a place of mind

UBC

INSTITUTE OF PARTICLE PHYSICS

The Belle II experiment

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U. British Columbia / IPP
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On behalf of the Belle II Canada group

Quick summary of Belle II

- Located at the SuperKEKB e^+e^- collider at KEK. “Nano-beams” scheme should give 40× the luminosity of KEKB.
- Belle II is an extensive upgrade of Belle. New tracking, charged particle ID, calorimeter electronics.
- First colliding beam data (without vertex detectors) in Spring 2018 “Phase 2”. 0.5 fb^{-1} recorded. Currently commissioning with full detector. Expect a few fb^{-1} by July 1, 100–200 fb^{-1} by summer 2020.
- Sufficient data for several beyond-the-SM searches.

Physics goals

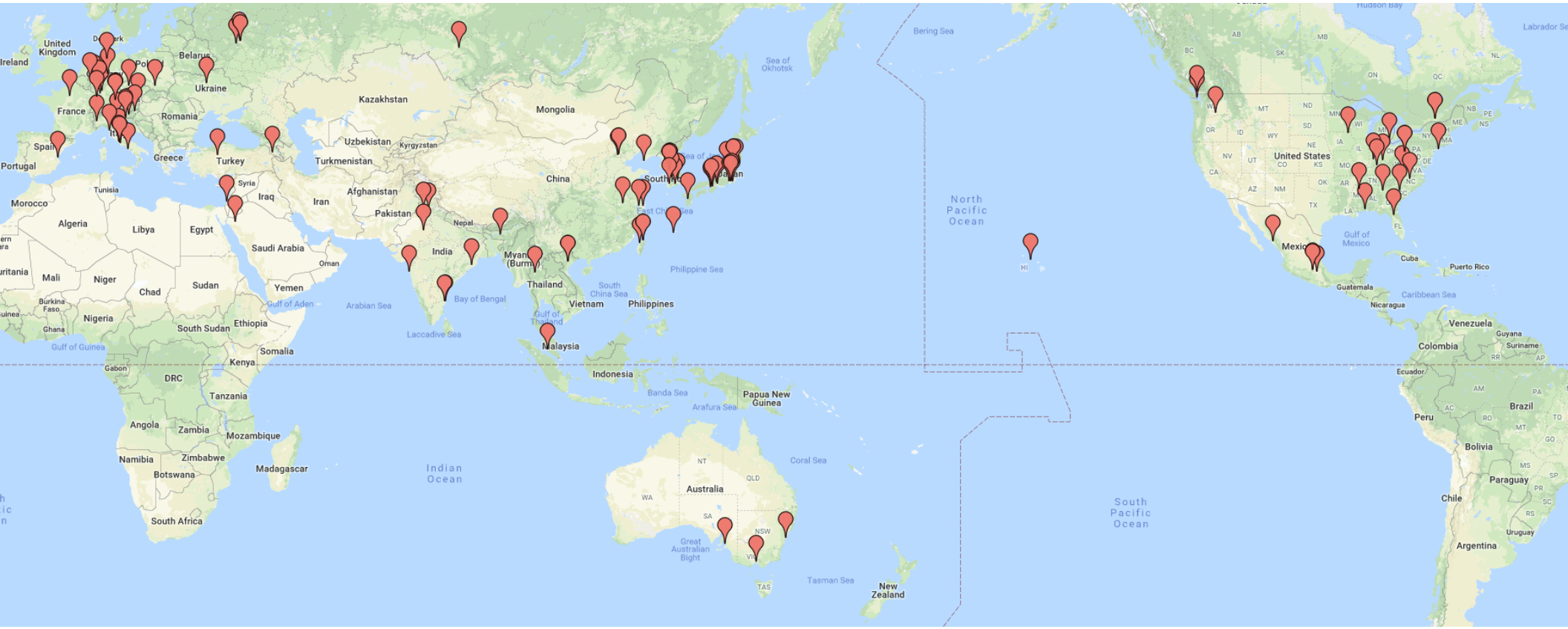
- Seek evidence for new physics through a wide range of measurements that are sensitive to the presence of heavy virtual particles.
  - asymmetries, rare decays, forbidden decays.

- Direct searches for beyond-the-Standard-Model particles.

- Continued investigation of CP violation and the weak force.

