ProtoDUNE-SP Beam Plug Installation

Installation Workshop · April 19, 2017

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Lawrence Berkeley Lab

Introduction

- Overview, Installation Timeline
- Phase I
  - Install Nitrogen System components to roof
  - Secure Nitrogen Hose in Cryostat
- Phase II
  - Mount Beam Plug into End Wall Field Cage
- Phase III
  - Uncoil and connect Nitrogen Hose to Beam Plug
- System Testing
- Shipping to CERN

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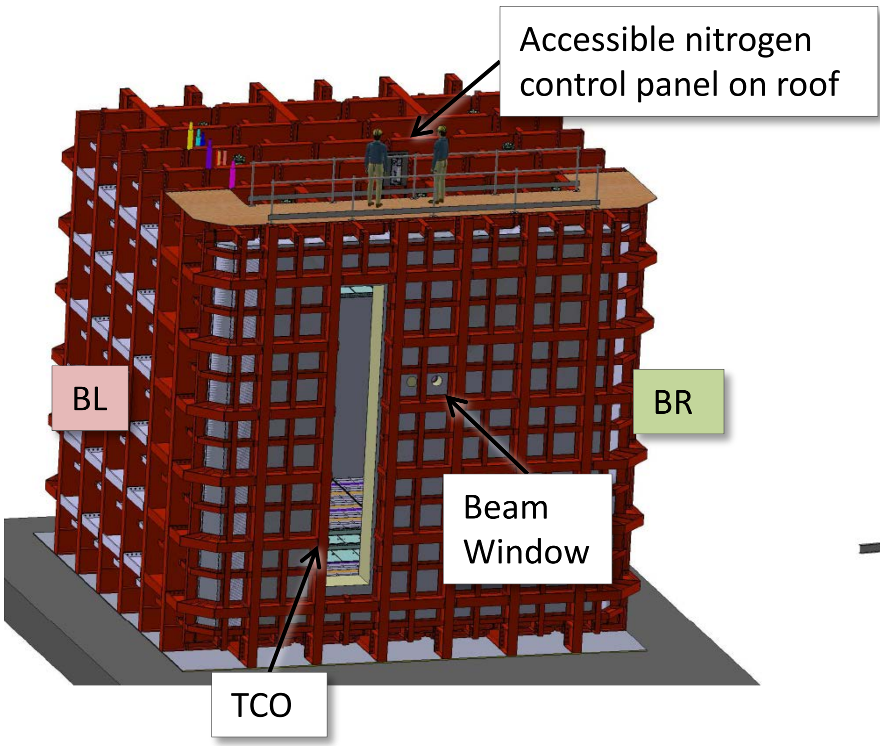
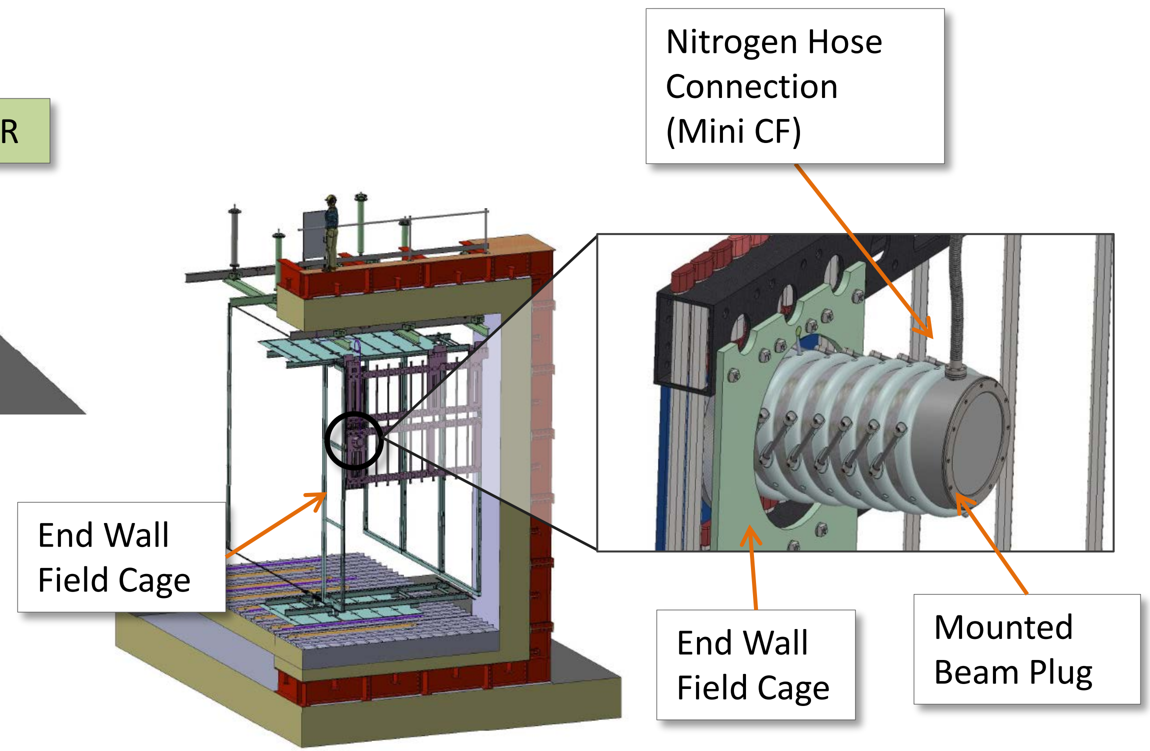
ProtoDUNE-SP Beam Plug at EHN1





Key Installation Related Events

- Testing at vendor, Blanche, 35 ton
- Shipping to CERN
- Installation & Testing
  - Phase I
  - Phase II
  - Phase III
- Commissioning

Phase I-III Installation Sequences

Order of insertion into cryostat through TCO :

A

Phase I

1. APA-DS–BR (PSL #1)
2. APA-MS–BR (PSL #2)
3. APA-US–BR (UK #1)
4. EW-DS–BR
5. EW-US-BR — Phase II
6. CPA-FC-DS
7. CPA–FC–MS
8. CPA–FC–US
9. APA-DS-BL (PSL #3)
10. APA-MS–BL (UK #2)
11. APA-US –BL (UK #3)
12. EW–DS–BL
13. EW–US-BL — Phase III

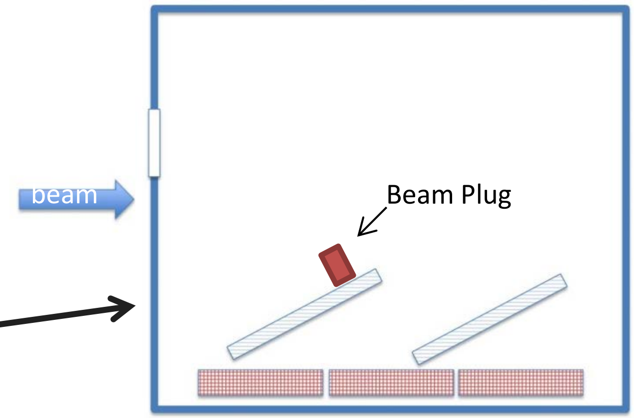
Order of installation into proper position :

B

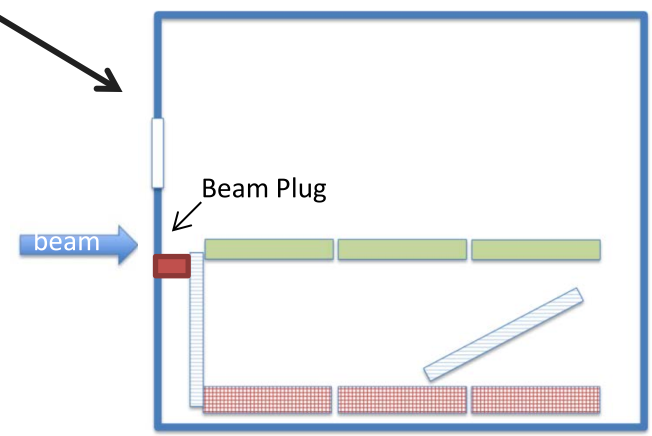
Phase I

1. APA-US–BR (UK #1)
2. APA-MS–BR (PSL #2)
3. APA-DS–BR (PSL #1)
4. EW-US–BR — Phase II
5. CPA-FC-US
6. CPA–FC–MS
7. CPA–FC–DS
8. EW-DS-BR — Phase III
9. APA-US-BL (PSL #3)
10. APA-MS–BL (UK #2)
11. APA-DS –BL (UK #3)
12. EW–US–BL
13. EW–DS-BL

Phase II *(Prior To Step 5A)*



Phase III *(After Step 8B)*



Graphics Source: Gina Rameika. Note: Phase timing shown approximate.

