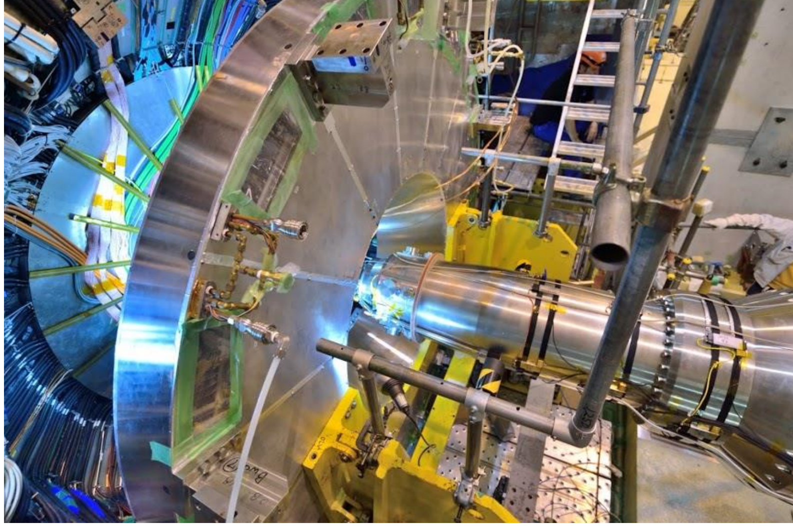
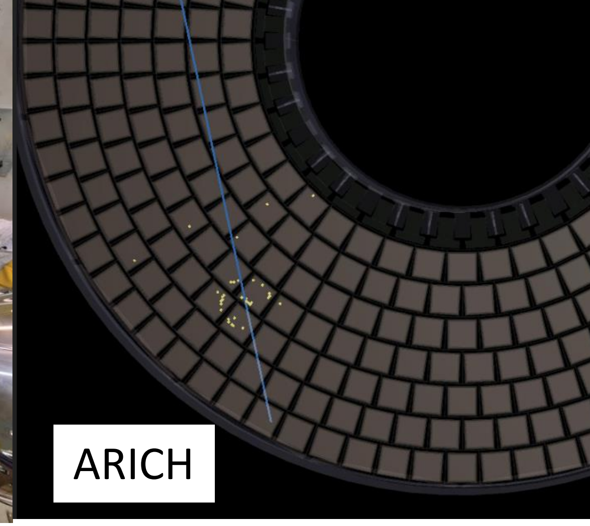
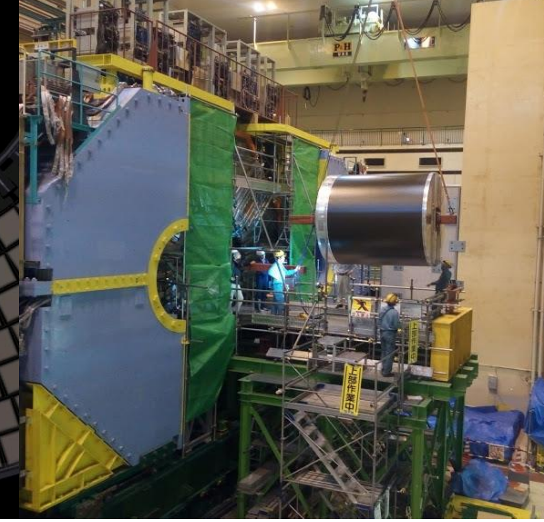






The Belle II Experiment: Status and Prospects

High Energy Accelerator Research Organization (KEK)

S. Tanaka on the behalf of the Belle II collaboration

39th International Conference on High Energy Physics

B factory experiment

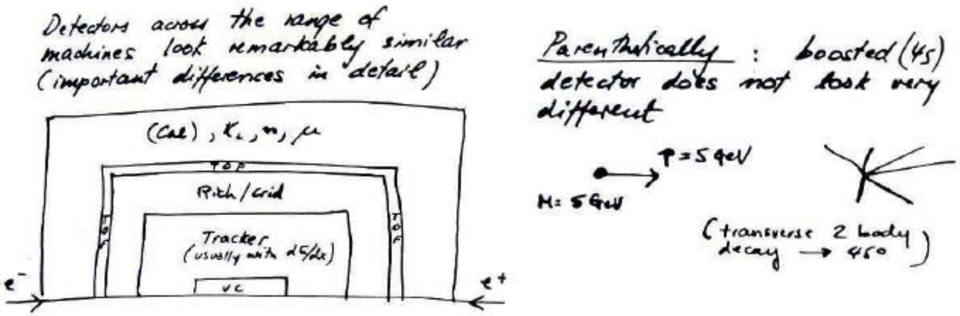
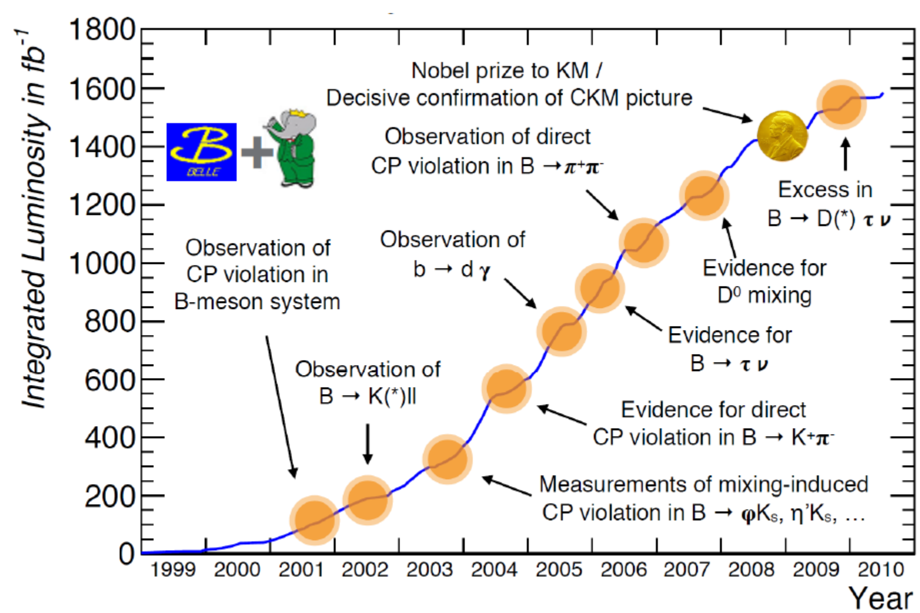


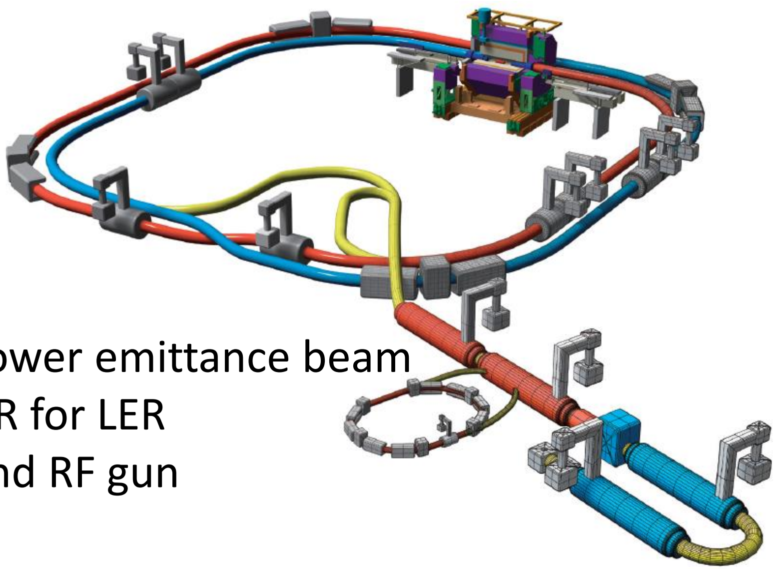
Figure 2: First presentation [17] of the boosted-$\Upsilon(4S)$ idea in 1987.

