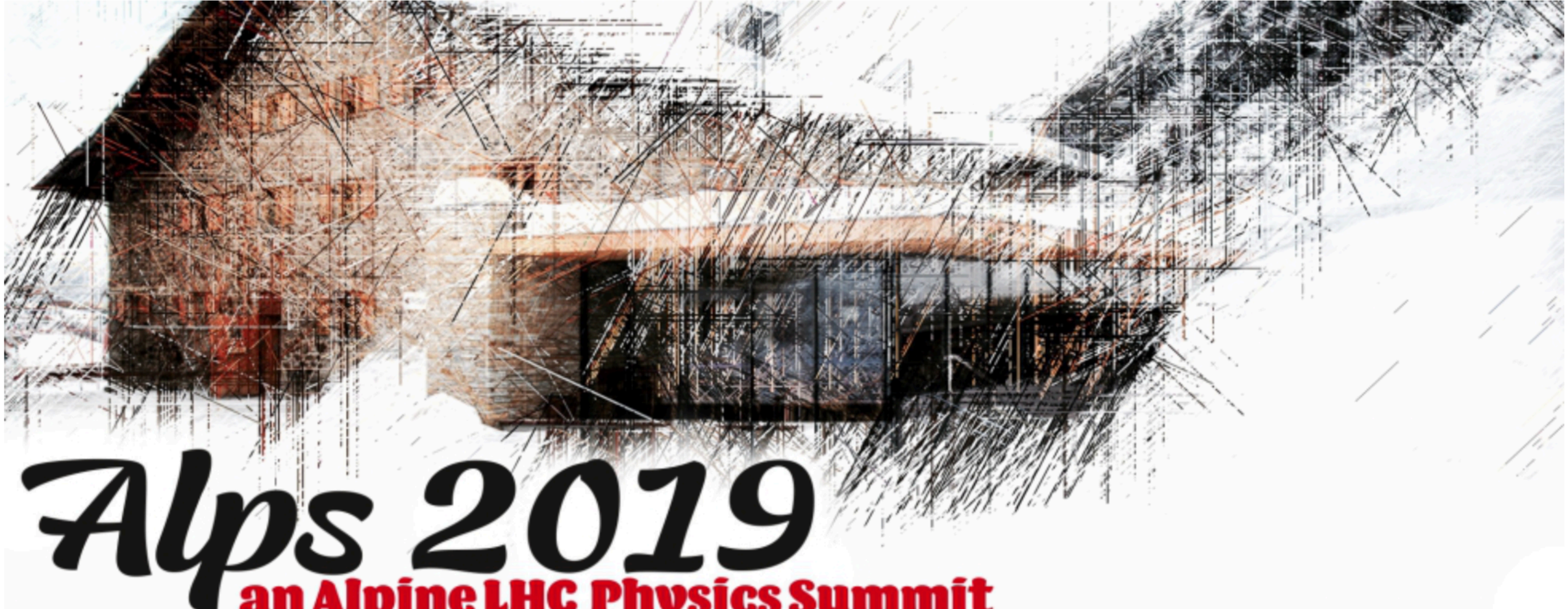


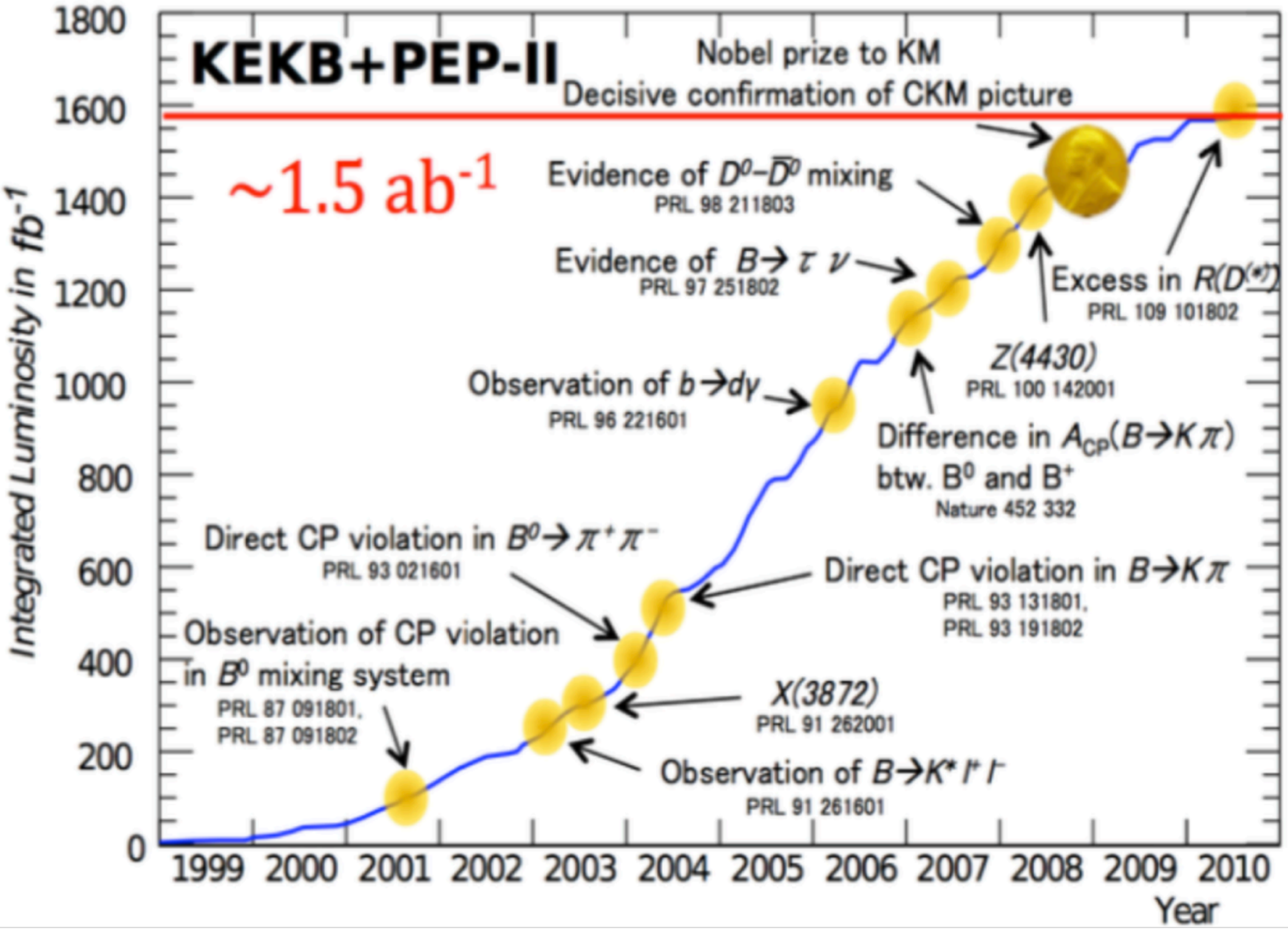
Belle II status and Physics prospects

Chiara La Licata (Kavli IMPU WPI) for the Belle II Collaboration

ALPS 2019, Obergurgl, April 24 2019

Achievements at B factories

10 successful years: significant contribution to the understanding of the flavour dynamics in the Standard Model



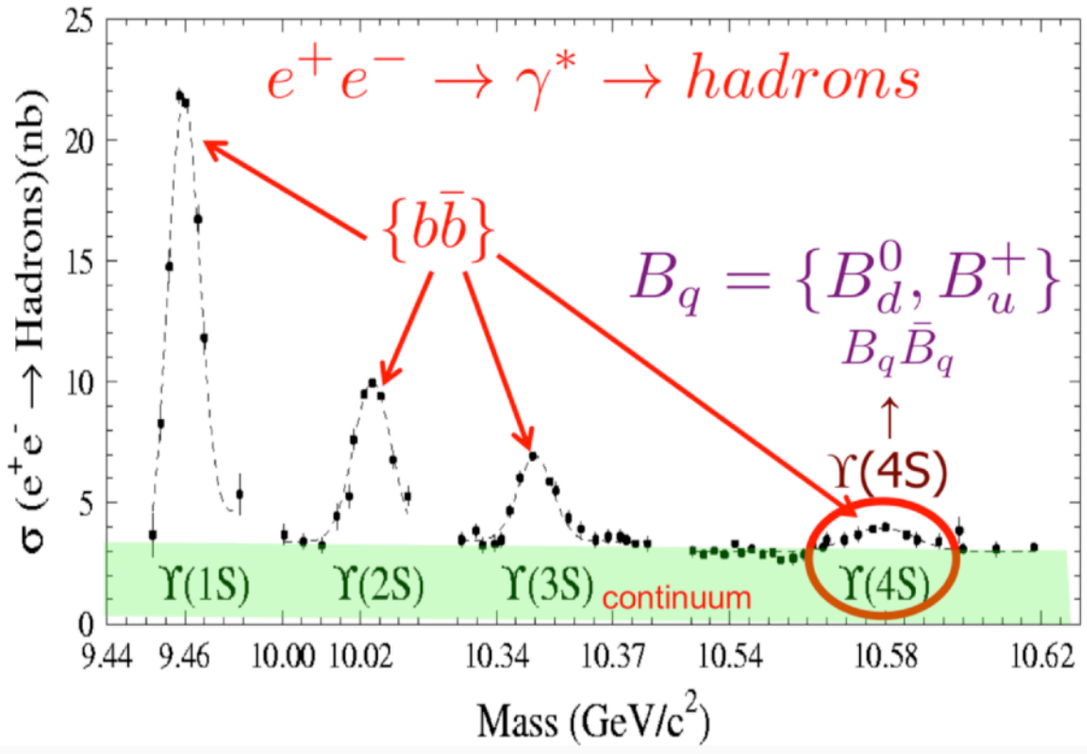
- Discovery of CP violation in B meson transitions and confirmation of the CKM description of flavour physics
- Precision measurement of the CKM matrix elements and the angles of the unitarity triangle
- Constraints on various new physics models
- Observation of several new hadronic states
- Strong evidence of D meson mixing

keys of success:

- large data sample
- clean event structure
- asymmetric beam energy
- excellent detector performances

Next generation B factory: SuperKEKB

Asymmetric e^+ e^- circular collider aiming at delivering the **highest instantaneous luminosity** ever reached



- **B factory (e⁺e⁻ -> Y(4S) -> BB)**

~ 900 BB pairs/second at design intensity

- **Charm factory**

~1.3 x 10^9 cc pairs per ab^{-1}

- **τ factory**

~0.9 x 10^9 $\tau\tau$ pairs per ab^{-1}

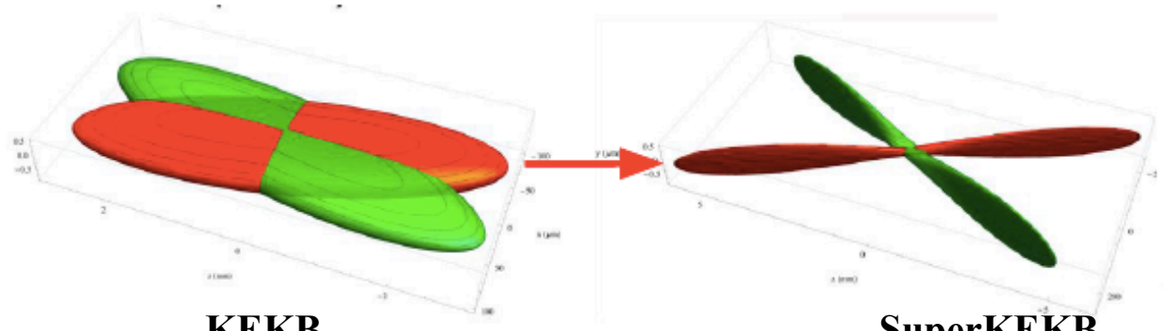
How to increase luminosity?

