Fermilab

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Fermilab Engineering Document
LCLS-II 1.3 GHz and 3.9 GHz Cryomodule Stand Design
ED000xxxx, Rev. -

Rev.	Date	Description	Originated By	Checked By	Approved By
-	26 Sep 2016	Initial Release	*Michael McGee*		

1. Introduction

The original cryomodule stand design was conceived by INFN (Milan) for DESY regarding use within XFEL. The modified version of the DESY cryomodule stand design was applied at New Muon Lab (NML) at Fermilab regarding support for both Cryomodules; CM1 and CM2[1]. In 2014, this same design was adapted for use at Cryomodule Test Facility (CMTF) within the Cryomodule Test Stand (CMTS-1) cave at Fermilab under a reduced magnetic material construction. Figure 1 shows the LCLS-II Cryomodule stand assembly solid model with two supporting stands.

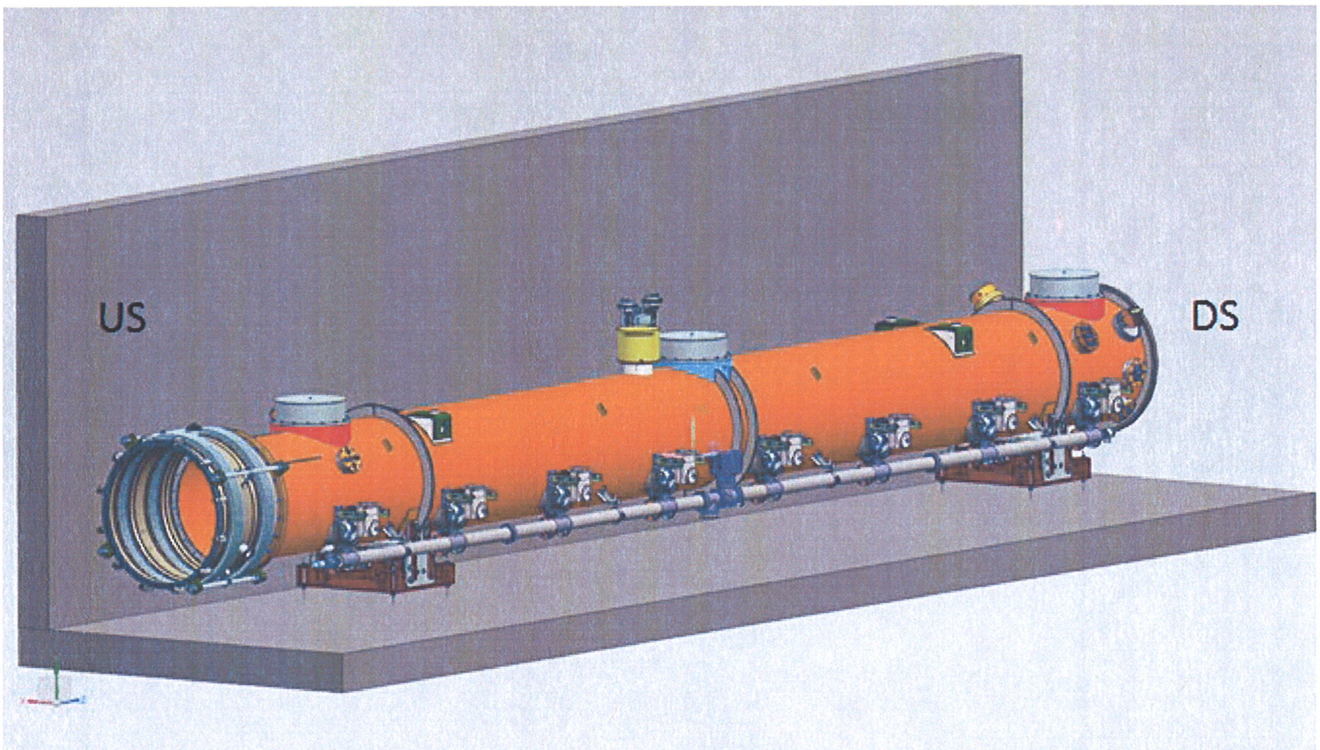

Figure 1: LCLS-II Cryomodule support stand solid model.

2. Stand Design and Functionality

The basic dimensions of the original INFN/DESY Stand design were conserved. The overall stand height was increased in order to accommodate vertical differences between the designs. The pseudo W-beam web material thickness was also increased to compensate for any reduction in strength as a result. The LCLS-II Stand design utilizes a pseudo W-beam construction. A description of the stand is provided in Figure 2 with the main components listed.

