Positron Source Status

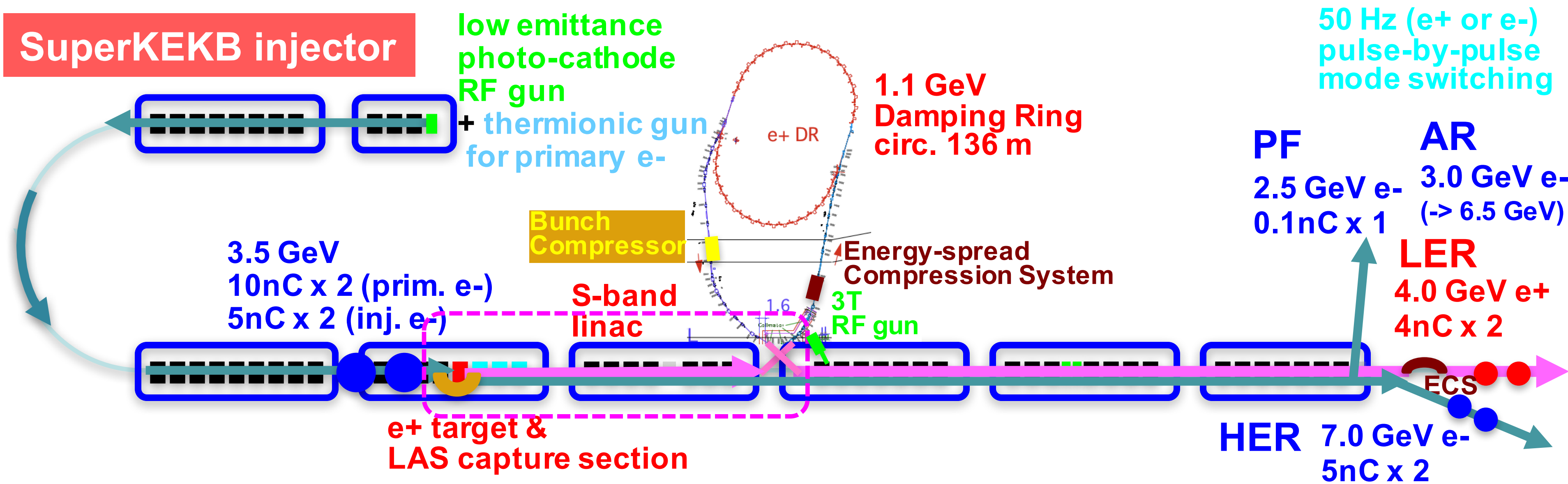
(2016 June 14)

