this experiment. Finally we are thankful to D. Nease for useful discussions regarding Table I.

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Observation of High-Mass Dilepton Pairs in Hadron Collisions at 400 GeV

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We report preliminary results on the production of electron-positron pairs in the mass range 2.5 to 20 GeV in 400-GeV p-Be interactions. 27 high-mass events are observed in the mass range 5.5–10.0 GeV corresponding to $\sigma=(1.2\pm0.5)\times10^{-35}$ cm^2 per nucleon. Clustering of 12 of these events between 5.8 and 6.2 GeV suggests that the data contain a new resonance at 6 GeV.

This is a first report of a double-arm-spectrometer study of electron-positron pairs produced in the reaction

$$p+\mathrm{Be}\to e^+e^- + \text{anything} \qquad (1)$$

using 400-GeV protons at Fermilab. The experiment is designed to observe e^+e^- pairs at high effective mass as a probe of continuum and resonant structures in the mass range of 2.5 to 20 GeV. Earlier observations of lepton pairs[1,2] at the Brookhaven National Laboratory Alternating Gradient Synchrotron in the mass interval 1.5–5 GeV demonstrated the existence of a continuum and of one narrow resonance. This experiment is sensitive to masses which approach the kinematic limit at Fermilab. A strong J/ψ peak, a ψ' peak, and a higher-mass signal between ~4.0 and 10.0 GeV are observed. Evidence of clustering of events near 6 GeV is presented and discussed.

Measurements of electron-positron pairs with high effective mass are made with the apparatus shown schematically in Fig. 1. The 400-GeV extracted beam of the Fermilab accelerator strikes a 224-μm-wide and 10-cm-long Be target in the proton center laboratory. Two symmetric spectrometer arms viewing the target at about 90° in the c.m. system detect electrons by essentially the same techniques used by this group[3] in the observation of direct electron production at high transverse momentum (p_t). One spectrometer arm bends charged particles up (label U) and the other down (label D). The magnetic spectrometer is composed of scintillation trigger counters, pro-

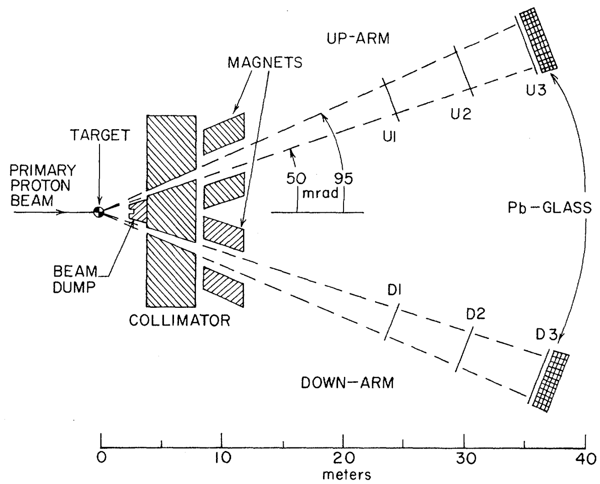

FIG. 1. Schematic diagram of the apparatus: U1-3 and D1-3 are sets of scintillation trigger counters, proportional wire chambers, and scintillation hodoscopes.

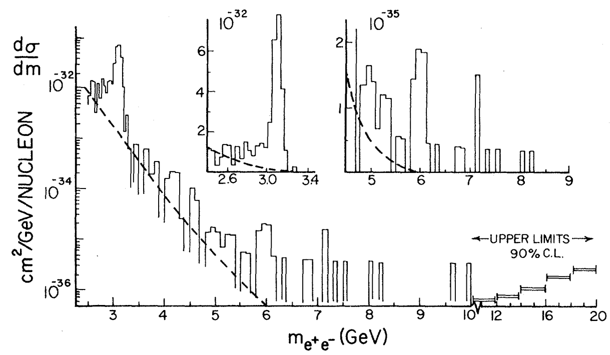

FIG. 2. Electron-positron mass spectrum: $d\sigma/dm$ per nucleon versus the effective mass. A linear A dependence is assumed. Note bin-width changes.

portional wire chambers, and vertical scintillation-counter hodoscopes. The angular acceptance of each spectrometer arm is ± 3.5 mrad vertically and extends from 50 to 95 mrad horizontally. Detection is done downstream of the magnet only and results in a typical momentum resolution of $\Delta p/p = 1.5\%$ (rms).