- Increase current: x2
- Reduced beam spot size (nano beam scheme): x20

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

beam current

vertical beta function at IP



KEKB SuperKEKB

Nano-beam scheme

L_{peak}: 8x10^{35} $cm^{-2}s^{-1}$ (40 x KEKB)

L_{int}: 50ab^{-1} by 2025 (50 x KEKB)

BELLE II detector

Many upgrades to increase the performance and cope with more severe background conditions

Vertex Detector

- 2 pixel layers
- 4 layers of double-sided silicon microstrip sensors

→Extended region

Central drift chamber

- Small cell size, longer lever arm

EM calorimeter

- upgrade of electronics
- CsI(Tl) crystals (high light output, short X_0)

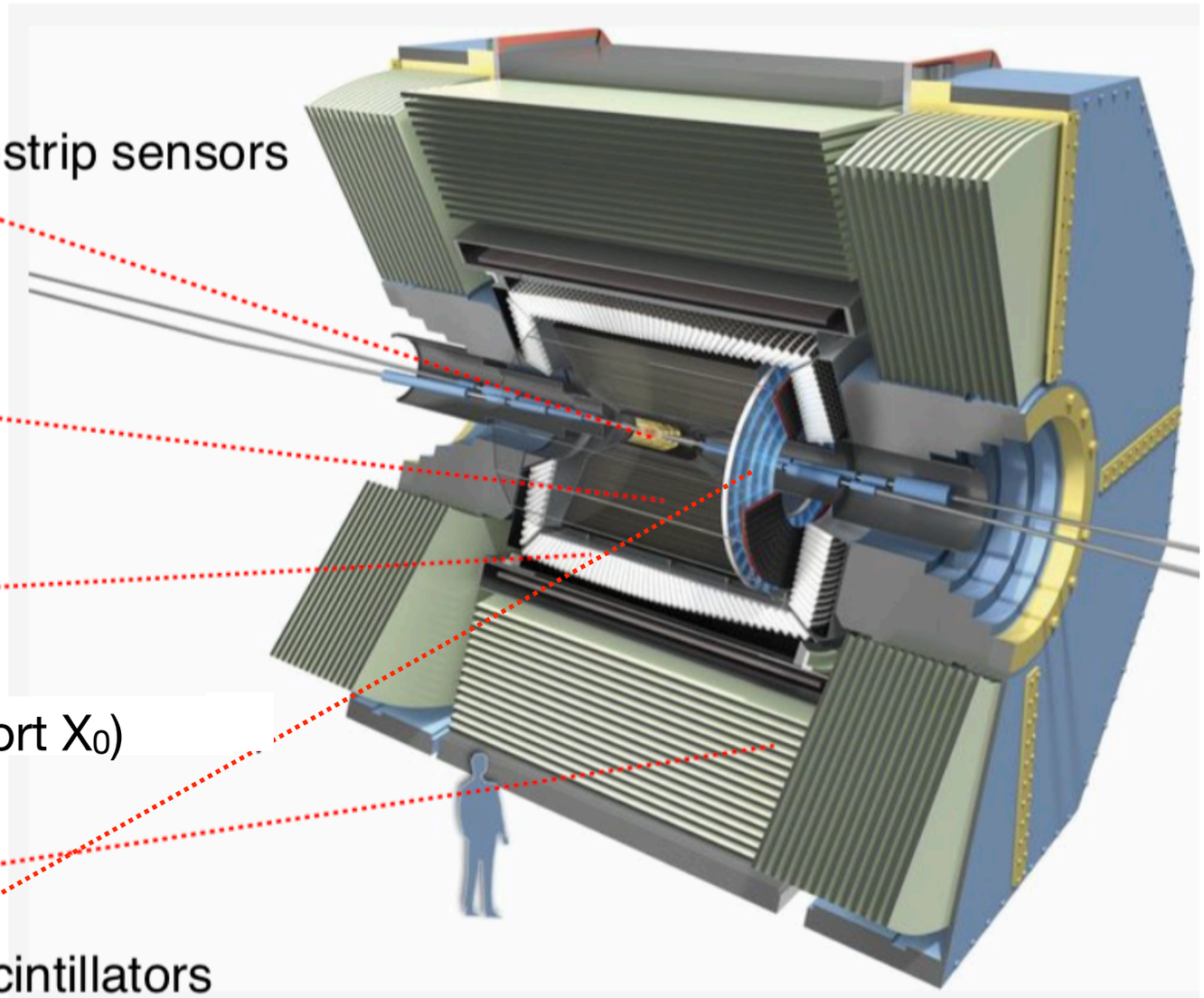
K_L and muon detector

-some RPCs layers substituted with scintillators

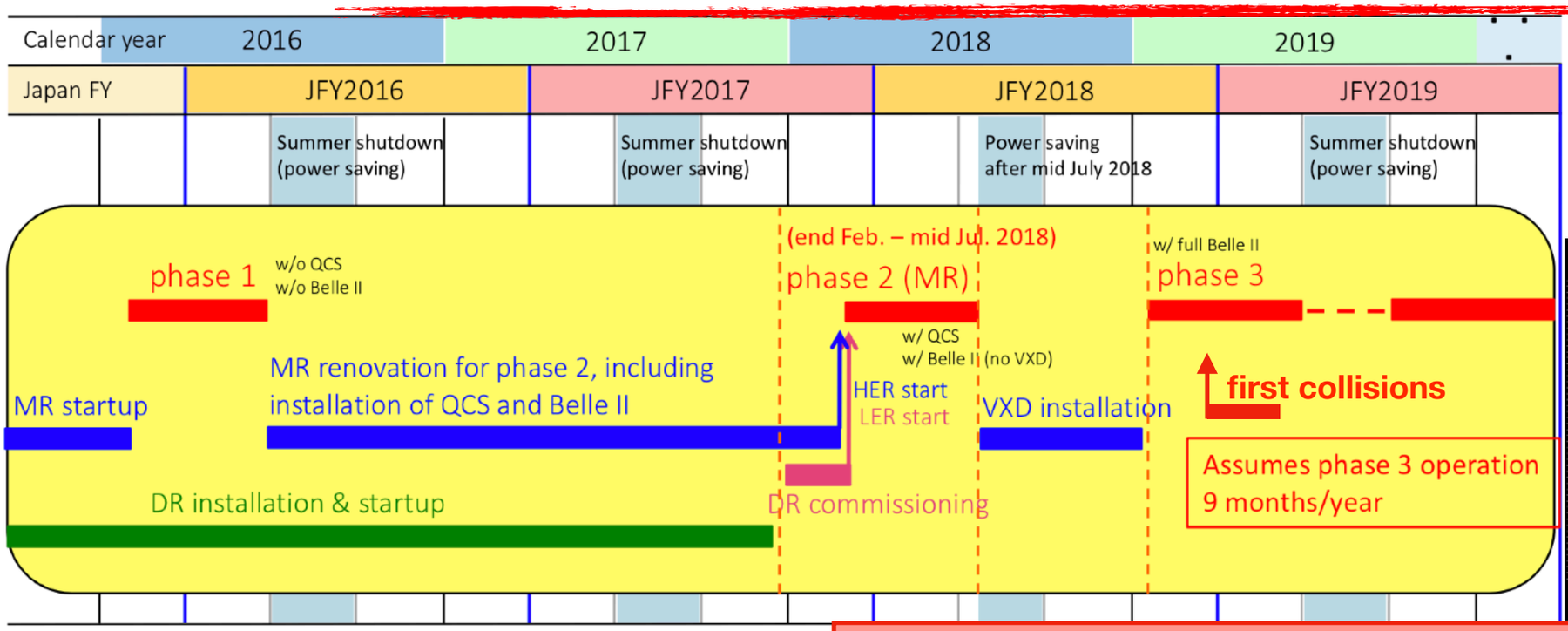
Particle identification

- time of propagation counter (barrel)
- Prox. focusing Aerogel RICH (forward)

