Status of Belle II / SuperKEKB, and plans for Dark Sector Physics

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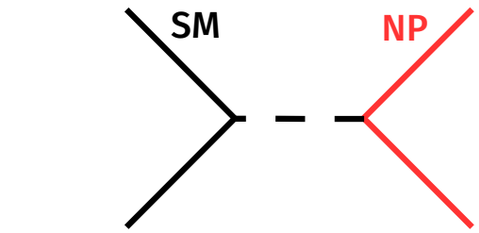
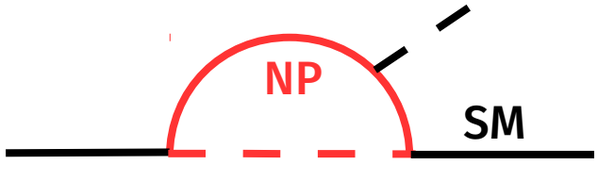
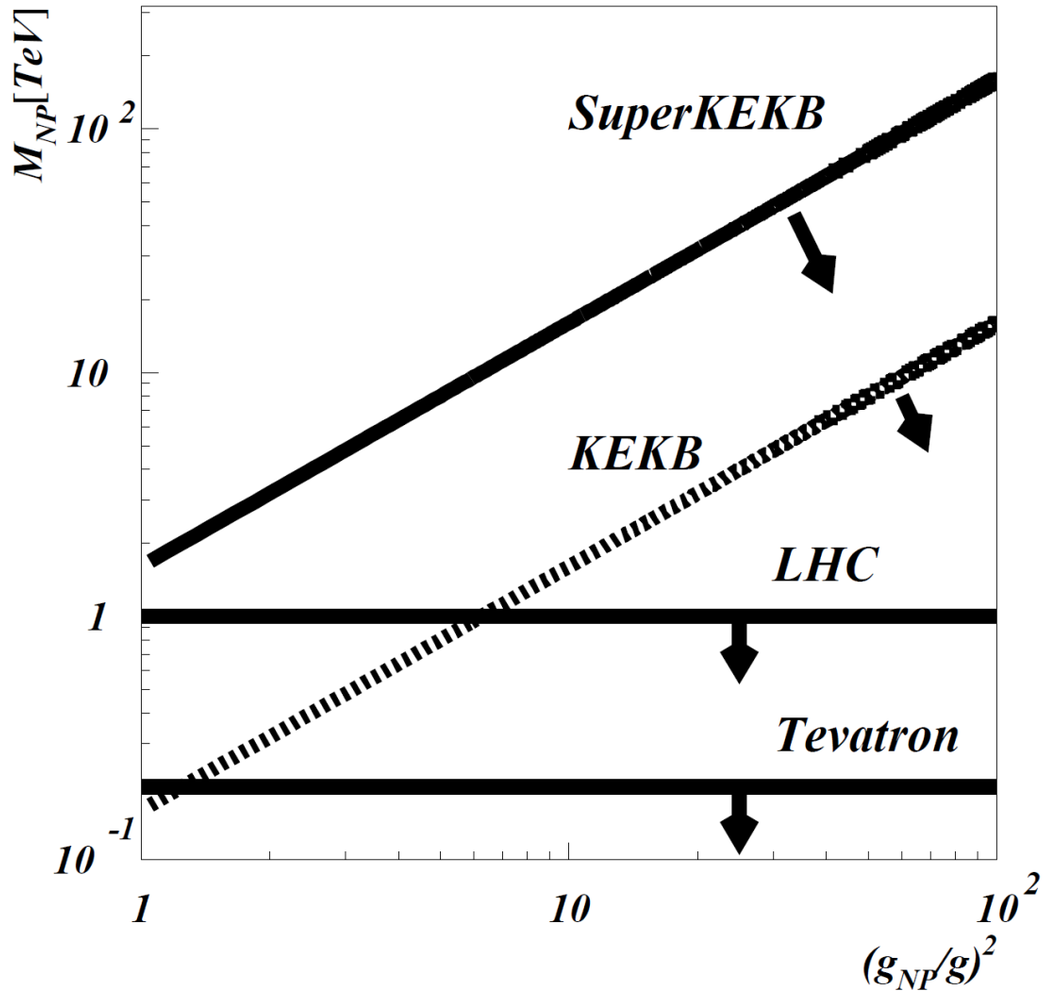
Energy or Intensity?

- Energy frontier:
  - Production of New Physics (NP) in collision final states.
  - Limited by beam energy.



- Intensity frontier:
  - NP in virtual processes.
  - Limited by statistics.



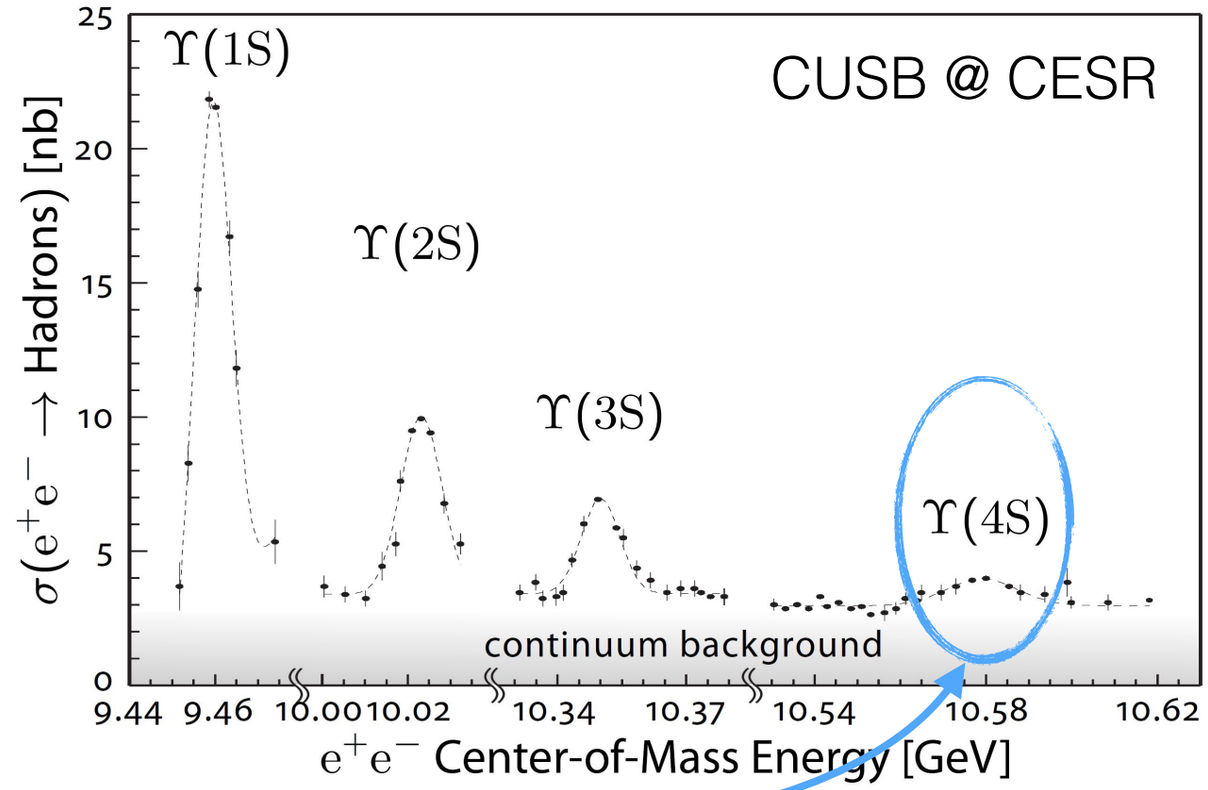


Belle and BaBar.

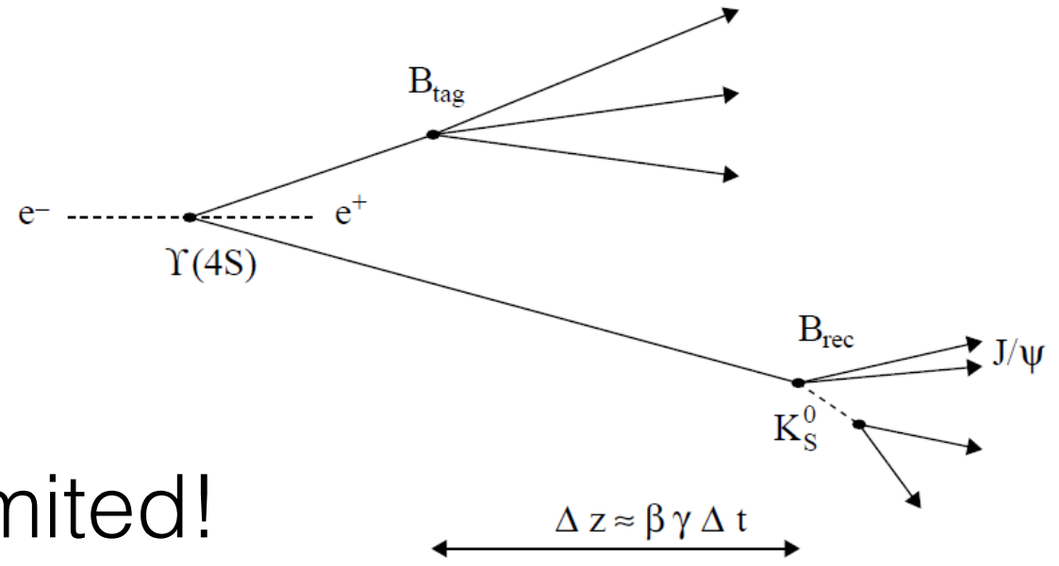
- Belle at KEKB, Japan and BaBar at PEP-II, USA.

- Very high luminosity:
  ~2×10^{34} /cm^2/s (Belle)

- Collision energy at Y(nS):
  Mainly at **E_{CM} = 10.58 GeV.**
  BR(Y(4S)→ B$\bar{B}$) > 96%



- Asymmetric beam energies:
  8 GeV (e^-) / 3.5 GeV (e^+) (Belle)
  → Boosted B$\bar{B}$ pairs.



- Many analysis still statistically limited!

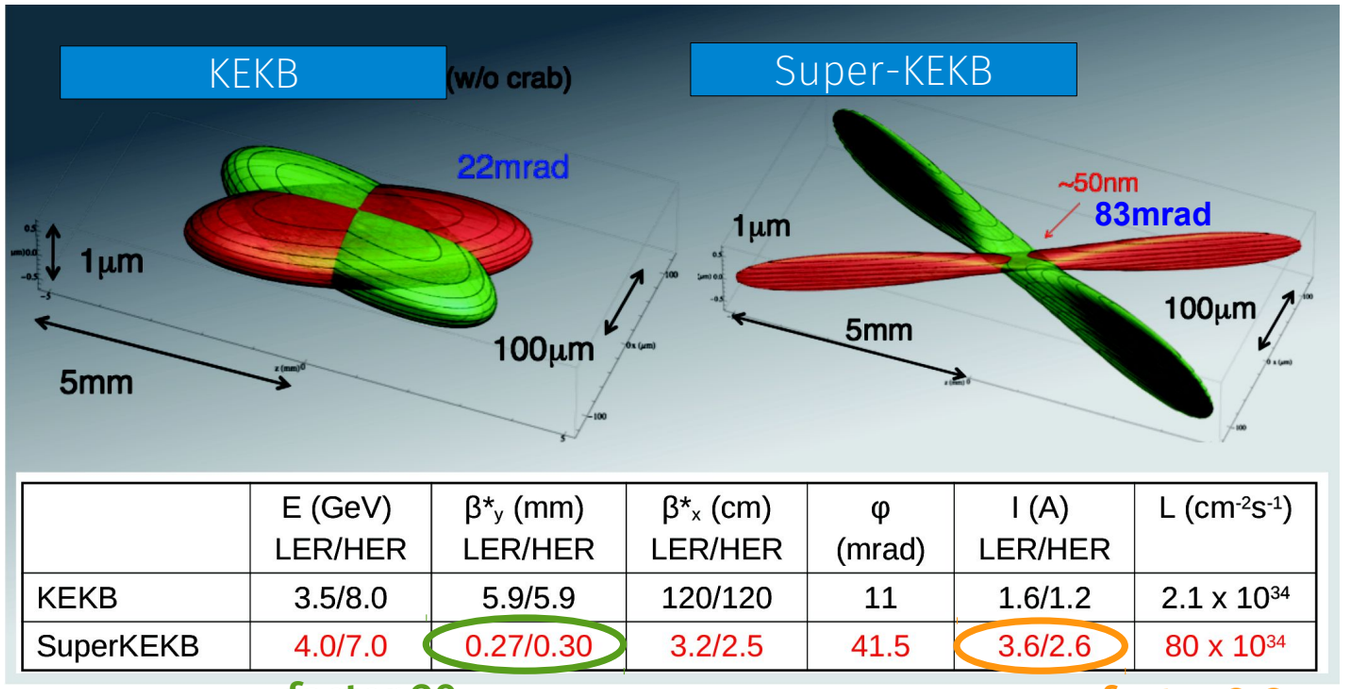
SuperKEKB.

First beams in 2016.
Commissioning ongoing.

