ProtoDUNE Cable Tray Design Update

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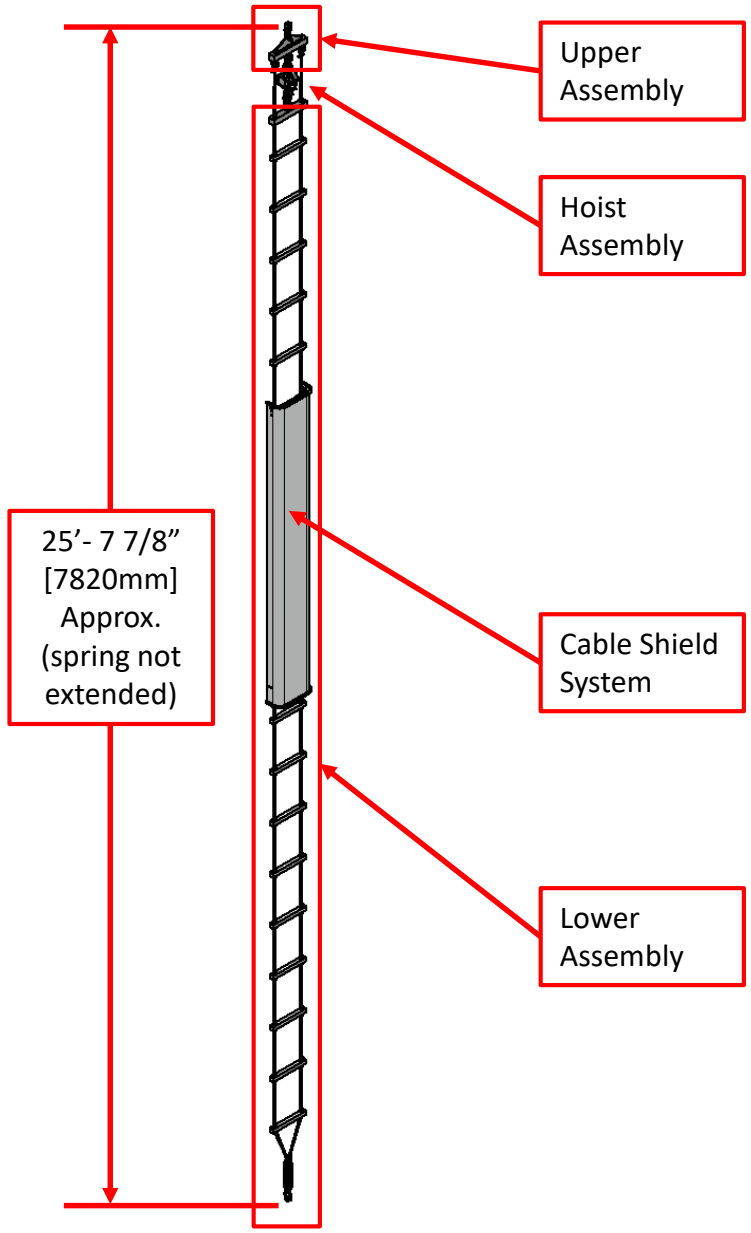
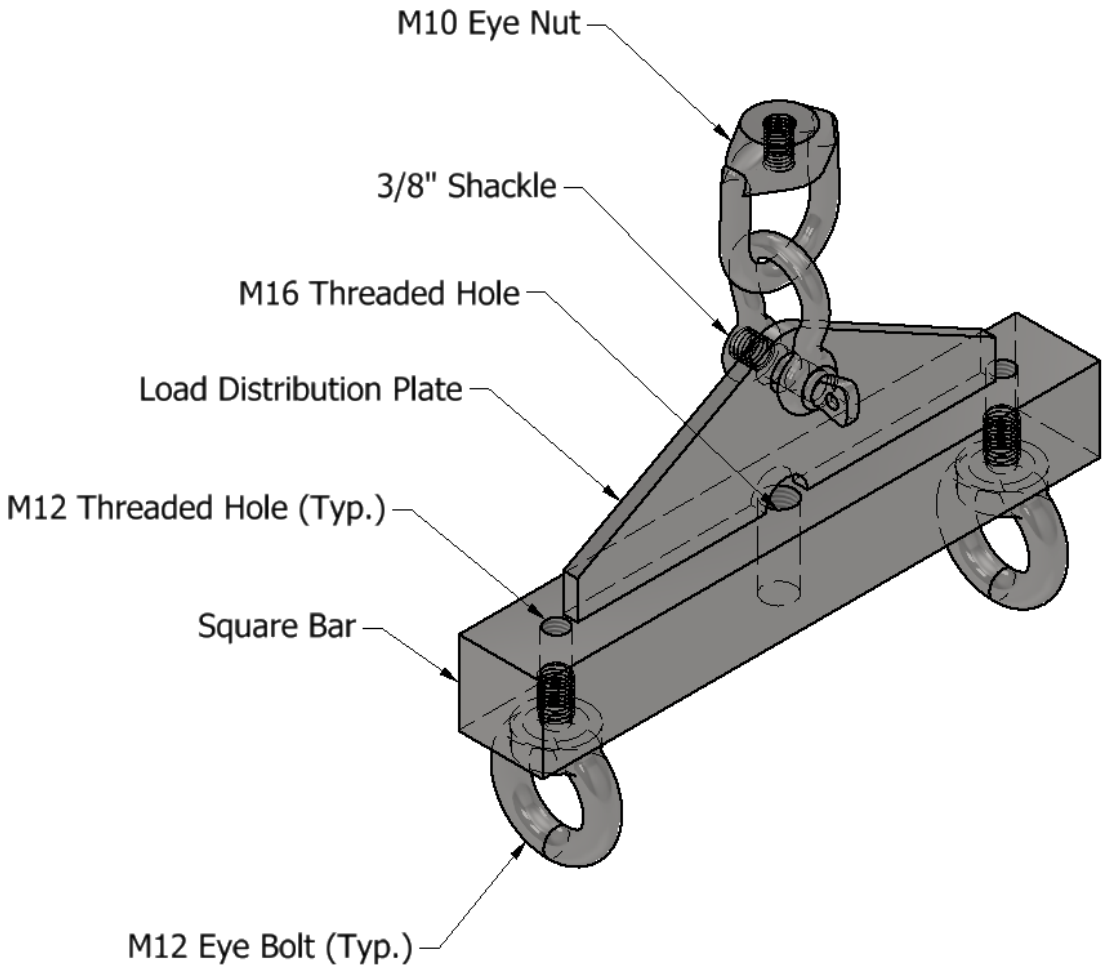
Design Overview

