



# Injector Upgrade: for Fast Beam-Mode Switch

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for the Injector Upgrade (IUC) WG members

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(based on the Multi-Energy Linac Scheme)

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3. Phase-III (Fast Beam-Mode Switch: KEKB e-/e+, PF e-, PF-AR e-)

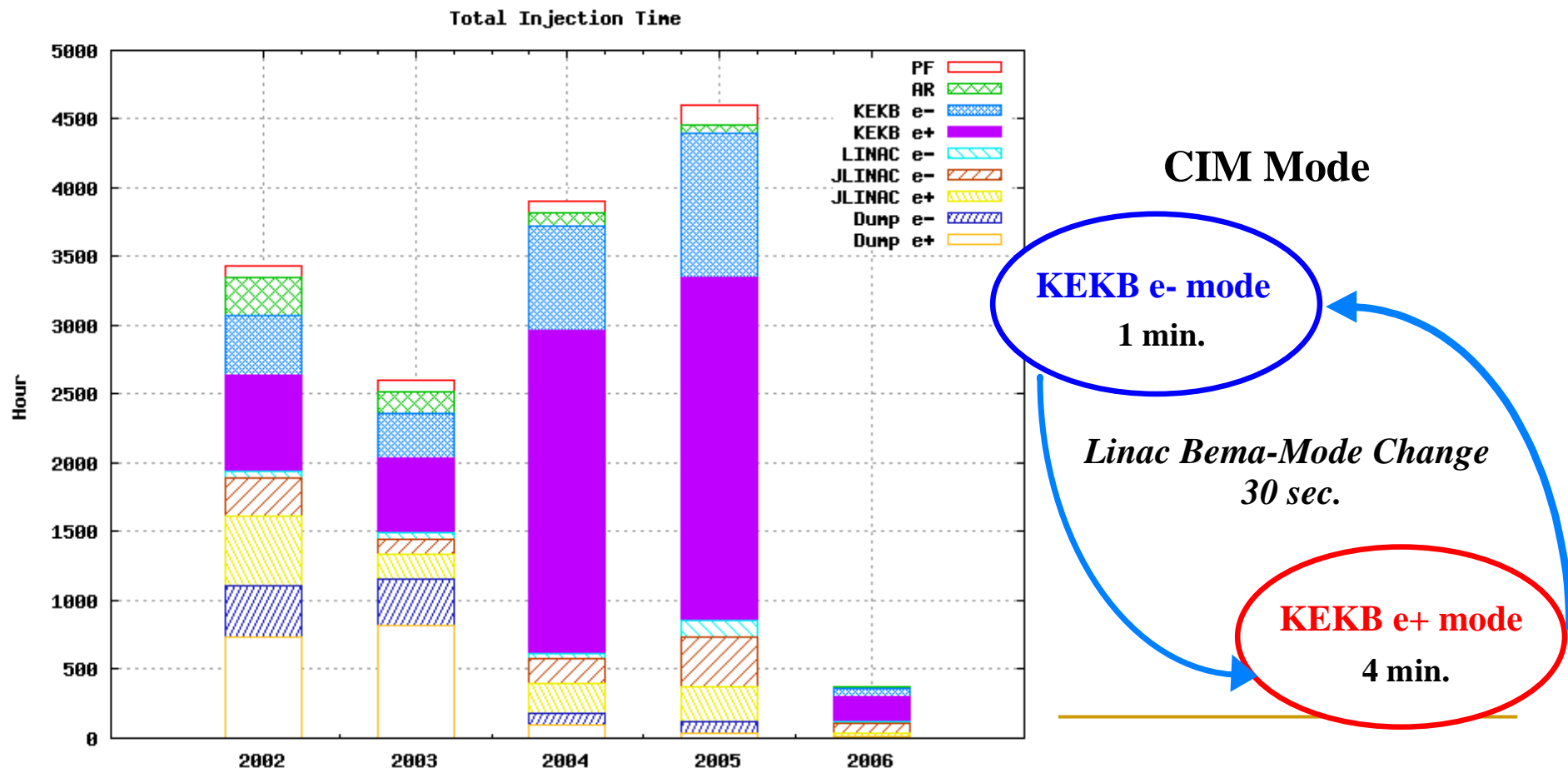
4. Summary

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- 1. Introduction -

## Beam operation statistics of Linac

- Injector linac for 4-rings (KEKB e-/ e+, PF, PF-AR)
- Continuous Injection Mode (CIM) has started in 2004.



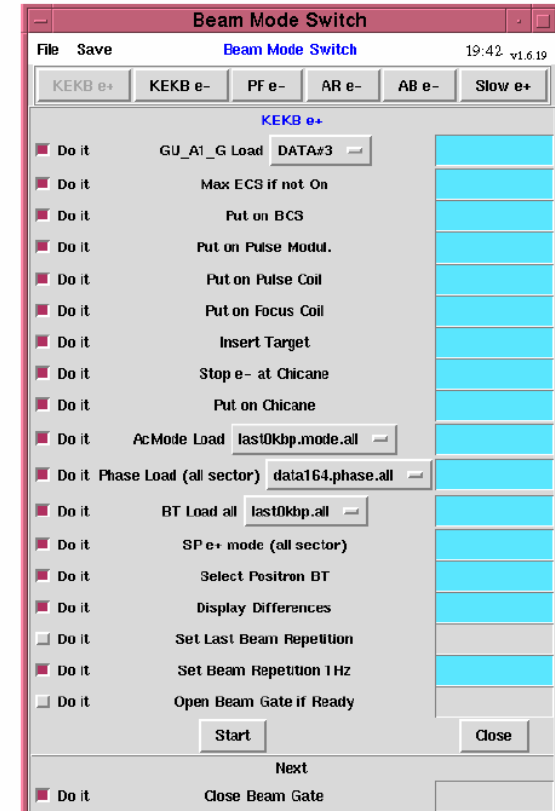
- 1. Introduction -

# Beam-Mode Switching Operation

- Change magnetic field
- Change timing
- Insert/ Remove e+ target (e-/ e+)
- Klystron mode (Acceleration/ Standby mode)
- Klystron (Sub-Booster Klystron) phase
- Etc.

Table 1: Devices at the KEK linac

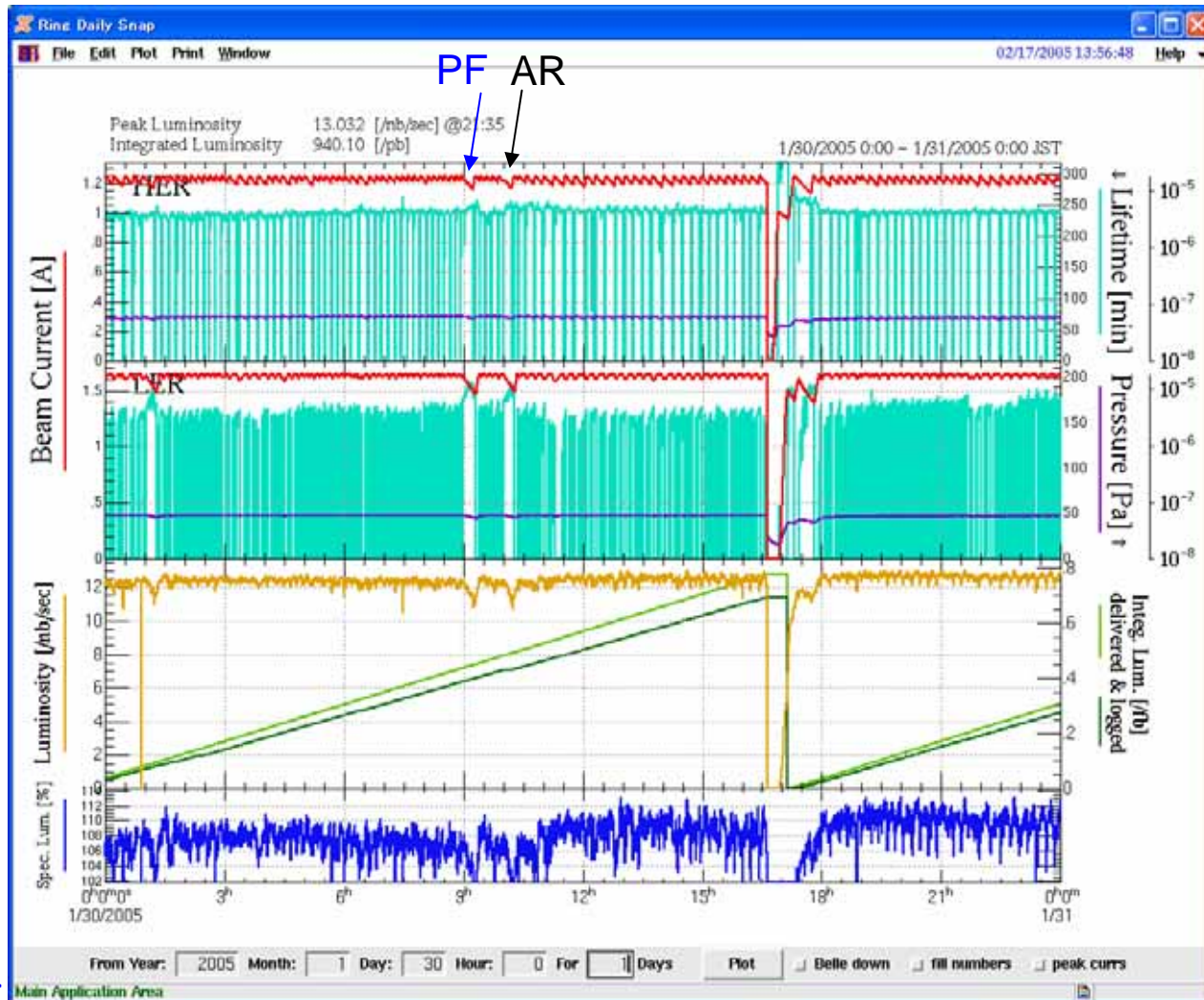
Device	total number	Front-end
beam-position monitor (BPM)	89	19 x VME
klystron	69	69 x PLC
magnet power-supply	499	45 x PLC
vacuum (ion pump)	284	17 x PLC
trigger-delay (timing signal)	141	5 x VME 11 x CAMAC