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



- Flavor physics
  - Verification of CKM mechanism
    - CKM matrix / unitarily triangle
  - CPV in B decays
- Limits on BSM physics
  - B/D's rare decays
  - $b \to s\gamma$, $b \to sl^+l^-$
  - LFV τ decays
- Exploring New particles
  - Four quark states

SuperKEKB (nano-beam scheme)



Lower emittance beam
DR for LER
and RF gun

Beam current

Beam-beam parameter

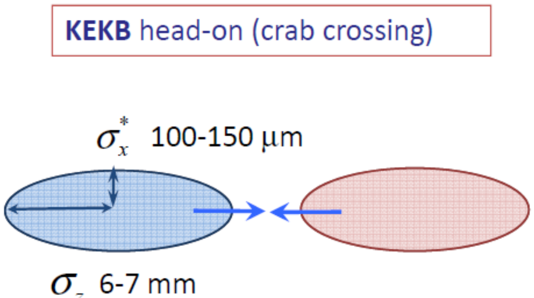
$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

σ: beam size

β function

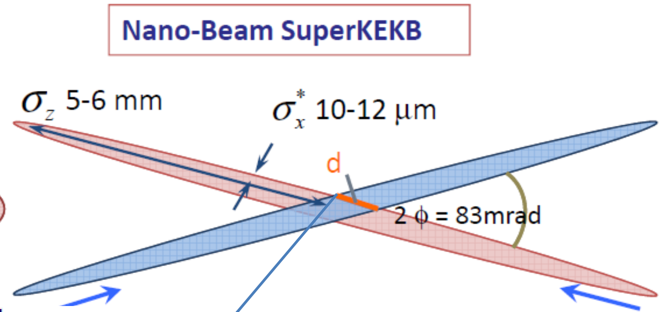
		KEKB		SuperKEKB		units	
		LER	HER	LER	HER		
Beam energy	**E_b**	**3.5**	**8**	**4**	**7.007**	**GeV**	
Beam crossing angle	**φ**	**22**		**83**		**mrad**	
β function @ IP	**β_x^*/β_y**	**1200/5.9**		**32/0.27**	**25/0.30**	**mm**	X 20
Beam current	**I_b**	**1.64**	**1.19**	**3.6**	**2.6**	**A**	X 2
Luminosity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

New Constraints by the nano-beam scheme

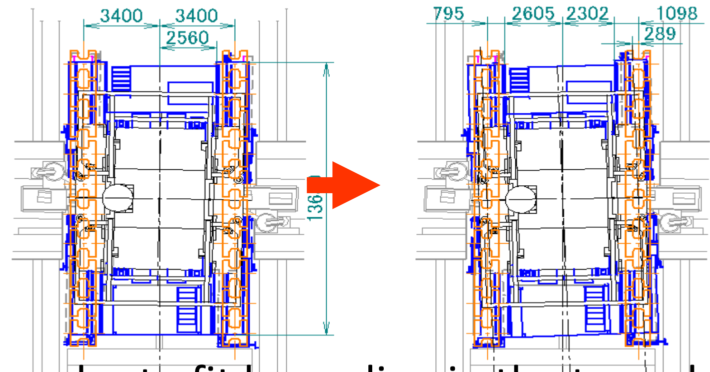


Hourglass requirement

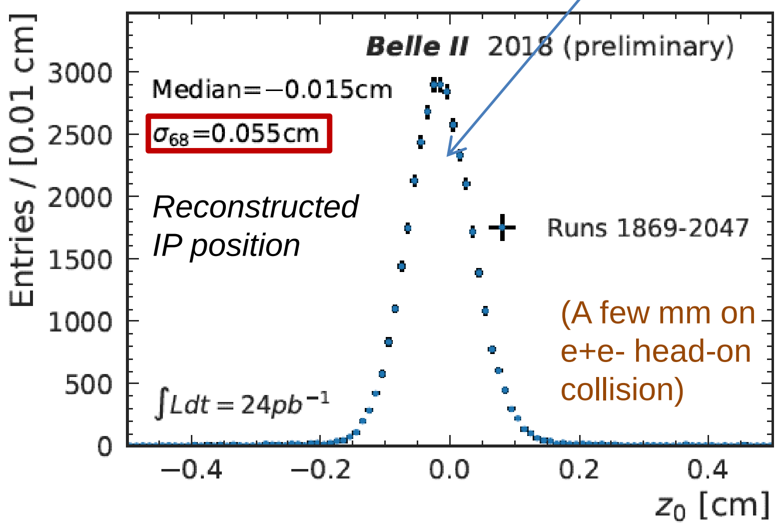
$\beta_y^* \geq \sigma_z$ ~ 6 mm

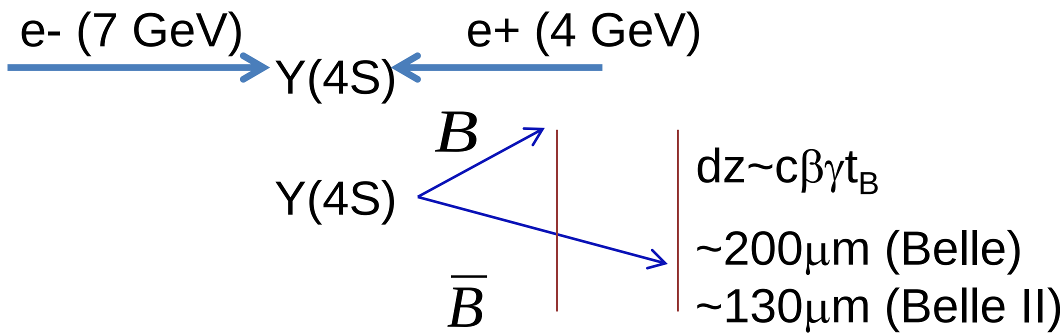


$\beta_y^* \geq \dfrac{\sigma_x^*}{\phi}$ ~ 300 μm



In order to fit beam line in the tunnel, Belle II detector has rotated.





