POSIPOL-2016 workshop in LAL, Orsay (France), 2016.09.15

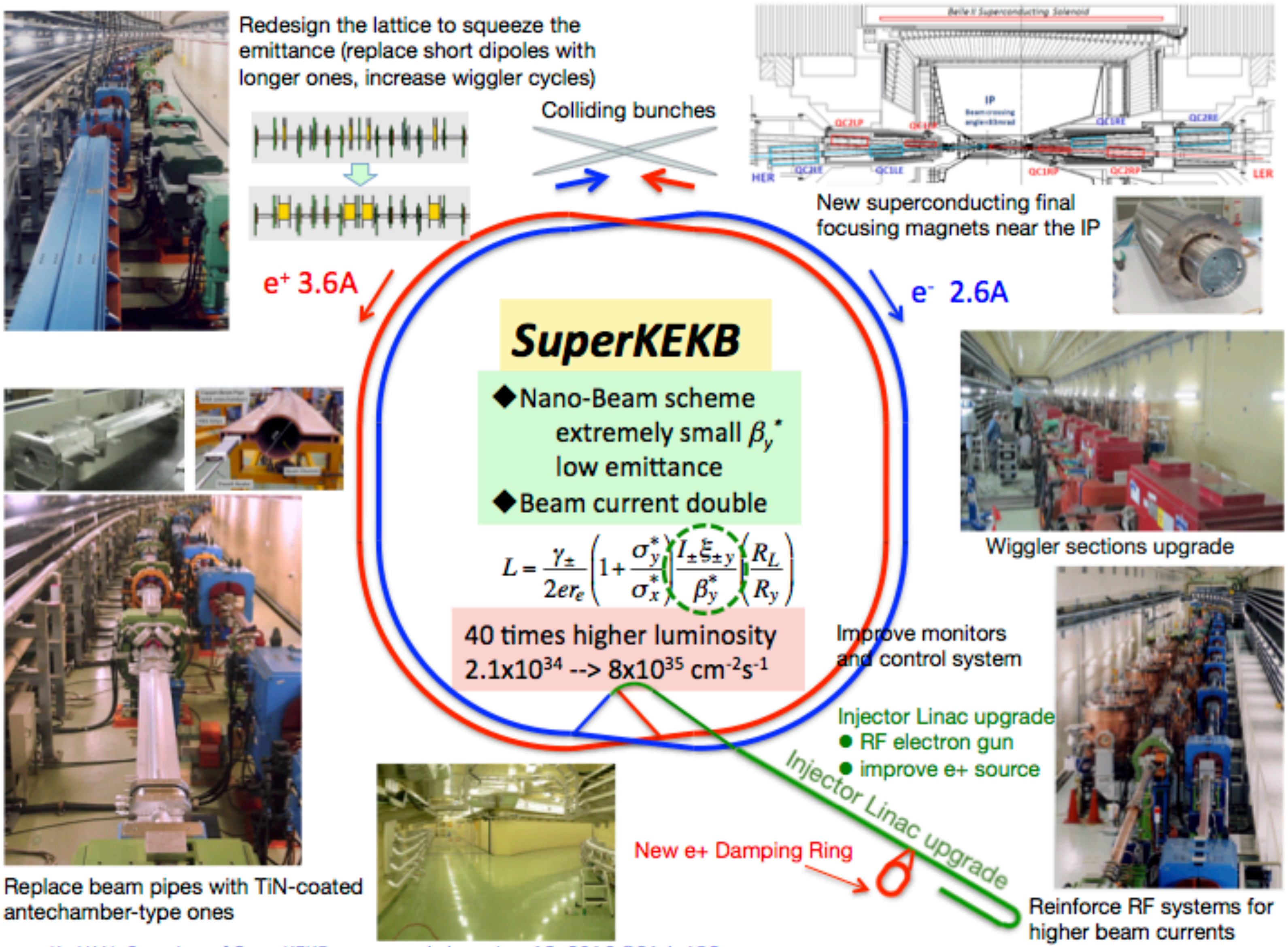
SuperKEKB positron source status

Takuya Kamitani (KEK)

Positron source members

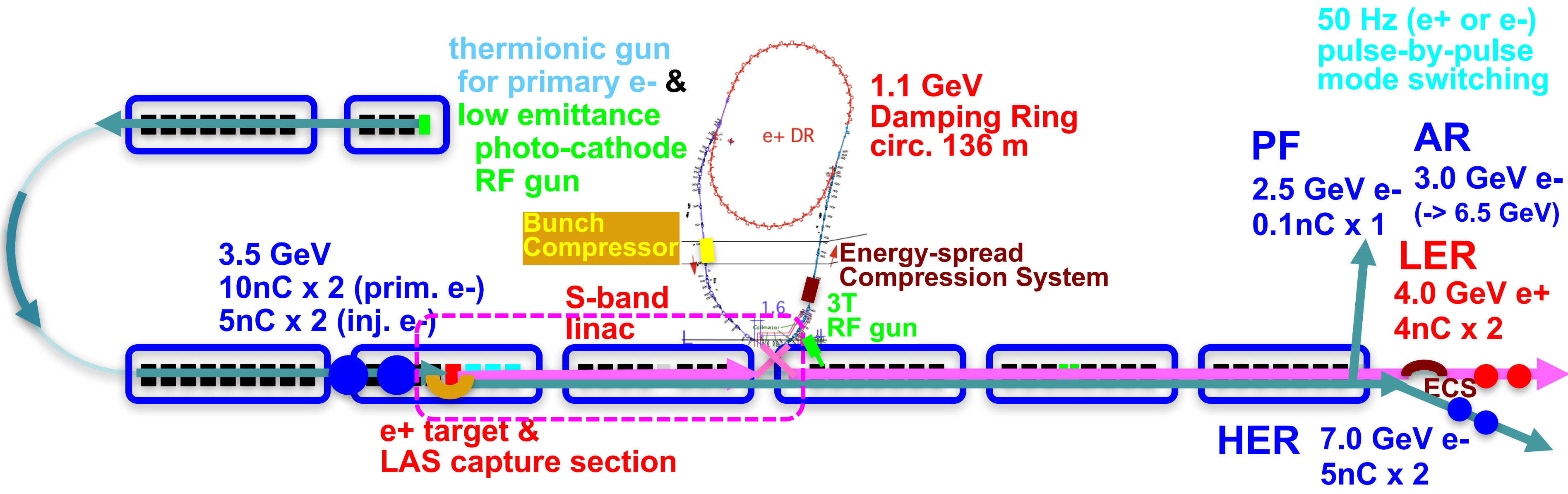
- KEK
  - Y. Enomoto, Yokoyama, Zang, Fukuda, Kamitani
  - Tanaka, Ikeda, Kakihara, Arakida, Ohsawa, A. Enomoto
  - Nakajima, Akemoto, S. Matsumoto, Higo
  - Miura, Miyahara, Sugimoto, Seimiya, Iida, Ohnishi
  - Okada, Takatomi, Someya, Kazama
- Mitsubishi Electric System Service Co.
  - Ushimoto, Suzuki, Kimura
- Toyama Co.
  - Iino, Morota, Sakai, Satoh

SuperKEKB overview



K. AKAI, Overview of SuperKEKB, status and plans, Jun. 13, 2016 @21th ARC 2

SuperKEKB Injector



Upgrade items in positron source

Low emittance e+ : (2000 -> $92_{[H]}/7_{[V]}$ mm)

