LINAC COMMISSIONING

First linac commissioning at the new sectors A and B

in October – December 1997

Y. Ogawa (Accelerator Laboratory)

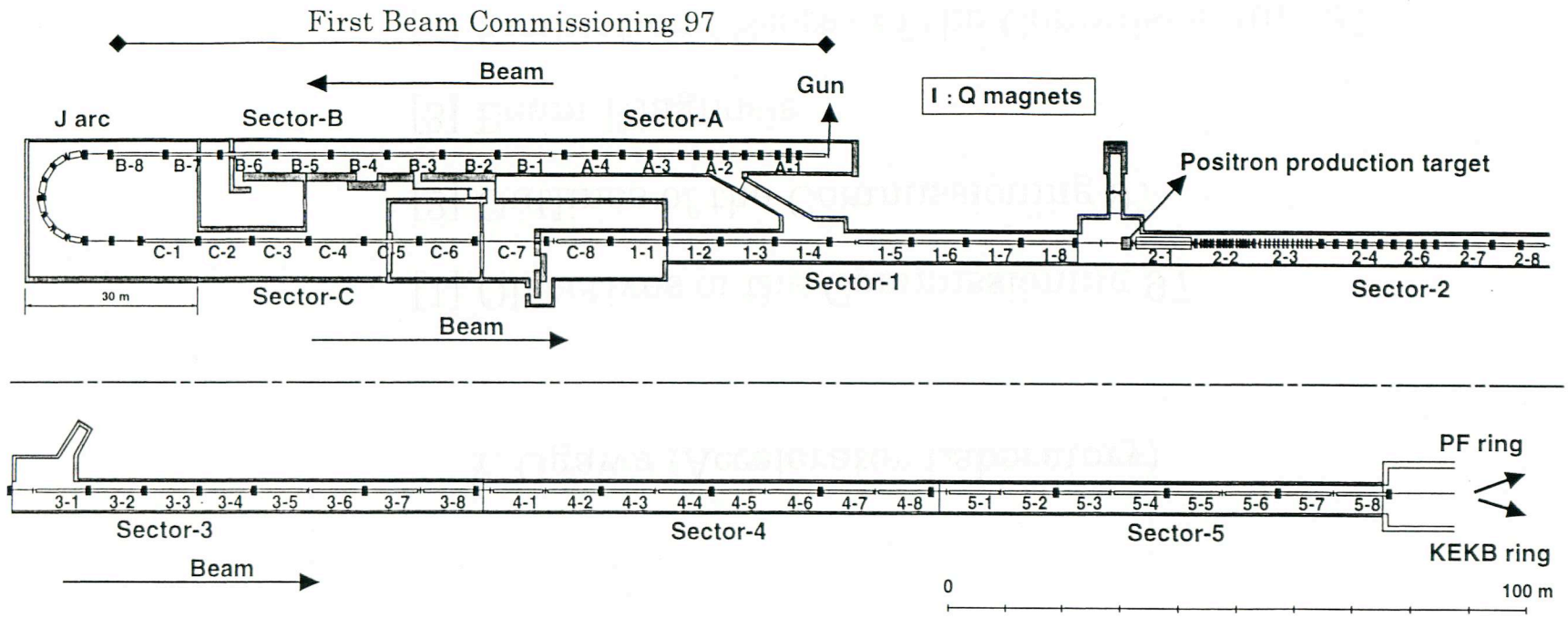
[1] Objectives of the Commissioning 97

[2] Outlines of the Commissioning 97

[3] Beam Diagnosis

[4] Evaluation / Scores of the Commissioning 97

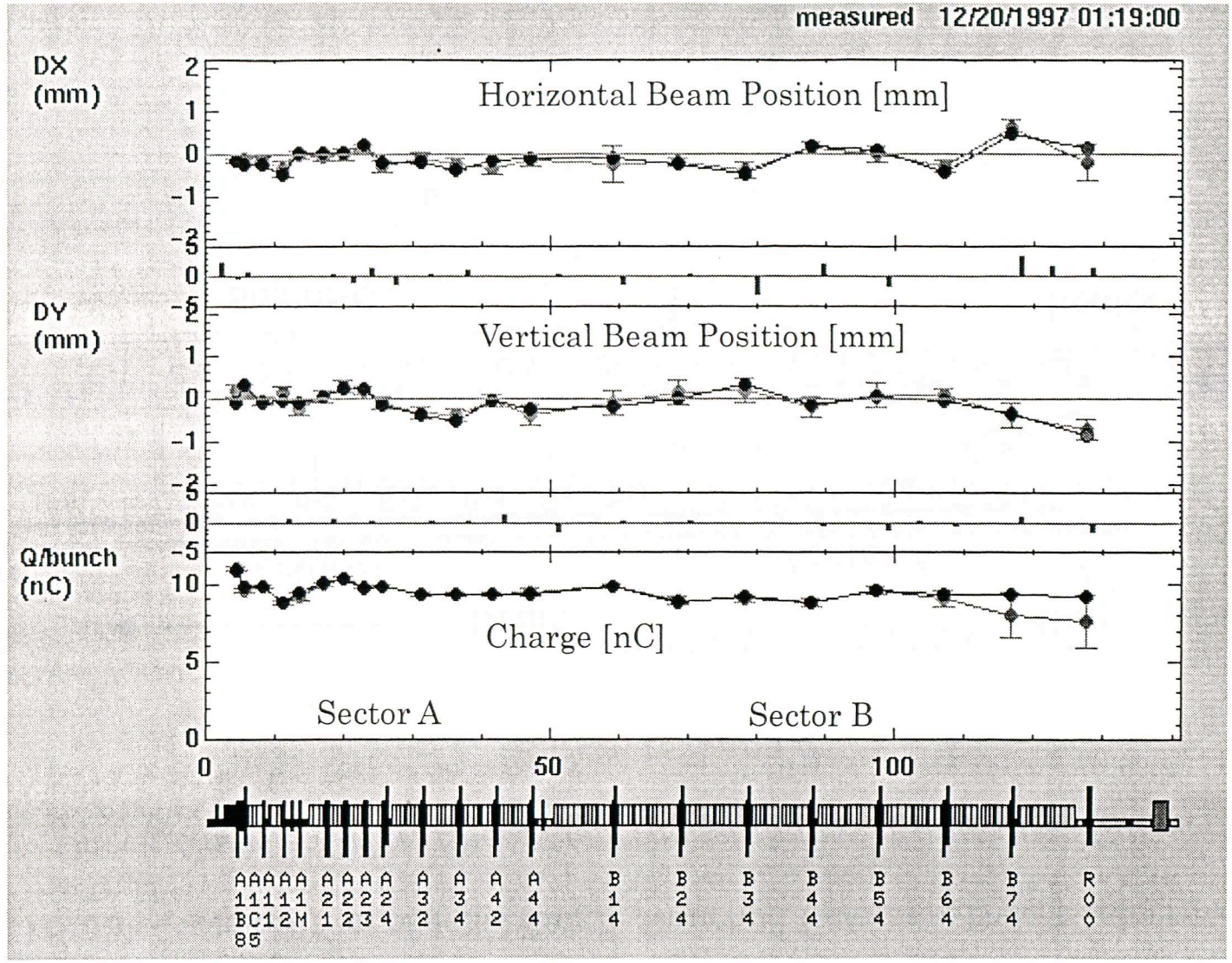
[5] Summary



Layout of the KEKB Linac

New sectors: A, B, J arc, C

Existing sectors: 1, 2, 3, 4, 5



First Acceleration of the 10-nC Single-Bunched Electron Beam at the Sectors A and B.

