HIDDeν

Hunting Invisibles: Dark sectors, Dark matter and Neutrinos

Belle II

Invisible Decays of a Dark Photon at Belle II

Invisibles 2021

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on behalf of the Belle II Collaboration

June 2nd, 2021

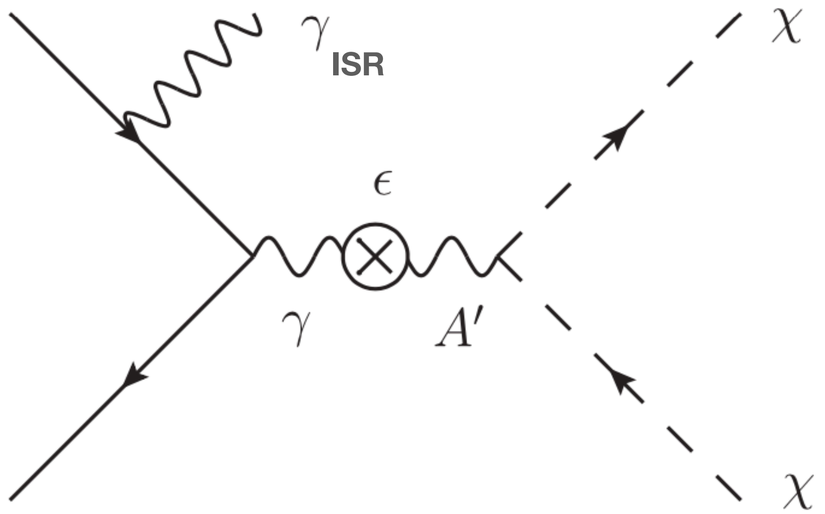
UBC

DESY.

Dark Photon at Belle II

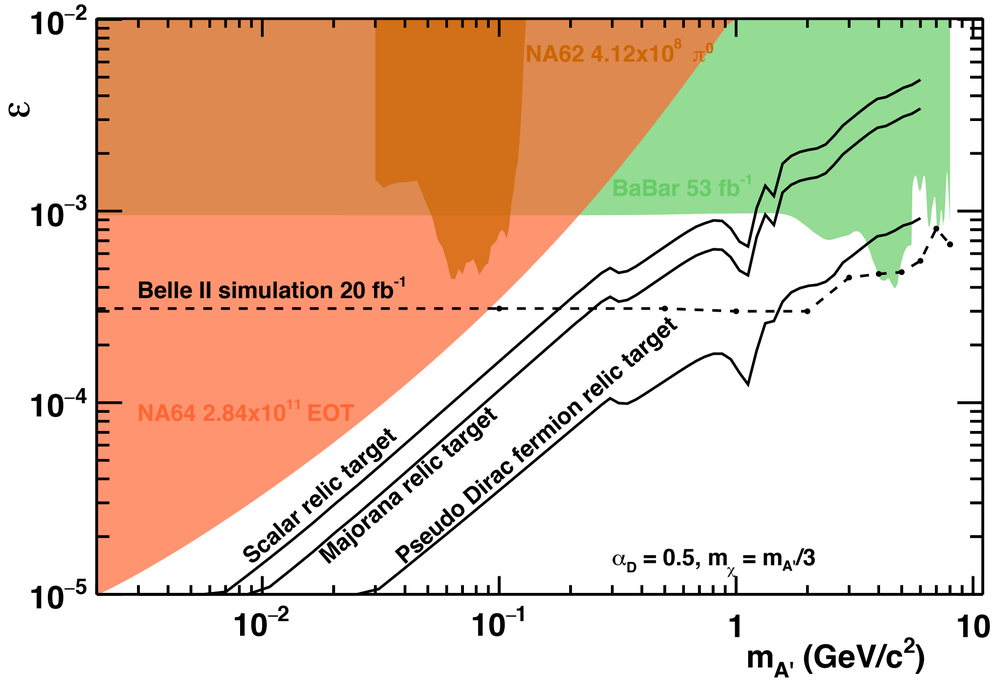
What?

- Dark sector mediator which couples to SM photon



How?

- Belle II looks into $e^+e^- \to \gamma_{ISR}\ A';\ \ A' \to \chi\chi$
- Final state: Single γ + Missing Energy
- $m^2_{A'} = 4E^*_{beam}(E^*_{beam} - E^*_{\gamma_{ISR}})$; Easy to find A' mass
- Newly designed trigger allows sensitivity down to 0.5 GeV of single photon



