IR Superconducting Magnets

K. Tsuchiya

1) Layout

2) Compensation solenoids (ESR, ESL)

3) Quadrupole magnets (QCSR, QCSL)

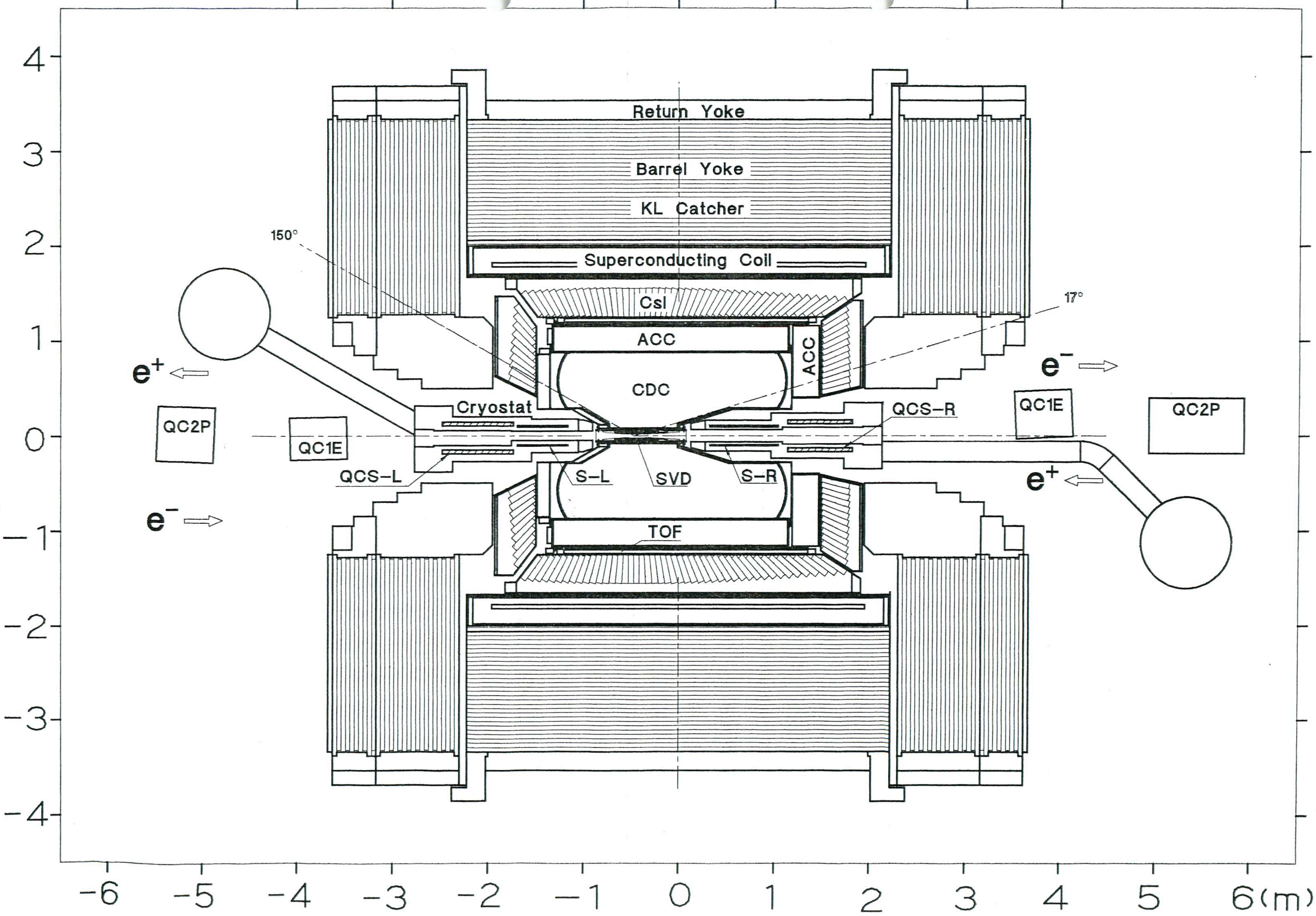
4) Corrector coils

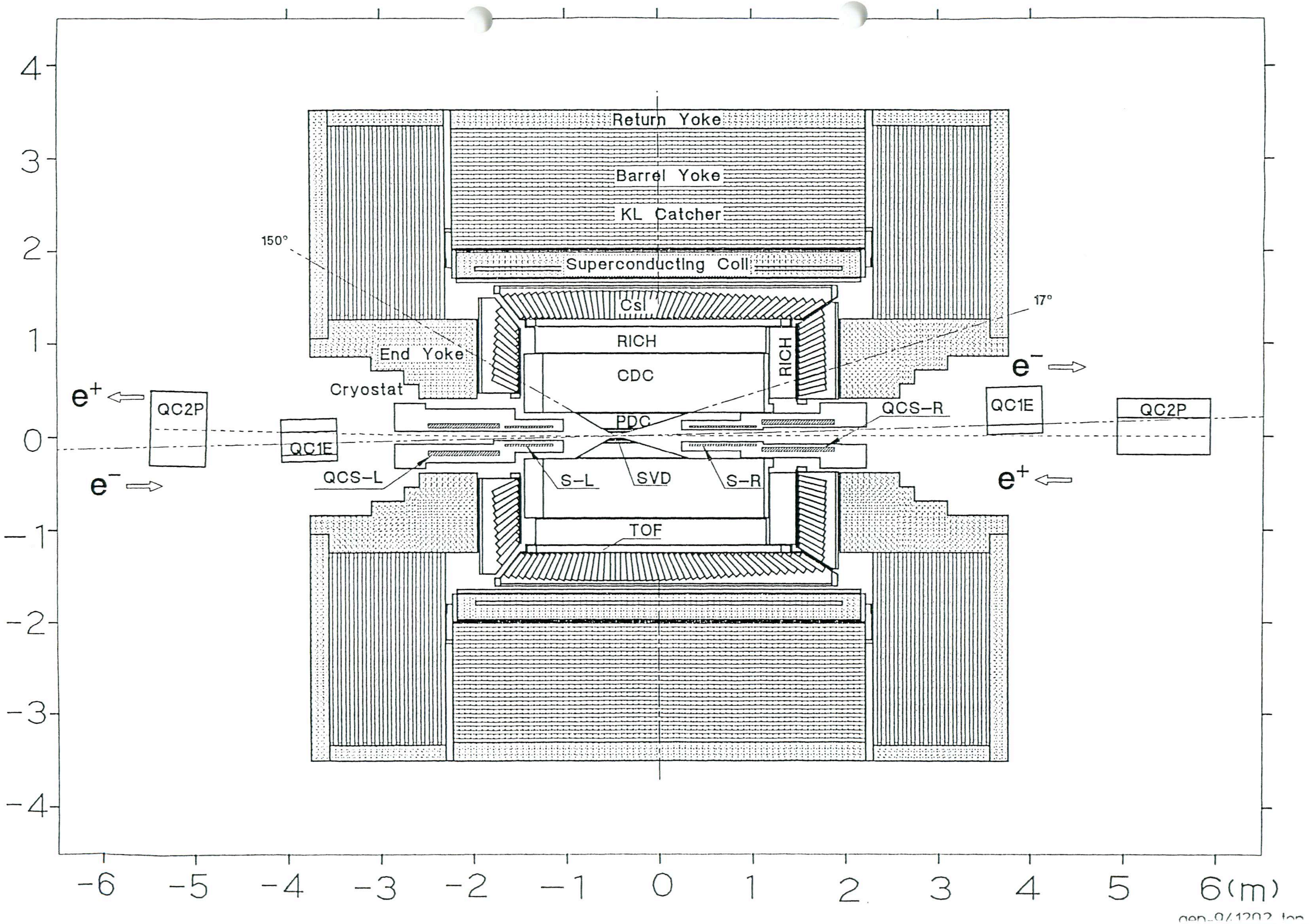
5) Cryostat

6) Excitation circuit

7) Cooling system

8) Schedule


Return Yoke
Barrel Yoke
KL Catcher
Superconducting Coil
CsI
ACC
CDC
ACC
TOF
SVD
S-L
S-R
Cryostat
QCS-L
QCS-R
QC1E
QC2P
QC1E
QC2P
150°
17°
e+
e-
e-
e+
4
3
2
1
0
-1
-2
-3
-4
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6(m)



