Decay of the J/ψ to $\Sigma^0\overline{\Sigma}^0$ Final State*

(MEMORANDUM)

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Abstract

With 7.8 million produced J/ψ events collected by the BES detector at the BEPC, the decay $J/\psi \to \Sigma^0\overline{\Sigma}^0$ is analysed. The branching ratio is measured to be $Br(J/\psi \to \Sigma^0\overline{\Sigma}^0) = (1.00 \pm 0.04 \pm 0.21) \times 10^{-3}$. The angular distribution is of the form $\frac{dN}{dcos\theta} = N_0(1 + \alpha cos^2\theta)$, from which we determine $\alpha = -0.26 \pm 0.27 \pm 0.11$.

1. Introduction

As is well-known, from the helicity formalism and general conservative principles regarding spin,party,etc, the angular distribution of B for the decay of a neutral vector resonance V into a baryon-antibaryon pair $B\overline{B}$ is given by[1]

$$\frac{dN}{dcos\theta} \sim 1 + \alpha cos^2\theta,$$

where θ is the emission angle of B in the V rest frame. The first order calculations[2,3] of perturbative QCD predict the theoretical value of α at J/ψ energy. Several other experiments have performed α measurements for $J/\psi \to p\overline{p}$[4,5,6,7], $\Lambda\overline{\Lambda}$[6,7], $\Sigma^0\overline{\Sigma}^0$[6,7] and $\Xi^-\overline{\Xi}^+$[6].

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†Data analyzed were taken prior to the participation of US members of the BES Collaboration.

In a previous paper[8], the measurement of α for $\Lambda\overline{\Lambda}$ using $7.8 \times 10^6 J/\psi$ produced in the BES detector has been reported. The BES value is in good agreement with the DM2 value[7] as well as the theoretical valus in Ref.[3]. Table 1 summarizes the theoretical predictions of α for the decay $J/\psi \to \Lambda\overline{\Lambda}, \Sigma^0\overline{\Sigma}^0$. Table 2 summarizes the experimental measurements of α for the decay $J/\psi \to \Lambda\overline{\Lambda}$.

This paper presents the BES measurement of α for the decay $J/\psi \to \Sigma^0\overline{\Sigma}^0$.

Table 1
Summary of theoretical expectations of α

Channel	Ref.[2]	Ref.[3]
$\Lambda\overline{\Lambda}$	0.32	0.51
$\Sigma^0\overline{\Sigma}^0$	0.31	0.43

Table 2
Summary of experimental measurements for decay $J/\psi \to \Lambda\overline{\Lambda}$

Detector	α	$Br(\times 10^{-3})$	Event
MARK II	0.72 ± 0.36	$1.58 \pm 0.08 \pm 0.19$	365
DM2	0.62 ± 0.22	$1.38 \pm 0.05 \pm 0.20$	1847
BES	0.52 ± 0.35	$1.08 \pm 0.06 \pm 0.24$	631

2. BES apparatus

The BES apparatus has been fully described elsewhere[9], the comparison of its main features with the other detectors is given in the preceding paper[8].

3. Selection of $\Lambda\overline{\Lambda}$

Since the decay to be searched includes $\Lambda\overline{\Lambda}$ pair in the final state, a set of cuts is used to select $J/\psi \to \Lambda\overline{\Lambda} + X$ events, where X is a system of neutral particle(s) and/or undetected charged particle(s).