- 1. Introduction -

= Typical KEKB Operation =

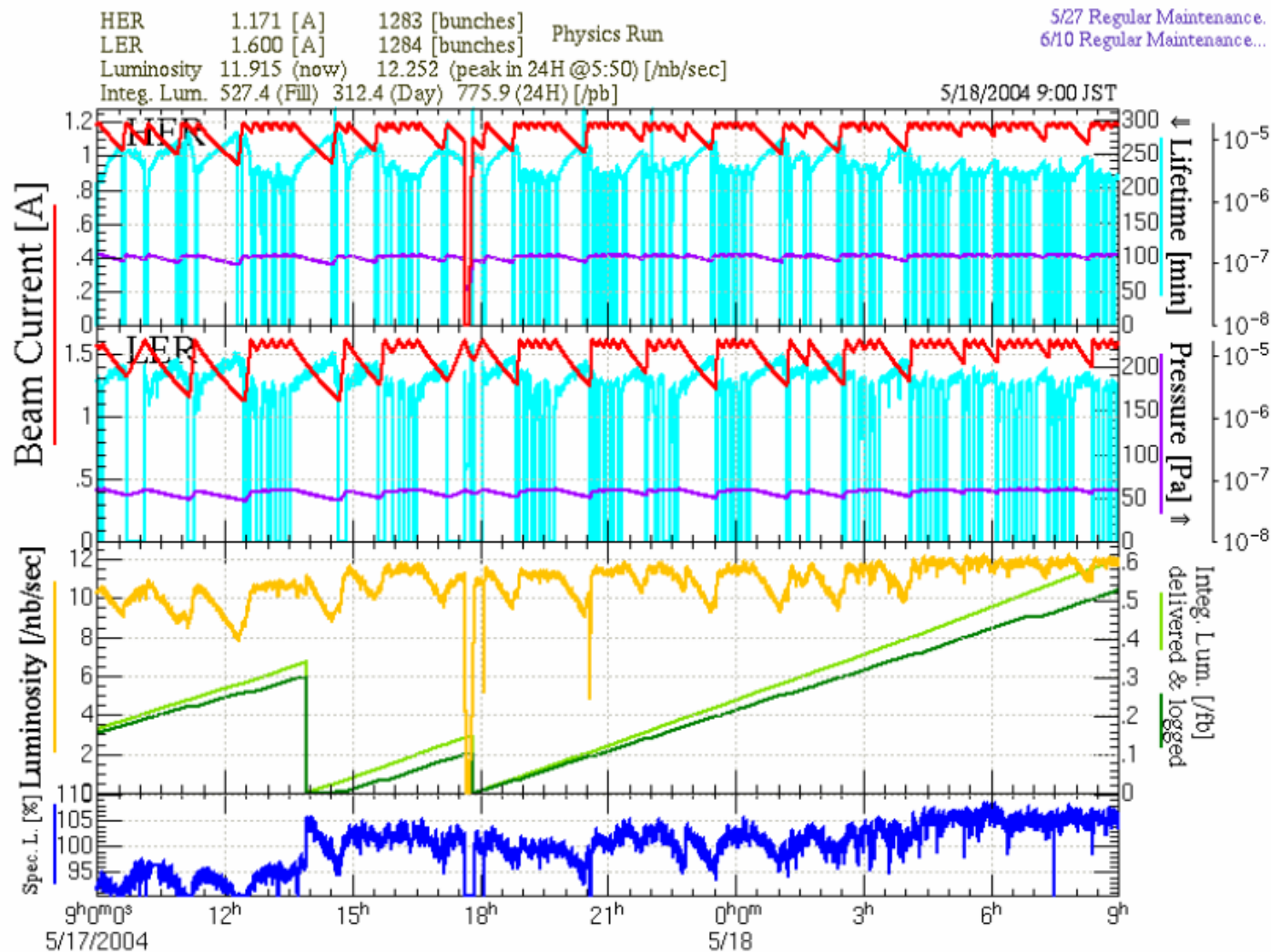
- KEKB-ring is operated under **Continuous Injection Mode**.
- PF and PF-AR need twice injection a day.



M.

## - 1. Introduction -

- Machine Study (PF, PF-AR) interrupts KEKB continuous injection.

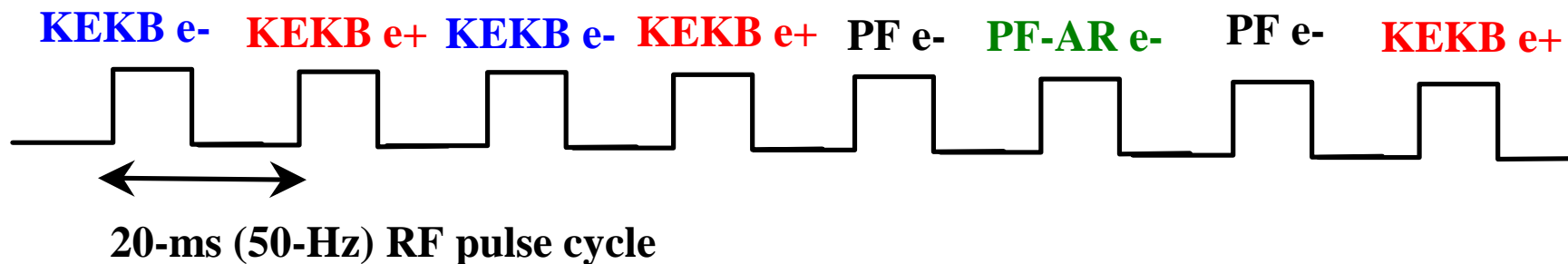


- 1. Introduction -

## = Issue of Beam Operation =

- Only one linac is used as an injector for 4-rings (time sharing).
- Changing the beam mode (KEKB  $\Leftrightarrow$  PF, PF-AR) takes time (Need ECS standardization)
- PF and PF-AR machine study need continuous injection.
- Super-KEKB needs Fast Beam-Mode Switch Injection (e- and e+).
- PF-ring needs the Top-up injection mode in the future.
- **Fast Beam-Mode Switch scheme is strongly required.**

