Search for Axion-like particle at BESIII

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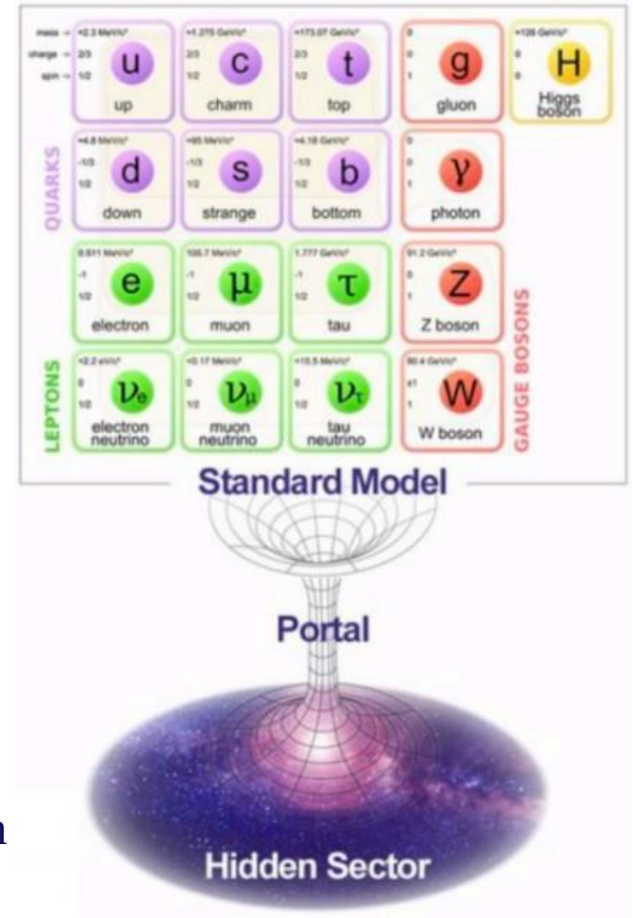
Motivation

- Many extensions of the Standard Model (SM) introduce light weak interacting dark matter (DM) hidden sectors
  - ✓ Motivated by recent experimental anomalies and theoretical prejudice
  - ✓ The DM hidden sectors couple to the SM particles via the so called "portals"

Portal	Particles	Operator(s)
"Vector"	Dark photons	$-\frac{\epsilon}{2\cos\theta_W}B_{\mu\nu}F'^{\mu\nu}$
"Axion"	Pseudoscalars	$\frac{a}{f_a}F_{\mu\nu}\widetilde{F}^{\mu\nu}, \frac{a}{f_a}G_{i\mu\nu}\widetilde{G}_i^{\mu\nu}, \frac{\partial_\mu a}{f_a}\overline{\psi}\gamma^\mu\gamma^5\psi$
"Higgs"	Dark scalars	$(\mu S + \lambda S^2)H^\dagger H$
"Neutrino"	Sterile neutrinos	$y_N L H N$



- ✓ These new particles can be accessible by high intensity e^+e^- collider experiments, such as **BESIII experiment**, if their masses are in the MeV-GeV range.

R. Essig et al., arXiv: 1311.0029 (2013)

Search for an Axion-like particle at BESIII

An Axion-like particle (ALP), a

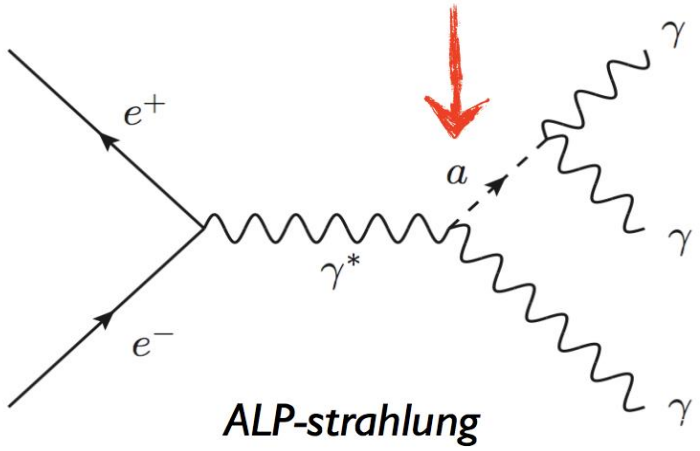
- Is a pseudo-scalar particle
- Introduced by the spontaneous breaking of Peccei-Quinn symmetry to solve the strong CP problem of the QCD

