



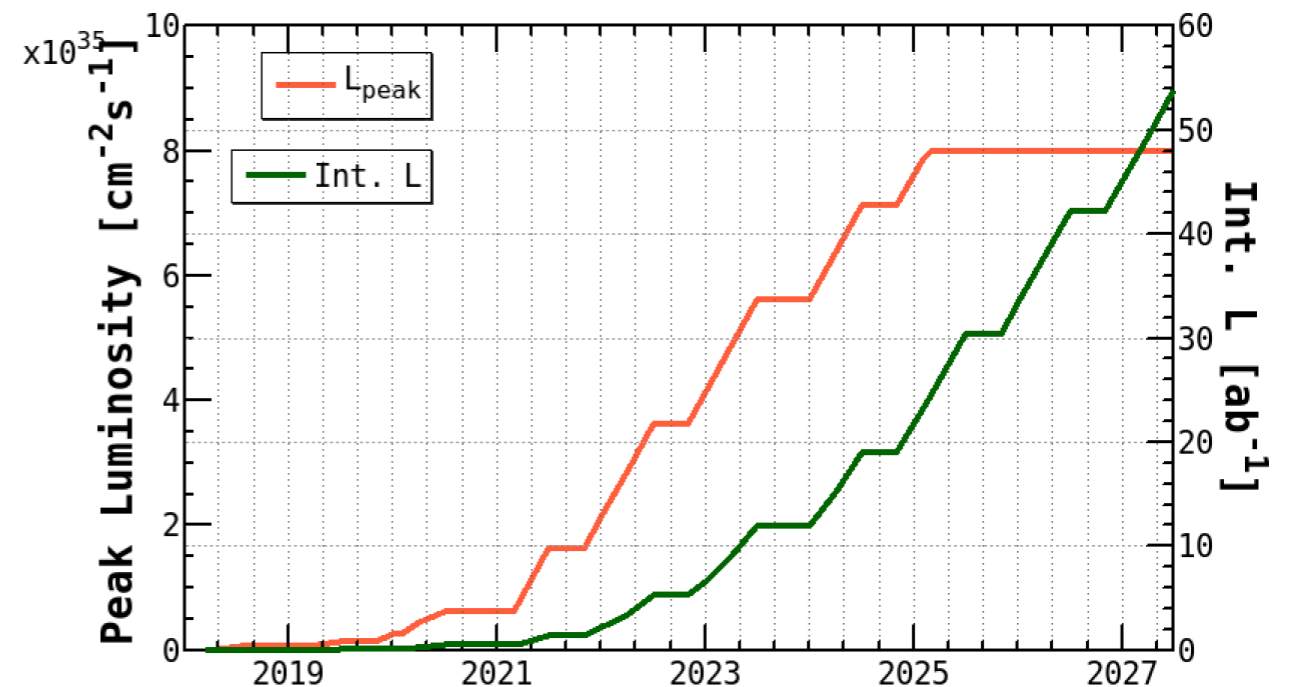
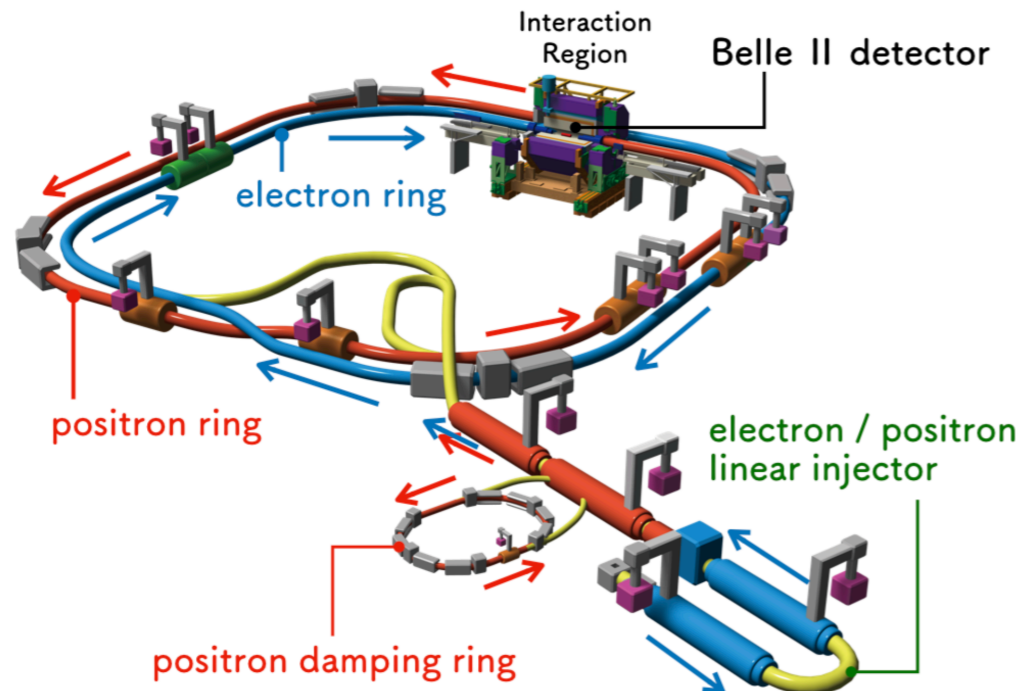
