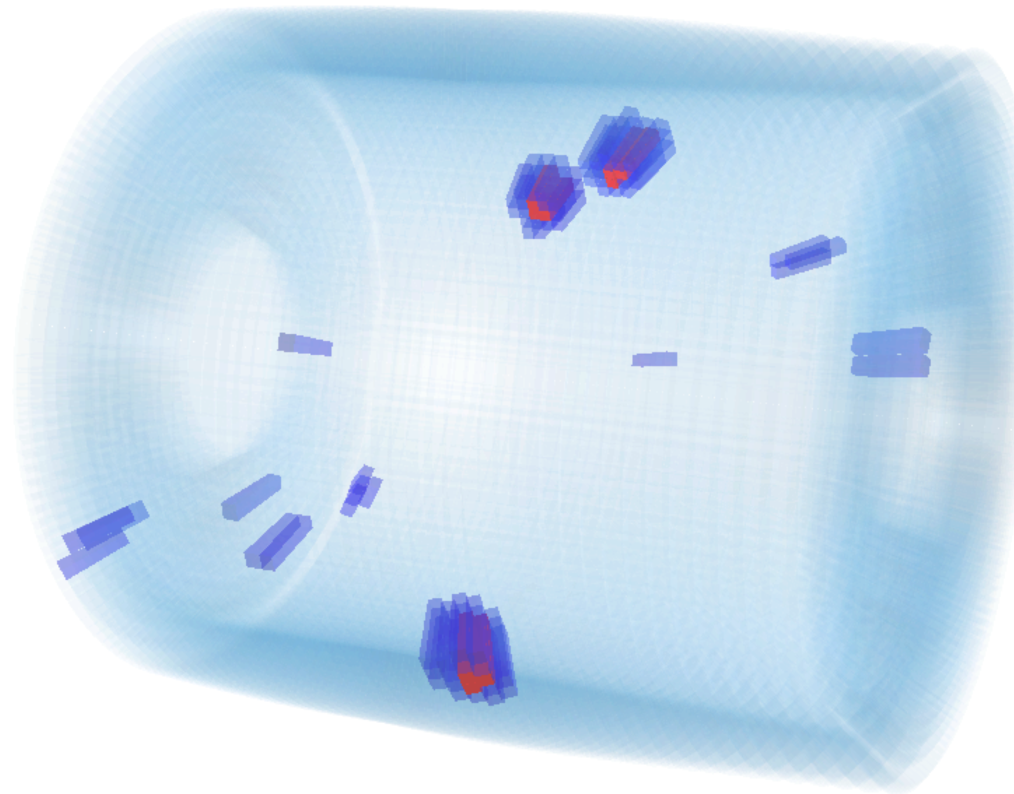
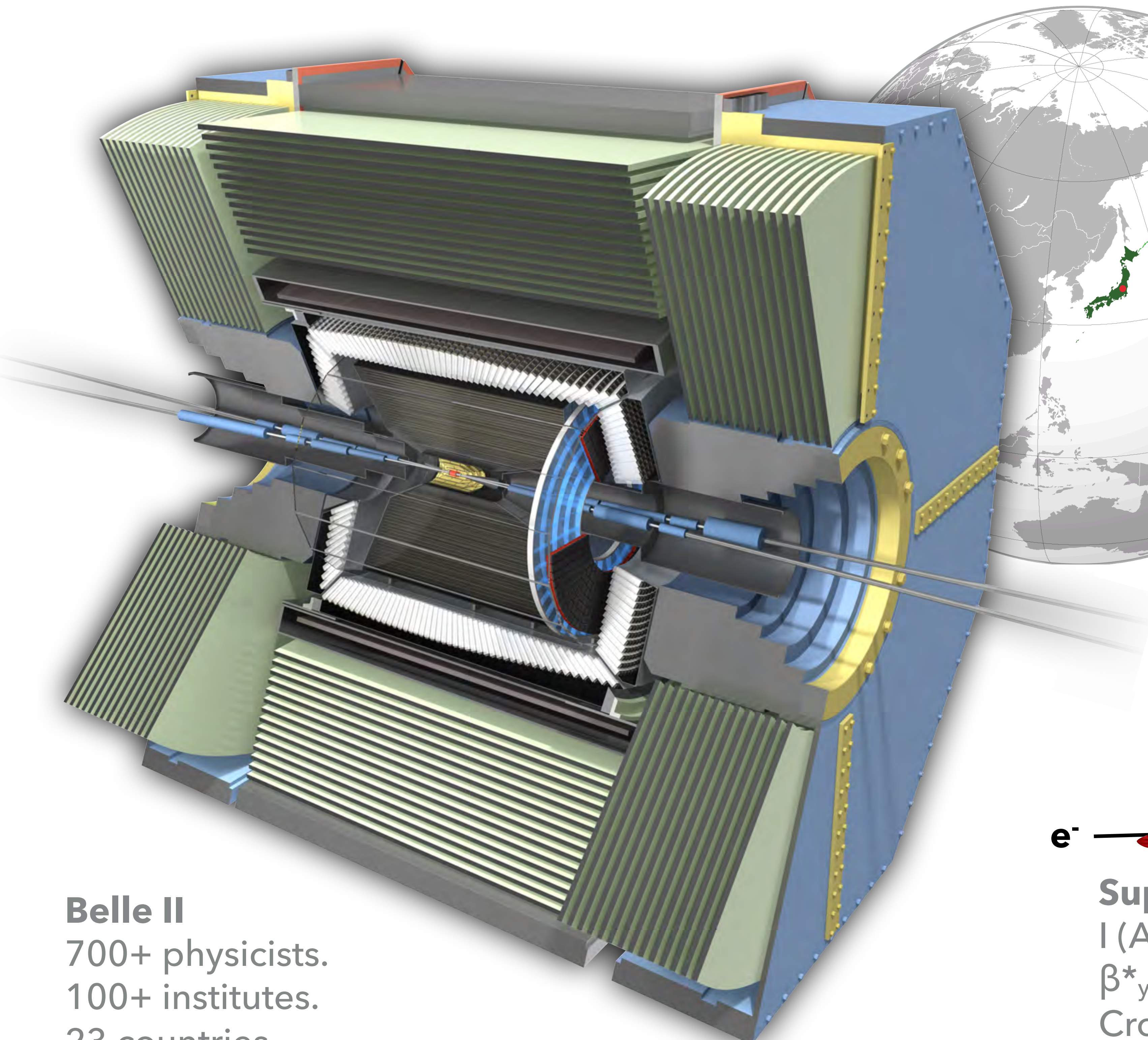
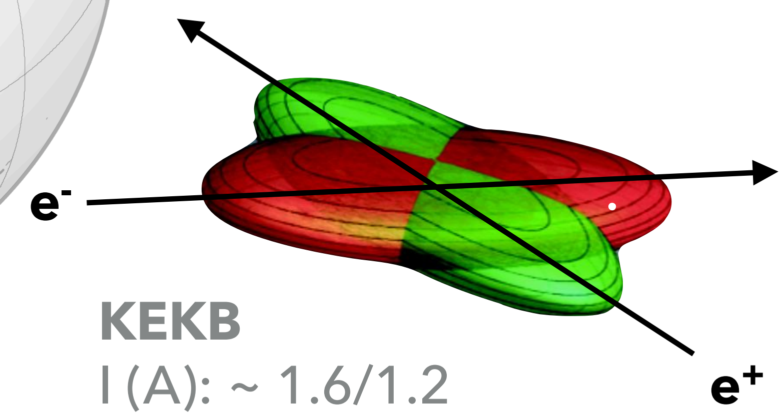


JULY 06 2017, EPS, VENICE
TORBEN FERBER (FERBER@PHYSICS.UBC.CA)

