CESR IR design

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Phase III upgrade motivation

- To increase long range beam-beam interaction limit caused by the first parasitic crossing (2.1m from IP).

$$\text{Long range beam-beam limit} \propto \frac{S^2}{\beta_y \sigma_x^2} \sim \frac{S^2}{\beta_y \beta_x} \frac{1}{\varepsilon_x}; \text{(empirical law)}$$

S - beam separation; σ_x - horizontal beam size; $\beta_{x,y}$ – beat function

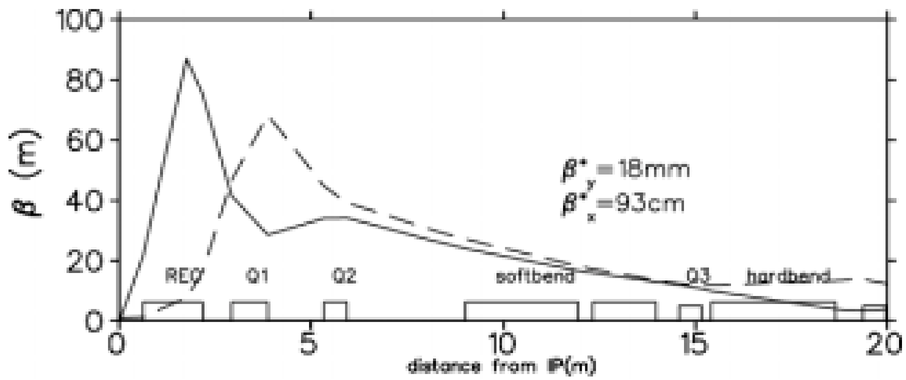
- To reduce vertical beta function at IP.

$$L_{\max} \propto \frac{\xi_x \xi_y}{\beta_y}$$

- To extend CESR energy operation range.

