Upgrade of KEK Electron/Positron Linac for the Both SuperKEKB and Light Sources

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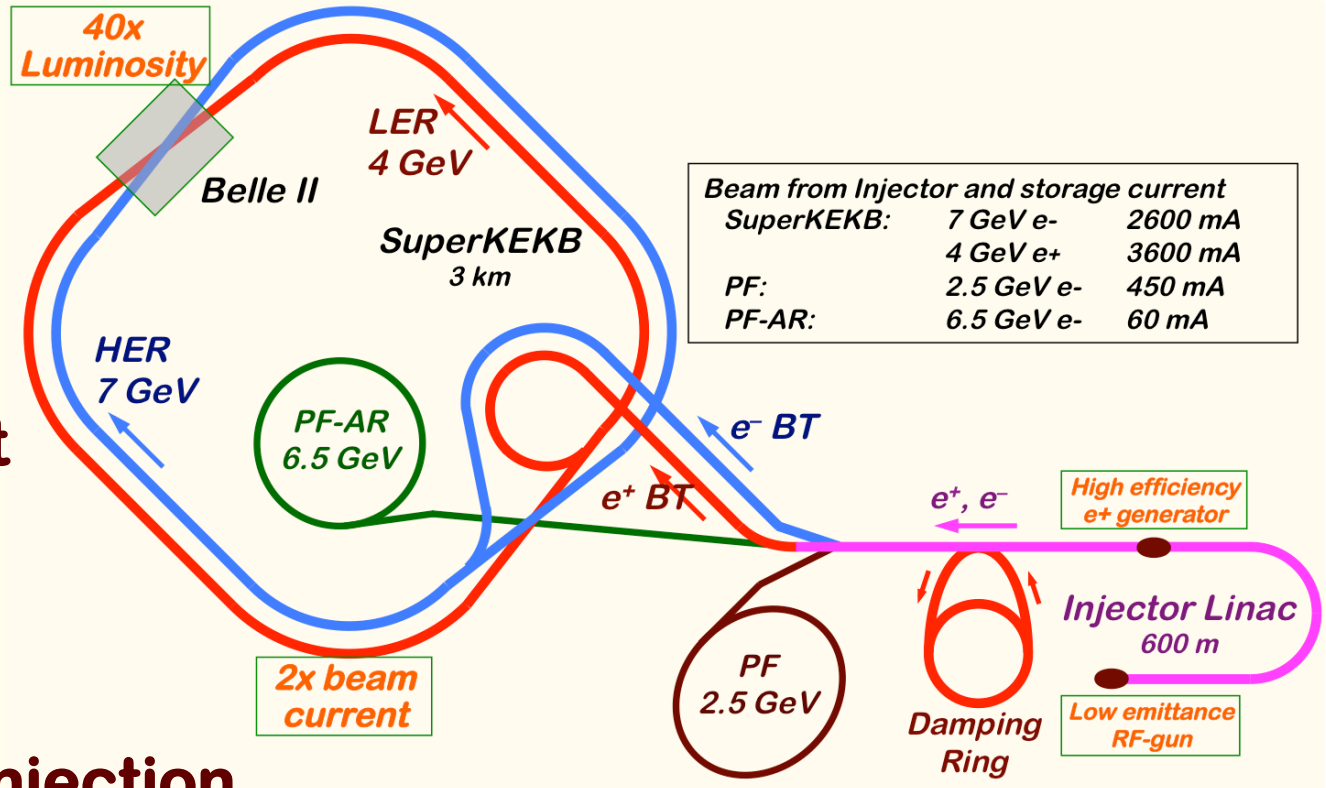
Mission of electron/positron Injector in SuperKEKB