**(quasi-simultaneous injection)**

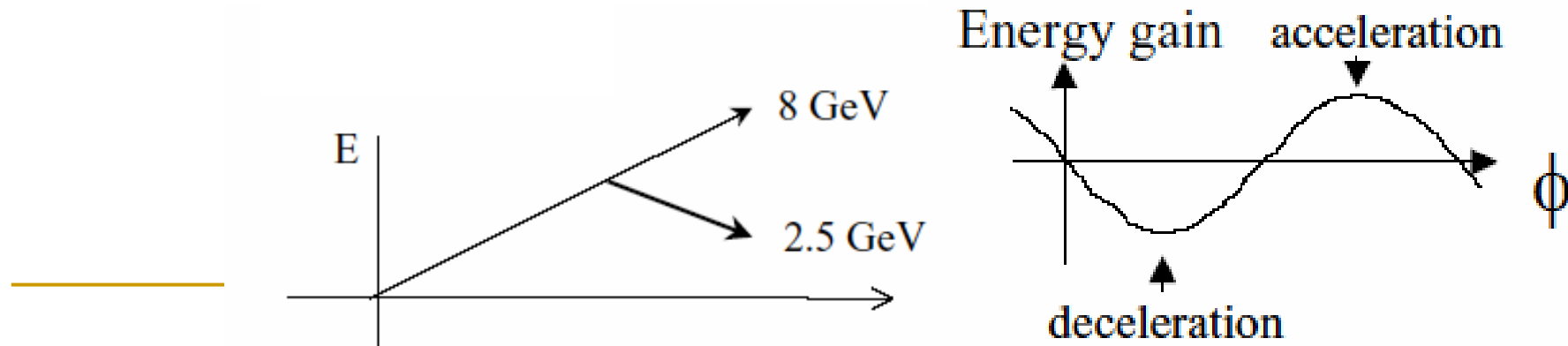




- 2. Fast Beam-Mode Switch Scheme-

= Multi-Energy Linac Scheme =

- Fast change of the magnetic field is difficult by using current system.
- *Use the common magnetic field (Quadrupole and Steering magnets)*
- Energy adjustment be done by changing sub-booster klystron phase quickly.
  - Beam is accelerated up to  $\sim 5.3$  GeV then decelerated to 2.5 GeV using deceleration phase (PF e-).
  - All beam modes (KEKB e-, e+ /PF /AR) use common electron gun (A1 gun).



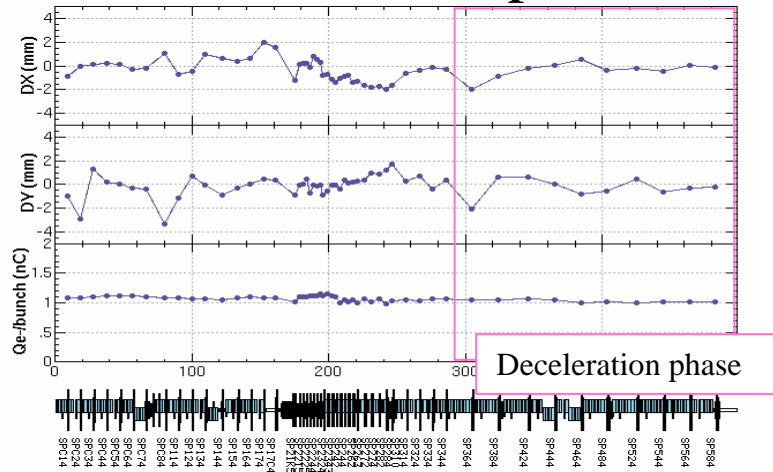


## - 2. Fast Beam-Mode Switch Scheme-

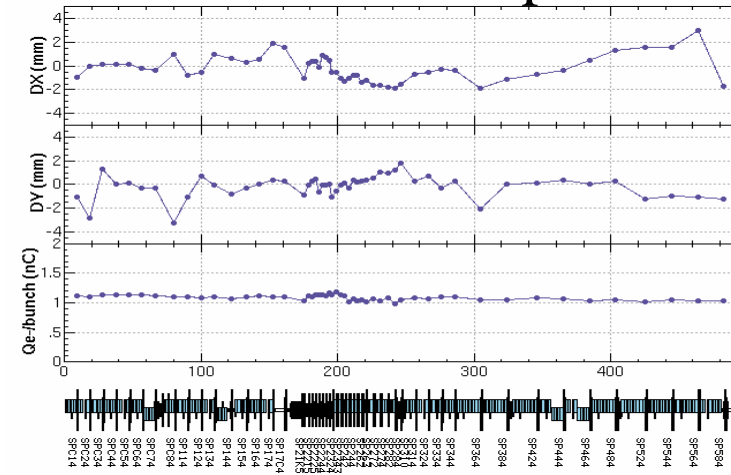
= Preliminary Machine Study for Multi-Energy Linac (1) =

- Common magnet setting has been tested for 2.5-GeV and 8-GeV e- beams.
- Optics difference comes from acceleration phase.
- *Orbit correction satisfies both energies can be made.*
- *Normalized emittance of 8-GeV is similar to 2.5-GeV e- optics.*

2.5-GeV e<sup>-</sup> optics (for PF)



8-GeV e<sup>-</sup> optics (for KEKB e-)



### Measurement of energy and emittance

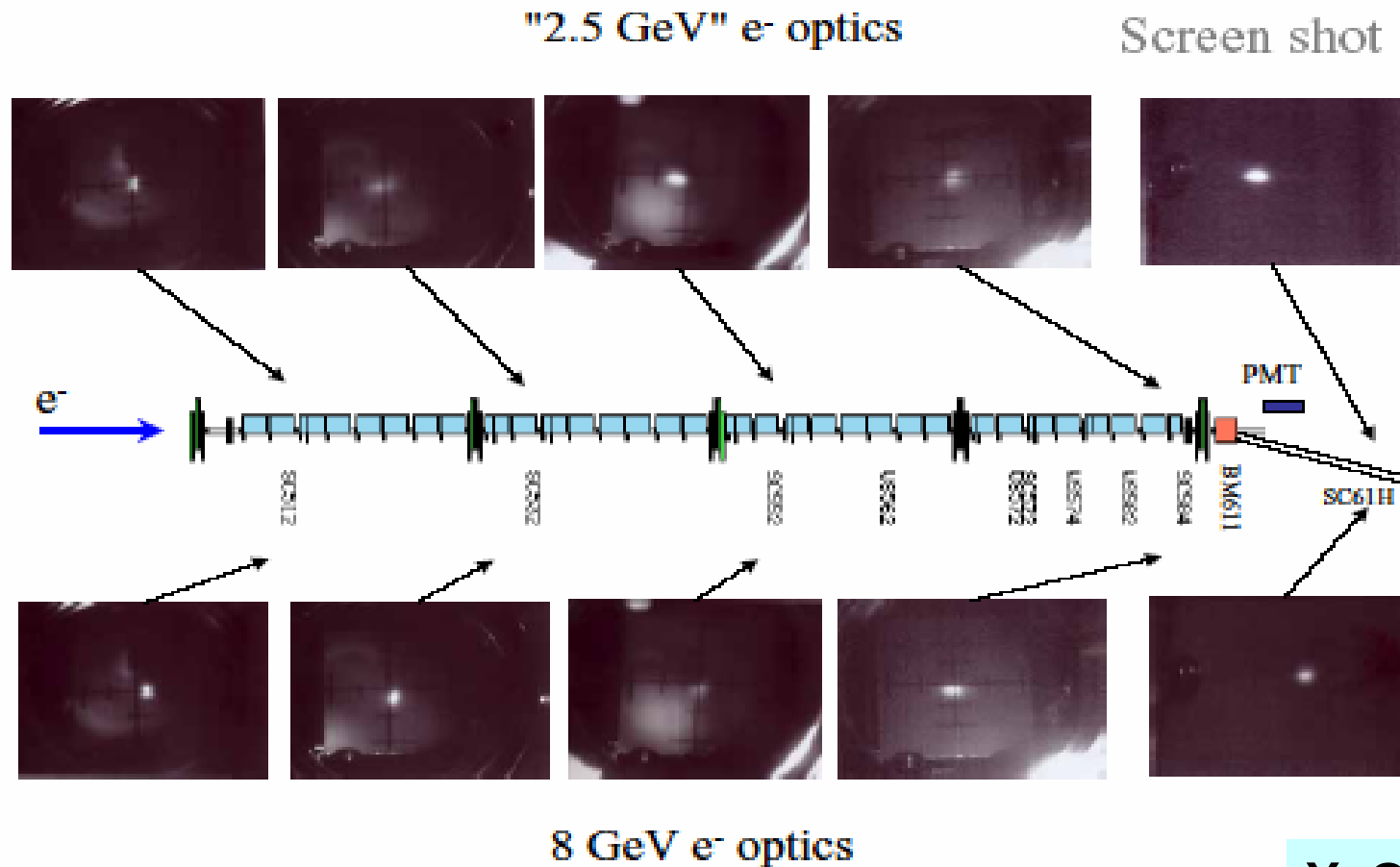
- Energy = 2.5 GeV (SC61H)
- $\gamma\epsilon_x = 3.6 \times 10^{-4}$  m
- $\gamma\epsilon_y = 6 \times 10^{-5}$  m