1. Aisle Seismic Restraint
2. Wall Seismic Restraint
3. Threaded Rod (x4)
4. Leveling Nut With Washer (x4)
5. Securing Nut With Washer (x4)
6. Embedded Base Plate

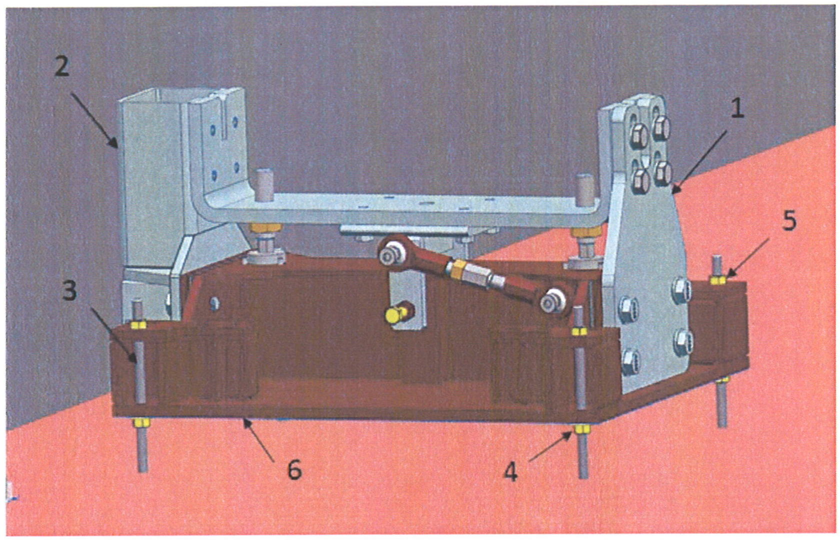

Figure 2: LCLS-II Cryomodule support stand solid model.

Each stand allows for +/- 3/8" adjustment in the vertical, transverse and longitudinal axis. The vertical adjustability also considers an additional 0.787" [20 mm] upward movement to compensate for any settling during the life of LCLS-II Project. Figure 3 shows each adjustment system and their respective locking feature (typically a jam nut). These features are implemented (locked) following final alignment. Besides these locking mechanisms, a more robust seismic restraint system is attached at each stand at the aisle and wall sides. These seismic restraint designs are not symmetric due to the existence of the input coupler vacuum manifold found on the aisle.

1. Vertical Adjustment and Locking System
2. Transverse Adjustment and Locking System
3. Longitudinal Adjustment and Locking System
4. Hardened Disc (x2)
5. Hardened Spherical End Rod (x2)
6. U-Bracket (Cryomodule Attachment)
7. Grout
8. Floor Elevation

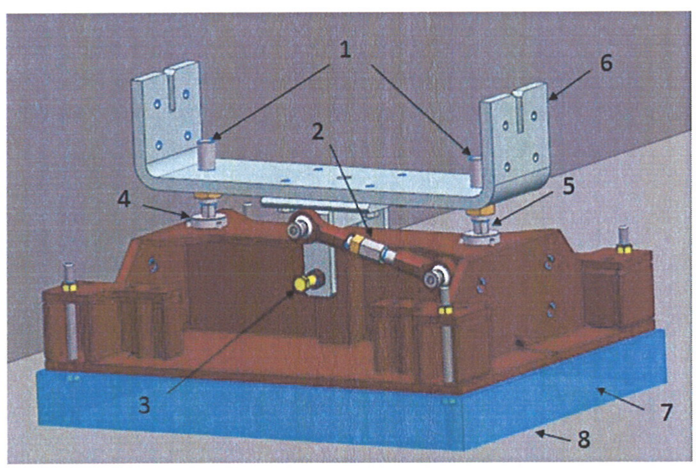

Figure 3: LCLS-II Cryomodule support stand (only) solid model.