Belle II collaboration

- 26 countries, 110 institutions, 750 collaborators, including 410 PhD physicists & 260 graduate students

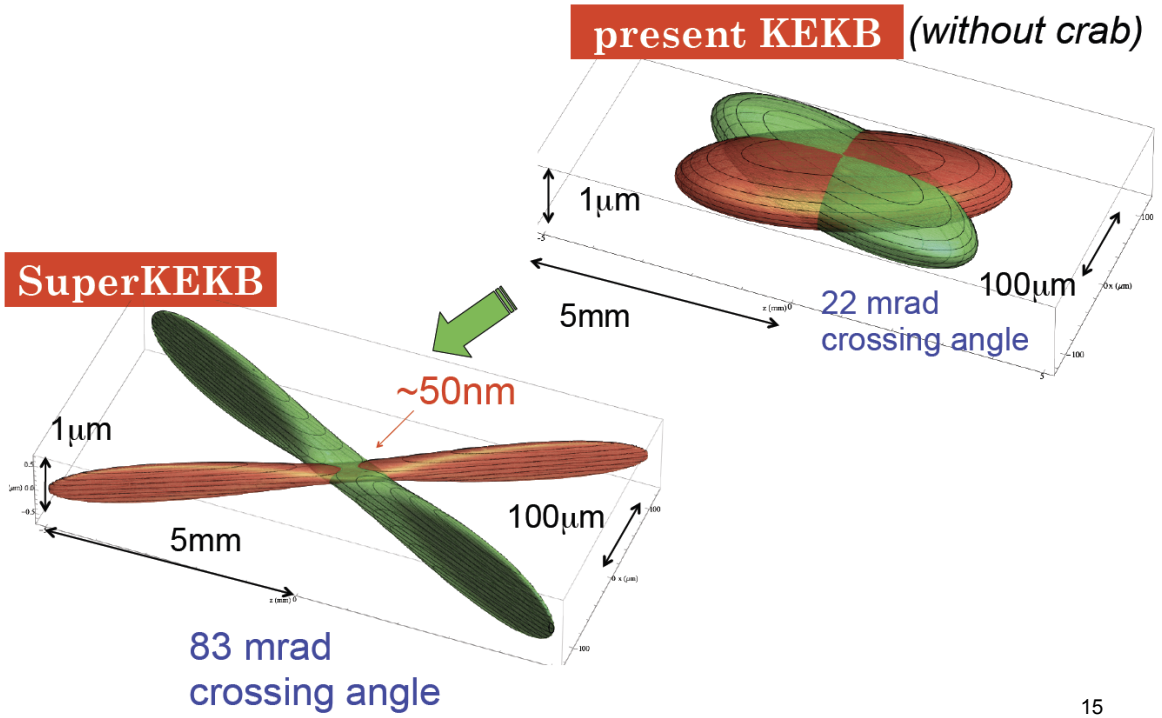


Canadian group
7 faculty (4.4 FTE), 10 grad students, 3 postdocs/RA

- **UBC**: C. Hearty, J. McKenna, R. Cheaib, E. Hill, A. Hershenhorn
- **Victoria**: J. M. Roney, R. Kowalewski, R. Sobie, A. Sibidanov, A. Beaulieu, S. Longo, C. Miller, M. Ebert
- **McGill**: S. Robertson, A. Warburton, K. Amirie, A. Fodor, H. Wakeling, R. Seddon, R. MacGibbon, T. Shillington
  - Increase to 13 GS by 2021.
  - 4 completed PhD + 7 MSc, 1 postdoc (inc. SuperB).

SuperKEKB

- Dramatic increase in luminosity largely from beam size.
  - “nanobeams” concept developed for SuperB.