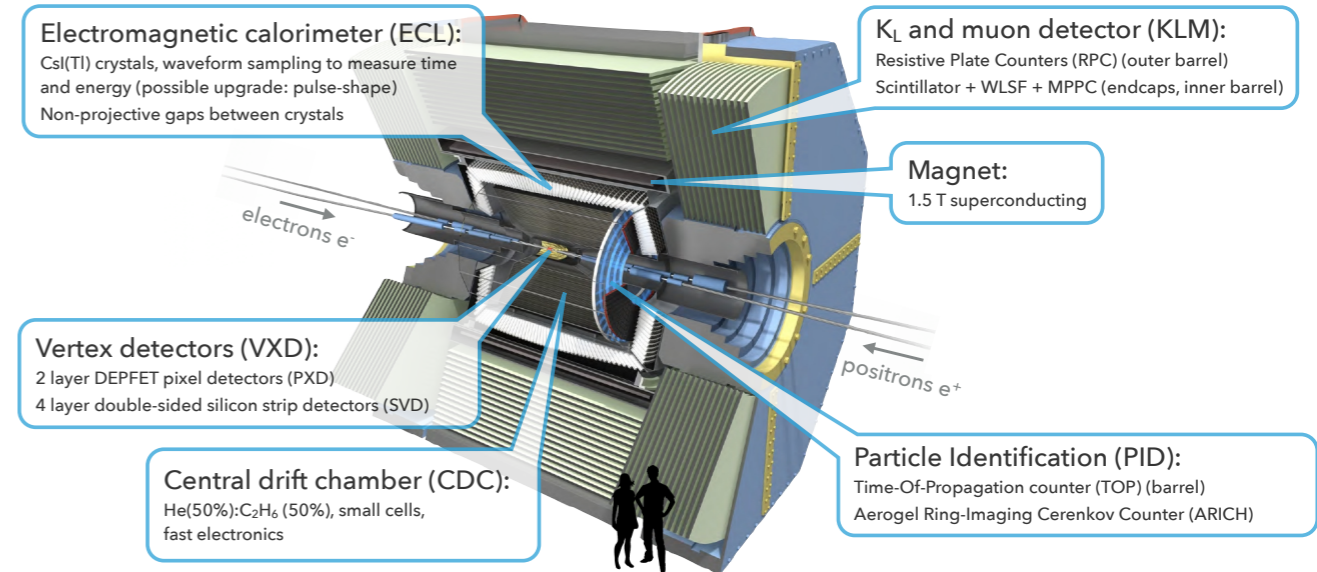
MICHEL BERTEMES