Phase III upgrade motivation

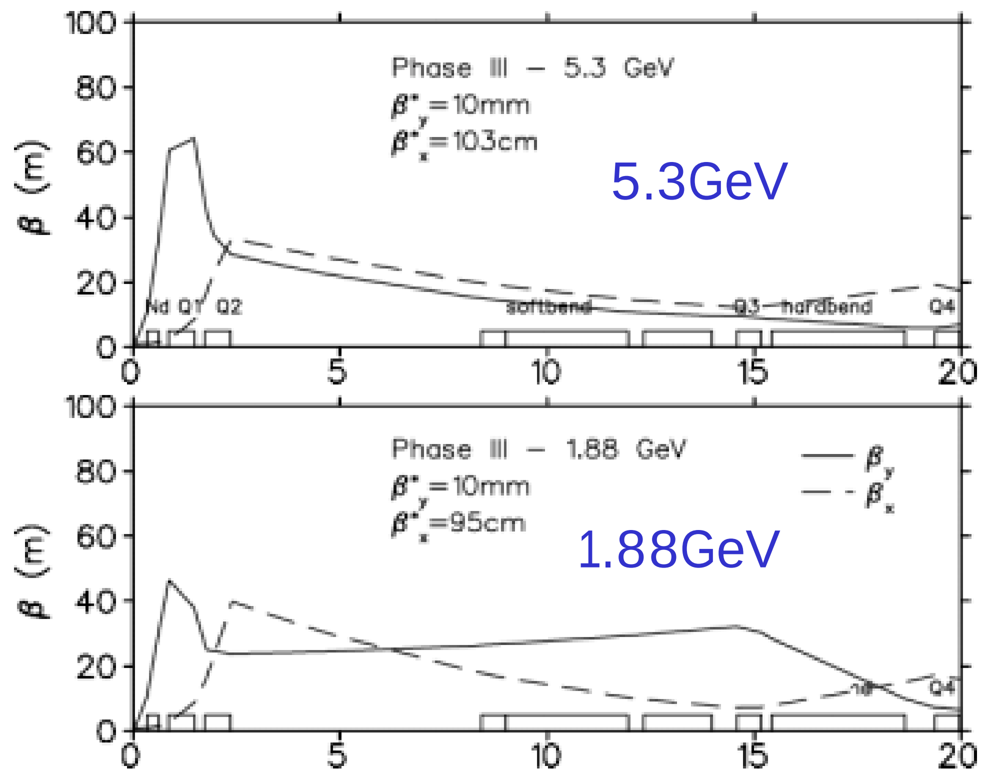
Phase II final focus, 1996-2001



	βy	βx
IP	18mm	93cm
1-st PC	~50m	~50m

Planed improvement:
Imax X 2.8, Lmax X 1.8

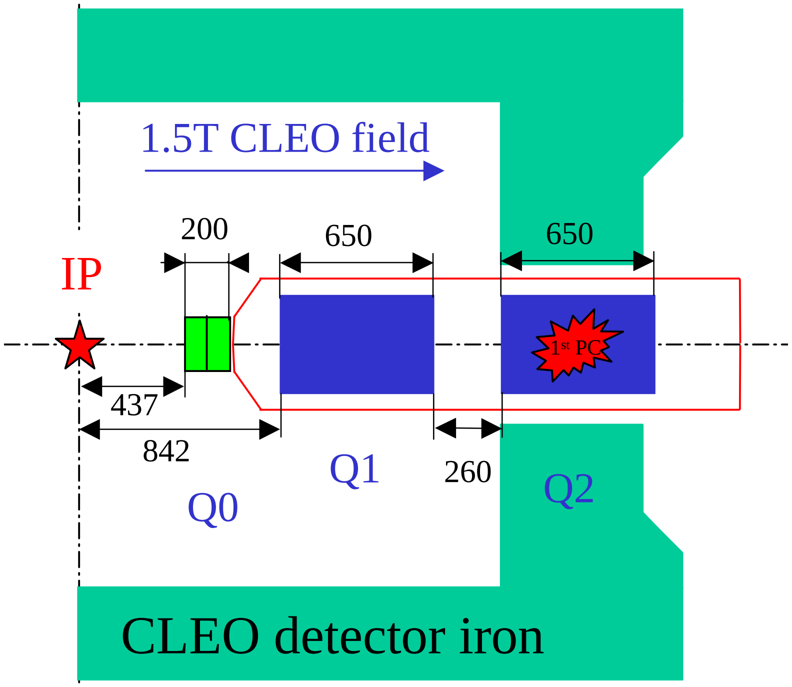
Phase III final focus, 2001 - ...