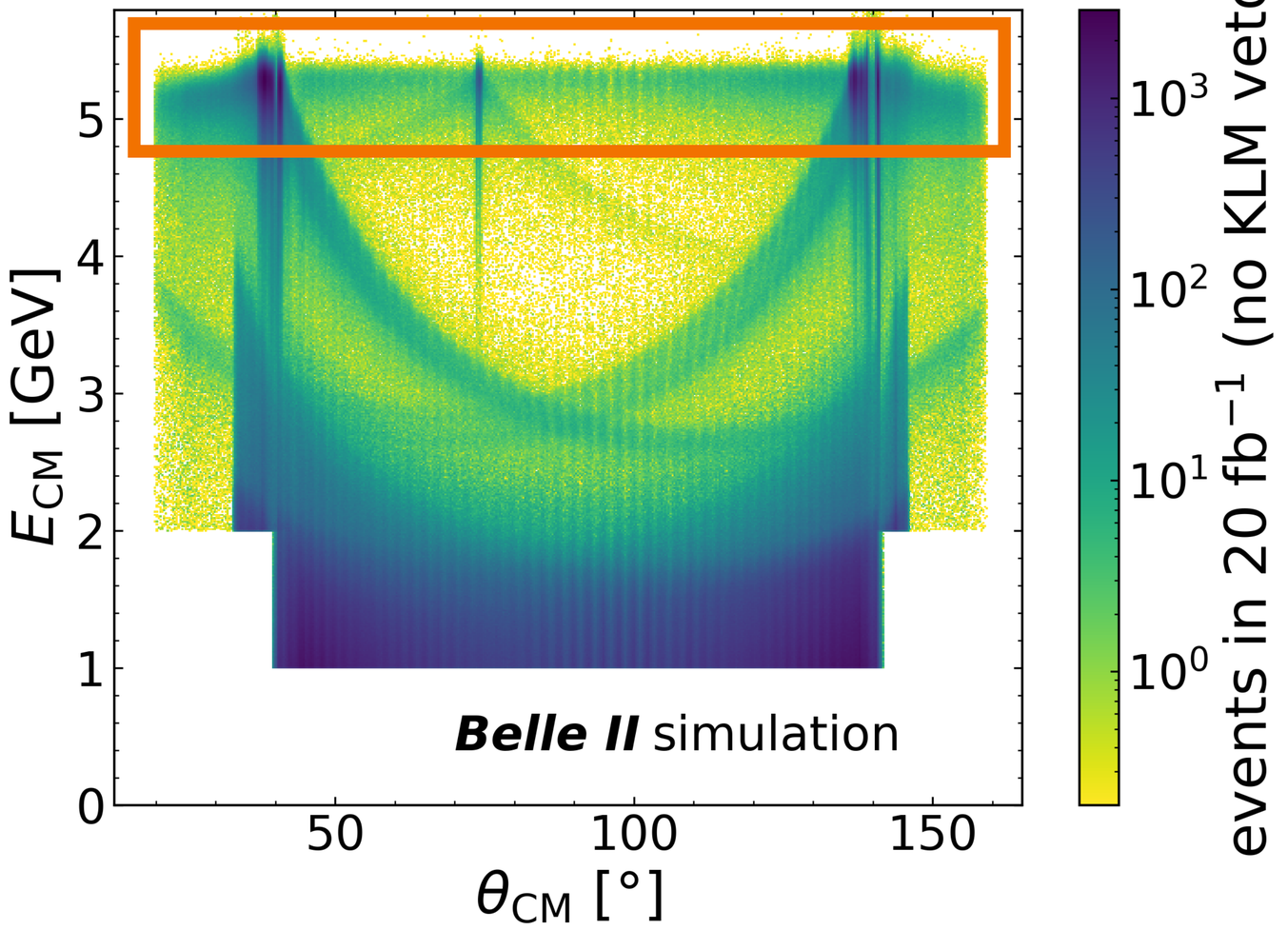
Based on M. Graham, C. Hearty, M. Williams, Annu. Rev. Nucl. Part. Sci. 2021. 71:37

Overview of search

Background Studies

- When single photon has E^* ~ 5 GeV, dominant background: $e^+e^- \to \gamma\gamma$, missing 1 γ
- How likely are we to miss a γ in our detector?
- Main detectors: Electromagnetic Calorimeter (ECL) and K-Long Muon (KLM) Detector

Predicted Background γ's Energy against Location



Belle II Simulation Preliminary

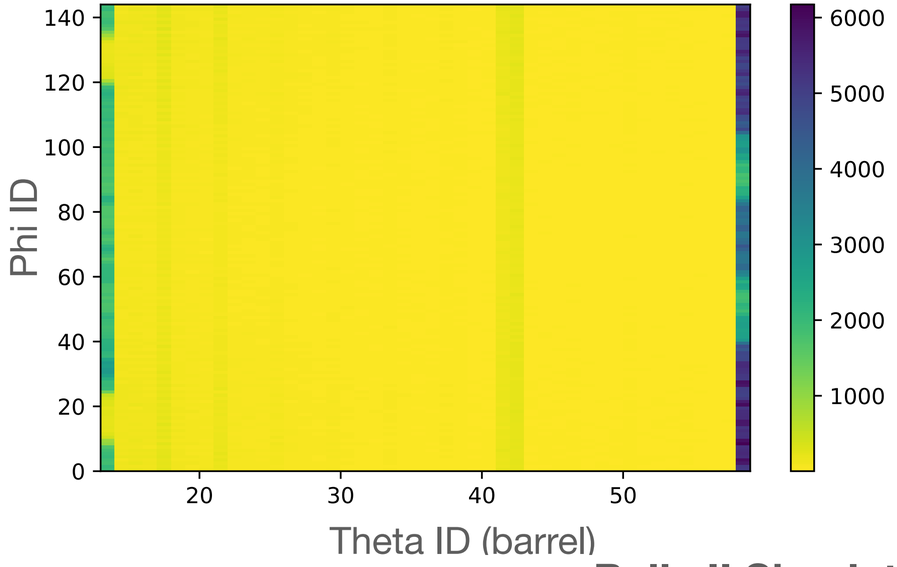
Working with $e^+e^- \to \gamma\gamma$ Background

