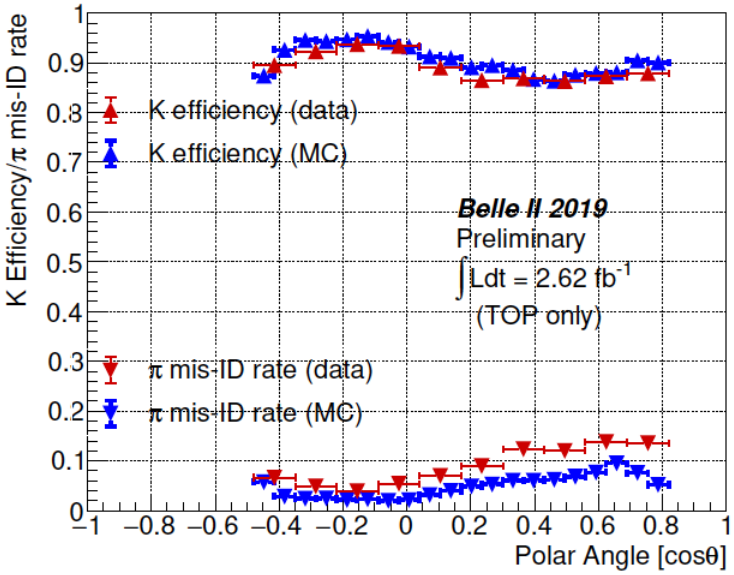
status and prospects



BEAUTY 2019

18th INTERNATIONAL CONFERENCE ON B-PHYSICS AT FRONTIER MACHINES

Ljubljana, Slovenia

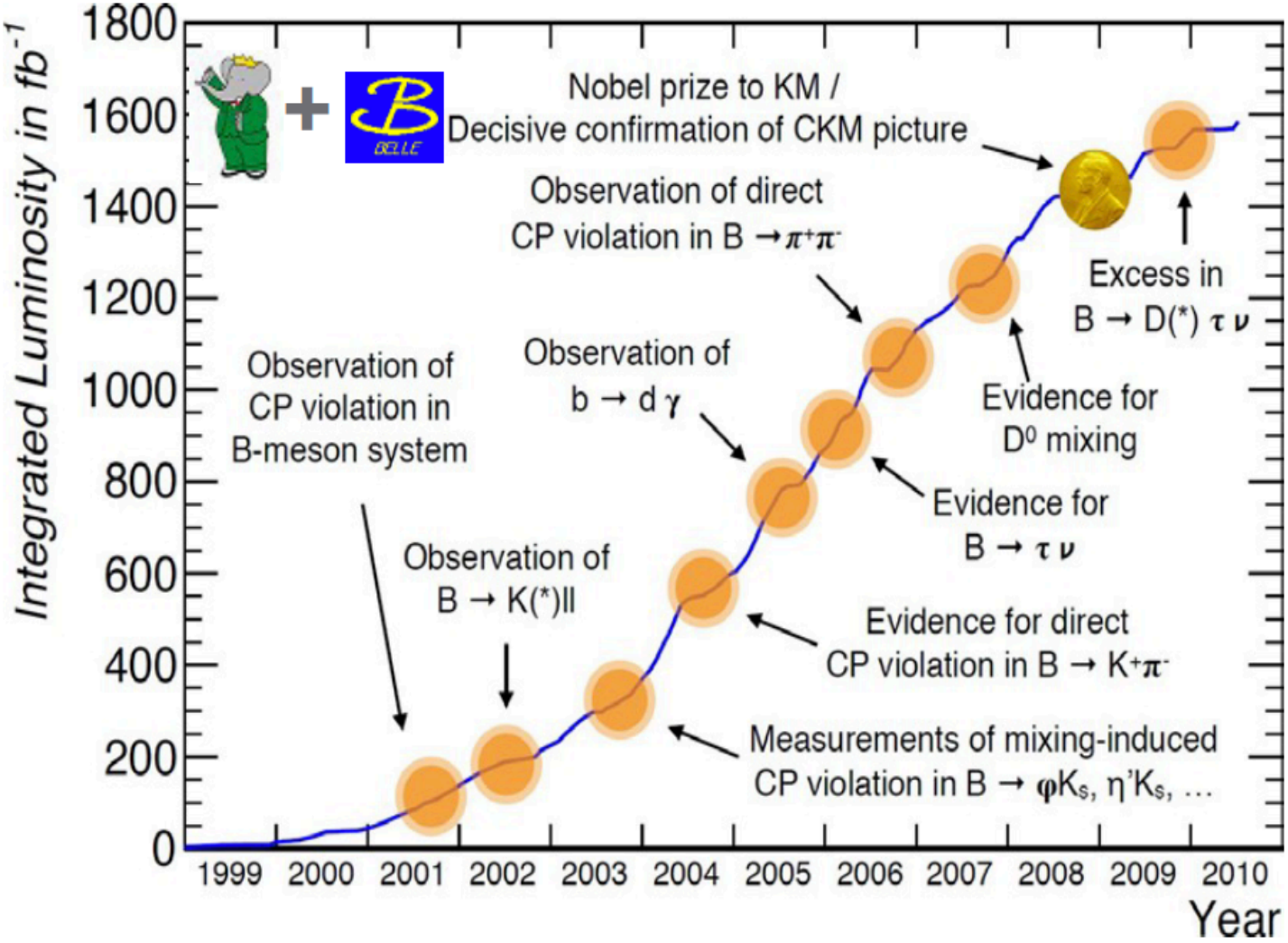
September 30 - October 4, 2019

Gagan Mohanty

tifr

☞ MC simulations yet to include embedded random triggers to correctly represent the beam background effects and electronic noise

