BTeV / C0 Interaction Region

Fermilab Accelerator Advisory Committee
Superconducting Magnet R&D

Jim Kerby
Technical Division
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BTeV Interaction Region

Design based on AP studies first completed in 2000 (J. Johnstone, TM-2139)

Q1-Q5 based on LHC IR Quad design, re-optimized for Tevatron installation

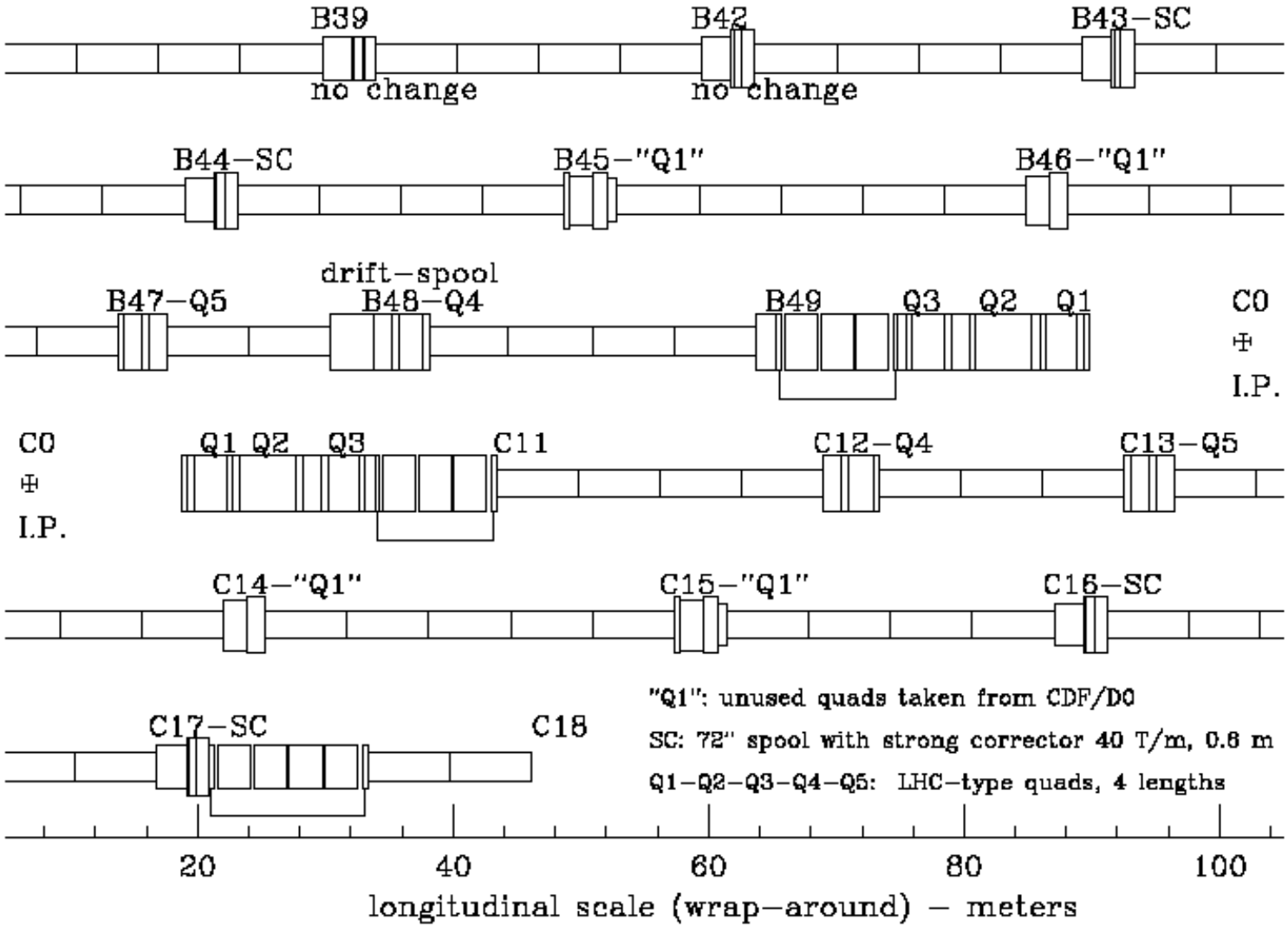
Q6-Q7 are LBQ "Q1", currently unused from CDF and D0

