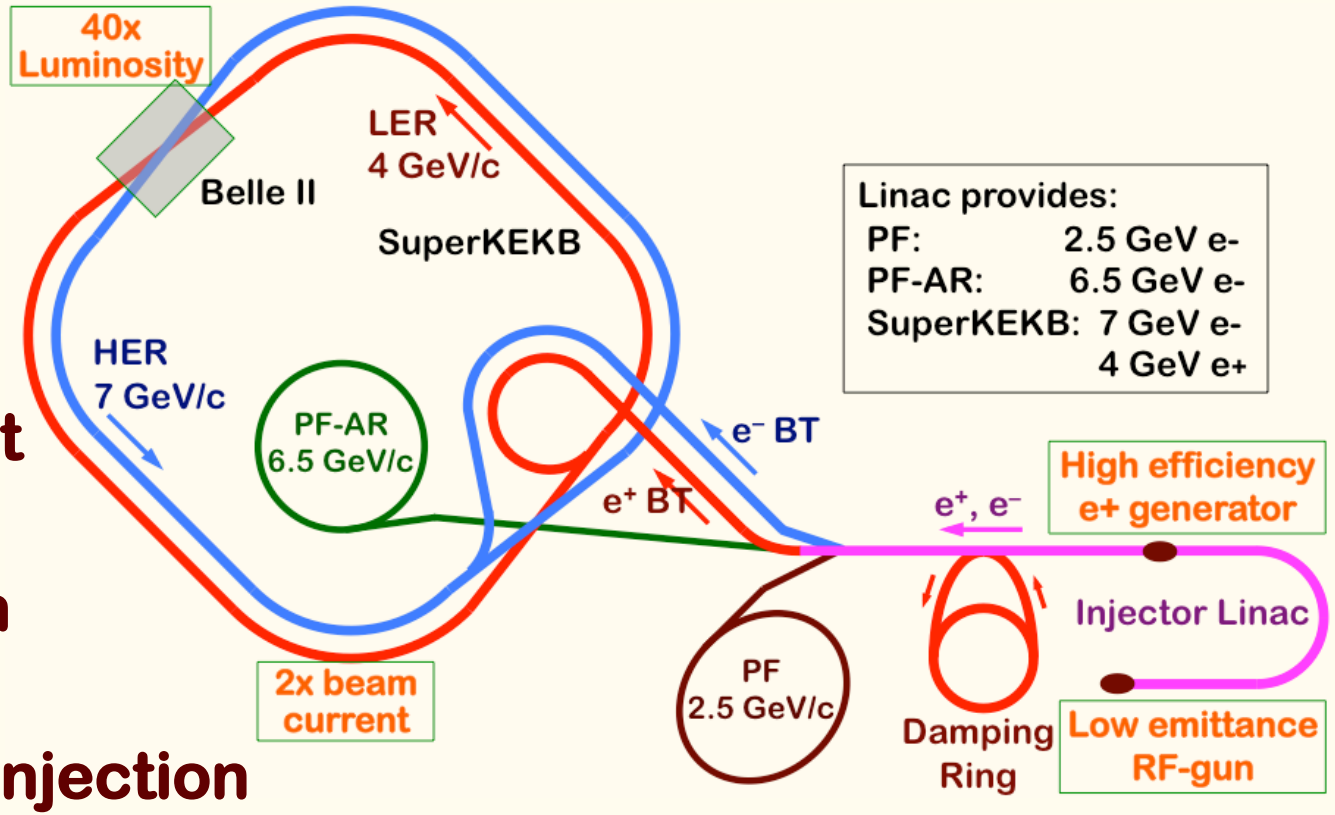
Overview of Injector Linac

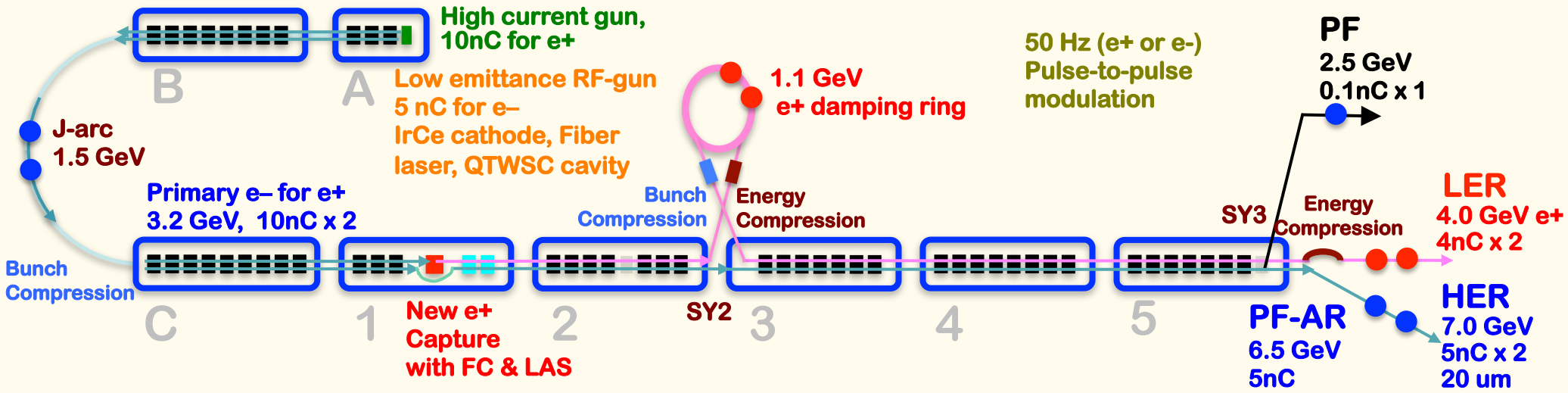
Kazuro Furukawa
for Injector Linac

Mission of electron/positron Injector in SuperKEKB

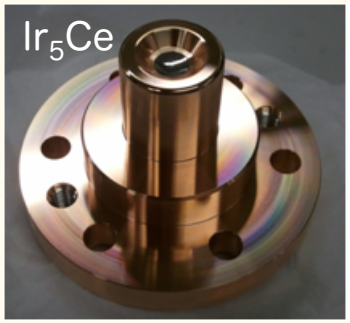
- **40-times higher Luminosity**
  - Twice larger storage beam → Higher beam current at Linac
  - 20-times higher collision rate with nano-beam scheme
    - → Low-emittance even at first turn → Low-emittance beam from Linac
    - → Shorter storage lifetime → Higher Linac beam current
- **Linac challenges**
  - Low emittance e-
    - with high-charge RF-gun
  - Low emittance e+
    - with damping ring
  - Higher e+ beam current
    - with new capture section
  - Emittance preservation
    - with precise beam control
  - 4+1 ring simultaneous injection

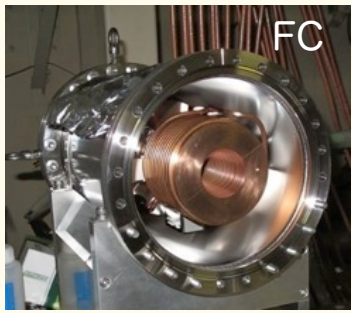


Linac Upgrade for SuperKEKB



- **Higher Injection Beam Current**
