Status and Prospects for SuperKEKB and Belle II

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Kobayashi-Maskawa Institute
for the Origin of Particles and the Universe

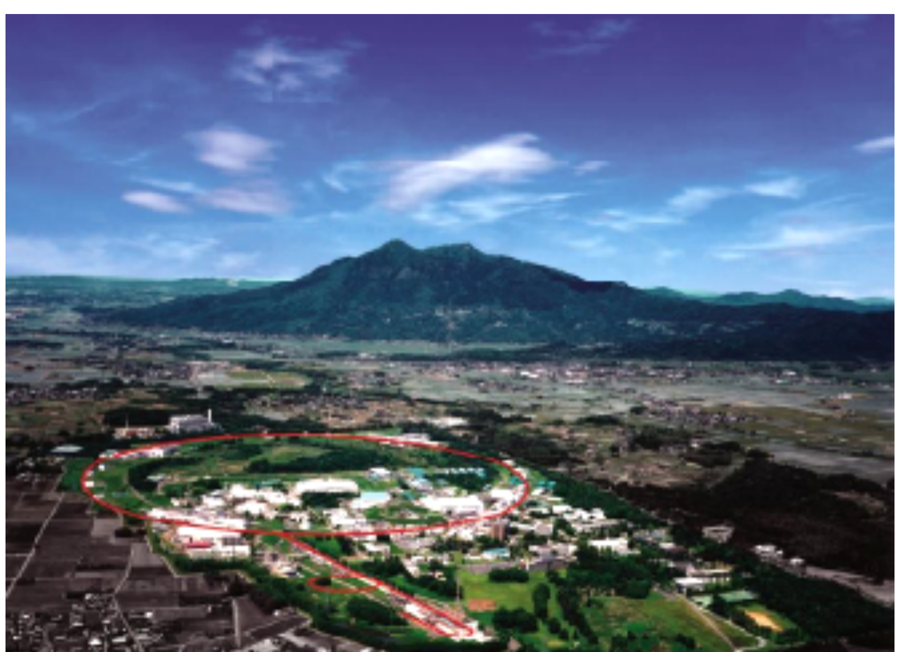
SuperKEKB/Belle II

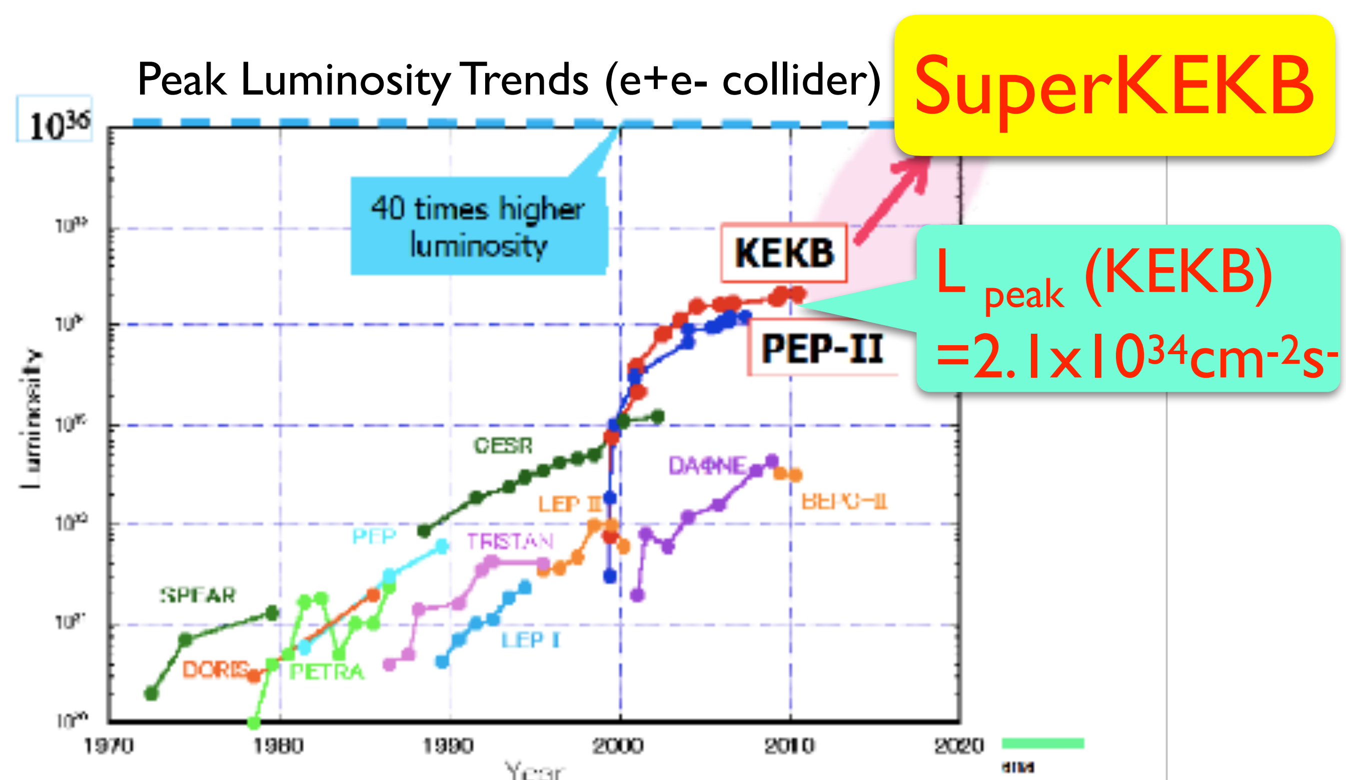
New intensity frontier facility at KEK

- Target luminosity ; $L_{peak} = 8 \times 10^{35} cm^{-2}s^{-1}$
  $\Rightarrow \sim 10^{10}$ $B\bar{B}$, $\tau^+\tau^-$ and charms per year !

  $L_{int} > 50\ ab^{-1}$

- Rich physics program
  - Search for New Physics through processes sensitive to virtual heavy particles.
  - New QCD phenomena (XYZ, new states including heavy flavors)   + more

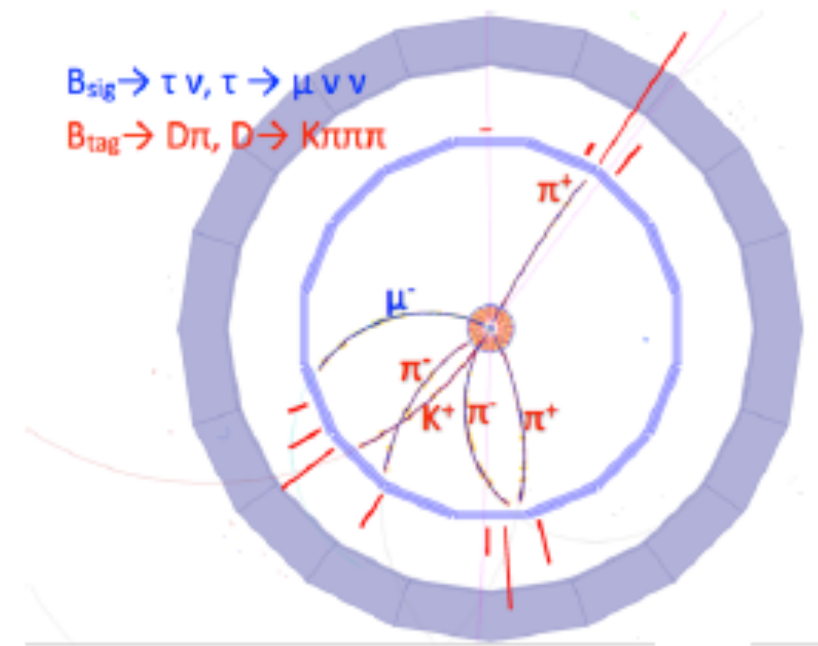




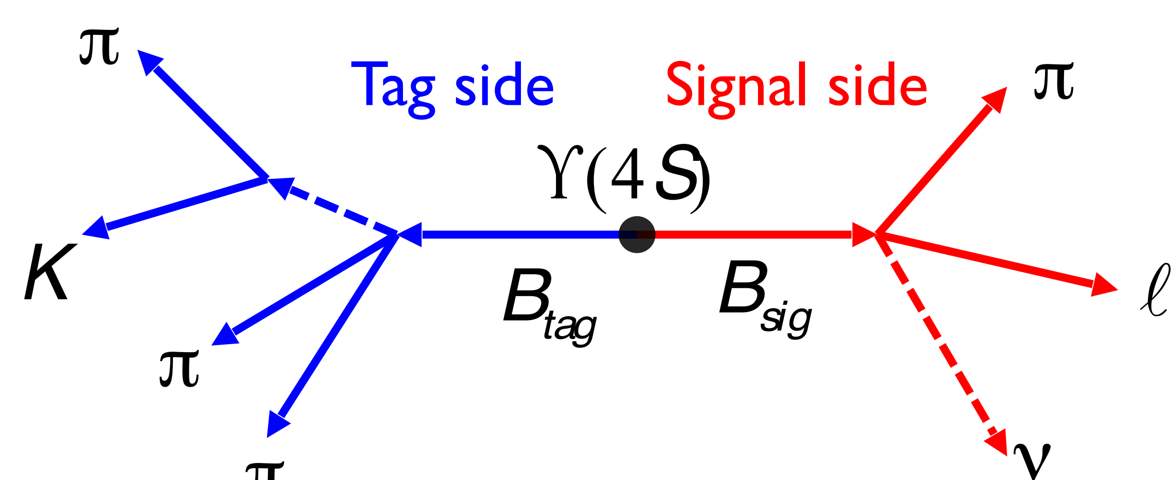
The first particle collider after the LHC !

Advantage of e^+e^- Flavor Factory

- Clean environment
  - Efficient detection of neutrals (γ, π^0, η, …)
- Quantum correlated $B^0\overline{B}{}^0$ pairs
  - High effective flavor tagging efficiency : ~34%(Belle II) ⟷ ~3% (LHCb)
- Large sample of τ leptons
  - Search for LFV τ decays at $O(10^{-9})$



- Full reconstruction tagging possible
  - A powerful tool to measure;
    - b→u semileptonic decays (CKM)
    - decays with large missing energy
    - etc.



$B \to \pi\, l\, \nu$

$B \to \tau\, \nu,\ D\, \tau\, \nu$

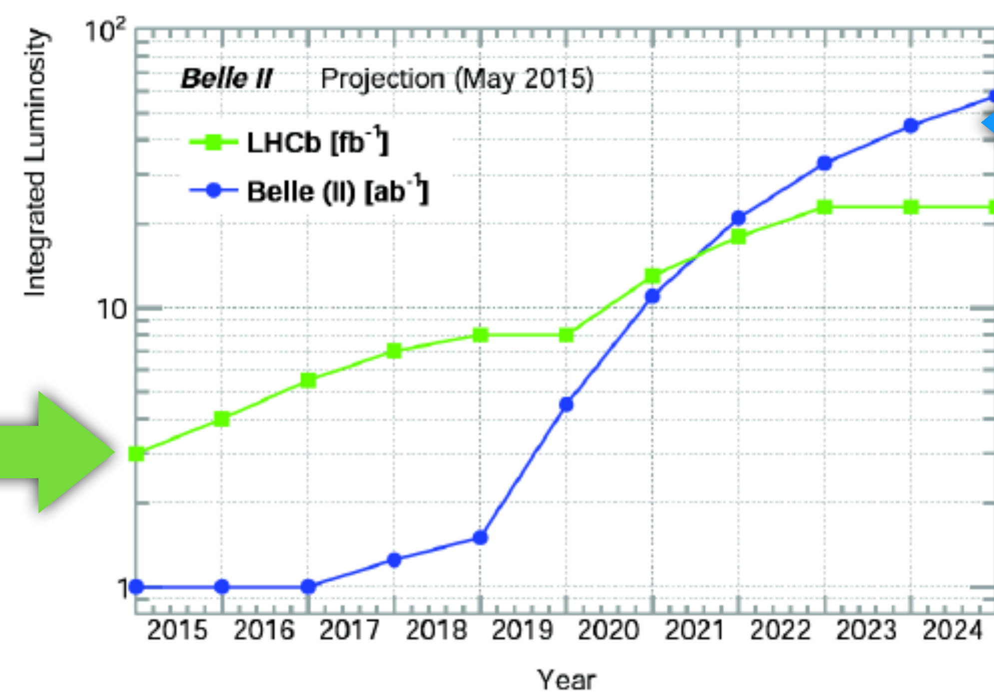
$B \to K\, \nu\, \nu$

- Systematics different from LHCb
  - Two experiments are required to establish NP

Belle II & LHCb

Heavy Flavor data (*B*/*D*/τ) with ultimate precision become available !

pp collision
large production rate



e^+e^- collision
low background

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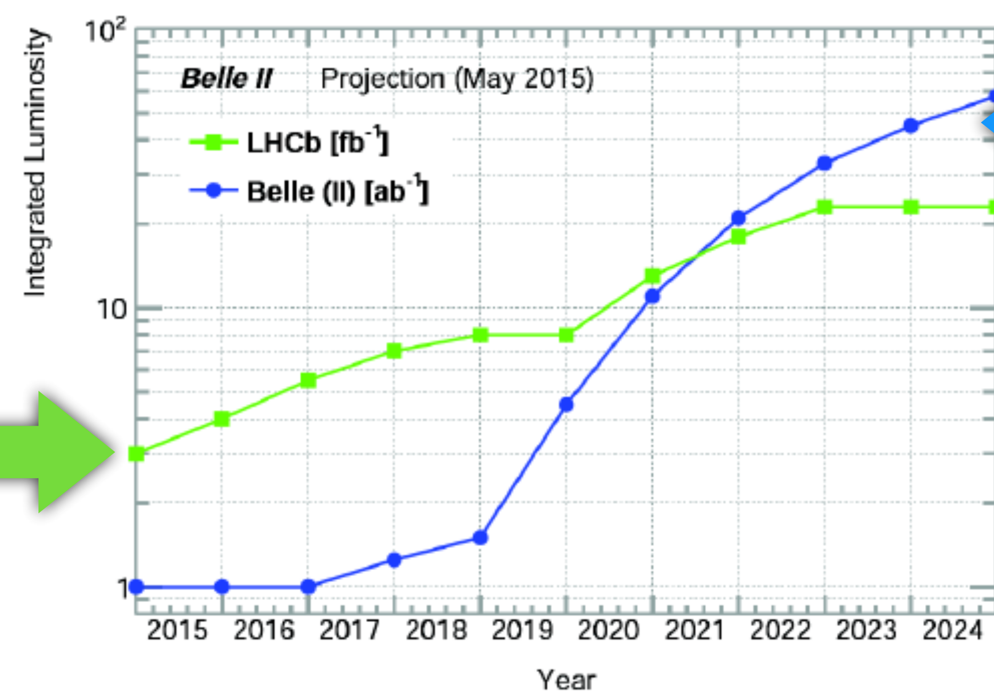

e⁺e⁻ collision
low background

Powerful !

Ferrari

Belle II & LHCb

Heavy Flavor data (*B*/*D*/τ) with ultimate precision become available !

pp collision
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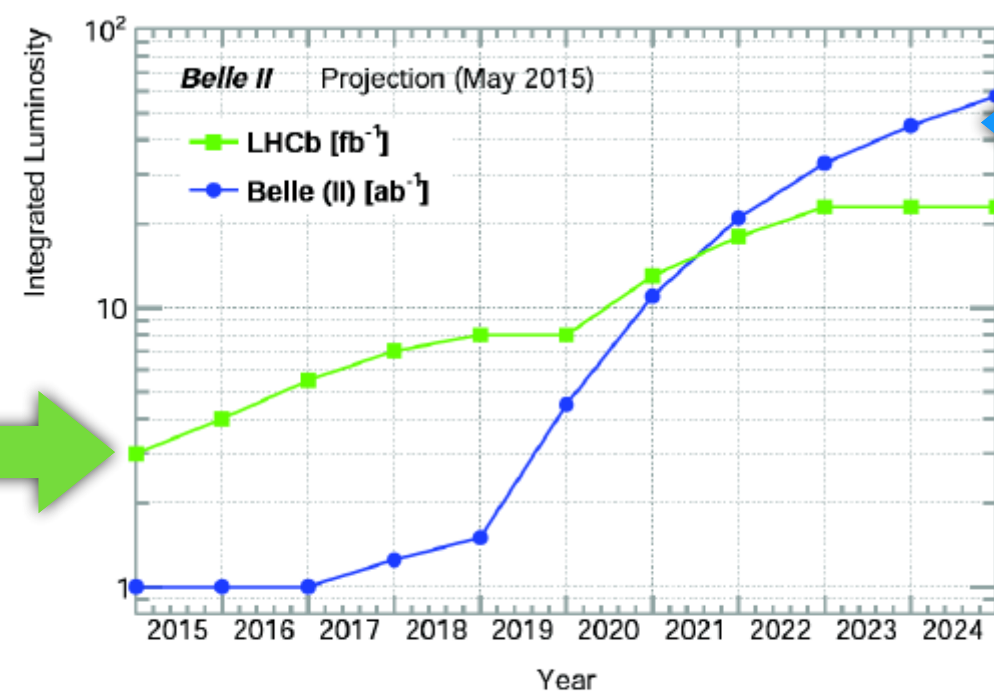


e$^+$e$^-$ collision
low background

Ferrari

Powerful !

Clean !

TOYOTA FCV
READY NOW !

Key Measurements @ Belle II

arXiv:1002.5012

- CPV in b→s penguin decays
- FCNC
- Tauonic decays
- LFV τ decays

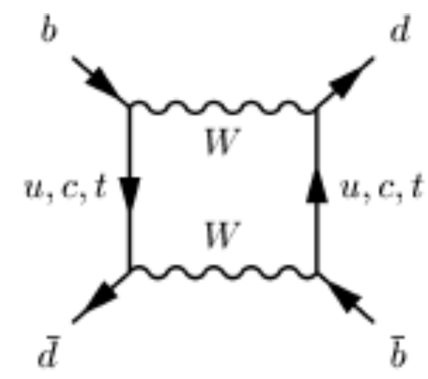
Observable	Belle 2006 ($\sim$0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})
Hadronic $b \to s$ transitions			
$\Delta S_{\phi K^0}$	0.22	0.073	0.029
$\Delta S_{\eta' K^0}$	0.11	0.038	0.020
$\Delta S_{K_S^0 K_S^0 K_S^0}$	0.33	0.105	0.037
$\Delta \mathcal{A}_{\pi^0 K_S^0}$	0.15	0.072	0.042
$\mathcal{A}_{\phi\phi K^+}$	0.17	0.05	0.014
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°
Radiative/electroweak $b \to s$ transitions			
$S_{K_S^0 \pi^0 \gamma}$	0.32	0.10	0.03
$\mathcal{B}(B \to X_s \gamma)$	13%	7%	6%
$A_{CP}(B \to X_s \gamma)$	0.058	0.01	0.005
C_9 from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$	-	11%	4%
C_{10} from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$		13%	4%
C_7/C_9 from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$	-		5%
R_K		0.07	0.02
$\mathcal{B}(B^+ \to K^+ \nu\nu)$	$^{\dagger\dagger} < 3\ \mathcal{B}_{\rm SM}$		30%
$\mathcal{B}(B^0 \to K^{*0} \nu\nu)$	$^{\dagger\dagger} < 40\ \mathcal{B}_{\rm SM}$		35%
Radiative/electroweak $b \to d$ transitions			
$S_{\rho\gamma}$	-	0.3	0.15
$\mathcal{B}(B \to X_d \gamma)$	-	24% (syst.)	
Leptonic/semileptonic B decays			
$\mathcal{B}(B^+ \to \tau^+ \nu)$	3.5σ	10%	3%
$\mathcal{B}(B^+ \to \mu^+ \nu)$	$^{\dagger\dagger} < 2.4 \mathcal{B}_{\rm SM}$	4.3 ab^{-1} for 5σ discovery	
$\mathcal{B}(B^+ \to D \tau \nu)$	-	8%	3%
$\mathcal{B}(B^0 \to D \tau \nu)$	-	30%	10%
LFV in τ decays (U.L. at 90% C.L.)			
$\mathcal{B}(\tau \to \mu\gamma)$ [10^{-9}]	45	10	5
$\mathcal{B}(\tau \to \mu\eta)$ [10^{-9}]	65	5	2
$\mathcal{B}(\tau \to \mu\mu\mu)$ [10^{-9}]	21	3	1

Ultimate measurements down to theory error !

Precision CKM

- Comparison between
  - tree-based ; $|V_{ub}| + \varphi_3$
  - loop-based ; $\varphi_1, \varphi_2, |V_{td}|$

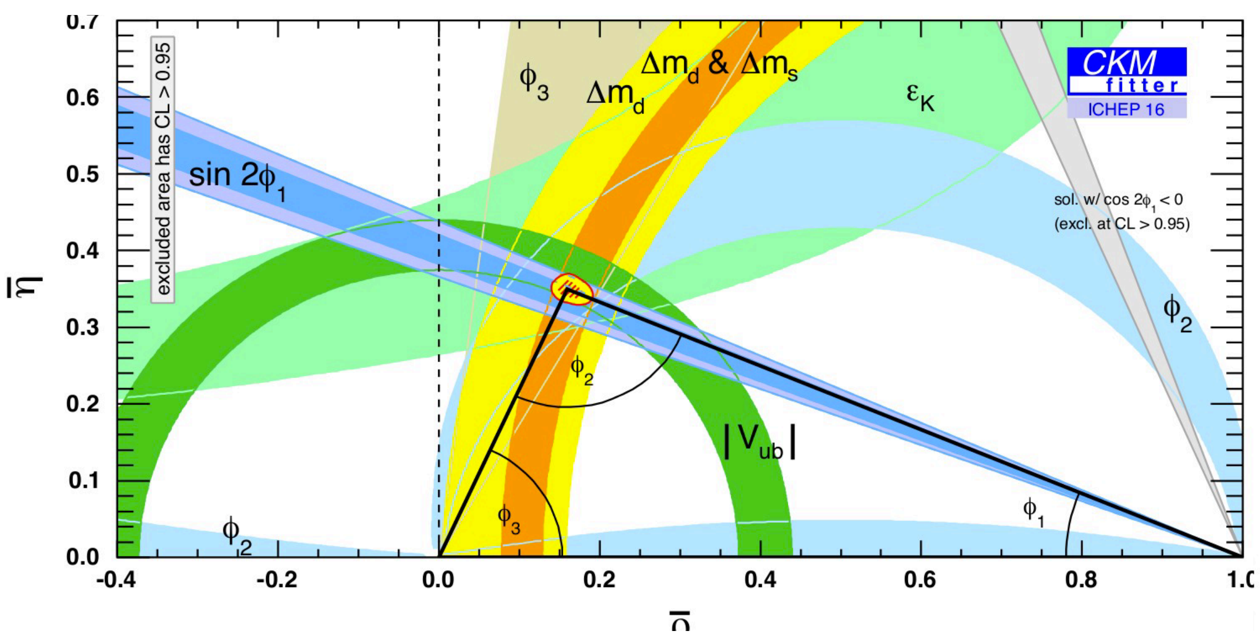
  → NP in loop
- Belle II is unique for $|V_{cb}|$ and $|V_{ub}|$



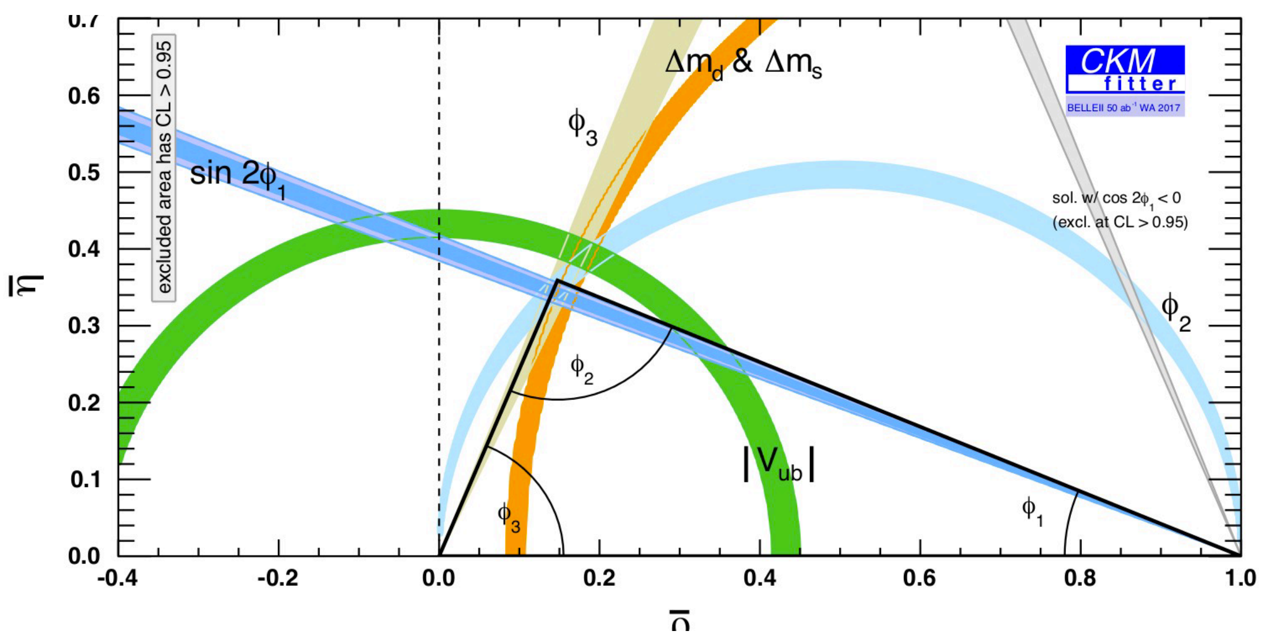
$$M_{12}^{d,s} = (M_{12}^{d,s})_{SM} \times (1 + h_{d,s} e^{2i\sigma_{d,s}})$$

Relative amplitude

State of the art 2016



Belle II 50 ab^{-1}



Precision CKM

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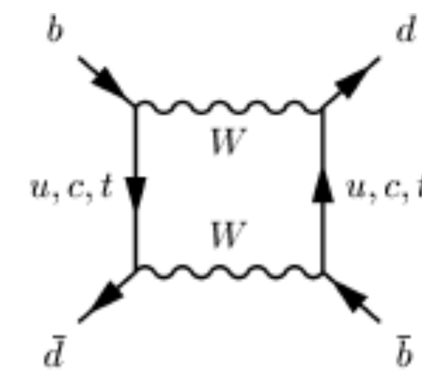

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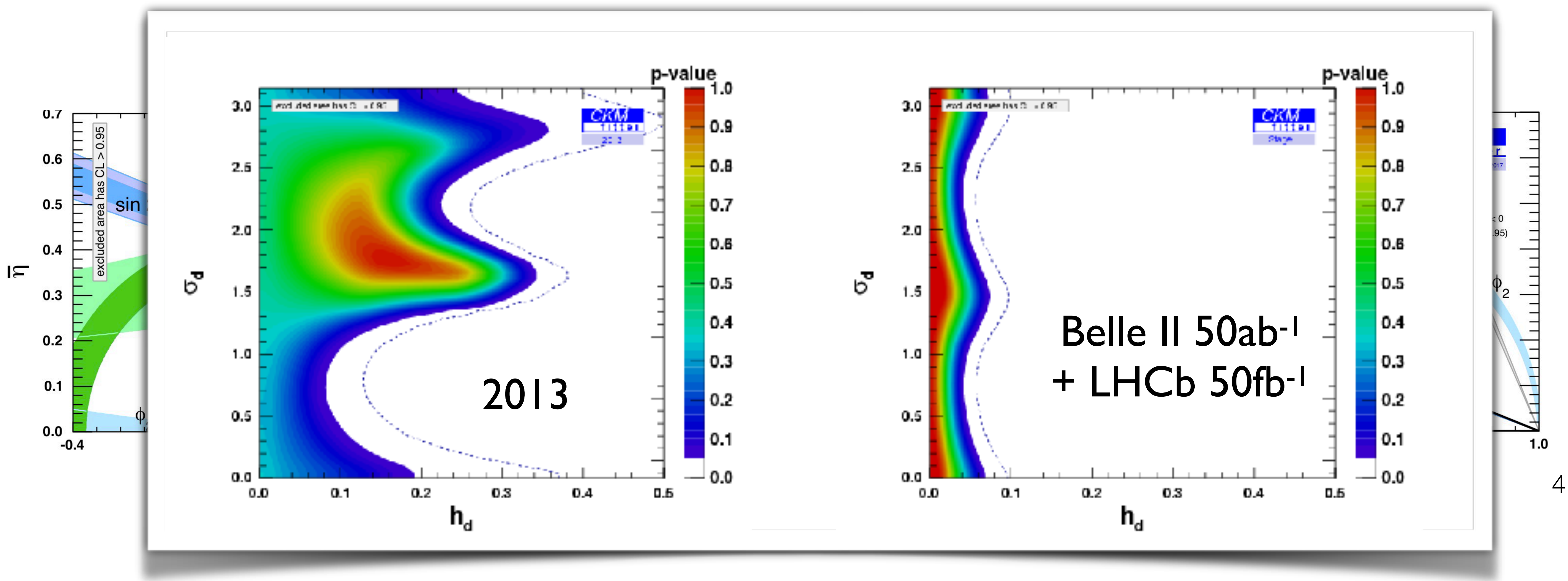
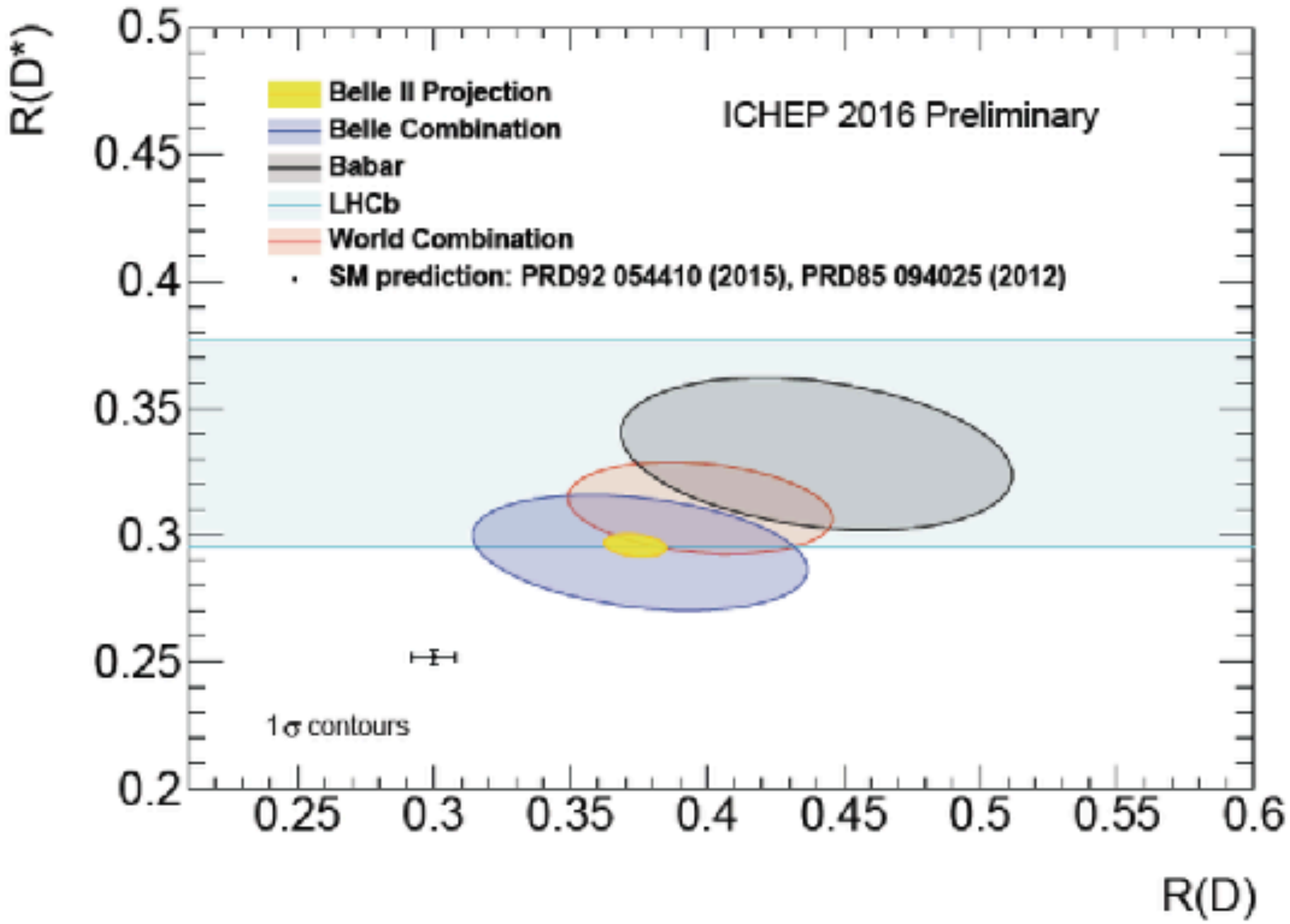
Relative amplitude

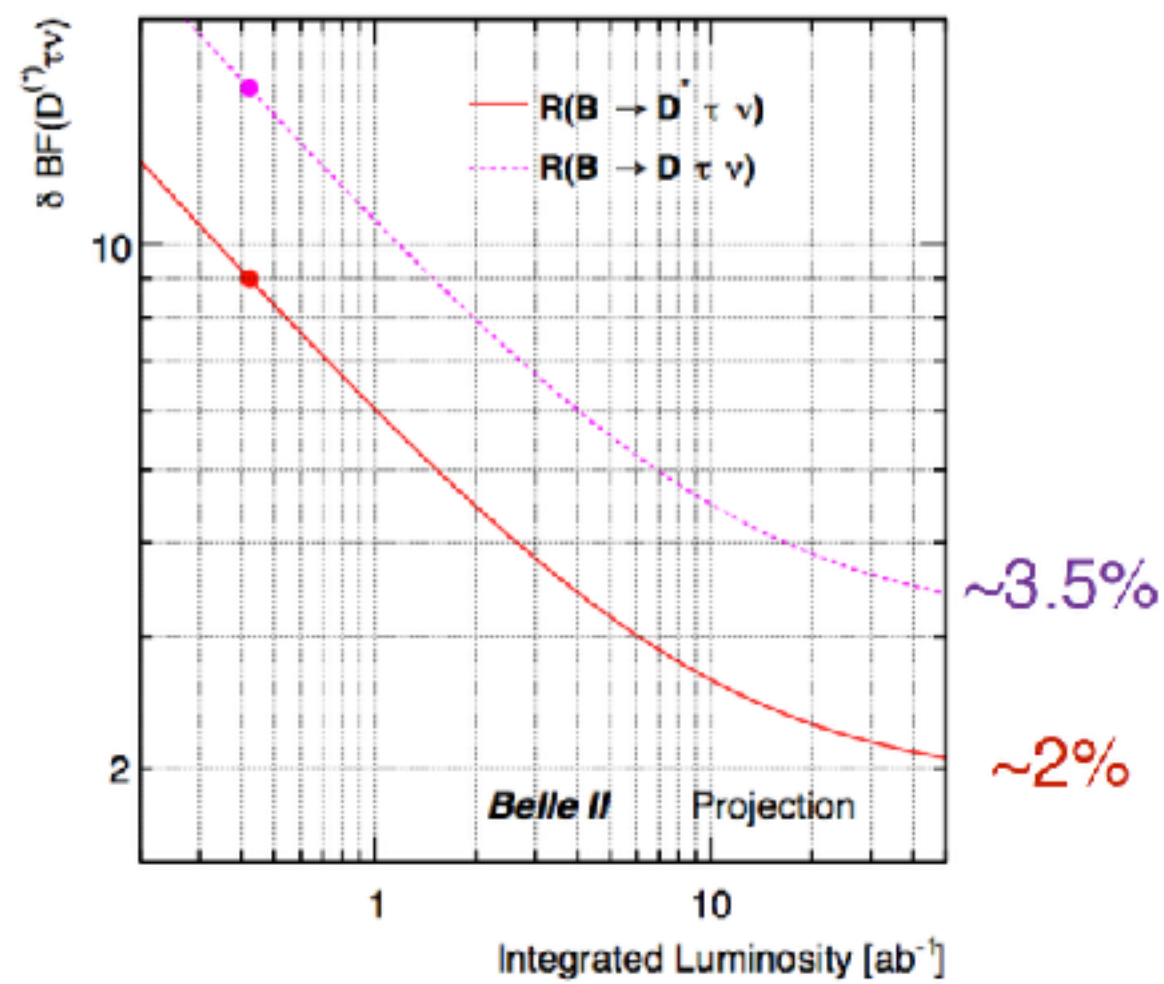


R(D) and R(D*) Anomaly

- Combined result (BaBar, Belle, LHCb) is 4.1 σ away from SM.
- Belle II can confirm the deviation with 5 ab^{-1}.