- **positron damping ring introduced**

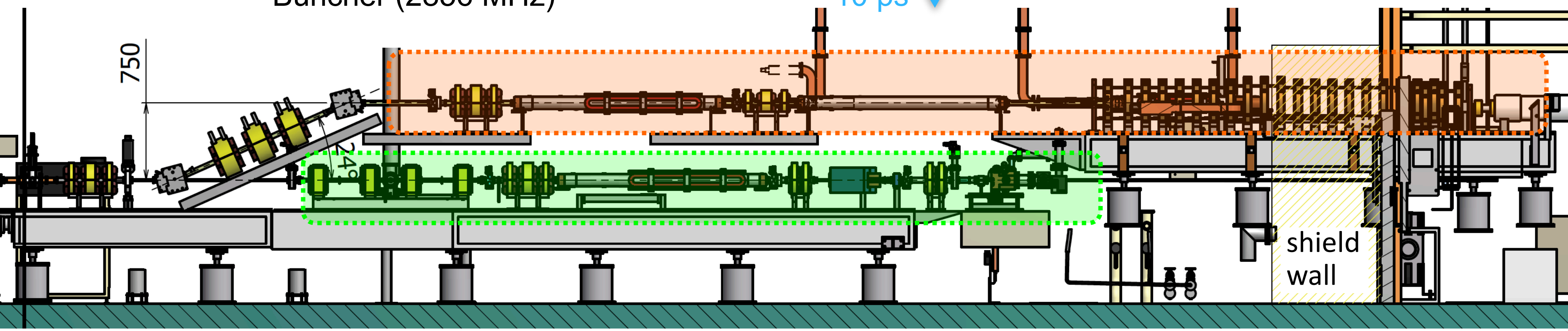
e+ intensity : (1 -> 4 nC/bunch)

- **new positron focusing lens: flux concentrator (3.5 T) + bridge coils (1.0 T)**
- **large-aperture (2a=30mm) accelerating structure (LAS) in capture section**
- **positron focusing beam line layout reorganized with 100 new quad. magnets**

Double-deck pre-injectors

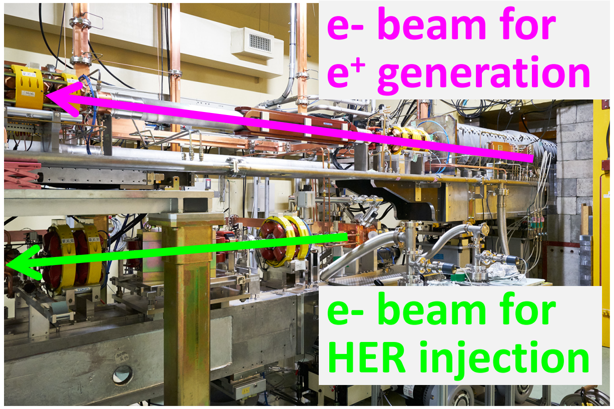
Upper deck (former KEKB pre-injector, reconstructed !)
thermionic gun + RF bunching section

Gun 200 kV (=> 5 MV/m)	1300 ps	bunch length
Sub Harmonic Buncher 1 (114 MHz)	500 ps	
Sub Harmonic Buncher 2 (571 MHz)	330 ps	
Prebuncher (2856 MHz)	70 ps	
Buncher (2856 MHz)	10 ps	