- Energy = 8 GeV (SC61H)
- $\gamma\epsilon_x = 2.5 \times 10^{-4}$  m
- $\gamma\epsilon_y = 4 \times 10^{-5}$  m

**Y. Ohnishi**

## - 2. Fast Beam-Mode Switch Scheme-

= Preliminary Machine Study for Multi-Energy Linac (2) =



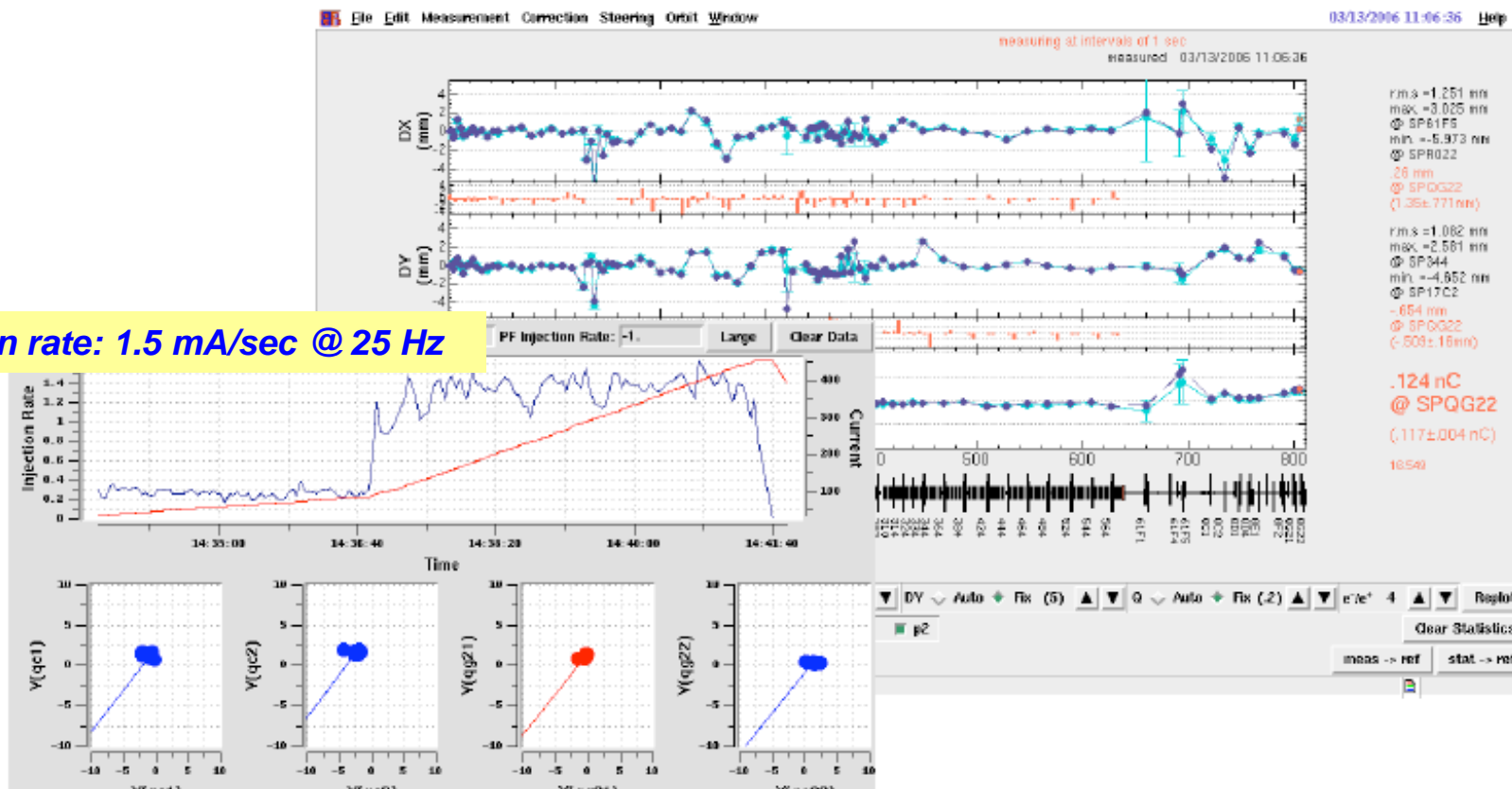
Y. Ohnishi

- *Multi-Energy Linac scheme is feasible for practical operation.*
- *Machine study is going on.*

# Preliminary Study Result: PF Injection on Multi-Energy Linac Scheme

- Injection rate is almost same with daily operation.
- KEKB injection should be tested on multi-energy scheme.

**Injection rate: 1.5 mA/sec @ 25 Hz**



- 3. Upgrade Plan-

## Upgrade work will be done by three phases:

- Phase-I (done): Construction of New PF-BT line (bypass ECS)  
Save time for switching beam mode between KEKB and PF.