Return Yoke
Barrel Yoke
KL Catcher
Superconducting Coil
CsI
RICH
CDC
PDC
SVD
TOF
RICH
End Yoke
Cryostat
QCS-L
QCS-R
S-L
S-R
QC1E
QC2P
QC1E
QC2P
150°
17°
e^+
e^-
e^-
e^+
4
3
2
1
0
-1
-2
-3
-4
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6(m)

Compensation solenoids (ESR and ESL)

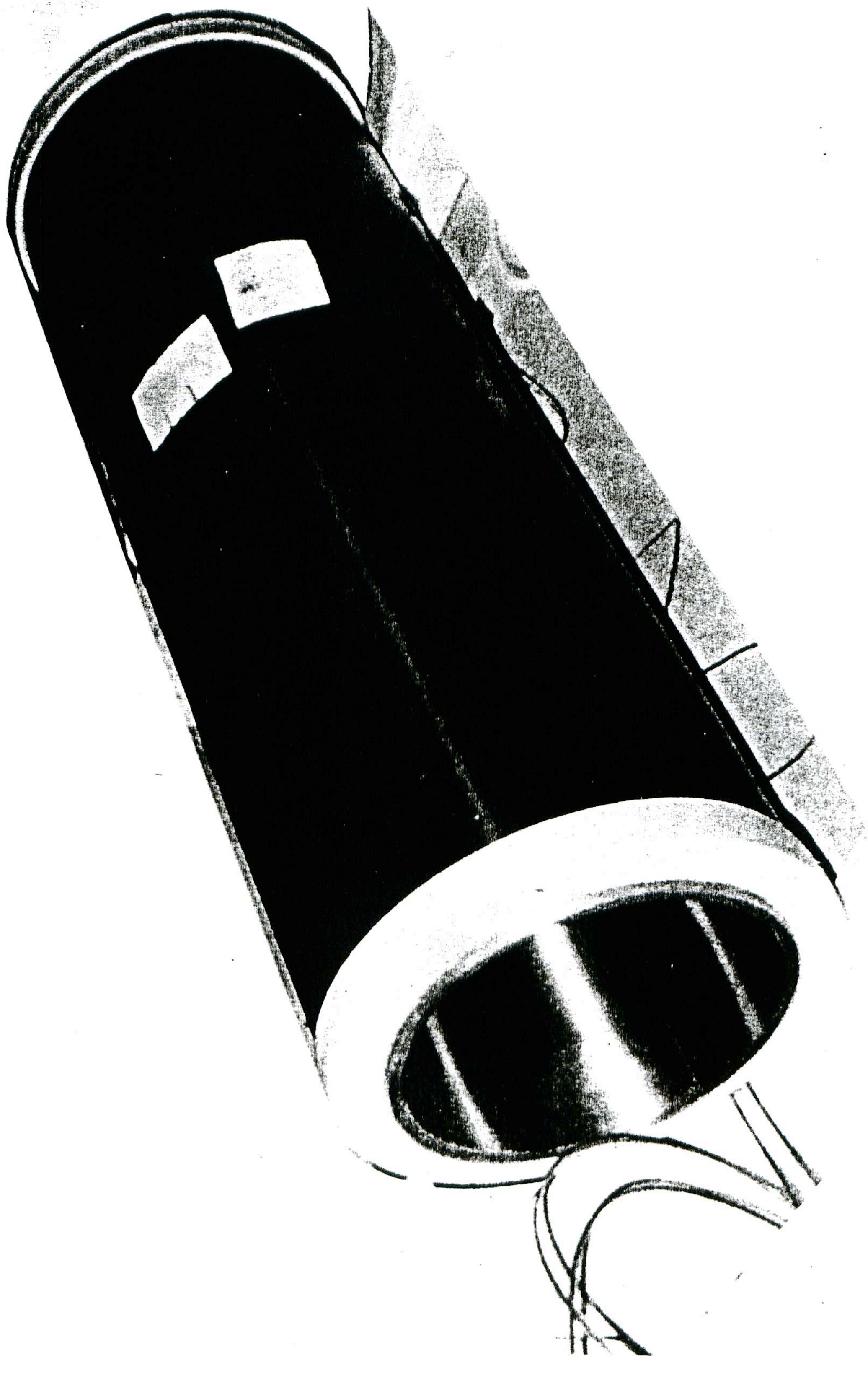
- A prototype solenoid has been fabricated and tested in order to confirm the soundness of the fabrication method.
- The prototype showed a good performance.
  no training quench, Tmax < 180 K
- The conductor fabrication was completed.
- The fabrication method has been fixed and the two solenoids are now being in fabrication.

* Final design parameters of the solenoids

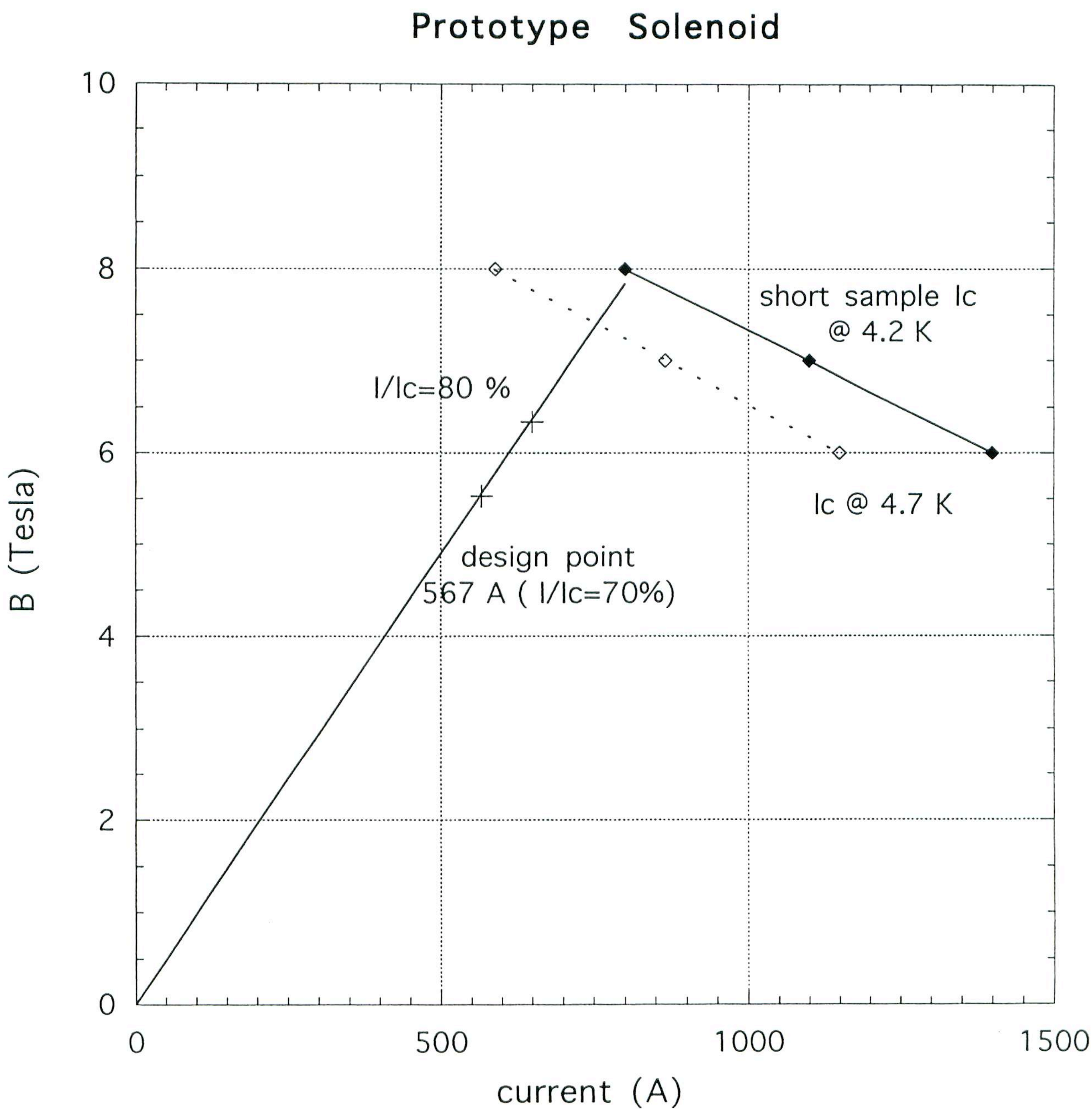
	ESR	ESL	prototype	
Central field	5.59	4.44	5.53	T
Current	581	480	567	A
Max. field on the conductor	5.62	4.50	5.56	T
Stored energy	245	120	241	kJ
Inductance	1.45	1.04	1.50	H
Coil current density	222.9	183.4	238	A/mm2
Magnetic pressure in radial direction	9.8	6.2		MN/m2
Coil				
IR	95	95	95	mm
OR	116.2	116.2	114.5	mm
Length	624	470	634.5	mm
No. of turns	5072	3808	5193	

