Electron / Positron Injector Linac Status

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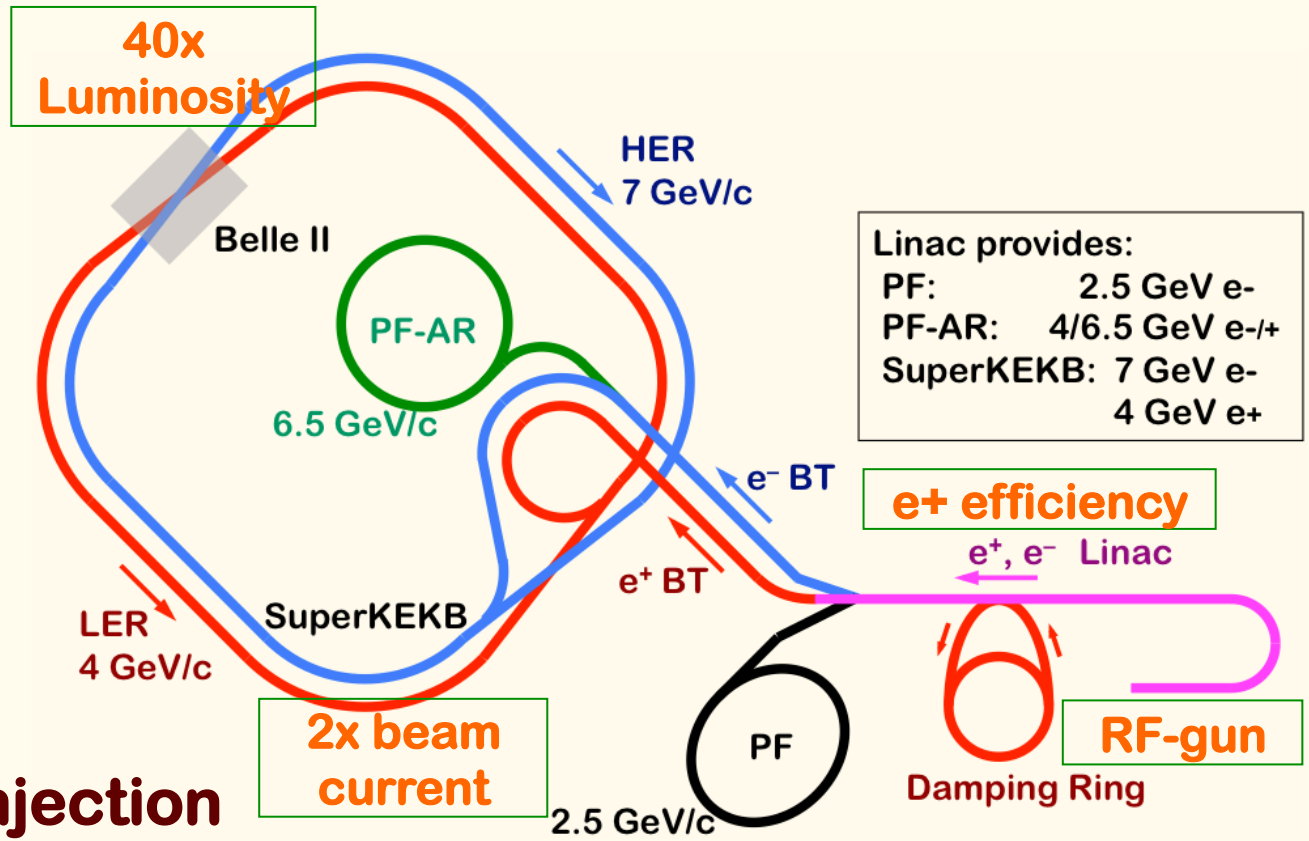
Mission of electron/positron Injector in SuperKEKB

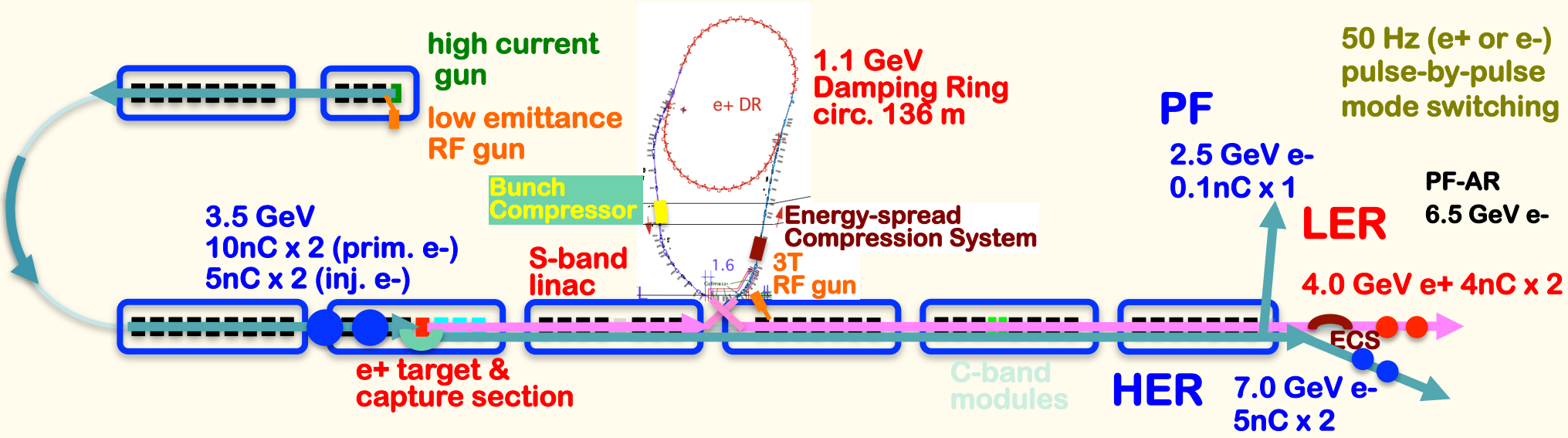
- **40-times higher Luminosity**
  - Twice larger storage beam → Higher beam current at Linac
  - 20-times higher collision rate with nano-beam scheme
    - → Low-emittance even at first turn → Low-emittance beam from Linac
    - → Shorter storage lifetime (→ Higher Linac beam current)
- **Linac challenges**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



Facility Upgrade

Ohsawa et al.

