Belle II Status

Beyond the LHCb Phase-Upgrade workshop

29-05–2017

G. Finocchiaro

INFN Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali di Frascati

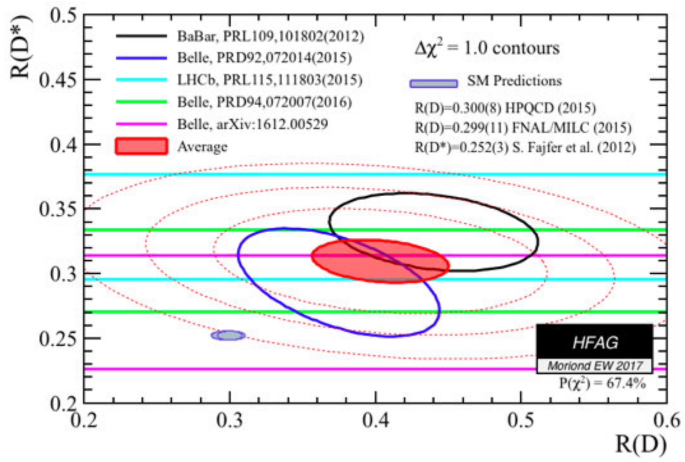
Outline

- Introduction
- Status of SuperKEKB
- Status of Belle II detector construction
- Commissioning status and plans

The mission of Belle II

In a nutshell: discover New Physics

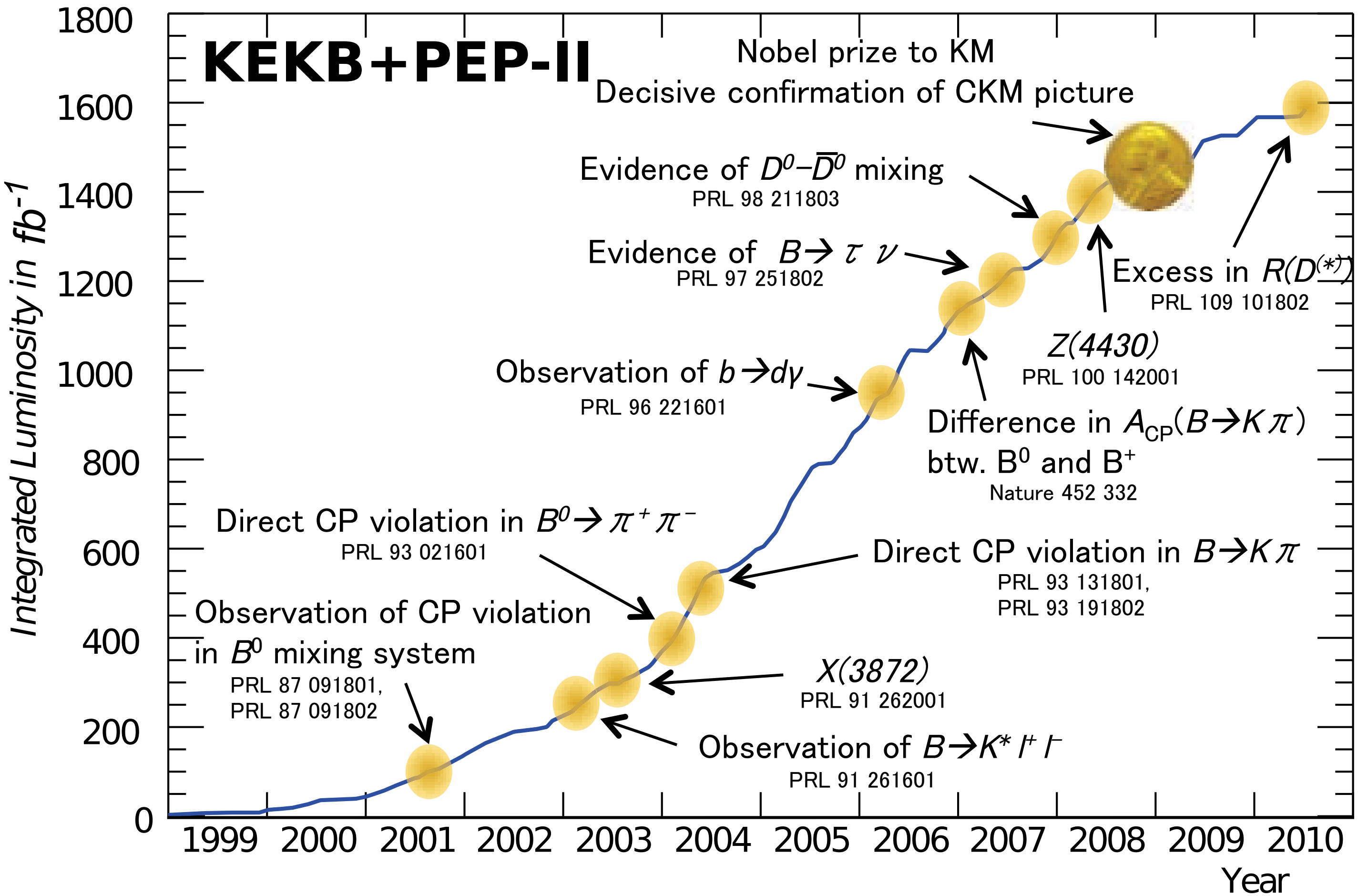
- SM supported by all experimental evidence at the current level of precision and energies
  - although discrepancies, or "tensions" do exist

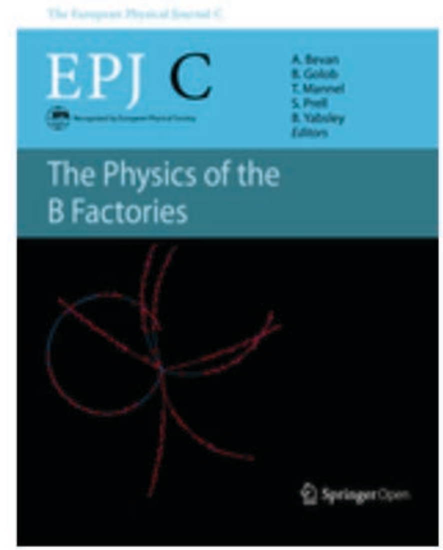


- However, the SM does not explain several fundamental questions
  - hierarchy of fermion masses, n. of generations, neutrino masses, matter-antimatter asymmetry, hierarchy of CKM matrix elements

Several (NP) scenarios, with new particles and interactions, which can be investigated at the "energy" or at the "intensity" frontier.

