Start of SuperKEKB

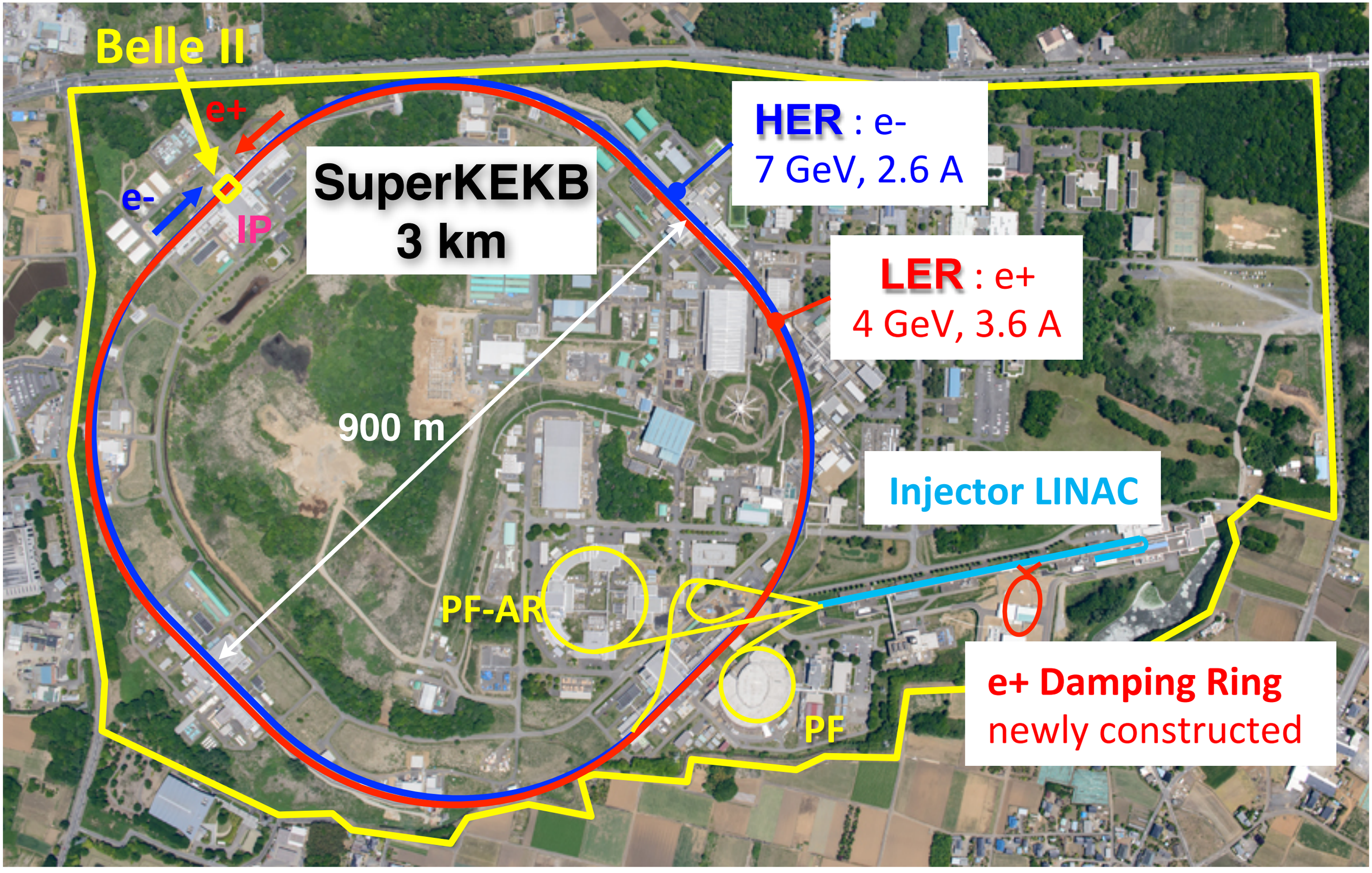
Y. Ohnishi (KEK)

on behalf of SuperKEKB accelerator group

*I cannot cover everything in the limited time although there are many efforts during the Phase-1 commissioning.

SuperKEKB Accelerator

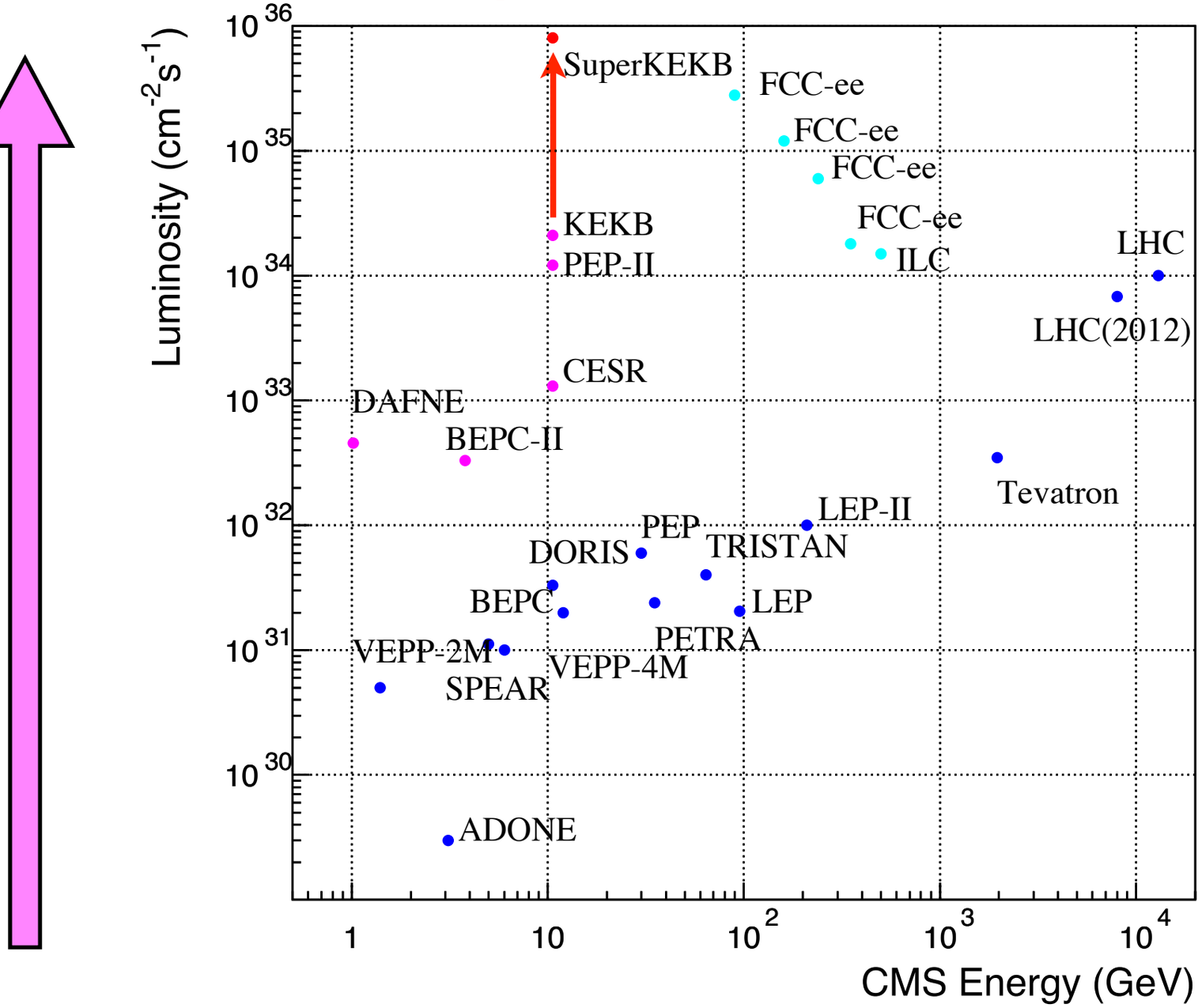
Target peak luminosity: 8 x 10^{35} cm^{-2} s^{-1}