Studying Efficiency of Sub-detectors

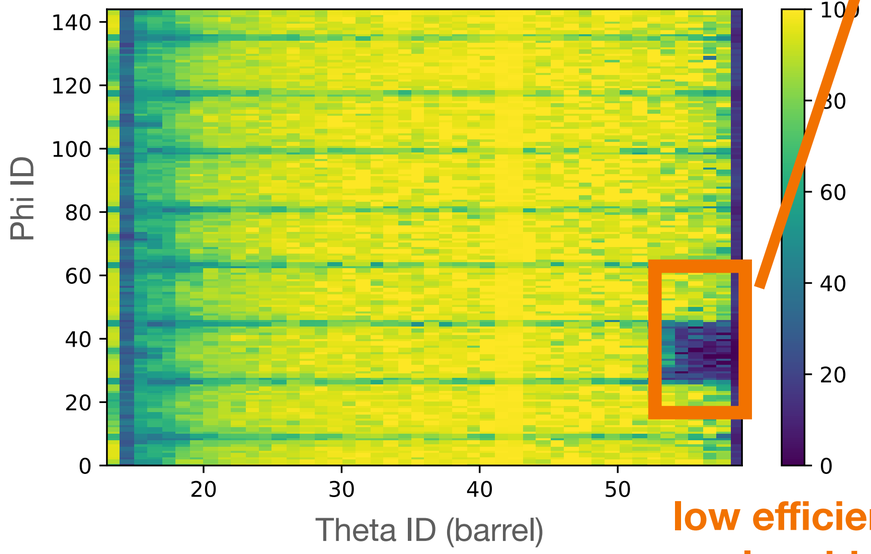
- Most of background come from gaps in the detectors, with a "high leakage γ" (roughly 4% of all γs)
- Study efficiency of detectors as a function of leakage energy; $E_{leak} = E_{beam} - E_{calorimeter}$ using $e^+e^- \to \gamma\gamma$ control sample

~ 4% of all photons are highly leaking

Photons in ECL with Leakage Energy > 2.8 GeV per crystal

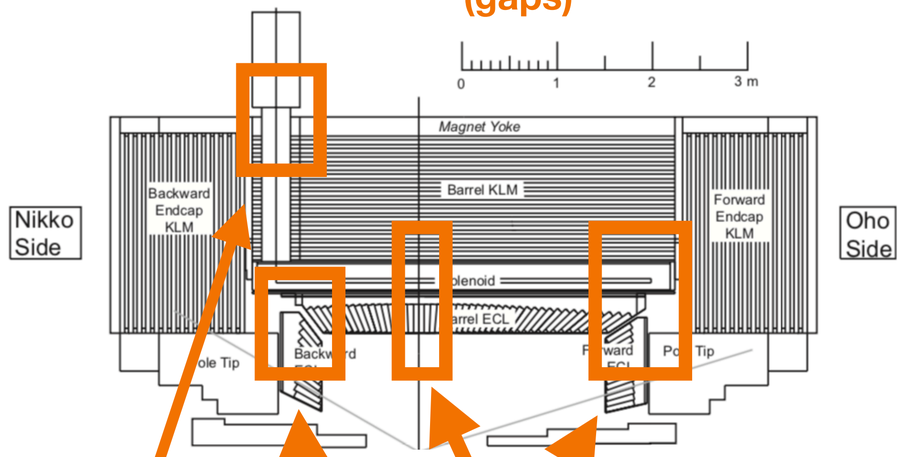


Fraction of the photons also detected in the KLM



Belle II Simulation Preliminary

Problematic Regions in Detector (gaps)



gaps for cables

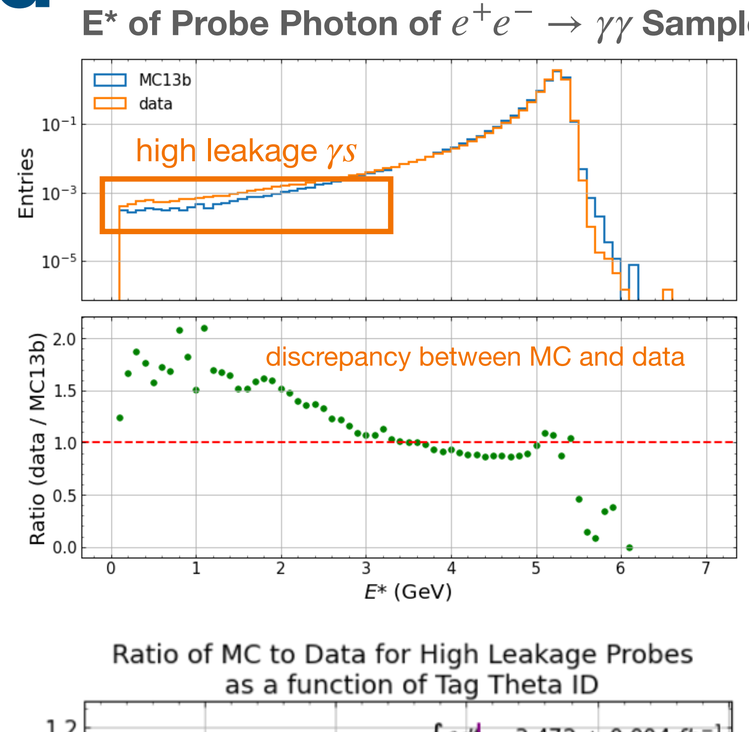
1.5mm aluminium structure gap

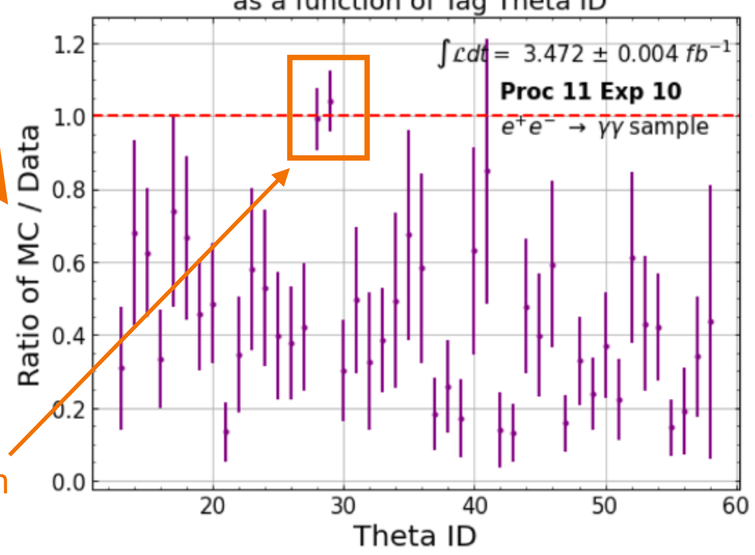
low efficiency due to solenoid structure

Working with $e^+e^- \to \gamma\gamma$ Background

Monte Carlo (MC) and Data discrepancy

- Next stage is to understand the background uncertainty on data (pre-blind process)
- Currently we see many more high leakage photons in data than in MC
- Gaps between crystals may be larger in data than MC
- Currently trying to quantify background in data by scaling MC





good agreement in 1.5 mm gap

Belle II Simulation Preliminary

Thank you for listening!