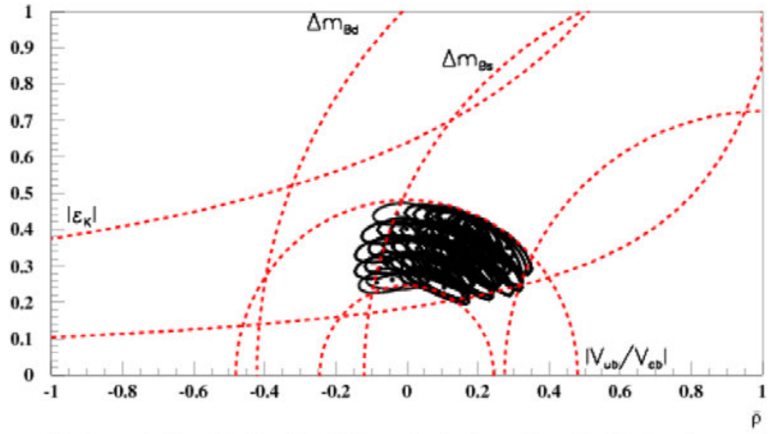
The B factory heritage





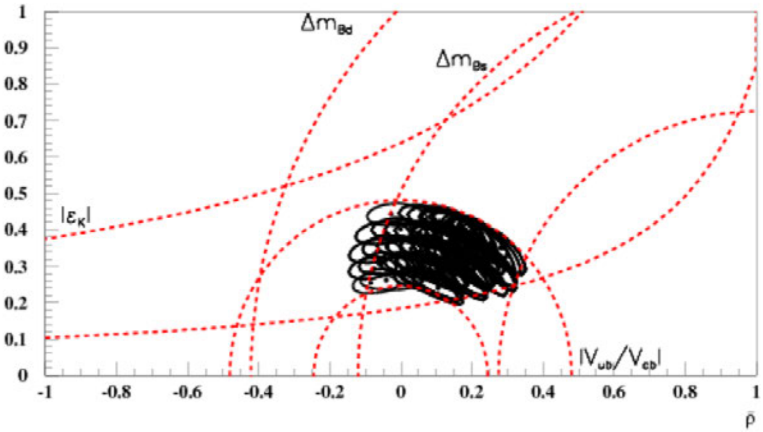
Past, present, and future

The UT before the B factories

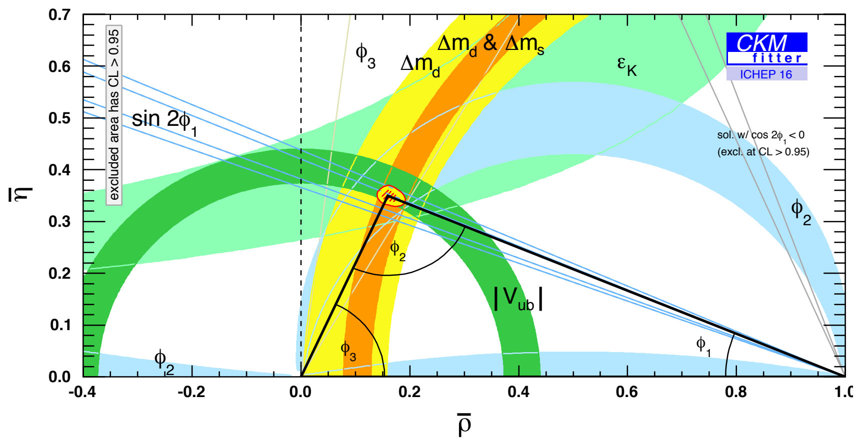


Past, present, and future

The UT before the B factories



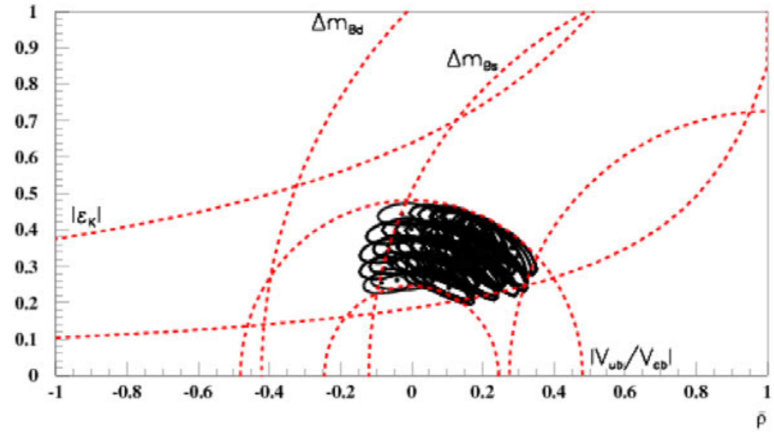
2016, 1.5 ab^{-1}



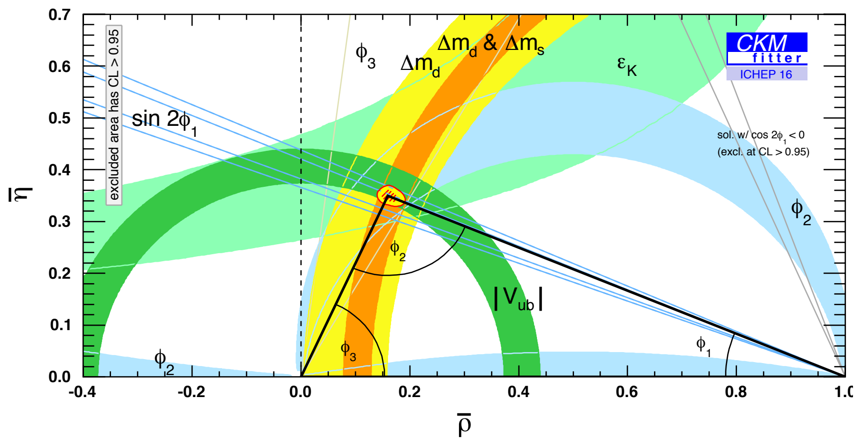
Tevatron and LHCb also included

Past, present, and future

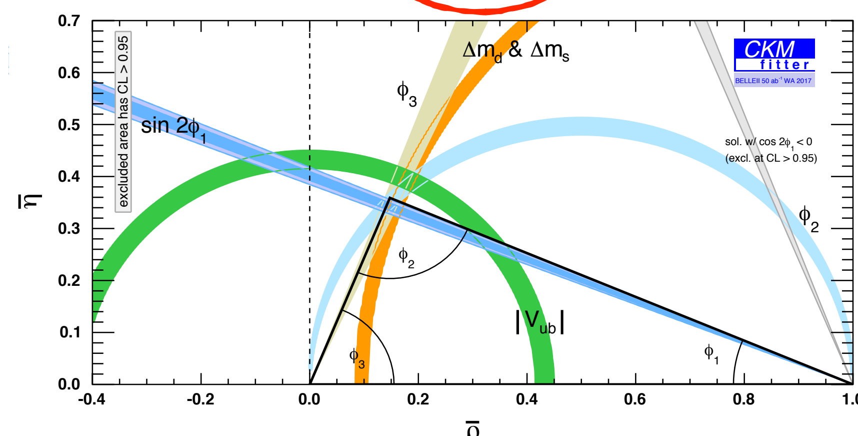
The UT before the B factories



2016, 1.5 ab^{-1}



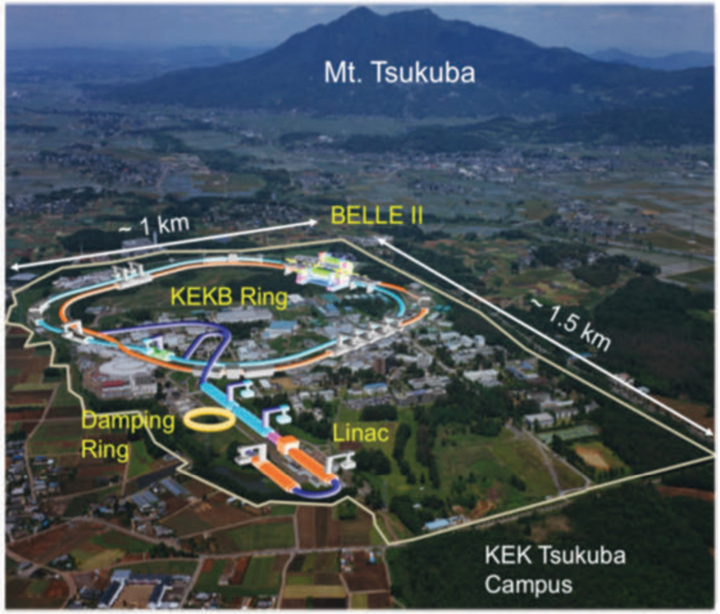
~2024, 50 ab^{-1}

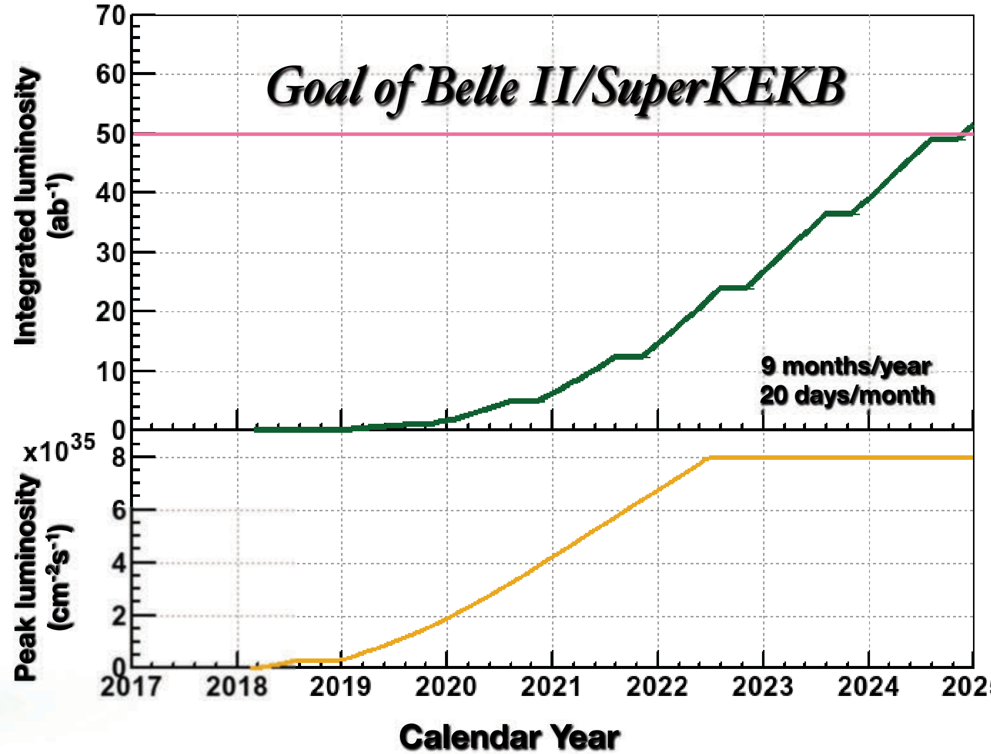


Central values are present World average

Tevatron and LHCb also included

Luminosity profile of the next generation B factory @ KEK

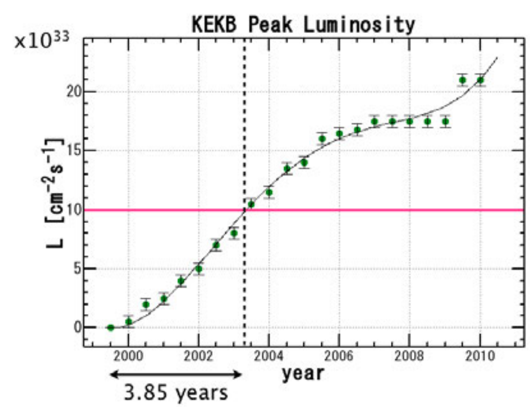




Expected data sample @ full luminosity

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}

* assuming 100% running at each energy

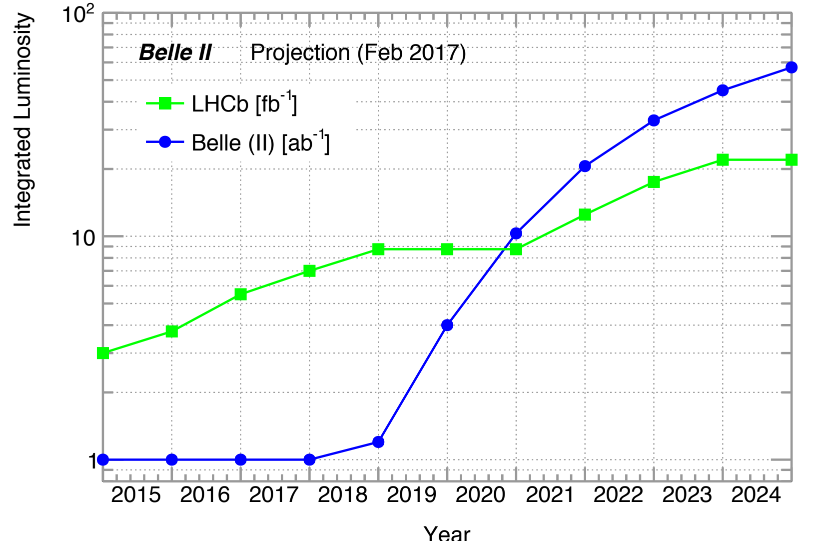


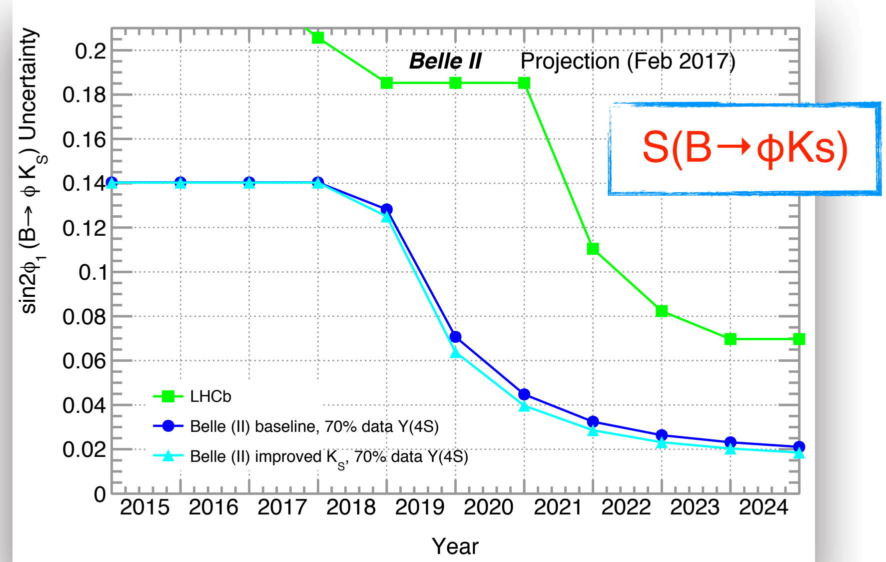
- Assumptions:
  - same commissioning time to reach nominal luminosity as in KEKB
  - 9 months/year running
  - All RF cavities in place

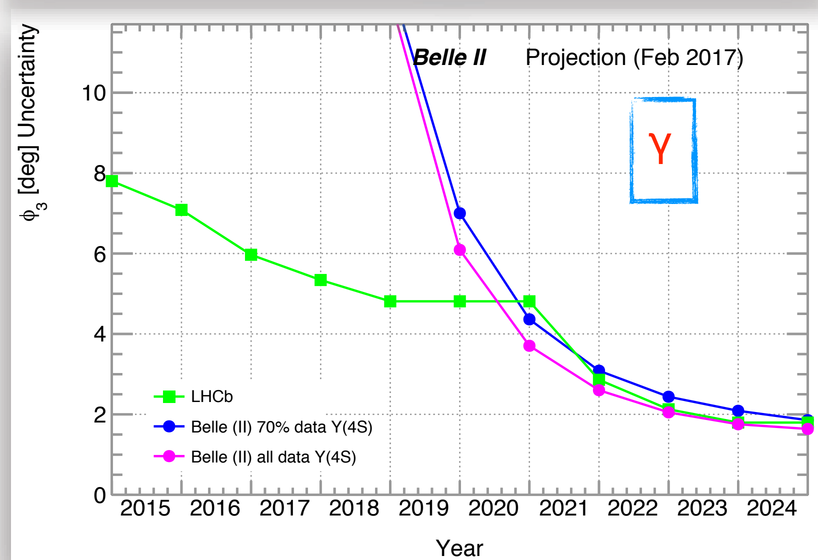
Complementarity/competition of Belle II with the LHCb Physics program

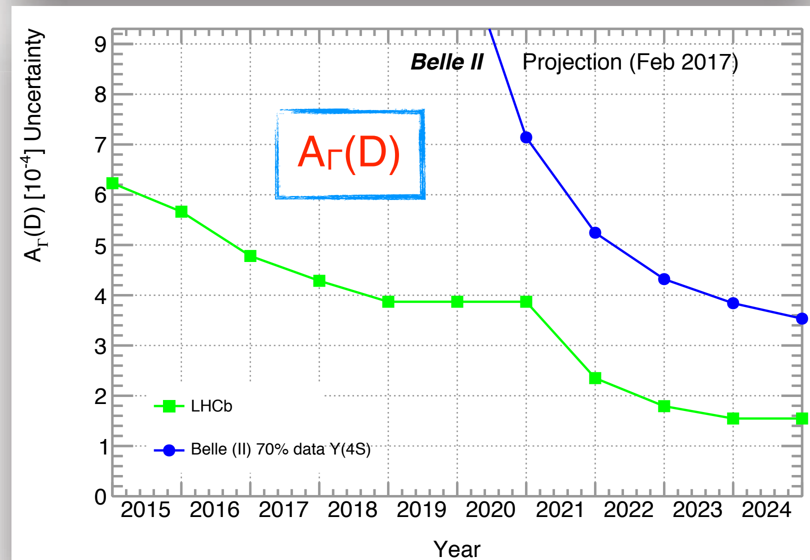
BELLE2-NOTE-PH-2015-004
Version 5.0
May 28, 2017

INTEGRATED LUMINOSITY

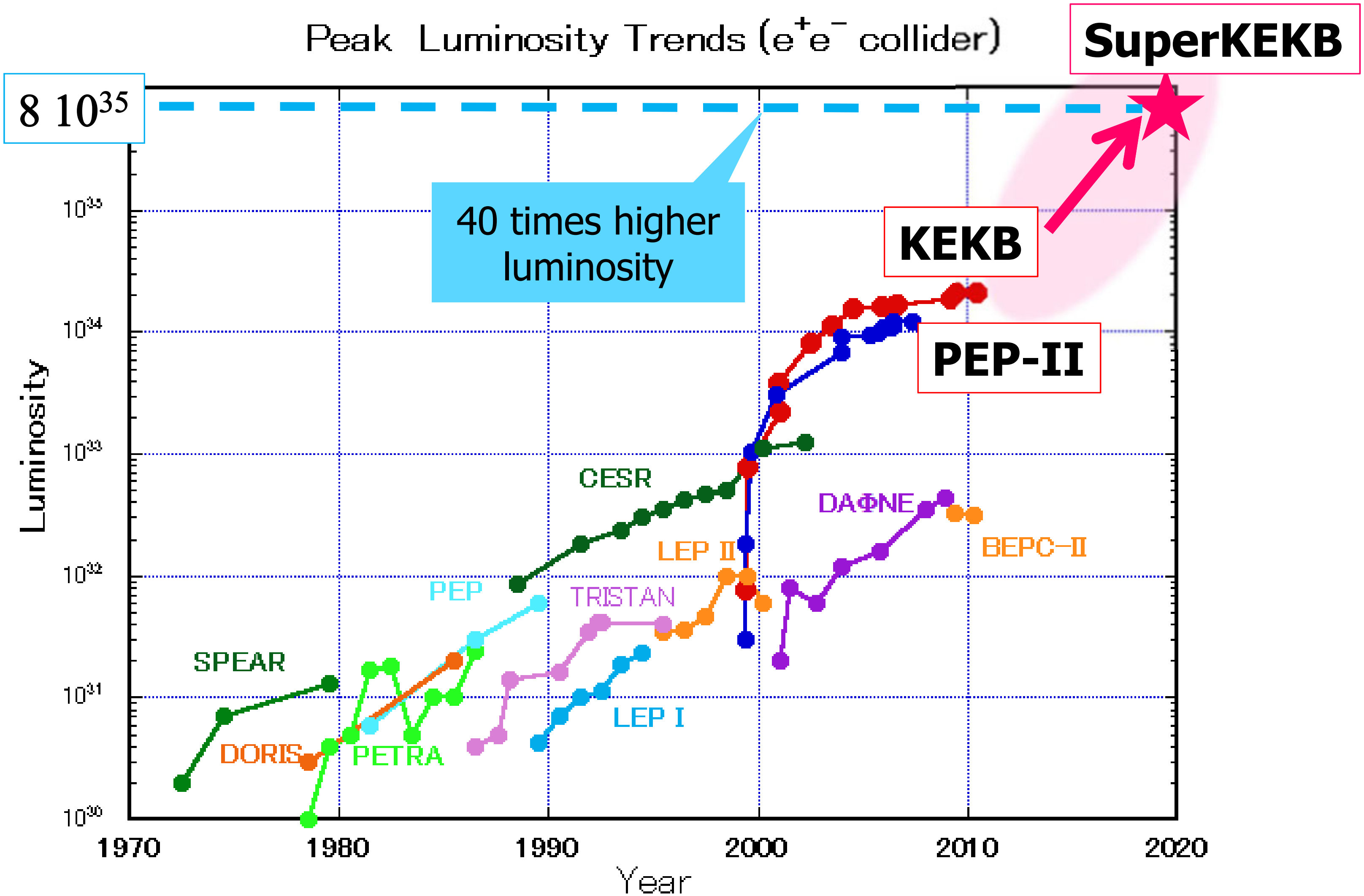








x 40!



Peak Luminosity Trends (e+e− collider)
SuperKEKB
8 10^35
40 times higher luminosity
KEKB
PEP-II
Luminosity
10^35
10^34
10^33
10^32
10^31
10^30
CESR
DAΦNE
LEP II
BEPC-II
PEP
TRISTAN
SPEAR
DORIS
PETRA
LEP I
1970
1980
1990
2000
2010
2020
Year

HowTo

Luminosity formula $$L = f_{coll} \times \frac{N^{+}N^{-}}{4\pi\sigma_x\sigma_y}$$

HowTo

Luminosity formula

$$L = f_{coll} \times \frac{N^+ N^-}{4\pi\sigma_x\sigma_y}$$

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

Lorentz factor

Beam current

Beam-Beam parameter

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

Vertical beta function at IP

Beam aspect ratio at IP
(0.01-0.02)

HowTo

Luminosity formula $$L = f_{coll} \times \frac{N^+ N^-}{4\pi\sigma_x\sigma_y}$$

Lorentz factor

Beam current

Beam-Beam parameter

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

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

Vertical beta function at IP

Beam aspect ratio at IP
(0.01-0.02)

"nano-beam" scheme, first proposed in the ***SuperB*** design (although eventually it was not applied there)

HowTo

Luminosity formula

$$L = f_{coll} \times \frac{N^+ N^-}{4\pi\sigma_x\sigma_y}$$

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

Lorentz factor

Beam current

Beam-Beam parameter

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

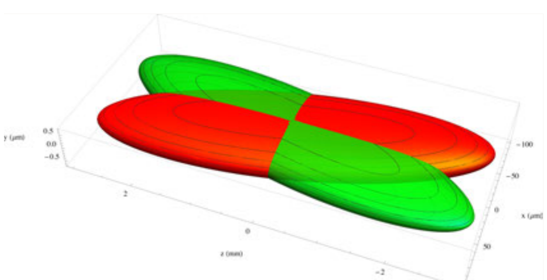
Beam aspect ratio at IP
(0.01-0.02)

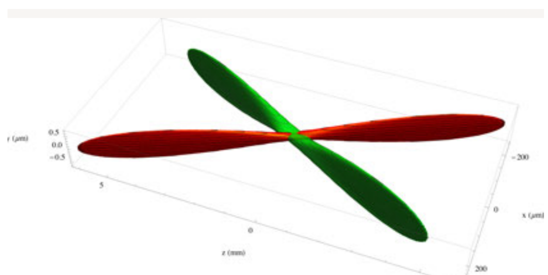
Vertical beta function at IP

I ↑ x 2

β^*_y ↓ x 1/20

"nano-beam" scheme, first proposed in the ***SuperB*** design (although eventually it was not applied there)





Very focused beams, large crossing angle: 83 mrad

KEK & SuperKEKB parameters

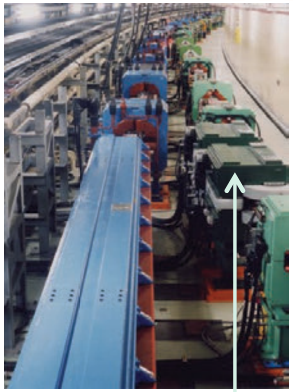
	KEKB Design	KEKB Achieved : with crab	SuperKEKB Nano-Beam
Energy (GeV) (LER/HER)	3.5/8.0	3.5/8.0	4.0/7.0
β_y^* (mm)	10/10	5.9/5.9	0.27/0.30
β_x^* (mm)	330/330	1200/1200	32/25
ε_x (nm)	18/18	18/24	3.2/5.3
$\varepsilon_y/\varepsilon_x$ (%)	1	0.85/0.64	0.27/0.24
σ_y(μm)	1.9	0.94	0.048/0.062
ξ_y	0.052	0.129/0.090	0.09/0.081
σ_z (mm)	4	6 - 7	6/5
I_{beam} (A)	2.6/1.1	1.64/1.19	3.6/2.6
$N_{bunches}$	5000	1584	2500
Luminosity (10^{34} cm^{-2} s^{-1})	1	2.11	80

Note:

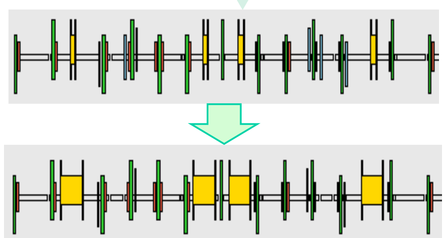
- Lower E_{HER} (RF power, low emittance)
- Higher E_{LER} (Touschek lifetime, low emittance)
- boost 0.42 —> 0.28

Transform KEKB into SuperKEKB

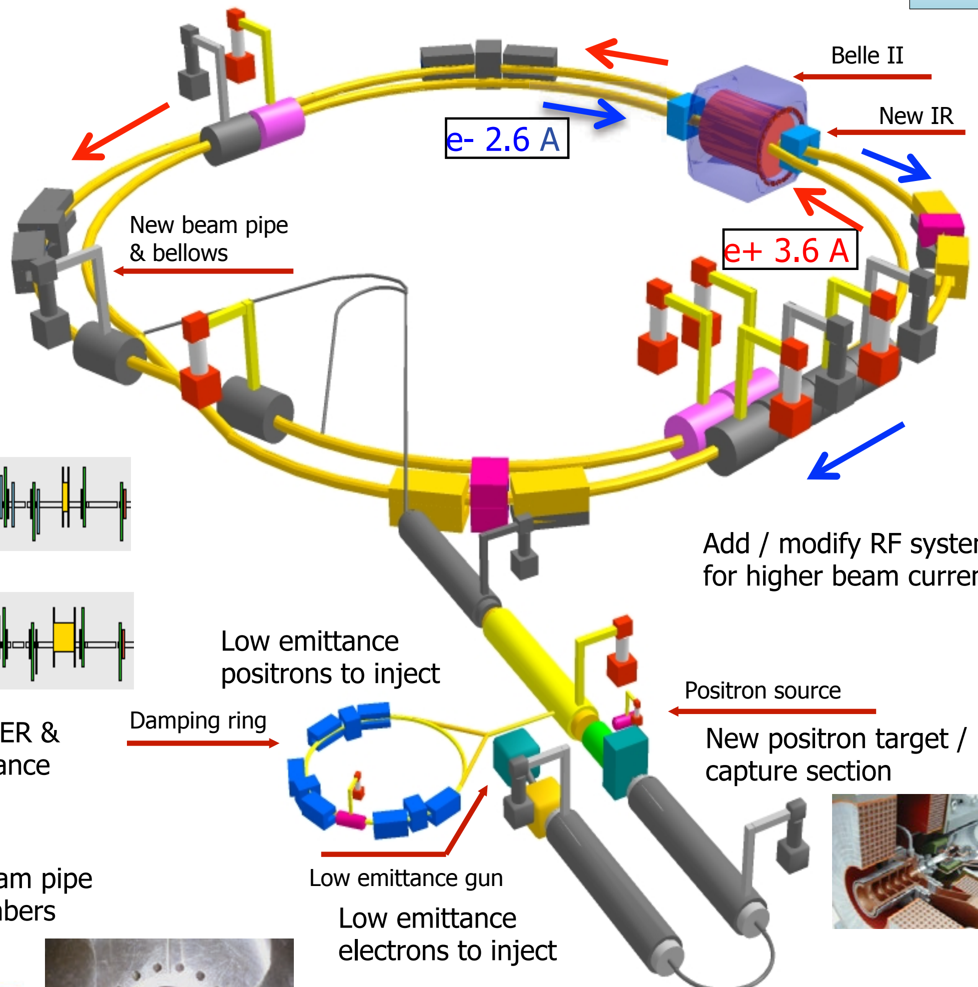
Grey is recycled, coloured is new

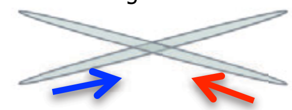


Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance



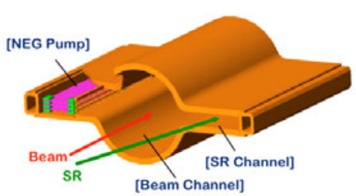


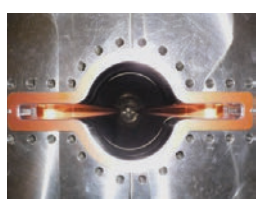
New superconducting / permanent final focusing quads near the IP

Add / modify RF systems for higher beam current

New positron target / capture section

TiN-coated beam pipe with antechambers





To get 40x higher luminosity

SuperKEKB Commissioning

Phase I (2016)

- Circulate both beams, no collisions. Tune accelerator optics, etc. Vacuum scrub. Beam studies. No Belle II.