Electrons deposit virtually all of their energy in the 27-radiation-length-deep lead and lead-glass calorimeter while muons and hadrons typically deposit less of their energy in the corresponding 1.5 absorption lengths. After calibration and corrections for particle entry position, the energy resolution of the lead-glass calorimeter is represented approximately by $\Delta E/E$ (rms) $=(0.6+4/\sqrt{E})\%$ for energy E in GeV.[3] Equality of the energy deposited in the lead-glass calorimeter and the measured particle momentum ($E/P=1$) indicates the probable passage of an electron through the spectrometer. The additional requirement of a characteristic energy distribution of the electromagnetic shower in the four layers of glass leads to a hadron rejection of better than 4×10^{-4} in each arm independently. The efficiency for electrons remains 0.80 ± 0.08 with these electron cuts.

The observed mass spectrum $d\sigma/dm$ for electron-positron pairs is presented in Fig. 2. To obtain cross sections we assumed that the production at all masses is similar to that which we observe for the $\psi(3100)$[4] and specify below in Eq. (2). Cross sections reported here have been corrected for trigger and reconstruction efficiencies which lead to a combined efficiency before electron cuts of 0.8 ± 0.1 for electron-pair events. Corrections have also been made for target absorption of the proton beam and for events lost due to bremsstrahlung of the electrons [estimated to be $(10\pm 5)\%$ of the events at 6 GeV] although approximately half of these will appear in the mass spectrum at lower masses.

The $\psi(3100)$ resonance is observed with a width of 40 MeV (rms) which is in good agreement with the calculated resolution of the apparatus. Further details of the ψ physics will be published separately.[4] We use, however, an inclusive yield

$$Ed^3\sigma/dp^3 \propto (1-|x|)^{4.3}\exp(-1.6p_t), \quad -1\leq x\leq 1, \qquad (2)$$

which characterizes data from this and other experiments on ψ production.[5] This form is used in all subsequent calculations of acceptance.

The dashed curve shown in the mass spectrum of Fig. 2 represents our determination of all sources of background. Observed single-arm electron candidates come from three sources: (1) direct electrons, (2) misidentified charged hadrons, and (3) conversion electrons from π^0 or η^0. The background for pair events then arises from accidental coincidences between single-arm electron candidates of these three types coming from different interactions or from correlated events giving electron candidates coming from the same interaction.

The accidental background is studied by taking single-arm triggers at the same time as the pair data. Off-line pairing of the single-arm electron candidates, reconstructed in exactly the same way as pair triggers, determines the *shape* of the mass distribution for the accidental background. Careful monitoring of the duty cycle using single and uncorrelated, but in-time, hadron-pair rates then gives the normalization for these accidental mass distributions. Although during the course of the experiment the average run intensity varied by a factor of 3, investigation finds no sinister correlation between high-intensity pulses and the accumulation of high-mass events.

The correlated backgrounds are measured by several methods. They consist of hadron-hadron and hadron-electron correlations. Backgrounds with misidentified charged hadrons simulating electrons are studied by looking at effective-mass distributions in which one or both tracks fail the $E/p \simeq 1$ electron criteria. Tracks surviving electron-shower cuts but with $E/p < 0.85$ are known to be hadrons and are 2.5 times more numerous than electron candidates. These events are accumulated simultaneously with the electrons and include accidentals. Backgrounds with a conversion electron as the electron candidate are studied by supplementary runs in which conversion of photons from π^0 and η^0 are amplified by a factor of 4 in each arm via the insertion of 1.14 mm of Cu in the spectrometer aperture upstream of the magnets. The amplification is over the electrons from Dalitz decay and external conversion in the irreducible 1% of a radiation length of matter remaining in the aperture.

The results of an analysis of the data described above is presented as the background curve in Fig. 2. It is dominated for masses less than 4 GeV by accidental coincidences. However, at masses greater than 4.5 GeV, correlated hadron pairs begin to dominate the background curve. Finally, above 5.5 GeV all sources of background are negligible compared to the observed electron-positron signal consisting of 27 events.

The background-subtracted data including all events between 5 and 10 GeV, when binned in coarse intervals (0.5 GeV), can be described by a distribution

$$\frac{d\sigma}{dm} \simeq \frac{4\times10^{-32}}{m^5}\ (\mathrm{cm}^2/\mathrm{GeV})/\mathrm{nucleon}. \qquad (3)$$

This mass dependence is not very well determined. The total cross section above 5.5 GeV is $(1.2 \pm 0.5)\times10^{-35}$ cm^2 per nucleon.

These high-mass events are presented in Fig. 3 as $(d^2\sigma/dmdy)_{y=0}$ evaluated over the rapidity interval $-0.20 < y < +0.30$ and binned in 0.5-GeV intervals. The results expressed in this way are highly model independent and therefore appropriate for confrontation with theoretical models.

