

An aerial photograph of the KEK Linac facility, showing various buildings, parking lots, and surrounding greenery. In the background, there are rolling hills and mountains under a clear sky. The text is overlaid on the top half of the image.

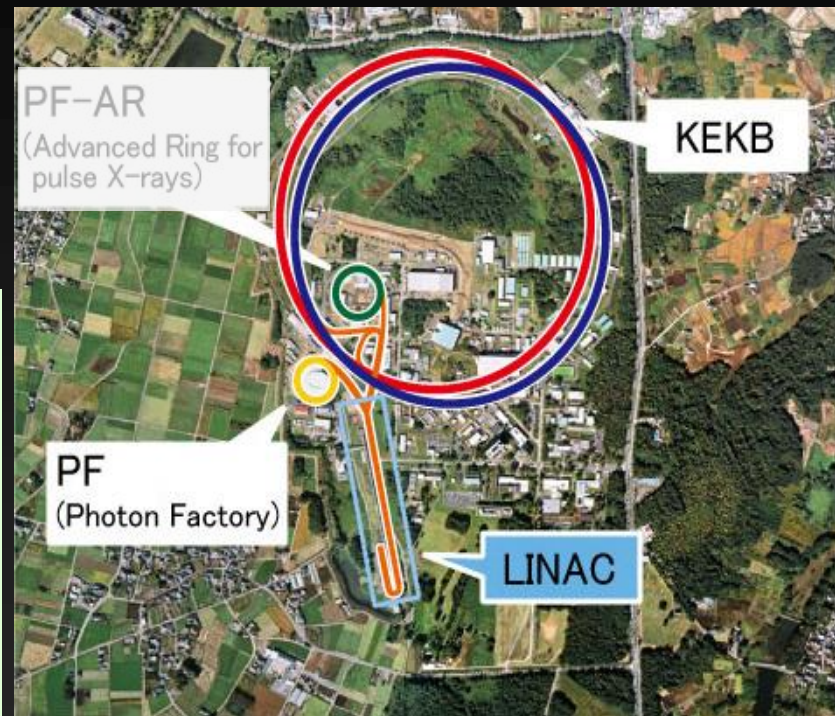
First Simultaneous Top-up Operation of Three Different Rings in KEK Injector Linac

Masanori Satoh (Acc. Lab., KEK)
for the injector upgrade group

Overview of Linac Beam Operation

Accelerator Complex in KEK Tsukuba Campus

- Linac
 - 600-m-long e-/e+ injector
 - 50 Hz
- Two Rings for High Energy Physics
 - KEKB
 - 8 GeV e- 1 nC x2 bunch
 - 3.5 GeV e+ 1 nC x2
 - (10 nC primary e-)
- Two Light Sources:
 - PF 2.5 GeV e- 0.1 nC
 - PF-AR 3 GeV e- 0.2 nC



Accelerator Complex in KEK Tsukuba Campus

- Linac
 - 600-m-long e-/e+ injector
 - 50 Hz



- Two Rings for High Energy Physics

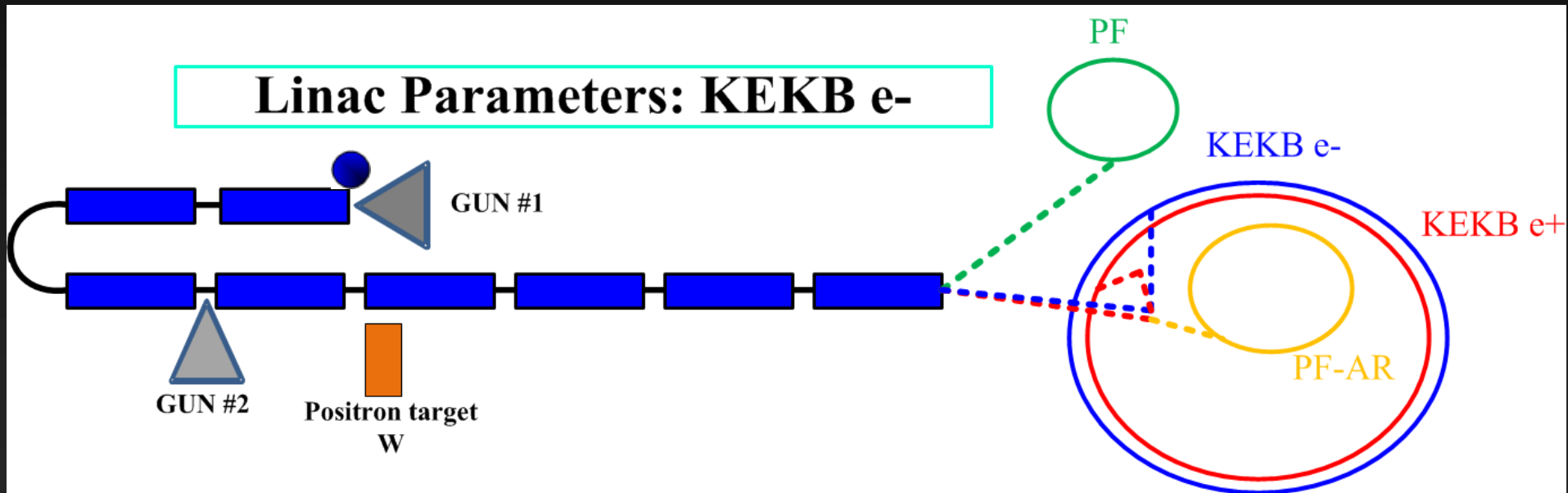
Four independent rings share only one injector.

- Two Light Sources:
 - PF 2.5 GeV e- 0.1 nC
 - PF-AR 3 GeV e- 0.2 nC

Linac Parameters

- Linac parameters should be changed to a optimized one for each beam injection.
 - Timing (trigger/delay)
 - RF phase
 - Magnet settings
 - Positron Target Insertion/Extraction
 - etc.

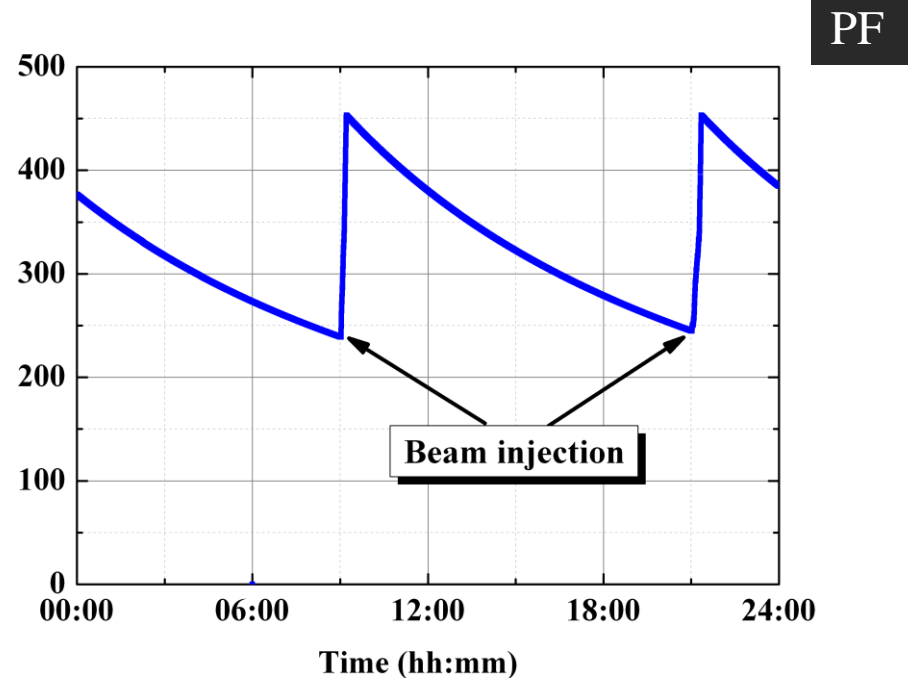
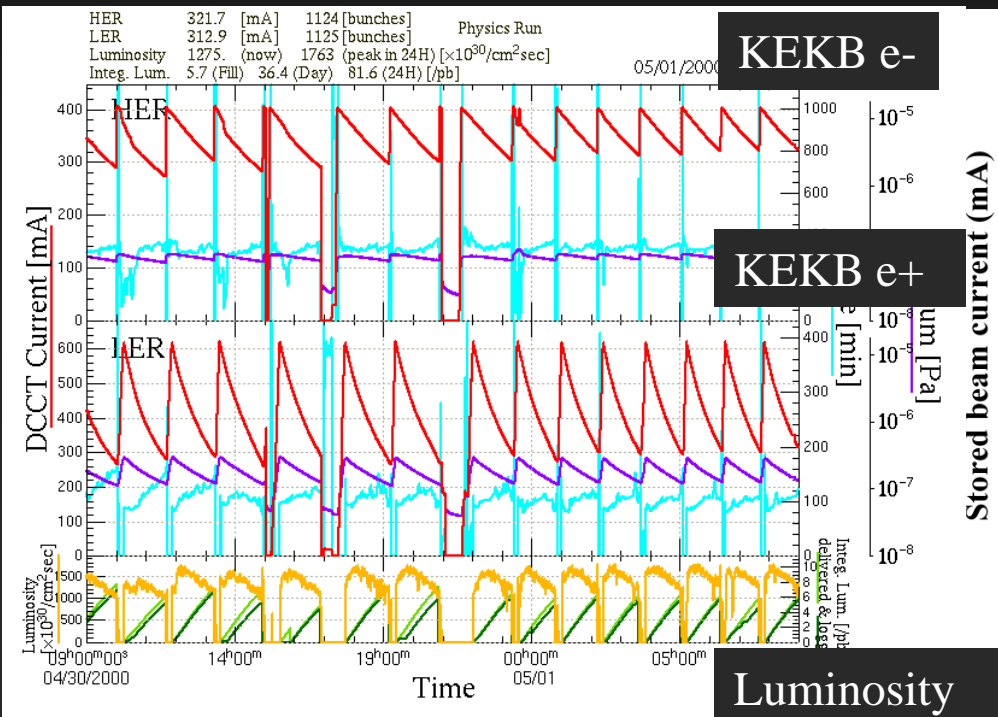
Linac Parameter Switch for KEKB e-



