Beam Transport Line

Kikuchi M./MAC/24Jan97

----

1. Transport line (Fig 1,2)

☐ Linac beam

normalized emittance	1.5e-3 (e+)	0.25e-3 (e-)
[unnormalized emittance	2.2e-7 (e+)	1.6e-8 (e-)]
energy spread	1.25e-3 (e+)	1.25e-3 (e-)

☐ Acceptance

transverse	2.6e-6 (e+)	2.6e-6 (e-)
energy spread	5e-3 (e+)	5e-3 (e-)

☐ Ring acceptance (worst case)

transverse	1.2e-5 (e+)	1.2e-5 (e-)
energy spread	5e-3 (e+)	5e-3 (e-)

1.1 Collimation system (Fig 1,3,4)

☐ Energy collimation

Necessary to match the energy acceptance of the ring as well as to reduce the beam loss in the tunnel.

Two sections are prepared:

BSY3 --- up to 10% is expected. Radiation shields accept 100% loss. (cf. simulation Fig 3,4)

Entrance of Arc-1 --- up to 1% is assumed. Radiation shields allow 1% loss.

Problem: Primary-beam scattered at the edge of collimator

Orbit of particles with energy loss Δ E and scattering angle $\Delta\theta$

$$x = R_{16}\Delta E / E + R_{12}\Delta\theta$$

R16 and R12 from BSY3 have their first maximum at downstream points which is not in the radiation-controlled area have no special shielding.

[R16 and R12 from the entrance of Arc-1 have also maximum at points in the Arc-1. Arc-1 is, however, in the radiation controlled area and there will be no problem.]

Quantitative estimation is undergoing.

☐ Emittance collimation

Two collimators which are 90 degree apart in each plane are placed in the slope of MR-Injection tunnel (for horizontal plane) and in the Arc-4 (for vertical plane). These places are deep in the underground and there will be no radiation problem.

1.2 Design of J-Arc (Fig 5,6)

Isochronous and achromatic with momentum band width of 1.8%.
Specification of Linac beam is $\pm$1.2%.

1.3 Magnets

Design is completed. All magnets were ordered and in fabrication

1.4 Beam position monitor etc.

☐ BPM (Fig 7,8,9,10)

Pick-up electrode L=15cm

Signal processing: 8 signals are combined through delay-cable. Combined signal are recorded in the digital oscilloscope. Overall speed is 1Hz. (Fig 7)

Experiment at the AR Injection line:

Precision < 0.16 mm (Fig 8)

Demonstrate a possibility of energy feedback to

Linac. (Fig 9,10)

☐ Wire scanner

Four wire scanners are installed at the straight section. (Fig 1)

2. Injection System

☐ Beta function at the injection point (Fig 11,12,13,14)

Beta-x of injection beam to minimize the injection aperture

[beam clearance 2.5 σ for injected beam

4 σ for circulating beam.

damping time 40ms (e-) 80ms (e+)

Effective septum-width 6mm]

--> Beta-x = 100 m

☐ Physical aperture at the septum

Decided the physical aperture at the septum as

1.2e-5 (e-) 2e-5 (e+) ,

corresponding to the septum position of 32mm(e-) and 43mm(e+) which are greater than aperture at the mask.

☐ Bump orbit

No DC-bump: use only kicker-bump in order to avoid adverse effects such as hysteresis of steering magnets, higher order dispersion and path length etc..

☐ Vacuum is not separated from the ring to avoid emittance increase due to multiple scattering in the window.

2.1 Septum magnets (Fig 15,16,17,18)

☐ Passive septum:

Full-sine 120 μ sec rather than half-sine 60 μ sec in order to reduce long-term leak field due to eddy current.

☐ Field stability of 0.5.10^-3 to decrease the injection amplitude due to septum jitter which is sizable if the field jitter is greater than 1.10^-3 .

2.2 Kicker magnets (Fig 19,20,21)

Lumped circuit type

		electrons		positrons	
		one-turn	multi-turn	one-turn	multi-turn
Deflection angle	mrad	0.34	0.37	0.825	0.87
Field	G	387	418	410	430
Current	kA	1.33	1.45	1.39	1.46
Pulse width	μ sec	2.5		2.5	
Frequency	Hz	50		50	
Vacuum chamber	mm^2	120w 85h		120w 85h	
Magnet length	m	0.25		0.25	
Number of magnet		4	3	4	3

☐ Power loss in the ceramic chamber

Power loss due to eddy current ~100w for 6 μ m (Fig19)

Power loss due to image current (Fig 20)

-Theory on axes-symmetric ceramic pipe with inner coating.
[A. Piwinski, IEEE NS-24 No3(1977)1364]

-Heating up of ferrite was not observed.

-Experiment is larger than the theory by factor of (5~8). (Fig 21)

-Power-loss in LER is estimated from theory multiplied by (5~8)
--> 715W~1140W for 6 μ m,
380W~610W for infinite thickness

Conclusion

Power loss is ~1kW in total ---> water-cooling is necessary.

3. Summary

☐ Acceptance of current design is compatible with the requirements of Linac and the rings.

☐ Collimation system has been designed.
Proposed collimator system is able to cut the energy tail of 10%.
Emittance collimation is also possible.

☐ Design of J-Arc has been completed. It is Achromatic and isochronous up to 1.8% and satisfies the specifications.

☐ Strip-line BPM system was developed. Precision is less than 0.2mm.

- ☐ Design of injection system.

  Prototype of passive septum magnet is under construction.
  Estimated power loss in the ceramic chamber amounts to 1kW.

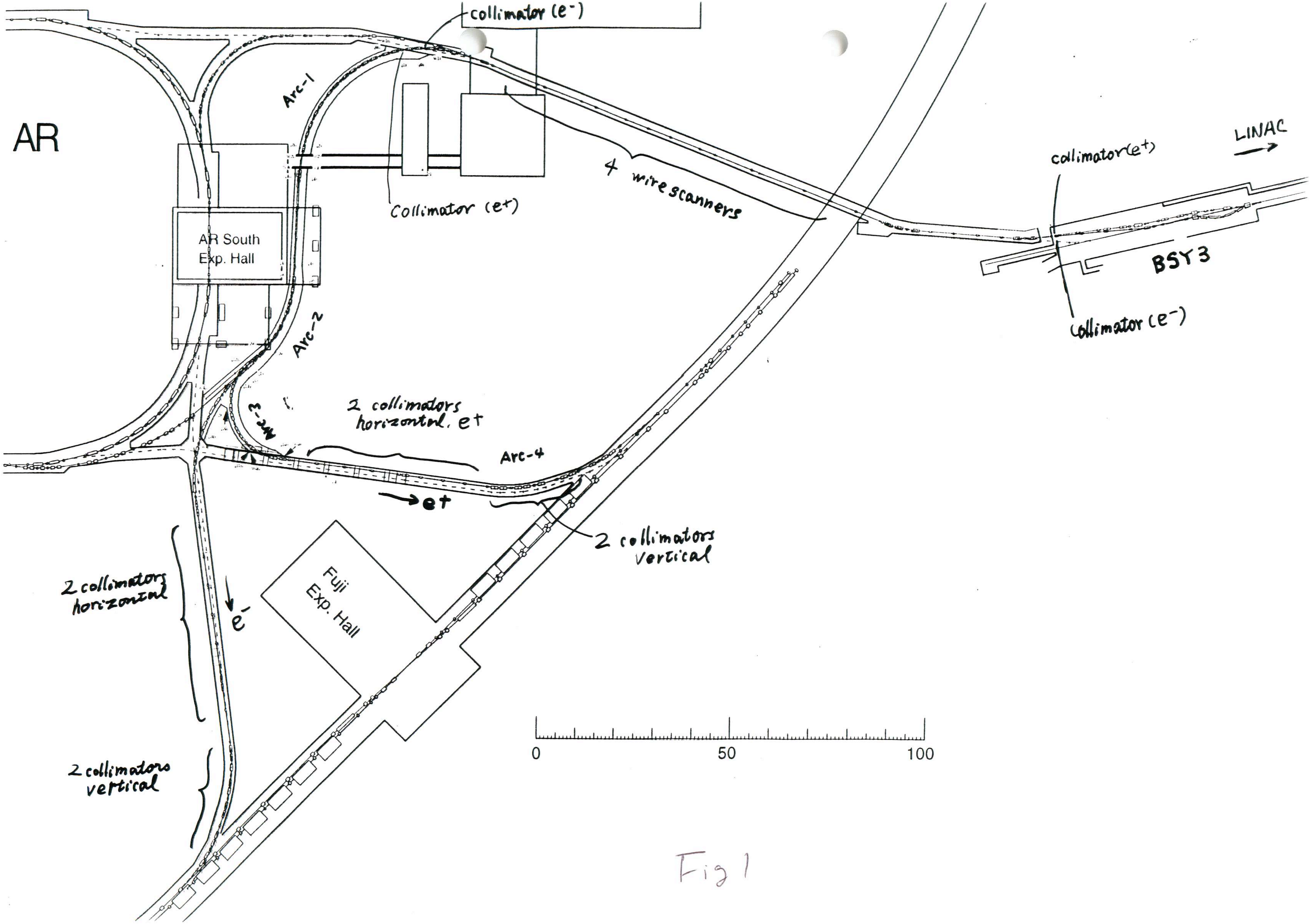
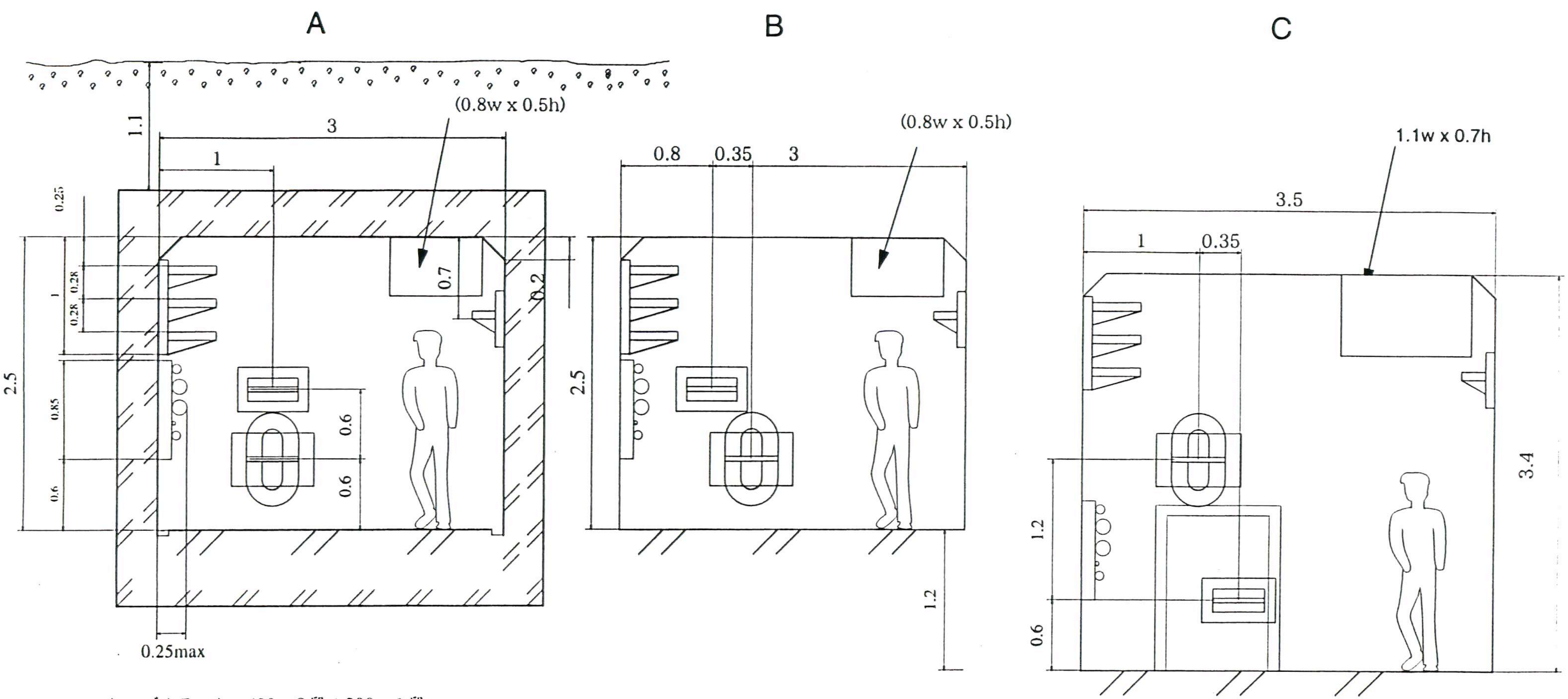