Luminosity VS CMS Energy

Luminosity Frontier

SuperKEKB

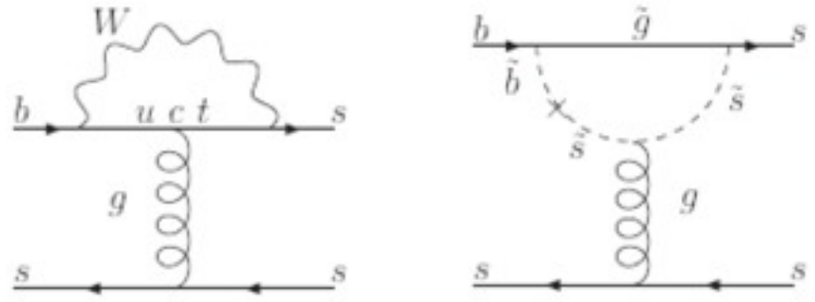


Energy Frontier

Why Luminosity Frontier ?

Number of physics events:

$$N = \int_0^T L\sigma dt$$



σ: Cross section determined by nature's law
L: Luminosity which we can improve with many efforts
T: Experimental period << human life-span

In the case of B meson production, σ is ~1 nb.
New physics will be much smaller than 1/10 - 1/100.

Rare or forbidden reaction !

☞ 10 - 100 times as high as the KEKB luminosity is necessary to explore new physics.

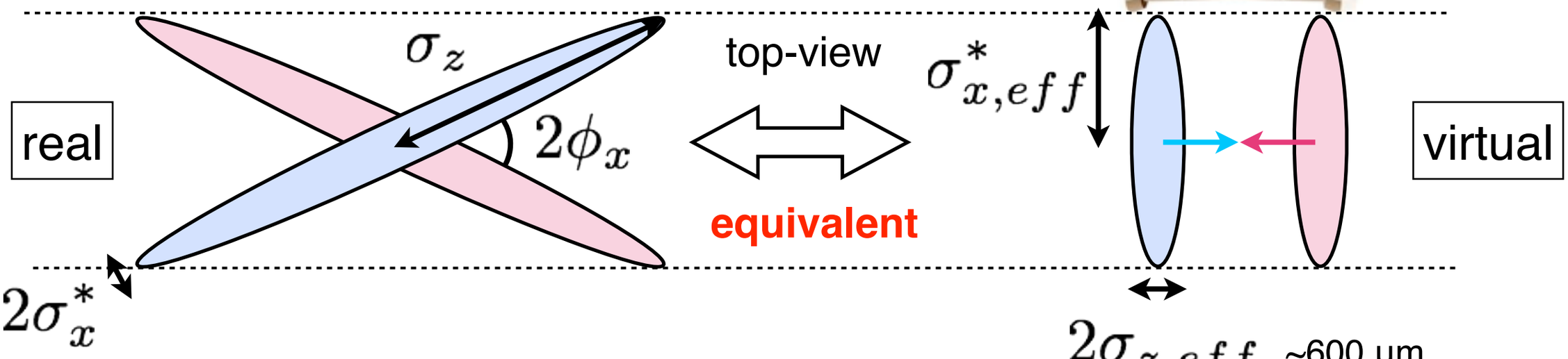
High statistics may open a new window.

Origin of flavor structure
Baryon-antibaryon asymmetry in Universe
Multiple Higgs Bosons ?
...

Nano-Beam Scheme

P. Raimondi et al.

"Narrow beams with large crossing angle"



$\sigma^*_{x,eff} = \sigma_z \phi_x$ ⟵ x and z can be exchanged.

$$\sigma_{z,eff} = \frac{\sigma_x^*}{\phi_x} < \beta_y^*$$

"***Extremely short bunch***" is indispensable.
The small horizontal beam-size makes it possible.

$$L = \frac{N_+ N_- f}{4\pi \sigma_x^* \sigma_y^*} = \frac{N_+ N_- f}{4\pi \sigma_z \phi_x \sqrt{\varepsilon_y \beta_y^*}}$$

If we can make both ε_y and β_y^* small with keeping their ratio constant, the luminosity can be boosted.

$$\xi_y \propto \frac{1}{\sigma_z \phi_x} \sqrt{\frac{\beta_y^*}{\varepsilon_y}}$$

Vertical emittance(ε_y) is one of keys.

Beam-beam exists an upper limit.

Strategy of Luminosity Upgrade

Alternative luminosity formula: $L \propto \frac{\xi_y \cdot I}{\beta_y^*}$ $\sigma_y^* = \sqrt{\varepsilon_y \beta_y^*}$

	KEKB		SuperKEKB		Luminosity gain
	LER	HER	**LER**	**HER**	
ξ_y	0.129	0.09	**0.088**	**0.081**	**x 1**
β_y^* [mm]	5.9	5.9	**0.27**	**0.30**	**x 20**
I [A]	1.64	1.19	**3.6**	**2.6**	**x 2**
σ_y^* [nm]	940	940	**48**	**62**	**nano beam !**
L [$cm^{-2}s^{-1}$]	2.1×10^{34}		**8×10^{35}**		**x 40**

Schedule

***Phase-1**: February 1st, 2016 - July 28th, 2016.* ✓

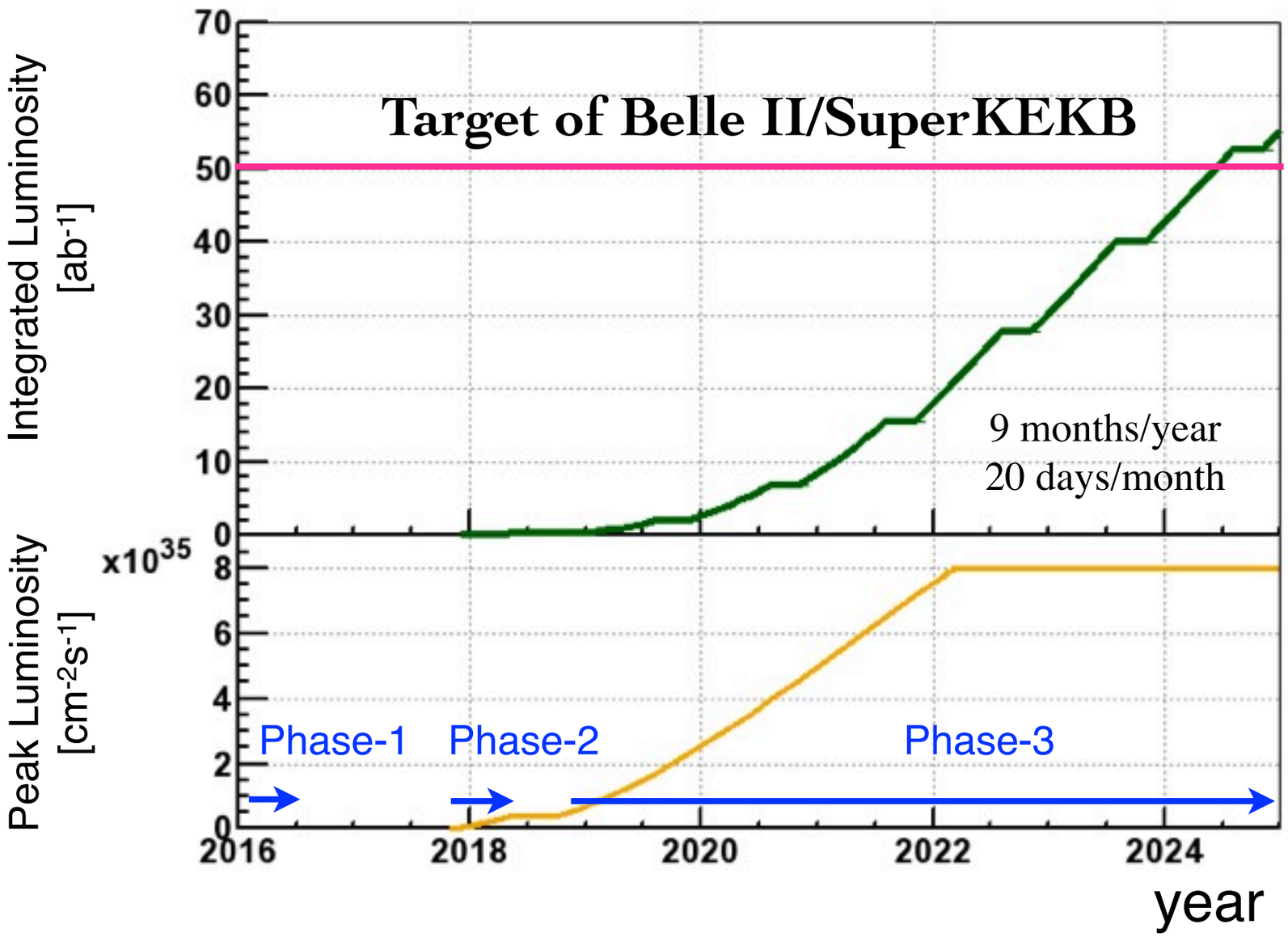
No final focus system, vacuum scrubbing, low emittance tuning

