How resistive does the field structure need to be?

ND-LAr Consortium Engineering Meeting

From a continuous plane..

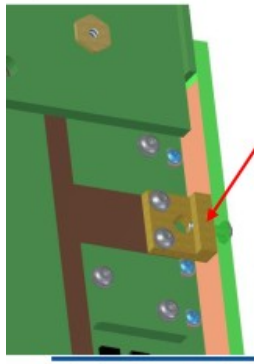
ND LArTPC Module Design
The Field Structure-
Resistive field cage

The resistive field cage is a fiberglass box with resistive coatings on the inner faces which grade the electric field from the cathode voltage in the center down to ground at each of the two anode support planes

For 2x2, the resistive field cage was made by laminating resistive film on the inner surfaces

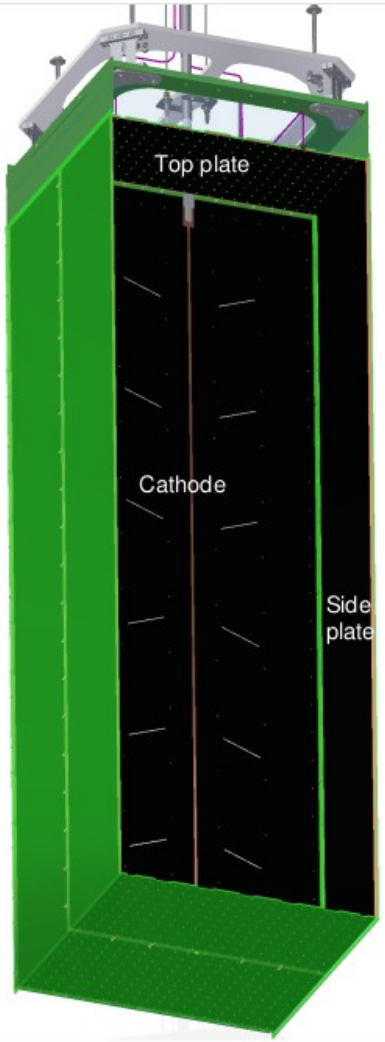
Due to budgetary constraints, a sprayed on resistive coating is being tested now. This coating may be done on the inside with carbon fill and on the outside without fill to prevent warpage (balance the laminate).

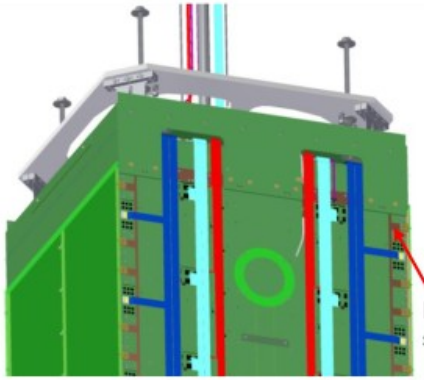
The metal edges are also being tested with deposited conductive coatings now due to the large size of the panels



Structural blocks also ground parts

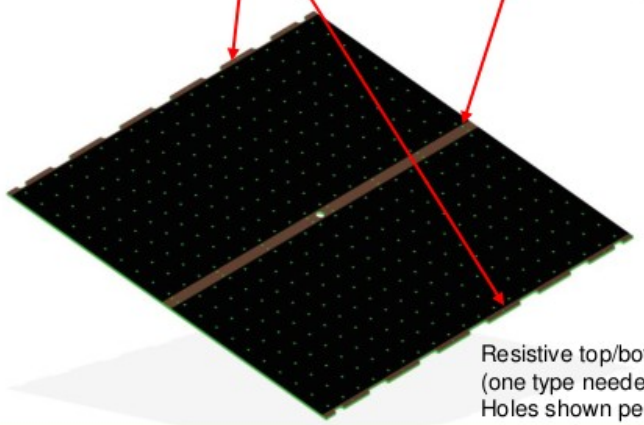
Resistive fiberglass box is stiff when screwed together as a unibody



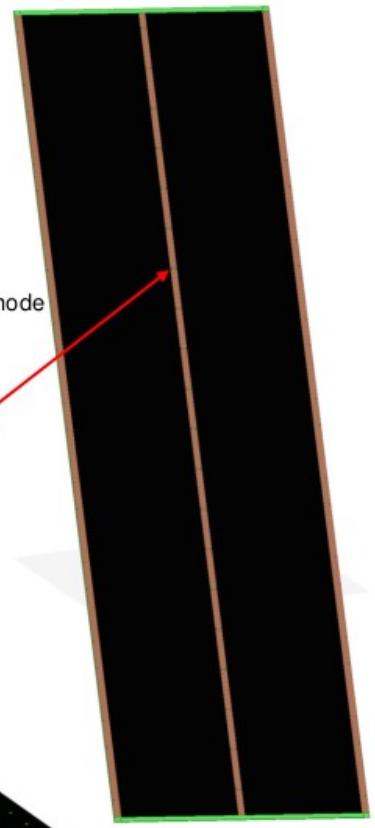


HV return on anode support plate

The center stripes are all "jumpered" together at the cathode and the two conductive edges are connected to each anode support plate to create the HV resistive circuit



