The Present Performance and Future Upgrade of the KEKB Electron Linac

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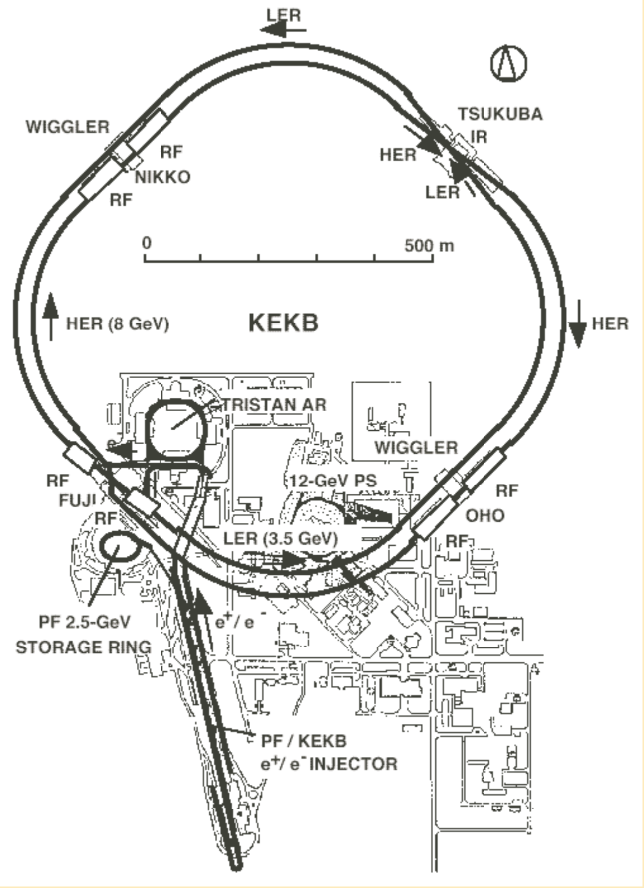
Introduction, KEK e^- Linac

- KEKB Asymmetric Collider Complex and Belle Detector for CP-Violation Study
- Stable and Robust Operation of Linac for Higher Experiment Efficiency
- Many Active Operation Parameters at Microwave Systems, etc.
- Frequent Switching between

KEKB e^-	**8 GeV** 1.28 nC Single Bunch
KEKB e^+	3.5 GeV 0.64 nC Single / **Dual** Bunch
	(Primary e^- **10 nC**)
PF e^-	2.5 GeV 0.2 nC Multibunch
PFAR e^-	2.5 / 3.0 GeV 0.2 nC Multibunch



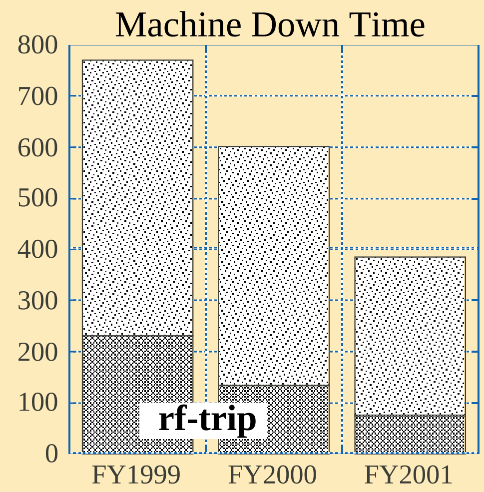
Regular Operation Statistics

◆ Basic Operation Performance

Ring	Charge [nC]	Energy [GeV]	Injection [/day]	Inj. Time [min.]	
KEKB e^-	**1.28**	**8.0**	**~14/18**	**~1.5**	
KEKB e^+(1)	**0.64** x **1**	**3.5**	**~14**	**~8**	**(single bunch)**
KEKB e^+(2)	**0.64** x **2**	**3.5**	**~18**	**~4**	**(double bunch)**
PF e^-	**0.2**	**2.5**	**1**	**~5**	
PFAR e^-	**0.2**	**2.5/3.0**	**12**	**~4**	

◆ Operation Hours

	FY1999	**FY2000**	**FY2001**
Beam Operation Time	**7297**	**7203**	**7239**
Machine Down Time	**768 (10.5%)**	**601 (8.3%)**	**385 (5.3%)**
Beam Loss Time	**74 (1.0%)**	**54 (0.8%)**	**22 (0.3%)**

