# TWO-BODY HADRONIC DECAYS OF THE 3.1 GeV RESONANCE

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DASP-COLLABORATION

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Hadronic two body decays of the 3.1 GeV resonance were measured and the following branching ratios were obtained: $\Gamma_{\pi^+\pi^-}/\Gamma_{\mu\mu} < 0.0046$, $\Gamma_{K^+K^-}/\Gamma_{\mu\mu} < 0.0084$, and $\Gamma_{p\bar{p}}/\Gamma_{\mu\mu} = 0.036 \pm 0.010$ assuming the $p\bar{p}$ decay distribution is $\sim 1 + \cos^2\theta$.

A study of the $\pi^+\pi^-$, $K^+K^-$, and $p\bar{p}$ decay modes of the 3.1 GeV resonance has been carried out at the DESY $e^+e^-$ storage rings DORIS using the double-arm spectrometer DASP. Results from this experiment for other decay channels of the 3.1 GeV resonance such as $e^+e^-$, $\gamma\gamma$, and $\mu^+\mu^-$ have already been published [1,2].

Fig. 1 shows the layout of DASP [1,2]. Two identical magnetic spectrometer arms are placed symmetrically with respect to the interaction point. A nonmagnetic detector is located between the two magnets [1]. A charged particle emitted at the interaction point in the direction of one of the magnet gaps passes through a scintillation counter ($S_0$) close to the beam pipe, a second scintillation counter which starts the time of flight measurement, two proportional chambers, a third scintillation counter ($S_M$), a wire spark chamber, the magnet gap, 6 wire spark chambers, a wall of 31 time-of-flight counters (F), and a wall of 11 shower counters (Sh) (6.2 radiation lengths of lead and scintillator). The shower counters are followed by 70 cm of iron plates and a wall of 9 scintillation counters (range counters).

The trigger condition for charged pair events was defined as the coincidence $(S_0 \cdot S_M \cdot F \cdot Sh)_{arm1} \times (S_0 \cdot S_M' \cdot F \cdot Sh)_{arm2}$. Events were collected at the 3.1 GeV resonance for an integrated luminosity of 56 $nb^{-1}$ by frequently stepping across the resonance.

In searching for two-body hadronic decays of the 3.1 GeV resonance only events where considered which had two tracks in the magnetic spectrometer arms and none in the nonmagnetic detector. The major source of background was muon and $e^+e^-$ pairs. The final $e^\pm$ frequently lost a significant amount of energy

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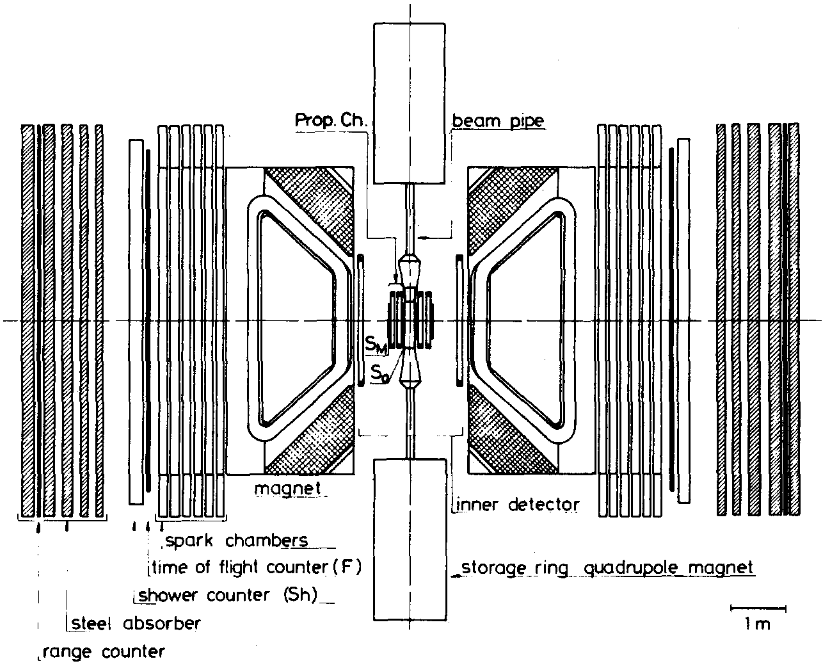


Fig. 1. Schematic view of the Double Arm Spectrometer (DASP) showing the two identical magnet arms. Most of the inner detector (not relevant for these results) has been omitted from the figure.

through bremsstrahlung. The lepton pairs were eliminated using momentum, range, shower, and time-of-flight information. The momentum accuracy was ±1.8% (rms) at 1.5 GeV/$c$ (see fig. 2a) with the magnet at 2/3 of full excitation. The response of the shower counter to minimum ionizing particles and electrons is shown in fig. 2b. The time-of-flight was measured to an accuracy of ±0.26 nsec (rms) over a flight path of 5 m.

The following criteria were chosen to select $\pi^+\pi^-$, $K^+K^-$, and $p\bar{p}$ events.

