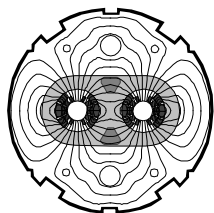


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the
**Large
Hadron
Collider**
project

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Date: 2004-02-25

Interface Specification

LBRS CRYO-ASSEMBLIES – D3 DIPOLES

Abstract

The superconducting D3 magnet consists of an LBRS cryo-assembly containing an MBRS magnet. Two LBRS cryo-assemblies, plus one spare, will be built. The installation locations are IR4L and IR4R. This document specifies the interfaces of the LBRS cryo-assemblies at the lead end to which the QQS will be attached, and at the non lead end to which the undulator magnet will be attached. The interfaces to the support jacks and alignment systems are also specified.

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0.1	2003-10-15	All	Submission for approval.
1.0	2004-02-11	9	Updated Figure 5 to reflect heat shield changes.
		10	Added text to describe heat shield configurations at lead and non-lead ends.
		12	Updated Table 2 to reflect new end configurations and position of heat shield lines e1 and e2.
		21	Added caption to Figure 14 to indicate view is from above.
		23	Revised footnote e of Table 6, -02 m/c bus duct capped at 10161.7 (was 10187.2).
	2004-02-25	all	Released version

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1. INTRODUCTION

Each superconducting D3 dipole cryo-assembly (LBRS) will be a dual aperture assembly comprised of two single aperture cold masses in a common vacuum vessel. Each cold mass (MBRS) contains a RHIC-type coil assembly [1],[2],[3], [4]. The D3 magnets, along with D4 magnets, are used at IR4 to increase the separation of the beams of the LHC from the nominal spacing of 194 mm to 420 mm so that individual RF cavities can be installed for each beam. The beams are then returned to the nominal 194 mm spacing [1].

Three D3 magnets will be built, one to be located on each side of IP 4, plus one spare. One side of the region is shown in Figure 1. D3 magnets operate at 4.5K in two-phase helium.

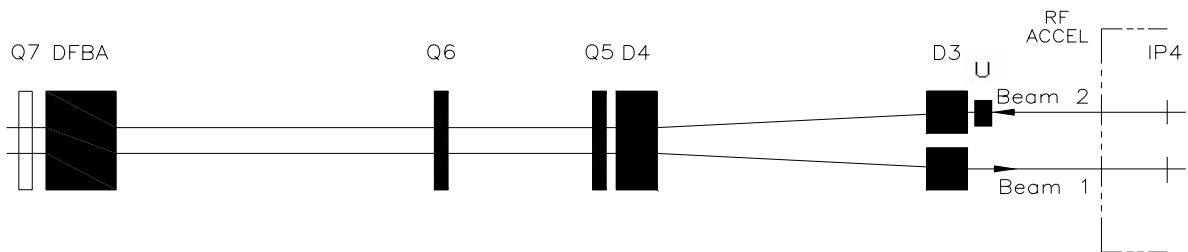


Figure 1 *Layout of D3 and D4 in the left side of Intersection Region 4. D3 and D4 change the beam separation from 194 mm to 420 mm.*

All three D3 cryo-assemblies are identical. The left side cold mass, as viewed from the lead end of the magnet (beam 2 in Figure 1), will be configured to enable CERN to attach an undulator magnet ("U" in Figure 1). The D3 cryo-assembly is turned 180° for use on the opposite side of the IP. The one spare D3 is built to replace either of the two installed units.

2. GENERAL SPECIFICATIONS

The LBRS cryo-assemblies use 8 cm aperture RHIC cold masses (but without sagitta), which employ the stressed yoke design as a collar rather than separate collared coils. There are two such cold masses in an LBRS cryo-assembly. The cryostat for D3 is 914mm (36 in) in diameter, the same as the LHC arc dipole. Table 1 contains a summary of the LBRS parameters.

Table 1 Specifications of the LBRS Cryo-assemblies

Item	Value
Quantity + (Spares)	2 + (1)
Operating Temperature	4.5 K
Beam Tube OD / ID	73 / 69 mm
Cold Mass Design	1 in 1
Cold Masses per Cryostat	2
Bore Spacing (cold)	414 mm [16.30 in]
Yoke Diameter	267 mm [10.51 in]
Shell Thickness	4.8 mm [0.190 in]
End Plate Thickness	32 mm [1.25 in]
Length (end plate – end plate) (centered wrt cryostat)	9.72 m [382.7 in]
Length (end volume – end volume) (not centered wrt cryostat; 100mm shorter at NLE)	10.13 m [398.8 in]
Cold Masses per Cryostat	2
Cryostat Length	9.646 m [379.75 in]
Cryostat Diameter	914 mm [36 in]
Cryo-assembly Mass	12020 kg [26440 lb]

3. GENERAL LAYOUT

3.1 CRYO-ASSEMBLY CROSS SECTION

The LBRS (D3) cryo-assembly cross section, as viewed from the lead end of the magnet, is shown in Figure 2.

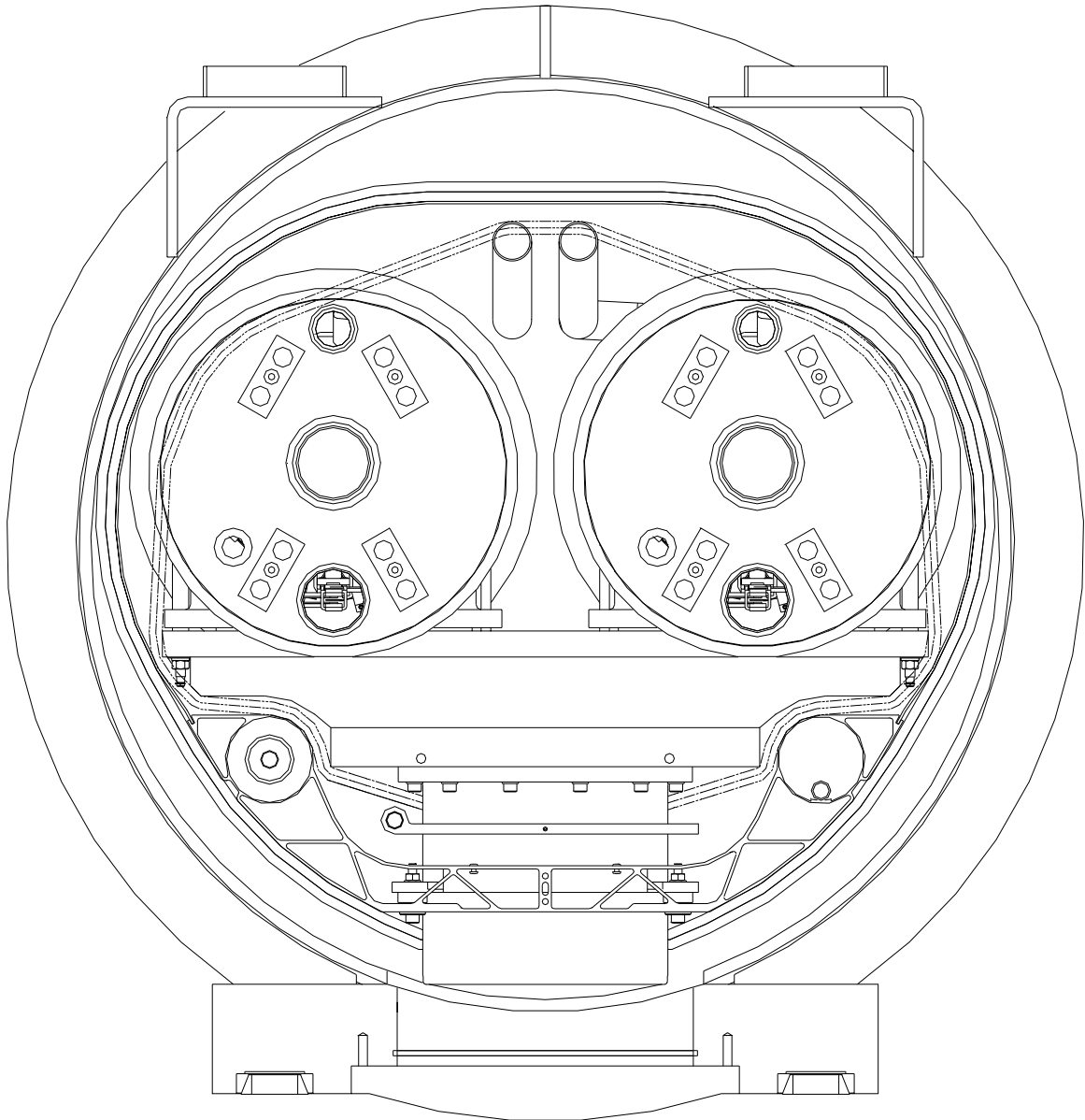


Figure 2 *Cross Section of the D3 (LBRS) Cryo-assembly viewed from the lead end of the magnet.*

3.2 LOCAL COORDINATE SYSTEM

Figure 3 shows the LBRS local coordinate system which is similar to the LHC standard for local coordinate systems [5] except that the origin is always located at the lead end of D3. The XZ plane is coincident with the flat face of the MBRS lead end volume ($Y=0$) of the left-hand cold mass¹ and is centered between the two cold bore tubes. Positive X always points toward the right-hand cold mass.

The coordinate system is defined in the same way for both warm and cold conditions, i.e. it is fixed to the left-hand cold mass and moves with it. This results in a displacement of the coordinate system due to thermal contraction. The cold origin is displaced 1.1mm in the negative Z-direction (down) with respect to the warm position. It is displaced 16 mm in the positive Y-direction. However, because it is defined as centered between the two beam tubes, the position of the origin does not change in the x direction.

