Stage II Plans
(a.k.a. Beam Plug Test)

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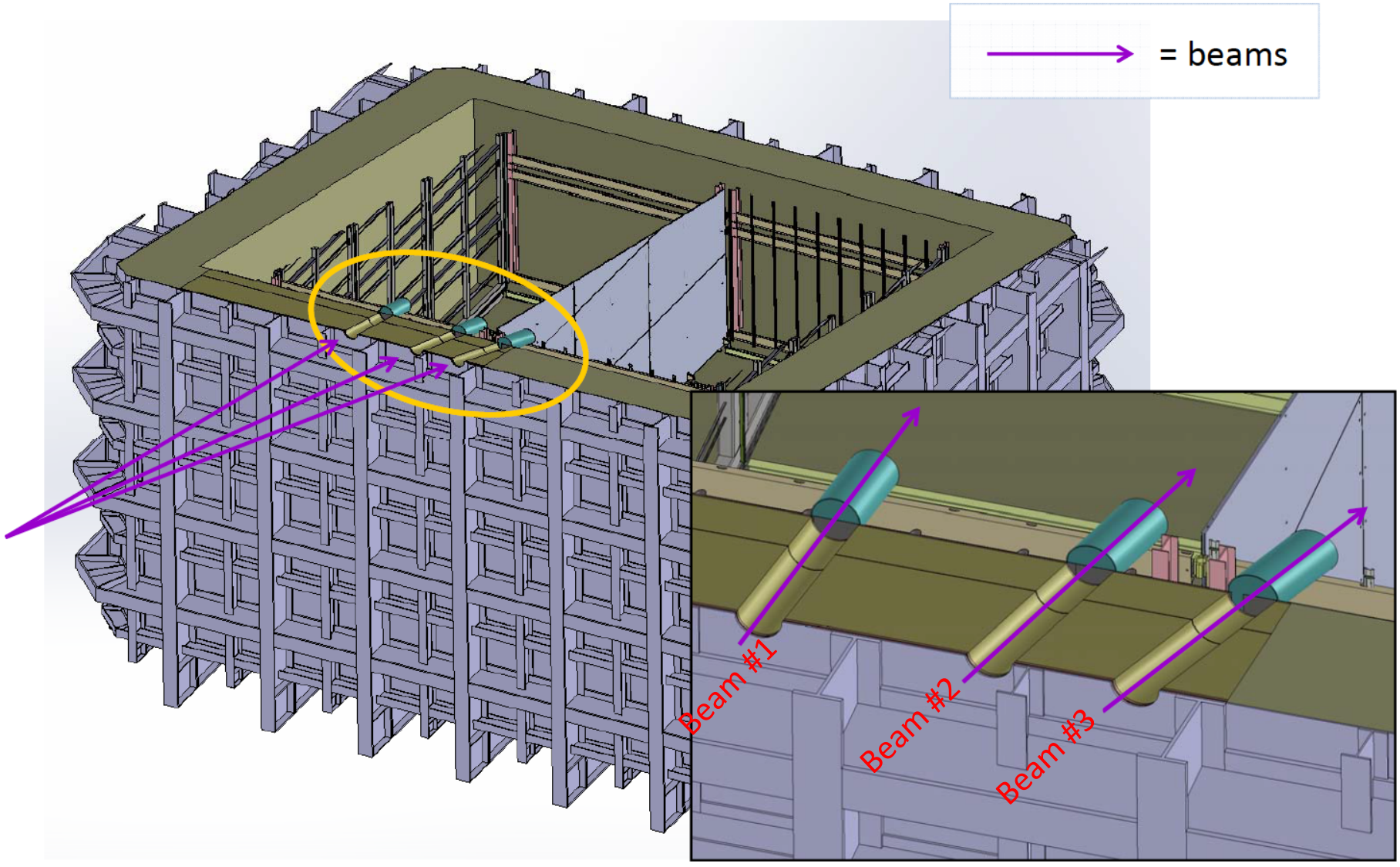
Mini-Review of the HV Test at PC4
28-July 2016

Possible Beam Window Locations for ProtoDUNE-SP



- Beam plug displaces about 50 cm of passive LAr layer
- Without beam plug, electron would shower before reaching TPC
- Plan is to install beam plug for beam position #3

Stage 2 plans:

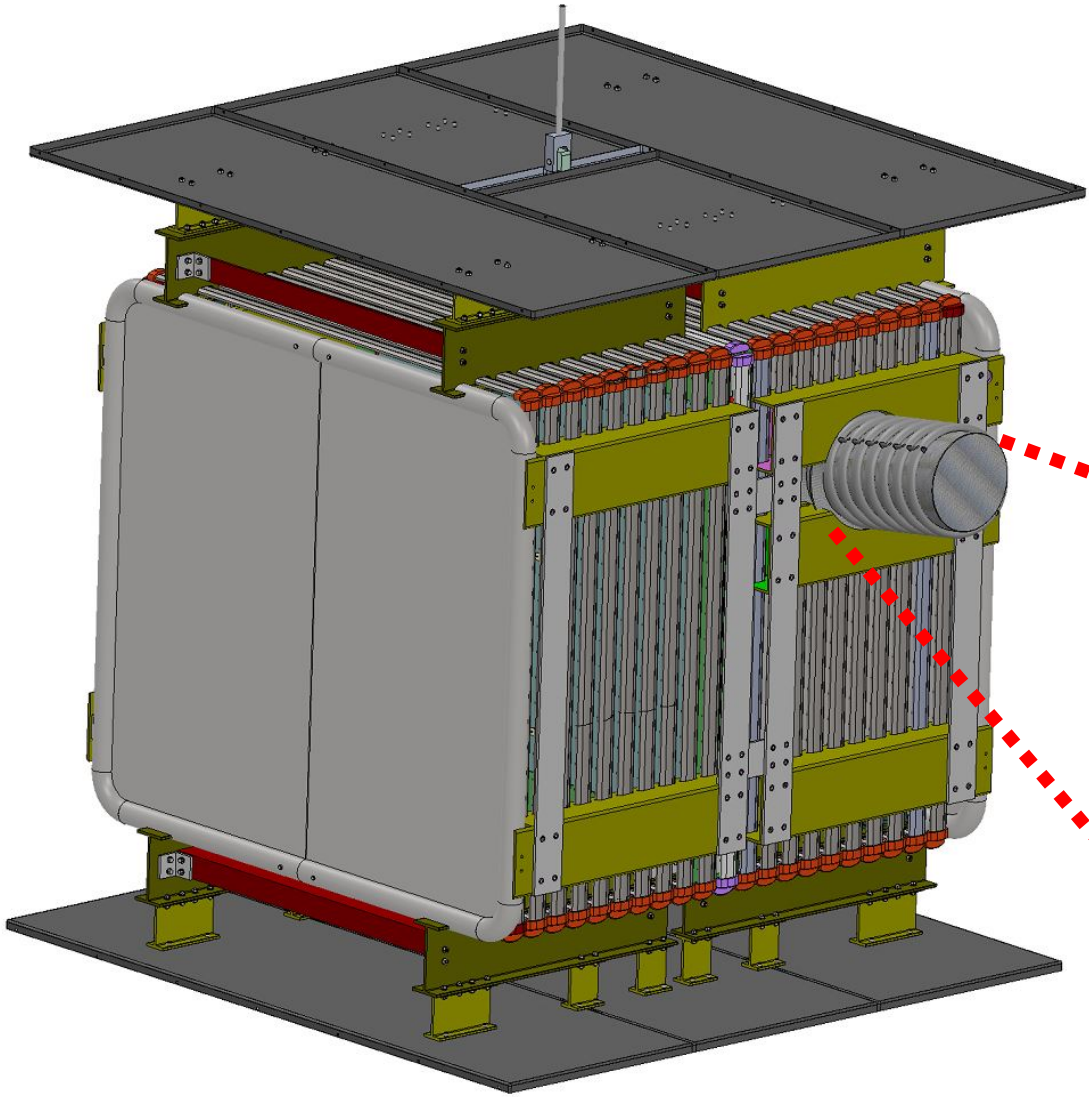
- After completion of stage 1 test, replace one field cage end-wall with one that has beam plug attached
- Verify beam plug does not interfere with the operations of the TPC (i.e. same HV performance w/ and w/o the beam plug)

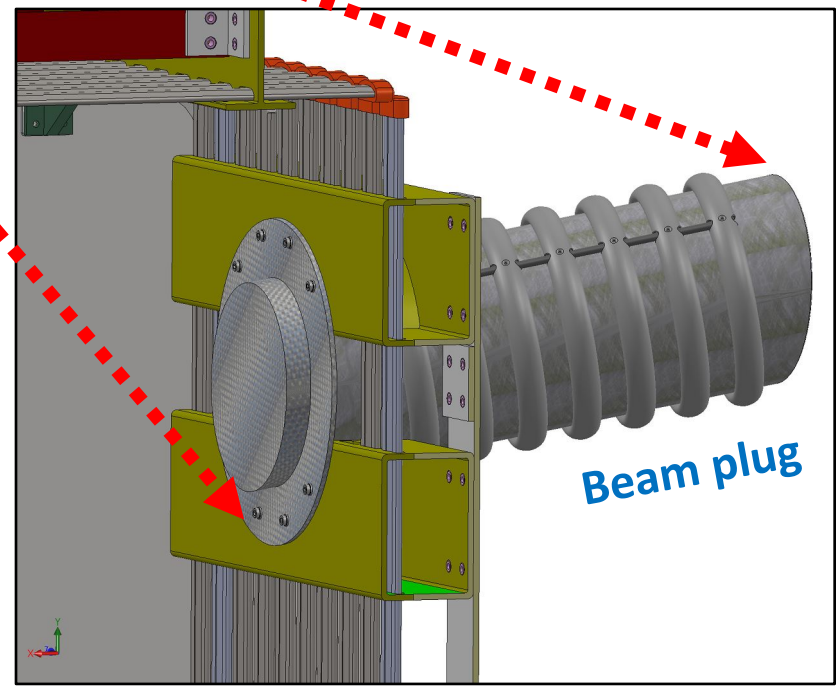
Beam plug team:

- C-J Lin - coordination
- Tim Loew - overall design
- Will Waldron - HV engineer
- Joe Wallig - Beam test and Ash River trial-assembly
- + students/postdoc from UCB/LBNL and inputs from campus faculty (H. Steiner, K-B Luk)

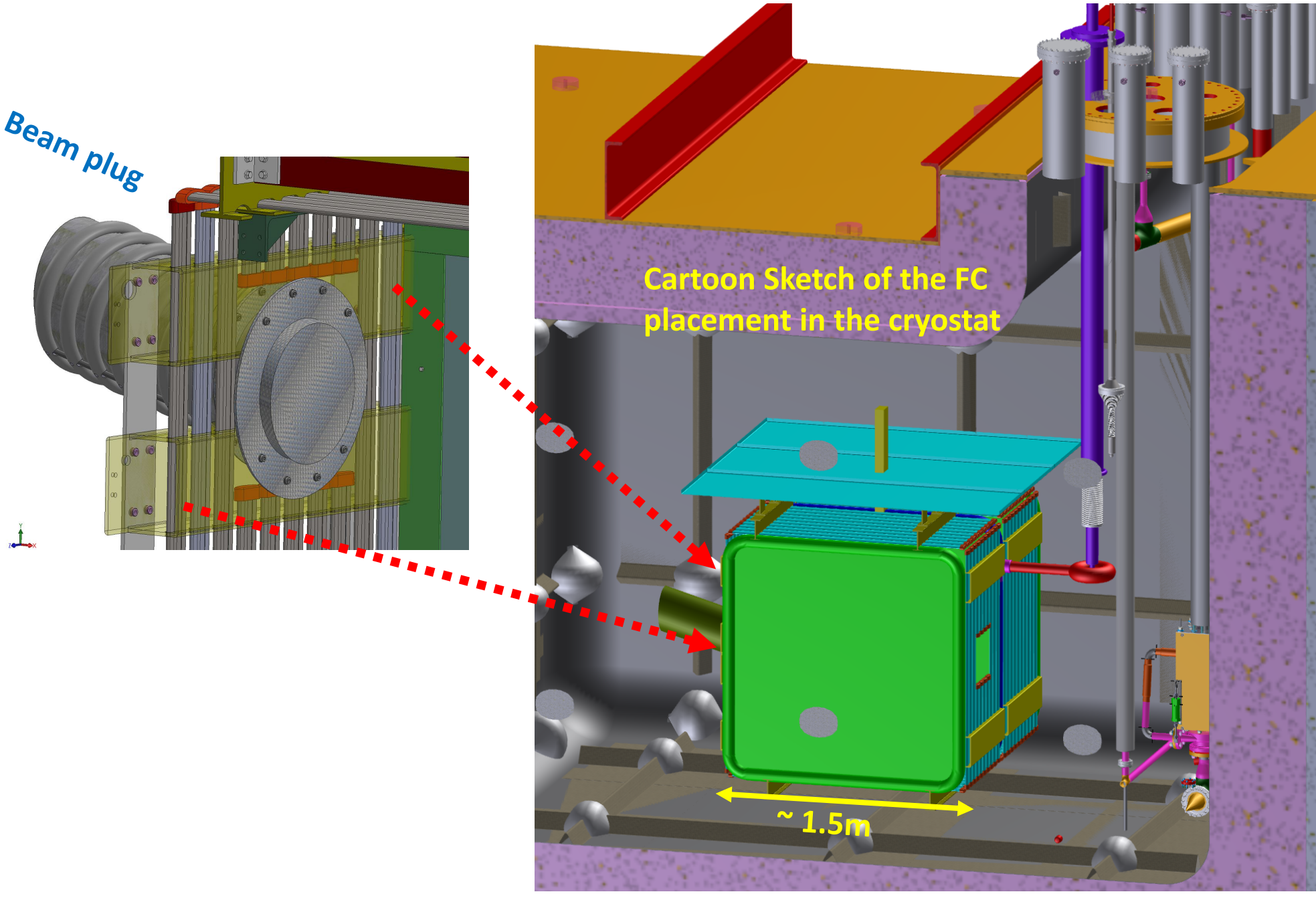
Stage 1 groups will also be involved in stage 2 tests