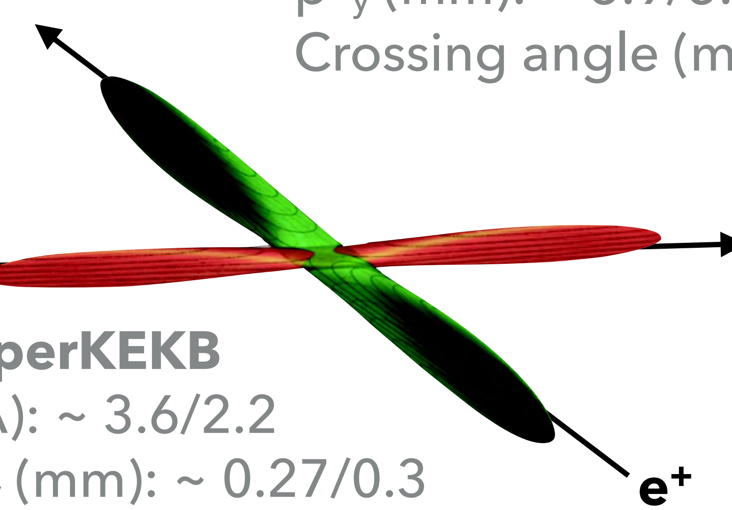
DARK SECTOR PHYSICS WITH BELLE II

BELLE II AT SUPERKEKB: INTENSITY FRONTIER AT 10.58 GEV





KEKB
I (A): ~ 1.6/1.2
β*$_y$ (mm): ~ 5.9/5.9
Crossing angle (mrad): 22

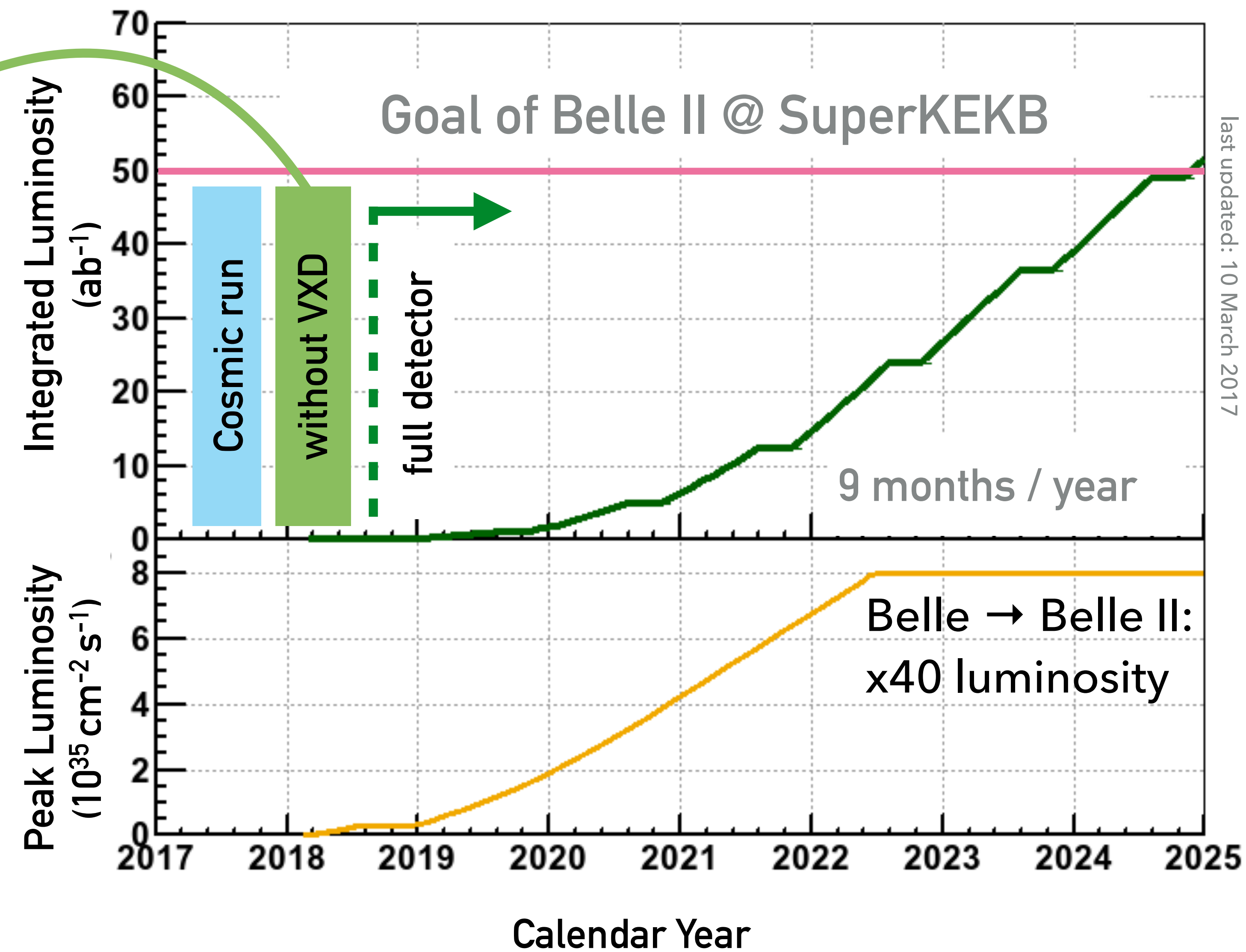


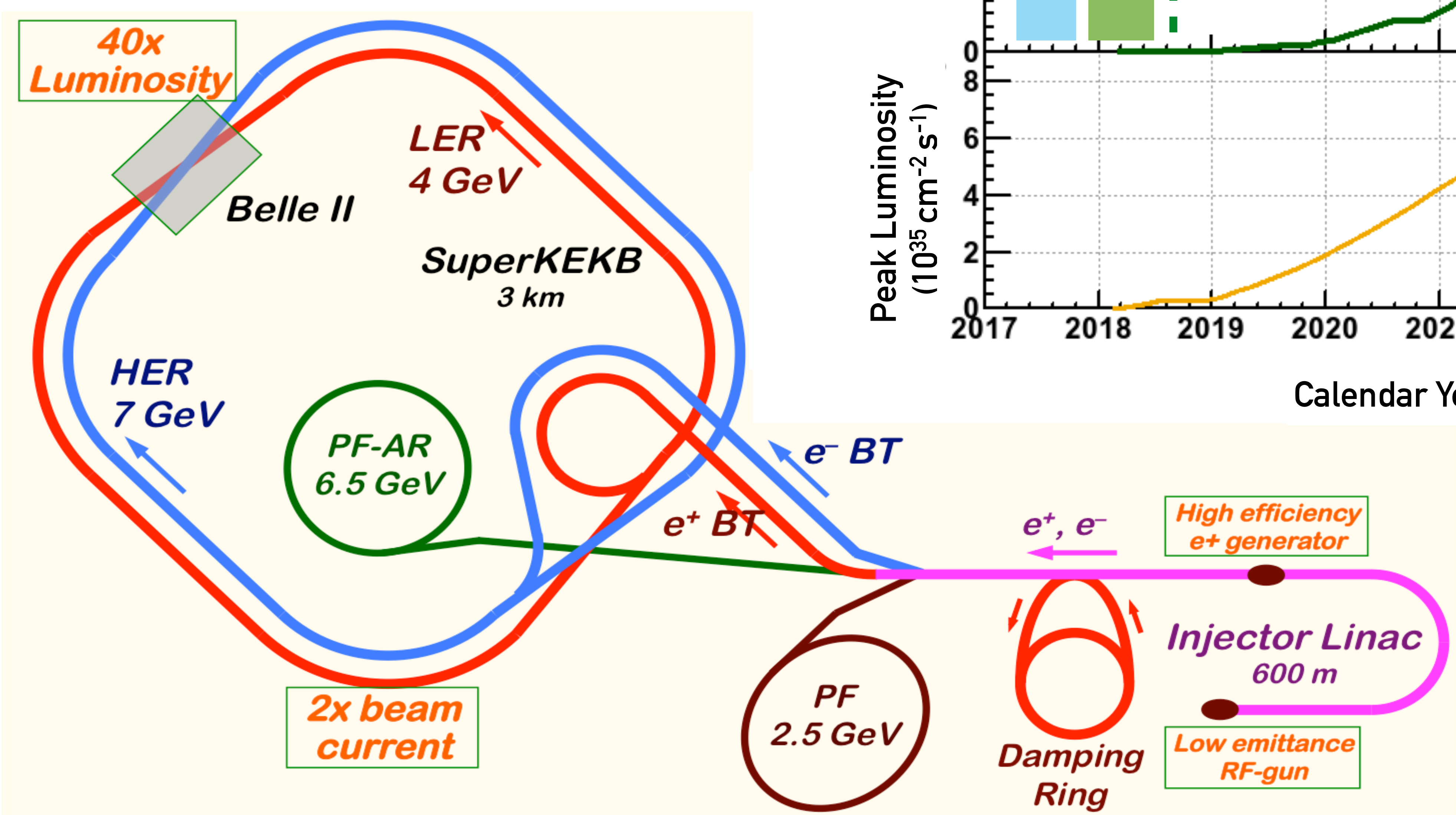
SuperKEKB
I (A): ~ 3.6/2.2
β*$_y$ (mm): ~ 0.27/0.3
Crossing angle (mrad): 83

Belle II
700+ physicists.
100+ institutes.
23 countries.

