Search for dark sector via charmonia decay at BESIII

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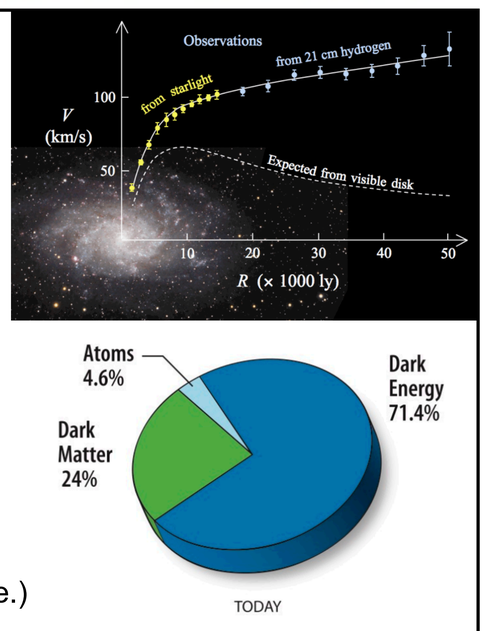
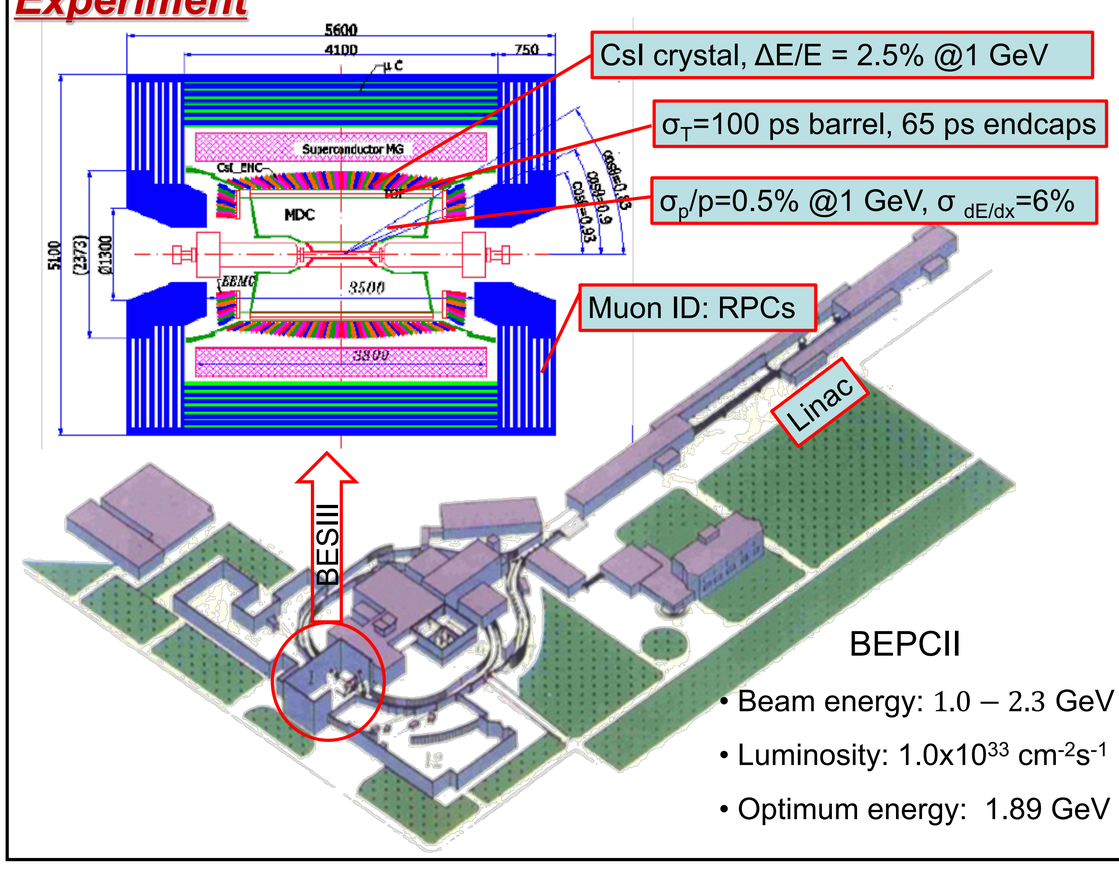
Motivation

- Numerous indirect astrophysical observations provide the existence of dark matter. However, the property of dark matter is still unclear.
- No observed result from collider experiment.
- Quarkonium decay is one way to search dark matter in collider experiments.



