Interaction Region

1) IR Overview (K. Tsuchiya)

2) Superconducting Magnets (K. Tsuchiya)

3) Special Quadrupole Magnets (M. Tawada)

for the KEKB Accelerator Review
Mar. 8-10,1999

IR Design

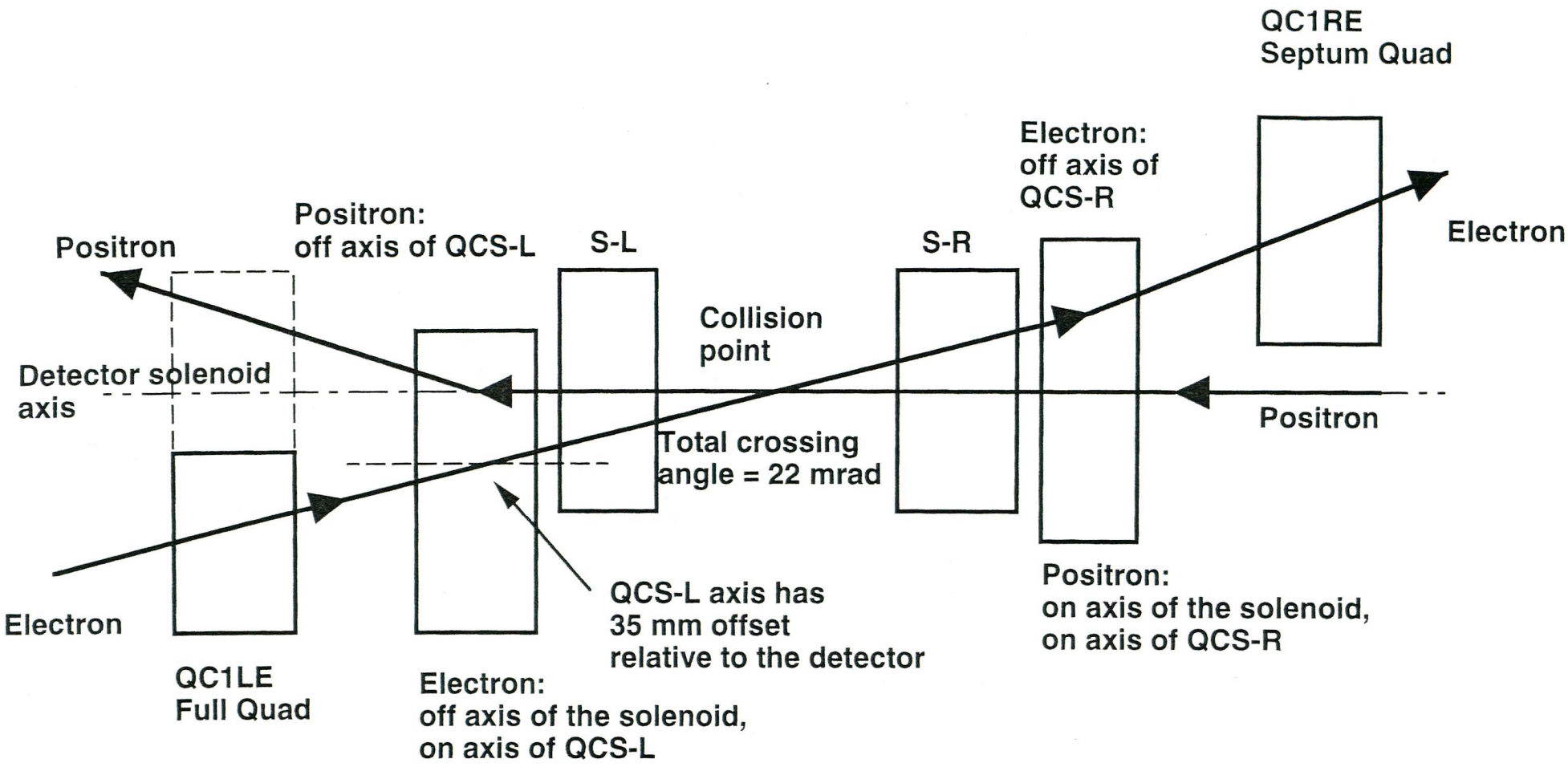
	LER	HER
Energy (GeV)	3.5	8.0
Current (A)	2.6	1.1

Crossing Angle (mrad)	2 x 11
Luminosity ($cm^{-2}s^{-1}$)	1×10^{34}
Bunch length (mm)	4
Bunch spacing (m)	0.59
β_x^* (m)	0.33
β_y^* (m)	0.01

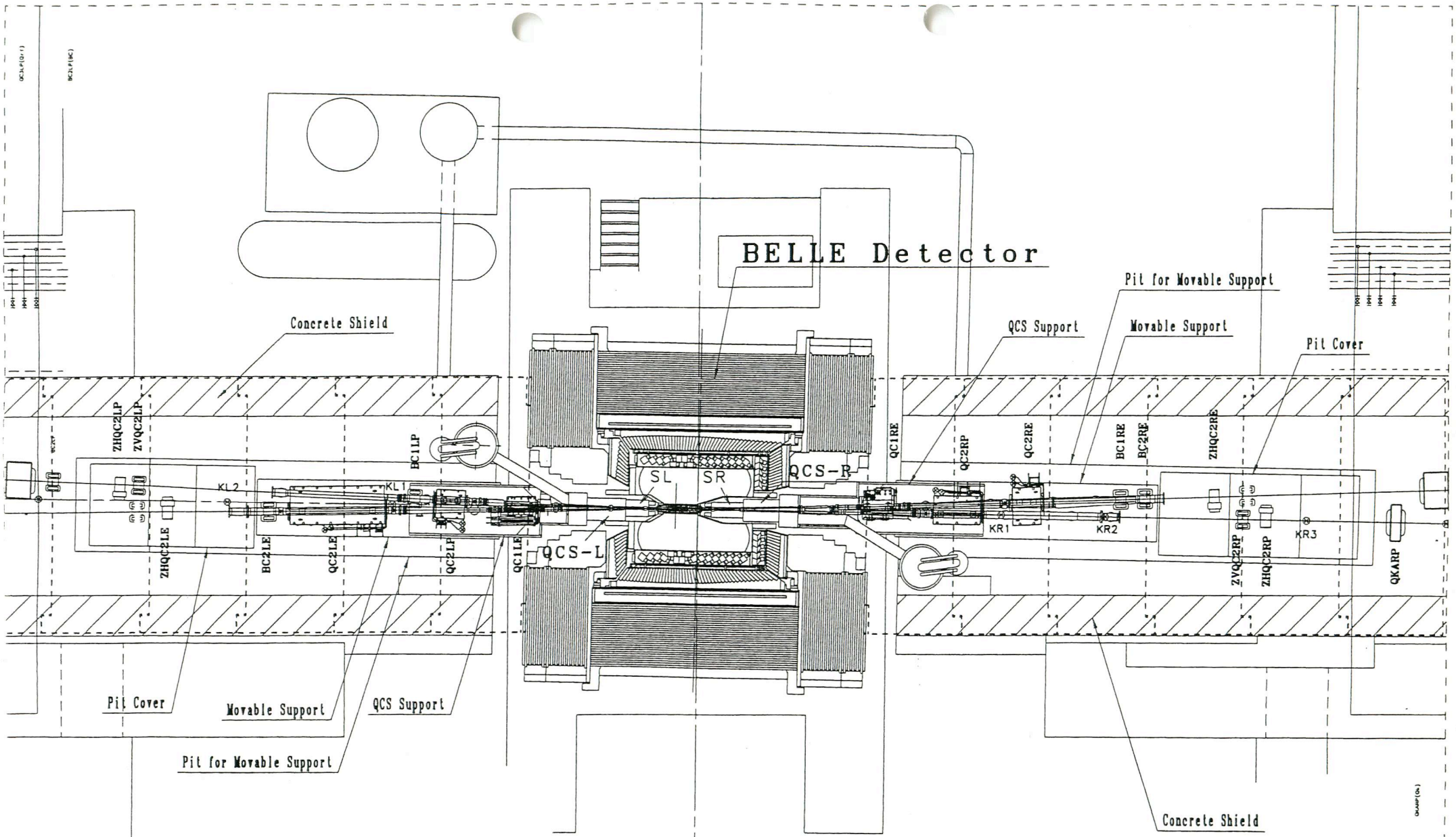
The beams collide with finite angle (2 x 11 mrad) at the interaction point (IP).