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm}{\beta_{y\pm}}\xi_{y\pm}\frac{R_L}{R_{\xi_y}}$$

beam current

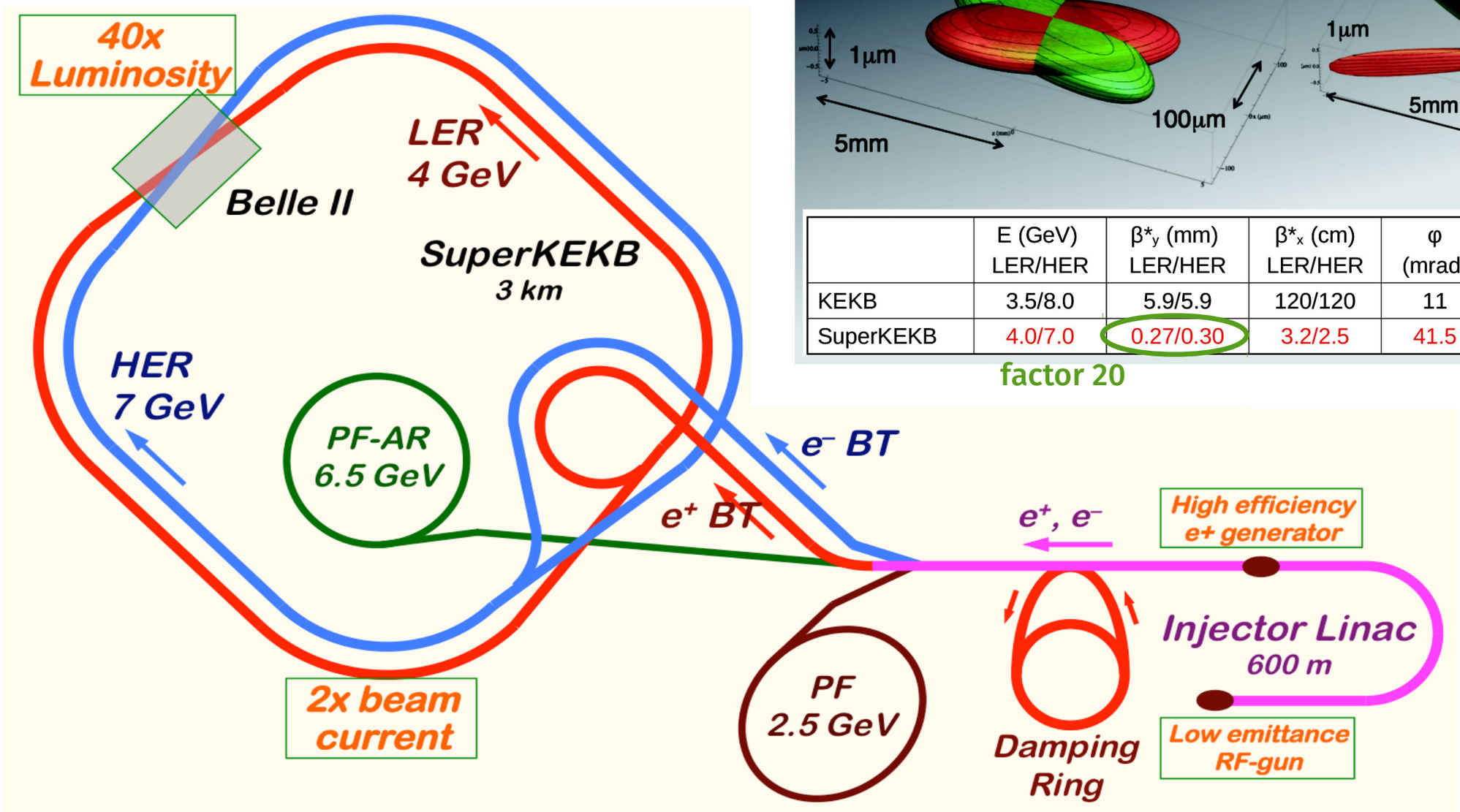
vertical beta function at IP



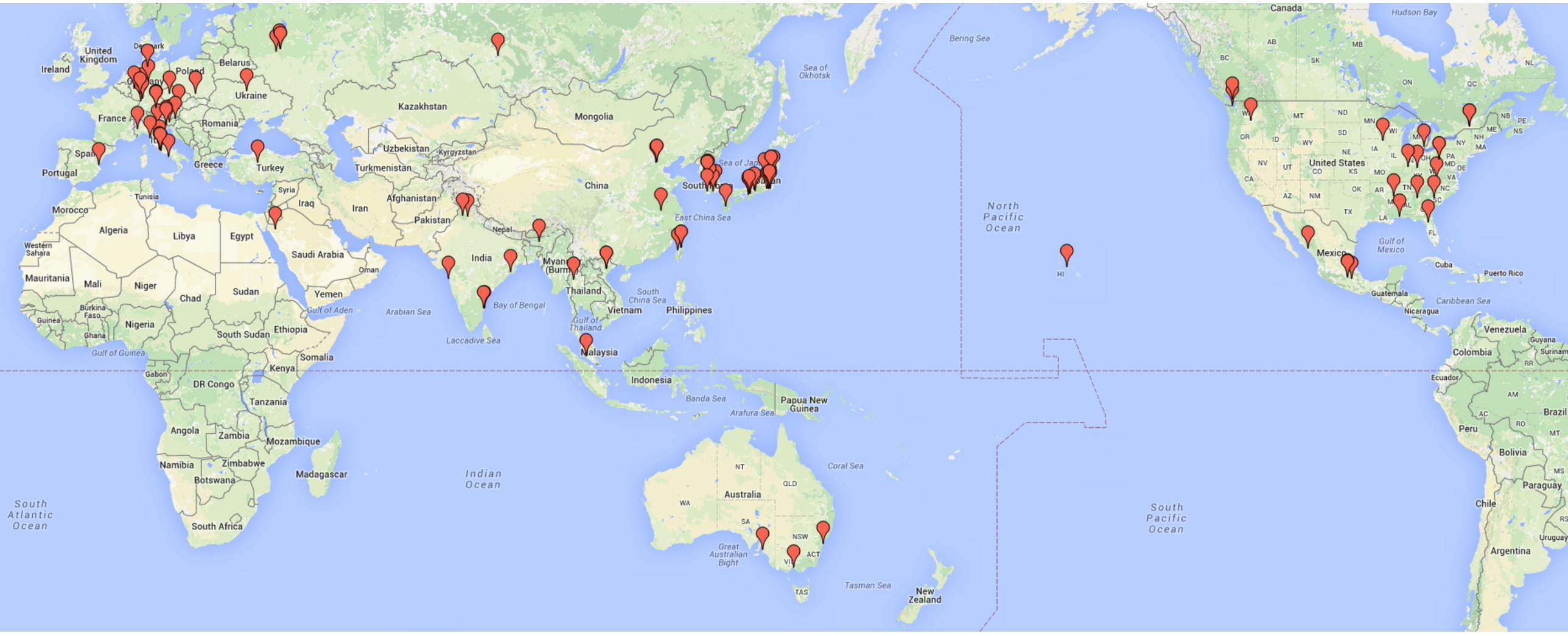
	E (GeV) LER/HER	β^*_y (mm) LER/HER	β^*_x (cm) LER/HER	φ (mrad)	I (A) LER/HER	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1×10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80×10^{34}

factor 20

factor 2-3

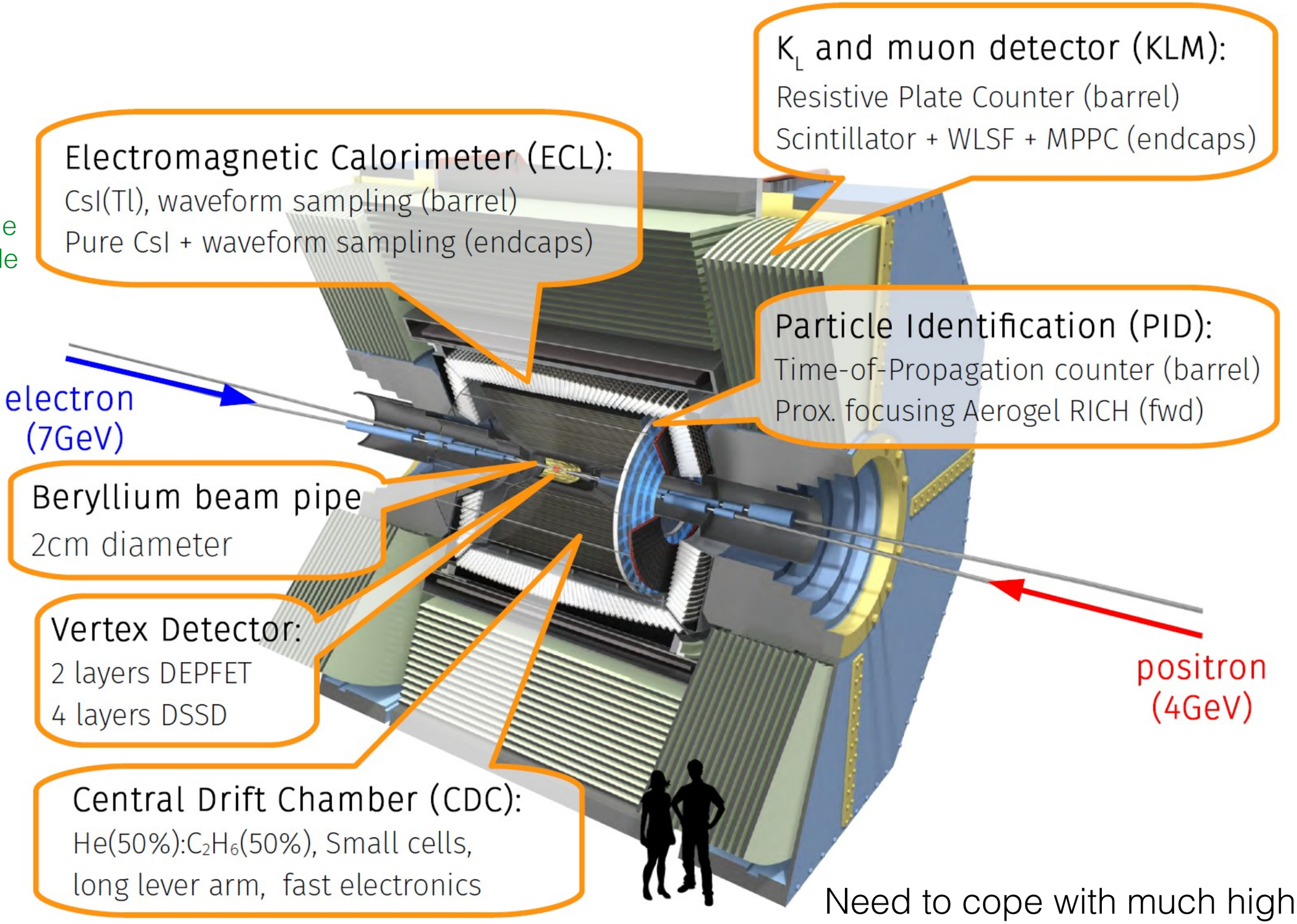


Belle II Collaboration.



728 members (including 262 grad students).
100 institutes.

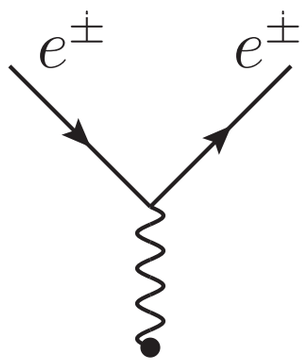
Belle II Detector.



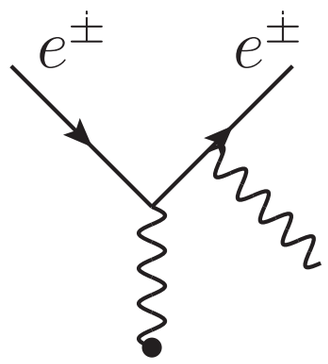
Need to cope with much higher luminosity and beam background.

Belle II: Backgrounds.

