KEKB
Accelerator Overview

Shin-ichi Kurokawa
KEK

June 6, 1995
KEKB Review

KEKB

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KEK B–Factory

Asymmetric, 2–ring, high–luminosity, electron–positron collider with one interaction point in TRISTAN tunnel

3.5 GeV(e^+) x 8.0 GeV(e^-)

Luminosity Goal
1 x $10^{34}cm^{-2}s^{-1}$

- KEKB Project was approved by the Japanese government in 1994 as a five–year project.

- Construction period
  April 1994 – March 1999

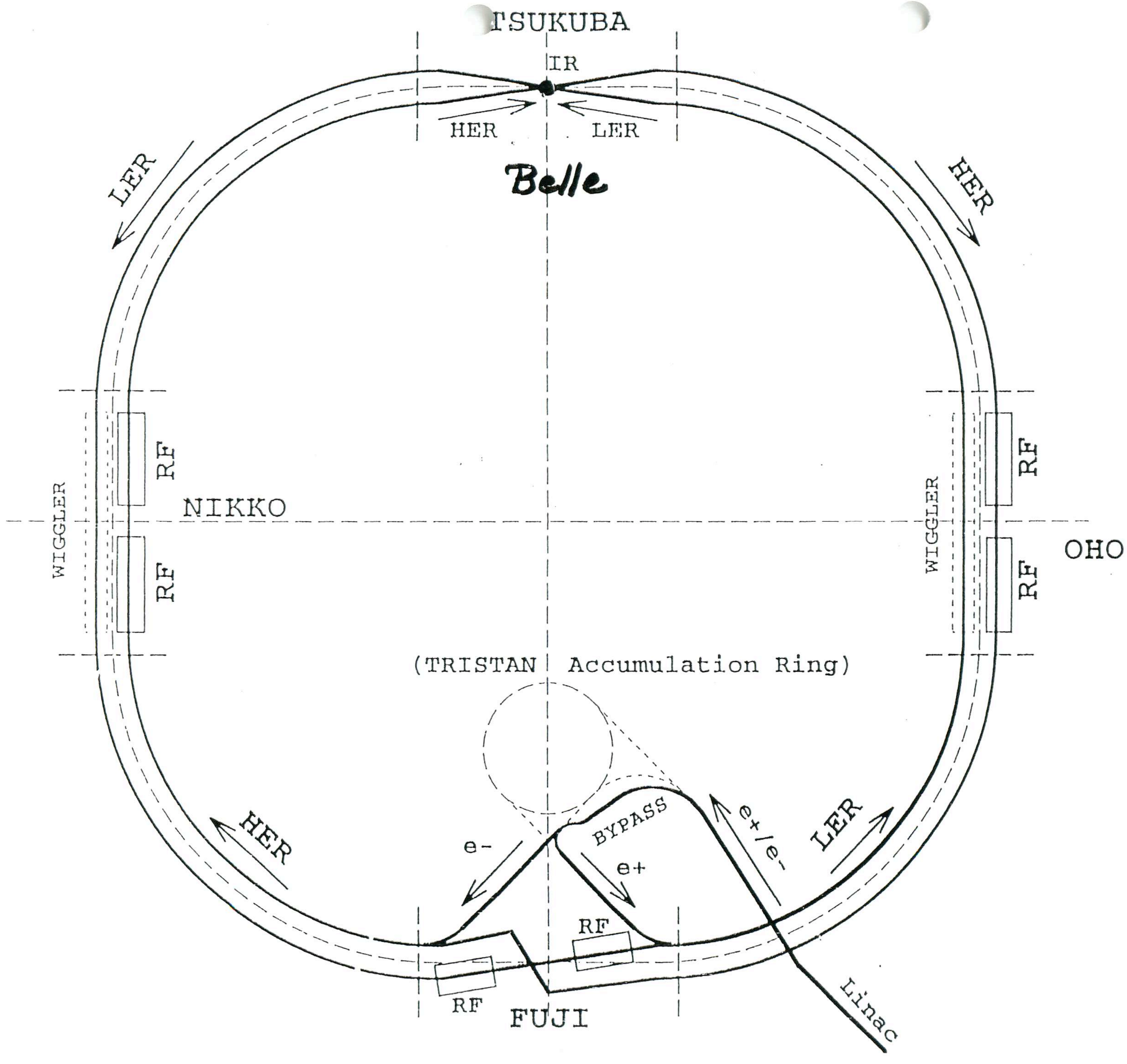
- Total budget
  380 M$ (1 $ = 100 yen)

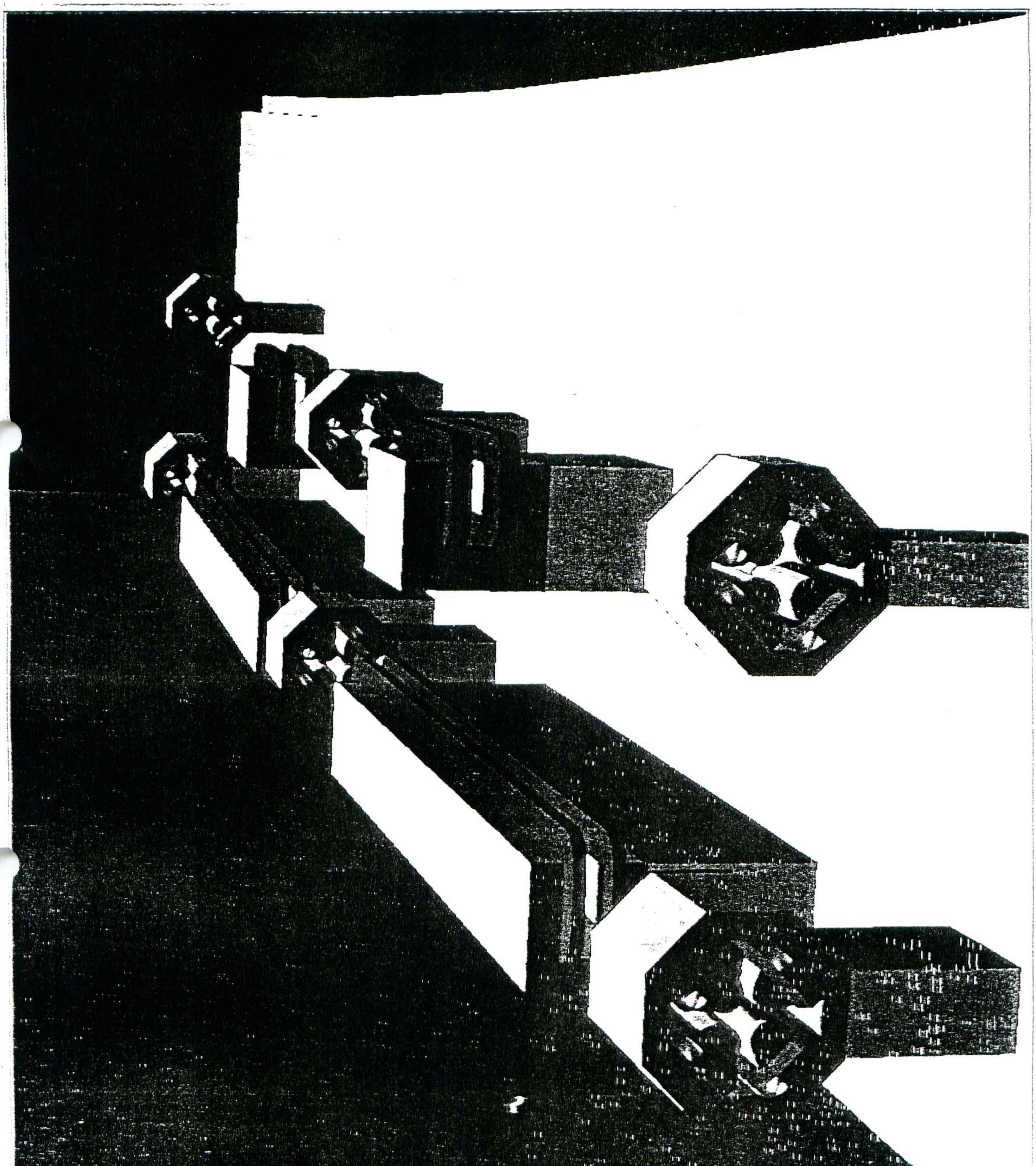
- KEKB is constructed on the basis of existing TRISTAN: two rings of KEKB will be installed in the existing TRISTAN tunnel. Infrastructure of TRISTAN will be maximally used.

- Electrons and positrons are to be directly injected into KEKB: 2.5 GeV linac will be upgraded to 8 GeV.

- Construction started from April 1994 and by the end of JFY1998 KEKB will be commissioned.

- Dismantling of TRISTAN will start from January 1996.


TSUKUBA
IR
HER
LER
Belle
LER
HER
RF
RF
NIKKO
WIGGLER
WIGGLER
RF
RF
OHO
(TRISTAN Accumulation Ring)
BYPASS
e-
e+
e+/e-
HER
LER
RF
RF
FUJI
Linac



$$\mathbf{L} = \mathbf{2.2 \times 10^{34}} \xi (\mathbf{1} + \mathbf{r}) \left(\frac{\mathbf{E \cdot I}}{\beta^*_\mathbf{y}} \right)_\pm$$

L : luminosity ($cm^{-2}s^{-1}$)

ξ : beam–beam tuneshift

$r = \sigma_y/\sigma_x$ (at IP)

$r=1$ round beam

$r=0$ flat beam

I : beam current (A)

E : beam energy (GeV)

$\beta_y{}^*$: β–value at IP (cm)

$+$: positron

$-$: electron

Parameters of KEKB have been chosen by taking the following into consideration:

- **To store high currents is the most difficult task.**

- **We should try to find out a set of parameters by which we can reach the highest luminosity with minimum currents.**

KEKB Parameters

- $3.5(e^+)$ x 8 GeV(e^-)
- 3016 m circumference
- Luminosity
  $10^{34} cm^{-2} s^{-1}$
- Finite–angle cossing ± 11 mrad
- Beam–beam tuneshift ~0.05
- $\beta y^* = 1$ cm
- Current
  $1.1A(e^-)$, $2.6A(e^+)$
- Number of bunches and bunch spacing
  5000 , 0.6 m

Linac Upgrade

– Upgrade Linac from 2.5 GeV to 8 GeV by:

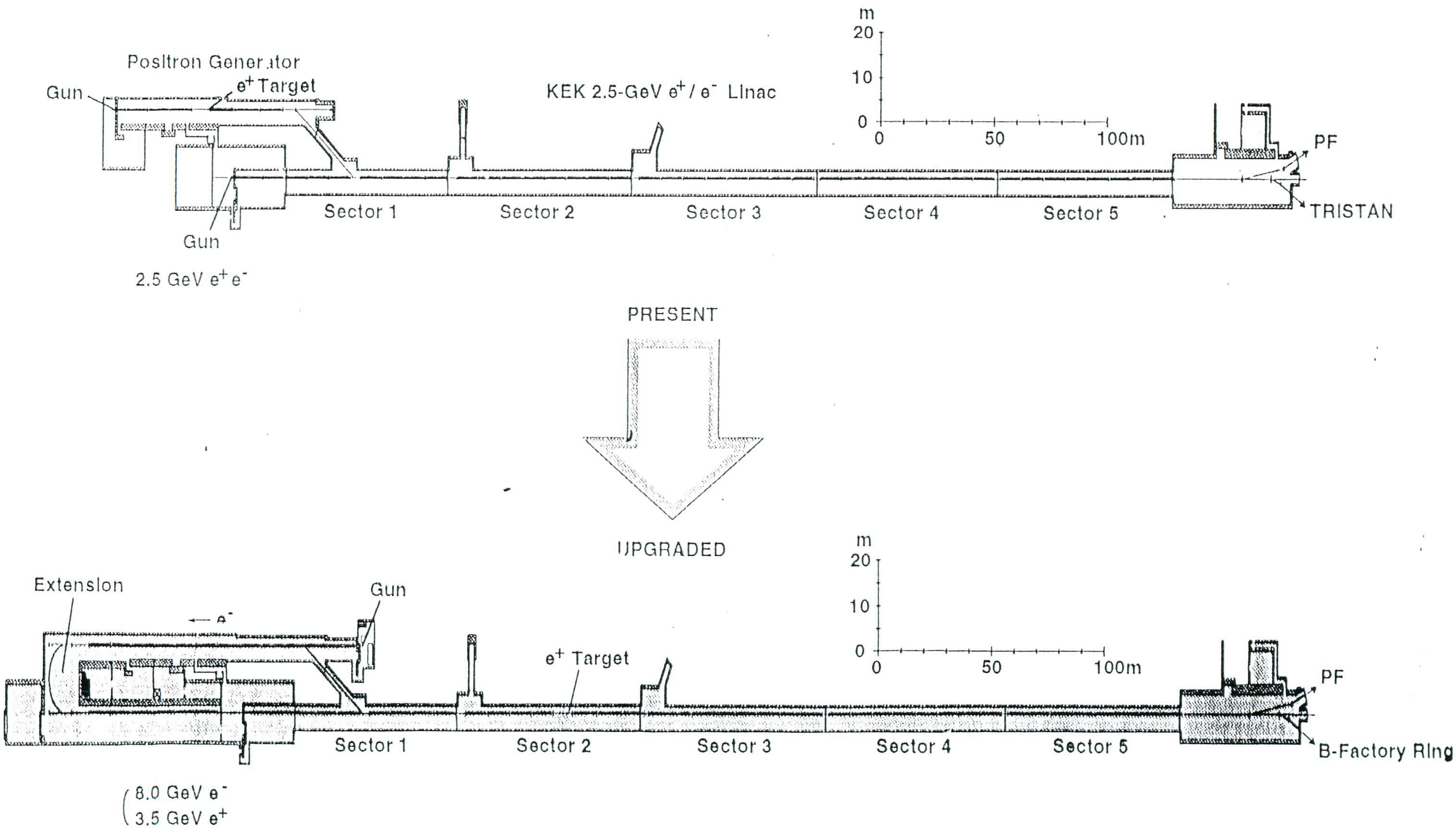
(1) Increase the number of accelerating structures.