KEKB injector linac
Takuya Kamitani

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 Injector



Upgrade items in positron source

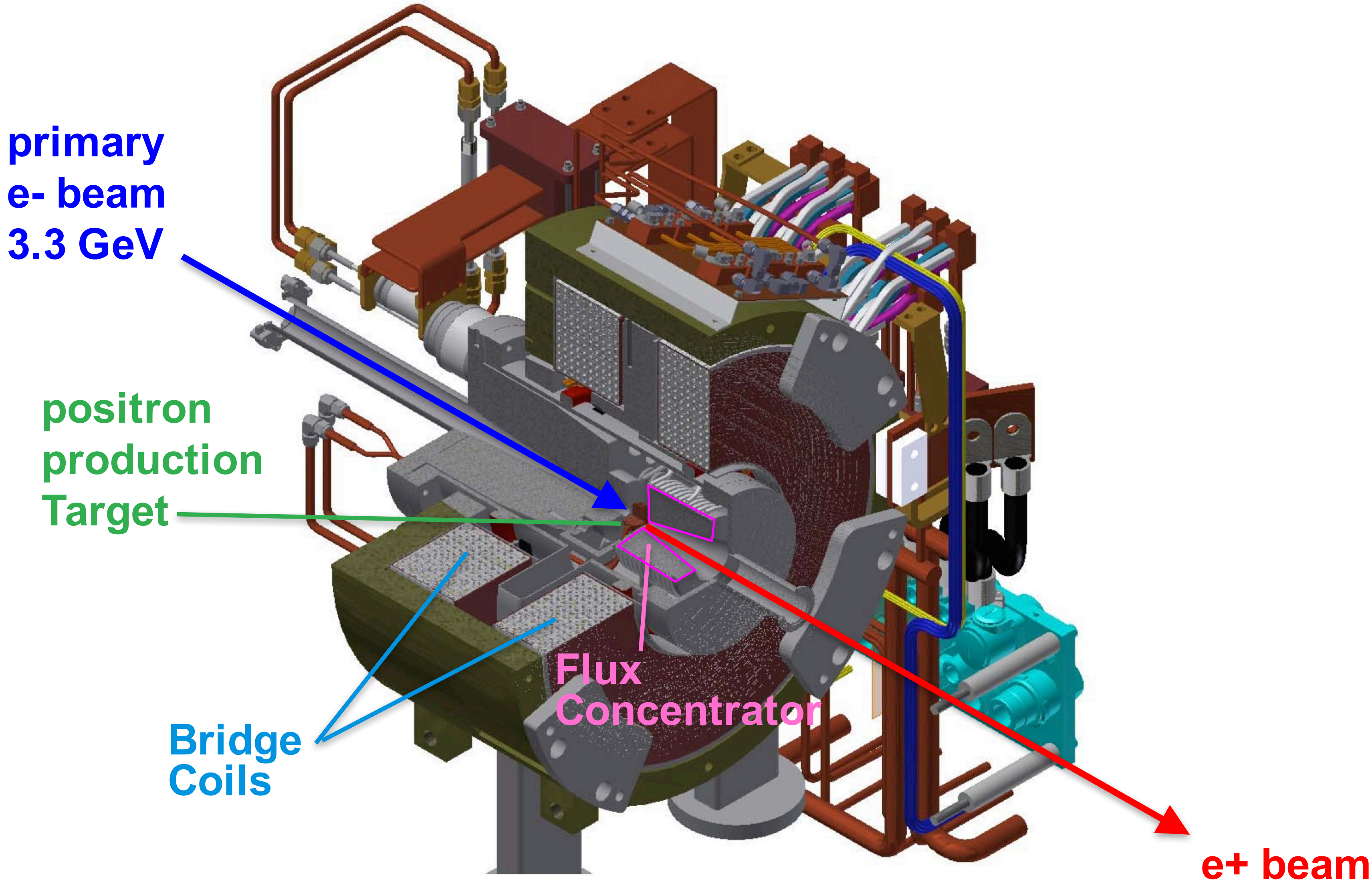
Low emittance e+

- **positron damping ring introduced**

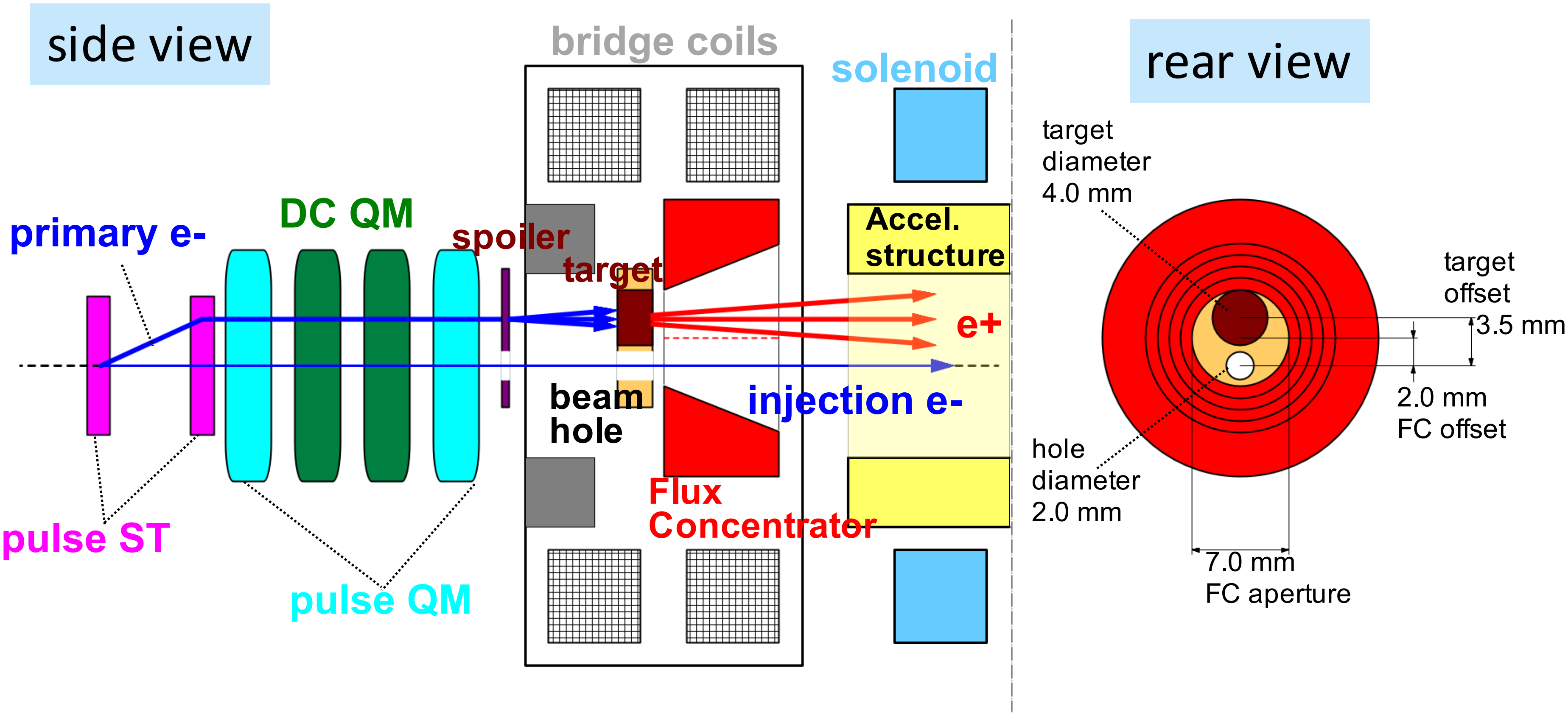
e+ intensity (x4)

- **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**

SuperKEKB positron source

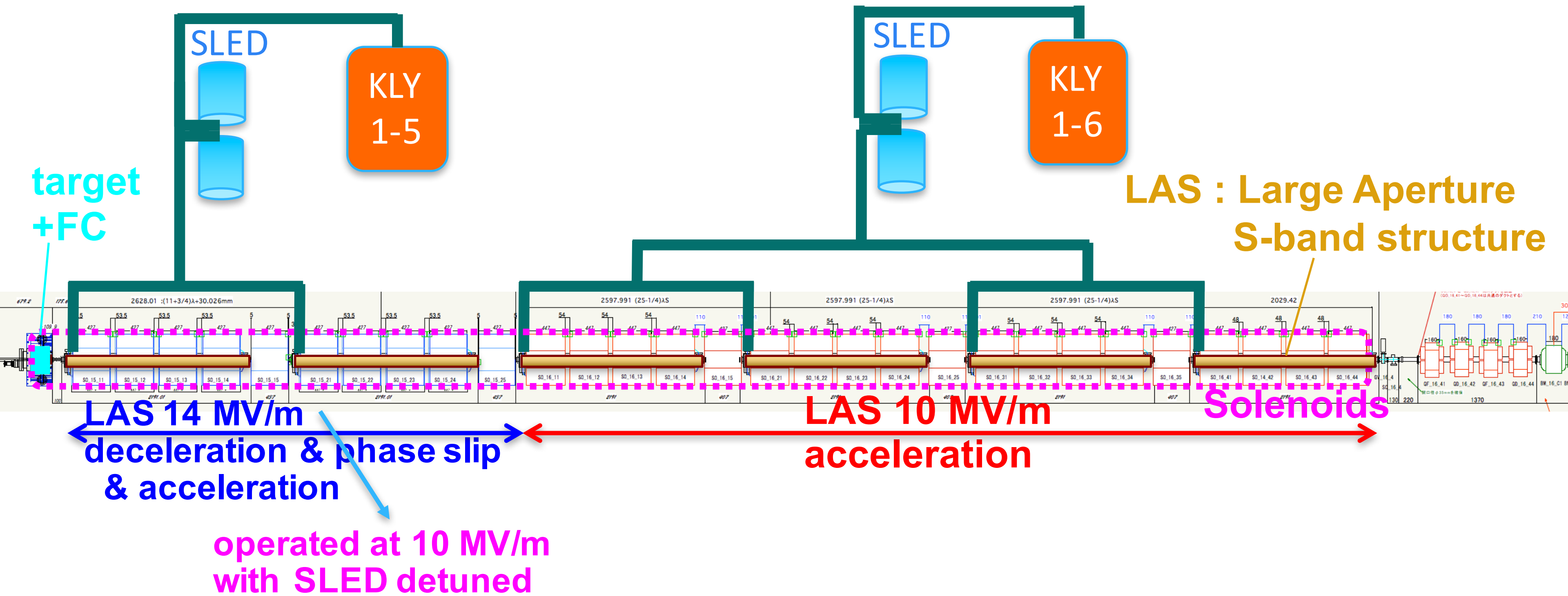


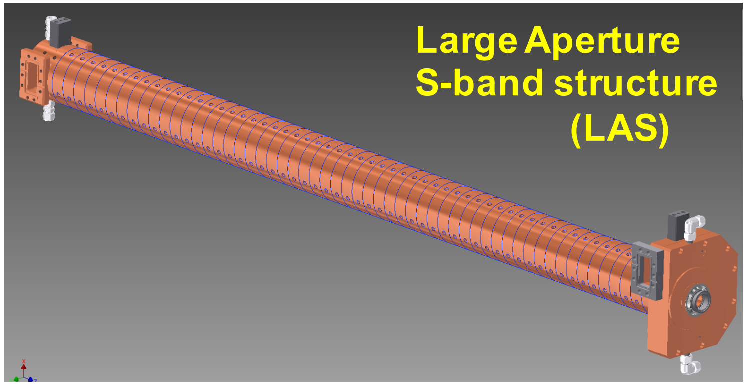
target offset & beam hole



- 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)

