Overview of KEKB

Shin-ichi Kurokawa
KEK

KEKB Accelerator Review Committee

February 23, 2001

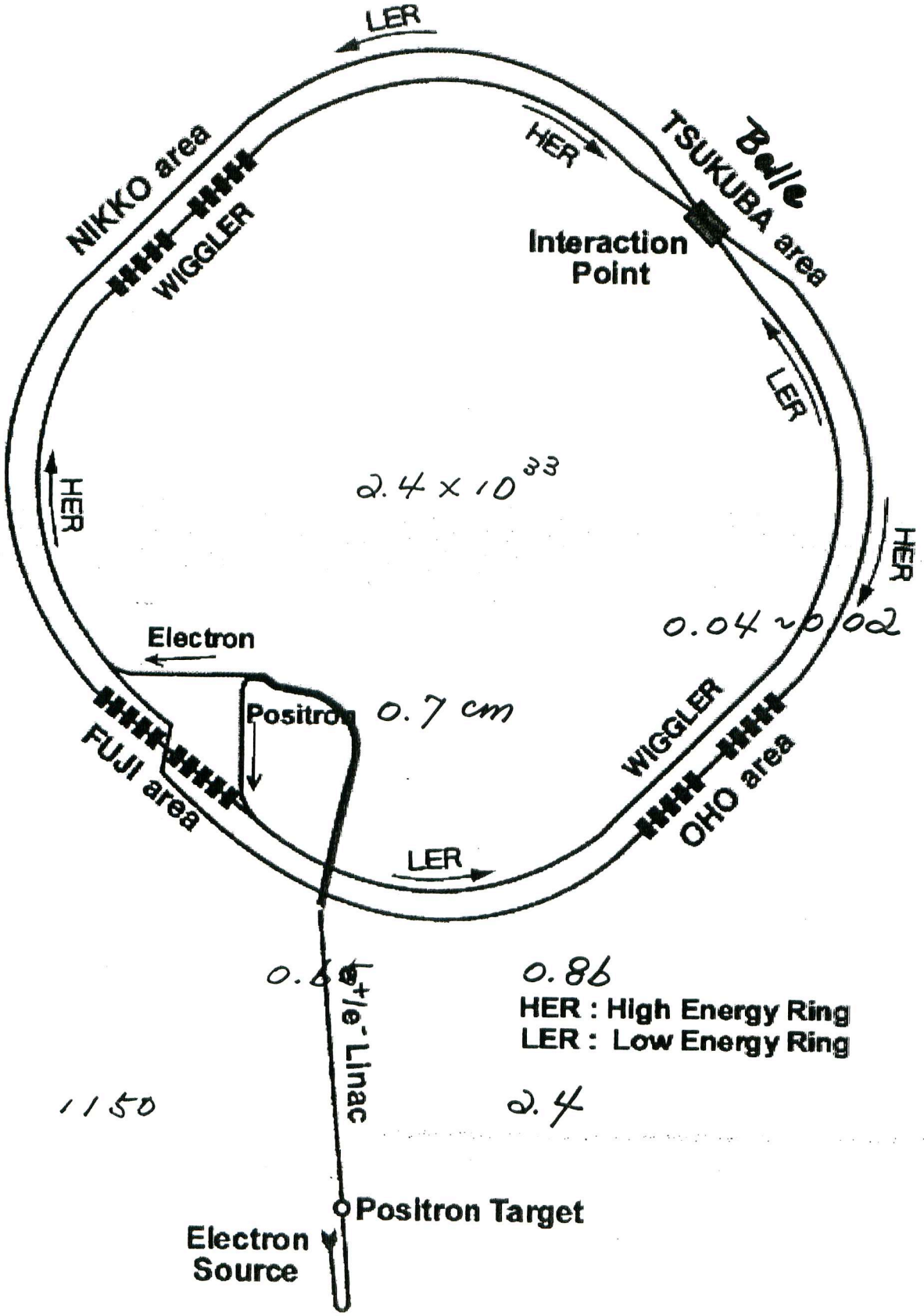
KEK B-Factory(KEKB)

3.5 GeV(e^+) x 8 GeV(e^-)
2-ring, asymmetric collider

design luminosity
$1 \times 10^{34} cm^{-2} s^{-1}$

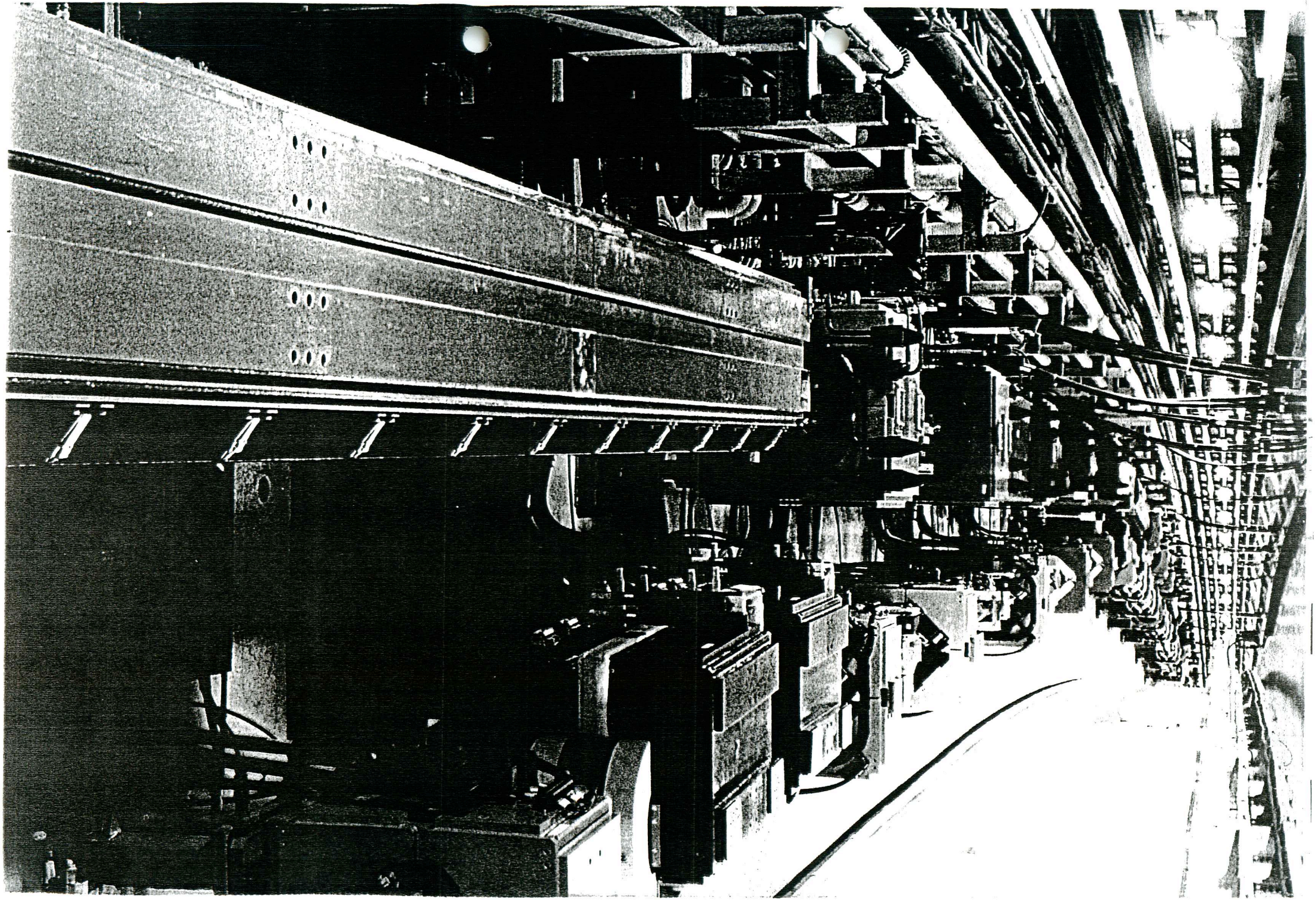
Features:

- **-5-year project (94-98)**
- **-budget 380 x 10^8yen**
- **-in TRISTAN tunnel**
- **-BELLE at IP**
- **-finite-angle crossing of 2 x 11 mrad at IP**
- **-crab crossing scheme** (*future*)


LER
HER
Belle
TSUKUBA area
Interaction Point
NIKKO area
WIGGLER
LER
HER
HER
2.4 × 10^33
0.04 ~ 0.02
Electron
Positron
0.7 cm
FUJI area
WIGGLER
OHO area
LER
0.6
e+/e- Linac
0.86
HER : High Energy Ring
LER : Low Energy Ring
1150
2.4
Positron Target
Electron Source

KEKB Parameters

- 3.5 GeV(e^+) x 8 GeV(e^-)
- 3016 m circumference
- Luminoisty $10^{34}cm^{-2}s^{-1}$
- Beam-beam tuneshift $\xi = 0.05$
- $\beta_y^* = 1$ cm
  $\sigma_x = 90$ μm, $\sigma_y = 1.9$ μm
- Currents 1.1 A(e^-), 2.6 A(e^+)
- 5000 bunches with 0.6 m spacing
- Crossing at 2 x 11 mrad at IP



Interaction Region

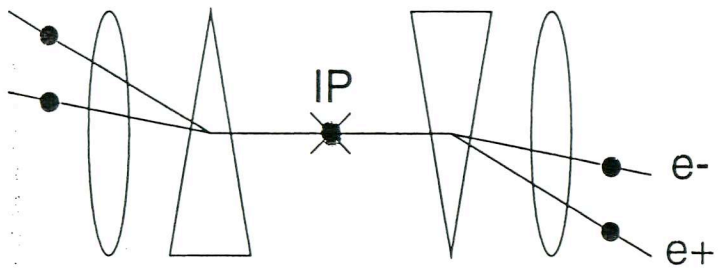
1. 2 x 11 mrad finite-angle crossing at IP to simplify IR and fill every bucket with beam.

2. Superconducting final-focus quads and anti-solenoids inside 1.5 Tesla BELLE detector solenoid.

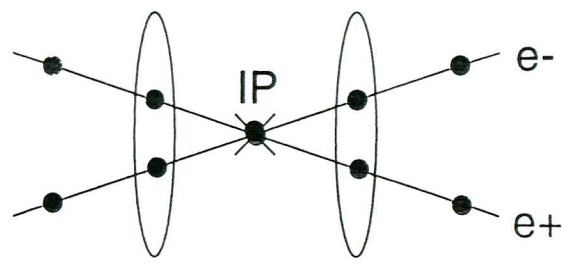
3. Crab-crossing scheme as a fall-back option. Superconducting crab cavities are being developed.

Finite Angle Crossing @ IP

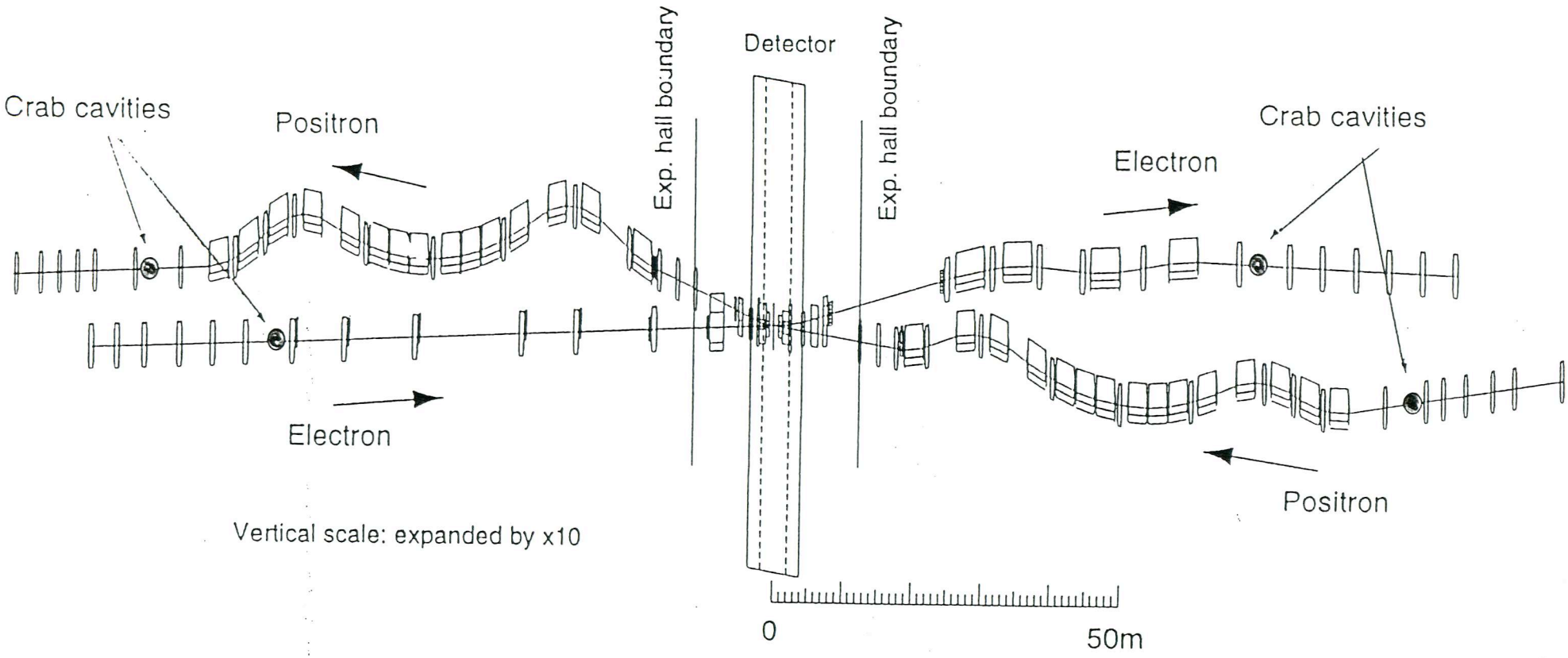
- No strong separation bend at IP
- No synchrotron radiation due to the bend
- No parastic collisions
- **Shorter bunch spacing**



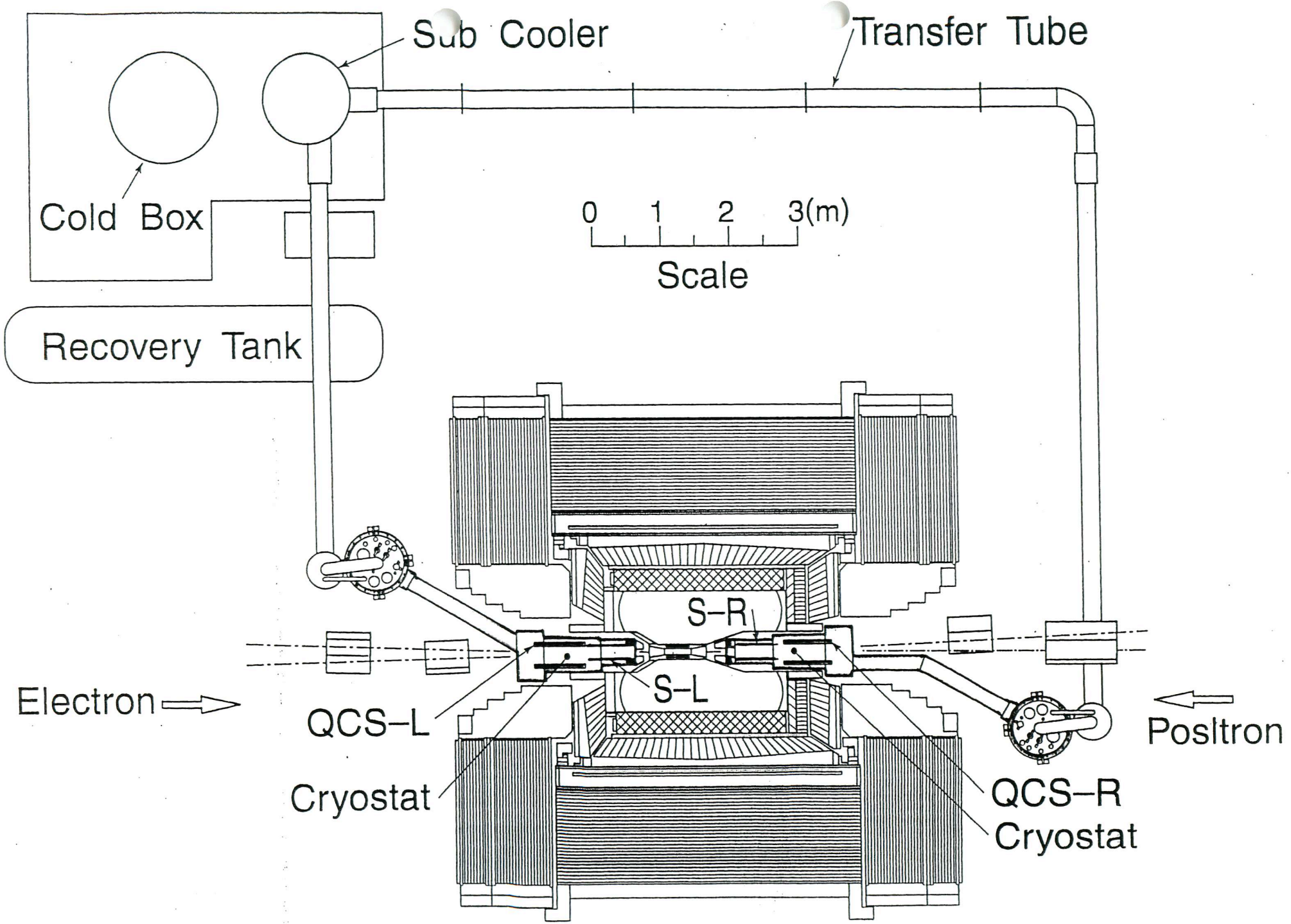
hean-on collision
PEP-II



finite angle crossing
KEKB


Crab cavities
Positron
Exp. hall boundary
Detector
Exp. hall boundary
Crab cavities
Electron
Electron
Positron
Vertical scale: expanded by x10
0
50m

± 11 mrad


Sub Cooler
Transfer Tube
Cold Box
0 1 2 3(m)
Scale
Recovery Tank
S-R
S-L
Electron
QCS-L
Posltron
Cryostat
QCS-R
Cryostat