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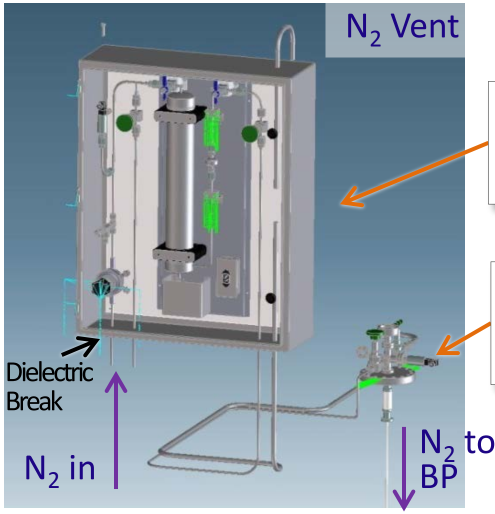
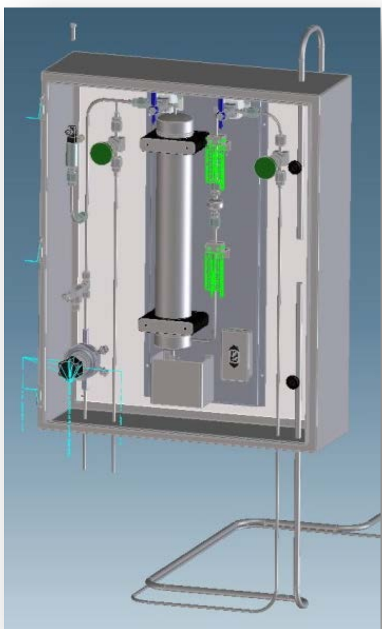
Phase I (Exterior): August/September 2017

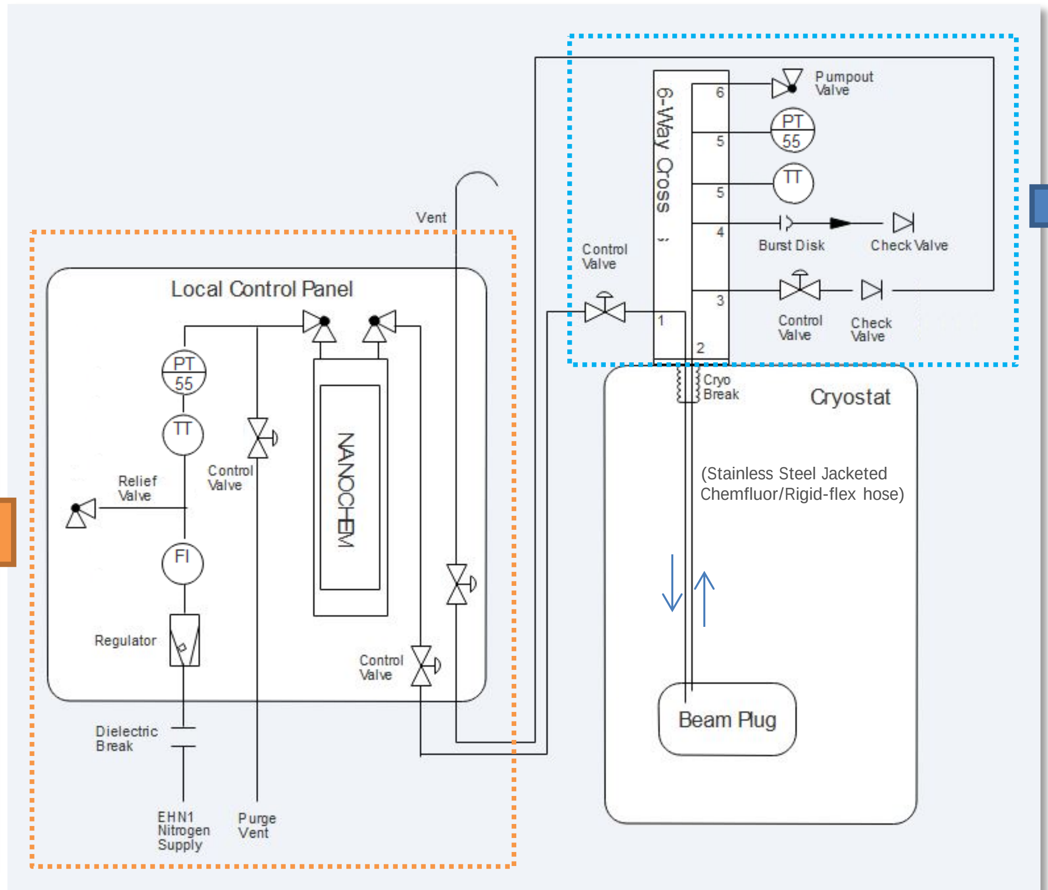


- Mounting Valve Cluster to Top Flange or other feedthrough (flange has underside cryo break).
- Mount Control Panel Box to Warm Frame I-beams within approximately 5 m of Valve Cluster (Unistrut frame).
- Prepare rigid welded Stainless supply and return lines between Control Panel Box and Valve Cluster outside cryostat.
- Box Services:
  - DC 24V power
  - Nitrogen gas supply line
- Sensor Readouts:
  - Temperature RTD (2X)
  - Pressure Sensors (2X)
  - Beam Plug Current Monitor

Phase I (Exterior): Flow Diagram



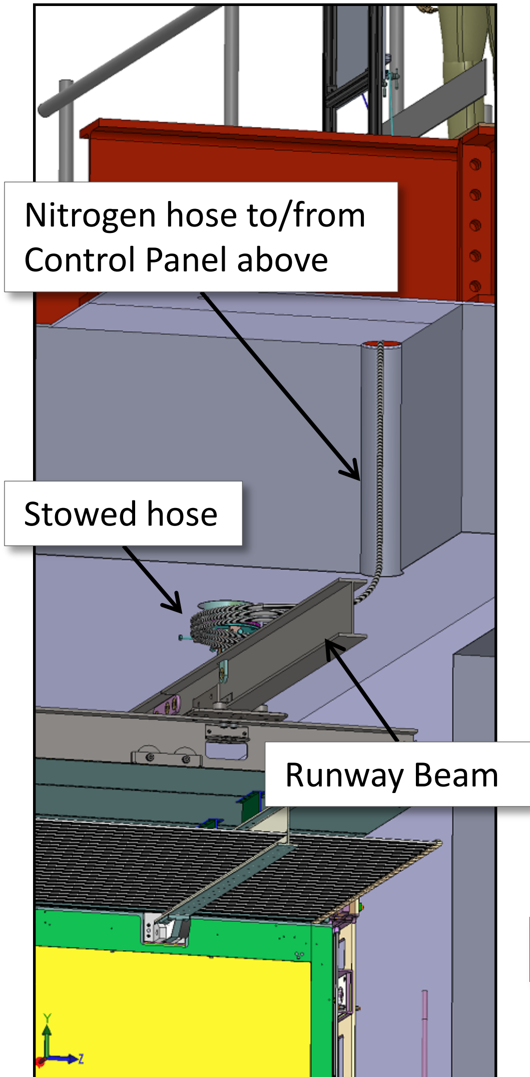
Control Panel



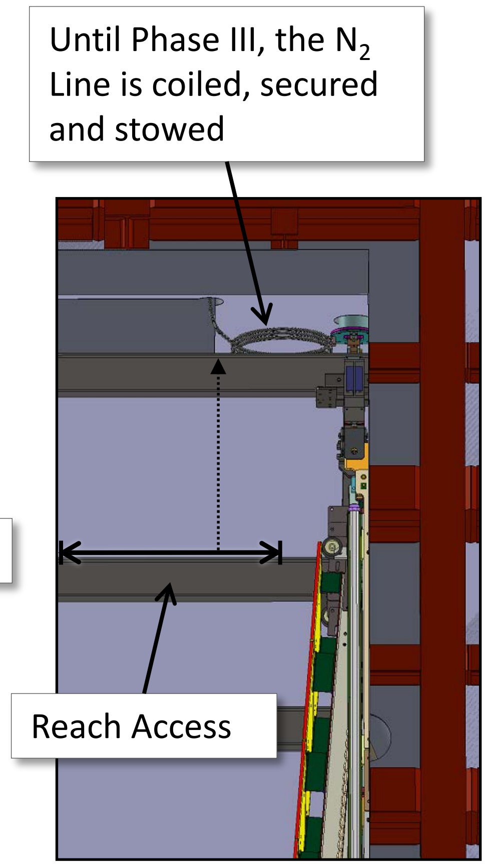
6-Way Mini Conflat Cross

Current March 2017

Phase I (Interior): Securing Nitrogen Hose



Hose Location



Port Location

- Nitrogen hose routed down into cryostat from feedthrough pipe above.
- Hose temporarily coiled and supported by Runway Beam until Bridge Beam C in position.
- Nitrogen Line leak tested.
- Clean Electrical Grounding with Dielectric Break verified.
- System installation and testing duration: 1-2 weeks

¾" Swagelok SS Braided Hose

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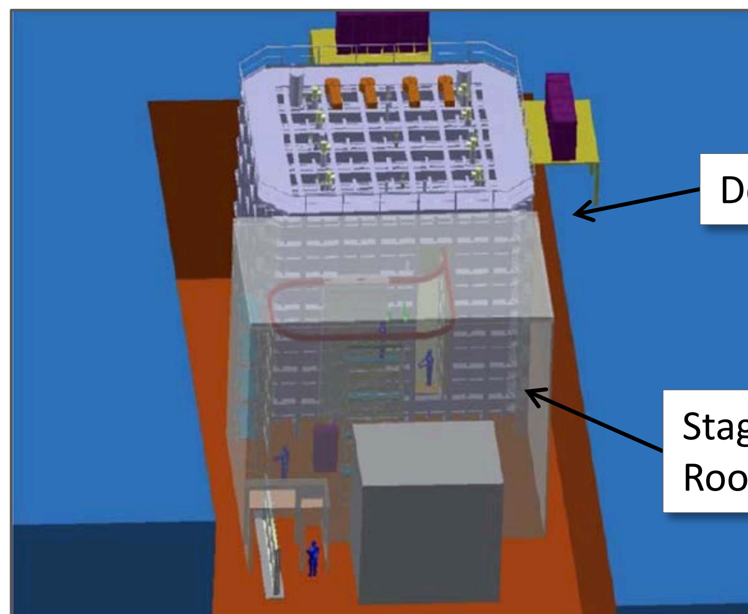
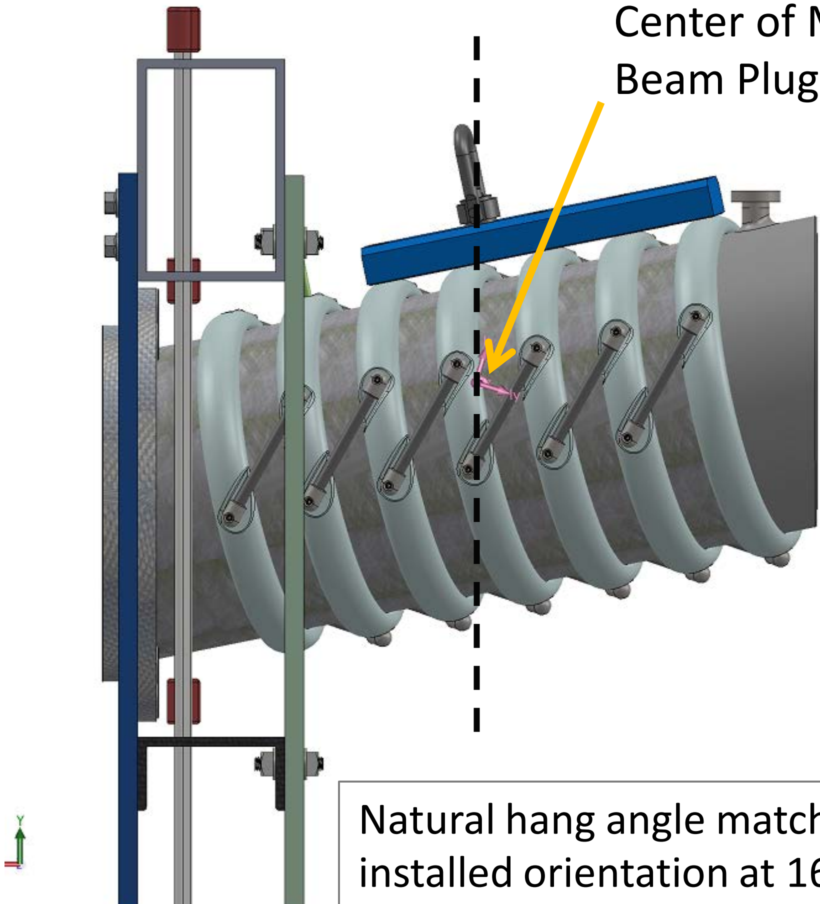
Phase II: November/December 2017

