Beam Feedback Systems and BPM Read-out System for the Two-Bunch Acceleration at KEKB Linac

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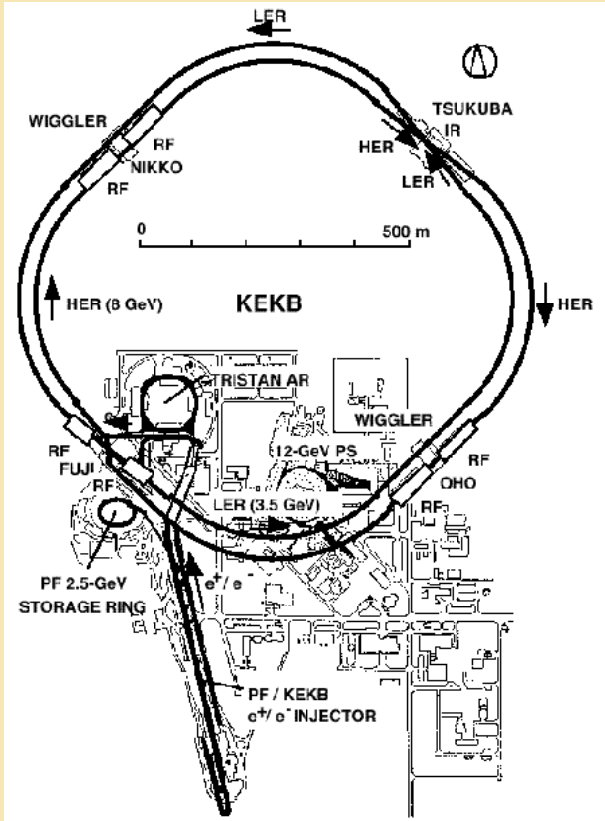
<URL:http://www-linac.kek.jp/>

Introduction



- Experiment Efficiency of CP Violation Study
  at KEKB Electron / Positron Collider
  → Now Electron 780mA, Positron 1200mA
  2.6A Positron will be Stored
  → Especially Quality and Quantity
  of Positron is Important

- Linac : 8GeV e^- 1.28nC / 3.5GeV e^+ 0.64nC 50pps

- Multi-Bunch Acceleration at Linac
  → Integer Relation 2856MHz : 508MHz = 275 : 49 in rf System
  Common Frequency 10.38MHz = 96.29ns (Bunch Separation)
  → Only 2 Bunch Possible

- Stable 2 bunch Acceleration
  → Longitudinal and Transverse Wakefield Effects
  Should be Managed

- Upgrade of Beam Instrumentation
  —> Should Observe Both 2 Bunches Simultaneously
  —> Should not Lose Accuracy for 2 Bunches Separated 96ns

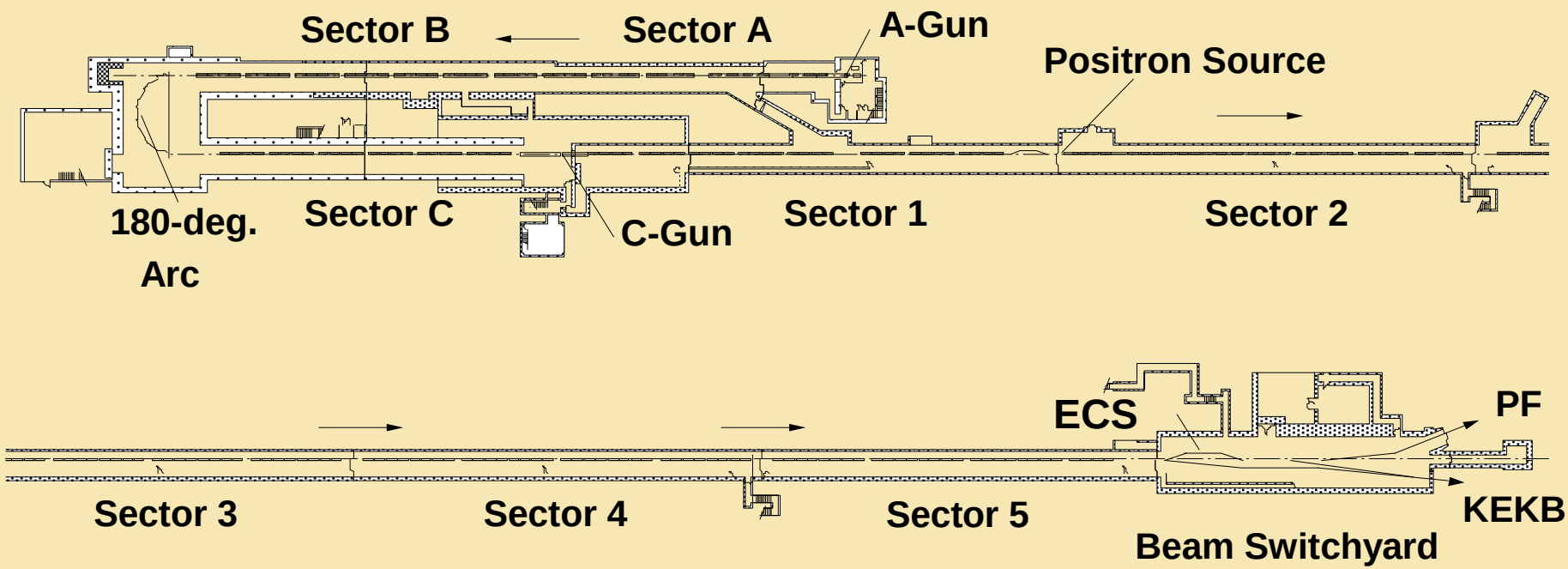
- Wire Scanner
  —> Split the Signal and Read ADC with the Separate Gate
  —> Possible to Measure the Emittance of Each Bunch