The Λ is identified by its $p\pi^-$ decay mode. Candidates for $J/\psi \to \Lambda\overline{\Lambda} + X$ events are selected by requiring exactly four reconstructed charged tracks in the drift chamber with zero net charge. Tracks with $\mid cos\theta_{ch} \mid < 0.85$ are accepted, where θ_{ch} is the polar angle with respect to the beam direction. Protons are identified by requiring that their time-of-flight (TOF) or the ionization energy loss (dE/dx) in the drift chamber be consistent with the particle mass hypothesis, i.e.

$$\frac{\mid t_{meas} - t_{exp}(p) \mid}{\sigma_t} \leq 3,$$

or

$$\frac{\mid t_{meas} - t_{exp}(p) \mid}{\sigma_t} < \frac{\mid t_{meas} - t_{exp}(i) \mid}{\sigma_t}, (i = \pi, k),$$

or

$$\frac{\mid (\frac{\mathrm{dE}}{\mathrm{d}x})_{meas} - (\frac{\mathrm{dE}}{\mathrm{d}x})_{exp}(p) \mid}{\sigma_{\mathrm{dE/d}x}} \leq 3,$$

or

$$\frac{\mid (\frac{\mathrm{dE}}{\mathrm{d}x})_{meas} - (\frac{\mathrm{dE}}{\mathrm{d}x})_{exp}(p) \mid}{\sigma_{\mathrm{dE/d}x}} < \frac{\mid (\frac{\mathrm{dE}}{\mathrm{d}x})_{meas} - (\frac{\mathrm{dE}}{\mathrm{d}x})_{exp}(i) \mid}{\sigma_{\mathrm{dE/d}x}}, (i = \pi, k),$$

where t_{meas} is the measured flight time, $t_{exp}(i)$ is the expected flight time for particle mass hypothesis i, and σ_t is the TOF resolution. The subscripts for dE/dx are of similar meanings.

The events with at least one particle satisfying proton (anti-proton) hypothesis are selected. The ideal case is that both of number of proton and number of anti-proton are equal to 1. In other case, the minimum $\mid M_{p\pi^-} - 1.116\ GeV \mid + \mid M_{\overline{p}\pi^+} - 1.116\ GeV \mid$ determines the combination of $p, \overline{p}, \pi^+$ and π^-. Fig. 1 shows the invariant mass distribution of $M_{p\pi^-}$ for $J/\psi \to p\pi^-\overline{p}\pi^+ + X$ candidates selected in the BES J/ψ data sample. By fitting it to a gaussian distribution plus a quadripolynomial function, a 3.0 MeV r.m.s mass resolution is estimated for the peak. To select a $\Lambda(\overline{\Lambda})$, the $M_{p\pi}$ invariant mass is required to be within $\pm$9MeV of 1116 MeV. The $\Lambda(\overline{\Lambda})$ signal is well isolated by this invariant mass cut. The $p\pi^-$ invariant mass for Monte Carlo data is shown in fig. 2. A 3.0 MeV r.m.s. mass resolution is obtained by fitting it to a gaussian distribution.

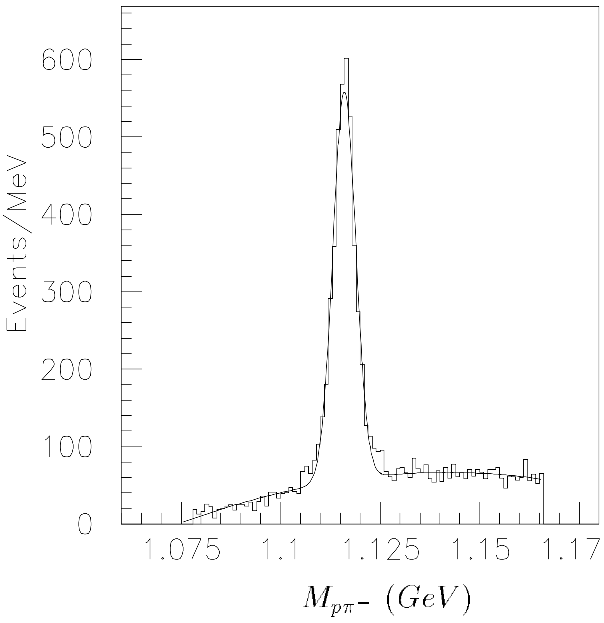

Fig. 1. Invariant mass distribution of $M_{p\pi^-}$ in $J/\psi \to p\pi^-\overline{p}\pi^+ + X$ candidates (histogram). The smooth curve is a fit with a Gaussian plus quadripolynomial.

