Bern deliverables update

Cubism - Braque's Bottle and Fishes, Paris c.1910-12

June 18th 2020

James Sinclair, LHEP

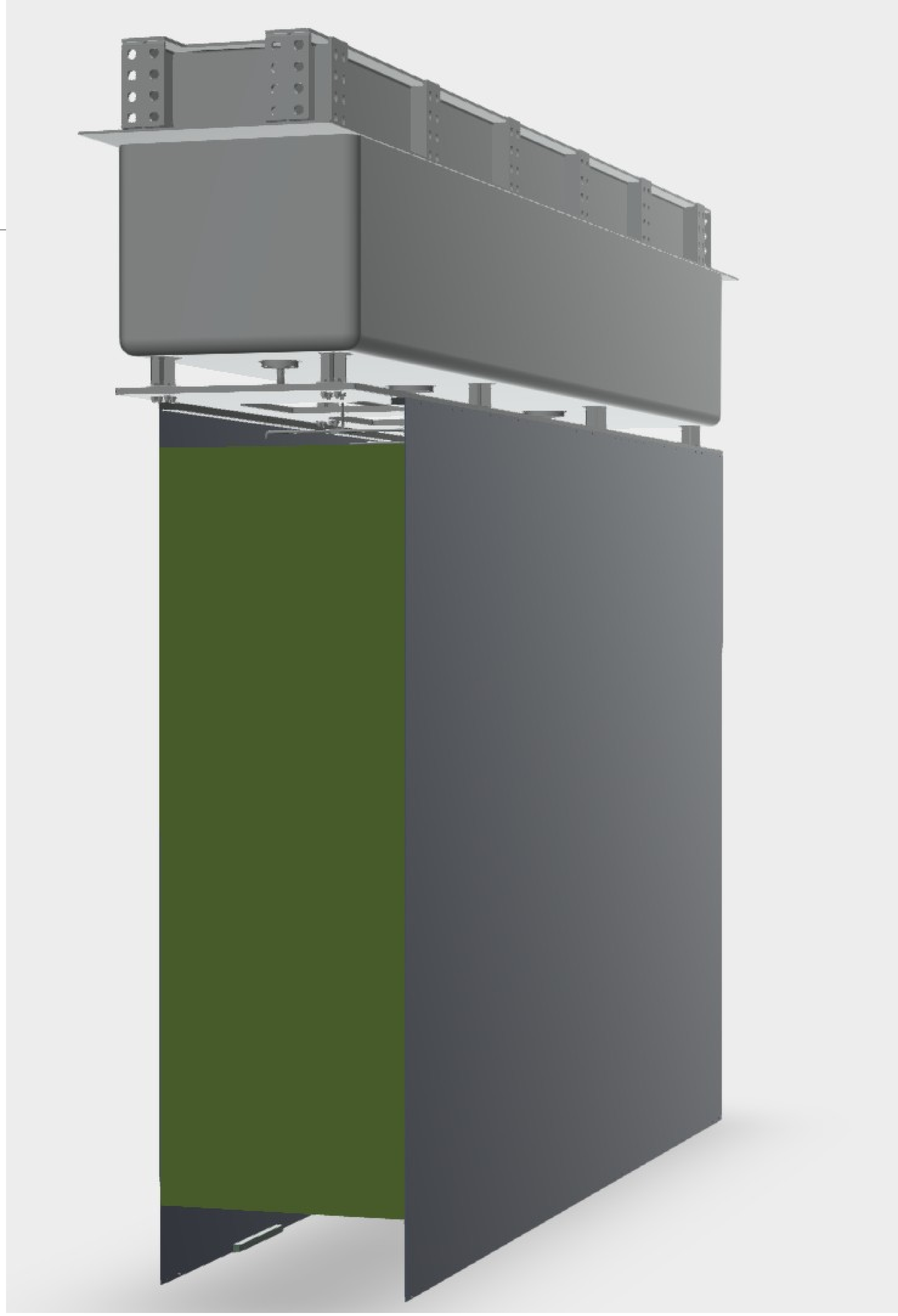
Module structure – No More Bucket!

Going to an open module design simplifies the design and increases the active volume.

The blue wall are essentially the anode support structure, and the green walls are the TPC sides.

