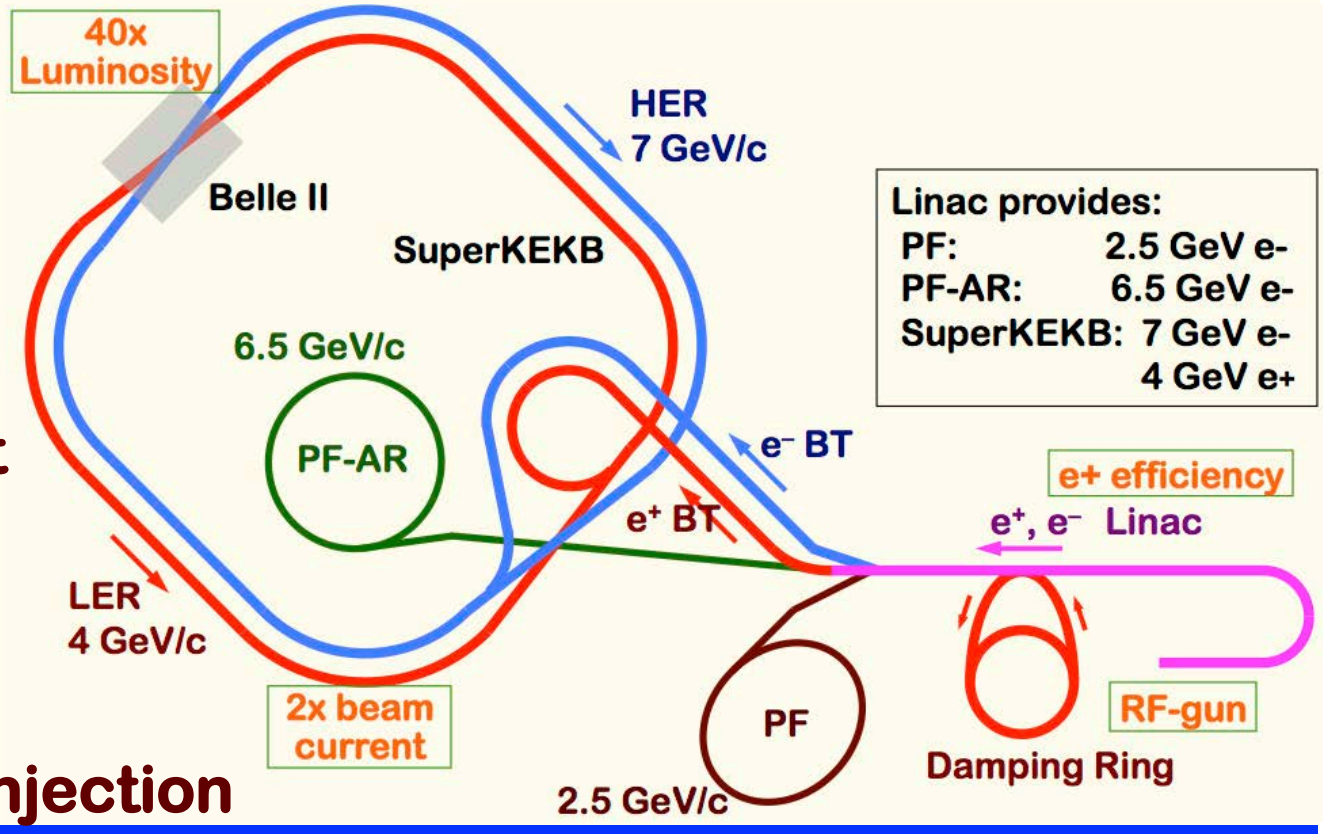
Overview of Injector Linac

Kazuro Furukawa
for Injector Linac

Mission of electron/positron Injector in SuperKEKB

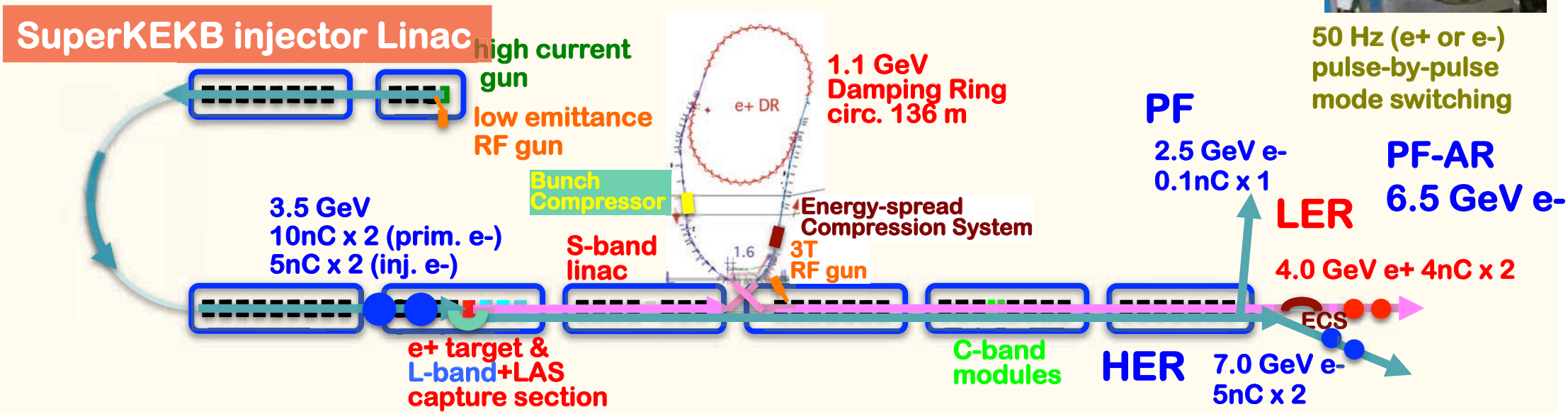
- **40-times higher Luminosity**
  - Twice larger storage beam → Higher beam current at Linac
  - 20-times higher collision rate with nano-beam scheme
    - → Low-emittance even at first turn → Low-emittance beam from Linac
    - → Shorter storage lifetime → Higher Linac beam current
- **Linac challenges**
  - 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