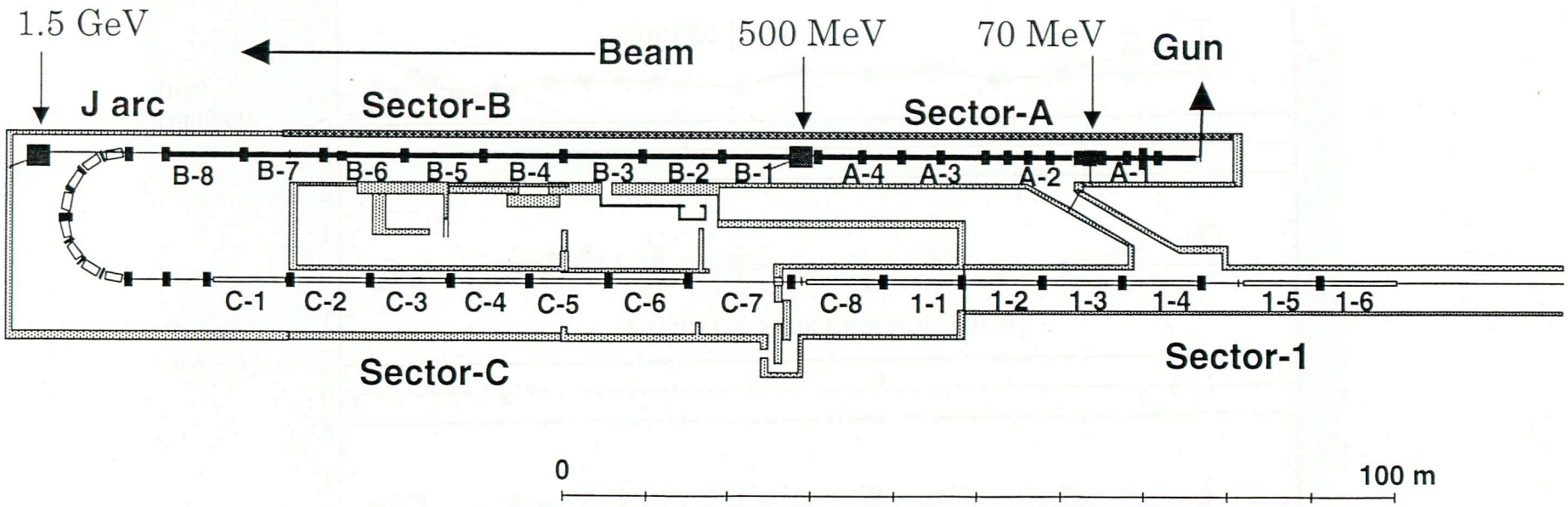
[1] Objectives of the Linac Commissioning 97

(a) Stable Acceleration of 10-nC Single-Bunched Beam for Positron Production

(b) Stable Acceleration of 1-nC Single-Bunched Beam for Direct Injection

Check *Charge, Orbit, Energy (spread, stability), Emittance, Bunch*

@ Sectors A and B



[2] Outlines of the Linac Commissioning 97

Period : 1997/10/16 – 12/24

Commissioning Team : Linac Commissioning Group = LCG

(comprising staffs of Linac and Ring)