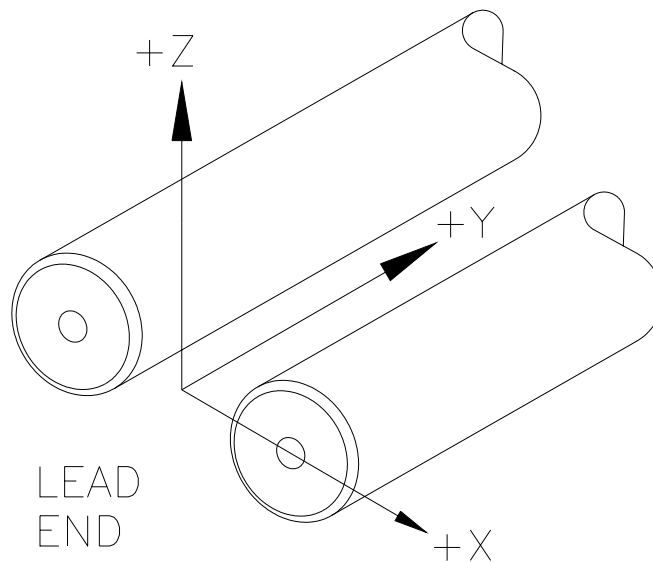


Figure 3 Local coordinate system for LBRS.

¹ The left-hand cold mass is designated the "-01" and the right-hand cold mass "-02".

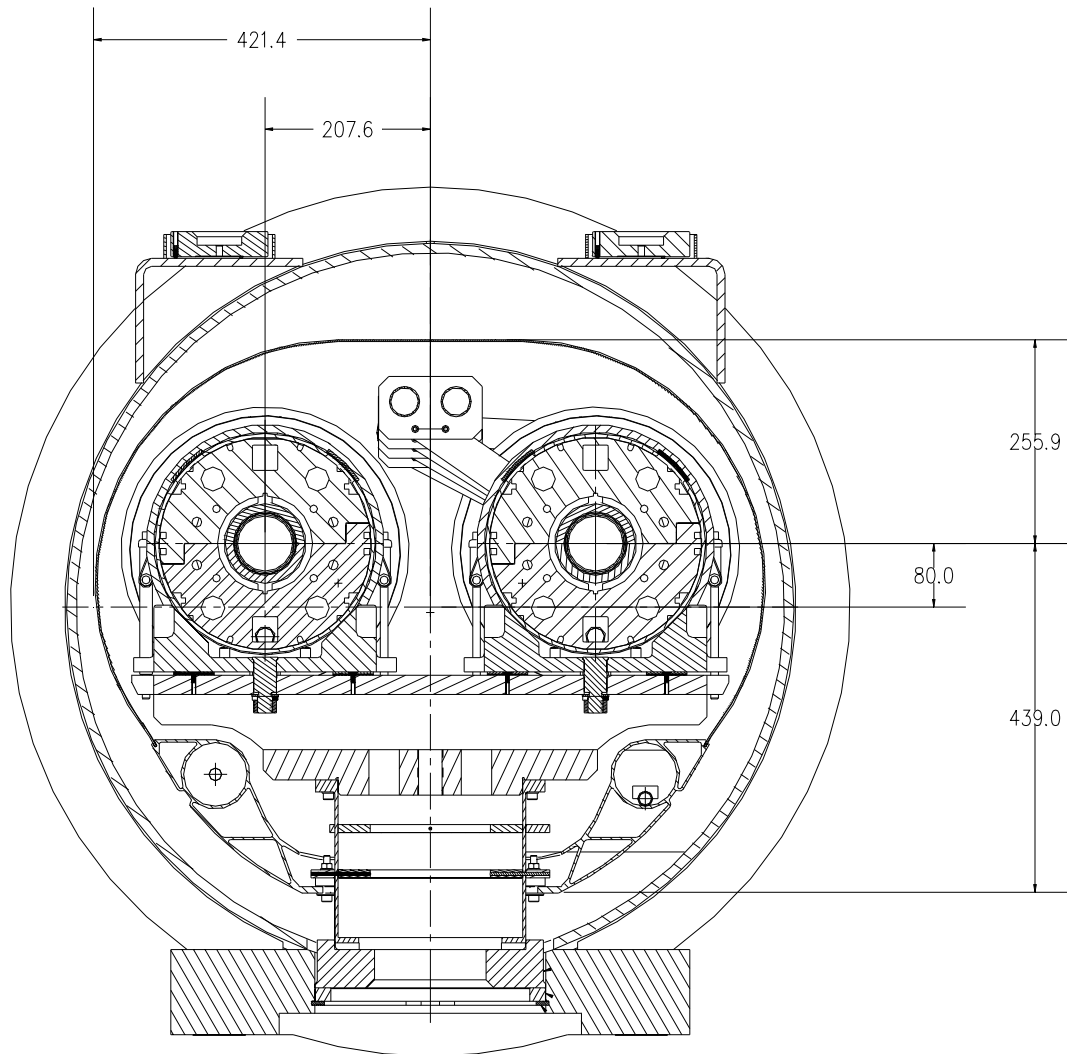


Figure 4 Overall Dimensions

3.3 PIPING

Figure 5 shows transverse and side views of the lead end of the magnets and cryostat. The letters used to label the pipes and tubes that BNL has designed into the system correspond (where applicable) to the header pipes, labelled in upper case letters on the CERN cryogenic flow diagrams, to which the magnet piping eventually connects. This figure also shows the tubing stubs protruding from the end volumes of the cold masses. Tubing stubs are needed to admit liquid helium, vent gaseous helium, and convey buses through liquid helium to the source of electrical power. The details of the cooling system are described in [6]. For further magnet detail refer to BNL drawing 14060290, sheets 1 through 4.

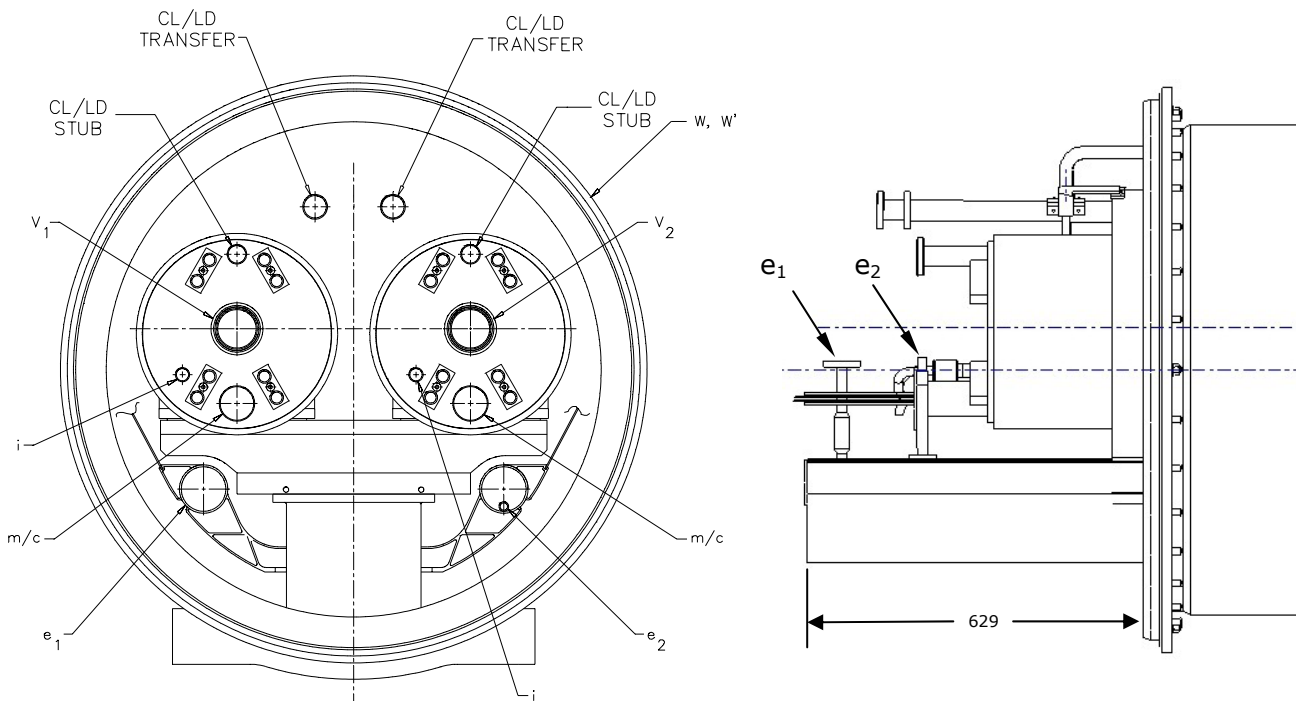


Figure 5 Connection nomenclature at the lead end

Coming out of the end volumes of each cold mass there are four tubing stubs, three at the lead end (m/c, CL/LD, and i), and one at the non-lead end (LD/CL). All stubs emanate from the flat faces of the end volumes.

Stubs labelled CL are used to admit liquid helium into the cold mass either in cooldown mode or steady state mode. Stubs labelled LD are used as vents to return helium gas, collected in the top of the end volume, to the cryogenic system, via the QQS added by CERN at the lead end. The functions of the CL/LD stubs and transfer lines are variable, as indicated by their dual labelling, the function depending upon the location in which the magnet is installed. When used as LD lines (venting), the two vent pipes from each cold mass may be connected together externally via a flex hose and suitable tube fittings, consistent with the cryogenic schematic. This allows for a common LD line in the QQS, reducing plumbing congestion. The m/c stubs at the lead end provide tubes to bring electrical power from the DFBM to each of the D3 cold

masses (and to the undulator by way of the supplied bus internal to the left cold mass), as well as for the liquid helium to provide bus cooling up to the lambda plug. The i stub is provided for the instrumentation leads to exit the end volume. An instrumentation feedthrough system (IFS) is attached by BNL to the i stub; CERN does not interface to the i stub, but does interface directly with the end of the IFS. The IFS is described in more detail in section 4.2.