- Streak Camera
  —> Observe with Separate Timing
  —> Possible to Measure the Longitudinal Bunch Structure

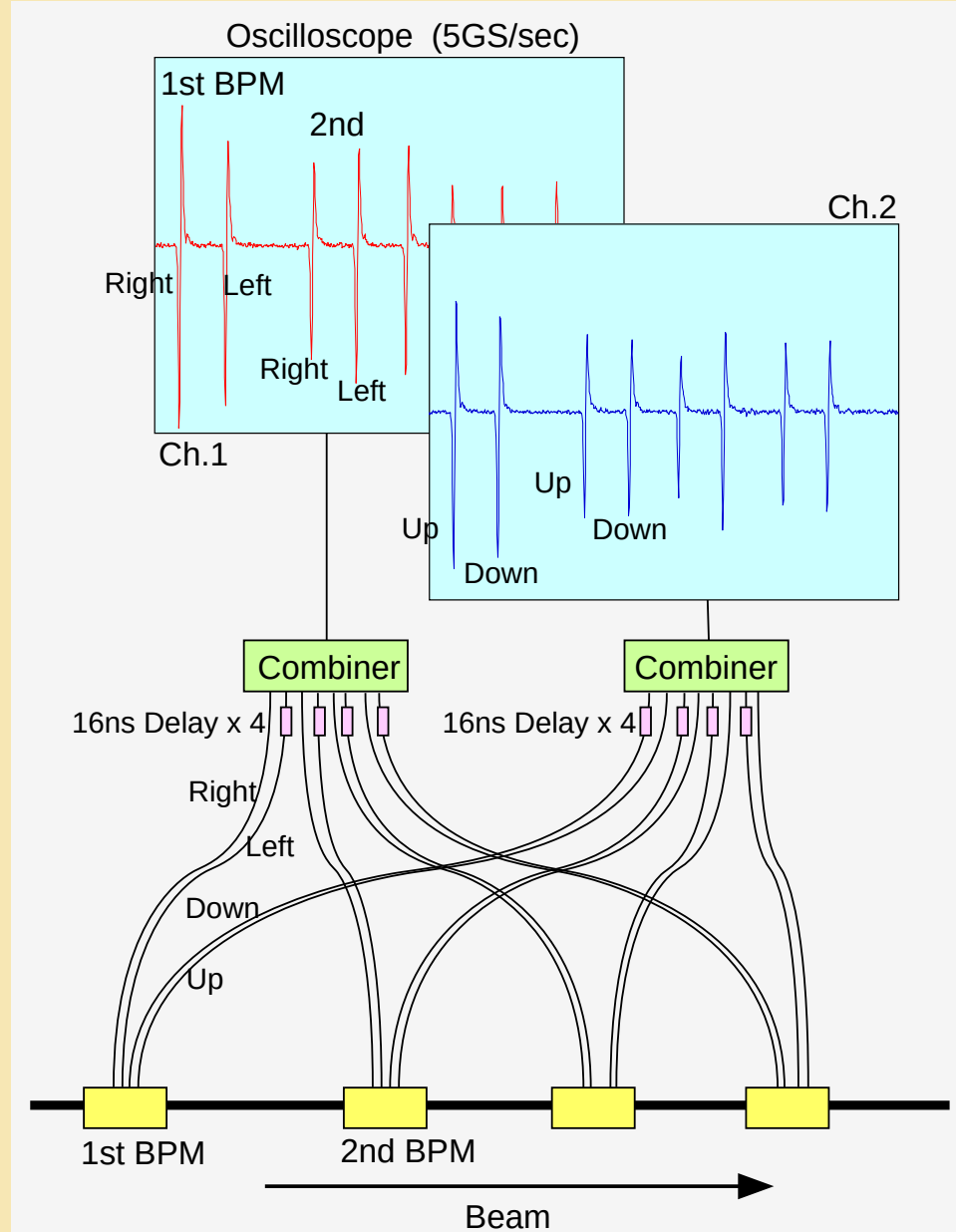
- Beam Position Monitor (BPM)
  —> Necessary to Read-out 90 Stripline-type BPMs
  —> Need to Process Two Signals Separated 96 ns