(2) Use high–power klystrons.

(3) RF multiplying by SLED.

– Increase the production energy of positrons from 250 MeV to 4 GeV; increase of positron intensity by factor 16 is expected.

UPGRADE OF THE KEK INJECTOR LINAC



Lattice Design

– Non–interleaved sextupole chromaticity correction

– 2.5 π/cell phase advance

– Variable α $-1 \sim 4 \times 10^{-4}$

– Variable ε_x $10 \sim 40$ nm

– Local chromaticity correction in LER

Coupled–Bunch Instabilities

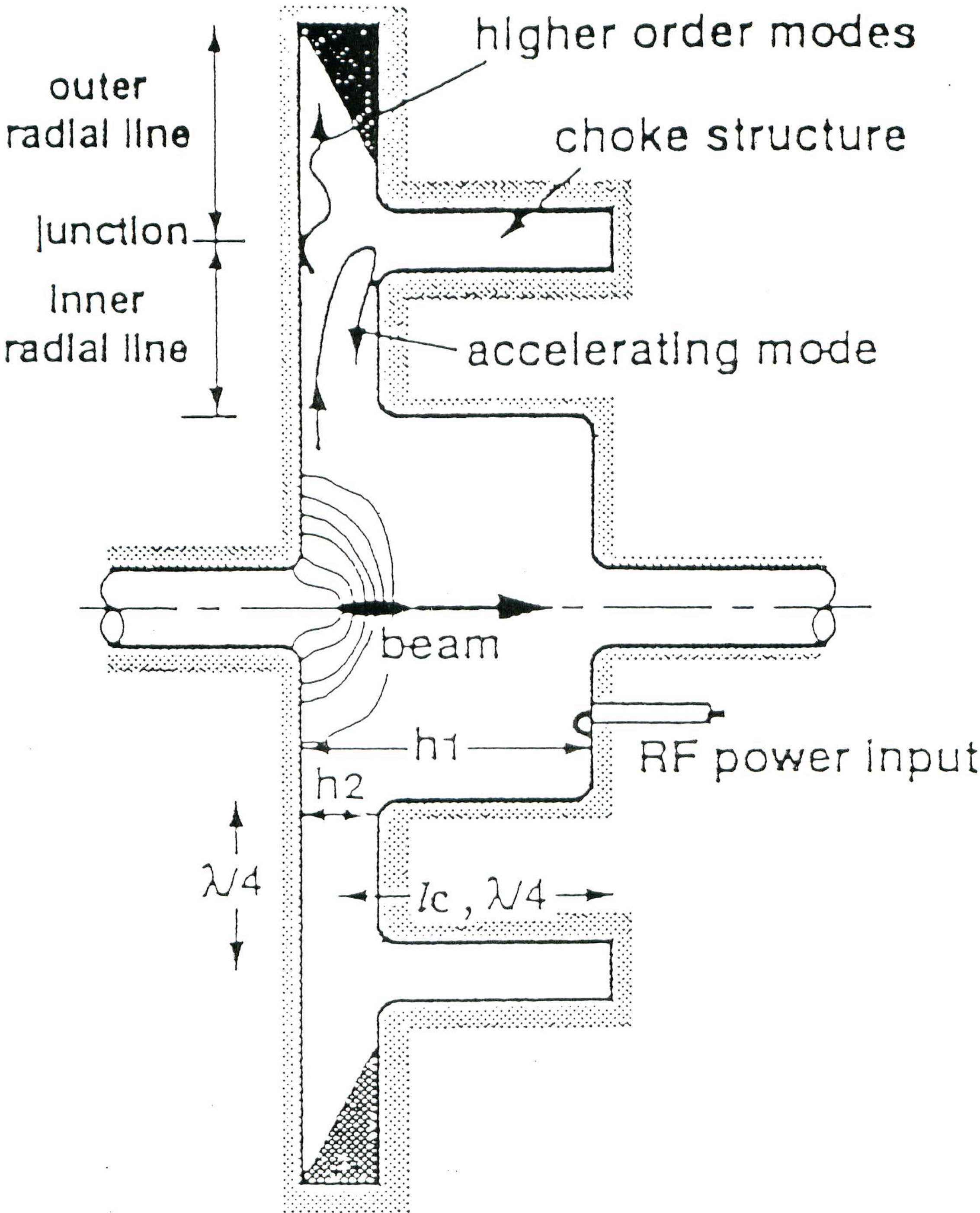