- A cable tray system was designed to allow for the routing of cables vertically along the wall of the cryostat.
  - The cables being routed would include the bottom drift electronics cables and the PD fibers.
- An integral cable shield would prevent interferences with the high field area at the cathode plane.
- A rope ladder-style construction would allow for pre-installation of the BDE cables during fabrication.
  - This would speed up and simplify the installation of the cable tray within the cryostat.



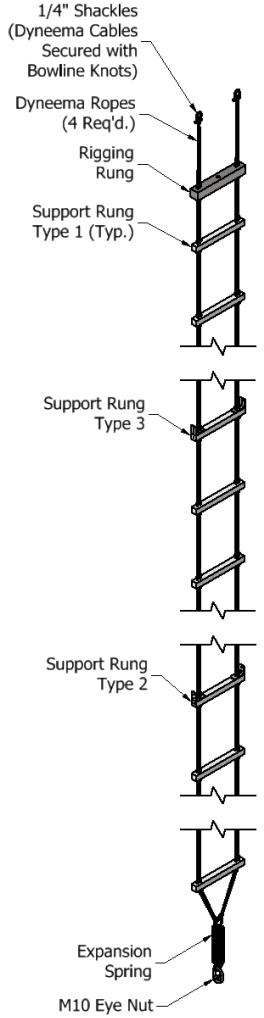
Upper Assembly

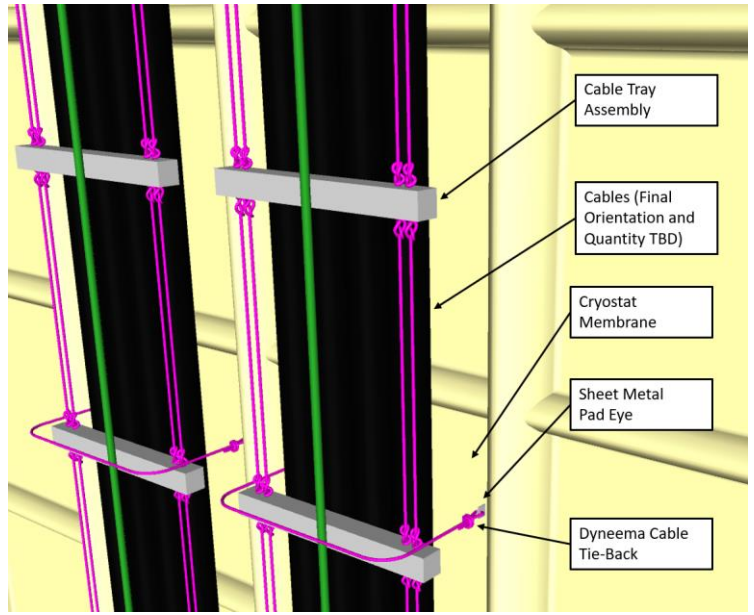
- Stainless steel square bar with a load distribution plate welded on top.
- The plate has a hole at the top to facilitate the attachment of a shackle connector.
- The square bar has threaded holes to allow for eye bolt attachment.
  - The central hole is for the attachment of the hoist system.
  - The outer holes are for the attachment of the eye bolts supporting the lower assembly cables.