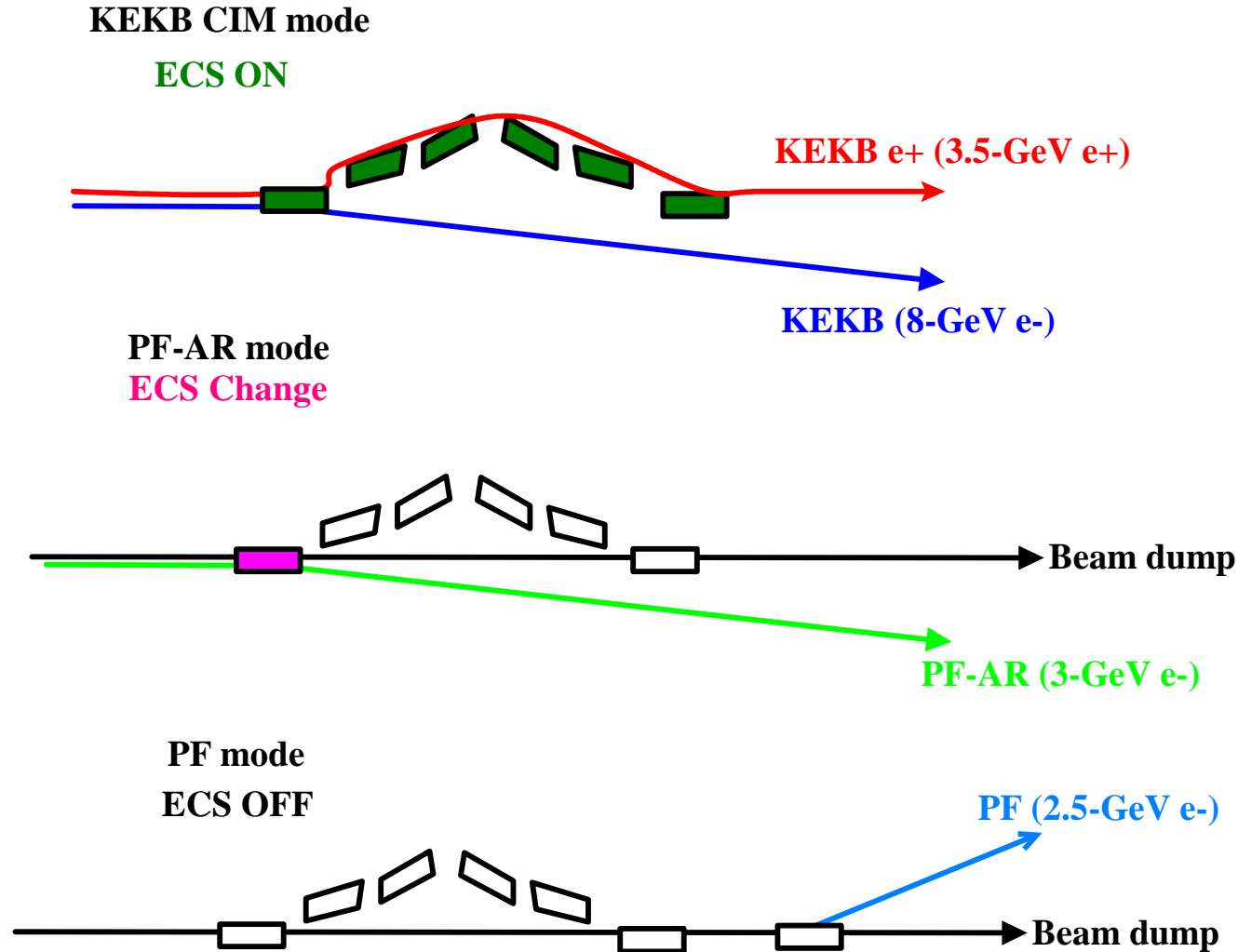
*= Use Multi-Energy Linac Scheme =*

- Phase-II: Fast Beam-Mode Switch (KEKB e-, PF e-)
- Phase-III: Fast Beam-Mode Switch (KEKB e-/ e+, PF e-, PF-AR e-)

- 3.1 Phase-I (Upgrade Plan)

# ECS handling for each mode

- KEKB  $\leftrightarrow$  PF/ PF-AR needs ECS standardization.



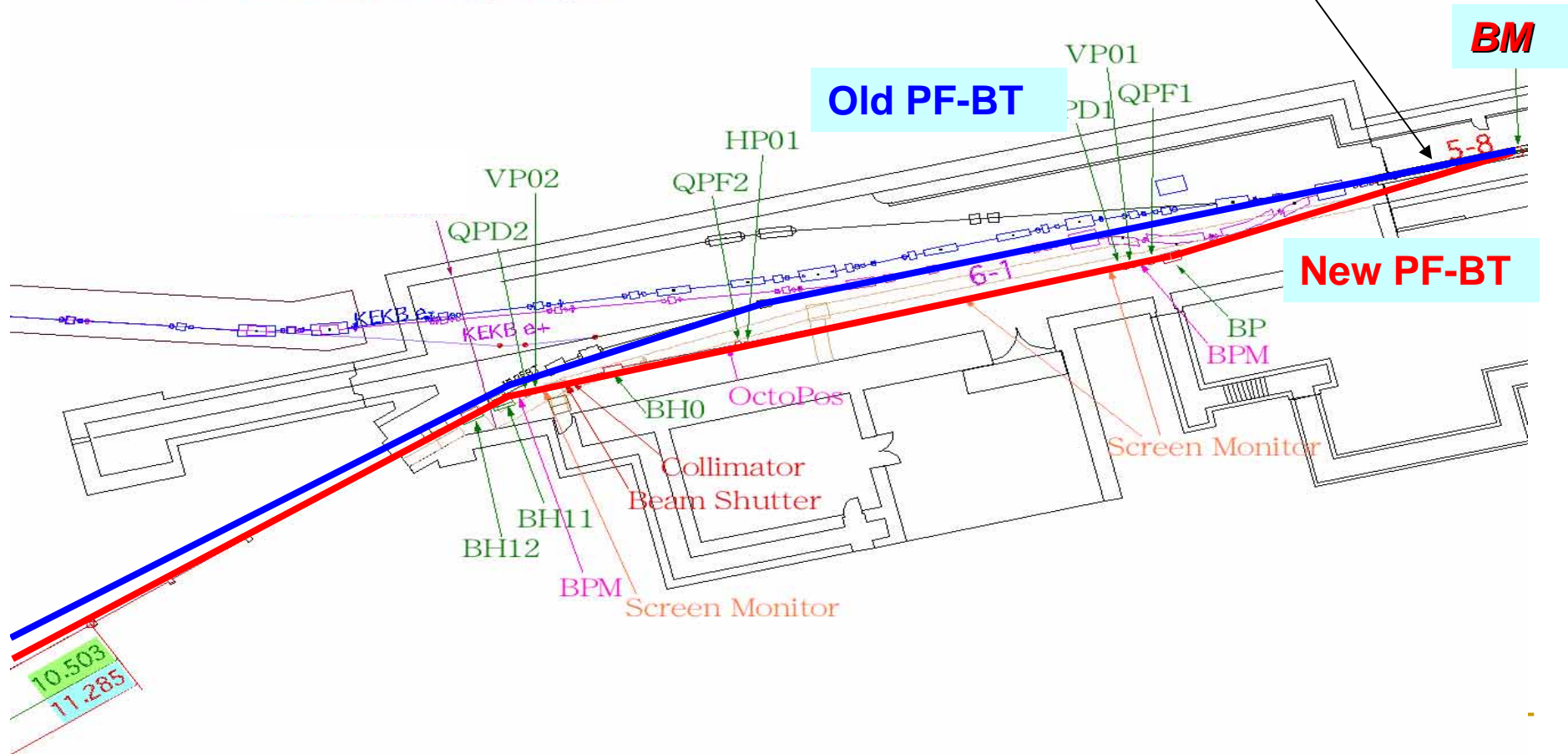
- 3.1 Phase-I (Upgrade Plan)

= Phase-I New PF-BT Layout =

- New PF-BT has been constructed in last summer.

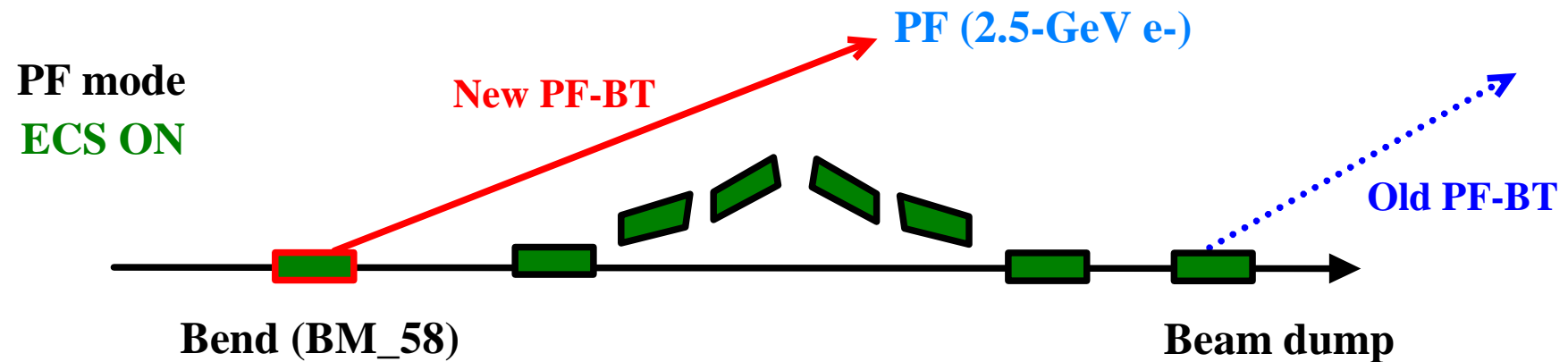
B\* ... Bending magnet  
QP\* ... Q-magnet  
HP\* ... Horizontal steering magnet  
VP\* ... Vertical steering magnet