* Conductor

conductor size (w/o insulation)	1.10 x 1.90	mm2
RRR of stabilizing copper	> 120	
Copper/SC ratio	1.0 ± 0.1	
filament dia.	< 28	μm
twist pitch	< 25	mm
critical current at 4.2 K		
	> 2000 A	@ 4 Tesla
	> 1700 A	@ 5 Tesla
	> 1400 A	@ 6 Tesla
	> 1100 A	@ 7 Tesla
Insulation	60 μm IMW (Polyimid)	



Jan. 16 '97


Prototype Solenoid
B (Tesla)
current (A)
0
2
4
6
8
10
0
500
1000
1500
short sample Ic
@ 4.2 K
Ic @ 4.7 K
I/Ic=80 %
design point
567 A (I/Ic=70%)

Quadrupole magnets (QCS-R and QCS-L)

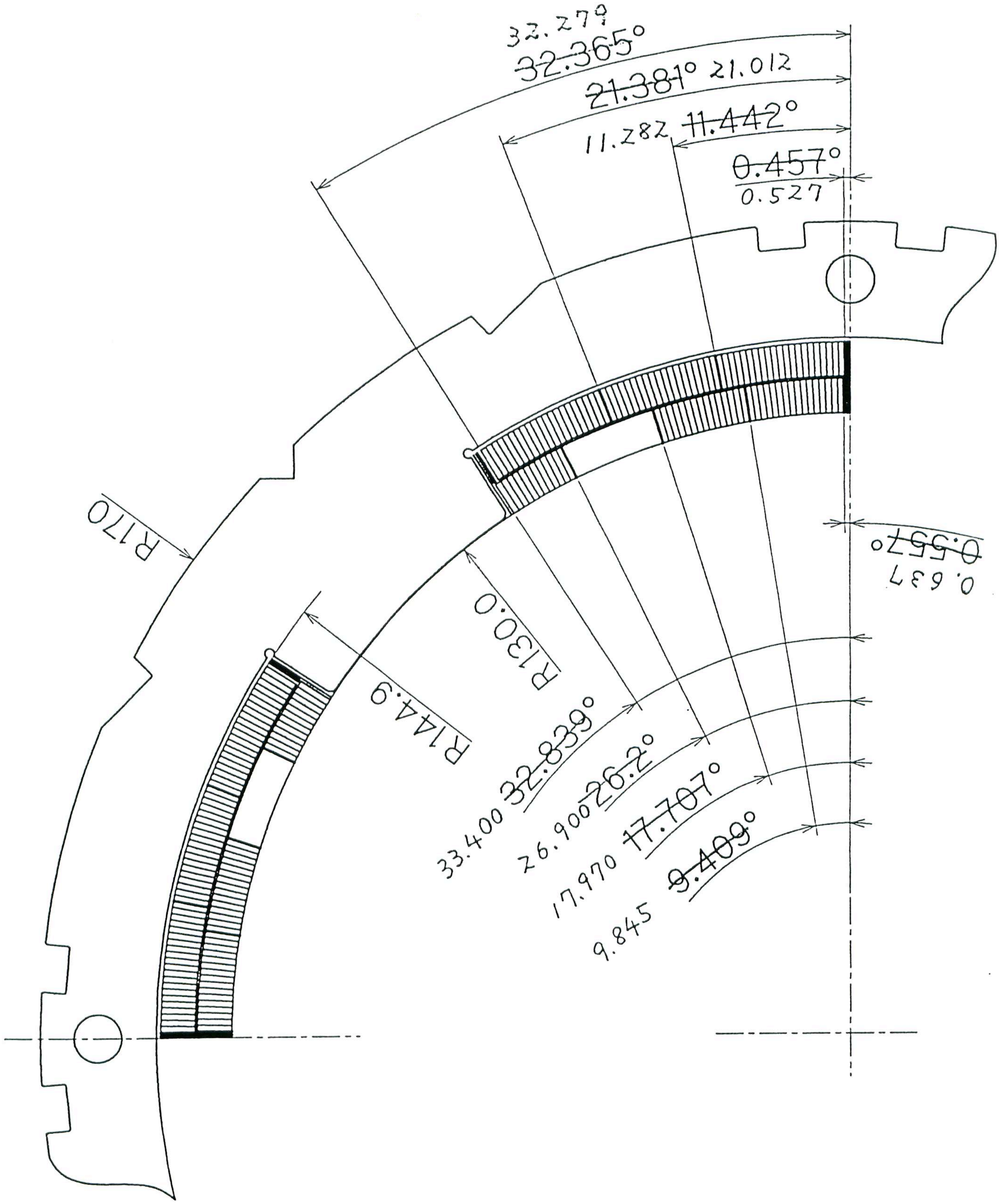
- The coil fabrication tooling had been prepared and first trial coils were made.
  coil size and Young's modulus measurement
- finalizing the production technologies.