collimator (e-)
AR
Arc-1
AR South
Exp. Hall
Collimator (e+)
4 wire scanners
collimator(e+)
LINAC
BSY3
collimator (e-)
Arc-2
Arc-3
2 collimators
horizontal, e+
Arc-4
e+
2 collimators
vertical
Fuji
Exp. Hall
e-
2 collimators
horizontal
2 collimators
vertical
0
50
100

Fig 1



ケーブルラック：400w 3 段＋200w 1 段

0 0.5 1 1.5 2 2.5

TYPICAL CROSS SECTION

Fig 2

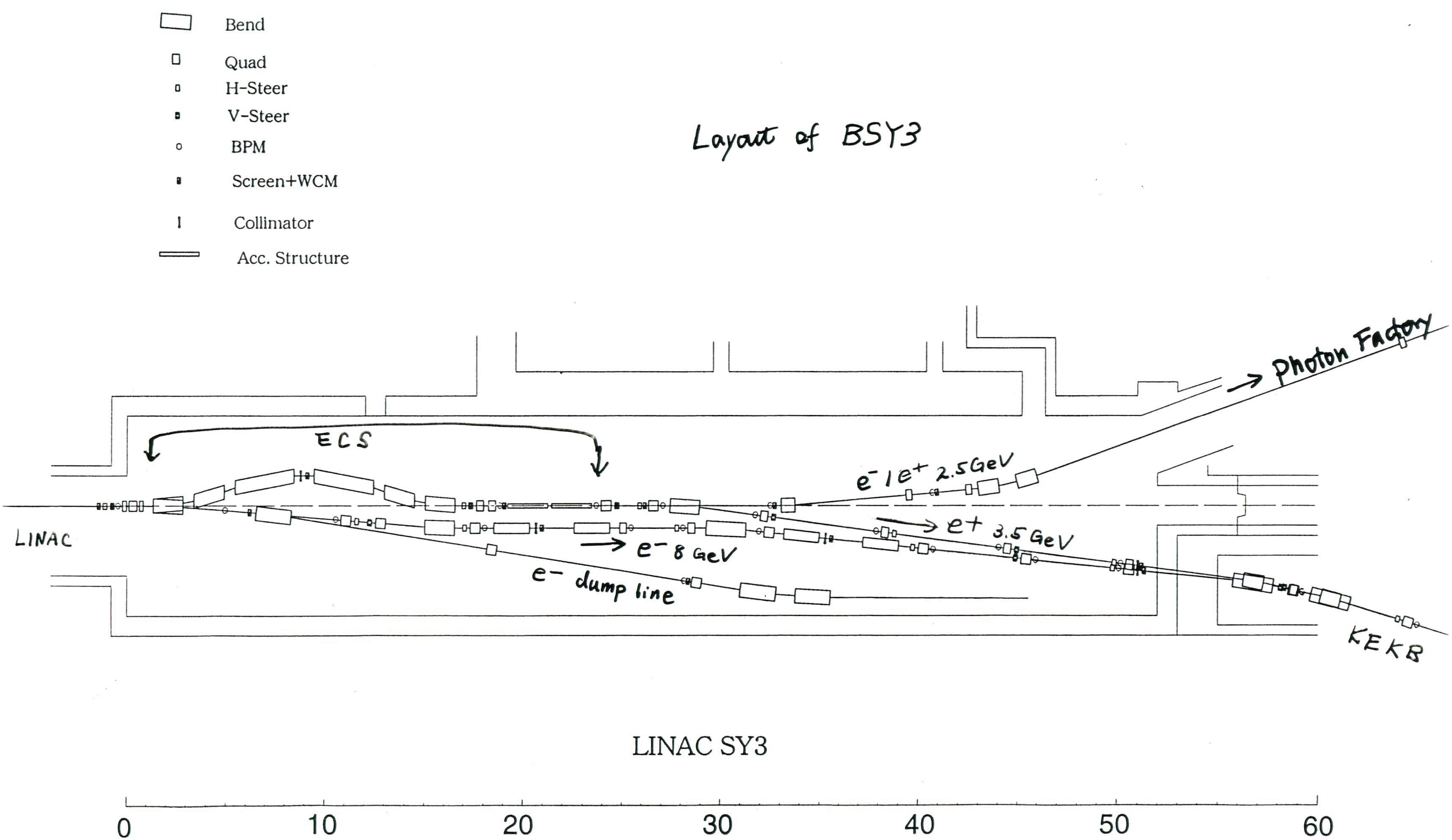

Bend
Quad
H-Steer
V-Steer
BPM
Screen+WCM
Collimator
Acc. Structure
Layout of BSY3
ECS
LINAC
→ Photon Factory
e⁻/e⁺ 2.5GeV
→ e+ 3.5 GeV
→ e⁻ 8 GeV
e⁻ dump line
KEKB
LINAC SY3
0
10
20
30
40
50
60

Fig. 2

Positrons after ECS

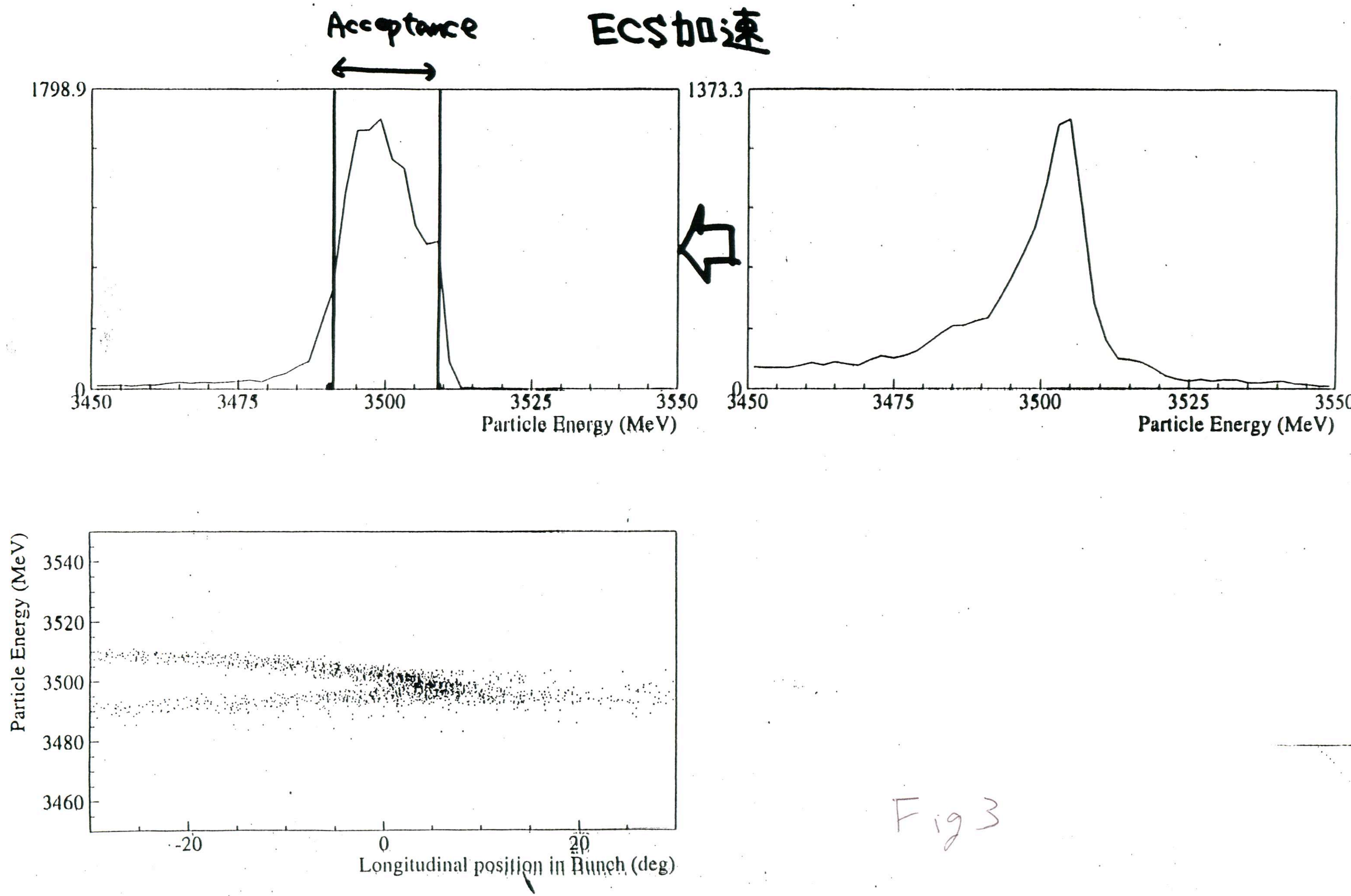
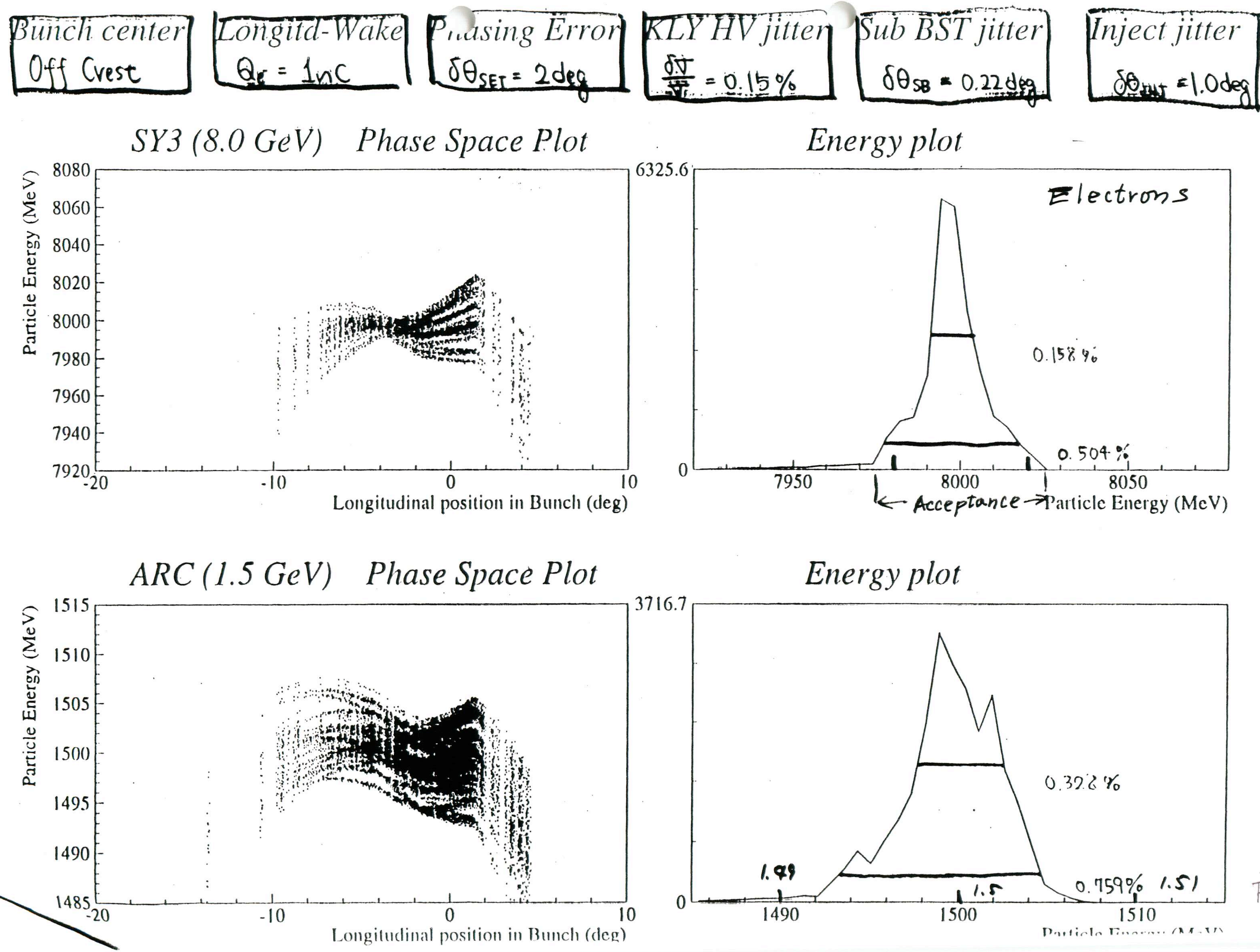