Shown within the cryostat are the shield supply and return pipes labelled e_1 and e_2 . Pipe e_1 is the shield pipe which is an integral part of the CERN-supplied heat shield extrusion and is therefore thermally connected to the shield. Pipe e_2 is a stainless steel line inserted within the shield and intentionally placed in poor thermal contact with it to prevent cooling instability. Cooling gas can enter either e_1 or e_2 first, and return through the other, without affecting shield function.

At the lead end of the magnet, the bottom shield extrusion is extended beyond the cryostat, and the e_1 and e_2 lines are turned upward as shown in Figure 5, to facilitate integration of the QQS (provided by CERN) onto the end of the magnet assembly. These details are shown on BNL drawing 14010508. The shield extends 629 mm beyond the flange of the cryostat. The interface positions of the ends of the e_1 and e_2 lines at the lead end of the magnet are given in Table 2. The flange on e_1 is not removed after cold testing at BNL since this line will be cut to a custom length when the QQS is added.

In Figure 6 are shown the equivalent two views of the magnet's non-lead end. The e_1 and e_2 lines exit horizontally at this end to facilitate connection to the undulator.

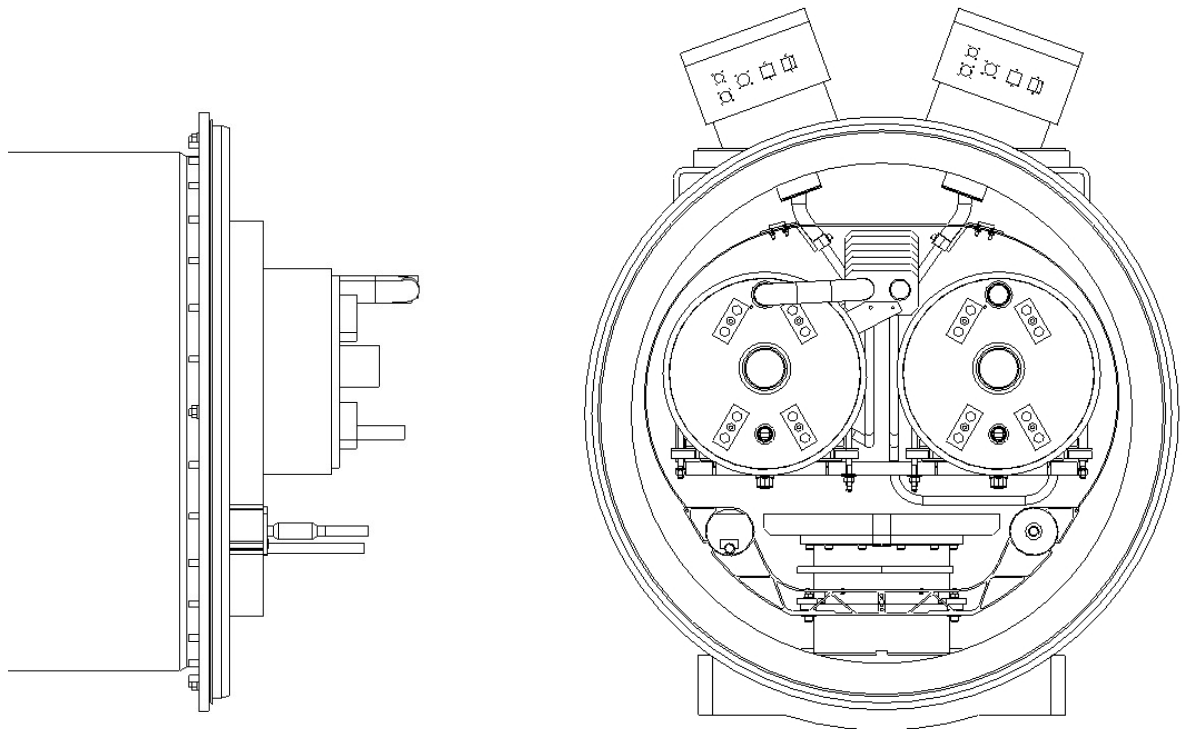


Figure 6 View of Non-Lead End of D3

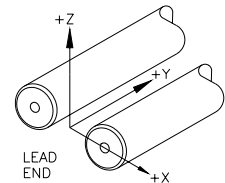
4. LBRS INTERFACES - LEAD END

The lead end of each cold mass (two per D3 assembly) always faces away from the IP and connects to the DFBM and the QQS. The magnet is fed cryogenics via the QQS, and bus power via the DFBM (both are built and attached by CERN). In addition, a CERN-built and supplied undulator magnet is attached after shipment to the left cold mass at the non-lead end of the D3 assembly. A separate through-bus, installed by BNL and integral to the left-hand D3 cold mass, is fed from the DFBM through the QQS and in turn feeds the undulator.

4.1 TUBE COORDINATES

The sizes of the various tubing stubs for the D3 magnet and their warm coordinate positions are shown in Table 2. Welding and cutting clearances have been taken into account in positioning these tubes so that there exist clearance envelopes of at least 50 mm radially around each pipe.

Table 2. Warm coordinate positions of the pipes at the lead end of D3. All "Y" coordinates are measured relative to the left-hand cold mass. Positions shown are for both cold masses. Most pipes are in standard US sizes.



Name	Description	OD x Wall Tube (mm)	Warm Coordinates					
			X (mm)	Z (mm)	Y (mm) ^d			
V1	Cold bore tube, left aperture	73 x 2.0	-207.6 ±1	0.0 ±1	-150.0 ±2			
V2	Cold bore tube, right aperture	73 x 2.0	207.6 ±1	0.0 ±1	-150.0 ±2			
CL/LD stub	Helium sup/ret on end vol (two)	38.1 x 1.65	±207.6 ±2	131.1 ±2	-75.0 ±2			
CL/LD xfer	Helium sup/ret transfer lines (two)	38.1 x 1.65	±32.4 ±3	216.6 ^c ±3	-75.0 ±3			
m/c	Bus/helium tubes (two)	63.5 x 1.65 89.4 x 1.65 ^a	±207.6 ±2	-134.2 ±2	-75.0 ±2			
e ₁	Heat shield sup/ret (connected)	69.9 x 26.2 ^a 17.2 x 1.0 ^b and 87.0 x 3.5 ^b	-270.0 ±3	-63.5 ±3	-272.6 ±3			
e ₂	Heat shield ret/sup (isolated)	17.2 x 1.0 19.0 x 1.65 ^b	270.0 ±3	-56.5 ±3	-122.1 ±3			
W	Cryostat (rotatable flange)	1055 x 61.5	0.0 ±3	-80.0 ±3	322.0 ±3			
W'	Cryostat (flange mount)	1008 x 59.0	0.0 ±3	-80.0 ±3	292.0 ±3			

Note a: Dimensions of flanges welded to tubes. The flange faces, when they are present, are located at the interface.

Note b: Dimensions of tube behind interface. A transition section is used to reach the metric interface dimension of 17.2 x 1.0.

Note c: Transfer lines are inclined to facilitate gas flow; lead end is always higher.

Note d: Y-coordinates are measured from the reference plane of the "-01" (left-hand) cold mass.

All of the tubes move due to cooldown from 300 K to 4.3 K. The changes in position are expressed as a combination of two movements. One movement is that of the origin of the coordinate system, Figure 3, which is centered between the two cold masses and moves downward due to the shrinkage of the cold masses and the support posts. The origin is displaced 1.1 mm in the negative Z-direction (downward) and 16 mm in the positive Y-direction toward the center of the magnet upon cooldown. The movements of pipes and the cold masses reflect the fact that all are fixed indirectly to the cryostat at the longitudinal midpoint, unless otherwise stated. The vertical contraction is based on commonly accepted data for the metallic parts, and on data from an engineering study conducted by V. Parma (CERN) for the composite materials.

The other movement of each tube is with respect to the origin. That movement is described in Table 3 for each tube. Tubes V1, V2, d, and m/c all move in a similar manner due to the shrinkage of stainless steel and their movements are expressed as a percentage of their distance from the origin. Heat shield tubes e_1 and e_2 move due to a combination of material shrinkages, and their movements are expressed as explicit distances toward (or away from) the origin.

Table 3 *Changes in pipe positions at the D3 lead end. In addition to these movements, the origin moves 1.1 mm in the negative Z-direction and 16 mm in the positive Y-direction upon cooldown. All pipes and the cold mass are fixed, either directly or indirectly, to the cryostat at the longitudinal midpoint, unless otherwise stated.*

Name	Description	Change in Position With Respect to the Origin
V1	Cold bore tube, left aperture	X: moves 0.3% toward origin. Z: moves 0.3% toward origin. Y: moves 0.3% toward origin.
V2	Cold bore tube, right aperture	
CL/LD stub	Helium supply/vent	
CL xfer	Helium vent/supply transfer line	
m/c	Bus/helium	
e_1	Heat shield sup/ret (connected) Anchored at shield's lead end	X: moves 0.4% (1.1 mm) toward origin. Z: moves 0.2 mm toward origin. Y: moves 4 mm away from origin. (Net movement, including movement of the origin, is 21 mm toward the cold mass center.)
e_2	Heat shield ret/sup (isolated) Anchored at shield's lead end	

4.2 ELECTRICAL CONNECTIONS

4.2.1 POWER AND INSTRUMENTATION

Figure 7 is a schematic diagram of the main power to the D3 magnet coils. Labelling of the terminals follows the convention specified in [7]. Figure 8 shows the instrumentation connections of one cold mass through the IFS tube to the outside of the cryostat. The second cold mass is identical but not shown.