Closest vertically focusing quad (QCS) has both beams.

Compensation solenoid and QCS are superconducting magnet.



Schematic layout of the magnets and the beam line near IP



Top View for Tsukuba Interaction Region

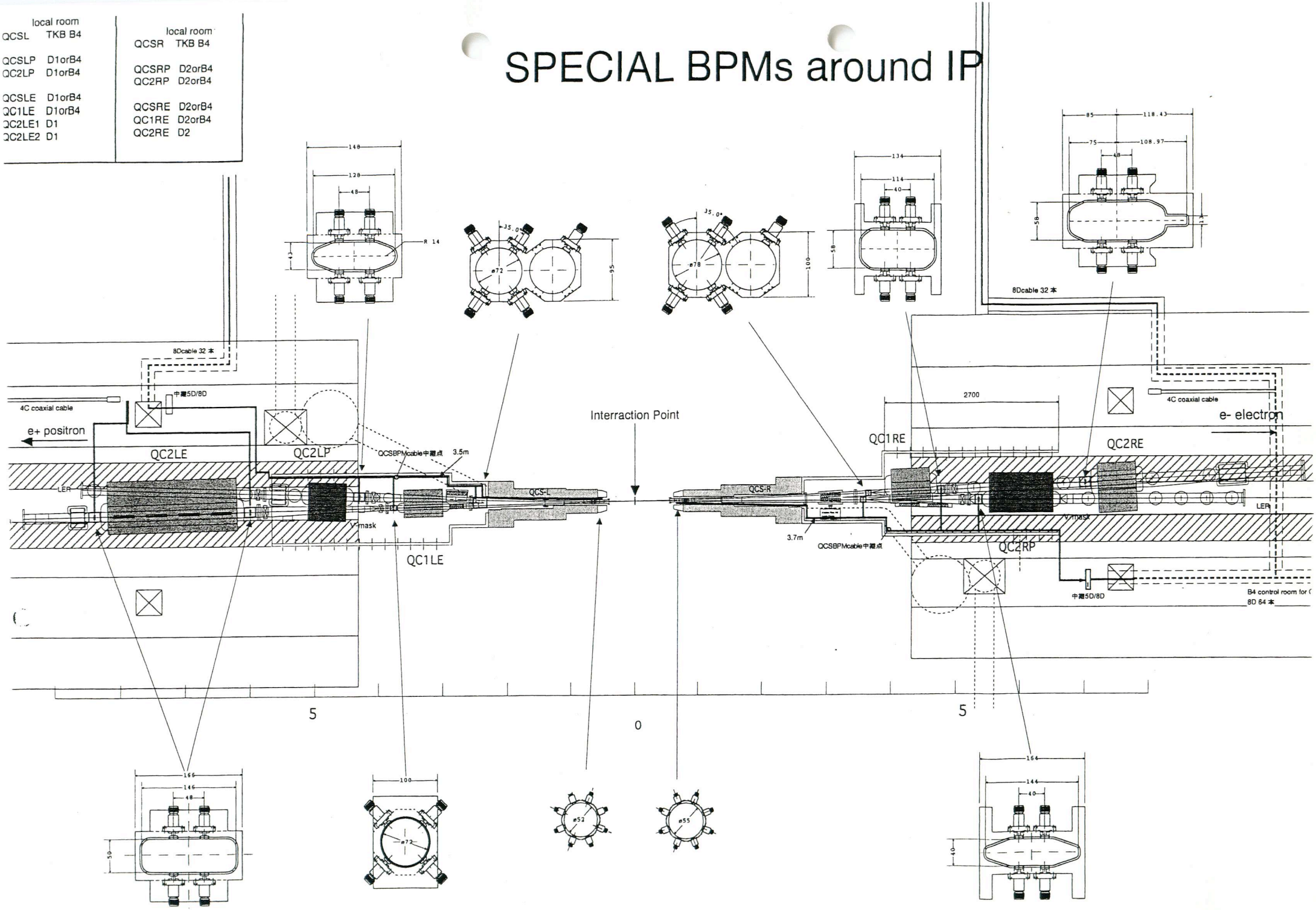
Scale = x 0.013

Tsukuba_IR_E_990111

SPECIAL BPMs around IP

local room	
QCSL	TKB B4
QCSLP	D1orB4
QC2LP	D1orB4
QCSLE	D1orB4
QC1LE	D1orB4
QC2LE1	D1
QC2LE2	D1

local room	
QCSR	TKB B4
QCSRP	D2orB4
QC2RP	D2orB4
QCSRE	D2orB4
QC1RE	D2orB4
QC2RE	D2



Hardware Construction and Installation

'97 Apr.

Completed construction of shield bridges in the Tsukuba Hall.
Installed the movable supports for IR magnets.

Aug.

SC magnets assemblies were delivered to KEK.
Installed the SC magnets into IR.

Sep.

Completed the cryogenic system for the SC magnets.

Oct.

Performed the first cool-down and excitation test of SC magnets.
Found cooling deficiency problem in the ends of cryostats. Improved the cooling channels of the cryostats.

'98 Jan.

Performed the second system test of SC magnets. All coils reached their target currents without quenching.

Feb.-Mar.

Obtained field map data on the beam line while exciting both Belle solenoid and SC magnets for IR.
Obtained field map data for particle tracking detector of Belle.

Apr.

Rolled out the Belle solenoid and structure.

Aug.

Completed the construction of Big-shield blocks and mini-shield blocks and delivered to IR. IR vacuum chambers were ready to install.

Sept.

Special IR quadrupoles were delived to KEK. Performed the field measurements of special quads.

Oct.

Made final decision not to roll-in Belle detector at the start of KEKB commissioning.

Nov.

Installed special quads and vacuum chambers into IR and assembled the beam line.

Completed the construction of IR.