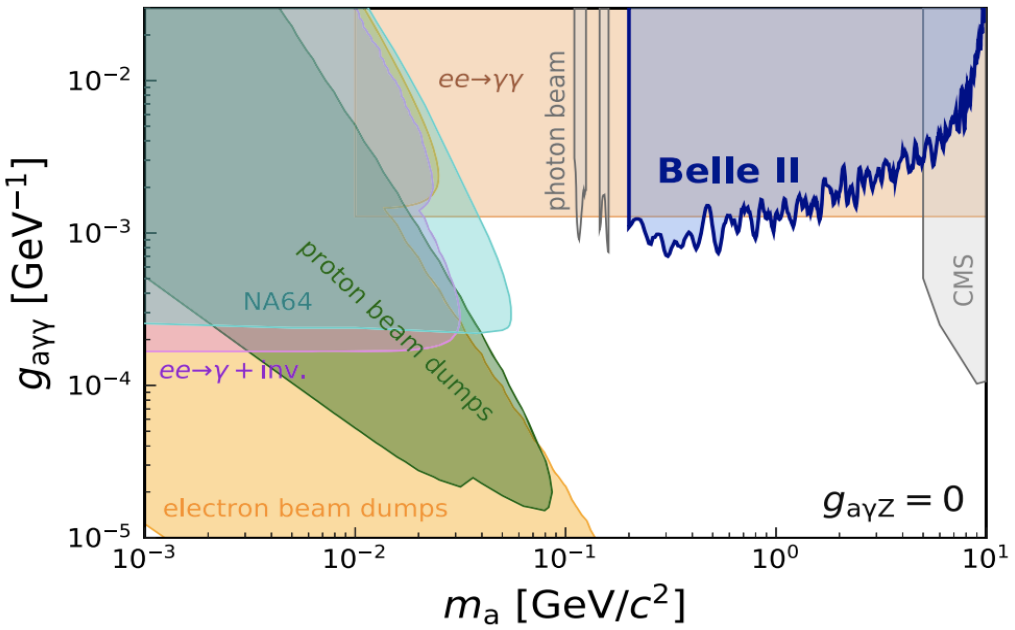
Phys. Rev. Lett. **38**, 1440 (1977); Phys. Rev. D **16**, 1791 (1977)

Phys. Rev. Lett. **40**, 223 (1978); Phys. Rev. Lett. **40**, 279 (1978)

- couples to bosons. Here focus on $a \to \gamma\gamma$
- has recently explored by Belle II using ALP-Strahlung process

Phys. Rev. Lett. **125**, 161806 (2020)



