Report on alignment/tuning/diagnostics at ATF and plans for JLC

2002.9.4 Junji Urakawa

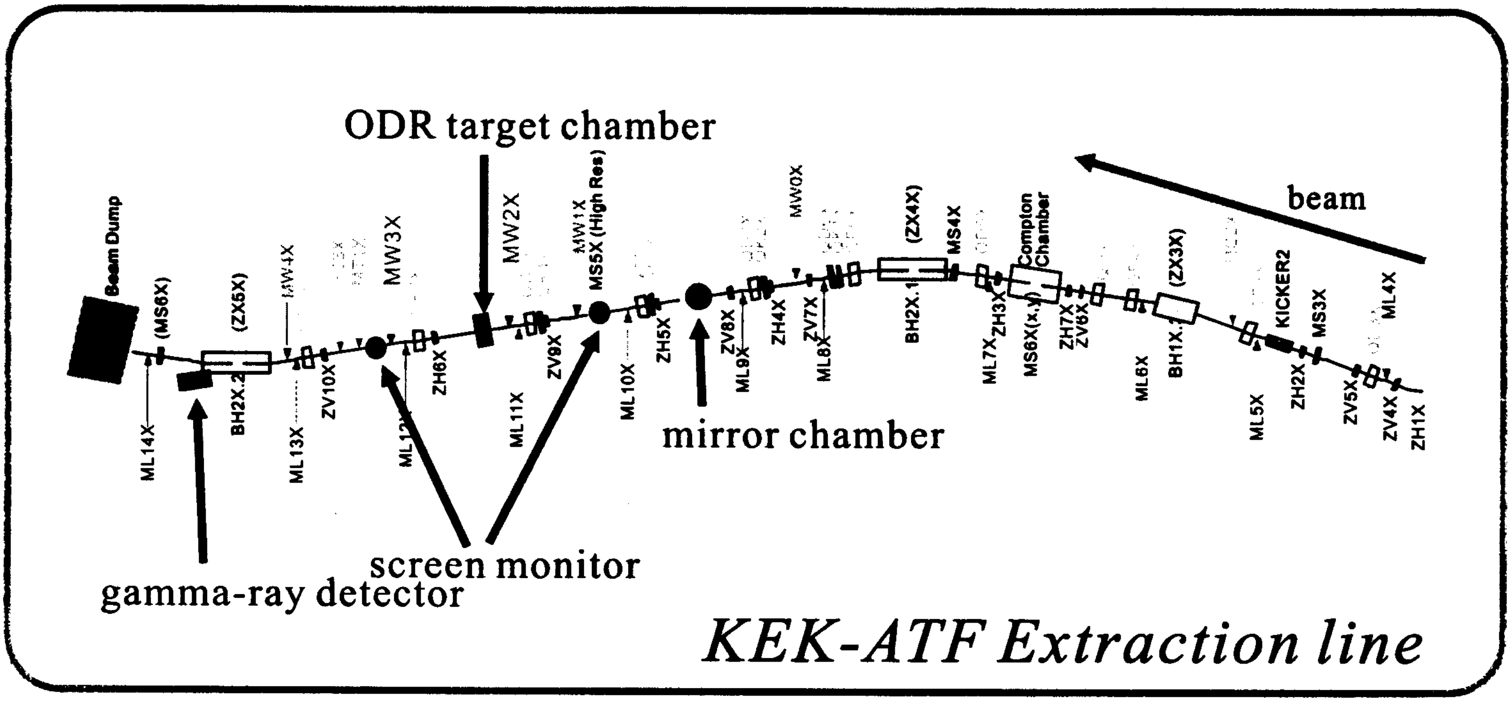
1. Introduction (Historical process on the establishment of 1st order optics and the stabilization)

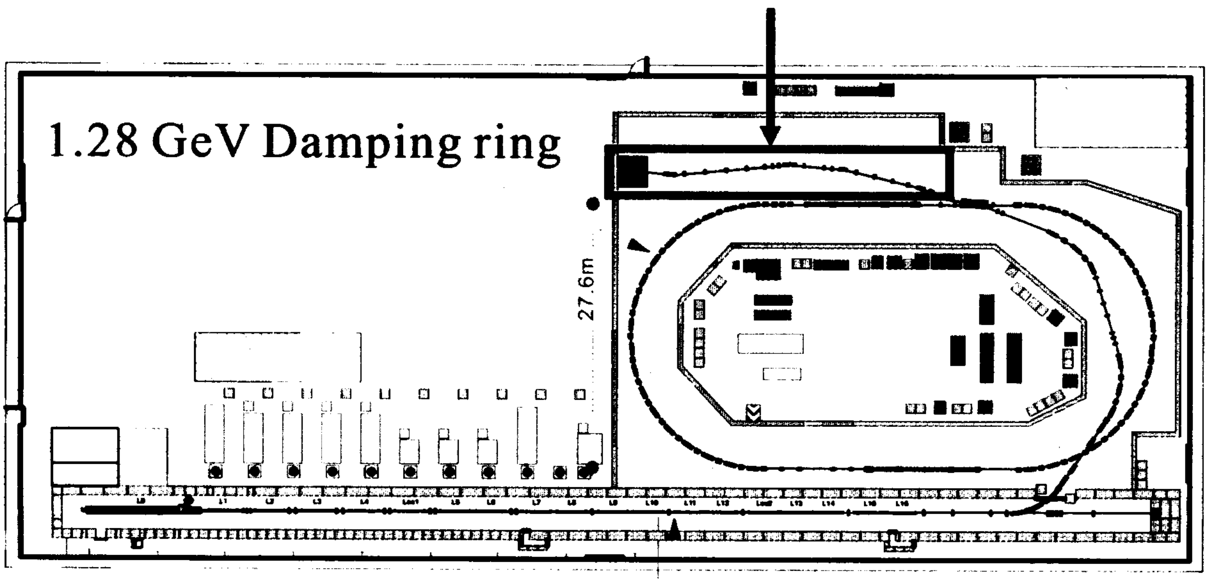
2. Alignment

3. Beam Tuning/Diagnostics

4. Summary (plans for JLC)

KEK-ATF(Accelerator Test Facility for JLC)





1.28GeV S-band LINAC

KEK-ATF parameter

energy 1.28GeV(γ~2500)

emittance vertical $(1.5\pm0.25)\times10^{-11}$ m rad

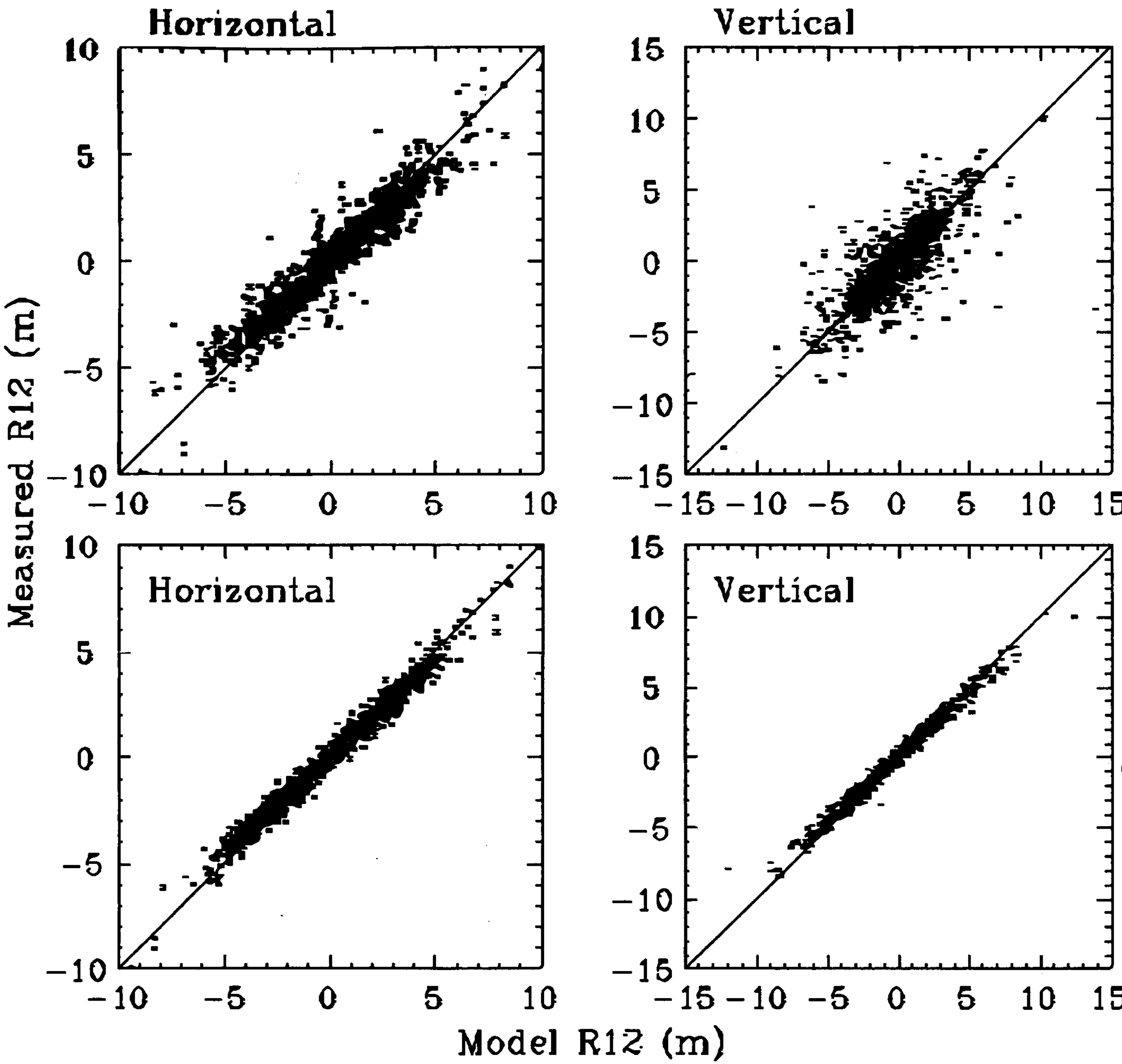
horizontal $(1.4\pm0.3)\times10^{-9}$ m rad

bunch length 20ps → 30ps

max intensity

1.2×10^{10} electrons/bunch

The Optics model improved after the correction. (data June 6, 1998)



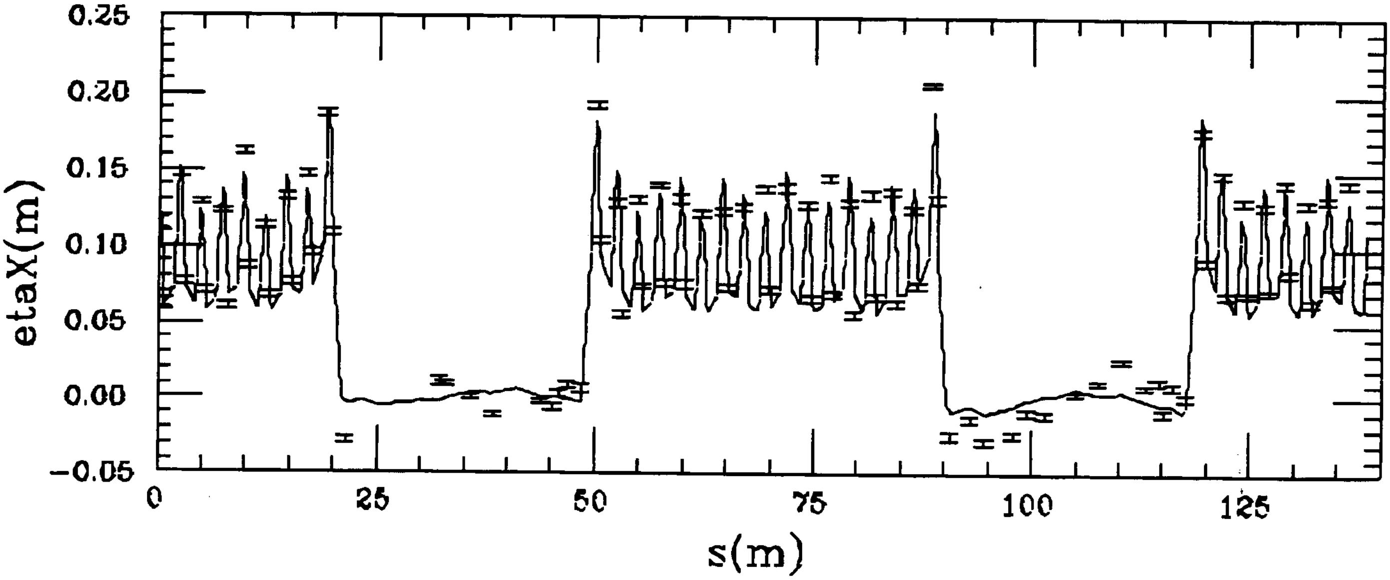
Original model

Corrected model
(based on data on March 19, 1998)

magnetic Field Error between Model and Meas. : ≤ 0.01% on March 1999

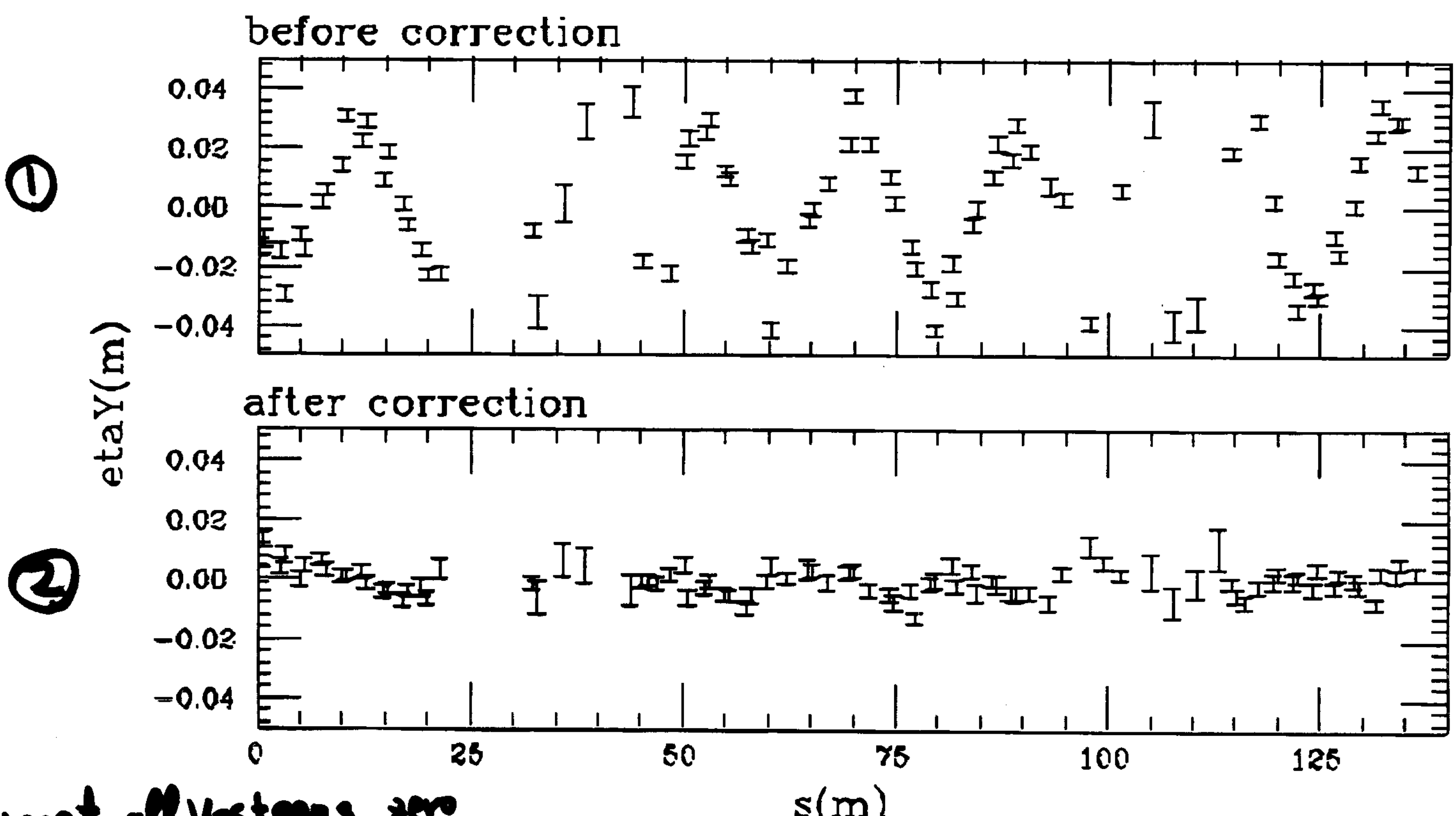
Horizontal dispersion.

Measured (plots) and model calculation (line).



Measured vertical dispersion.