End Wall Field Cage with Beam Plug Mockup at Ash River Trial Assembly

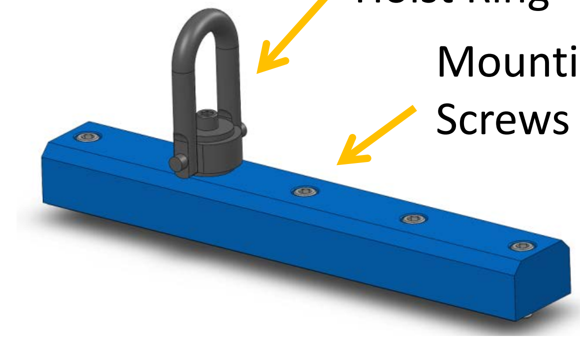
- Beam Plug installed into End Wall Field Cage in Clean Room outside of cryostat.
- Beam Plug and End Wall Field Cage inserted into Detector together during Step 5A *(slide 5)*.

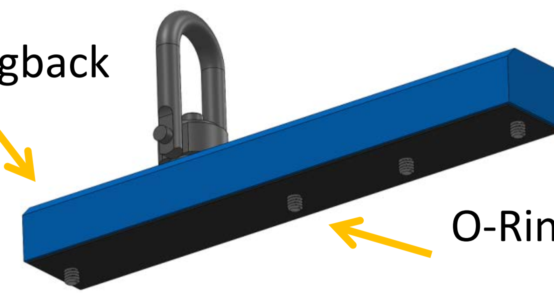


Phase II: Lift and Mount Tool



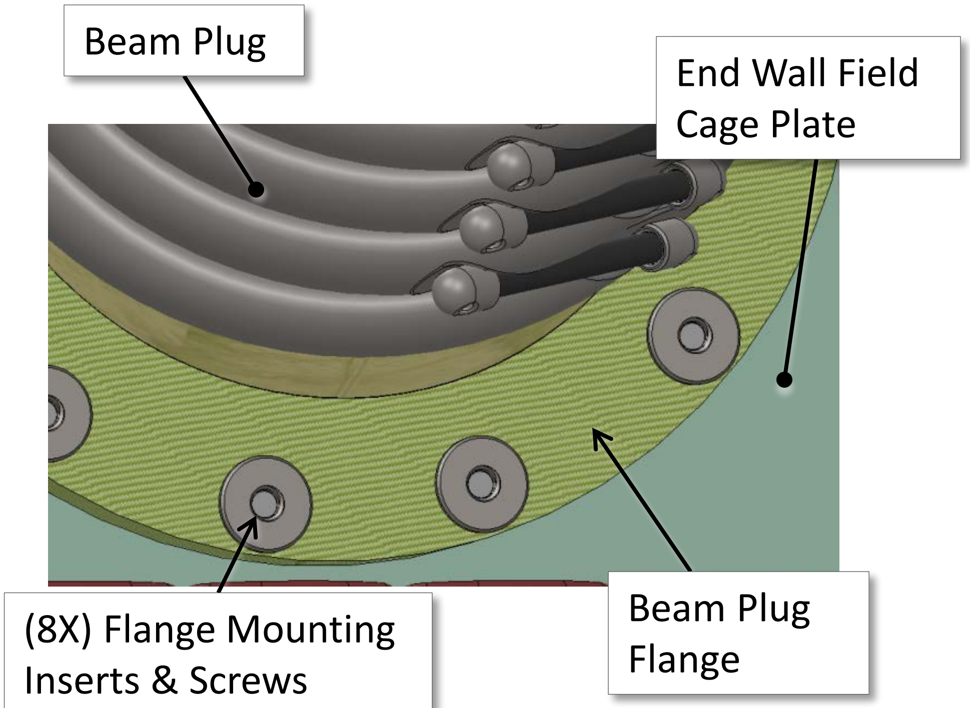
Natural hang angle matches installed orientation at 16.2° (compound angle)



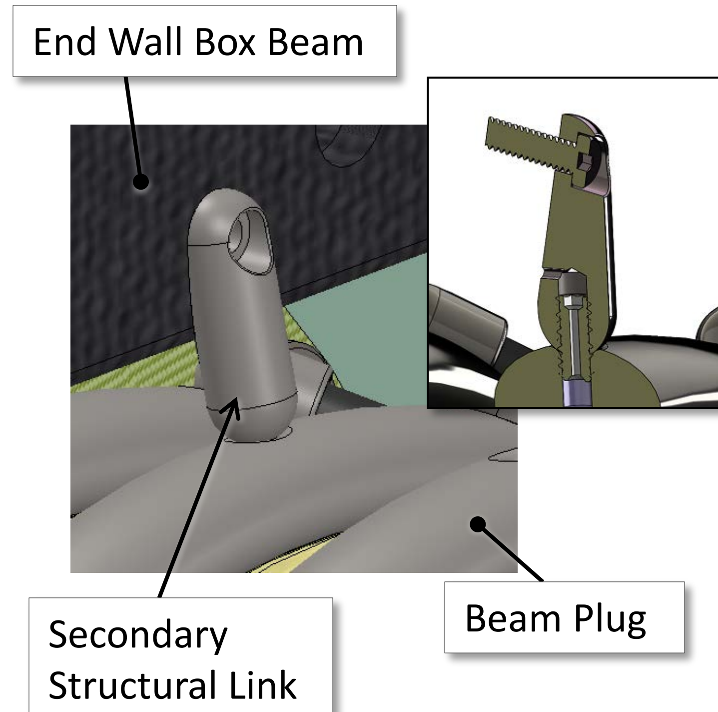


- Annodized Al 6061 Bar strongback
- Four 6 mm silver-plated socket head cap screws
- A80 Buna-n or Teflon o-rings at joints
- Stainless steel swivel safety hoist ring rated for 300 lb
- Lifting device mounts to electrode rings, balanced about the center of mass.