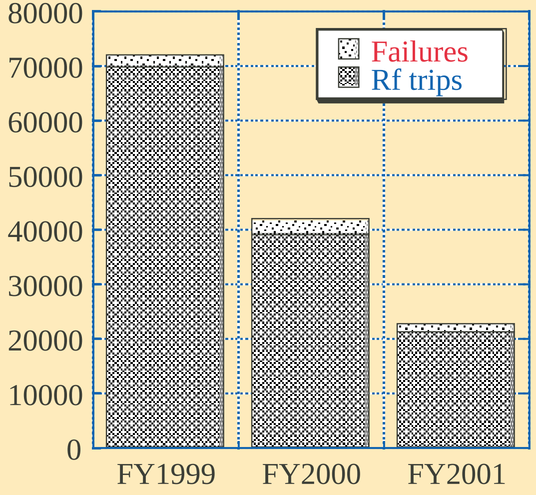


Machine Down: Machine was not ready. (including rf-trip, 10-minute maintenance, etc)
Beam Loss: Machine was not ready when an injection was requested.

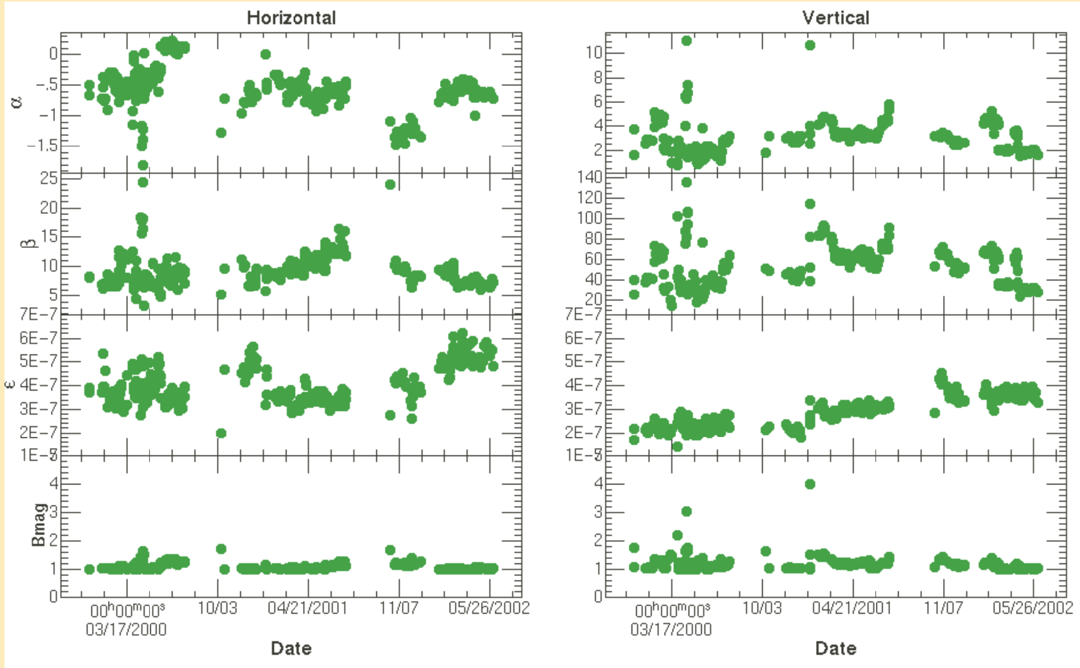
Beam Quality Control

◆ rf System Optimization

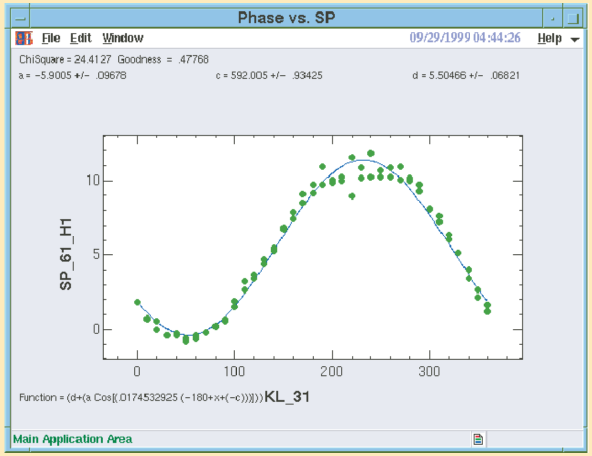
[Routine Monitoring of Beam / Machine Parameters]



