OVERVIEW OF BEAM INSTRUMENTATIONS

KEKB Beam Monitor Group

S.Hiramatsu

1. Beam Position Monitors* (BPMs)
2. Beam Current Monitors (DCCTs)
3. Beam Loss Monitors (Ionization chambers)
4. SR Monitors* (SR Image, Streak camera & Interferogram)
5. Others

   Turn-by-turn BPMs

   Bunch current & Tune monitors*

   Fast CTs

   Wall-current monitors (not installed yet)

   Realtime Bunch-length monitors (on tuning)

   Direct BPM button signals (instead of screens)

   IP BPMs

   Bunch-by-bunch feedback*

*Detailes of the BPM system, Synchrotron Light Monitors and the Bunch-by-bunch Feedback System will be presented separately by Tejima, Mitsuhashi and Kikutani.

1. Beam Position Monitors

- Electrostatic pickup with 4 buttons (12mmϕ)

  454 BPMs @ LER / 443 BPMs @ HER

- All BPMs were calibrated at the calibration stand.

  calibration error; <20μm

- Setting errors against the Q-magnet reference were measured with laser displacement sensors.

  measuring error; <50μm

- Electronics system is installed in VXI stations distributed in 20 local control buildings (LC).

  22-24 BPMs / LC/ Ring

  Interfaced by VME to FDDI (EPICS)

- Measurable range; 1mA-2.6A (desired >10mA for resolution)

  max. bunch current <2mA to avoid electronics damage

- Frontend electronics (special 240 VXI modules)

  superheterodyne (signal; 1GHz, IF; 20kHz)

  beam signal detection; spectrum analysis by DSP

  max. S/N~90-92dB ; position error 0.5-1μm(rms)

  (8 average of 2048-point FFT)

- Processing time; proportional to S/N (resolution)

  <1sec/BPM at max. S/N~90-92dB

- One frontend processes 4 BPMs(2 of LER & 2 of HER) .

  available for extension to 480 frontends ⇒ 2nd step?

- Measured resolution; 1-5μm (average ~2μm) @ I_b=11mA

- **Need to calibrate center offsets with beams; on going program**

2.DCCTs

- Developed KEKB-original DCCTs.

  measurable range; 100μA-3A (target; 10μA-3A)

  response; DC-10kHz

  drift; ~3μA/deg

- A new feedback circuit free from the modulation-ripple by the magnetic-core unbalance was developed.
- Used for the beam stopper trigger.

3. Beam Loss Monitors

- 109 (5 m long)/23 (8-10m long) ion-chambers made of air-insulated coaxial cables FC-20D were distributed in the KEKB tunnel / BT line.
- System sensitivity (for a 5m long ion-chamber);

  9.1mV/mR (@x1) /91mV/mR (@x10) /910mV/mR(@x100)

- 8 ion-chambers at BT line are used for the radiation safety interlock.
- Ion-chambers at ring are used for beam tuning and beam abort trigger.

4. Synchrotron Radiation Minitors

- SR-extraction & Primary optical lines

  LER; FUJI(QR4/QR5)-D8 (40m)

  HER; OHO(QR3/QR4)-D4 (40m)

- Primary beam extracted by a Be mirror will be divided into 3 lines.

  (a) Beam image - focused onto CCD camera

  Diffraction spreading of 30-40μm will be corrected.

  (b) Streak camera - measurement of bunch length and structure

  (c) Double-slit interferometer - beam size & profile measurement

  Measured vertical beam size; σ=240μm (HER @157mA).

- Wavefront distortion by the extraction mirror deformation will be corrected in real time by **wavefront-correction-mirror** (servo-controlled deformable mirror with 31 piezo-actuators) and Shack-Hartmann interferometers to monitor the mirror deformations.

  * WII be installed in April.

5.Others

5-1 Turn-by-turn BPMs

- 4 BPMs in LER and 4 BPMs in HER can be switched to turn-by-turn BPM detectors which are wideband signal processors with ~20MHz bandwidth.
- 509MHz component of the pickup signal is processed by wideband synchronous detectors.

x/y-resolution at test bench;	~50μm @I_b=0.1mA
phase resolution;	~0.5deg
rf-clock phase dependence;	~ ±100μm

5-2 Bunch Current and Tune Measurement

- Bunch current is detected by the frontend similar to that of the bunch-feedback system using $\cos(4\omega_{rf}t)$ reference.
  * Available for 50Hz data-processing of 5000 bunches.
  * Beam injection is controlled by bunch-current monitors.
- Transverse and longitudinal tunes are measured by spectrum analyzers using feedback kickers to excite beam oscillations.

5-3 Fast CTs

- Each ring of LER and HER has a fast CT for rough observation of beam bunch configulation in the early stage of commissioning.
- Response; ~nsec

5-4 Wall Current Monitors

- Wall current monitors for bunch identification in LER and HER are planned.
- Completed design & fabrication but not installed yet (~ April?).

5-5 Realtime Bunch-length Monitors

- Bunchlength is estimated from the ratio of two frequency components of the button signal.

  f_1=509MHz, f_2=2.54/3.56/4.07/4.58/5.09GHz

- Under tuning with a streak camera of the SR monitor.

5-6 Direct BPM Button Signals

- KEKB-rings have **no screen monitor.**
- Direct signals of 4 pickup electrodes of each BPM was monitored at local stations instead of screen monitors.

  * detectable bunch current ~10μA (charge ~0.1nC)
- Digital oscilloscope images were sent to CCR by videos.
- The location where the beam was lost and the rough displacement of the beam were immediately idendified in the first ring-commissioning.

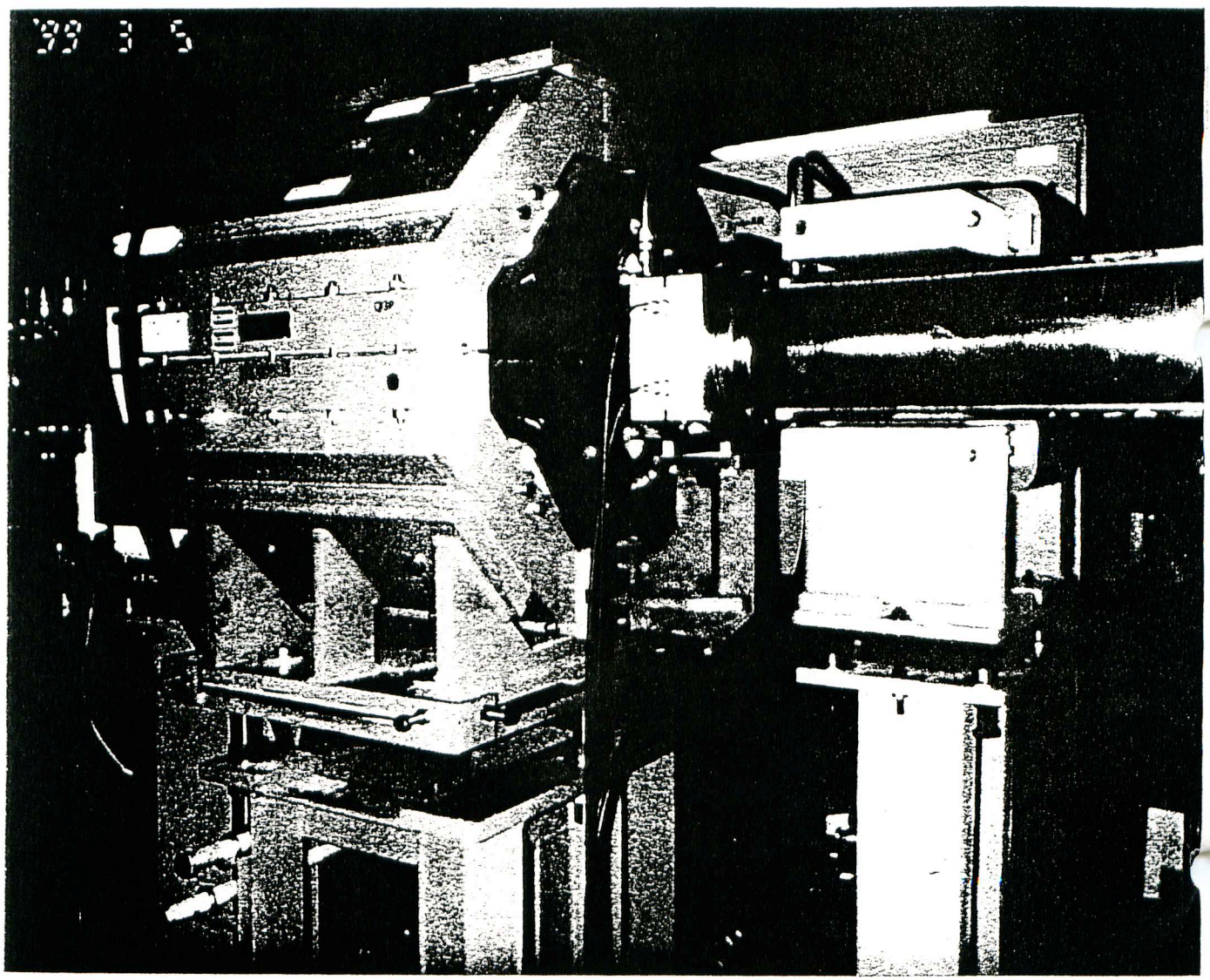
5-7 Special BPMs at IP

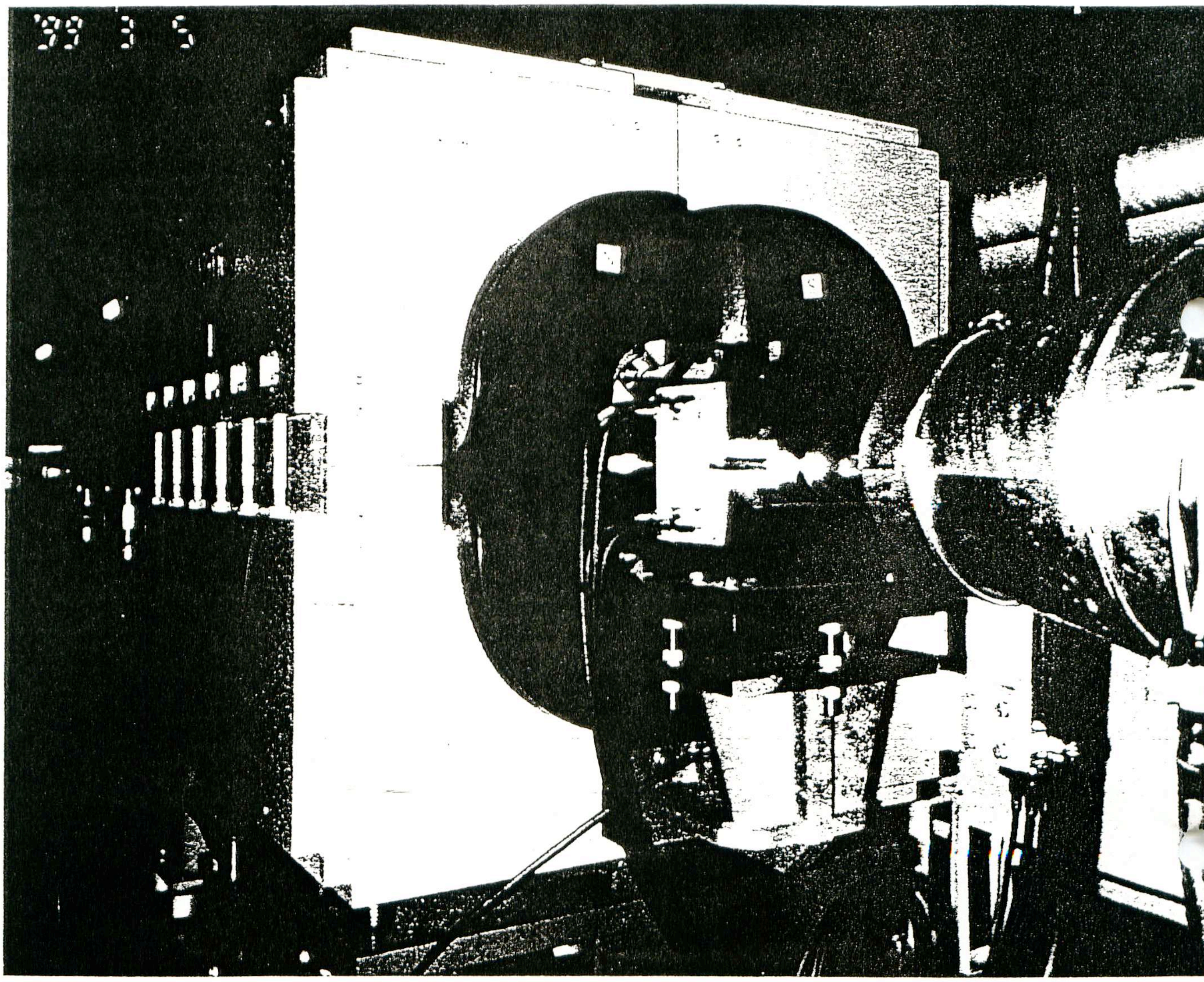
- Specially desinged 4 BPMs were installed in the QCS beam chamber (55mmϕ inner diameter) for the orbit feedback at IR.
  * Both of e^- and e^+ pass the BPM signal pickup.
  * pickup; 8 buttons with 6mmϕ diameter
  * e^- orbit and e^+ orbit can be resolved separately by the nonlinearity of the pickup sensitivity ; expected resolution ~ a few μm
- 2 of them will be operated rutinely in the KEKB operation.
- 10Hz signal processing is available for the orbit feedback.
- Under installation of electronics.
  Operation will start in March.