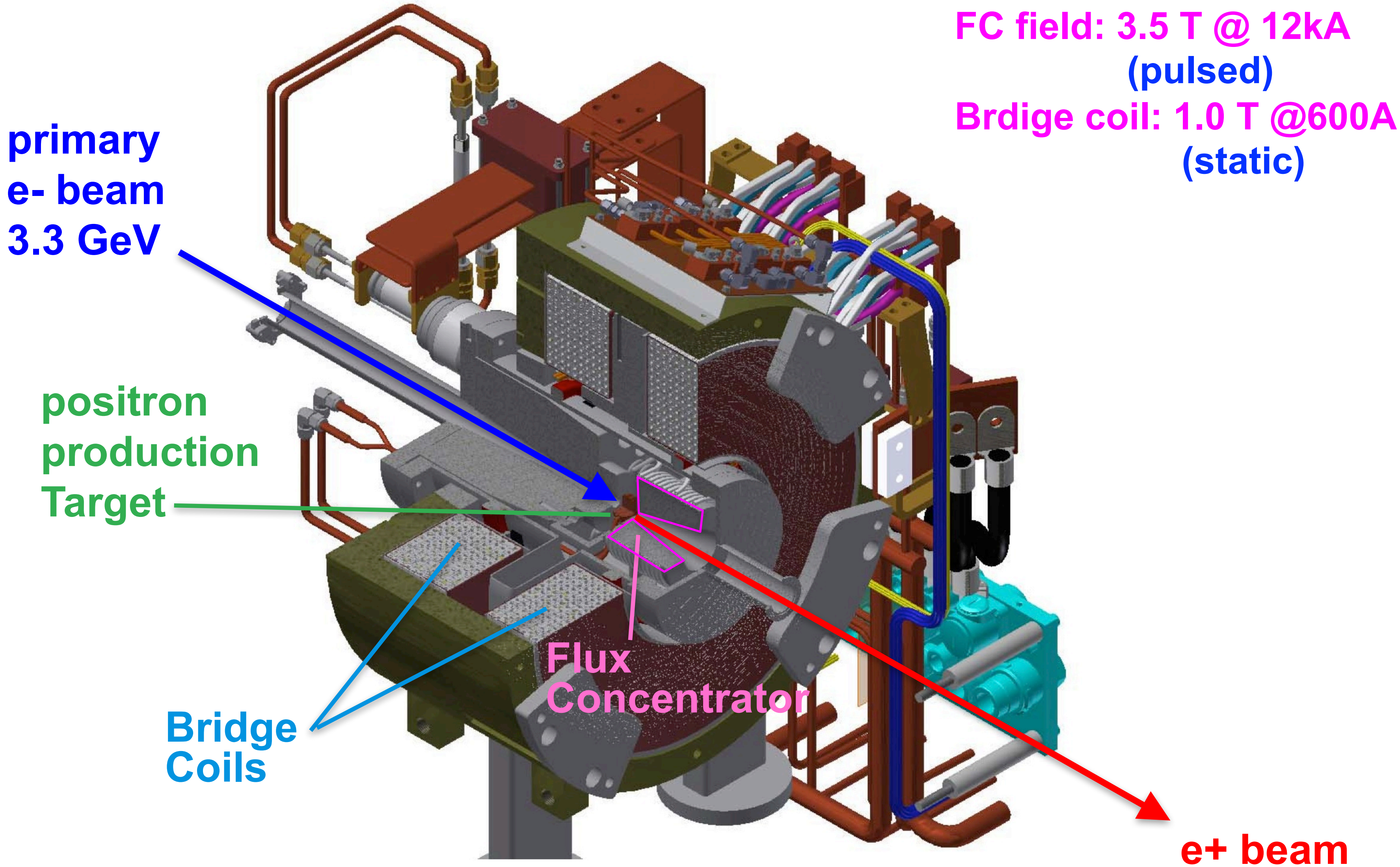


Lower deck
photo-cathode RF gun
+ magnetic bunching

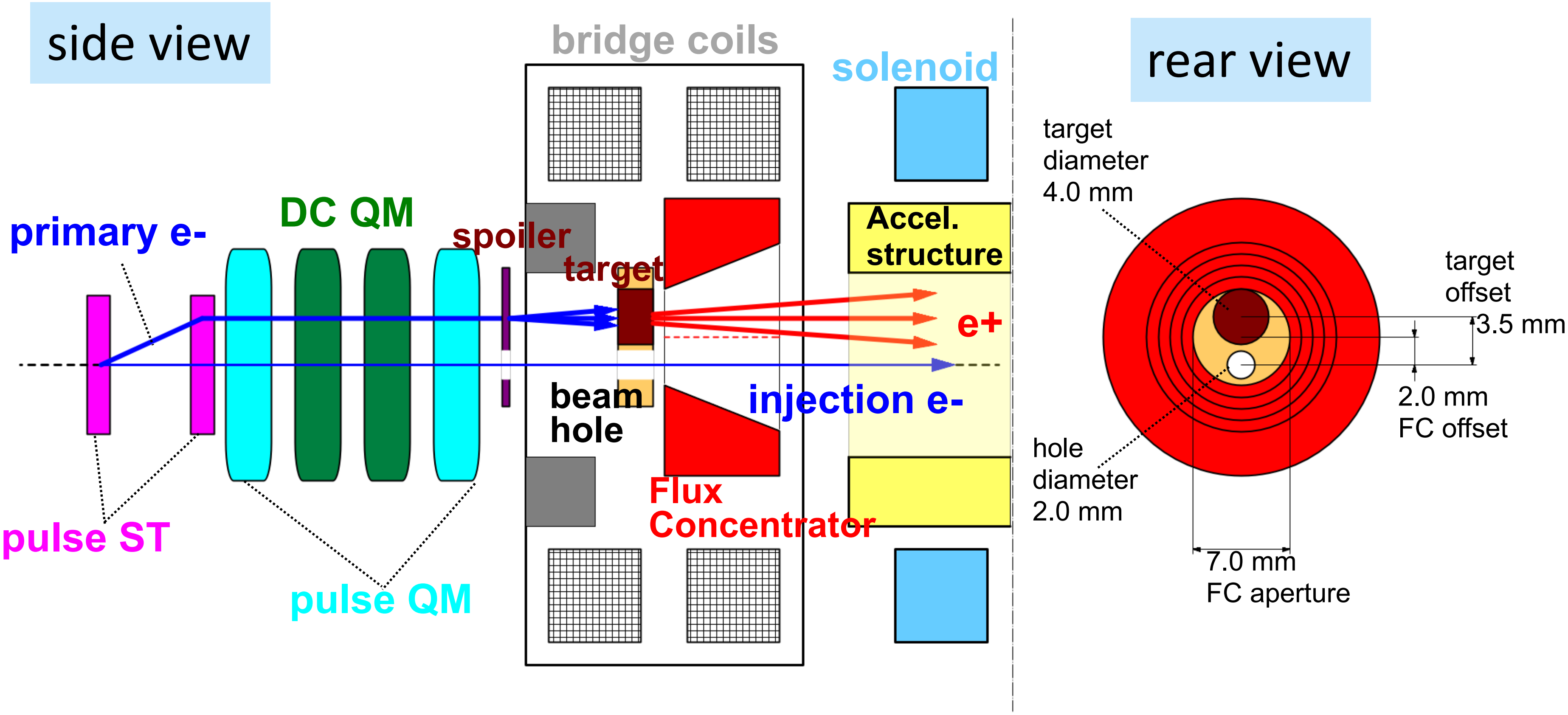
RF gun	25 ps	bunch length
Chicane	10 ps	



SuperKEKB positron source

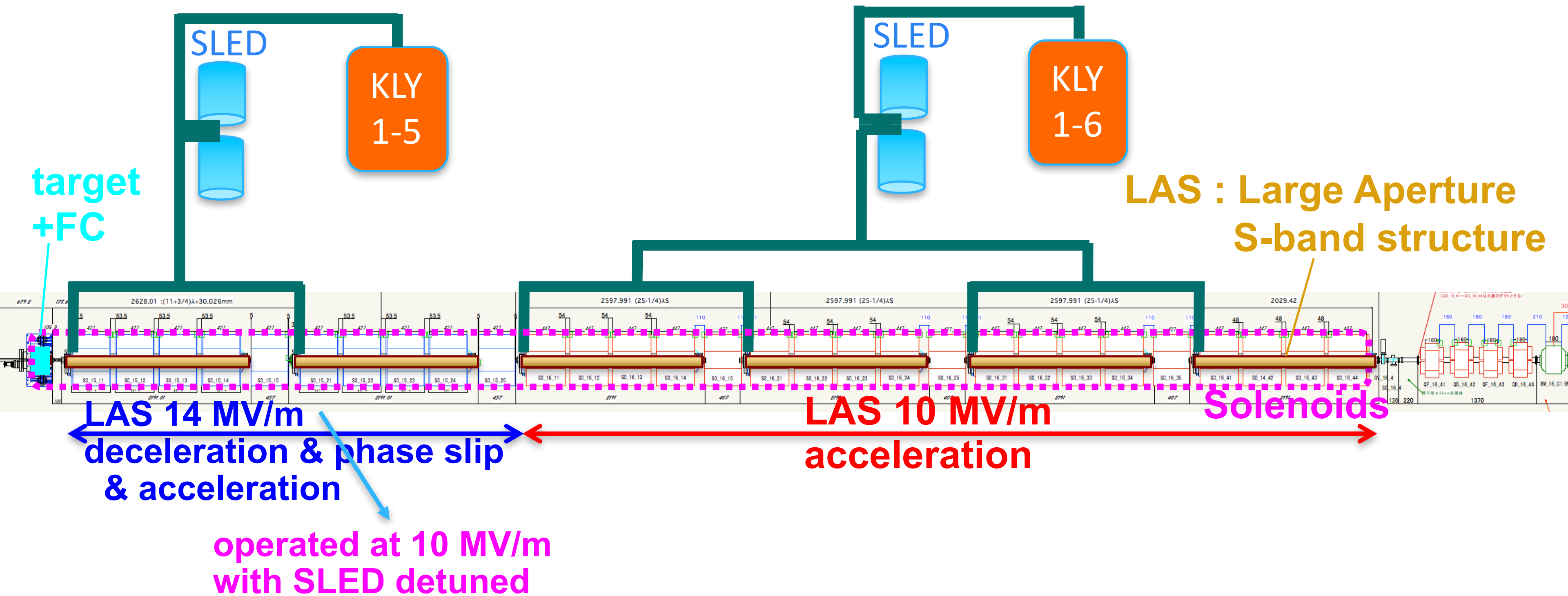


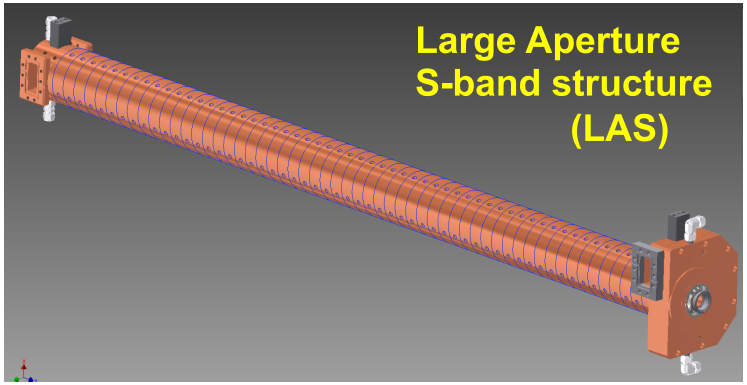
target offset & beam hole



- injection e- beam : on axis to preserve low emittance
- primary e- beam : 2.5 mm off axis to minimize e+ yield degradation
  (target offset 3.5 mm, FC offset 2.0mm)