'99 Feb. 28

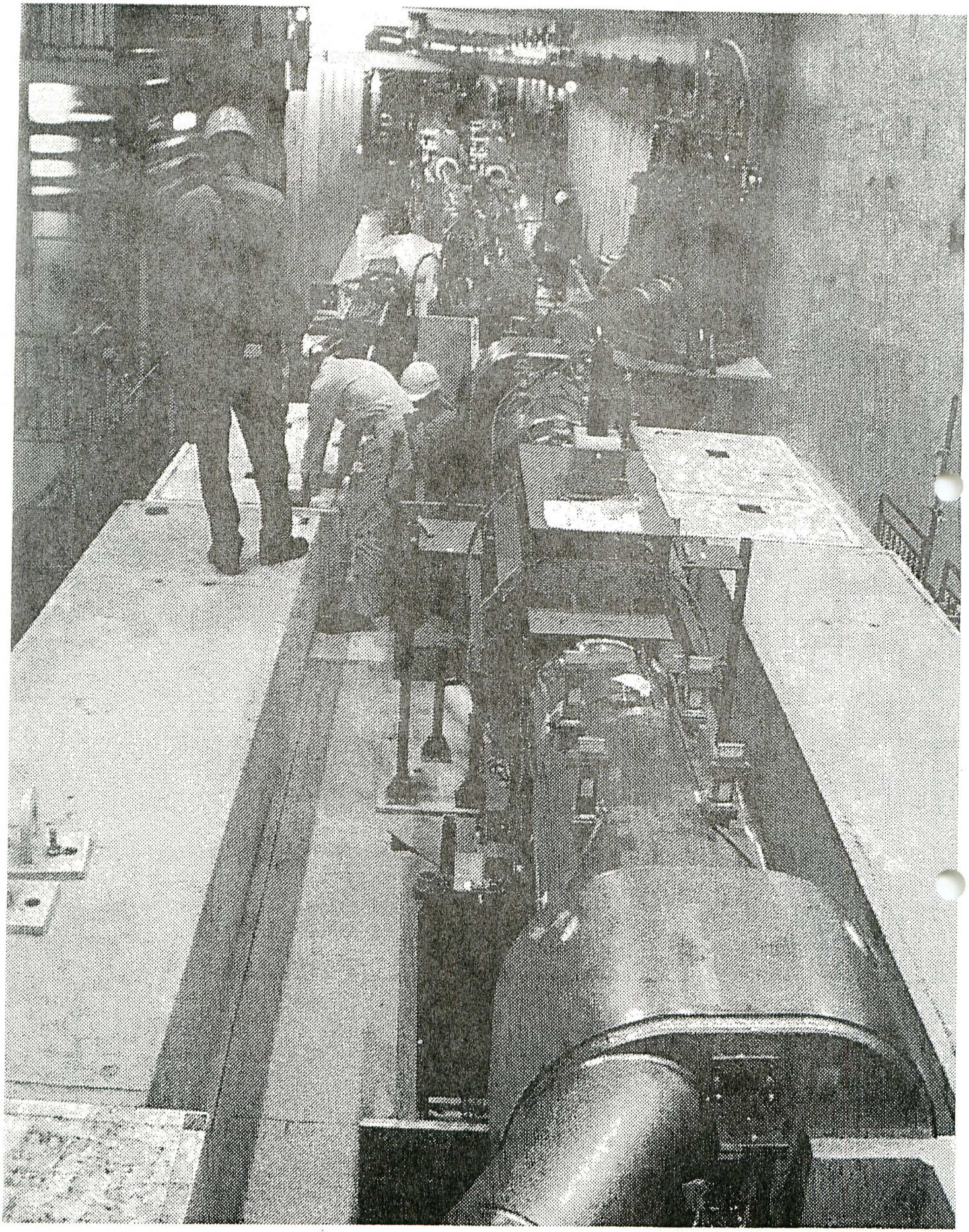
QC2RE vacuum chamber trouble happened. Synchrotron light deformed the chamber and caused vacuum leak.

Future schedule

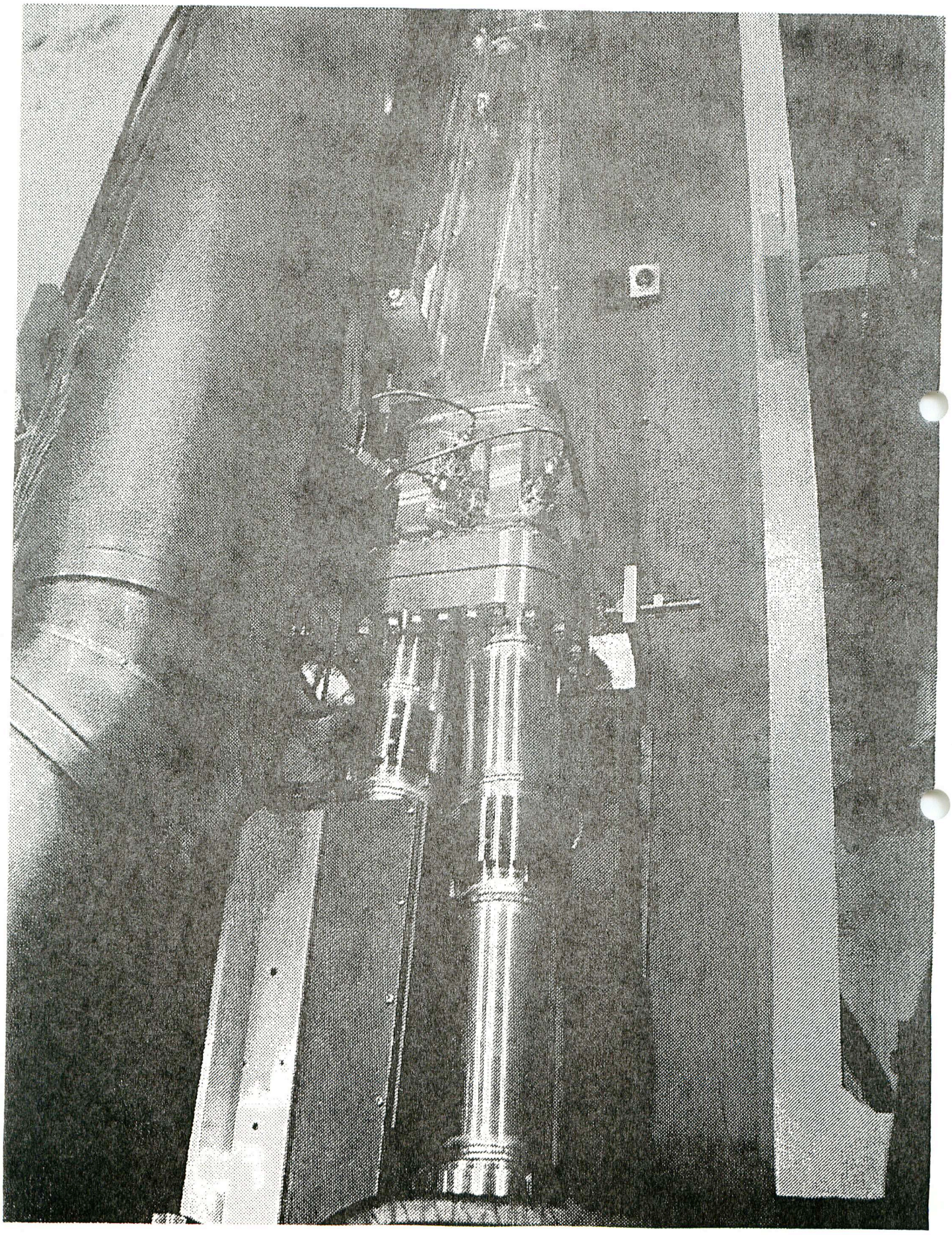
'99 Apr.- May (5 weeks)

Belle detector will be rolled into the beam line.