  - To Meet the larger stored beam current and shorter beam lifetime in MR
  - 4~8-times larger bunch current for electron and positron
- **Lower-emittance Injection Beam**
  - To meet nano-beam scheme in the ring
  - Positron with a damping ring, Electron with a photo-cathode RF gun
  - Emittance preservation by alignment and beam instrumentation
- **Quasi-simultaneous injections into 4 storage rings (PPM)**
  - SuperKEKB e^-/e^+ rings, and light sources of PF and PF-AR
  - Improvements to beam monitors, low-level RF, controls, timing, etc

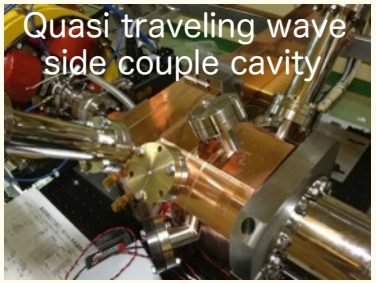




Linac Upgrade Progress towards SuperKEKB (1)

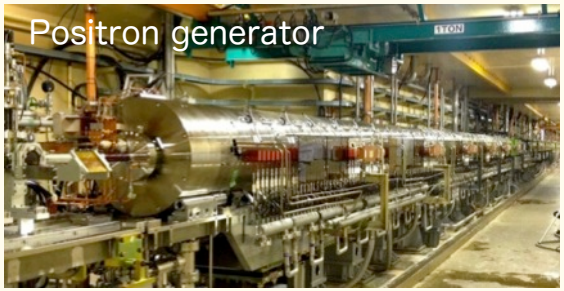
High-charge low-emittance RF gun development

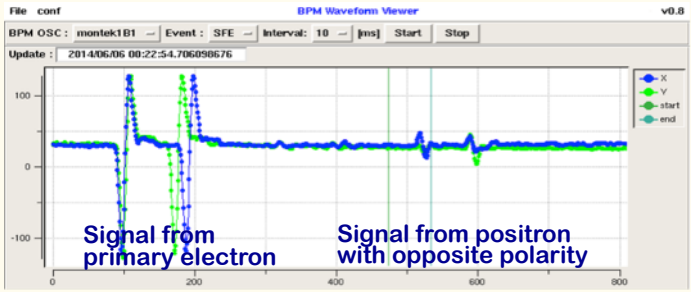
- QTWSC cavity and Ir5Ce photo cathode works well



Positron generation confirmation for the first time

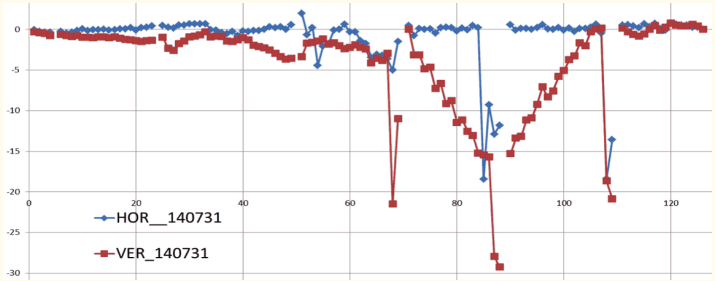
- Good agreement with the simulation results