The TPC walls between modules could share a common substrate, however, for the purpose of testing single modules two independent walls may be needed

The anode support would extend beyond the TPC, to allow for fixations between module without disturbance to E-field.



Module structure – Liquid level?

Liquid level is set by ullage requirements.

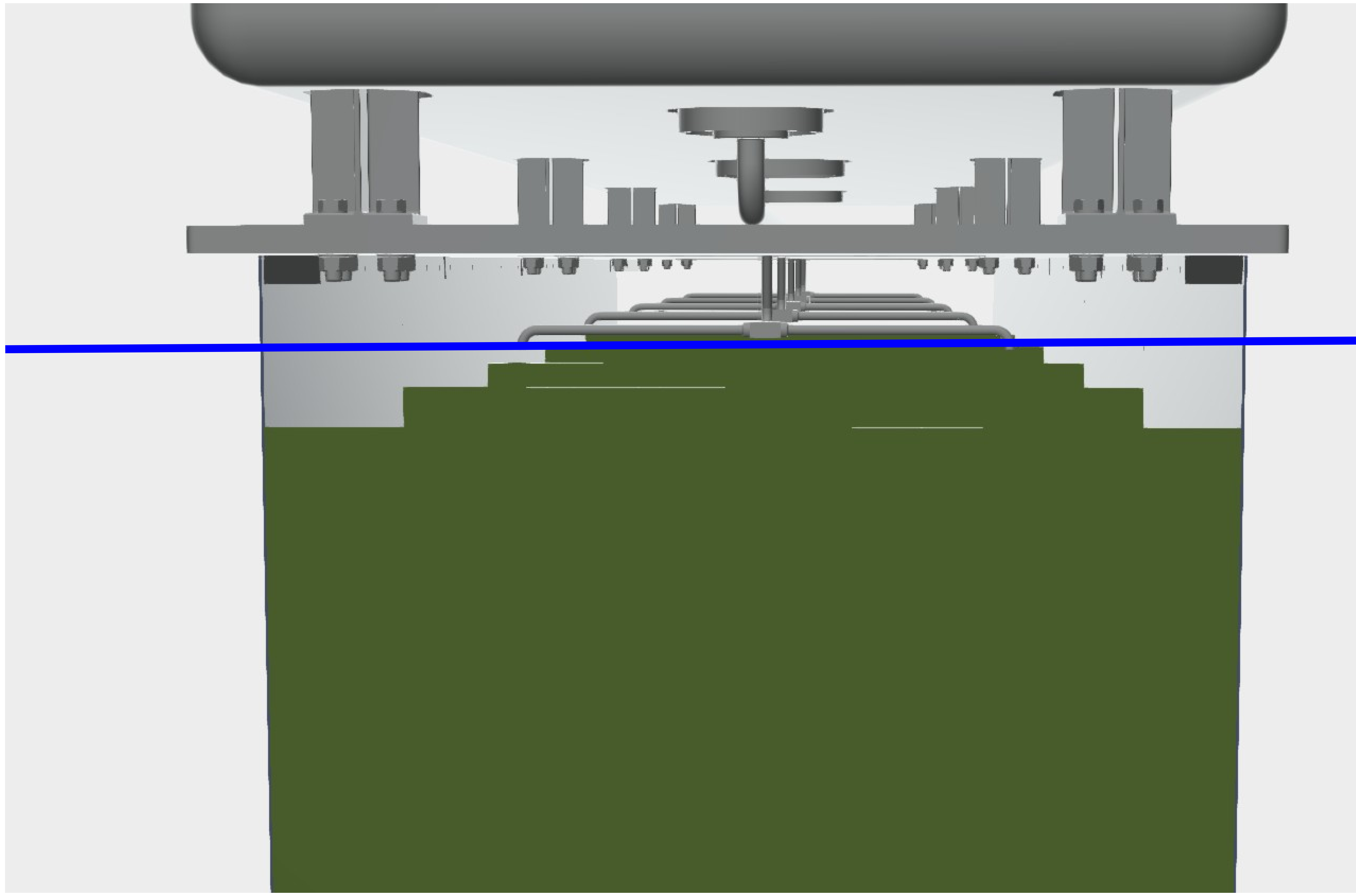
Fermilab requested 10% ullage volume for 2x2.