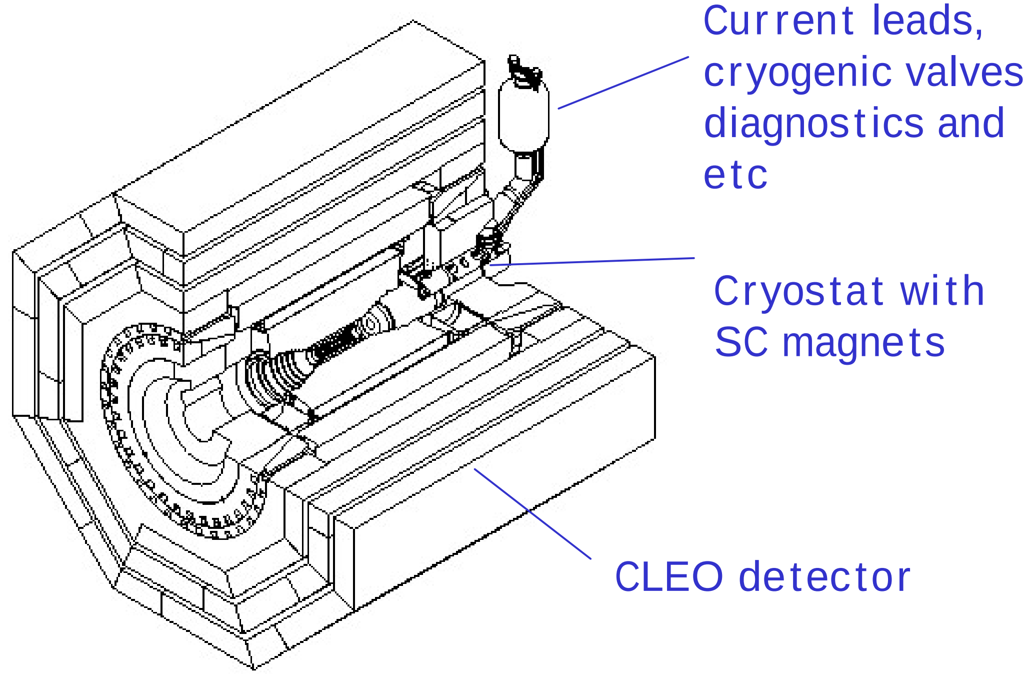


	βy	βx
IP	10mm	103cm
1-st PC	~30m	~30m

CESR Phase III IR layout.

CBN97-21, James J. Welch, Gerald F. Dugan, Emery Nordberg and David Rice, The Superconducting Interaction Region Magnet System for the CESR Phase III Upgrade.





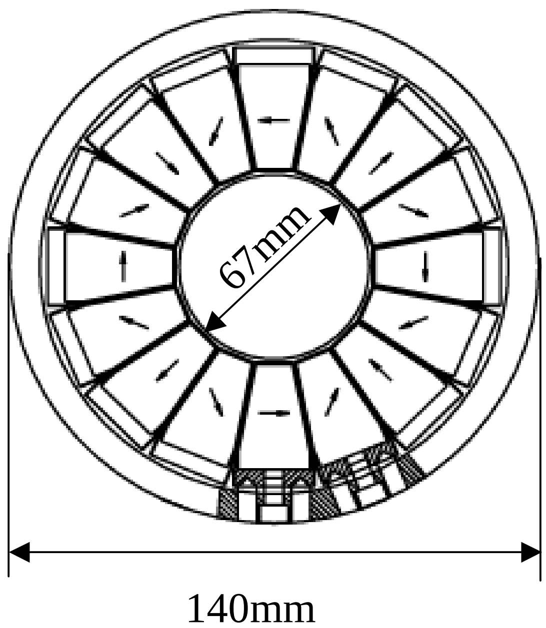
Magnet	F/D	Type	L[mm]	ID [mm]	G[T/m]	Manufactured in
Q0	D	Permanent magnet	184	67	32	Lab
Q1	D	Super-Conductive	650	145*	48	TESLA Engineering Ltd, UK
Q2	F	Super-Conductive	650	145*	48	

* warm bore inner diameter

Permanent magnet quadrupole (Q0)

W. Lou, D. Hartill, D. Rice, D. Rubin, J. Welch, Permanent Magnet Quadrupoles For CESR Phase-III Upgrade. In Proc. PAC97, p. 3236

- Material: Neodymium Iron Boron (NdFeB). Can sustain to 1.5T of the reversal CLEO field and cheaper than SmCo
- Pole field ~1.1T (G = 32 T/m)
- L = 186mm (2 sections x 9.3cm)
- Temperature stability: dG/G ~ - 0.1%/deg
- Field Quality: ~ 5e-4 multipole field error (dB/B) at 30mm radius