Precise alignment for emittance preservation

- Recovering after earthquake
- Reaching specification of 0.2mm



Utility upgrade during summer 2014

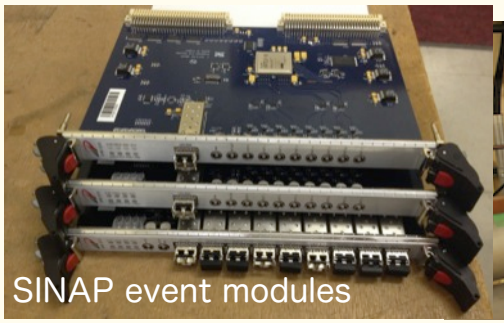
- for electricity (+1.5MW) and cooling water (+1400L/min)

Linac Upgrade Progress towards SuperKEKB (2)

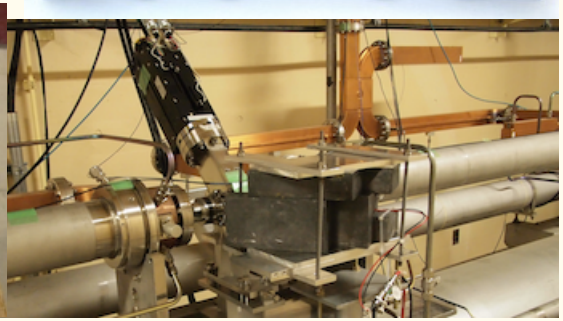
- **High power modulator upgrades**
- **Low-level RF controls/monitor**
  - Pulse-to-pulse modulation (PPM) between 4+1 rings
  - More spaces for increased number of devices

- **Beam instrumentation**
  - Large aperture beam position monitors (BPM)
  - Precise/fast and synchronized BPM readout system
  - Wire scanners and beam loss monitors

- **Event timing system**
  - Combination of MRF and SINAP modules
  - Essential for PPM operation
  - High timinng precision
  - Bucket selection at DR and MR



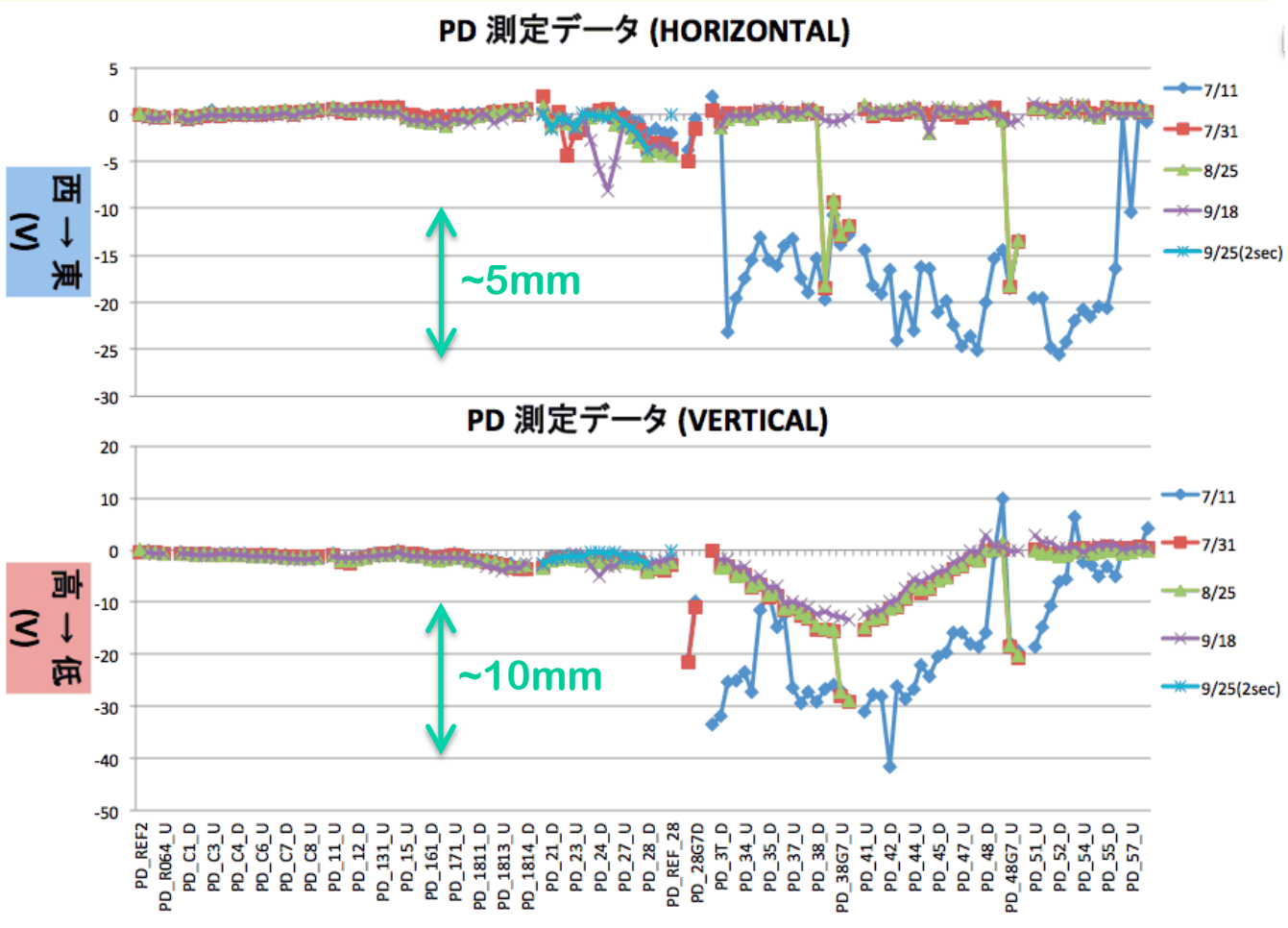
SINAP event modules



Alignment progress in 2014

Higo et al.