Resistive top/bottom
(one type needed)
Holes shown permit fluid flow



Resistive side panel
(one type needed)

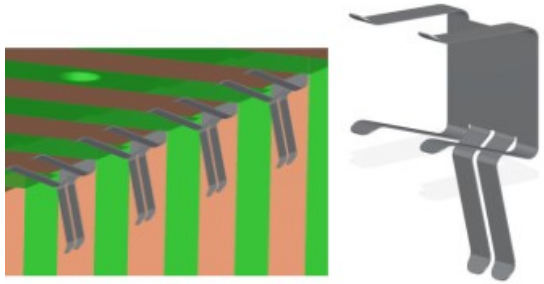
...to discreet resistors

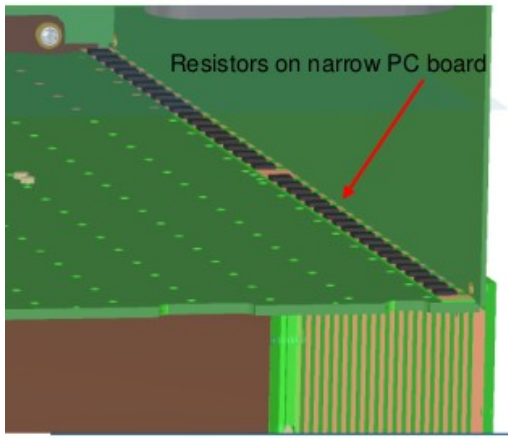
ND LArTPC Module Design

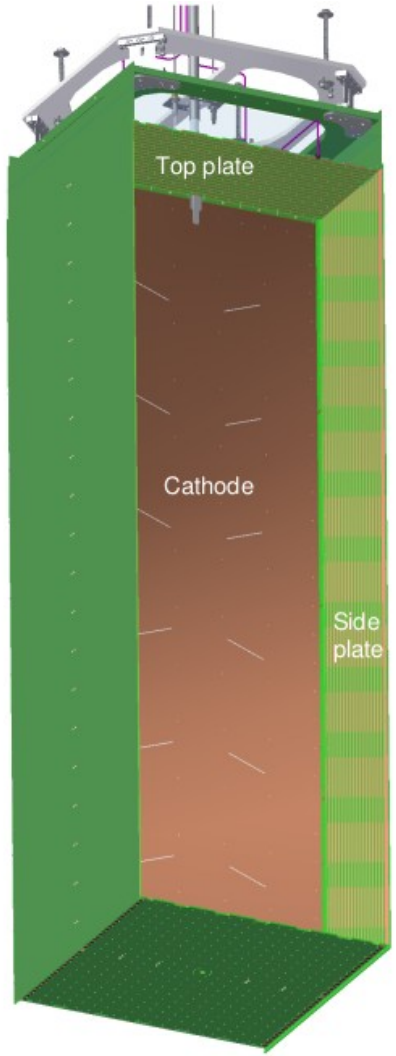
The Field Structure-

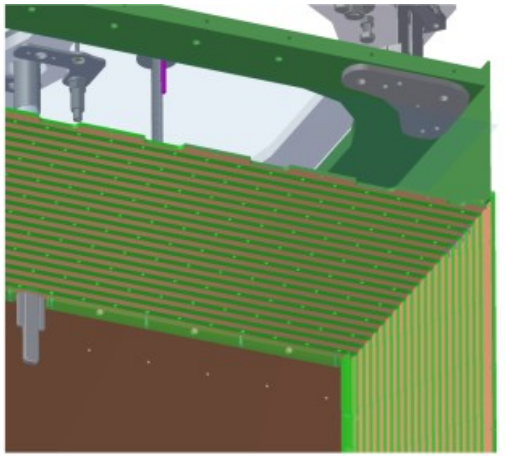
Conventional field cage

A conventional metal strip / resistor chain type field cage is also possible as an alternative solution