Observable: $R = \dfrac{Br(B \to D^{(*)}\tau\nu)}{Br(B \to D^{(*)}\ell\nu)}$

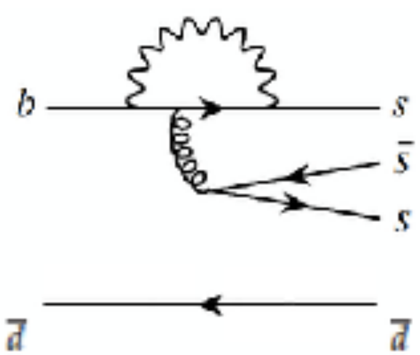


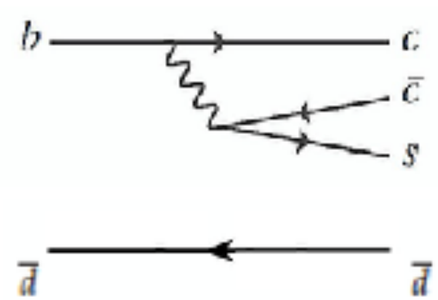


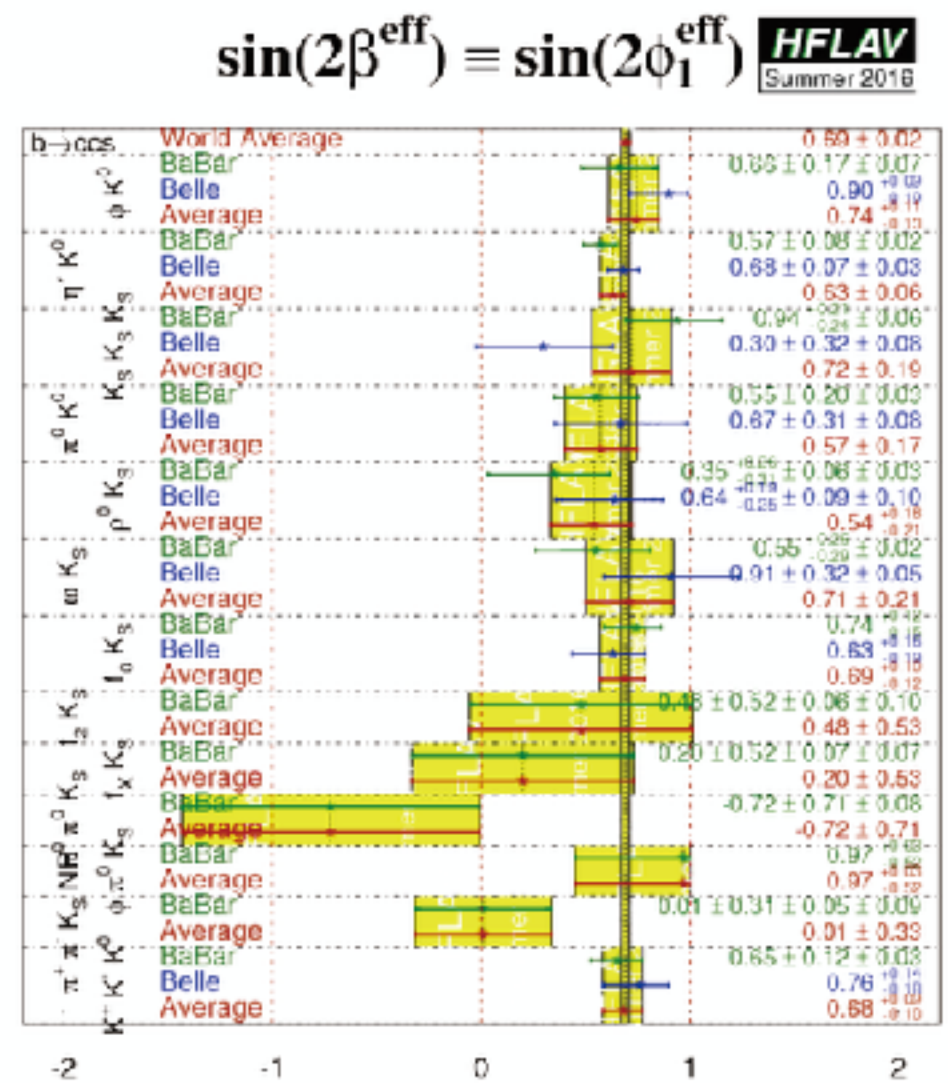
New Source of CP Violation

- New Physics models often involves additional CP-violating phases.
- Additional phase can be detected by comparing mixing induced CP asymmtries in pengin- and tree- dominated modes.
  - Time-dependent CPV in b → s decays such as B → φK⁰, η'K⁰, K⁰K⁰K,
  - In SM, CPV(penguin) = CPV(B0→J/ψK0)

    If NP, CPV(penguin) ≠ CPV(B0→J/ψK0)







Belle II has improved
- Acceptance for Ks decay vertex
- Vertex resolution

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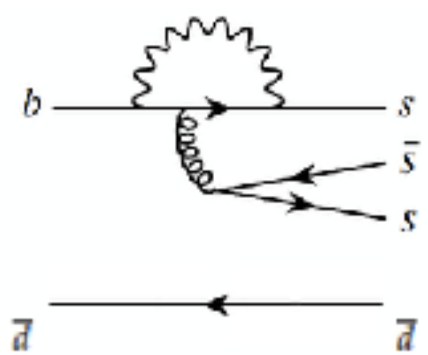
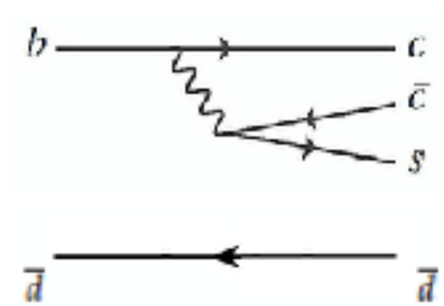
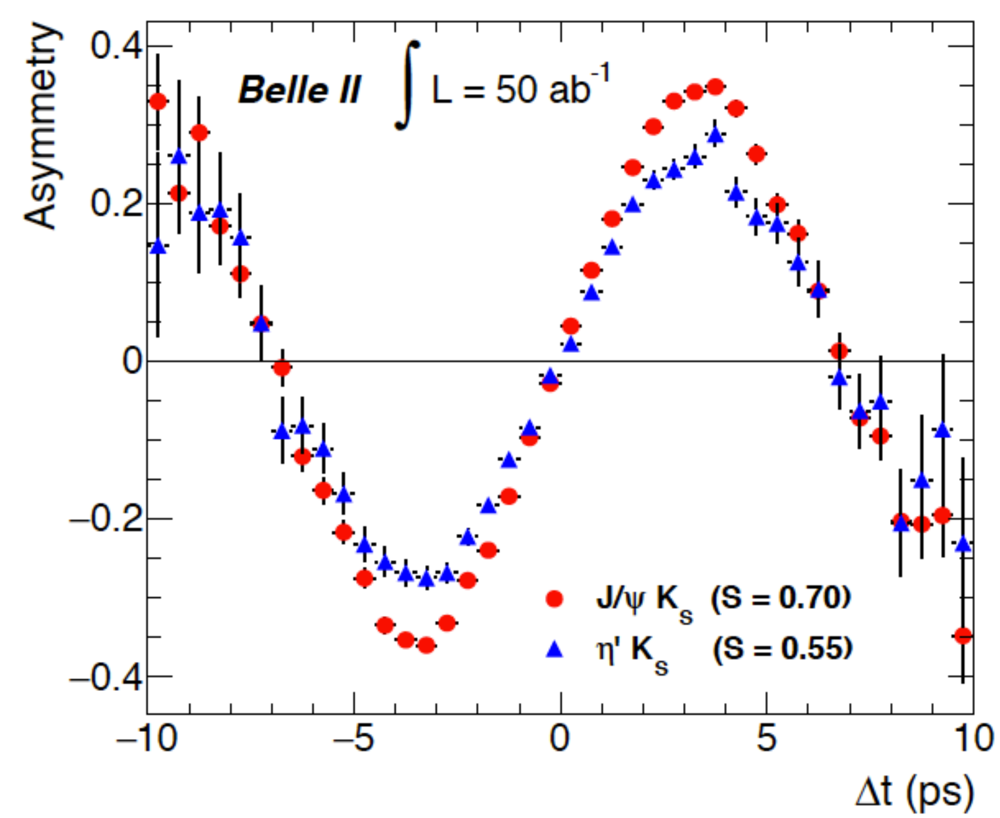
S(η'Ks)







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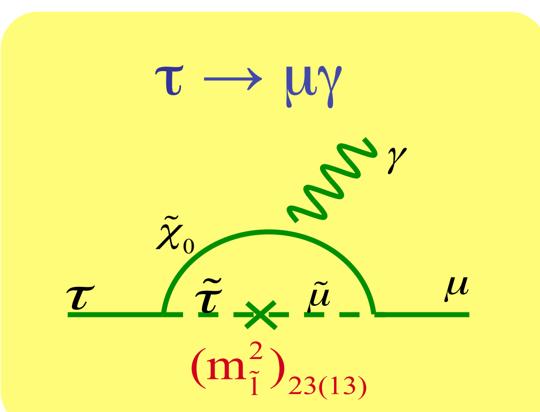
Lepton Flavor Violation

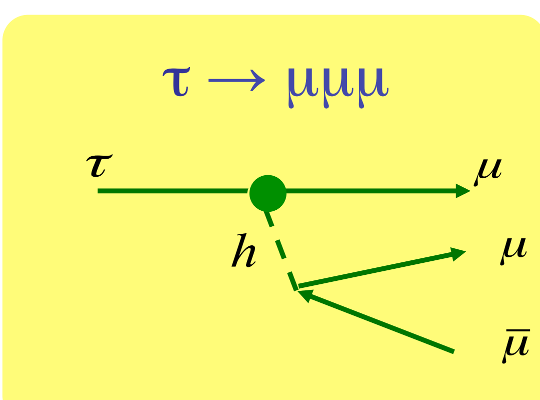
- Super B factory is also "Super τ factory".
- If LFV observed, it is ambiguous signature of NP.
- Sensitivity will be…
  - τ→μγ : BG non-free : $\propto 1/\sqrt{L}$
  - τ→μμμ : BG free : $\propto 1/L$

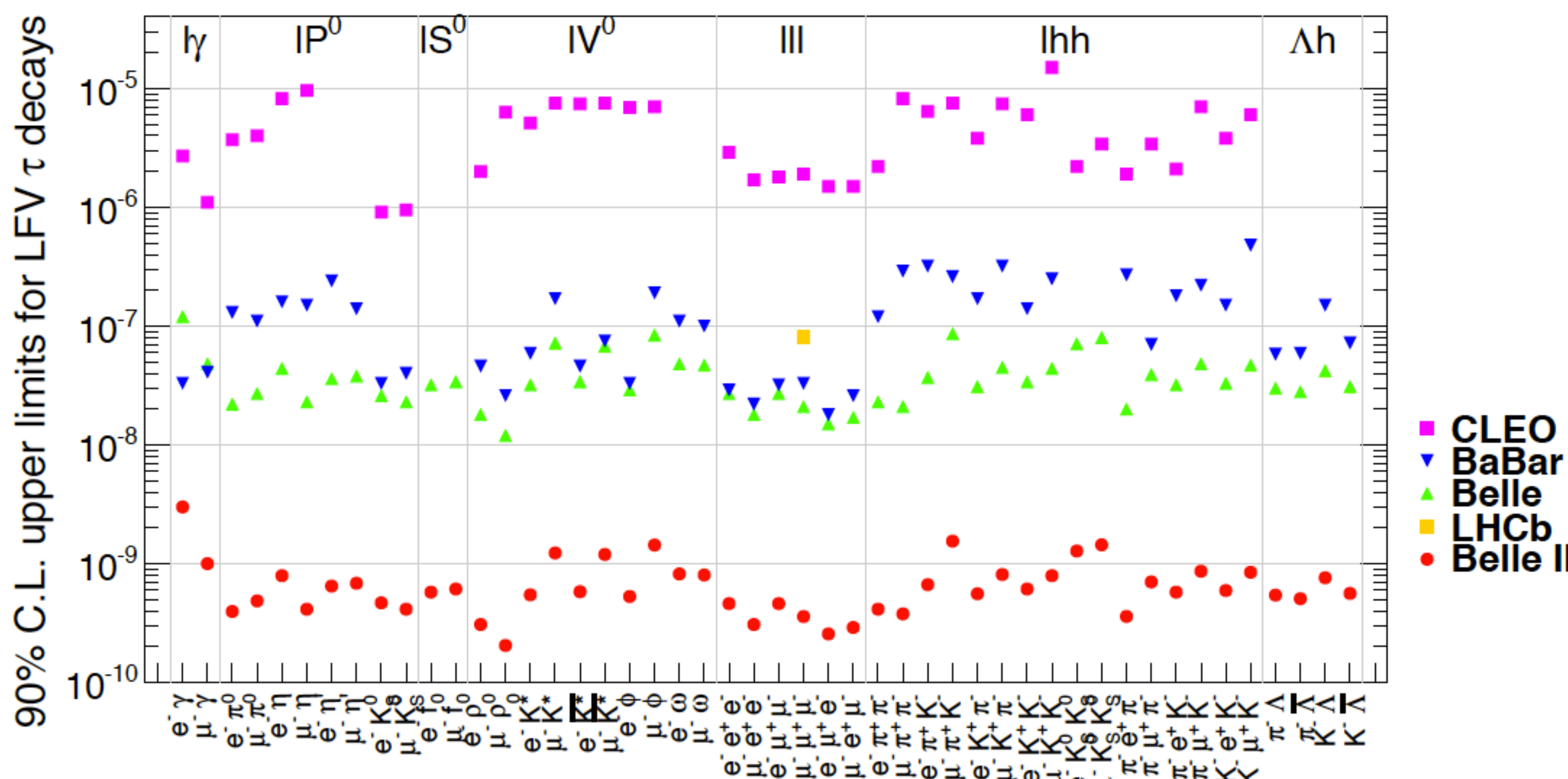
Expected limits:

Br(τ→μγ) ~ O(10^{-9})

Br(τ→μμμ) ~ O(10^{-9})→O(10^{-10})







SuperKEKB Accelerator

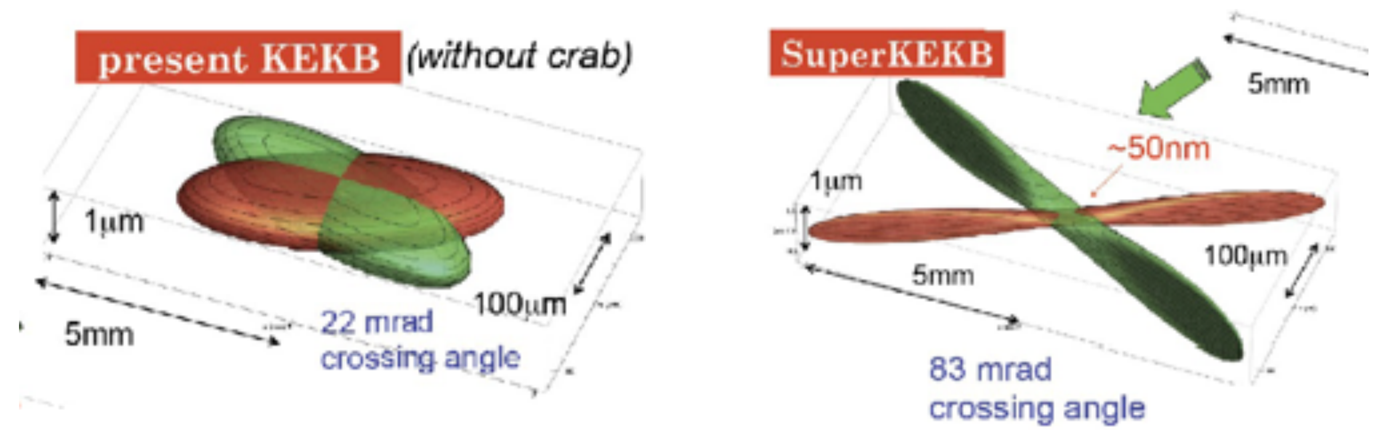
- Low emittance (“nano-beam”) scheme employed (originally proposed by P. Raimondi)

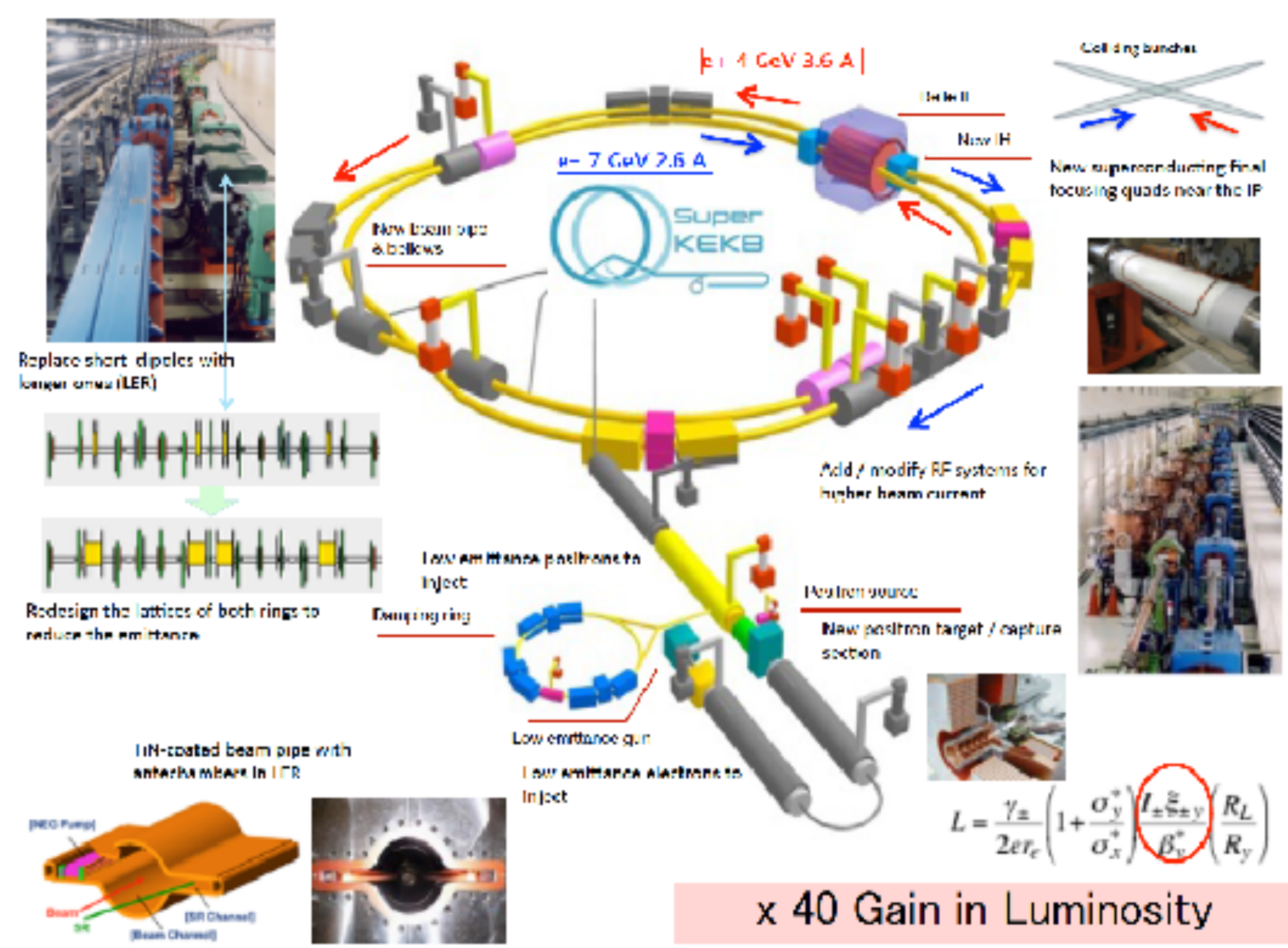
Machine parameters

	SuperKEKB LER/HER	KEKB LER/HER
E(GeV)	4.0/7.0	3.5/8.0
ε_x (nm)	3.2/4.6	18/24
β_y at IP(mm)	0.27/0.30	5.9/5.9
β_x at IP(mm)	32/25	120/120
Half crossing angle(mrad)	41.5	11
I(A)	3.6/2.6	1.6/1.2
Lifetime	~10min	130min/200min
L(cm^{-2}s^{-1})	80×10^{34}	2.1×10^{34}

x20 (β_y at IP)

x2 (I(A))



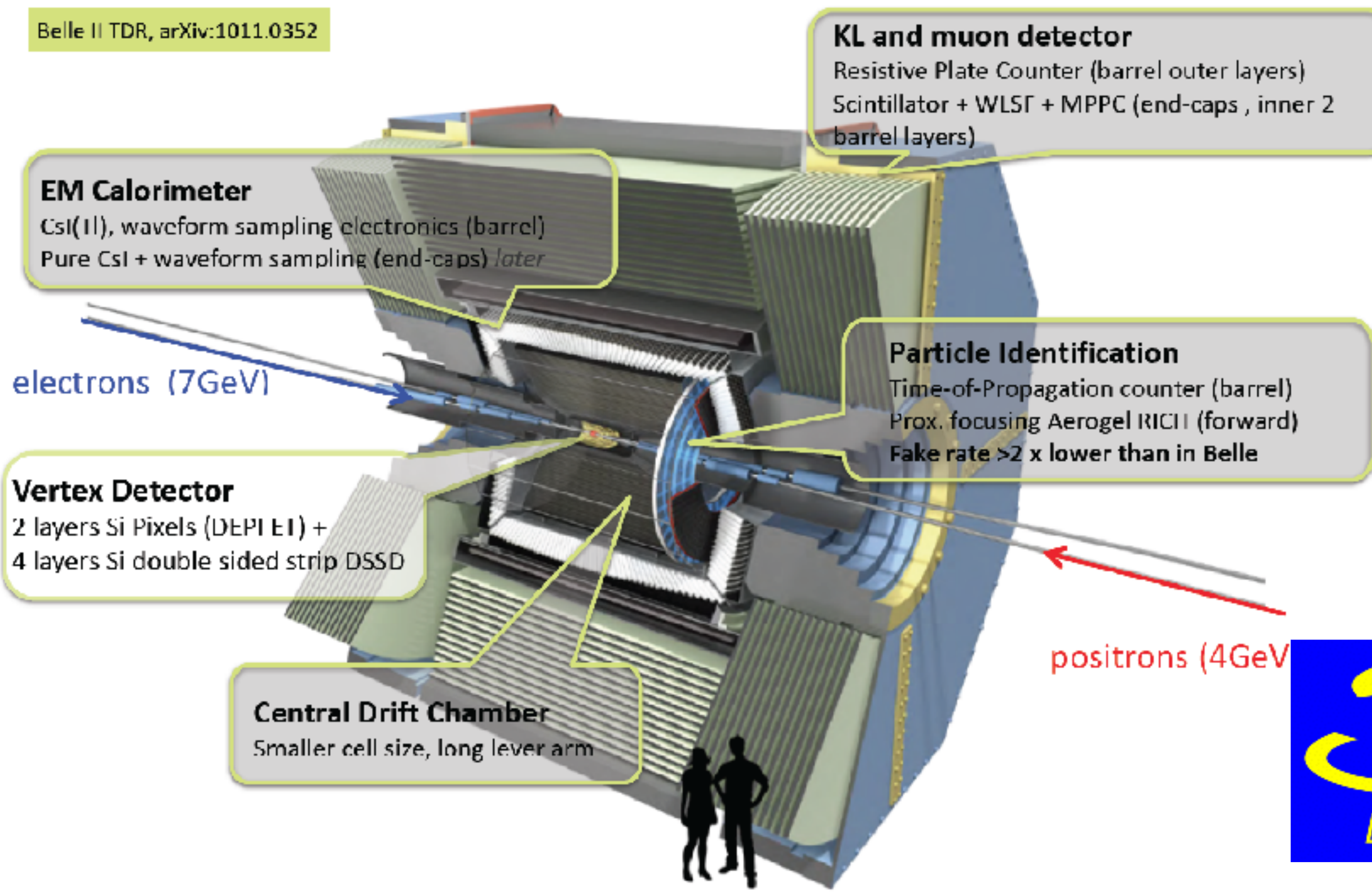


$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

x 40 Gain in Luminosity

Belle II Detector

- Deal with higher background (10-20×), radiation damage, higher occupancy, higher event rates (L1 trigg. 0.5→30 kHz)
- Improved performance and hermeticity



Belle II Collaboration

As of Oct. 2017

25countries/regions
105 institutions
~750 researchers

Europe	300
Austria	13
Czechia	6
France	14
Germany	110
Israel	3
Italy	76
Poland	13
Russia	42
Slovenia	16
Spain	4
Ukraine	3

Asia			346
Saudi Arabia	1	Korea	43
Australia	33	Malaysia	6
China	33	Vietnam	3
India	44	Taiwan	28
Japan	150	Thailand	2
		Turkey	3

America	129
Canada	28
Mexico	12
USA	89

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Visit by French Ambassador, Laurent Pic, October 11, 2017

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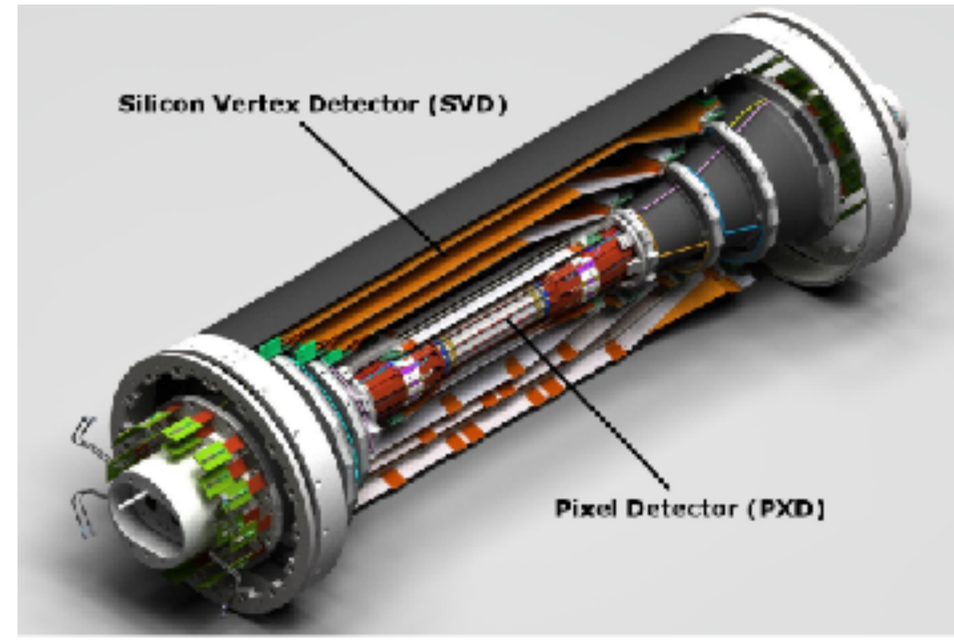
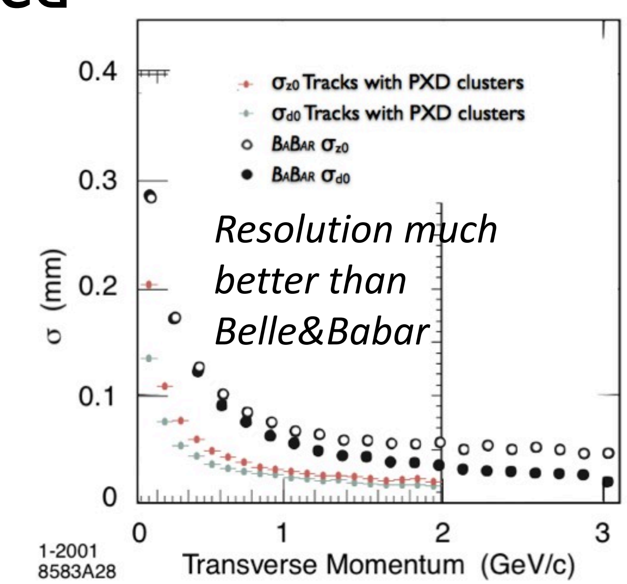
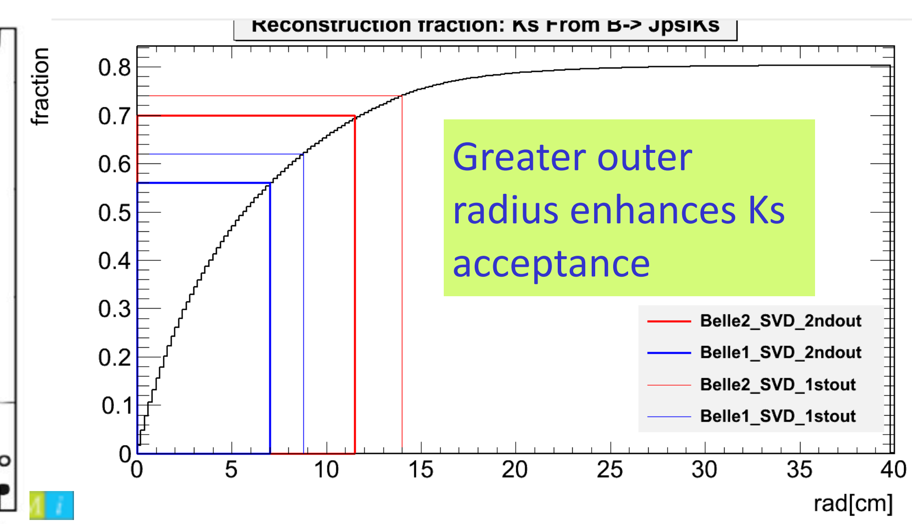
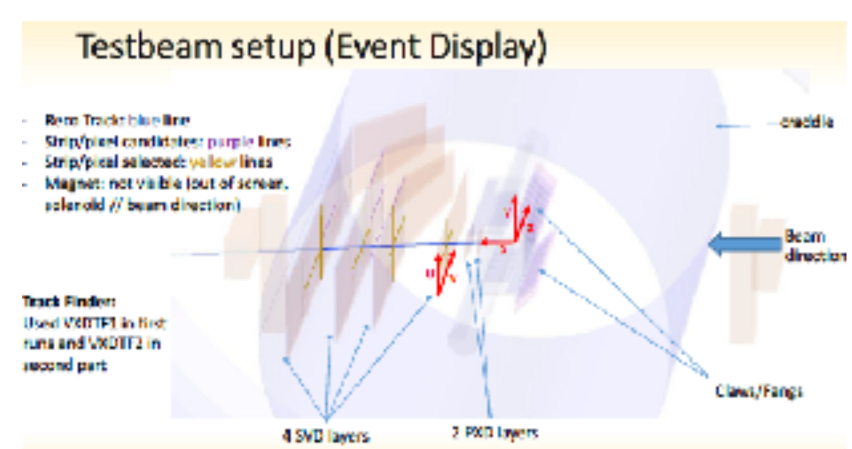
Belle II Vertex Detector

- Critical component for CPV measurements
- New vertex detectors:
  - PXD: 2-layer pixel detector based on DEPFET (Depleted P-channel Field Effect Transistor) technology.
  - SVD: 4-layer DSSD (Double Sided Silicon Detector).
- Smaller beam pipe radius
  - =1cm (2cm → 1.5cm @ Belle)
- Larger outer radius
  - Improved Ks acceptance
- Excellent performance (position resolution, efficiency) confirmed in beam test at DESY.







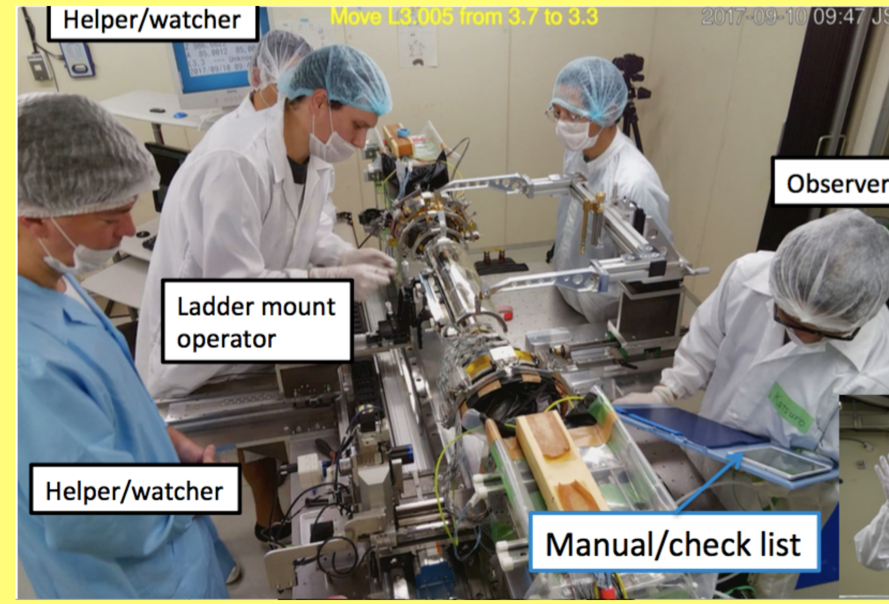


Status of VXD production

SVD

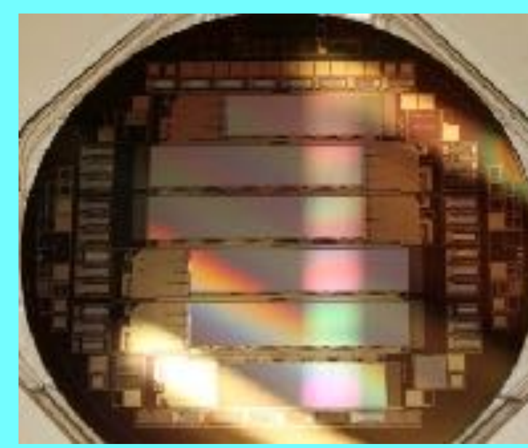
- Ladder production: completed at 3 out of 5 sites.
  - will be finished by Feb. 2018.
- Ladder mount started (Sep.7, 2017)
  - L3 mount completed (Sep.19, 2017)
  - Completion of the 1st half shell (Dec. 2017)
  - Completion of the 2nd half shell (Apr. 2018)

Ladder mount tools and procedures have undergone a series of technical reviews and were finally approved on Sep 5, 2017

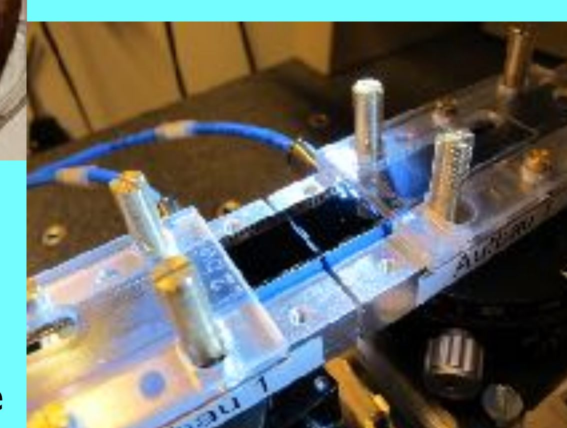


PXD

- Almost twice the required number of prime grade sensors
  - 40 sensors are required.
- Module assembly has started
  - Module assembly yield is ~100% so far
- Arrival of the assembled PXD at KEK: mid. of April, 2018



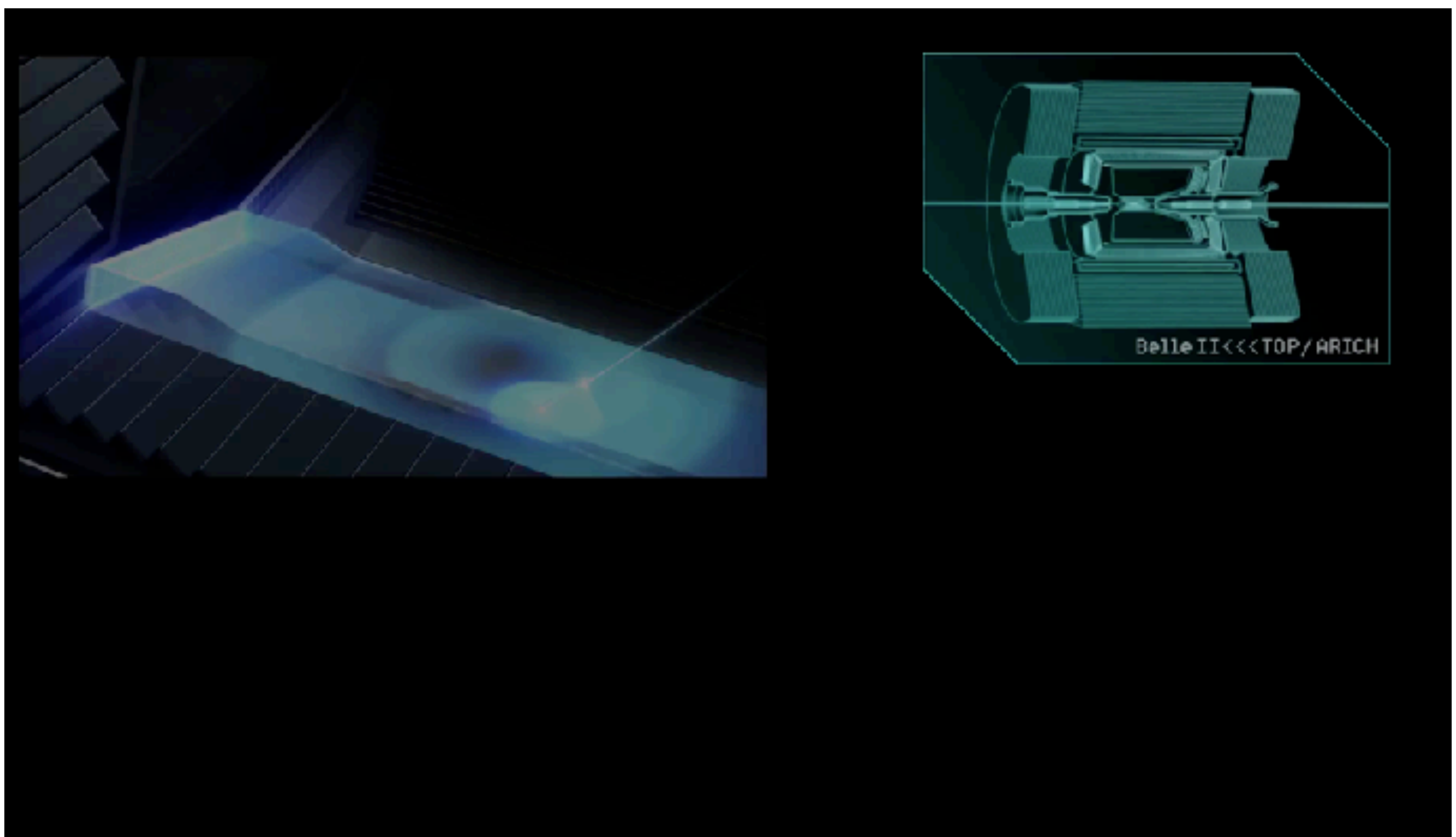
DEPFET sensor wafer produced at MPG-HLL (Munich)



Two PXD sensor glued together to make a module

Particle Identification

- Novel Ring-Imaging CHerenkov (RICH) counters
  - TOP (Time-Of-Propagation) Counter
  - A-RICH (Aerogel RICH) Counter



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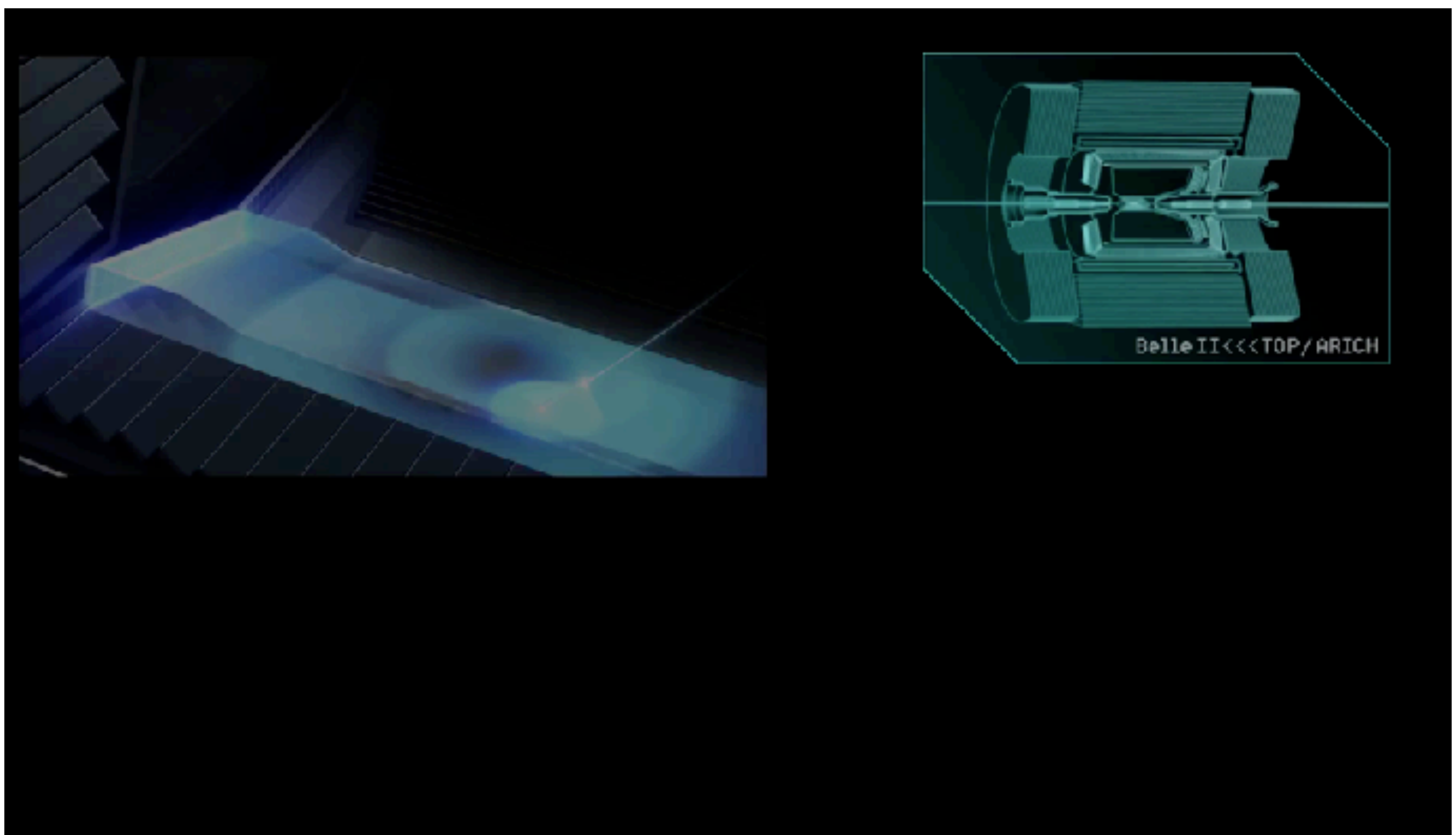
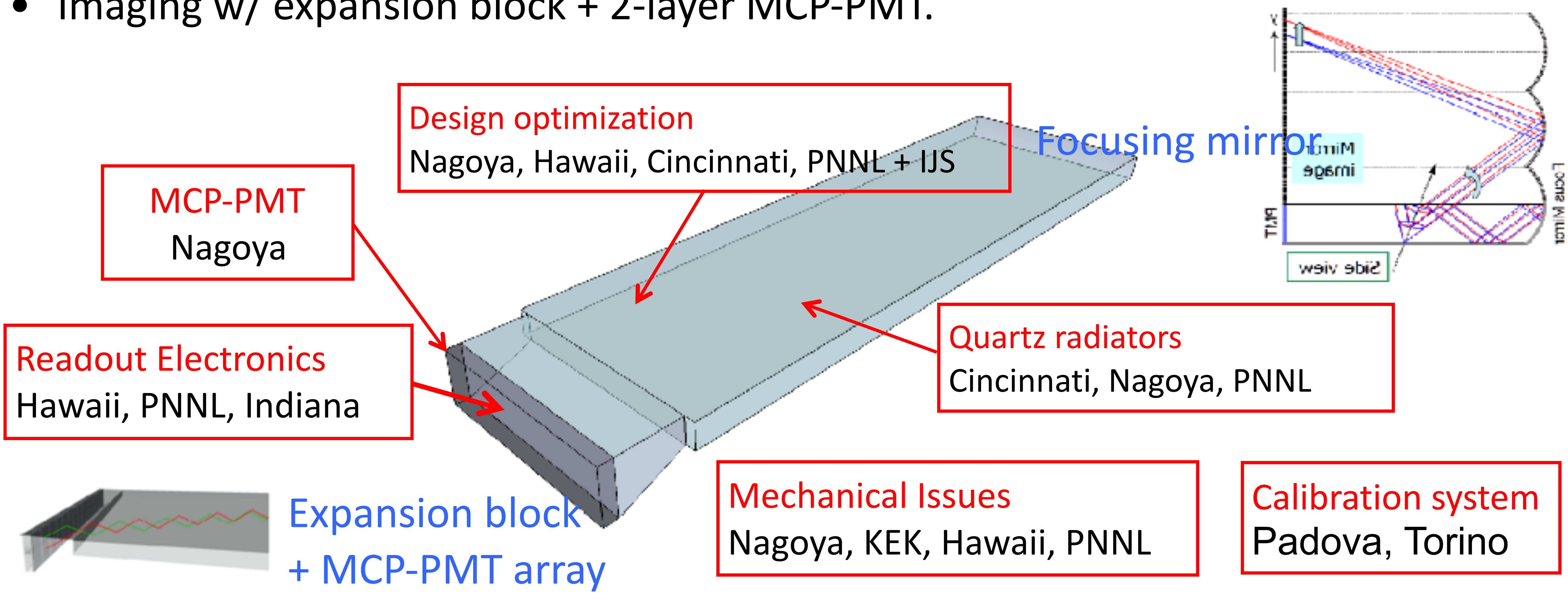


Belle II TOP Detector

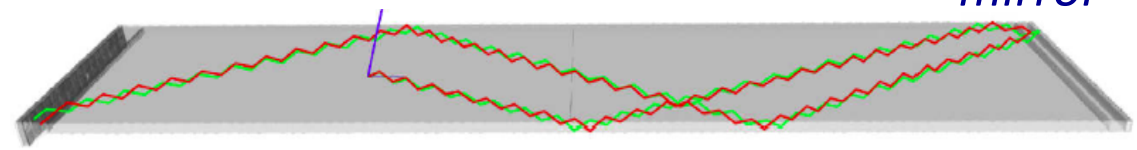
- Cherenkov ring imaging using precision timing (σ_{TTS} < 50ps/photon).
- Very compact, suitable for collider geometry.
- Focusing mirror for correcting chromatic dispersion effect.
- Imaging w/ expansion block + 2-layer MCP-PMT.