● e- 1 nC

Original Beam Operation for KEKB e-/e+, PF

- KEKB e-/e+ : every 90 min.
- PF (PF-AR) : twice daily



Improvement of Integrate Luminosity at KEKB

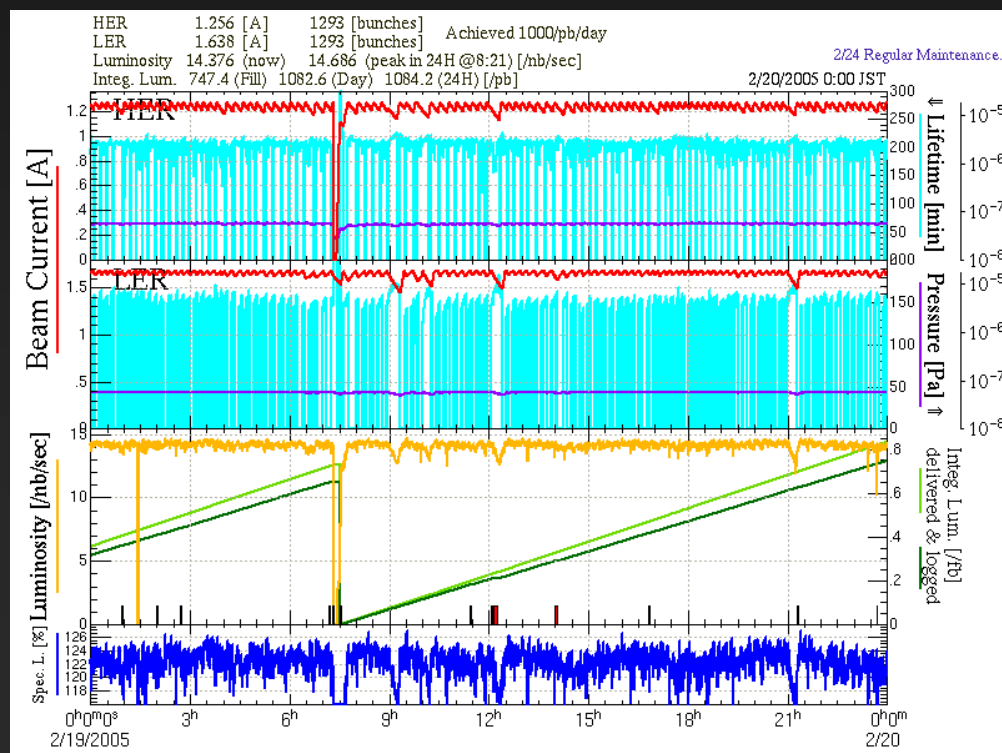
- Continuous Injection Mode (CIM)
 - Quasi Top-up Injection
- Linac Parameters are frequently switched

CIM Mode

KEKB e- mode
1 min.

Linac Bema-Mode Change
30 sec.

KEKB e+ mode
4 min.



More Improvement

- Much higher current stability is required for KEKB.

At the same time,

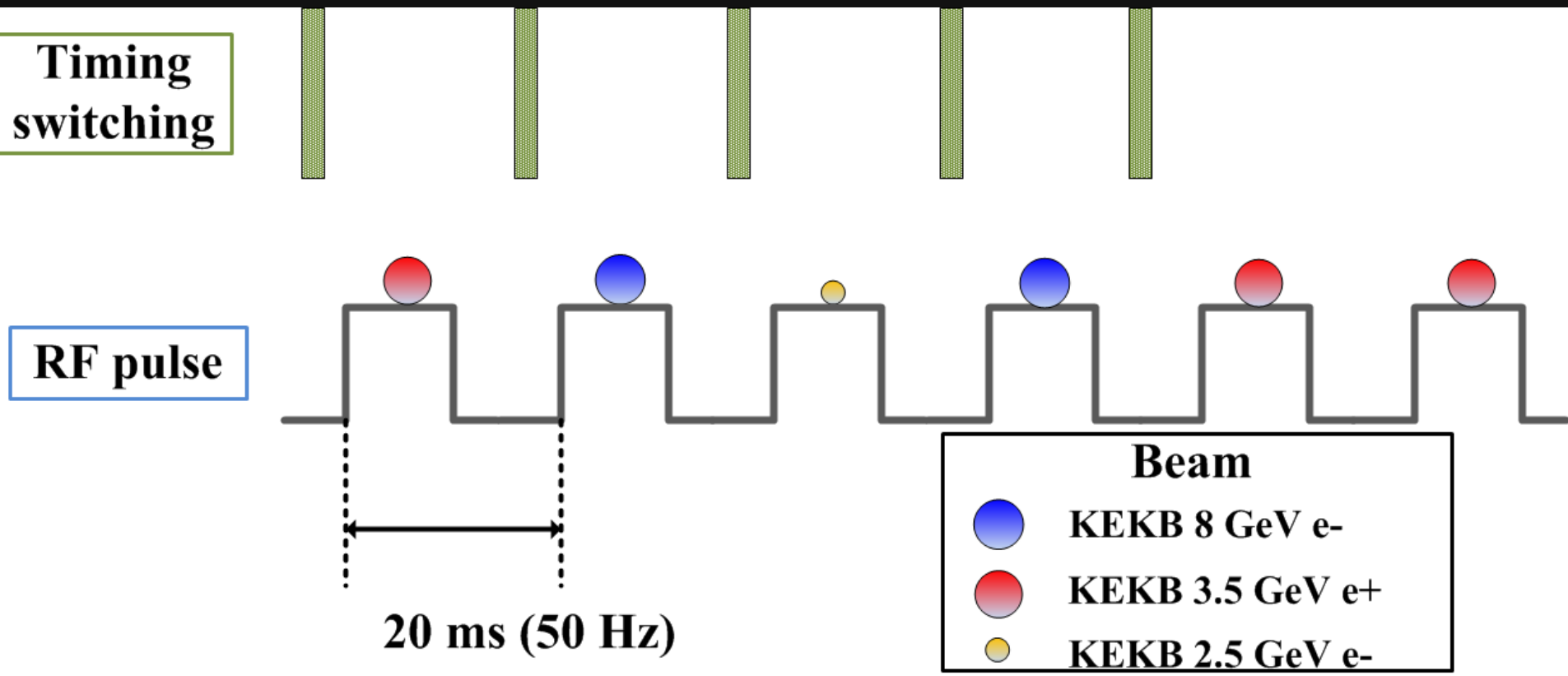
- PF Top-up is also strongly required.

Linac Upgrade: Simultaneous 3-rings Top-up

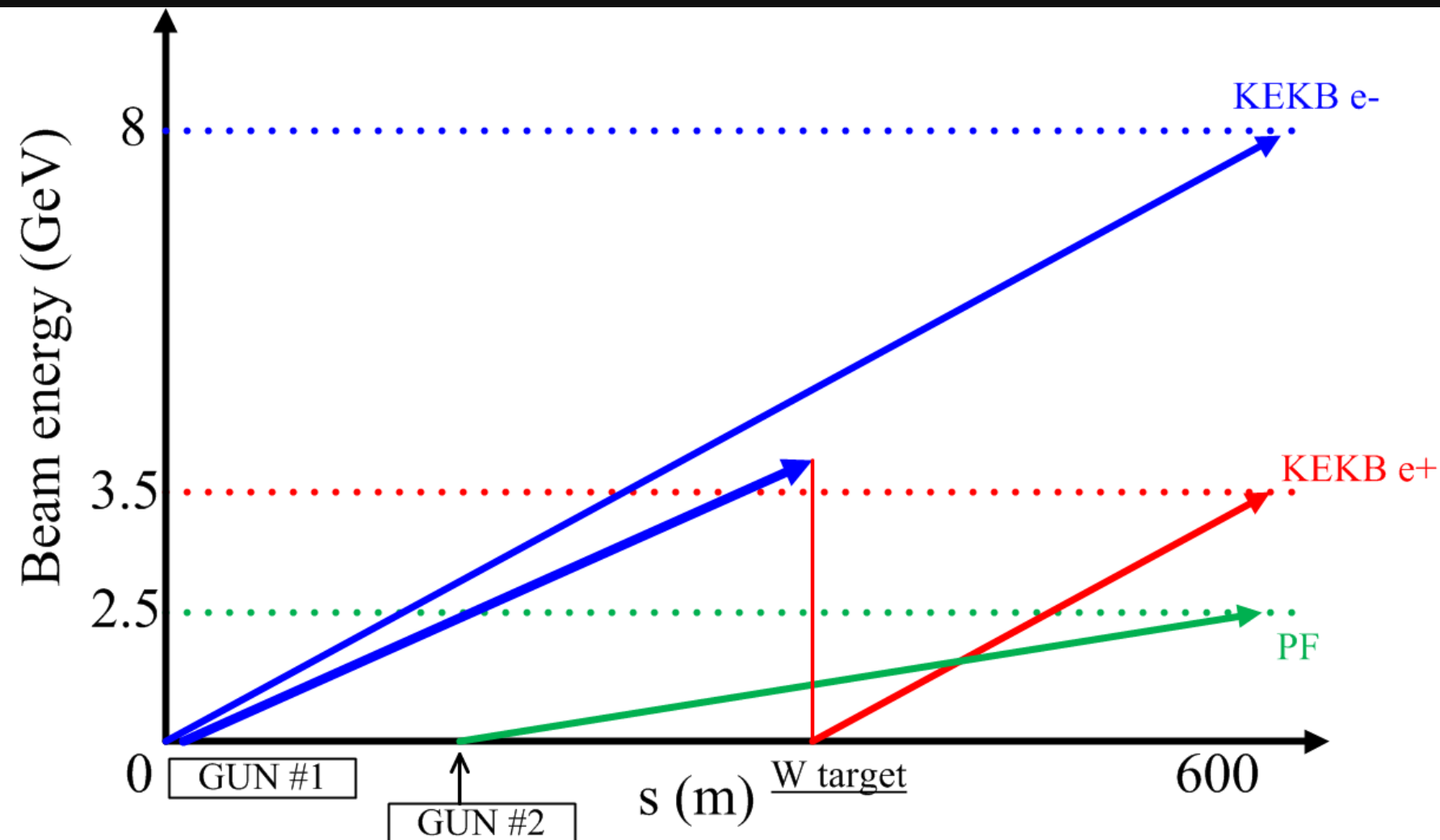
Operation Scheme for Simultaneous Top-up (Multi-energy Linac Scheme)