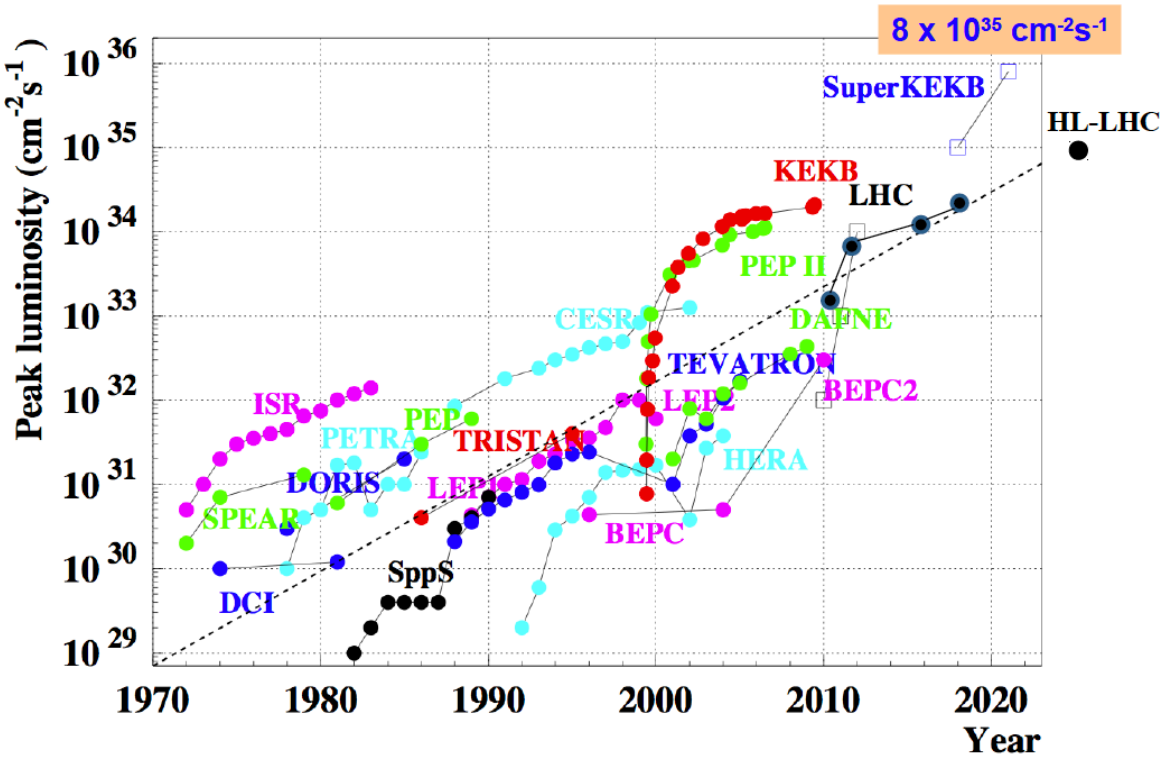
First-generation e^+e^- flavor factories



- Success culminated in 2008 Nobel prize in Physics
- Rich legacy left for next-gen expt. EPJ C74, 3026 (2014)

So, why another e^+e^- flavor factory?

- Precision CKM metrology ➔ Standard Model (SM) candle
- New CP violating phase? ➔ CP violation in B and D decays
- Any imprint of new physics beyond SM in FCNC transitions? ➔ radiative and electroweak penguin decays
- How about charged Higgs boson or leptoquark? ➔ tree-level B decay to $\tau\nu$ or $D^{(*)}\tau\nu$ final state
- New physics in tau lepton sector ➔ search for lepton flavor violating (LFV) tau decays
- Can we chase down dark matter from bottom? ➔ hidden dark sector



☞ Belle II @ SuperKEKB will address these questions with almost two orders of magnitude larger dataset than Belle+BABAR

Snapshots of what Belle II can achieve?

Observables	Expected the. accuracy	Expected exp. uncertainty	Facility (2025)
UT angles & sides			
ϕ_1 [°]	***	0.4	Belle II
ϕ_2 [°]	**	1.0	Belle II
ϕ_3 [°]	***	1.0	LHCb/Belle II
$\|V_{cb}\|$ incl.	***	1%	Belle II
$\|V_{cb}\|$ excl.	***	1.5%	Belle II
$\|V_{ub}\|$ incl.	**	3%	Belle II
$\|V_{ub}\|$ excl.	**	2%	Belle II/LHCb
CP Violation			
$S(B \to \phi K^0)$	***	0.02	Belle II
$S(B \to \eta' K^0)$	***	0.01	Belle II
$\mathcal{A}(B \to K^0\pi^0)[10^{-2}]$	***	4	Belle II
$\mathcal{A}(B \to K^+\pi^-)$ $[10^{-2}]$	***	0.20	LHCb/Belle II
(Semi-)leptonic			
$\mathcal{B}(B \to \tau\nu)$ $[10^{-6}]$	**	3%	Belle II
$\mathcal{B}(B \to \mu\nu)$ $[10^{-6}]$	**	7%	Belle II
$R(B \to D\tau\nu)$	***	3%	Belle II
$R(B \to D^*\tau\nu)$	***	2%	Belle II/LHCb
Radiative & EW Penguins			
$\mathcal{B}(B \to X_s\gamma)$	**	4%	Belle II
$A_{CP}(B \to X_{s,d}\gamma)$ $[10^{-2}]$	***	0.005	Belle II
$S(B \to K^0_S\pi^0\gamma)$	***	0.03	Belle II
$S(B \to \rho\gamma)$	**	0.07	Belle II
$\mathcal{B}(B_s \to \gamma\gamma)$ $[10^{-6}]$	**	0.3	Belle II
$\mathcal{B}(B \to K^*\nu\overline{\nu})$ $[10^{-6}]$	***	15%	Belle II
$R(B \to K^*\ell\ell)$	***	0.03	Belle II/LHCb
Charm			
$\mathcal{B}(D_s \to \mu\nu)$	***	0.9%	Belle II
$\mathcal{B}(D_s \to \tau\nu)$	***	2%	Belle II
$A_{CP}(D^0 \to K^0_S\pi^0)$ $[10^{-2}]$	**	0.03	Belle II
$\|q/p\|(D^0 \to K^0_S\pi^+\pi^-)$	***	0.03	Belle II
$A_{CP}(D^+ \to \pi^+\pi^0)$ $[10^{-2}]$	**	0.17	Belle II
Tau			
$\tau \to \mu\gamma$ $[10^{-10}]$	***	< 50	Belle II
$\tau \to e\gamma$ $[10^{-10}]$	***	< 100	Belle II
$\tau \to \mu\mu\mu$ $[10^{-10}]$	***	< 3	Belle II/LHCb

☞ From Belle II physics book arXiv:1808.10567 (to appear in PTEP)

