Overview of KEKB Accelerator

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KEK

KEKBMAC
January 22, 1997

KEKB

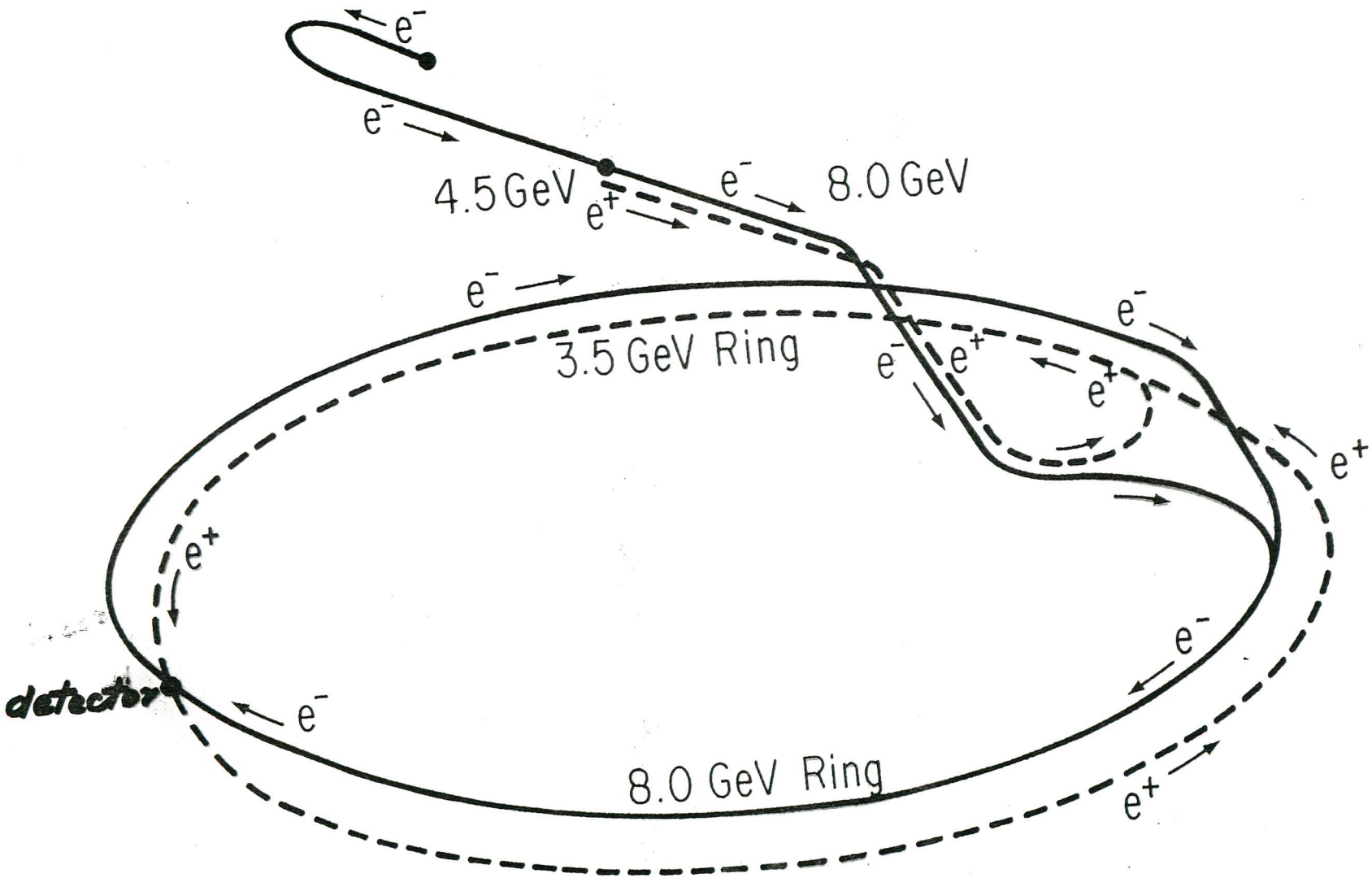
=

KEK B-Factory

Asymmetric, 2-ring,
high-luminosity,
electron-positron collider with
one interaction point
in TRISTAN tunnel
optimized for CP-violation
detection at b-quark sector

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

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


e⁻
e⁻
4.5 GeV
e⁺
e⁻
8.0 GeV
e⁻
3.5 GeV Ring
e⁻
e⁺
e⁺
e⁻
e⁺
e⁺
e⁻
detector
e⁻
8.0 GeV Ring
e⁺

Linac and Injection

-Present 2.5 GeV linac is being upgraded to 8 GeV to facilitate full-energy injection and to increase positron intensity.

-Possibility of a small damping ring for positrons (1 GeV, half way along the linac) was suggested and will be studied soon.

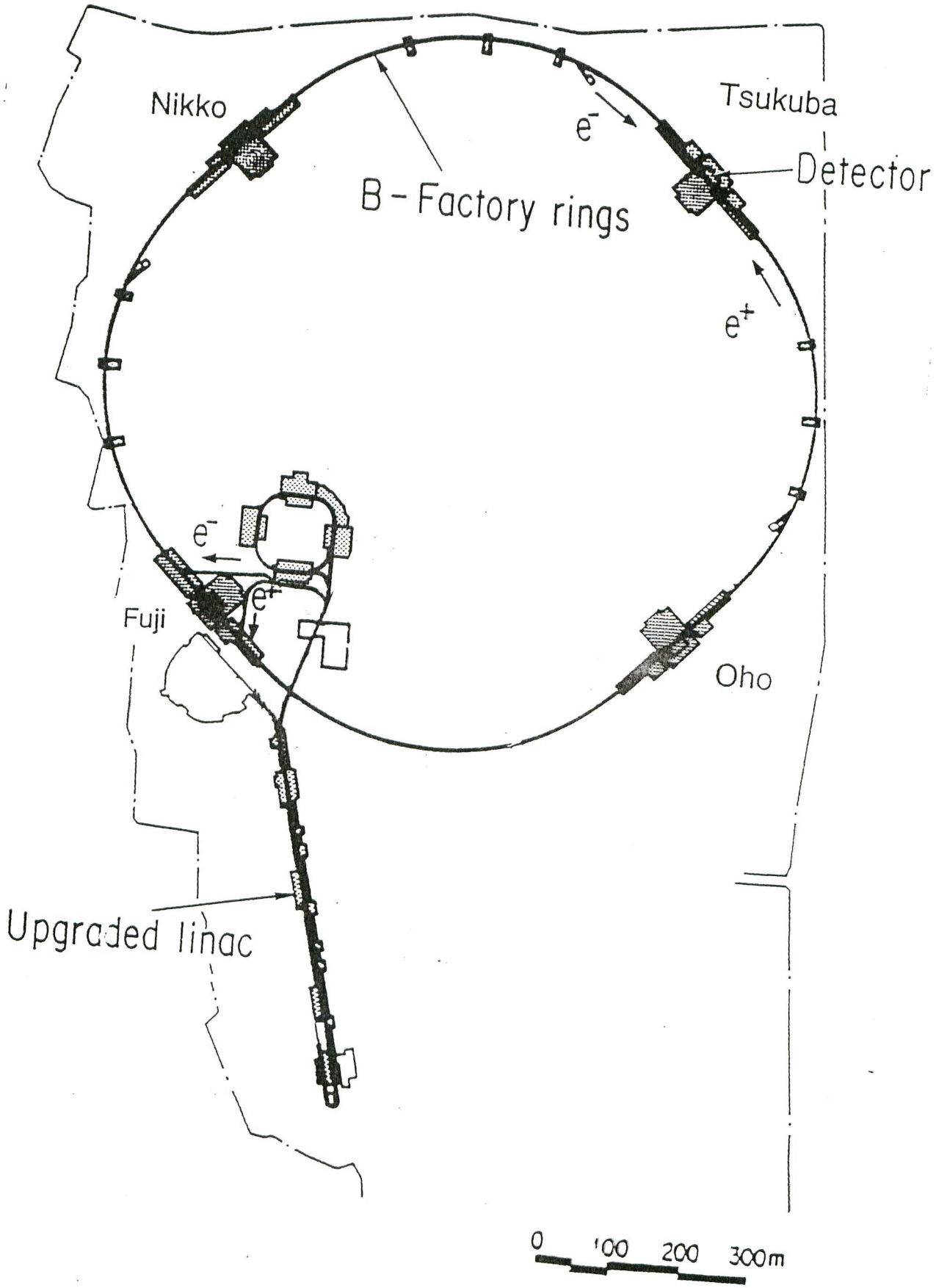
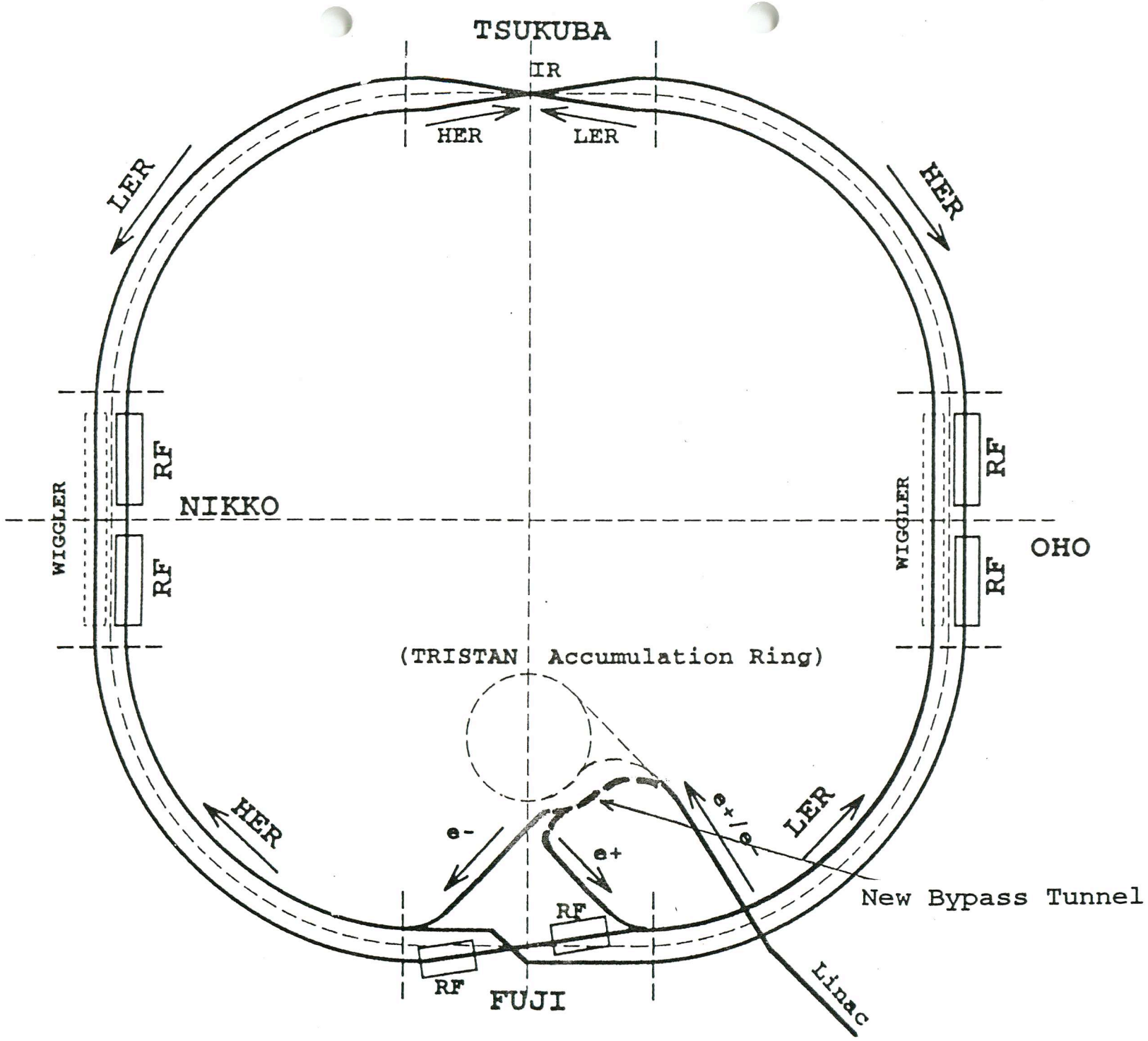
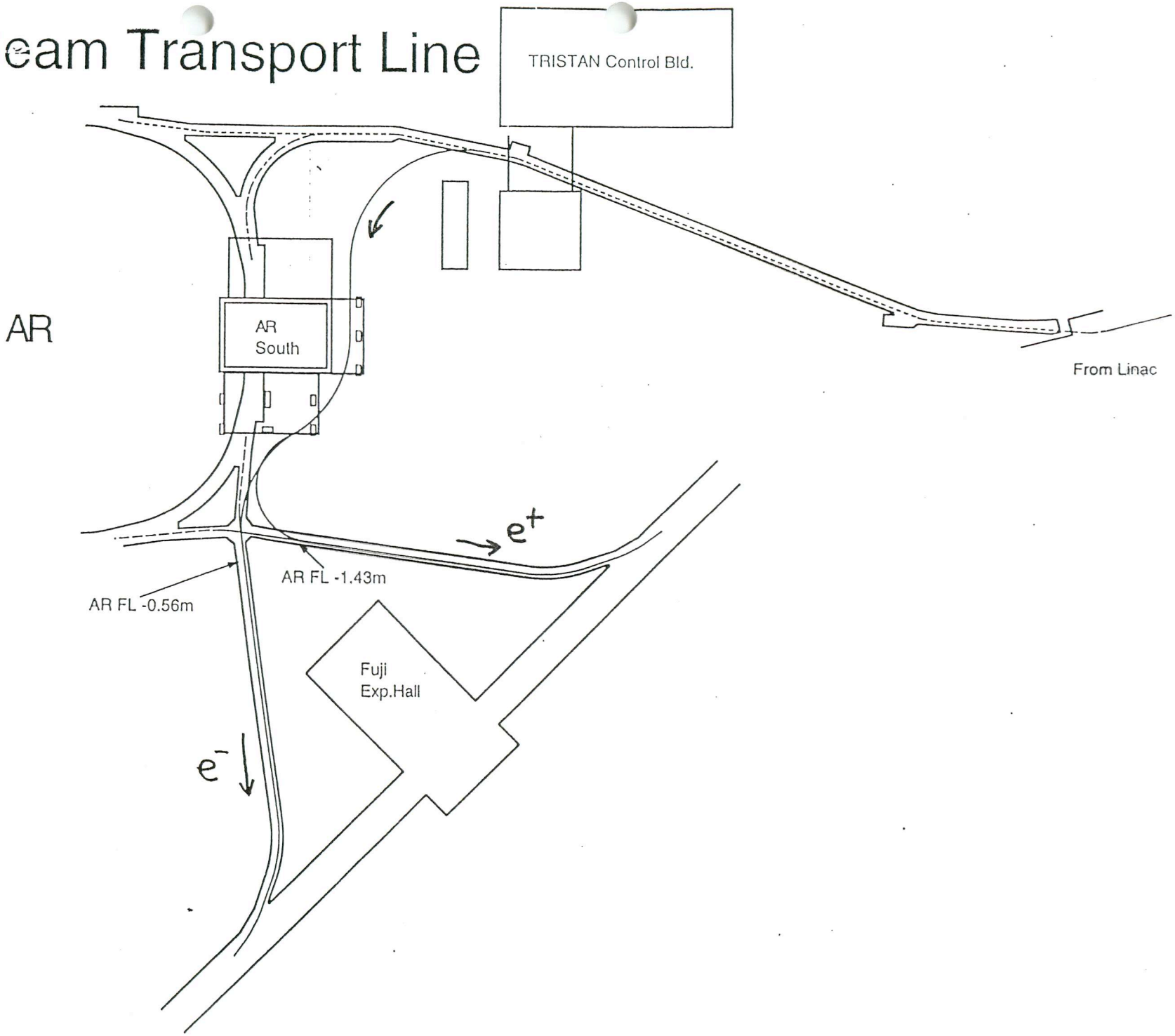


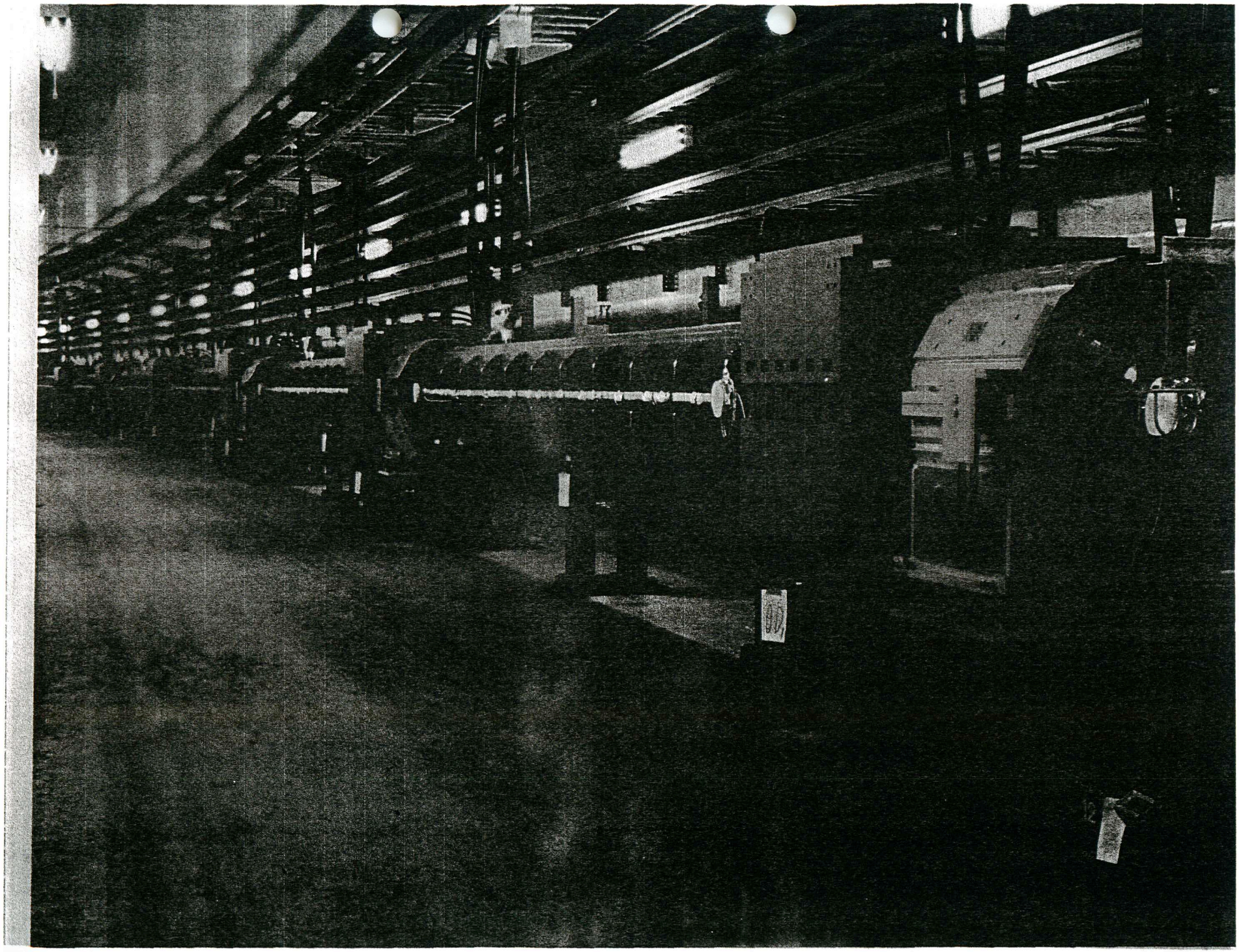
Fig. 2. Layout of KEKB within the KEK site.