5-8 Bunch-by-feedback

- Transverse bunch-by-bunch feedback systems for HER/LER worked well and are indispensable to increase the beam current higher than 100mA.
- Memory system where the displacement of every bunch can be memorized during 4000 turns will be powerfull to study FII & PEI.

$\Rightarrow$ **Details will be given in Kikutani's talk.**


'99 3 5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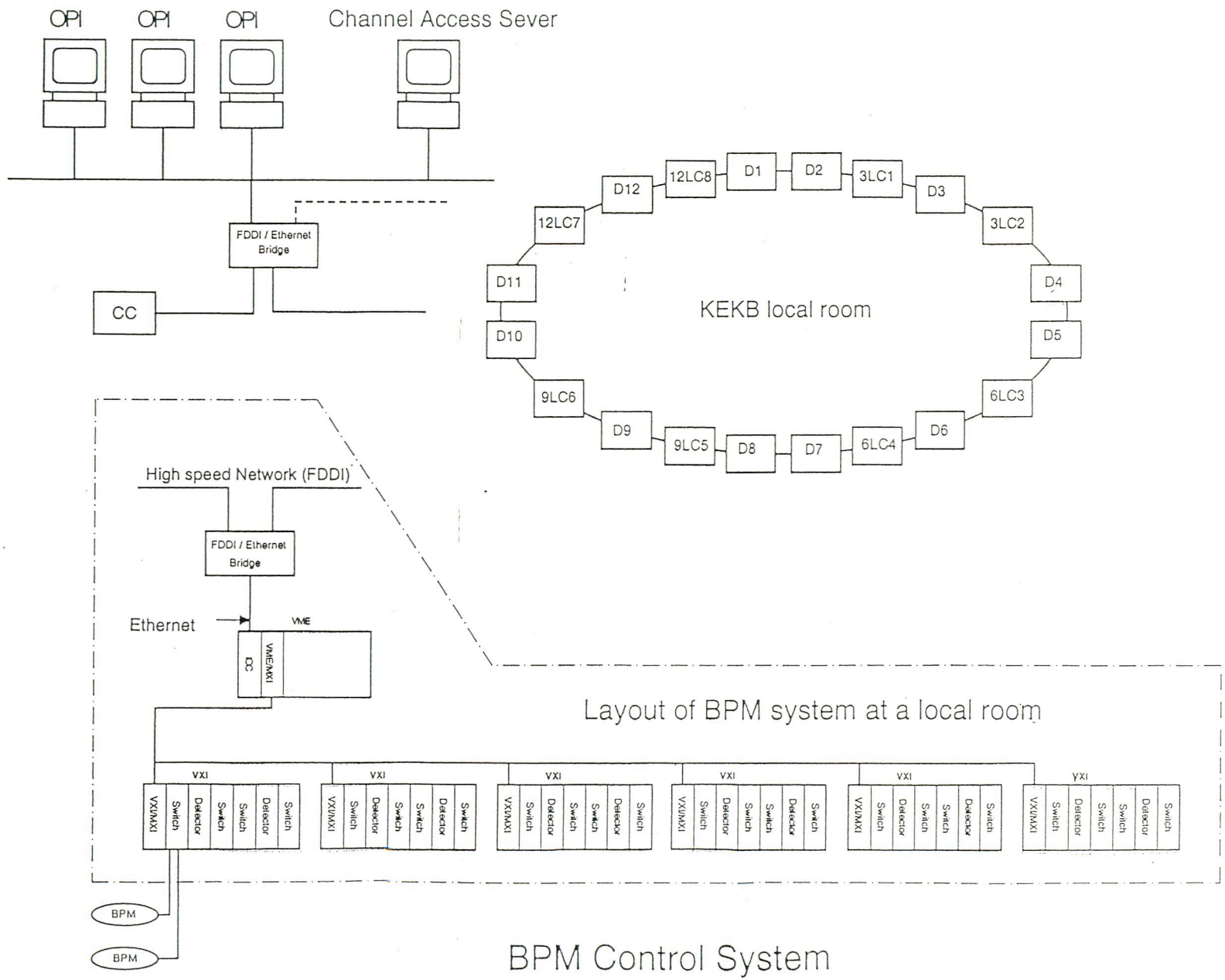
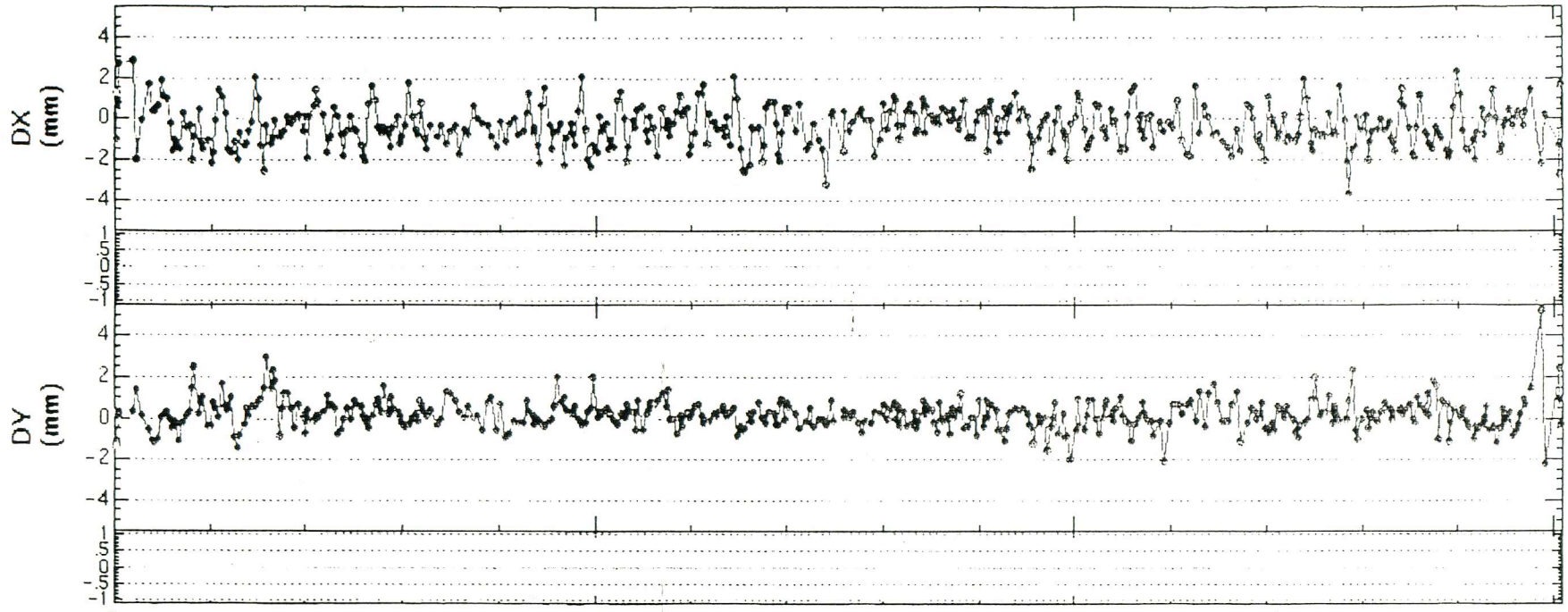

OPI
OPI
OPI
Channel Access Sever
FDDI / Ethernet Bridge
CC
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
3LC1
3LC2
6LC3
6LC4
9LC5
9LC6
12LC7
12LC8
KEKB local room
High speed Network (FDDI)
FDDI / Ethernet Bridge
Ethernet
VME
I/O
VME/MXI
Layout of BPM system at a local room
VXI
VXI/MXI
Switch
Detector
BPM
BPM
BPM Control System

HER Orbit Correction



r.m.s =1.083 mm
max. =2.866 mm
@ M005QC3LE
min. =-3.653 mm
@ M378QF4E

r.m.s =.74 mm
max. =5.217 mm
@ M439QC4RE
min. =-2.255 mm
@ M440QC3RE

QCSL114 QKALE QC5LE QS2TLE QD5E.2 QD3E.2 QD3E.3 QD5E.5 QD1E.3 QT5TNE QD1E.4 QD5E.8 QD3E.8 QD3E.9 QD5E.11 QR7NE.1 QR2NE.1 QDRNE.3 QDRNE.5 QF4NE.2 QS8NE.2 QD3E.11 QD5E.15 QD1E.8 QD5E.18 QT1NFE.1 QT3NFE.2 QD3E.16 QD3E.17 QD5E.21 QD1E.12 QD5E.24 QF5E QX6E.1 QX2E.2 QX7E.2 QM6E QF6E.13 QD1E.13 QD5E.28 QD3E.24 QD3E.25 QT1FOE.1 QT4FOE.2 QD5E.31 QD1E.17 QD5E.34 QD3E.30 QS8OE.1 QR4OE.1 QDROE.2 QFROE.4 QR3OE.2 QR7OE.2 QD5E.38 QD3E.32 QD3E.33 QD5E.41 QD1E.21 QT5OTE QD1E.22 QD5E.44 QD3E.38 QF4E.39 QD5E.47 QS2TRE QKERE QKARE

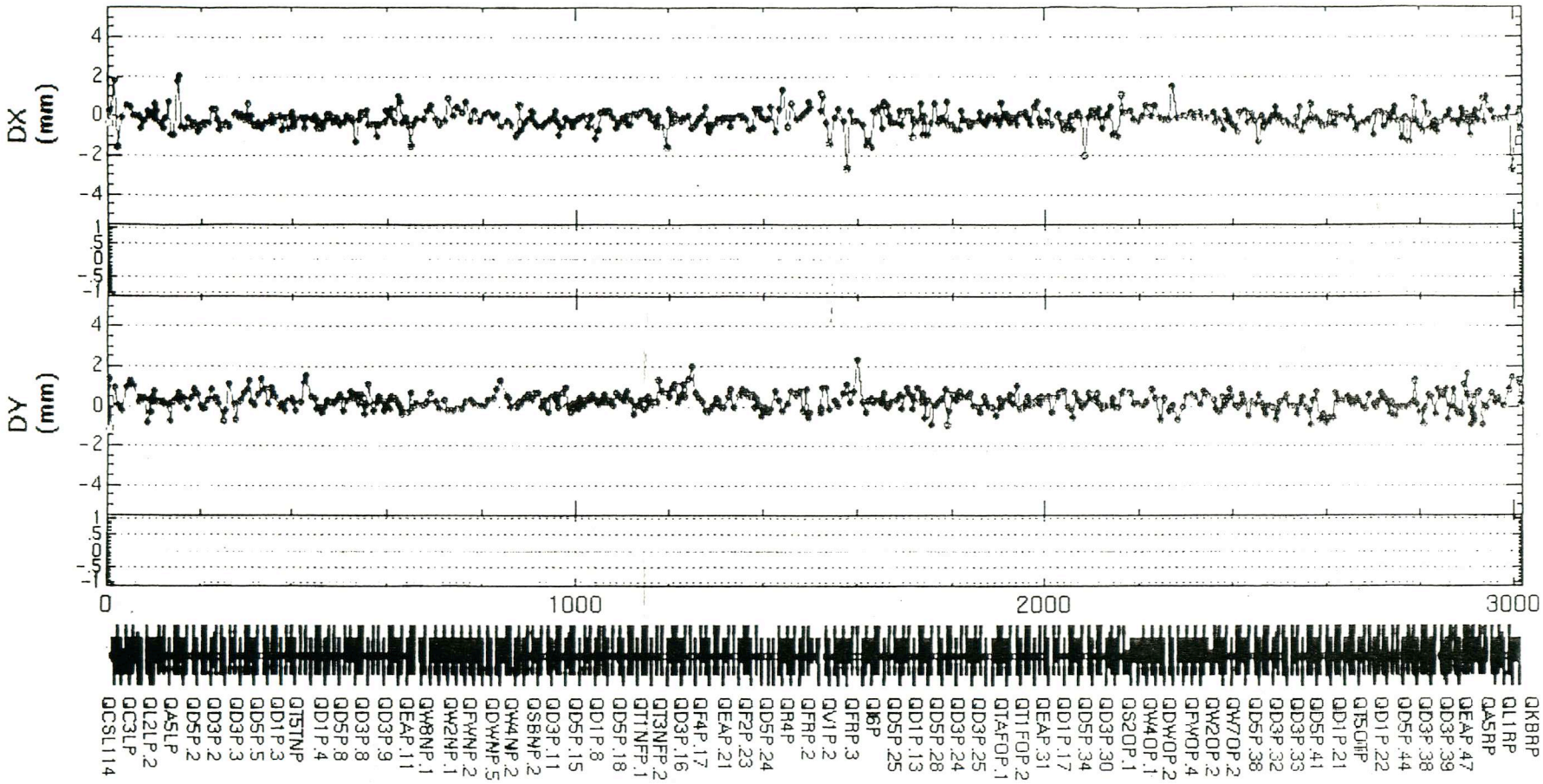
range | DX Auto Fix (5) ▲ ▼ | DY Auto Fix (5) ▲ ▼ | Replo

