



# 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



# Belle II Detector

## EM Calorimeter

CsI(Tl), waveform sampling electronics

## KL and muon detector

Resistive Plate Counter (barrel outer layers)  
Scintillator + WLSF + MPPC  
(end-caps, inner 2 barrel layers)

electrons (7 GeV)

## Vertex Detector

2 layers Si Pixels (DEPFET) +  
4 layers Si double sided strip DSSD

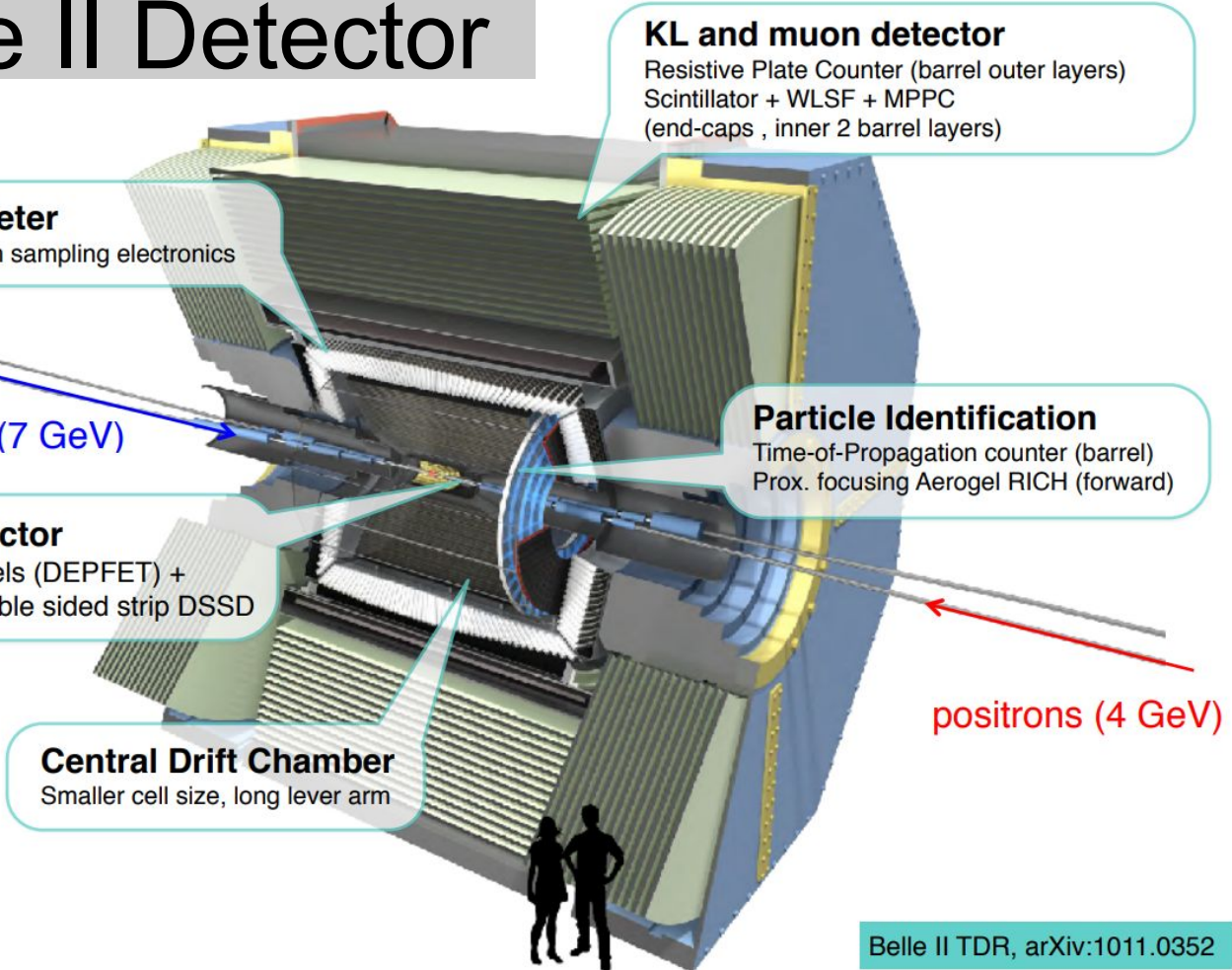
## Particle Identification

Time-of-Propagation counter (barrel)  
Prox. focusing Aerogel RICH (forward)