Fig 3

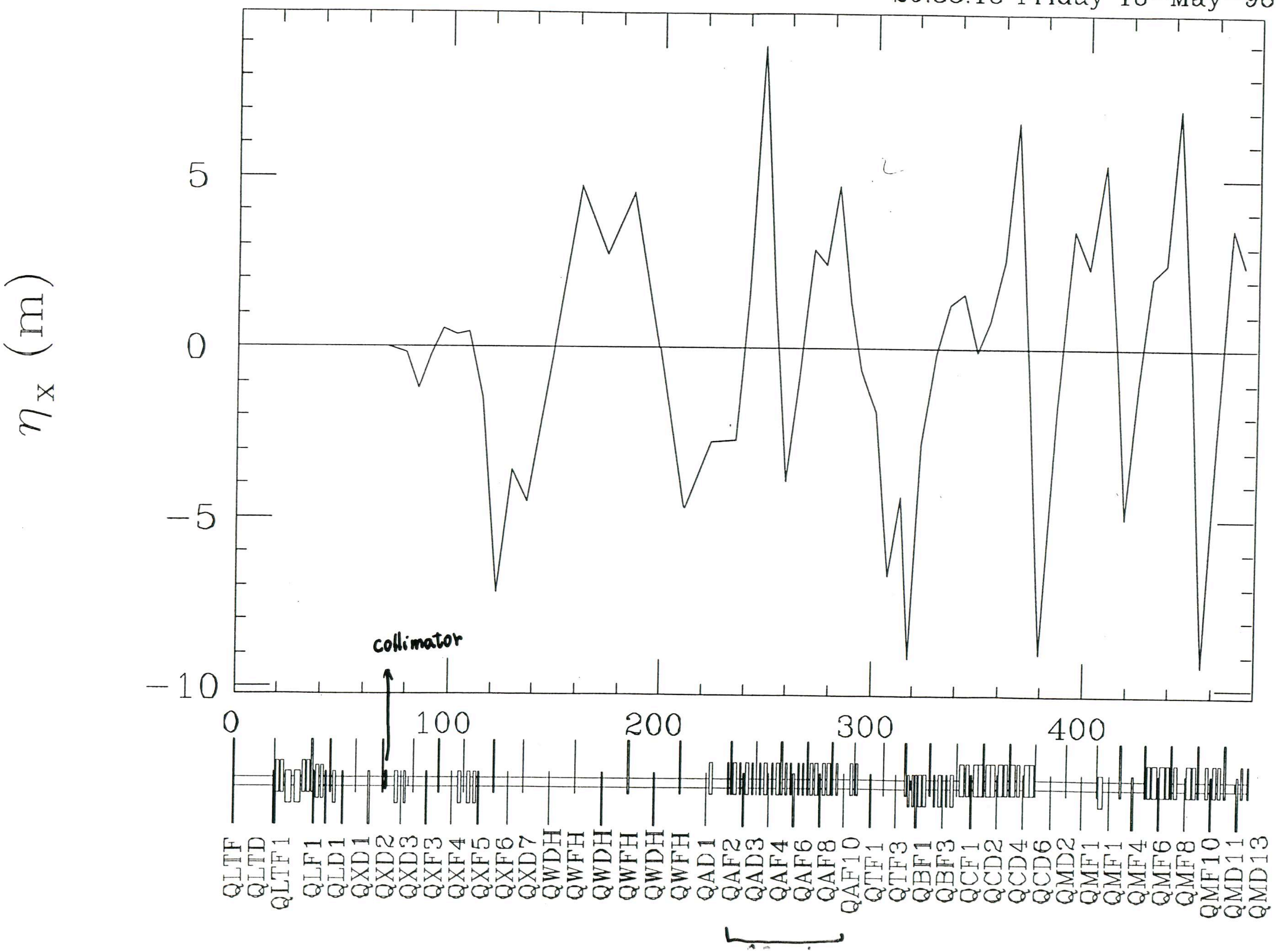


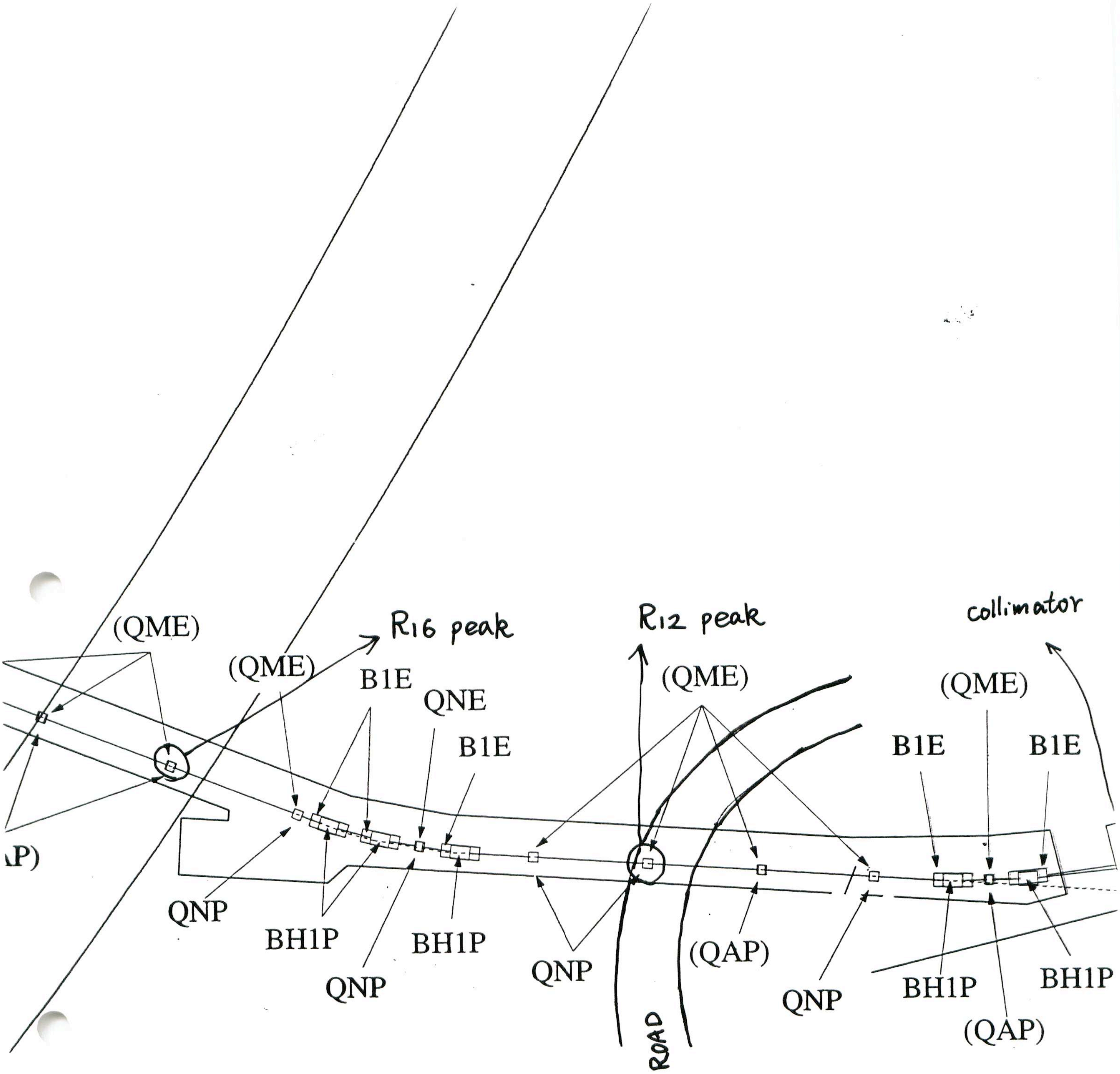
Bunch center
Off Crest
Longitd-Wake
Q_T = 1nC
Phasing Error
$\delta\theta_{SET}$ = 2deg
KLY HV jitter
$\frac{\delta V}{V}$ = 0.15%
Sub BST jitter
$\delta\theta_{SB}$ = 0.22deg
Inject jitter
$\delta\theta_{INJ}$ = 1.0deg
SY3 (8.0 GeV) Phase Space Plot
Particle Energy (MeV)
Longitudinal position in Bunch (deg)
Energy plot
Electrons
0.158%
0.504%
Acceptance
Particle Energy (MeV)
ARC (1.5 GeV) Phase Space Plot
Particle Energy (MeV)
Longitudinal position in Bunch (deg)
Energy plot
0.328%
0.759%
1.49
1.5
1.51