Phase II: Beam Plug Connections

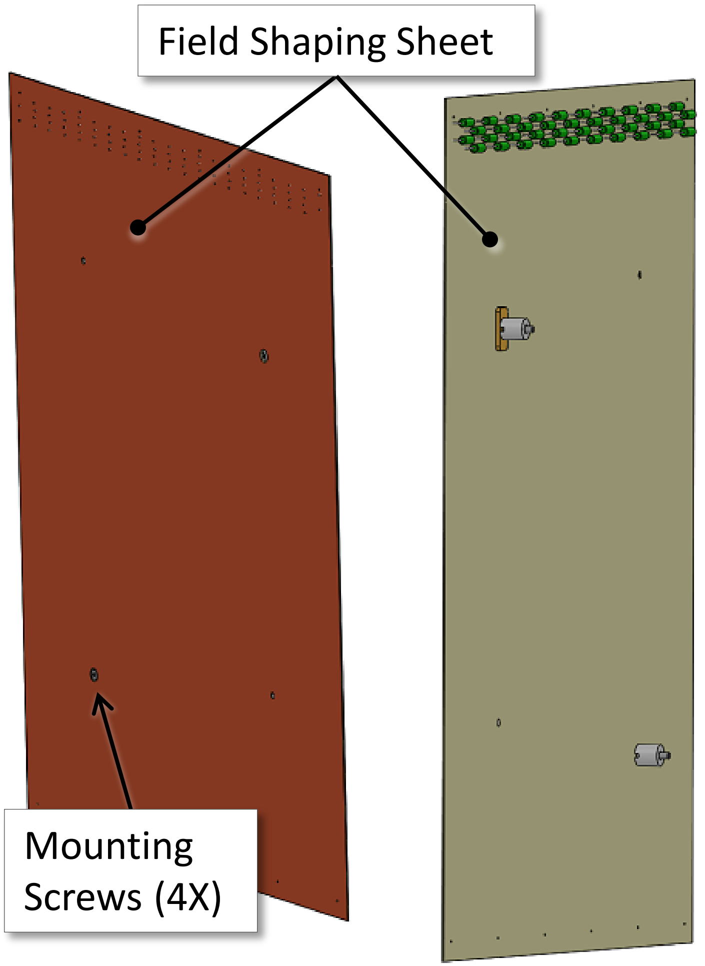


Bolt Pattern Mounts Beam Plug Flange to Downstream Plate

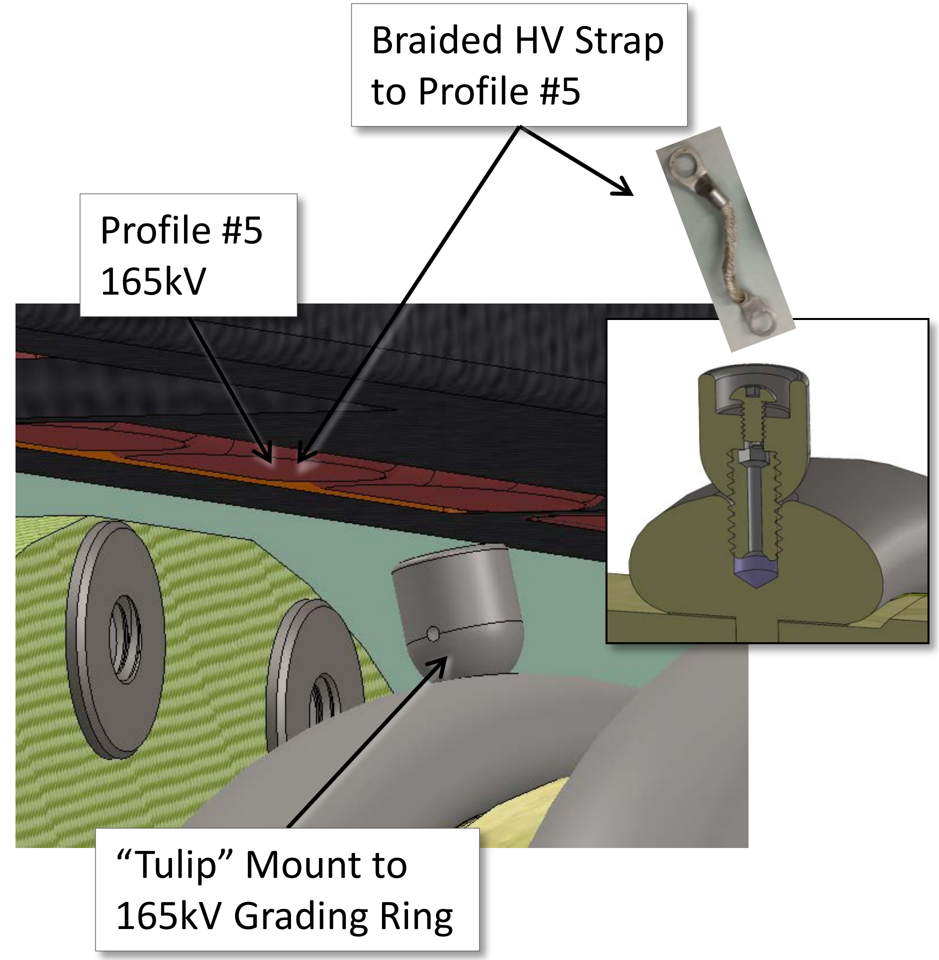


Beam Plug Secondary Support to Upstream Side of End Wall Box Beam

Phase II: Beam Plug Connections



Mini Field Cage to Beam Plug End Cap



HV Grading Ring to Profile #5

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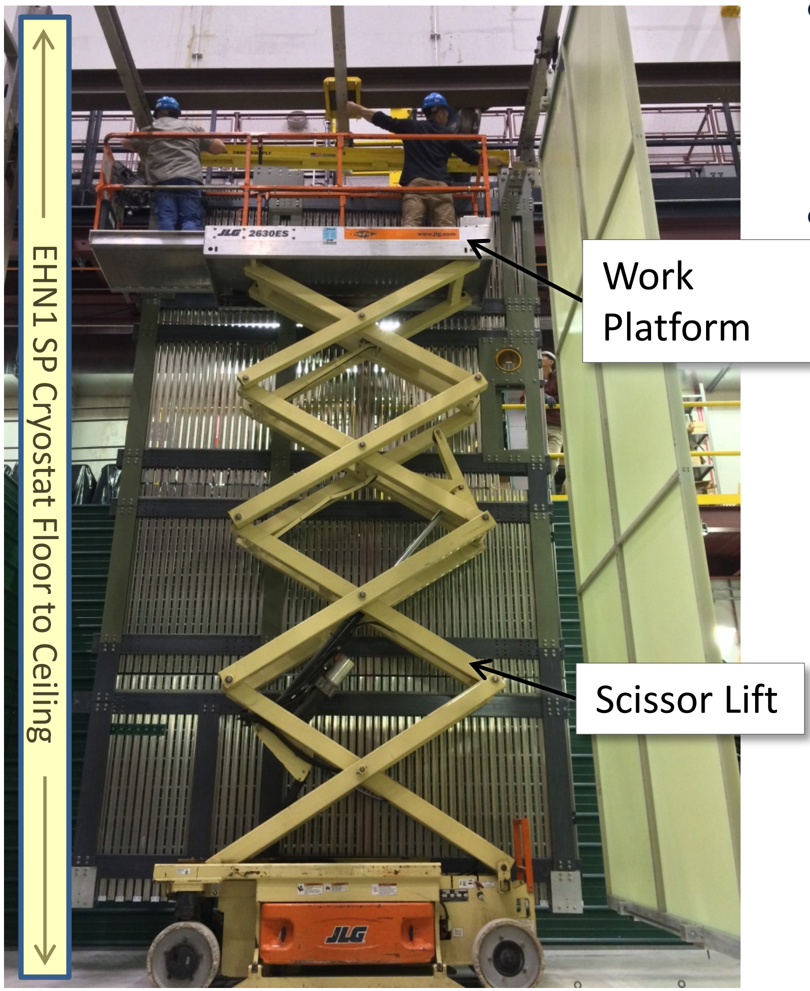
Phase III: December 2017



Scissor Lift at Ash River Trial Assembly

- Beam Plug and End Wall Field Cage in position inside the detector.
- Scissor Lift is used to access Beam Plug location before north drift End Wall Field Cages are in their final configuration.

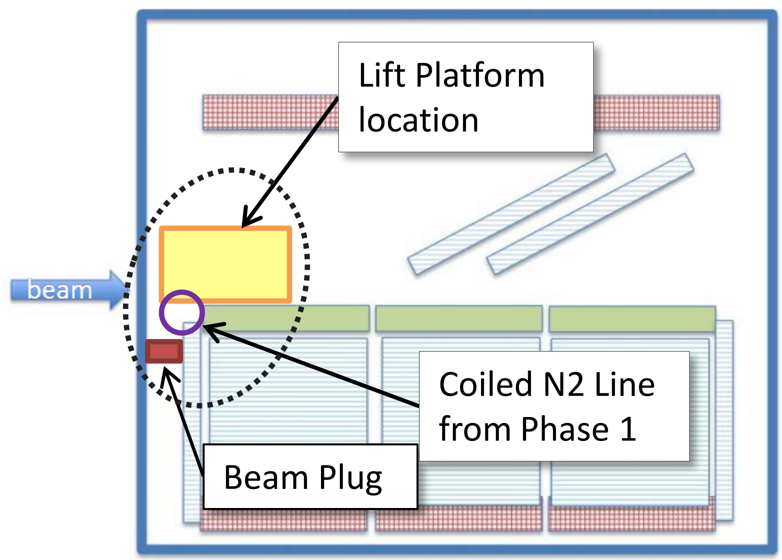
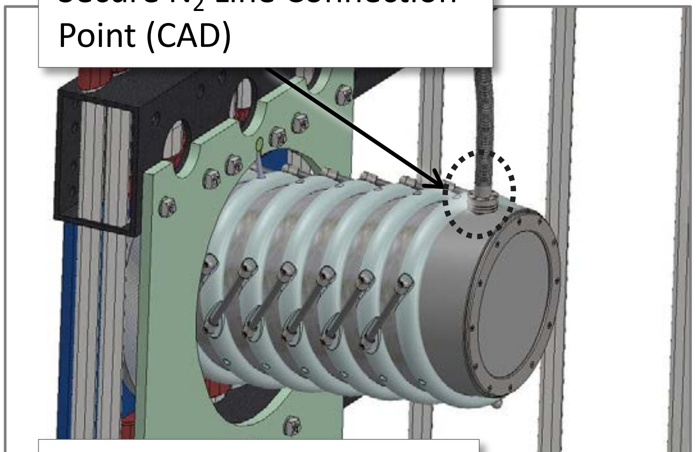


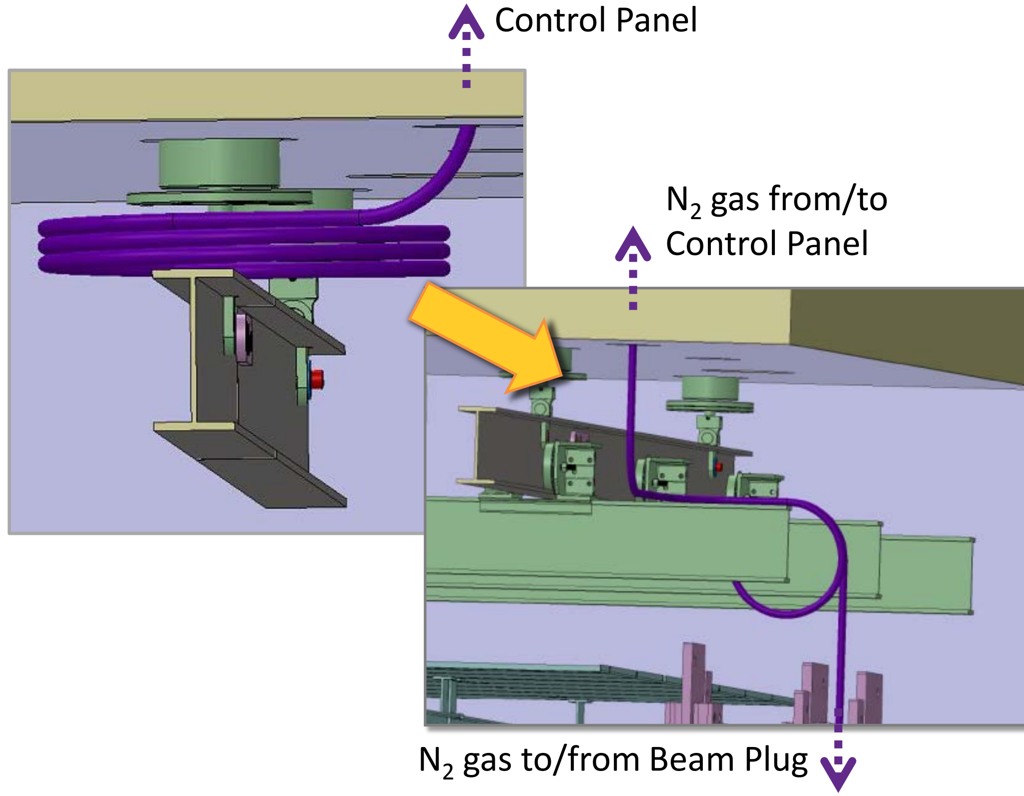
Image: Gina Rameika

Phase III: Connecting Nitrogen Hose



Phase III-type of view from Ash River.
(Will be within arms reach at EHN1.)