- For the first time after earthquake at downstream sectors
- Several measurements during summer
- Measurement reproducibility was confirmed up to ~0.2 mm
- While there existed several conflicting measurements, consistent scheme has been established
- Movement of tunnel by several 10's of micrometer was observed (→ mover)
- Further work necessary in 2015, for alignment and girder replacement



T.Kamitani

Positron Generation

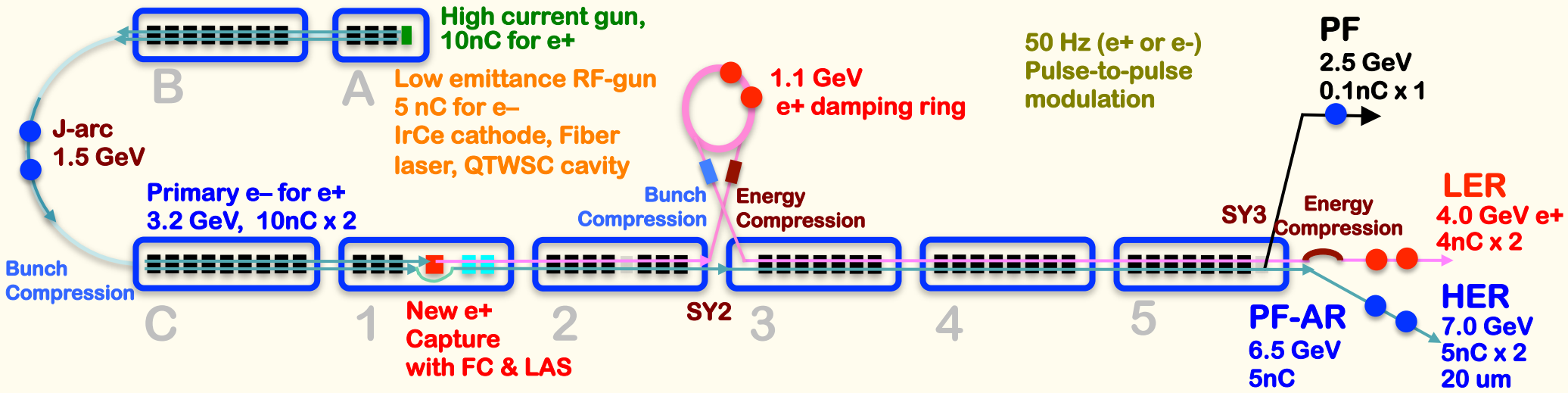
1) **Installation of positron generator for SuperKEKB in April 2014**
   (Beamline construction since summer 2013)
   (positron target, spoiler, Flux Concentrator, bridge coils, LAS structures [x6], DC solenoids [16+13], e+/e- separator, quads [>90])

2) **Commissioning of positron beam, observation of the first positron after reconstruction for SuperKEKB, further improvements expected**

	Primary e- [nC]	Positron [nC]	Efficiency	Parameters
June 2014	0.6	0.12	20%	FC 6.4kA, Solenoids 370A, LAS capture field 10 MV/m
Specification (at SY2)	10.0 (x17)	5.0 (x42)	50% (x2.5)	FC 12kA, Solenoids 650A, LAS capture field 14 MV/m
DR injection (2017?)		4.0	40%	Energy spread acceptance 0.5%

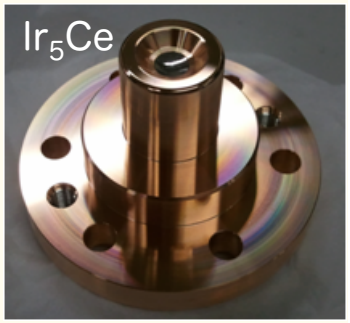
3) Oct.~Dec.2014 : Linac commissioning
Jan.~May.2015 : Construction
Jul.~Sep.2015 : Construction
Jun. : Linac commissioning
Oct.~Jan.2016 : Linac commissioning