Correction elements are new design

Spools include new correctors, HTS leads, and new space constraints

LOCATION	MAIN QUADS	SPOOL SLOT	TRIMS	STRENGTHS	MISC
Triplets (a) B49 / C11	Q1 /Q3 96.5" Q2 173.5" (LHC)	56.175"	HD + VD SQ	≥0.48 T.m ≥7.5 T.m/m	HBPM + VBPM 10 kA 200 A
B48 / C12	Q4 79" (LHC)	56.175"	HD / VD SQ	0.48 T.m 7.5 T.m/m	HBPM / VBPM 10 kA + 5 kA
B47 / C13	Q5 54" (LHC)	56.175"	HD / VD SQ	0.48 T.m 7.5 T.m/m	HBPM / VBPM 10 kA
B46 / C14 (b)	Q6 55.19" (LBQ)	56.149"	HD + VD SQ	TSP	HBPM + VBPM 5 kA
B45 / C15 (b)	Q7 55.19" (LBQ)	56.149"	HD + VD SQ	TSP	HBPM + VBPM 5 kA 5.024" Spacer
B44 / C16	66.1"	72"	HD / VD Q* Sx	0.48 T.m 25 T.m/m 450 T.m/m^2	
B43 / C17	66.1"	72"	HD / VD Q* Sx	0.48 T.m 25 T.m/m 450 T.m/m^2	

BTeV Interaction Region – Preliminary Layout



Main Quadrupoles

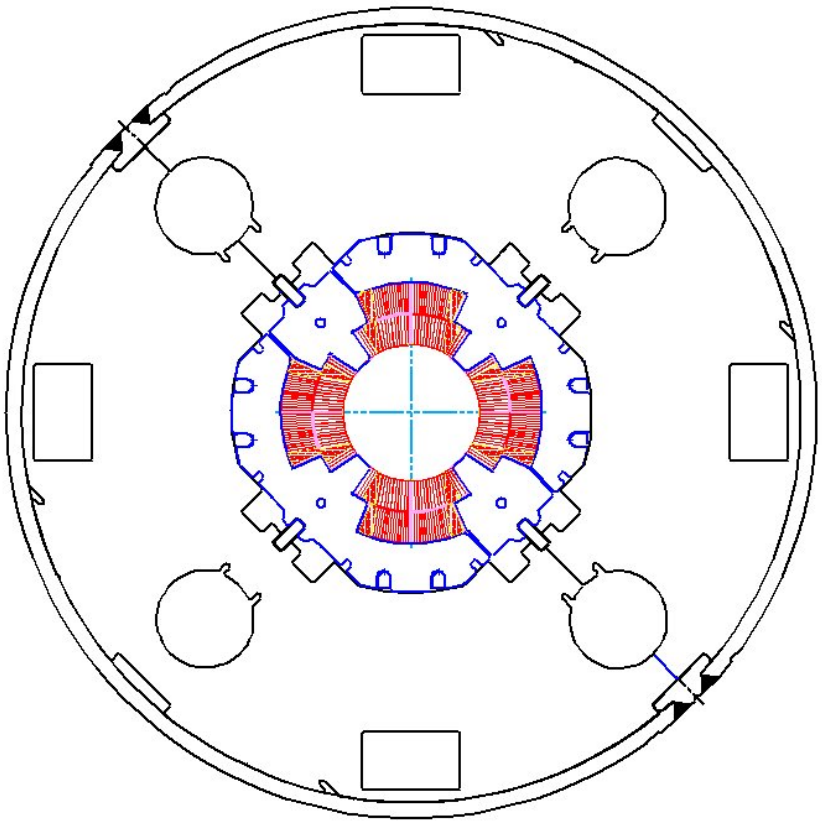
The Main Quadrupoles include “LHC” type magnets for Q1-Q5, relocated FNAL-LBQ magnets for Q6-Q7, and standard lattice quads further out.

The LBQ and lattice quads exist, and can be relocated directly to C0. Adequate spares exist as well.