Stage 2 Configuration

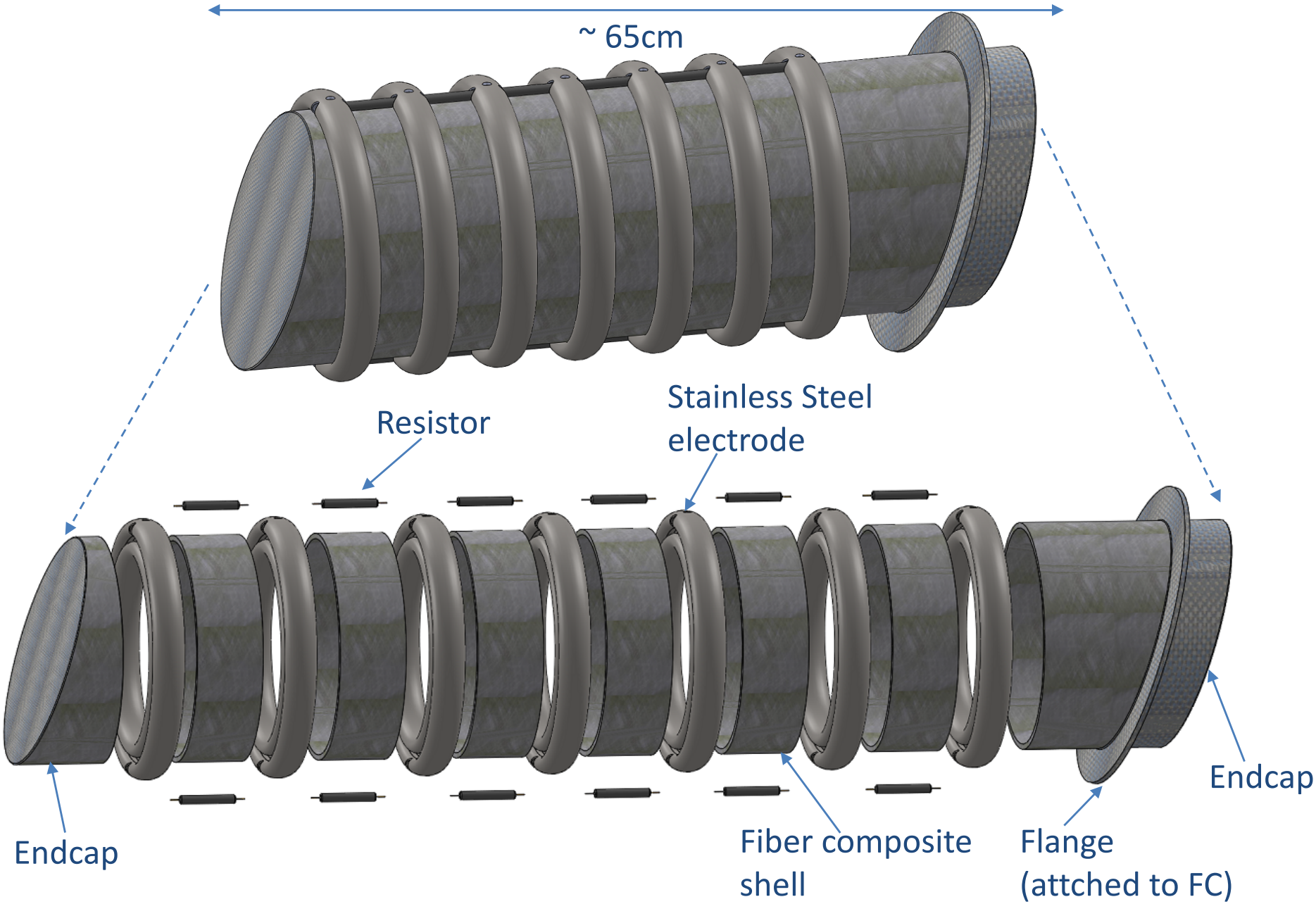




Note: mounting scheme with the FC is not finalized


Beam plug
Cartoon Sketch of the FC placement in the cryostat
~ 1.5m

Beam Plug

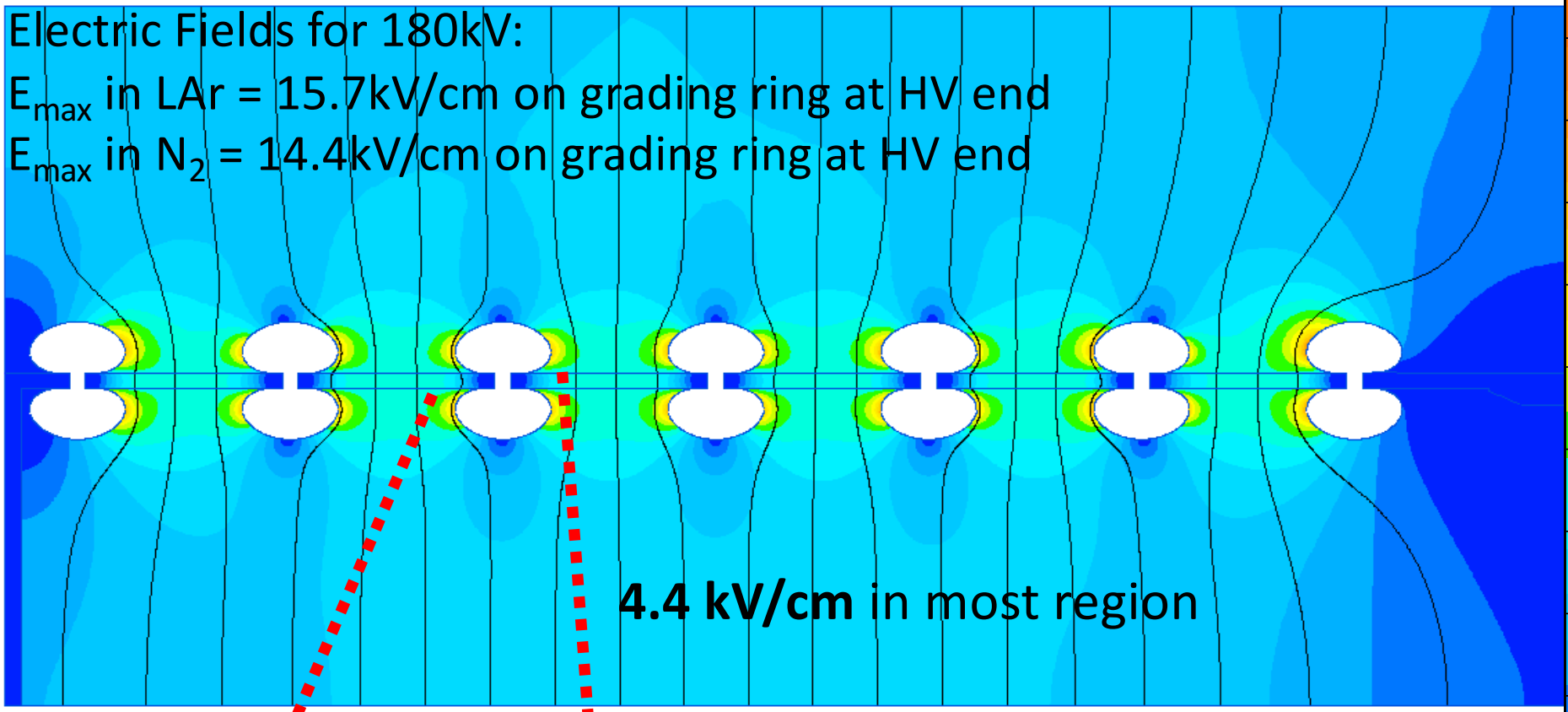


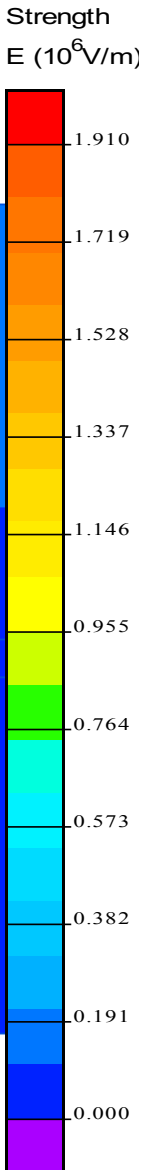
Sections are bonded using cryogenically-rated adhesive to ensure leak-free joint

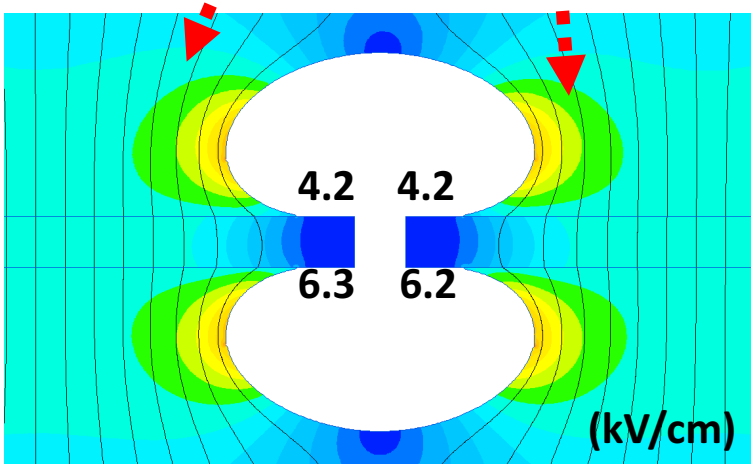
Beam Plug Design Requirements

Parameter	Value	Notes
Dimensions **Internal Diameter**	 20 cm	See CAD model
Length	480 mm 537 mm 659 mm	Ground Cap to Flange Overall (Flat to Flat) Overall (Maximum)
End Cap Angle	16.2°	
Flange Angle	16.2°	
Tolerances	ASME Y14.5 2009	Where Useful to Convey Design Intent & Function
Material	180 kV end to end	Electrically Insulating Selected from or tested per FNAL LAr purity list.
Operating Temperature	25° C -185 °C	Room Temperature LAr Temperature
Interface	Cryostat Wall; HV Field Cage	Minimize Distance; Rigid Structural; Electrode at HV Potential
Electrode Rings	304/316 Stainless Steel	
Operating Pressure (Internal)	78.6 psi 22.9 psi	Ambient Temperature LAr Temperature
Pressure Environment (External)	14.7 psi 19.9 psi	Ambient Temperature LAr Temperature
Pressure Ratios (Internal/External)	5.3 1.15	Ambient Temperature LAr Temperature
Internal Volume	15.5 liter (est.) 22 liter (est.)	Internal External displacement
Minimum Safety Factor	3	
Pressure Test Factor	2	
High Voltage Test	180 kV equivalent	HV tests conducted by LBL
Flange Interface		Geometry per LBL ICD
Weight Load	75 lb [34 kg]	Estimated
Buoyancy Load	67.5 lb [31 kg]	Estimated
Pressure Port		
Permeability	6.6×10^{-5} torr-l/s 5.9×10^{-5} torr-l/s	Total Volumetric, N_2 gas He gas Equivalent
Operating Lifetime	1 yr	
Thermal Cycles	3	Per Lifetime
Shock Loading		No shock loading