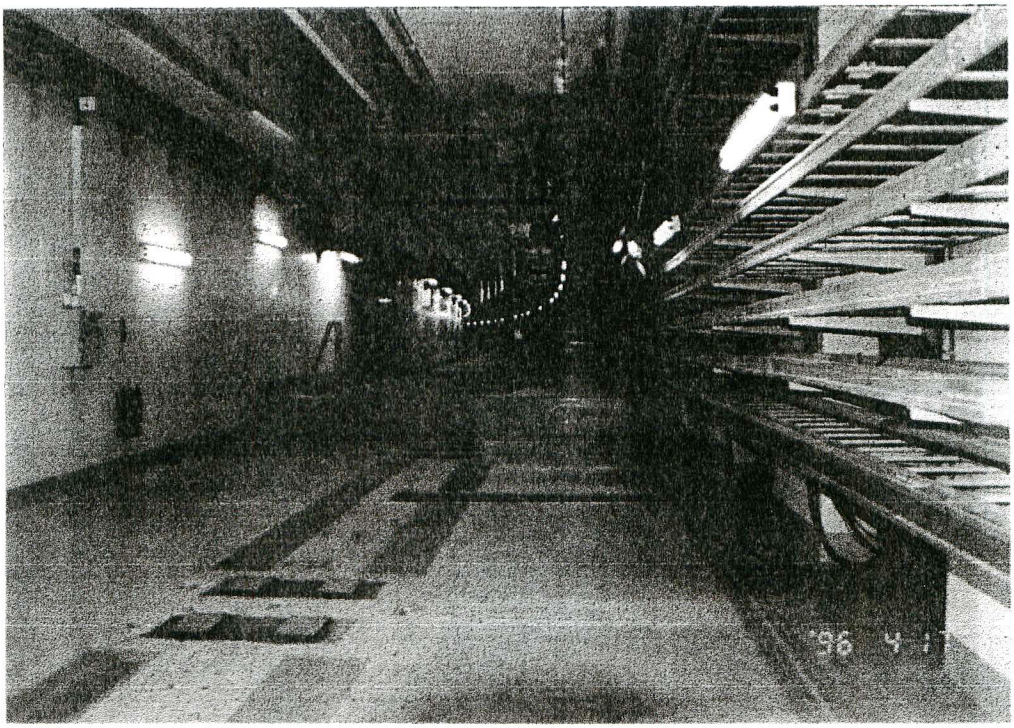

TSUKUBA
IR
HER
LER
LER
HER
RF
RF
WIGGLER
NIKKO
RF
RF
WIGGLER
OHO
(TRISTAN Accumulation Ring)
HER
e-
e+
e+/e-
LER
New Bypass Tunnel
RF
RF
FUJI
Linac

KEKB Beam Transport Line



Scale 1/1000

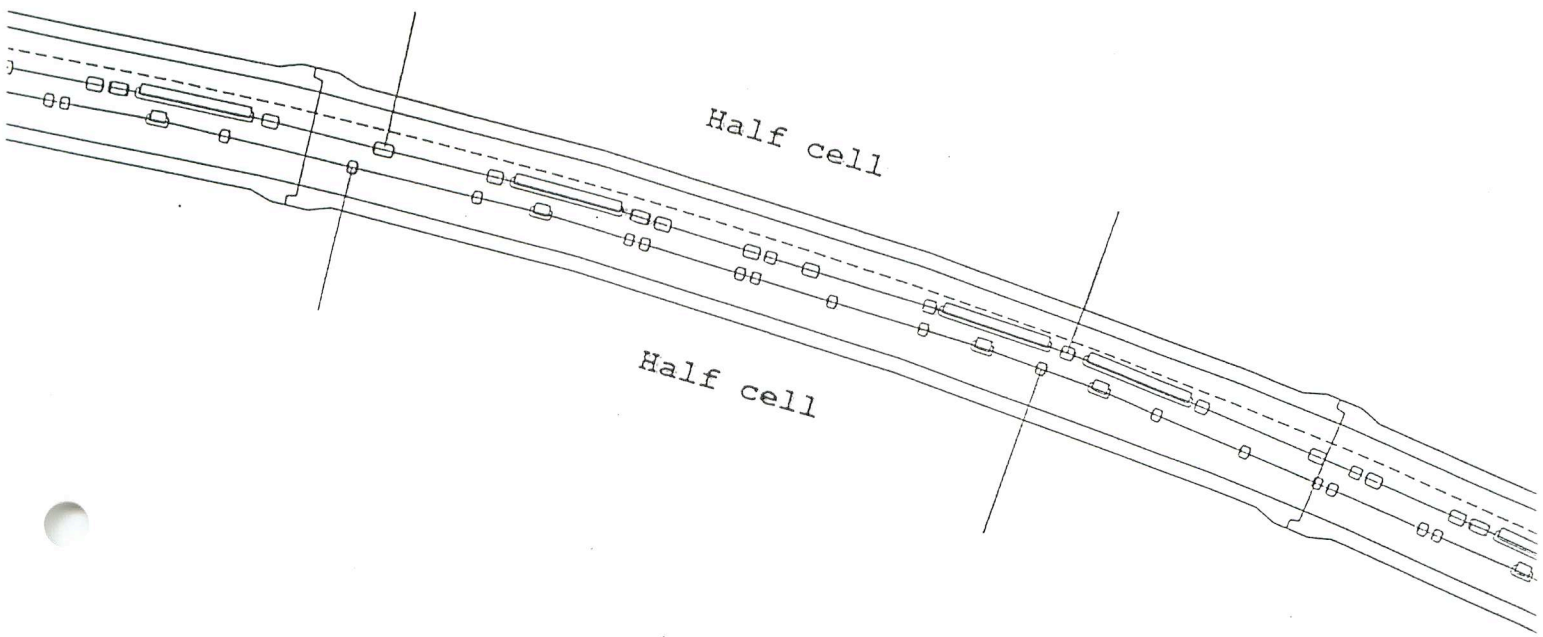




STRAIGHT SECTION

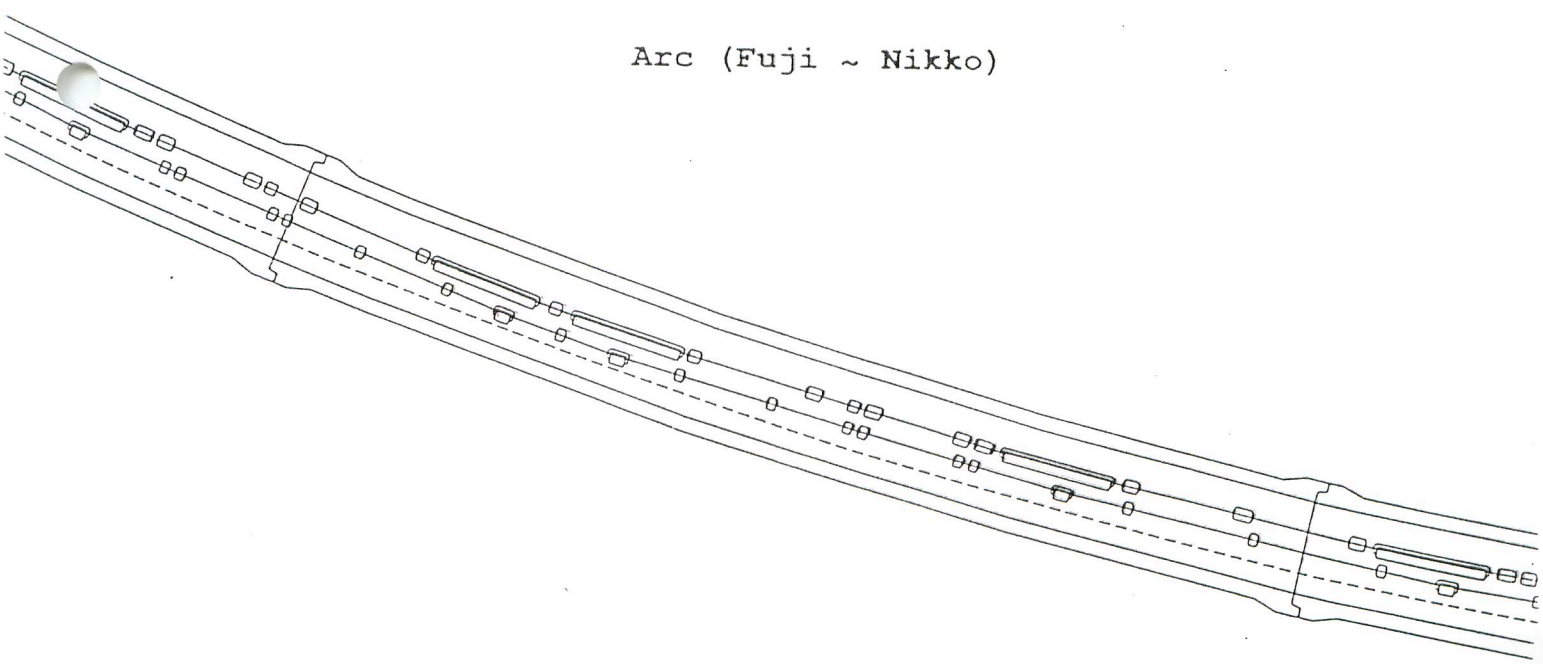
ARC SECTION

Arc (Tsukuba ~ Oho)

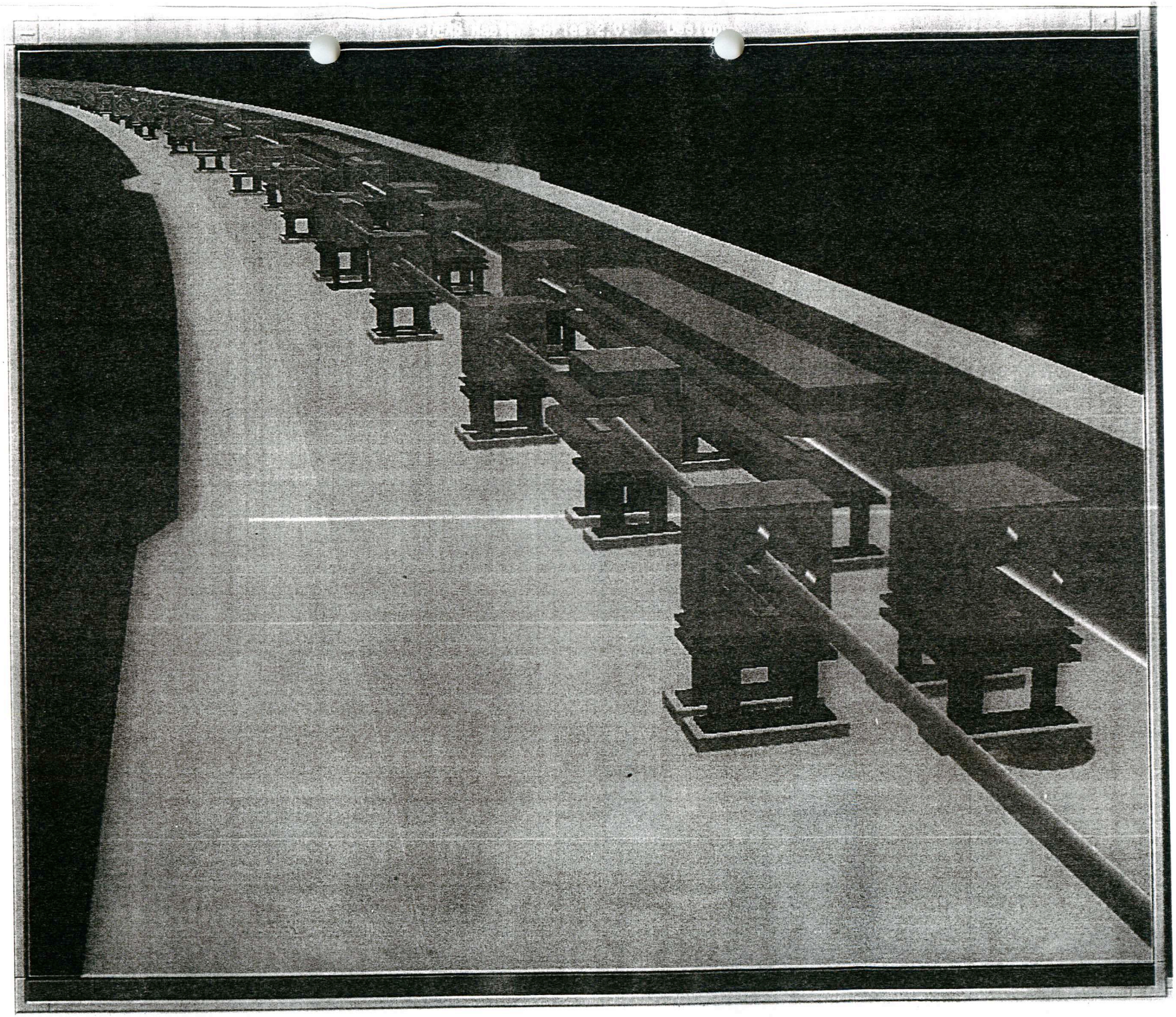


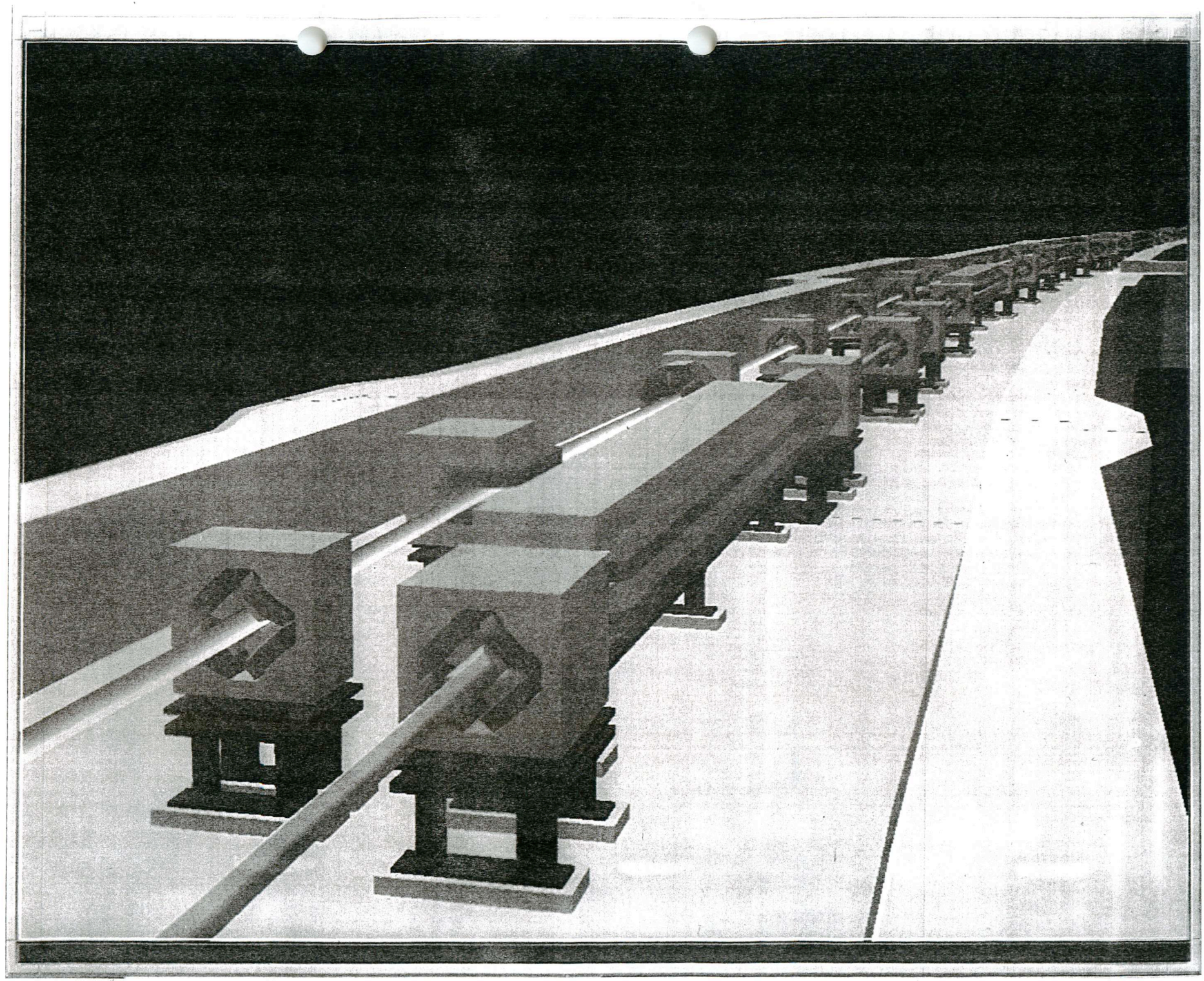
TR2 (S=1/200

Arc (Fuji ~ Nikko)



FR2 (S=1/200)





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

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

ξ : beam–beam tuneshift

r = σ_y/σ_x (at IP)

$r=1$ round beam

$r=0$ flat beam

I : beam current (A)

E : beam energy (GeV)

β_y^*: β–value at IP (cm)

+ : positron

– : electron

KEKB Parameters

- $3.5(e^+)$ x 8 GeV(e^-)

- 3016 m circumference

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

- Finite-angle cossing $\pm$ 11 mrad

- Beam-beam tuneshift 0.05

- βy^* = 1 cm

- Current
  1.1A(e^-), 2.6A(e^+)

- Number of bunches and bunch spacing
  5000 , 0.6 m

Table 1: Main Parameters of KEKB

Ring		LER	HER	
Energy	E	3.5	8.0	GeV
Circumference	C	3016.26		m
Luminosity	$\mathcal{L}$	1×10^{34}		$cm^{-2}s^{-1}$
Crossing angle	θ_x	±11		mrad
Tune shifts	ξ_x/ξ_y	0.039/0.052		
Beta function at IP	β_x^*/β_y^*	0.33/0.01		m
Beam current	I	2.6	1.1	A
Natural bunch length	σ_z	0.4		cm
Energy spread	σ_ε	7.1×10^{-4}	6.7×10^{-4}	
Bunch spacing	s_b	0.59		m
Particles/bunch	N	3.3×10^{10}	1.4×10^{10}	
Emittance	$\varepsilon_x/\varepsilon_y$	$1.8\times10^{-8}/3.6\times10^{-10}$		m
Synchrotron tune	ν_s	$0.01 \sim 0.02$		
Betatron tune	ν_x/ν_y	45.52/45.08	47.52/43.08	
Momentum compaction factor	α_p	$1\times10^{-4} \sim 2\times10^{-4}$		
Energy loss/turn	U_o	0.81†/1.5††	3.5	MeV
RF voltage	V_c	$5 \sim 10$	$10 \sim 20$	MV
RF frequency	f_{RF}	508.887		MHz
Harmonic number	h	5120		
Longitudinal damping time	τ_ε	43†/23††	23	ms
Total beam power	P_b	2.7†/4.5††	4.0	MW
Radiation power	P_{SR}	2.1†/4.0††	3.8	MW
HOM power	P_{HOM}	0.57	0.15	MW
Bending radius	ρ	16.3	104.5	m
Length of bending magnet	ℓ_B	0.915	5.86	m

†: without wigglers, ††: with wigglers

Tentative New Baseline of Commissioning Schedule

1. Mid May-June 1998
   Commissioning of full upgraded linac

2. July-Mid September 1998
   Shutdown

3. October 1998
   Commissioning of full KEKB accelerator system

Commissioning strategy with Belle detector are being discussed.