Precision CKM metrology

Direct and mixing-induced CP violation in B decays

(Semi-)leptonic B decays

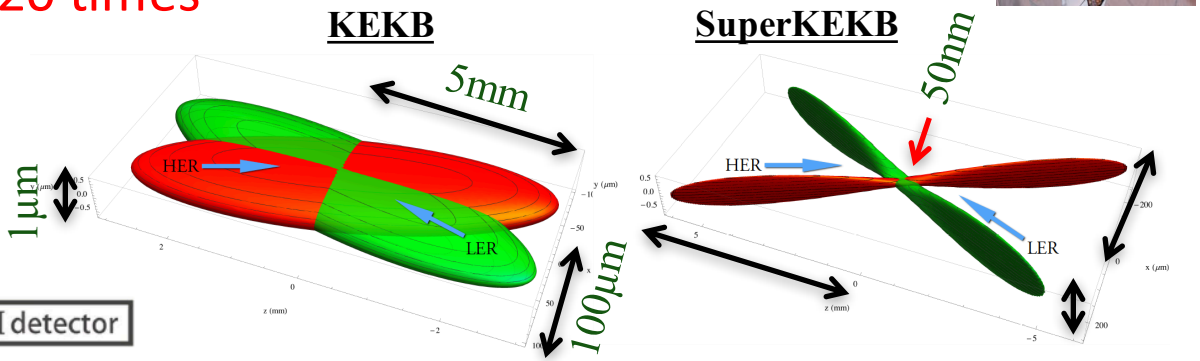
Radiative & electroweak penguins

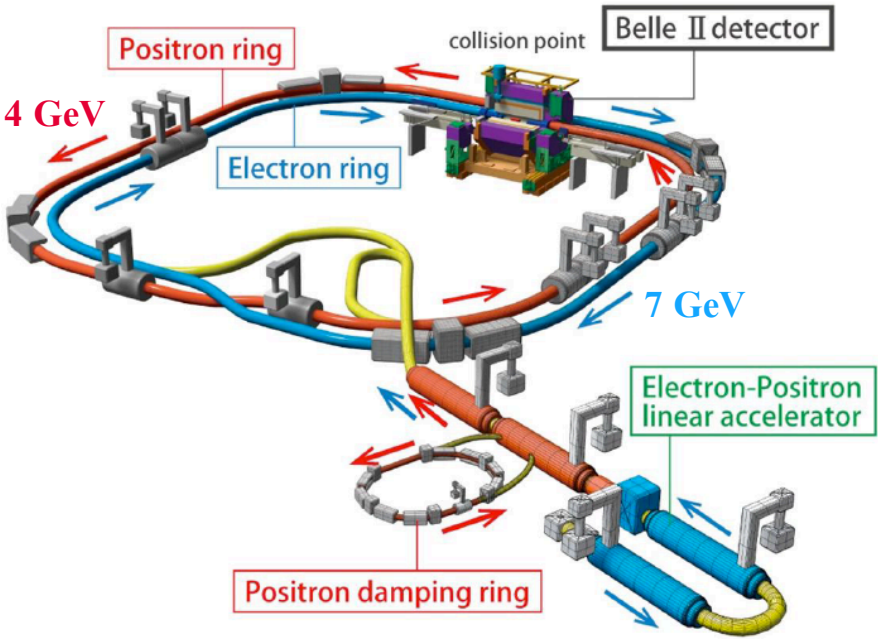
Vibrant charm program

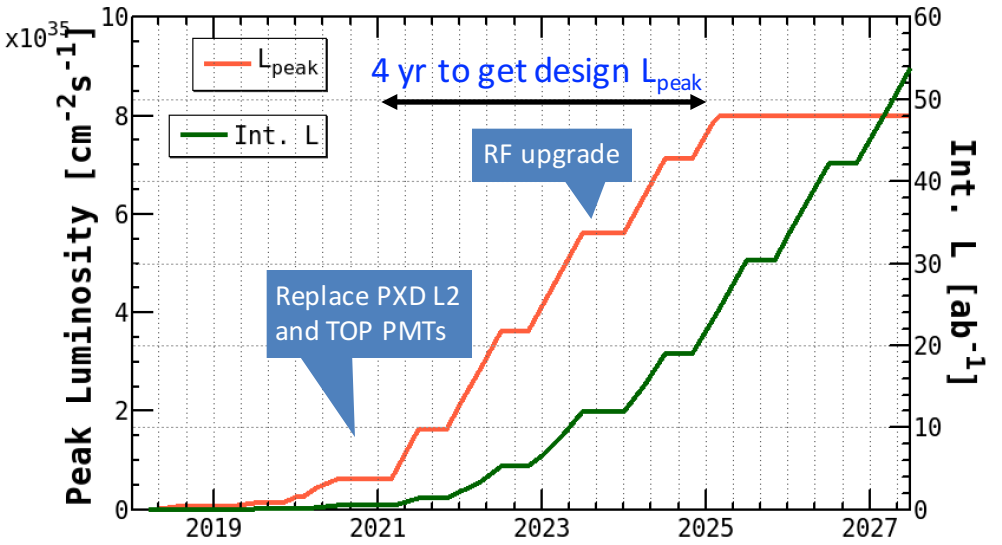
Search of LFV tau decays

Super KEKB: New intensity frontier machine

- Targets to deliver e^+e^- collisions at a peak luminosity of $8 \times 10^{35}\ cm^{-2}s^{-1}$, 40 times that of KEKB
  - ✧ Increase beam currents twice
  - ✧ Reduce beam size by 20 times