Positron Capture Section

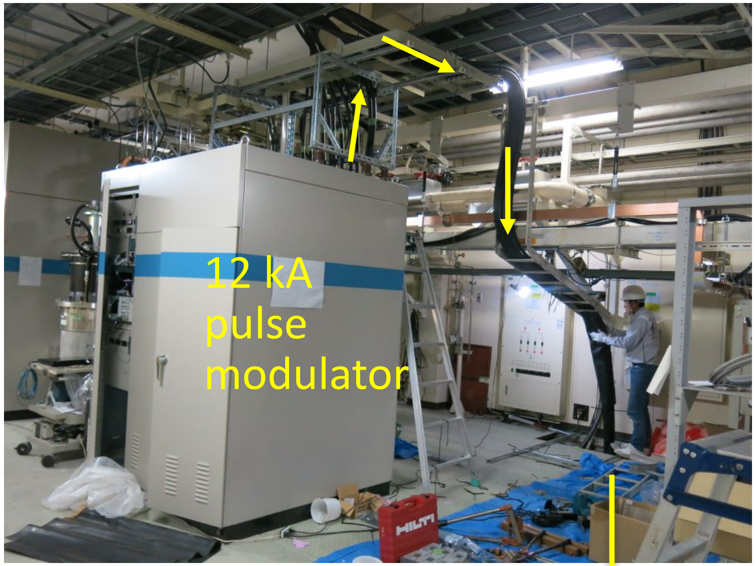


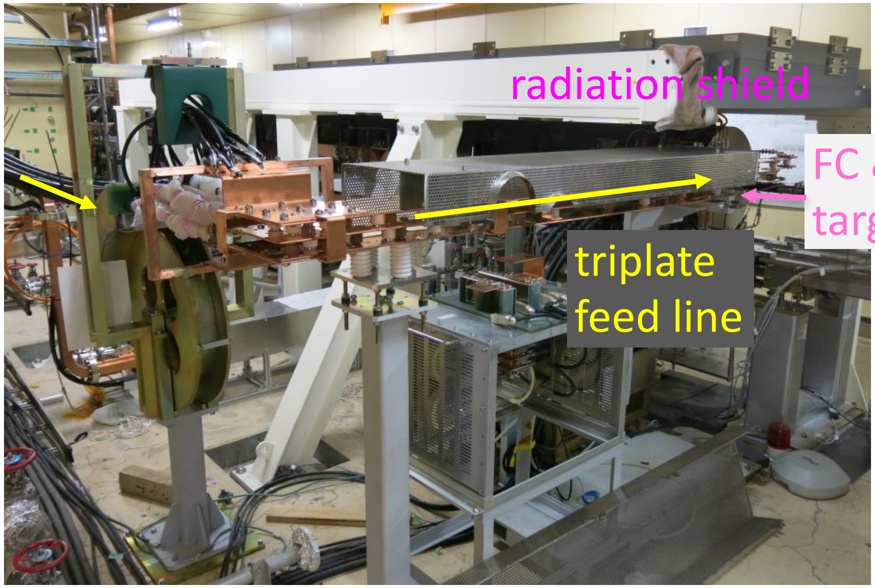


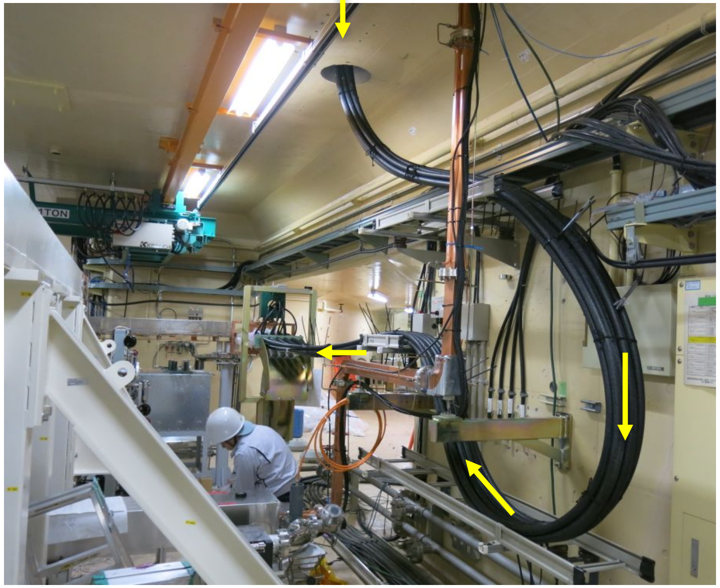
- LAS with SLEDs for sufficient field gradient
- breakdown issue of LAS in solenoid field
- needs careful RF conditioning

SuperKEKB e+ source (2015 August)

- Fully equipped for commissioning
  - FC assembly #1 (FC-base #3)
  - 12-kA pulse modulator for FC
    - new coaxial cables
    - new triplate feeder line
    - snubber circuit
  - Bridge Coils
  - DC solenoids
  - LAS accel. structures







Topics after last POSIPOL

1. Gas-bursting of FC under bridge coil field
   in start-up for full current (12 kA) operation

2. FC-head copper hardening issue & FC teststand

3. Linac stand-alone pre-commissioning of e+ source

4. e+ status in SuperKEKB Phase-1 commissioning

FC processing with Bridge Coil field

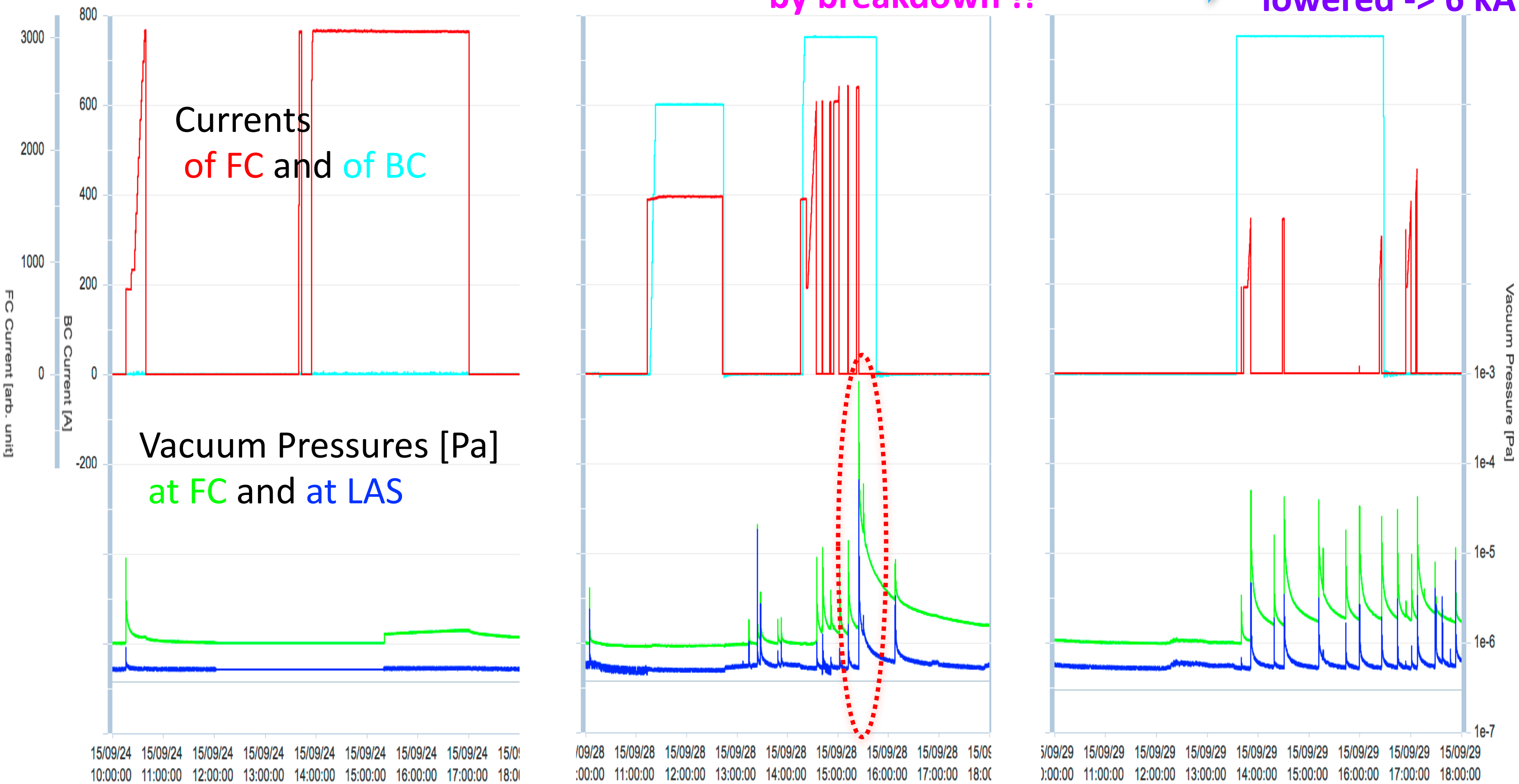
2015.09.24
FC stable at I_{FC} = 11.5 kA
w/o BC field

2015.09.28
Huge gas burst occurred
at I_{FC} = 9.8 kA @I_{BC} = 750A

2015.09.29
Gas bursts occurred
even w/o BC field

Irreversible damage in FC
by breakdown !!