RF system

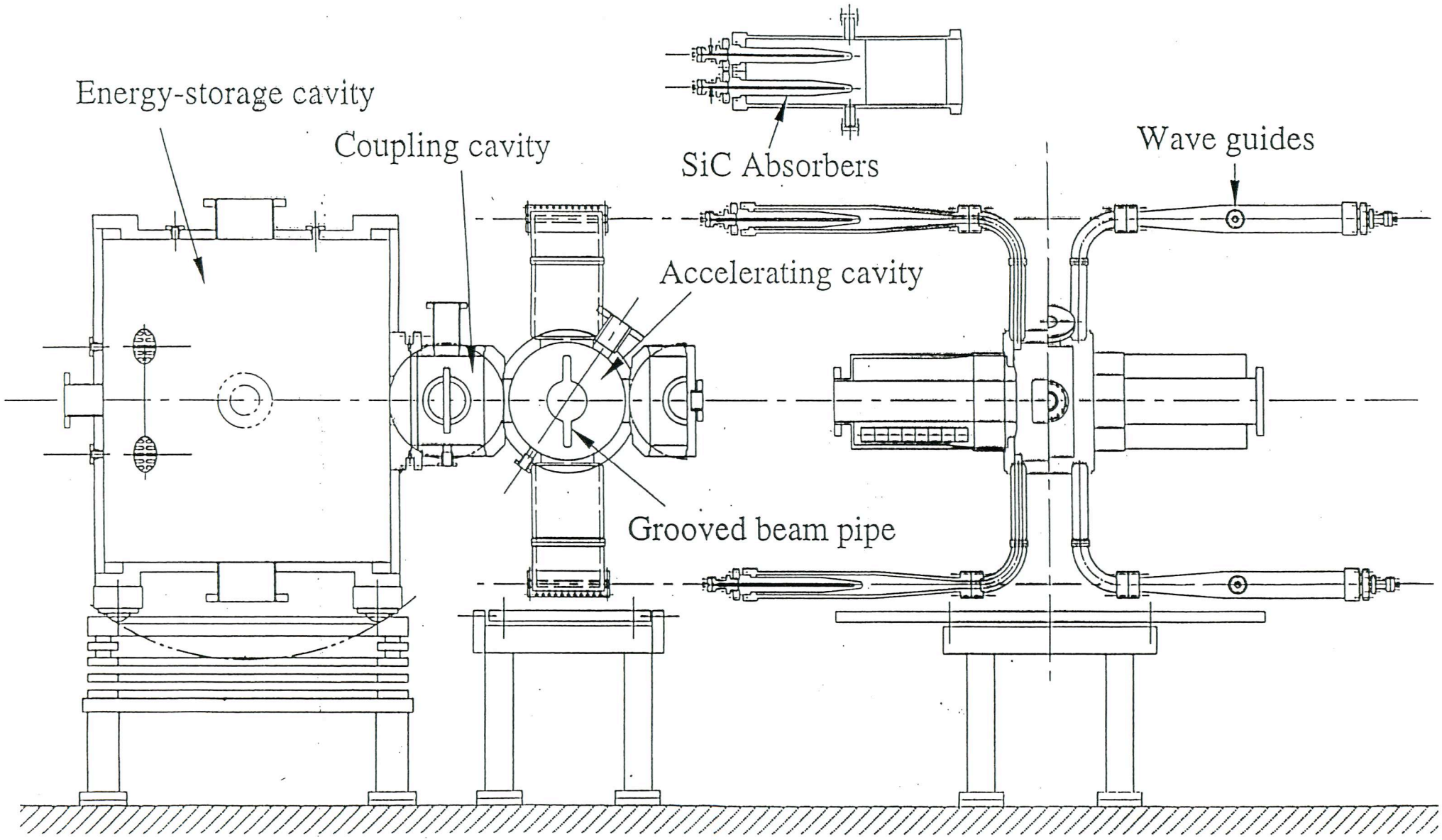
- Number of cavities:

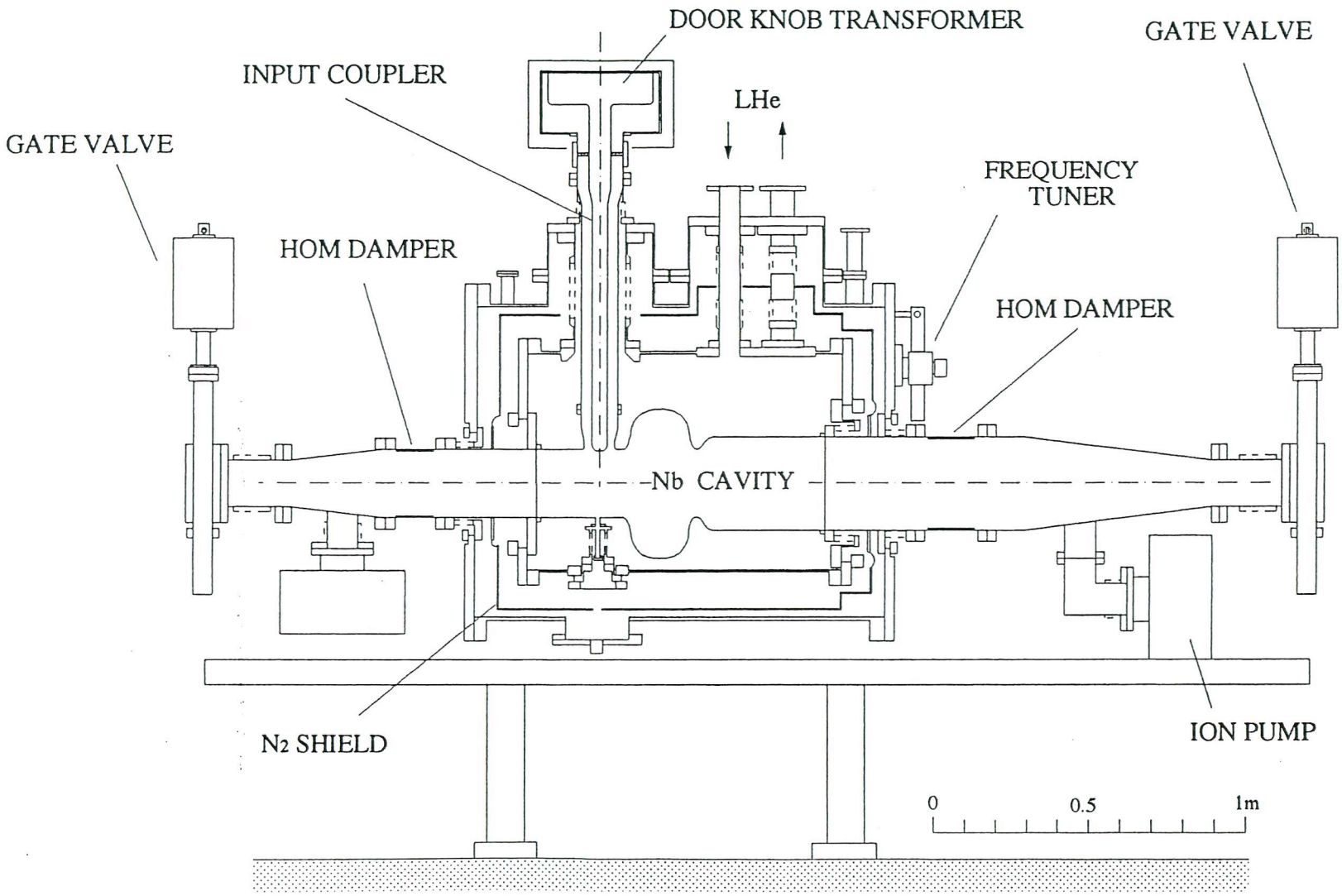
		t=0	Oct. 99	Oct. 00	Oct. 01
LER	ARES	12	16	16	20
HER	ARES	6	10	10	12
	SCC	4	4	8	8

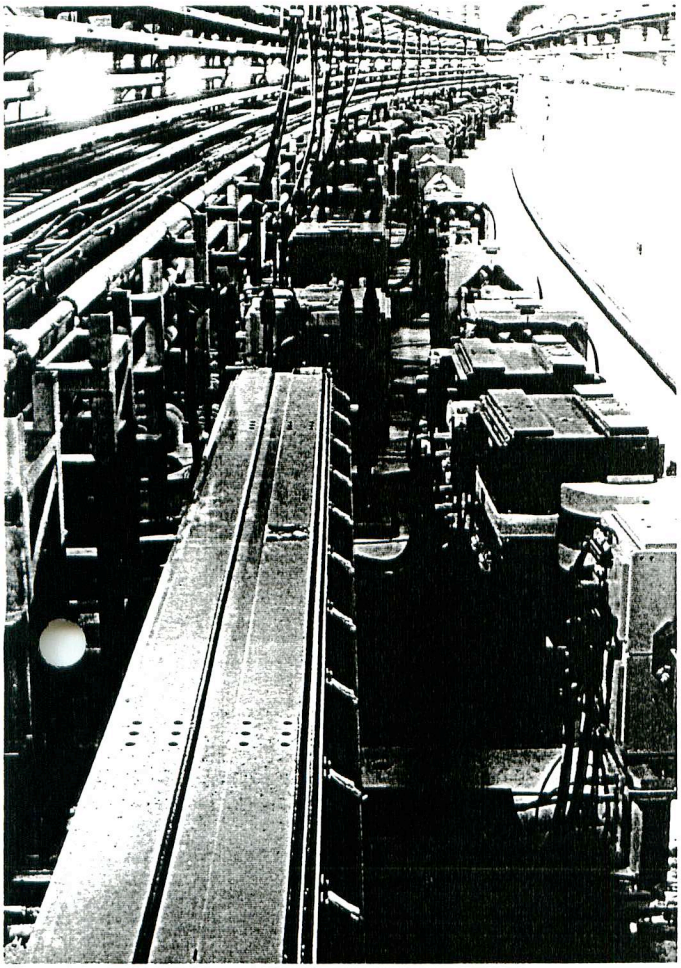
- ARES and SCC are working without any problems

- 380 kW is delivered by a SCC

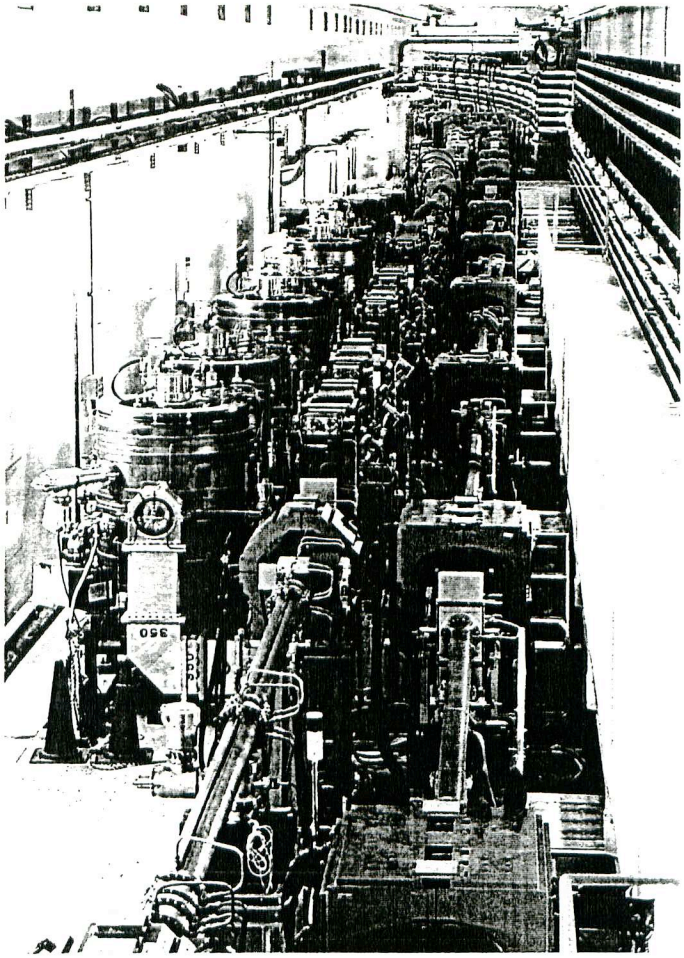
- Breakdowns of SCC is quite rare


Energy-storage cavity
Coupling cavity
SiC Absorbers
Wave guides
Accelerating cavity
Grooved beam pipe

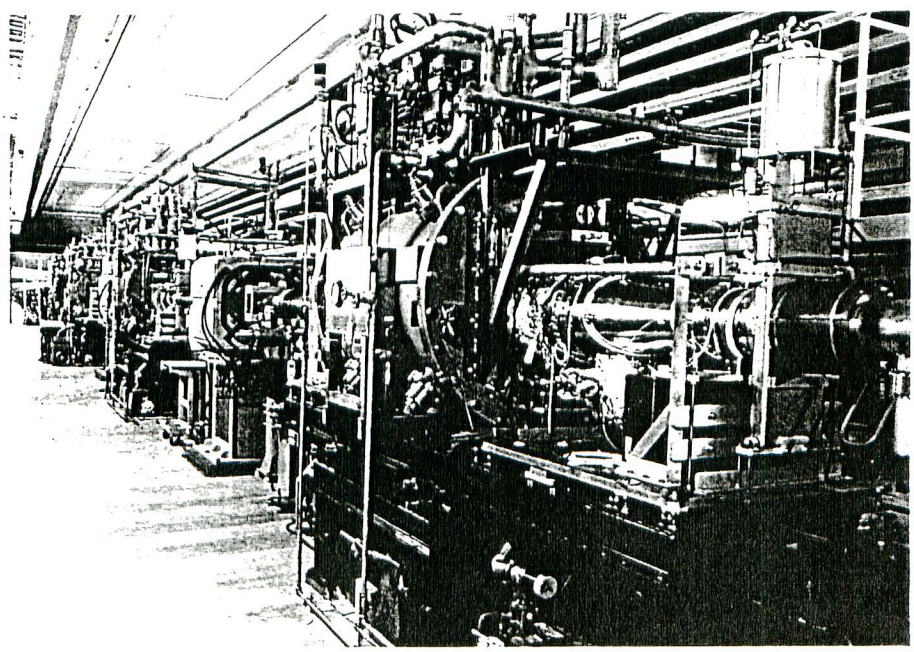

DOOR KNOB TRANSFORMER
GATE VALVE
INPUT COUPLER
LHe
GATE VALVE
FREQUENCY TUNER
HOM DAMPER
HOM DAMPER
Nb CAVITY
N2 SHIELD
ION PUMP
0
0.5
1m



HER (left), LER (Right)

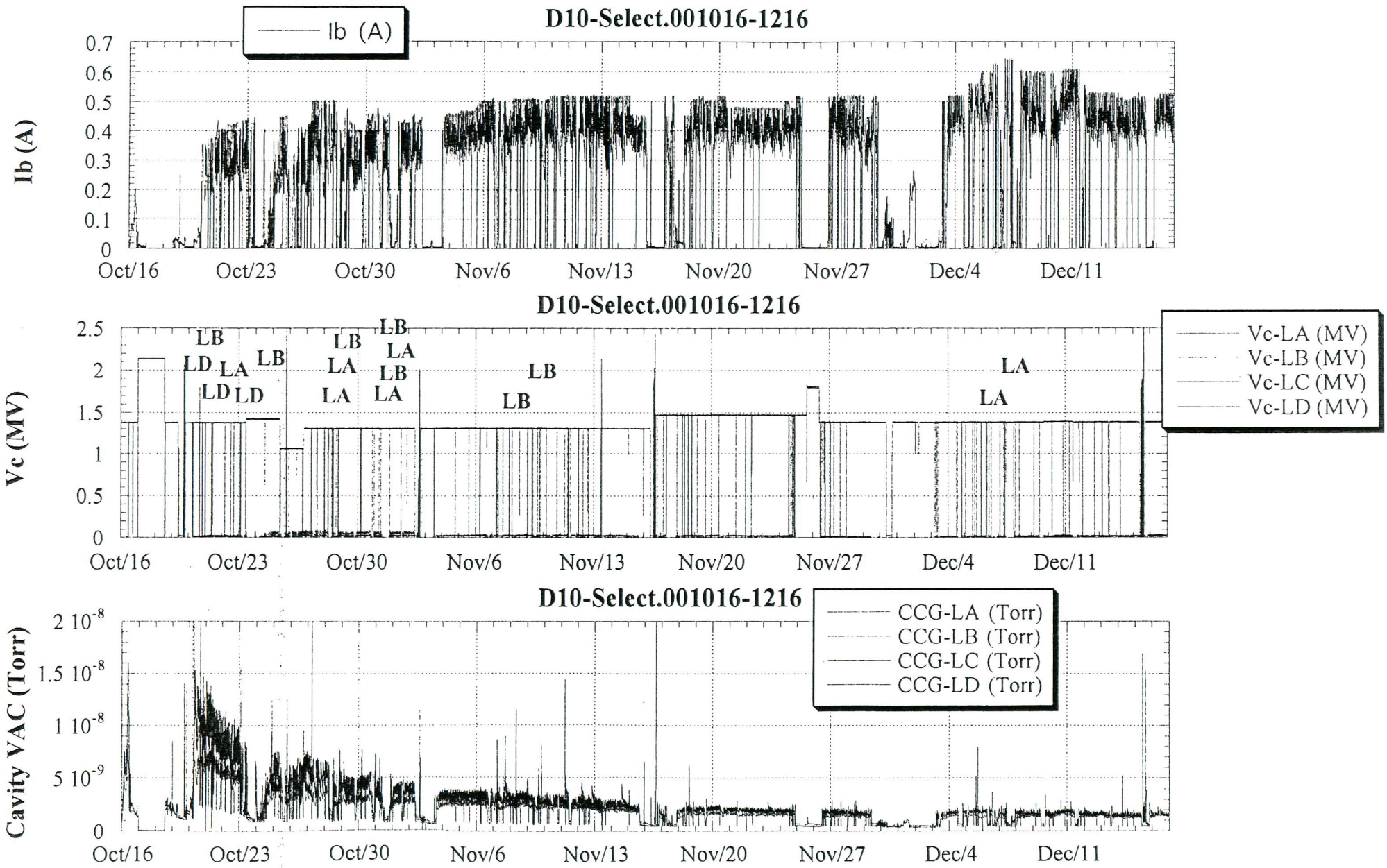


ARES (Normal conducting RF
for LER,left), HER(Right)