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



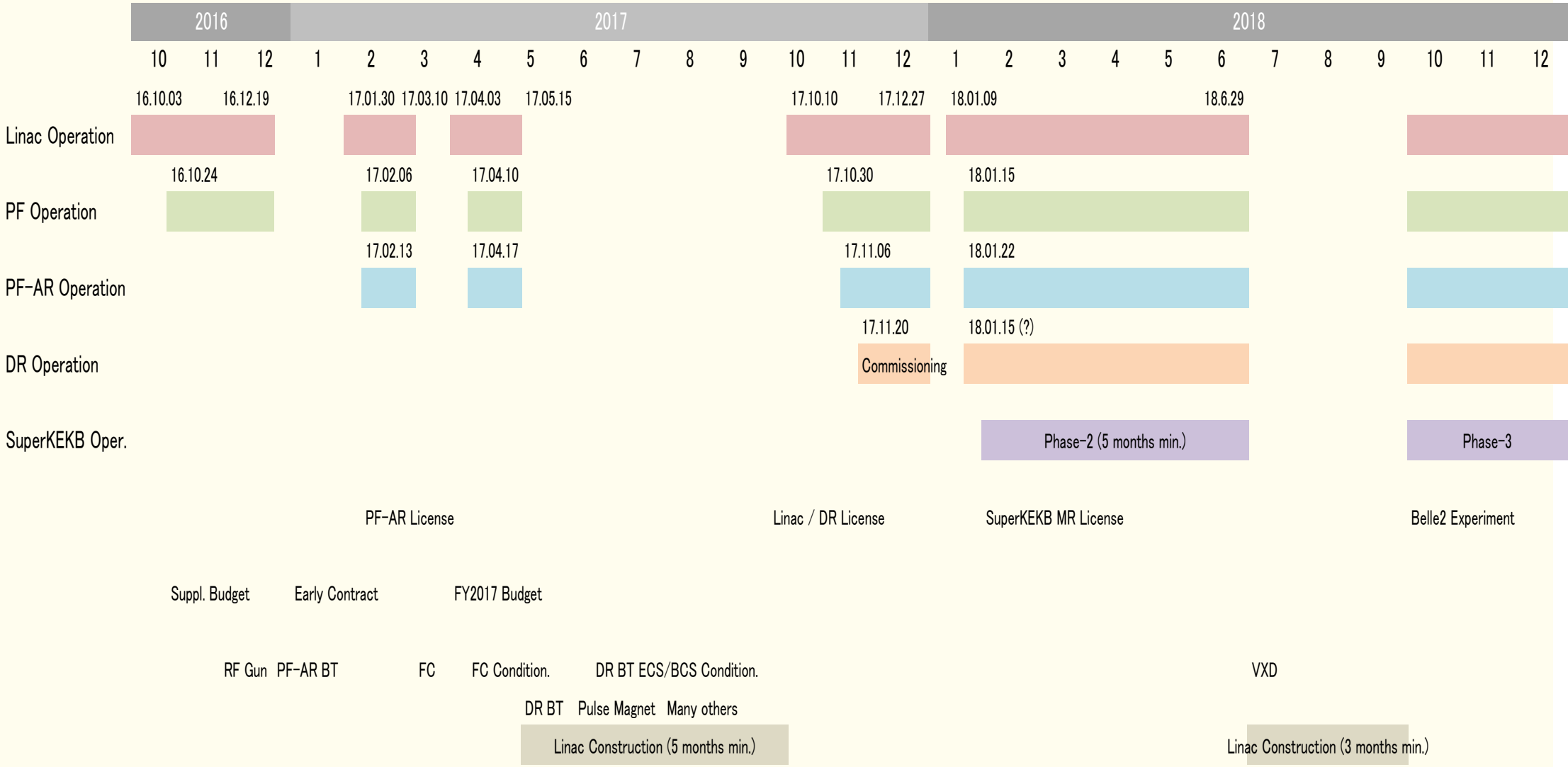
Required injector beam parameters

Stage	KEKB (2010)		Phase-I (2016)		SuperKEKB (final)	
Item	e+	e–	e+	e–	e+	e–
Energy	3.5 GeV	8.0 GeV	4.0 GeV	7.0 GeV	4.0 GeV	7.0 GeV
Bunch charge	Primary e-10nC → 1 nC	1 nC	Primary e-8nC → 0.4 nC	1 nC	Primary e-10nC → 4 nC	5 nC
Norm. Emittance ($\gamma\beta\varepsilon$) (μrad)	2100	200	2400	150	100/20 (Hor./Ver.)	50/20 (Hor./Ver.)
Energy spread	0.125%	0.125%	0.5%	0.5%	0.1%	0.1%
No. of Bunch / Pulse	2	2	2	2	2	2
Repetition rate	50 Hz		25 / 50 Hz		50 Hz	
Simultaneous top-up injection	3 rings (KEKB e–/e+, PF)		No top-up		4+1 rings (SuperKEKB e–/e+, DR, PF, PF-AR)	

Linac Injector Status

- Phase-3 (Collision exp.) should not be delayed
- Injector construction was delayed about 2 years because of resource availability
- Important equipment was postponed until FY2017
  - Most of damping-ring related epuipment
  - Many of lower-emittance related equipment
    - including 30 pulsed focusing magnets, 36 steering magnets, ~13 girders
- Minimum of 5 months required to purchase, fabricate, install and test
- Supplemental budget in FY2016 is not enough
  - Best effort ! (asuming enough budget in FY2017)
  - KEKB construction
    - Linac shutdown for 9 months in 1997, after many devices were fabricated in 1996

Possible Rescheduling

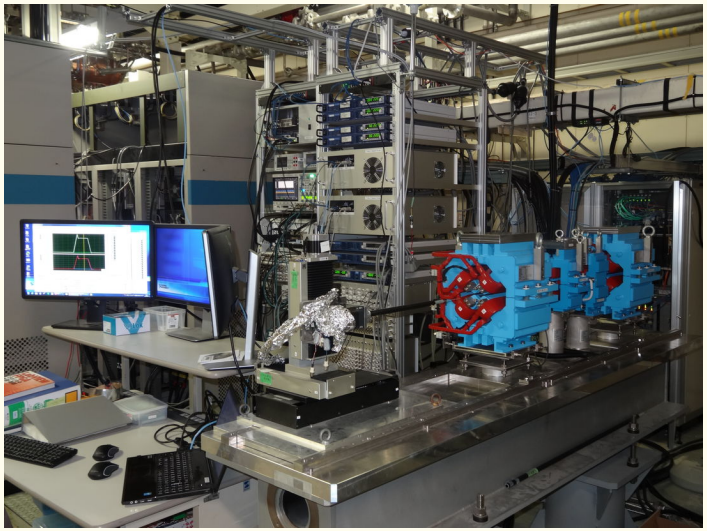


Pulsed magnet installation

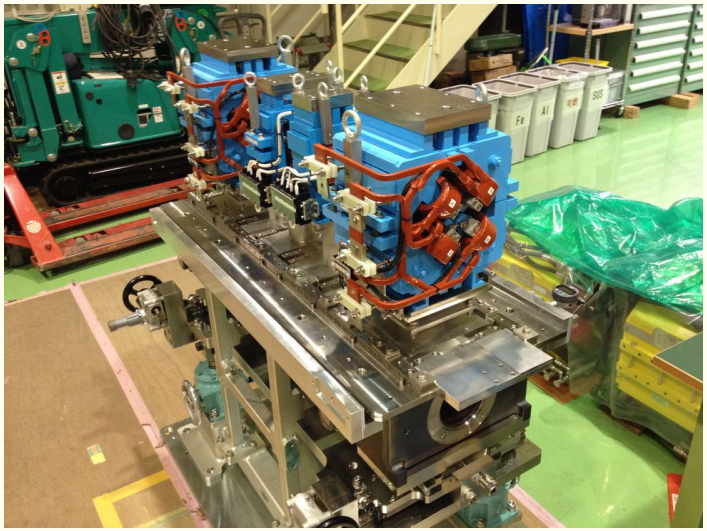
- 30 quads and 36 steerings and ~13 girders will be installed at summer 2017
  - 1 mH, 330 A, 340 V, 1 ms
  - Energy recovery to save power (~75%)
  - Can change the magnetic field every pulse (50 Hz)
    - To support PPM operation or virtual accelerators
- Magnets are ready
- Power supply tests were OK
- Pulsed power supplies and girders will be mass-produced in 2017

