

CE cable contraction

Length change of a ProtoDUNE CE data cable in liquid Nitrogen is measured.

Original length at room temperature: $45 \frac{3}{4}''$ (45.75'')

The cable was then immersed in liquid nitrogen for 1 minute.
Cable length was measured immediately after taken out from liquid nitrogen.
Length change in liquid nitrogen (-196°C): $\frac{7}{32}''$ (0.21875'')

Shrinkage rate: $0.21875''/45.75''/(20^\circ\text{C}-(-196^\circ\text{C}))=2.2\text{e-}5/^\circ\text{C}$

CE data cable shrinkage in liquid Argon:

Cable length in conduit is about 13m
Liquid argon temperature: -186°C

Length change in liquid Argon:

$$12\text{m} \times (20^\circ\text{C}-(-186^\circ\text{C})) \times 2.2\text{e-}5/^\circ\text{C} = \mathbf{0.054\text{ m} = 54\text{ mm}}$$



Stainless steel 304 contraction

Table 3A. Integrated Linear Thermal Expansion Coefficients for Metals.

Coeff.	6061 -T6 Aluminum	304 SS	718 Inconel	Beryllium copper	Ti-6Al-4V	NbTi
a	-4.1272E+02	-2.9546E+02	-2.366E+02	-3.132E+02	-1.711E+02	-1.862E+02
b	-3.0640E-01	-4.0518E-01	-2.218E-01	-4.647E-01	-2.171E-01	-2.568E-01
c	8.7960E-03	9.4014E-03	5.601E-03	1.083E-02	4.841E-03	8.334E-03
d	-1.0055E-05	-2.1098E-05	-7.164E-06	-2.893E-05	-7.202E-06	-2.951E-05
e	0	1.8780E-08	0	3.351E-08	0	3.908E-08
data range	4-300 K	4-300 K	4-300 K	4-300 K	4-300 K	4-300 K