- **Addition of electric power and cooling water is crucial for the upgrade**
  - However, the facility division starts the design only after the budget is secured
  - It was only approved in JFY2012 (the facility budget is different from the project one)
- **Basic schedule**
  - Design JFY2012, Building JFY2013, Facility JFY2014
  - Should not affect PF and PF-AR operation
  - Not available during initial commissioning



Positron capture section	Damping ring BT (LTR, RTL)	Switch yard (3SY)
920 kVA, 900 lit/min	310 kVA	300 kVA, 460 lit/min

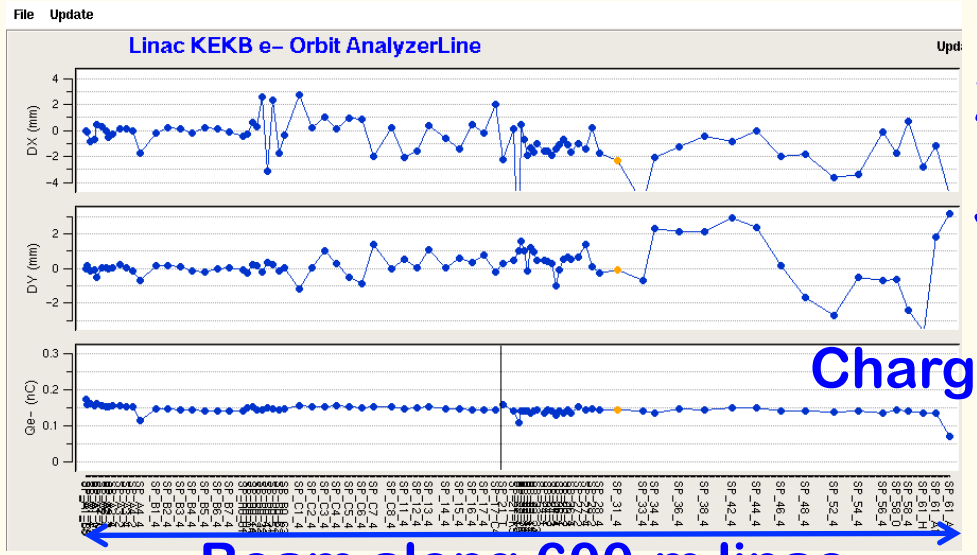
Girder Recovery and Alignment

Higo et al.

- Re-constructing soft-structure girder into hard-structure
- Alignment with
  - 120m and 480m long-baseline laser between girders
  - Laser tracker within a girder (~20m)
  - Beam-based tests
  - Target: 0.1mm local / 0.3mm global alignment (from beam dynamics simulation)
    - Several iterations necessary for low-emittance beam transport
- Beam transport/acceleration test for 600m (Nov.2012)
  - For the first time after the earthquake


Girder Distortion


Girder Reinforcement

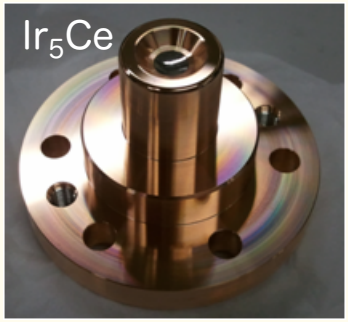


Microwave Power Source Upgrade

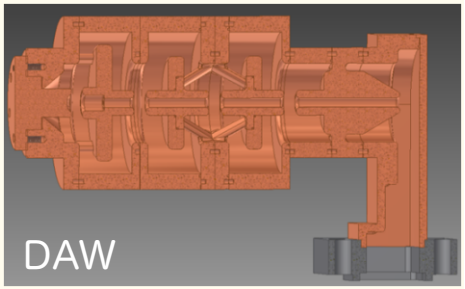
- **Pulsed power modulators** — Michizono et al.
  - Nine compact modulators are introduced
  - Share the same basic design for klystron, flux concentrator, and gun high voltage
- **Fast LLRF controllers, power amplifiers, and LLRF monitors**
  - For simultaneous injection and bucket selection
  - Pulse-to-pulse stability monitor
  - 50Hz event-based synchronized controls

RF Gun Development

Yoshida et al.