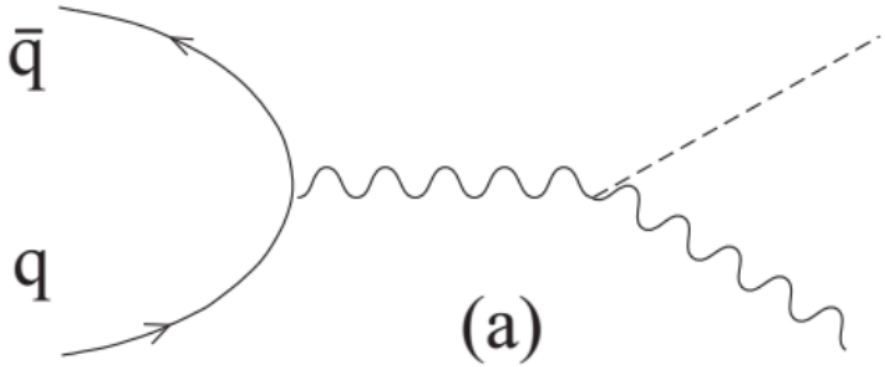


Search for an Axion-like particle at BESIII

- Axion-like particle can also be accessed via radiative decays of J/ψ

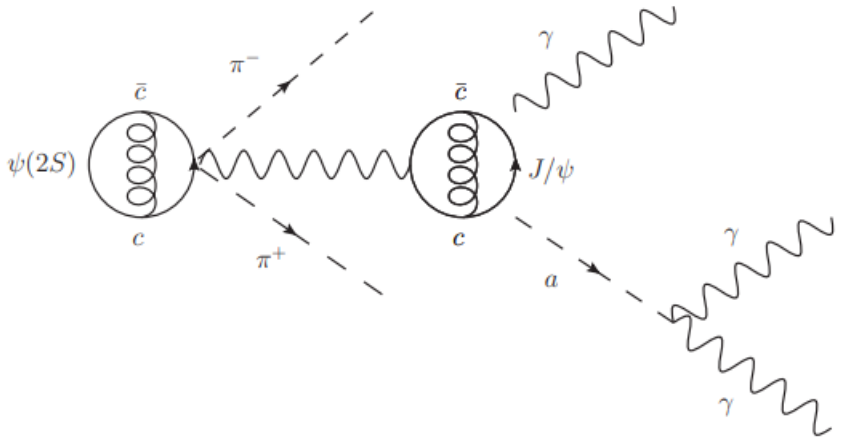
$$\mathcal{B}(J/\psi \to \gamma a) = \frac{m_{J/\psi}^2}{32\pi\alpha} g_{a\gamma\gamma}^2 \left(1 - \frac{m_a^2}{m_{J/\psi}^2}\right)^3 \mathcal{B}(J/\psi \to e^+e^-)$$

Phys. Rev. D **52**, 1755 (1995)