- Common DC Magnet Setting
- Several Pulsed Magnets
- Fast Beam Energy Control
 - Fast Low-Level RF Phase Control
 - Fast High Power Klystron Timing Control

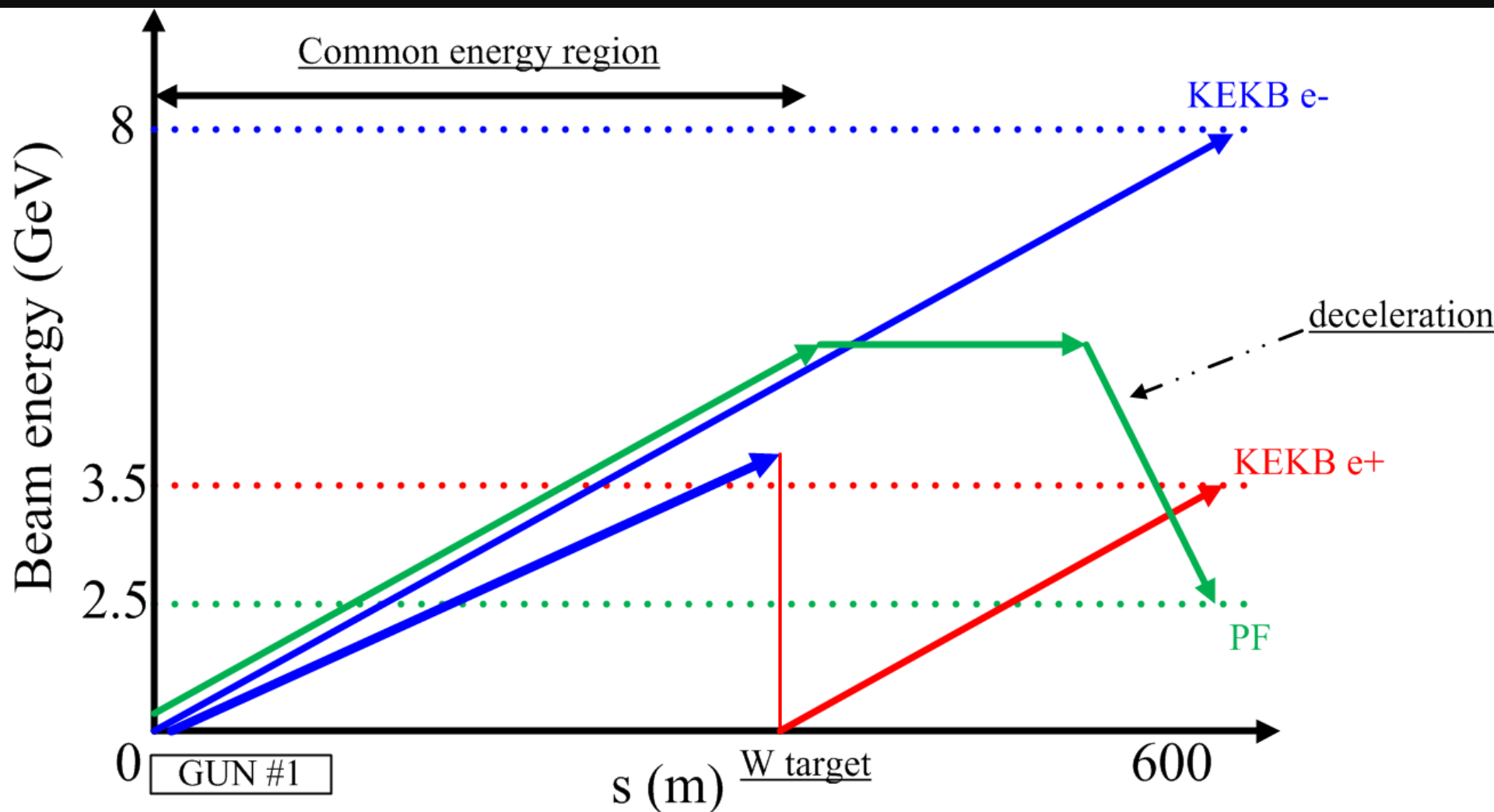
Fast Switching of 3 different beams



Beam Energy along linac for each Injection Beam



Beam Energy along linac for each Injection Beam

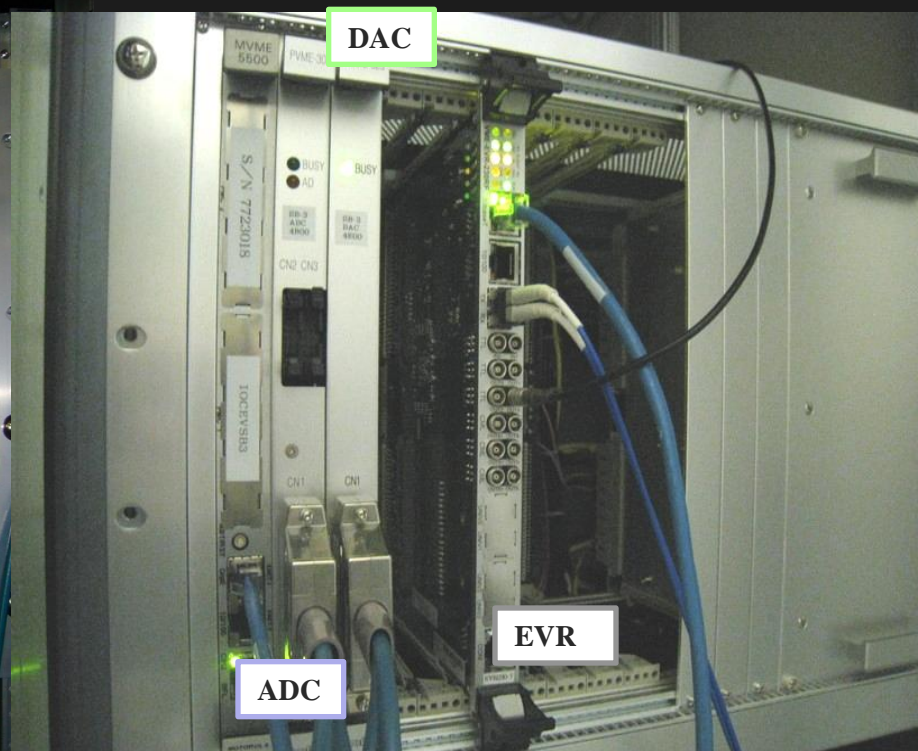
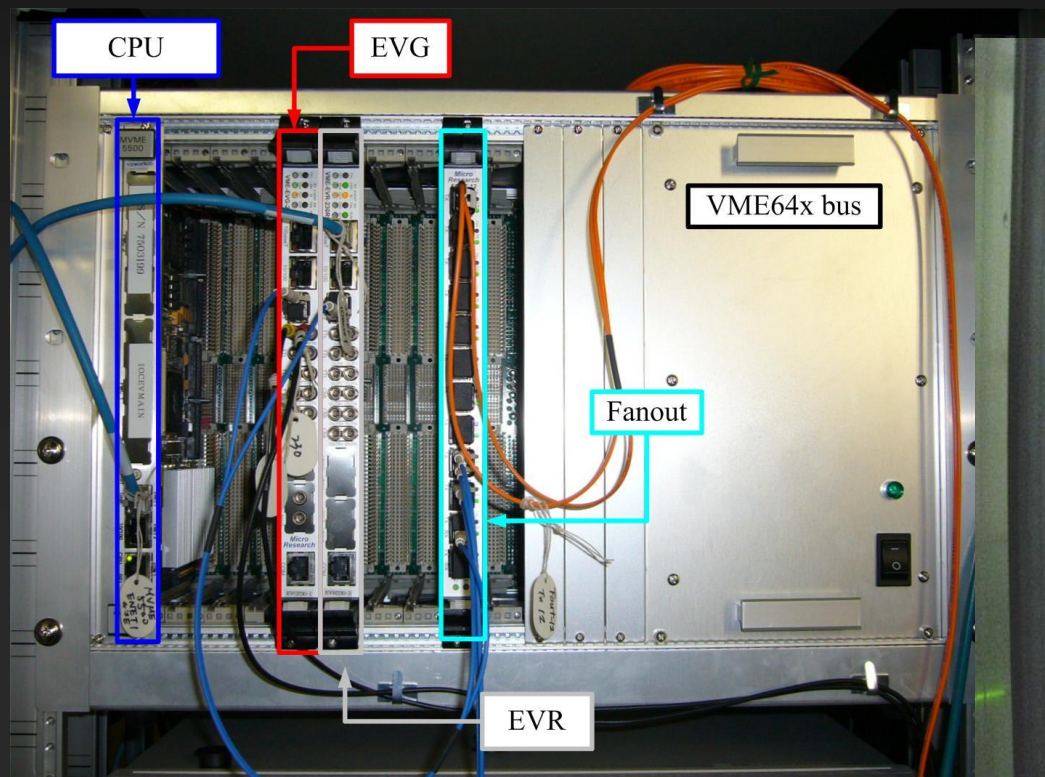