The Q1-Q5 magnets are a modest redesign of the LHC quadrupoles

- The collared coil assembly remains the same
- Magnetic length(s) shorter than LHC
- Operating temperature of 4.5K instead of 2K
- Re-design yoke & cryostat to accommodate Tevatron beam height (<10.5”)
- Splice and bus design redone for new yoke diameter

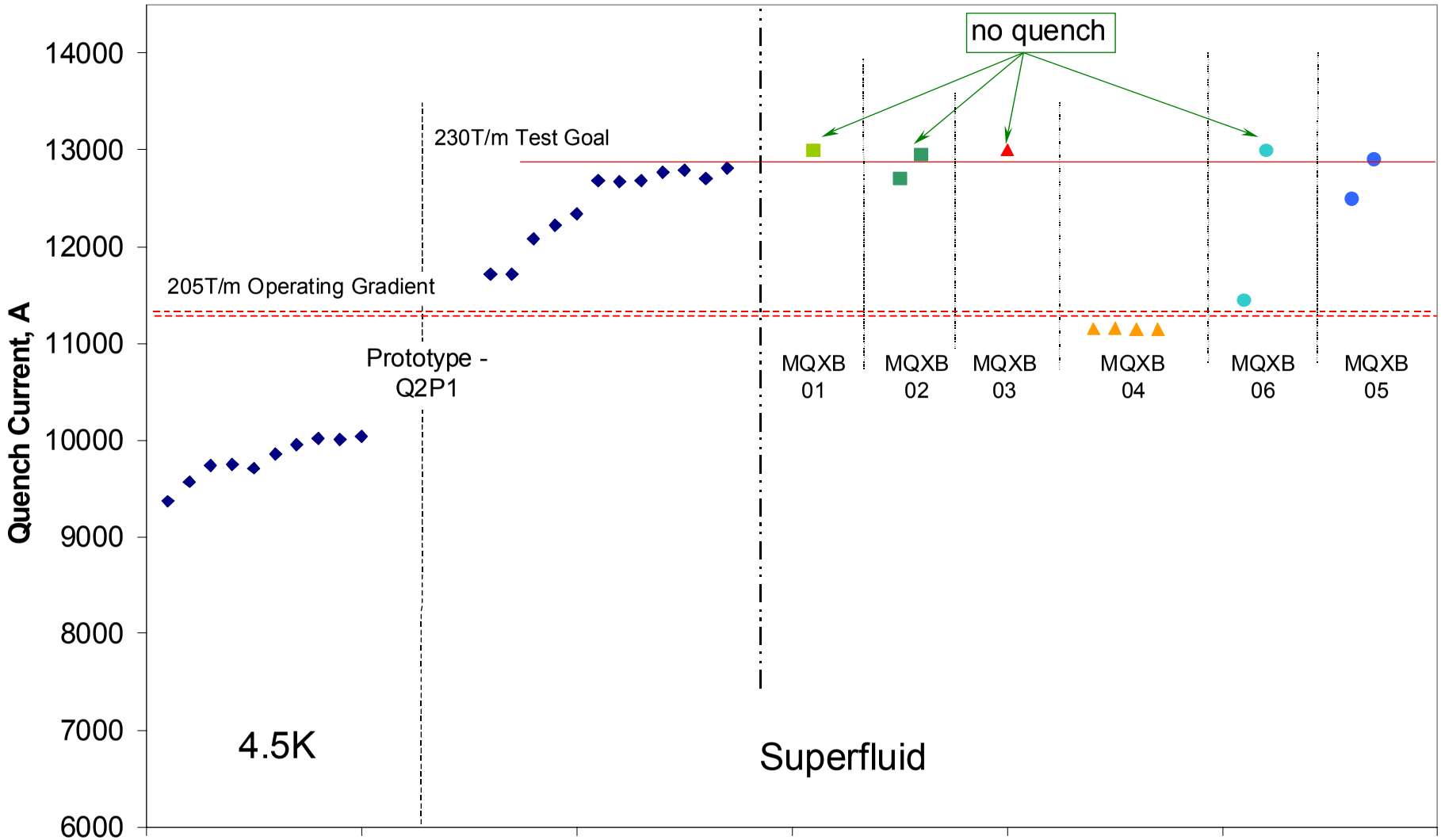
LHC IR Quadrupoles for Q1 – Q5



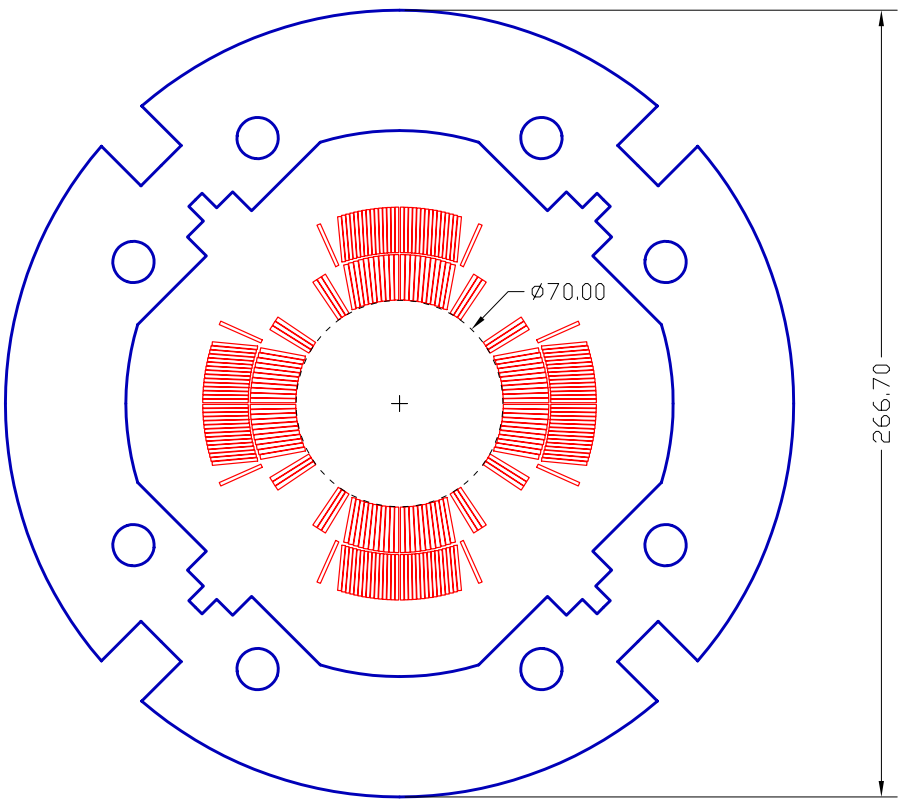