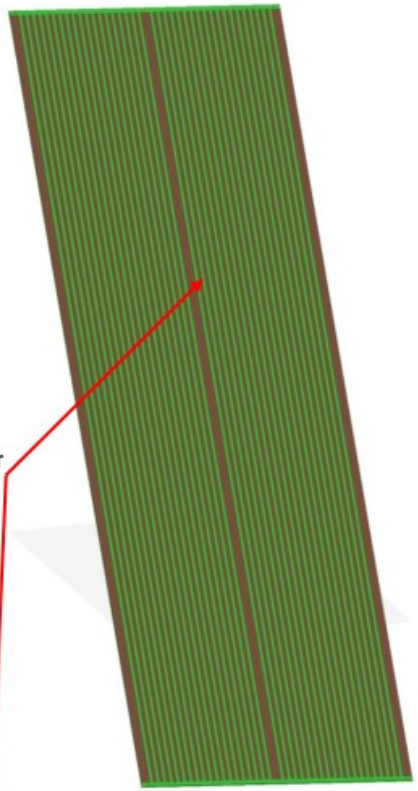




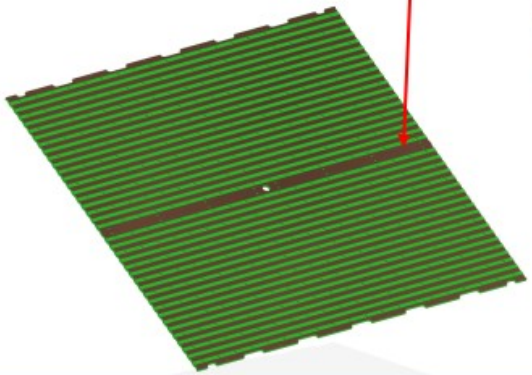




The center stripes are all "jumpered" together at the cathode and the two conductive edges are connected to each anode support plate to create the HV resistive circuit. The stripes are connected to a resistor chain with photo-etched spring clips.



Striped side panel
(one type needed)



Conventional top/bottom
(one type needed)
Holes shown permit fluid flow

What are the design requirements?

In a continuous resistive plane the sheet resistance is set to meet constrains on heat input.

(Low resistance → High current → unhappy cryo coolers)

HV breakdown protection is intrinsic.

In a discreet resistor design the resistor chain is again selected to meet power requirements.

What extent of HV breakdown protection is needed?

HV breakdown protection in DUNE

The use of DR8 for field shaping came out of break down mitigation efforts for the FD. See Sergio Rescia and Bo Yu's "Cathode HV Discharge Mitigation Design" (DocDB 1320-v2).

Why were Bo and Sergio worried?:

No detector had reached its designed voltage

180 kV at the cathode

100 J stored energy

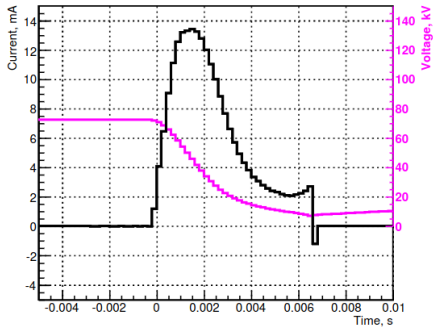
Argon dielectric of 40 kV/cm, breakdowns within 4.5 cm requires 20 cm deep clearance volumes to cryostat

Assumed discharge times of 1 ns

VERY HIGH CURRENT!! O(100) kA

HV breakdown protection in ND-LAr

A core concept of ArgonCube is to mitigate HV risk through detector segmentation. What does that do to the numbers?:



25 kV at the cathode

27 mJ/TPC stored energy

Argon dielectric of 40 kV/cm, possible breakdowns within 0.6 cm of cathode. G10 provided 200 kV/cm shielding to TPC

(2016 JINST 11 P03017) Measure discharges times in LAr from 70 kV in 6 ms, N.B. full-metal HV path. Conservatively, assume discharge times of 3 ms at 25 kV.

Current = 0.4 mA

“The high-voltage risk”

Stored energy in mJ is not considered dangerous to people or infrastructure. What is it dangerous to?

Armin and Kevin have both refereed to a high-voltage risk to the ASICs.

What is the maximum allowable current rate of the ASICs?

What failure modes would realize this risk?

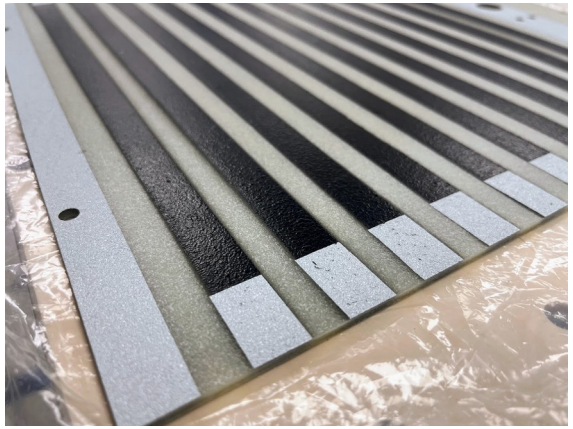
How would we dump that massive amount of energy to a pixel tile?

Is further breakdown protection needed in ND-LAr

Until 2019 field shaping rings were still baseline for NDLAr, along with other stranger concepts...

Are metallic field shaping rings bad? If so, why?

Are resistive field shaping rings needed? If so, how resistive should they be?



N.B. with resistive rings the aspect ratio is a long way from square. Therefore, the carbon loading has to be increased to a point that inhibits coating (graphite has very low friction...)