Electrostatic Calculation for Electrodes

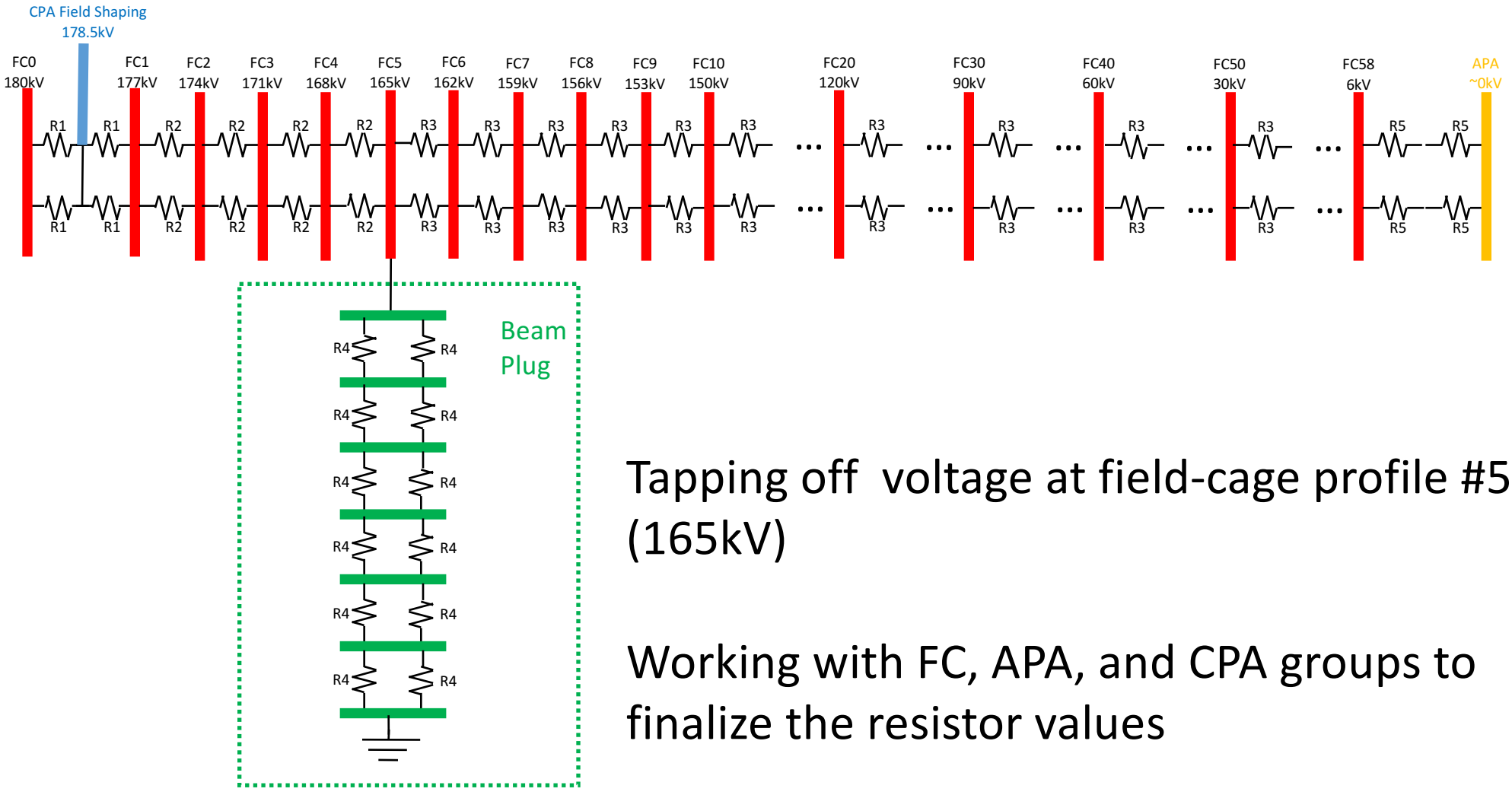






Peak field is acceptably low

RESISTOR DIVIDER CHAIN



Tapping off voltage at field-cage profile #5 (165kV)