Before and After dispersion Correction

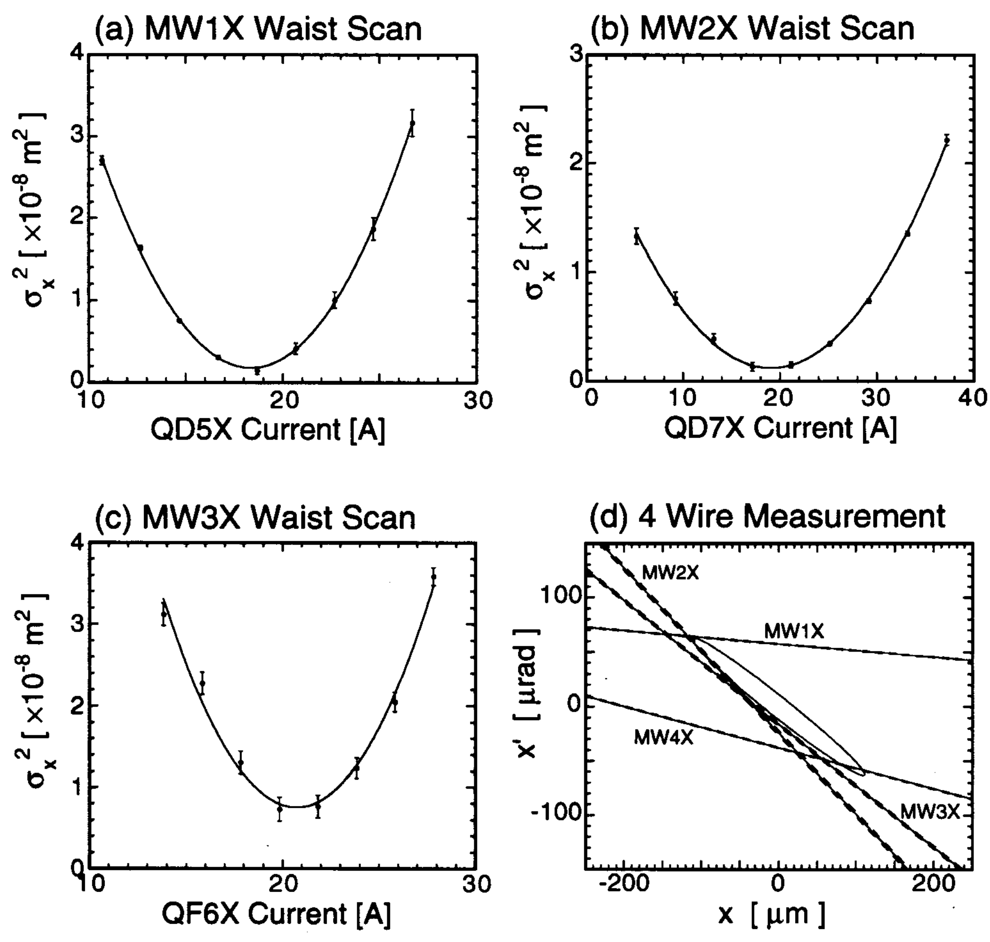


⓪ reset all V-steers zero
① COD_y correction
② η_y correction

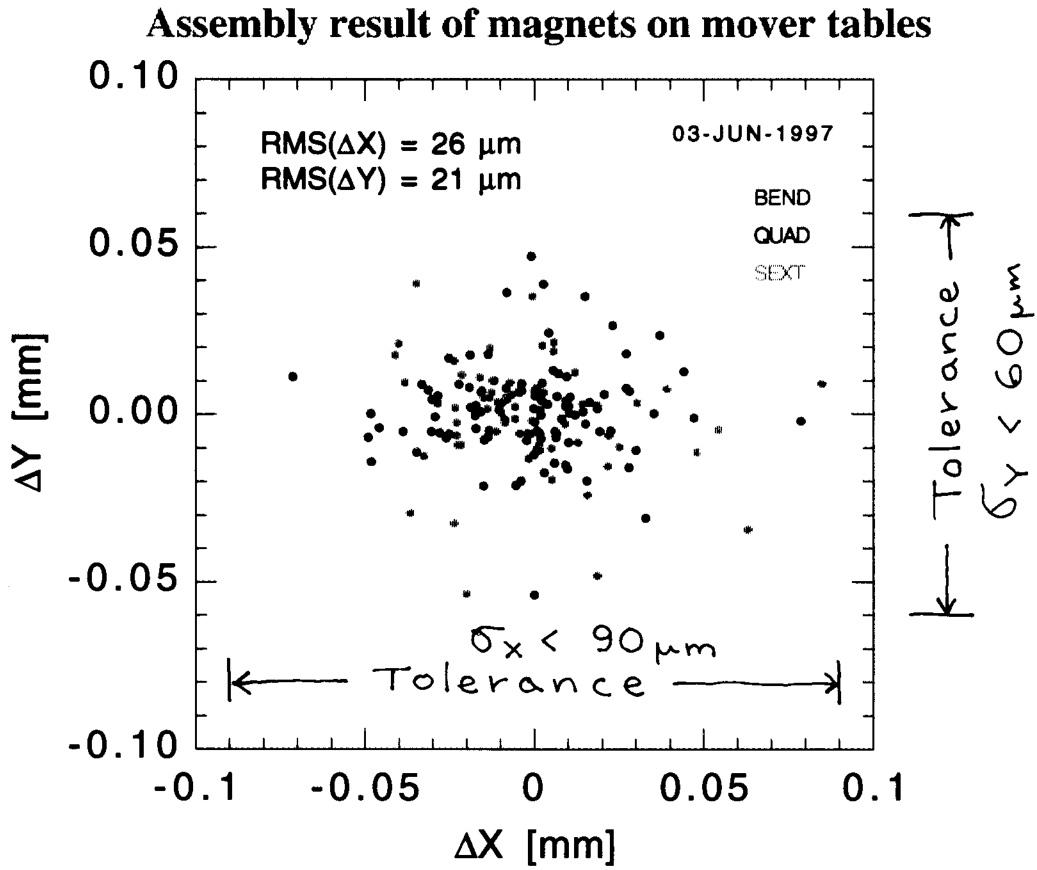
by Okugi

Horizontal Emittance Evaluation

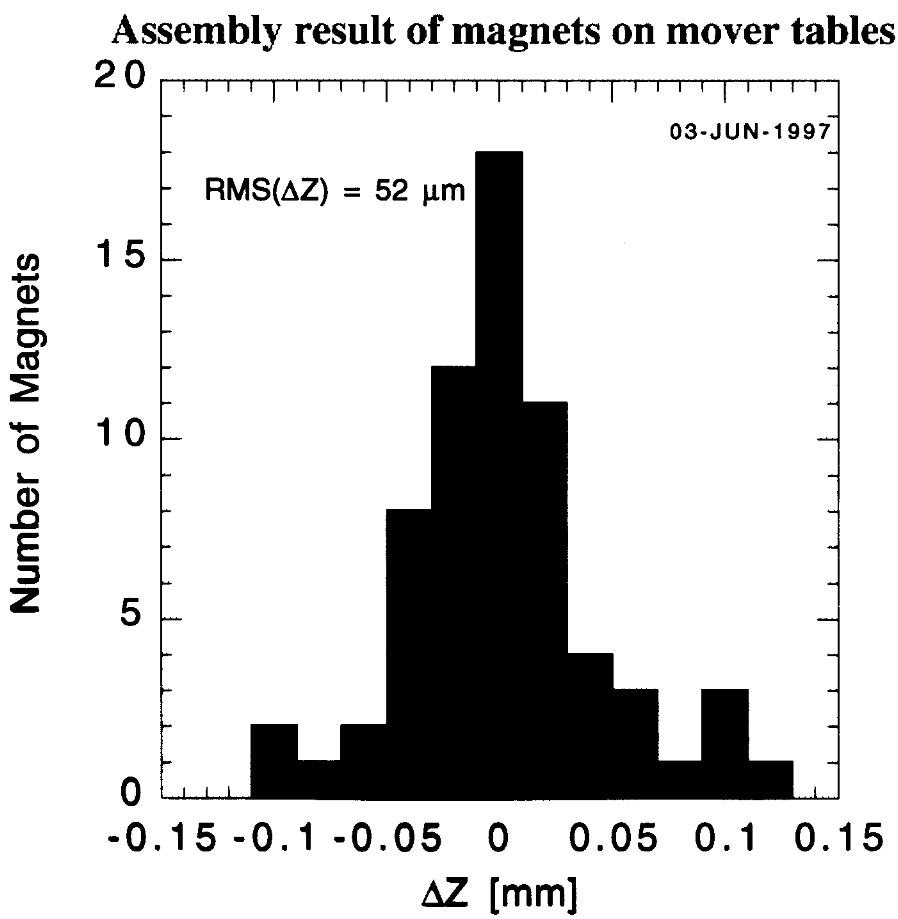
Two different methods are used for horizontal emittance evaluation. One is a waist scan method, and the other is a four wire method. The waist scan method is the method to evaluate a beam emittance by measuring a beam size with single wire scanner while changing strength of a quadrupole magnet located upstream of the wire scanner.The four wire method is the method to evaluate a beam emittance by measuring beam sizes with four wire scanners.



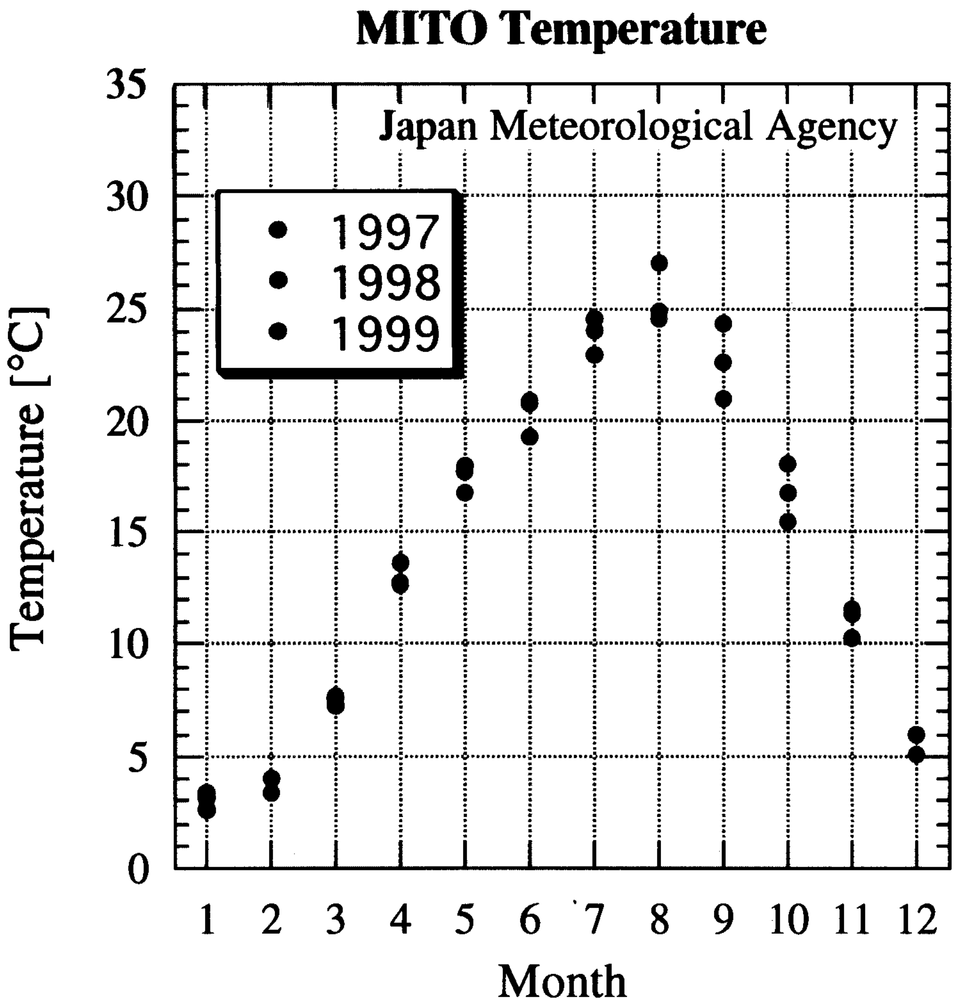
Method	Monitor	Emittance [nm]	B_{mag}
Waist Scan	MW1X	1.47 ± 0.06	1.03 ± 0.07
Waist Scan	MW2X	1.27 ± 0.06	1.00 ± 0.03
Waist Scan	MW3X	1.38 ± 0.05	1.02 ± 0.05
Four Wire	All Monitors	1.29 ± 0.11	1.06 ± 0.34
Average		1.37 ± 0.03	α_x:3.83 β_x:6.77

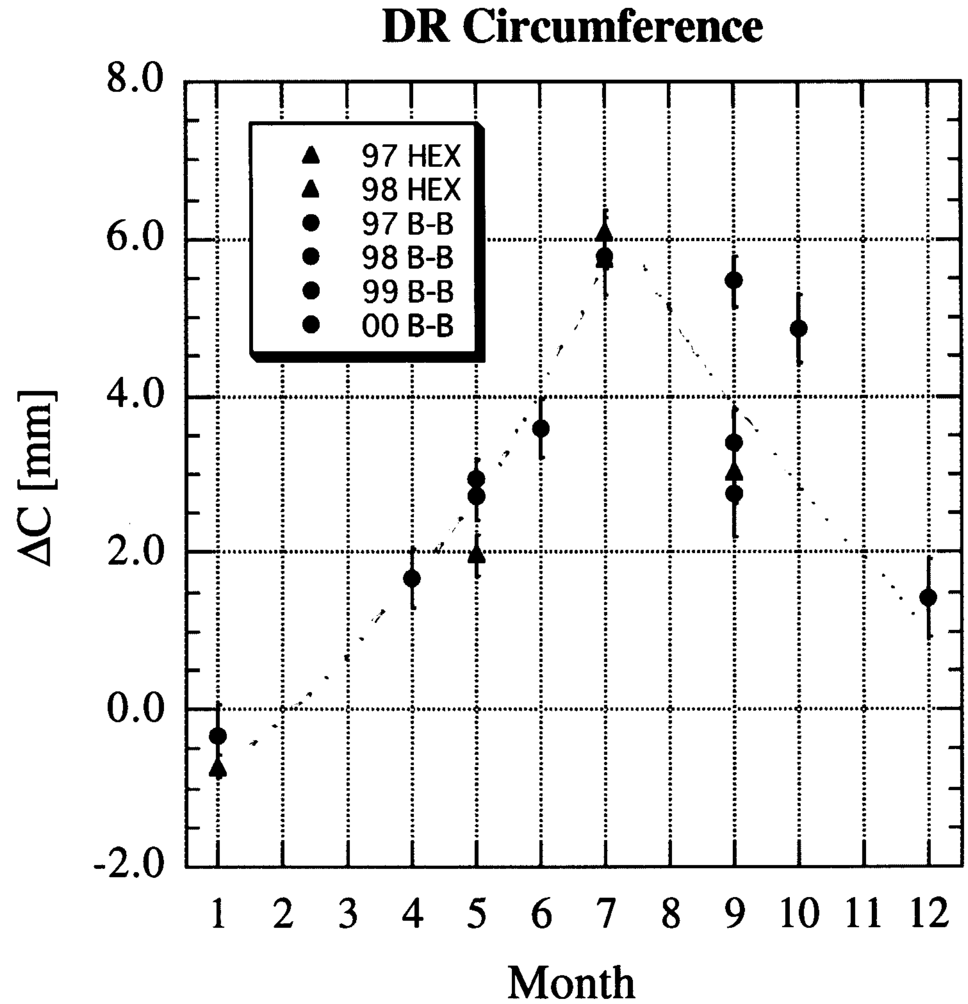


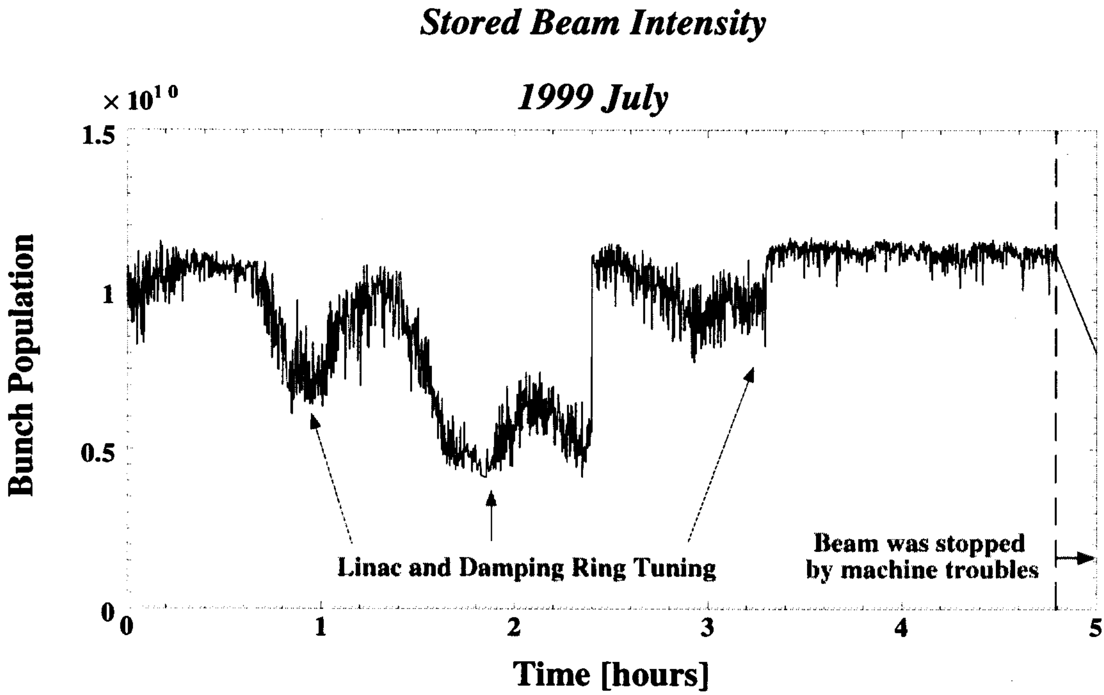
Assembly result of magnets on mover tables
RMS(ΔX) = 26 μm
RMS(ΔY) = 21 μm
03-JUN-1997
BEND
QUAD
SEXT
ΔY [mm]
ΔX [mm]
0.10
0.05
0.00
-0.05
-0.10
-0.1
-0.05
0
0.05
0.1
σx < 90 μm
Tolerance
Tolerance
σY < 60 μm



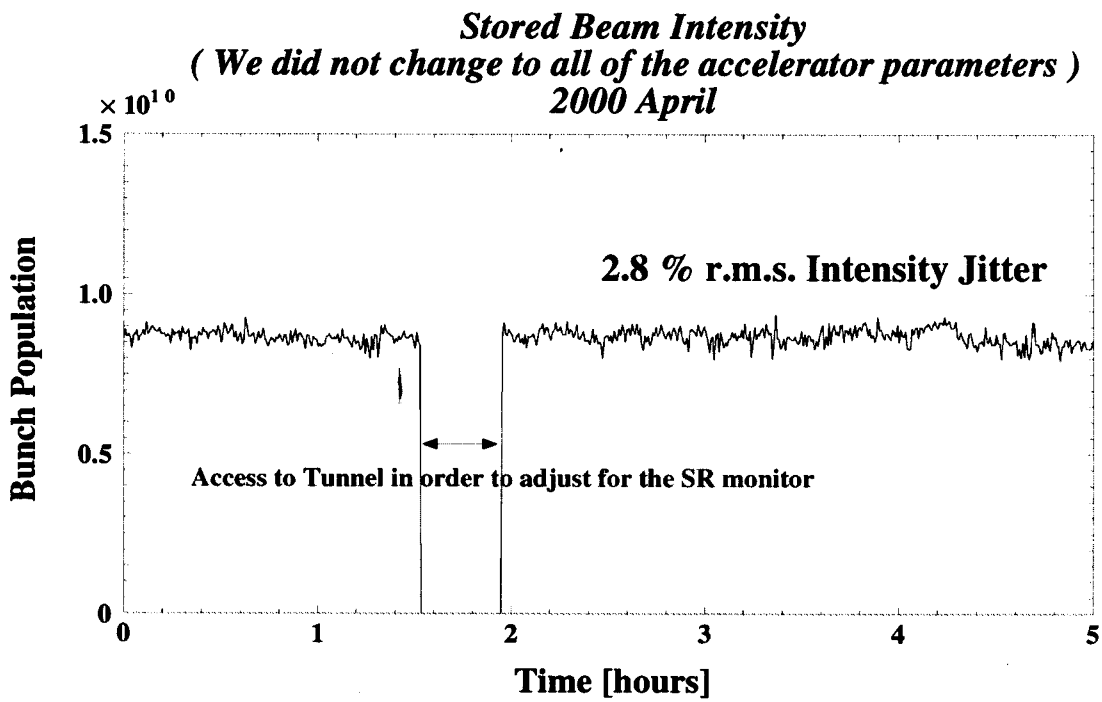
Assembly result of magnets on mover tables
03-JUN-1997
RMS(ΔZ) = 52 μm
Number of Magnets
ΔZ [mm]
20
15
10
5
0
-0.15
-0.1
-0.05
0
0.05
0.1
0.15


MITO Temperature
Japan Meteorological Agency
1997
1998
1999
Temperature [°C]
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12
Month

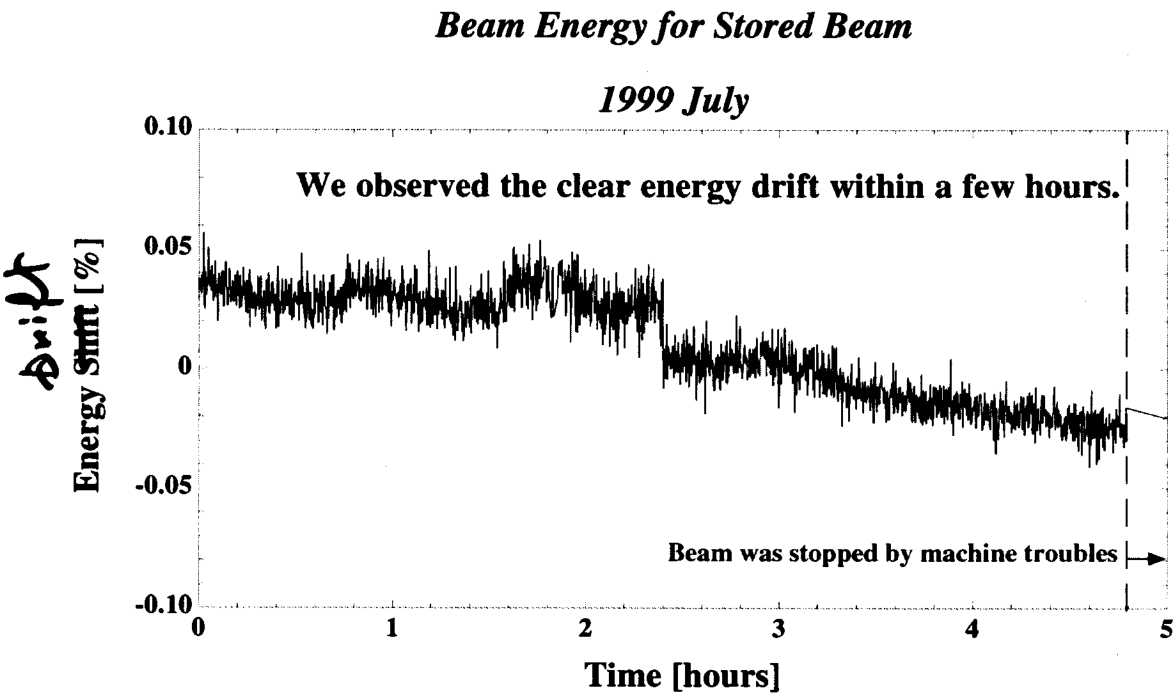

DR Circumference
97 HEX
98 HEX
97 B-B
98 B-B
99 B-B
00 B-B
ΔC [mm]
8.0
6.0
4.0
2.0
0.0
-2.0
1 2 3 4 5 6 7 8 9 10 11 12
Month



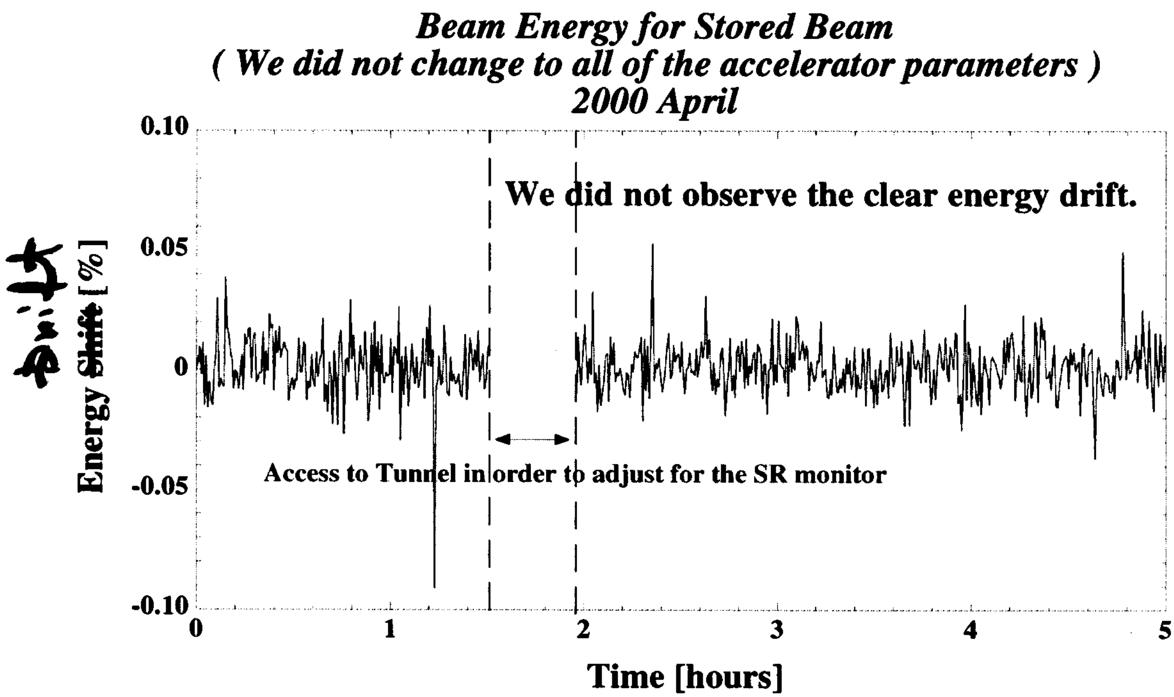
Stored Beam Intensity
1999 July
× 10^10
1.5
1
0.5
0
Bunch Population
0
1
2
3
4
5
Time [hours]
Linac and Damping Ring Tuning
Beam was stopped
by machine troubles