The identical stand design is used at the upstream (US) and downstream (DS) support of both the 1.3 GHz and 3.9 GHz cryomodules. However, each stand will function differently in the longitudinal direction, one fixed and one free to move (sliding). This longitudinal freedom allows for bending in the vessel and thermal expansion/contraction. The placement of the fixed stand, for example, either US or

DS is to be determined. The ability for longitudinal movement was built into the original DESY/INFN stand design as the (4) hardened supporting rods bear on (4) hardened discs (items 4 and 5 in Figure 3). The LCLS-II Cryomodule stand design allows for the set of seismic restraints to either constrain the cryomodule longitudinally or slide as necessary. In the case of the longitudinally sliding configuration, a flanged sleeve design prevents the clamping force given the torqueing of (4) bolts from locking the stand. These sleeves are coupled with a slot and a (DL-5) Dichronite dry film lubricant coating which exists on the surfaces of the relative sliding plates.

Figures 4(a) and 4(b) provide the details regarding this flanged sleeve design and application. The only difference between the fixed and sliding stand configuration involves the use of the sleeve or its removal. An ASTM A-325 [SAE J429] Grade 5, 1"-8 hex head bolt was specified for this connection with a (lubed) torque value of 480 ft-lbs[2] is applied to tighten each bolt in either case, fixed or sliding. The upper connection of (4) SHCS M24-3 x 60 mm long, Class 8.8 (~Grade 5) is made using a (lubed) torque value of 407 ft-lbs[3]. Chesterton 622 white grease, H1 food-grade lubricant[4] will provide lubrication for all threaded connection and resists breakdown due to high radiation.

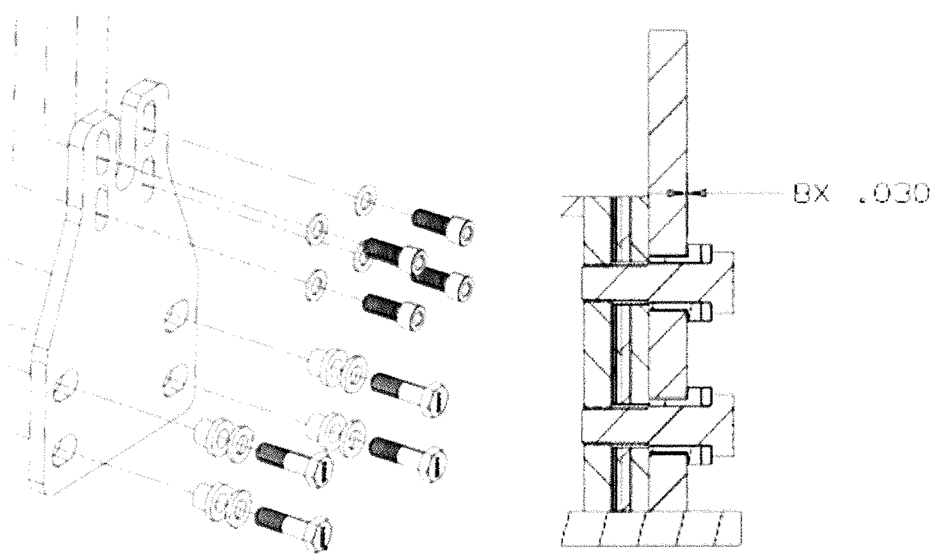

Figure 4(a): Iso-view of sleeve attachment. **4(b):** Section-view of sleeve implemented for sliding configuration.

3. Stand Design Seismic Analysis

A seismic and structural analysis of the LCLS-II Stand design was completed[5]. The seismic loading on each stand was considered under LCLSII-4.5-EN-0226 (Cryomodule Seismic Design Criteria) and document, SLAC-I-720-0A24E-001-R004 (Seismic Design Specification for Buildings, Structures, and Systems: 2014). Structurally, the ASIC Manual of Steel Construction was applied[6]. In general, allowable stress in each case is found using values from structural steel.

4. Prototype Stand at CMTS-1

A set of prototype LCLS-II cryomodule stands were fabricated for the Cryomodule Test Stand 1 (CMTS-1) at CMTF, Fermilab.

4.1 Reduced Magnetic Design Option

Initially, the stands for CMTS-1 considered the reduced magnetic design (material) consisting mainly of 316 L stainless steel. Recent findings show that the cavity quality factor, Q_0 is enhanced by expelling the magnetic flux during rapid cooldown. Meeting the LCLS-II Q_0 specification of 2.7×10^{10} requires an ambient magnetic field of 5 mGauss or less, averaged over the RF surface of the cavities[7,8]. Stray magnetic fields external to the cryomodule may be more than the assumed average and must be minimized.