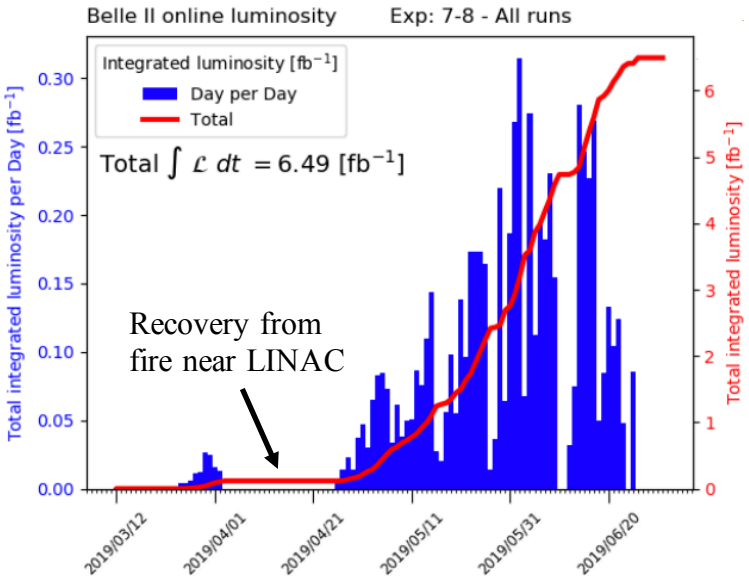






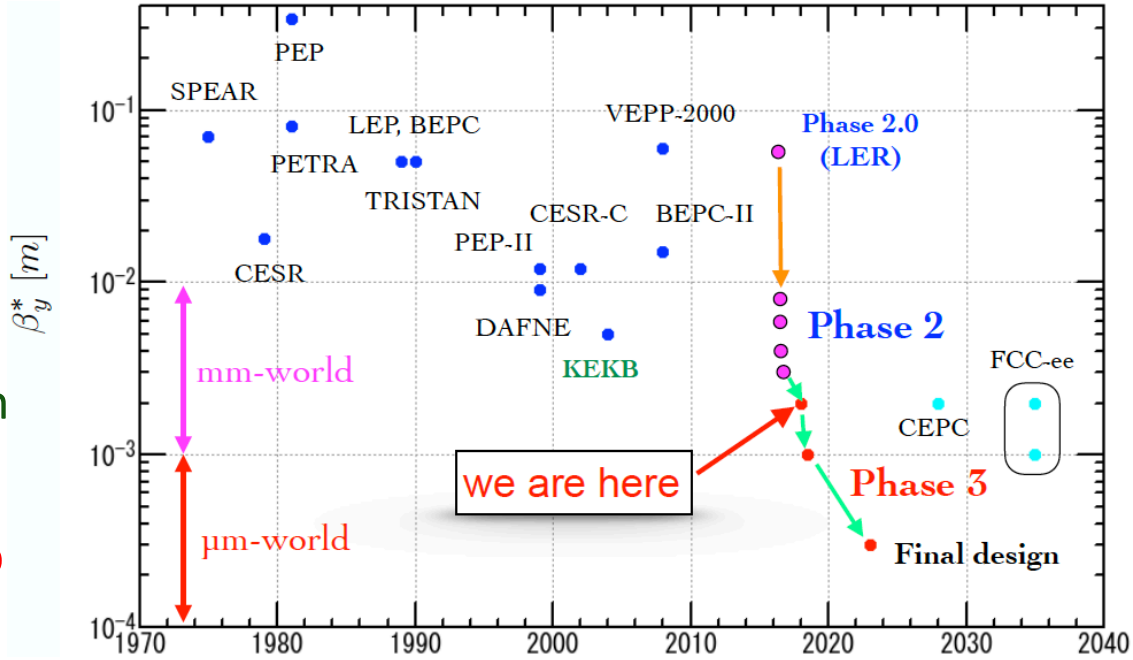
- ➢ First new particle collider after LHC!

How far have we gone?



- Phase 2 (2018): beam commissioning (establish nano-beam scheme, reach the KEKB luminosity, and measure beam backgrounds) as well as for doing some physics with partial vertex detector
- Phase 3 (2019 onward): physics run with almost complete vertex detector

- Reached β_y^* = 33 mm in 2018
- Went down β_y^* = 2 mm by end of Summer 2019 (with Belle II off) ➔ starting point for fall run
- ☞ Design luminosity requires one more order-of-magnitude jump to β_y^* = 0.3 mm



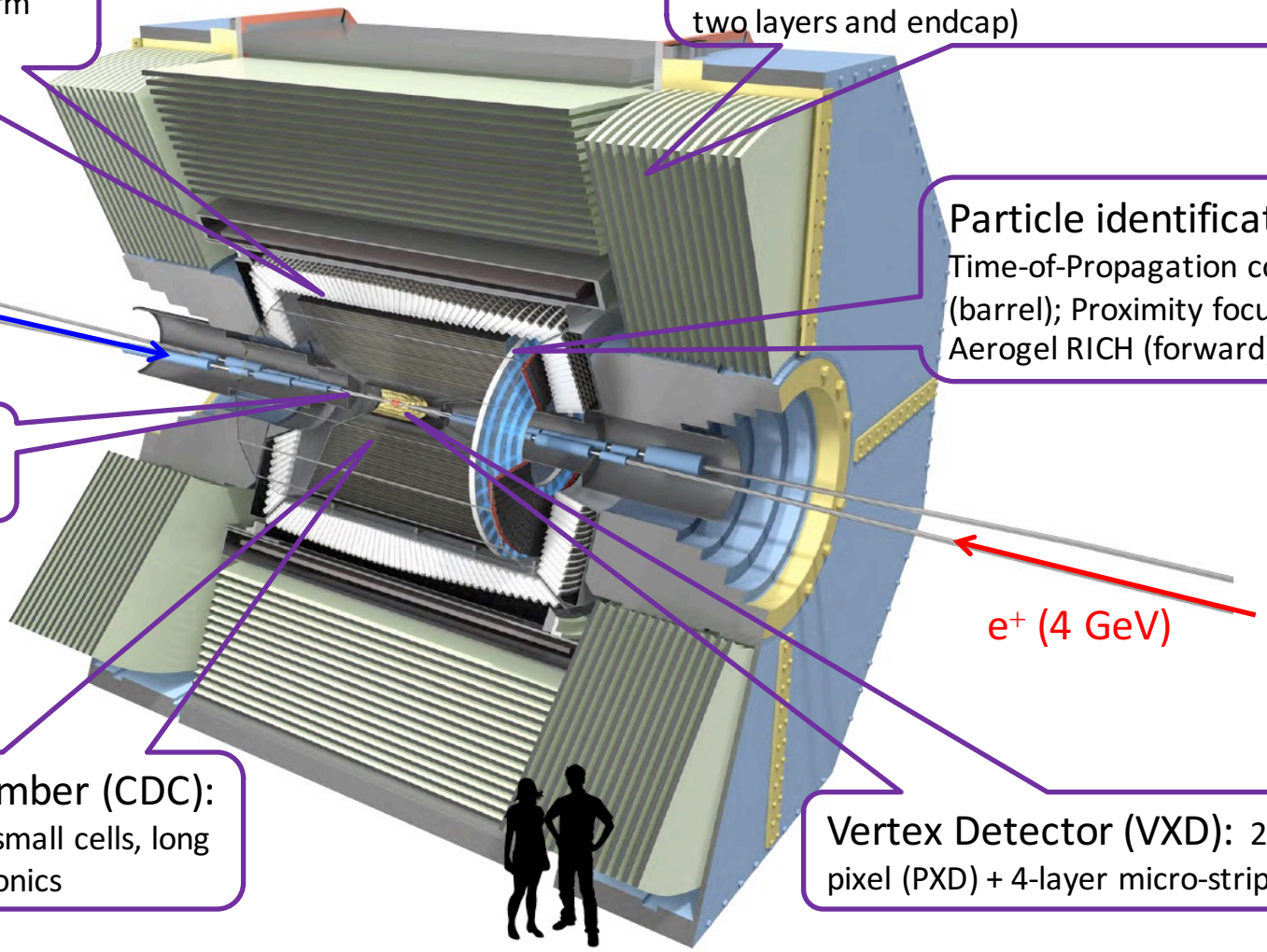
- Currents achieved: 880 (940) mA for e^+ (e^-) beam ➔ need 3 (4)× scale up