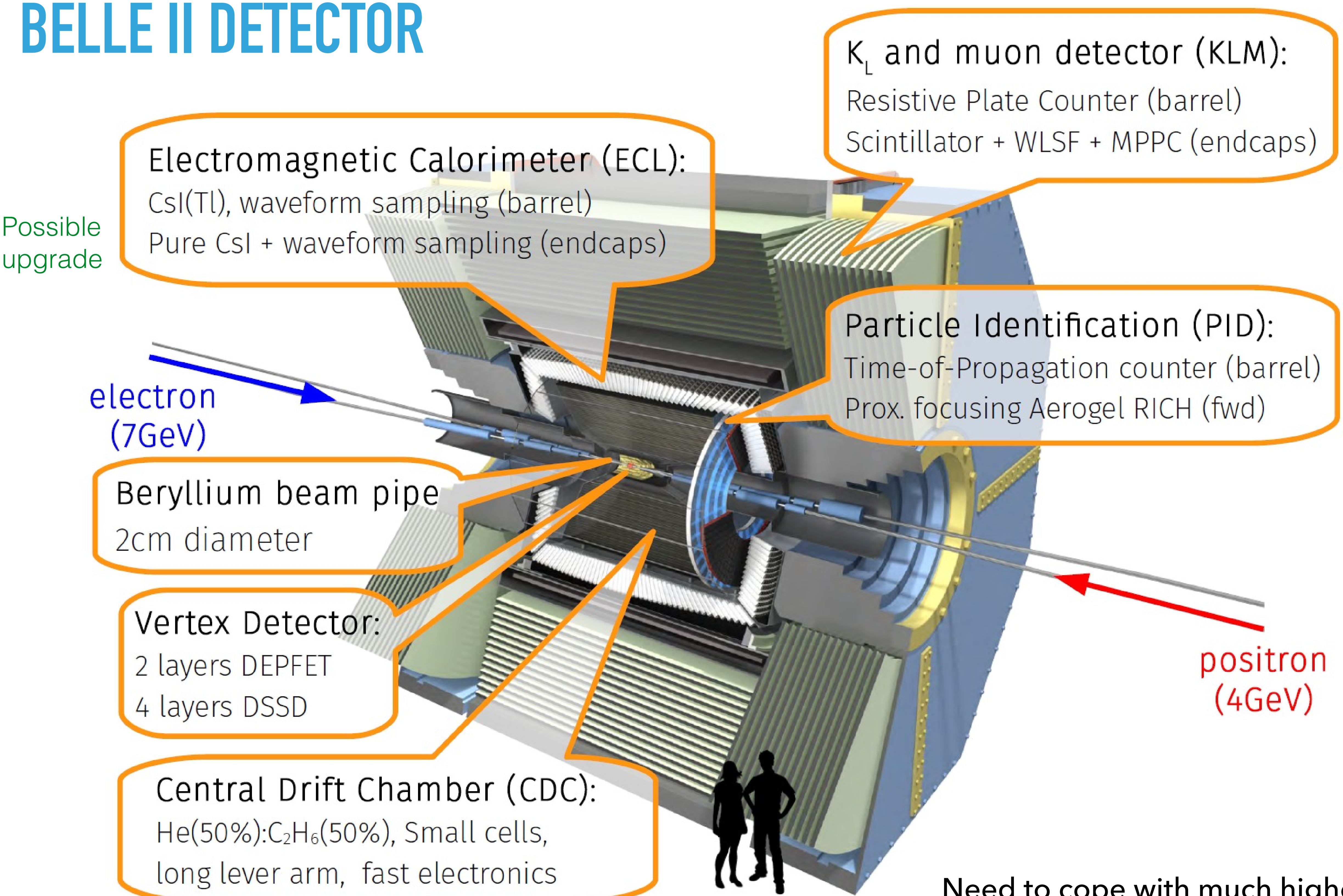
SUPERKEKB AND TIMELINE

"Phase 2" goal:
Peak luminosity as at the end of Belle: $1\times10^{34}\ cm^{-2}s^{-1}$



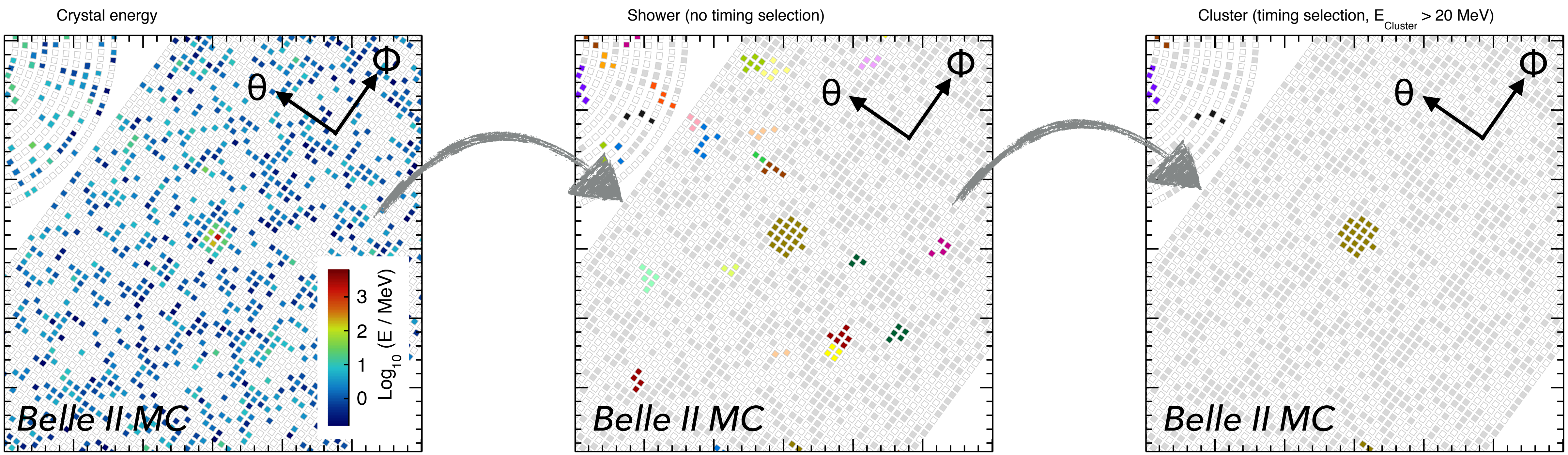


BELLE II DETECTOR



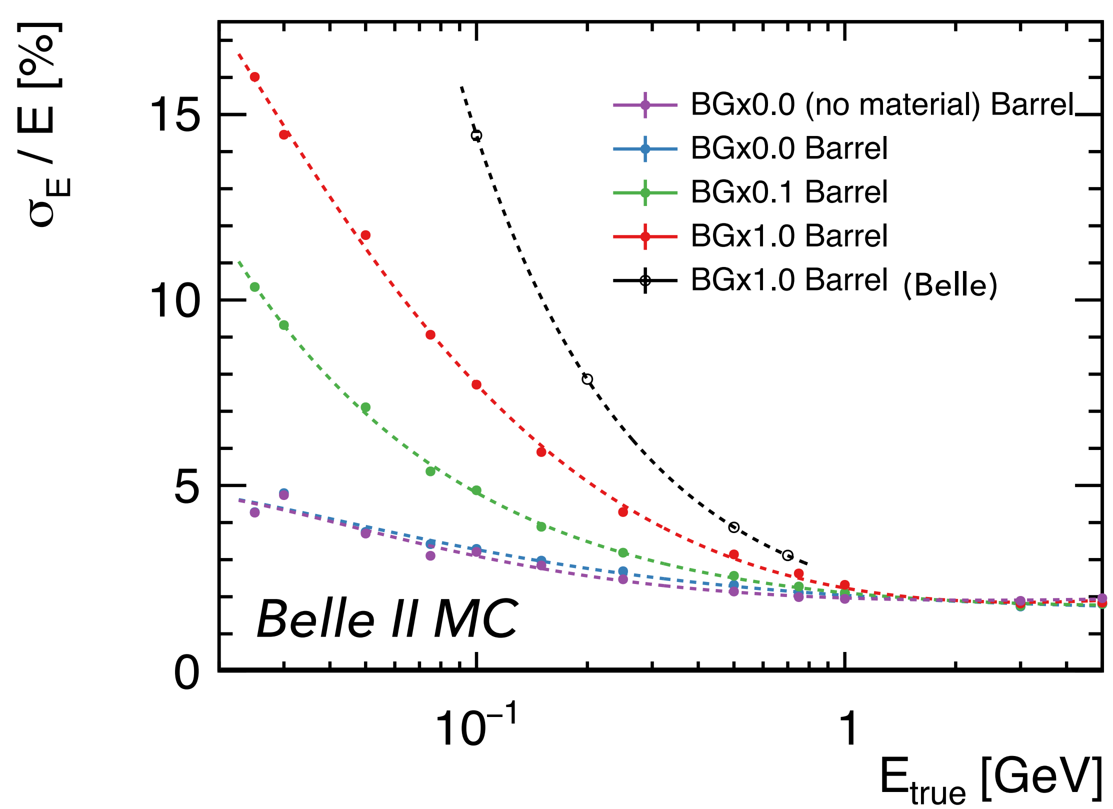
Need to cope with much higher luminosity and beam backgrounds.

BELLE II DETECTOR: ELECTROMAGNETIC CALORIMETER (ECL)



Effects of beam background:
> Degrades energy resolution.
> Radiation damage.
> Pile-up and increased event size.
> Physics background.

→ Upgrades of hardware (detector) and software (reconstruction) are crucial.



WHY BELLE II FOR DARK SECTOR SEARCHES?

Belle II 2018 (``Phase 2''):

Low initial luminosity (like Belle), but trigger and computing can already handle 20×Belle rate:
→ Unique chance to use novel triggers for small datasets.

Belle II 2025:

Huge dataset of 50 ab^{-1}.
(x50 Belle, x100 BaBar)

Belle II vs Belle:

New low multiplicity triggers.

Larger drift chamber.

Belle II vs BaBar:

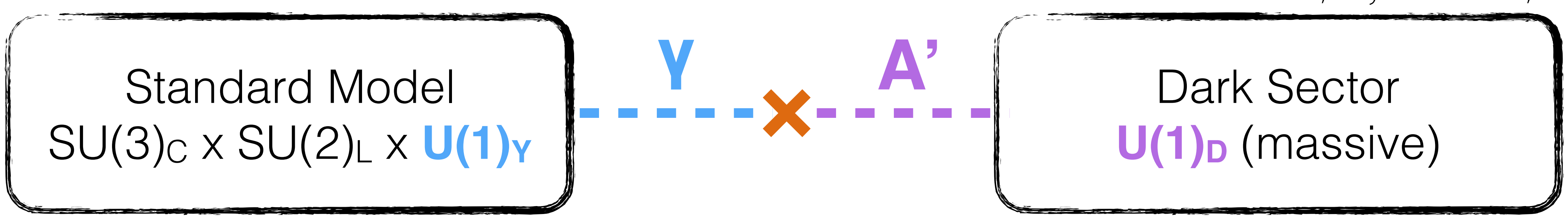
Non-projective calorimeter (much more hermetic).