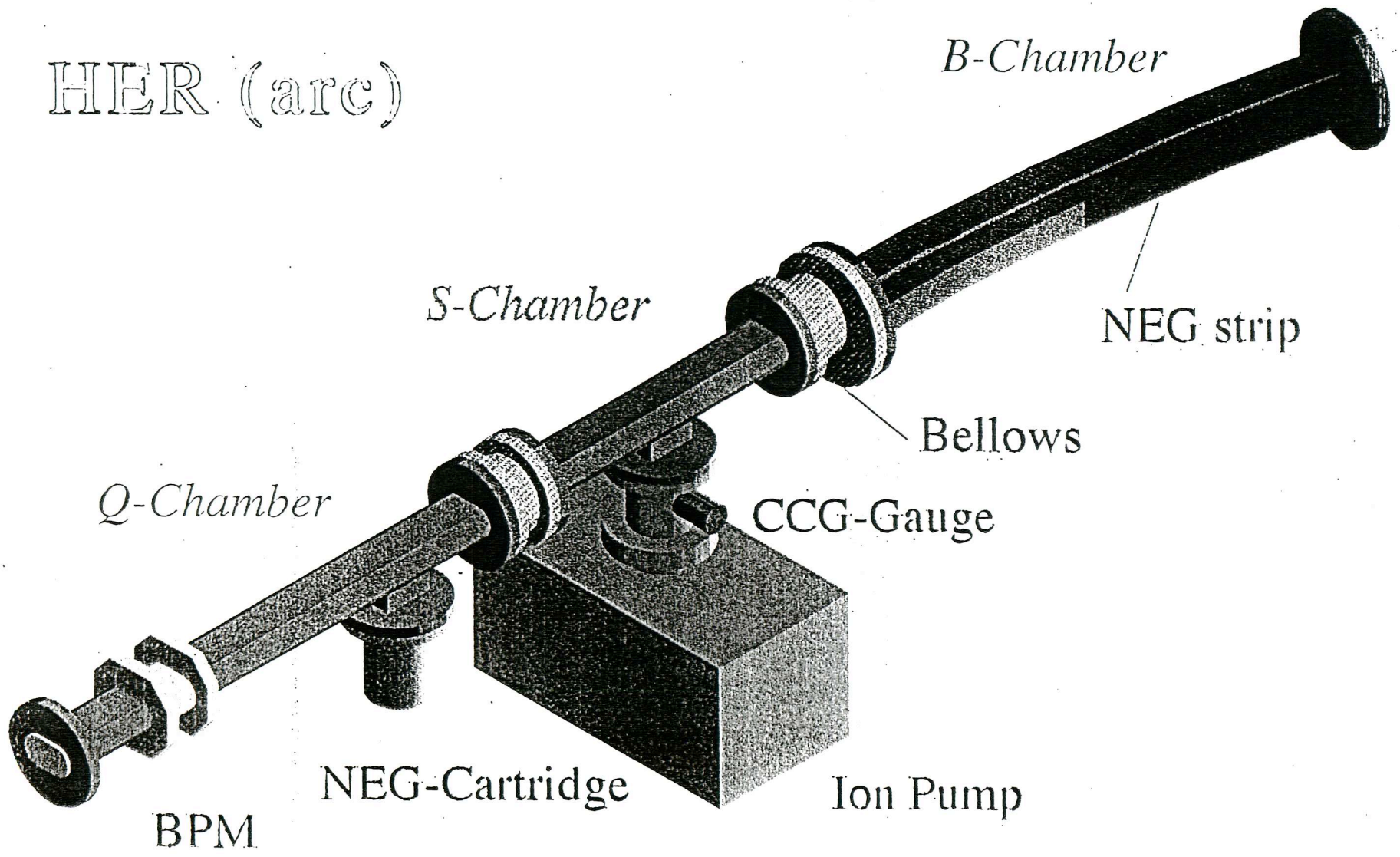


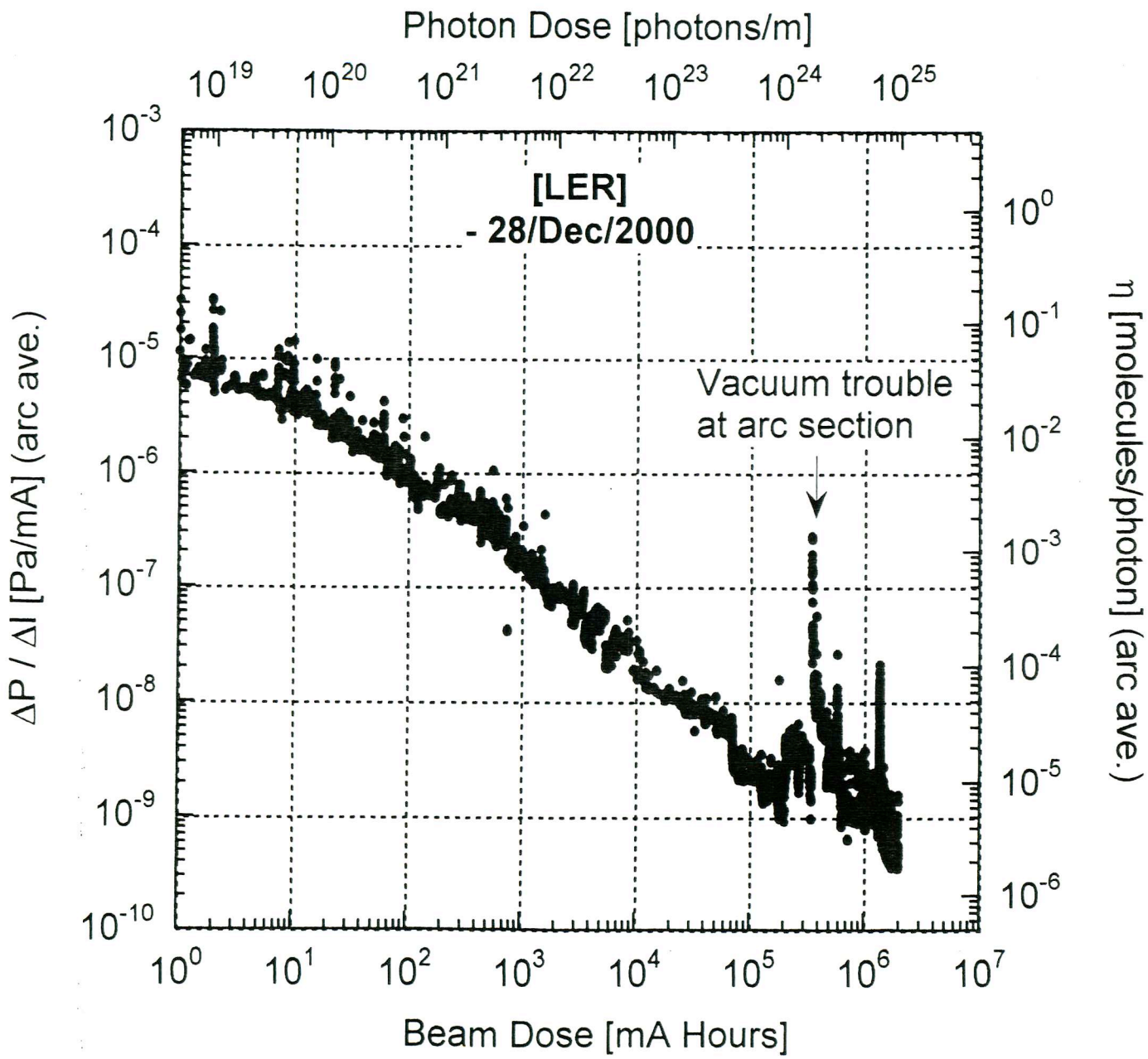
Superconducting RF
for HER

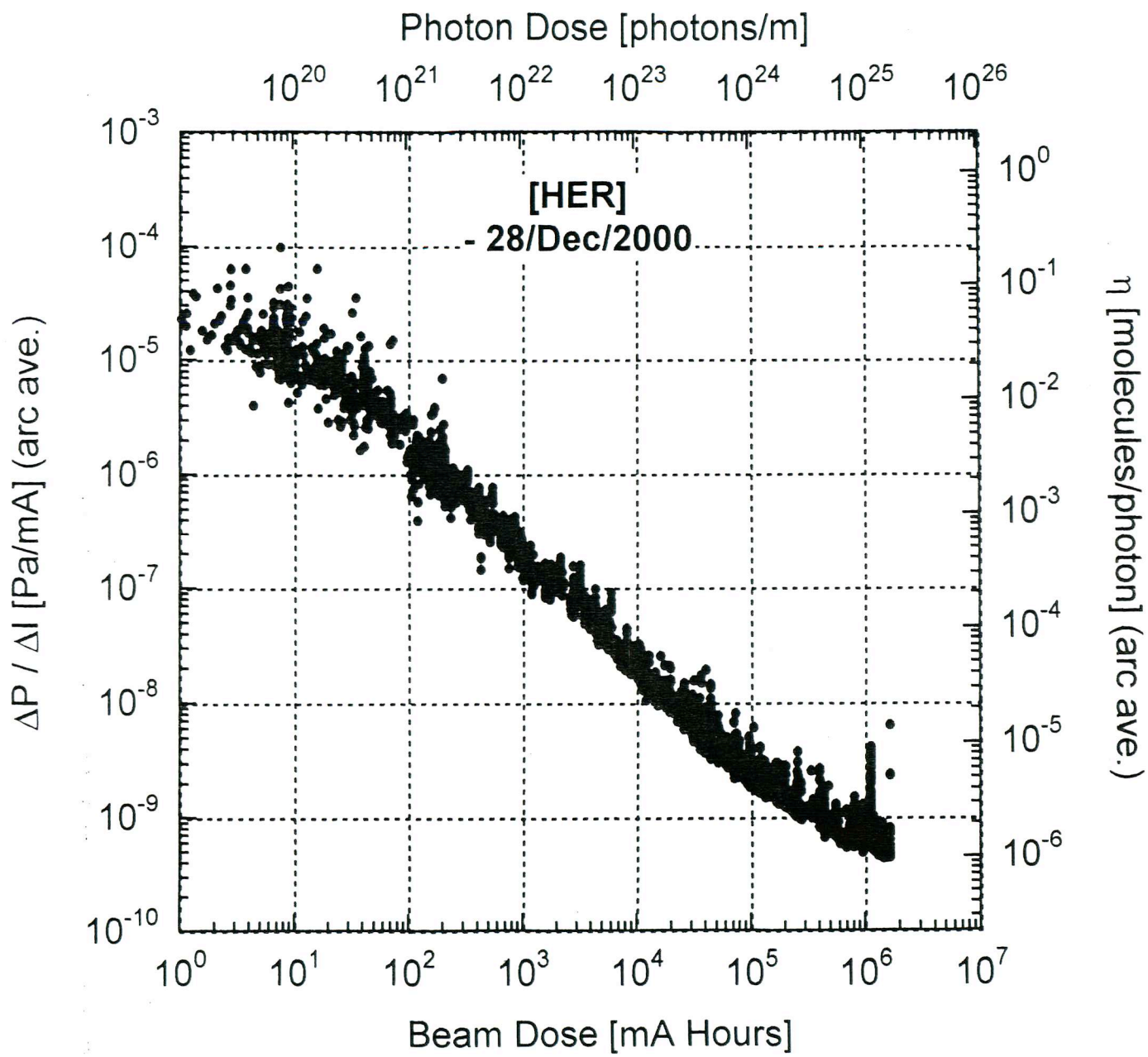
Trips of D10 cavities



HER (arc)


B-Chamber
S-Chamber
NEG strip
Bellows
Q-Chamber
CCG-Gauge
NEG-Cartridge
Ion Pump
BPM


Photon Dose [photons/m]
10^19 10^20 10^21 10^22 10^23 10^24 10^25
[LER]
- 28/Dec/2000
Vacuum trouble
at arc section
ΔP / ΔI [Pa/mA] (arc ave.)
η [molecules/photon] (arc ave.)
10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10
10^0 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7
Beam Dose [mA Hours]

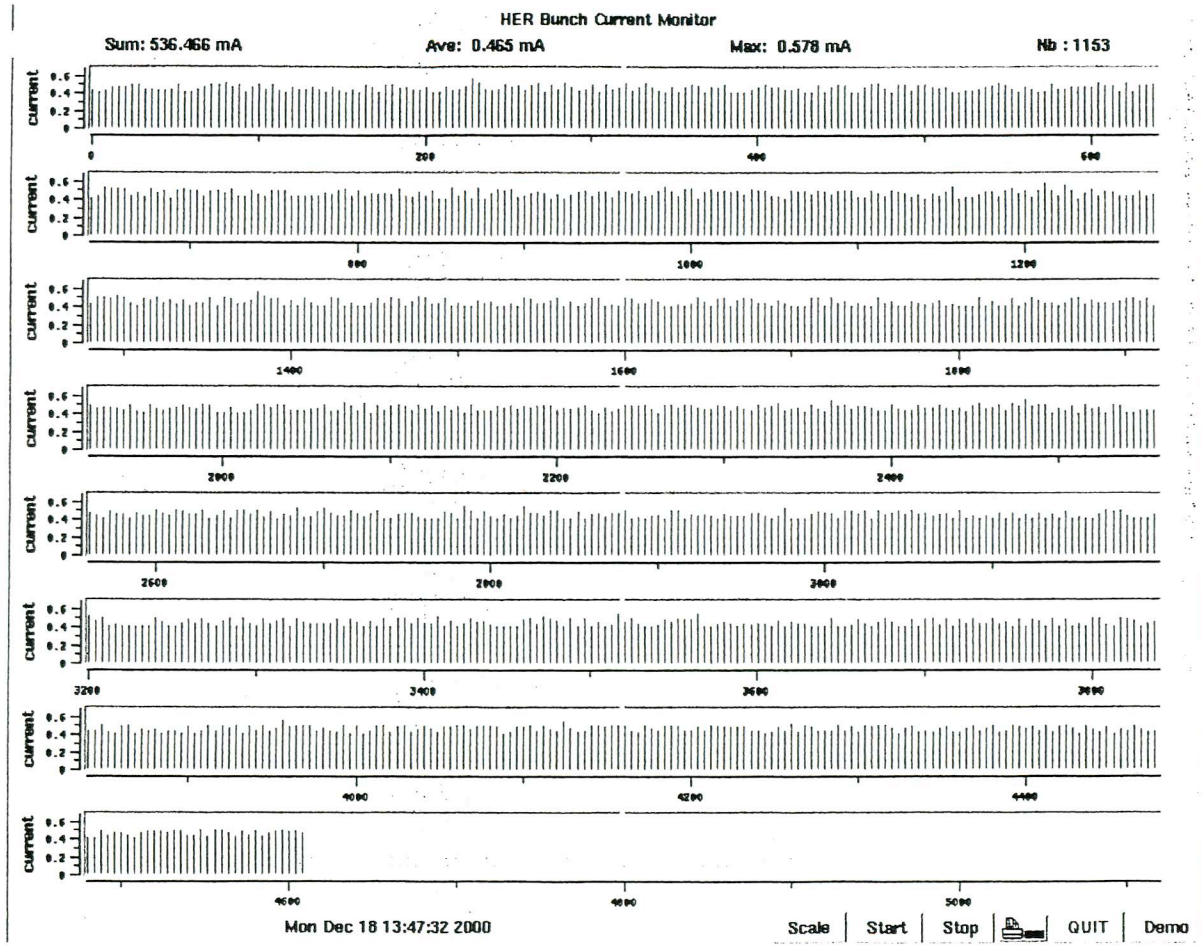

Photon Dose [photons/m]
10^{20} 10^{21} 10^{22} 10^{23} 10^{24} 10^{25} 10^{26}
[HER]
- 28/Dec/2000
10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10}
10^{0} 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6}
$\Delta P / \Delta I$ [Pa/mA] (arc ave.)
η [molecules/photon] (arc ave.)
10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7}
Beam Dose [mA Hours]

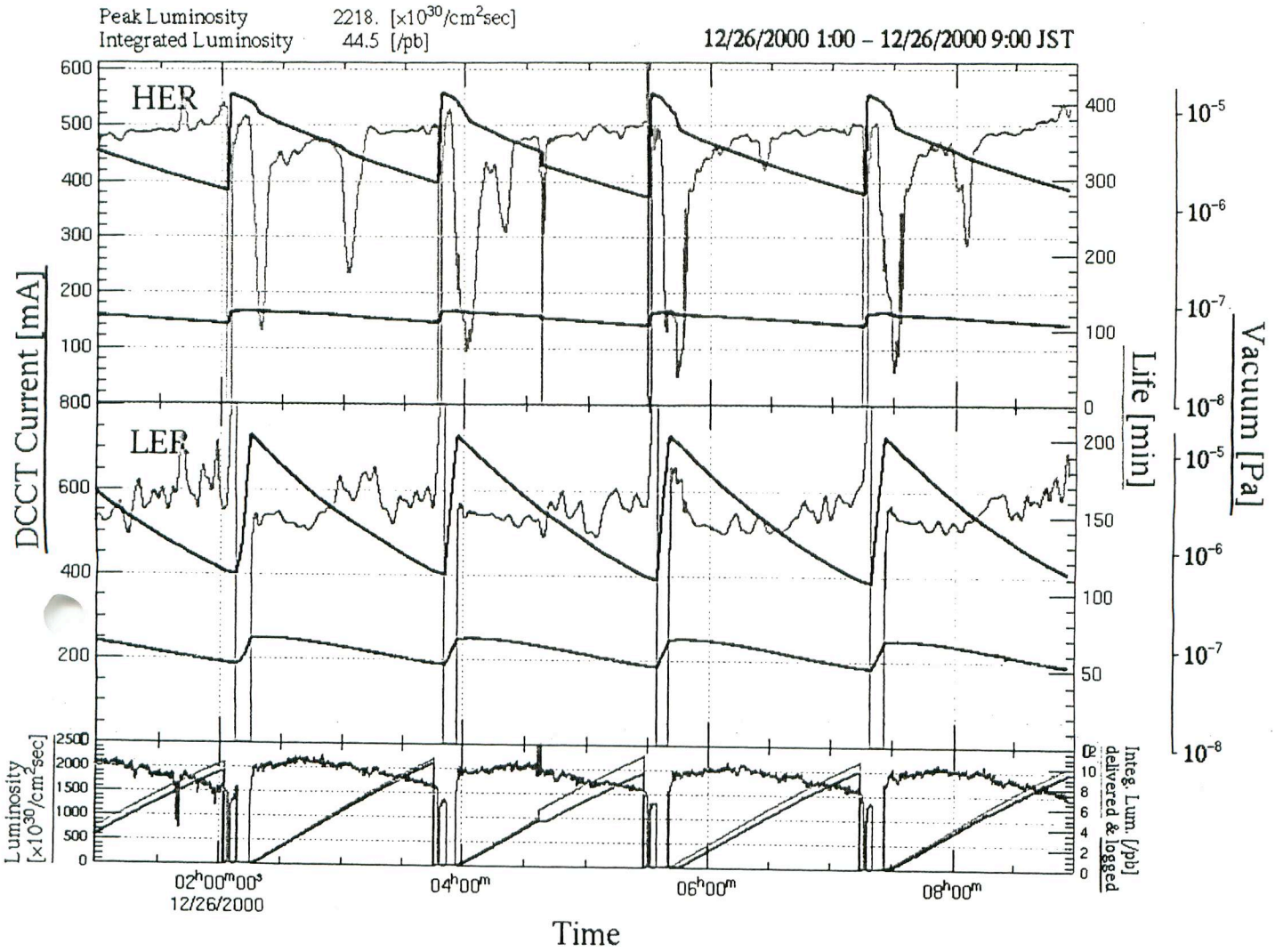
94/4 -98/11	**Construction**
98/12/1	**Commissioning of HER started**
99/1/10	**Commissioning of LER started**
99/4/19	**End of 1st stage commissioning**
99/5/1	**BELLE roll-in**
99/5/25	**Start of operation with BELLE**
99/6/1	**Observation of 1st hadroninc event**