Industry standard for LNG is 5%.

ICARUS operated at 2%.

2x2 actually has 7%.

Fermilab must confirm what is needed.



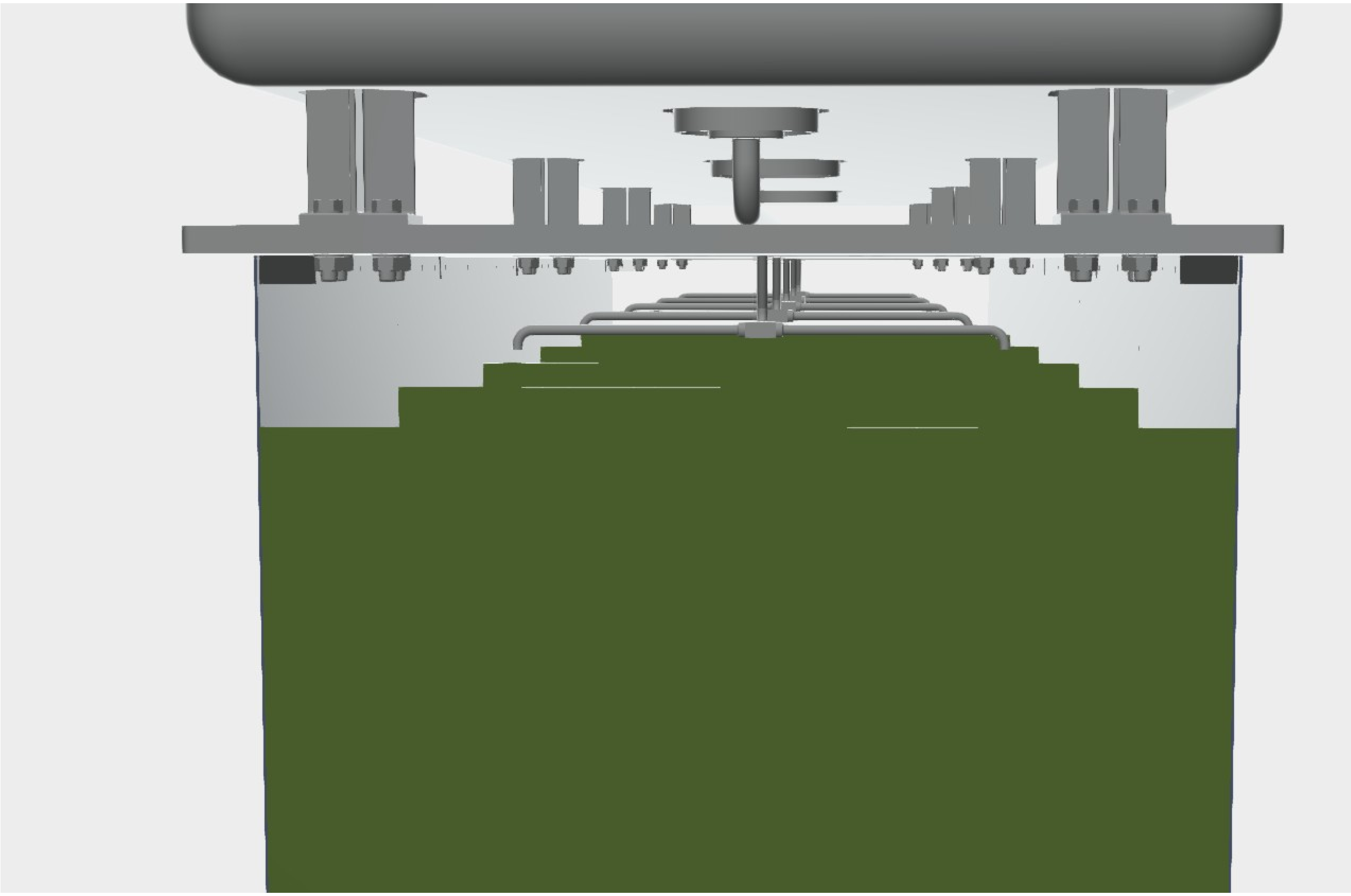
Module structure - Cryogenics

To achieve a 10% ullage volume, the LAr level would be 47 cm below top flange.