Phase II (2018)

- First collisions. Develop beam abort. Tune accelerator optics, etc. (nano-beam). Beam studies. Belle II (w/o vertex detectors).

Commissioning Requirements

SuperKEKB

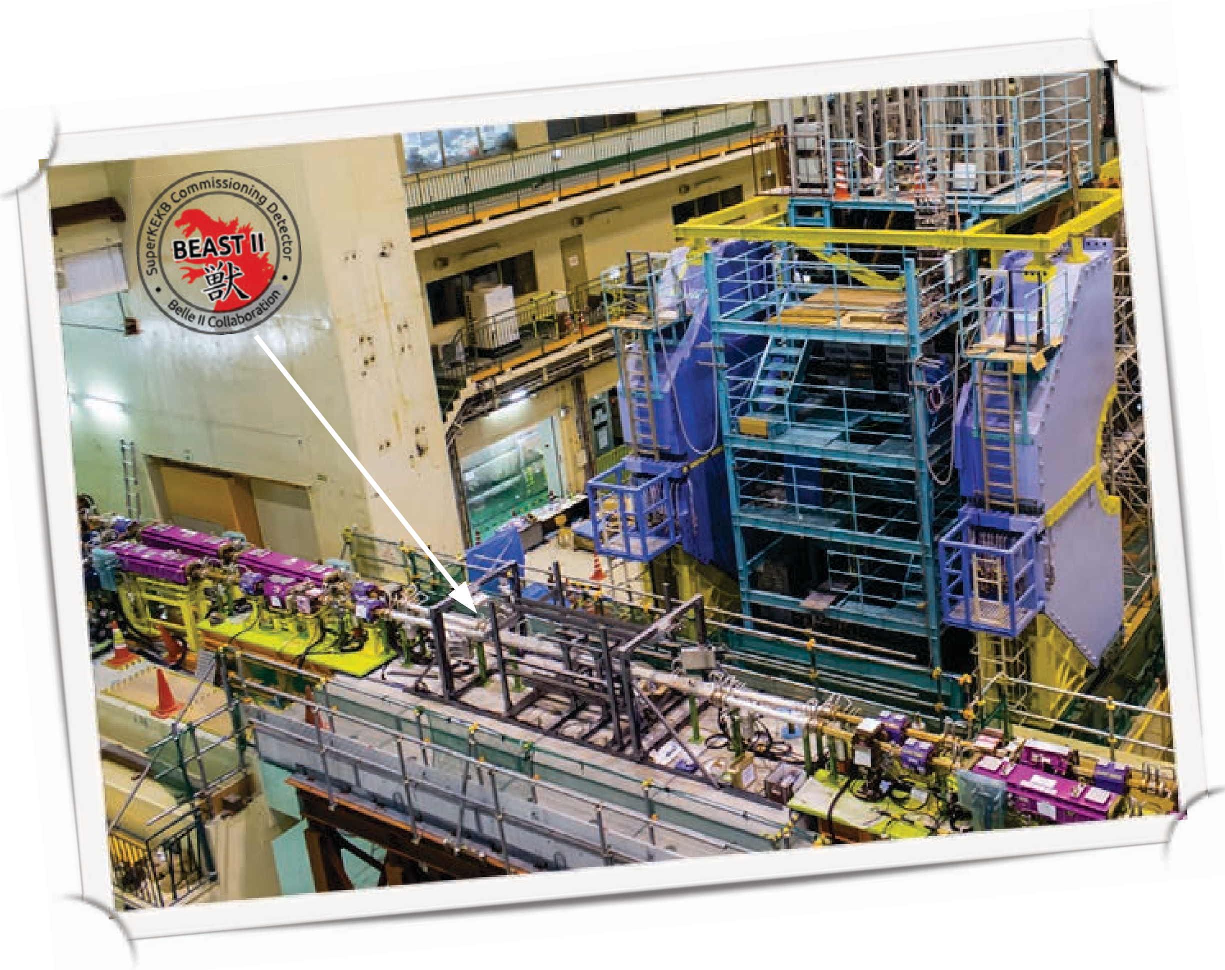
- Real-time monitoring of beam conditions
- Quantify effects of tuning, collimators, etc., on beam loss
- Isolate the type and source of beam loss
- Inform beam loss simulations to optimise performance

Belle II

- Guarantee a safe-enough radiation environment for Belle II
- Mitigate beam backgrounds (with physical shielding, electronic gating, magnet tuning, etc.) around IP
- Inform beam background simulations so they are properly accounted for in physics analysis

BEAST II - phase 1

Beam **E**xorcisms for **A** **St**able Belle II Experiment



Detector Systems

System	Detectors Installed	Unique Measurement
PIN Diodes	64/64	Neutral vs charged radiation dose
Diamonds	4/4	ionizing radiation dose
Micro-TPCs	2/2	fast neutron flux++
He-3 tubes	4/4	thermal neutron flux
Crystals	6/6 CsI(Tl) 6/6 CsI 6/6/ LYSO	EM energy spectrum
BGO	8/8	luminosity
“CLAWS” Scintillator	8/8	Injection backgrounds

Expected SuperKEKB Backgrounds

Phase I (no collisions)

***Touschek* scattering:**

- intra-bunch scattering process
- dominant with highly compressed beams
- 20 times higher

Beam-gas scattering:

- Bremsstrahlung (negligible) & Coulomb interactions (up to 100 times higher) with residual gas atoms & molecules

Synchrotron radiation:

- emission of photons by charged particles (e^+e^-) when deflected in *B*-field

Phase 2 (collisions)

***Radiative Bhabha* process:**

photon emission prior or after *Bhabha* scattering

interaction with iron in the magnets leads to neutron background

***Two photon* process:**

- very low momentum e^+e^- pairs via $e^+e^- \rightarrow e^+e^-e^+e^-$
- increased hit occupancy in inner detectors

Injection Background:

- covered later in the talk

Testing background heuristic model

Beam-Gas & Touschek

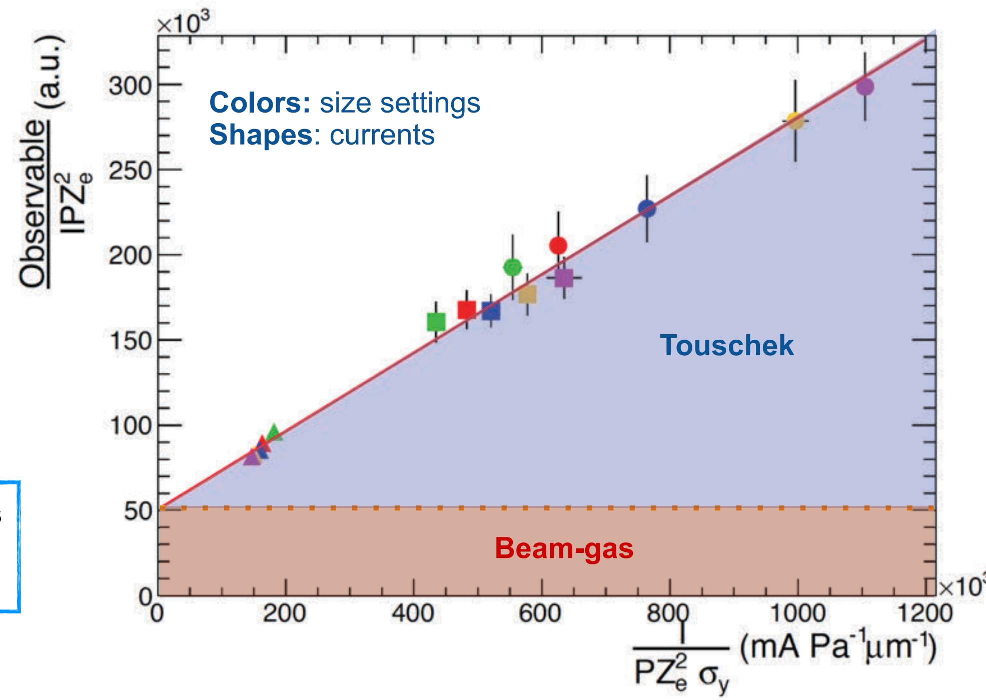
$$Observable = B \cdot IPZ_e^2 + T \cdot \frac{I^2}{\sigma_y}$$

- Size-sweep (5 runs) and current (3 runs) scan
- Observable comes from BGO crystals
- Rewrite so beam-gas is flat:

$$\frac{Observable}{IPZ_e^2} = B + T \cdot \frac{I}{PZ_e^2 \sigma_y}$$

- Quality of linear fit validates model
- Fit measures sensitivities B (offset) and T (slope)

Ze: an “effective” atomic number of the gas mixture in the pipe, recorded by a residual gas analyser



Good agreement with the model!

However, MC and data do not agree (yet) when comparing different detector data. We understand some of the disagreements, but not all of it. This is good, it proves we needed BEAST!

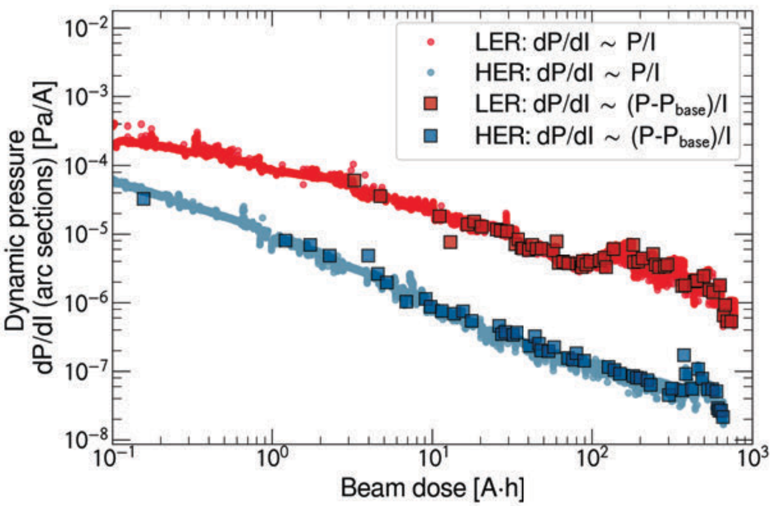
Ongoing work to refine our understanding of SuperKEKB, BEAST and simulation for phase II

Beam scrubbing in phase1

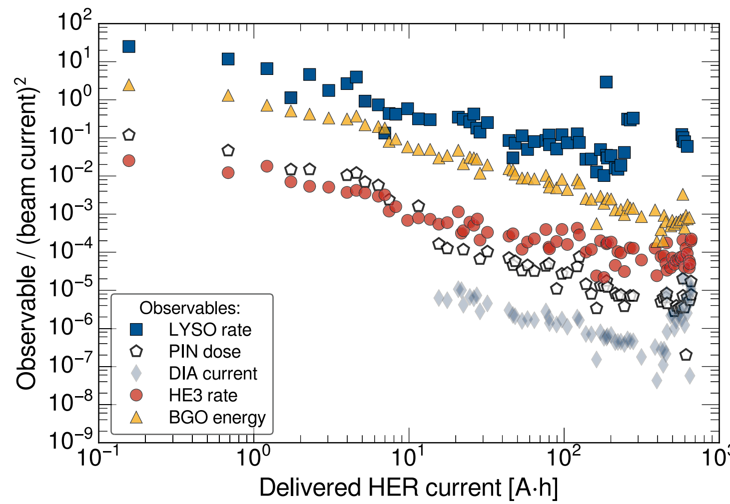
Cleaning a new beam pipe

- A key goal of phase 1 was to "scrub" the beam pipes
  - High currents stimulate desorption of impurities from beam pipe walls
  - Over time, **vacuum improves** lowering beam-gas backgrounds
- BEAST quantified distinct improvements in beam-gas in phase 1
- Scrubbing not yet at final physics run quality

SuperKEKB measurements of dP/dI vs integrated current

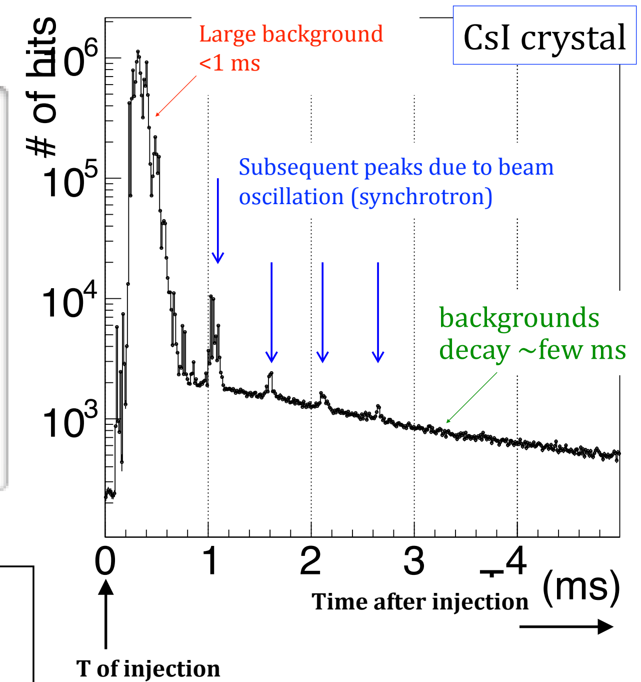


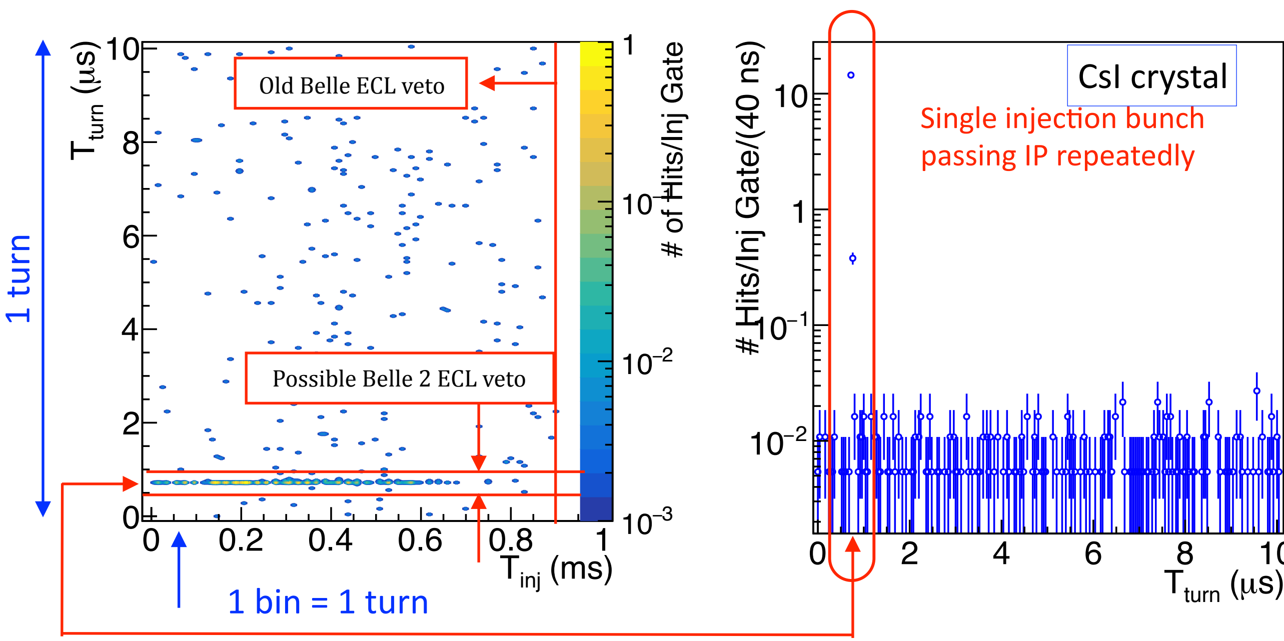
BEAST measurements of Rates/I^2 vs integrated current



BEAST II - Phase 1: injection background

- Continuos injection @ 100 Hz during B-factory operation
  - Belle injection ECL DAQ veto scheme would produce 10% dead time!
  - → Study background time structure
- Injection perturbs the orbit parameters of (almost) only the injected bunch
  - → High backgrounds lasting few ms after injection are highly correlated in time with the injected bunch



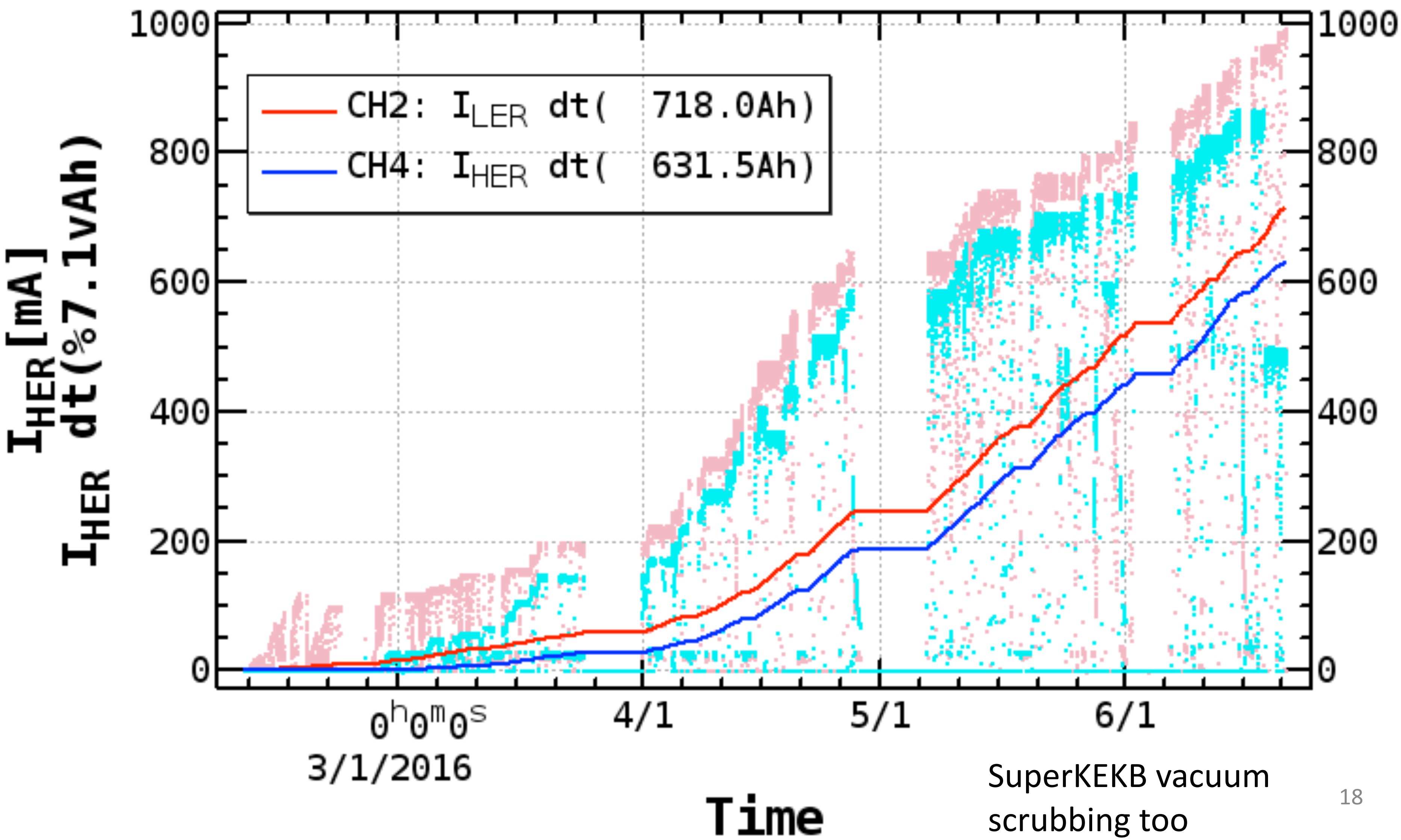


Run #	Data (# of turns)	Simulation (# of turns)
14	52.5±0.5	52.3
3	53.1±1.4	53.3
10	40.6±0.7	40.6
9	41.7±1.0	42.4

Table 26: Measured values of the synchrotron oscillation period obtained from injection background data. The measurement is compared with those obtained from a tracking-based, simulation of the beam orbits, using for the machine parameters the same values in use during each run.