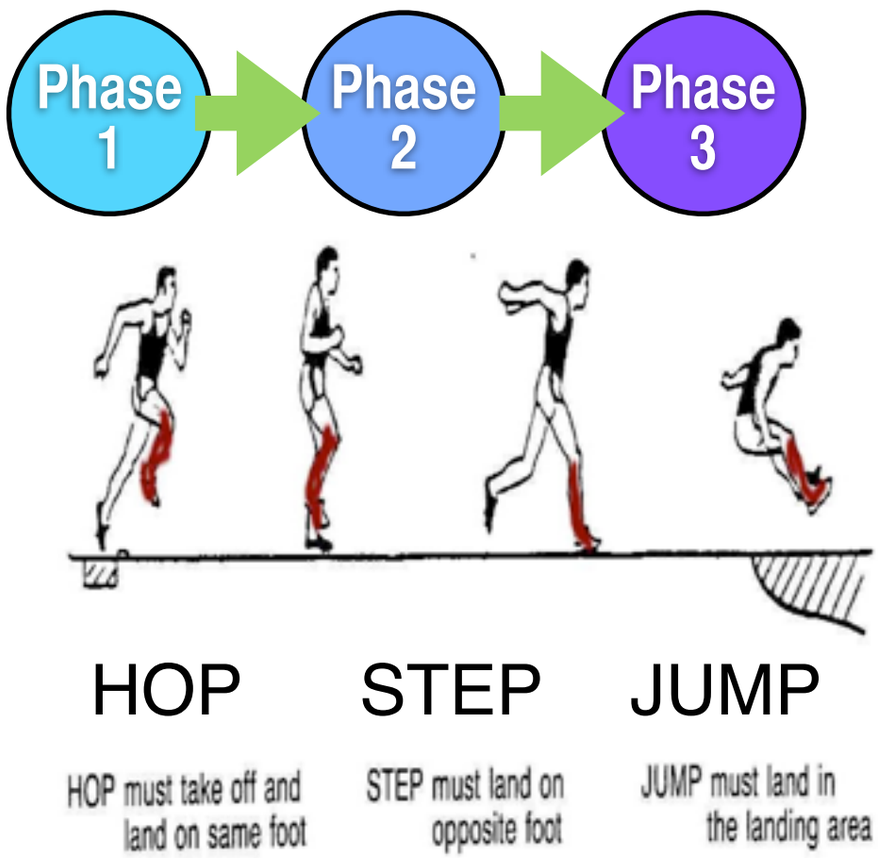
***Phase-2**: November 2017 - April 2018*

Final focus system, Belle II without vertex detector, **the first collision**

***Phase-3**: October 2018 -*

Physics run **with full detector**, squeezing beta and increasing currents



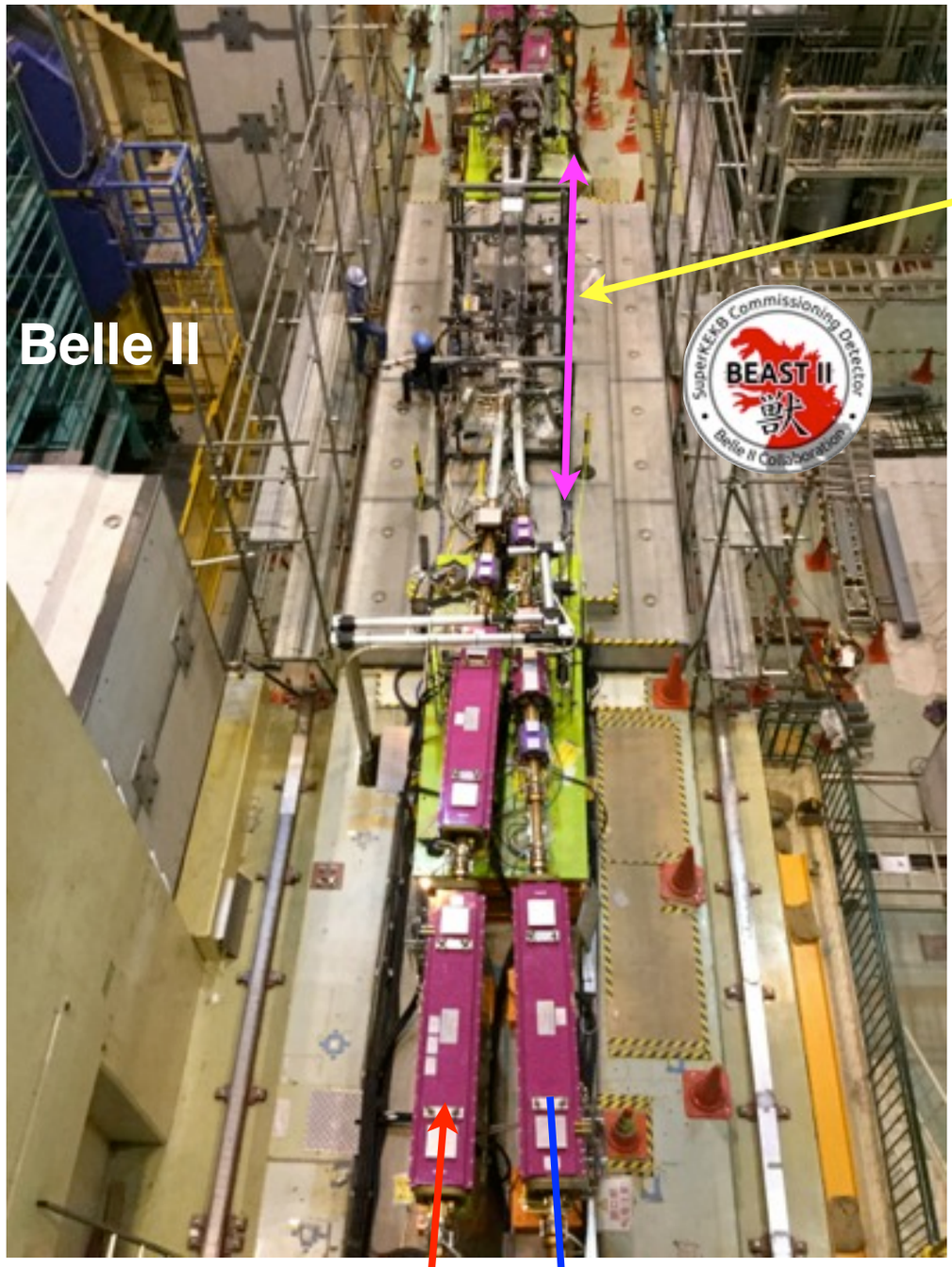


Five Big Issues (FBI)

