The status and prospects of the BELLE-II experiment

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On Behalf of the Belle II Collaboration

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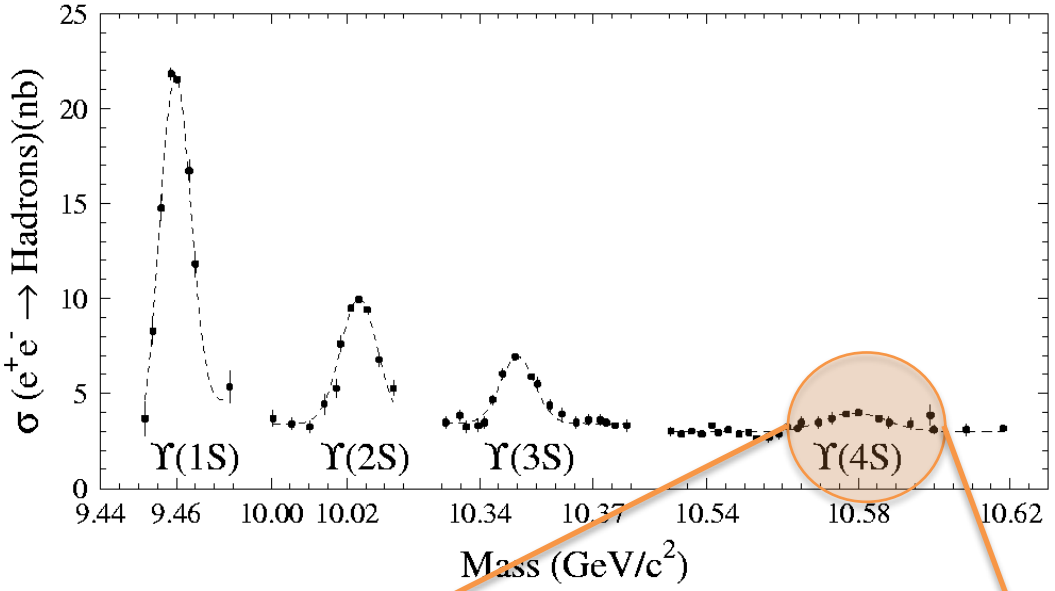
上海交通大学和李政道研究所，上海

The B Factories

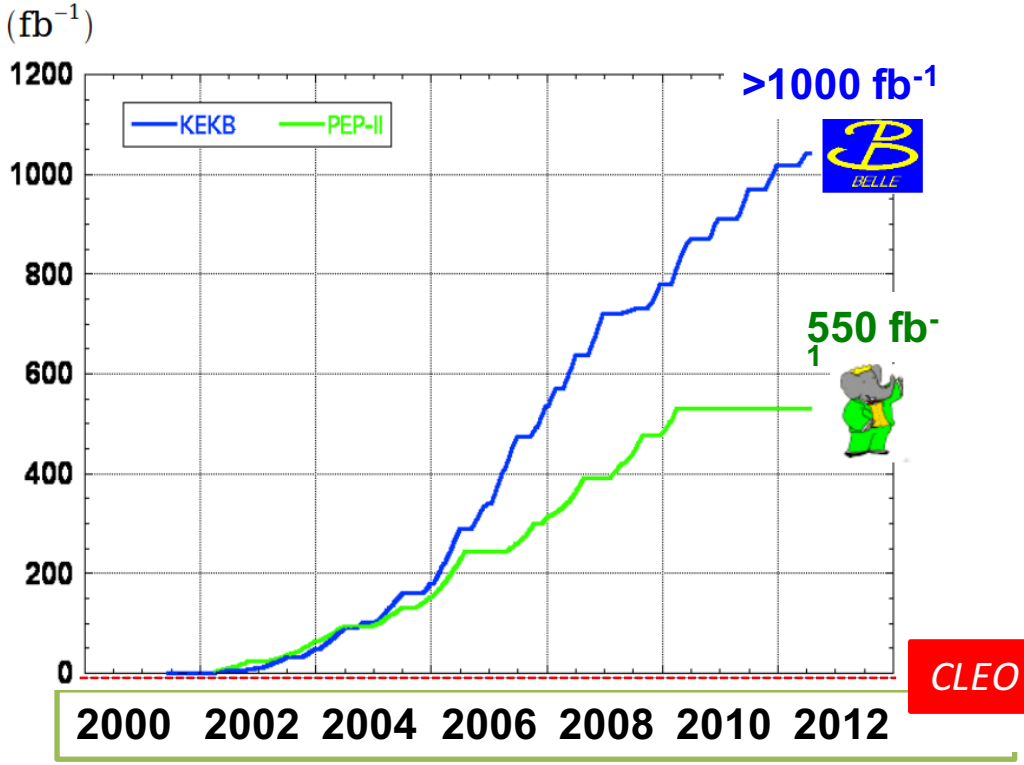
- Belle at KEKB

  BABAR at PEP-II

- Very high luminosity:
  - ✓ ~2x10^{34}/cm^2/s (Belle)(twice the design value)
- Asymmetric beams:
  - ✓ 8GeV e$^-$/3.5 GeV e$^+$ (Belle)
    - → Boosted BB pairs
      - (→ time dep. CPV)



The Belle + BaBar Era



CLEO 11 fb^{-1}

Channel	Belle	BaBar	Belle II (per year)
$B\bar{B}$	7.7×10^8	4.8×10^8	1.1×10^{10}
$B_s^{(*)}\bar{B}_s^{(*)}$	7.0×10^6	–	6.0×10^8
$\Upsilon(1S)$	1.0×10^8		1.8×10^{11}
$\Upsilon(2S)$	1.7×10^8	0.9×10^7	7.0×10^{10}
$\Upsilon(3S)$	1.0×10^7	1.0×10^8	3.7×10^{10}
$\Upsilon(5S)$	3.6×10^7	–	3.0×10^9
$\tau\tau$	1.0×10^9	0.6×10^9	1.0×10^{10}

Belle-II Goal: *40 x present = 4 x 10^{10} BB pairs* ***...but how to do it?***

How to achieve 40x luminosity? Super-KEKB

Lorentz factor

Beam current

Beam-Beam parameter

× 40

× 2

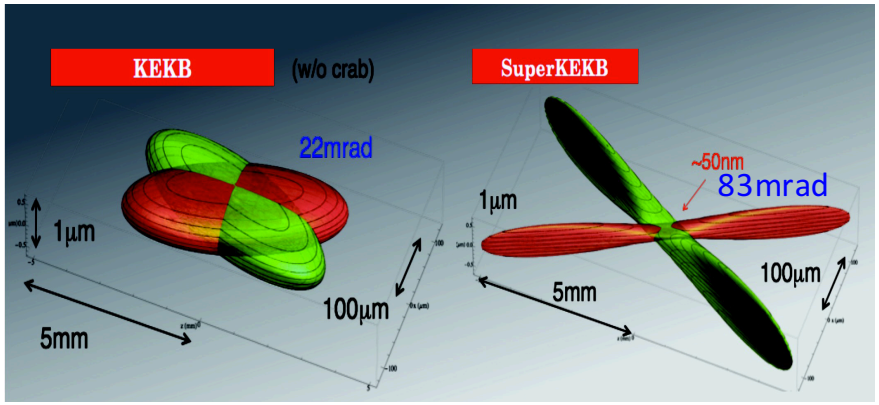
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{y\pm}}{\beta_{y\pm}^*}\frac{R_L}{R_{\xi_y}}$$