Remove 58 accelerating unit



# New PF-BT to bypass the ECS magnets

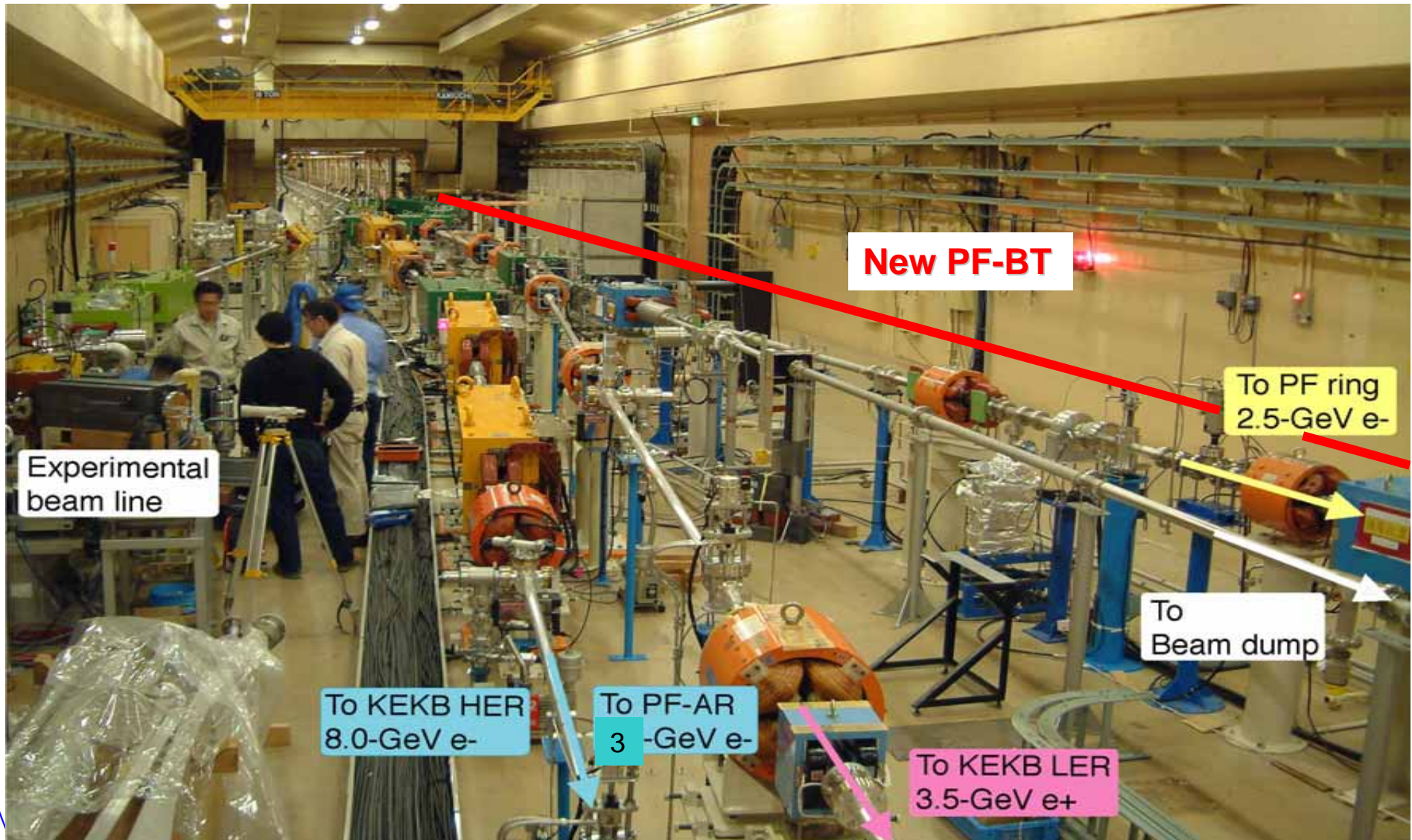
- ECS is always ON. (KEKB e-/ e+ and PF modes)
- It shorten time for beam mode change. (KEKB $\leftrightarrow$ PF)





- 3.1 Phase-I (Upgrade Plan)

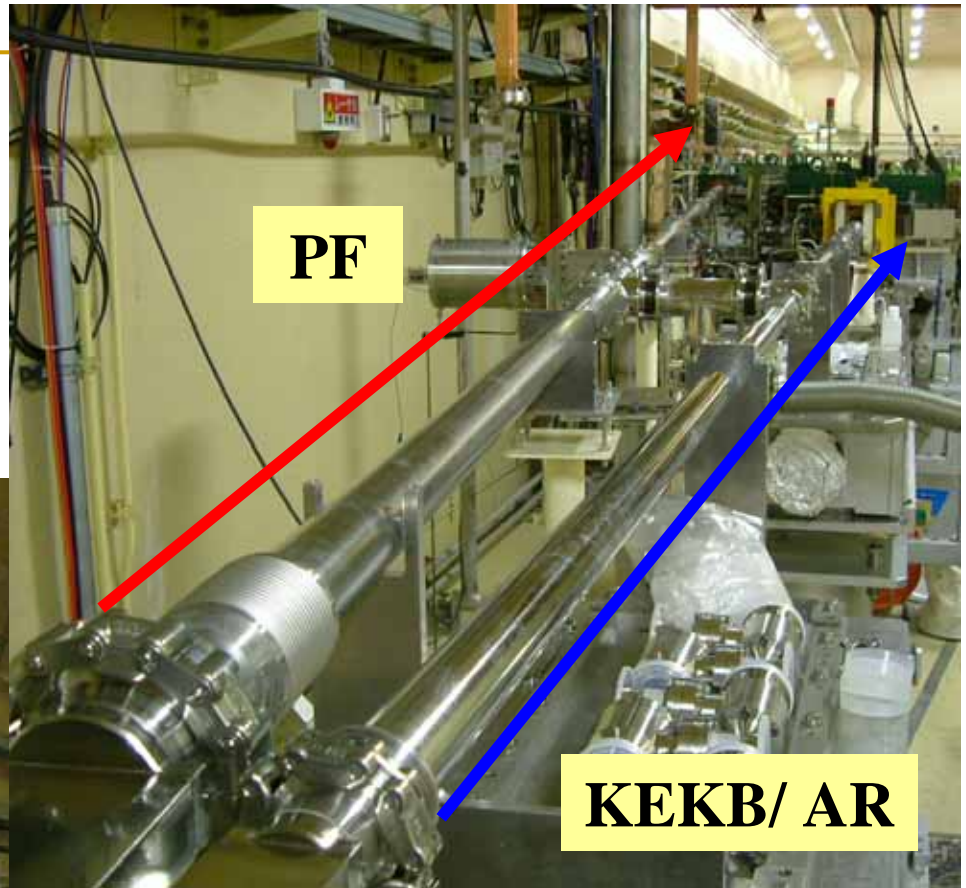
# Photograph of 3-SY (Before Phase-I)





= After Phase-I =

Switch DC Bend



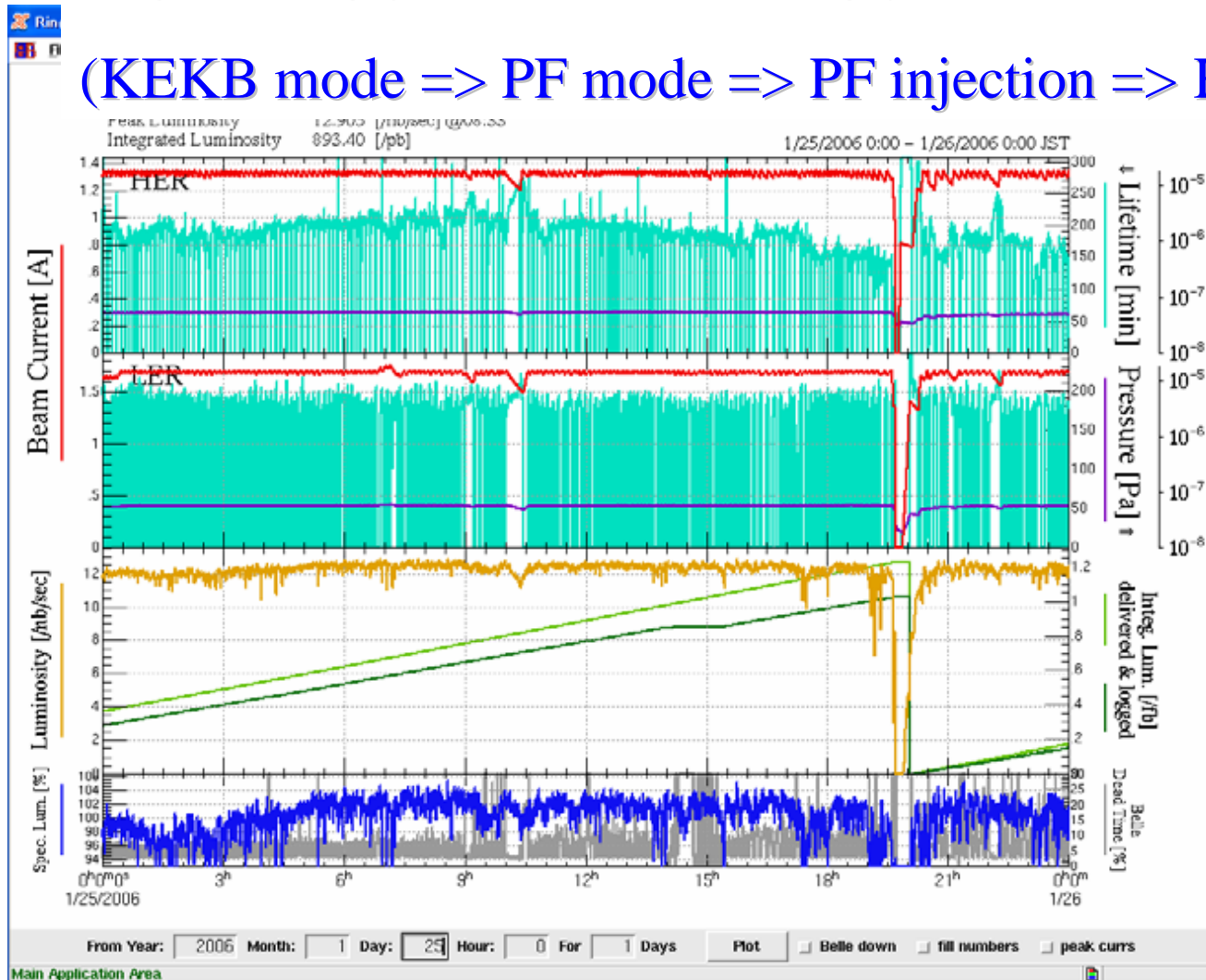
# New PF-BT (since FY05 summer)