Belle II collaboration

- Close to 950 researchers from 112 institutions in 26 countries
- Slovenia is an important player
  - ☞ Leadership position, as well as key contributions to detector, reconstruction software and computing

Belle II: A 21st century HEP experiment

☞ Designed to operate with a performance similar or better than Belle, but in a harsh beam background condition



EM Calorimeter (ECL): CsI(Tl) crystals, waveform sampling readout

K_L and muon detector (KLM): Resistive plate counter (barrel outer); plastic scintillator + WLS fiber + SiPM (barrel inner two layers and endcap)

Particle identification: Time-of-Propagation counter (barrel); Proximity focusing Aerogel RICH (forward)

e^- (7 GeV)

Beryllium beam-pipe (10 mm radius)

e^+ (4 GeV)

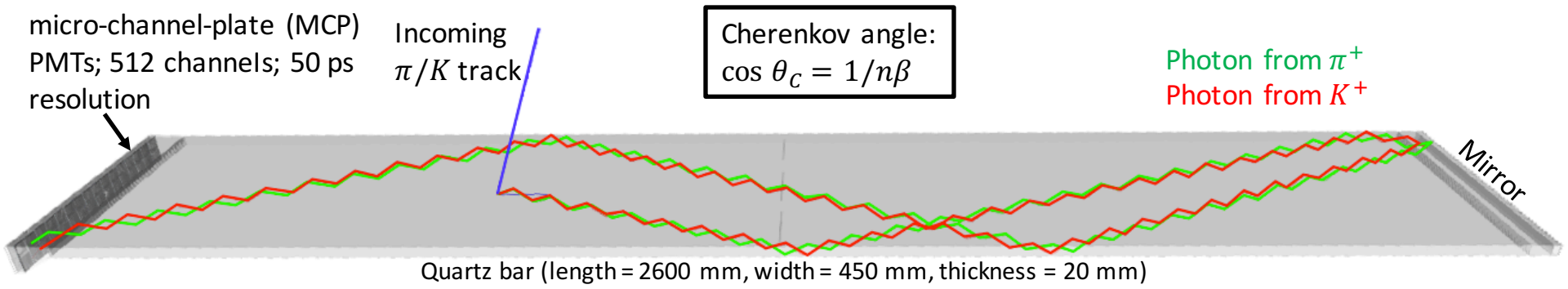
Central Drift Chamber (CDC): He(50%)+C_2H_6(50%), small cells, long lever arm, fast electronics

Vertex Detector (VXD): 2-layer pixel (PXD) + 4-layer micro-strip (SVD)

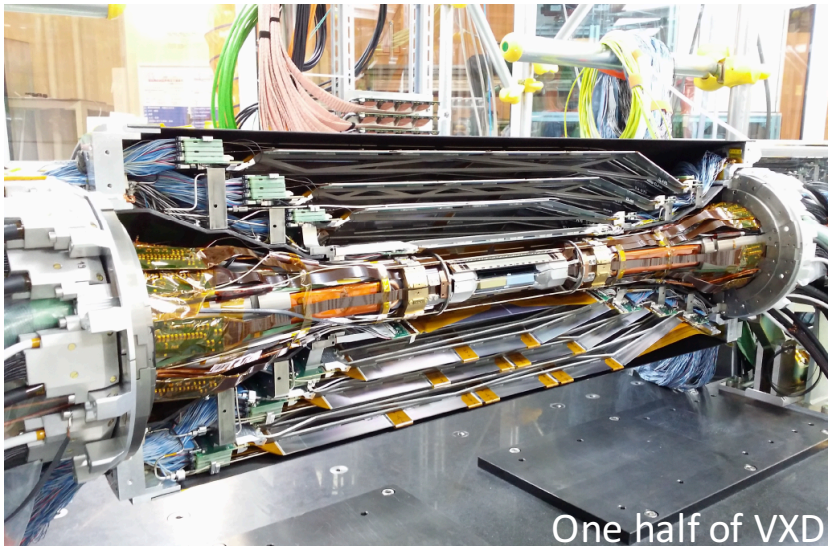
Two detector highlights

Barrel PID (imaging TOP): Japan, US, Slovenia and Italy

☞ Example of Cherenkov-photon paths for 2 GeV pion and kaon traversing in a TOP quartz bar



VXD (6 layer Si for vertexing & inner tracking)