Flow of Commissioning :

(1) Check Gun (200 kV, 2-3 ns) Orbit

(2) Tuning of Bunching Section => Charge, Energy [20 MeV], Bunch [10-20 ps]

SHB1 [114 MHz], SHB2 [571 MHz], Prebuncher, Buncher [2856 MHz]

(3) Matching to Regular Acceleration Units => Energy, Emittance

(4) Acceleration Test at Sectors A and B

(5) Calibration of BPMs and Wall Current Monitors by Beam

(6) Wire Scanner Test

(7) Measurements of Beam Parameters

[3] Beam Diagnosis

(1) Gun Beam Orbit : Rotation in the Solenoid Coils

(2) Bunch Structure : OTR + Real-Time Streak Camera System

(3) Charge : Relative Calibration of Wall Current Monitors by Longitudinal Wake

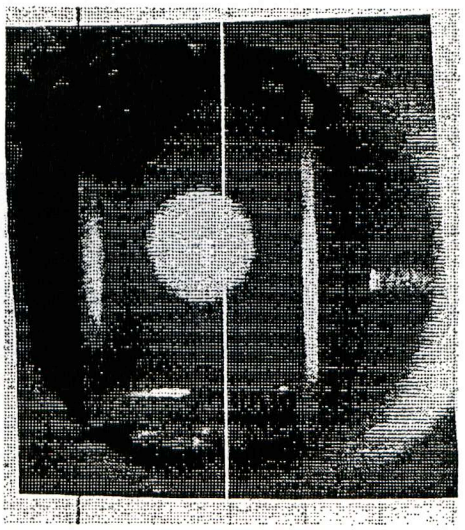
(4) Orbit : BPM Calibration by Beam (Resolution, Offsets, Remapping)

Fine Orbit Tuning

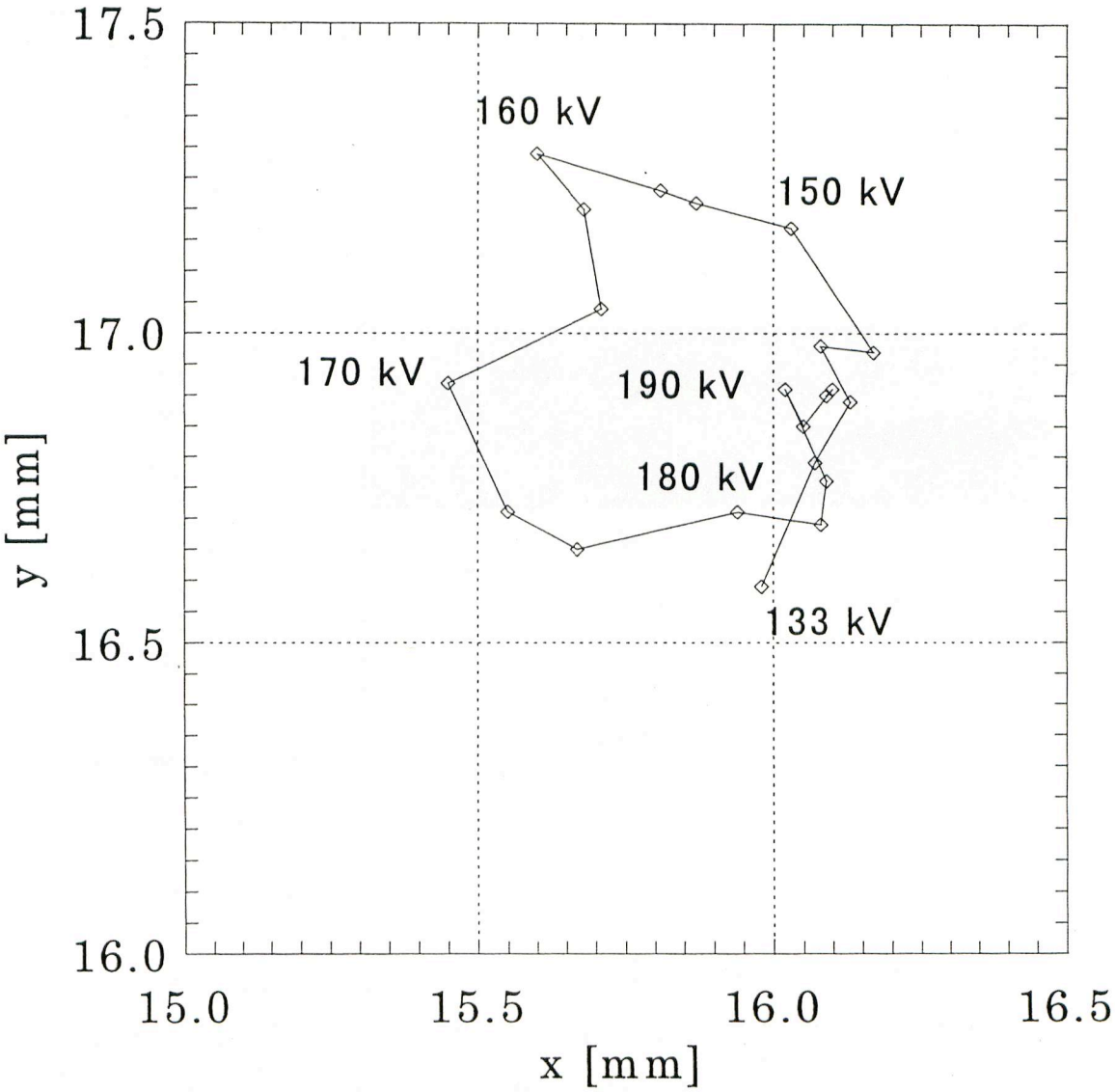
(5) Energy : Energy Gain, Energy Spread, Stability