LHC IR Quadrupole Magnet Features

- NbTi Coil; SS collar
- 70mm bore diameter;
- 400mm OD yoke; 416mm OD
- 2K operating temperature
- 205T/m collision gradient
- 215T/m maximum gradient
- 250T/m short sample
- Cryostat designed to accommodate 490mm KEK magnet and external heat exchanger for LHC IR energy deposition

LHC IR Quadrupole Quench Performance

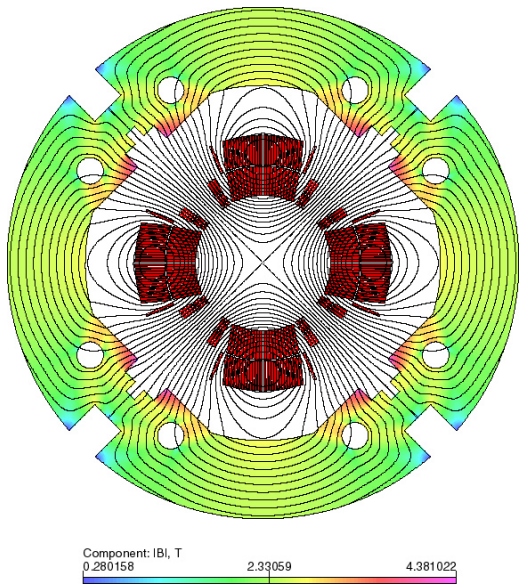


C0 Q1 – Q5 Quadrupoles



LHC optimized for C0:

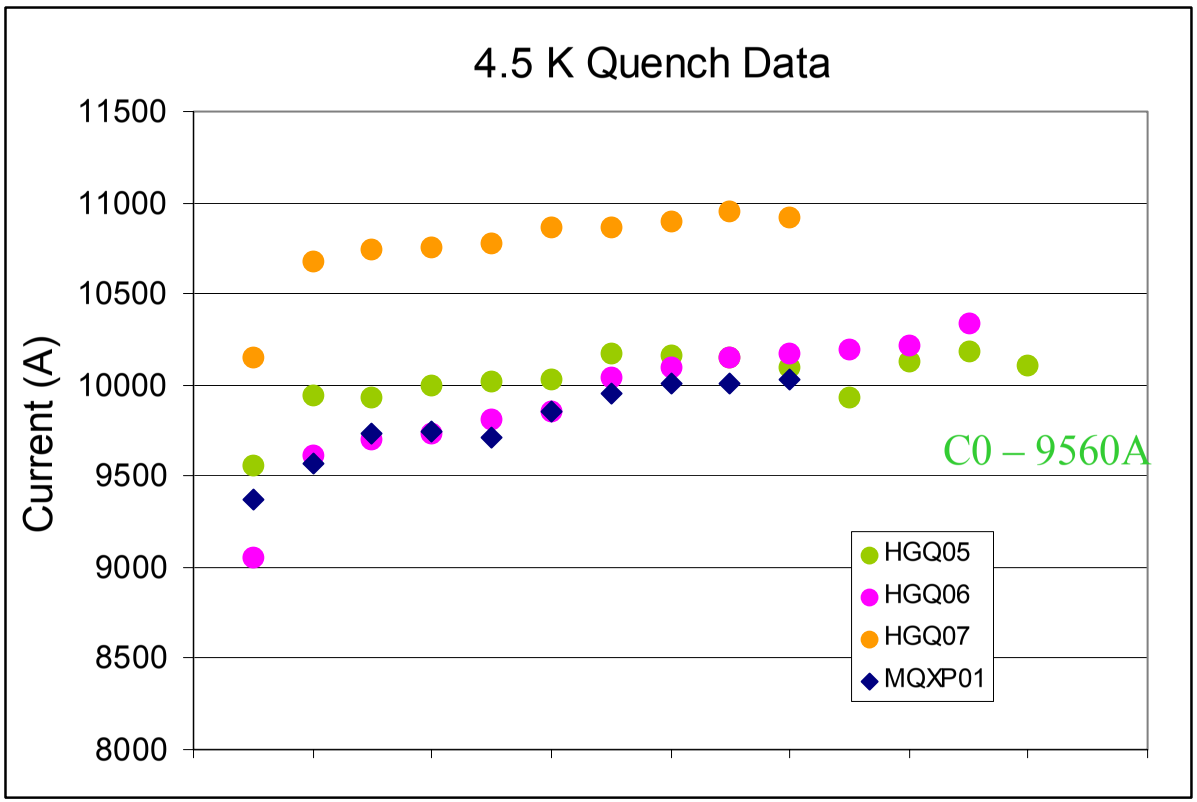
- Coil cross section & mechanical support the same
- Operates at 4.5K
- Iron yoke OD reduced ~130mm
- Beam Height reduced to ~250mm



Main Quadrupoles

Model Magnet (2m long) and Prototype (5.5m) performance at 4.5K exceeds C0 requirements