*$\pi^+\pi^-$ pairs*

a. The measured momenta of both tracks had to lie in the interval 1.40–1.70 GeV/$c$.

2. The tracks had to be collinear, the difference in the projected angles being less than 0.1 rad.

3. The vertex had to be within 5 cm of the nominal intersection point along the beam lines.

4. The shower pulse height for each particle had to be less than five times that for a minimum ionizing particle.

5. No range counter fired.

6. In order to eliminate those muons at the extreme ends of the polar angular acceptance which could fire the time-of-flight and shower counters but miss the range counters, a cut in polar angle was made. Depending on the charge and the magnet polarity: $-0.25 < \cos\theta < 0.55$ or $-0.55 < \cos\theta < 0.25$.

*$K^+K^-$ pairs*

1. The measured momenta had to be between 1.32 and 1.62 GeV/$c$.

2. The criteria 2–6 were the same as for $\pi^+\pi^-$ pairs.

No events were found which satisfied either the selection criteria for $\pi^+\pi^-$ or for $K^+K^-$ pairs (nor for $\eta^+K^-$ or for $\pi^-K^+$ pairs). In order to arrive at upper limits for the branching ratios we normalize to the muon pairs from the decay of the 3.1 state observed in the same data runs [2]. Assuming a decay distribution $\sim \sin^2\theta$ valid for a $J^P = 1^-$ state and unpolarized beams[‡] one obtains the following upper limits (90% C.L.)

$$\Gamma_{\pi^+\pi^-}/\Gamma_{\mu\mu} < 0.0046, \qquad \Gamma_{K^+K^-}/\Gamma_{\mu\mu} < 0.0084.$$

Corrections were applied for losses by nuclear absorption (correction factor 1.09 for $\pi^+\pi^-$, 1.08 for $K^+K^-$) and by decay (1.10, 2.10).

‡ Effects on the decay distribution due to beam polarization were negligible in this experiment.

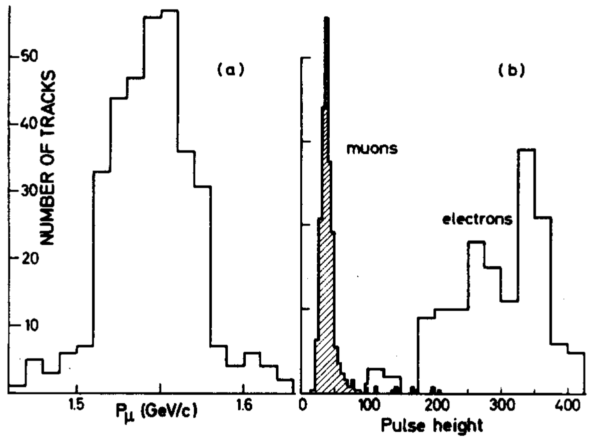


Fig. 2. (a) Momentum distribution for muons from $e^+e^- \to \mu^+\mu^-$ measured at the 3.1 resonance. (b) Distribution of the pulse height for 1.5 GeV muons (shaded) and electrons (unshaded) measured in the shower counter (Sh) of the outer detector. Candidates for the reactions $e^+e^- \to \mu^+\mu^-$, $e^+e^-$ were selected. The muons were identified by the range counters, the electrons (positrons) in arm 1 by the requirement that the particle detected in arm 2 had given a pulse height larger than five times the pulse height for a minimum ionizing particle.

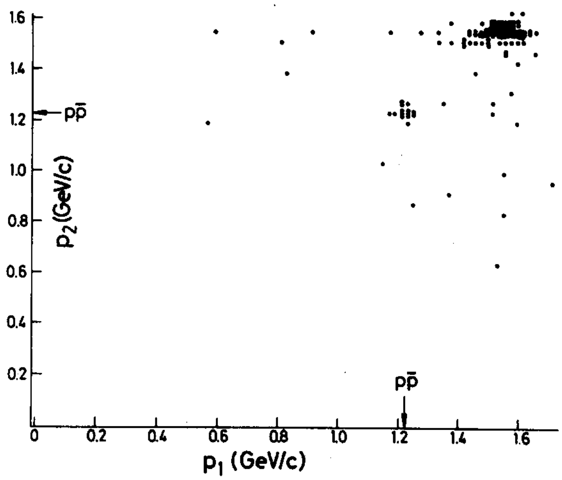


Fig. 3. Momentum in arm 1 versus momentum measured in arm 2 for candidates for $e^+e^- \to p\bar{p}$. The selection criteria are explained in the text. Events outside the $p\bar{p}$ cluster are from the data sample without the time-of-flight measurement; the cluster at $P_1 = P_2 = 1.55$ GeV/$c$ results from muons missing the range counters.

*$p\bar{p}$-pairs.* The pp candidates had to satisfy the follow-lowing selection criteria.