Issues at the initial commissioning (Phase-1)

1. **Beta Functions at IP ($\beta_{x,y}^*$)**
   - Final Focus system (FF) to squeeze beams at the IP
2. **Vertical Emittance (ε_y)**
   - How to reduce machine error ?
3. **Collective Effects and Lattice Nonlinearity**
   - Beam-Beam, Electron-Cloud, nonlinear magnetic fields of FF
4. **Beam Lifetime and Detector Background**
   - Touschek effect, Beam-gas scattering(vacuum pressure), Movable Collimators
5. **Beam Energy**
   - Y(1S) to Y(6S)

"Interaction Region"



crossing angle:
83 mrad

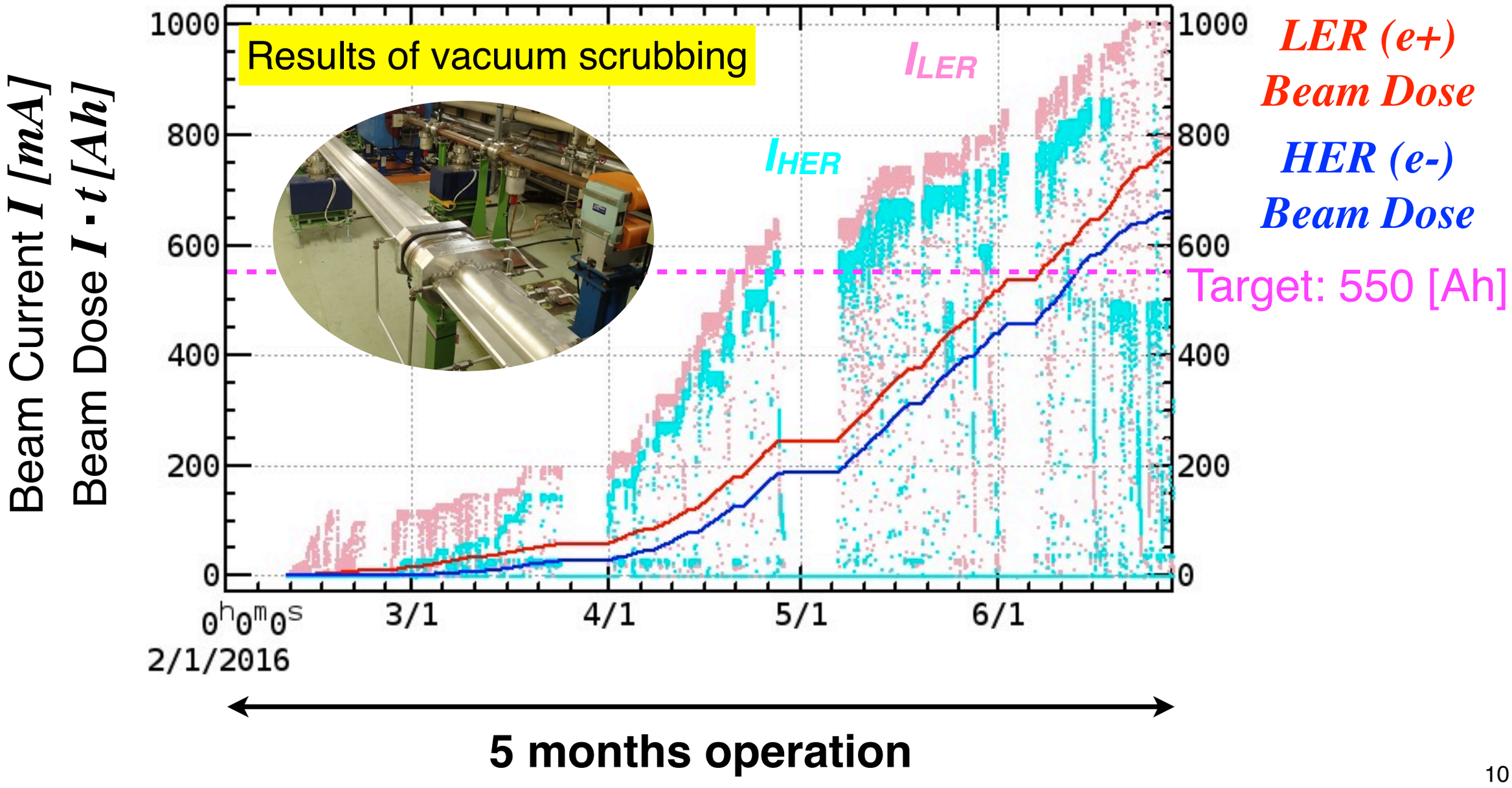
No Final Focus system,
BEAST detector to study backgrounds
(outside of the region, the same magnet configuration as the Phase-2.)

- **Vacuum scrubbing**
  - new ante-chambers
  - to reduce detector background at Phase-2
- **Check of apparatus & software**
  - RF system and Vacuum system
  - magnet control and beam monitors
- **Low emittance tuning**
  - vertical emittance, reduction of machine error