There are two ways to approach the stray field issue (or minimize the effect); provide magnetic shielding or eliminate the source(s). Each girder consists of common structural steel found either in Europe (used by DESY) or within the USA (applied here at Fermilab). The chosen approach involved changing the original girder material specification from A36 structural steel to 316L stainless steel. This change also applies to any hardware used within the design, especially near the cryomodule. Structural steel hardware (such as critical girder and Hilti ™ bolt connections) used with the original design have been retained in the CMTS-1 girder design. These components are far enough from the cavity string to prevent stray field exposure. We learned through this process that permabilities below 1.05 and stray magnetic fields of 500 mGauss above background at contact were achievable[9].

However, even if the cryomodule stands were constructed from a non-permeable material, other permeable (or potentially magnetic) sources within the SLAC tunnel still exist. Stay magnetic issues will be addressed during fabrication and at the QC stage of procurement through measurement and possible degaussing of affected components.

4.2 Prototype Stand

In March of 2016, the two prototype cryomodule stands were loaded using the pCM vacuum vessel and the yellow strongback cryomodule lifting fixture (see Figure 5). Then, each stand was adjusted in the vertical, transverse and longitudinal direction to check functionality. It was determined that less than 50 ft-lbs of torque was needed to drive the cryomodule in any direction. Note that small incremental changes are necessary to efficiently move the cryomodule as binding may occur when an un-coordinated adjustment (US and DS) is attempted. Also, the horizontal tie-rods need to be loosened while driving longitudinally.

