Beam-Stability Issues in the KEKB Injector Linac

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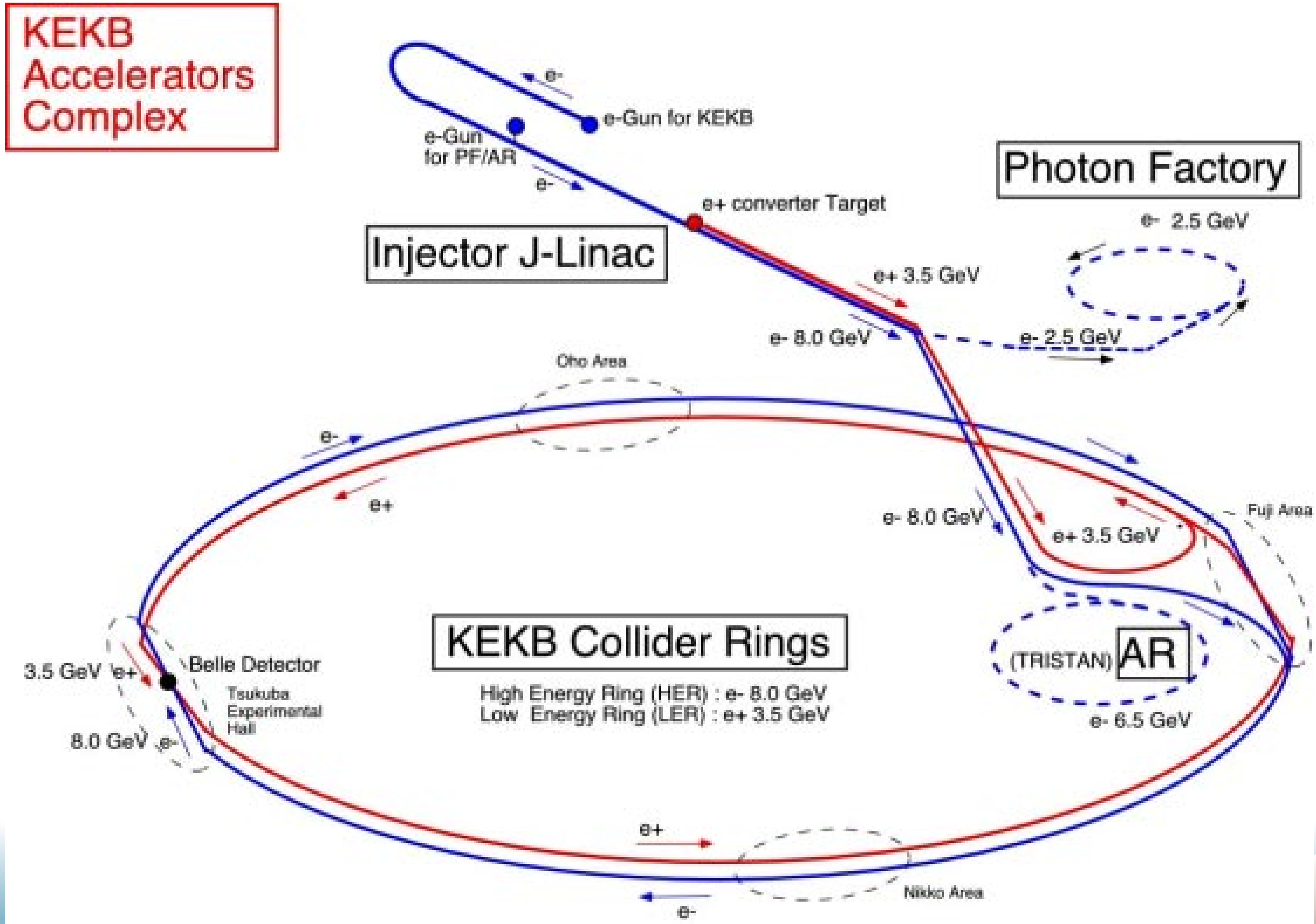
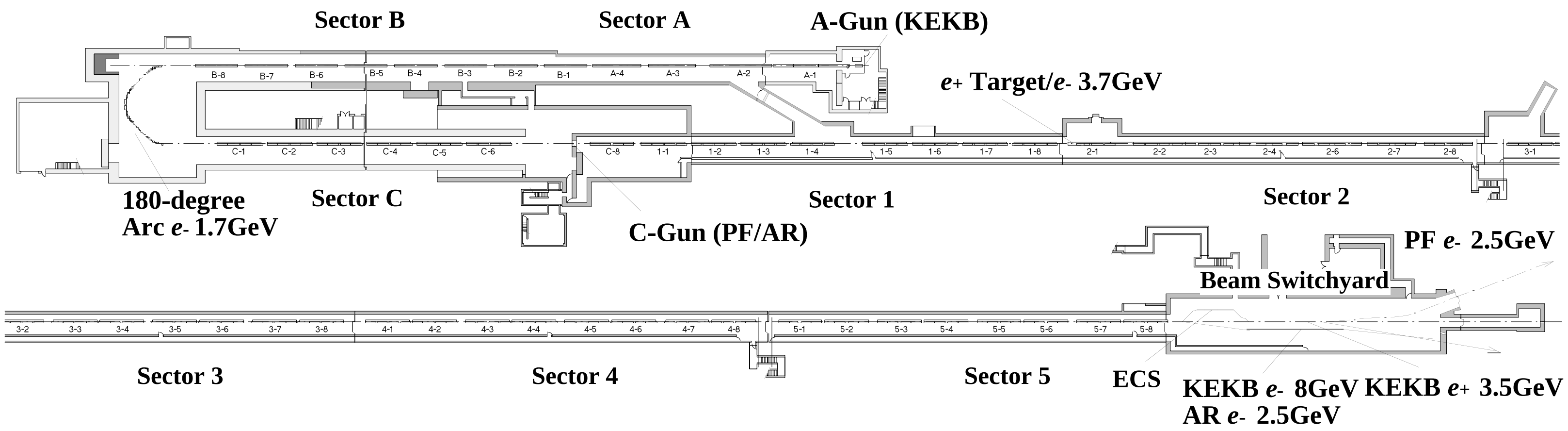
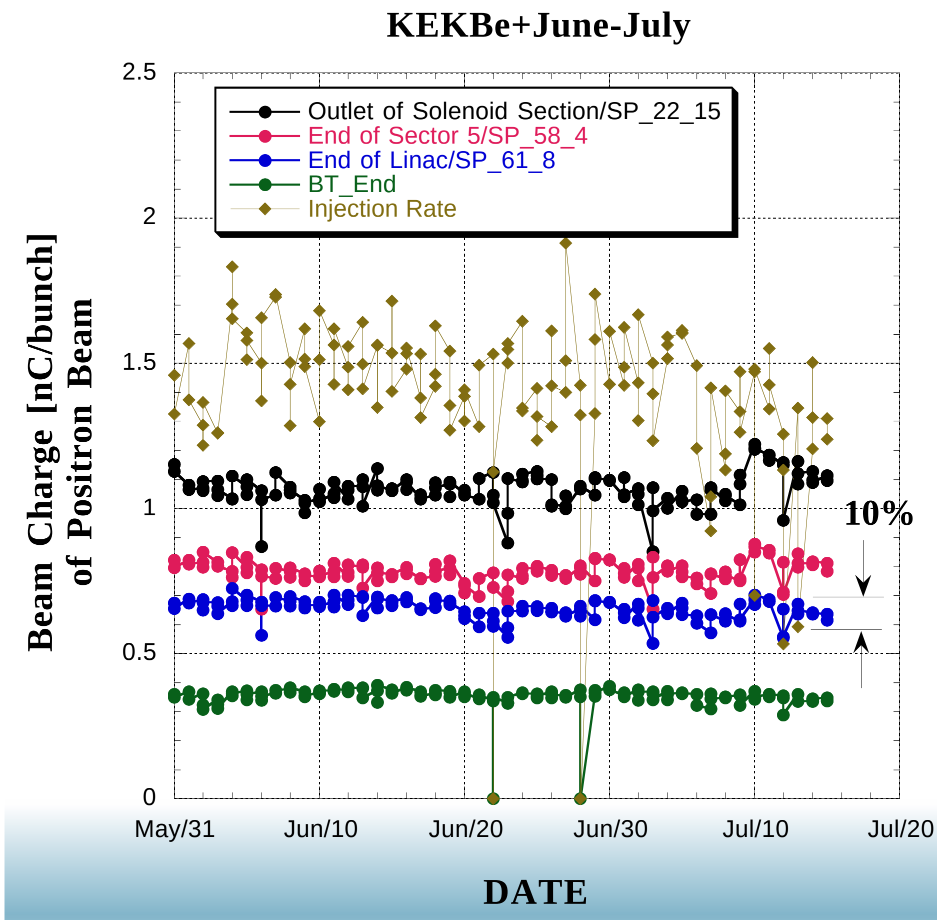
KEKB Accelerator Complex

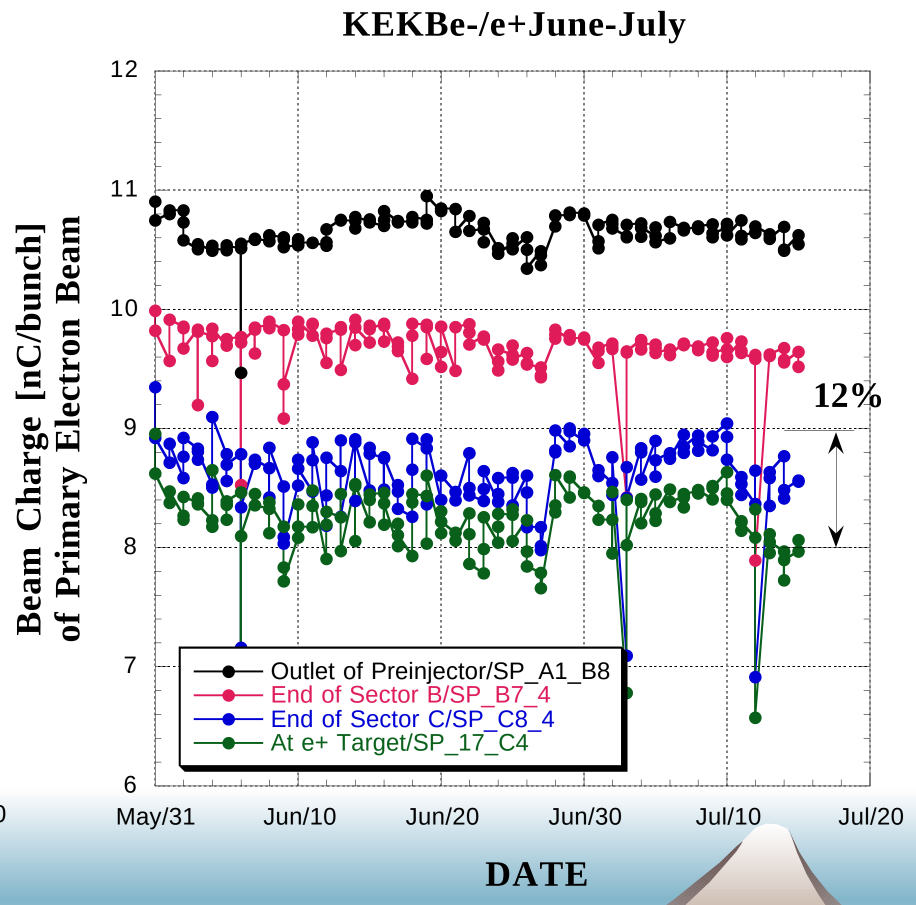


Layout of the KEKB Injector Linac



Operation Log of the KEKB e^-/e^+ Beam Currents





Typical Beam Parameters for the KEKB Injection

Parameters	e^-@BT	e^+@BT	e^-/e^+
Energy [GeV]	8.0	3.5	3.7[1)]
Charge [nC]	0.8/1*	0.4/0.6*	8.0[1)]
$\Delta E/E$ [%@1σ]	0.05	0.15	0.5[2)]
$\gamma\varepsilon_x/\gamma\varepsilon_y$ [mm@1σ]	0.31/0.31	2.4/2.0	3.5/1.8[3)]
Injection Rate [mA/s]@50 Hz	4 (>95%)	1.8 (>95%)	

The symbol "*" shows the parameters measured at the end of linac, and subscripts 1), 2) and 3) depict the parameters at the positron target, at the center of the J-arc line, and at the end of the sector B (E=1.7 GeV), respectively.

KEKB Operation

- ***Stable high injection*** rates were performed by

(1) ***dedicated beam*** and ***rf feedback systems***, and

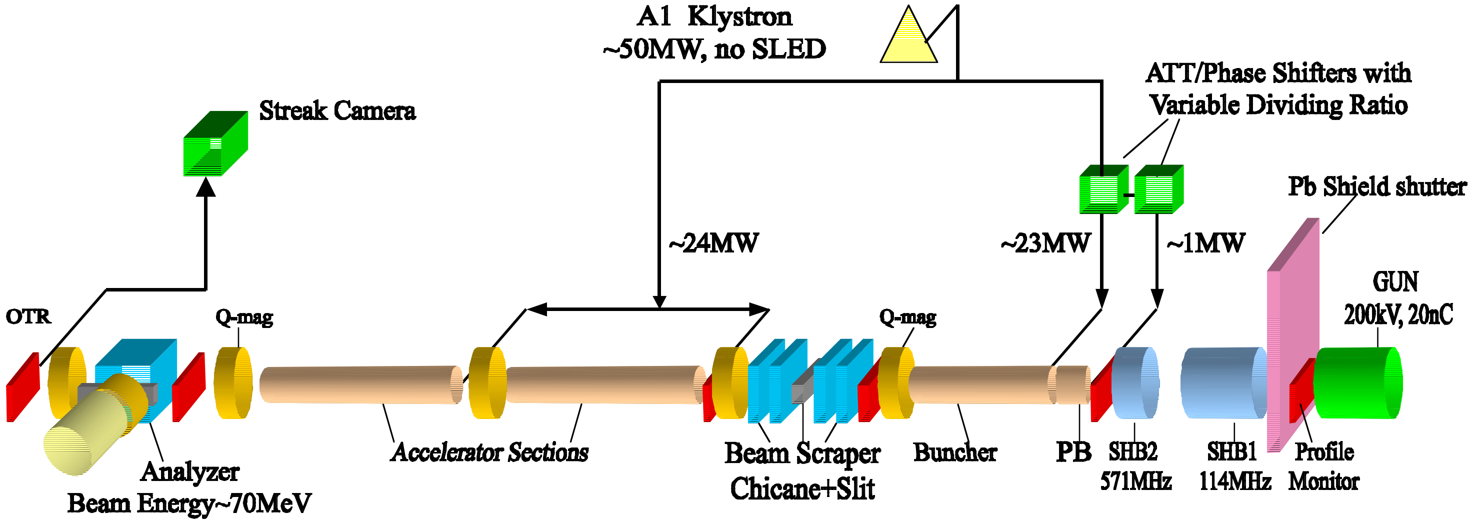
(2) daily monitoring of the ***optics matching*** and ***beam emittances***, and the ***energy spread of the beams*** by wire scanners, and fine injection tuning.

- ***Beam and rf feedback systems*** have been stably operated

(1) for ***beam orbits*** and ***beam energy***, and

(2) for the ***pre-injector***.