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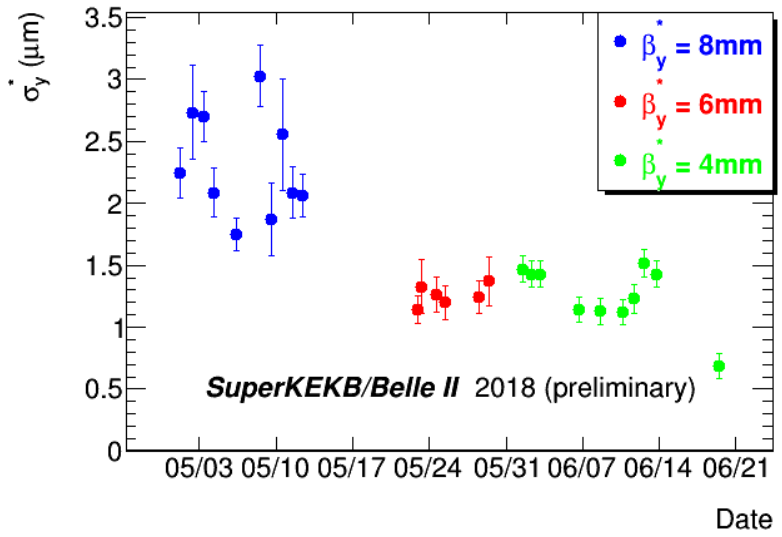
Phase 2 commissioning

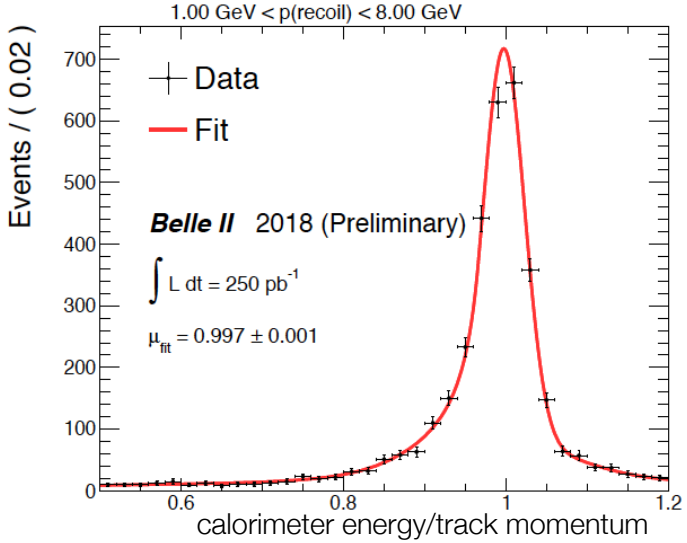
- SuperKEKB commissioning run with colliding beams, April – July 2018. Full Belle II outer detector, but only samples of vertex detectors.

- Verified nano-beams scheme; established that backgrounds were low enough to install vertex detectors.

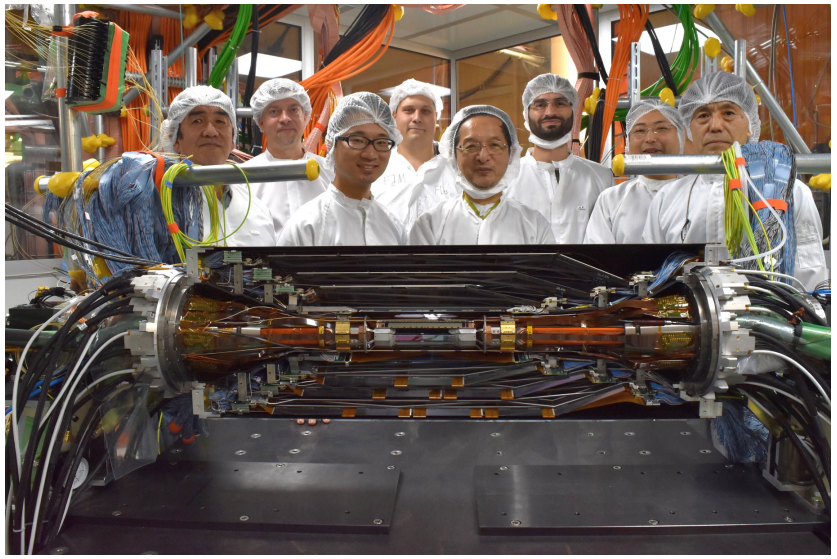
Beam size from beam-beam scans



photons from $e^+e^- \to \mu^+\mu^-\gamma$



Phase 3 commissioning



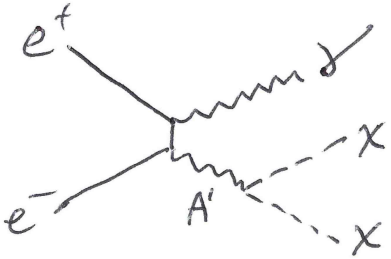
- Vertex detectors installed in the fall (only 1 pixel layer).