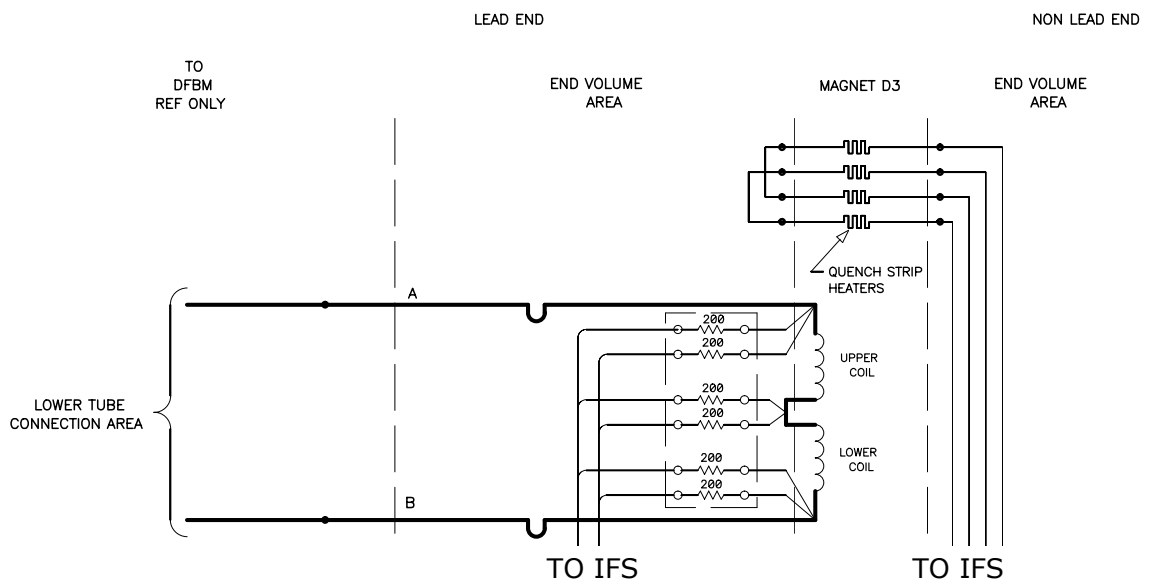


Figure 7 *Electrical Schematic: Main magnet power, quench heater power, and voltage taps.*

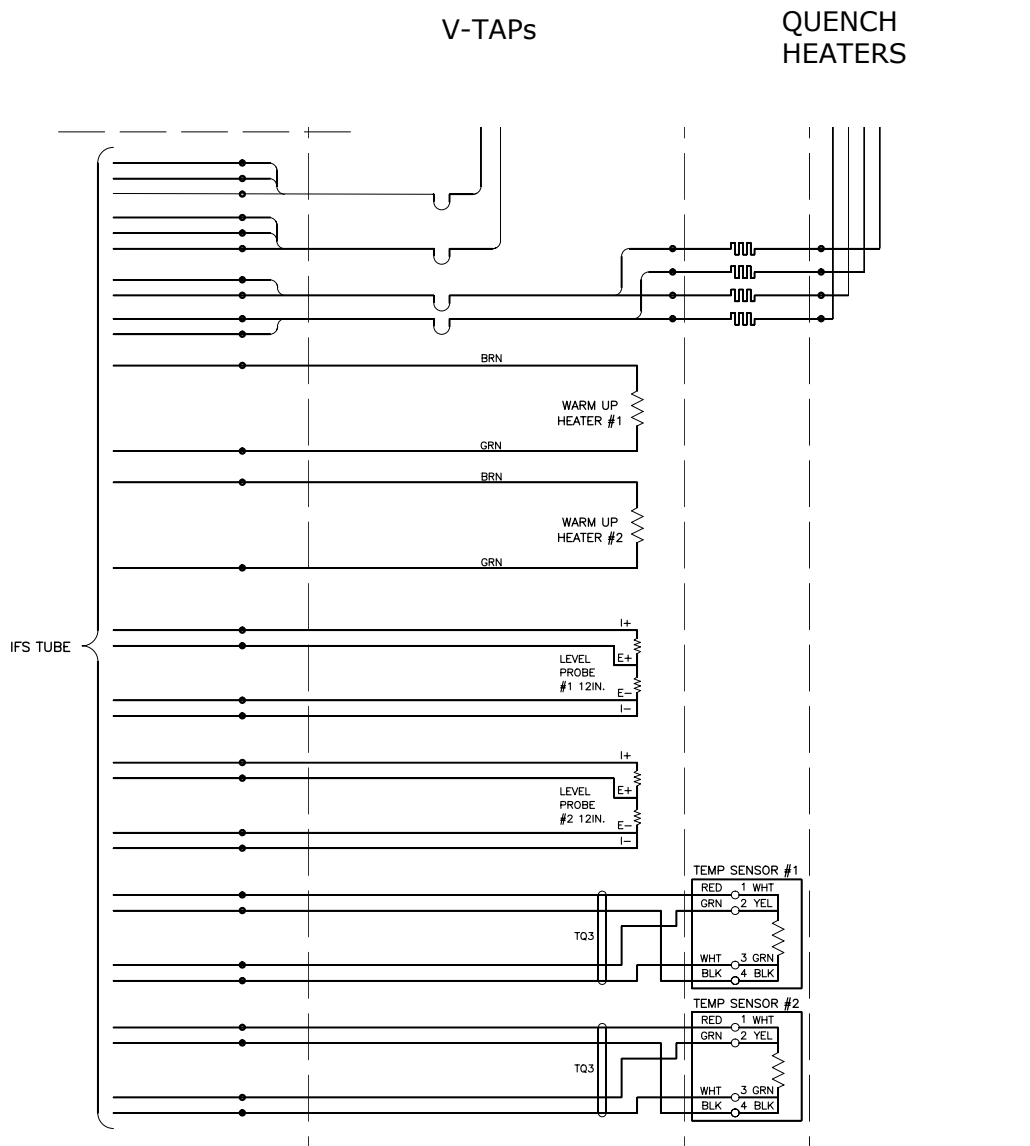


Figure 8 Electrical Schematic: Warm-up heaters, temperature sensors, and liquid level probes.

A bus/flex joint assembly will be used in each lead end volume to accommodate expansion and contraction of the powering bus relative to cold mass contraction, and the bus motion in the DFBM (see Figure 9). The motion allowed for the flex joint is ± 30 mm [1.18 inches] from the rest position. The electro-mechanical design inside the end volume will connect the coil halves in series to the bus/flex joint assembly. CERN will connect the coils of each cold mass in series. The connection, either inside the DFBM or before that point in the QQS, is not part of the BNL work scope.

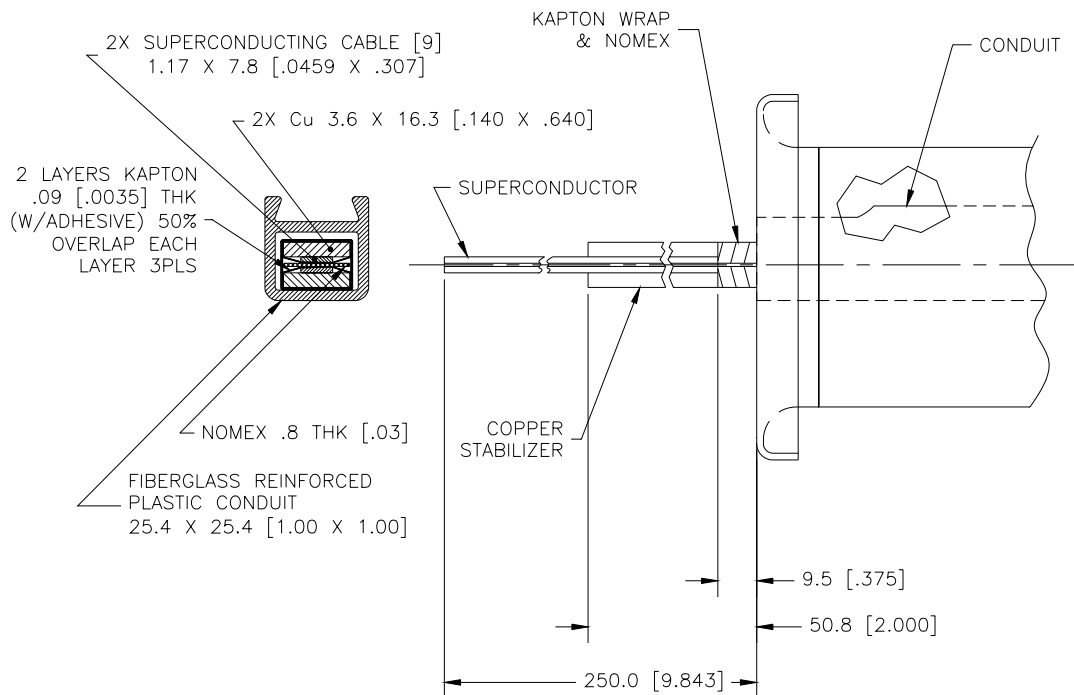


Figure 9 Bus bar interface at the m/c stub. Flex joint in neutral rest position. Dimensions are given in mm [inches].

The undulator bus is a flexible four conductor cable located within the lower bus slot of the yoke. It extends out of each end volume a minimum of 1250 mm and is to be trimmed to length when interconnected to adjacent equipment. The adjacent equipment must also provide service loops to accommodate thermal contraction. Although the bus is not constrained within the D3 cold mass, it is not designed to move within it during thermal excursions.

The construction of the bus is shown in Figure 10. Each of the four conductors is itself made from a twisted triplet of superconductor wire. Each triplet, rated at 650A as noted, is Kapton insulated and Tefzel coated. The entire cable assembly is also wrapped with Kapton insulation, and this is further wrapped with fibreglass cloth tape to provide abrasion resistance.