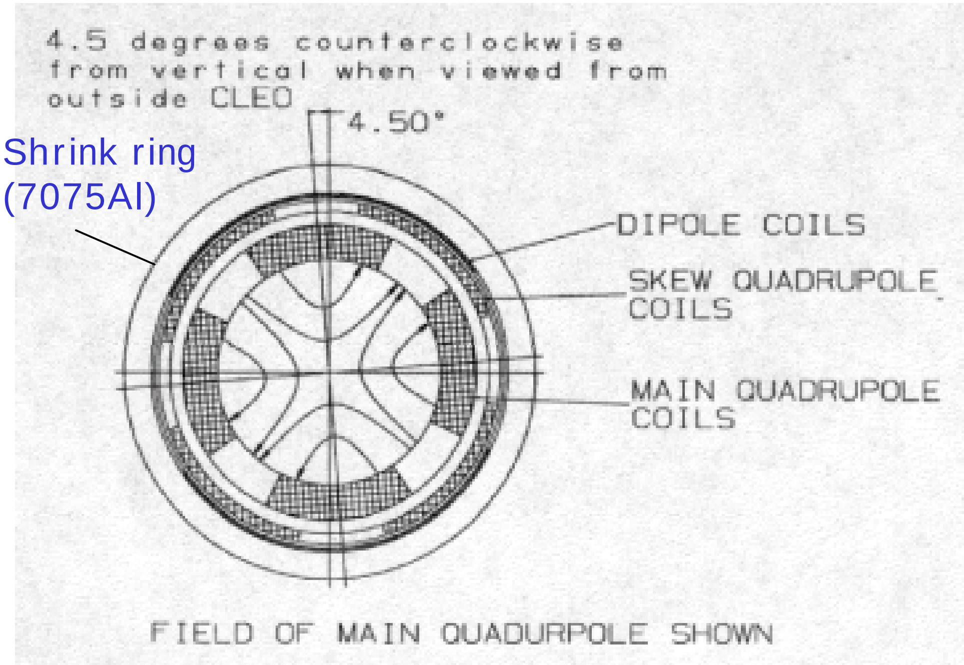


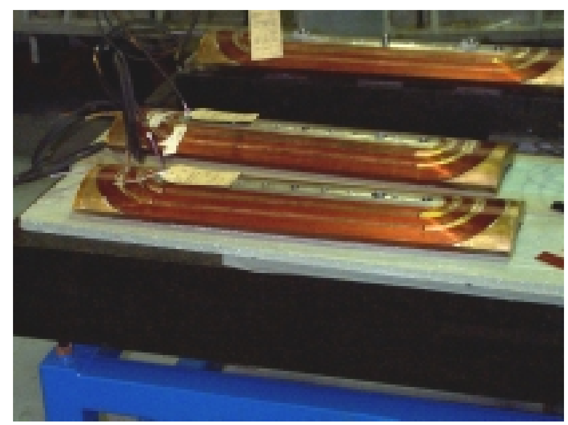
PM quad cross section. Arrows show direction of PM blocks magnetization.

Super-conducting quads (Q1,Q2)

Multi-layer design

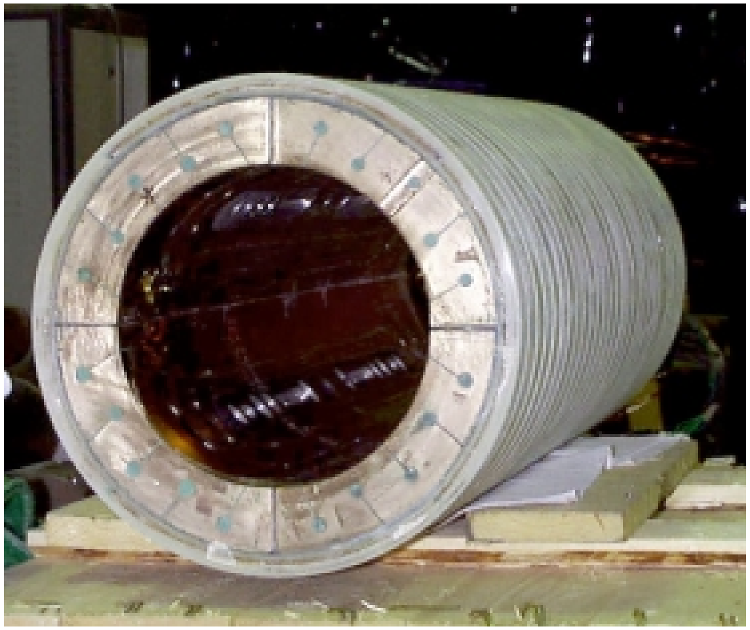
Shrink ring (7075Al)