Geometrical reduction factors (crossing angle, hourglass effect) ***(0.8-1.0)***

× 1/20

Vertical beta function at IP

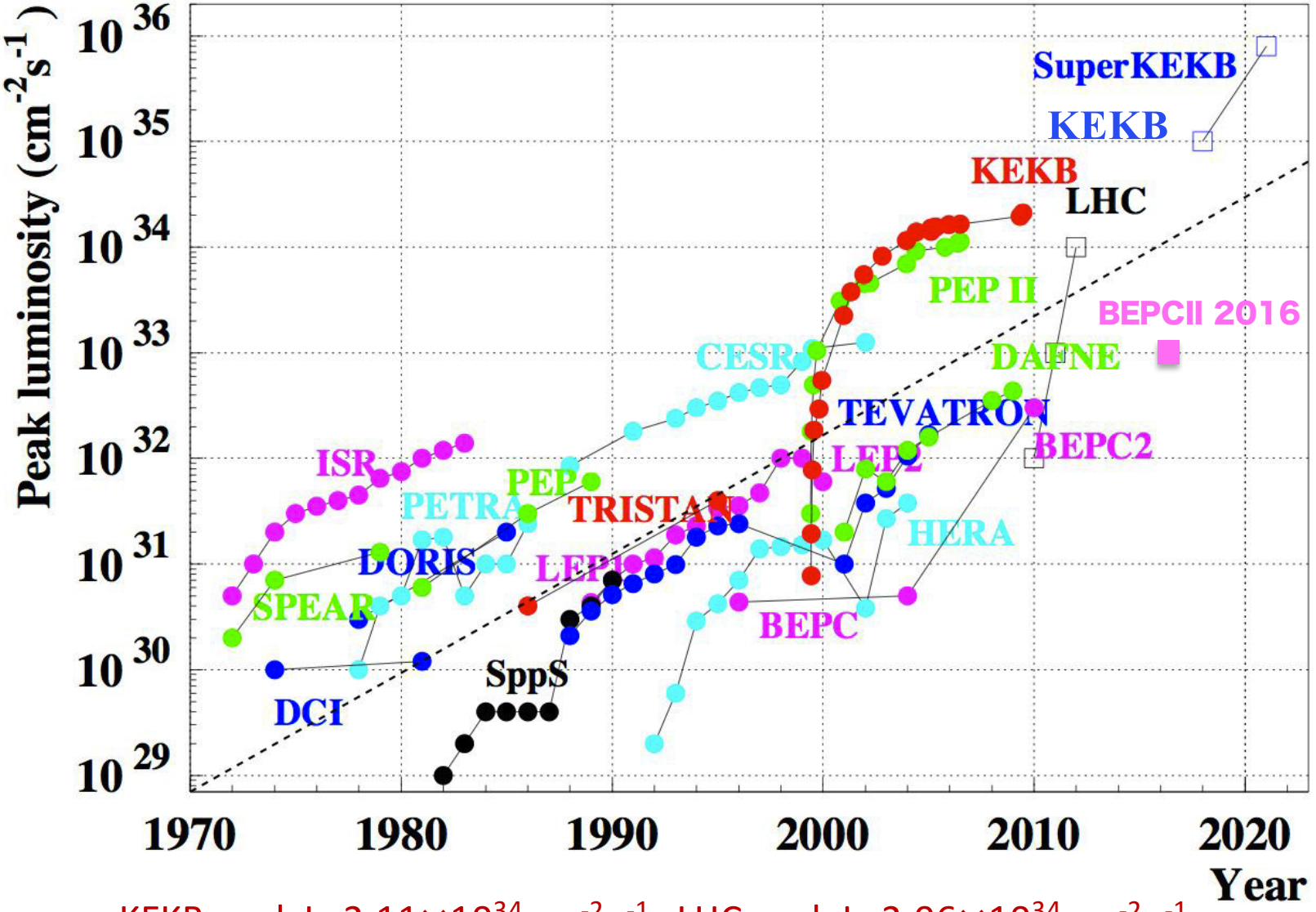
Beam aspect ratio at IP ***(0.01-0.02)***



	KEKB Achieved	SuperKEKB
Energy (GeV) (LER/HER)	3.5/8.0	4.0/7.0
ξ_y	0.129/0.090	0.090/0.088
β_y^* (mm)	5.9/5.9	0.27/0.41
I (A)	1.64/1.19	3.60/2.62
Luminosity ($10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	2.11	80

beam size: *100 μm(H) x 2 μm(V) → 10 μm(H) x 59 nm(V)*

Next generation B-factories

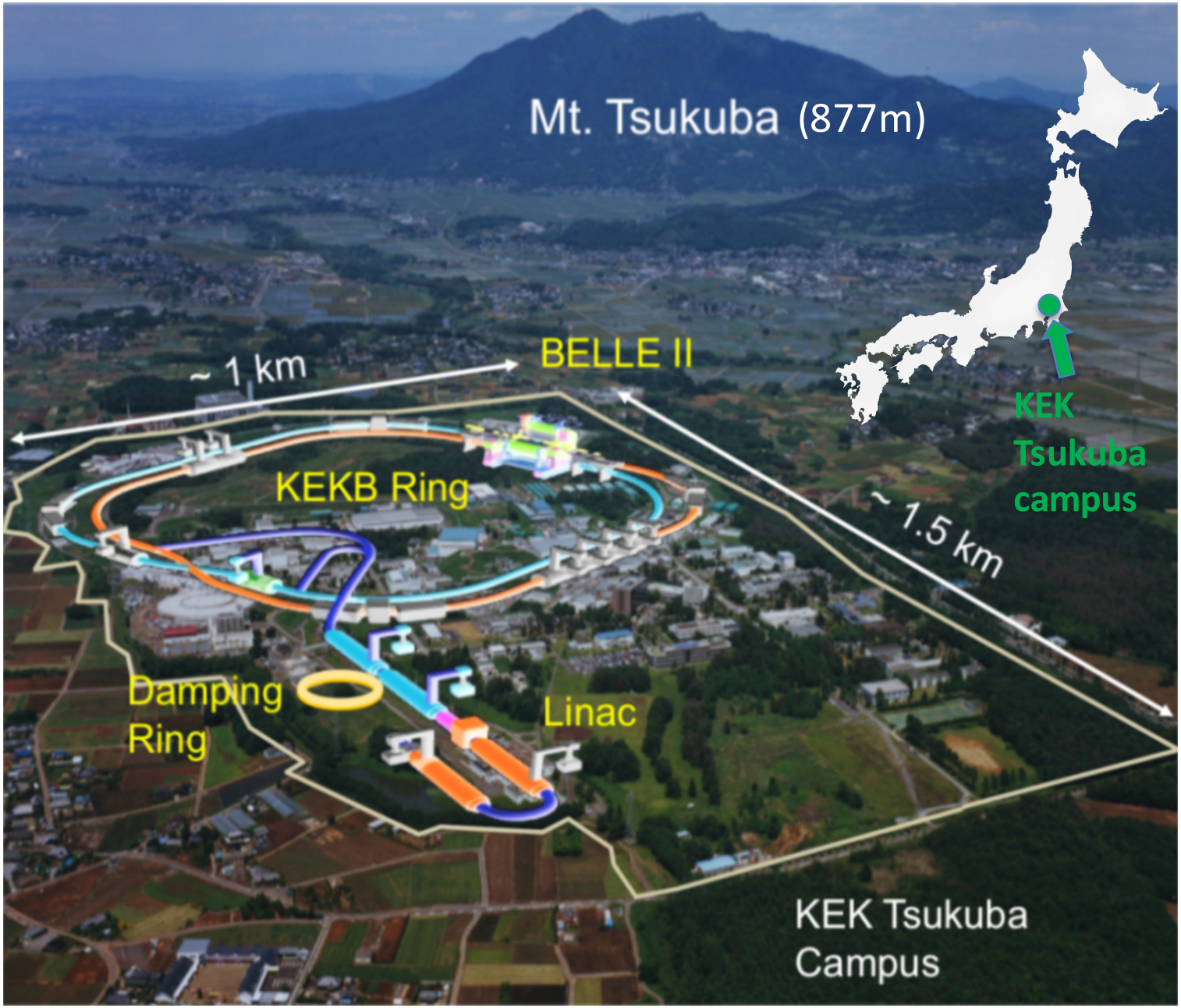


8×10^{35}

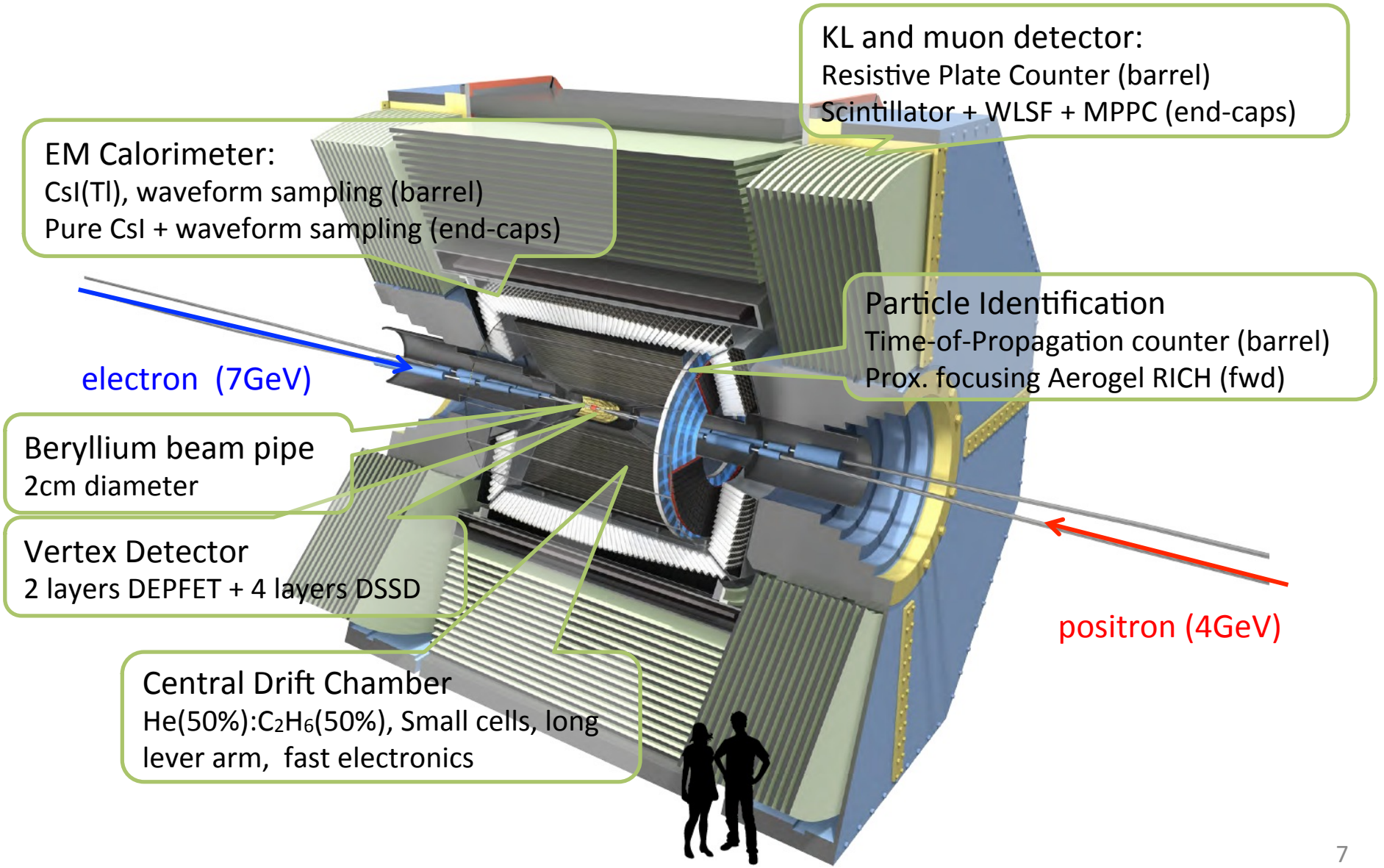
KEKB peak L: 2.11×10^{34} cm^{-2} s^{-1} , LHC peak L: 2.06×10^{34} cm^{-2} s^{-1}

SuperKEKB and Belle II

KEK is located in Tsukuba, Japan (50km away from Tokyo)



Belle II detector



Belle II collaboration

http://belle2.kek.jp (April. 11 2018)

Base on Belle II collaboration. Many people from Belle and Babar.

