Present Status and Future Upgrade of KEKB Injector Linac

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Present Status
Upgrade in the Near Future
R&D towards SuperKEKB

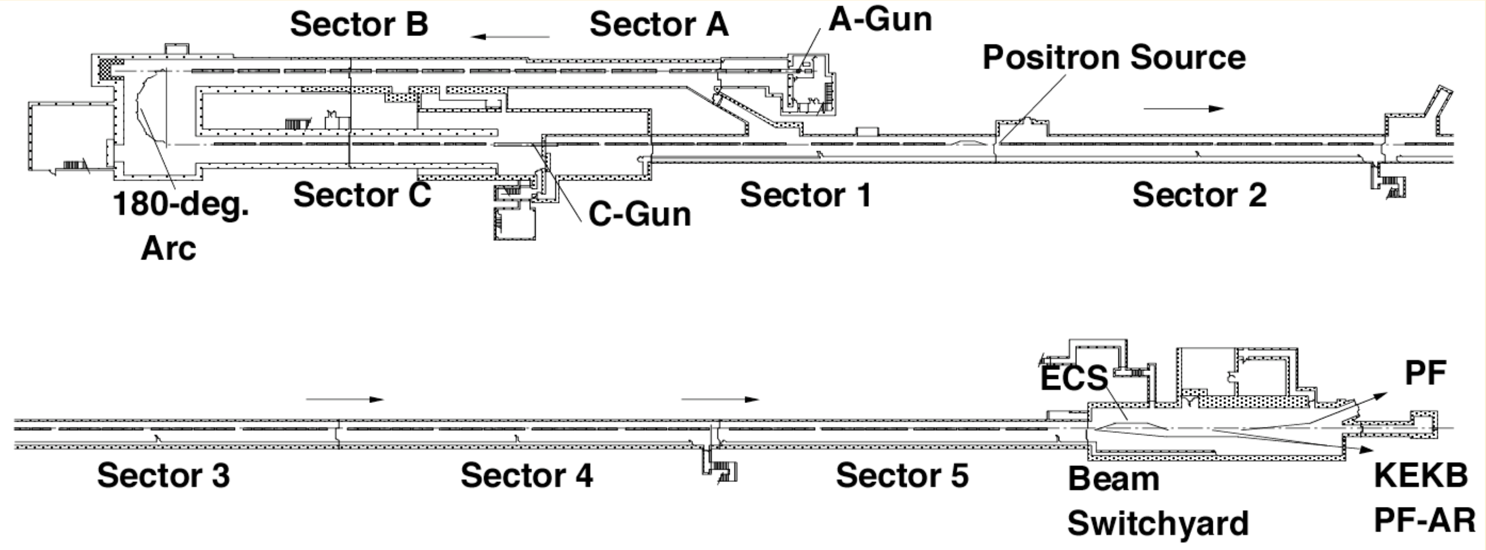
Electron/Positron Injector Linac

◆Machine Features

- 600m Linac with 59 S-band rf Stations, most of them Equipped with SLED to provide 20MeV/m
- Dual Sub-Harmonic Bunchers to achieve 10ps for 10nC, and Energy Compression System for Positron

◆Beam Characteristics

- 8GeV 1.2nC Electron and 3.5GeV 0.6nC x2 Positron for KEKB
- 2.5GeV 0.2nC for PF, 3.0GeV 0.2nC for PF-AR