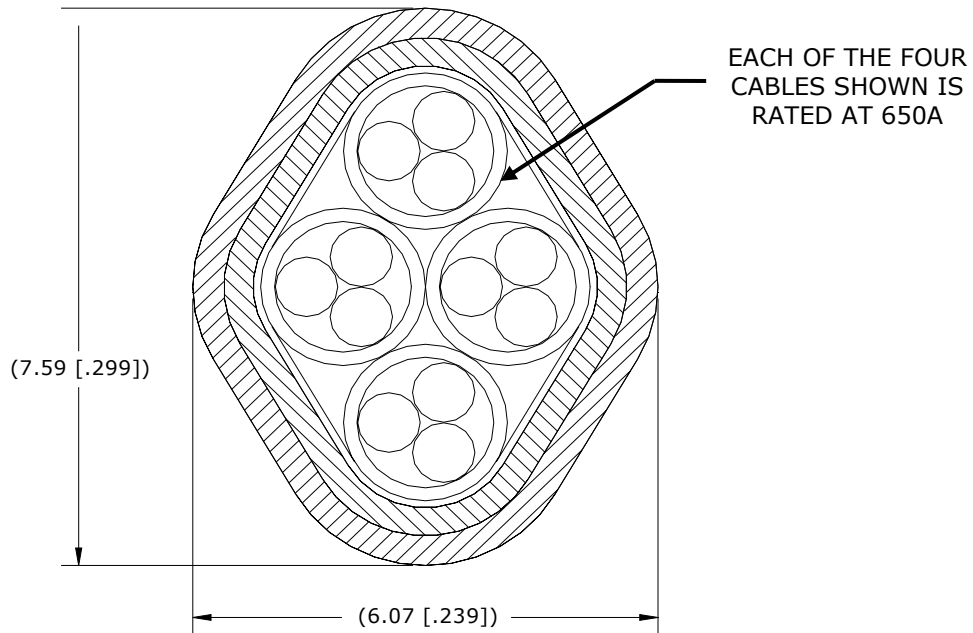


Figure 10 Cross Section of Undulator Bus

Instrumentation supplied in D3 is shown in Table 4. All instrumentation and control wiring is routed along and lashed to the flex joint, with expansion loops between terminations and the flex joint lash point to provide for differential thermal contraction internal to the magnet. The instrumentation listed is for one cold mass; the other is a duplicate. Each cold mass has its own dedicated IFS, discussed in more detail in section 4.2.2

Table 4 Instrumentation and control wiring exiting each cold mass through its i stub to enter the IFS.

Lead	Description
Temperature sensors	2 twisted quads (total 8 wires, #30 AWG.)
Voltage taps	2 cables (3-#28 AWG wires each) red = "A" coil lead black = "B" coil lead yellow = upper/lower coil crossover joint
Quench heaters	4 wires, #22 AWG
Warm-up heater	2 twisted pairs (total 4 wires, #26 AWG.)
Liquid Level Sensors	2 twisted quads (total 8 wires, #32 AWG.)

There are two temperature sensors located within each cold mass on the outside of the yoke near the longitudinal center. One of these sensors is redundant. The temperature sensors are the short type thermometer assemblies (36 mm x 12 mm x 4.2 mm) typically used by CERN [8]. The sensors have been calibrated and supplied to BNL by CERN.

The 3-wire voltage tap cables consist of three Tefzel-over-Kapton insulated wires within an outer helical wrap of 0.04 mm thick Kapton. The voltage tap leads are soldered to the "A" and "B" leads and to the crossover splice between upper and lower coils for each aperture, as close as possible to the lead end of the coils. Tefzel is used only as a convenience for color coding and Kapton retention; no credit is taken for electrical insulating properties.

The quench protection heater leads power the Q.P. heaters in two independent circuits to create a level of redundancy in case of failure in one circuit.

Two cryogenic warm-up heaters are located within the lead end volume.

All D3 magnets have helium level sensors provided in the lead end volume that are used to control the cryogenic operation of D3. Two sensors are provided; one redundant. Although either end of D3 can be the higher end depending upon the tunnel installation location, it is acceptable to have level sensors in the lead end only because the tunnel slope is quite small at this location and the gas/liquid interface is easily kept above the level of the coil.

4.2.2 INSTRUMENTATION FEEDTHROUGH SYSTEM – IFS

The IFS (Instrument Feedthrough System, Figure 11), is a copy of the CERN design to the maximum extent possible. The instrumentation wiring exits the end volume through the i stub into the IFS separating from the main power buswork on the flex joint within the end volume. It exits the cryostat in the standard way, but there are notable exceptions: the stainless tube from the cold mass to the thermalisation point is larger in diameter consistent with the wire sizes used by BNL, there are two feedthroughs per cryostat (one for each cold mass), and the two 40-pin feedthroughs are interconnected. One IFS interface box serves as a "master" and the other as a "slave". At installation, CERN will connect to both boxes. See Figure 13 for identification of "Master" and "Slave" interface boxes.

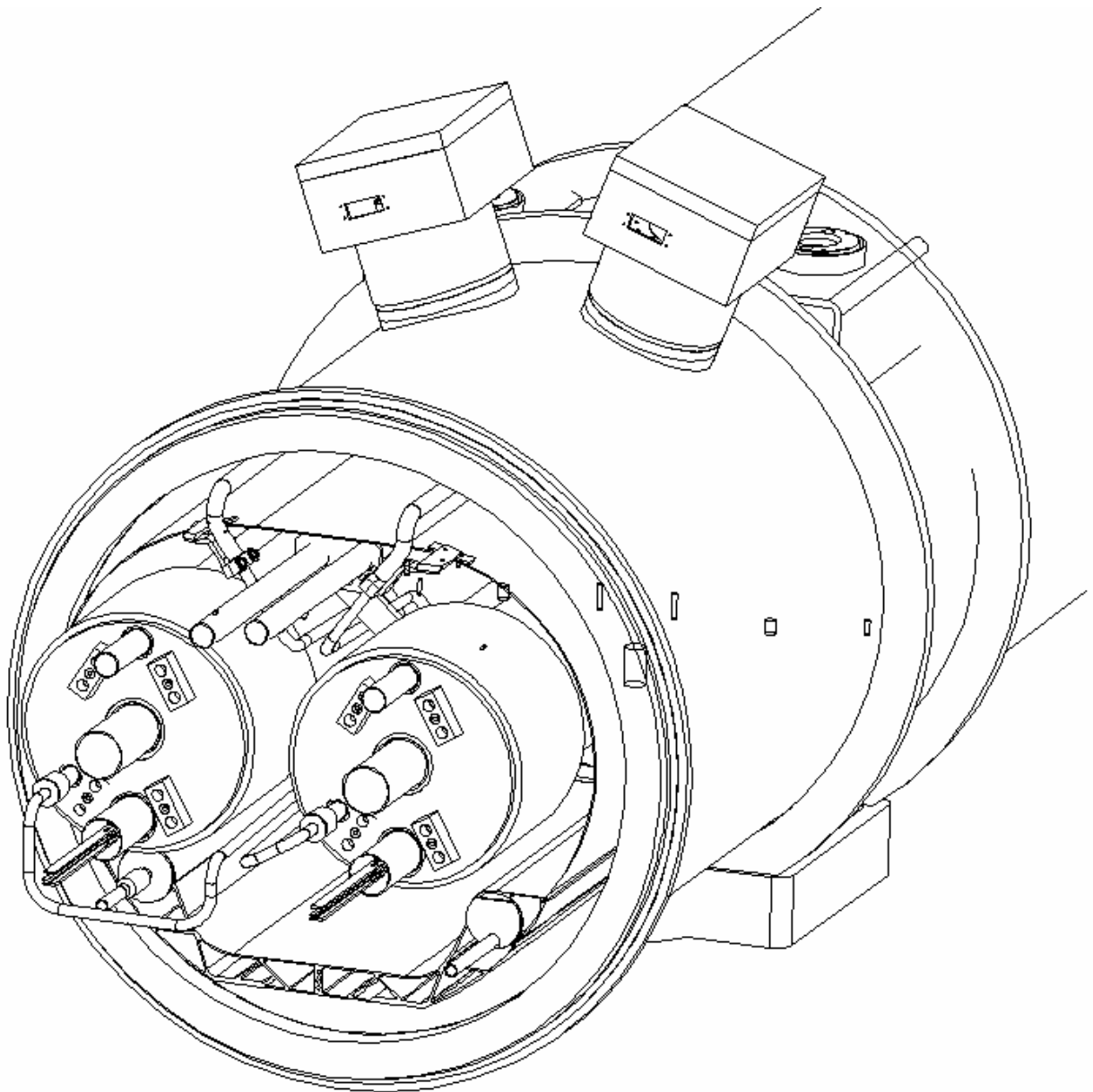


Figure 11 IFS lines and interface boxes on the vacuum vessel.

