Branching fractions for ψ' decays to octet-baryon pairs[†]

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Abstract

A sample of 3.4M ψ' decays registered in the BES detector are used to study final states containing pairs of octet baryons. We report preliminary branching ratio values for:

Decay Mode		Branching fraction
$\psi' \rightarrow$	$p\overline{p}$	$(2.73 \pm 0.21 \pm 0.33) \times 10^{-4}$
$\rightarrow$	$\Lambda\overline{\Lambda}$	$(2.14 \pm 0.31 \pm 0.26) \times 10^{-4}$
$\rightarrow$	$\Sigma^0\overline{\Sigma^0}$	$(1.11 \pm 0.38 \pm 0.25) \times 10^{-4}$
$\rightarrow$	$\Xi^-\overline{\Xi^-}$	$(0.83 \pm 0.28 \pm 0.12) \times 10^{-4}$

These results are compared to expectations based on flavor-$SU(3)$ symmetry.

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I. INTRODUCTION

In the quarkonium model, the ψ' is the first radial excitation of the ^3S $c\bar{c}$ bound state. As such, its properties are expected to be relatively straight-forward to understand, at least in terms of those of the J/ψ ground state. Somewhat surprisingly, these expectations do not always hold. In particular, there are two rather dramatic anomalies associated with the ψ':

1. The $\rho\pi$-puzzle. One major puzzle in hadronic ψ decays is the large discrepancy between the decay widths for $J/\psi(1s) \to \rho\pi$ and K^*K and the corresponding widths for $\psi(2s)$ decays. These modes are expected to proceed via $\psi \to ggg$, with widths that are proportional to the square of the $c\bar{c}$ wave function at the origin, which is well determined from dilepton decays. The prediction, known as *"the 14% rule,"* is

$$\frac{Br(\psi' \to X_{had})}{Br(J/\psi \to X_{had})} = \frac{Br(\psi' \to e^+e^-)}{Br(J/\psi \to e^+e^-)} = 0.147 \pm 0.023,$$

where X_{had} designates any exclusive hadronic decay channel. Experimentally, the $\psi(2s) \to \rho\pi$ and K^*K are reduced by over a factor of twenty from these naive expectations [1].

2. The ψ' anomaly. The CDF group has reported a large anomaly in the charmonium production rate in high energy $\bar{p}p$ collisions [2]. It is expected that the J/ψs are mainly decay products of χ states, which are expected to be copiously produced by gluon-gluon fusion. This channel is not expected to be available for ψ' production, and these are expected to be primarily produced via B meson decays. Experimentally, the J/ψ production rate is a factor of two or three above expectations, while that for ψ's exceeds expectations by as much as a factor of thirty.

These anomalies call into question the underlying assumption behind the theoretical predictions, namely that the ψ' is a pure $c\bar{c}$ state.

A. $\psi' \to B_8\overline{B_8}$

In the context of flavor $SU(3)$, a pure $c\bar{c}$ state is a flavor singlet and, in the limit of $SU(3)$ flavour symmetry, the phase-space-corrected reduced branching ratios to any baryon octet pair, $|M_i|^2$, where

$$|M_i|^2 = \frac{Br(\psi' \to B_i\overline{B_i})}{\pi p^*/\sqrt{s}}$$

(p^* is the momentum of the baryon in the ψ' rest frame), should be the same for every octet baryon, B_i. Deviations from this rule would indicate a non-$c\bar{c}$ component of the charmonium wave function. The reduced branching fractions for $J/\psi \to B_8\overline{B_8}$ decays are shown in Fig. 1. The $SU(3)$ relation works reasonably well, although there may be some preference for the $p\bar{p}$ mode.

This relation has not been tested for the ψ', where the only relevant branching ratio that has been measured is $\psi' \to p\bar{p}$, and that with rather poor precision [3], [4].

FIGURES

FIG. 1. Reduced branching fractions $|M_i|^2$ for $J/\psi(1s) \to B_i\overline{B_i}$, where $B_i = p$, Λ, Σ^0, and Ξ^-. The data are from the PDG tables.

