Detector Support System Requirements

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DSS Conceptual Design Review

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Outline - Summary of Requirements

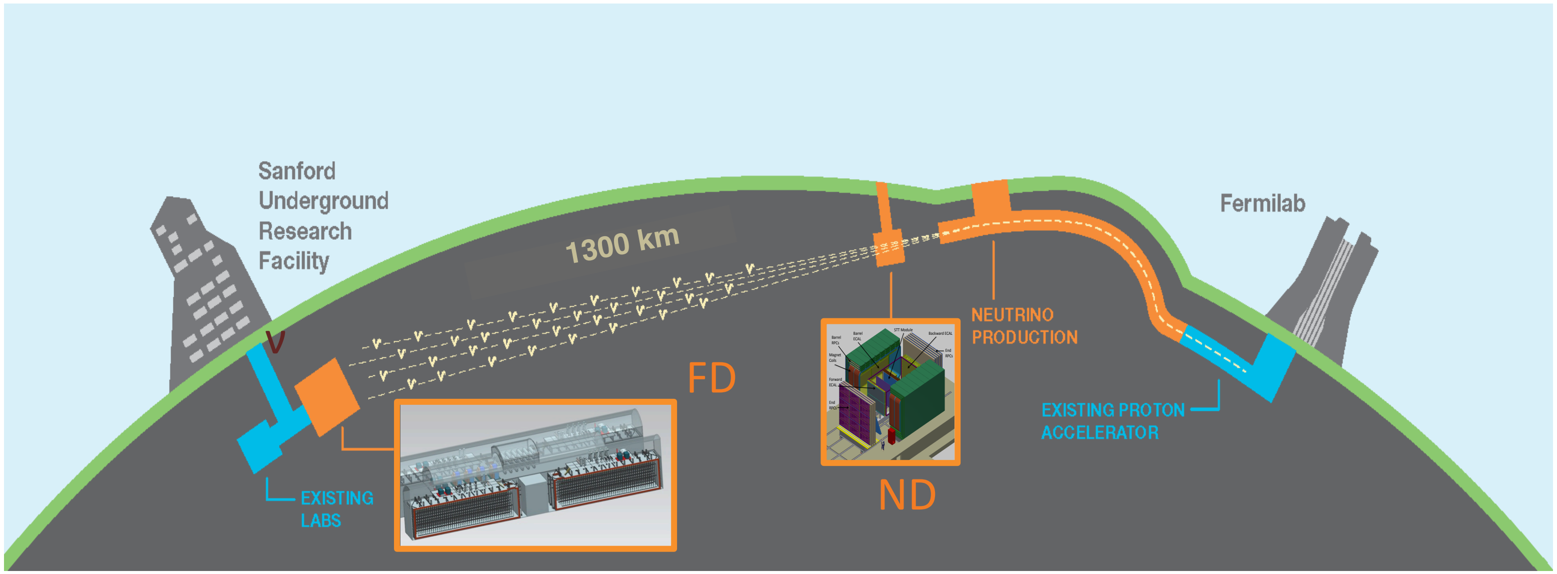
The scientific design specifications are:

1. The CPA to APA centerline distance and tolerance envelope must be maintained 3574mm +/-35 mm when warm. (Drift uniformity <1%)
2. Minimize the gaps that develop between APAs during cool down less than 20mm
3. Define the position of the detector components when warm relative to each other within 3mm
4. The DSS is electrically connected to the cryostat ground
5. The APA/CPA/FC/Endwall are electrically isolated from the DSS
6. The DSS penetrations must be purged with GAr to maintain a positive pressure in order to prevent contaminates from diffusing to the liquid
7. All materials must be compatible for operation in ultrapure LAr
8. The DSS will insure that detector components shall not be less than 400mm from the membrane flat surface
9. The DSS beam will be fully in the 5% ullage at the top of the cryostat.

The mechanical design specifications are:

1. Support the weight, both dry and wet, of the TPC-Time Projection Chamber (Endwall, top/bottom FC, APA, CPA) ~135 metric tons
2. Be able to accommodate the roof movement – THE ROOF DEFORMATIONS NEED TO BE DEFINED
3. Accommodate the variation in the feed thru locations and variation in the flange angle due to installation tolerances and the loading on the warm structure.
4. Accommodate the shrinkage of the detector and DSS from ambient temperatures to LAr temperatures.
5. Install through the TCO
6. The instrumentation cabling must not interfere with the DSS.
7. The DSS beam will be fully in the 5% ullage at the top of the cryostat.