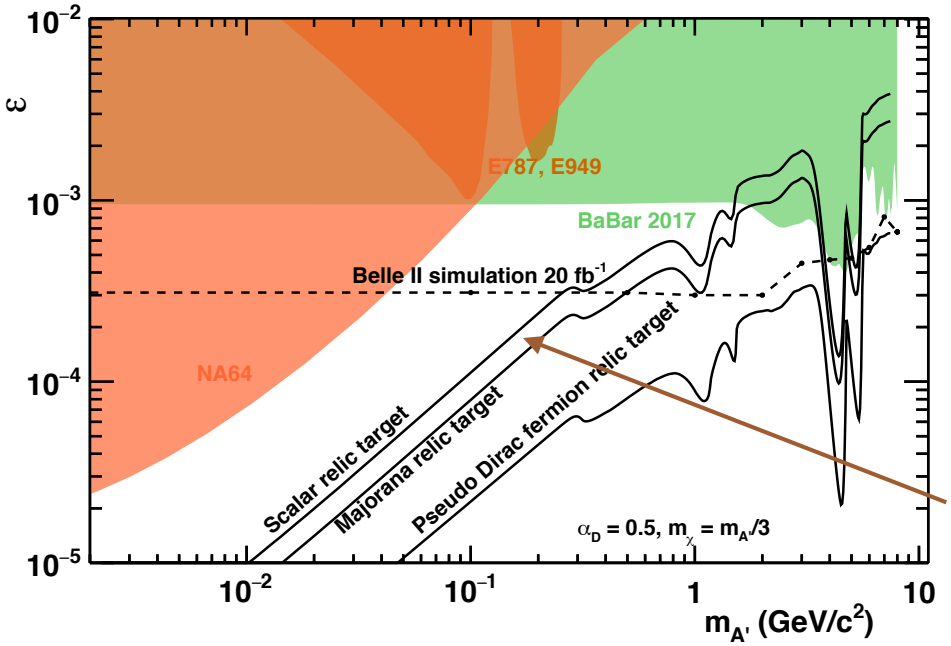
- Goals:
  - increase current
  - continuous injection
  - improve backgrounds (new collimators)
  - but not push beams any smaller

- March – June 2019, but lost a month due to fire.

Near and mid-term physics priorities

- **Search for invisible decays of a dark photon:**
  - "dark sector" contains dark photon that mixes with SM photon, plus dark matter particle.
  - hope to surpass BaBar limits (60 fb^{-1}) with smaller dataset due to better calorimeter performance.



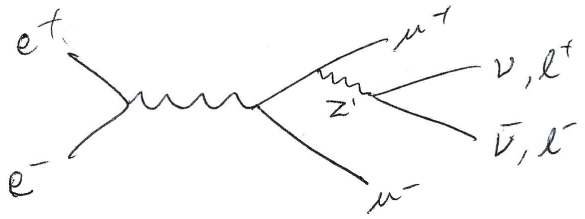


Belle II projection, 20 fb^{-1} KEK-2018-27, arXiv: 1808.10567 [hep-ex]

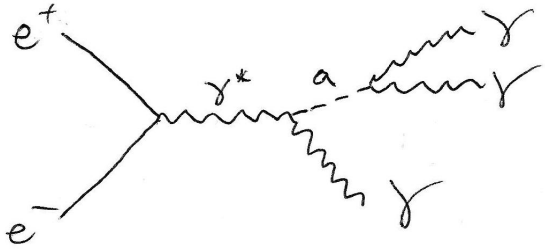
BaBar limit, 60 fb^{-1} Phys. Rev. Lett. 119, 131804 (2017)

Derived from E. Izaguirre, G. Krnjaic, P. Schuster, N. Toro, Phys. Rev. Lett. 115, 251301 (2015)