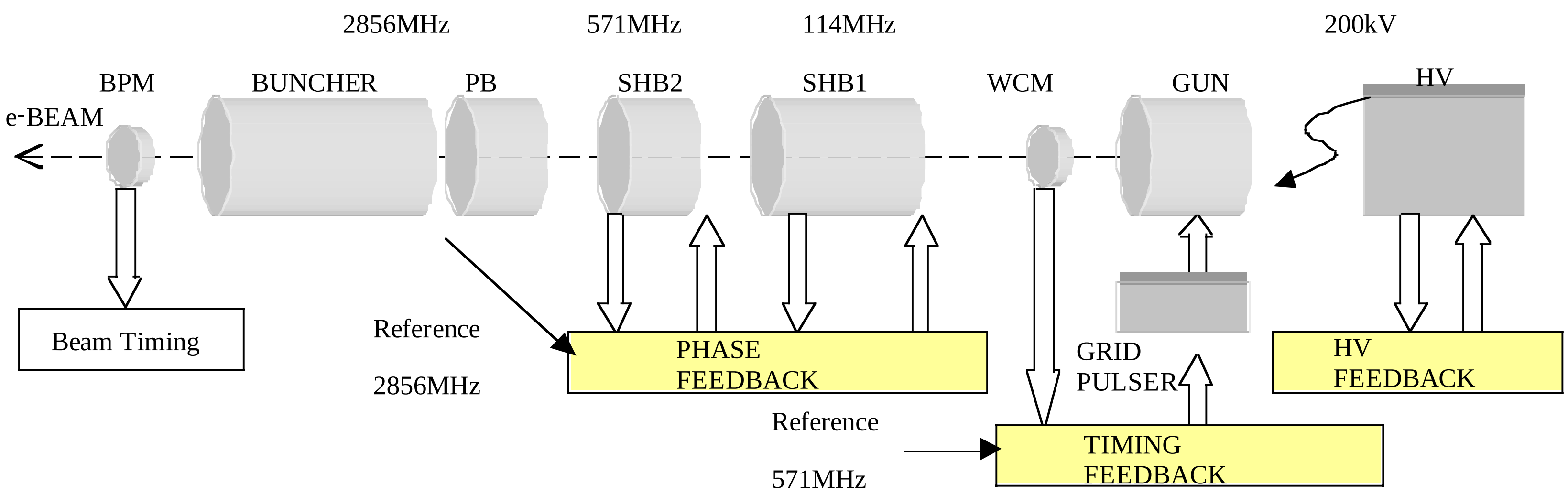
Pre-Injector System



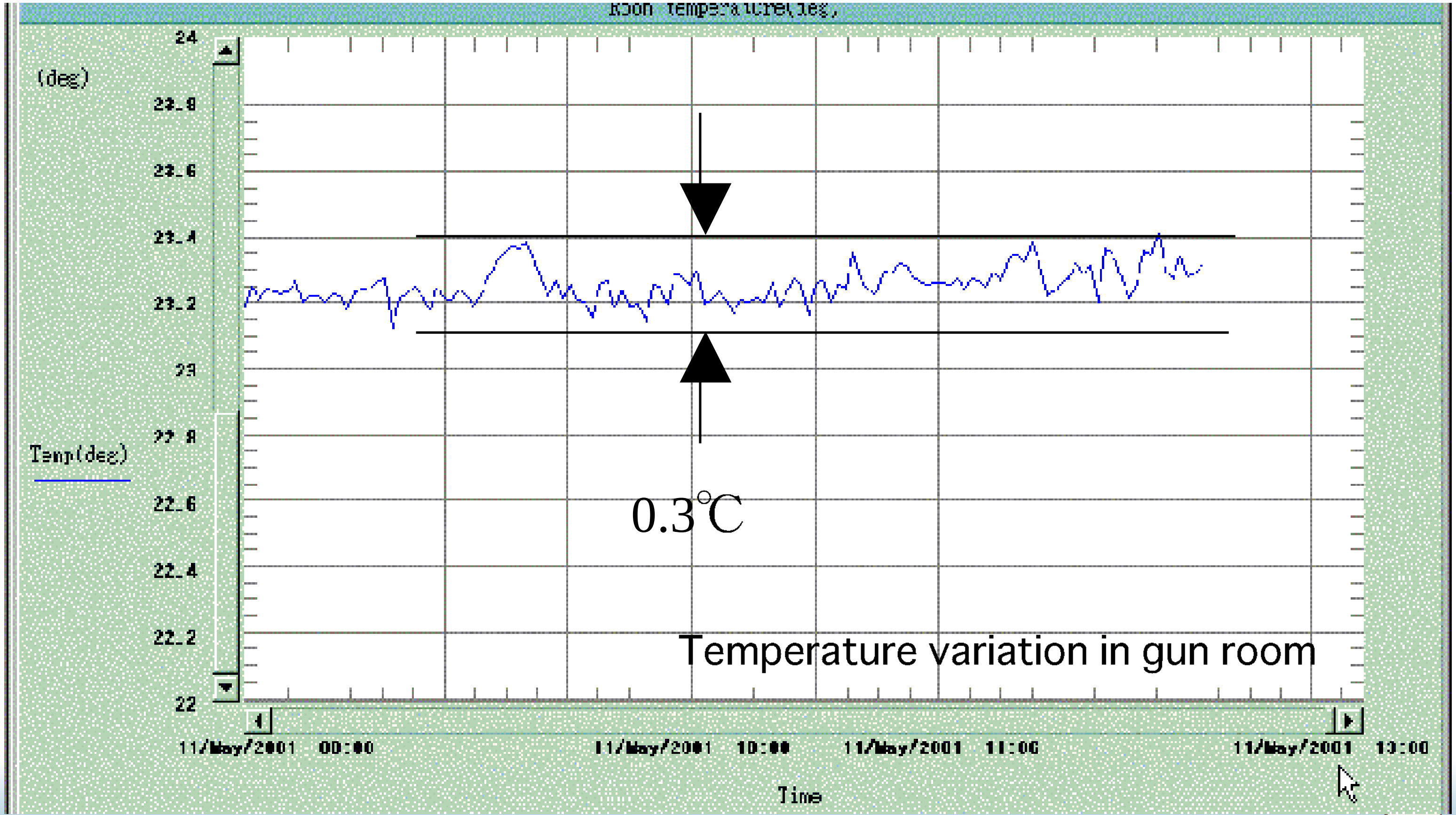
Schematic layout of the pre-injector

Element	Repetition or Frequency	- period	Voltage or Power
Grid pulser	1~50 Hz	-	450~800 V
Gun	50 Hz	-	200 kV
25th SHB1 (standing wave)	114 MHz	8.75 ns	11 kW
5th SHB2 (standing wave)	571 MHz	1.75 ns	7 kW
Prebuncher (travelling wave)	2856 MHz	350 ps	1 MW
Buncher (travelling wave)	2856 MHz	350 ps	23 MW
Accelerating sections (travelling wave)	2856 MHz	350 ps	12 MW x 2
Common frequency of linac/KEKB rings	10.385 MHz	96.289 ns	-

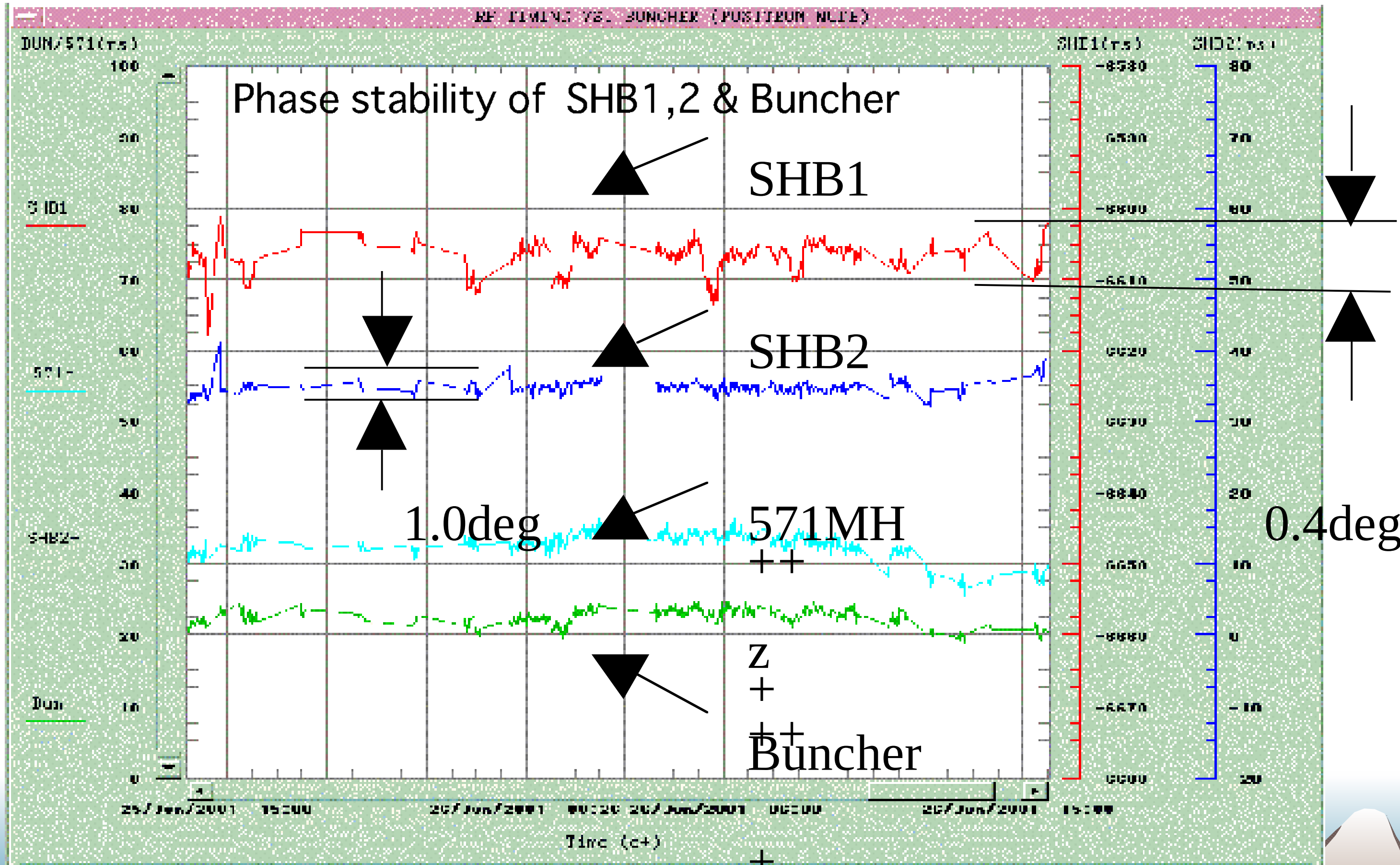
Pre-Injector System: Feedback System



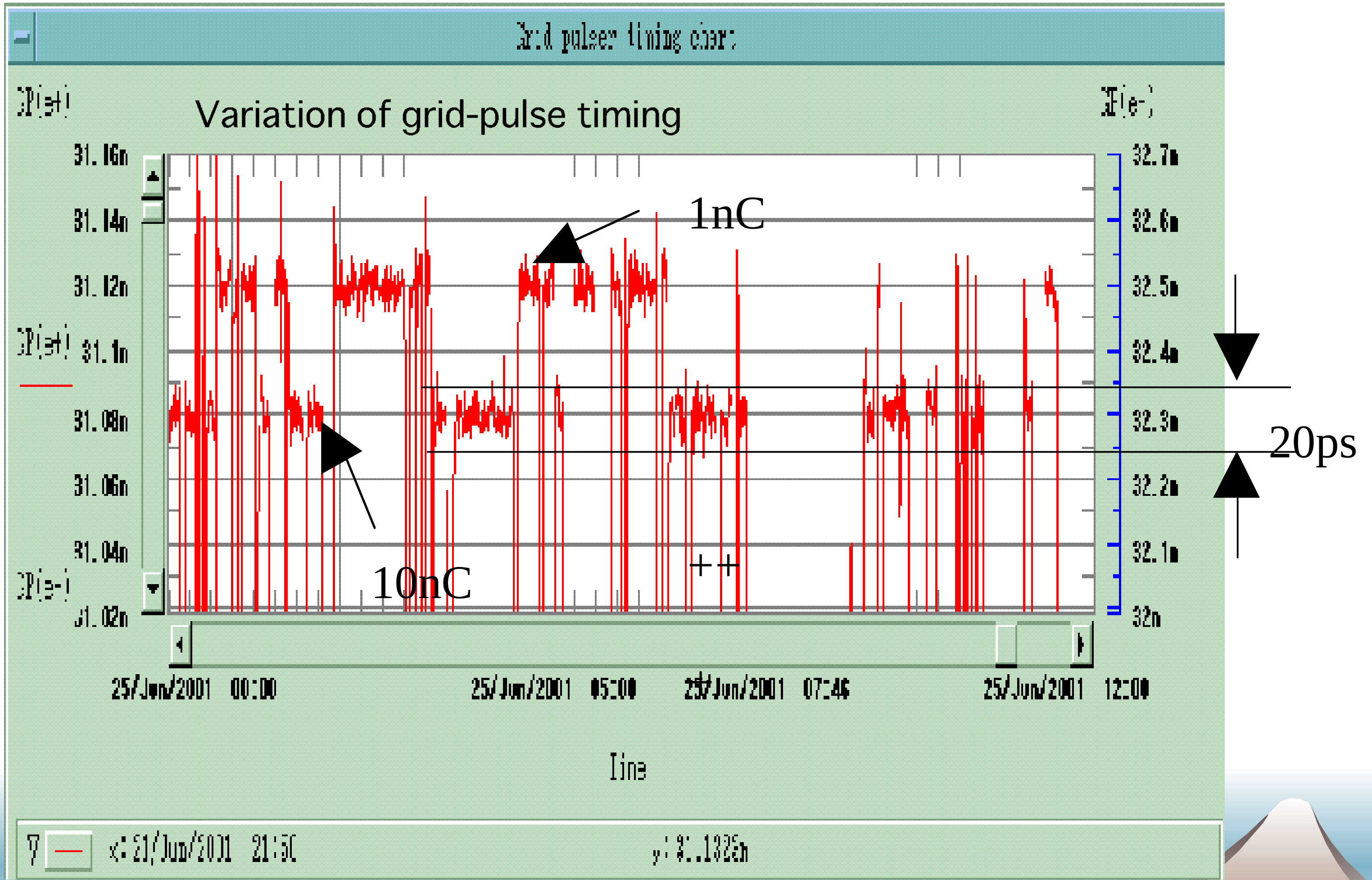
Pre-Injector System:Temperature Variation in Gun Room



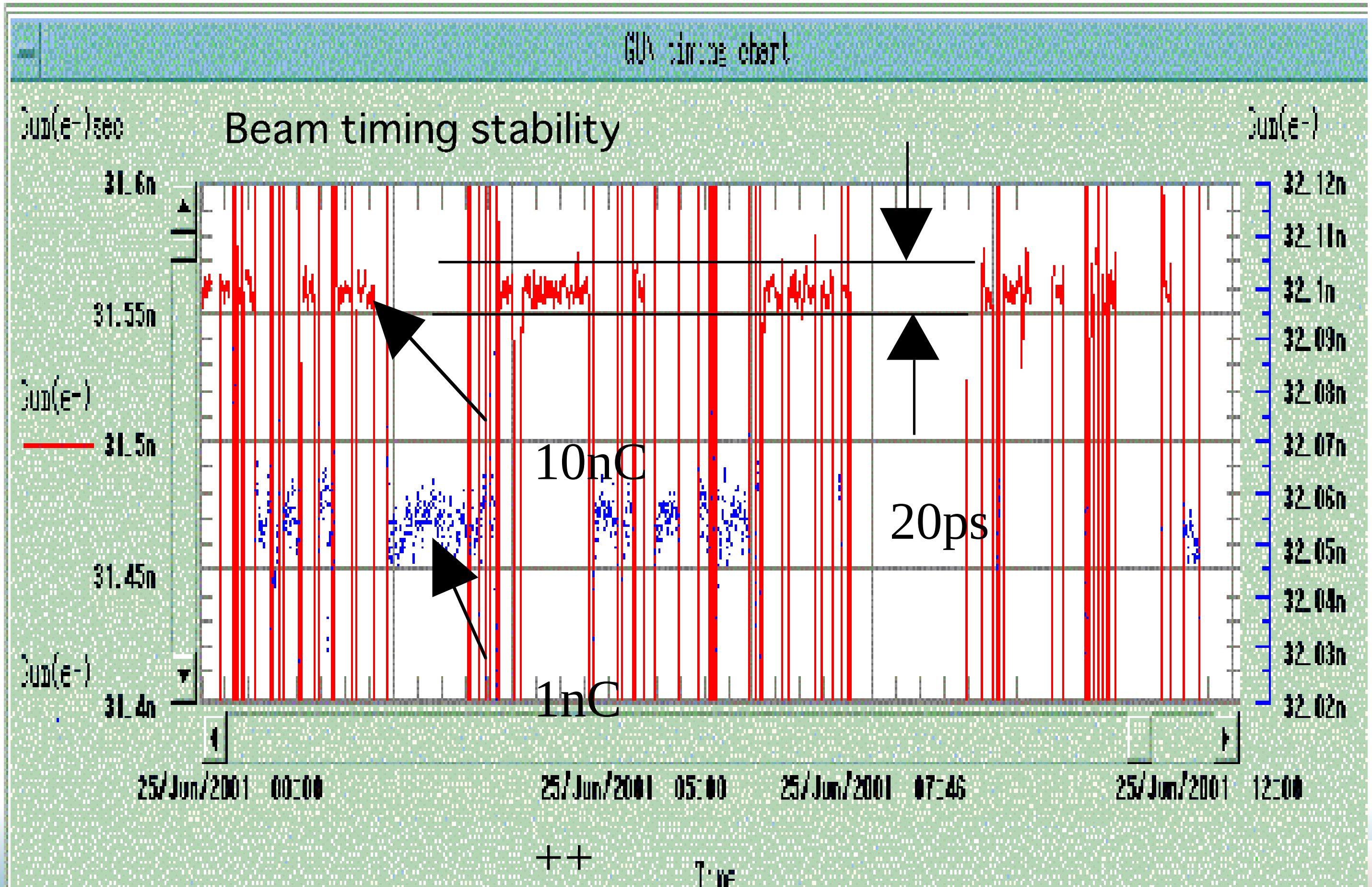
Pre-Injector System: Phase Stability of SHB1, 2 & Buncher