## Central Drift Chamber

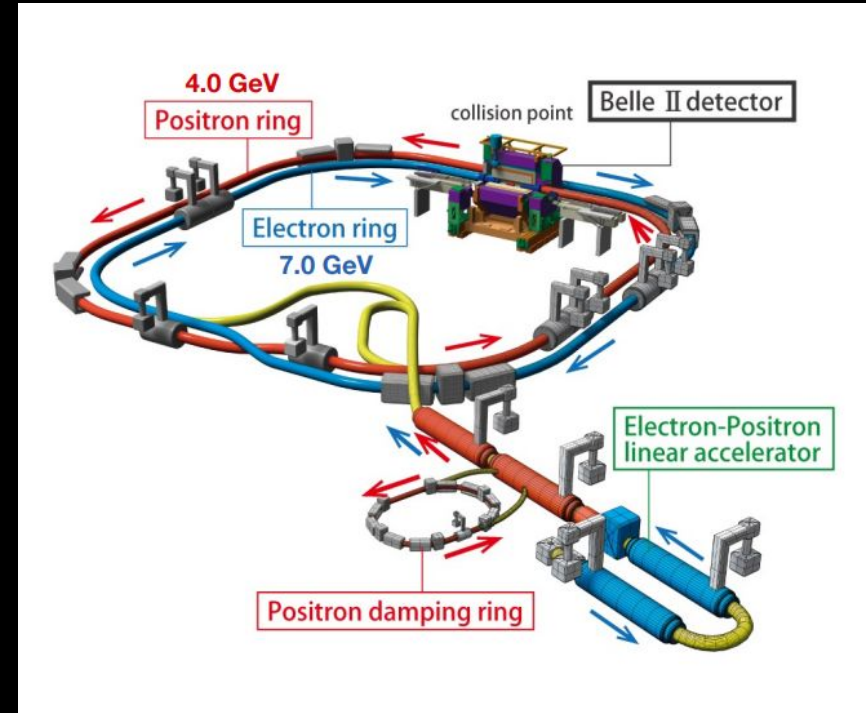
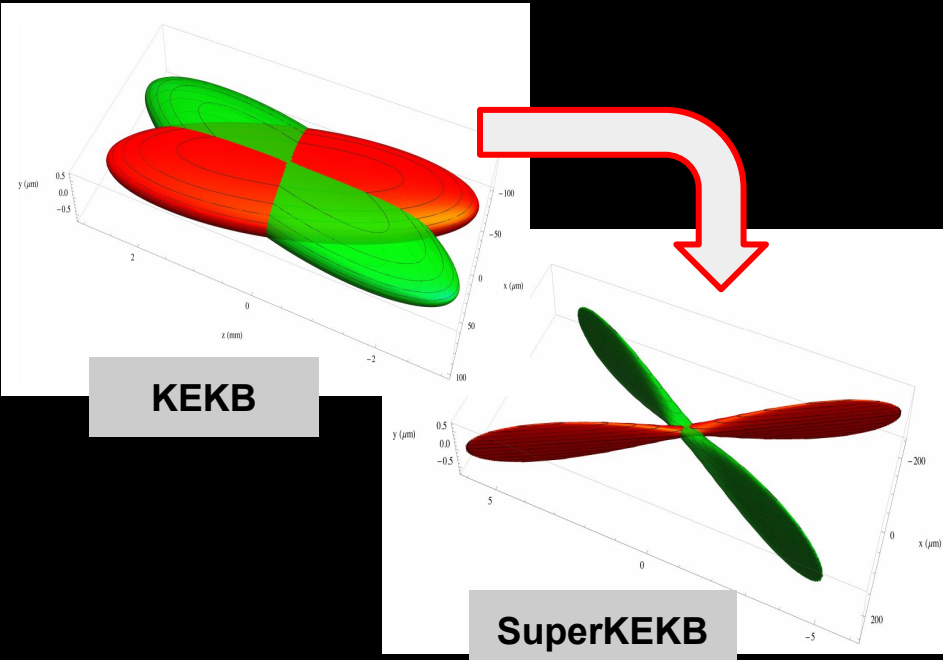
Smaller cell size, long lever arm

positrons (4 GeV)



