ERRATUM to SLAC-PUB-1504

Discovery of a Narrow Resonance in

e^+e^- Annihilation

A factor of $\sqrt{2}$ was omitted from the calculation of the experimental upper limit to the width of $\psi(3105)$. The correct value is 1.9 MeV rather than 1.3 MeV. However, the curve in Figure 1a showing the calculated tail of the resonance is correct.

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DISCOVERY OF A NARROW RESONANCE IN e^+e^- ANNIHILATION*

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ABSTRACT

We have observed a very sharp peak in the cross section for $e^+e^- \rightarrow$ hadrons, e^+e^-, and possibly $\mu^+\mu^-$ at a center-of-mass energy of 3.105 ± 0.003 GeV. The upper limit to the full width at half maximum is 1.3 MeV.

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We have observed a very sharp peak in the cross section for $e^+e^- \rightarrow$ hadrons, e^+e^-, and possibly $\mu^+\mu^-$ in the SLAC-LBL magnetic detector[(1)] at the SLAC electron-positron storage ring SPEAR. The resonance has the parameters

$$E = 3.105 \pm 0.003 \text{ GeV}$$
$$\Gamma \leq 1.3 \text{ MeV} \qquad \text{(FWHM)}$$

where the uncertainty in the energy of the resonance reflects the uncertainty in the absolute energy calibration of the storage ring. (We suggest naming this structure $\psi(3105)$.) The cross section for hadron production at the peak of the resonance is $\gtrsim$ 2300 nb, an enhancement of about 100 times the cross section outside the resonance. The large mass, large cross section, and narrow width of this structure are entirely unexpected.

Our attention was first drawn to the possibility of structure in the $e^+e^- \rightarrow$ hadron cross section during a scan of the cross section carried out in 200 MeV steps. A 30% (6 nb) enhancement was observed at a center-of-mass (CM) energy of 3.2 GeV. In June of this year, we repeated the measurement at 3.2 GeV and also made measurements at 3.1 and 3.3 GeV. The 3.2 GeV results reproduced, the 3.3 GeV measurement showed no enhancement, but the 3.1 GeV measurements were internally inconsistent – 6 out of 8 runs giving a low cross section and 2 runs giving a factor of 3 to 5 higher cross section. This pattern could have been caused by a very narrow resonance at an energy slightly larger than the nominal 3.1 GeV setting of the storage ring; the inconsistent 3.1 GeV cross sections then being caused by setting errors in the ring energy. The 3.2 GeV enhancement would arise from radiative corrections which give a high energy tail to the structure.

During the past week we have repeated the measurements using much finer energy steps and using a nuclear magnetic resonance magnetometer to monitor the ring energy. The magnetometer, coupled with measurements of the circulating beam position in the storage ring made at 16 points around the orbit, allowed the relative energy to be determined to 1 part in 10^4. The determination of the absolute energy setting of the ring requires the knowledge of $\int B d\ell$ around the orbit and is accurate to $\pm$ 0.1%

The data are shown in Figure 1. All cross sections are normalized to Bhabha scattering at 20 mrad. The cross section for the production of hadrons is shown in Fig. 1a. Hadronic events are required to have in the final state either ≥ 3 detected charged particles or 2 charged particles acoplanar by $> 20^{\circ}$.[(2)] The observed cross section rises sharply from a level of about 25 nb to a value of 2300 $\pm$ 200 nb at the peak[(3)] and then exhibits the long high energy tail characteristic of radiative corrections in e^+e^- reactions. The detection efficiency for hadronic events is 45% over the region shown. The error quoted above includes both the statistical error and a 7% contribution from uncertainty in the detection efficiency.

Our mass resolution is determined by the energy spread in the colliding beams which arises from quantum fluctuations in the synchrotron radiation emitted by the beams. The expected Gaussian C.M. energy distribution (σ = 0.56 MeV) folded with the radiative processes,[(4)] is shown as the dashed curve in Fig. 1a. The width of the resonance must be smaller than this spread; thus an upper limit to the full width at half maximum is 1.3 MeV.

Figure 1b shows the cross section for e^+e^- final states. Outside the peak this cross section is equal to the Bhabha cross section integrated over the acceptance of the apparatus.[1]

Figure 1c shows the cross section for the production of collinear pairs of particles, excluding electrons. At present, our muon identifications system is not functioning and we therefore cannot separate muons from strongly interacting particles. However, outside the peak the data are consistent with our previously measured μ-pair cross section. Since a large $\pi\pi$, or KK branching ratio would be unexpected for a resonance this massive, the two-body enhancement observed is probably but not conclusively in the μ-pair channel.