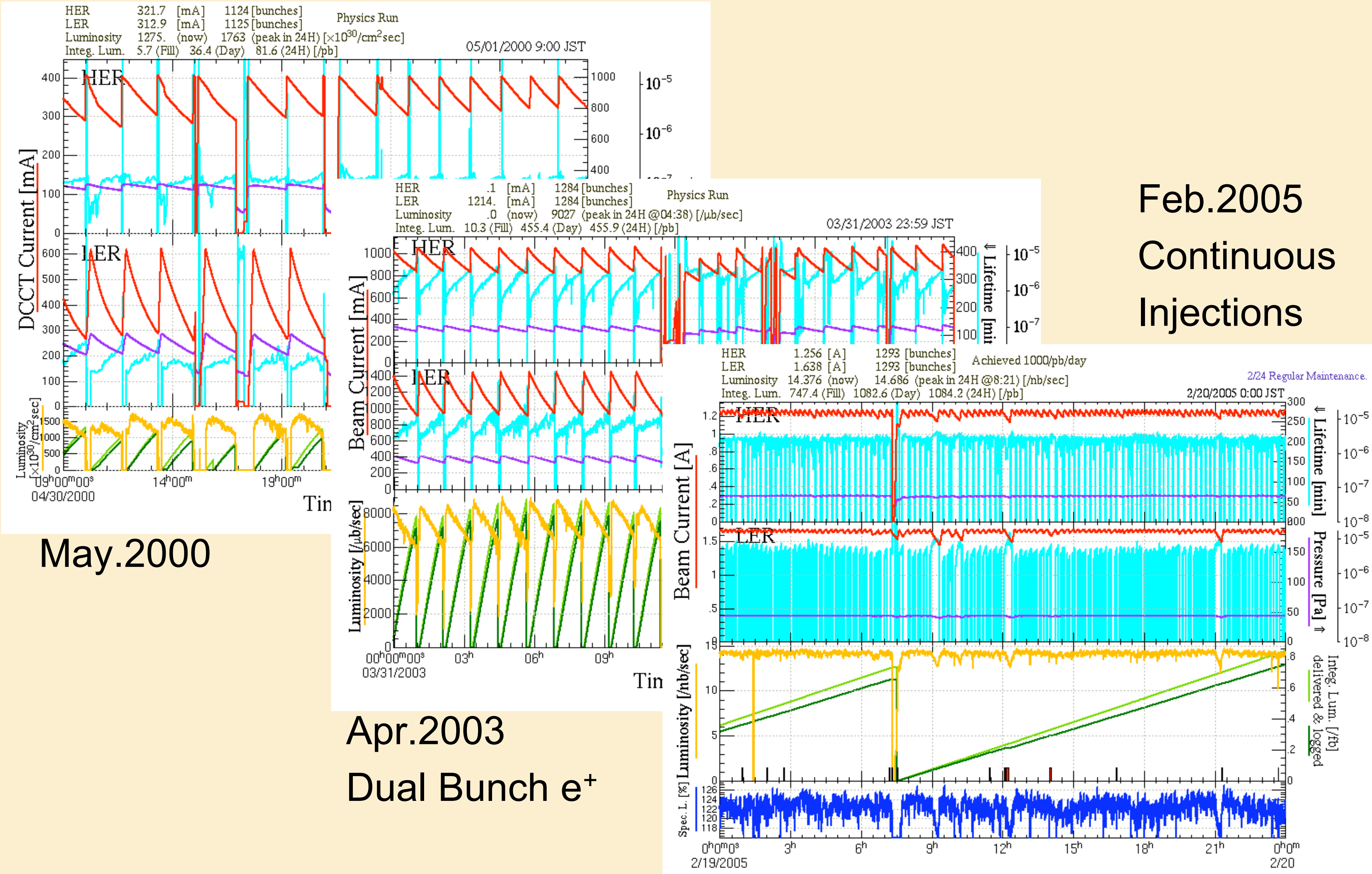


Linac in KEKB Commissioning

- Challenging Projects since 1998
  - Commissioning (1998~)
  - Overcoming rf Breakdowns
    at the Bunching section and Positron Capturing section (1999~2000)
  - Positron Injection with Dual Bunches in a Pulse (2001~2002)
  - Reduction of Failure Rate with Careful Management
    of the Equipment and Beam Parameters, especially at rf Trip Rate (2002)
  - C-band R&D for the Future SuperKEKB (2003~)
  - Continuous Injection of both Positron and Electron Beams (2004)

- Recent Operation
  - About 7000 hours/year
  - Machine-trouble time (when some part of the machine is broken): 2~3%
  - Beam-loss time (when beam could not be delivered): ~0.5%
  - Routine management
    of rf Power, rf Phasing, Optics Matching, Energy Spread Optimization

Increase of the Injection Efficiency



Feb.2005

Continuous

Injections

May.2000

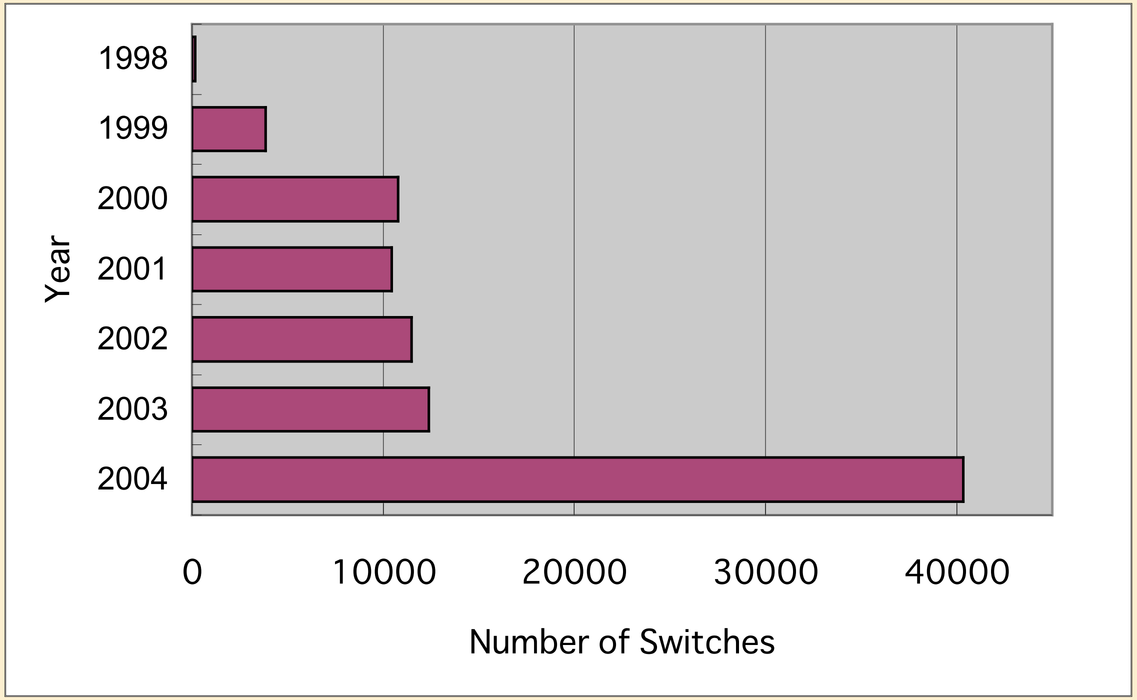
Apr.2003

Dual Bunch e^+

Continuous Injection Mode

◆Reliability of the Operation

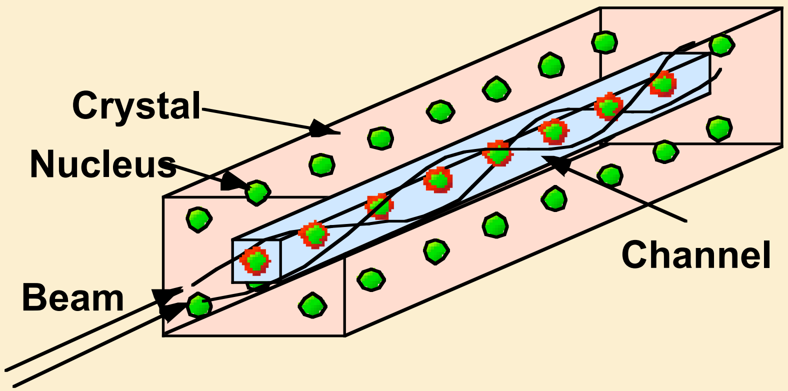
- Frequent Switch was not Considered in the Design
  - Vacuum Bellows, Mechanical Phase Shifters, etc.
- Improvement in each Hardware Component,
  as well as Operation Software
- No Reliability Degradation is Observed

