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

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ABSTRACT

We have observed a second sharp peak in the cross section for $e^+e^- \rightarrow$ hadrons at a center-of-mass energy of 3.695 ± 0.004 GeV. The upper limit of the full width at half maximum is 2.7 MeV.

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The recent discovery of a very narrow resonant state coupled to leptons and hadrons[1,2,3] has raised the obvious question of the existence of other narrow resonances also coupled to leptons and hadrons. We therefore began a systematic search of the mass region accessible with the SLAC e^+e^- storage ring SPEAR and quickly found a second narrow resonance decaying to hadrons. The parameters of the new state (which we suggest calling $\psi(3695)$) are

$$M = 3.695 \pm 0.004 \text{ GeV}$$
$$\Gamma < 2.7 \text{ MeV (FWHM)}$$

where the mass uncertainty reflects the uncertainty in the absolute energy calibration of the storage ring.

The $\psi(3695)$, like the $\psi(3105)$, was found using the SLAC-LBL magnetic detector at SPEAR.[4] The luminosity monitoring, event acceptance criteria, and storage ring energy determination have been described previously.[1]

The new feature of this run is the search procedure used to hunt for narrow e^+e^- resonances. In the search mode the storage ring energy is increased in about 1 MeV steps ($E_{CM} = 2 \times E_{BEAM}$) every three minutes. The data taken during each step are analyzed in real time and the relative cross sections computed at the end of each step. Figure 1a shows the search mode data taken during a calibration scan over the previously discovered $\psi(3105)$. Figure 1b shows the data taken during the first scan which began at a ring energy of 1.8 GeV. A clear indication of a narrow resonance with a mass of about 3.70 GeV is seen. It should be emphasized that we have not yet scanned any mass region other than that between 3.6 and 3.71 GeV.

On finding evidence of a resonance in the $e^+e^- \rightarrow$ hadron cross section, we switched to the normal SPEAR operating mode of longer runs at fixed energy. In this mode, smaller energy changes are possible than in the search mode. Figure 2 shows the cross section for $e^+e^- \rightarrow$ hadrons, corrected for the detection efficiency of about 55% over the energy region shown.

Our mass resolution is determined by the energy spread in the colliding beams, which depends on the energy of the beams. The expected Gaussian C.M. energy distribution (σ = 1.2 MeV) folded with the radiative processes,[6] is shown as the dashed curve in Figure 2. The width of the resonance must be smaller than this spread; thus, an upper limit to the full width at half maximum is 2.7 MeV.

In summary, the colliding beam data now show two narrow resonances in the hadron production cross section. Our determination of the parameters of the resonance are:

	Mass (GeV)	Γ (FWHM) (MeV)
$\psi(3105)$	3.105 ± 0.003	< 1.9[5]
$\psi(3695)$	3.695 ± 0.004	< 2.7

We are continuing the search for others.

We thank the SPEAR operations staff for the technological tour de force they accomplished whereby we are able to scan the machine energy in small, well defined steps. We also acknowledge the cooperation of the Stanford Center for Information Processing in expediting the computation needs of this experiment.

REFERENCES

1. J.-E. Augustin et al., Phys. Rev. Lett 33 (1974)
2. J. J. Aubert et al., Phys. Rev. Lett 33 (1974)
3. C. Bacci et al., Phys. Rev. Lett 33 (1974)
4. J.-E. Augustin et al., to be published
5. In reference (1) 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 which appears in Ref. (1). However, the curve in Figure 1a of Ref. (1) showing the calculated tail of the resonance is correct.
6. G. Bonneau and F. Martin, Nucl. Phys. B27, 321 (1971)

FIGURE CAPTIONS

1. Search mode data taken (a) in a one hour calibration run over the $\psi(3105)$ (average luminosity of 2×10^{29} cm^{-2} sec^{-1}) and (b) during the run in which the $\psi(3695)$ was found (average luminosity of 5×10^{29} cm^{-2} sec^{-1}).
2. Total cross section for $e^+e^- \rightarrow$ hadrons corrected for detection efficiency. The dashed curve is the expected resolution folded with the radiative corrections. The errors shown are statistical only.