810 colleagues, 108 institutions, 25 countries/regions

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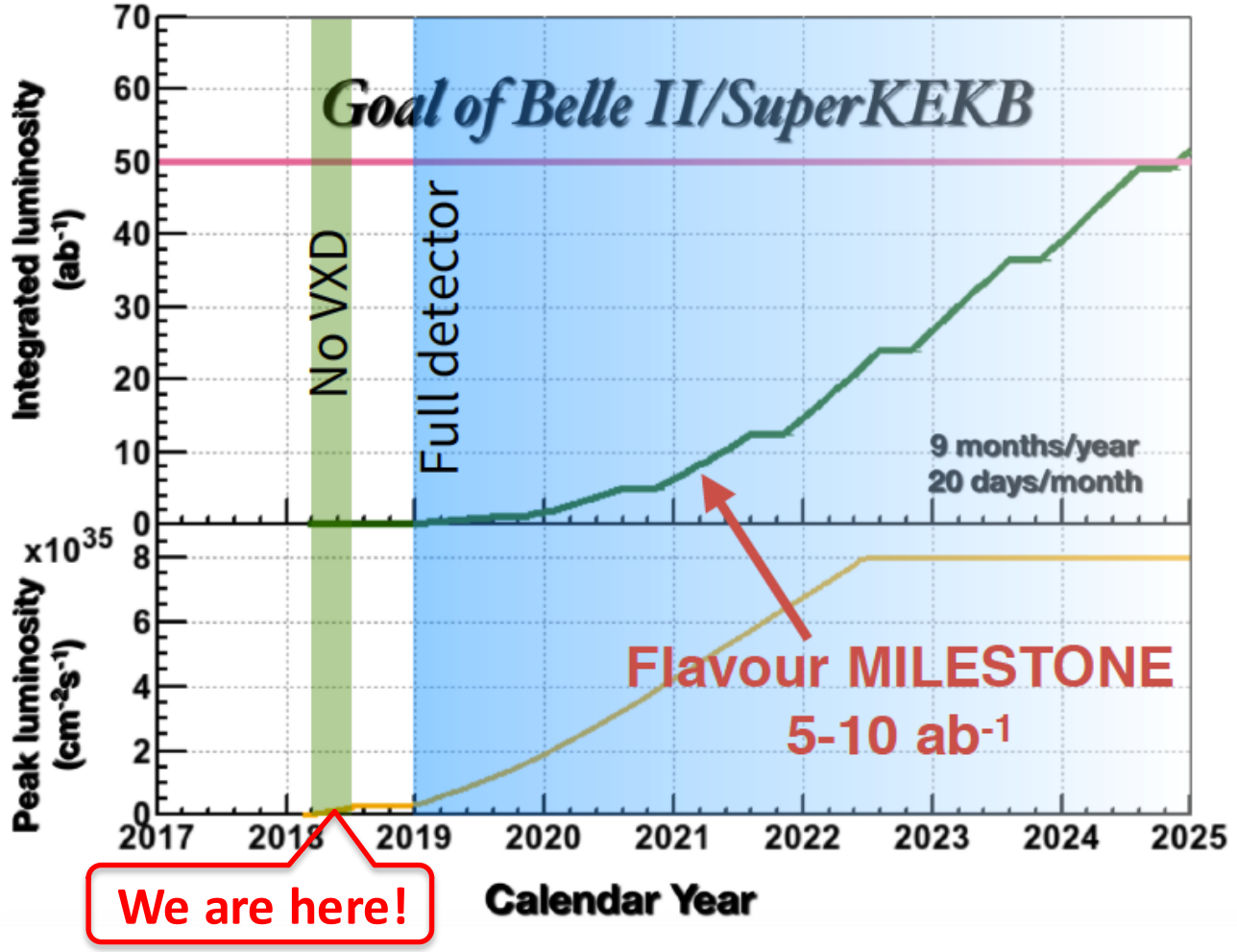
SuperKEKB / Belle II Luminosity projections



Belle II/SuperKEKB is gradually being launched

Phase 1 w/o Belle II (2016…done)

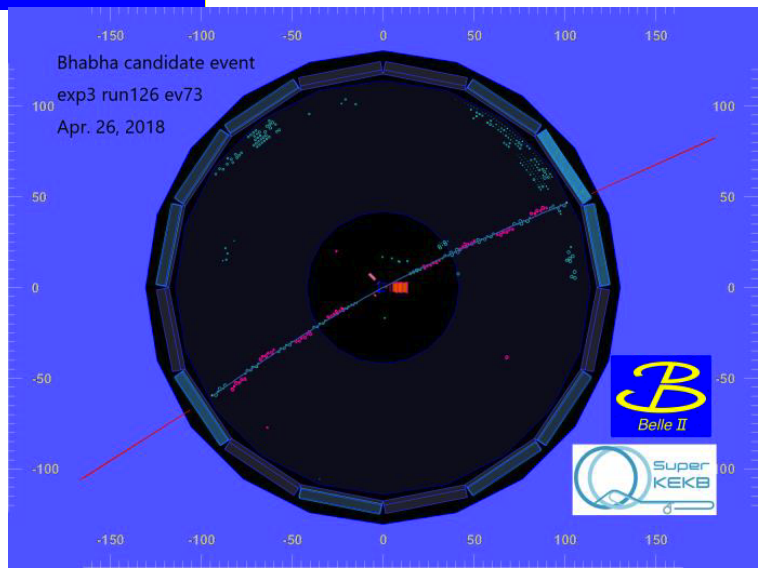
Phase 2 partial Belle II (since 2018…ongoing!)

Phase 3 full Belle II (plan for early 2019)

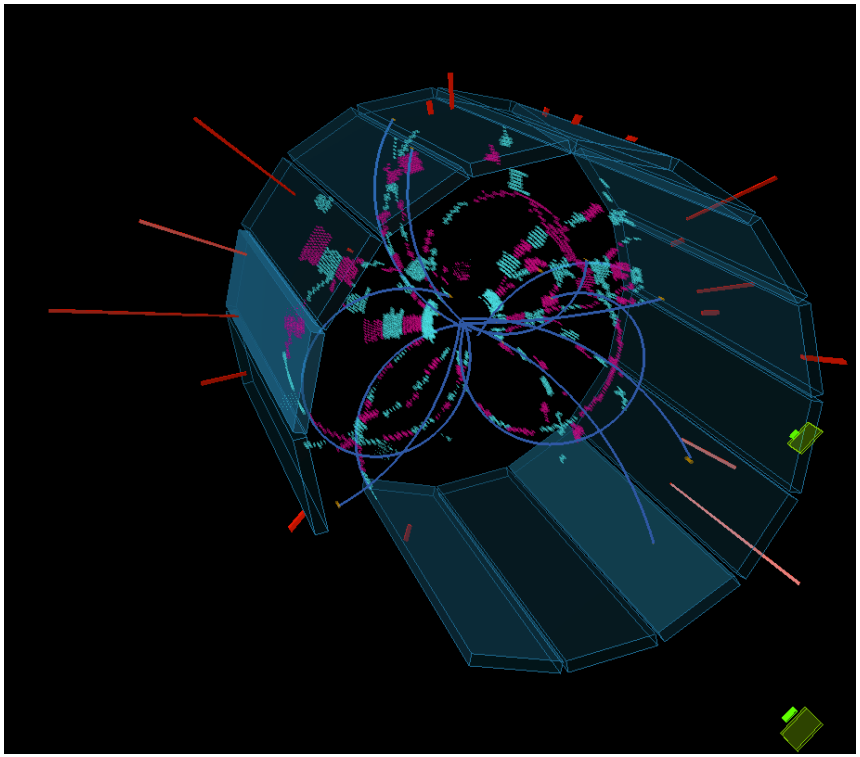
Belle II status

First collisions at Apr 26!