LER 1000mA達成！！！

June 21, 2016: LER beam current exceeded **1 Ampere**



SuperKEKB vacuum
scrubbing too

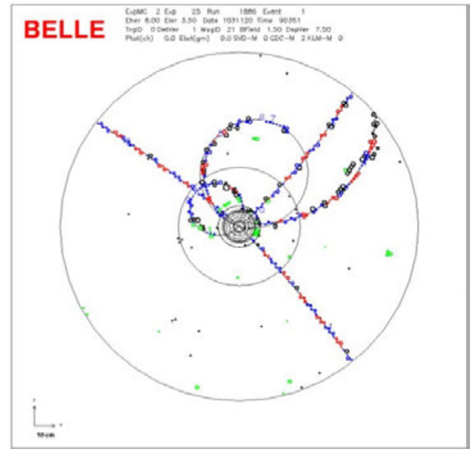
Startup of SuperKEKB (3 months)

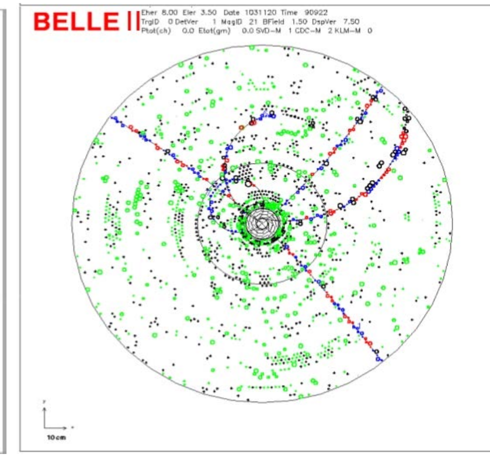
Y. Funakoshi, June '16 B2GM

- Much faster startup than KEKB
  - KEKB beam currents achieved after first 3 months
    - LER: ~300mA, HER: ~200mA (540mA, 300mA: 4 months)
  - SuperKEKB beam currents achieved after first 3 months
    - LER: ~650mA, HER: ~590mA (820mA, 740mA: 4 months)
- Compared with KEKB…
  - Each hardware component has been upgraded with experiences at KEK and has worked fine (RF, Magnet, Vacuum...)
  - The bunch-by-bunch feedback system has more effectively suppressed instabilities.
  - Operational tools (such as closed orbit correction system) has worked fine based on experiences at KEKB.
  - Less machine troubles than KEKB so far

Belle II detector upgrade

Background increase x factor 10–20





Factor x40 luminosity also brings in:

- Higher occupancy, pile-up, fake hits
- increased trigger and DAQ rates
- radiation damage

Upgrade the detector

- starting point is the Belle detector
- in practice, reuse the crystal CsI(Tl) calorimeter, the solenoid, the KLM barrel detector

Table 22: Beam background types (12th background campaign).

type	source	rate [MHz]
radiative Bhabha	HER	1320
radiative Bhabha	LER	1294
radiative Bhabha (wide angle)	HER	40
radiative Bhabha (wide angle)	LER	85
Touschek scattering	HER	31
Touschek scattering	LER	83
beam-gas interactions	HER	1
beam-gas interactions	LER	156
two-photon QED	-	206

← Total rates from simulation

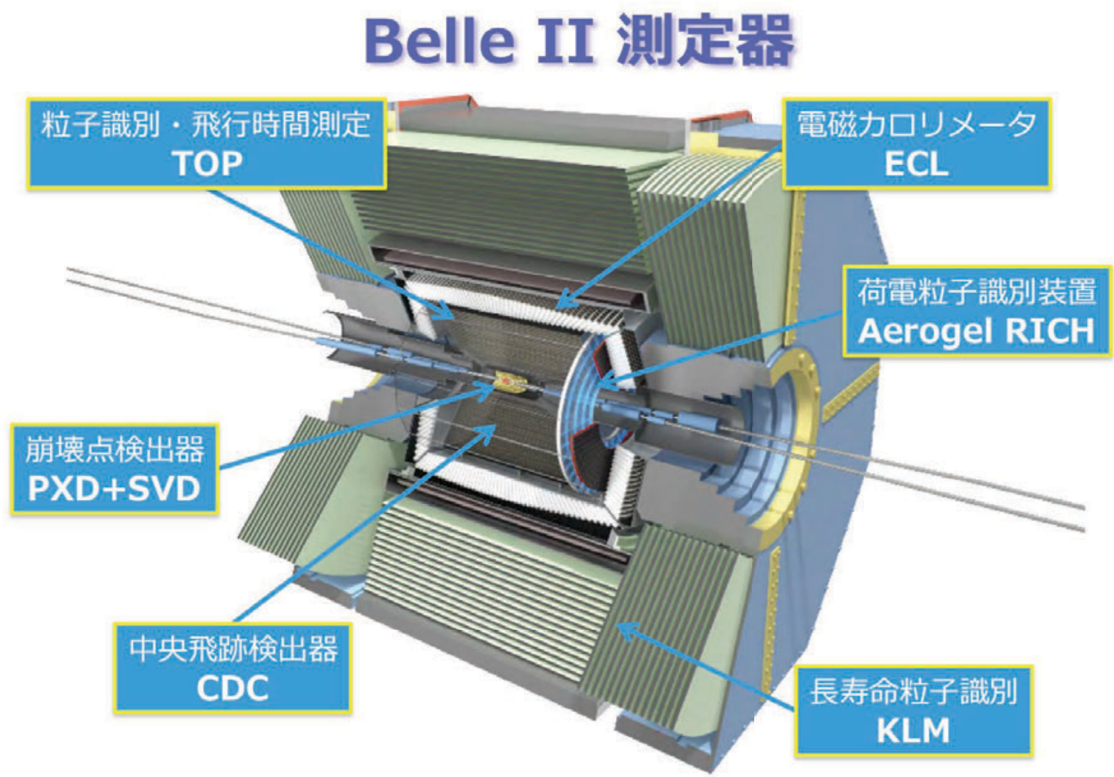
Total number of hits per event in each sub-detector

component	background	generic $B\overline{B}$
PXD	10000 (580)∗	23
SVD	284 (134)	108
CDC	654	810
TOP	150	205
ARICH	191	188
ECL	3470	510
BKLM	484	33
EKLM	142	34

* in parentheses numbers without 2-γ QED

Backgrounds are ~ x20 Belle

Belle II detector upgrade

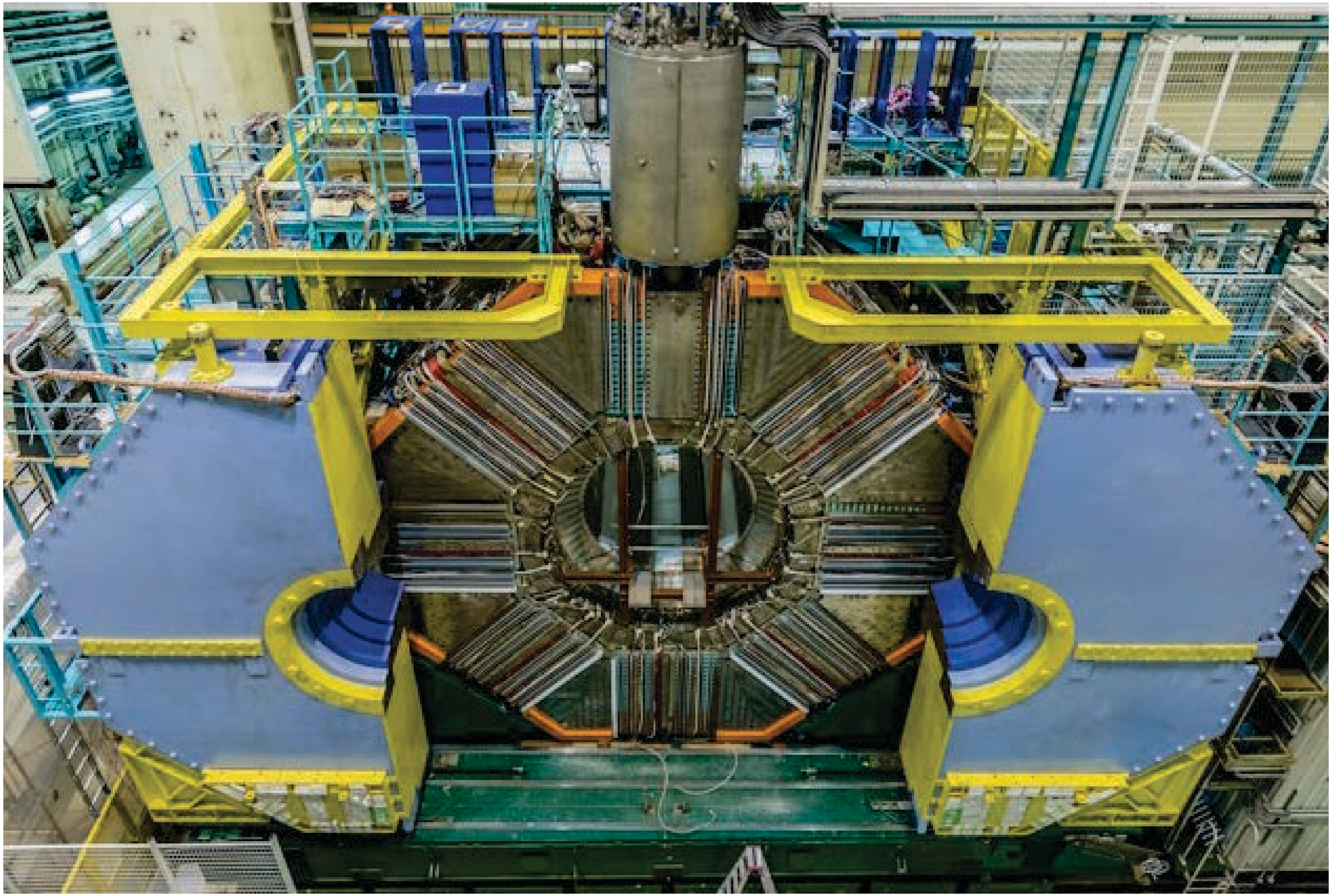


- Fast signal shaping and waveform fit of e.m. calorimeter signals to preserve excellent energy resolution in high-pileup environment
- Increase K_S efficiency by ~30%)
- Improve IP and secondary vertex resolution (~factor 2)
- Better K/π separation (π fake rate decreases by ~2.5)
- Improve π^0 reconstruction

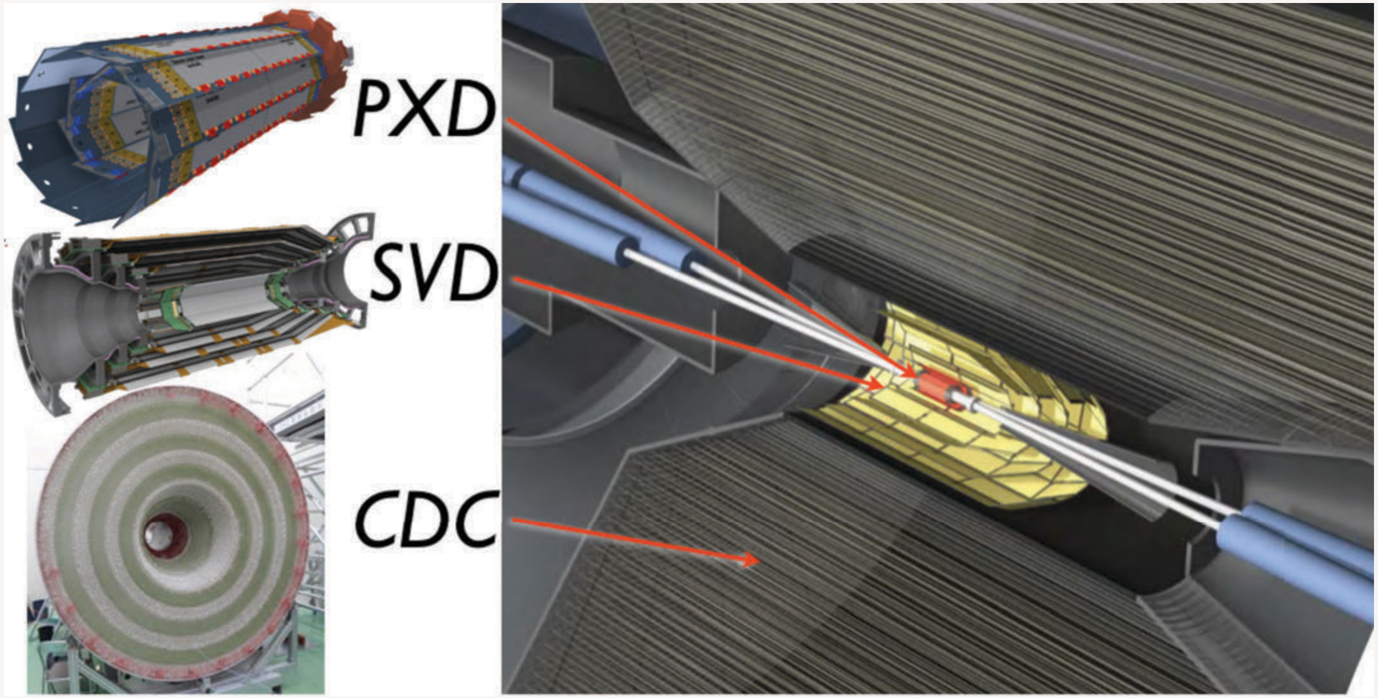
In the end, a better detector than Belle, in a harsher environment

Reduced boost (0.44 ⟶0.28) yields better hermeticity for rare searches

Highlights of Belle II construction and commissioning

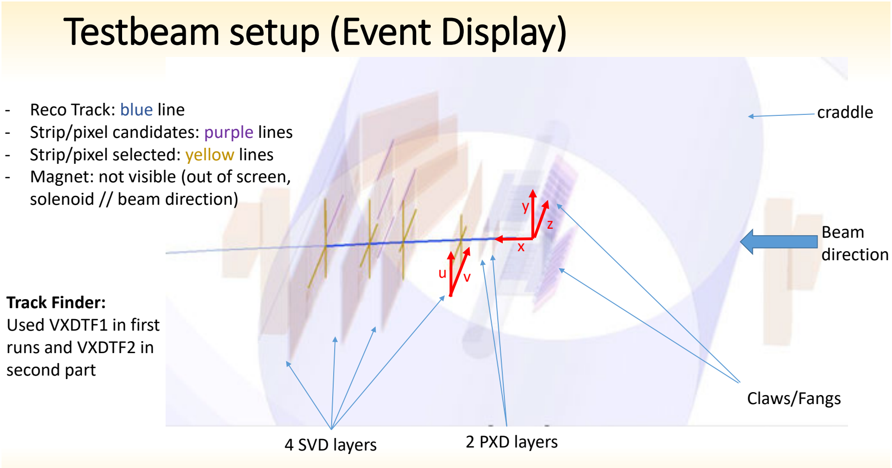


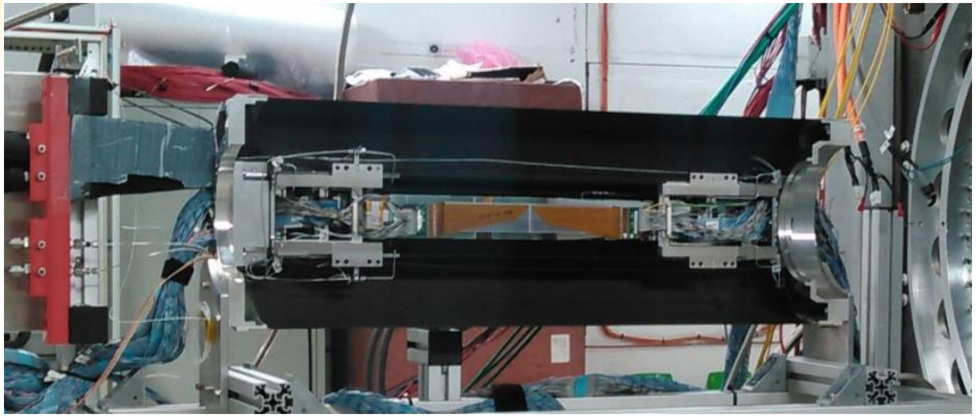
The tracking system



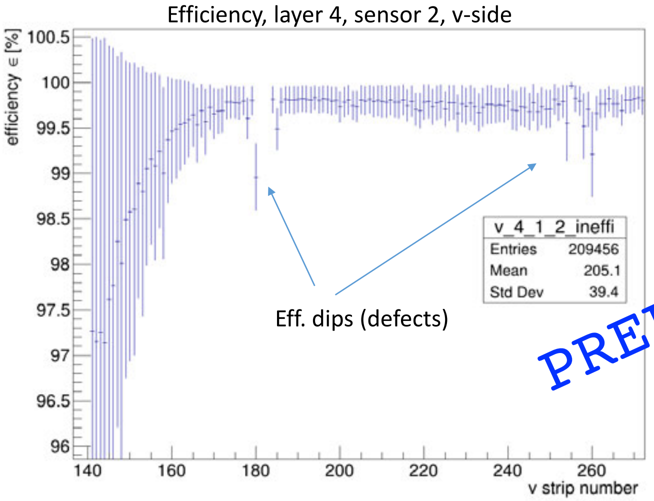
Component	Type	Configuration	Readout	Performance
Beam pipe	Beryllium double-wall	Cylindrical, inner radius 10 mm, 10 μm Au, 0.6 mm Be, 1 mm coolant (paraffin), 0.4 mm Be		
PXD	Silicon pixel (DEPFET)	Sensor size: 15×100 (120) mm^2 pixel size: 50×50 (75) μm^2 2 layers: 8 (12) sensors	10 M	impact parameter resolution $\sigma_{z_0} \sim 20\ \mu$m (PXD and SVD)
SVD	Double sided Silicon strip	Sensors: rectangular and trapezoidal Strip pitch: 50(p)/160(n) - 75(p)/240(n) μm 4 layers: 16/30/56/85 sensors	245 k	
CDC	Small cell drift chamber	56 layers, 32 axial, 24 stereo r = 16 - 112 cm - 83 $\leq z \leq$ 159 cm	14 k	$\sigma_{r\phi} = 100\ \mu$m, $\sigma_z = 2$ mm $\sigma_{p_t}/p_t = \sqrt{(0.2\% p_t)^2 + (0.3\%/\beta)^2}$ $\sigma_{p_t}/p_t = \sqrt{(0.1\% p_t)^2 + (0.3\%/\beta)^2}$ (with SVD)