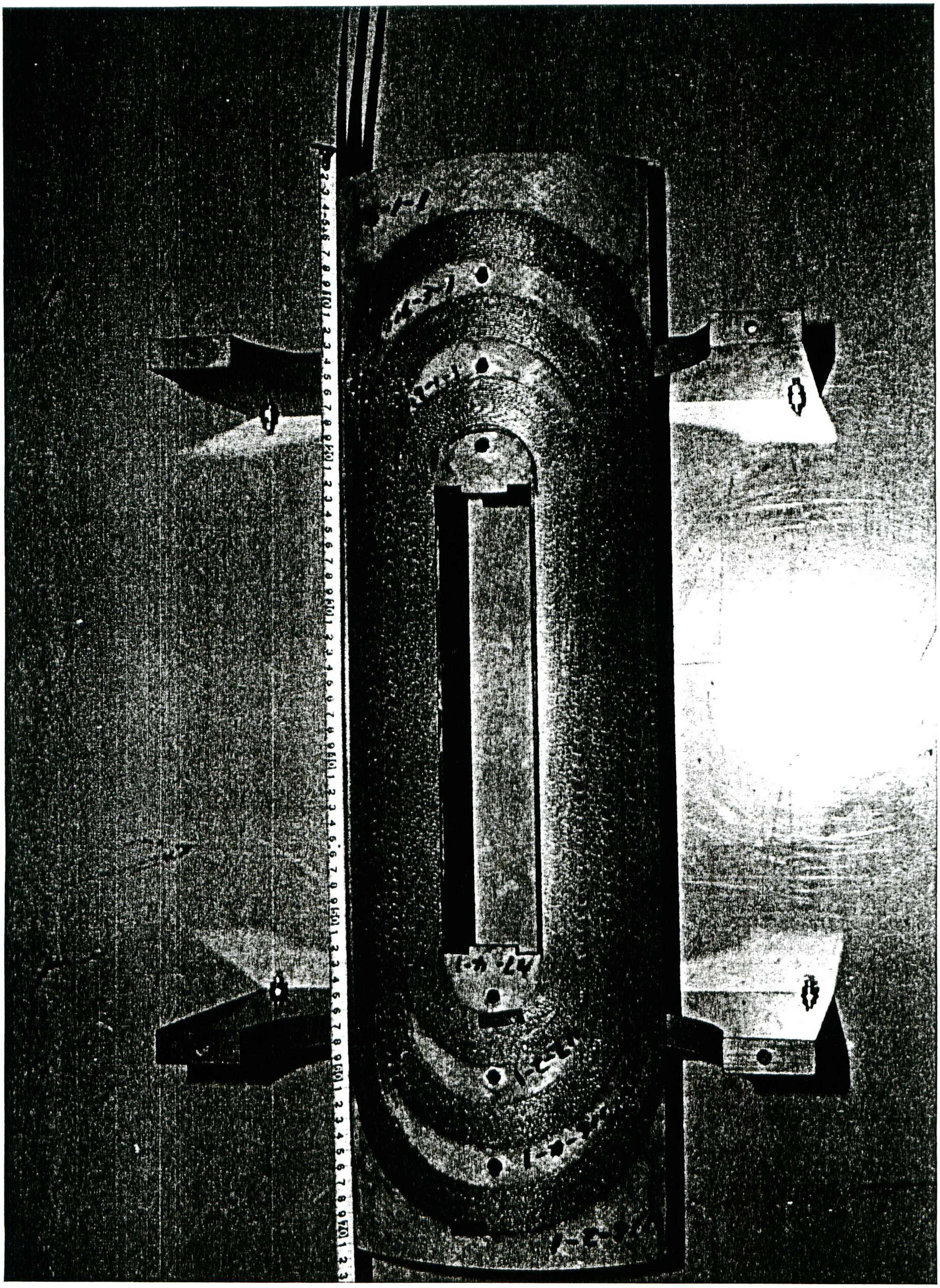
* Main parameters of the quadrupole magnets.

	QCS-R	QCS-L	
Field gradient	21.26	21.26+ ~0.12	T/m
Current	2963	2963	A
Main coil			
Inner radius	130	130	mm
Outer radius	144.9	144.9	mm
Total number of turns	106	106	turns/pole
Length of the coils	521	617	mm
Collars outer diameter	340	340	mm
Integrated field uniformity (at r= 40 mm)			
B3L/B2L	± 1.6x10-4	1x10-4 ± 1.6x10-4	
B4L/B2L	± 1x10-4	± 1x10-4	
B5L/B2L	± 0.5x10-4	± 0.5x10-4	
B6L/B2L	± 0.5x10-4	± 0.5x10-4	
A3L/B2L	± 1.5x10-4	± 1.5x10-4	
A4L/B2L	± 1x10-4	± 1x10-4	
A5L/B2L	± 0.3x10-4	± 0.3x10-4	
A6L/B2L	± 0.1x10-4	± 0.1x10-4	
(Yoke contribution + Construction error; 1 mm axial, 0.1mm azimuthal, 0.1mm radial)			
Effective magnetic length	385	483	mm
Max. field on the conductor	4.3	4.3	T
Stored energy	73.4	92.1	kJ
Inductance	16.7	21.0	mH
Longitudinal magnetic forces	192	188	kN
Resultant of magnetic forces per meter length in the coil quadrant			
Fx (horizontal)	159	159	kN/m
Fy (vertical)	-366	-366	kN/m

* Main parameters of the cable

	specification	measured	
strand diameter	0.590 ±0.003	0.589	mm
filament dia.	< 6.5	6.4	μm
surface condition	coated with Sn-5Ag		
RRR of stbilizing copper	> 150	155 - 169	
Copper ratio	1.8 ± 0.1	1.75 - 1.82	
cable dimensions			
hight	7.00 ± 0.025	7.006 ± 0.009	mm
small width	1.057 ± 0.006		mm
large width	1.123 ± 0.006		mm
mid. thickness	1.090 ± 0.006	1.089 ± 0.003	
key stone angle	0.54 ± 0.1	0.49 ± 0.006	deg.
number of strands	24	24	
cable twist pitch	60 ± 5	61.5	mm
critical current in cable at 4.2 K			
	> 5460 A	6620*A	@ 5 Tesla
	> 4460 A	5210*A	@ 6 Tesla
	> 3430 A	3780*A	@ 7 Tesla
	* estimated from strand's Ic		
Insulation	25μm Upilex tape(10 mm width) 50 % overlapped + 50μm Upilex tape(6 mm width) with 25μm epoxy helical wound with 1 mm gap		


32.279
~~32.365°~~
~~21.381°~~ 21.012
11.282 ~~11.442°~~
~~0.457°~~
0.527
R170
R130.0
R144.9
~~0.557°~~
0.637
33.400 ~~32.839°~~
26.900 ~~26.2°~~
17.970 ~~17.707°~~
9.845 ~~9.409°~~



Correction coils

- Flat prototype coils have been made at BNL.
- The assembly technologies are currently under development using the prototype coils.
- Four sets of correction coils have been ordered, and will be shipped by the middle of February.

*<u>Main parameters of the skew quad coil</u>

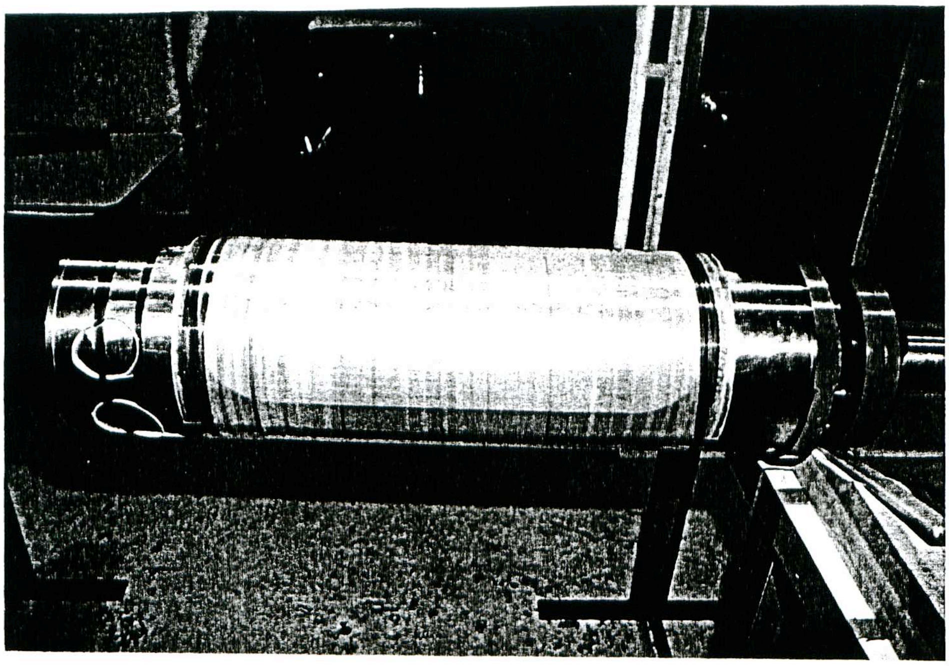
Field gradient		0.44		T/m
G •L		0.2174		T/m •m
Current		50		A
Effective length		0.495		m
Stored energy		28.7		J
Inductance		22.94		mH
Harmonics @ r=4 cm				
	a1		± 25 x 10-4	
	a3		± 10 x 10-4	
	a6	3x10-4	± 0.2x10-4	
	b1		± 25 x 10-4	
	b2	1	± 30 x 10-4	
	b3		± 10 x 10-4	
	b6		± 0.2 x 10-4	
Coil	length	560		mm
	radius @mid-wire	123.533		mm
	no of turns	100		turns/pole