Read-out System of BPMs

- 18 Measurement Stations along the 600-m Linac
  Connected with 4 - 10 BPMs
  (90 in Total)



- Signal Processing
  —> Avoid Overlap with Delay-lines
  —> Overlay with Combiner
  —> Waveform Digitization
  with Oscilloscope (2ch 5Gs/s)
- Timing Trigger
  —> Beam Synchronized Trigger
  along the Linac by 571MHz rf
- Pre-process with VME Computer
  —> Adjust Dynamic Range
  According to Beam Mode
  (Sometimes x1 -> x30)
  —> Read thru GPIB
  —> Locate and Process
  Each Signal in the Waveform



Improvement for 2-Bunch Acceleration

- Acquire 2 Beam-bunch Information in One rf Pulse
  —> Difficult with Dedicated Electronics
  (Challenging Issue for Next 50Hz Read-out System)
  —> Easier with Oscilloscope
  Waveform becomes Shifting and Overlapping by 96ns
- Overlap of Signals
  Each Signal is 5ns in Full-width, 1ns Peak-to-peak
  —> Pack Signals down to 8ns
  Sometimes Add Delay Lines
- Read Resultant Non-overlapping Signals thru Oscilloscope

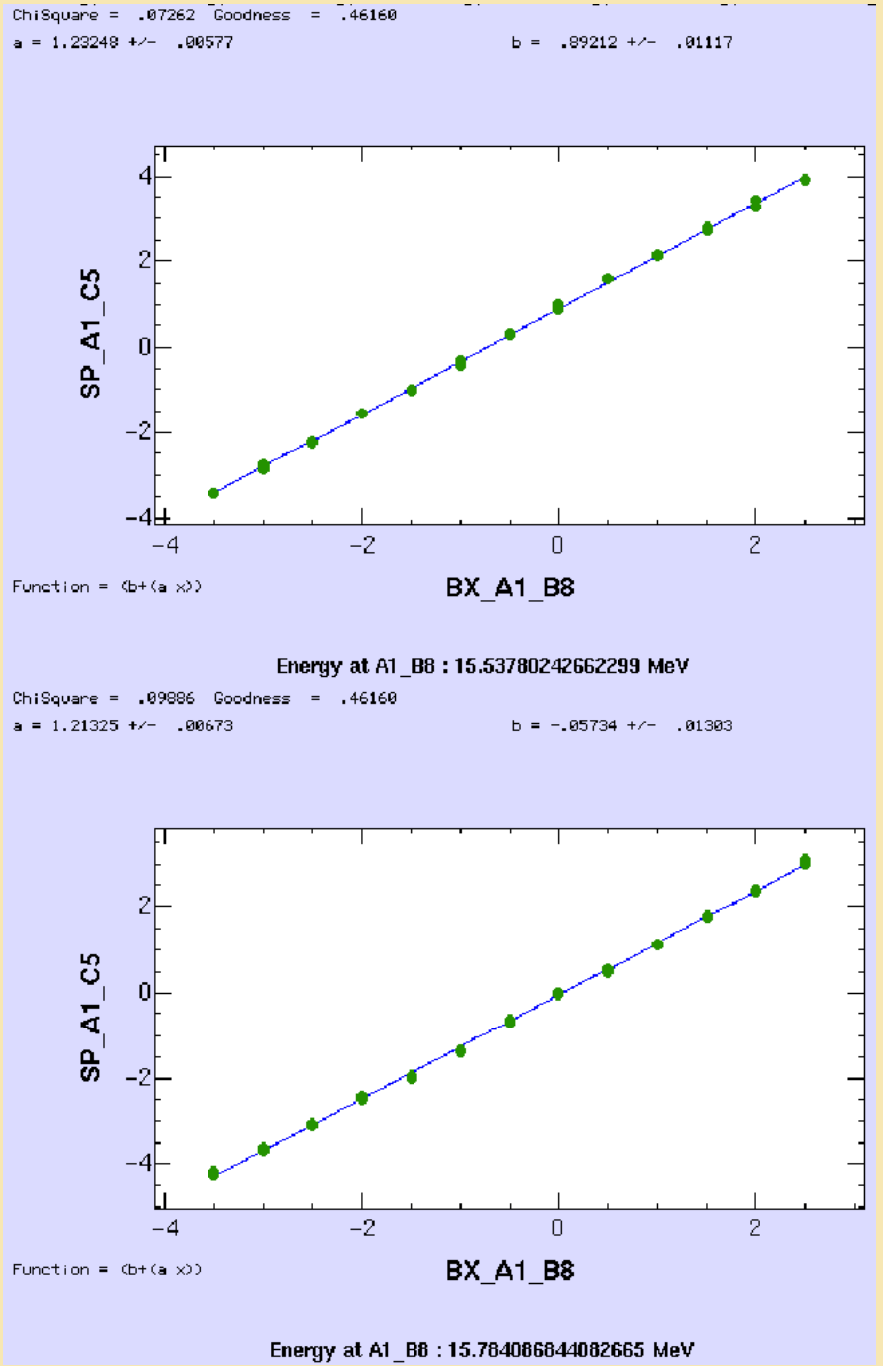
- Apply Calibration Information
  - Mapping Function of 3rd Order Polynomial (BPM)
  - Attenuation Factors of Cables and Oscilloscope
  - Position Offsets by Beam-based Alignment
    - Database was Expanded

- Server Computers
  - —> Read all Measurement Station thru Network
  - —> Collect 2-Bunch Data of all 90 BPMs in One Shot, Every Second
    - Commands were Added

- Many Piece of Operation Software
  - —> Many Beam Feedback Loops and Orbit Displays, etc.
  - —> Read Once in 1 - 5 Second from Server

Example Operation Software

- Many Software Panels are Used
  in Beam Study and Operation
- Energy Measurement at Buncher Exit
  Electron Energy Measured
    Changing a Steering Magnet
    After Adjusting Gun Timing
      First Bunch: 15.5MeV
      Second Bunch: 15.8MeV
  Almost Equal, Good Reproducibility