Pre-Injector System:Variation of Grid-Pulse Timing



Pre-Injector System:Variation of Beam Timing



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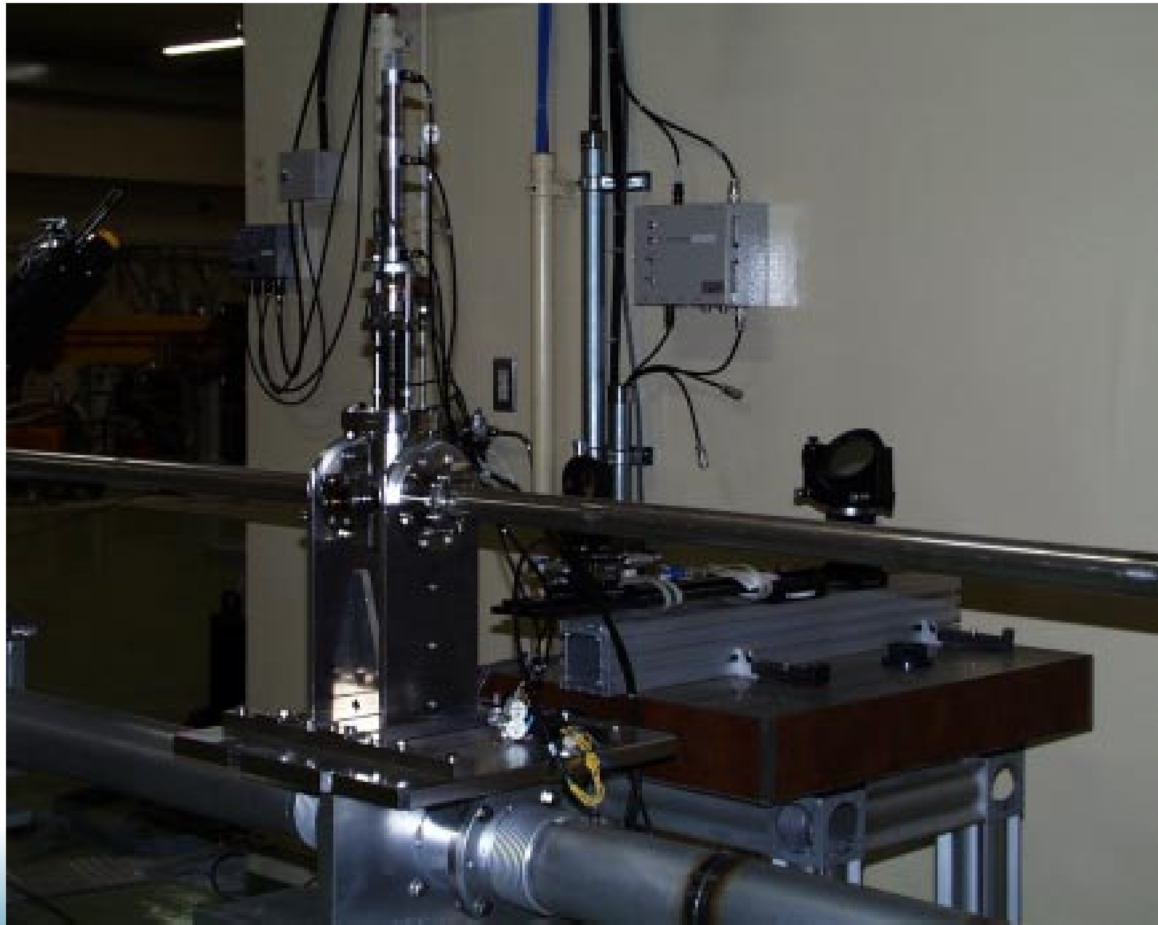
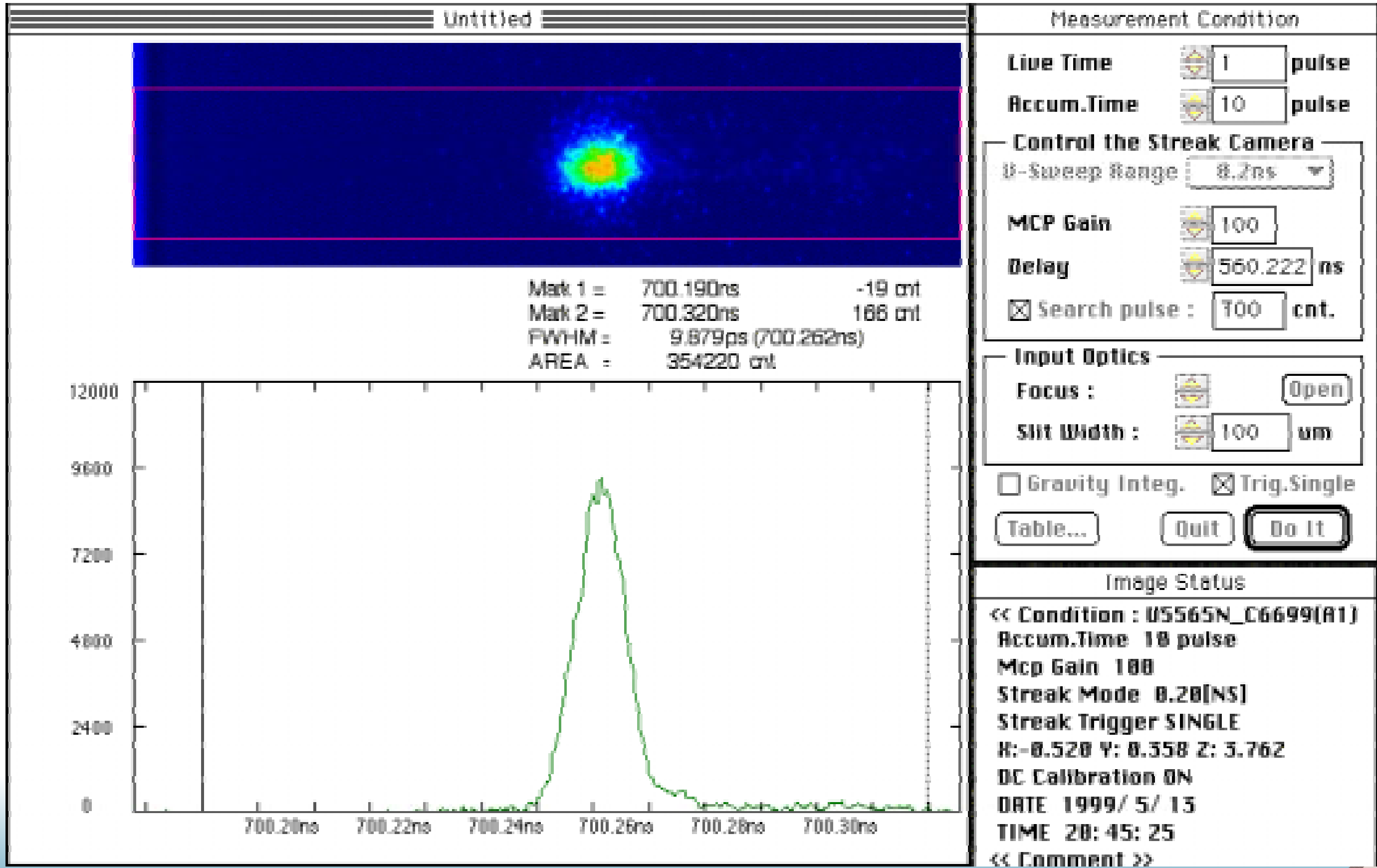
Control & RF Feedback System of the Gun Beam

	Tolerance	Stability	FB	Remraks
Gun High Voltage [%]	±0.38	~0.05	ON	200kV
Gun Beam Timing [ps]	±45	20	ON	
SHB1 RF Power [%]	-	~1	ON	114.2MHz/11kW
SHB1 Phase [deg.]	±1.1	0.5	-	
SHB2 RF Power[%]	-	~1	ON	571.2MHz/7kW
SHB2 Phase[deg.]	±1.3	1.0	-	
Buncher Power [%]	±0.47	~1	-	2856MHz/~23MW
Buncher Phase [deg.]	±1.7	±1.0	-	

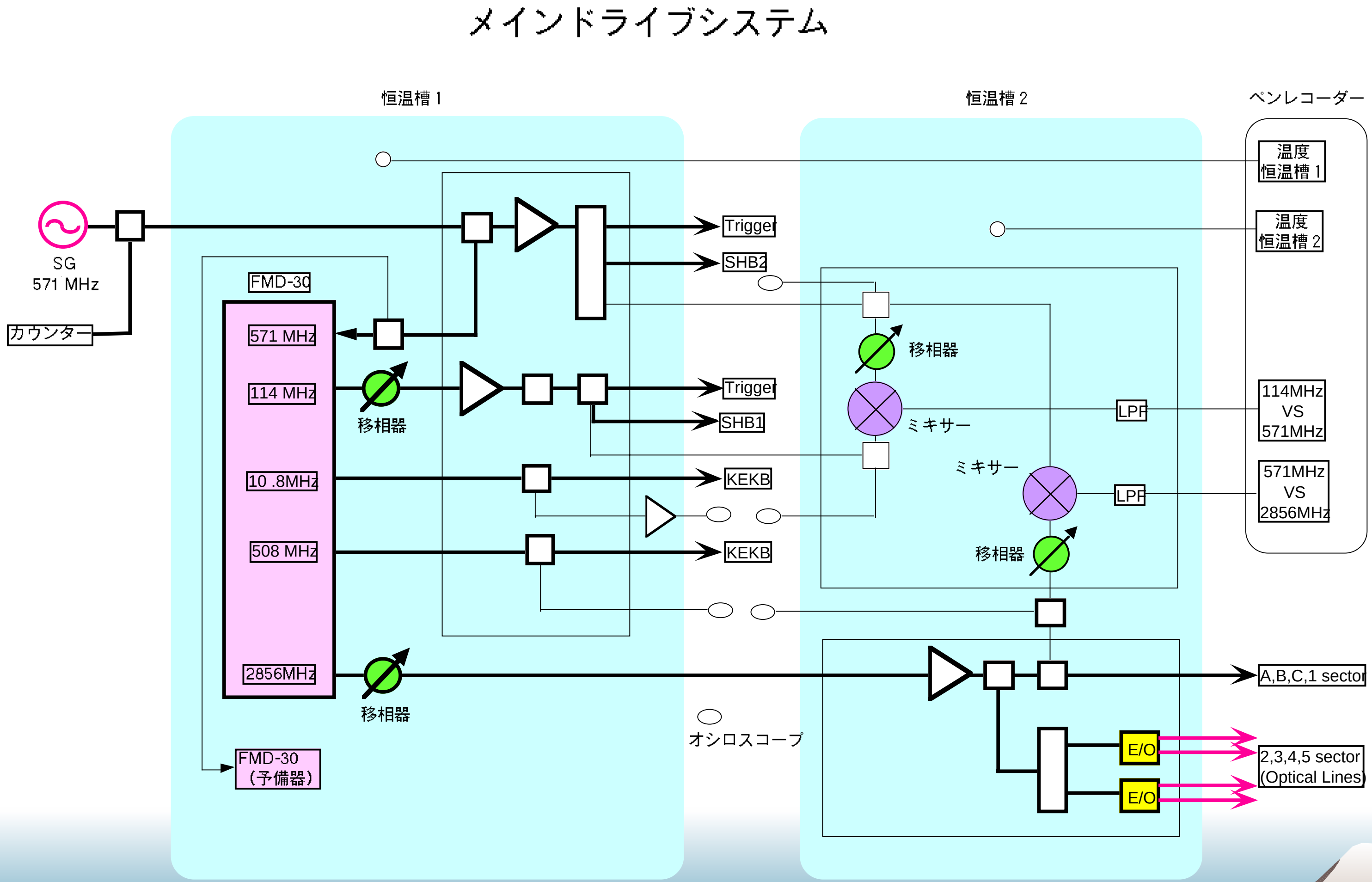
Optical-Transition Monitor



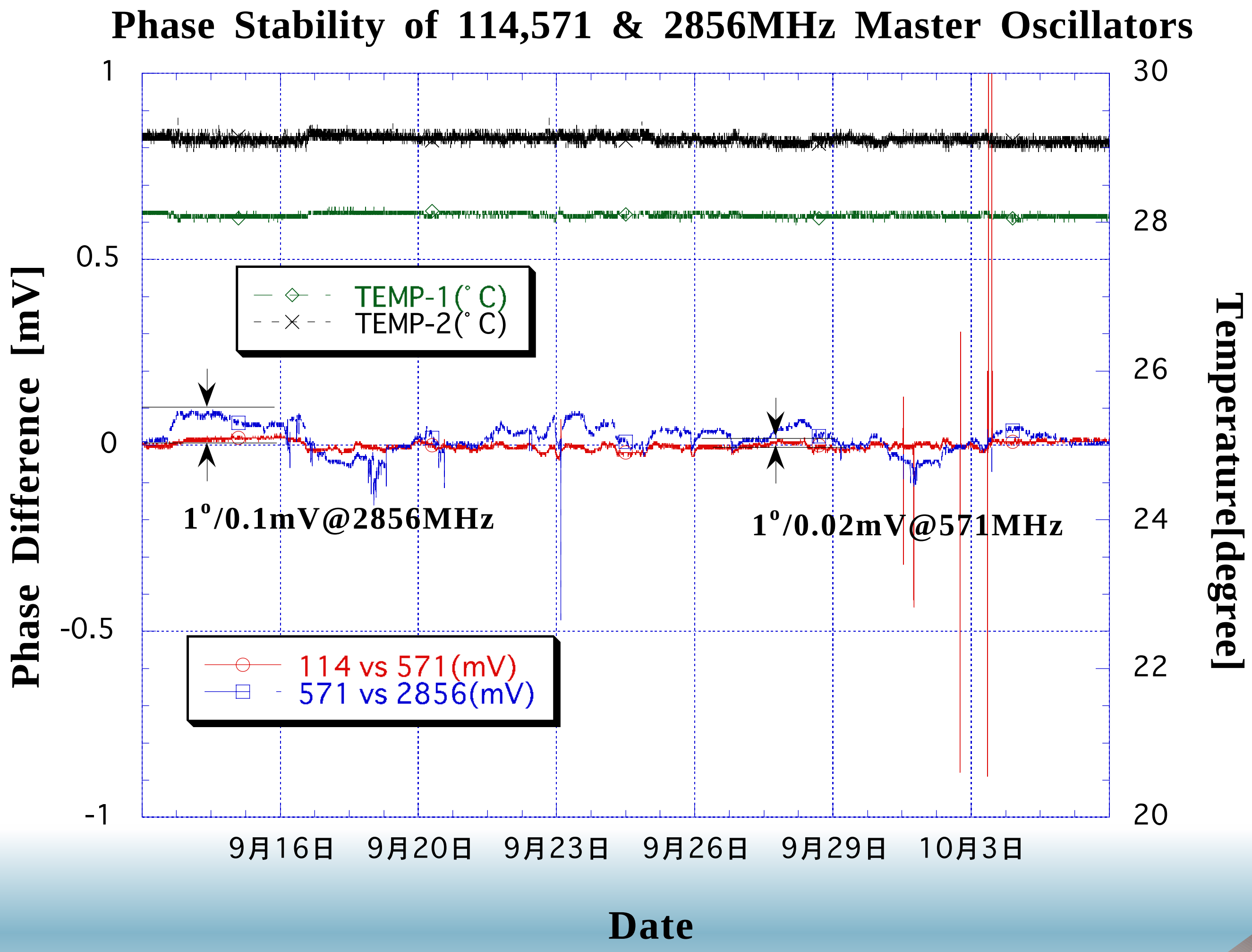
Bunch Profile Measurement Using OTR Monitor