Tentative Milestones

- April 1994	Project approval and start of construction
- July 1995	Bidding for LER main equipment
- Dec. 1995	Start of dismantling of TRISTAN
- May 1996	Bidding for HER main equipment and QCS
- July 1996 - Oct. 1996 - Nov. 1996	Beam test at AR
- Dec. 1996	Start of bypass tunnel construction
- Jan. 1997	Start of installation of magnets in the tunnel

- Oct. 1997	Completion of new bypass tunnel
- May-June 1998	Commissioning of full upgraded linac and transport lines
- Oct. 1998	Commissioning of full KEKB accelerator
- Early 1999	Start of physics experiment

Lattice Design

- Non-interleaved sextupole chromaticity correction

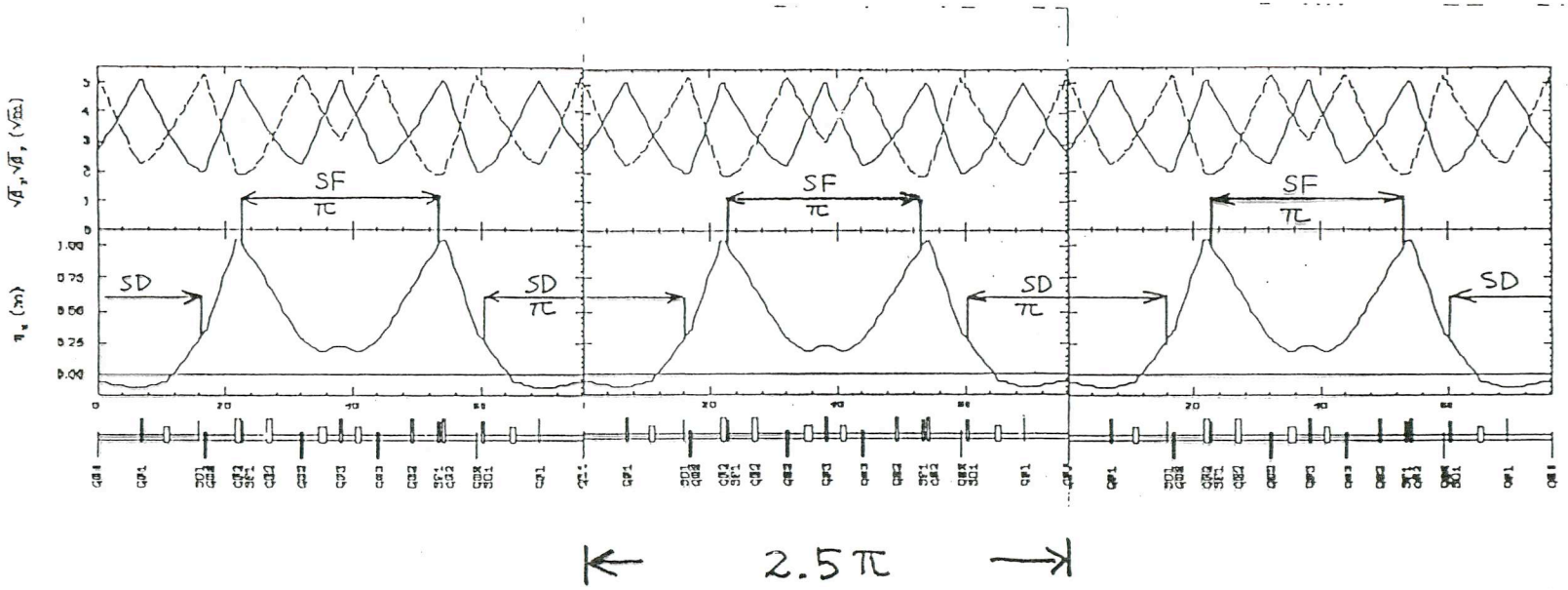
- 2.5 π/cell phase advance

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

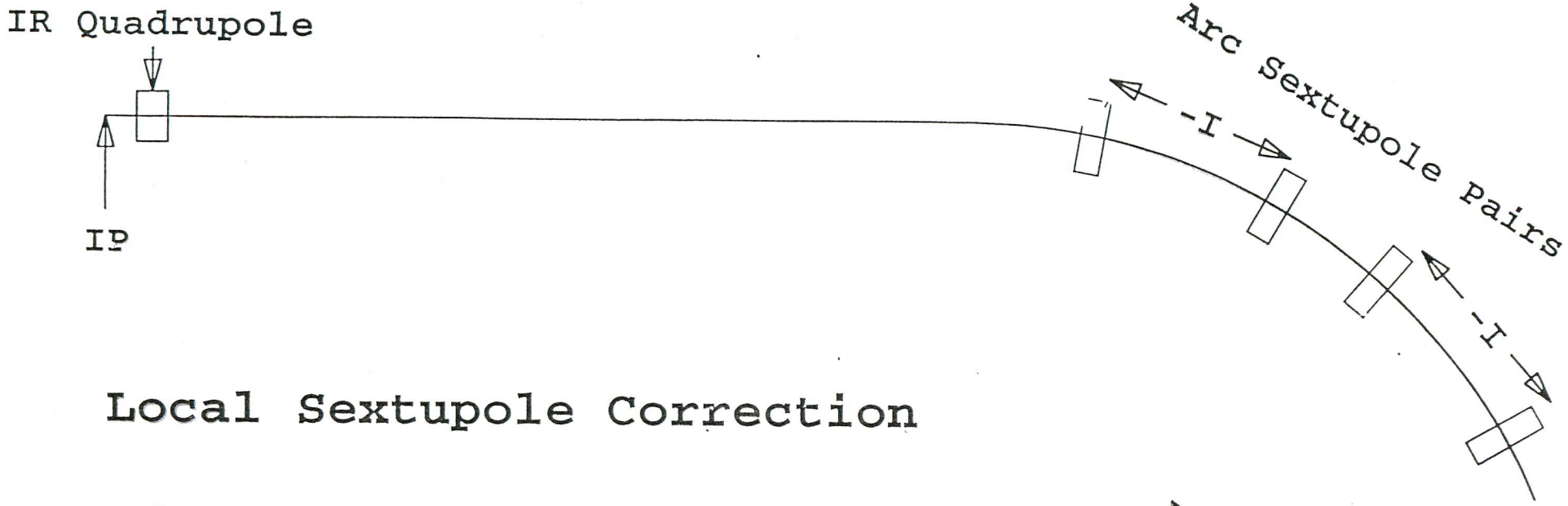
- Variable ε_x 10 $\sim$ 40 nm

- Local chromaticity correction in LER

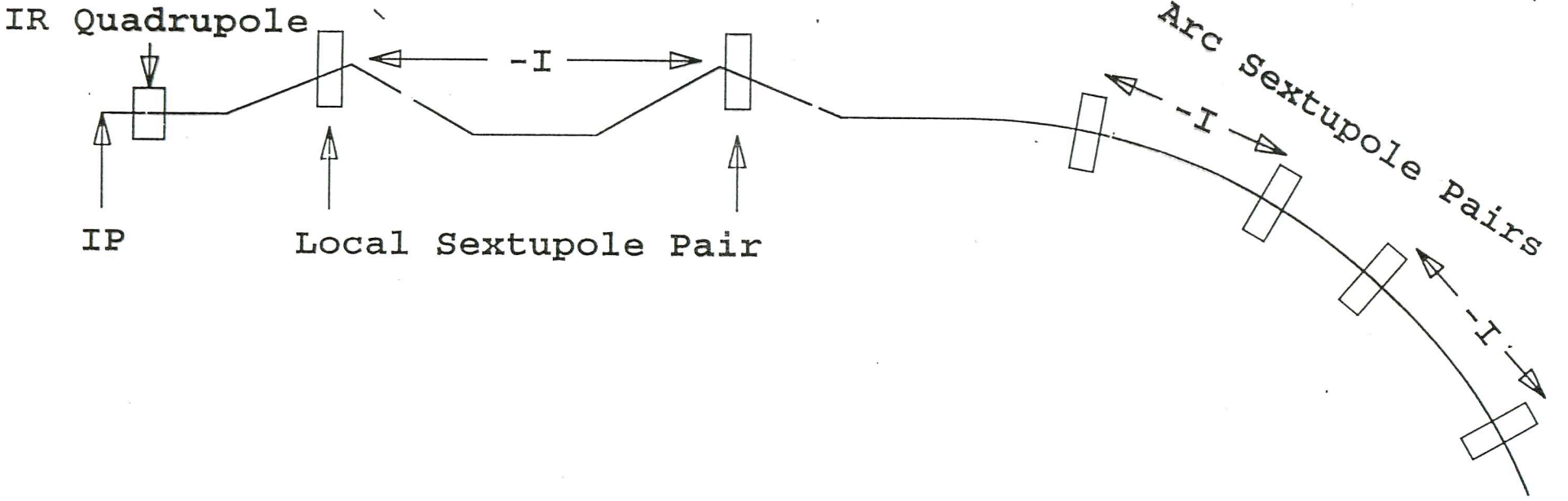
2.5π cell, LER

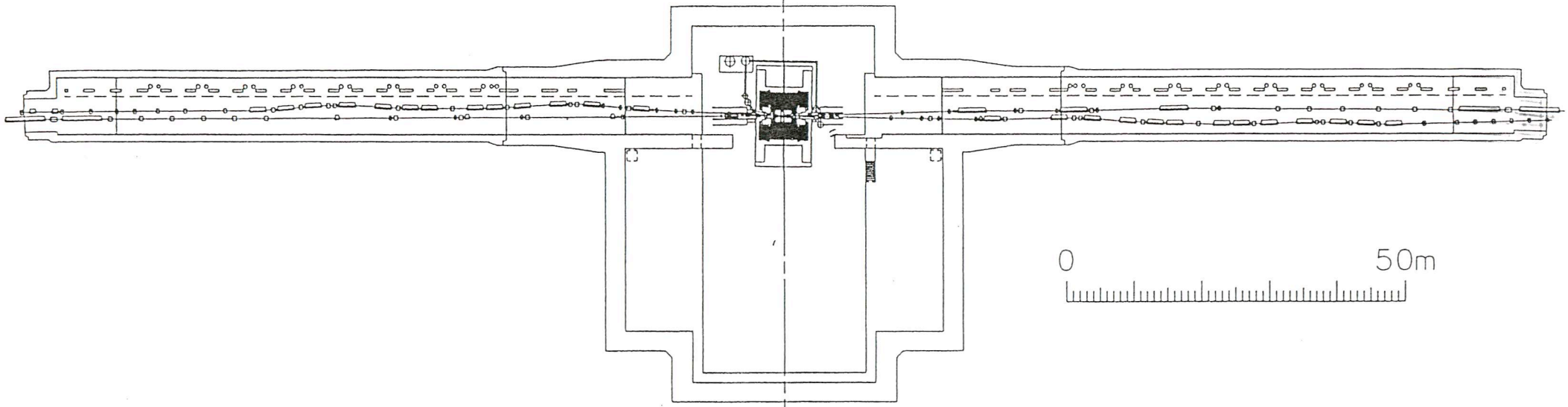


Non-local Sextupole Correction



Local Sextupole Correction





Tsukuba

Cavities

1. ARES

-Two types of ARES were tested at AR up to 500 mA.

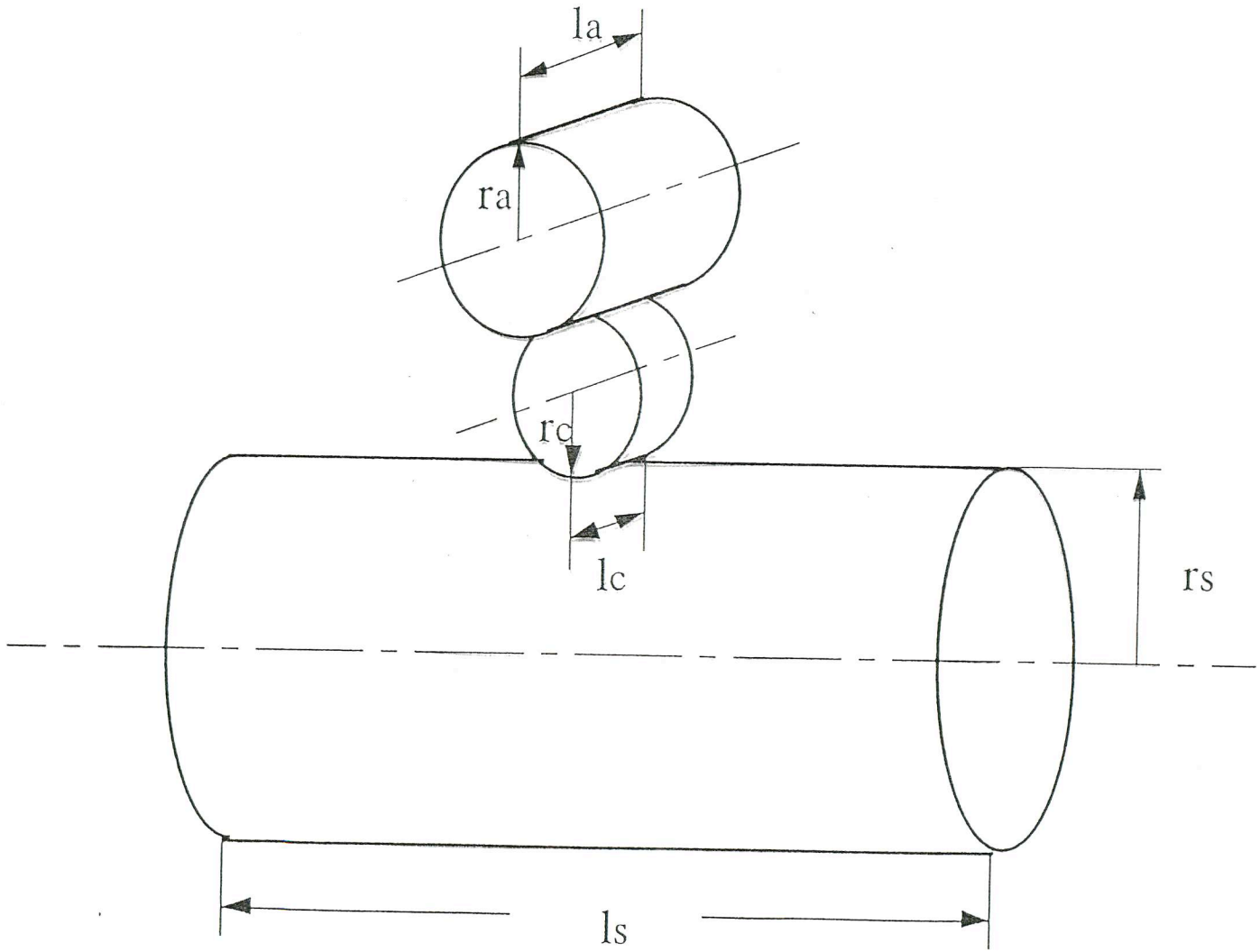
- Mass production will start from JFY1997.