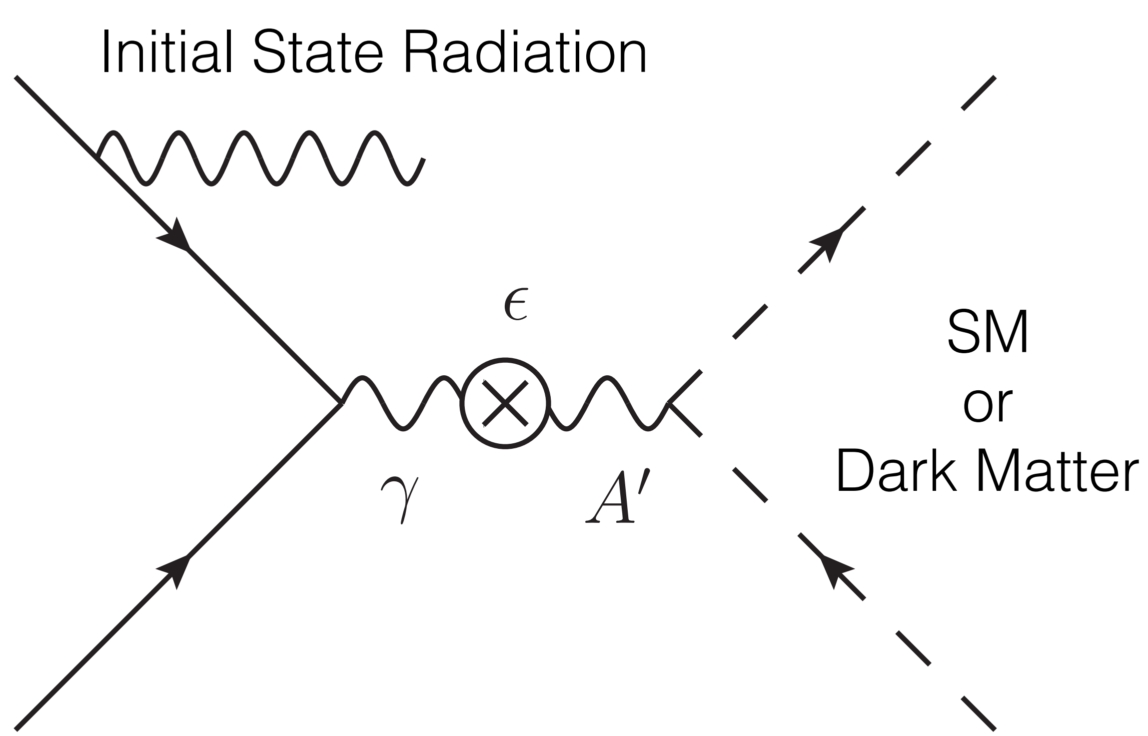
Better muon detector.

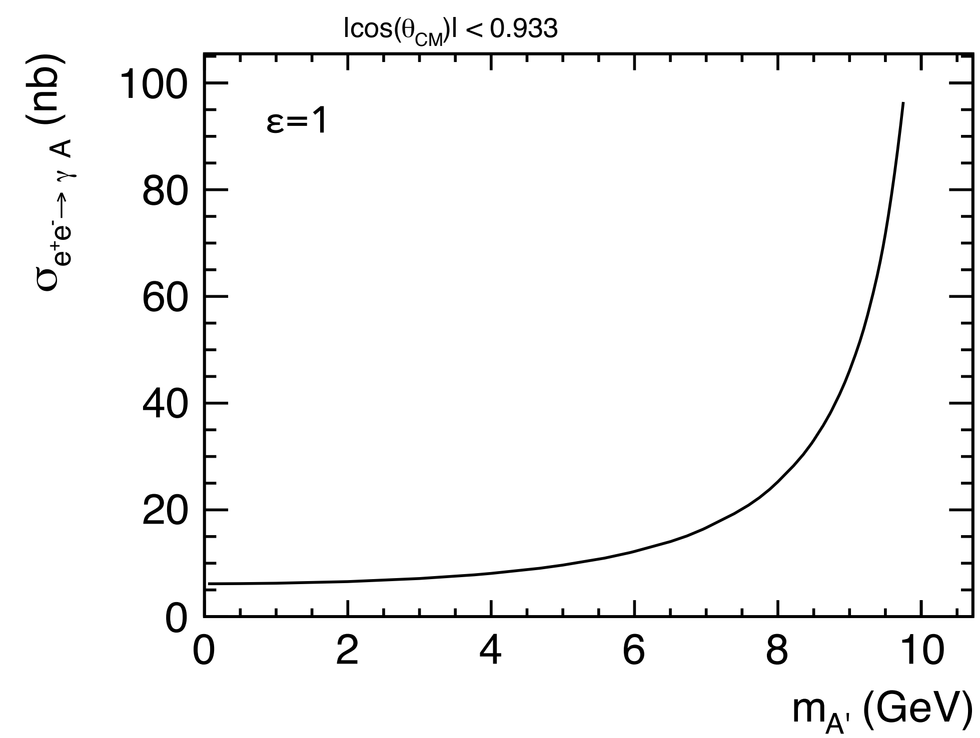
SEARCHING FOR DARK MATTER: VECTOR PORTAL

- In the so called Vector Portal, a (massive) Dark Photon A can mix with the SM photon with strength ε.