# From KEKB to SuperKEKB

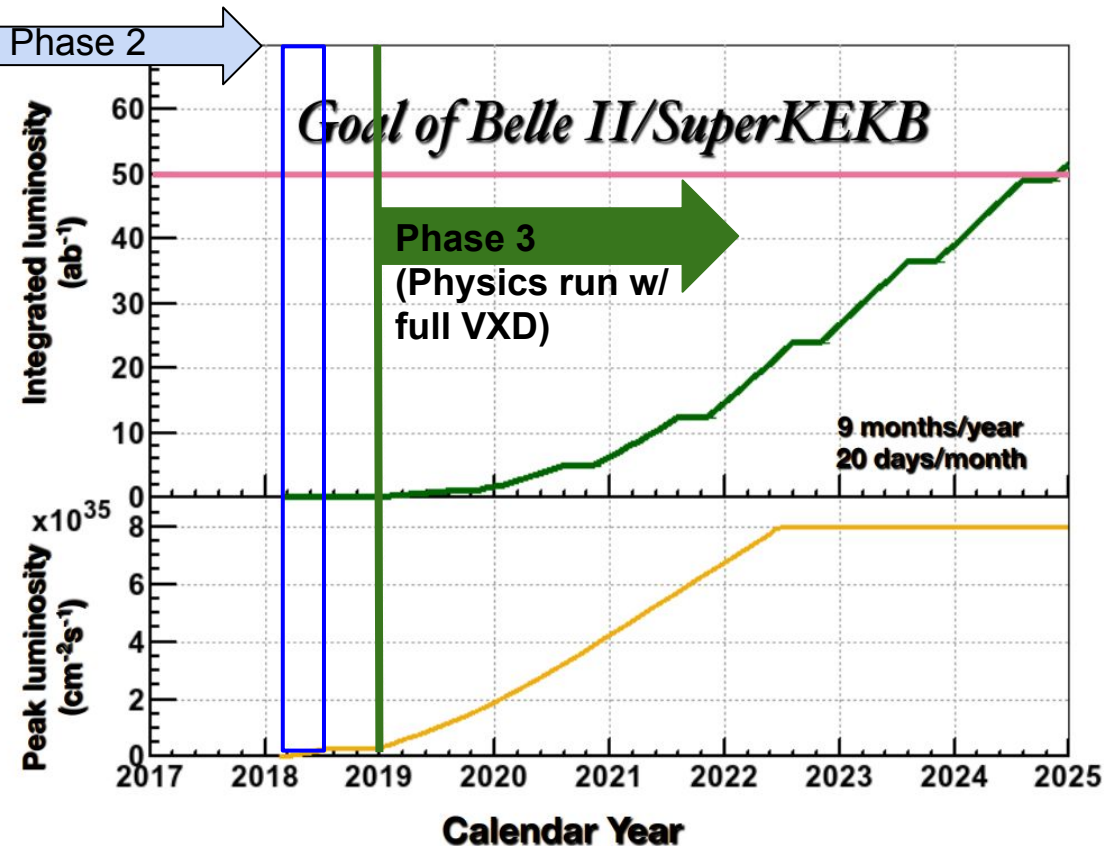
- SuperKEKB: The B-factory at KEK
- Asymmetric  $e^- - e^+$  collider
- 10.58 GeV com energy



