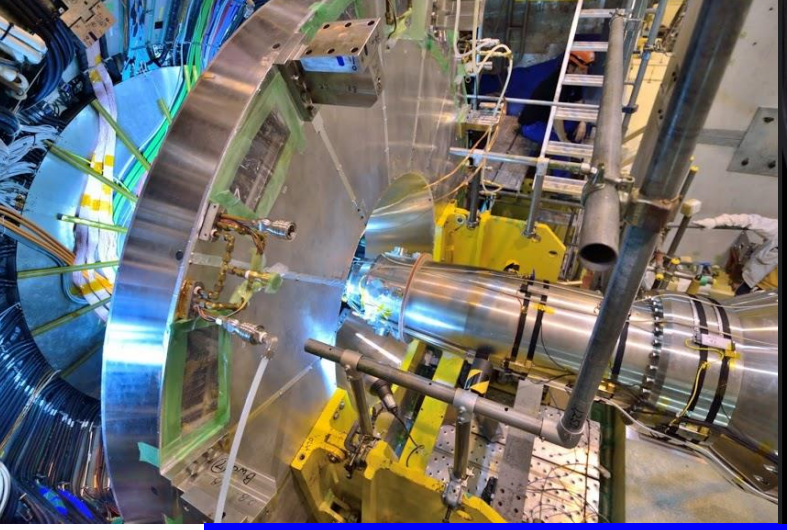
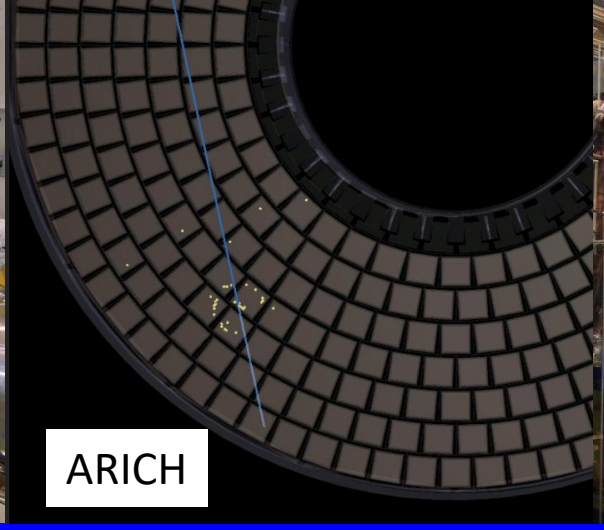
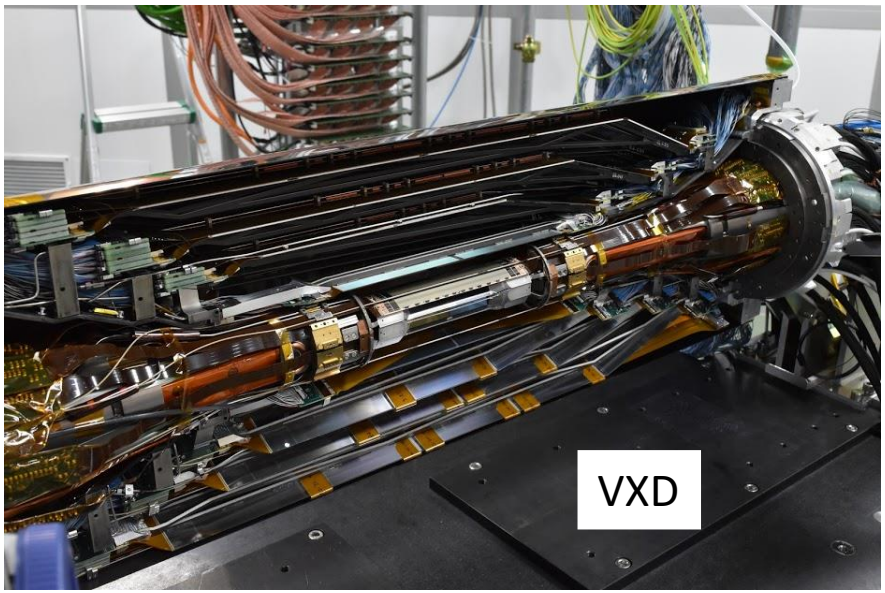


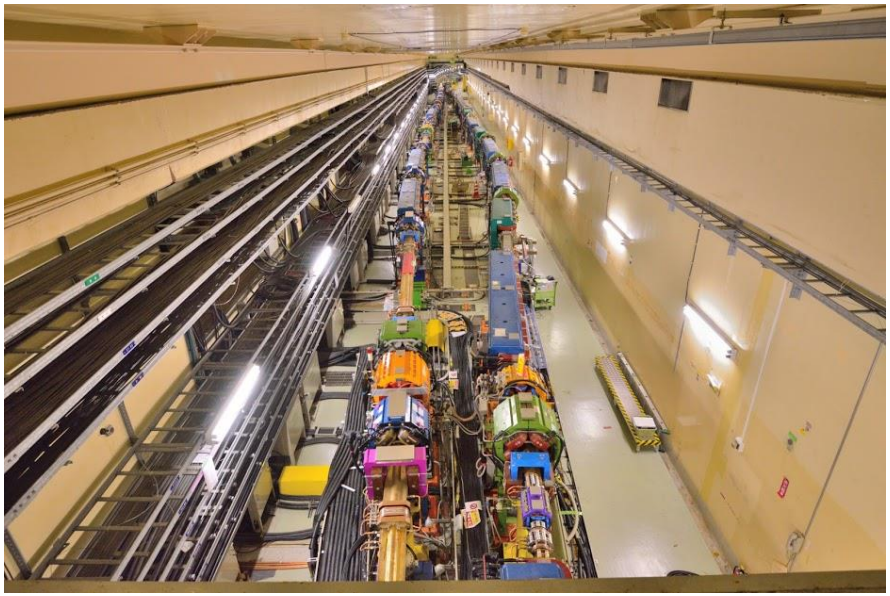


The Status and First Results from Belle II

Shuji Tanaka on behalf of the Belle II collaboration
High Energy Accelerator Research Organization (KEK)

the XXXIX International Symposium on Physics in Collisions (PIC2019)