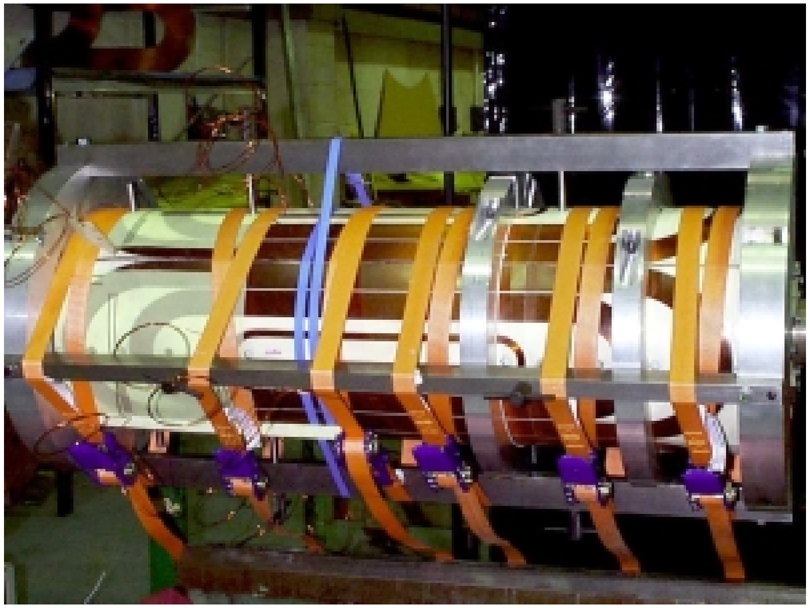


Length = 650mm	ID	Thickness	Max. field/gradient
Main quad coils	184.0mm	37.4mm	48.4 T/m
Skew quad coils	269.4mm	3 layers x 1.27 = 3.81	4.8 T/m
Dipole coils	280mm	1 layer x 1.27	0.13 T

Illustration (1)