Lower Assembly

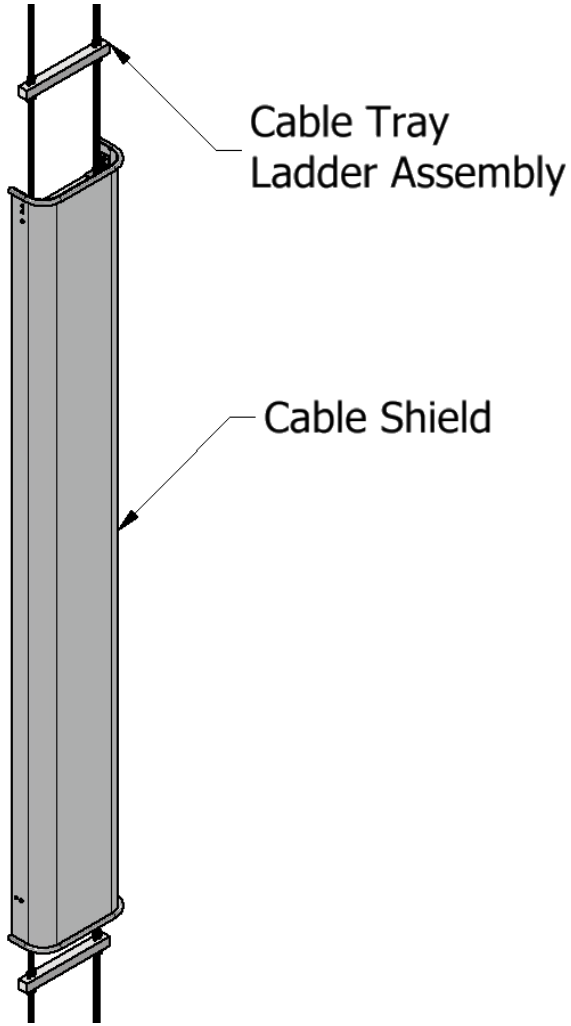
- The lower assembly consists of a stainless steel rigging rung and a series of FRP square bars connected with (4) Dyneema cables.
  - The cables pass through holes in each rung and will hold them in place using Figure-8 knots top and bottom.
  - The rigging rung has a central threaded rod to allow for the attachment of the hoist system.
  - The FRP bars will act as the main attachment point for all cables being routed (using cable ties).
  - An extension spring at the bottom will connect to the lower membrane using an eye nut and will help the system remain taut during thermal cycling of the cryostat.
- A series of Dyneema cable tie-backs can be used to attach to wall-mounted pad eyes to help the system remain in place.
  - The single attachment point at both the top and bottom could lead to rotation of the assembly.





