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BESIII: Recent results and perspectives

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Summary. — Some of the recent results obtained by BESIII experiment at BEPCII are reported together with preliminary results on $J/\psi \to p\bar{p}$ and $J/\psi \to n\bar{n}$ and future prospects for initial state radiation (ISR) physics at BESIII.

PACS 13.20.Fc – Decays of charmed mesons.
PACS 13.25.Gv – Decays of J/ψ, Υ, and other quarkonia.

1. – Introduction

The BESIII experiment is running at the Beijing Electron Positron Collider BEPC-II, a major upgrade of the previous BEPC, at the Beijing Institute of High Energy Physics, IHEP. BEPCII is a two-ring e^+e^- collider operating in the 2 GeV to 4.6 GeV center-of-mass energy range, designed for a peak luminosity of $10^{33}\,\text{cm}^{-2}\,\text{s}^{-1}$ at a beam current of 0.93 A.

BESIII is a magnetic, omni purpose spectrometer [1]; the cylindrical core of the detector consists of a helium-gas–based drift chamber, a plastic scintillator time-of-flight system, and a CsI(Tl) Electromagnetic Calorimeter, all enclosed in a superconducting solenoidal magnet providing a 1.0 T magnetic field. The solenoid is supported by an octagonal flux-return yoke with resistive plate counter muon identifier modules interleaved with steel. Charged tracks and photons acceptance is 93% of 4π, and the charged tracks momentum and photon energy resolutions at 1 GeV are 0.5% and 2.5%, respectively.

The physics program, primarily aimed to investigate hadron spectroscopy and τ-charm physics, is described elsewhere [2].

The unprecedented BEPCII luminosities and the high BESIII performance allowed to collect data samples at J/ψ and ψ'energies already significantly larger with respect to those available in the literature; the analyses reported herewith have been performed on 225×10^6 J/ψ and 106×10^6 ψ'events.

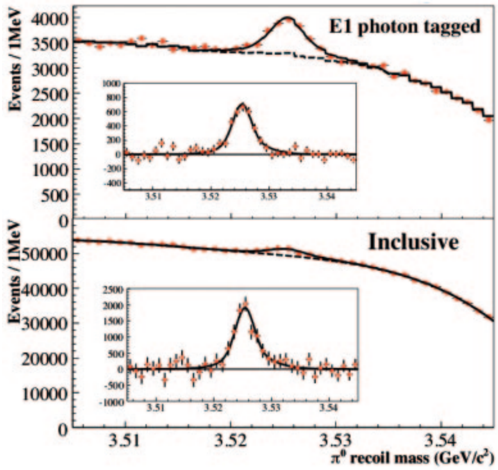

Fig. 1. – The π^0 recoil mass spectra and fits for: the $E1$-tagged analysis: $\psi' \to \pi^0 h_c, h_c \to \gamma\eta_c$ (top); the inclusive analysis: $\psi' \to \pi^0 h_c$ (bottom). Fits are shown as solid lines, background as dashed lines; insets show the background-subtracted spectra.

2. – Measurements of $h_c(^1P_1)$ in ψ'decays

Clear signals have been observed (fig. 1) for $\psi' \to \pi^0 h_c$ with and without the subsequent radiative decay $h_c \to \gamma\eta_c$. The determination [3] in the same experimental scenario of both $\mathcal{B}(\psi' \to \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$ and $\mathcal{B}(\psi' \to \pi^0 h_c) \times \mathcal{B}(h_c \to \gamma\eta_c) = (4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$ allows to access $\mathcal{B}(h_c \to \gamma\eta_c) = (54.3 \pm 6.7 \pm 5.2)\%$. $M(h_c) = 3525.40 \pm 0.13 \pm 0.18\,\text{MeV}/c^2$ and $\Gamma(h_c) = 0.73 \pm 0.45 \pm 0.28\,\text{MeV}$ ($< 1.44\,\text{MeV}$ at 90% CL) have been determined as well.

Our measurements for $\mathcal{B}(\psi' \to \pi^0 h_c)$, $\mathcal{B}(h_c \to \gamma\eta_c)$ and $\Gamma(h_c)$ are the first experimental results for these quantities; the values obtained for $M(h_c)$ and $\mathcal{B}(\psi' \to \pi^0 h_c) \times \mathcal{B}(h_c \to \gamma\eta_c)$ are consistent with previous CLEO results [4] and of comparable precision. The measured $1P$ hyperfine mass splitting $\Delta\ M_{hf} \equiv \langle M(1^3P)\rangle - M(1^1P_1) = -0.10 \pm 0.13 \pm 0.18\,\text{MeV}/c^2$ is consistent with no strong spin-spin interaction. For a detailed discussion of such results in the framework of the existing experimental evidences and theoretical predictions see ref. [3].