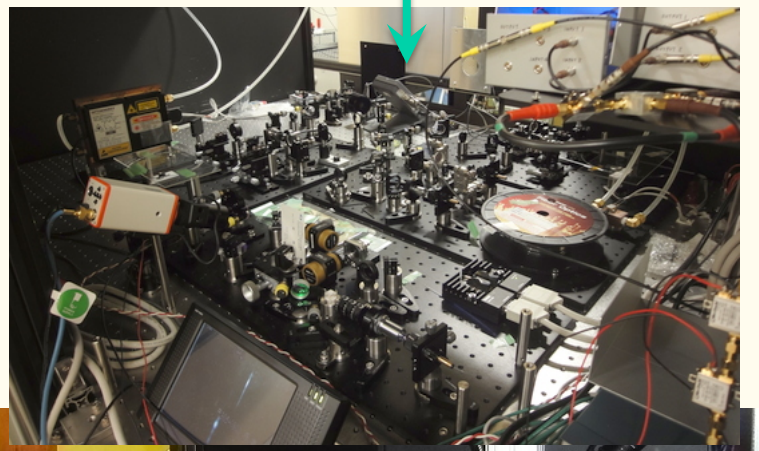
- **Photo cathode : stability, longer life, efficiency**
  - At first LaB_6, then Ir_5Ce → 5nC / bunch
- **Laser : higher power, temporal profile control**
  - Nd:YAG medium, LD excitation → ~1.5mJ / 30ps / pulse at 266nm
  - Polarization control for slant irradiation
  - Yb:YAG fiber laser is introduced

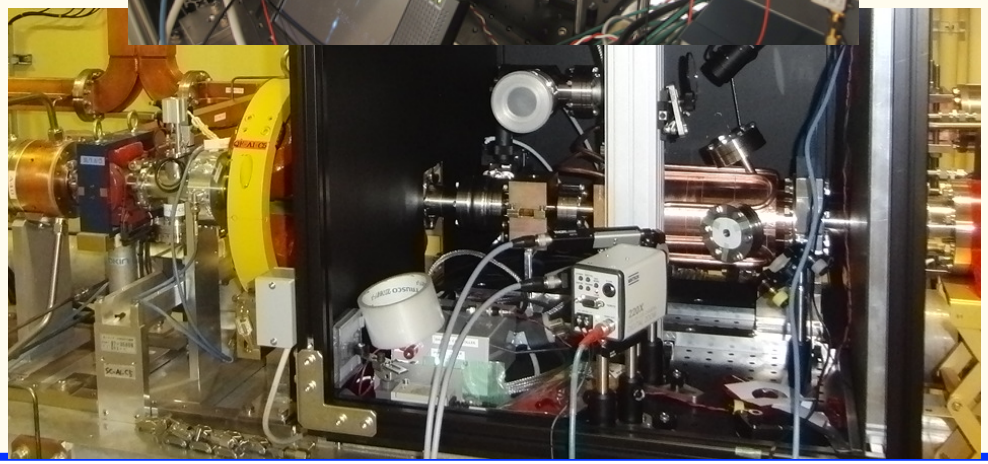


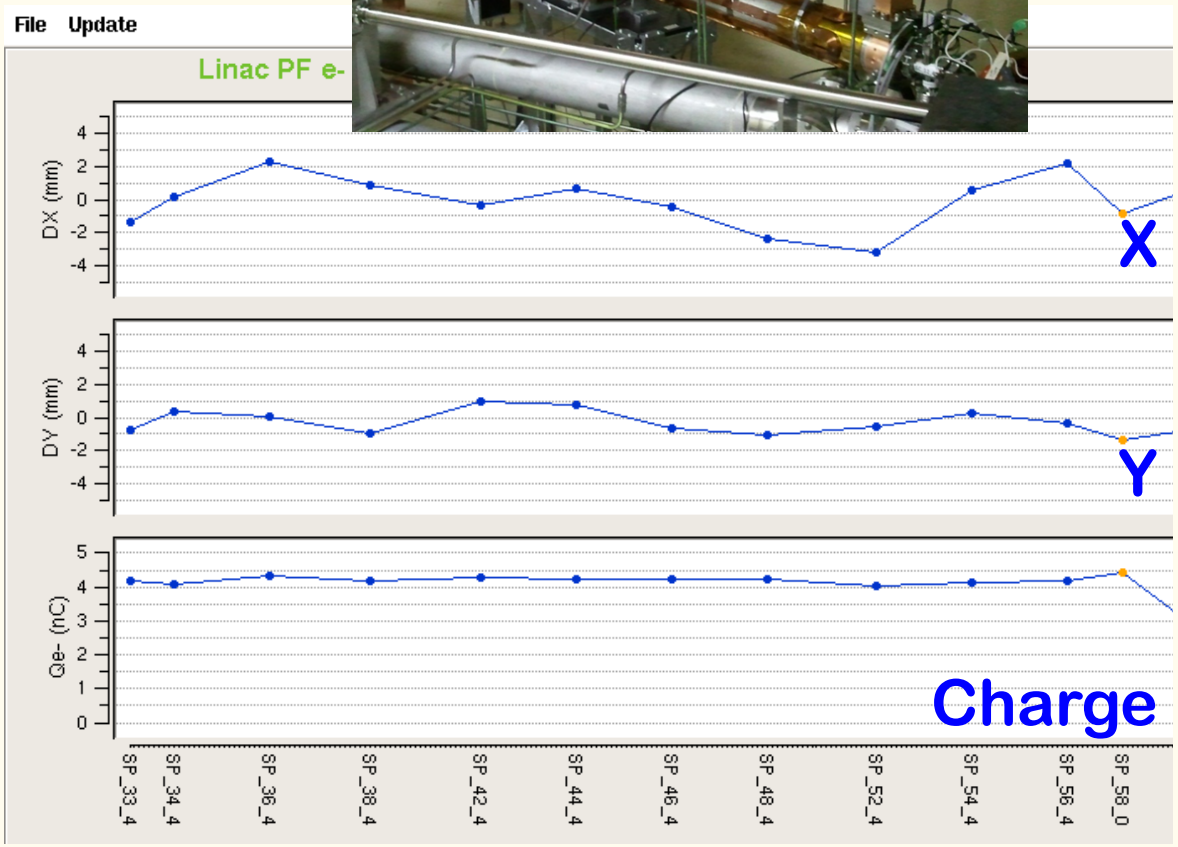
- **Cavity : better focusing field, higher gradient**
  - DAW (Disk and washer) type cavity
  - Development of quasi-travelling-wave side-coupled cavity as well
- **Test stands**
  - RFgun at A-1 is constructed with fiber laser for SuperKEKB
  - RFgun at 3-2 was used to inject into PF with proper synchronization
  - Long-period demonstration will be performed