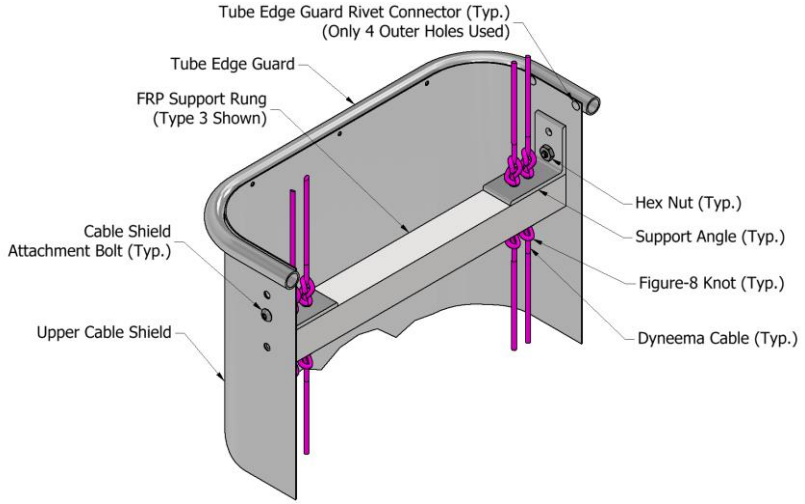
Cable Shield System

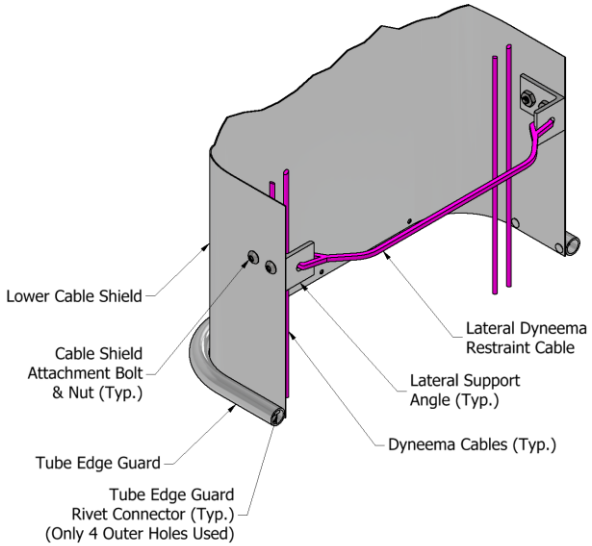
- The cable shield is an aluminum sheet metal piece that is mounted at the center of the cable tray assembly.
- The design is intended to limit the interference of the cable tray assembly in the high field area at the cathode plane.
- A set of bent aluminum tubes is attached at each end to mask the sharp edges present.
- The fabrication and testing of this part has not yet been finalized.



Cable Shield System (Cont.)

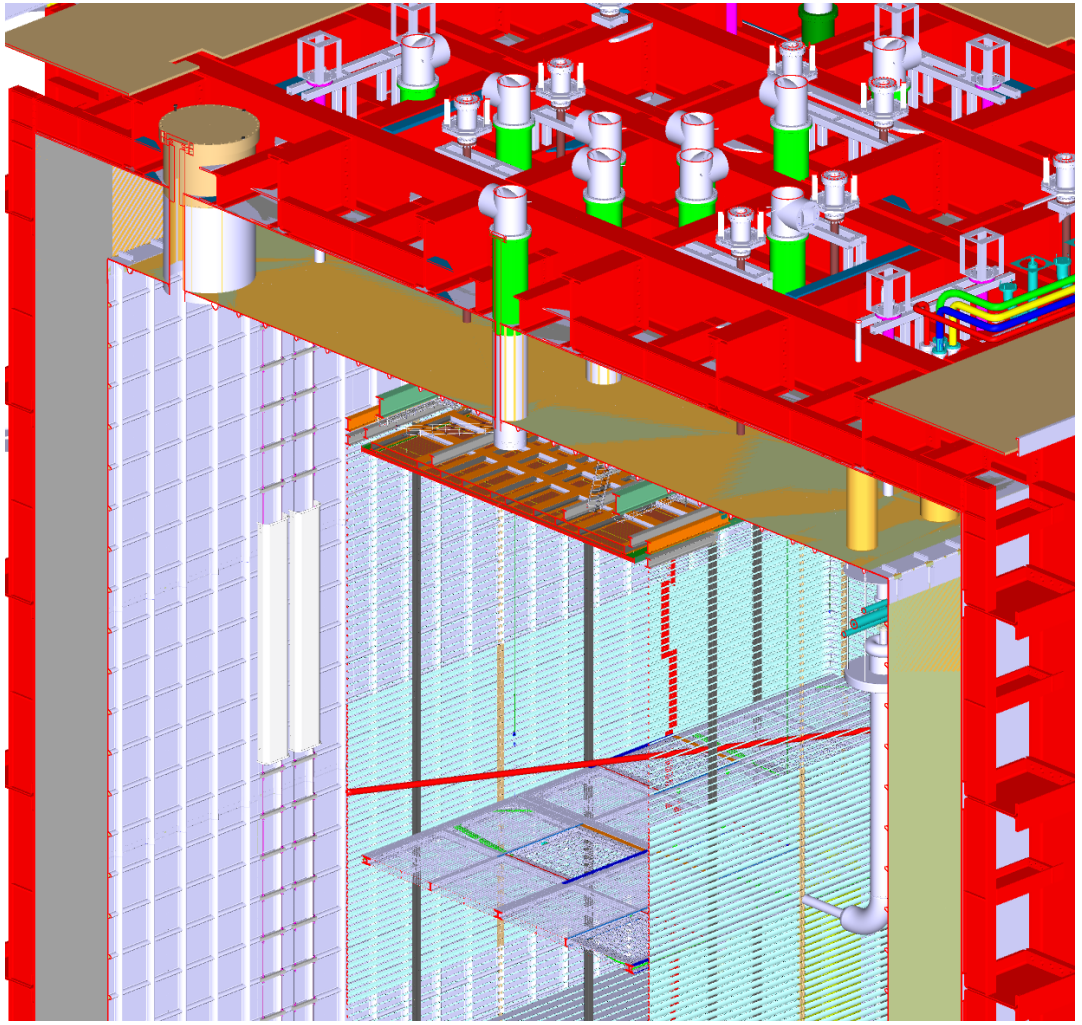
- The cable shield will attach to the lower assembly support angle with a single pair of #10-24 bolts.
- The tube edge guards will be attached to the sheet metal with rivets.
  - The quantity and attachment method will need to be verified with prototype testing.
- The single attachment point at the top is to minimize overstressing of the metal due to thermal effects.
- The lower section of the shield would be loosely secured to the lower assembly with a lateral Dyneema restraint cable.