$$\frac{L_T - L_{293}}{L_{293}} = (a + bT + cT^2 + dT^3 + eT^4) \cdot 10^{-5}$$

At T = 88K

$$\frac{L_{88} - L_{293}}{L_{293}} = -0.00272 \text{ m/m}$$

12m long stainless steel conduits will shrink

$$12\text{m} \times 0.00272 \text{ m/m} = 0.033 \text{ m} = 33 \text{ mm}$$

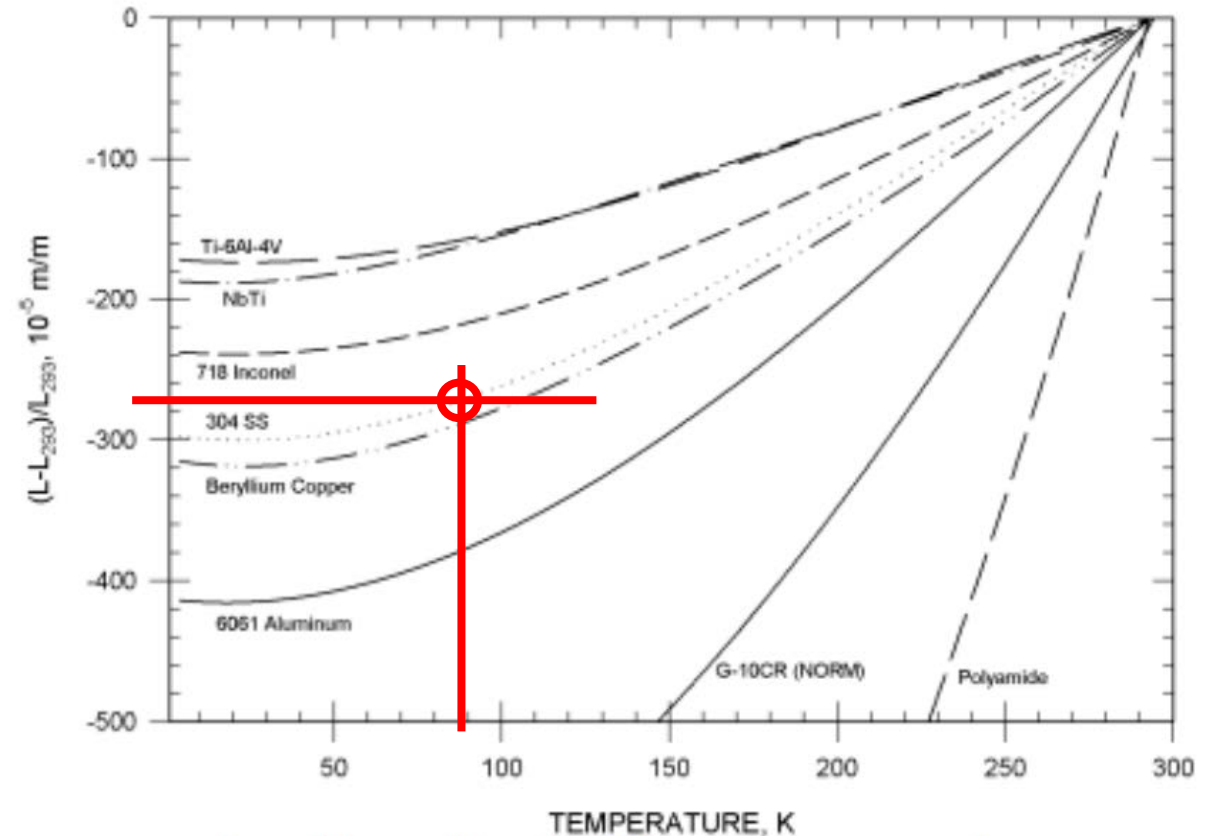
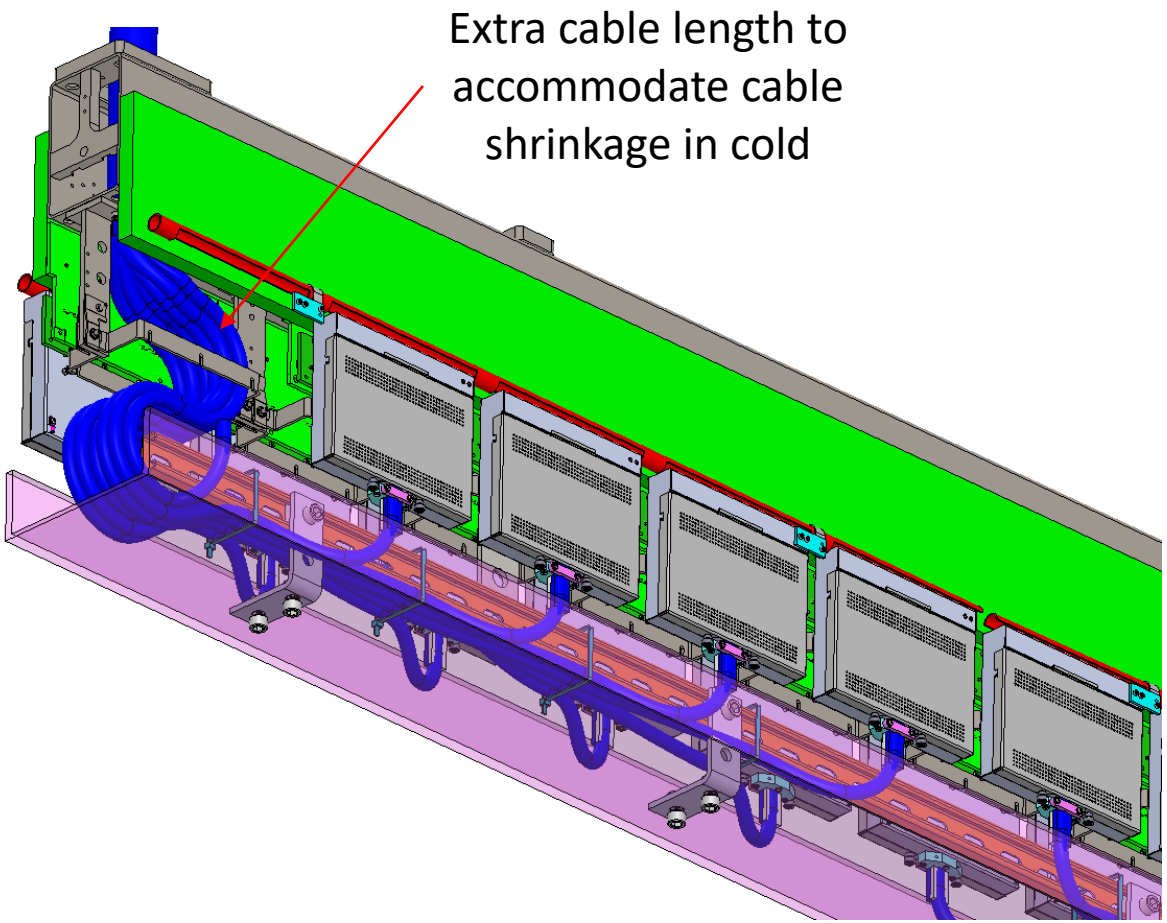
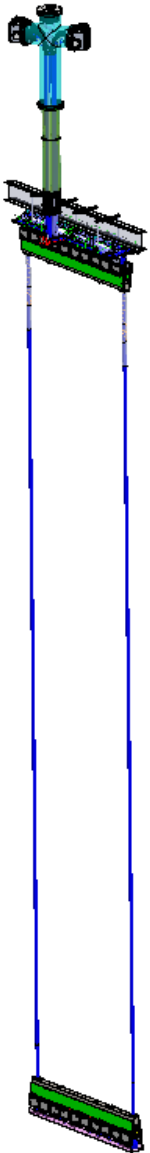