Pulsed magnet development

- **Pulsed magnet test stand**
  - Long-term stability was confirmed



- **Successful beam tests**
  - 25-Hz (50-Hz) switching



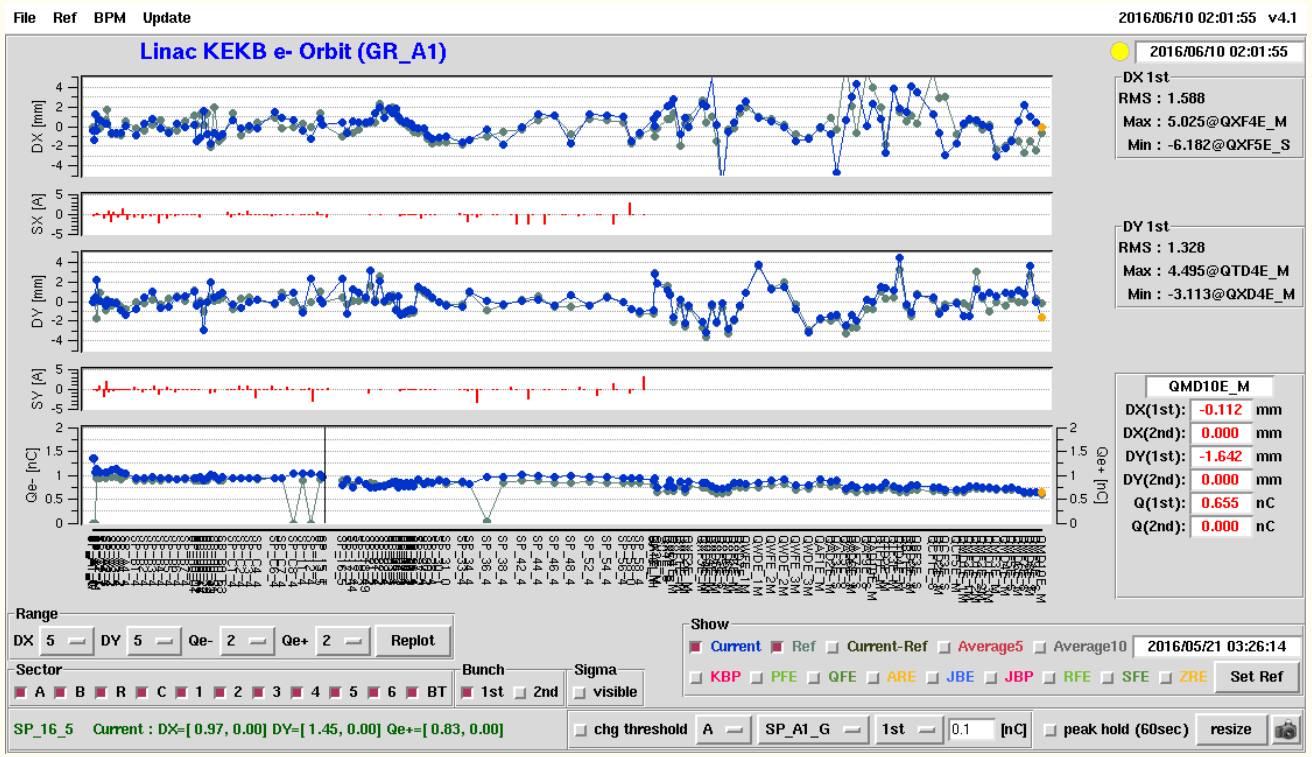
- **Girders were designed**
  - Waiting for mass-production
  - Ready for Phase-3 specification

Photo cathode RF gun

- **Successful HER injection during Phase 1**
  - **For 11 days**
  - **Synch. issues resolved**
  - **Emittance to be improved**

	Horizontal (projection)	Vertical (projection)
A1 chicane	28.3 (31.8)	26.4 (29.4)
A1 M	20.3 (20.8)	17.7 (18.3)
B sector dump	48.5 (52.7)	21.7 (22.2)