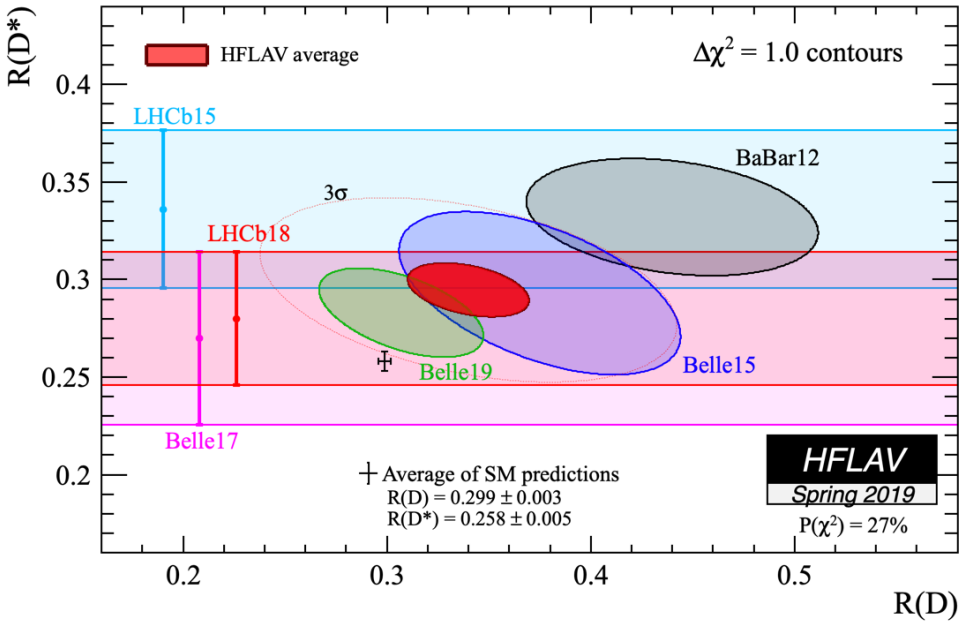
- **Search for Z′ coupling to 2nd and 3rd generations:**
  - dark sector gauge boson could directly couple to SM. Couplings to 1st generation strongly constrained.
  - no existing limits on low-mass Z′, which would decay to $\nu\bar{\nu}$.

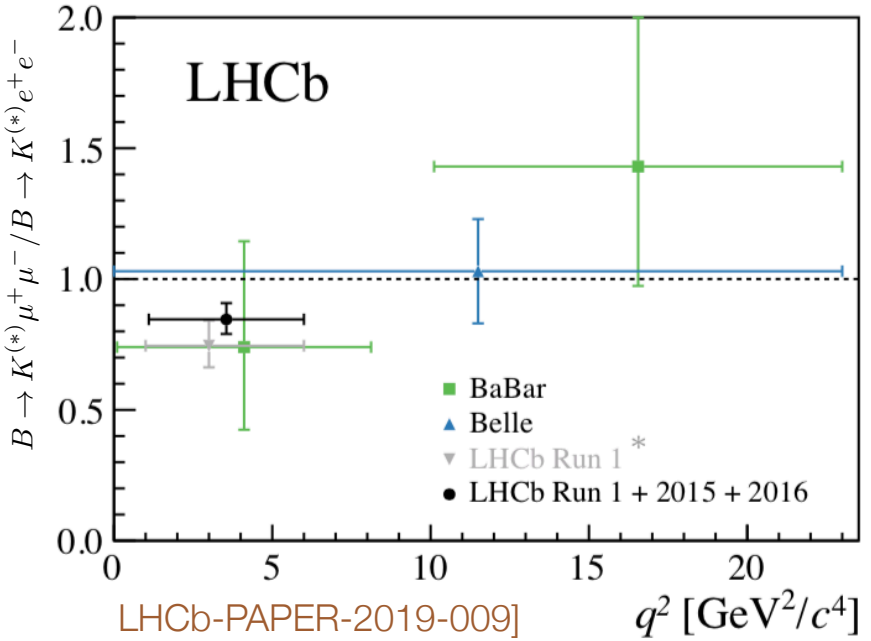


- **Search for axion-like particles:**
  - Pseudo-scalars that couple to bosons; focus on γ coupling initially.
  - Based on Dolan, Ferber, Hearty, Kahlhoefer & Schmidt-Hoberg, JHEP 1712, 094 (2017).
  - no existing limits.