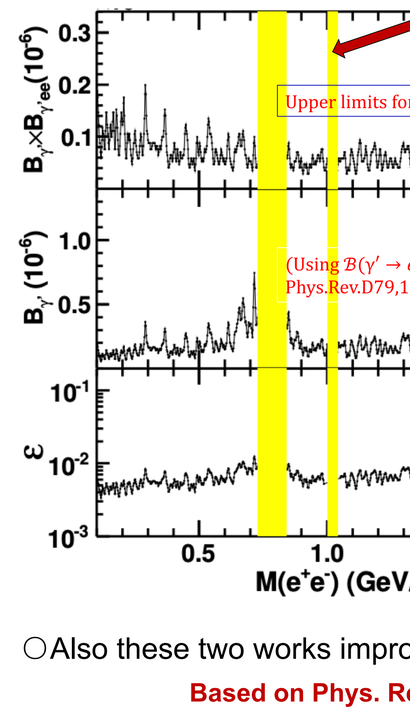
- BESIII has accumulated 10 Billion J/ψ and 0.5 Billion ψ(3686). (World largest data sample.)
  (1.3 Billion J/ψ are accumulated in 2009&2012 year.)

Experiment



- Beam energy: 1.0 – 2.3 GeV
- Luminosity: 1.0×10^{33} cm^{-2}s^{-1}
- Optimum energy: 1.89 GeV

Search for dark photon via $J/\psi \to \gamma'\eta^{(\prime)}, \gamma' \to e^+e^-$



◎ Models with an extra U(1) gauge group predicts a massive vector boson force carrier, called a dark photon(γ'). **[Phys.Lett. 166B(1986) 196-198]**

◎ The dark photon can couple to the SM photon and decay into SM particles.

◎ Mixing strength could be extracted in: **[JHEP 0907 (2009) 051]**

$$\frac{\mathcal{B}(J/\psi \to \gamma'\eta^{(\prime)})}{\mathcal{B}(J/\psi \to \gamma\eta^{(\prime)})} = \varepsilon^2 |F_{J/\psi}| \frac{\Lambda^{3/2}(m^2_{J/\psi}, m^2_{\eta^{(\prime)}}, m^2_{\gamma'})}{\Lambda^{3/2}(m^2_{J/\psi}, m^2_{\eta^{(\prime)}}, m^2_{\gamma})}$$

$$|F_{J/\psi}| = \frac{\Lambda^2}{\Lambda^2 - m^2_{\gamma'}},\ \Lambda = m_{\psi(2S)} \qquad \Lambda^{3/2}(m_1^2, m_2^2, m_3^2) = (1 + \frac{m_3^2}{m_1^2 - m_2^2})^2 - \frac{4m_1^2 m_3^2}{(m_1^2 - m_2^2)^2}$$

○ Reconstruct η with $\gamma\gamma/\pi^+\pi^-\pi^0$, η' with $\gamma\pi^+\pi^-/\eta\pi^+\pi^-$.

○ Veto γ conversion background by electron-positron pair vertex.

○ Searching signal on M(e^+e^-).

○ No significant signal observed. Upper limits @ 90% C.L. are calculated.

○ Also these two works improved corresponding branching fraction precision.

Based on Phys. Rev. D. 99, 012006 (2019) & Phys. Rev. D 99, 012013 (2019)

Search for $\omega/\phi \to$invsible via $J/\psi \to \eta\omega/\phi$

◎ In SM, $\mathcal{B}(\omega/\phi \to \nu\bar{\nu})$ is really low(~ $10^{-13}/10^{-11}$). **[Phys.Rev.D98,113006(2108)]**

◎ Many beyond SM theories can enhance $\mathcal{B}(\omega/\phi \to$invsible), such as NMSSM, extra U(1) Model ... **[Phys.Lett.110B(1982)250, Phys.Rev.D72,103508(2005)]**

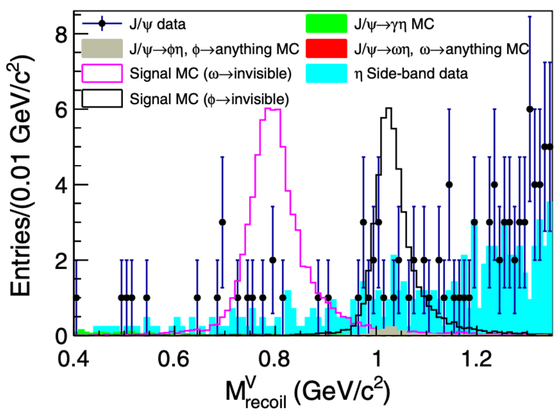
◎ BESIII searched $\omega/\phi \to$invisible **first time** on 1.3B J/ψ, by tagging $\eta(\pi^+\pi^-\pi^0)$.

◎ To minimize the systematic uncertainty, the result is measured with:

$$\frac{\mathcal{B}(V \to invisible)}{\mathcal{B}(V \to visible)} = \frac{N_{sig}^{invisible} \cdot \epsilon^{visible}}{N_{sig}^{visible} \cdot \epsilon^{invisible}}$$

○ Searching signals on M^V_{recoil}.
No obvious signals found.

○ By maximum likelihood fit, N(signal) is only 1.4±3.6 for $\omega \to$invsible and -0.6±4.5 for $\phi \to$invsible.