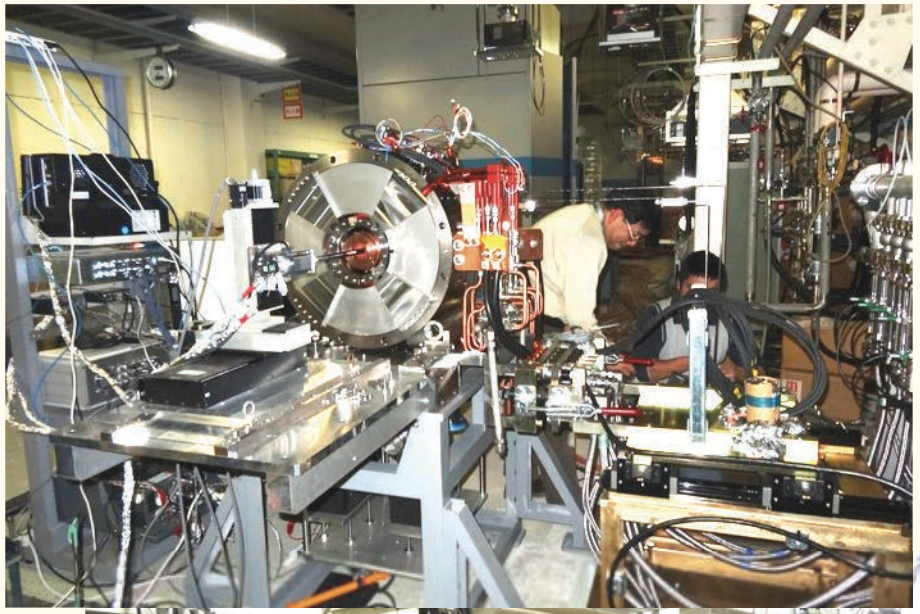
- **Higher Injection Beam Current**
  - To Meet the larger stored beam current and shorter beam lifetime in the ring
  - 4~8-times larger bunch current for electron and positron
- **Lower-emittance Injection Beam**
  - To meet nano-beam scheme in the ring
  - Positron with a damping ring, Electron with 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 instrumentation, low-level RF, controls, timing, etc

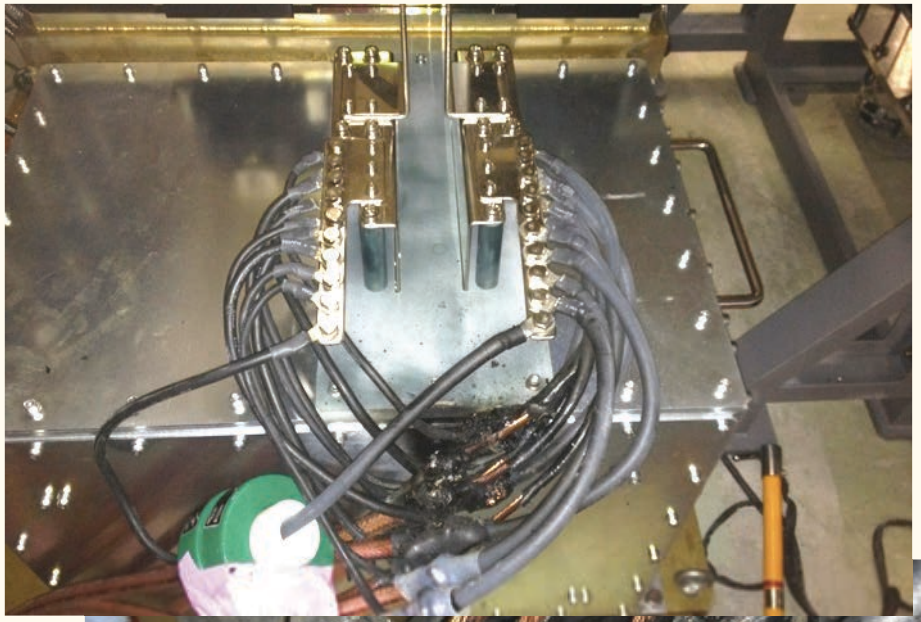
50 Hz (e+ or e-)
pulse-by-pulse
mode switching