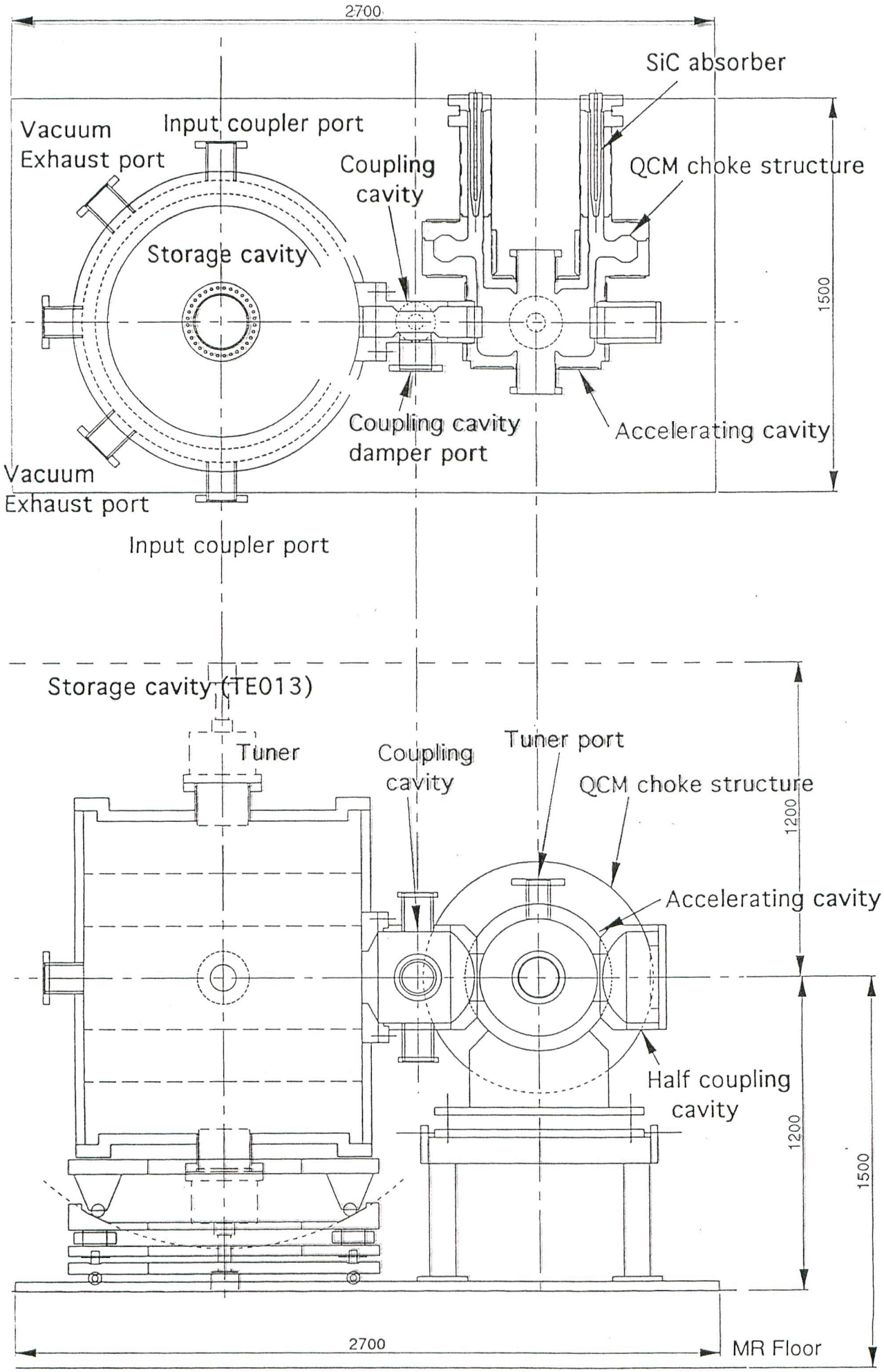
2. SCC

-First1prototype was installed in AR and beam-tested up to 570 mA.

3. Installation(by 1998 end)

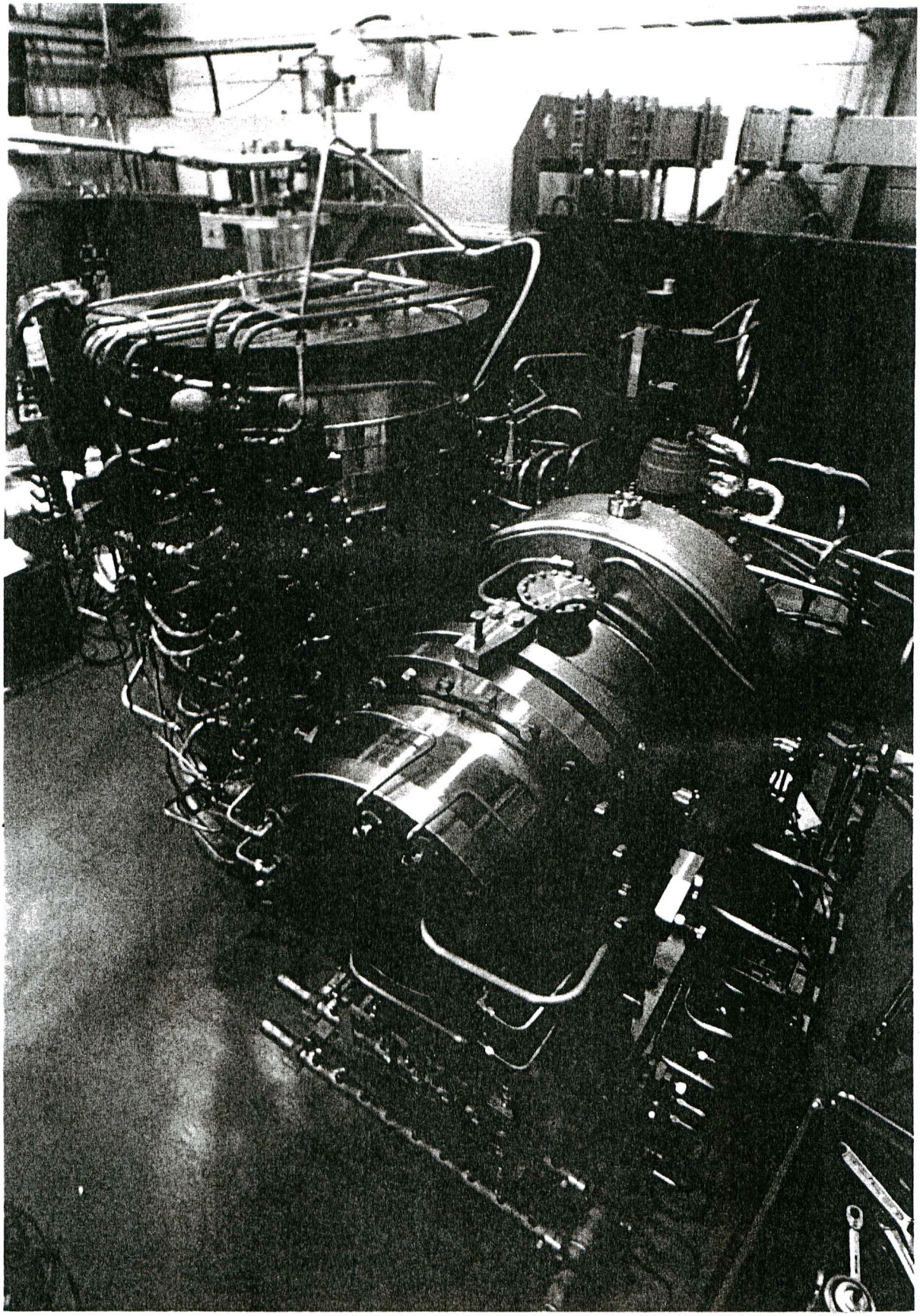
- LER: 10 ARES (at Fuji)
- HER: 5 SCC (at Nikko)
  16 ARES (at Oho)

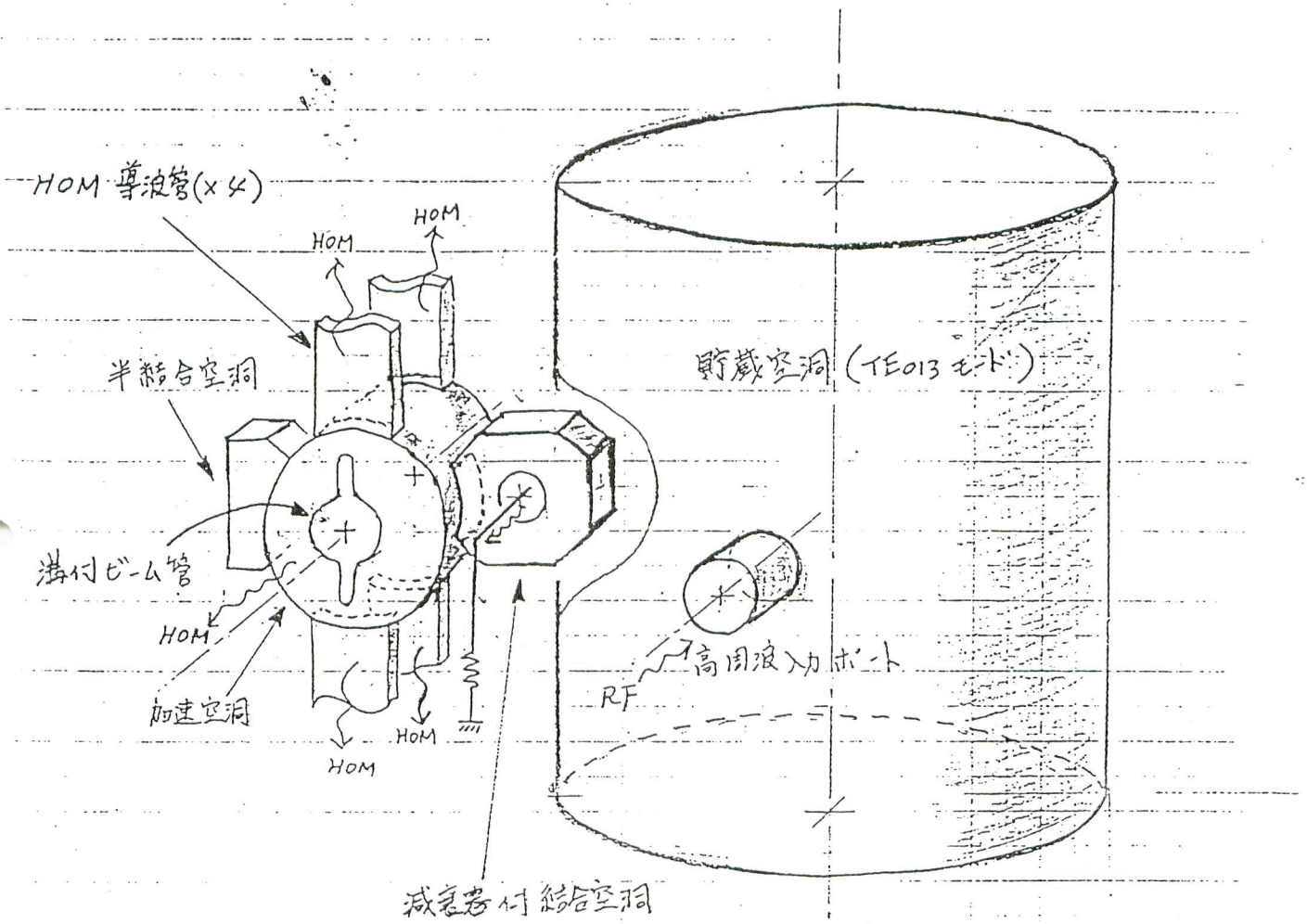

la
ra
rc
lc
rs
ls



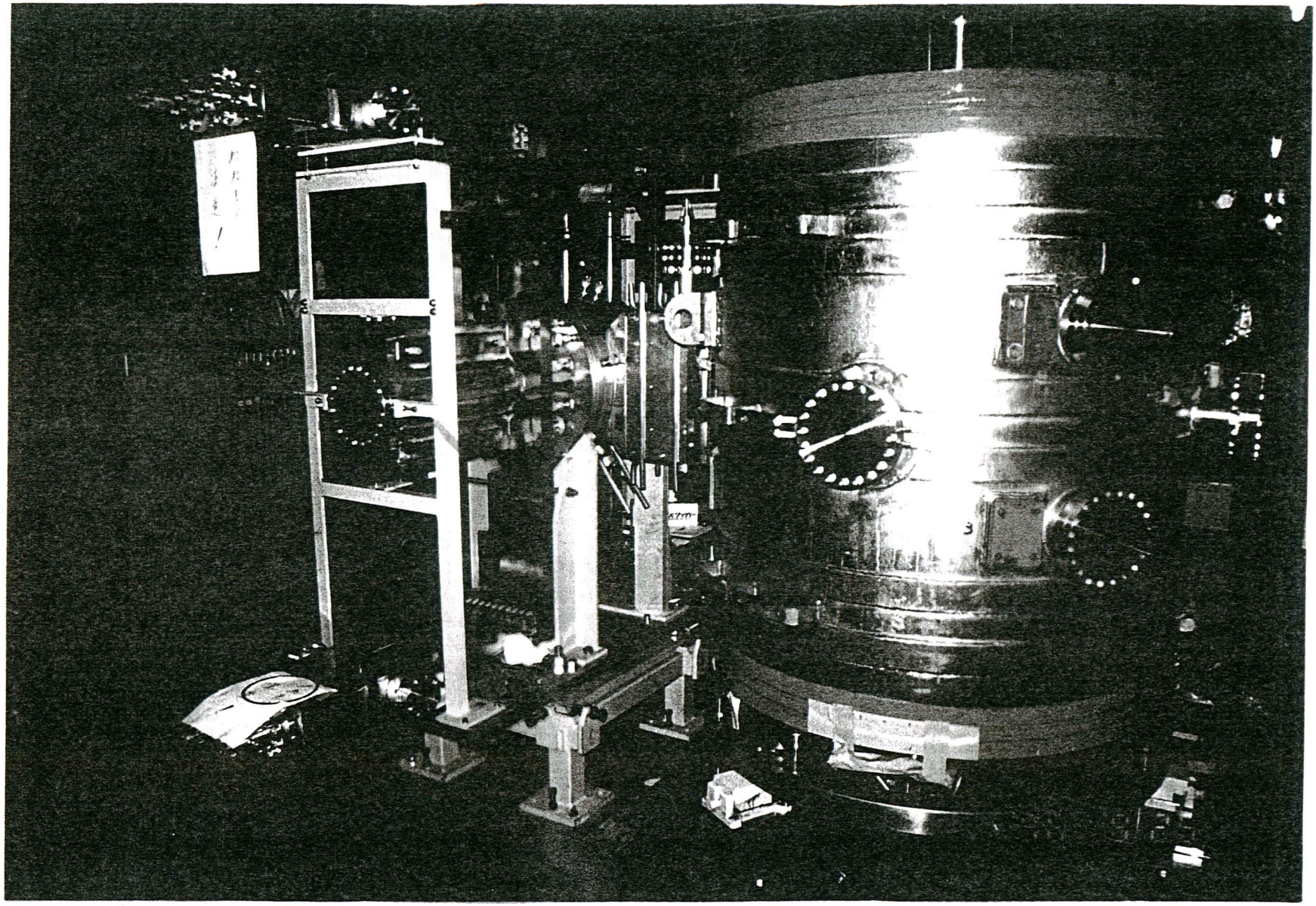
ARES (TE013)