Stored Beam Intensity
(We did not change to all of the accelerator parameters)
2000 April
× 10^10
1.5
1.0
0.5
0
Bunch Population
2.8 % r.m.s. Intensity Jitter
Access to Tunnel in order to adjust for the SR monitor
0
1
2
3
4
5
Time [hours]



Beam Energy for Stored Beam
1999 July
We observed the clear energy drift within a few hours.
Beam was stopped by machine troubles
Energy Shift [%]
drift
0.10
0.05
0
-0.05
-0.10
0
1
2
3
4
5
Time [hours]



Beam Energy for Stored Beam
(We did not change to all of the accelerator parameters)
2000 April
Energy Shift [%]
drift
0.10
0.05
0
-0.05
-0.10
0
1
2
3
4
5
Time [hours]
We did not observe the clear energy drift.
Access to Tunnel in order to adjust for the SR monitor

Single bunch low emittance beam generation

DR beam tuning

Magnets alignment

Vacuum level

keep ave. pressure less than 1 E-6 Pa

COD correction

correct within +/- 0.5 mm both x and y

Dispersion correction

correct Y dispersion within +/- 5mm without disturbing Y COD

Coupling correction by skew-Q component from SX trim coil

minimizing Y orbit response from X steer kick

minimizing tune separation at coupling resonance

reduce betatron coupling less than 0.2%

Extracted beam tuning

Orbit correction within +/- 1 mm

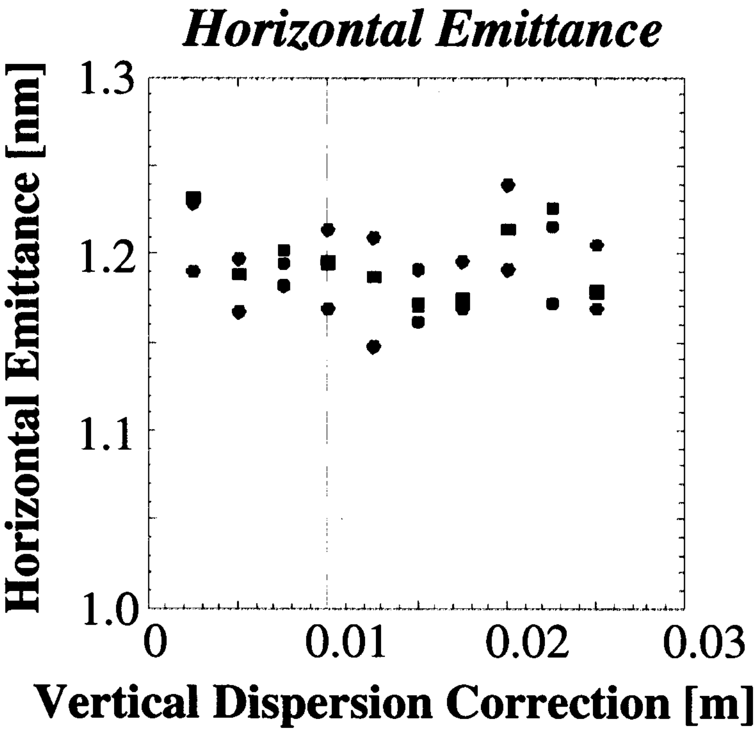
Dispersion correction at wire scanner

correct X, Y dispersion less than 10mm

$\leq$ 5mm (necessary)

2/27/2001 Hayano

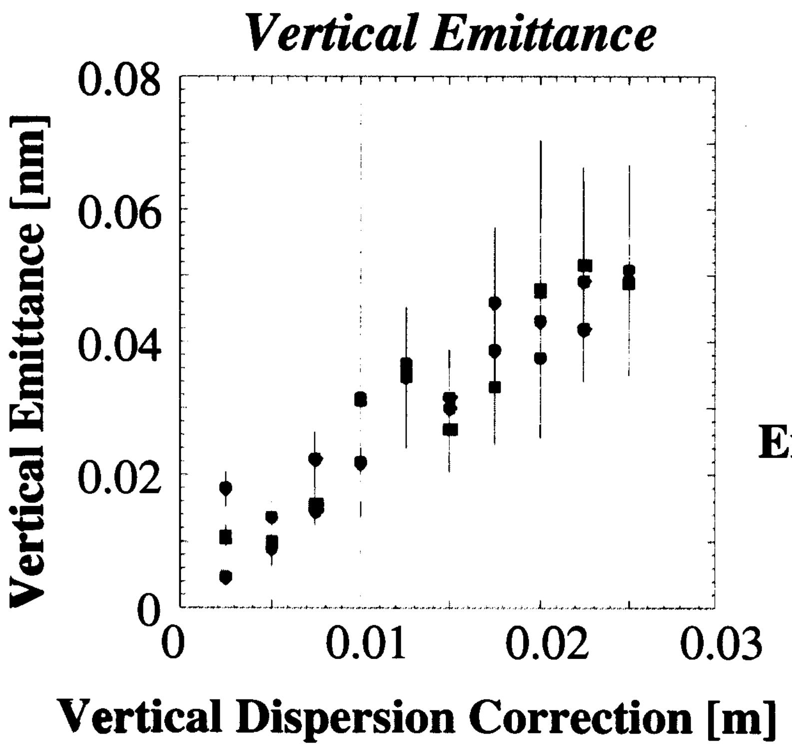
2.0 mm peak to peak Horizontal COD
1.0 mm peak to peak Vertical COD



30 μm Alignment Error
40 μm Alignment Error
50 μm Alignment Error

Horizontal Emittance Enhancement

from 1.07 nm to 1.20 nm



30 μm Alignment Error
40 μm Alignment Error
50 μm Alignment Error

Expected Vertical Emittance

0.005 nm - 0.03 nm

参考

Recent progress in Accelerator Test Facility at KEK

K. Kubo, KEK, Tsukuba, Japan, for ATF Collaboration

Abstract

The mission of the ATF at KEK is to test the feasibility of the production of multibunch beams with extremely low transverse emittance for future linear colliders. Until this summer the main goal had been to produce low emittance beams with single bunch operation. Recently, we established a tuning method of the damping ring for the small vertical dispersion and small x-y orbit coupling. Simulation studies indicate that low vertical emittance should be attainable with this tuning. Substantial progress has been made in the past year in reducing the measured vertical beam emittance at ATF. We observed that the beam emittance and beam momentum spread vary, depending on the bunch population and RF voltage. This suggests the existence of strong intra-beam scattering effects in the beam with very low vertical emittance in the ring. Some technical issues associated with the beam size measurements are also noted. Multibunch operation is another main program of ATF. A bunch train consisting of 18 bunches was produced, accelerated in the linac, injected in the damping ring and extracted to the extraction line. Development of bunch-by- bunch instrumentation is also reported.

1 INTRODUCTION

ATF consists of an S-band linac, a damping ring and an extraction line[1]. The ring has been designed to produce extremely low emittance beam. The designed natural horizontal emittance is 1.1×10^{-9} rad-m and the target value of vertical emittance is 1% of that. History and summary of the past beam operation are reviewed in references [1][2].

The initial stage operation of ATF has been focussing on confirmation of low emittance beam production at a low repetition rate (1.56 Hz). As detailed in Section 2 of this paper, substantial commissioning experiences have been accumulated, and the target vertical emittance has been achieved at the bunch intensity of about 2×10^9. Thus, studies are currently also being started on multibunch beam which is essential for future linear colliders. Beam loading compensation of the multibunch beam in the injector linac has been successfully tested. However, issues with uniformity of the bunch intensity and bunching still remain. They are discussed in Section 3. Section 4 describes the hardware improvement programs at ATF.

2 SINGLE BUNCH OPERATION

2.1 Low emittance tuning in DR

Our tuning method of the damping ring for low vertical emittance is a series of corrections as follows:

- COD correction.
- Vertical COD + dispersion correction.
- Coupling correction.

The strengths of a set of steering magnets is calculated to minimize

$$\sum_{BPM} x_{meas}^2 \text{ and } \sum_{BPM} y_{meas}^2 \qquad (1)$$

in the COD correction and to minimize

$$\sum_{BPM} y_{meas}^2 + r^2 \sum_{BPM} \eta_{y,meas}^2 \qquad (2)$$

in the vertical COD + dispersion correction. Here, x_{meas}, y_{meas} and $\eta_{y,meas}$ are beam horizontal position, vertical position and vertical dispersion measured at each BPM. In this COD + dispersion correction, both the vertical COD and vertical dispersion are considered simultaneously. The factor r is the relative weight of the dispersion and COD, and it was chosen to be 0.05 based on a simulation study. For the coupling correction, trim coils of all 68 sextupole magnets are wired so as to produce skew quadrupole fields. The strengths of these skew fields is calculated to minimize

$$\sum_{steer}\left[\sum_{BPM}(\Delta y_{steer})^2 \Big/ \sum_{BPM}(\Delta x_{steer})^2\right] \qquad (3)$$

Here, Δx_{steer} and Δy_{steer} are measured horizontal and vertical position responses to each horizontal steering magnet. Usually, two horizontal steering magnets, which are apart by approximately $3/2\pi$ in horizontal and $1/2\pi$ in vertical phase advance, are chosen for this correction.

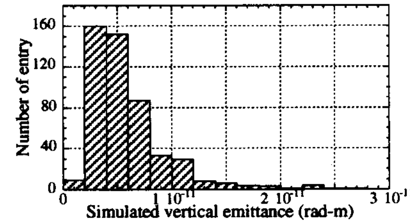


Fig. 1, Distribution of simulated vertical emittance after damping ring tuning.

Simulations were performed to study this tuning method where realistic magnet misalignment and random errors of BPM are considered [3]. Fig. 1 shows the distribution of the vertical emittance from 500 random seeds for magnet alignment errors and BPM errors in the

3pm at zero current.

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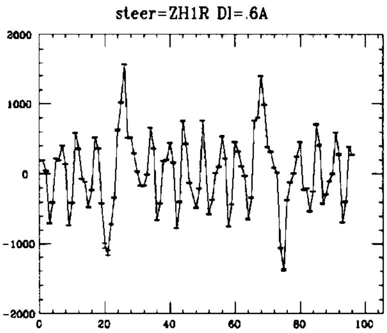
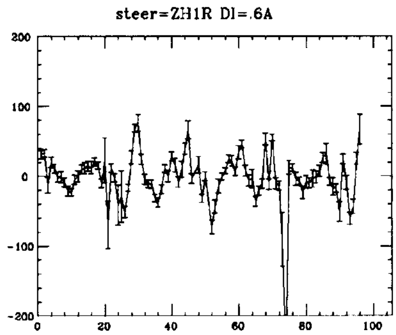
Coupling correction using skew-Q of SX trim

minimizing Y orbit response by X steer kick

ZH1R steer kick

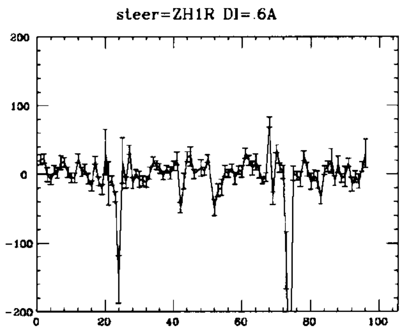
X





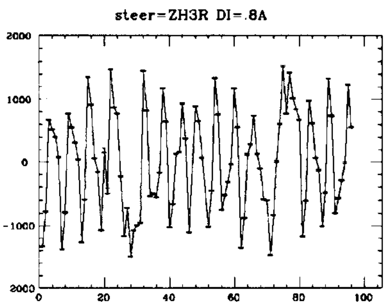
Y response

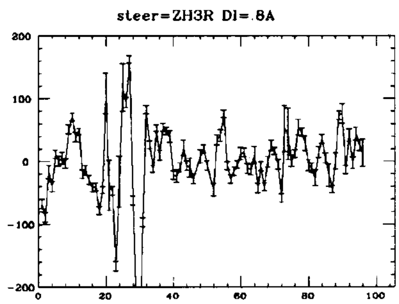
Y response
after correction



ZH3R steer kick

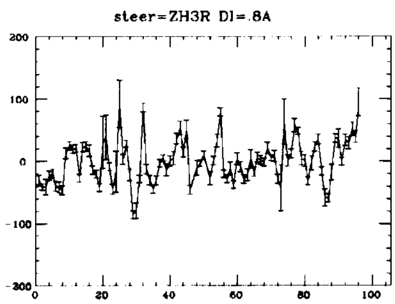
X





Y response

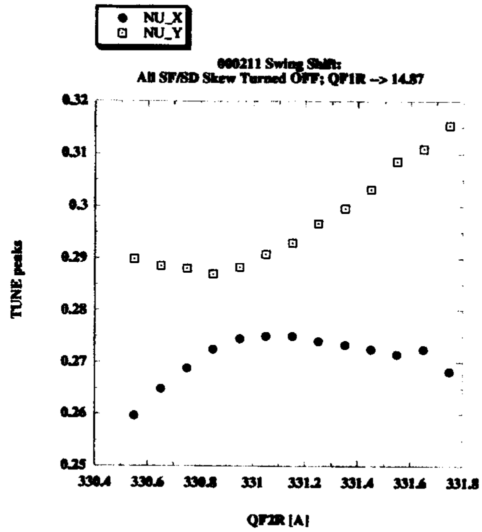
Y response
after correction

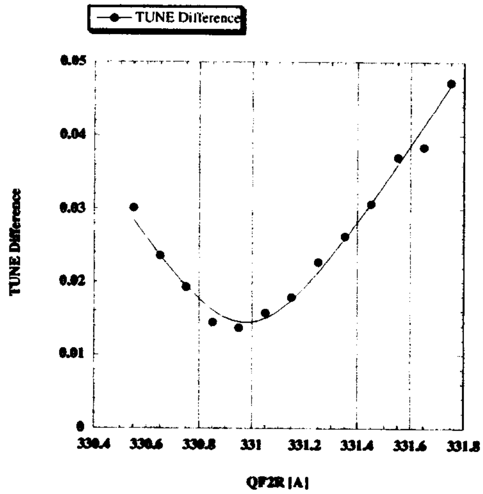


Coupling correction on coupling resonance

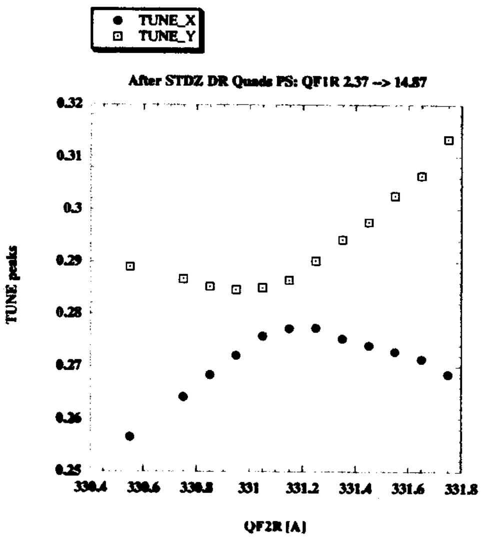
minimizing tune separation at coupling resonance

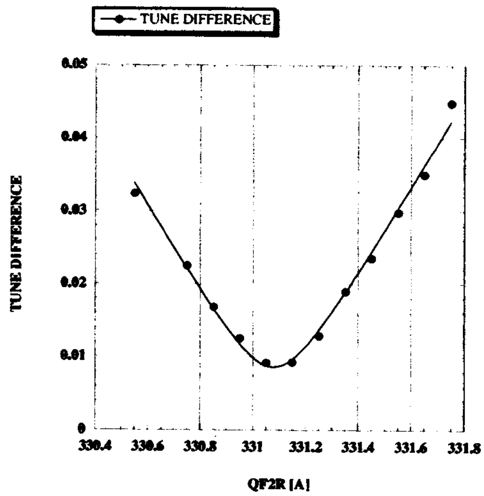
skew off
k=1.4%



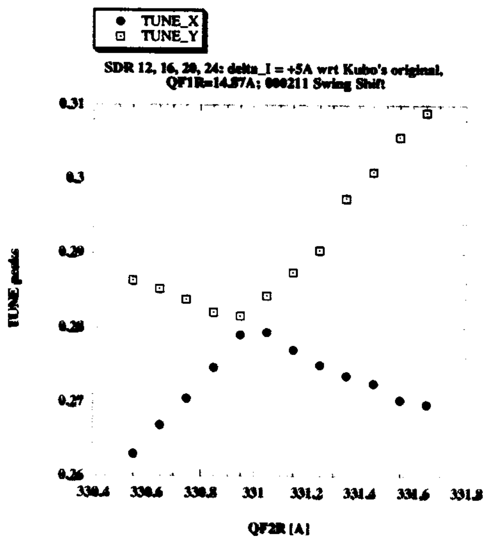


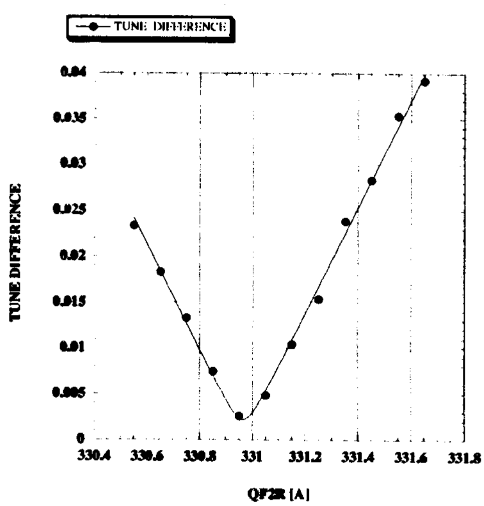
skew corr.
by using Y
orbit
response
k=0.9%





