Dark Sector Searches at Belle II

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On behalf of the BELLE II Collaboration

- Belle II and SuperKEKB
- Invisible Dark Photon
- ALPs
- Future Outlook
From KEKB to SuperKEKB

- SuperKEKB: The B-factory at KEK
- Asymmetric $e^-$ - $e^+$ collider
- 10.58 GeV com energy

**Doubled** Beam currents and change to ‘nanobeam’ (shown at left)
- $40\times$ KEKB instantaneous luminosity
- $50\times$ KEKB integrated luminosity
Belle II Data Taking Plan

Phase 2:
- 1/8th of Vertex Detector
- Primarily for commissioning nanobeams
- Achieved luminosity of $5.5 \times 10^{33}$ cm$^{-2}$s$^{-1}$
- $\int L \, dt \sim 0.5$ fb$^{-1}$

Phase 3:
- Full physics running with Vertex Detector
- $\int L = 50$ ab$^{-1}$ planned
- Begin in 2019
Phase 2 Data: Particle Re-discoveries

\[ \int L \, dt = \sim 5 \text{ pb}^{-1} \]

- Data

\[ m_{\gamma\gamma} \text{ (GeV/c}^2) \]

\[ m(\pi^+\pi^-) \text{ (GeV/c}^2) \]

\[ \pi^0 \]

\[ K_s \]
Dark Sector Searches: Invisible Dark $\gamma$ and ALPs

**Vector:** Dark $\gamma \rightarrow$ Invisible

**Pseudoscalar:** Axion-Like Particles
Dark $\gamma \rightarrow $ Invisible

- Light (GeV scale) hidden dark sector weakly coupled to SM by dark photon $A'$
- Experimental signature: only 1 high-energy photon in detector
- Needs single photon trigger
  - Not present in Belle
  - Only present of $\sim$10% of BaBar
  - Implemented for Phase 2
- ~No true physics backgrounds
  - Only missing particle backgrounds:
    - Radiative bhabha, $\gamma\gamma$ events with one $\gamma$ not reconstructed
Dark $\gamma \rightarrow $ Invisible: Prospects

Improved luminosity and calorimeter hermiticity can allow great improvement!
Dark $\gamma \rightarrow$ Visible dileptons: Heavier DM

Projected Sensitivity

Belle II TiP Report
Axion-Like Particles (ALPs)

- Pseudoscalars that couple to bosons
  - Can target photon coupling $g_{a\gamma\gamma}$
- Coupling not related to mass
  - Different from QCD axions
- Three-Photon signature
  - One $\gamma$ from recoil
  - Pair from $a \rightarrow \gamma\gamma$
- Four calorimeter signatures
  - (Determined by displacement, $\theta$ of photon pair)
Projected ALP Sensitivity

- Only coupling to $\gamma$
- Coupling to $\gamma$ + $Z$

Parameters and Graphs:
- $g_{\gamma Z} = 0$
- $g_{\gamma \gamma} = -2 \tan \theta_W g_{\gamma \gamma}$

Graph Details:
- Belle II 3$\gamma$ (20 fb$^{-1}$)
- Belle II 3$\gamma$ (50 ab$^{-1}$)
- Belle II $\gamma +$ inv (20 fb$^{-1}$)
- Belle II $\gamma +$ inv (50 ab$^{-1}$)
- SHiP
- LHC
Summary

- Belle II Phase 2 finished last month with $5.5 \times 10^{33}$ cm$^{-2}$s$^{-1}$, $\int L \, dt \sim 0.5$ fb$^{-1}$.
- Specially designed triggers and low backgrounds mean improvements may be possible even with a small data set.
- Phase 3 to begin in 2019, $\rightarrow$ final luminosity goal of 50 ab$^{-1}$

Other searches possible!

- Magnetic Monopoles
- Invisible Z', Z' $\rightarrow$ LFV (e -μ coupling)
- Dark scalars
- Dark Higgs
- Off-shell A' decays
- Even more…