99/6/9	**First physics run** **Average L=1.05 x 10^{31}** **Integrated L=505/nb** **Observed 1269 hadronic events**
99/6/27 **-8/5**	**Physics run** **Peak L=2.9 x 10^{32}** **Integrated L=26/pb**
99/8/5 **-10/12**	**Summer shutdown** **4 ARES in LER and** **4 ARES in HER were added**
99/10/12	**Operation resumed**
99/10/24 **-12/16**	**Physics run** **Peak L=6.9 x 10^{32}** **Integrated L=300/pb**

99/12/27 -00/1/11	**New-year shutdown**
00/2/18	**Peak L=1.03 x 10^{33}**
00/5/8	**Int L/day=90.7/pb**
00/7/23	**Peak L=2.04 x 10^{33}**
00/7/23	**Logged L by BELLE 6.83/fb**
00/7/25	**Start of summer shutdown** **1) 4 SCC added** **2) Movable masks and bellows replaced** **3) Solenoid winding over LER chambers**

00/10/10	**Operation resumed**
00/12/25 **12/20-26**	**Peak L=2.37 x 10^{33}** **Int L/day=135.3/pb** **Int $L/week$=880/pb**
00/12/28	**Logged L by BELLE** **11.09/fb**
00/12/28 **-01/01/16**	**New-Year shutdown** **Solenoid winding**
01/01/16	**Operation resumed**
01/02/16	**Logged L by BELLE** **13.00/fb**
01/02/19	**Peak L=2.47 x 10^{33}**
01/07/15	**Start of summer shutdown**

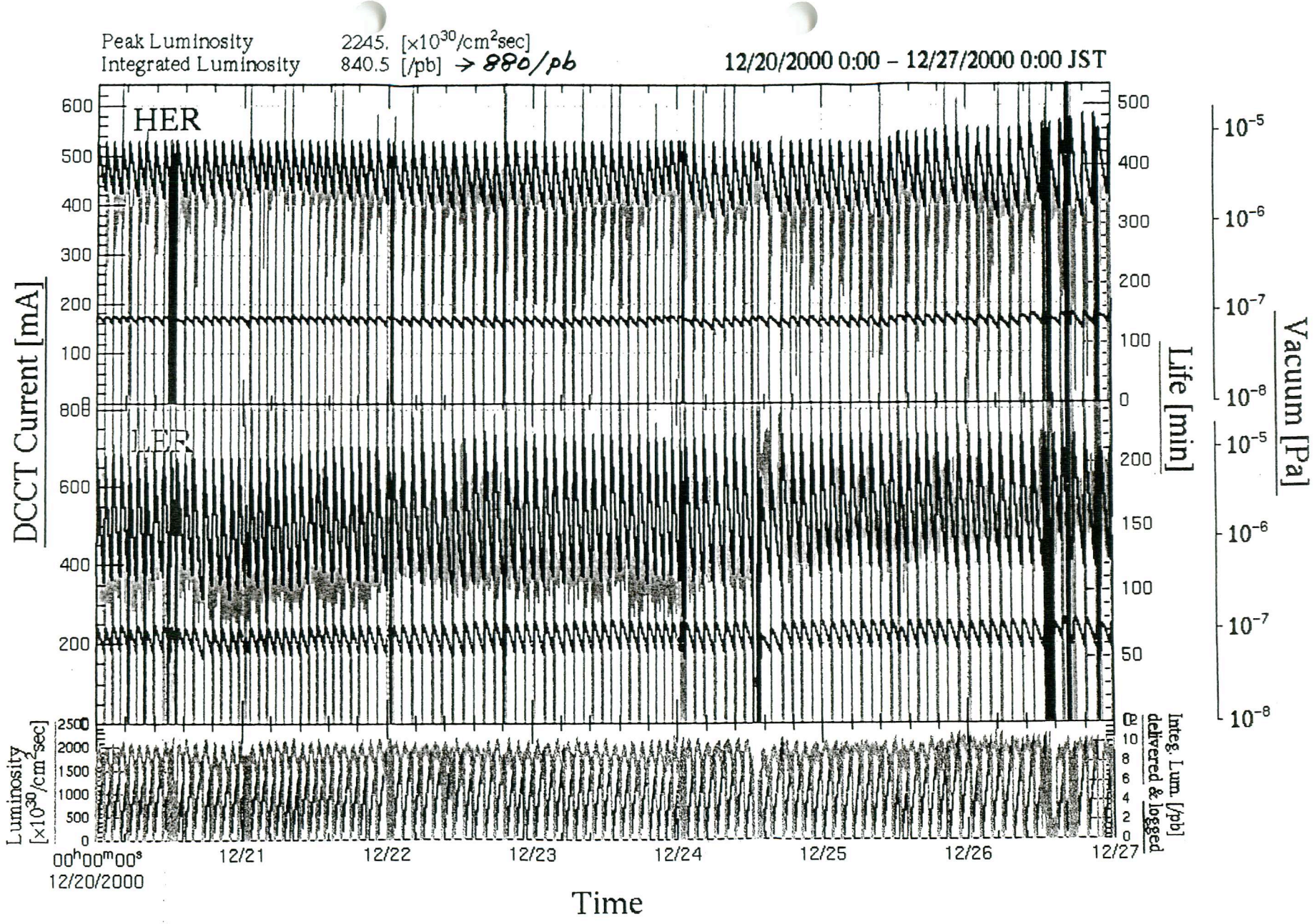

HER Bunch Current Monitor
Sum: 536.466 mA
Ave: 0.465 mA
Max: 0.578 mA
Nb : 1153
current
Mon Dec 18 13:47:32 2000
Scale
Start
Stop
QUIT
Demo



From Year: 2000 Month: 12 Day: 26 Hour: 1 For 1/3 Days Replot Print transparency

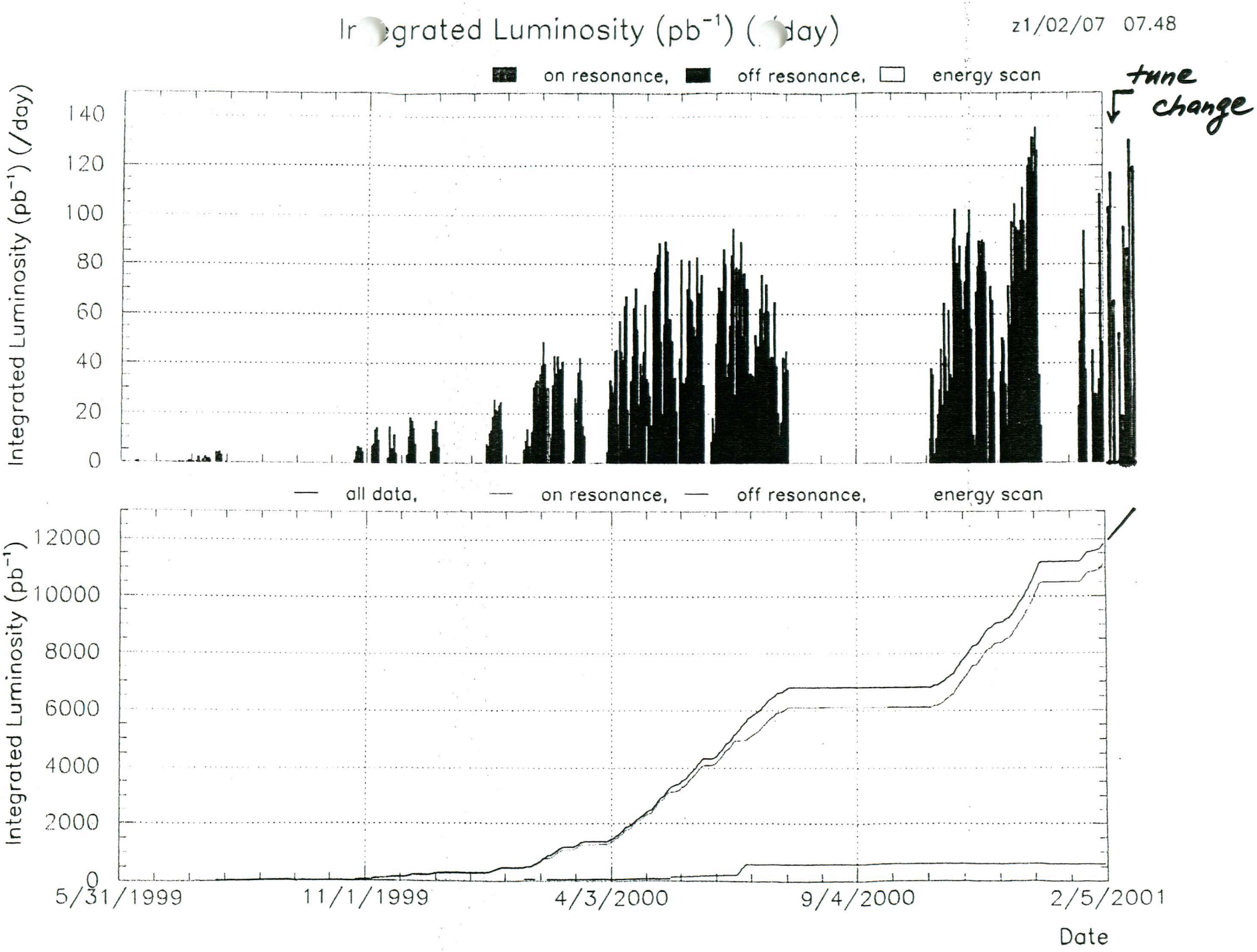
lard Copy

File Edit Window 12/27/2000 00:05:39 Help



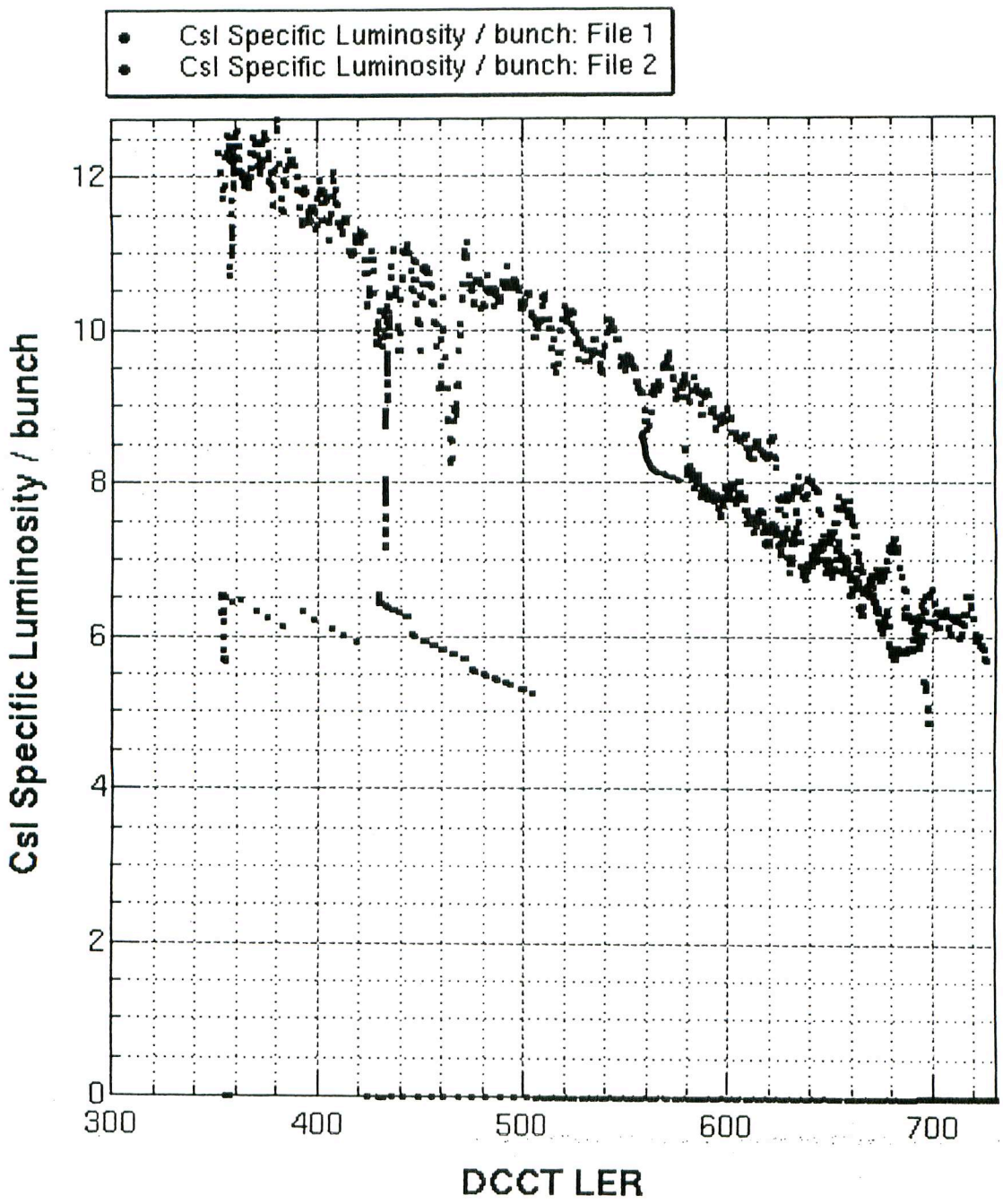
From Year: 2000 Month: 12 Day: 20 Hour: 0 For 7 Days Replot Print transparency

Hard Copy


Integrated Luminosity (pb⁻¹) (/day)
z1/02/07 07.48
on resonance, off resonance, energy scan
tune change
Integrated Luminosity (pb⁻¹) (/day)
0
20
40
60
80
100
120
140
all data, on resonance, off resonance, energy scan
Integrated Luminosity (pb⁻¹)
0
2000
4000
6000
8000
10000
12000
5/31/1999
11/1/1999
4/3/2000
9/4/2000
2/5/2001
Date
runinfo ver.1.36 : Exp3 Run1 – Exp11 Run240 : BELLE LEVEL latest

File 1 Fill#: 3391 Lum2000_12_24_4_24_47.dat

File 2 Fill#: 3813 Lum2001_2_17_8_1_26.dat



	x	y
Tune old	.52	.10
Tune new	.52	.63

Performances of KEKB

	As of 00/07/25	As of 00/12/28
Energy e^+/e^- (GeV)	3.5/8.0	3.5/8.0
Peak luminosity ($10^{33}cm^{-2}s^{-1}$)	2.04	2.37
Current e^+/e^- (A) at peak L	0.47/0.42	0.60/0.49
Maximum current e^+/e^- (A)	0.75/0.50	0.86/0.65
Number of bunches	1146	1153
Bunch spacing(ns)	8	8
Beta function at IP β_y^*(cm)	0.7	0.7
Beam sizes at IP σ_x^* / σ_y^*(μm)	112(e^+)145 (e^-)/1.7	
Beam-beam tuneshift e^+ ξ_x/ξ_y	0.036/0.037	0.045/0.038
e^- ξ_x/ξ_y	0.029/0.023	0.042/0.020
Max int. luminosity/day (1/pb)	90.6	135.3
Max int. luminosity/week (1/pb)	505	880
Logged luminosity by BELLE (1/fb)	6.83	11.09

Issues

1. Luminosity

- **Present performance of KEKB corresponds to 3/fb/month and 25/fb/year.**

- **In order to improve the performance, beam-beam tuneshift and stored currents should be made larger.**

2. Beam-beam limit and crab cavities

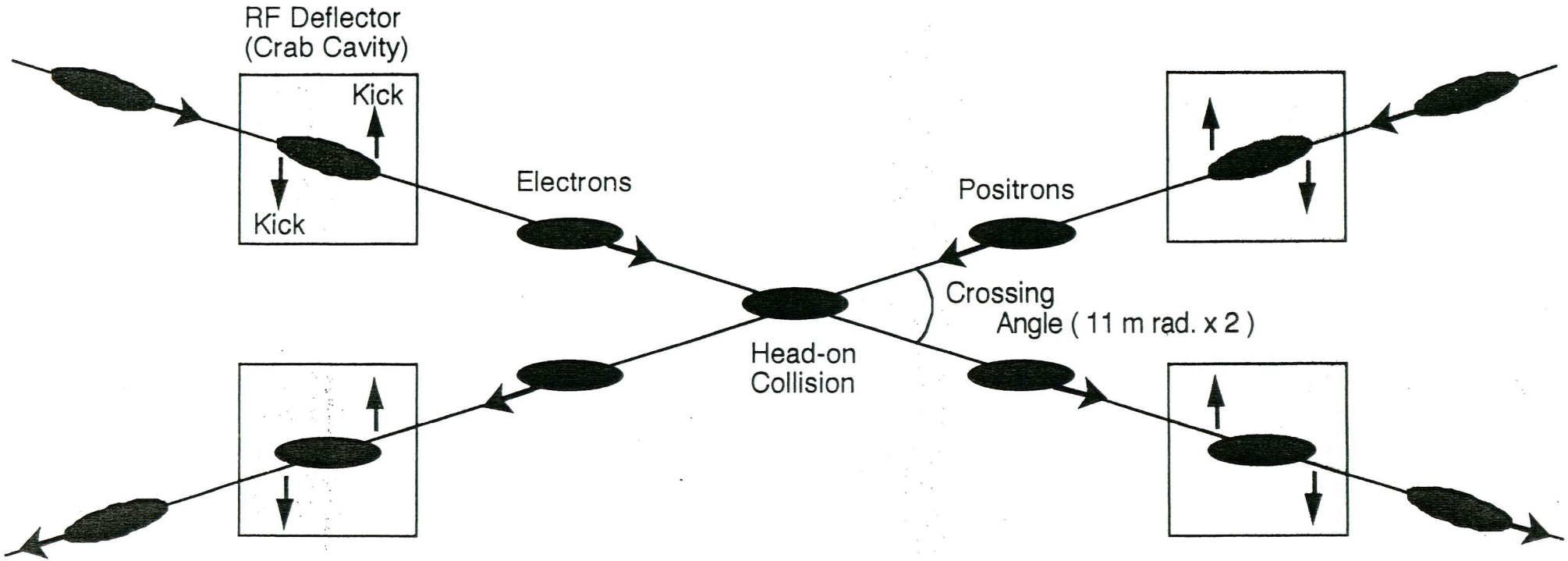
- Even with crossing at an angle, reasonable tuneshift of 0.02-0.04 have been achieved.