Ring -T- T-N -N- N-F -F- F-O -O- O-T @ BPMx @ BPMy

Feb. 21 12:42

180mA

LER Orbit Correction



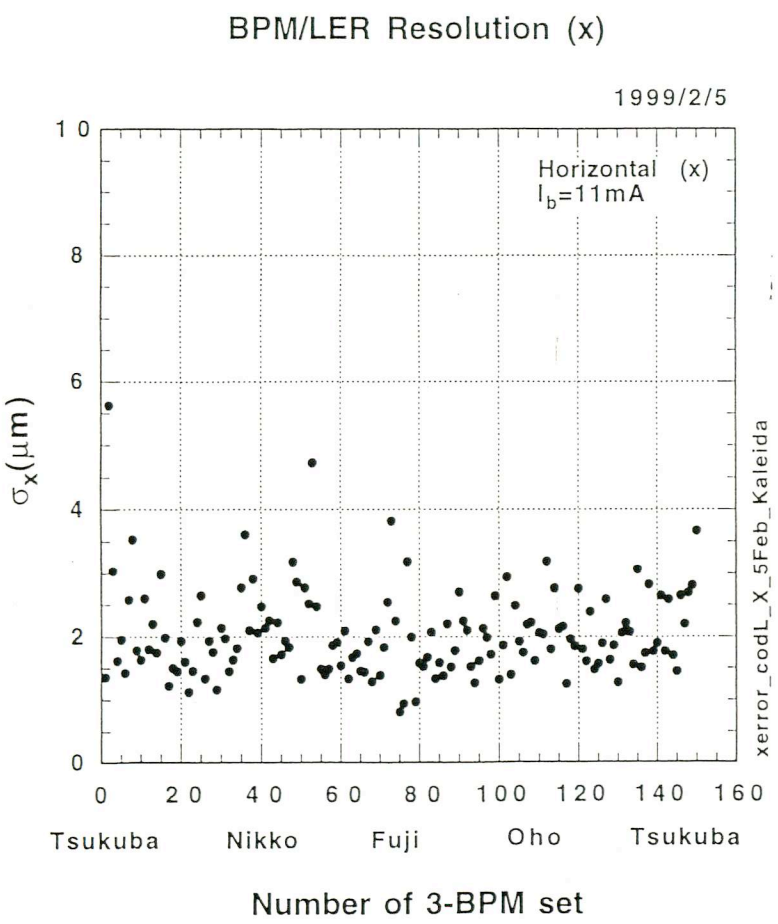
r.m.s =.529 mm
max. =2.022 mm
@ M026QEAP
min. =-2.738 mm
@ M452QC3RP

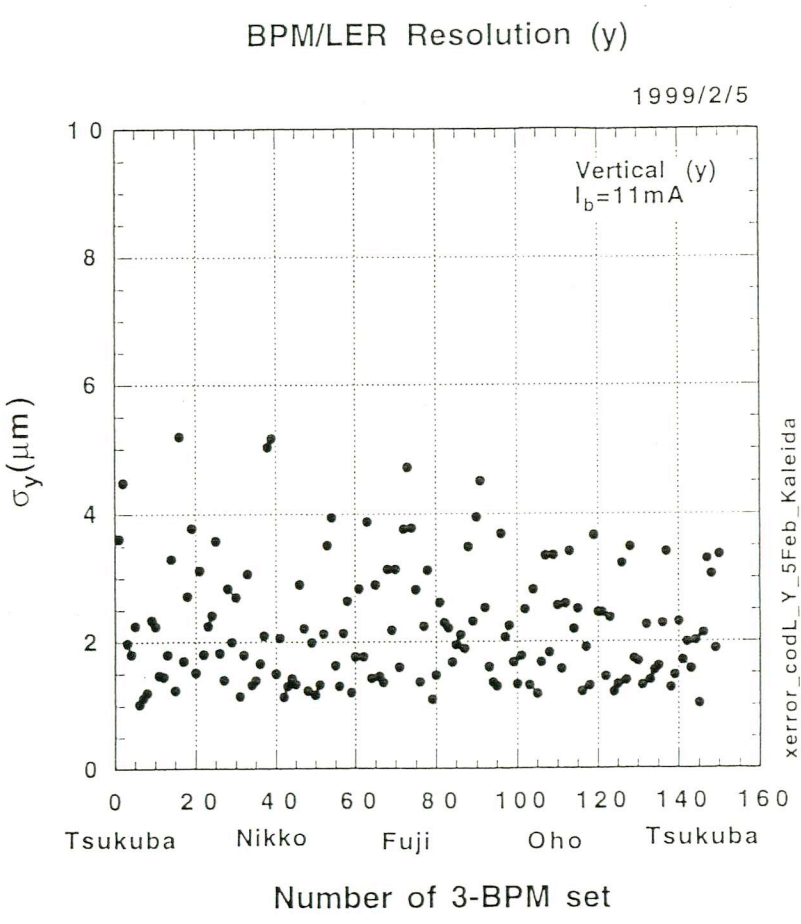
r.m.s =.532 mm
max. =2.367 mm
@ M239QI6P
min. =-1.155 mm
@ M002QC2LP

range | DX Auto Fix (5) ▲ ▼ | DY Auto Fix (5) ▲ ▼ Replot

Ring -T- T-N -N- N-F -F- F-O -O- O-T @ BPMx @ BPMy

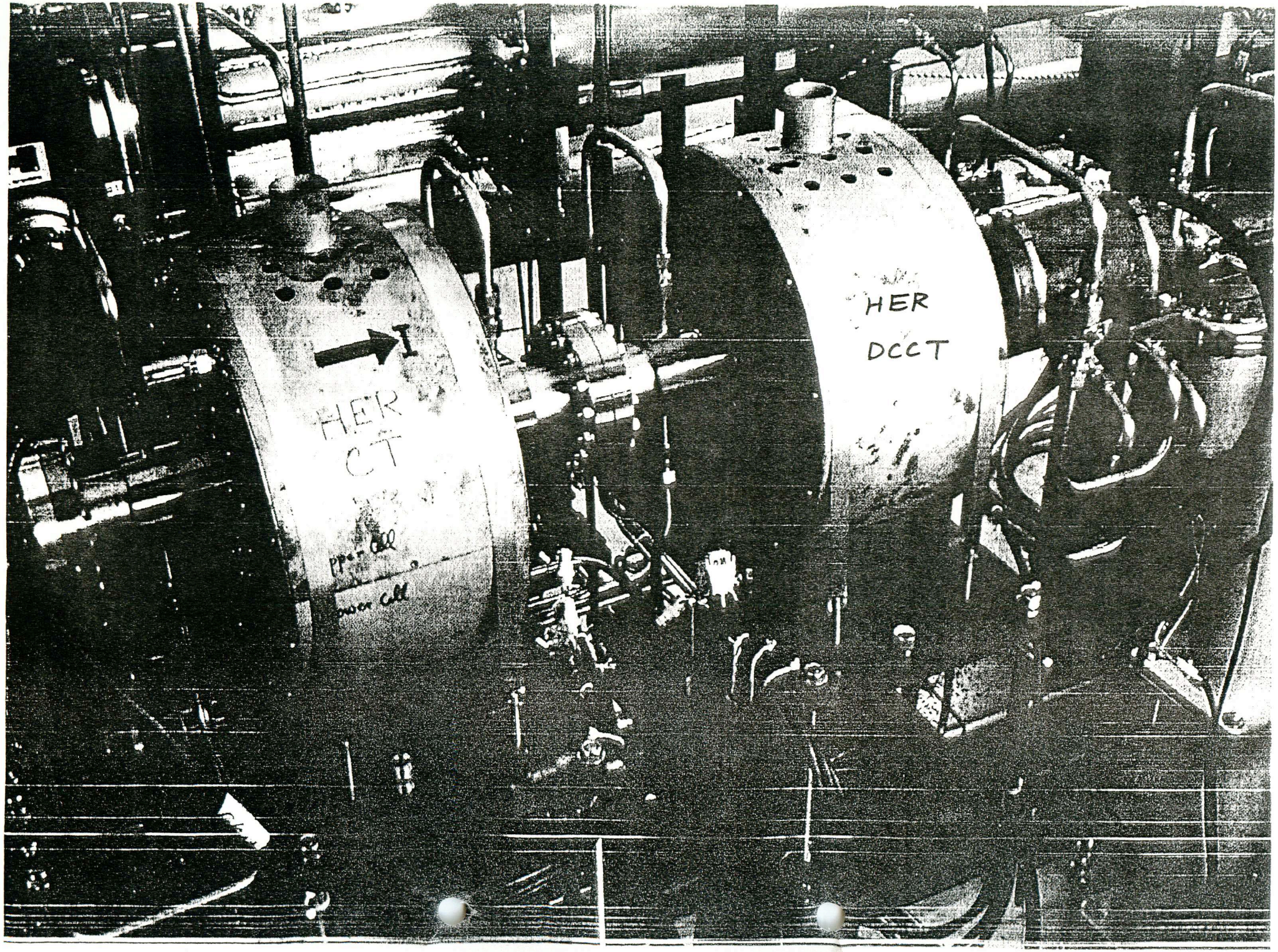
Feb 28 05:33
1258 mA

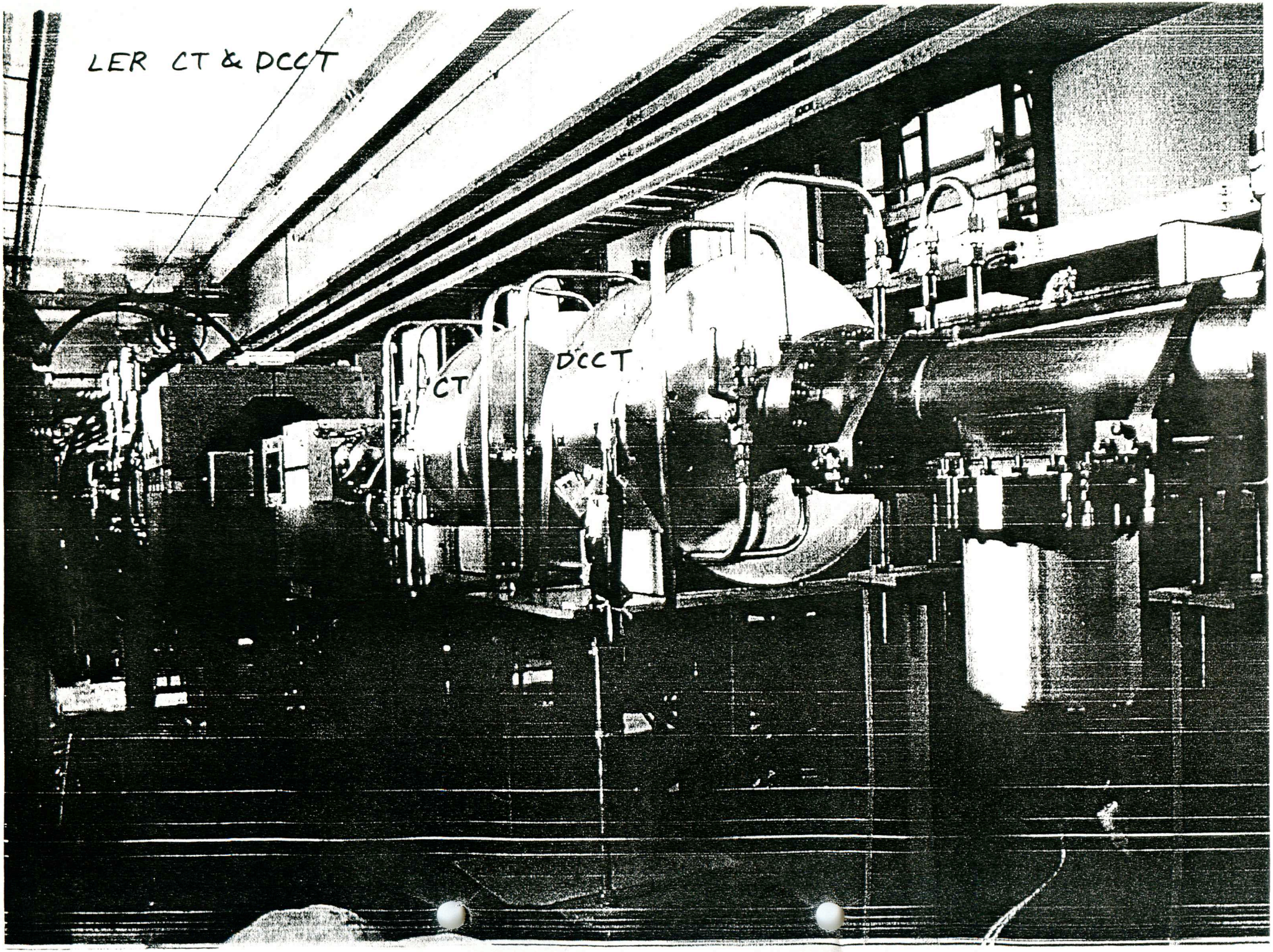


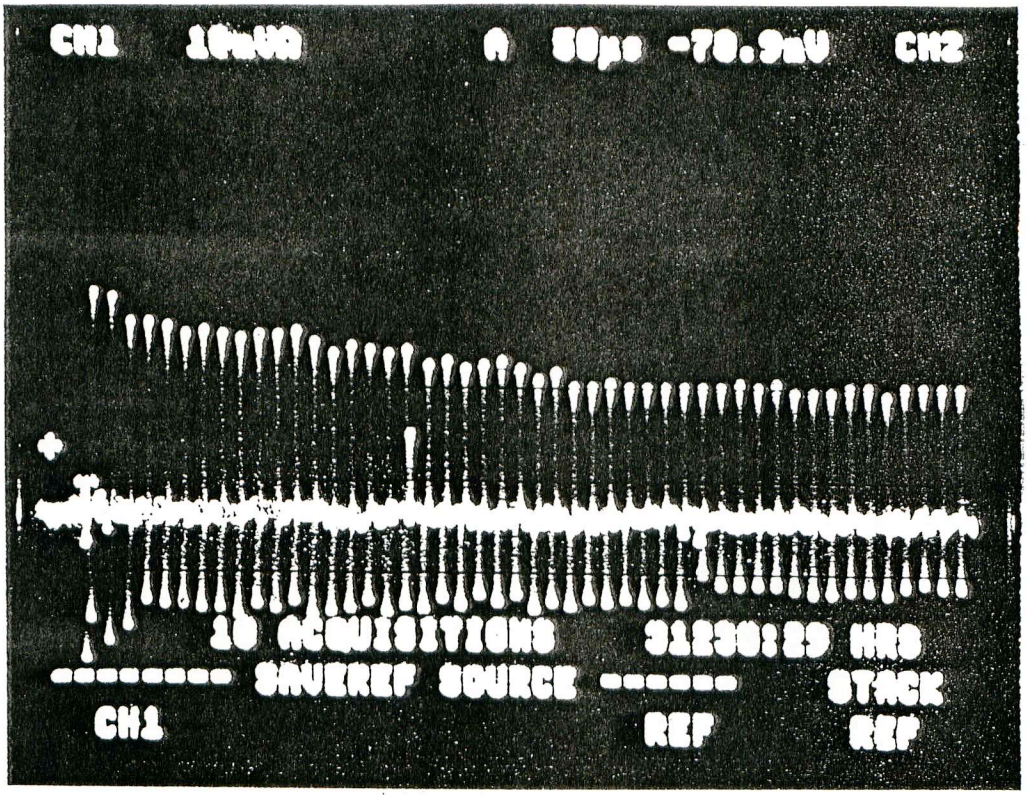


BPM#(n-1); x_1 BPM#n; x_2 BPM#(n+1); x_3

$$x_3 = ax_1 + bx_2 + c \quad \Rightarrow \quad \sigma = \sqrt{\frac{\left\langle \left\{ x_3 - (ax_1 + bx_2 + c) \right\}^2 \right\rangle}{1 + a^2 + b^2}}$$