– HOM of cavity

- Choke–mode, NC cavity
- Single–cell, single–mode SC cavity

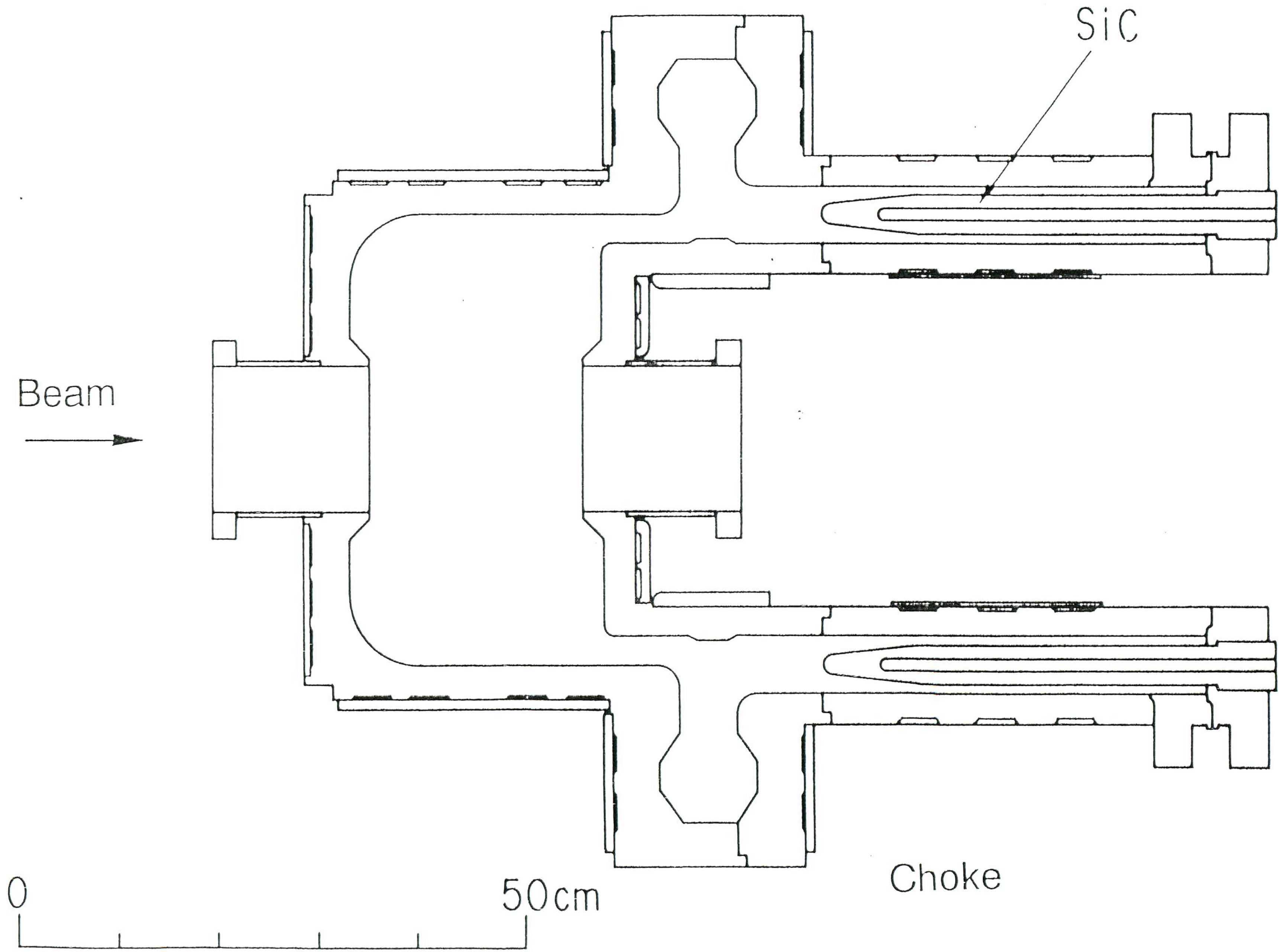
– Fundamental mode of cavity

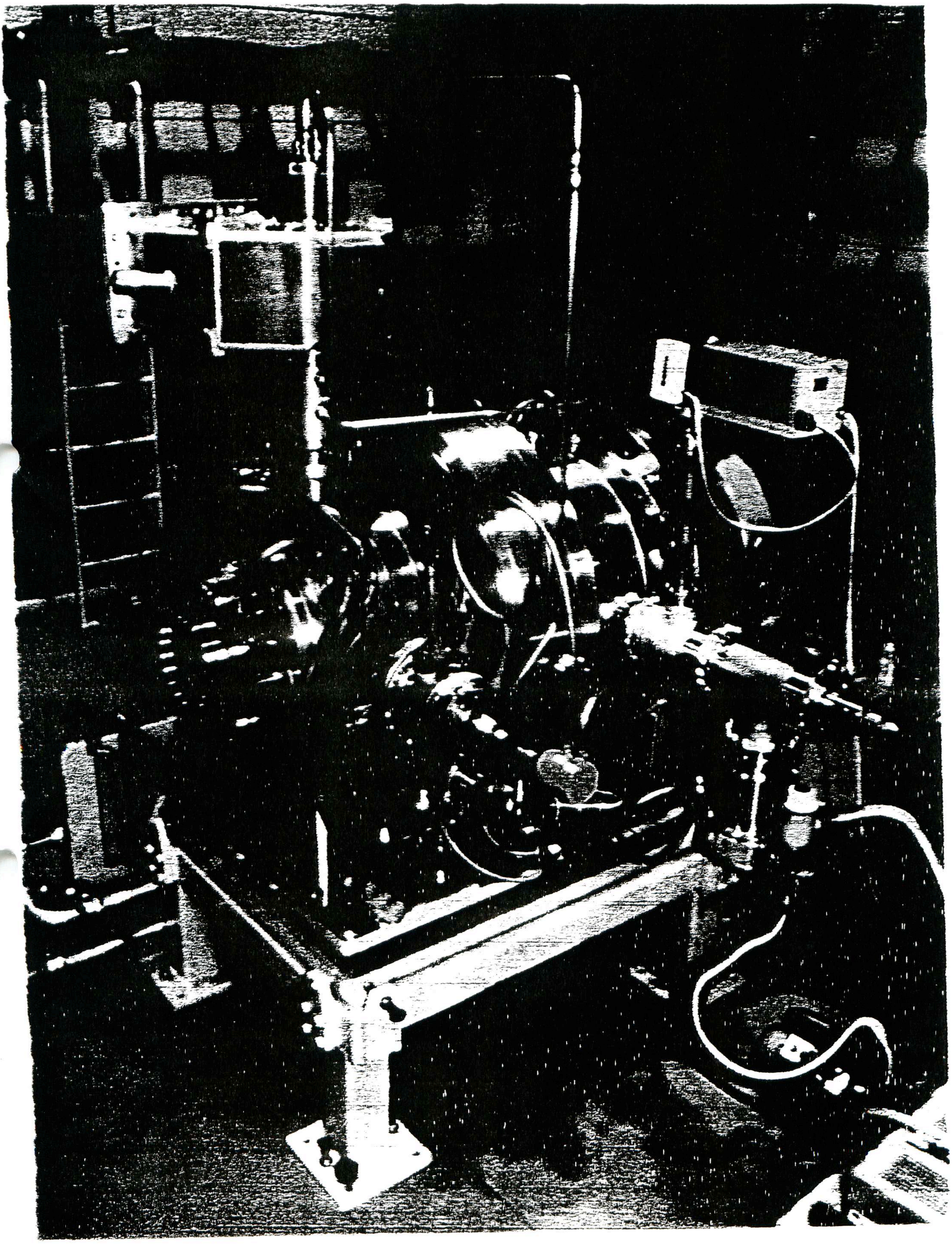
- ARES
- High gradient SC cavity

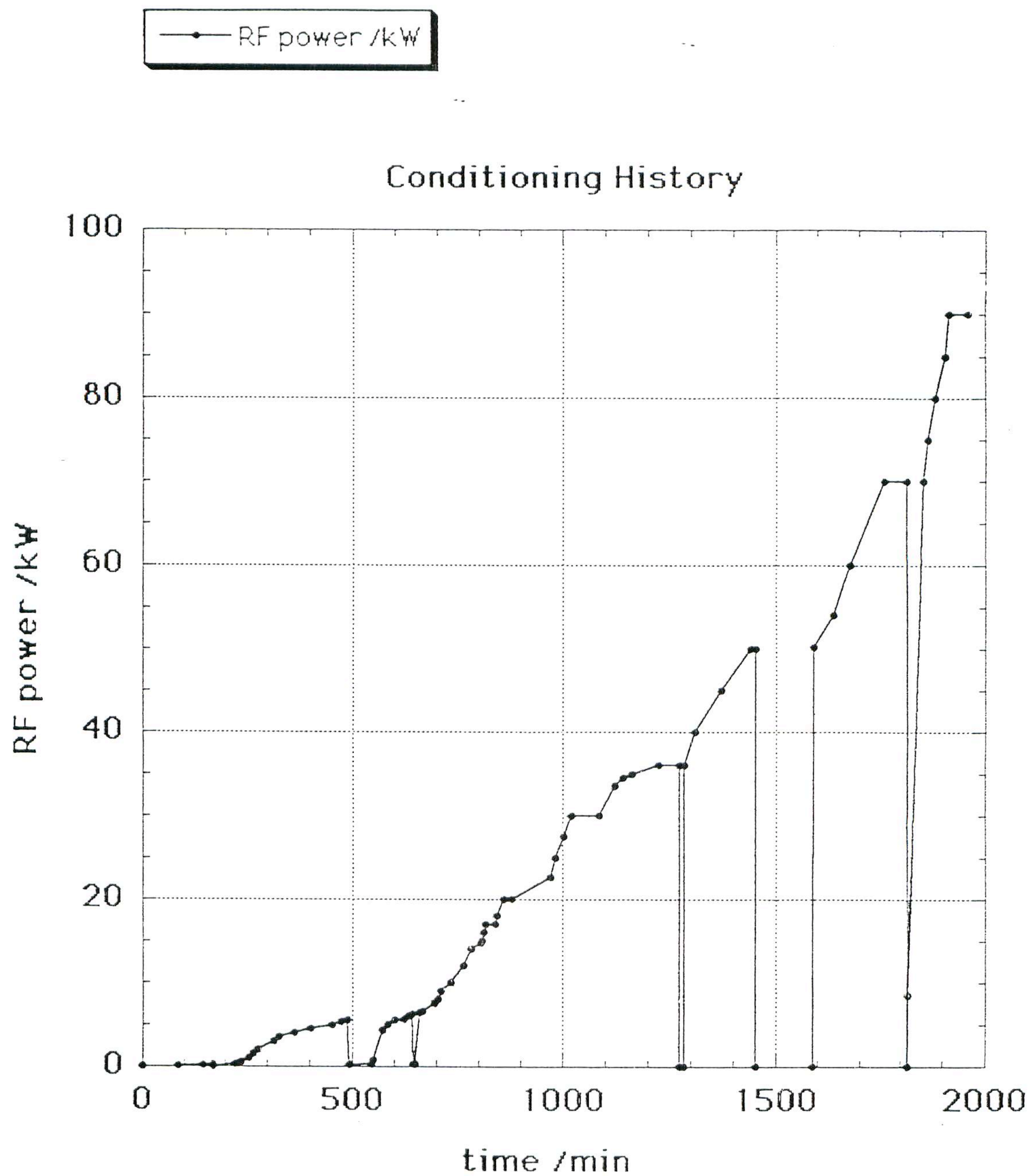
– Resistive wall of vacuum chamber



Choke-mode Cavity by T. Shintake


SiC
Beam
Choke
0
50cm



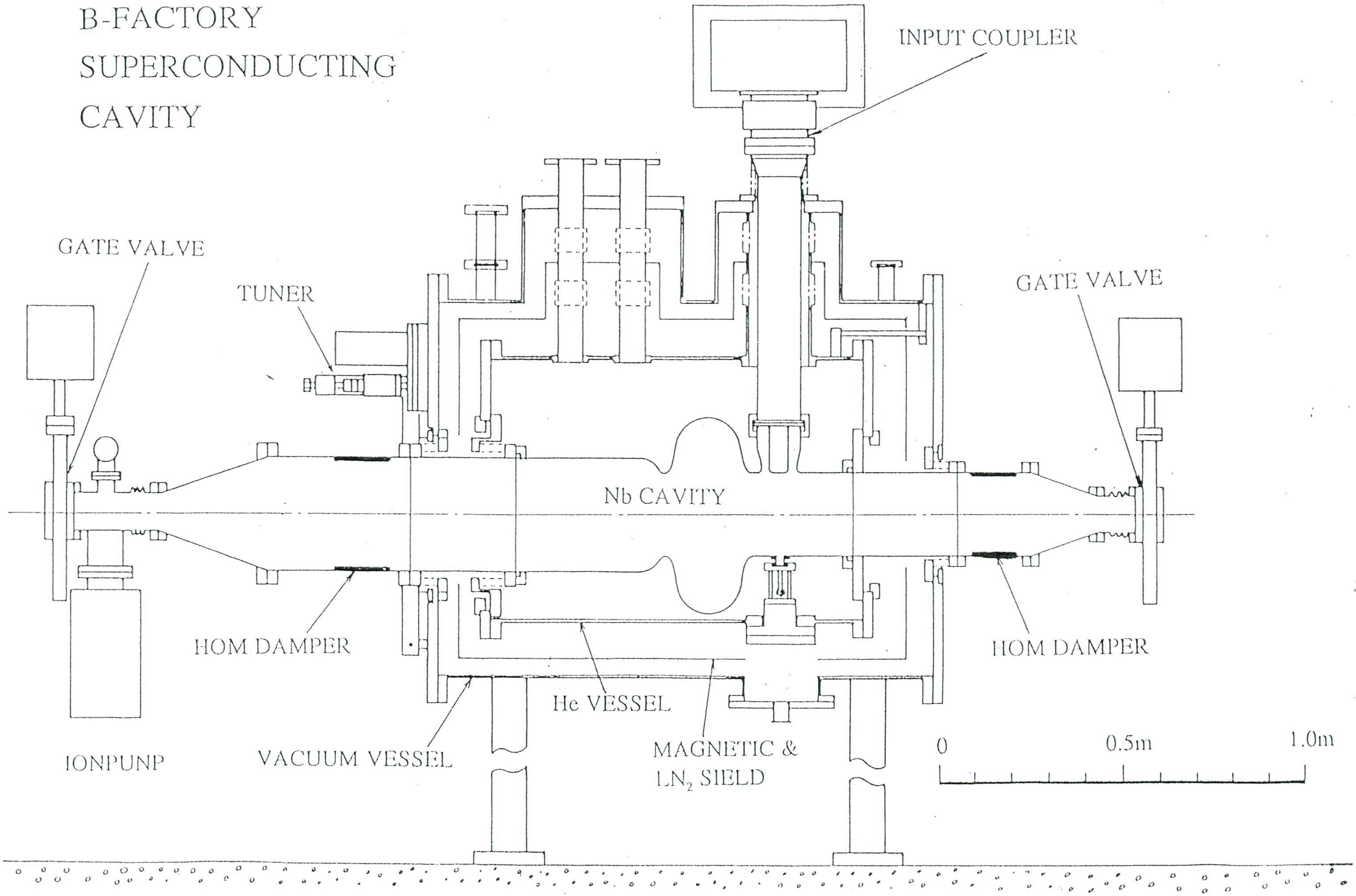


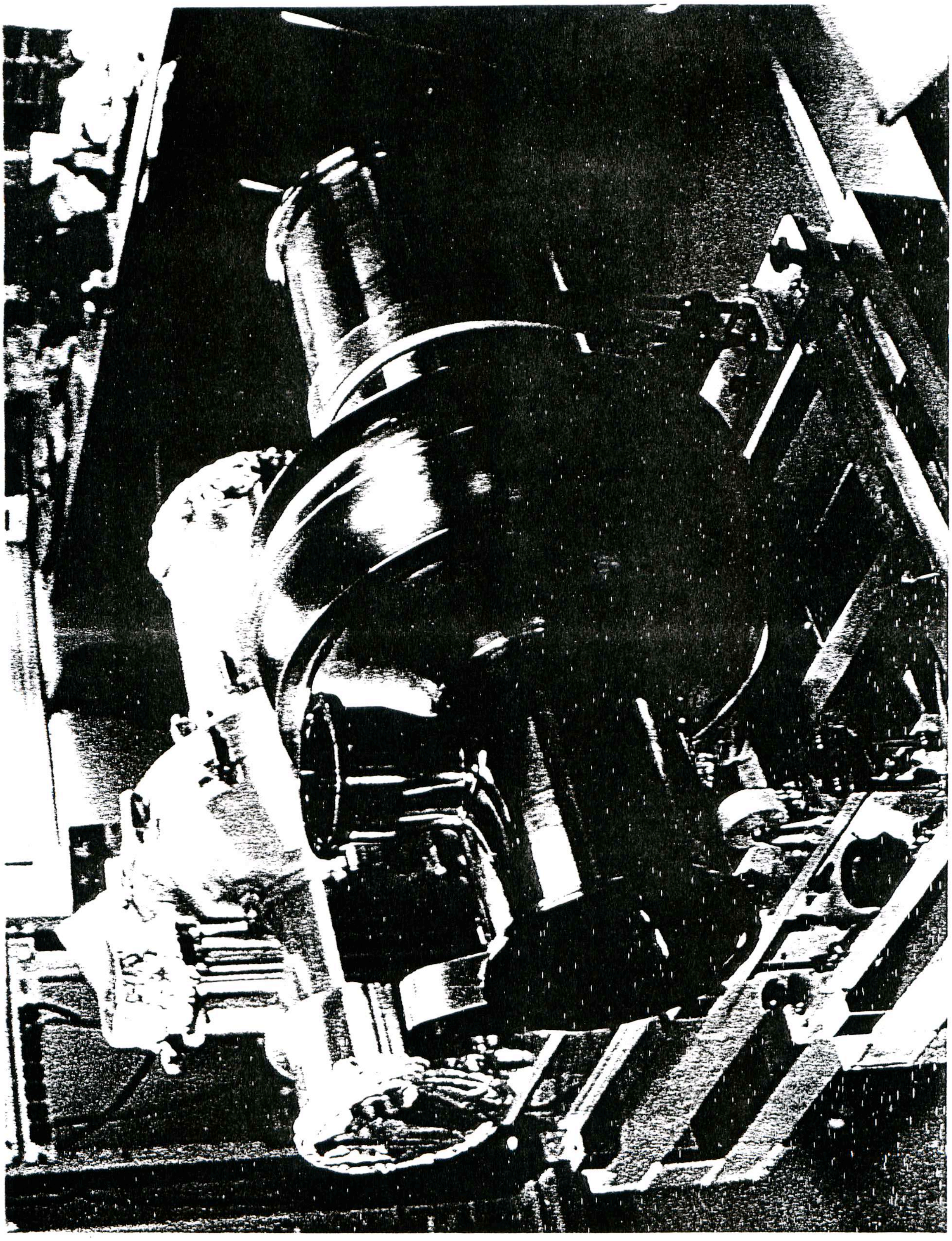
Now Input power 110 KW