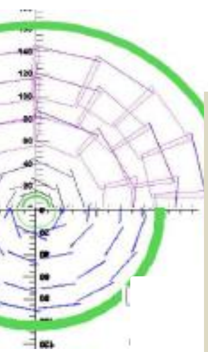
SuperKEKB βγ=0.28 : e$^-$(7GeV), e+ (4GeV)
KEKB βγ=0.42: e$^-$(8GeV), e+ (3.5GeV)

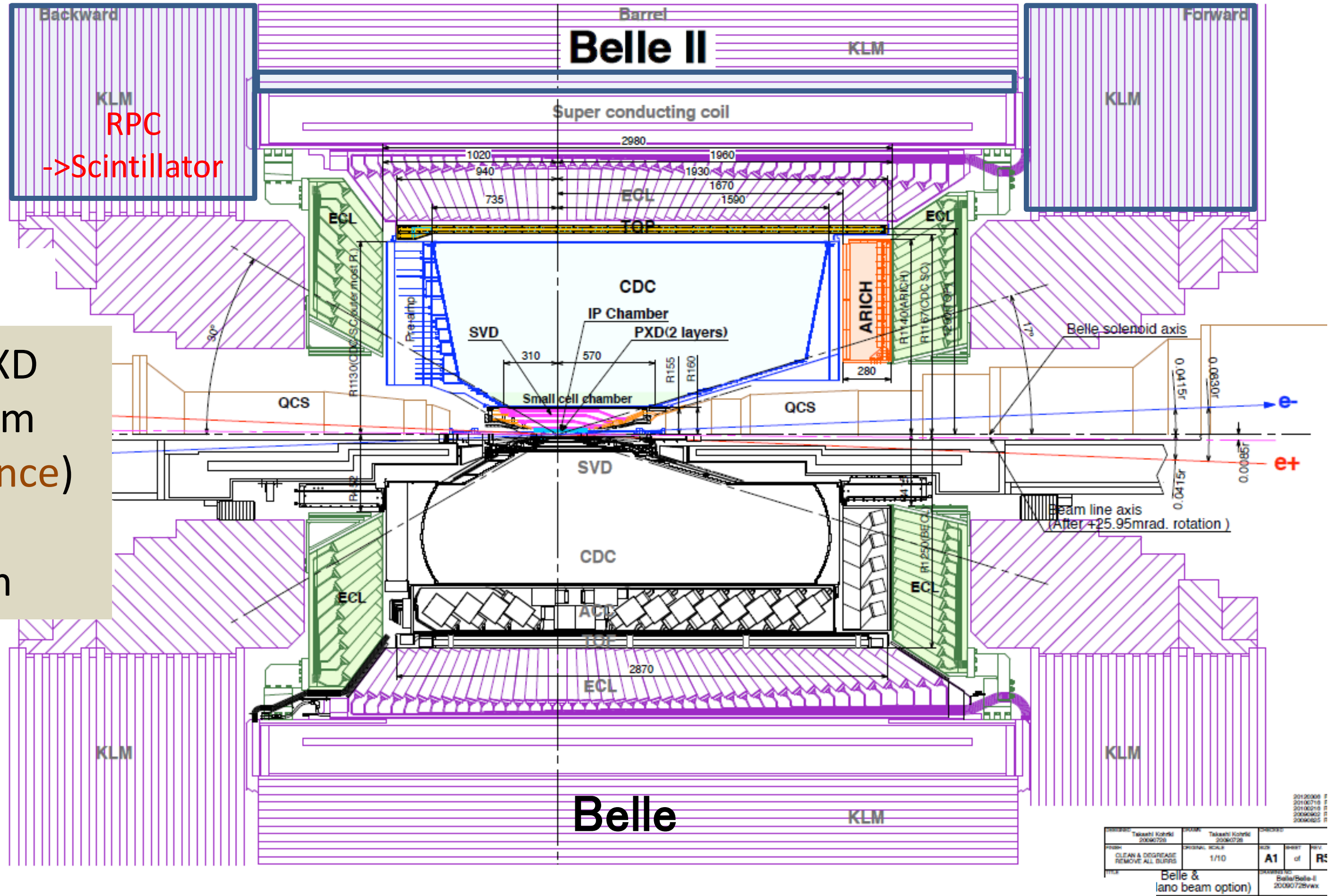
LER (3.5 GeV -> 4GeV):
- for longer Touschek lifetime ∝ E ^{3}

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

To realize nano-beam, we admit Lorentz boost factor down to 2/3 w.r.t. KEKB.

Detector layout (Belle -> Belle II)





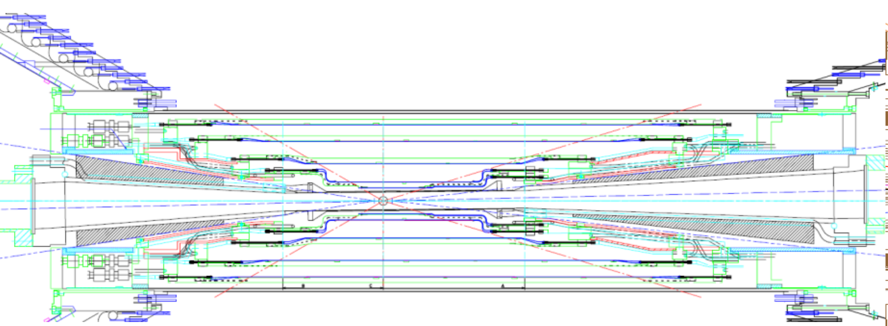
Belle II VXD
R=14-140mm
(Ks acceptance)
Belle SVD
R=20-88mm

SVD 4 layers (DSSD)	→	2 DEPFET + 4 DSSD
CDC:		small cell, long lever arm
ACC+TOF	→	TOP+ARICH (Better K/p separation)
ECL:		waveform sampling
KLM: RPC	→	Scintillator+SiPM

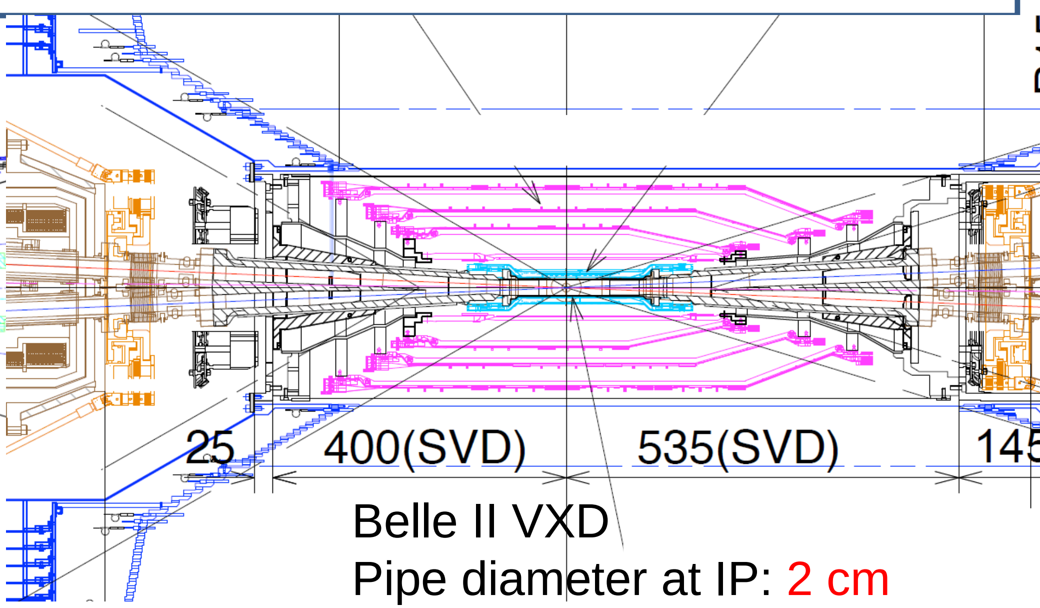
(Endcap and inner two layer of Barrel for neutron BG)