For more information, please check my poster ☺️

Questions?

Backup Slides

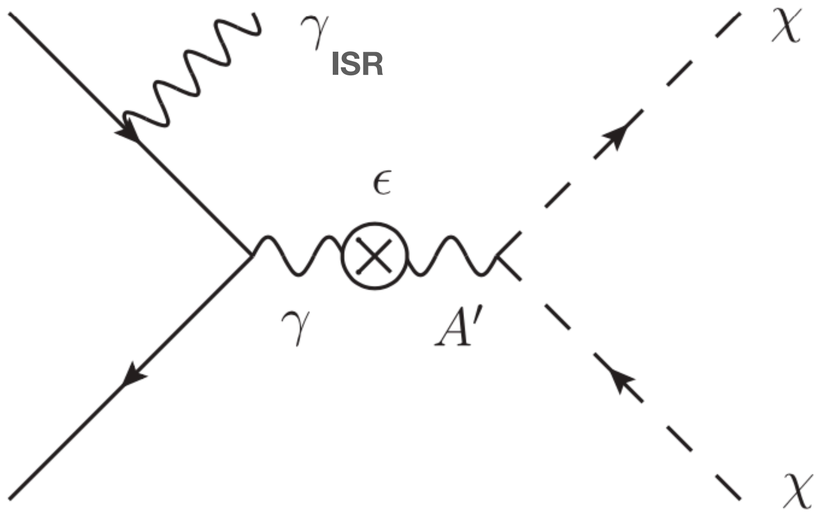
Searches in Other Experiments

- Direct competitor: BaBar

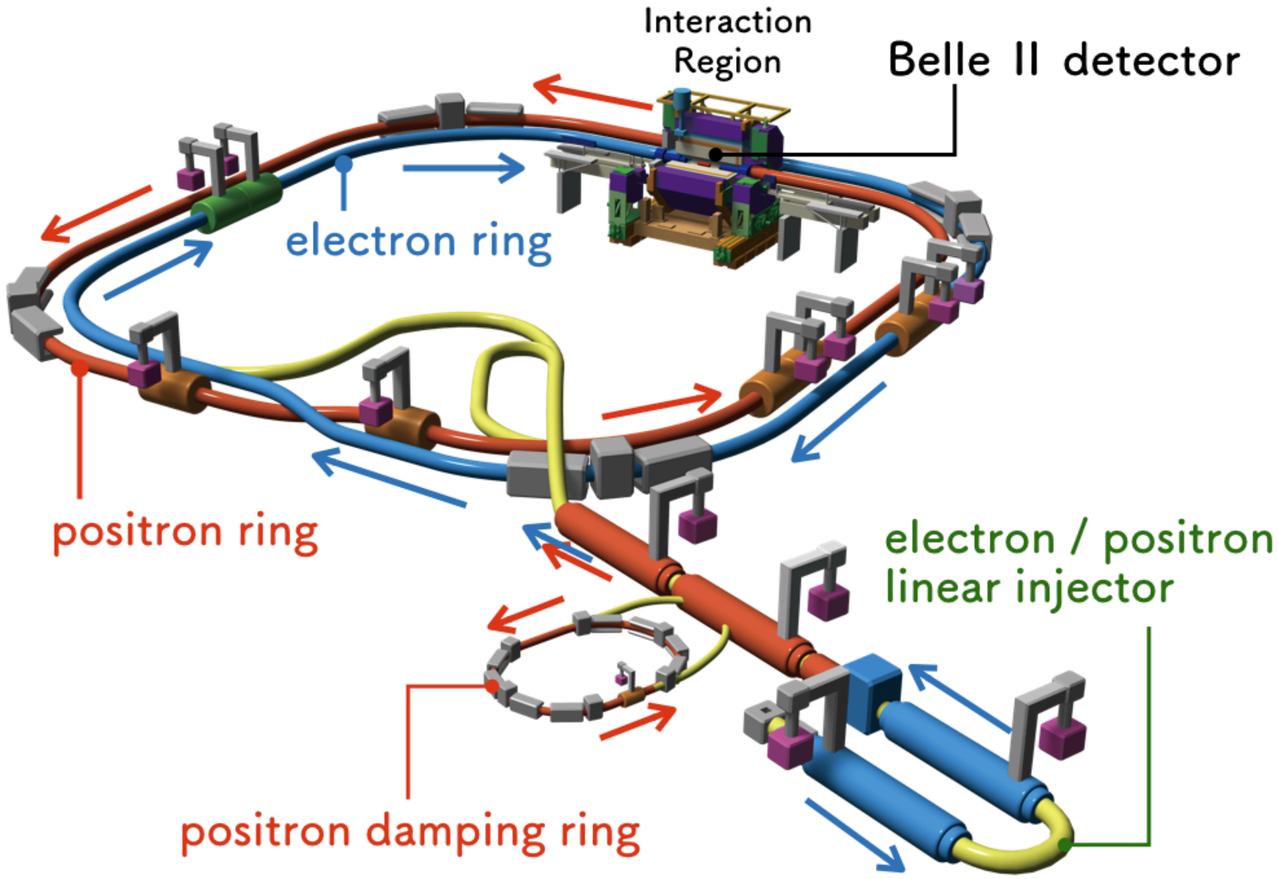
Phys. Rev. Lett.119 (2017) 13, 131804

- Complementary search: NA64

https://arxiv.org/abs/1906.00176

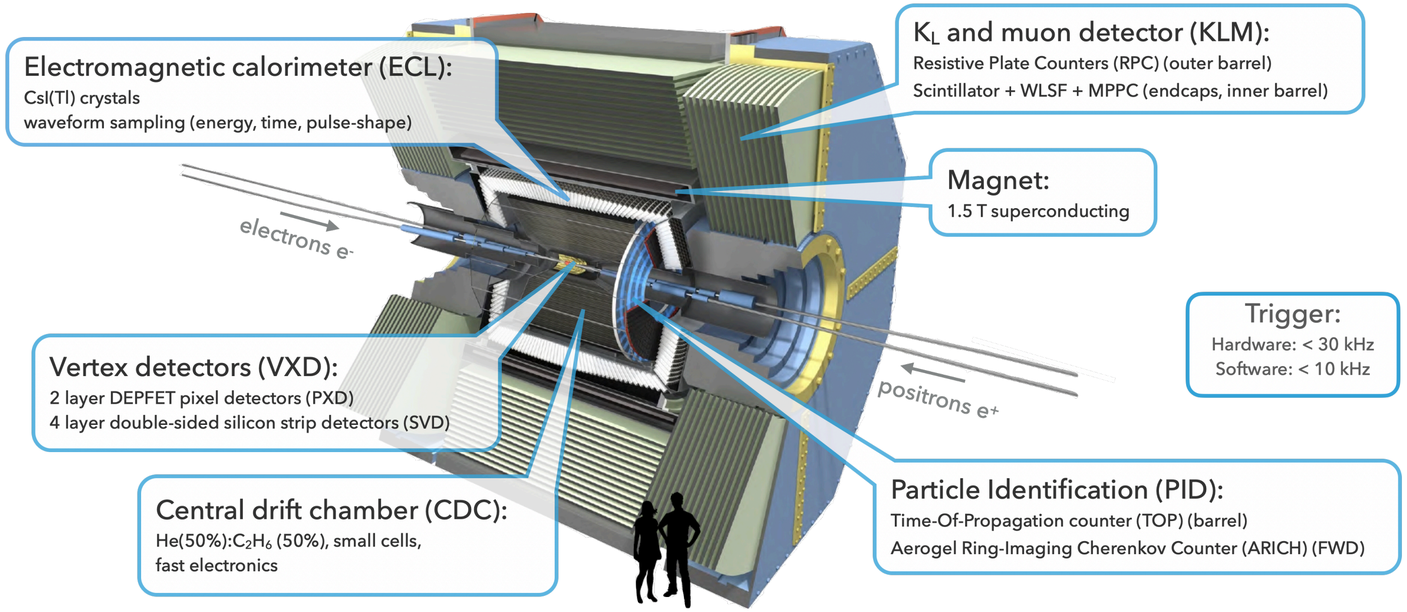