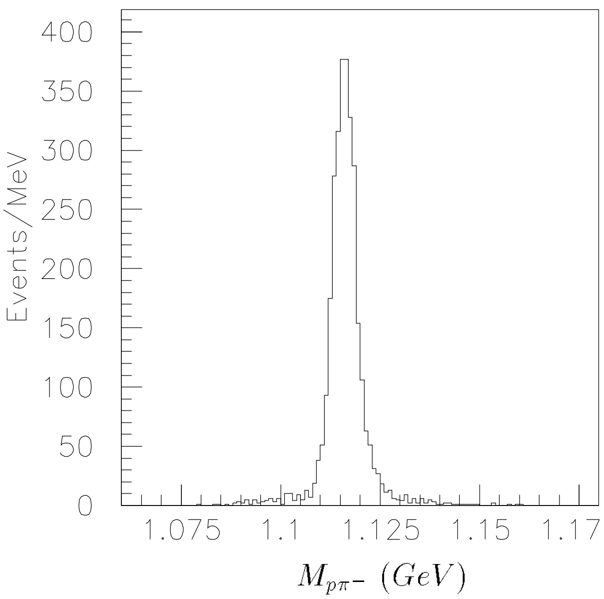

Fig. 2. Invariant mass distribution of $M_{p\pi^-}$ for Monte Carlo data.

4. Selection of the final state and the result

The energy distribution of the $\Lambda\overline{\Lambda}$ pair, $E_{\Lambda\overline{\Lambda}}$,for $J/\psi \to \Lambda\overline{\Lambda} + X$ candidates is shown in fig. 3.

The enhancement centered at 2.9 GeV is due to the decay $J/\psi \to \Sigma^0\overline{\Sigma}^0$,where $\Sigma^0 \to \Lambda\gamma$. Fig. 4 shows $E_{\Lambda\overline{\Lambda}}$ distrution for Monte Carlo data for the decay $J/\psi \to \Sigma^0\overline{\Sigma}^0$. 642 events are left by requiring $2.80 < E_{\Lambda\overline{\Lambda}} < 2.98 GeV$. The contaminations from the decays $J/\psi \to \Lambda\overline{\Lambda}, \Xi^0\overline{\Xi}^0$ and $\Sigma^{0*}\overline{\Sigma}^{0*}$ are estimated to be 1.0%, 2.3% and 0.08% respectively in the following way. 10^4 Monte Carlo events $J/\psi \to \Lambda\overline{\Lambda} \to p\pi^-\overline{p}\pi^+$ are selected through the same cut conditions. 19 enevts remains, which gives the contamination,

$$N_{J/\psi} \times Br(J/\psi \to \Lambda\overline{\Lambda}) \times Br^2(\Lambda \to p\pi^-) \times \frac{19}{10000} \times \frac{1}{642} = 1.0\%,$$

where $N_{J/\psi} = 7.8 \times 10^6$, $Br(J/\psi \to \Lambda\overline{\Lambda}) = 1.08 \times 10^{-3}$ [8], $Br(J/\psi \to p\pi^-) = 0.639$. 54 events is selected out of 10^4 Monte Carlo events $J/\psi \to \Xi^0\overline{\Xi}^0$, which gives the contamination to be 2.3%. Using Monte Carlo events $J/\psi \to \Xi^0\overline{\Xi}^0$ with the branching ratio equal to 0.9×10^{-3} given by PDG96[10] and $J/\psi \to \Sigma^{0*}\overline{\Sigma}^{0*}$ to fit data within $2.3 < E_{\Lambda\overline{\Lambda}} < 2.75 GeV$, one get the fraction for $J/\psi \to \Sigma^{0*}\overline{\Sigma}^{0*}$ to be 1.395×10^{-3}. The comparison of the superposition of $\Lambda\overline{\Lambda}$ energys distributions for the Monte Carlo events $J/\psi \to \Lambda\overline{\Lambda}, \Sigma^0\overline{\Sigma}^0, \Xi^0\overline{\Xi}^0$ and $\Sigma^{0*}\overline{\Sigma}^{0*}$ to data is shown in fig. 3. From the fraction, the contamination from the decay $J/\psi \to \Sigma^{0*}\Sigma^{0*}$ is obtained. Fig. 4 also shows the $\Lambda\overline{\Lambda}$ energy distributions for the Monte Carlo events $J/\psi \to \Lambda\overline{\Lambda}$, $\Xi^0\overline{\Xi}^0$ and $\Sigma^{0*}\overline{Sigma}^{0*}$.