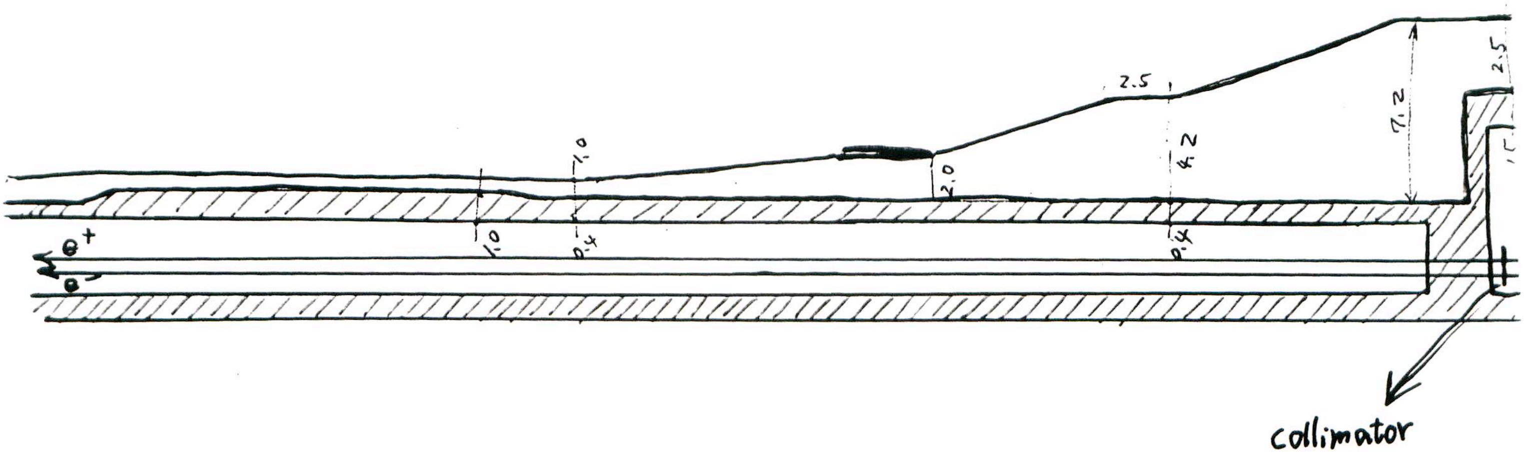
Fig 4

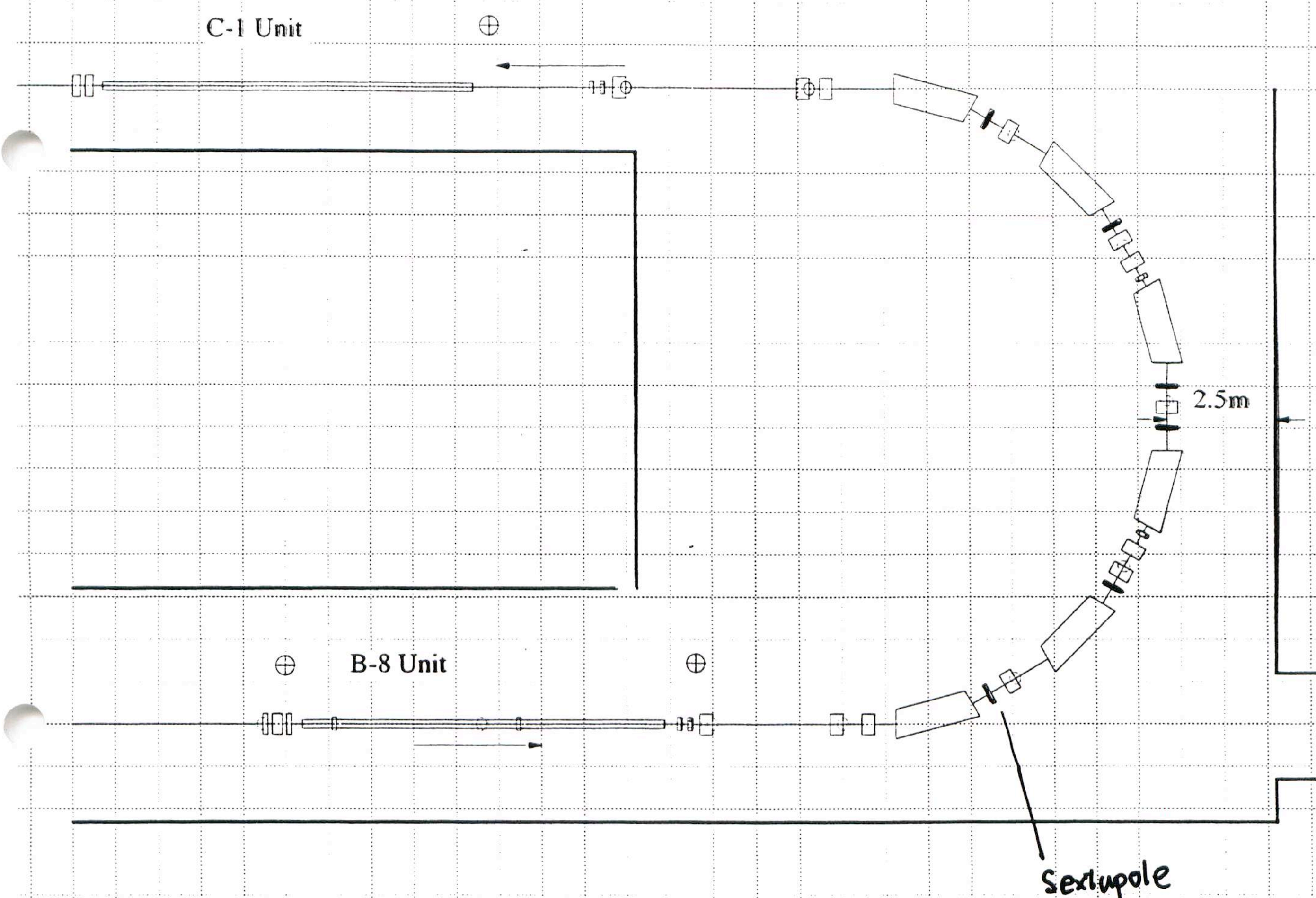
Positron Line V9.124:R16 from QXF2

20:33:13 Friday 10-May-96




(QME)
(QME)
R16 peak
B1E
QNE
B1E
R12 peak
(QME)
collimator
(QME)
B1E
B1E
AP)
QNP
BH1P
BH1P
QNP
QNP
(QAP)
QNP
BH1P
BH1P
(QAP)
ROAD