○ Using the Bayesian approach, the upper limits at the 90% C.L. are calculated:

$$\frac{\mathcal{B}(\omega \to invisible)}{\mathcal{B}(\omega \to \pi^+\pi^-\pi^0)} < 8.1\times10^{-5} \qquad \frac{\mathcal{B}(\phi \to invisible)}{\mathcal{B}(\phi \to K^+K^-)} < 3.4\times10^{-4}$$

with $\mathcal{B}(\omega \to \pi^+\pi^-\pi^0)$, $\mathcal{B}(\phi \to K^+K^-)$ in PDG:

$$\mathcal{B}(\omega \to invisible) < 7.3\times10^{-5} \qquad \mathcal{B}(\phi \to invisible) < 1.7\times10^{-4}$$

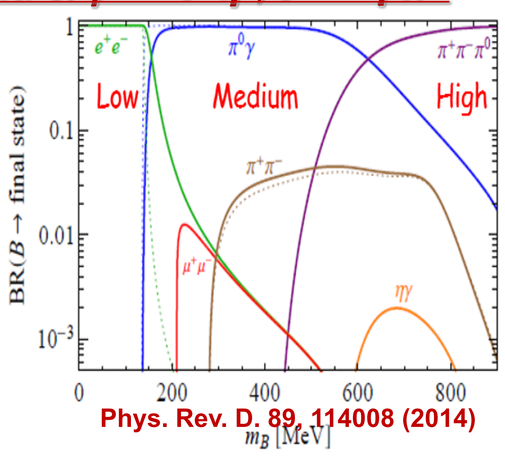
Based on Phys. Rev. D. 98, 032001 (2018)

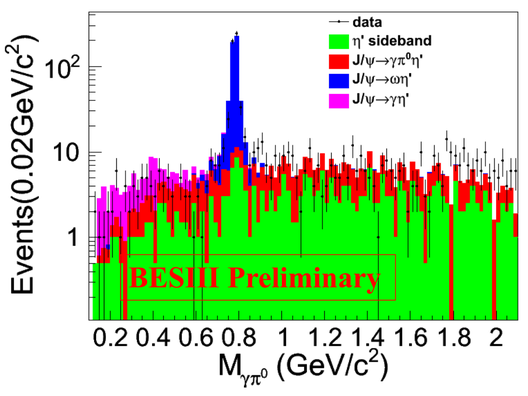
Search for dark gauge boson via $J/\psi \to U'\eta', U' \to \gamma\pi^0$

◎ A new gauge boson could couple to quarks. **[Phys.Lett.B221,80(1989)]**

◎ Belle reported a search for $\eta \to \gamma U'$, $U' \to \pi^+\pi^-$. **[Phys.Rev.D94,092005(2016)]**

◎ BESIII searched $J/\psi \to \eta' U', U' \to \gamma\pi^0$ **first time** using 1.3B J/ψ data sample.

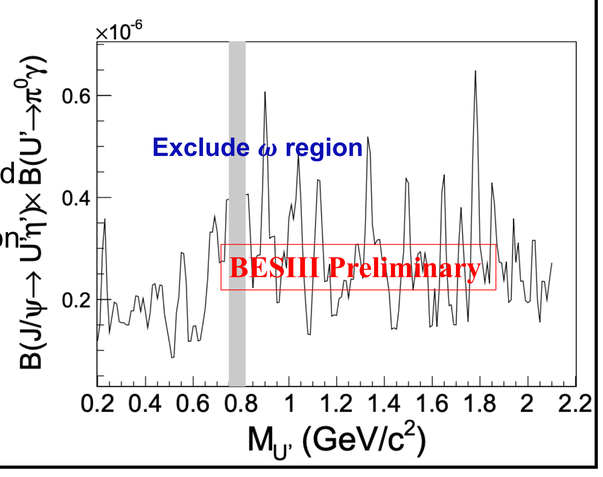




○ Reconstruct η' by $\pi^+\pi^-\eta(\gamma\gamma)$.

○ Search dark boson at M($\gamma\pi^0$).

○ No significant signal observed.

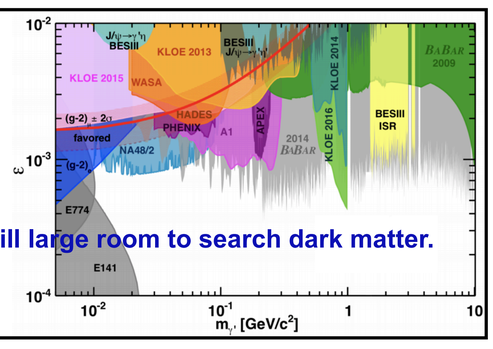


○ Upper limit @90% C.L. are computed.

○ This work also improved the precision of Branching fraction of J/$\psi \to \omega\eta'$ by a factor of 1.4.

Summary and outlook

- Using 1.3 B J/ψ sample, BESIII has searched for $\omega/\phi \to$invisible, dark photon via $J/\psi \to \eta^{(\prime)}e^+e^-$ and dark boson via $J/\psi \to \eta' U', U' \to \gamma\pi^0$ for **first time**. No significant signal observed.
- Other processes looking for dark sector are ongoing, such as J/$\psi \to$ invisible, J/$\psi \to \gamma$ invisible, $\chi_{cJ} \to \gamma$ invisible, $\Lambda \to \gamma$ invisible...



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