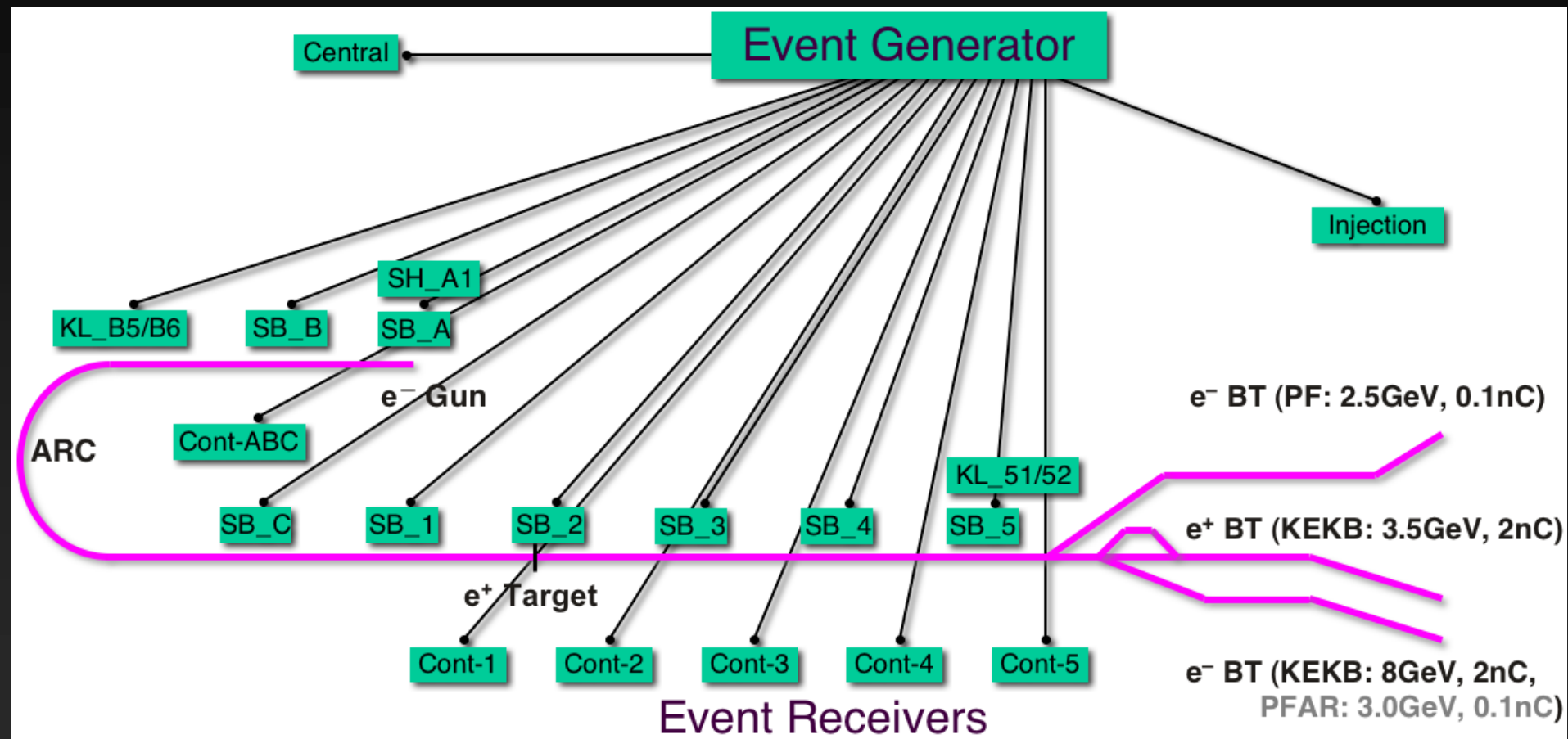
Fast Timing Control

- Event Based System -

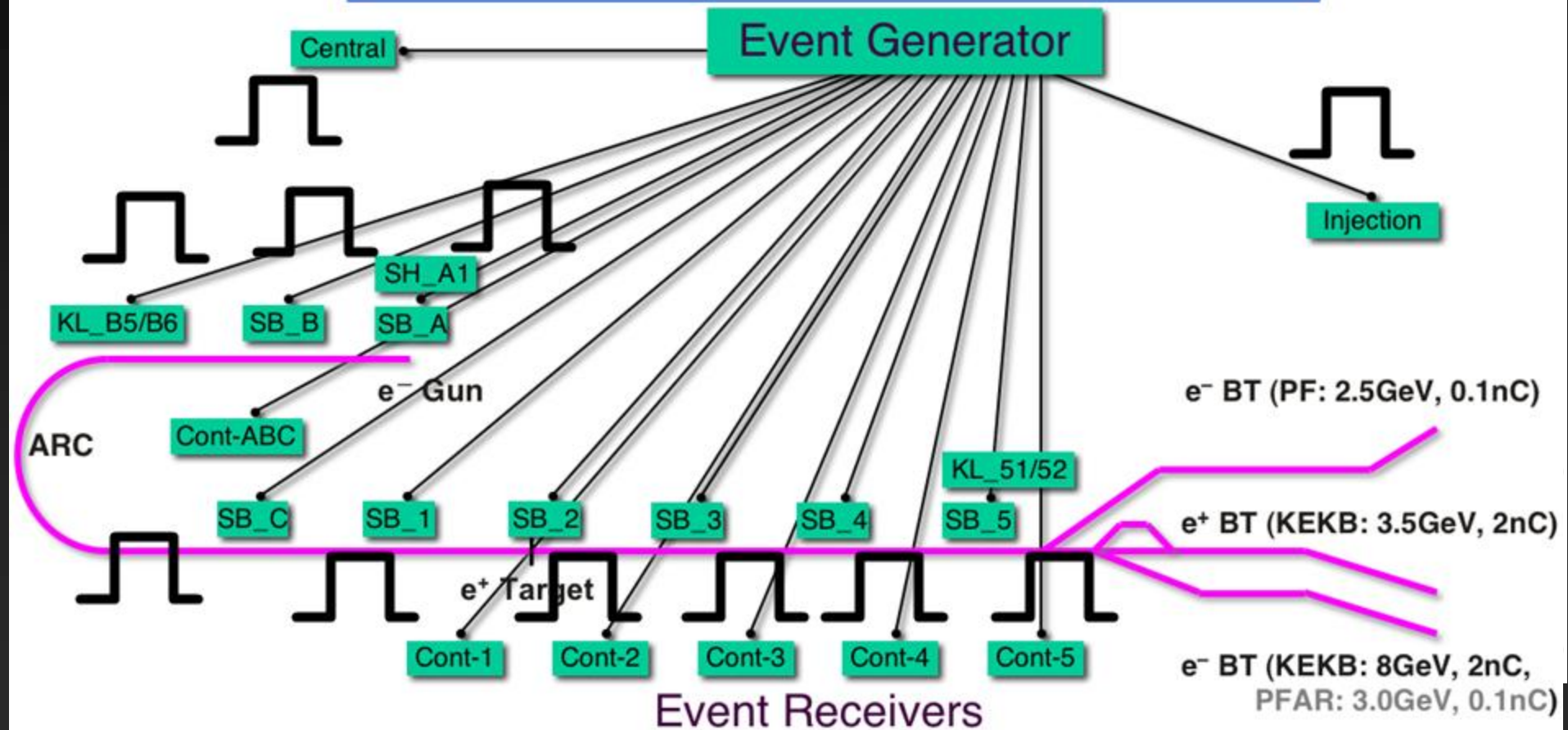
Event System: MRF230 EVG/EVR

- One EVG x1, EVR x21 (on EPICS/VxWorks)
- To change ~ 100 parameters in every 20 ms.
 - Trigger/delay for Klystron, Pulsed magnet, Gun, etc.
 - Low-Level RF Phase