Fig. 5 shows the Λ angular distribution for the events. The detection efficiency for the events depends on the Λ direction. Fig. 6 shows Λ angular distribution of detection efficiency by selecting 2×10^4 Monte Carlo events $J/\psi \to \Sigma^0\overline{\Sigma}^0 \to \Lambda\gamma\overline{\Lambda}\gamma \to p\pi^-\gamma\overline{p}\pi^+\gamma$ through the same selection conditions. The efficiency corrected angular distribution is shown in Fig. 7. Fitting this angular distribution to the theoretical form[1,2,3]

$$\frac{dN}{dcos\theta} = N_0(1 + \alpha cos^2\theta),$$

yields

$$\alpha = -0.26 \pm 0.27 \pm 0.11,$$

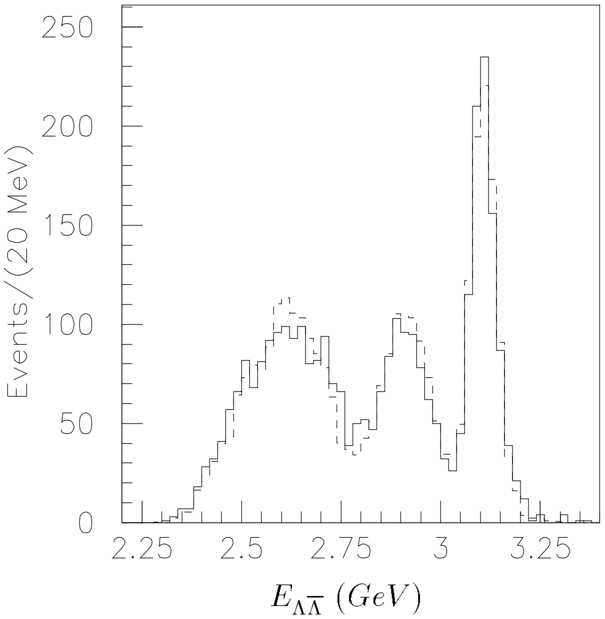

Fig. 3. Solid line is $\Lambda\overline{\Lambda}$ pair energy distribution for data of $J/\psi \to \Lambda\overline{\Lambda} + X$. The dashed line is the superposition of $\Lambda\overline{\Lambda}$ energy distributions for the Monte Carlo events $J/\psi \to \Sigma^{0*}\overline{\Sigma}^{0*}$, $\Xi^0\overline{\Xi}^0$,$\Sigma^0\overline{\Sigma}^0$,$\Lambda\overline{\Lambda}$.