SuperKEKB



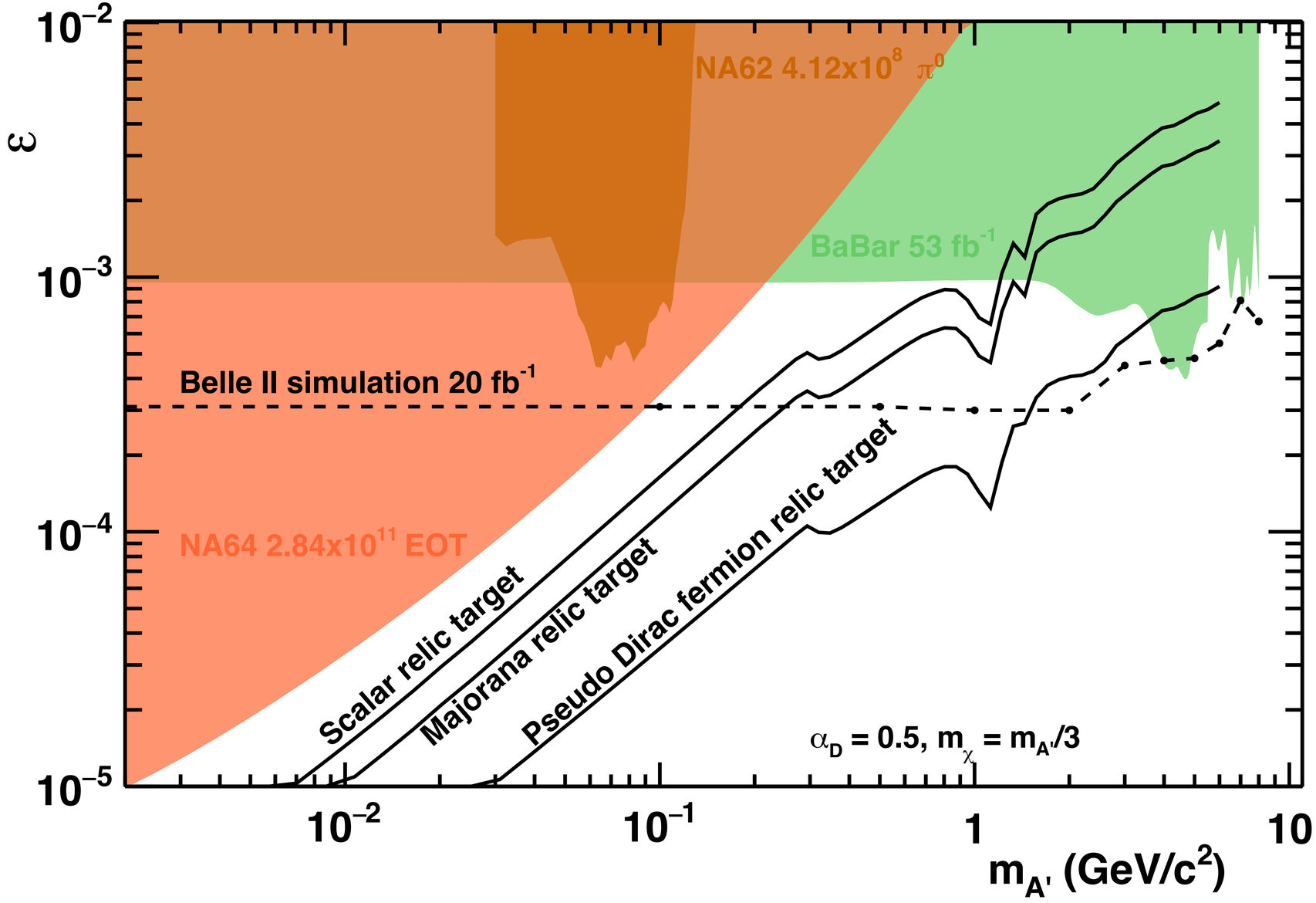
- SuperKEKB is an asymmetric particle accelerator with a circumference of 3 km located in Japan.
- Operates at resonance energy of $\Upsilon(4S)$ at $10.58\ \mathrm{GeV}$.
- New world record for instantaneous luminosity of $2.4 \times 10^{34} cm^{-2} s^{-1}$ was achieved in June 2020.