*Holdom, Phys. Lett B166, 1986

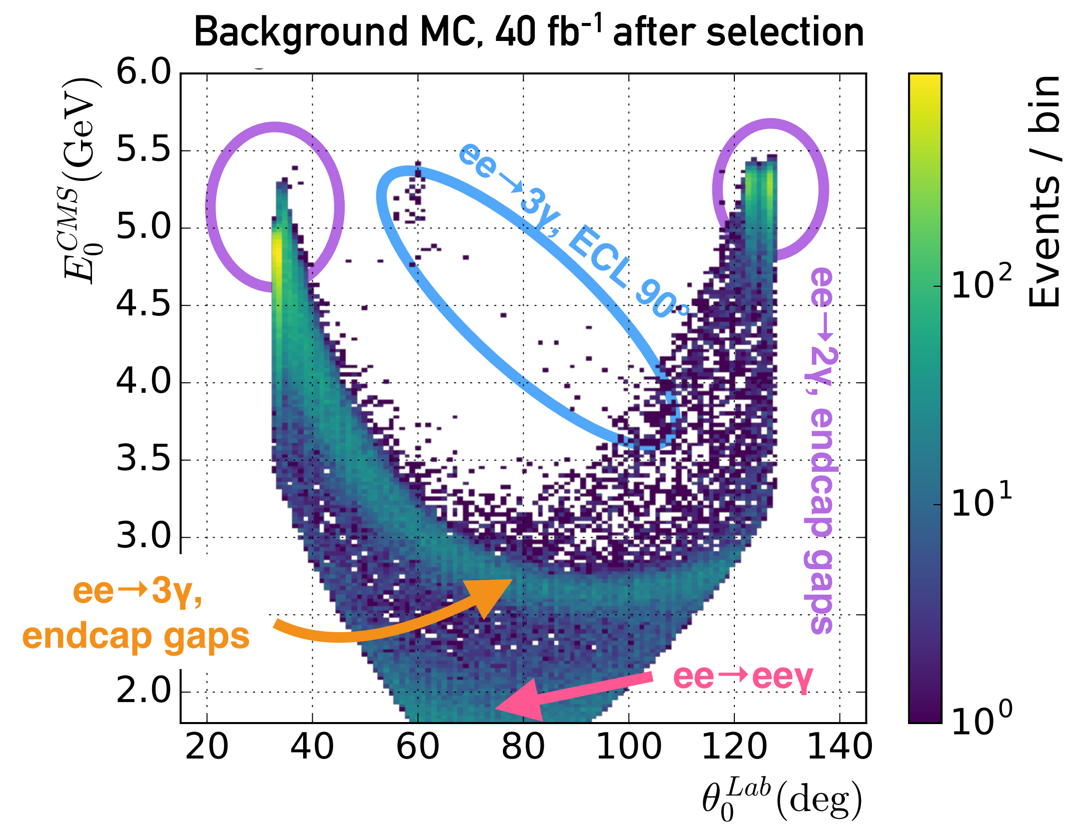


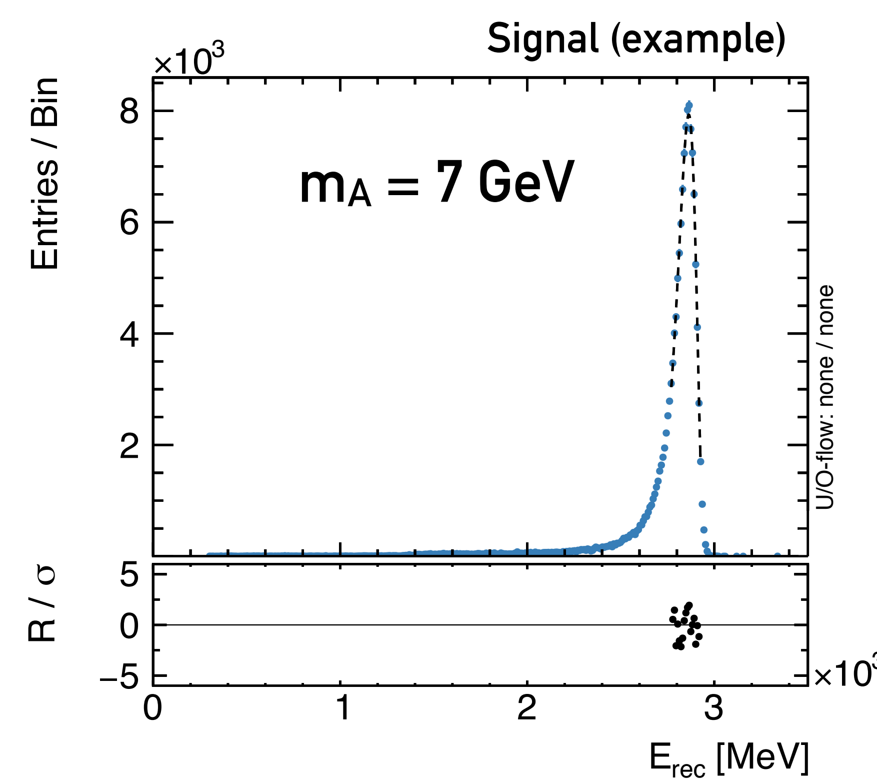




SEARCHING FOR DARK MATTER: VECTOR PORTAL

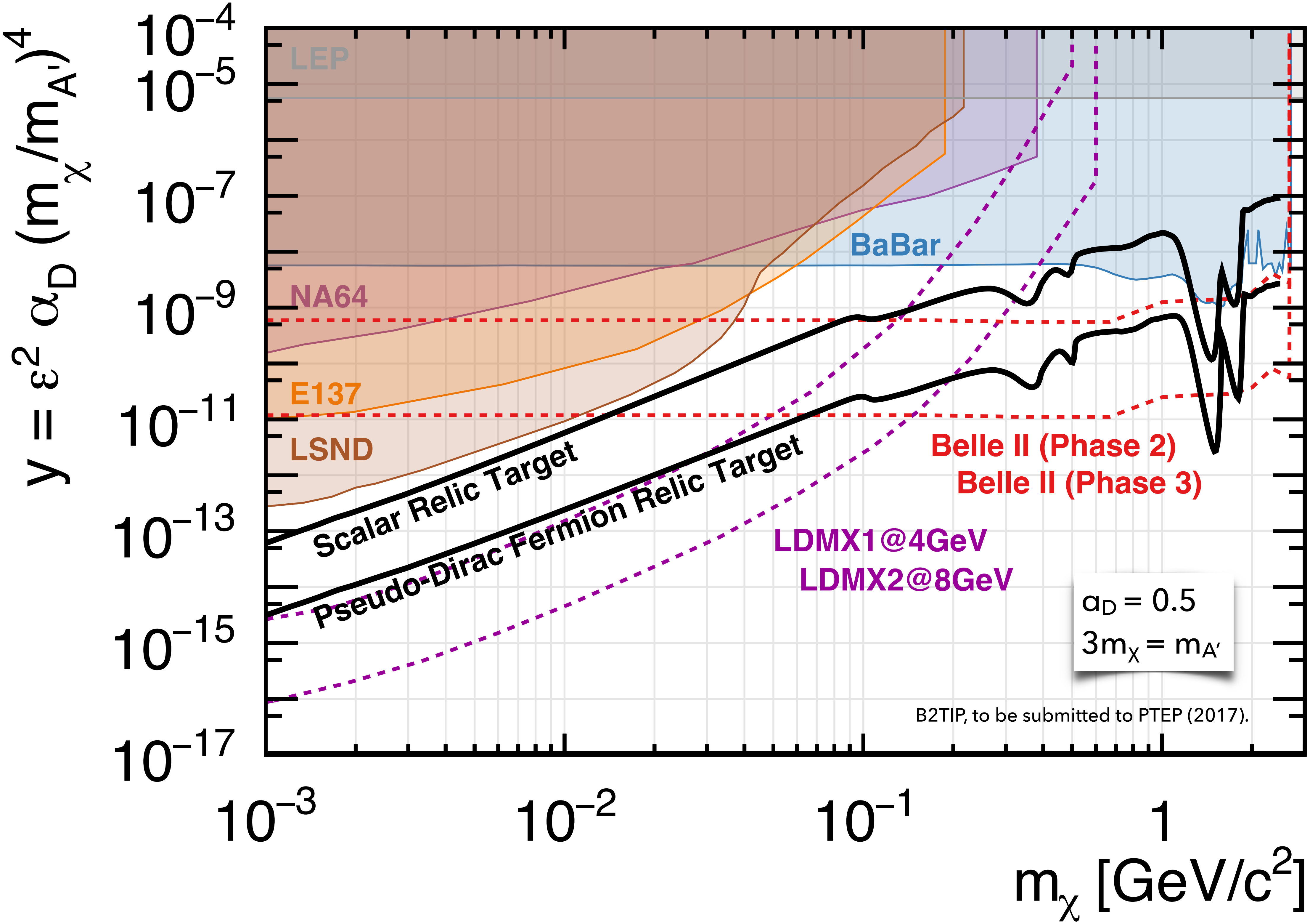
- Search for a bump in the photon recoil mass spectrum.
- Main backgrounds: ee→eeγ and ee→ γγ(γ) with all but one γ undetected.





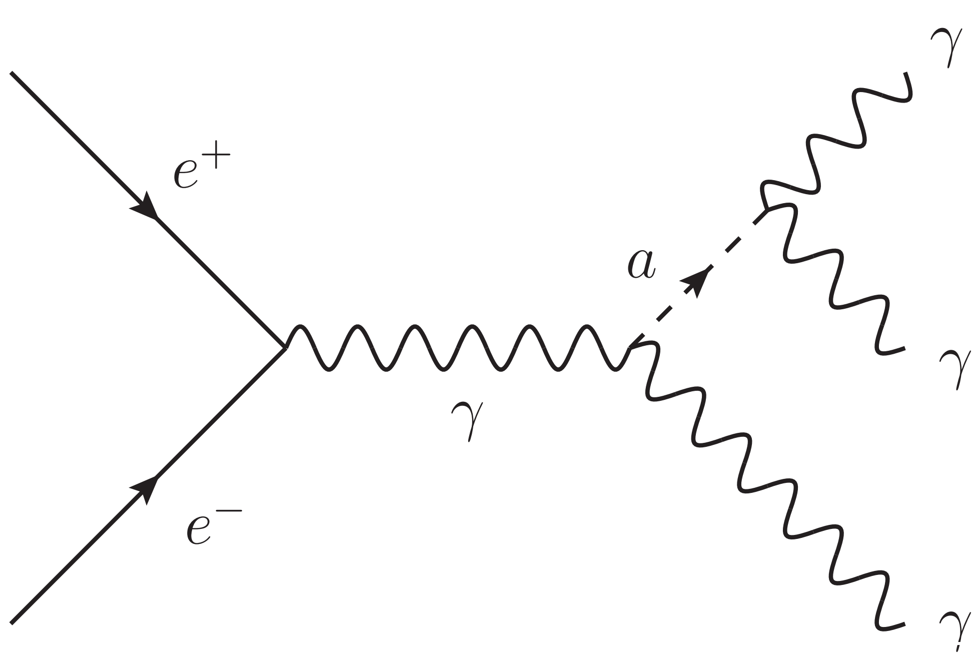
Trigger	γγ	Bhabha (both e have θ* > 1°)	Bhabha (one e has θ* < 1°)	Total
1 GeV* E*>1 GeV and second cluster E* < 0.2 GeV	0.2 nb	0.4 nb	1.6 nb	2.2 nb rate@1/40 lumi: 0.05 kHz rate@final lumi.: 1.76 kHz
2 GeV* E*>2 GeV and eclbhabhaveto and bhabhveto	0.5 nb	2.9 nb	0.1 nb	3.5 nb rate@1/40 lumi: 0.08 kHz rate@final lumi.: 2.80 kHz