II. THIS EXPERIMENT

We report preliminary results of measurements of the branching fractions for $\psi' \to B_i\overline{B_i}$, where $B_i = p$, Λ, Σ^0, and Ξ^-, using a sample of 3.4M ψ' events produced via e^+e^- annihilations at the BEPC collider and detected in the BES detector.

A. The BES detector

The Beijing Electron Spectrometer, BES, is a conventional cylindrical magnetic detector that is coaxial with the BEPC colliding e^+e^- beams. It is described in detail in Ref. [5]. A four-layer central drift chamber (CDC) surrounding the beampipe provides trigger information. Outside the CDC, the forty-layer main drift chamber (MDC) provides tracking and energy-loss (dE/dx) information on charged tracks over 85% of the total solid angle. The momentum resolution is $\sigma_p/p = 0.017\sqrt{1+p^2}$ (p in GeV/c), and the dE/dx resolution for hadron tracks is $\sim 11\%$. An array of 48 scintillation counters surrounding the MDC provides measurements of the time-of-flight (TOF) of charged tracks with a resolution of ~ 450 ps for hadrons. Outside the TOF system, a 12 radiation length, lead-gas barrel shower counter (BSC), operating in self-quenching streamer mode, measures the energies of electrons and photons over $\sim 80\%$ of the total solid angle. The energy resolution is $\sigma_E/E = 0.22/\sqrt{E}$ (E in GeV), and the spatial resolutions are $\sigma_\phi = 4.5$ mrad and $\sigma_z = 4$ cm. Surrounding the BSC is a solenoidal magnet that provides a 0.4 Tesla magnetic field in the central tracking region of the detector. Three double layers of planar counters instrument the magnet flux return (MUID) and are used to identify muons of momentum greater than 0.5 GeV/c. Endcap time-of-flight and shower counters extend coverage to the forward and backward regions.

B. The ψ' data samples

The data were accumulated in two runs: a ~ 2.2 pb^{-1} data sample accumulated between December 1993 and January 1994, and a ~ 4.5 pb^{-1} data sample accumulated between December 1994 and March 1995.

III. EVENT SELECTION

A. $\psi' \to p\overline{p}$

The experimental signature for the decay $\psi' \to p\overline{p}$ is two back-to-back, oppositely charged tracks each with three-momentum $p = 1.586$ GeV/c. The positive track, the p, typically deposits one-half or less of its 0.91 GeV kinetic energy in the BSC; the negative $\overline{p}$ undergoes an annihilation process in the BSC approximately half the time, producing an energy cluster that can occasionally exceed the beam energy.

Backgrounds arise from other two-body decays of the ψ', cosmic rays, and cascade decays of the types $\psi' \to \pi\pi J/\psi$ and $\psi' \to \gamma\chi_c$, where the J/ψ or χ_c decay to a two-body final state and the accompanying particles are not seen in the detector.

1. $p\overline{p}$ selection criteria:

We extract a clean sample of $\psi' \to p\overline{p}$ events by imposing the following selection requirements on the recorded event samples:

1. two, and only two, well reconstructed oppositely charged tracks;
2. both tracks are within the polar angle region $|\cos\theta| \leq 0.6$;
3. at least one of the two tracks is not positively identified by the MUID as a muon;
4. a difference between the time-of-flight of the two tracks of $|t_+ - t_-| \leq 4.0$ ns;
5. a BSC energy deposit associated with the positive track that is $E_+ \leq 0.8$ GeV;
6. less than 100 MeV of BSC energy in clusters that are isolated from either track; and
7. a difference in momentum between the two tracks of $|p_+ - p_-| \leq 0.2$ GeV/c.

The $|\cos\theta| \leq 0.6$ requirement restricts the tracks to the solid angle region that is well covered by the MUID system. The MUID requirement eliminates obvious $\psi' \to \mu^+\mu^-$ and continuum e^+e^-