Belle II

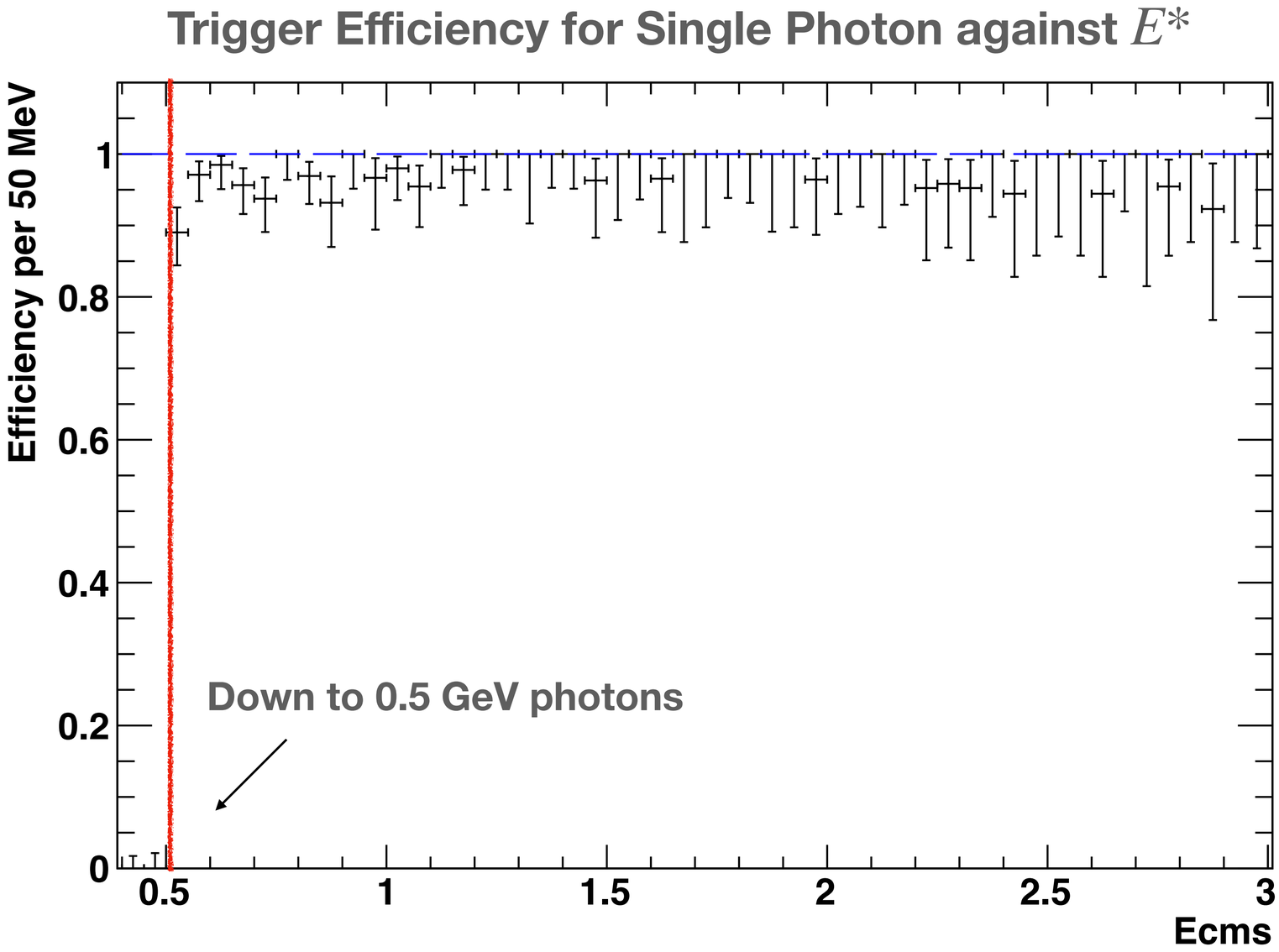


- TheBelleII experiment aims to make precise measurements of CP violation in the weak sector, as well as find New Physics Beyond the Standard Model of Particle Physics.
- Current aim is to collect $50ab^{-1}$ by 2031.
- International collaboration with nearly 1000 physicist and engineers from 115 institutions in 26 countries.