Figure 3. Integrated linear thermal expansion of various materials.

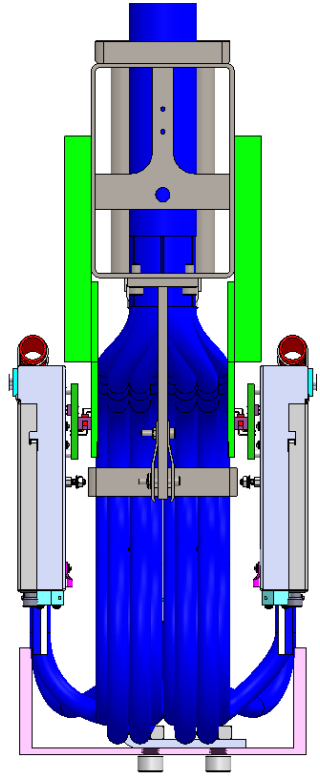
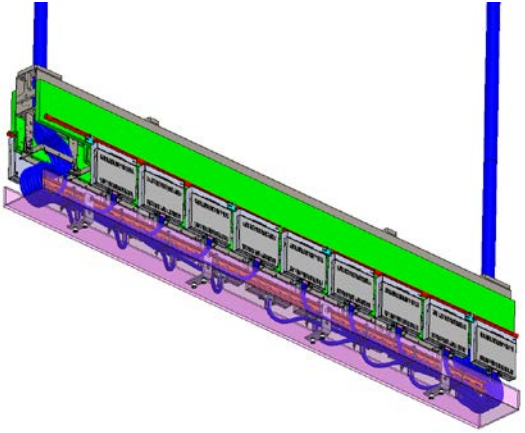
* Cryogenic Material Properties Database, NIST

Differential shrinkage between conduit and cable is 54 mm – 33 mm = 21 mm

Cabling at lower APA



Extra cable length to accommodate cable shrinkage in cold



Cable contraction cold test

1. Cable bundle in conduit to be tested in cold box at CERN
2. Cable performance in tension (can be done at room temperature)
3. ...