Requirements on Belle-> Belle II upgrade

- 40 times higher Luminosity
  - Huge BG： need to control BG with 20 times level than Belle
    - Effective shielding and Collimator optimization
  - Higher rate capability of DAQ, Trigger and data transfer (max.:30kHz)
  - To avoid signal pile-up, replacing with faster FE
    - SVD, CDC, ECL
- Keeping physics acceptance even if the beam crossing angle is changed from 22 to 83 mrad by the nano-beam scheme



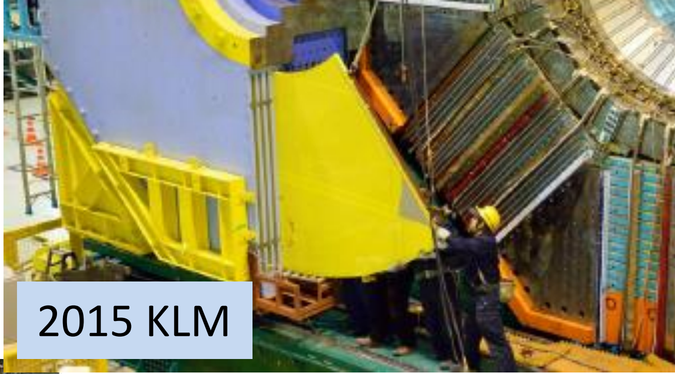
Belle SVD
Pipe diameter at IP: 3 cm

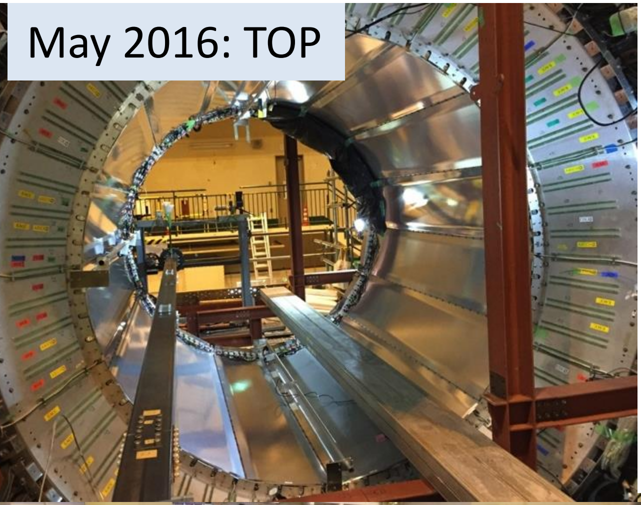


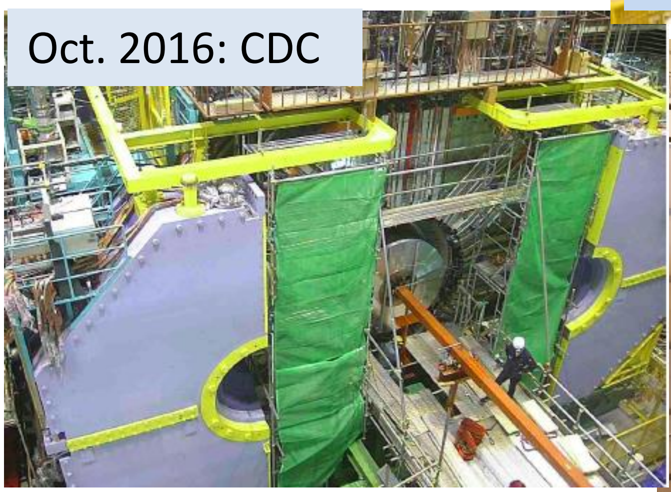
Belle II VXD
Pipe diameter at IP: 2 cm
PXD (new)