◆ Emittance and Matching Condition

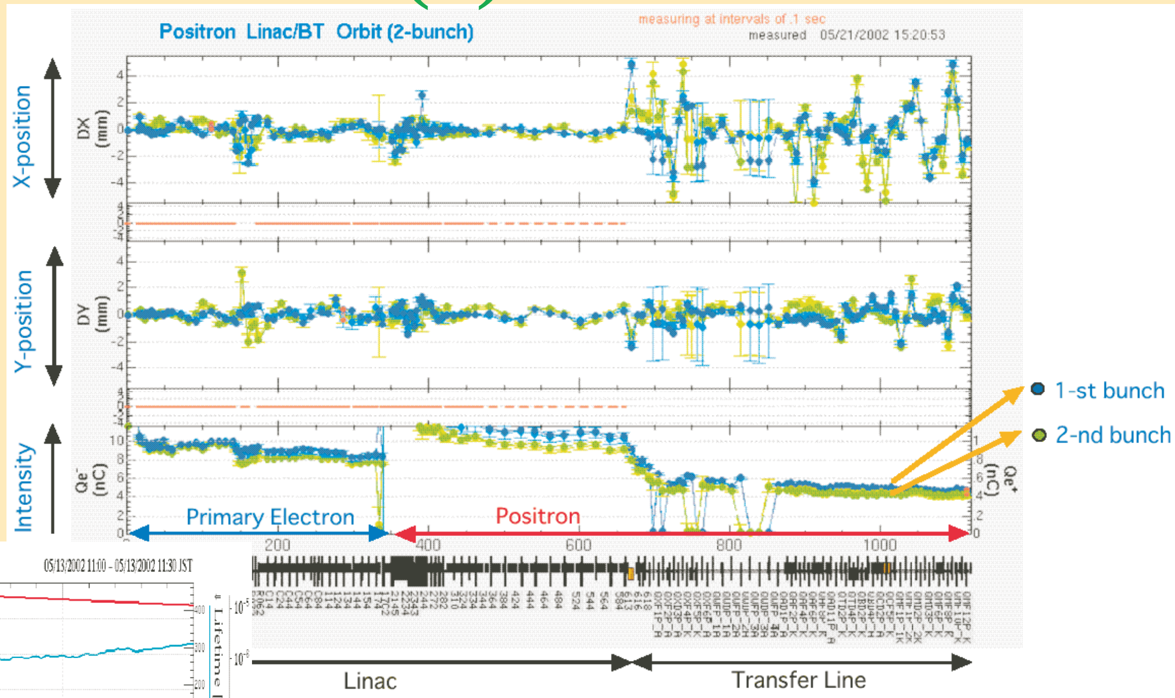


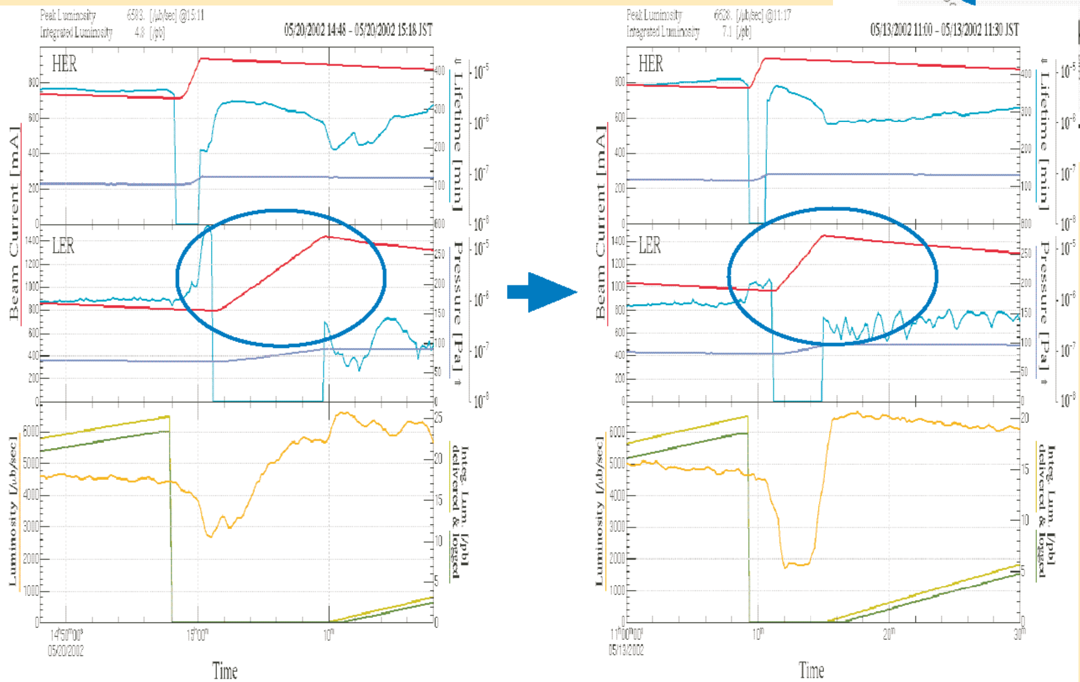
◆ rf Phasing



Advanced Injection for KEKB (1)