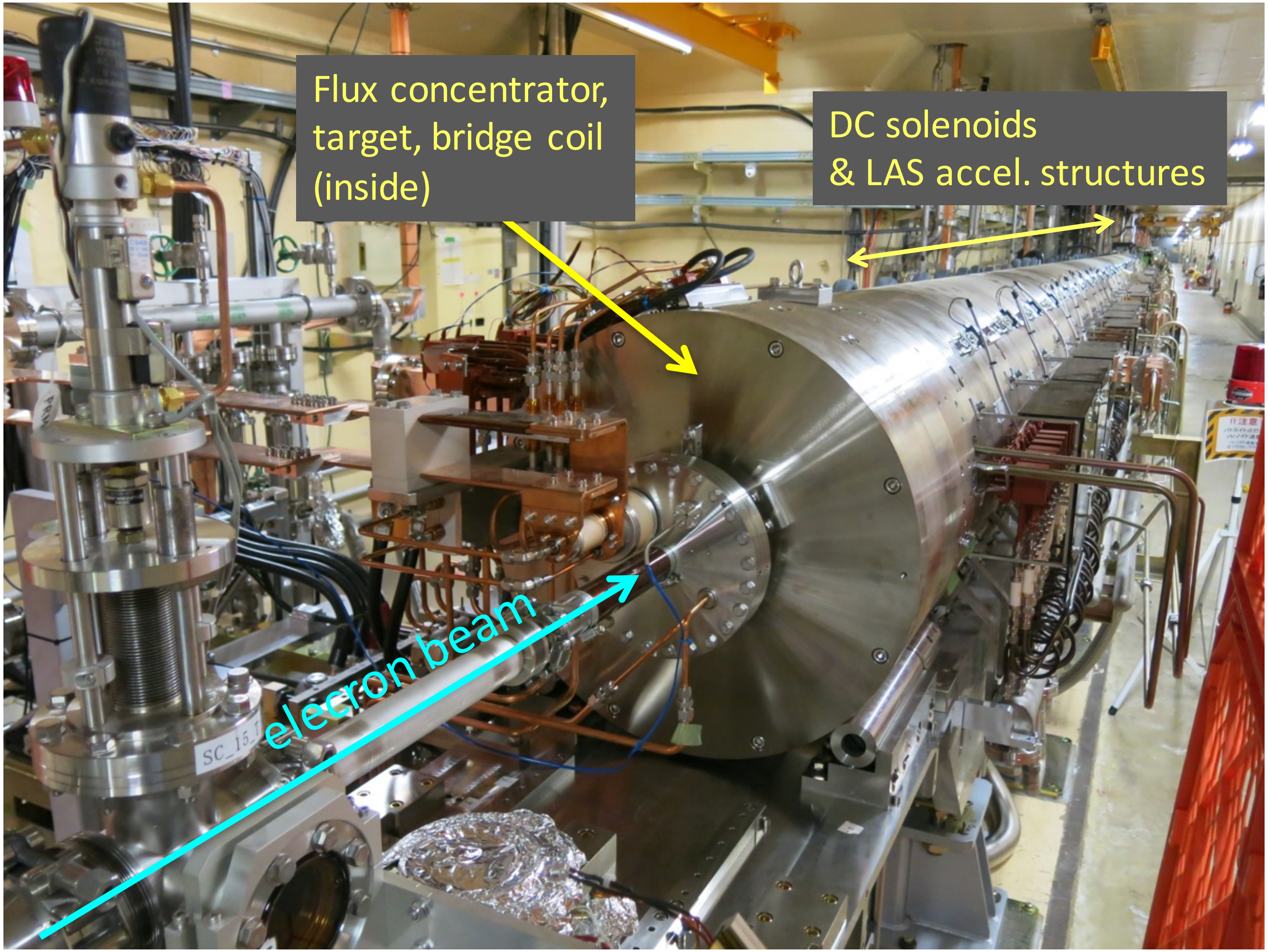
Positron Capture Section





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

e+ capture section in linac tunnel



e^+ status at previous Review (2015/02/24)

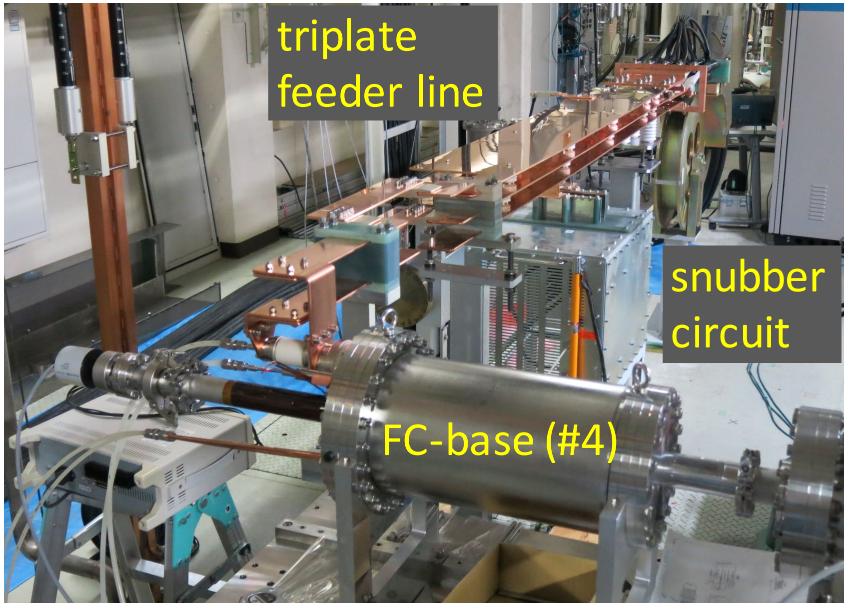
- **e^+ source components had been installed and operated at limited performance**
  - FC : I_{FC} = 6 kA (spec. 12 kA) with temporary pulse modulator
  - BC : I_{BC} = 600 A (=full spec)
  - DC Solenoids : I_{DC} = 370 A (spec. 650 A)
  - Acc. field : E_{ACC} = 10, 12 MV/m (spec. 14, 10 MV/m)
  - DR not yet available

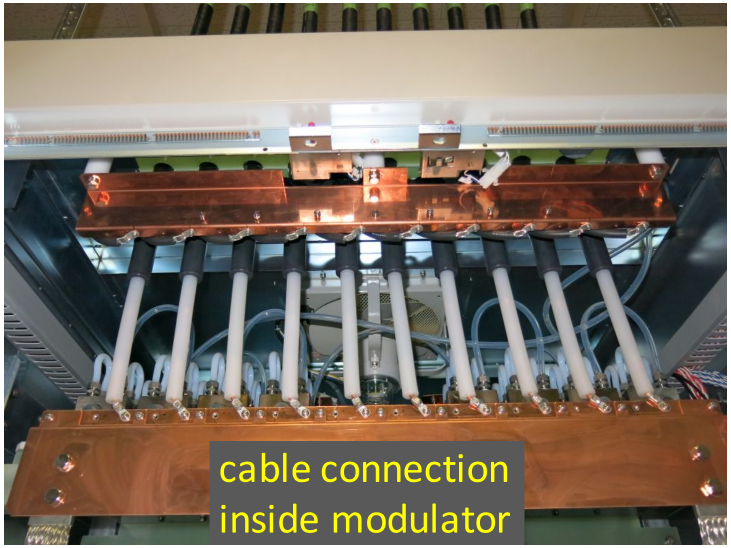
- **(Linac stand-alone) e^+ initial commissioning** **(first e^+ for SuperKEKB)**
  - Q(e+) = 0.12 nC@SY2 with Q(e-) = 0.60 nC, E(e-) = 3.1 GeV
    spec. (5.0 nC after DR -> 4.0 nC) (10.0 nC) (3.3 GeV)
  - Y(e+) = (0.12 nC / 0.60 nC) = 20% @SY2 (= at entrance to DR)

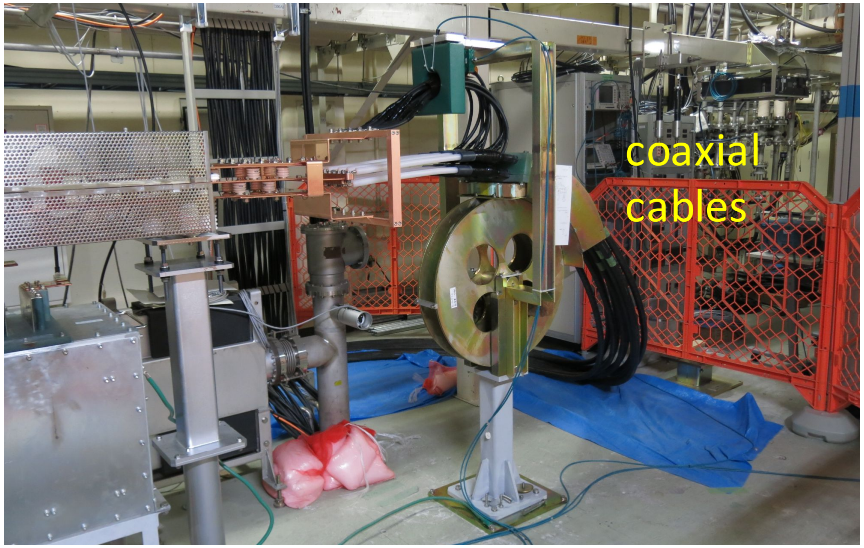
- **FC coaxial feeder cable accident**
  higher voltage tolerance
  -> renewal planned for thicker cable (insulator 2.3 -> 7.4 mm)
  and parallel plate feeder line (two plates -> triplate)
  lower induced voltage

FC test stand (2015 July)

- test operation performed with
  - spare FC-base (#4)
  - 12-kA pulse modulator
  - new coaxial cables
  - new triplate feeder line
  - snubber circuit
  - but w/o bridge coils
- full-spec (12 kA) operation for continuous 200 hours achieved with no serious breakdowns and problems