- **Search for lepton universality violation:**
  - hottest B physics topic; closest thing to a deviation from the SM seen at the LHC.
  - $B \to D^{(*)}\tau\nu_\tau$: BaBar, Belle, LHCb; 3σ
    - Racha Cheaib (UBC) is leading this analysis, and co-convenes the semileptonic working group.
  - $B \to K^{(*)}\mu^+\mu^-$: currently dominated by LHCb; 2.5σ





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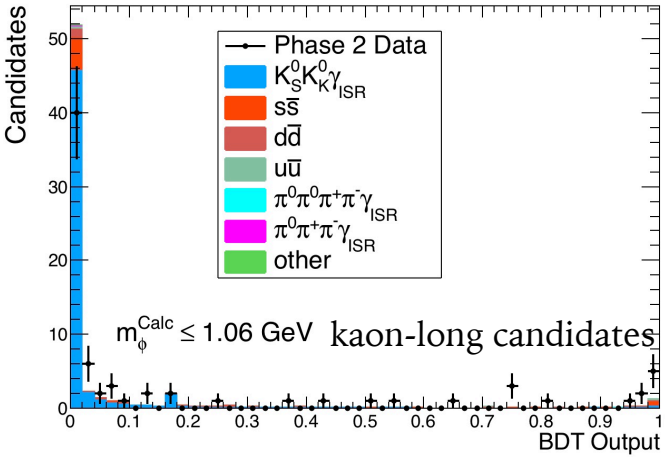
Canadian (non-physics-analysis) activities

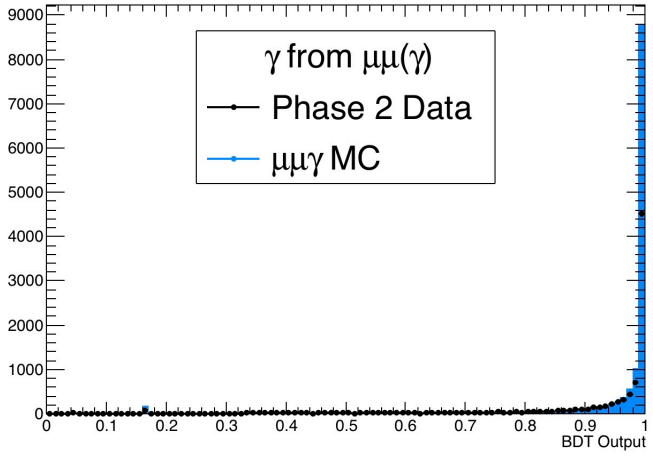
- Responsible for calorimeter calibration; contribute to software and operations
  - Savino Longo (Victoria PhD student): development of pulse-shape discrimination techniques to distinguish hadronic from electromagnetic showers.

hadronic identification based on PSD

K_L data (points) and MC



photons data (points) and MC



- Background monitoring

- Level 1 and high-level trigger menu
  - plus contributions to HLT hardware via RTI grants.

- Computing

- Mike Roney is chair of the executive board, which advices the Spokesperson. Chris Hearty was chair of the institutional board, and chairs the governance committee. Steve Robertson is a member of the publications committee.

Publications

- No publications yet from colliding beam data.

M. J. Dolan, T. Ferber, C. Hearty, F. Kahlhoefer and K. Schmidt-Hoberg, "Revised constraints and Belle II sensitivity for visible and invisible axion-like particles," JHEP **1712**, 094 (2017) [arXiv:1709.00009 [hep-ph]].

M. Battaglieri *et al.*, including C. Hearty, "US Cosmic Visions: New Ideas in Dark Matter 2017: Community Report," arXiv:1707.04591 [hep-ph].

R. Seuster *et al.*, including R. Sobie, "Context-aware distributed cloud computing using CloudScheduler," J. Phys. Conf. Ser. **898**, no. 5, 052039 (2017).

R. Seuster, K. Casteels, C. Leavett-Brown, M. Paterson and R. Sobie, "Enabling Research Network Connectivity to Clouds with Virtual Router Technology," J. Phys. Conf. Ser. **898**, no. 8, 082047 (2017).

G. Ciezarek, M. Franco Sevilla, B. Hamilton, R. Kowalewski, T. Kuhr, V. Lth and Y. Sato, "A Challenge to Lepton Universality in B Meson Decays," Nature **546**, 227 (2017) [arXiv:1703.01766 [hep-ex]].