# After Phase-I

- Bema-Mode Switch “KEKB  $\leftrightarrow$  PF” has been much improved.
- 5 min. 30 sec.  $\Rightarrow$  2 min. 30 sec.

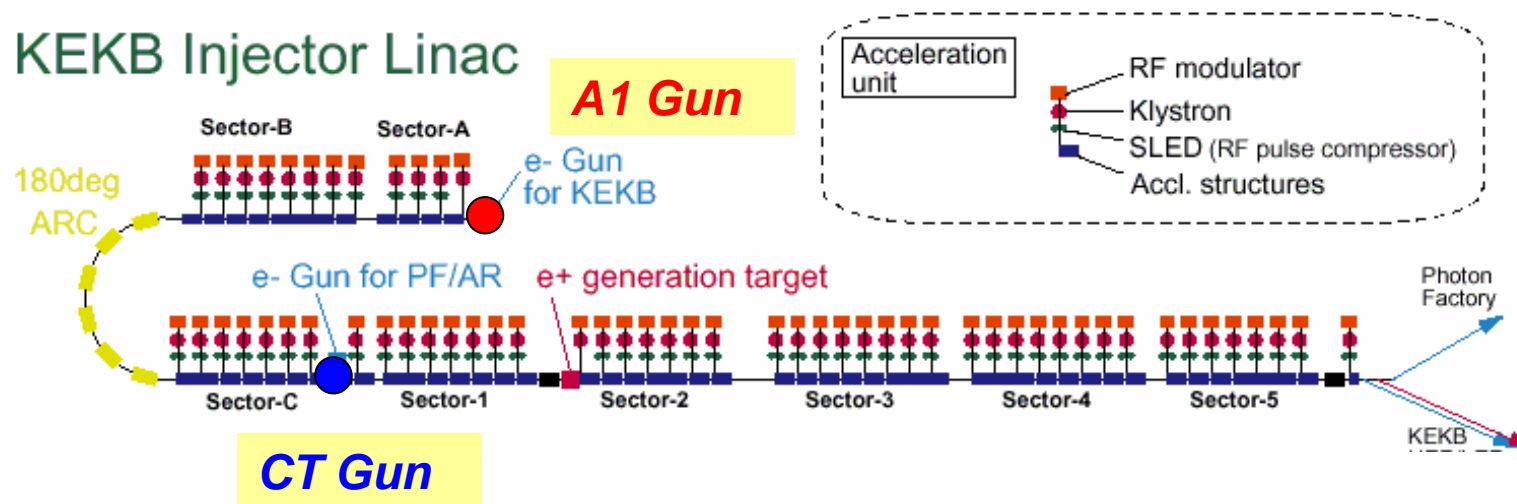
(KEKB mode  $\Rightarrow$  PF mode  $\Rightarrow$  PF injection  $\Rightarrow$  KEBB mode)



- 3.2 Phase-II (Upgrade Plan)

- Fast Beam-Mode Switch: KEKB e- and PF mode

- Multi-Energy Linac Scheme
- KEKB and PF use a common electron gun (A1).



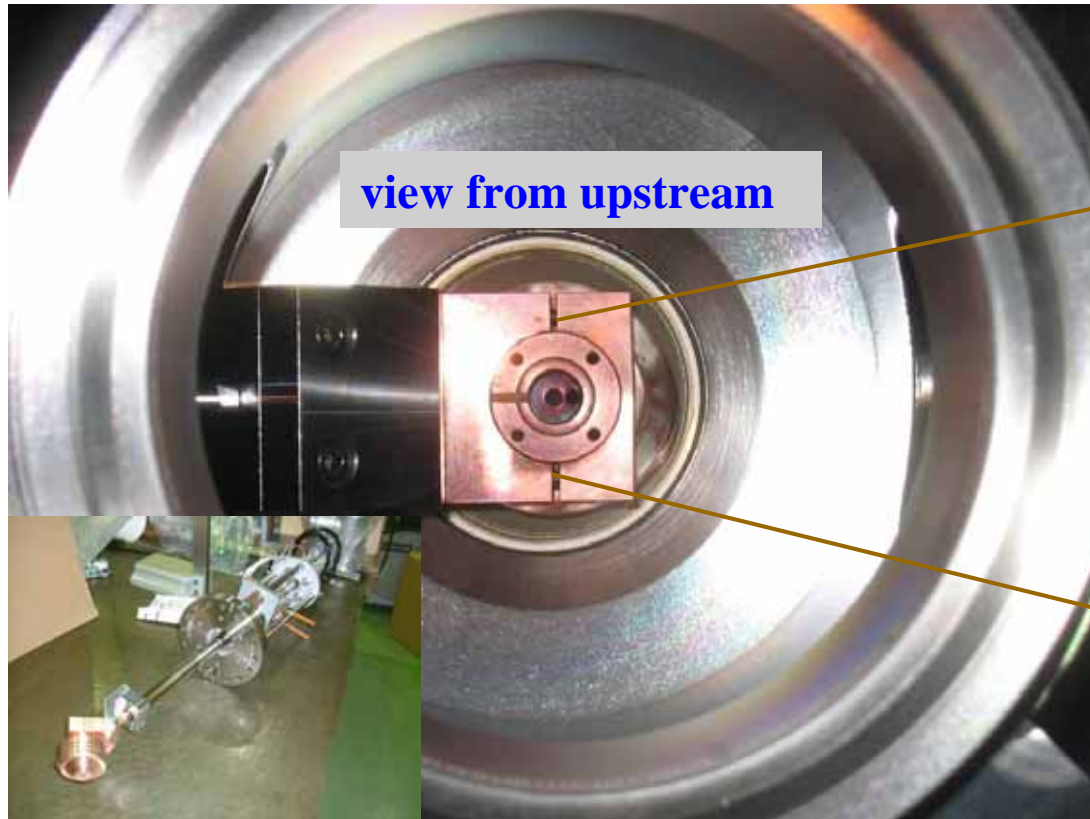
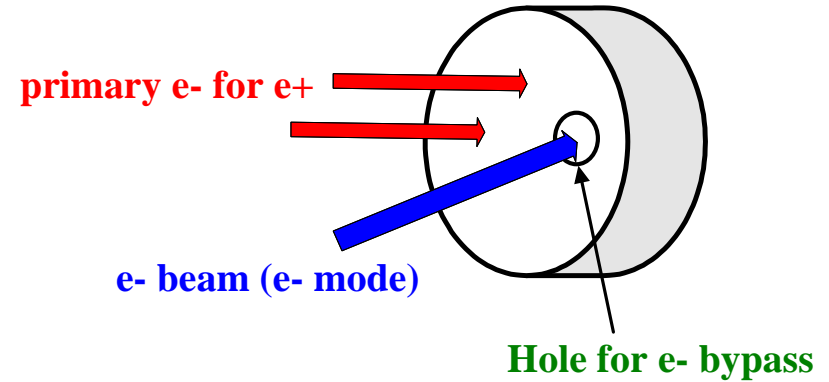