Emittance measurement



Bunch profile measurement

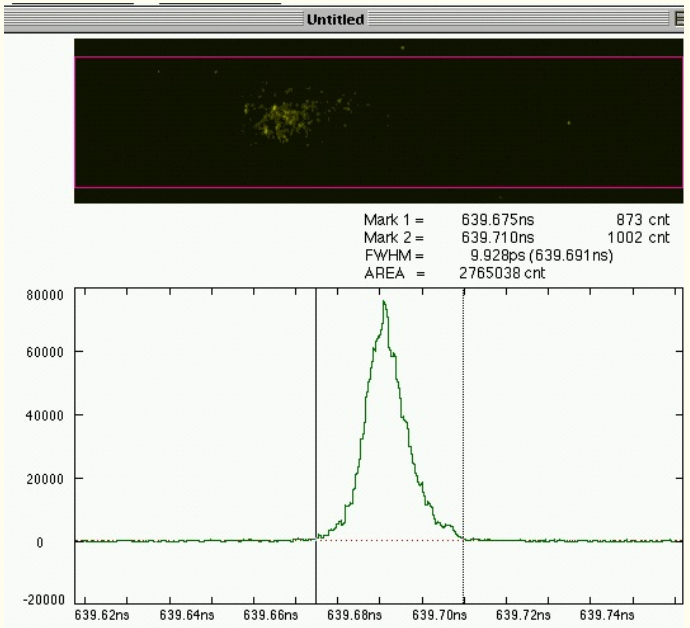
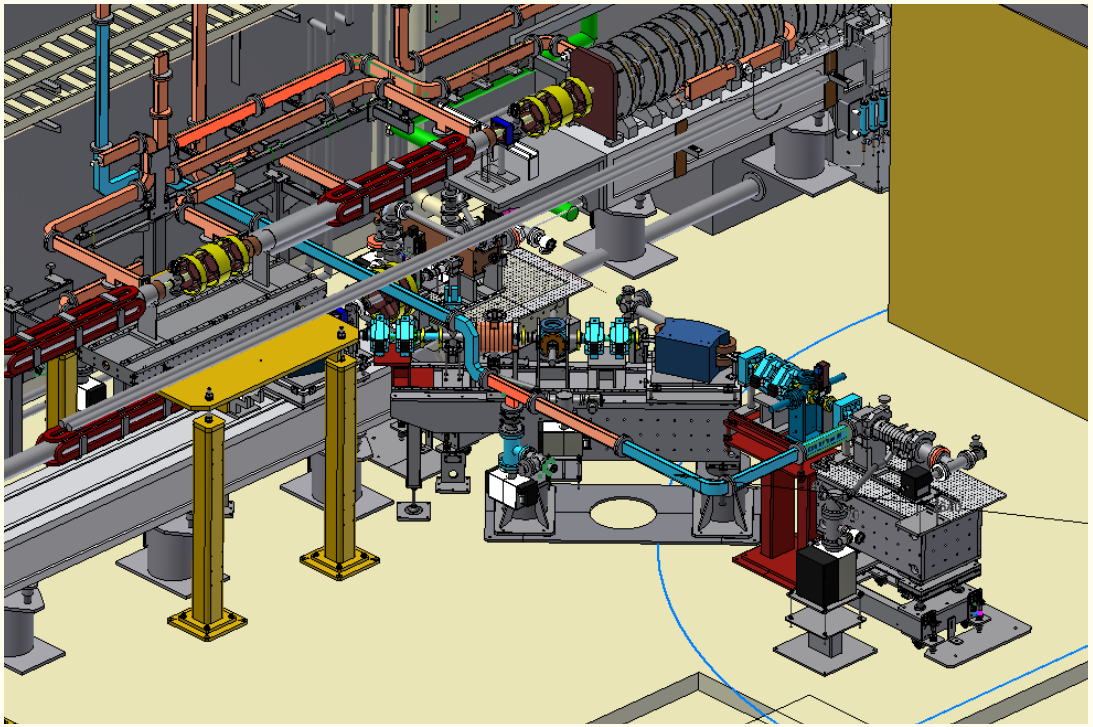
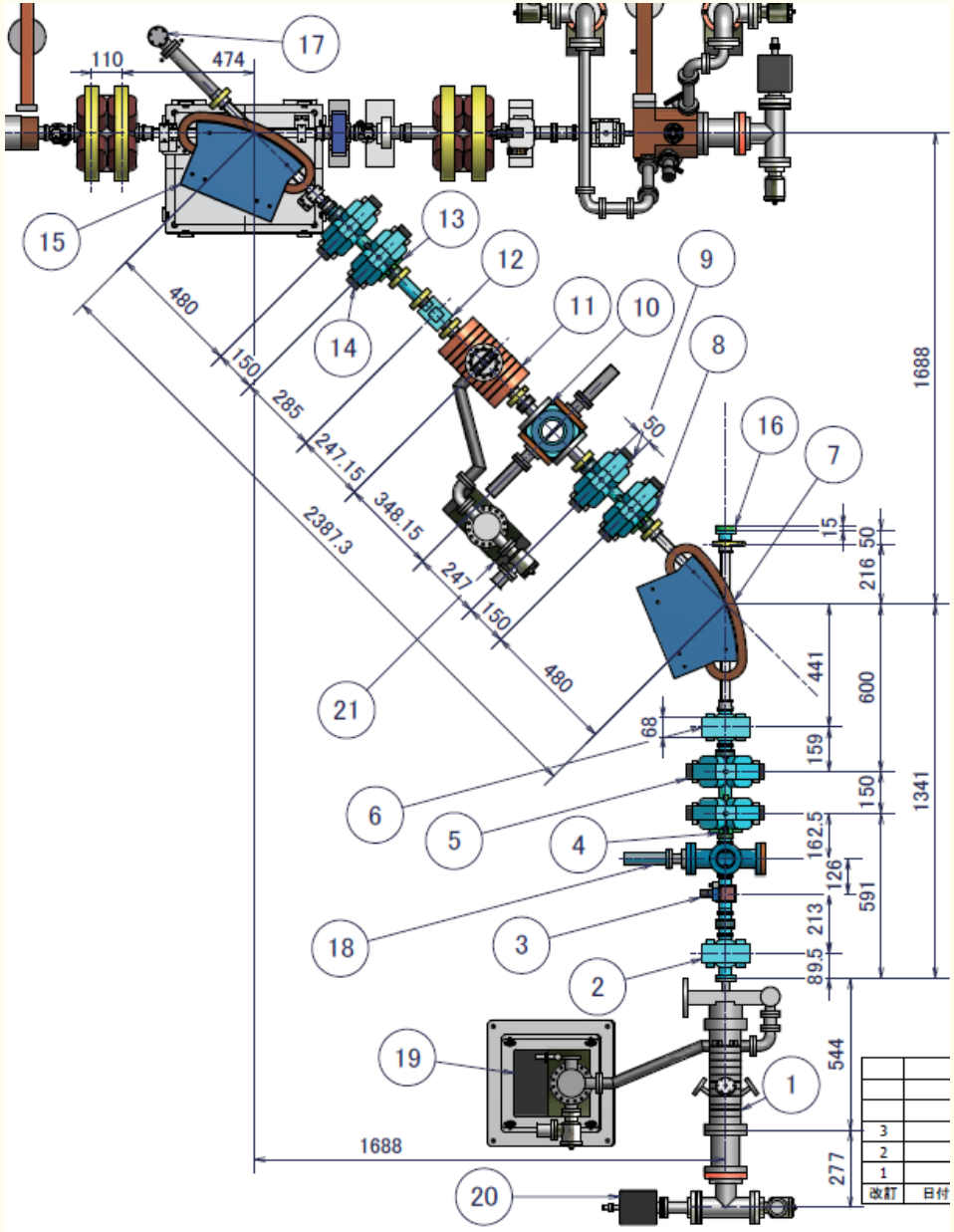