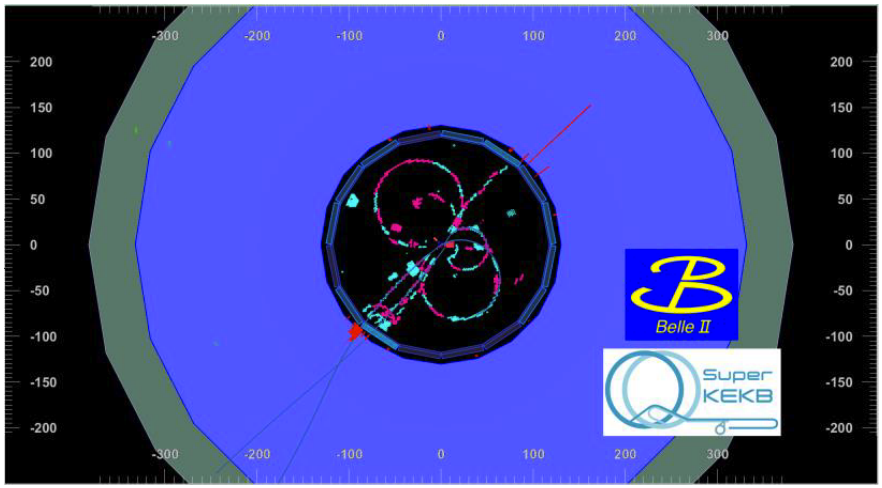
First collisions: Some "first" events



Bhabha event

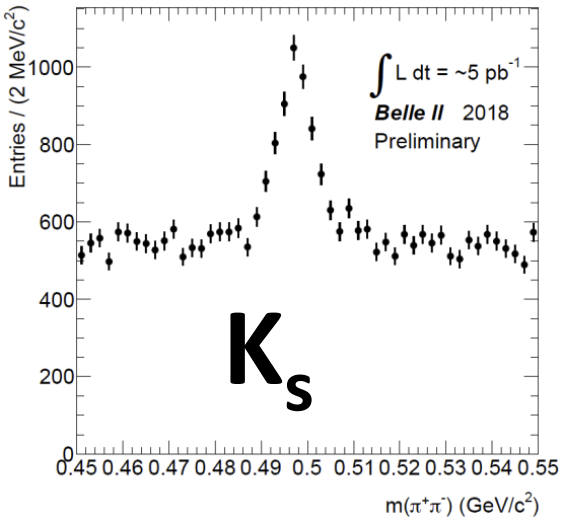


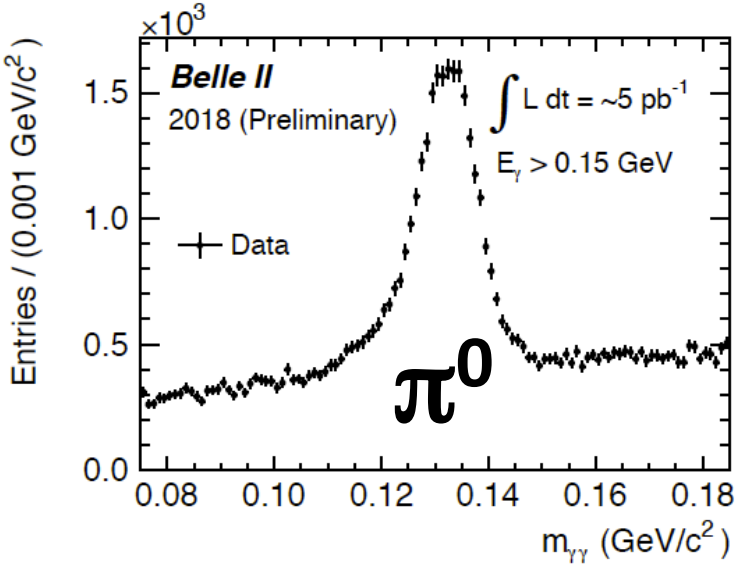
$B\bar{B}$ like event

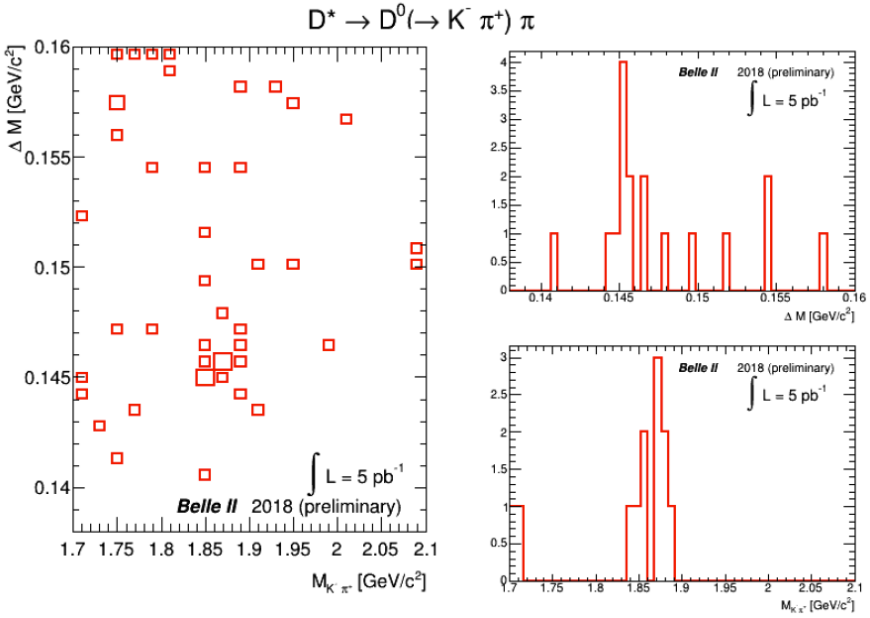


Hadronic event

… and revisit PDG







D*+

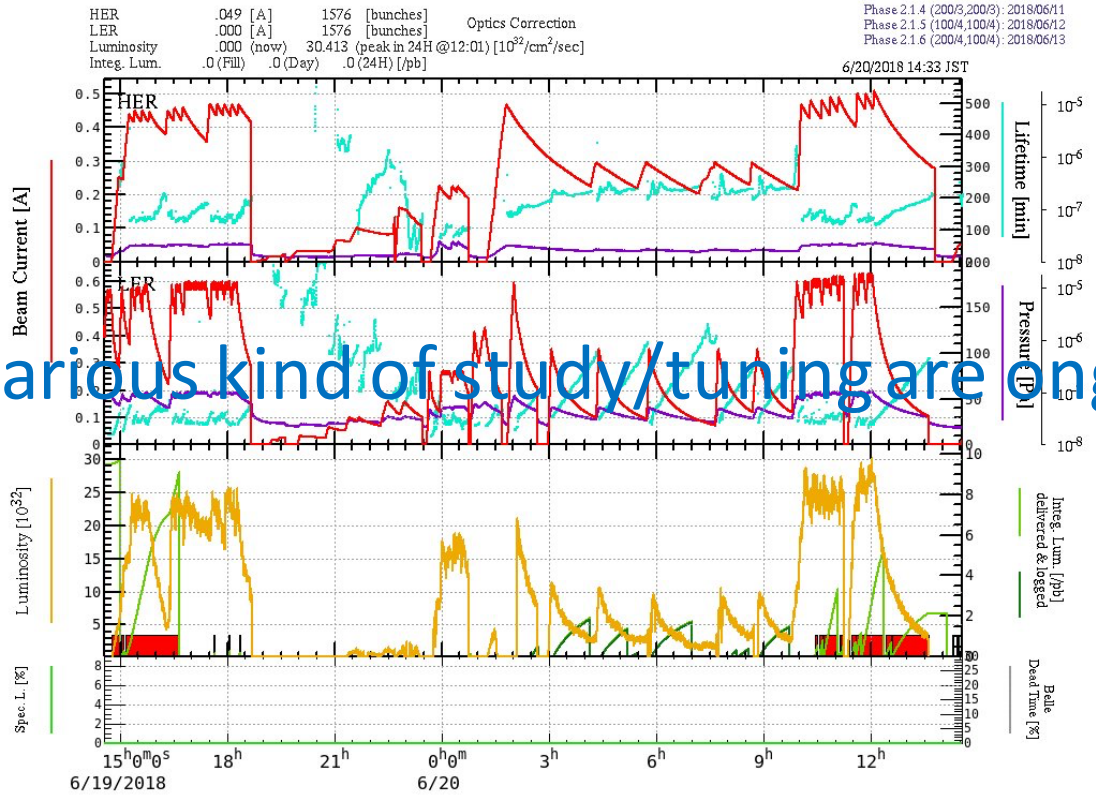
Phase 2 status

Phase 2 operation continues until July 17th

Achievement so far

Peak luminosity: ~ 3.0×10^{33} $cm^{-2}s^{-1}$ (3/20 of KEKB record)