In the open system only a LAr inlet/diffuser is need per module. This can serve as a gas diffuser, but a separate line maybe needed.

The LAr inlet should be below the liquid surface during normal operation.

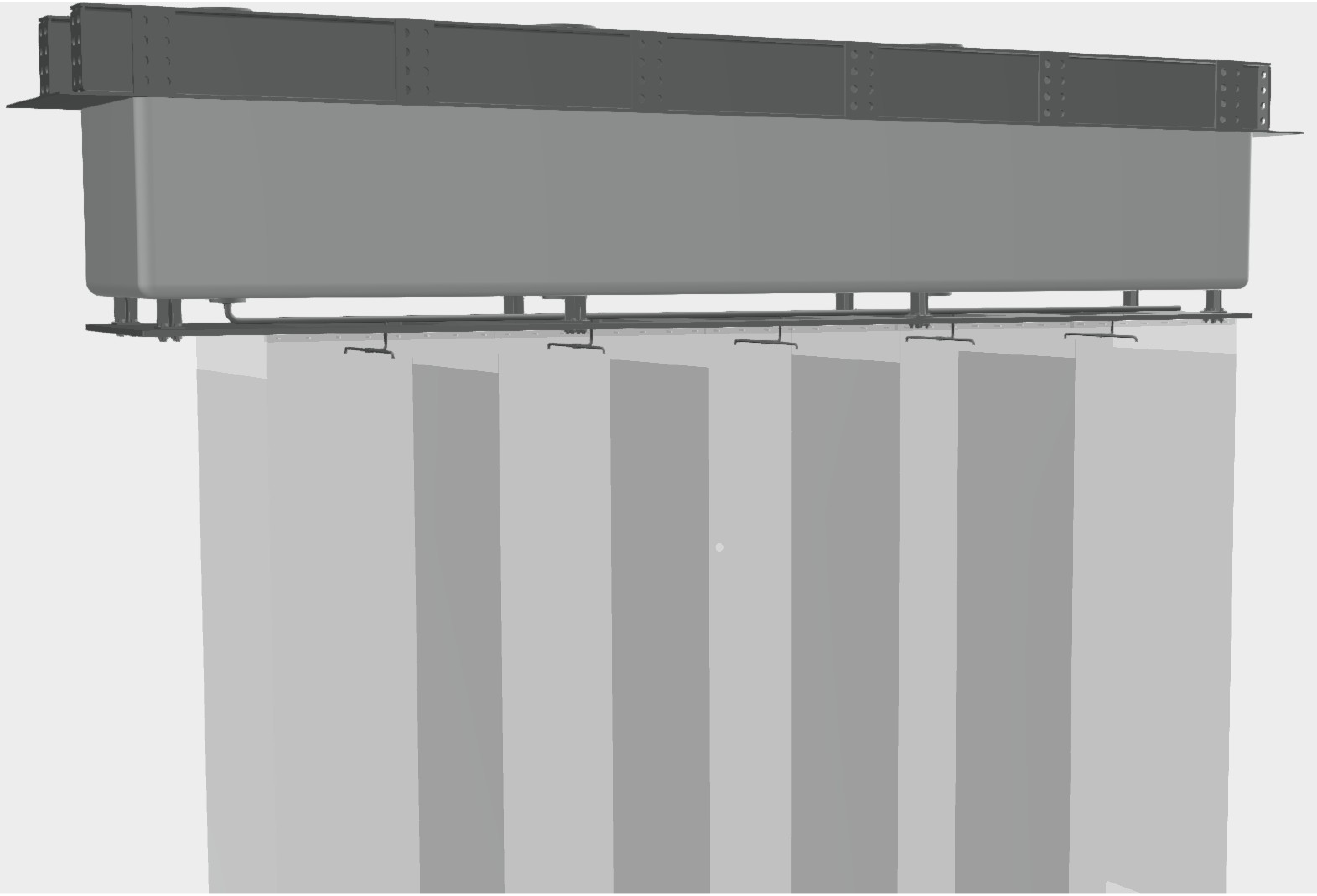
Level measures and LAr outlet and all other cryogenic instrumentation are part of the cryostat system.



Module structure – LAr flow

Only pipe work needed is for LAr inlet/diffusion above modules.