- Nitrogen Hose weight approx 5 kg
- Hose is uncoiled and connected to the Beam Plug via metal seal Conflat flange.



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Beam Plug System Testing

- **At Vendor**:
  - Material Coupon Samples
    - Fiberglass and adhesive bond tension test at 77 K
  - Beam Plug
    - Initial leak check at room temperature <7.8 x 10^{-5} std cc/s
    - Internal pressurization to 50 psi @77 K
    - Second leak check at room temperature <7.8 x 10^{-5} std cc/s
    - External pressure check at room temp 50 psi
    - Final leak check at room temperature <7.8 x 10^{-5} std cc/s
  - Nitrogen Hose (Swagelok)
    - Leak check to 1 x 10^{-5} std cc/s
- **At FNAL:**
  - HV Test at Blanche (Development Unit, Full Unit)
  - System and HV Test at 35 Ton (Full Unit)
- **At LBL:**
  - Beam Plug leak check at 77 K
  - Control Panel leak check at room temperature
  - Material radioactivity levels
- **At CERN:**
  - Control Panel and Nitrogen Hose leak check (Phase I)
  - Control Panel, Nitrogen Hose & Beam Plug leak check (Phase III)
  - Current Monitor function

Material Coupon Testing

Three Ring Development Unit

Full Beam Plug

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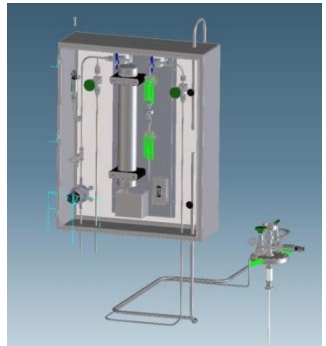
Shipping



	Nitrogen Control Panel	Beam Plug
Vendor → LBL	n/a	May 2017
LBL → FNAL	May 2017	May-Jun 2017
FNAL → CERN	Aug-Oct 2017	Jul-Aug 2017

- Control Panel and Beam Plug will be shipped in separate approved wood crates to arrive on schedule for Phase I and Phase II
- Beam Plug and Nitrogen Hose will be cleaned and bagged for assembly clean room entry

Outstanding Questions

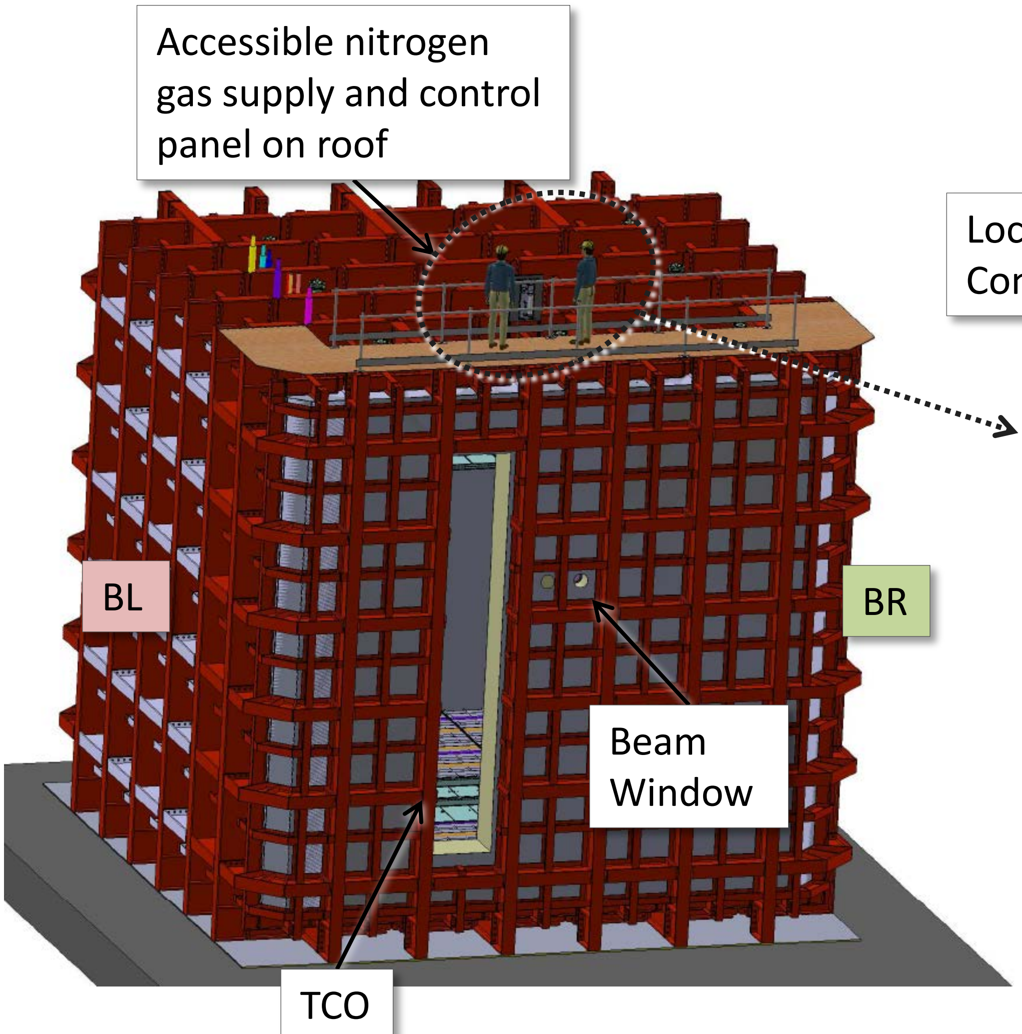
- Details of lifting and maneuvering the Beam Plug into place during Phase II clean room installation
- Material selection and best method for mounting secondary structural support to box beam
- Ensuring clearance to unknown primary membrane corrugation locations
- Reported as-built cryostat wall thickness may contact beam plug even with 3 mm design gap
- Ensure adequate wrench tool access & clearance for mounting Nitrogen Hose to Beam Plug port
- TCO clearance of End Wall with Beam Plug mounted
- Will there be an End Wall-to-APA structural connector?
- Arrange rigid steel tubing installation at CERN (bend, weld, clean)
- Cut locations and interface to box beam for profiles #4-7 near Beam Plug
- Detail for securing Nitrogen Hose to Runway and Bridge beams.
- Verify ease of connection high for Beam Plug grading ring to profile #5

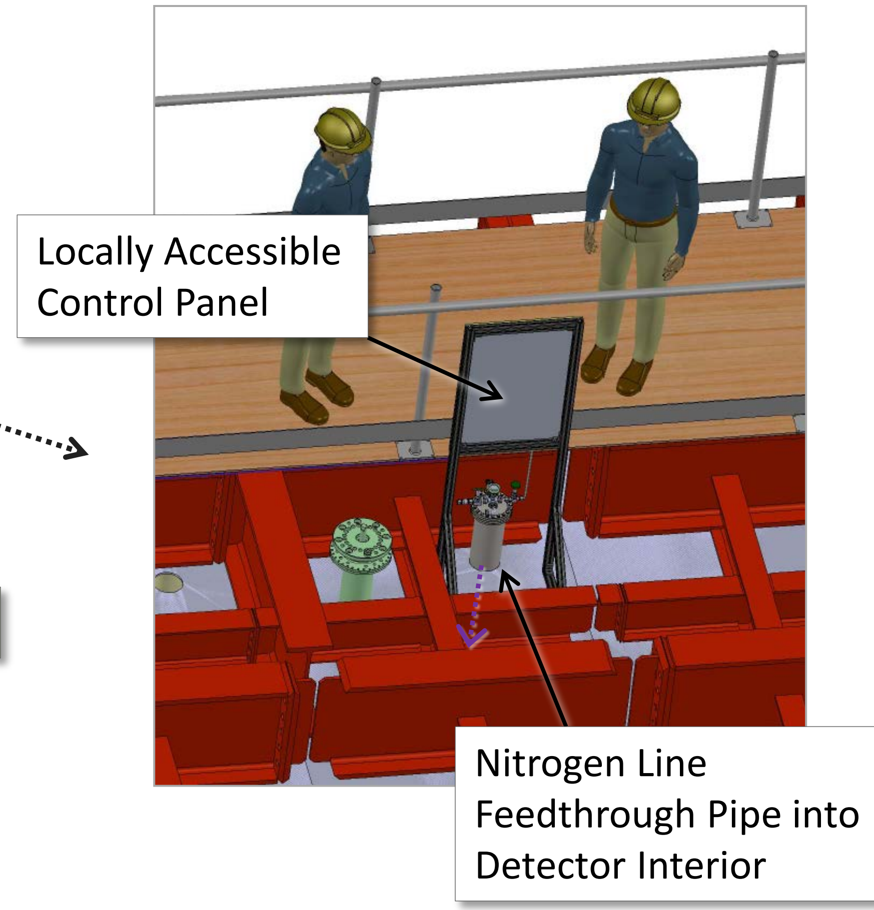
Summary

- Beam Plug system is in final stages of development with fabrication and testing underway
- Tests performed and planned for materials strength and radioactivity, structural integrity, He leak check and high voltage holding capacity
- Beam Plug installation will proceed in three phases within TPC installation schedule
- Services and work needed at CERN have been identified and are being communicated
- Hands-on experience at Ash River and 35-Ton for mounting Beam Plug to End Wall