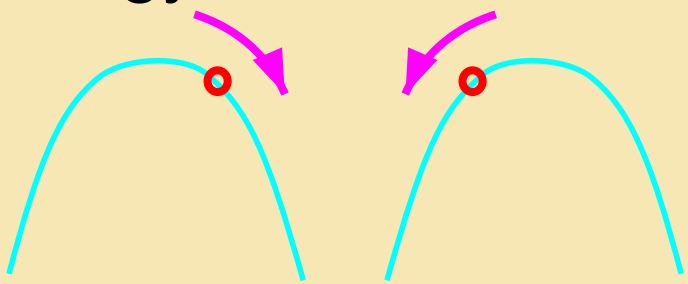


Beam Feedback Loops

- More than 30

  Software Feedback Loops

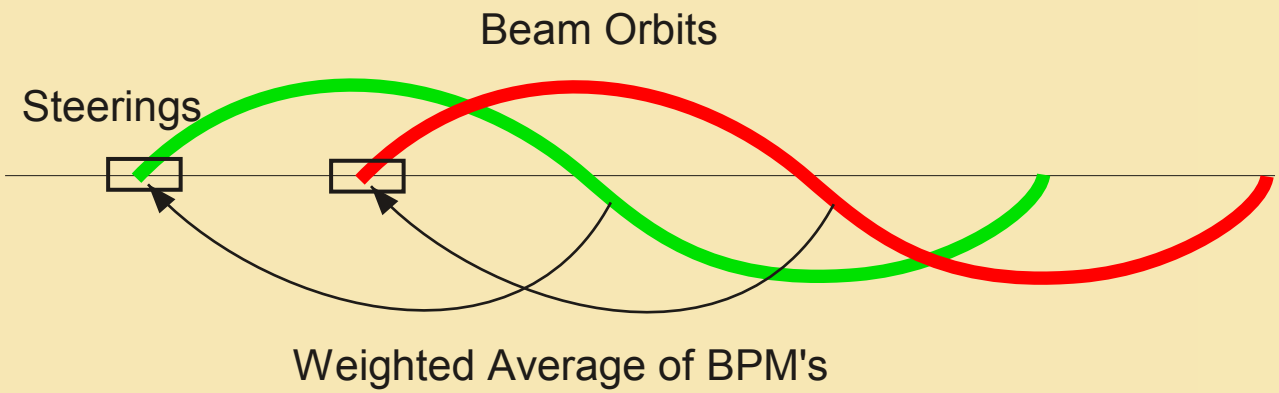
- Energy Feedback