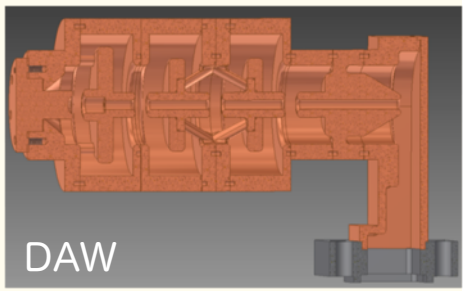
Linac Upgrade for SuperKEKB



◆ Low emittance RF-gun development

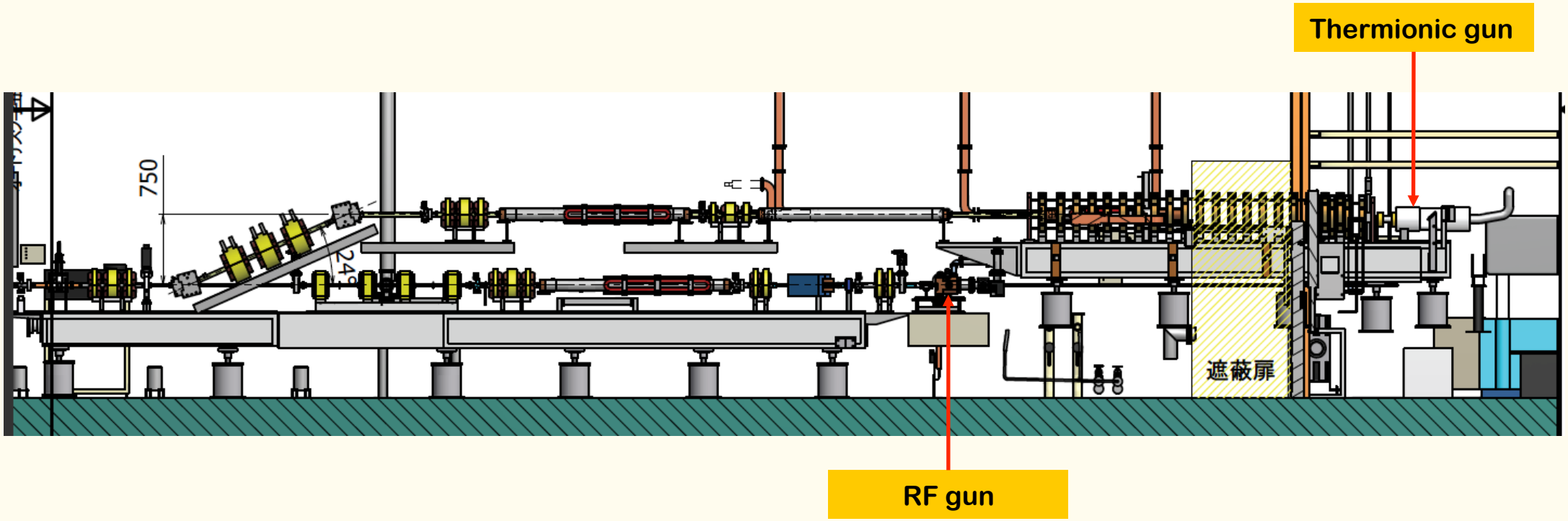
- ❖ Photo-cathode: stability, long-lifetime, quantum efficiency
  - ⌑ LaB6, Ir5Ce and other possibilities, 5nC/bunch achieved
- ❖ Laser : high-power, stability, bunch profile management
  - ⌑ Nd:YAG media, LD excitation, 1.5mJ / 30ps achieved
  - ⌑ Fiber laser development for profile control
- ❖ Cavity : field optimization
  - ⌑ Disk and washer (DAW) cavity
  - ⌑ Quasi traveling-wave (QTWSC) cavity
- ❖ Operation : higher stability and reliability
  - ⌑ PF injection was tested, longer-term tests, backups, are planned





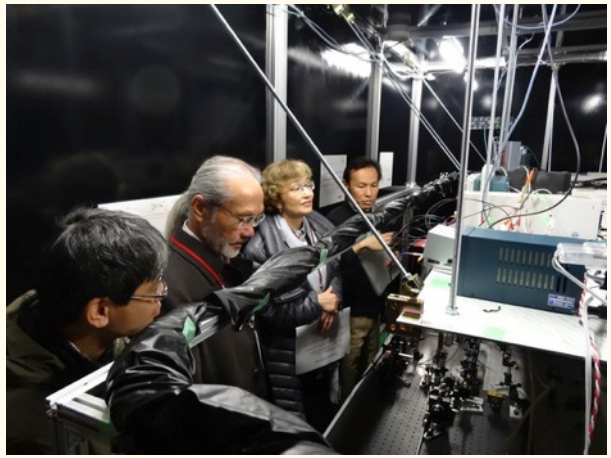
Preparation of Thermionic Gun

- **Under refurbishment**
  - Raise by 75cm not to conflict with straight RF-gun
    - Instead of angled RF-gun
  - ~ May.2015.
- **May serve primary electron for positron generation**



RF-gun Review Meeting

- Thanks to reviewers
  - Dr. Tsumoru Shintake, OIST, chair
  - Dr. Matt Poelker, JLAB
  - Dr. Sasha Gilevich, SLAC
  - Dr. Yosuke Honda, cERL/KEK



- Feb.19,20.2015.
- Phylosophy of simplicity and robustness
- Cavity and photo-cathod seems to be OK
- Concentration on the laser without temporal manipulation
  - Phase-1 and (partial) Phase-2 should be OK

2014 Reviewer's Comments (final-1)

Summary

- Overall, the ARC Review Committee congratulates the accelerator team on very solid progress on construction of SuperKEKB and its injector and firmly expects that beam commissioning of the rings will start in 2015.
- With key components of the injector now installed and operational, significant effort should be devoted to achieving the necessary beam stability to support commissioning of new and critical downstream components.