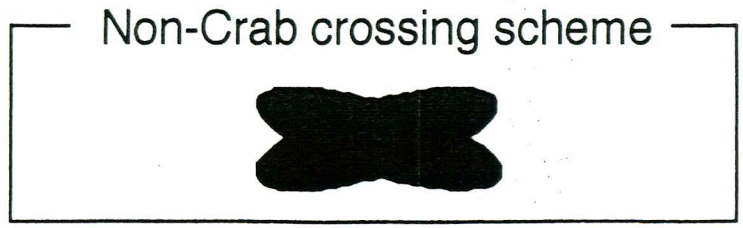
- We are developing crab cavities expecting that they will improve the tuneshift over 0.05. Crab cavities will be able to be installed in 2003.

3. β_y^*

- 7 mm βy^* (design is 10 mm) has been already achieved

Crab Crossing Scheme

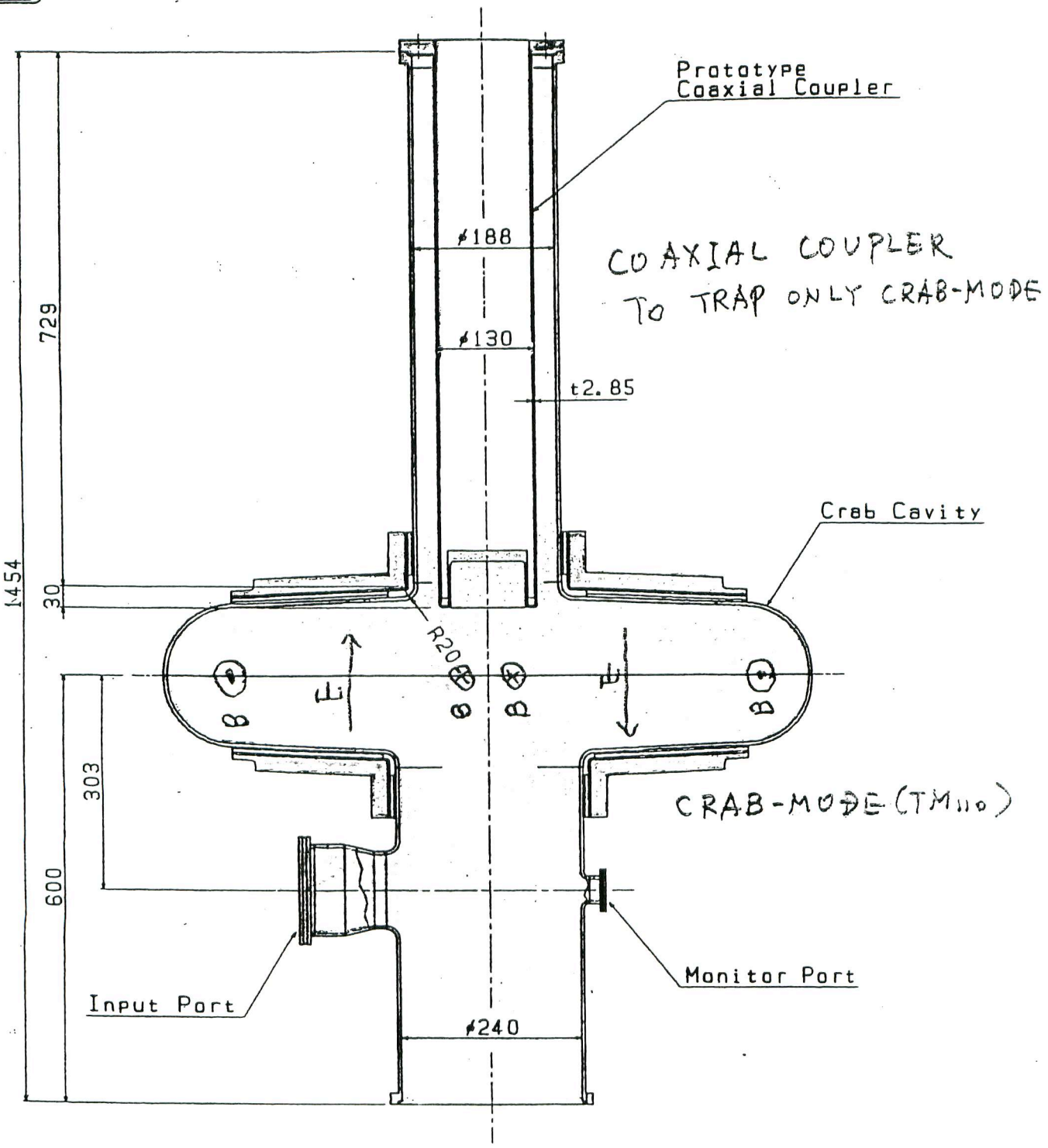




The Crab crossing scheme allows a large crossing angle collision without introducing any synchrotron-betatron coupling resonances.

Crab Cavity Group

SQUASHED CELL CAVITY

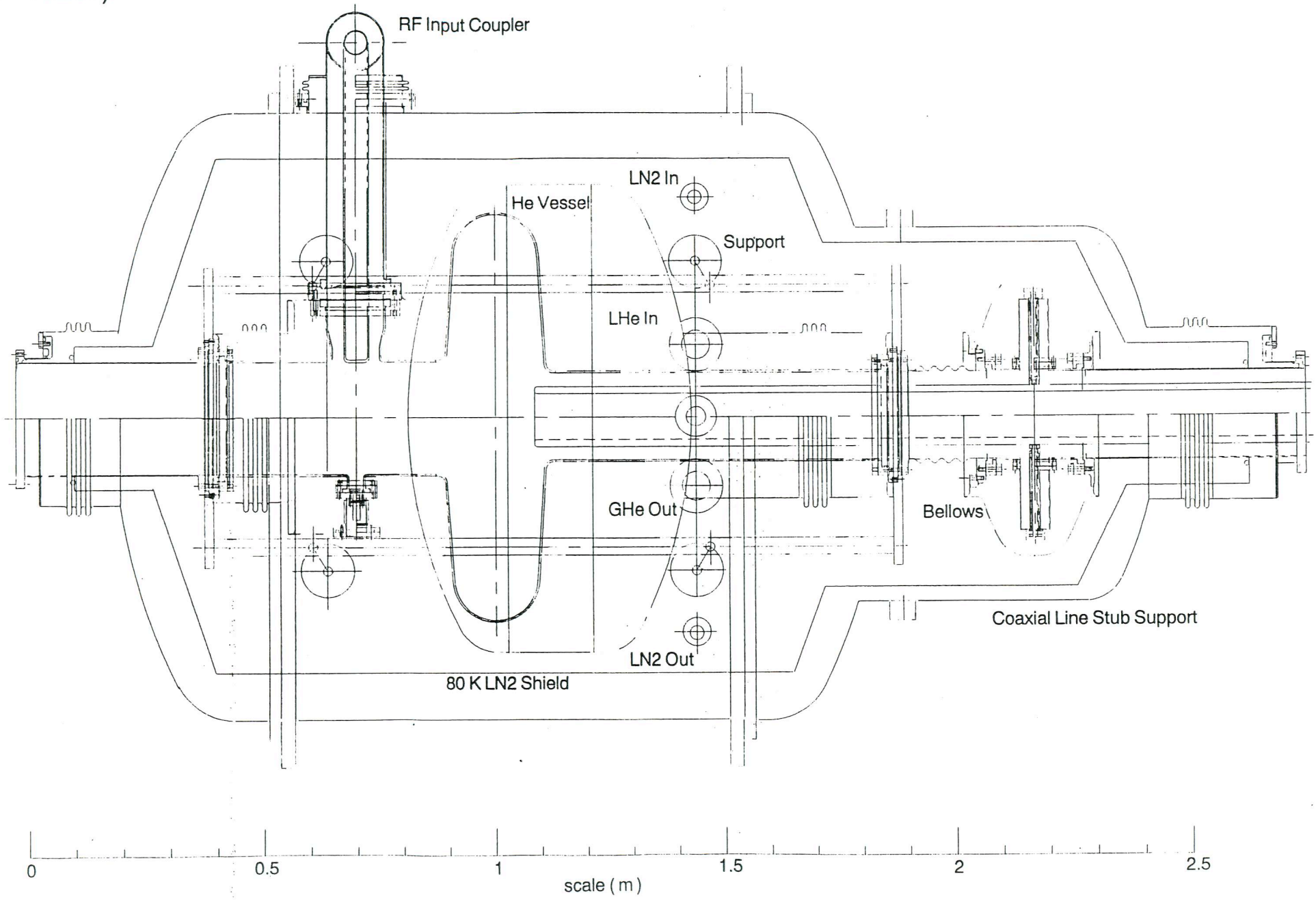


COAXIAL COUPLER
TO TRAP ONLY CRAB-MODE

CRAB-MODE (TM_{110})

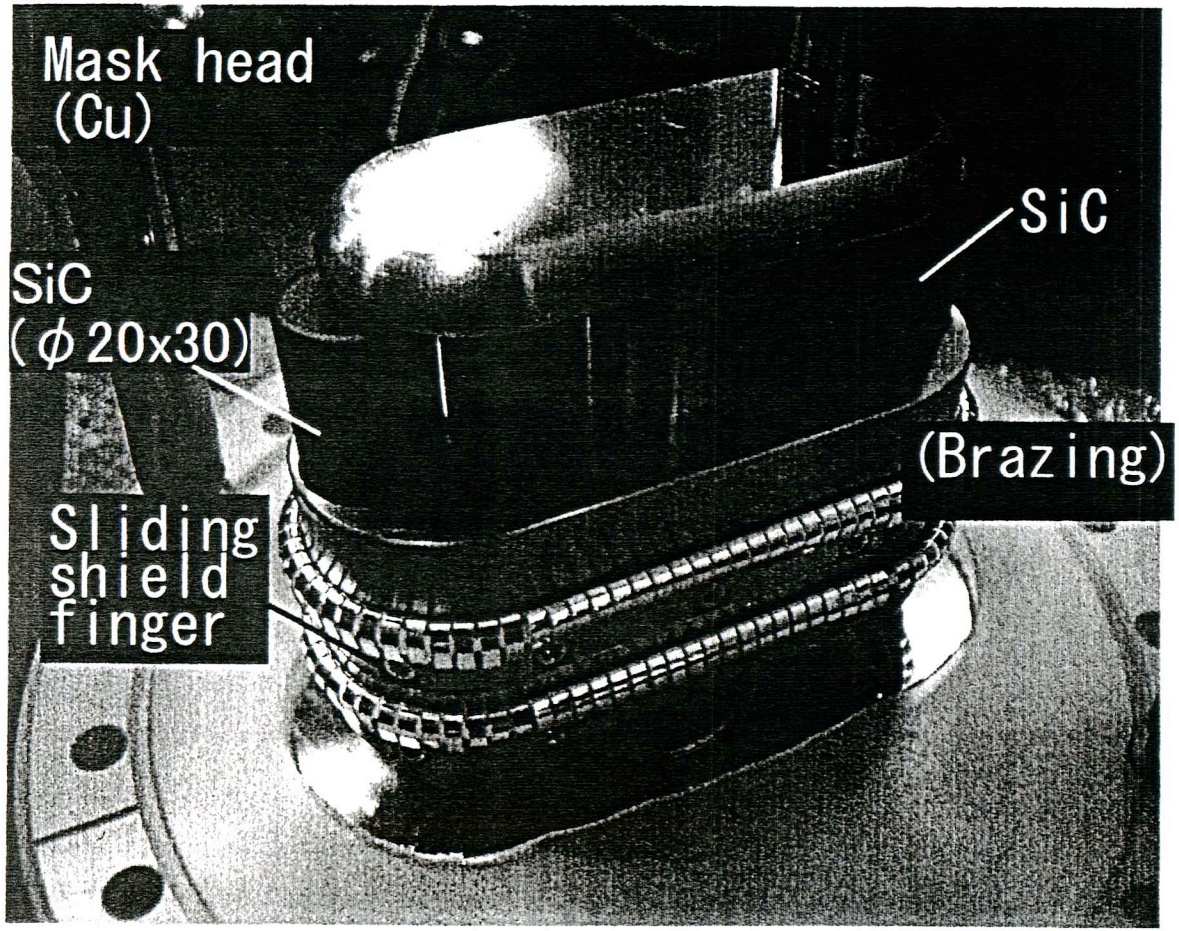
Cross section of the Crab Cavity with the Prototype Coaxial Coupler

CRYOSTAT FOR KEKB CRAB CAVITY
(TOP VIEW)



Ver.3.1, 3.2

Masks with HOM damper



Features

- Basic structure is the same as Ver.3.0.
- HOM damper (SiC) is equiped.

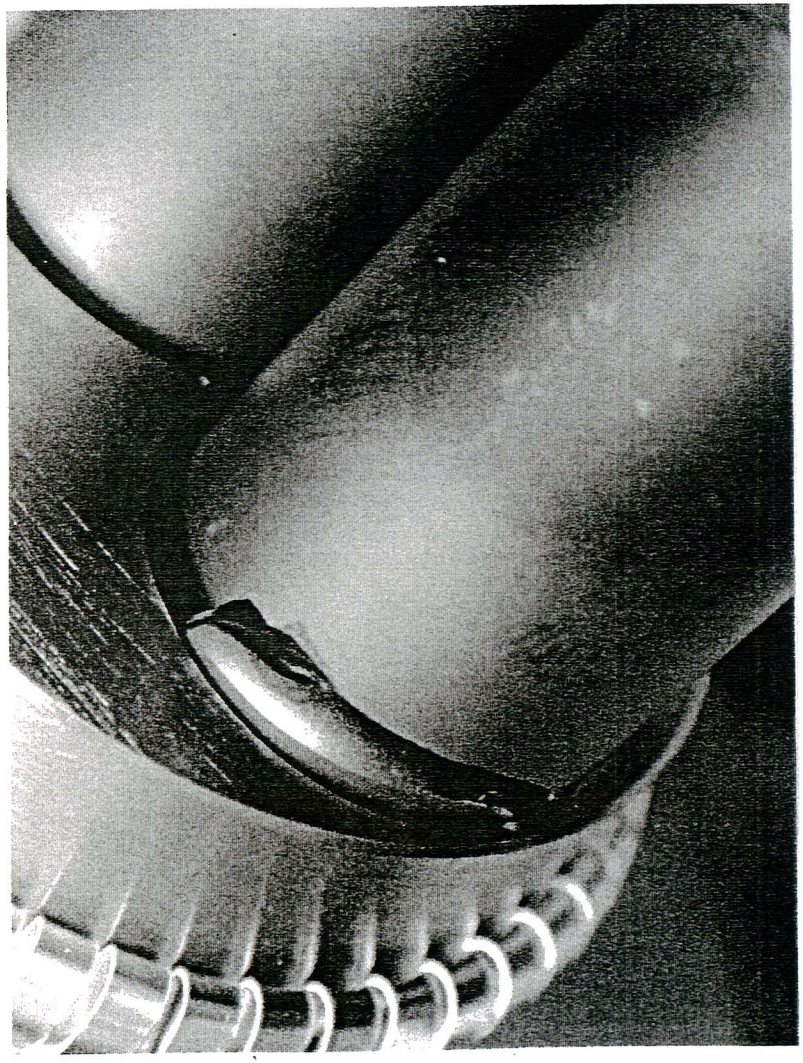
  Low Q (～40)

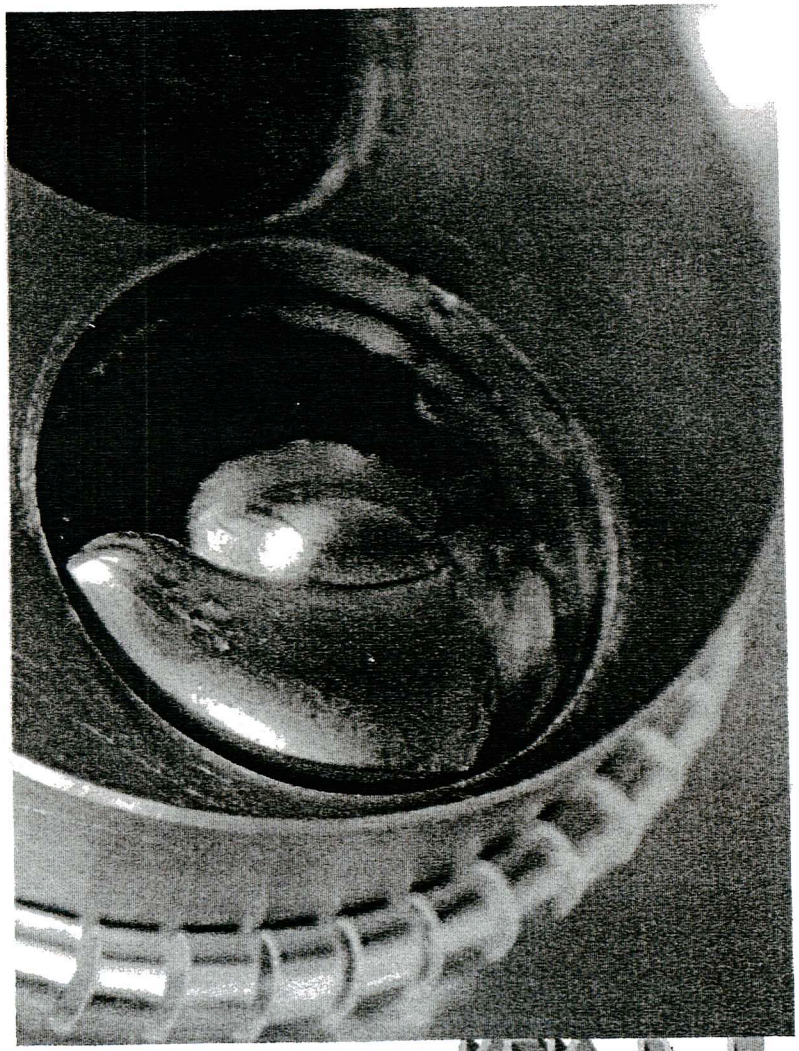
- In calculation, the input power of SiC is reasonable unless the frequency of a trapped mode and that generated by the beam are mached.