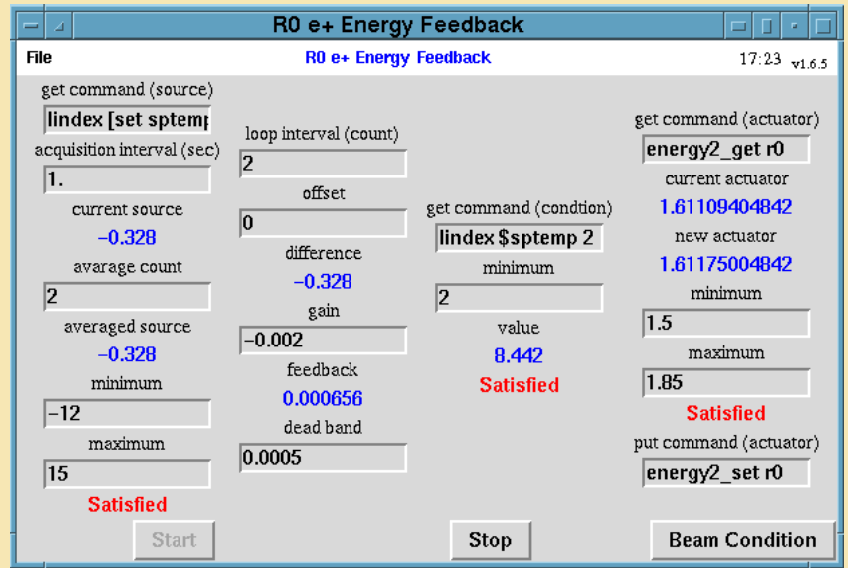


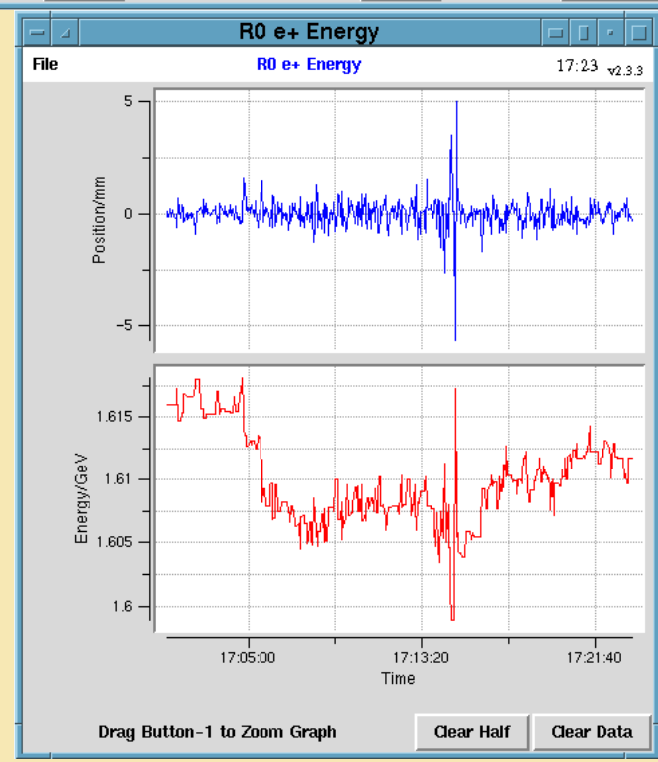
Beam Position

Beam - rf Phase

- Orbit Feedback and Others

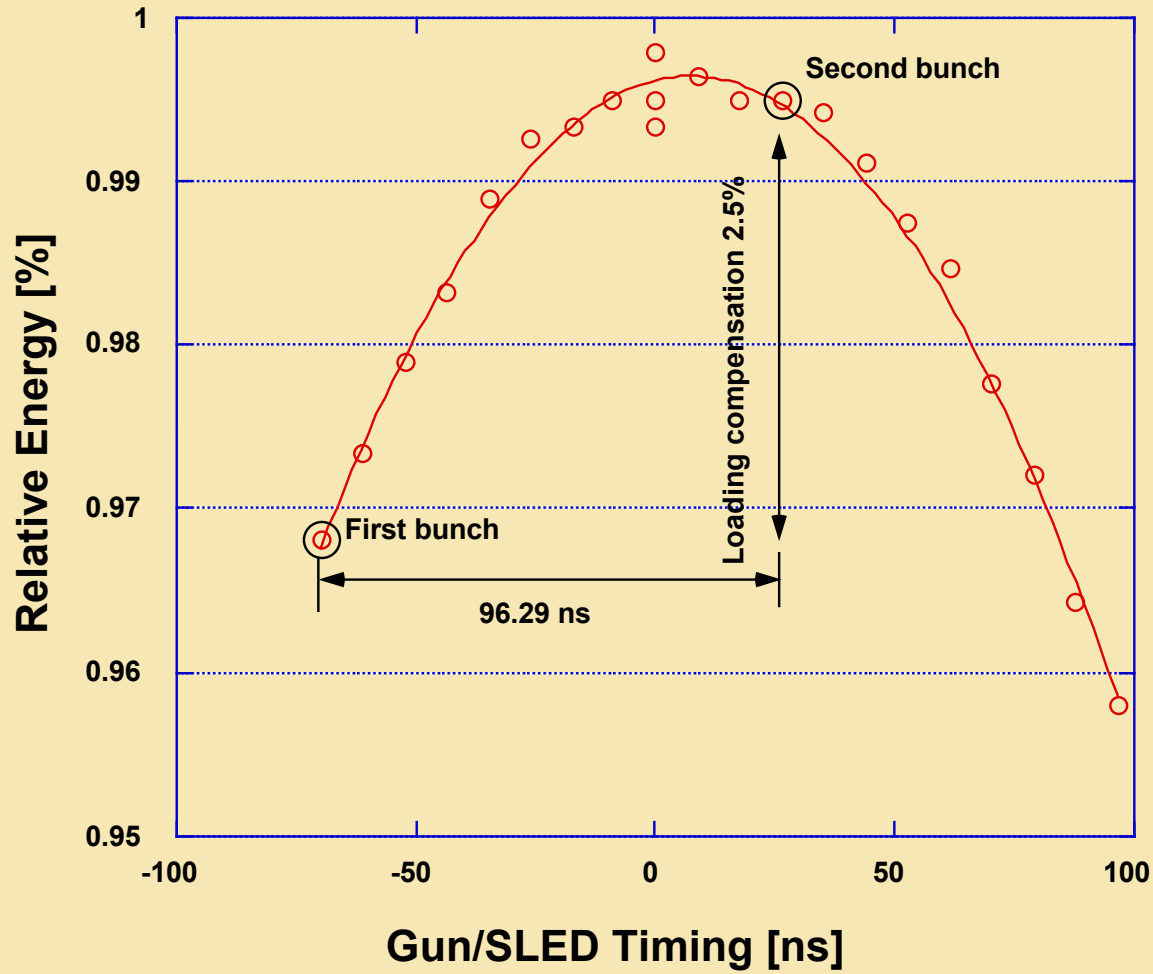