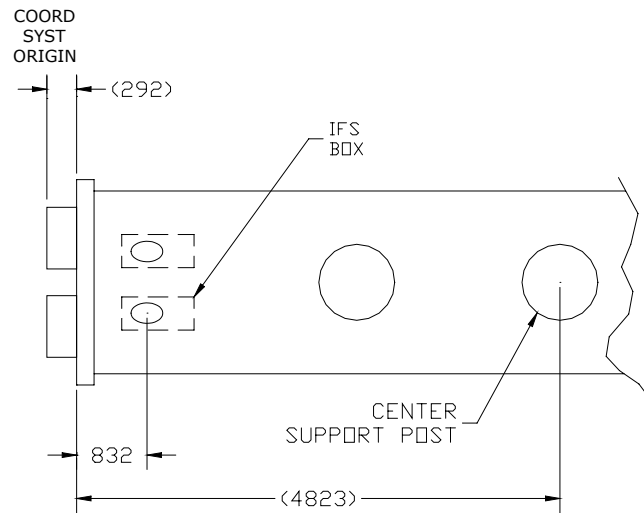
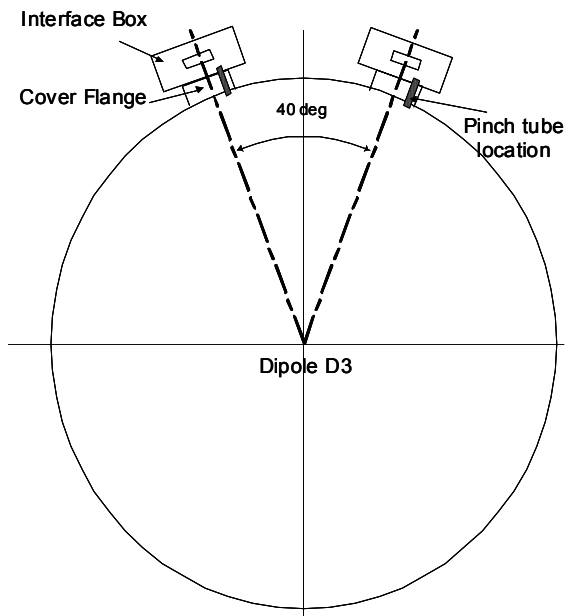
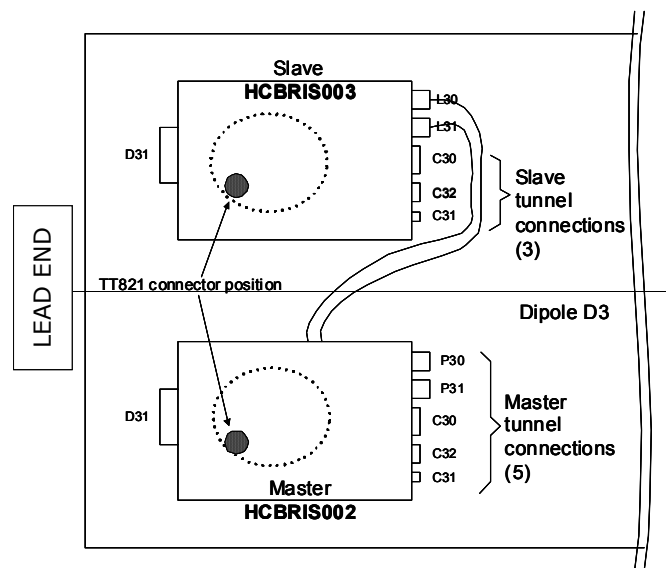


Figure 12 Location of IFS Feedthrough and Box

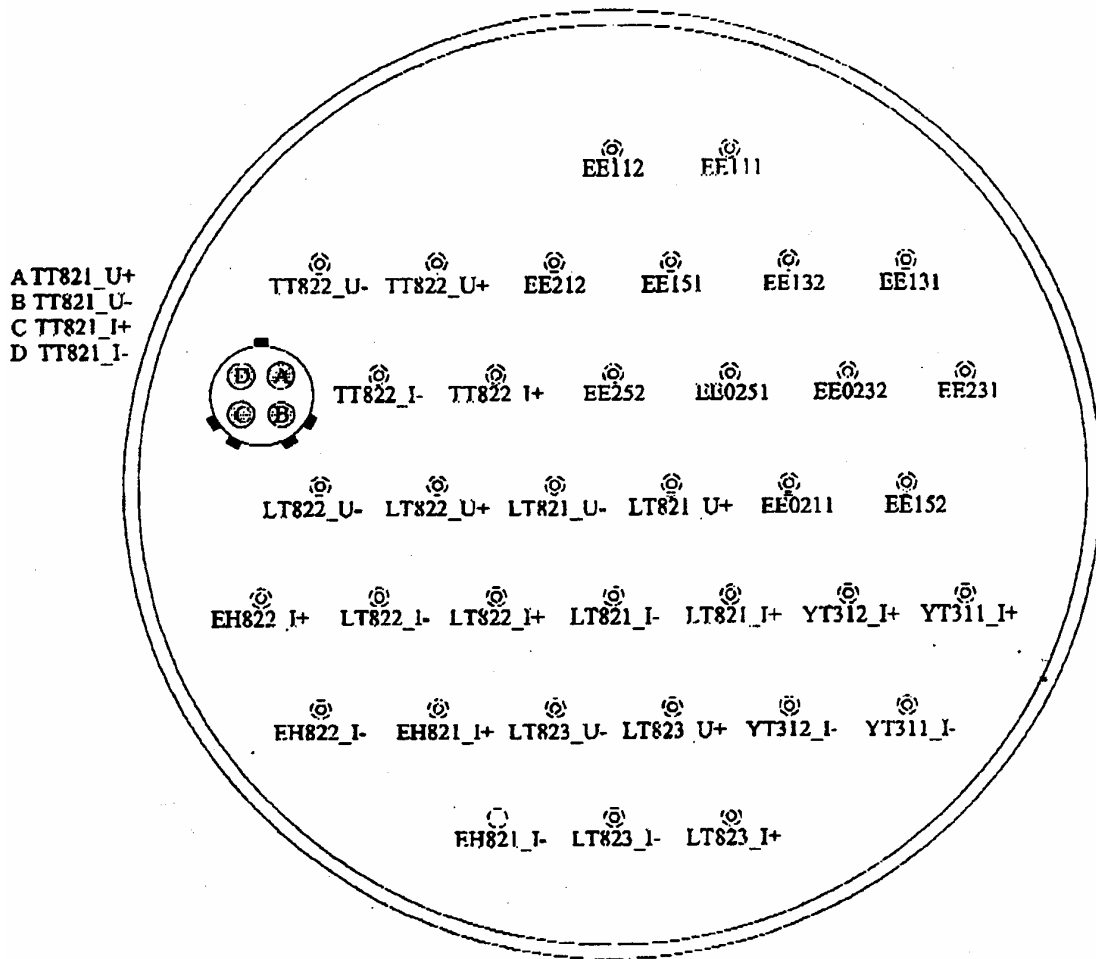


VIEW LOOKING AT LEAD END



VIEW LOOKING FROM TOP

Figure 13 Identification of "Master" and "Slave" interface boxes



**Figure 14 Pin Numbering and Location of TT821 4-Pin Feedthrough,
Viewed From Above**

Table 5 Feedthrough Pin Connections

D3 IFS "COVER FLANGE", LEFT COLD MASS					
TT821	COLD MASS TEMP 1 U+	LT821	COLD MASS HELIUM LEVEL 1 U+	EE111*	V-TAP
	COLD MASS TEMP 1 U-		COLD MASS HELIUM LEVEL 1 U-	EE112*	V-TAP
	COLD MASS TEMP 1 I+		COLD MASS HELIUM LEVEL 1 I+	EE131*	V-TAP
	COLD MASS TEMP 1 I-		COLD MASS HELIUM LEVEL 1 I-	EE132*	V-TAP
TT822	COLD MASS TEMP 2 U+	LT822	COLD MASS HELIUM LEVEL 2 U+	EE151*	V-TAP
	COLD MASS TEMP 2 U-		COLD MASS HELIUM LEVEL 2 U-	EE152*	V-TAP
	COLD MASS TEMP 2 I+		COLD MASS HELIUM LEVEL 2 I+	EE2XX*	Not used
	COLD MASS TEMP 2 I-		COLD MASS HELIUM LEVEL 2 I-	YT311	QUENCH PROTECTION HEATER CKT#1
EH821	CRYOGENIC HEATER 1 I+	LT823	Not used	YT312	QUENCH PROTECTION HEATER CKT#1
	CRYOGENIC HEATER 1 I-		Not used		QUENCH PROTECTION HEATER CKT#2
EH822	CRYOGENIC HEATER 1 I+		Not used	YT312	QUENCH PROTECTION HEATER CKT#2
	CRYOGENIC HEATER 1 I-		Not used		

D3 IFS "COVER FLANGE", RIGHT COLD MASS					
TT821	COLD MASS TEMP 1 U+	LT821	COLD MASS HELIUM LEVEL 1 U+	EE1XX*	Not used
	COLD MASS TEMP 1 U-		COLD MASS HELIUM LEVEL 1 U-	EE211*	V-TAP
	COLD MASS TEMP 1 I+		COLD MASS HELIUM LEVEL 1 I+	EE212*	V-TAP
	COLD MASS TEMP 1 I-		COLD MASS HELIUM LEVEL 1 I-	EE231*	V-TAP
TT822	COLD MASS TEMP 2 U+	LT822	COLD MASS HELIUM LEVEL 2 U+	EE232*	V-TAP
	COLD MASS TEMP 2 U-		COLD MASS HELIUM LEVEL 2 U-	EE251*	V-TAP
	COLD MASS TEMP 2 I+		COLD MASS HELIUM LEVEL 2 I+	EE252*	V-TAP
	COLD MASS TEMP 2 I-		COLD MASS HELIUM LEVEL 2 I-	YT311	QUENCH PROTECTION HEATER CKT#1
EH821	CRYOGENIC HEATER 1 I+	LT823	Not used	YT312	QUENCH PROTECTION HEATER CKT#1
	CRYOGENIC HEATER 1 I-		Not used		QUENCH PROTECTION HEATER CKT#2
EH822	CRYOGENIC HEATER 1 I+		Not used	YT312	QUENCH PROTECTION HEATER CKT#2
	CRYOGENIC HEATER 1 I-		Not used		

*V-Tap Key 1ST DIGIT(XXX): 1=LEFT BORE; 2=RIGHT BORE
 2ND DIGIT(XXX): 1=UPPER COIL; 3=CENTER CROSSOVER; 5=LOWER COIL
 3RD DIGIT(XXX): 1=MAIN TAP; 2=REDUNDANT TAP

5. LBRS INTERFACES – NON-LEAD END

The installation connections needed at the non-lead end are the beam line connections, electrical connections to the undulator, and the piping connections from the transfer line to the undulator. In addition, the heat shield, MLI blankets, and cryostat closure joining the undulator to D3 need to be provided. The scope of this work is outside the BNL domain.