INVISIBLES19

DARK SECTOR WITH BELLE II

BELLE II AND SUPERKEKB

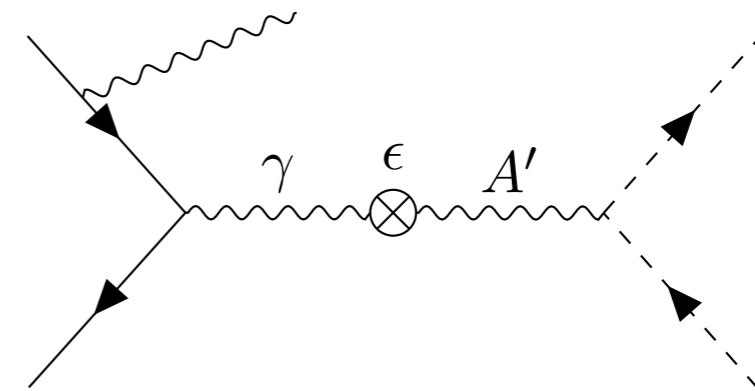
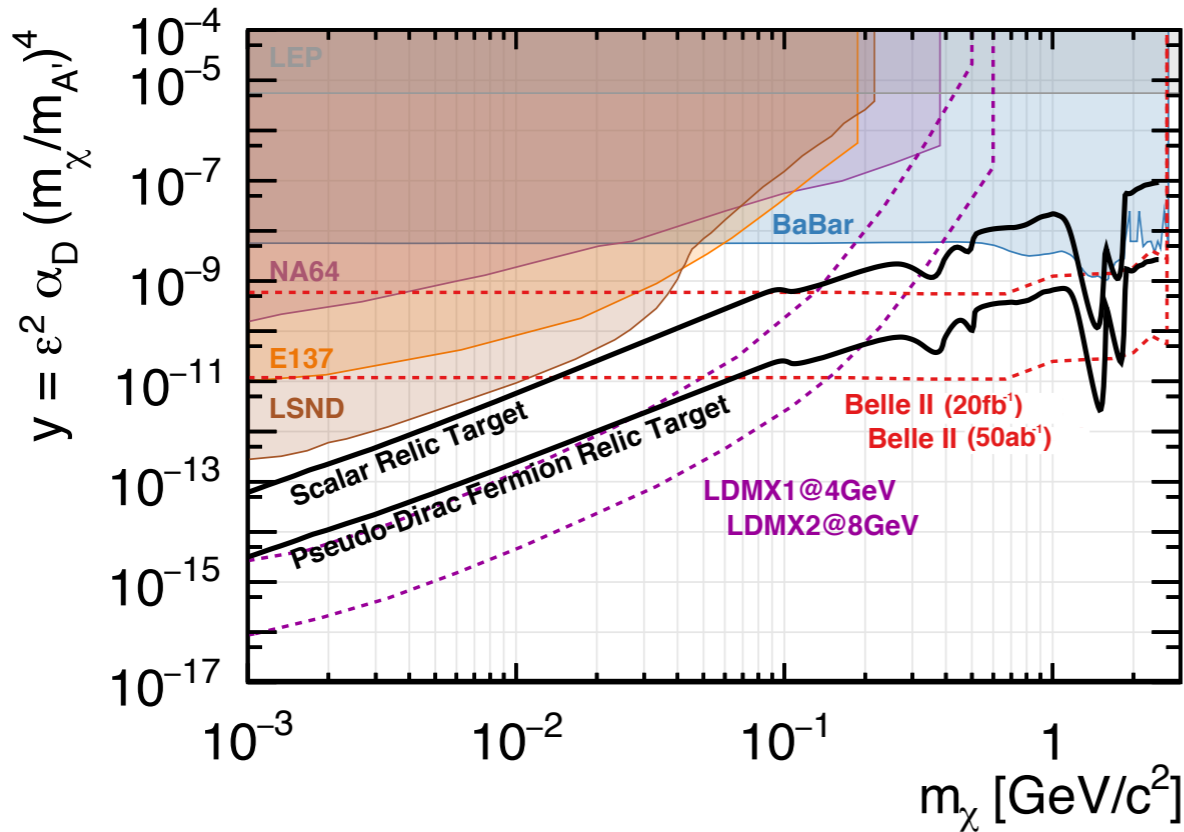
- ▶ located at IP of e^+e^- collider SuperKEKB in Tsukuba, Japan
- ▶ commissioning run from Feb to Jul 2018, regular operations started in Mar 2019
- ▶ operated at 10.58 GeV ($= m_{\Upsilon(4S)}$)
- ▶ design luminosity $8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
- ▶ rich physics program: B and D physics, quarkonium and low mass dark sector



→ collect 50 times more data than Belle



DARK PHOTON

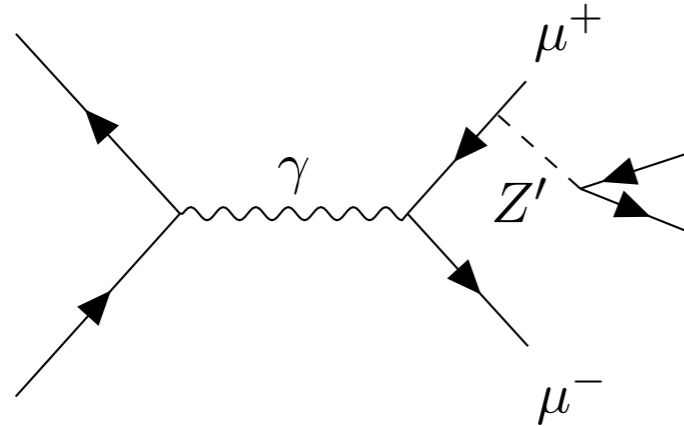


Trigger	Rate at full luminosity
$E^* > 1\text{GeV} + \text{second cluster with } E^* < 0.3\text{GeV}$	4kHz (barrel) 7kHz (endcaps)
$E^* > 2\text{GeV} + \text{Bhabha veto}$	5kHz (barrel)