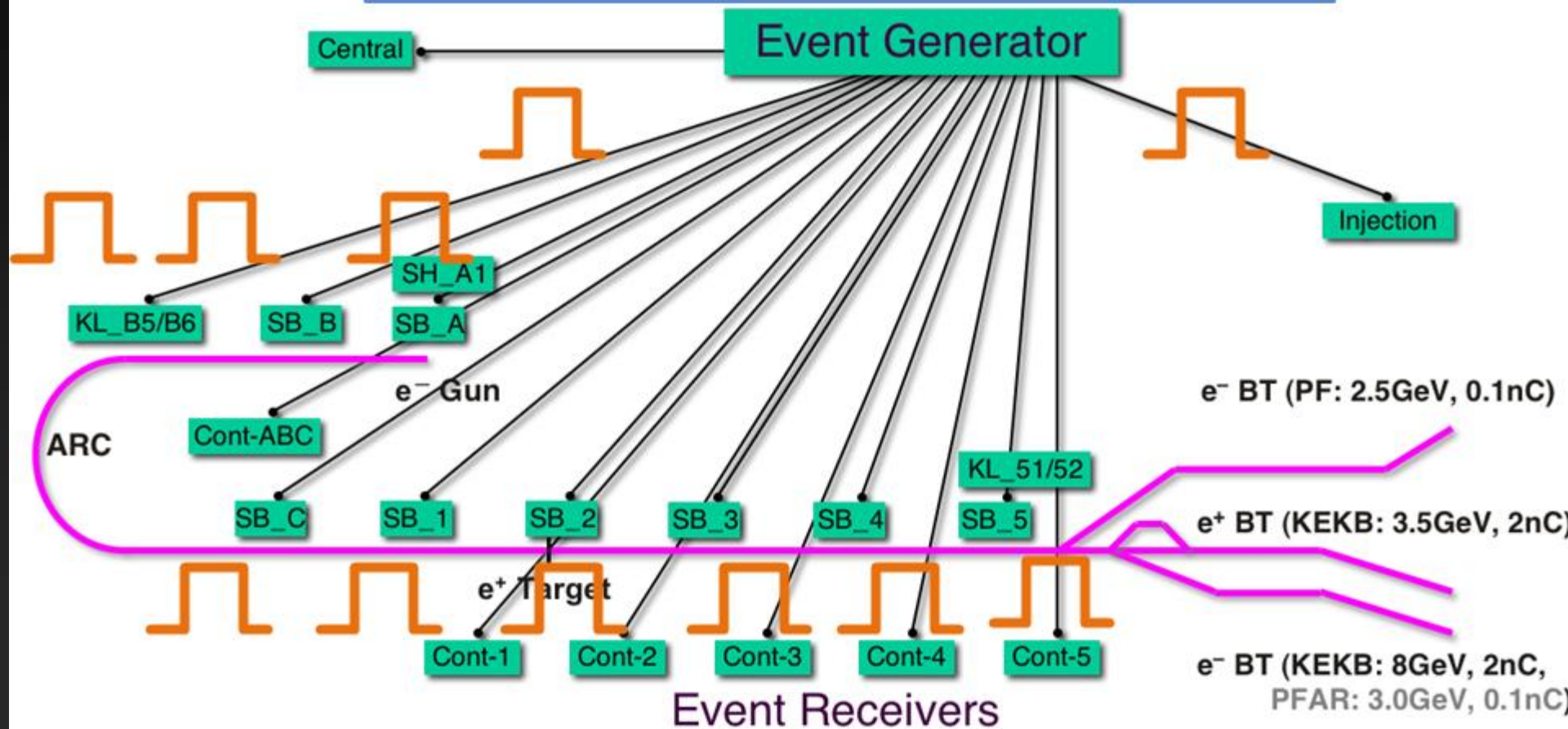


Set Event Code for KEKB e-





Set Event Code for PF



New PF-BT

Original PF-BT

Beam switchyard

KEKB e-/e⁺ Injection
ECS ON

ECS

PF

Original
PF-BT

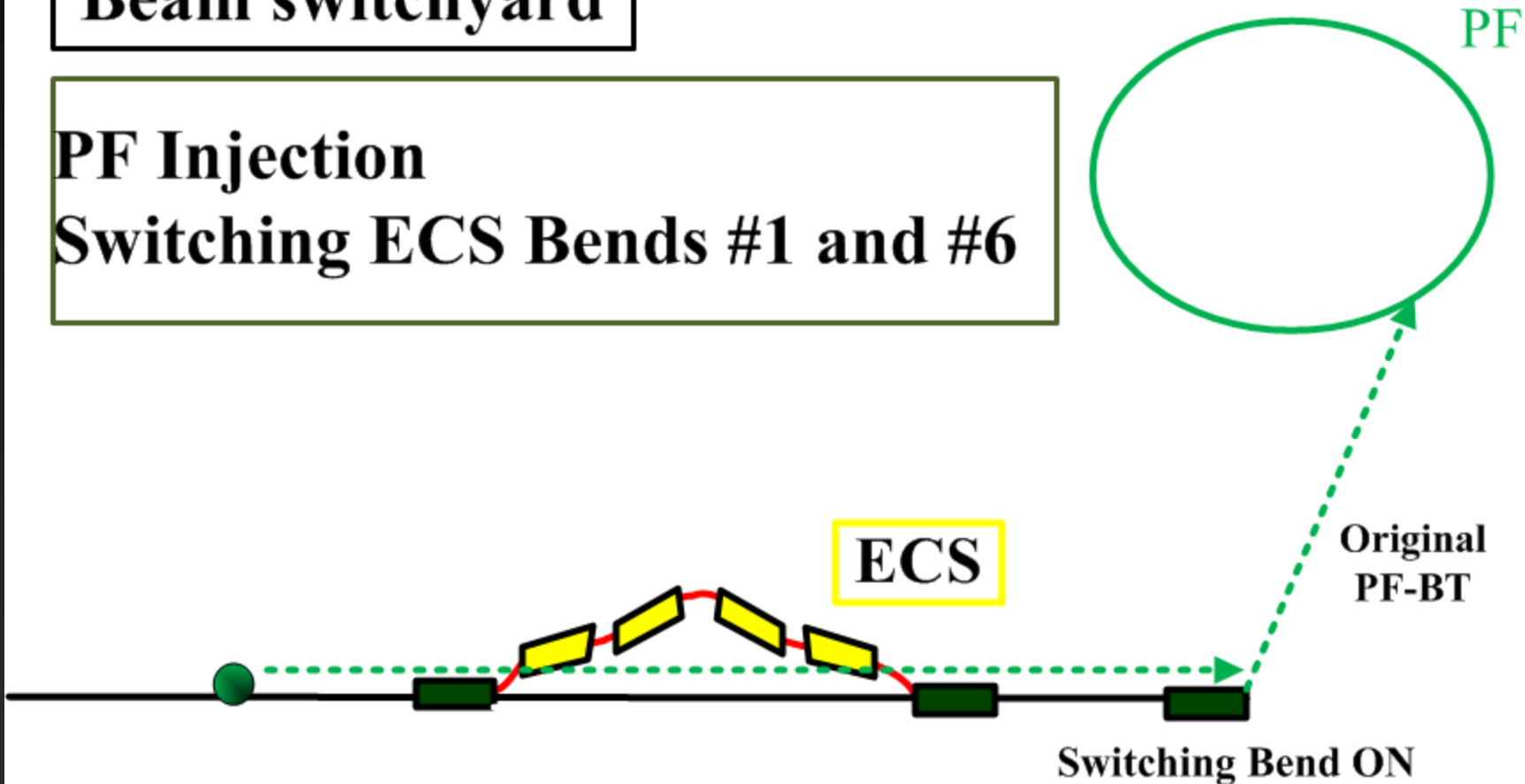
KEKB e⁺
(3.5 GeV)

KEKB e⁻
(8 GeV)

Original PF-BT

Beam switchyard

PF Injection
Switching ECS Bends #1 and #6



Switching Bend ON

Construction of New PF-BT

Beam switchyard

**Simultaneous Top-up
ECS ON
Pulsed Switching Bent**

New PF-BT

ECS

Pulsed Bend

PF

KEKB e+
(3.5 GeV)

KEKB e-
(8 GeV)

Pulsed Bend and Power Supply

Pulsed bend:

Beam bending angle:	7 deg. (up to 3 GeV)
Max. magnetic field:	1.36 T
Gap:	157 x 30 mm (W x H)
Coil:	1 turn

Power supply:

Max. current:	32 kA (12.5 Hz) 27 kA (25 Hz)
Pulse width:	200 μ s (half-sinusoidal)
Stability:	0.1%

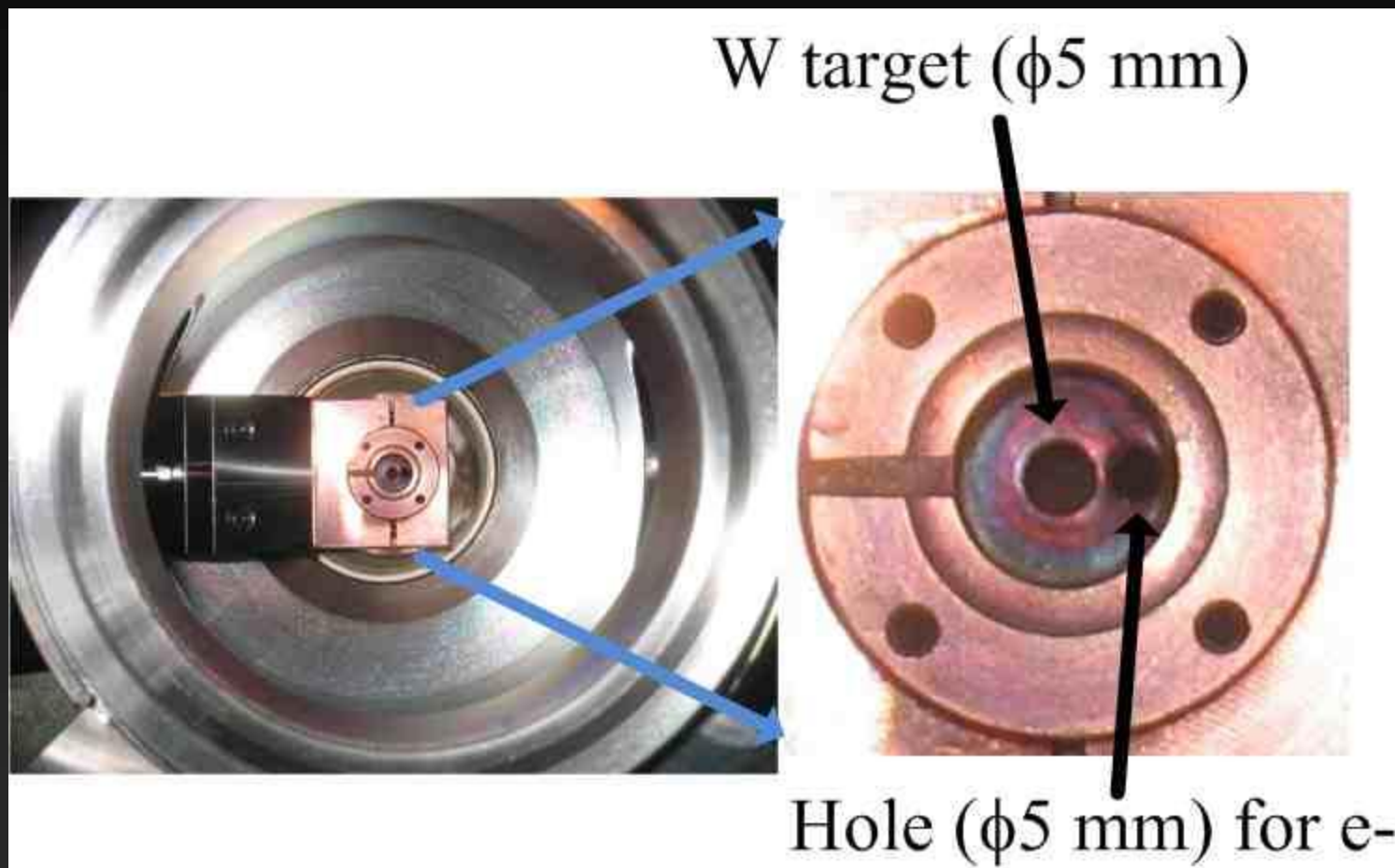
Ceramic chamber:

Length:	1200 mm
Coating:	Ti (1 μ m)

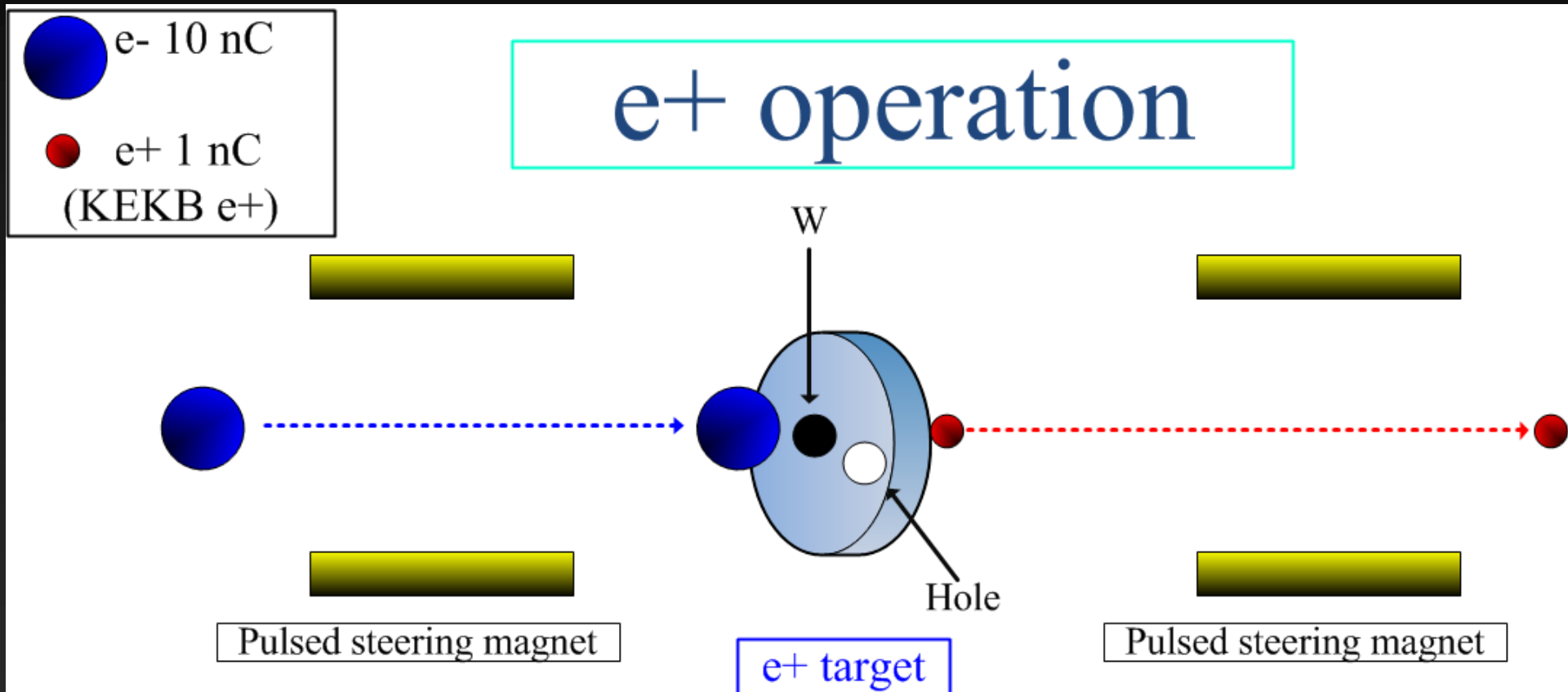


Fast Switching Between e^- and e^+ Operation

Photograph of New Target



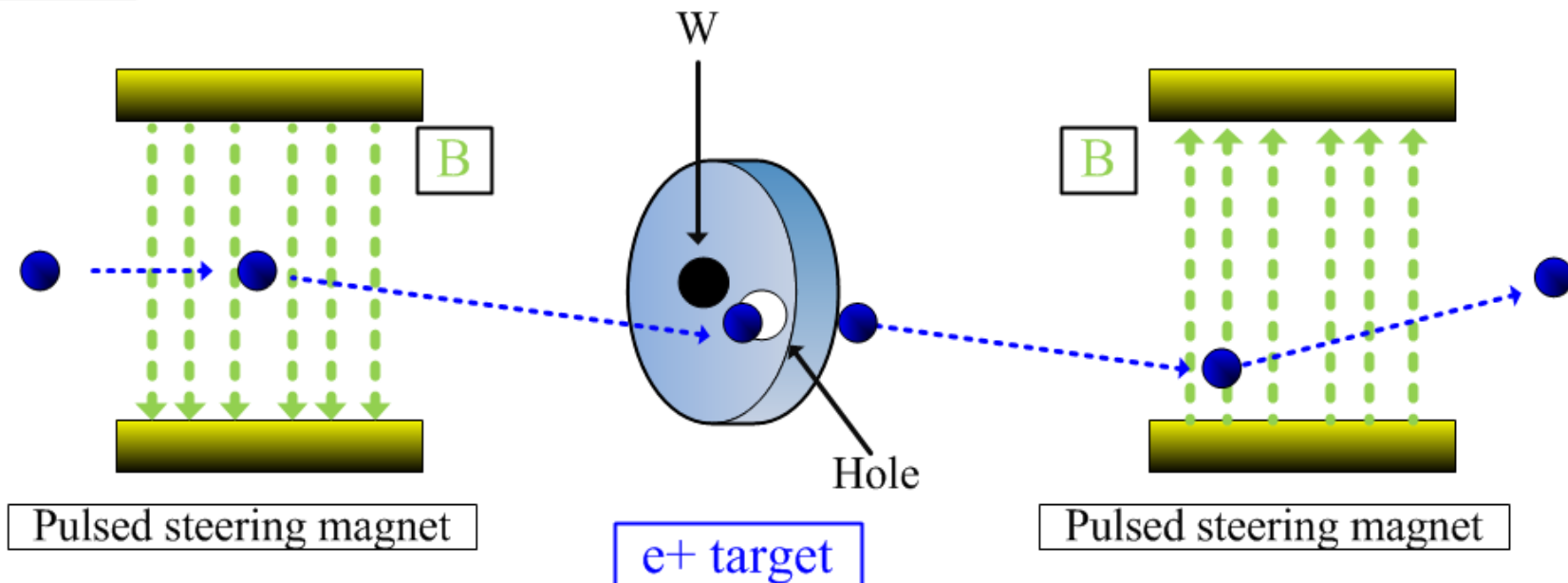
Fast Switching e-/e+ Scheme



Fast Switching e-/e+ Scheme

● e- 1 nC
(KEKB e-)

e- operation



Result of Beam Study

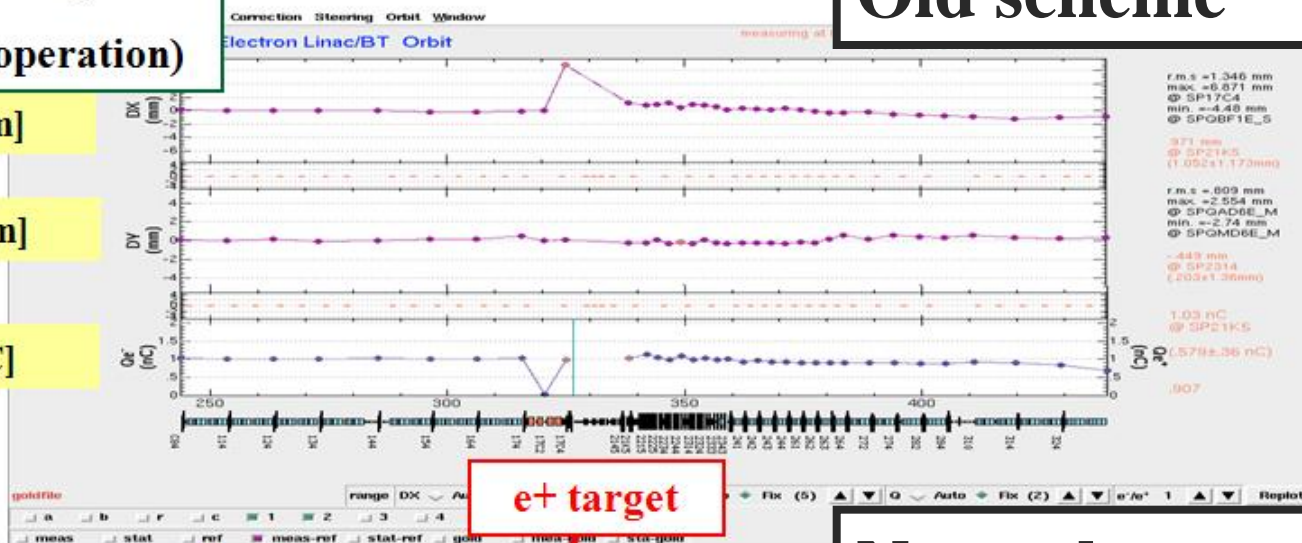
Old scheme

w/o e^+ target
(normal operation)