Beam Current and Beam Dose

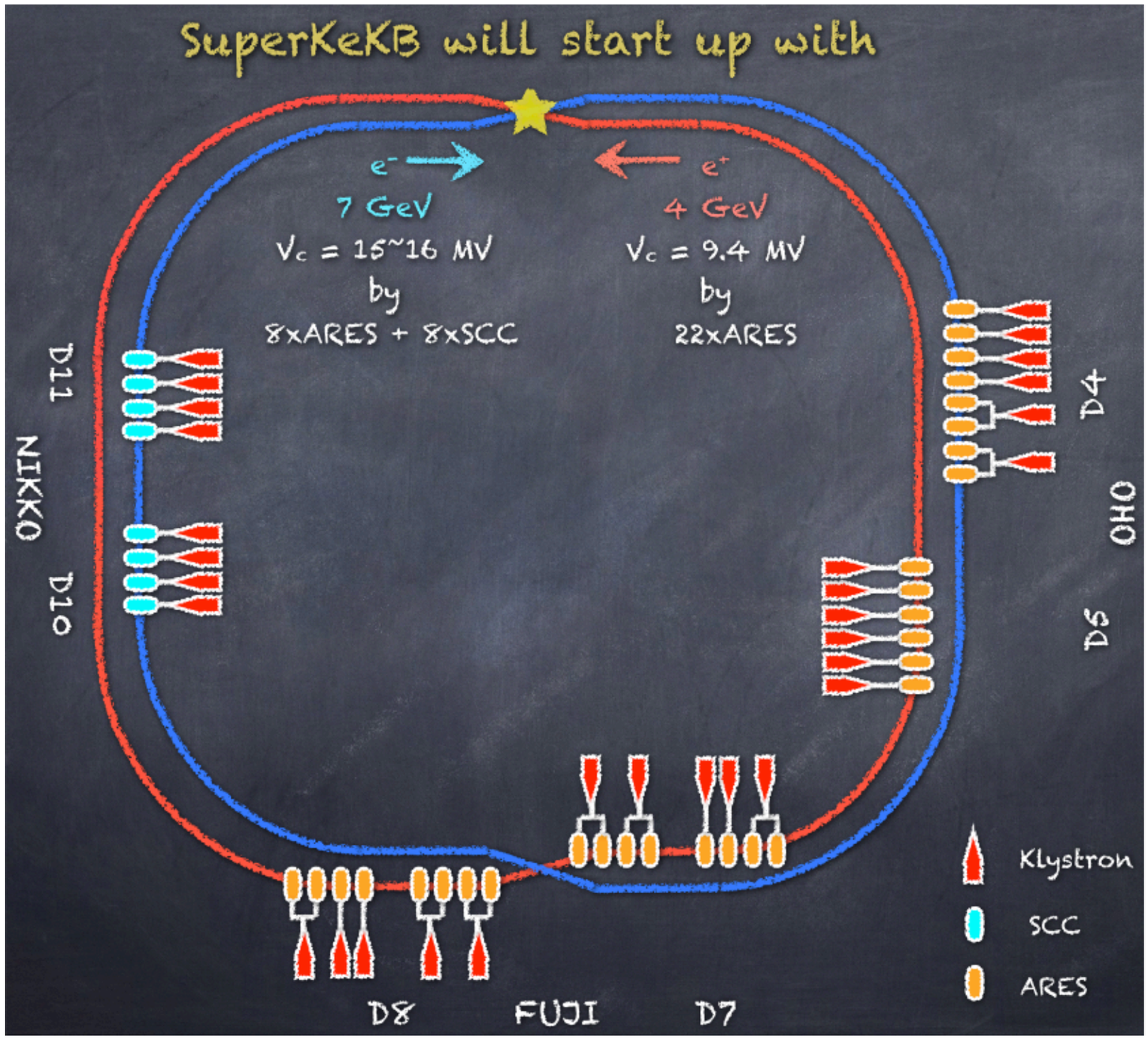
Beam current of 1 [A] and **Beam dose of 780 [Ah]** were achieved in LER.
Ave. pressure: ~10^{-6} [Pa]

Beam current of 0.87 [A] and **Beam dose of 660 [Ah]** were achieved in HER.
Ave. pressure: ~10^{-7} [Pa]

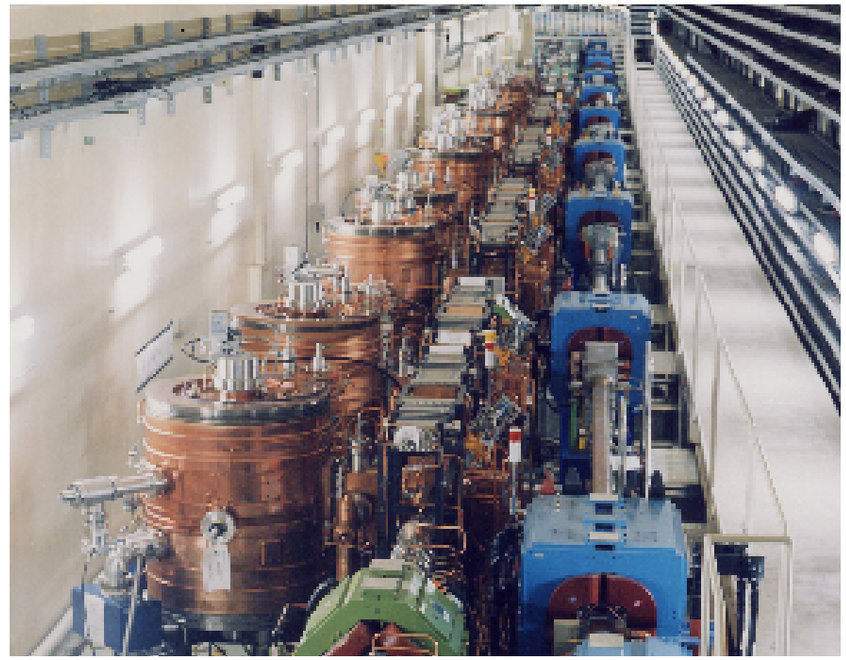


RF system has been operated without serious trouble.

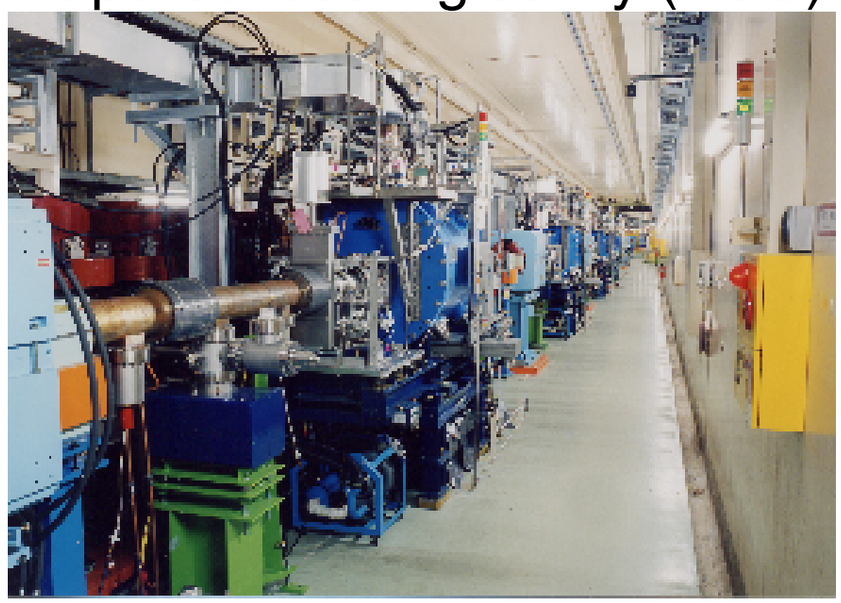
Total Vc: 8 MV in LER / 12.5 MV in HER at Phase-1



Normal conducting cavity (ARES)