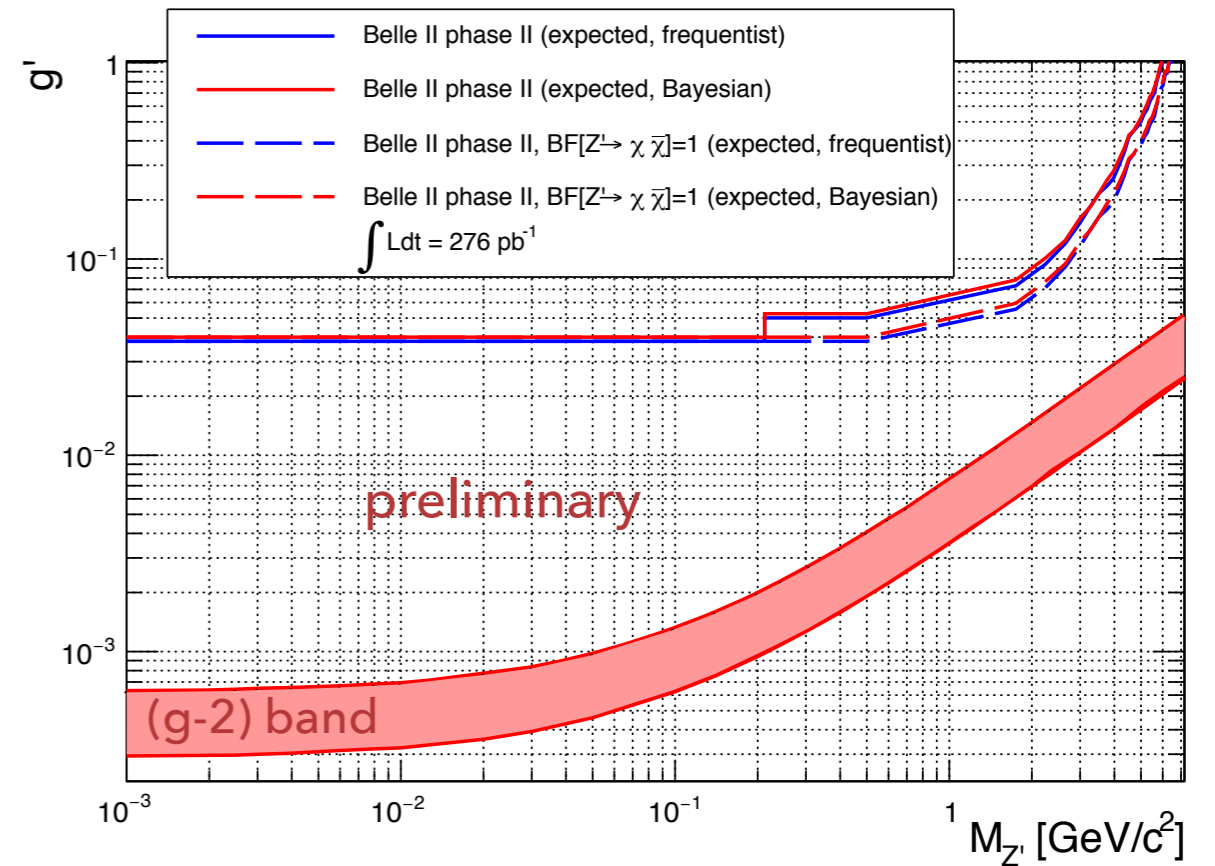
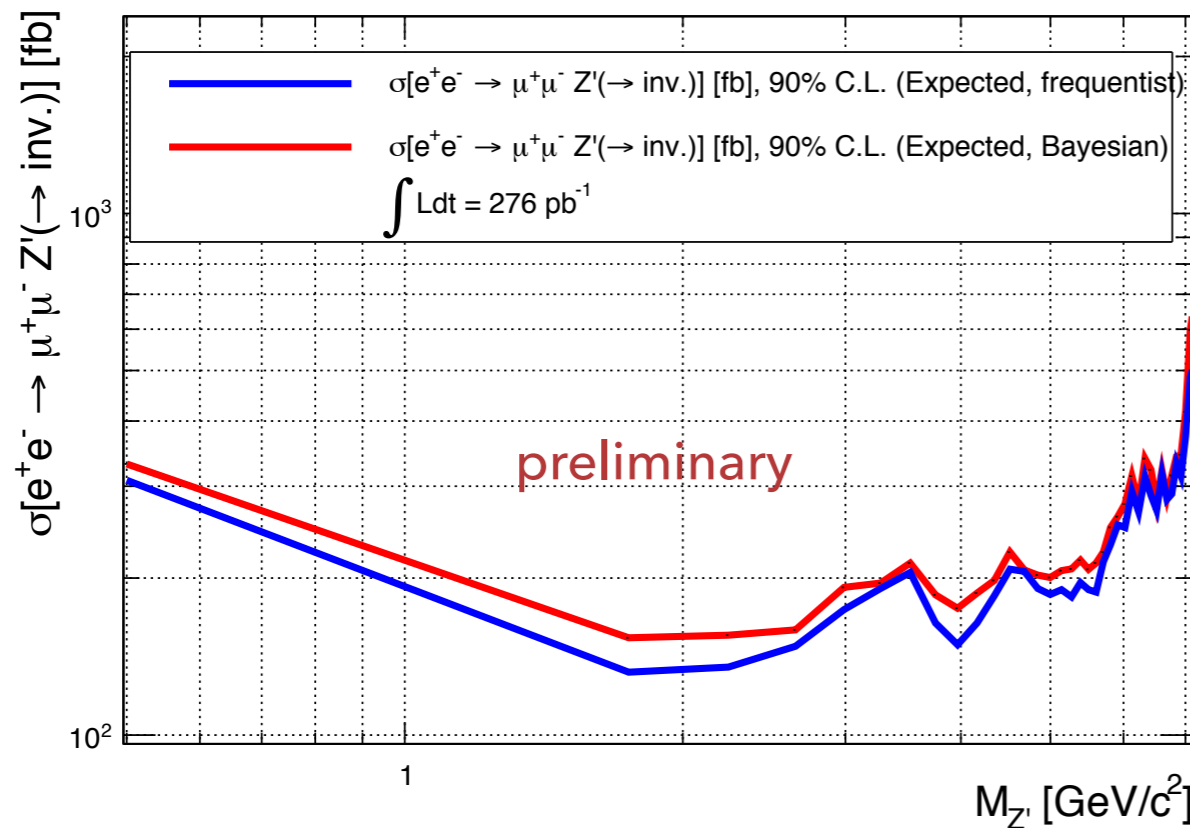
- ▶ dark photon A' can couple to the SM photon via kinetic mixing parameter ϵ
- ▶ consider on-shell A' decays, different experimental signatures according to $m_{A'}$
 - if A' is the lightest DS particle, decay into SM, peak in invariant mass of decay products
 - if A' is not the lightest DS particle, decay into DM, mono-chromatic ISR photon