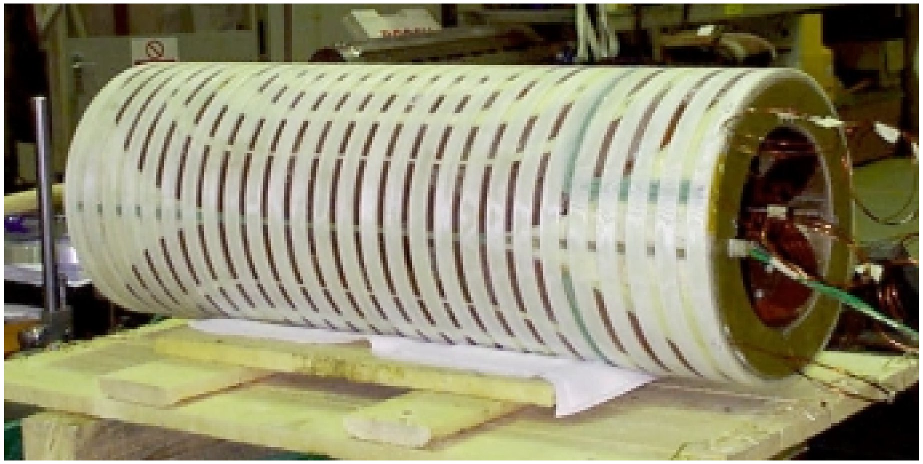


4 quadrupole coils assembly



Skew quadrupole coils attachment

Cold mass assembly, seen dipole coils



Cryostat general characteristics

Warm bore ID = 145mm
OD = 495mm
Length = 2160mm
Heat load < 60W at 4.6K

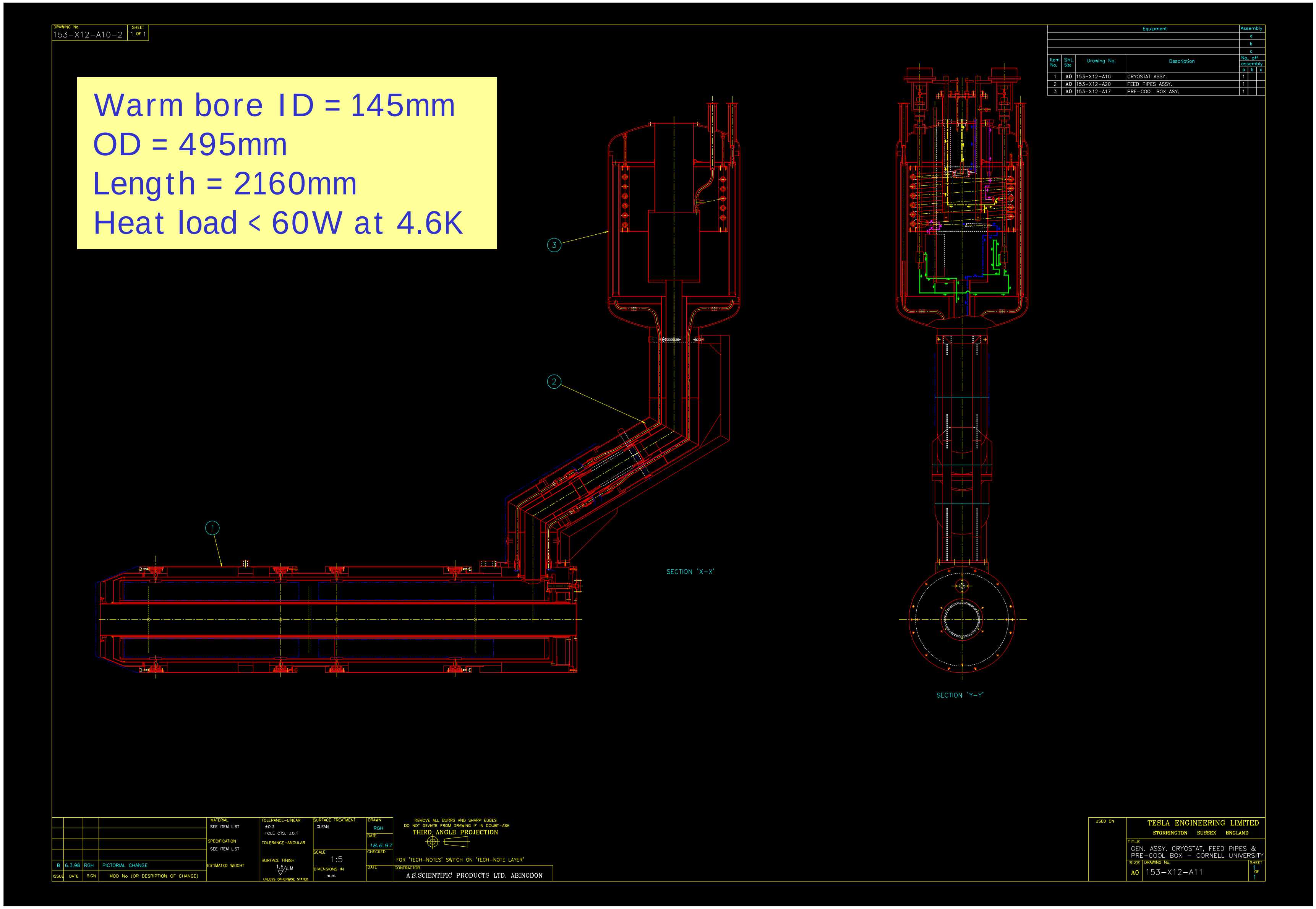


Illustration (2)

Two cold masses
assembly (in TESLA)

Magnets in Cornell

Super-conducting quads: main quadrupole field quality

$$B_y + iB_x = $$
$$= \sum_n (x+iy)^n (b_n + ia_n)$$

Q1: I=1200A
Gl=31Tm/m

Q2: I=600A
Gl=16Tm/m

Multipole field errors are given at 50mm radius.