Overview of Injector

- **But** significant challenges related to achieving Super KEKB luminosity remain: operation at higher bunch charge for both electron and positron beams, demanding emittance requirements, tight requirements on monitoring the beam position, and a demanding schedule that requires commissioning of many new components including the positron source and positron damping ring. The earthquake and Super KEKB construction has alerted KEK staff to tunnel motion, 0.1mm/day, comparable to the quadrupole and RF cavity alignment specification.
- To achieve Super KEKB luminosity requirement, the staff will pursue a phased approach, beginning with "modest" bunch charge and emittance and working their way to final goals over ~3 years.
  - Optimizing beam with many simulation works to achieve goal within available resources
  - Staged beam commissioning with low → high charge and normal → low emittance

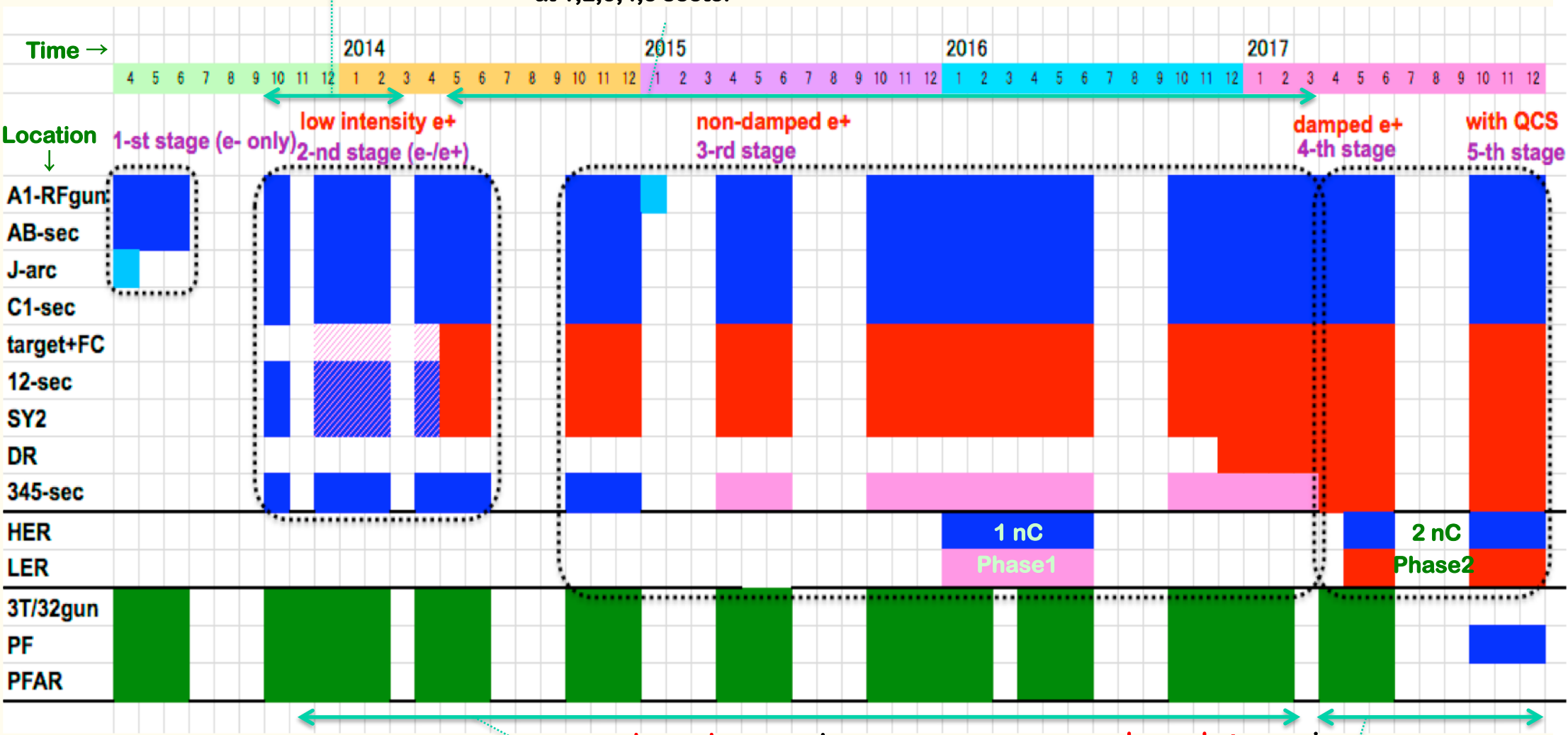
Linac Schedule Overview

RF-Gun e- beam commissioning at A,B-sector

e- commiss. at A,B,J,C,1

e+ commiss. at 1,2 sector (FC, DCS, Qe- 50%)
e- commiss. at 1,2,3,4,5 sector

Phase1: high emittance beam for vacuum scrub
Phase2,3: low emittance beam for collision