→ single photon trigger

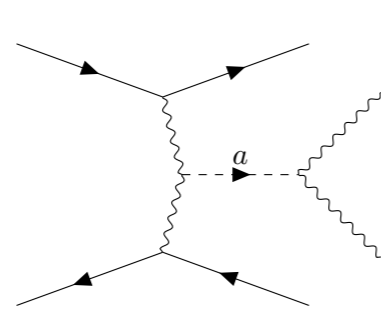
DARK Z'



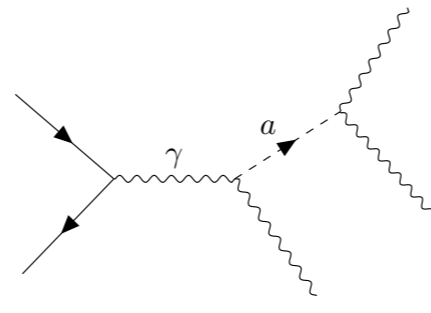
- ▶ extend SM by adding a $U(1)'$ group
- ▶ new massive gauge boson Z' coupled to $L_\mu - L_\tau$ via g'
- ▶ focus on invisible Z' decay produced with pair of muons
- ▶ search for two muons with missing energy and bump in mass recoiling against two muons



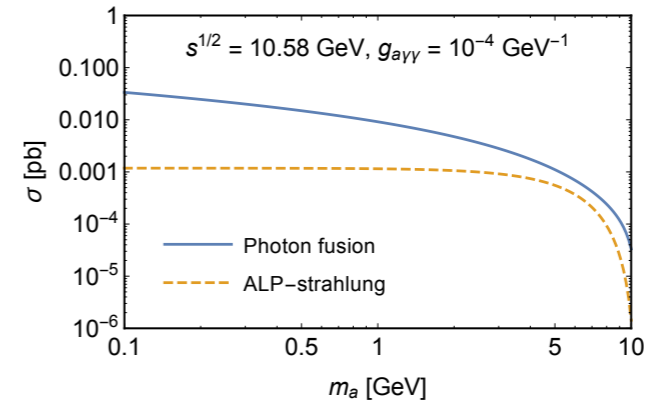
ALPS



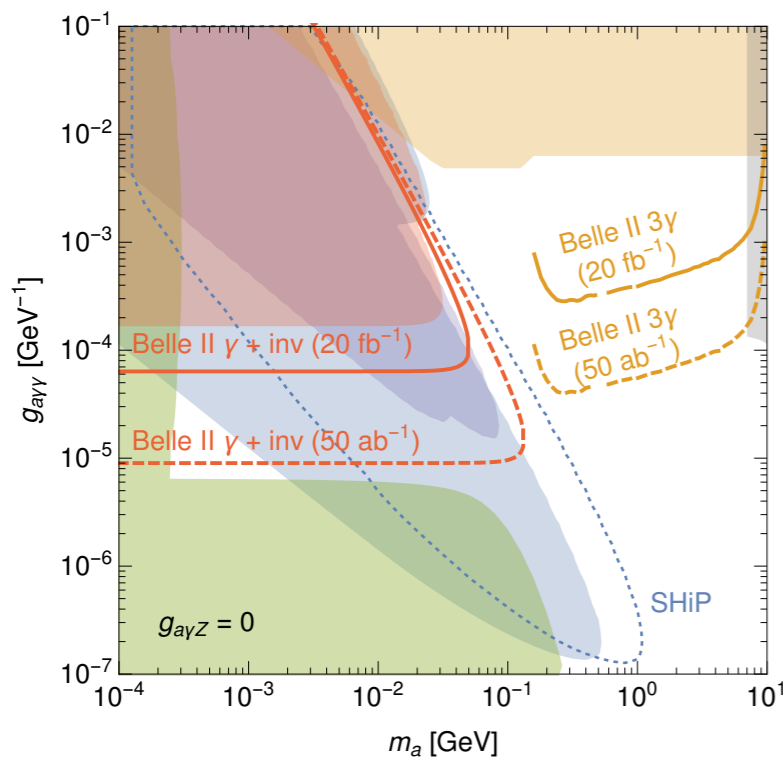
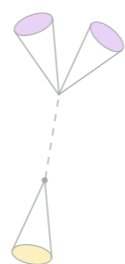
ALP-fusion