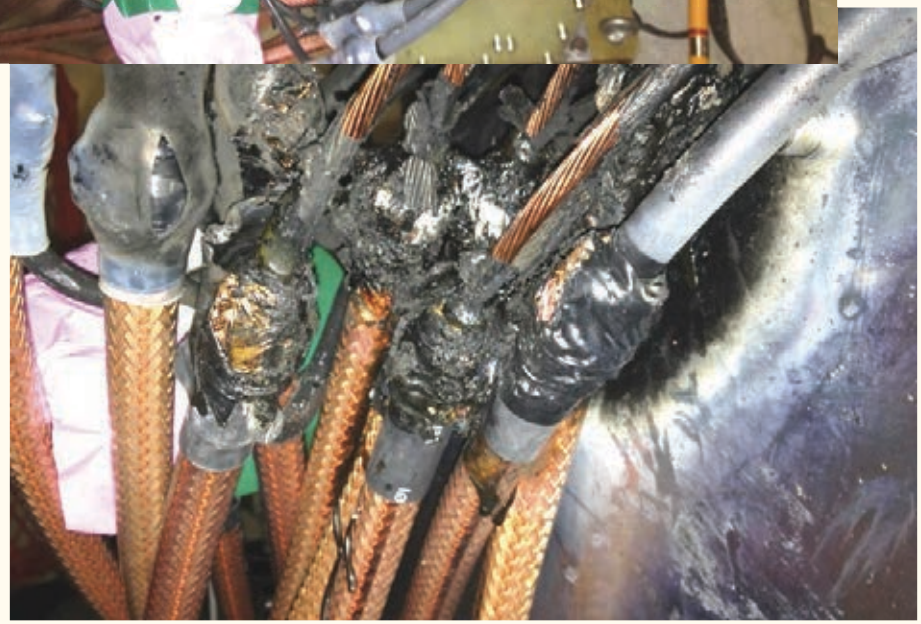


Fire during flux concentrator development

- One of small problems – Cables burned by 20cm





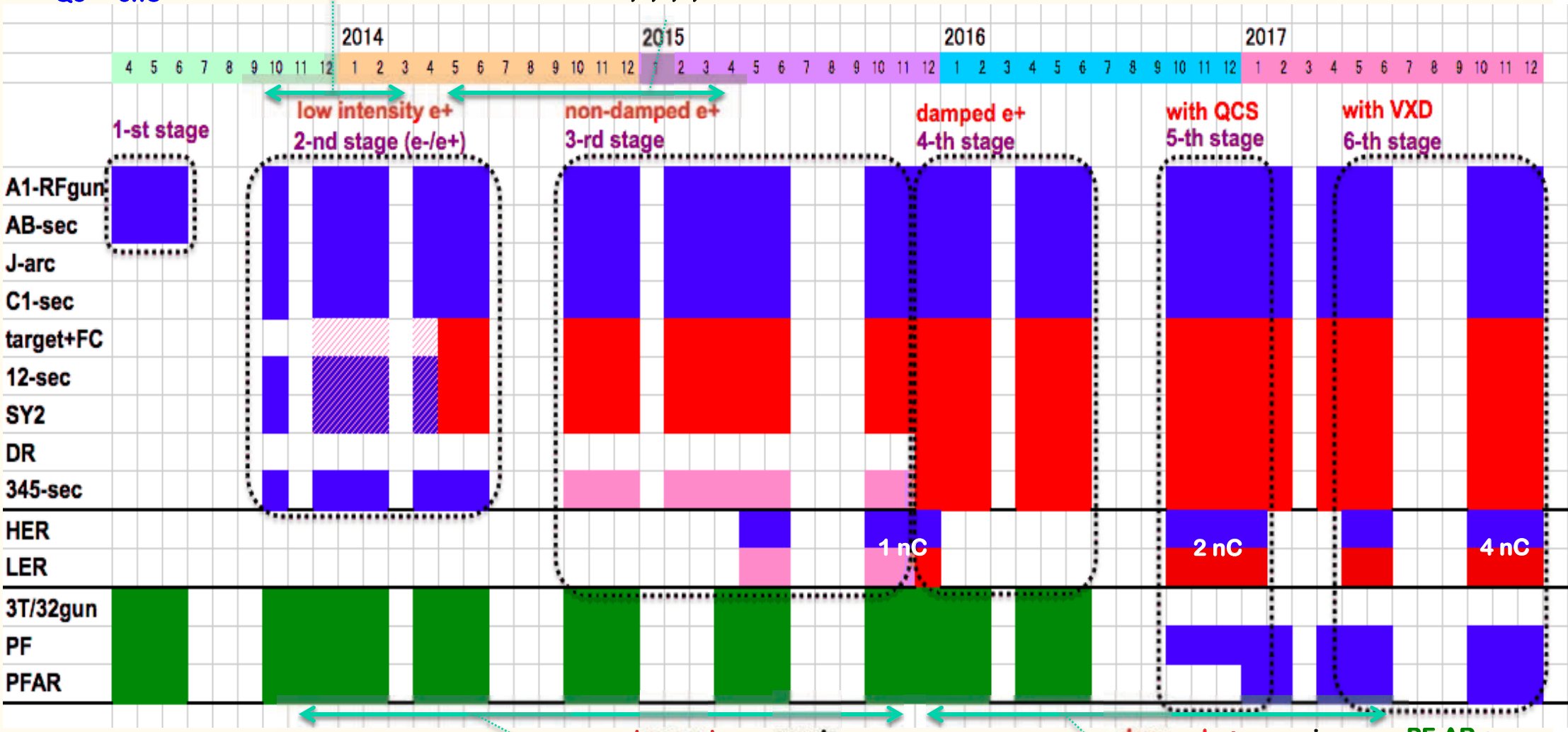


Linac Schedule Overview

RF-Gun e- beam commissioning at A,B-sector Qe- = 5nC

e- commiss. at A,B,J,C,1 Qe- = 5nC

e+ commiss. at 1,2 Qe+ = 0.5nC (FC, DCS, Qe- 50%)
e- commiss. at 1,2,3,4,5 Qe- = 5nC



: 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

PF-AR e- commiss.

Several Workshop around Injector Linac

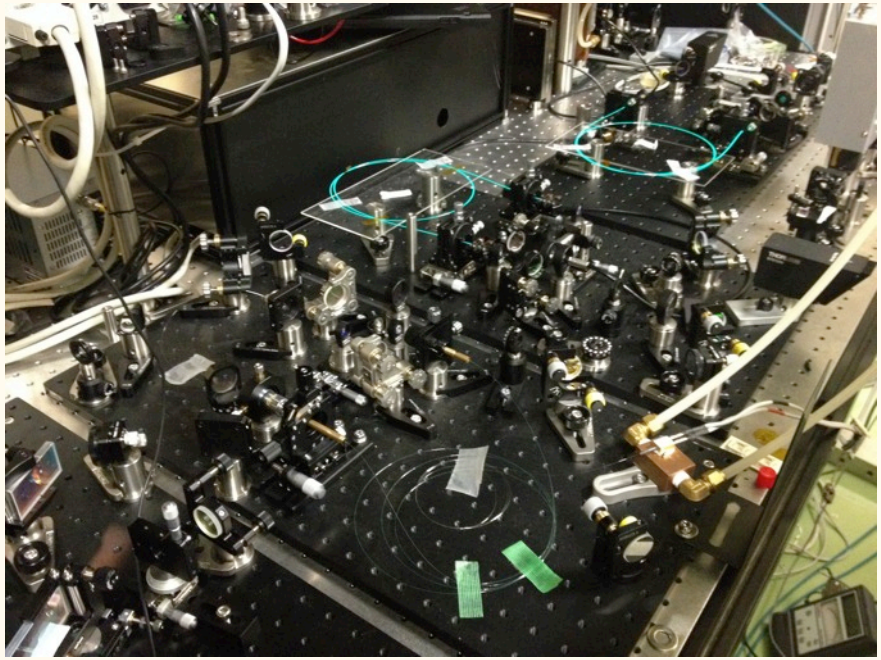
- **Technology choice for beam position monitor (BPM)**
  - Indispensable for emittance preservation
  - ~10μm precision (~100μm in KEKB project), about 100 BPMs, event-based controls
  - Review by experts from SLAC, Steve Smith and Andrew Young
  - Many valuable discussions on filter design, digital signal processing, etc.
  - One of the developments was chosen for performance, operation, and budget
- **Laser and photo-cathode RF gun workshop**
  - 6 presentations, 16 participants
  - The same objectives of low emittance and higher stability
  - Injector linac is unique on higher beam charge with lower energy spread
  - Should exchange technology/information continuously
- **Accelerator structure processing workshop**
  - 22 participants
  - Many discussions on duration (more than a month), and the system
  - No baking necessary, longer processing and better monitors, better interlock needed