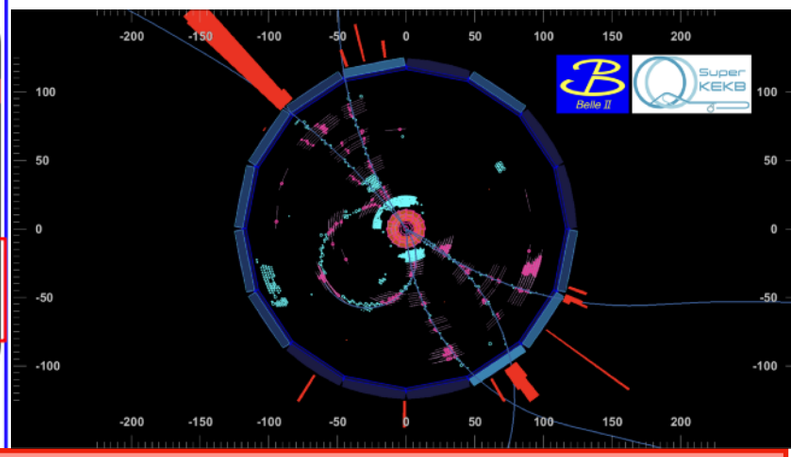
fake rate >2 lower than in Belle

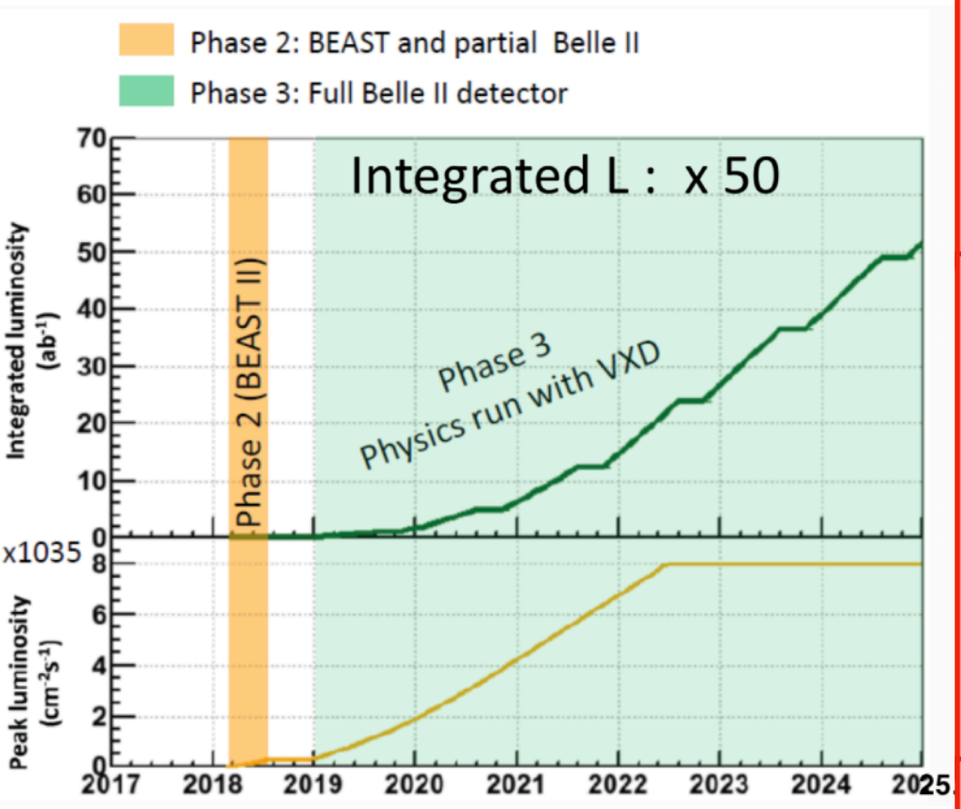


Timeline



25 March 2019:
first collisions during phase3





Phase 1 (Feb - June 2016):

- No Belle II, No Solenoid , and no final focusing magnet
- Single Beam background study
- Beam storage, vacuum scrubbing, optics studies, no collisions

Phase 2 (March - July 2018):

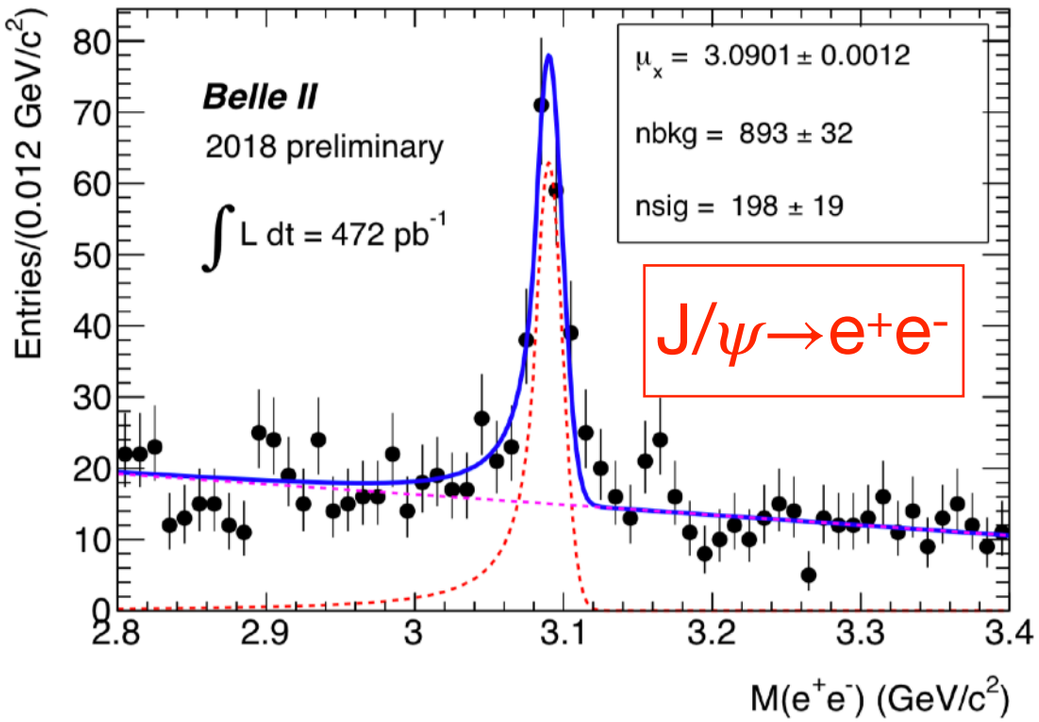
- Complete Belle II detector except for Vertex Detector
- Machine background measurements, good rad-hardness of VXD confirmed
- first collisions
- Maximum luminosity: ~5×10^{33} cm^{-2} s^{-1}
- Integrated luminosity: ~0.5 fb^{-1}

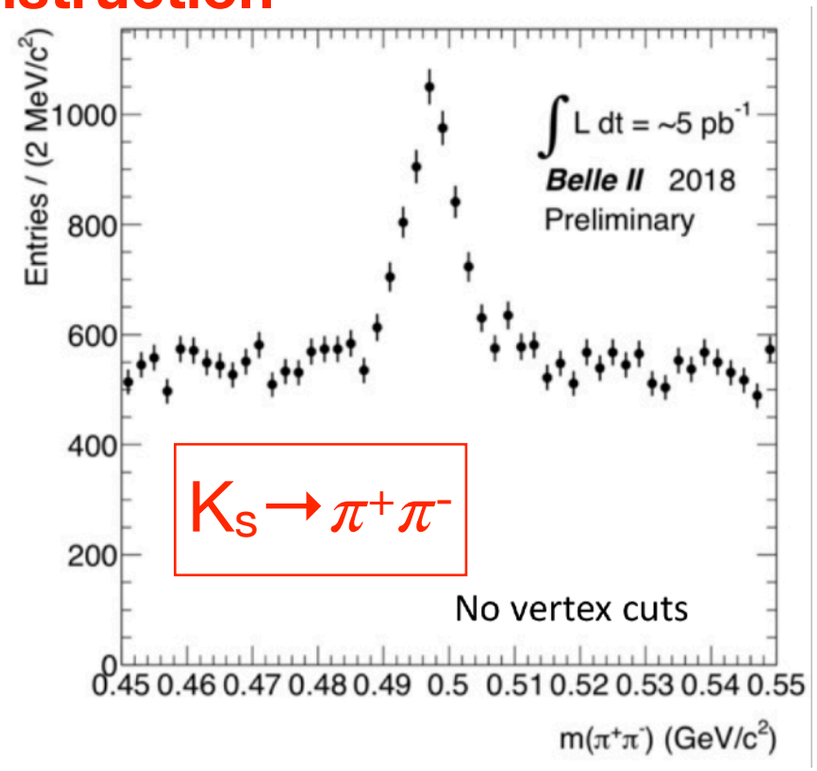
Phase 3 (from March 2019):

- Full Belle II detector. Physics run.