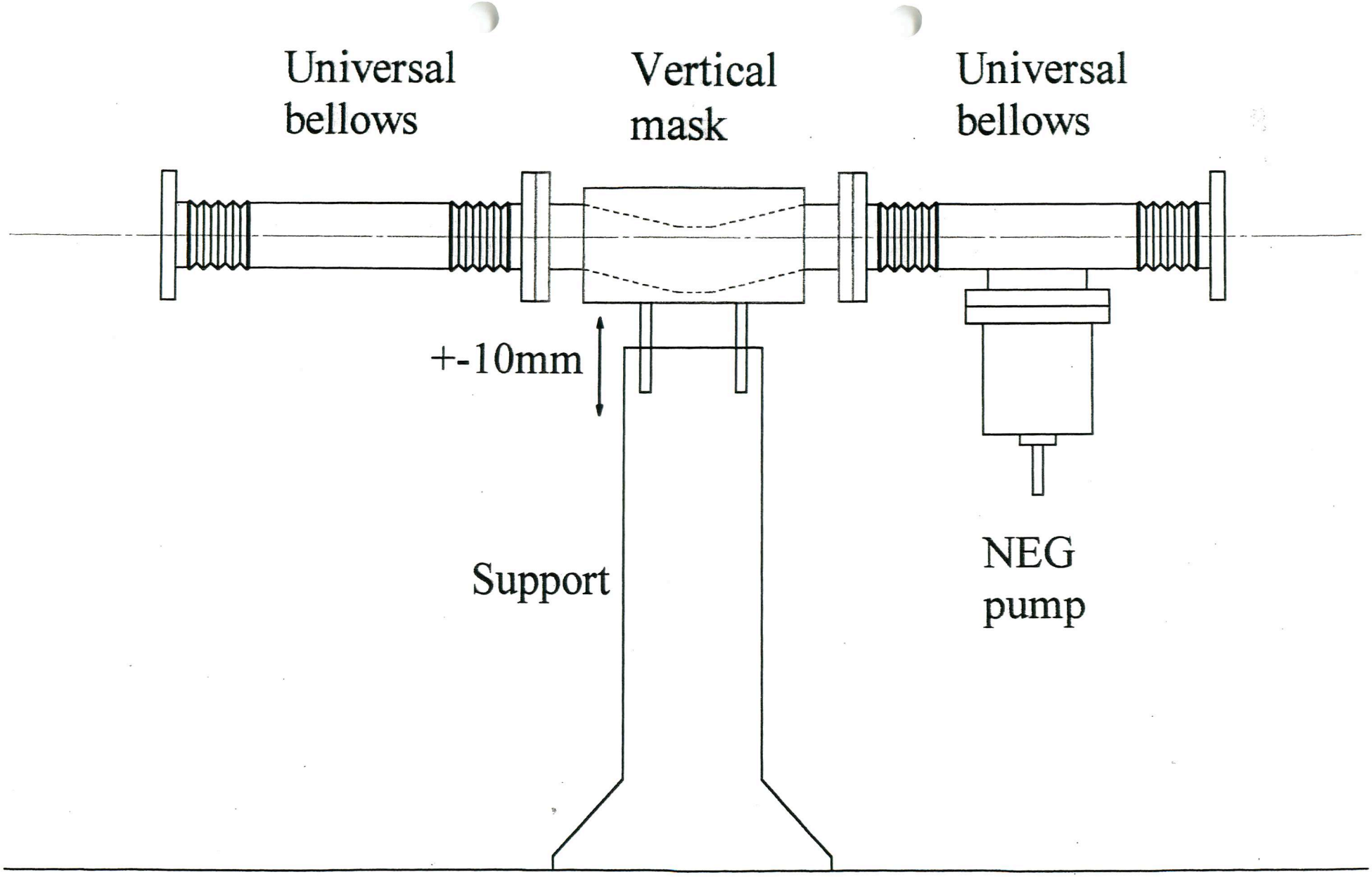
Ver.3.1 Troubles

An SiC has broken

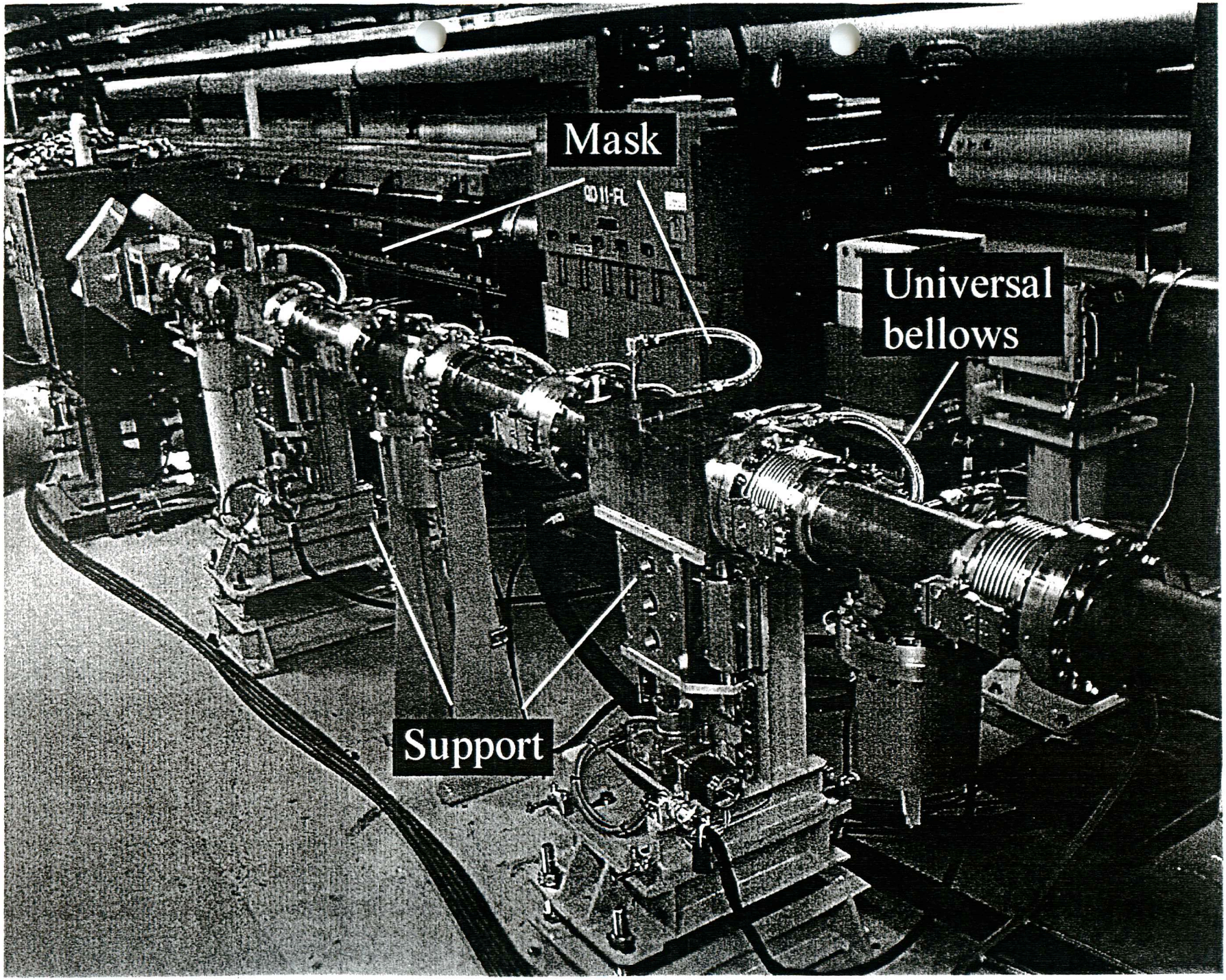
After the operation at 700 mA for about 2 monthes, one SiC was found to be broken.





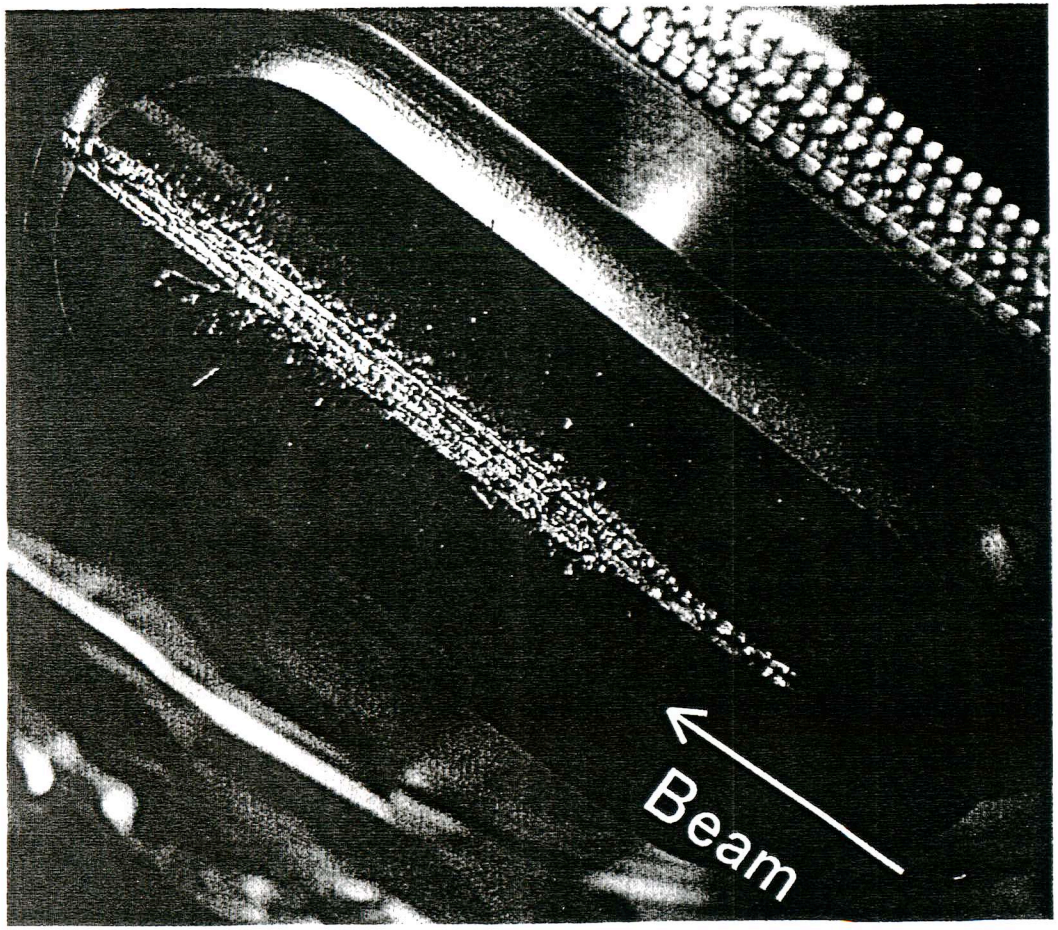


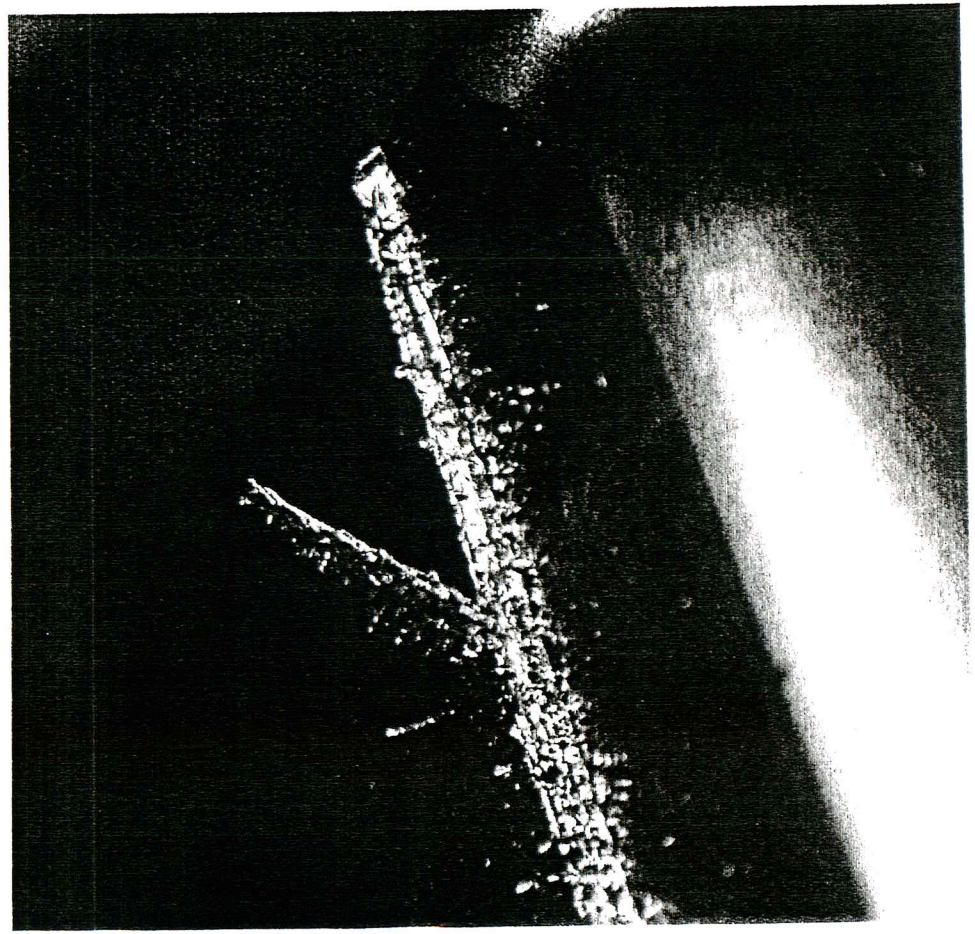
Configuration of Type-1 movable mask.


Mask
Universal
bellows
Support

Ver.3.2 Troubles

Groove on the mask head (Cu)





4. Beam currents

- **Weak vacuum components (movable masks and IP bellows) limited the stored currents.**

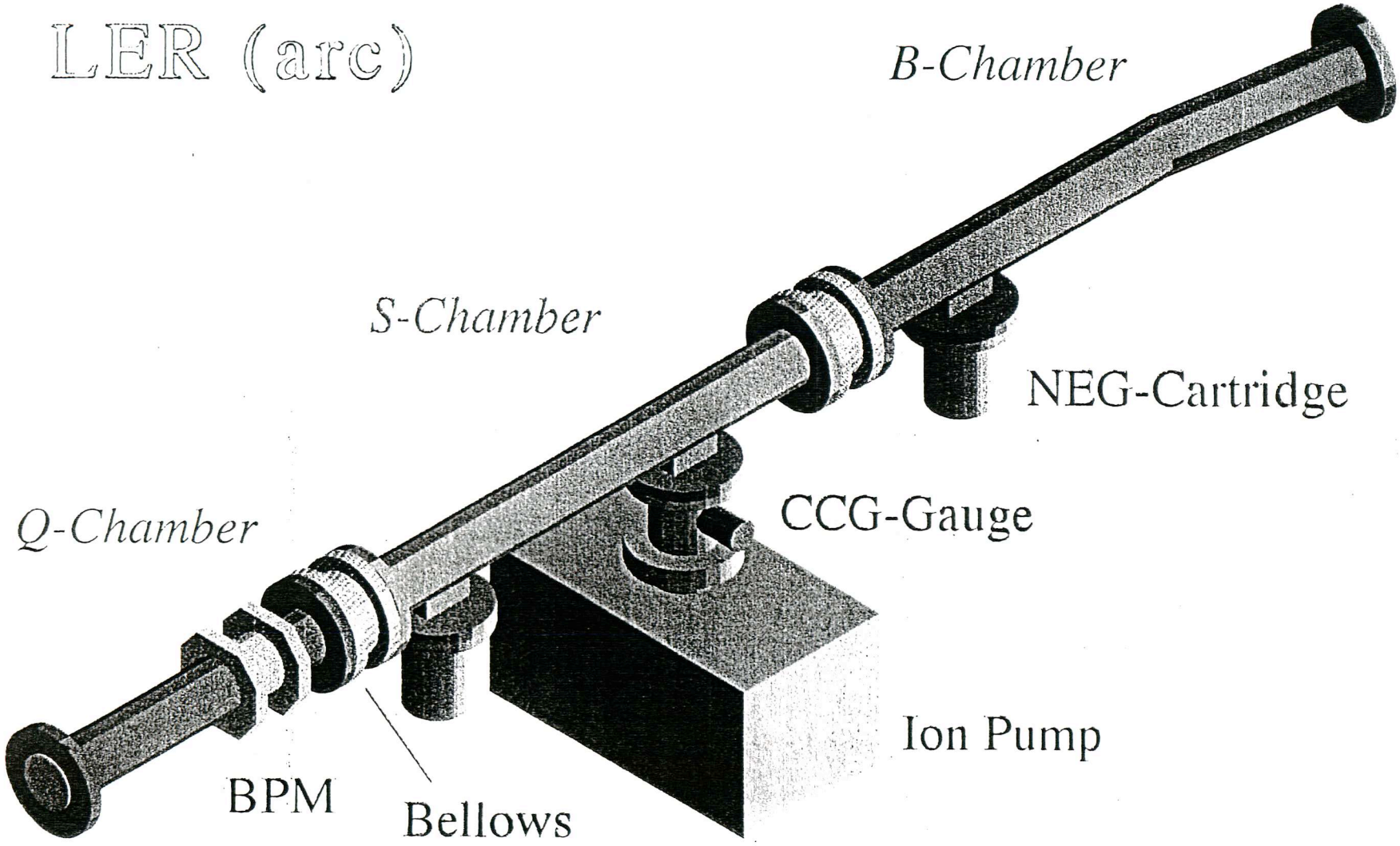
- **During 2000 summer shutdown these components have been replaced.**

- **HER current is still limited by movable masks. We will be ready to replace them anytime after April.**

- **Solenoid coils partly cured the beam blow-up. We are not sure whether solenoids will cure the problem completely, after every field-free region is covered by them.**

- **R&D on ante-chamber has just started.**

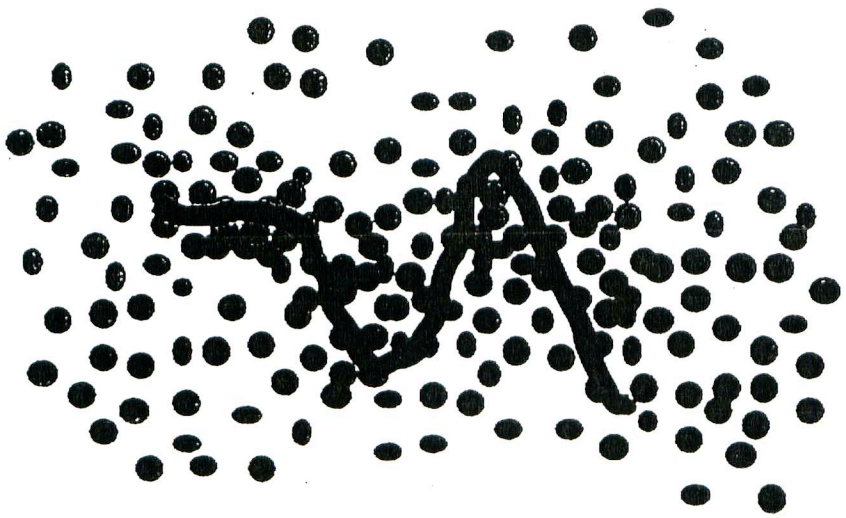
LER (arc)


B-Chamber
S-Chamber
NEG-Cartridge
Q-Chamber
CCG-Gauge
Ion Pump
BPM
Bellows

3.Beam break-up(BBU)/Head-tail instability by the photoelectron cloud

To explain the blow-up, the beam break up/head-tail instability in a bunch caused by the electron cloud is proposed.