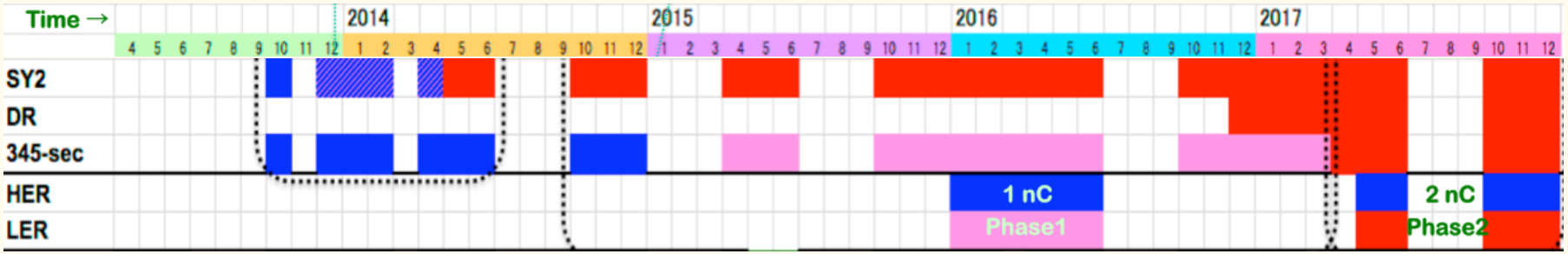


: Electron
: Positron
: Low current electron

non damped e+ commiss.
at 1,2, 3,4,5 sectors
e- commiss. at A→5 sectors

damped e+ commiss.
at 1→5 Qe+ = 1~4nC
e- commiss.
at A→5 Qe- = 1~5nC

Injector linac schedule and RF-gun



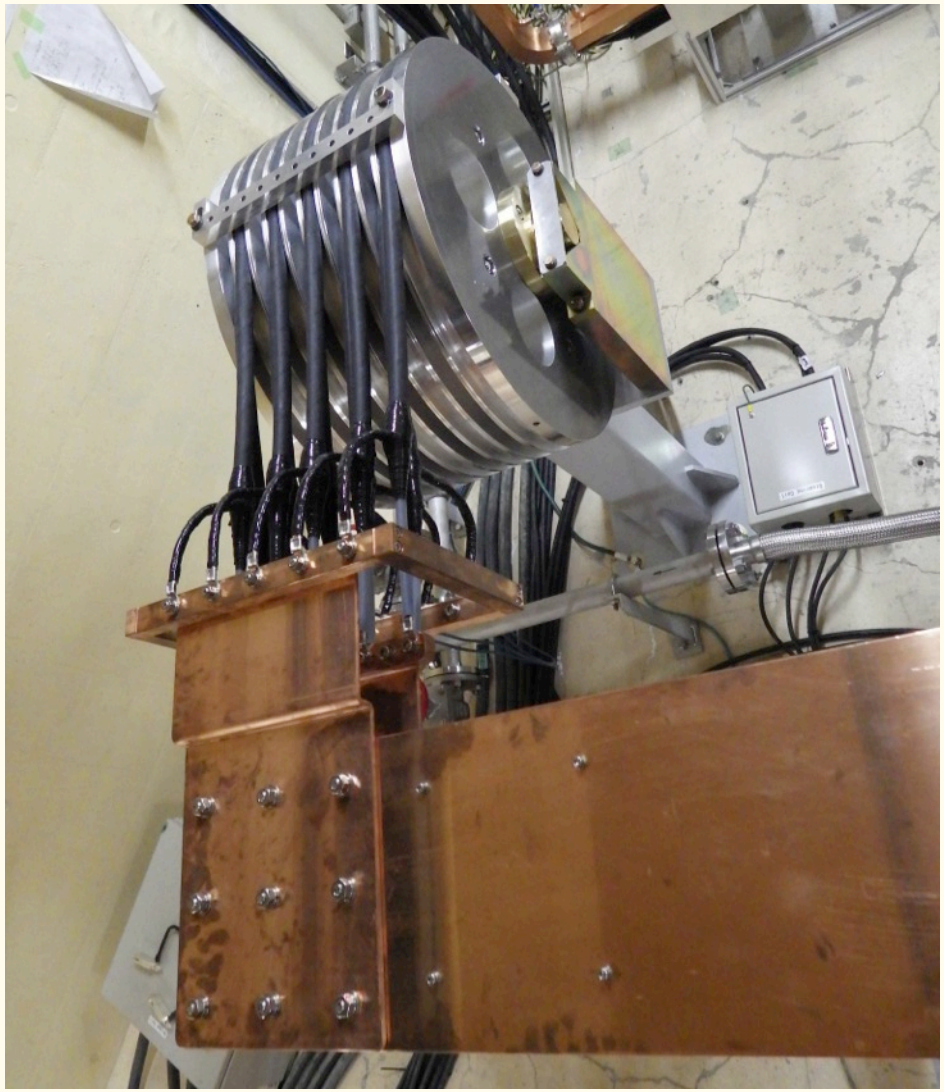
- **Feb.2016 – Jun.2016: Phase-1 commissioning**
  - Non-low-emittance, 1nC electron/positron beams, without damping ring (DR)
    - With combination of RF-gun and thermionic gun
    - ex. Electron with 1nC RF-gun, Positron with ~6nC thermionic gun
      - (depends on downstream configuration after DR delay affecting PF/PF-AR injections)
- **Dec.2016 – May.2017, Damping ring commissioning**
  - 1nC – 2nC positron beam, to/from DR
- **Jun/Oct.2017 – Feb.2018, Phase-2 commissioning**
  - Low-emittance (20mm.mrad, 0.1%), 2nC electron/positron beams, with DR
    - Low-emittance electron beam with RF-gun, 2nC
    - Primary beam for positron with RF-gun or thermionic gun, 5nC
- **Oct.2018 – …, Phase-3 commissioning**
  - Low-emittance (20mm.mrad, 0.1%), High charge electron/positron beams, with DR
    - Low-emittance electron beam with RF-gun, 4nC
    - Primary beam for positron with RF-gun or thermionic gun, 10nC

2014 Reviewer's Comments (final-2)

- **Commissioning**
  - Drive laser stability issues are a key concern (timing stability, amplitude stability and pointing stability).
    - → Combination with thermionic gun
- **RF gun and Emittance Preservation**
  - However, the QTW laser system is very complex, and with complexity comes risk. (…)
    - → Concentrate on laser system without pulse shaping
      - Recommendation at rf-gun review
- **Positron Source**
  - A fire at the solenoid flux concentrator has introduced a ~ 4 month delay in commissioning.
    - → First positrons were observed
    - → Careful safety investigations again
    - → High-current radiation shield
- **Timing System**
  - There is still significant software development to complete and much hardware to integrate.
    - → Successful tests with light source beams