6

Sub-detector installation

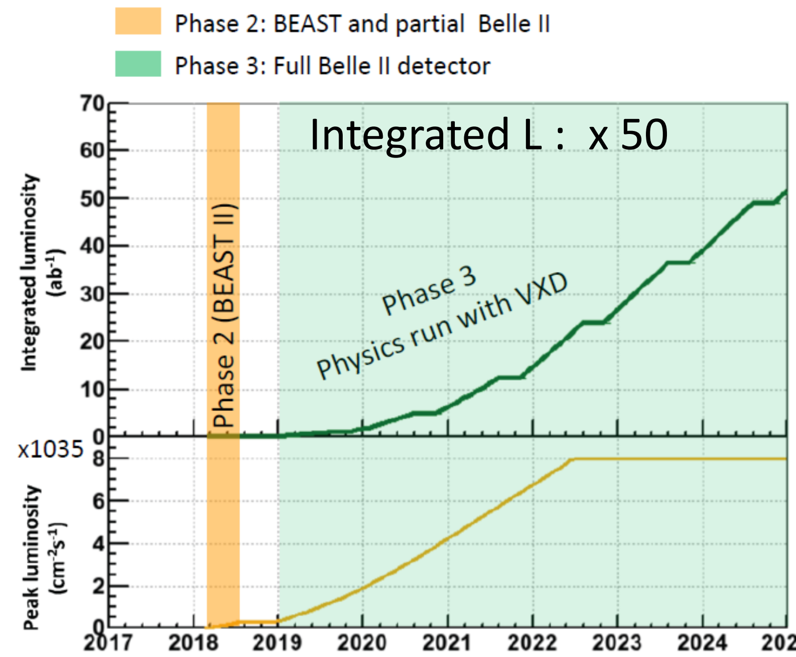


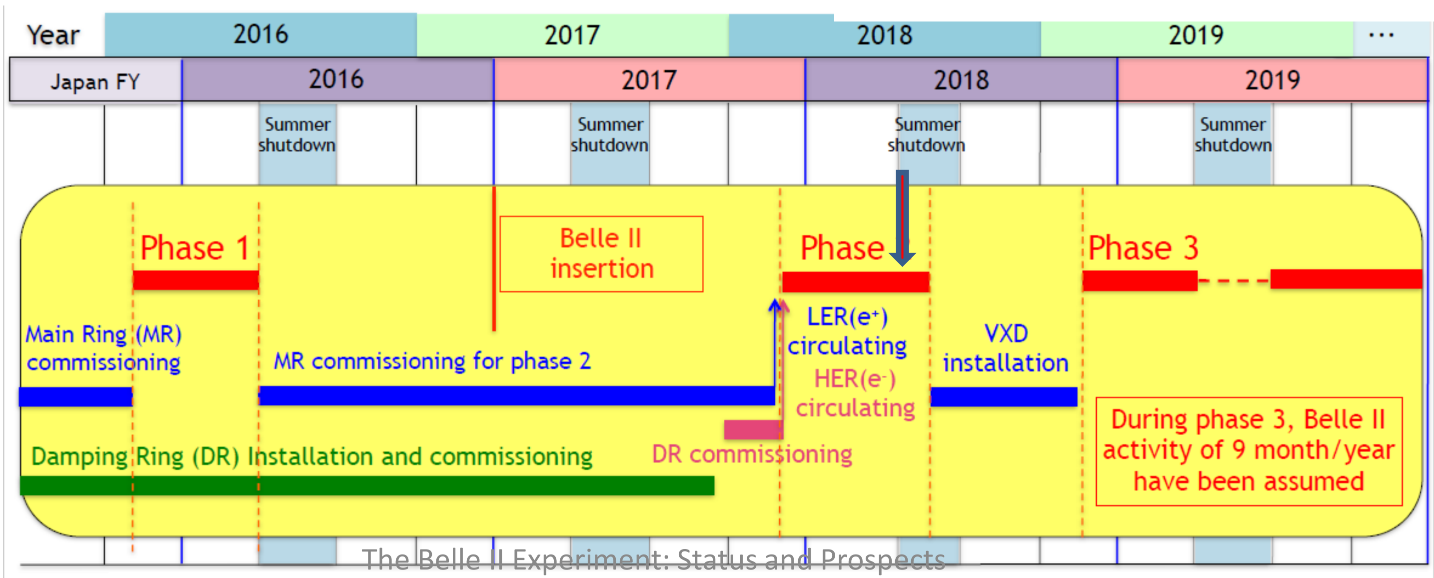




Belle II /superKEKB commissioning

- Phase 1 (finished): Beam operation without final focus magnets and Belle II
  - Commissioning of beam transportation and vacuum scrubbing
- Phase 2(4month): 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
- Phase 3 (2019): final detector configuration

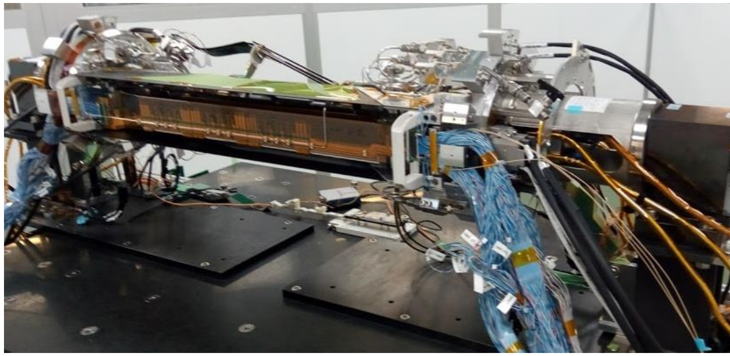




Phase 2 VXD

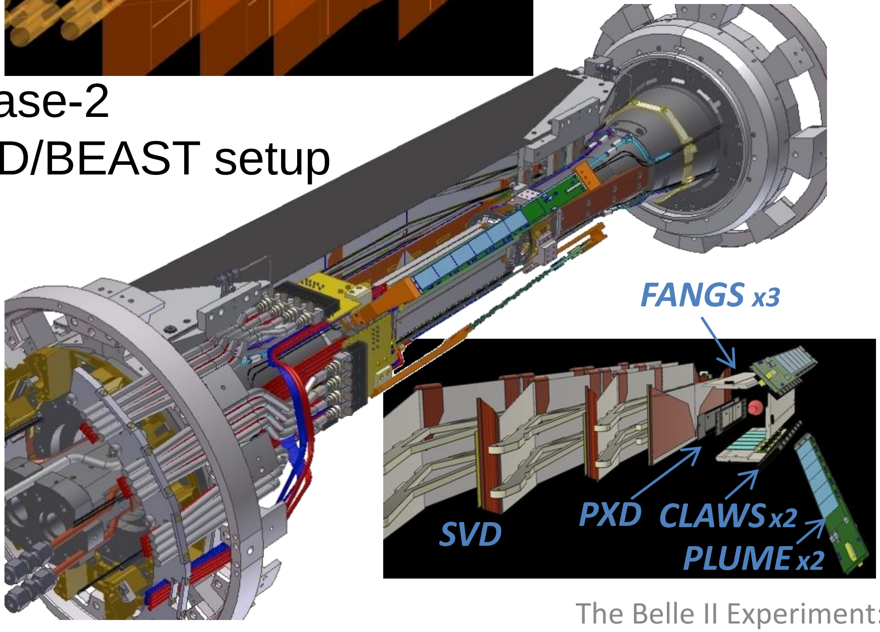
Phase 2 VXD:

- Mechanical components are the same with phase 3
- 1 ladder/payer 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