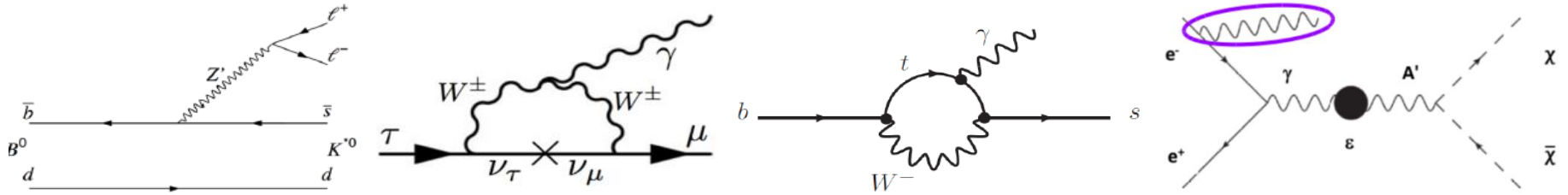


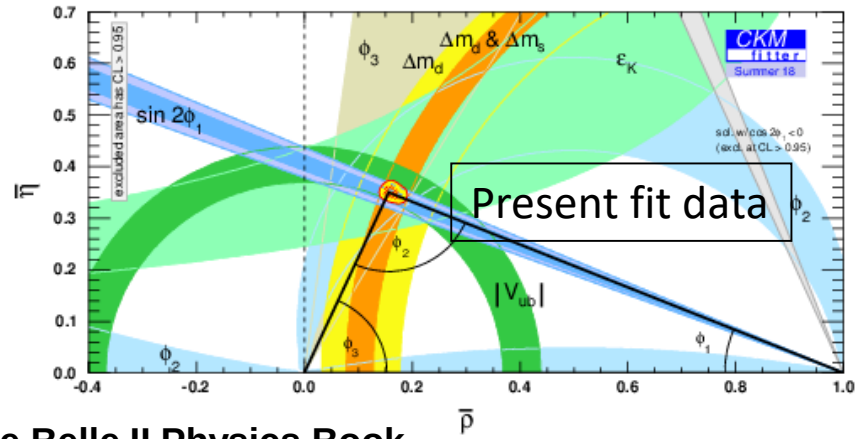
Experimental targets on Belle II

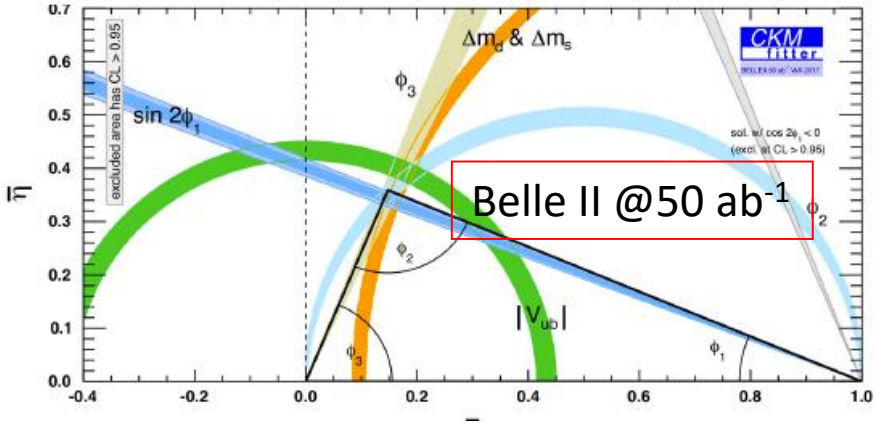
By analyzing huge statistics (x 50 than Belle) of B/ D mesons and τ leptons

1. Measuring CP violation with B meson
2. Fine verification of CKM mechanism which causes CP violation
3. Exploring new physics by large statistics data
   - ★ FCNC (Rare processes),
   - ★ Testing of Lepton number/flavor violation (SM-forbidden processes),
   - ★ Direct searches for new states; Dark sector.

Unsolved puzzles summarized by P. LEWIS (talk on 17th)

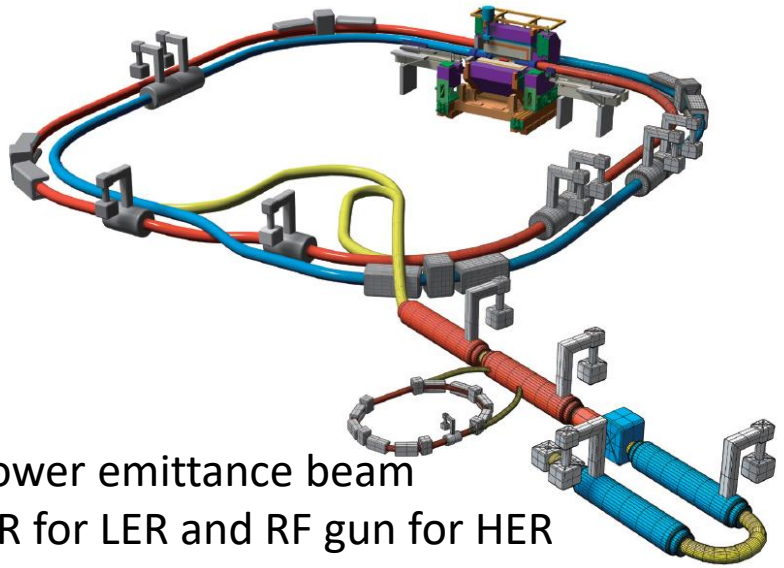






The Belle II Physics Book
Outcome of the B2TIP (Belle II Theory Interface) Workshops
(https://arxiv.org/abs/1808.10567)

SuperKEKB (nano-beam scheme)



Lower emittance beam
DR for LER and RF gun for HER

Beam current

Beam-beam parameter

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

σ: beam size

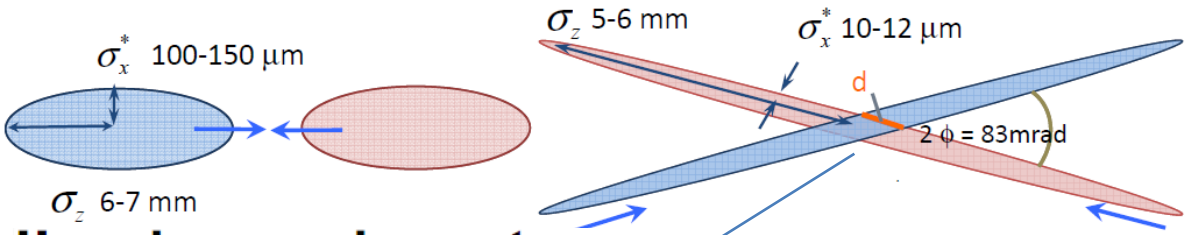
β function

		KEKB		SuperKEKB		units	
		LER	HER	LER	HER		
Beam energy	E_b	3.5	8	4	7.007	GeV	
Beam crossing angle	φ	22		83		mrad	
β function @ IP	β_x^*/β_y	1200/5.9		32/0.27	25/0.30	mm	X 20
Beam current	I_b	1.64	1.19	3.6	2.6	A	X 2
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$	X 40

New Constraints by the nano-beam scheme

KEKB head-on (crab crossing)

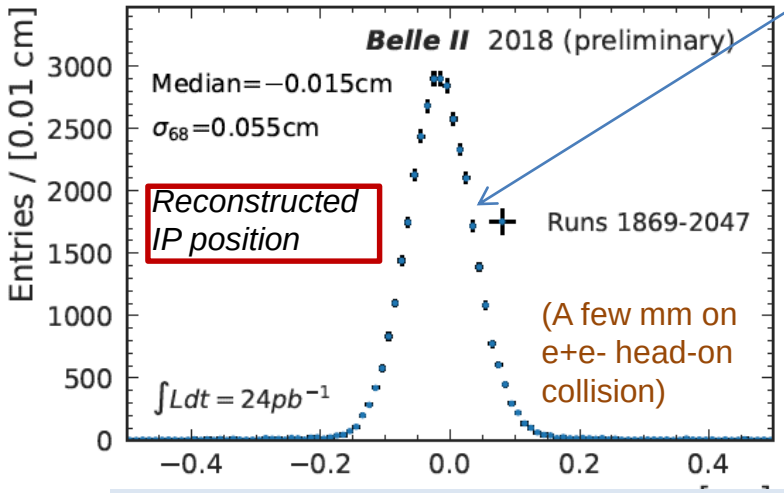
Nano-Beam SuperKEKB



Hourglass requirement

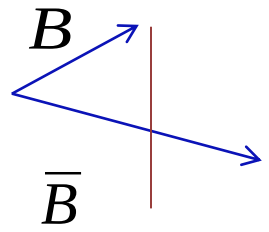
$\beta_y^* \geq \sigma_z$ ~ 6 mm

$\beta_y^* \geq \frac{\sigma_x^*}{\phi}$ ~ 300 μm



e- (7 GeV) e+ (4 GeV)

Y(4S)



Length~cβγt_B

~200μm (Belle)

~130μm (Belle II)

SuperKEKB βγ=0.28 : e^-(7GeV), e+ (4GeV)

KEKB βγ=0.42: e^-(8GeV), e+ (3.5GeV)

LER (3.5 GeV -> 4GeV):
- for longer Touschek lifetime ∝ E^3

HER (8 GeV -> 7GeV):
- Lower emittance beam ∝ $1/E^2$
- Lower Synchrotron radiation loss

●To realize nano-beam, Lorentz boost factor is decreased down to 2/3.