Fire during flux concentrator development

- **One of small problems – Cables burned by 20cm**
  - **This was reported last year**



Near-misses at Linac

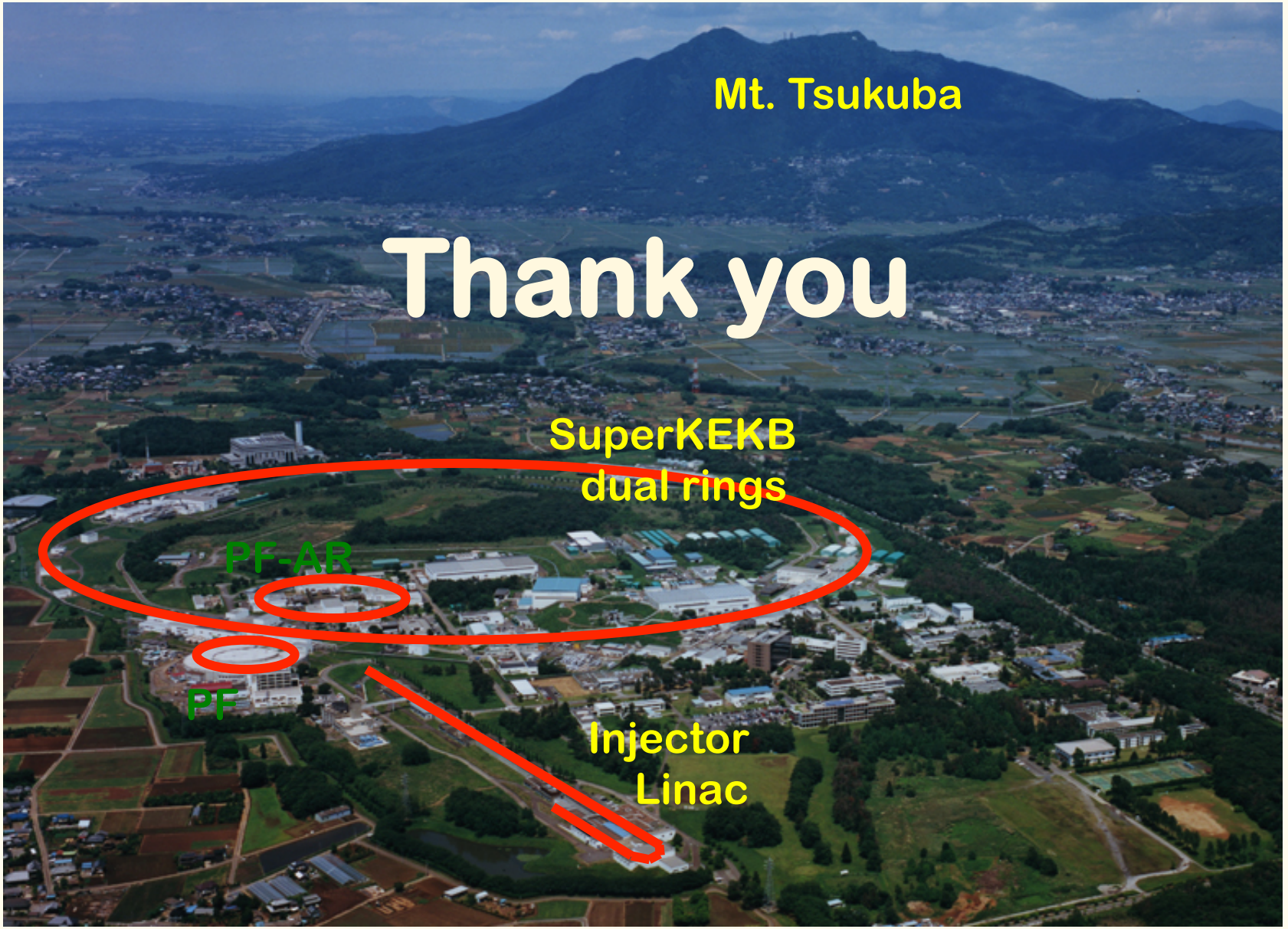
- May.12.2014. Despiker at KL_A2 high power modulator overheated
  - Aging → Devices in the same lot were replaced
- May.12.2014. Coil of a bending magnet BM_28_4 overheated
  - Communication error
- Dec.9.2014. High power cable overheated at the terminal of flux concentrator power supply
  - Corona discharge → Thicker cable

Presentations for Injector Linac

- **Alignment *20'***
  - Speaker: Toshiyasu Higo
- **RF gun review *20'***
  - Speaker: Matt Poelker (JLab)
- **Electron gun and transport *40'***
  - Speaker: Mitsuhiro Yoshida
- **Positron source upgrade *40'***
  - Speaker: Takuya Kamitani
- **Injector commissioning *40'***
  - Speaker: Masanori Satoh

Summary

- Steady progress towards first MR injection
- Finishing earthquake disaster recovery in FY2014
- Will make staged improvements before 2018
- Will balance between final beam quality and staged operation
- Will select optimized route depending on available resources


Mt. Tsukuba
Thank you
SuperKEKB
dual rings
PF-AR
PF
Injector
Linac