(6) Emittance : Emittance Growth

[3]-(1) Beam Diagnosis
Gun Beam Orbit :
Rotation in the Solenoid Coils



Gun Beam Profile

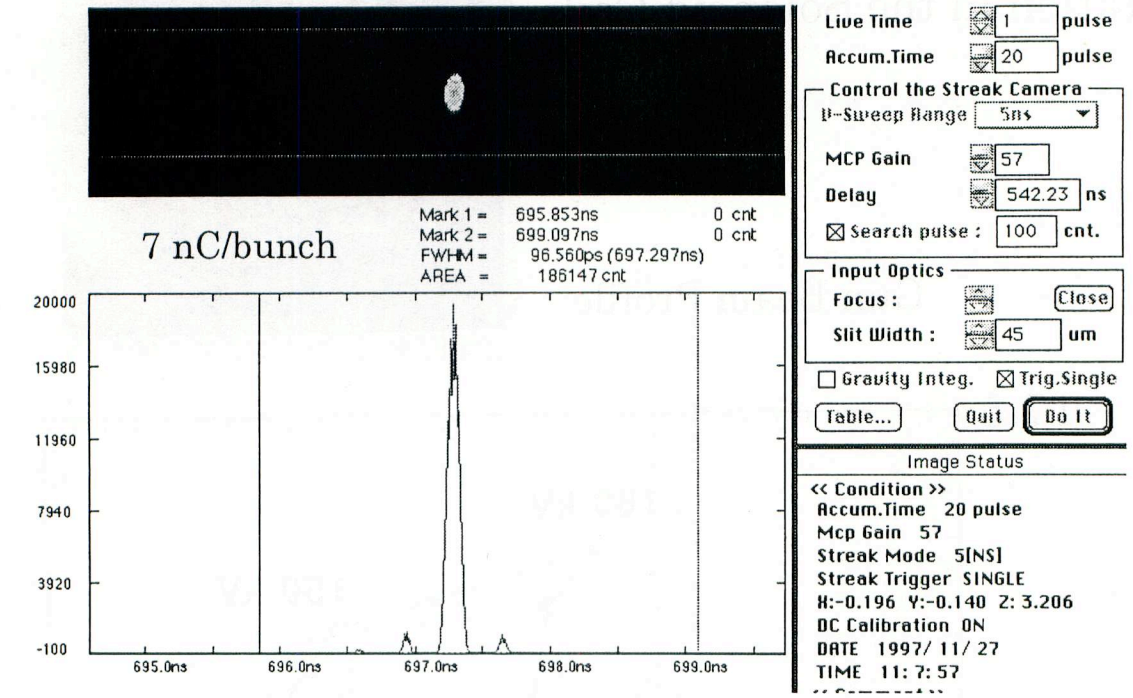


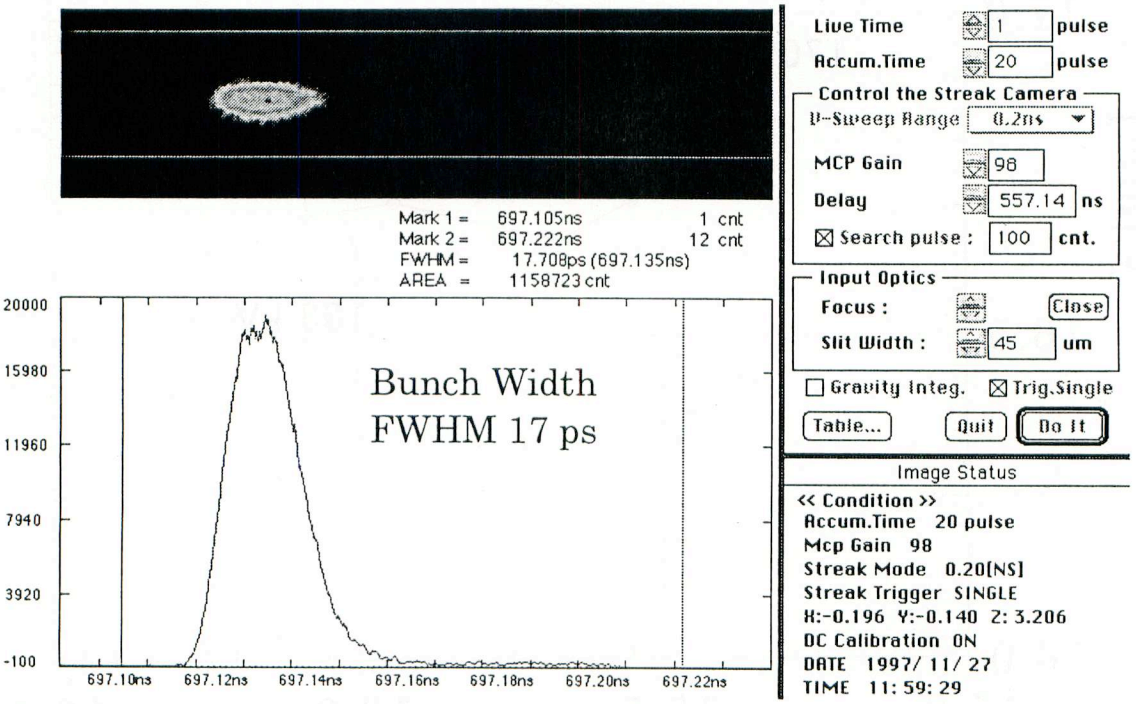
Very small orbit rotation as a function of gun high voltage.

