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Search for invisible decays at BESIII

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BESIII experiment has collected the world's largest data sets at the J/ψ and $\psi(3686)$ resonances. The huge clean data sample provide an excellent chance to search for new physics. In this proceeding, we review some recent search results of invisible decays from BESIII. These include the quarkonium invisible decays $\omega \to invisible$, $\phi \to invisible$ and $J/\psi \to \gamma + invisible$; and the first search for the $\Lambda \to invisible$ in the baryon sector.

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PoS(PANIC2021)437

1. Introduction

Understanding the nature of dark matter is an important and challenging task in astronomy and particle physics. The existence of dark matter is well established with strong indirect evidence from astronomy. However, there is still no direct evidence of the dark matter particles yet.

BESIII [1] has accumulated the largest data sets in the world at the J/ψ and $\psi(3686)$ resonances, with 10^{10} J/ψ and 4.48×10^8 $\psi(3686)$ events, respectively. Benefiting from the well known kinematic information of the electron and positron in collision, the low background level and the huge data sets, BESIII has unique advantage in studying the hadron invisible decays. In these e^+e^- collision events, the decay daughter particles of the hadron under study are barely interacting with the detector material, hence "invisible" to our detector. And the other particles from the collision could be used for trigger and reconstruction.

In recent years, the BESIII experiment has performed several searches, not only for the invisible decays of quarkonia, but also for the baryon for the first time.

2. Search for $\omega \to invisible$ and $\phi \to invisible$

The quarkonium is made up of a quark and its antiquark. In the Standard Model (SM), a quarkonium could decay invisibly via the annihilation into a neutrino and anti-neutrino pair via a virtual Z boson, which is highly suppressed. However, it could be enhanced by some new physics mechanism. For the two light quarkonia ω and ϕ, the branching fractions of decays to $\nu\bar{\nu}$ are $(2.79 \pm 0.05) \times 10^{-13}$ and $(1.67 \pm 0.02) \times 10^{-11}$, respectively [2]. While they could be enhanced to 10^{-8} with the extra contribution from light dark matter particles [3].

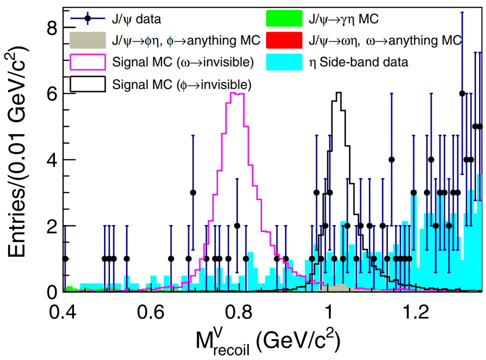

Figure 1: Invariant mass recoiling against the η candidates for data, signal Monte-Carlo and some key backgrounds.

This study [4] is performed with 1.3 billion J/ψ events. The quarkonia under study are obtained from the process $J/\psi \to V\eta$, where $V = \omega/\phi$ decays invisibly and $\eta \to \pi^+\pi^-\pi^0$ decay is utilized for trigger and reconstruct the event. The invariant mass recoiling against η is calculated to search for the ω or ϕ. No obvious signal is observed in Figure 1, hence upper limits are reported. Instead of giving the branching fraction of the invisible decays directly, the ratio of branching fractions $\frac{B(\omega \to invisible)}{B(\omega \to \pi^+\pi^-\pi^0)}$ and $\frac{B(\phi \to invisible)}{B(\phi \to K^+K^-)}$ are determined to cancel the systematic uncertainties stem from the reconstruction of the tag side, the total number of J/ψ and the branching fraction of

PoS(PANIC2021)437

$J/\psi \to V\eta, \eta \to \pi^+\pi^-\pi^0$. With the Bayesian approach, the upper limits of the ratios of ω and ϕ decays at the 90% C.L. are set to be 8.1×10^{-5} and 3.4×10^{-4}, respectively.

3. Search for $J/\psi \to \gamma + invisible$

In this work [5], the search for J/ψ radiative decays into an invisible particle has been performed, using the J/ψ candidates produced in the process $e^+e^- \to \psi(3686) \to \pi^+\pi^- J/\psi$. The data sample has $(4.48 \pm 0.03) \times 10^8$ $\psi(3686)$ events. To tag the J/ψ candidates, $\pi^+\pi^-$ are reconstructed, and then a good photon is reconstructed in the recoil side. No significant signal is observed. The upper limits on the branching fractions are set by scanning the assumed invisible particle mass in the region from 0 up to 1.2 GeV/c^2. The upper limit for a zero mass of the invisible particle is 7.0×10^{-7} and improved by a factor of 6.2 compared to CLEO-c's result [6].

4. Search for $\Lambda \to invisible$

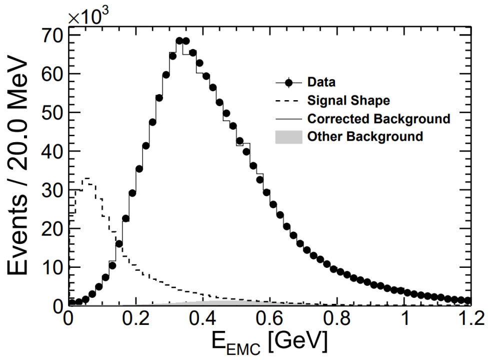

Figure 2: The total energy in the EMC detector. The dots with error bars are data. The dashed line is the signal shape with arbitrary normalization. The solid line shows the $\Lambda \to n\pi^0$ background shape after calibration. The grey shaded area is the other background contributions.

The invisible decays of baryons are also very important and challenging. Baryons are fundamental constituents of the universe visible matter. Some models proposed that the invisible decays of baryons not only could happen but also could be used to interpret the discrepancy [7] of neutron lifetime measured in beam method [8] and bottle method [9].

With the 10 billion J/ψ events taken at J/ψ peak, the first search for the invisible decay $\Lambda \to invisible$ has been carried out in the process $J/\psi \to \Lambda\bar{\Lambda}$ [10]. To reconstruct the signal of Λ, $\bar{\Lambda} \to \bar{p}\pi^+$ is used as the tag.And the signal is searched for on the distribution of total energy in the Electro-Magnetic Calorimeter (EMC), as shown in Figure 2. To describe the main background $\Lambda \to n\pi^0$, a data driven method is performed to calibrate the behavior of neutron (not anti-neutron) in EMC, which not described well in simulation. The neutron and anti-neutron behave very differently in the EMC, hence in this study, $\bar{\Lambda}$ is only used as the tag with the decay mode $\bar{\Lambda} \to \bar{p}\pi^+$. No obvious signal are found for the Λ invisible decay. The upper limit of branching fraction is determined to be 7.4×10^{-5} at the 90% C.L.

PoS(PANIC2021)437

5. Summary

With huge J/ψ and $\psi(3686)$ samples collected in the clean e^+e^- annihilation with BESIII detector, invisible decays of quarkonia (ω, ϕ, J/ψ) and Λ baryon are searched. More data of $\psi(3686)$ will be taken soon. In the future, more interesting searches could be performed and some published results could also be improved with larger data sample.

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PoS(PANIC2021)437