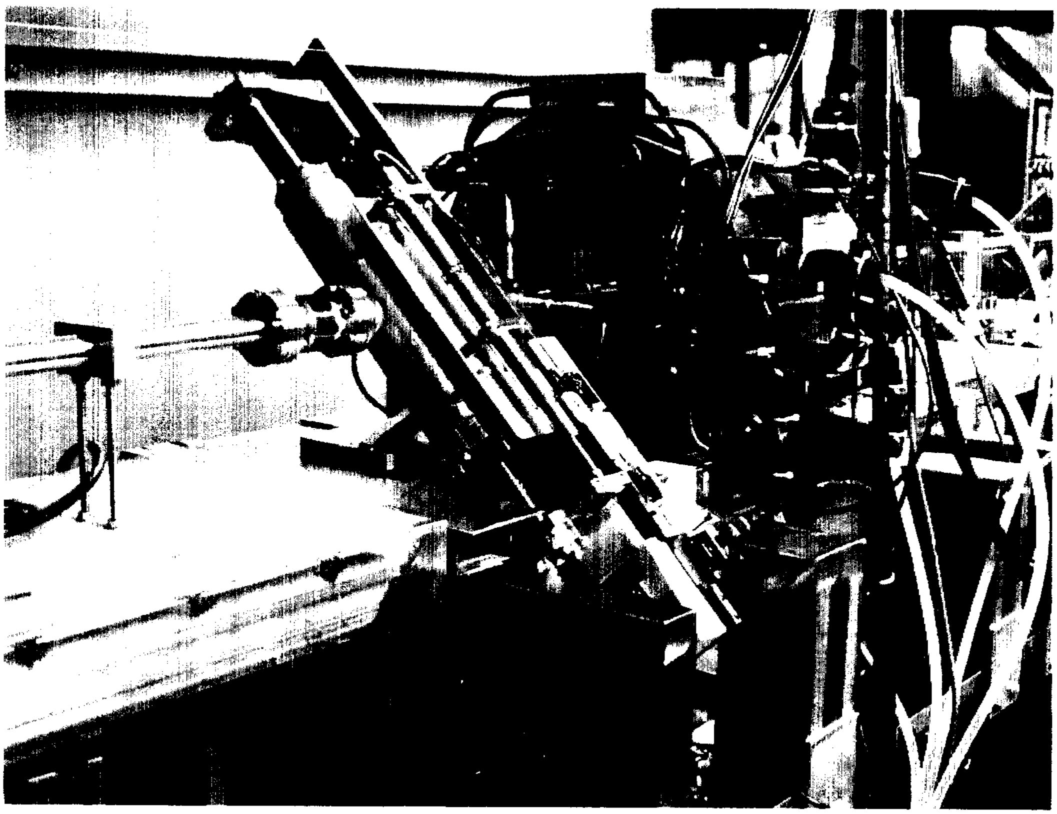
additional
manual
skew corr.
k=0.2%





Tungsten Wire Scanner in EXT-line

5 monitors installed in Ext line



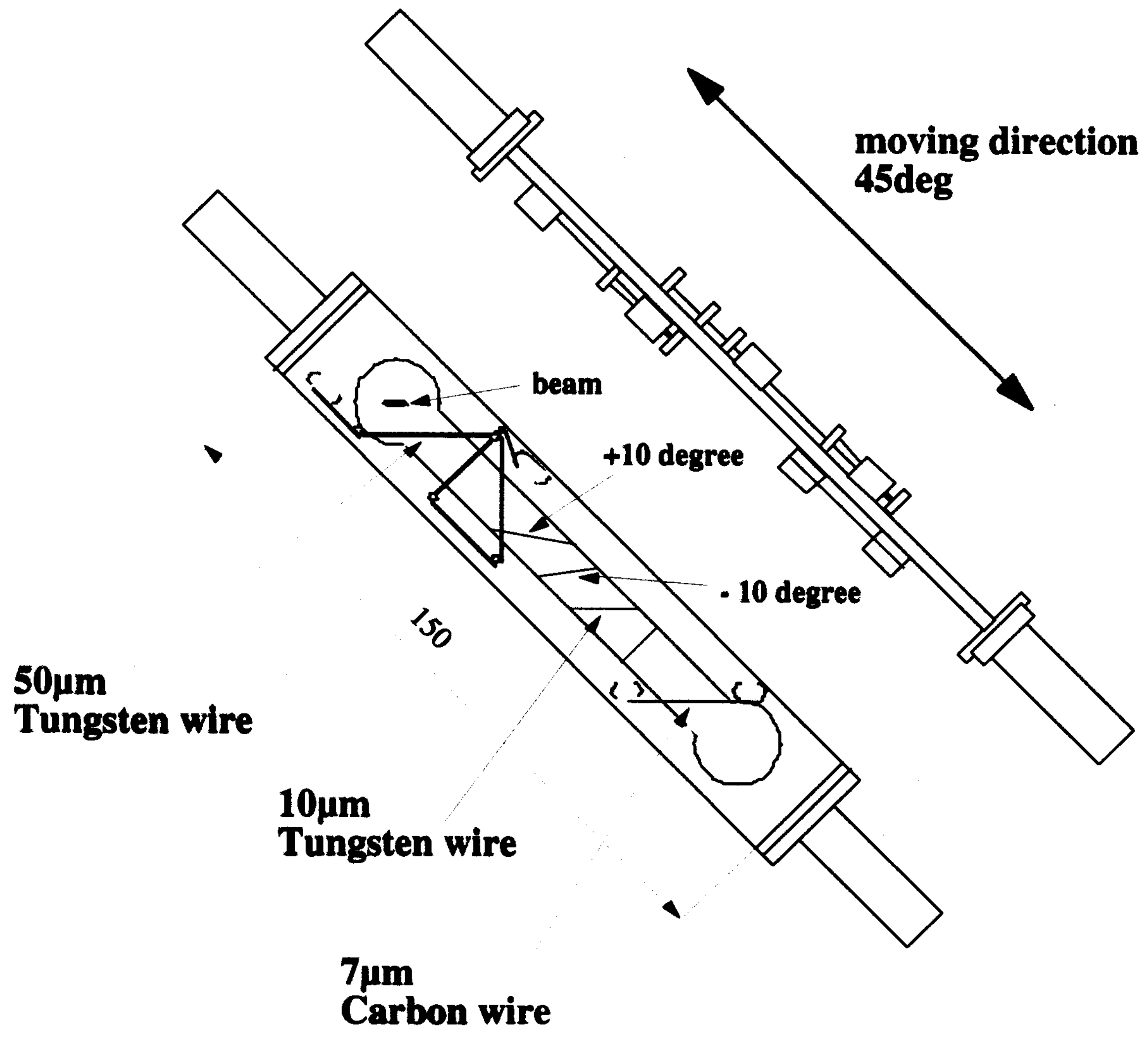
10 and 50μm gold plated tungsten wire
7 μm Carbon wire
down to 5μm beam size measureable

Air cherenkov+PMT γ-detector for single bunch

Air cherenkov+APD γ-detector for multi-bunch

Wire Scanner Wire mount

+/-10 degree wire, 7μm Carbon wire

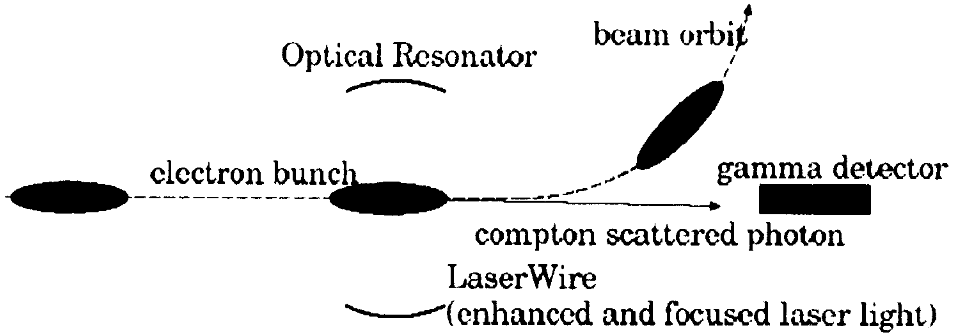


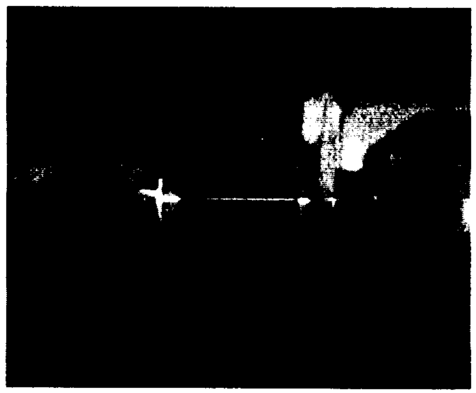
0.5μm-step stepping moter stage

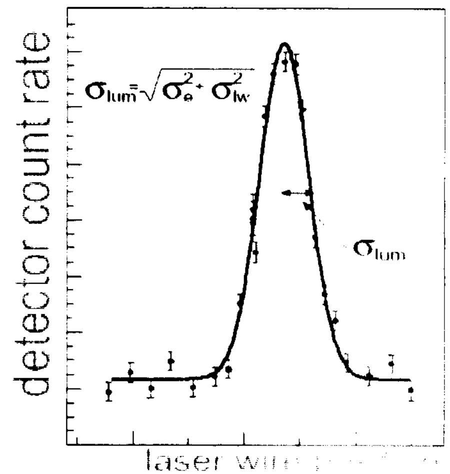
0.5μm resolution digital scale

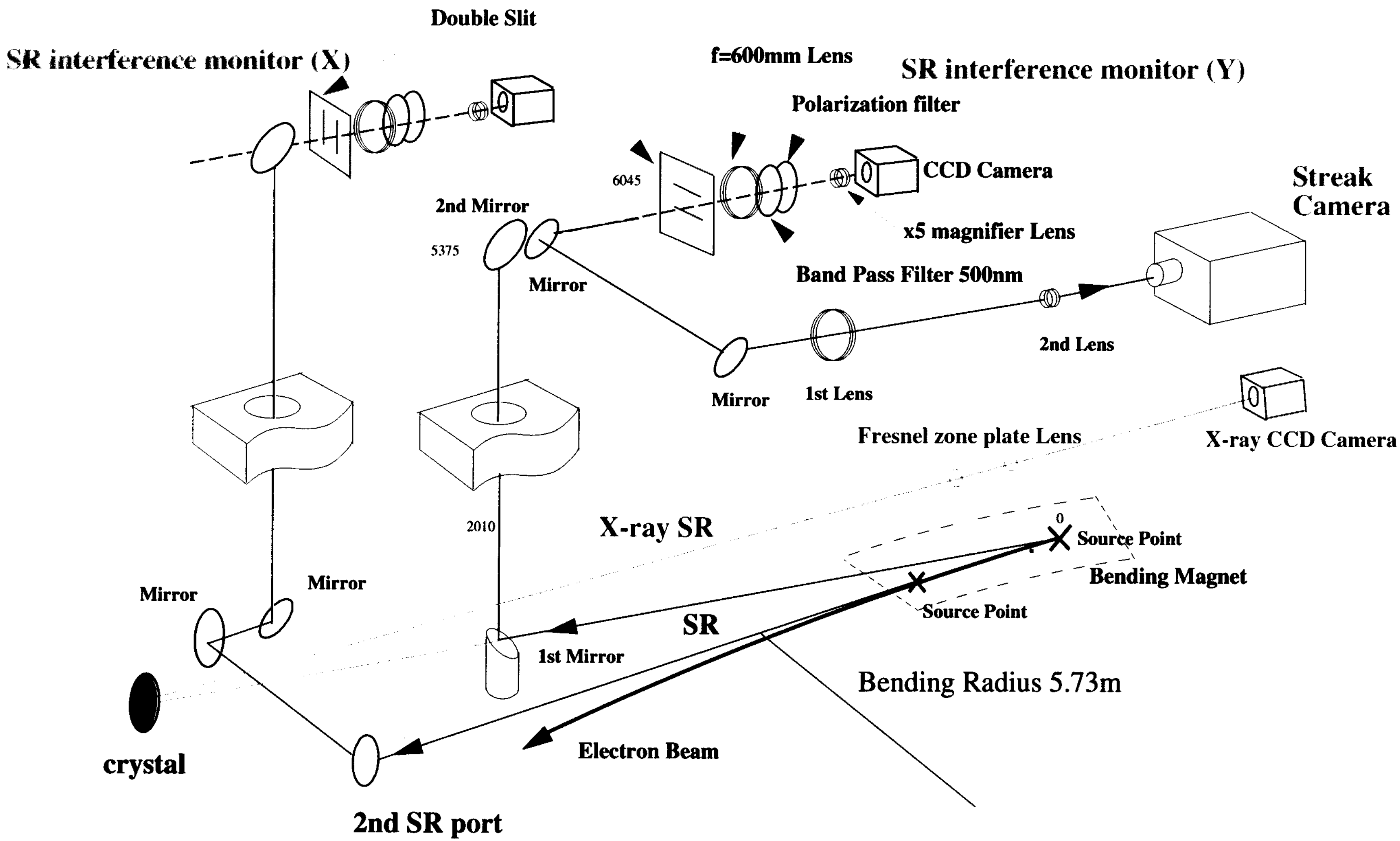
■Laser wire monitor (principle)

- use thin laser light (laserwire) as a target
- detect compton scattered gamma ray
- scan laserwire position measuring gamma ray yield