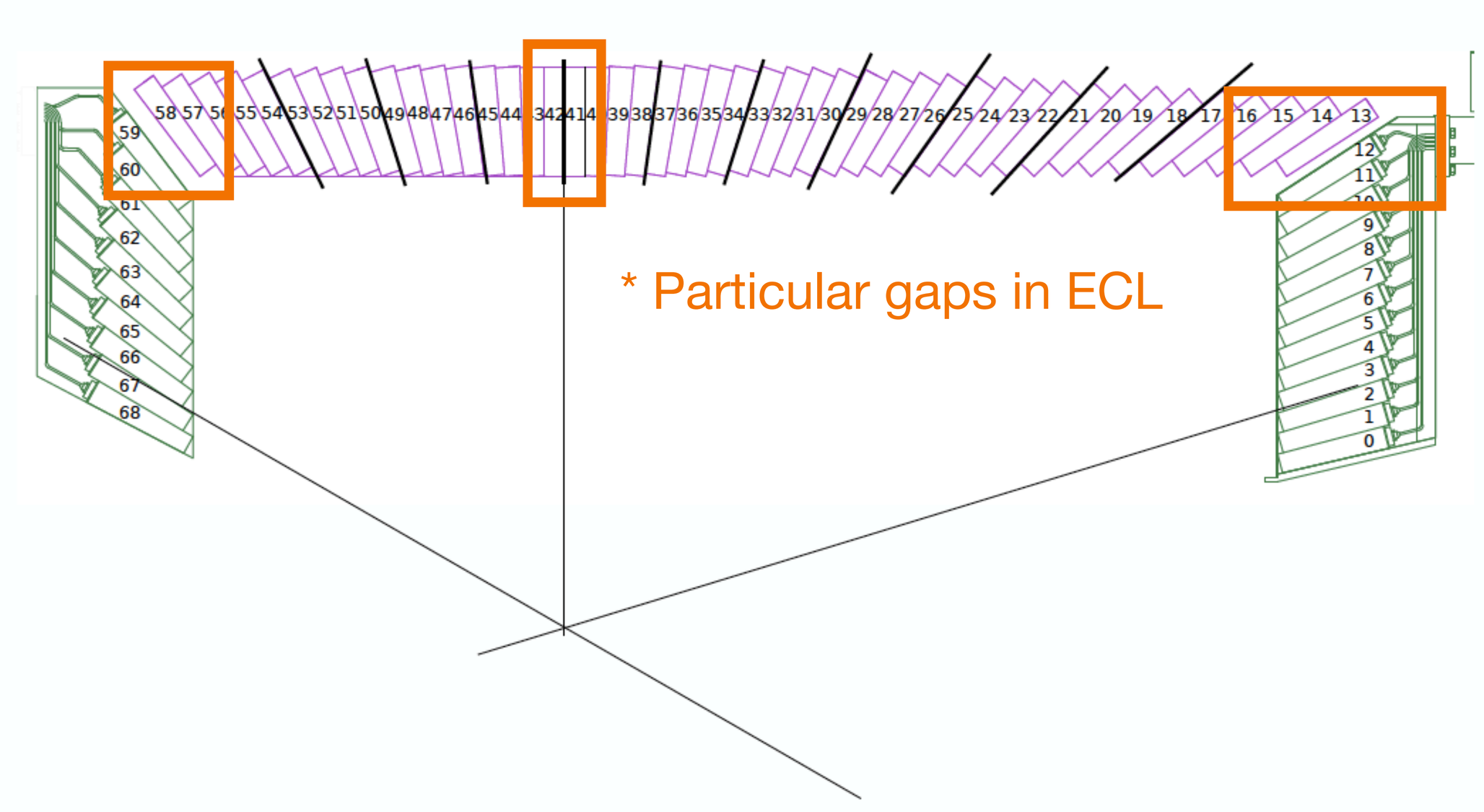
Sensitivity



Trigger Efficiency



Electromagnetic Calorimeter Geometry



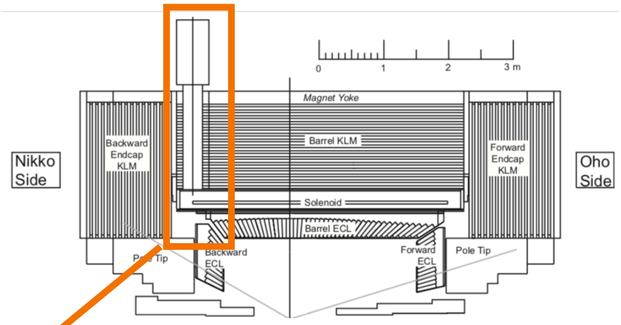
Event Selection of $e^+e^- \to \gamma\gamma$

- use 2 most energetic photons per event
- $4.5 < E_0^* < 7.0$ GeV
- $0.1 < E_1^* < 7.0$ GeV
- no charged tracks with $p_t > 0.2$ GeV/c coming near from IP
- $\Delta\phi^* > 178°$
- $178° <$ theta sum* $< 182°$