I
HER
CT
HER
DCCT


LER CT & DCCT
CT
DCCT

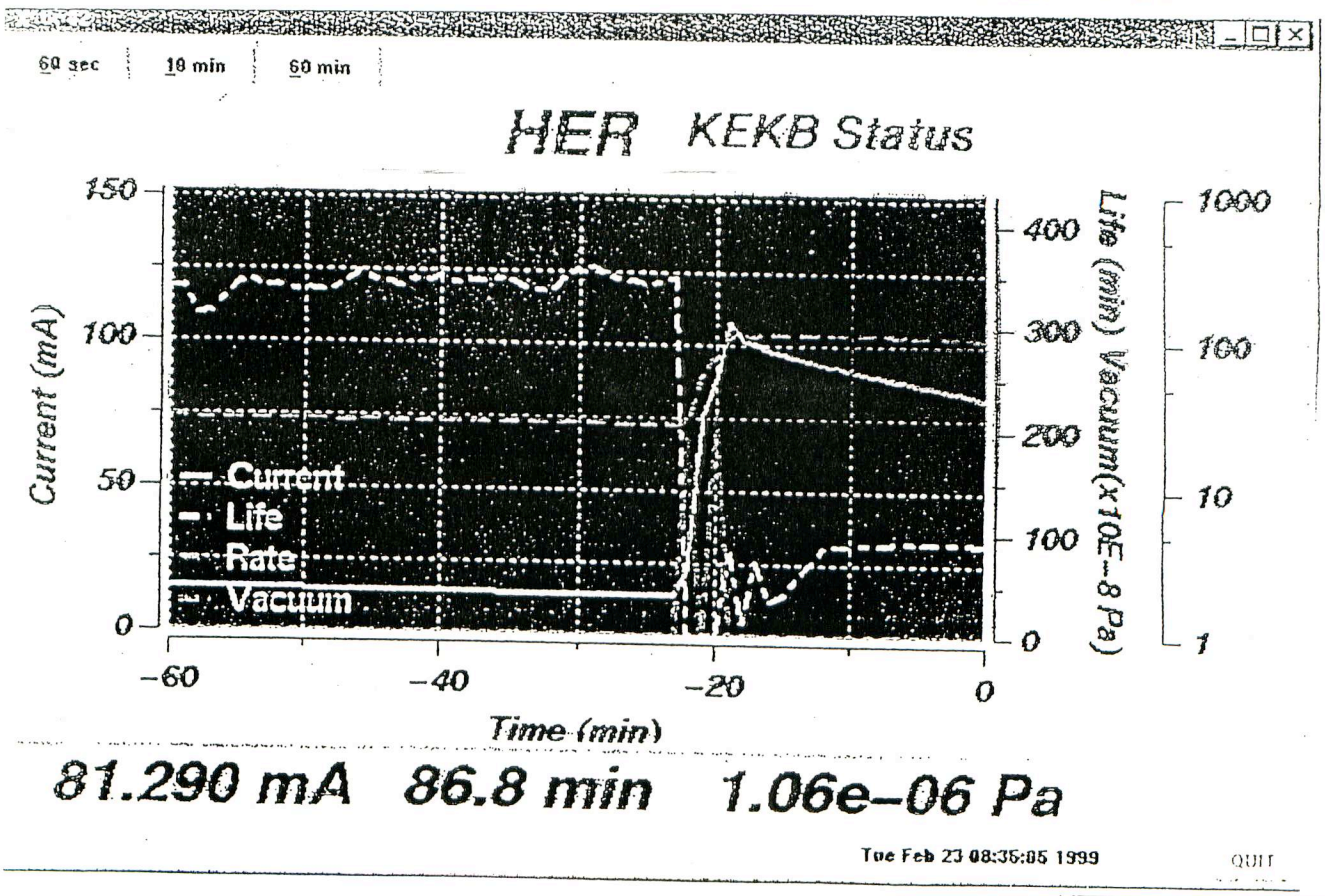


HER-CT

single bunch

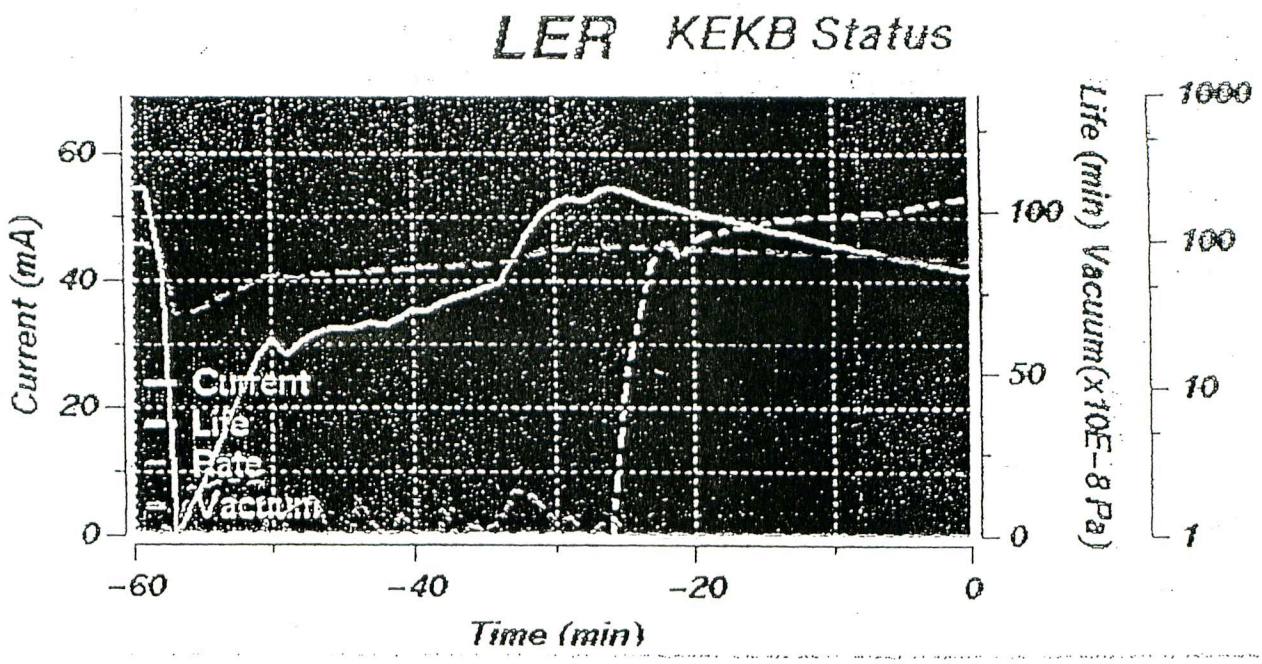
0.25mA

HER-DCCT



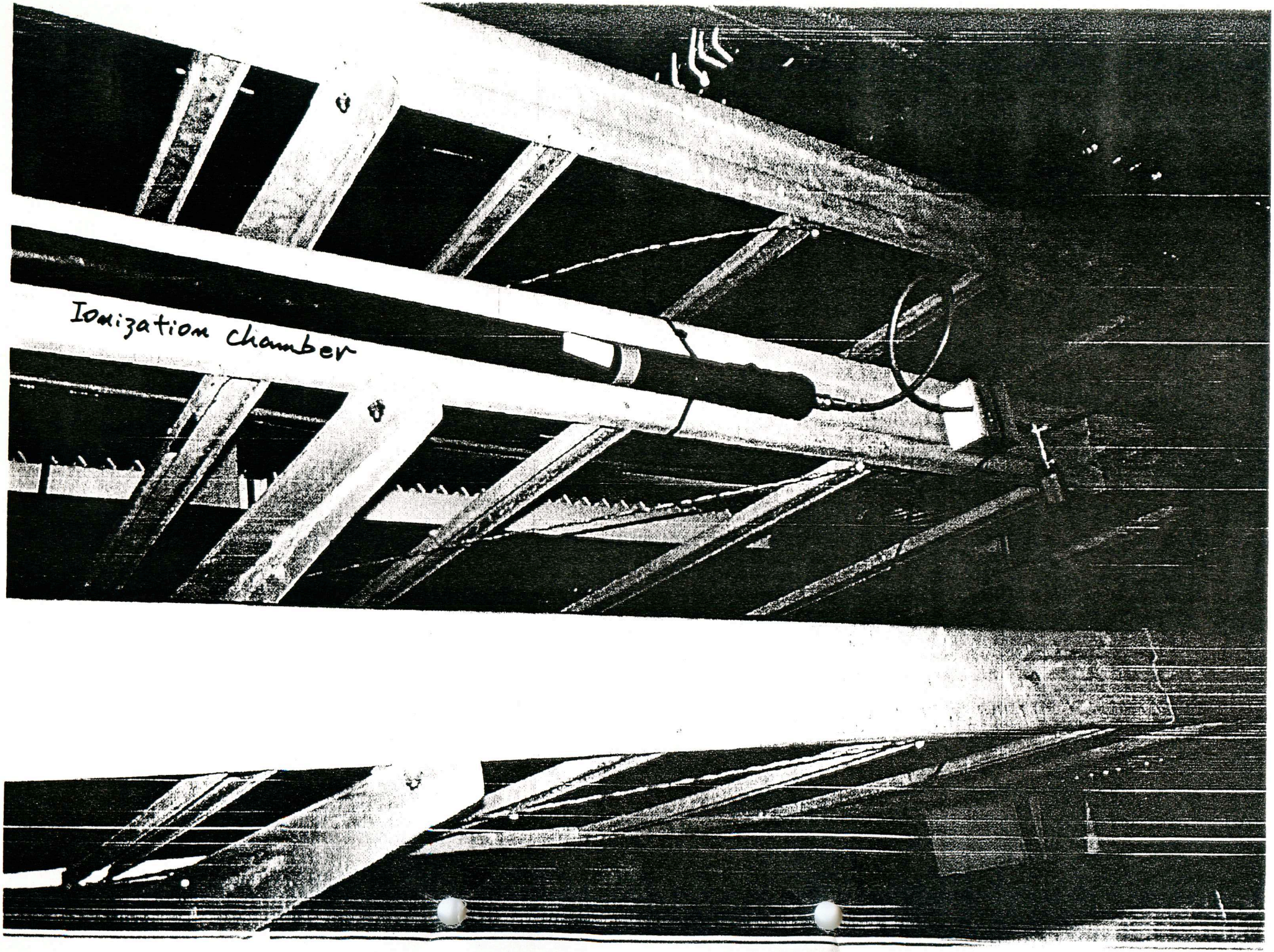
LER-DCCT

60 sec 10 min 60 min

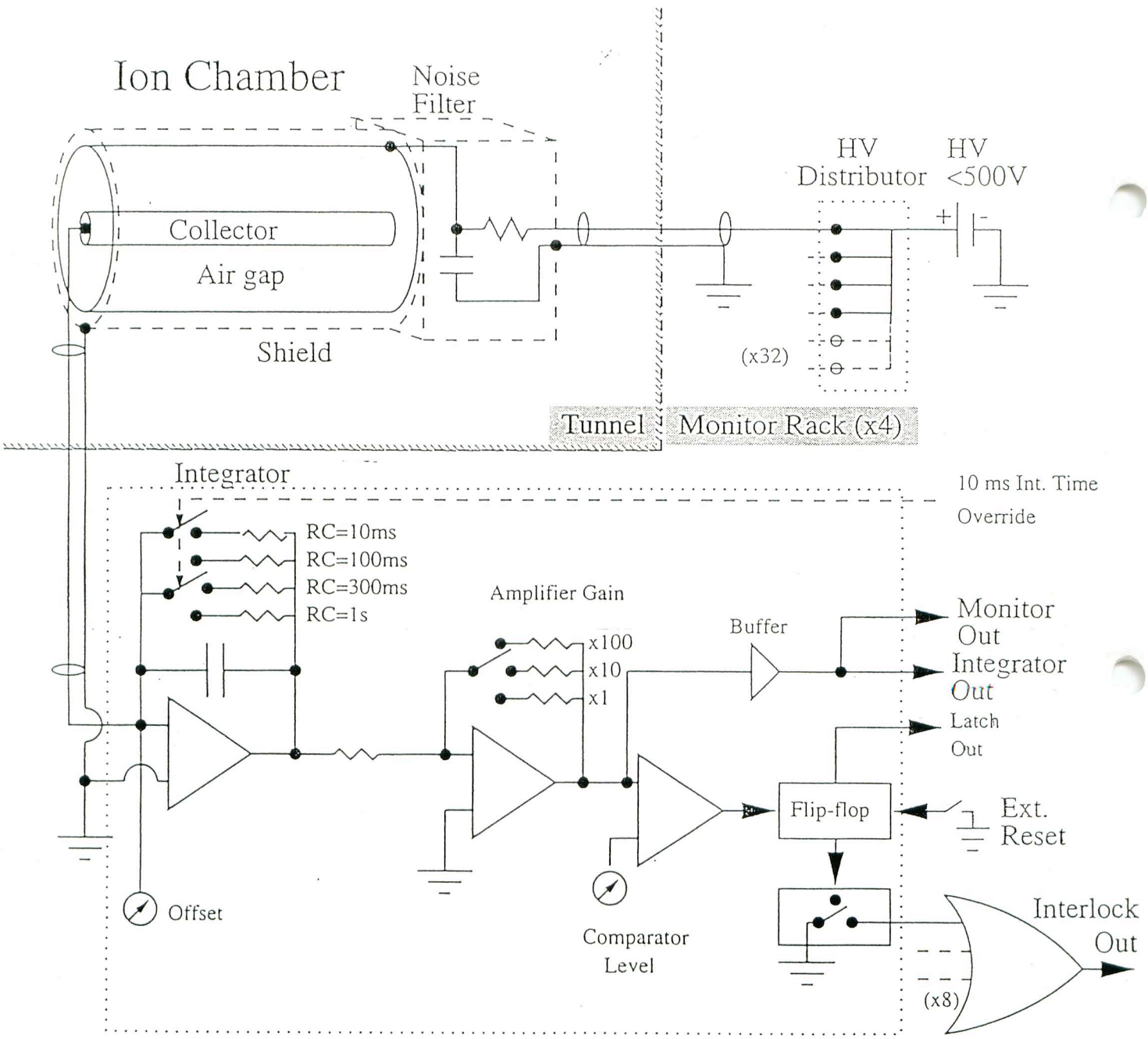


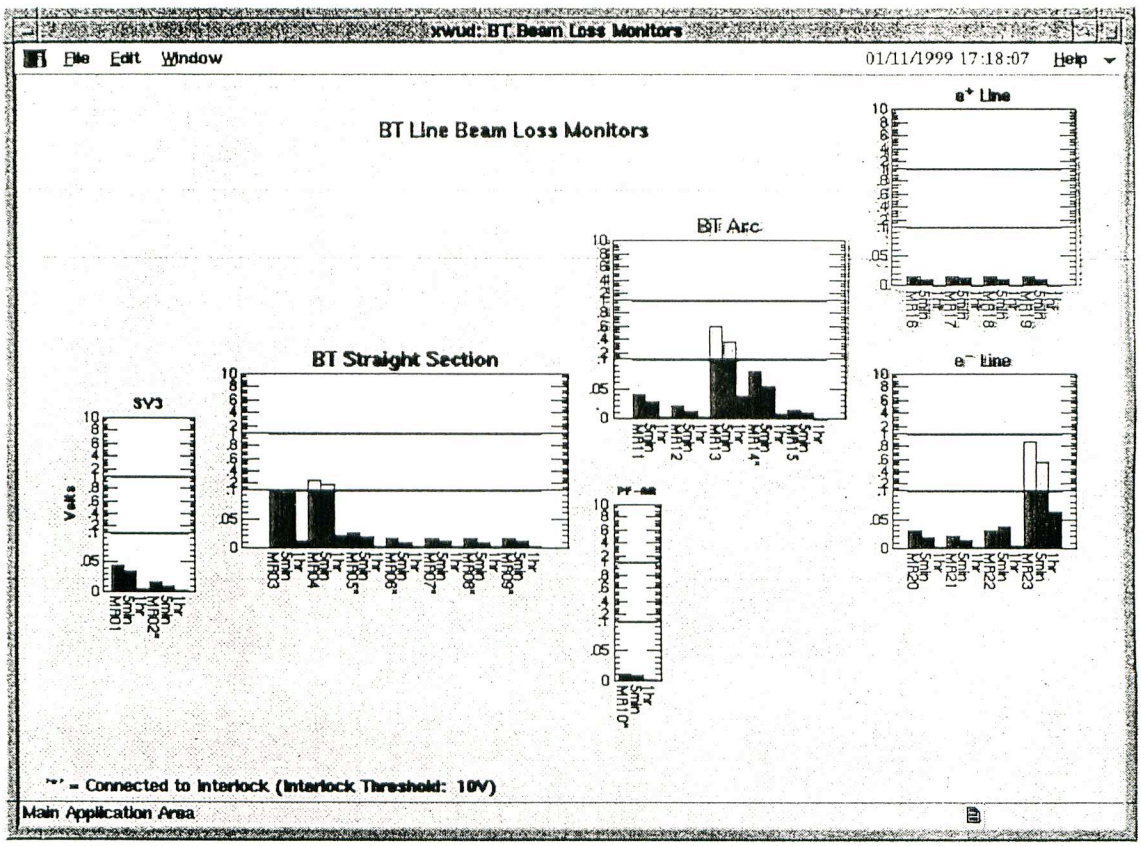
41.508 mA 104.9 min 7.67e-07 Pa

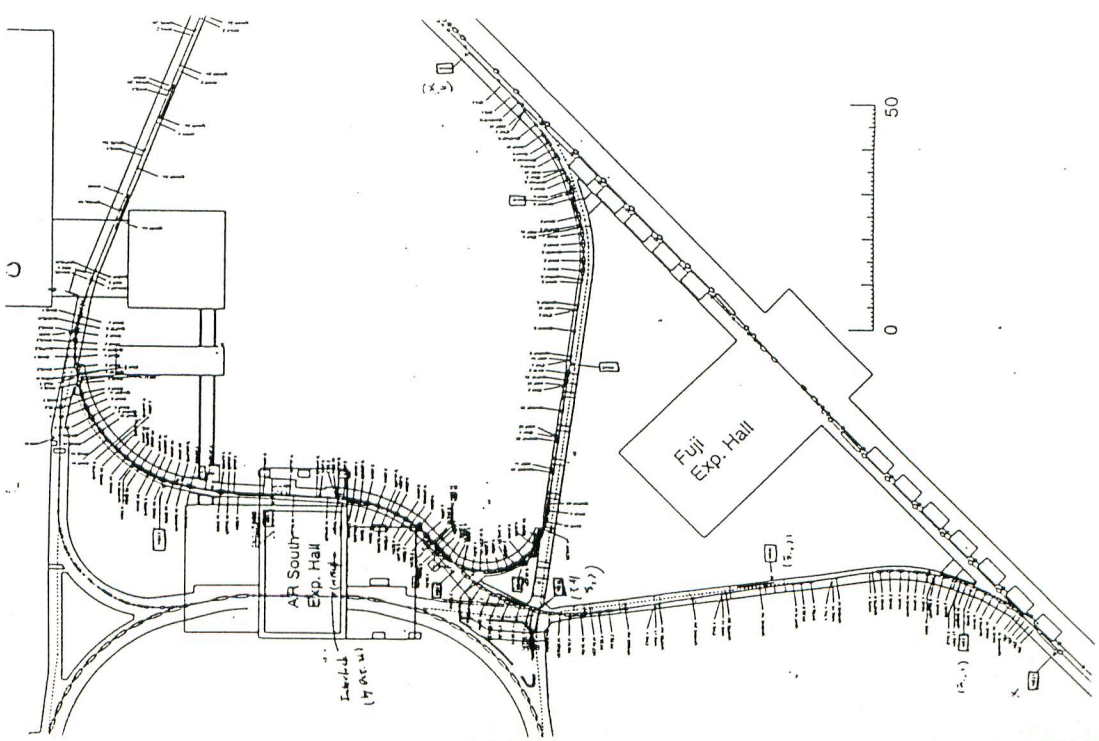