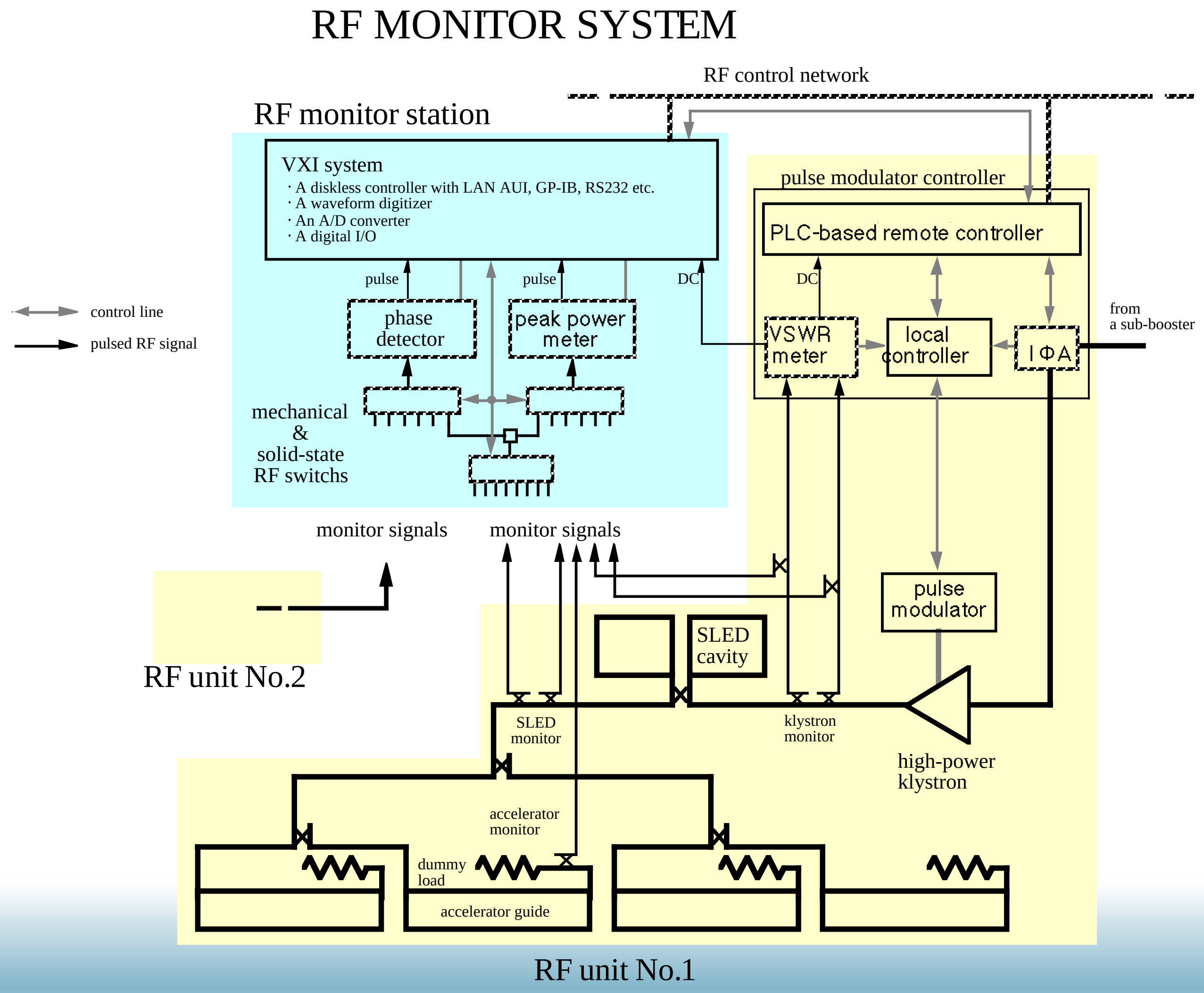
RF Stability:Main Drive System



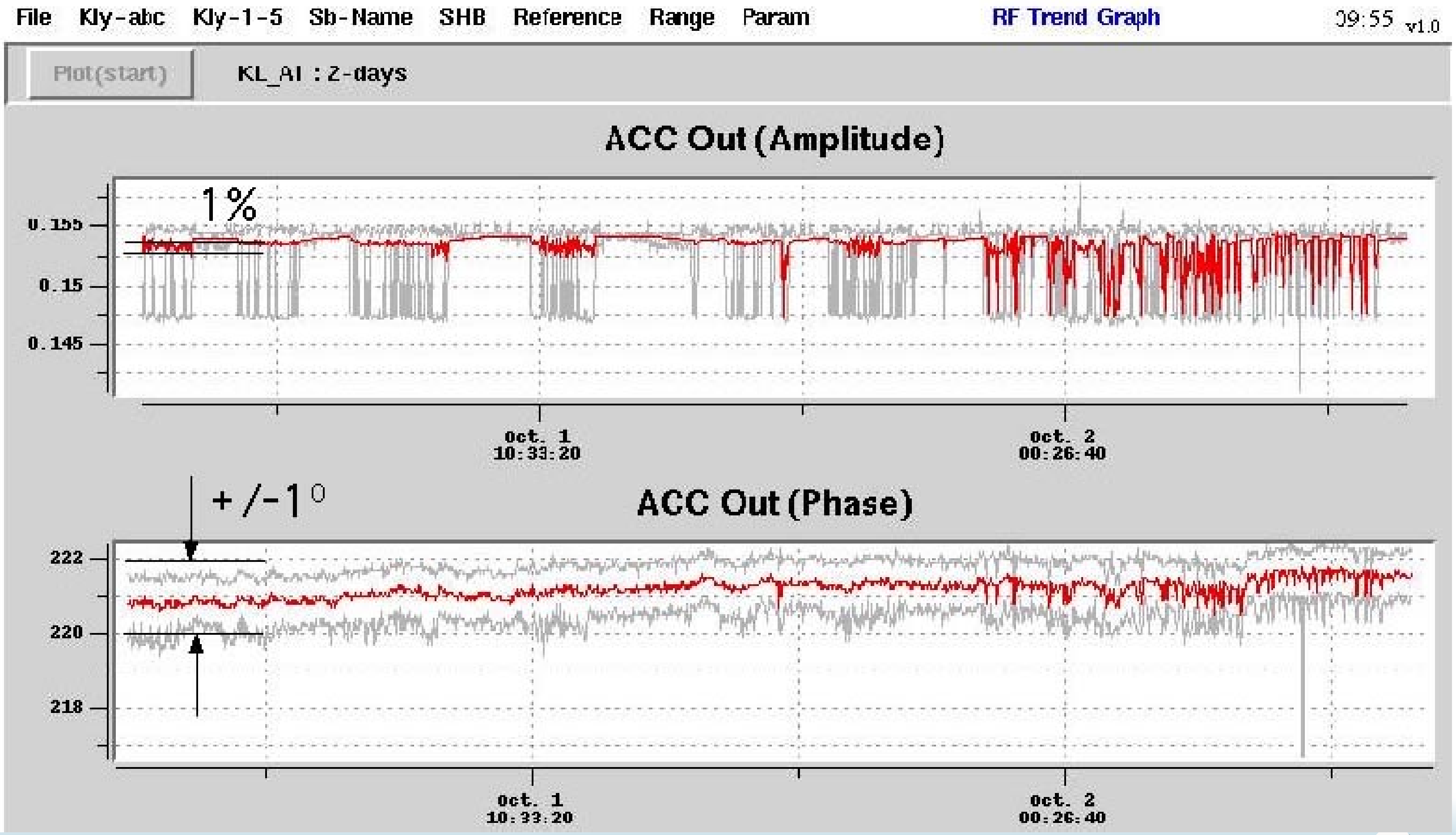
Stability of RF:Trend Graphs



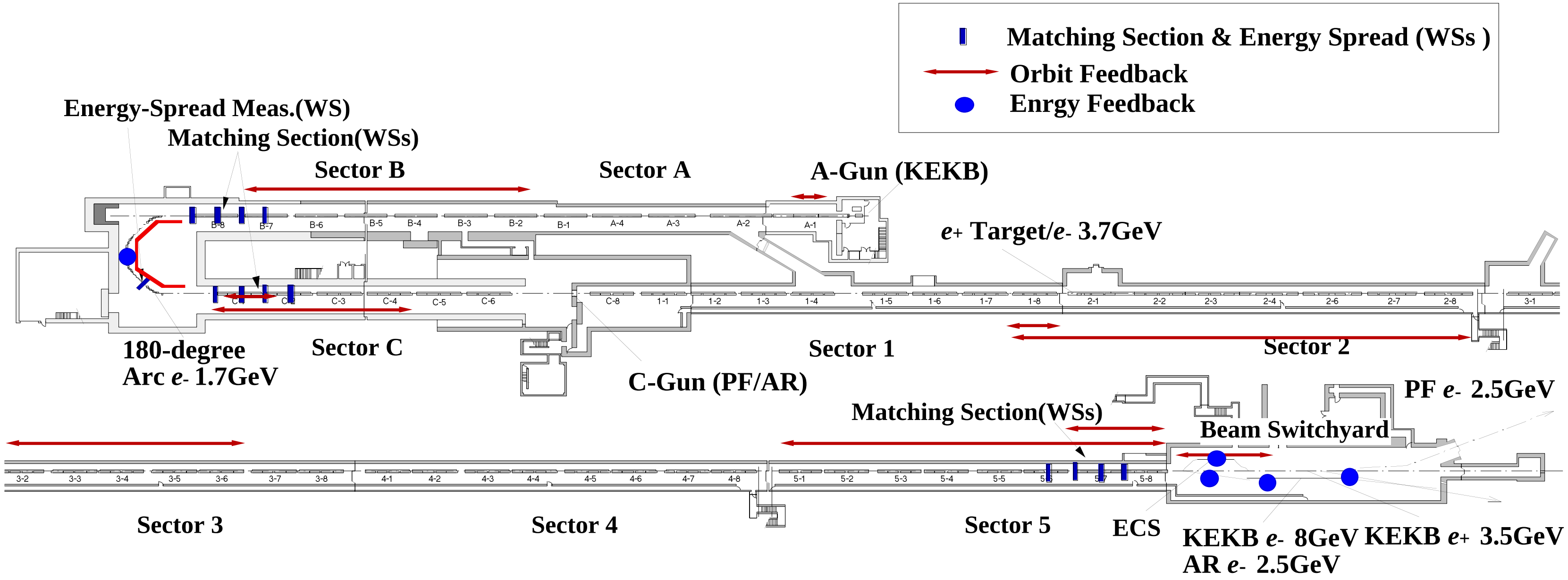
Stability of RF: Monitor System



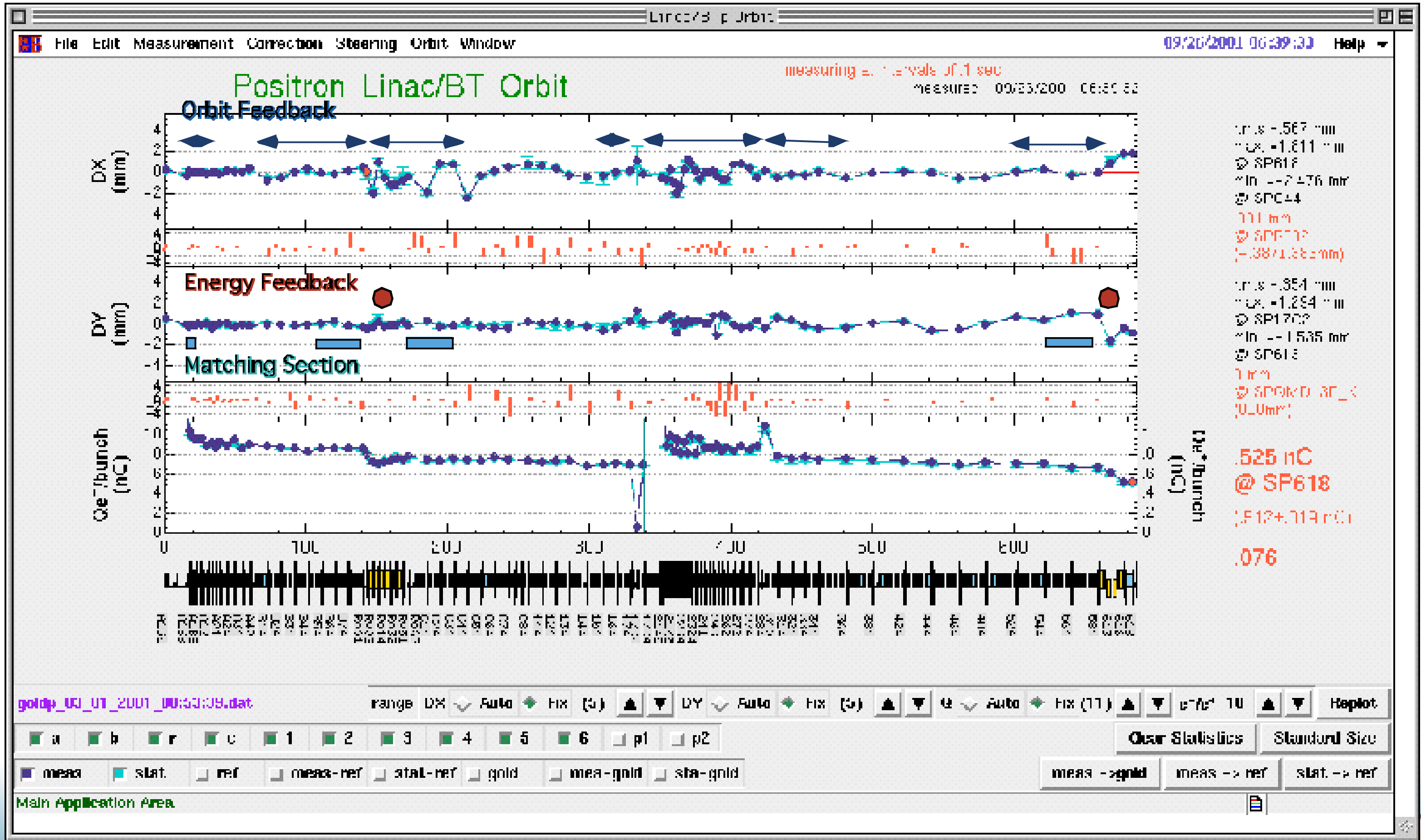
Stability of RF:Trend Graphs



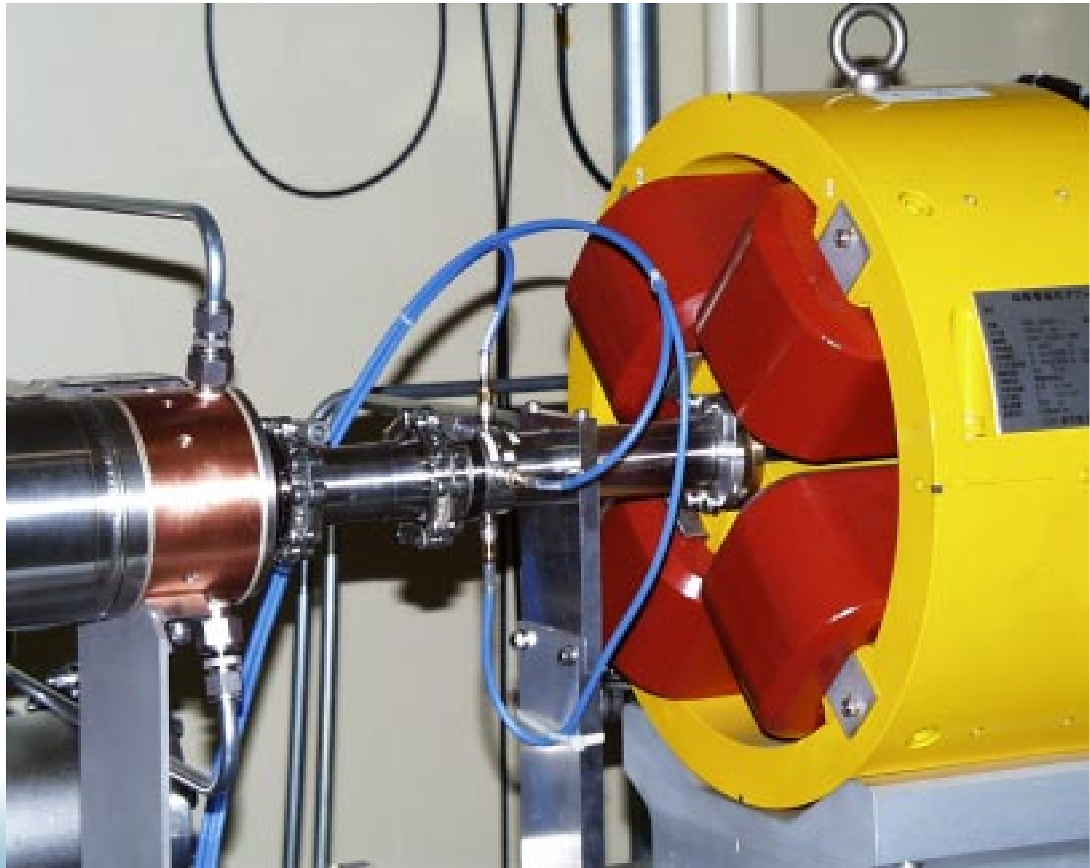
Beam Feedback Systems



Typical e^+ Beam Orbits & Charge for the KEKB Operation



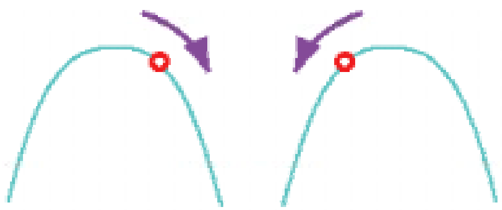
Beam Orbit & Energy Stability: Beam-Position Monitor

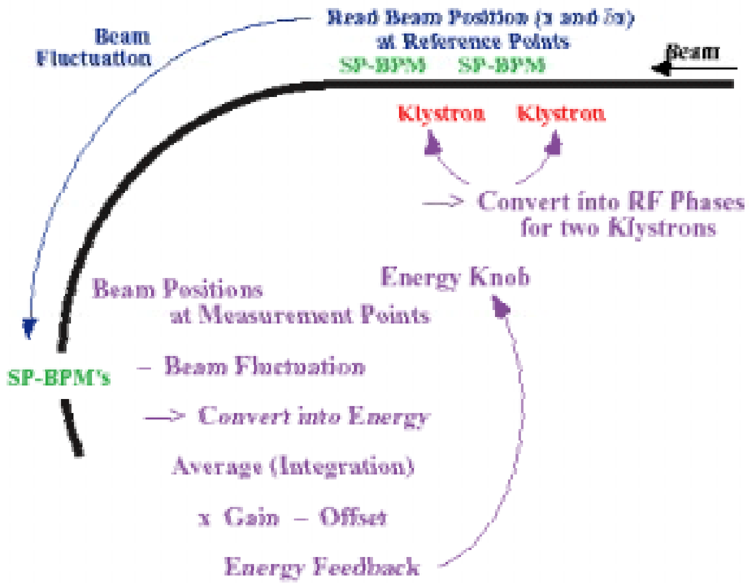


Beam Energy Stability: Principle of Feedback

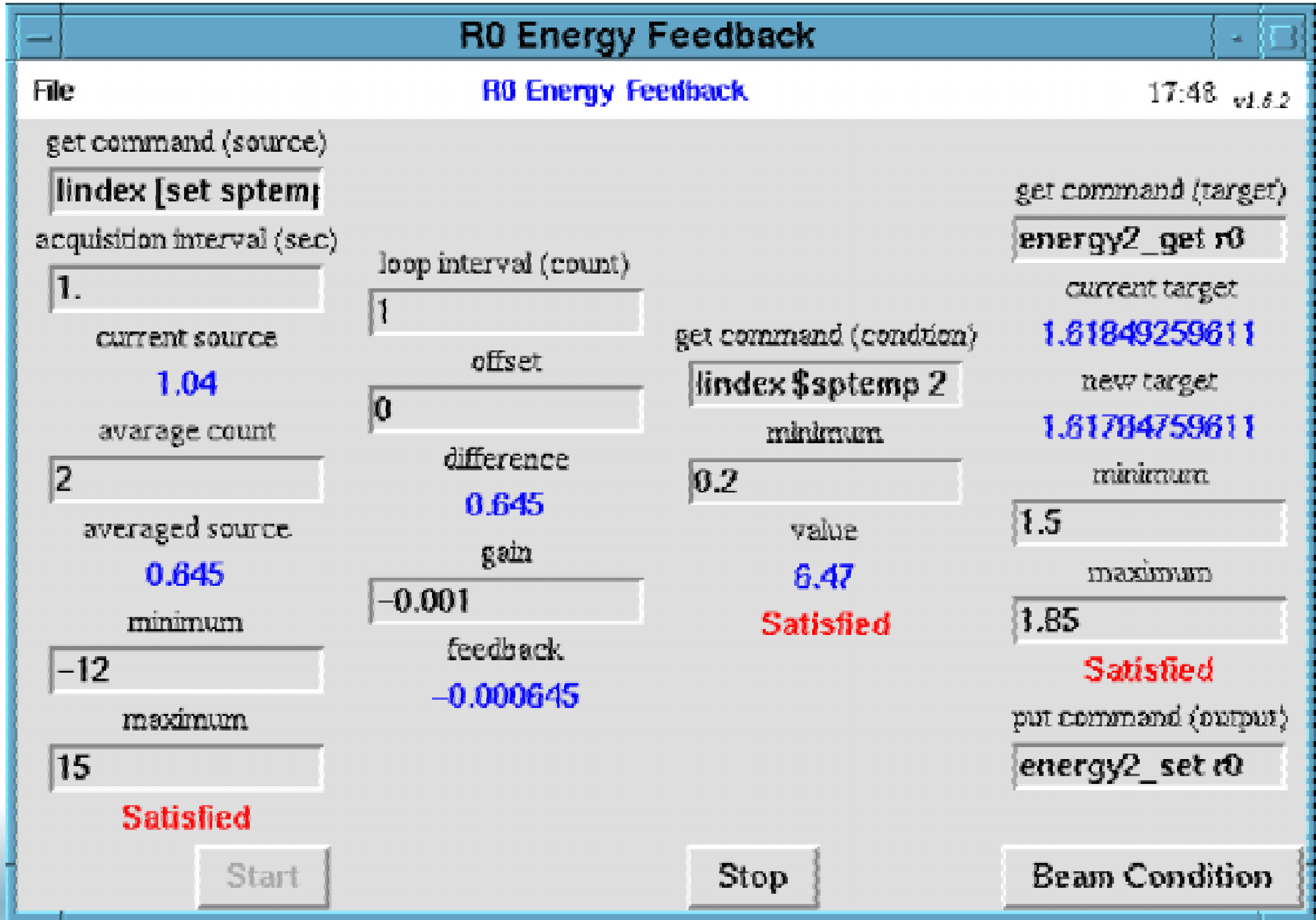
Beam Energy Tuner & Feedback

- Energy Tuner — Energy (Software) Knob
  Microwave Phases at two Adjacent Klystrons
  (Voltage may change both Phase and Amplitude)