**Doubled** Beam currents and change to 'nanobeam' (shown at left)

- **40x** KEKB instantaneous luminosity
- **50x** KEKB integrated luminosity

# Belle II Data Taking Plan



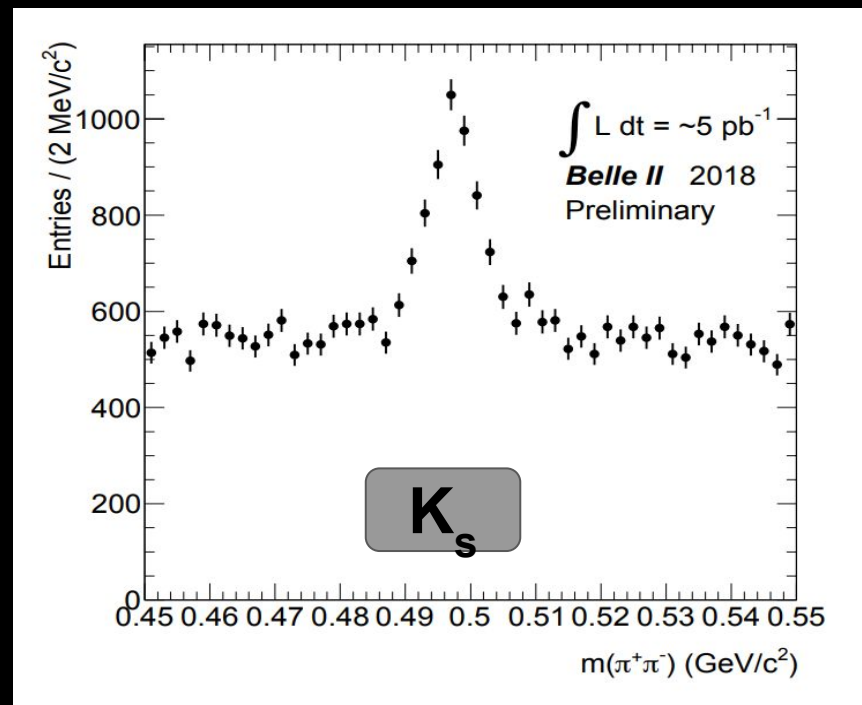
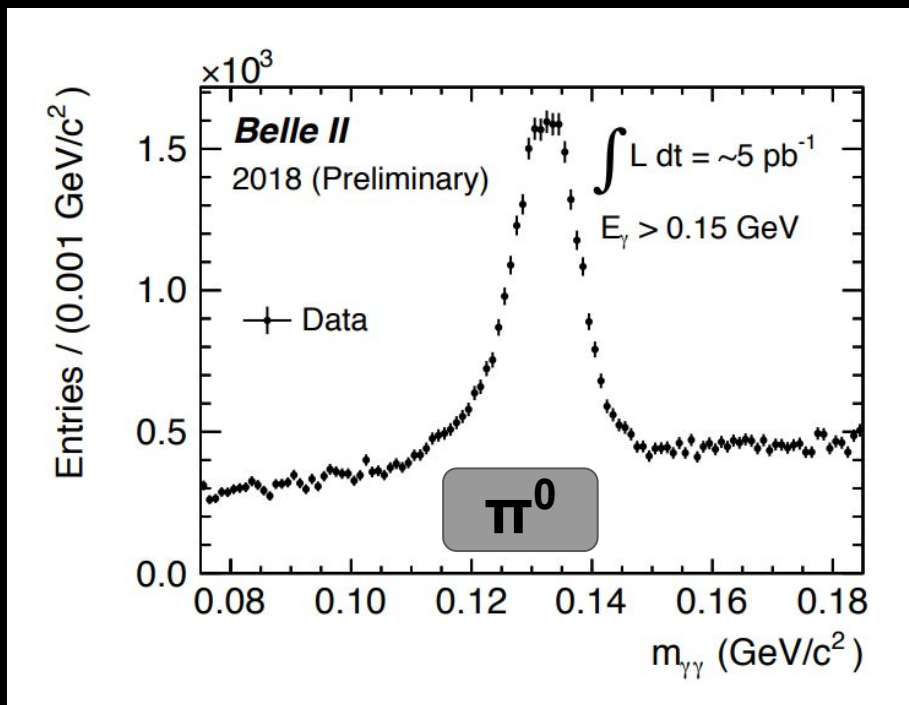
## Phase 2:

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

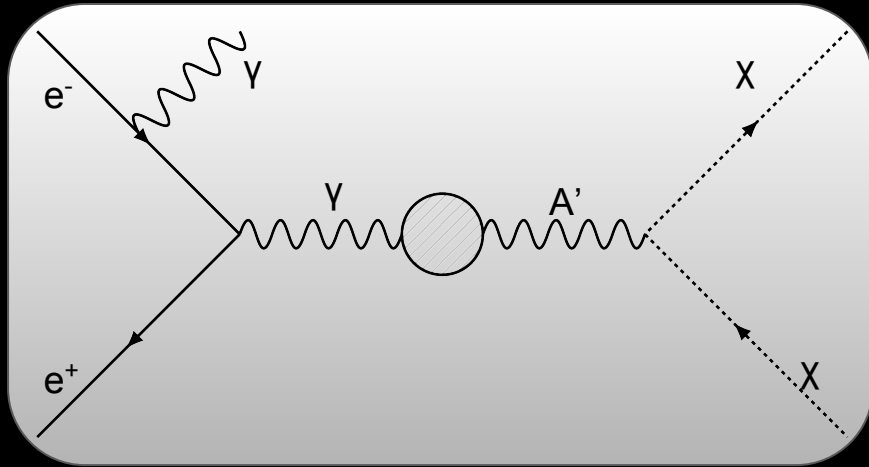
## Phase 3:

- Full physics running with Vertex Detector
- $\int L = 50 \text{ ab}^{-1}$  planned
- Begin in 2019