○Thanks to Nano-beam scheme: diameter of IP beam pipe is reduced from 3cm to 2cm

Detector layout (Belle -> Belle II)

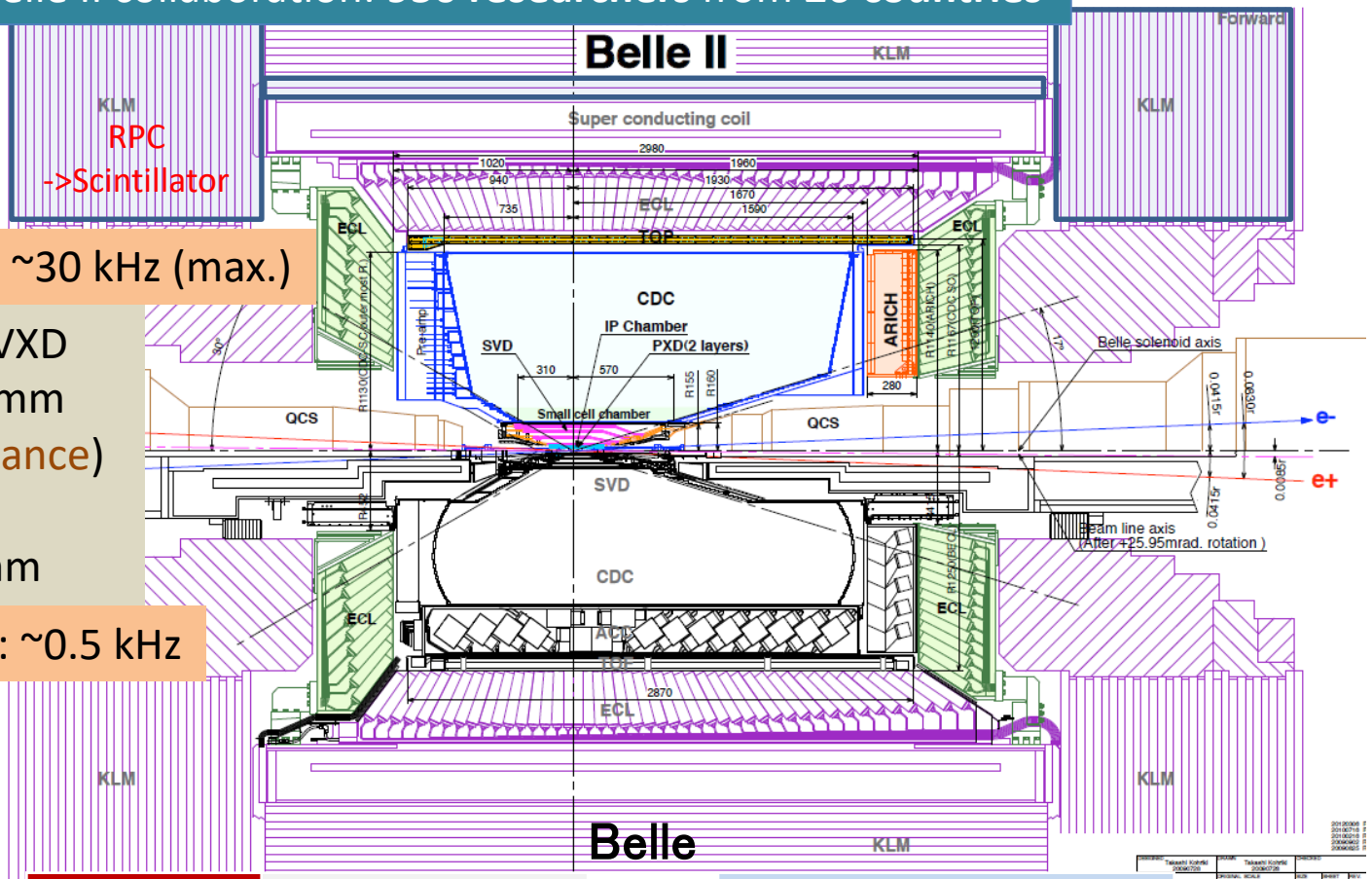
Belle II collaboration: **950 researchers** from **26 countries**

KLM
RPC
->Scintillator

Trigger rate: ~30 kHz (max.)

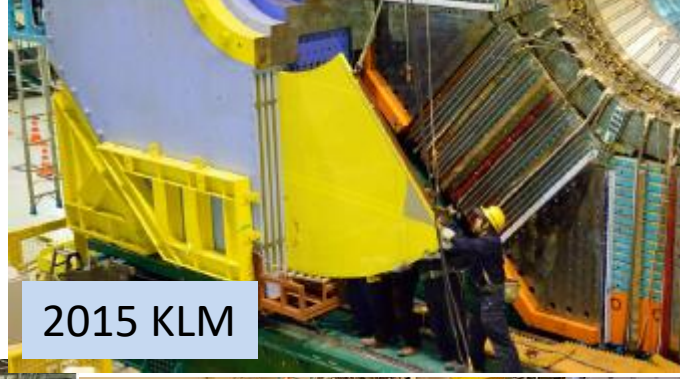
Belle II VXD
R=14-140mm
(Ks acceptance)
Belle SVD
R=20-88mm

Trigger rate: ~0.5 kHz



VXD	SVD (4layers DSSD)	2 DEPFET(PXD) + 4 DSSD(SVD)
Particle ID	ACC + TOF	TOP + ARICH
Muon + K_L	RPC	RPC + Scintillator
CDC, ECL		Faster FE

Sub-detector installation



Belle II /superKEKB commissioning

Phase 1 (2016):

- Beam operation without final focus magnets and Belle II
- Commissioning of beam transportation and vacuum scrubbing

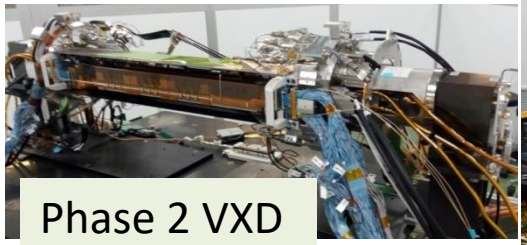
Phase 2 (2018): Start data taking with Beam collision

- Target Luminosity ~10^{34} $cm^{-2}s^{-1}$ which is comparable with KEKB
- No final VXD but one ladder/layer with background sensors
  - L(peak) = 5.5 x 10^{33} $cm^{-1}s^{-1}$ (0.5 fb^{-1} data has collected)

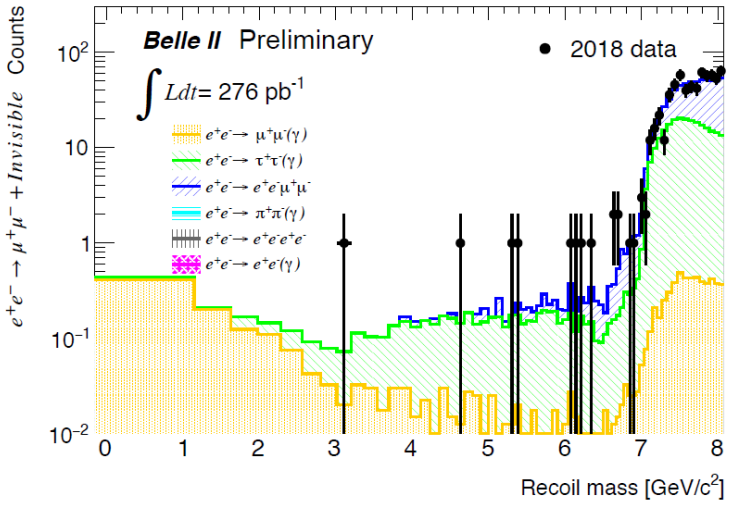
Phase 3 (2019-): Final detector configuration

- SVD; 4 layers
- PXD : 2 layers
- (2 ladders (out of 12) in second layer)