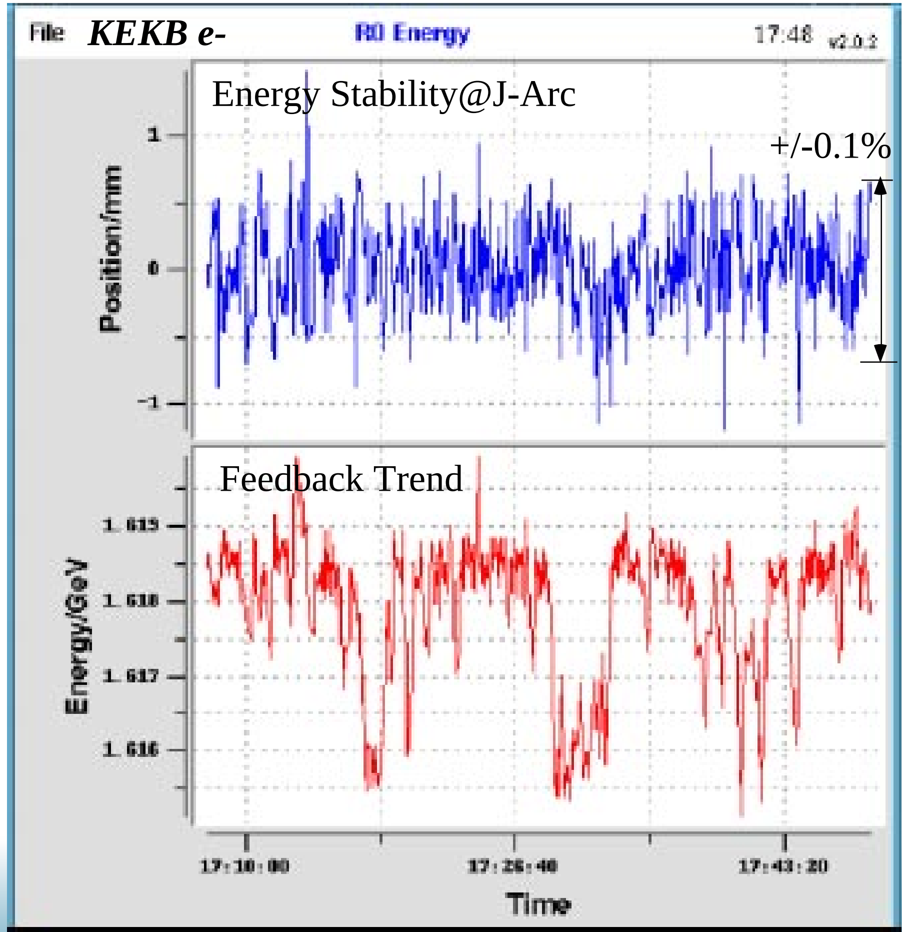




Beam Energy Stability: Control Panel



Beam Energy Stability: Trend graphs



Beam Orbit Stability: Principle of Feedback

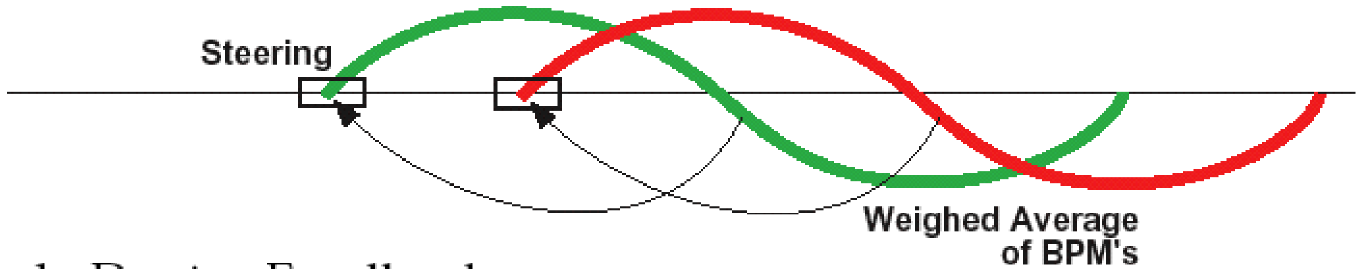
Other Feedback Loops

- Simple Orbit Feedback

  Monitor: Weighed Average of BPM's over 1 Betatron Wavelength

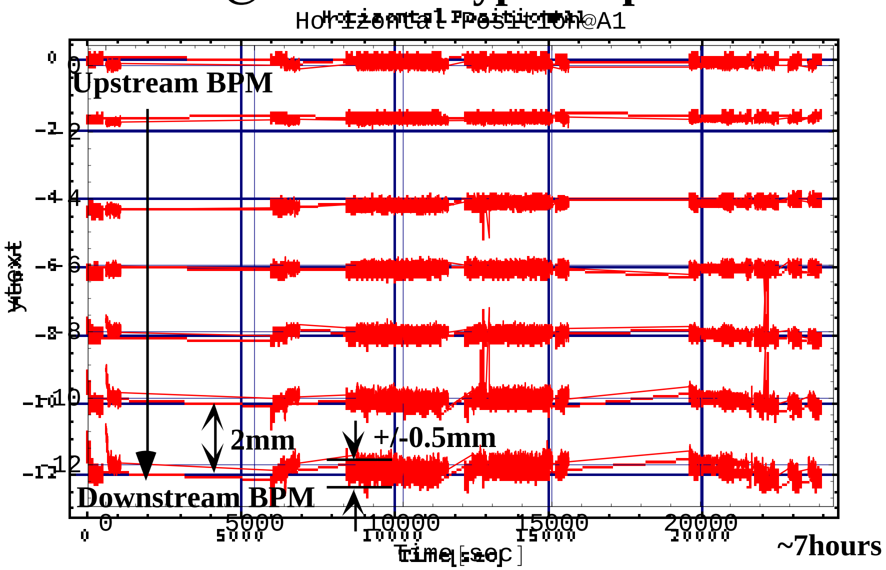
  Tuner: Two Steerings with 90-degree phase advance

  (Difficult to Predict Orbit Because of Wake Fields)