1. Both momenta had to be less than 1.4 GeV/$c$.

2. The same criteria 2–5 as for $\pi^+\pi^-$ and $K^+K^-$ pairs had to be fulfilled with the exception that no pulse height cut was made on the negative particle ($\bar{p}$ candidate).

3. For that portion (~ 1/2) of the data for which time-of-flight measurements were available the value of $\beta = v/c$ was required to be within 0.70–0.88 (the nominal value for 3.1 GeV $\to p\bar{p}$ decays is 0.79). No genuine $p\bar{p}$ events were lost by this cut.

Fig. 3 shows for the events selected the two-dimensional distribution of the momentum measured in spectrameter arm one versus the momentum measured in arm two. A well isolated cluster of 14 events is observed centered at $P_1 = P_2 = 1.22$ GeV/$c$, the nominal momentum value for protons from the $p\bar{p}$ decay of a state with mass 3090 MeV. In the data sample with time-of-flight measurements no additional $p\bar{p}$ events were found when the shower pulse height cut was removed.

The branching ratio to be deduced from the observed $p\bar{p}$ events depends on the form of the angular distribution $W(\cos\theta)$ used to extrapolate to the full solid angle. Three possibilities corresponding to different relative contributions of the nucleon magnetic form factor $G_M$ and electric form factor $G_E$ were considered:

1.) the electric contribution is zero,

$$G_E = 0\colon\ W(\cos\theta) \sim 1 + \cos^2\theta$$

2.) $$W(\cos\theta) \sim \text{const}$$

3.) the magnetic contribution is zero,

$$G_M = 0\colon\ W(\cos\theta) \sim \sin^2\theta.$$

The observed angular distribution is consistent with any of these possibilities.

The following values of the branching ratio were found:

$$\Gamma_{p\bar{p}}/\Gamma_{\mu\mu} = \begin{cases} 0.036 \pm 0.010 \text{ for } W \sim 1 + \cos^2\theta \\ 0.030 \pm 0.009 \text{ for } W \sim \text{const} \\ 0.022 \pm 0.006 \text{ for } W \sim \sin^2\theta. \end{cases}$$

These numbers have been corrected for nuclear absorption of p and $\bar{p}$ (correction factor 1.26).

The absence of $\pi^+\pi^-$ events supports the isospin and $G$-parity assignment $I^G = 0^-$ [3]. The fact that the $K^+K^-$ decay rate is also small suggests that the 3.1 GeV particle is an $SU_3$ singlet state.

The upper limits given on $\Gamma_{\pi^+\pi^-}/\Gamma_{\mu\mu}$ and $\Gamma_{K^+K^-}/\Gamma_{\mu\mu}$ are close to the level at which decay into $\pi^+\pi^-$ or $K^+K^-$ pairs should occur via the one photon channel

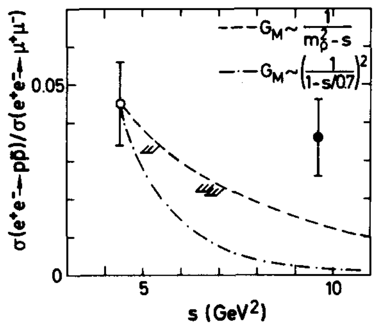


Fig. 4. The ratio $\sigma(e^+e^- \to p\bar{p})/\sigma(e^+e^- \to \mu^+\mu^-)$ as measured in this experiment (•), and from ref. [5] (○). The upper limits (/////) were obtained from measurements of $\bar{p}p \to e^+e^-$, $\mu^+\mu^-$ [6]. The curves show a $\rho$-pole and a dipole behaviour for $G_M$ normalized to the point at $s = 4.4$ GeV$^2$.

(e.g. $3.1 \to \gamma \to \pi^+\pi^-$). Extrapolating the available data [4] on $\sigma(e^+e^- \to \pi^+\pi^-)$ to $E = 3$ GeV or using a rho-pole formula one finds

$$\Gamma_{3.1\to\gamma\to\pi^+\pi^-}/\Gamma_{\mu\mu} \approx \sigma_{e^+e^-\to\pi^+\pi^-}/\sigma_{e^+e^-\to\mu^+\mu^-}$$

$$\approx 0.001 \text{ to } 0.01.$$

The ratio for the $K^+K^-$ case is expected to be of the same order of magnitude [4].

Fig. 4 shows the ratio $\sigma_{e^+e^-\to\, p\bar{p}}/\sigma_{e^+e^-\to\, \mu^+\mu^-}$ as measured in our experiment with the Frascati point at a total cms energy squared $s = 4.4$ GeV$^2$ [5], and the upper limits determined from measurements of the reverse reaction $p\bar{p} \to e^+e^-$, $\mu^+\mu^-$ [6]. Our data point and the upper limits from $p\bar{p} \to e^+e^-$, $\mu^+\mu^-$ are shown for the case $G_E = 0$. The ratio measured at the resonance is above the value obtained by any plausible extrapolation of the data below the resonance. Therefore, the observed $p\bar{p}$ decay is probably a direct decay of the 3.1 GeV resonance.

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