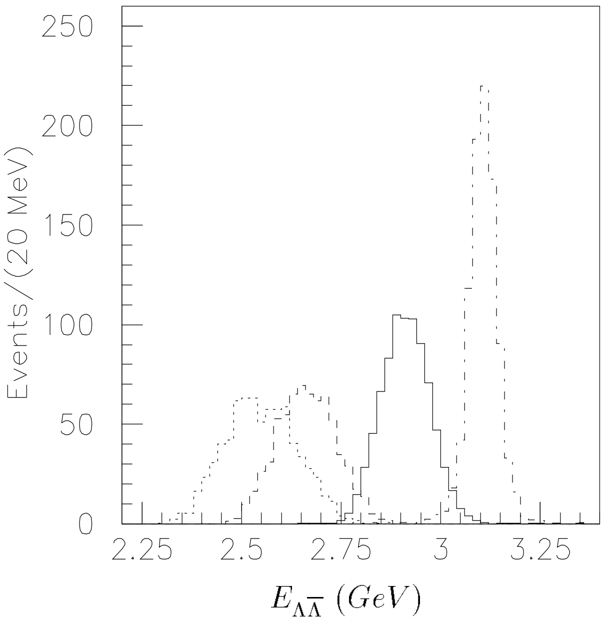

Fig. 4. The four bumps from left to right are the decays $J/\psi \to \Sigma^{0*}\overline{\Sigma}^{0*}$, $\Xi^0\overline{\Xi}^0$,$\Sigma^0\overline{\Sigma}^0$ and $\Lambda\overline{\Lambda}$ from Monte Carlo simulations respectively.

where θ is the angle between the Λ and e^+ beam.

4035 Monte Carlo events are left and detection efficiency ϵ is obtained to be 0.202×0.639^2,which gives the branching ratio,

$$Br(J/\psi \to \Sigma^0\overline{\Sigma}^0) = \frac{N}{\epsilon N_{J/\psi}} = (1.00 \pm 0.04 \pm 0.21) \times 10^{-3},$$

where $N_{J/\psi}$ is BES J/ψ total number,$N_{J/\psi}$= $7.8 \times (1 \pm 0.2) \times 10^6$.

Above 0.27 and 0.04 are statistical errors. The systematic errors 0.11 and 0.21 originate from the cut condition uncertainties. The systematic errors are estimated in such a way. Requiring $p\pi$ invariant mass satisfying $\mid M_{p\pi} - M_\Lambda \mid \leq 6, 7, 8, 9, 10, 11$ and 12, the errors for α and Br are 0.05 and 0.04 respectively. Requiring the polar angle with respect to the beam direction for the charged particles satisfying $\mid cos\theta_{ch} \mid \leq$ 0.80,0.81,0.82,0.83,0.84, 0.85,0.86 and 1., the errors are 0.03 and 0.01. Requiring the region for $\Lambda\overline{\Lambda}$ system energy to be $[2.79, 2.99]$, $[2.80, 2.98]$, $[2.81, 2.97]$, $[2.82, 2.96]$,$[2.83, 2.95]$ and $[2.84, 2.94]$ GeV,the erros are 0.09 and 0.02. The error for Br caused by the uncertainty of J/ψ total number is 0.2. The error for Br caused by the contaminations is 2.5%.

Duo to the Λ and Σ^0 within a cone of 4 degree, the Λ angular distribution is a good approximation to the $5Sigma^0$ angular distribution.

4. Conclusions

Table 3 summarizes the branching ratios and α value measured by the BES for the decay $J/\psi \to \Lambda\overline{\Lambda}$, together with those previously reported by Mark II and DM2.

The statistics of the events in BES result is near to that of DM2. The branching ratio and α obtained by this experiment are in agreement with those of DM2 within errors as shown in table 3, but the shape of the angular distribution is obviously different from that of DM2. Besides the better symmetry, the α value is negative, which is aslo different from the theoretical expectation[2,3]. Duo to the large statistic errors, the sign of α is still uncertain, which should be studied further from experiment with large statistics of J/ψ data. If it is so, theory needs more precise calculations.