Photo cathode RF gun

- **Secondary RF gun installation**
  - Incorporate recommendations from review meetings
  - Laser, light guides, cavity, etc
  - Installed at the beginning of 2017

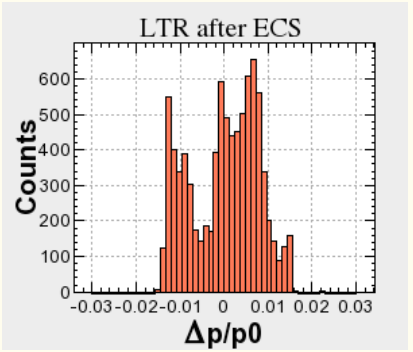




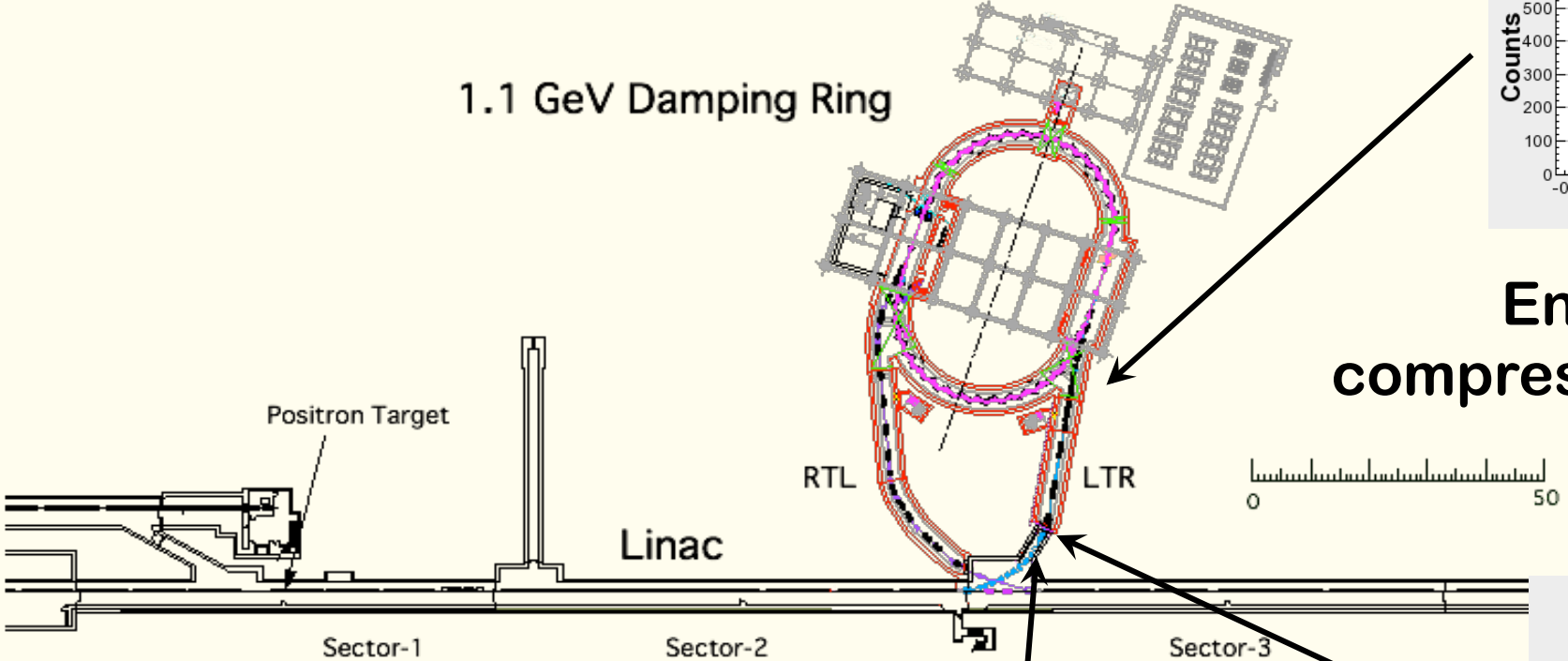
Damping Ring System Layout

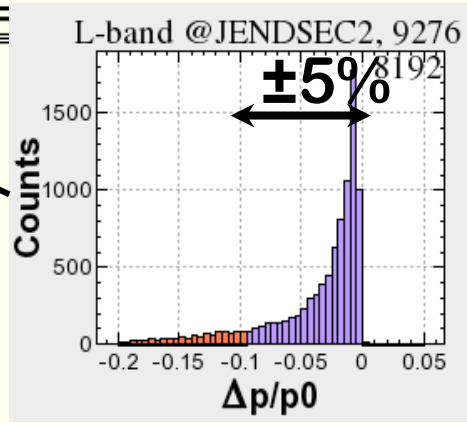
M. Kikuchi

±1.5%



Energy compression

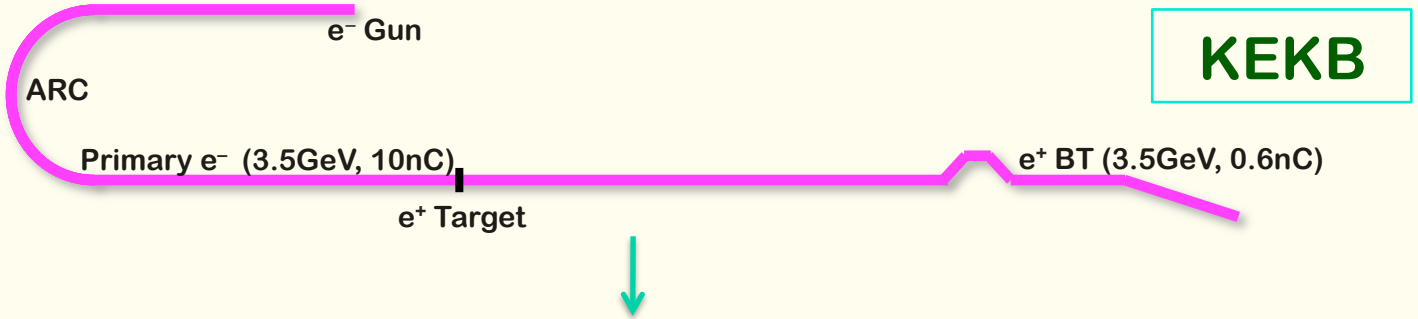




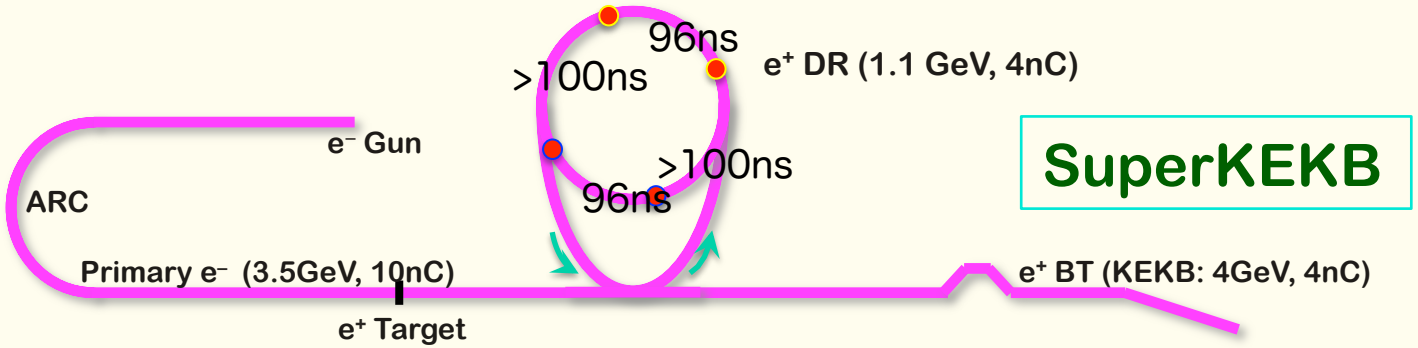
Collimators in the arc
20% is cut at tail

Bucket selection in Phase-2 with DR

- **Without DR, simply wait up to 5120 x 96 ns ~ 490 μs**
  - 96 ns : highest common frequency between linac – ring