[3]-(2) Beam Diagnosis

Bunch Structure :

OTR + Real-Time Streak Camera System





Observation of bunch structure. Optical transition radiation (OTR) from the thin metal plate inserted into the beam line at the end of sector A1 is analyzed by a real-time streak camera system newly developed for linacs.

[3]-(3) Beam Diagnosis

Charge : Relative Calibration of Wall Current Monitors by Longitudinal Wake

(a) Motivation

Calibration of Wall-Current Monitors for Single-Bunched Beam (10-20 ps)
No Signal Sources for Very Short Pulses except for Beam Itself

(b) Method

Principle of Relative Calibration of WMs by Longitudinal Wake
Power of Longitudinal Wake Field : $\propto$ $(\text{Charge})^2$
Assumption : Same Bunch Width for All Bunches

Procedure
(i) Measure Wake Power with Long Beam Pulses (e.g. 0.5 ns)
(ii) Measure Wake Power with Single-Bunched Beam (10-20 ps)
(iii) Square Root of the Ratio => Ratio of Charge

(c) Results

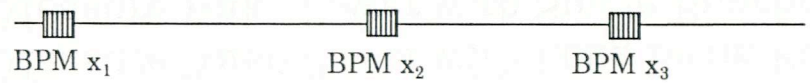
Preliminary Analysis =>
20 % Larger than Extrapolated Value based on LCR Model of WMs

[3]-(4) Beam Diagnosis

Orbit : BPM Calibration by Beam (Resolution, Offsets, Remapping)

Fine Orbit Tuning

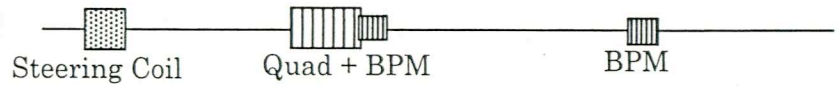
(a) Resolution : Three BPMs



$x_3 = a\,x_1 + b\,x_2 + c$ x_i : BPM Signals (Beam Position); a, b, c: Constants

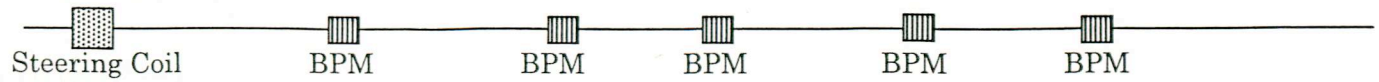
Assumption : $\sigma_{x1} = \sigma_{x2} = \sigma_{x3}$

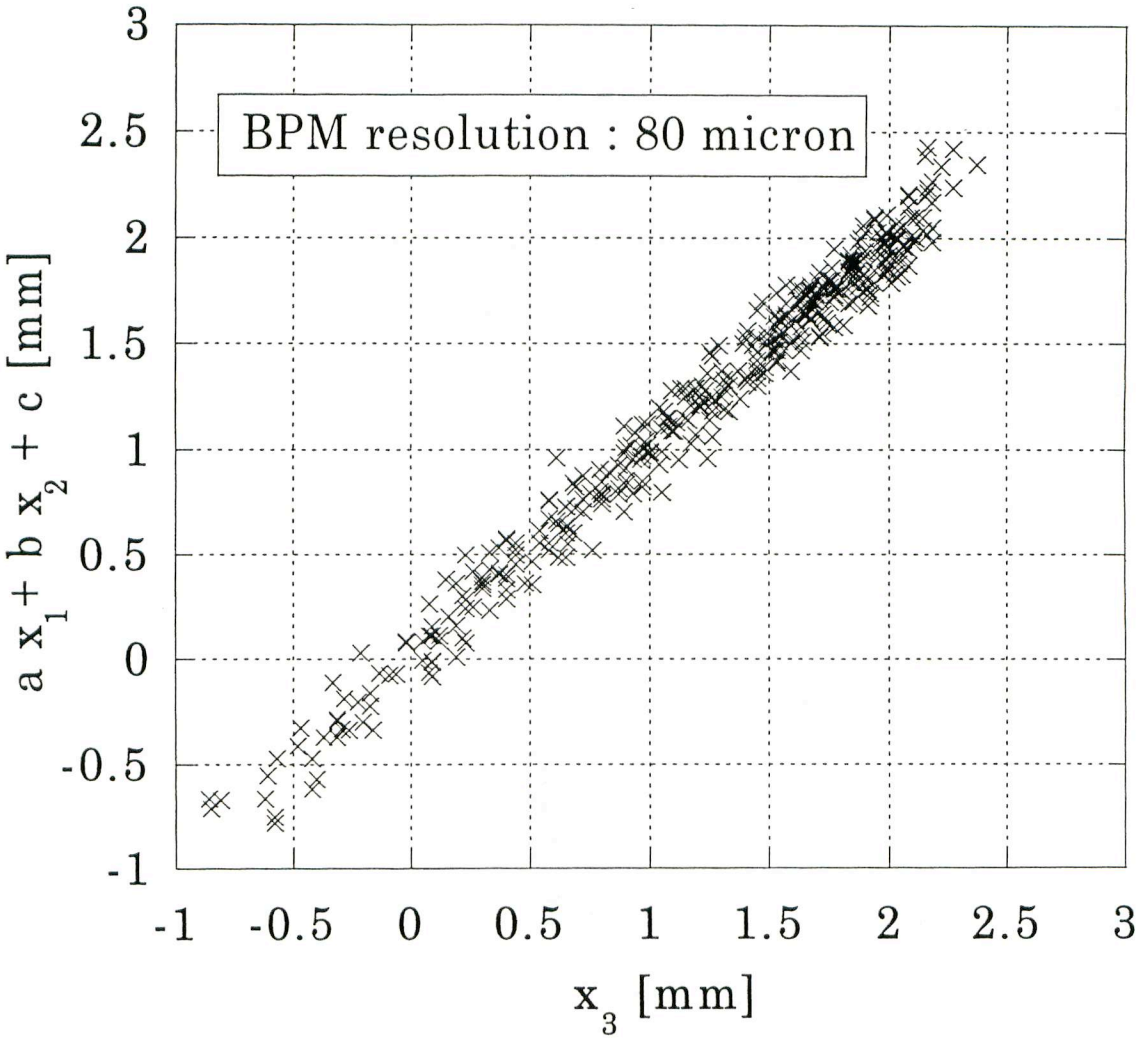
(b) Offsets : Two BPMs & Quadrupole Magnets