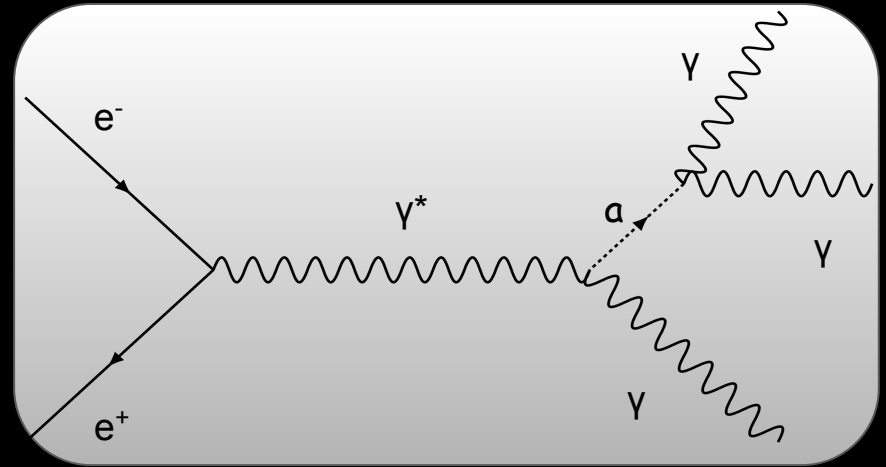
# Phase 2 Data: Particle Re-discoveries



# Dark Sector Searches: Invisible Dark $\gamma$ and ALPs



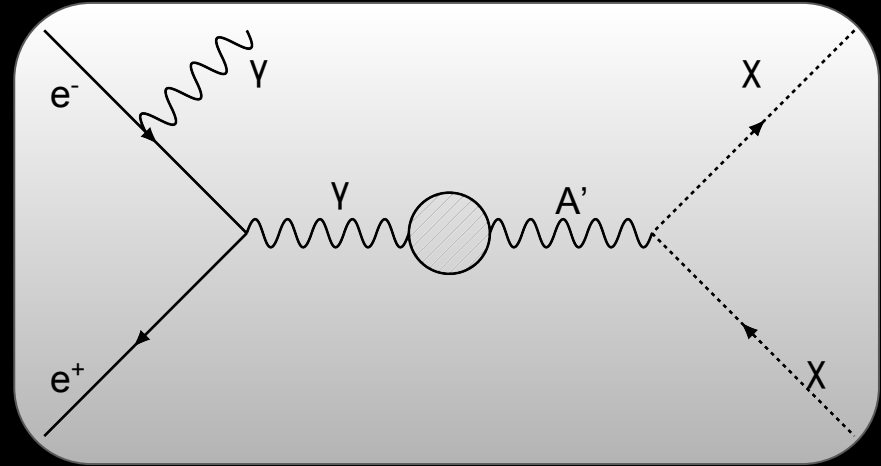
**Vector:** Dark  $\gamma \rightarrow$  Invisible



**Pseudoscalar:** Axion-Like Particles

# Dark $\gamma \rightarrow$ Invisible

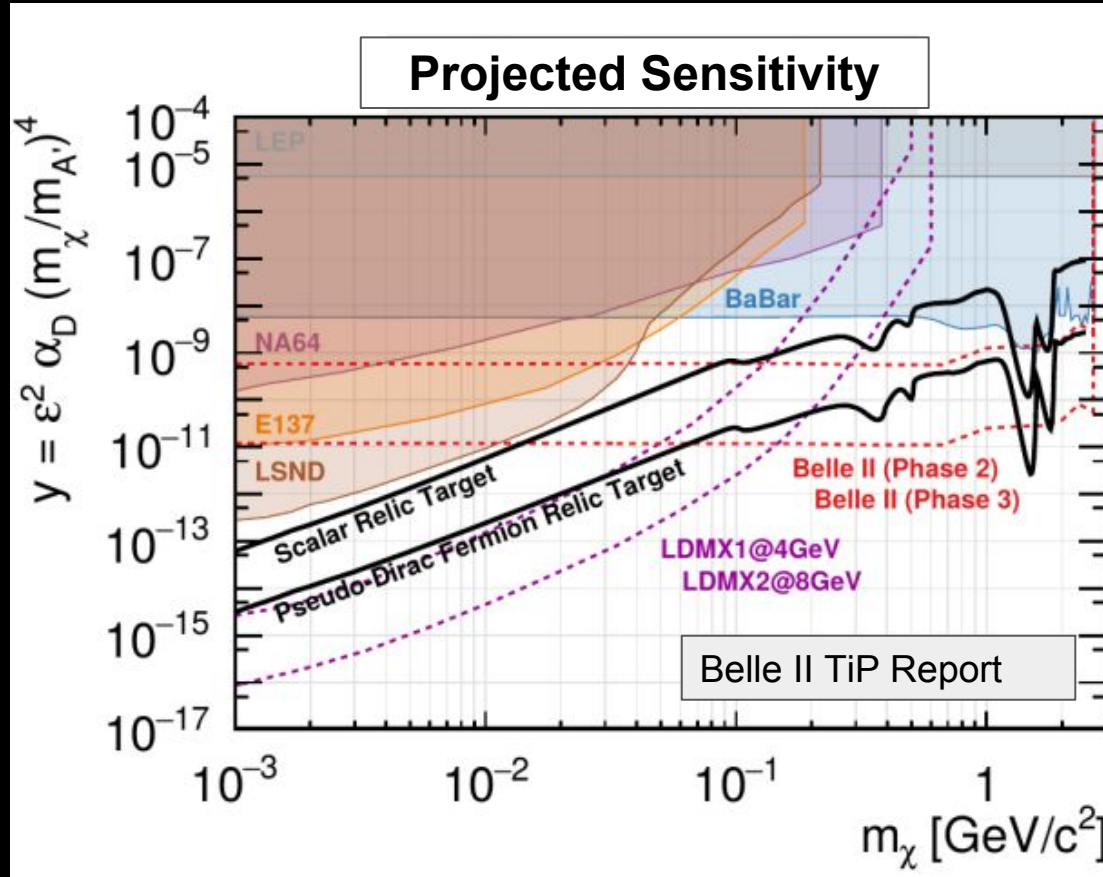
- Light (GeV scale) hidden dark sector weakly coupled to SM by dark photon  $A'$
- Experimental signature: only 1 high-energy photon in detector
- Needs single photon trigger
  - Not present in Belle
  - Only present of  $\sim 10\%$  of BaBar
  - Implemented for Phase 2
- $\sim$ No true physics backgrounds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