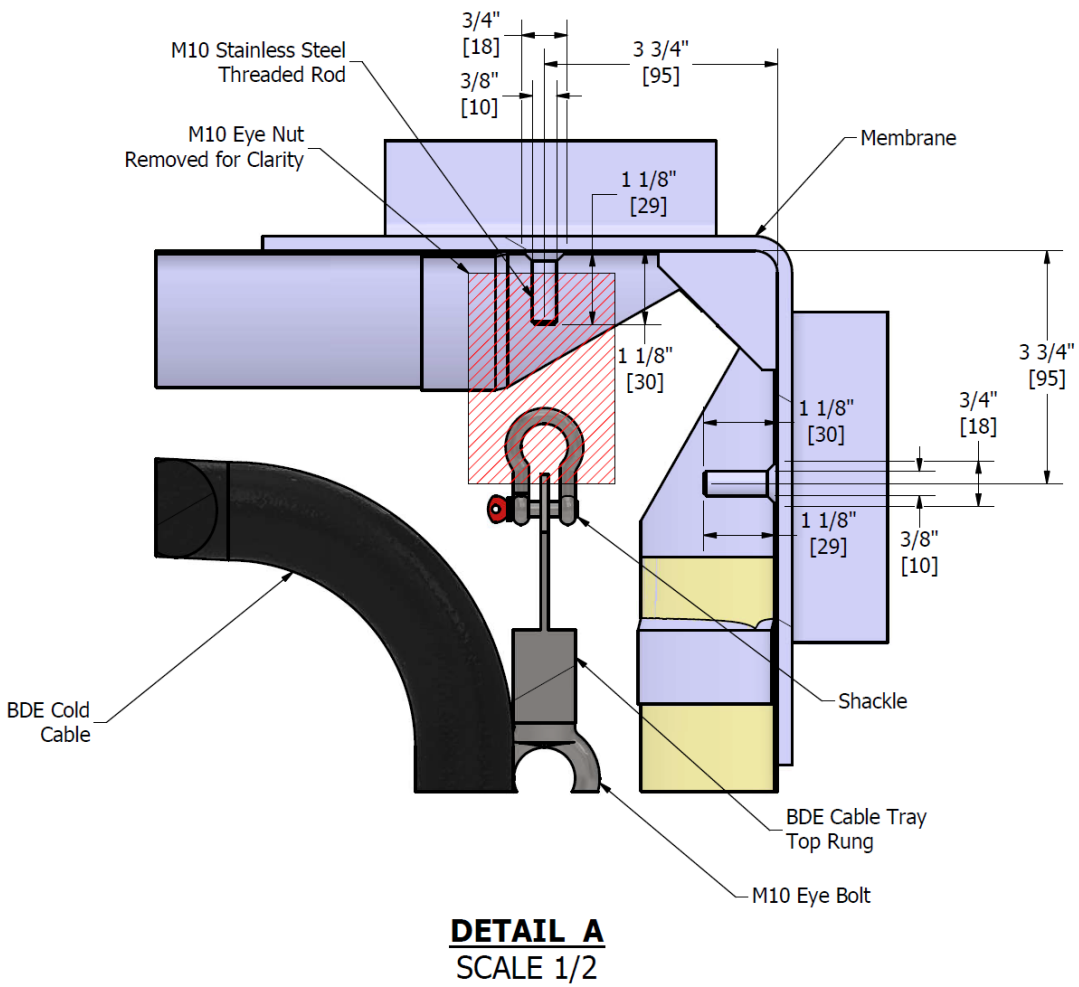


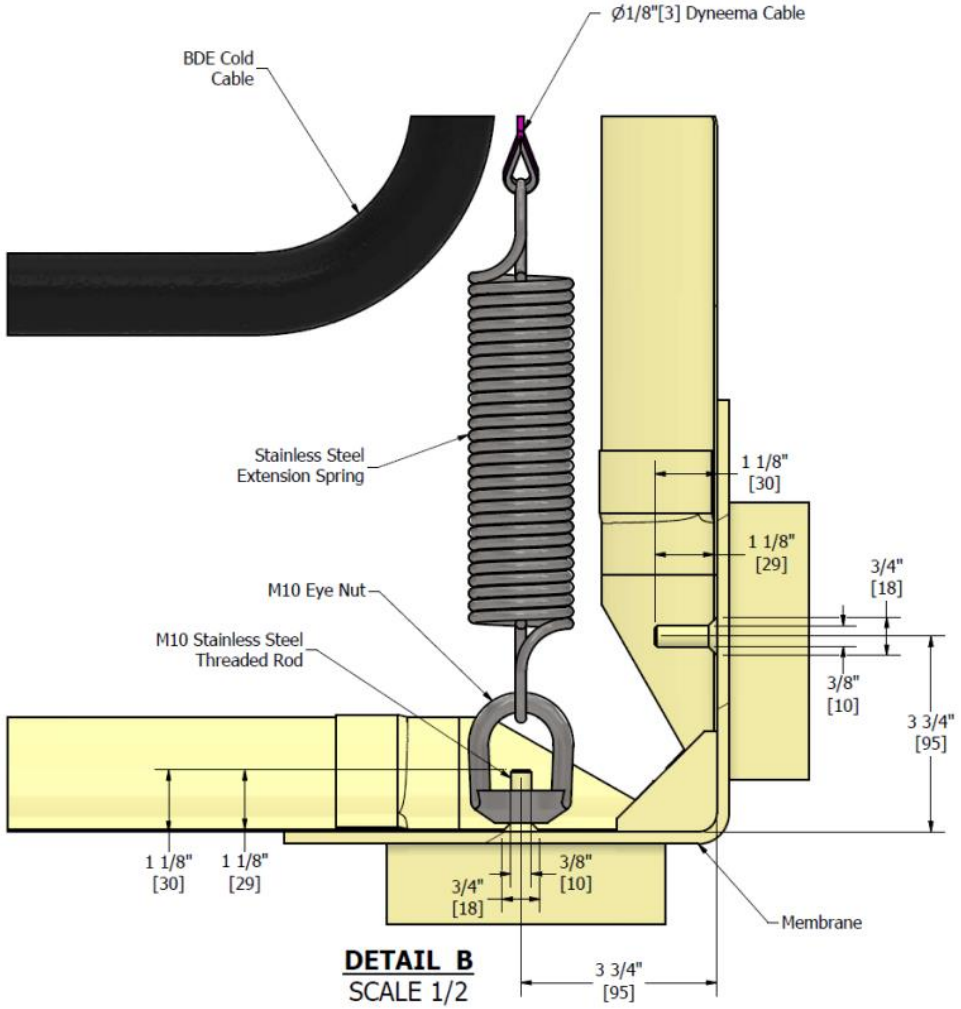
Design Requirements – Installation Location

- There are very few mounting locations available along the cryostat walls.
- (2) Cable trays will be required to be installed in the ProtoDUNE cryostat.
  - **The precise location has not yet been finalized.**
- The sole location available for the attachment of these cable trays is the upper and lower M10 threaded rods that penetrate through the membrane.
  - The 340mm spacing and 95mm distance of the threaded rod to the membrane wall limited the size and design of the cable tray.
- A threaded eye nut would be used to attach the upper rung assembly and the lower extension spring to the threaded rods.