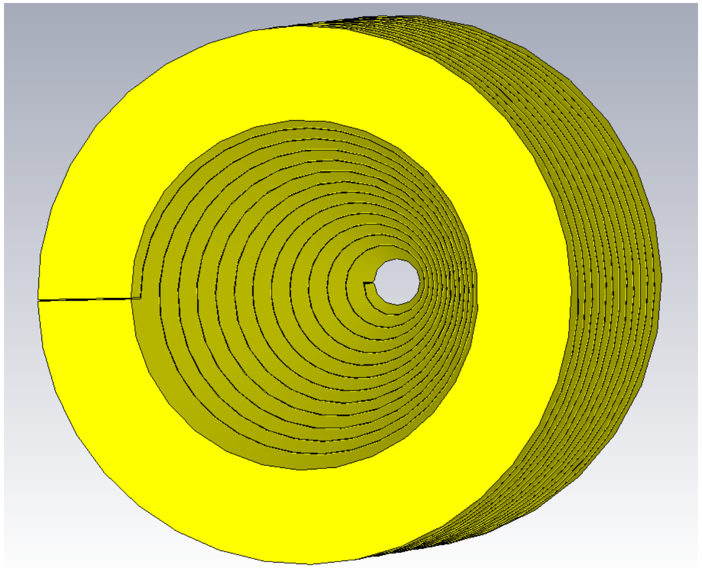
Operable current
lowered -> 6 kA



FC copper block work hardening

- In December, 2015, Y. Enomoto and T. Higo visited SLAC and discussed with the positron experts (A. Kulikov and E. Bong) on the FC gas bursting issue.
- They suggested that the work hardening of the OFC block of FC is essential against the damage by breakdown. (We neglected this process!)
- "Work hardening (strain hardening)" is a method of strengthening of a metal by repeated plastic deformation.

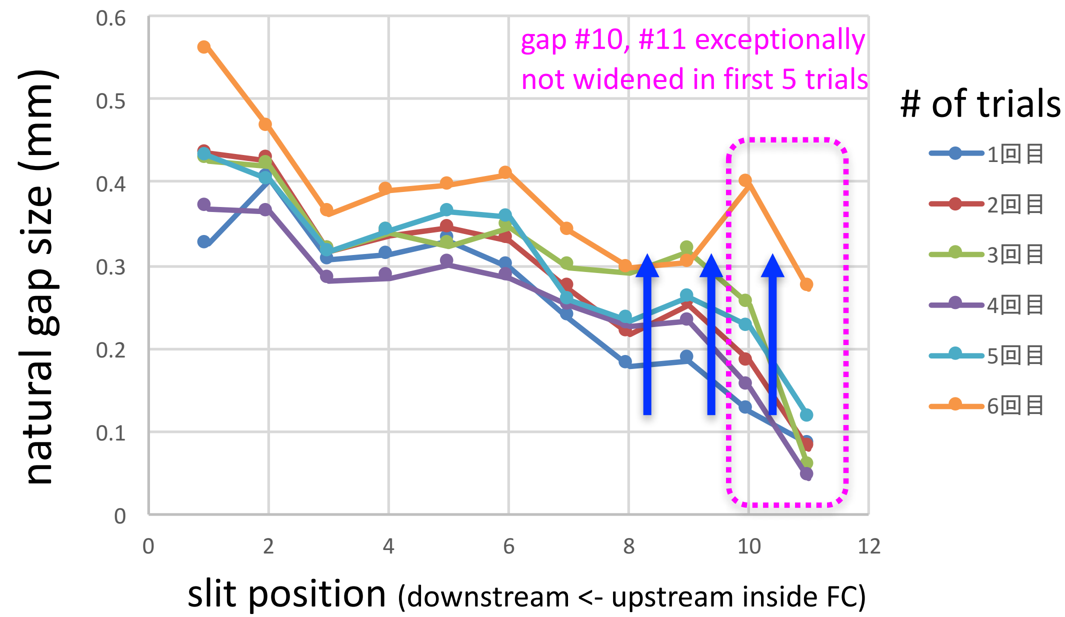
- When a breakdown occurs in FC, the spiral structure is deformed but it springs back to the original shape if it is work hardened.
- Unless work hardened, deformation remains permanently and makes very narrow gap in the slit.

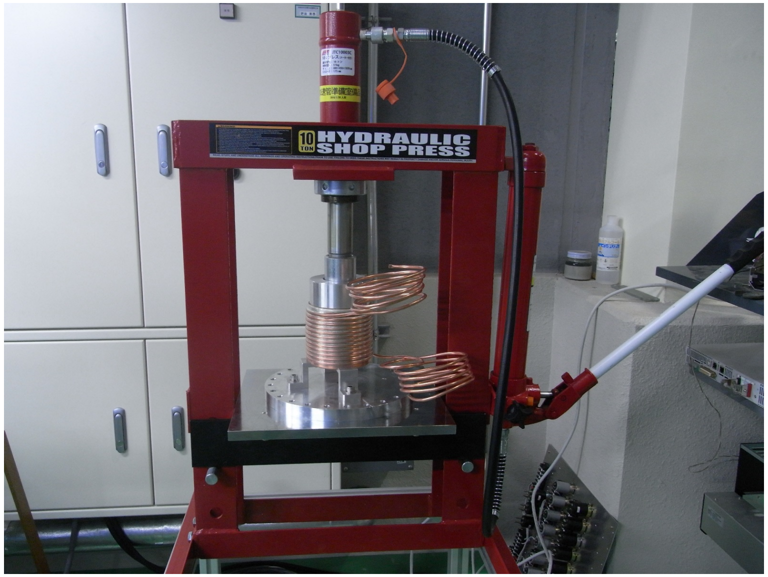


Hardening test of a sample block

Hardening Procedure

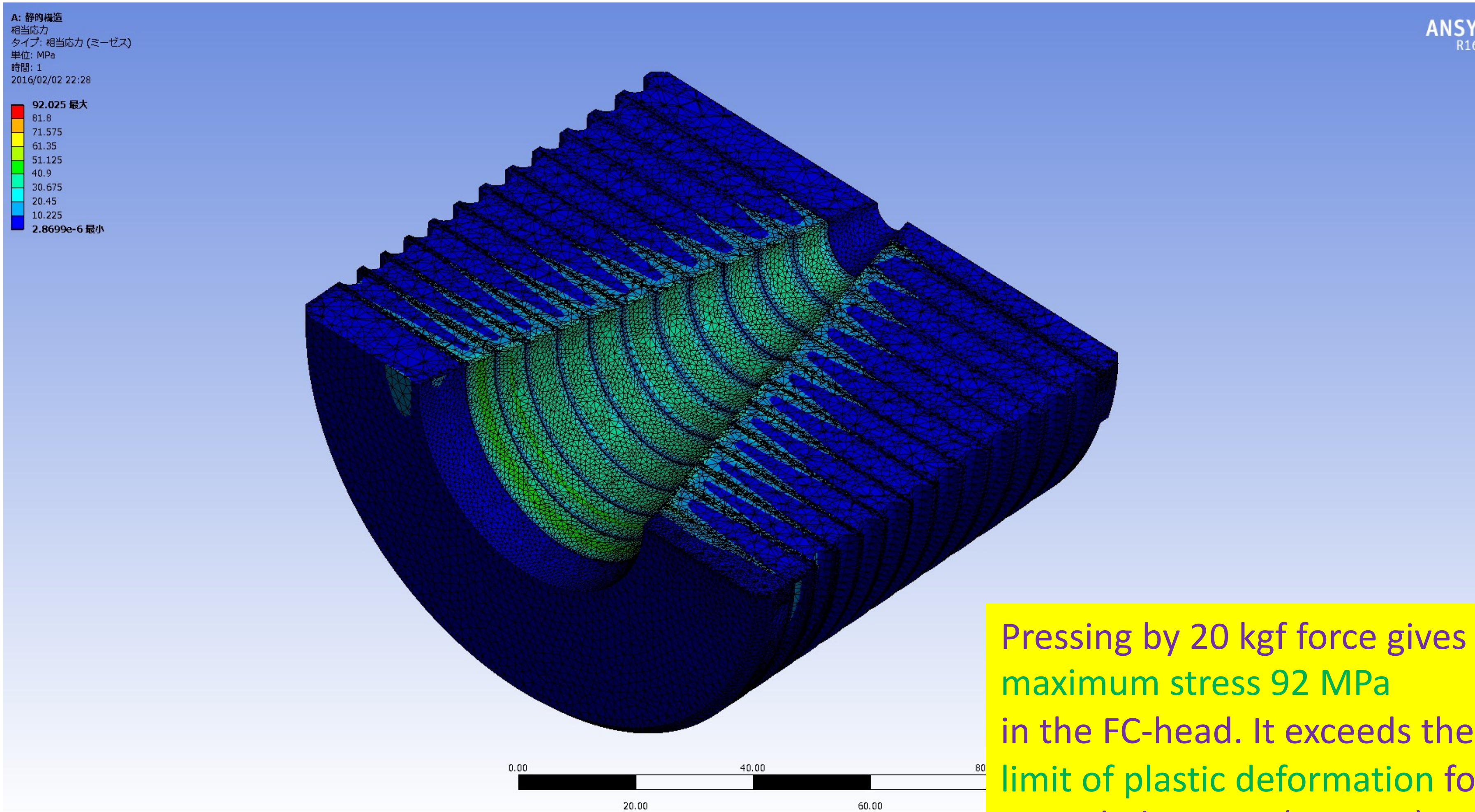
1. Press FC-head till the gaps are contacted.
2. Insert spacers into the slit.
3. Remove the spacers.
4. Measure the gap size.
5. Repeat them from (1)