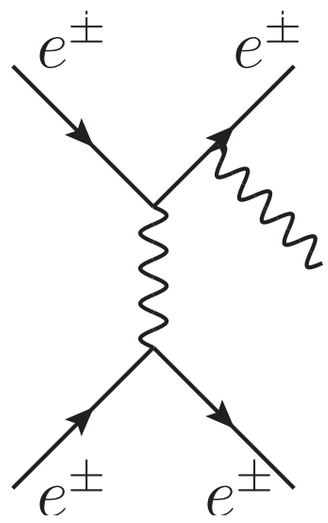
Coulomb



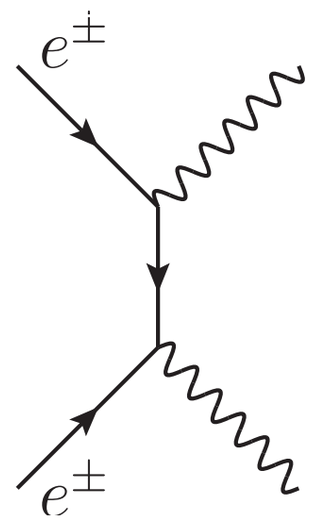
Bremsstrahlung



Bhabha

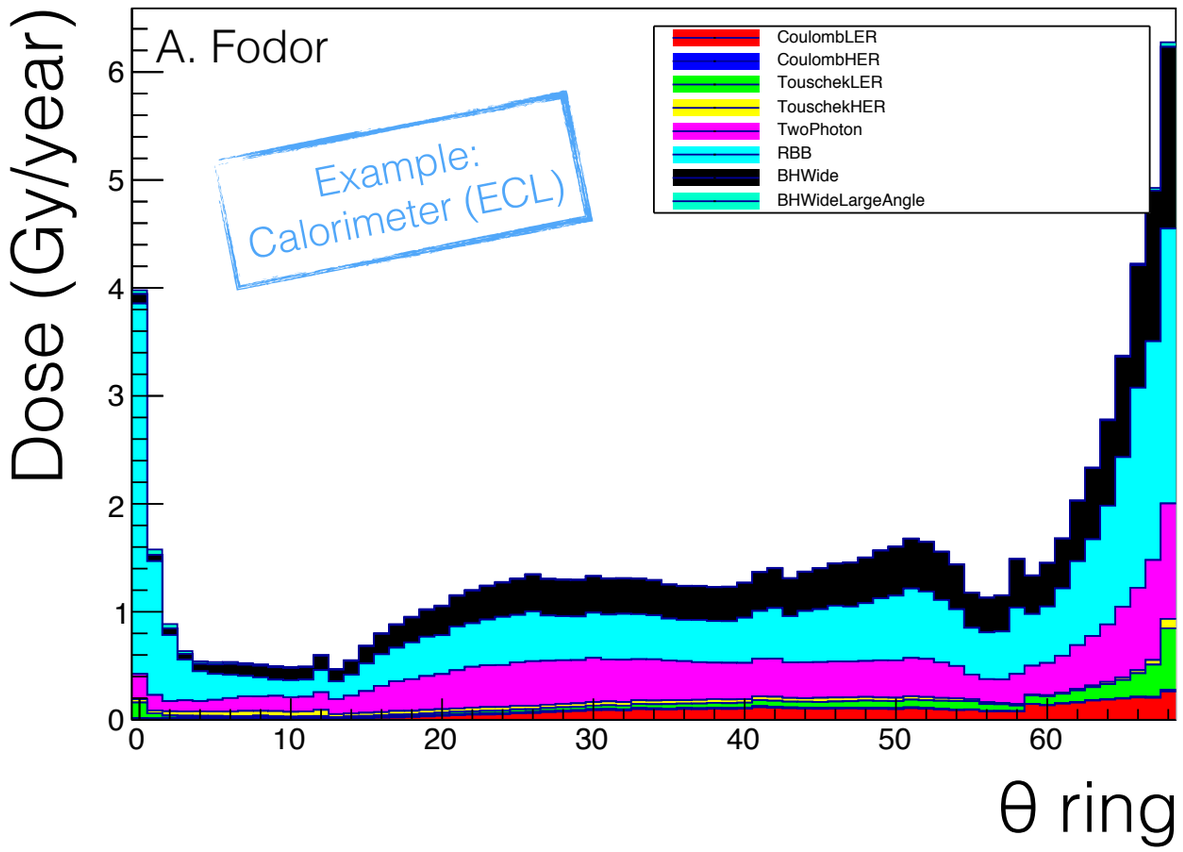


Two Photon



+ Synchrotron Radiation

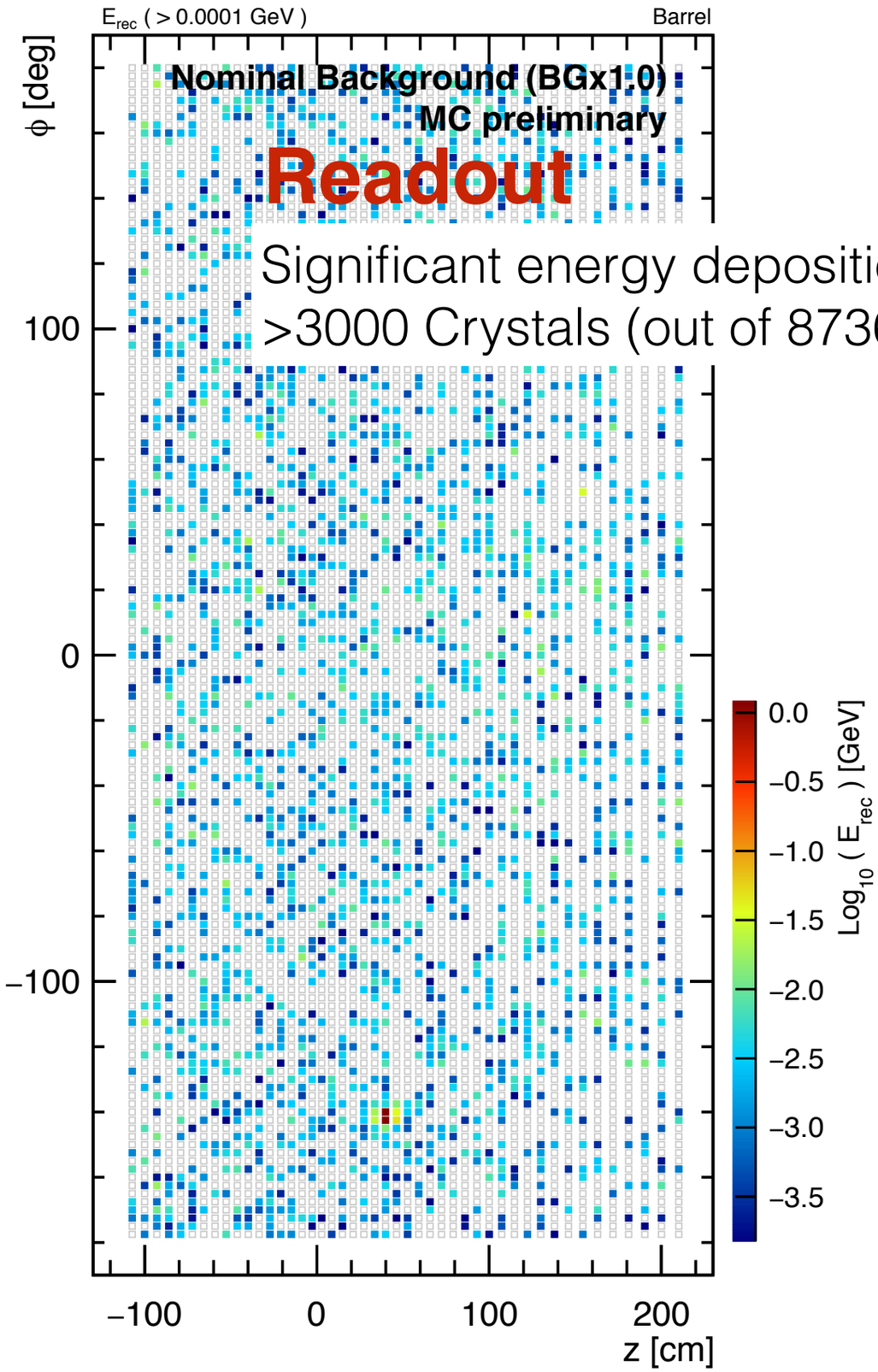
+ Touschek



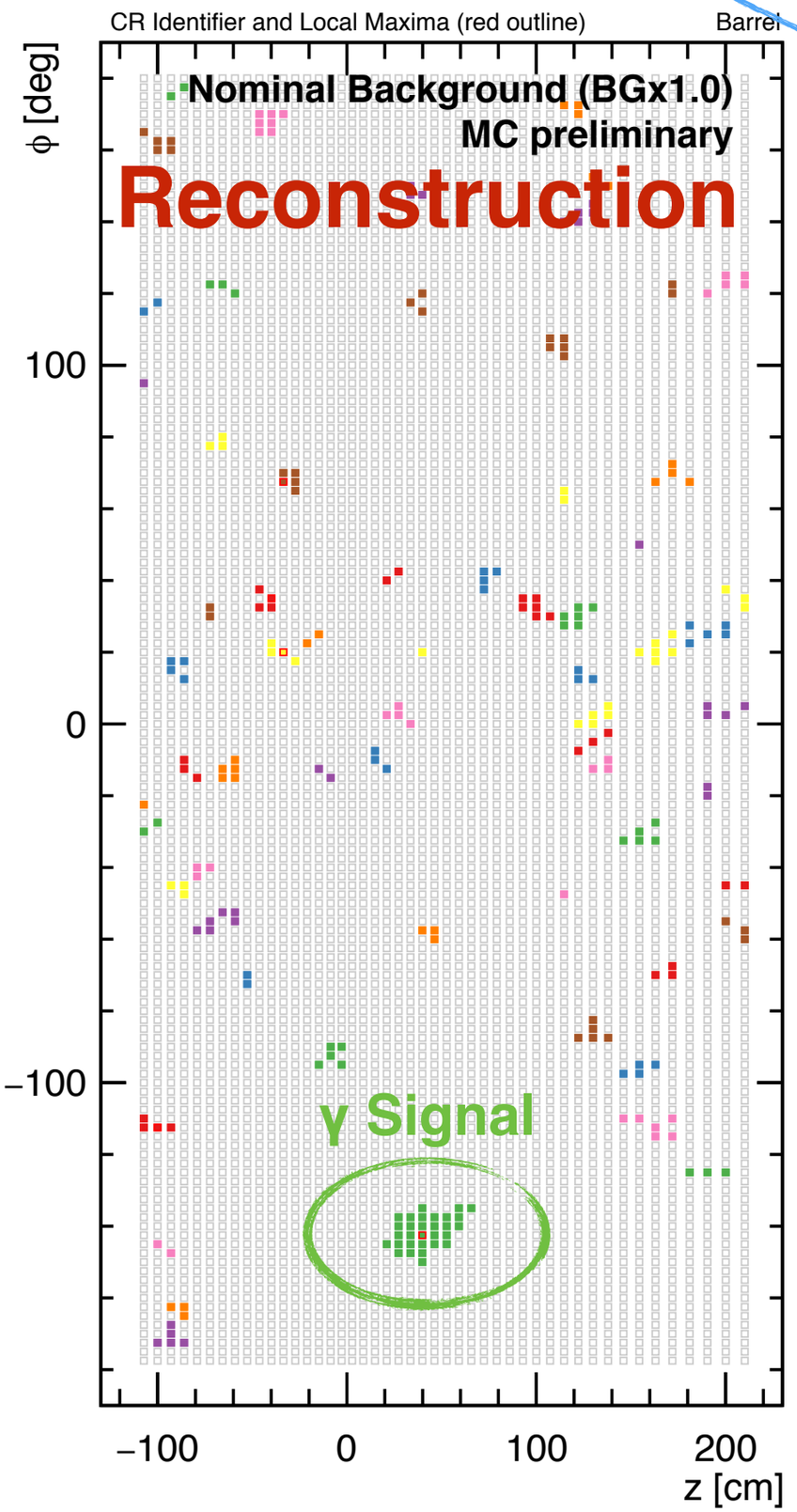
- Degrades calorimeter resolution.
- Radiation damage.
- Pile-up and event size.
- Physics background.

Belle II: Backgrounds.

Example: Calorimeter (ECL)

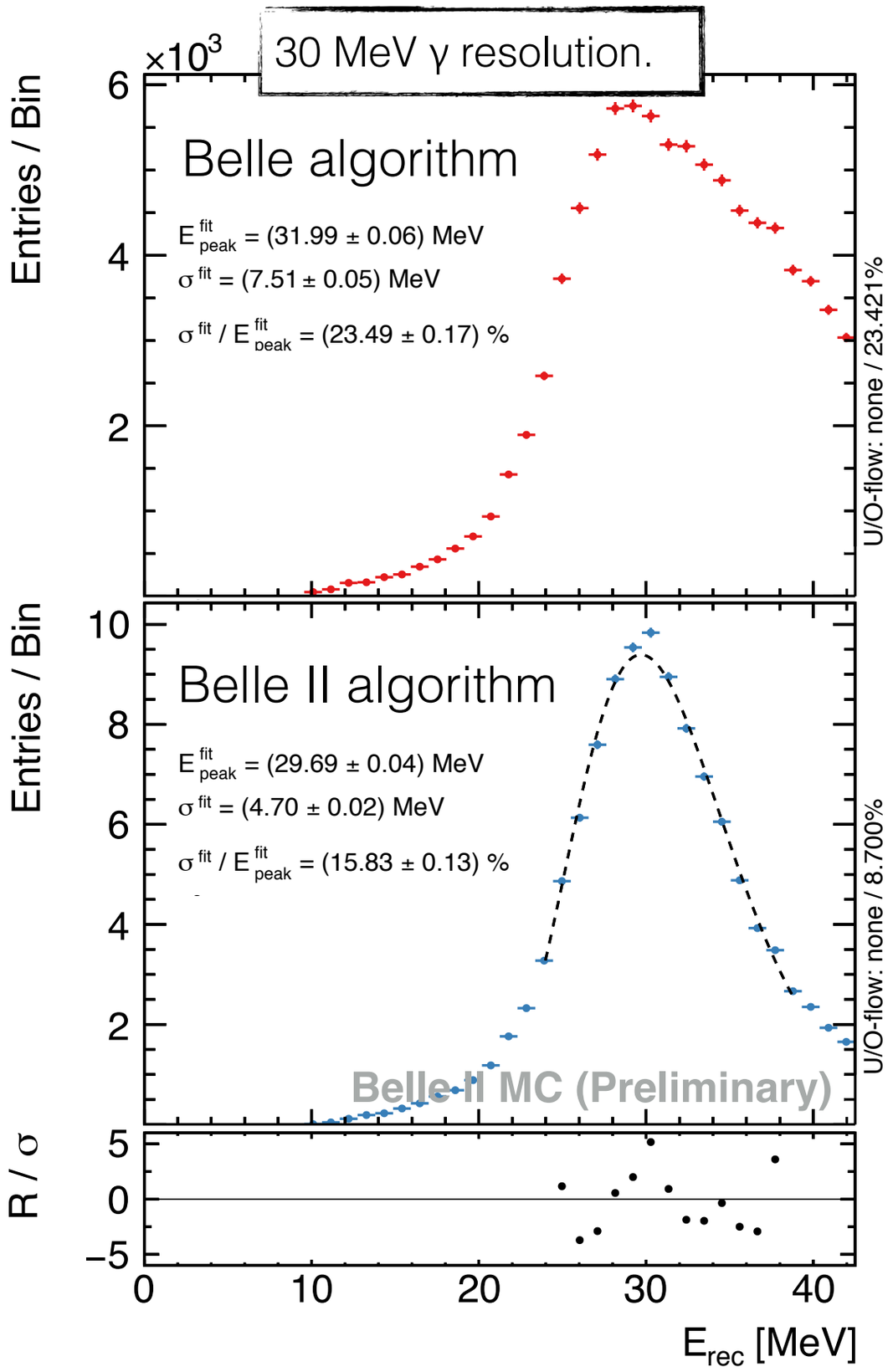


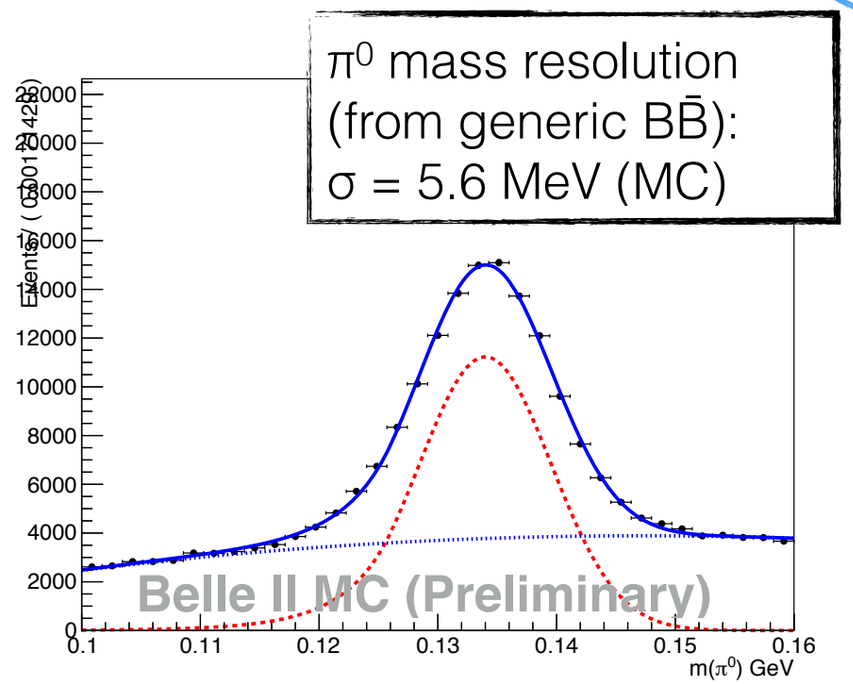
Significant energy deposition in >3000 Crystals (out of 8736).