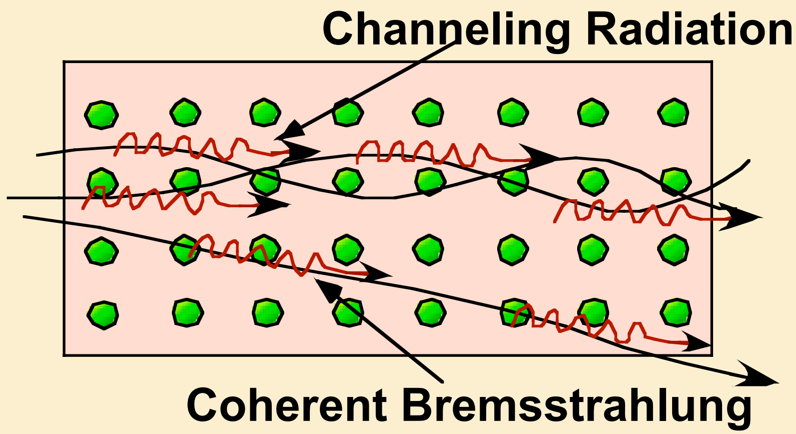


Positron Generation with Crystalline Tungsten

(Collaboration between KEK, Tokyo Metro. Univ., Hiroshima Univ., Tomsk Polytech., LAL-Orsay)

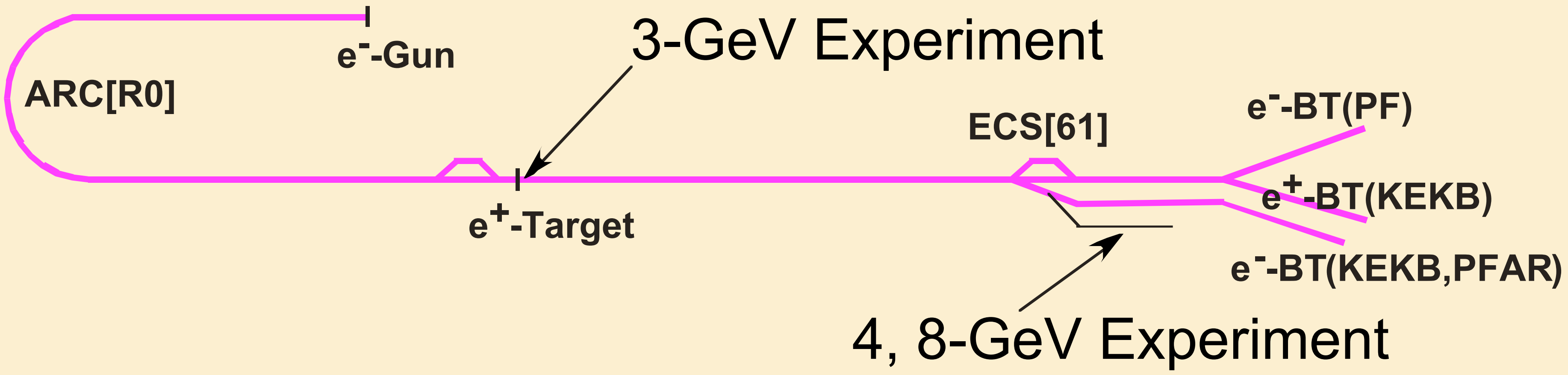
- High Intensity Positron is Always a Challenge in Electron-Positron Colliders
  - Positron Production Enhancement by Channeling Radiation in Single Crystal Target was Proposed by R. Chehab et. al (1989)
  - The Effect was Confirmed Experimentally in Japan (INS/Tokyo, KEK) and at CERN