A. Model (F. Zimmermann, K. Ohmi)



- Electrons which is generated by the synchrotron radiation form a cloud by the attractive force of multi-bunch positron beam.

- Beam breakup/head-tail oscillation in a bunch occurs by the mediation of the cloud.

C-Yoke Magnets and Solenoids

- 1999 Autumn – 2000 Summer
  Permanent magnets quads (C-yokes) were used.

- 2000 Summer Shutdown
  Solenoids (50-gauss) were wound in LER over 800 m

- 2000 – 2001 New Year Shutdown
  Solenoids were wound in LER over additional 400 m

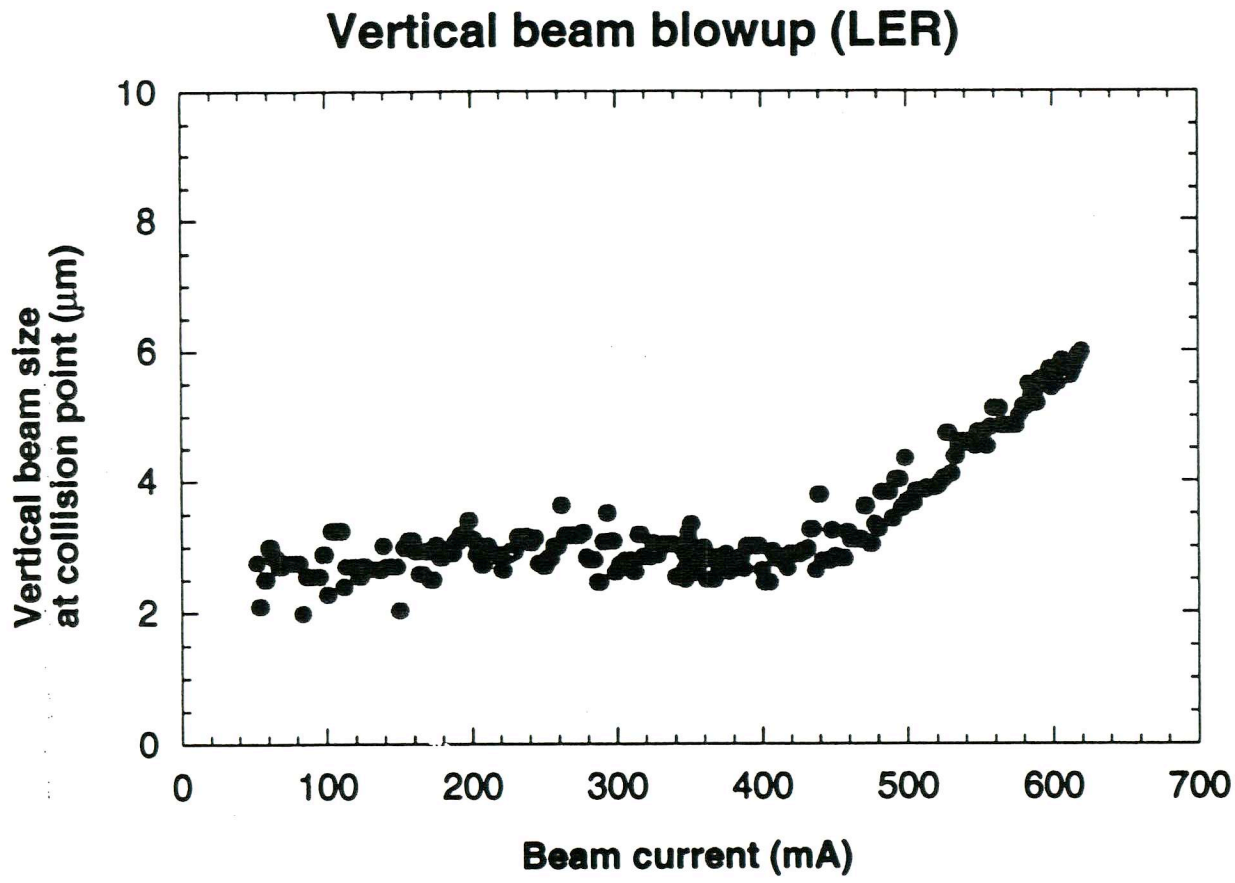
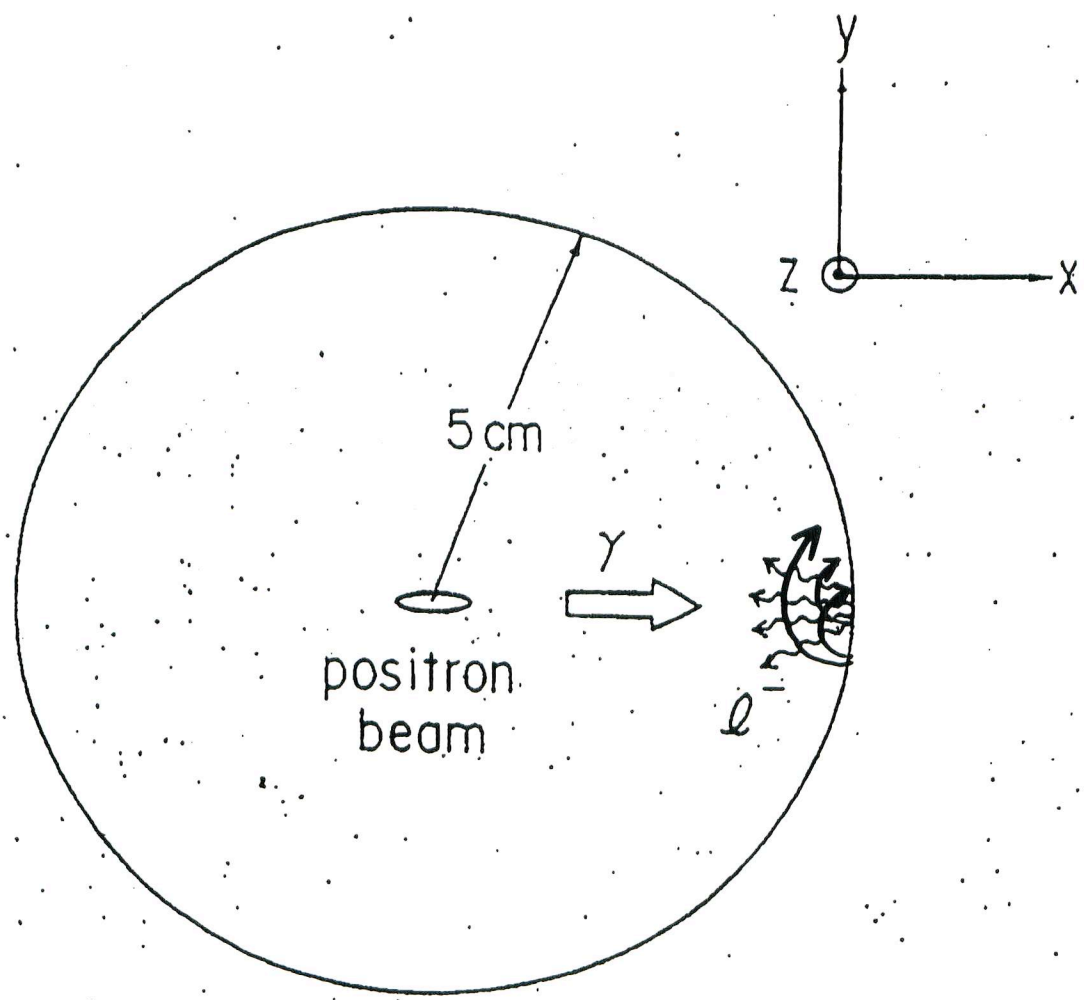
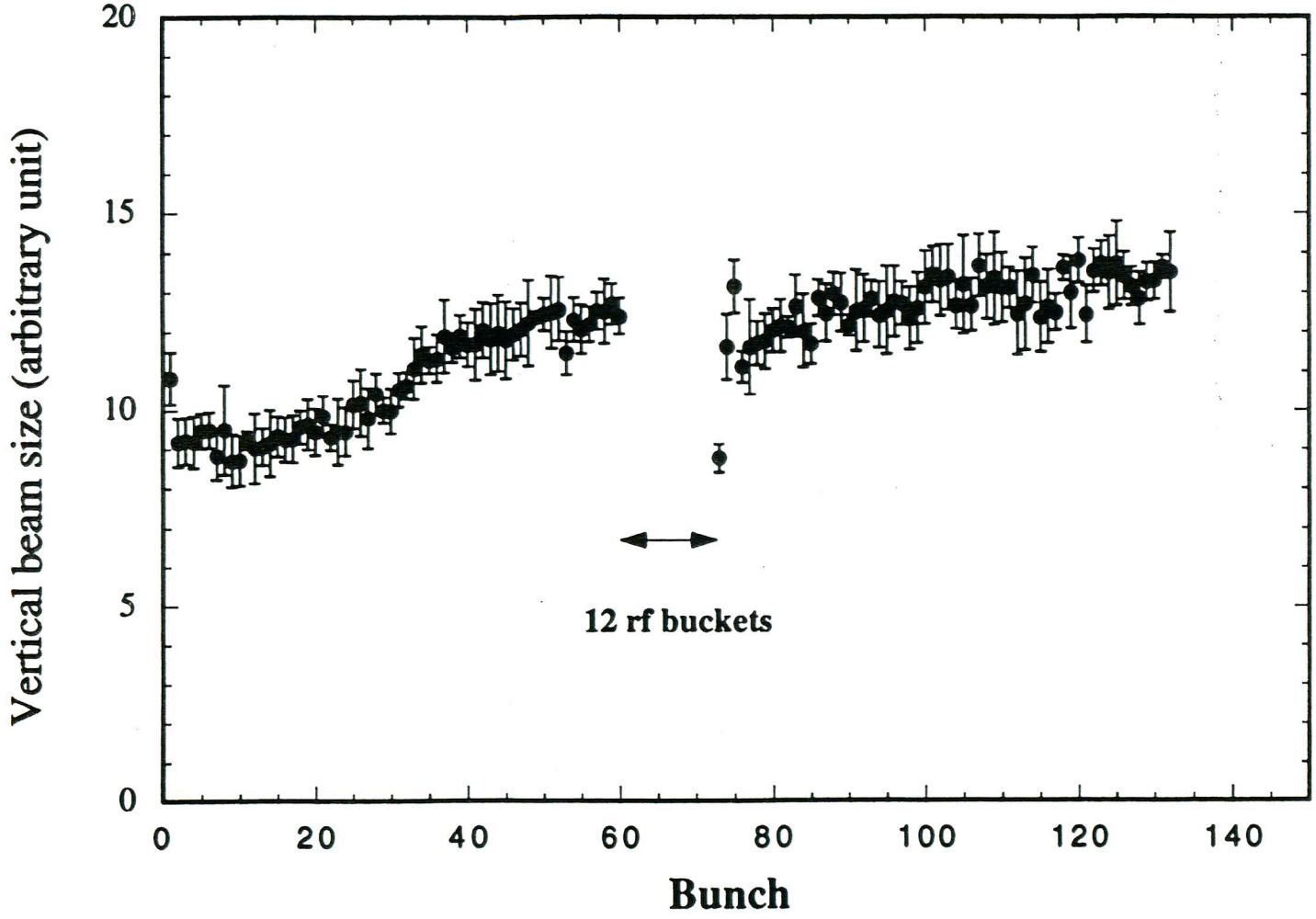
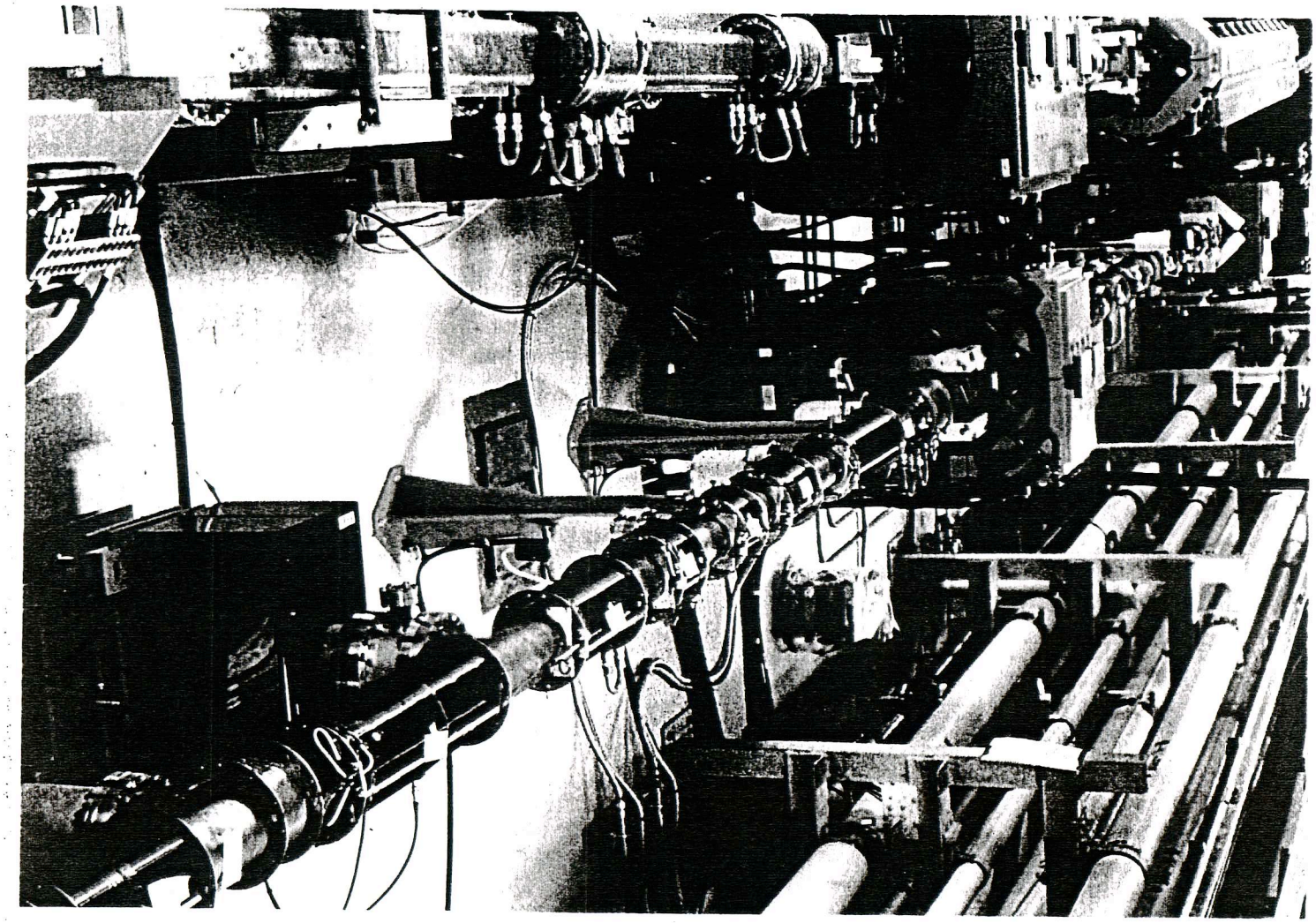

Vertical beam blowup (LER)
Vertical beam size
at collision point (μm)
10
8
6
4
2
0
0
100
200
300
400
500
600
700
Beam current (mA)

Photo-Electron Instability




Vertical beam size (arbitrary unit)
20
15
10
5
0
0
20
40
60
80
100
120
140
Bunch
12 rf buckets