3. – Confirmation of $p\bar{p}$ mass threshold enahancement

An anomalous near threshold enhancement in $p\bar{p}$ invariant mass spectrum, X(1860), was observed by BESII experiment in the process $J/\psi \to \gamma p\bar{p}$ [5]. An interesting feature of this enhancement is that corresponding structures are not observed in near-threshold $p\bar{p}$ cross-section measurements [6]. These non-observations disfavour the attribution of the mass-threshold enhancement to the pure effects of $p\bar{p}$ final state interactions. The discovery of the enhancement has stimulated a number of theoretical speculations [7]. One of these is the intriguing suggestion that it is an example of $p\bar{p}$ bound state [8], sometimes called baryonium [9]. BESIII studied the $p\bar{p}$ invariant mass spectrum using both the decay channel of $\psi' \to \pi^+\pi^- J/\psi, J/\psi \to \gamma p\bar{p}$ [10] and direct $J/\psi \to \gamma p\bar{p}$, confirming the enhancement as can be clearly seen in fig. 2. For a complete description of this analysis see ref. [10].

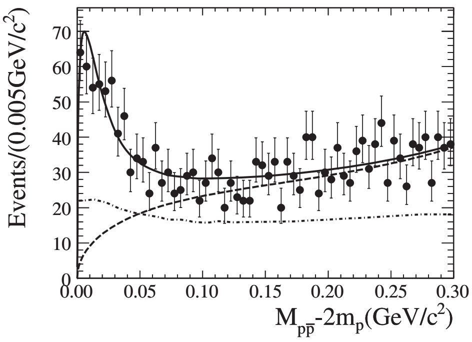

Fig. 2. – $p\bar{p}$ invariant mass spectrum from the $\psi' \to \pi^+\pi^- J/\psi(J/\psi \to \gamma p\bar{p})$, the solid curve is the fitting result, the dashed curve is the background, the dash-dotted line is the efficiency curve as described in [10].

4. – Preliminary results on $J/\psi \to p\bar{p}$ and $J/\psi \to n\bar{n}$

$J/\psi \to p\bar{p}$ and $J/\psi \to n\bar{n}$ have been identified and studied on the base of 225.2M J/ψ events collected with BESIII in 2009. The J/ψ meson is interpreted as a bound state of a charmed quark and a charmed antiquark $c\bar{c}$. The decay processes $J/\psi \to p\bar{p}, n\bar{n}$ are octet-baryon-pair decay modes and should be a very good laboratory for testing pQCD, because of the 3 gluons in the OZI violating J/ψ strong decay just matching the 3 $q\bar{q}$ pairs. The ratio between the two branching ratios can be used to evaluate the phase angle between strong and the electromagnetic (e.m.) amplitudes in the process $J/\psi \to N\bar{N}$ [11-13]. Because the isospin of the J/ψ is 0, strong decay amplitudes of $J/\psi \to p\bar{p}$ and $J/\psi \to n\bar{n}$ must be equal, while the e.m. decay amplitudes are expected to have opposite sign, like the magnetic moments. If all these amplitudes are almost real, as expected if pQCD holds [11-15], the interference between strong and e.m. amplitudes would decrease (by almost a factor of two, according to the present data off the $\mathcal{B}(J/\psi \to n\bar{n})$ with respect to $\mathcal{B}(J/\psi \to p\bar{p})$). On the contrary, if strong and e.m. decay amplitudes are orthogonal, the strong decay dominates and the two branching ratios are expected to be equal. In previous experiments, $J/\psi \to p\bar{p}$ has been measured with good accuracy, while $J/\psi \to n\bar{n}$ has been measured with quite a large uncertainty [16, 17]. Nevertheless they appear to be equal within the errors, at odd with the pQCD expectation.

The angular distributions of $J/\psi \to N\bar{N}$ can be written as a function of the angle between the baryon direction and the beam (θ_B):

$$\frac{\mathrm{d}N}{\mathrm{d}\cos\theta_B} = A(1 + \alpha\cos^2\theta_B)\,,$$

where A is a normalization factor. These angular distributions also deliver details of the baryon structure and have potential to distinguish different theoretical models based on first-order QCD [11-15].