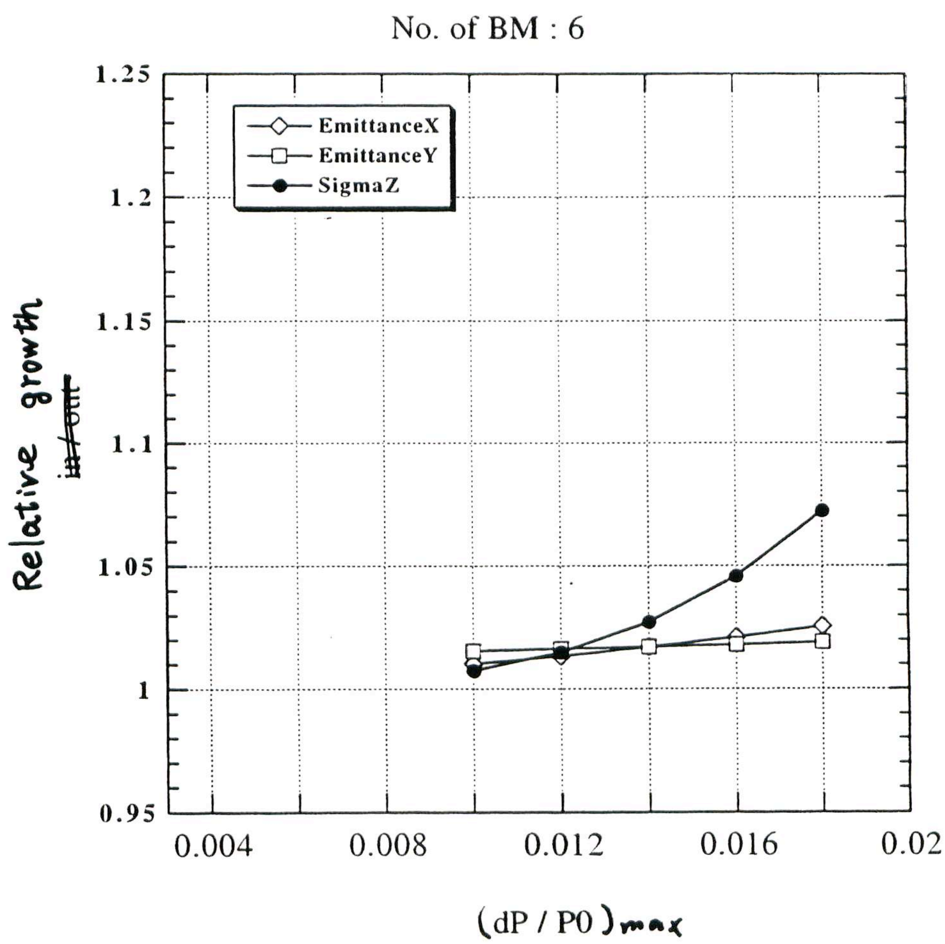

collimator

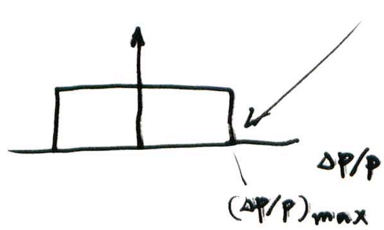


Layout of J-Arc

Fig 5

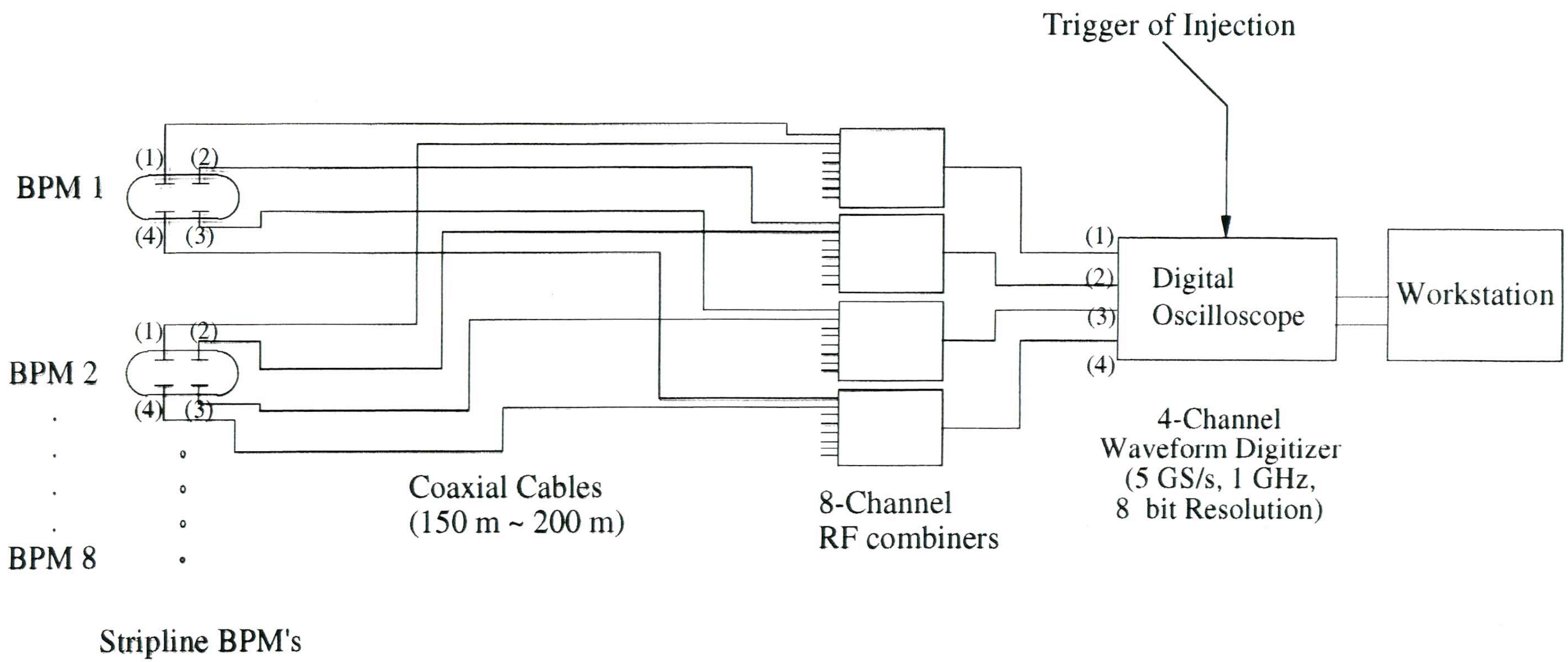
Emittance growth in J-arc





uniform distribution
in momentum

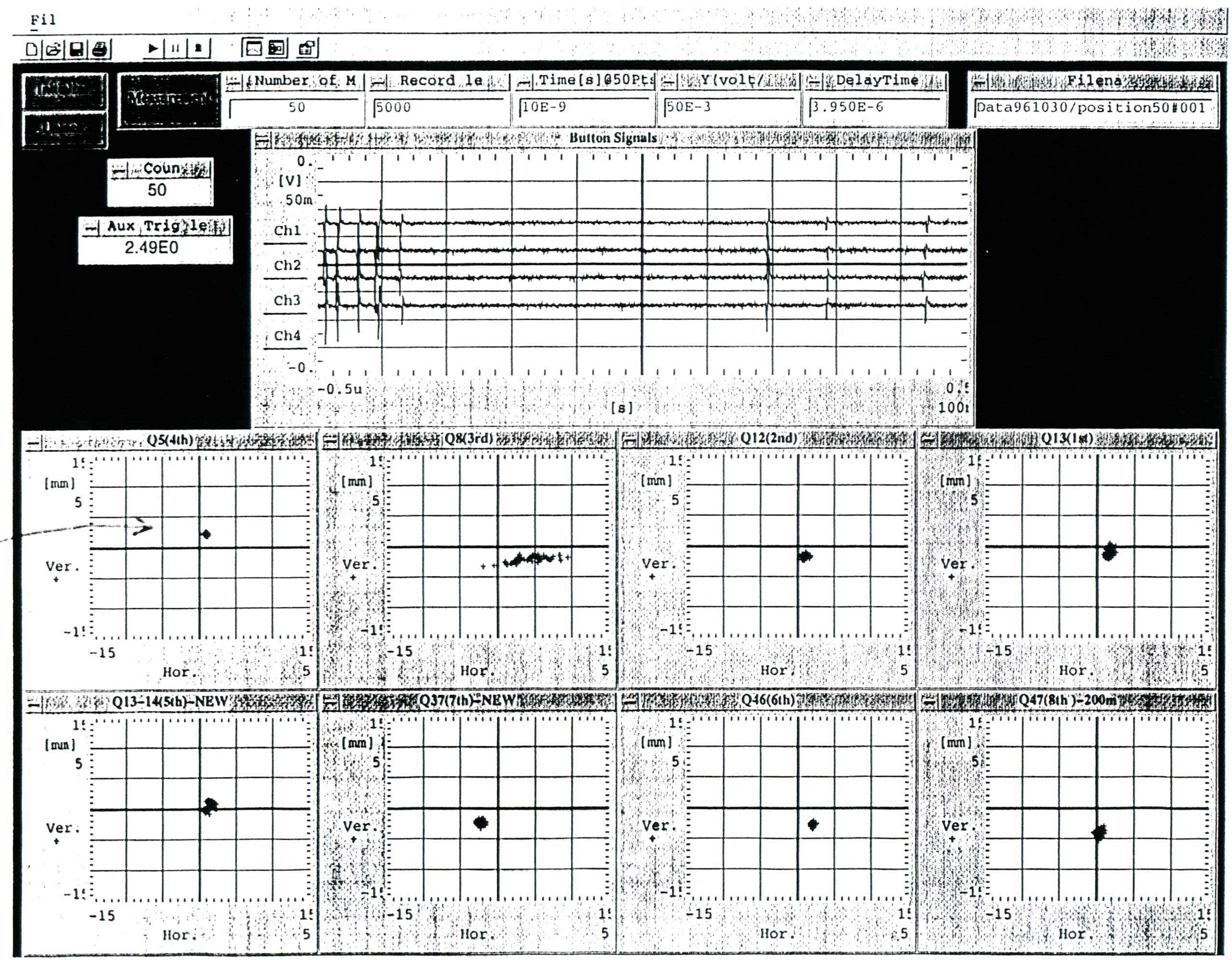
Fig 6



Signal processing scheme of the single-pass BPM system

Fig 7

Wed 30/Oct/1996 19:30:34 JST



50 data

標準偏差
standard deviation
2.16 mm

Fig.8

'96 10/29(火) フィードバックなし

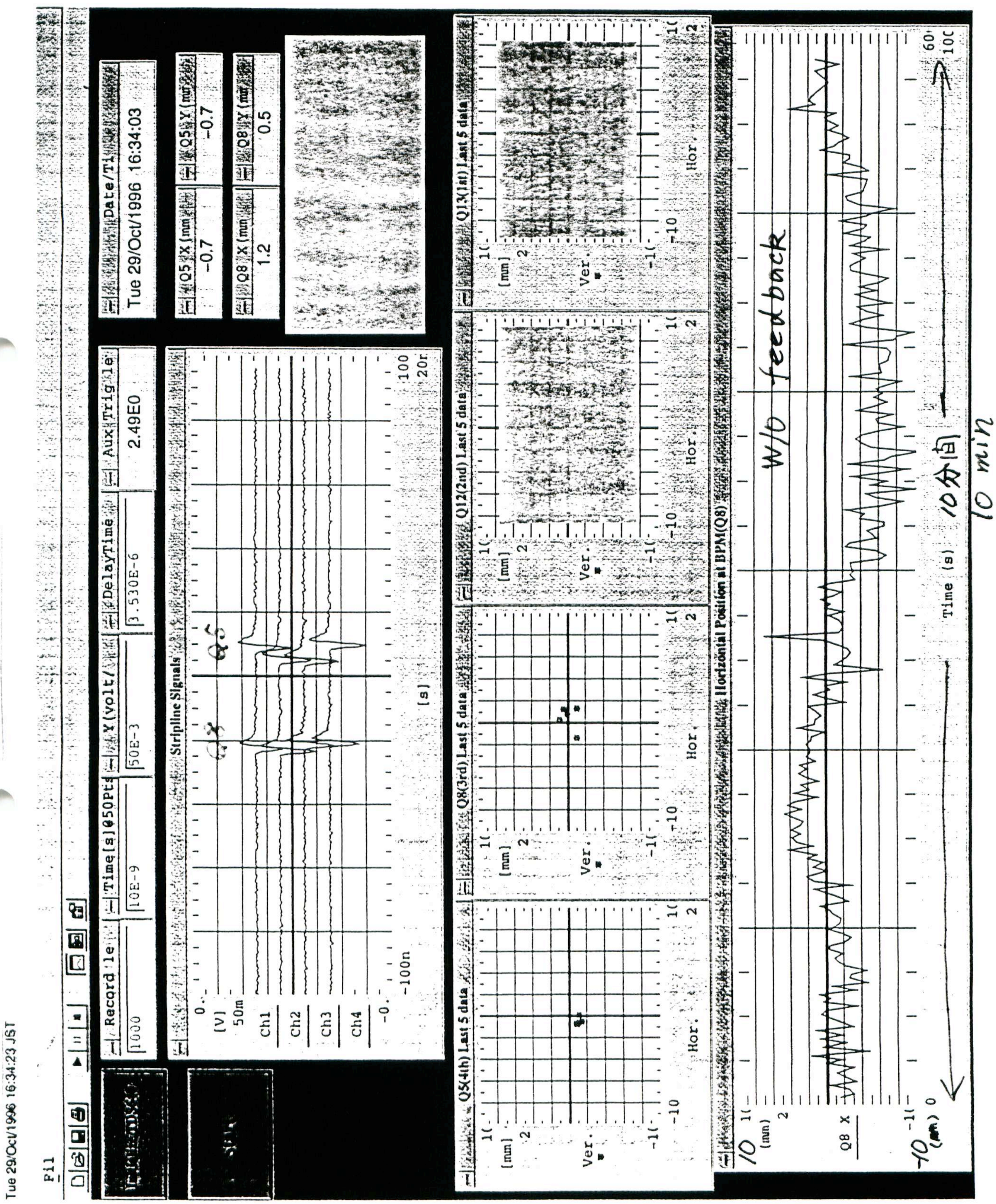


Fig 9

Klystron 5-8 rf-phase feedback

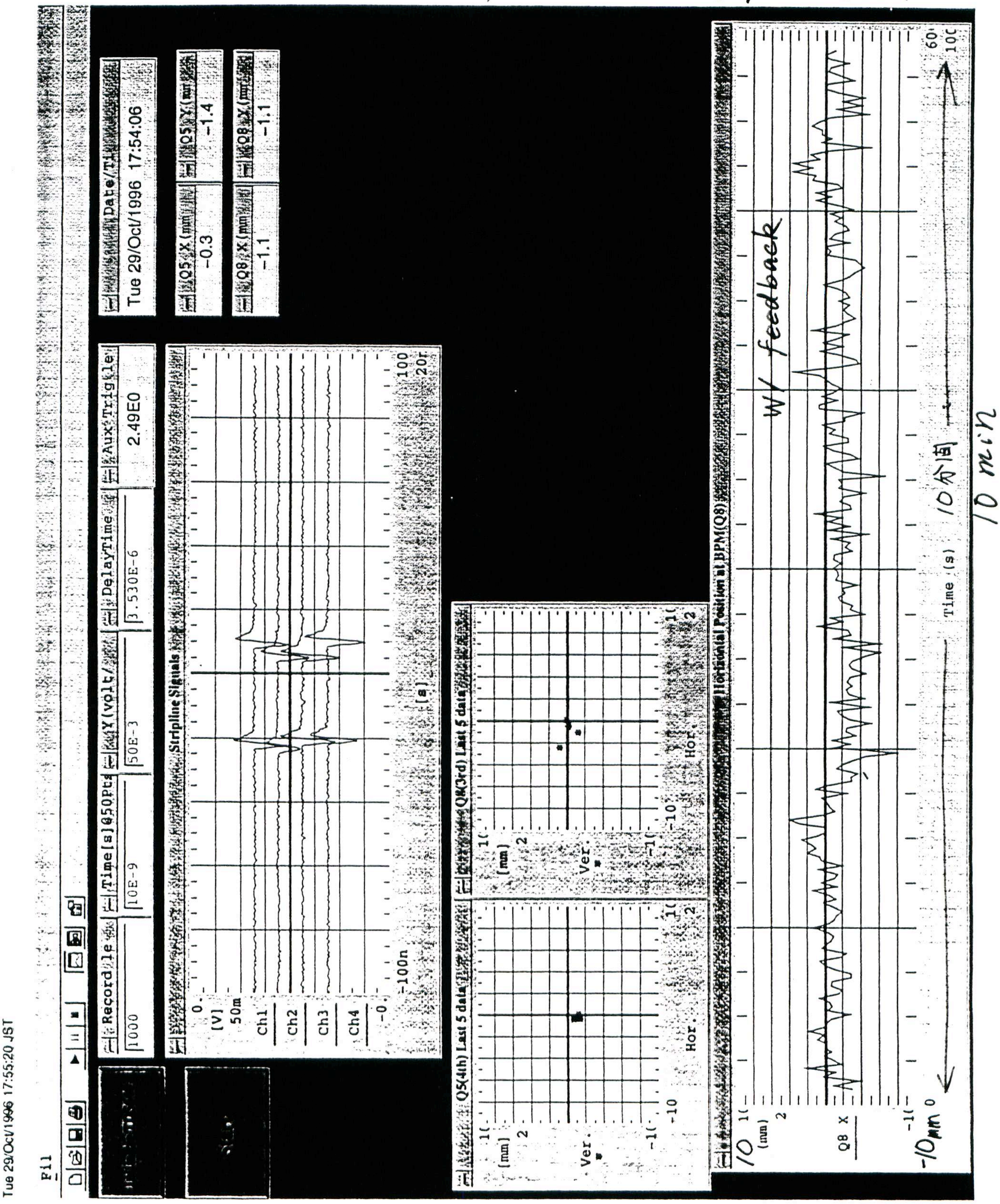


Fig 10

Electron

e−:2Ji(micro m) for beta (RING)={40,60,80,100,120} m

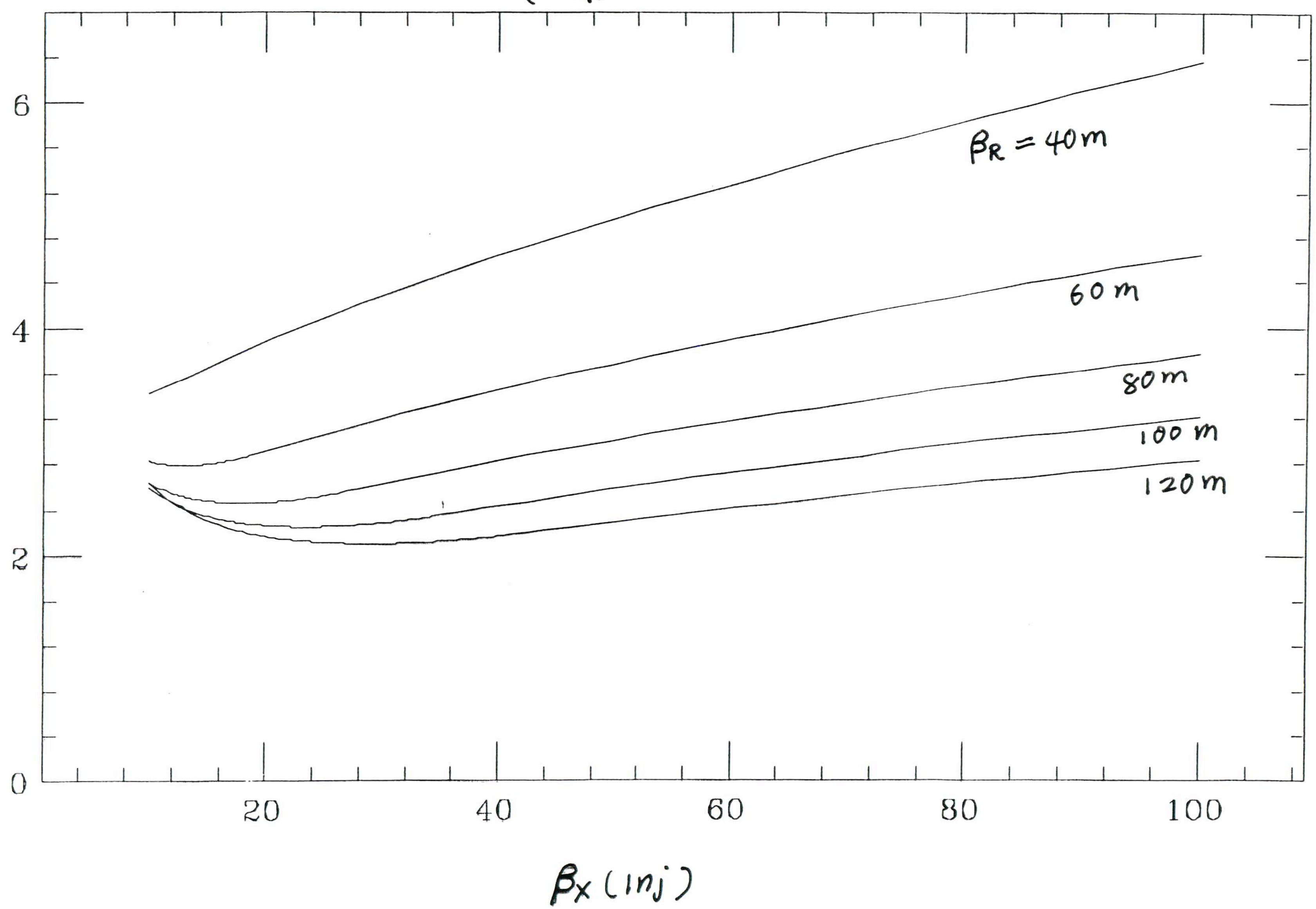


Fig 11

Positron

e+:2Ji(micro m) for beta={40,60,80,100,120} m (RING)

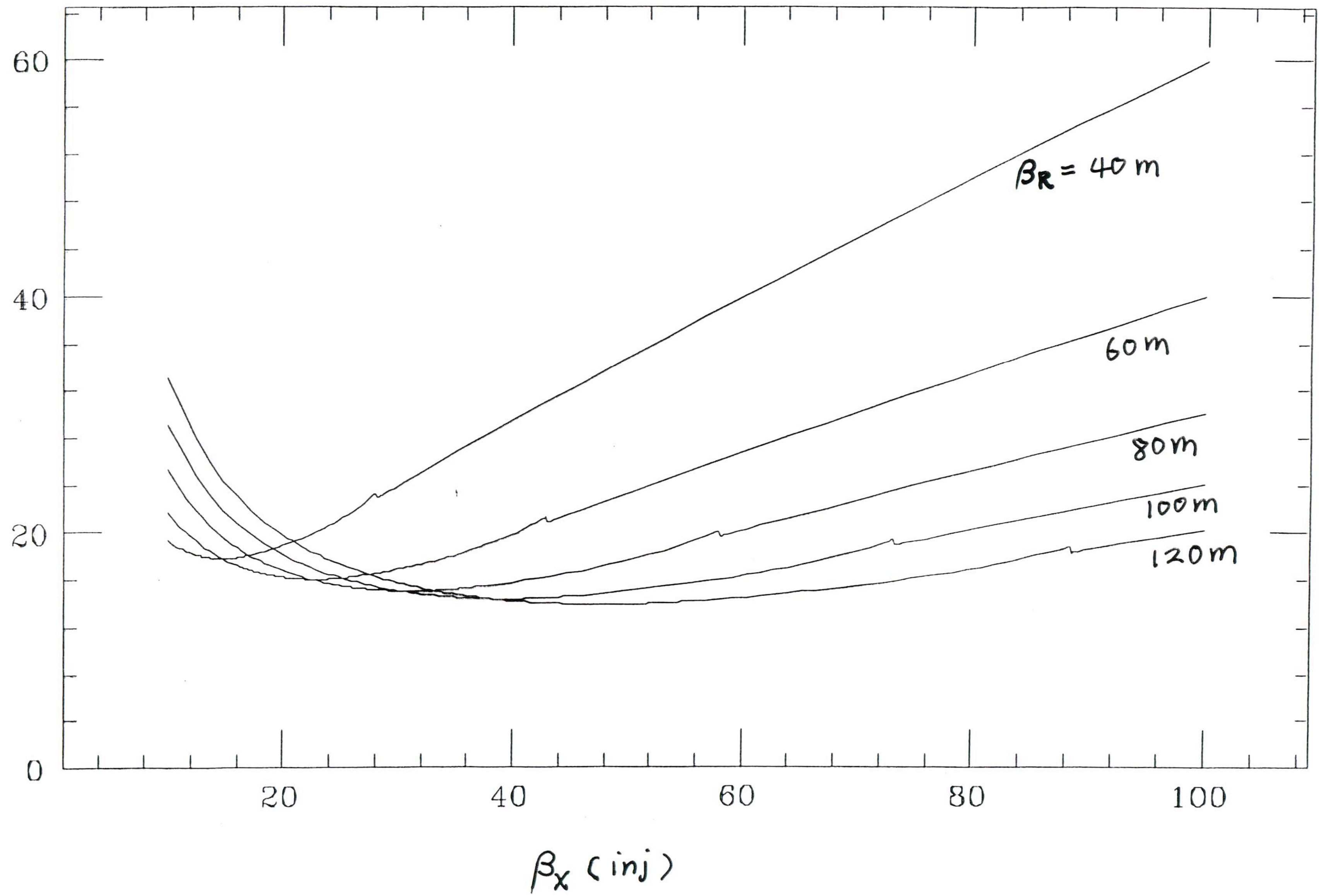


Fig 12

Electron

Ring emittance	1.80E-08	(m)