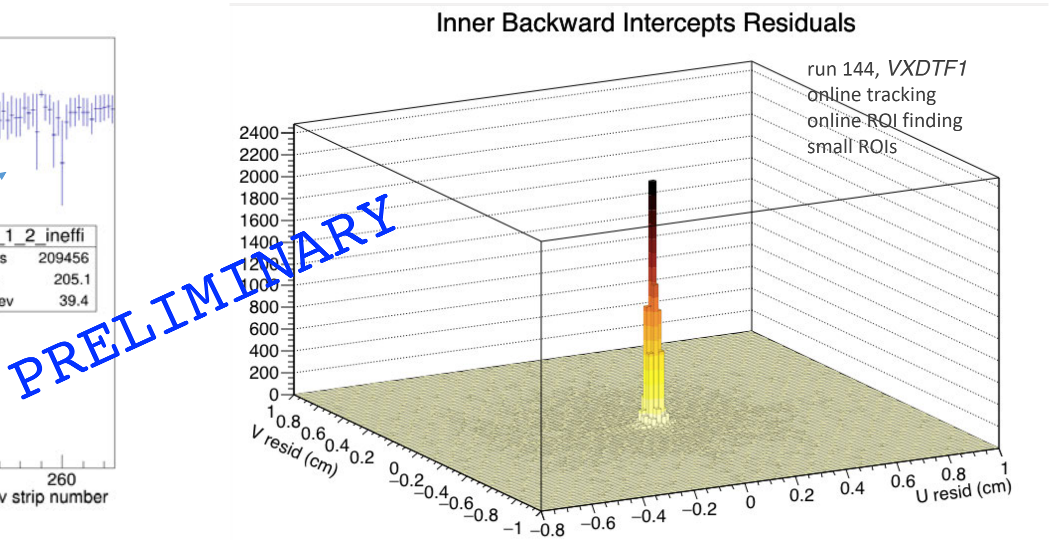
Combined PXD+SVD beam test at DESY



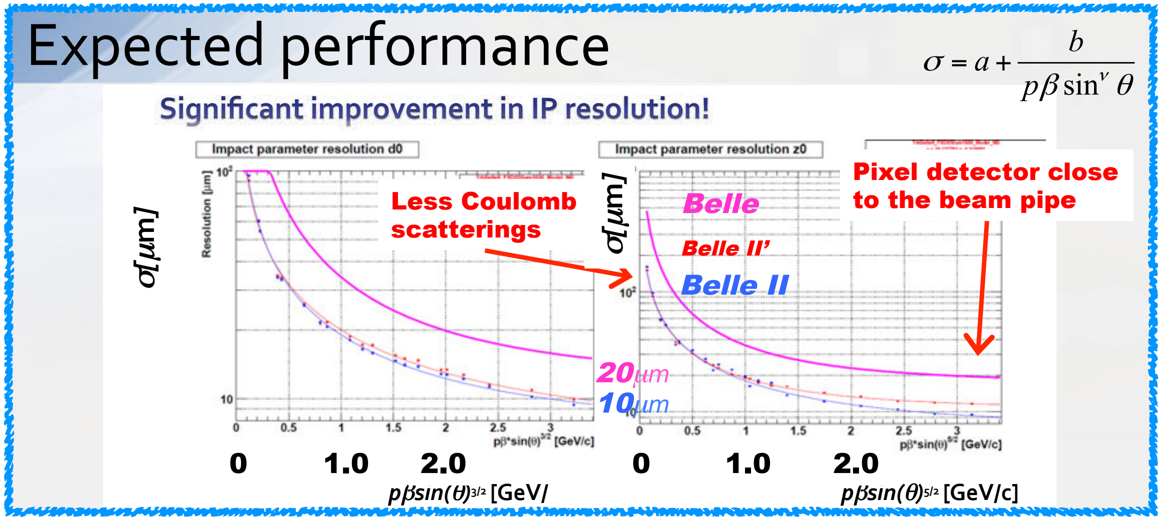


- Measure efficiency and resolution, test Region Of Interest PXD readout scheme on HLT module (online!), test new track-finding algorithm

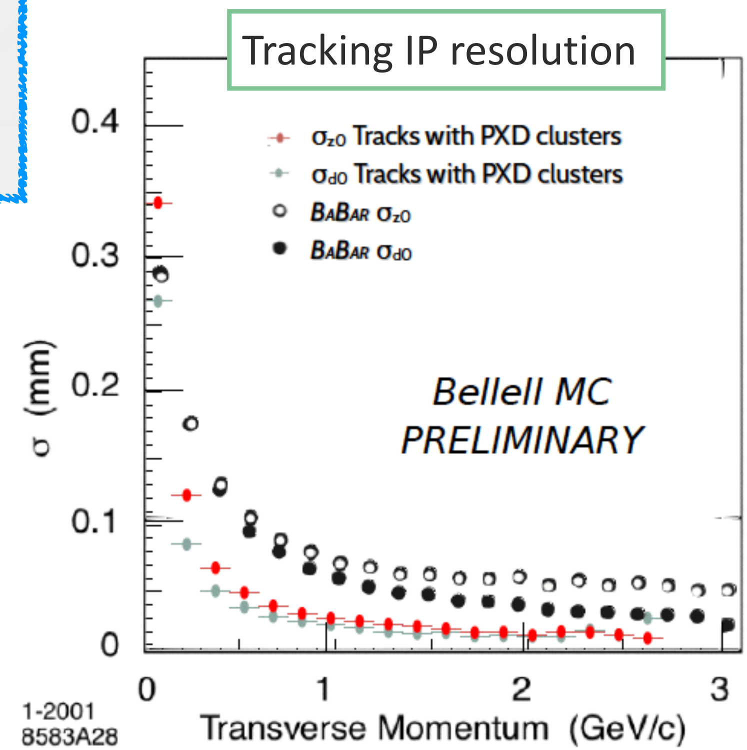




Improvements of vertex detector



Y. Ushiroda, ICHEP 2010

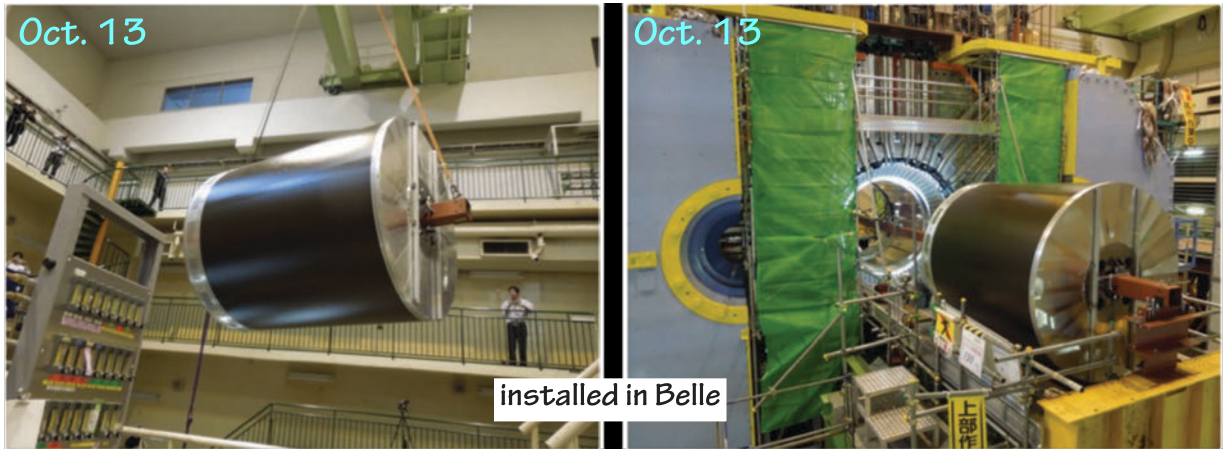


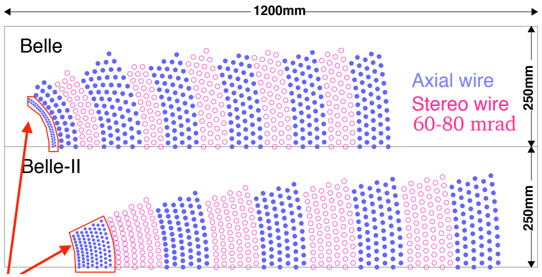
Feb. 2016 BPAC

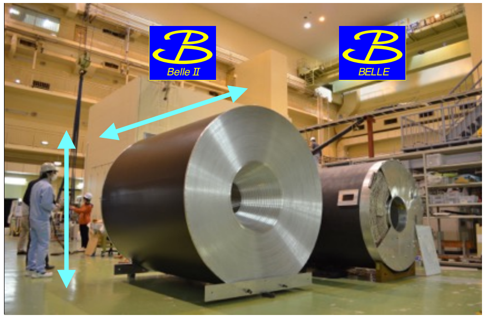
- Extrapolations of detector performance confirmed after beam-test results, and realistic software implementation
- Currently, in spite of $\langle\beta\gamma\rangle^{\text{Belle II}} = 28/44 \cdot \langle\beta\gamma\rangle^{\text{Belle}}$

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

The Central Drift Chamber (CDC)

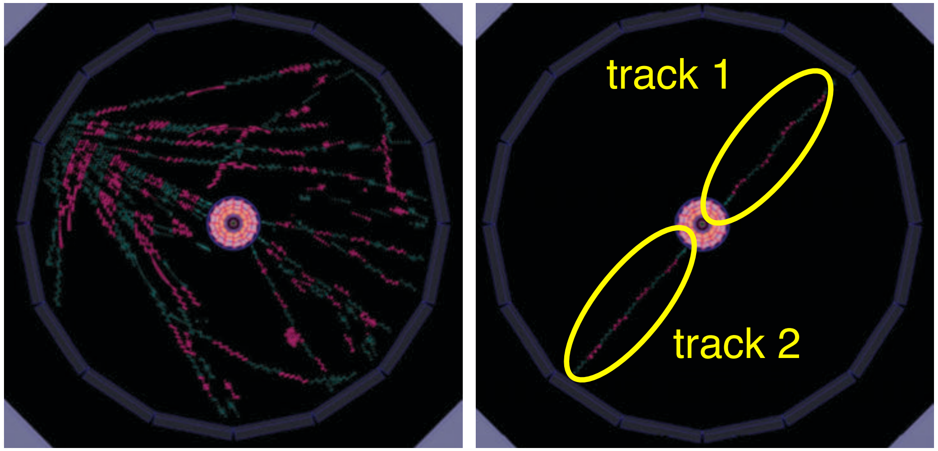


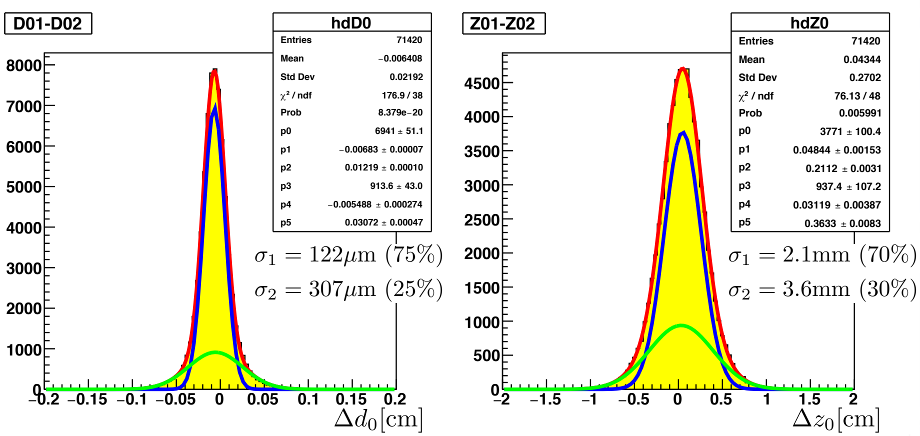




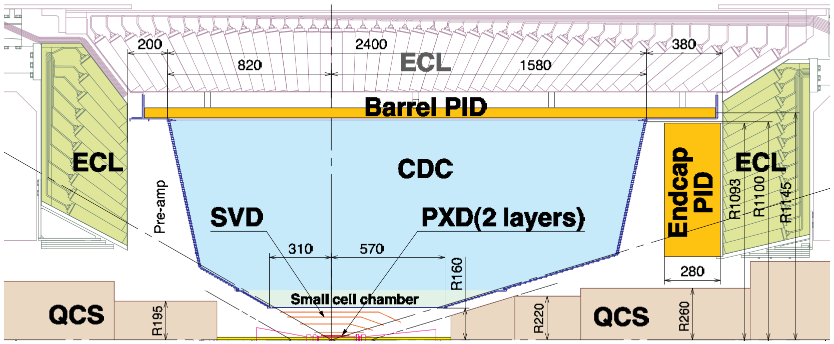
- Installed Oct, 2016

- Commissioning with cosmic ray tracks is ongoing



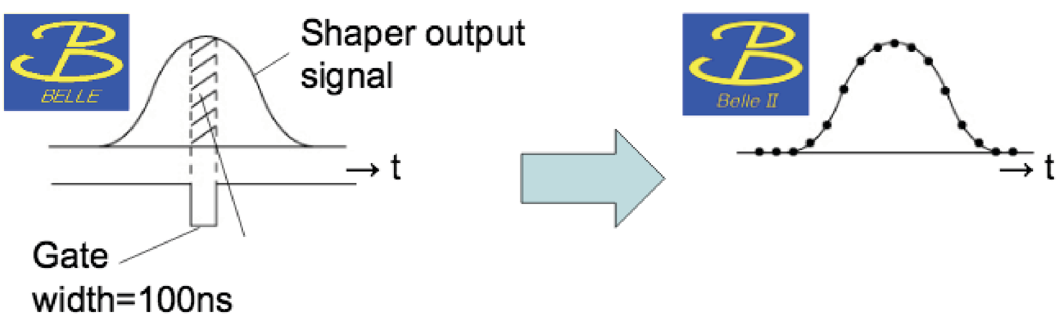


Electromagnetic calorimeter (ECL)

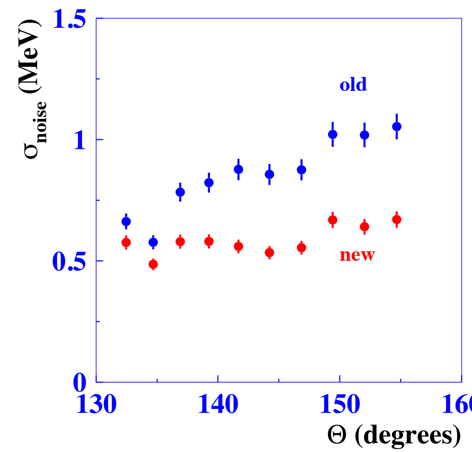


Belle calorimeter: 8736 CsI(Tl) crystals
6624 Barrel
1152 Fwd Endcap
960 Bwd Endcap

- High rates (machine+physics) ⇒ upgrade of electronics
  - shorter signal shaping (1µs —> 500ns)
  - the waveform is sampled (~2MHz)
  - waveform fit to extract signal time and amplitude