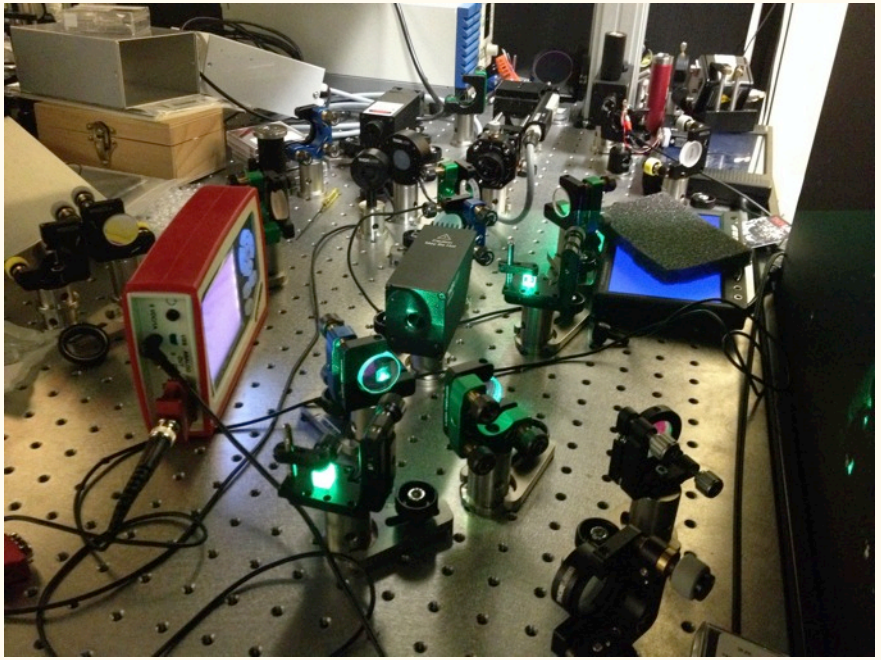
SuperKEKB Workshop (Nov.2013)

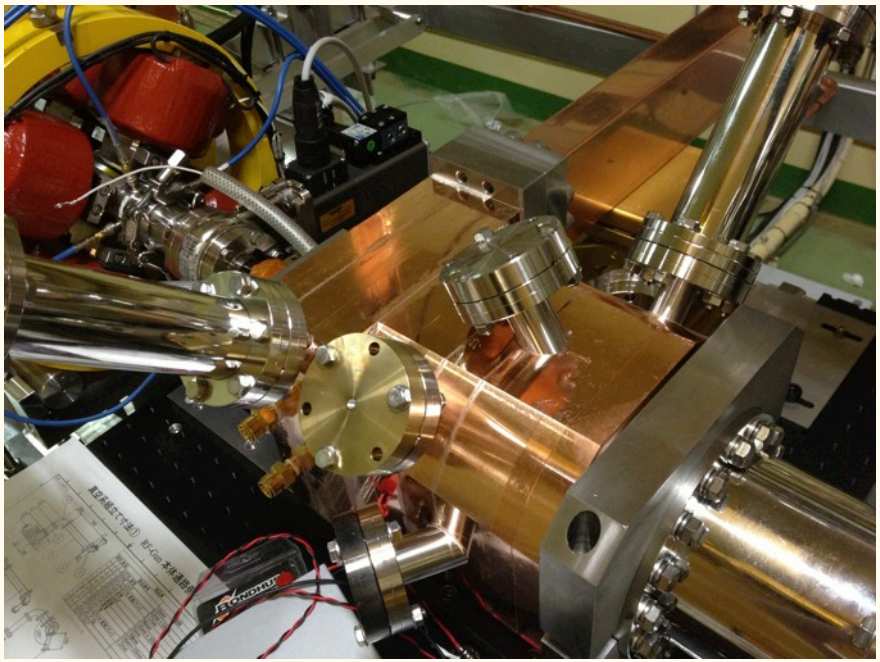
- PEDD dependent on beam repetition?
  - SLAC study was on single-pulse energy density
    - may need further investigation
- Fiber loss monitor blackening around target?
  - Can be replaced routinely
- Diamond loss detector?
  - Is worth comparing in the future
- Orbit stability tolerance against beam size?
  - Pinhole 2mm and beam sigma 0.3mm are possible
    Beam orbit jitter will be studied, as well as for emittance preservation
- Rotating target/spoiler?
  - Should be studied for the beam current larger
- Frequency synchronization btw. linac/ring?
  - All SKEKB frequencies are generated from common freq. with ring circumference compensation
- Beam charge variation pulse-pulse?
  - Can be important
  - Technically possible with different event assignment
  - Means different injection modes with different orbit stabilization for wakefield
- Target quad – pulsed ?
- Beam jitter should be small
- DR extraction angle jitter
  - Offset injection position/angle jitter should be small

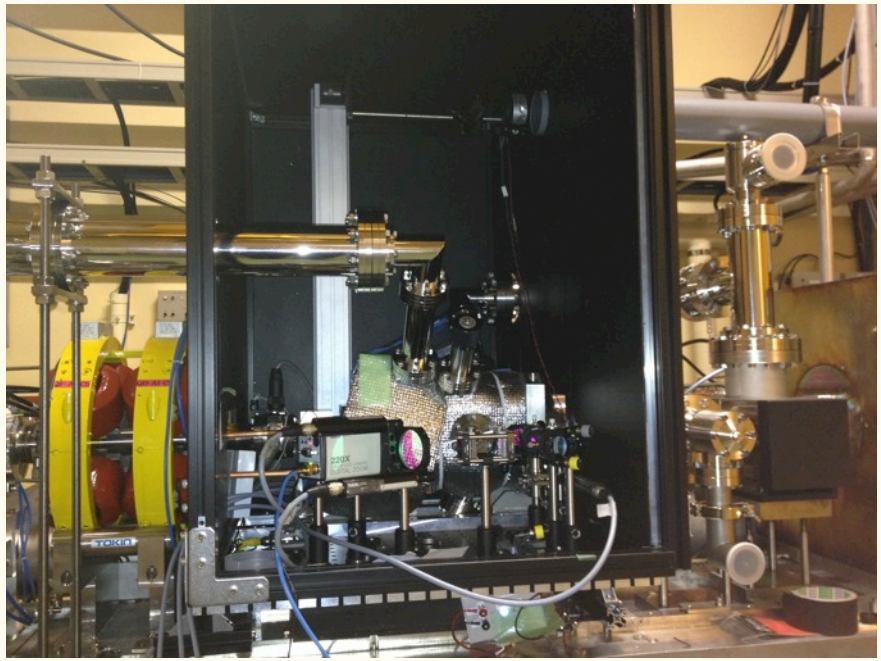
Photo-cathode RF-gun Development

- **A1 RF-gun (GR_A1) under test**
  - Big progresses are quasi-traveling wave side-coupled cavity, Ir5Ce photo-cathode, Yb fiber laser
  - Should understand those many new components for real stable operation
  - 5-nC per bunch was re-confirmed with new configuration
  - 600-m transport was confirmed (with small charge)
  - Longitudinal laser pulse manipulation is necessary for energy-spread and stability management