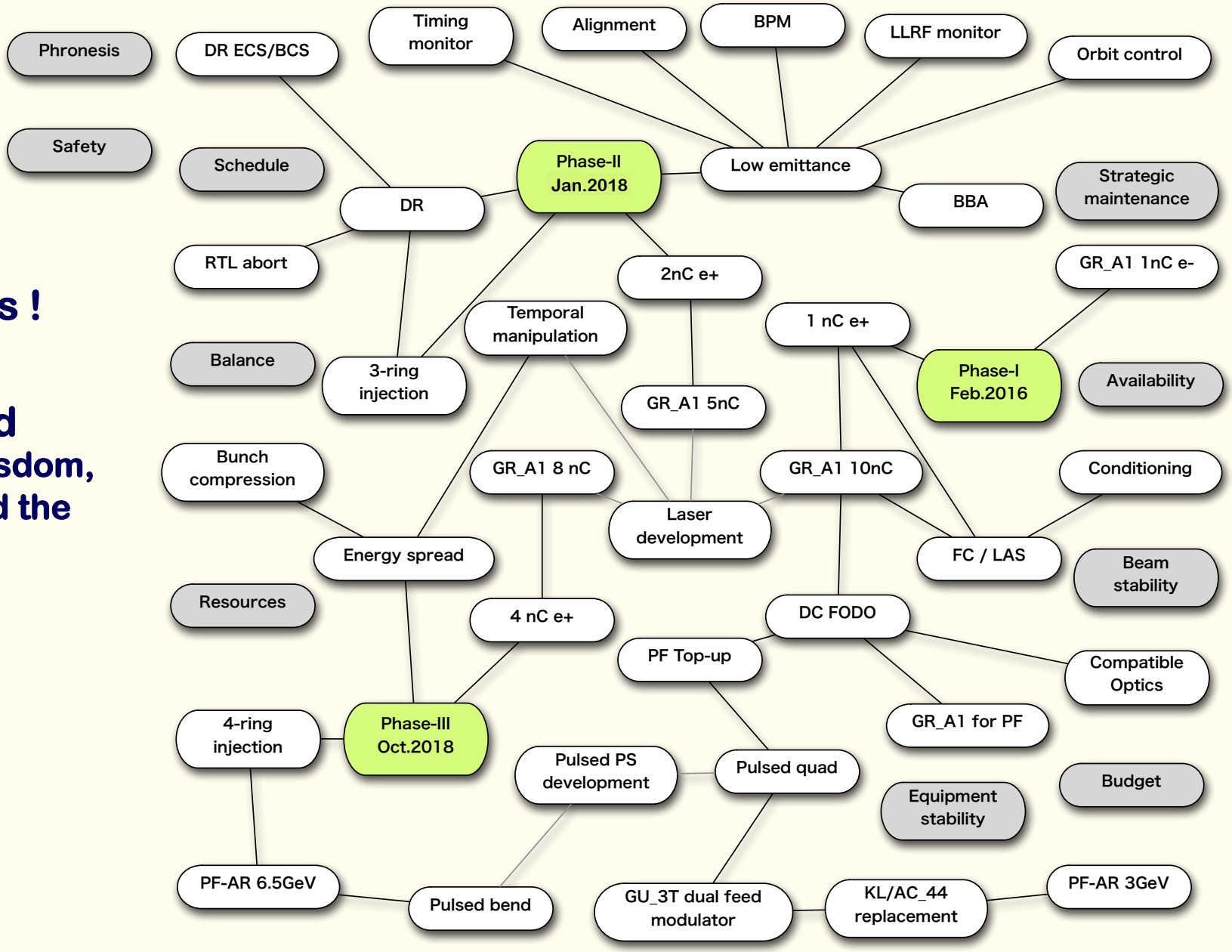
- **With DR, in order to select arbitrary bucket in MR, have to wait up to ~4.5 ms, even if a bucket in DR was carefully selected**
  - Power supply can wait only 2 ms, one of only 2798 buckets in 5120 buckets can be selected, may have to change LLRF condition at latter half of linac every pulse



  - Can be a big challenge in LLRF precision

Subjects to Consider

- **Have to consider too many subjects !**
- **Phronesis needed**
  (Greek: Practical wisdom, Ability to understand the Universal Truth)



Injection for Both Experiments of Light-source and B-factory

- Proper operation schedule to meet experimental characteristics of those storage rings
- Search for common ground with respect for those experiments
- Should find and confirm solutions in gradual changes
- Improve the machine using virtual accelerator concept, if applicable