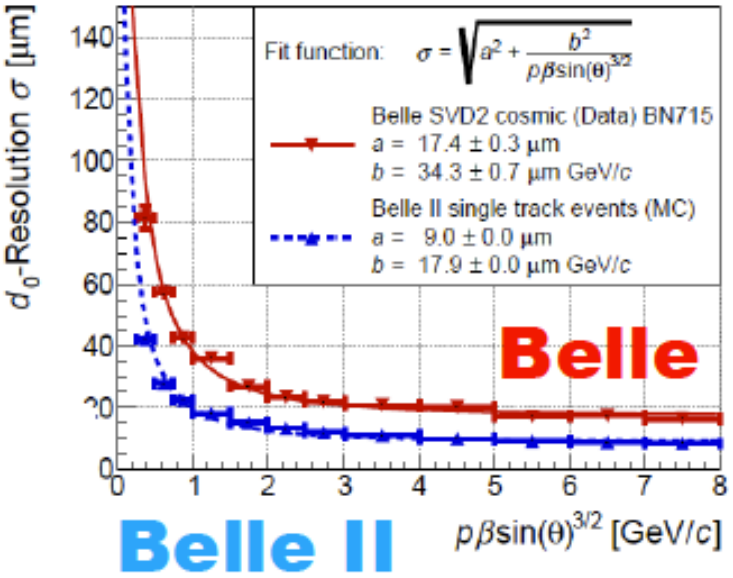
Integrated luminosity: ~ 180 pb^{-1} as of June 4th

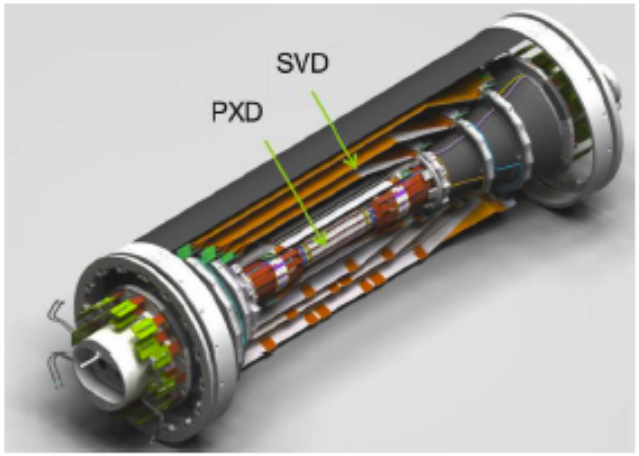


Still various kind of study/tuning are ongoing

Phase 3 preparation

- After phase 2, vertex detectors will be installed to Belle II
  - 4 layer silicon strip (SVD) + 2 layer pixel (PXD)
- Significantly improve the vertex resolution
  - Compensated for reduced boost



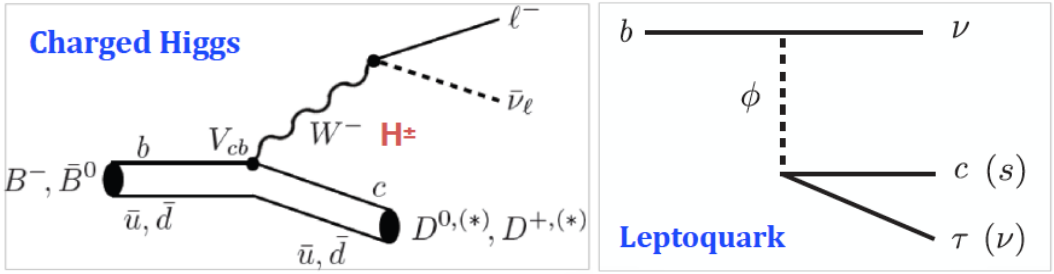


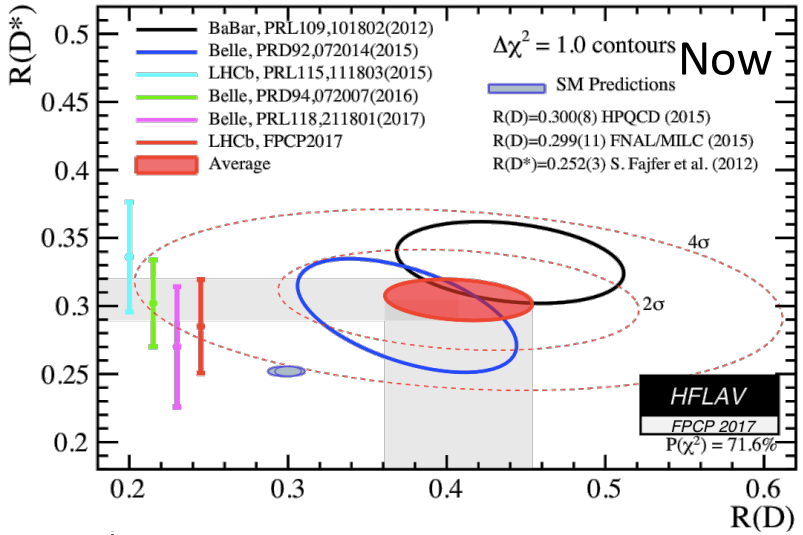
$$\sigma_{\Delta_t}^{\text{Belle II}} \sim \frac{3}{4}\sigma_{\Delta t}^{\text{Belle}}$$

Belle II physics prospects

Lepton Universality in $B \to D^{(*)}\ell\nu$

$$R(D^{(*)}) = \frac{\mathrm{Br}(B \to D^{(*)}\tau\nu)}{\mathrm{Br}(B \to D^{(*)}\mu\nu)}$$





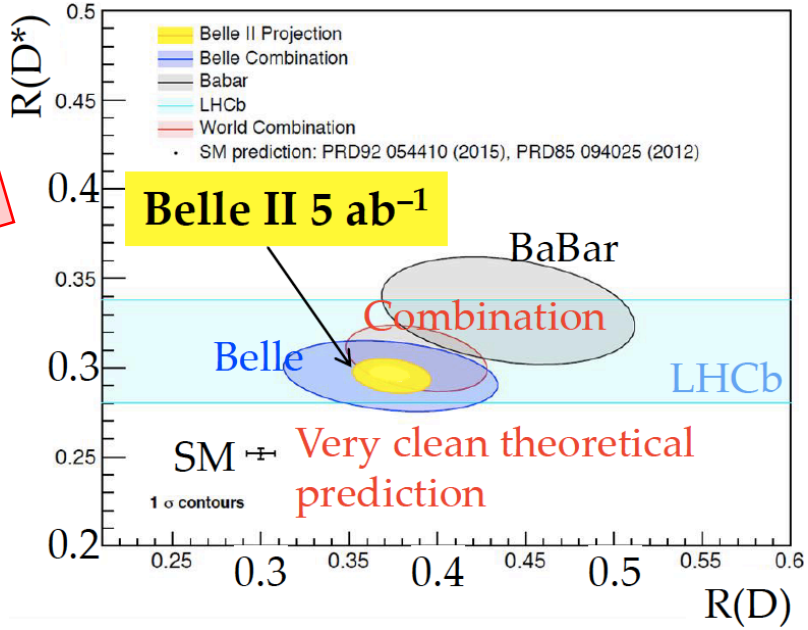
	Exp	SM
$R(D^*)$	0.304±0.013±0.007	0.252±0.003
$R(D)$	0.407±0.039±0.024	0.300±0.008

HFAG (FPCP2017)

The experimental observation is away from the SM prediction at a 4.1σ level.

Belle II $5ab^{-1}$

The $R(D^{(*)})$ is a sensitive parameter to a new physics beyond the SM.



Belle II should be able to confirm the excess with ~$5ab^{-1}$ data.

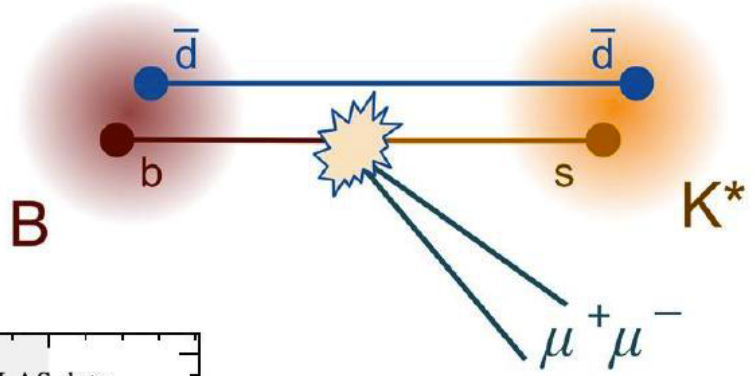
Lepton Flavor Universality in $B \to K^{(*)} \ell \ell$

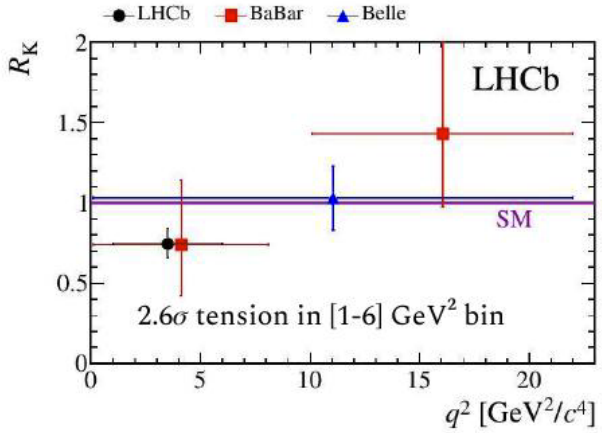
$$R_{K^{(*)}} = \frac{BR(B \to K^{(*)} \mu\mu)}{BR(B \to K^{(*)} ee)}$$