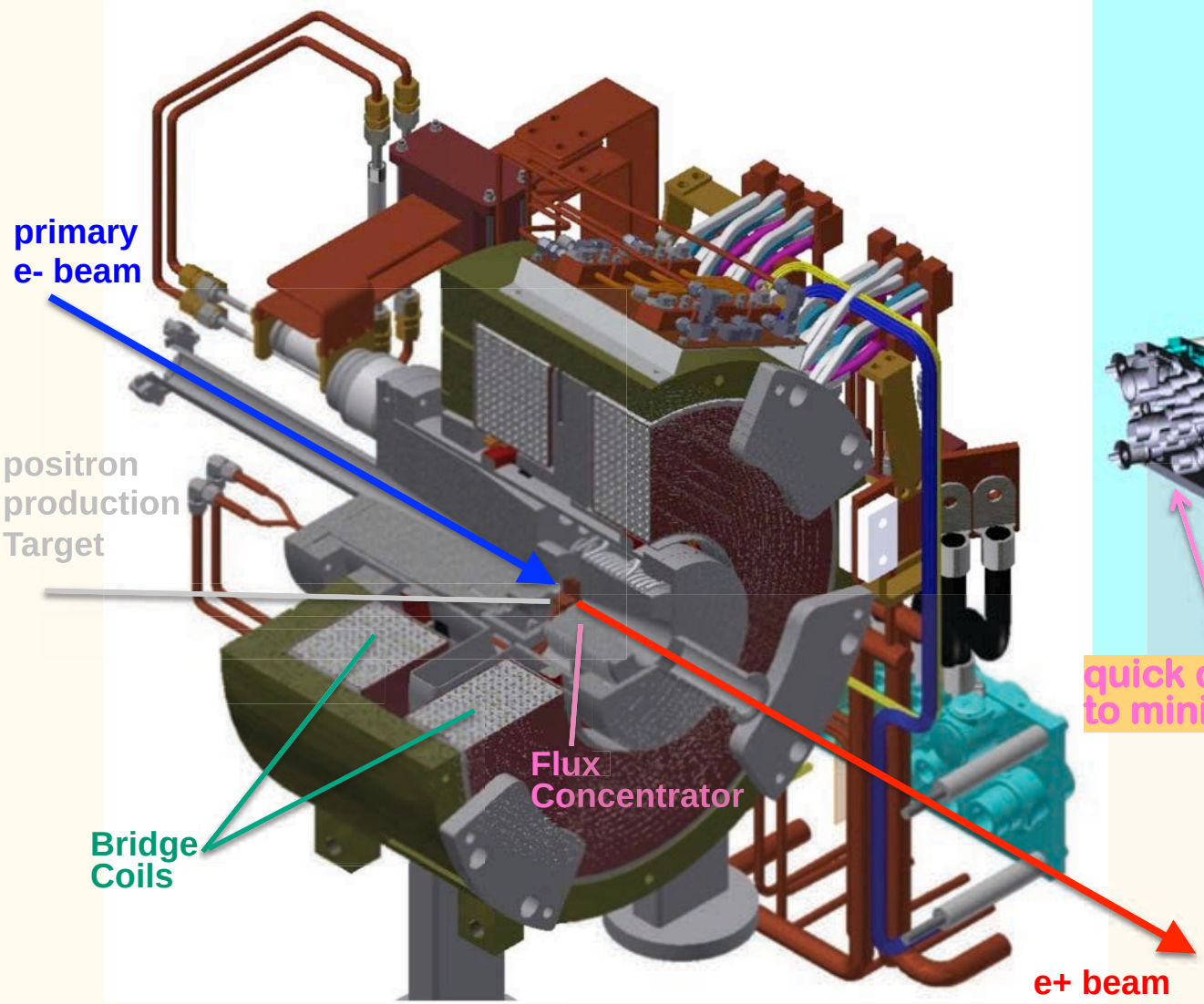


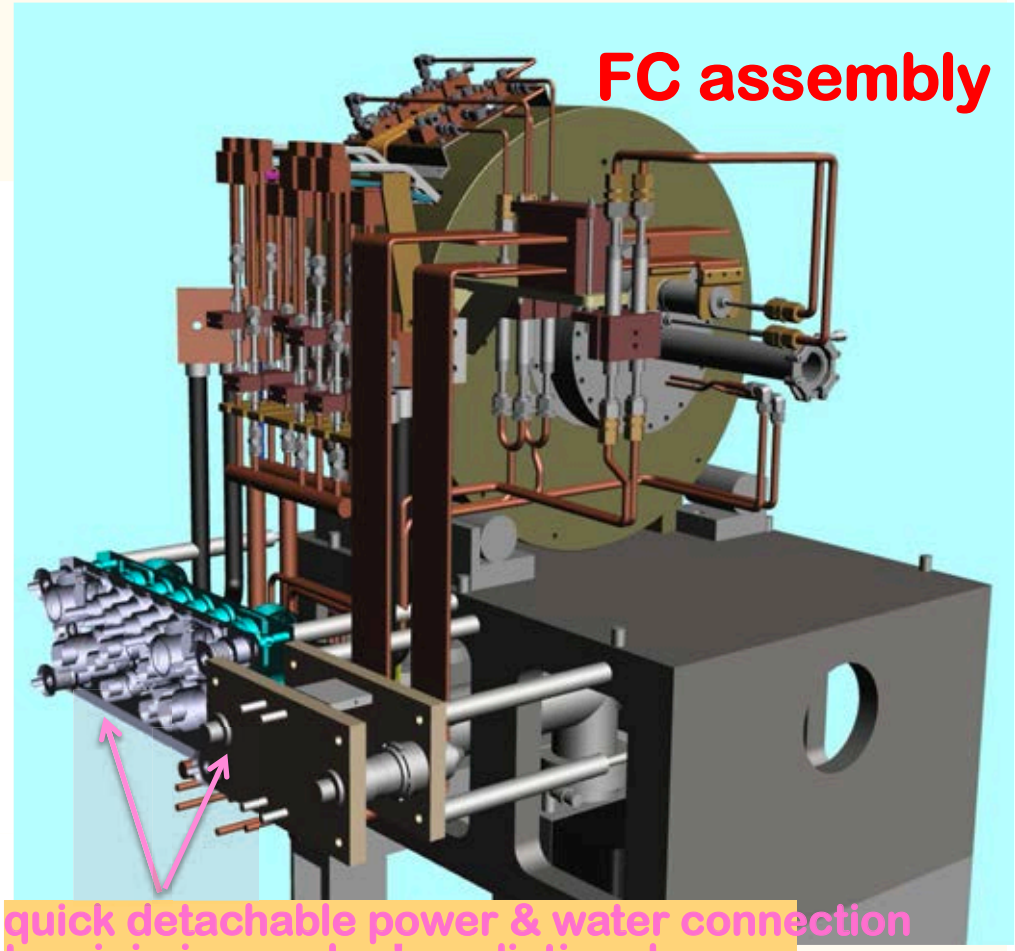


Positron Source

- High current positron is required
- Positron capturing with flux concentrator (FC) and large aperture s-band structure (LAS)
- Deceleration field to reduce satellite bunches
- Pinhole beside target for electron beam
- Protection system with beam spoilers