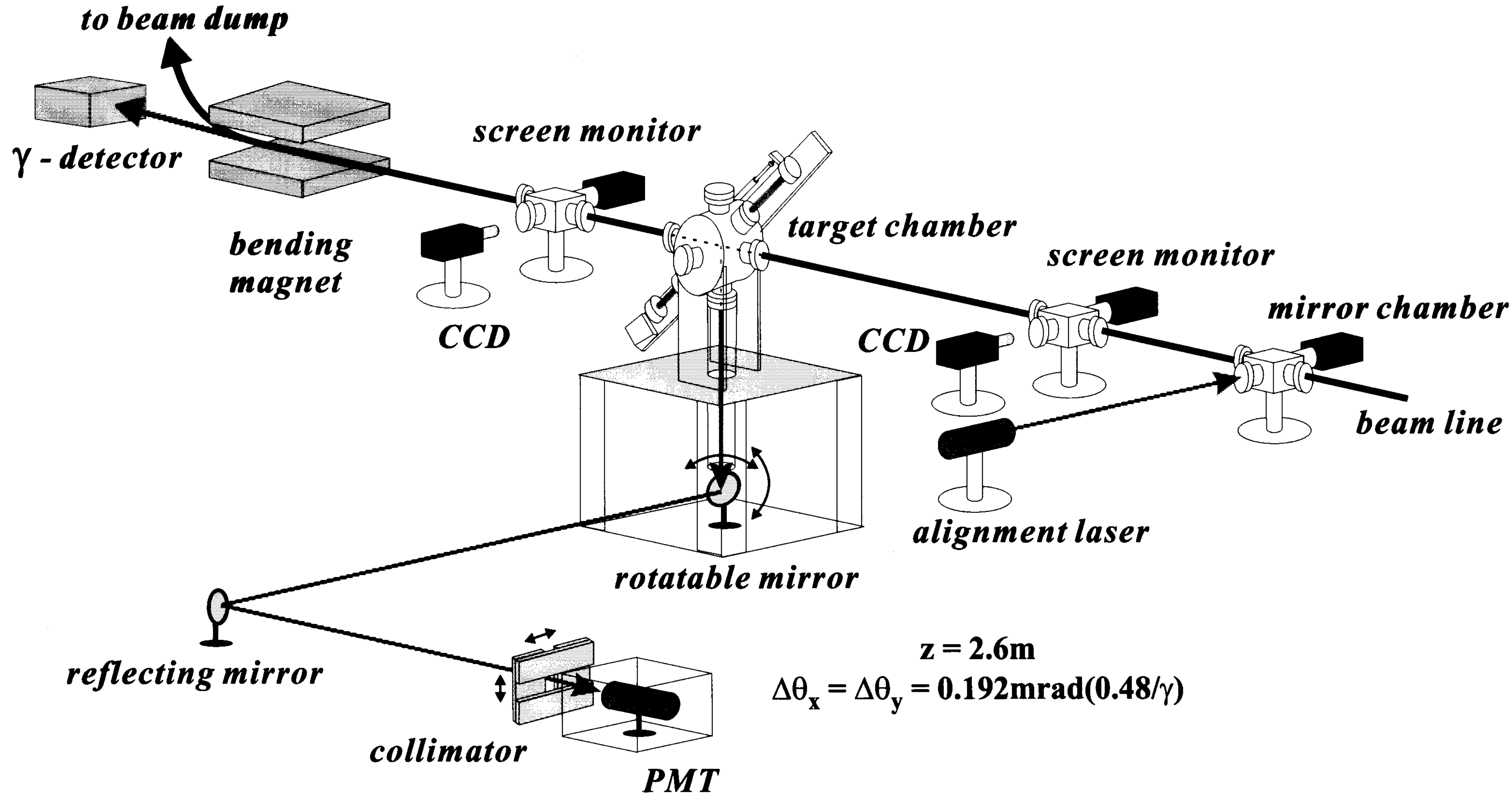




SR monitor optics set-up

X-ray SR port in Jan. 2002

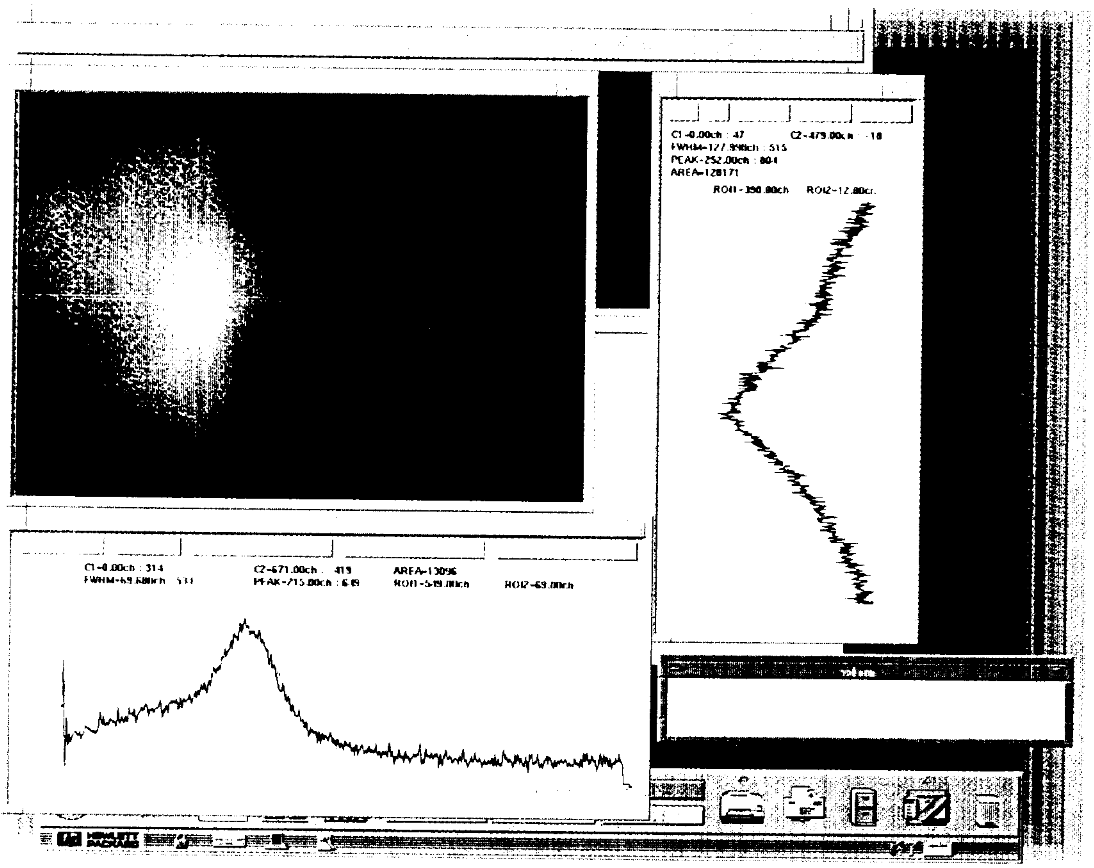
Experimental layout



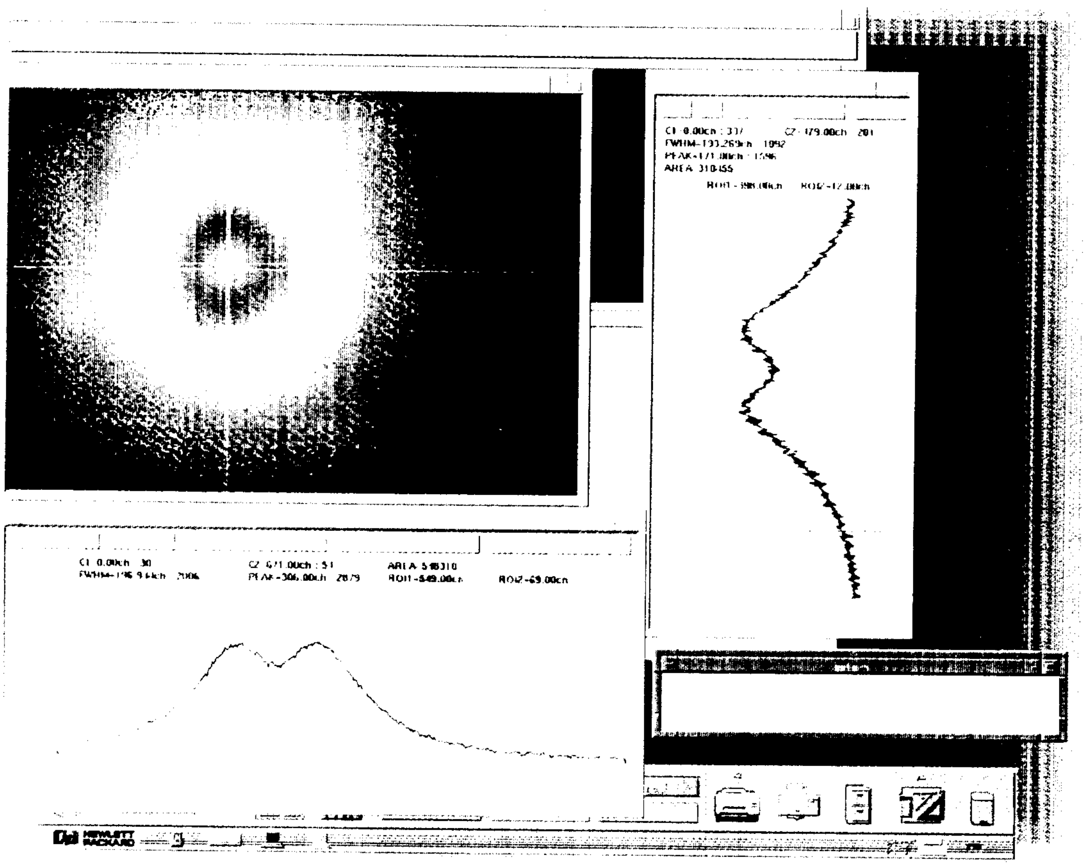
PMT energy range ~ 0.3 - 0.65μm

ODR and OTR measuerd by IIT at one shot

ODR

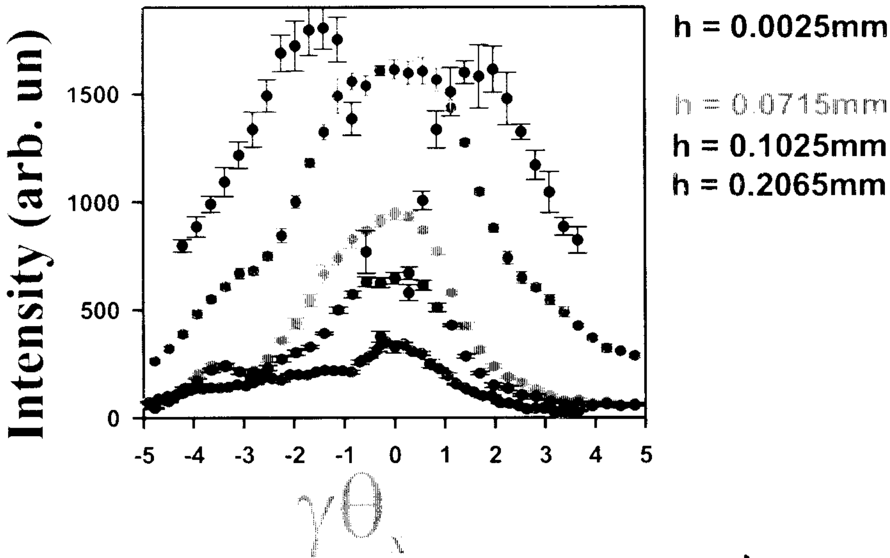


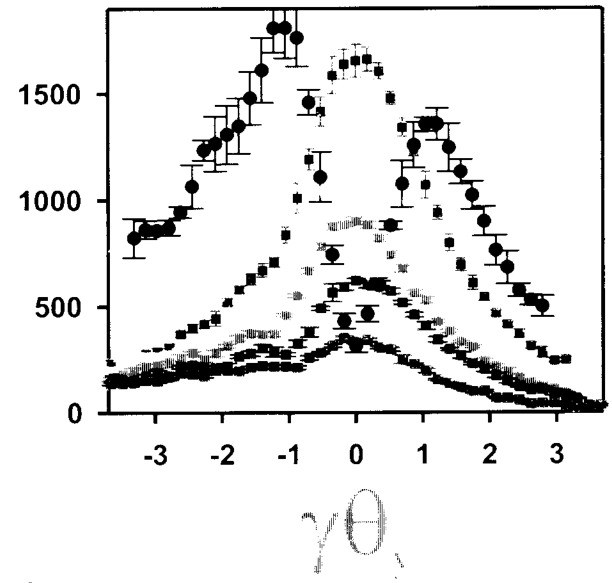
OTR



Measurements WITHOUT optical filters

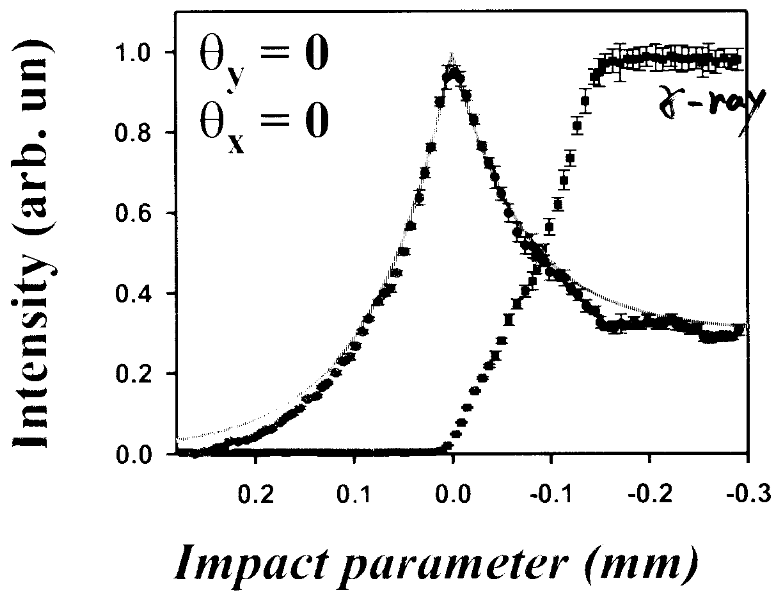
ODR (OTR) angular distributions

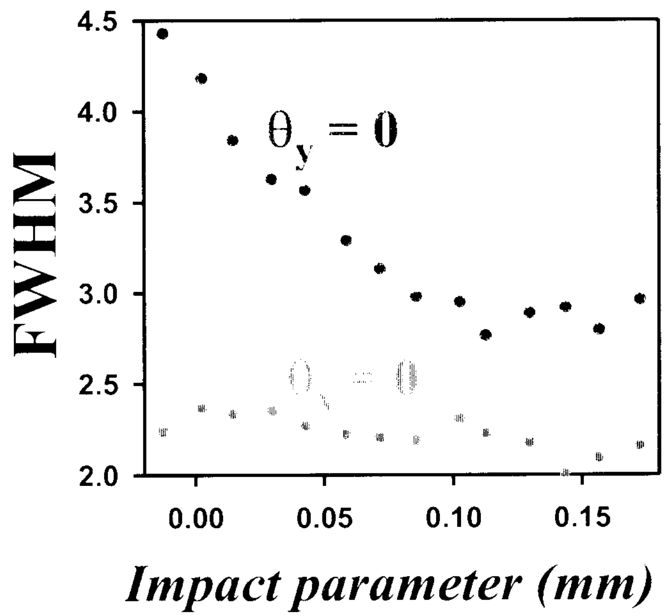




Preliminary

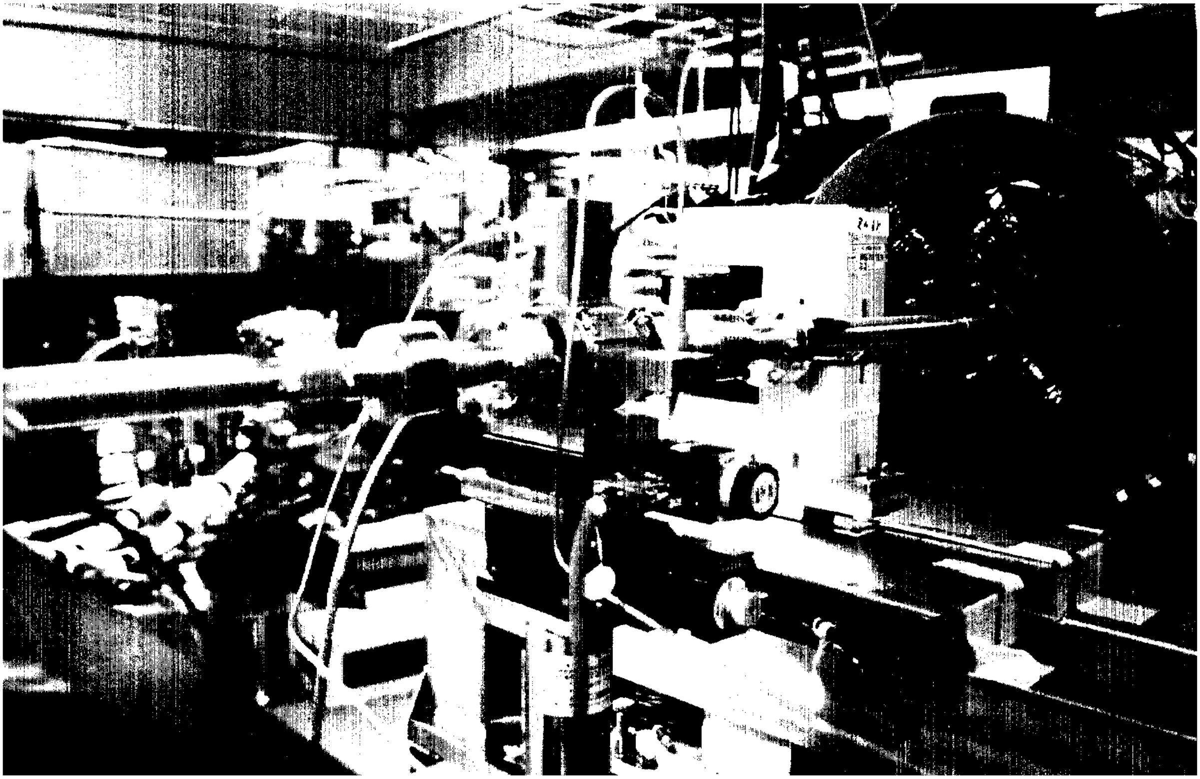
Dependence on Impact Parameter





Cavity BPM installation in EXT line

relative position measurement
for precise dispersion control



max. resolution 0.2μm for 100μm range
mover stage resolution 0.3μm

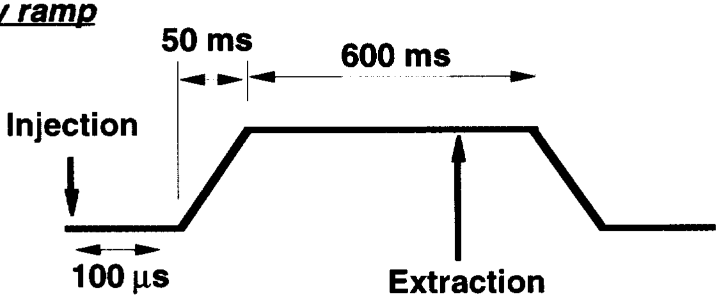
dispersion can be reduced less than 2mm
2mm dispersion -> 1.6μm beam size effect

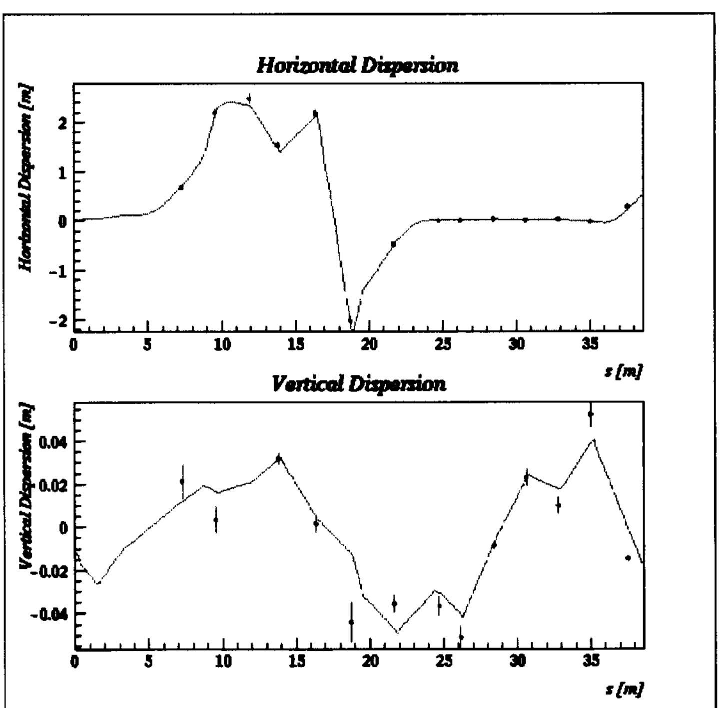
2mm dispersion -> 5.2μm position shift by 4kHz freq. change

Dispersion measurement

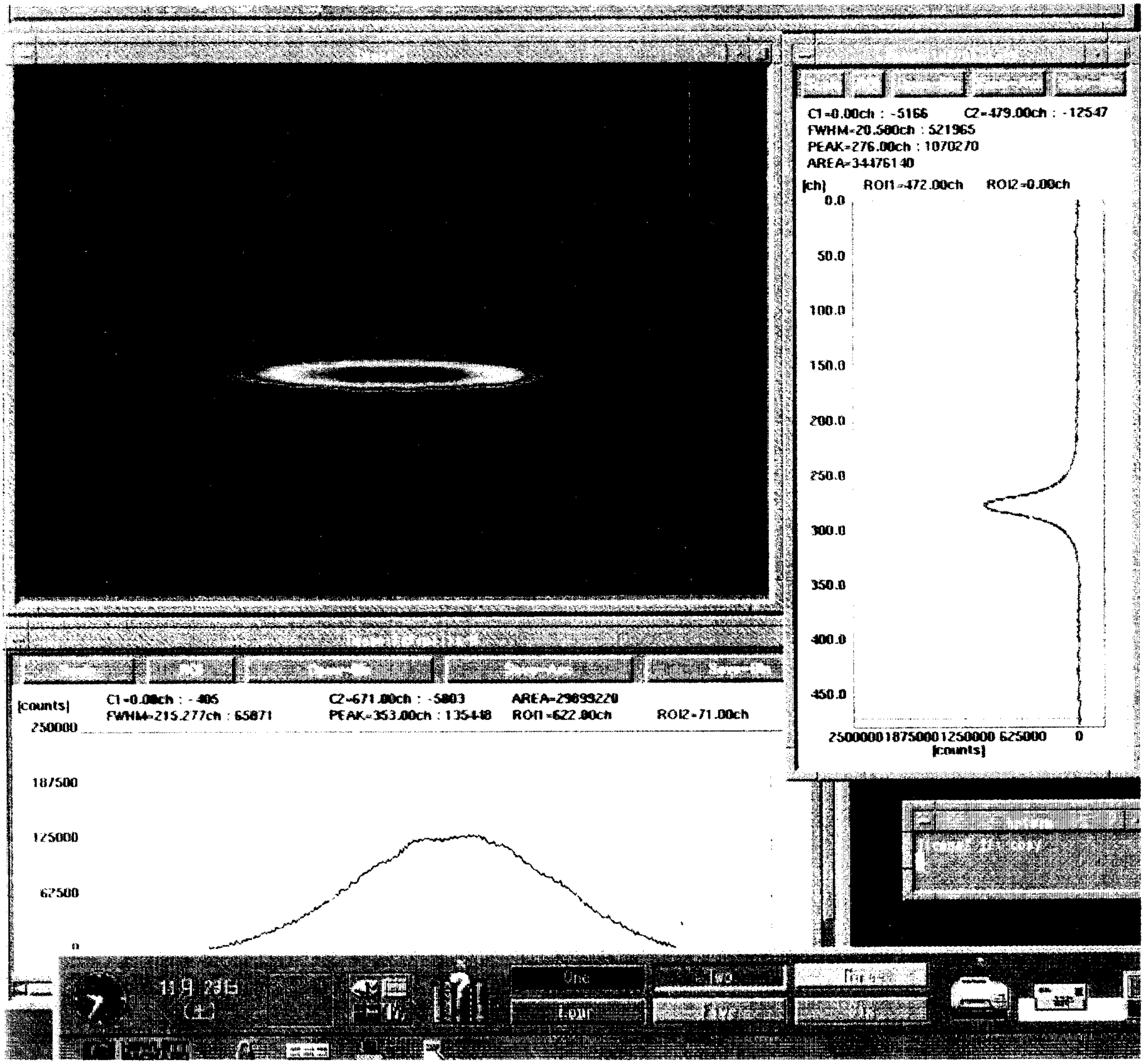
The dispersion in the extraction line is measured by detecting the orbit change induced by changing of rf frequency in the ring. **At injection into the ring, rf frequency has to be synchronized with the linac rf. A few 100 μs after the injection, the rf frequency is ramped over a time period of 50 ms. The beam is extracted from the damping ring about 450 ms after the end of the frequency ramp. The orbit change is proportional to $\eta \Delta f_{rf} / \alpha_c$, where α_c is momentum compaction factor. The η and η' at the extracted point from the ring and α_c are fit by the measured coefficients. The energy spread was measured using screen monitor at the place of large dispersion.**

Frequency ramp



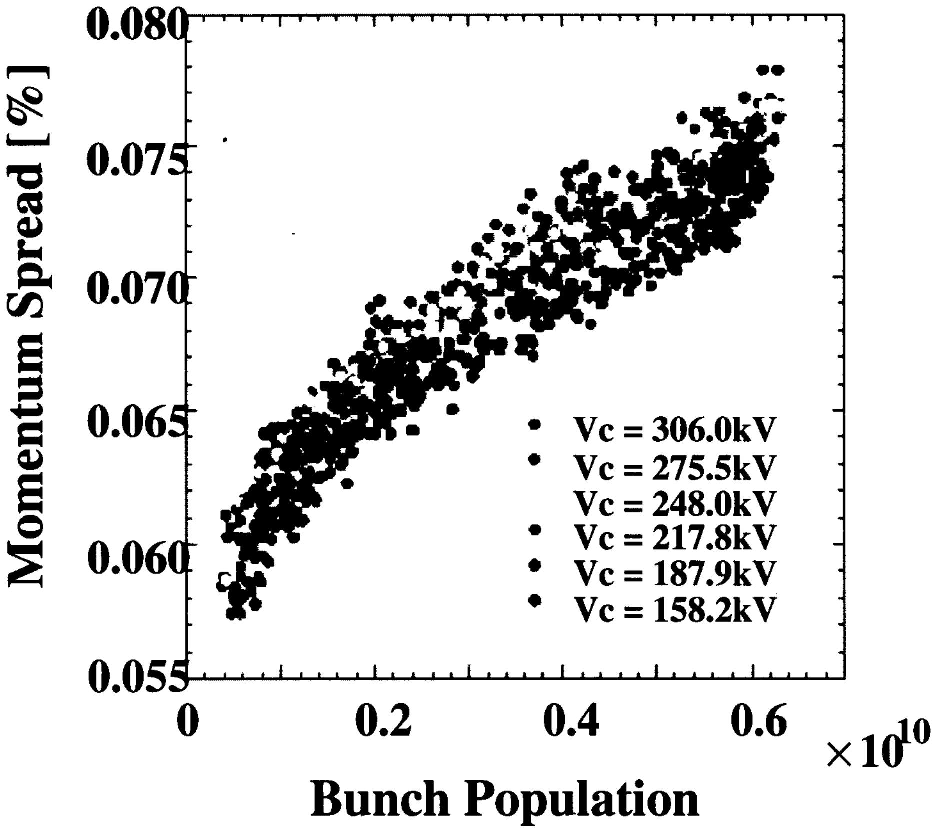


Measured horizontal and vertical dispersion in the extraction line (plot) and fitted result (line).

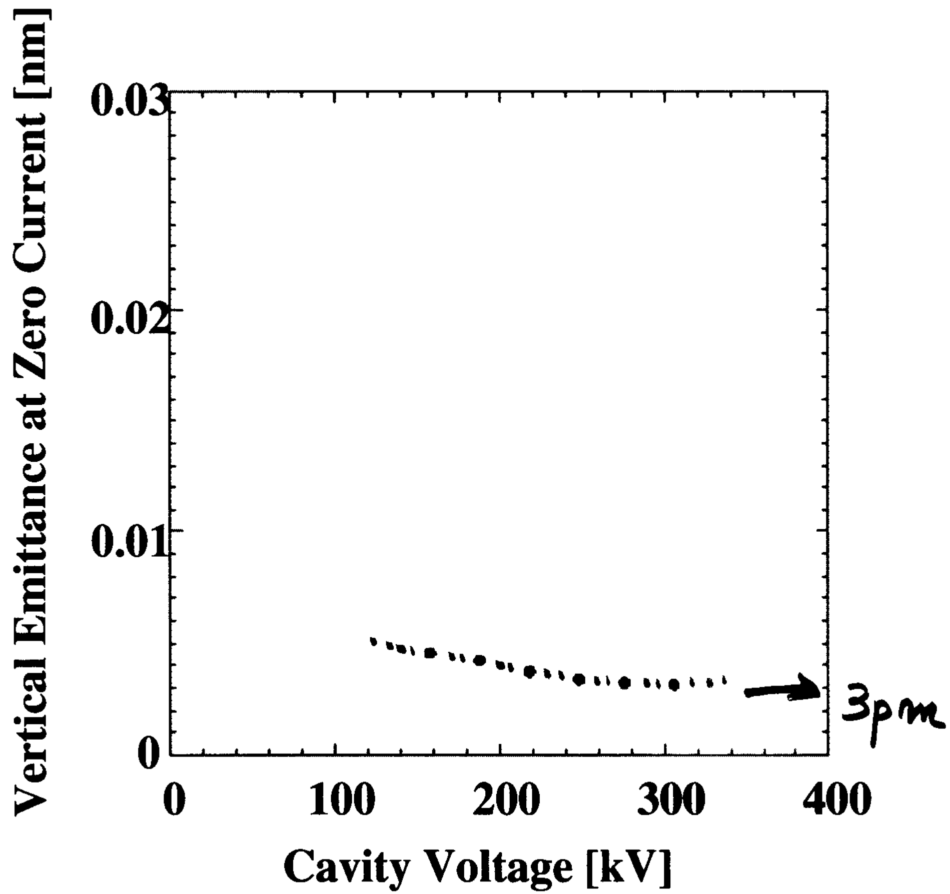

C1=0.00ch : -5166
C2=479.00ch : -12547
FWHM=20.580ch : 521965
PEAK=276.00ch : 1070270
AREA=34476140
[ch]
ROI1=472.00ch
ROI2=0.00ch
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
2500000
1875000
1250000
625000
0
[counts]
[counts]
C1=0.00ch : -405
FWHM=215.277ch : 65871
C2=671.00ch : -5803
PEAK=353.00ch : 135448
AREA=29899220
ROI1=622.00ch
ROI2=71.00ch
250000
187500
125000
62500
0