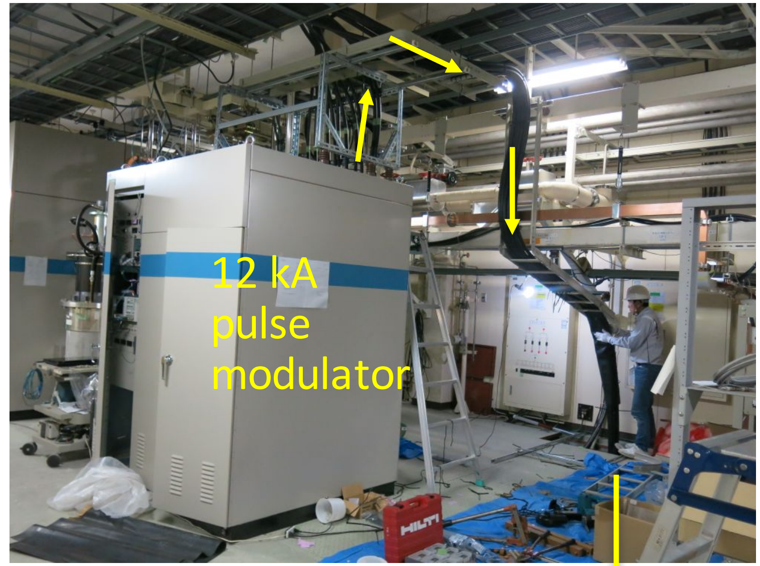


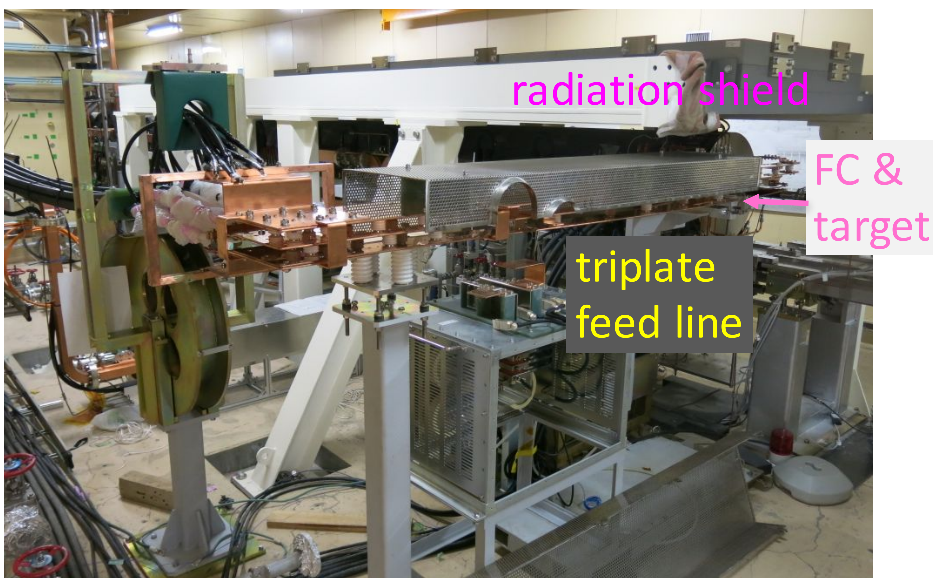


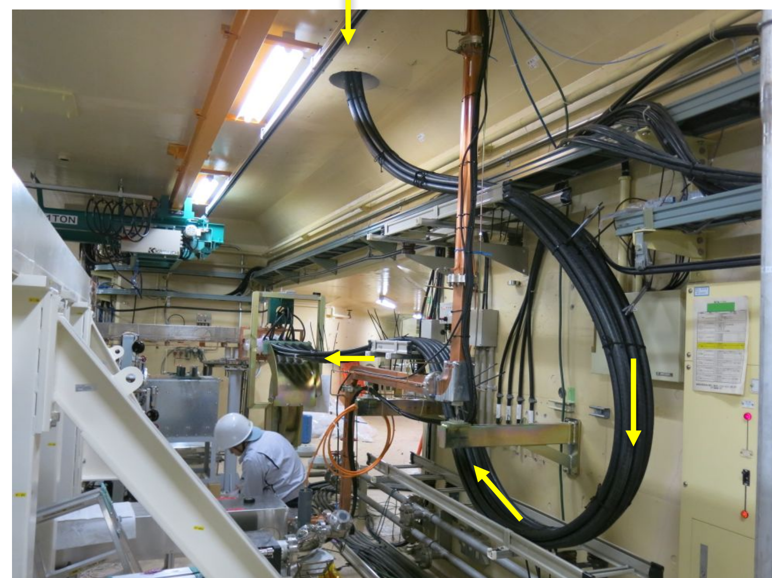


Installation in linac tunnel (2015 August)

- Installed for beam operation
  - 12-kA pulse modulator
  - new coaxial cables
  - new triplate feeder line
  - snubber circuit
- Same as before
  - FC assembly #1 (FC-base #3)
  - Bridge Coils
  - DC solenoids & accel. structures







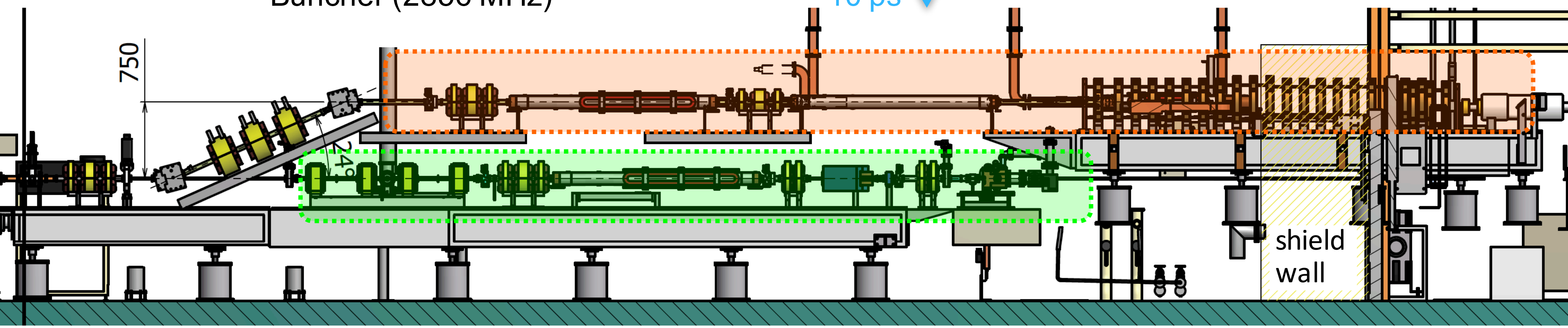
Double-deck pre-injectors

Upper deck (former KEKB pre-injector, reconstructed !)

thermionic gun + RF bunching section

Gun 200 kV (=> 5 MV/m)	1300 ps
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

