

Displaced or Invisible? ALPs from B decays at Belle II

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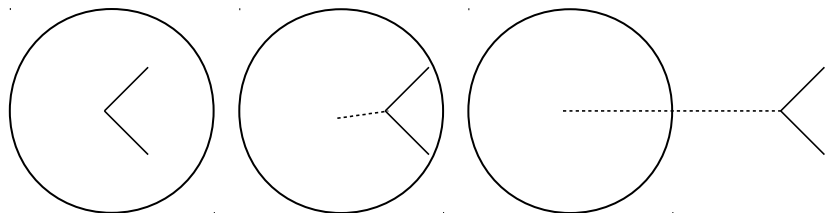
LLP11:

Searching for long-lived particles at the LHC and beyond

Based on [2201.06580]; RS supported by GRK 1940

Long-lived Particles

- ▶ Complementary detector signatures:
 - ▶ Displaced decays
 - ▶ Missing energy
 - ▶ Other signatures



Axion-like particles

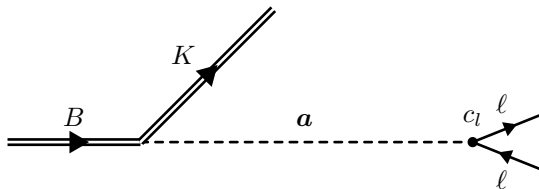
- ▶ Use as benchmark model
- ▶ Effective Model of Standard Model + ALP
- ▶ Couples in the UV to either fermions or W -bosons

$$\mathcal{L}_{\text{eff,UV}} = \sum_f \frac{c_{ff}(\mu)}{2} \frac{\partial^\mu a}{f_a} (\bar{f} \gamma_\mu \gamma_5 f) + c_{WW} \frac{a}{f_a} \frac{\alpha_2}{4\pi} W_{\mu\nu}^A \widetilde{W}^{\mu\nu,A}$$

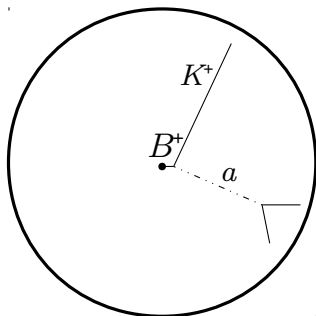
using Bauer, et al. [2012.12272]

Belle II

- ▶ Belle II is an e^+e^- -collider:
 - ▶ Small boost
 - ▶ Clean background
 - ▶ Optimised for rare B -decays
 - ▶ Full solid angle
- ▶ We produce ALP in $B^+ \rightarrow K^+ a$



Displaced decays

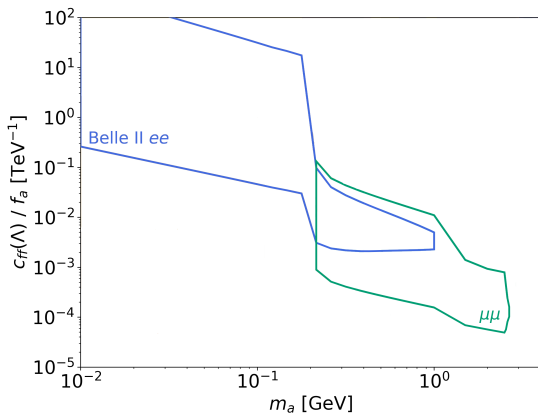


- ▶ The ALP decays into pair of visible particles
- ▶ Within the tracking system (CDC)

$$N_{disp} = N \times Br(B \rightarrow Ka) \times \left(e^{-\frac{d_{res}}{\gamma\beta c\tau}} - e^{-\frac{R}{\gamma\beta c\tau}} \right) \times Br(a \rightarrow f\bar{f}) \times \varepsilon$$

Displaced ALP decays

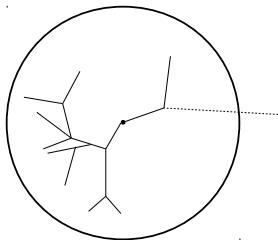
- ▶ $B^+ \rightarrow K^+ a, a \rightarrow \mu^+ \mu^-, e^+ e^-$ displaced
- ▶ Simulated with EvtGen data
- ▶ Assume zero background



Invisible decays

- ▶ ALP decays outside of detector
- ▶ The other B decays generically
- ▶ Inclusive search
- ▶ Analysis of B - and continuum backgrounds