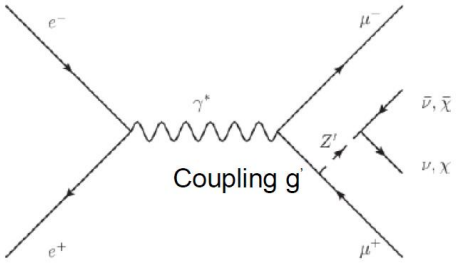

IP setup in phase 1

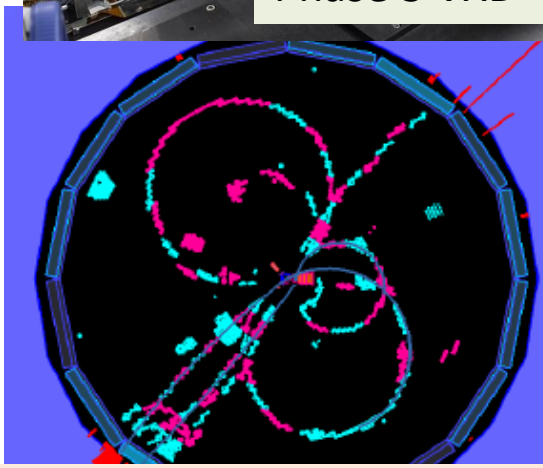

Phase 2 VXD


Phase 3 VXD

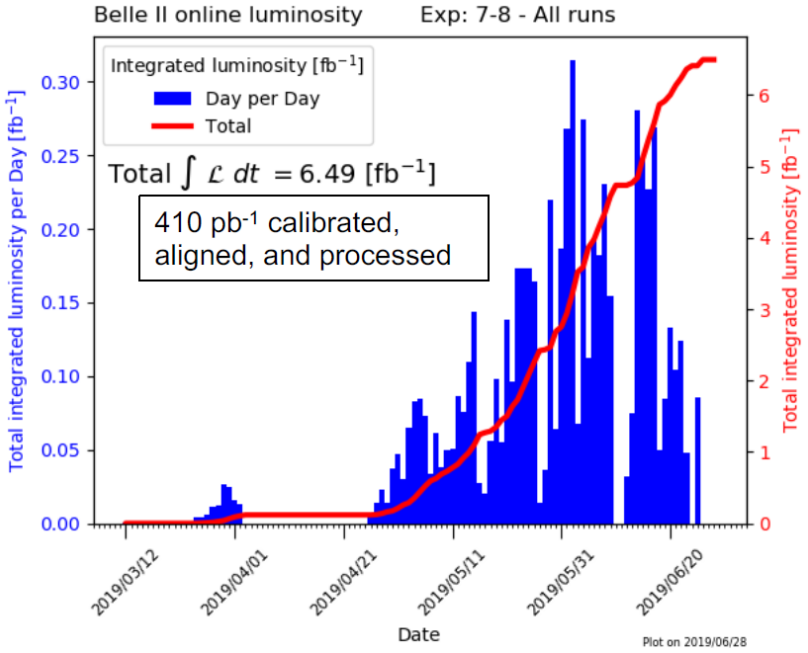


$e^+ e^- \to \mu^+ \mu^- Z'$ (invisible)
with phase 2 data
(No significant excess)




First hadronic event (26th Apr. 2018)

Phase 3 run



Phase 3 run started from 2019 March.
(Full Belle II detector)

L(peak) = 6.1 x 10^{33} cm $^{-1}$s^{-1} (physics run)

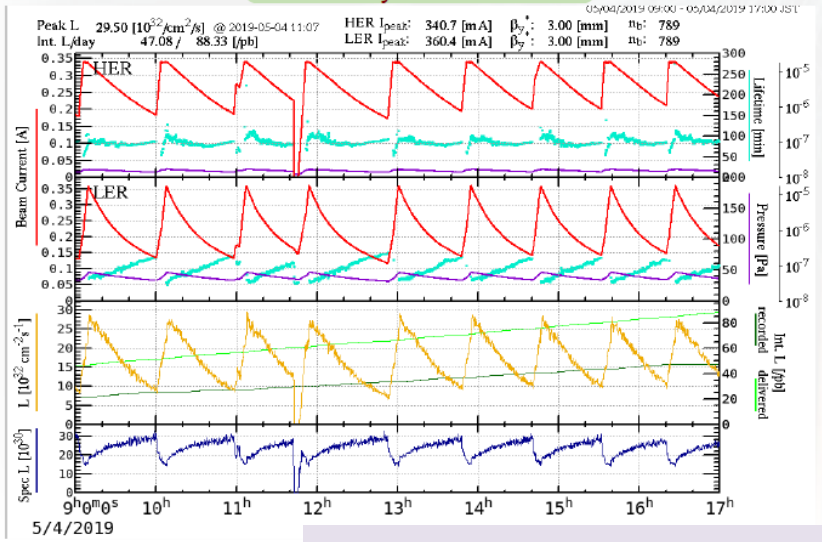
(Final Target: 8 x 10^{35} cm $^{-1}$s^{-1})

L(peak) = 12 x 10^{33} cm $^{-1}$s^{-1}

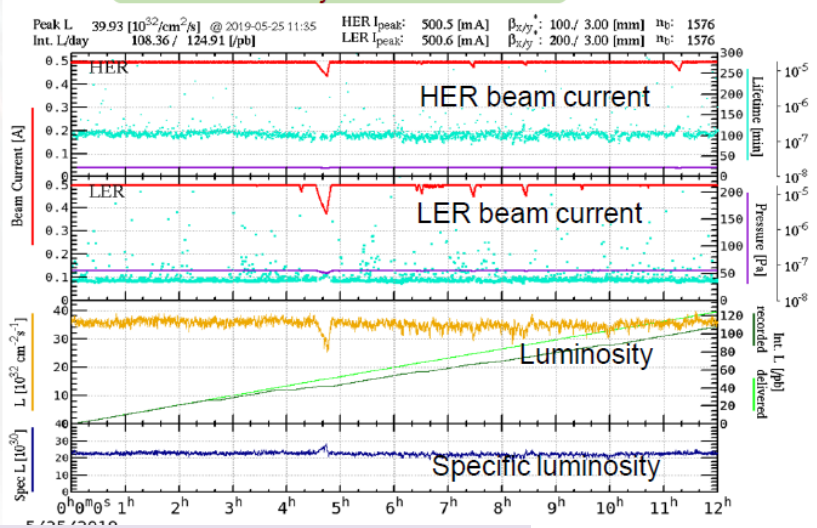
(Belle II off, high current challenge study)

Total integrated L: ~6.5 fb^{-1}

Decay mode run



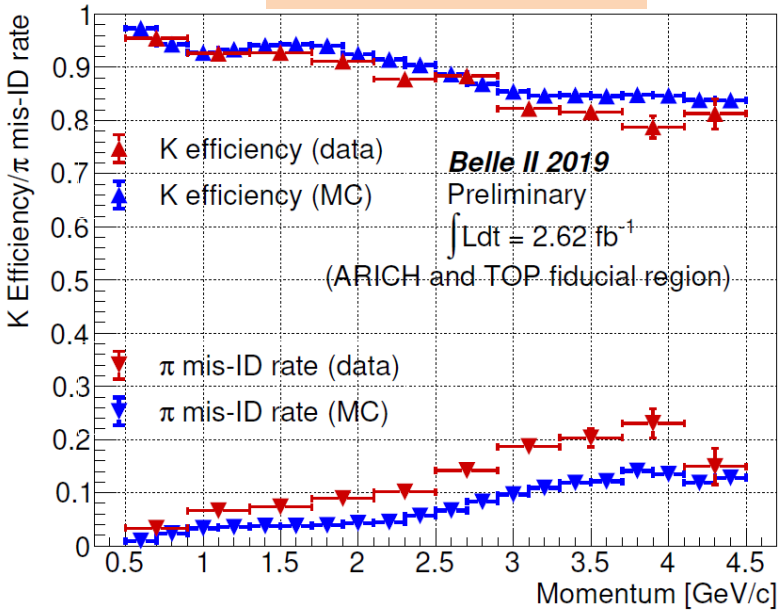
Continuous injection mode run



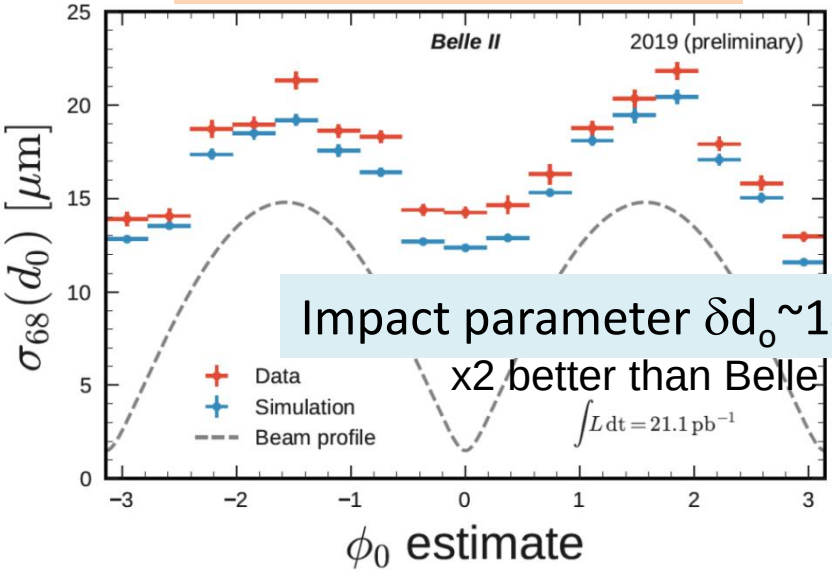
Continuous beam injection started from 14th, May.