To reduce the effects of loss of purity in the bulk volume, the anode supports should be extended beyond the LAr diffusers, to direct the flow of clean LAr across each TPC.



HV Scheme – overview

One power supply serves a row of 5 modules.

The power supply is connected to the modules by a single low-pass filter.

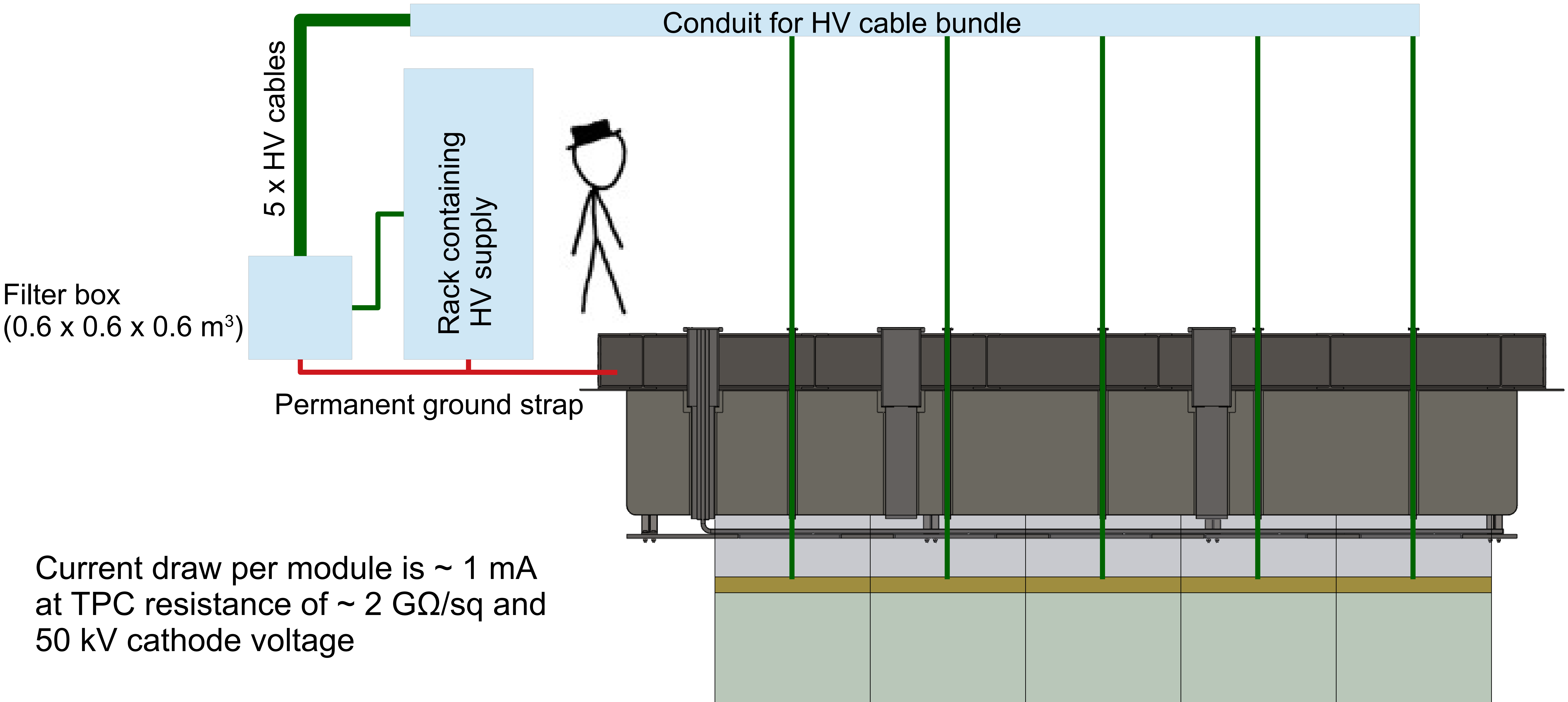
After the filter 5 resistive cables connects to the feedthrough/cathode.

The variations in length of the 5 cables are accounted for by adding a resistor for each cable after the filter.

For safety and to reduce ground loops. Cables are bundled together in conduit until they reach their feedthrough.