Beam Acceleration Test (RF-gun)

- **Step-by-step beam tests**
  - 4.5nC 240m acceleration
  - Fiber-laser-based RF-gun



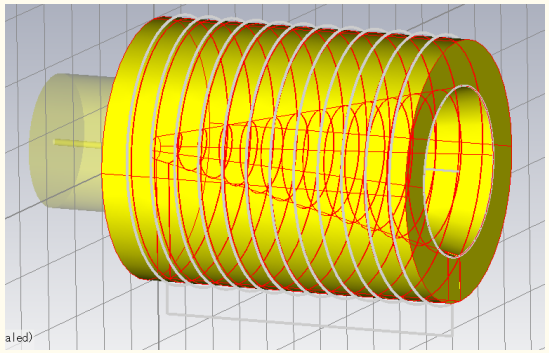


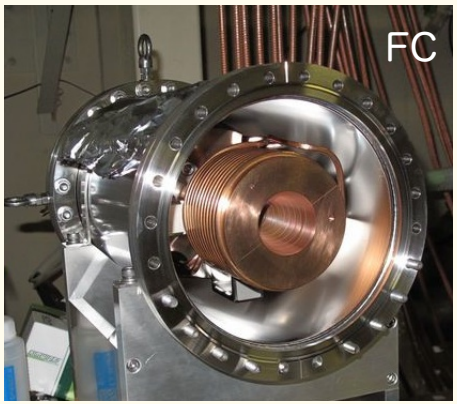


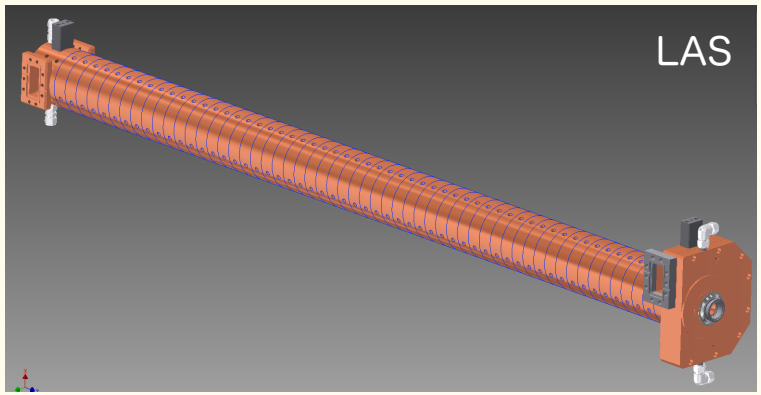
Positron Capture Section Development

Kamitani et al.

- **Flux concentrator (FC)**
  - Collaborations with BINP, IHEP and SLAC
  - Finalized optimization of field and mechanical design
  - Fabricated 1st version of 2nd generation, being tested
- **Large-aperture S-band (LAS) cavity structure**
  - Positron capture tracking simulation
  - L-band structure as backup with co-linear load
- **Magnet design and fabrication**
  - Solenoid and pulsed steering and quad magnet system
- **Reliability**
  - Strategy for failed component replacement with detachable girder, etc
  - Acceleration gradient distribution and optimization with backups







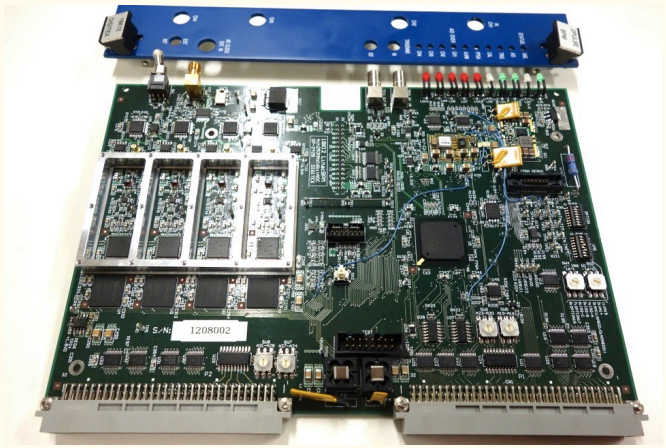
Beam Monitors: BPM and WS

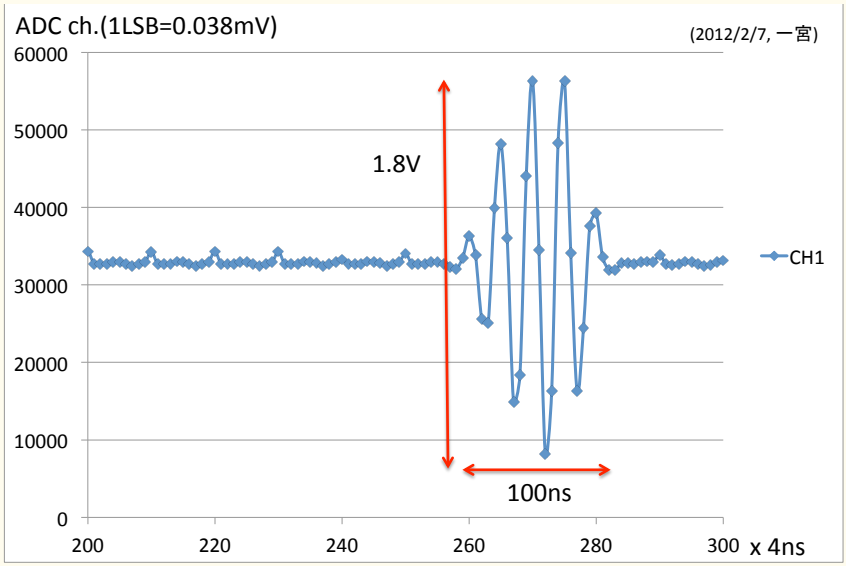
Suwada et al.