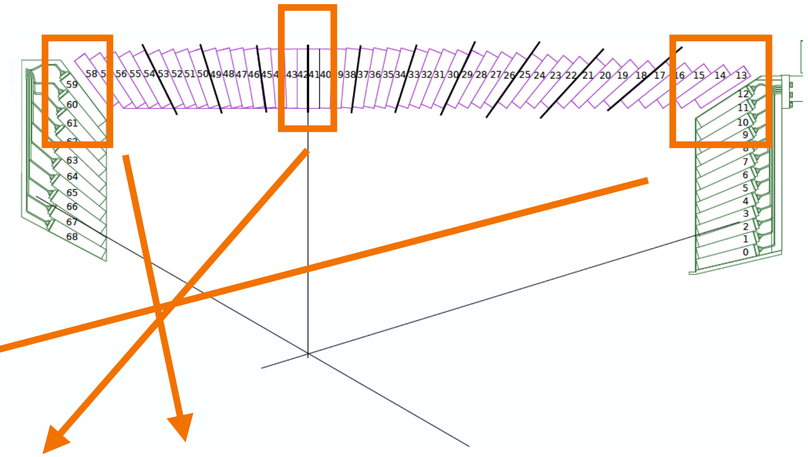
- Using tag and probe method for both gg events:
  - Tag: E* > 4.5 GeV
  - Probe: Must be in barrel (Theta ID 14 to 57)
- Event can contain two tags/two probes

Detector Efficiency

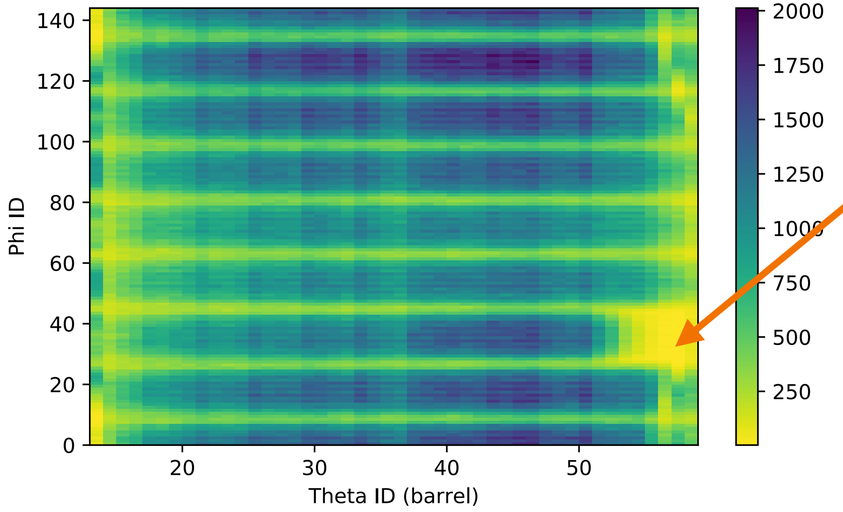
E_{leak} < 0.35 GeV (very little leakage)



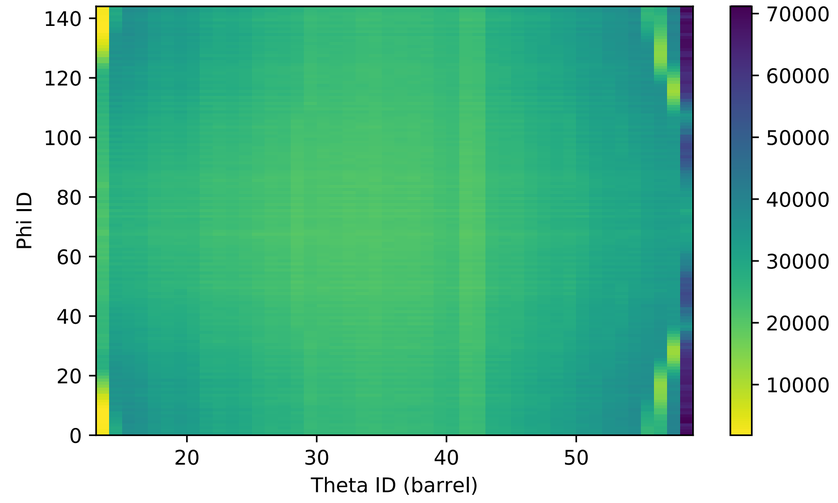
*Each bin is a crystal



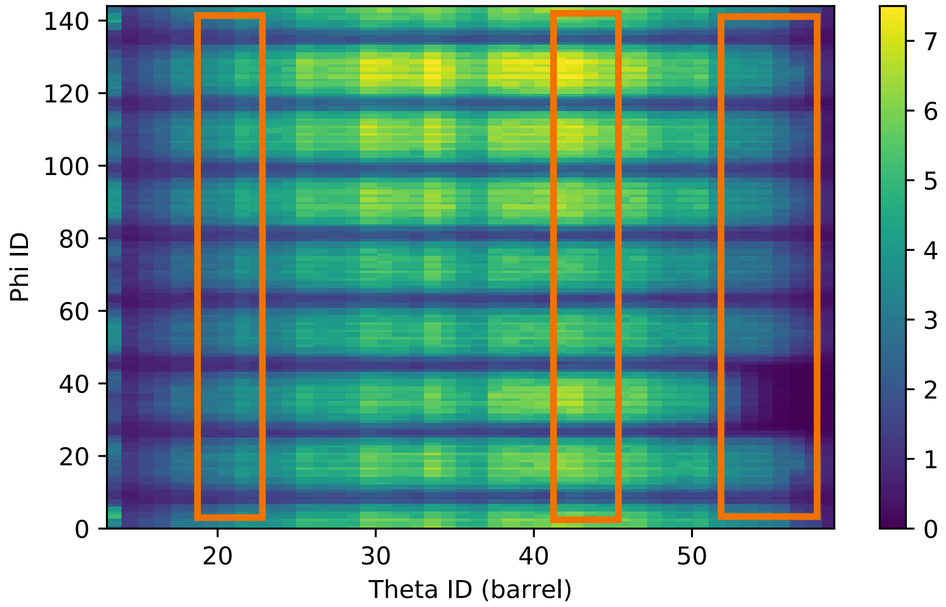
KLM Probe Photons with Eleak < 0.35 GeV



ECL Probe Photons with Eleak < 0.35 GeV



% of ECL photons found in KLM, Eleak < 0.35 GeV



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Detector Efficiency

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