-arm–right-arm coincidences are shown in Fig. 1(b). The mean-time distribution is also displayed on-line to enable us to control the accidentals to a small level.

(c) There are three Cherenkov counters in each arm to identify all the hadronic products simultaneously. The first Cherenkov counter is filled with gaseous hydrogen at 1 atm to give a measure of the electron yield and to function as a vacuum pipe to reduce multiple scattering. The second Cherenkov counter is filled with 1.0 to 1.2 atm of isobutane, to identify π mesons. The last Cherenkov counter, located at the end of the spectrometer, is filled with ethylene up to 20 atm and triggers on kaons and pions. Protons are identified by requiring a trajectory from a common point in the target triggering hodoscopes but not Cherenkov counters.

The mass acceptance for hadron pairs ($\Delta m = 1$ GeV) is smaller than the acceptance of the spectrometer for electron pairs ($\Delta m = 2$ GeV) because of Cherenkov-counter cutoff. To cover a mass region from 1.25 up to 5.0 GeV six overlapping measurements were done. The overlapping settings were essential to eliminate statistical fluctuations and any systematic biases in the spectrometer. Mass resolution has been calibrated by measuring the width of the J, and found to be compatible with 5 MeV.[1] Binning was done in 12.5-MeV bins which is the full width at half-maximum of the resolution.

Typical spectra are shown in Fig. 1(c) for $K^+\pi^-$, Fig. 1(d) for $\pi^-\pi^+$, and Fig. 1(e) for π^+K^- for meson states and in Figs. 2(a)–2(d) for baryon states of π^-p, K^-p, $\pi^+\bar{p}$, and $K^+\bar{p}$, respectively, all at the lowest mass setting. Figure 3 shows the six overlapping settings for $\bar{p}p$ and Fig. 4 shows the spectrum for the five overlapping settings in the K^-p state [the lowest mass setting is in Fig. 2(b)]. Similar results exist for all reactions ($K^+\pi^-$, $K^-\pi^+$, $\pi^-\pi^+$, K^+K^-, $K^+\bar{p}$, $\pi^+\bar{p}$, and $\pi^-\bar{p}$) and will be presented elsewhere.[4]

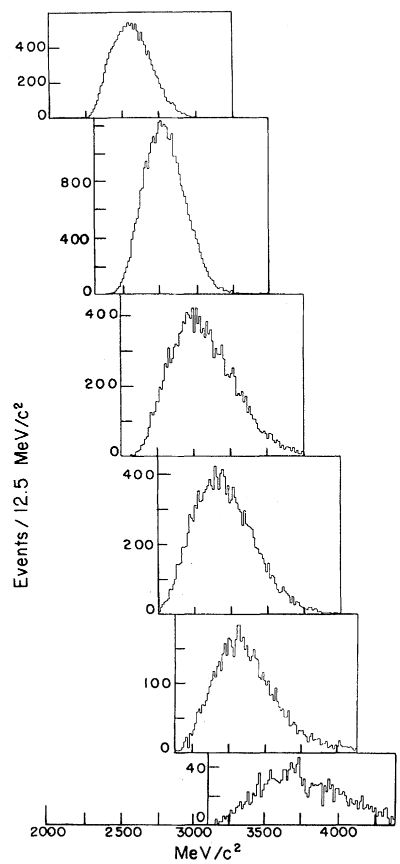

FIG. 3. $\bar{p}p$ mass spectra for the six overlapping mass settings of the spectrometer.

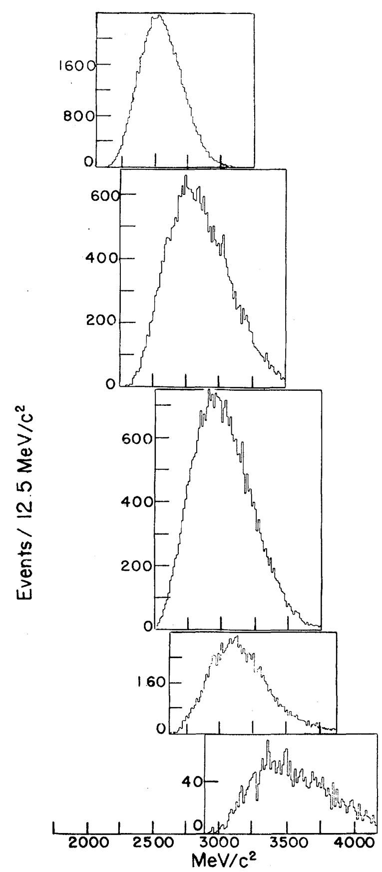

FIG. 4. K^-p mass spectra for the five overlapping settings of the spectrometer. [The lowest mass setting is in Fig. 2(b).]

TABLE I. Upper limit on the cross sections for narrow resonances at three different masses.

h^+x^- \ m	2.25 GeV	3.1 GeV	3.7 GeV
π^+K^-	1×10^{-33}	4×10^{-35}	1×10^{-35}
$K^+\pi^-$	4×10^{-33}	8×10^{-35}	4×10^{-35}
$p\bar{p}$	...	4×10^{-34}	2×10^{-35}
K^+K^-	1×10^{-33}	5×10^{-35}	1×10^{-35}
$\pi^+\pi^-$	8×10^{-33}	5×10^{-34}	3×10^{-35}
pK^-	7×10^{-33}	4×10^{-34}	3×10^{-35}
$K^+\bar{p}$	2×10^{-33}	4×10^{-35}	8×10^{-36}
$p\pi^-$	4×10^{-32}	4×10^{-33}	5×10^{-34}
$\pi^+\bar{p}$	2×10^{-33}	4×10^{-35}	7×10^{-36}

The spectrum increases with mass because of the increase of the acceptance, and then decreases again at higher mass because of the production mechanism. The individual spectra exhibit the expected statistical fluctuations, *but there is no sharp peak in the mass region 1.25–5.0 GeV when all the overlapping spectra are compared.*

Using a production mechanism for a particle in the c.m. system of

$$d^3\sigma/dp_\perp{}^{*2}\,dp_\parallel{}^* = c\exp(-6p_\perp{}^*)/E^*,$$

independent of $p_\parallel{}^*$ and a persistent 5-standard-deviation peak above the background as a candidate for a new particle, we obtain typical upper limits of production times branching ratio for new resonances shown in Table I.

This result contradicts most of the present theoretical attempts to understand the existence of the J particle based on the charm model or the baryon-antibaryon model and so forth.[5] It should be noted, however, that the analysis at the present stage does not exclude an ordinary wide resonance of a width of a few hundred MeV. Finding such a resonance would depend on a detailed analysis of the acceptance and production mechanism, which we have not done.

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Duality Violation and the Production and Decay of New and Old Mesons*

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It is shown that the O meson, the $J^P=1^-$ daughter of the Pomeron, is quite successful in predicting a number of rates for duality-violating processes.

Recently Freund and Nambu[1] have succeeded in constructing a model for the duality-violating $\varphi \to \rho\pi$ and $\psi(3105) \to \rho\pi$ amplitudes which meets with quantitative success. Basically, the decays proceed via pole dominance through an intermediary, the $O(J^P=1^-)$ meson, an SU(4) singlet and the daughter of the Pomeron. We extend the Freund-Nambu model to production and to other decays,