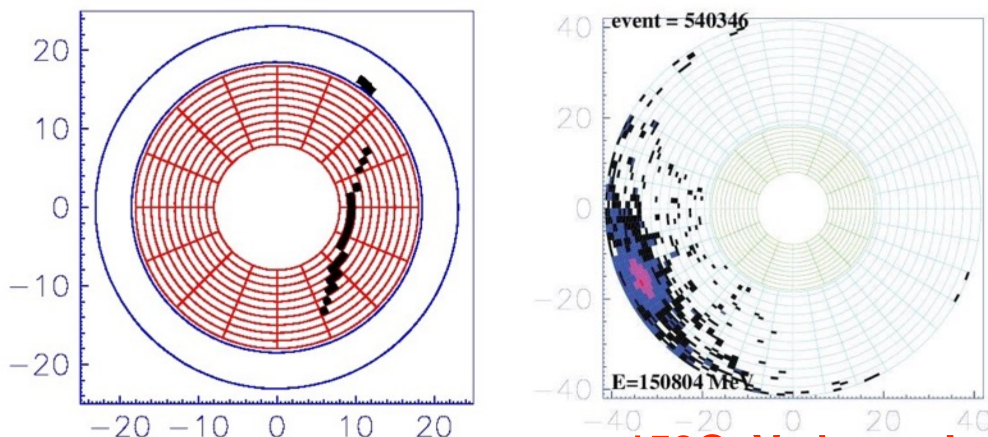
Early prototype tested at Belle



ECL commissioning

Jan 2017
BWD endcap installation

Barrel ECL under CR test since 2015
Endcap calorimeter CR test ongoing



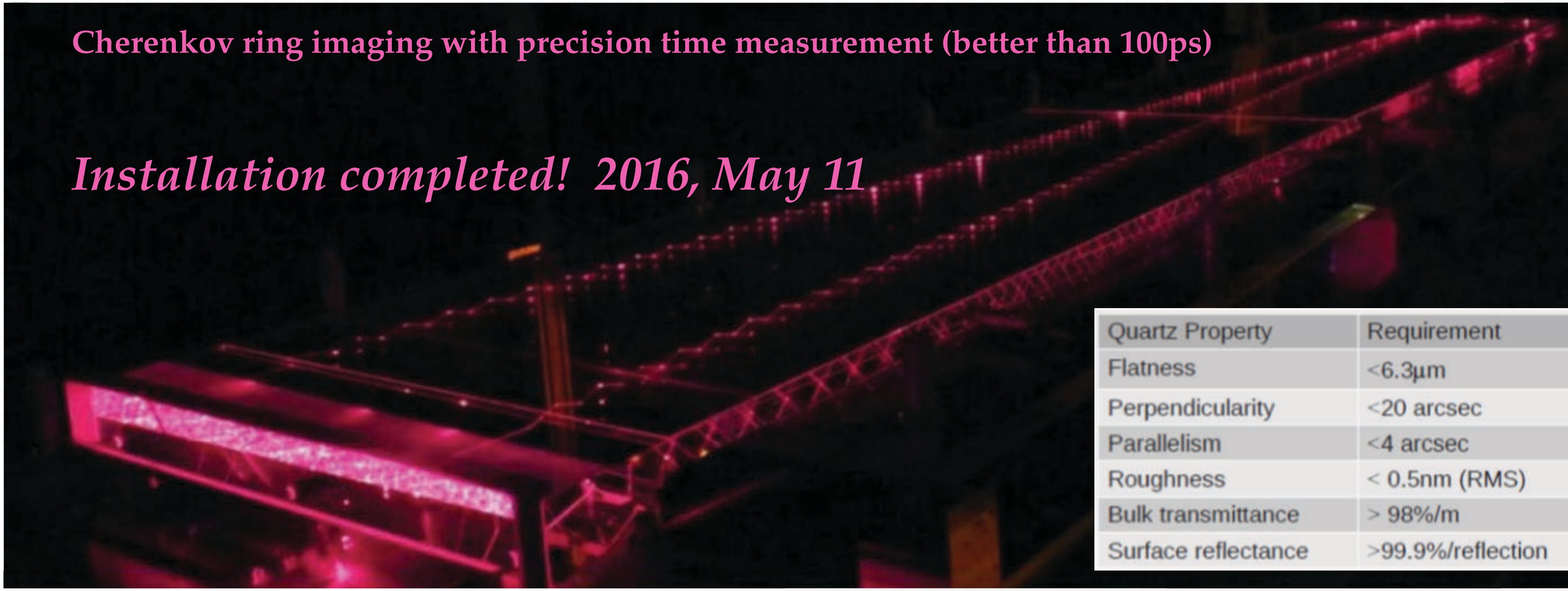
150GeV shower!

CDC-ECL cosmic ray test

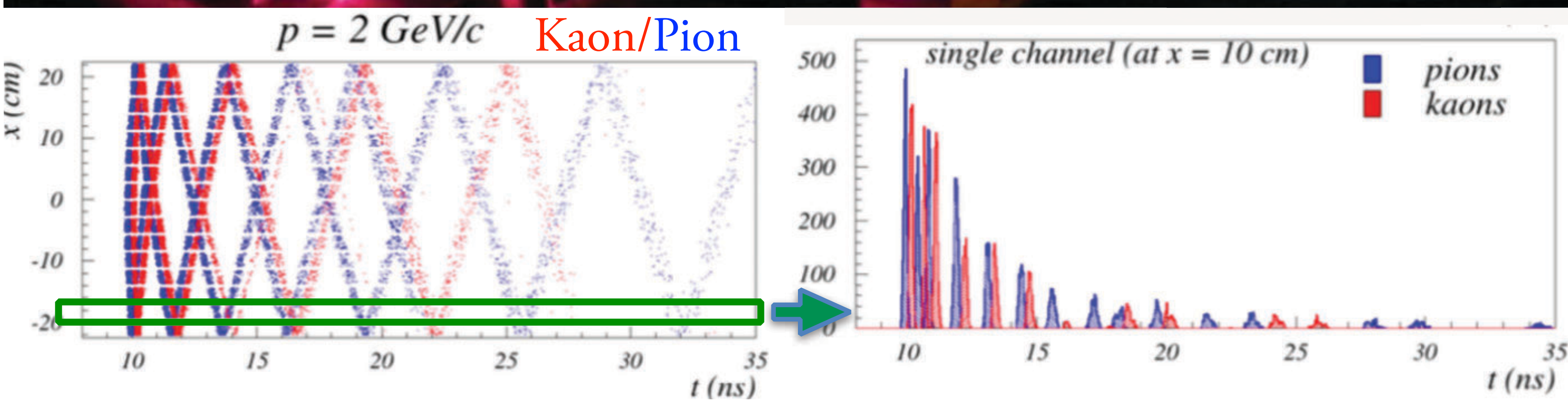
Barrel PID: Time Of Propagation (TOP)

Cherenkov ring imaging with precision time measurement (better than 100ps)

Installation completed! 2016, May 11



Quartz Property	Requirement
Flatness	<6.3μm
Perpendicularity	<20 arcsec
Parallelism	<4 arcsec
Roughness	< 0.5nm (RMS)
Bulk transmittance	> 98%/m
Surface reflectance	>99.9%/reflection



TOP: running the installed detector

Gain operational experience in 1.5 T B-field !

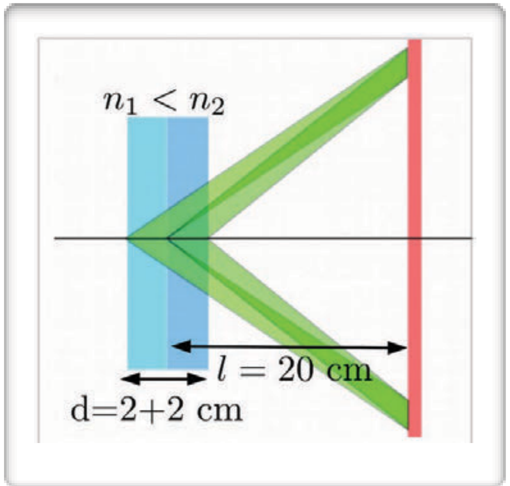
- Issue with PMTs discovered: PMT-MCPs use a magnetic Kovar (Cobalt-Nickel alloy)… and move with the B-field on!
- Repair to main issue completed (added shims between PMT and FE board to push PMTs in place).
- result of GEANT4 simulation of air gaps (different thickness) between quartz and PMT inserted in Belle II reconstruction for different fractions of affected PMTs ==> Effect on pion or K mis-id/efficiency very small
- Cause delay on global installation schedule

- High statistics laser/cosmic running for all modules with stable ASIC configuration completed, both with and without B-field to understand performance differences
- Significant progress on firmware, including the crucial feature extraction

Forward PID: the Aerogel RICH

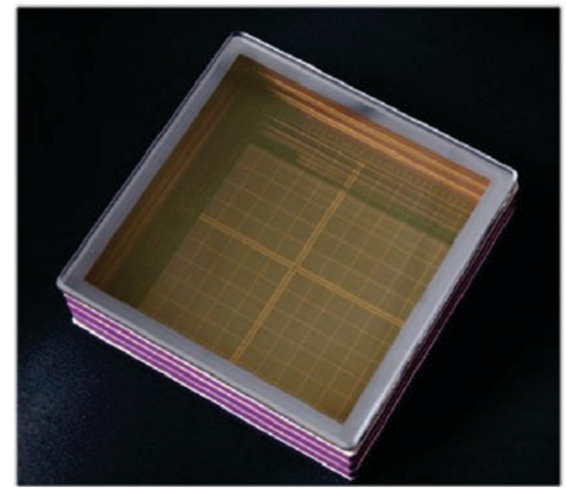
- Use two aerogel layers in focusing configuration to increase n. of photons without resolution degradation

$n_1 = 1.045,\ n_2 = 1.055$

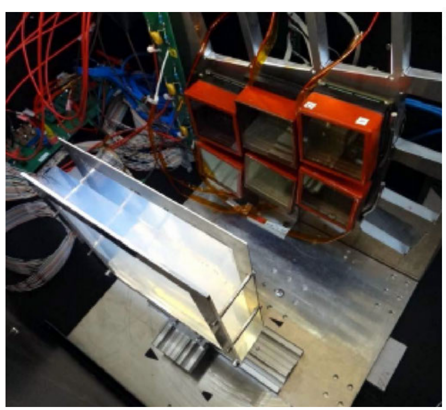


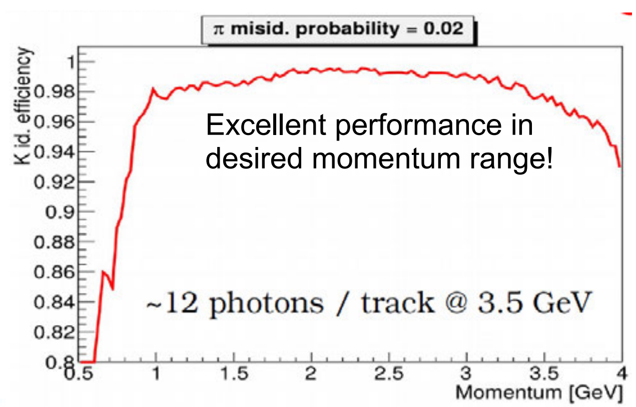
HAPD – Hybrid Avalanche Photo-Detector

- Developed in collaboration with Hamamatsu photonics
- Basic requirements: - 1.5 T - n,γ tolerance ($10^{12}\ n/\mathrm{cm}^2$)
- position resolution
- large coverage (3.5 m^2)



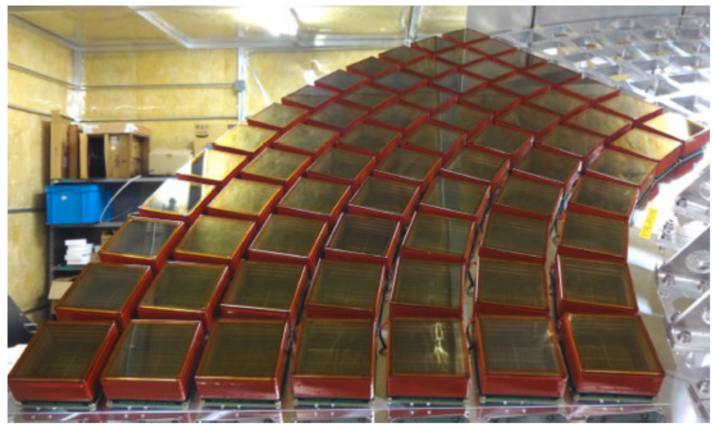
Beam test measurements

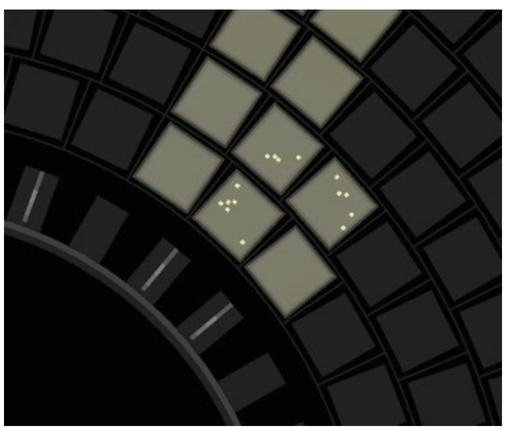




ARICH Rings from cosmic ray muons

First events from CR tracks recorded in a partially instrumented sector of the ARICH

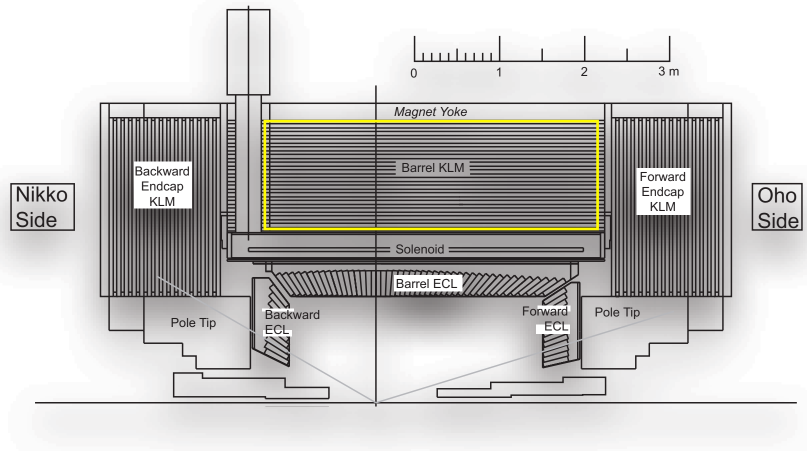




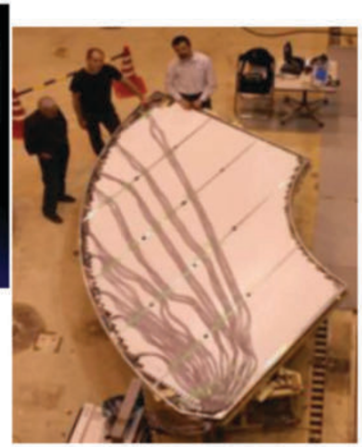
Production of aerogel tiles and HAPDs is finished. Expect to complete installation on the structure before July, and install in Belle II in September.

The KLong a Muon detector KLM

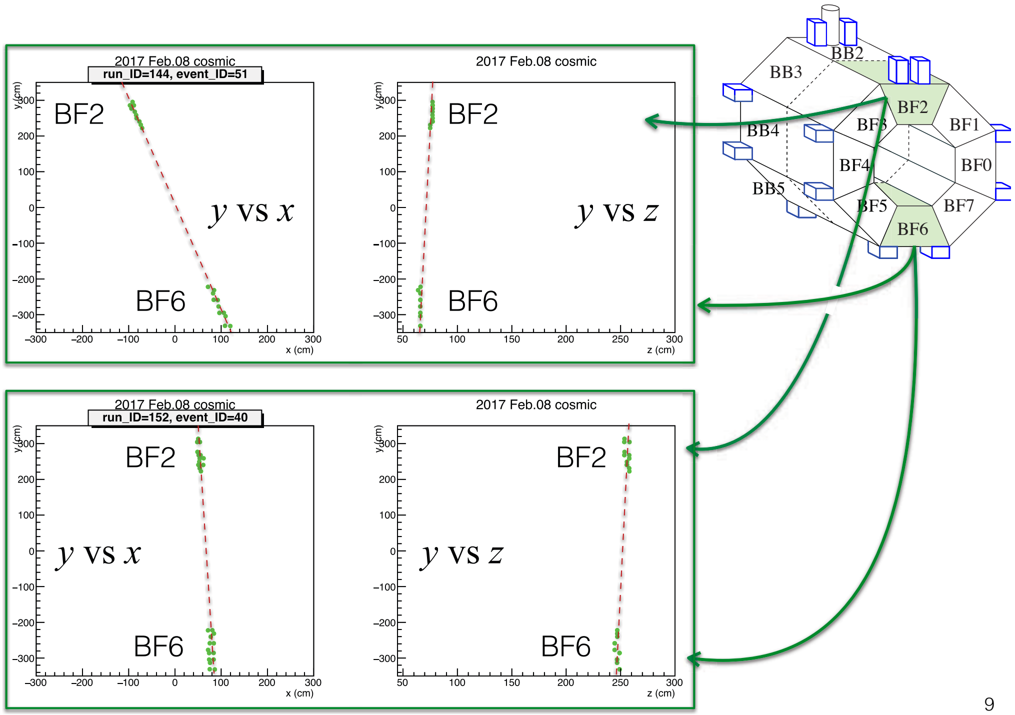
- 14 iron layers 4.7cm thick
- 15 barrel active layers
  - ✓ 2 x [scintillator strips + WLS + SiPM] ⇐ **NEW**
  - ✓ 13 x [double glass RPC + 5 cm orthogonal phi, z strips]
- 14 endcap active layers
  - ✓ 14 x [scintillator strips + WLS + SiPM] ⇐ **NEW**



- All endcap active layers + 2 innermost layers in barrel replaced with scintillator strips to resist neutron background
- Installation is complete
- Commissioning with cosmic rays ongoing