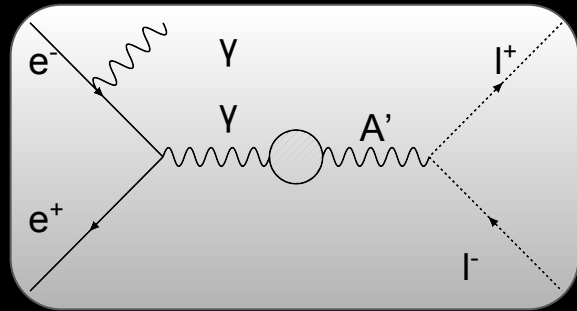
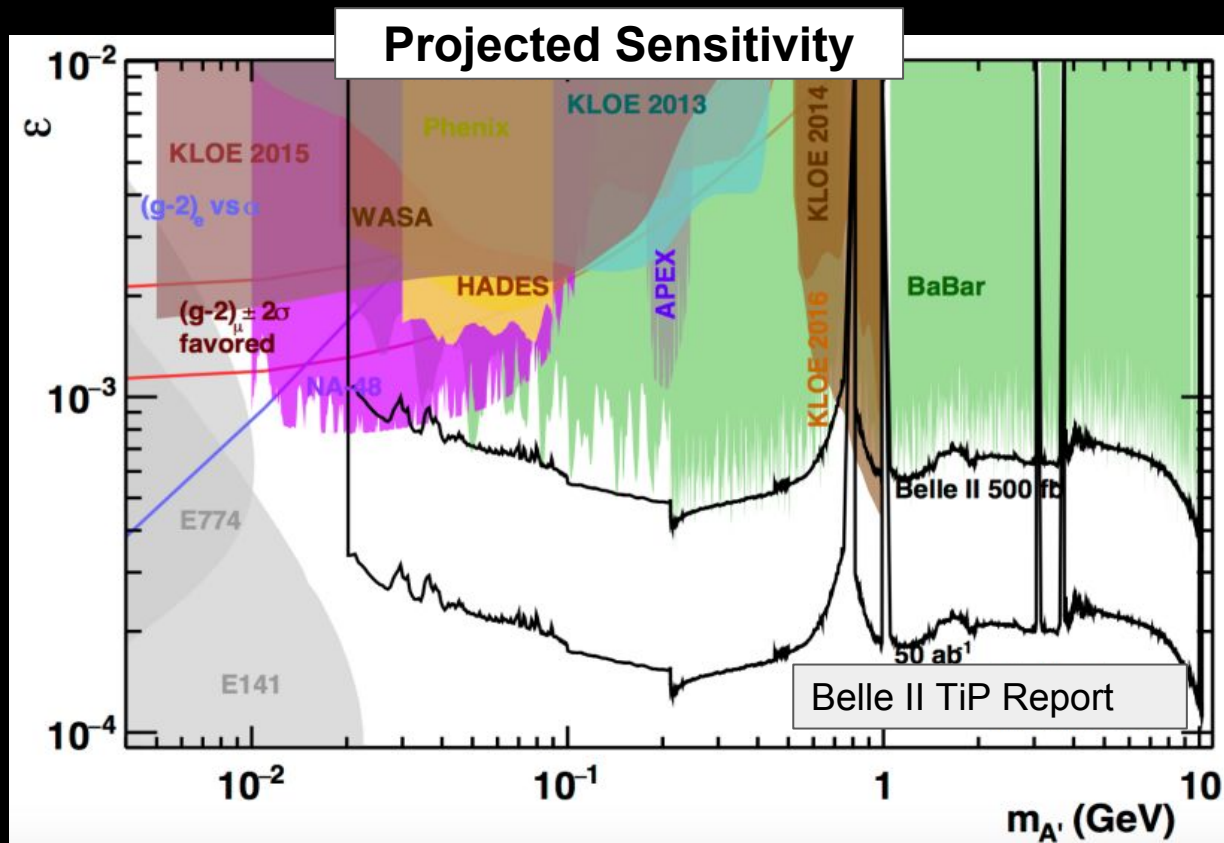


# Dark $\gamma \rightarrow$ Invisible: Prospects

Improved luminosity and calorimeter hermeticity can allow great improvement!