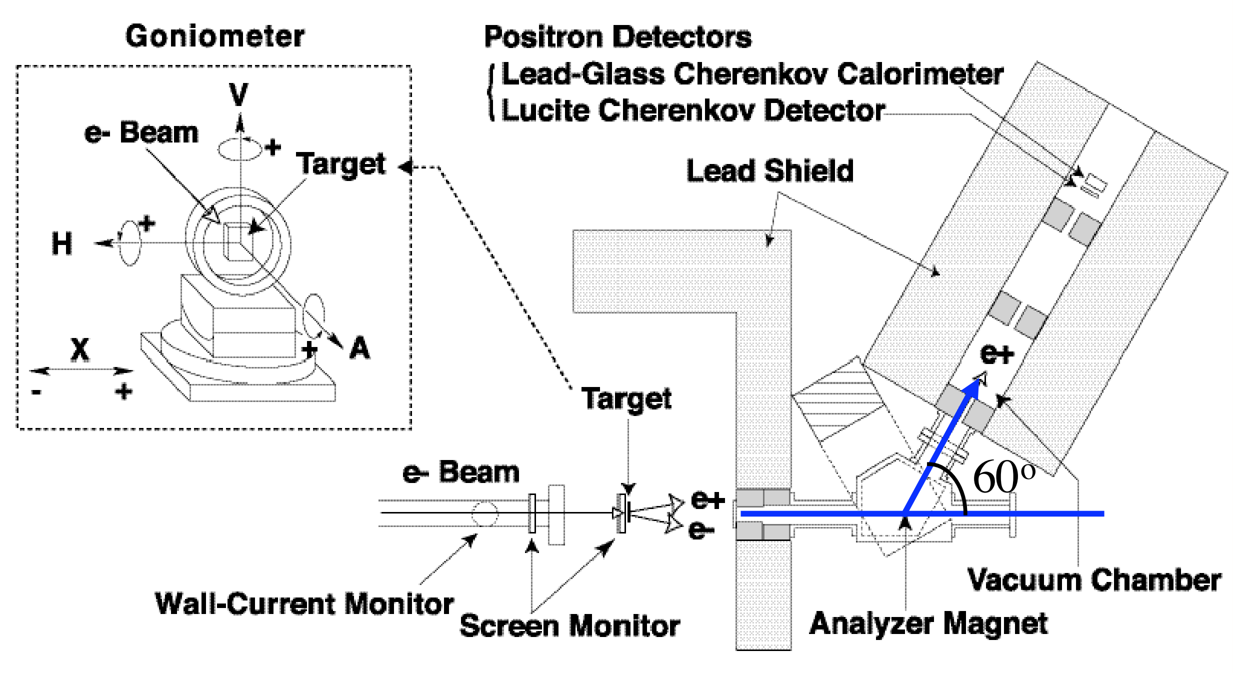


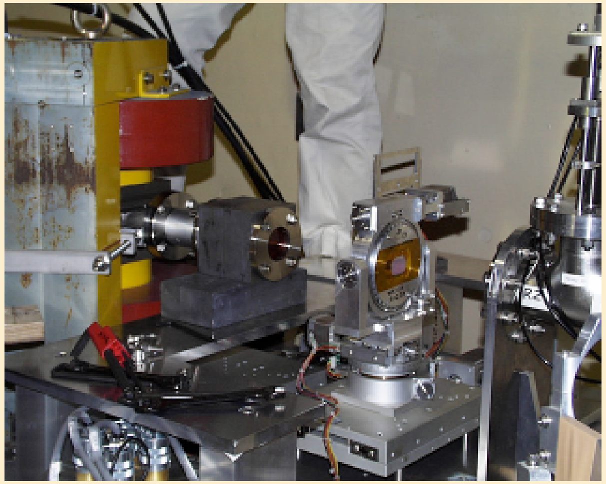
Experiment at KEK

- Positron Production Enhancement Measurement
  - Target Thickness Dependence
    (2.2, 5.3, 9mm for Tungsten Crystal, 2 ~ 28mm for Amorphous)
  - Out-going Positron Energy Dependence (5 ~ 20MeV)
  - Incident Electron Energy Dependence (3 ~ 8GeV)
  - Single Target or Hybrid Target
  - Target other than Tungsten,
    Crystals used for Calorimeters, Silicon, Diamond

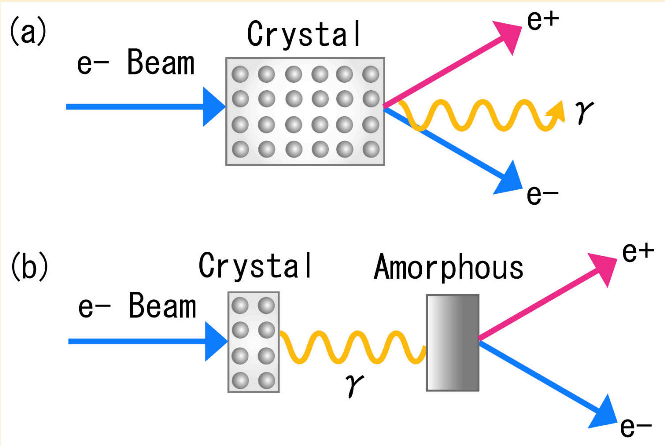


Experimental Setup

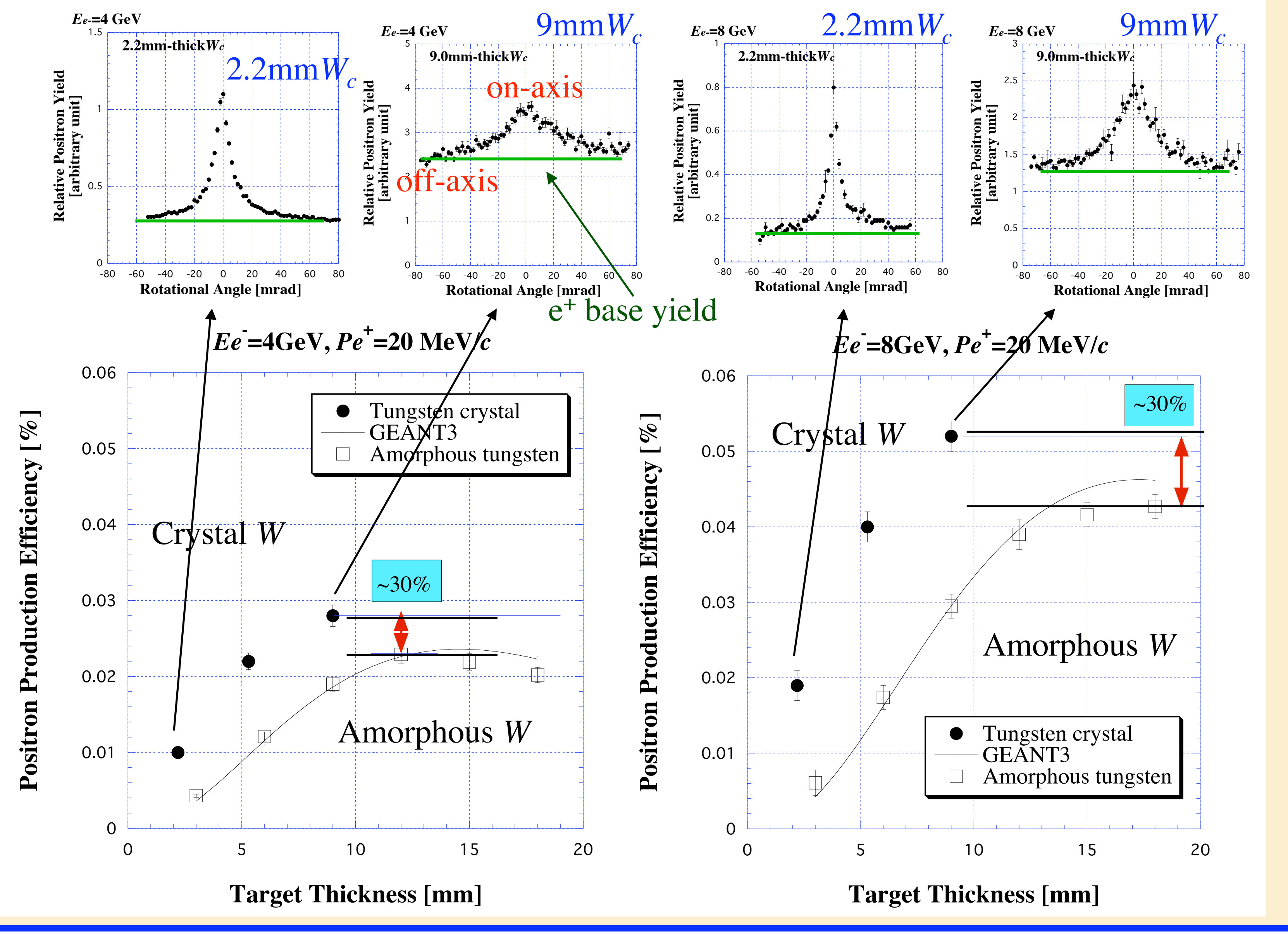




Single Target
Hybrid Target



Typical Experimental Measurements



Results and Considerations

- With Tungsten Single Crystal, the Absolute Positron Yields were Enhanced by ~26% at E_{e+}=20MeV, and by ~15% (average) in the range of E_{e+}= 5~20MeV compared with the Maximum Yield in the Amorphous Tungsten.
- Diamond Hybrid Target has been Suggested to Produce 3-Times more Photons (V.N.Baier et al.), but We need >15mm Thick Diamond while We could test only 5mm. And the Radiation Damage is Unknown.
- Another Experiment is Planned just before Summer Shutdown to Refine the Results, and The Optimized Crystalline Tungsten is Planned to Replace the Present Positron Target. The Design of the Target is Under way.