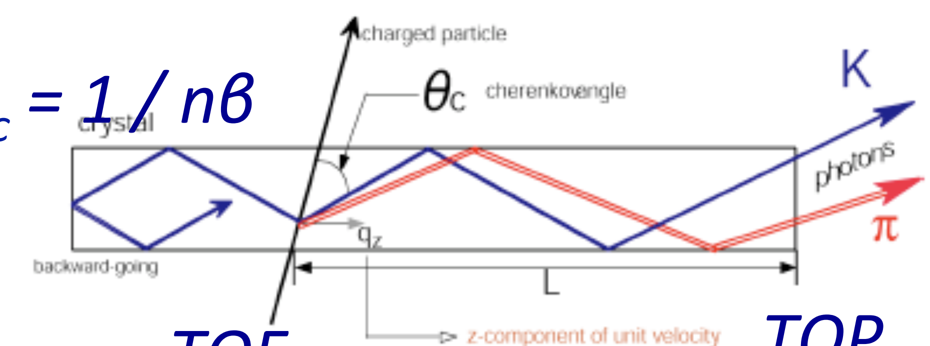


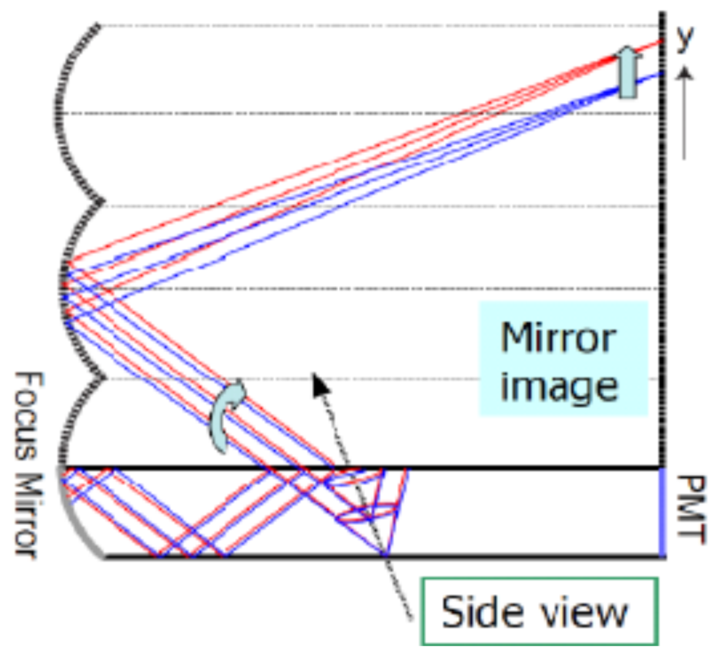
Collaboration of
Japan (Nagoya, KEK) + US (PNNL, Cincinnati, Hawaii, Indiana, Pittsburgh, South Carolina) + Slovenia (IJS) + Italy (Padova, Torino)

Belle II TOP Principle

- Cherenkov ring imaging based on precision timing
  - Diff. in Cherenkov angle
    - → Diff. in Path length
      - → Diff. in Time Of Propagation (TOP)
- Compact geometry suitable for collider experiment
  - No stand-off to image Cherenkov light in X-Y
- Measure TOF + TOP (100-200ps) from IP
- Focusing mirror at the bar end to correct chromatic dispersion (~100ps).
  - Long focusing length to enlarge Δy diff.
- Key technologies
  - Single photo detection with ~50ps resolution
  - Accurately polished quartz optics (~5Å)







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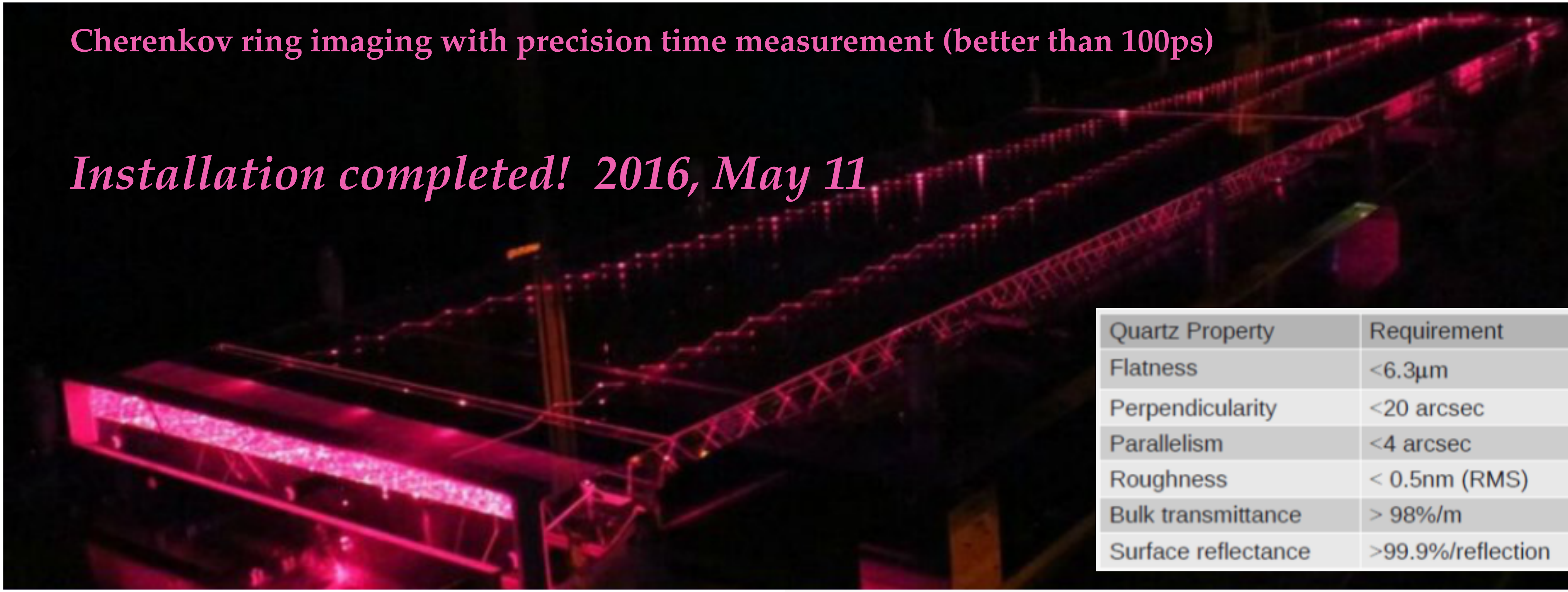
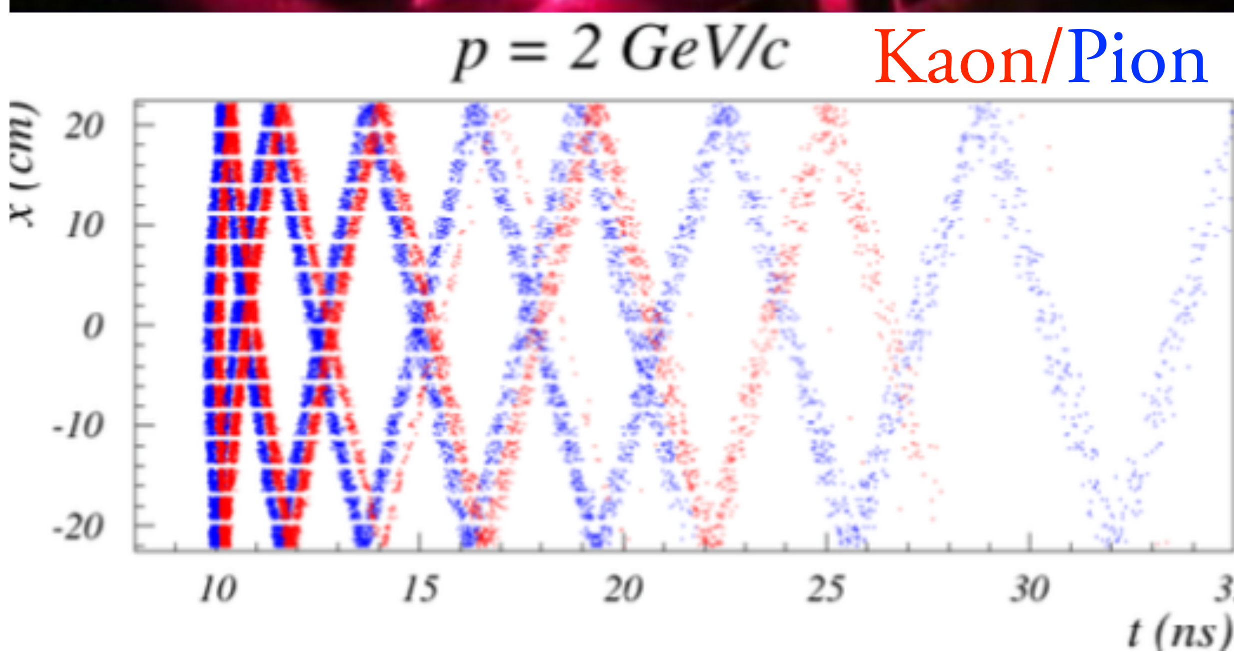
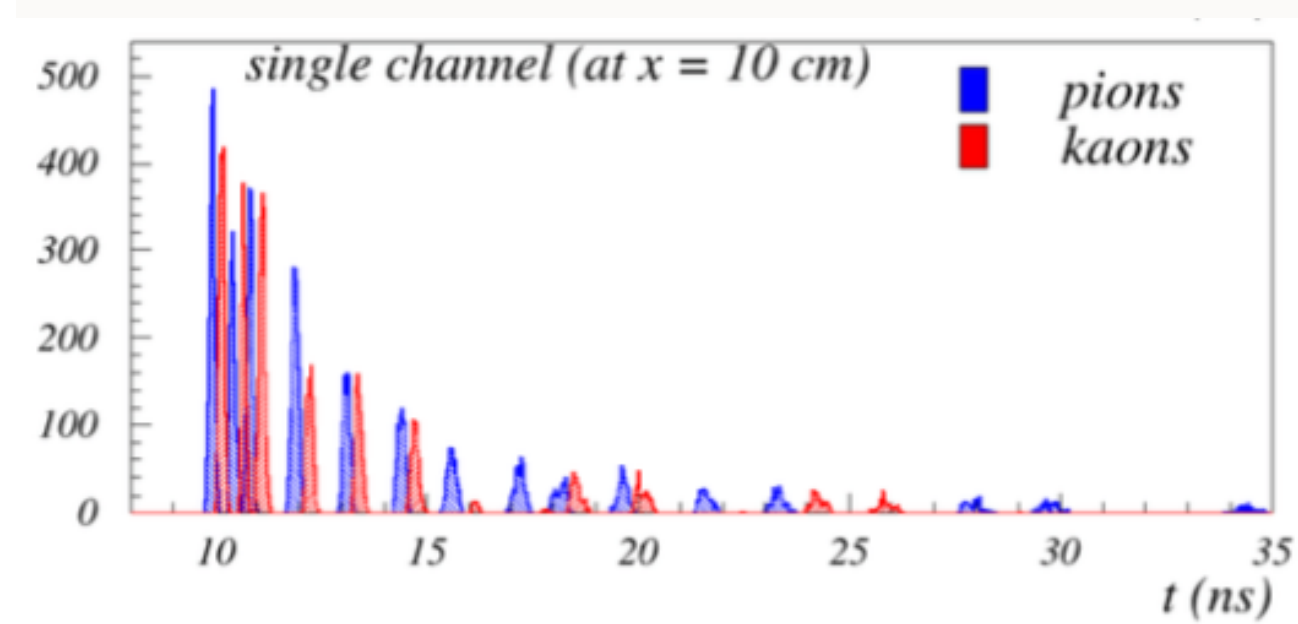


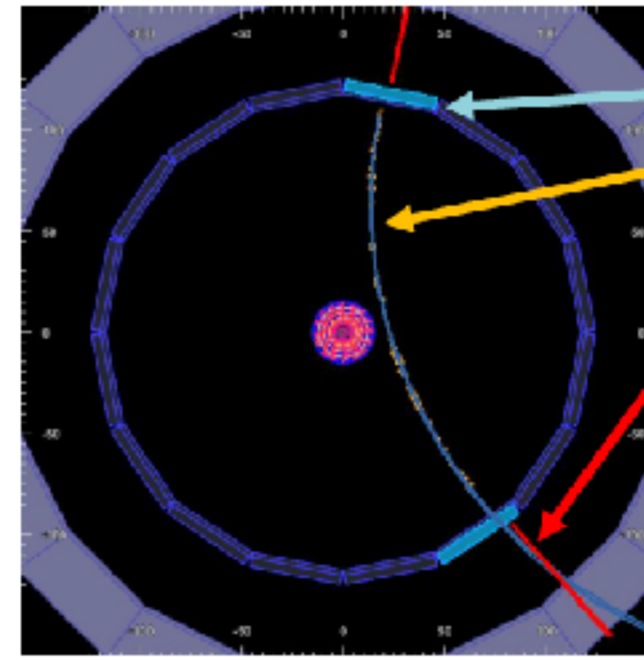
Quartz Property	Requirement
Flatness	<6.3µm
Perpendicularity	<20 arcsec
Parallelism	<4 arcsec
Roughness	< 0.5nm (RMS)
Bulk transmittance	> 98%/m
Surface reflectance	>99.9%/reflection





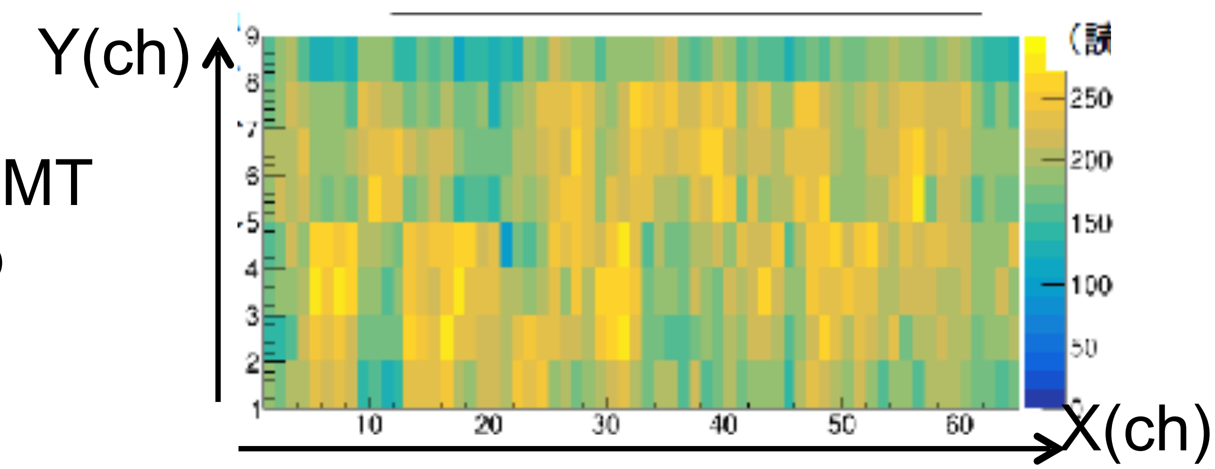
TOP Data in Cosmic Ray Run

- Module N_{hit} distribution is as expected: $\langle N_{hit} \rangle = \sim 20$
- Module efficiency is high with BKLMhit > 0
  - 12(7) out of 16 modules have eff. > 90%(95%)
- Still have to understand and study
  - N_{hit} stability
  - Detailed comparison between data and MC (for N_{hit} and track momentum dist.)
  - Time calibrated (x, t) ring image

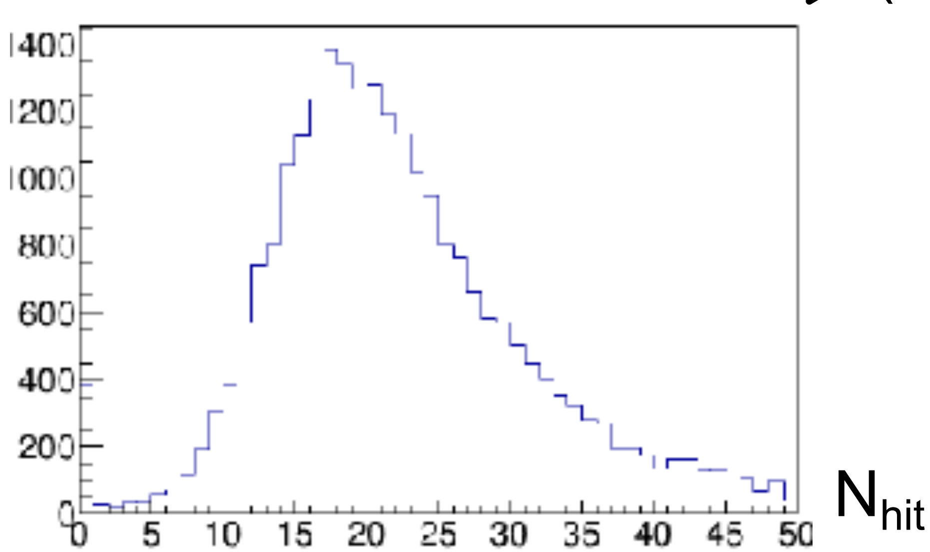


TOP
CDC
ECL

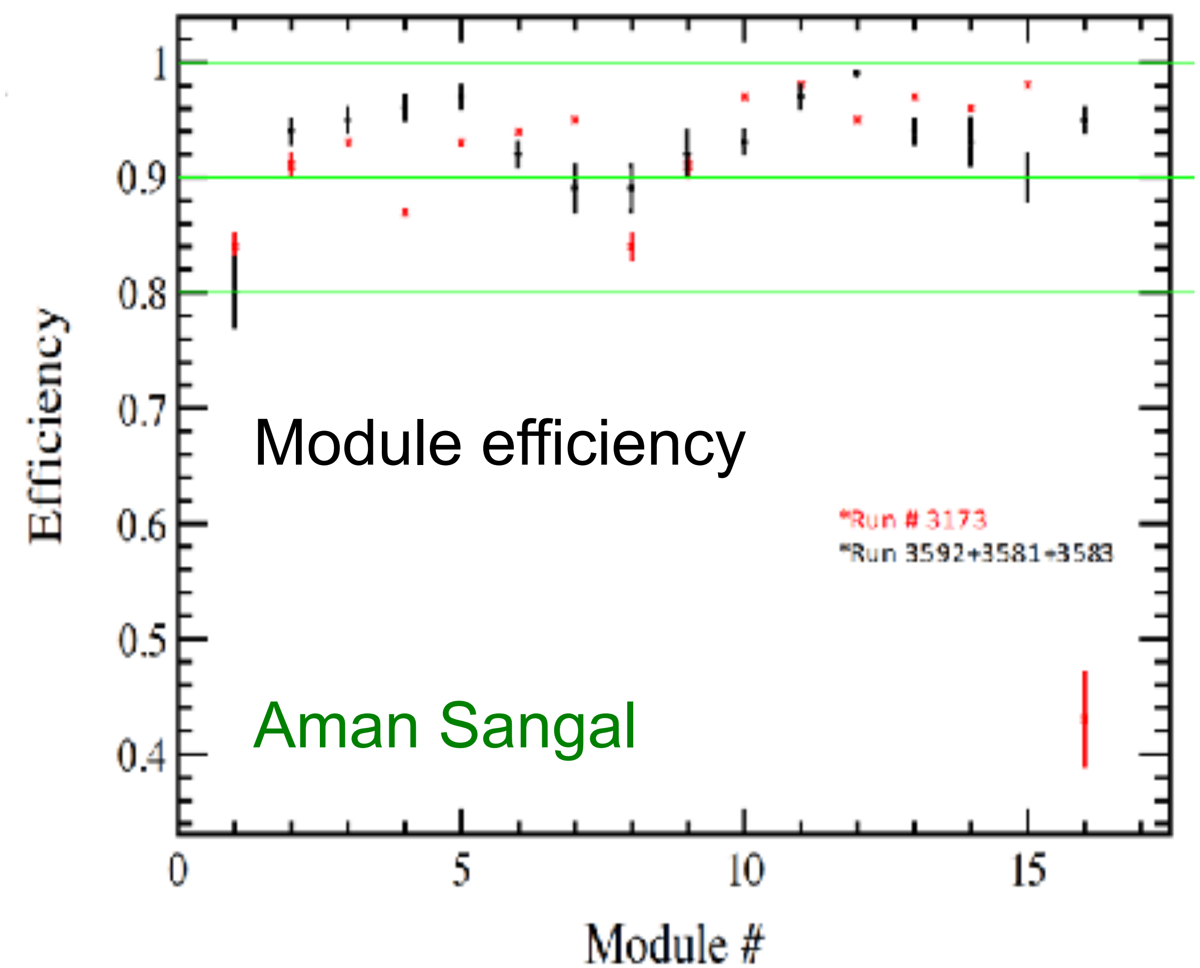
MCP-PMT hit map



Typical N_{hit} distribution



Noritsugu Tsuzuki



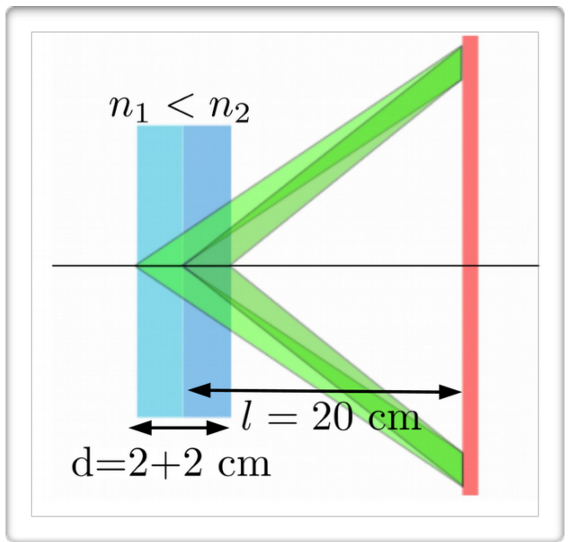
Aman Sangal

Forward Aerogel RICH

- Proximity focusing RICH with aerogel radiator.
- Two-layer configuration with slightly different refractive indices to increase number of deteted photons without lossing angular resolution.

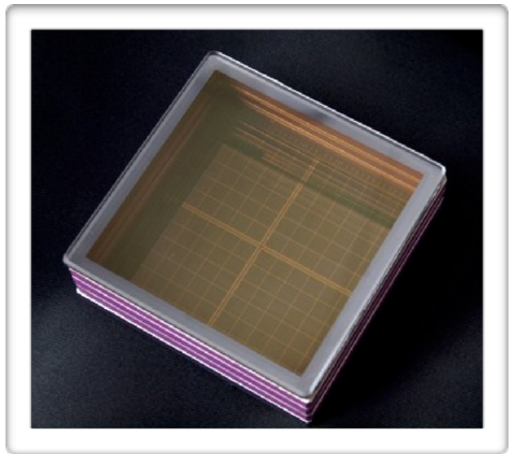
Use two aerogel layers in focusing configuration to increase n. of photons without resolution degradation

$n_1 = 1.045,\ n_2 = 1.055$

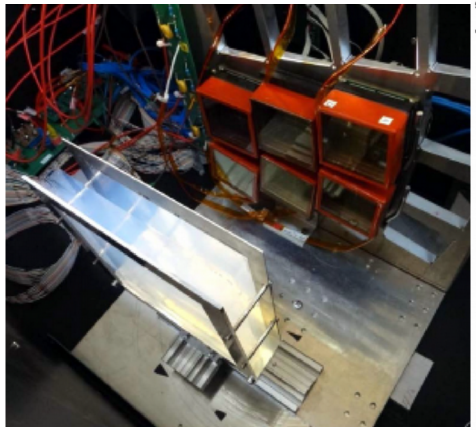


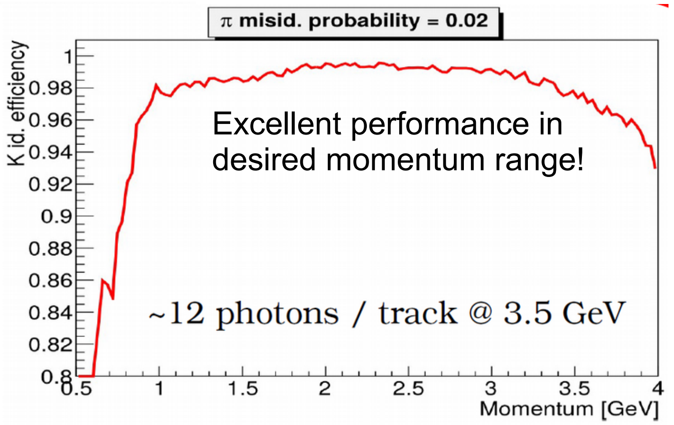
HAPD – Hybrid Avalanche Photo-Detector

- 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

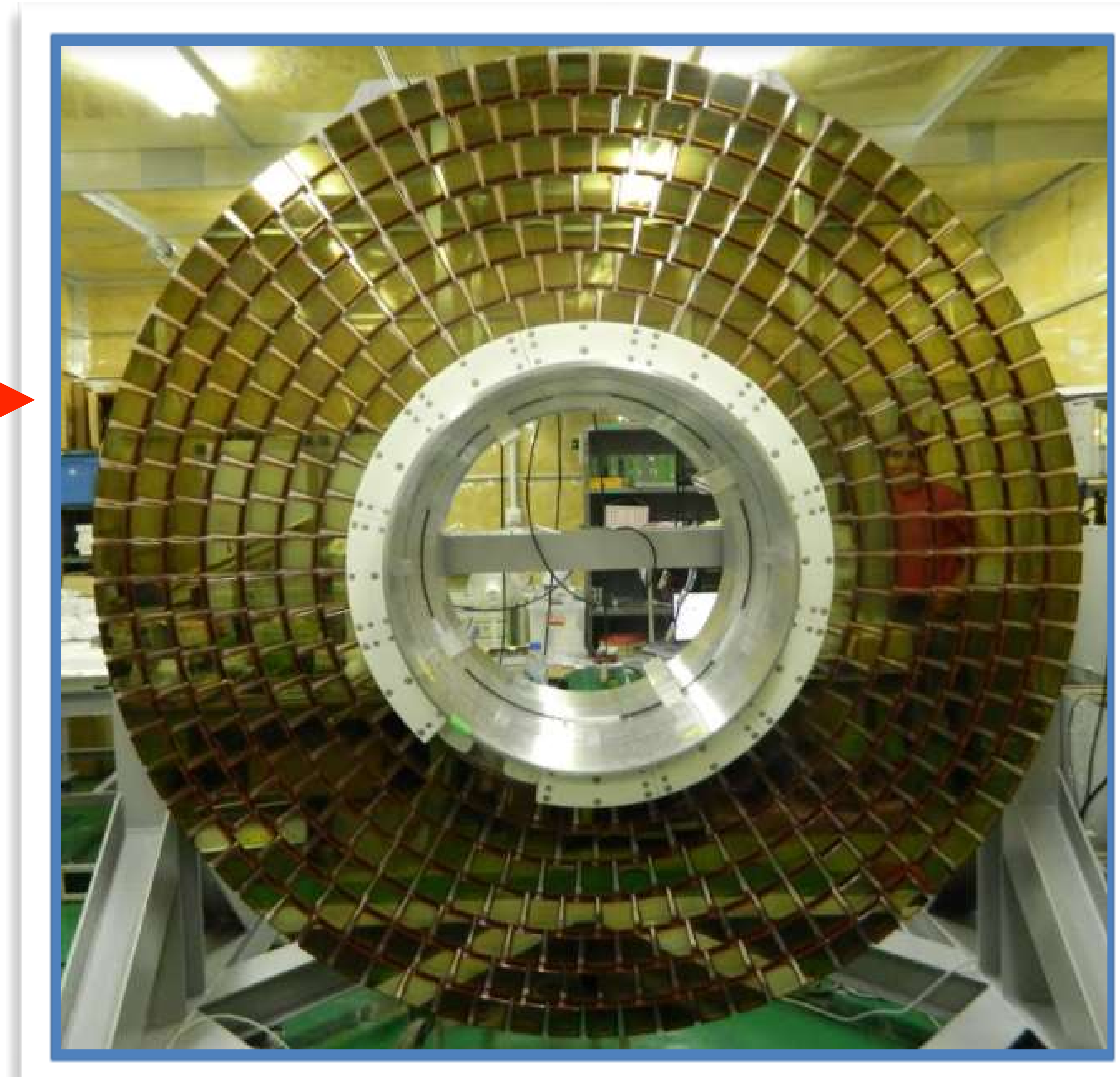




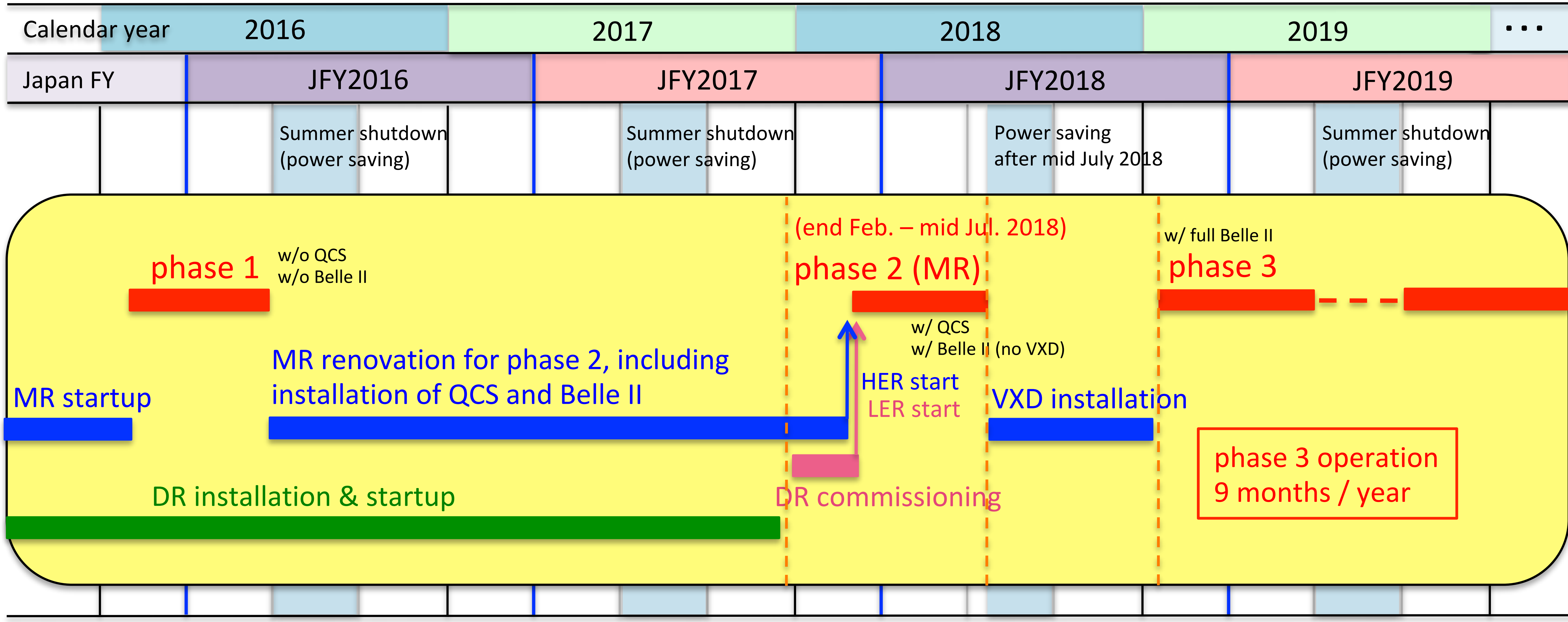
cont'd

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

- Production of aerogel tiles and HAPDs is finished.
- Installation on the structure complete!
- Install in Belle II in September.