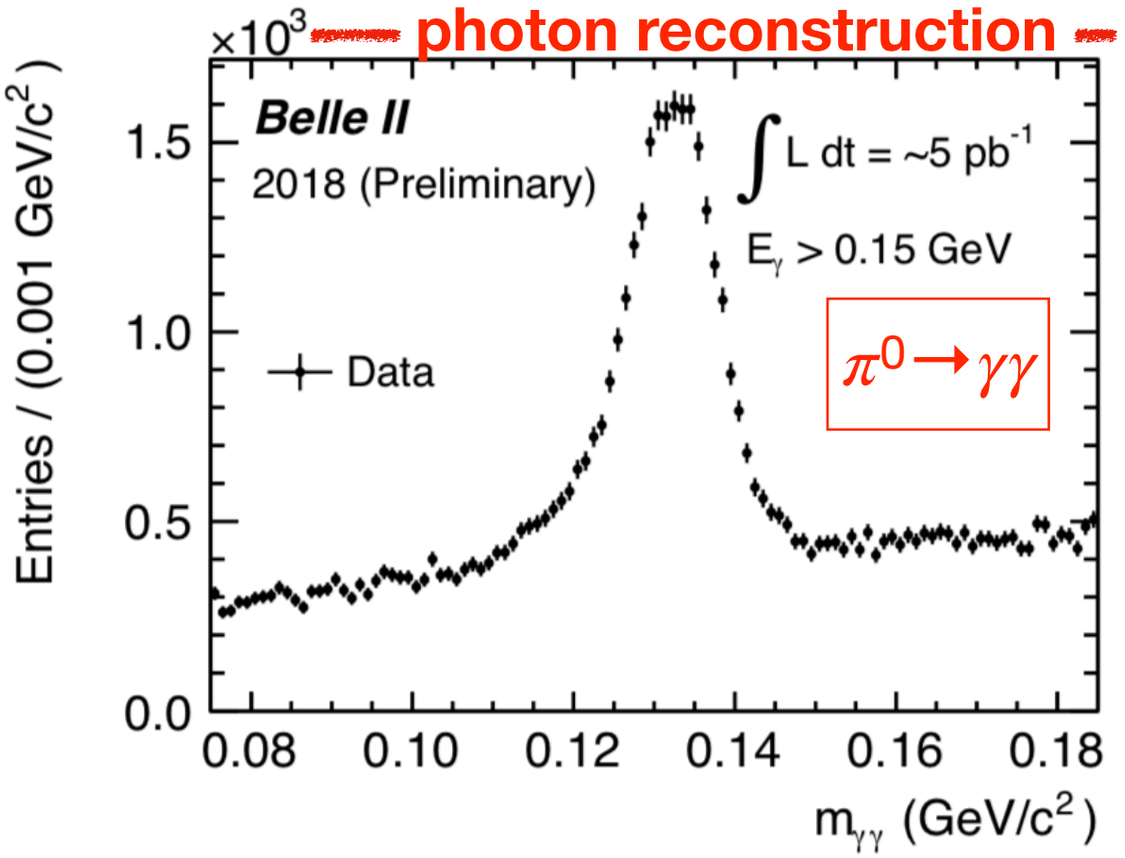
The first Belle II results

charged tracks reconstruction

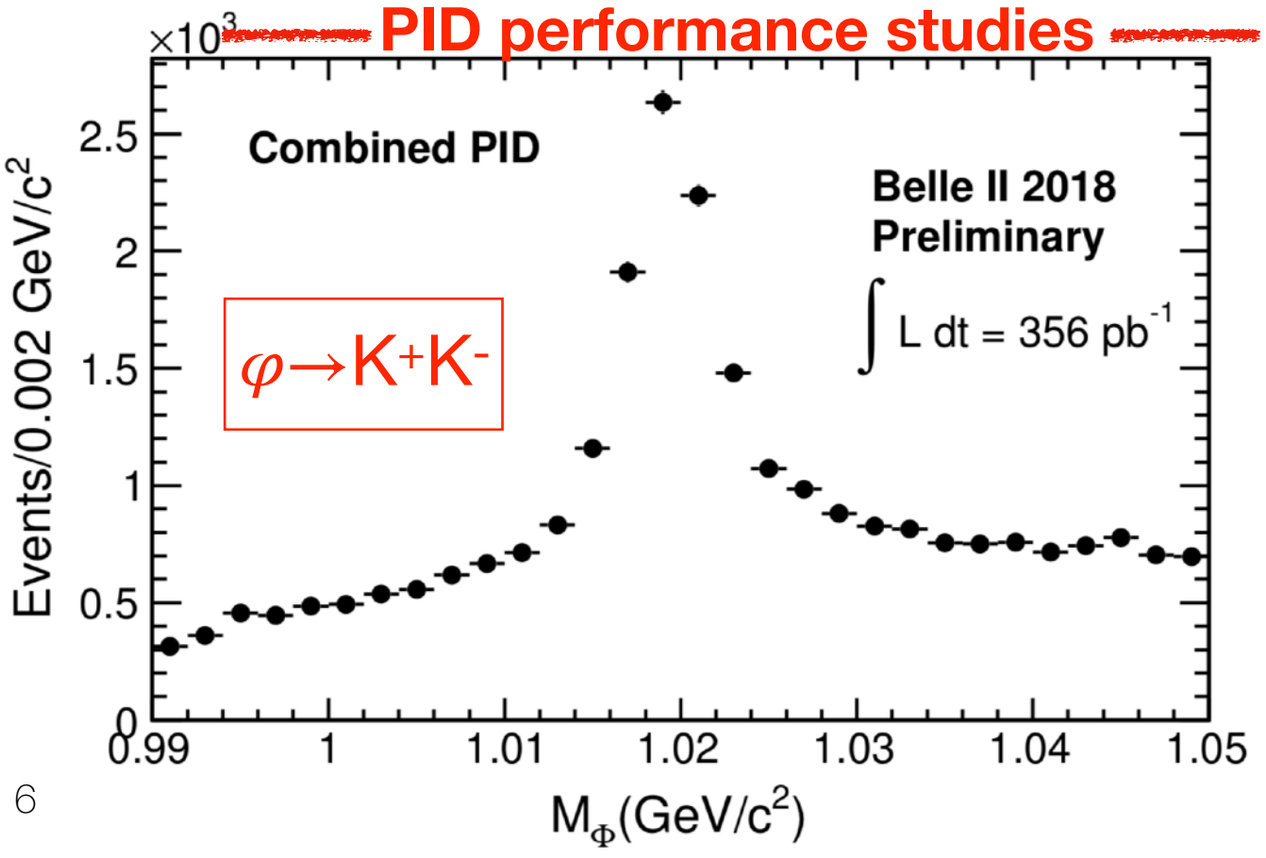




photon reconstruction

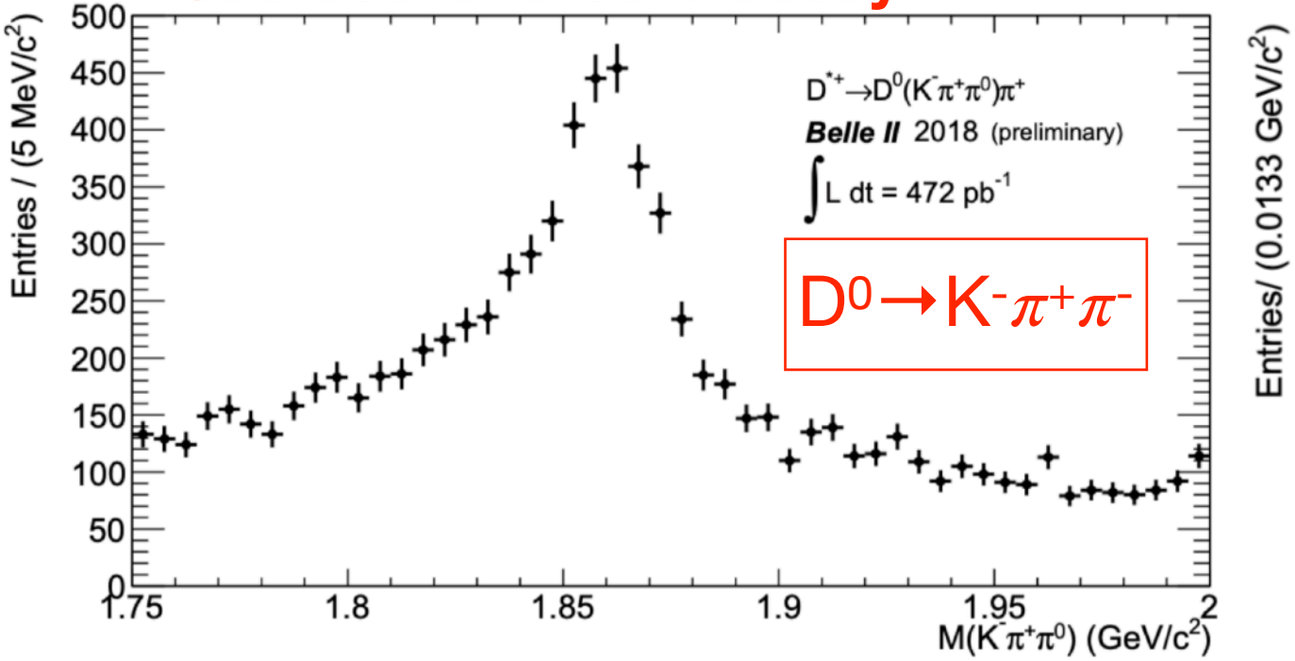


PID performance studies

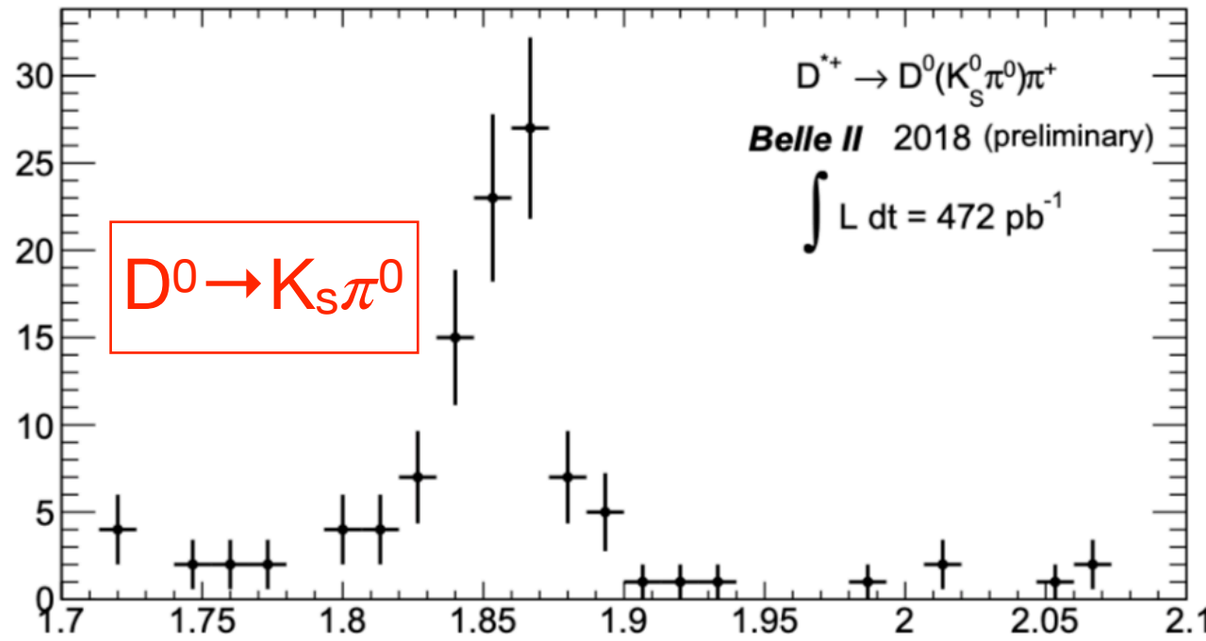


Charm and Beauty rediscovery

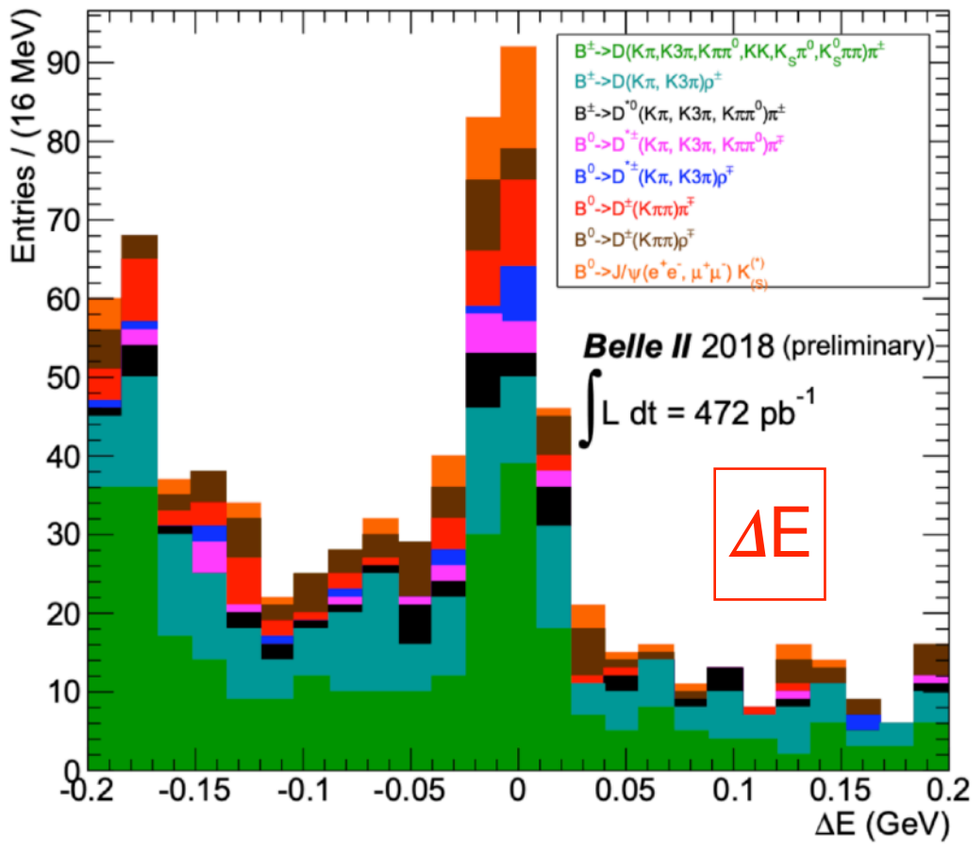
Cabibbo favored D decay

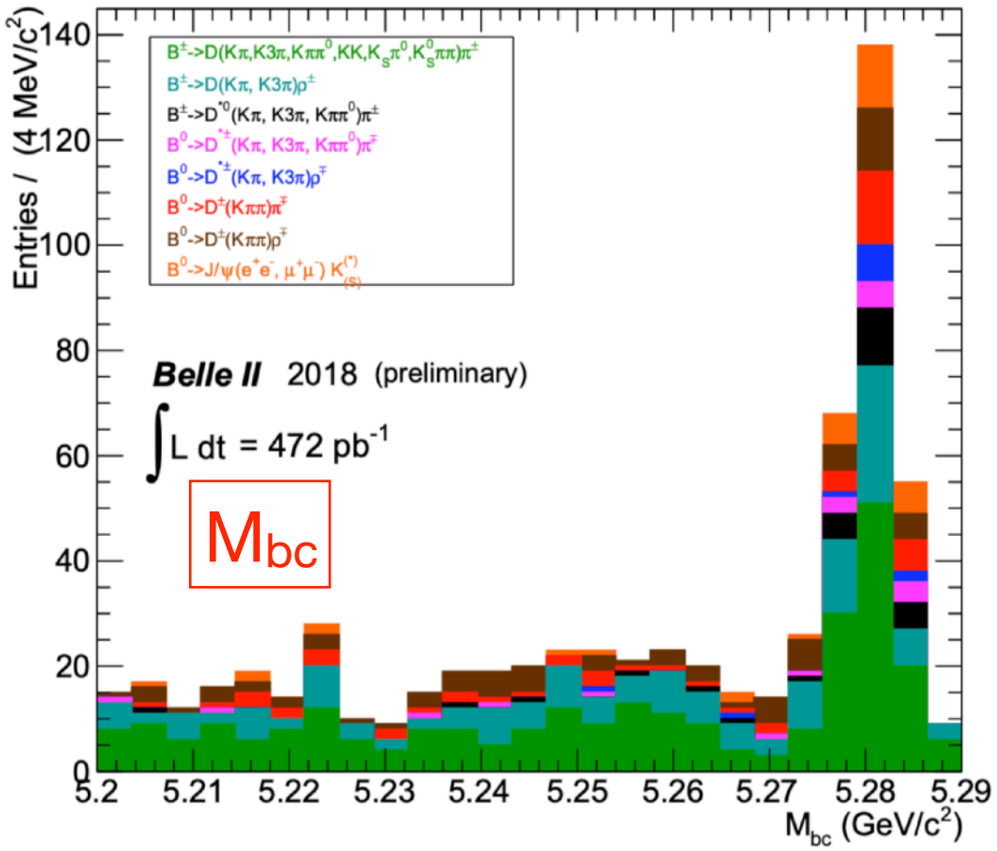


Singly Cabibbo suppressed D decay