bunch length



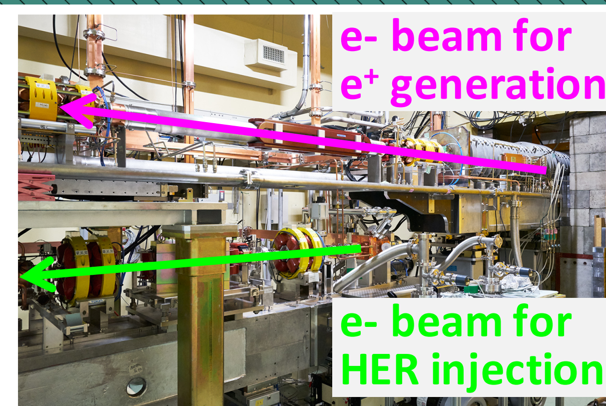
Lower deck

photo-cathode RF gun

+ magnetic bunching

RF gun	25 ps
Chicane	10 ps

bunch length



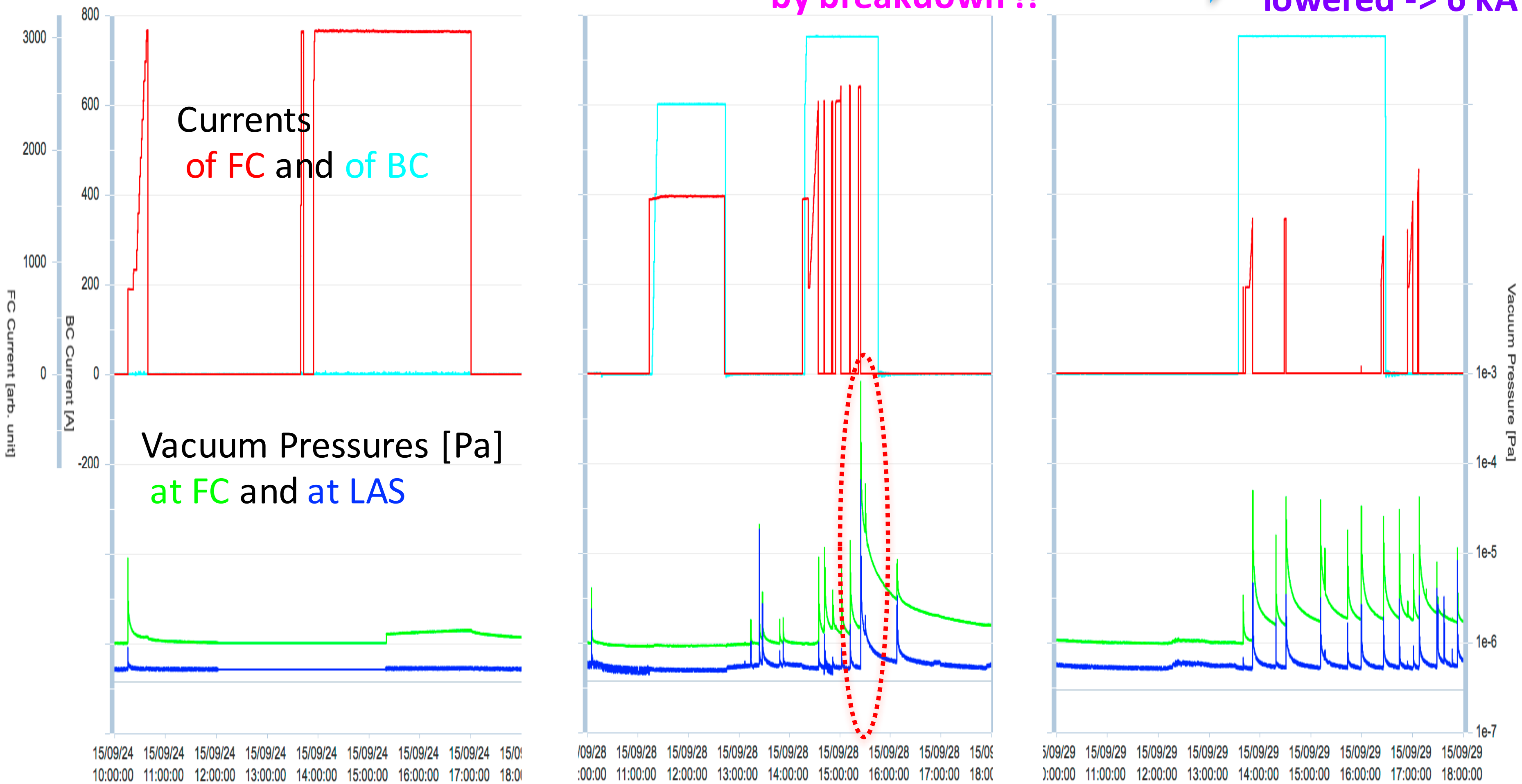
FC processing with BC field

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

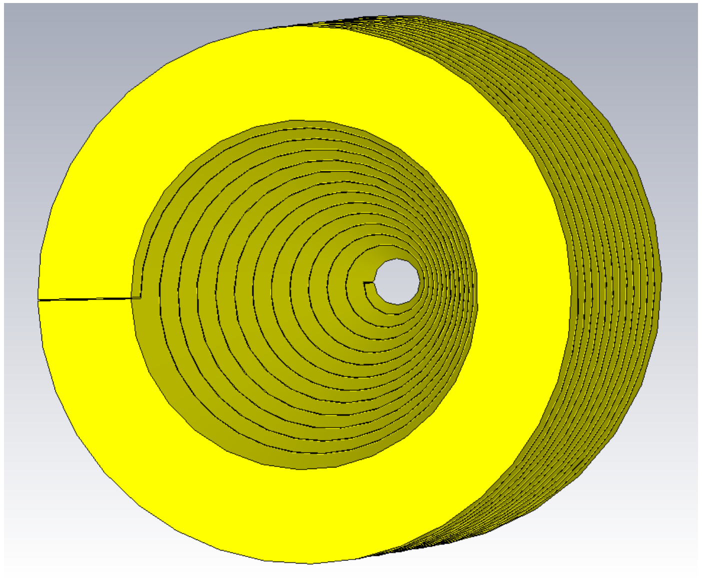
Irreversible damage in FC by breakdown !! ⇨ **Operable current lowered -> 6 kA**



FC copper block work hardening

- 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.

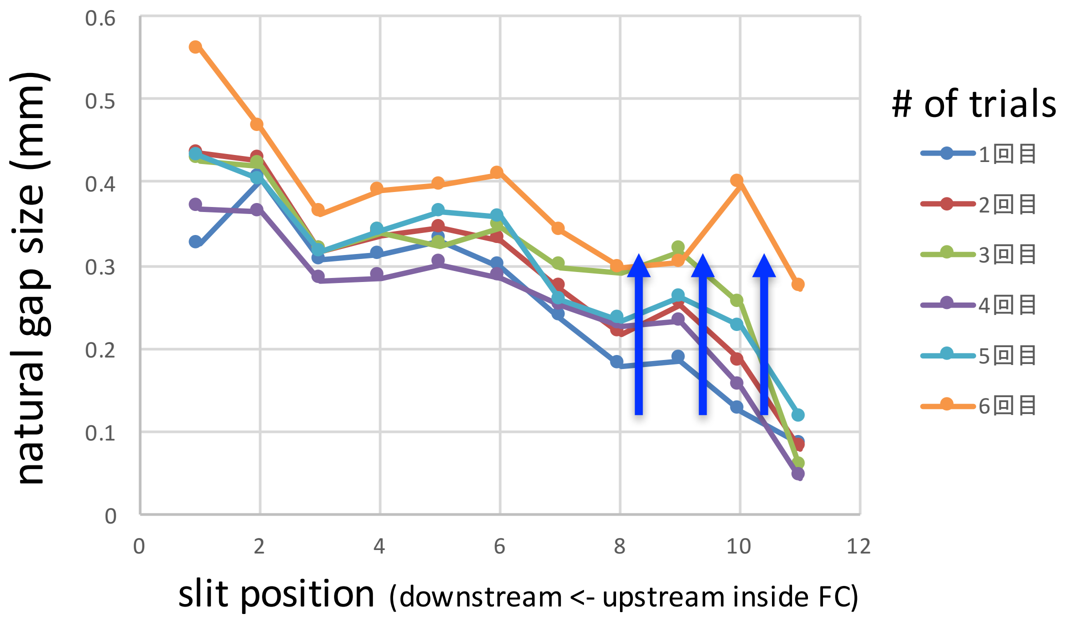
- When a breakdown occurs in FC, the spiral structure is deformed but it springs back to the original shape if it is work hardened.
- Unless work hardened, deformation remains permanently and makes very narrow gap in the slit.