Performance check

K/π identification



Vertex resolution with VXD



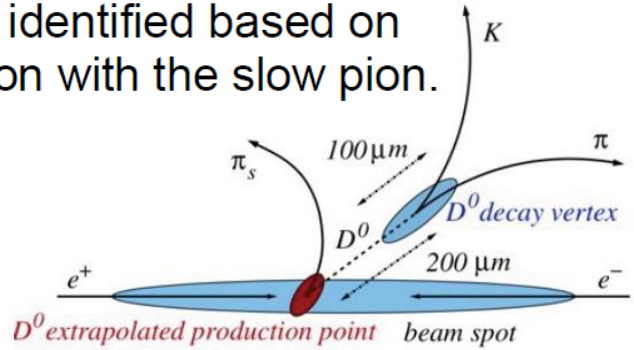
Impact parameter δd_0~14 μm

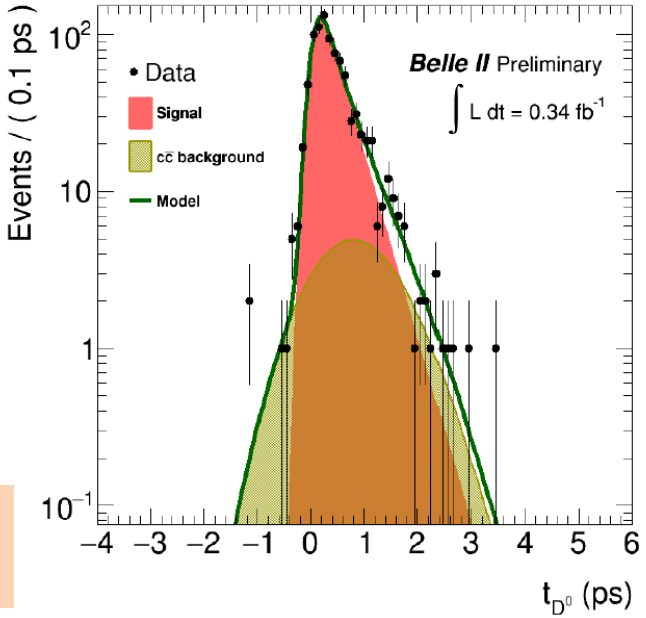
x2 better than Belle

Measured on a control sample:

$$D^{*+} \to D^0 \pi_s^+ ; D^0 \to K^- \pi^+$$

Kaon (pion) track is identified based on the charge correlation with the slow pion.





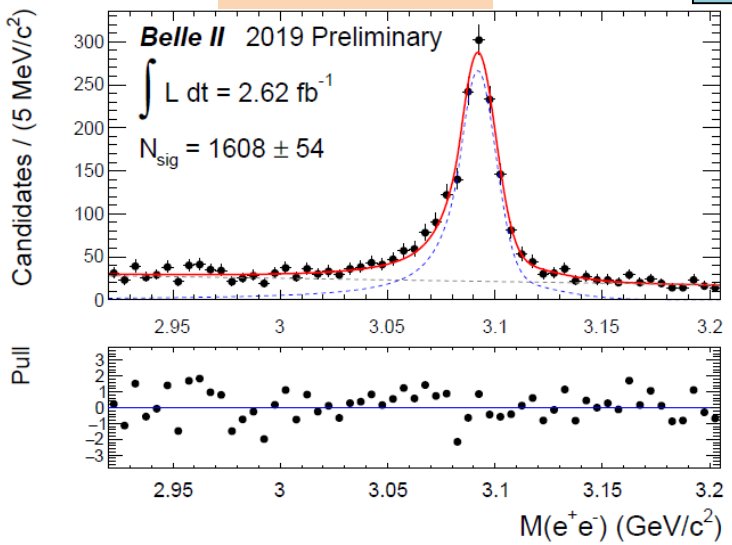
D^0 lifetime with a small data set

τ_{D0} = (370 ± 40) fs

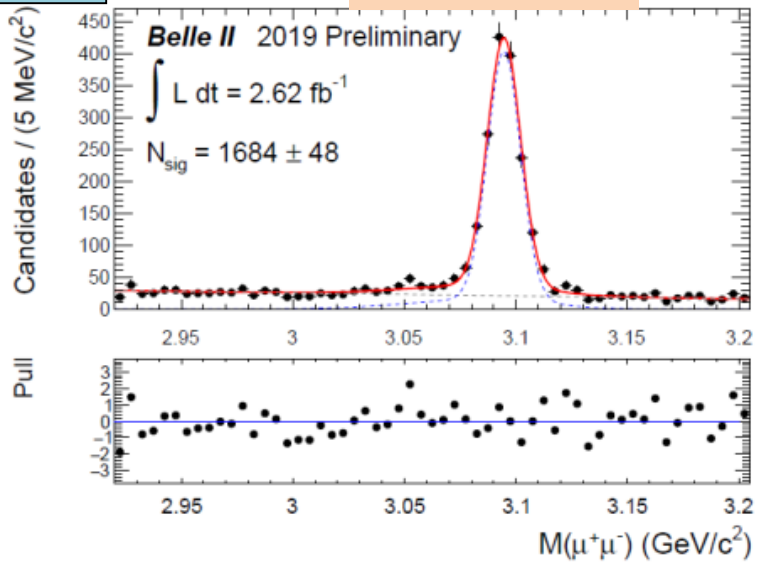
Particle reconstruction

B-> J/ψ X

J/ψ -> e^+e^-

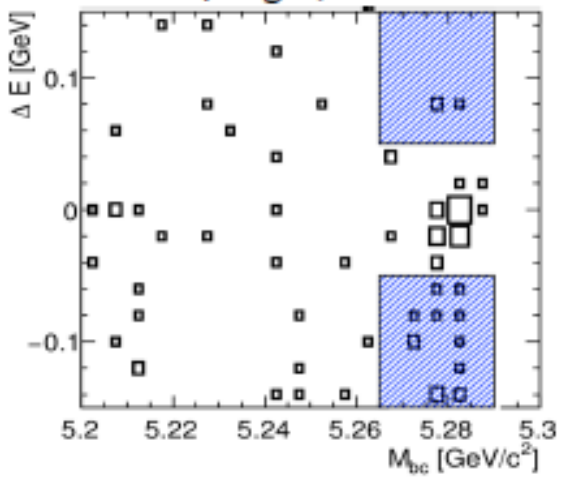


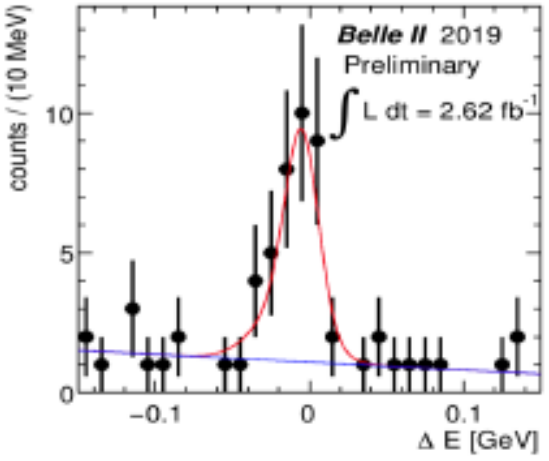
J/ψ -> $\mu^+\mu^-$

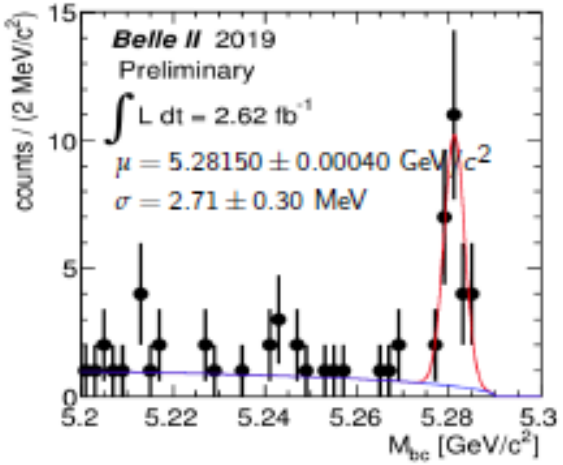


- $B^0 \to J/\psi K^0_S$ (CP eigenstate) with $J/\psi \to \ell^+\ell^-$ (ℓ=e, μ)