SuperKEKB/Belle II Schedule



Phase 1 (w/o final focusing Q, w/o Belle II):
- Accelerator system test and basic tuning,
- **Vacuum scrubbing**,
- **Low emittance tuning**, and
- **Beam background studies**

Phase 2 (w/ final focusing Q, w/Belle II but background monitors instead of vertex detectors)
- **Verification of nano-beam scheme**
  target: $L>10^{34}$ $cm^{-2}s^{-1}$
- Understand **beam background** especially in vertex detector volume

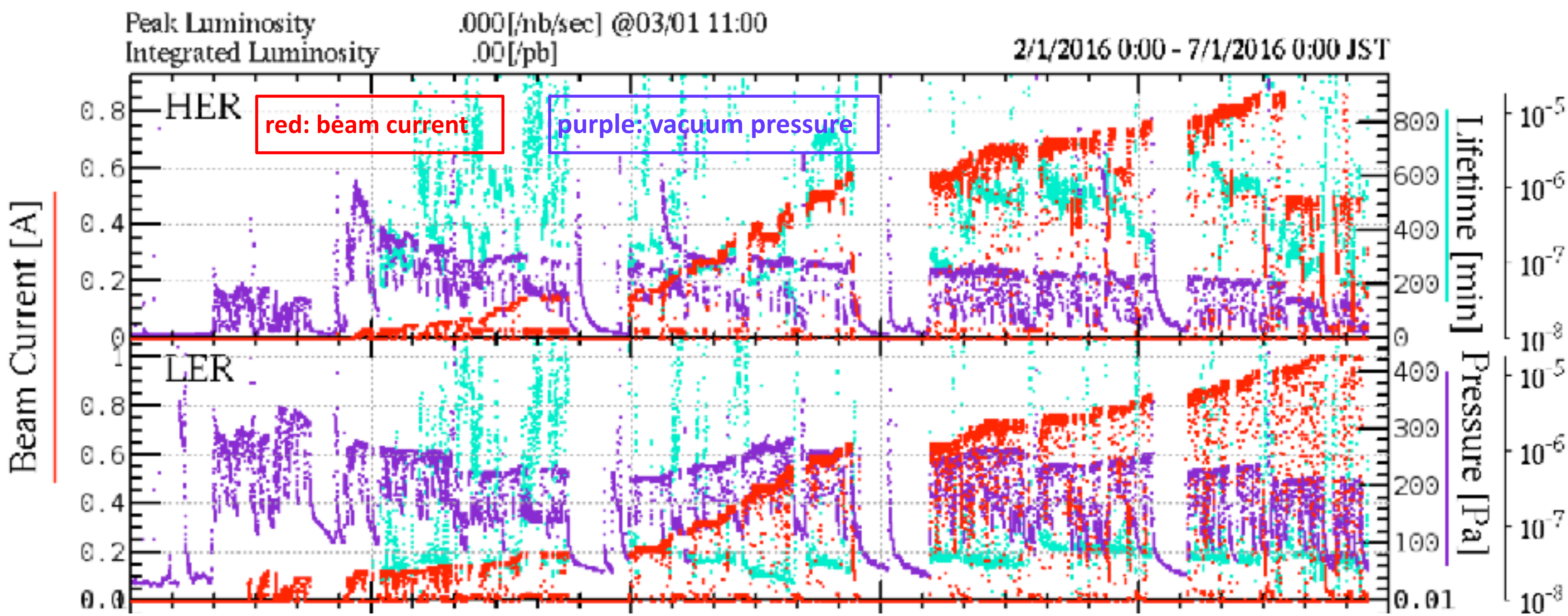
Phase 1 Commissioning

Feb. - June 2016

Phase 1 milestones (in 2016)

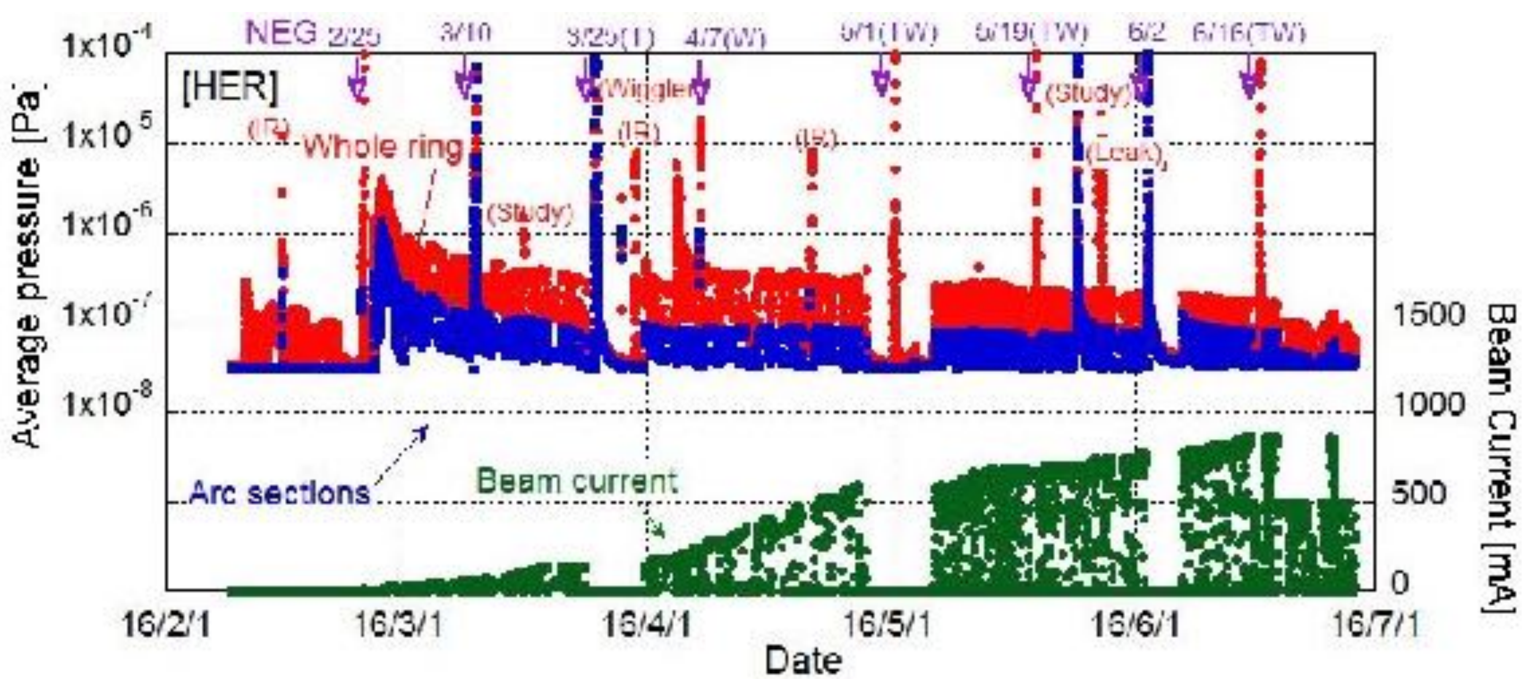
- Feb. 1: BT tuning started
- Feb. 8: LER injection tuning started
- Feb. 10: beam storage in LER
- Feb. 22: HER injection tuning started
- Feb. 26: beam storage in HER

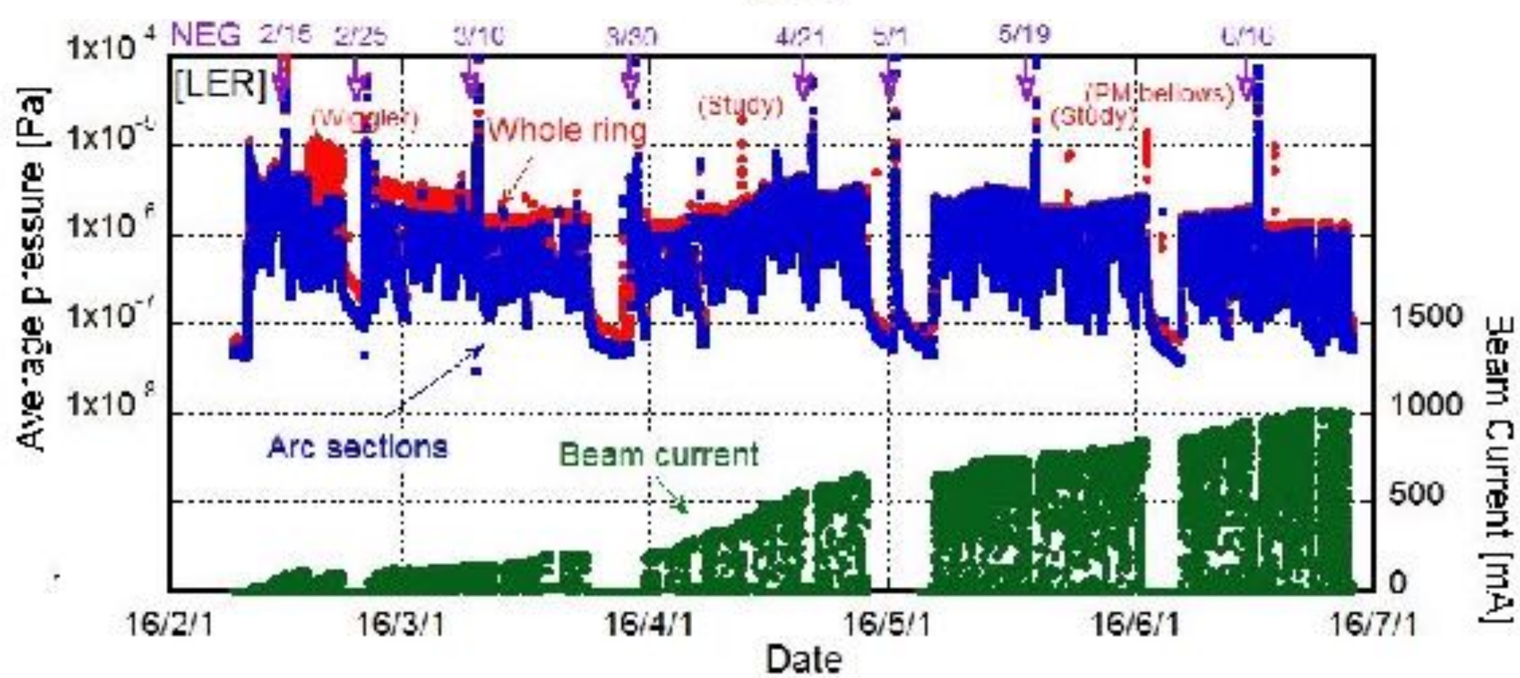
	HER	LER
Max. current [mA]	870	1010
Integrated current [Ah]	660	780
Avg. pressure [Pa]	~2×10^{-7}	~1×10^{-6}
Lifetime [min.]	~ 400	~ 70



Vacuum Scrubbing

- The vacuum system worked well with newly introduced components.
- Integrated beam currents satisfied requirement for Belle II roll-in.





[HER]

- Base pressure: $\sim 3\times10^{-8}$ Pa
- Max. beam current: 870 mA
- Int. beam current: 660 Ah
- Avg. Pressure: $\sim 2\times10^{-7}$ Pa
  (arc sections) $\sim 6\times10^{-8}$ Pa
- Lifetime ~ 400 min.

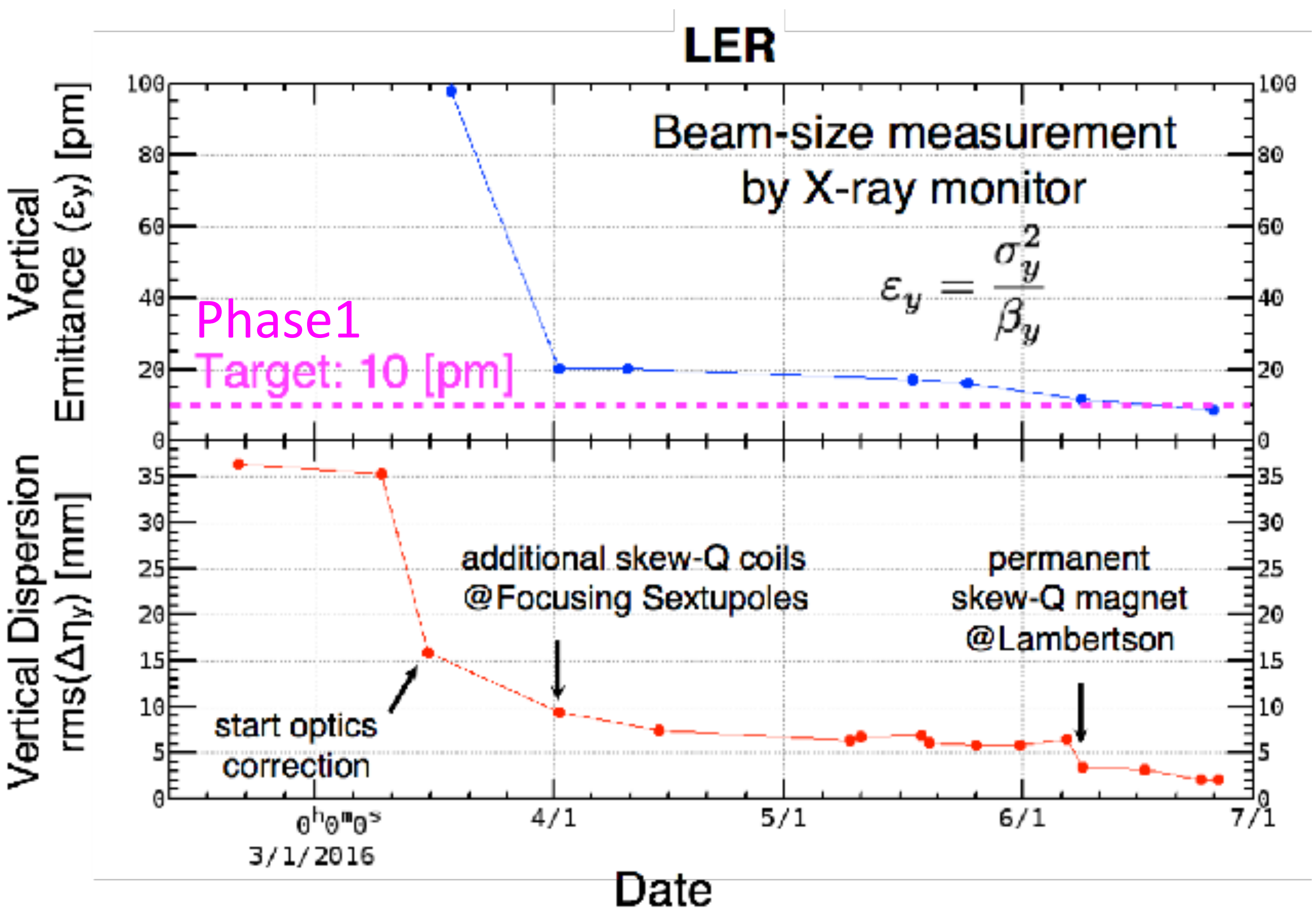
[LER]

- Base pressure: $\sim 5\times10^{-8}$ Pa
- Max. beam current: 1010 mA
- Int. beam current: 780 Ah
- Avg. Pressure: $\sim 1\times10^{-6}$ Pa
- Lifetime: ~ 70 min.
  (with Emittance control Knob ON)

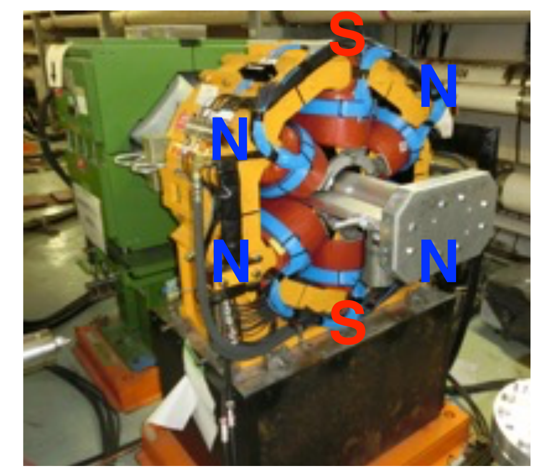
Y. Suetsugu et al.

Low Emittance Tuning

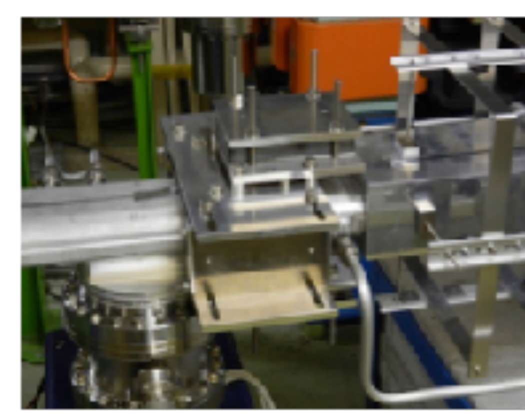
- Optics corrections have been worked successfully in both rings.
- Phase I target of vertical emittance has been achieved in LER.
- More calibration of X-ray monitor in HER needed in Phase 2.



skew-Q corrector coil on sextupole



permanent skew-Q to correct error field of Lambertson



Phase 1 Beam Background Study

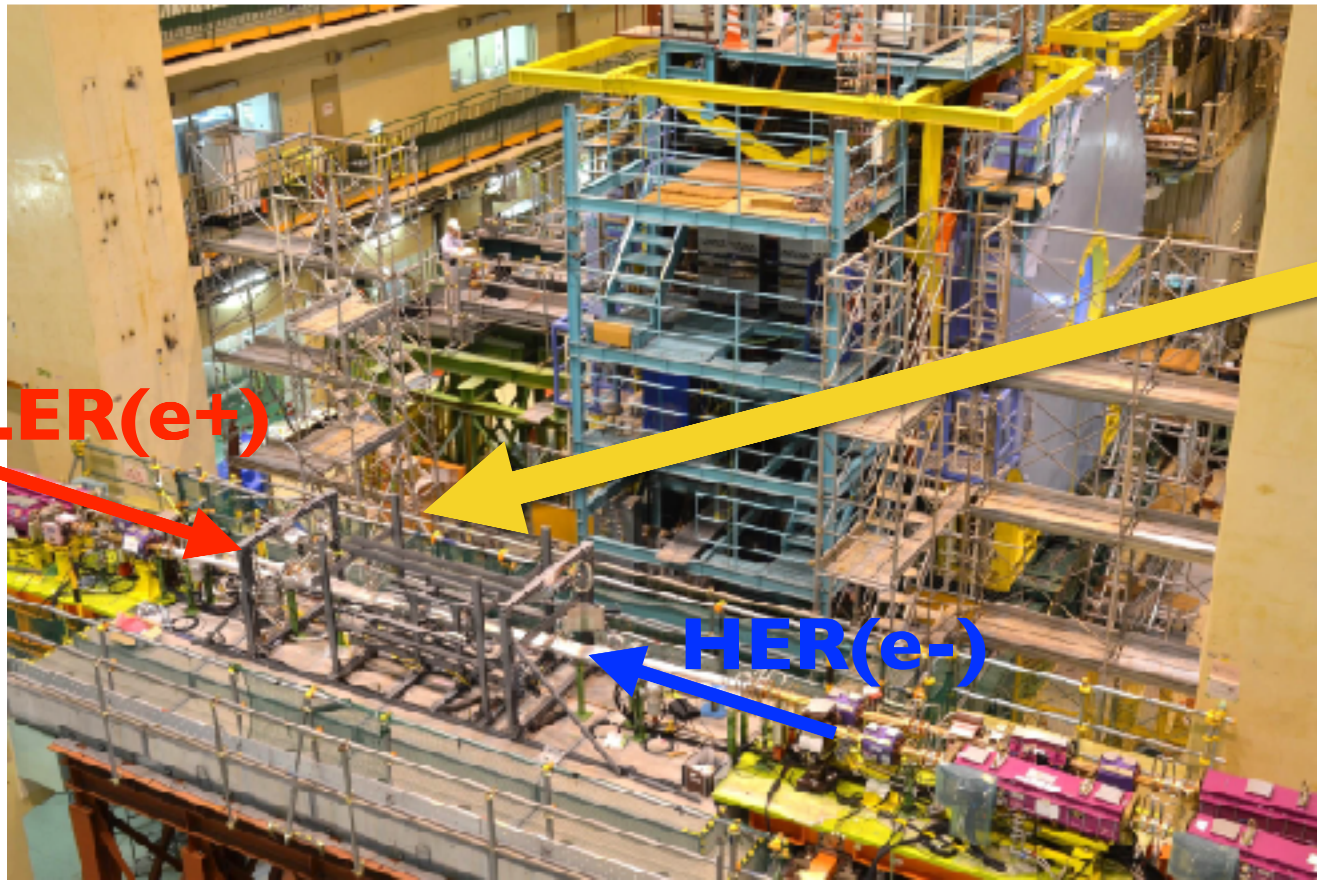
Interaction region during Phase 1

Beam **E**xorcism for **A** **S**table Experimen**T**

Dedicated Background Monitors

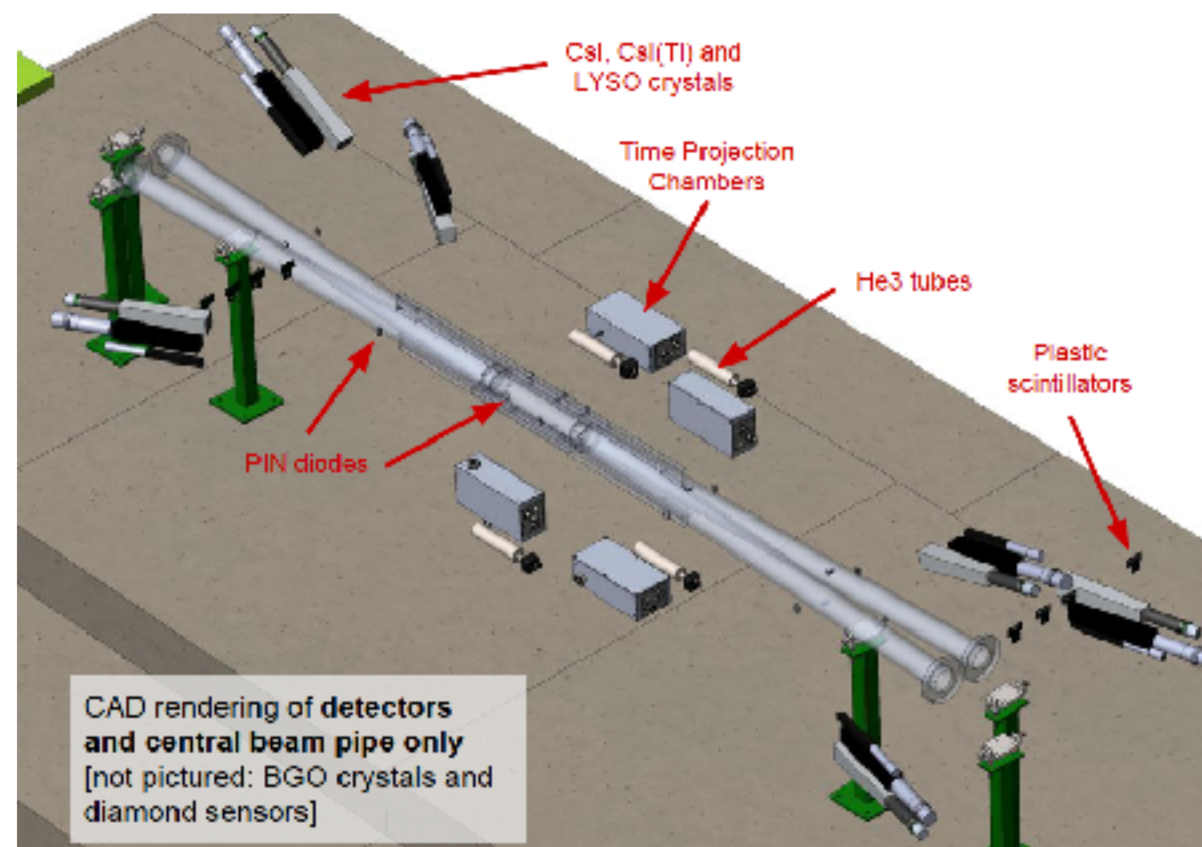
Phase 1 Beam Background Study

Interaction region during Phase 1



Beam **E**xorcism for **A** **S**table Experimen**T**

Dedicated Background Monitors



7- detector system providing :

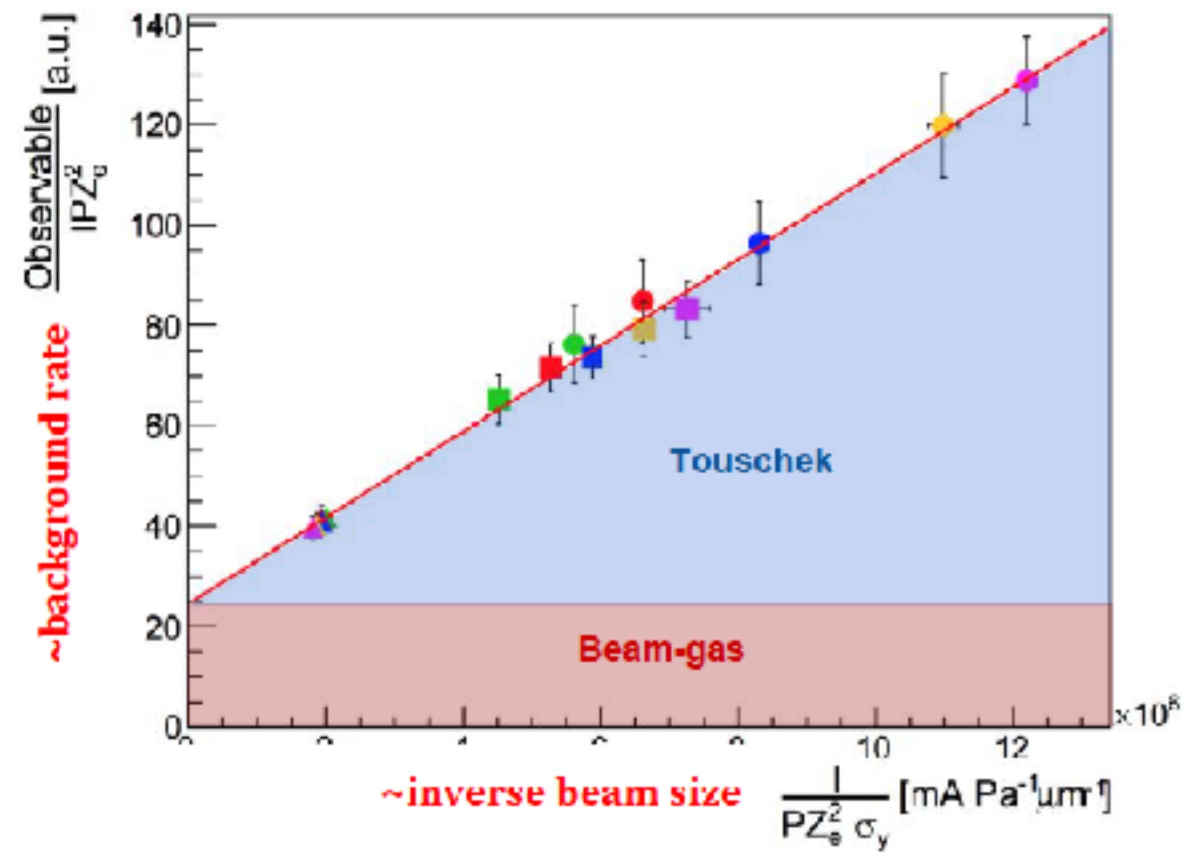
- Thermal neutron rate
- Fast neutron tracking
- Neutral and charged dose rates
- EM spectrum and dose
- Bunch-by-bunch injection background
- More…

Phase 1 Beam Background Study

Beam background

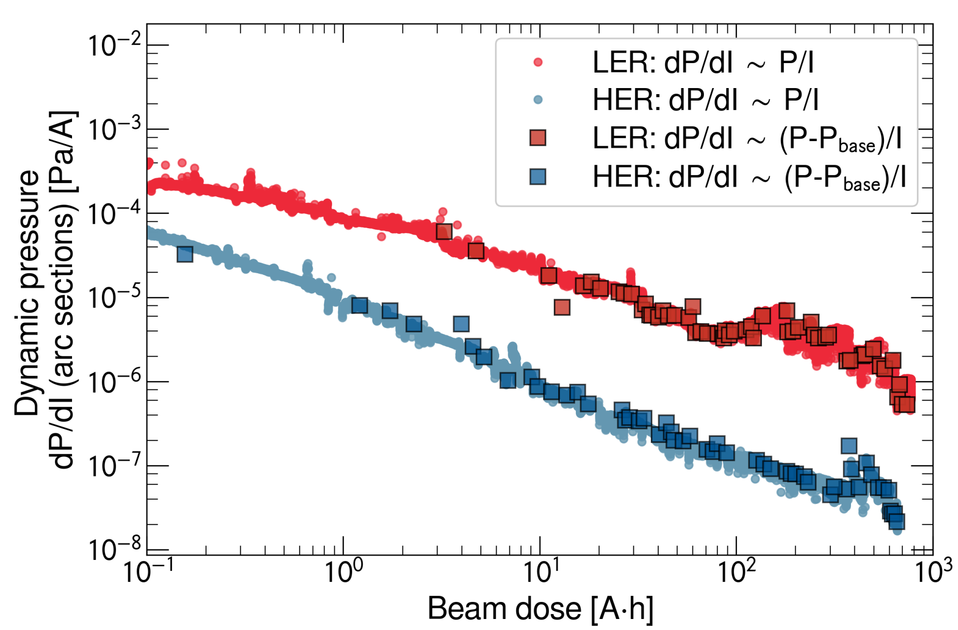
Change beam size to decompose Touschek (intra-bunch Coulomb) and beam-gas scatterings

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

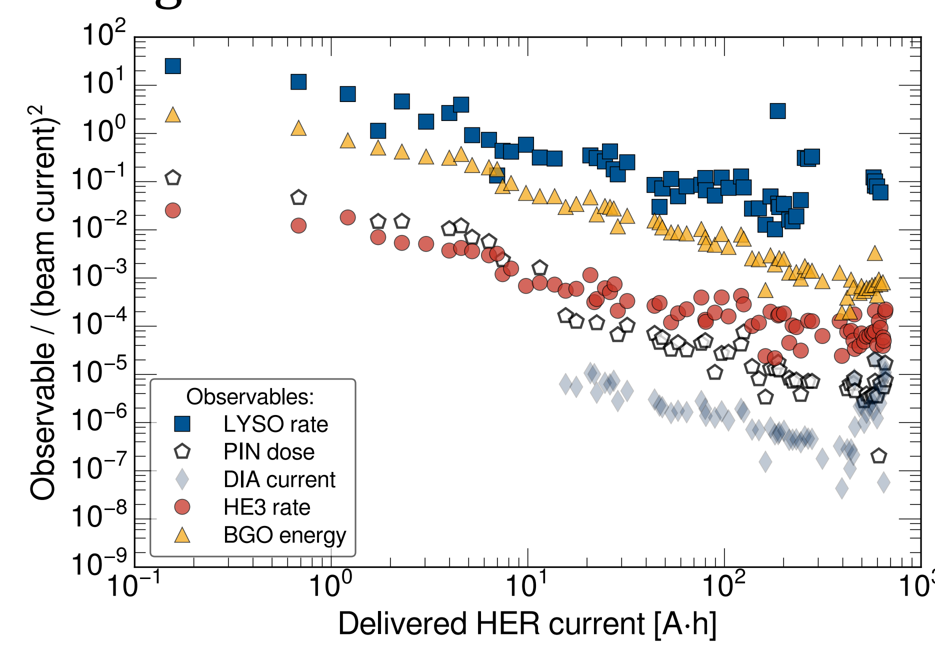


Beam scrubbing

SuperKEKB measurements of dP/dI vs integrated current



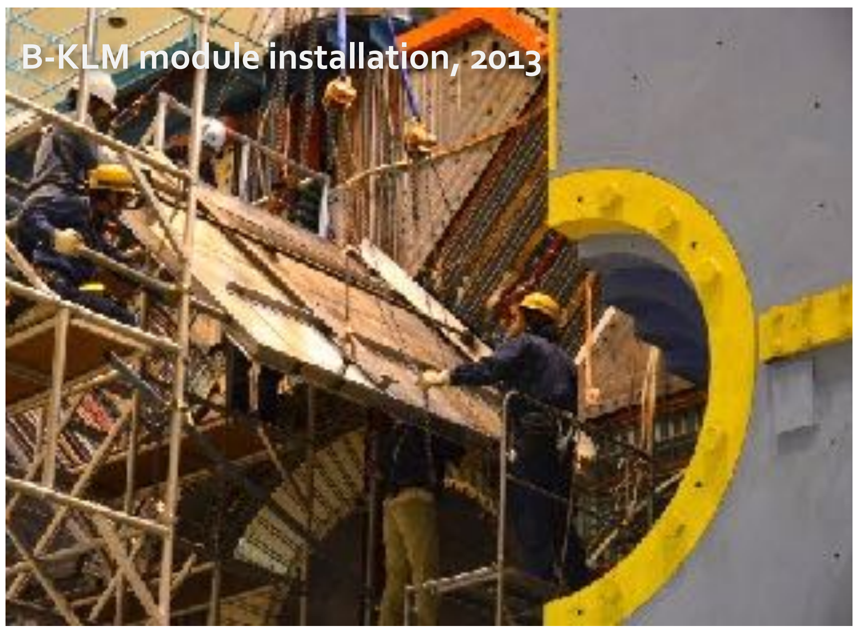
BEAST measurements of Rates/I^2 vs integrated current