ARES空洞 架台構造
[illegible] 1995年5月22日

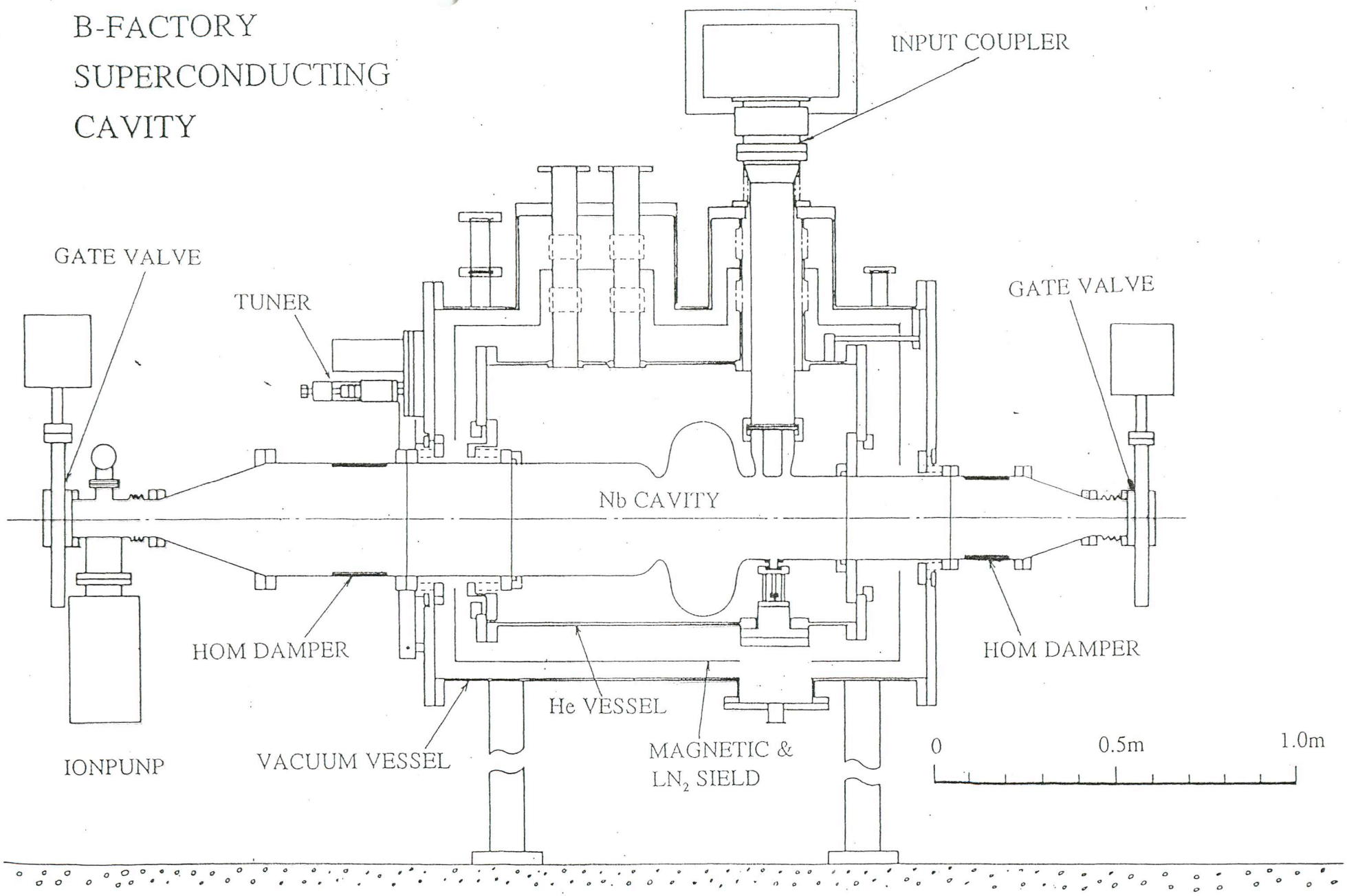


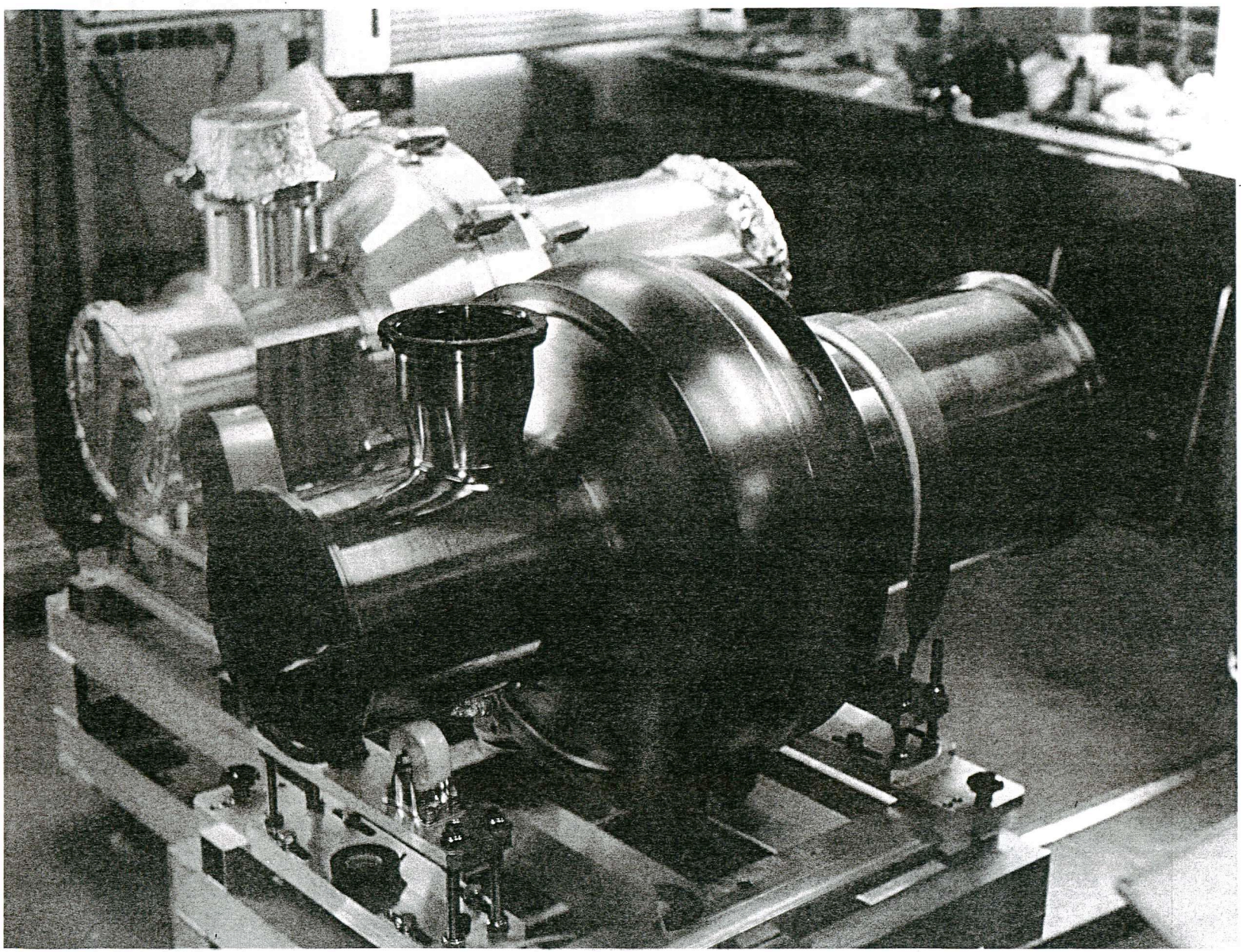

HOM 導波管(×4)
HOM
HOM
半結合空洞
貯蔵空洞 (TE013 モード)
溝付ビーム管
HOM
加速空洞
HOM
HOM
RF
高周波入力ポート
減衰器付結合空洞

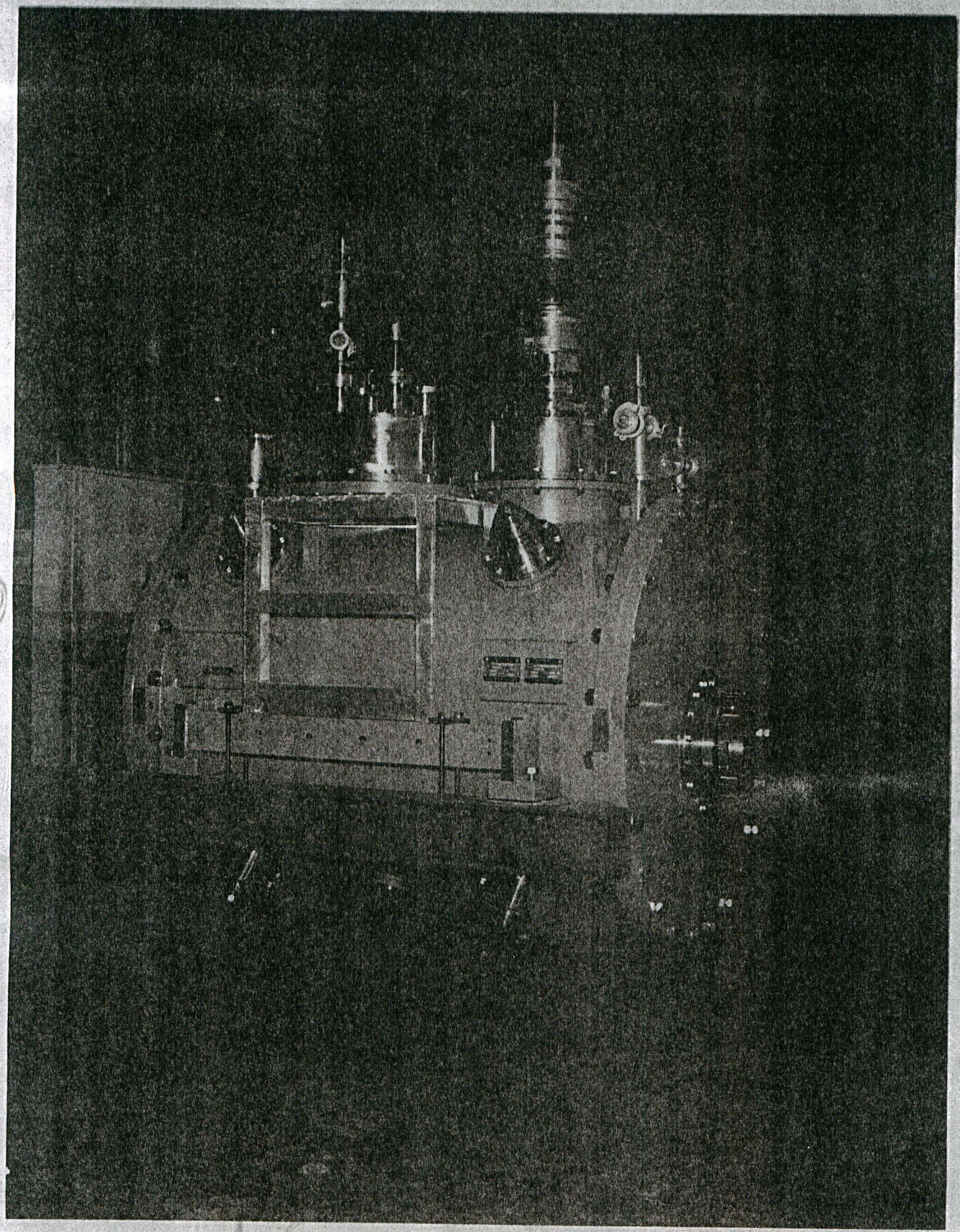
96試 ARES 空洞

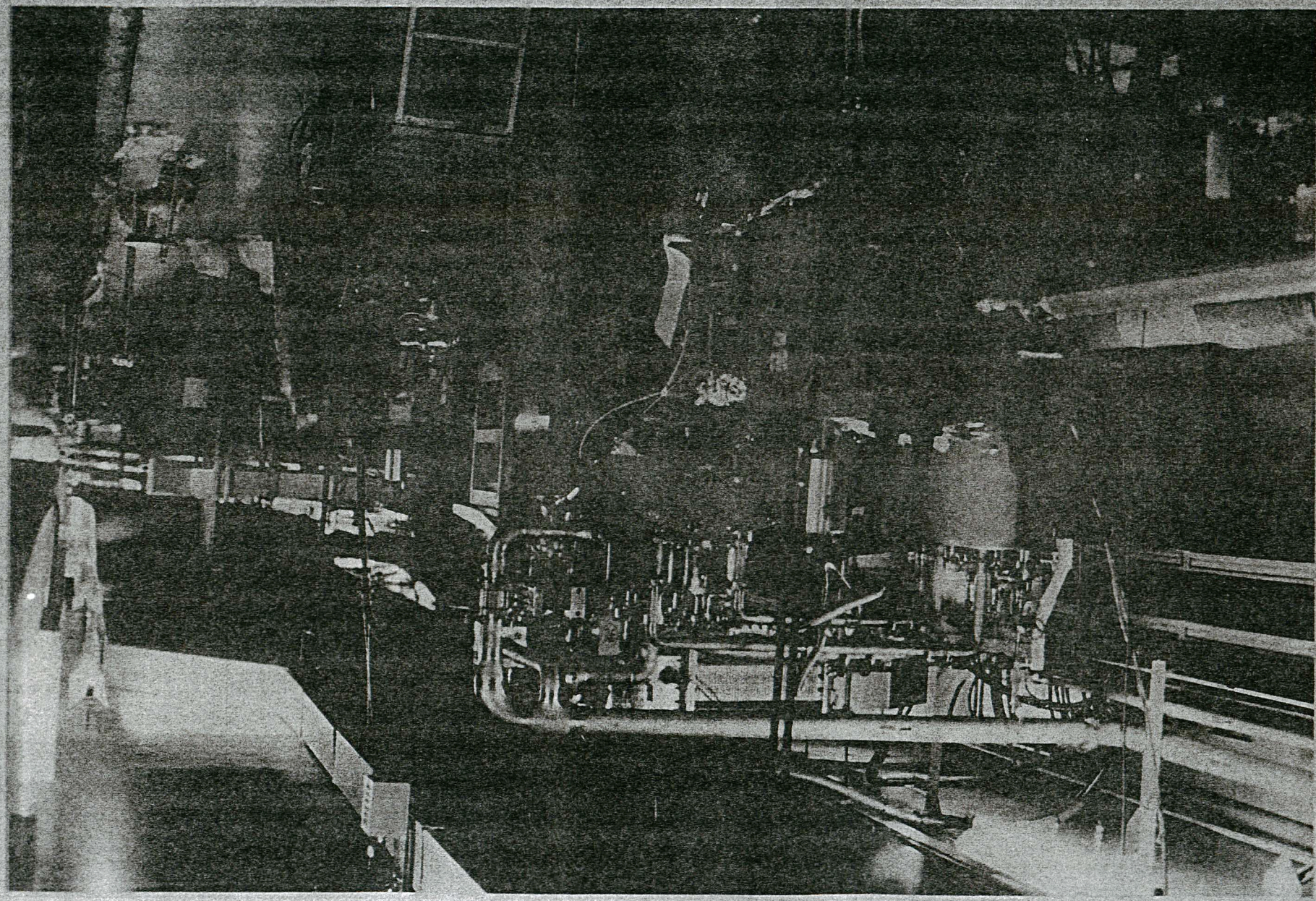


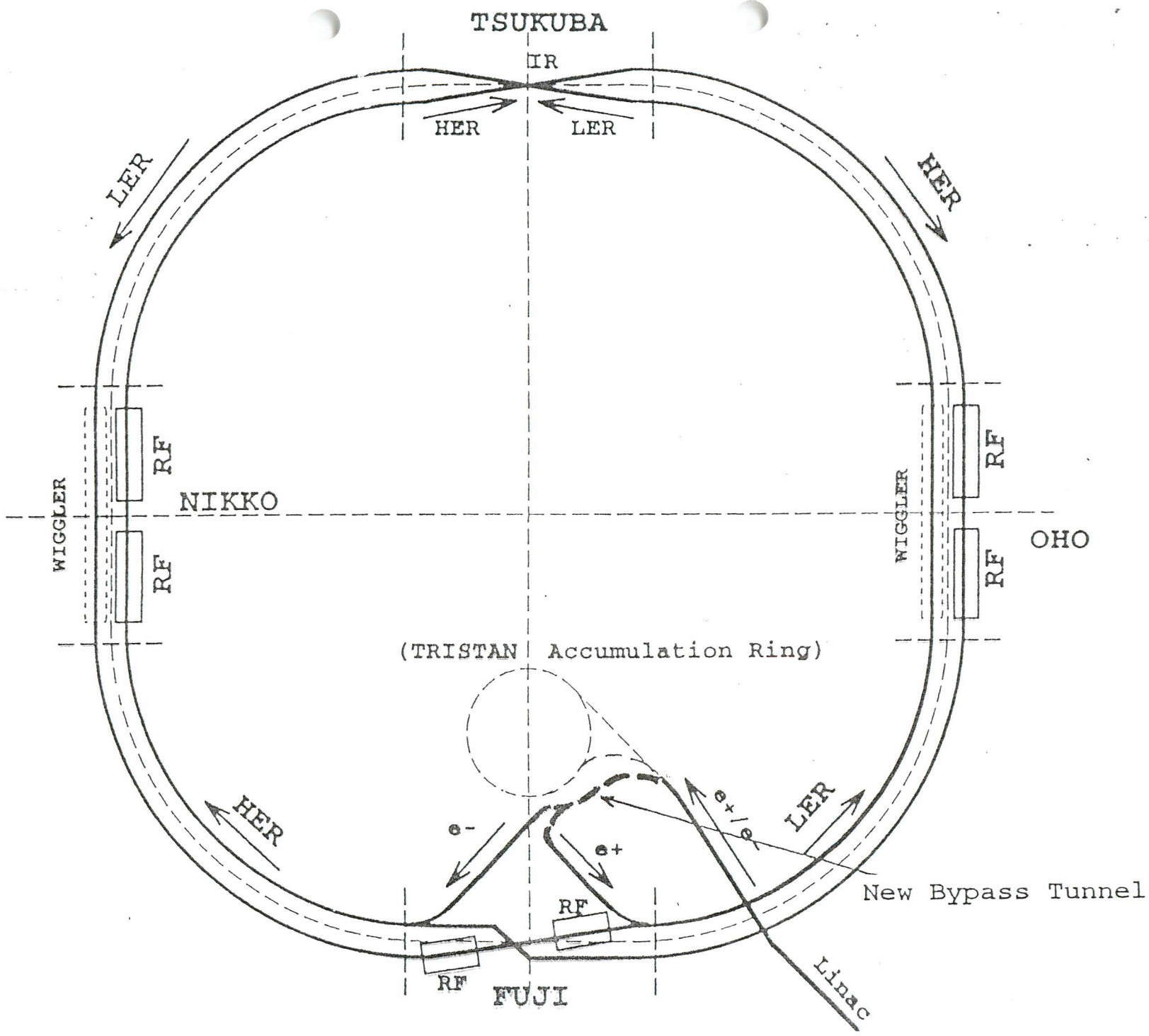
B-FACTORY SUPERCONDUCTING CAVITY










TSUKUBA
IR
HER
LER
LER
HER
RF
RF
WIGGLER
NIKKO
RF
RF
WIGGLER
OHO
(TRISTAN Accumulation Ring)
HER
e-
e+
e+/e-
LER
New Bypass Tunnel
RF
RF
FUJI
Linac

Interaction Region

- Our choice is a finite-angle crossing of ± 11 mrad.

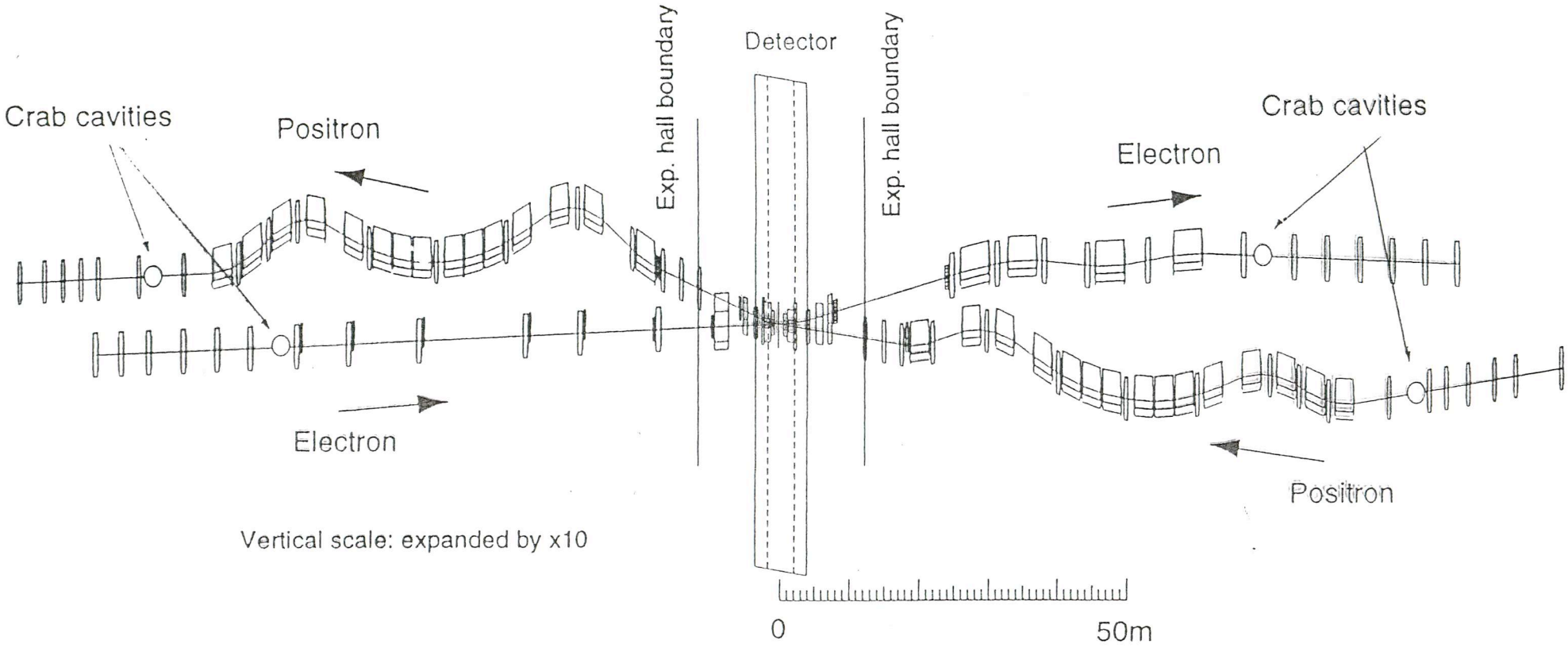
- Simulation study has shown no substantial increase of tails at our opearting point.