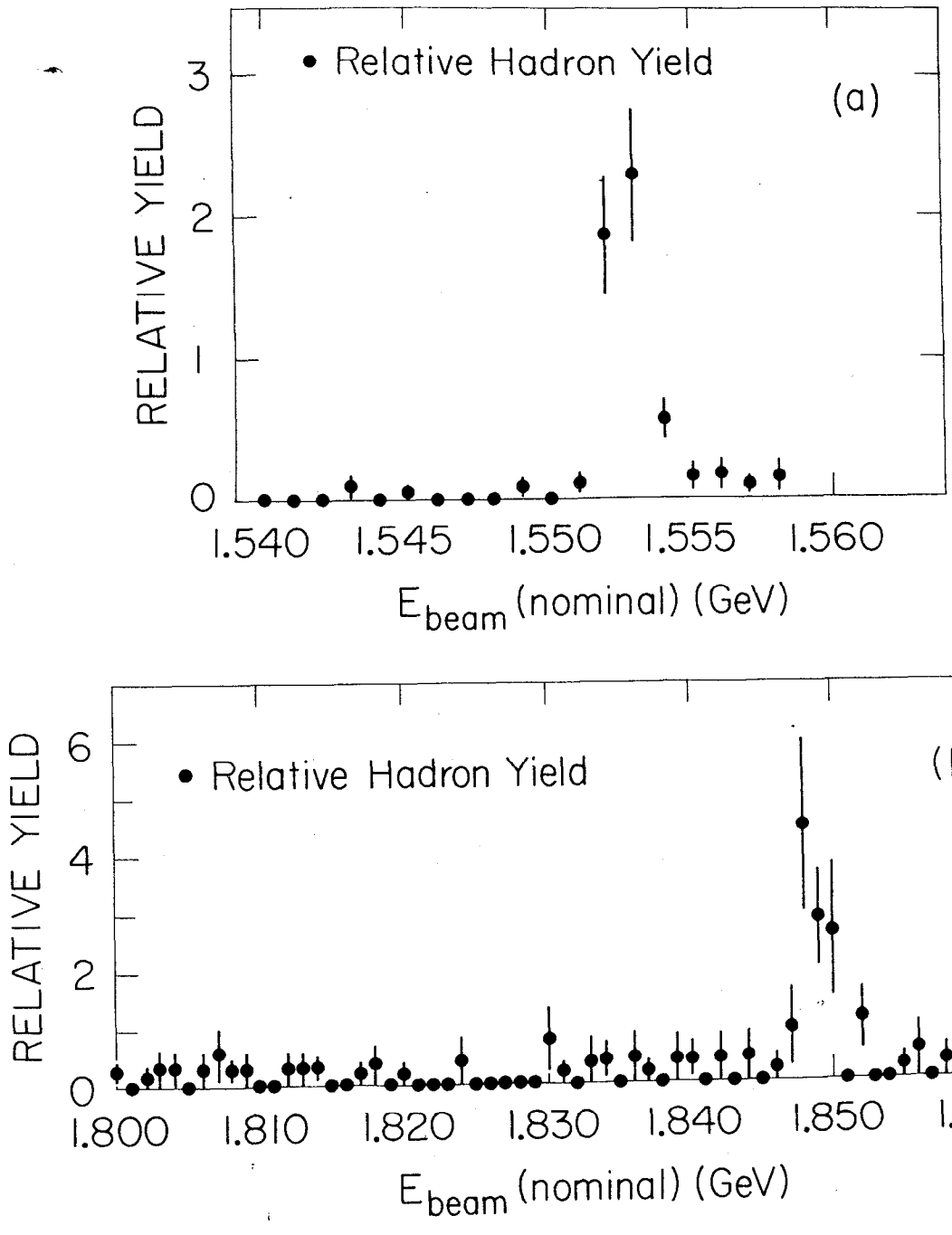
• Relative Hadron Yield
(a)
RELATIVE YIELD
0
1
2
3
1.540
1.545
1.550
1.555
1.560
E beam (nominal) (GeV)
• Relative Hadron Yield
(b)
RELATIVE YIELD
0
2
4
6
1.800
1.810
1.820
1.830
1.840
1.850
1.860
E beam (nominal) (GeV)
2621C1