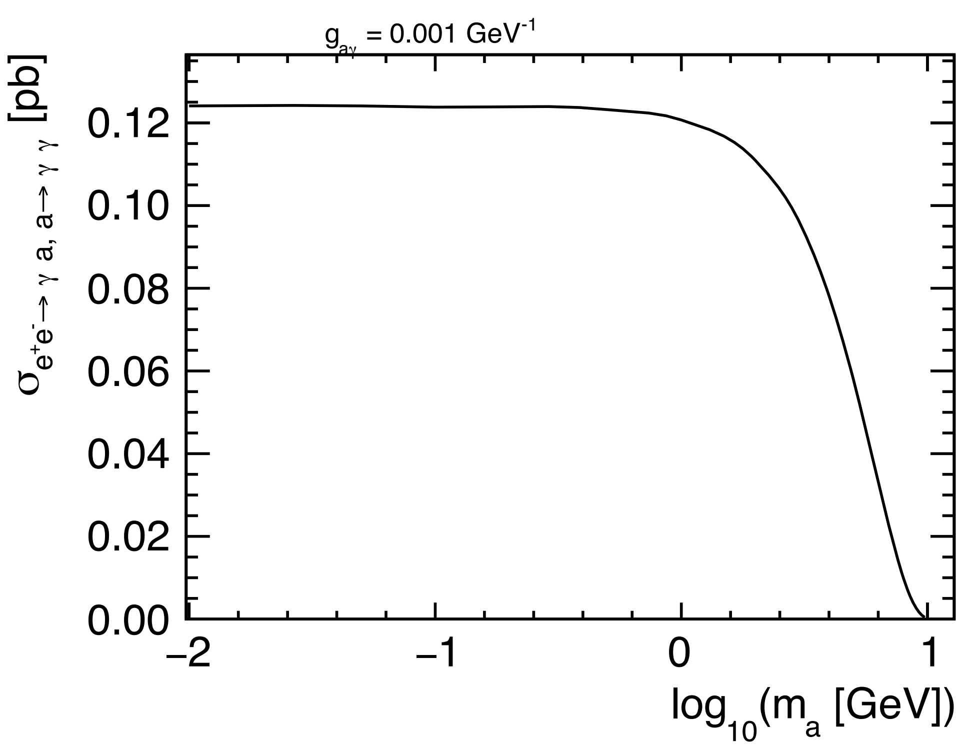
SEARCHING FOR DARK PHOTONS AT BELLE II



SEARCHING FOR AXION LIKE PARTICLES

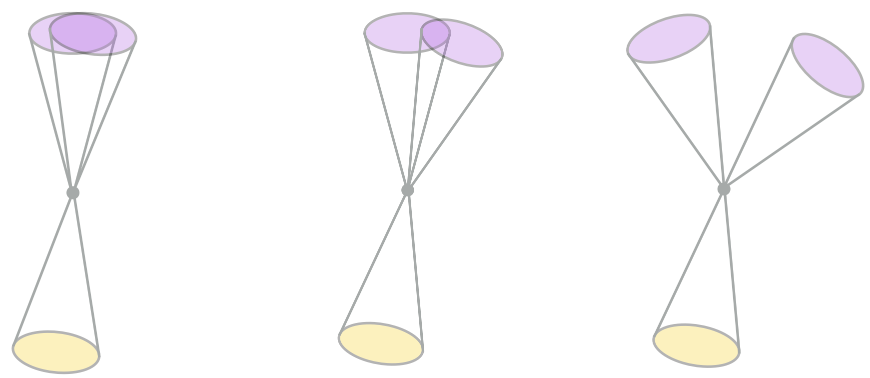
- Axion-like particles (ALPs) are pseudo-scalars and couple to bosons. Unlike Axions, ALPs have no relation between mass and coupling.
- They can be Dark Matter candidates, Dark Sector mediators, and they appear in many BSM scenarios.
- Focus on coupling to photons for Belle II.



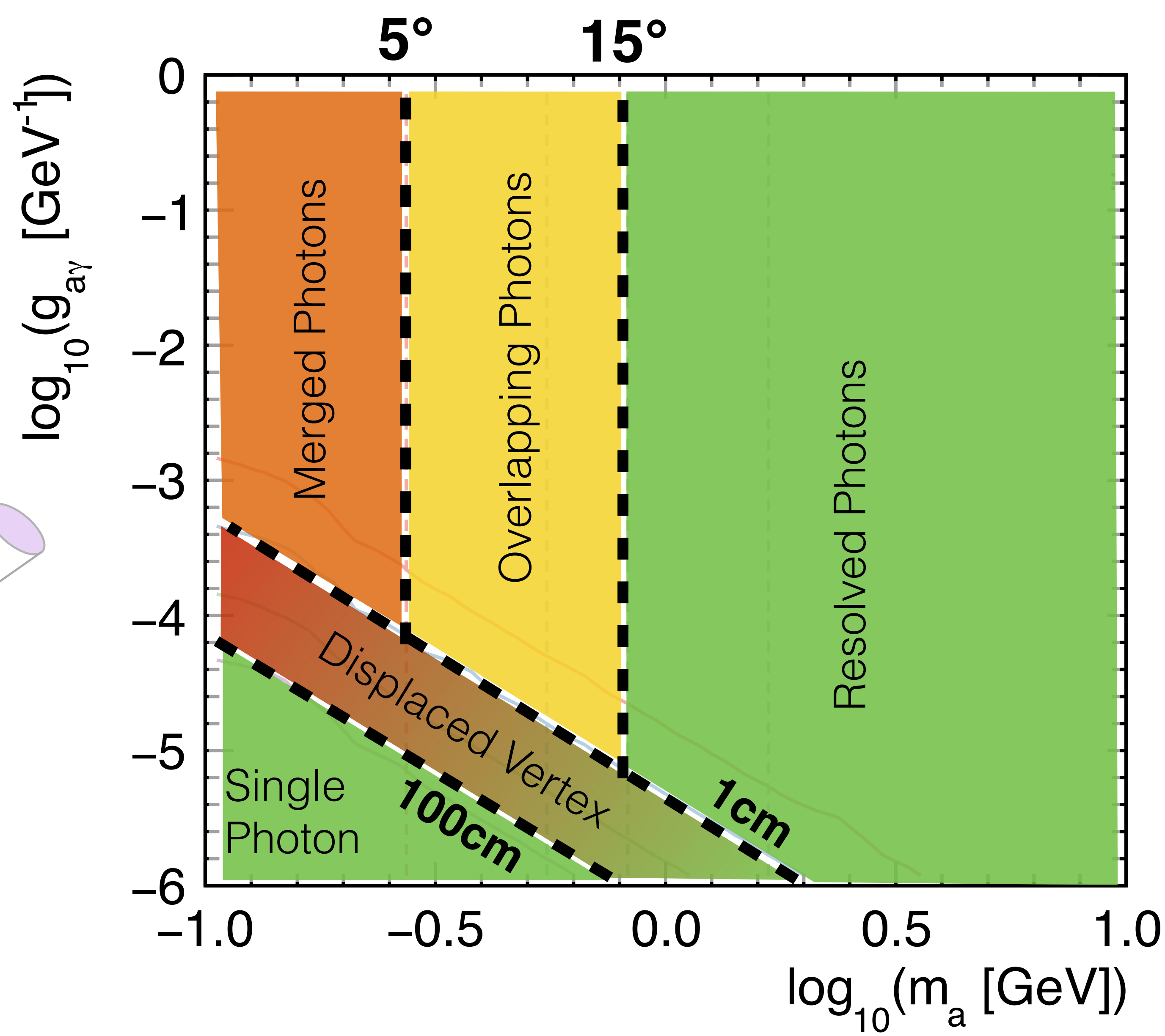


SEARCH FOR AXION LIKE PARTICLES AT BELLE II

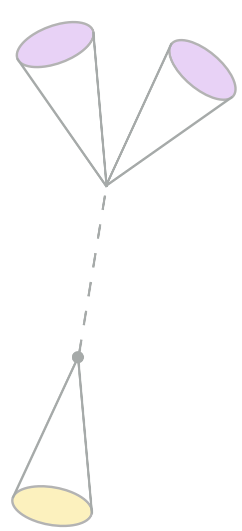
Two of the photons overlap or merge.



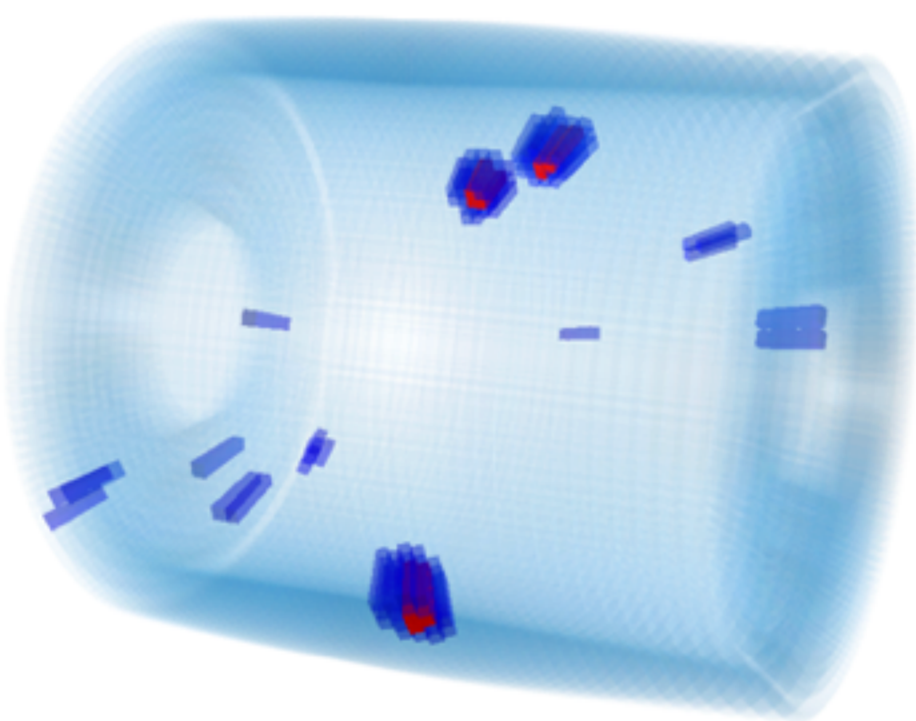
Three resolved, high energetic photons **(focus in this talk)**.



ALP decays outside of the detector: Single photon final state.