Inj emittance	1.60E-08	(m)
Septum jitter	0.1	(%)
Rep time	100	(ms)
Damping time	40	(ms)
--- at QM5 ----		
Ring beta	89.7375	(m)
Inj beta w/o septum jitter	20	(m)
Inj beam-size w/ septum jitter(2.5 sigma)	1.86171	(mm)
w/o septum jitter(2.5 sigma)	1.41421	(mm)
Ring beam-size(4 sigma)	5.08374	(mm)
Effective septum-width	6.24326	(mm)
Injection aperture	5.14E-06	(m)
--- at the septum ---		
Ring beta	83.0356	(m)
Inj beta	9.2	(m)
Inj beam-size(2.5 sigma)	1.796	(mm)
Ring beam-size(4 sigma)	4.89022	(mm)
Effective septum-width	6	(mm)
Aperture at the septum	1.20E-05	(m)
Position at Kicker	26.676	(mm)
Angle "	-1.7283	(mrad)
Maximum amplitude of injected beam	20.669	(mm)
Septum position	31.5662	(mm)
DC-bump height	0	(mm)
" angle	0	(mrad)
Inj position	39.3622	(mm)
" angle	-2.7478	(mrad)
--- Magnet strength ---		
Kicker	0.930091	(mrad)
DC-bumper	0	(mrad)