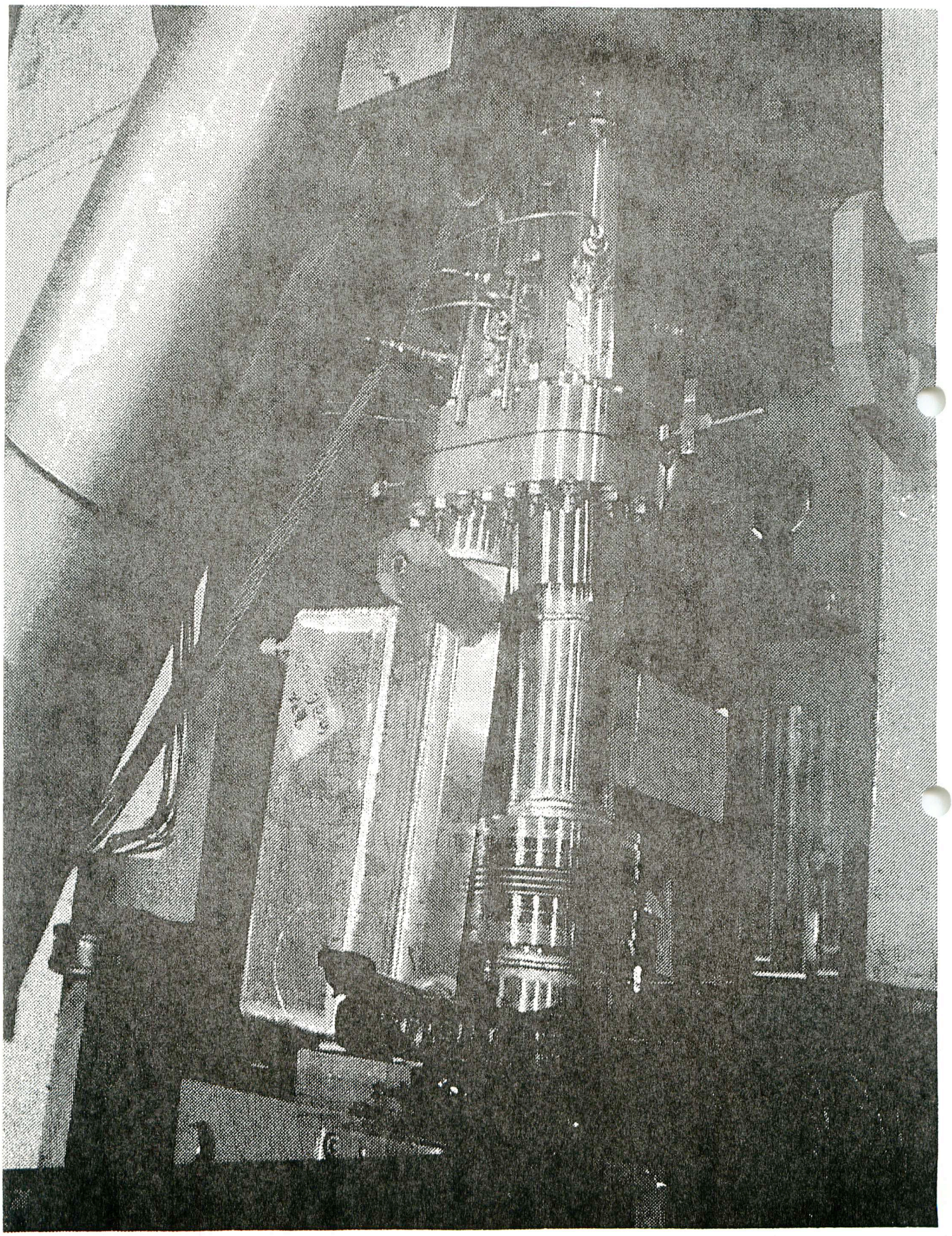
Installed Superconducting Magnet System ('98 April)



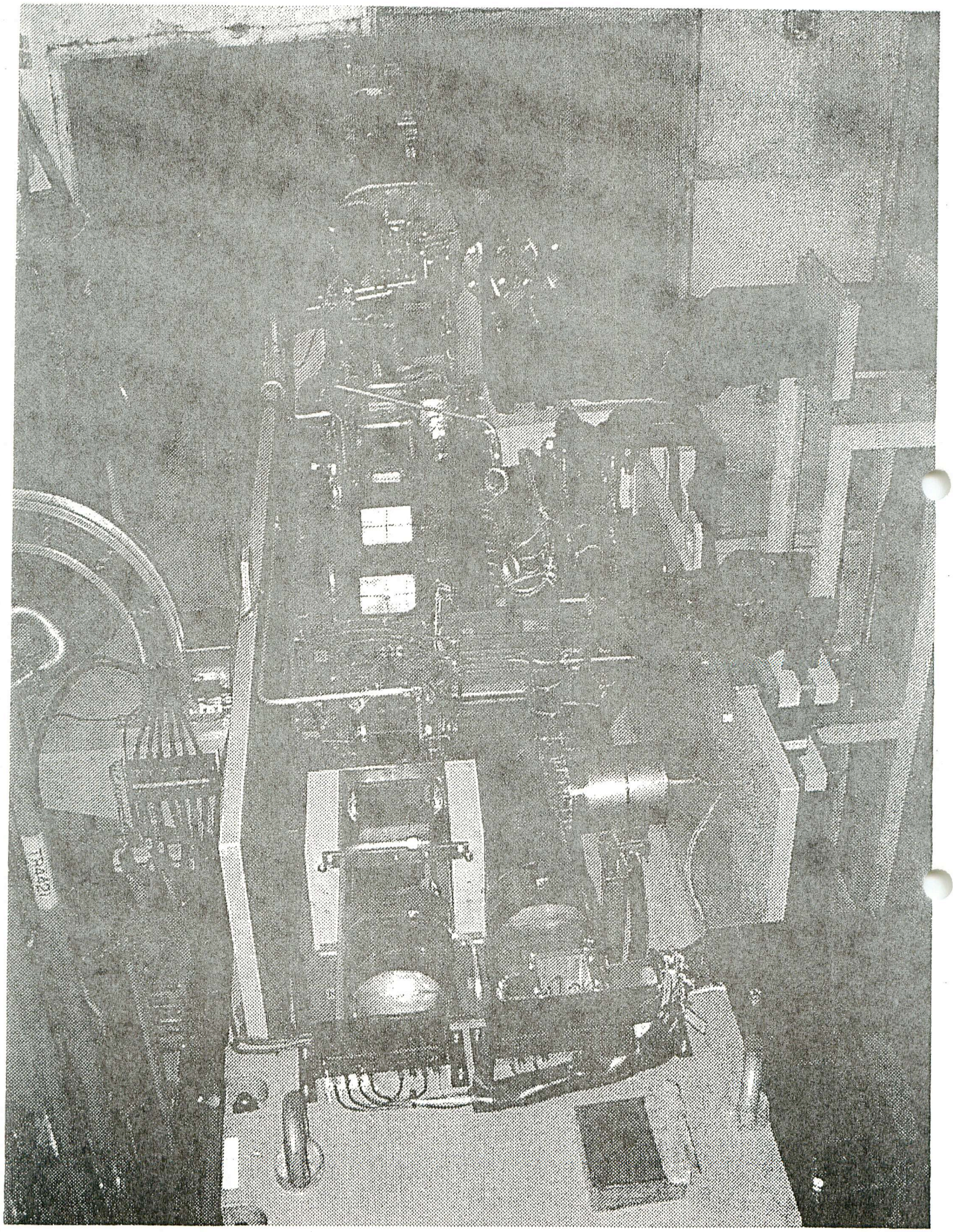
Construction of IP region ('98 November)