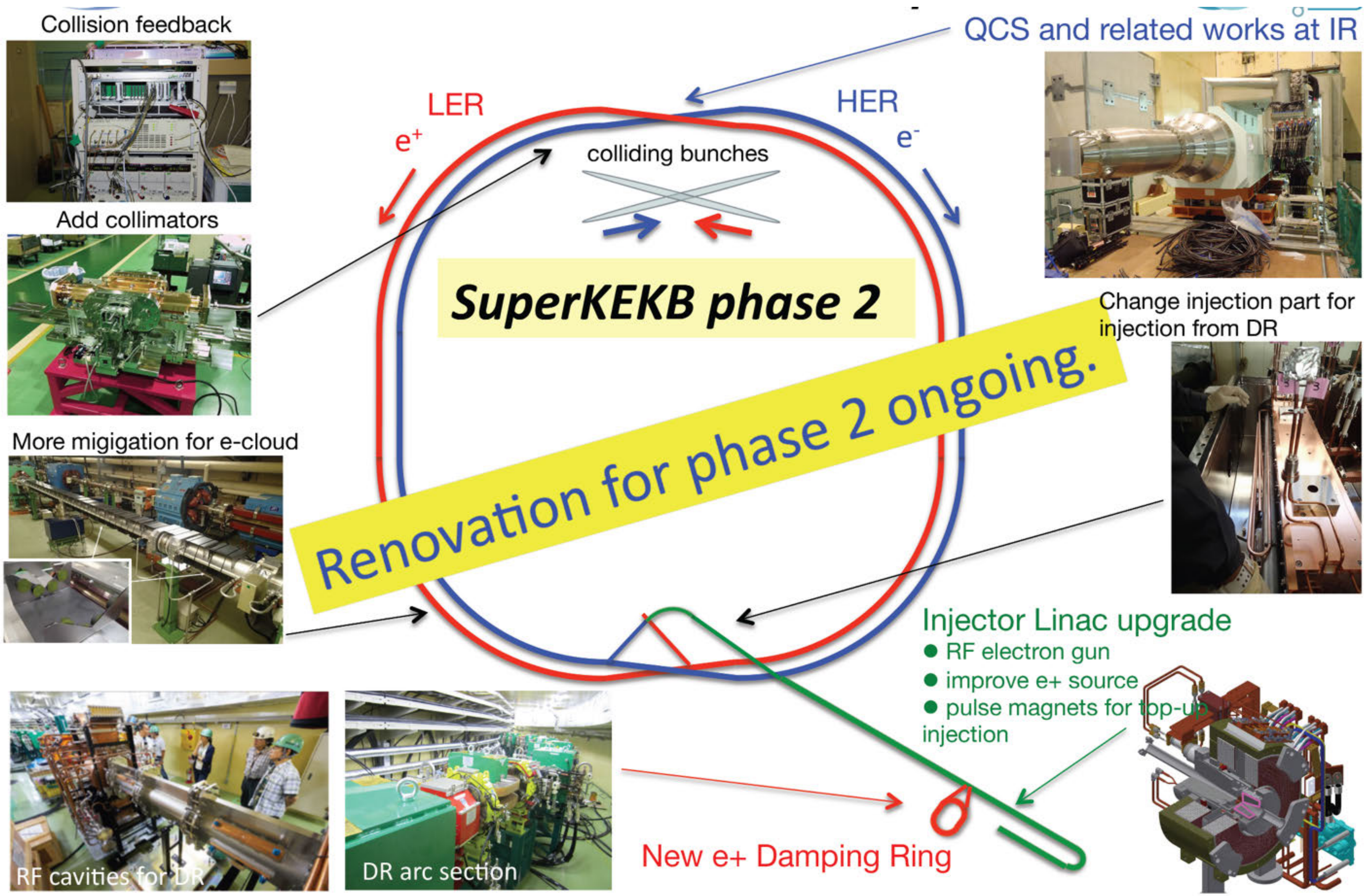
Barrel KLM commissioning



CR track fitted independently in the two sectors

Readout on all octants will be installed and commissioned by the Summer

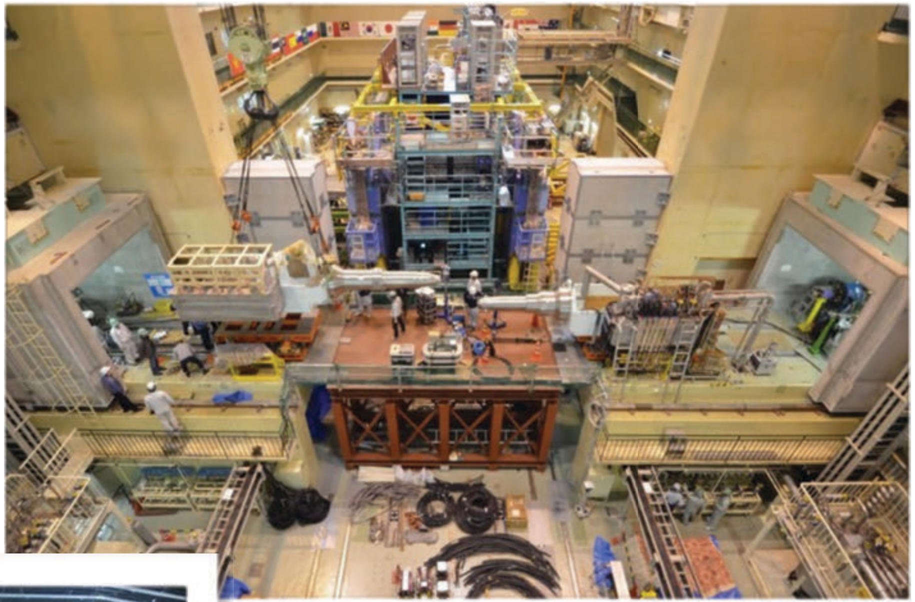
SuperKEKB: Preparations for Phase 2 Commissioning



Final focus magnets

Superconducting quadrupole magnets with 30+25 coils

The second one delivered on Feb 13



World's most complex SC final focus!

April 11, 2017 - Belle II Milestone!

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS
CERNCOURIER
VOLUME 57 NUMBER 5 JUNE 2017

FACILITIES

Belle II rolls in

On 11 April, the Belle II detector at the KEK laboratory in Japan was successfully "rolled-in" to the collision point of the upgraded SuperKEKB accelerator, marking an important milestone for the international B-physics community. The Belle II experiment is an international collaboration hosted by KEK in Tsukuba, Japan, with related physics goals to those of the LHCb experiment at CERN but in the pristine environment of electron–positron collisions. It will analyse copious quantities of B mesons to study CP violation and signs of physics beyond the Standard Model (*CERN Courier* September 2016 p32).

"Roll-in" involves moving the entire 8 m-tall, 1400 tonne Belle II detector system from its assembly area to the beam-collision point 13 m away. The detector is now integrated with SuperKEKB and all its seven subdetectors, except for the innermost vertex detector, are in place. The next step is to install the complex focusing magnets around the Belle II interaction point. SuperKEKB achieved its first turns in February, with operation of the main rings scheduled for early spring and phase-II "physics" operation by the end of 2018.

Compared to the previous Belle experiment, and thanks to major upgrades made to the former KEKB collider, Belle II will allow much larger data samples to be collected with much improved precision. "After six years of gruelling work with many unexpected twists and turns, it was a moving and gratifying experience for everyone on the team to watch the Belle II detector move to the interaction point," says Belle II spokesperson Tom Browder. "Flavour physics is now the focus of much attention and interest in the community and Belle II will play a critical role in the years to come."

KEK

The Belle II detector is now in place at the SuperKEKB facility in Japan.

Extra! Extra!

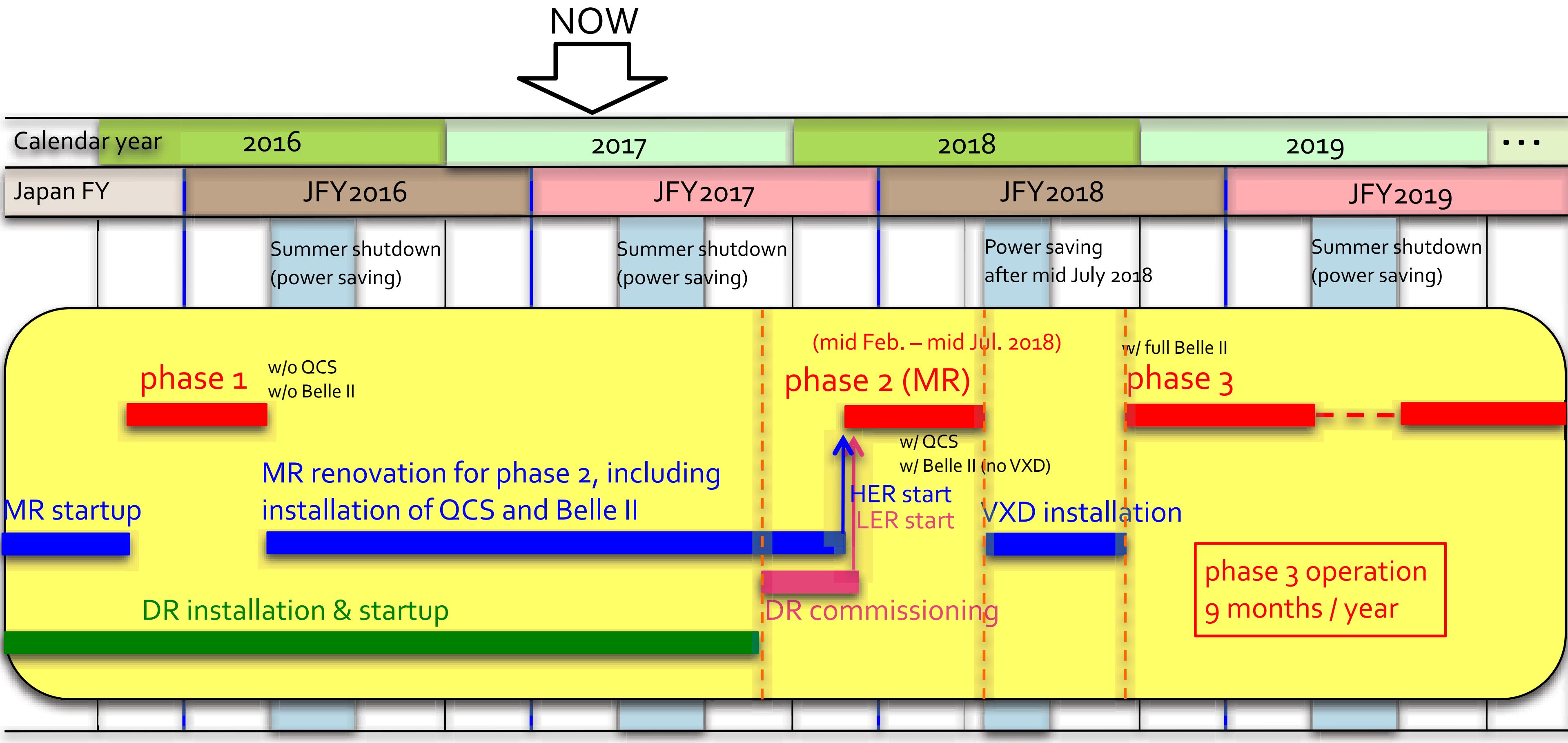
So, **when do we start** Belle II ?

So, **when do we start** Belle II ?

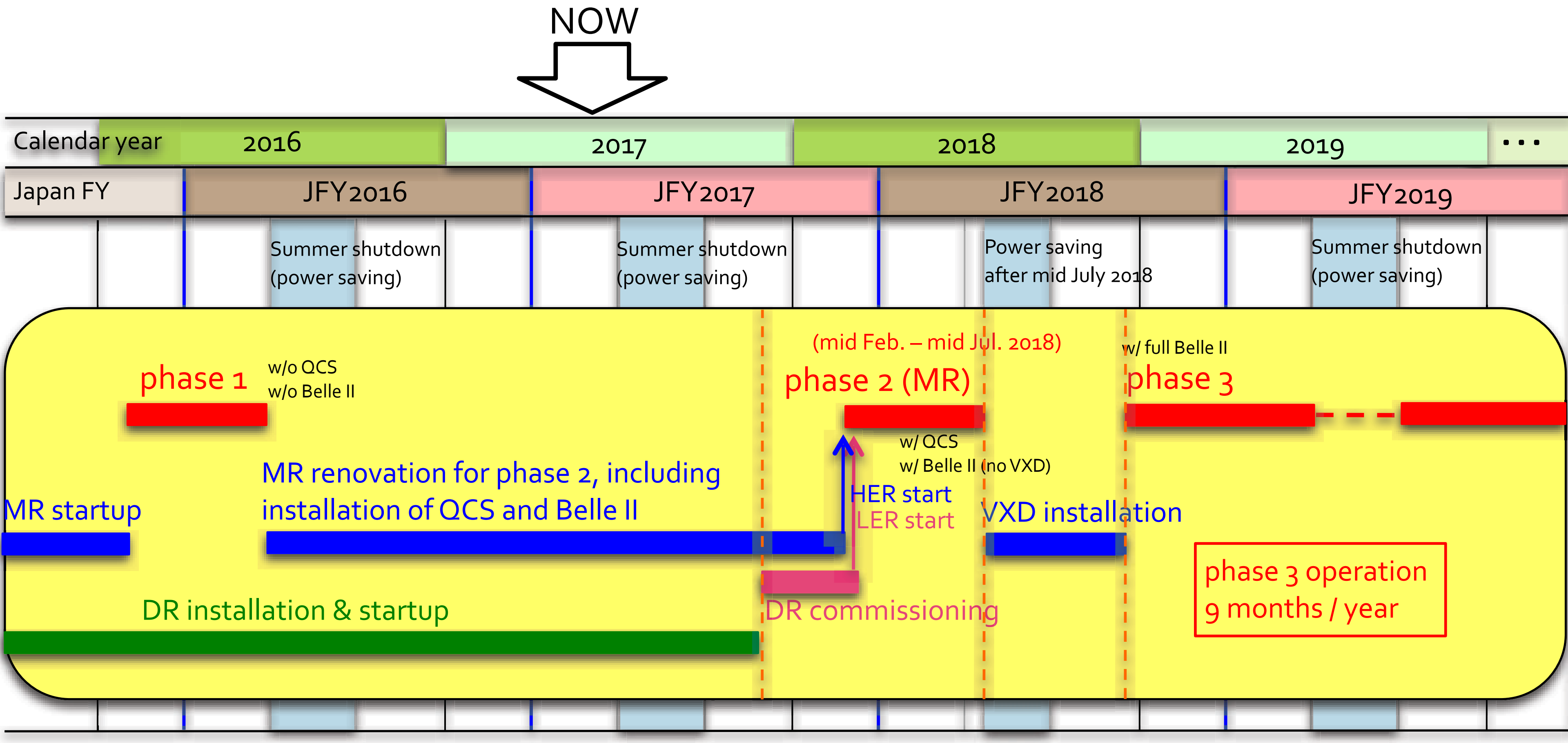
WHAT'S NEXT:

- June 2017: B-field measurement, global cosmic ray run
- September 2017: ARICH and forward ECL (+ commissioning vertex detector) installation
- Nov 2017 - Spring 2018: Phase 2 commissioning, with two main goals:
  - ✓ tune SuperKEKB with nanobeams - eventually reach KEKB design luminosity
  - ✓ ensure background levels are compatible with vertex detector operation
  - ✓ then, if compatible with the above, also do some physics without vertex detectors - at the Υ(6S)?
- Summer 2018: install vertex detectors
- End 2018: full detector operation - start of Physics run

SuperKEKB/Belle II schedule



SuperKEKB/Belle II schedule



ご清聴ありがとうございました

(GOSEICHOU ARIGATOU GOSAIMASHITA)

Backup slides

Target of Commissioning in Phase 2

Verification of Nano-Beam Scheme

Low Emittance with Large Piwinski Angle

Specific Luminosity, $L_{sp} > 4 \times 10^{31}$ [$cm^{-2}s^{-1}/mA^2$]

$L_{sp} = 1.7 \times 10^{31}$@KEKB

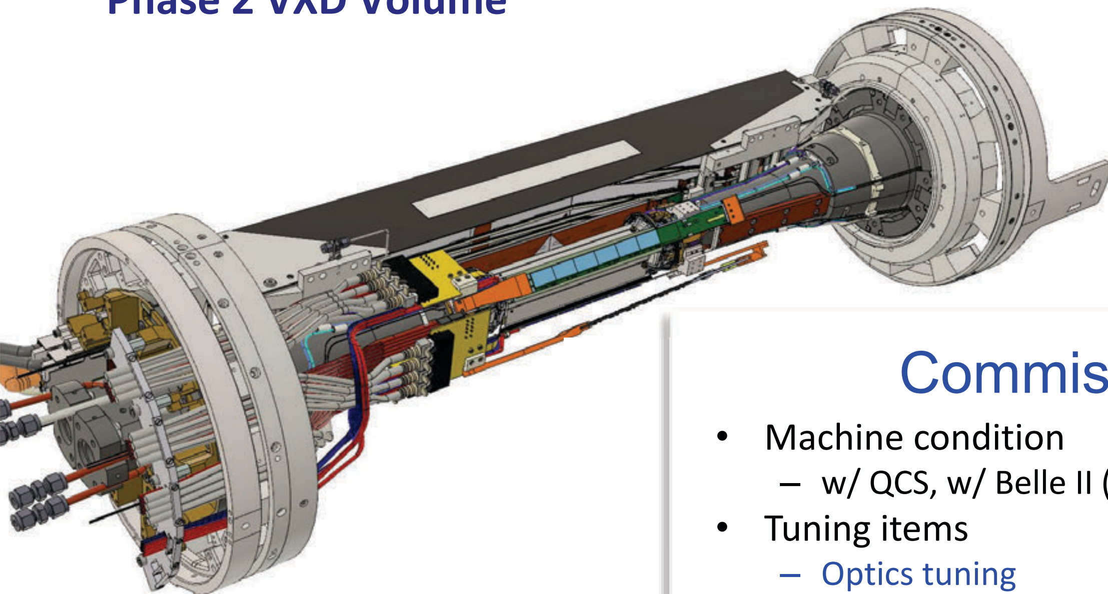
Beam-Beam Parameter, $\xi_y > 0.05$

Reduce **Beam Background** for Belle II detector
before we move on Phase 3

Phase-2 commissioning is only **5 months** from mid of February to mid of July.