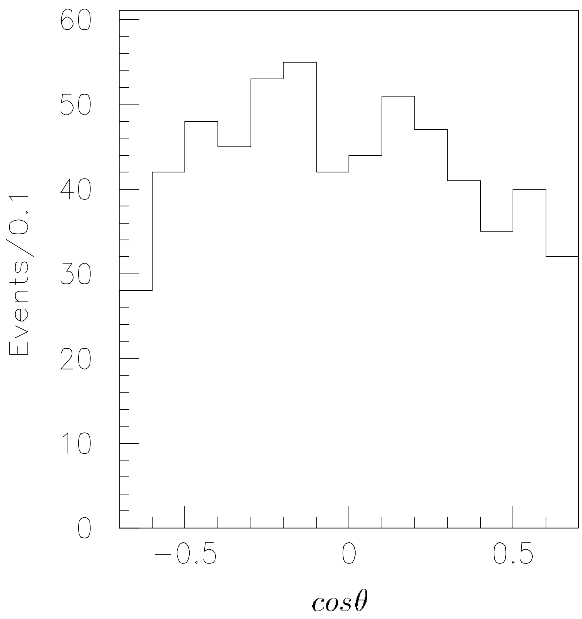

Fig. 5. Angular distribution for the detected events.

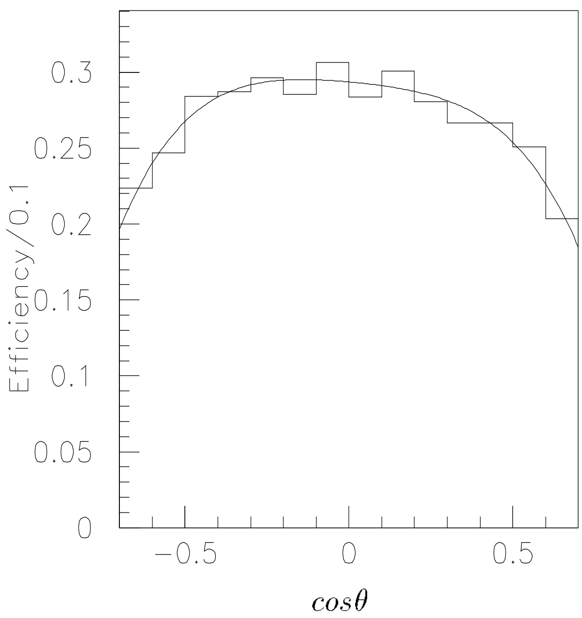

Fig. 6. Detection efficiency .

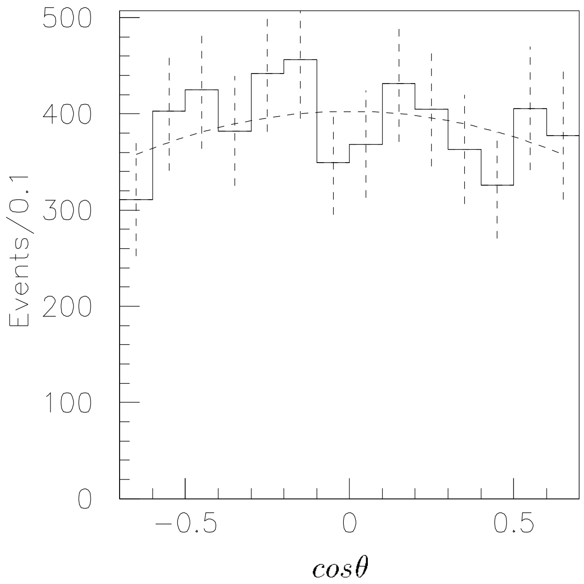

Fig. 7. Efficiency corrected angular distribution .

Table 3
Experimental measurements for $\Sigma^0\overline{\Sigma}^0$ channel

Detector	α	$Br(\times 10^{-3})$	Event
MARK II	0.70 ± 1.10	$1.58 \pm 0.16 \pm 0.25$	90
DM2	0.22 ± 0.31	$1.06 \pm 0.04 \pm 0.23$	884
BES	-0.26 ± 0.29	$1.00 \pm 0.04 \pm 0.21$	642

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