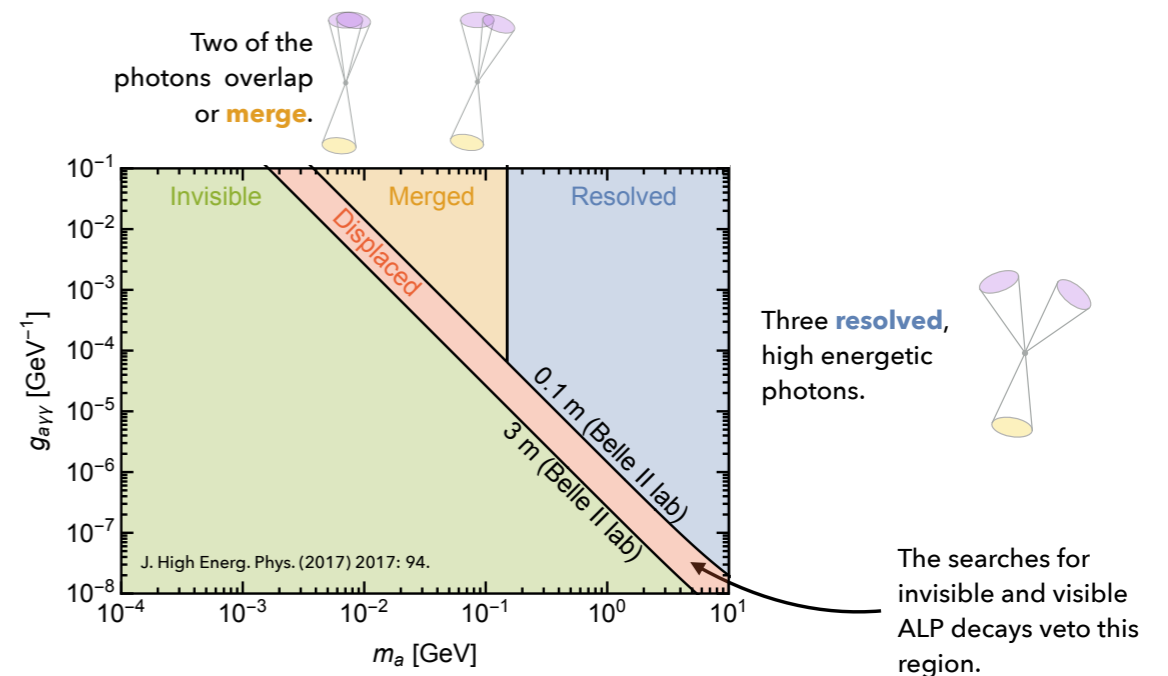
ALP-strahlung



- ▶ axion-like particles are pseudoscalar bosons appearing in different extensions to the SM
- ▶ coupling and mass of ALPs are taken to be independent
- ▶ simplest approach at Belle II is via two photon coupling $g_{a\gamma\gamma}$
 - ALP-fusion, dominates, high QED background
 - ALP-strahlung, most promising search channel

ALP decays outside of the detector or decays into **invisible** particles: Single photon final state.



CONCLUSION

- ▶ Belle II: start of data taking, different low mass DS analysis
- ▶ Dark Photon: kinetic mixing with SM photon, single photon trigger, ECL hermeticity
- ▶ Dark Z': coupling to muons and tauons, bump in recoil mass, (g-2) anomaly
- ▶ ALPs: two photon coupling, different signatures according to mass and coupling

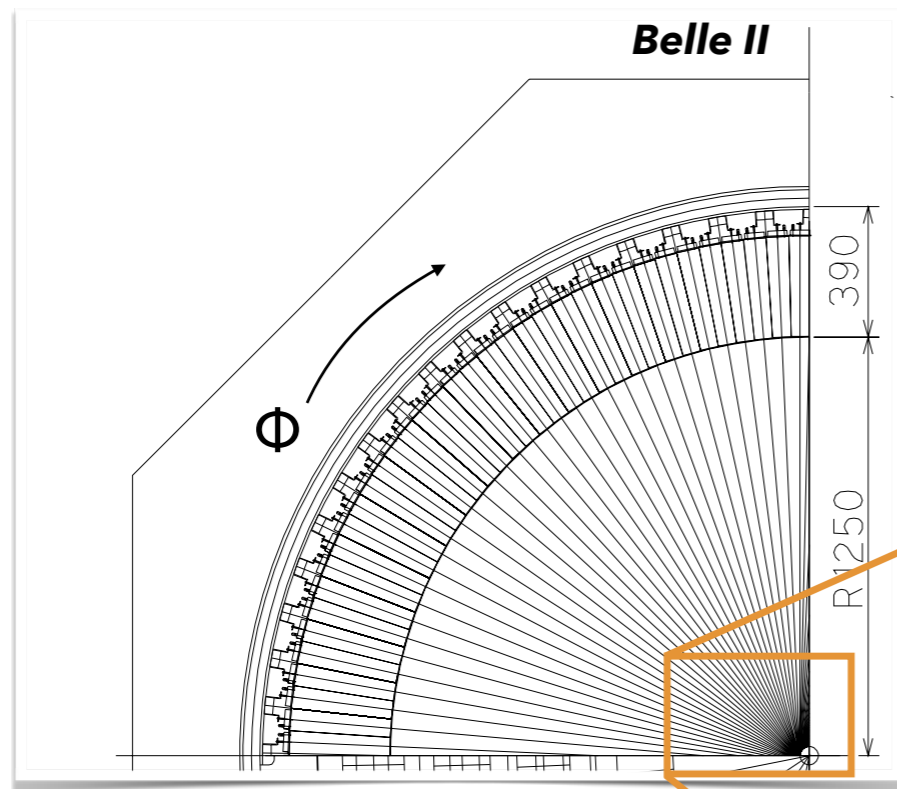
THANK YOU FOR YOUR ATTENTION!