Figure 1

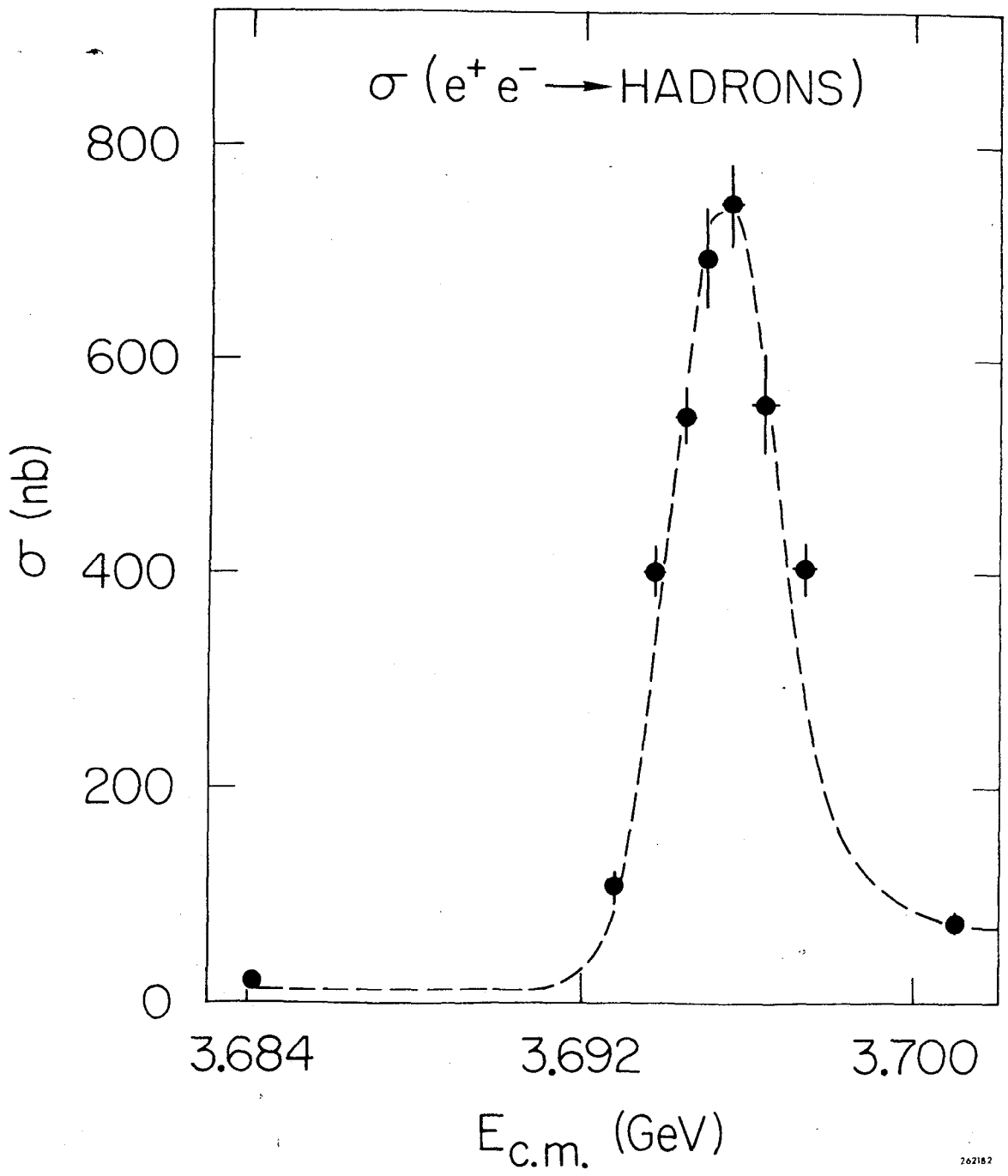
σ (e+ e− → HADRONS)
800
600
400
200
0
σ (nb)
3.684
3.692
3.700
Ec.m. (GeV)
262182

Figure 2