論文内容の要旨

論文題目　Study of $\Delta^{++}\bar{\Delta}^{--}$ Production from J/ψ Decay Using the BES-II Detector

BES−II 測定器による J/ ψ 崩壊からの $\Delta^{++}\overline{\Delta}^{--}$ 生成の研究

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We measured the branching fraction of the decay $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ using the data collected at BES-II experiment. BES-II experiment collected 58M J/ψ events with BEPC collider operated at the energy of 3.097GeV. The dominant process of J/ψ decay into baryon antibaryon pairs is the three-gluon process and the subsequent creation of quark-antiquark pairs forming a final baryon-antibaryon pairs. The theoretical studies on the production of baryon-antibaryon pairs from J/ψ have been conducted in the framework of perturbative QCD. The experimental studies have also provided various measurements on production of octet and decuplet baryon-antibaryon pairs from J/ψ. However, a measurement on the decay $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ has got left behind because of the broad width of Δ baryon. Taking advantage of the abundant J/ψ data of BES-II, we conducted a precise measurement on the decay $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$.
The organization of this thesis is as follows. After an introduction to the decay $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ at Chapter1, detector components of BES-II experiment and BEPC are described at Chapter2. The measurement of the branching fraction of $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ is described in Chapter 3, and its systematic error is discussed in Chapter 4. The measurement is compared with the theoretical prediction in Chapter 5. The conclusion is written in Chapter 6.

1 Analysis of $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ (Chapter 3)

Because of its broad decay width ($\sim$ 120MeV), $\Delta^{++}(\bar{\Delta}^{--})$ baryon immediately decays into proton and π^+ (antiproton and π^-) at the e^+e^- interaction point. Taking this characteristic into account, we imposed the following conditions in the event selection.

- There are 4 charged tracks which originate in e^+e^- interaction point and are identified as proton, antiproton and $\pi^{\pm}$.
- Momentum sum of the 4 tracks should be, in principle, 0.
- Event topology between Δ^{++} and $\bar{\Delta}^{--}$ should be almost back-to-back.

After the event selection, a broad peak of Δ baryon can be found in the invariant mass spectrum of Δ^{++} as shown in Fig.1. However, there also exist a considerable background. Possible sources of background we consider here are as follows.

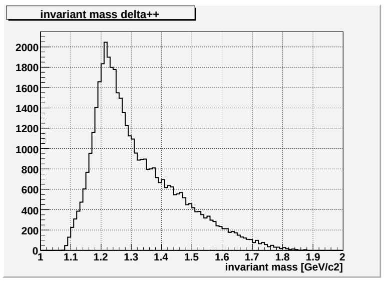


Figure 1: The invariant mass spectrum of Δ^{++} of data. After the event selection, a broad peak from Δ^{++} appears.

$$\begin{array}{ll} J/\psi \to \Delta^{++}\bar{\mathrm{p}}\pi^- & J/\psi \to \mathrm{N}^{*+}(1710)\bar{\mathrm{p}} \\ J/\psi \to \Delta^{--}\mathrm{p}\pi^+ & J/\psi \to \bar{\mathrm{N}}^{*-}(1710)\mathrm{p} \\ J/\psi \to \mathrm{p}\pi^+\bar{\mathrm{p}}\pi^-(\text{continuum}) & J/\psi \to \mathrm{N}^{*+}(1900)\bar{\mathrm{p}} \\ J/\psi \to \mathrm{N}^{*+}(1440)\bar{\mathrm{p}} & J/\psi \to \bar{\mathrm{N}}^{*-}(1900)\mathrm{p} \\ J/\psi \to \bar{\mathrm{N}}^{*-}(1440)\mathrm{p} & \end{array}$$

Due to the broad Breit-Wigner width of Δ baryon, both signal ($\Delta^{++}\bar{\Delta}^{--}$) and background events spread all over the two dimensional invariant mass spectrum (Fig.2), which means that we cannot use cut-based analysis to determine the signal-to-background ratio. Therefore, the binned maximum likelihood analysis technique was used. The likelihood function is based on the two dimensional invariant mass spectrum of Δ baryons. The function is constructed from Poisson distribution which gives the probability of observing d_i content at bin $i(i = 1...M)$ when f_i contents are predicted.

$$\mathcal{L} = \prod_{i=1}^{\mathrm{M}} \frac{f_i^{d_i} e^{-f_i}}{d_i!}$$

The predicted bin content f_i at bin i are constructed from Monte Carlo simulation, where signal and backgrounds exist with the ratio as below.

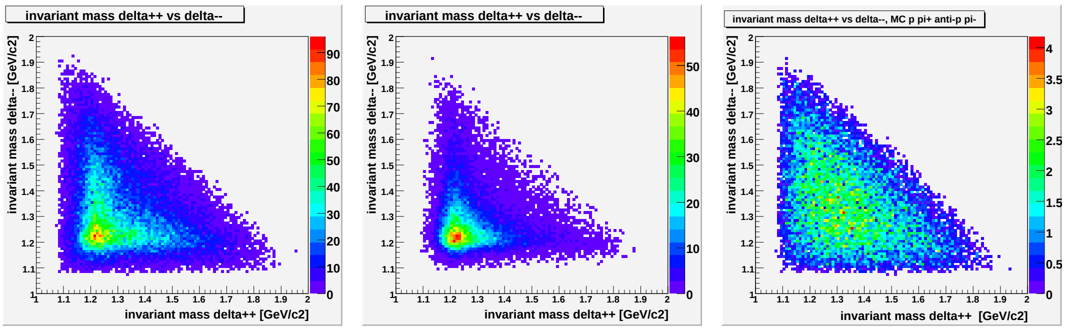
$$\begin{array}{cccccccc} & \Delta^{++}\bar{\Delta}^{--} : & \Delta^{++}\bar{\mathrm{p}}\pi^+ : & \bar{\Delta}^{--}\mathrm{p}\pi^- : & \mathrm{p}\pi^+\bar{\mathrm{p}}\pi^- : & \mathrm{N}^*(1710)\mathrm{p} : & \mathrm{N}^*(1440)\mathrm{p} : & \mathrm{N}^*(1900)\mathrm{p} \\ = & A : & B : & B : & C : & D : & E : & F \end{array}$$