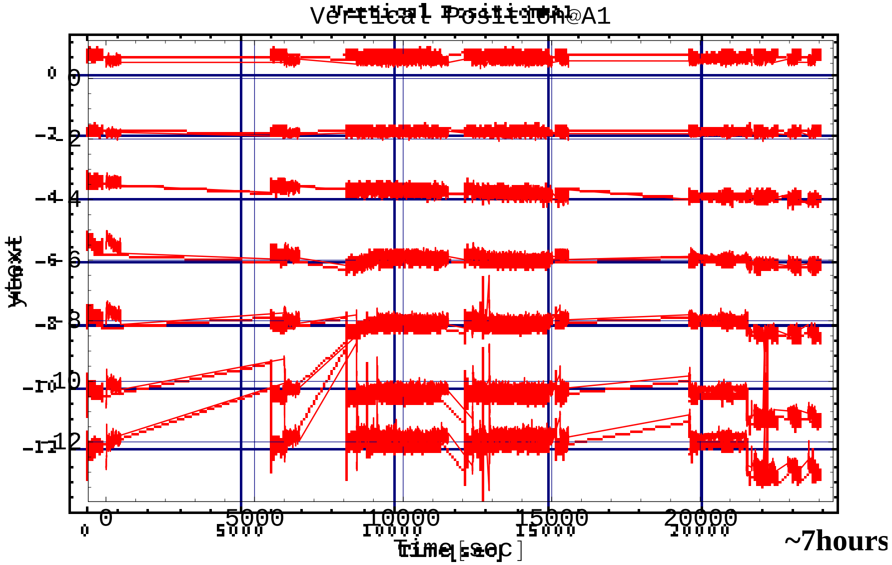


Beam Orbit Stability: Trend Graphs

KEKB e-/e+@A1 under typical operation

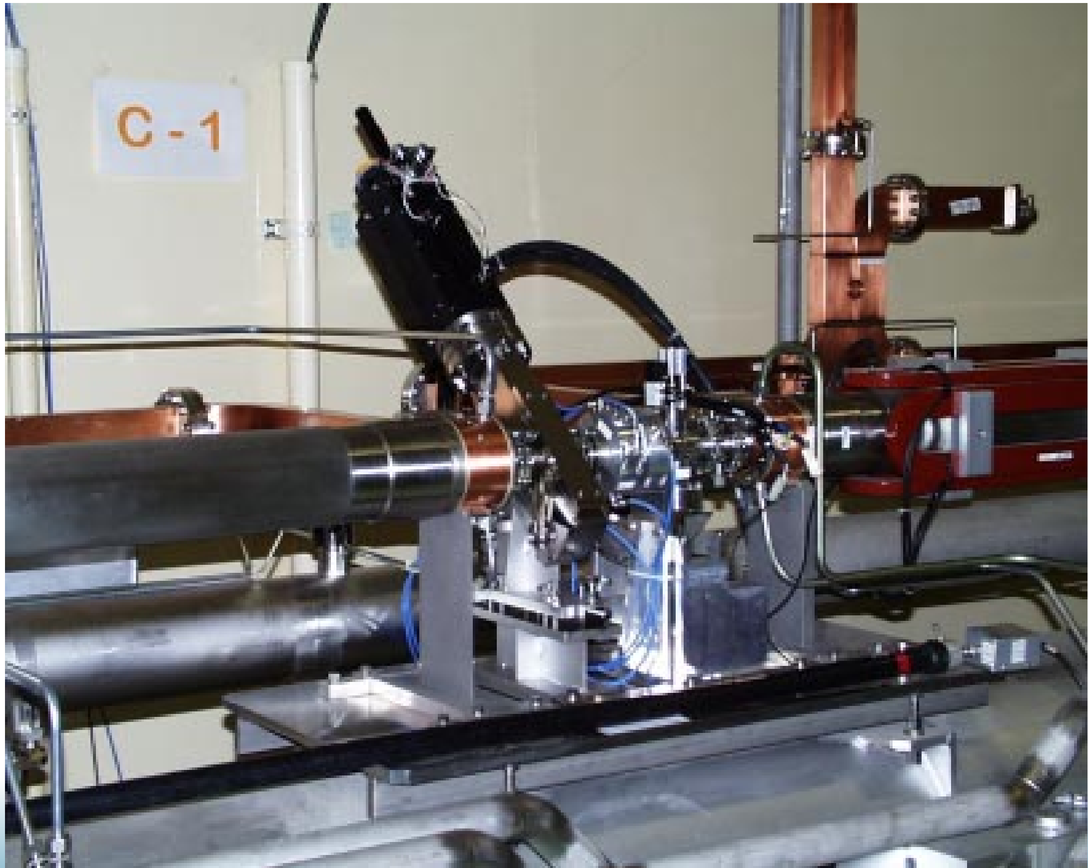


Horizotal Orbit Stability@A1

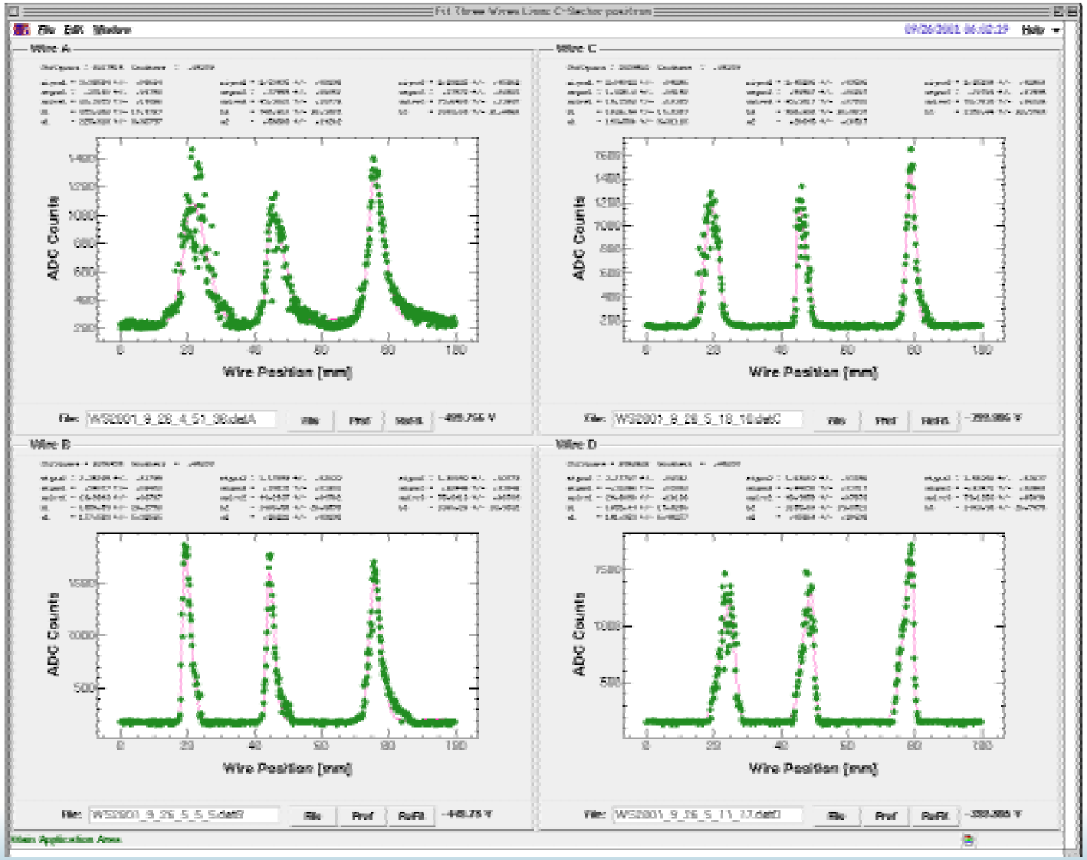


Vertical Orbit Stability@A1

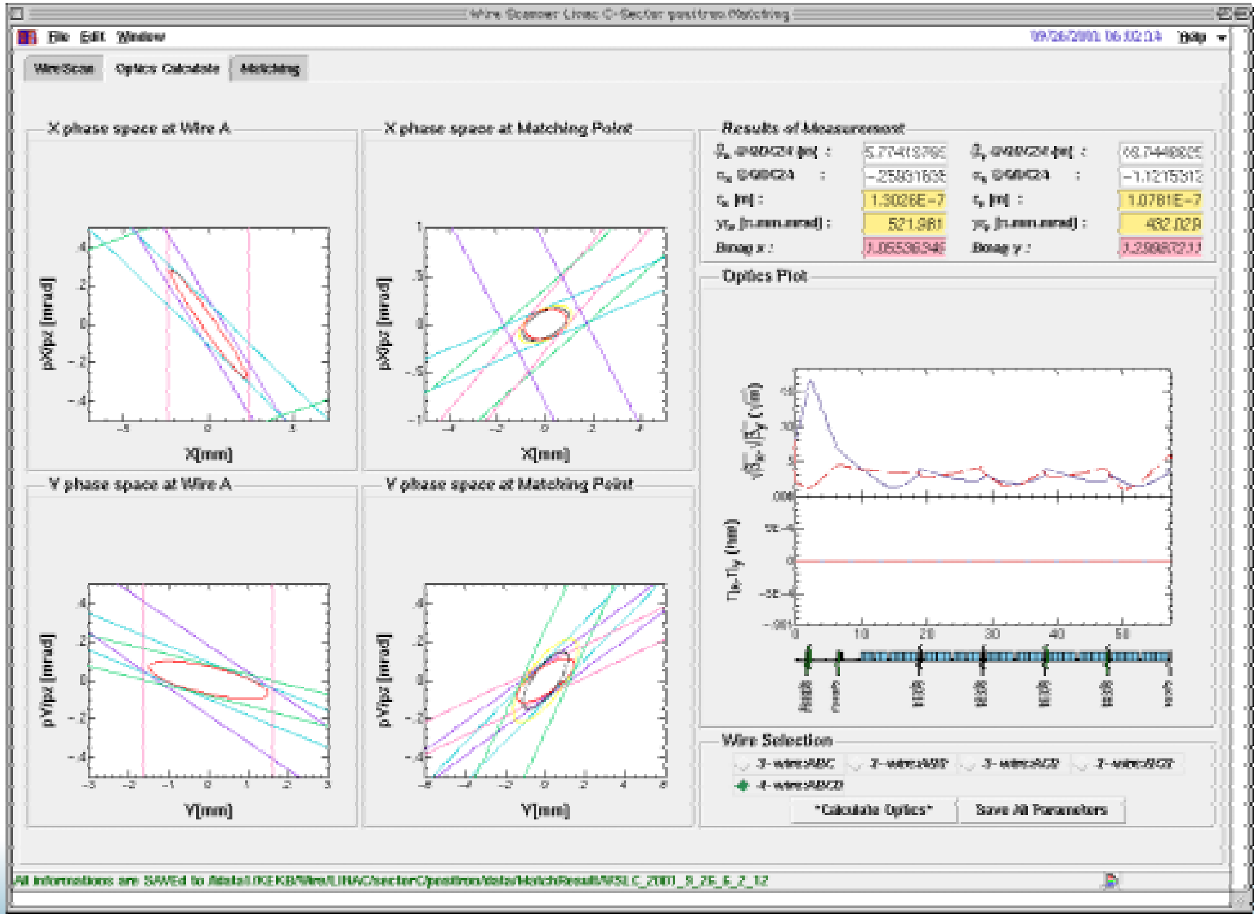
Beam Optics Stability: Wire Scanner



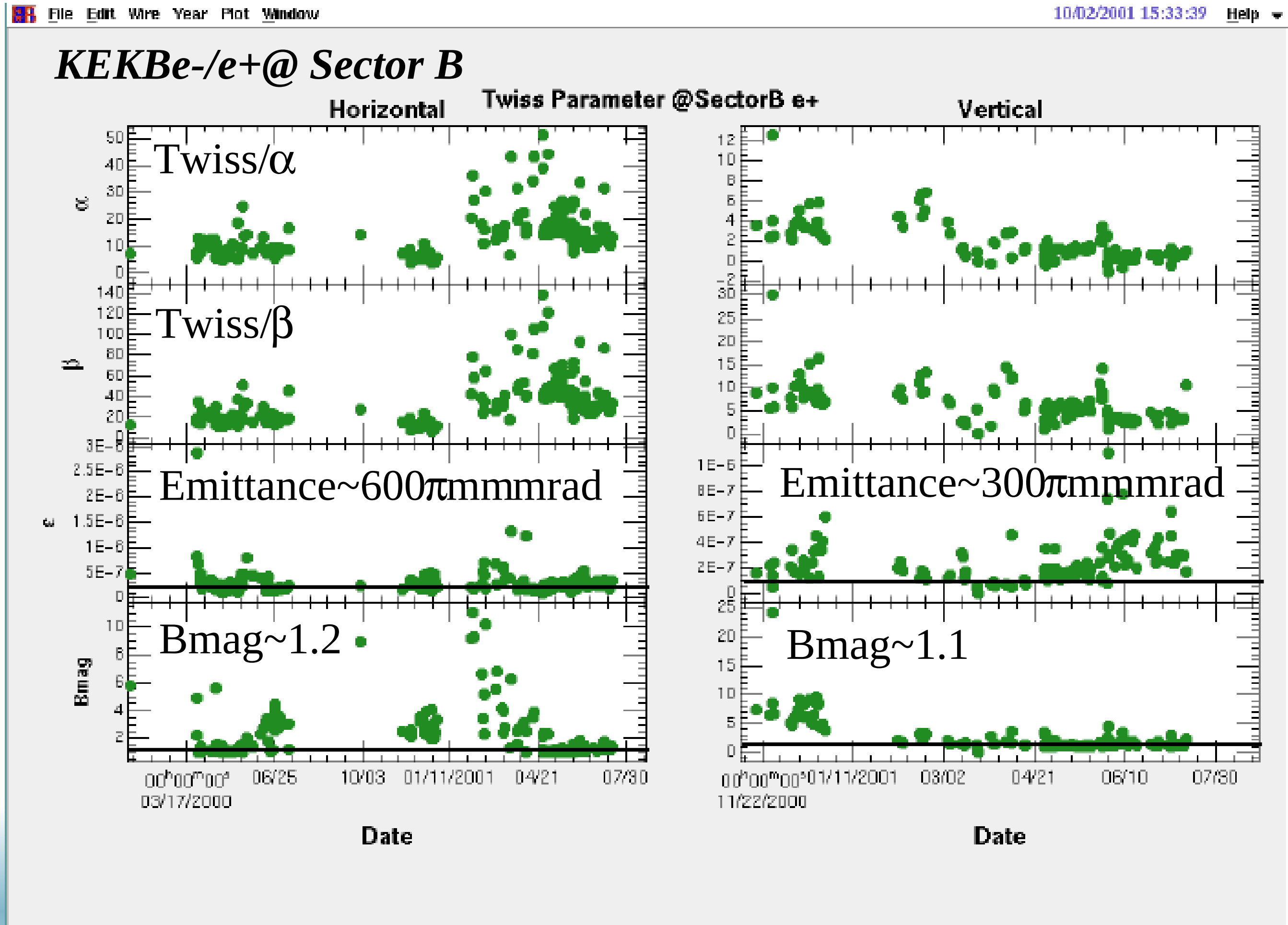
Beam Optics Stability:Measurement Using Four Successive WSs



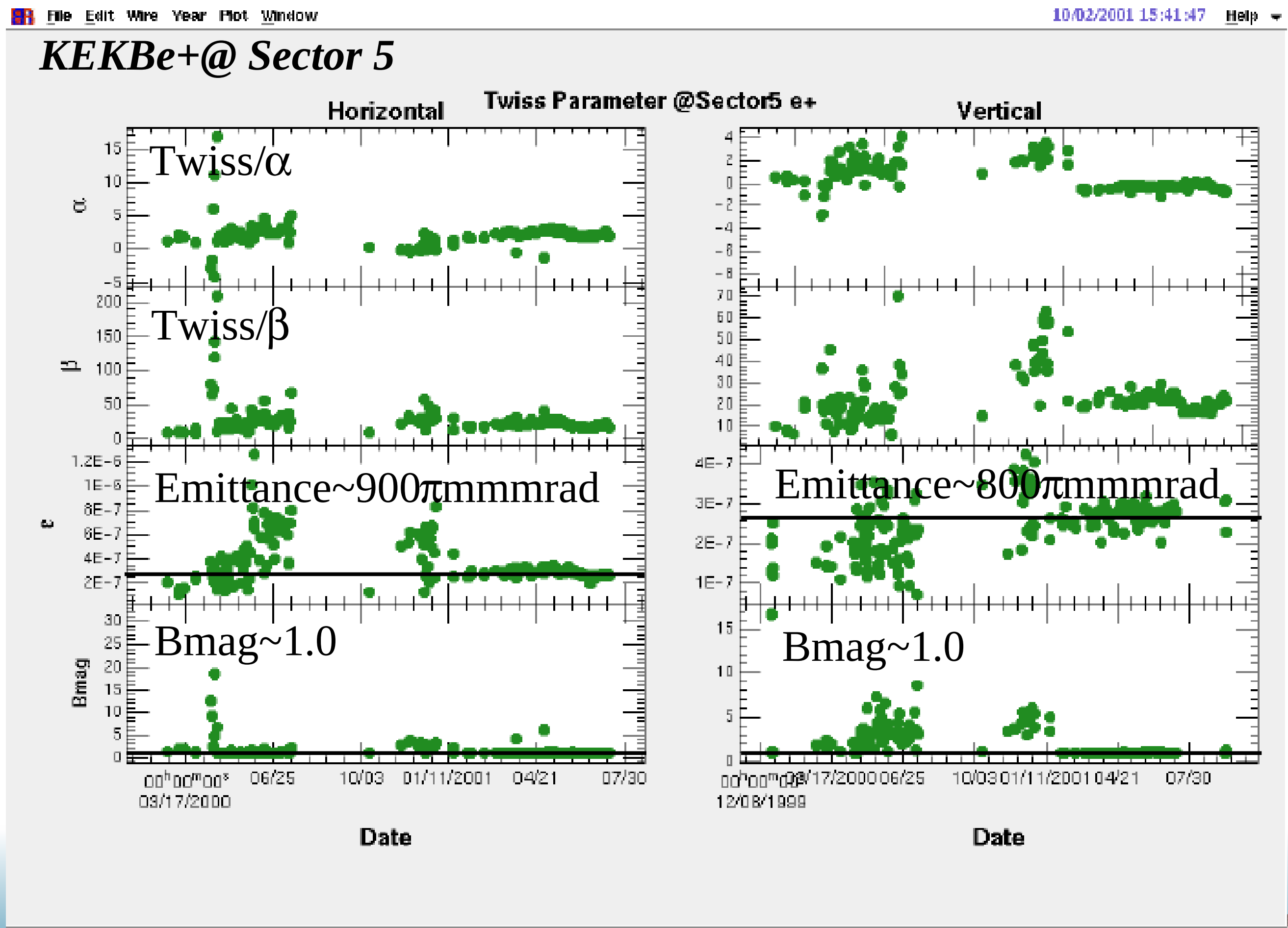
Beam Optics Stability: Optics Matching



Beam Optics Stability: Daily-Logged Parameters

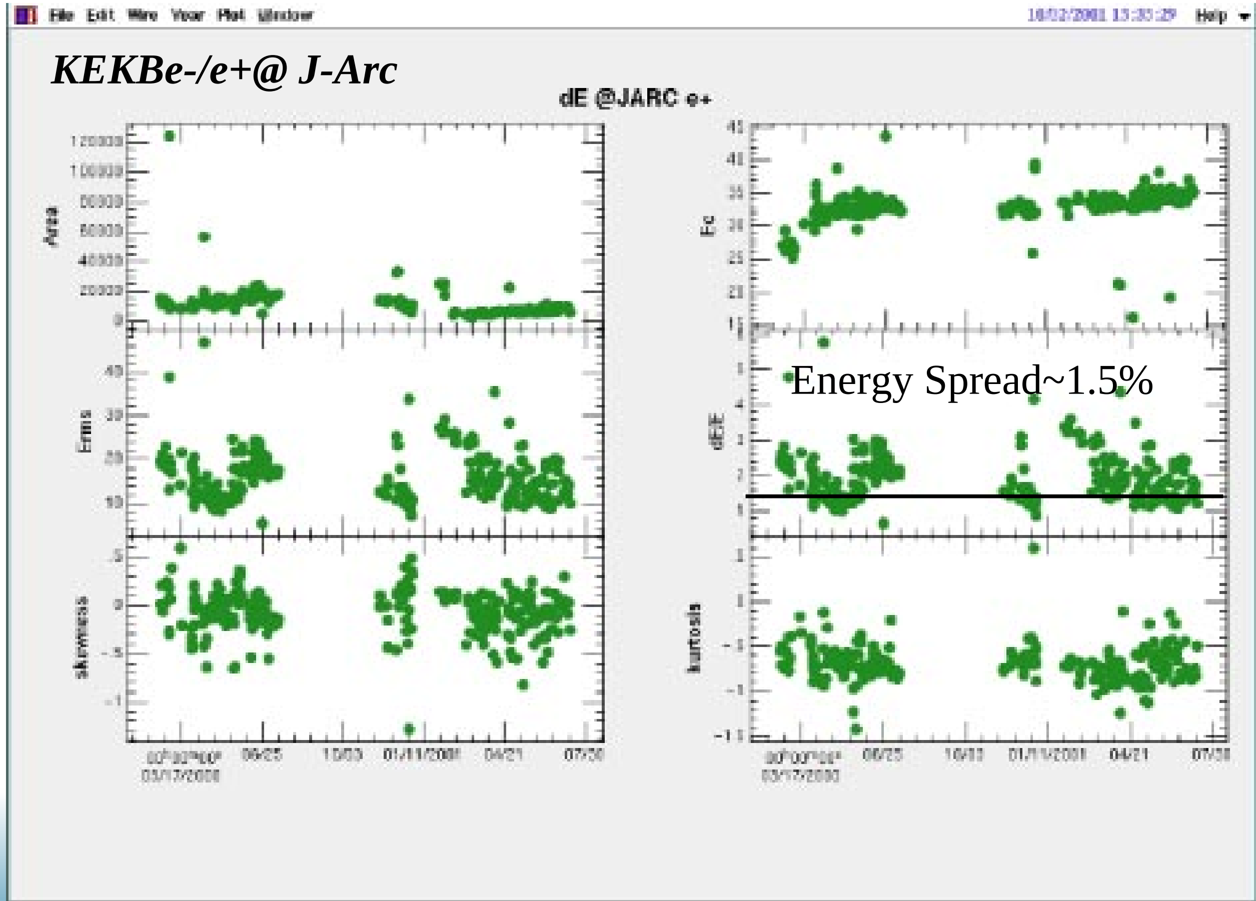


Beam Optics Stability: Daily-Logged Parameters

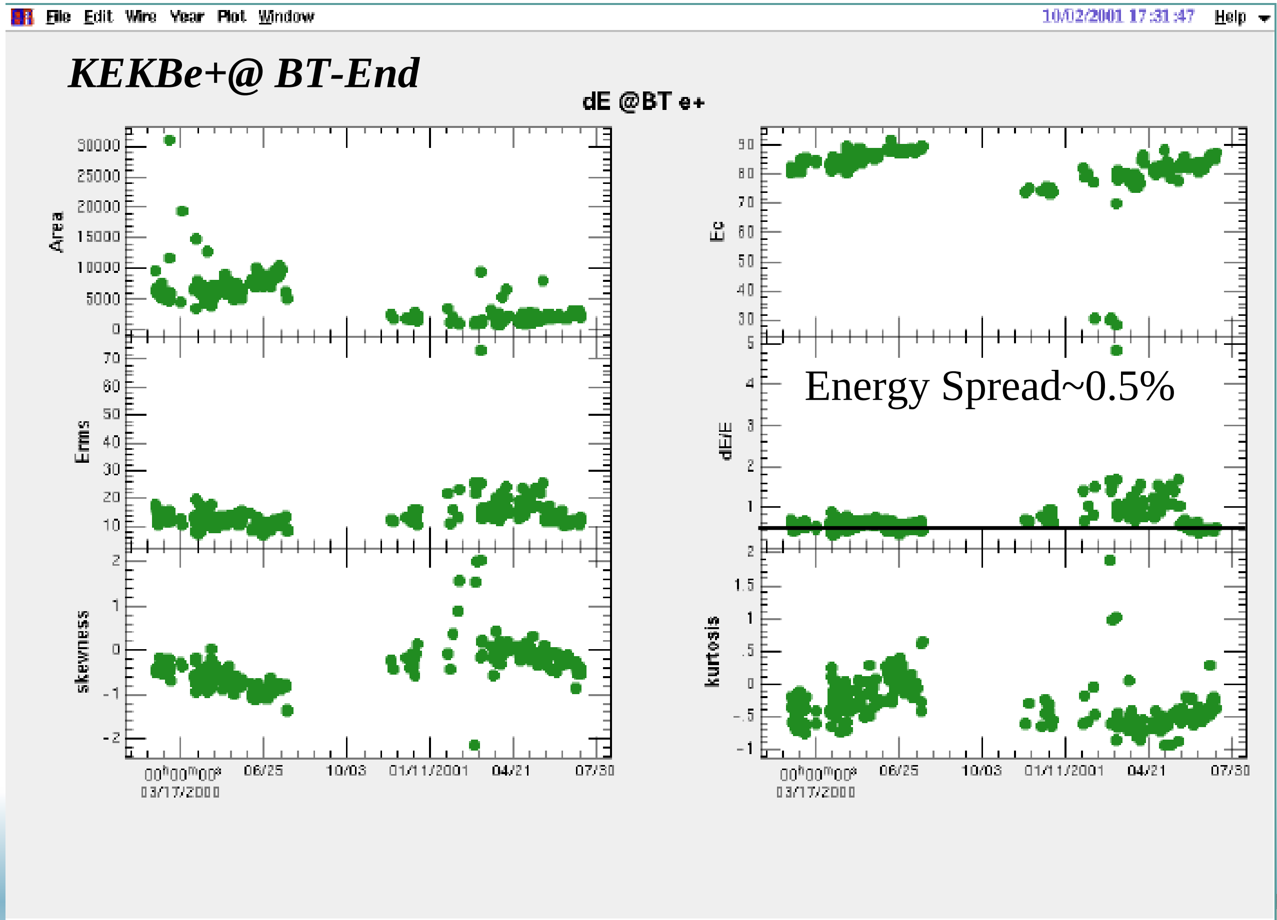


Energy Spread Stability: Energy Spread Monitor by WSs

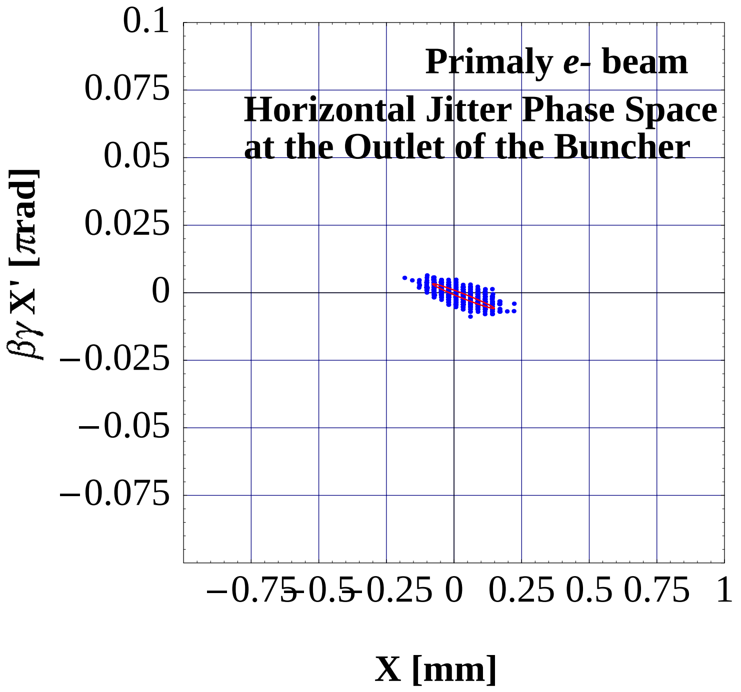
Energy Spread Stability: Daily-Logged Parameters