X [mm]

Y [mm]

I [nC]



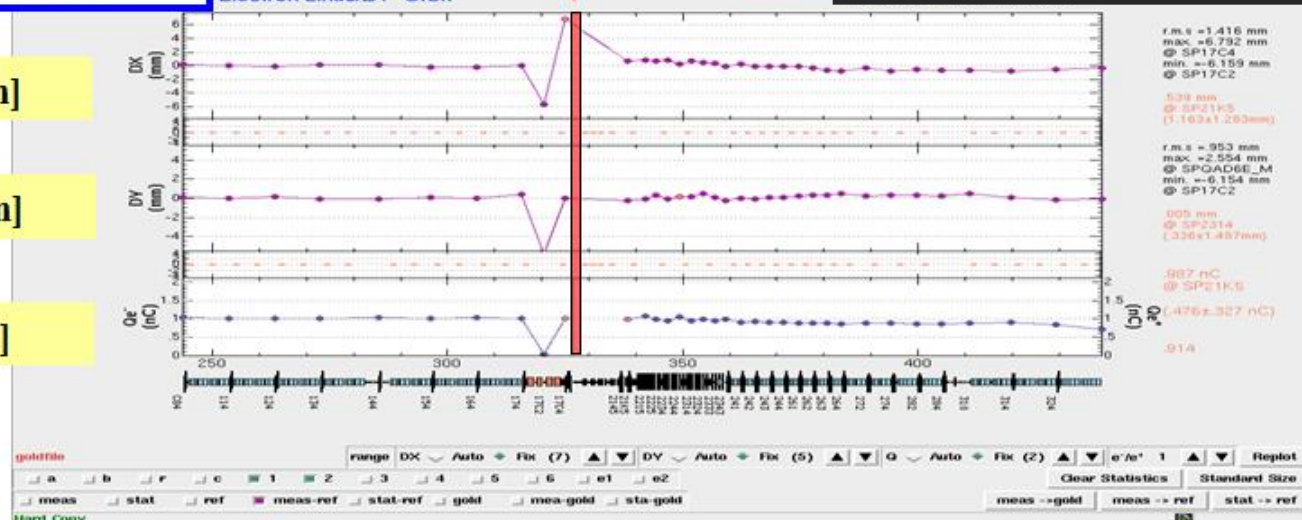
New scheme

w/ e^+ target

X [mm]

Y [mm]

I [nC]

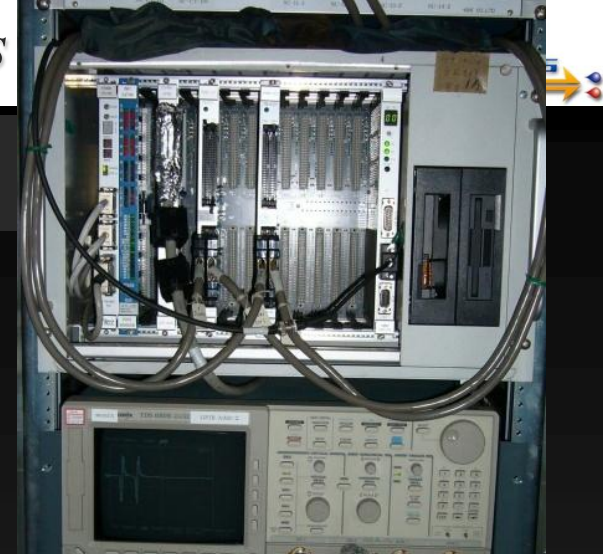


Fast Beam Position Measurement

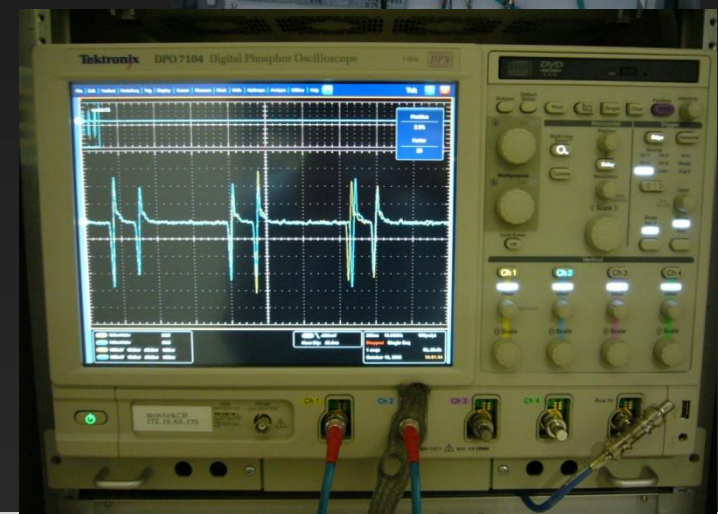


BPM-DAQ System Upgrade:

- Old System:
 - 5 GSa/s, 8 bits, 1 GHz Analogue BW
 - GPIB control
 - Measurement performance: up to 1 Hz
- New System:
 - 10 GSa/s, 8 bits, 1 GHz Analogue BW
 - 100 Mbps/GbE Network
 - DAQ Speed: more than 50 Hz
 - Twenty four systems have been installed.



Old System
(VME + Oscilloscope with GPIB)

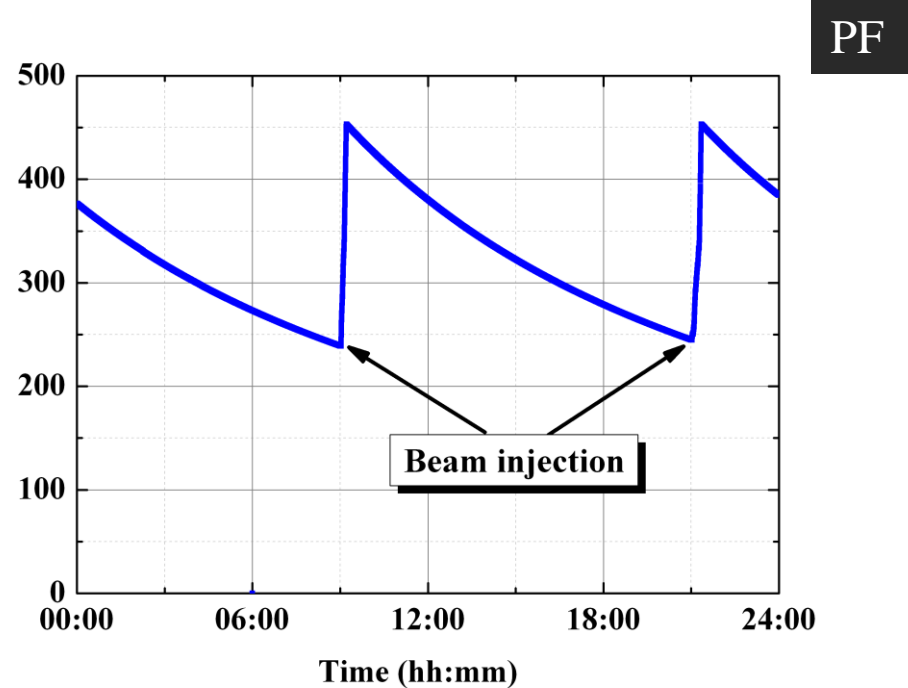
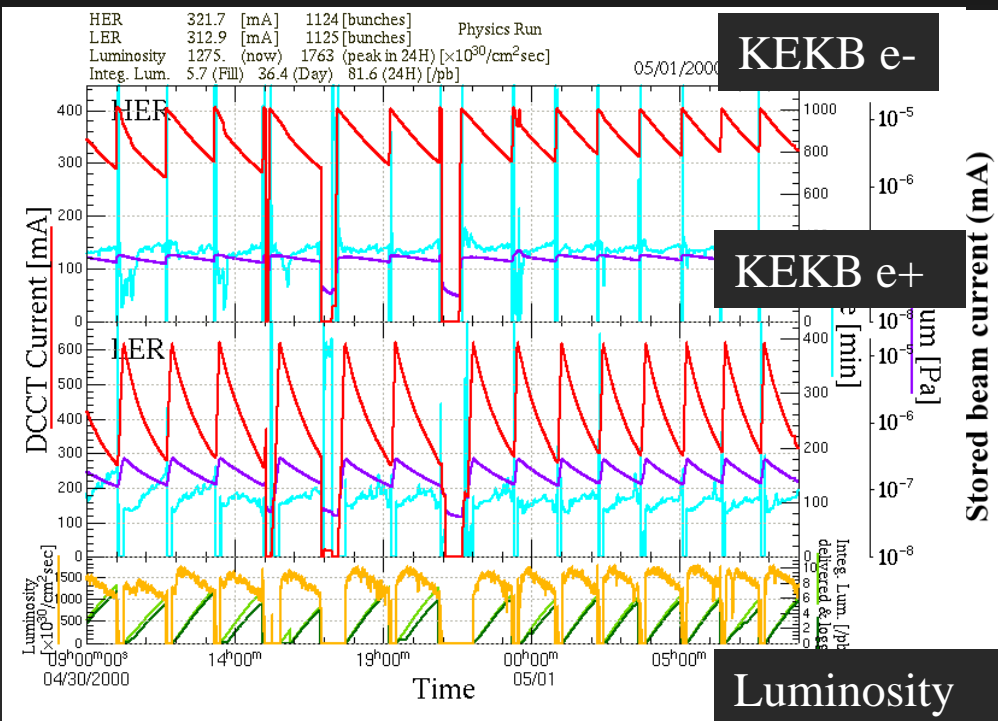