kicker max $\frac{32}{26.7} \times 0.93 = 1.11$

one-turn $\frac{39.4}{26.7} \times 0.93 = 1.37$

Fig 13

Positron

Ring emittance	1.80E-08	(m)
Inj emittance	2.20E-07	(m)
Septum jitter	0.1	(%)
Rep time	100	(ms)
Damping time	80	(ms)
--- at QM5FL ----		
Ring beta	102.145	(m)
Inj beta w/o septum jitter	25	(m)
Inj beam-size w/ septum jitter(2.5 sigma)	6.02147	(mm)
w/o septum jitter(2.5 sigma)	5.86302	(mm)
Ring beam-size(4 sigma)	12.1425	(mm)
Effective septum-width	6.31503	(mm)
Injection aperture	1.63E-05	(m)
--- at the septum ---		
Ring beta	92.3	(m)
Inj beta	17.1909	(m)
Inj beam-size(2.5 sigma)	5.72653	(mm)
Ring beam-size(4 sigma)	11.5425	(mm)
Effective septum-width	6	(mm)
Position at Kicker	31.4226	(mm)
Angle "	3.32048	(mrad)
Maximum amplitude of injected beam	38.8213	(mm)
Aperture at the septum	2.00E-05	(m)
Septum position	42.9651	(mm)
DC-bump height	0	(mm)
" angle	0	(mrad)
Inj position	54.6916	(mm)
" angle	6.29991	(mrad)
--- Magnet strength ---		
Kicker	1.9063	(mrad)
DC-bumper	0	(mrad)

kicker max $\frac{43}{31.4} \times 1.906 = 2.61$

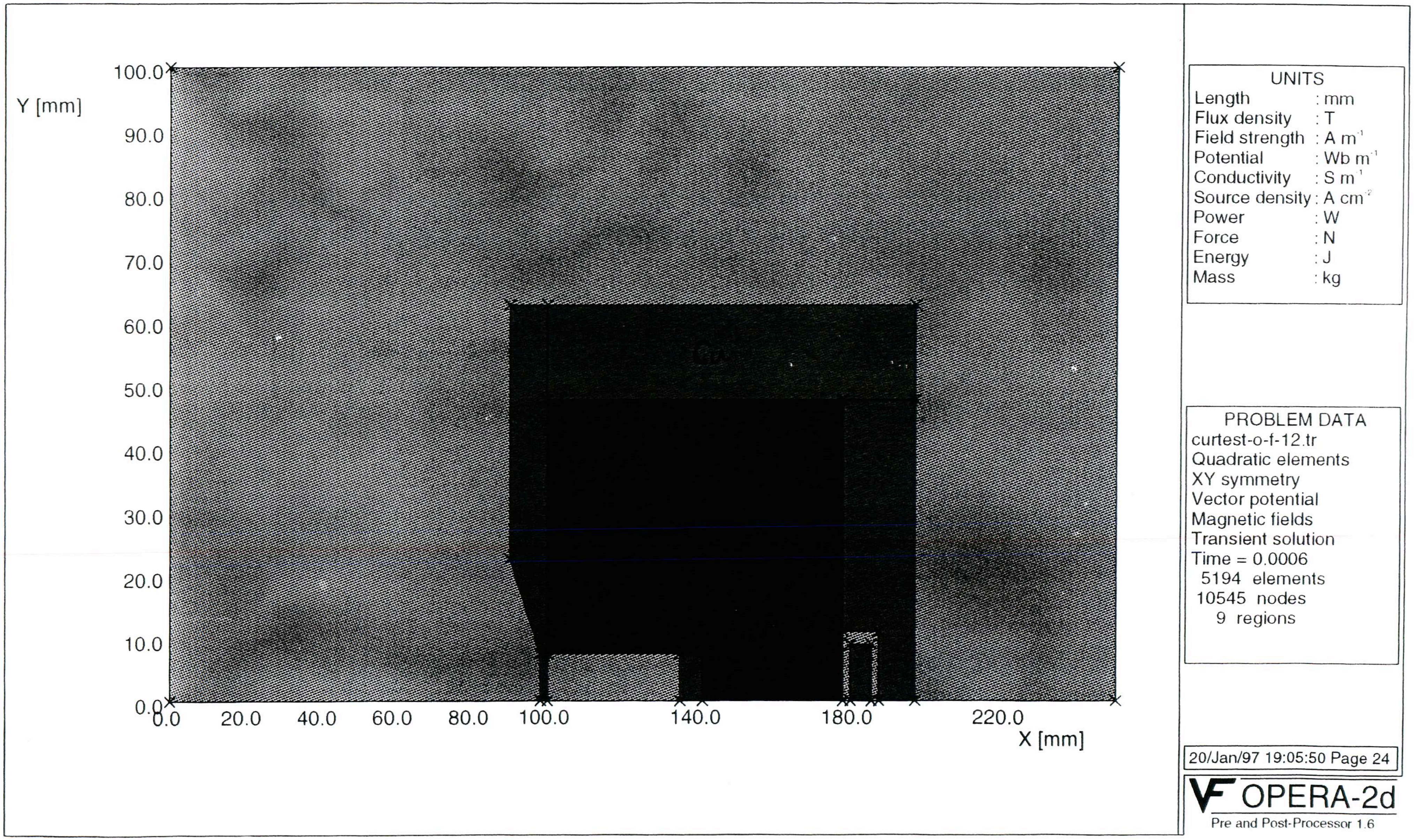
one-turn $\frac{54.7}{31.4} \times 1.906 = 3.32$

Fig 14

Passive septum parameter(e-)

Deflection angle(mrad)	40
Peak magnetic field(T)	1.2
Septum thickness(mm)	1
Free aperture(mm)	$10^{H} \times 38^{W}$
Core length(m)	1
Number of turn	1
Magnet inductance(μ H)	6.1
Pulse width(μ sec)	120
Repetition(Hz)	50
Peak current(kA)	9.0
Peak voltage(kV)	3.4
Current stability(%)	0.05

Fig 15



100.0
Y [mm]
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
20.0
40.0
60.0
80.0
100.0
140.0
180.0
220.0
X [mm]
UNITS
Length : mm
Flux density : T
Field strength : A m⁻¹
Potential : Wb m⁻¹
Conductivity : S m⁻¹
Source density : A cm⁻²
Power : W
Force : N
Energy : J
Mass : kg
PROBLEM DATA
curtest-o-f-12.tr
Quadratic elements
XY symmetry
Vector potential
Magnetic fields
Transient solution
Time = 0.0006
5194 elements
10545 nodes
9 regions
20/Jan/97 19:05:50 Page 24
OPERA-2d
Pre and Post-Processor 1.6

Fig 16

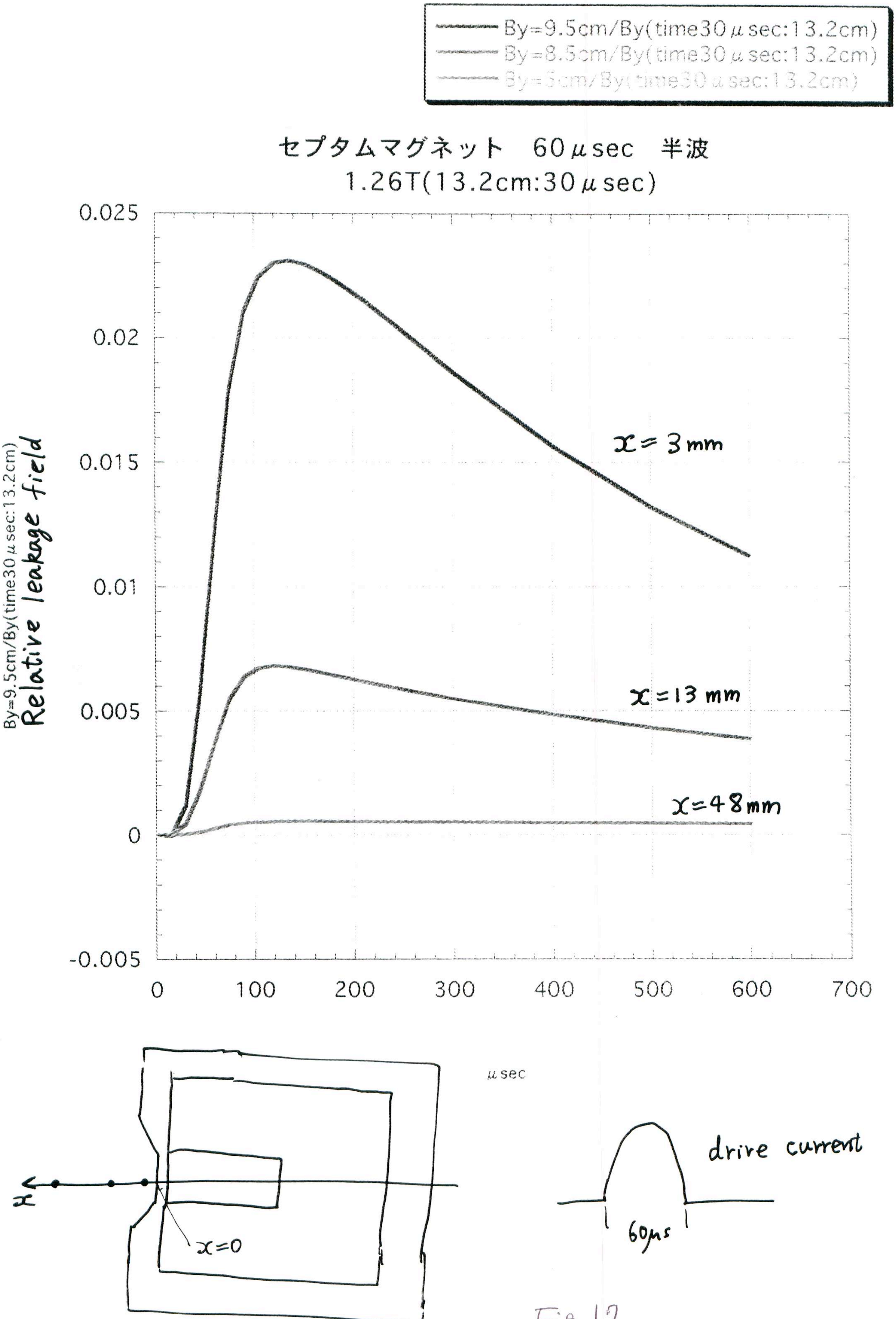

By=9.5cm/By(time30μsec:13.2cm)
By=8.5cm/By(time30μsec:13.2cm)
By=5cm/By(time30μsec:13.2cm)
セプタムマグネット　60μsec　半波
1.26T(13.2cm:30μsec)
By=9.5cm/By(time30μsec:13.2cm)
Relative leakage field
0.025
0.02
0.015
0.01
0.005
0
-0.005
0
100
200
300
400
500
600
700
μsec
x=3mm
x=13 mm
x=48mm
x
x=0
drive current
60μs