Figure 3 indicates good agreement with recent

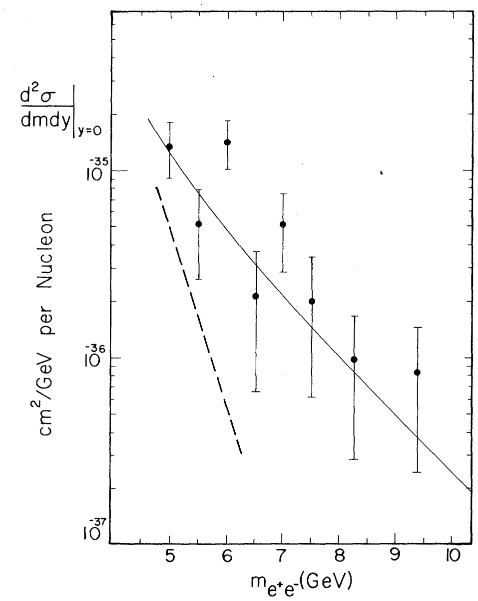

FIG. 3. $(d^2\sigma/dmdy)_{y=0}$ versus effective mass. The dashed line represents background contribution and the solid line is the prediction of Ref. 6.

versions of the parton-annihilation model[6] if a color degree of freedom is added. We note however that the high-mass dileptons have a p_t distribution at least as flat as the ψ. It is interesting that 12 of the 27 events cluster at 6 GeV, falling within a mass range roughly consistent with the mass resolution of the apparatus ($\sigma \simeq 70$ MeV). Upper limits on $d\sigma/dm$ for masses above 10.0 GeV are indicated in Fig. 2.

The events near 6 GeV correspond to a total cross section of $\sigma B = (5.2 \pm 2.0)\times10^{-36}$ cm^2 per nucleon under the assumptions of Eq. (3) and of a linear A dependence.[7] We have studied the probability for a clustering of events as is observed here to result from a fluctuation in a smooth distribution, e.g., Eq. (3). To avoid the difficult problems involved in the statistical theory associated with small numbers of events per resolution bin, a Monte Carlo method was used. Histograms were generated by throwing events according to a variety of smooth distributions, modulated by the mass acceptance, over the mass range 5.0 to 10.0 GeV. Clusters of events as observed occurring anywhere from 5.5 to 10.0 GeV appeared less than 2% of the time.[8] Thus the statistical case for a narrow (< 100 MeV) resonance is strong although we are aware of the need for confirmation. These data, at a level of 5×10^{-4} of the $\psi(3100)$, come in at a rate of 0.5 events per "ideal" day with 5×10^9 interactions per pulse. A dimuon version of this experiment, designed to increase significantly the high-mass dilepton data, is now in progress at Fermilab.

In summary, we have established a signal of massive dileptons above 5 GeV. A statistically significant clustering near 6 GeV suggests the existence of a narrow resonance.[9] The data are in good agreement with a color-added parton model although the broad transverse-momentum behavior is not predicted by the model.

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[9]We suggest the name Υ (upsilon) be given either to the resonance at 6 GeV if confirmed or to the onset of high-mass dilepton physics.

Evidence for a New Strangeness-One Pseudoscalar Meson*

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The $J^P=0^-$ partial waves of the $K\pi\pi$ system in the reactions $K^\pm p\to K^\pm\pi^+\pi^-p$ at 13 GeV are presented. Structure in intensities and relative phase variations suggest the existence of a pseudoscalar resonance, the K', with a mass of ~1400 MeV and a width of ~250 MeV decaying predominantly into ϵK.

The observation of pseudoscalar resonances is of fundamental importance to our understanding of the meson spectrum. Within the quark model[1] higher-mass recurrences of these states can occur only as radial excitations of the $L=0$ $q\bar{q}$ system. Evidence[2] for radial excitations in the meson system is provided by the ρ' and the ψ', although each of these states could have an alternative assignment in the $L=2$ $q\bar{q}$ supermultiplet. In this paper we present results which suggest the existence of a pseudoscalar, strangeness-one resonance, the K', with a mass in the vicinity of 1400 MeV.

The data on which these results are based were obtained in a spectrometer experiment studying the reactions $K^\pm p\to K^\pm\pi^+\pi^-p$ at 13 GeV. The salient features of the experiment[3-5] are high statistics, good resolution, K-π identification, and $K^\pm$ relative normalization uncertainty of ±2%. We have described previously[3,4] the principal $J^P=1^+$ and 2^+ partial waves[6] of the $K^\pm\pi^+\pi^-$ system. In addition to isolating a small, but clear, $K^*(1420)$ signal, we presented evidence for the existence of two axial-vector mesons, Q_1 with a mass of ~1300 MeV and Q_2 at ~1400 MeV.

As they are germane to our discussion of the