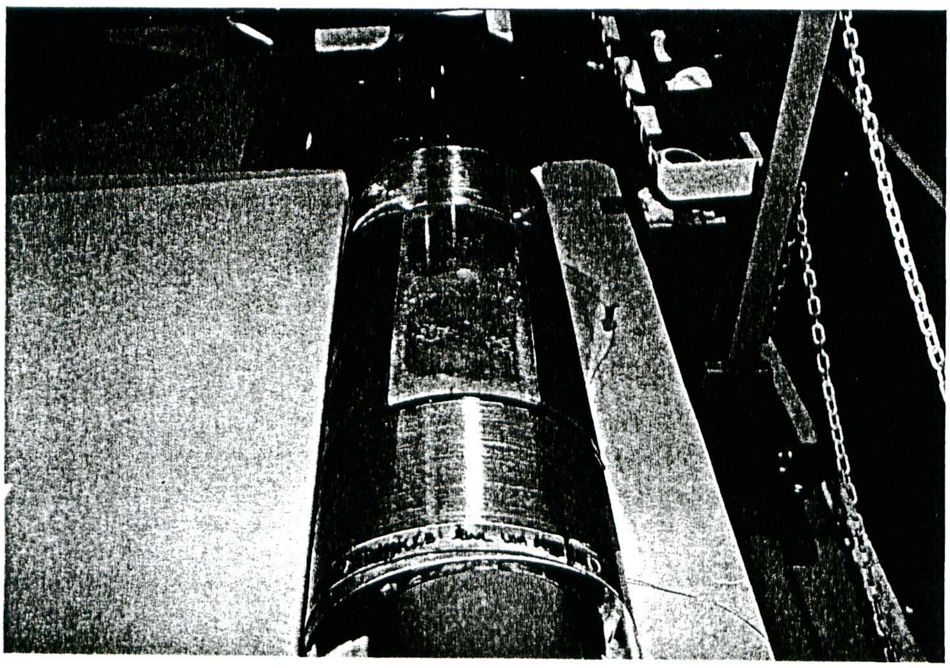
*<u>Main parameters of the dipole coil (H steering)</u>

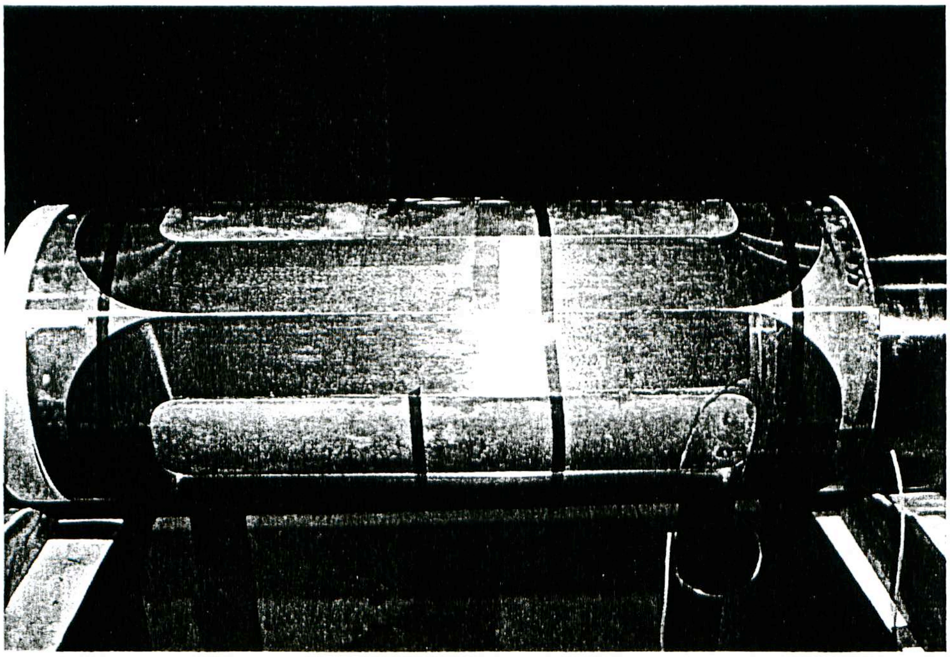
Field		0.056		T
B •L		0.0244		T •m
Current		50		A
Effective length		0.437		m
Stored energy		63		J
Inductance		45.24		mH
Harmonics @ r=4 cm				
	b1	1	± 20 x 10-4	
	b2	- 0.3x10-4	± 2.5 x 10-4	
	b3	- 7.3x10-4	± 5 x10-4	
	b5	- 26.1x10-4	± 0.2x10-4	
	a1	- 4.7x10-4	± 40 x 10-4	
	a2	- 2.8x10-4	± 2.5 x 10-4	
Coil				
	length	564.5		mm
	radius @mid-wire	126.886		mm
	no of turns	213		turns/pole

*Main parameters of the skew dipole coil (V steering)

Field	0.056	T
B •L	0.0242	T •m
Current	50	A
Effective length	0.433	m
Stored energy	54.7	J
Inductance	43.78	mH
Harmonics @ r=4 cm		
a1	1	± 20 x 10-4
a2	- 0.3x10-4	± 2.5 x 10-4
a3	- 8.9x10-4	± 5x10-4
a5	- 27.4x10-4	± 0.2x10-4
b1	- 4.7x10-4	± 40 x 10-4
b2	- 2.9x10-4	± 2.5 x 10-4
Coil		
length	560	mm
radius @mid-wire	125.159	mm
no of turns	211	turns/pole







Cryostat

- The diameter of the front end was reduced to keep more realistic space between the cryostat and the physics detector.
- The length of the support rod was shortened from 75 mm to 67 mm.
  The increase of the heat load due to this change is < 0.5W.

Excitation circuit

- The design of the excitation circuits was fixed, and the fabrication of the power supplies started.
  QCS-R and QCS-L will be excited in series with one power supply and the other coils will be excited by their own power supply.

Cooling system

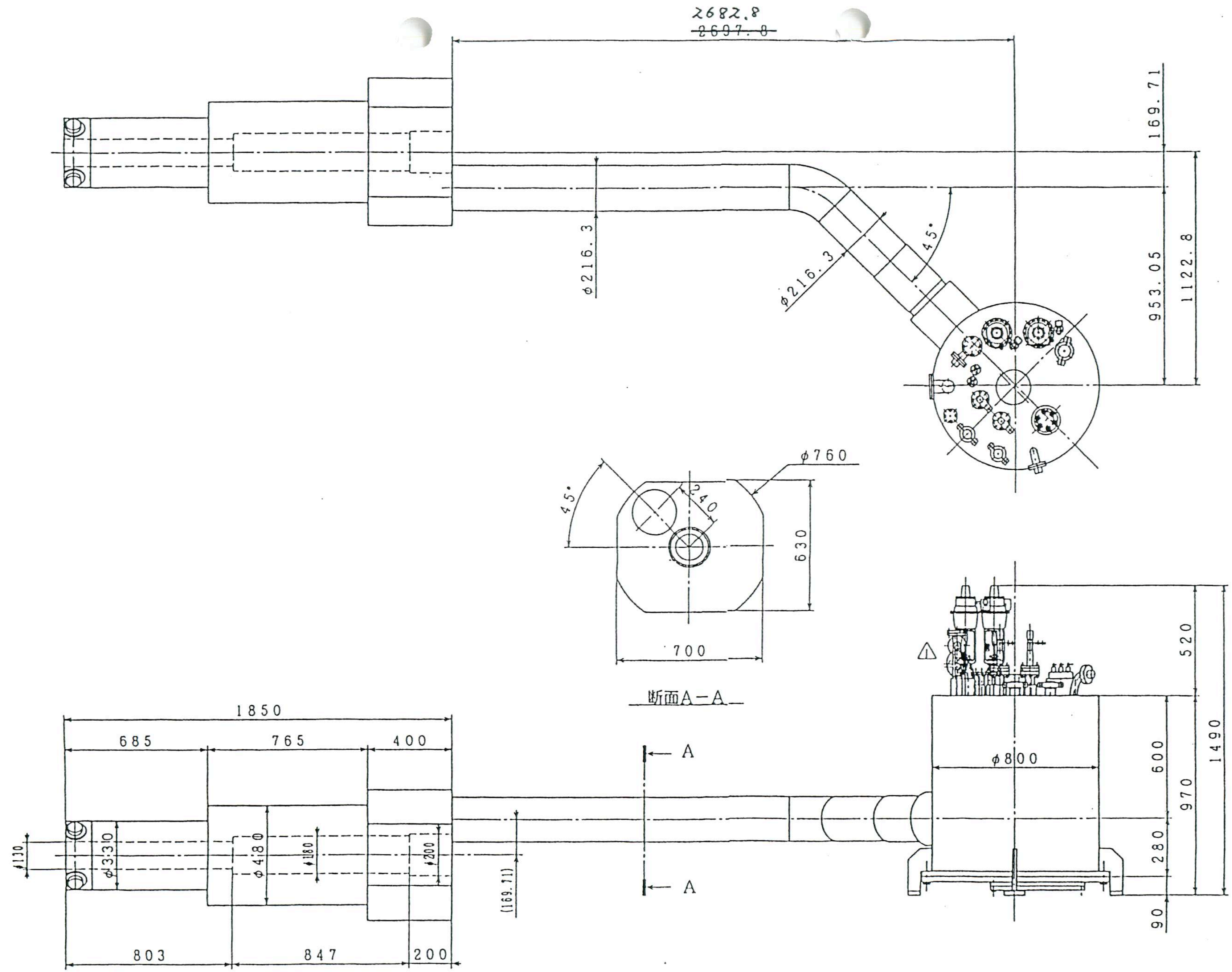
- Layout of the cryogenic equipment was fixed.
- The transfer lines are in fabrication stage.
- A refrigerator, which has been used for the TRISTAN mini-beta quadrupole, will be reused for this system.