Detector Location Tolerance



- No absolute position accuracy required!
  - At 1300km the flux varies <1% over 1km
- Requirements on the detector location are driven by engineering considerations, detector performance considerations, and the cryostat interface.

Detector Volume Requirement

- Detector fiducial volume needs to be known better than the 1% level.
  - DUNE will measure asymmetries so the volume is needed to normalize the data sets.

The charge-parity (CP) asymmetry is defined as

$$\mathcal{A}_{cp} = \frac{P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\bar{\nu}_\mu \to \bar{\nu}_e)}$$

  - Detector motion under cooldown needs to be understood to insure the 1% precision in defining the fiducial volume.

1. The CPA to APA centerline distance and tolerance envelope must be maintained 3574mm +/-35 mm when warm. (Drift uniformity <1%)

Cold?

FDmod-gen-004	A DUNE far detector module shall provide a well-defined fiducial volume for the detector lifetime.	fiducial volume tolerance	1%
FDmod-gen-005	A DUNE far detector module shall provide a stable fiducial volume for the detector lifetime.	fiducial volume tolerance	1%

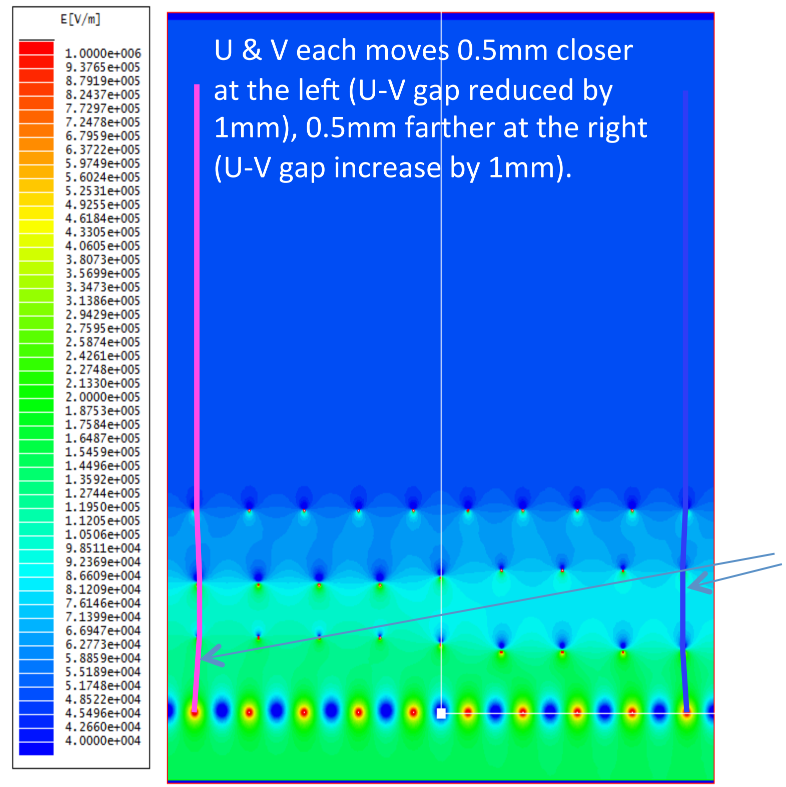
LBNF-DUNE requirements DOCDB 112

APA plane mechanical distortions

- The induction planes must fulfill the transparency condition at > 99%.
  - Needed for both calorimetry and tracking.
- This defines the APA flatness specification.
- Field calculations show 0.5 mm wire displacement OK.
- APA distortion studies show that this corresponds to a +/-5mm tolerance on flatness.
  - APA flatness tolerance
- Possible APA distortions will reduce the allowable tolerance of the DSS +/- 5 mm.

Nominal wire plane spacing: 3/16”
G & X wire pitch: 4.5mm
U & V wire pitch: 5mm

G and X planes remain at nominal position



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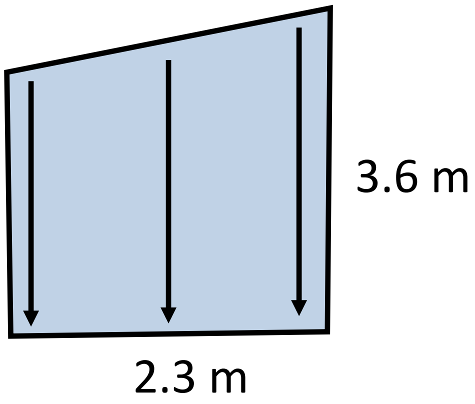
Design Goal for DSS position tolerance