- Limited performance with present 8-bit 10GS/s digitizers (oscilloscopes)

New BPM readout for precise orbit/emittance controls

- Fast attenuator for 0.1-10nC (SuperKEKB, PF, PFAR) dynamic range
- Helical BSF (300MHz) for 2-bunch (96ns apart) readout
- 16bit 250MS/s ADC, FPGA data processing
- 50Hz event-control synchronization

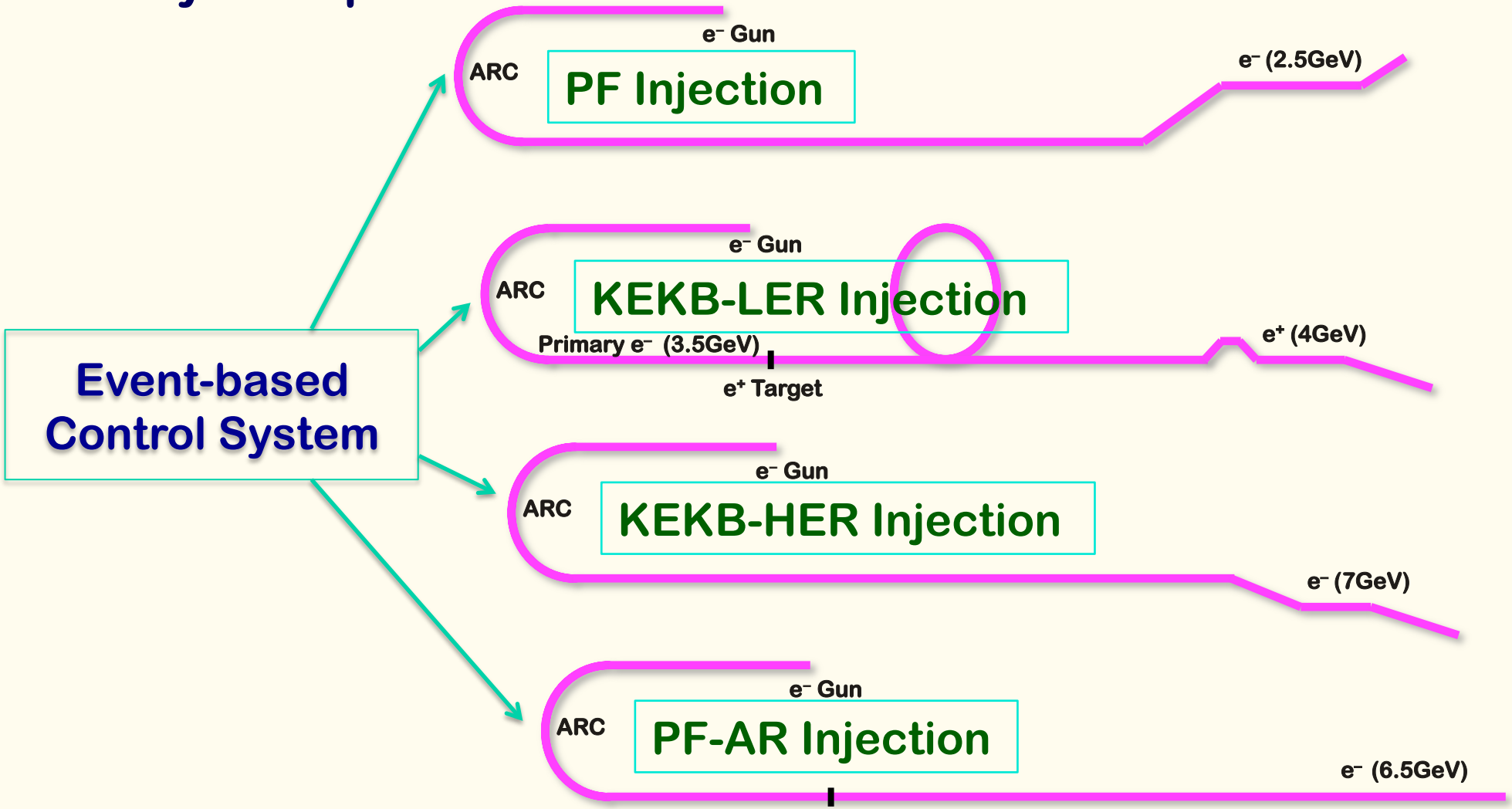