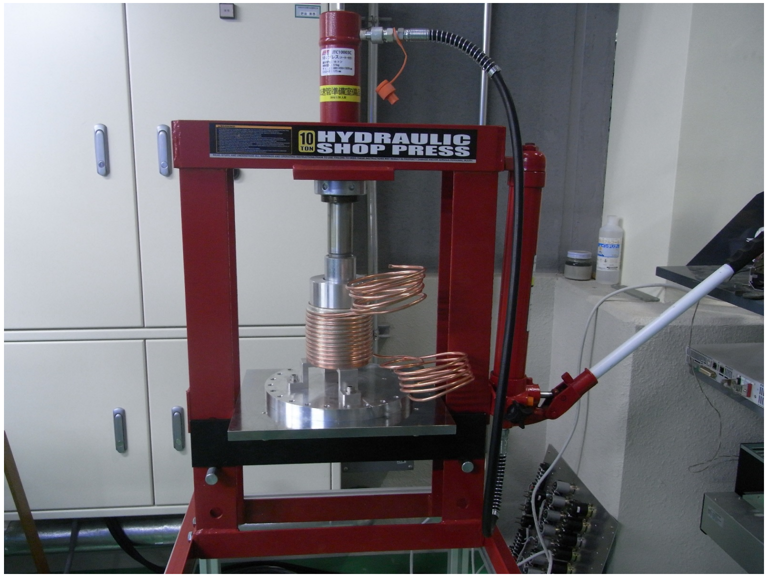


Hardening test

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) (~ 100 times)



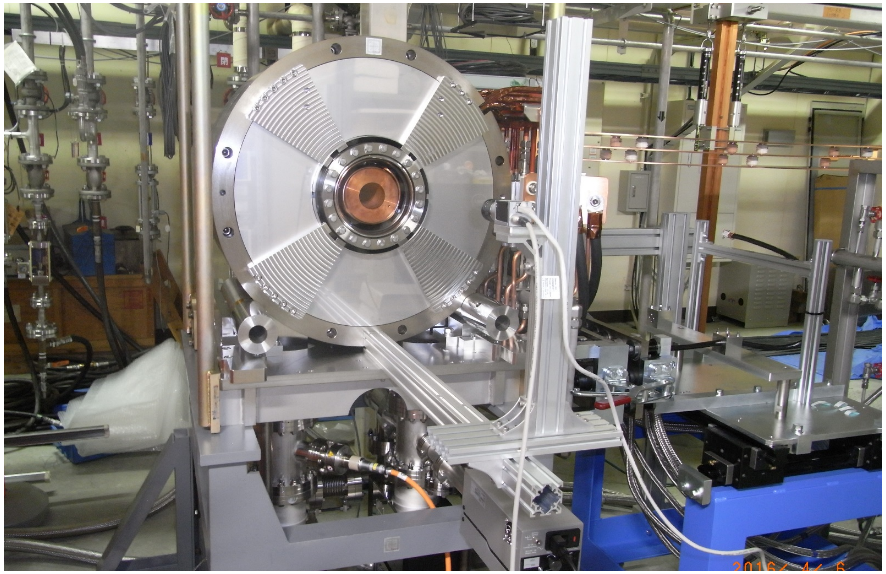


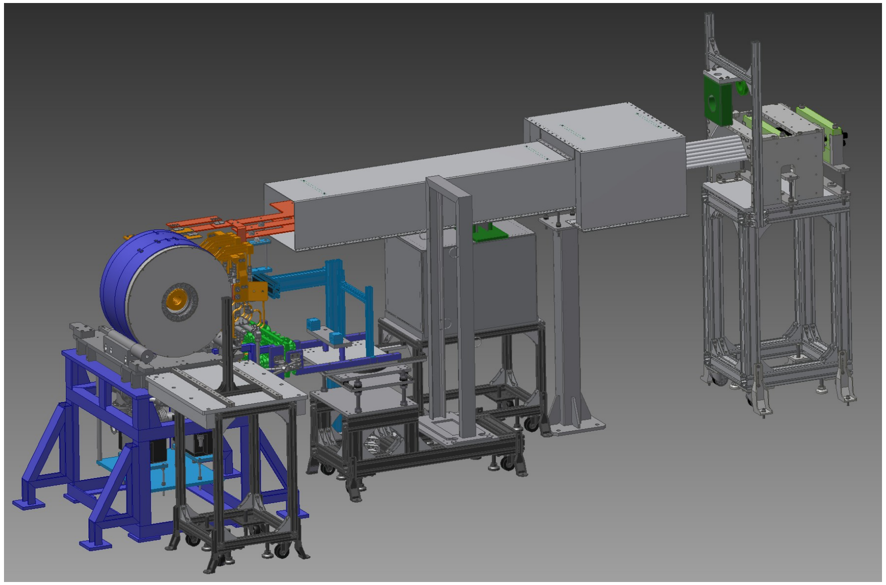
The natural gap size transfers to the spacer thickness (0.3 mm) by repeated hardening.

FC assembly #2 & test stand

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

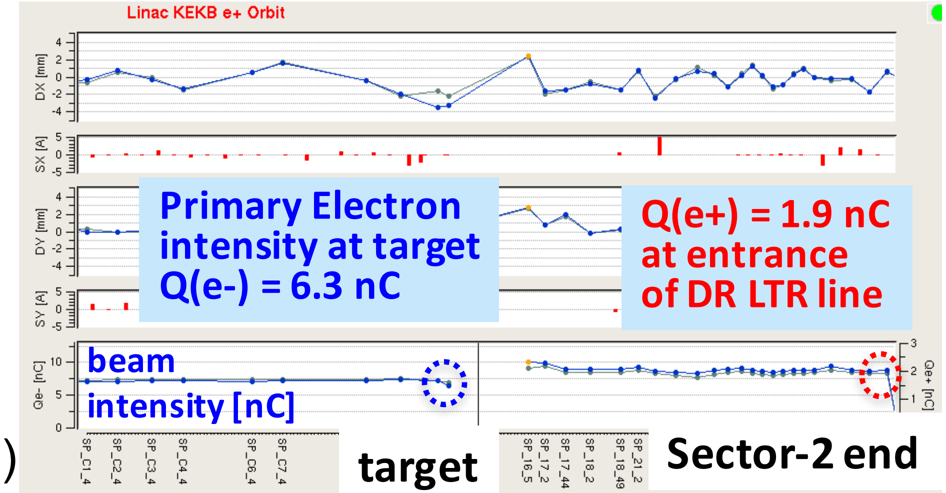
- Test-1: operation with FC-head #4 (not work-hardened model) to see what happens in the same situation as the damaged FC.
  [2016 June, soon]
- Test-2: operation with FC-head #5 (well work-hardened model) to check the operability at full current (12 kA) under the BC field.
  [2016 August ~]



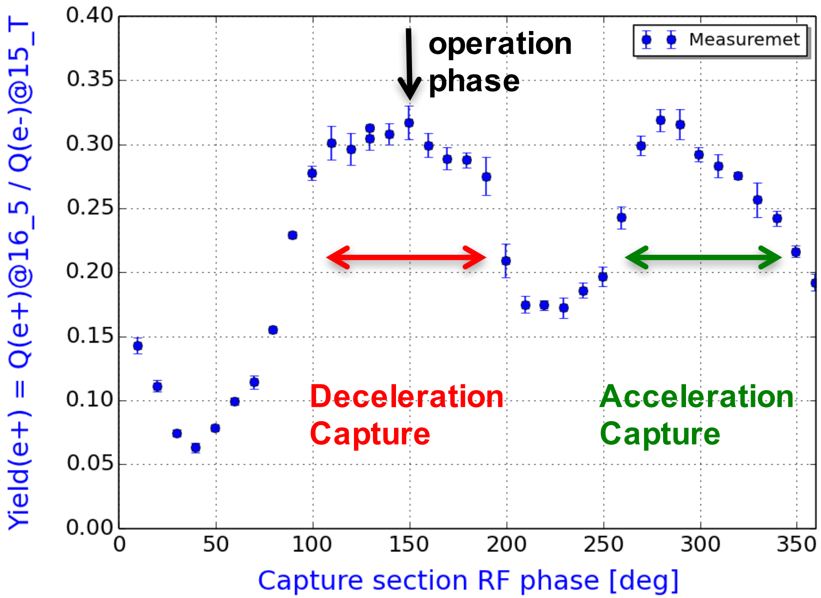


e^+ beam performance (2015 Nov.)