Flux Concentrator Assembly

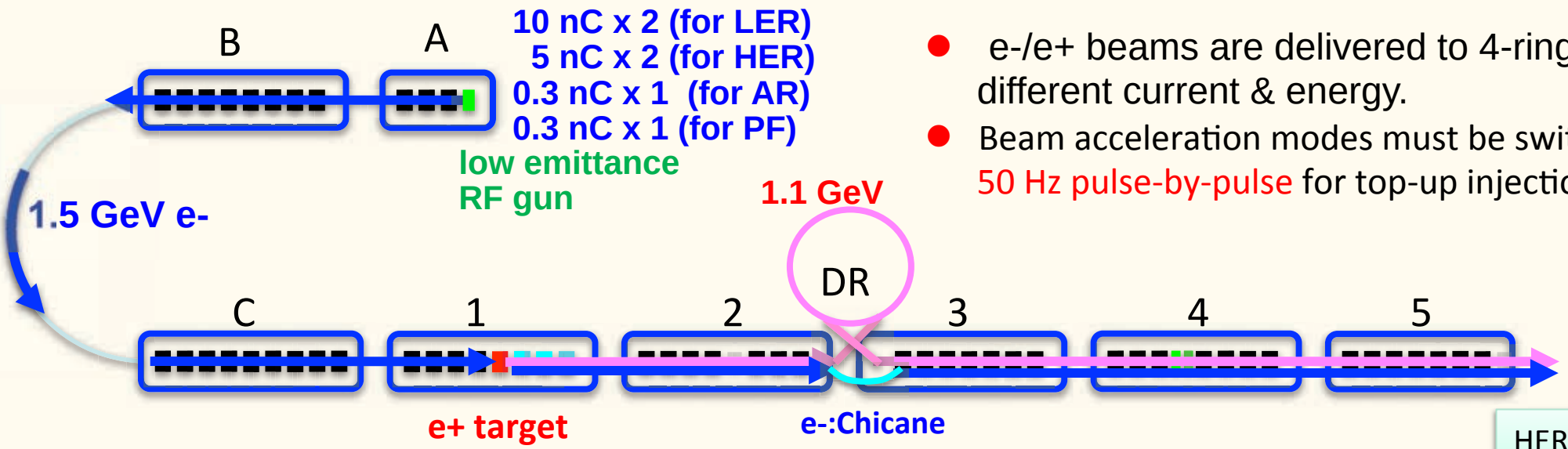




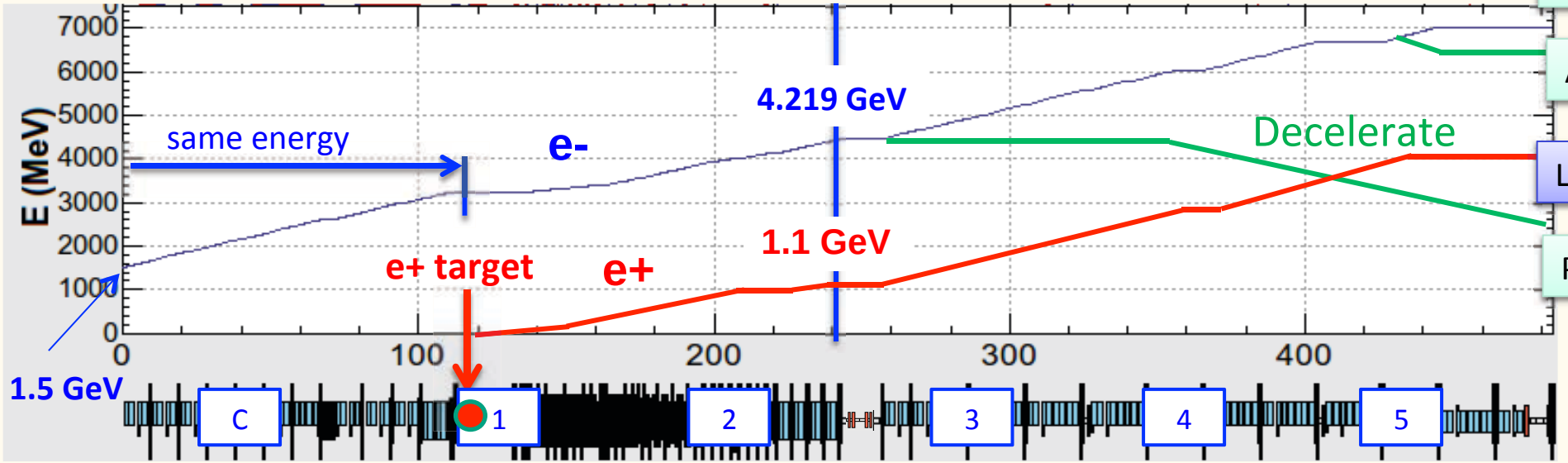
Improved beam optics design

- Pulsed quad addition – Simultaneous injection
- FODO → Doublet – Emittance preservation
- Orbit correction simulation
- Further emittance preservation even with alignment tolerances
- Optimization of installation scheme for available budget

Energy profiles and beam properties



- e-/e+ beams are delivered to 4-rings with different current & energy.
- Beam acceleration modes must be switched by 50 Hz pulse-by-pulse for top-up injection.