(c) Recalibration : Mapping by Beam

(d) Fine Orbit Tuning : Response Functions of BPMs to Steering Coil





Measurements of resolution for beam position monitors (BPM) using 7-nC single-bunched beams. x_1, x_2 and x_3 are displacements measured with three BPMs, while a, b and c are constants comprising components of beam transfer matrix and offsets of BPMs. The relation of $x_3 = a\ x_1 + b\ x_2 + c$ is assumed. The data spread around this plane (a line in this figure) determines the resolutions.

[3]-(5) Beam Diagnosis

Energy : Energy Spread, Stability

(a) Energy

Three Energy Analyzing Stations :

A1 : 70 MeV, A4 : 500 MeV, B8 : 1500 MeV

(b) Spread

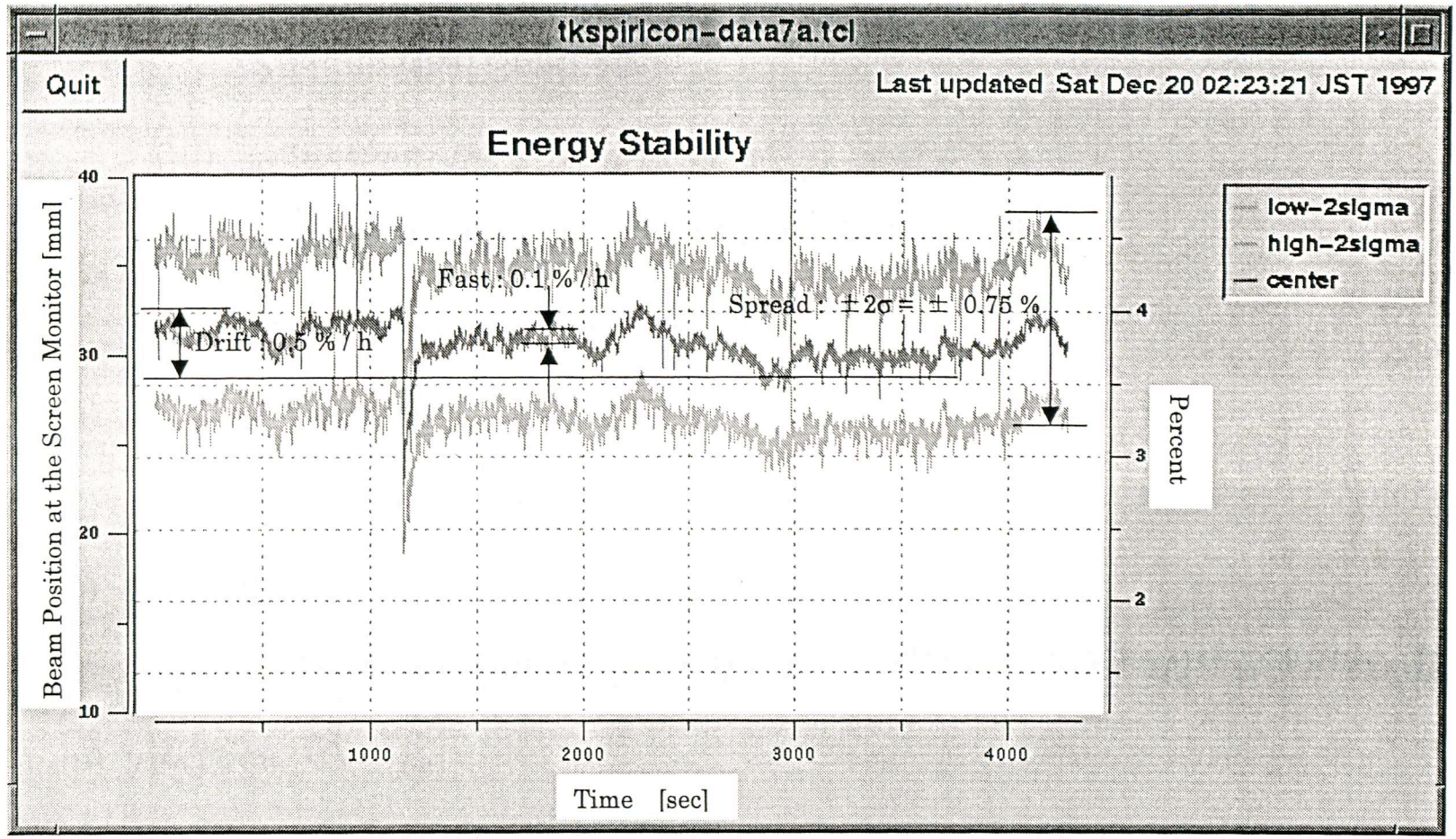
$\pm 2\sigma$:± 0.75 % for 7-nC and 10-nC Beams