Beam-pipe r = 10 mm

DEPFET pixels: Germany, Czech Republic, Spain…

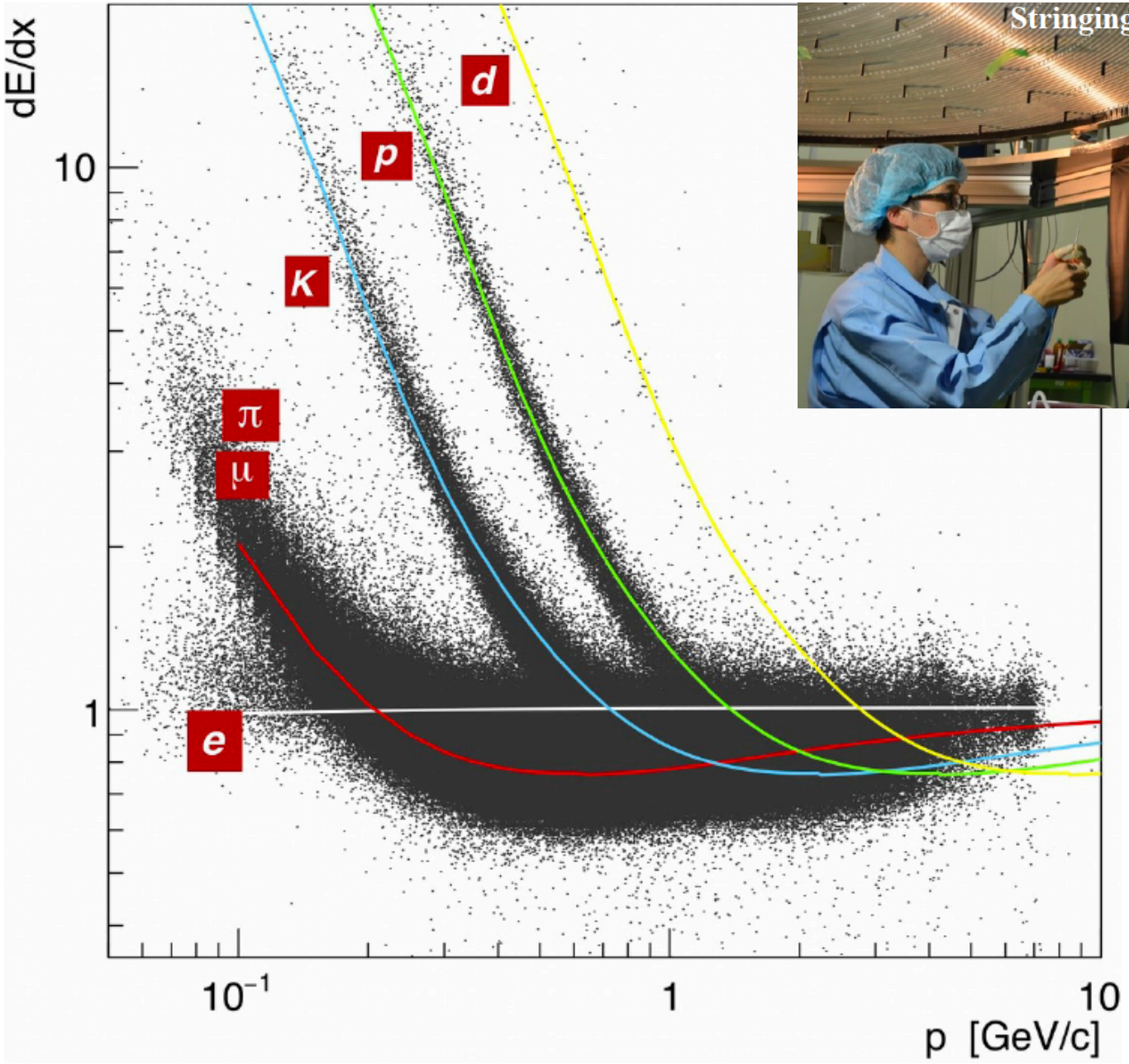
- Layer 1 r = 14 mm
- Layer 2 r = 22 mm (2/12 now, rest in 2020)

DSSD (double sided micro-strips)

- Layer 3 r = 38 mm (Australia)
- Layer 4 r = 80 mm (India)
- Layer 5 r = 115 mm (Austria)
- Layer 6 r = 140 mm (Japan)