E. Kou *et al.* [Belle II Collaboration], "The Belle II Physics Book," arXiv:1808.10567 [hep-ex].

P. M. Lewis *et al.*, "First Measurements of Beam Backgrounds at SuperKEKB," Nucl. Instrum. Meth. A **914**, 69 (2019) doi:10.1016/j.nima.2018.05.071 [arXiv:1802.01366 [physics.ins-det]].

A. Aleksejevs, S. Barkanova, J. M. Roney and V. Zykunov, "NLO radiative corrections for Forward-Backward and Left-Right Asymmetries at a B-Factory," arXiv:1801.08510 [hep-ph].

S. Longo and J. M. Roney, "Hadronic vs Electromagnetic Pulse Shape Discrimination in CsI(Tl) for High Energy Physics Experiments," JINST **13**, no. 03, P03018 (2018).

M. Tanabashi *et al.*, [Particle Data Group] "Semileptonic B meson decays and the determination of $|V_{ub}|$ and $|V_{cb}|$, Phys. Rev. D **98**, 030001 (2018).

J. P. Lees *et al.* [BaBar Collaboration], "Search for a Stable Six-Quark State at BABAR," arXiv:1810.04724 [hep-ex] (submitted to PRL).

Computing

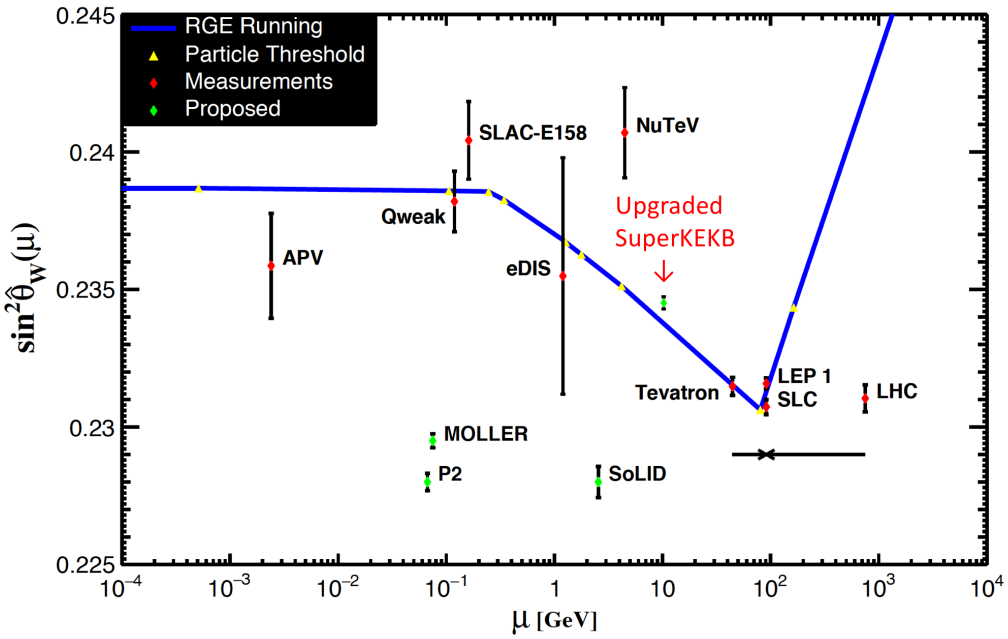
- Randy Sobie is leading the development of cloud computing tools for Belle II (CFI grant).

- Canada produced 13% of MC in 2018, all cloud.
  - 70% of resources were Compute Canada allocation; remainder were private (e.g. Amazon cloud).

- We have an agreement to support 10% of the raw data (20% of one copy), plus associated reconstruction, starting 2021.
  - 10 PB, 10000 cores thru 2025, ≈10× current allocation.
  - CFI request in preparation.

Synergy with other projects: polarization

- Mike Roney is leading an accelerator physics proposal to polarize the SuperKEKB electron beam. Will enable precision electroweak measurements using left-right asymmetries.
  - ~2025 start



- Components: source, spin transport, polarimeter.

- International (non-KEK) collaborators include SLAC and French groups.

- NSERC project grant application this fall, potentially leading to a CFI application.
  - co-applicants from U. Manitoba and TRIUMF.
  - Mike is the only overlap in personnel with Belle II.