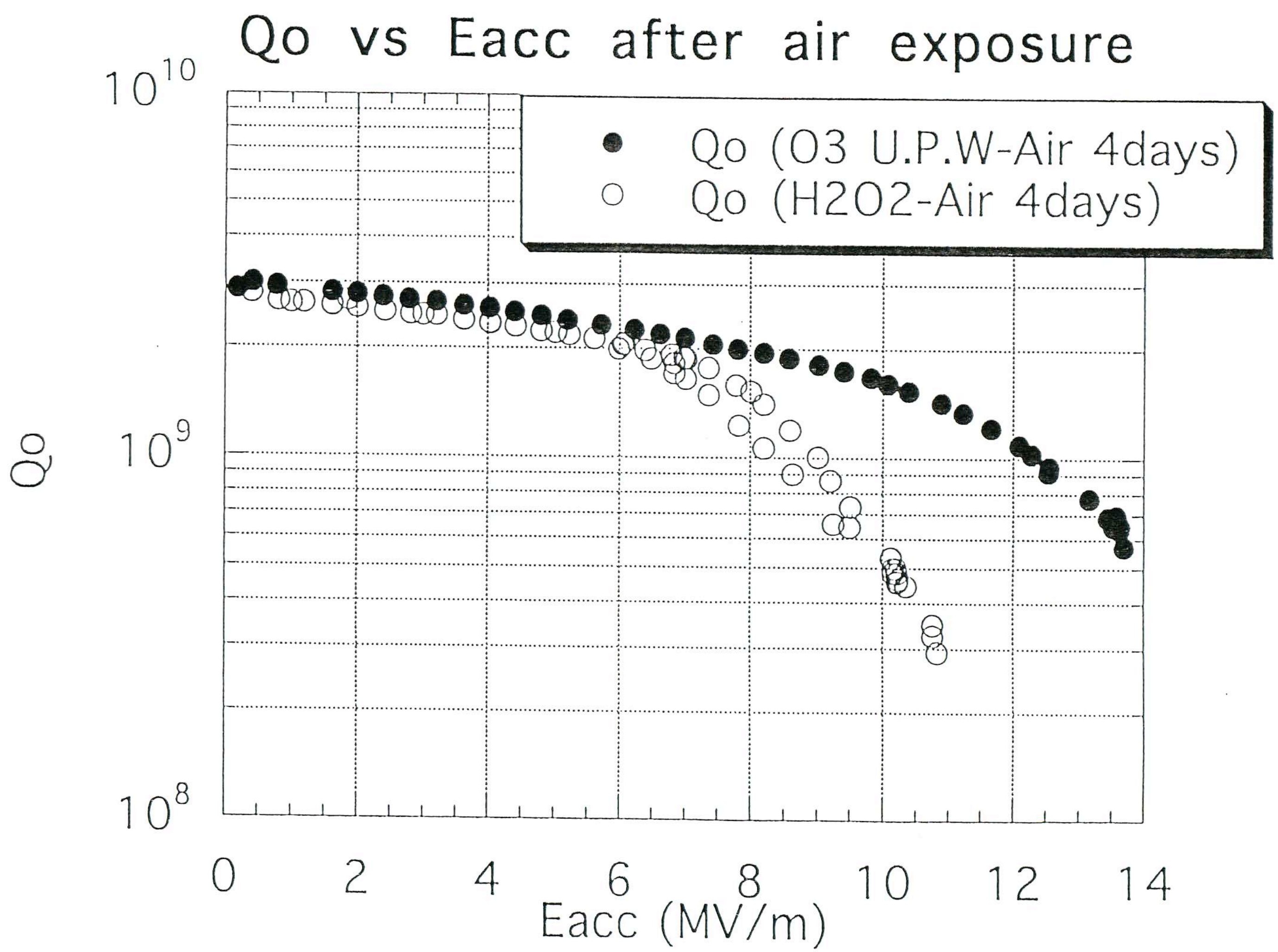
↓

0.73 MV

B-FACTORY SUPERCONDUCTING CAVITY

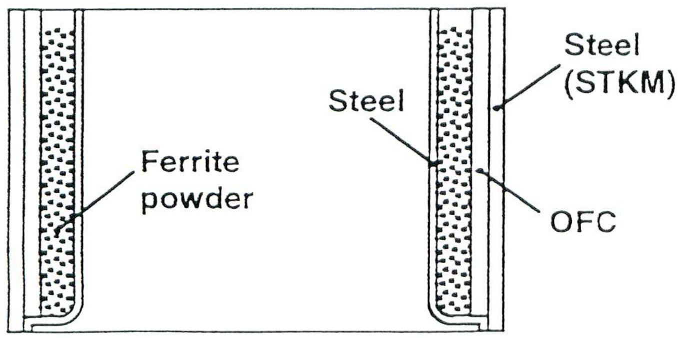




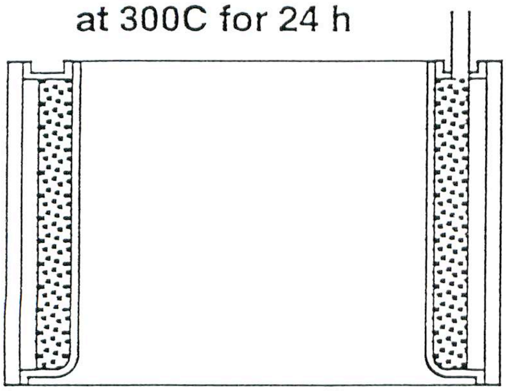

Qo vs Eacc after air exposure
Qo (O3 U.P.W-Air 4days)
Qo (H2O2-Air 4days)
Qo
10^10
10^9
10^8
0
2
4
6
8
10
12
14
Eacc (MV/m)

Manufacture Process

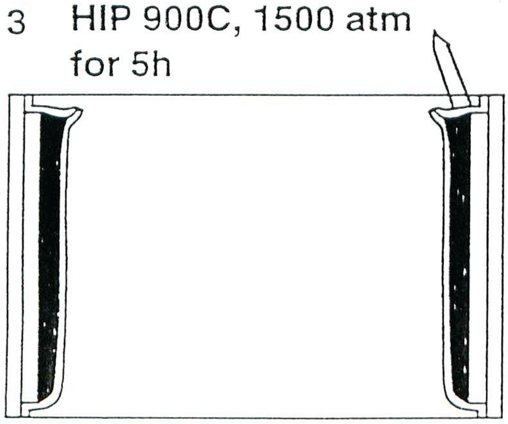
1 Packing of powder
Mechanical press



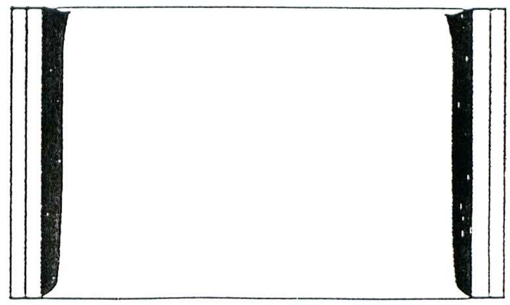
2 Seal, evacuate to degas
at 300C for 24 h