Signal yield:
$N(B^0 \to J/\psi K_S) = 26.9 \pm 5.2$

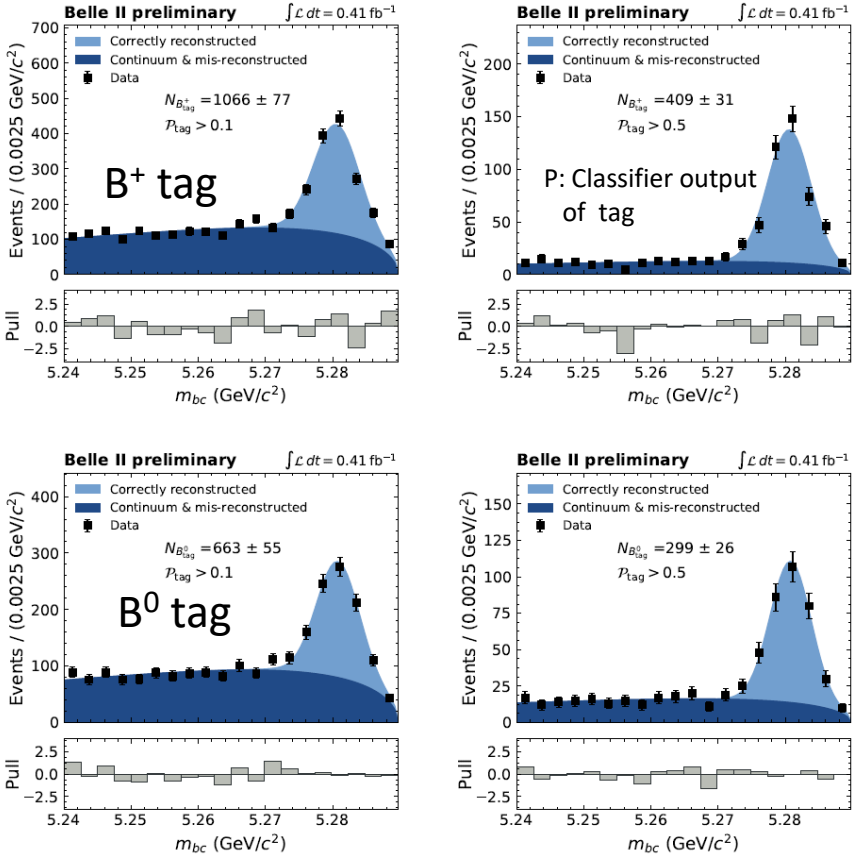


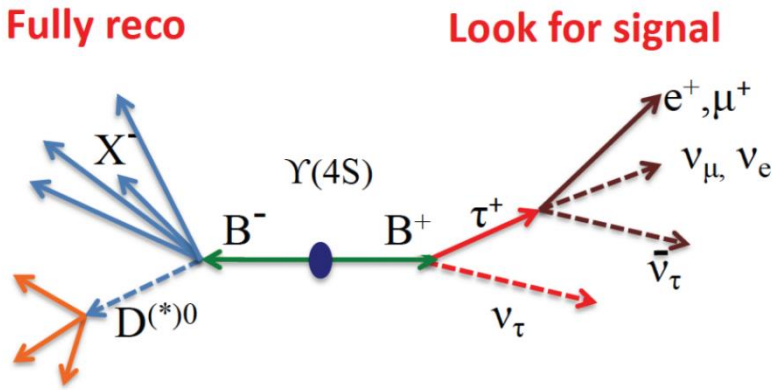


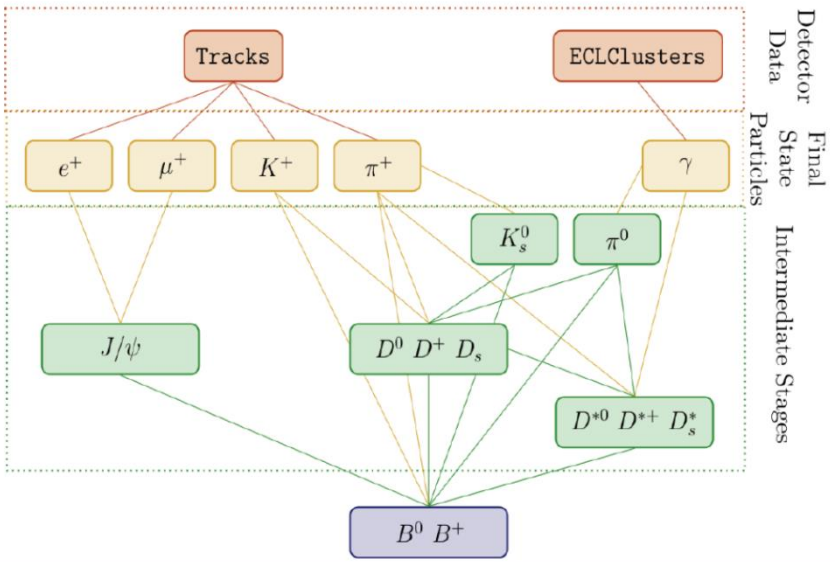


Full Event Interpretation Reconstruction

For signal with weak signature
(missing momentum in final state)
Tag with semileptonic decays
(Higher efficiency)
Tag with hadronic decays:
(cleaner events with better momentum information)







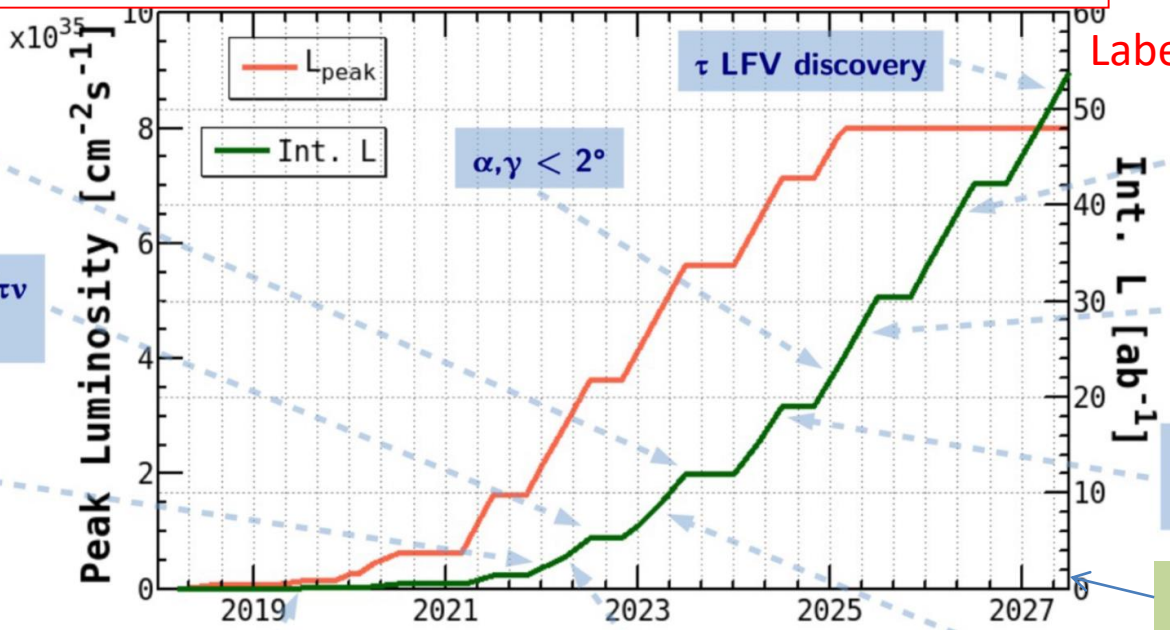
$$M_{bc} = \sqrt{(E_{cm}/2)^2 - p^2_{recon}}$$