Fully reconstructed b→c





CKM UT triangle

Very broad program of research spanning B, charm and τ physics, but also QED/QCD, quarkonium, light new physics direct searches etc.

Dark sector coverd by Torben Ferber

CPV in B decays precision measurement through tree modes, NP search in B-$\bar{B}$ mixing

- CKM sides:

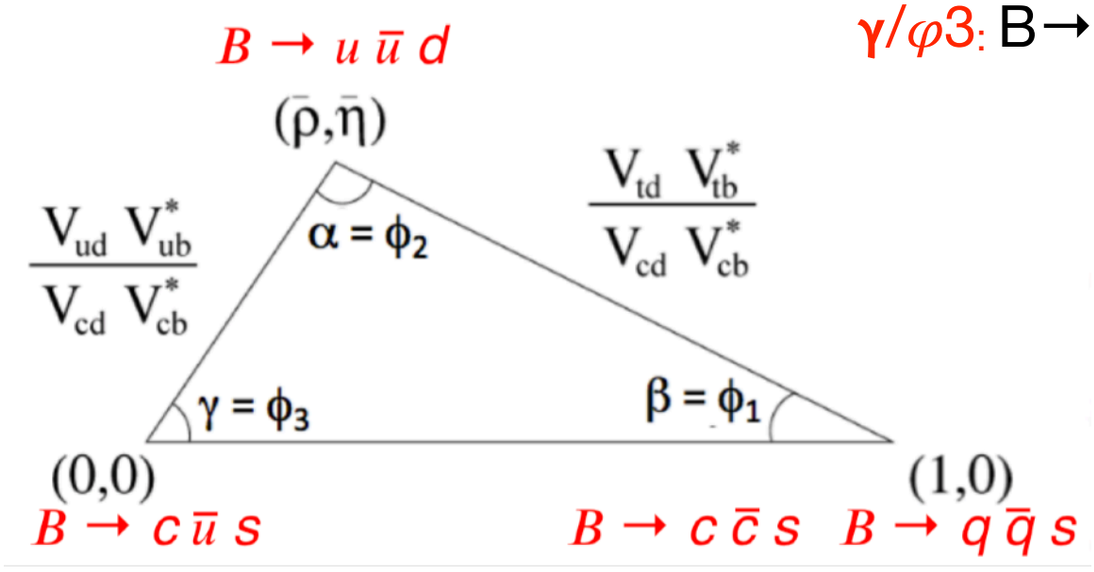
  B → D$^{(*)}$lν, πlν, τν, μν

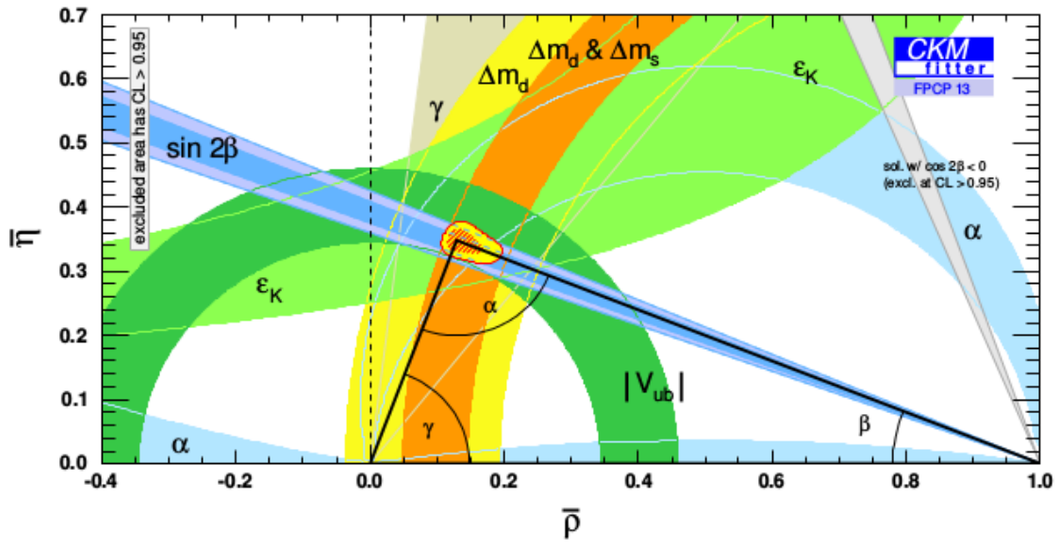
- CKM angles:

  α/φ_2: B→$\pi\pi$, B→$\rho\rho$

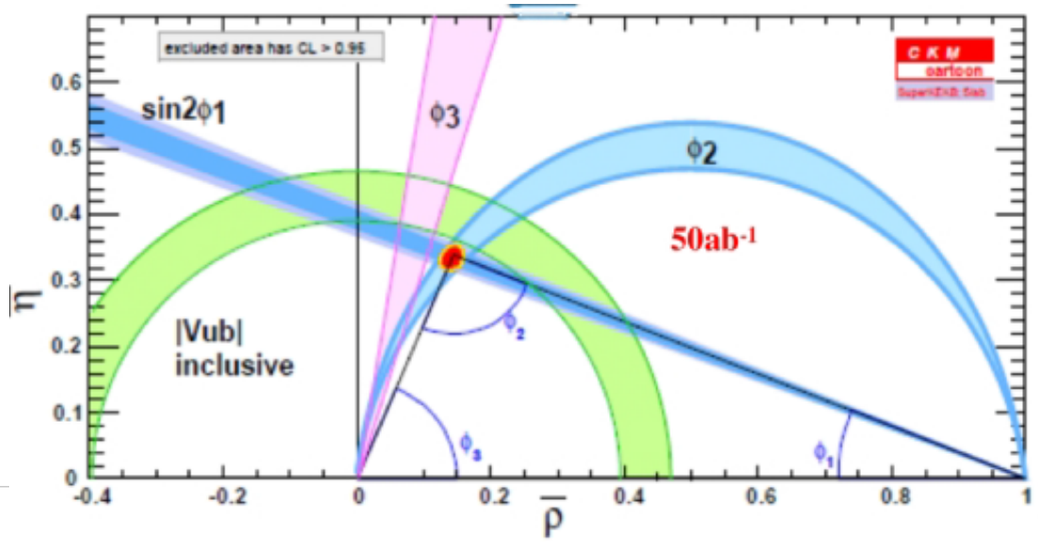
  β/φ_1: B→J/ψ K_s

  γ/φ_3: B→D$^{(*)}$ K$^{(*)}$



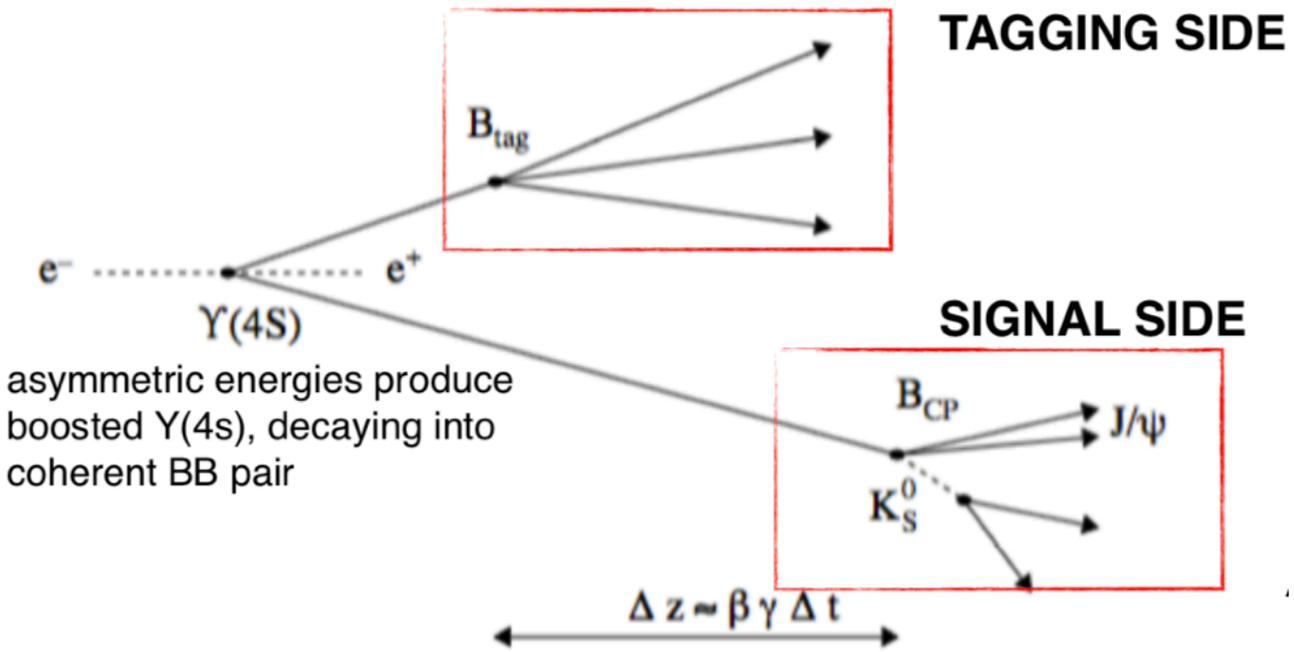


projection @ 50 ab^{-1}



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

Time-dependent CP Violation



Time-dependent rate asymmetry of B meson decays into CP eigenstates

$$a_{f_{CP}}(\Delta t) = \frac{\Gamma[B(\Delta t)] - \Gamma[\bar{B}(\Delta t)]}{\Gamma[B(\Delta t)] + \Gamma[\bar{B}(\Delta t)]} =$$

$$= C\, cos(\Delta M \Delta t) + S\, sin(\Delta M \Delta t)$$

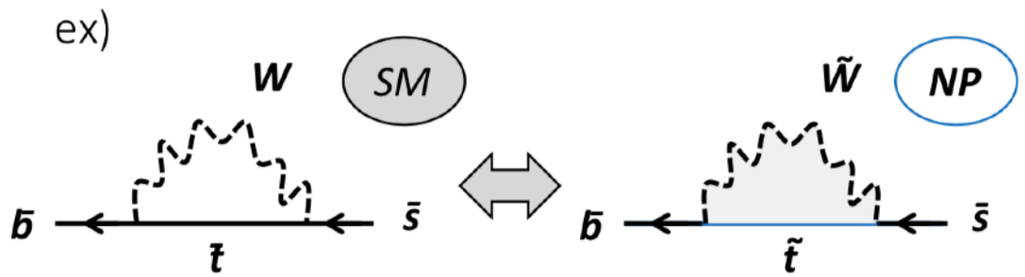
C = direct CPV

S = $\sin(2\phi_i^{eff})$ mixing induced CPV

Searches for deviation from SM predictions.

The C and S are sensitive to NP

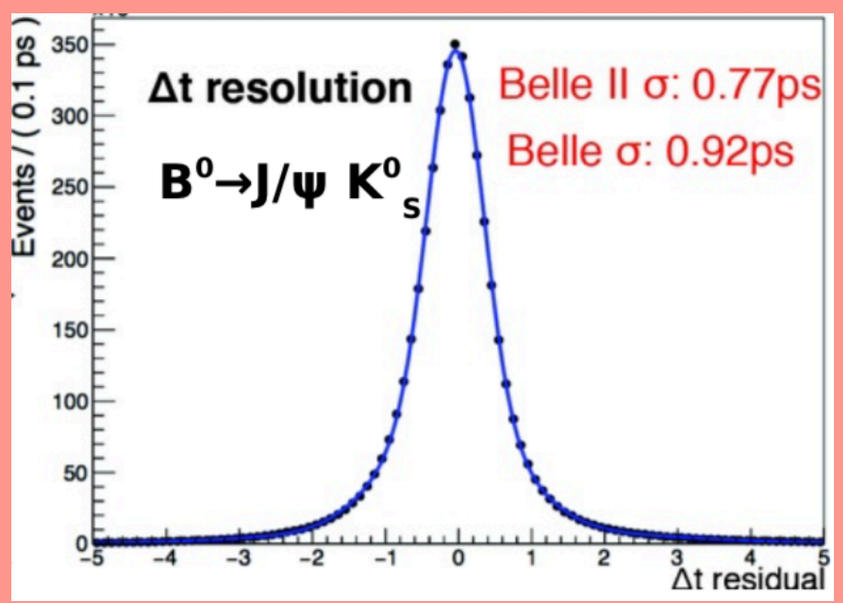
ex)



B→φK_s as an example for b→sq$\bar{q}$

Key aspects:

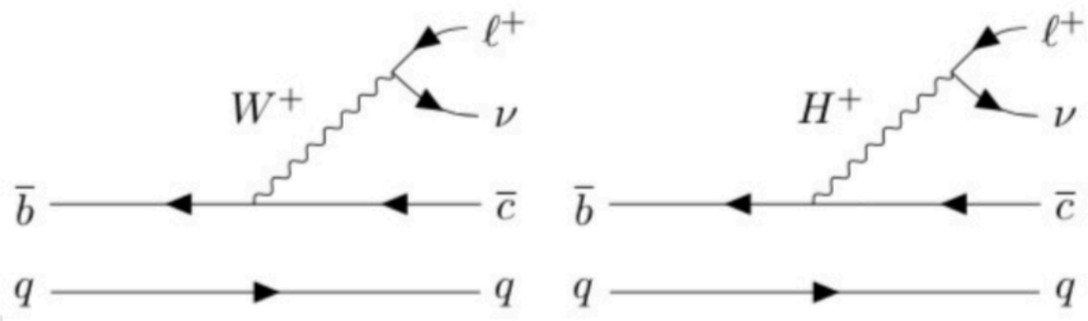
- flavour tagger: ε_{EFF} = 35.84% ($\varepsilon_{EFF}^{BELLE}$ = 30.04%)
- Δt resolution -> vertex fitting



R(D$^{(*)}$) anomaly

lepton universality test

$$R(D^{(*)}) = \frac{Br(B \to D^{(*)} \tau \nu)}{Br(B \to D^{(*)} l \nu)} \qquad l = e, \mu$$



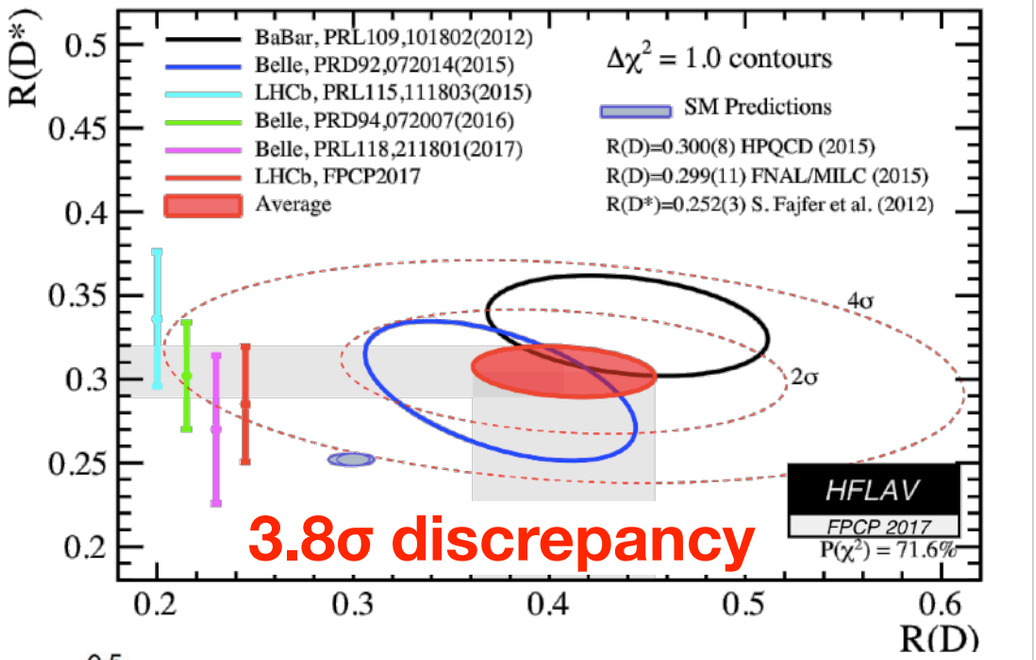
Measurements from BABAR, Belle and LHCb all independently deviate from SM (combined ~3.1σ with the last Belle update)