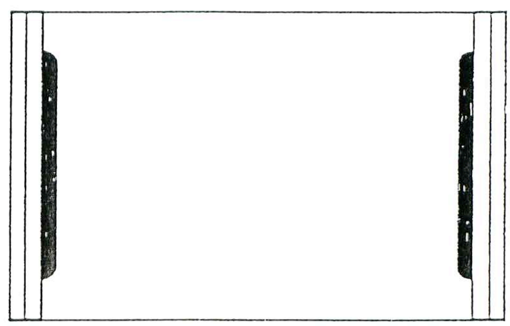
3 HIP 900C, 1500 atm
for 5h



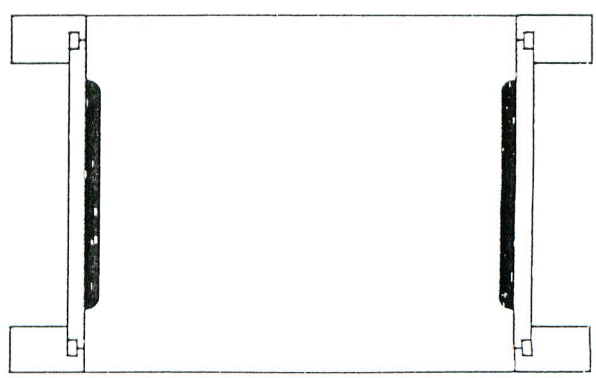
4 Remove inner and end cans

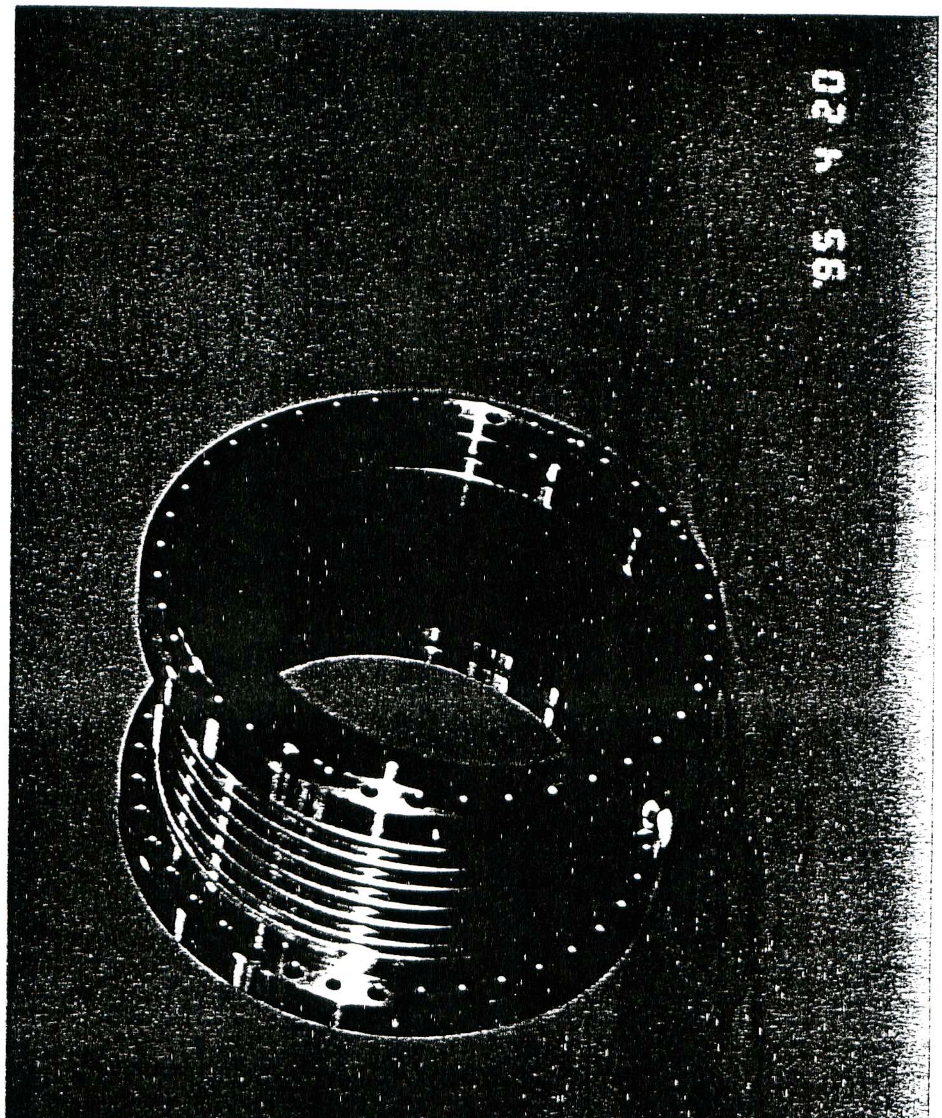


5 Machine ferrite



6 Electron beam weld
of end flanges




'95 4 20

Detuning Δf for beam-loading compensation

$$\Delta f = -\frac{I \sin\phi}{2V_c} \frac{R}{Q} f_{RF}$$

$$= -\frac{P_b \tan\phi}{4\pi U}$$

ϕ : synchronous phase

P_b : beam power

U : stored energy

$\Delta f \rightarrow$ small

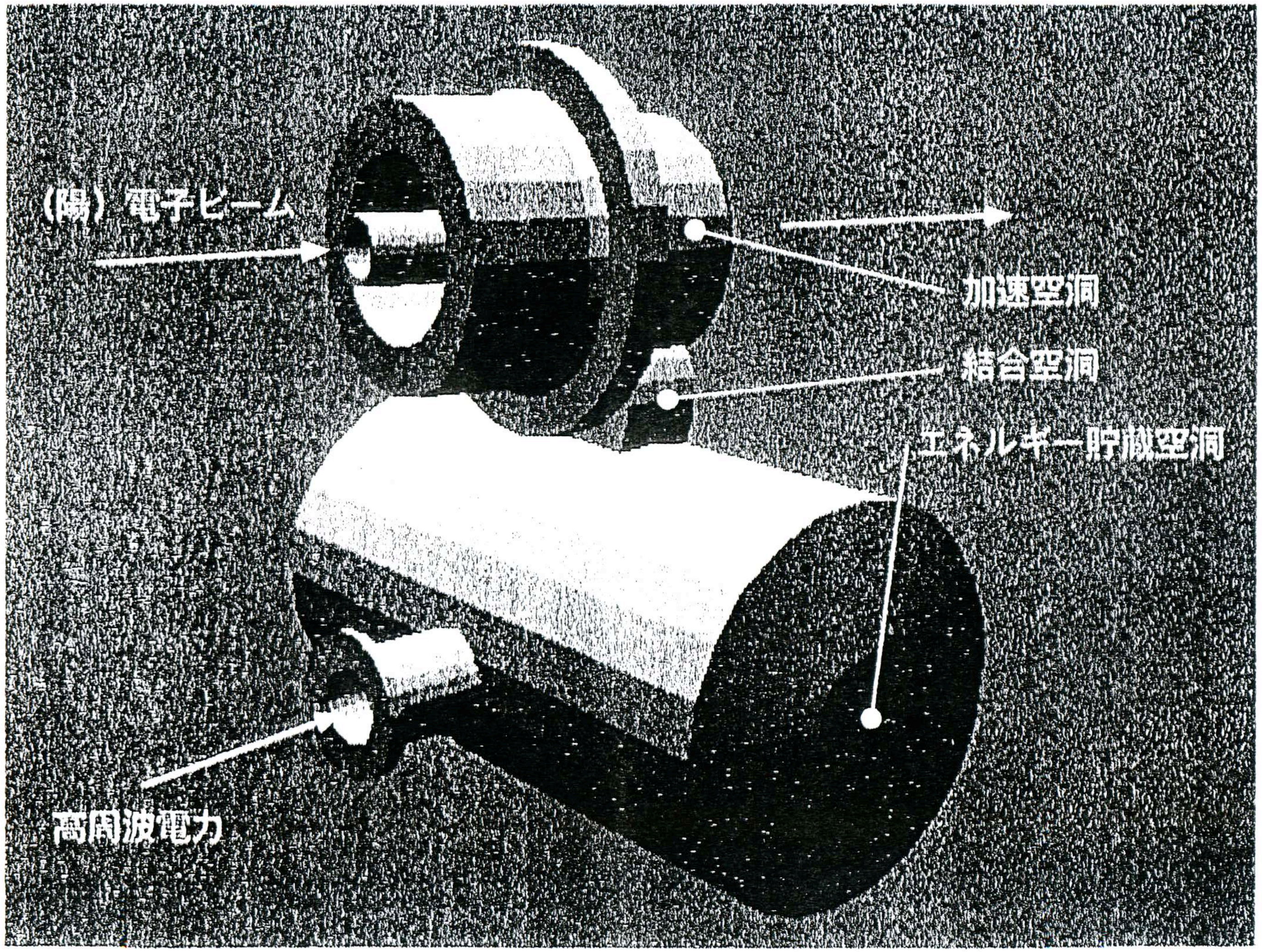
$V_c \rightarrow$ large

$R/Q \rightarrow$ small

$U \rightarrow$ large

ARES

Accelerator Resonantly Coupled with Energy Storage



Accelerator Resonantly coupled with Energy Storage (ARES)
for KEKB

Normal conducting cavity with a low loss storage cavity cell can mitigate coupled–bunch instability due to fundamental mode

Q ∝ stored energy/energy loss
-> large

R/Q –> small $\sim 13\ \Omega$

Δf –> small ~ 16 kHz $\ll 100$ KHz

Q_L –> large $\sim 3 \times 10^4$

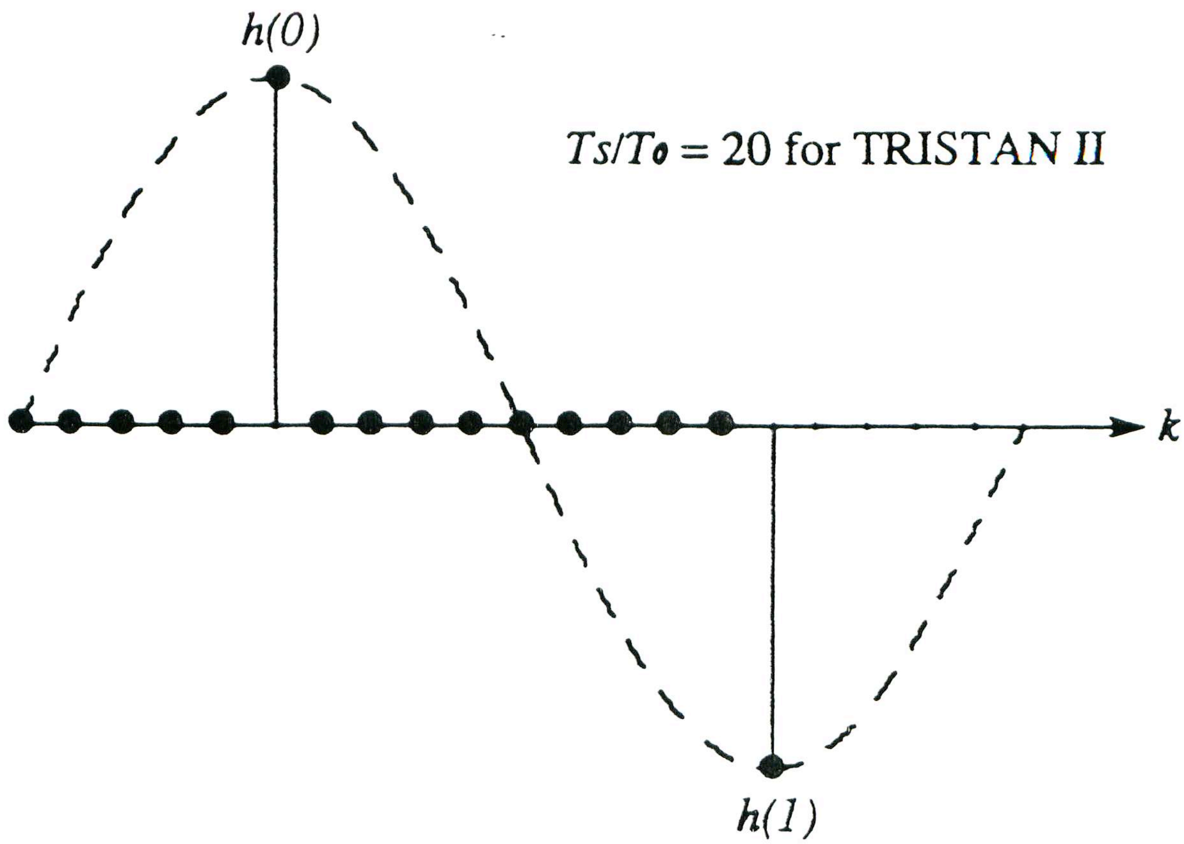
SCC is immune to beam-loading due to its large V_c

Bunch–by–Bunch Feedback

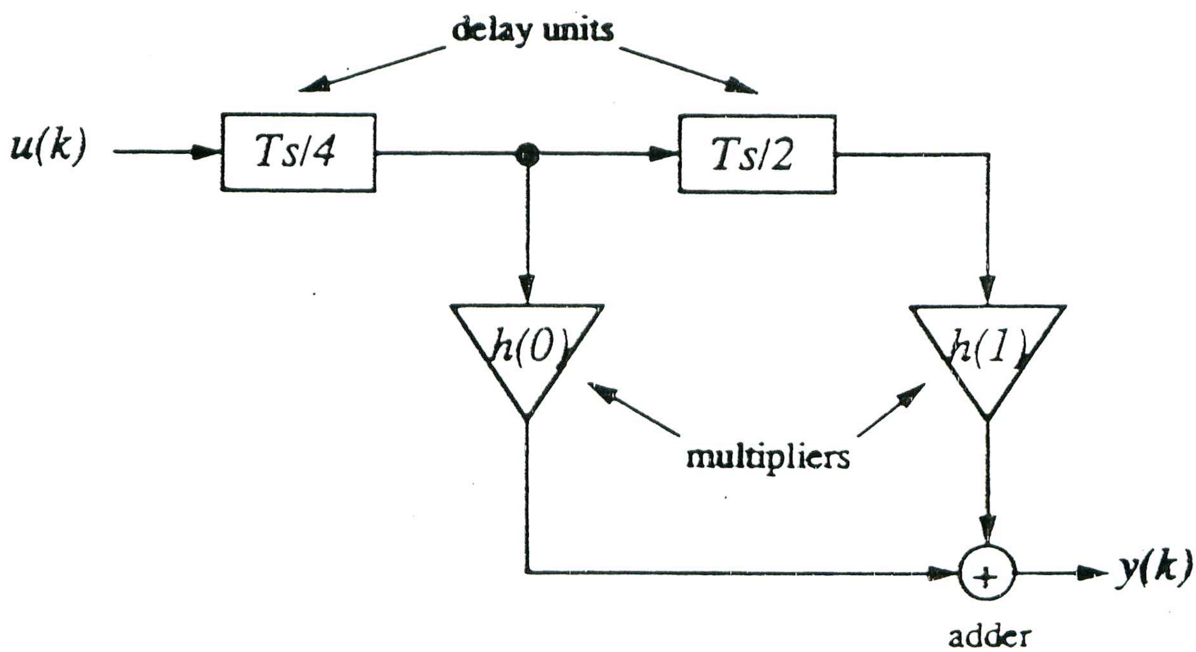
– Bunch–by–bunch beam feedback of a few msec damping time will stabilize residual oscillations of bunches.

– To construct a feedback system that copes with 2–nsec buch spacing is a big challenge. Extensive R&D is going on.

– Digital signal processing on the basis of 2–tap FIR filter is promising.