- We should be prudent prepare for a crab-crossing scheme.

- Crab cavities will be ready by one year after the firstcollision.

- Superconducting quads have been ordered; system test with BELLE solenoid will be in autumn of 1997.

- R&D of QC1EL is in progress.

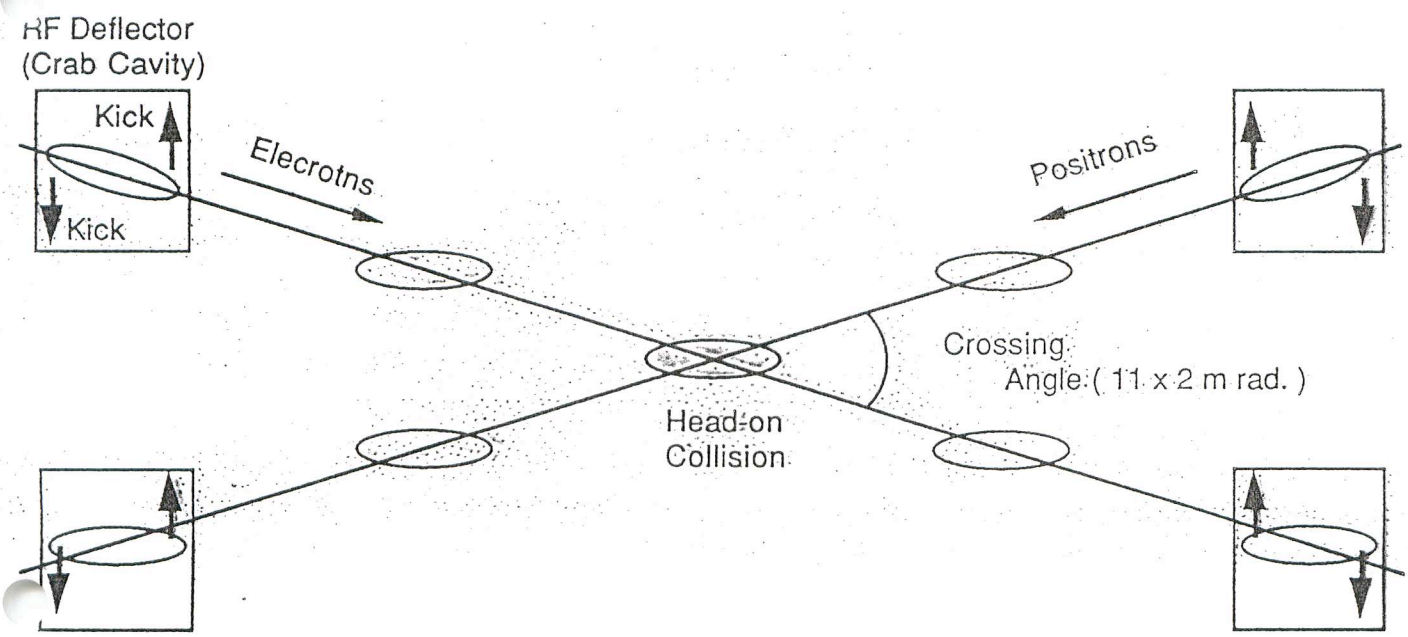

Crab cavities
Positron
Exp. hall boundary
Detector
Exp. hall boundary
Electron
Crab cavities
Electron
Positron
Vertical scale: expanded by x10
0
50m

Why crab crossing ?

The crab crossing scheme allows a large crossing angle collision without introducing any synchrotron-betatron coupling resonances. 2,3)

2) R. B. Palmer, SLAC-PUB-4707, 1988.
3) K. Oide and K. Yokoya, SLAC-PUB-4832, 1989.

Crab crossing scheme

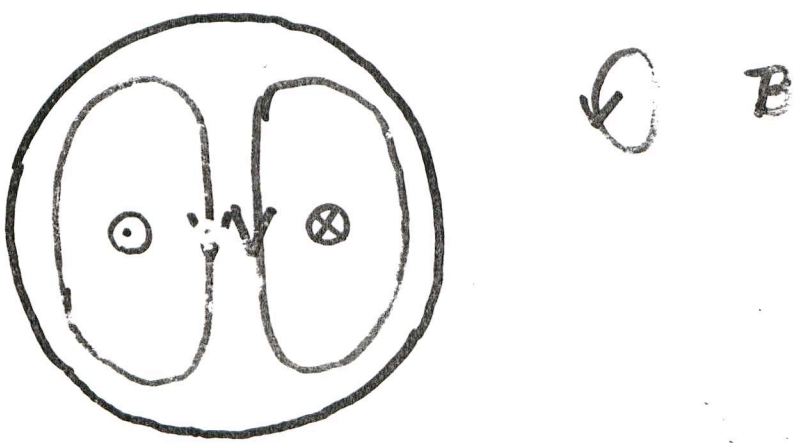


Why superconducting cavity ?

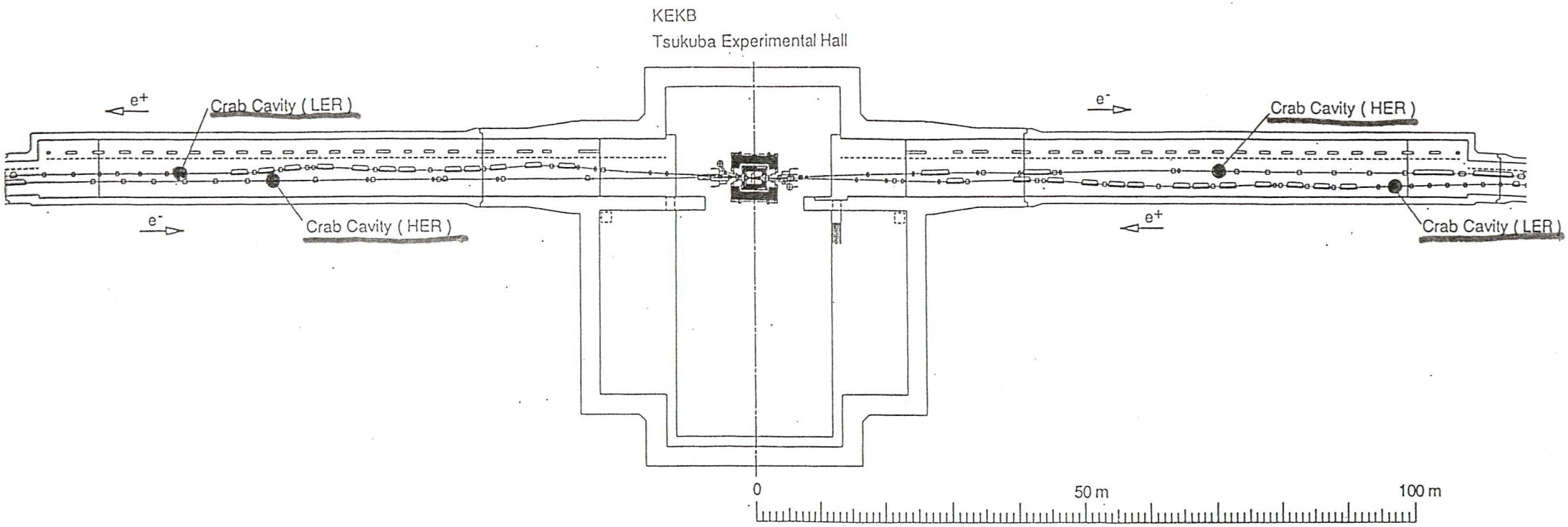
	LER	HER	
Beam Energy	3.5	8.0	GeV
RF Frequency	508.887		MHz
Crossing Angle	±11		mrad
βx	0.33	0.33	m
βcrab	20	100	m
Required kick	1.41	1.44	MV

Crab Cavity

- Crab Mode = TM110



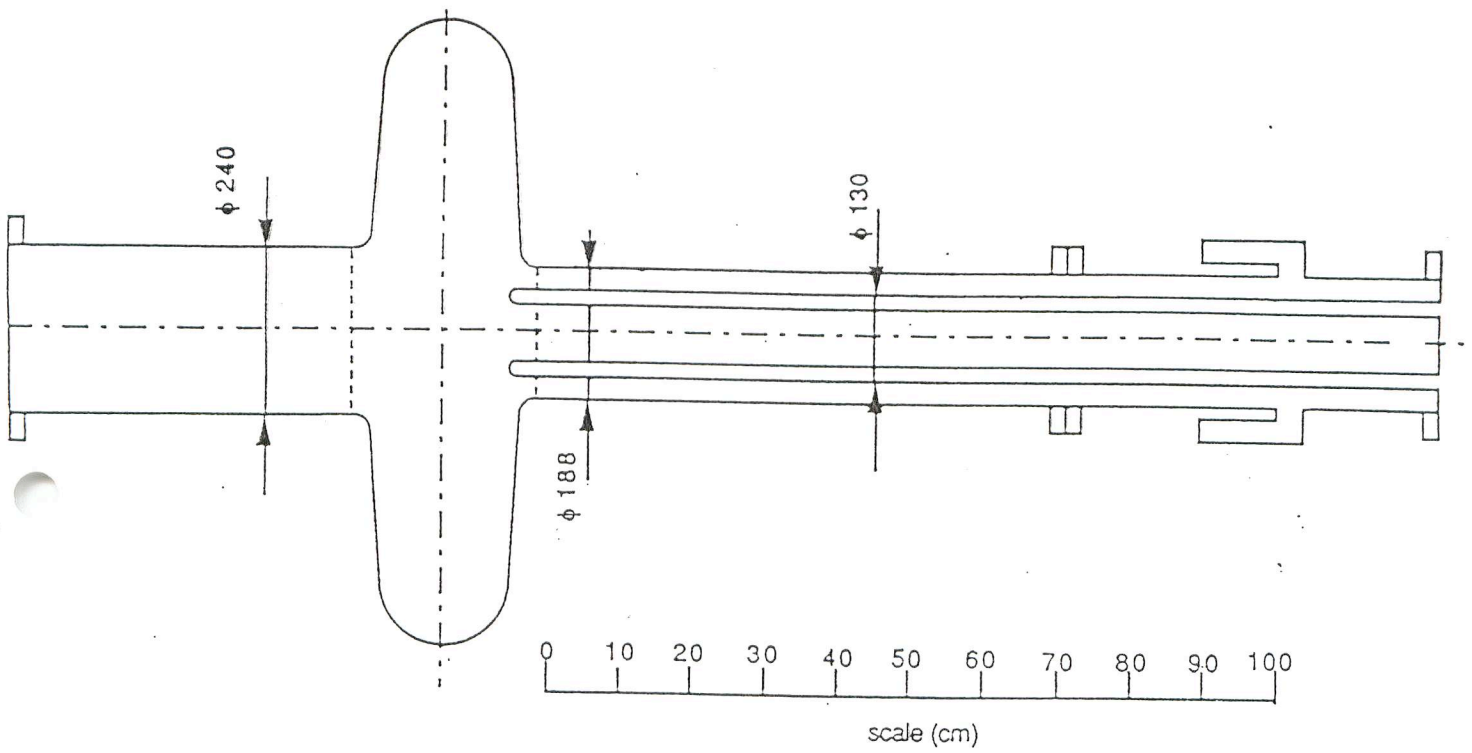
- Not only HOMs but also fundumental mode should be damped.

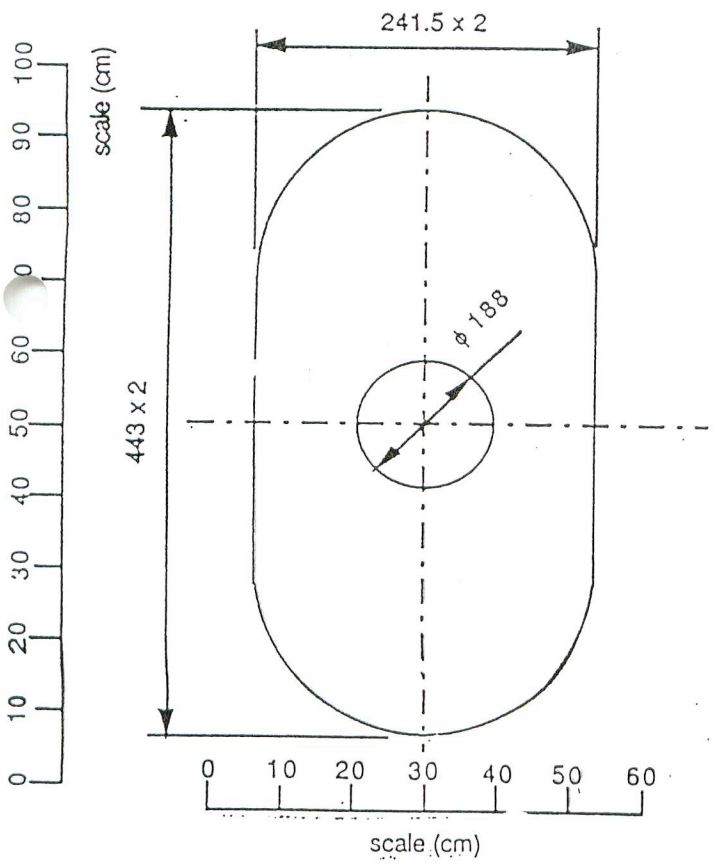

KEKB
Tsukuba Experimental Hall
e+
Crab Cavity (LER)
e-
Crab Cavity (HER)
e-
Crab Cavity (HER)
e+
Crab Cavity (LER)
0
50 m
100 m

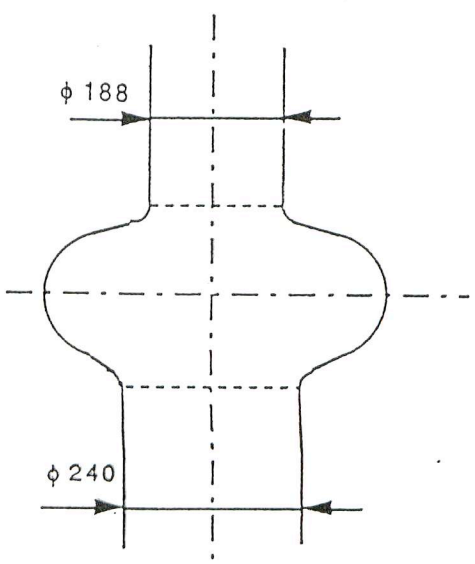
Crab Cavity Group

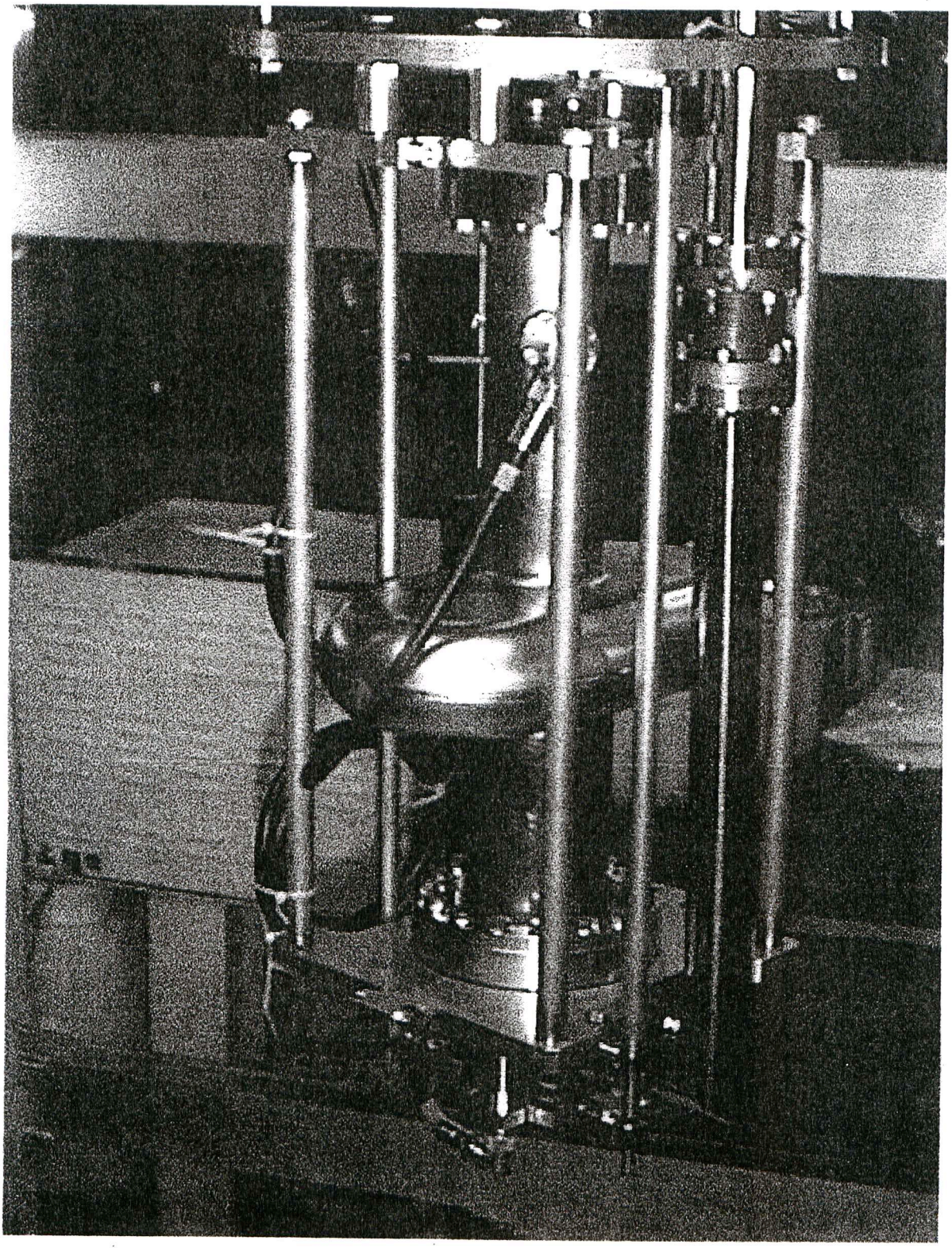
KEK-B Crab Cavity

Mar.24, 1995
K. Hosoyama
(revised from Mar. 16)