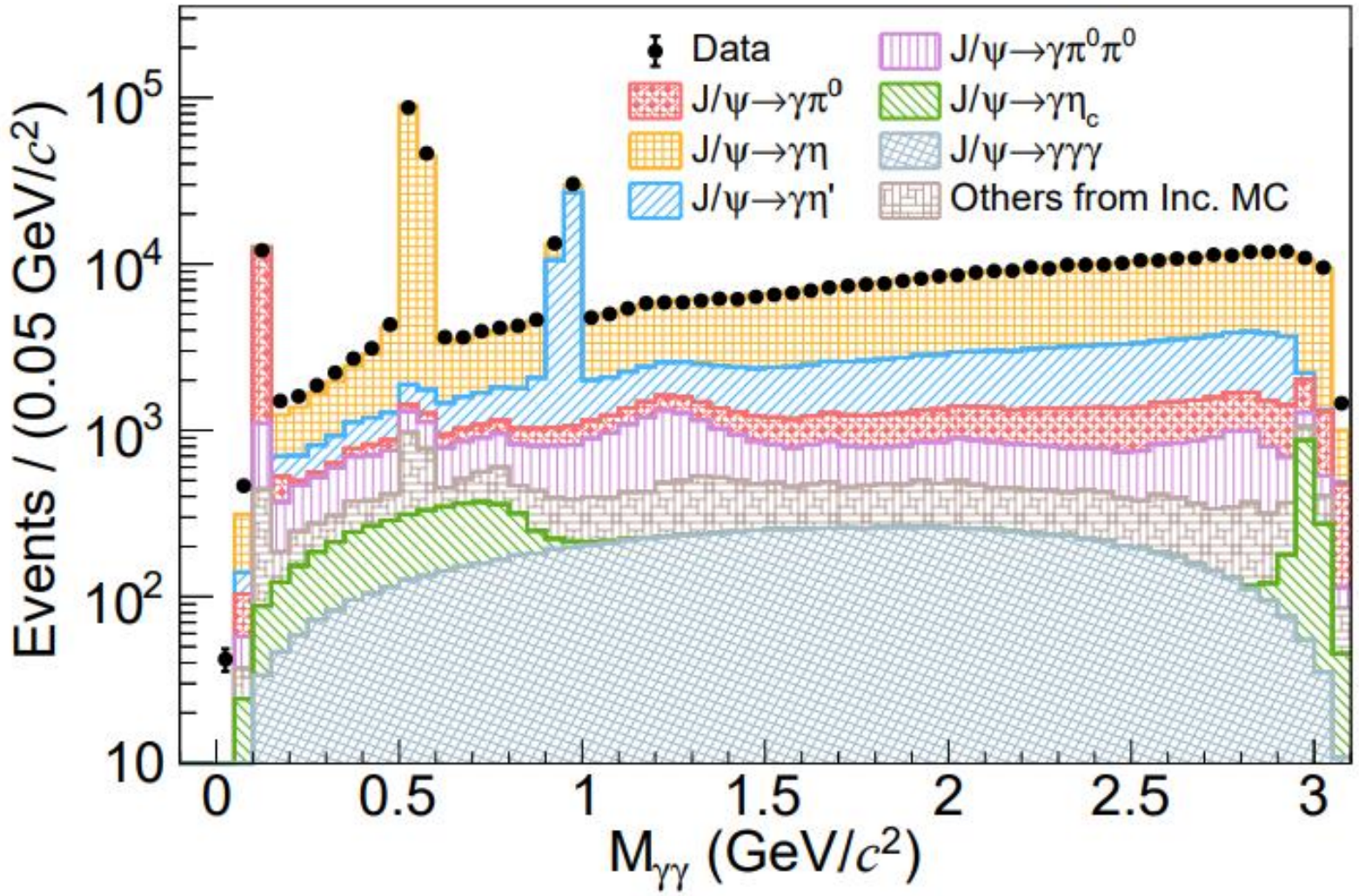


- 2.7 billion of $\psi(2S)$ data collected by the BESIII experiment provide an ideal avenue for this search.

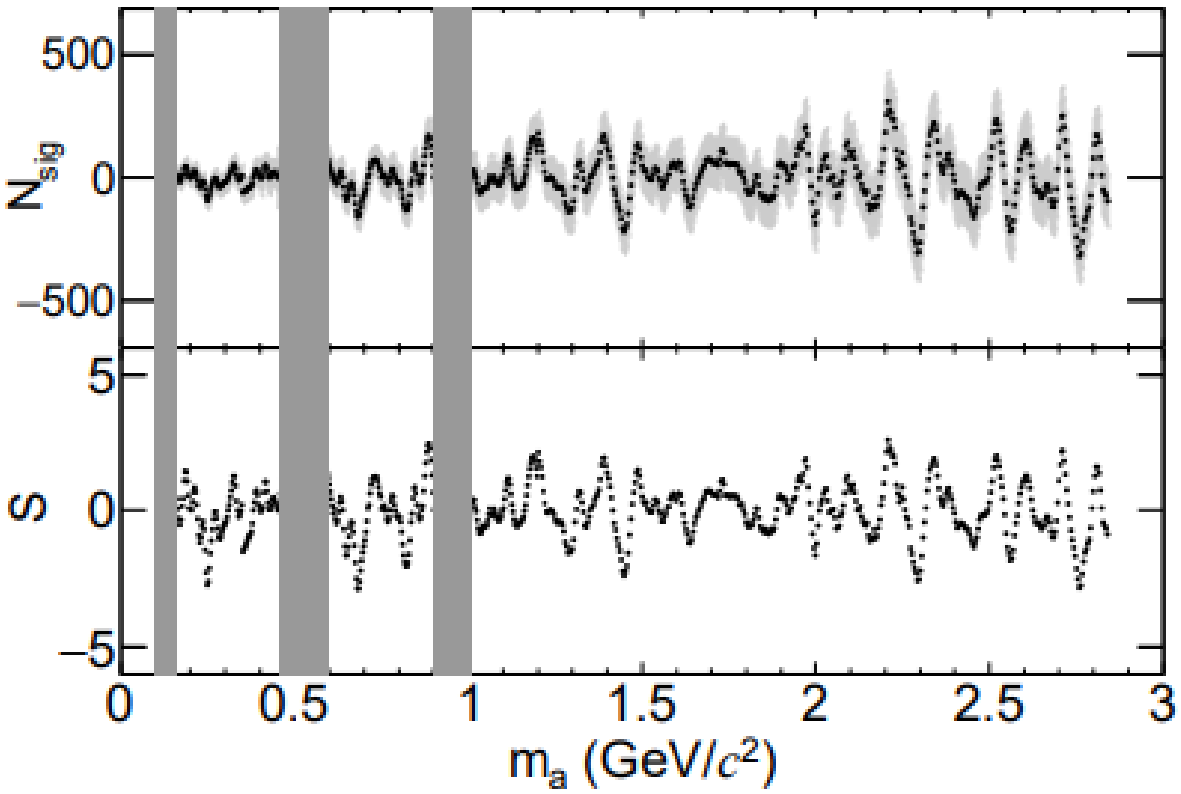
- A J/ψ data sample can be obtained from $\psi(2S) \to \pi^+\pi^- J/\psi$ transition