Summary

- The Belle II experiment at SuperKEKB is a powerful tool to find a sign of new physics beyond the SM by precision measurement of huge statistics of heavy flavor decays.
- From last year, Belle II physics run has started
  - First physics results: re-discovery of B meson, Z' , B mixing,
  - Full event interpretation.
  - From this Oct., Autumn beam operation will start

β^*_y squeezing: 1.5mm -> 1.2mm -> 1.0mm -> 860μm -> 740μm -> 635μm -> 550μm-> 470μm -> 405μm -> 350μm -> 300μm

(current value: 2mm)



Labels (incl. some dreams)

- $B\to\eta' K_S$ new CP
- Confirm $B\to D^*\tau\nu$ new physics
- Resolve $|V_{ub}|$ puzzle
- τ LFV discovery
- $\alpha,\gamma < 2°$
- W_R in $B\to\rho\gamma$
- $B\to K\nu\nu$ SM discovery
- $B\to Kee$ LFUV new physics
- Belle+Babar : 1.6 ab^{-1}
- $ee\to A'(\chi\chi)\gamma$
- $ee\to\pi\pi(\gamma)$ precision for $(g-2)_\mu$
- $B\to\mu\nu$ discovery

All the details are in "The Belle II Physics Book" E. Kou, P. Urquijo et al.,

https://arxiv.org/abs/1808.10567
https://inspirehep.net/record/1692393/

Bkup

B factory experiment

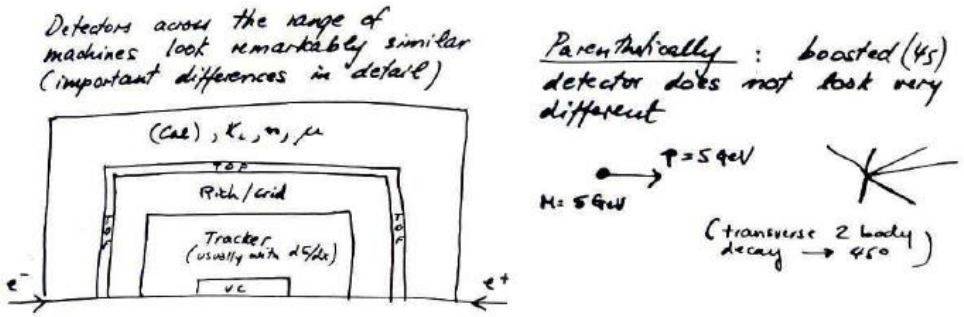
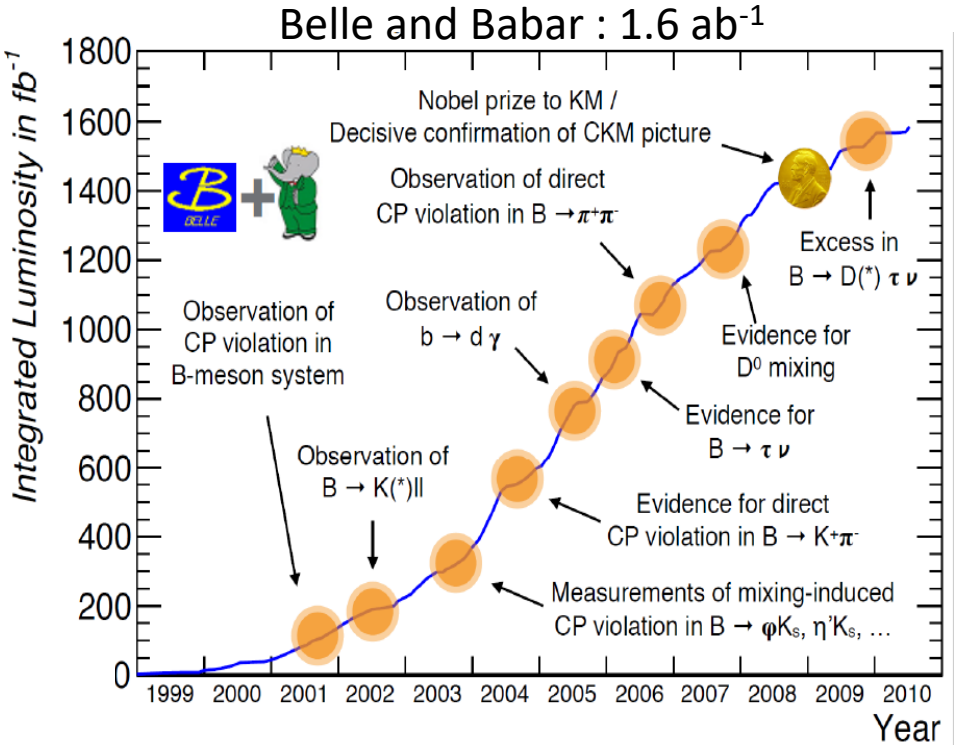


Figure 2: First presentation [17] of the boosted-$\Upsilon(4S)$ idea in 1987.

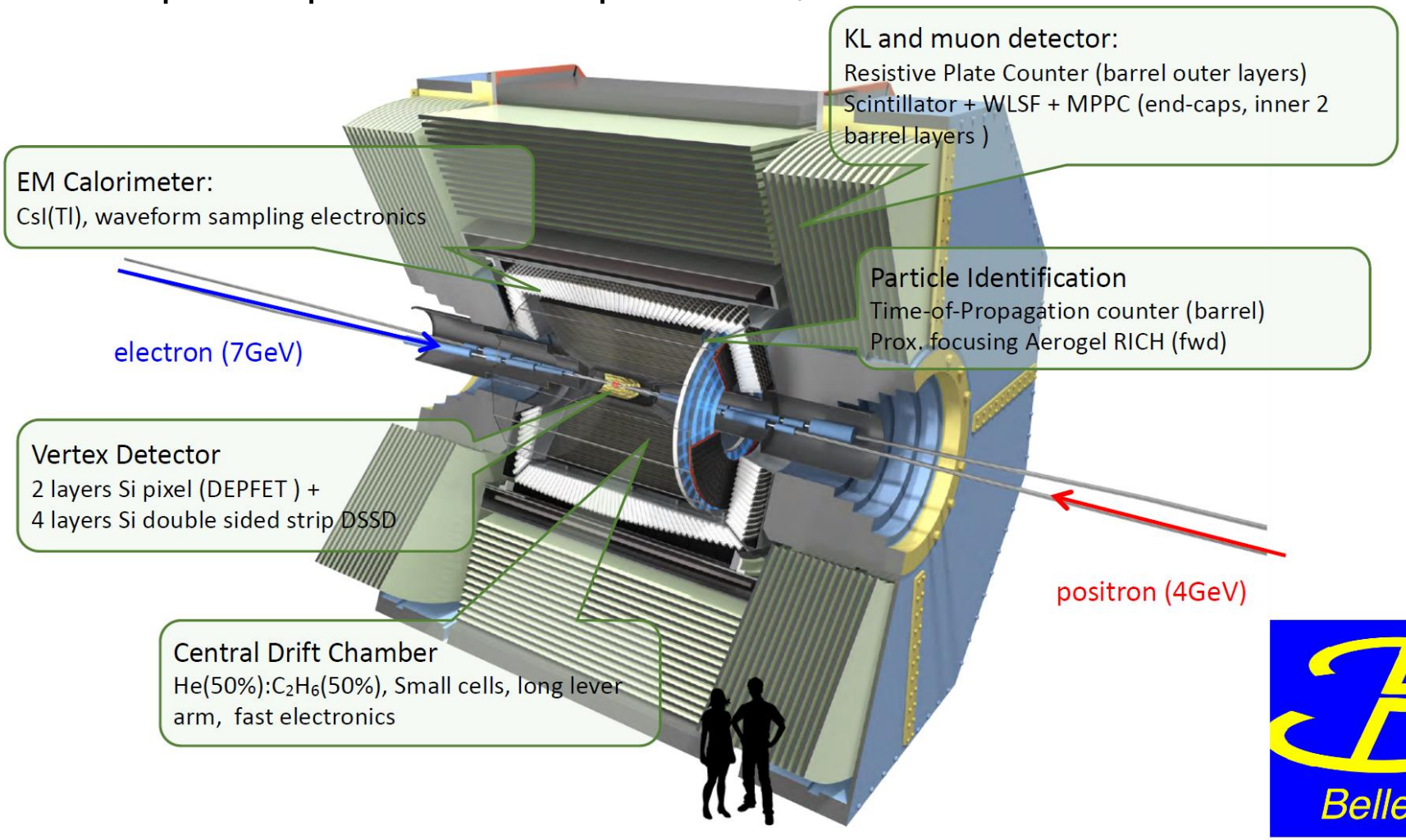
- **Asymmetric High luminosity e^+e^- collider** can provide high statistics of
  - boosted B/D meson and also
  - τ lepton