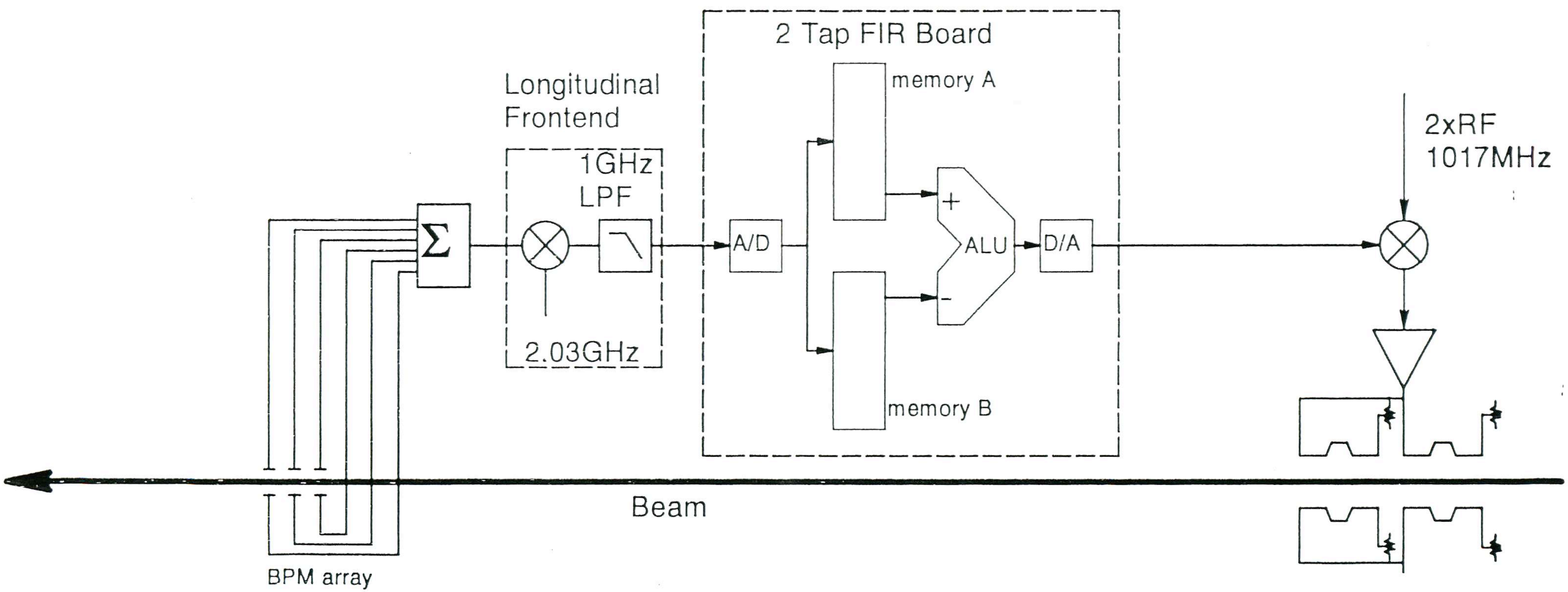


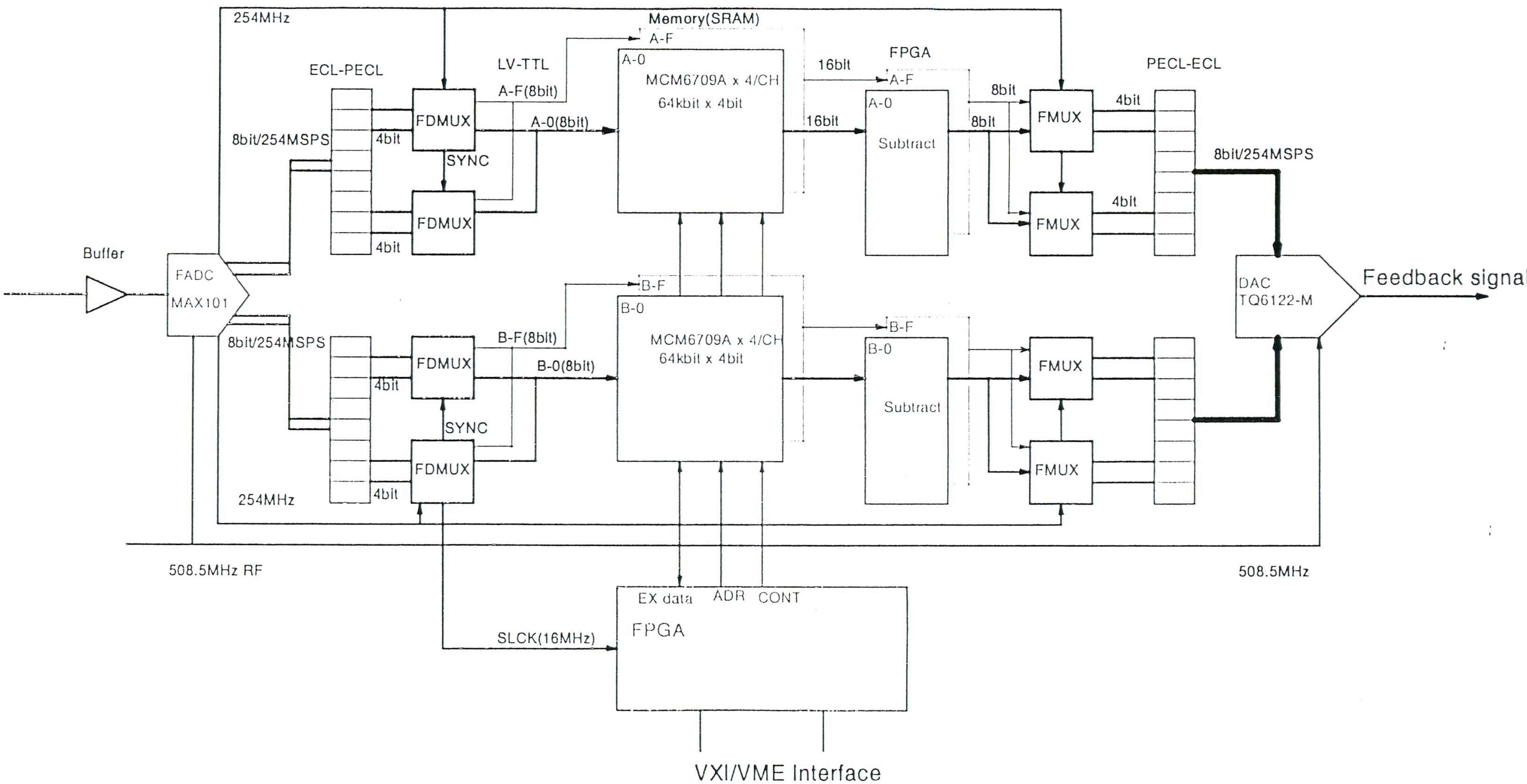
Impulse response

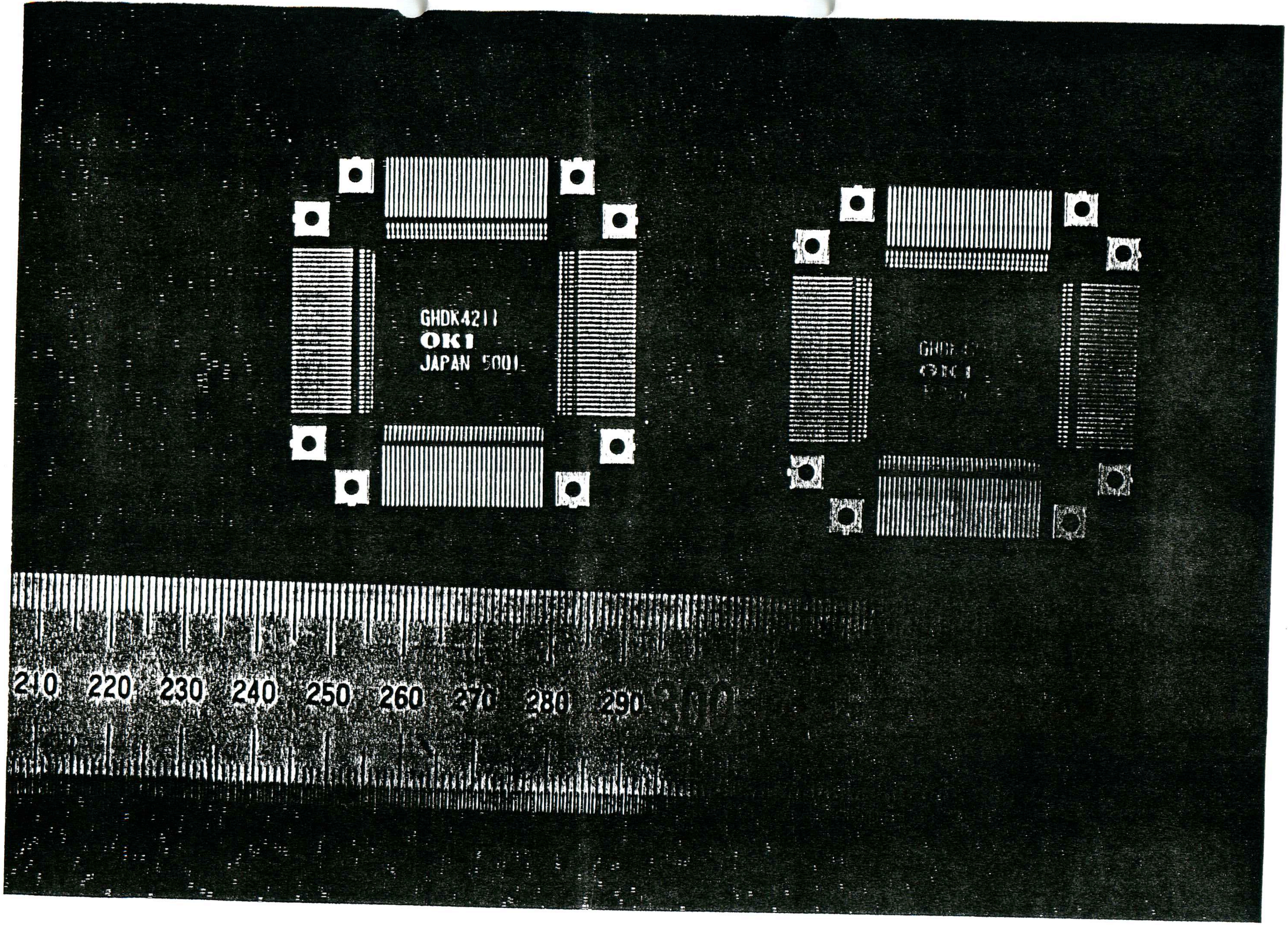


Implementation of 2-tap peak gain mode FIR filter

Longitudinal Bunch Feedback System




254MHz
Memory(SRAM)
A-F
ECL-PECL
LV-TTL
A-F(8bit)
A-0
MCM6709A x 4/CH
64kbit x 4bit
16bit
FPGA
A-F
A-0
Subtract
8bit
PECL-ECL
4bit
FDMUX
A-0(8bit)
8bit/254MSPS
4bit
SYNC
16bit
8bit
FMUX
8bit/254MSPS
FDMUX
4bit
FMUX
Buffer
FADC
MAX101
DAC
TQ6122-M
Feedback signal
B-F
B-0
B-F
8bit/254MSPS
FDMUX
B-F(8bit)
MCM6709A x 4/CH
64kbit x 4bit
B-0(8bit)
B-0
FMUX
Subtract
4bit
SYNC
FDMUX
FMUX
254MHz
4bit
508.5MHz RF
508.5MHz
EX data
ADR
CONT
FPGA
SLCK(16MHz)
VXI/VME Interface

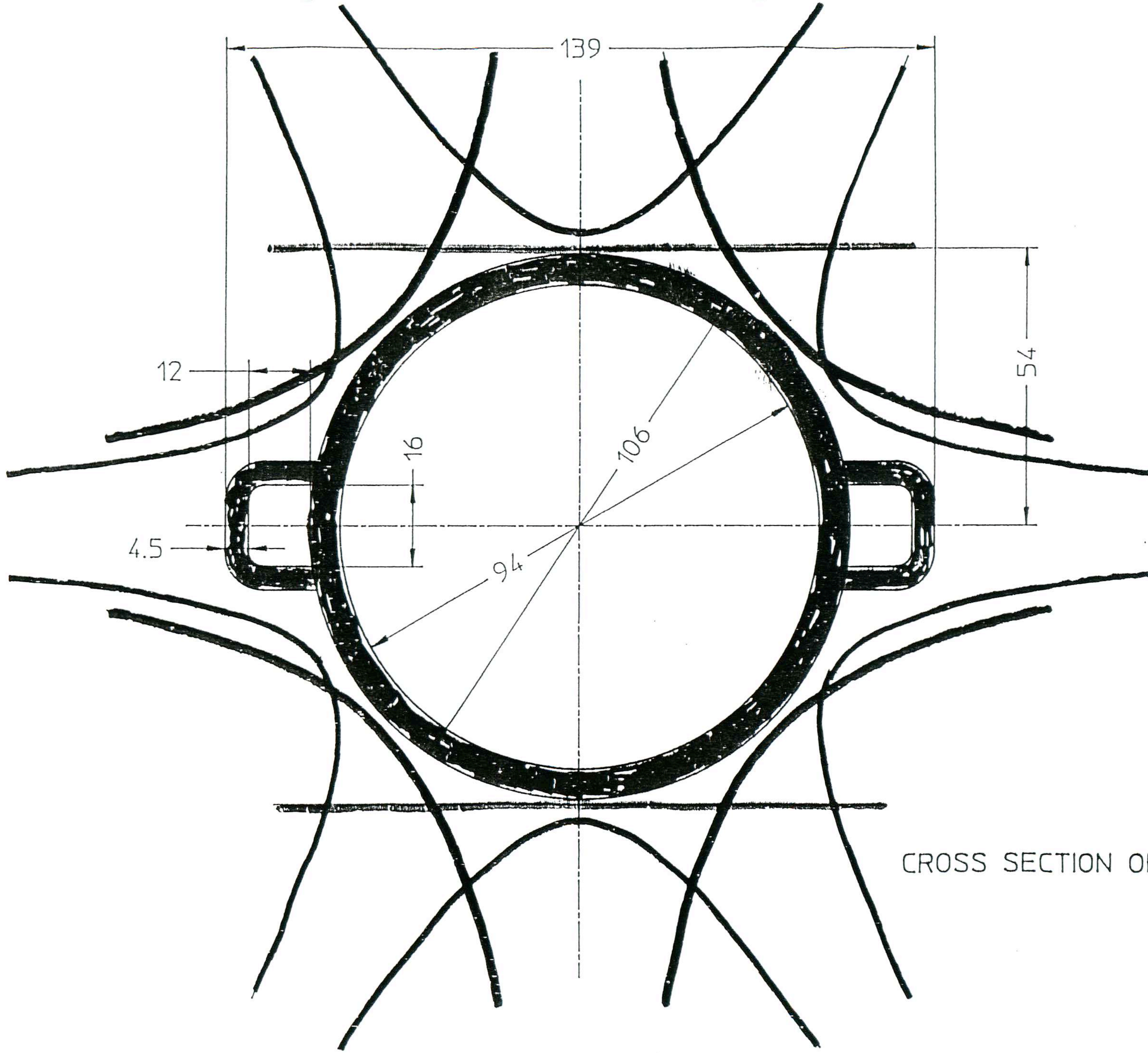

GHDK4211
OKI
JAPAN 5001
210 220 230 240 250 260 270 280 290 300

Material of Vacuum Chambers

material	Al	Cu	SS
Photo−desorption	+	++	++
Self−shielding	−	++	++
Thermal conductivity	+	+to++	−
Strength	+	−to+	++
Ease of fabrication	++	+	++
Experience	++	+	++
Cost	$	$	$$

KEKB choice is Cu.