The jacket of all cables (HV→filter & filter→detector) must share common ground with the filter and detector. The detector and rack grounding must be a permanent dedicated lines, regardless of ground loops.

HV Scheme – overview



Current draw per module is ~ 1 mA
at TPC resistance of ~ 2 GΩ/sq and
50 kV cathode voltage

HV Cable

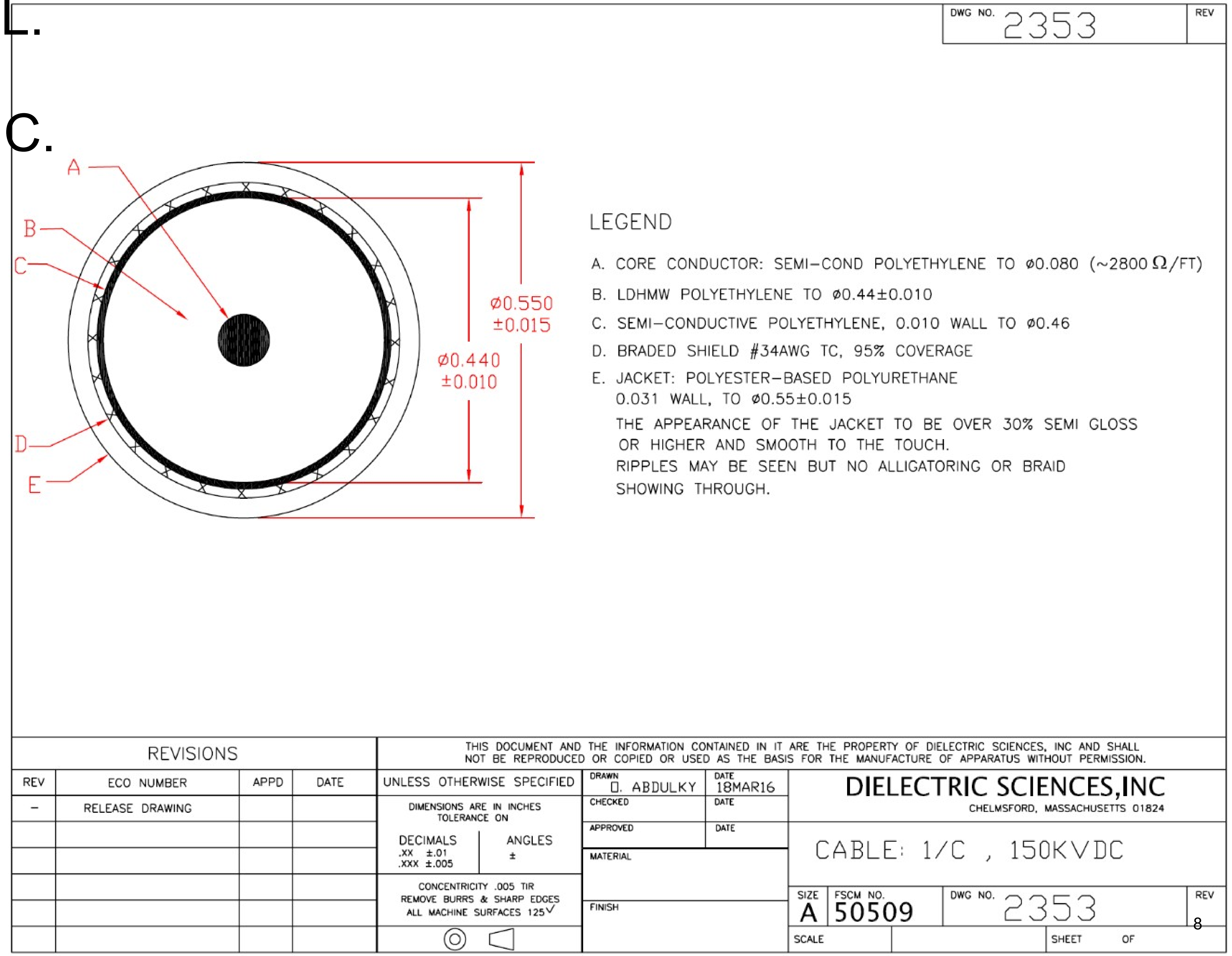
The HV cable is sourced via SLAC/LBNL.

It is produced by Dielectric Sciences, INC.