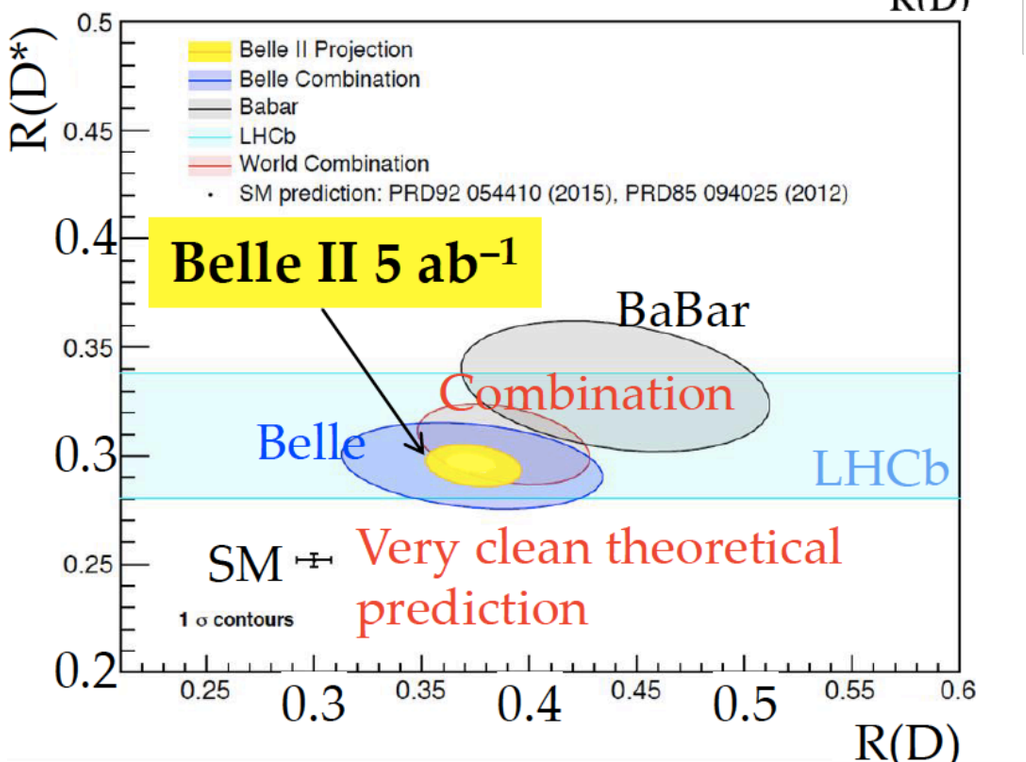
$R_{D(*)}^{SM} = 0.258 \pm 0.005$, $R_D^{SM} = 0.299 \pm 0.003$

	5 ab^{-1}	50 ab^{-1}
R_D	$(\pm 6.0 \pm 3.9)\%$	$(\pm 2.0 \pm 2.5)\%$
R_{D^*}	$(\pm 3.0 \pm 2.5)\%$	$(\pm 1.0 \pm 2.0)\%$

1808.10567

partial cancellation of theoretical uncertainties related to hadronic effects and measurements systematics

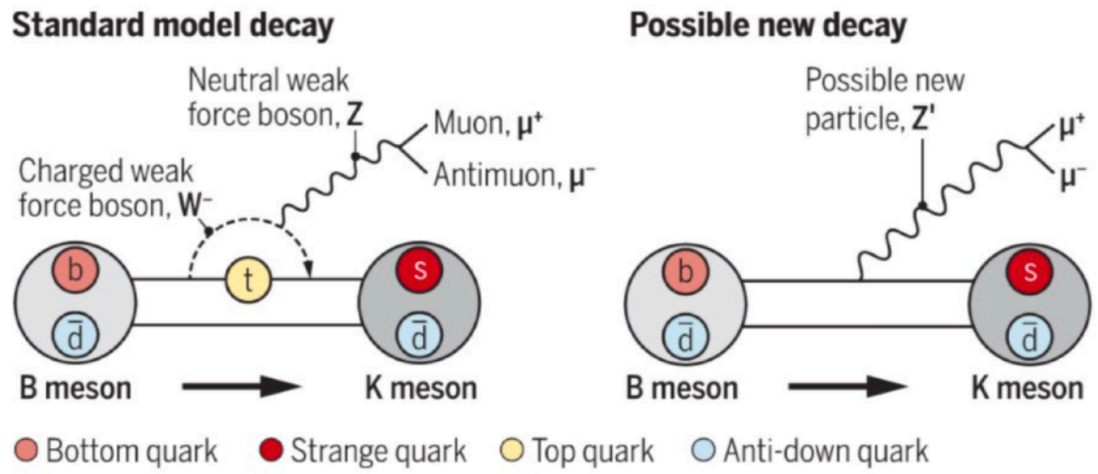


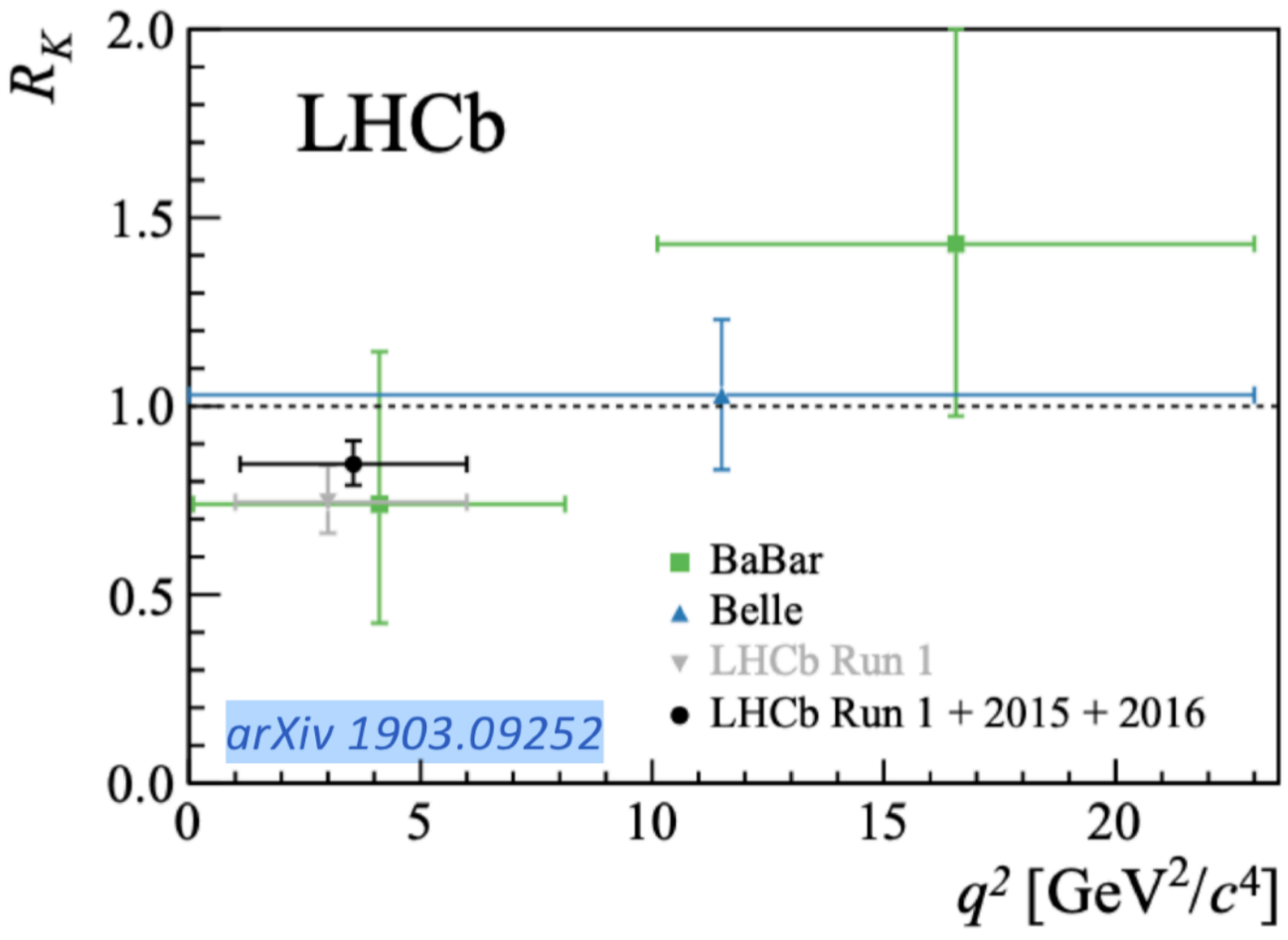


R(K$^{(*)}$) anomaly

$$R(K^{(*)}) = \frac{Br(B \to K^{(*)} \mu^+ \mu^-)}{Br(B \to K^{(*)} e^+ e^-)}$$

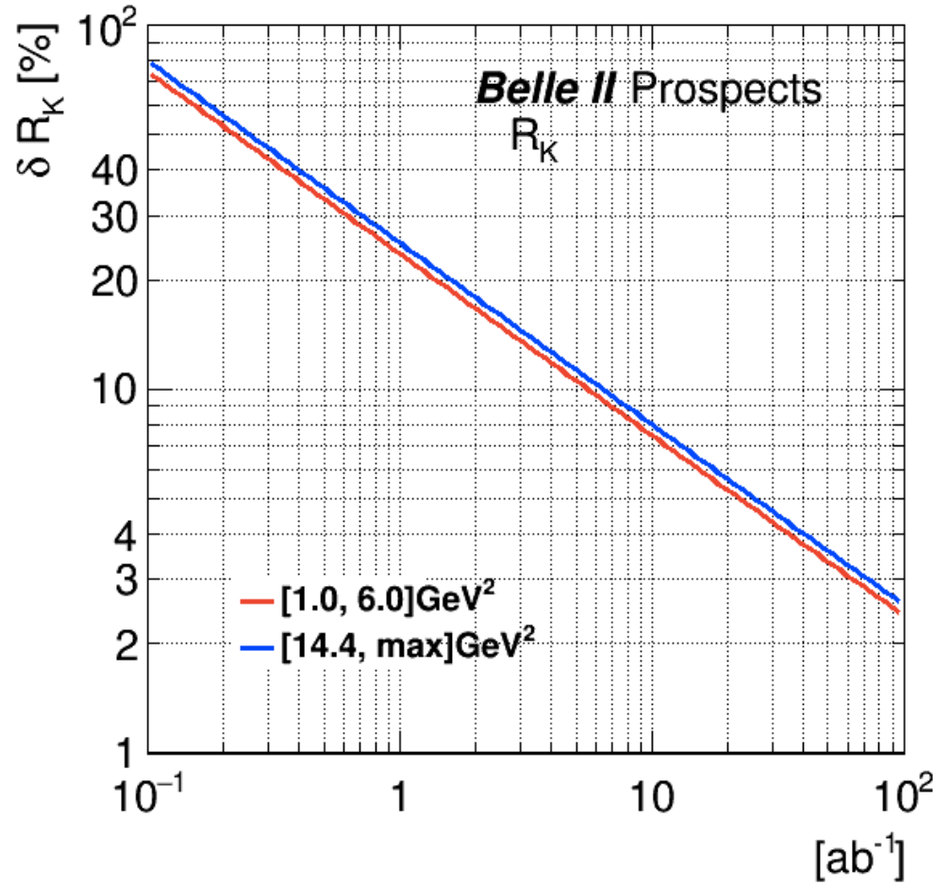
LHCb measurements in tension with SM expectations for ratio of muon and electronic final states