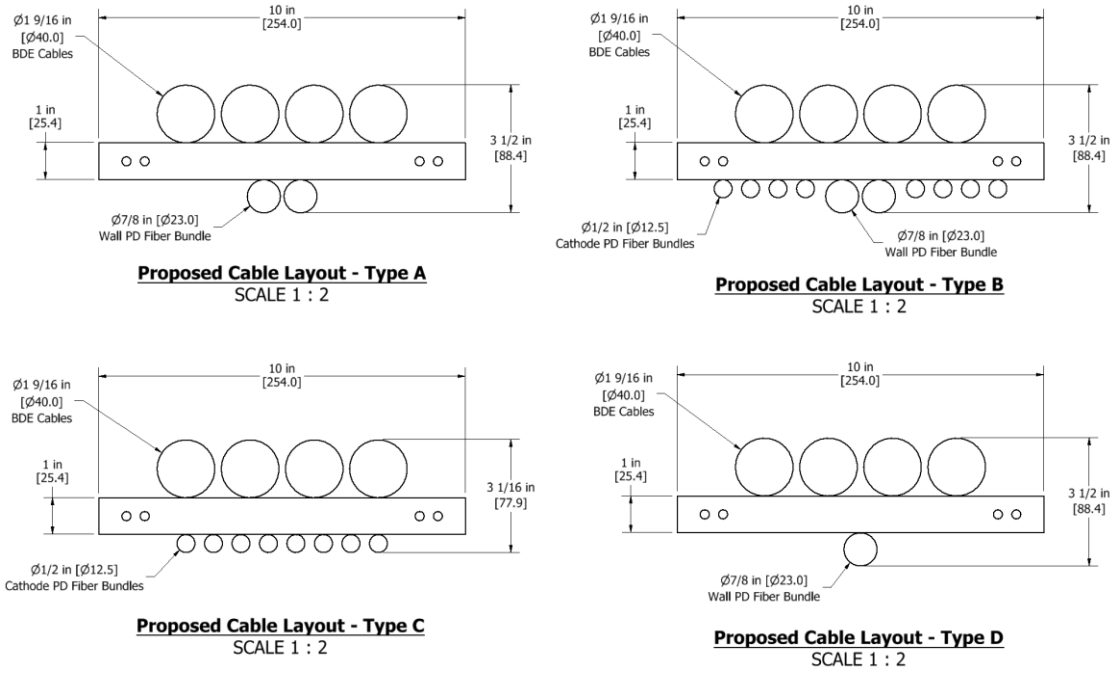
Design Requirements – Installation Location (Cont.)





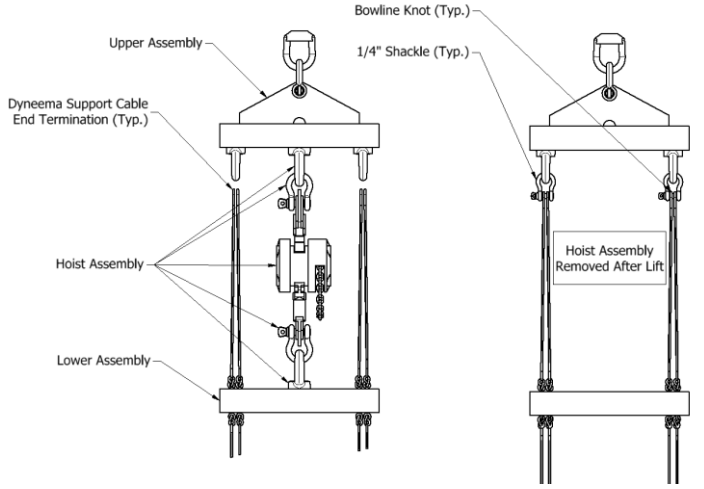
Design Requirements – Cable Routing

- The assembly was designed to be capable of supporting the worst-case cabling required for the FD2 cryostat.
  - Routed behind (on the wall-facing side)
    - (4) Ø40mm BDE bundles
  - Routed in front
    - (2) Ø23mm Wall PD bundles
    - (8) Ø12.5mm Cathode PD bundles
- The worst-case cable load for the full-height FD2 cryostat is 487 lb. [221 kg].
- The ProtoDUNE cable routing is expected to be similar, but with a reduced load due to the shorter cryostat wall height.
  - The cable tray load-bearing components (rungs) for both the FD2 and ProtoDUNE assemblies are identical.



Design Requirements – Installation

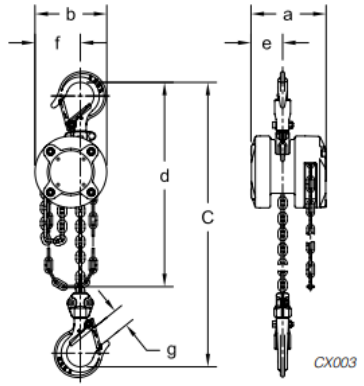
- The main benefit of the ladder-style cable tray design is the ability to minimize the installation time within the cryostat.
  - The main BDE cables can be installed during fabrication off site onto the lower assembly.
  - The lower assembly would be rolled onto a custom cable reel and transported to the installation site.
  - After the upper assembly is attached to the top membrane, a hoist system utilizing a CX003 ¼ US ton chain hoist can be attached to both the top and rigging rungs using eye bolts and shackles.