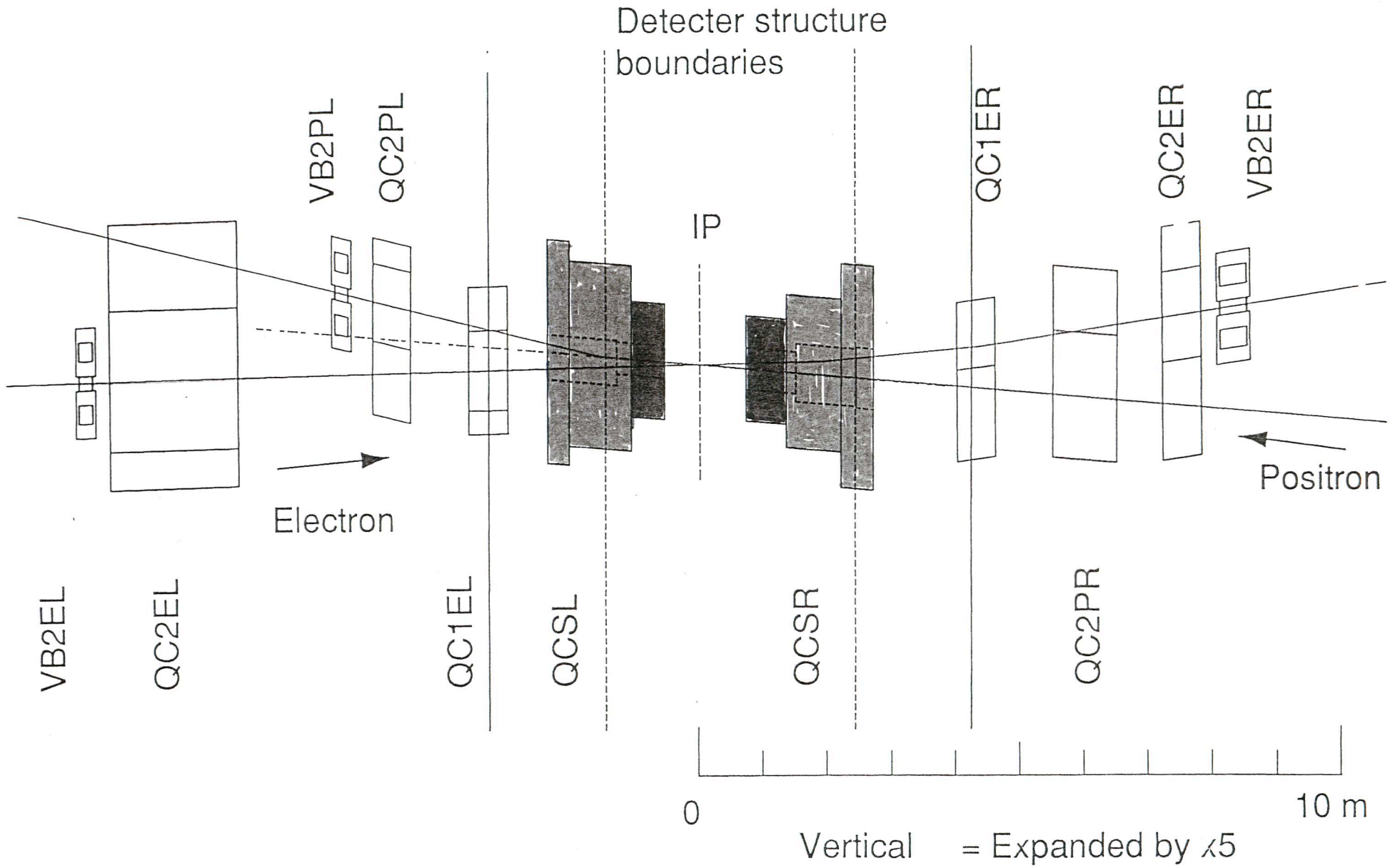


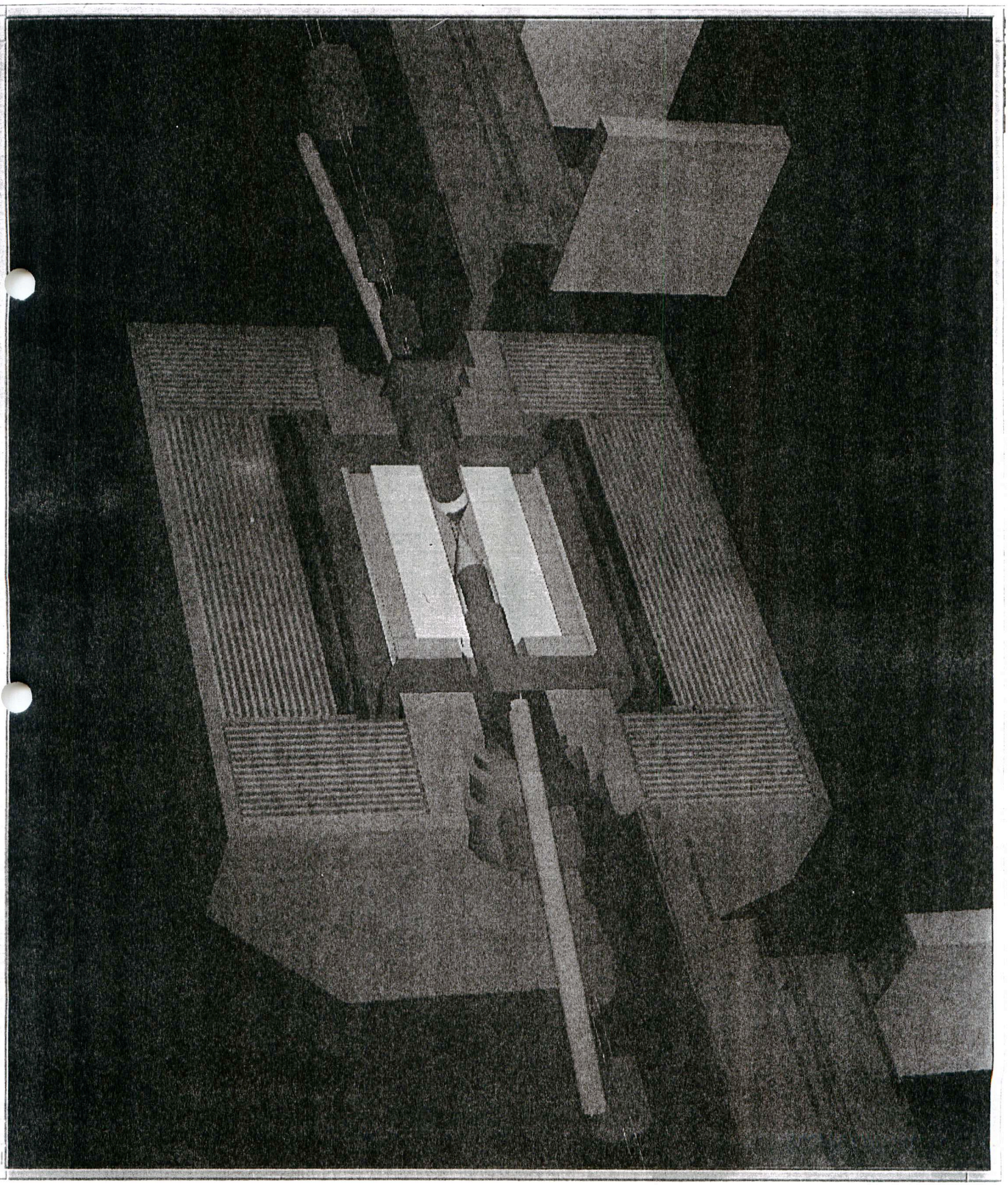


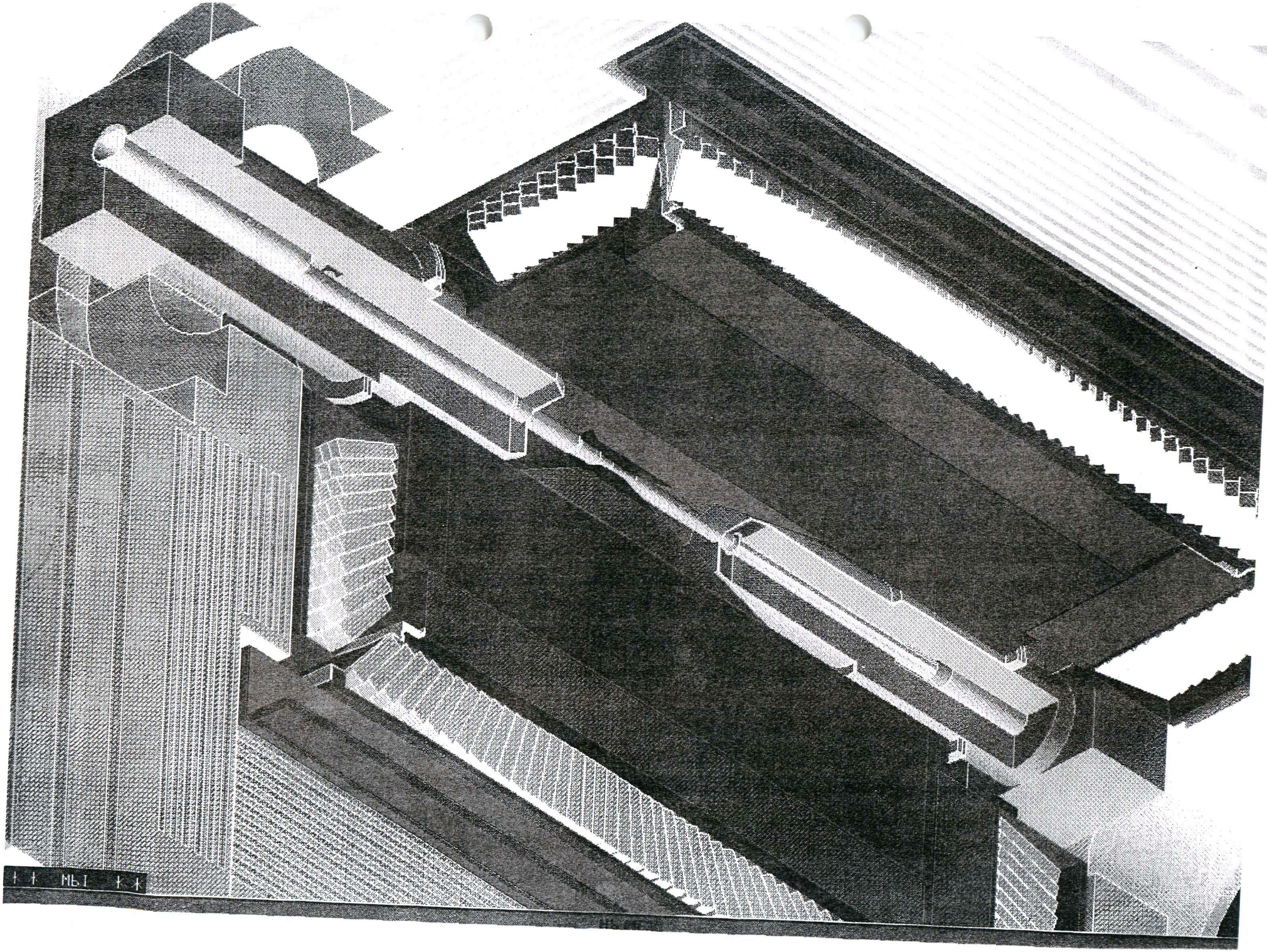


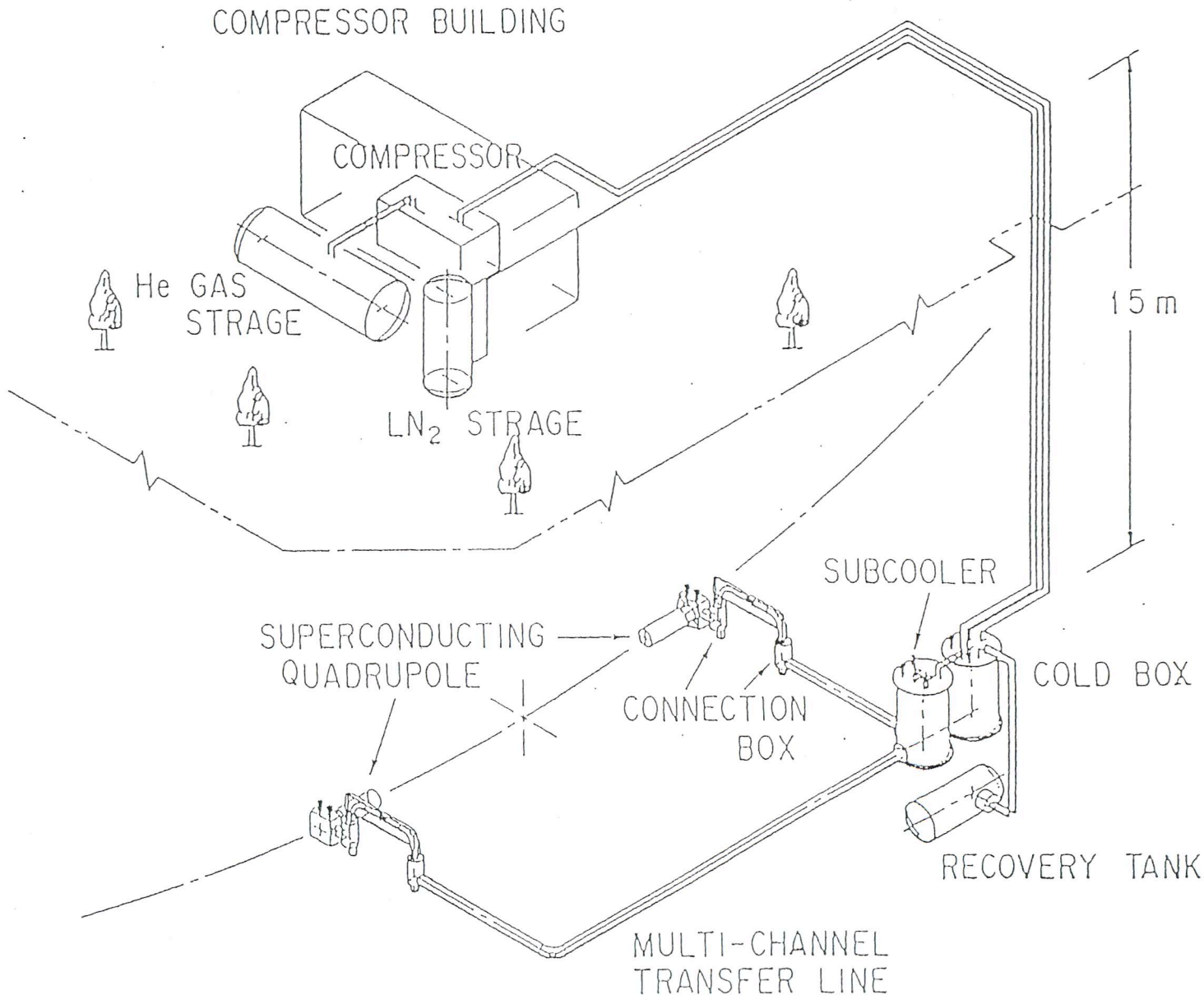


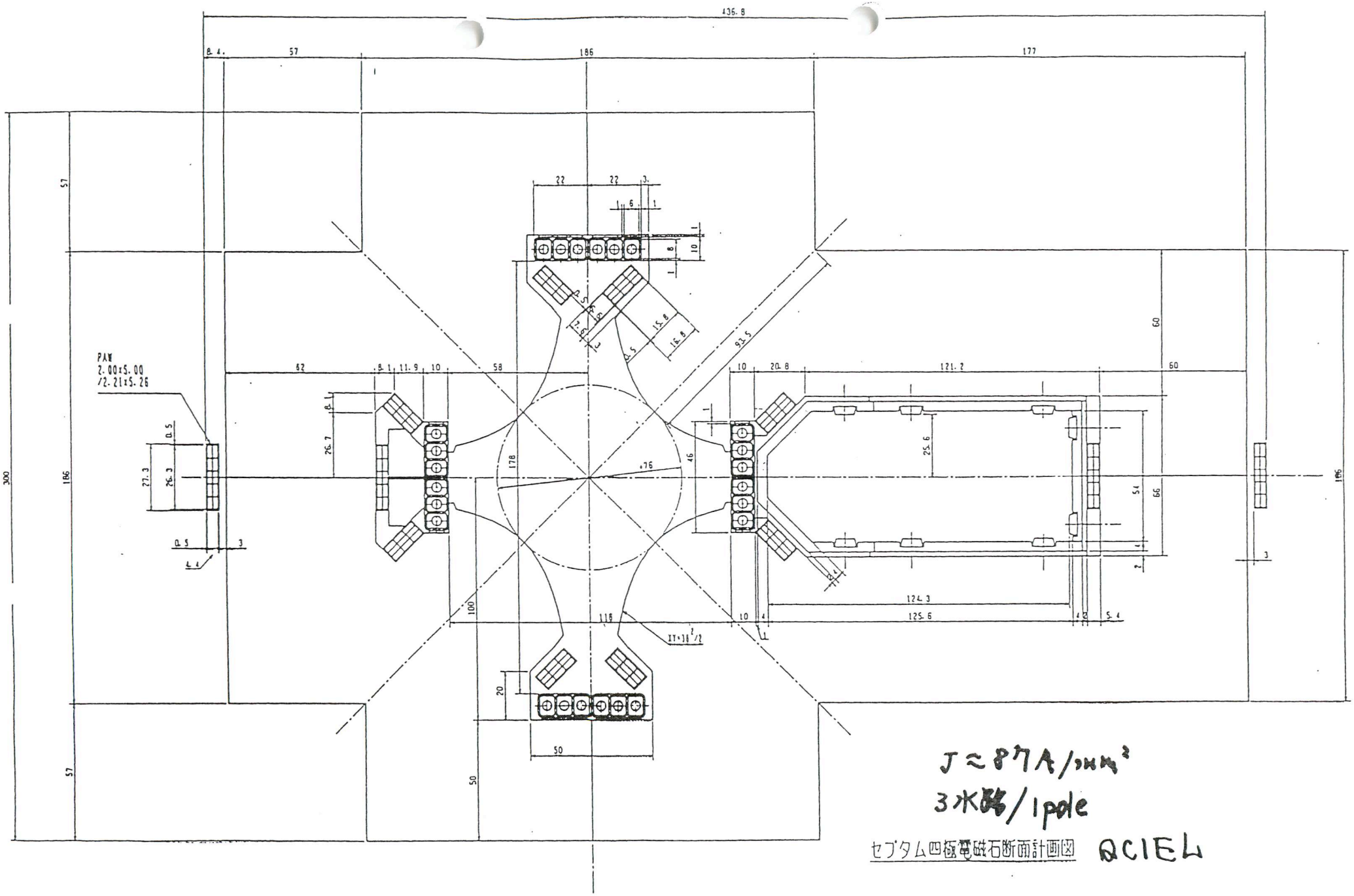
1/3 Scale Nb Crab Cavity (1.5 GHz)


Detecter structure
boundaries
VB2PL
QC2PL
IP
QC1ER
QC2ER
VB2ER
Positron
Electron
VB2EL
QC2EL
QC1EL
QCSL
QCSR
QC2PR
0
10 m
Vertical = Expanded by x5






COMPRESSOR BUILDING
COMPRESSOR
He GAS
STRAGE
LN2 STRAGE
15 m
SUBCOOLER
SUPERCONDUCTING
QUADRUPOLE
CONNECTION
BOX
COLD BOX
RECOVERY TANK
MULTI-CHANNEL
TRANSFER LINE



J≃87A/mm²

3水路/1pole

セプタム四極電磁石断面計画図 QCIEL

Photoelectron Instability (PEI) and Fast-Ion Instability (FII)

PEI:

(1) PEI is a serious concern for LER.