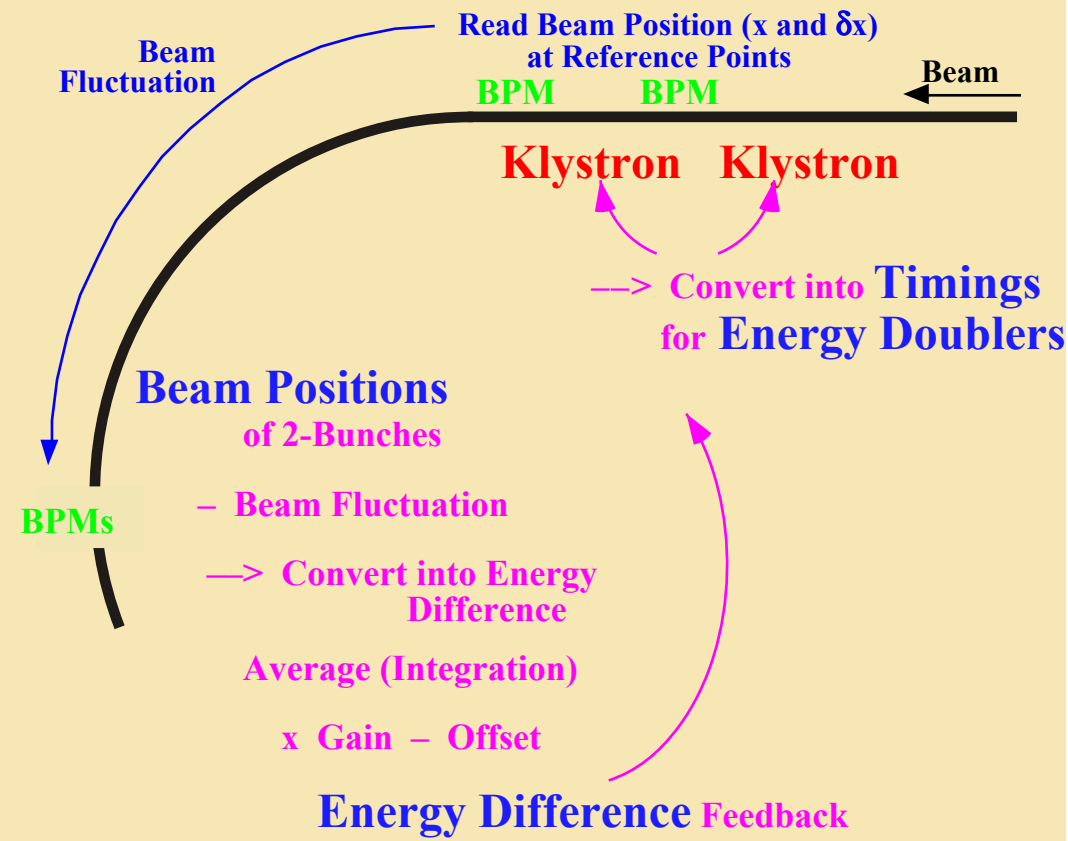
1st and 2nd Bunch Energy Two-Bunch Acceleration

- Loading Evaluation
  Comparing Beams
  of 8nC & 0.8nC
- Relation between
  Energy vs. rf Timing