Belle II Integration

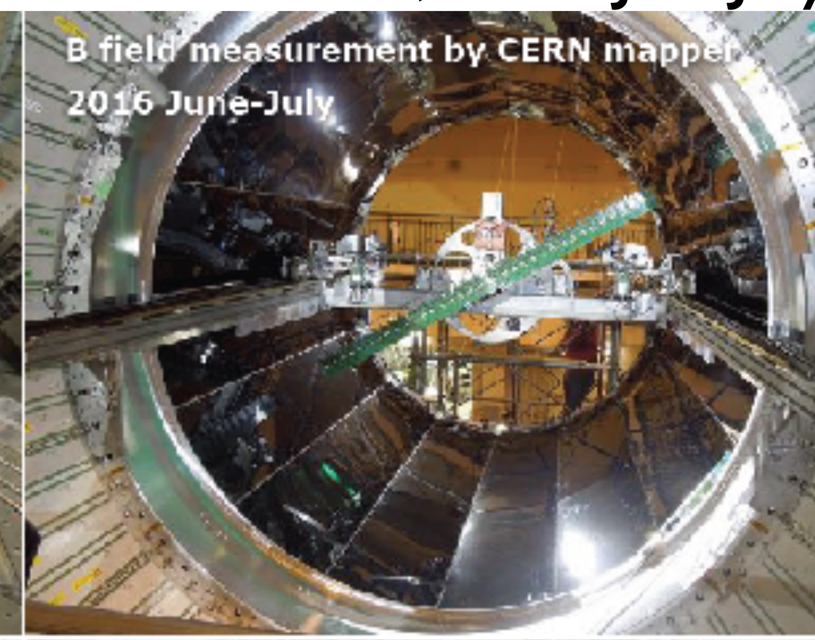
2013 - 2017 Feb. at roll-out position

B-KLM, 2013



TOP, 2016 Feb-May

B field meas., 2016 Jun-July

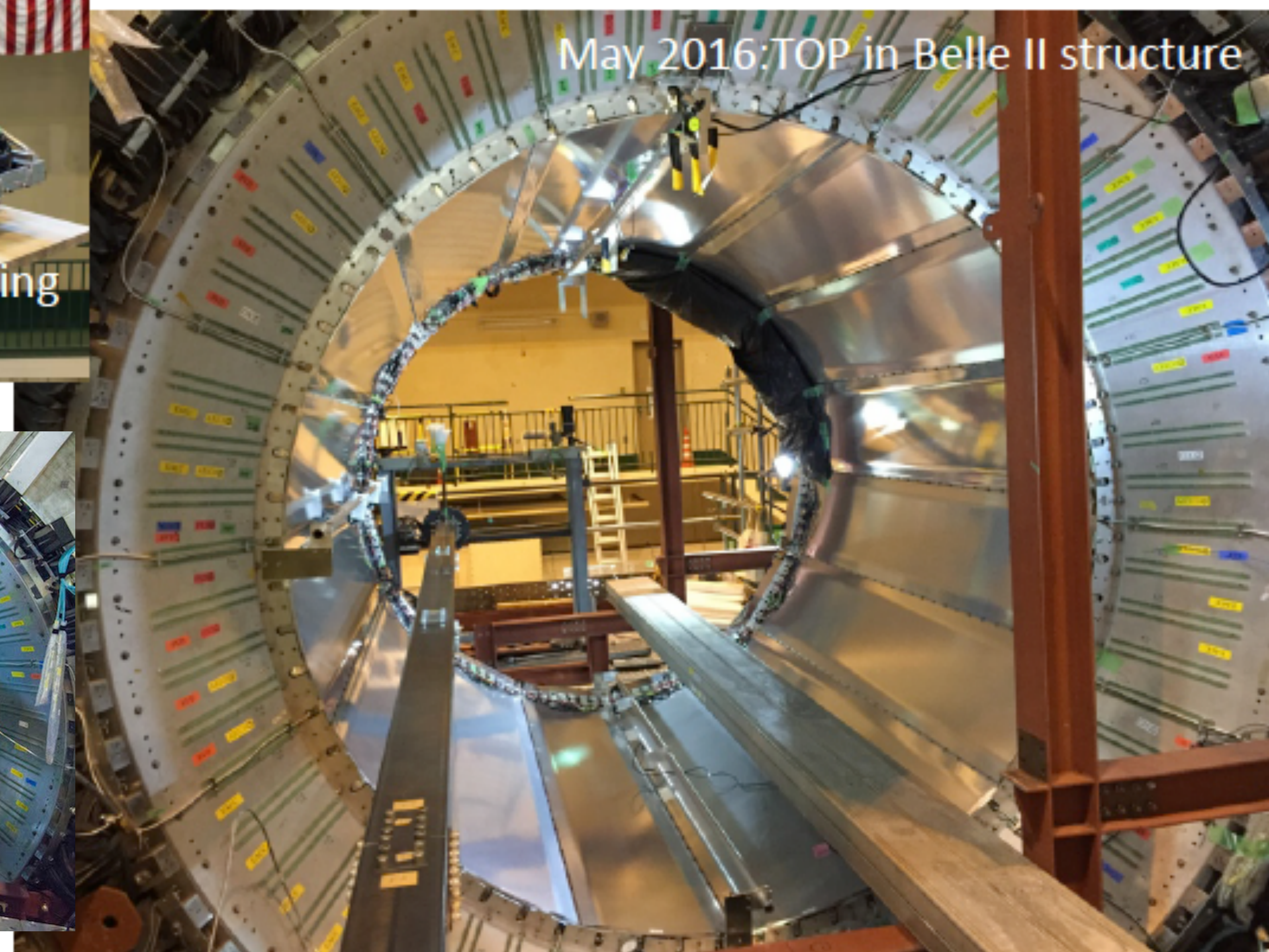


E-KLM, 2014

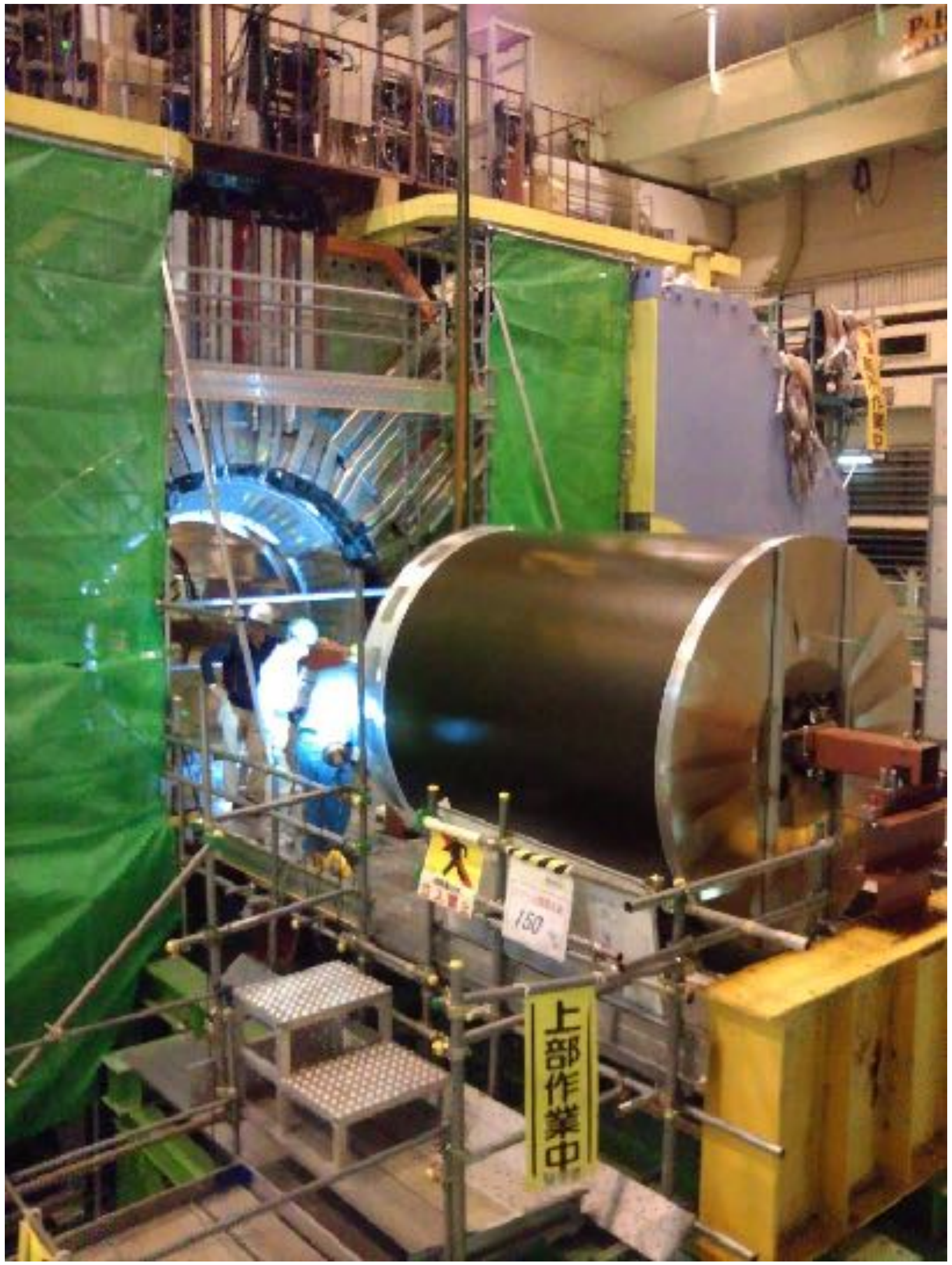
CDC 2016 Oct-Dec

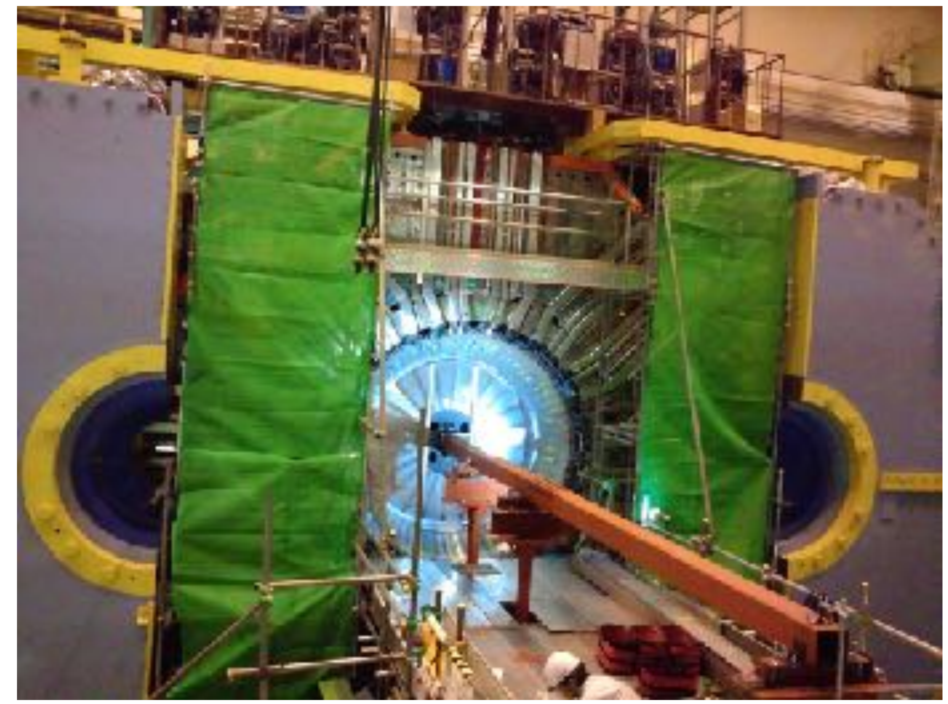
BW endcap, 2017 Jan-Feb

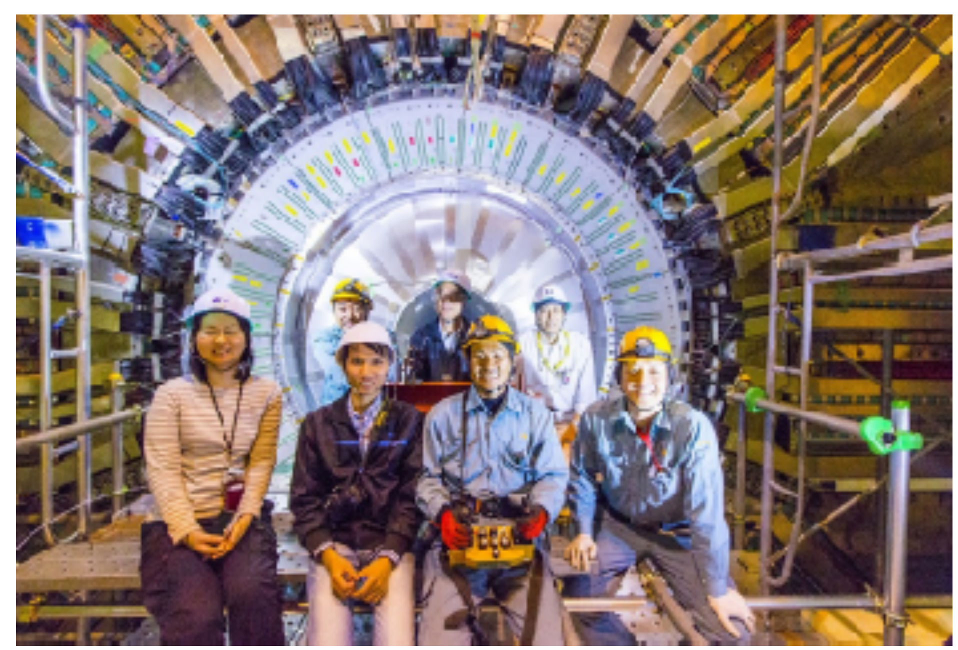
TOP Installation



CDC Installation





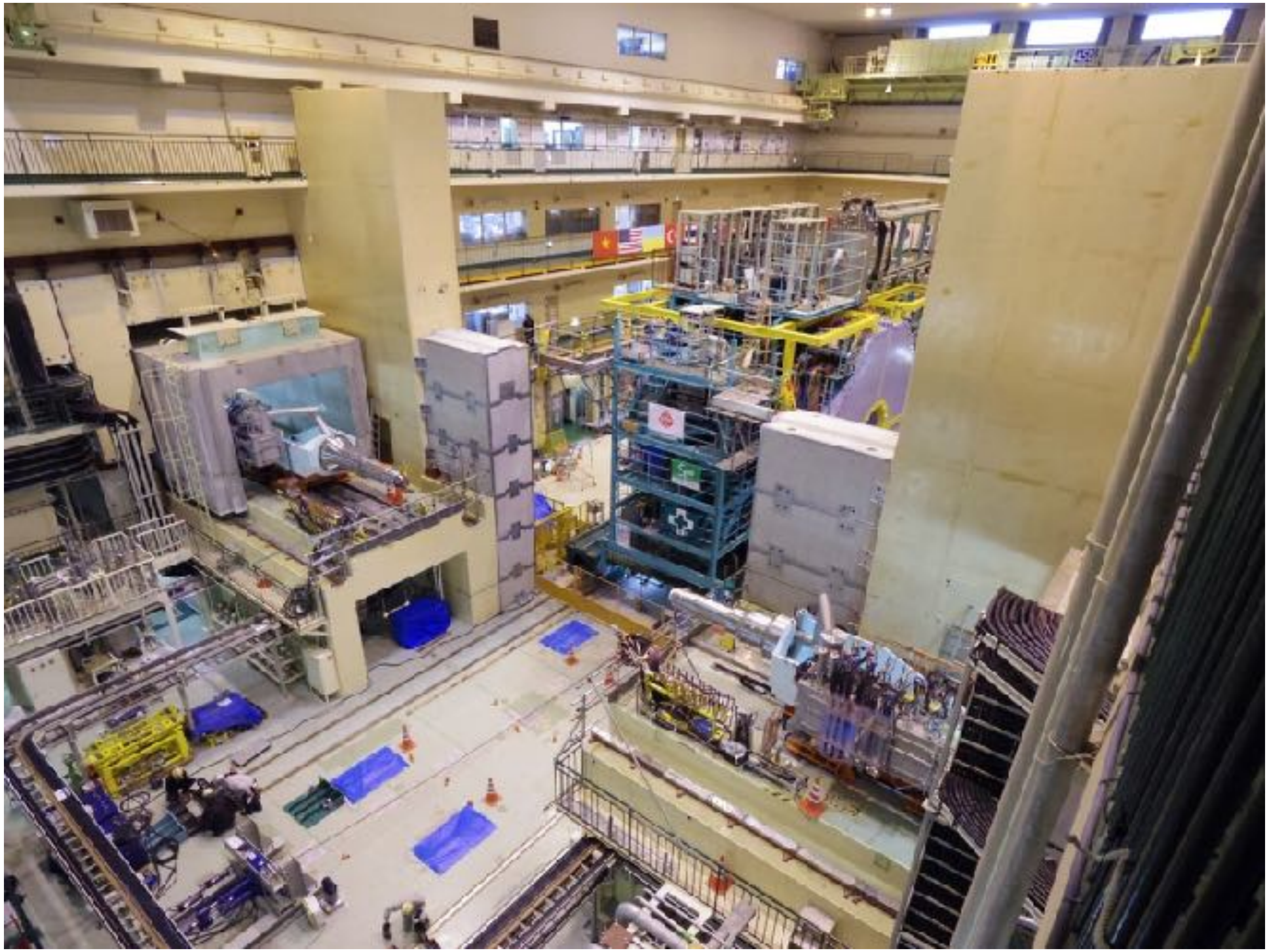


Belle II ready to roll in

Belle II ready to roll in

Belle II Roll-In

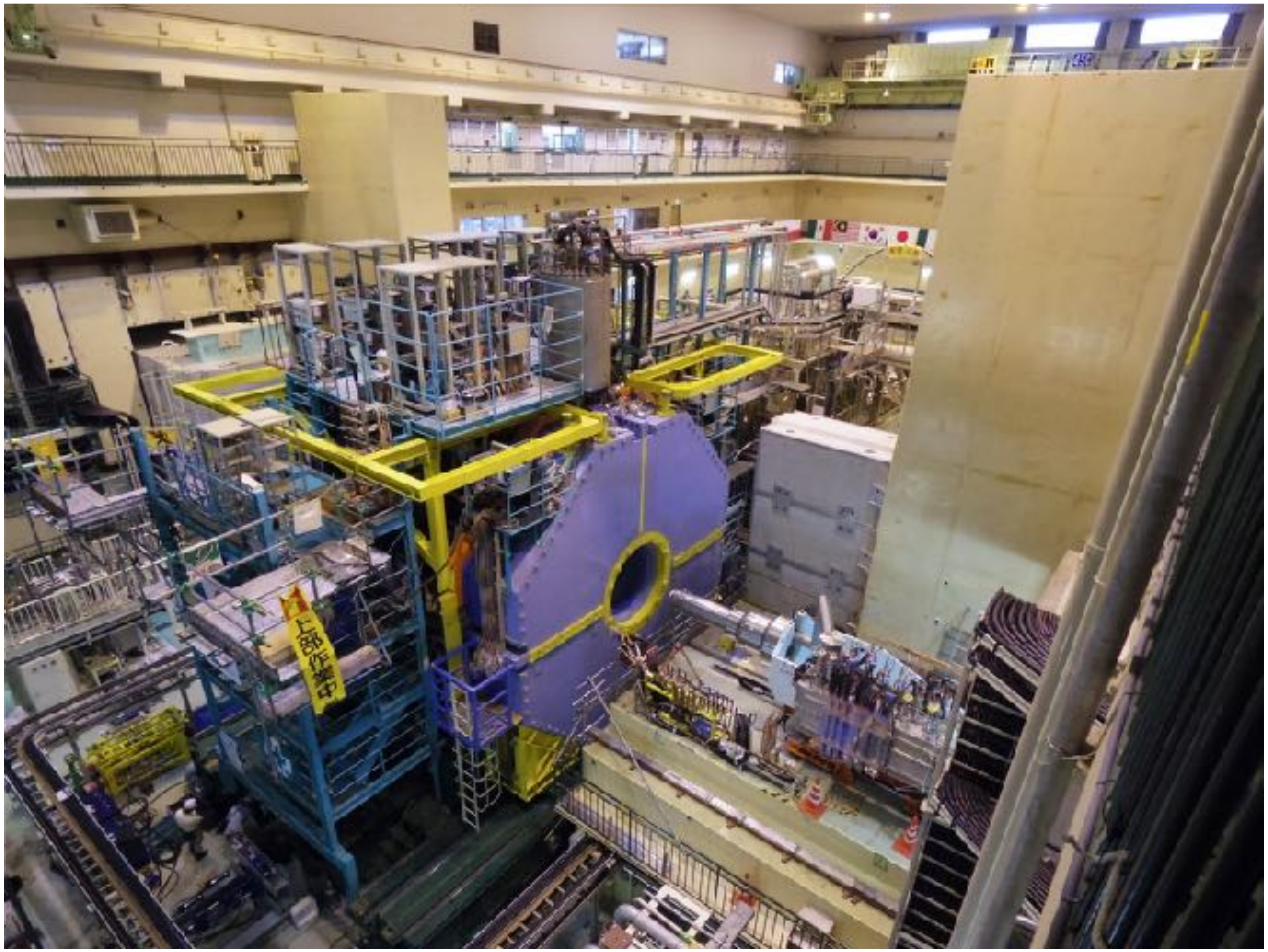
April 11, 2017



Belle II rolled-in to the beam line on April 11th, 2017
One of the most significant milestones in the construction phase

Belle II Roll-In

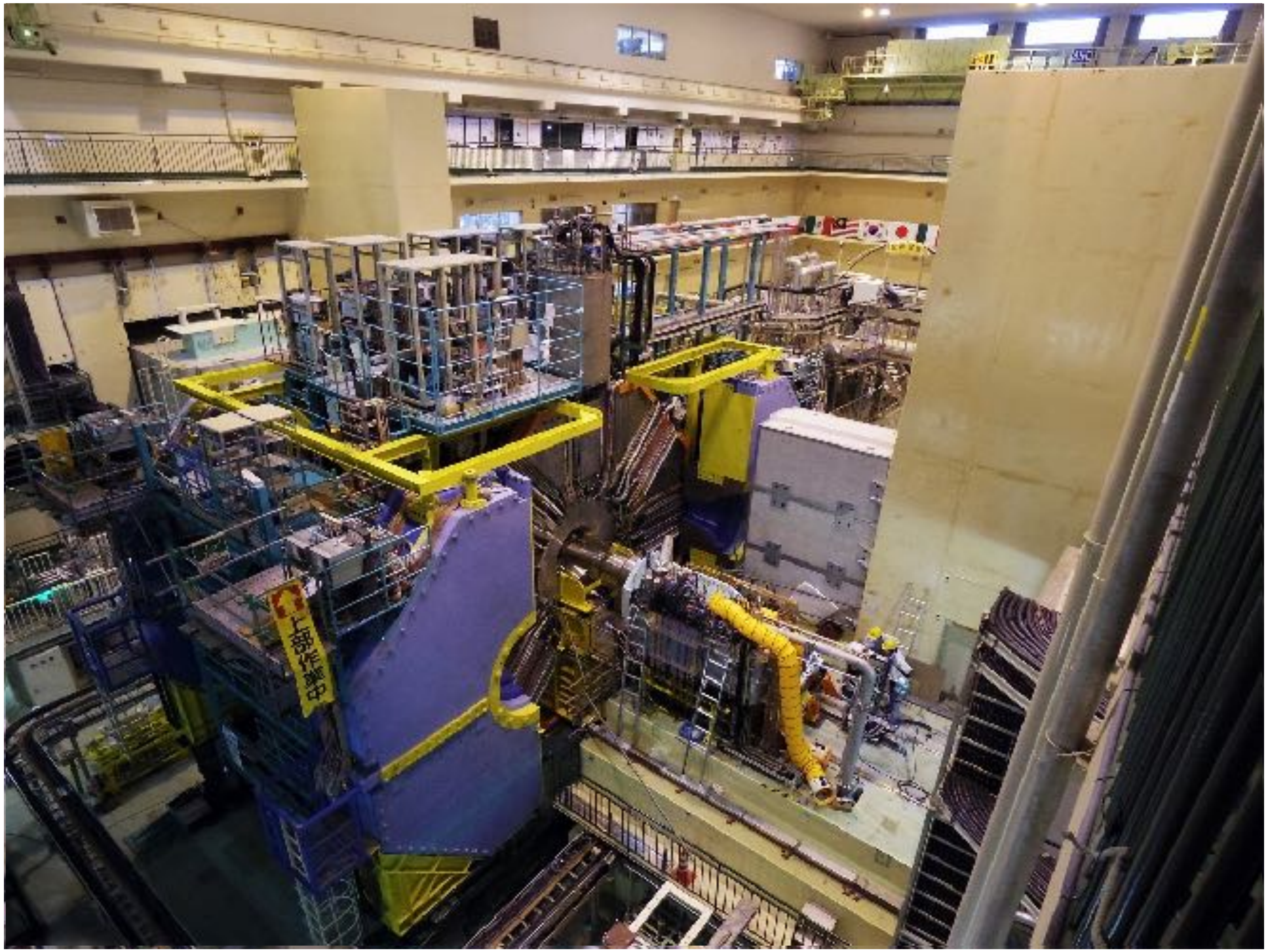
April 11, 2017



Belle II rolled-in to the beam line on April 11th, 2017
One of the most significant milestones in the construction phase

Belle II Roll-In

April 11, 2017

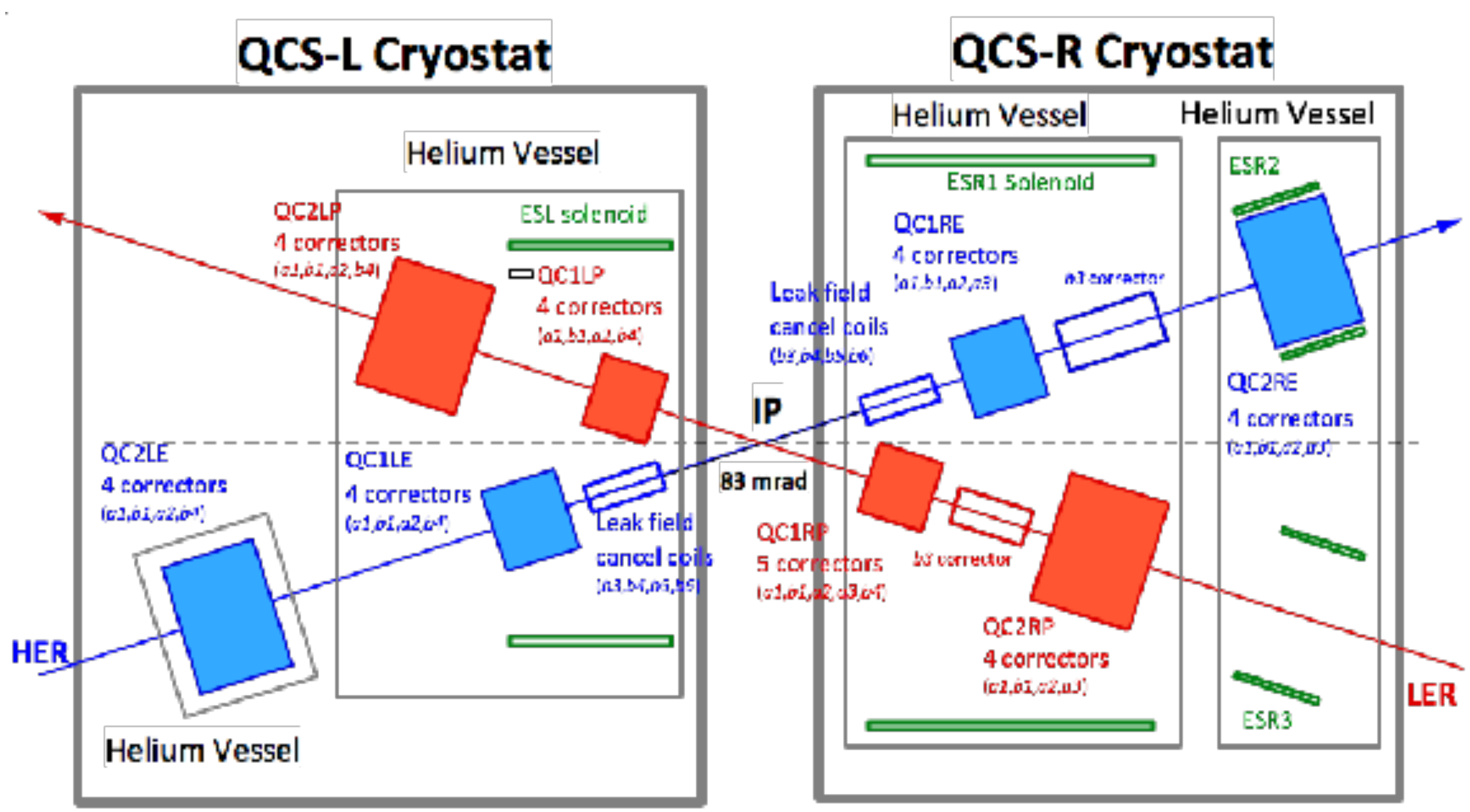


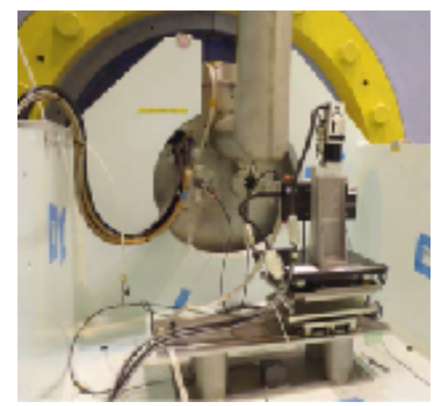
Belle II rolled-in to the beam line on April 11th, 2017

One of the most significant milestones in the construction phase

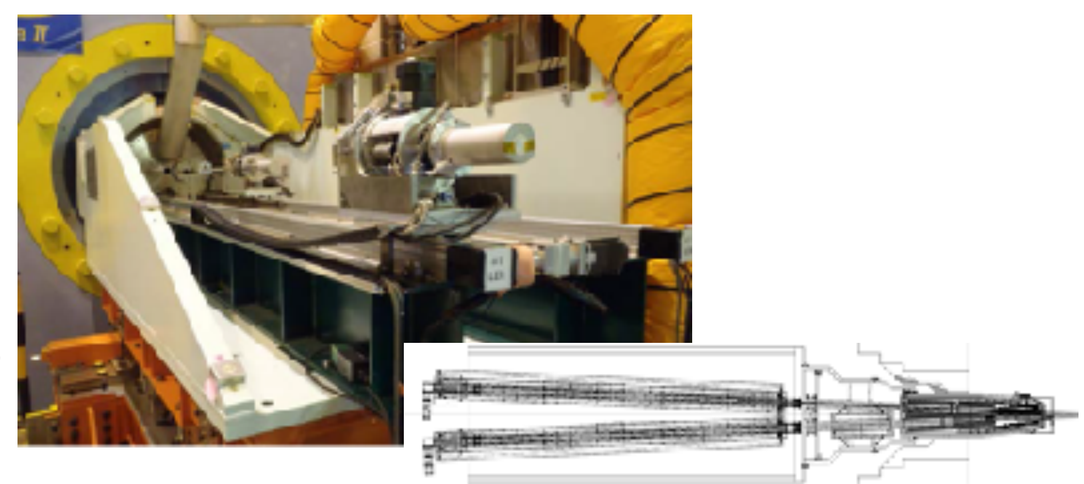
Field Measurement of QCS + Solenoid

- The QCS system is the key ingredient of the nano-beam collisions.
  - 55 superconducting coils in 2 cryostats
- Performance test of the QCS system carried out May - August, 2017.
  - Cool-down and excitation together with the Belle II solenoid at 1.5 T.
  - Careful magnetic field measurements with Single Stretched Wire (SSW), Harmonic coils and hall probe.





SSW
A Φ0.1mm BeCu wire stretched on the beam line through the two cryostats, moved in the field to measure the center and angle from induced voltage.
(collaboration with Fermilab)

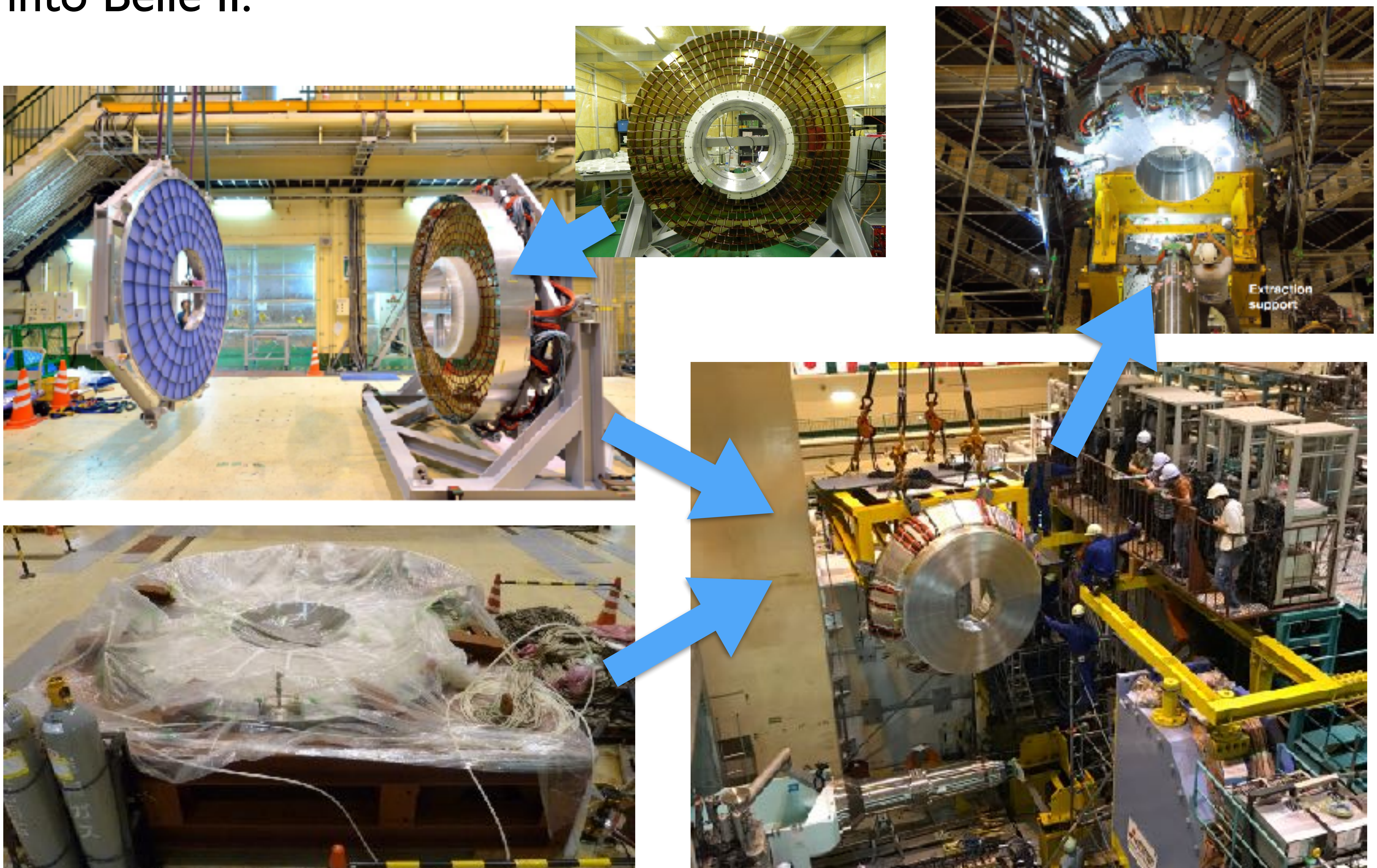


Harmonic coils
The multipole field components as the error components were measured with the 6 harmonic coils.

Forward End-cap Installation

Sep.-Oct., 2017

- Two sub-detectors (A-RICH + FW ECL) are combined and installed into Belle II.

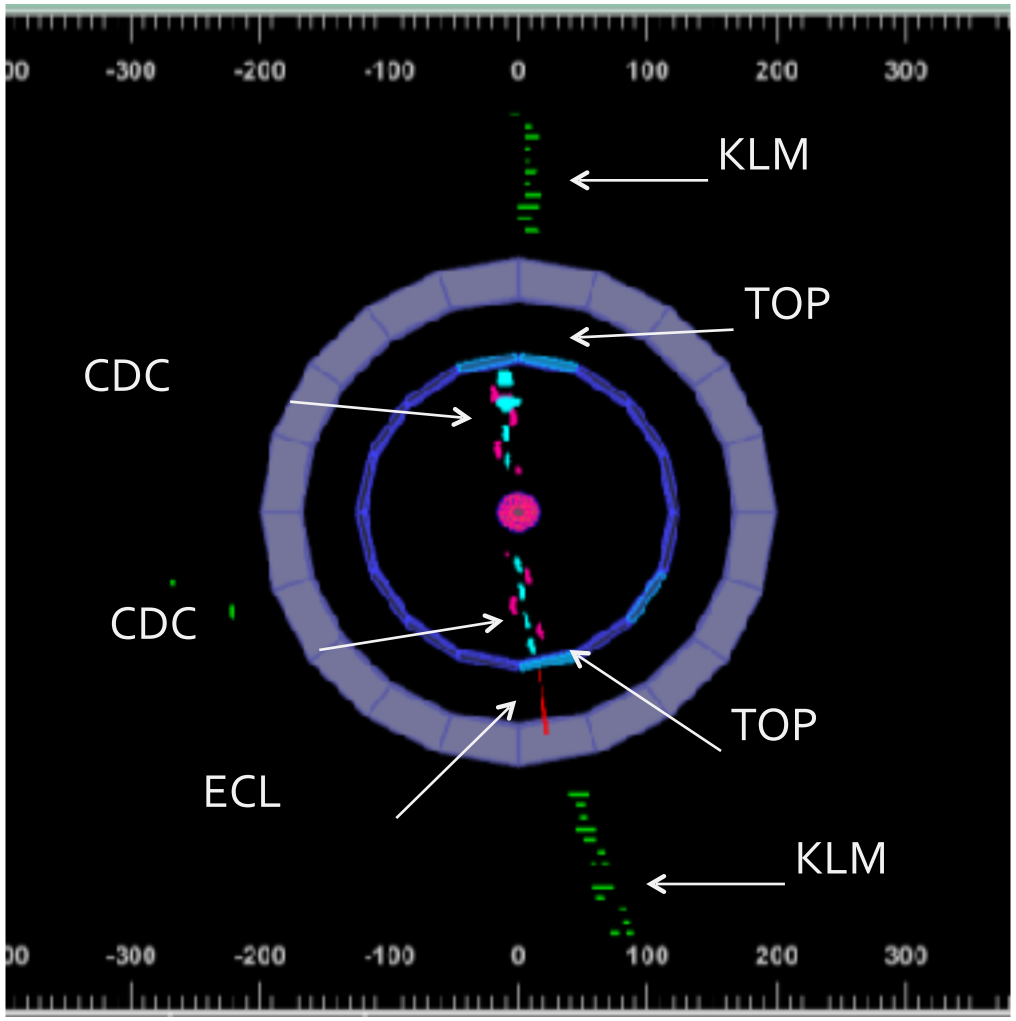


Readout Integration

- Readout integration of installed sub-detectors and central DAQ is in progress.
- Global cosmic ray runs with B=1.5 Tesla in July and August, 2017.
    - Trigger rate at ~100Hz → plan to do stress test up to 30kHz

Belle II control room

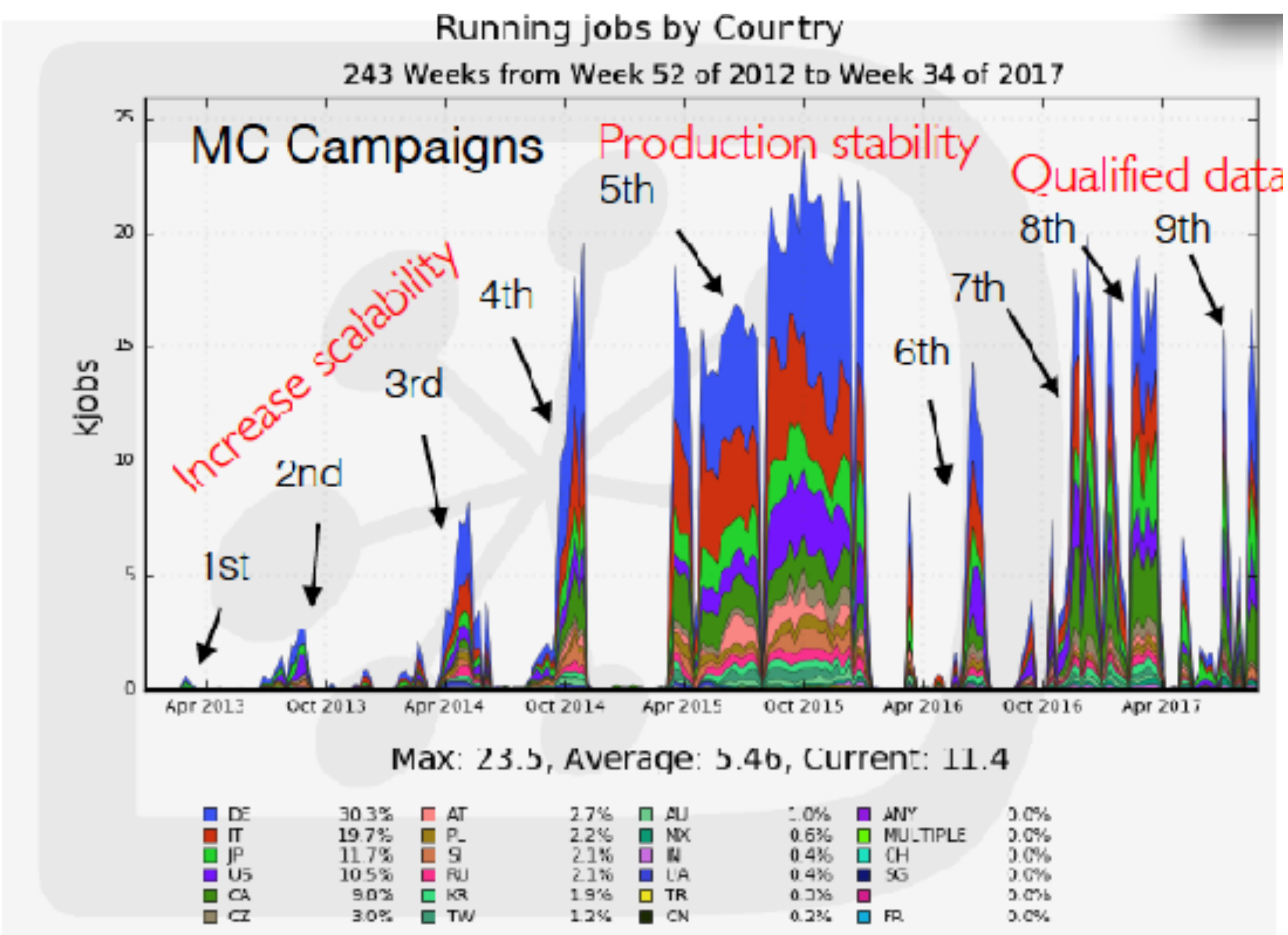
Typical cosmic ray event

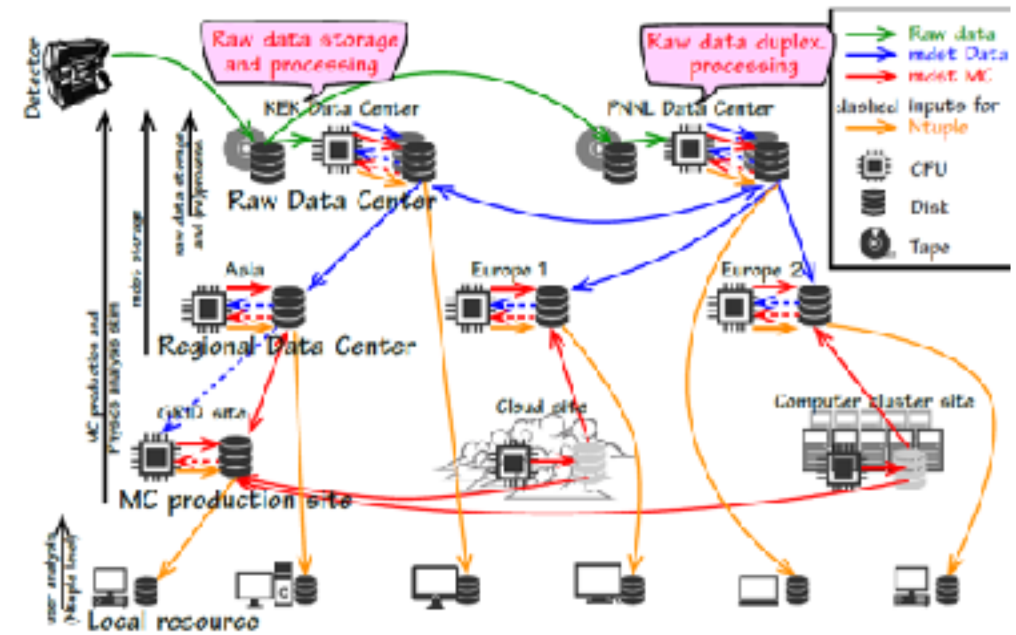


Belle II Computing

Distributed computing following the LHC model

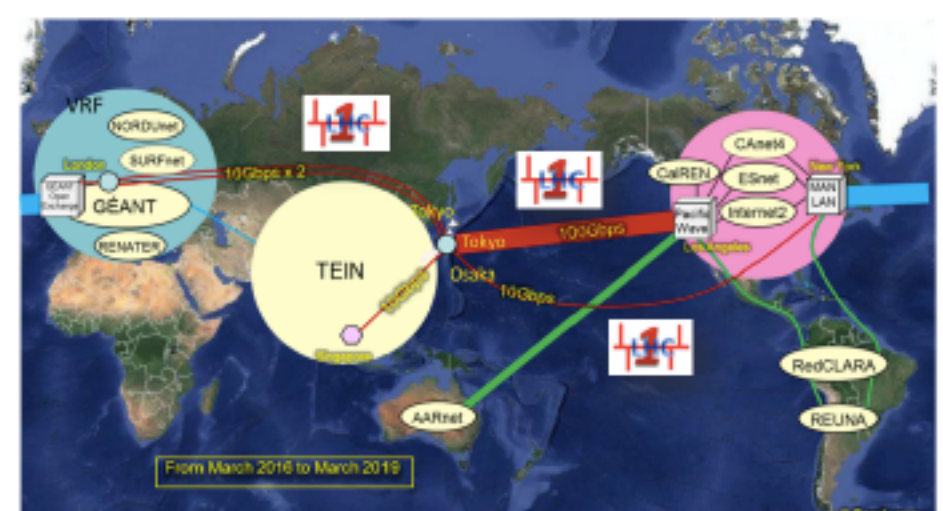
- Manage the processing of massive data sets
- Production of large MC samples
- Many concurrent user analysis jobs



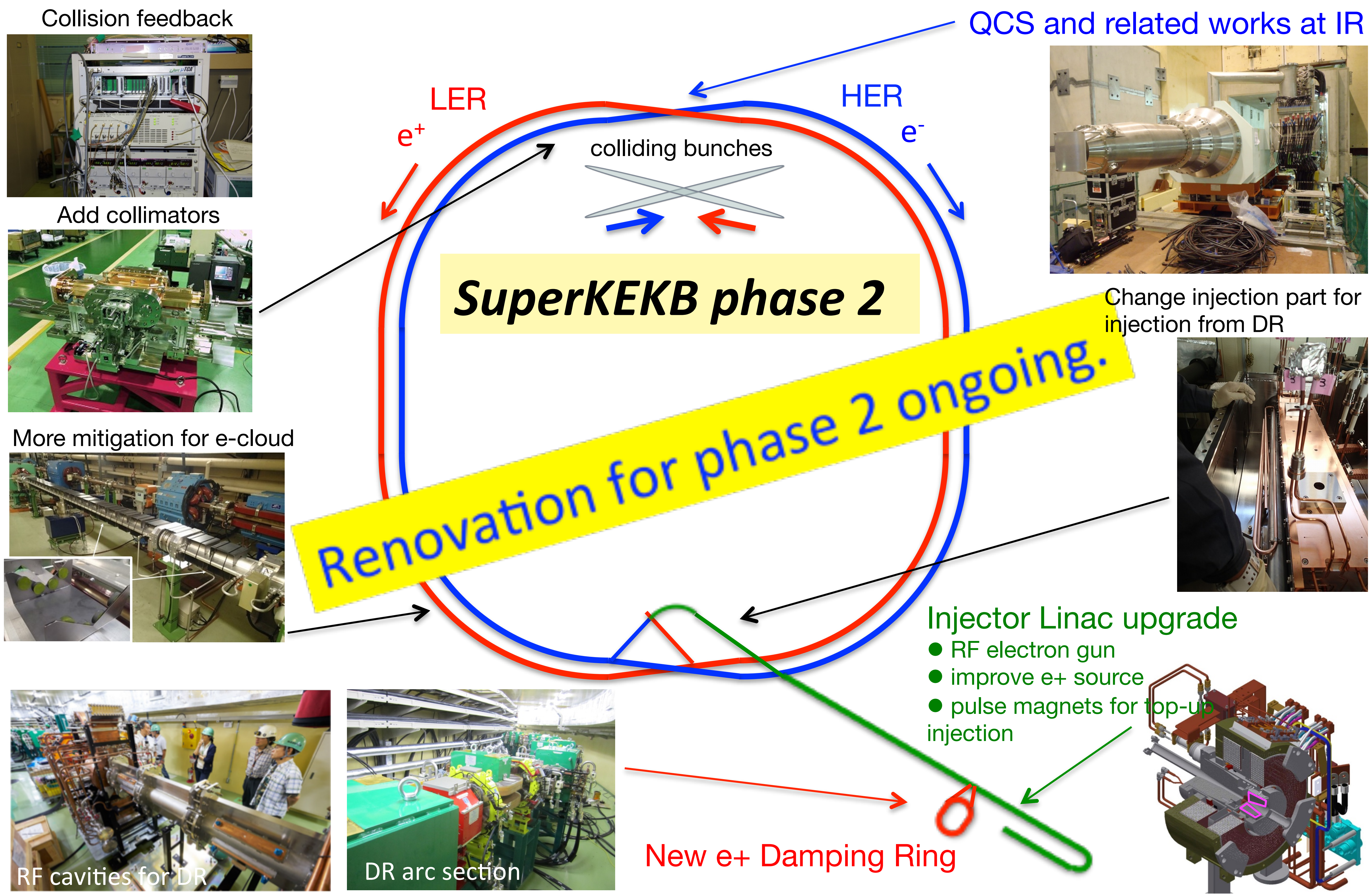


High speed networking data challenge in 2016:

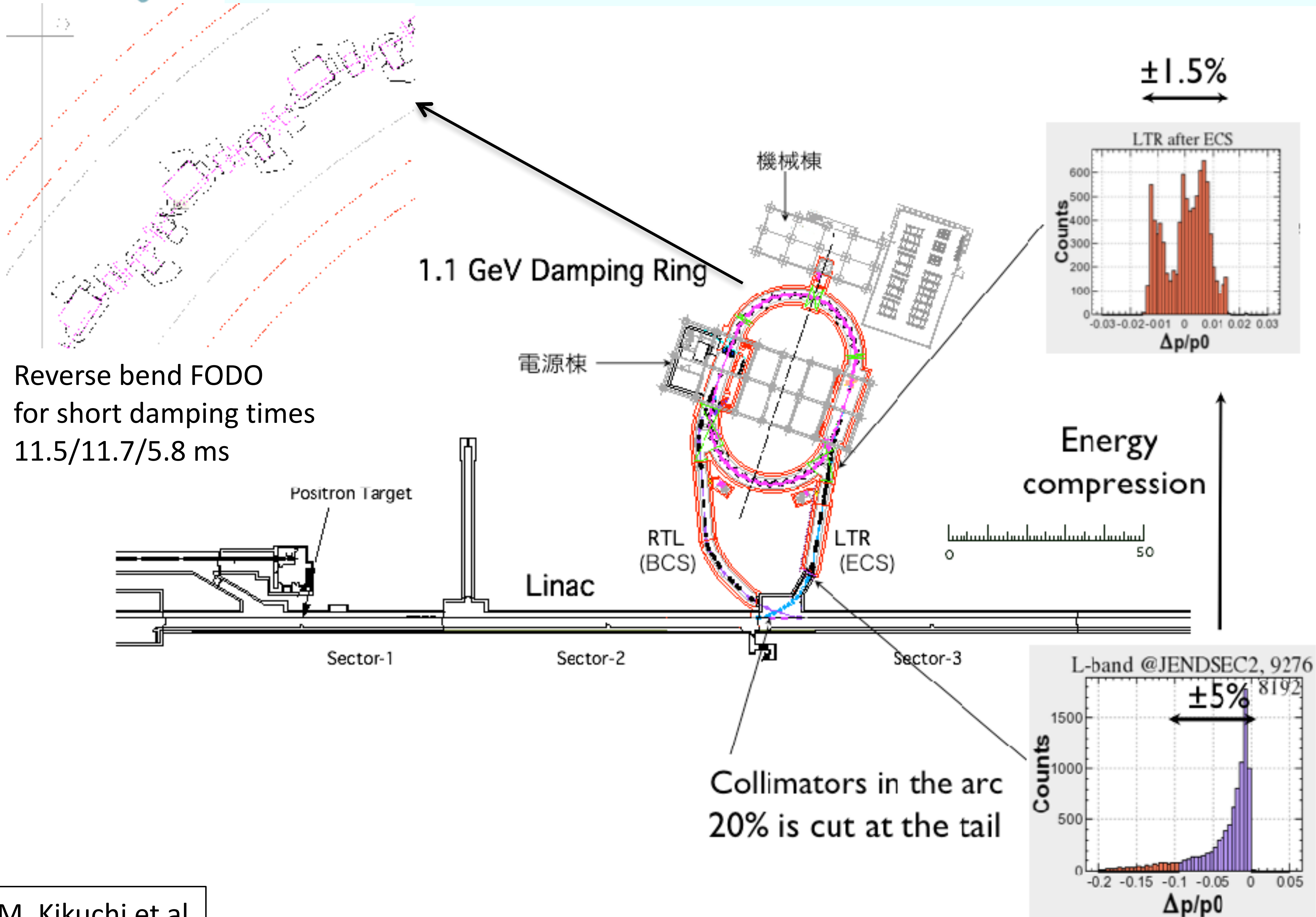
- Belle II networking requirements are satisfied



Machine Preparation for Phase 2



Positron Damping Ring



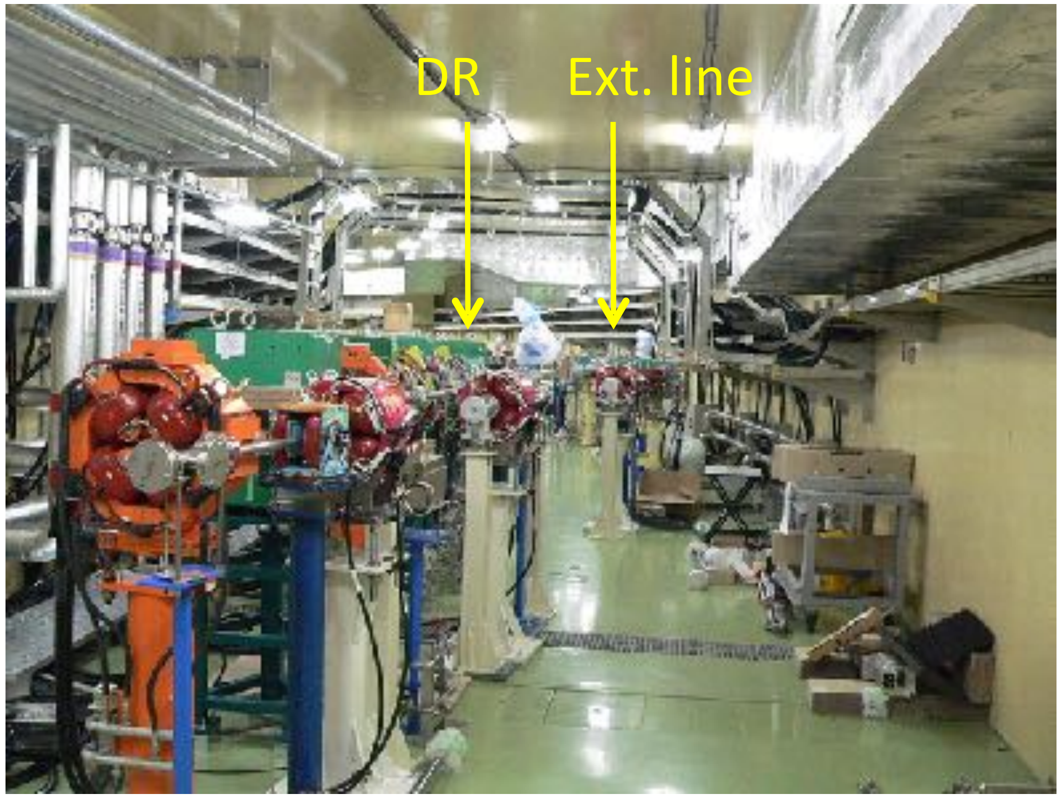
Reverse bend FODO
for short damping times
11.5/11.7/5.8 ms

M. Kikuchi et al.

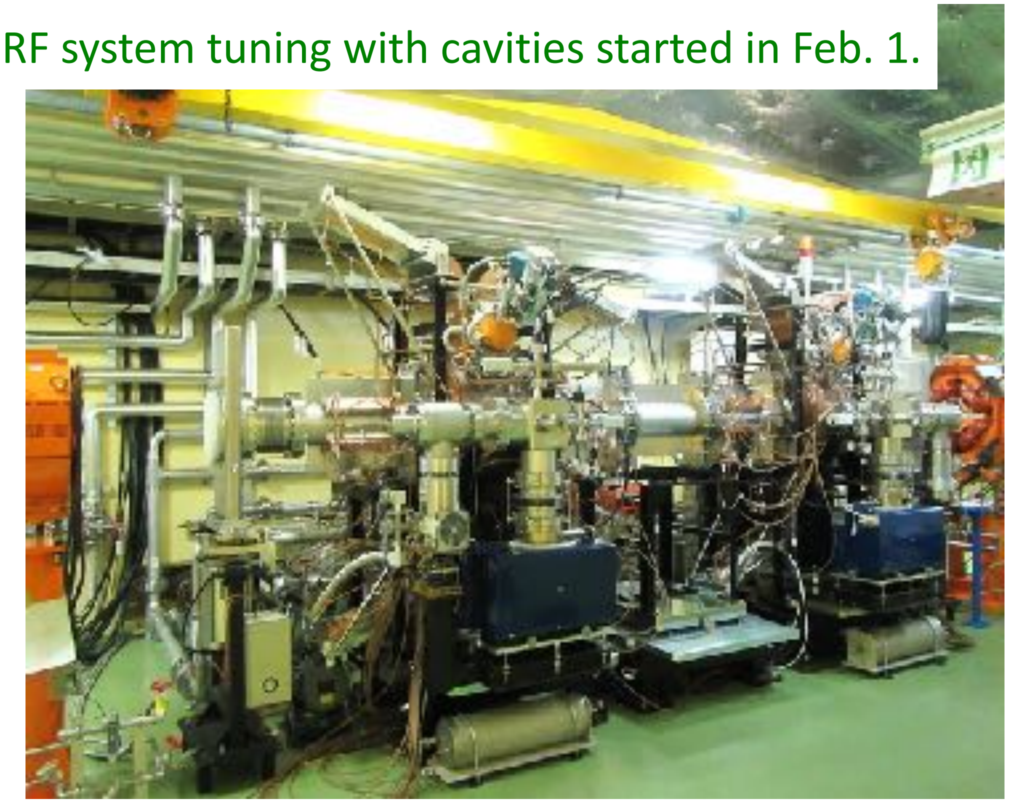
Positron Damping Ring

Installation phase-4
Beam pipes (ring) and vacuum pumps
Magnets alignment (coarse)
Cooling channels for magnets
Beam pipes at BT and Linac side
Installation of ECS and BCS cavities and waveguides
Installation of septums and kickers
Magnets alignment (fine)
Adjustment of power supplies
High power RF cavity conditioning
High power conditioning of ECS and BCS accelerating units
Evacuation of beam pipes

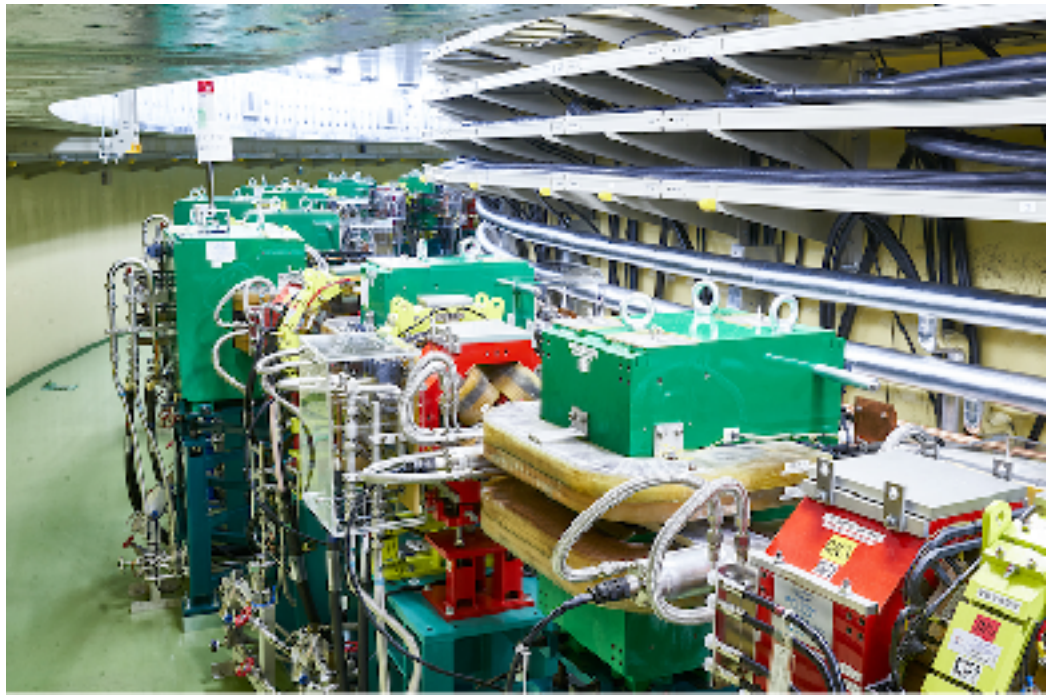
DR and the extraction line



RF system tuning with cavities started in Feb. 1.



Arc cells of DR



M. Kikuchi, K. Akai et al.

Phase 2 Commissioning

Machine commissioning strategy

1. Start with low beam current
2. Squeeze beams to achieve specific Luminosity

   $L_{sp} = L/(I_+ I_- n_b) = 2\times10^{31}/cm^2/s/mA^2$

   cf. $L_{sp} = 1.7\times10^{31}/cm^2/s/mA^2$ @KEKB
3. Increase number of bunches (n_b) from 394 to 1576, keeping bunch current constant:

   $I_+ = 0.64mA$, $I_- = 0.51mA$
4. Further squeeze beam to achieve $L_{sp} = 4\times10^{31}/cm^2/s/mA^2$, and even $8\times10^{31}/cm^2/s/mA^2$

Machine Parameters

SuperKEKB can exceed the peak luminosity of KEKB when we achieve $\xi_y > 0.05$

	Phase 2.2 (8x8)		Phase 2.3 (4x8)		Phase 2.4 (4x4)	
	LER	HER	LER	HER	LER	HER
$I_L \times I_H, n_b$	1000 mA x 800 mA, 1576 bunches (3-bucket spacing)					
β_x^* [mm]	256	200	128	100	128	100
β_y^* [mm]	2.16	2.40	2.16	2.40	1.08	1.20
$\varepsilon_y/\varepsilon_x$ [%]	5.0		1.4		0.7*	
ξ_x	0.0104	0.0041	0.0053	0.0021	0.0053	0.0021
ξ_y	0.0257	0.0265	0.0484	0.0500	0.0496	0.0505
I_{bunch} [mA]	0.64	0.51	0.64	0.51	0.64	0.51
L [$cm^{-2}s^{-1}$]	1×10^{34} (tentative target)		2×10^{34}		4×10^{34}	
L_{sp} [$cm^{-2}s^{-1}/mA^2$]	1.97×10^{31}		3.94×10^{31}		7.88×10^{31}	

* conserve β_y^*/ε_y

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Phase 2 Commissioning

Machine commissioning strategy

1. Start with low beam current
2. Squeeze beams to achieve specific Luminosity
   $L_{sp} = L/(I_+ I_- n_b) = 2\times10^{31}/cm^2/s/mA^2$
   cf. $L_{sp}=1.7\times10^{31}/cm^2/s/mA^2$ @KEKB
3. Increase number of bunches (n_b) from 394 to 1576, keeping bunch current constant:
   $I_+ = 0.64mA$, $I_- = 0.51mA$
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Machine Parameters

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	Phase 2.2 (8x8)		Phase 2.3 (4x8)		Phase 2.4 (4x4)	
	LER	HER	LER	HER	LER	HER
$I_L \times I_H$, n_b	1000 mA x 800 mA, 1576 bunches (3-bucket spacing)					
β_x^* [mm]	256	200	128	100	128	100
β_y^* [mm]	2.16	2.40	2.16	2.40	1.08	1.20
$\varepsilon_y/\varepsilon_x$ [%]	5.0		1.4		0.7*	
ξ_x	0.0104	0.0041	0.0053	0.0021	0.0053	0.0021
ξ_y	0.0257	0.0265	0.0484	0.0500	0.0496	0.0505
I_{bunch} [mA]	0.64	0.51	0.64	0.51	0.64	0.51
L [$cm^{-2}s^{-1}$]	1×10^{34} (tentative target)		2×10^{34}		4×10^{34}	
L_{sp} [$cm^{-2}s^{-1}/mA^2$]	1.97×10^{31}		3.94×10^{31}		7.88×10^{31}	

* conserve β_y^*/ε_y

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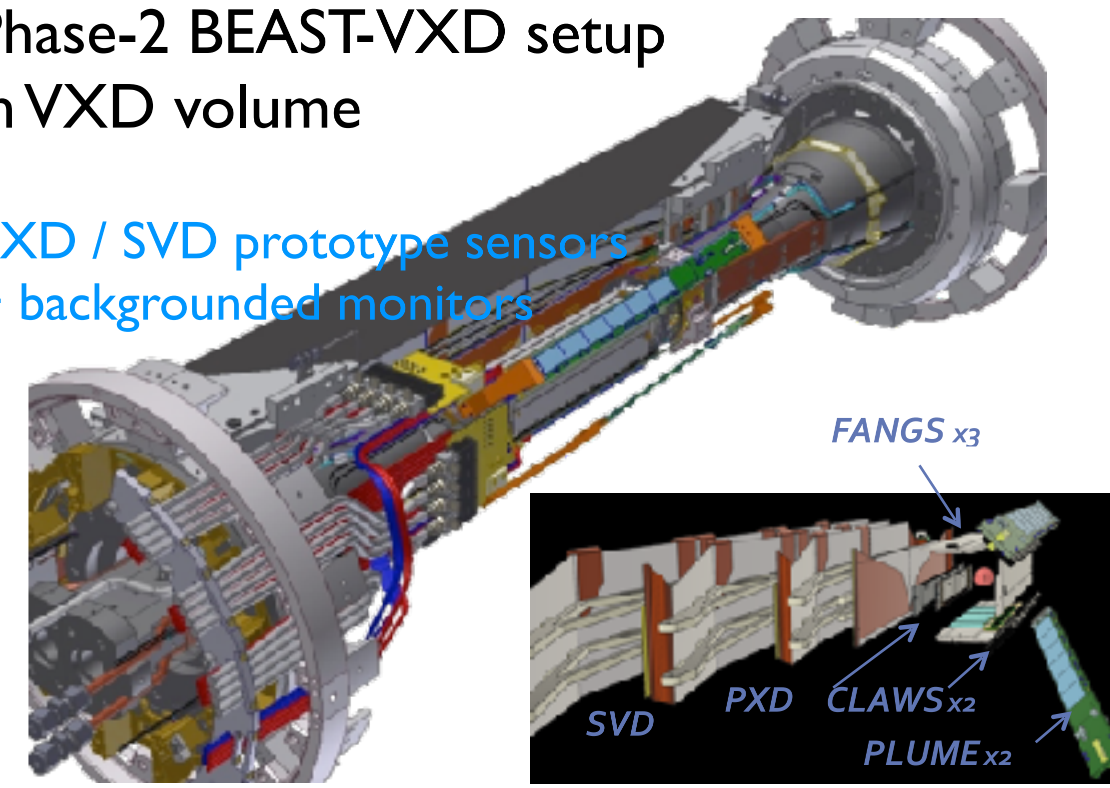
Beam background study

Study	Purpose
Beam-size scan	Measure Touschek BG component
Vacuum bump study	Measure Beam-gas BG component
Collimator study	Find optimal setting
Injection study	Measure injection BG time structure, improve injection efficiency
Luminosity scan	Measure lumi. BG component

Phase-2 BEAST-VXD setup in VXD volume



Phase 2 Commissioning

Machine commissioning strategy

1. Start with low beam current
2. Squeeze beams to achieve specific Luminosity

   $L_{sp} = L/(I_+ I_- n_b) = 2\times10^{31}/cm^2/s/mA^2$

   cf. $L_{sp}=1.7\times10^{31}/cm^2/s/mA^2$ @KEKB
3. Increase number of bunches (n_b) from 394 to 1576, keeping bunch current constant:

   $I_+ = 0.64mA$, $I_- = 0.51mA$
4. Further squeeze beam to achieve $L_{sp} = 4\times10^{31}/cm^2/s/mA^2$, and even $8\times10^{31}/cm^2/s/mA^2$

Machine Parameters

SuperKEKB can exceed the peak luminosity of KEKB when we achieve $\xi_y > 0.05$

	Phase 2.2 (8x8)		Phase 2.3 (4x8)		Phase 2.4 (4x4)	
	LER	HER	LER	HER	LER	HER
$I_L \times I_H, n_b$	1000 mA x 800 mA, 1576 bunches (3-bucket spacing)					
β_x^* [mm]	256	200	128	100	128	100
β_y^* [mm]	2.16	2.40	2.16	2.40	1.08	1.20
$\varepsilon_y/\varepsilon_x$ [%]	5.0		1.4		0.7*	
ξ_x	0.0104	0.0041	0.0053	0.0021	0.0053	0.0021
ξ_y	0.0257	0.0265	0.0484	0.0500	0.0496	0.0505
I_{bunch} [mA]	0.64	0.51	0.64	0.51	0.64	0.51
L [$cm^{-2}s^{-1}$]	1×10^{34} (tentative target)		2×10^{34}		4×10^{34}	
L_{sp} [$cm^{-2}s^{-1}/mA^2$]	1.97×10^{31}		3.94×10^{31}		7.88×10^{31}	

* conserve β_y^*/ε_y

21

Beam background study

Study	Purpose
Beam-size scan	Measure Touschek BG component
Vacuum bump study	Measure Beam-gas BG component
Collimator study	Find optimal setting
Injection study	Measure injection BG time structure, improve injection efficiency
Luminosity scan	Measure lumi. BG component

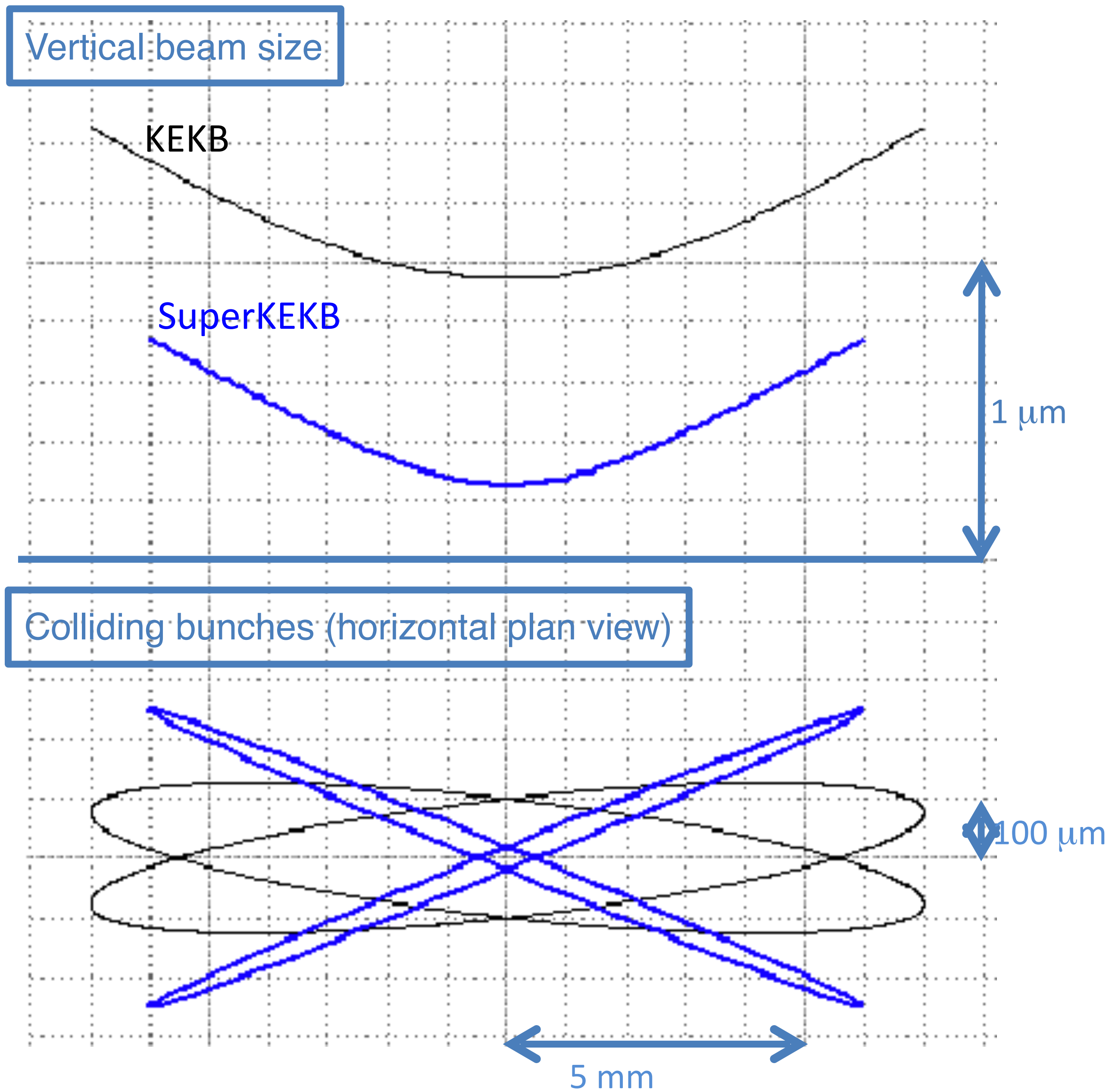
Parameter

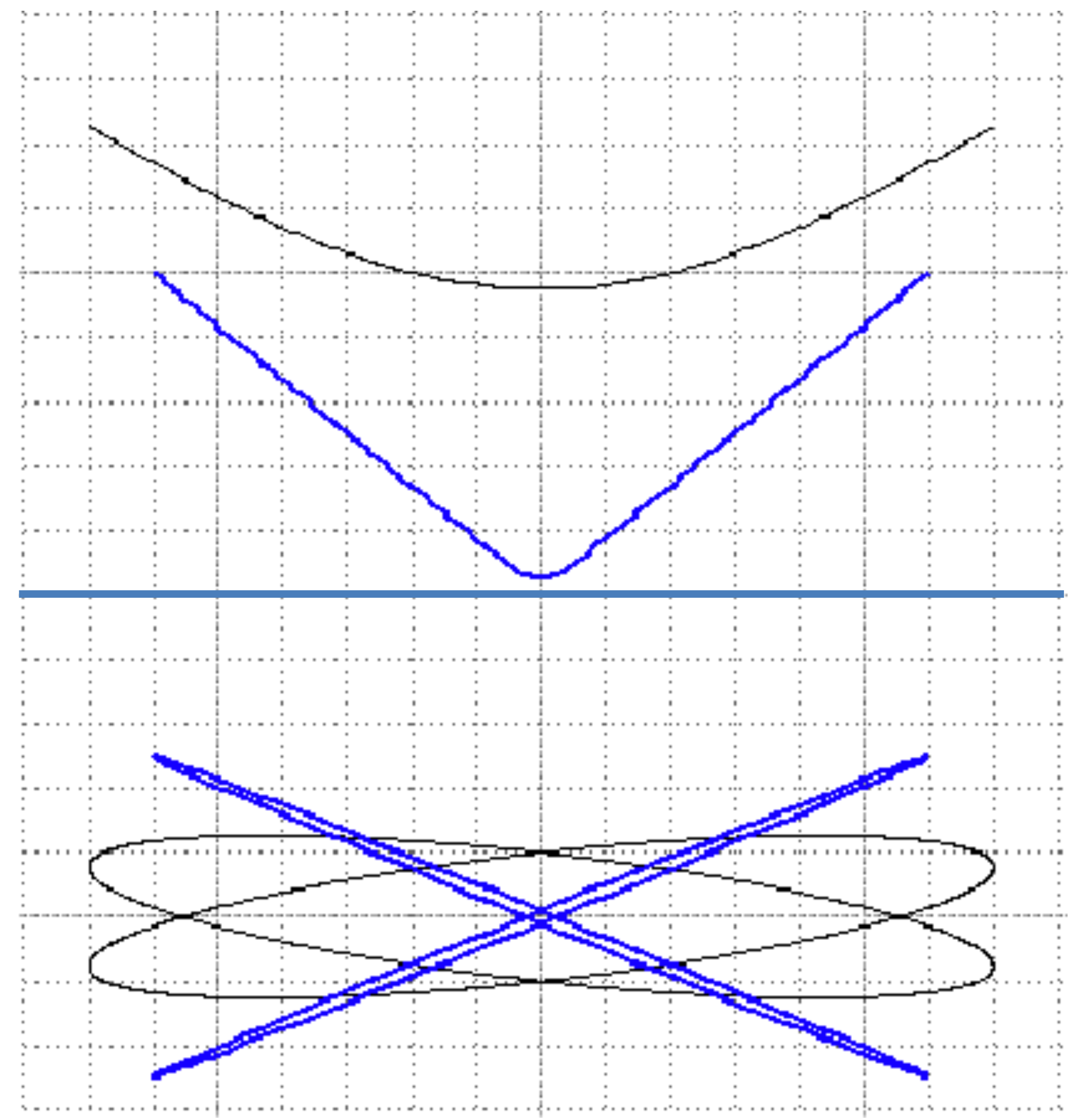
	KEKB LER /HER	**Phase 1**	**Phase 2 4x8**	**Phase 3**
β_x^* (mm)	1200 / 1200	/	128 / 100	32 / 25
β_y^* (mm)	5.9 / 5.9	/	2.16 / 2.4	0.27 / 0.30
ε_x (nm)	18 / 24	2.0 / 4.6	2.1 / 4.6	3.2 / 4.6
ε_y (pm) , coupling	1498 / 1598	~ 10 / -	29.4 / 64.4, 1.4% (105 / 230, 5.0%)	8.64 / 12.9 (0.27% / 0.28%)
ξ_y	0.129 / 0.090	-	0.0484 / 0.0500 (0.0257 / 0.0265)	0.088/0.081
σ_y^* (μm)	0.94 / 0.94	-	0.25 / 0.39 (0.48 / 0.74)	0.048/0.062
I_{beam} (A)	1.64/1.19	1.01/0.87	1.0/0.8	3.6/2.6
$N_{bunches}$	1584	1576	1576	2500
Luminosity (10^{34} cm^{-2} s^{-1})	2.1	-	2 (1)	80

Nano-beam Scheme

Phase 2 "4x8"
$\beta_x^* = 128$ mm, $\beta_y^* = 2.16$ mm
$\varepsilon_y = 29.4$ pm (coupling 1.4%)

Phase 3
$\beta_x^* = 32$ mm, $\beta_y^* = 0.27$ mm
$\varepsilon_y = 8.64$ pm (coupling 0.27%)



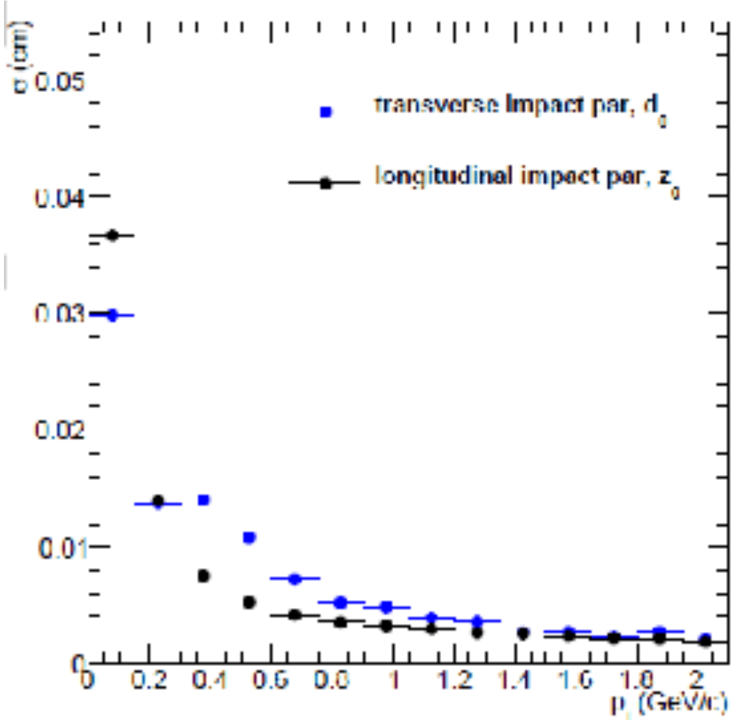


SuperKEKB
- バンチはLERのパラメタで記述

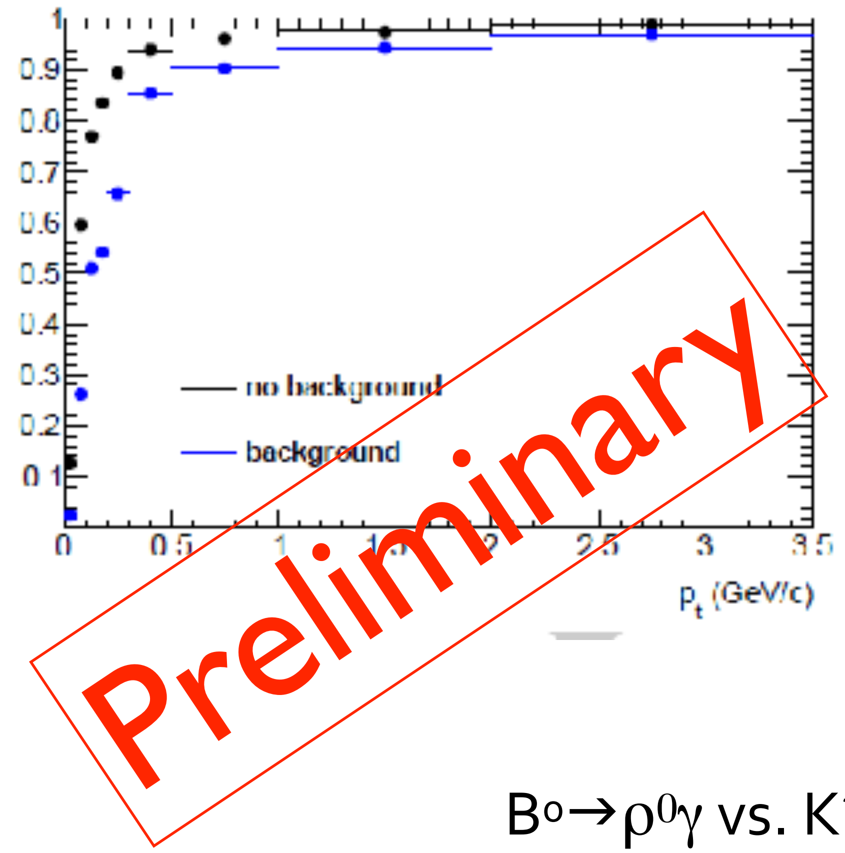
KEKBは比較のため
- 水平方向は有限交差角衝突の場合を記述
- 垂直方向は21.08/nb/s 達成時の推定値(σ_y^*~0.94 μm)を記述

Belle II Expected Performance

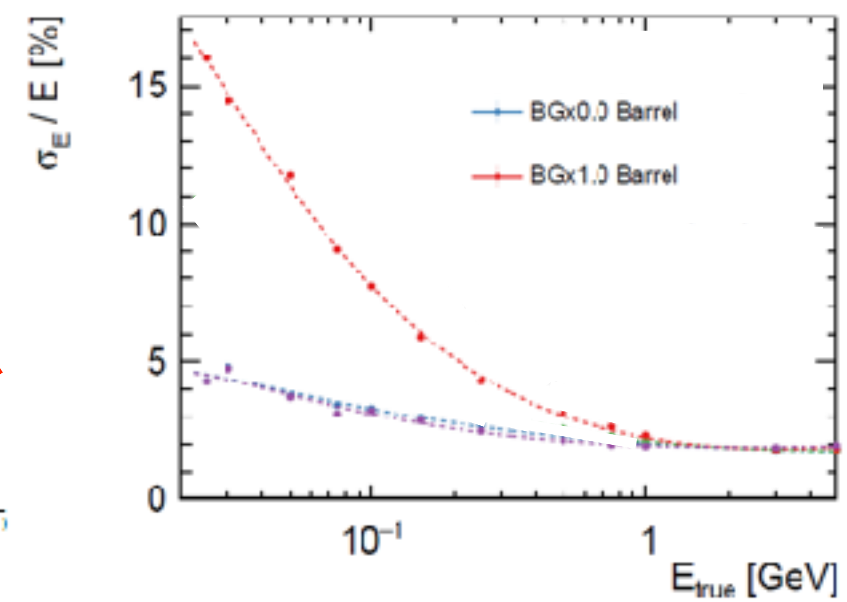
IP resolution



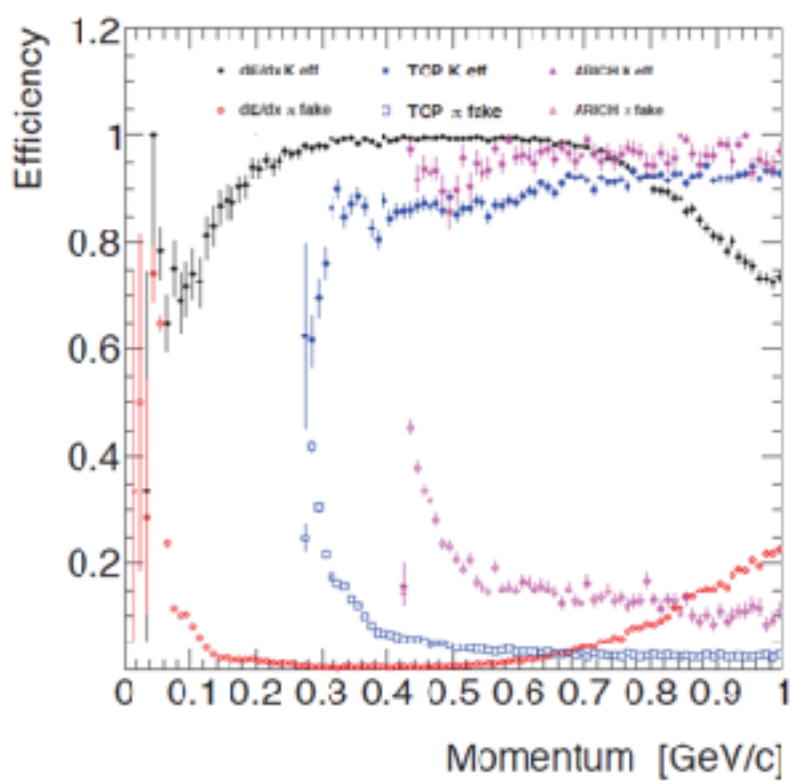
Tracking efficiency vs. p_t



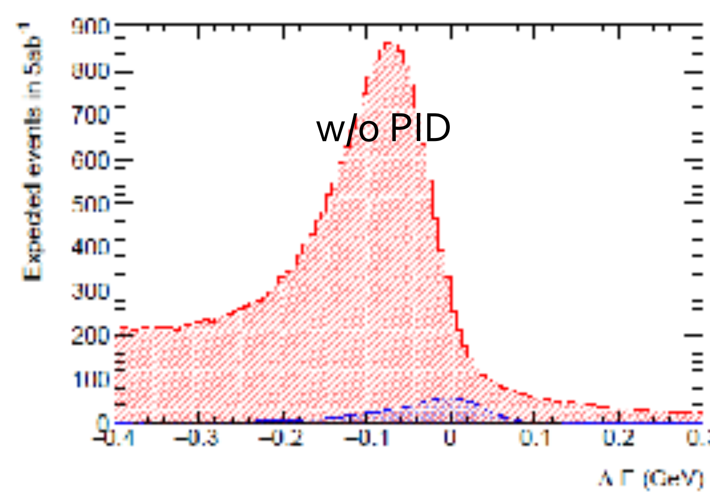
Energy resolution
Better w/ no background,
worse w/ background