Tue Feb 23 08:34:26 1999 QUIT

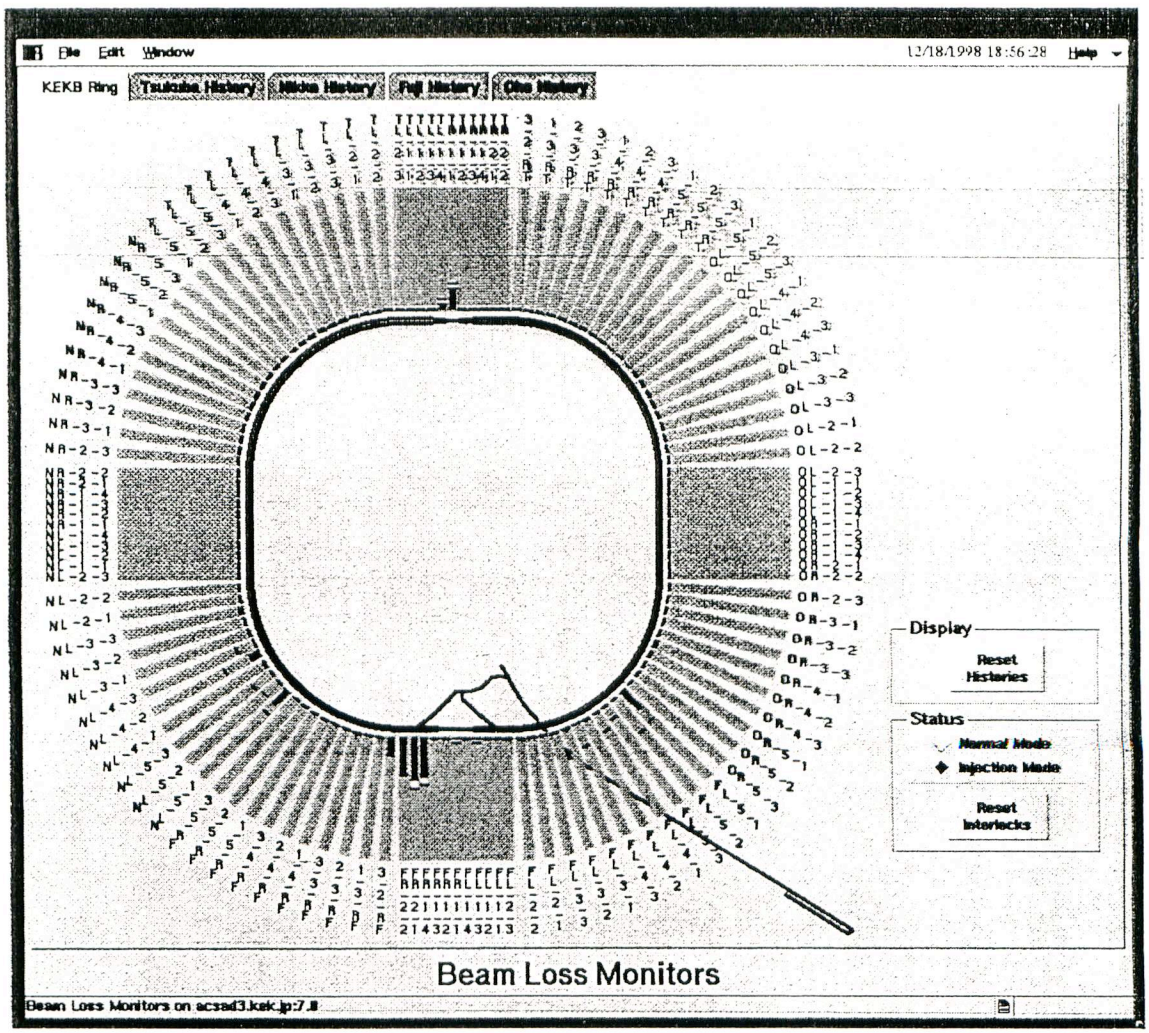

Ionization chamber

KEKB Ring Beam Loss Monitor Block Diagram




xwud: BT Beam Loss Monitors
File Edit Window
01/11/1999 17:18:07 Help
BT Line Beam Loss Monitors
e+ Line
BT Arc
BT Straight Section
SV3
e- Line
Volts
'*' = Connected to Interlock (Interlock Threshold: 10V)
Main Application Area