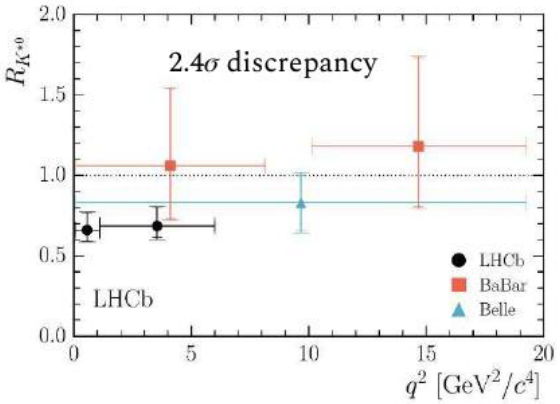
- Theoretical uncertainties cancel in the ratio
- The SM prediction is 1 with high precision
- R_K and R_{K^*} give complementary info

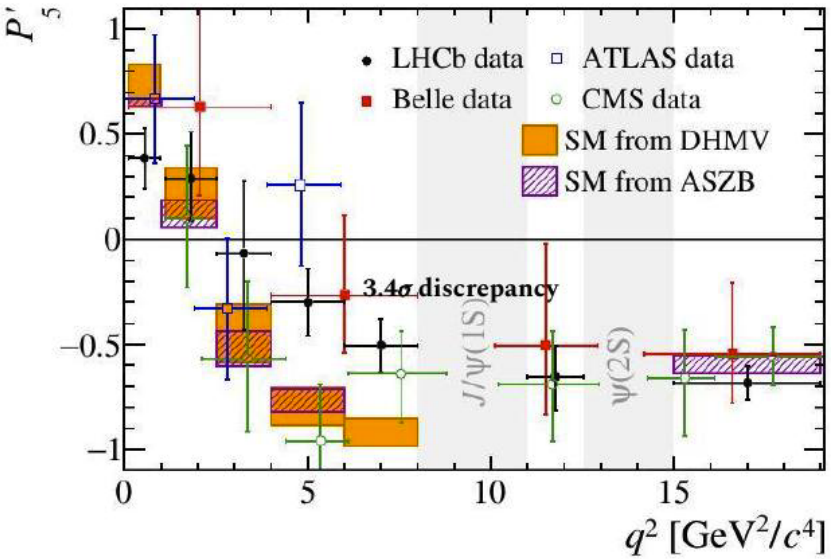
$$P_5' \ (B \to K^* \mu^+ \mu^-)$$

One of the optimised angular observables









Ongoing discussion about the interpretation and theory predictions

Lepton Flavor Universality in $B \to K^{(*)} \ell^+ \ell^-$

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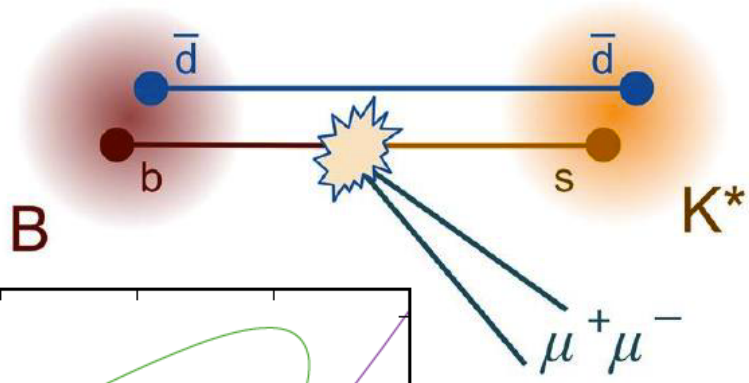
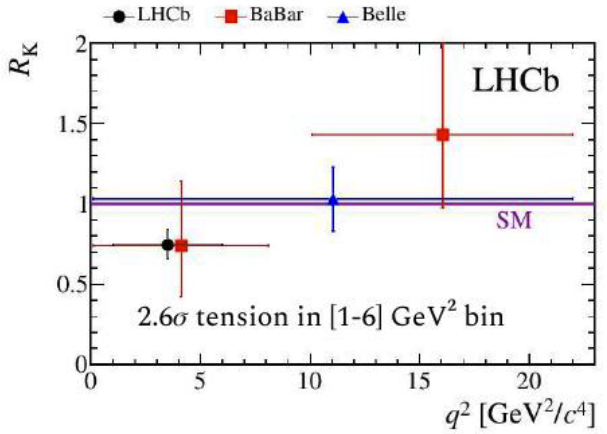
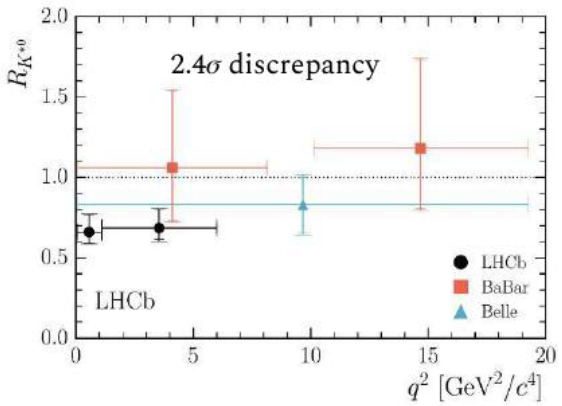
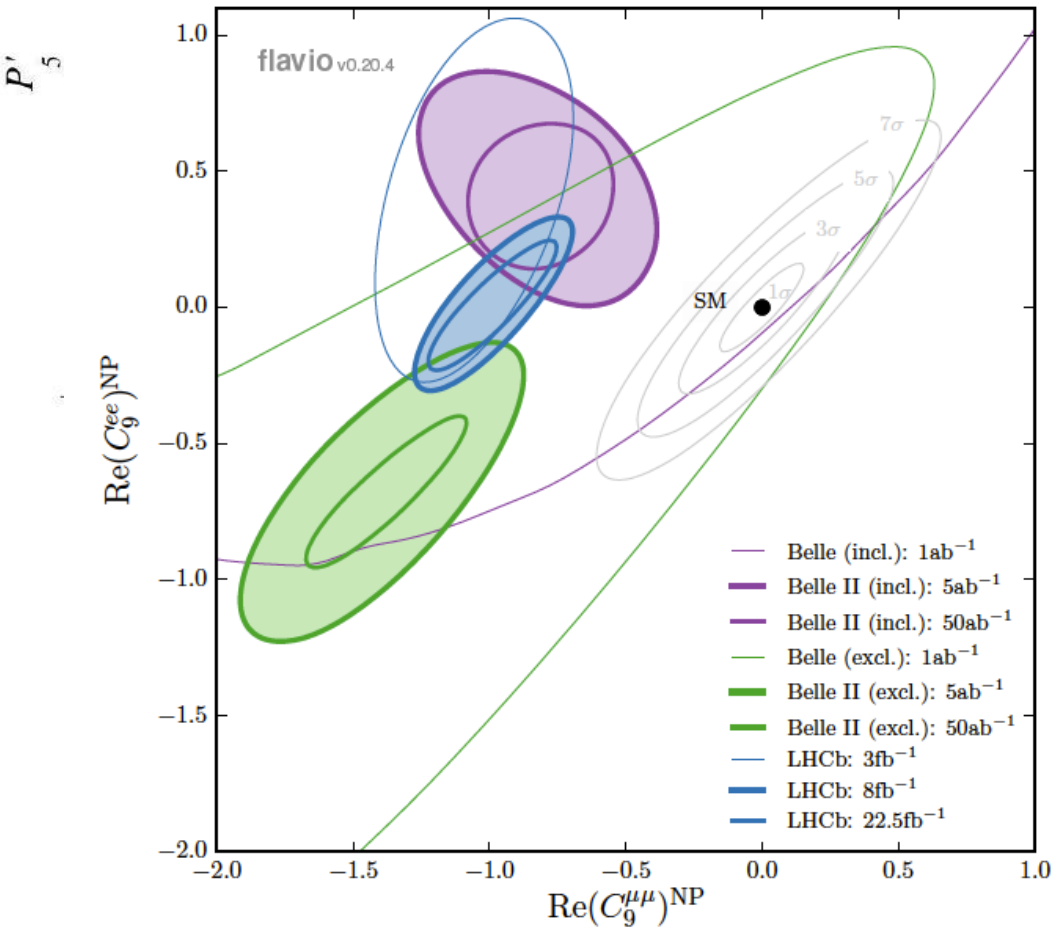