Fig 17

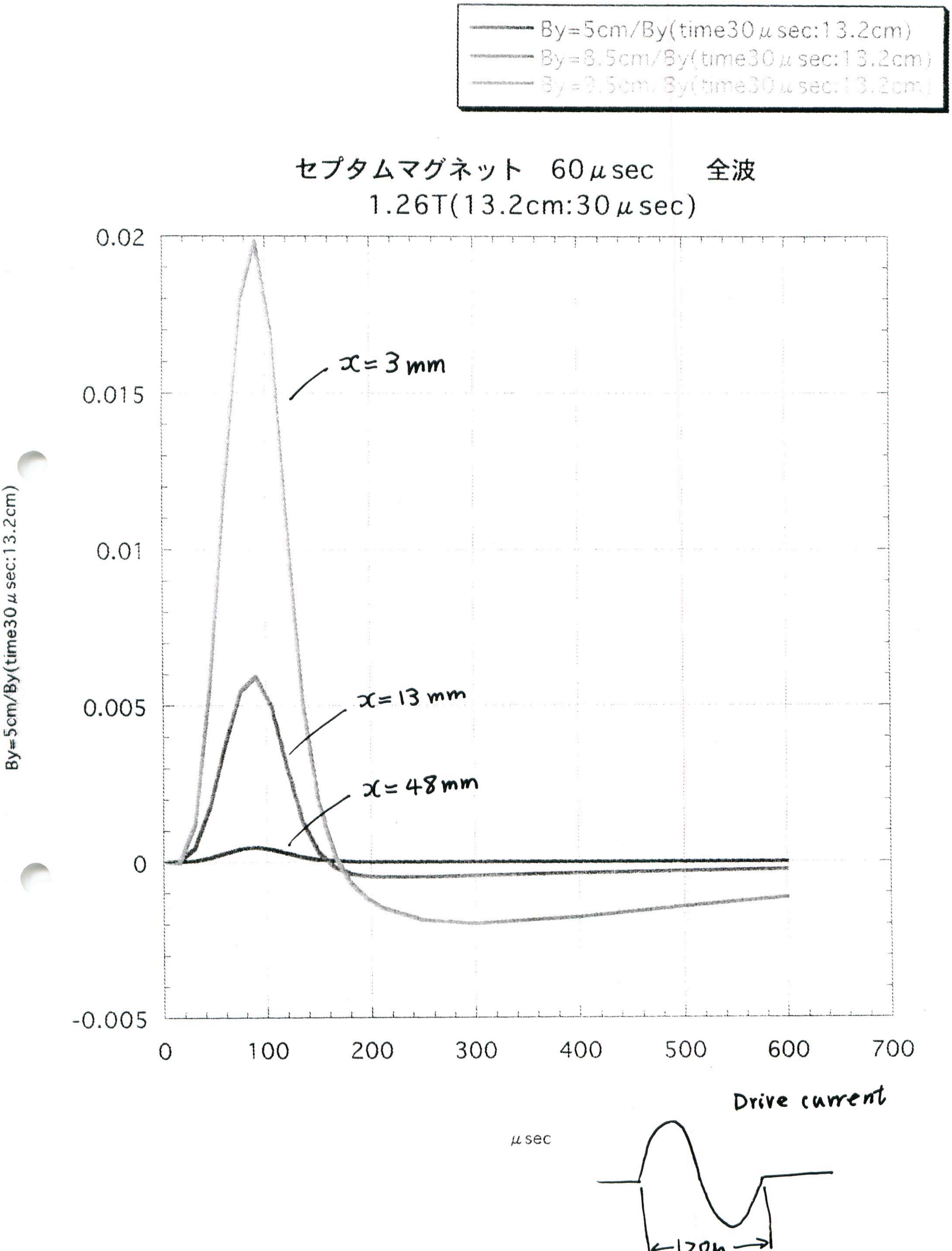

By=5cm/By(time30μsec:13.2cm)
By=8.5cm/By(time30μsec:13.2cm)
セプタムマグネット 60μsec 全波
1.26T(13.2cm:30μsec)
By=5cm/By(time30μsec:13.2cm)
0.02
0.015
0.01
0.005
0
-0.005
0
100
200
300
400
500
600
700
x=3 mm
x=13 mm
x=48 mm
μsec
Drive current
120μ

Fig 18

Test of the ceramic chamber for KEKB Kicker Magnet system

1997 Jan

KEKB Beam Transport Group

1: Power Dissipation due to Eddy Currents

Bench Test

B = 0.675 K Gauss

Frequency 50 Hz

Ceramic chamber coating thickness 2.5 μm 6 μm

Power Loss	Test Bench	Calculation
2.5 μm (W)	40W	65W
6 μm (W)	60W	120W

Fig 19

2:Power Dissipation due to Image Currents

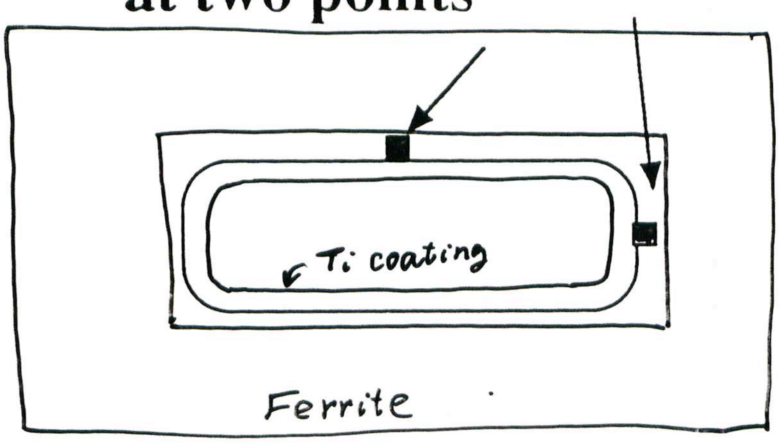
<AR large current accelerator study in 1996>

Setup

Three Kinds of ceramic Chambers are installed on AR east side straight section .

The temperatire were measured at the two positions of each chamber.

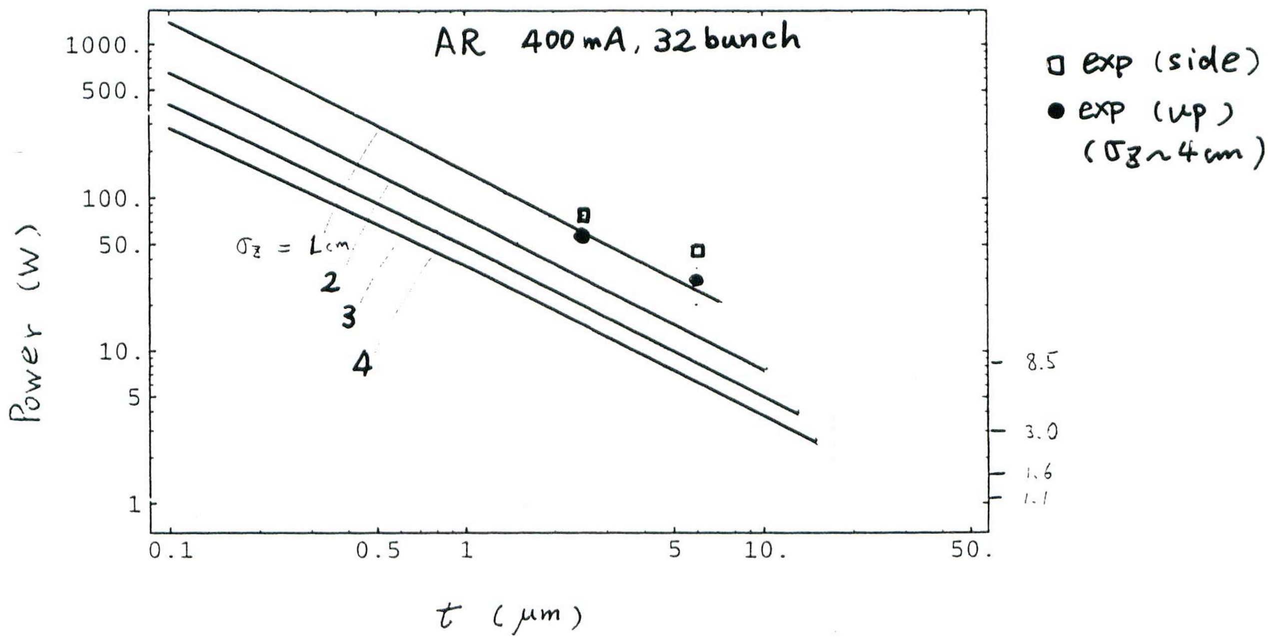
Measure Temperature at two points



Coating Thickness

Chamber 1	2.5 μ m	
Chamber 2	4 μ m	← water-cooled at fringes
Chamber 3	6 μ m	

Fig 20


AR 400 mA, 32 bunch
□ exp (side)
● exp (up)
(σz ~ 4 cm)
σz = 1 cm
2
3
4
8.5
3.0
1.6
1.1
Power (W)
t (μm)

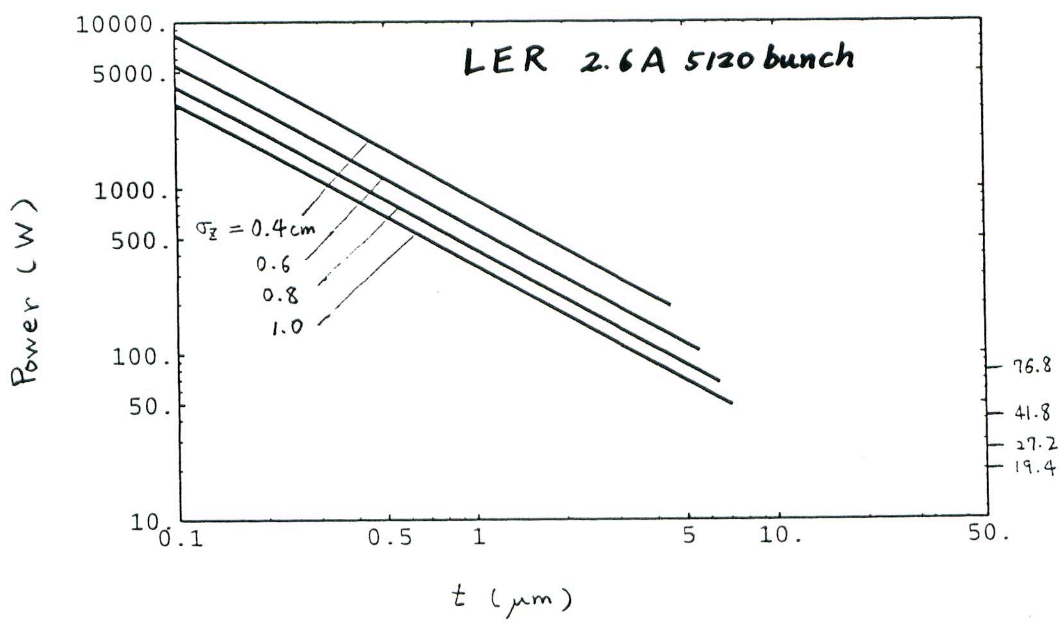

LER 2.6A 5120 bunch
σz = 0.4 cm
0.6
0.8
1.0
76.8
41.8
27.2
19.4
Power (W)
t (μm)

Fig 21