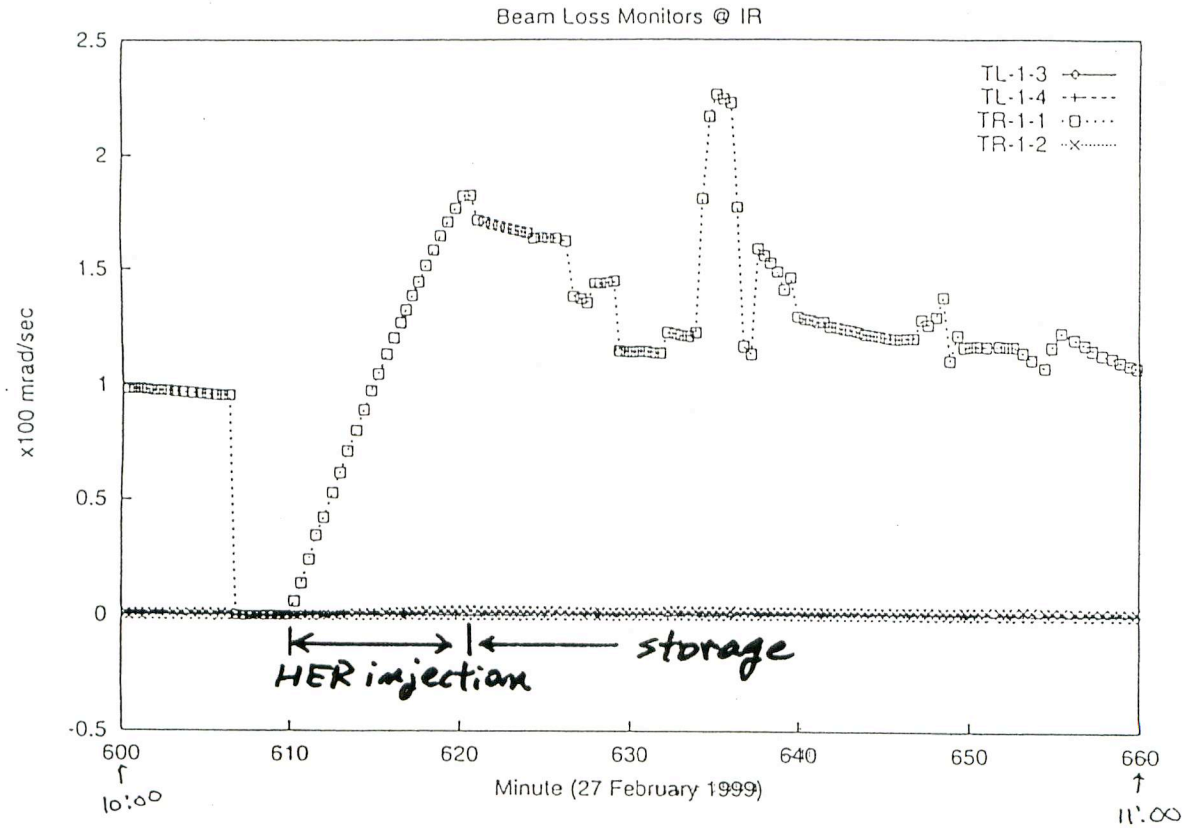

AR South Exp. Hall
Fuji Exp. Hall
50
0

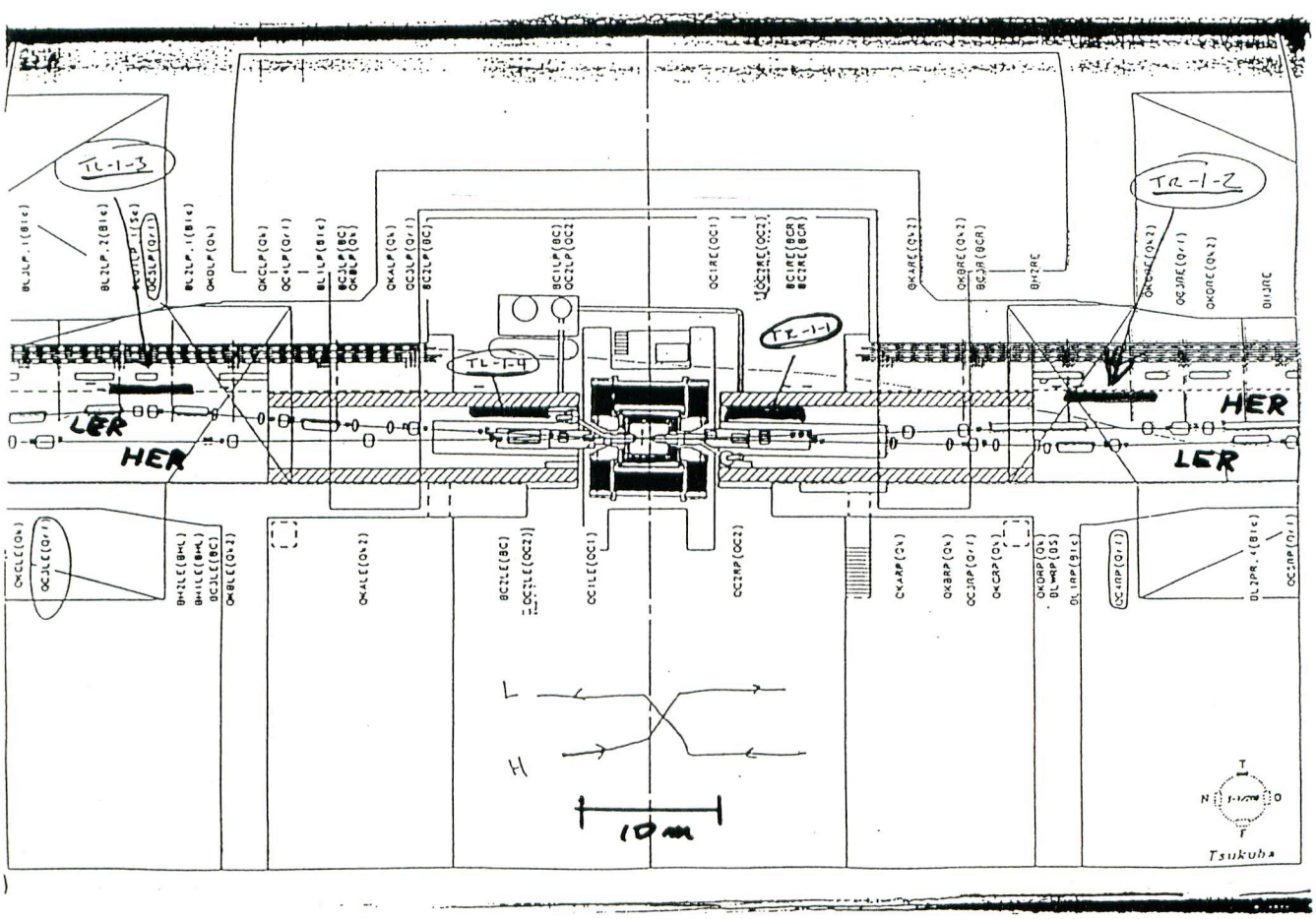

File Edit Window
12/18/1998 18:56:28 Help
KEKB Ring
Tsukuba History
Nikko History
Fuji History
Oho History
Display
Reset Histories
Status
Normal Mode
Injection Mode
Reset Interlocks
Beam Loss Monitors
Beam Loss Monitors on acsad3.kek.jp:7.8

Beam loss monitor signal at IP during HER operation

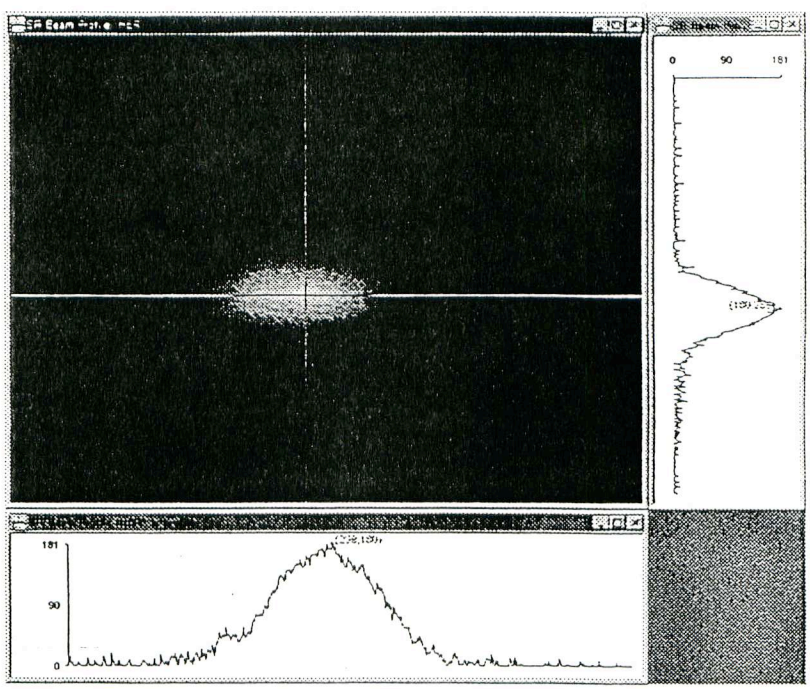
27 Feb. 1999

10:00 - 11:00

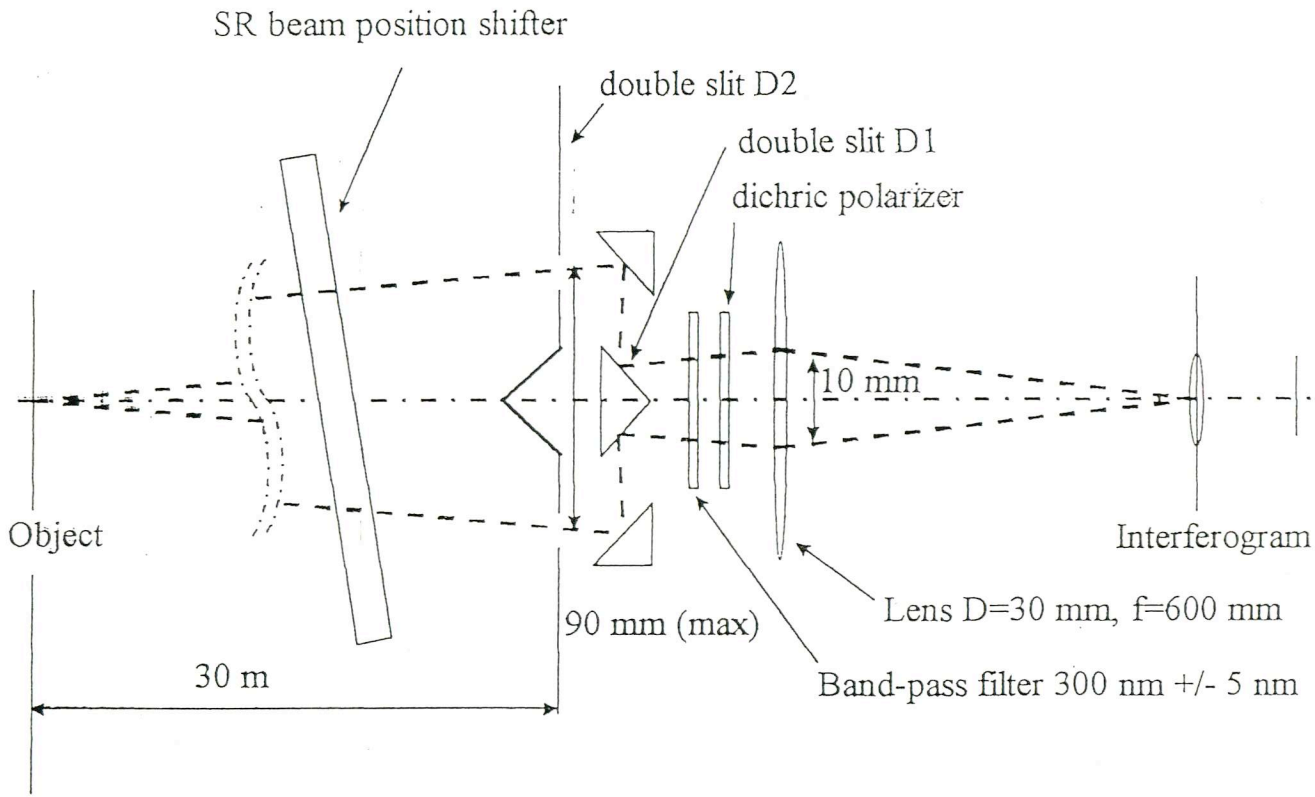




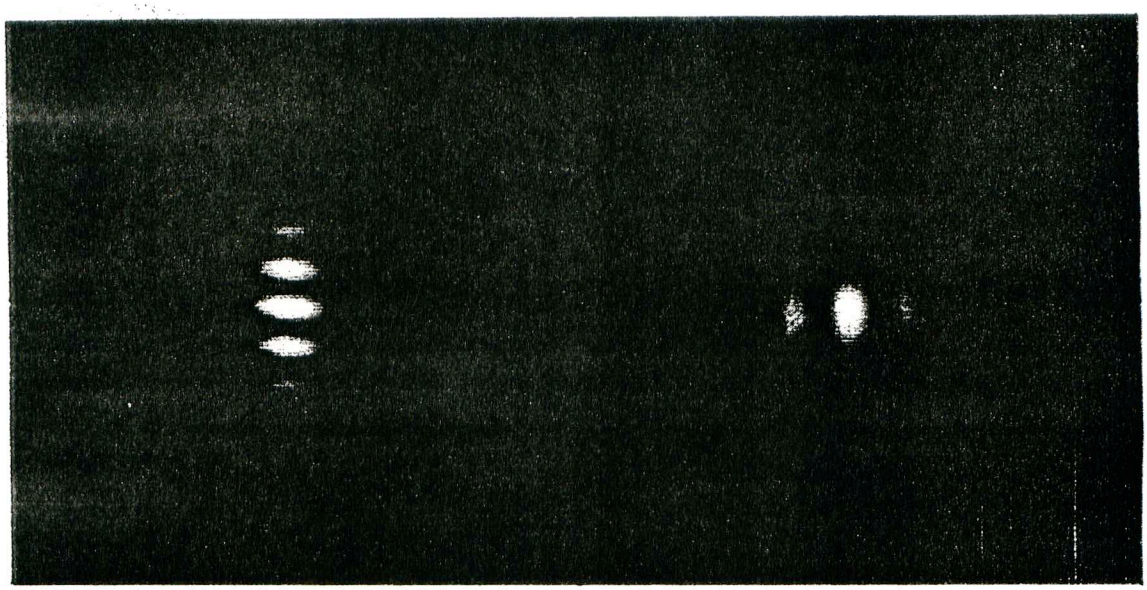
SR image / HER



Double-slit interferometer

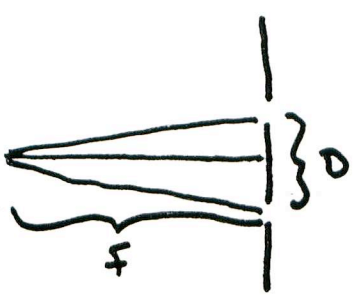


H.E.R. (Doubl-slit interferometer)



$$\sigma_{BEAM} = \sqrt{\frac{\lambda^2 f^2}{2\pi^2 D^2} \ln\left(\frac{1}{\gamma}\right)}$$