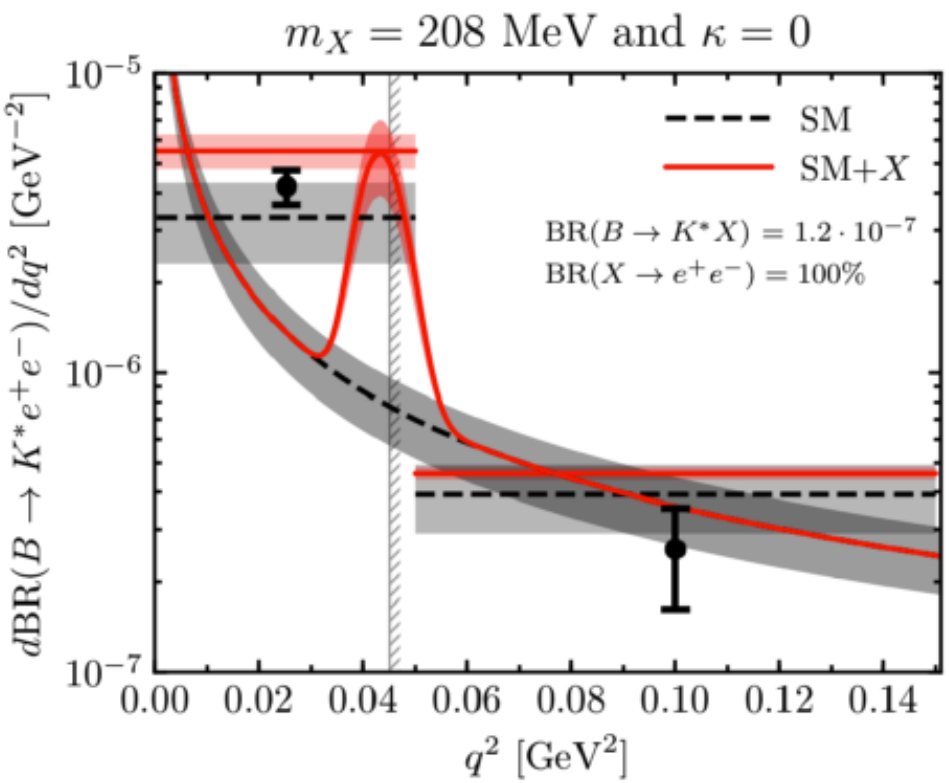


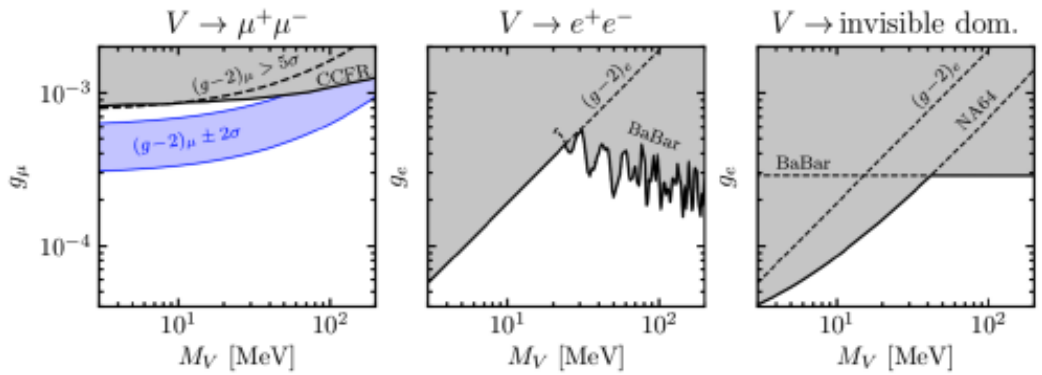


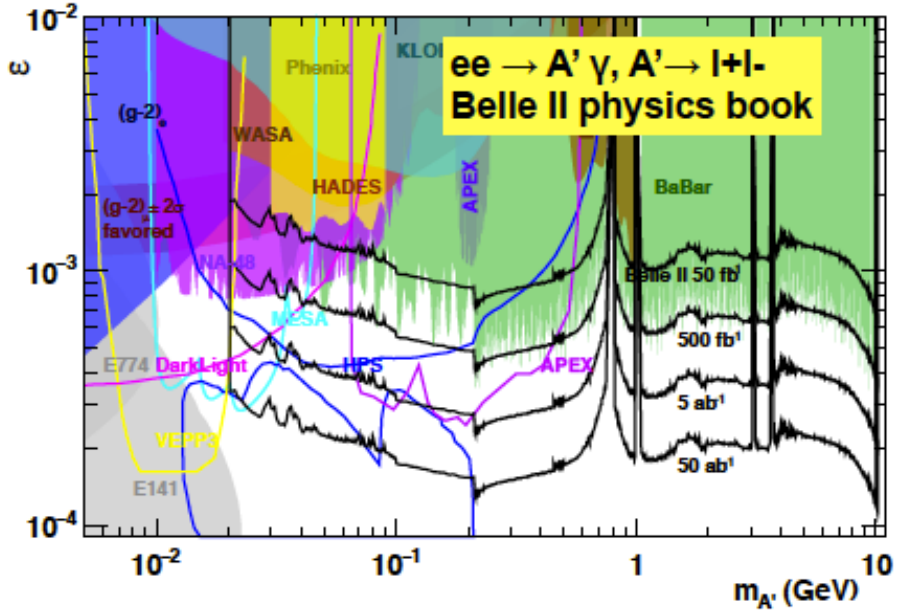


Dark Photon and Dark Matter

W. Altmannshofer, arXiv:1711.07494

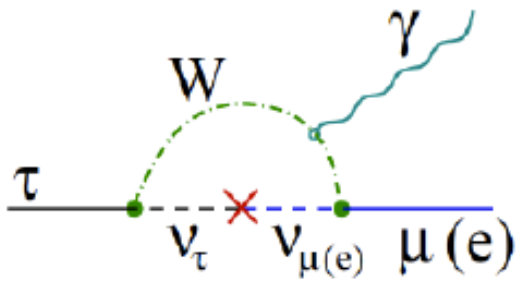






Lepton Flavor Violation

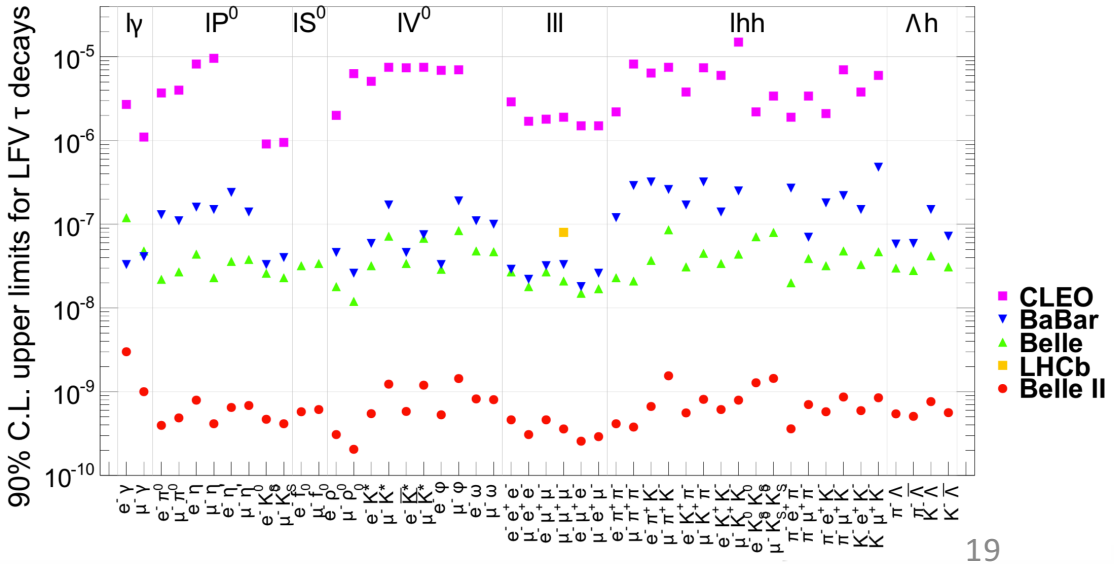
- Extremely suppressed in the SM



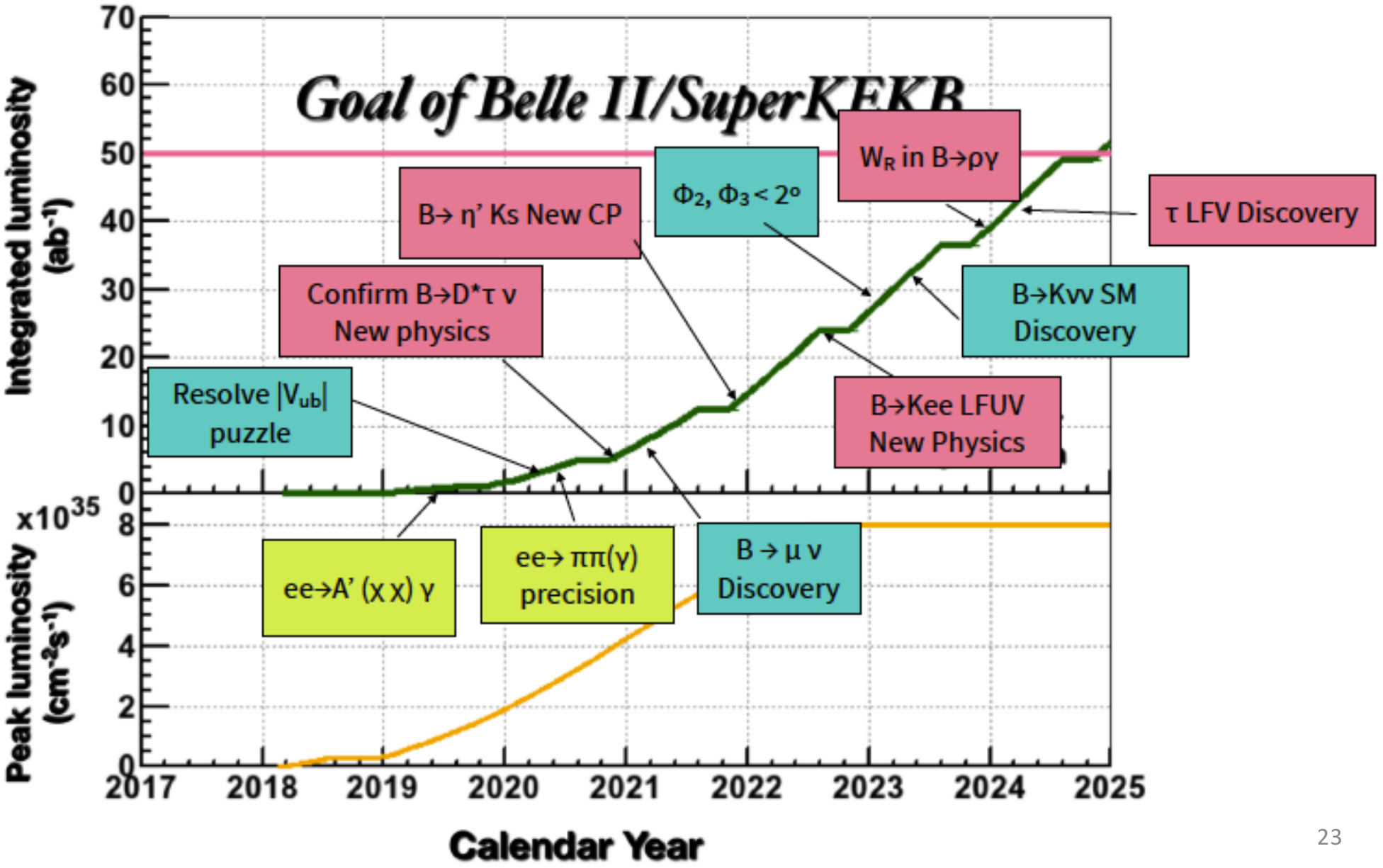
$$\mathcal{B}(\tau \to l\gamma) = \frac{3\alpha}{32\pi}\left|\sum_i U^*_{\tau i} U_{\mu i} \frac{\Delta^2_{3i}}{m^2_W}\right|^2 \leq 10^{-53} \sim 10^{-49}$$