*Estimated heat loads

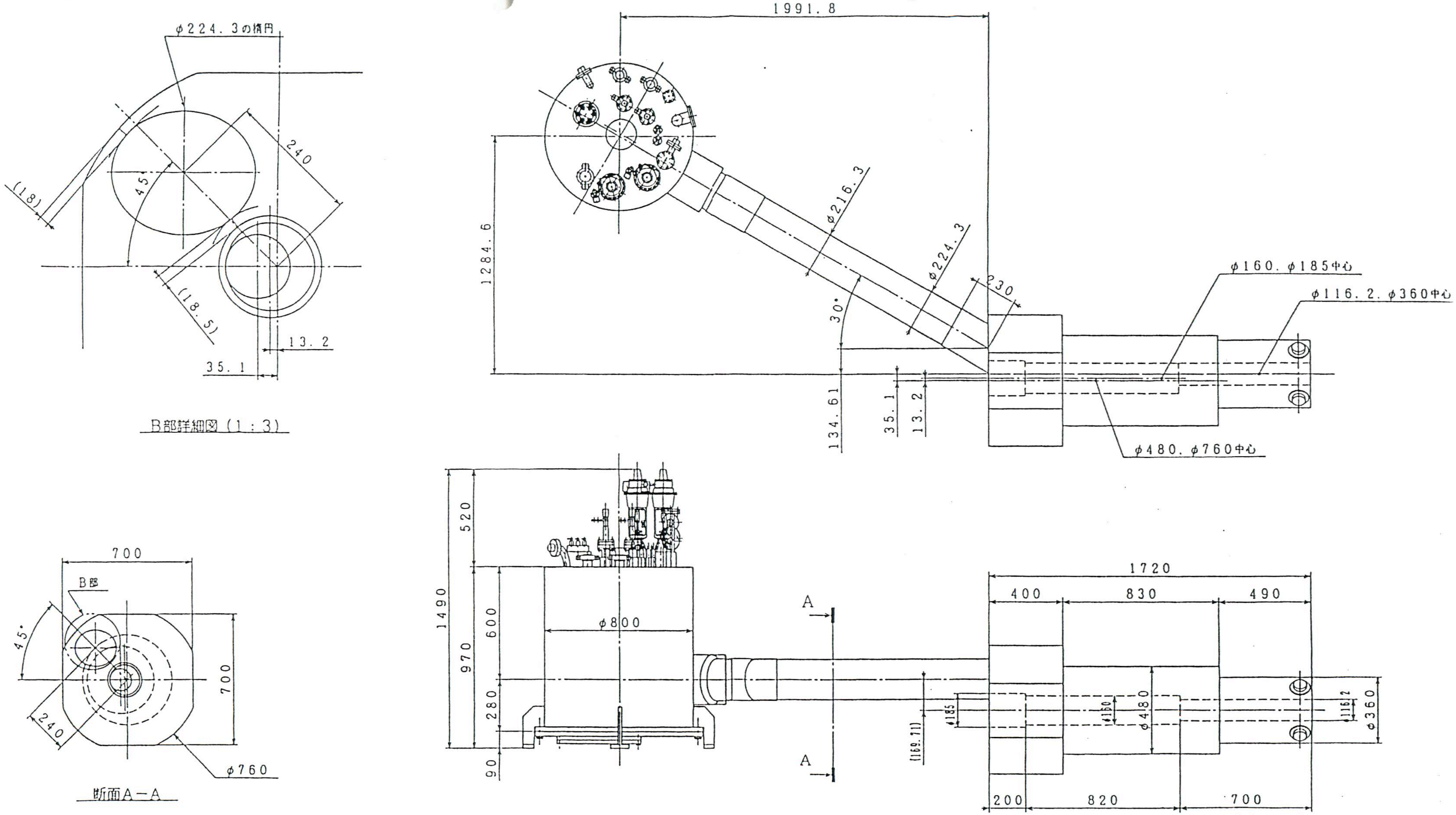
a) Current leads			
	QCS	main leads	14 L/h
		auxiliary lead	1 L/h
	ESR, ESL		7 L/h
	Correctors		7 L/h
b) Cryostats (right side and left side)			
			35 W
c) Transfer line			
	multi-channel TRT (25m)		25 W
	connection TRT		21 W
	Total		29 L/h + 81 W

*Measured capacity of the existing refrigerator(TRISTAN mini-beta quad)