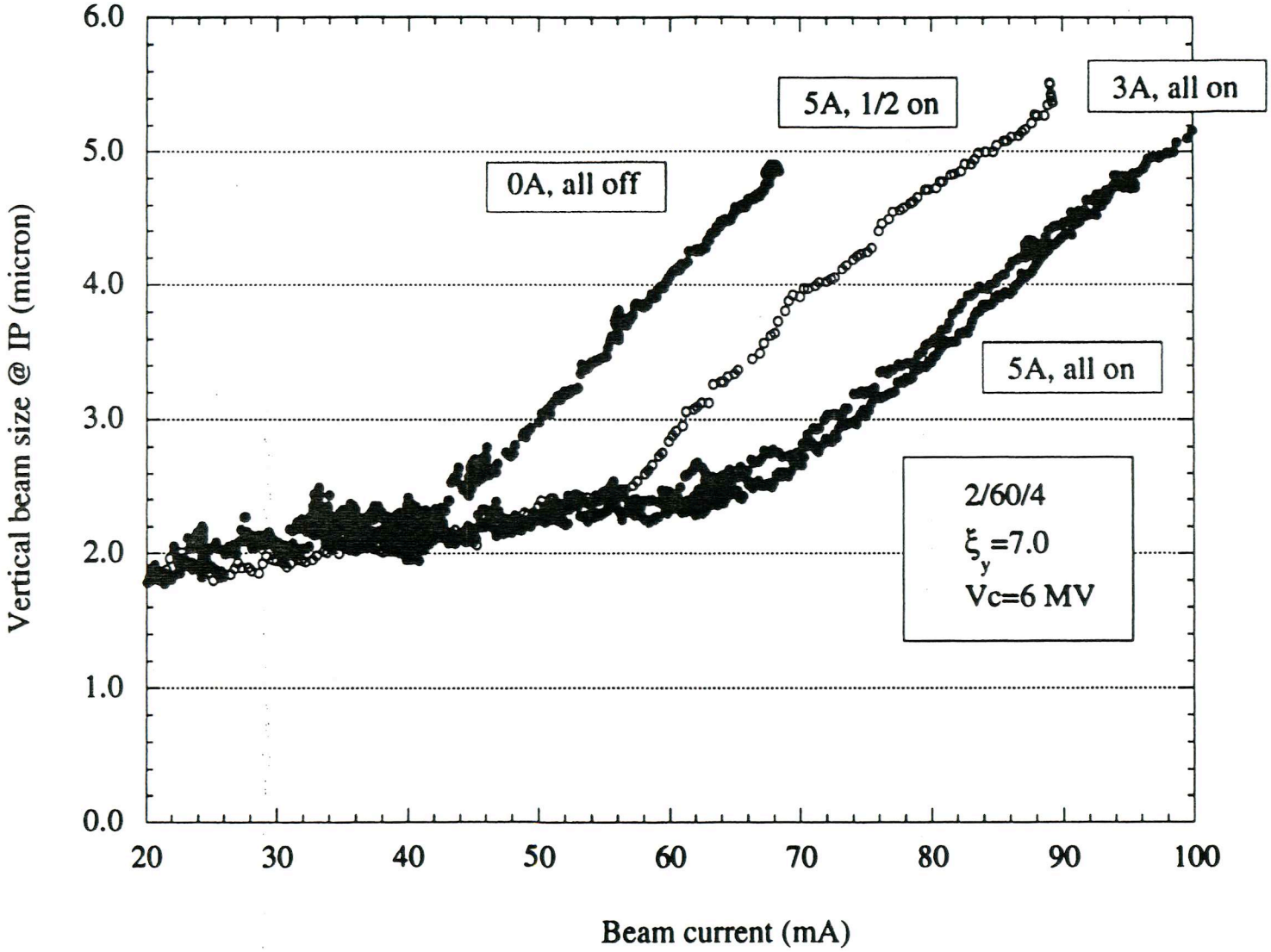
- **Solenoid coils partly cured the beam blow-up. We are not sure whether solenoids will cure the problem completely, after every field-free region is covered by them.**

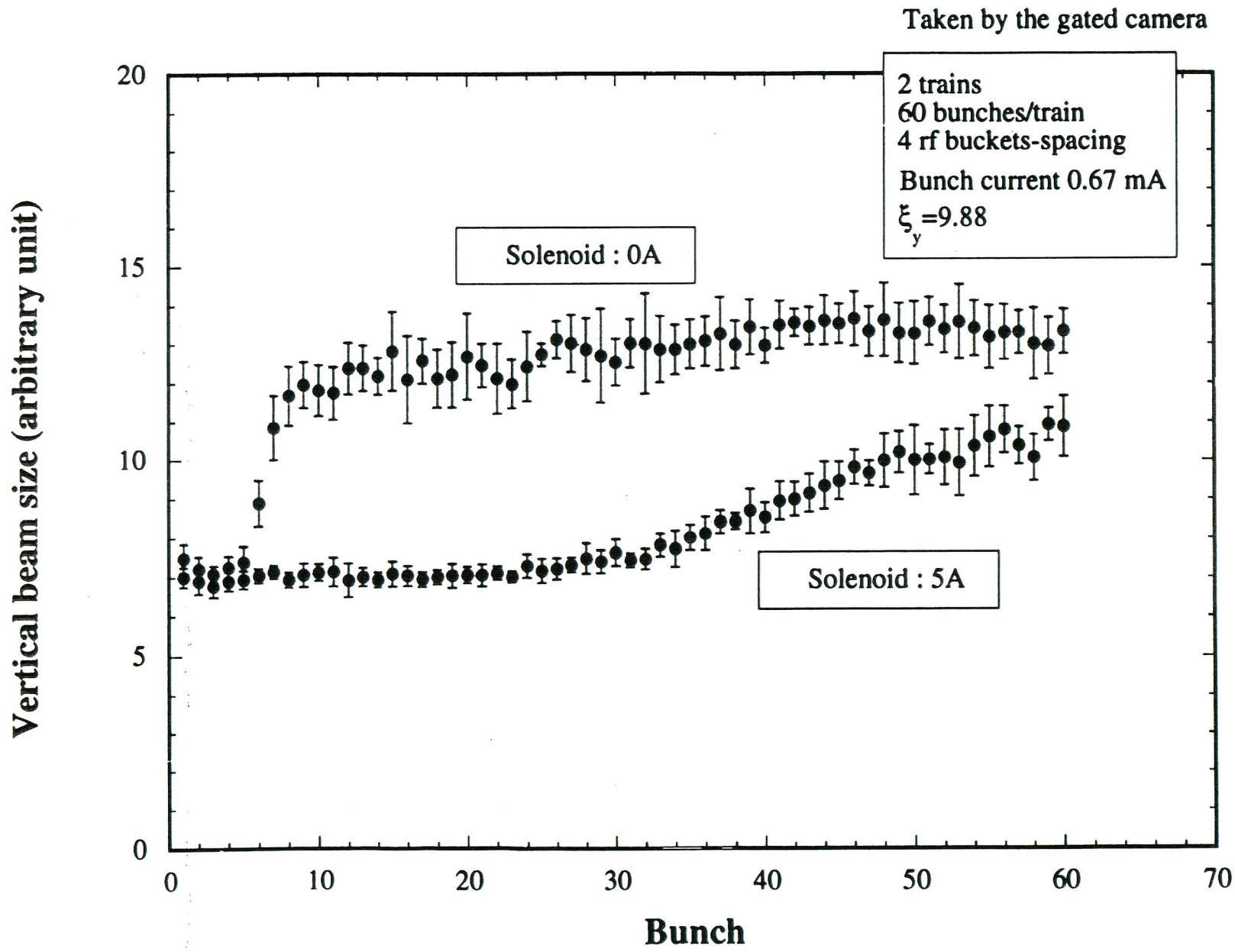
- **R&D on ante-chamber has just started.**

5. Prospects of luminosity increase

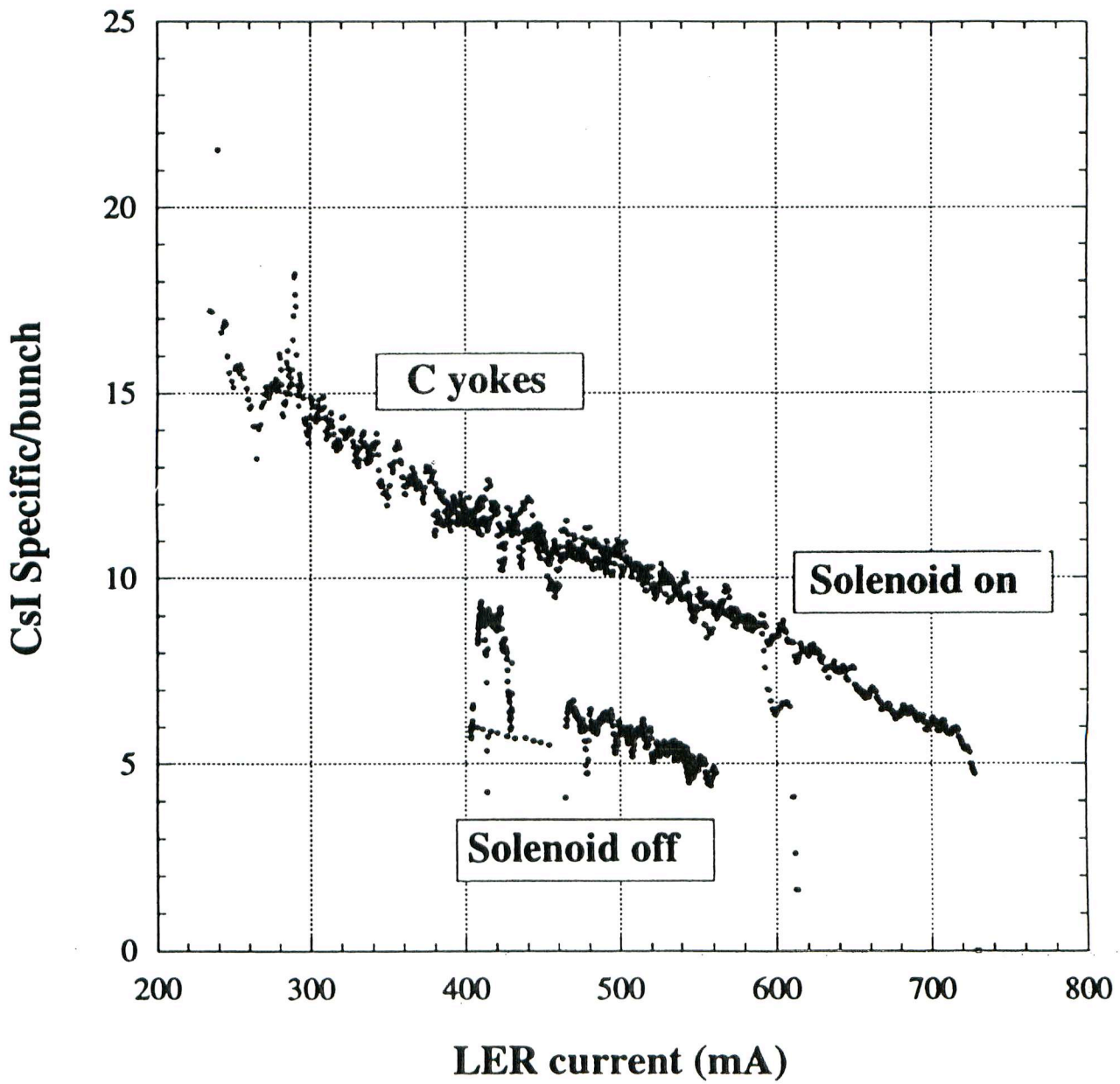
- **By the summer of 2003, luminosity will go up by increasing currents an decreasing bunch spacing, even with mild beam-beam tuneshift of 0.03 up to 7 x 10^{33}cm^{-2}s^{-1}. We assume that beam blow-up will be cured.**

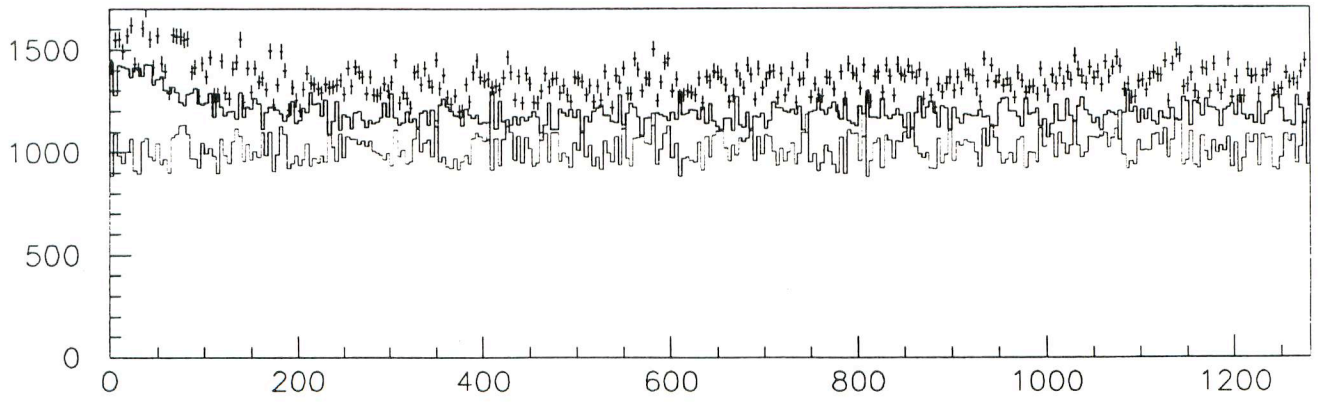
Effect of solenoid on vertical beam size (LER)



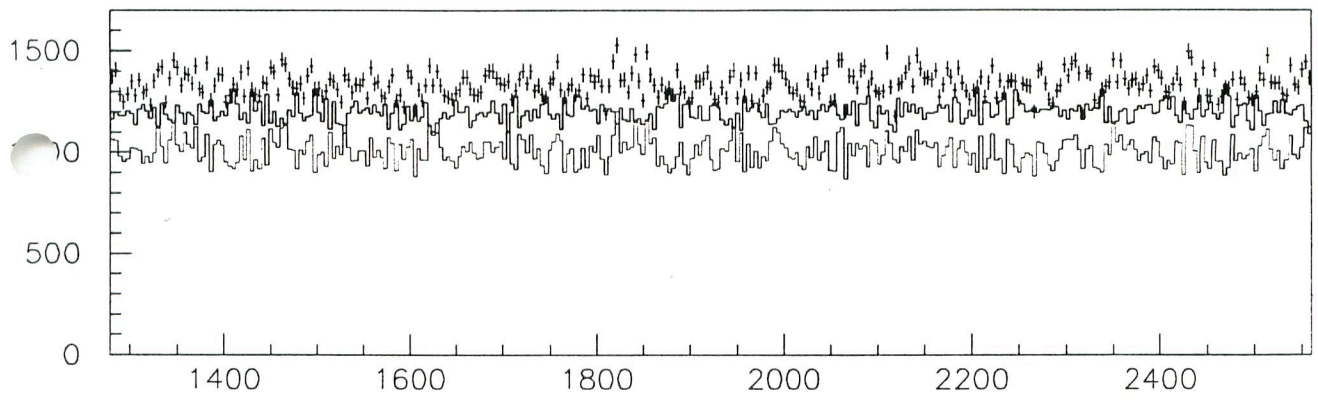

Taken by the gated camera
2 trains
60 bunches/train
4 rf buckets-spacing
Bunch current 0.67 mA
ξ_y =9.88
Solenoid : 0A
Solenoid : 5A
Vertical beam size (arbitrary unit)
Bunch
0
5
10
15
20
0
10
20
30
40
50
60
70

Effect of solenoid on luminosity

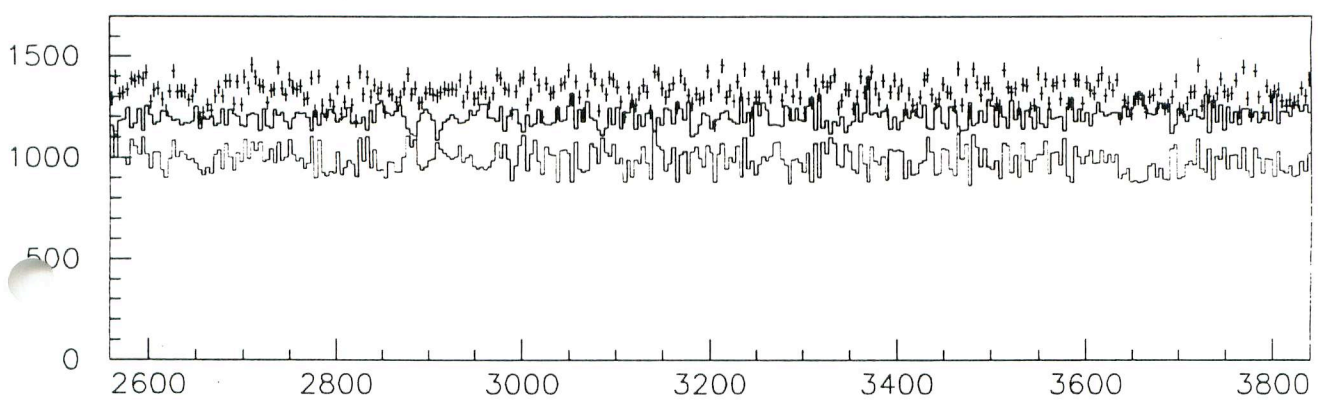




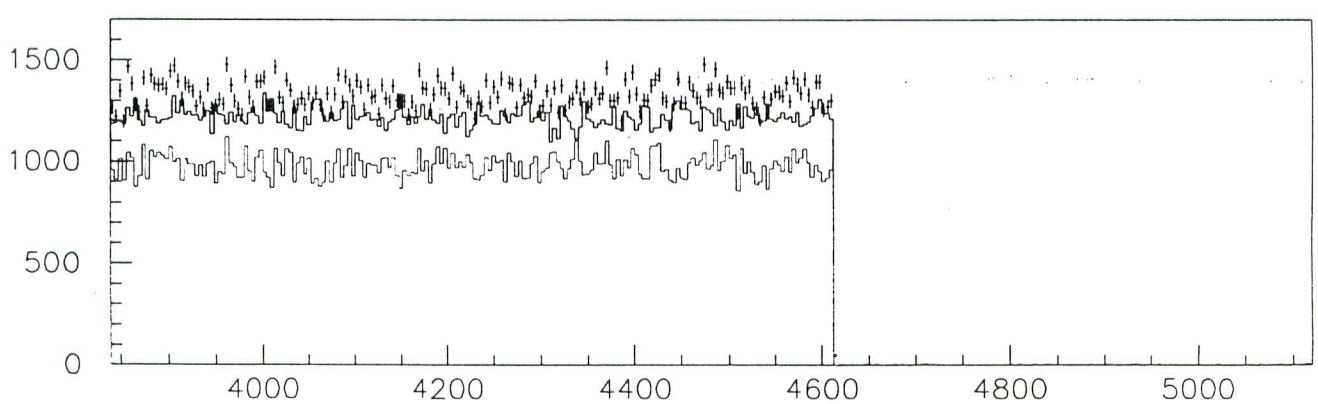
bunch number of 4526 turns



bunch number of 4526 turns



bunch number of 4526 turns



bunch number of 4526 turns

Summary

- During a year from the last committee meeting, the peak and integrated luminosity have been improved almost by factor 3. KEKB and BELLE have shown that these are machines that can produce real physics.

- We have been struggling to devise good movable masks and become close to final solutions.

- Most important issues at present is to suppress beam-blowup in LER and make it possible to fill the beam with shorter bucket spacing in order to get higher luminosity. Many works have

been and are being done to solve the problem.

- **Discussion on super KEKB of $10^{35}cm^{-2}s^{-1}$ has just started.**