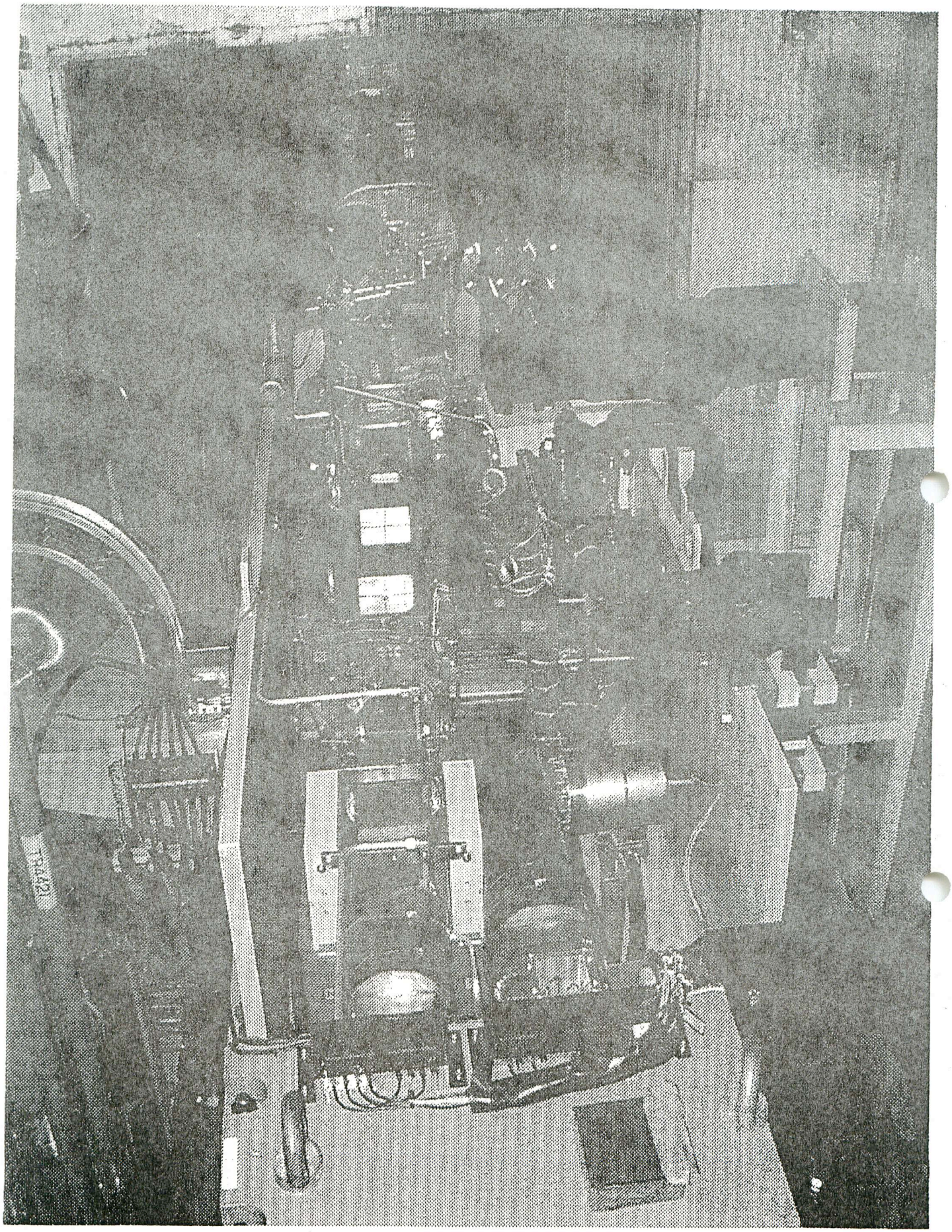
Crotched vacuum chamber in QCSR-QC1RE area



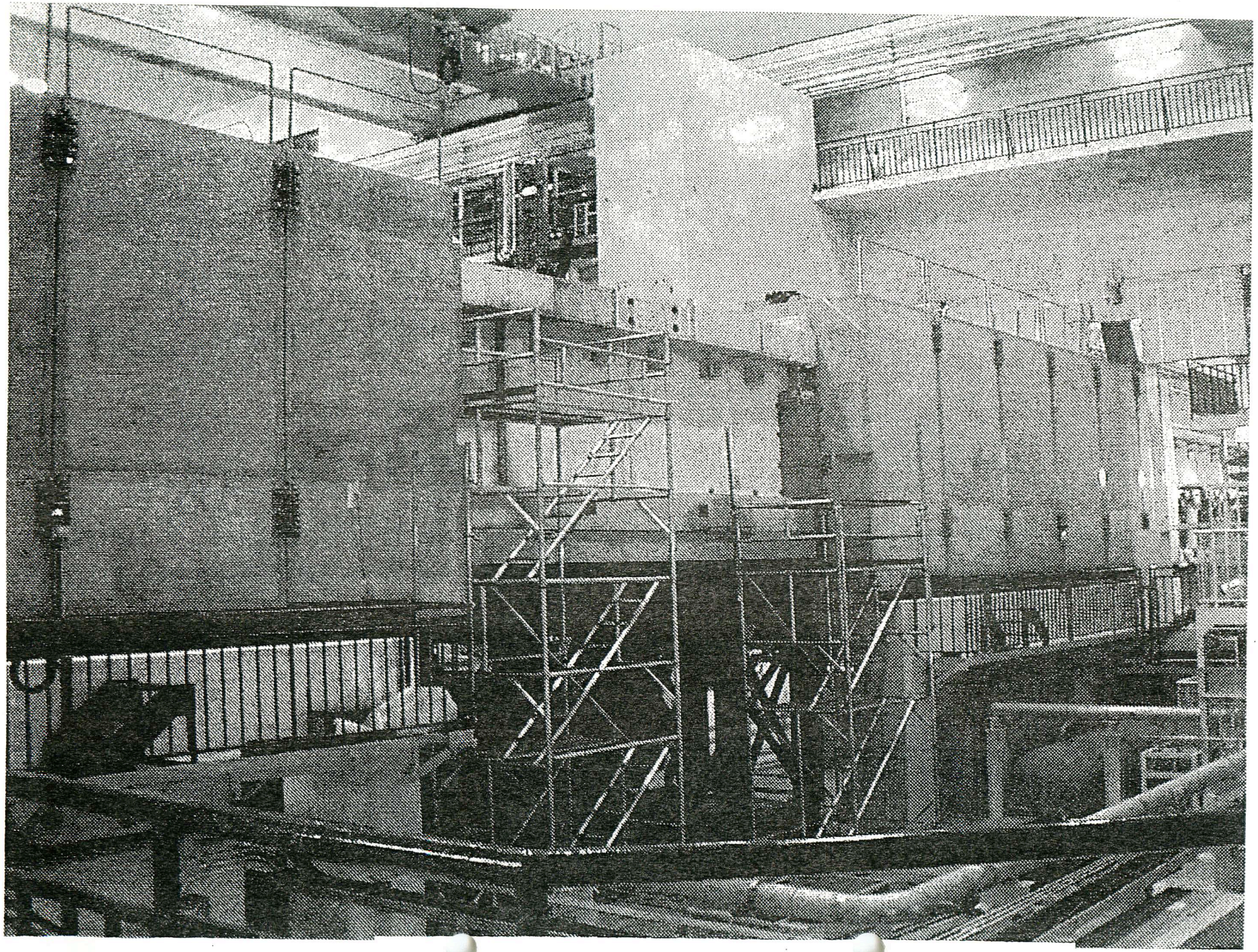
Crotched vacuum chamber in QCSL-QC1LE area



Left side beam line of IP



Left side beam line of IP



IR covered with concrete shield blocks ('98 December)

Superconducting Magnets for IR

1) Compensation solenoid
    S-L, S-R
2) Quadrupole magnets with correctors
    QCS-L, QCS-R
    correctors
        skew quadrupole
        horizontal steering
        vertical steering
3) Movement of the cryostat

COMPENSATION SOLENOIDS (SL and SR)

functions;

- to minimize the effect of the detector solenoid field on the accelerator beams.