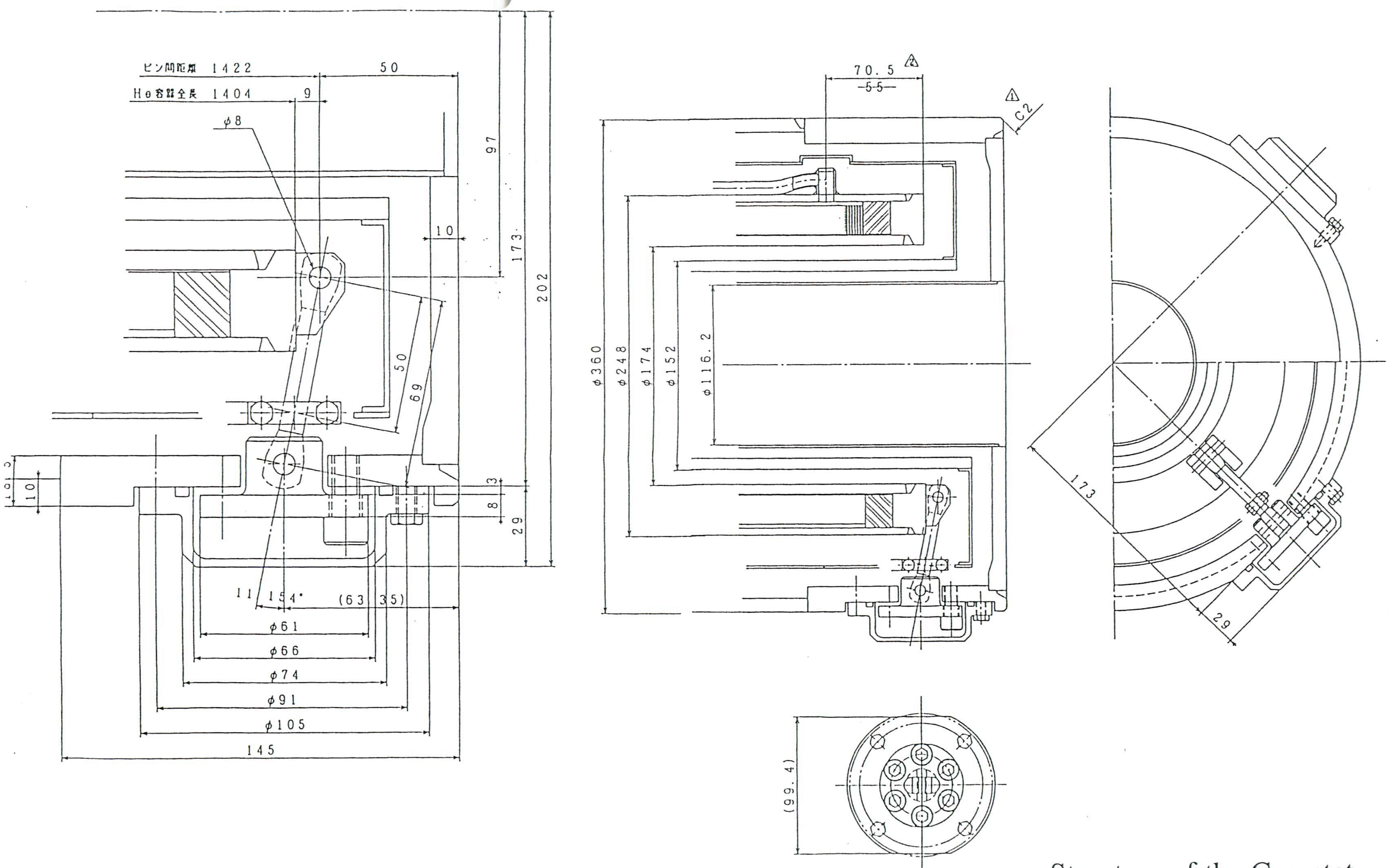
30 L/h +150 W (970 Nm3)
30 L/h + 193 W (1050 Nm3)



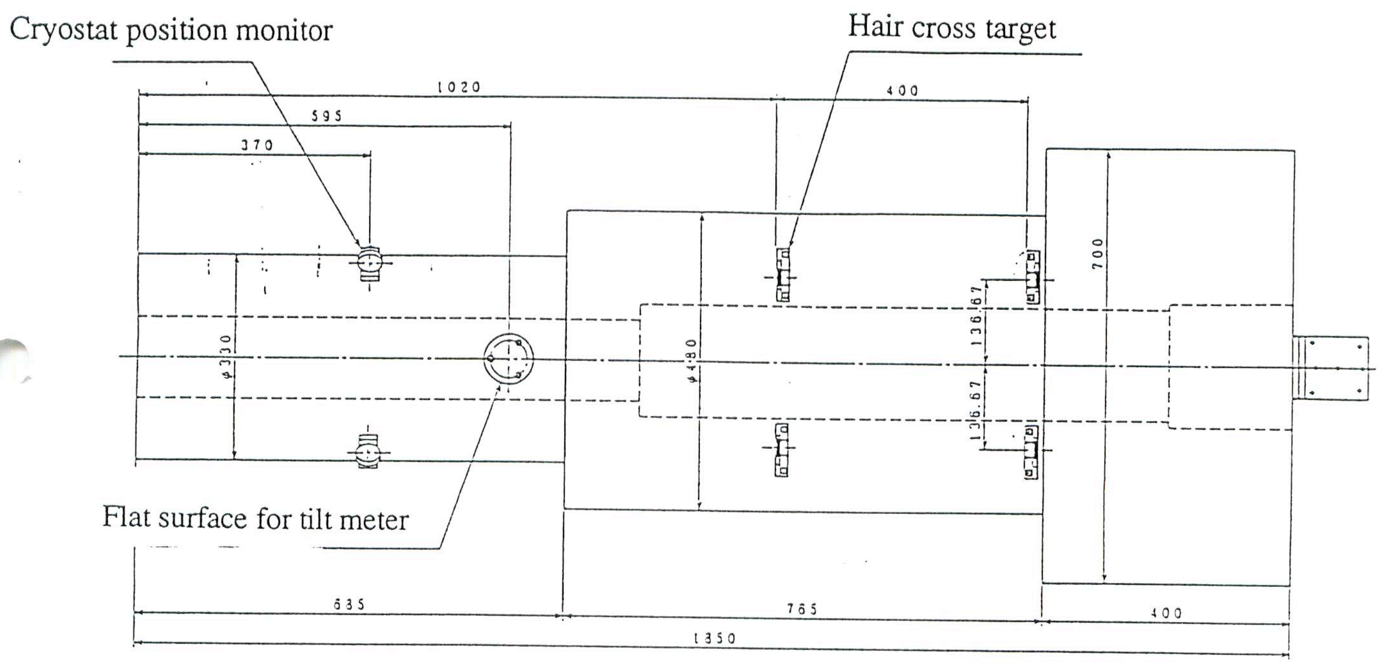
Forward (Right Side) Cryostat 1997.01.16



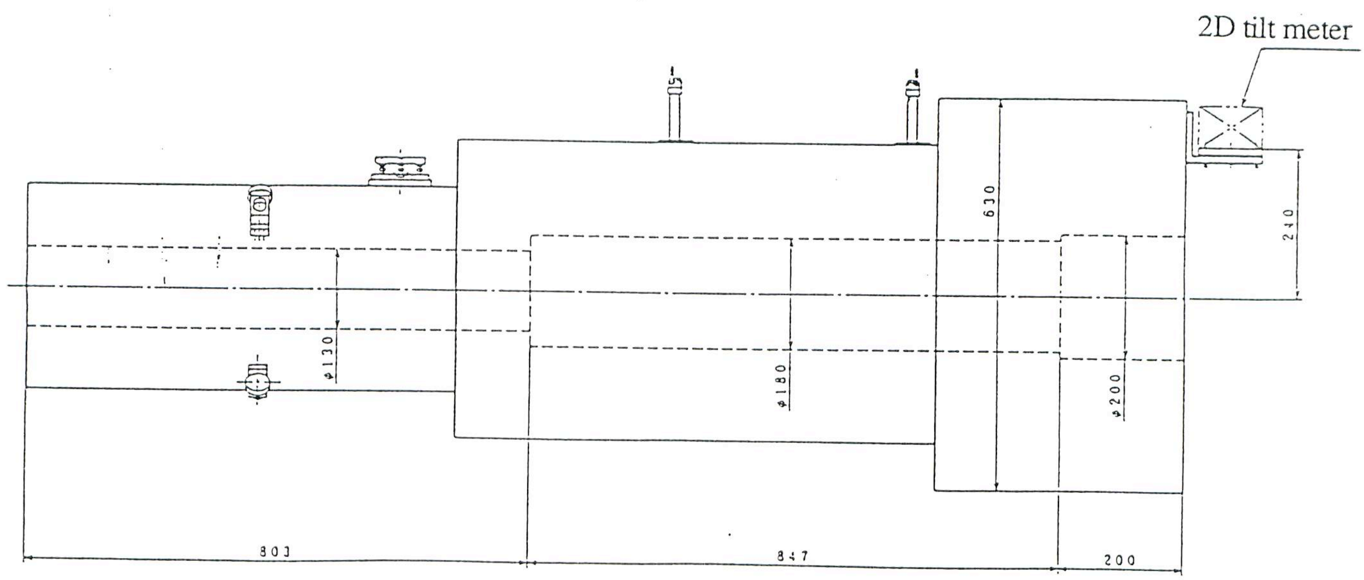
Backward (Left Side) Cryostat 1997.01.16