- The CPA to APA centerline distance and tolerance envelope must be maintained 3574mm +/-30 mm when cold. (Drift uniformity <1%)
- A substantial margin should be maintained on this tolerance so that even when cold the distortion are significantly less than the requirement.
- Engineering the DSS to substantially better than +/-30 mm was the design goal.
  - Given that a 60m stainless steel beam will contract 150mm designing a system where the thermal motion was well understood was a priority during the design phase.
  - Detector placement precision after cooling was an important factor in selecting the I-Beam support concept and thermal contraction plan.
  - The present design is expected to be accurate to the 6-9mm level cold.
  - Details will be given in the structural talk.

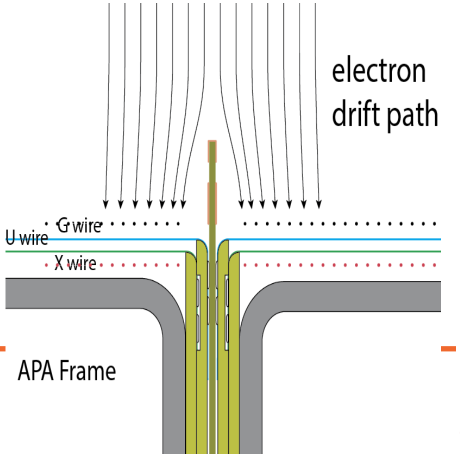
Impact on dE/dx from mechanical distortions

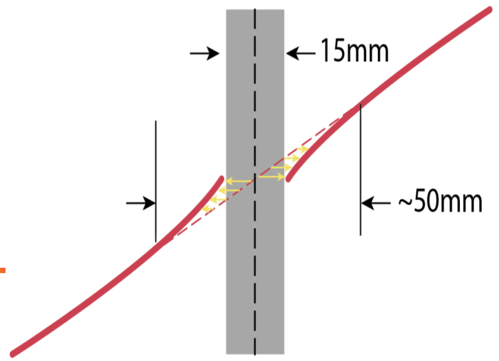


- Suppose the drift volume becomes a trapezoid instead of a rectangle due to distortion and the drift distance on one side is 1 cm longer than on the other side, the electric field is different by 0.3% between the two sides.
- For a track near the cathode that is parallel to the wire planes, the reconstructed track would appear to have a smaller angle w.r.t the wire planes. The maximum change to dE/dx would be .01/2.3 = 0.4% due to this distortion. This is negligible for particle ID.

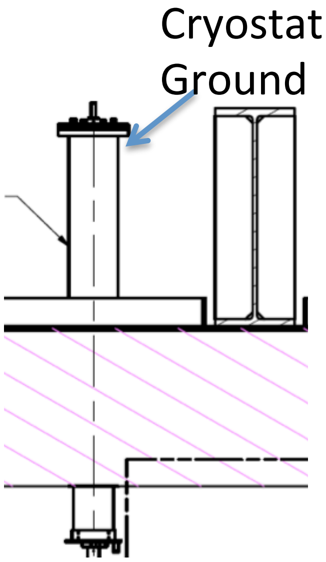
Gaps between APAs

- Situation: 20 mm gap between APAs
  - Natural consequence of modular design
  - Between 3rd and 4th APA, an additional 17 mm gap
- Physics considerations for $\nu_\mu \rightarrow \nu_e$ **oscillation**
  - Energy reconstruction :
    - Gap leads to loss of ionization electrons
    - Its value can be estimated by multiple methods: for track, rely on the track length, for shower or non-stopping track, can use the adjacent energy to fill in the gap
    - Expect no impact on the energy resolution, which is dominated by neutrons in the final state
  - Event ID:
    - Vertex has to be away from the gap,
    - Loss in fiducial volume is expected, but a natural consequence caused by cool down
- Mitigation method: electron diverter
  - Ensure all charge will be collected, better estimation of the energy in gap
  - Stable distortions in the reconstructed event topology can be calibrated