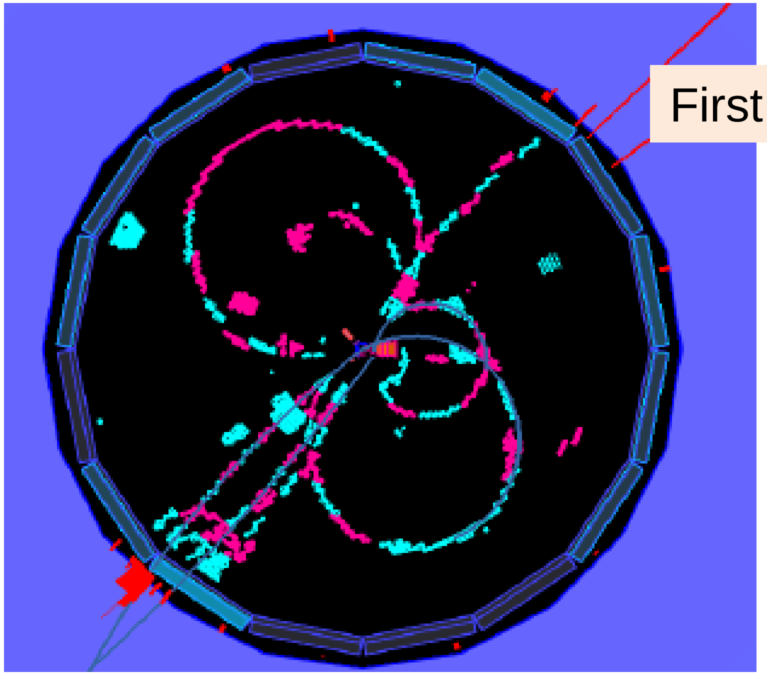
Phase-2
VXD/BEAST setup



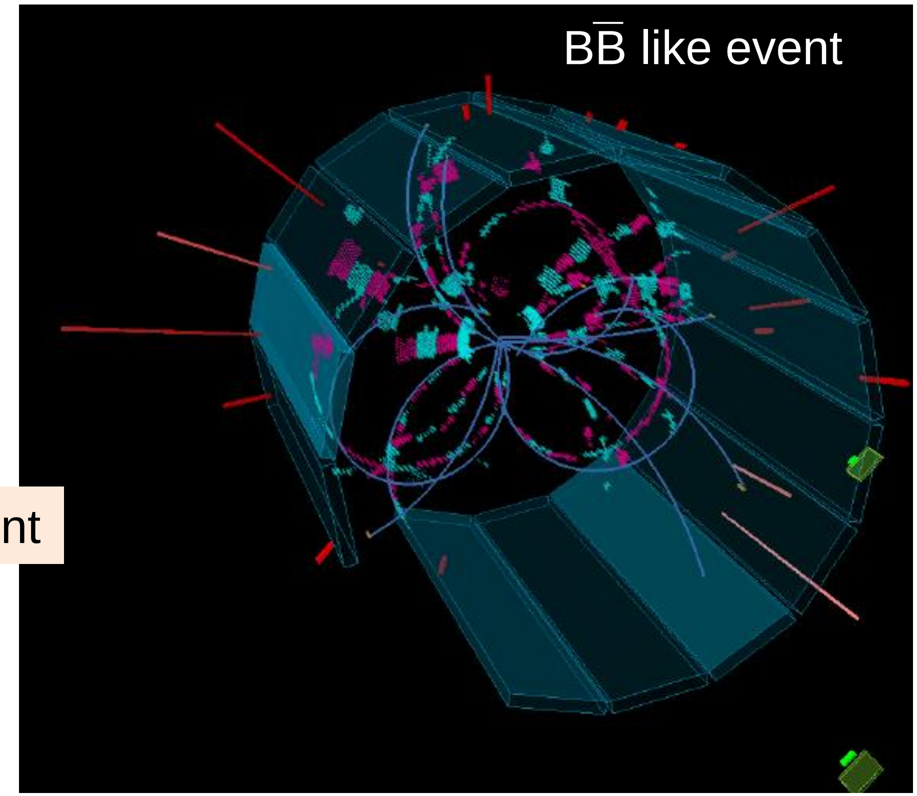
FANGS	Silicon pixel sensor : x-ray energy spectrum for SR
CLAWS	Scintillators w/ SiPMTs: Beam injection noise
PLUME	Two-side silicon pixel sensors: hit rate measurement in radially
Micro-TPC	Fast neutron from EM shower
He-3 tube	Thermal neutron
Scintillators +PIN diode	BG measurement around the final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

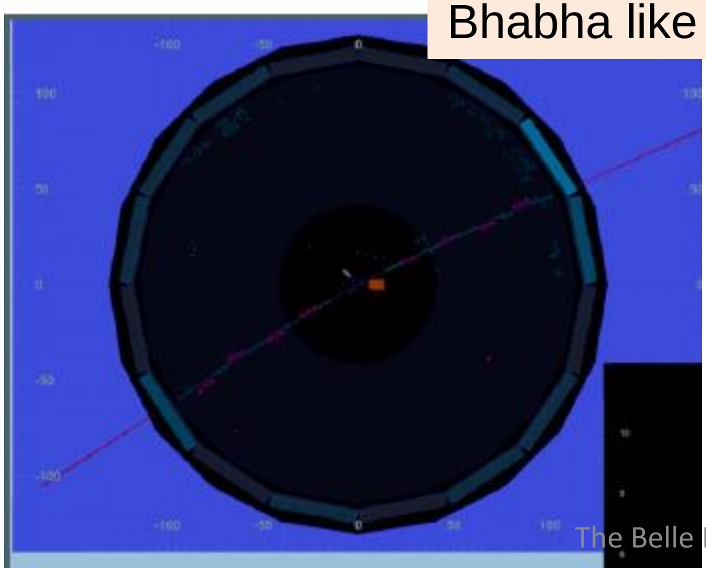
Integrated dose： film dosimeters

First event



First hadronic event (26^{th} Apr.)





Bhabha like event

Latest Machine achievement

L~ 5.39x10^33 cm^{-2}s^{-1}

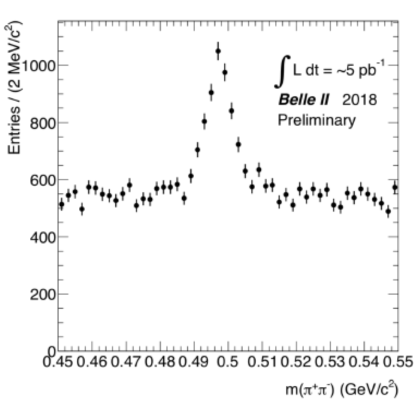
LER: 800mA

HER: 745mA

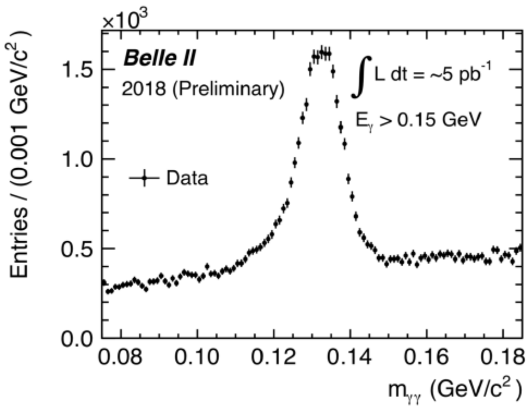
First studies

Hadron reconstruction (based on 5 pb^{-1} data) (corrected ~0.5 fb-1)

$K_S \to \pi^+ \pi^-$



$\pi^0 \to \gamma \gamma$



Phase 2 Objective:

1, Luminosity measurement, hadronic events, B/D counting

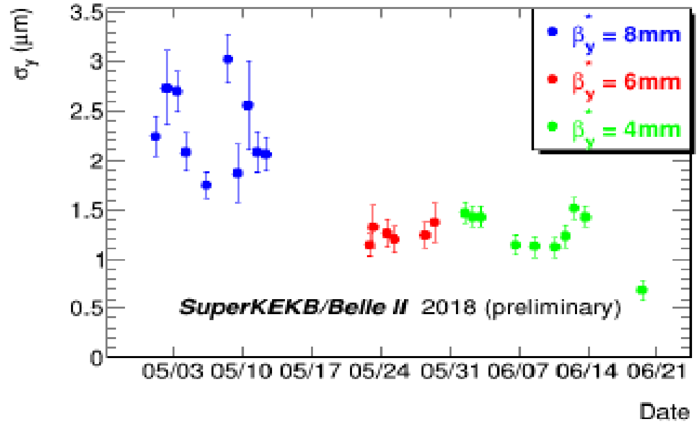
2, Re-discovery of hadronic events (for calibration)

3, Performance measurements
(tracking, neutrals, hadron ID, lepton ID, trigger)

4, Dark matter search
e+e- -> γX, e+e- -> γ ($\gamma\gamma$)