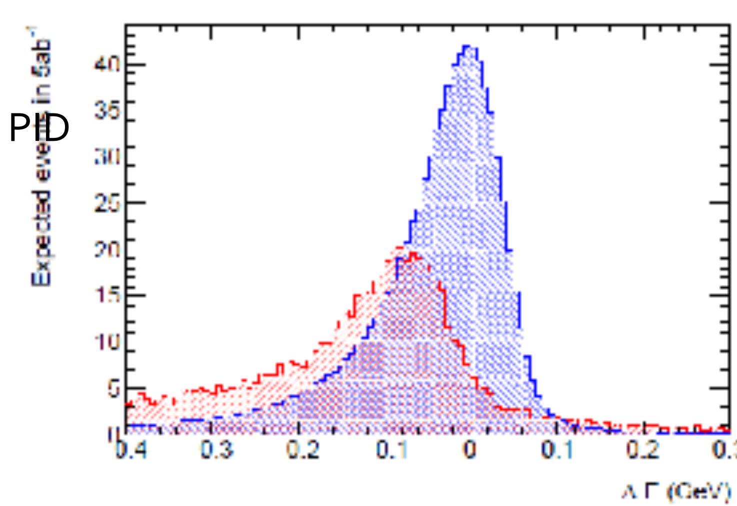


K/π PID



$B^0\to\rho^0\gamma$ vs. $K^{*0}\gamma$





Phase 2 Physics

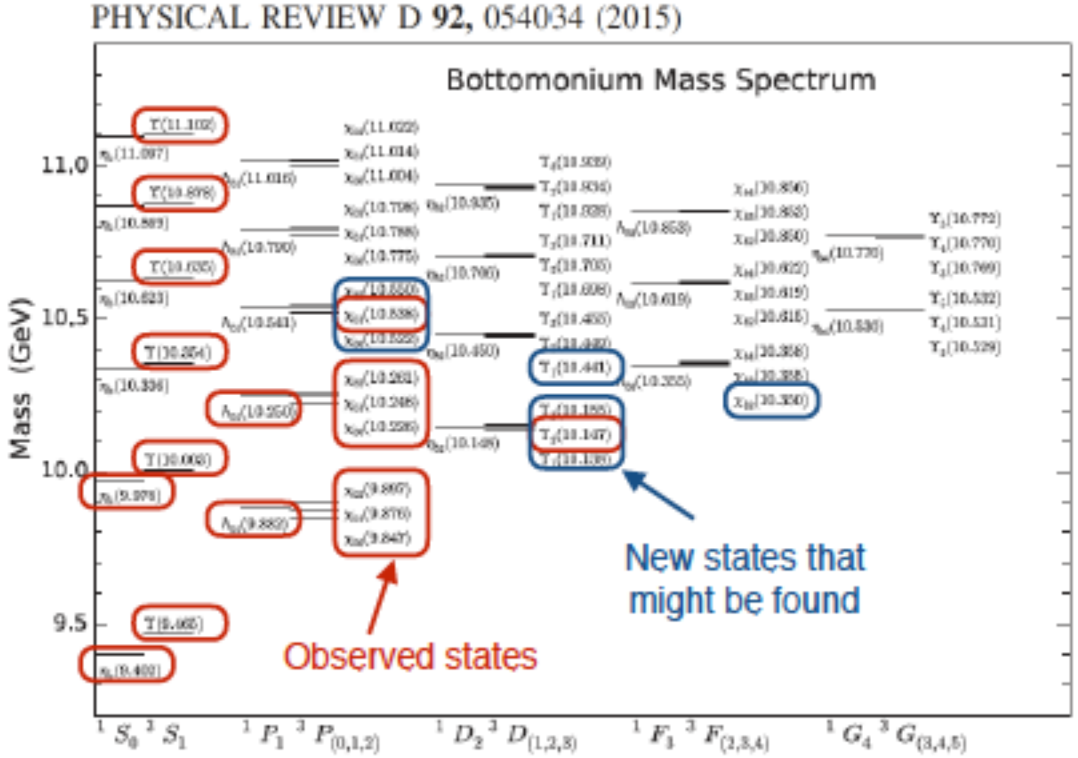
Plan for 4-5 months of machine studies → 1-2 months may contain useful data, w/ L ~ $1\times10^{34}cm^{-2}s^{-1}$ → 20-40 fb^{-1}

- Runs on unique E_{CM}, e.g. Υ(6S)

Experiment	Scans Off. Res.	$\Upsilon(6S)$ fb^{-1}	$\Upsilon(5S)$ fb^{-1}	$\Upsilon(5S)$ 10^6	$\Upsilon(4S)$ fb^{-1}	$\Upsilon(4S)$ 10^6	$\Upsilon(3S)$ fb^{-1}	$\Upsilon(3S)$ 10^6	$\Upsilon(2S)$ fb^{-1}	$\Upsilon(2S)$ 10^6	$\Upsilon(1S)$ fb^{-1}	$\Upsilon(1S)$ 10^6
CLEO	17.1	-	0.1	0.4	16	17.1	1.2	5	1.2	10	1.2	21
BaBar	54	R_b scan			433	471	30	122	14	99	–	
Belle	100	~ 5.5	36	121	711	772	3	12	25	158	6	102

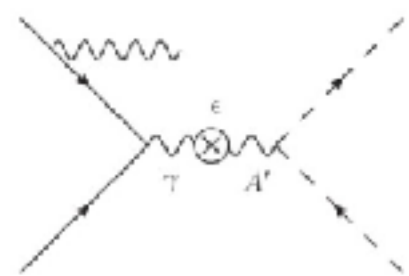
- Bottomonium (-like) physics

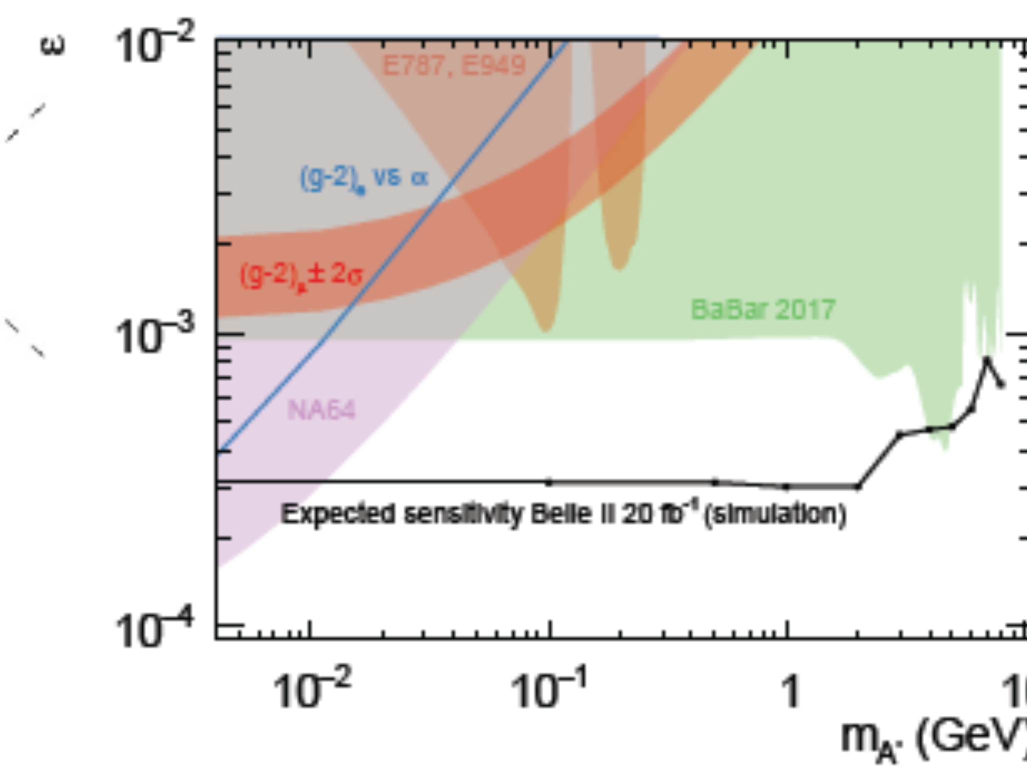
PHYSICAL REVIEW D 92, 054034 (2015)



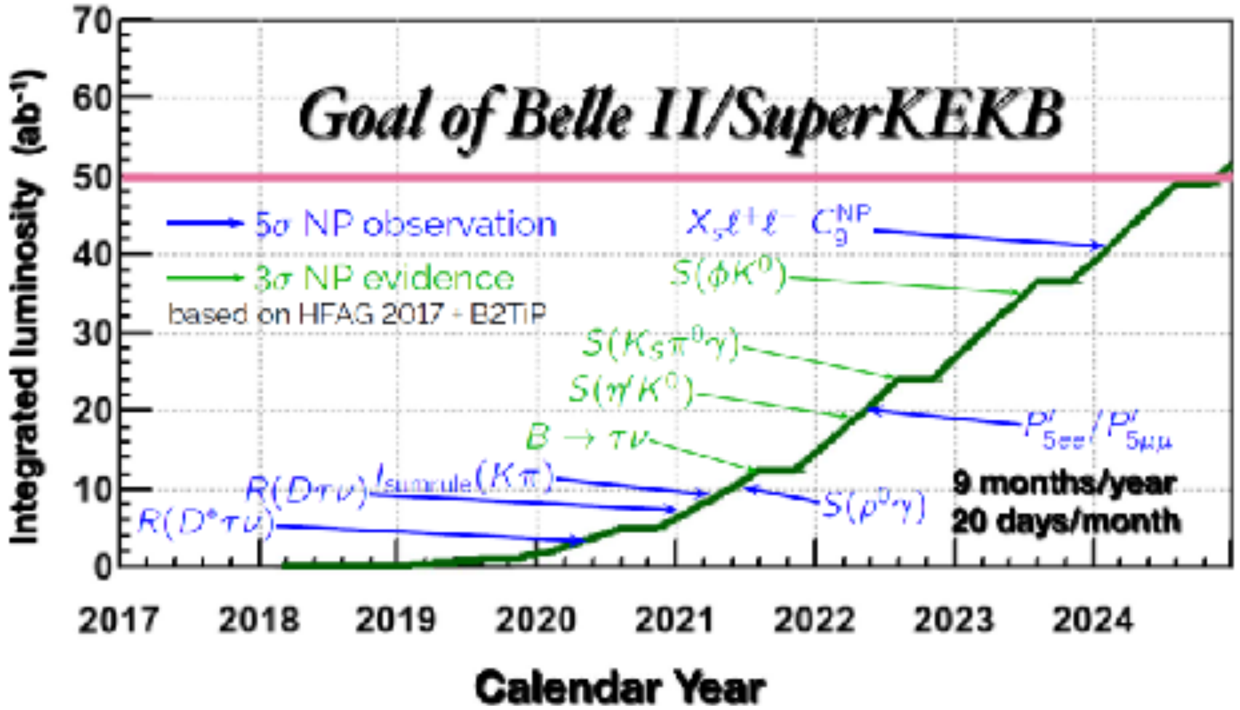
- Light DM search w/ 20fb^{-1}

dark photon: A' → γ + invisible

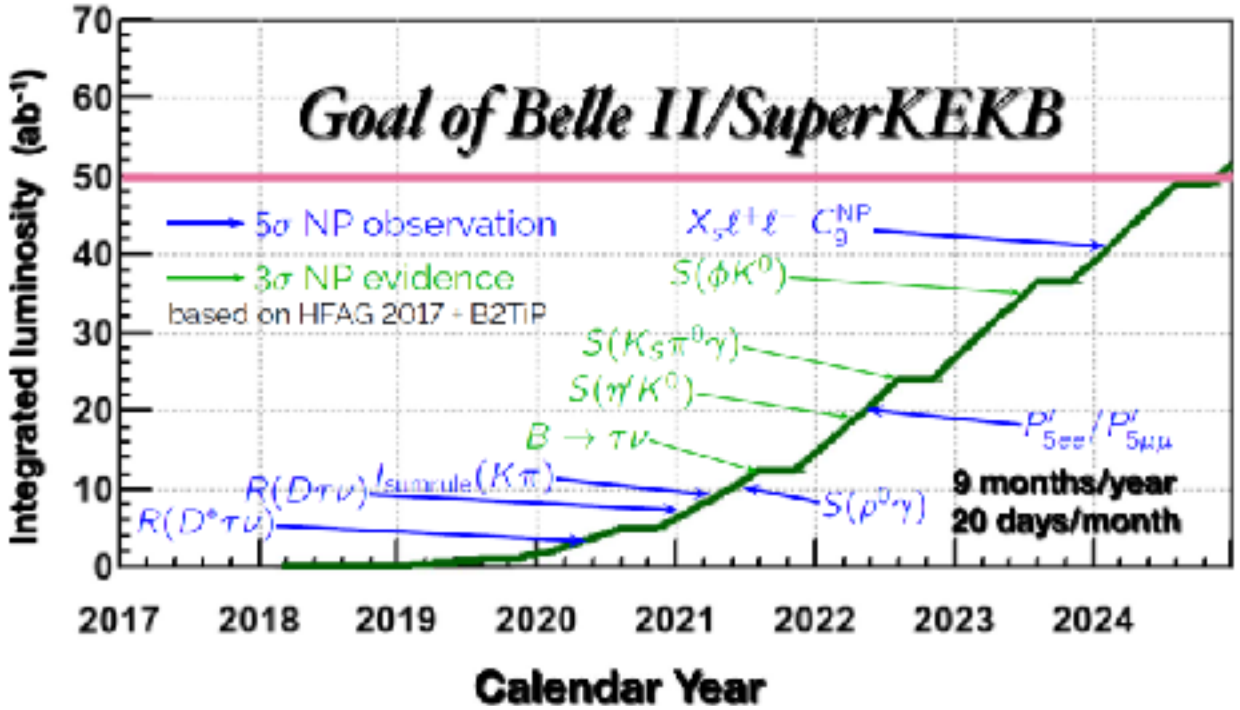


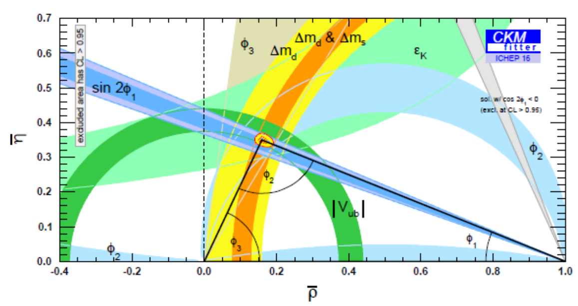


Physics Prospects (Phase 3)



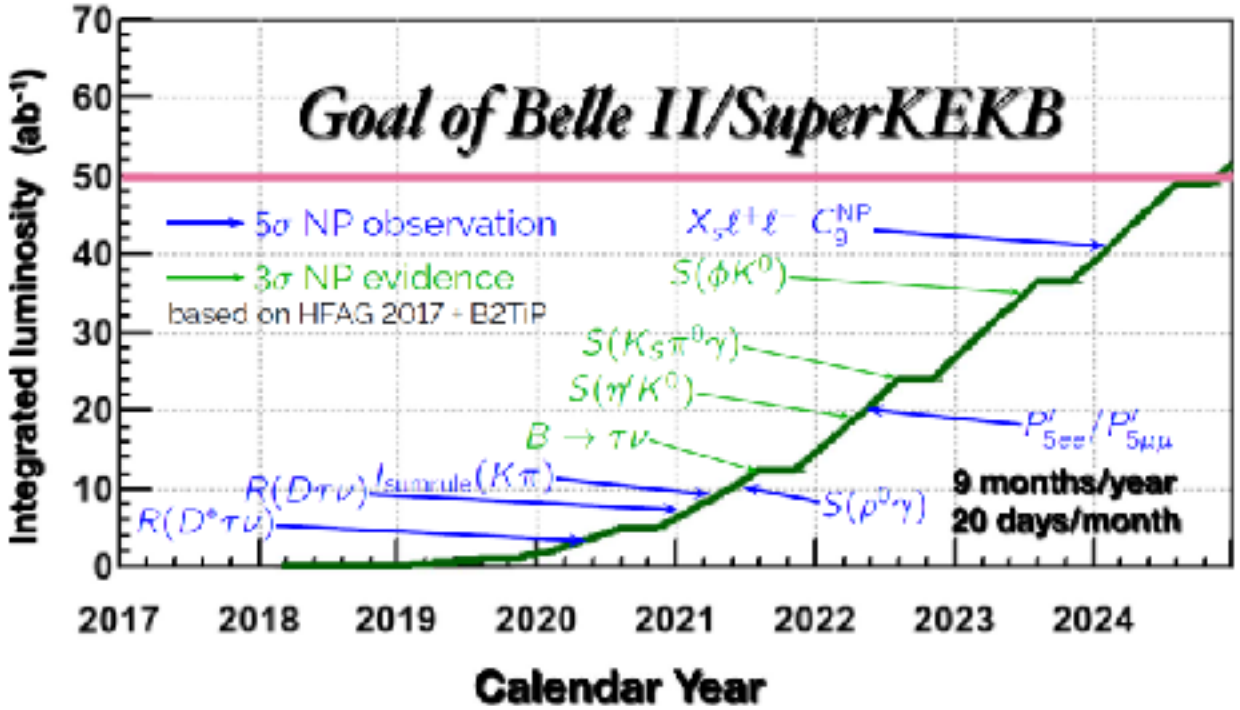
Physics Prospects (Phase 3)





CKM

Physics Prospects (Phase 3)



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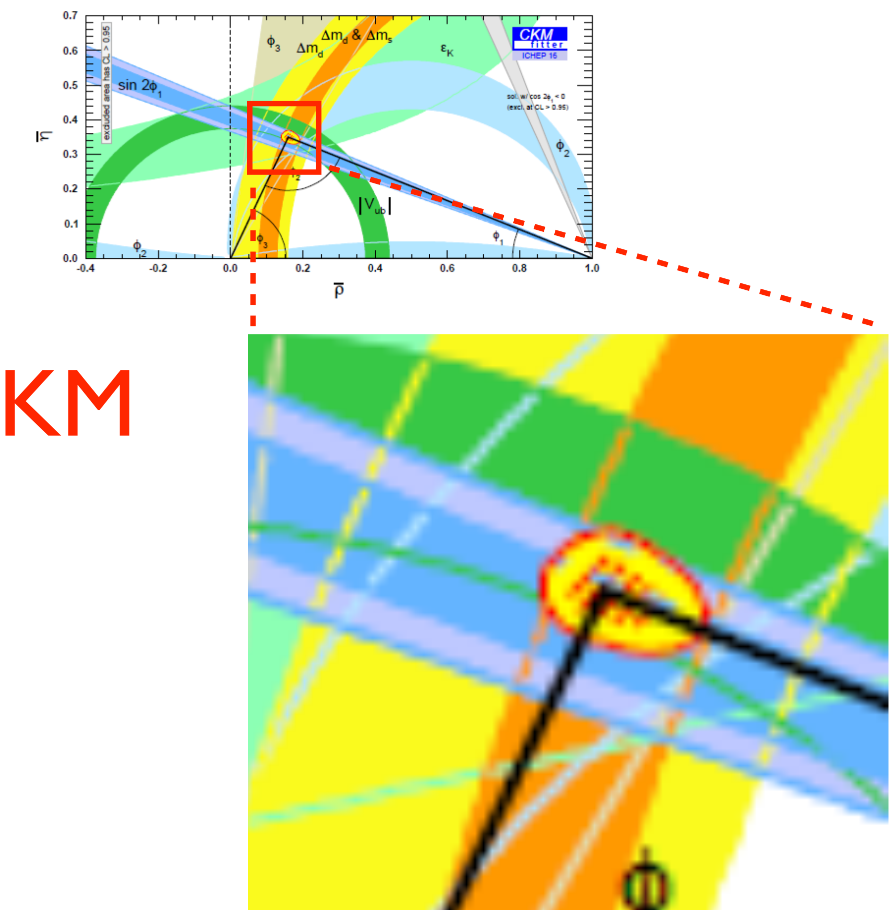
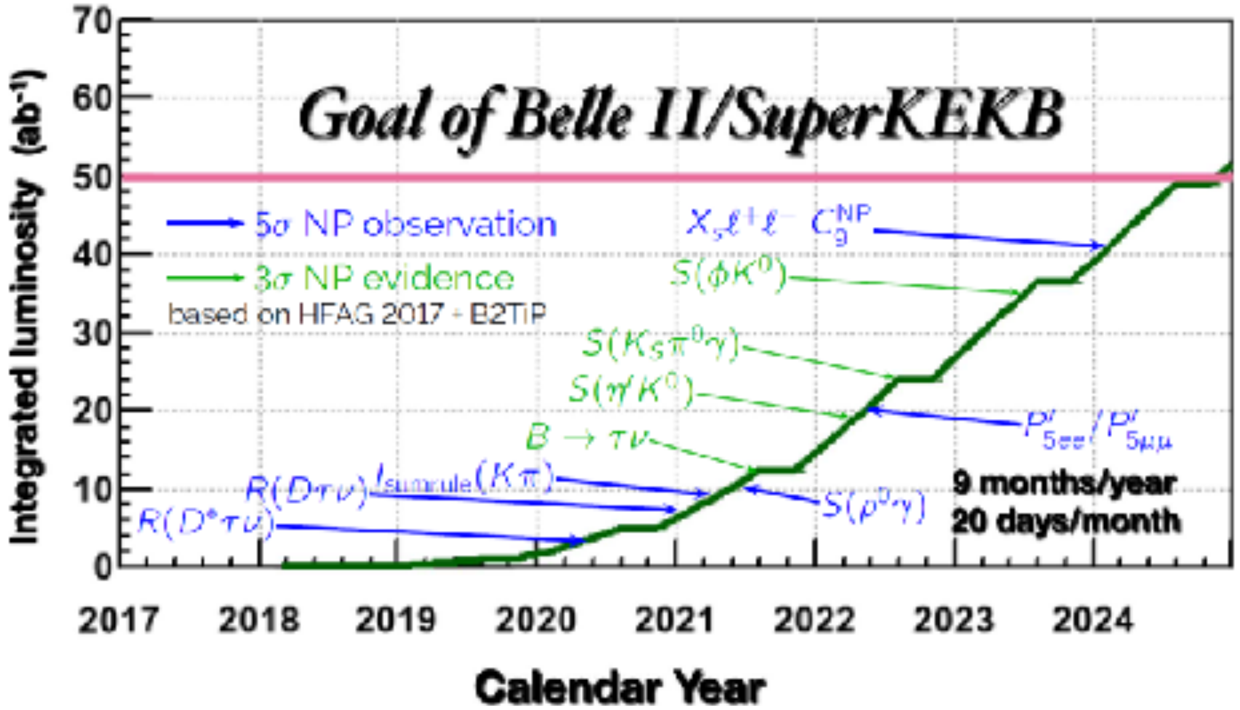


Physics Prospects (Phase 3)



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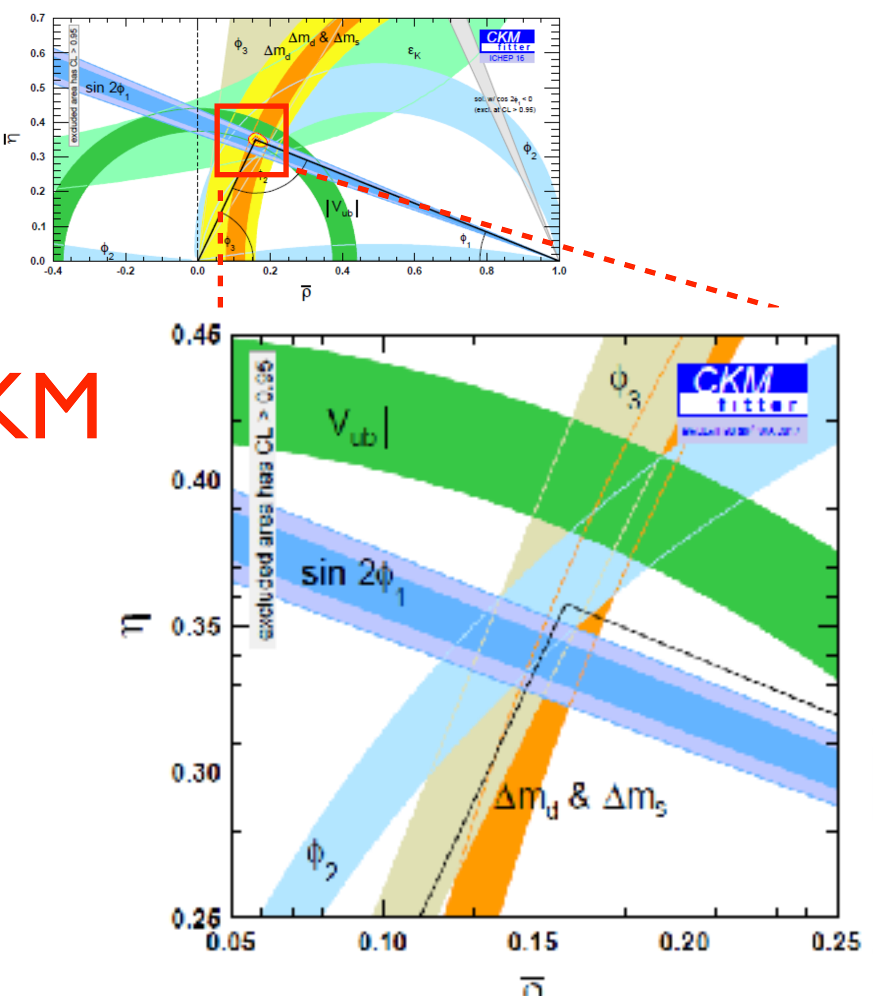
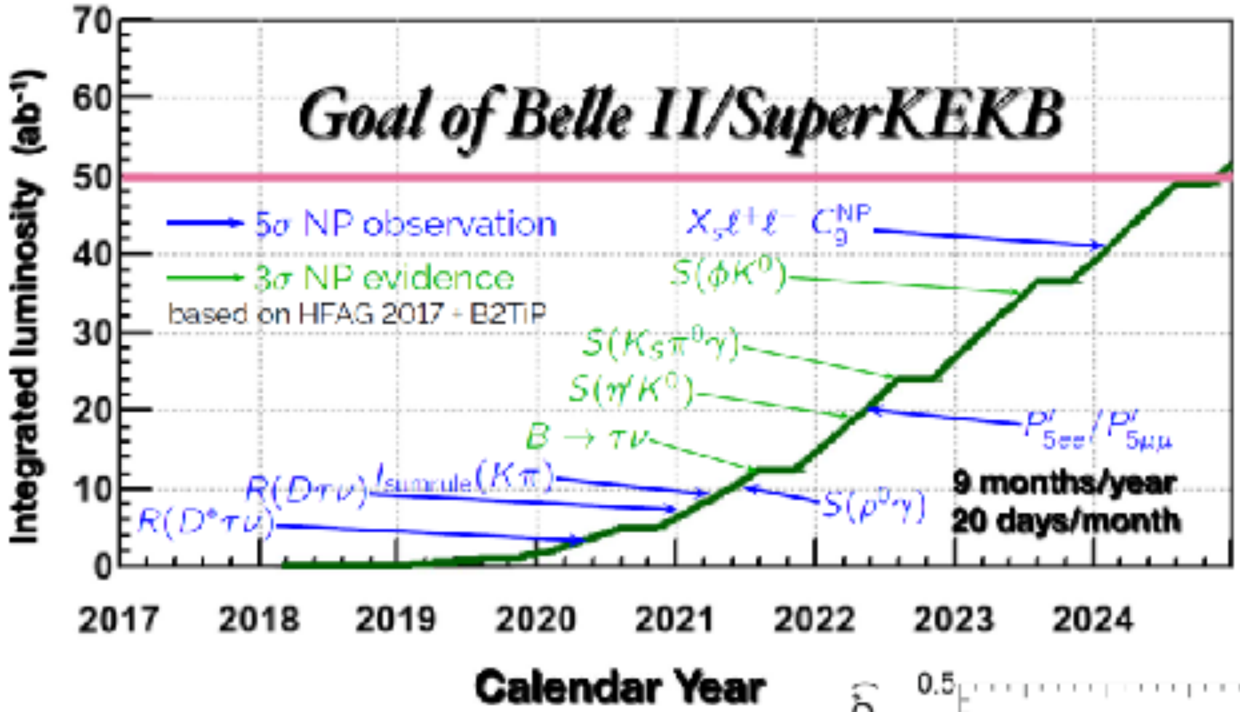


Physics Prospects (Phase 3)



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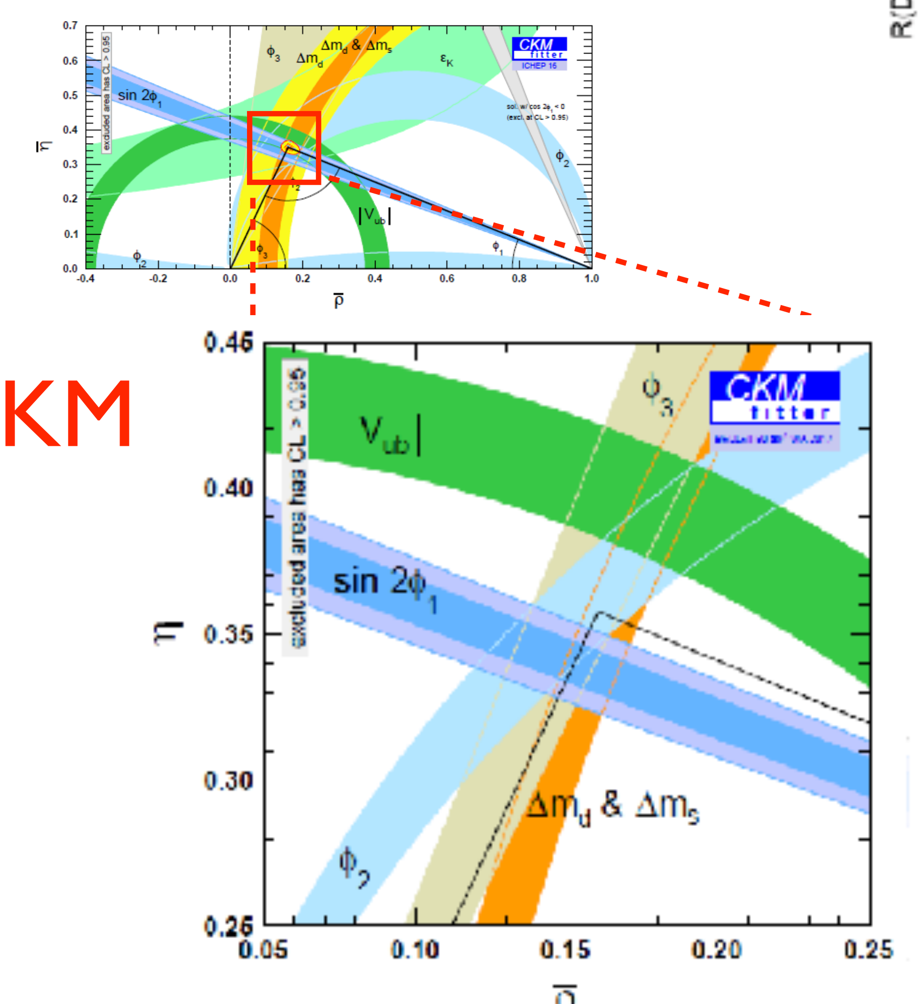
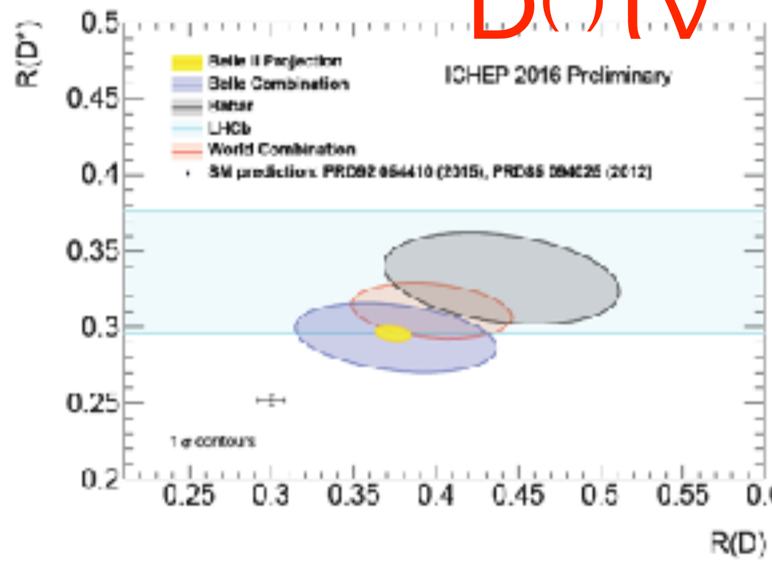
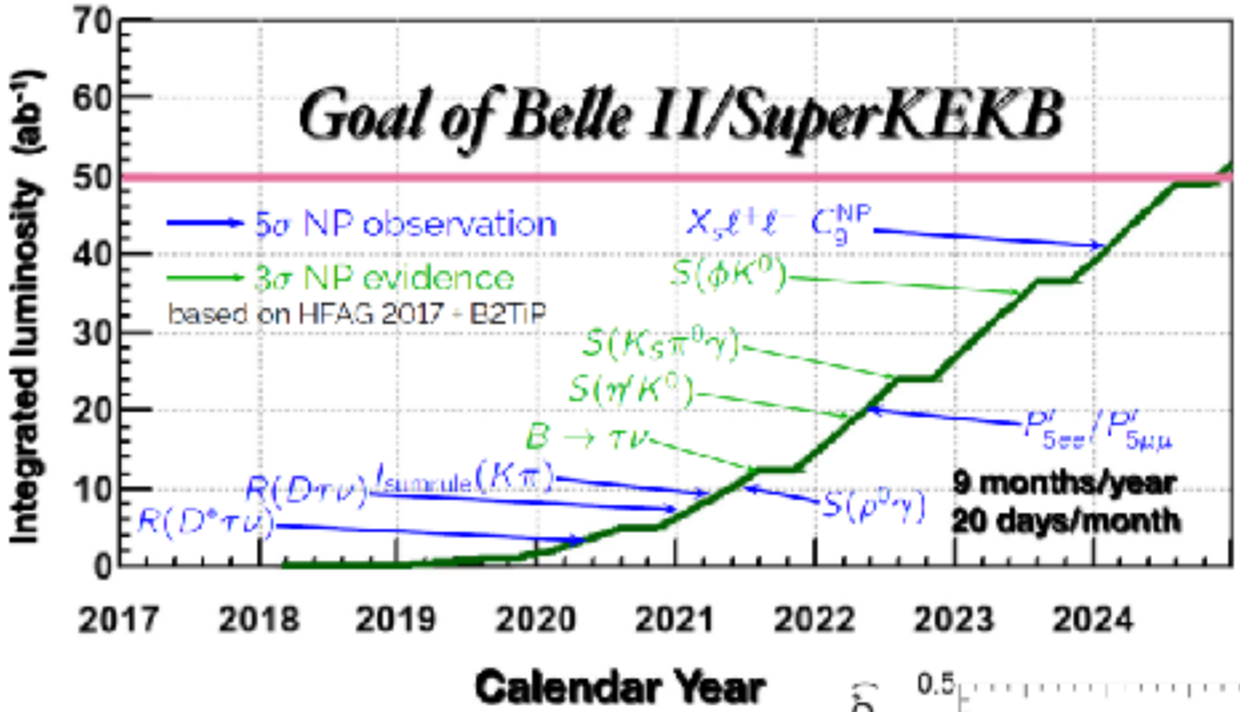


D(*)τν



Physics Prospects (Phase 3)



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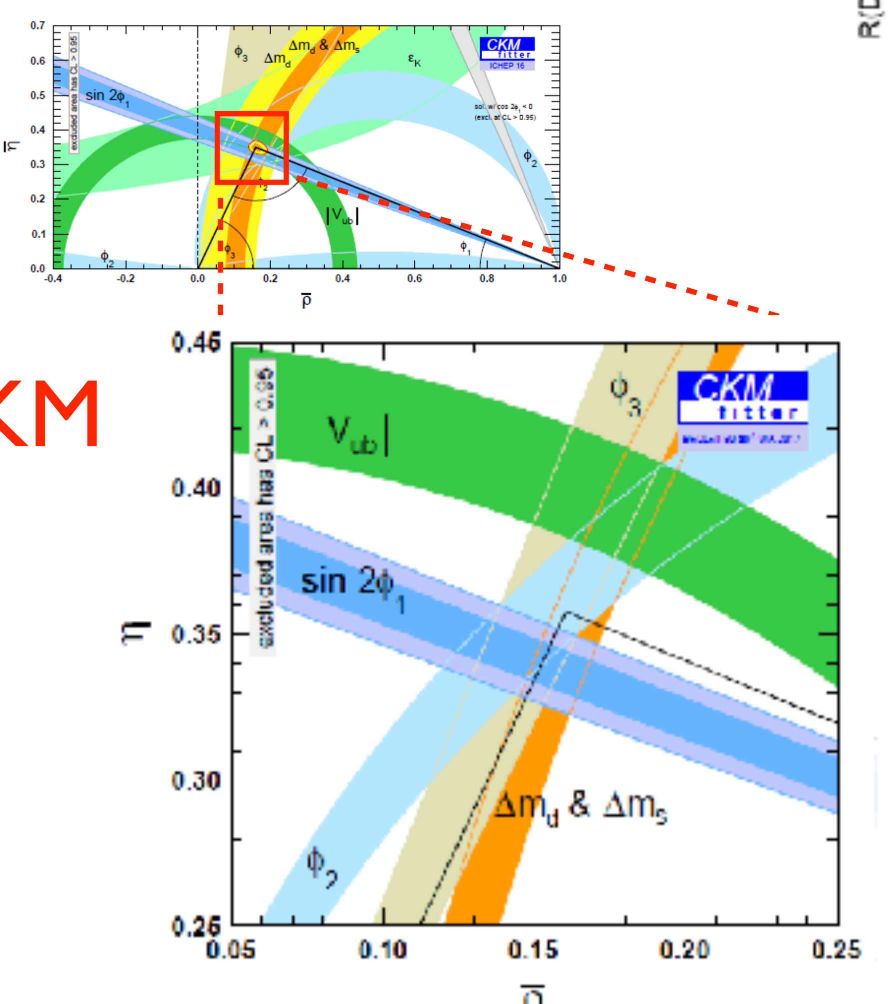
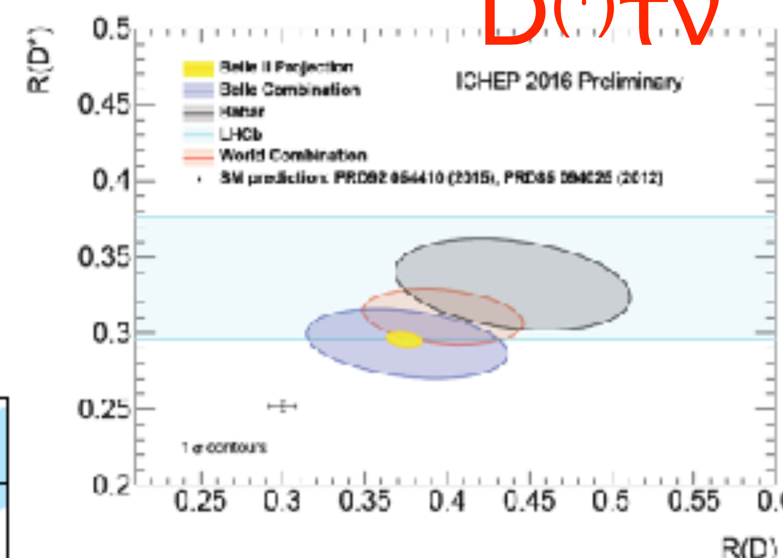
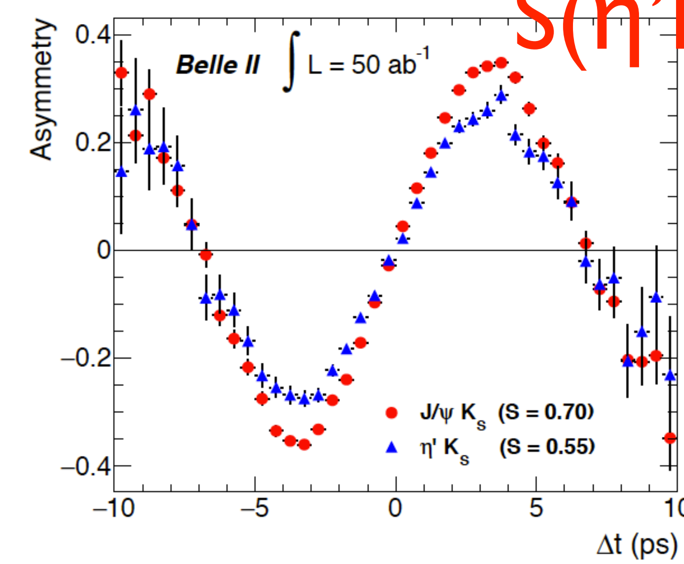