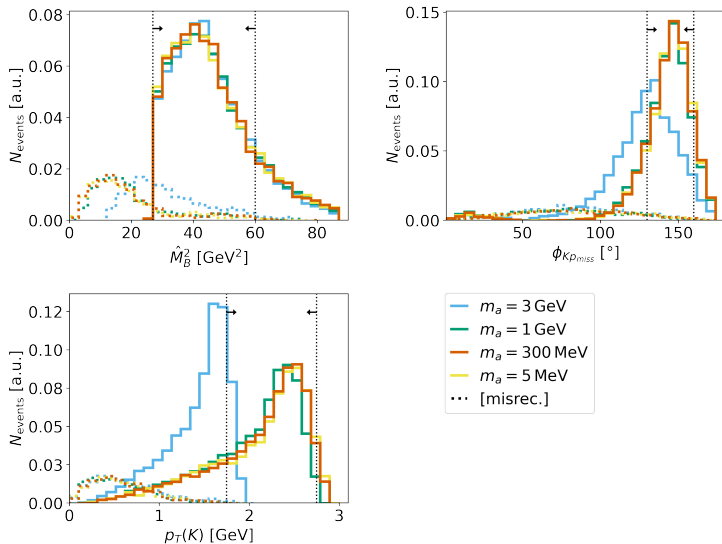
$$N_{inv} = N \times Br(B \rightarrow Ka) \times e^{-\frac{R}{\gamma\beta c\tau}} \times \epsilon$$



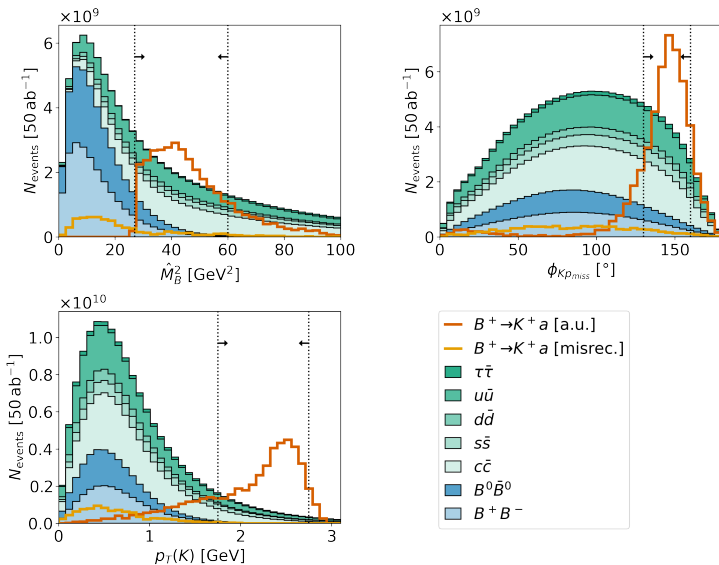
Kinematic variables of the system

- ▶ The decay $B \rightarrow Ka$ is given by its final state momenta
 - ▶ $p(K), p(a)$
 - ▶ $p(a)$ is not measurable
 - ▶ p_{miss} is measurable
- ▶ We choose the following variables to describe our system:
 - ▶ Kaon transverse momentum $p_T(K)$
 - ▶ Opening angle between kaon and missing momentum $\phi_{Kp_{miss}}$
 - ▶ Reconstructed B -meson mass \hat{M}_B^2 from $p(K), p_{miss}$
- ▶ There are often several kaons in a decay
 - ▶ Choose highest p_T kaon
 - ▶ Misreconstructed events from choosing wrong kaon

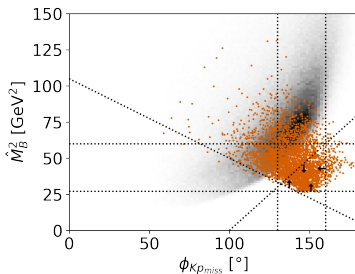
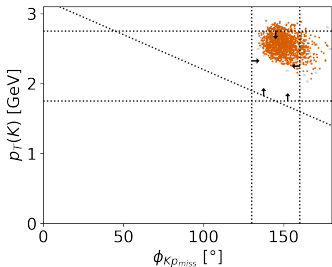
Kinetic variables in our signal samples



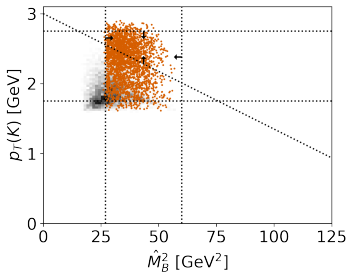
Kinetic variables in our backgrounds



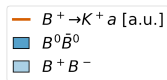
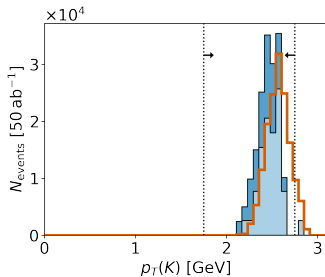
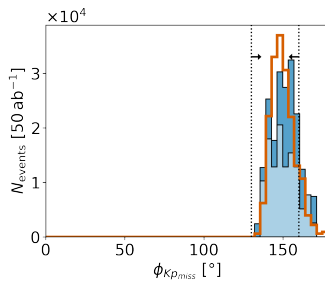
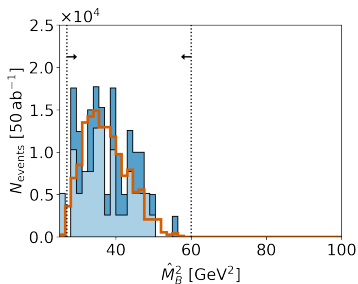
Placing cuts on the distributions