$\pm 2\sigma$:± 0.58 % for 1-nC Beam

(c) Stability (7-nC and 10-nC Beams)

Fast : 0.1 %

Drift : 0.5 % /h



Energy stability measured at the end of the sector B8. Image of the screen monitor after the bending magnet (B8) was processed for Gaussian fit; upper and lower curves indicate energy spread ($\pm 2\sigma$), and the center curve shows the mean value of energy (1.5 GeV).

[3]-(6) Beam Diagnosis

Emittance : Emittance Growth

(a) Observation Points

Injector [Bunching Section] (20 MeV), A4 (500 MeV), B8 (1500 MeV)

(b) Methods

Quadrupole + Screen (Injector, A4, B8), Quadrupole + Wire Scanner (B8)

(c) Parameters

Charge / bunch : 1 nC, 7 nC, 10 nC

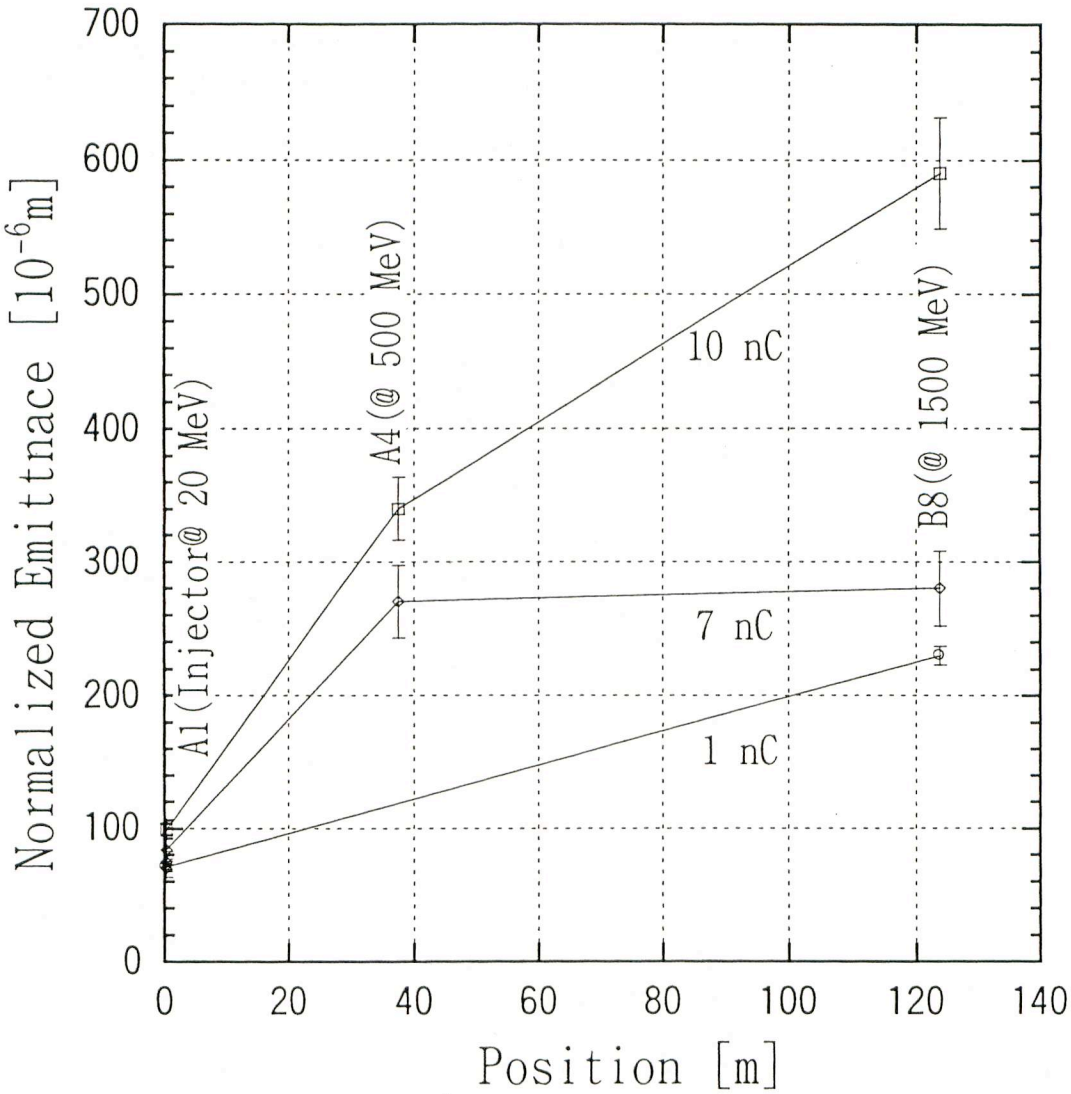
(d) Emittance Growth

(i) Chromaticity : Energy Spread at the End of Injector

(ii) Mismatch : from Injector to Regular Sections

(iii) Transverse Wake-Field Effects

➔ Numerical Simulation



Example of the observed emittance (horizontal) growth along the linac. The energy spread at the end of bunching section and a mismatching to the regular acceleration sections might be the main cause for the emittance growth. Simulations including wake field effects are being performed.

[4] Evaluation/Score of the KEKB Linac Commissioning 97
@ Sector A and B

1998.3.6

Beam Type	Primary Electron Beam for e^+ Production : > 10 nC			Electron Beam for Direct Injection to the KEKB ring : 1.2 nC		
	Target Value	Achieved Value	Score	Target Value	Achieved Value	Score
Gun						
Charge[*1]	13 nC	~ 16 nC	A	1.5 nC	----------	A
Pulse Width (FW)	2.0 ns	3.6 ns	B	2.0 ns	----------	A
Bunch Structure						
Satellite	< 2 %	7nC: ~ 2 %	A	0 %	~ 0 %	A
		10nC: ~ 20 %	C			
Width (FWHM)	16 ps	7nC: 17 ps	B	5 ps	10 ps[*3]	--
		10nC: 20 ps	B			
Beam @Sector B8						
Charge[*1]	> 10 nC	> 10 nC	A	1.2 nC	~ 1.0 nC	A
Transmission (A1-B8)	100 %	~ 100 %	A	100 %	~ 100 %	A
Energy	1.5 GeV	max 1.8 GeV	A	1.5 GeV	1.6 GeV	A
		normal 1.5 GeV	A			