(2) PEI was first observed at KEK PF and needs to be experimentally confirmed.

(3) Experiments were done at BEPC by IHEP-KEK collaboration in June and December 1996.

(4) PEI was observed at BEPC. Phenomenon was very similar to that observed at PF.

FII

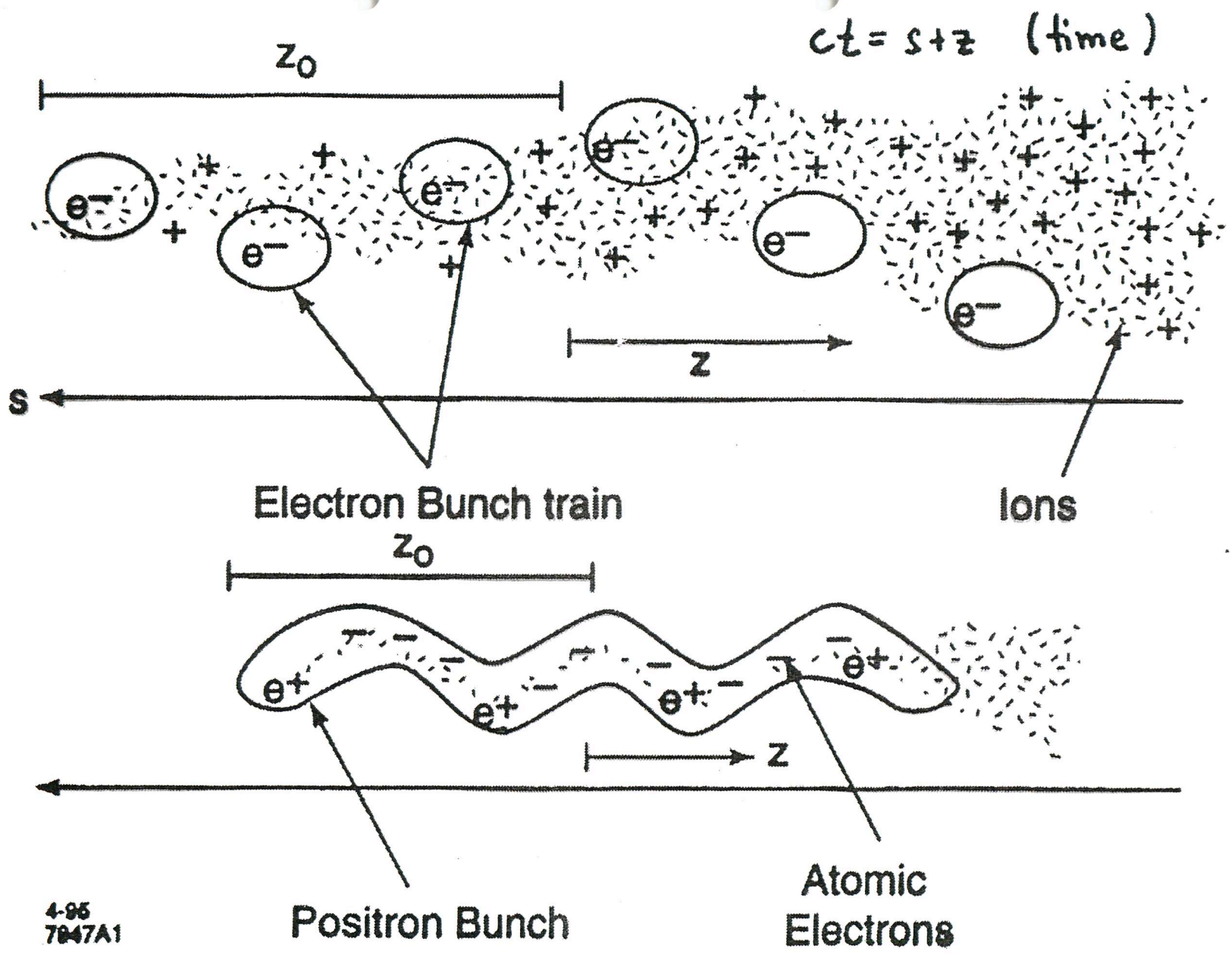
(1) FII is a large concern for HER.

(2) Only two experiments so far: one at LBL and the other at KEK AR.

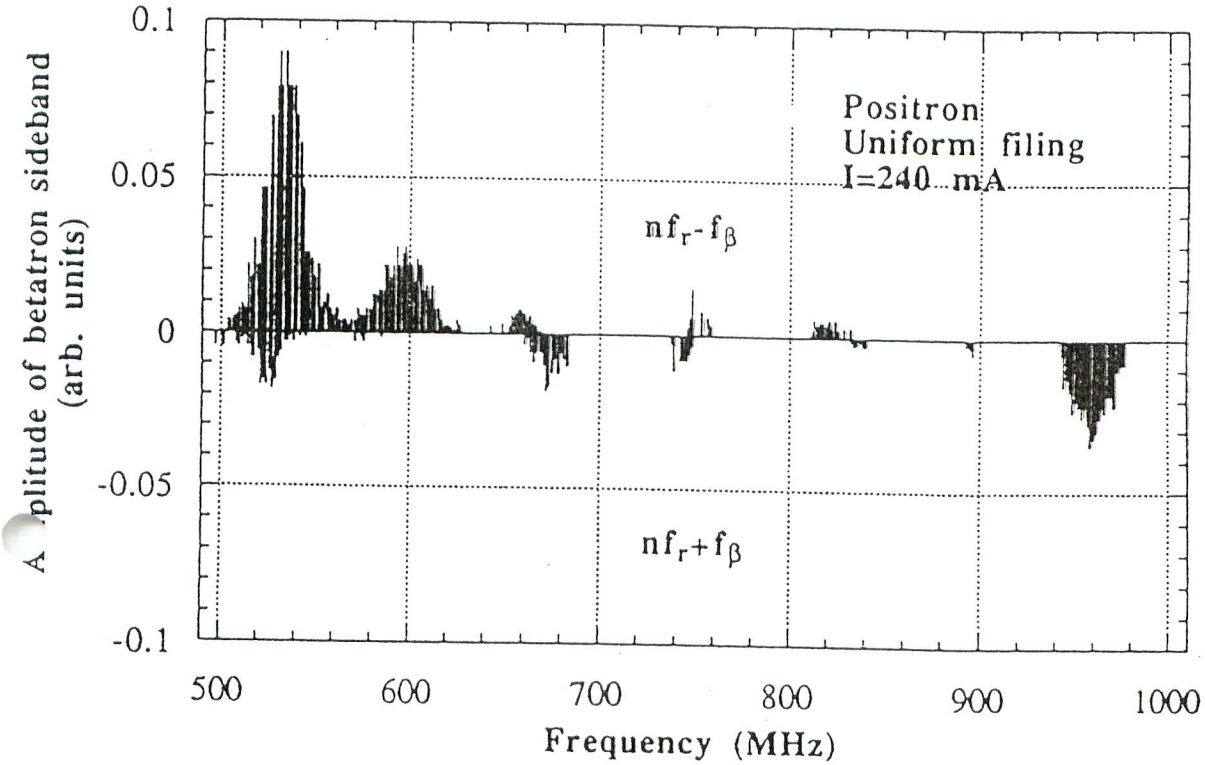
(3) These experiments observed increasing transverse oscillation amplitude along a bunch train.

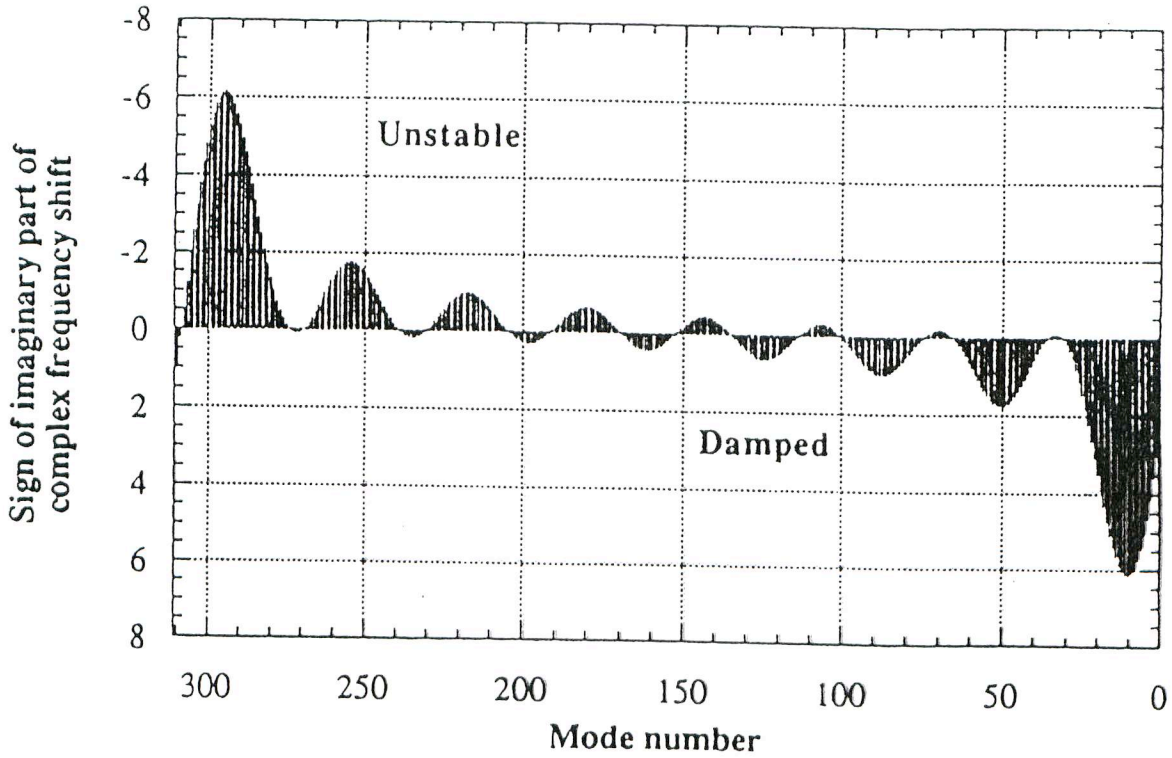
(4) Further test is planned at POSTECH jointly by PAL and KEK.

International workshop at KEK on July 8-11, 1997.


ct = s + z (time)
z_0
e⁻
z
s
Electron Bunch train
Ions
z_0
e+
z
Positron Bunch
Atomic
Electrons
4-96
7847A1

PF


Amplitude of betatron sideband (arb. units)
0.1
0.05
0
-0.05
-0.1
Positron
Uniform filing
I=240 mA
$nf_r - f_\beta$
$nf_r + f_\beta$
500
600
700
800
900
1000
Frequency (MHz)


Sign of imaginary part of complex frequency shift
-8
-6
-4
-2
0
2
4
6
8
Unstable
Damped
300
250
200
150
100
50
0
Mode number

BEPC

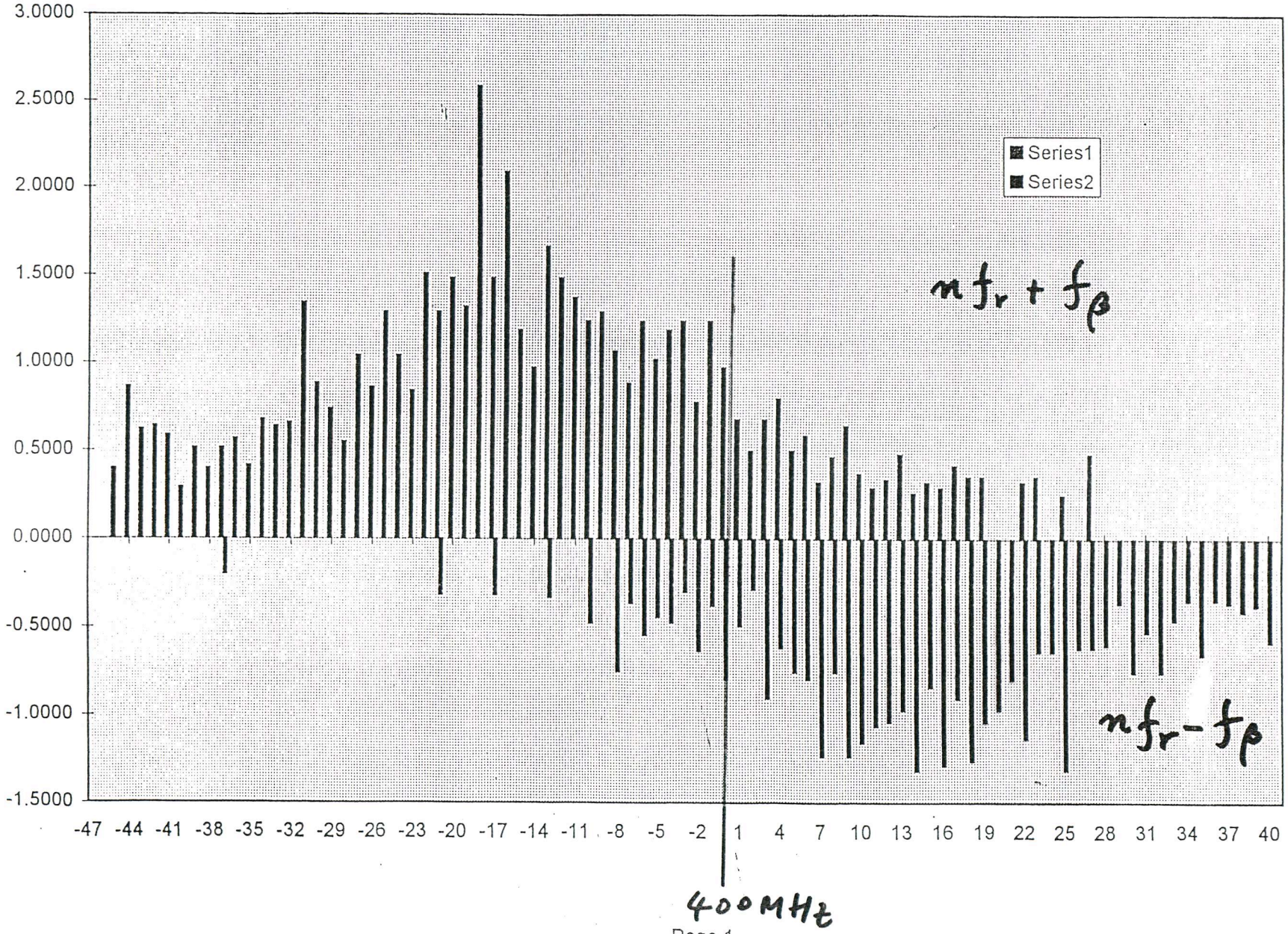


Chart2
3.0000
2.5000
2.0000
1.5000
1.0000
0.5000
0.0000
-0.5000
-1.0000
-1.5000
-47 -44 -41 -38 -35 -32 -29 -26 -23 -20 -17 -14 -11 -8 -5 -2 1 4 7 10 13 16 19 22 25 28 31 34 37 40
Series1
Series2
$nf_r + f_\beta$
$nf_r - f_\beta$
400MHz

Machine Studies at AR

- July, October and Novemeber 1996.

- Multi-bunch, high-current (500 mA) beam in AR at 2.5 GeV.

- Replace all APS cavities with cavities for KEKB (one ARES-A, two full ARESs, and one SCC).

- These cavities were beam-tested successfully.

- Prototype bunch-by-bunch feedback system was tested and worked.

- FII was observed !?

Results of Beam Test in TRISTAN AR
(July, October, November)

(1) Superconducting Cavity

Beam current	570 mA(1.1 A)
Accelerating voltage	2.5 MV(1.5 MV)
HOM power	4.2 kW(5 kW)
Beam power	168 kW(400 kW)

(2)Normal-conducting Cavity

Two types of ARES were successfully operated with 500 mA

(3)Feedback System

500 MHz bunch-by-bunch beam feedback system worked well both for transverse and longitudinal directions

(4)Instability

Fast-ion instablity was observed

Summary

- Construction is going smoothly.

- Big progress on cavities and feedback system on the basis of AR beam study.

- Equipment is now being delivered to KEK and about to be installed in the tunnel.

- Milestones for commissioning have been established.

- Collaboration on PEI experiment is productive.

- Collaborations with IHEP and BINP on steering magnets fabrication.