New system
EPICS embedded IOC

SIMULTANEOUS TOP-UP OPERATION OF KEKB e^-/e^+ and PF

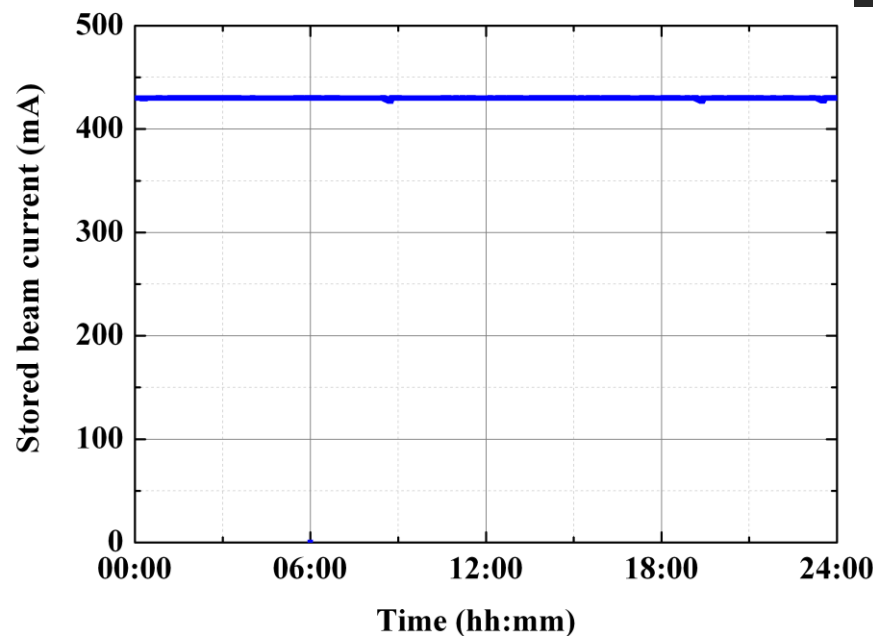
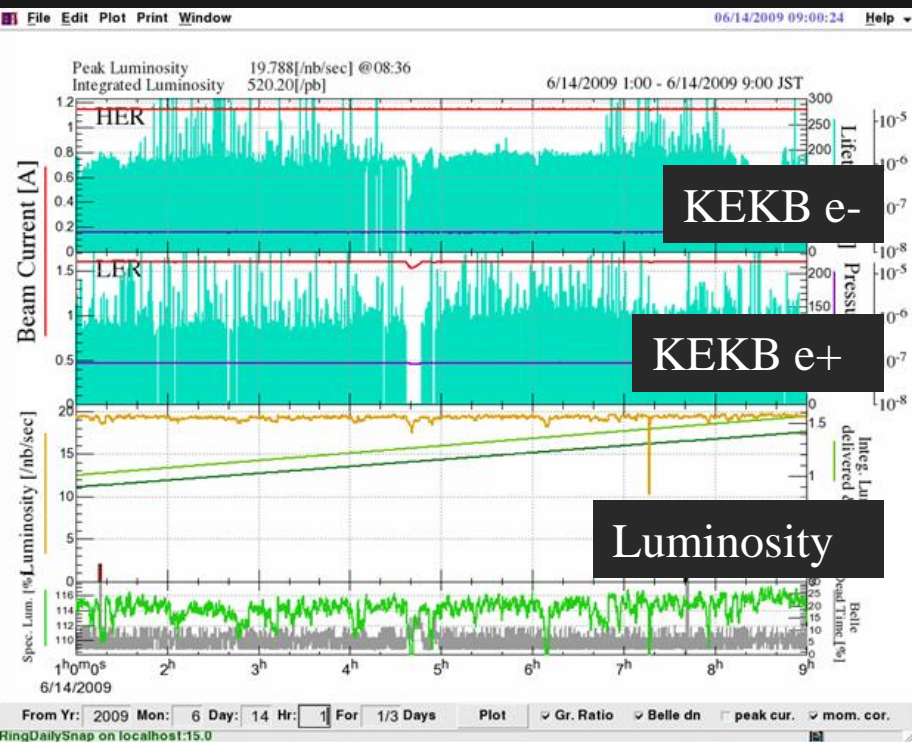
Simultaneous Top-up Operation

- Beam current stability in Original Operation
 - KEKB: 300 mA ($\sim 50\%$)
 - PF: 240 mA ($\sim 53\%$)



Simultaneous Top-up Operation

- Beam current stability since Apr. 2009
 - KEKB: 1 mA ($\sim 0.05\%$) : e^- : 12.5 Hz, e^+ : 25 Hz
 - PF: 0.05 mA ($\sim 0.01\%$) : 0.5 Hz



- AR-BT and KEKB-BT share the long part of beam line.
- AR-BT: ~ 3.1 GeV
- Tight tunnel space

BT dedicated for PF-AR

Common BT for KEKB and PF-AR

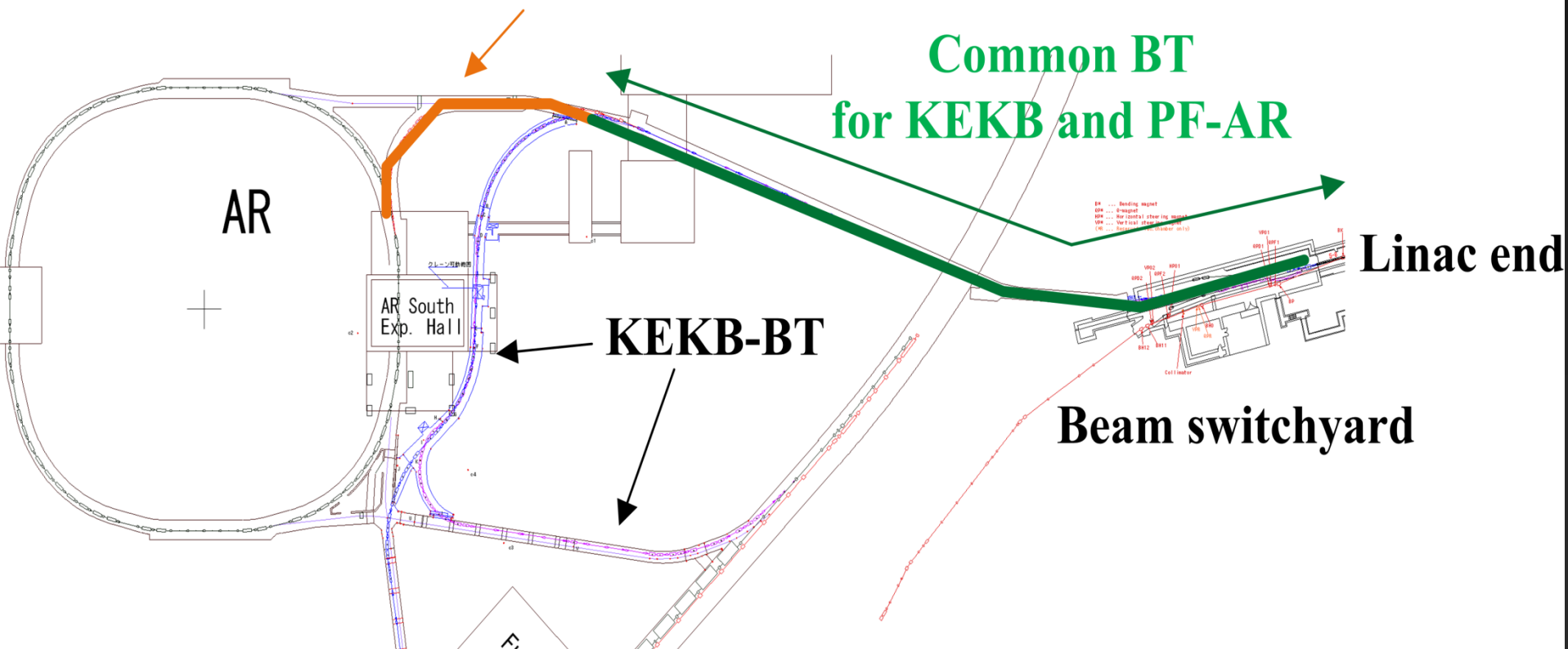
Linac end

Beam switchyard

KEKB-BT

AR

AR South
Exp. Hal



Toward SuperKEKB Operation

- Beam lifetime \sim 10 minutes.
- PF-AR injection will be a crucial problem
 - Interrupt top-up injection (15 min. twice daily)
- In SuperKEKB operation, Beam Energy will be changed.
 - e⁻: 8 GeV \Rightarrow 7 GeV
 - e⁺: 3.5 GeV \Rightarrow 4 GeV
- e⁺ beam with 4 GeV will be available for PF-AR injection.
 - AR-BT Upgrade
 - Pulsed Bend switching between AR-BT and KEKB-BT

Summary and Future Plan

- *Simultaneous Top-up for KEKB e-/e+, and PF was achieved successfully.*
 - Beams with different energy and charge (0.1 nC to 10nC)
 - 2.5 GeV (PF), 3.5 GeV (KEKB e+), 8 GeV (KEKB e-)
 - Development of Many Subsystems and Many Beam Studies.
 - Many People's Contributions and Efforts
 - **Great Improvement of Experimental Efficiency at both of KEKB and PF**
- Towards SuperKEKB:
 - We are planning the simultaneous injection including PF-AR.
 - Simultaneous top-up (SKB e-/e+, PF) and PF-AR **4 GeV e+**

Thank you for
your attention!