- No retraining seen



LHC IR Quadrupole Cryostat

Extra radial space
for KEK magnets

External Heat Exchanger for
IP1/5 dynamic heat load

C0 Q1 – Q5 Cryostat Design Considerations

Tevatron beam height must be accommodated

- Avoid tunnel excavation

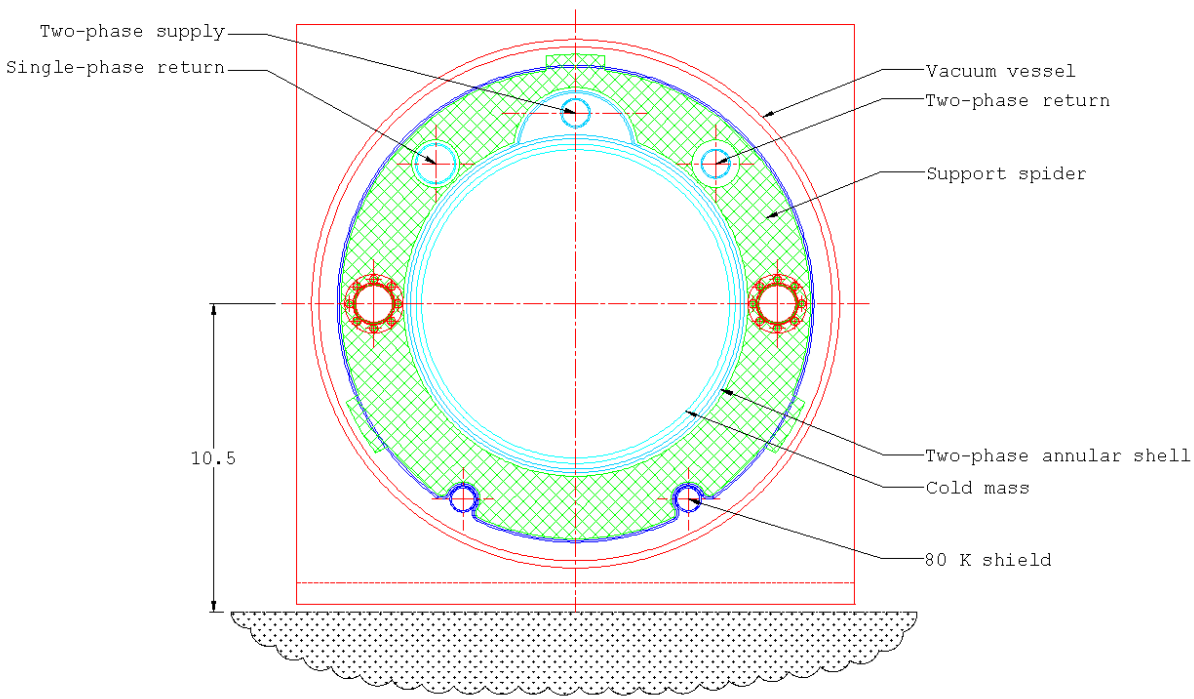
2 phase cooling at 4.5K needs to be incorporated

- Several options, inside and outside the cold mass shell

Interfaces differ depending on location

- Some "Tevatron like"
- Others could be "new"

Real design just starting



C0 Main Quadrupoles - Summary

The Q1-Q5 quadrupoles required for C0 are interpolations of the LHC design

- The quench performance (and field quality) are well understood
- Magnetic lengths are shorter than LHC
- The quadrant splices and end support (external to the coil) must be redesigned to reduce the diameter
- The cryostat should be much reduced in diameter, to limit or eliminate civil (re)construction needs
- Interface details need to be worked out
- Production parts and effort are well understood based on LHC experience
- Preliminary procurements could start now

The Q6-Q7 and further quadrupoles, are FNAL- LBQ and lattice quads required are relocated from unused positions elsewhere in the tunnel or (literally) off the shelf.

Correction Elements / Spools

The C0 IR requires four different correction elements, packaged in five (seven?) different spools

- Existing TSP spools are moved w/ the LBQ Q1s at Q6/Q7 positions

Correction element AP requirements are not yet fixed

Details of Tevatron interfaces not yet completely understood

Components include technical hurdles

- Magnet designs
- HTS Leads

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Triplets [a] B49 / C11	Q1 /Q3 96.5" Q2 173.5" (LHC)	56.175"	HD + VD SQ	≥0.48 T.m ≥7.5 T.m/m	HBPM + VBPM 10 kA 200 A
B48 / C12 B47 / C13	Q4 79" (LHC) Q5 54" (LHC)	56.175" 56.175"	HD / VD SQ HD / VD SQ	0.48 T.m 7.5 T.m/m 0.48 T.m 7.5 T.m/m	HBPM / VBPM 10 kA + 5 kA HBPM / VBPM 10 kA
B46 / C14 [b] B45 / C15 [b]	Q6 55.19" (LBQ) Q7 55.19" (LBQ)	56.149" 56.149"	HD + VD SQ HD + VD SQ	TSP TSP	HBPM + VBPM 5 kA HBPM + VBPM 5 kA 5.024" Spacer
B44 / C16 B43 / C17	66.1" 66.1"	72" 72"	HD / VD Q* Sx HD / VD Q* Sx	0.48 T.m 25 T.m/m 450 T.m/m^2 0.48 T.m 25 T.m/m 450 T.m/m^2	

C0 Correction Magnet Elements

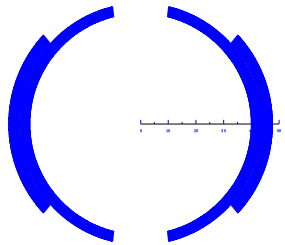
Strengths desired for preliminary C0 optics stronger in most cases than existing Tev spools

Preliminary designs using ‘ribbon’ cable windings have been developed and could be acceptable

Alternative designs of multipole windings being investigated

Manufacturing capability for these elements can be ‘simple’, but does not exist in house at this time.