an, bn	Unit #1	Unit #2	Unit #3	Unit #4	Unit #5
b1	10000	10000	10000	10000	10000
b2	7.0	-29.4	-6.8	5.7	-10.14
b3	1.6	-4.6	-3.4	-5.4	-4.28
b4	0.1	-0.9	-0.9	0.9	-1.87
b5	-8.5	-7.6	-7.5	-6.1	-6.45
b6	0.0	-0.5	0.4	-0.3	-0.37
b7	0.0	0.2	0.1	0.3	-0.25
b8	-0.1	-0.1	-0.3	0.0	-0.08
b9	-0.6	-0.5	-0.7	-0.6	-0.54
a2	1.6	4.8	2.1	-20.6	1.83
a3	2.2	-0.1	-0.4	2.2	-0.65
a4	-1.4	0.4	0.5	1.5	-0.52
a5	1.9	1.3	1.7	0.7	-0.77
a6	0.3	0.4	0.4	0.6	0.12
a7	0.6	0.2	0.5	1.1	0.13
a8	0.5	0.2	0.3	0.4	0.00
a9	0.3	0.3	0.2	0.4	-0.02

Super-conducting quads: skew field quality

I = 245A
Gl = 2.3Tm/m

Multipole error fields are given at 50mm radius.

an, bn	SQ #1	SQ,#2	SQ #3	SQ #4
b1	0.0	0.0	0.0	0
b2	-2.7	-12.21	-7.6	31.5
b3	-1.9	-5.4	-3.8	-2.7
b4	-2.8	-0.3	-1.5	-1.6
b5	1.3	1.5	-5.4	-5.8
b6	-1.0	-0.5	0.7	-0.8
b7	-1.2	-0.9	-0.9	-0.6
b8	-0.9	0.41	0.6	-0.7
b9	-0.7	0.26	-0.8	-0.2
a1	10000	10000	10000	10000
a2	84	4.8	-3.6	17.9
a3	6.1	-0.1	-3.9	-4.2
a4	-0.42	0.4	0.2	-0.4
a6	-2.0	0.4	0.3	2.5
a7	0.34	0.2	0.0	-0.4
a8	0.23	0.2	-0.3	1.0
a9	-0.6	0.3	-0.2	0.4