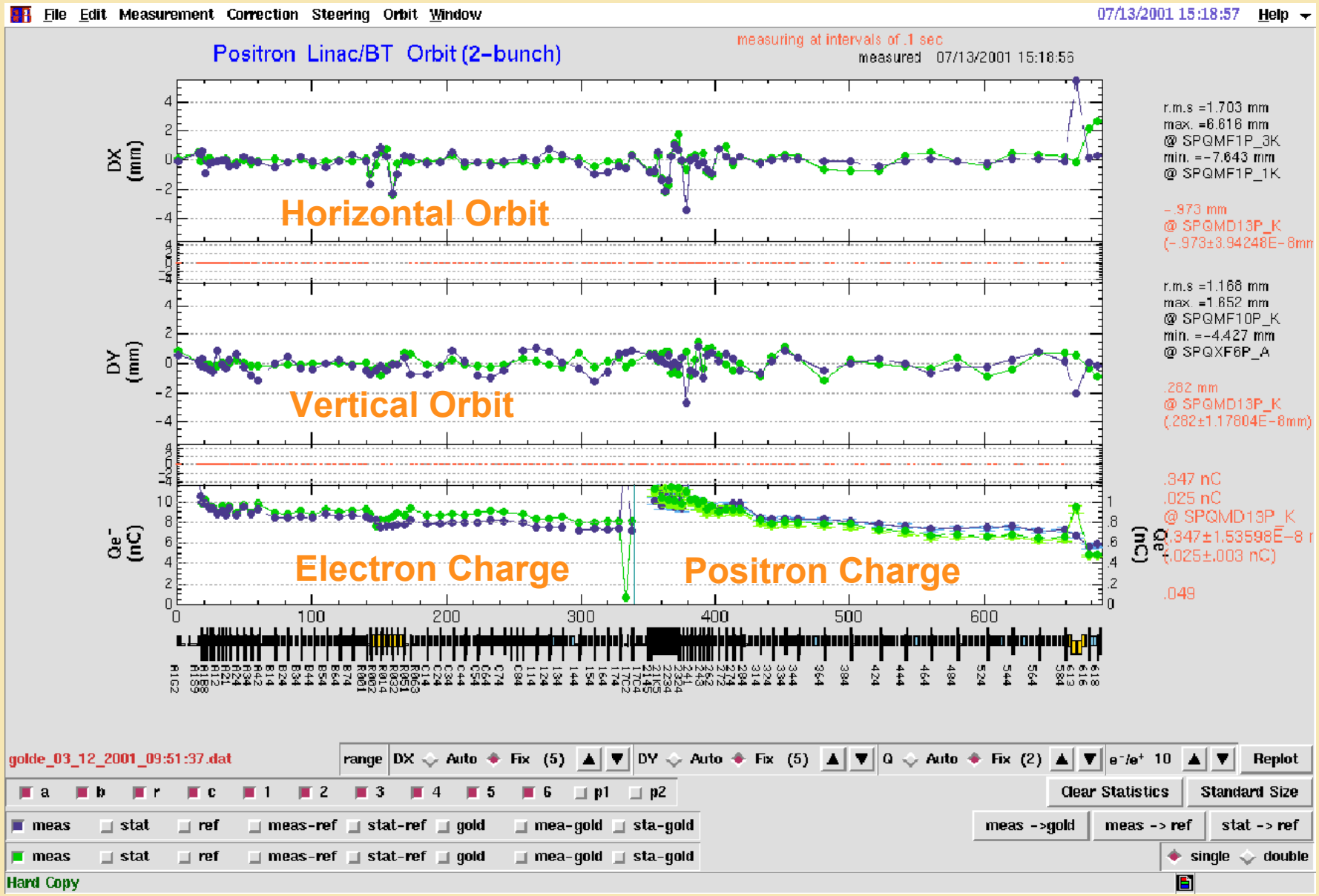


New Feedback for Energy Equalization

- Need to Equalize Beam Characteristics of Two Bunches
  Suppress Difference of Beam Characteristics from Wakefields
- Energy Difference from Longitudinal Wakefields
  Change Energy Gain
  by rf Timing
  of SLED (Energy Doubler)



Successful Acceleration of 2 Bunches (Blue and Green)



Conclusion

- For 2-bunch Operation of KEKB Injector Linac
  Built 2-Bunch Simultaneous Read-out System
  of 90 Beam Position Monitors
- Indispensable to Understand
  Differences of Beam Characteristics of 2 Bunches
- Many Operation Software Panels Have Been Built
- Beam Feedback Systems
  Extended Orbit / Energy Stabilization
  Installed New Energy Equalization
  Essential for Beam Operation
- Now Carrying Beam Study for Injection into KEKB Ring

Thank you ...

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

Four Beam Modes at KEKB Linac

- 4 Downstream Rings Require Quite Different Beams
- Switching Reproducibility and Reliability are Crucial
- 7300 hours of Operation in FY1999

  But Only 73 hours of Beam Loss Time

Ring	HER	LER	PF	AR
Particle	electron	positron	electron	electron
Energy	8 GeV	3.5 GeV	2.5 GeV	2.5 GeV
Charge	1.28 nC	0.64 nC	0.2 nC	0.2 nC
		(primary 10 nC)		
Bunch	single	single	1 ns	1 ns
Repetition	50 Hz	50 Hz	25 Hz	25 Hz
Store	500 mA	700 mA	400 mA	40 mA
Time	1-2 min	5-10min	3-5 min	2-5 min
Interval	1-2 hr	1-2 hr	24 hr	2-4 hr