- Flavor physics
  - Verification of CKM mechanism
  - CPV in B decays
- Limits on BSM physics
  - B/D's rare decays
  - b -> sγ, b-> sl^+l^-
  - LFV τ decays
- Exploring New particles
  - hadron spectroscopy
  - Dark matter



Belle II detector

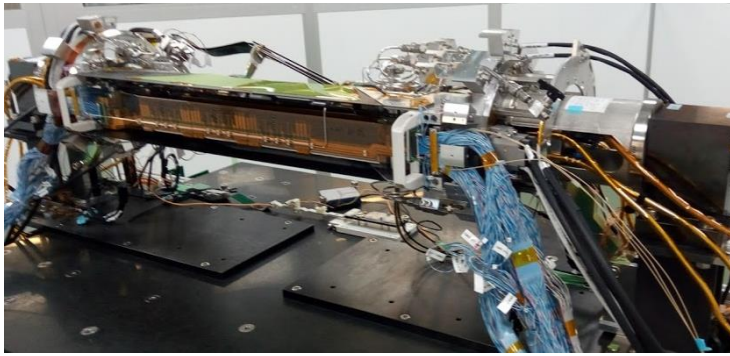
- Trigger rate capability : 0.5 -> 30kHz(max.)
- Expected BG is 20 times higher than KEKB
- Improved performances: particle ID, vertex measurement



Phase 2 VXD(2018)

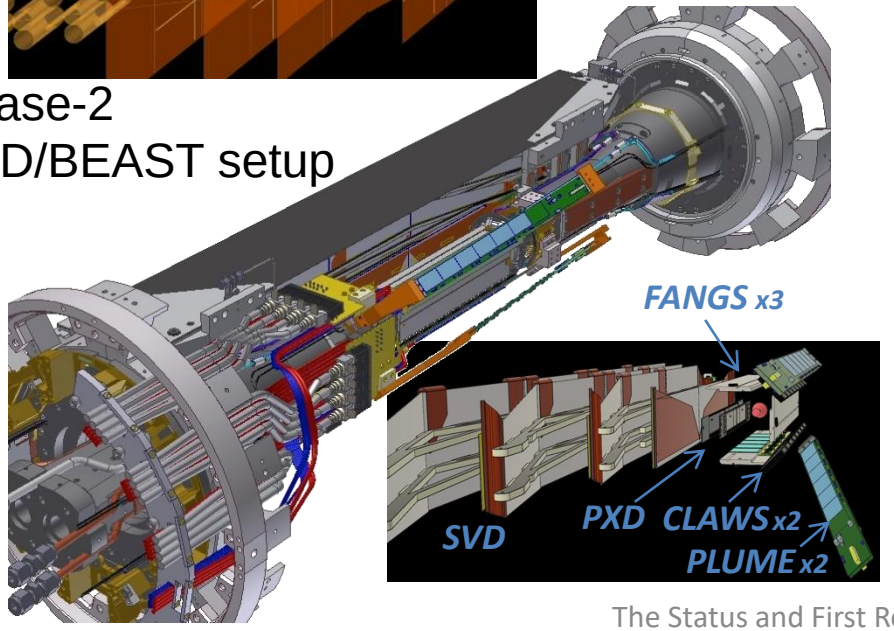
Phase 2 VXD:

- Mechanical components are the same with phase 3
- 1 ladder/layer of PXD, SVD
  - BG hit rate, DAQ test and RoI tracking study
- BG sensors only for phase 2
  - To judge BG condition for phase 3 VXD



BG sensors in phase 2 VXD

Phase-2
VXD/BEAST setup



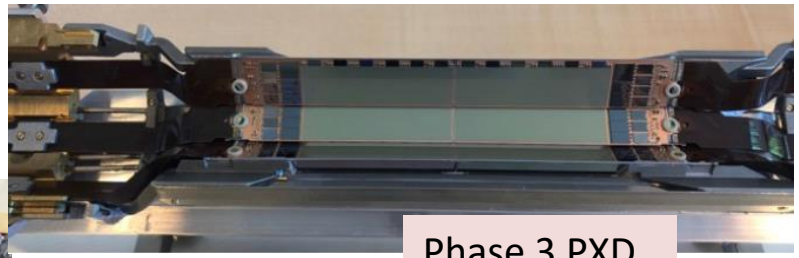
FANGS	Silicon pixel sensor : x-ray energy spectrum for SR
CLAWS	Scintillators w/ SiPMTs: Beam injection noise
PLUME	Two-side silicon pixel sensors: hit rate measurement in radially
Micro-TPC	Fast neutron from EM shower
He-3 tube	Thermal neutron
Scintillators +PIN diode	BG measurement around the final focus magnets
Diamond sensor	BG dose measurement @IP Aborting beam to protect VXD

Integrated dose : film dosimeters

Phase3 VXD (2019)

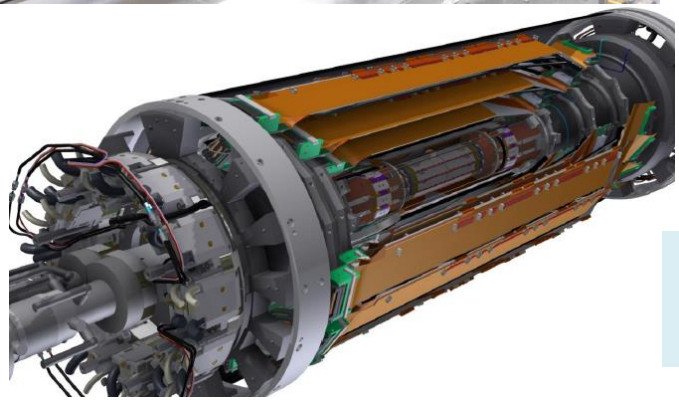
Beam Pipe r = 10mm
DEPFET
Layer 1 r = 14mm
Layer 2 r = 22mm
DSSD
Layer 3 r = 39mm
Layer 4 r = 80mm
Layer 5 r = 115mm
Layer 6 r = 140mm

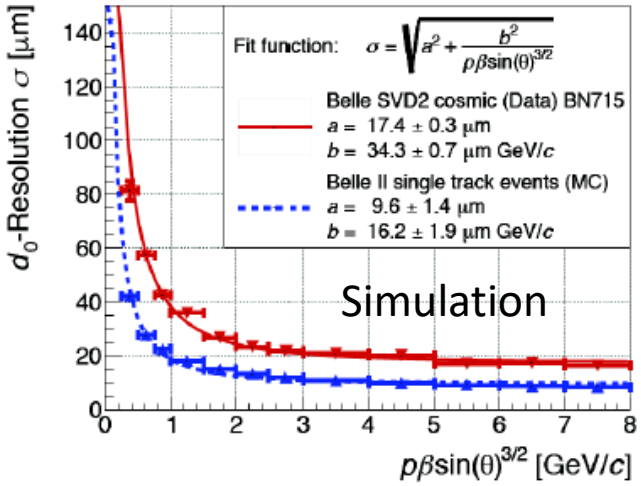
IP Beam pipe



Phase 3 PXD

SVD





VXD can provide factor 2 or more better impact parameter resolution in spite of lowered Lorenz boost.