- Many BSM model enhances the LFV decays
- Belle II can access variety of τ LFV decays to test many NP models

Model	Br($\tau \to \mu\gamma$)	Source
SUSY+GUT	10^{-7}	PRD 66(2002)11501
SUSY SO(10)	10^{-8}	PRD 68(2003)033012
SM+ heavy ν_R	10^{-9}	PRD 66(2002)034008
Non-universal Z'	10^{-9}	PLB 547(2002)252
Little Higgs	10^{-10}	JHEP 0705, 013 (2007)
SUSY Higgs	10^{-10}	PLB 566(2003)217
SM	10^{-40}	EPJ C8 (1999) 513



Roadmap

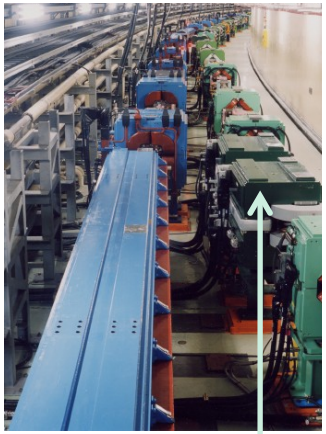

Goal of Belle II/SuperKEKB
Integrated luminosity (ab⁻¹)
Peak luminosity (cm⁻²s⁻¹)
x10³⁵
Calendar Year
2017
2018
2019
2020
2021
2022
2023
2024
2025
Resolve |Vub| puzzle
Confirm B→D*τ ν New physics
B→ η' Ks New CP
Φ2, Φ3 < 2°
WR in B→ργ
τ LFV Discovery
B→Kνν SM Discovery
B→Kee LFUV New Physics
ee→A' (x x) γ
ee→ ππ(γ) precision
B → μ ν Discovery

Summary

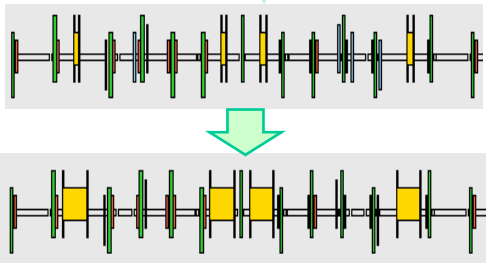
- New collider SuperKEKB → $\mathscr{L}^{int} = 50ab^{-1}$ before 2026
- Improved detector performances: good neutral particles reconstruction, resonances, decay vertices and events with high missing energy.
- Fundamental physics studies: CKM matrix, CPV, LFV, FCNC, dark sector.
- Installation and insertion of the detector: 11 Aprile 2017
- Actual status, phase 2: first data analysed without vertex detector.
- Phase 3: data taking will start in February 2019 with the whole detector installed.

Thank you for your attention

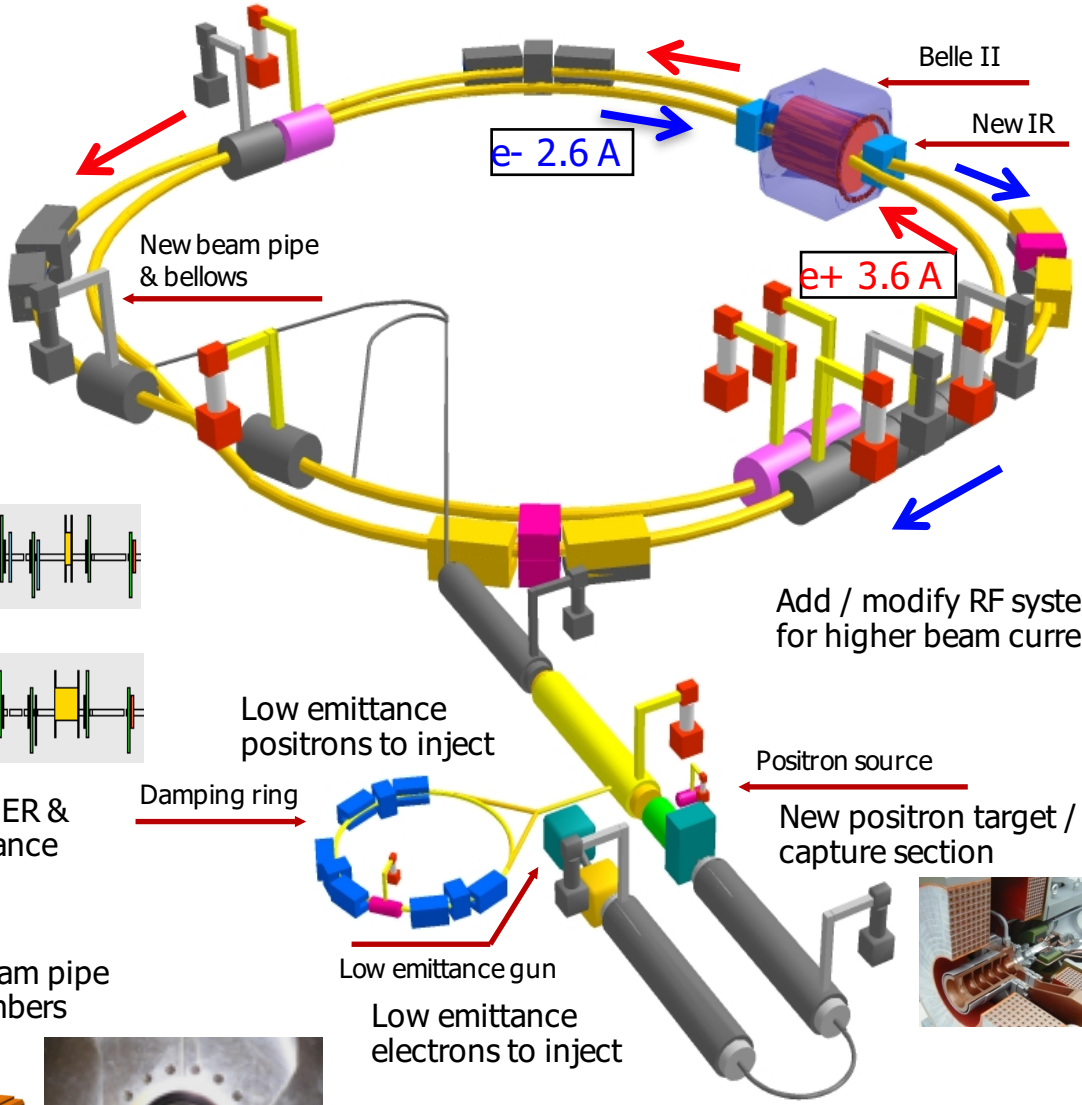
KEKB→SuperKEKB



Replace short dipoles with longer ones (LER)

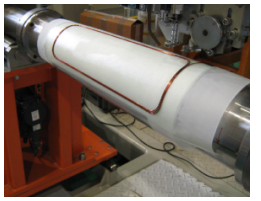


Redesign the lattices of HER & LER to squeeze the emittance



Colliding bunches

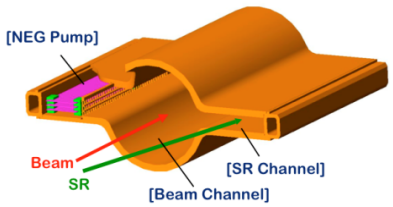
New superconducting /permanent final focusing quads near the IP

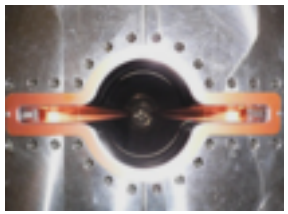


Add / modify RF systems for higher beam current

New positron target / capture section

TiN-coated beam pipe with antechambers





To get 40x higher luminosity