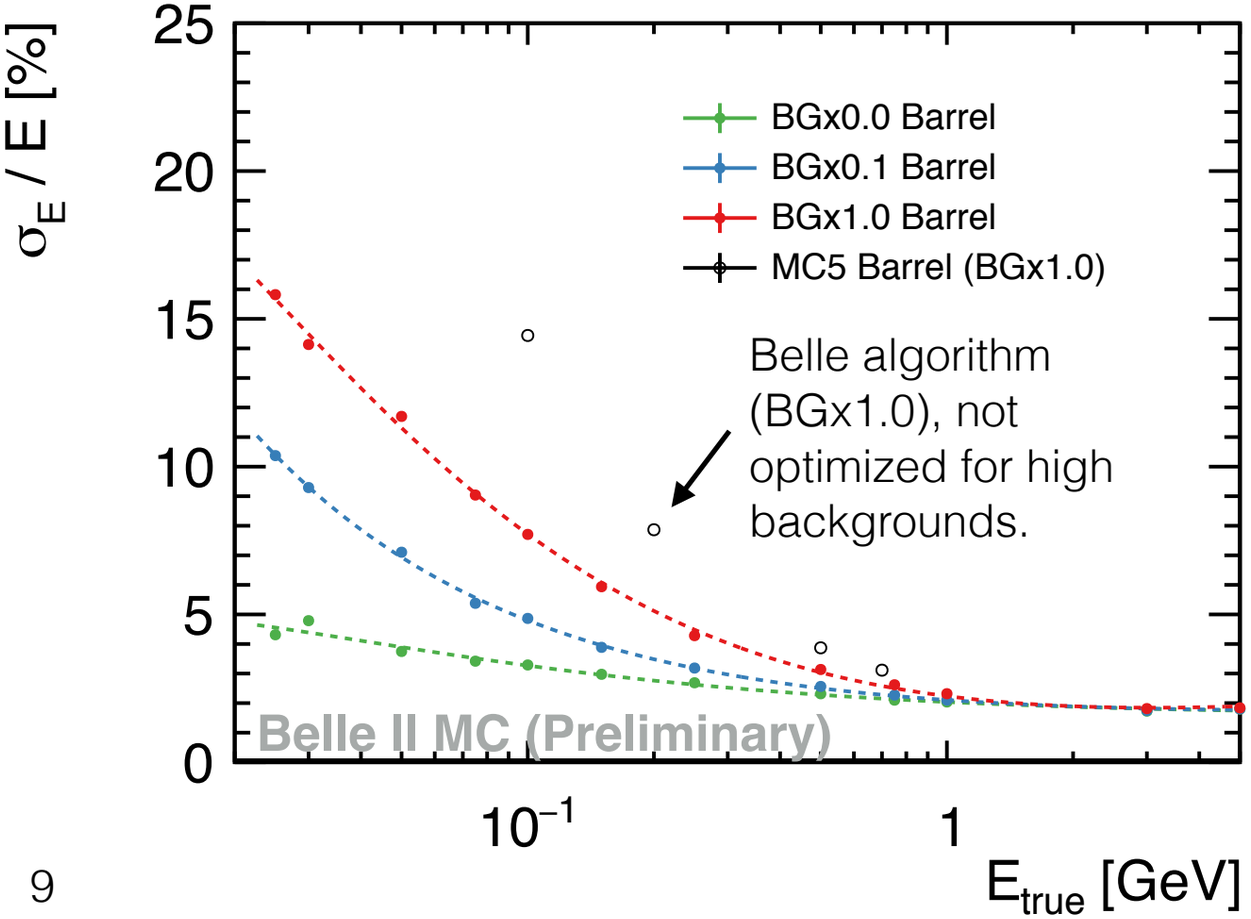


Belle II: Performance.

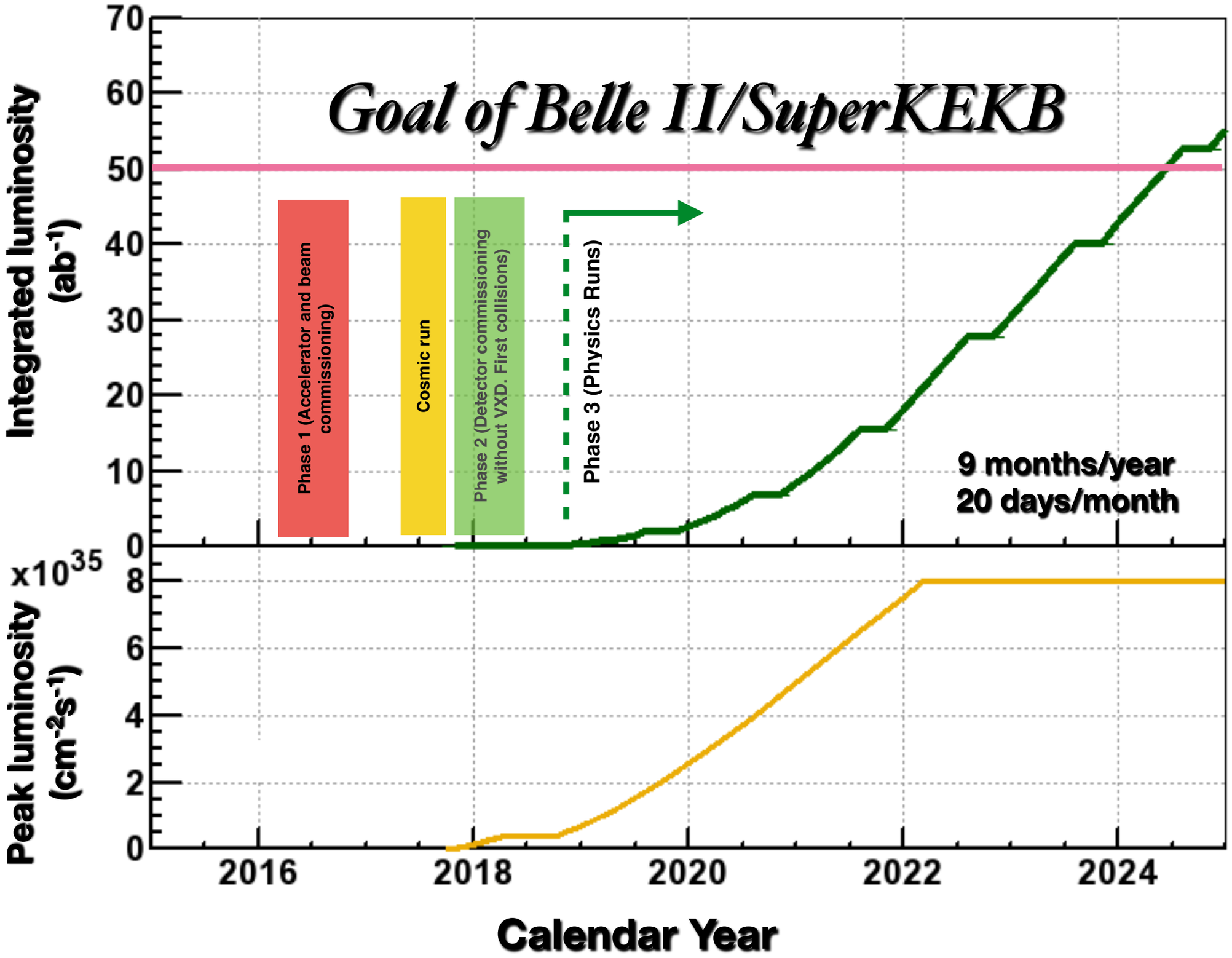
Example: Calorimeter (ECL)







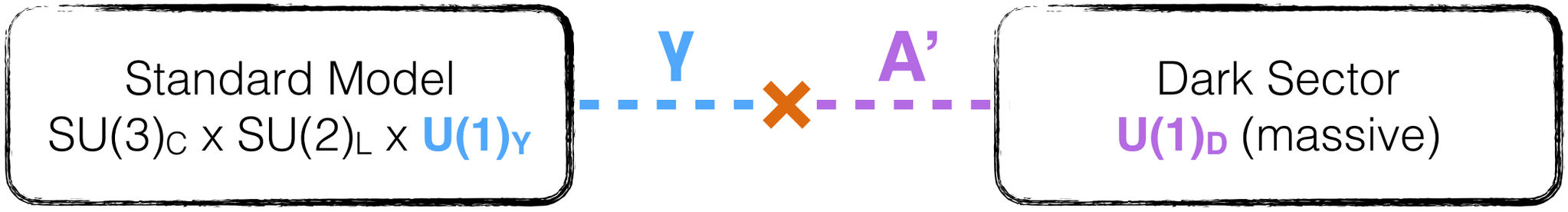
Belle II: Luminosity Projection.

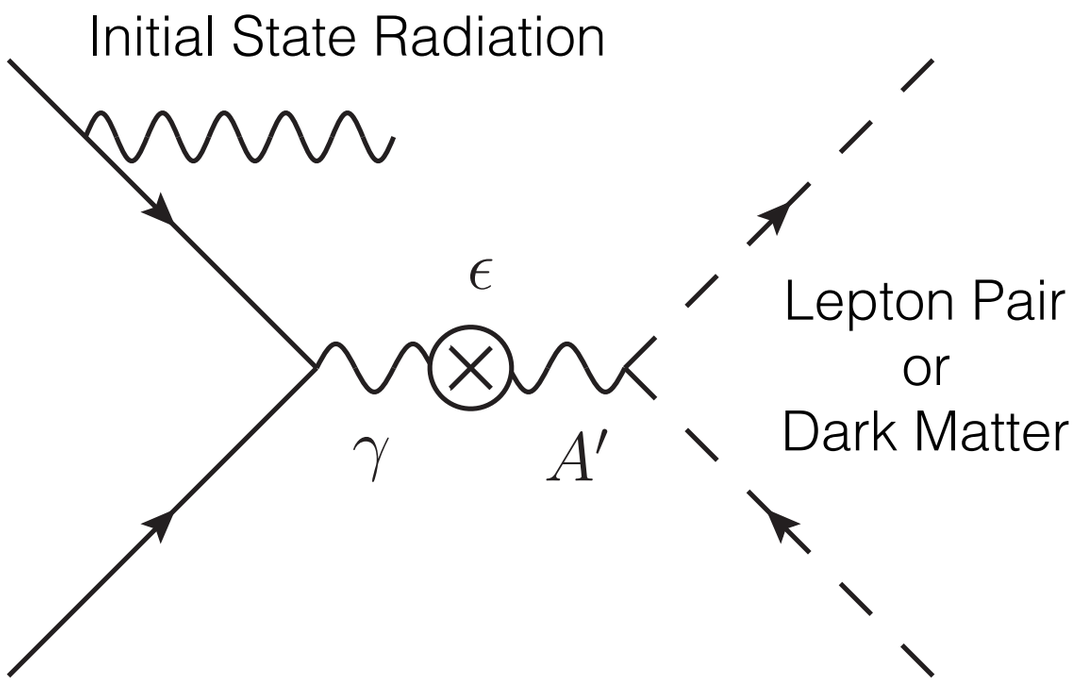


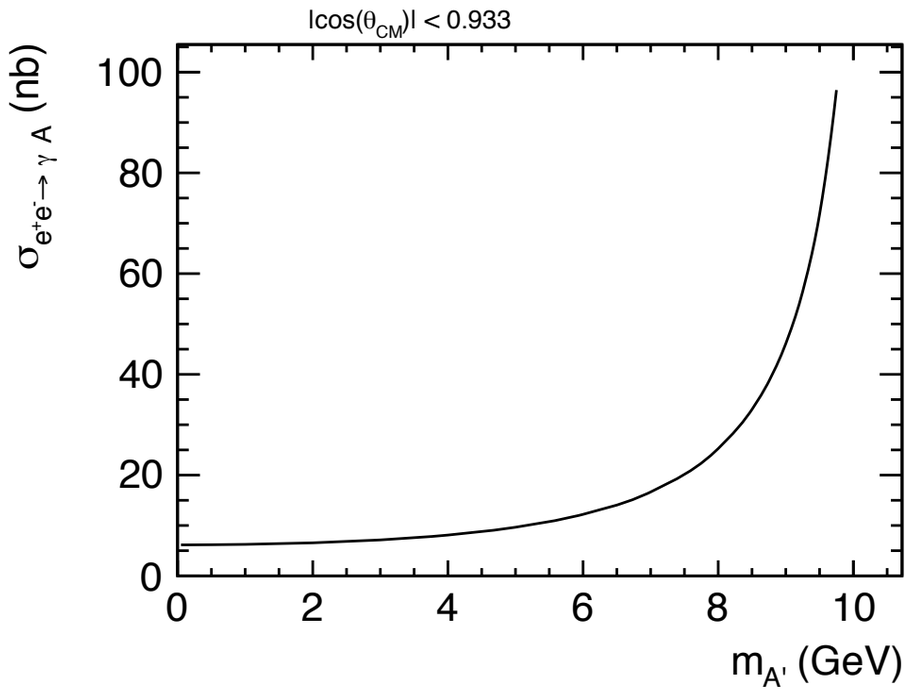
Dark Photon searches.

- In the so called “vector portal”, a dark photon **A’** mixes* with the SM photon **γ** with strength **ε**:

*Holdom, Phys. Lett B166, 1986

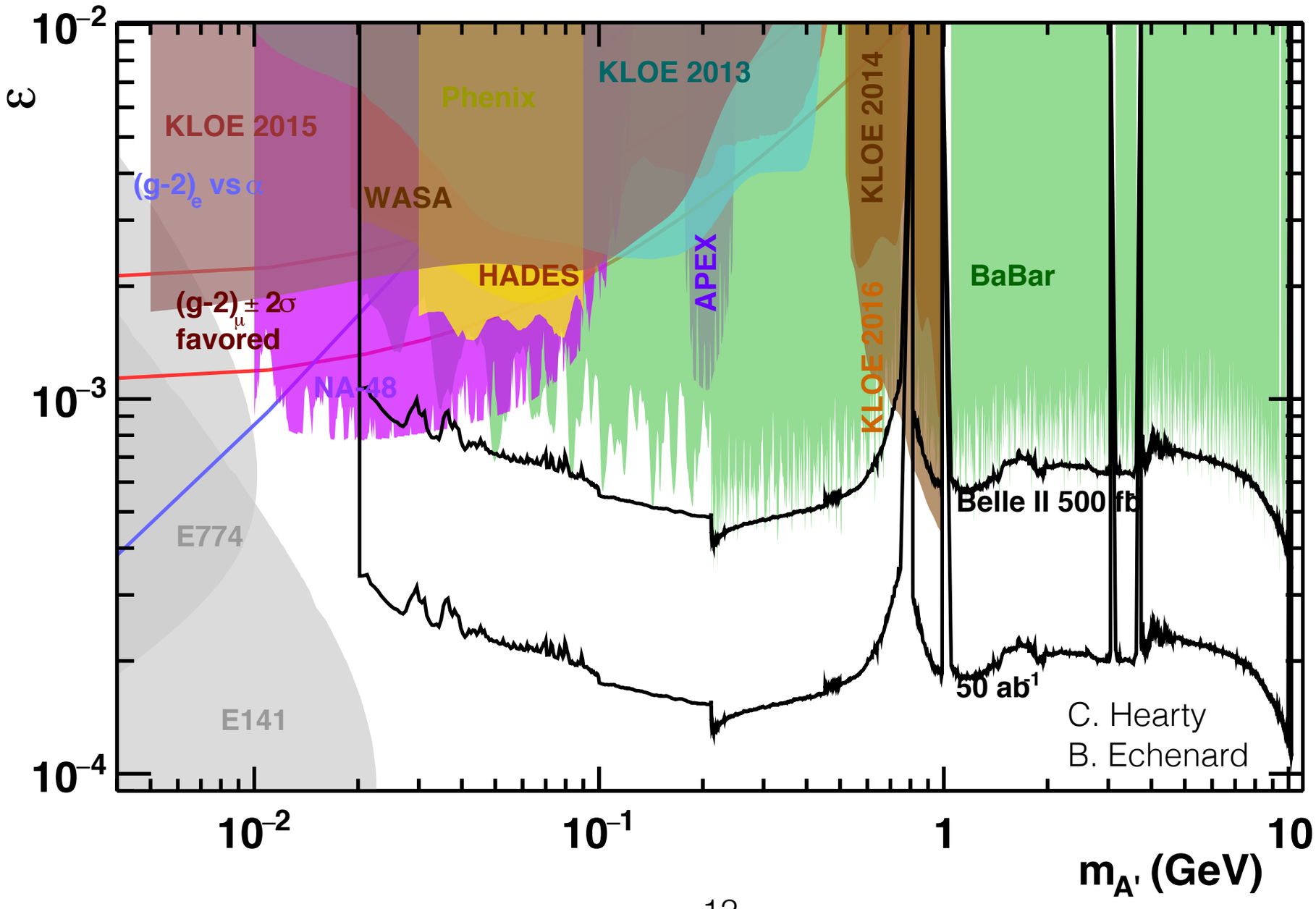




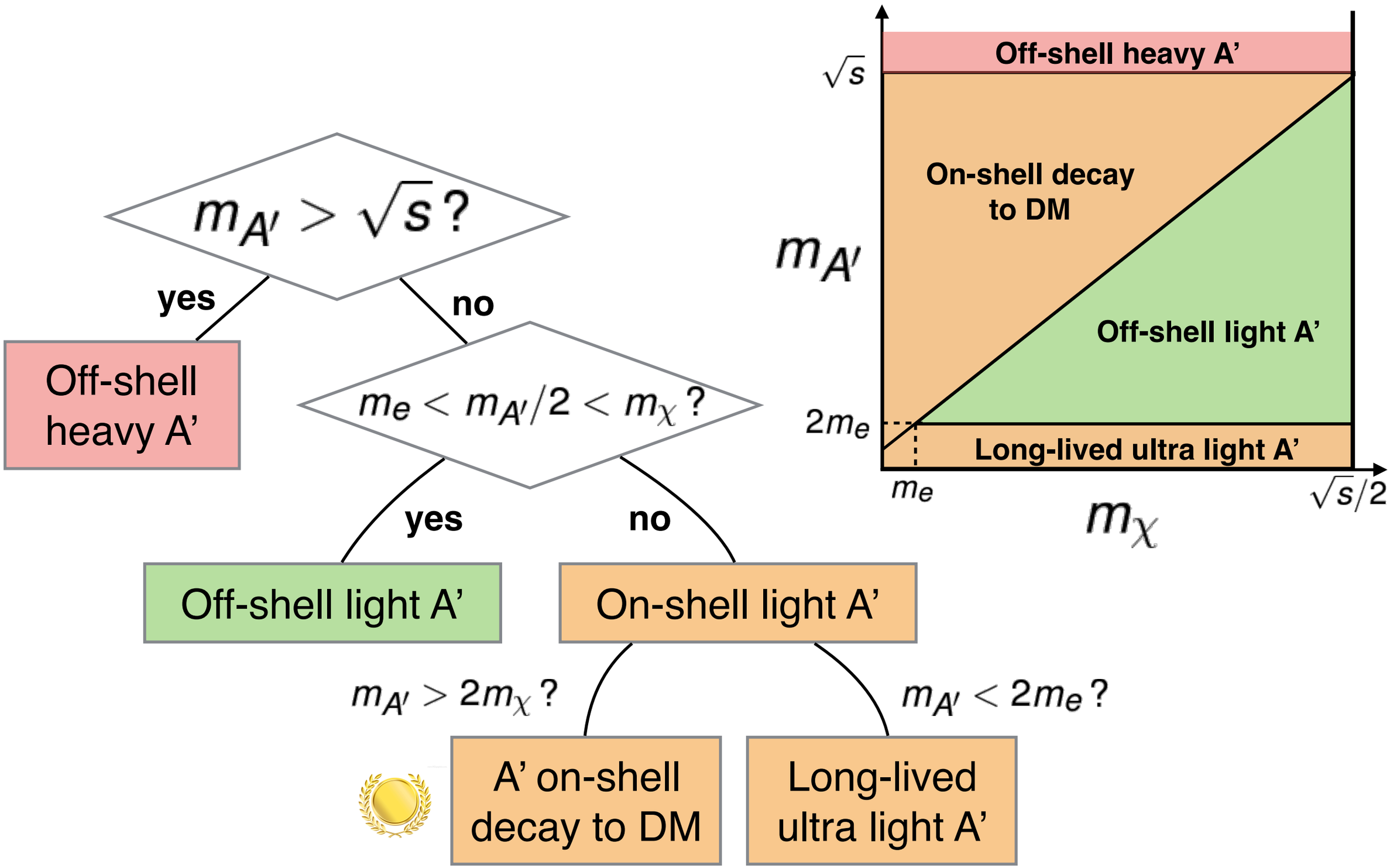


Dark Photon to Leptons.

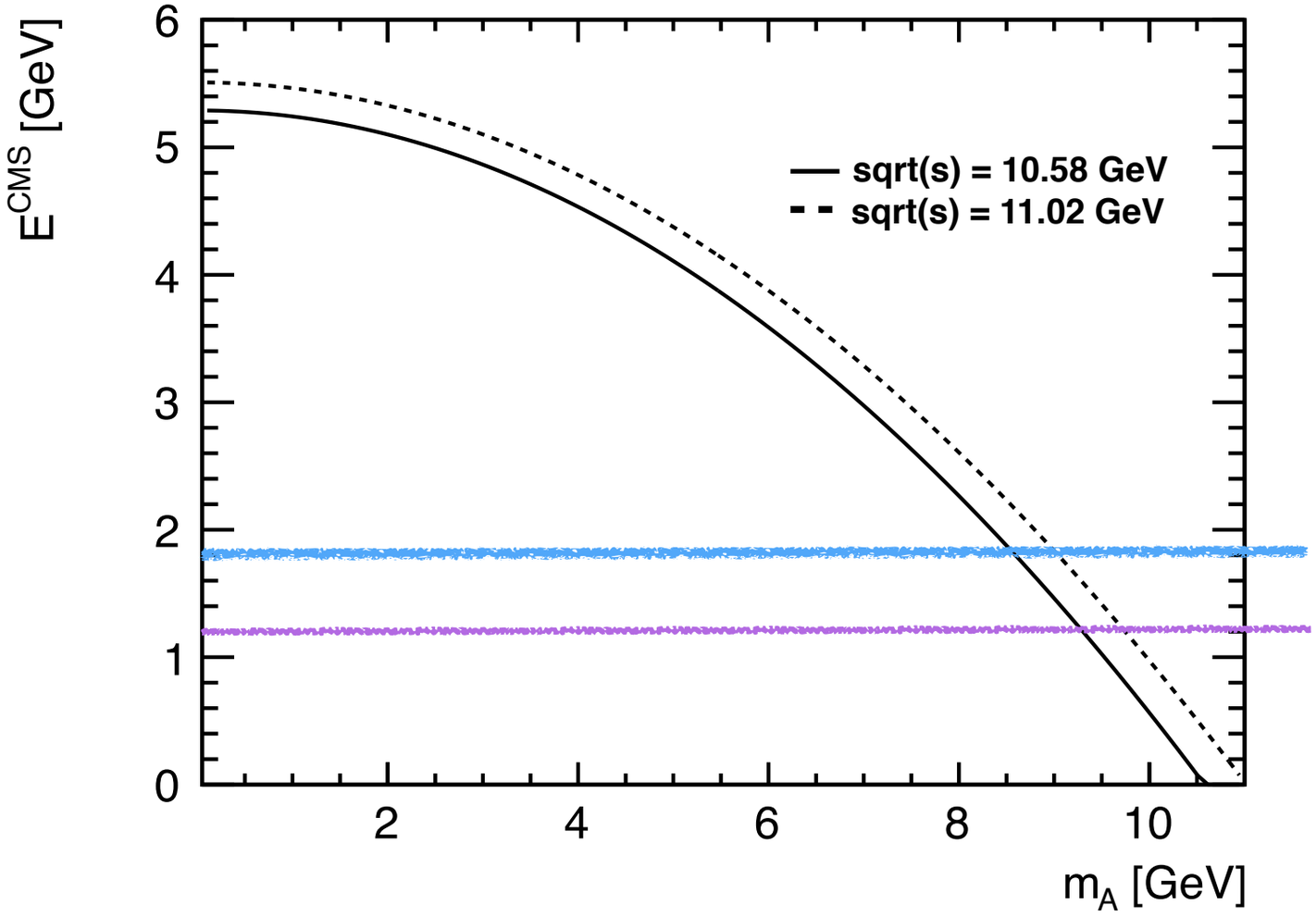
- Belle II limit scaled from BaBar: two times better mass resolution (larger drift chamber), better trigger efficiency for ee final states.



Dark Photon to Dark Matter.



Dark Photon to Dark Matter.



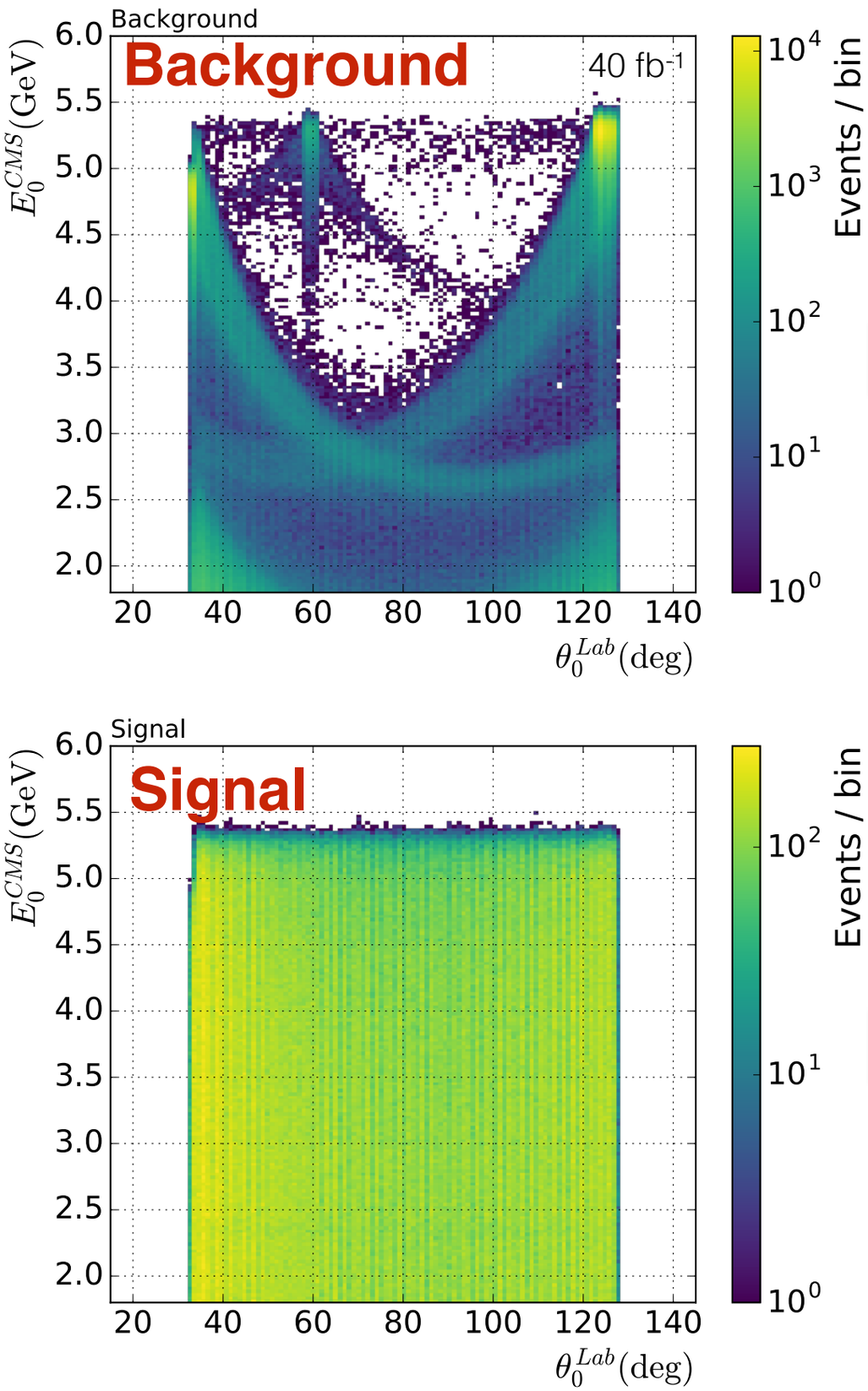
$$E_\gamma = \frac{s - M_{A'}^2}{2\sqrt{s}}$$

- Energy resolution for E_{ECL}>1.8 GeV is about 2 %, almost independent of beam backgrounds.

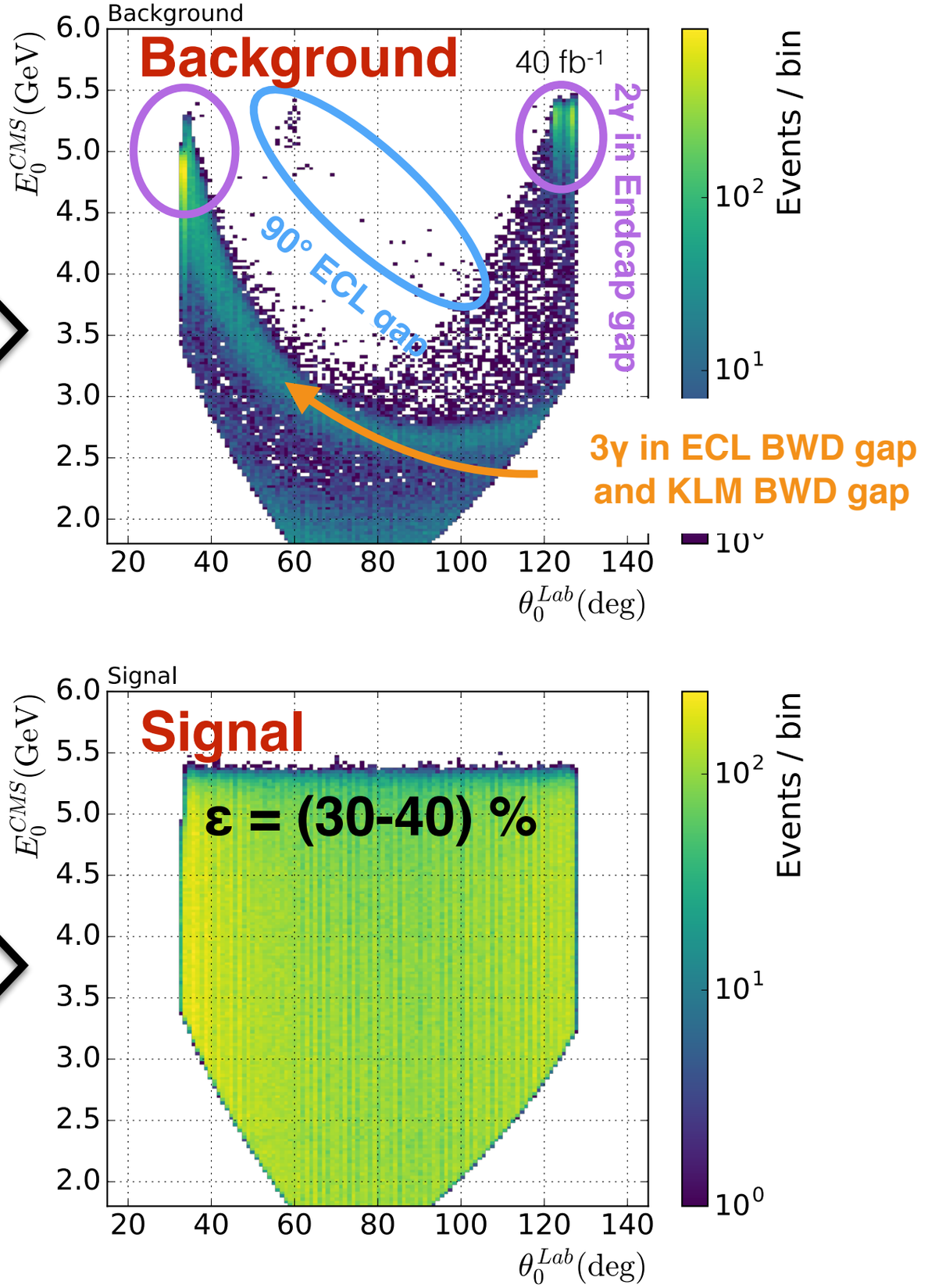
- Dark Photon mass resolution below $m_A \approx 2.5$ GeV too poor to determine m_A but we can still make an observation.