- Double Bunch Injection
  Positron Double Bunch
  in one rf Pulse





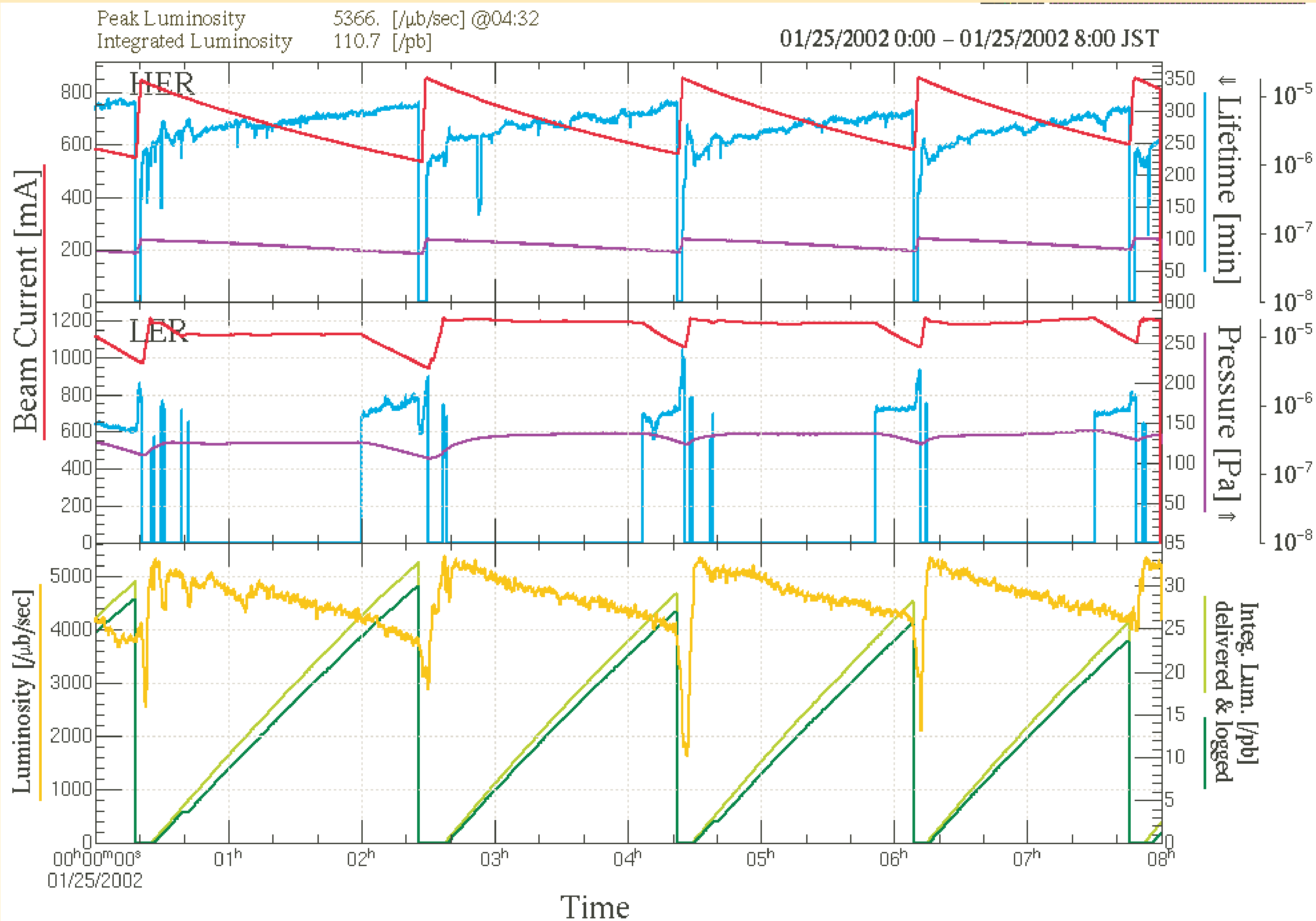
- Doubled the Injection Rate
  Luminosity Increase ~8%
  (Bunch Pattern Restriction)
  Already 4-week Experience