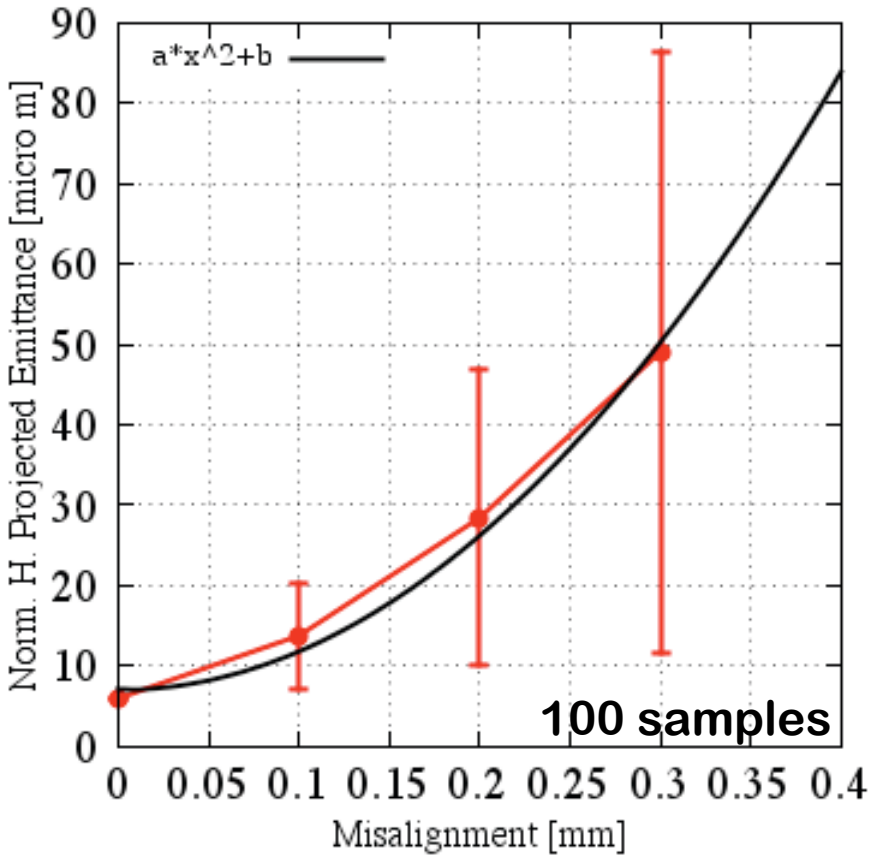
HER: 7 GeV e-
5 nC x2
AR: 6.5 GeV e-
0.3 nC x1
LER: 2.5 GeV e+
4 nC x2
PF: 2.5 GeV e-
0.3 nC x1

Beam optics should satisfy the fast beam-mode switching.

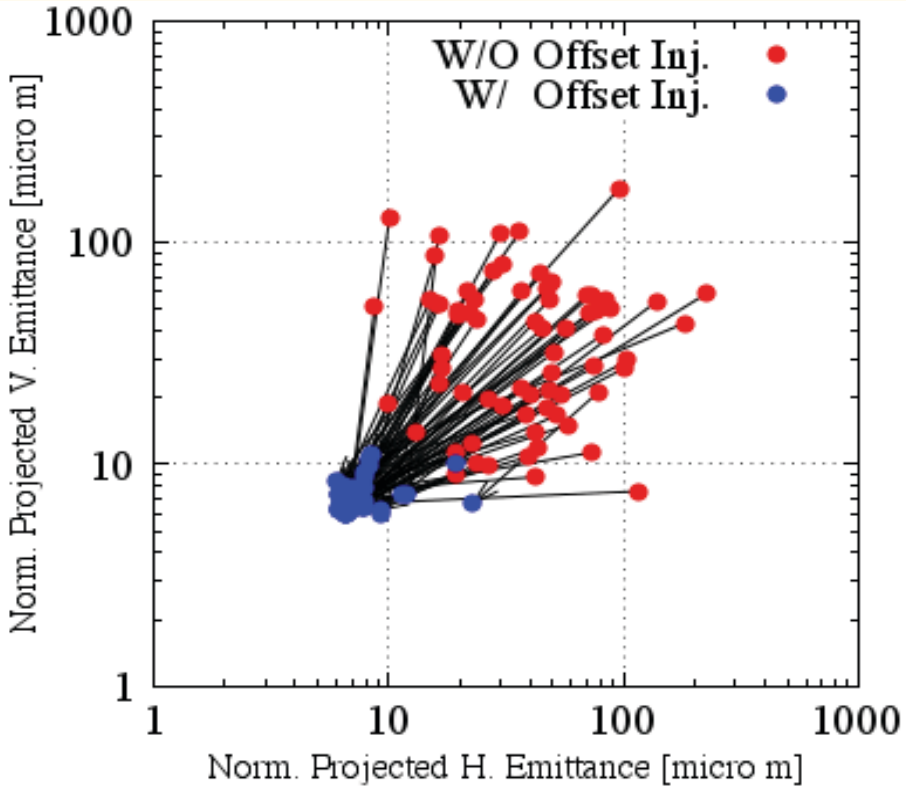
Emittance Preservation

- Offset injection may solve the issue
- Orbit have to be maintained precisely

Mis-alignment leads to Emittance blow-up



Orbit manipulation compensates it



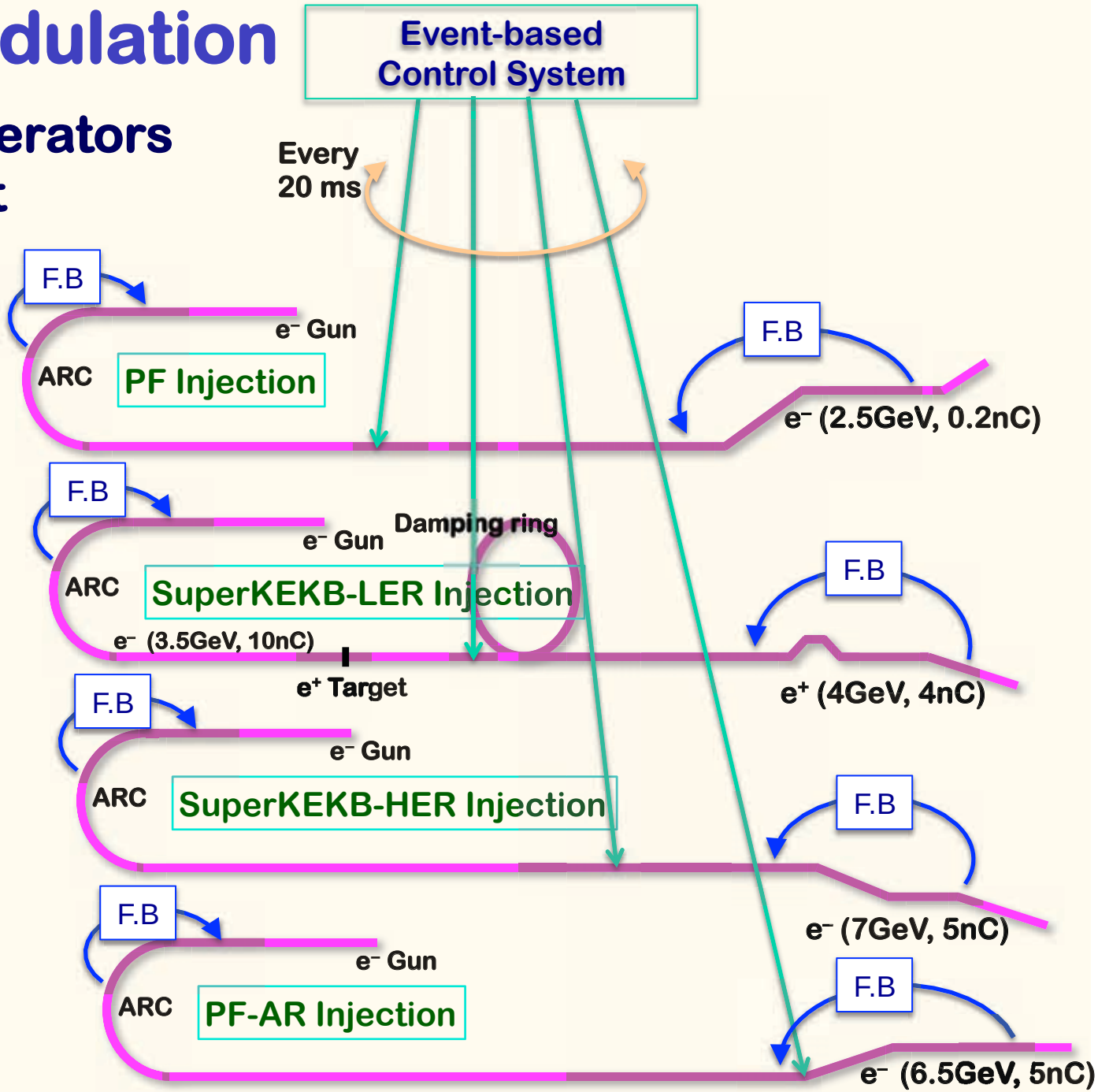
Sugimoto et al.