Dark Photon to Dark Matter.

Phase 2 geometry (no VXD)
Phase 2 beam backgrounds

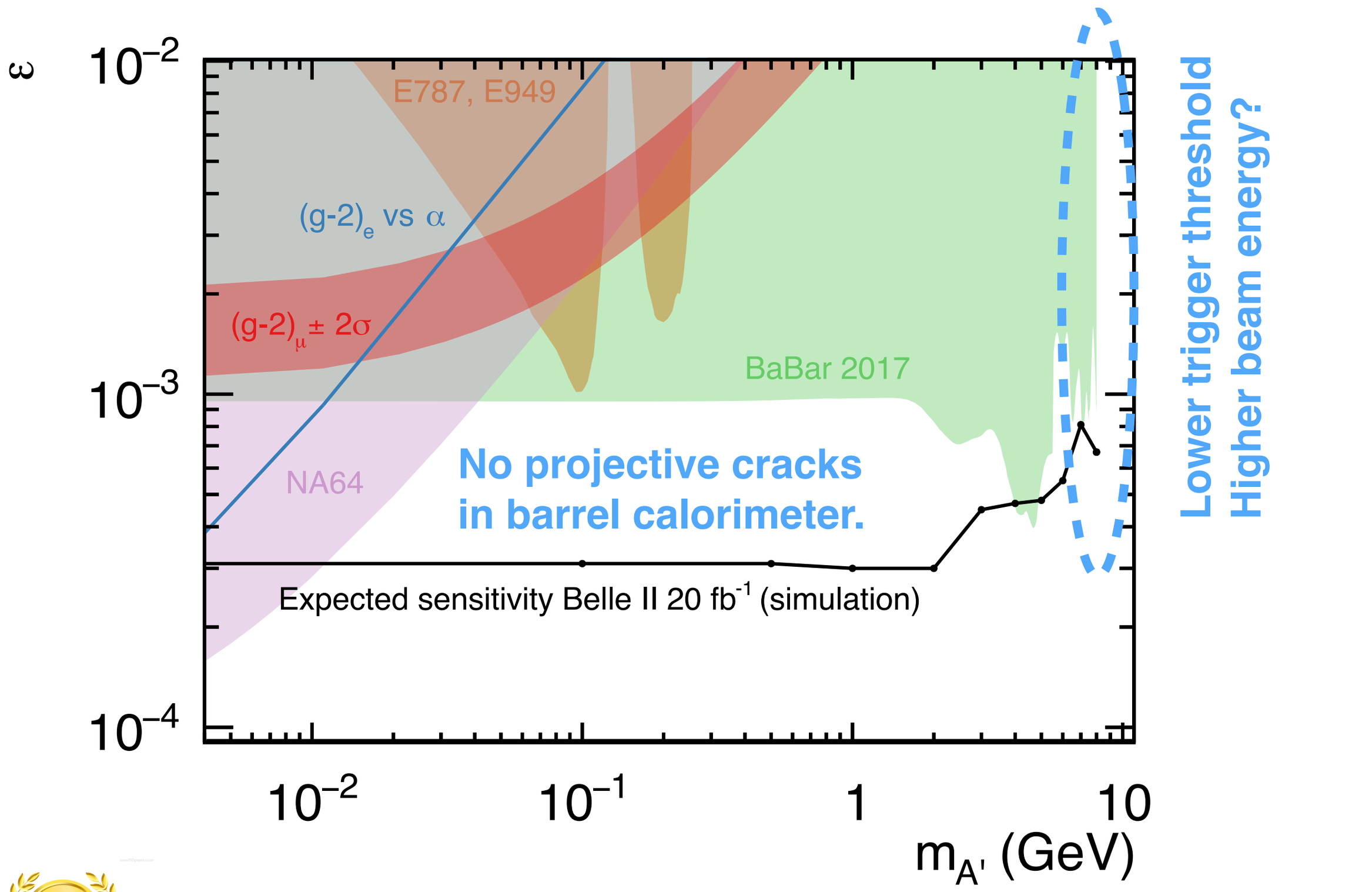


selection



selection

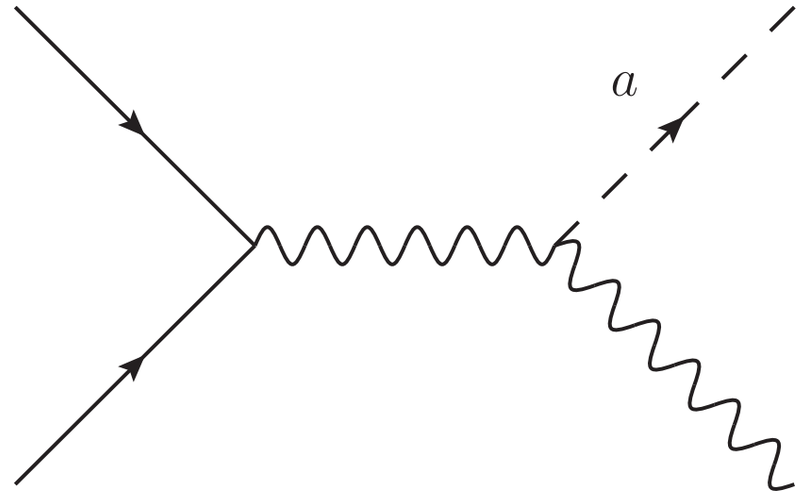
Dark Photon to Dark Matter.



→ "Golden mode" for Phase 2 early data.

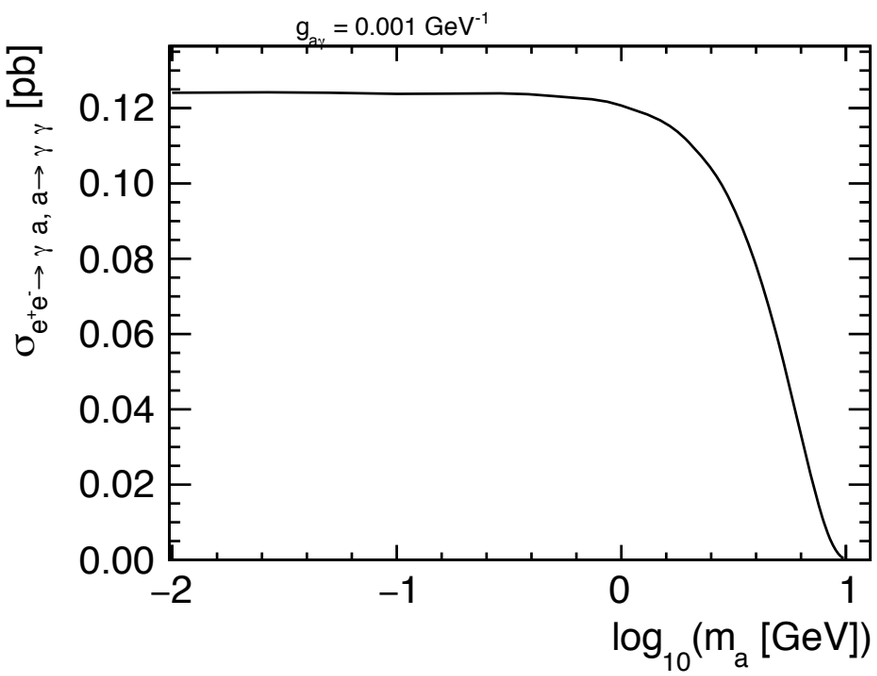
Axion-like particles.

- Axion-like particles couple to to all bosons. For Belle II, the coupling $g_{a\gamma}$ to photons has the by far largest cross section and is the only one accessible for the direct search.



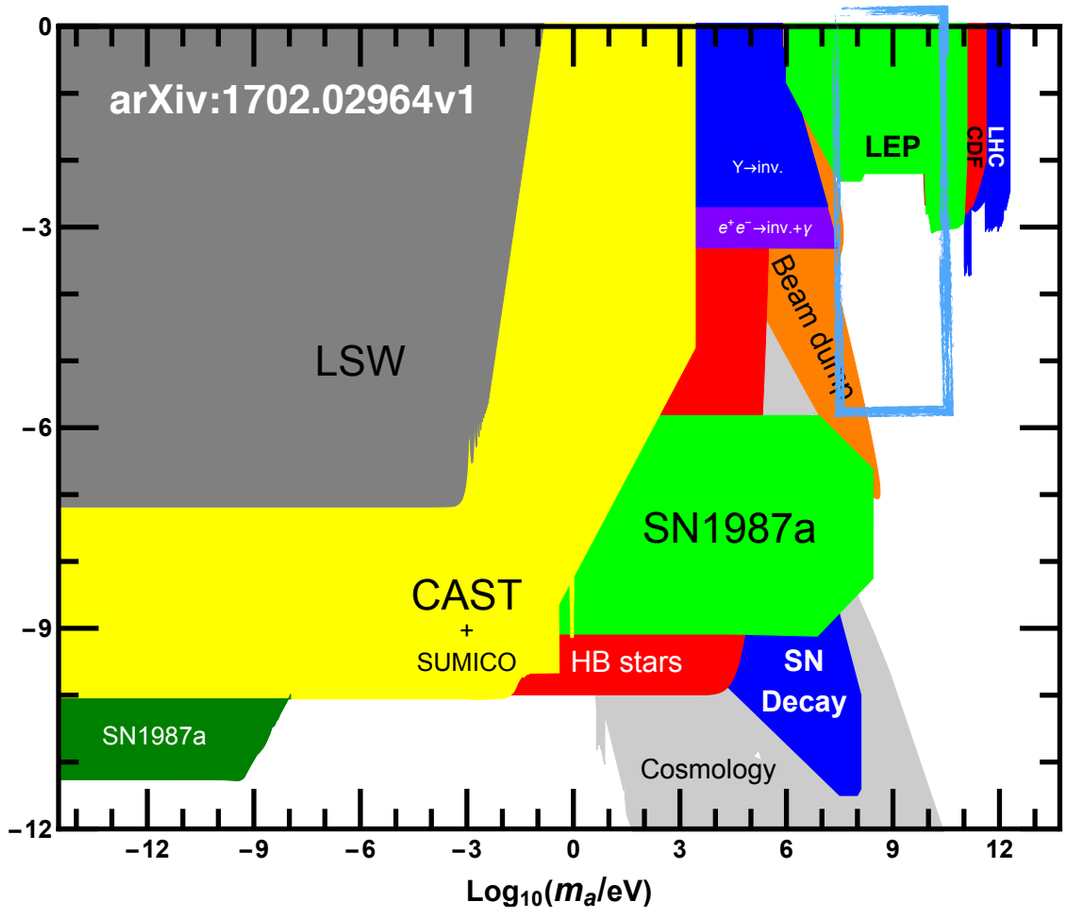
- Complementary: g_{aW} can be probed in some B decays [1,2].

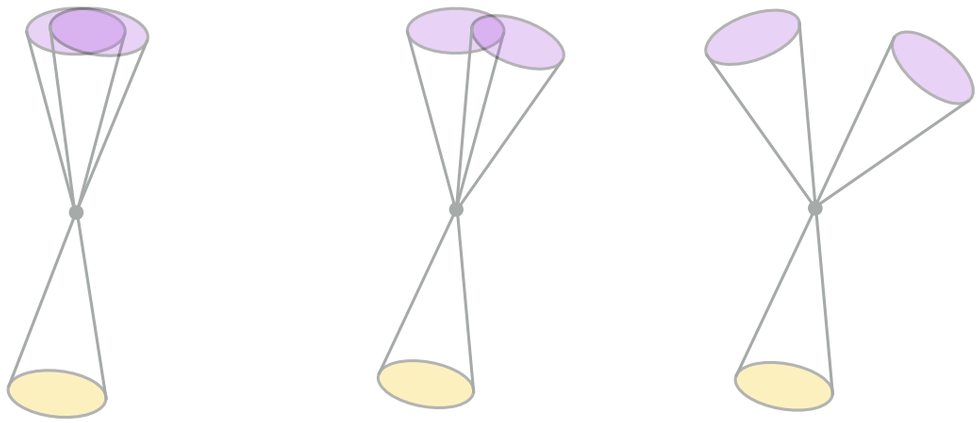
- Assume all axions decay into two photons $a \rightarrow \gamma\gamma$.