Upgrade Towards Simultaneous Injection

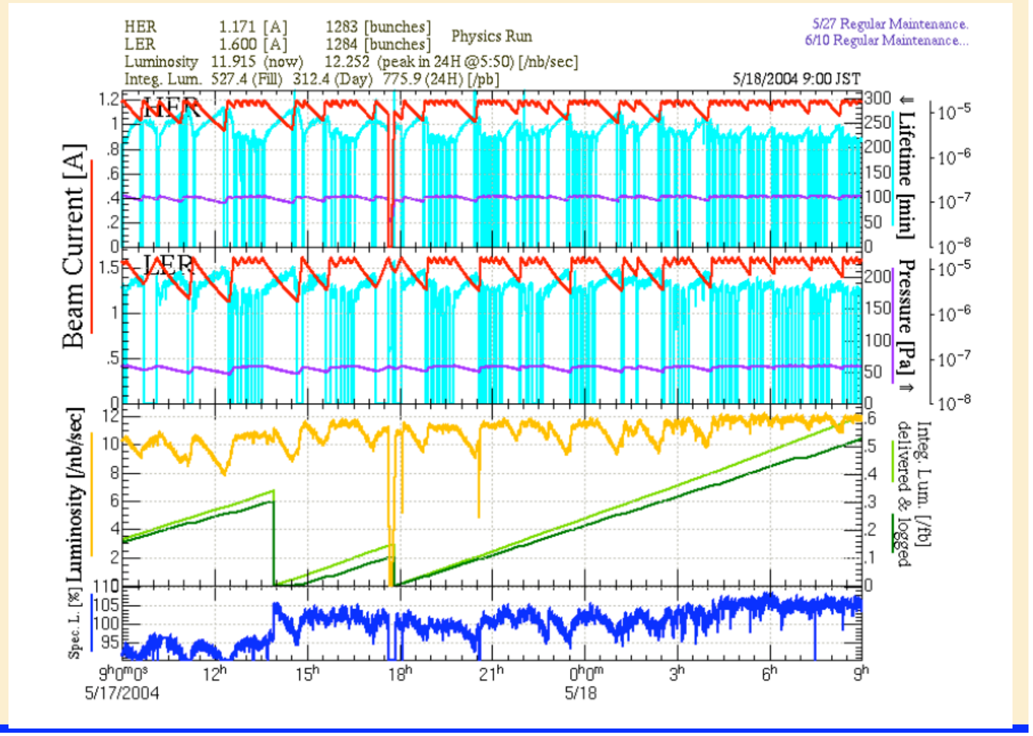
(Collaboration Working Group between PF, KEKB, Linac and Others)

◆Requirements

- ❖One Linac is used for 4 Storage Rings (Time Sharing)
- ❖Switching between KEKB and other Modes takes ~3 minutes because ECS Magnets have to be standardized.
- ❖Machine Studies in PF and/or PF-AR Interrupt the KEKB Continuous Injection.
- ❖PF Needs Top-up (Continuous) Injection in the Future for Advanced Measurement.

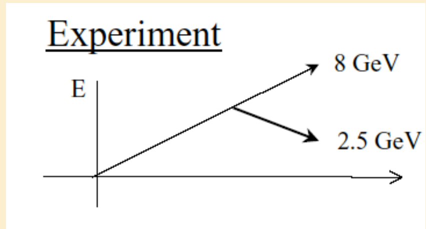
◆Possible Solution

- ❖Simultaneous Injection Scheme is Strongly Suggested.
- ❖Beam Switches pulse-by-pulse could be Employed.
- ❖Needs Pulse Bend. Magnet to Kick PF Beam

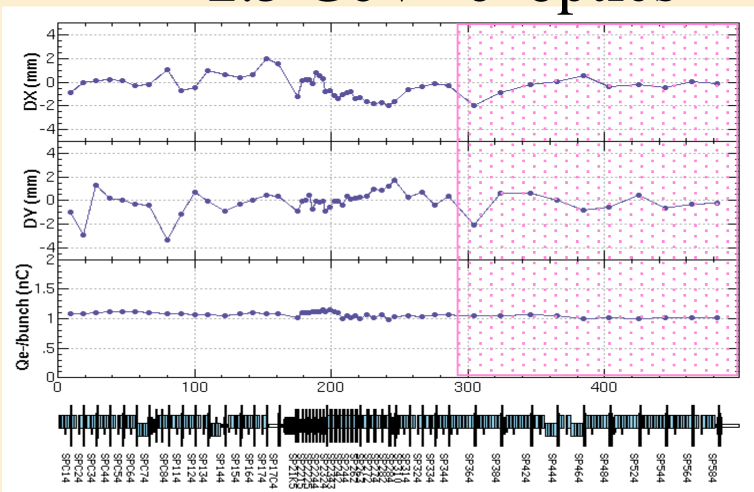


Fast Beam Switches

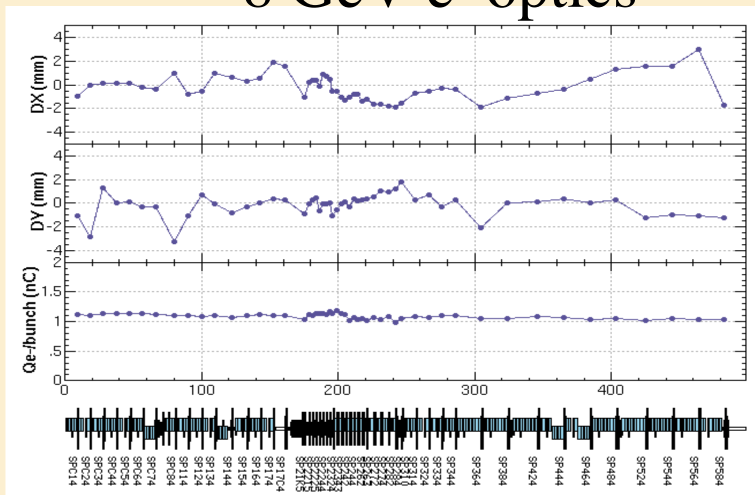
- Fast Change of the Magnetic Field is Difficult
  - Common Magnetic Field (Quad and Steering Magnets) should be Used.
  - Energy Adjustment can be Achieved with Low-level rf Controls.
    - With Additional Circuits and Controls.
  - The Beam is Accelerated up to ~5.3GeV
    then further Accelerated to 8GeV for KEKB,
    or Decelerated to 2.5GeV for PF.



