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SEARCH FOR NARROW RESONANCES IN e^+e^- ANNIHILATION IN THE MASS REGION 3.2 TO 5.9 GeV*

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ABSTRACT

We have searched the mass region 3.2 to 5.9 GeV for evidence of narrow resonances in $e^+e^- \rightarrow$ hadrons. We find no evidence for any such resonances other than the $\psi(3695)$ in this region with a sensitivity ranging from about 12 to 45% of the integrated cross section of the $\psi(3695)$. The more stringent bounds apply to resonances of a few MeV width, while the looser bounds apply to resonances of up to 20 MeV width.

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After the discovery of the $\psi(3105)$,[1,2] we began a systematic search for other narrow resonances in e^+e^- annihilation. In the first run of this search, which extended from 3.60 to 3.71 GeV, the $\psi(3695)$ was discovered.[3] The search has been continued and now covers the mass region 3.2 to 5.9 GeV. No evidence for other narrow resonances has been found.

The search, performed at the SLAC e^+e^- colliding beam facility SPEAR, used the SLAC-LBL solenoidal magnetic detector. The properties of this detector have been described previously.[4] Events from the process $e^+e^- \rightarrow$ hadrons are identified in the detector by the observation of three or more charged tracks or two charged tracks acoplanar with the incident beams by more than 20°. The detection efficiency for hadronic events varies from about 50% to 70% over the energy range of the search. The luminosity is determined by the measurement of e^+e^- scattering at 20 mrad. Details of the determination of the detection efficiency, backgrounds, and other corrections to the measurement of total hadronic cross sections are discussed elsewhere.[5]

The mass resolution is determined by the energy spread in the colliding beams which arises mainly from quantum fluctuations in the synchrotron radiation emitted by the beams. The resolution varies as the energy squared and ranges from 2.0 to 6.9 MeV (fwhm) as the center of mass energy ($E_{c.m.}$) increases from 3.2 to 5.9 GeV.[6]

The search was conducted by automatically increasing the center-of-mass energy (twice the beam energy) by 1.88 MeV every few minutes. Data taken during each step were analyzed in real time and the relative cross sections were computed at the end of each step. The data were also written on magnetic tape for later reanalysis. After each fill of the rings, the starting energy was normally set to overlap the previous scan by a few steps. A few mass regions were scanned more than once.

Figure 1 shows the relative cross sections for $e^+e^- \rightarrow$ hadrons in 1.88 MeV steps in $E_{c.m.}$. The $\psi(3695)$ is clearly visible, but no other structure is evident. Multiple measurements at the same energy step have been combined, but the region around the $\psi(3695)$ represents a single scan of average luminosity and time span. The average time spent at each step was 2.7 minutes at an average luminosity of 1.1×10^{30} cm^{-2} sec^{-1}.

We have set upper limits on the integrated cross sections for the production of narrow resonances in this mass region. The integrated cross section is defined

$$\Sigma = \int \sigma(E_{c.m.})\, dE_{c.m.}$$

where σ is the resonant cross section and is assumed to be a Breit-Wigner line shape. We quote limits in terms of Σ since it is the only resolution-independent parameter we can measure if the resonance width is less than the mass resolution. It is also directly related to the partial decay width of the resonance into electron pairs, Γ_{ee}. If the resonance has spin one,

$$\Gamma_{ee} = \frac{m^2}{6\pi^2} \frac{\Sigma}{B} ,$$

where m is the mass of the resonance and B is the branching ratio into hadrons.

The limits were set by hypothesizing the existence of resonances at each energy and comparing the expected to the observed yield using Poisson statistics. We made a conservative background subtraction of 16 nb for $E_{c.m.} \leq$ 5.0 GeV and 12 nb for $E_{c.m.} >$ 5.0 GeV for nonresonant hadron production.[5] The limits for radiatively corrected[7] integrated cross sections at the 90% confidence level are given in Table I. For comparison, the integrated cross section of the $\psi(3695)$ is of order 5000 nb MeV. Thus, the upper limits range from 12 to 45% of the integrated cross section of the $\psi(3695)$, with sensitivity decreasing as the resonance width increases.

We plan to continue to search for narrow resonances at higher masses.

FOOTNOTES AND REFERENCES

1. J.-E. Augustin *et al.*, Phys. Rev. Letters **33**, 1406 (1974).
2. J.J. Aubert *et al.*, Phys. Rev. Letters **33**, 1404 (1974).
3. G.S. Abrams *et al.*, Phys. Rev. Letters **33**, 1453 (1974).
4. J.-E. Augustin *et al.*, Stanford Linear Accelerator Center Report No. SLAC-PUB-1501 (1974), to be published.
5. J.-E. Augustin *et al.*, Stanford Linear Accelerator Center Report No. SLAC-PUB-1520 (1975), to be published.

6. The resolutions given are those arising from quantum fluctuations in the synchrotron radiation emitted by the circulating beams. This energy spread has a Gaussian distribution. There can also be a contribution to the spread from instabilities in high peak current beams. By measuring the peak cross sections of the $\psi(3105)$ and $\psi(3695)$ as a function of circulating beam current we have determined that for the currents used in this experiment the increased energy spread was less than 50% at 3.1 GeV and less than 25% at 3.7 GeV. This effect is expected to decrease rapidly with increasing energy.

7. D.R. Yennie, Cornell University Report No. CLNS-291 (1974), to be published; Y.S. Tsai and D.R. Yennie, private communications.

8. The largest fluctuation is centered at 3.795 GeV, where 8 events were detected for 2 expected. There is an independent reason for considering this

a fluctuation rather than a signal. A narrow resonance with an integrated cross section of 1470 nb MeV located at 3.795 GeV would yield a radiative tail of about 13 nb at 3.800 GeV (see Ref. 7). We have previously taken extensive data at 3.800 GeV and these data cannot reasonably support the existence of a radiative tail of that size (see Ref. 5). If this fluctuation is excluded, then the limit on a narrow resonance in the region 3.720 to 4.000 GeV changes from 1470 to 850 nb MeV.

FIGURE CAPTION

1. Relative cross sections for $e^+e^- \rightarrow$ hadrons.