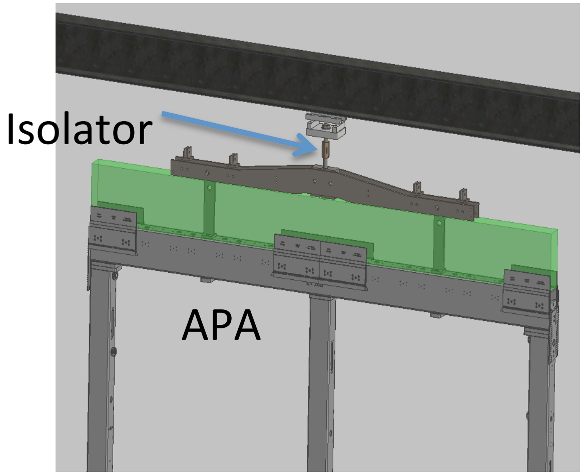


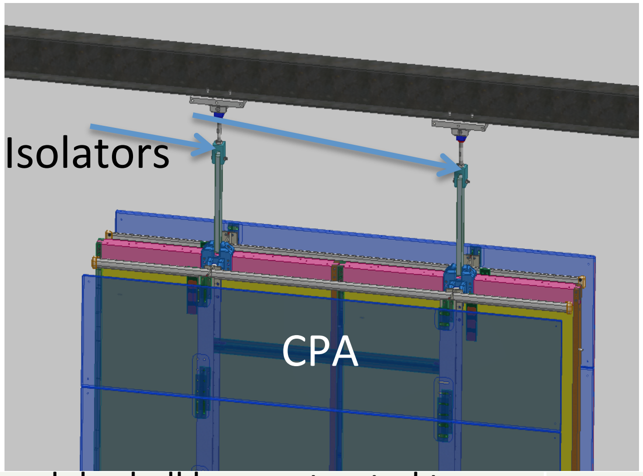
Grounding and Shielding

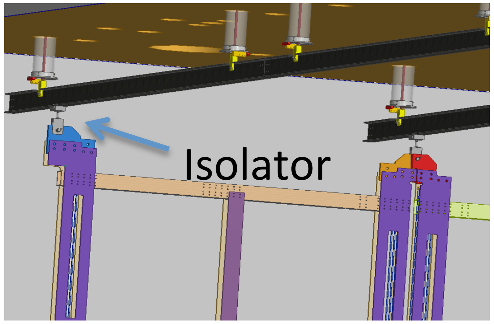


- All detector systems must conform to the DUNE grounding and shielding plan.
  - Same requirement as ProtoDUNE-SP

4. The DSS is electrically connected to the cryostat ground
   - The DSS shall be electrically isolated from all detector components.
5. The APA/CPA/FC/Endwall are electrically isolated from the DSS



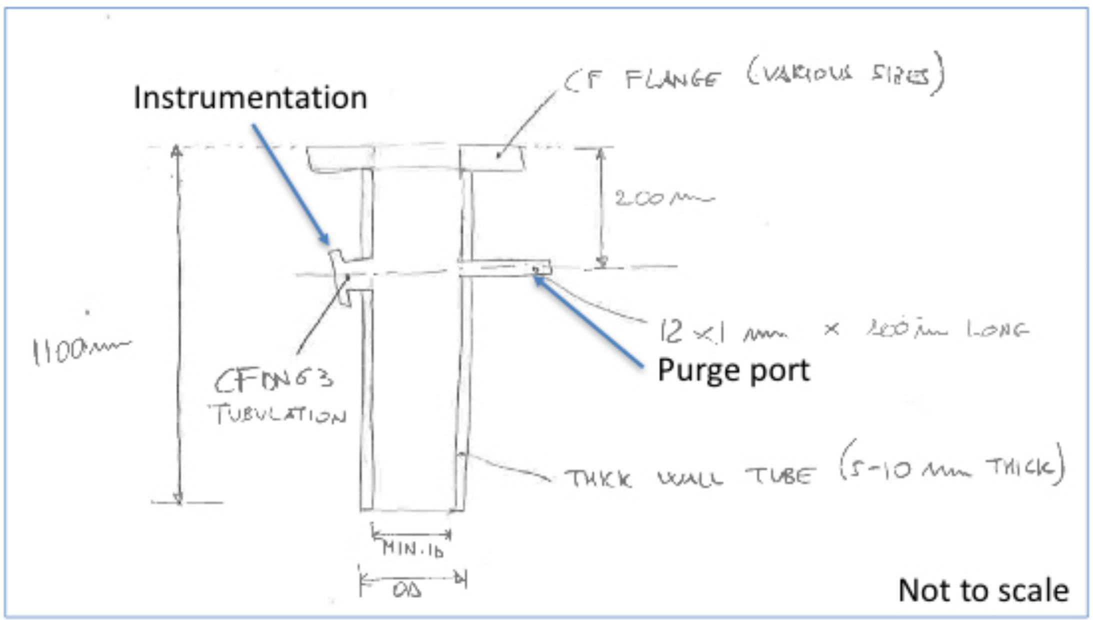




FDmod-gen-017	A DUNE far detector module shall be constructed to comply with all requirements set by the DUNE grounding and shielding committee.	DUNE Doc 285	