It has found application in nEXO (arXiv1805.11142)

Resistance: 8.4 kΩ/m

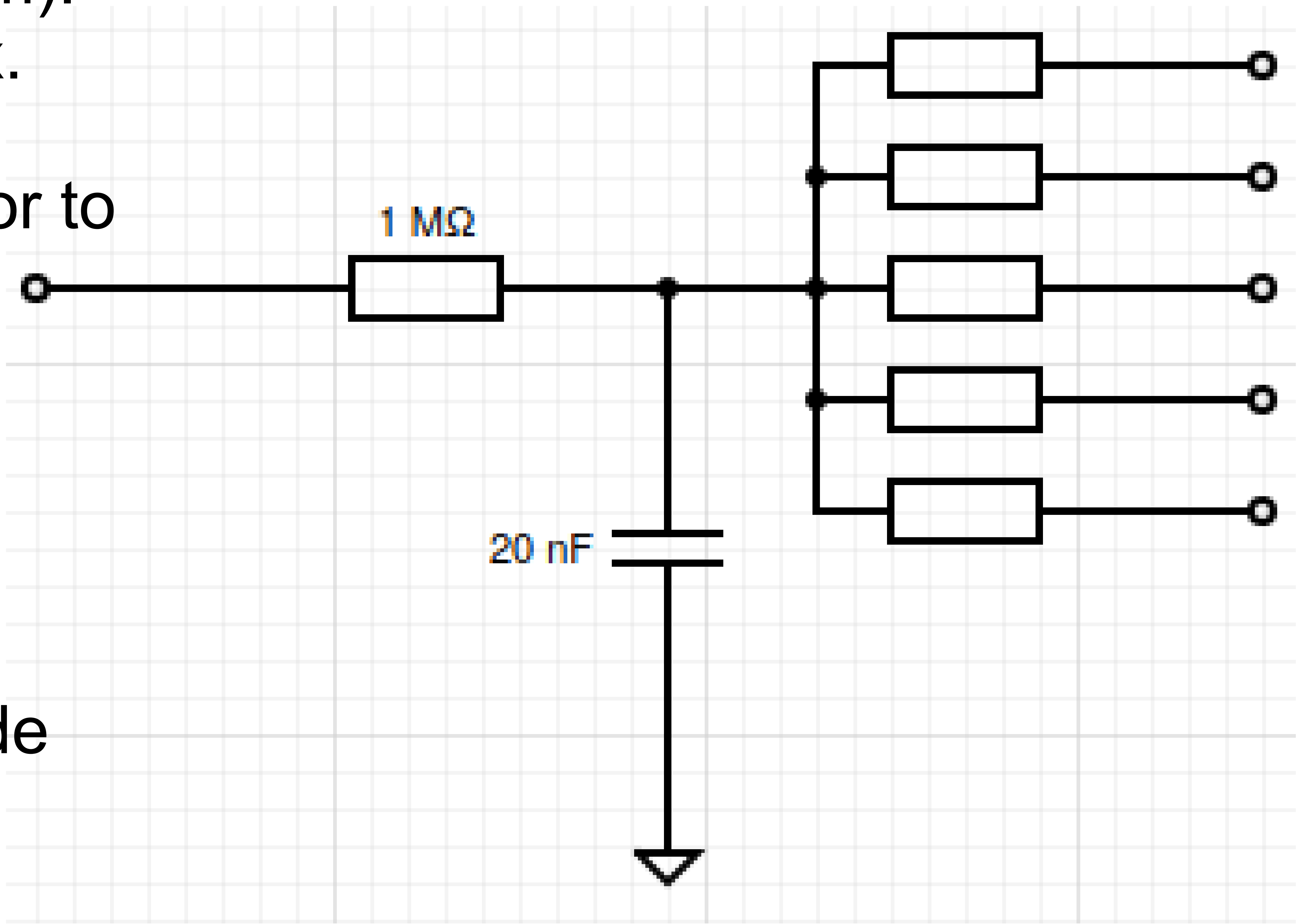
Capacitance: 90 pF/m



HV filter

A metallic box approximately 0.6 x 0.6 x 0.6 m^3, filled with transformer oil (Nytro 10 XN, www.nynas.com). All connections made vertically, through lid of box.