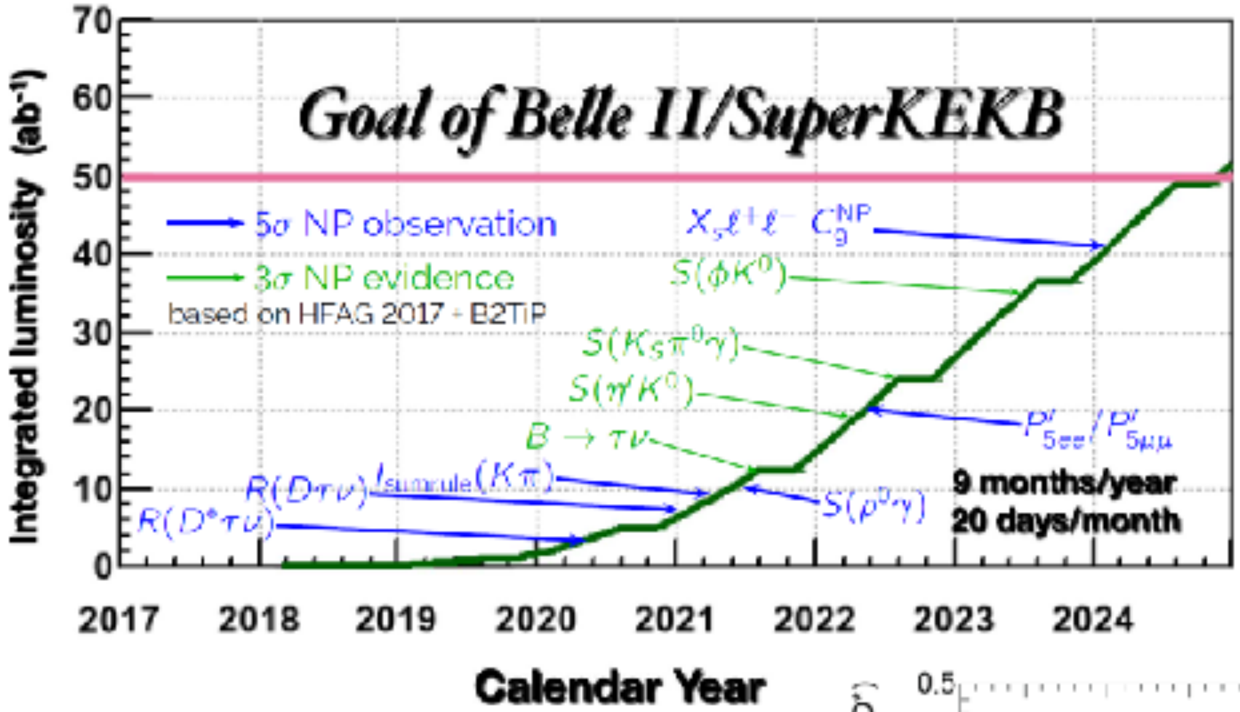
D(*)τν

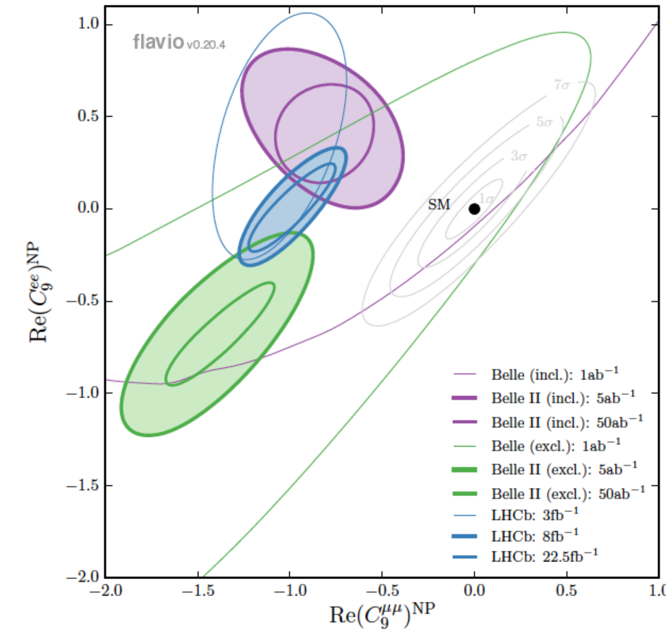


S(η'Ks)



Physics Prospects (Phase 3)

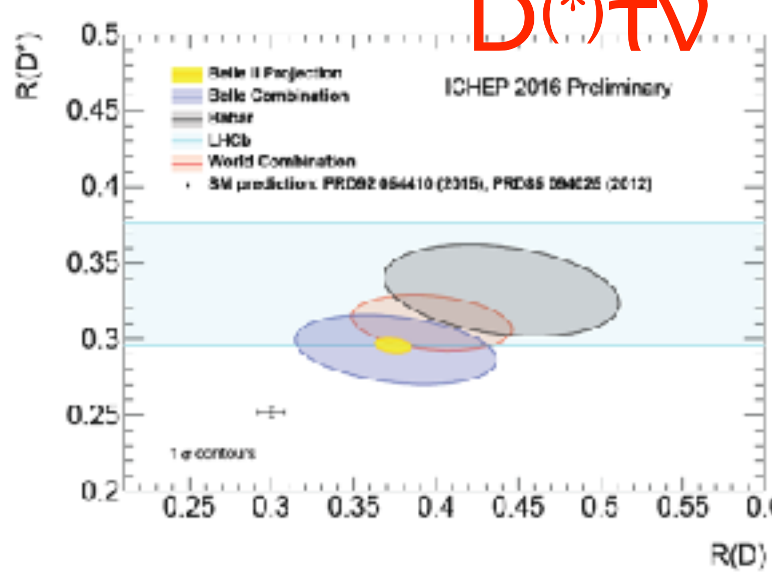




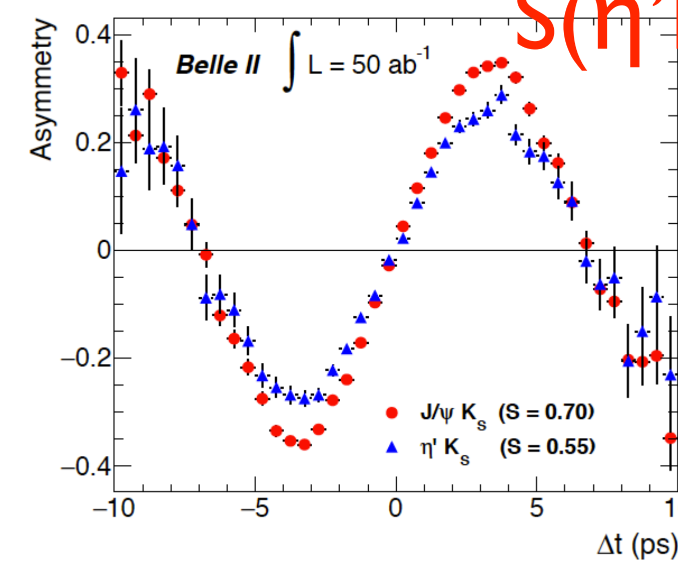
K(*) ll

Xs ll

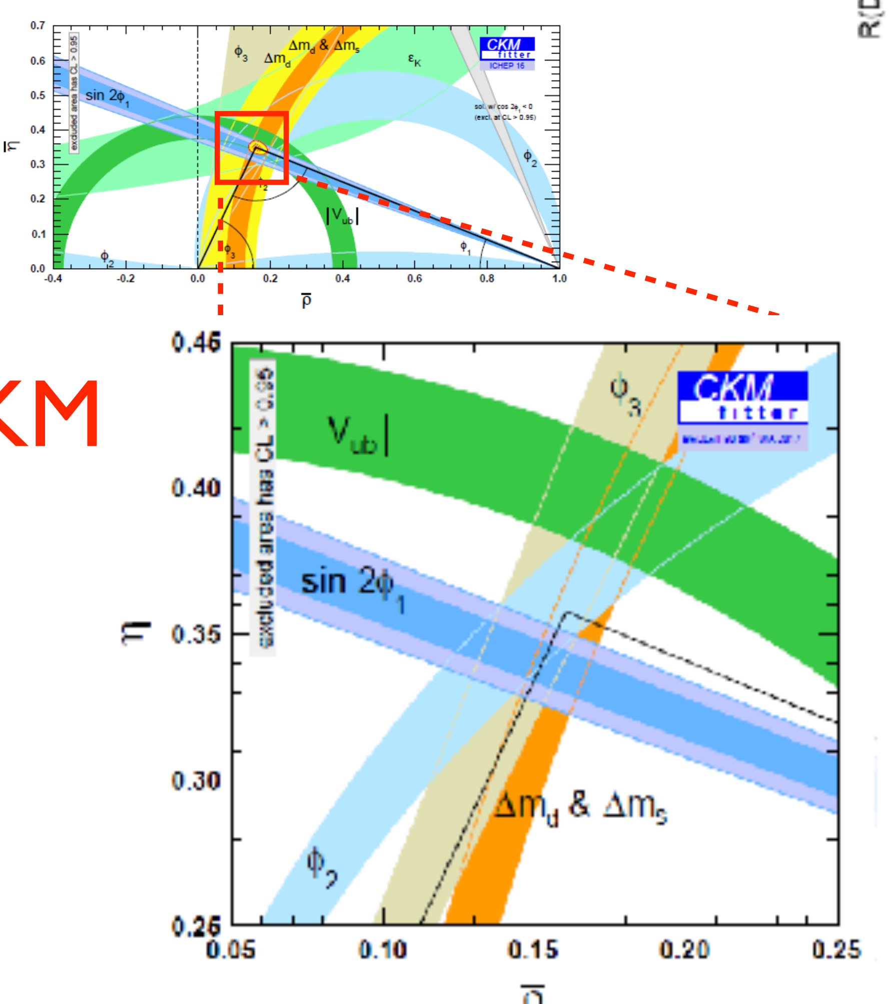
D(*)τν



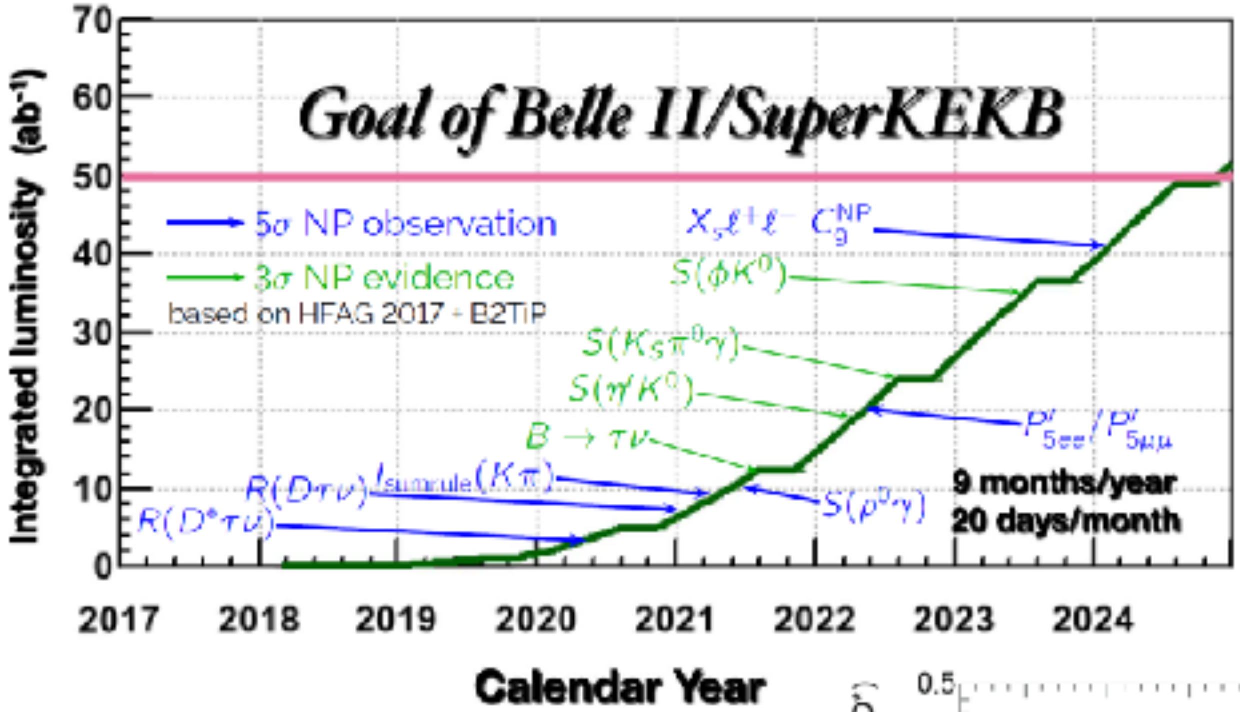
S(η'Ks)

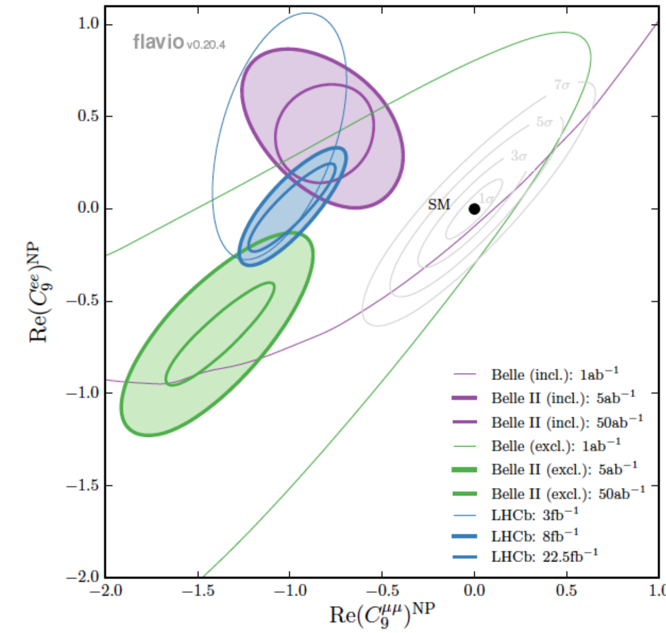


CKM



Physics Prospects (Phase 3)

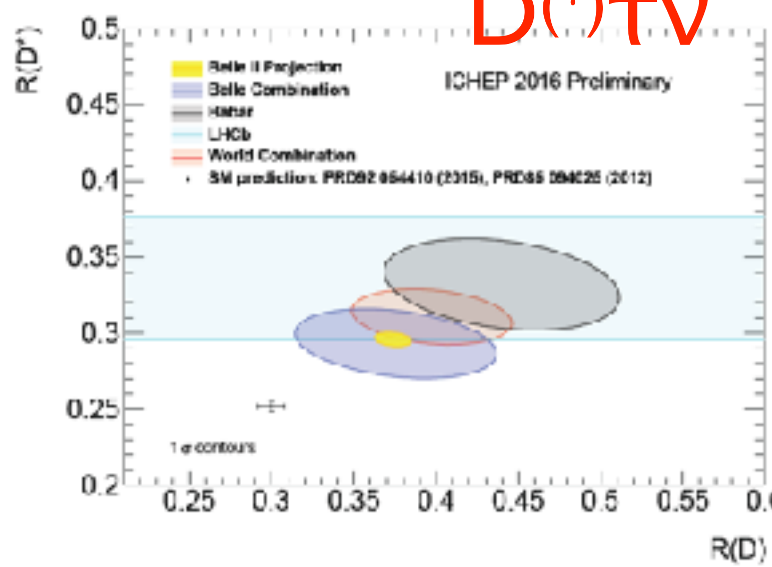




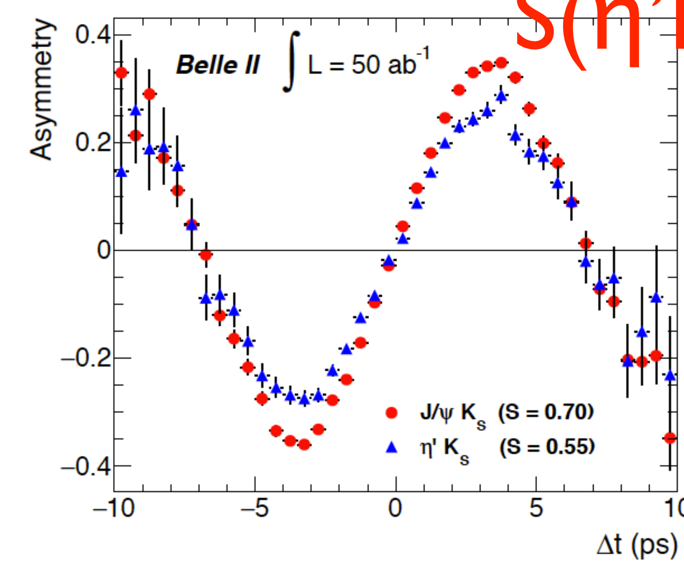
K$^{(*)}$ ll

Xs ll

D$^{(*)}$τν



S(η'Ks)



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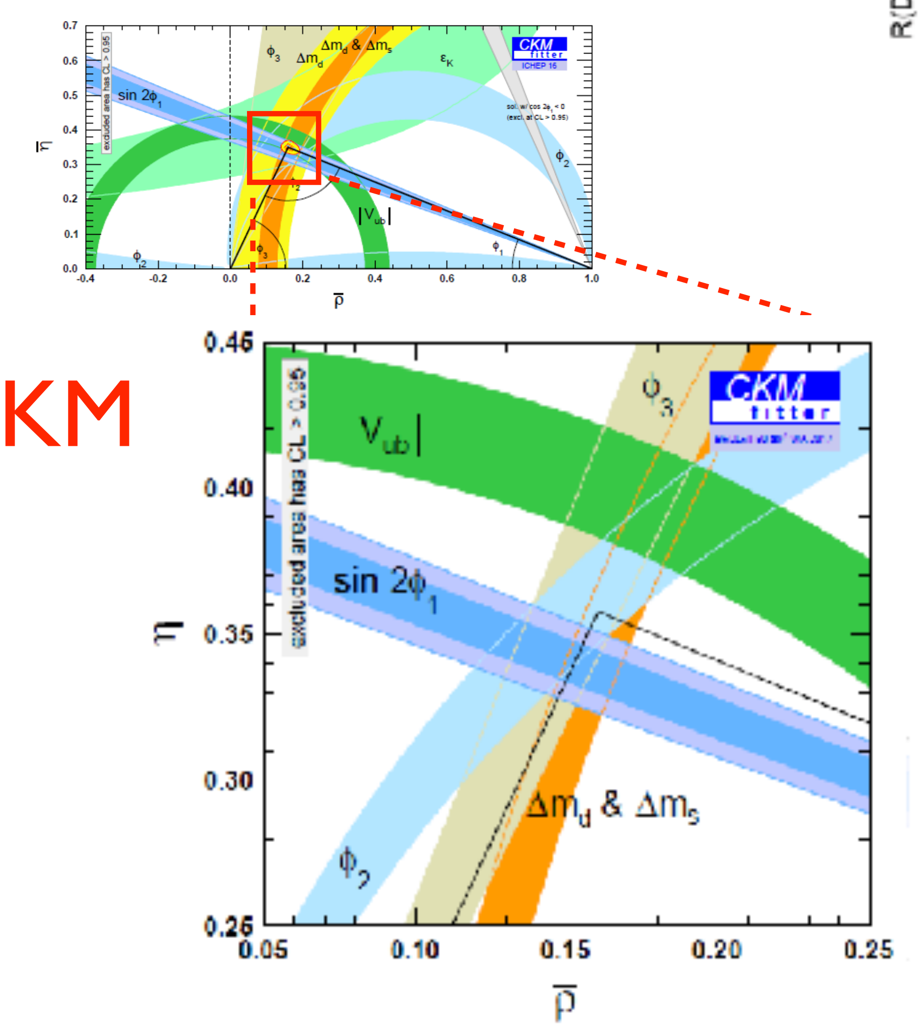
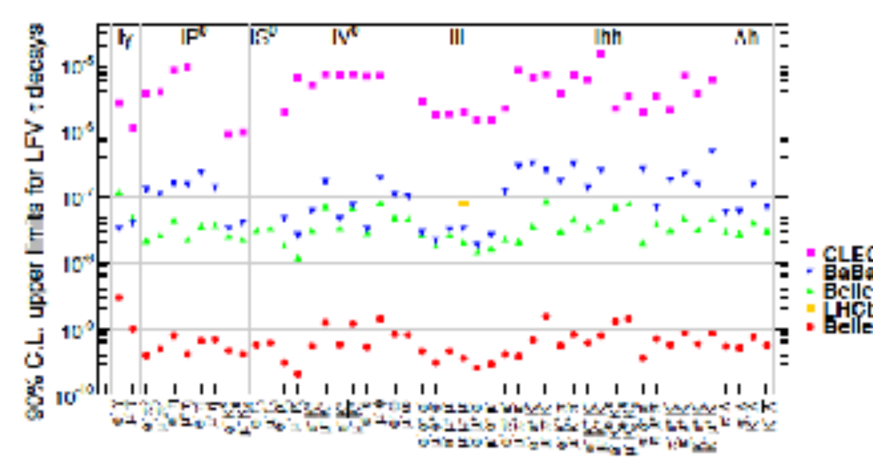


τ LFV

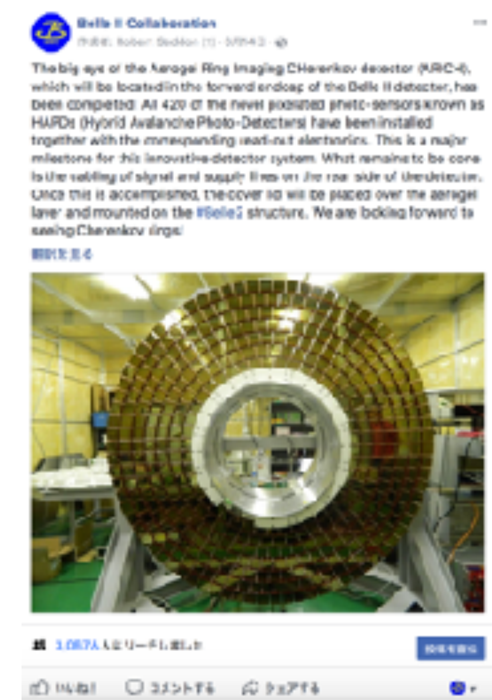


Summary

- Phase 1 commissioning in 2016 was successful.
- Phase 2 preparation in progress
  - All sub-detectors except for VXD have been installed.
  - Global cosmic ray runs with B field in Summer 2017.
  - Damping ring starts in Dec.2017, Main ring in Feb.2018.
  - Plan for background study and physics programs under discussion.
- Vertex detectors (SVD+PXD) construction in full swing. They will be installed after phase 2
- Phase 3 will start in late JFY2018.

Rich physics results will come soon !

Belle II Outreach



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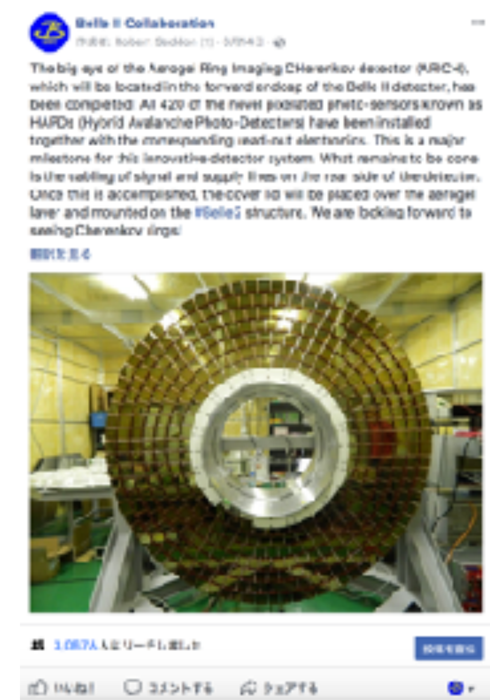
Also public HP: belle2.jp

Belle II Outreach

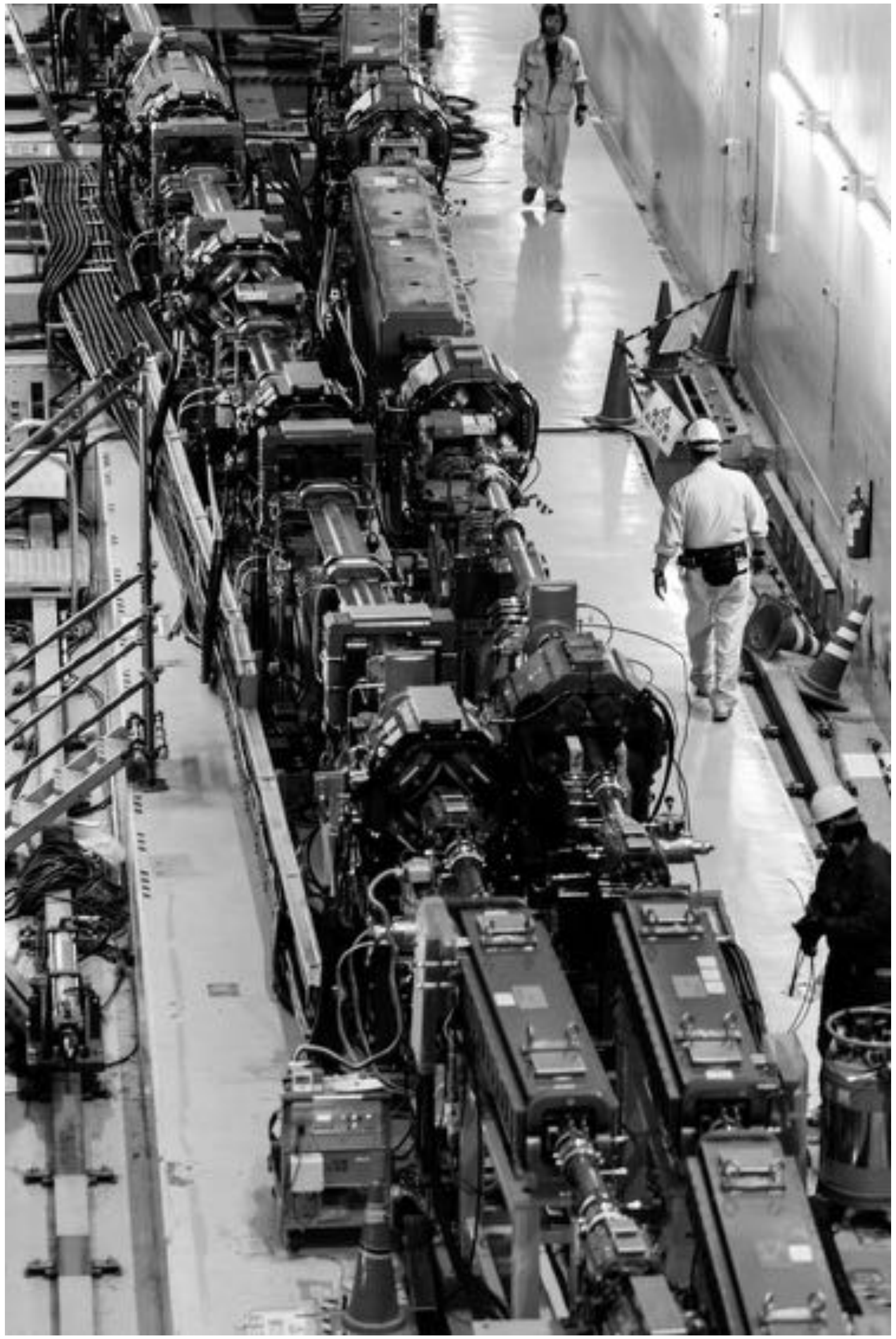


Follow Us & Like Us @Belle2collab

Also public HP: belle2.jp

Thank you !

Backup Slides



Pressure Rise due to Electron Cloud

SuperKEKB Phase-1運転の成果(4)

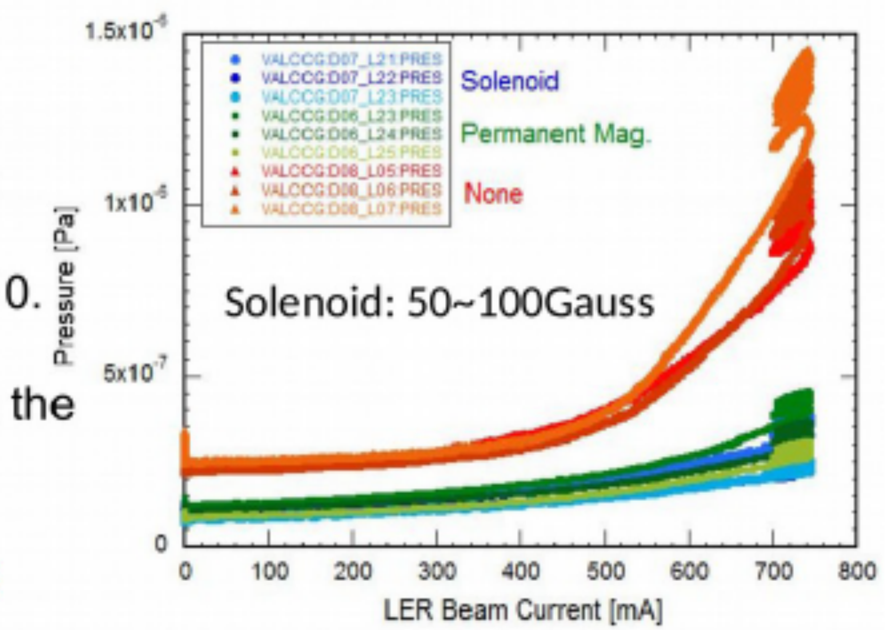
電子雲による圧力上昇LER(1)

Y. Suetsugu

Nonlinear pressure rise against beam current in LER

- The pressures at whole LER ring showed the nonlinear behavior against the beam current.
- The behavior is quite similar to that of electron currents measured at aluminum parts without TiN coating.

- We have aluminum bellows chambers along the ring without TiN coating. The bellows chamber has a length of 0.2 m and located every 3 m on average. Number of such bellows chamber is 810.
- Countermeasure
  - Installation of solenoid magnets at the bellows.
  - We have installed permanent solenoid magnets at all of bellows chambers during short operation break (June 02-05)



24th B2GM “Accomplishments in Phase I commissioning” p.13より

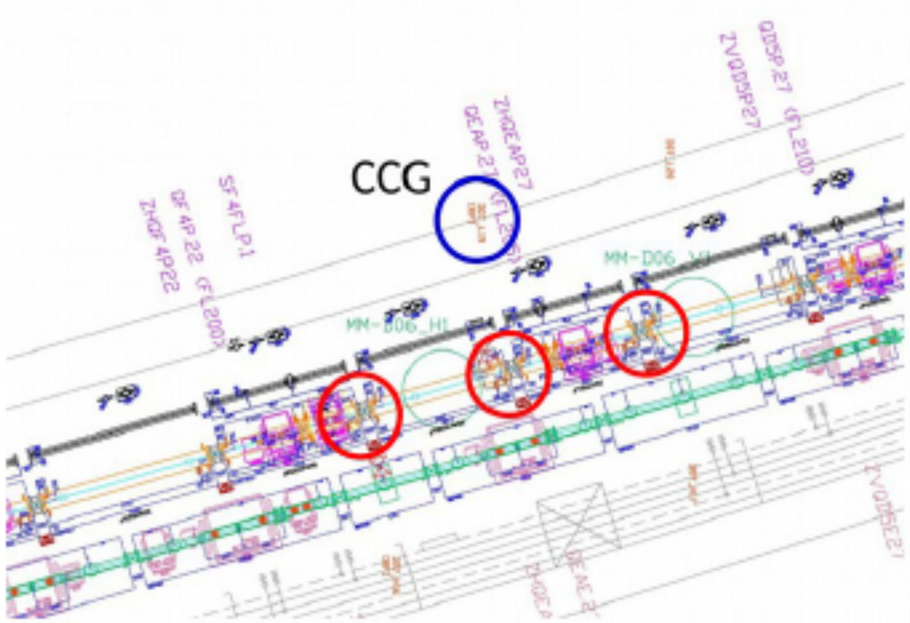
Cont’d

SuperKEKB Phase-1運転の成果(5)

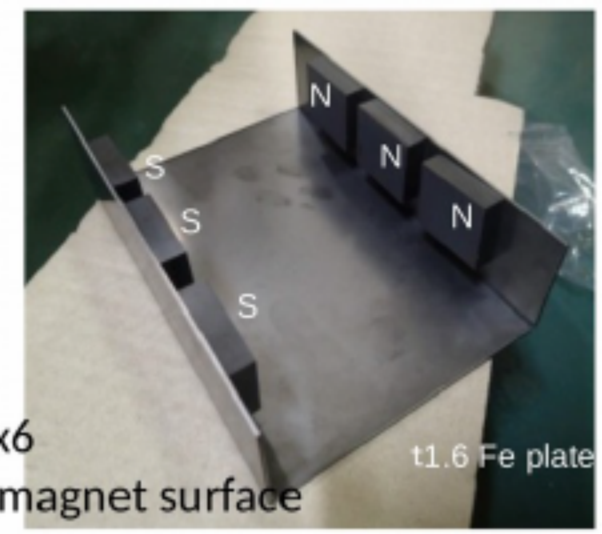
電子雲による圧力上昇LER(2)

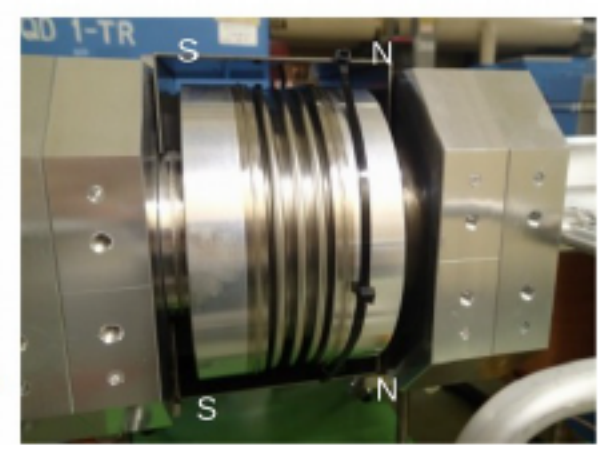
Preliminary test(4/25)

- Permanent Skew-Q magnets



30 x35 x6
970G@magnet surface





Inside bellows
In the middle Bz = 60〜120 G

24th B2GM “Accomplishments in Phase I commissioning” p.14より

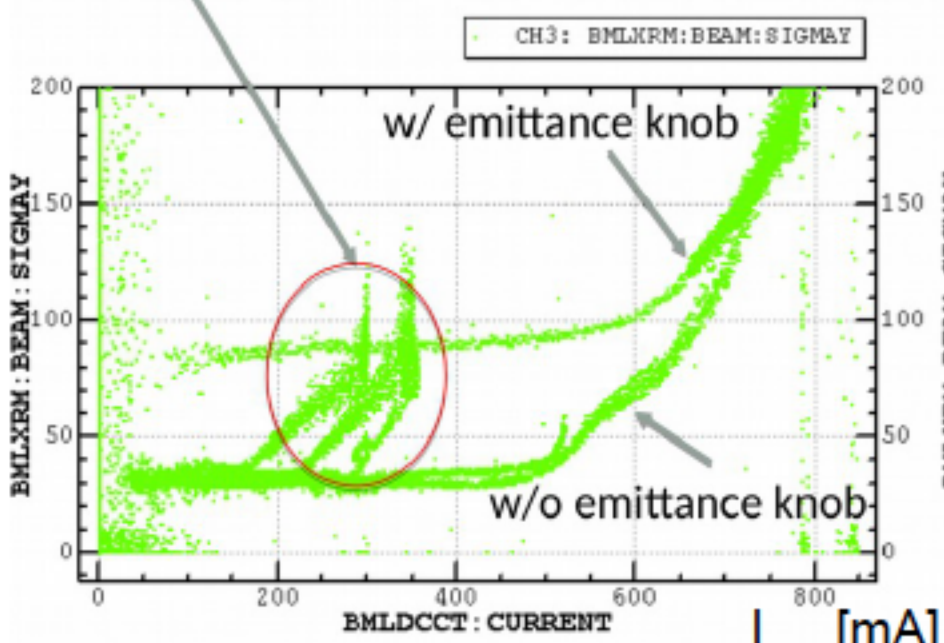
Cont'd

SuperKEKB Phase-1運転の成果(6)

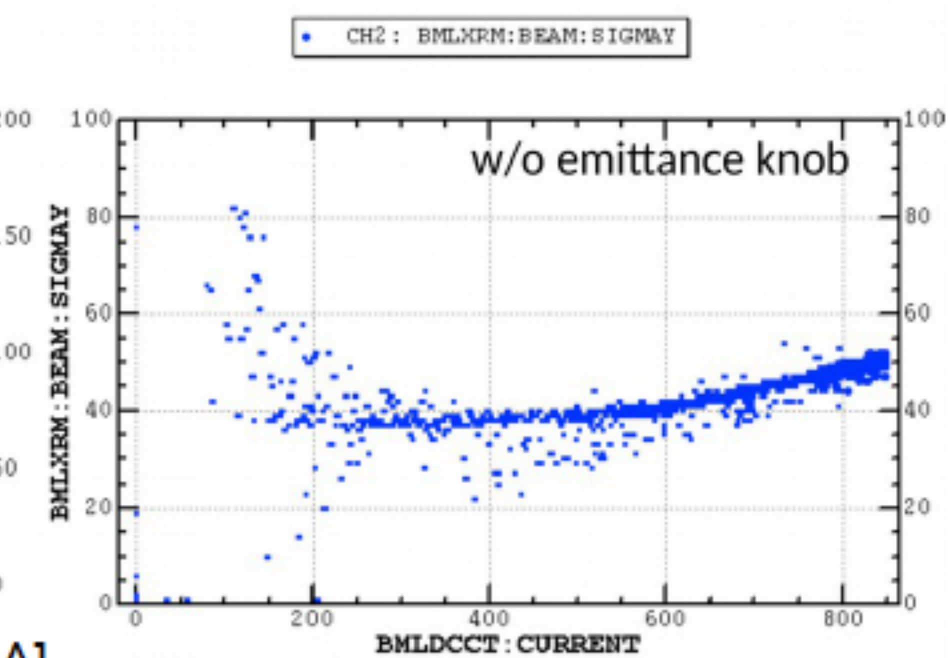
電子雲による圧力上昇LER(3)

LER vertical beam size blowup

Blowup study with shorter bunch spacing



3.06 spacing (1576 bunches)



3.06 spacing (1576 bunches)

June 1st (before installation of solenoids at bellows chambers)

June 6th (after installation of solenoids at bellows chambers)

One of the motivation of installing solenoids was to check their effects to the beam size.

24th B2GM “Accomplishments in Phase I commissioning” p.15より