Scientific DSS requirements

6. The DSS penetrations must be purged with GAr to maintain a positive pressure in order to prevent contaminates from diffusing to the liquid
7. All materials must be compatible for operation in ultrapure LAr

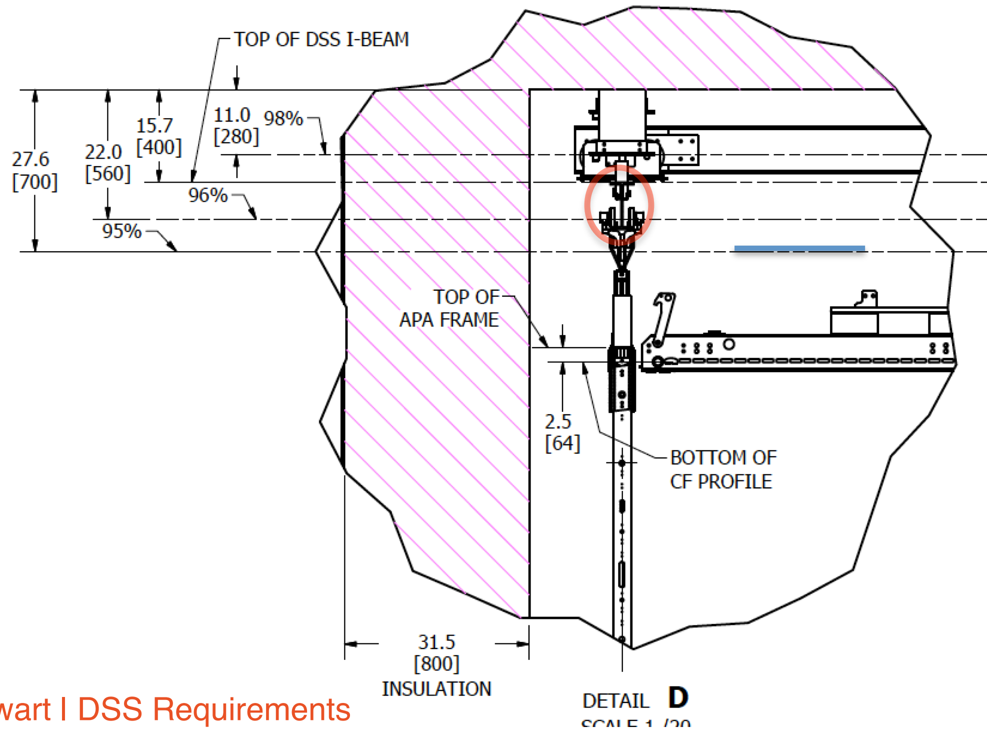


All Metal DSS construction ensures material compatibility

I-Beam height requirement

9. The DSS beam will be fully in the 5% ullage at the top of the cryostat.

- The beam should be either fully submerged in liquid or fully in gas. If the beam is partially covered then thermal induced distortions may distort the detector.



Mechanical Design Specifications

- Support the weight, both dry and wet, of the TPC-Time Projection Chamber (Endwall, top/bottom FC, APA, CPA) ~135 metric tons

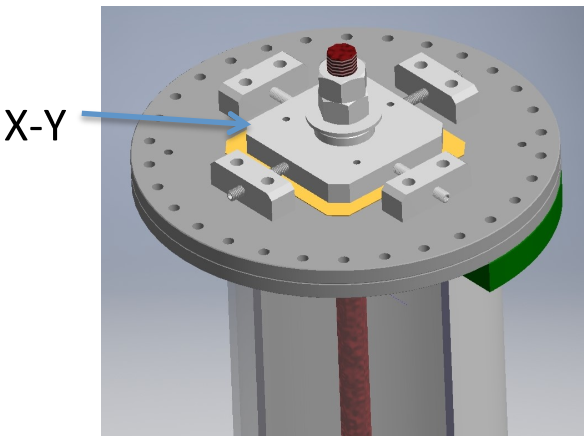
Component	# in Detector	Dry Weights				Wet Weights			
		Unit Weight		Total Weight		Unit Weight		Total Weight	
		kg	lbs	kg	lbs	kg	lbs	kg	lbs
APA	75	1048.0	2305.6	78600.0	172920.0	752.0	1654.4	56400.0	124080.0
CPA	100	198.0	435.6	19800.0	43560.0	170.0	374.0	17000.0	37400.0
Top/Bottom FC	200	145.1	319.2	29020.0	63844.0	129.0	283.8	25800.0	56760.0
Endwall	8	932.0	2050.4	7456.0	16403.2	900.0	1980.0	7200.0	15840.0
Total				134876.0	296727.2			106400.0	234080.0