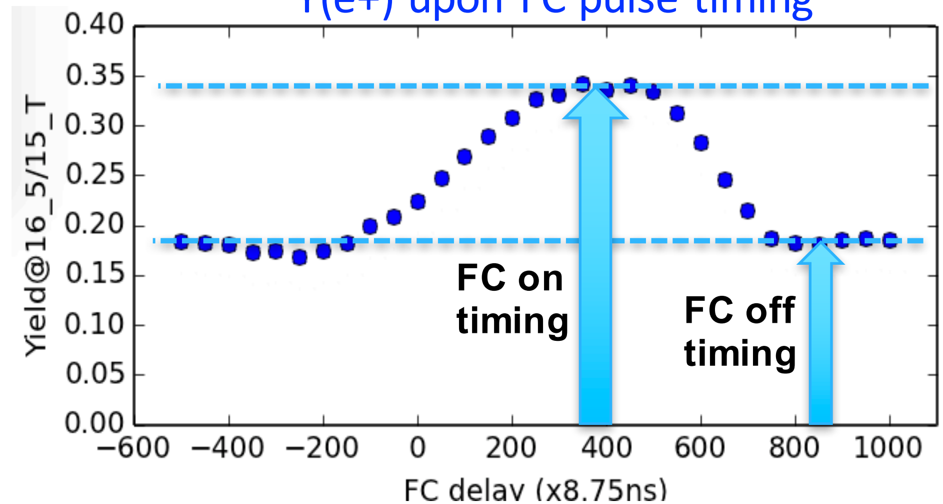
- Beam tuning to optimize e+ yield performed in 2015 Oct ~ Dec.
- I_{FC} = 6 kA (design 12 kA)
  enhancement by FC ~ 1.8
- Q(e-) = 6.3 nC @ target
  Q(e+) = 1.9 nC at SY2
  Y(e+) = 1.9/6.3 => 30 % (design 50 %)



Y(e+) upon capture RF phase



Y(e+) upon FC pulse timing



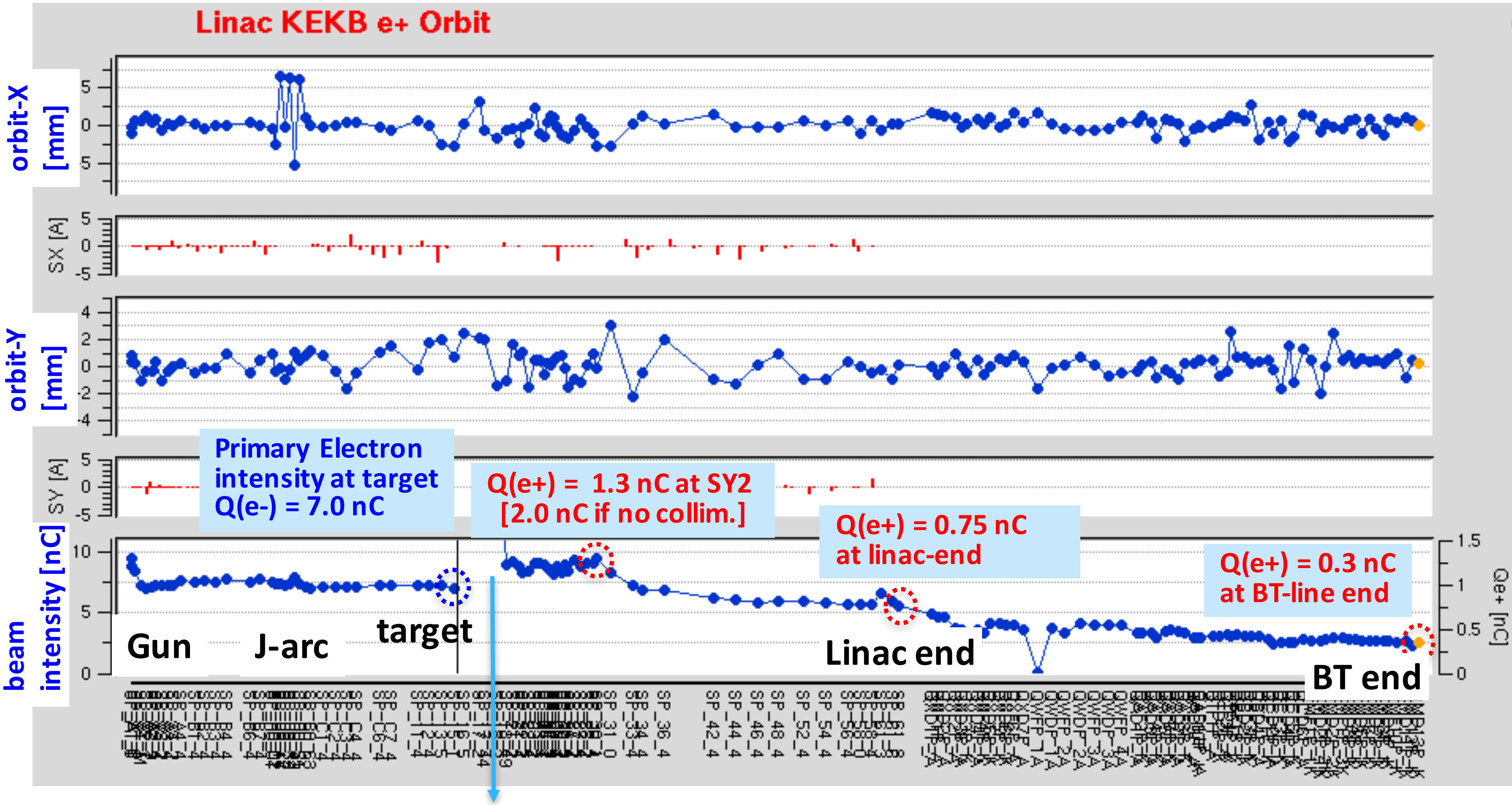
Yield enhancement by FC (6 kA) ~ 1.8

Is achieved e^+ charge consistent with simulations ? (committee member's question)

- We do not have a simulation result which reflect all the operation condition.
(GEANT simulation [e^+ generation at target]
+GPT simulation [e^+ capture simulation]
+SAD tracking simulation [e^+ transport in linac & BT line])
  - precise beam spot size on the target is unknown
    -> planning to install thin screen monitor and triggered camera in this summer shutdown
  - DC solenoid field distribution modified to optimize e+ intensity
  - FC 6 kA situation
  - Lower LAS acceleration field situation
- Possible comparison
simulation expectation now is Y(e+) ~ 45 % at capture section exit and the observed Y(e+) ~ 30 % at after the 1-6 chicane.
- It is my homework for next KEKB Review.