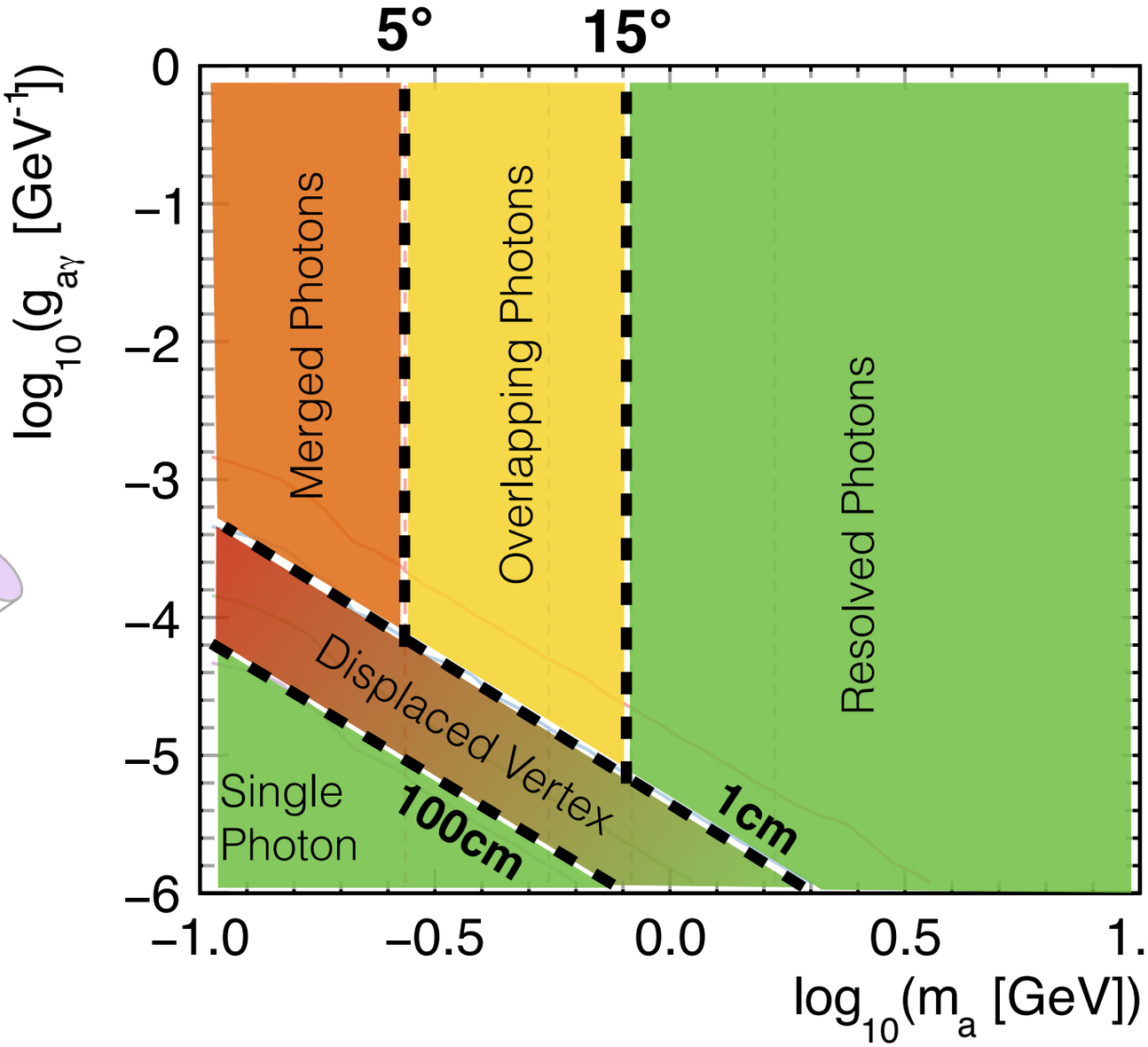


1) https://arxiv.org/abs/1409.4792
2) https://arxiv.org/abs/1611.09355

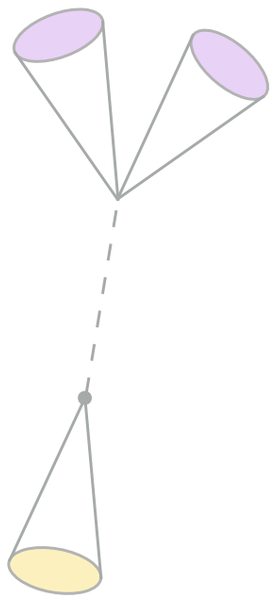
Axion-like particles.







Sensitivity during Phase 2 with optimized triggers under study.



Summary.

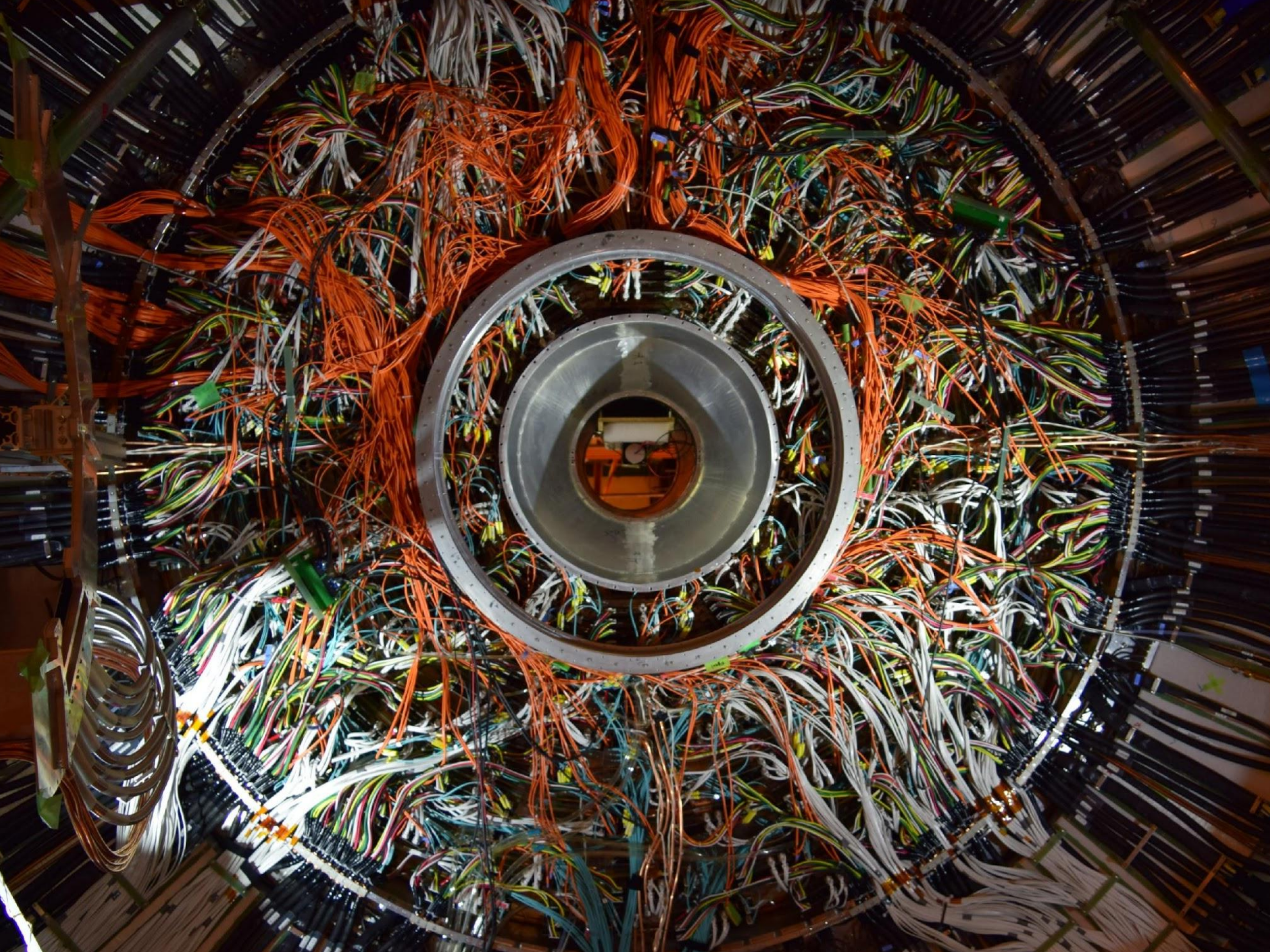
- Belle II offers high sensitivity to New Physics at the intensity frontier, largely complementary to LHCb.

- Significantly higher beam backgrounds and much higher collision rate require improved hardware and new reconstruction algorithms.

- Belle II will start detector commissioning (no VXD) end of 2017 until mid 2018 (“Phase 2”).

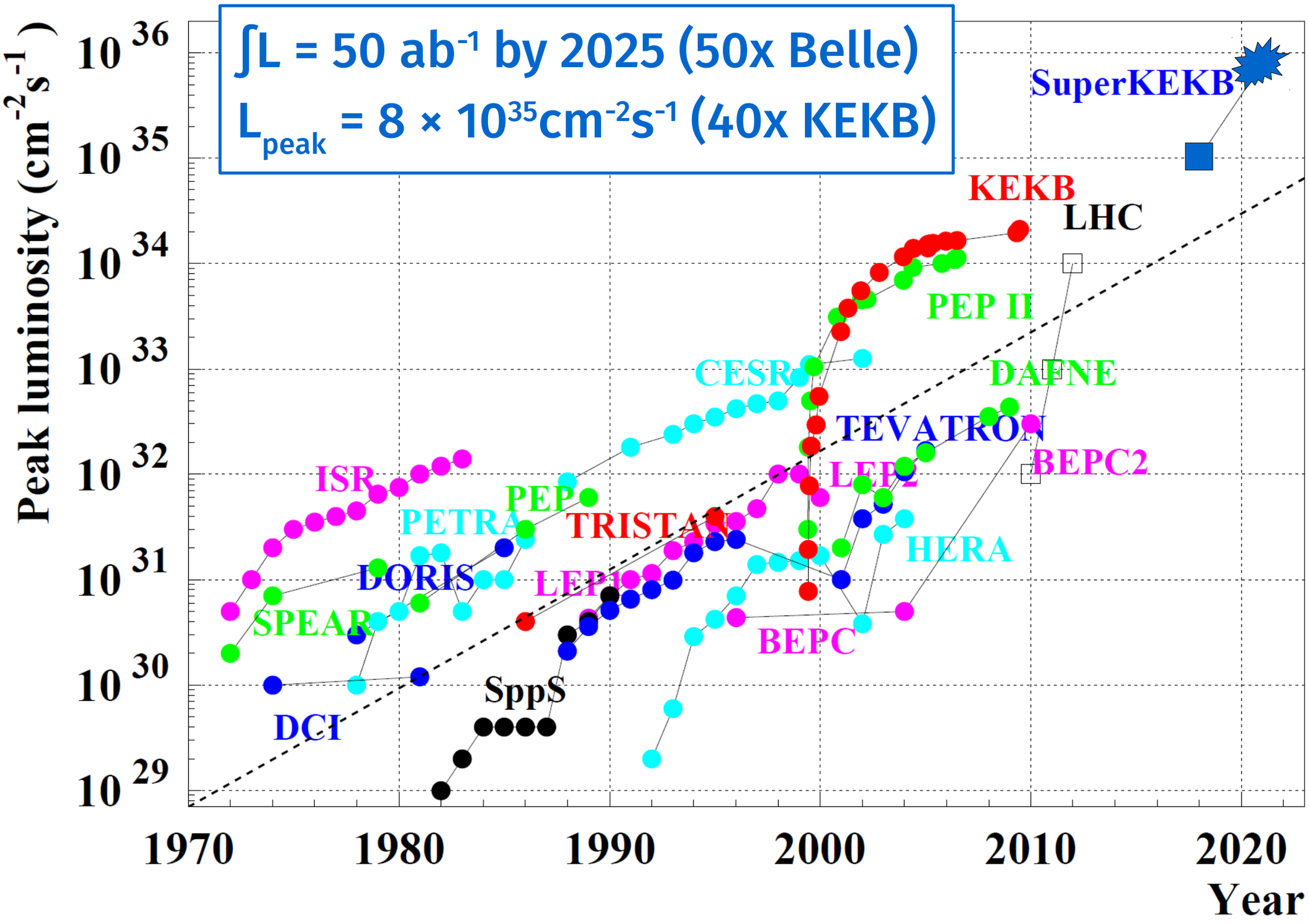
- The search for a dark photon decaying invisibly, and the search for an axion like particle may be possible even in “Phase 2”.

- Physics data taking starts end of 2018. “50 × Belle” by 2025.



Backup

Peak luminosity over time.



Beam Paramaters.

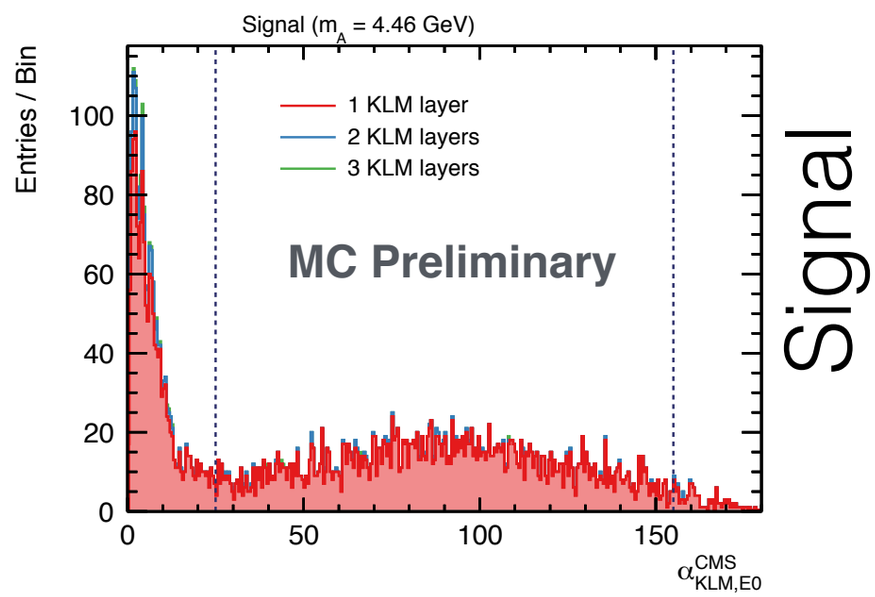
	LER (e^+)	HER (e^-)	
Energy	4.0	7.0	GeV
Half crossing angle	41.5		mrad
Horizontal emittance	3.2	4.6	nm
Emittance ratio	0.27	0.25	%
Beta functions at IP (x/y)	32 / 0.27	25 / 0.30	mm
Beam currents	3.6	2.6	A
Beam-beam parameter	0.0881	0.0807	
Luminosity	8×10^{35}		$\mathrm{cm}^{-2}\mathrm{s}^{-1}$

Experiment	Scans/Off. Res.	$\Upsilon(5S)$ 10876 MeV		$\Upsilon(4S)$ 10580 MeV		$\Upsilon(3S)$ 10355 MeV		$\Upsilon(2S)$ 10023 MeV		$\Upsilon(1S)$ 9460 MeV	
	fb^{-1}	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6
CLEO	17.1	0.4	0.1	16	17.1	1.2	5	1.2	10	1.2	21
BaBar	54	R_b scan		433	471	30	122	14	99	–	
Belle	100	121	36	711	772	3	12	25	158	6	102

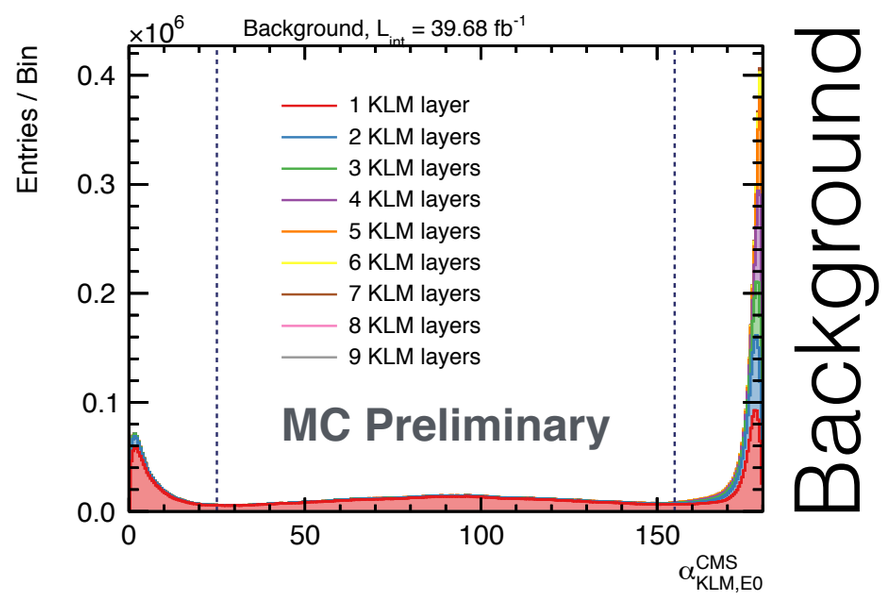
Backgrounds: KLM veto.