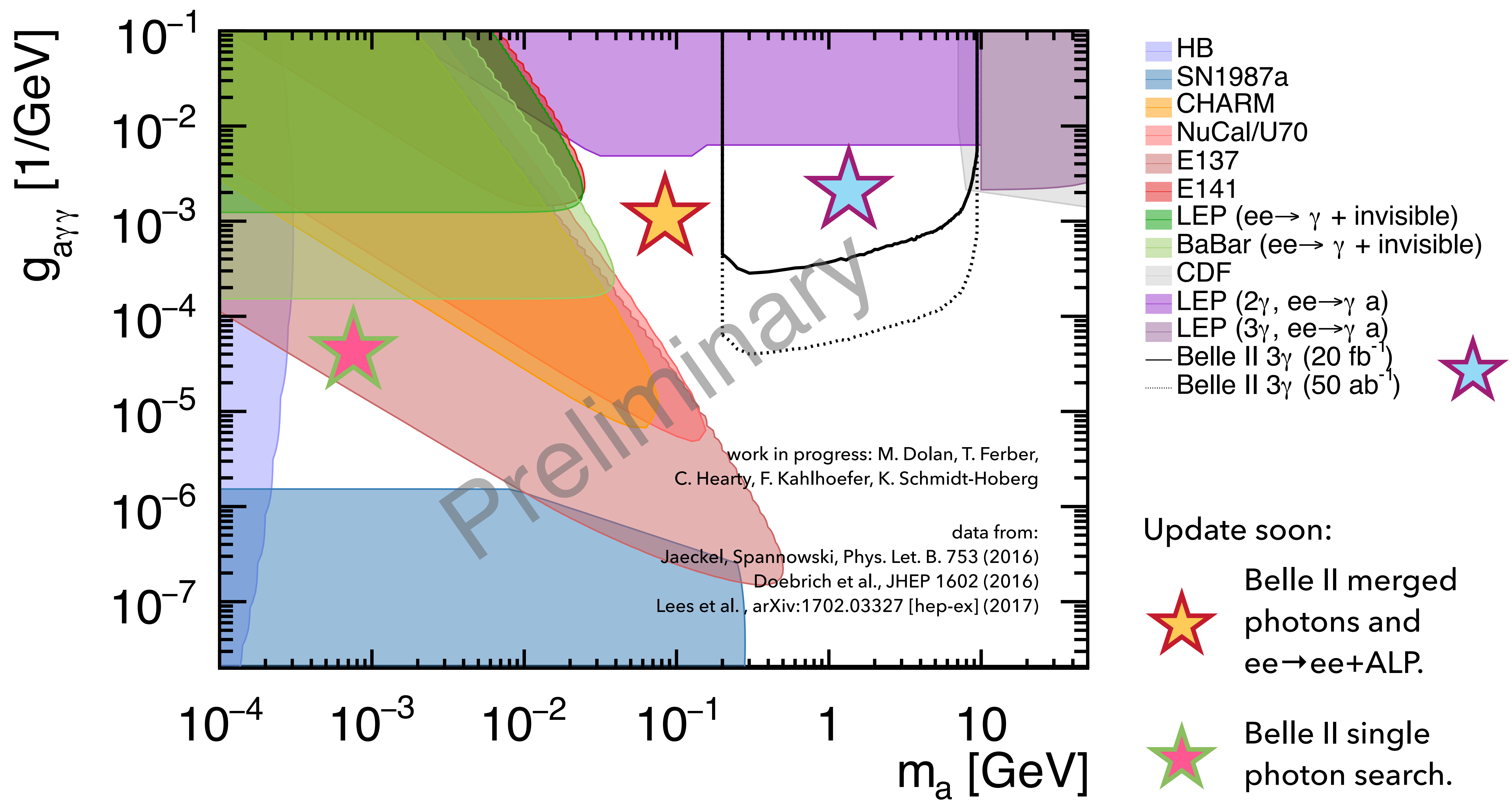
SEARCH FOR AXION LIKE PARTICLES



Trigger	Total (γγ)
2 GeV* Barrel E*>2 GeV and polar angle in ECL barrel	1.7 nb rate@1/40 lumi: 0.03 kHz rate@final lumi.: 1.36 kHz
2 GeV* ECL E*>2 GeV and polar angle in ECL trigger acceptance excluding extreme endcaps	2.8 nb rate@1/40 lumi: 0.06 kHz rate@final lumi.: 2.24 kHz

- Focus on the resolved 3γ final state with $m_A \geq 0.2$ GeV.
- Search for a bump in the two photon invariant mass spectrum.
- Main backgrounds:
  - ee→γγγ
  - ee→γγ + beam induced background photon
  - ee→γγ (γ→ee) pair conversion outside tracking detectors.

SEARCH FOR AXION LIKE PARTICLES



Update soon:

Belle II merged photons and ee→ee+ALP.

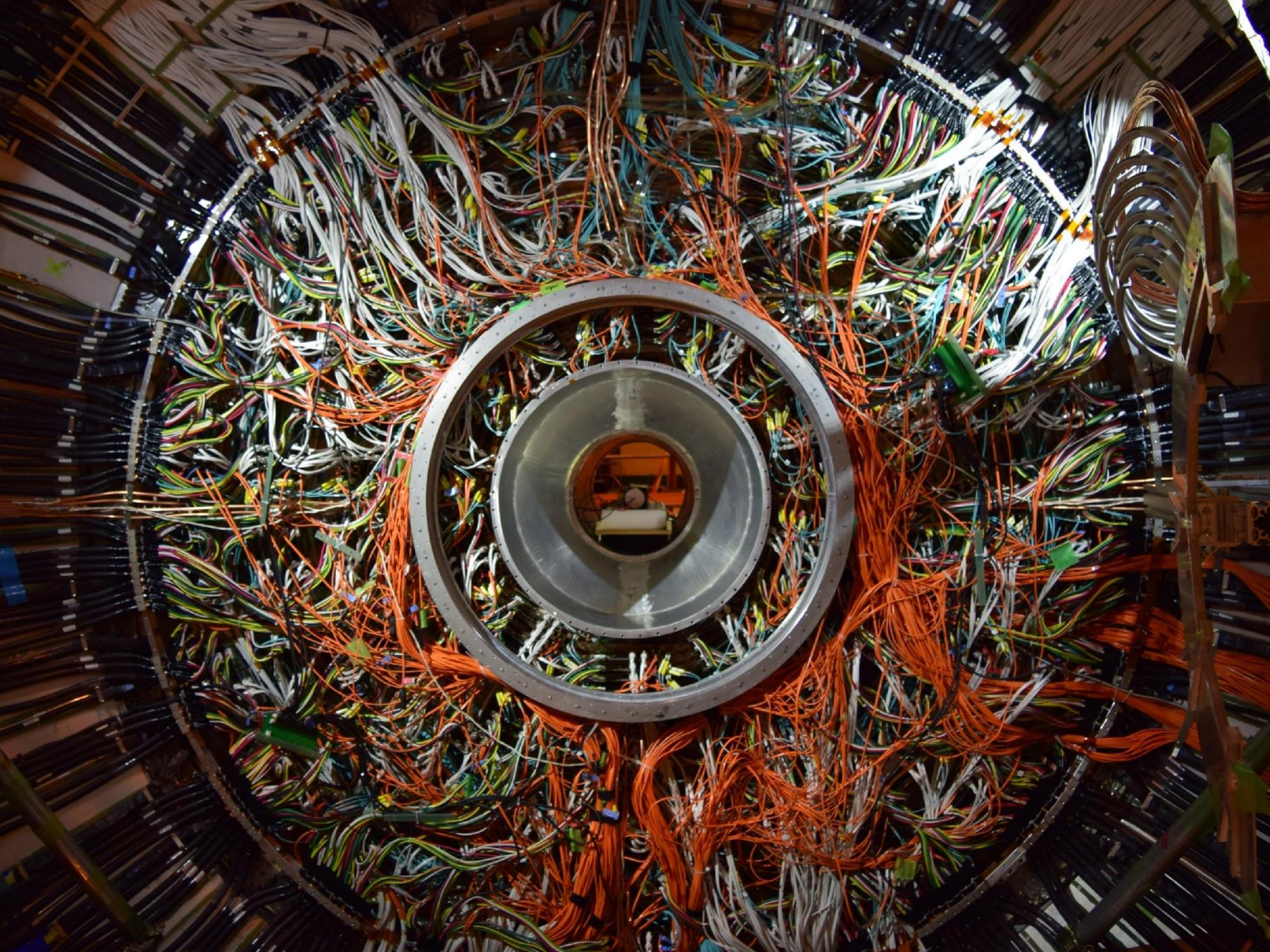
Belle II single photon search.

ALP coupling to two photons only.