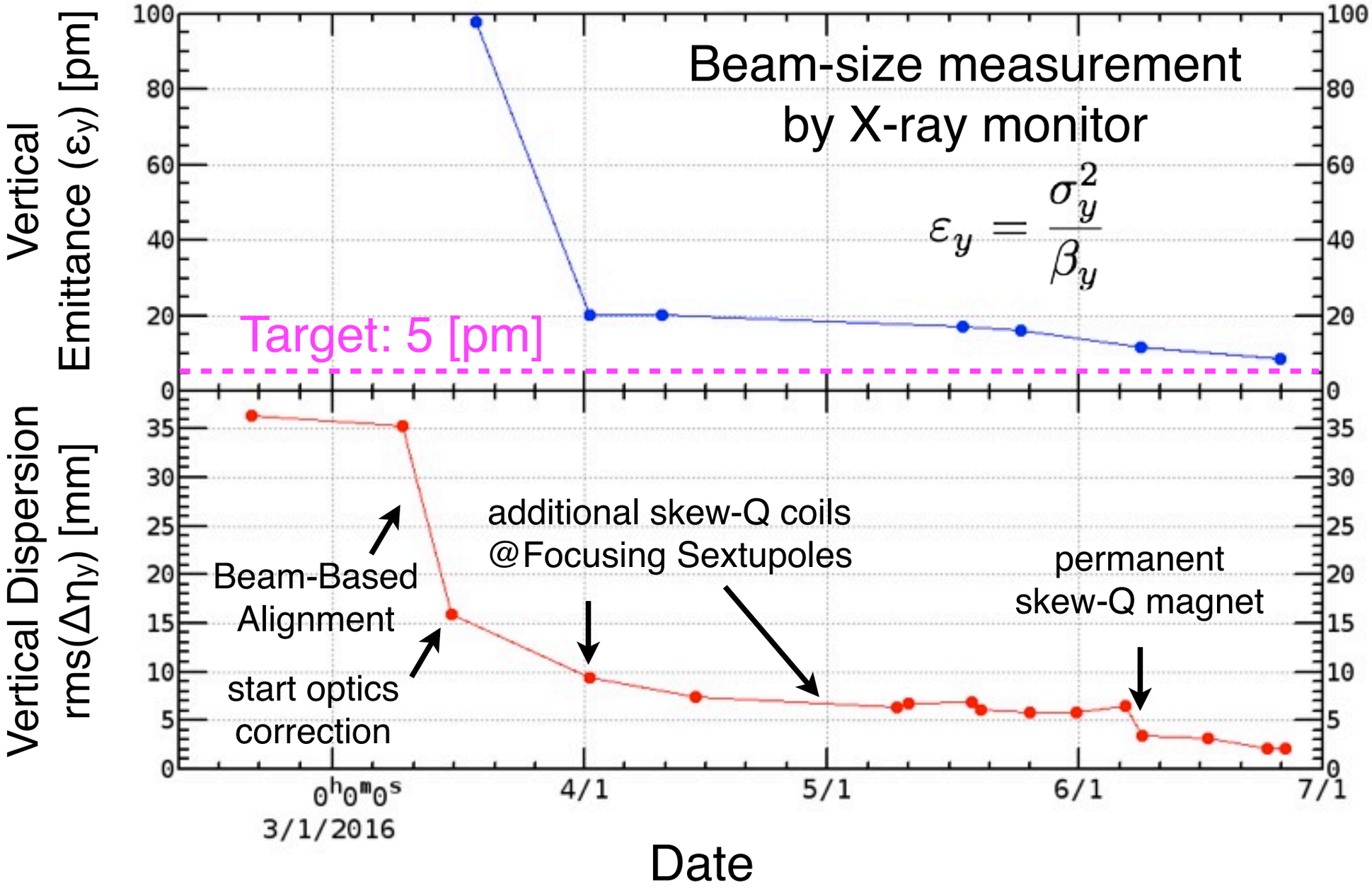
Superconducting cavity (SCC)



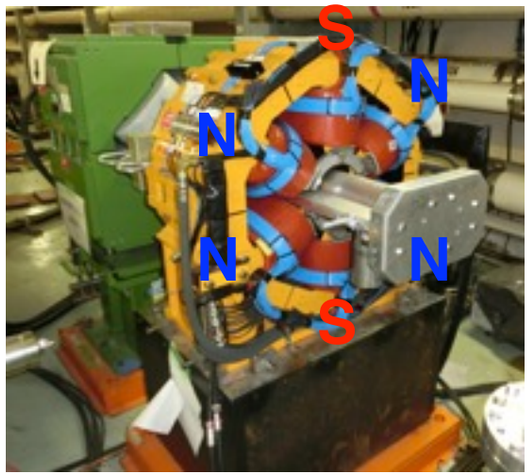
Low Emittance Tuning: Reduce Machine Error

Optics corrections have been worked successfully.
Vertical emittance of ~8 [pm] has been achieved.

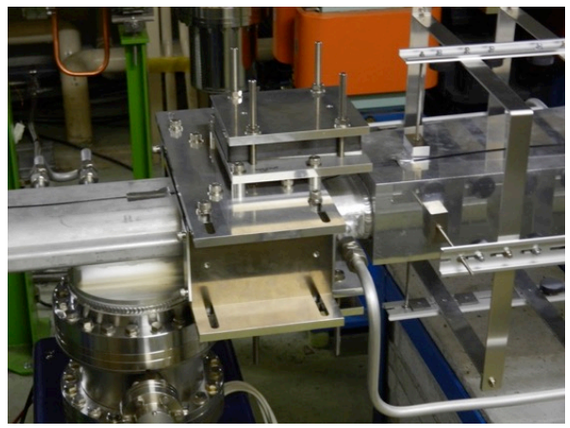
LER



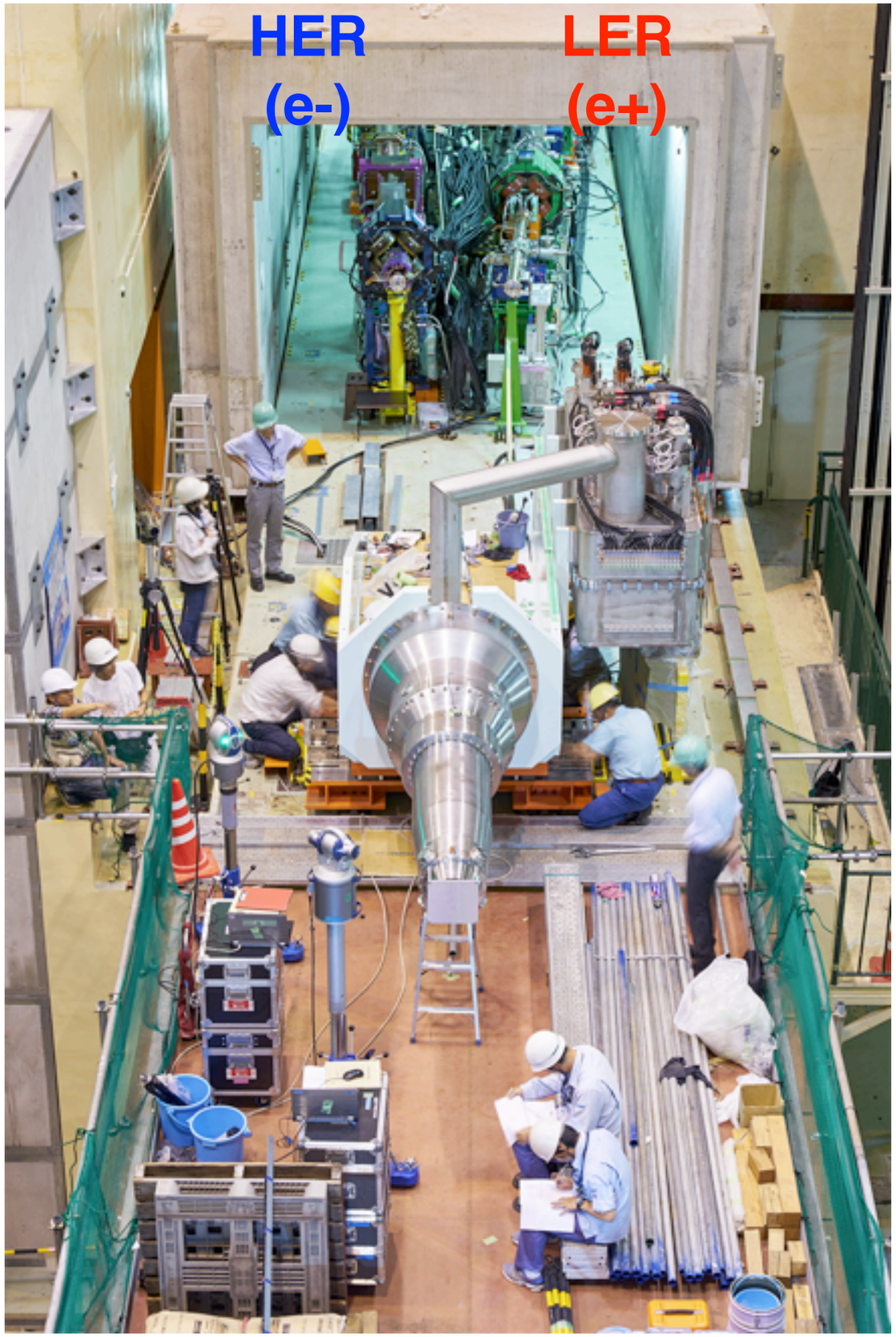
skew-Q corrector coil (cyan) @ sextupole