Extra Slides

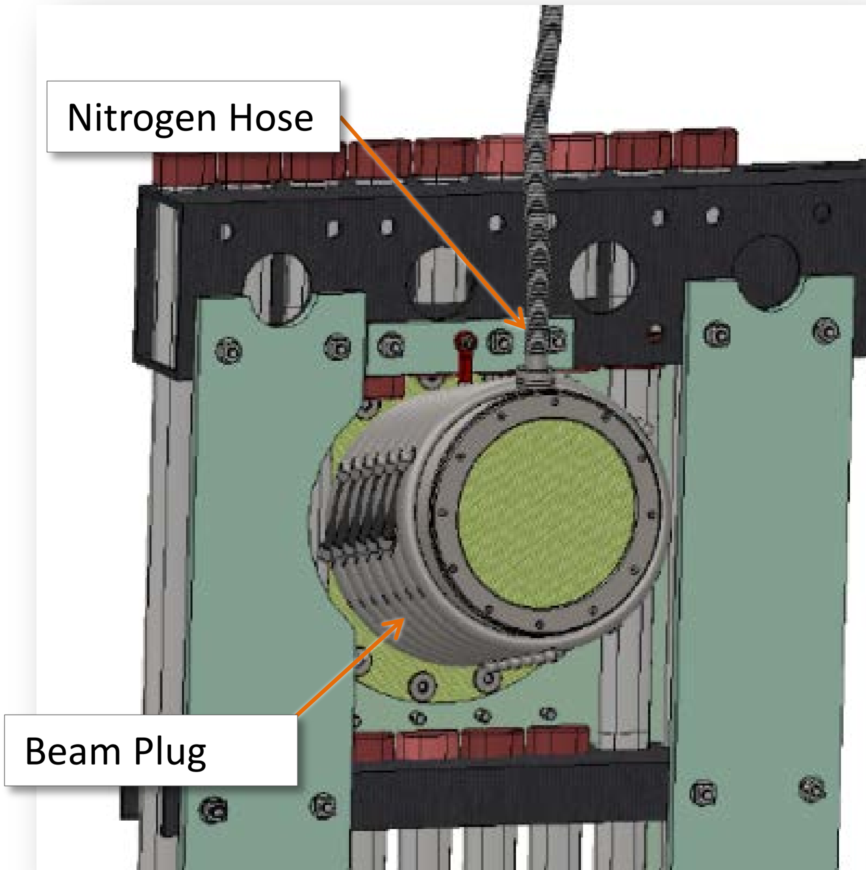
ProtoDUNE-SP Beam Plug at EHN1





Nitrogen Gas System Details

Manual control at Panel, initially adjusted to low flow rate



Beam Plug Nitrogen Gas System

Supply Gas Requirements

Temperature	10-20 °C
Pressure	30-50 psig
Flow Rate	3 ml/min
Lifetime Volume	2000 l/yr (at 20 °C ,40 psi)
Purity	< 500-1000 ppm

Flow Rate	Heat Dissipated
3 ml/min*	140 mW
	480 mW/m^2

* 11 mg/min

Beam Plug Operating Pressure (88 K)

ProtoDUNE-SP NP-04	Pressure	~ 1.375 bar
	Max Pressure	< 1.5 bar*
HV@PC4	Pressure	~ 1 bar

* CERN pressure vessel designation limit

Matheson NANOCHEM Gas Purifier

Purifies nitrogen boil-off gas of moisture and non-methane condensables

Purifier mounted to an LN dewar at the LBL Advanced Light Source

Purifier mounted into Gas Flow Control Panel

N_2 Source Purity	Lifetime
99%	9 months (even available at this level?)
99.50%	18 months ←
99.95%	9 years ←
100.00%	>10 years

Calculatin Source: Matheson

Pressure = 60 psig – higher than operating (conservative)

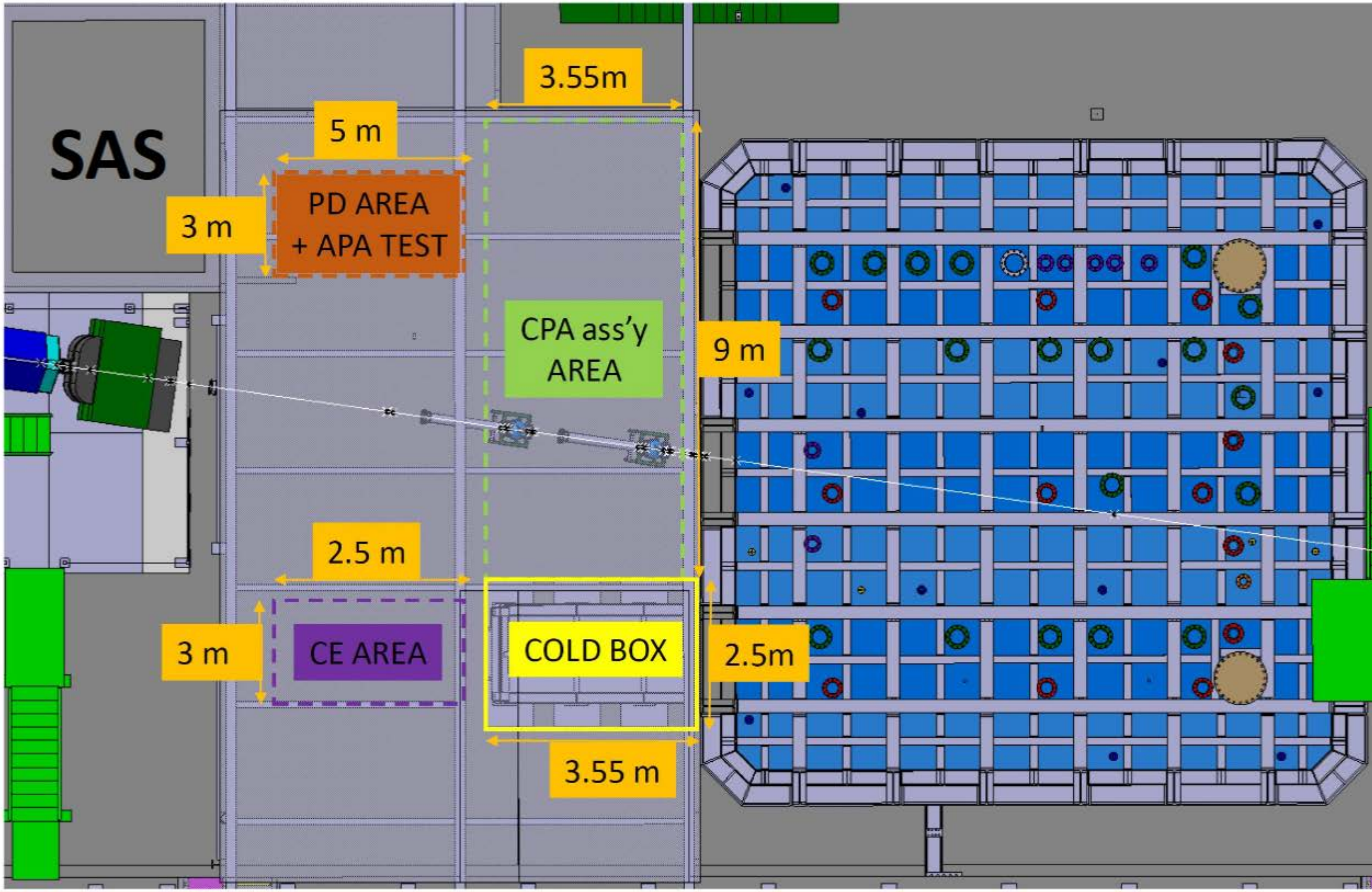
Flow = 0.003 STP liters of gas per minute continuously (est. 11 mg/min in operation)

	Specification	Typical Performance
H_2O	< 100 ppt	< 100 ppt (APIMS)
O_2	< 100 ppt	< 50 ppt (APIMS)
CO_2	< 100 ppt	< 50 ppt (APIMS)
CO	< 1 ppb*	< 1 ppb (APIMS)*
NMHC	< 100 ppt	< 100 ppt (APIMS)#

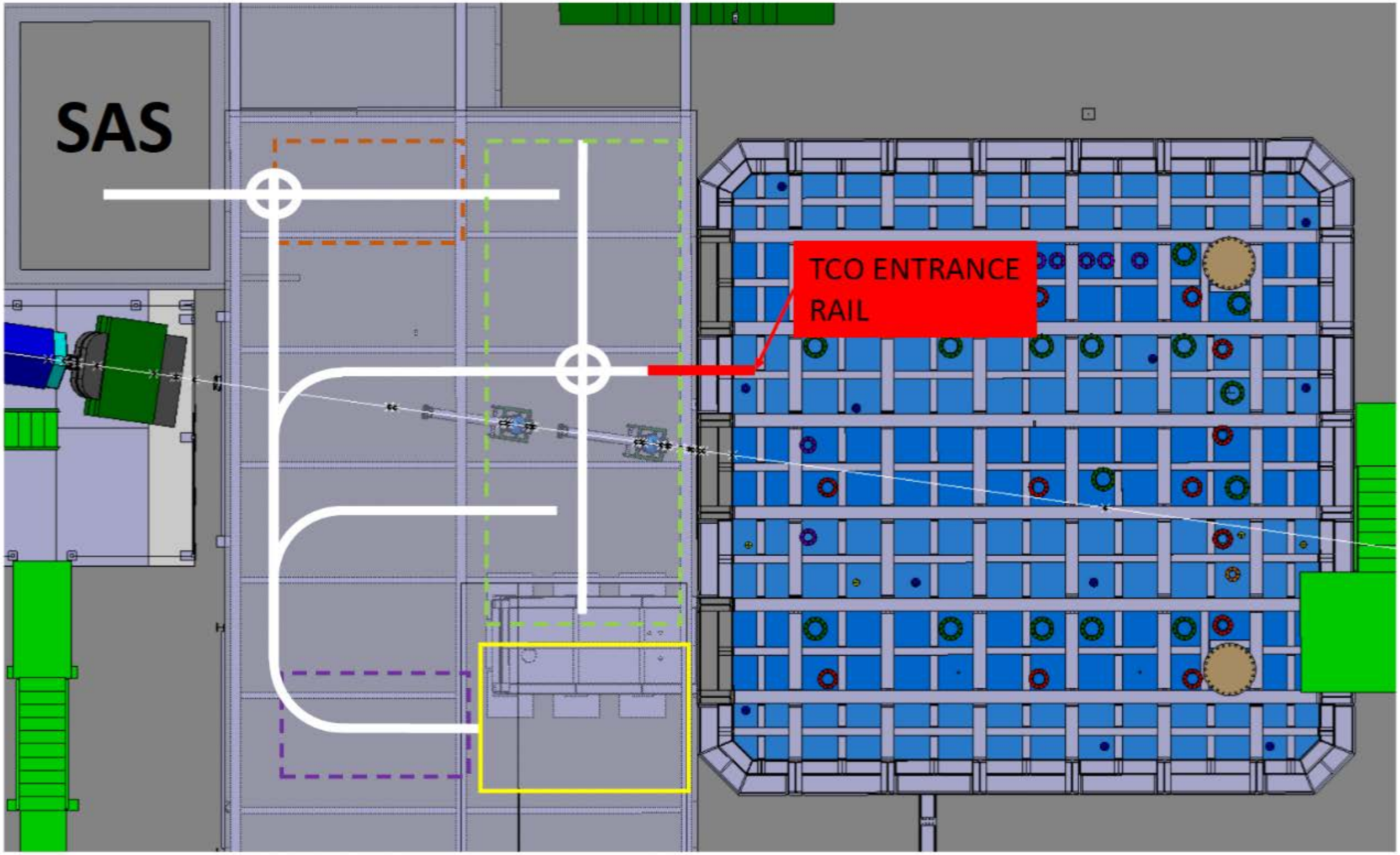
* < 1 ppb CO is obtained at low flow rates and low CO challenge (< 1 ppm) only.