"2.5 GeV" e^- optics



8 GeV e^- optics



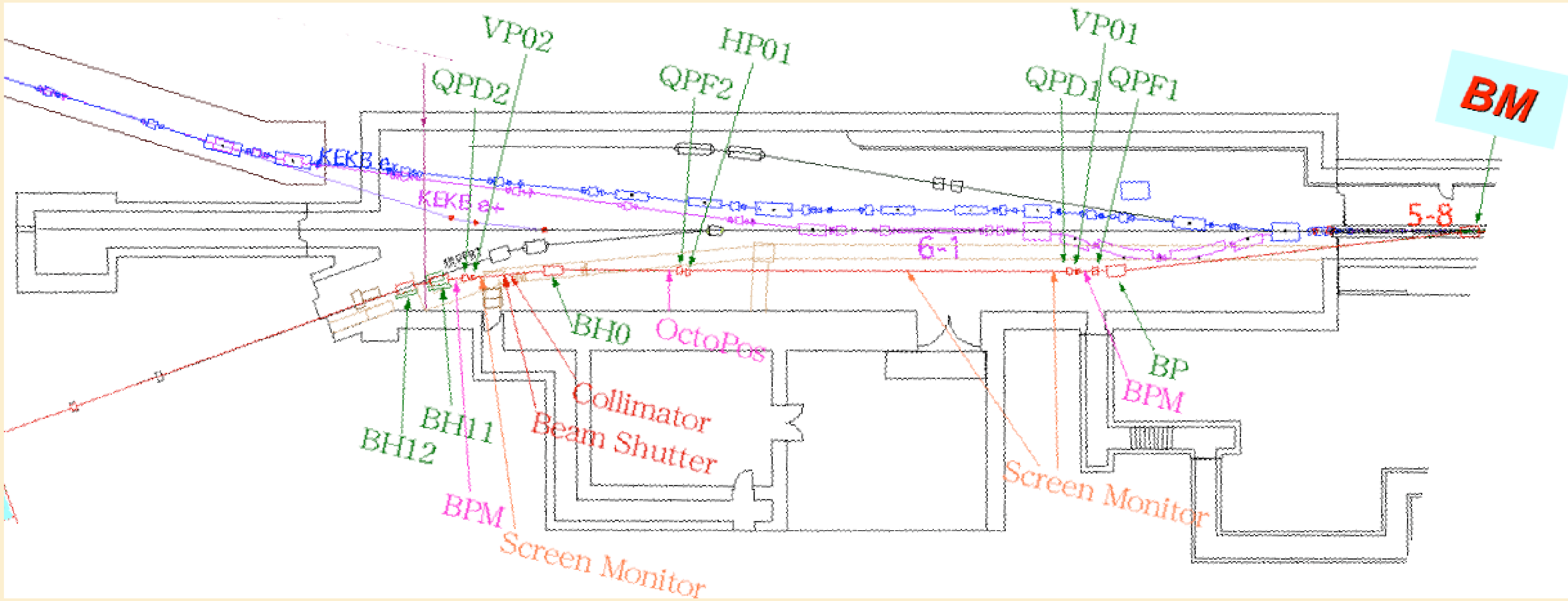
Preliminary Test
by Y.Onishi

- Energy = 2.7 GeV (SC61H)
- $\gamma\varepsilon_x$ = 3.6x10^{-4} m
- $\gamma\varepsilon_y$ = 6x10^{-5} m

- Energy = 8 GeV (SC61H)
- $\gamma\varepsilon_x$ = 2.5x10^{-4} m
- $\gamma\varepsilon_y$ = 4x10^{-5} m