5, BG measurement to confirm phase 3 operation

Squeezing Vertical beam size

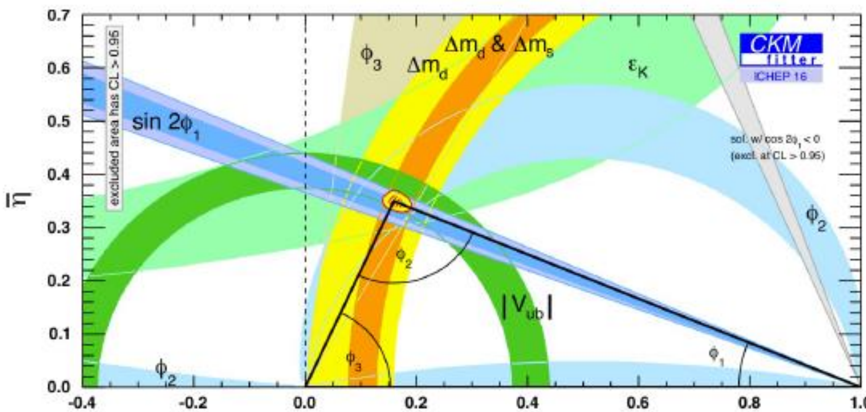


By reconstructing IP, the beam Size change in each beam optics has confirmed

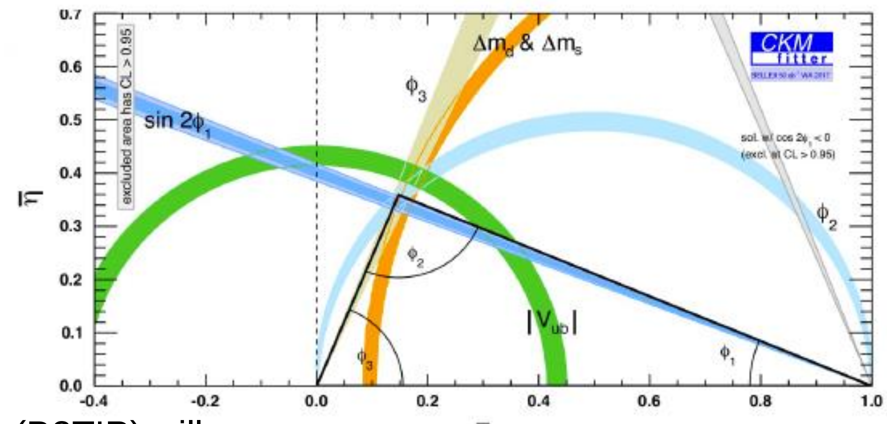
Experimental targets on Belle II

1. Measuring CP violation with B meson
2. Fine verification of CKM mechanism which causes CP violation
3. Exploring new physics by high statics data

State of the art 2016

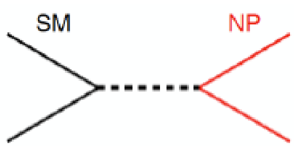


Belle II 50 ab^{-1}

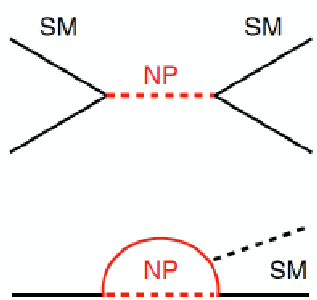


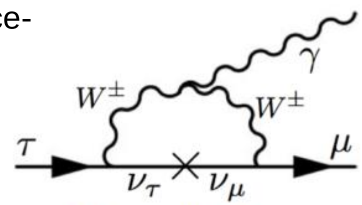
Belle II physics report via Belle Theory Interface Platform(B2TIP) will be public soon. (https://confluence.desy.de/display/BI/B2TiP+WebHome#space-menu-link-content)

Energy frontier
Direct production of new particles - limited by beam energy

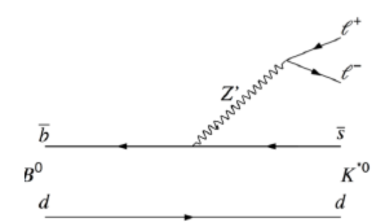


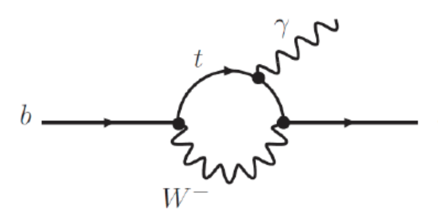
Intensity frontier:
indirectly reveal NP virtual particles in loops – probe energy above 10 TeV





SM prediction:
$BF(\tau \to l\gamma) \sim 10^{-40}$





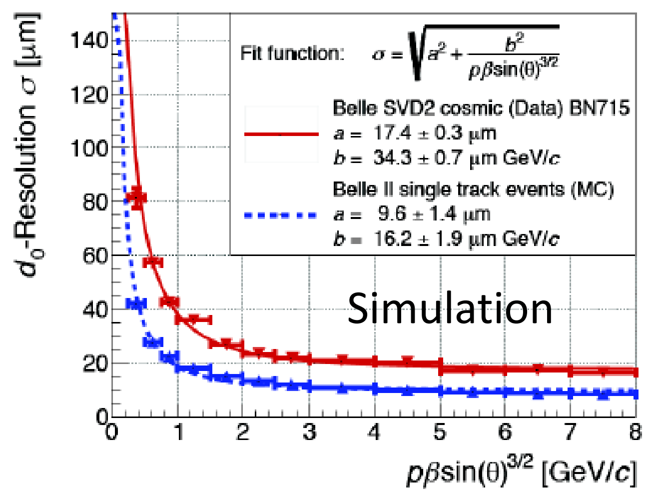
Vertex Detector (Phase 3)

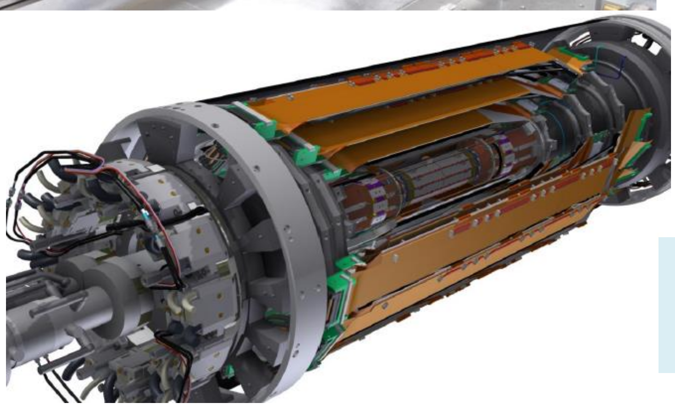
Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 39mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**

IP Beam pipe

Phase 3 PXD
1^{st} layer at phase 3 start

SVD



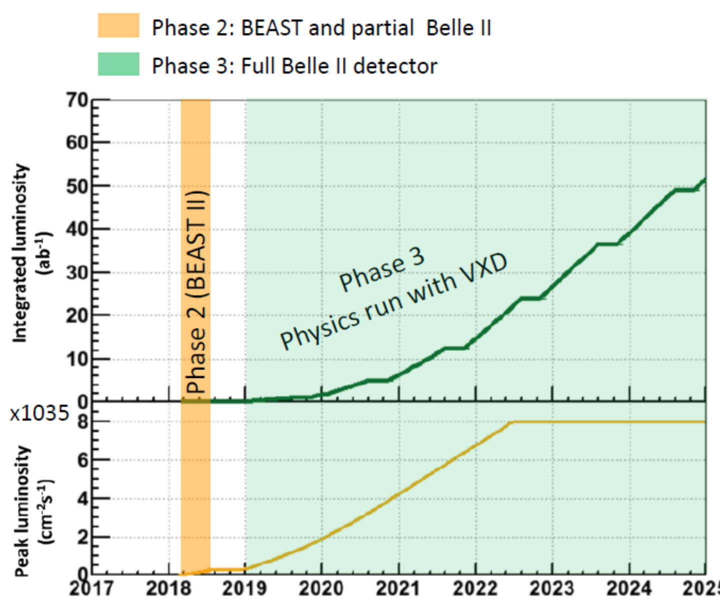


VXD can provide factor 2 or more better impact parameter resolution in spite of lowered Lorenz boost.