New wire scanner readout was also developed

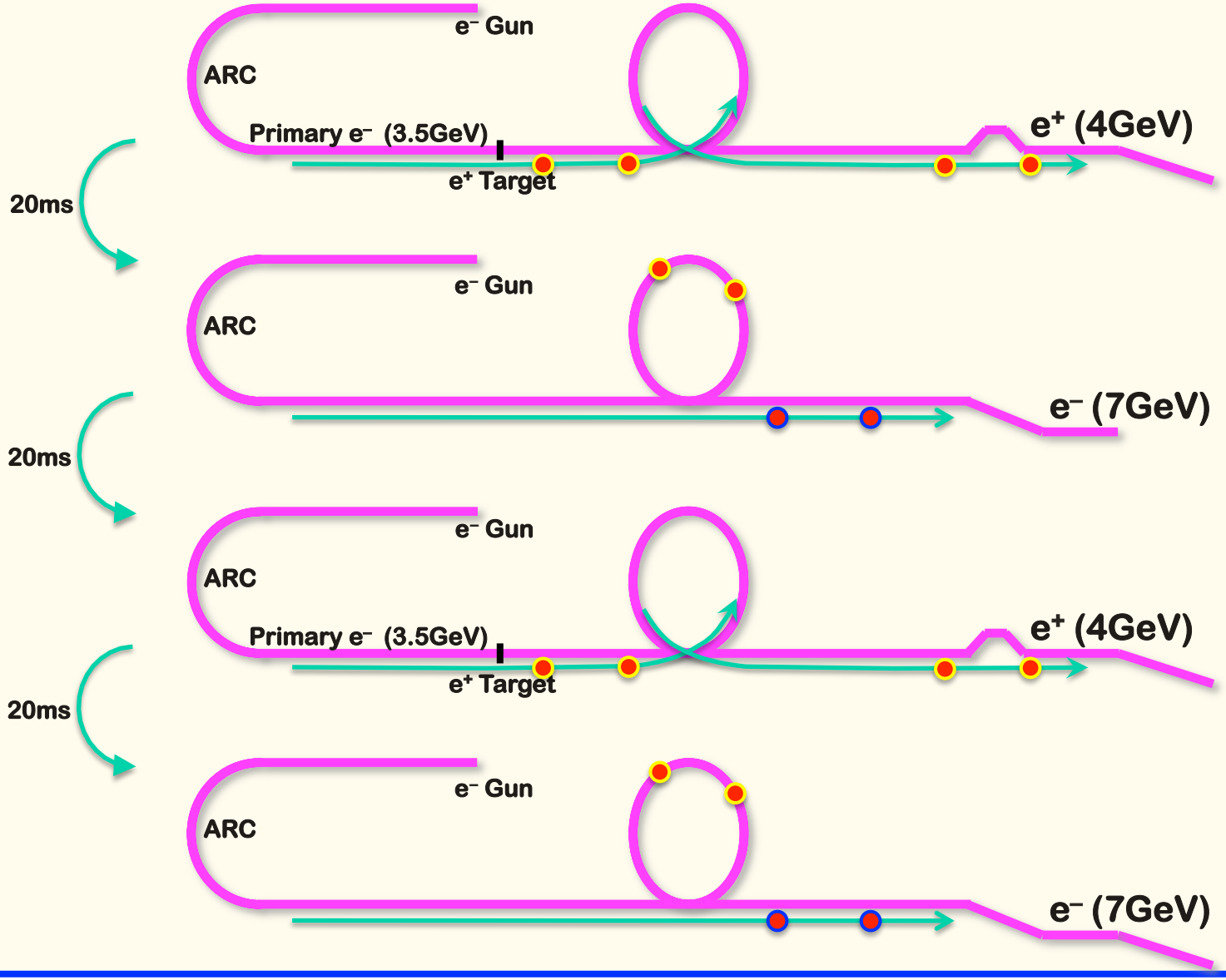
Single Machine, Multiple Virtual Accelerators (VAs)

- Simultaneous injection, one of the VAs is active at a time
- Independent parameter set for each VA, ~200 parameters are switched every 20ms pulse



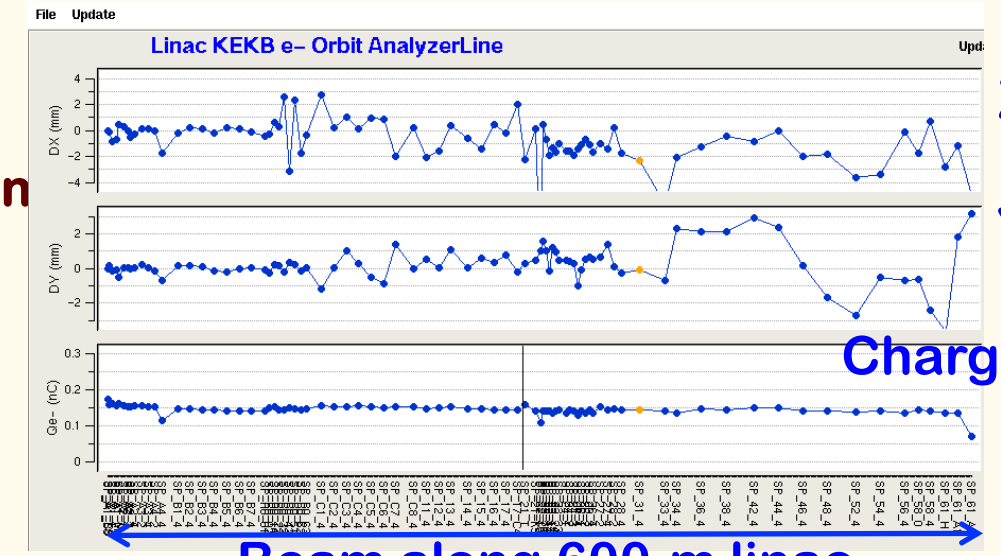
Example of Beam Mode Pattern : e⁺ 25Hz / e⁻ 25Hz