Vertical Emittance Evaluation from Momentum Spread Enhancement

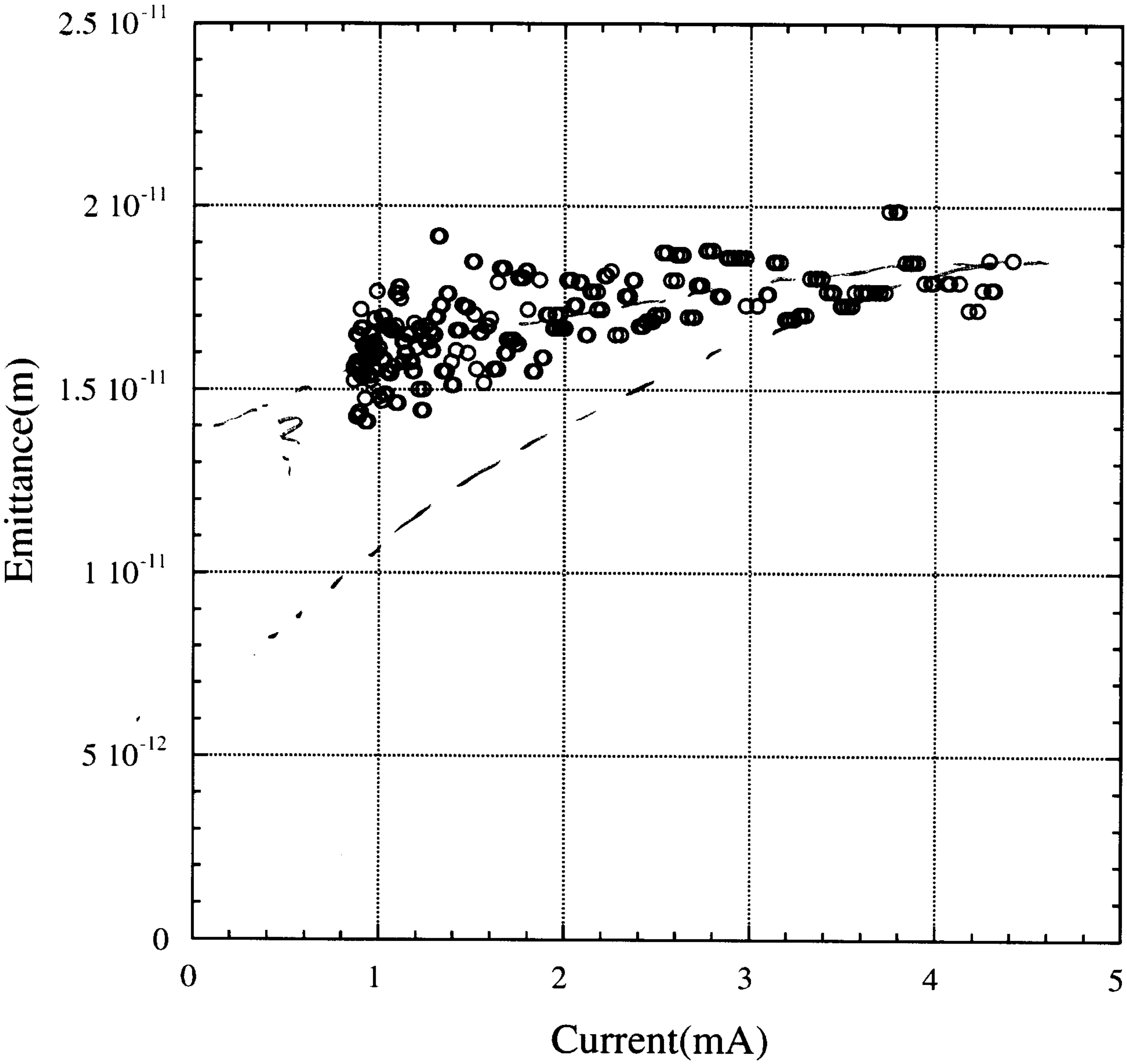
Vc Dependence of Momentum Spread



Vertical Emittance Evaluation



Current Dependence of Vertical Emittance



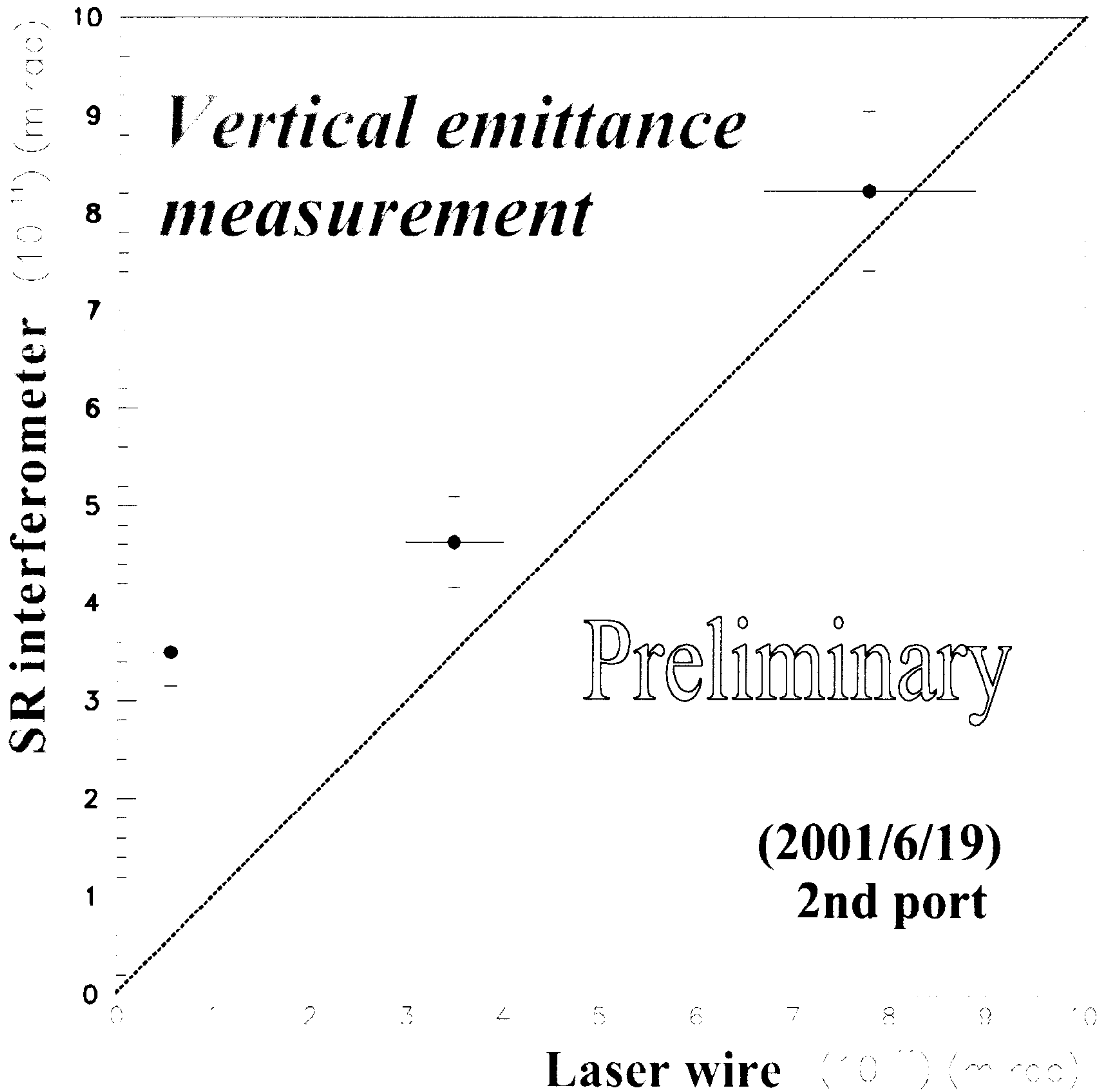
SR interferomenterによって計測した垂直エミッタンスの電流依存性　-　測定系は実際の値に対し最大値を計測するが、< 1.8x10-11m(@4mA)を計測した。

measured by SR interferometer.

(cali ?

IBS effect maybe strong.
?

SR interferometer vs Laser wire

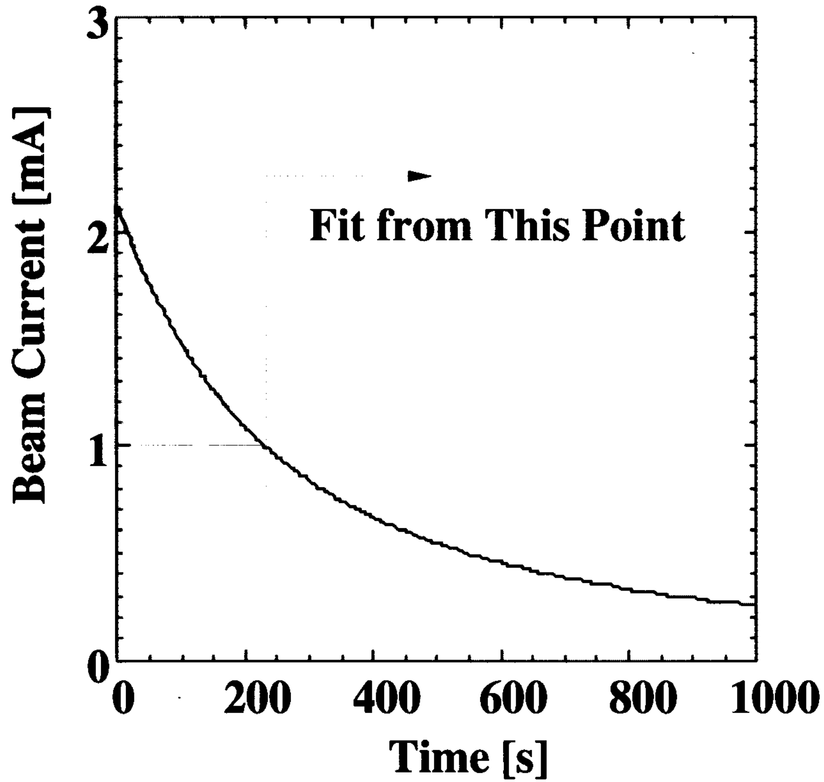


The vertical emittance measurement by both SR and LW (SR error is only statistic)

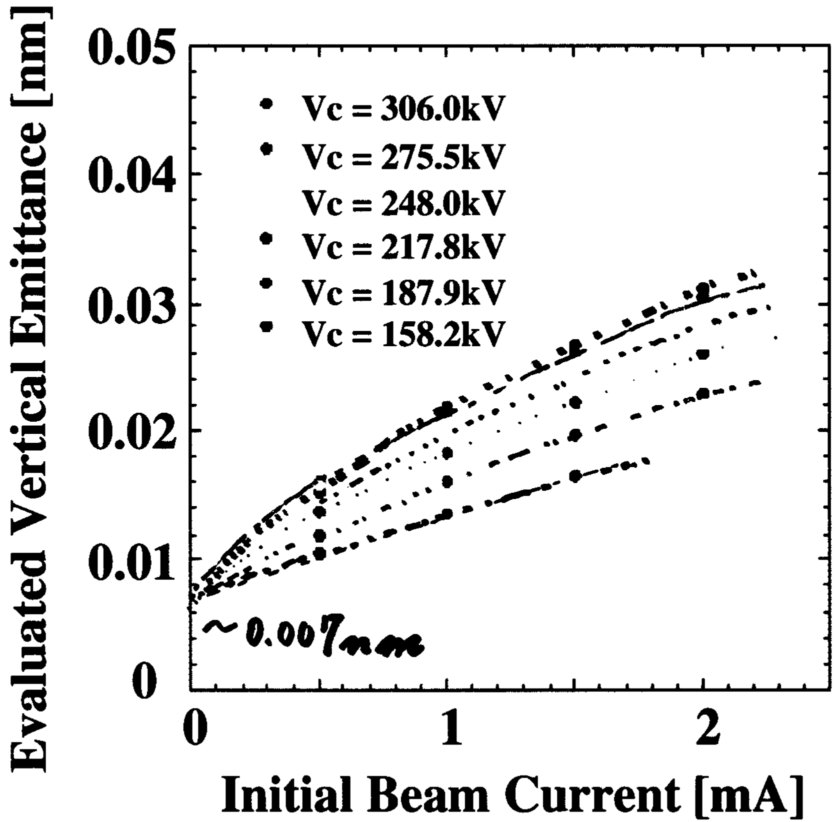
Laser wire reach to 0.5 *10^-11 m rad on the other hand SR was saturated on lower emittance region.

Vertical Emittance Evaluated by the Touschek Beam Lifetime

Example of the Current Decay
(Vc = 280 kV)

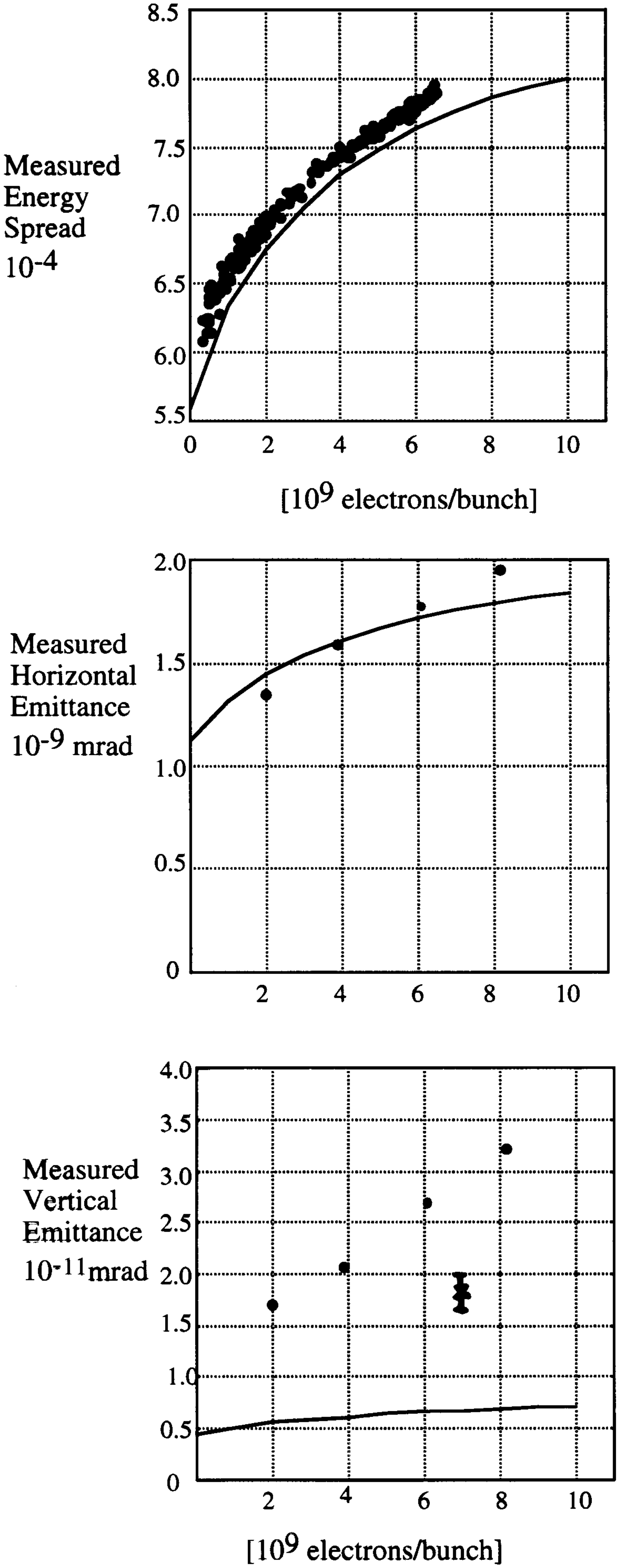


Vertical Emittance Evaluation

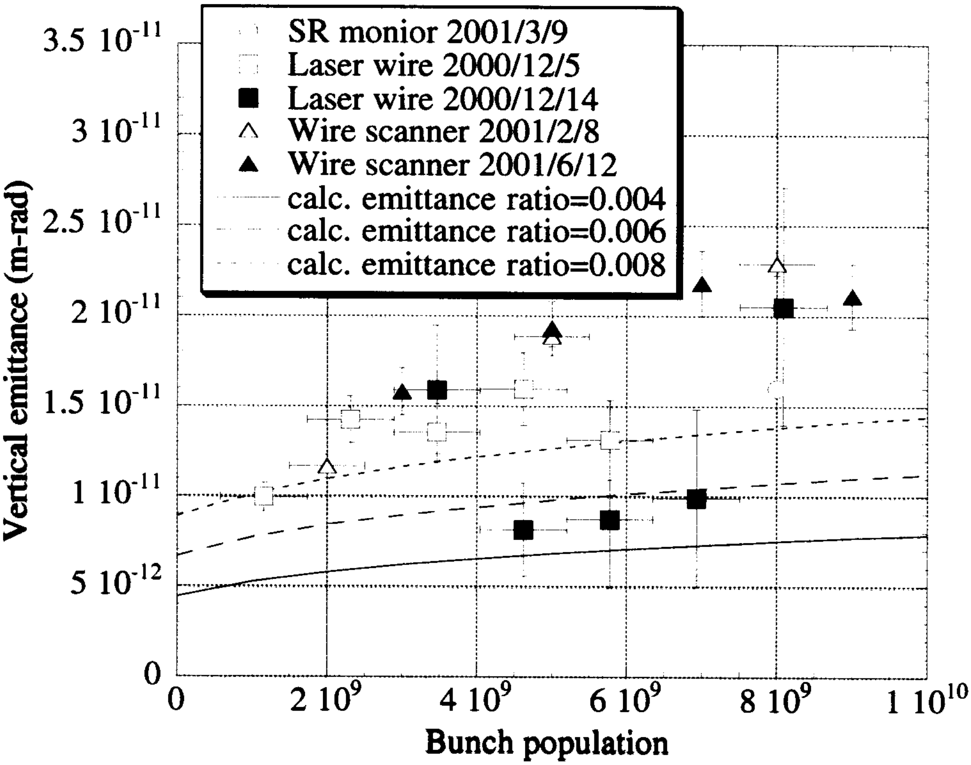


At the Zero-Current, The Vertical Emittance was Roughly 0.005 nm.