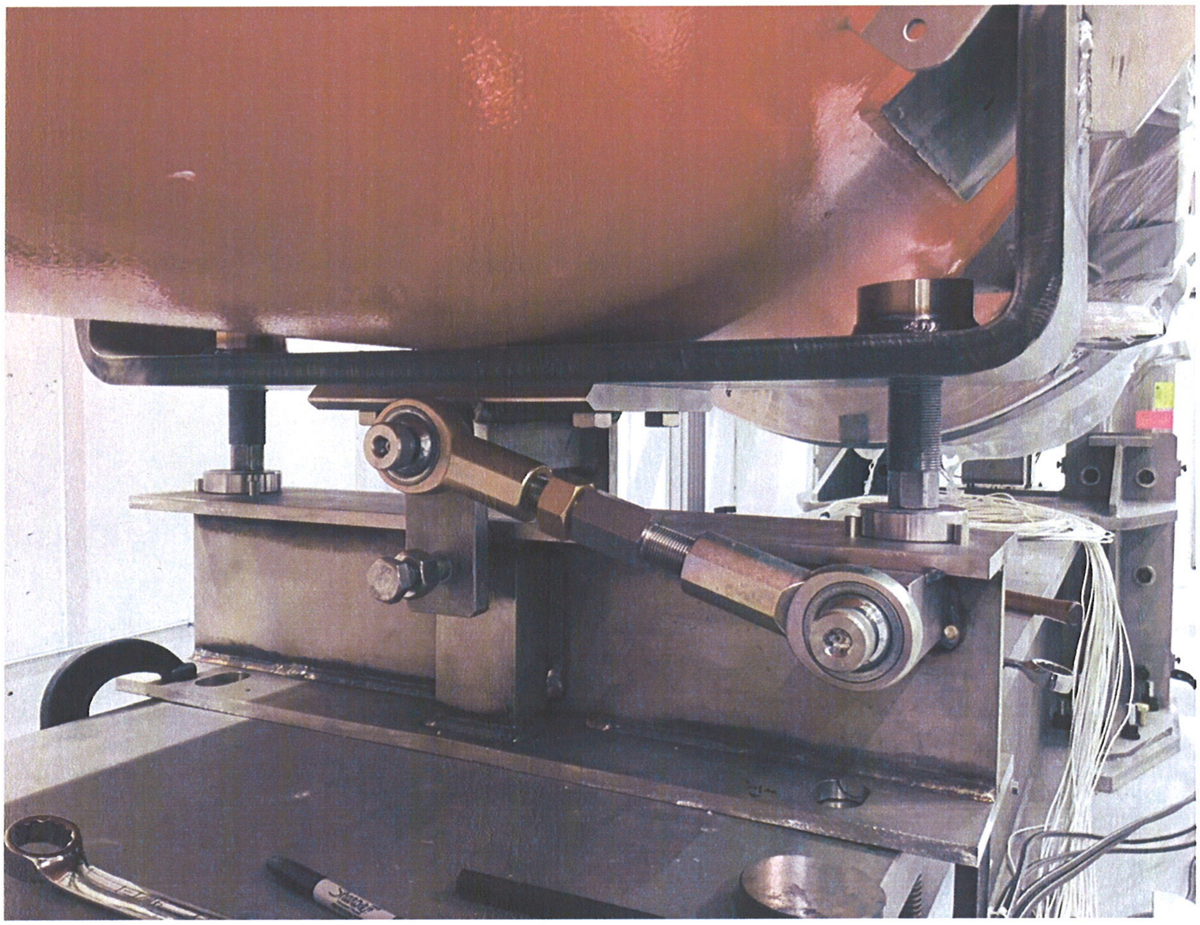

Figure 5: CMTS-1 DS reduced magnetic stand (prototype).

5. Procurement & Fabrication

Under Fermilab drawing F10063423 SLAC/LCLS-II CROMODULE – ADJUSTABLE SUPPORT ASSEMBLY, a fabrication specification, "LCLS-II 1.3 GHz and 3.9 GHz Cryomodule Stand Specification as created.

6. Tunnel Installation

The proposed LCLS-II 1.3 GHz and 3.9 GHz Cryomodule stand installation at SLAC involves three basic steps; preparation, stand placement and installation. Work to remove the existing SLAC components will proceed. Following this removal effort, all existing grout from the old supports will also be removed. The floor will then be cleaned and prepared for the LCLS-II components. A drilling template with fiducials and an alignment crew using a laser tracker system will locate the (4) holes needed for the 5/8"- 11 threaded rods. A contractor crew will then drill the holes at a maximum depth of 12-1/2" using a stationary Hilti-style drill motor and diamond tip drill bits at each stand location along the LCLS-II beamline. The diamond tip drill may only be used to cut through existing rebar, as the tunnel foundation is considered cracked concrete. Finally, the rods will be installed at each location after cleaning out the holes. The 5/8" – 11 ASTM A193 B8 Class 1 steel threaded rods cut to length (assuming a maximum embedment of 12-1/2") and HIT-RE 500 V3 adhesive system by Hilti applied[10]. This adhesive system is then allowed to cure.

Each of the (4) 5/8" – 11 rods are lubricated and a nut with oversized washer is positioned ~ 4" above the floor. The cryomodule preassembled stand (without seismic restraints) is lowered onto the (4) nuts using a ½ Ton folding floor crane, eyelets and (2) lifting straps. Then, the stand load is completely lowered onto the threaded supports and crane is removed. A second nut and washer set is attached at each support point.

Nominally, the upper surface of each embedded base plate is found 4.135" above the LCLS-II tunnel floor (see Figure 6). This floor is pitched in two directions; 0.286 degrees north-to-south based on the Earth's curvature and 0.62 degrees east-to-west for drainage purposes. Also, the floor's elevation varies +/- 1" along the LCLS-II tunnel length. The double (above and below plate) nut design found at each 5/8" – 11 supporting rod allows a leveling feature for each base plate as well as a torqueing feature. Each embedded base plate is roughly leveled using the lower 5/8" – 11 nuts and then checked using laser tracker system. Once each embedded base plate has been located and a torque of 110 ft-lbs is evenly applied to secure each base plate. Alignment spot-checks are used to track any movement of the embedded base plates while torqueing. This procedure is repeated for the other stand base plates while moving DS.

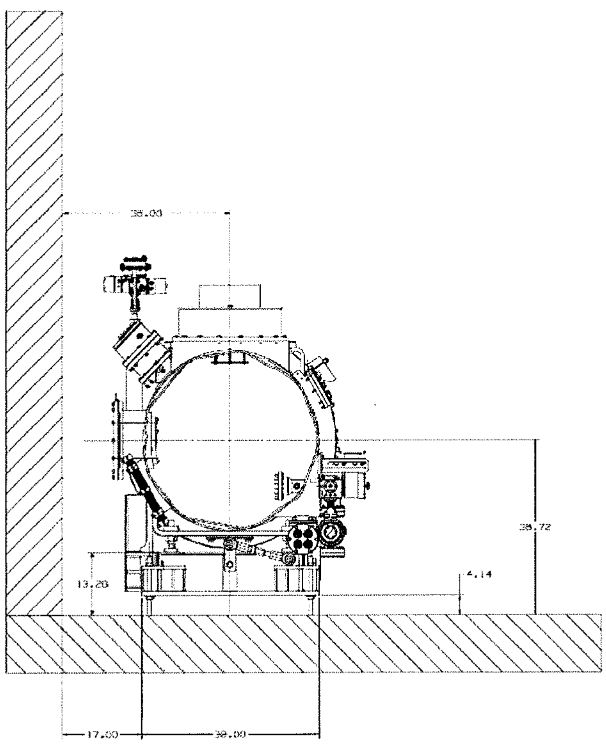

Figure 6: LCLS-II Cryomodule installation at SLAC.