The ratios A to F are variables in the likelihood function. The log-likelihood function is calculated with simultaneously with changing all the values of the fractions A to F. A set of fractions $(A^*, B^*, C^*, D^*, E^*, F^*)$ at the absolute minimum of the log-likelihood function are used to determine the number of signal events. After dividing the number of signal events with selection efficiency, we obtain the the following branching fraction.

$$\mathrm{Br}(J/\psi \to \Delta^{++}\bar{\Delta}^{--}) = 1.65 \pm 0.16(\text{fit}) \times 10^{-3}$$

2 Study on Systematic error (Chapter 4)

The uncertainties with backgrounds as listed below are considered as a source of systematic error.



(a) data (b) MC, $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ (c) MC, $J/\psi \to \mathrm{p}\pi^{+}\bar{\mathrm{p}}\pi^{-}$

Figure 2: The two dimensional invariant spectrum of Δ^{++} vs $\bar{\Delta}^{--}$ of (a) data (b) $\Delta^{++}\bar{\Delta}^{--}$ of MC (c) $\mathrm{p}\pi^{+}\bar{\mathrm{p}}\pi^{-}$ of MC.

- Breit-Wigner width of Δ baryon
  Breit-Wigner width of Δ baryon has been measured to be $118 \sim 125$ MeV, and PDG sets typical decay width to be ~ 120 MeV, which is narrower than the one used in the likelihood analysis (130 MeV). Therefore, we conducted the likelihood analysis with two different widths ($\Gamma_0 = 118, 125$ MeV), and recalculated the branching fraction of $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$.

- Breit-Wigner width of N^*
  There are several N^* resonances which have similar mass. For example, two N^* resonances exist around the invariant mass of ~ 1.7 GeV: $\mathrm{N}^*(1710)$ and $\mathrm{N}^*(1720)$. Also, there is uncertainty with the Breit-Wigner width of N^* baryons. Therefore, we conducted the likelihood analysis with three sets of Monte Carlo event samples with different masses and widths. Then, the branching fraction of $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ is recalculated.

- interference effects
  Since the final states of decays $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ and $J/\psi \to \Delta^{--}(\Delta^{++})\mathrm{p}\pi^{+}(\bar{\mathrm{p}}\pi^{-})$ are all $\mathrm{p}\pi^{+}\bar{\mathrm{p}}\pi^{-}$, interferences between them could be observed. Hence, the interferences between $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ and $J/\psi \to \Delta^{--}(\Delta^{++})\mathrm{p}\pi^{+}(\bar{\mathrm{p}}\pi^{-})$ and the interference between $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$ and $J/\psi \to \mathrm{p}\pi^{+}\bar{\mathrm{p}}\pi^{-}$ are incorporated into the likelihood function, and the likelihood analysis was conducted.

- selection efficiencies
  Uncertainty due to systematic effects in event selection are analyzed . Cut conditions imposed in the event selection were altered by certain amounts, and the likelihood analysis were conducted to see the effects on the branching fraction of the decay $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$.

- detection efficiencies
  In estimating the branching fraction of $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$, the difference in tracking and particle identification(PID) efficiency between Monte Carlo and data could be a source of systematic uncertainty. Therefore, the tracking and PID efficiency is calculated both

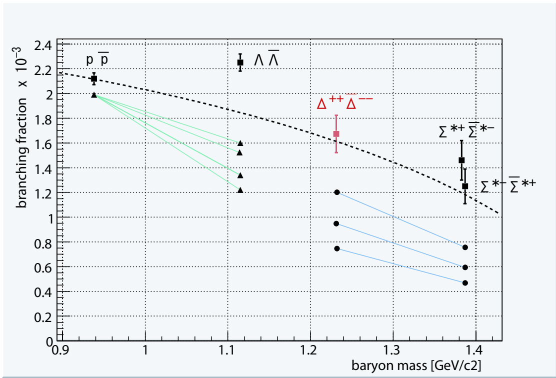


Figure 3: The observed branching fraction of the decay J/ψ into baryon-antibaryon pairs. The red square dot shows our result on $J/\psi \to \Delta^{++}\bar{\Delta}^{--}$. The dashed line shows the phase space suppression. The triangular and circle dots is the theoretical prediction by Bolz and Kroll

with MC samples and data using $J/\psi \to \Lambda\bar{\Lambda}$ events. Then, its difference is taken into account as a systematic error

The above listed studies give the following systematic error.

$$\text{Br}(J/\psi \to \Delta^{++}\bar{\Delta}^{--}) = 1.65 \pm 0.16(\text{fit}) \pm 0.21(\text{sys}) \times 10^{-3}$$

3 Discussions and Conclusion (Chapter5, 6)

Fig.3 shows the gross structure of branching fraction of J/ψ decay into decuplet baryon-antibaryon pairs as a function of baryon mass. Our measurement is well described by the phase space suppression factor, $\rho_{p.s.} = \sqrt{M_{J/\psi}^2 - 4M_B^2}/\sqrt{M_{J/\psi}^2 - 4M_p^2}$, where M_B denotes the baryon mass and M_p denotes the mass of proton. In this figure, theoretical predictions by Bolz and Kroll are also shown with triangular and circle dots. Our measurement is significantly higher than their prediction. This is probably due to the contribution from the electromagnetic process.