} FWD/BWD Italy

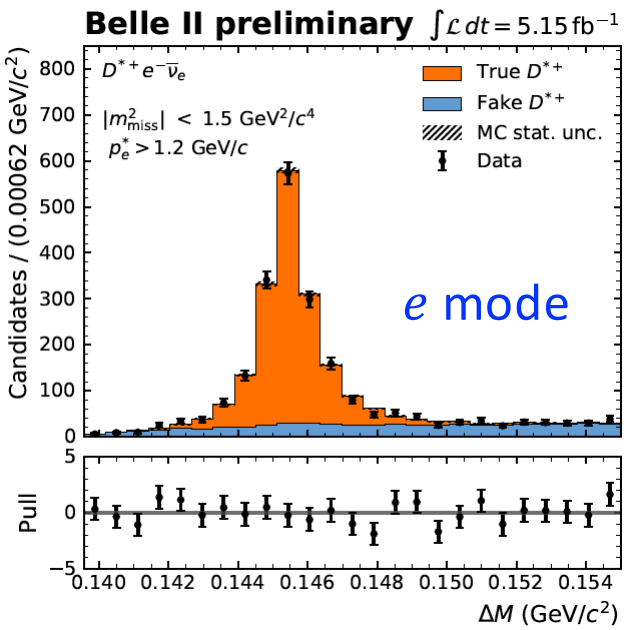
A performance example: dE/dx in CDC

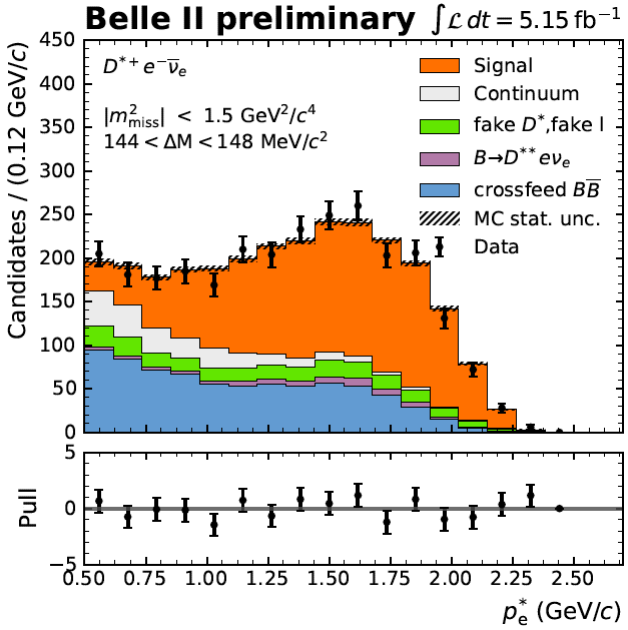


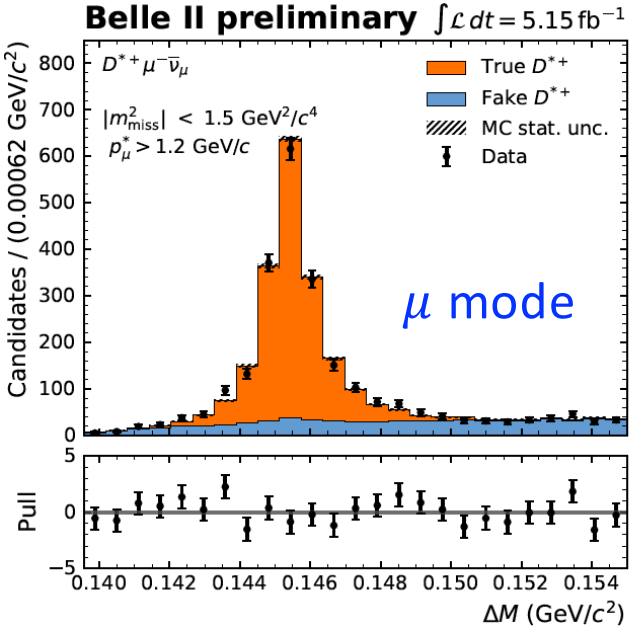
- Obtained with early calibrations in the hadronic event sample
- Important role in identifying charged particles

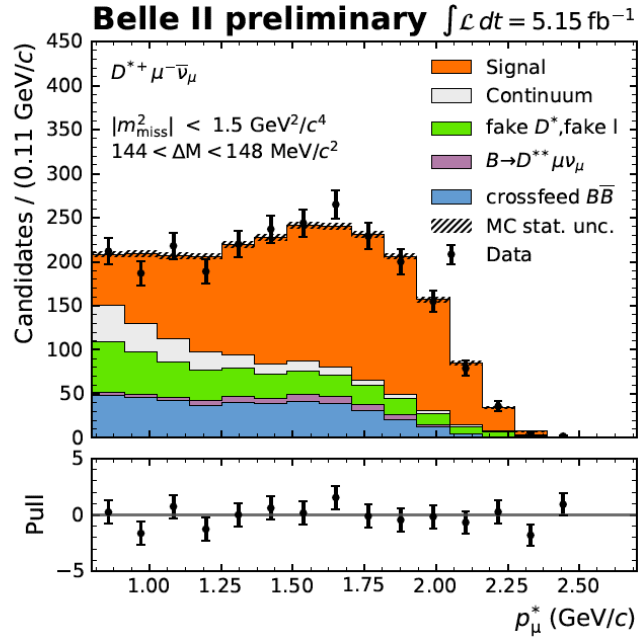
☞ More performance results in Tenchini's talk

A physics example: fresh from





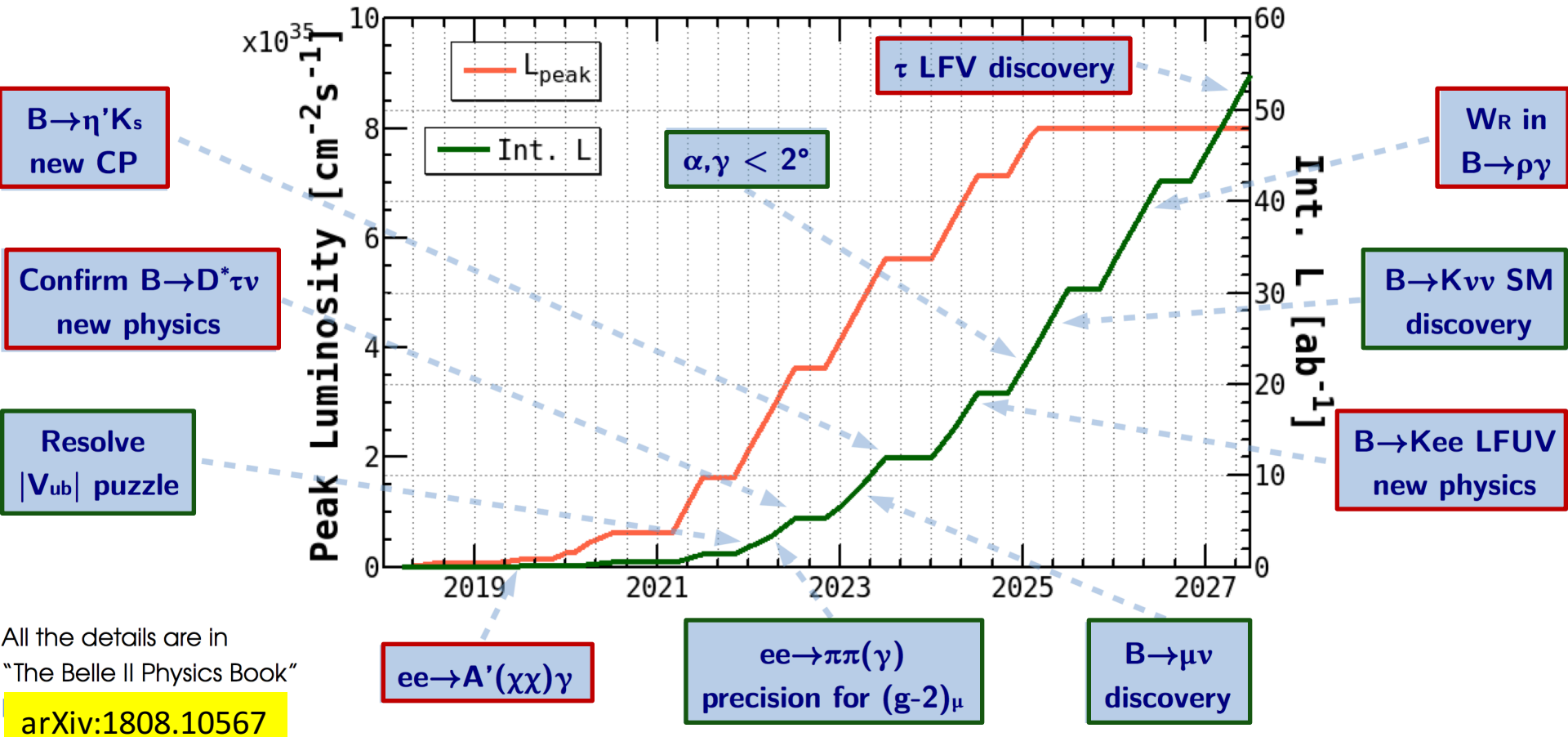




- Study of the untagged $B \to D^* \ell \nu_\ell$ mode with 5.15 fb^{-1} early phase-3 data
- Over 1k signal events found in both electron and muon modes