Energy Spread ($\pm 2\sigma$)	$\pm$1.2 %	7nC: $\pm$0.75[*5] %	(A)	($\pm$0.25 %)[*4]	$\pm$0.58 %	--
		10nC: $\pm$0.75[*5] %	(A)			
Energy Stability (p-p)	< 0.2 %	fast 0.1 %	A	(< 0.05 %)[*4]	----------	--
		drift 0.5 %/h	C		----------	--
Norm. Emittance (B_{mag})						
Injector x($\times 10^{-6}$)	60 m	7nC: 70 (1.0) m	A	60 m	71 (1.2) m	A
		10nC: 100 (1.1) m	B			
y($\times 10^{-6}$)	60 m	7nC: 98 (1.1) m	B	60 m	66 (1.2) m	A
		10nC: 110 (1.1) m	B			
A4 x($\times 10^{-6}$)	----------	7nC: 270 (2.0) m	--	----------	----------	--
		10nC: 340 (1.8) m	--			
y($\times 10^{-6}$)	----------	7nC: 270 (2.1) m	--	----------	----------	--
		10nC: 320 (1.2) m	--			
B8 x($\times 10^{-6}$)	< 1200 m	7nC: 290 (1.7) m	A	(1100m)*[4]	230 (1.6) m	--
		10nC: 640 (1.0) m	A			
y($\times 10^{-6}$)	< 570 m	7nC: 590 (1.2) m	A	(1100m)*[4]	500 (1.8) m	--
		10nC: 730 (1.4) m	B			
Orbit						
Deviation(rms) Δx	< 0.1 mm	0.3 mm	B	< 0.1 mm	----------	--
Δy	< 0.1 mm	0.3 mm	B	< 0.1 mm	----------	--
Variation Δx	< 0.1 mm	$\pm$0.2 mm	B	< 0.1 mm	----------	--
Δy	< 0.1 mm	$\pm$0.2 mm	B	< 0.1 mm	----------	--
BPM						
Resolution	< 0.1 mm	~ 0.1 mm	A	< 0.1 mm	----------	--
Offset[*2]	< 0.1 mm	0.1~0.2 mm	A	< 0.1 mm	----------	--
Repetition Rate	50 pps	5 pps	--	50 pps	5 pps	--

[*1]Under calibration, [*2]Calibrated, [*3]Not tuned, [*4]KEKB ring injection, [*5]Spectrum has a low-energy tail.

[5] Summary

(1) Achievement

(i) Acceleration of 10-nC Single-Bunch Beam (1.5 GeV)

(ii) Acceleration of 1-nC Single-Bunched Beam (1.5 GeV)

(iii) Beam Instrumentation

BPM, Bunch Monitor, Wire Scanner, Wall Current Monitor,...

(iv) Good Agreement between Real Beam and Model Optics

(v) Software Development in parallel with Commissioning

(2) Remaining Issues

(i) Complete Suppression of Satellite Bunches for 10-nC Beam

(ii) Optimization of Energy Spectrum and Stabilization of Energy

(iii) Suppression of Emittance Growth by Orbit Control