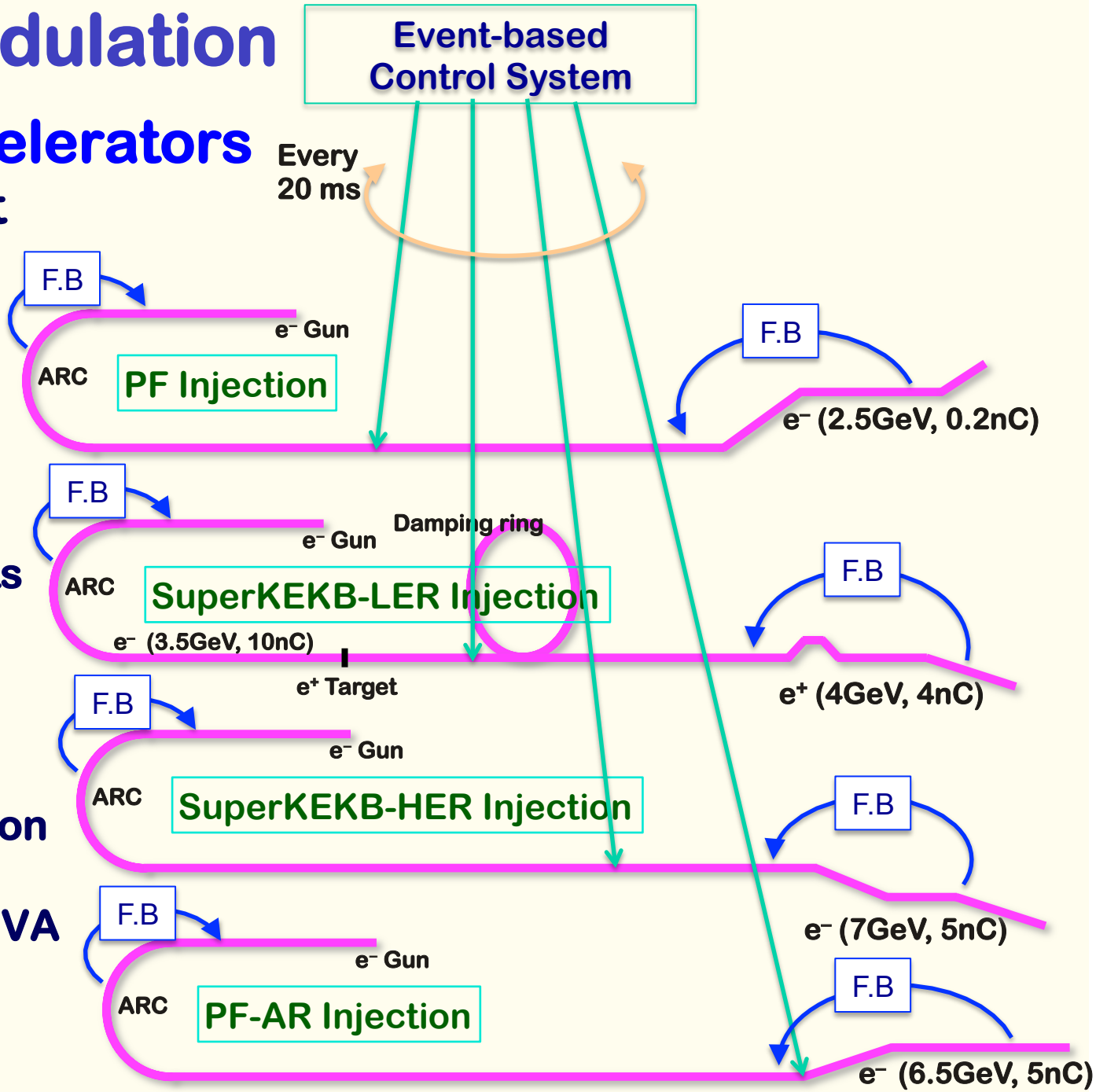
Pulse-to-pulse modulation

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

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

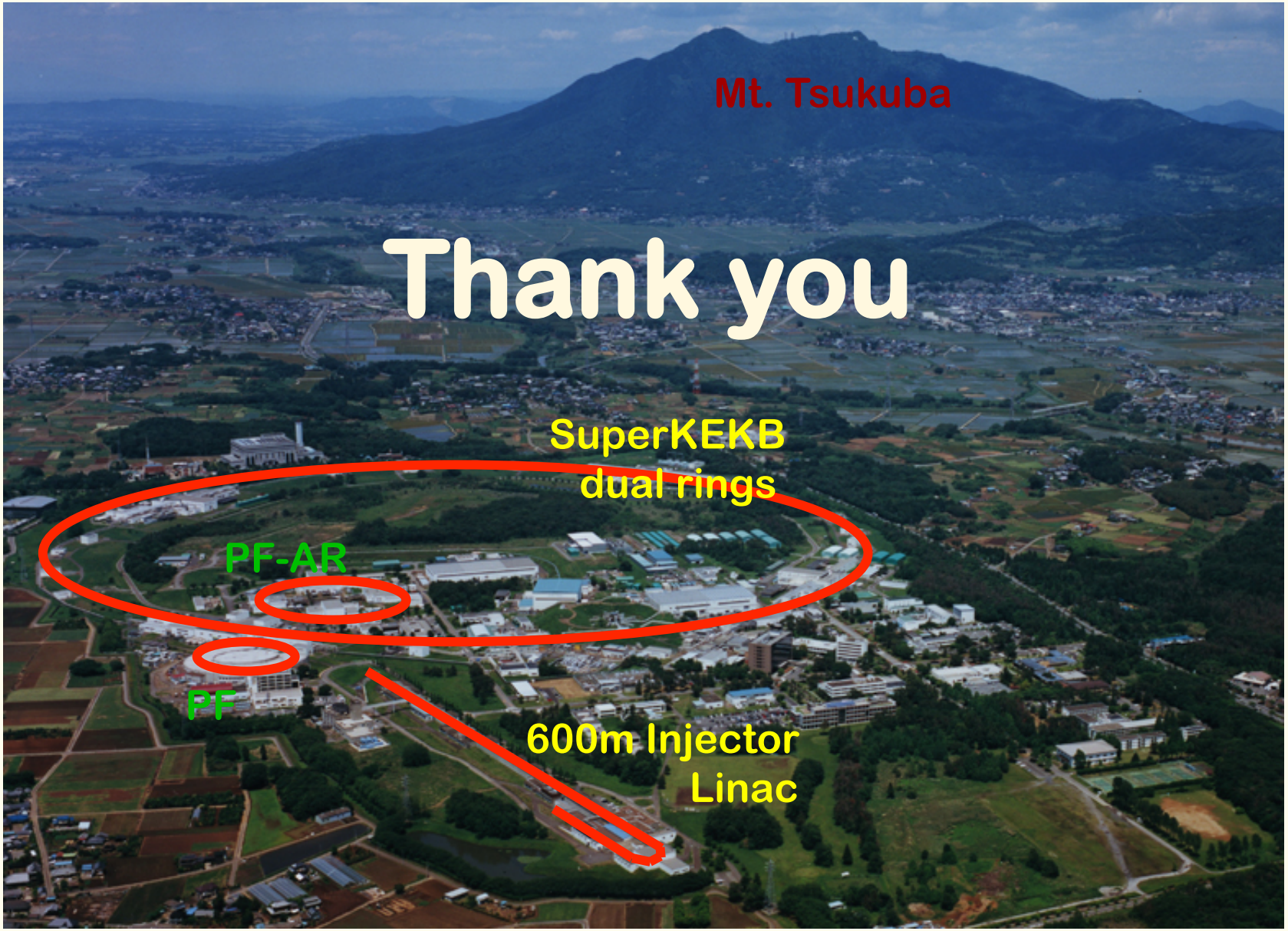
Independent parameter sets
for each VA (20ms)
>200 parameters
for equipment controls
many more
for beam instrumentation

maybe with additional PPM VA
of stealth beam
for measurement



Summary

- Injection into SuperKEKB is a challenge with higher beam charge and lower emittance
- Steady progress towards designed injection beam in steps
  - Alignment: almost confident on the required precision (0.1-mm local, 0.3-mm global), need to maintain for longer term
  - Positron generator: another license test, need discharge analysis
  - RF gun: following recommendations at review meetings
- Will install all of remaining equipment at summer 2017
- Will balance between final beam quality and progressive operation
- Will balance between particle physics and photon science
- With some Phronesis we may enjoy beam commissioning



Conference papers at <http://www-linac.kek.jp/linac/>