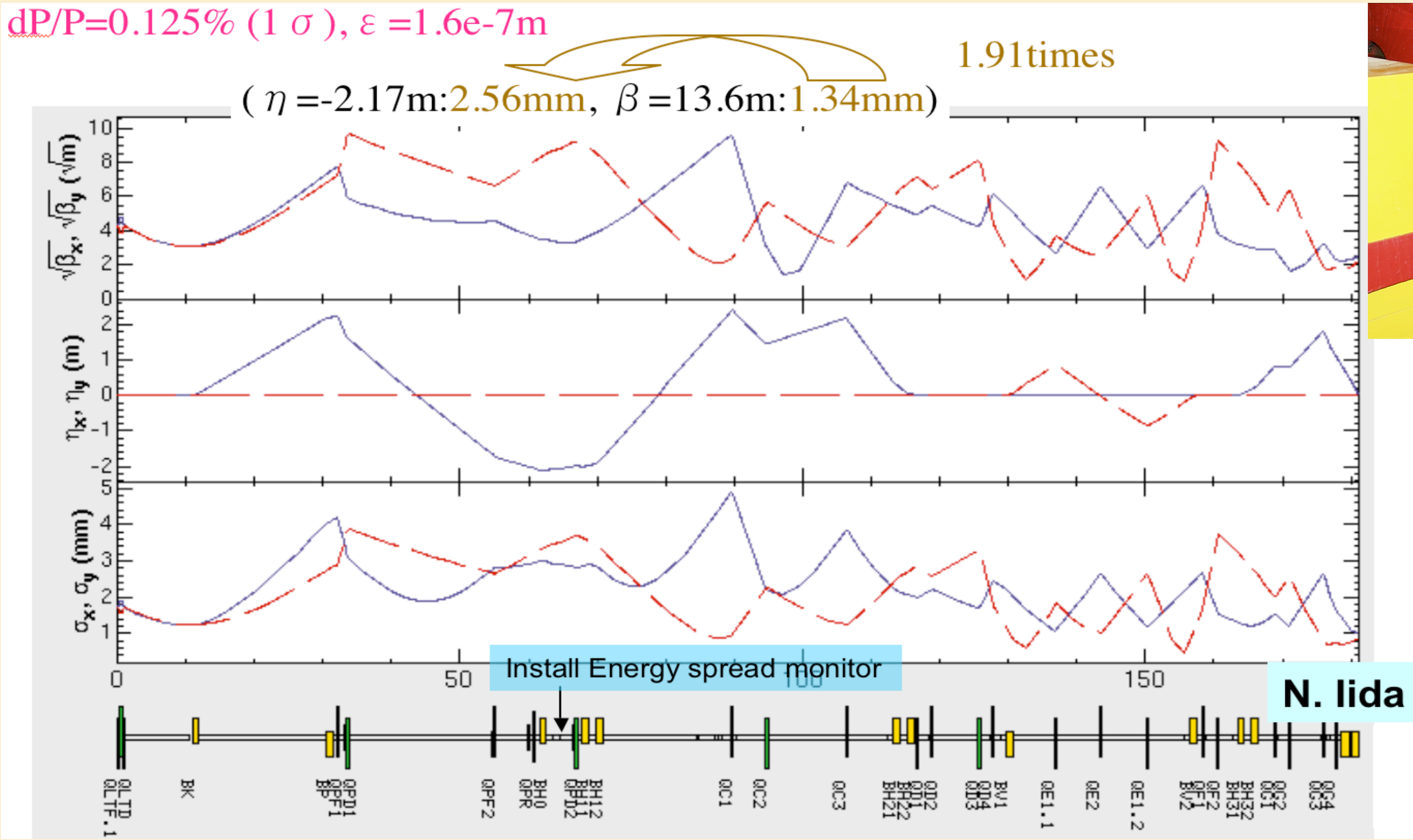
Upgrade Overview

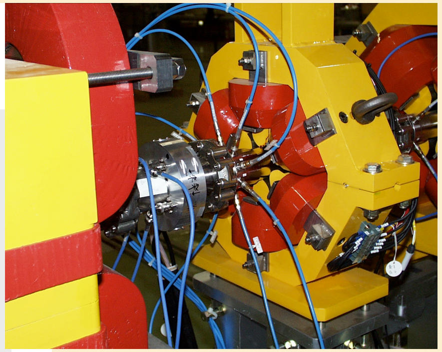
- Upgrade would be Carried in 3 Phases
  - Phase-I: Construction of New PF-BT Line Summer 2005
  - Phase-II: Simultaneous Injection between KEKB e– and PF e–
  - Phase-III: Simultaneous Injection including KEKB e+ (,PF-AR)
- It was decided to be Carried out as Soon as Possible.



PF Beam Transport Optics Design

- The New PF-BT Optics Design is Fixed
- Spare Parts are Collected based on the Design, if Exists
- Other Components are being Designed or being Fabricated
- Phase-I Components (except Pulse Bend) will be Installed at this Summer





Energy Spread Monitor

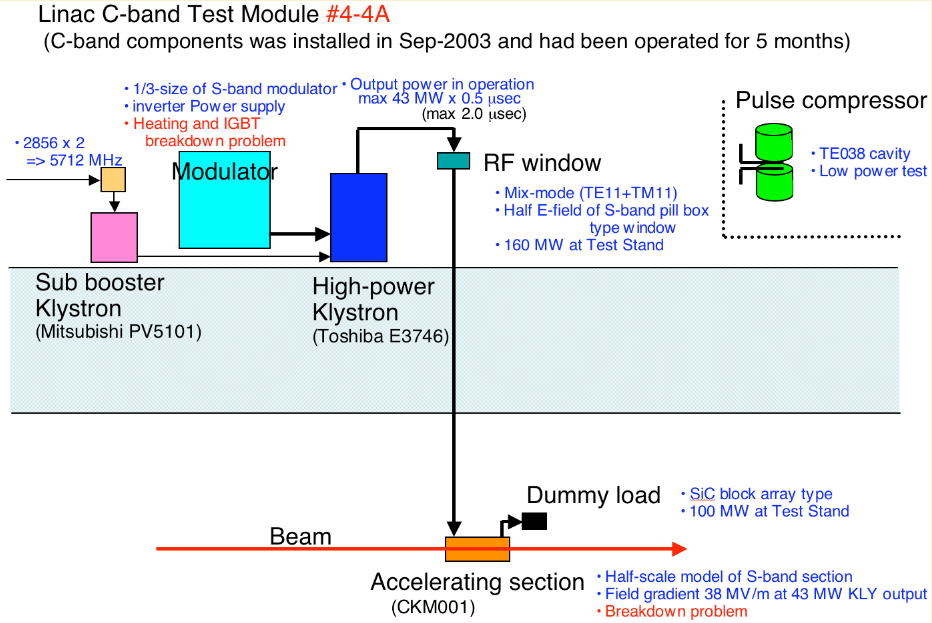
C-band R&D towards SuperKEKB

- Higher Luminosity in SuperKEKB
  - (1) Squeezing Beta at Interaction Region
  - (2) Increase of Beam Currents
  - (3) Crab Cavities
  - (4) Exchange of Energies of Electron/Positron to Cure e-Cloud Issues
  - etc.
- For Linac (4) is the Major Challenge as well as (2)
  - Higher Gradient Acceleration with C-band Structure is Considered to Achieve 8GeV Positron
- ~24 rf Stations will be Converted
  - From: Single S-band rf Station + 2m x 4 Acc Structure = ~160MeV
  - To: Dual C-band rf Station + 1m x 16 Acc Structure = ~320MeV

    ==> 8GeV Positron can be Provided
- Dumping Ring to Meet the IR Design will also be Employed