an integral of Bz along the beam line= 0

$$\int_L Bz\, dl = 0, \quad \int_R Bz\, dl = 0$$

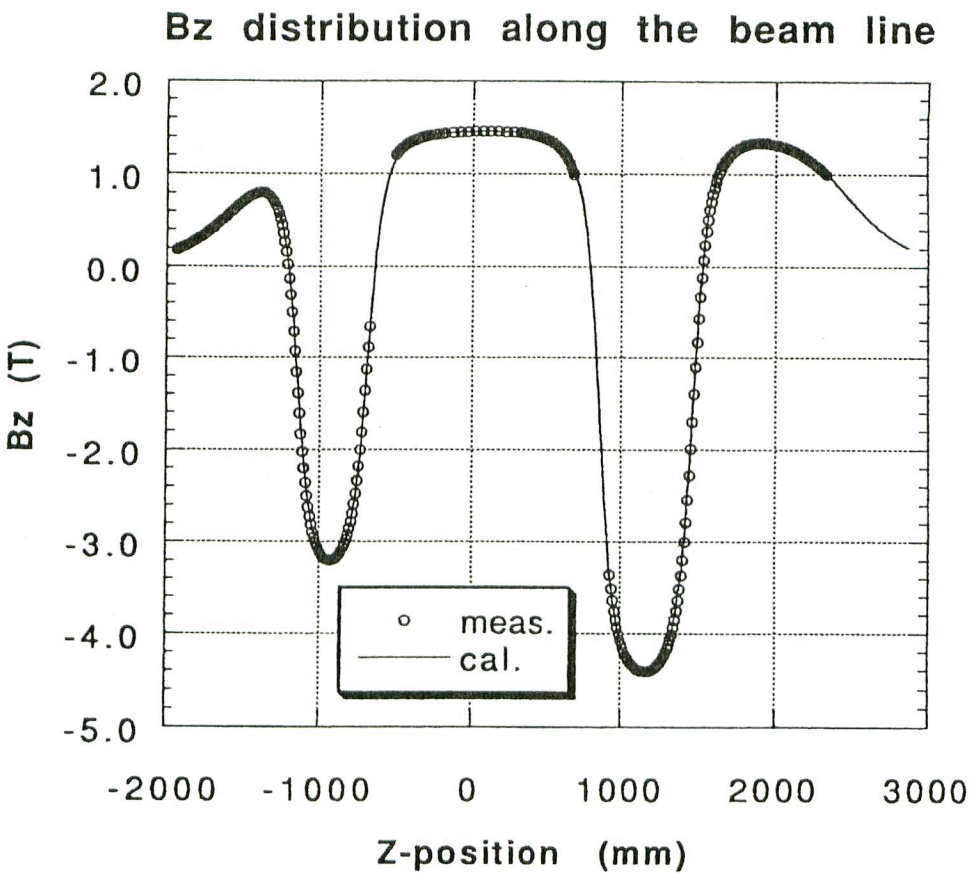
*Main Parameters of the Solenoids

	S-L	S-R	
Central field	4.53	5.80	T
Current	487	603	A
I /Ic	59	75	%
Max. field on the conductor	4.59	5.83	T
Stored energy	121	258	kJ
Coil current density	193.8	233.0	A/mm^2
Coil			
IR	95	95	mm
OR	115	115	mm
Length	461	616	mm
No. of turns	3749	4981	

*Test Results

System test in January 1998

Both solenoids reached 110% of Id without quenching.


Bz distribution along the beam line
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
Bz (T)
meas.
cal.
-2000
-1000
0
1000
2000
3000
Z-position (mm)

QUADRUPOLE MAGNETS WITH CORRECTORS
(QCS-L and QCS-R)

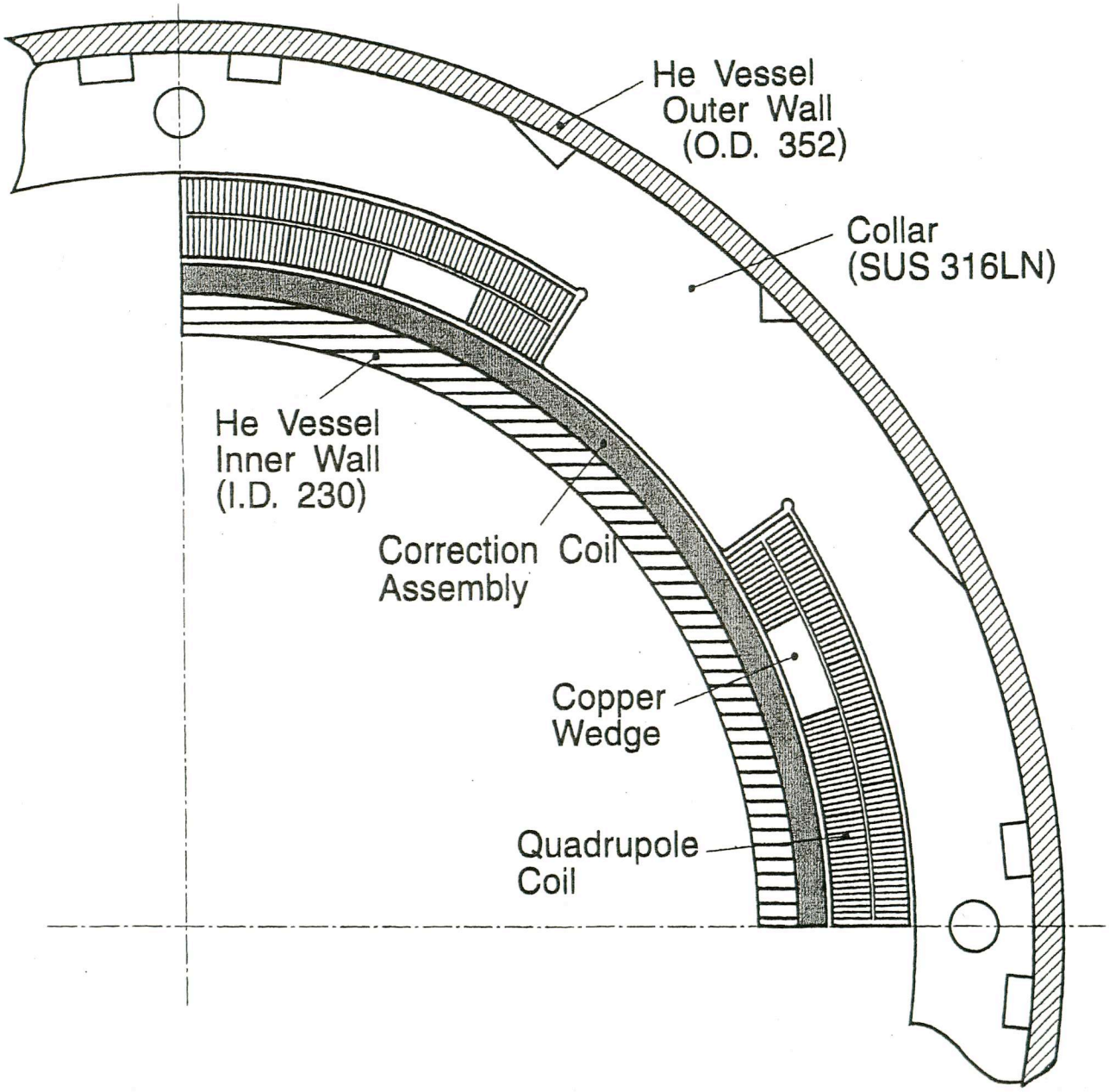
features;