The natural gap size transfers to the spacer thickness (0.3 mm) by repeated hardening.

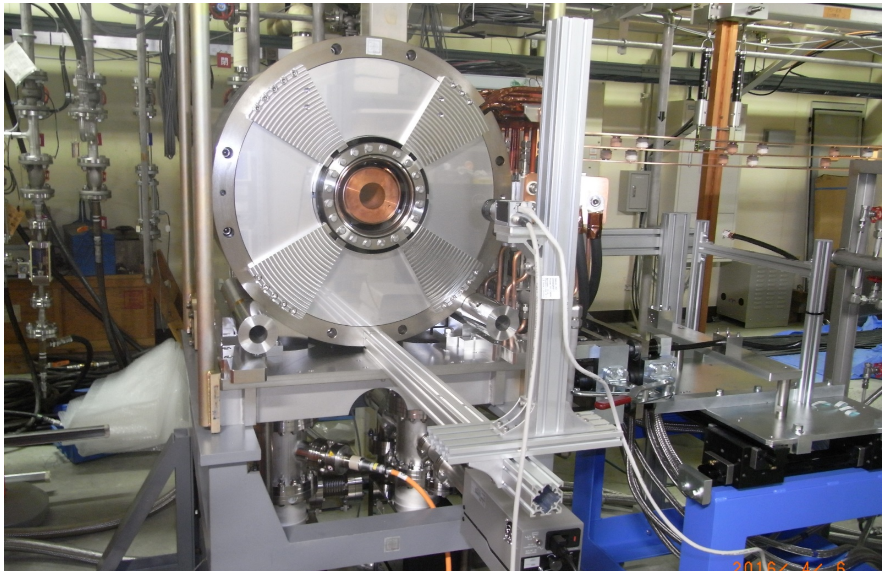
work hardening ANSYS simulation

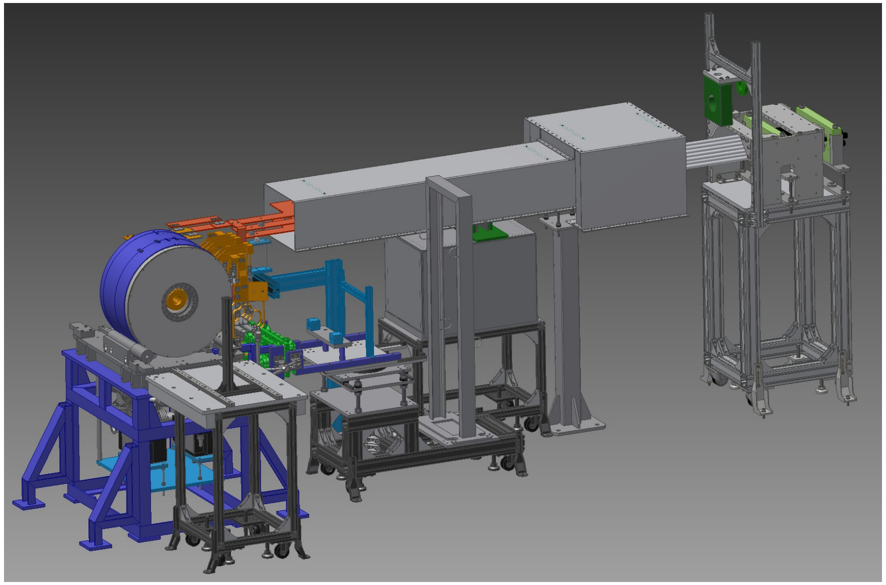


Pressing by 20 kgf force gives maximum stress 92 MPa in the FC-head. It exceeds the limit of plastic deformation for annealed copper (50 Mpa) and sufficient for work (strain) hardening.

FC assembly #2 & test stand

- Operation test with BC field is essential. It is suggested FC vibration is larger under BC field.
- FC assembly #1 is radio-activated in the beam line.
- Construct assembly #2 for operation with BC field at test stand.





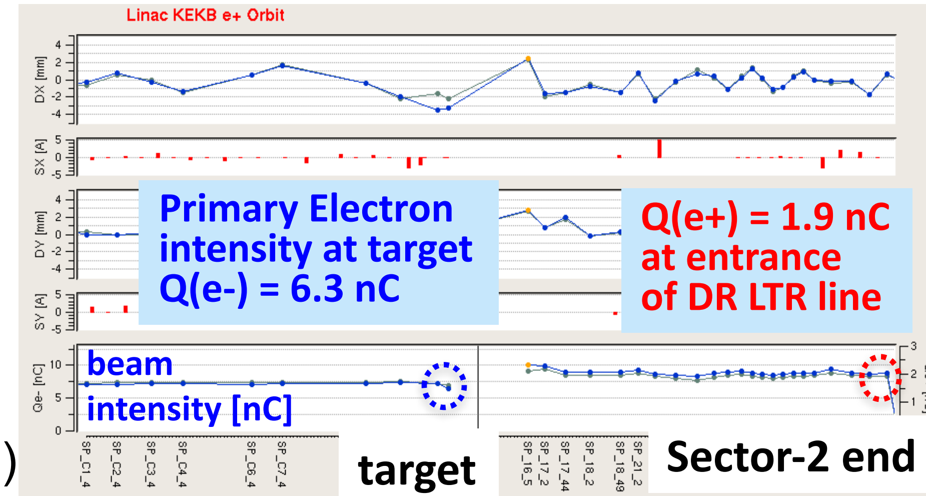
- Test-1: operation with FC-head #4 (not work-hardened model) to see what happens in the same situation as the damaged FC-head #3.
  → non-hardened FC successfully achieved full-current (12 kA) operation with BC field
  (What's the difference to FC#3 ?)
- Test-2: operation with FC-head #5 (well work-hardened model) to check the operability at full current (12 kA) under the BC field.