Low-pass filter with large capacitor & small resistor to prevent voltage drop.



– at 1 MΩ and 20 nF, cut off is ~10 Hz

– at 5mA, voltage drop across filter is 5 kV

– additional resistors at outlet set to match cathode voltages given differing cable lengths

– jacket of inlet and outlet must share ground with capacitor

HV filter - capacitors

50+ kV rated 20 nF capacitors are not commercial available. Therefore we propose connecting an array of capacitors in parallel.

Identified a 2 nF capacitor (EPSP9202MA) from www.hvproducts.de

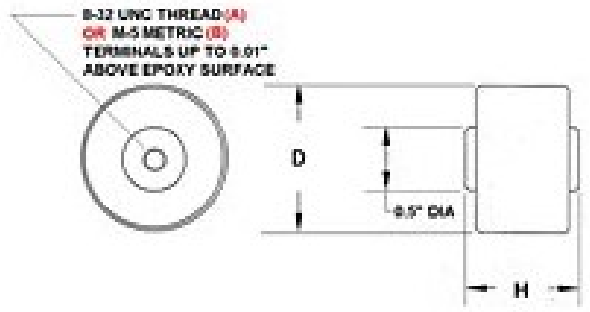
Tested at 65 kV

70 mm tall x 35 mm diameter

Cost ~ 90 EUR per unit, 70 units required

EPSP Pulse Power Ceramic Capacitors

- High Amplitude, Short Pulse Rated
- Up to 50 kV_{DC} Max Working Voltage
- Compact & Epoxy Encapsulated
- Low (0.5%) Dissipation Factor
- Stable Class I Dielectric



Results 1 - 13 of 13

Part Number	CAP	V_{MAX} (DC)	V_{TEST} (DC)	Physical Depth (D)	Physical Height (H)
EPSP3142MA	1400 pF	20 kV	30 kV	1.50 in 38 mm	0.906 in 23 mm
EPSP3252MA	2500 pF	20 kV	30 kV	1.89 in 48 mm	0.906 in 23 mm
EPSP3402MA	4000 pF	20 kV	30 kV	2.26 in 60 mm	0.906 in 23 mm
EPSP5941MA	940 pF	30 kV	45 kV	1.50 in 38 mm	1.02 in 26 mm
EPSP5172MA	1700 pF	30 kV	45 kV	1.89 in 48 mm	1.02 in 26 mm
EPSP5272MA	2700 pF	30 kV	45 kV	2.26 in 60 mm	1.02 in 26 mm
EPSP7701MA	700 pF	40 kV	55 kV	1.50 in 38 mm	1.26 in 32 mm
EPSP7132MA	1300 pF	40 kV	55 kV	1.89 in 48 mm	1.26 in 32 mm
EPSP7202MA	2000 pF	40 kV	55 kV	2.26 in 60 mm	1.26 in 32 mm
EPSP9501MA	500 pF	50 kV	65 kV	1.50 in 38 mm	1.38 in 35 mm
EPSP9901MA	900 pF	50 kV	65 kV	1.89 in 48 mm	1.38 in 35 mm
EPSP9202MA	2000 pF	52 kV	65 kV	2.75 in 70 mm	1.38 in 35 mm
EPSP CUSTOM	500 to 4000 pF	20 kV 30 kV 40 kV 50 kV	N/A	N/A	N/A

Results 1 - 13 of 13

HV Supply

The HV supply should be able to provide 60 kV and 5 mA.

These are within the range of standard supplies from most manufacturers.

Stephen Pordes of ProtoDUNE recommends **Heinzinger** or **Fug-Elektronik**.

We have had good experience with **Spellman**.

I will reach out for quotes.

Comments on single/segmented cathode

The detector volumes must remain optically segmented.

The filter for such a system would be the same, with the number of lines out changing.

For a segmented cathode, the capacitance is 170 pF, and the stored energy in case of discharge is 0.21 J.

For a shared cathode, the capacitance is 850 pF, and the stored energy is 1.06 J.

The increase in energy is tolerable. But, we would be prone to failure of single a single.

In segmented cathode approach, redundancy can be built in. However, this must be weighed against the cost of additional components (feedthroughs and cabling).

A single cathode with a redundant switchable feedthourgh maybe the best approach.