Following the preassembled stand installation phase, each cryomodule will be transported to its location via tunnel transport device, moved into the beamline and lowered onto the stands. Alignment will follow as stand adjustments are made to position each cryomodule. Finally, the wall and aisle seismic restraints are attached to each stand. The attachment of the seismic restraints is the most challenging phase of the installation. Access to the wall-side seismic restraints is made from the tunnel floor beneath each cryomodule using a mechanics creeper as shown in Figures 7(a) and 7(b). A pneumatic impact tool with hex head wrench is used on the (4) upper connections, SHCS M24-3 fasteners (shown in Figure 4(a)) to reach the recommended torque values.

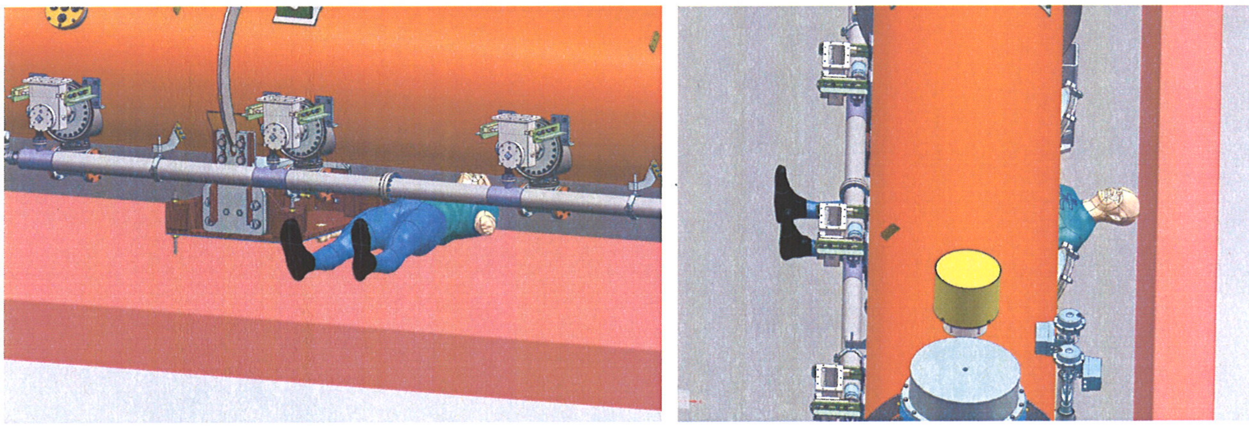

Figure 7(a): Floor access through aisle. **7(b):** Plan-view of lower access.

7. References

[1] Fang, I. and R. Wands, "Analysis of RF Cavity Support Stand," Fermilab (PPD), September 26, 2007.

[2] http://www.americanboltcorp.com/tech/techtorque.pdf

[3] http://www.cncexpo.com/MetricBoltTorque.aspx

[4] http://chestertonlubricants.chesterton.com/en-us/Products/Pages/622.aspx

[5] Wands, R. "LCLS II Cryomodule Stand Analysis," SLAC – LCLS-II-4.5-EN-0418-R0, September 2016.

[6] American Institute of Steel Construction, "Manual of Steel Construction – Allowable Stress Design," 9th Edition, 1989.

[7] Crawford, A., "A Study of Magnetic Shielding Performance of a Fermilab International Linear Collider Superconducting RF Cavity Cryomodule," Fermilab, September 2, 2014.

[8] Crawford, A. and I. Terechkine, "Impact of Material Magnetization on the Magnetic Field Inside LCLS Cryomodule," Fermilab Document TD-15-012, June 25, 2015.

[9] McGee, M.W., "Cryomodule Test Stand Reduced-magnetic Support Design at Fermilab," International Particle Accelerator Conference, Busan, South Korea, 2016.

[10] https://www.us.hilti.com/anchor-systems/injectable-adhesive-anchors/241382