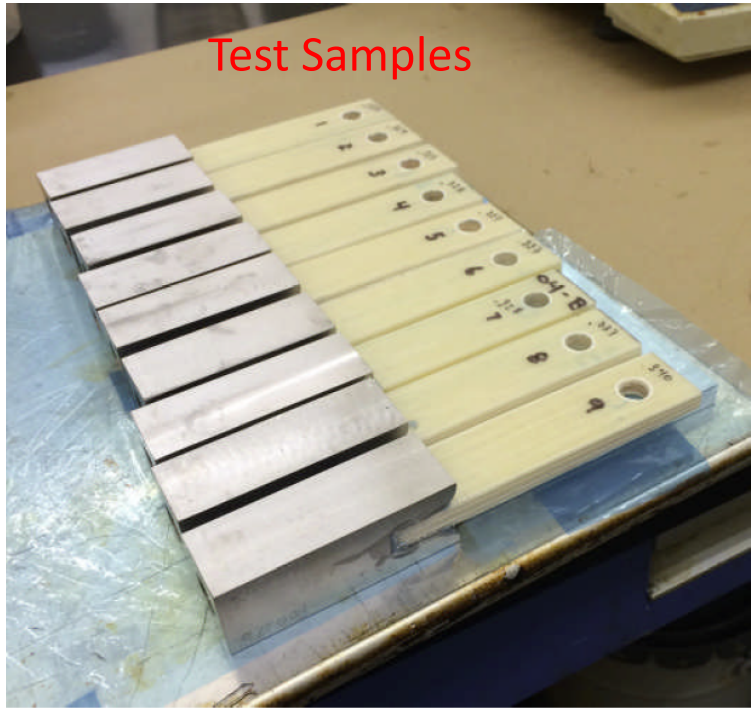
Working with FC, APA, and CPA groups to finalize the resistor values

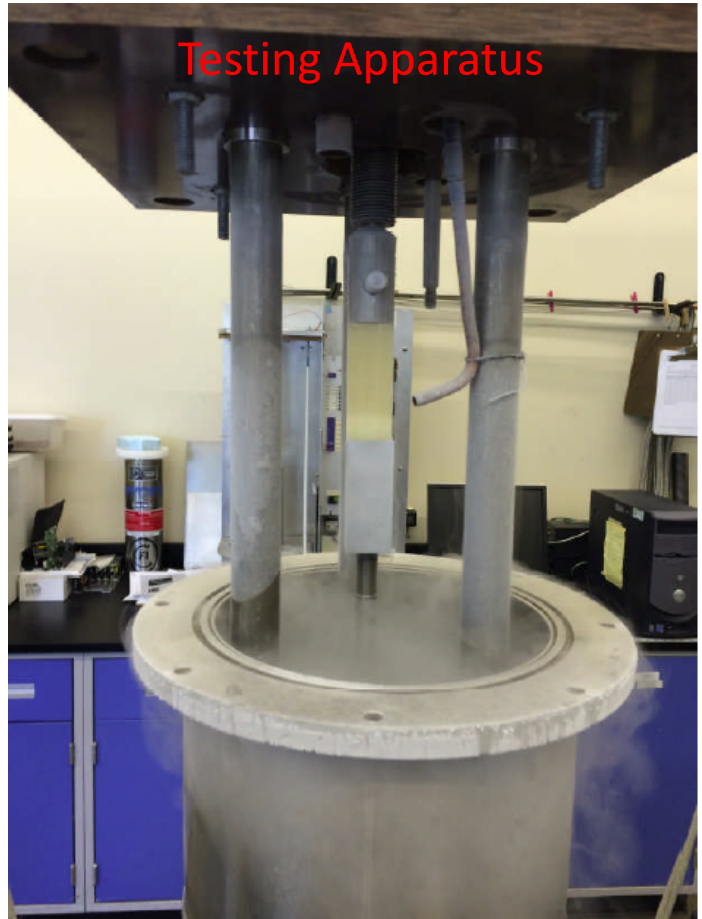
Beam Plug Testing Program

A suite of tests are planned leading up to the HV test @ PC4

Mechanical bonding test (completed):

- Validate electrode ring/composite material joint for adhesive shear strength
- Performed at cryogenic temperature (LN) by the vendor
- Excellent result -> nominal safety factor of 6 for shear failure





Beam Plug Testing Program

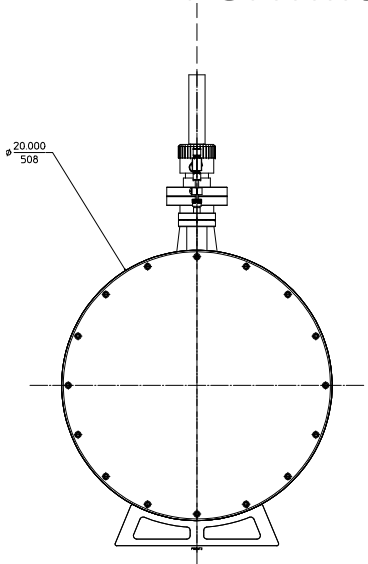
Measure dielectric strength of composite (ongoing):