The $e^+e^- \rightarrow$ hadron cross section is presumed to go through the one photon intermediate state with angular momentum, parity and charge conjugation quantum numbers $J^{PC} = 1^{--}$. It is difficult to understand how, without involving new quantum numbers or selection rules, a resonance in this state which decays to hadrons could be so narrow.

We wish to thank the SPEAR operations staff for providing the stable conditions of machine performance necessary for this experiment. Special monitoring and control techniques were developed on very short notice and performed excellently.

REFERENCES

1. The apparatus is described in Augustin et al., Phys. Rev. Lett. in press.

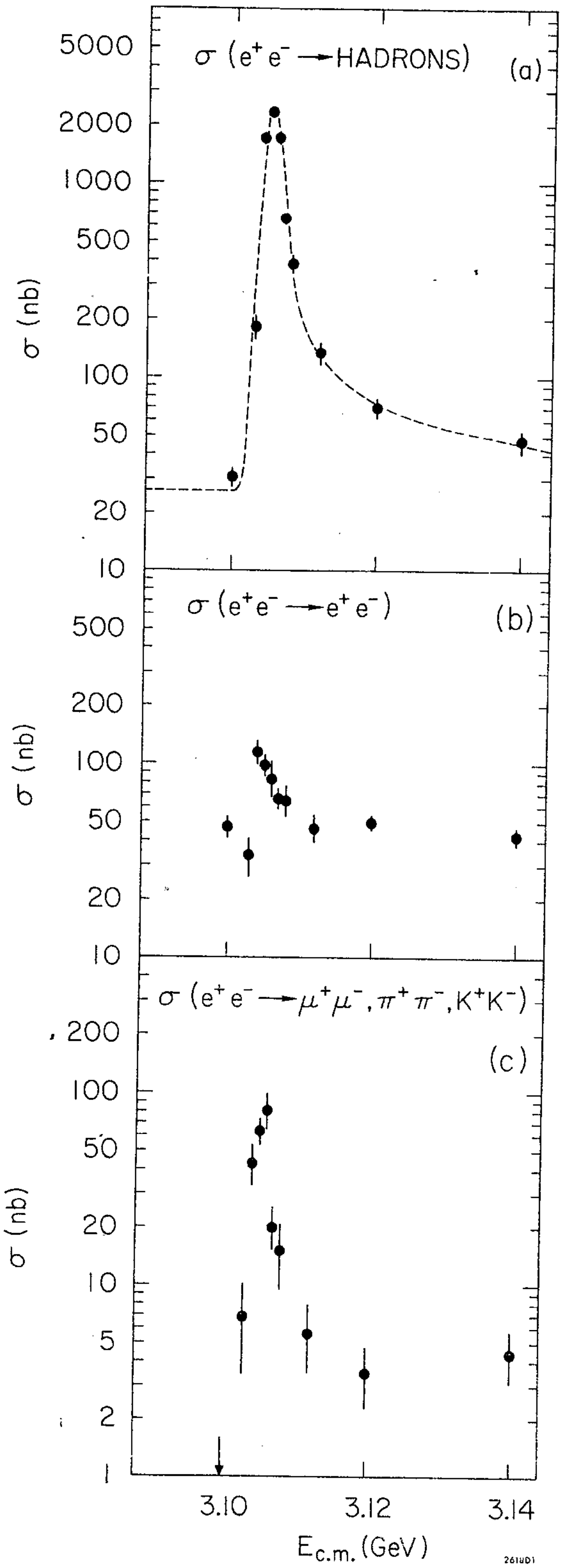
2. The detection efficiency determination will be described in a future publication.

3. While preparing this manuscript we were informed that the M.I.T. group studying the reaction $pp \rightarrow e^+e^- + x$ at BNL has observed an enhancement in the e^+e^- mass distribution at about 3100 MeV.

4. G. Bonneau and F. Martin, Nuc. Phys B27, 381 (1971).

FIGURE CAPTION

Cross section vs. energy for (a) multihadron final states, (b) e^+e^- final states, and (c) $\mu^+\mu^-$, $\pi^+\pi^-$ and K^+K^- final states. The curve in (a) is the expected shape of a δ-function resonance folded with the Gaussian energy spread of the beams and including radiative processes. The cross sections shown in (b) and (c) are integrated over the detector acceptance. The total hadron cross section, (a), has been corrected for detection efficiency.



σ (e⁺e⁻ → HADRONS)
(a)
5000
2000
1000
500
200
100
50
20
10
σ (nb)
σ (e⁺e⁻ → e⁺e⁻)
(b)
500
200
100
50
20
10
σ (nb)
σ (e⁺e⁻ → μ⁺μ⁻, π⁺π⁻, K⁺K⁻)
(c)
200
100
50
20
10
5
2
1
σ (nb)
3.10
3.12
3.14
Ec.m. (GeV)
2610D1