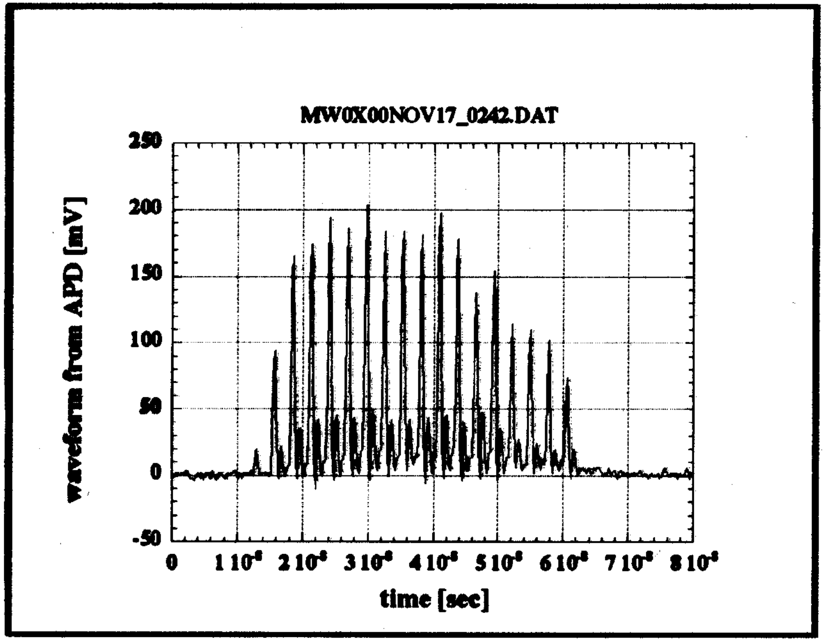
Low Emittance



Single Bunch Y emittance

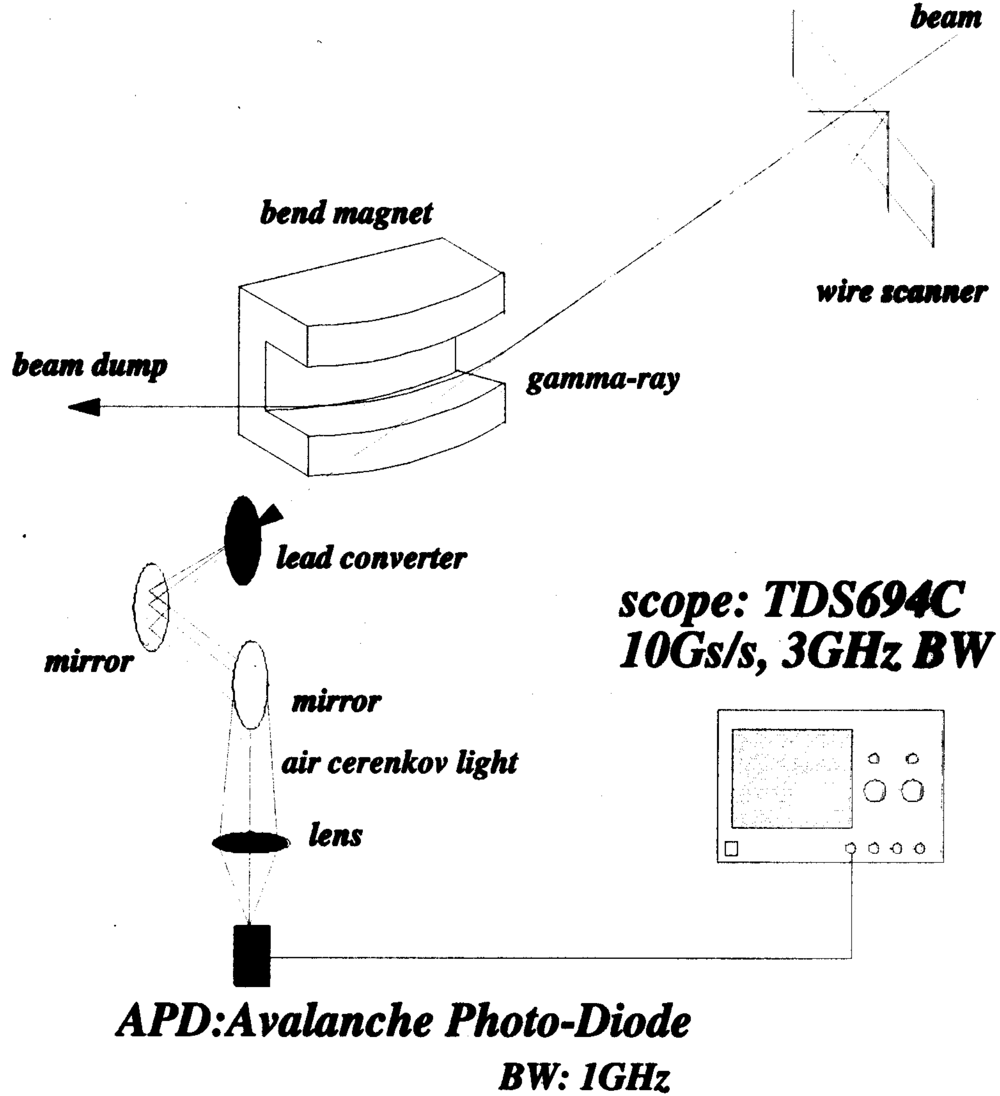


Wire scanner multibunch detection

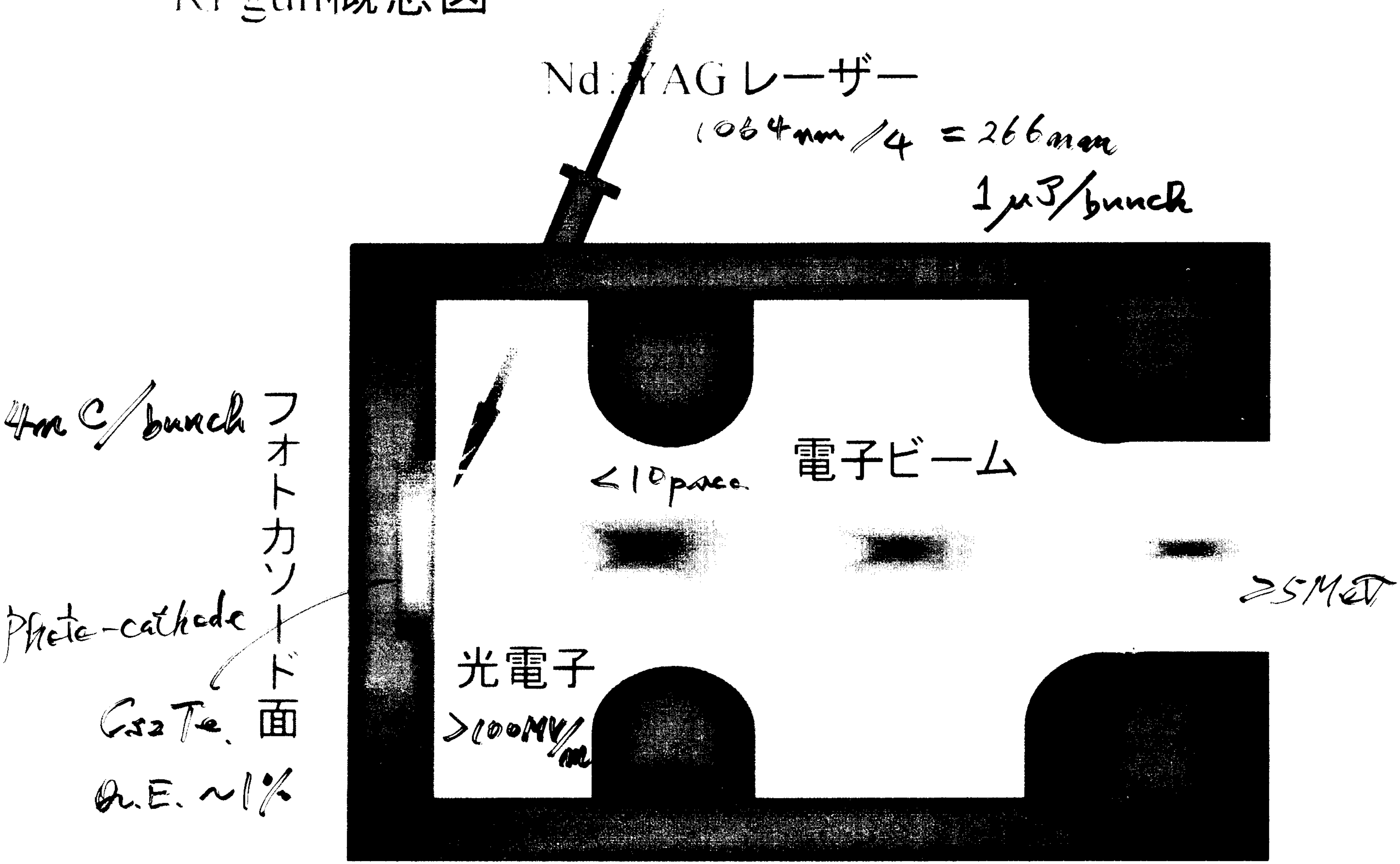


Waveform from APD detector with wire on beam

Peak detection by software through GPIB



RFgun概念図

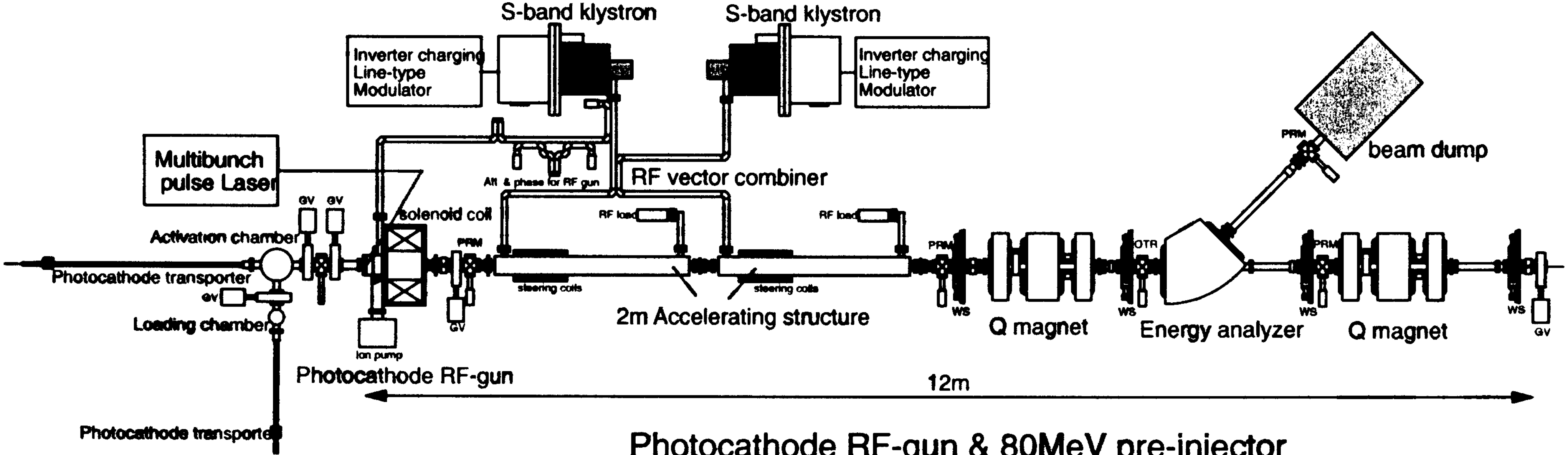


Nd:YAGレーザー
1064nm/4 = 266nm
1μJ/bunch
4nC/bunch
フォトカソード面
Photo-cathode
Cs2Te
Q.E. ~1%
電子ビーム
<10psec
光電子
>100MV/m
25MeV

~3×10^{-6} rad·m

~200 bunches /train

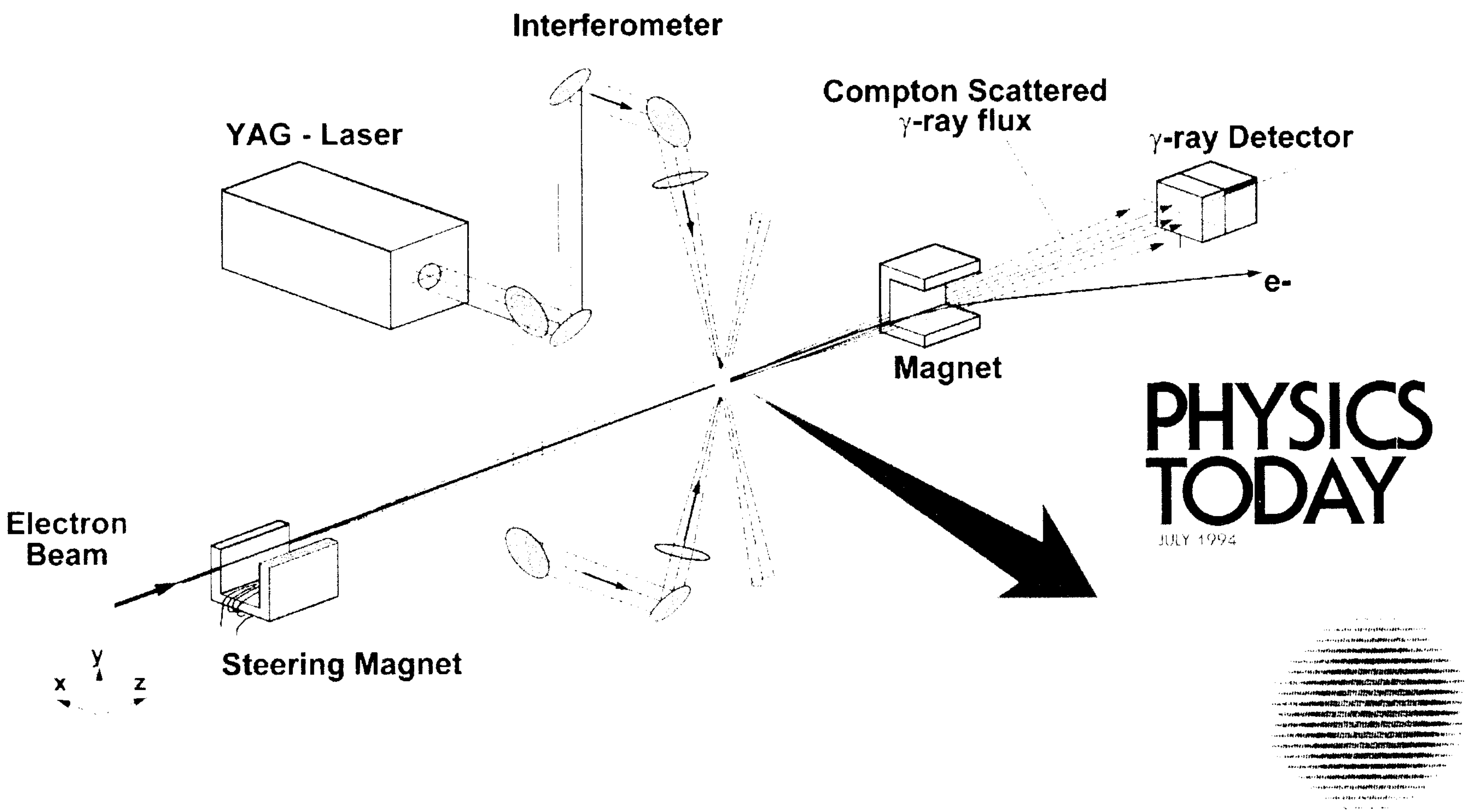
~10^{10} electrons /bunch



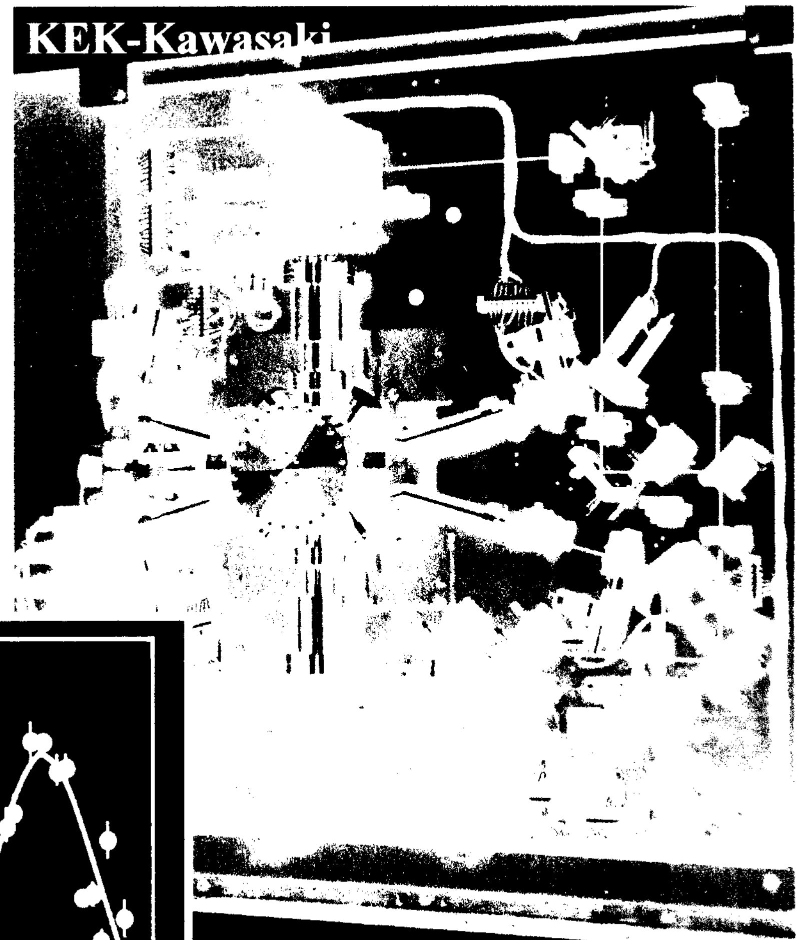
Photocathode RF-gun & 80MeV pre-injector
for positron production Linac