Advanced Injection for KEKB (2)

- Continuous Injection
  - During Experiment

- Detector Veto
- Beam Pipe Heating
- Switch to PFAR

Luminosity Increase ~20%



- Both “Double-Bunch Injection” and “Continuous Injection” in the upcoming Autumn Operation

Linac / Ring Upgrade for SuperKEKB

- for Precise Measurement of ***B***-meson System Parameters and Search for New Physics (ex. SUSY)

  SuperKEKB : Luminosity of 10^{35} cm^{-2} s^{-1}

  with Major Upgrade of Linac and Ring

- Luminosity Increase
  - (1) Squeezing Beta at Interaction Region (by factor of 3.3)
  - (2) Increasing e^- and e^+ Beam Current (by factor of 3.3)
  - (3) Exchanging Energies of e^- and e^+ (to cure e^- cloud issues)

- for Linac

  (3) is the Major Challenge, as well as (2)

  Two Schemes are Considered
  - (a) Higher Gradient with C-band Structures
  - (b) Recirculation of Positron

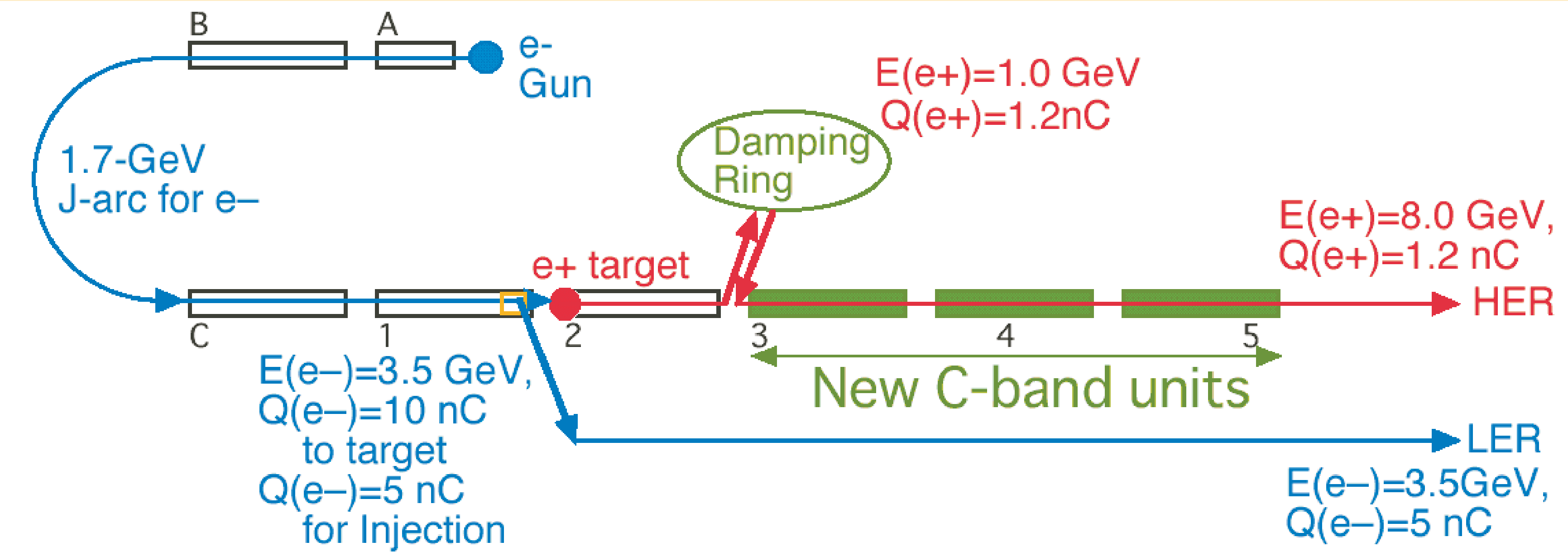
Linac Energy Upgrade with C-Band

- e^+ 8.0 GeV with Doubling the Acceleration Gradient

    C-Band Structures : 21 –> 42 MeV / m, 320MeV / unit, 24 Units

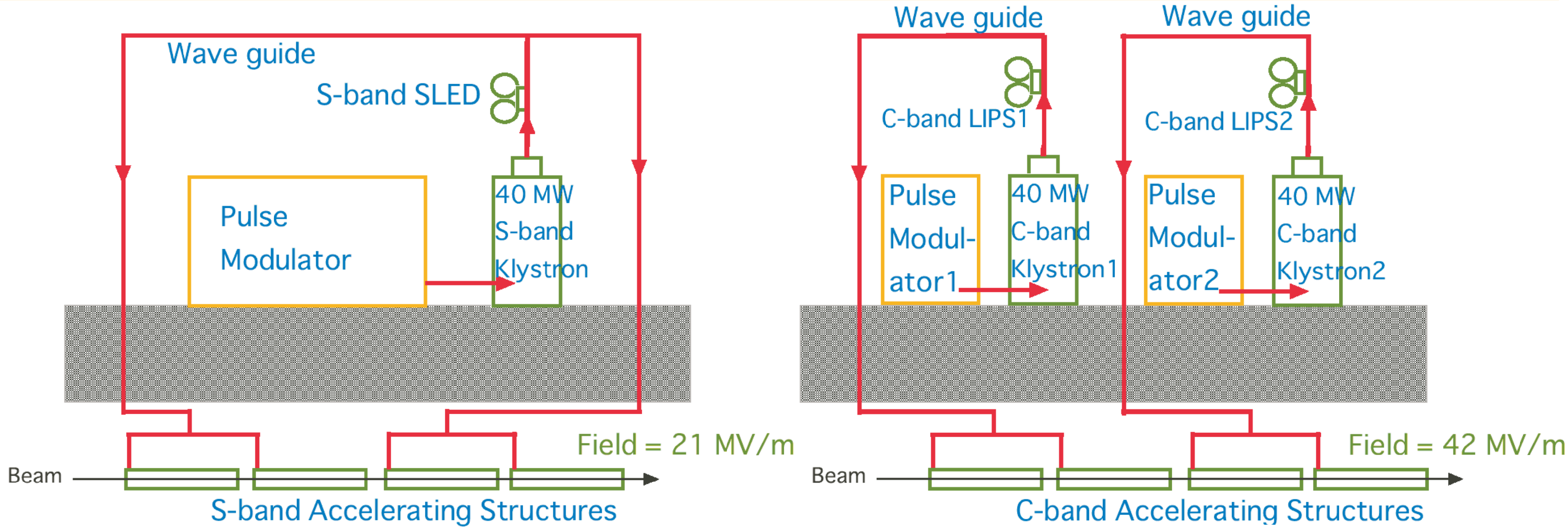
- Lower Emittance with e^+ Damping Ring
    - (1) for Smaller Aperture of the C-Band Structures
    - (2) for Design of the Interaction Region at the Ring

- Overview of the Scheme (Green Part is New / Upgrade)