Preliminary results from BESIII are: $\mathcal{B}(J/\psi \to p\bar{p}) = (2.112 \pm 0.004 \pm 0.027) \times 10^{-3}$, $\mathcal{B}(J/\psi \to n\bar{n}) = (2.07 \pm 0.01 \pm 0.14) \times 10^{-3}$. These results improve by a large factor the former measurements and strongly support the orthogonalty of strong and e.m. amplitudes. Angular distributions are described by $1+\alpha\cos\theta$ with $\alpha = 0.595 \pm 0.012 \pm 0.015$ for $J/\psi \to p\bar{p}$ and $\alpha = 0.50 \pm 0.04 \pm 0.21$ for $J/\psi \to n\bar{n}$.

5. – Initial state radiation technique at BESIII and zero-degree detector

Processes of annihilation to hadrons can be studied in a wide center-of-mass (CoM) energy range at a high-luminosity machine using the initial state radiation (ISR) technique in the reaction $e^+e^- \to H\gamma$, where H could be a generic hadronic final state and the recoiling photon is emitted by one of the initial leptons. The cross section for this process is related to the direct $e^+e^- \to H$ cross section $\sigma_H(s)$ by

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}x\,\mathrm{d}\cos\theta}(s_M, x) = W(x,\theta)\sigma_H(s_M(1-x))\,, \tag{1}$$

where $\sqrt{s_M}$ is the initial e^+e^- CoM energy, $x = 2E_\gamma/\sqrt{s_M}$ is the fractional energy of the ISR photon and $\sqrt{s_M(1-x)} \equiv \sqrt{s}$ is the effective CoM energy at which the final state H is produced.

The function W which multiplies σ_H in eq. (1) is the radiator function, it gives the probability for ISR photon to be emitted with scattering angle θ and energy E_γ.

An important feature of the ISR technique is that a wide range of energies is scanned simultaneously in one experiment, so that no structure is missed and the relative normalization uncertainties in data from different experiments or accelerator parameters are avoided. Furthermore, for large values of x the hadronic system is collimated, reducing efficiency issues and allowing measurements at energies down to production threshold.

Usually, ISR measurements are performed by requiring the detection of the initial photon in the main detector. Such a constraint, being the ISR angular distribution peaked at small angles, reduces the statistics by a factor of about five.

At the BEPC-II facility there is the unique possibility to install two small calorimeters ($\sim 50\,\mathrm{cm}^2$ of cross-section each) along the beam line, just outside BESIII detector, that can cover the very-forward and very-backward region (few milliradians around $\theta = 0$ and $\theta = \pi$). Such a detection device, called zero-degree detector, ZDD, will be used to tag the forward-backward initial-state-photons, increasing by at least a factor of two the main detector acceptance. The ZDD is a lead-scintillating fiber calorimeter instrumented with photomultipliers, that are connected through bundles of white scintillating fibers which work as light-guides. A first station will be installed in the summer 2011 in the forward direction, the second station is planned to be installed in the following year.

We are interested in using the ISR technique in BESIII to measure baryon-antibaryon hadronic cross sections, *i.e.* cross sections of processes like $e^+e^- \to \mathcal{B}\overline{\mathcal{B}}\gamma_{\mathsf{IS}}$, where $\mathcal{B}$ stands for a generic baryon. Thanks to BESIII capability of detecting neutral particles, we have a unique opportunity to measure the $n\overline{n}$ cross section. There are two main sources of background: $e^+e^- \to n\overline{n}\pi^0$ and $e^+e^- \to n\overline{n}\pi^0\gamma_{\mathsf{IS}}$. The $n\overline{n}\pi^0$ background, once the ISR photon is tagged in the ZDD, is suppressed by a factor (ZDD-solid angle)$/4\pi \sim 4\times10^{-5}$.

The ISR process $e^+e^- \to n\overline{n}\pi^0\gamma_{\mathsf{IS}}$, when the π^0 remains undetected, has the same signature of the signal. To reduce such a background we relay first in the BESIII efficiency in detecting π^0's and second, for those events where π^0 photons escape detection, we use the kinematic fit procedure which reduces to only a few % the ratio [$n\overline{n}\pi^0\gamma_{\mathsf{IS}}$ background events]/[$n\overline{n}\gamma_{\mathsf{IS}}$ signal events].

6. – Conclusions

With the largest sample of J/ψ and ψ'in the BESIII detector, many measurements have been possible and only few of them are reported here. More physics issues on τ-charm can be addressed in the next future, and also new prospects are open for baryon form factors.

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