OBSERVATION OF A NARROW RESONANCE AT 9.46 GeV
IN ELECTRON – POSITRON ANNIHILATIONS

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We observe a narrow resonance in the reaction $e^+e^- \to$ hadrons using the DASP detector at the DORIS storage ring. The mass is found to be (9.46 ± 0.01) GeV and the observed width is compatible with the storage ring resolution of ± 8 MeV. The energy-integrated cross section results in an electronic width $\Gamma_{ee} = (1.3 \pm 0.4)$ keV.

A study of the reaction $p + N \to \mu^+\mu^- + X$ recently performed at FNAL [1] showed a muon pair mass spectrum with two or perhaps three peaks between 9 and 11 GeV/c^2. The authors identified these peaks with three new mesons, $\Upsilon(9.4)$, $\Upsilon'(10.0)$ and $\Upsilon''(10.4)$. In analogy with the J/ψ mesons, these new mesons were interpreted [2] as bound states of a fifth quark-antiquark pair, in which case their production in electron-position annihilation would allow a study of their decay modes and their spectroscopy.

We have therefore used the upgraded electron-positron storage ring DORIS at DESY to search for a similar structure in the energy dependence of the cross section for the reaction

$$e^+e^- \to \text{hadrons} .$$

We report here on a first analysis of data taken from

April 17 to May 5, 1978 in the centre-of-mass range 9.20 to 9.48 GeV.

The double ring multi-bunch machine DORIS has been transformed [3] into a single ring, single-bunch machine in order to reach centre-of-mass energies of 10 GeV. The geometry near the two intersection regions has been modified to minimize synchrotron radiation and to obtain a zero crossing angle for the two beams. Typical beam currents for this experiment were 15 mA per beam, with a luminosity of about 10^{30} cm^{-2} s^{-1}.

The r.m.s. beam energy spread, extrapolated from lower energies, is ± 6 MeV at 4.7 GeV and corresponds to a mass resolution of ± 8 MeV. The uncertainty of the absolute centre-of-mass energy is estimated to be ± 10 MeV [4].

The measurements were performed with the Double Arm Spectrometer DASP. The apparatus consists of a non-magnetic inner detector which covers a solid angle of about 50% of 4π and two magnetic outer detectors

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which cover approximately 5% of 4π. The properties of the detector have been described before [5].

Data were taken at centre-of-mass energies 9.20 GeV, 9.30 GeV and in the energy range from 9.35 GeV to 9.48 GeV. For each energy an integrated luminosity of 6 to 30 nb^{-1} was accumulated.

The storage ring luminosity was continuously monitored by a counter system of four telescopes positioned at scattering angles of 8° to record small angle Bhabha scattering. Large angle Bhabha scattering was recorded with the inner detector independently. The two methods agreed to within ±15%.

About 10^4 triggers lead to one good event. To reject interactions with residual gas in the storage ring and cosmic rays, the following selection criteria were applied:

Particle tracks were reconstructed with the five layer scintillator hodoscopes of the inner detector. At least three tracks were required which did not all lie in the same hemisphere. The total energy deposited in the shower counters was required to be more than 450 MeV with no single track depositing more than 3.5 GeV. Events which passed this test were visually scanned for tracks in the proportional tube counters of the inner detector and the multiplicity noted. Again, at least three tracks (including showers) were required which did not all lie in the same hemisphere. They had to originate from a common vertex point close to the interaction region.

Finally, the accepted events were computer-reconstructed, and the particle track angles and vertices were determined. The overall efficiency of this selection procedure was about 42%. We estimate the remaining background to be less than the statistical error.

The cross sections obtained are shown in fig. 1.

A clear resonance signal is observed at a mass of (9.457 ± 0.010) GeV. The error reflects the present precision of the energy calibration of DORIS. The measured r.m.s. width of the resonance is 7.6 MeV, in perfect agreement with the mass resolution of the machine, and exactly what would be expected for a narrow resonance.

The partial width Γ_{ee} can be determined from the integrated cross section $\int \sigma_h \, dE$ for hadron production, assuming the partial width for the decay into an e^+e^- pair to be small compared to the total width. In order to derive the hadronic cross section from the measured visible section, we normalized with $R = \sigma_h/\sigma_{\mu\mu}$
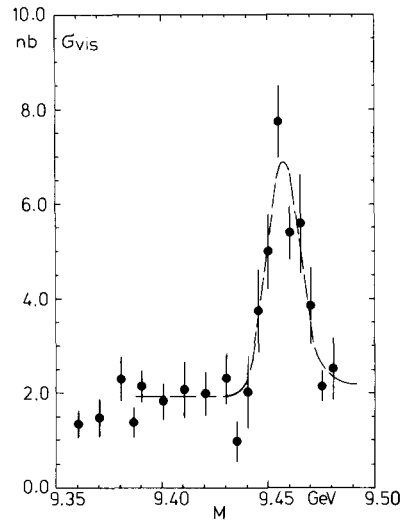

Fig. 1. Visible cross section of the reaction $e^+e^- \to$ hadrons as defined by the trigger and the selection criteria. The dashed curve represents the best fit including gaussian resolution and radiative corrections.

= 4.5 ± 0.5 at 9.4 GeV. Furthermore, we assumed that the acceptance of the detector did not change from outside to inside the resonance. This assumption is supported by our observation that the mean multiplicity
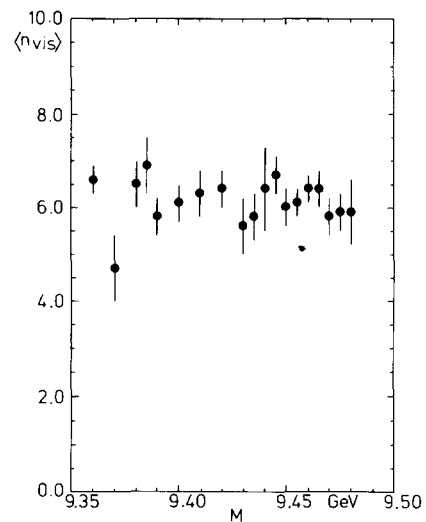

Fig. 2. Average multiplicities as found in the visual scan of the selected events (charged particles + photons).

of the detected particles (fig. 2) is constant to within 15% in the energy region covered by the experiment, including points in the resonance.

With this procedure we get an integrated hadronic cross section of $\int \sigma_h \, dE = (330 \pm 100)$ nb MeV, where radiative corrections [6] have already been applied. The error contains the estimated systematic uncertainty. For the electronic width we obtain $\Gamma_{ee} = (1.3 \pm 0.4)$ keV.

We conclude that the observed resonance is the $\Upsilon(9.4)$ meson recently discovered by Herb et al. [1]. Our experiment supports the existence of a fifth quark, because the observed value of the electronic width Γ_{ee} is in perfect agreement with the predictions [7] of models which assume the $\Upsilon(9.4)$ to be the ground state of a new family of quark-antiquark states with a fifth quark of about 4.7 GeV mass.

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