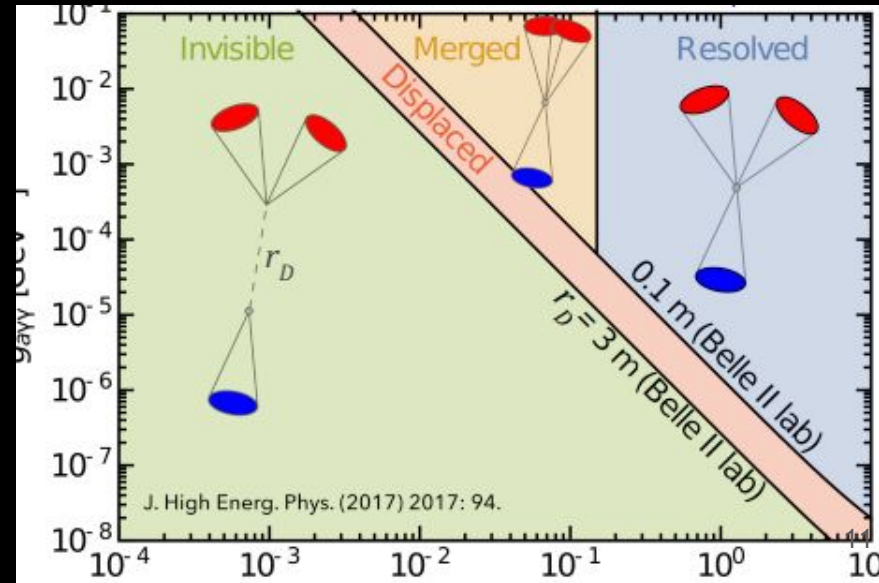
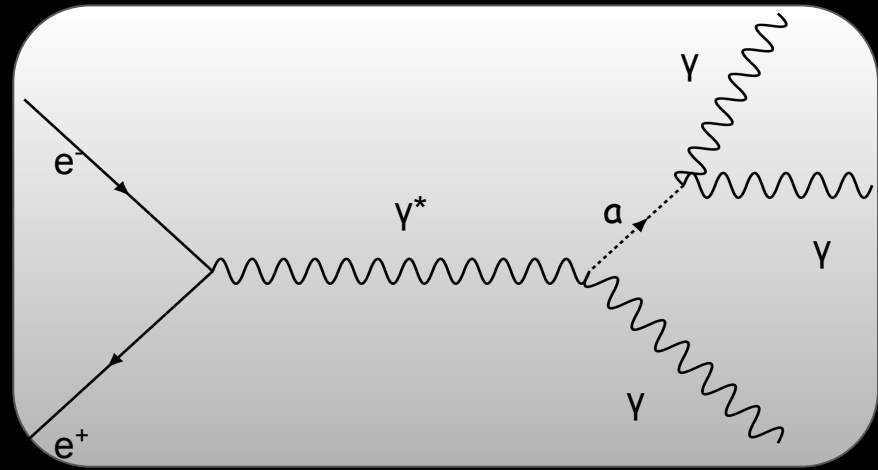