- Interleaved e+ and e-, dependency between pulses mostly decoupled
- With bucket selection at the both DR and MR



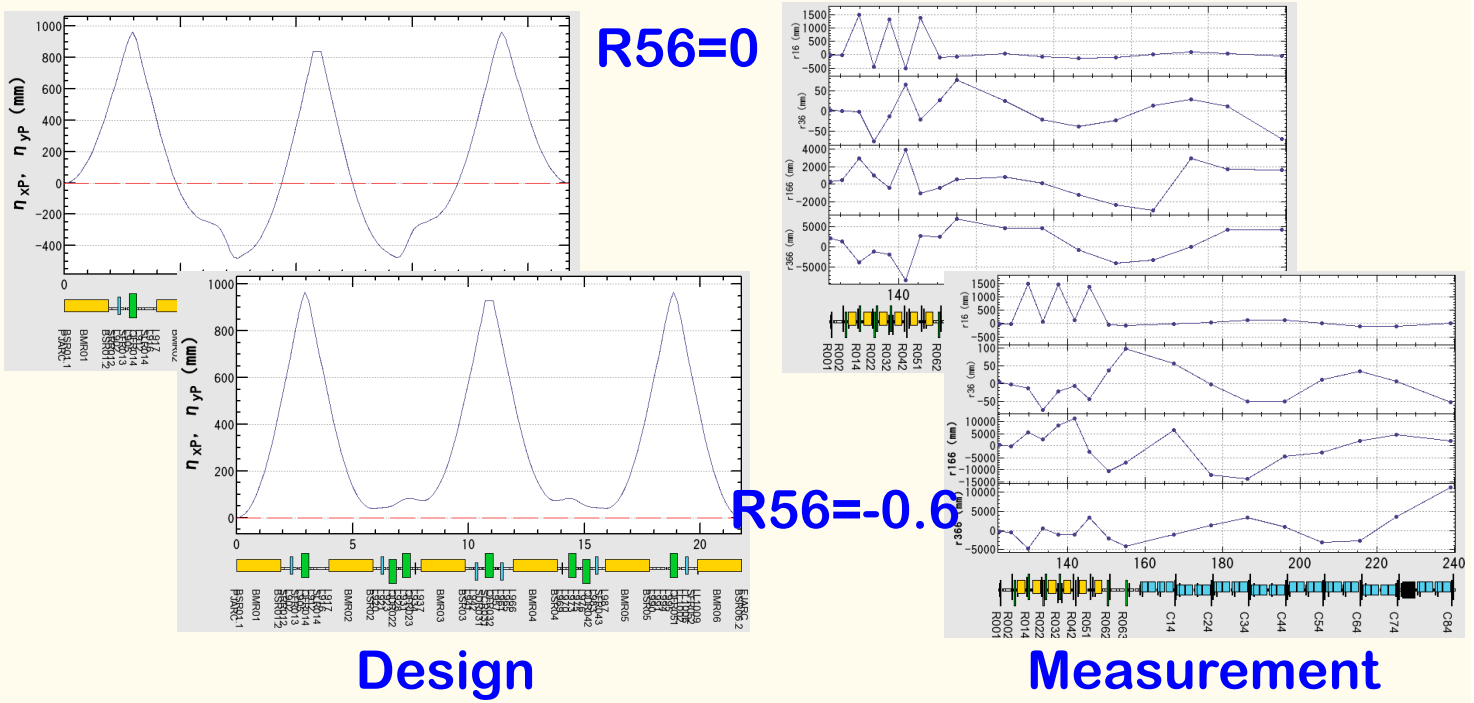
Preliminary Beam Tests in Autumn 2012

- Beam test along 600-m Linac
- for the first time after the earthquake
- Latter half was tuned for PF/PFAR injection
- Alignment will be recovered by 2014



- For energy spread optimization
- Longitudinal beam profile management
  by photo-cathode RF-gun (30ps square shape)
- and bunch compression at the middle of linac are crucial

  - Preliminary R56 control was performed
  - Design and measurement of dispersion function with R56=0 and R56=-0.6



Schedule

- Winter 2013 : DR switchyard / DR tunnel construction
- Spring 2013 : A1-RF-gun, Alignment
- Summer 2013 : Installation of many components
  - ECS, FC (gen.2), DC solenoids, Klystron modulators, WS, etc
- Autumn 2013 : e– then e+ commissioning (limited current)
  - Half Linac: PF injection, Day: construction, Night: commissioning
- Spring 2014 : Pulsed steering, Alignment
- Summer 2014 : Installation of additional components
  - Cooling water, FC (gen.3), BPM, Pulsed magnets, New PFAR BT, etc
- Autumn 2014 : Linac Full Commissioning
- Winter 2015 : MR (then DR) injection commissioning
- …

Summary

- Much progress in disaster recovery and construction
- Development for T=0 (~1nC) was mostly completed
- Development for full spec. will be tested
- Many development items are connected with beam emittance and energy spread management
- Still expecting many challenging items to overcome
- Injector should start at first !
- With some *Phronesis* (Greek: practical wisdom, ability to understand the universal truth), we believe we can achieve the target

Thank you

Review 2013 and Reviewer's Comments (preliminary)

- **Overview of Injector Construction Status and Schedule**
  - The Linac Group setup prioritized work scopes with back-up options. The overall scheme is very logical, and the committee is convinced by their near term plan.
- **RF gun**
  - Install and test the QTWSC gun as planned. Operate it for a long period to check its reliability and performance stability.
- **Alignment and Support**
  - The Linac alignment and support is less mature. There should be some effort to accelerate this to avoid the possibility of impacting commissioning.
- **Positron Source**
  - The target size should fit into the available space between the yoke and flux concentrator. The discharge waveform of the modulator for the flux concentrator with cables should be checked experimentally.
- **Commissioning (of Electron Beam)**
  - After identifying the parameters that the linac electron beam needs to meet, a detailed set of procedures should be made for each parameter. An overall time schedule to carry out these procedures should be developed to match times needed by the four rings.