Pulse-to-pulse modulation

- **Four PPM virtual accelerators for SuperKEKB project**

maybe with additional PPM VAs for stealth beam measurements

based on Dual-tier controls with EPICS and event-system



Instrumentation

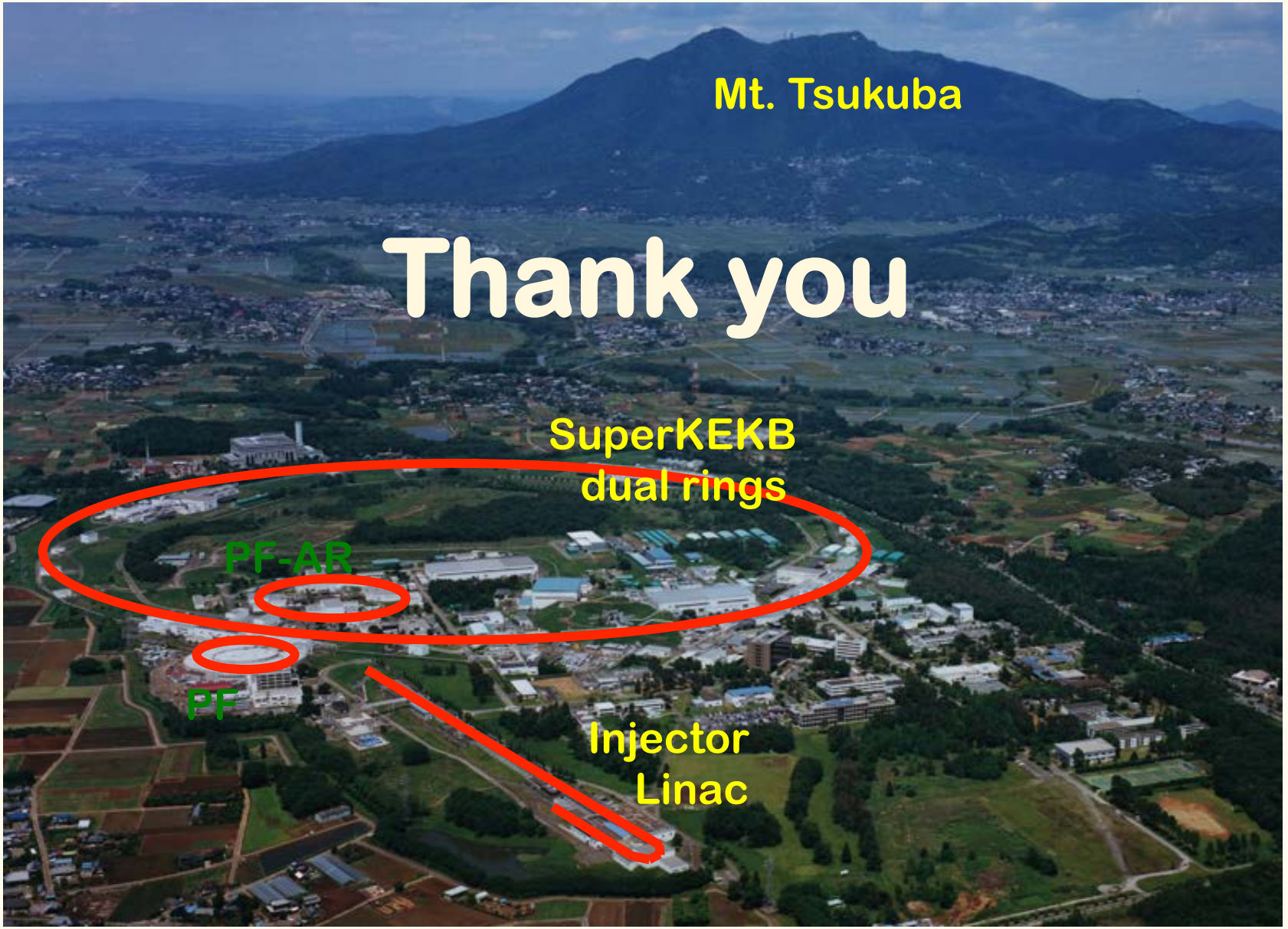
- **RF stability is crucial for the beam**
  - LLRF monitor is being developed
  - 60 high-power klystrons and 10 middle-power systems
  - 50Hz synchronized data acquisition with event (beam-mode) recognition
  - 0.1% amplitude and 0.1degree phase resolution

Presentations for Injector Linac

- **Injector commissioning *40'***
  - Speaker: Masanori Satoh (KEK)
- **RF gun and emittance preservation *40'***
  - Speaker: Mitsuhiro Yoshida (KEK)
- **Positron source *30'***
  - Speaker: Takuya Kamitani (KEK)
- **Timing synchronization *20'***
  - Speaker: Hiroshi Kaji (KEK)
- **LLRF development *20'***
  - Speaker: Takako Miura (KEK)

Summary

- Steady progress towards first MR injection in 2015
- Will finish earthquake disaster recovery in 2014
- Will make staged improvements before 2017
- Will balance between final beam quality and stable/staged operation
- Will select optimized route depending on available resources


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