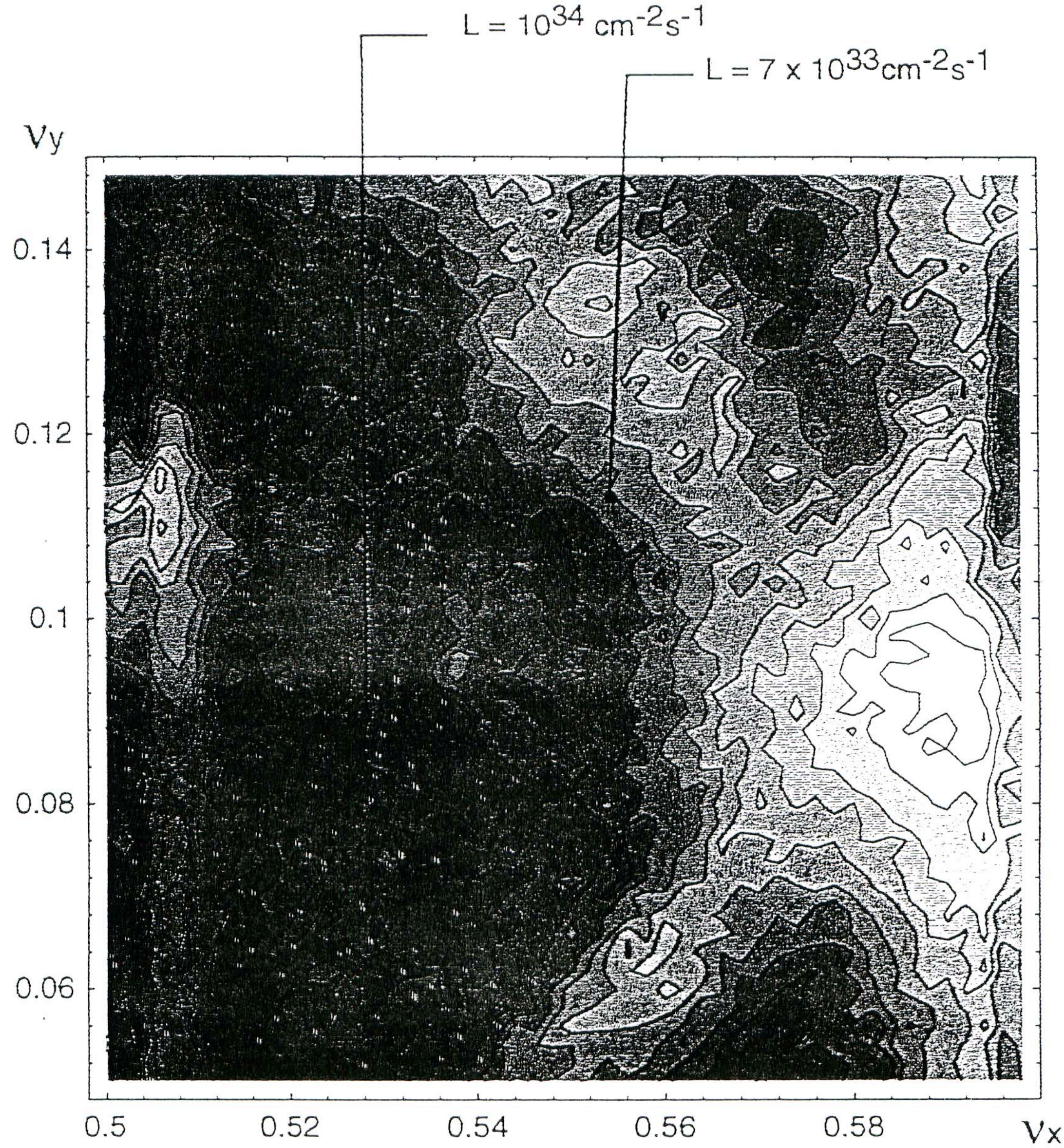
- +superior vacuum properties
- +superior thermal properties
  - – ease thermal management
- +superior self−shielding
  - – eliminates Pb cladding



CROSS SECTION OF LER

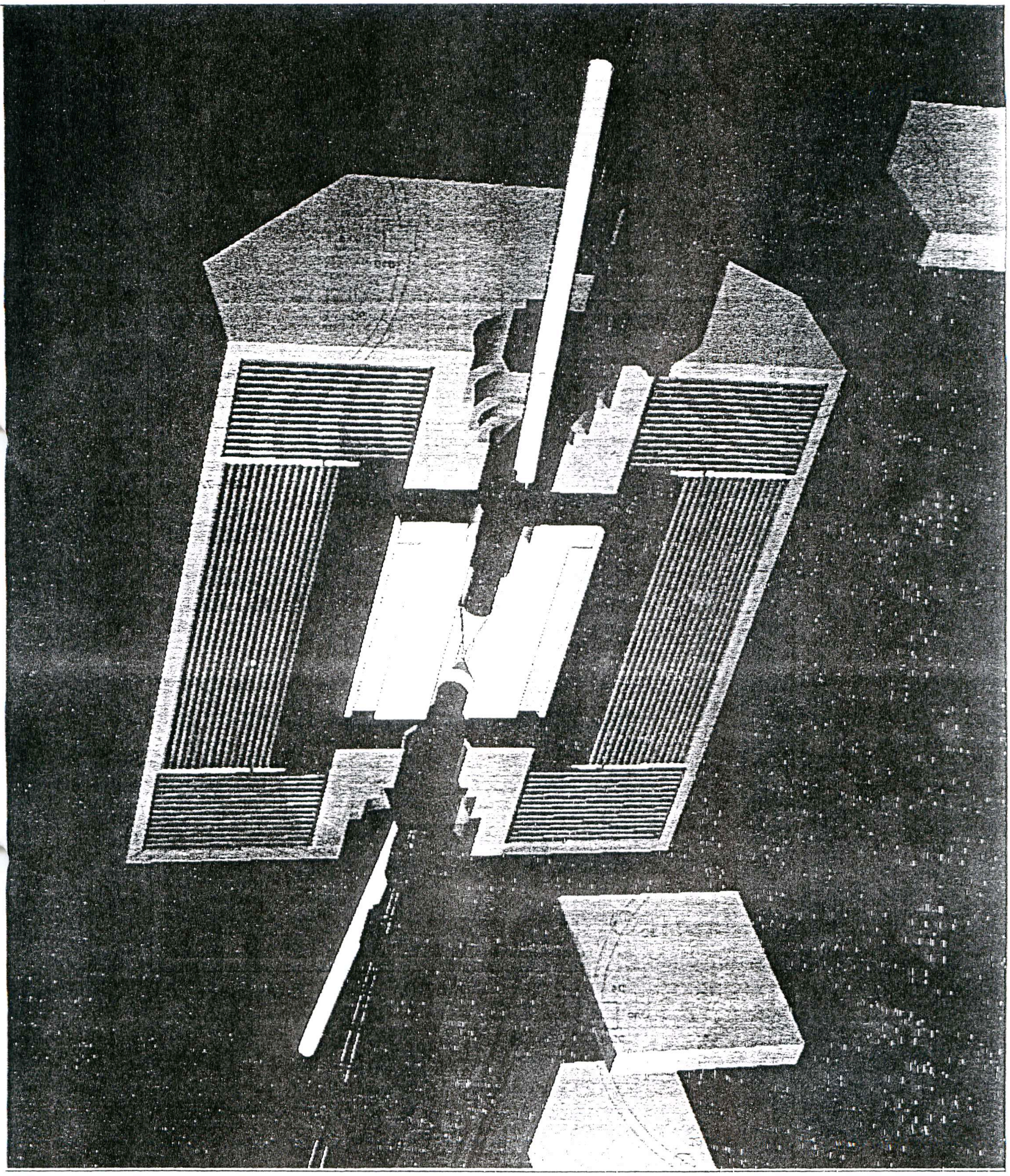
Crossing Angle	Hardware	Beam
0 mrad	Very compact separation bends necessary (permanent mag.)	Rapid beam separation is critical to stay away from parasitic crossing effects.
2 mrad	Superconducting separation bend is feasible with reasonable B field.	Synchro-beta is OK
5 mrad		Comfortable for parasitic crossing effects.
8 mrad	Separation bend no longer needed.	
10 mrad		Sychro-beta due to beam-beam appears OK? *
11 mrad	KEKB	
20 mrad	Single-quad for two beams becomes painful.	Need for Crab crossing is increased

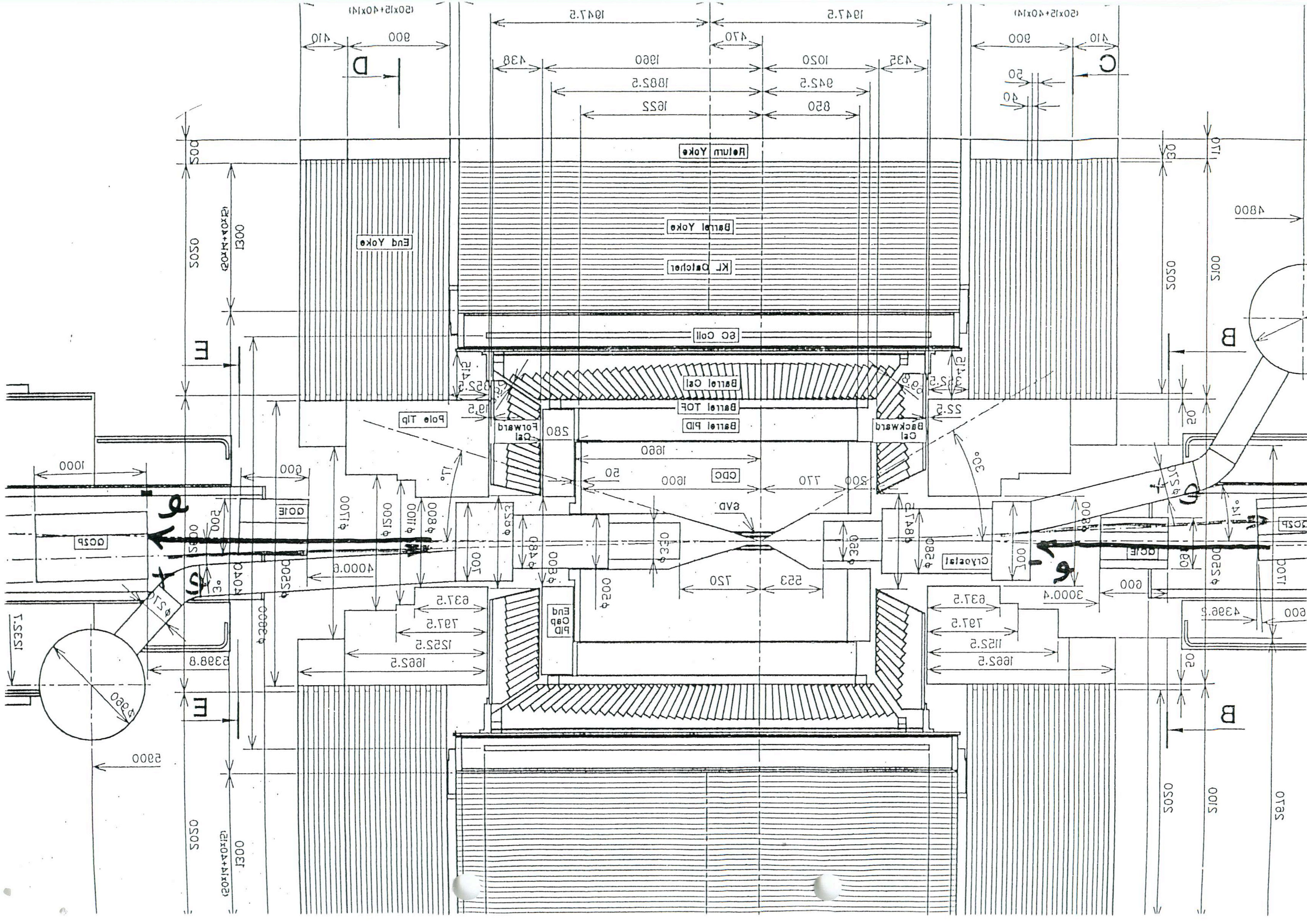
* Superconducting crab-cavity R&D has started