Review Items in 2012 and Reviewer's Comments

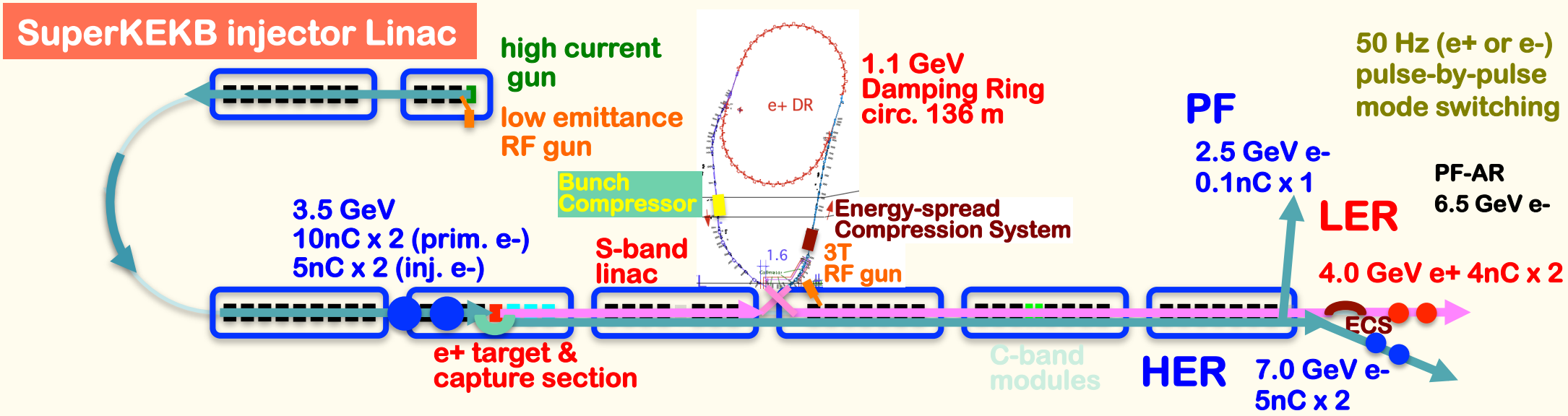
- **Linac disaster recovery**
  - Earthquake is a natural disaster, a *Force Majeure*. In view of the manpower shortage in the Linac and Storage Ring groups, the committee suggests that the management team look into timeline, milestones and resources, and revise the schedule accordingly.

- **RF gun and low-emittance transport**
  - Aggressively pursue a demonstration of the QTW gun with LaB_6 cathode and the full power laser.

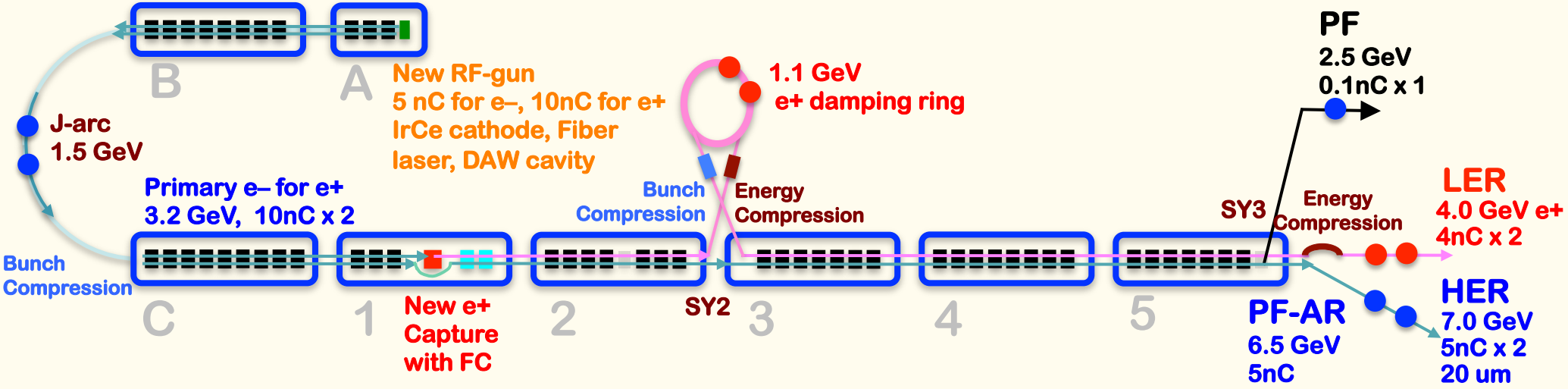
- **Positron source**
  - CSR effects in the bunch compressor should be examined. A protection scheme for the target should be developed at least conceptually.

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**
  - SuperKEKB e^-/e^+ rings, and light sources of PF and PF-AR
  - Improvements to beam instrumentation, low-level RF, controls, timing, etc



Linac Upgrade for SuperKEKB



- As a high-field (several Tesla) pulsed solenoid for the positron source of the SuperKEKB injector, KEK is going to fabricate a SLAC-type flux concentrator.
- Technical advices from the IHEP experts and design information by the IHEP drawings are quite useful in the development.

Flux Concentrator