NMHC – Non-Methane Hydrocarbons. Typical performance expressed for Butane.

Access in the Cleanroom Area



Cleanroom rail transport system

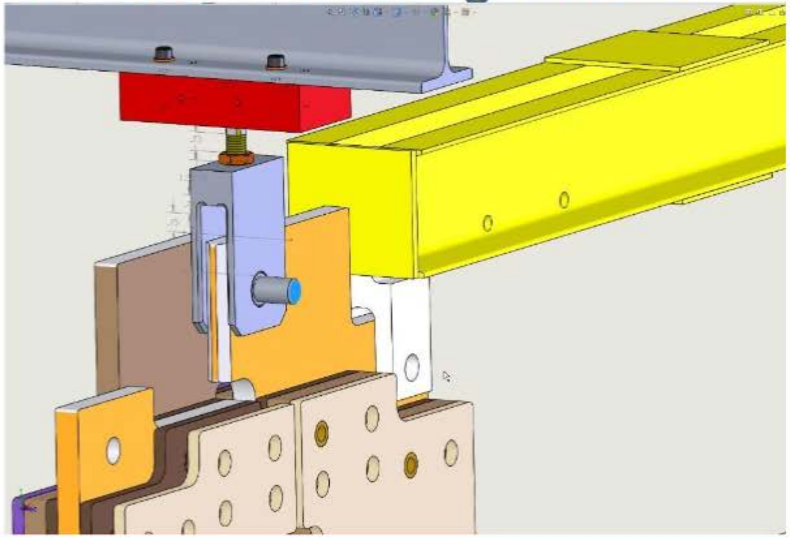


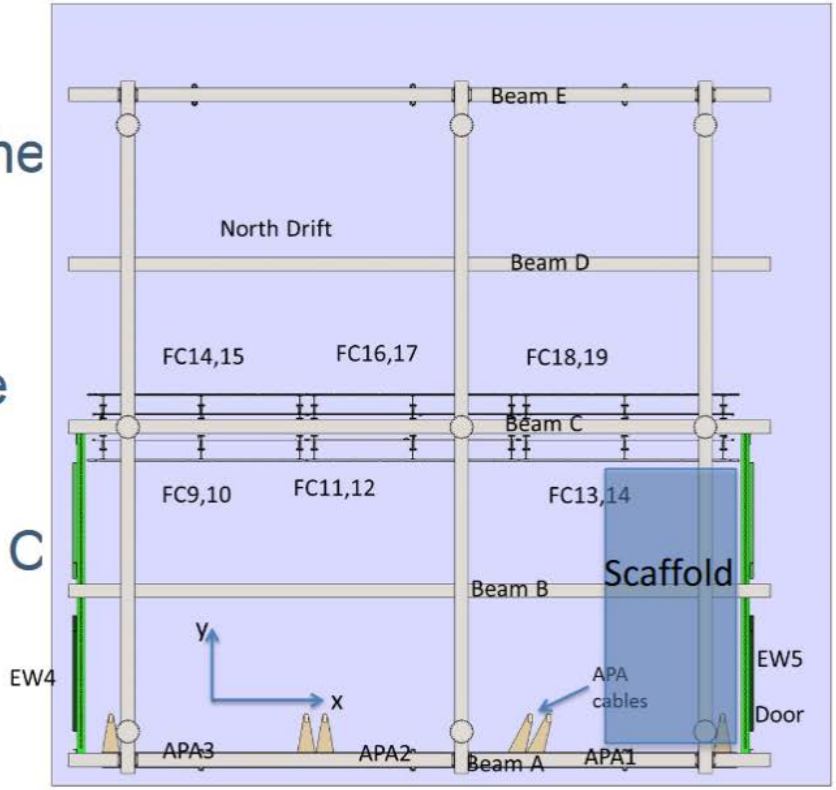
Access in the Cleanroom Area

- TPC materials will be lowered via crane through the roof of the SAS shown in the plan view on slide 3. Materials will be lowered via crane for access in the 8m x 13m clean room. A scissor lift can be used to transfer the load from the crane to the dedicated rail system shown on slide 5. Other items can be placed on a cart and wheeled in the double doors.
- Scissor lifts can used through out the clean room for the majority of the work. The highest required working platform elevation for access needed for installing the cold electronics, transferring load to rail system, etc. is ~8m (26 feet) and they should be large enough to hold 2 people plus some equipment (200kg?)
- We will need a minimum of 2 scissor lifts ~ plus some lower height rolling 1-2m tall work platforms
- We will need several sized rolling carts, smaller ones for tools and parts, at least one large one for the field cages 4m x 2.5m rated for 1000kg

End Wall

- Beam B with End Wall 4 & 5 on it can be moved into position using the spreader bar, swivel and trolley.
- The end walls can not be mounted until installation of Beam C with the complete set of CPA/FC
- EW4 and 5 are hung on Beam A & C





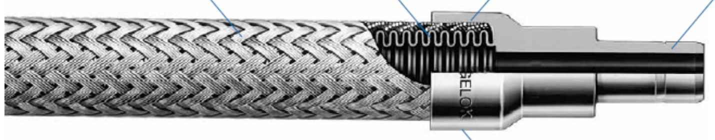
Access via 2m x 2.5m x6m scaffolding will need to be moved for each End Wall, difficult reach to center mount

304/316 SS Swagelok Metal Hose

FJ Series Metal Hose

Features

- General purpose all-metal hose.
- 316L stainless steel annular convoluted core.
- Size range of 1/4 through 2 in. and working pressures from vacuum to 1600 psig (110 bar).
- Single braid layer of 304 stainless steel promotes hose pressure containment (M).
- End connections welded in accordance with ASME Boiler and Pressure Vessel Code Section IX.
- Optional 316L stainless steel braid available to provide greater corrosion resistance.
- Commonly used in high-temperature vacuum or general purpose applications where permeation is undesirable.
- Custom assemblies available.
- Options include hose covers, hose tags, and additional helium leak testing. See page 337 for details.



Technical Data

Nominal Hose Size in. (mm)	Inside Diameter in. (mm)	Outside Diameter in. (mm)	Minimum Center Line Bend Radius in. (cm) Static	Minimum Center Line Bend Radius in. (cm) Dynamic	Temperature Range °F (°C)	Working Pressure at −325 to 300°F (−200 to 148°C) Vacuum to ... psig (bar)	Minimum Burst Pressure at 70°F (20°C) psig (bar)	Bulk Hose Weight lb/ft (kg/m)
1/4 (6.4)	0.25 (6.4)	0.47 (11.9)	1.00 (2.54)	4.33 (11.0)	−325 to 800 (−200 to 426)	1600 (110)	6400 (440)	0.11 (0.16)
3/8 (9.7)	0.38 (9.5)	0.68 (17.3)	1.20 (3.05)	5.91 (15.0)		1470 (101)	5880 (405)	0.20 (0.30)
1/2 (12.7)	0.50 (12.7)	0.81 (20.5)	1.50 (3.81)	6.50 (16.5)		1110 (76.4)	4500 (310)	0.22 (0.33)
3/4 (19.0)	0.75 (19.0)	1.20 (30.5)	2.10 (5.33)	8.86 (22.5)		860 (59.2)	3440 (237)	0.37 (0.55)
1 (25.4)	1.00 (25.4)	1.50 (38.0)	2.70 (6.86)	10.2 (25.9)		680 (46.8)	2720 (187)	0.50 (0.74)
1 1/4 (31.8)	1.25 (31.8)	1.80 (45.7)	3.10 (7.87)	11.8 (30.0)		680 (46.8)	2720 (187)	0.61 (0.91)
1 1/2 (38.1)	1.50 (38.1)	2.13 (54.0)	3.90 (9.91)	13.4 (34.0)		520 (35.8)	2080 (143)	0.85 (1.26)
2 (50.8)	2.00 (50.8)	2.66 (67.5)	5.10 (13.0)	15.4 (39.1)		450 (31.0)	1800 (124)	1.10 (1.65)

Pressure-Temperature Ratings

Ratings are based on ASME Code for Pressure Piping B31.3, Process Piping.

Nominal Hose Size, in.	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2
Temperature °F (°C)	Working Pressure, vacuum to ... psig (bar)							
−325 (−200) to 300 (148)	1600 (110)	1470 (101)	1110 (76.4)	860 (59.2)	680 (46.8)	680 (46.8)	520 (35.8)	450 (31.0)
400 (204)	1488 (102)	1367 (94.1)	1032 (71.1)	800 (55.1)	632 (43.5)	632 (43.5)	484 (33.3)	419 (28.8)
500 (260)	1376 (94.8)	1264 (87.1)	955 (65.7)	740 (50.9)	585 (40.2)	585 (40.2)	447 (30.8)	387 (26.6)
600 (315)	1296 (89.2)	1191 (82.0)	899 (61.9)	697 (47.9)	551 (37.9)	551 (37.9)	421 (29.0)	365 (25.1)
700 (371)	1232 (84.8)	1132 (77.9)	855 (58.8)	662 (45.6)	524 (36.0)	524 (36.0)	400 (27.5)	347 (23.8)
750 (398)	1200 (82.6)	1103 (75.9)	833 (57.3)	645 (44.4)	510 (35.1)	510 (35.1)	390 (26.8)	338 (23.2)
800 (426)	1184 (81.5)	1088 (74.9)	821 (56.5)	636 (43.8)	503 (34.6)	503 (34.6)	385 (26.5)	333 (22.9)

FJ Series Metal Hose

Testing

Every Swagelok FJ series hose assembly is inboard helium leak tested to a maximum leak rate of 1×10^{-5} std cm^3/s.