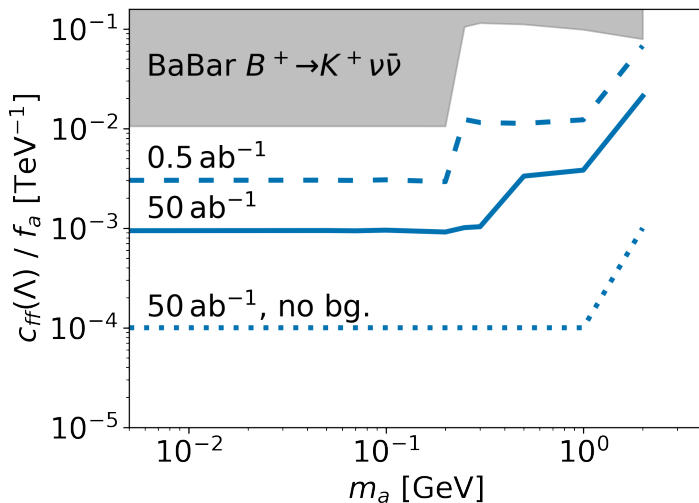
- $B^+ \rightarrow K^+ a$
- backgrounds



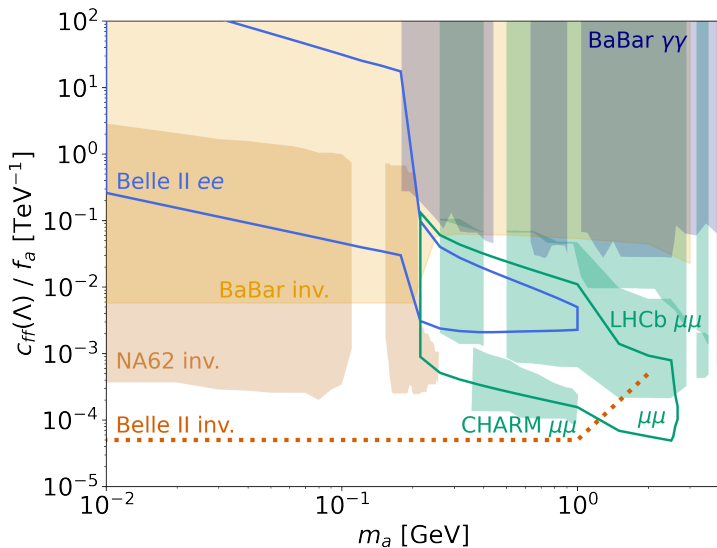
Placing cuts on the distributions



Bounds from invisible decays



Displaced or Invisible?

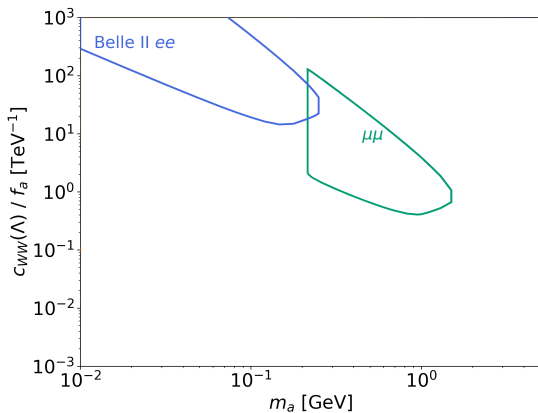


Conclusion

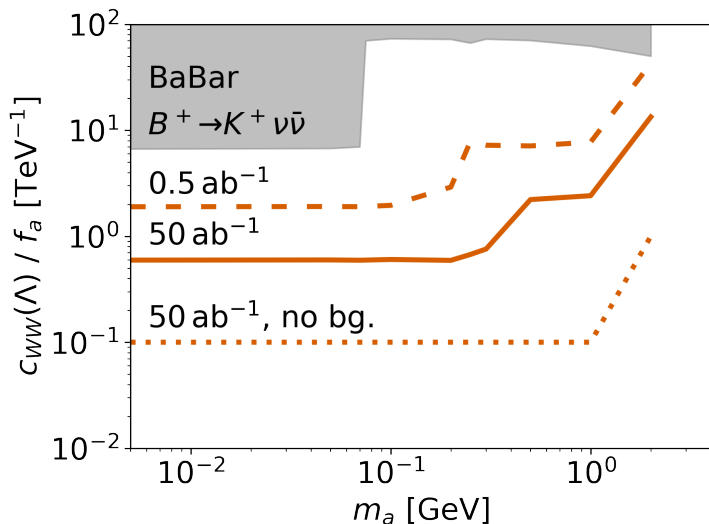
- ▶ Belle II is a good detector for long-lived particles
- ▶ Invisible searches:
 - ▶ Require elaborate background cuts
 - ▶ Consistently high potential
- ▶ Displaced searches are useful for characterising LLPs
- ▶ This varies from model to model and detector to detector

Backup plots

Displaced ALP decays



Bounds from invisible decays



Displaced or Invisible?