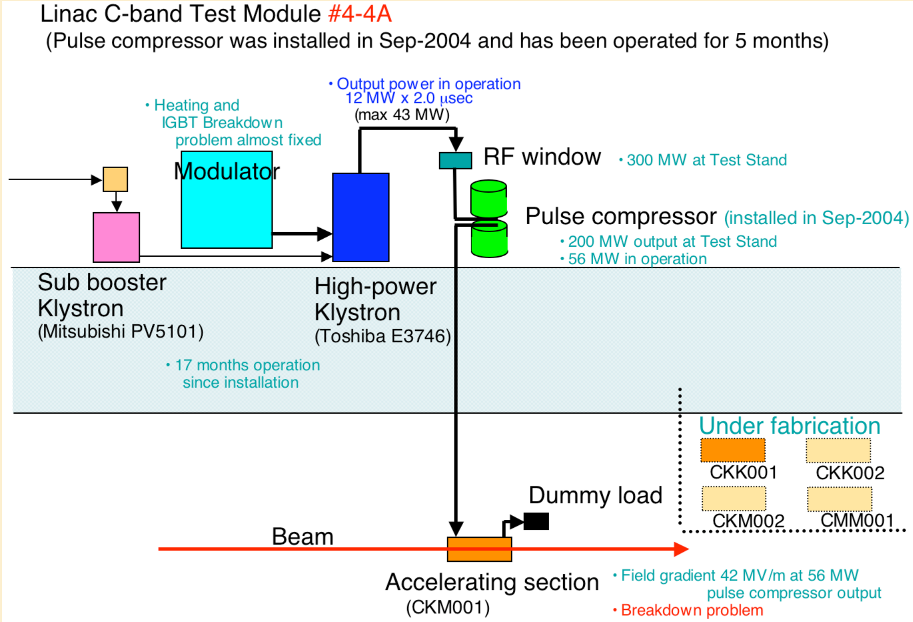
Advances in C-band R&D

- Apr.2002-Aug.2003.
  - Design and Installation of
    - First rf Station
    - First Acc. Structure
      - Basically Scale down of S-band One



- First Accelerated Beam (Oct.2003)
  - ~38MV/m at 43MW

- Sep.2003-Aug.2004.
  - Design and Installation of
    - First LIPS type rf Compressor (SLED)
      - TE038 mode
  - Further Improve for Real Operation



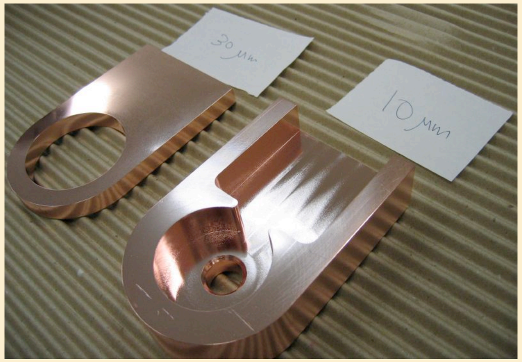
- Accelerated Beam with rf Pulse-Compressor
  - ~42MV/m at ~56MW (12MW from Kly.)

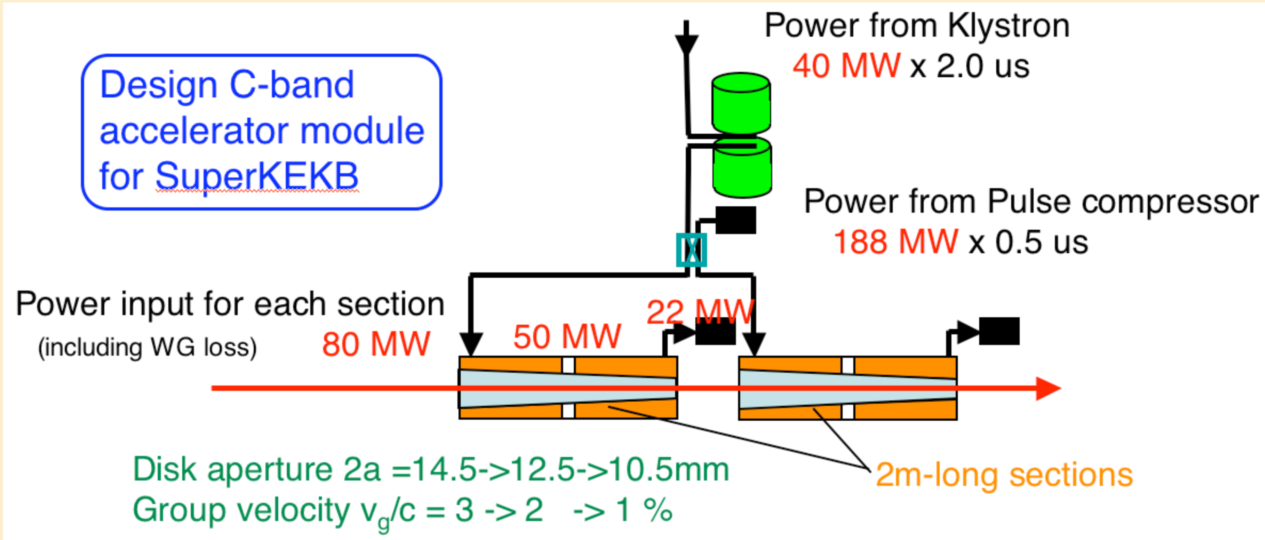
C-band Components

- Klystron & Pulse Modulator
  - Compact (1/3 size), Cooling and IGBT breakdown Issues Solved
- rf Window
  - Mix (TE11+TM11) mode Traveling Wave, 300MW Transmission
- rf Pulse Compressor
  - TE038 mode (instead of TE015), Q_0=132,000, 200MW Achieved in Test
- Accelerating Structure
  - Based on half-scale of S-band Structure
  - 2/3p Traveling-wave, Quasi-constant-gradient, Electroplating
  - Because of such Simple Design, a few Trips / hour Observed
    - Expected to be Solved in the Next Summer
- rf Low-level and booster Klystron
  - May need Modification in Real Operation

Improvements in Coming Summer

- Four Accelerating Structures are under Fabrication
  - Designed in KEK, and Fabricated in KEK or MHI
- Several Features are Applied especially at Coupler
  - Standard or Non-standard (Full-length) Coupler Cell
  - Thick and Smooth Shape Coupler Iris
  - Coupler Axis offset for Field Correction
  - Electro-polishing at Coupler
  - Constant Impedance





Summary

- Operational Improvements and Future Projects are Carried with Balancing between them
- Continuous Injection Surely Improved KEKB Luminosity
- Simultaneous Injection Project will Help both KEKB and PF Advanced Operation, and also Other Rings in Future
- Oriented Crystalline Positron Target may Enhance Positron Production
- C-band R&D for Future SuperKEKB Advances Steadily but relatively Rapidly, and the Results seem to be Promising