FC-head #5

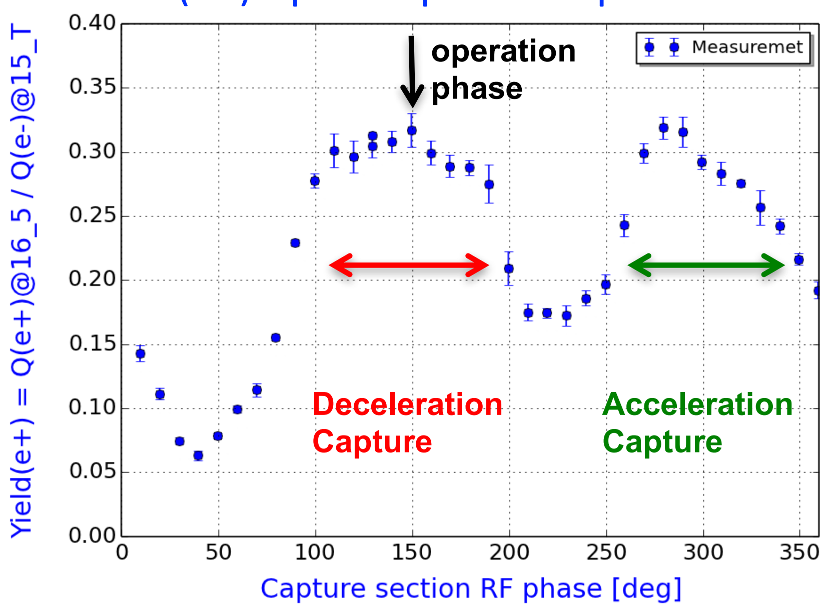

Well work-hardened and
installed in FC assembly #2.
Test operation has recently
started at test stand.

Pre-commissioning performance (2015 Nov.)

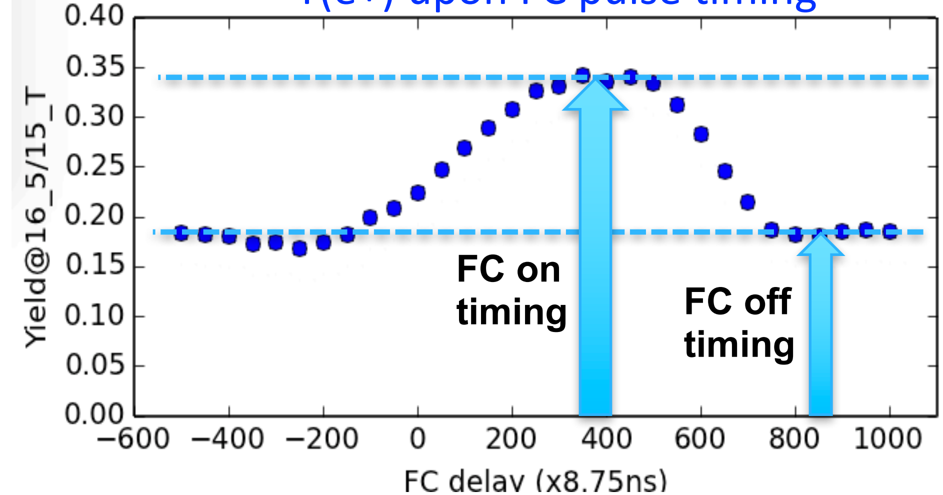
- Beam tuning to optimize e+ yield performed in 2015 Oct ~ Dec.
- I_{FC} = 6 kA (design 12 kA)
  enhancement by FC ~ 1.8
- Q(e-) = 6.3 nC @ target
  Q(e+) = 1.9 nC at SY2
  Y(e+) = 1.9/6.3 => 30 % (design 50 %)



Y(e+) upon capture RF phase



Y(e+) upon FC pulse timing

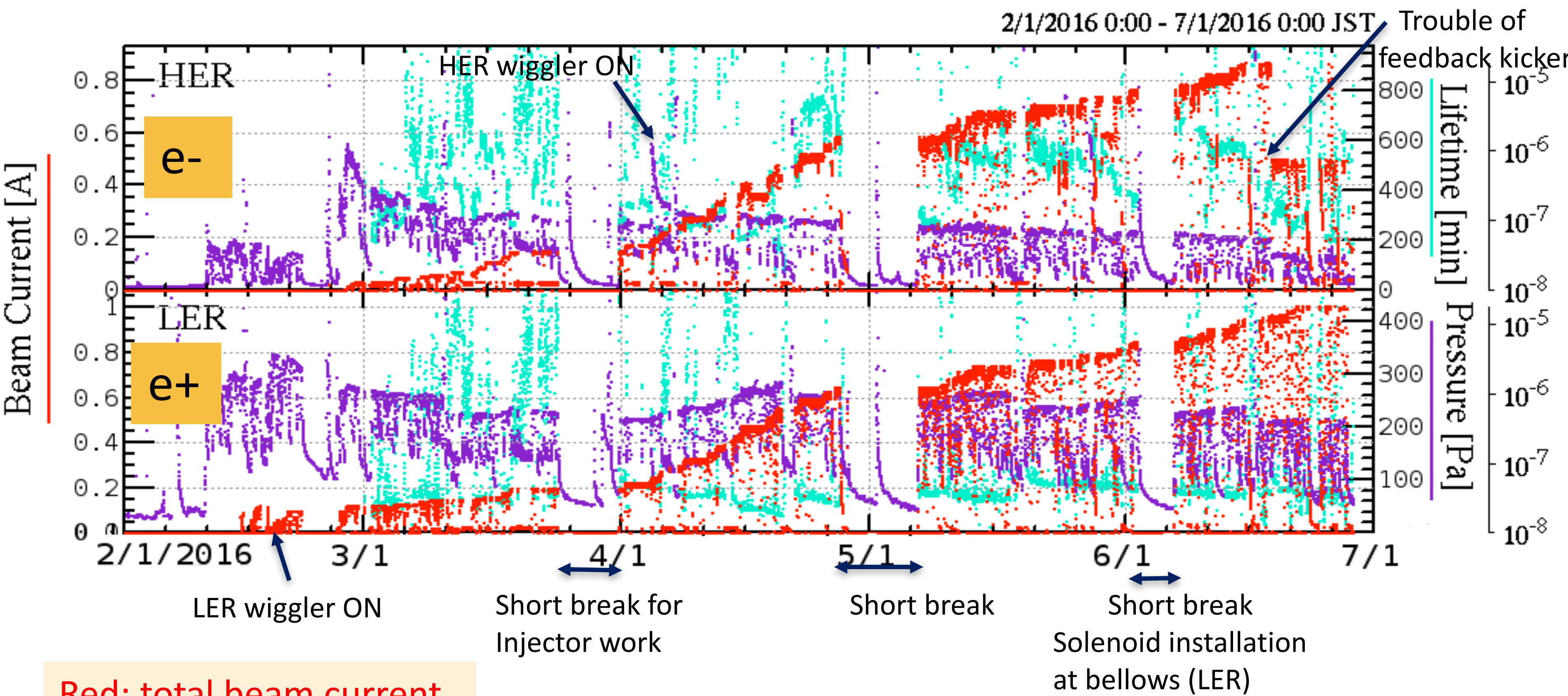


Yield enhancement by FC (6 kA) ~ 1.8

SuperKEKB Phase-1 commissioning

- Phase-1 (2016 February -> June) operation condition
  - no beam collision
  - Superconducting Final Focusing system not installed
  - Belle-II detector not installed
  - e+ damping ring not installed
- Goals in Phase-1 operation
  - start-up and tuning of machine components
  - beam scrubbing of vacuum components
  - low emittance tuning of storage rings (vertical emittance < 10 pm)
- Injection beam requirement
  - low intensity beam OK: Q(e-) ~ 1 nC, Q(e+) ~ 0.3 nC
  - large emittance beam accepted: (e-) ~ 300 um, (e+) ~ 1200 um