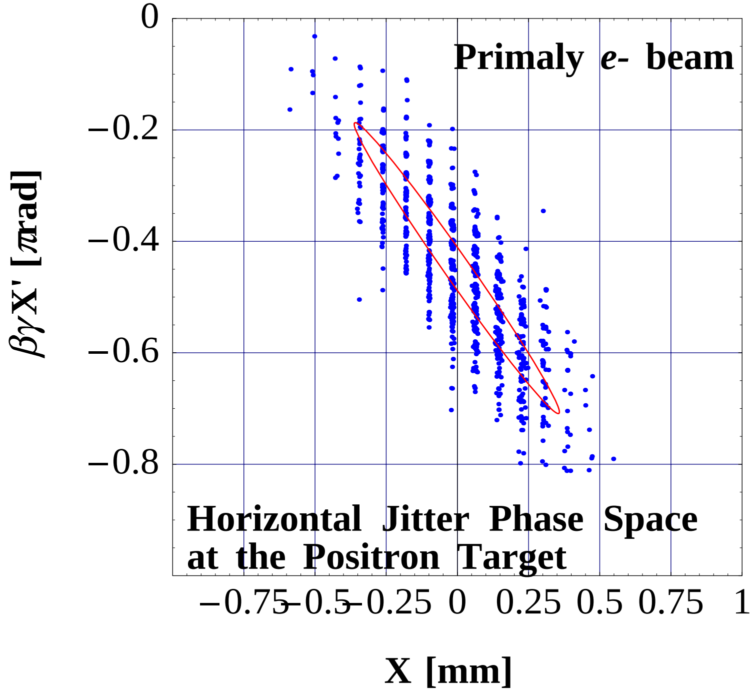


Energy Spread Stability: Daily-Logged Parameters

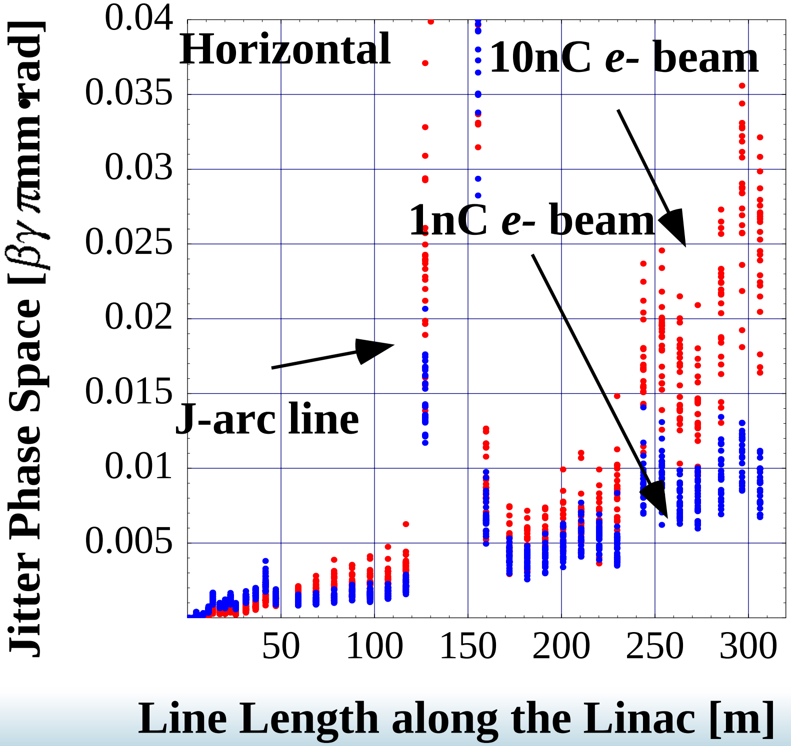


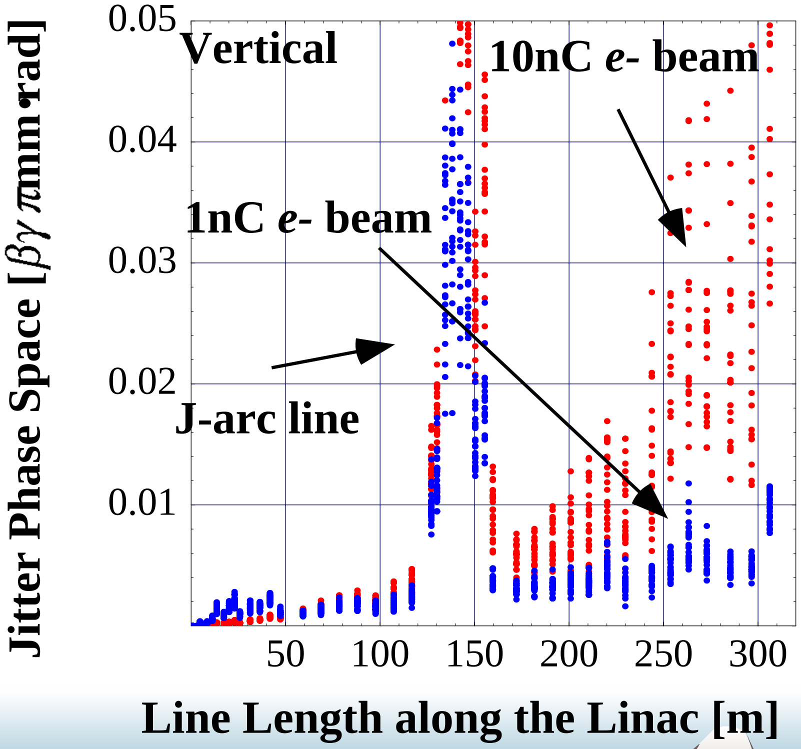
Beam Trajectory Jitter Analysis (Jitter Emittance)



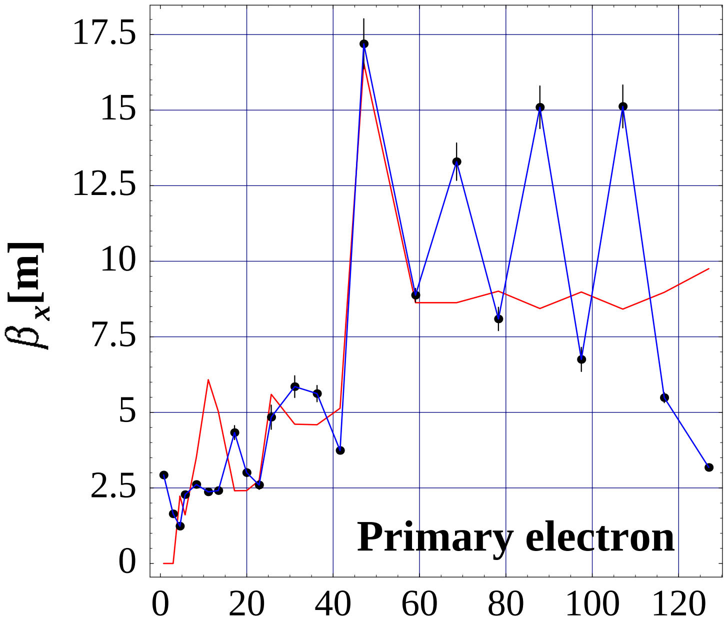


Beam Trajectory Jitter Analysis (Blow up of Jitter Emittance)

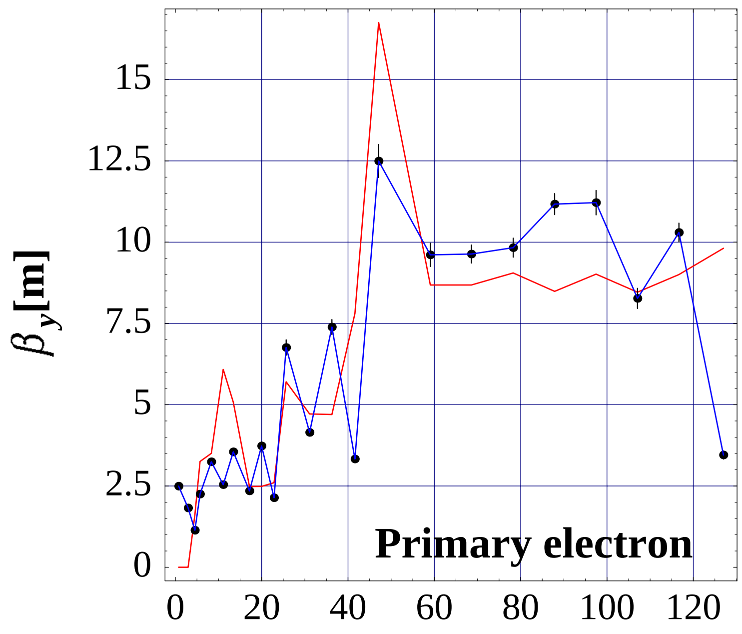




Beam Trajectory Jitter Analysis (β Function Measurement)

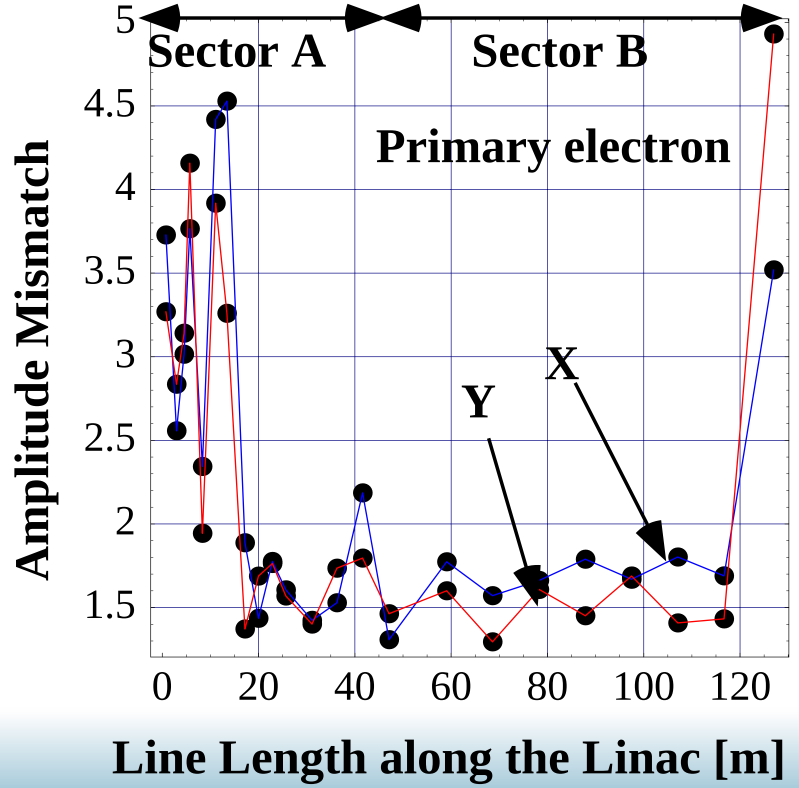


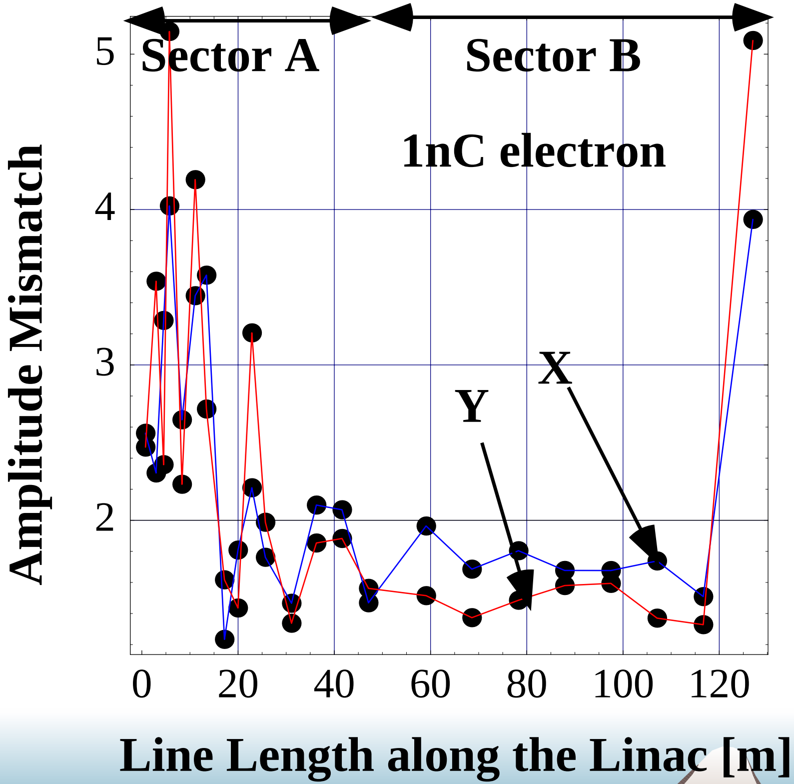
Line Length along the Linac [m]



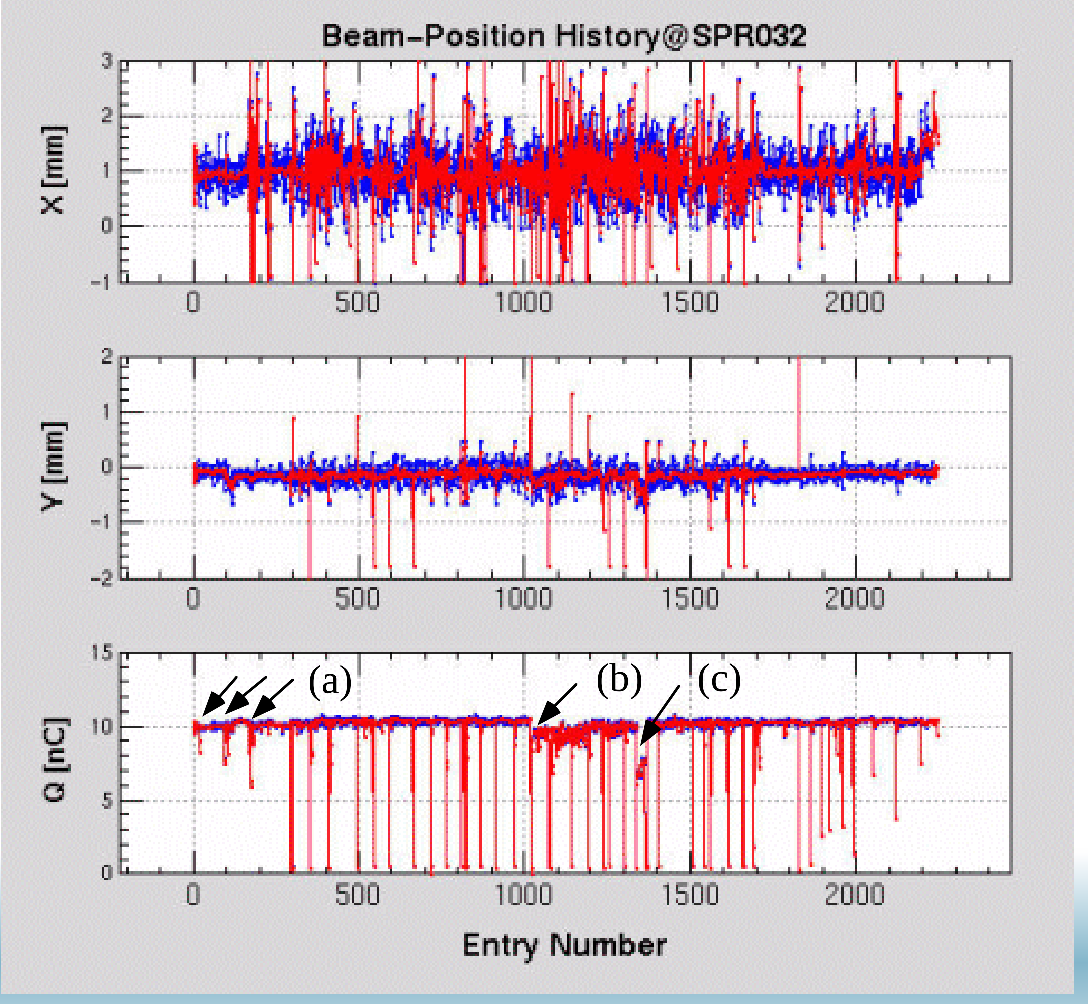
Line Length along the Linac [m]

Beam Trajectory Jitter Analysis (β Mismatch Parameter)