SuperKEKB e^+ injection beam

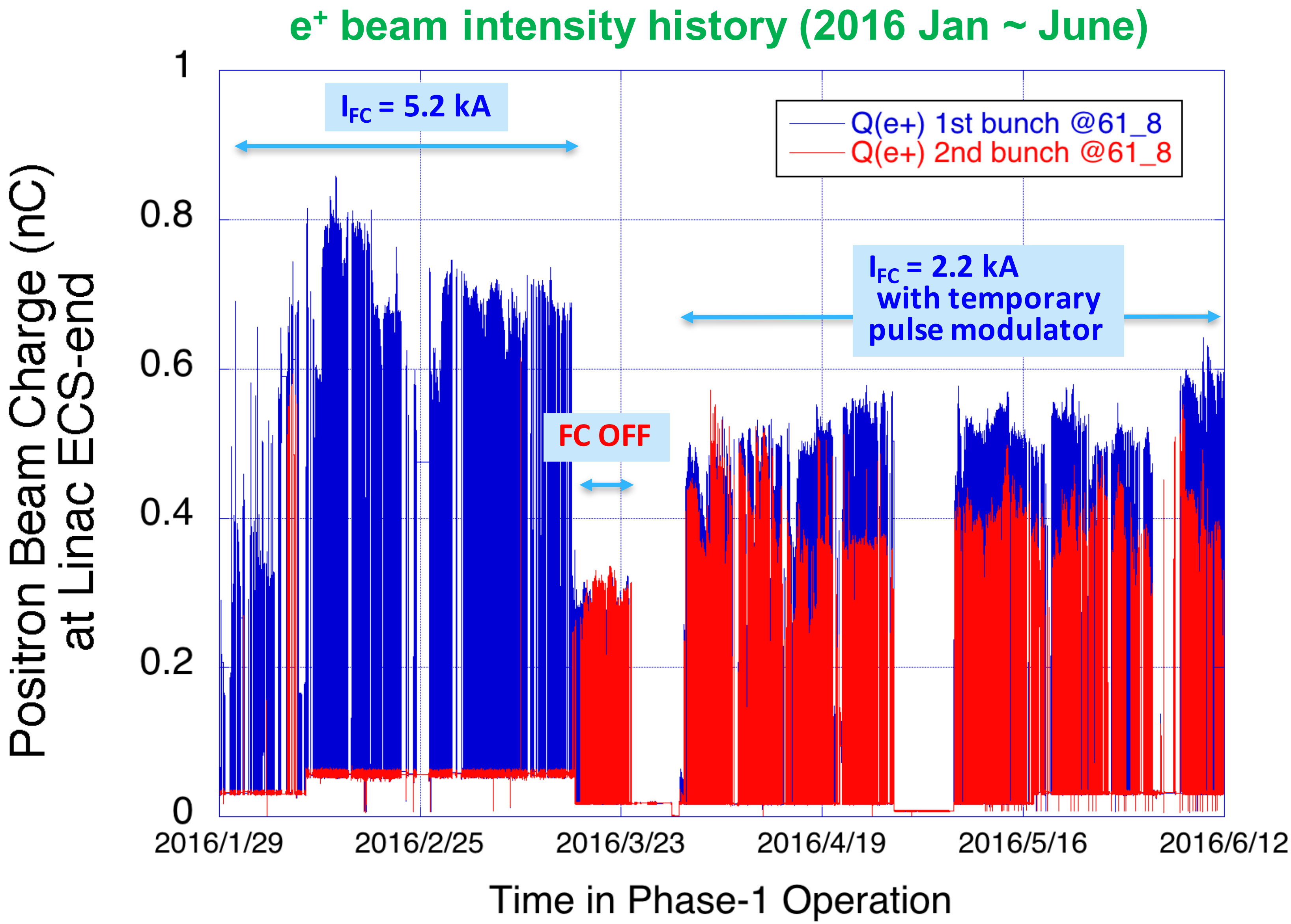
Typical e^+ injection beam at linac and BT-line



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

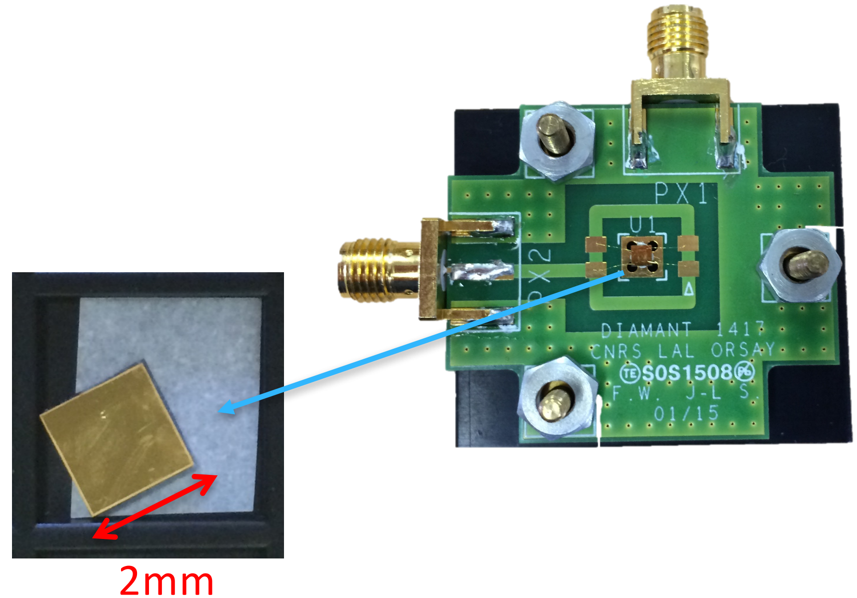
Due to limited beam acceptance, inevitable beam loss occurs in linac & BT-line in direct injection w/o DR.

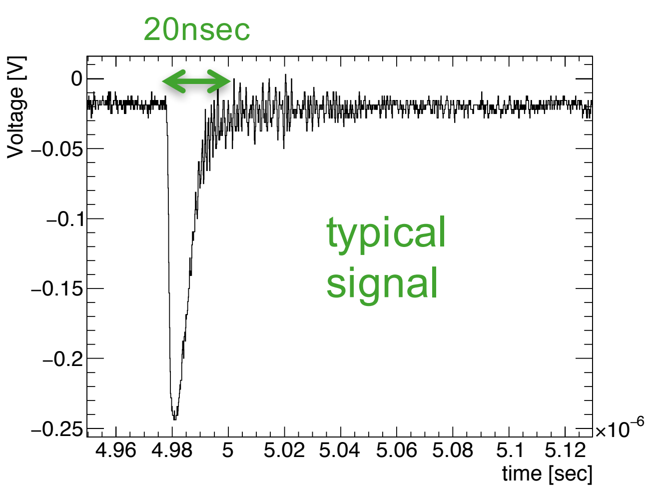
SuperKEKB e^+ beam performance

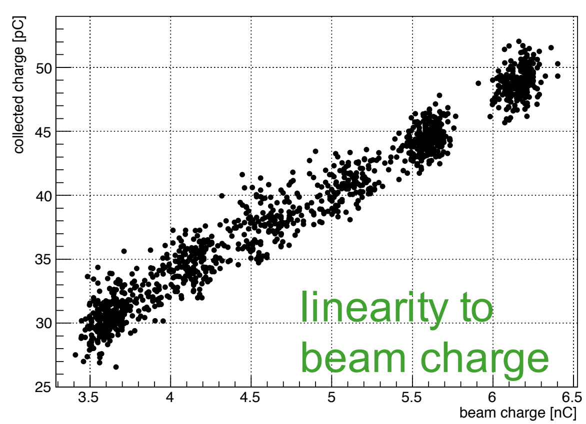


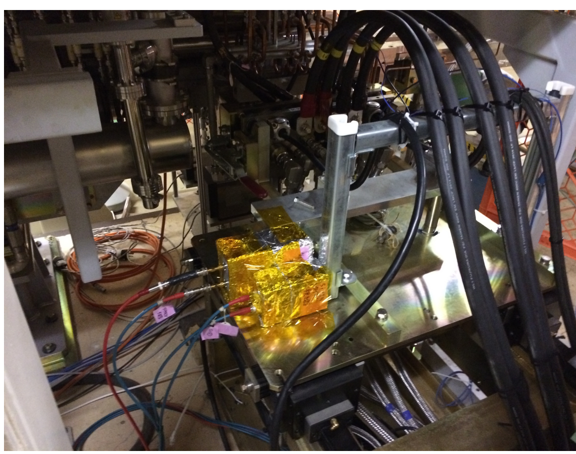
Diamond beam loss monitor

- Radiation-hard diamond beam loss monitor was developed by S. Kazama in collaboration with V. Kubytskyi and P. Bambade (LAL Orsay)
- single crystal CVD diamond
  2.0 mm x 2.0 mm x 0.5 mm
  with electrode (Ti, Pt, Au)
  operated at 400 V.
- Detect beam hit/no-hit
  (1) on beam spoiler and (2) on target









Summary

1) Though test operation of spare FC (#4) with new modulator, new cables, new triplate feeder but w/o BC was successful up to 12 kA, a serious damage occurred in FC (#3) with BC field (2015 Sep.) and operable current has been 5 ~ 6 kA.

2) Importance of work-hardening process of FC-head was recognized. Test stand with FC assembly #2 has been constructed to perform tests of not-hardened and well-hardened models with BC field. (2015 June ~)

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 2016 Feb. 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 2016 Dec. ~ 2017 Jan. DR commissioning and LER injection in Phase-2 will be started in 2017 Nov.