- large bore and short length quadrupole
- correction coils are in the bore

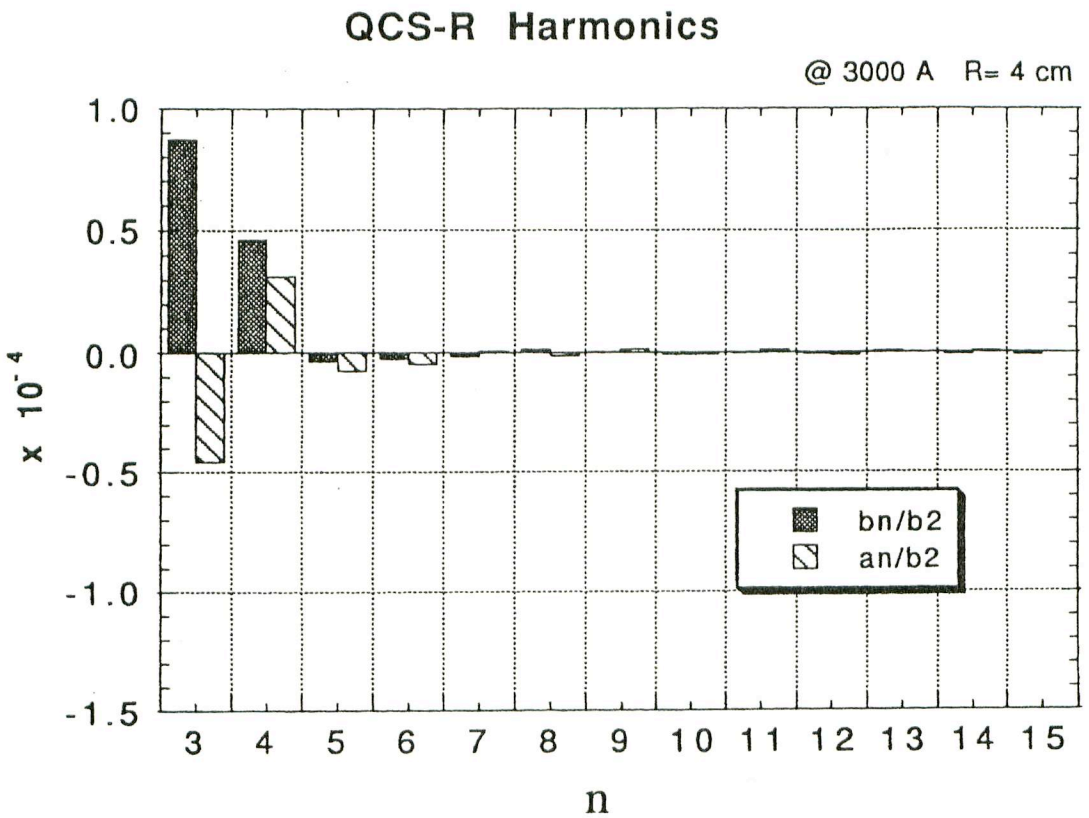
Main parameters

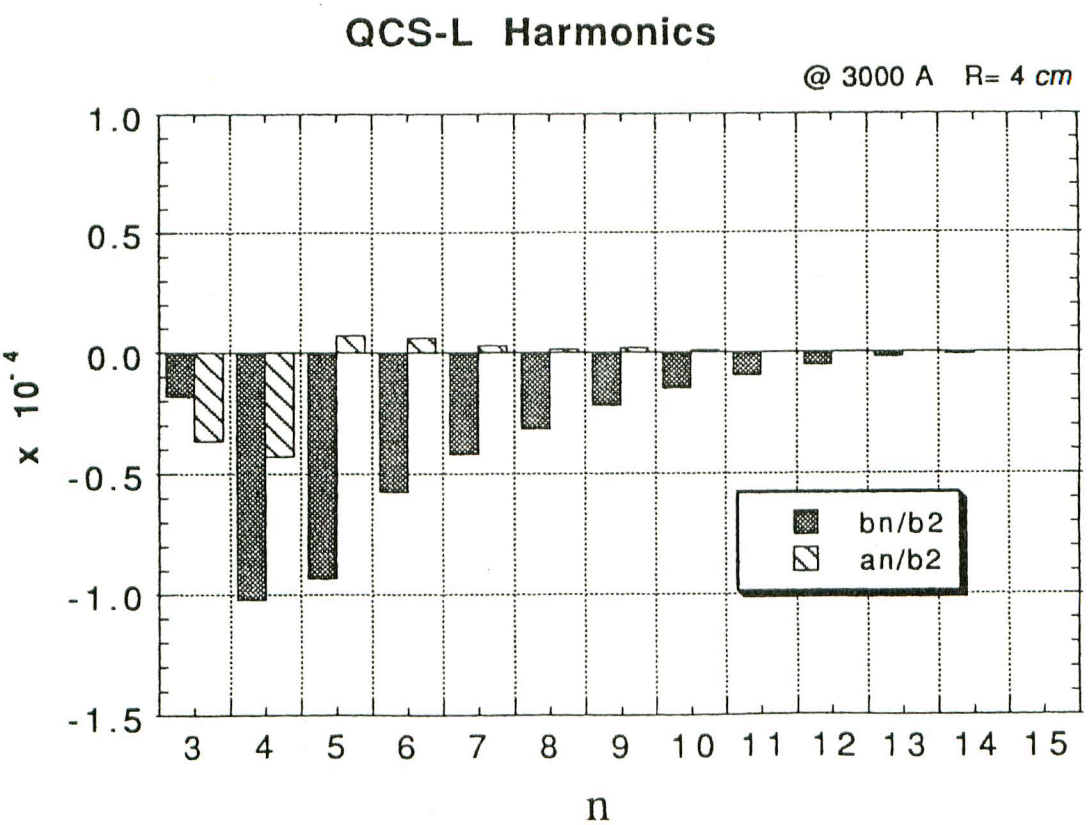
	QCS-L	QCS-R	
Field gradient	21.66 (21.78)	21.73 (21.78)	T/m
Current	2963	2963	A
Effective length	483 (486.1)	385 (387.7)	mm
Max. field on the conductor	4.2	4.2	T
I/Ic at 4.5 K	70	70 %	
Main coil			
Inner radius	130	130	mm
Overall length	521	617	mm
Collar outer dia.	340	340	mm
Stored energy	87.5	69.7	kJ

* ( ) ; measured value


He Vessel
Outer Wall
(O.D. 352)
Collar
(SUS 316LN)
He Vessel
Inner Wall
(I.D. 230)
Correction Coil
Assembly
Copper
Wedge
Quadrupole
Coil

90 8


QCS-R Harmonics
@ 3000 A R= 4 cm
1.0
0.5
0.0
-0.5
-1.0
-1.5
x 10^-4
3 4 5 6 7 8 9 10 11 12 13 14 15
n
bn/b2
an/b2


QCS-L Harmonics
@ 3000 A R= 4 cm
1.0
0.5
0.0
-0.5
-1.0
-1.5
x 10^-4
3 4 5 6 7 8 9 10 11 12 13 14 15
n
bn/b2
an/b2

Correction coils

functions;

- correct the alignment errors of the QCS magnets

features;

- various forces and torques work on the coils
- very thin coil (made by muti-wiring technique)
  total thickness of 3 correctors; ~ 5.6 mm

Main Parameters of the Correction Coils

	Design	Measured		
		L-side	R-side	
Skew quad coil				
G	0.44			T/m
GL	0.2174	0.212	0.2122	T/m·m
Coil IR	123.5			mm
Number of turns	106	106	106	/pole
Alignment error	0	0.22	-27.43	mrad
Horizontal steering coil				
B	0.05			T
BL	0.0244	0.0255	0.0250	Tm
Coil IR	126.9			mm
Number of turns	213	213	213	/pole
Alignment error	0	4.59	3.85	mrad
Vertical steering coil				
B	0.05			T
BL	0.0242	0.0253	0.0247	Tm
Coil IR	125.2			mm
Number of turns	211	211	211	/pole
Alignment error	0	1.57	-13.04	mrad

*Design current of these coils are 50 A.

*Alignment error is the angular difference between the mid-planes of QCS coil and corrector.

Movement of the cryostat

Various forces and torques work on each coil.

- axial magnetic forces on S-L and S-R are 22 kN and 2.8 kN, respectively.
- force works on the horizontal steering is rather large when it is excited in Belle solenoid field.