Release-00-08-00
Phase2 geometry
Phase 2 beam backgrounds

Veto on KLM cluster back to back to G0.

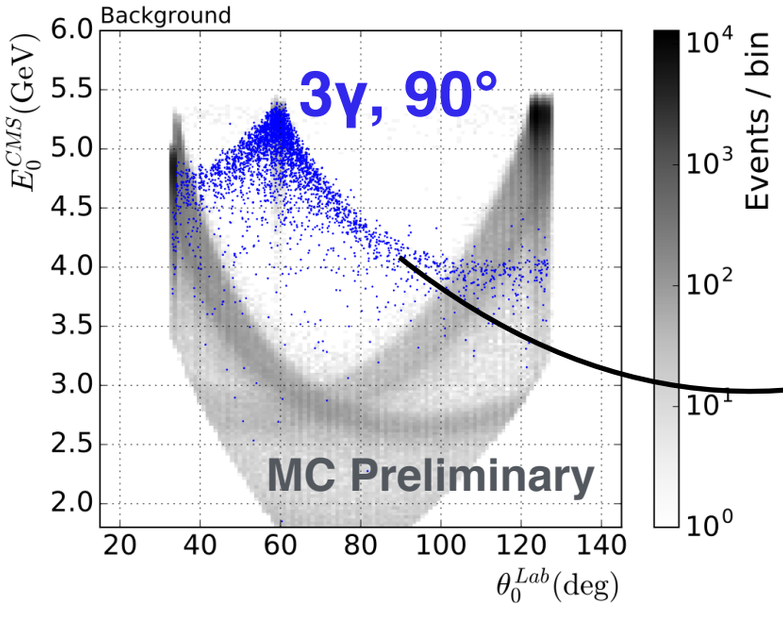


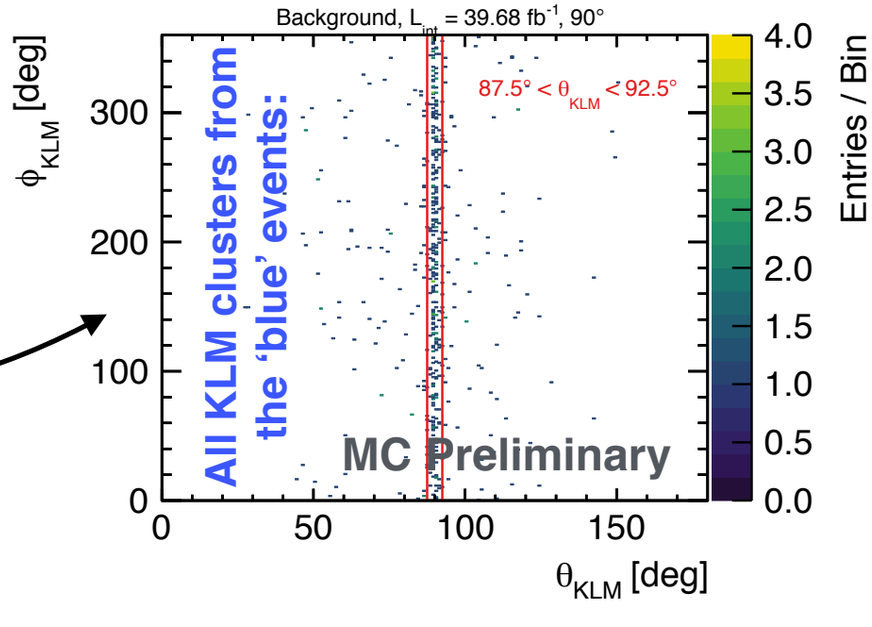
Signal



Background

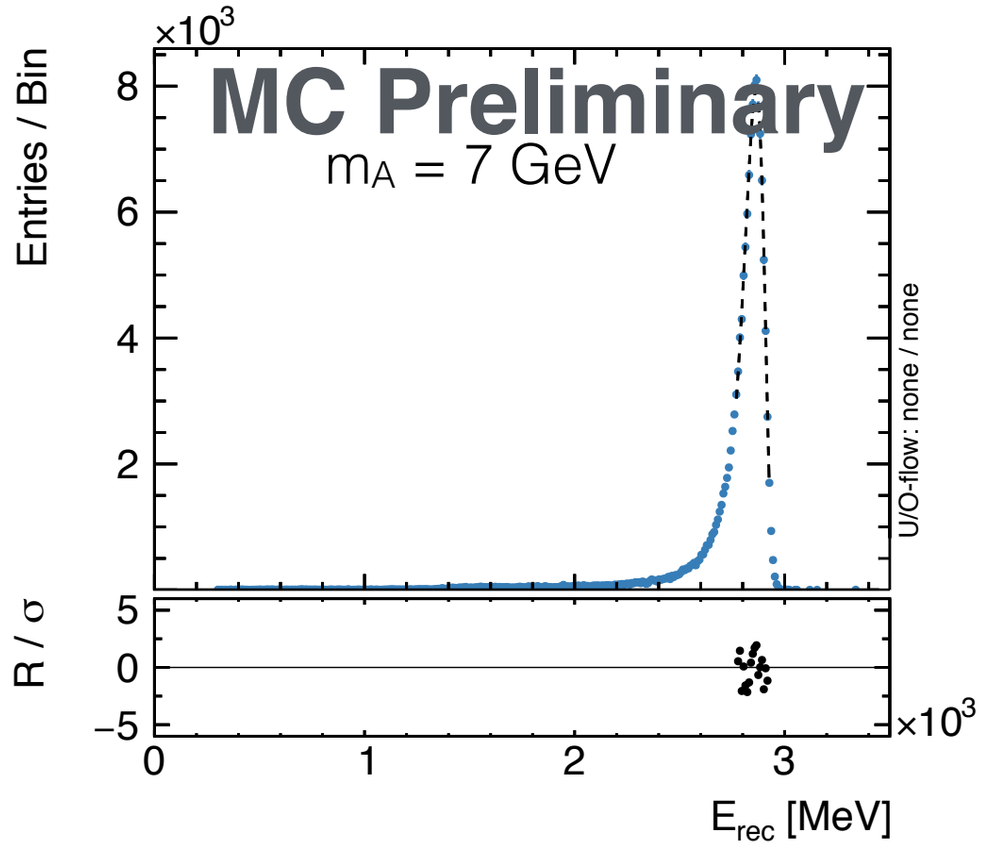
Veto on KLM cluster, e.g. 90° ECL gap:





Dark Photon to Dark Matter.

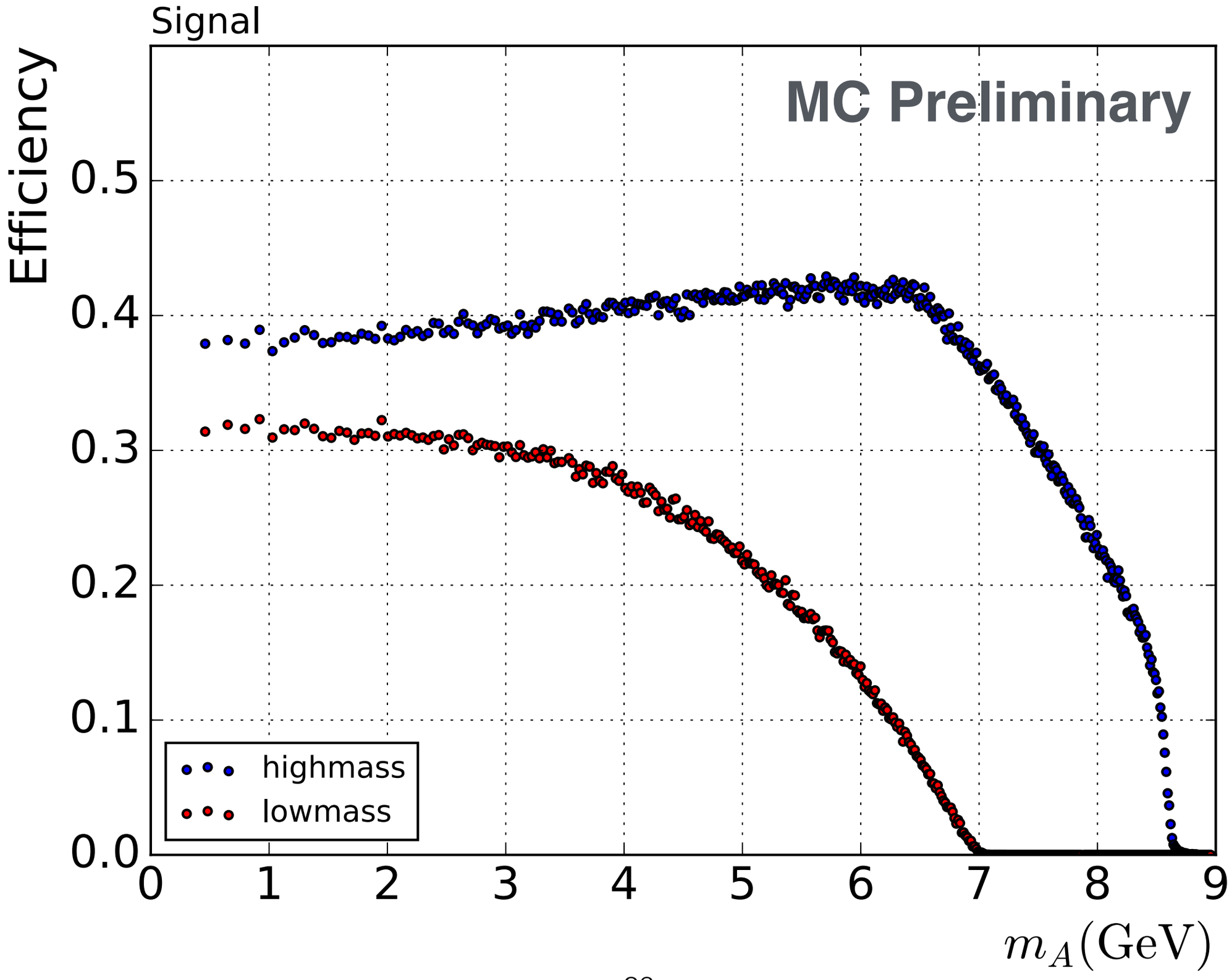
Preselection (reconstructed):
Calorimeter clusters sorted by energy in center of mass (CMS): G_0, G_1
$33° < \theta_0^{Lab} < 127°$ (~100% trigger efficiency)
E_0^{CMS}-dependent cut on θ_0^{Lab} for low E_0^{CMS}
$E_1^{CMS} < 0.1$ GeV (background dependent)
All Tracks $p_t < 0.2$ GeV
No KLM cluster back to back to G_0 in CMS
No KLM clusters in KLM veto regions (background dependent)



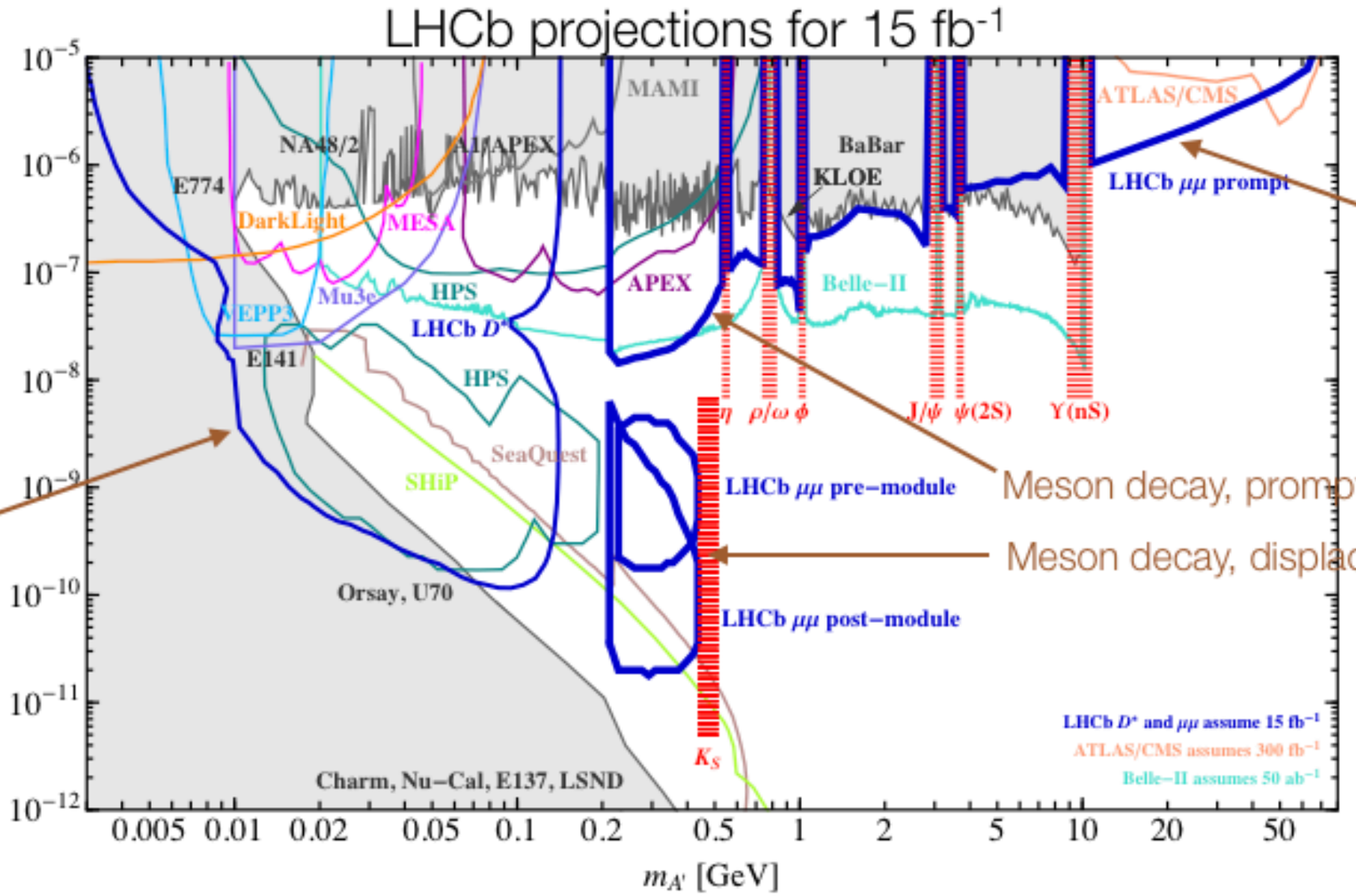
Example Dark Photon Peak

Backgrounds: Efficiency.

Release-00-08-00
Phase2 geometry
Phase 2 beam backgrounds



Dark Photon: Planned Searches.



Mike Williams

arXiv:1603.08926v1