Phase 3 VXD installation in 2018

Summary

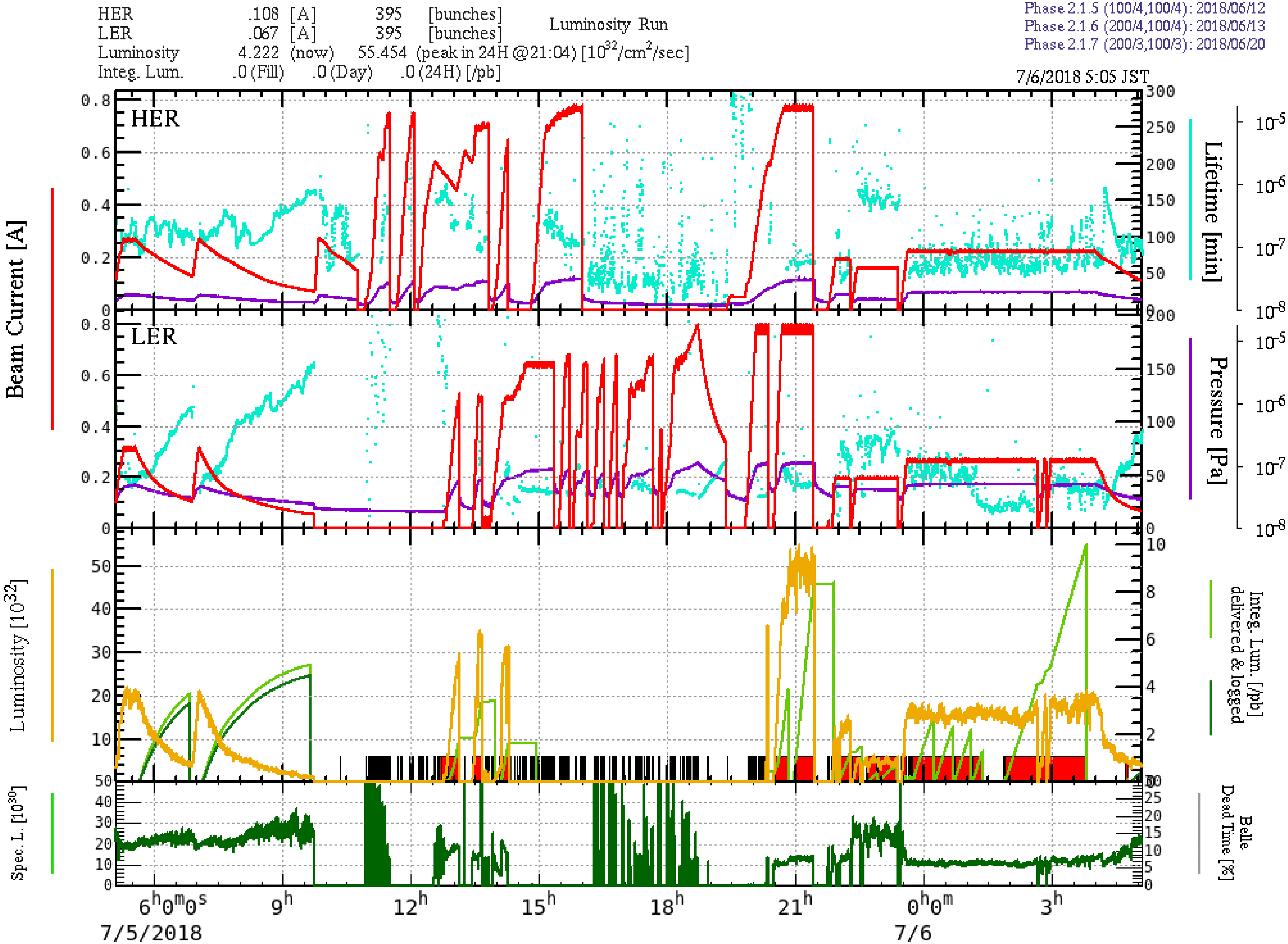
- Phase 2 Belle II detector with superKEKB has completed in 2018 Mar.
- After the beam tuning, First beam collision has observed on 26^{th} Apr.
- Phase2 Belle II operation is schedule from Apr. to middle of July 2018.
  - Phase 2 VXD equip 1 ladder/layer of PXD/SVD
  - DAQ, Trigger optimization
  - Event reconstruction parameter optimization
  - Rediscovery of heavy flavor
  - Performance measurement (tracking, particle ID, trigger)
  - Understanding/control BG
- Phase3 operation with full Belle II detector is scheduled from next spring.



Bkup

Summary of detector performance.

Measurement	Belle	Belle II
B Vertex Reconstruction (typical)	$\sigma_z = 61\,\mu\text{m}$	$\sigma_z = 26\,\mu\text{m}$
Tracking	$\sigma_{p_t}/p_t = 0.0019 p_t\ [\text{GeV}/c] \oplus 0.0030/\beta$	$\sigma_{p_t}/p_t = 0.0011 p_t\ [\text{GeV}/c] \oplus 0.0025/\beta$
$K\pi$ ID	Kaon efficiency $\epsilon_K \simeq 0.85$ with pion fake rate $\epsilon_\pi \simeq 0.10$ for $p = 2\,\text{GeV}/c$	$\epsilon_K \simeq 0.90$ with $\epsilon_\pi \simeq 0.04$ for $p = 2\,\text{GeV}/c$
Calorimetry	$\frac{\sigma E}{E} = \frac{0.066\%}{E} \oplus \frac{0.81\%}{\sqrt[4]{E}} \oplus 1.34\%$	$\frac{\sigma E}{E} = 7.7\%$ at 0.1 GeV, 2.25% at 1 GeV
Muon ID	Muon efficiency $\epsilon_\mu \simeq 0.90$ with fake rate $\epsilon \simeq 0.02$ for $p_t > 0.8\,\text{GeV}/c$ tracks	$\epsilon_\mu = 0.92 - 0.98$ with $\epsilon = 0.02 - 0.06$ for $p > 1\,\text{GeV}/c$
L1 Trigger	500 Hz typical average, Efficiency for hadronic events $\epsilon_{\text{hadron}} \simeq 1$	30 kHz max. average rate, $\epsilon_{\text{hadron}} \simeq 1$
DAQ	~5% dead time at 500 Hz L1 rate	<3% dead time at 30 kHz L1 rate



HER .108 [A] 395 [bunches]
LER .067 [A] 395 [bunches]
Luminosity 4.222 (now) 55.454 (peak in 24H @21:04) [10^32/cm^2/sec]
Integ. Lum. .0 (Fill) .0 (Day) .0 (24H) [/pb]
Luminosity Run
Phase 2.1.5 (100/4,100/4): 2018/06/12
Phase 2.1.6 (200/4,100/4): 2018/06/13
Phase 2.1.7 (200/3,100/3): 2018/06/20
7/6/2018 5:05 JST
HER
LER
Beam Current [A]
Lifetime [min]
Pressure [Pa]
Luminosity [10^32]
Integ. Lum. [/pb]
delivered & logged
Spec. L. [10^30]
Belle Dead Time [%]
6h0m0s
9h
12h
15h
18h
21h
0h0m
3h
7/5/2018
7/6