; γ = VISIBILITY = $\frac{\text{Peak} - \text{Valley}}{\text{Peak} + \text{Valley}}$

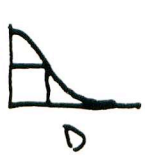


$\lambda = 0.0005$ mm

$f = 37600$ mm

D = slit separation mm

σ_{Beam} = Beam site

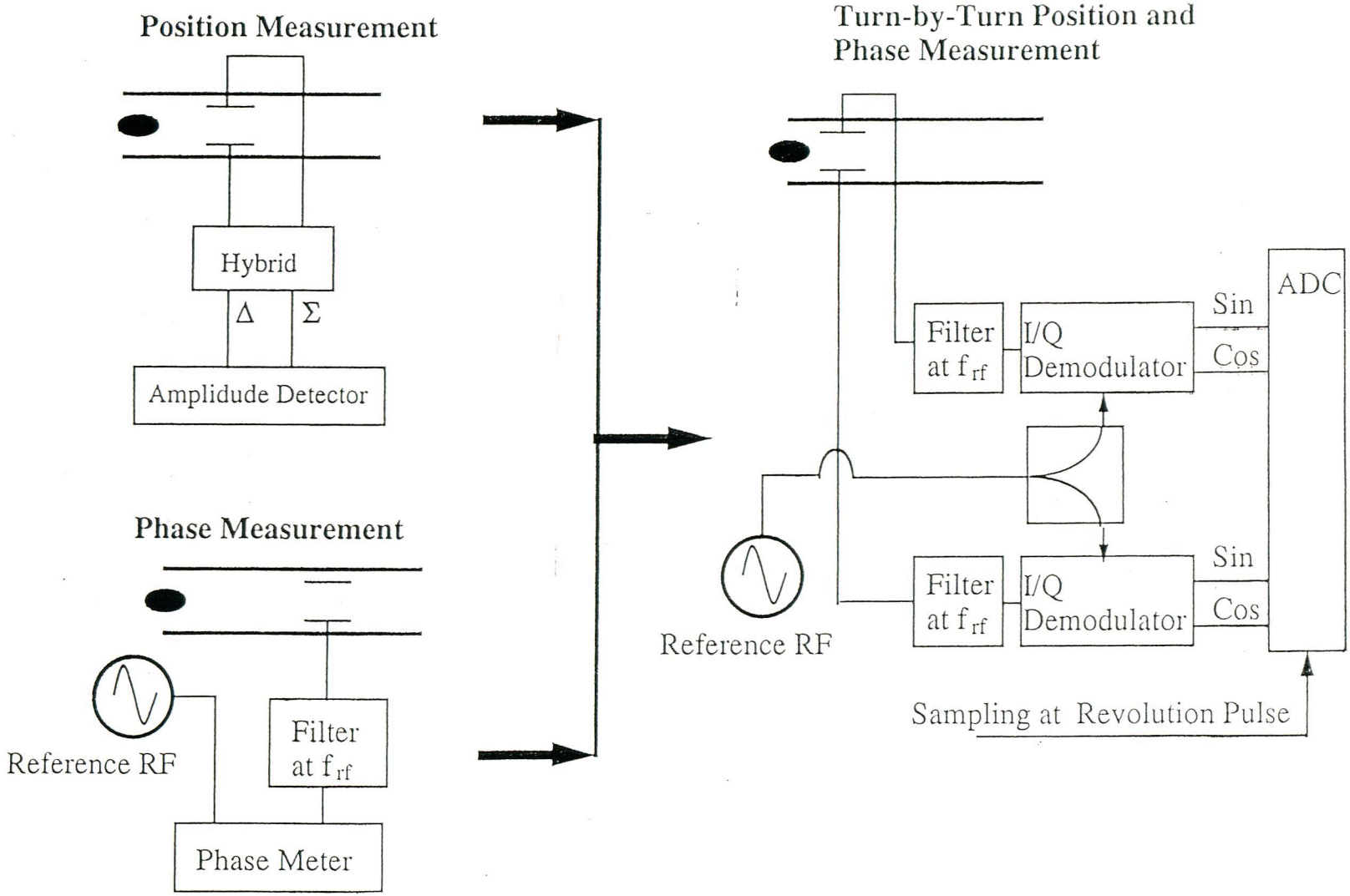
FIT: 

Then @ $D = 15$, $\gamma = 0.61 \Rightarrow \ln\frac{1}{\gamma} = 0.5$

$$\Rightarrow \sigma_{Beam} = \frac{\lambda f}{2\pi D_{1\sigma}}$$

$\sigma_Y = 360\ \mu m$

$\sigma_x = 548\ \mu m$



March 3, 1999
T. Ieiri

Dec 13, 1998 # HER Injection without accelaration 14:22:53

get Avr.

7558	8098.622
8981	8280.123
7173	8113.806
9104	8183.711
6228	8246.470
9146	8209.656
6941	8044.109
8987	8277.394

start | 10 second

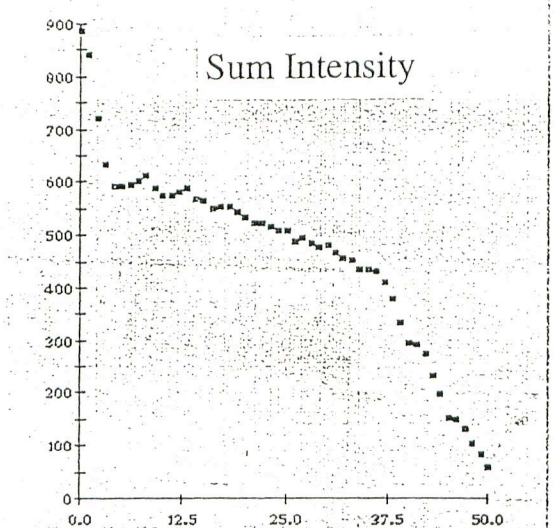
0

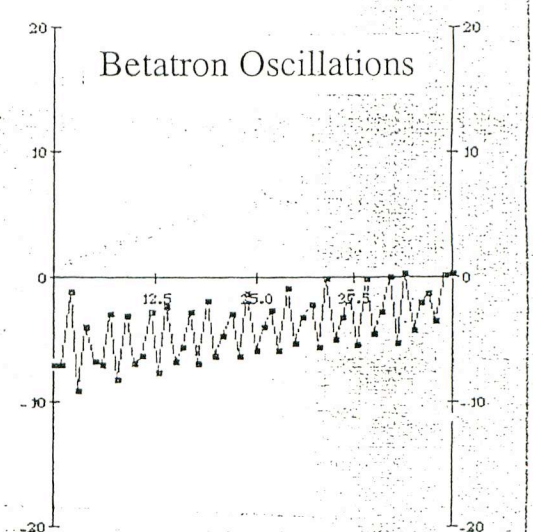
1

CALC

4 kW | Passive

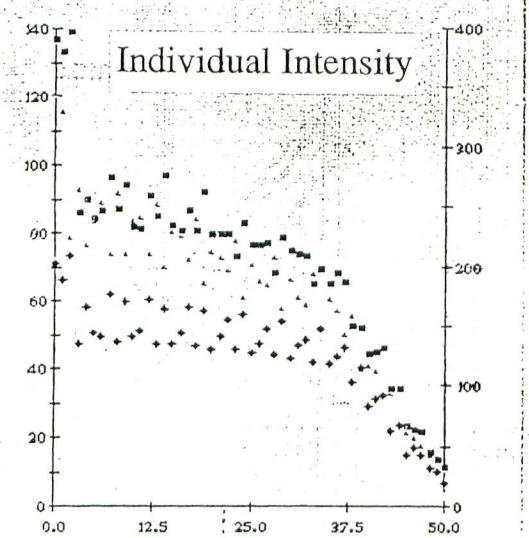
EXT | 1 second

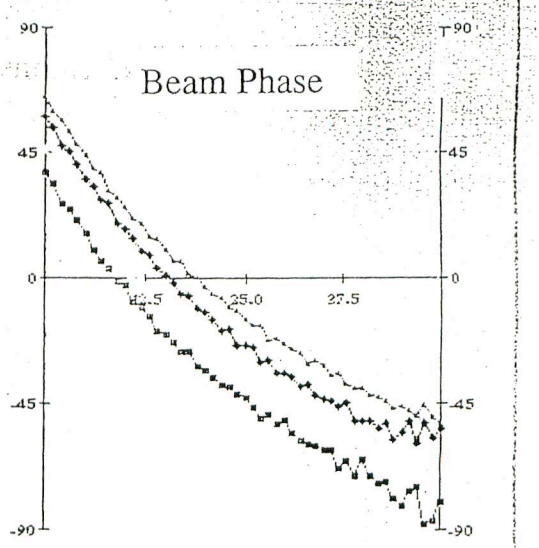




INT.

POS (X,Y) [mm] 1.723





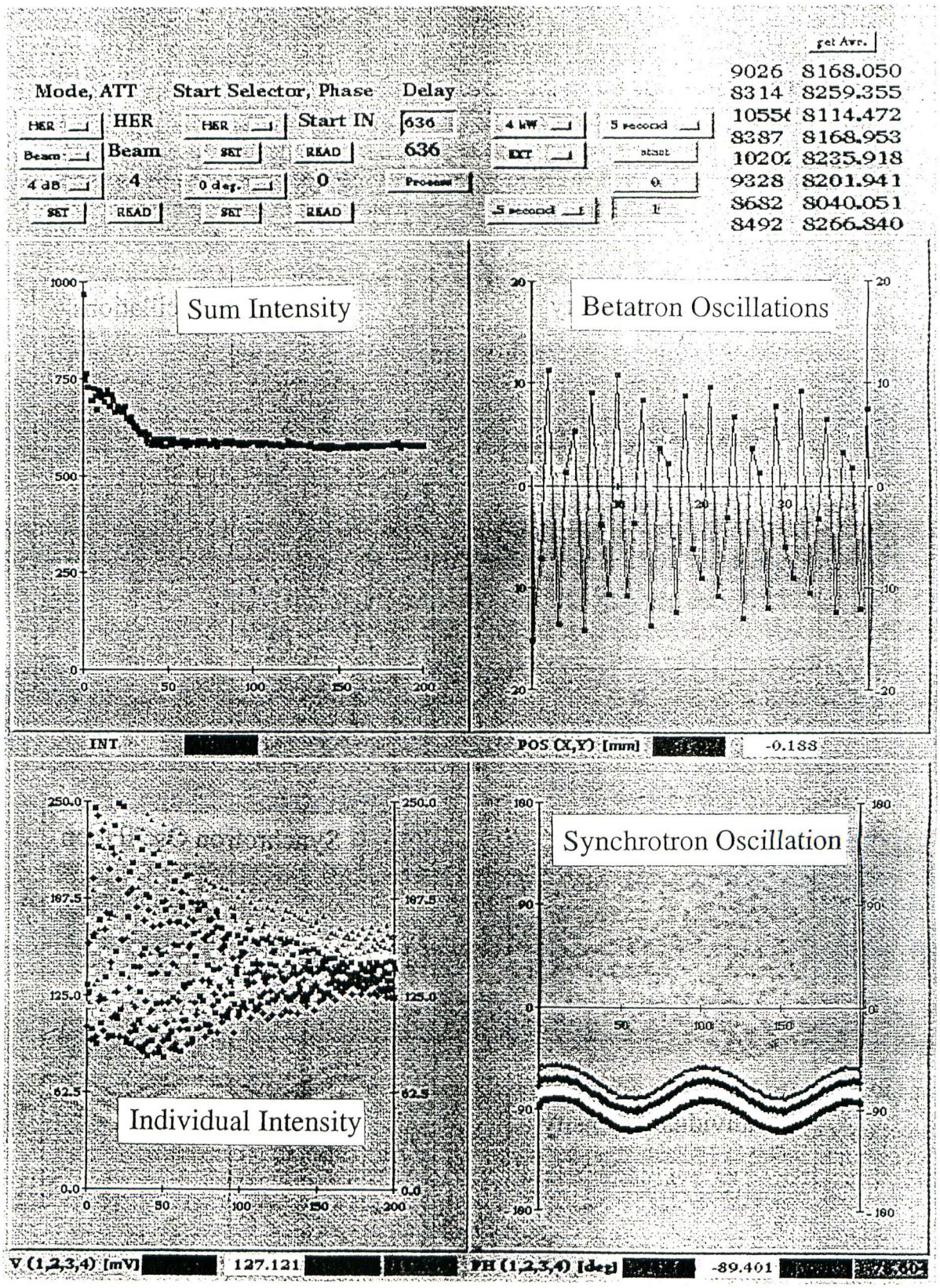
V (1,2,3,4) [mV] 2.990

PH (1,2,3,4) [deg] -13.361

Feb 6, 1999

HER Single-Turn Injection

12:27:35



- Bunch length is obtained from the beam spectrum picked-up by a button electrode.
- The natural bunch length is designed to be 4 mm, so the spectrum extends to more than 10 GHz.
- However, detected frequency is less than 5 GHz, which requires a high resolution detector.
- The bunch length is monitored in real time with high resolution.