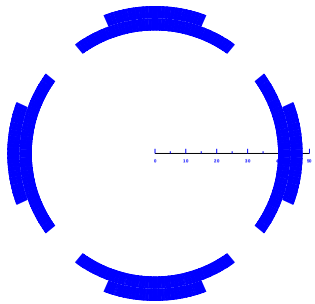
We are in contact w/ other laboratories on these elements (BNL, CERN, LBNL, IHEP…).



MAIN FIELD: -2.72302
NORMAL REL. MULTIPOLES (1.D-4):

b 1:	10000.00000	b 2:	0.00000	b 3:	0.28608
b 4:	0.00000	b 5:	-2.04319	b 6:	0.00000
b 7:	-12.34659	b 8:	0.00000	b 9:	-3.02231
b10:	0.00000	b11:	3.04107	b12:	0.00000
b13:	-0.79544	b14:	0.00000	b15:	0.15444
b16:	0.00000	b17:	-0.04985	b18:	0.00000

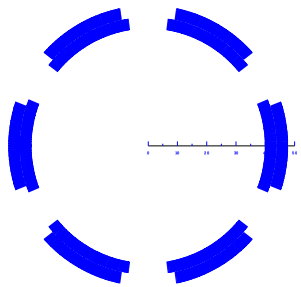
BLOCK NUMBER	1
PEAK FIELD IN CONDUCTOR 142 .(T)	3.113
LOWEST FIELD IN CONDUCTOR 1 .(T)	1.263
SUPERCONDUCTOR CURRENT DENSITY (A/MM^2)	1473.657
COPPER CURRENT DENSITY (A/MM^2)	736.828
PERCENTAGE ON THE LOAD LINE	57.922
QUENCHFIELD (T)	5.374
PERCENTAGE OF SHORT SAMPLE CURRENT	38.904
PEAK FIELD / MAIN FIELD	1.143



MAIN FIELD: -1.32877
NORMAL REL. MULTIPOLES (1.D-4):

b 1:	0.00000	b 2:	10000.00000	b 3:	0.00000
b 4:	0.00000	b 5:	0.00000	b 6:	0.95365
b 7:	0.00000	b 8:	0.00000	b 9:	0.00000
b10:	-3.02539	b11:	0.00000	b12:	0.00000
b13:	0.00000	b14:	0.54676	b15:	0.00000
b16:	0.00000	b17:	0.00000	b18:	-0.18754

BLOCK NUMBER	1
PEAK FIELD IN CONDUCTOR 67 .(T)	2.402
LOWEST FIELD IN CONDUCTOR 1 .(T)	0.820
SUPERCONDUCTOR CURRENT DENSITY (A/MM^2)	1473.657
COPPER CURRENT DENSITY (A/MM^2)	736.828
PERCENTAGE ON THE LOAD LINE	50.818
QUENCHFIELD (T)	4.727
PERCENTAGE OF SHORT SAMPLE CURRENT	35.266
PEAK FIELD / MAIN FIELD	1.808



MAIN FIELD: -0.74201
NORMAL REL. MULTIPOLES (1.D-4):

b 1:	0.00000	b 2:	0.00000	b 3:	10000.00000
b 4:	0.00000	b 5:	0.00000	b 6:	0.00000
b 7:	0.00000	b 8:	0.00000	b 9:	0.43488
b10:	0.00000	b11:	0.00000	b12:	0.00000
b13:	0.00000	b14:	0.00000	b15:	-2.74894
b16:	0.00000	b17:	0.00000	b18:	0.00000

BLOCK NUMBER	1
PEAK FIELD IN CONDUCTOR 39 .(T)	2.196
LOWEST FIELD IN CONDUCTOR 1 .(T)	0.611
SUPERCONDUCTOR CURRENT DENSITY (A/MM^2)	1473.657
COPPER CURRENT DENSITY (A/MM^2)	736.828
PERCENTAGE ON THE LOAD LINE	48.751
QUENCHFIELD (T)	4.504
PERCENTAGE OF SHORT SAMPLE CURRENT	34.332
PEAK FIELD / MAIN FIELD	2.959