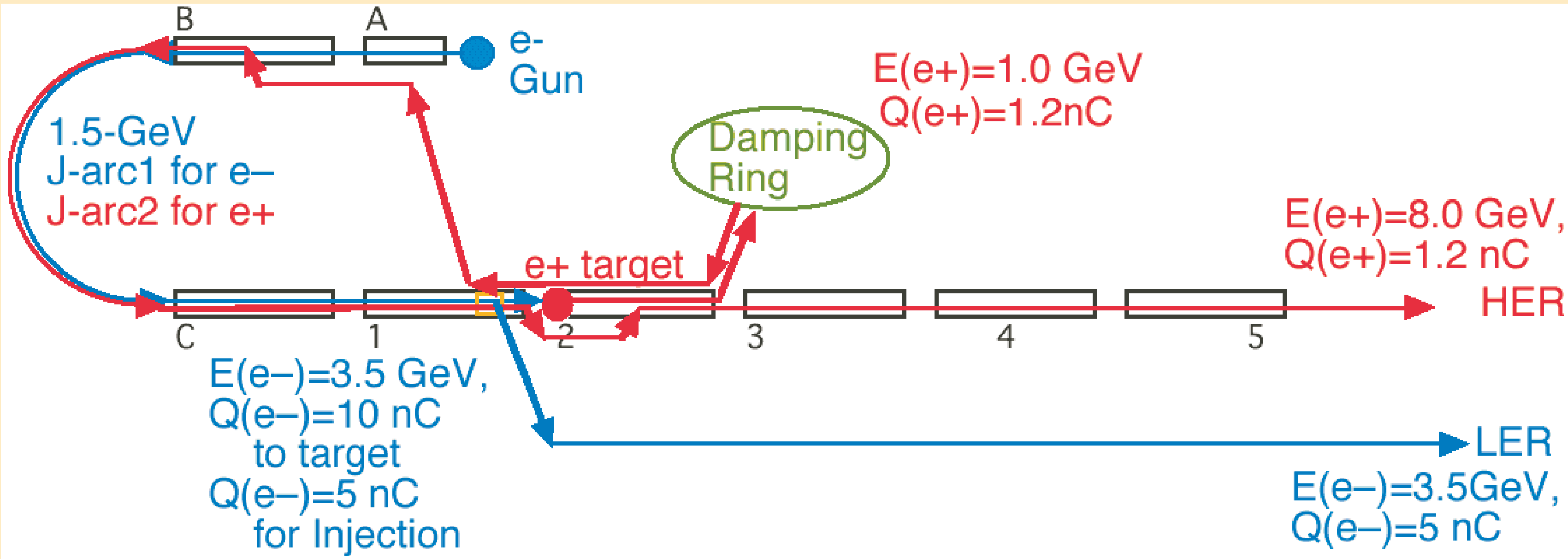
C-Band (5712MHz) Components R & D

- Being Designed for KEKB Linac, Based on the Development by JLC C-Band Group
- C-Band Klystron: 50MW from Toshiba
- Pulse Modulator: Compact Type, First Version under Production
- Driver Klystron: Modified 40kW, Designing
- Pulse Compressor: TE038 LIPS Type, Designing
- Acceleration Structure: $2\pi/3$-mode, under Fabrication
- rf Components: Designing
- High-Power / Acceleration Test at Spring 2003



Linac Energy Upgrade with Recirculation (Backup)

- No Major Change in Acceleration Components
  - Damping Ring to Keep Positron for the Next Pulse
- Slightly Complicated Operation Scheme
  - Return Line, Bypass Lines at Arc and Target
  - Multi-Bunch Acceleration with Very Different Characteristics
    - Before / After the Target
- Overview of the Scheme



Linac Beam-Current Enhancement

- e^- Beam Charge:
  - 3 mA /s —> 15 mA /s (Injection Rate)
  - 1 nC /pulse —> 5 nC /pulse (3.5 GeV)
  - Already Achieved for Primary Beam for e^+ Generation
  - Emittance Control May be Necessary
- e^+ Beam Charge:
  - 1.5 mA /s —> 3 mA /s (Injection Rate)
  - 0.6 nC /pulse —> 1.2 nC /pulse (8.0 GeV)
  - Flux Concentrator for Energy Acceptance (Planning)
  - Double Bunch Acceleration and Damping Ring (?)
- Continuous Injection
  - Already Achieved
- Simultaneous e^- and e^+ and Injection
  - Transport Line Lengths, Injection Timing (?)