The warm coordinate positions and tubing diameters of the beam tubes, helium tube stubs, and cryostat vacuum flange are given in Table 6. The cold Y-coordinate positions are also shown. The cold X- and Z-cold coordinate positions are the same as for the lead end (Table 2) with the exception of the CL/LD transfer lines. Note that the warm Z-coordinate positions for the CL/LD transfer lines at the non-lead end are 76.2 mm lower than at the lead end. The local coordinate system, which is referenced to the lead end volume moves with cooldown as described in Section 3.2.

Table 6 Coordinate Positions for the D3 non-lead end on the left side of the IP.

Name	Description	OD x Wall		Coordinate Positions					
		Tube (mm)	X (mm)	Z (mm)	Warm Y (mm)		Cold Y (mm)		
V1	Cold bore tube, left aperture ^a	73 x 2.0	-207.6 ±1	0.0 ±1	10200 ±3	10170 ±3			
V2	Cold bore tube, right aperture ^a	73 x 2.0	207.6 ±1	0.0 ±1	10200 ±3	10170 ±3			
CL/LD stub	Helium sup/ret on end vols (two)	38.1 x 1.65	±207.6 ±2	131.1 ±2	10200 ±2	10170 ±3			
CL/LD xfer	Helium sup/ret transfer lines (two)	38.1 x 1.65	±32.4 ^d ±3	140.4 ^{c,d} ±3	10200 ^d ±3	10170 ^b ±3			
m/c	Bus/helium tubes (two)	25.4 x 1.65	±207.6 ±2	-117.0 ±2	10200 ^e ±2	10170 ±3			
e ₁	Heat shield supply/return (connected)	17.2 x 1.0 87.0 x 3.5 ^b	-270.0 ±3	-290.0 ±3	10174 ±3	10039 ±3			
e ₂	Heat shield return/supply (isolated)	17.2 x 1.0 19.0 x 1.65 ^b	270.0 ±3	-320.5 ±3	10174 ±3	10049 ±3			
W	Cryostat	1055 x 82.5	0.0 ±3	-80.0 ±3	9938 ±3	9922 ±3			

Note a: "Left" and "right" apertures are defined as viewed from lead end.

Note b: Transfer lines and heat shield lines are anchored at lead end.

Note c: Transfer lines are inclined to facilitate gas flow; lead end always higher.

Note d: Dimensions applicable to -01 (left hand) cold mass only. The -02 cold mass is connected to the CL/LD transfer line and does not interface to CERN equipment.

Note e: Dimensions applicable to -01 (left hand) cold mass only. The -02 cold mass is capped by BNL at 10161.7 mm.

6. LBRB – TUNNEL FLOOR INTERFACES

Figure 15 is a bottom view of the cryostat, showing the positions of the internal support posts and the recesses in the CERN vacuum vessel castings which interface with the support jacks. The three internal support posts are positioned at the longitudinal center of the vacuum vessel and 3594 mm (141.5 in) to either side of center. The bottoms of the support posts attach to CERN vacuum vessel castings which are integral to the vessel at the three locations. The two cold masses inside the vessel are supported on three transverse beams which are connected to the tops of the posts, one beam at each post location. Cold mass sliding is accomplished at the interface between cradle and beam, and the two cold masses are able to slide independently of one another. This design was driven by the possibility of less than ideal cryogenic system operation and allows for differences in temperature between the two cold masses. An additional benefit is that all three CERN posts can be fixed at the lower end, simplifying construction. The heat shield is able to slide relative to the fixed end posts, and is anchored at the fixed center post.

To support the cryostatted magnet assembly, CERN "PMPS" jacks will be used between the floor and the bottom surface of the two outboard vacuum vessel castings. The castings (and the CERN-supplied vacuum port covers) are designed with recesses into which will fit GE-45-SX spherical washers to mate with the jacks. Two jacks will be used at one end of the magnet and one jack at the other. The single jack is located below the magnet midpoint and it interfaces with the recess and washer in the CERN supplied port cover. The jacking points are located coincident with the longitudinal center positions of the posts.

The central cold mass support post is partially reacted by the beam stiffness of the vacuum vessel but is shimmed differently from the end posts to eliminate mid-point sag of the cold masses inside. The midpoint jack support to the tunnel floor at this location can be used to bring the cold mass to a straight, level condition during tunnel installation if further adjustment is necessary.

The outboard floor jacks are capable of resisting axial loads resulting from unbalanced bellows forces due primarily to the vacuum load. Therefore, these forces are transmitted to the tunnel floor through the jacks rather than reacted to adjacent magnet elements.

7. LBRB – ALIGNMENT SYSTEM INTERFACES

The location of the magnetic field center of the cold mass within the vacuum vessel is known by taking measurements of the cold mass fiducials on the shell and on the end volumes during fabrication and transferring these data to cryostat fiducial locations at the Taylor-Hobson (T-H) spheres in accordance with the CERN preferred method of surveying. The cold mass position relative to the T-H spheres will be measured at BNL. The documentation package shipped with each magnet will include the survey information taken during manufacture. The cold mass position can be checked after shipment to CERN by viewing the end volume and T-H fiducials and comparing the measurements with the data supplied by BNL.

The nominal locations of the Taylor-Hobson spheres with respect to the magnetic axis of the dipole magnet are given in Figure 16.

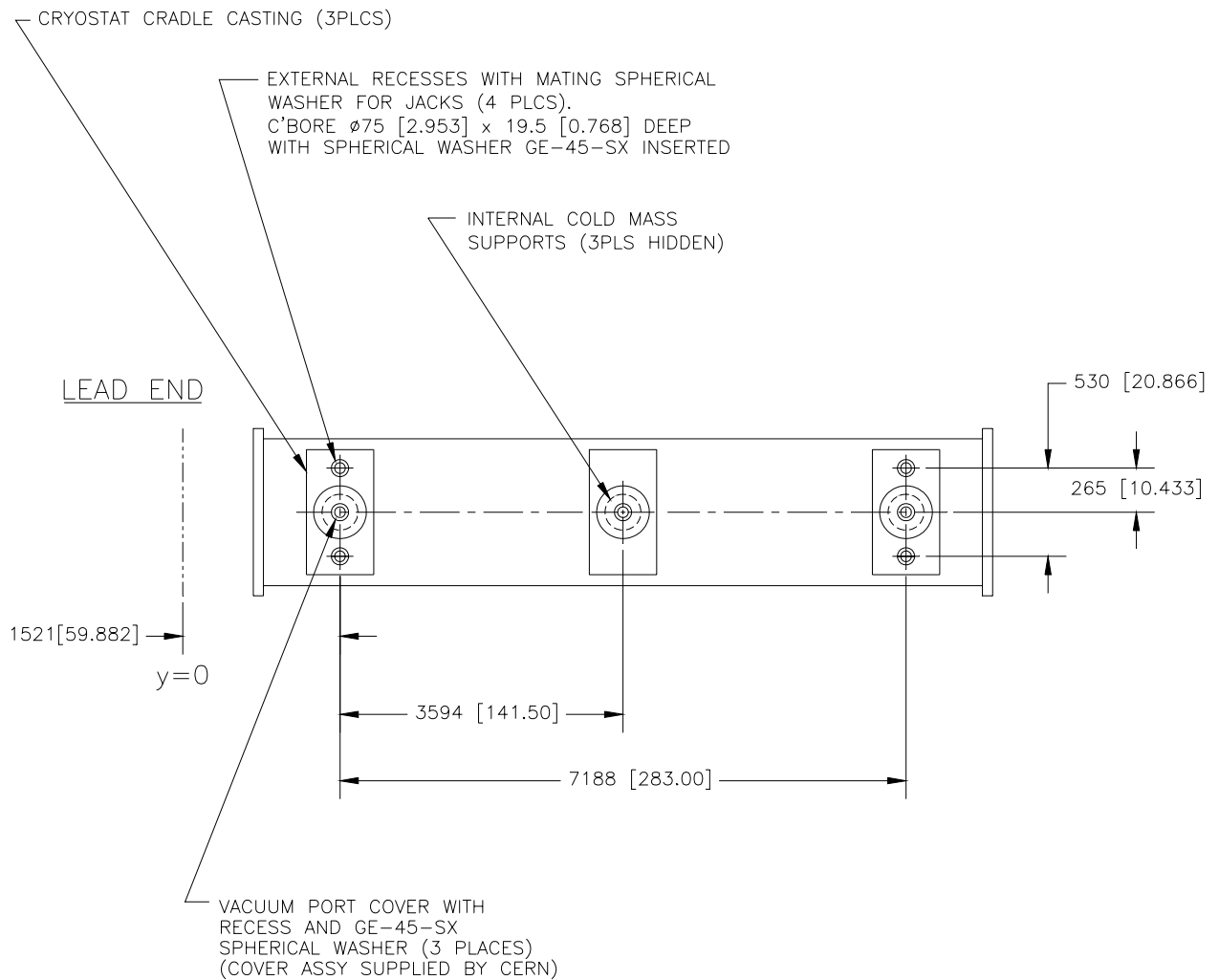


Figure 15 Jack Locations on the bottom of the LBRB cryostat. Dimensions are given in mm [inches].