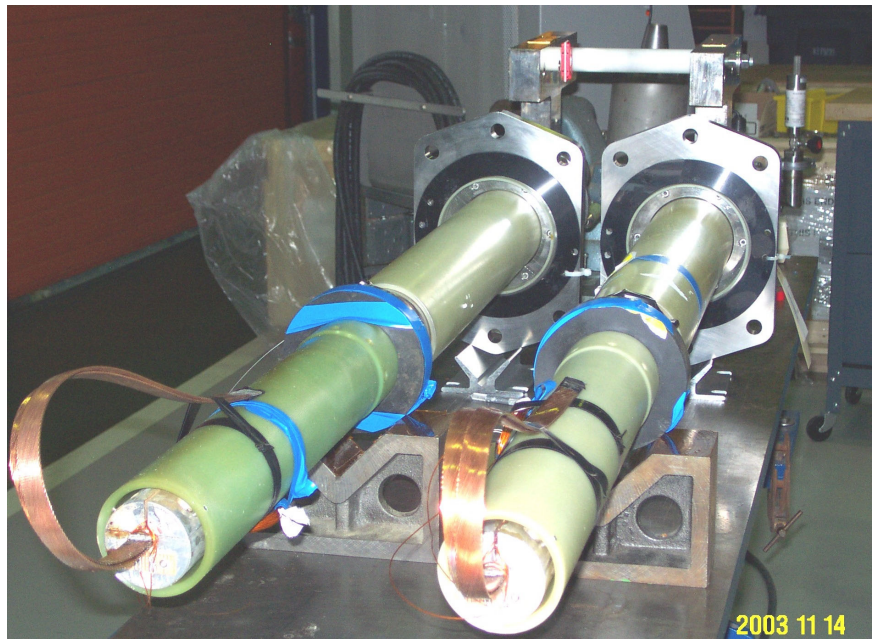
C0 IR / HTS Leads

10kA and 5kA HTS leads are required in the new spools to limit the load to the Tevatron cryogenic system.

5kA (actually 6kA) leads exist, having been developed by FNAL / industry partnership several years ago.

10kA leads do not exist. Tests are needed to confirm that the existing 6kA design either will or won't extend to this current.

- If successful, we need to procure more of the same design
- If not, a new design must be developed and proven.



Correction Elements / Spools

For just the installed components (no spares), this requires:

- 12 dipoles; 6 normal/skew quads; 4 sextupoles; 4 ‘strong’ quads
- 6 pair 10kA leads; 2(?) pair 5kA leads
- 5 (7?) related but different spool assembly designs, need 2 of each

Typically for Tevatron components there would be a completed assembly available “off the shelf” for installation in case of a failure

- This would increase the total spool count from 14 to 21

There are vendors capable of making each of the major components (magnetic elements and leads), and the final assemblies

- This requires the interfaces be well known and understood up front
- The lead time for the procurement process must be factored in
- Initial contacts with the vendors need to start soon; for the moment there is great uncertainty in the cost and their level of interest

Magnetic Elements - Schedule

The "LHC" style quadrupoles will occur in series with the FNAL-LHC effort.

- No interference with production tooling or LHC tests
- Lead time on parts in some cases 1 year…certain procurements could start now. Some reqs are in preparation
- Final tested assemblies could be ready for installation in mid-2008

The correction elements / spool pieces need to converge to a optimized technical and economical baseline

- We have a 'working' technical baseline (a good start)
- There are many details to work out and iterate upon
- Trade offs of magnetic elements and options need to be explored
- Initial conversations with vendors must occur soon (LHC experience helps here as well)
- Having tested and completed assemblies before mid-2008 likely a challenge

Lead times on infrastructure and some materials will drive the schedule very soon

BTeV / C0 Interaction Region

An active working group exists

- The P5 recommendation, and the recent Director's Review suggest that it's life expectancy is > 2 months.
- The IR effort has leaders appointed in BD and TD
- There is an active working group with the right sorts of people

The main quadrupoles are interpolations of an existing, proven design

- There are many details to work out

The spool pieces have great uncertainty associated with them

- AP requirements
- Execution of magnetic design and production
- HTS leads
- Integration

We are working toward a technical baseline, in preparation for a baseline review next summer

- There are multiple intermediate reviews over the next months