permanent skew-Q to correct error field

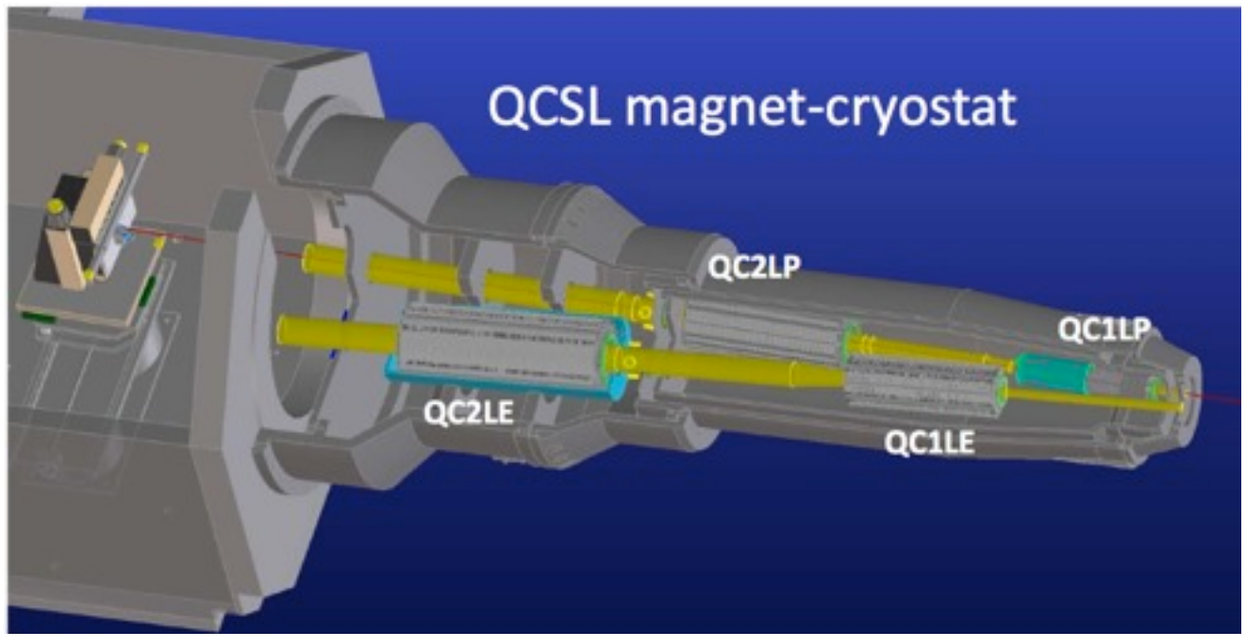


Final Focus Magnets in the Beam-line



August 1st, 2016

Superconducting Magnets



4 quadrupoles (QC1, QC2)
+ 16 corrector coils
+ 4 cancel coils (for leakage field)
+ anti-solenoid
for the left side

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Conclusion

- Vacuum scrubbing was finished with 1 [A] and more than 750 [Ah] in LER.
- Apparatus such as RF system, beam instrumentations, etc. were operated in good shape.
- Low emittance tuning has been performed. Almost good
- We are ready to Phase-2; Machine commissioning for collision. Next milestone is a proof of "Nano-Beam" scheme.
- First physics runs in late 2017
- Countdown to the next generation B-factory toward more than 10^{35} $cm^{-2}s^{-1}$

Backup Slides

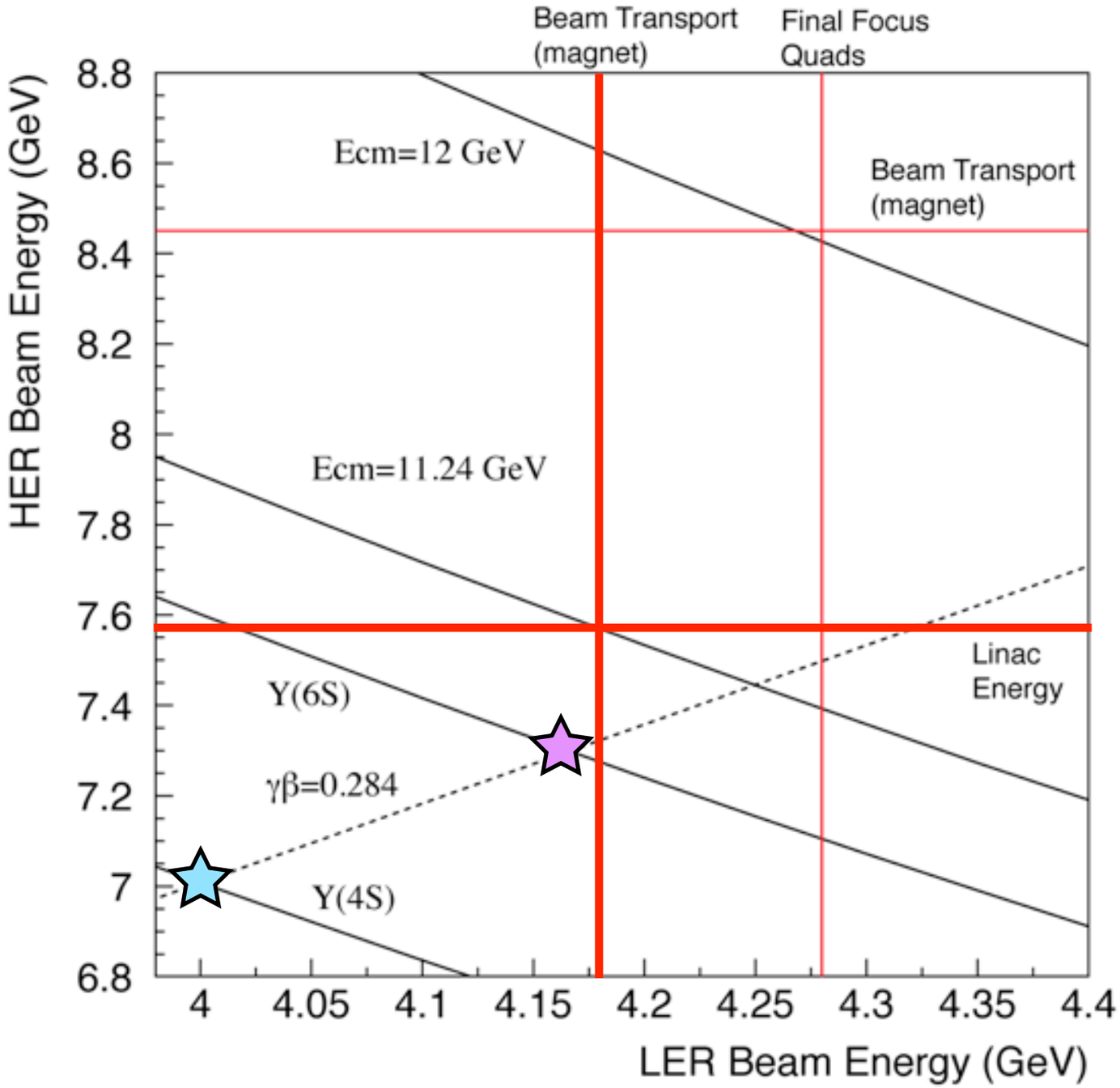
Machine Parameters

2013/July/29	LER	HER	unit	
E	4.000	7.007	GeV	
I	3.6	2.6	A	
Number of bunches	2,500			
Bunch Current	1.44	1.04	mA	
Circumference	3,016.315		m	
$\varepsilon_x/\varepsilon_y$	3.2(1.9)/8.64(2.8)	4.6(4.4)/12.9(1.5)	nm/pm	0:zero current
Coupling	0.27	0.28	%	includes beam-beam
β_x^*/β_y^*	32/0.27	25/0.30	mm	
Crossing angle	83		mrad	
α_p	3.18×10^{-4}	4.53×10^{-4}		
σ_δ	$8.10(7.73)\times10^{-4}$	$6.37(6.30)\times10^{-4}$		0:zero current
V_c	9.4	15.0	MV	
σ_z	6.0(5.0)	5(4.9)	mm	0:zero current
ν_s	-0.0244	-0.0280		
ν_x/ν_y	44.53/46.57	45.53/43.57		
U_0	1.86	2.43	MeV	
$\tau_{x,y}/\tau_s$	43.2/21.6	58.0/29.0	msec	
ξ_x/ξ_y	0.0028/0.0881	0.0012/0.0807		
Luminosity	8×10^{35}		$cm^{-2}s^{-1}$	