We measured the movement of the cryostat due to the large electromagnetic forces work on the coils.

static movement

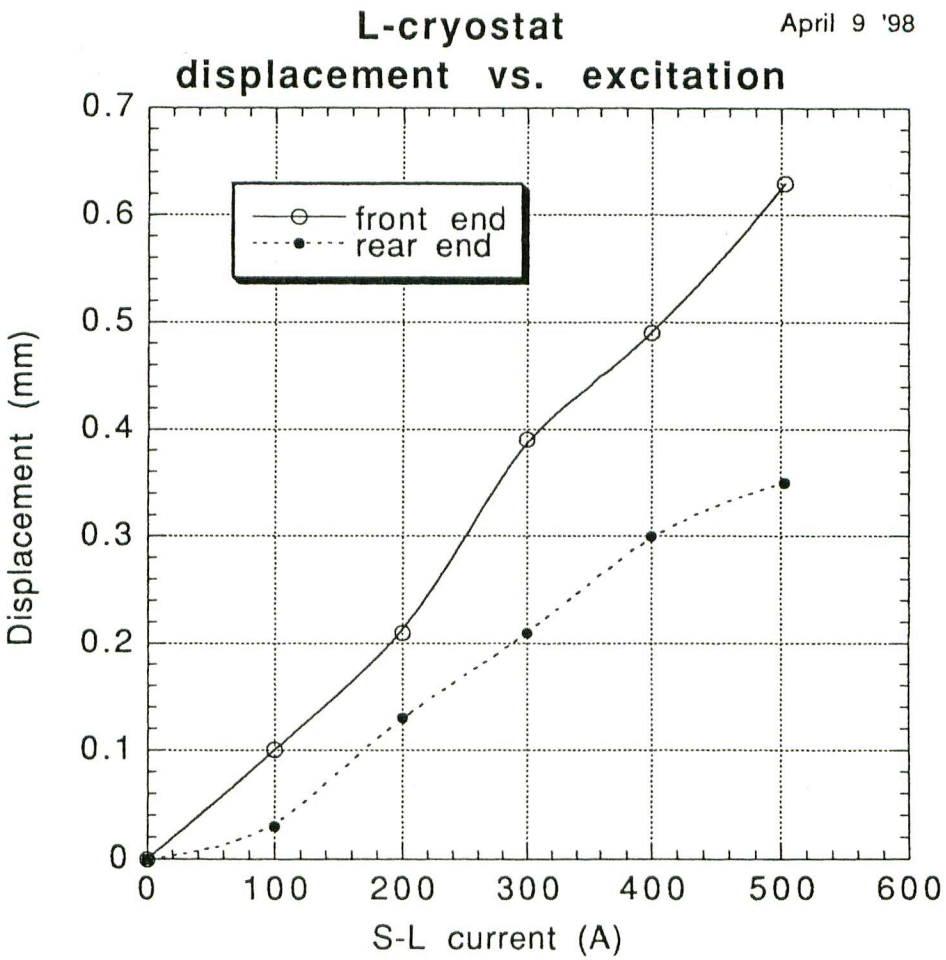
We can observe another kind of small movement which might be related to the cooling condition of the cryostat.

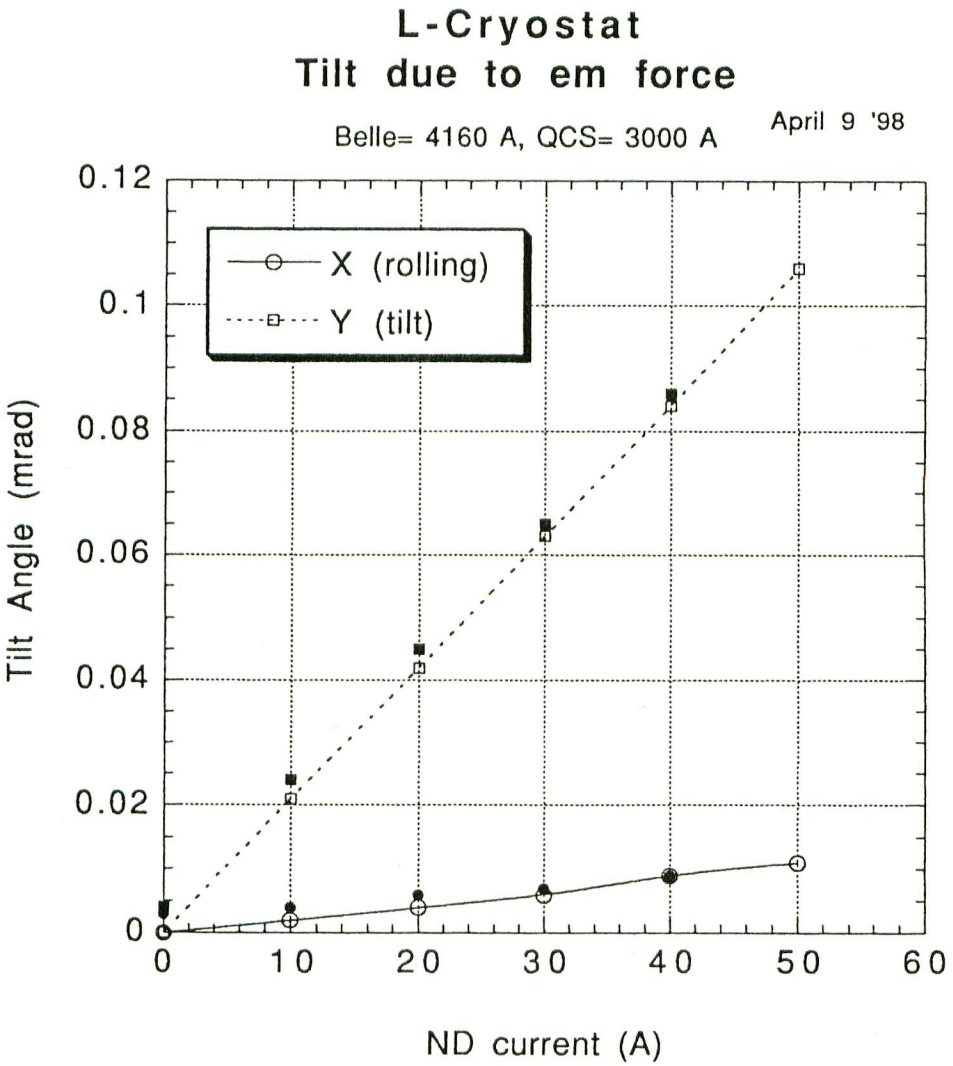
Major electromagnetic force and torque works on each coil.

	Fx	Fy	Mx	My	Mz
QCS-L	-1000 N (yoke)	800 N (det. sol) 1000 N (S-L)	200 Nm (det. sol) -500 Nm (S-L)		
Normal D-L	51800 N (QCS-L)	-1800 N (det. sol) 200 N (S-L)	1100 Nm (det. sol) -100 Nm (S-L)		
Skew D-L	-1900 N (det. sol) 200 N (S-L)	55200 N (QCS-L)		-1200 Nm (det. sol) 100 Nm (S-L)	
Skew Q-L					4800 Nm (QCS-L)
Normal D-R	42400 N (QCS-R)	400 N (det. sol) -200 N (S-R)	2300 Nm (det. sol) -100 Nm (S-R)		
Skew D-R	400 N (det. sol) -200 N (S-R)	45300 N (QCS-R)		-2400 Nm (det. sol) 100 Nm (S-R)	
Skew Q-R					3800 Nm (QCS-R)

In parenthesis is the coil or the yoke which produces the force and/or torque.
The coils listed in the left column, except for the QCS-L, are trim coils in the QCS-L or QCS-R.

The axial magnetic forces on S-L and S-R are 22 kN and 2.8 kN, respectively, when they are excited in Belle detector solenoid (B=1.5 T).


L-cryostat
displacement vs. excitation
April 9 '98
front end
rear end
Displacement (mm)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
S-L current (A)


L-Cryostat
Tilt due to em force
Belle= 4160 A, QCS= 3000 A
April 9 '98
X (rolling)
Y (tilt)
Tilt Angle (mrad)
0.12
0.1
0.08
0.06
0.04
0.02
0
0
10
20
30
40
50
60
ND current (A)

Summary

- Superconducting magnet system is working well.

- It seems that some part of the beam orbit drift is related to the cryostat condition.
  However, we have not yet determined the definite parameter of the cryostat that causes the drift.