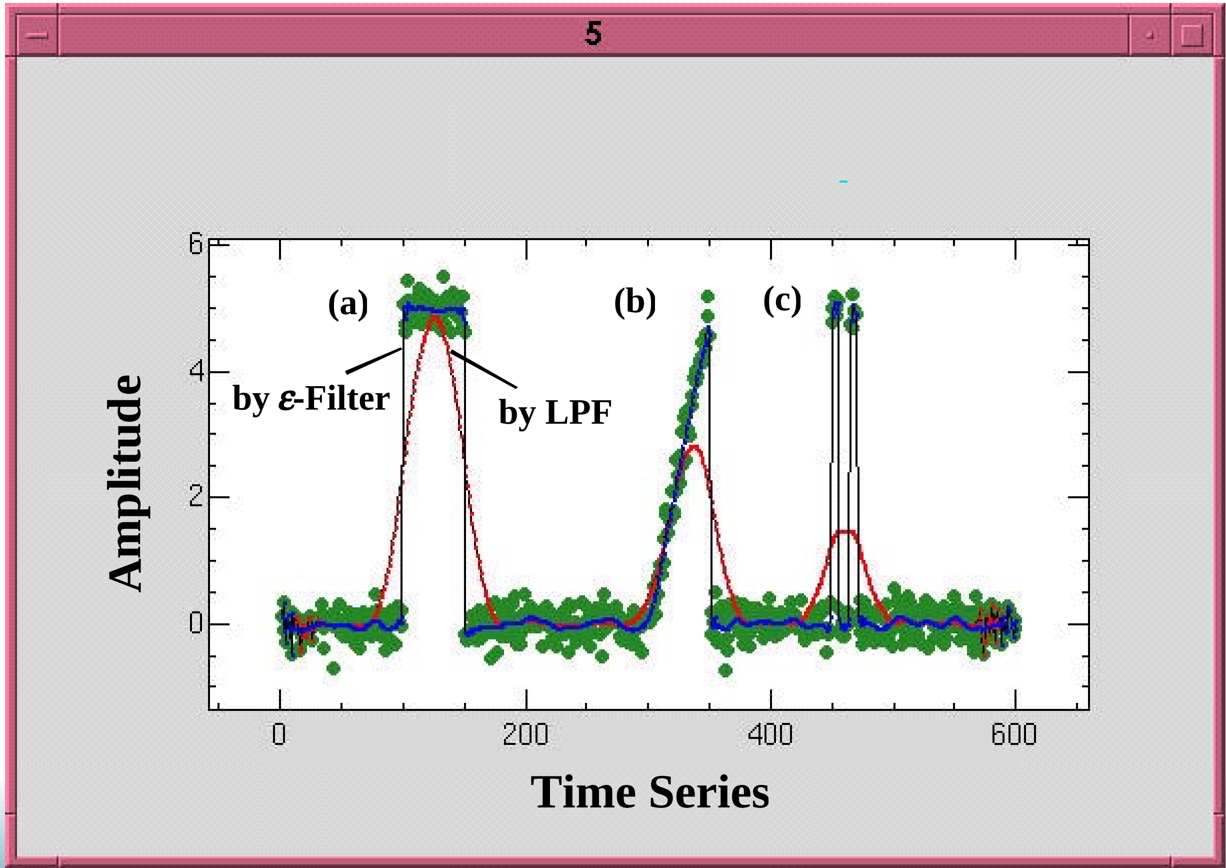




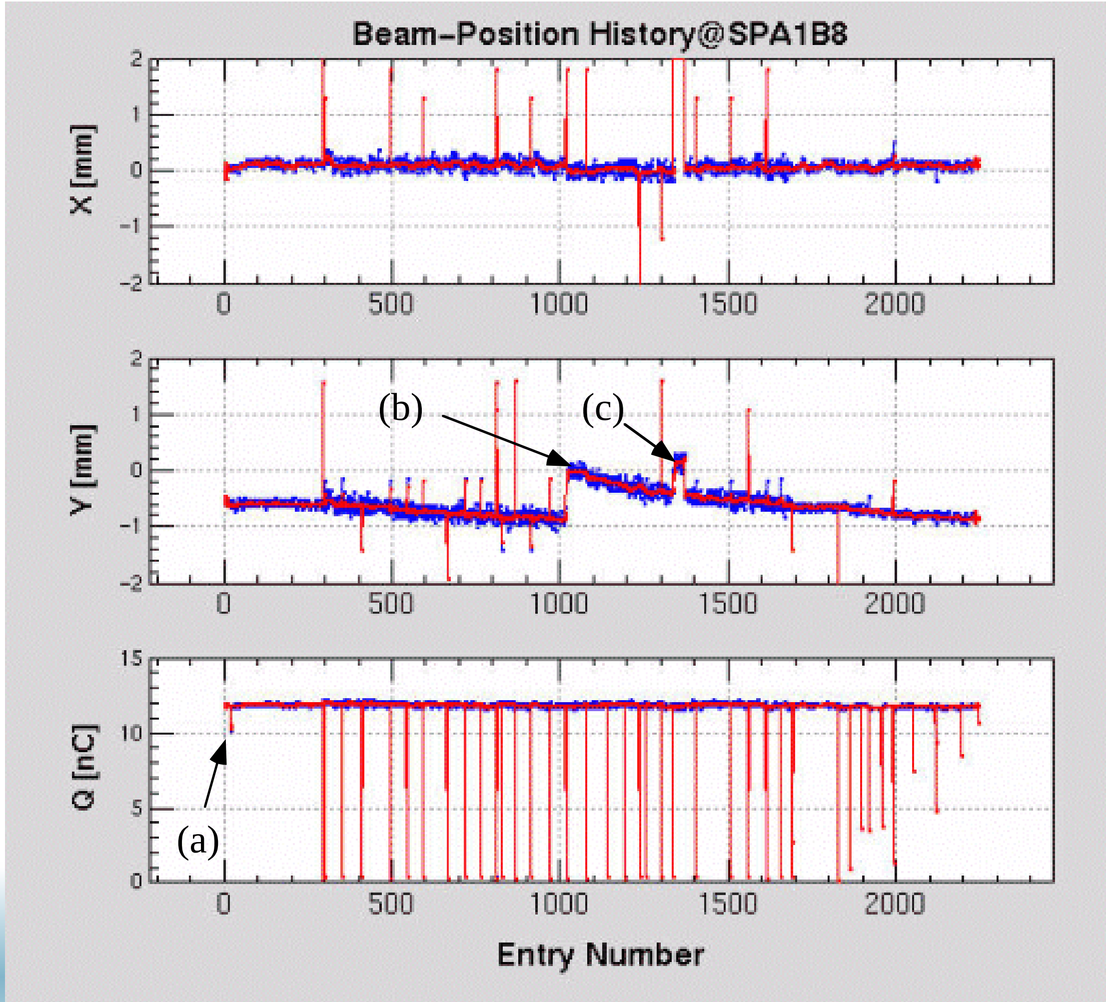
Beam-Energy Stability: Recording System



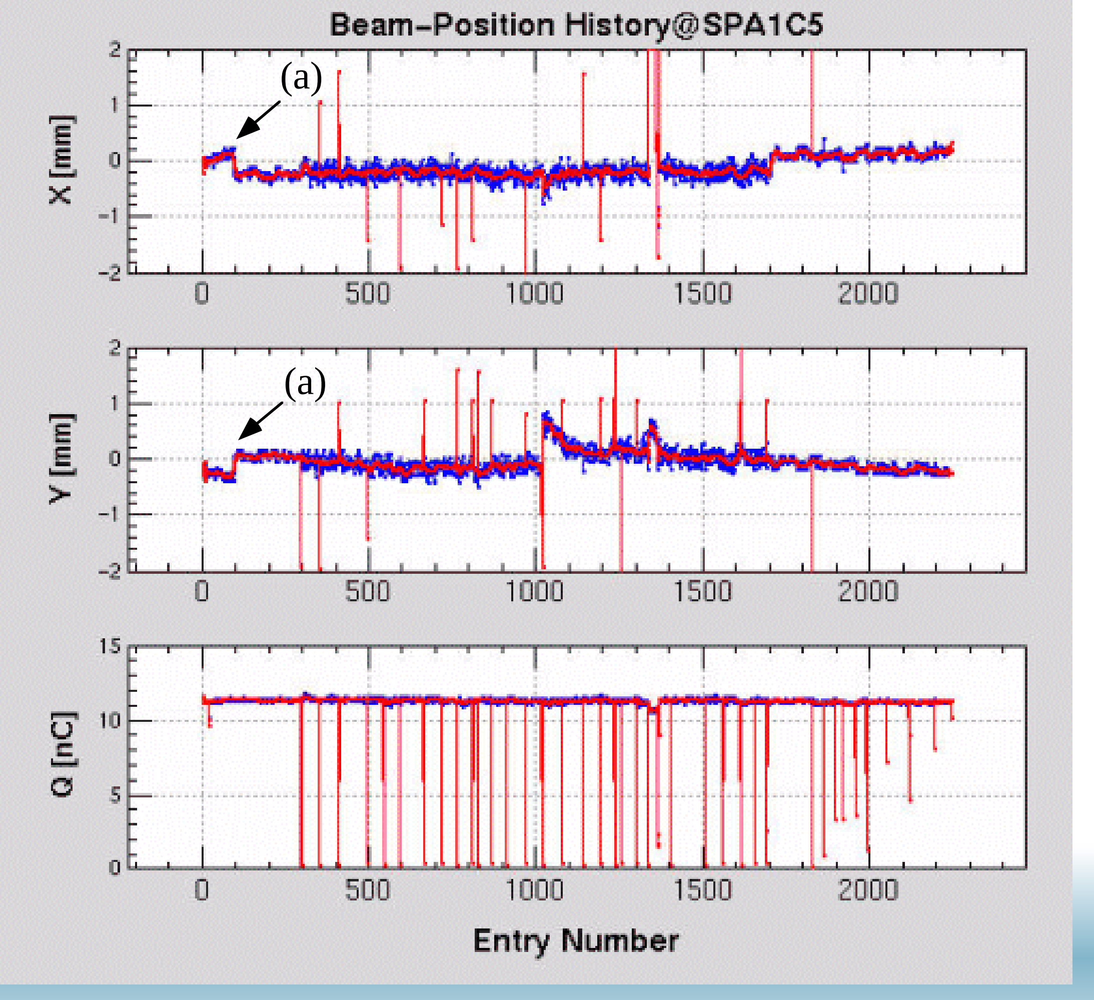
Beam-Energy Stability: Step Variation Detection Algorism Using an ε-Filter



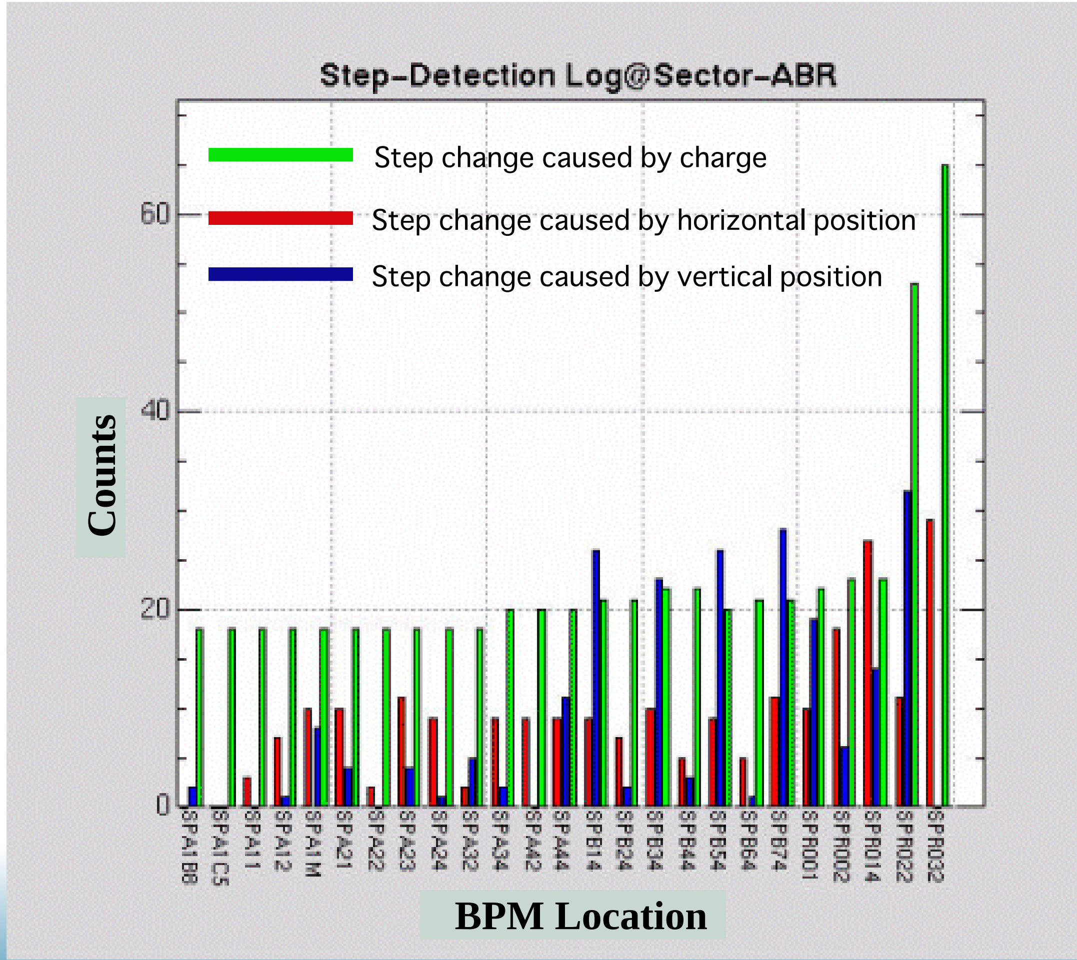
Beam-Energy Stability: Recording System



Beam-Energy Stability: Recording System



Beam-Energy Stability: Recording System



Conclusions

♦ ***Daily Operation***

It has been almost established for the KEKB by

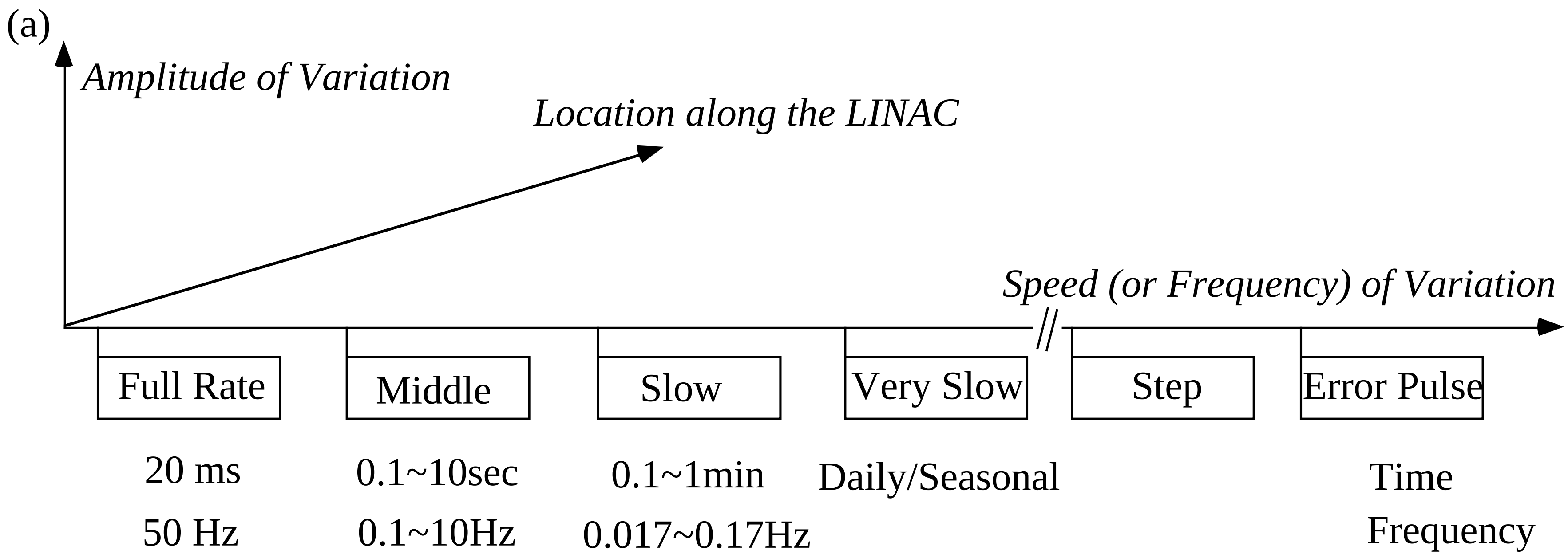
- Frequent beam diagnosis and check,
- Dedicated beam and rf feedback systems, and
- Several-times/month check of machine and instrumentation.

♦ ***Systematic Evaluation on the Beam Stability Issues***

It is strongly required to specify origins causing the beam instabilities which need to be investigated by

- three factors, that is, frequency and amplitude of variation, and location.

Strategic Scheme for the Beam Stability Issues



Strategic Scheme for the Beam Stability Issues (cont.)

(b)

Full Rate
- Trigger System
- Pulsed Devices
  - RF
  - Pre-injector
    - Gun/SHB
    - Buncher/Prebuncher
  - Pulsed Coil
- Beam Dynamics

Slow
- Thermal Stability
  - Temerature of Cooling Water
  - Room Temperature

Step
- Operation Action/Mechanical
- Power Supply (AC Line)

Middle
- Microphonic
  - Vibration of Acc. Girder
  - Quad
- Power Supply (AC Line)
- DC Devices (Magnet)

Very Slow
- Thermal Stability
  - Outdoor Temperature

Error Pulse
- Error Pulses, Misfires/Arcing
  - Breakdown

Several Plans in Progress

- ***More Refined Beam Feedback System***

  •Global orbit feedback/Continuously Controlled orbit Correction(*CCC*)

  •Refined energy feedback taking into account the beam optics

- ***More Dedicated Beam Monitors***

  •Nondestructive energy-spread monitor(ESM)

  •Pulse-to-pulse data-acquisition(DAQ) and detection system for BPMs and ESMs

- ***More Dedicated Control System***

  •New DAQ scheme synchronously measuring all data from the monitor, rf, pulsed devices and facility environments.