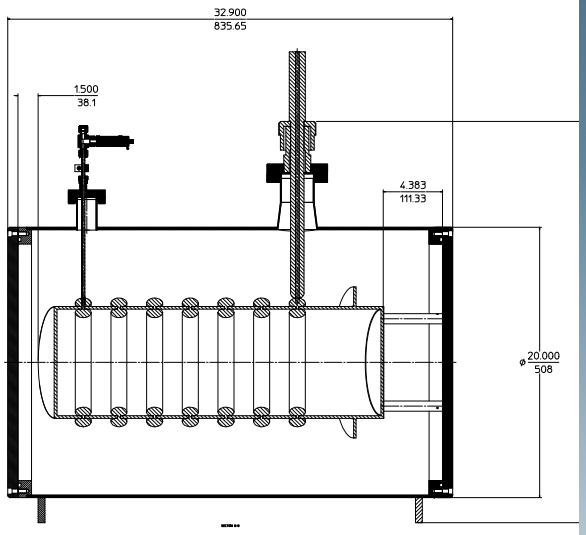
- Samples received from vendor
- We are setting up the test apparatus at LBNL
- Study electric breakdown along the surface and through the bulk of the composite material
- Results available within a week

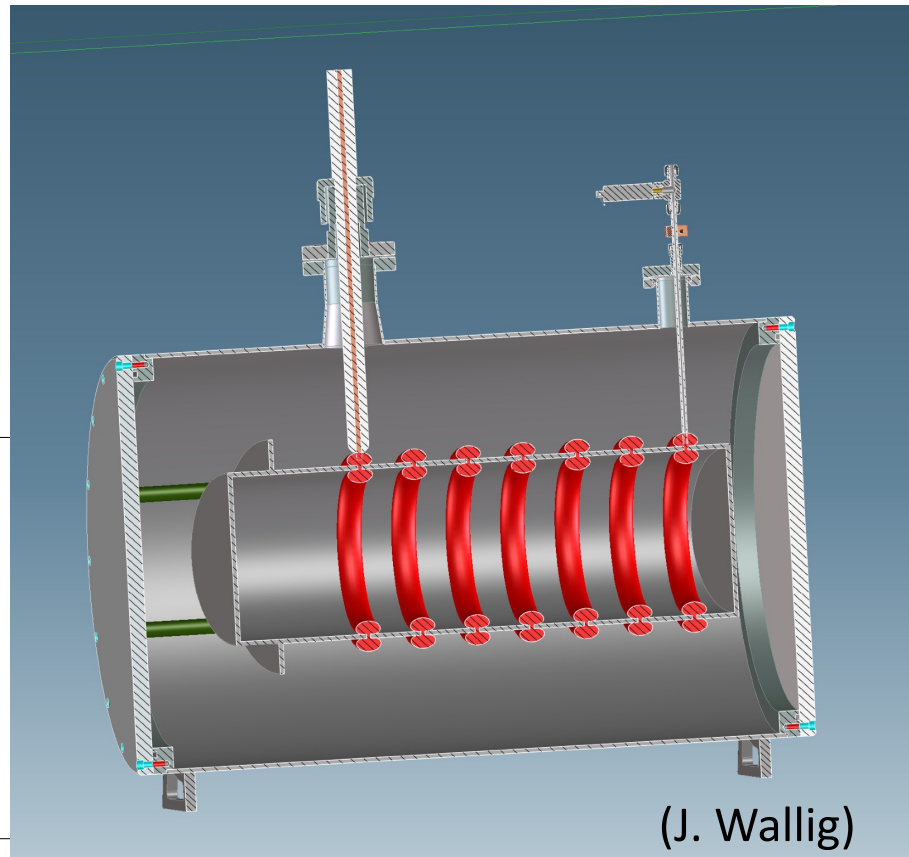
Beam Plug Testing Program

Beam test (planned):

- Electron beam through the beam plug with the grading rings at nominal HV (~160 kV across the beam plug)
- Verify the design does not cause HV breakdown inside the plug when running with charged particle beam
- Test as a function of N_2 gas pressure and beam rate
- Test at room temperature; will adjust the internal pressure to cover all range relevant to cryogenic operations
- Test beam at either SLAC ESA or Fermilab M-Center this Fall







(J. Wallig)

Beam Plug Testing Program

Material compatibility (starting soon):

- Testing all components (grading ring, fiber composite, resistors) for compatibility with LAr
- Using the Material Test-stand (LUKE) in PAB @ Fermilab

Radioactivity (as components become available):

- Measure radioactivity of fiber composite materials and grading ring electrodes
- Using the Low-Background Counting Facility at LBNL

Full-scale cryogenic test(planned):

- Testing the production unit in LAr using the BLANCHE test-stand at PAB
- Stand-alone testing up to the maximum voltage allowed by BLANCHE (~150 kV)
- Time frame: late November to December

Summary

- Beam plug is critical to the physics program of ProtoDUNE-SP
- A suite of tests are planned leading up to the Stage II PC4 test
- Stage II is the ”grand finale” of the beam plug test program:
  - Full integration with the FC and other TPC HV systems
  - Identical mechanical mount to the field cage as ProtoDUNE-SP
  - In LAr with nominal HV
- Will have a review for Stage II later in the year