For additional testing, see **Testing**, page 337.

Cleaning and Packaging

Swagelok FJ series hose components are cleaned in accordance with Swagelok *Standard Cleaning and Packaging (SC-10)* (MS-06-62), page 1174. Each hose is bagged individually and boxed; longer hoses are coiled, bagged, and boxed.

⚠ **Do not subject flexible metal hose to pressure surges, shock, or pulsations, where the peak pressure is greater than 50 % of the working pressure rating.**

Ordering Information

Custom Hose Assemblies

Build a hose assembly ordering number by combining the designators in the sequence shown below.

Typical Ordering Number

1	2	3	4	4	5	6		5	6
SS -	FJ	4	TA4	PM4 -	28 -	F	or	71CM -	F
					in.			cm	

1 Material

End Connections

SS = 316 stainless steel

2 Hose

FJ = FJ series metal hose

3 Nominal Hose Size, in.

4 = 1/4 16 = 1
6 = 3/8 20 = 1 1/4
8 = 1/2 24 = 1 1/2
12 = 3/4 32 = 2

4 End Connections

*See **End Connection Designator** column in tables on next page.*

5 Overall Length

*Inches or centimeters, in whole numbers. Include **CM** as shown for centimeter lengths.*

6 Options

For multiple options, add designators with a dash between each designator.

A = Armor guard
CRN = Lanyard tag with CRN
F = Fire jacket
F1 = Thermosleeve
H7 = Helium leak test (1×10^{-7} std cm^3/s)
N3 = Nitrogen pressure test
W = Hydrostatic test
Z = 316L SS braid material

Mat Tags

MA = Gray MO = Orange
MB = Blue MP = Purple
MC = Brown MR = Red
MG = Green MW = White
MK = Black MY = Yellow
MN = Pink

Other Tags

T = Lanyard tag
T2 = Two lanyard tags
T5 = Clamp tag

*Specify text for tags. See **Hose Tag Text** table, page 338.*

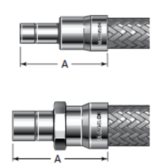
See page 337 for detailed descriptions of options.

Hose OD: 1.20” ID .75”
Fitting OD: 1.32”
Weight: 11 lb @23 ft length
Displaced LAr:

FJ Series Metal Hose

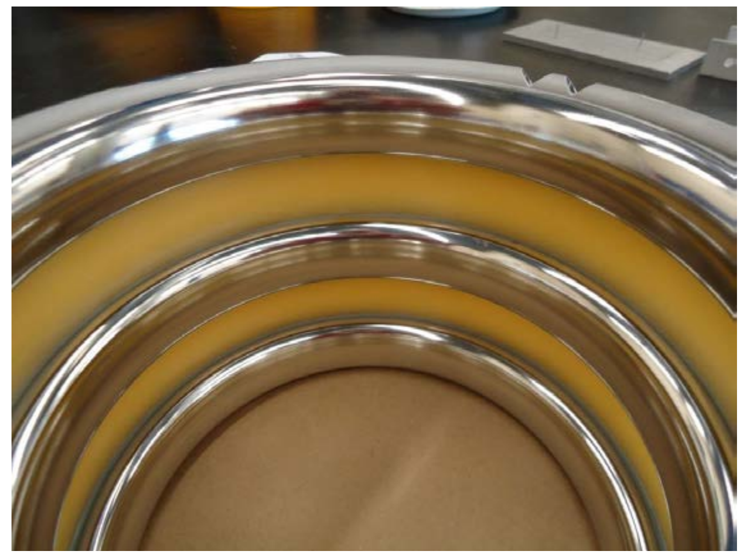
End Connections

Swagelok Tube Adapters

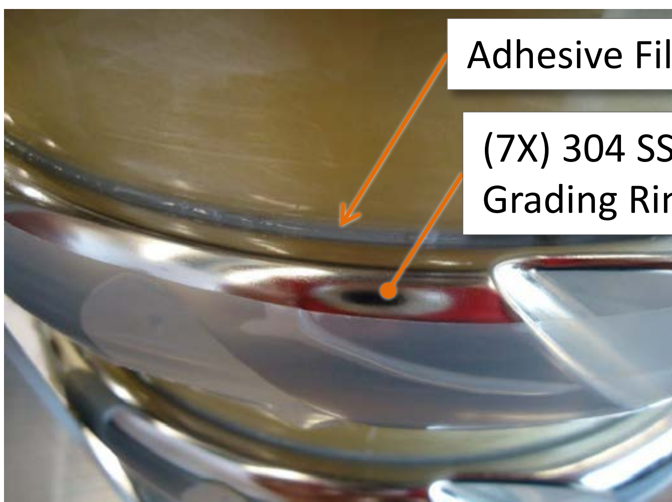


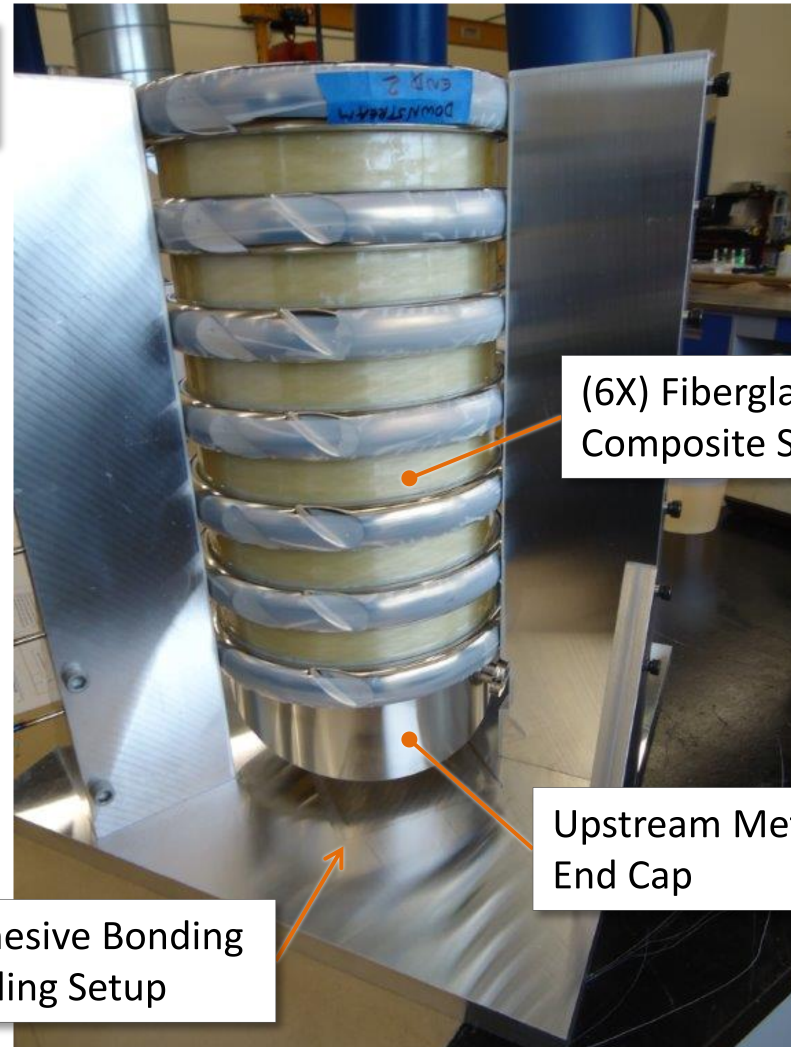
Tube Adapter Size	Nominal Hose Size Designator	End Connection Designator	Dimensions A	Dimensions Minimum Inside Diameter	Dimensions Maximum Outside Dimension
Dimensions, in. (mm)					
1/4	4	TA4	1.52 (38.6)	0.18 (4.6)	0.54 (13.7)
3/8	6	TA6	1.81 (46.0)	0.27 (6.9)	0.78 (19.8)
1/2	8	TA8	2.16 (54.9)	0.37 (9.4)	0.93 (23.6)
3/4	12	TA12	2.50 (63.5)	0.58 (14.7)	1.32 (33.5)
1	16	TA16	2.99 (75.9)	0.80 (20.3)	1.63 (41.4)
1 1/4①	20	TA20	3.91 (99.3)	1.02 (25.9)	2.18 (55.2)
1 1/2①	24	TA24	4.47 (114)	1.25 (31.8)	2.61 (66.3)
2①	32	TA32	5.45 (138)	1.72 (43.7)	3.48 (88.4)

Beam Plug Development Unit



Beam Plug Fabrication Progress





Material Selection

- Materials used:
  - Composite Rings: S-2 Glass/epoxy matrix composite; filament wound.
  - Metal Electrodes: Stainless steel 304
  - Cryogenic adhesive: Hysol 9309.2 NA epoxy with glass spheres
  - Ground End Cap: Stainless Steel 304
  - HV End Cap: S-2 glass/epoxy matrix composite; filament wound. Bonded to machined G-10 CR plate.
  - HV Flange Mounting Hardware: Stainless Steel 304
  - Secondary Support: Torlon or 304 SS

- Materials have and are being tested for LAr purity and radioactivity levels.

Material Radioactivity Levels

- Some samples have been counted at the Low Background Counting Facility at LBNL

MATERIAL	STATUS
Cryogenic Epoxy (Hysol 9309.2 NA)	Very low activity
Stainless Steel 304	Not yet counted
OHMITE MOX 940 resistors	In queue; expected to be high, but low mass quantity and outside active region volume.
S-2 Glass/Epoxy Composite	^{40}K rate is ~ 5 Bq but net effect expected to be low
G-10 CR Plate	Not yet counted

Results presented to the DUNE Radio Purity Working Group and materials approved for use in ProtoDUNE