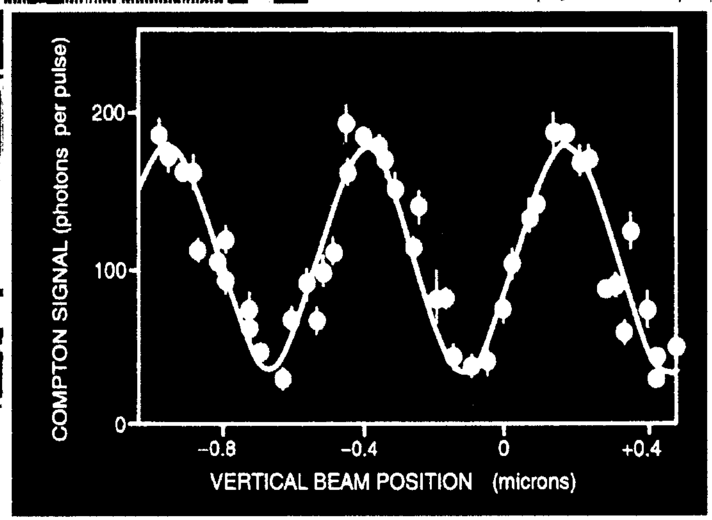
Nanometer Beam Size Measurement

Spot size Monitor based on Laser Interferometry

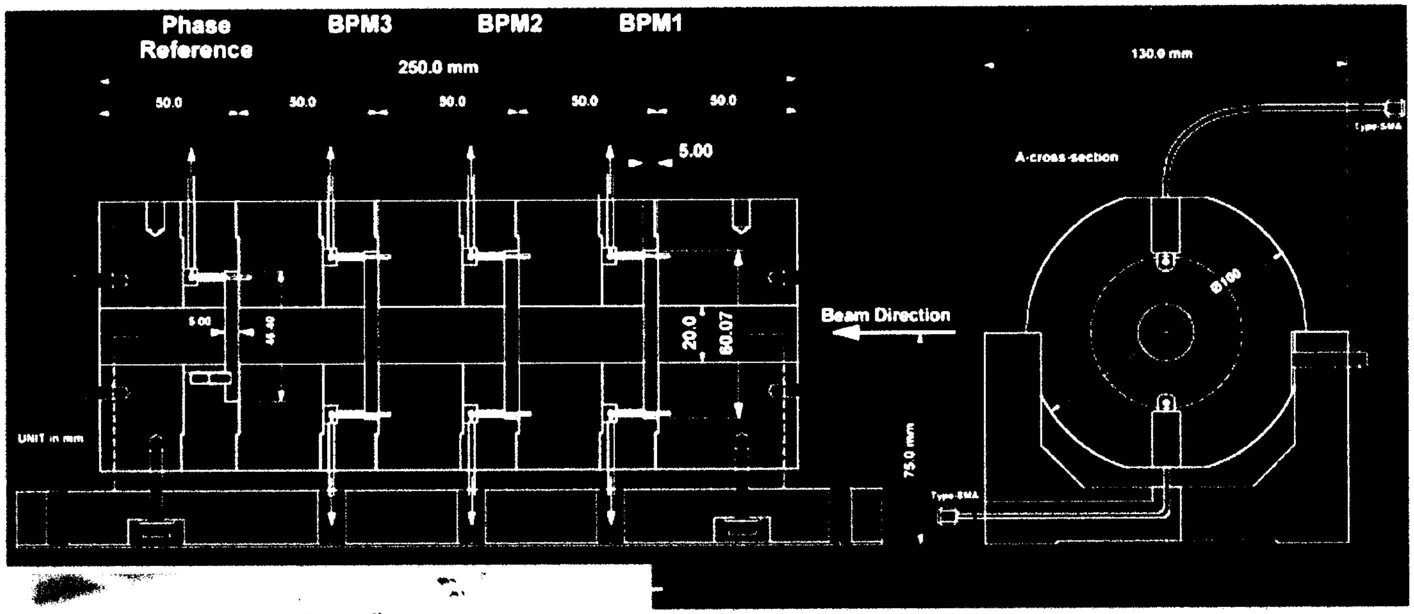


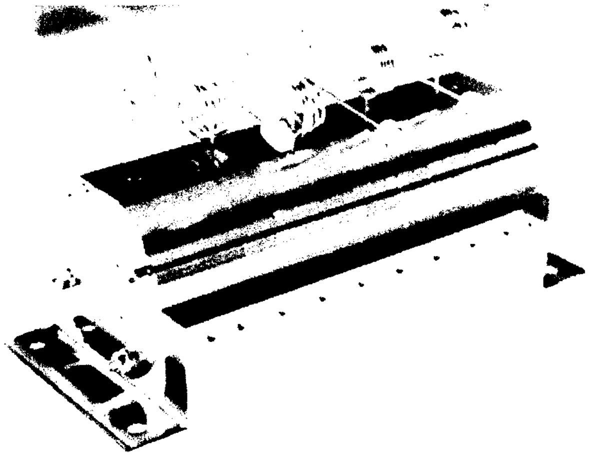
Experimental Test at FFTB



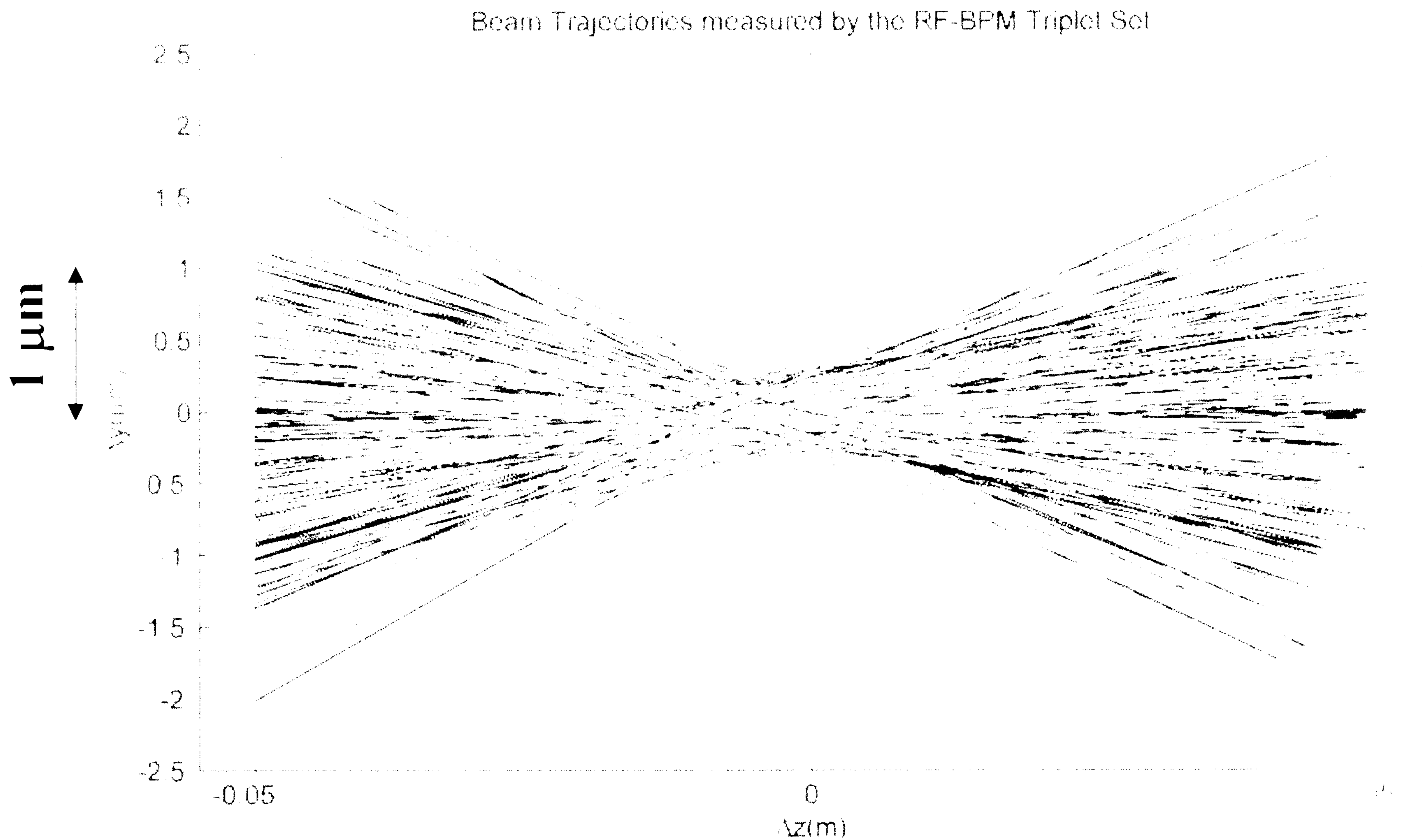


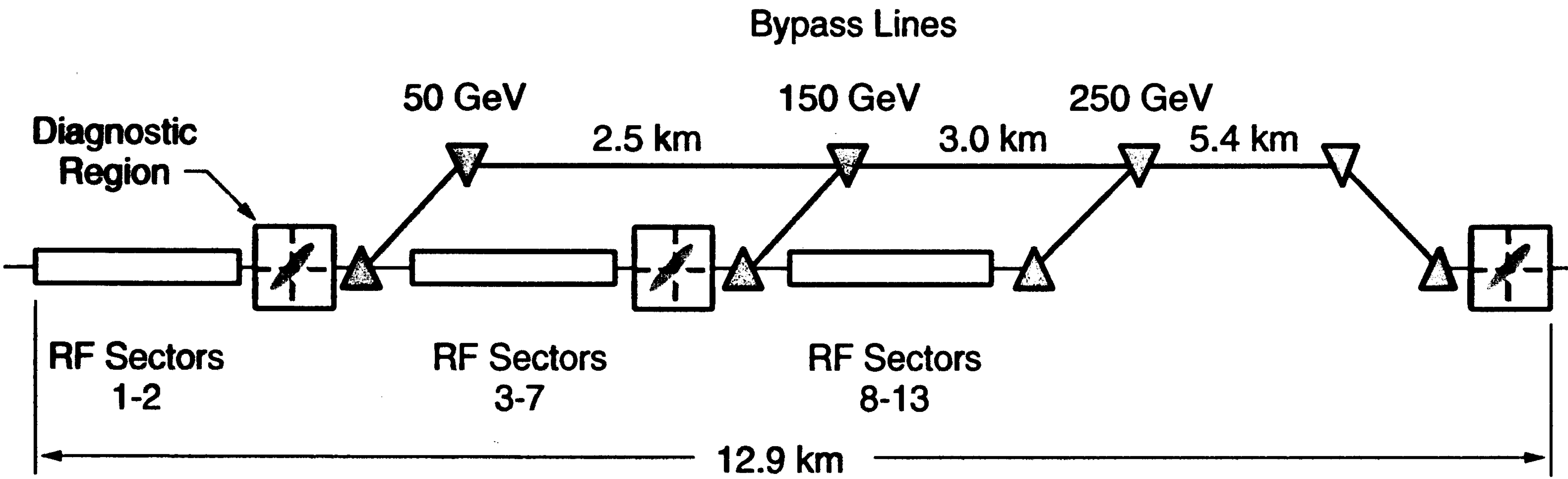
RF-BPM tested at FFTB





Nanometer Beam Position Monitor

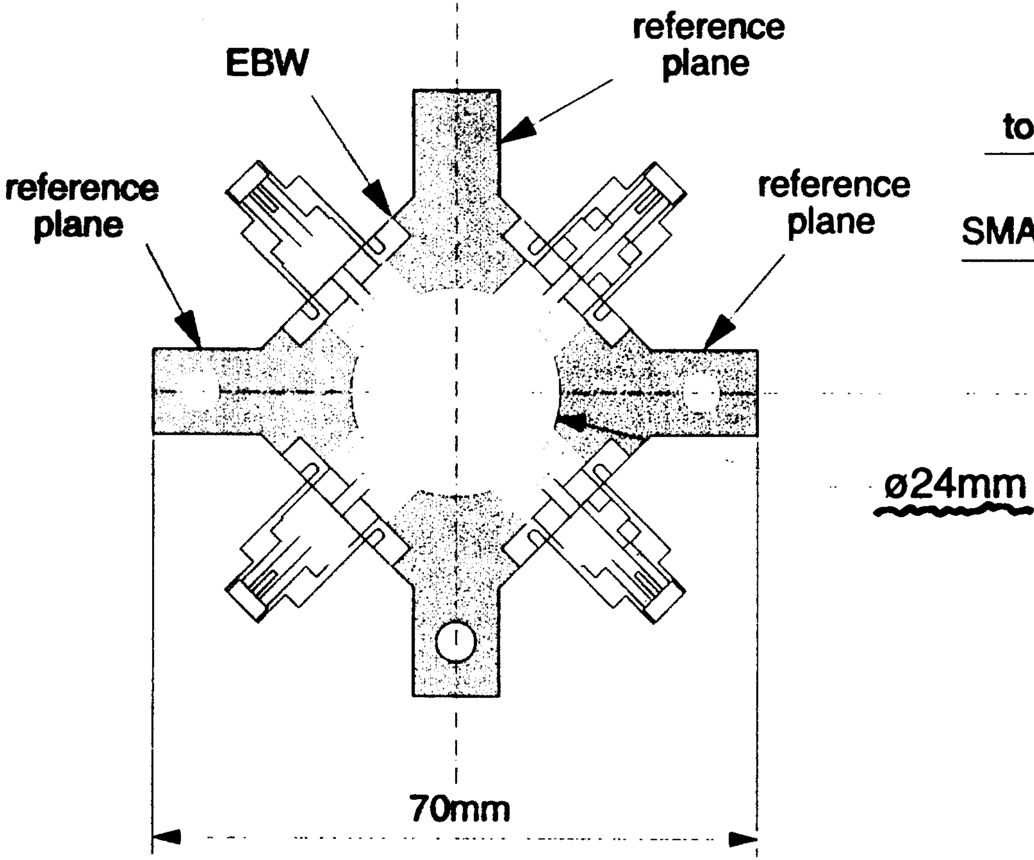




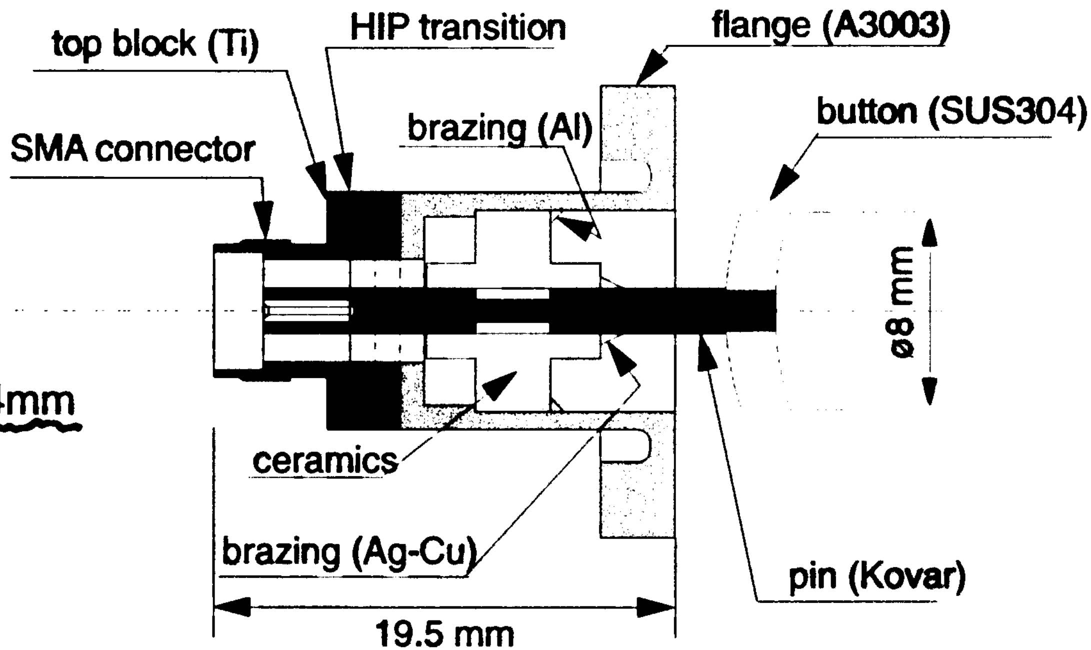
Bypass Lines
50 GeV
150 GeV
250 GeV
Diagnostic
Region
2.5 km
3.0 km
5.4 km
RF Sectors
1-2
RF Sectors
3-7
RF Sectors
8-13
12.9 km

1μm Resolution at 10^{10} particles/bunch by single beam pass.

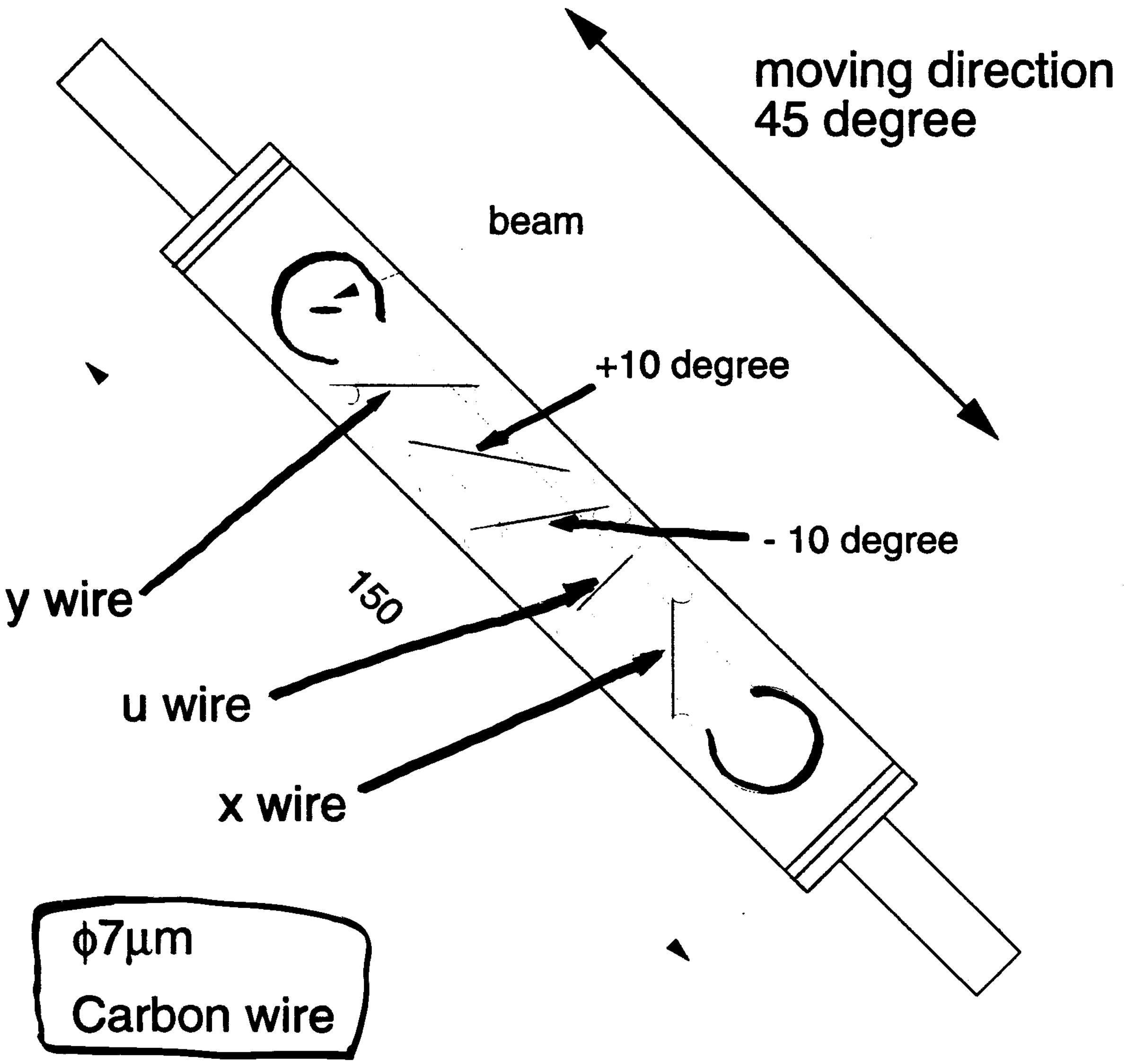
1GHz > 714MHz Signal Process.



cross section of BPM camber



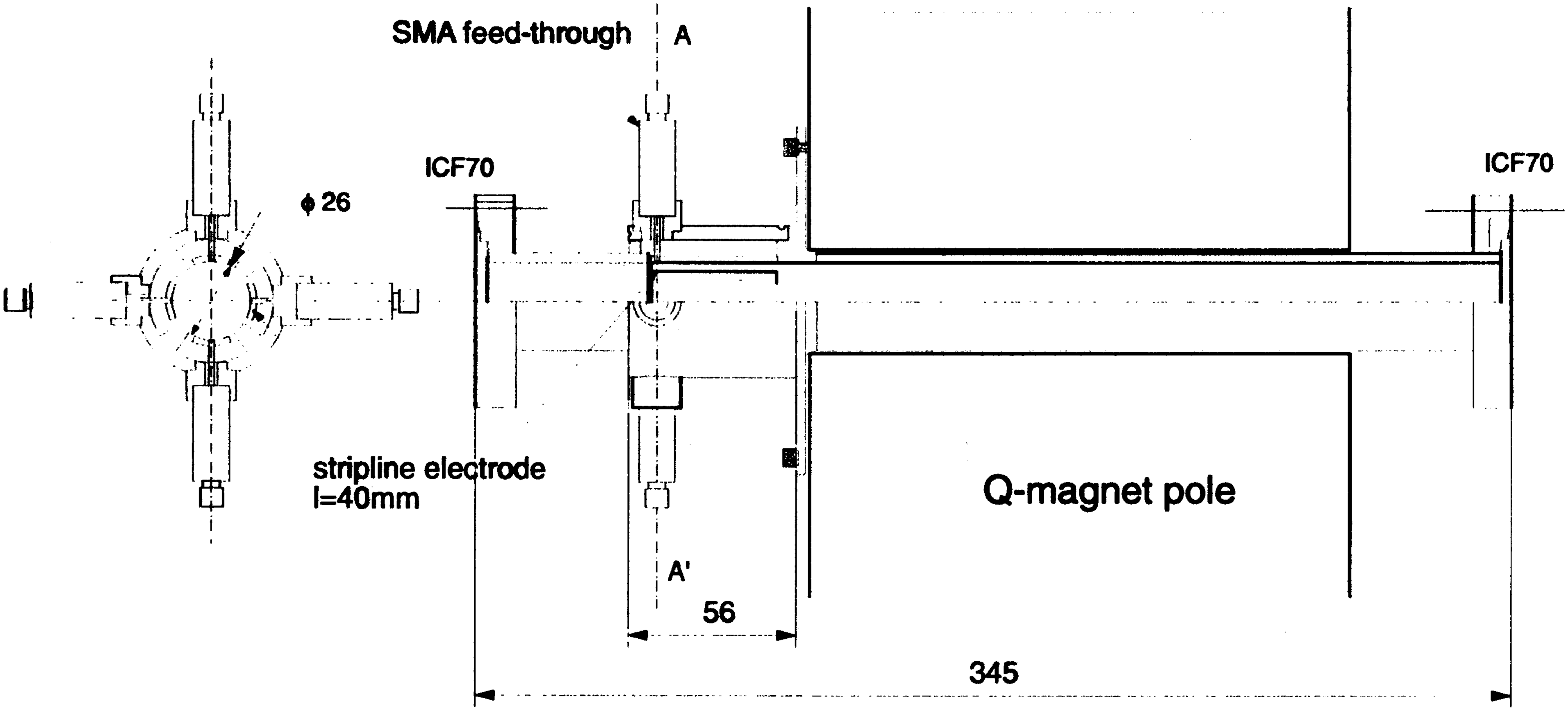
Button electrode assembly

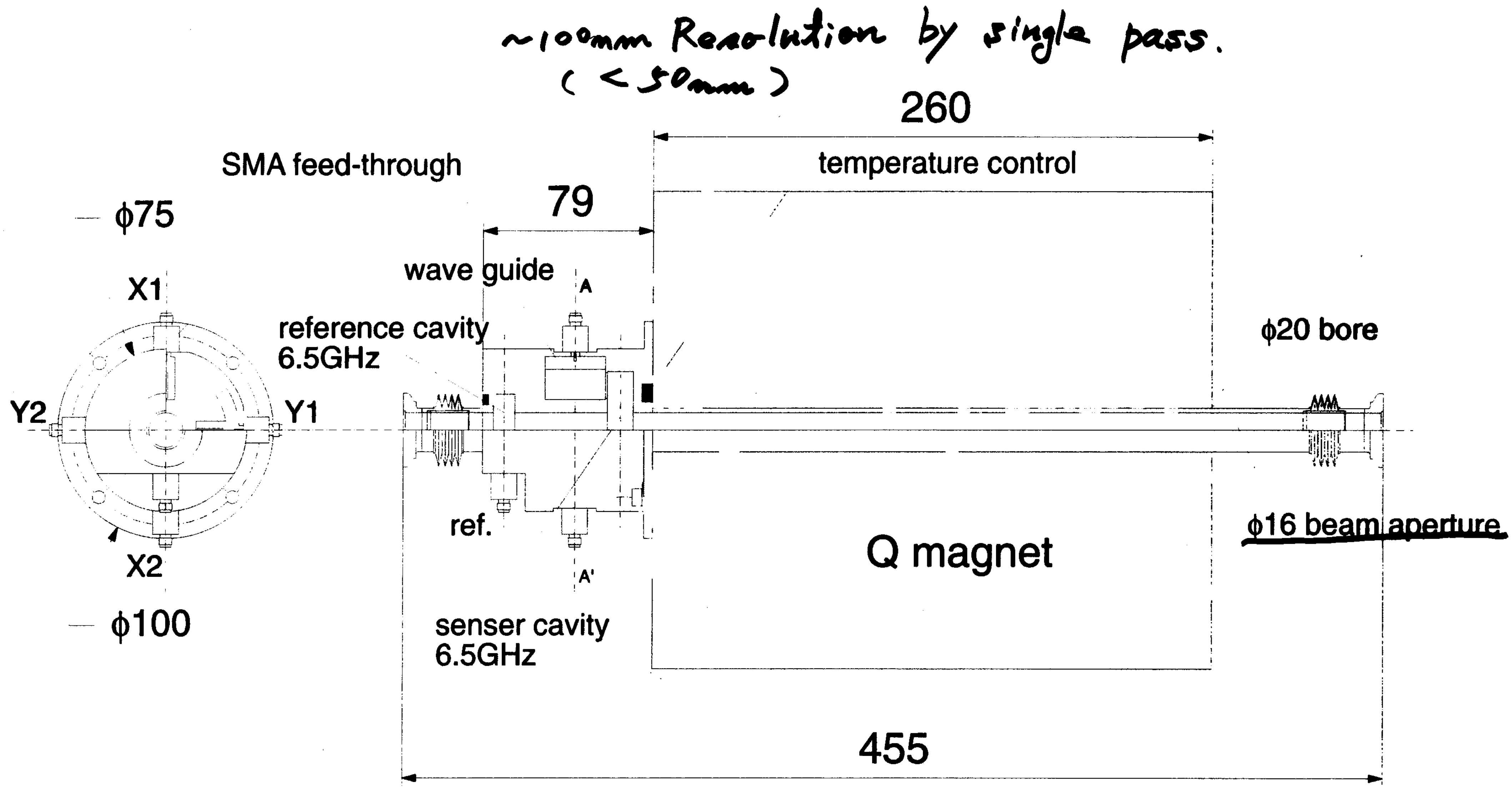


0.5μm-step stepping moter stage

0.5μm resolution digital scale

1μm Resolution by single pass.
(<)




~100nm Resolution by single pass.
(< 50nm)
260
temperature control
SMA feed-through
79
φ75
wave guide
A
X1
reference cavity
6.5GHz
φ20 bore
Y2
Y1
ref.
φ16 beam aperture
Q magnet
X2
A'
φ100
senser cavity
6.5GHz
455

Summary

Luminosity

Low emittance tuning has been established. dE/E, X emittance were consistent with IBS theory prediction. 3pm Y emittance at zero current is expected.
(EXT Y emittance is larger than expected.)

Instrumentation

Laser wire in DR, EXT wire scanner, EXT cavity BPM are worked well. EXT OTR, ODR, X-ray SR monitor are commissioned. BBA is under the study.

Multibunch operation

Ring scrubbing by Multibunch beam makes vertical emittance reduced.
Multibunch wire scanner is commissioned and Multibunch BPM is under the study.

Misc. studies

Pol.-positron study: pol. High brilliance Gamma-ray was generated.
Photo-cathode RF-gun was tested. Multibunch RF-gun study is in progress.
DR BPM upgrade is in progress.