SuperKEKB Phase-1 overview

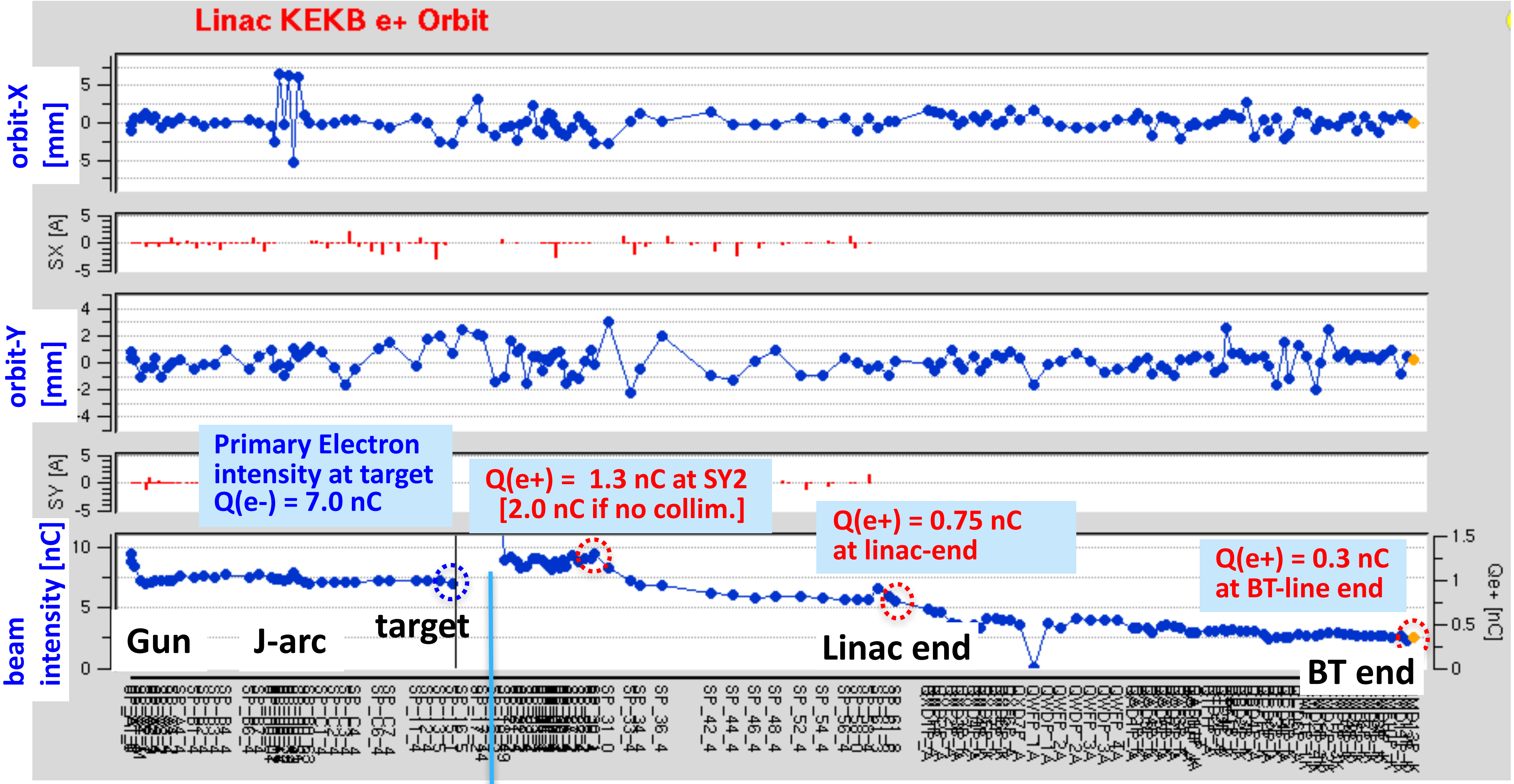


Red: total beam current
Purple: vacuum pressure
Cyan: beam lifetime

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

SuperKEKB e+ injection beam

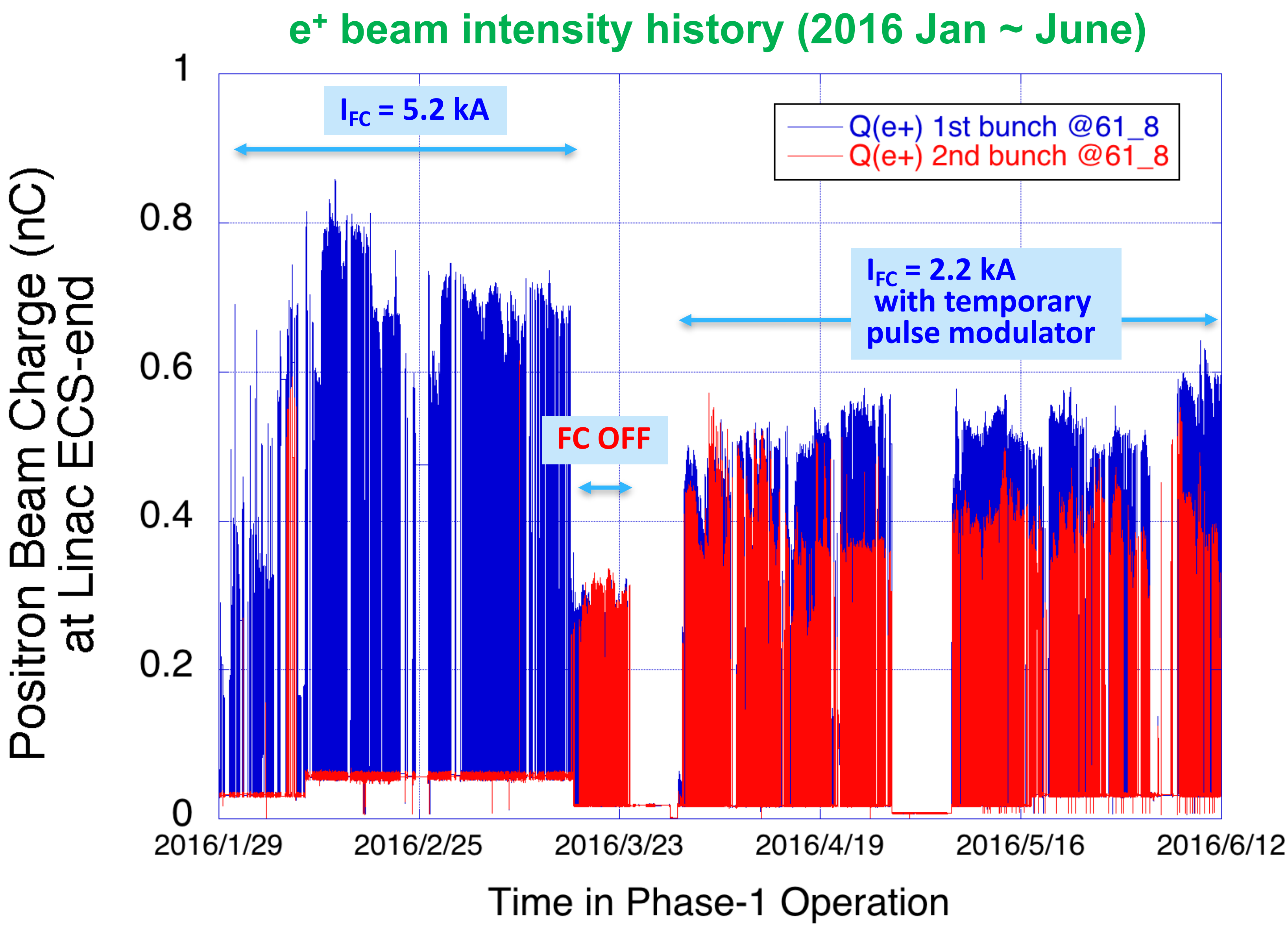
Typical e+ injection beam at linac and BT-line



Beam collimators inserted to localize beam loss in low energy region.

Due to limited beam acceptance, inevitable beam loss occurs in linac & BT-line in direct injection w/o DR.

SuperKEKB e$^+$ beam performance



Summary

1) **Breakdown in FC-head (#3) occurred under BC field gave a serious damage (September 2015) and operable current limited ~ 6 kA (half of the design value).**

2) **Importance of work-hardening process of FC-head was recognized. Test stand with new FC assembly #2 has been constructed to perform tests of non-hardened and well-hardened models with BC field. (June 2016 ~)**

3) **Positron yield Y(e+) = 30% (Q(e+)=1.9nC/Q(e-)=6.3nC) achieved with 6 kA FC current at entrance of DR-LTR line. Stable e^+ injection to LER has been achieved (Q(e+)@BT-end ~ 0.3nC x 2-bunch) since February 2016. Beam loss in linac and BT line is due to operation w/o DR.**

4) **After finishing operation at test stand, FC assembly #2 will be installed in the beam line in March 2017. DR commissioning and LER injection in Phase-2 will be started in October 2017.**