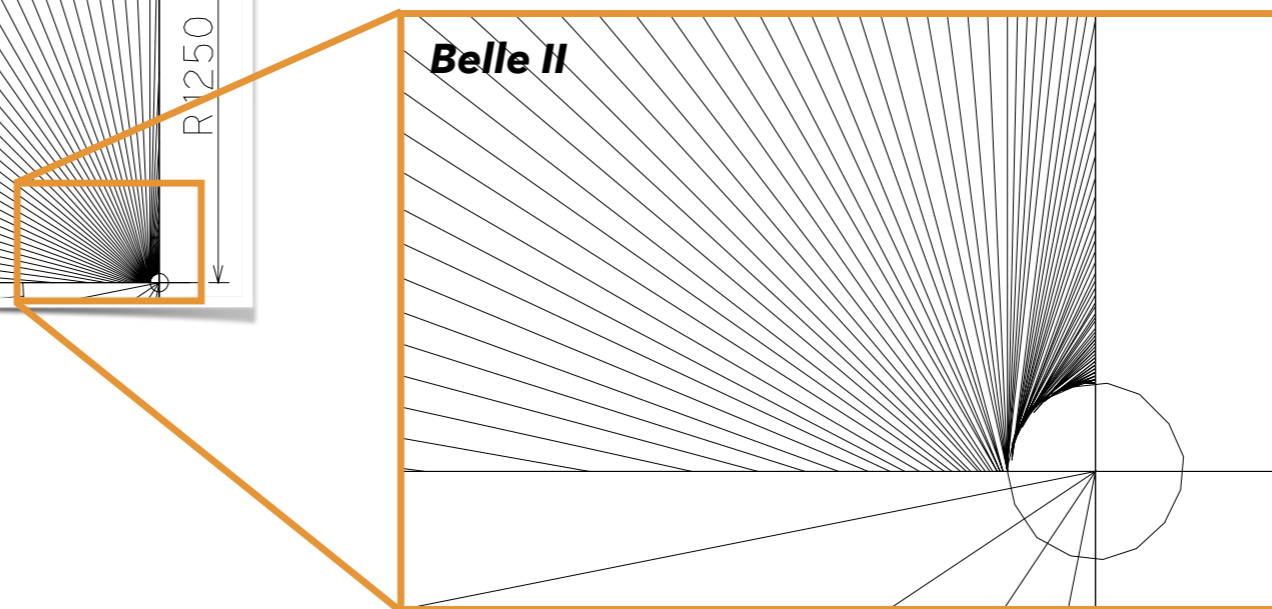
BACKUP



DARK PHOTON



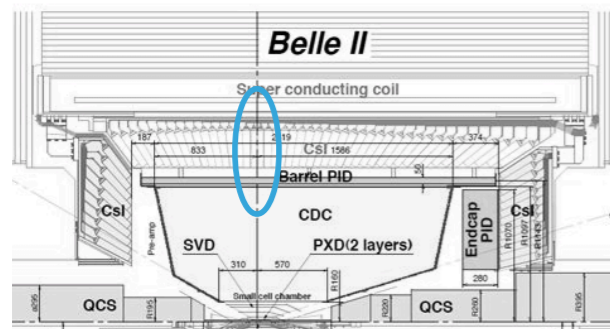
- ▶ Belle II ECL has no projective cracks in Φ
- ▶ excellent to measure charge asymmetries
- ▶ not optimal for uniform photon efficiency