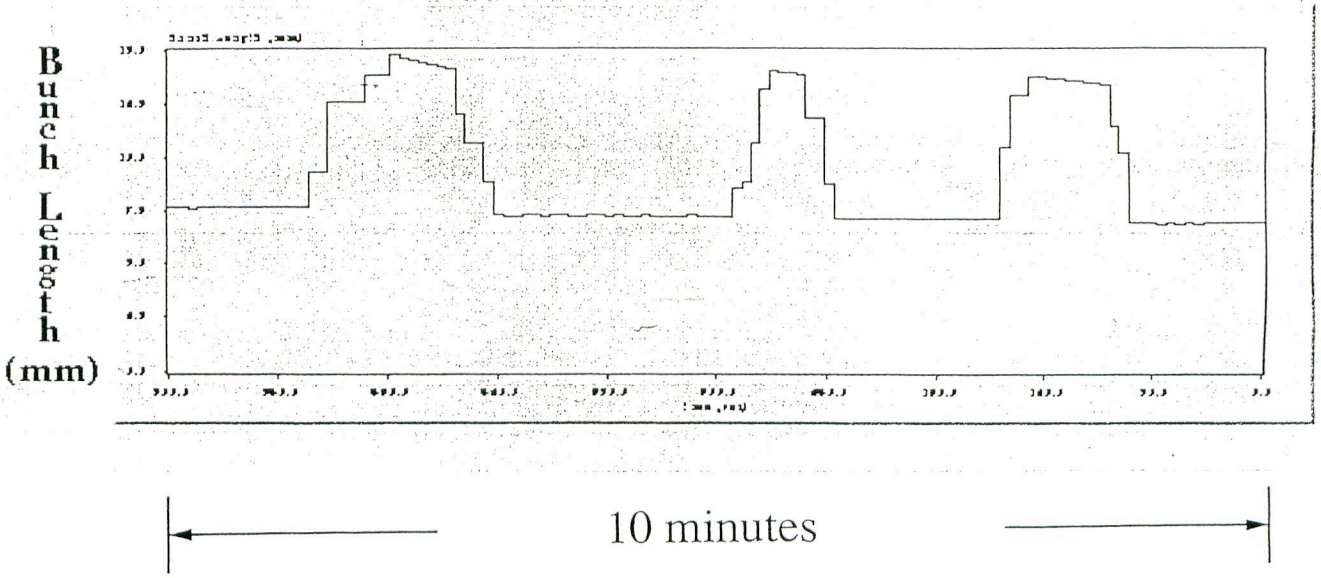
HER/LER Bunch Spectrum Monitor

RUN / STOP RUN EXIT

MODE		MODE 1 | MODE 2 | MODE 3
SPEED	HIACCURACY	NORMAL | HIACCURACY
RESOLUTION	7.5d	AUTO | 3.5d | 4.5d | 5.5d
FILTER	ON	OFF | ON
	8	s

BUNCH LENGTH 6.89 mm

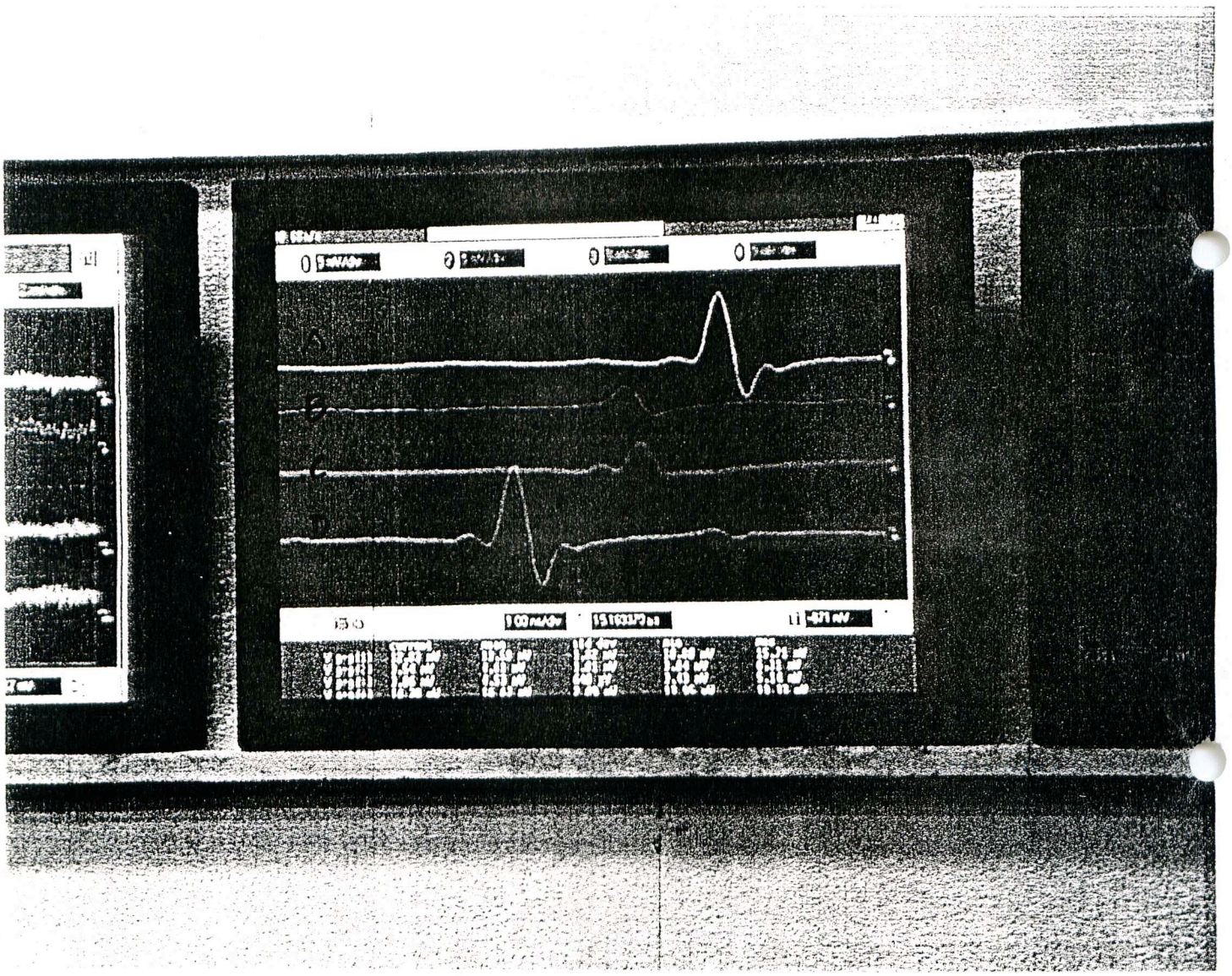
V1 = 1.76223 V V1 / V2 = 1.03124

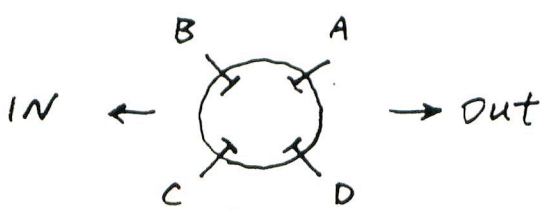


10 minutes

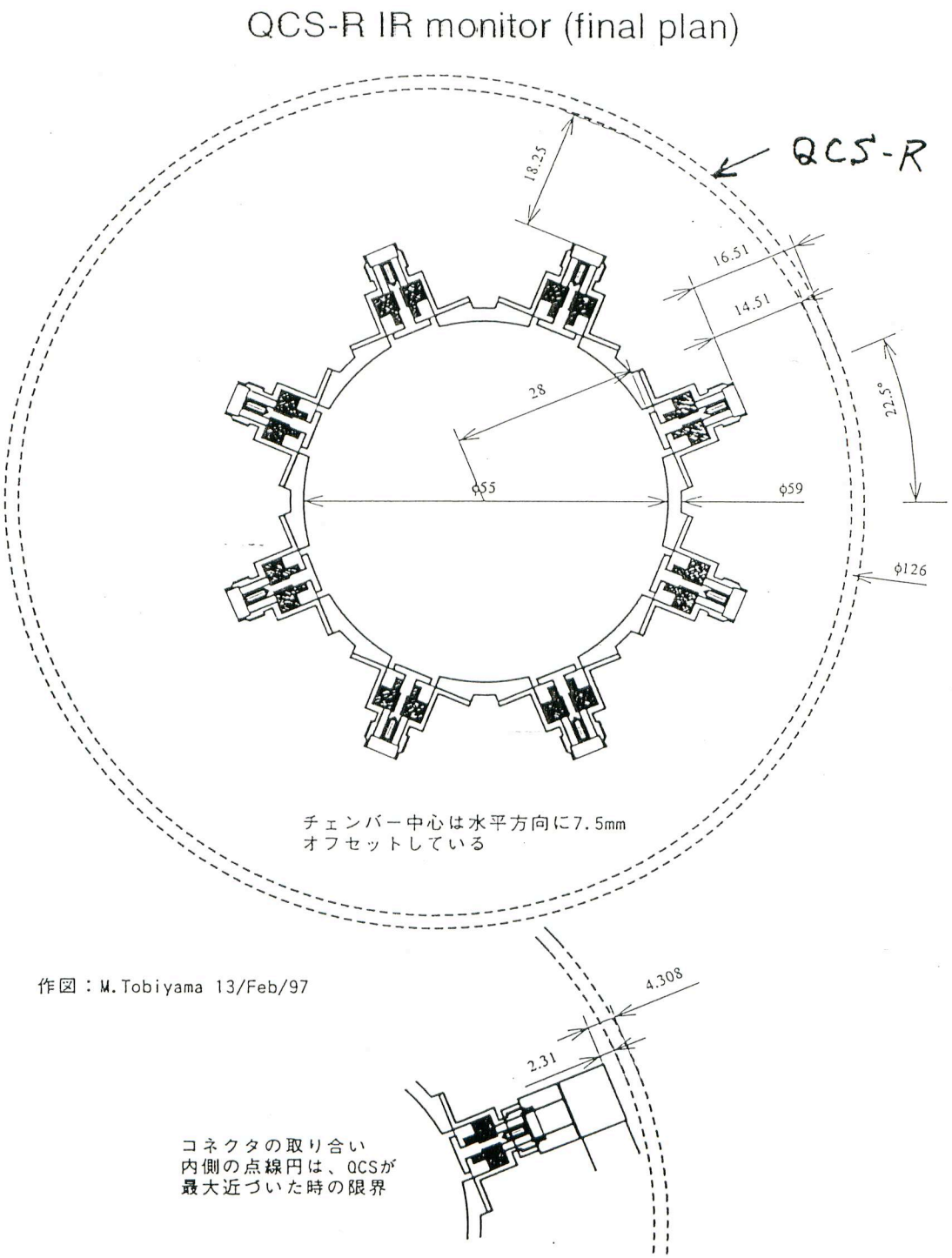
The Vc is changed to reduce single-bunch current at HER.
The bunch length changes according to the Vc.

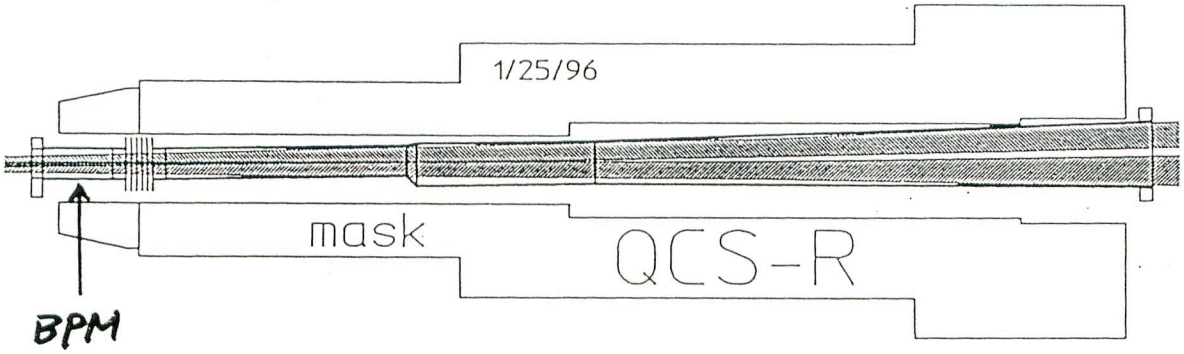
HER Buttom signal

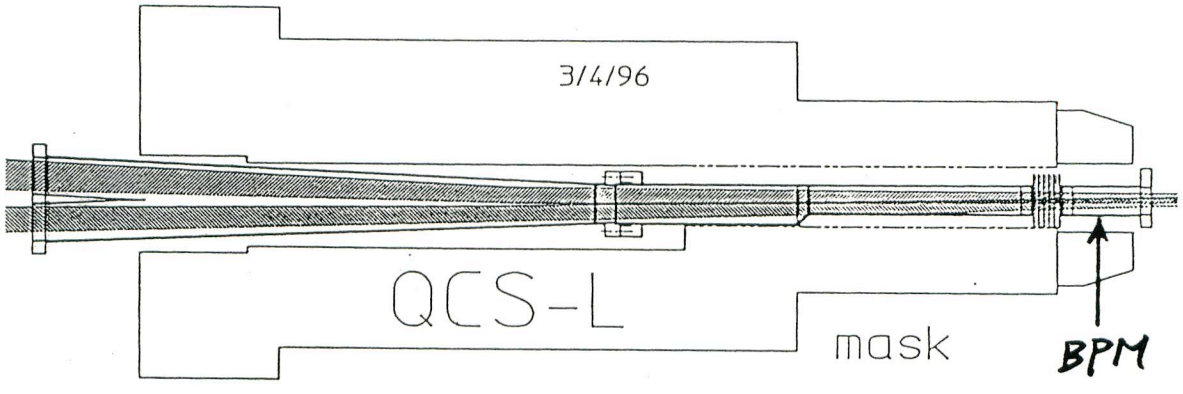




BPM at IP (in QCS)




1/25/96
mask
QCS-R
BPM


3/4/96
QCS-L
mask
BPM