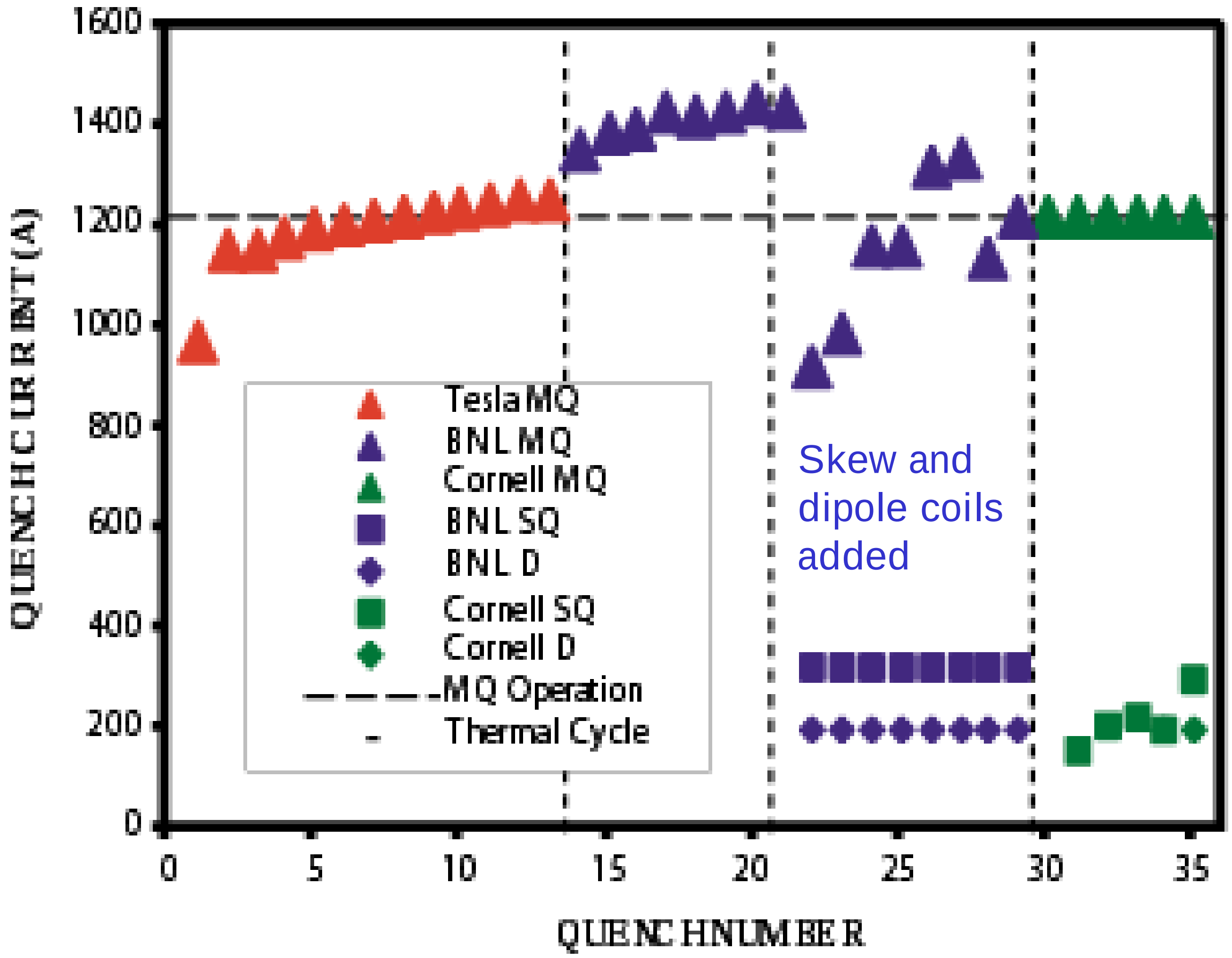
Super-conducting quads: dipole field quality (function is not being used)

I = 195A
Bl = 0.0862Tm

Multipole error fields are given at 50mm radius.

an, bn	D #1	D #2	D #3	D #4
b0	0.0	0.0	0.0	0.0
b1	14.6	-10.9	47.0	316.2
b2	-10.7	21.0	9.0	12.5
b3	-1.0	1.2	-5.5	4.8
b4	-9.5	-9.9	1.0	-5.4
b5	0.2	0.5	-8.1	10.8
b6	3.7	1.9	0.2	2.5
b7	0.3	-0.7	0.0	-0.1
b8	-0.6	-0.7	-0.1	-0.6
a0	10000	10000	10000	10000
a1	25.9	-41.4	29.2	-6.7
a2	-62.8	43.3	12.4	-16.3
a3	1.0	12.0	-5.6	9.7
a4	-17.5	-16.6	-12.5	-11.7
a6	-2.0	0.6	3.9	-3.9
a7	8.34	5.3	2.7	2.9
a8	-0.72	1.0	-0.2	0.9

Super-conducting quads: unit #1 quench history



Project time table

- October 1995, General concept and technical specifications by J. Welch (CBN 95-18)
- February-May 1996, design study and construction ordered to TESLA Engineering Ltd of England.
- October 1997, start main quadrupole coils winding.
- October 1998, four main coil assembly test in TESLA.
- July 1999, prototype test and magnetic measurement in BNL
- April 2000, magnets delivery in Cornell.
- Summer 2001, magnets are installed.

Conclusion

Installation of super-conducting quadrupoles in combination with PM quadrupoles:

1. Improved final focus efficiency: $\beta^{*}y \sim 10mm$, $\beta y_{max} \sim 40m$
2. Increased long range beam-beam interaction limit caused by first parasitic crossing (2.1m from IP).
3. Extended CESR energy operating range from 5 down to 1.8GeV.