$$R_K = 0.846^{+0.060\ +0.016}_{-0.054\ -0.014}$$

Consistent with SM at 2.52 σ

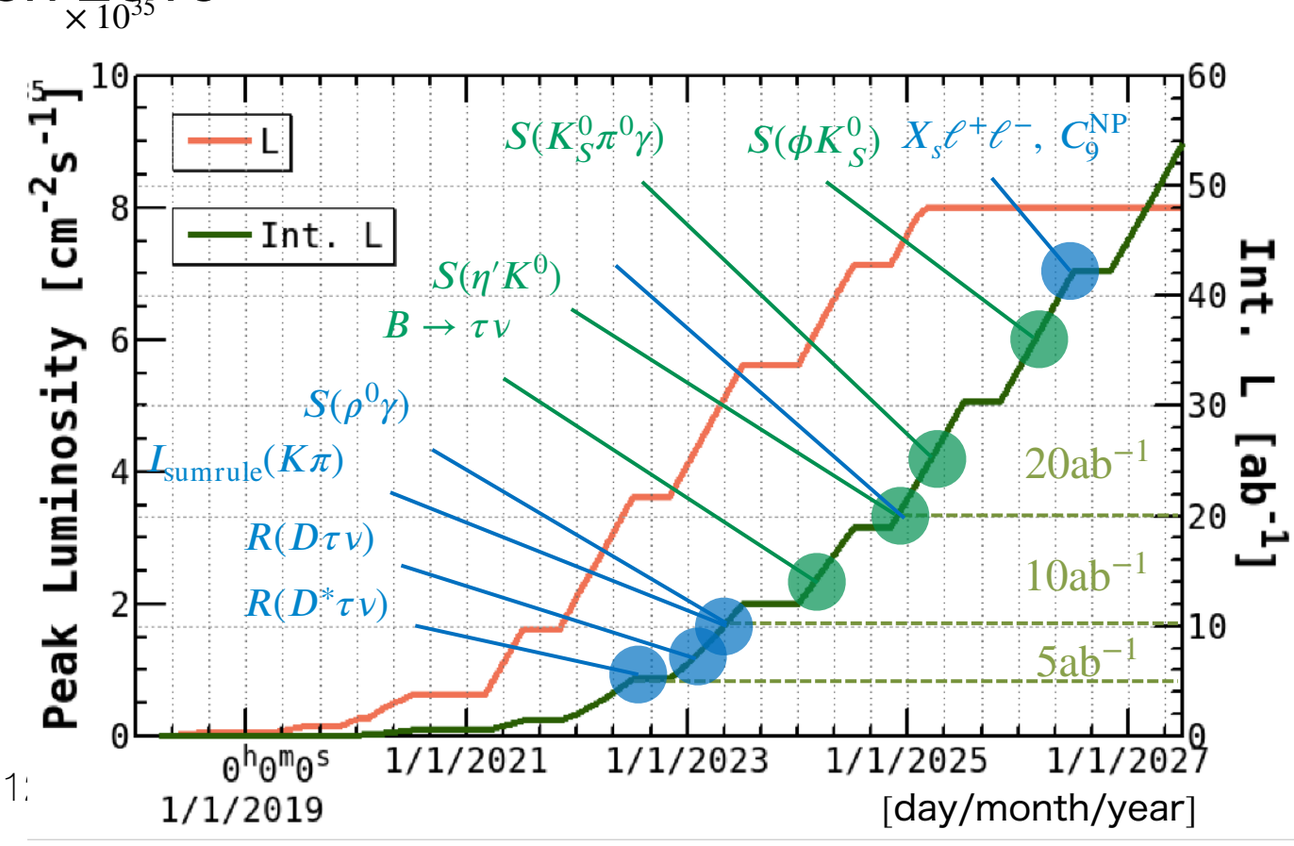


accuracy better than ~10% with 10 ab^{-1} collected by Belle II

Summary

- During Phase 2 accelerator commissioning run (March - July 2018) Belle II collected its first data sample.
- Peak luminosity of 5.5×10^{33} $cm^{-2}s^{-1}$ and ~0.5 fb^{-1} integrated
- Understanding of the machine backgrounds
- Data sample permits validation of detector performance, exercising of physics tools
- ”Rediscovery” heavy flavor: charm and beauty
- Physics run already started in March 2019

Plausible scenario: 10fb^{-1} integrated from March to June 2019. Variations on the integrated luminosity depending on the machine and detector performance.



backup

Early phase 3 program

Plausible scenario: 10fb-1 integrated from March to June 2019. Variations on the integrated luminosity depending from the on machine and detector performance.

Semileptonic

- $B \rightarrow \pi l \nu$ and $\rho l \nu$ untagged (CLEO saw a signal with 2.66 fb^{-1})

Time Dependent CP Violation/Charm

- D lifetimes (2 fb^{-1})
- Doubly Cabibbo suppressed $D^0 \rightarrow K^+ \pi^-$, $D^0 \rightarrow K^+ \pi^- \pi^0$ (10 fb^{-1})
- B lifetimes (2-10 fb^{-1})
- Time dependent B mixing (10 fb^{-1})

Radiative/Electroweak Penguins

- $B \rightarrow K^* \gamma$ ($b \rightarrow s$) (2 fb^{-1}) rediscover penguins
- $B \rightarrow Xs \gamma$ ($b \rightarrow s$) (~10 fb^{-1} depending on off-resonance data taking)

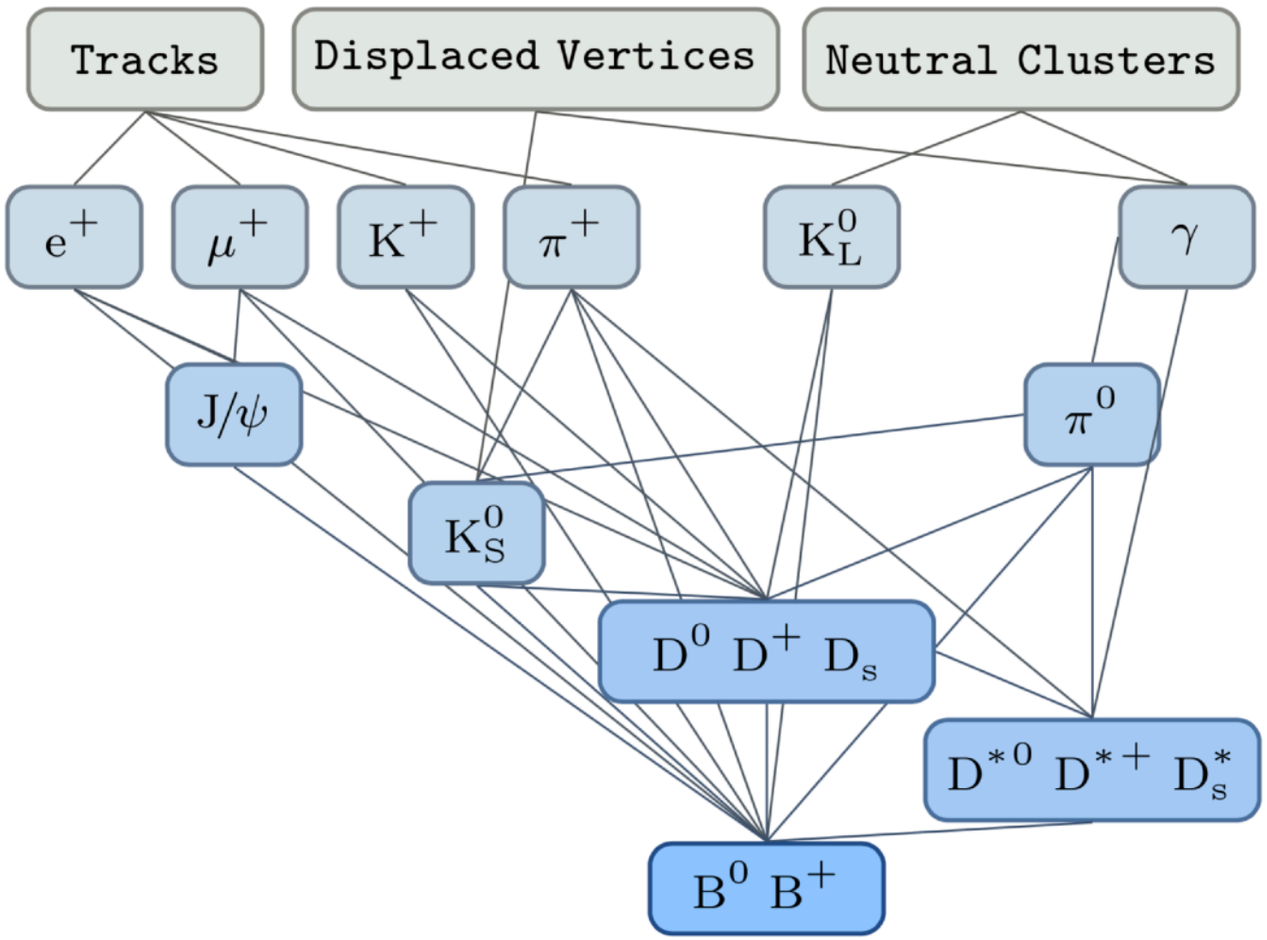
Hadronic B decays (not time dependent)

- $B \rightarrow K \pi$ ($b \rightarrow u$) (10 fb^{-1})
- $B \rightarrow \Phi K$ ($b \rightarrow s$) (10 fb^{-1})
- $B \rightarrow J/\psi K$ (with more significance 2-10 fb^{-1})

++ Dark Sector Physics

Publications

Full event reconstruction



First studies of performance the hadronic tagging in Belle II data

- FEI (Full event interpretation) technique based on boosted decisions trees
- It allows the reconstruction of exclusive B-tag mesons candidates from over than 100 decay channels
- Essential analysis technique to study final states with single or multiple neutrinos. It recovers missing kinematic information