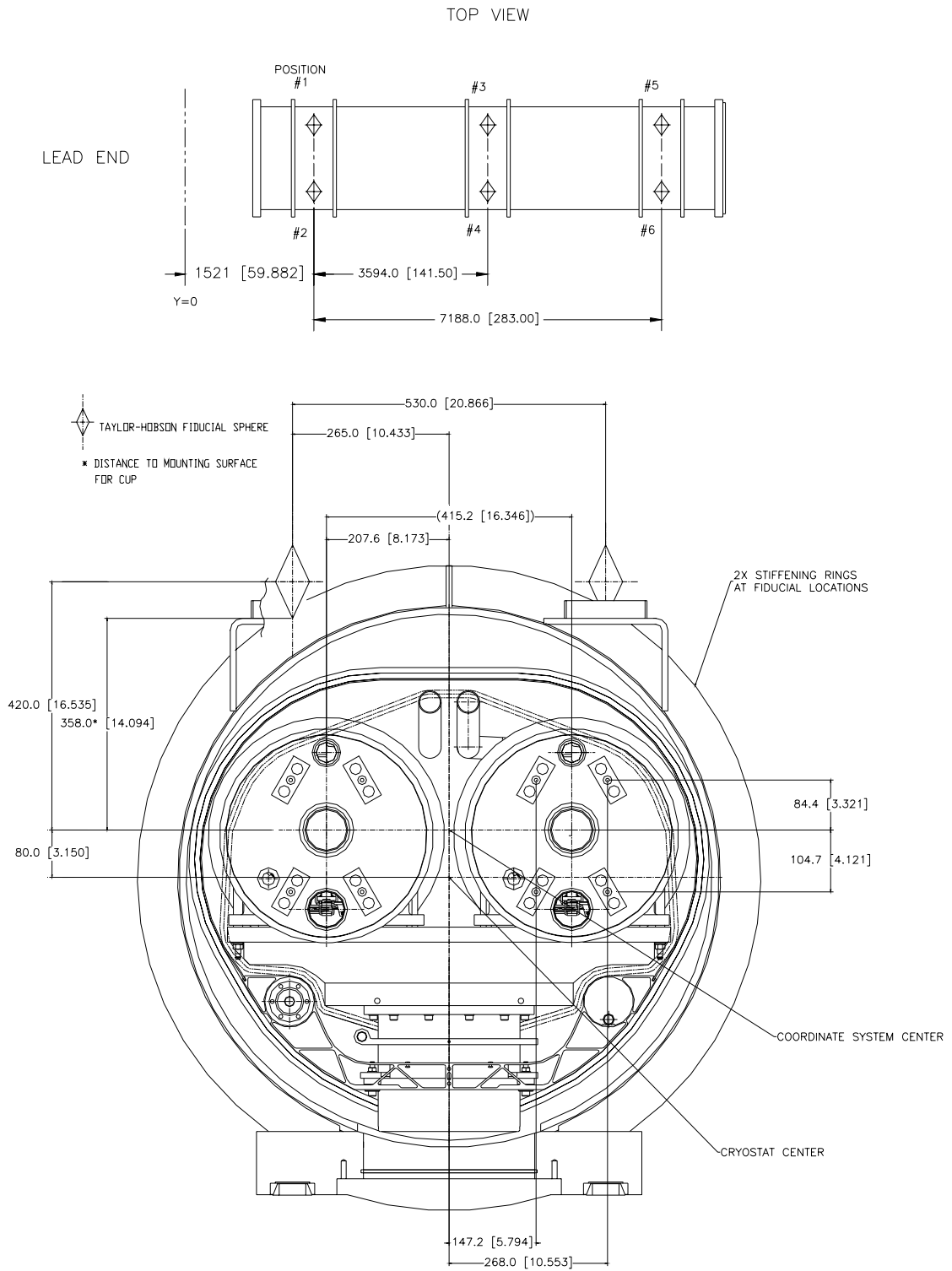


Figure 16 Fiducial locations on the LBRB cryostat. Dimensions are given in mm [inches].

8. INTERFACES WITH THE VACUUM SYSTEM

The insulating vacuum in D3 is pumped solely via its connection to the QQS. By previous agreement, the vacuum vessel provides no port for installing vacuum pumps.

9. HANDLING INTERFACES

The appropriate lifting points on the magnet vacuum vessel are shown in Figure 17. The magnet assembly may be lifted and transported using either of the rigging techniques shown. Suitable chafe resistance for slings must be provided by those performing the lift.

If the magnet is to be lifted from below, for instance by the tunnel transport fixture, it should be contacted at the two locations indicated in the 2-point lift, minimum; other lift points would be adjacent to the support castings, either side. Note that the center of mass of the magnet assembly is located about 80 mm above the geometric center of the vacuum vessel. If supported from below only, it is therefore unstable against rotation about the longitudinal axis.

The allowable accelerations during transport around the CERN site and in the tunnel will not be exceeded as long as generally accepted rigging techniques are employed and reasonable care is exercised. Since the composite support posts are the most fragile component within the magnet assembly, and since those posts are identical in composition to the arc dipole support posts built by CERN and its contractors, the same techniques and cautions that apply to those magnets should be applied to movement of the D3 magnet. Shipping restraints similar to those used for overseas shipment may be attached as desired.

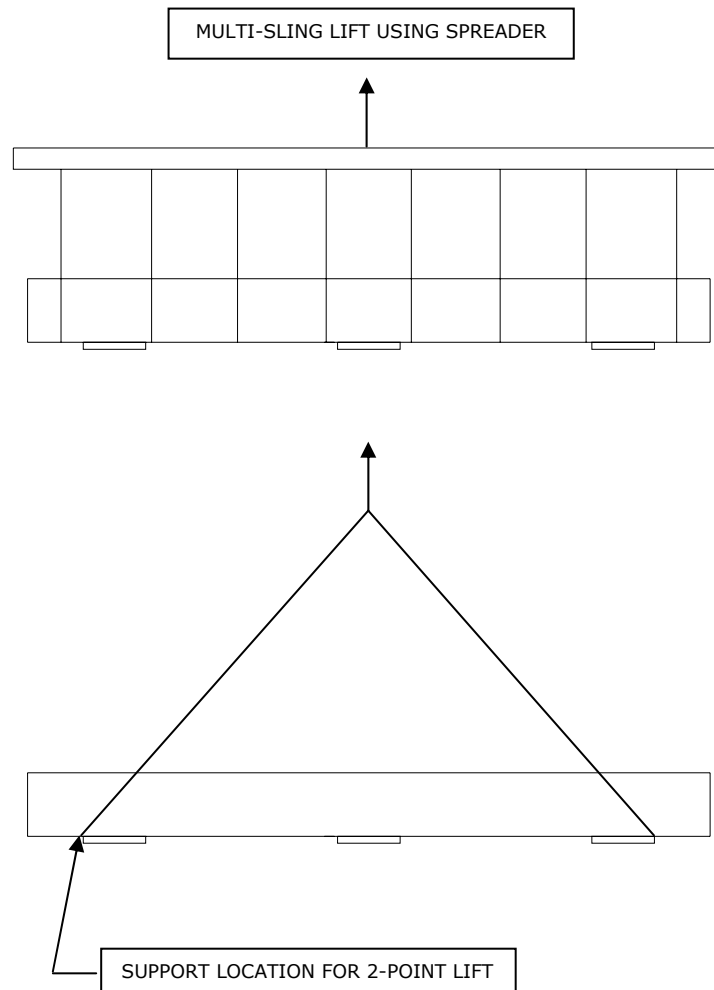


Figure 17 Lifting Methods

10. LBRS READY FOR TRANSPORT TO CERN

The magnet assembly will be shipped with the ends of the vacuum vessel enclosed using transparent plastic sheeting that is securely taped to the vessel and encloses the end of the cold mass as well. The pipes are not individually closed, but are free to communicate with each other within the volume formed by the "bags" at each end and the vacuum vessel.

The volume thus enclosed is purged of air and back-filled with dry N_2 immediately before shipment. Upon delivery at CERN, the enclosed volume must be opened in order to recover the accelerometers and temperature sensors and to remove the shipping restraints from the magnet ends, and ship all these back to BNL. The re-closure of the vessel and cold mass then becomes the responsibility of CERN, and may be accomplished using existing end cans used for the CERN arc dipoles.

11. LIST OF DRAWINGS

	LHC Drawing No.	BNL Drawing No.	Title
[a]	To be assigned	14060290	Magnet Assembly, Tested & Shipped
[b]	To be assigned	14060323	Magnet Assembly, Cryostatted
[c]	To be assigned	14010508	Assembly, Combined Cold Masses
[d]	To be assigned	14010488	Assembly, Cold Mass
[e]	To be assigned	14010487	Assembly, Yoke Containment
[f]	To be assigned	14060174	Flange, m/c Pipe

12. REFERENCES

- [1] Design Report for the Interaction Region Dipoles and RF Region Dipoles, Brookhaven National Laboratory, January 18, 2000.
- [2] "Superconducting Beam Separation Dipoles: D1 (MBX), D2 (MBRC), D3 (MBRS), D4a (MBRA), D4b (MBRB)," LHC Functional Specification, LHC-MBR-ES-0001.00.
- [3] "Configurations of BNL-built LHC Dipole Magnets," Brookhaven National Laboratory, Magnet Note 586, December 7, 1999.
- [4] BNL Magnet Division Specification, "LHC Dipole Magnet Beam Tube Material," LHC-MAG-M-1010, <http://magnets.rhic.bnl.gov/maps/documents\LHC-MAG-M-1010.pdf>.
- [5] "Arc Cryomagnet Extremities," LHC-LI-ES-0001, rev 2.0, 20 August 1999.
- [6] "Beam Separation Dipole D3 Cooling," LHC Cooling Specification, LHC-LBRS-ES-0001.
- [7] "LHC Magnet Polarities," LHC-DC-ES-0001, rev 1.1, 19 June 1999.
- [8] Balle, C., "Mounting of Industrial Type Cryogenic Thermometers," version 2.0, CERN, 19 Feb 1999.