# Dark $\gamma \rightarrow$ Visible dileptons: Heavier DM

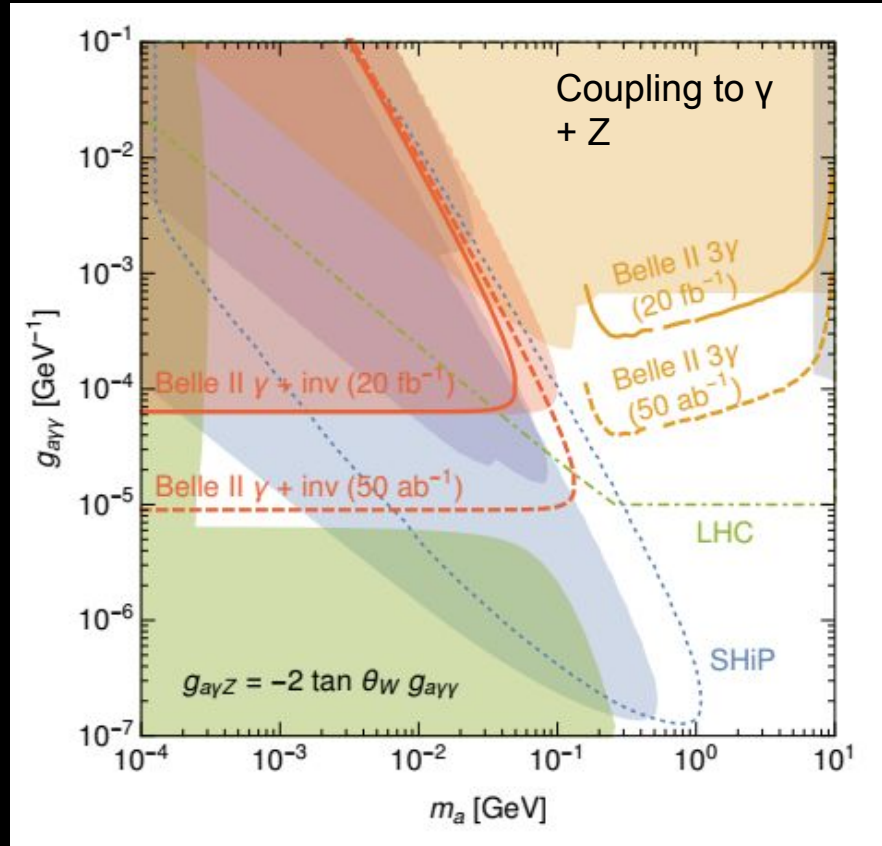
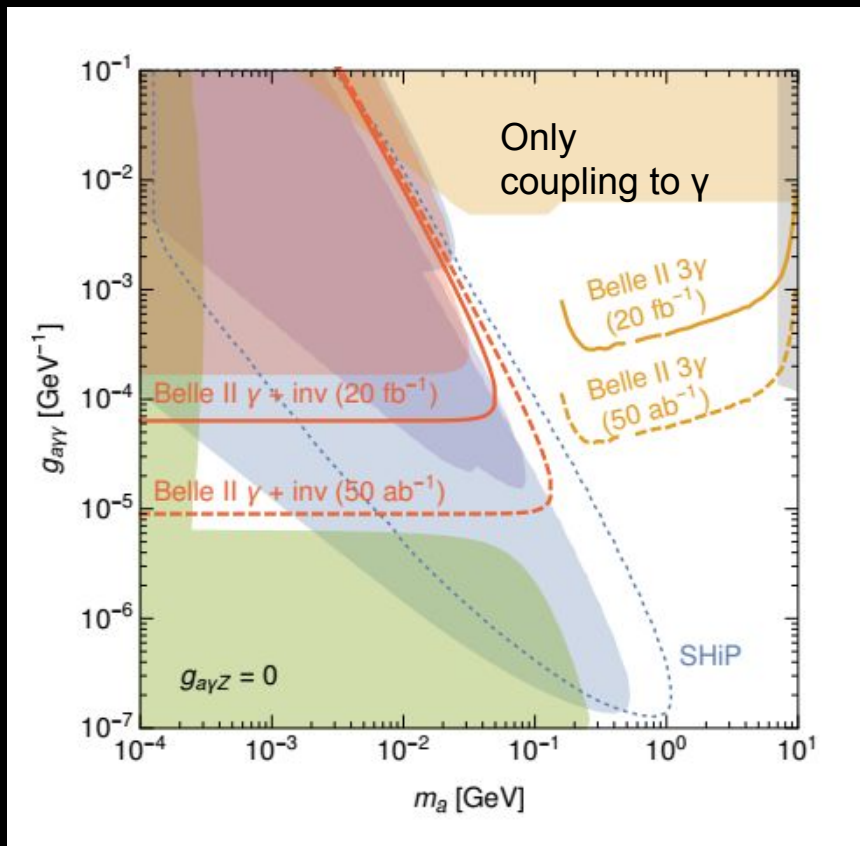


# Axion-Like Particles (ALPs)

- 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





# Summary

- Belle II Phase 2 finished last month with  $5.5 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ ,  $\int \mathcal{L} dt \sim 0.5 \text{ fb}^{-1}$
- 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  $50 \text{ ab}^{-1}$

## Other searches possible!

- Magnetic Monopoles
- Invisible  $Z'$ ,  $Z' \rightarrow \text{LFV}$  (e - $\mu$  coupling)
- Dark scalars
- Dark Higgs
- Off-shell  $A'$  decays
- Even more...

# Backup Slides