SUMMARY

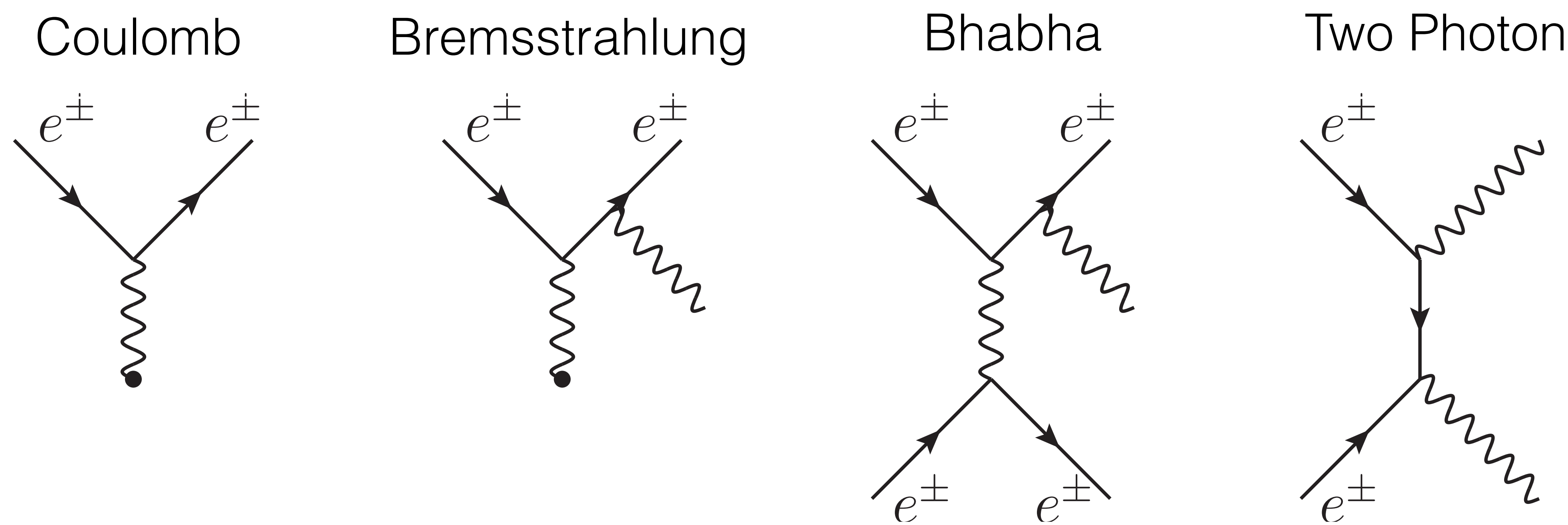
- The early running of Belle II offers possibilities for unique physics analyses in the dark sector (including visible and displaced topologies not covered in this talk).
- The search for light dark matter is competitive with BaBar already with 2018 data due to the more hermetic calorimeter.
- Belle II Physics Book in preparation* (Belle II detector, simulation, software, analysis tools, physics program incl. dark sectors), to be submitted for publication in 2017.
- Belle II physics data taking starts April 2018. Full detector (including VXD) starts end of 2018.

* https://confluence.desy.de/display/BI/B2TiP+ReportStatus



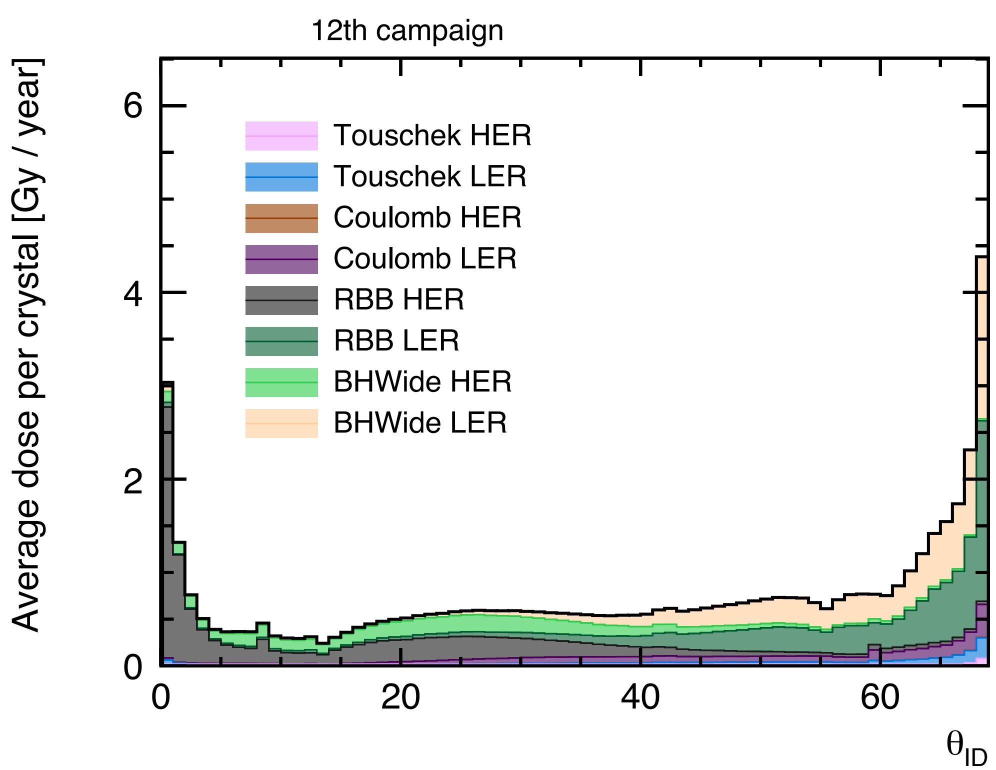
BACKUP

BELLE II BEAM BACKGROUND



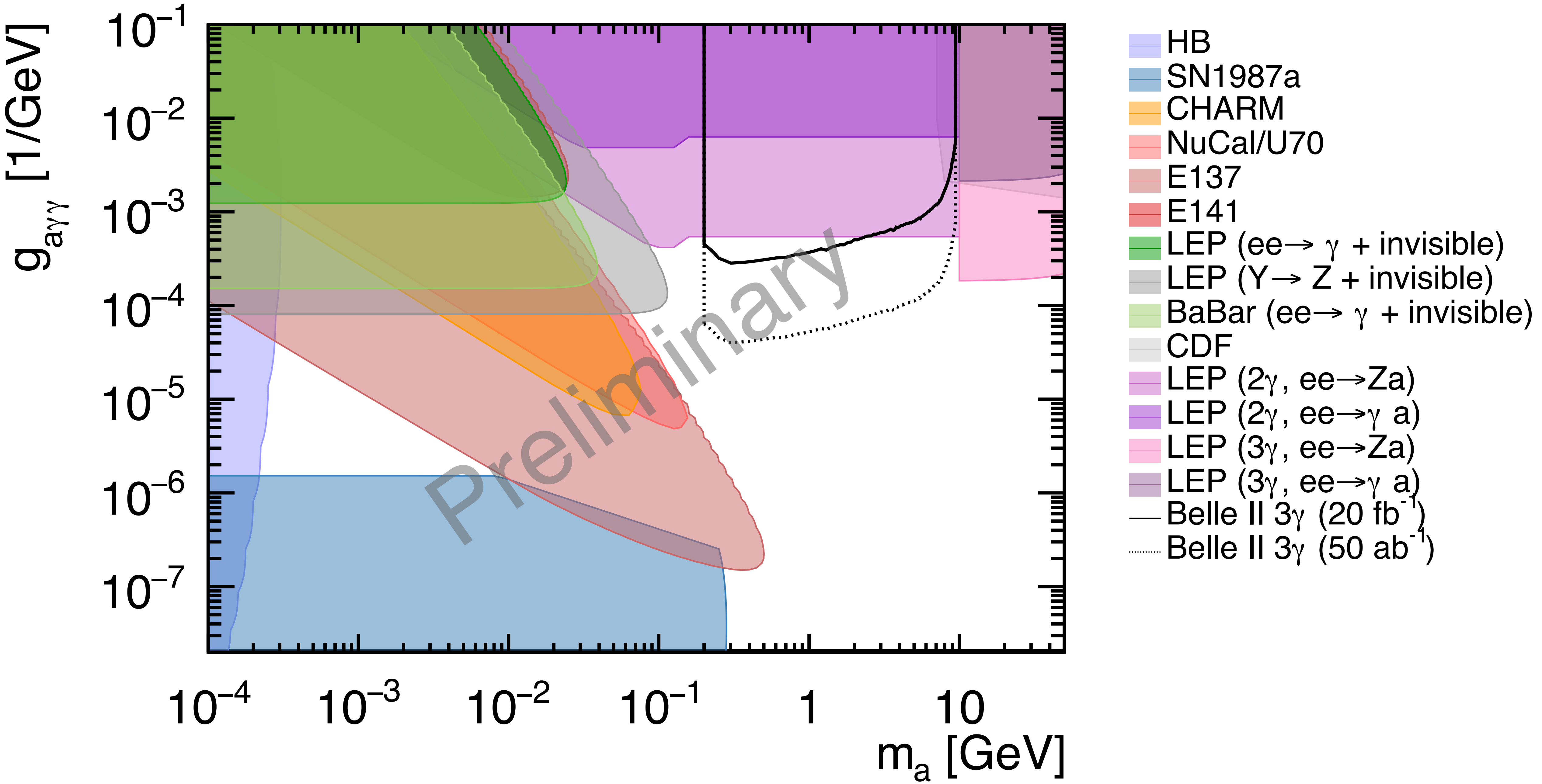
+ Synchrotron Radiation

+ Touschek



- Degrades calorimeter resolution.
- Radiation damage.
- Pile-up and event size.
- Physics background.

SEARCH FOR AXION LIKE PARTICLES



ALP coupling to two photons or Z bosons.

SINGLE PHOTON TRIGGERS

Trigger	$\gamma\gamma$	Bhabha		Total
		both e have $\theta^* > 1°$	one e has $\theta^* < 1°$	
1 GeV* E*>1 GeV and second cluster E* < 0.2 GeV	0.2 nb	0.4 nb	1.6 nb	2.2 nb rate@1/40 lumi: 0.05 kHz rate@final lumi.: 1.76 kHz
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ALP TRIGGERS

Trigger	Total ($\gamma\gamma$)
2 GeV* Barrel E*>2 GeV and polar angle in ECL barrel	1.7 nb rate@1/40 lumi: 0.03 kHz rate@final lumi.: 1.36 kHz
2 GeV* ECL E*>2 GeV and polar angle in ECL trigger acceptance excluding extreme endcaps	2.8 nb rate@1/40 lumi: 0.06 kHz rate@final lumi.: 2.24 kHz