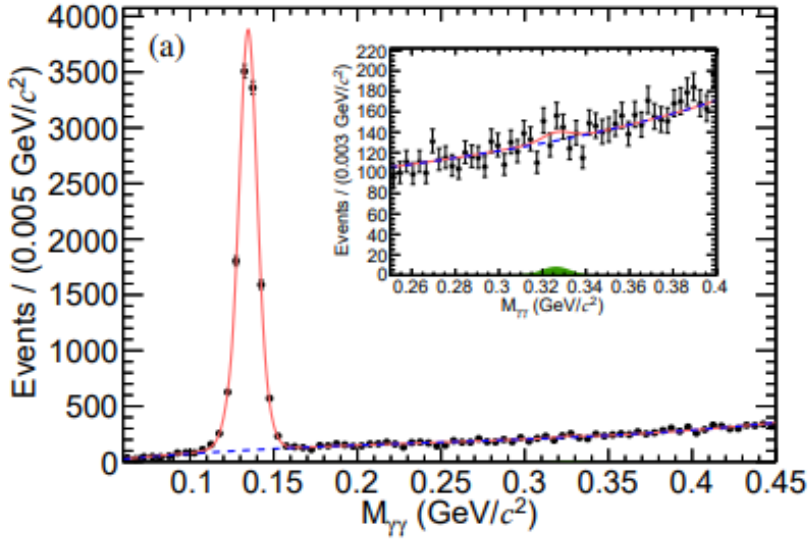


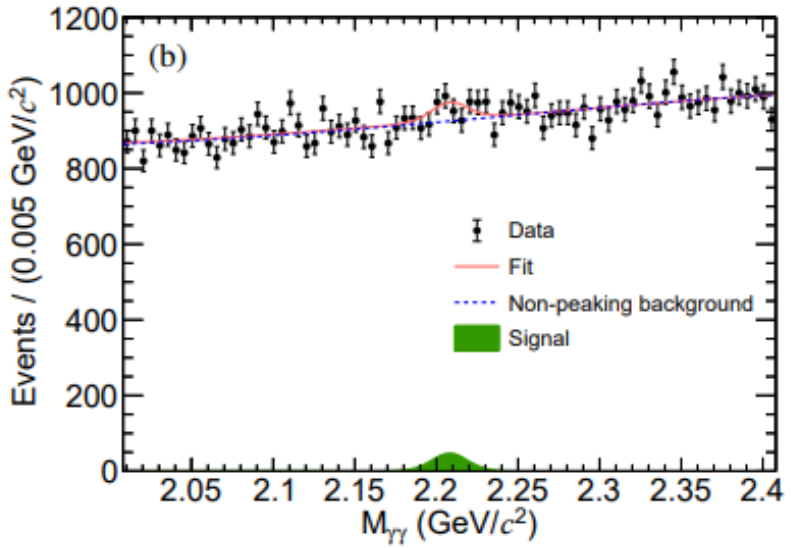
Di-photon invariant mass spectrum



Maximum Likelihood fit for a narrow Axion-like particle search

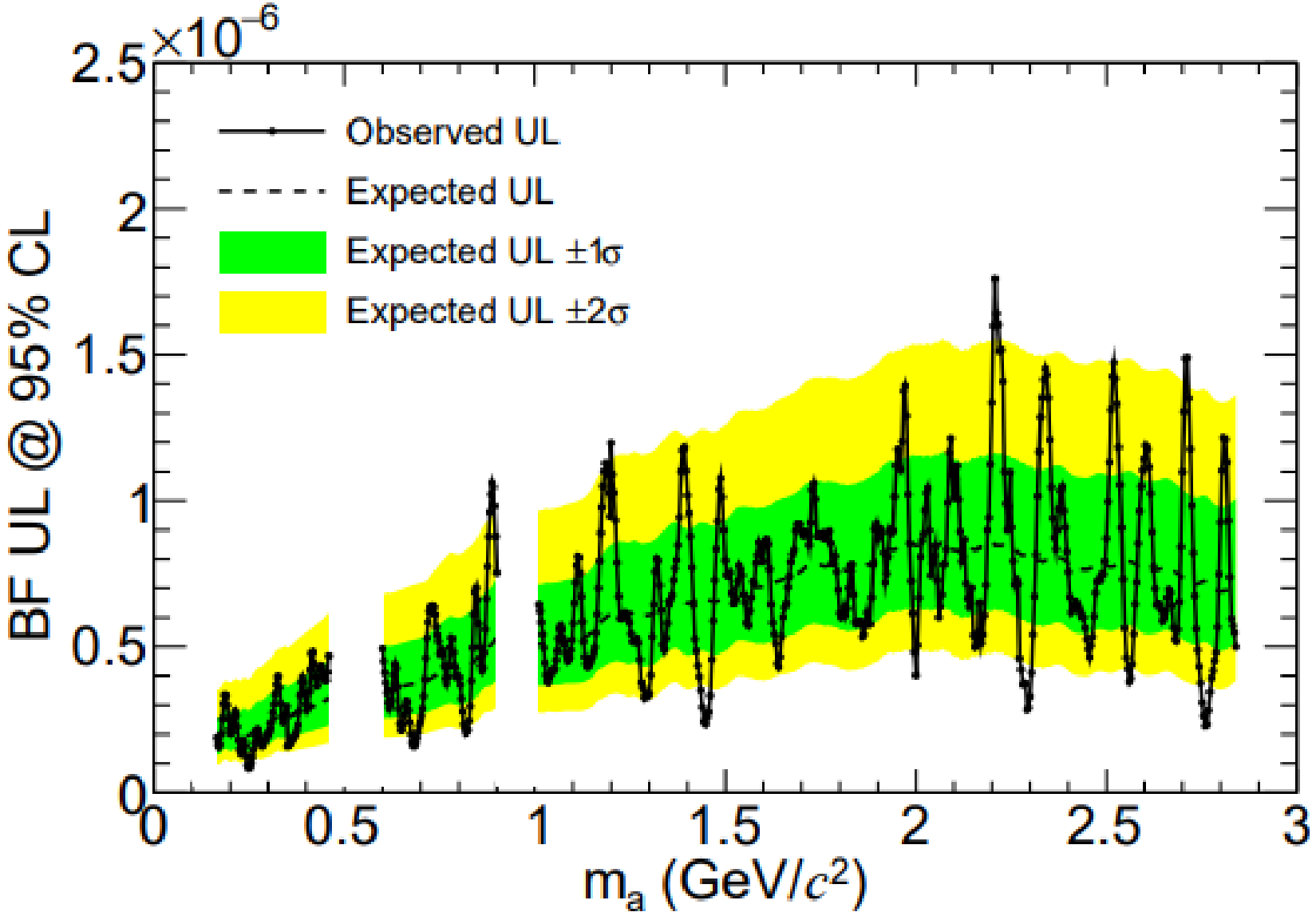




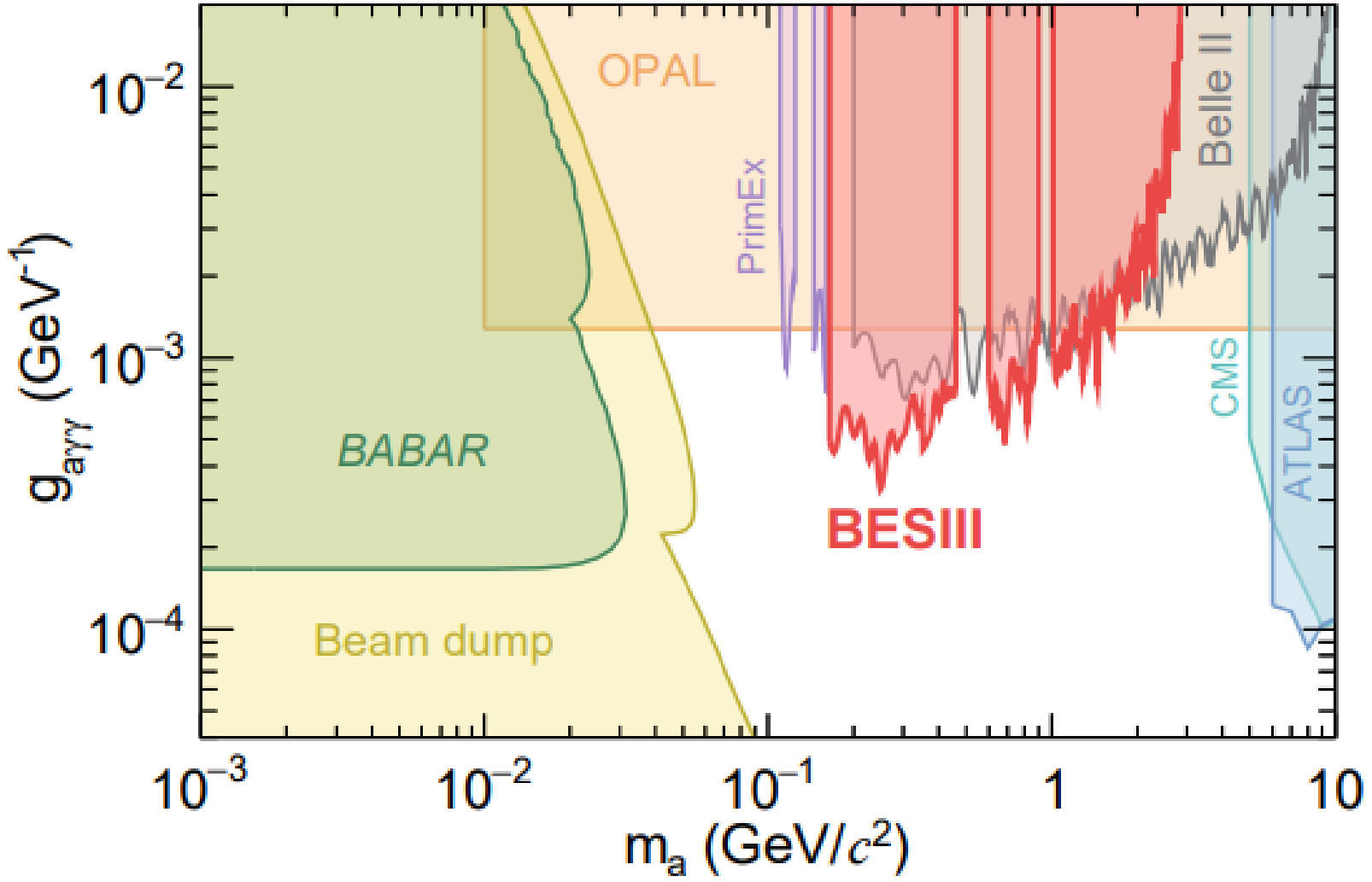


No evidence of an Axion-like particle production

95% confidence level upper limit on product branching fraction



95% confidence level upper limit on coupling of ALP to a photon-pair



- Our limit is significantly better than the Belle II measurement in the low-mass region.
- 10 billion of J/ψ data collected by the BESIII experiment may further improve sensitivity of $g_{a\gamma\gamma}$.
- Submitted to **Phys. Lett. B, arXiv:2211:12699 (2022)**

Summary and conclusion

- We search for an Axion-like particle in radiative decays of J/ψ using 2.7 billion of $\psi(2S)$ data collected by the BESIII detector .
- A J/ψ data sample has been obtained from $\psi(2S) \to \pi^+\pi^- J/\psi$ transition.
- We find no evidence of the production of an Axion-like particle.
- Set 95% confidence upper limit on the coupling of Axion-like particle with a photon-pair.
- Our limit is significantly better than Belle II measurement in the low-mass region.
- Submitted to **Phys. Lett. B, arXiv:2211:12699 (2022).**

Thanks!