- 3.3 Phase-III (Upgrade Plan)

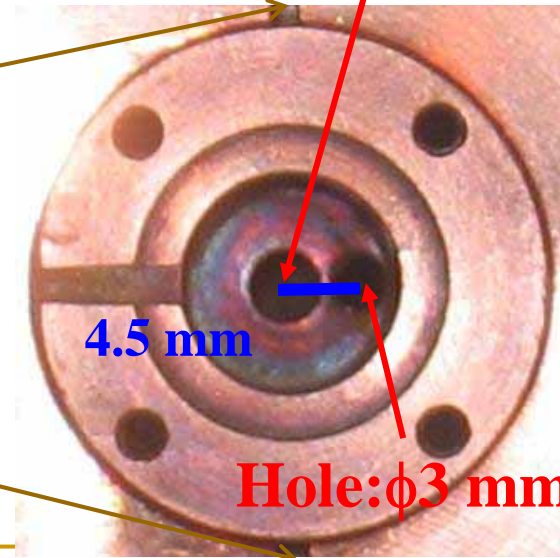
= Fast Beam-Mode Switch: KEKB e-/ e+, PF, PF-AR =

For fast switch (e-/ e+ mode) :

- Use e+ target with a hole.
- Control e- beam orbit.

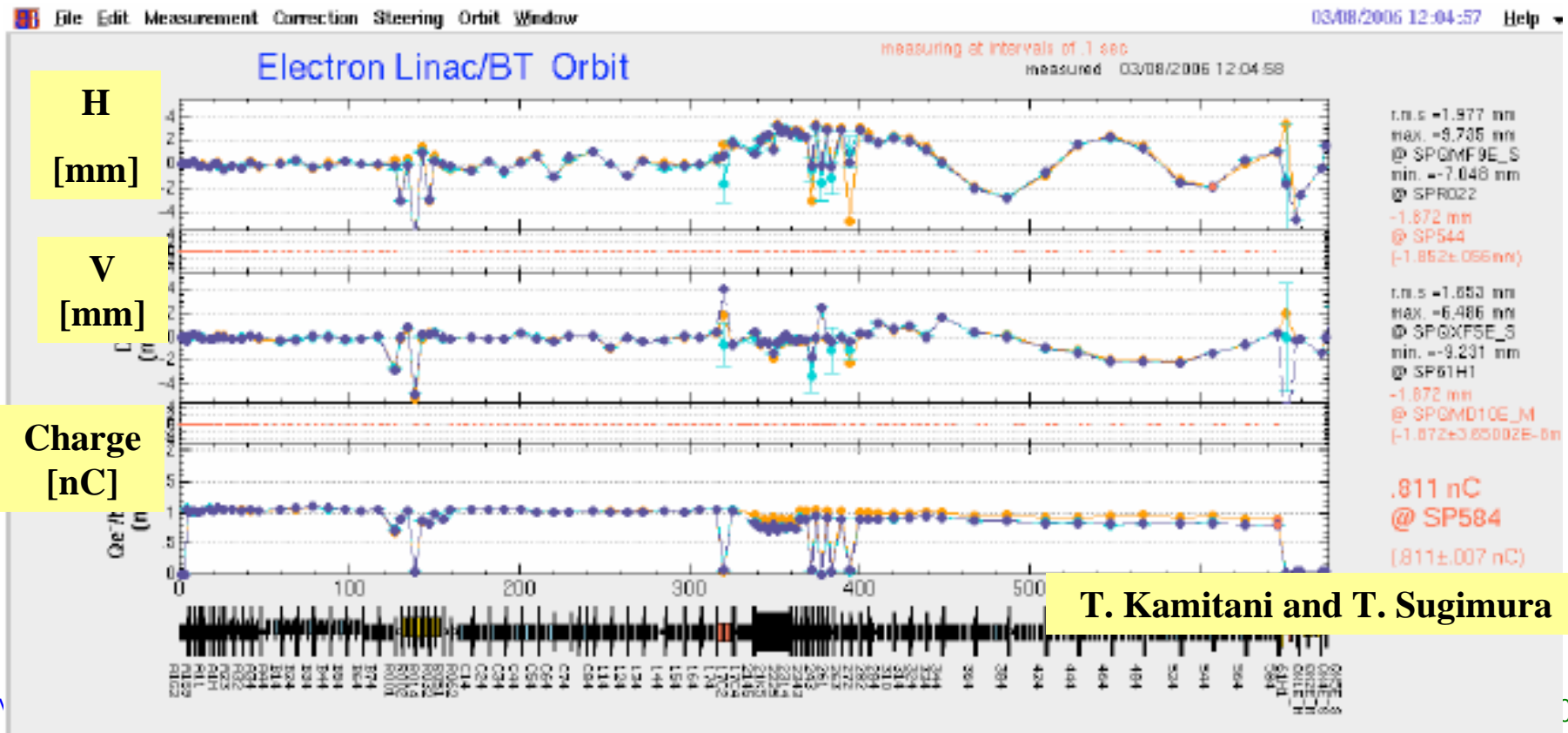


Amorphous tungsten target:  $\phi 5$  mm



## Preliminary Machine Study Result: e<sup>+</sup> target with a hole

- Orange dots: w/o target (normal operation)
- Blue dots: target (with a hole)
- Traversing rate is about 90% in comparison with normal operation.



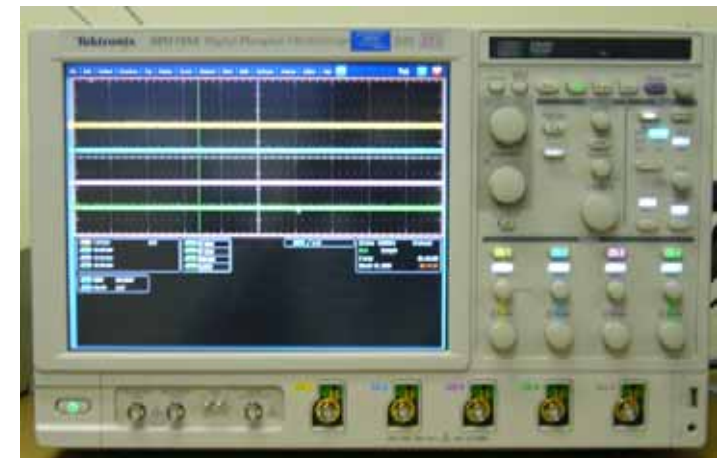


## Remaining Hardware Issue:

- BPM DAQ System should be upgraded to measure beam position up to 50 Hz.
- New System is under test.
- Timing system should control the complicated operation mode in Phase-III.
- Event generator (EG) and Receiver (ER) based on VME-64 will be tested soon.



**BPM DAQ system  
(VME + Oscilloscope with GPIB)**



**New system under test  
(Fast Win. Based-Oscilloscope/ EPICS)**

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# Scenario for PF-AR Injection

- It is difficult to realize PF-AR Top-up (6.5-GeV) w/o large budget. (Current PF-AR BT can transport beam 3.1-GeV max. )
- One solution: Use KEKB e+ (3.5-GeV) beam for PF-AR injection. It also needs large budget.
  - Need to replace some PS of bend (@AR-BT).
  - Need to replace Septum and Kicker PS
  - Need pulsed bend and PS
  - Cost estimation and design work should be done soon.

## 4. Summary

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- KEKB injector linac upgrade project has started in last summer toward Fast Beam-Mode Switch.  
(KEKB e-/ e+, PF e-, PF-AR e-).
- Phase-I completed (New PF-BT line):
  - It can shorten time for beam mode switch (KEKB $\leftrightarrow$ PF)
- Phase-II and III
  - Use “Multi-Energy Linac scheme”:
  - Use common magnetic field and fast change of rf phase.
  - Machine study result shows feasibility.
  - Machine study is going on.
- Need detailed design work of beam operation.
- After complete upgrade, linac beam operation will become more effective.