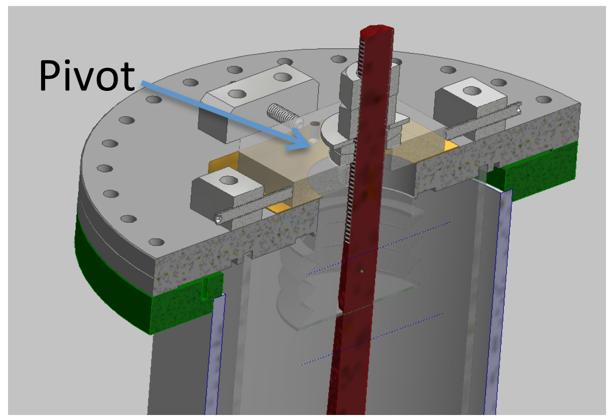
- No agreements on the maximum loads of the components are available.
- Component designs are still changing so the final loads are not yet determined.
- Loads were computed based on information from ProtoDUNE.
- Substantial margin exists in the present design.

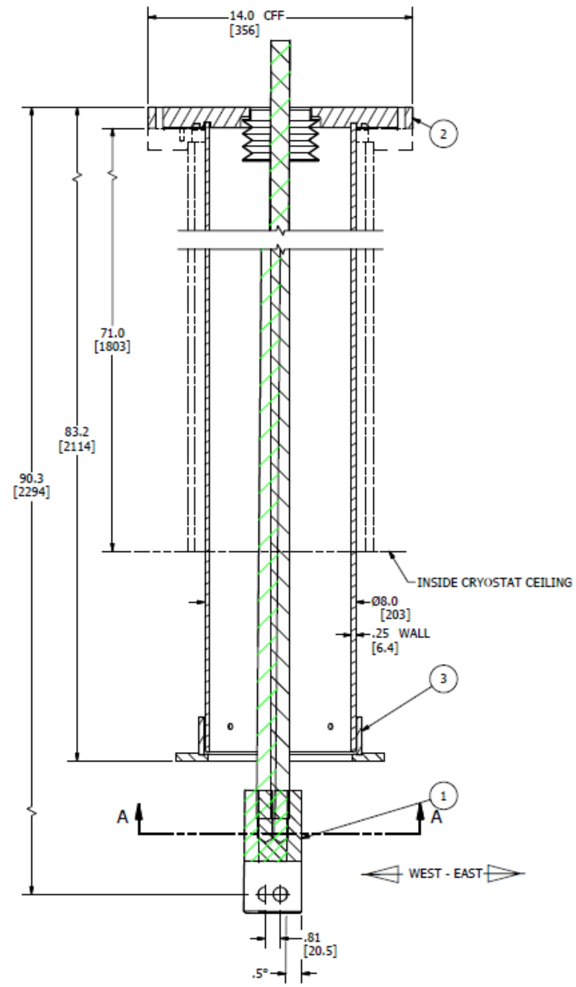
Roof Deflections

2. Be able to accommodate the roof movement
   - THE ROOF DEFORMATIONS NEED TO BE DEFINED
3. Accommodate the variation in the feed thru locations and variation in the flange angle due to installation tolerances and the loading on the warm structure.

- Clear requirements from the cryostat group were not available so reasonable assumptions were made.







- The axis of the cryostat crossing tube must lie within a 36mm diameter cylinder positioned along the nominal axis.
- The outer alignment tube has 25 mm clearance to the membrane crossing tube.

Mechanical Design

4. Accommodate the shrinkage of the detector and DSS from ambient temperatures to LAr temperatures.
5. Install through the TCO

- The shrinkage and the installation through the TCO will be covered in the structural and installation talks.

Instrumentation Cabling

6. The instrumentation cabling must not interfere with the DSS.

- The cryogenic instrumentation group has requested that electrical feedthrus be made available in the crossing tubes.
- The space between the crossing tube and the support rod alignment tube is available for the cabling.
- Details of this interface have not yet been developed.

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