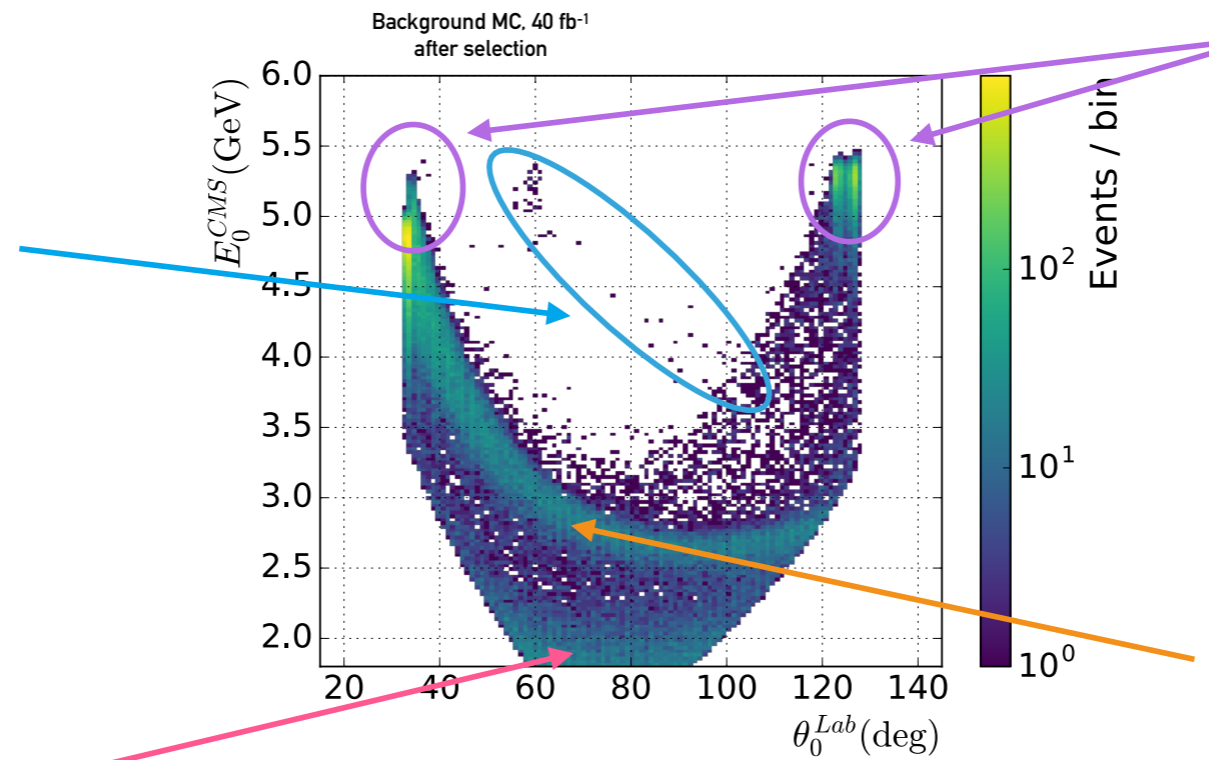


DARK PHOTON

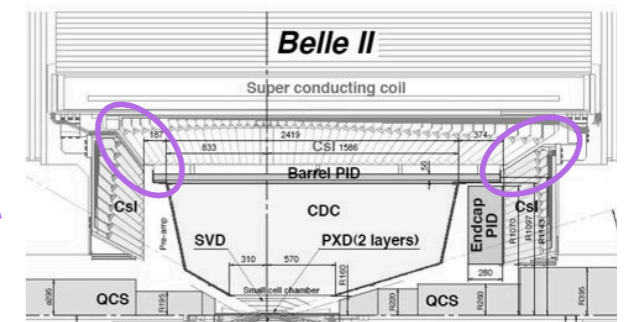
- ▶ different background contributions



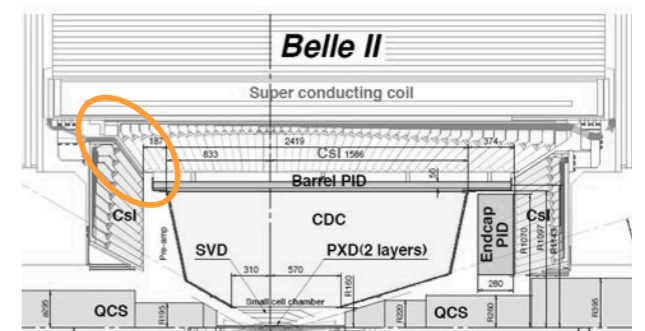
$ee \rightarrow 2\gamma$ and 3γ
 1 γ in ECL 90° gap
 1 γ out of ECL acceptance



$ee \rightarrow eey$
 both electrons
 out of tracking acceptance



$ee \rightarrow 2\gamma$
 1 γ in ECL BWD or FWD gap



$ee \rightarrow 3\gamma$
 1 γ in ECL BWD gap
 1 γ out of ECL acceptance

ALPS

- ▶ select events with three ECL clusters with $E > 0.25$ GeV and search for bump in 2 photon mass spectrum
- ▶ main backgrounds are $ee \rightarrow \gamma\gamma\gamma$, $ee \rightarrow \gamma\gamma$ and $\gamma \rightarrow ee$
- ▶ requires single photon trigger for long-lived ALPs