Linac Beam Measurement and Quality Control

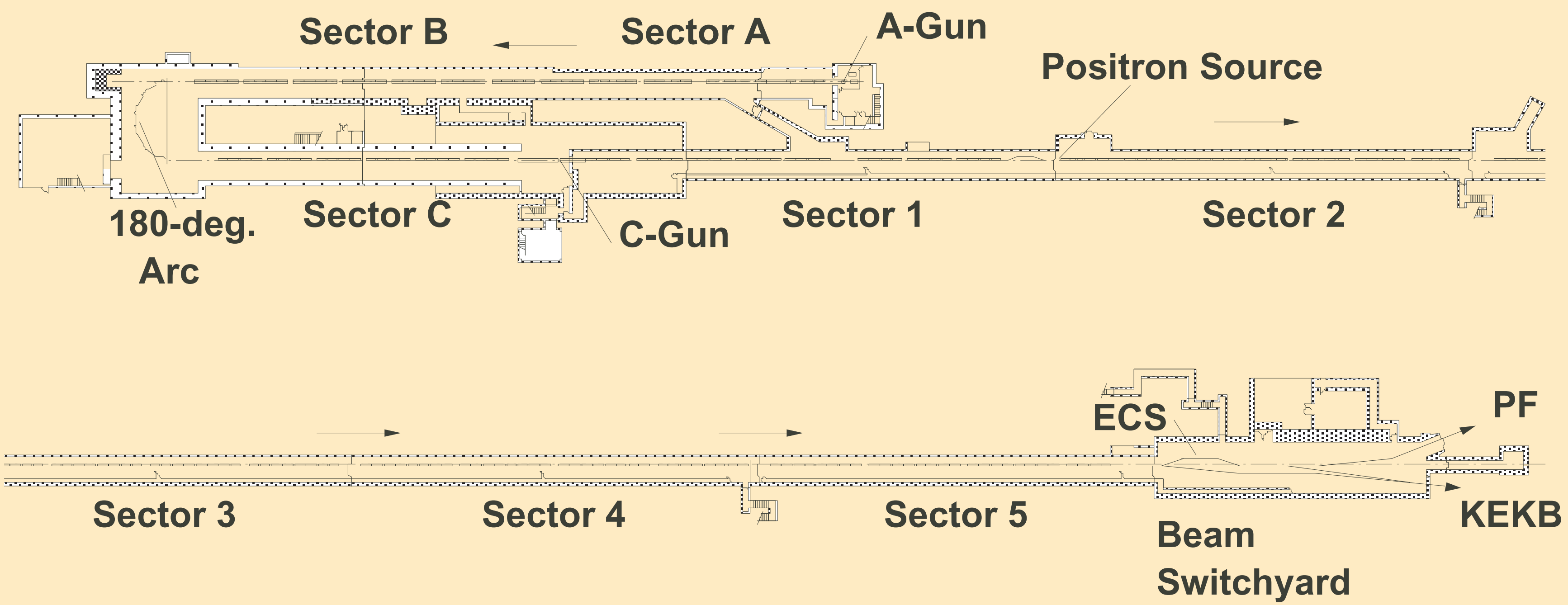
- Beam Measurement
  - Between Injections —> During Continuous Injection
- Stealth Bunch Measurement Possibility
  - Between Injection Bunches
  - Fast Kicker, To Prevent Dirty Beam Injection
  - Fast Actuator Installation
    - ex. Fast Phase Shifter is under Development
  - Synchronous Data Acquisition Improvement
  - Timing System Modification
- Fast (50Hz) Data Acquisition
  - Under Development for BPM with Fast Digitizer
  - Need to Measure Dual Bunch Simultaneously
- Need More Beam Quality Control

Conclusions

- Linac Operates Well with Low Down Rate
  - Contributes to KEKB / Belle Achievement
- Beam / Machine Quality Control, Dual-Bunch Injection,
  - Continuous Injection are Improving
  - Enhance Integrated Luminosity
- Linac Upgrade Design for SuperKEKB
  - Energy Exchange (8-GeV e^+) is the Major Challenge
  - With C-Band Technology at First
  - R & D Started This Year, and First Test at Spring 2003
- Miscellaneous Improvements are Planned
  - Considering for SuperKEKB

Layout of KEKB Linac

- 600m Linac with 59 S-band rf Stations,
  56 of them have SLED with Gain of 160MeV
- Double (114MHz, 571MHz) Sub-Harmonic Buncher
  to Achieve 10ps Pulse Width and 10nC



Design Beam and Achieved Performance

			8-GeV electron		3.5-GeV positron	
			Goal	Achieved	Goal	Achieved
(1) Gun	Energy	keV	200	200	200	200
	Intensity	nC/pulse	1.5	2	13	14
	Pulse width	ns	2	1.8	2	2.8
(2) Buncher	Energy	MeV	16	16	15	15
	Energy spread (σ)	MeV			2	2
	Intensity	nC/pulse	1.4	1.9	>10	11
	Efficiency			95%		90%
	Emittance γβε (σ)	mm	0.06	0.04	0.06	0.08
	Bunch width	ps	5	6	16	10
(3) Arc	Energy	GeV	1.5	1.7	1.5	1.7
	Energy spread (σ)	MeV	0.6%	0.29%	0.6%	0.38%
	Jitters (p-p)					0.1%
	Drift (with feedback)				<0.2%/h	
	Emittance γβε (σ)	mm		0.17		1.7
	Transmission			100%	>95%	100%
(4) e+ target	Energy	GeV			3.7	3.7
	Intensity	nC/pulse			>10	10
	Transmission					96%
(5) e+ Solenoid exit	Intensity	nC/pulse				2.4
	Specific yield	e+/e-GeV				6.8%
(6) Linac end	Energy	GeV	8	>8	3.5	>3.5
	Energy spread (σ)	MeV	0.15%	0.05%	0.125%	0.15%
	Intensity	nC/pulse	1.28	>1.28	>0.64	0.82
	Specific yield	e+/e-GeV				2.3%
	Transmission			>80%		
	Emittance γβε (σ)	mm	0.25	0.31	1.5	1.4
	Pulse repetition	pps	50	50	50	50