☞ For more on physics, see talks by Yonenaga (rare decays), Graziani (dark sector), Yusa (CP violation in B decays), and Kwon (charm)

Prospects: physics harvesting



All the details are in "The Belle II Physics Book"

arXiv:1808.10567

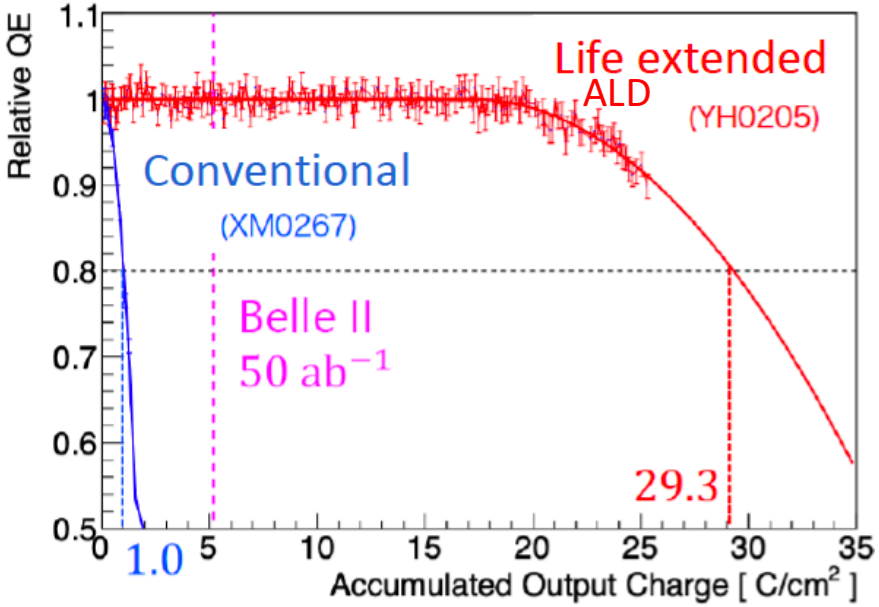
Sure shot

Wish list

☞ Adapted from Forti's talk at EPS-HEP 2019

Prospects: improvements to detector

- Short term:
  - Replace the conventional with atomic-layer-deposition (ALD) MCP-PMTs for the TOP counters
  - Complete installation of PXD layer-2
  - DAQ upgrade



- Medium term:
  - Looking at options for making the detector more resilient against beam-induced background and radiation bursts

- Longer term:
  - Started to think about possibilities for luminosity upgrade; e.g., Belle II VXD open workshop http://indico.cern.ch/event/810687/

Closing words

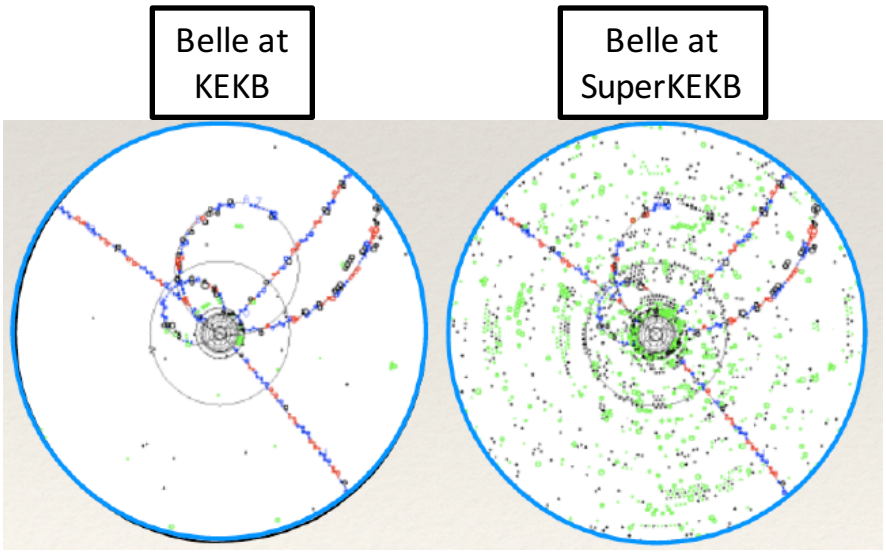
- Belle II will probe new physics at the intensity frontier ➔complementary to high-p_T programs of ATLAS and CMS
- As for LHCb, there is healthy competition and complementarity between the two experiments
- 1st physics run in Spring 2019 has completed delivering ~6.5 fb^{-1}➔ fall run is about to begin
- Detector and machine initial performances have been good; we expect the road ahead to be bit long before achieving our design goal

Additional information

Comparison: KEKB vs. SuperKEKB

parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	ϕ	11		41.5		mrad
Horizontal emittance	ϵ_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.37	0.40	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0881	0.0807	
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

Beam backgrounds



- e^+e^- colliders are clean, however at high L_{peak} values beam backgrounds can become a challenge
- At the highest luminosities, QED processes e.g., $e^+e^- \rightarrow e^+e^-(\gamma)$ & $e^+e^- \rightarrow e^+e^-e^+e^-$ will dominate

- Currently, single beam backgrounds are dominant, larger for the e^+ beam
  - beam-gas (residual gas in beam-pipe)
  - Touschek (intra-bunch scattering)
  - injection-induced
  - "dust events" (occasional large losses)
- CDC HV trips with large background
- Beam abort protection against spikes due to radiation
- Simulation and collimator studies