CX MINI HAND CHAIN HOIST — SPECIFICATIONS & DIMENSIONS

Cap. (Tons)	Product Code	Headroom C (in)	Std. Lift (ft)	Pull to Lift Load (lbs)	Over-haul Ratio	a (in)	b (in)	d (ft)	e (in)	f (in)	g (in)	Load Chain Diameter (mm) x Chain Fall Lines	Net Weight (lbs)	Shipping Weight Approx. (lbs)	Weight for Additional One Foot of Lift (lbs)
1/4	CX003	8.5	10	33	34	3.5	3.3	6.8	1.5	2.1	0.8	3.2 x 1	5.6	6.1	0.3
1/4	CX003	8.5	20	33	34	3.5	3.3	16.6	1.5	2.1	0.8	3.2 x 1	9.5	10.0	0.3

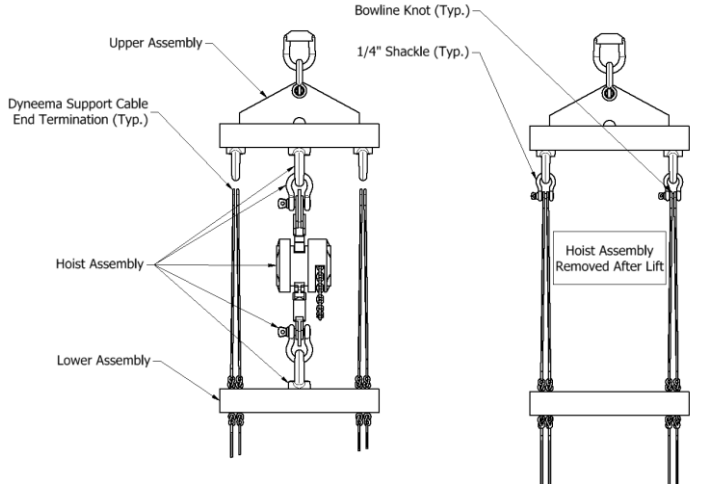
Weights are approximate.



1/4 Ton CX

Design Requirements – Installation (Cont.)

- After connecting the lower assembly to the bottom membrane with the extension spring, this component would then be lifted using this hoist and brought to its final installation elevation.
  - During this process, the hoist would also stretch the extension spring to help keep the entire ladder taut.
- The upper Dyneema cables would then have knots formed around the top rung eye bolts and shackles.
  - This process would need to be validated – would these knots need to be tested in the cryostat after formation?
- After the cables have secured the lower assembly to the top rung, the hoist system can be removed and shifted to the next cable tray installation location.



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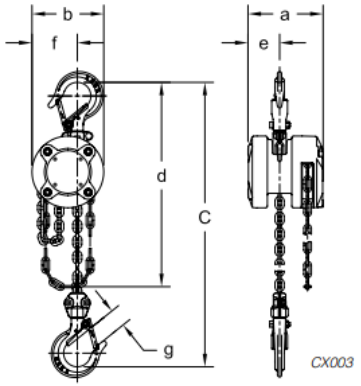

1/4 Ton CX

Engineering Status

- An engineering note for the FD2 cable tray was submitted to the compliance office for review, and if possible, would cover both the FD2 and ProtoDUNE designs.
  - The main differences between the designs are the assembly height, the cable shield size, and the extension spring.
  - The FD2 loads checked are greater than the cable loads expected in ProtoDUNE.
- Prototype testing is still required to fully validate the design.
  - While the rungs were checked using FEA software, the knots integral to the design would need to be physically tested.
  - The extension spring capacity and selection would need to be verified.
  - The cable shield would need to be fabricated and tested in a cold box.

Engineering Status (Cont.)

- This design seems promising but will require further testing to ensure that all components can withstand the applied loads in a cryogenic environment for an extended amount of time.
- In addition, the formation of the main load-bearing knots in the cryostat will need to be analyzed.
  - Need to determine how this knot would be tested to certify that it meets all design and safety standards.
- Two prototype assemblies have been delivered to ProtoDUNE.
  - Further analysis and testing are required before these are allowed to be installed.
  - The upper cables were cut short and may prevent the intended installation method from being used.
  - The cable shield has not been fabricated at this time.
- A possible alternative would be to switch to a commercially available vertical cable tray.
  - The main drawback would be reintroducing the bulk of the cable installation to inside the cryostat.