Structure of the Cryostat

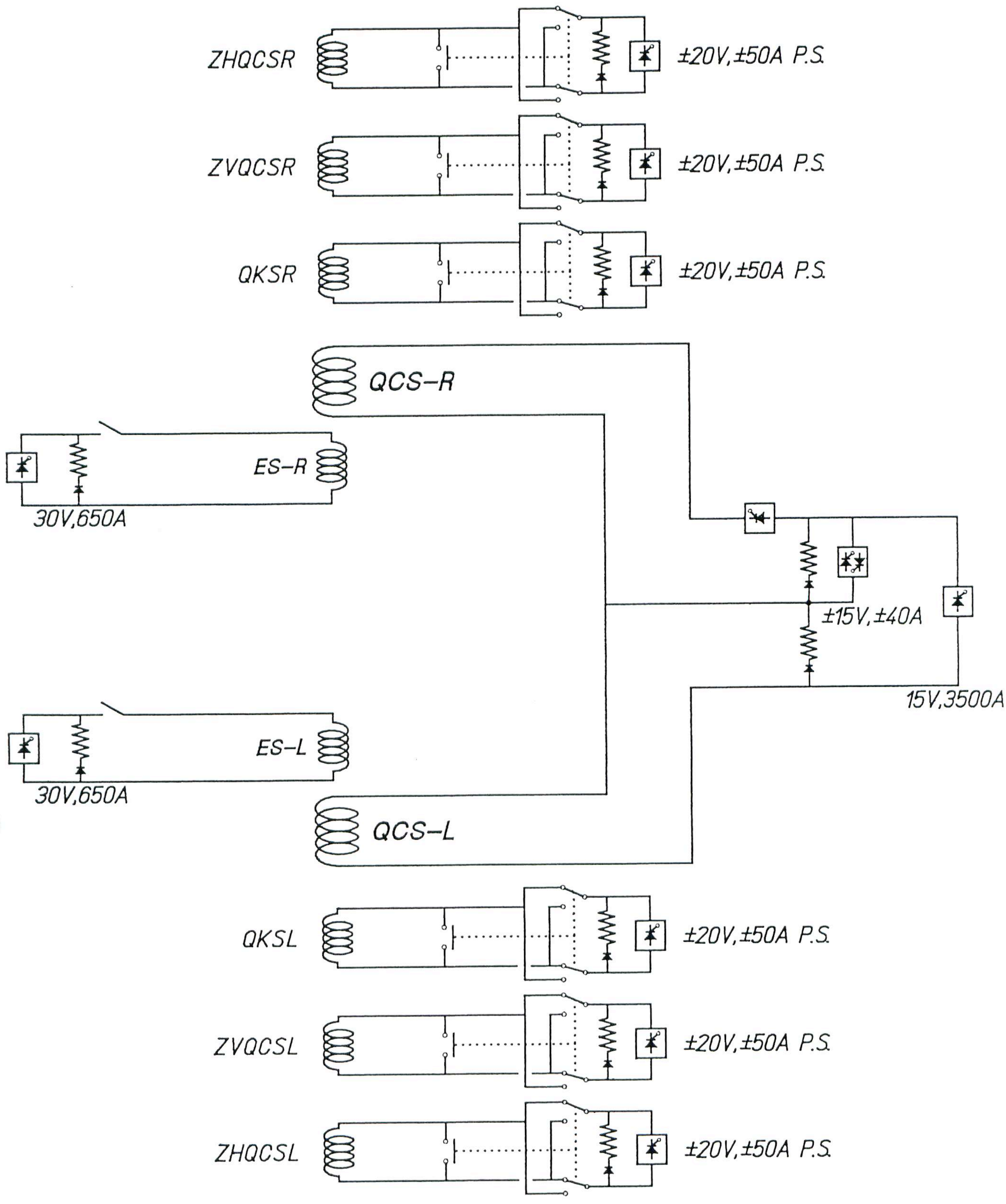


Top view of the cryostat

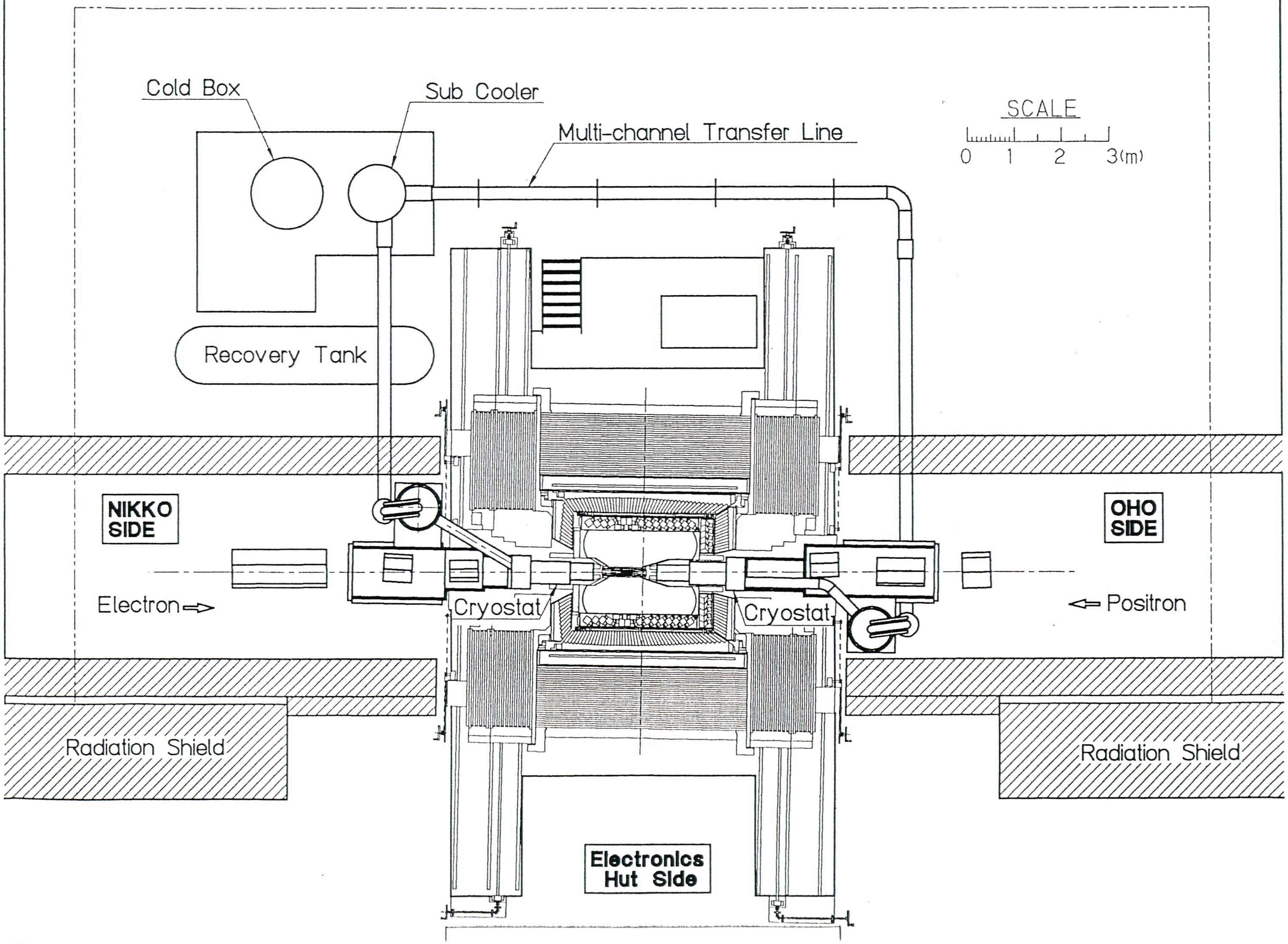


Side view of the cryostat

Equipment for Cryostat Alignment


ZHQCSR
±20V,±50A P.S.
ZVQCSR
±20V,±50A P.S.
QKSR
±20V,±50A P.S.
QCS–R
ES–R
30V,650A
±15V,±40A
15V,3500A
ES–L
30V,650A
QCS–L
QKSL
±20V,±50A P.S.
ZVQCSL
±20V,±50A P.S.
ZHQCSL
±20V,±50A P.S.

Layout of Cryogenic Equipment



KEKB IR Superconducting Magnets Schedule

Dec. 16 '96