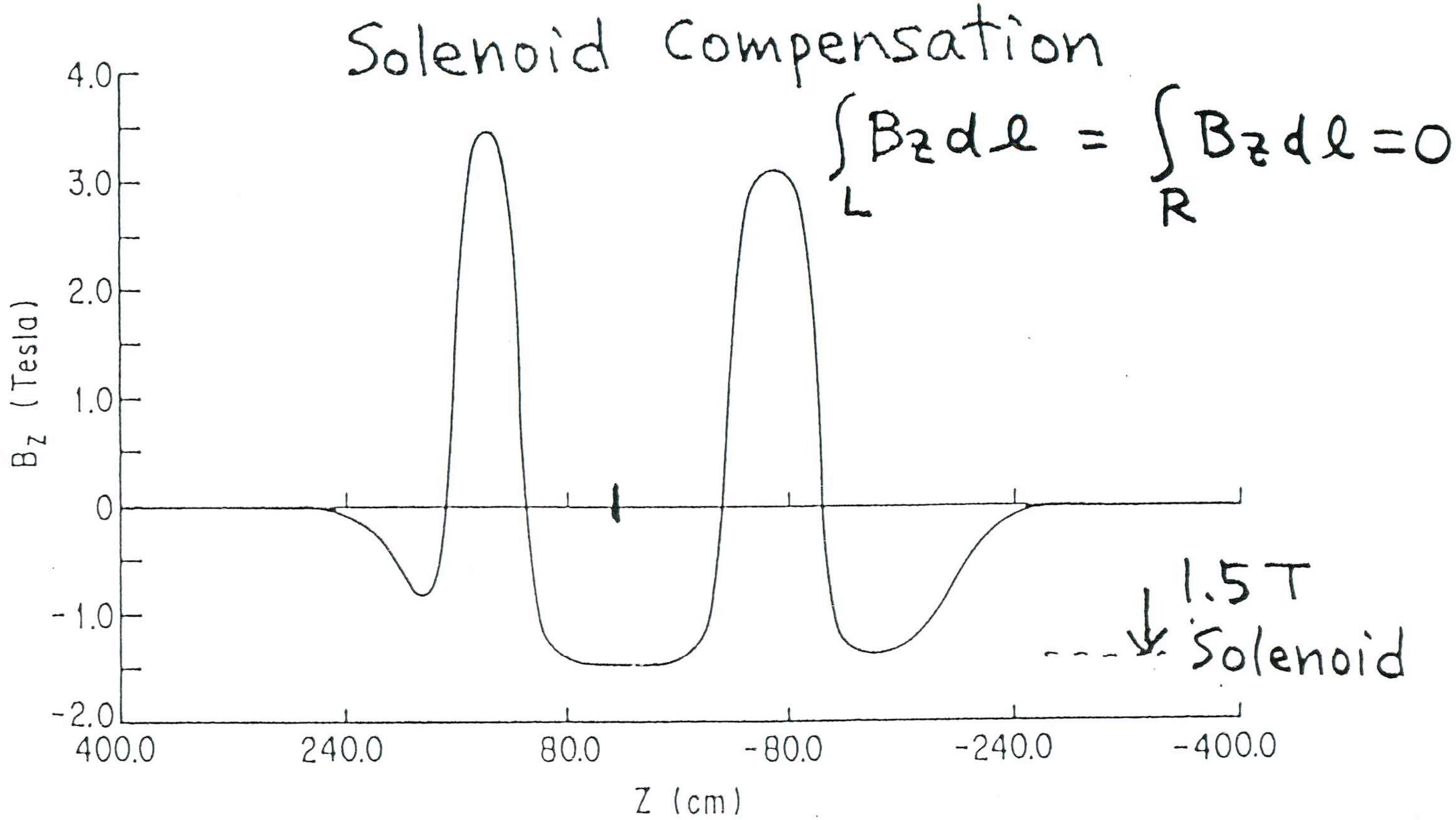
L = 10^34 cm^-2s^-1
L = 7 x 10^33 cm^-2s^-1
νy
0.14
0.12
0.1
0.08
0.06
0.5
0.52
0.54
0.56
0.58
νx

$\nu_s \sim 0.01$




Return Yoke
Barrel Yoke
KL Catcher
End Yoke
SC Coil
Barrel Cal
Barrel TOF
Barrel PID
Pole Tip
Forward Cal
Backward Cal
End Cap PID
CDC
SVD
QC2P
QC1E
Cryostat
B
C
D
E

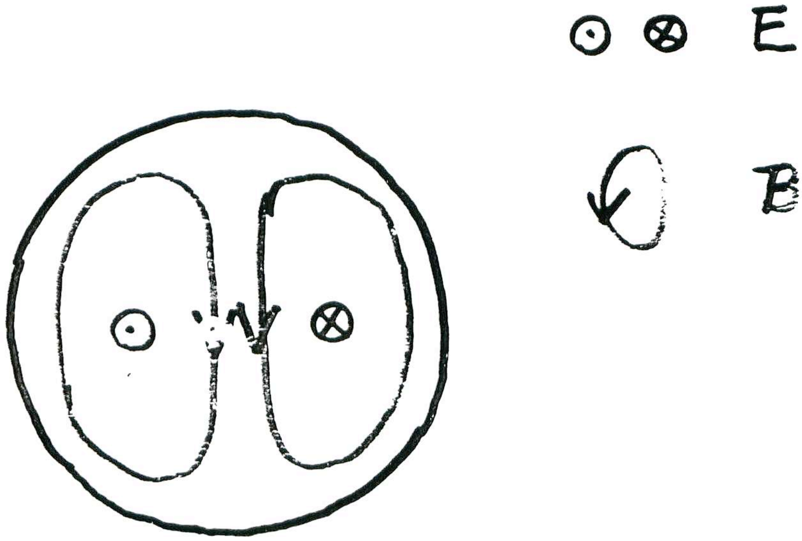
magnets.



Distribution of axial magnetic field B_z along the axis of the experimental facility.

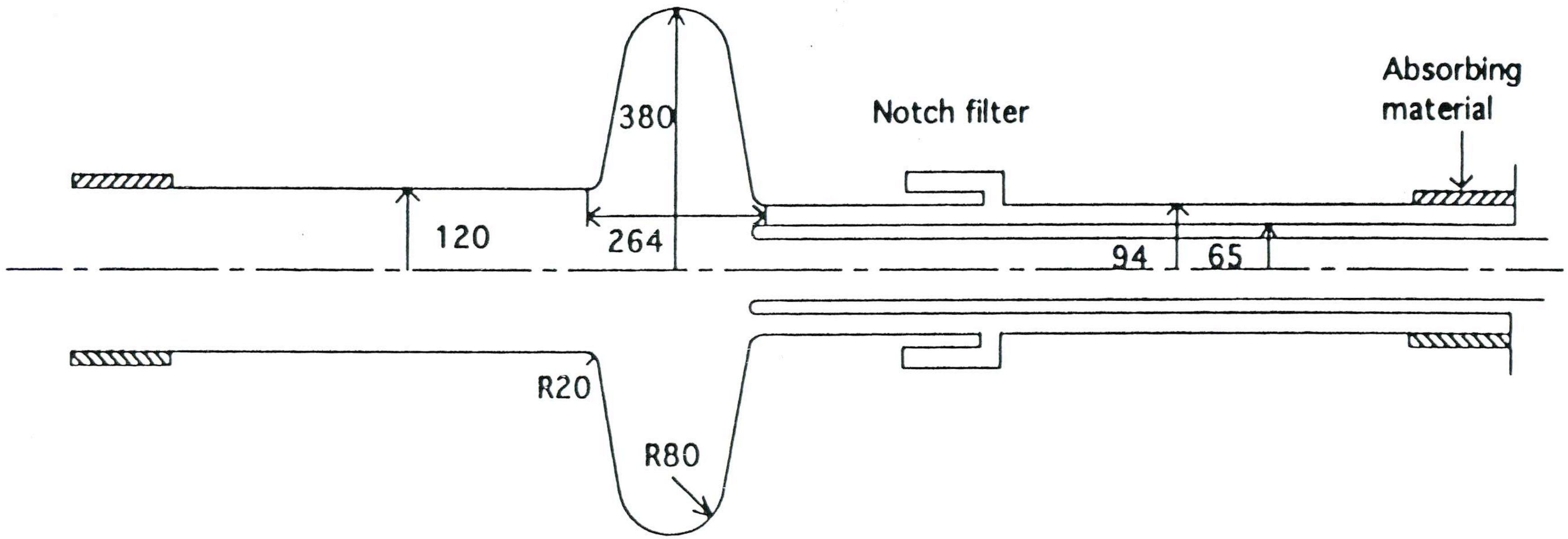
Crab Cavity

- Crab Mode = TM110



- Not only HOMs but also fundumental mode should be damped.

Akai at Cornell



We decided that the KEKB control system would be built on the basis of EPICS.

Machine Study Plan at AR

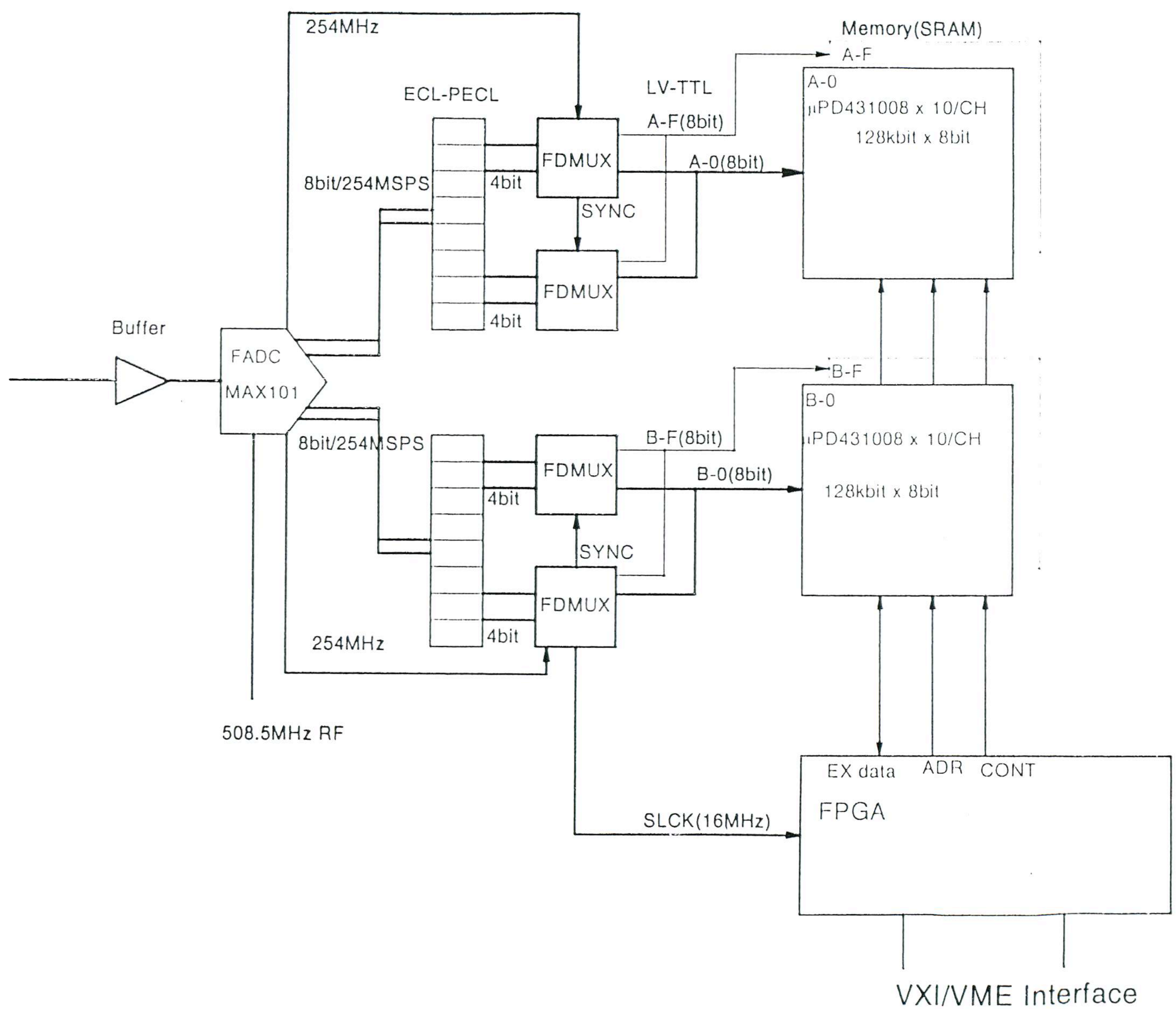
- Storage of multi–bunch, high–current (500 mA) beam in TRISTAN AR

- Replace present APS cavities with cavities (ARES and SCC) for KEKB

- Bunch–by–bunch beam feedback will be tested

- Fast ion instability will be also tested

- July, November and December of 1996 (3 months)


254MHz
ECL-PECL
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Memory(SRAM)
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μPD431008 x 10/CH
128kbit x 8bit
FDMUX
A-0(8bit)
8bit/254MSPS
4bit
SYNC
FDMUX
4bit
Buffer
FADC
MAX101
B-F
B-0
B-F(8bit)
μPD431008 x 10/CH
8bit/254MSPS
FDMUX
B-0(8bit)
4bit
128kbit x 8bit
SYNC
FDMUX
254MHz
4bit
508.5MHz RF
EX data
ADR
CONT
FPGA
SLCK(16MHz)
VXI/VME Interface

Milestones

– April 1994	**Project approval and start of construction**
– July 1995	**Bidding for LER main equipment**
– Jan. 1996	**Start of dismantling of TRISTAN**
– May 1996	**Bidding for HER main equipment**
– Jan. 1997	**Start of installation in the tunnel**
– Jan. 1998	**Completeion of new bypass tunnel**
– April 1998	**Completion of linac upgrade**
– Jan. 1999	**Start of commissioning of rings**

Table 2 Budget Profile of KEKB

Fiscal year	Accelerator and linac	Detector	Operational	Total
1994	14.61	5.37		19.98
1995	30.41	11.61		42.02
1996	76.53	18.63		95.16
1997	98.49	16.29		114.78
1998	73.96	8.10	32.00	114.06
Total	294.00	60.00	32.00	386.00

Unit: 10^8 yen

Summary

1. KEKB Project was approved by the government in 1994.

2. Machine design incorporates new ideas and technologies such as non–interleved sextupole chromaticity correction, finite–angle crossing, ARES–type cavities, 2–tap FIR filtering, etc.

3. Construction of the machine and BELLE detector has started.

3. R&D on critical items are underway.

4. Construction will take 5 years; commissioning will be in JFY1998.