BEAST II - Phase 2

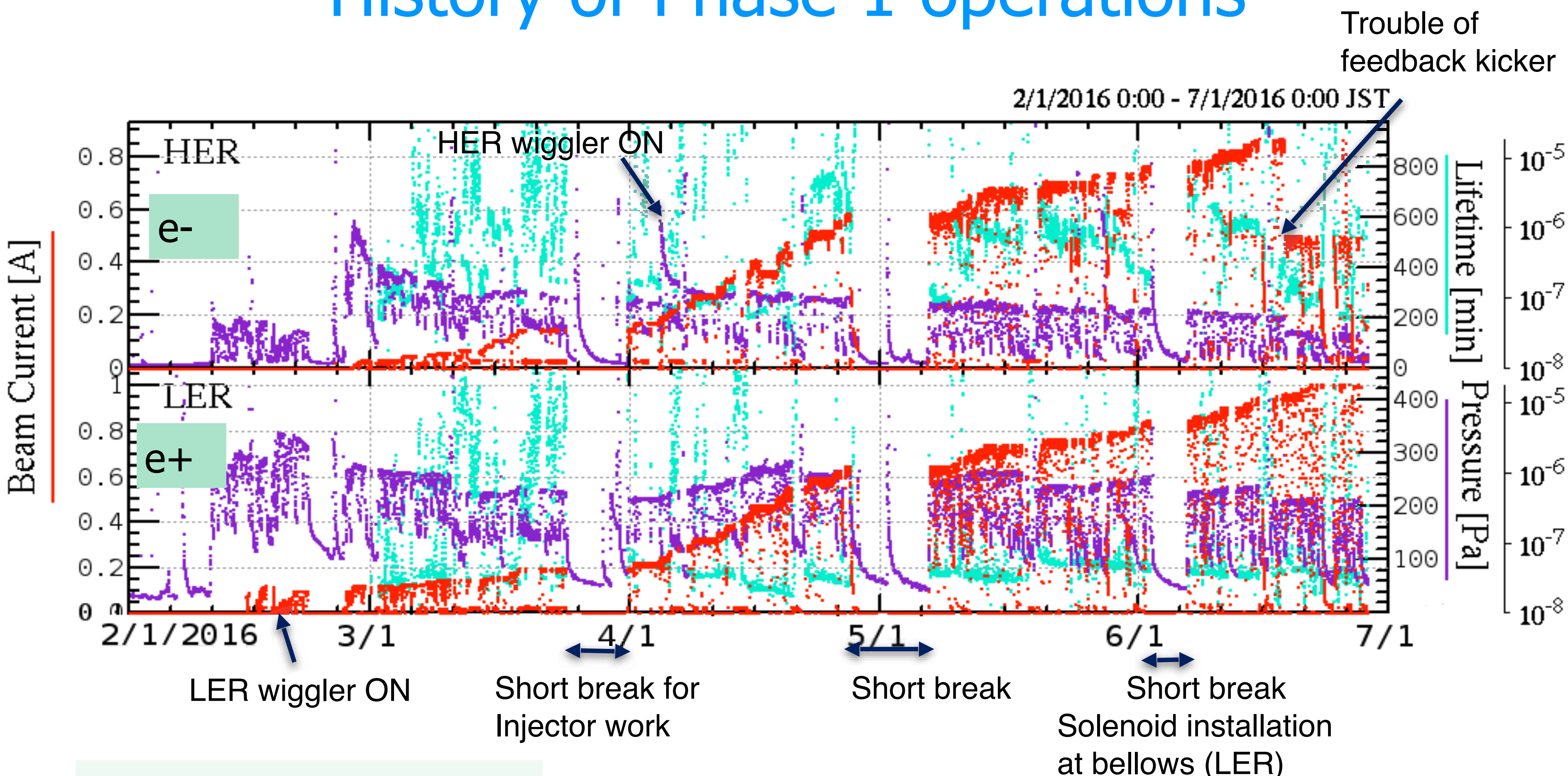
Phase 2 VXD Volume



Commissioning phase 2 (~5 months)

- Machine condition
  - w/ QCS, w/ Belle II (w/o VXD), full accelerator tuning
- Tuning items
  - Optics tuning
    - Tentative target values of IP beta's: β_x^*: x4, β_y^*: x8
    - Optics tuning with QCS and Belle II solenoid
    - Low emittance tuning w/ Belle II solenoid
    - Optics tuning w/ beam collision
  - Detector beam background
    - Study with Belle II detector, test of continuous injection (BEAST)
  - Beam collision tuning
    - Orbit feedback (fast feedback, dithering system)
    - Collision tuning w/ "Nano-Beam" scheme
  - Luminosity tuning
    - Tuning knobs (x-y coupling at IP etc.)
    - Tentave target luminosity: 1 x 10^{34} cm^{-2} s^{-1} (design of KEKB)
  - Increase of beam currents (instability, RF power, vacuum issues)
    - Detector background may possibly give some restriction.
    - Continue upgrade for RF system (support ~70% of design beam currents)

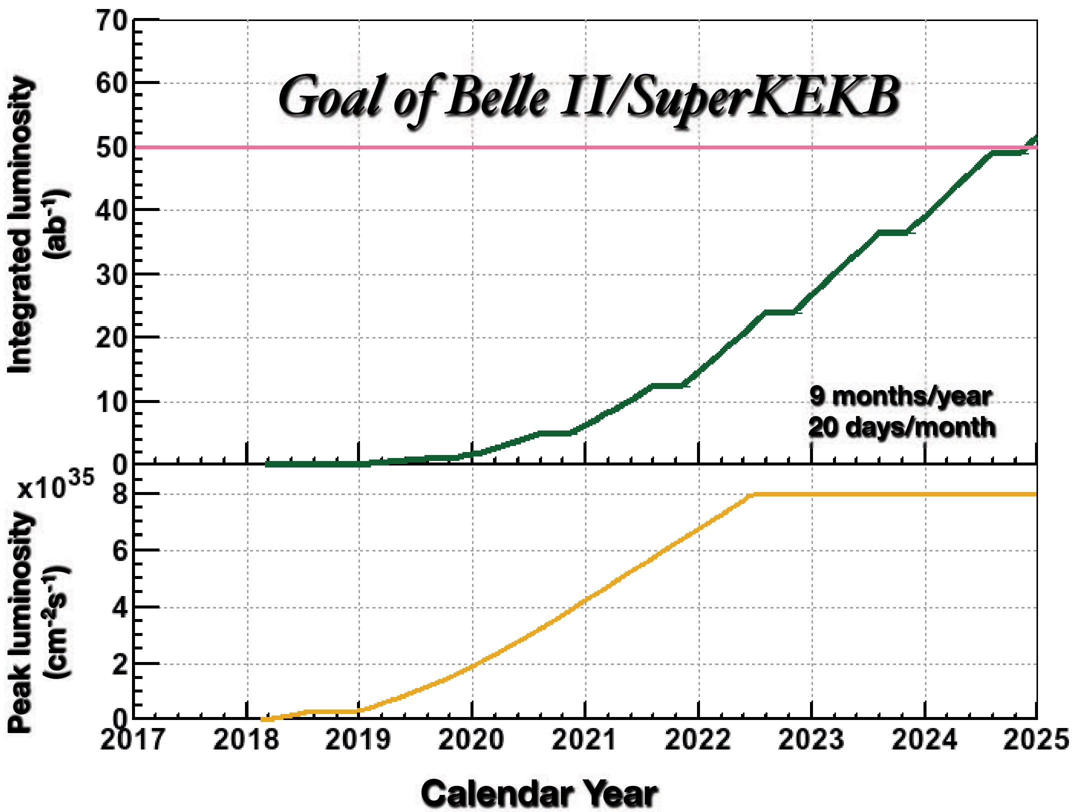
History of Phase 1 operations



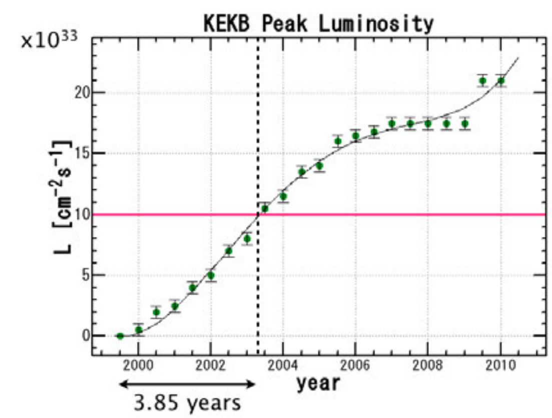
Red: total beam current
Purple: vacuum pressure
Cyan: beam lifetime

HER:
870 mA, 5.7×10^{-8} Pa, ~200 min. (6/17)
LER:
1010mA, 4.7×10^{-7} Pa, ~60 min. (6/22)

Luminosity profile of a next generation B factory



- Assumptions:
  - same commissioning time to reach nominal luminosity as in KEKB
  - 9 months/year running
  - All RF cavities in place



Expected yearly data sample @ full luminosity

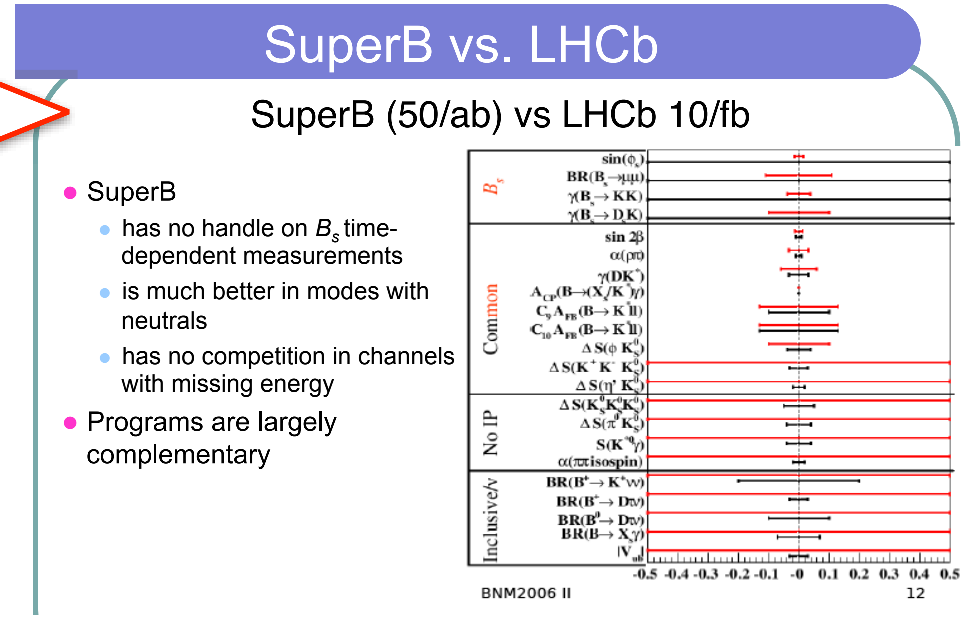
Channel	Belle	BaBar	Belle II (per year)*
$B\bar{B}$	7.7×10^8	4.8×10^8	1.1×10^{10}
$B_s^{(*)}\bar{B}_s^{(*)}$	7.0×10^6	–	6.0×10^8
$\Upsilon(1S)$	1.0×10^8		1.8×10^{11}
$\Upsilon(2S)$	1.7×10^8	0.9×10^7	7.0×10^{10}
$\Upsilon(3S)$	1.0×10^7	1.0×10^8	3.7×10^{10}
$\Upsilon(5S)$	3.6×10^7	–	3.0×10^9
$\tau\tau$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

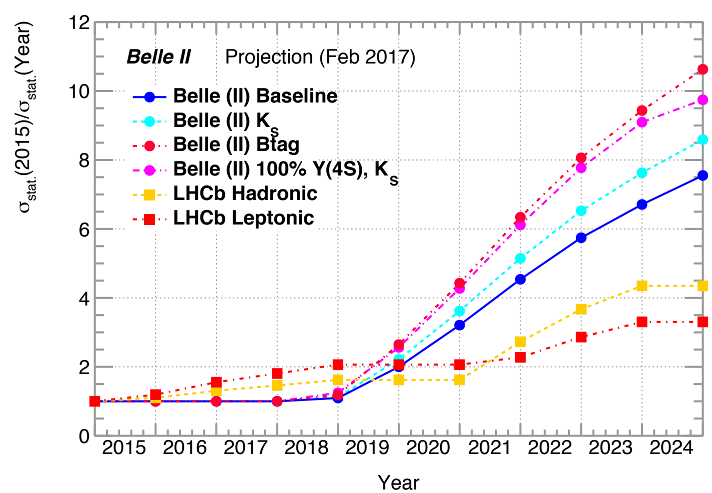
* assuming 100% running at each energy

NP-sensitivity at Belle II and comparison with LHCb

- Comparison table in 2008
- Must revise the extrapolations in view of recent developments (e.g. LHCb achievements)
- Extrapolation of *Belle* II sensitivity by scaling *B*-factory measurements as:

$$\sigma_{BelleII} = \sqrt{(\sigma_{stat}^2 + \sigma_{sys}^2)\frac{\mathcal{L}_{Belle}}{50\ \mathrm{ab}^{-1}} + \sigma_{\mathrm{irred}}^2}$$

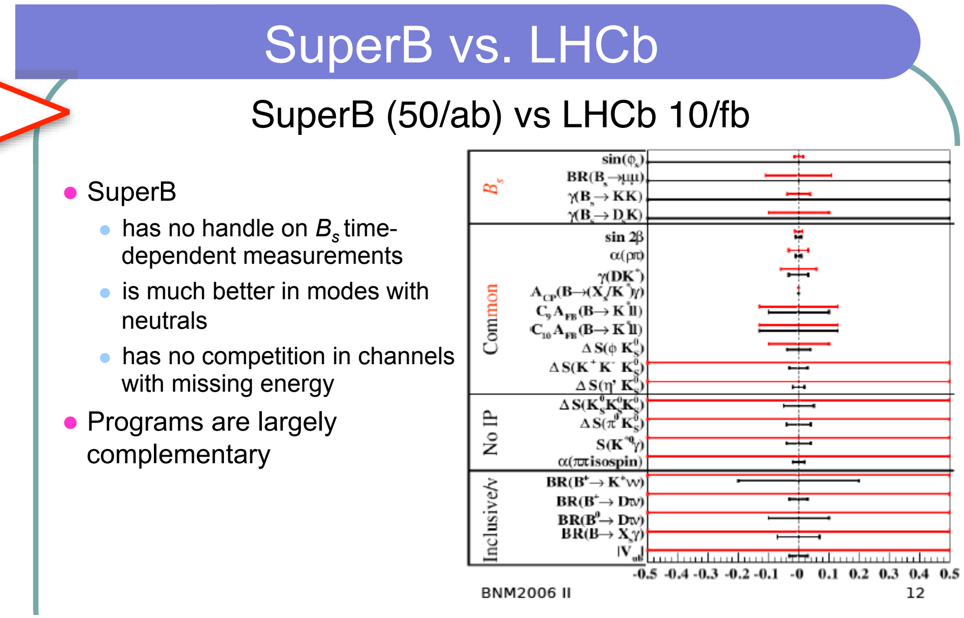


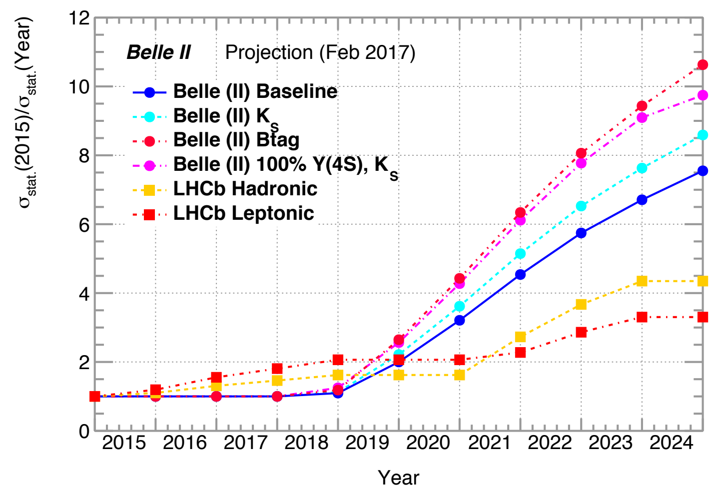


NP-sensitivity at Belle II and comparison with LHCb

- Comparison table in 2008
- Must revise the extrapolations in view of recent developments (e.g. LHCb achievements)
- Extrapolation of *Belle* II sensitivity by scaling *B*-factory measurements as:

$$\sigma_{BelleII} = \sqrt{(\sigma^2_{stat} + \sigma^2_{sys})\frac{\mathcal{L}_{Belle}}{50\ \mathrm{ab}^{-1}} + \sigma^2_{\mathrm{irred}}}$$



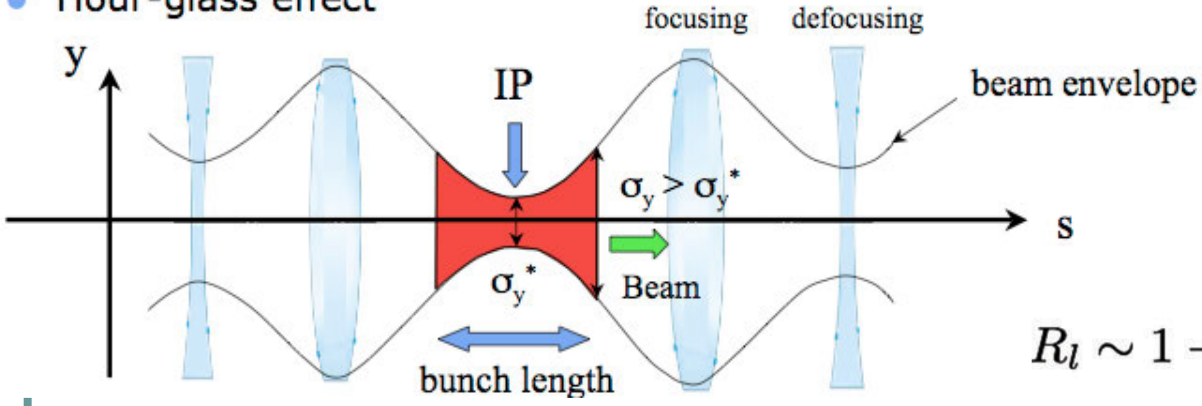


Yield gain in a few data taking configurations

The hourglass effect

$$L \propto \frac{I_{\pm}\xi_{\pm y}}{\beta_y^*} R_l$$

- Hour-glass effect



ANGULAR DIVERGENCE @ IP
X
TRANSVERSE SIZE @ IP
=
EMITTANCE (RING CONSTANT)

$$R_l \sim 1 - \left(\frac{\sigma_z}{2\beta_y}\right)^2 + \mathcal{O}\left(\frac{\sigma_z}{\beta_y}\right)^4$$

- Small amplitude @ IP not efficient with long bunches
  - particles in the head and tail of the bunch will see a larger β_y

  ➔ "β_y^* should be comparable to the *overlapping area*"
- In a storage ring
  - it is comparably easier to achieve small horizontal size and emittance than to make short bunches
  - vertical emittance/size scale with the horizontal ones