Beam Energy

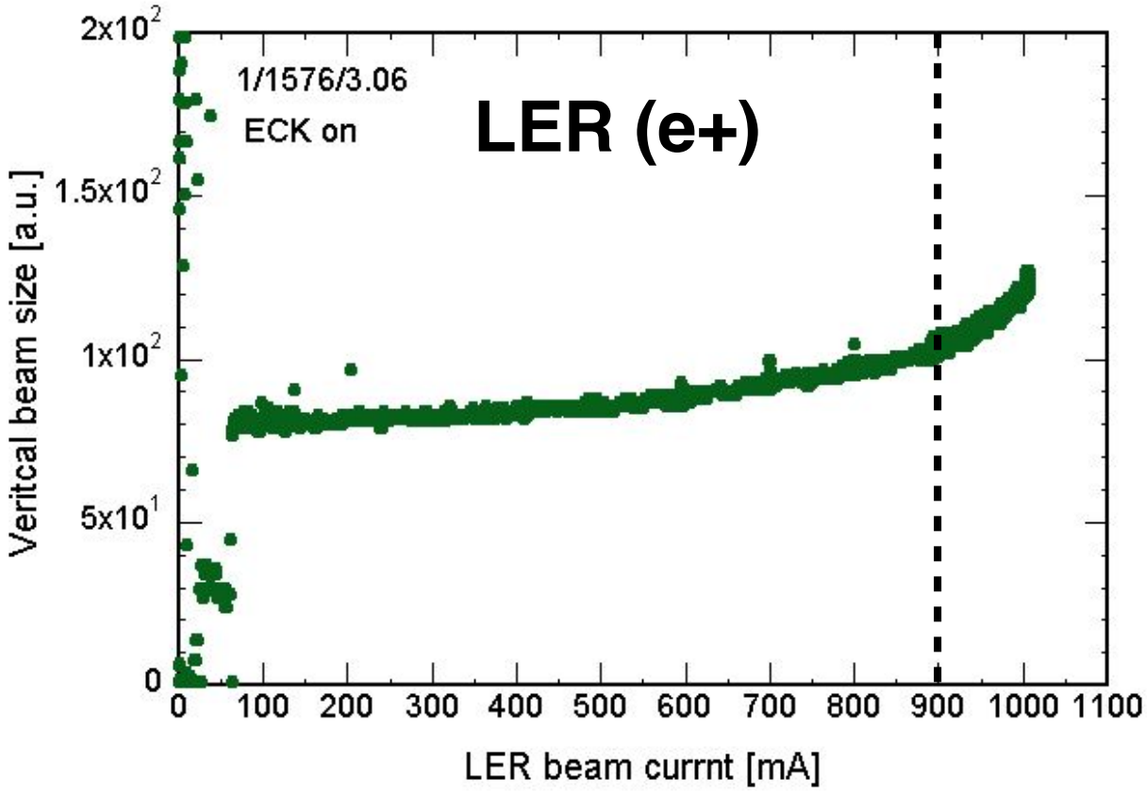
Start from Y(4S) operation at Phase-2. 5 months operation at Phase-2

Max. CMS energy is 11.24 GeV (boost factor changes).



Observation of Electron Cloud at Phase-1

Beam blow-up was observed above 900 mA for 3 bucket spacing

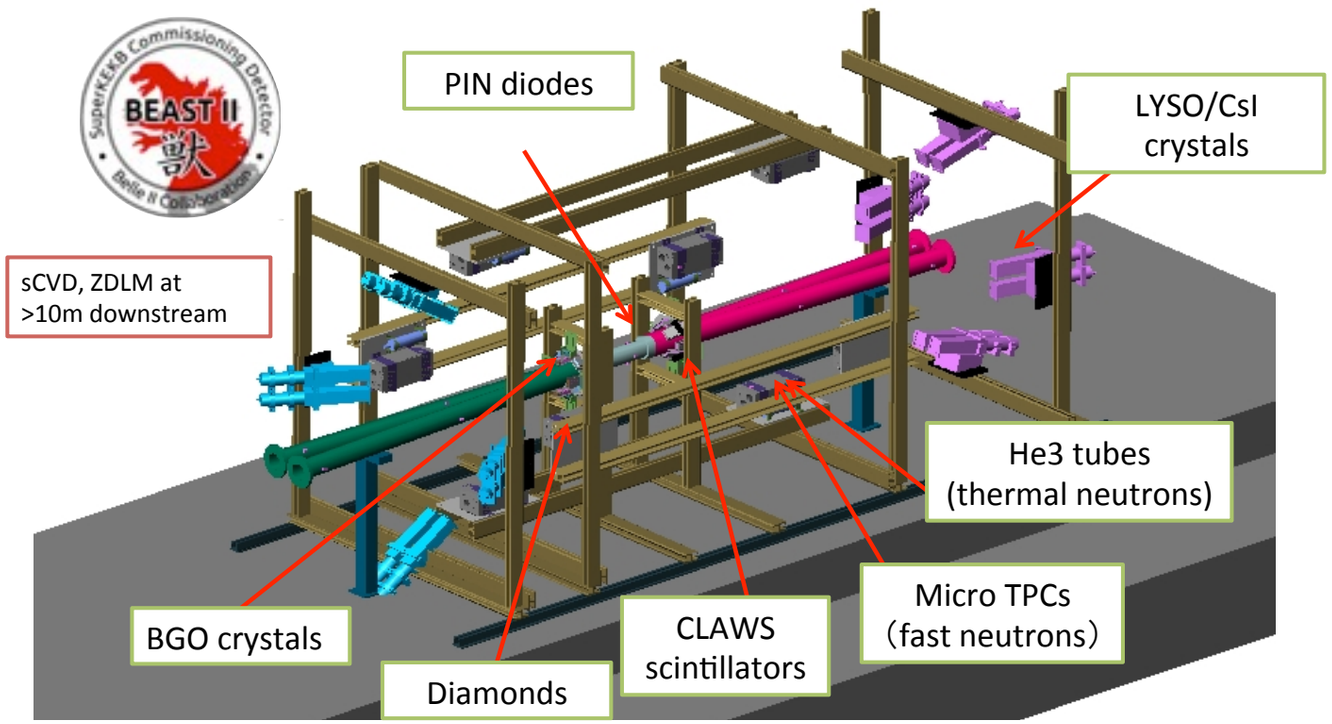


Cure of electron cloud (EC): solenoids for drift space

Ante-chamber and TiN coating is not enough to suppress EC at higher than 1 [A] beam current.

We need more solenoid at drift space or waiting aging effect to realize the target luminosity.

BEAST II Commissioning Detector



BEAST II
for Phase-1

BEAST data shows the LER backgrounds decreasing as vacuum scrubbing proceeds.