High Voltage Segmentation Options for the LBNE- LArTPC

Hans Jostlein May 25, 2010

Abstract

We consider the segmentation of the HV distribution.

Segmentation is of interest in the (unlikely) event that a HV plane suffers breakdown, e.g. from a broken wire. In that case one would like to minimize the lost volume impacted by this failure.

Options range from using a single HV supply and feedthrough serving collectively all planes, to using individual HV feeds for each cathode plane.

We propose a system where each pair of cathode planes has its own HV feed, and where the embedded cathode planes use a dual set of mesh layers to allow loss- free independent operation of the drift spaces separated by the cathode plane.

Introduction

The LAr20 detector for LBNE has 224 cathode plane assemblies, arranged in 112 (vertical) pairs. Of these, half are on the periphery of the detector assembly, and half are mounted in between pairs of APA planes.

The cathode planes operate at 123 kV. HV supplies are located outside the cryostat, and feed the HV via feedthroughs that reach into the LAr to prevent breakdown. They connect (within the LAr) via conductors that may be made from 1/4" SS tubing.

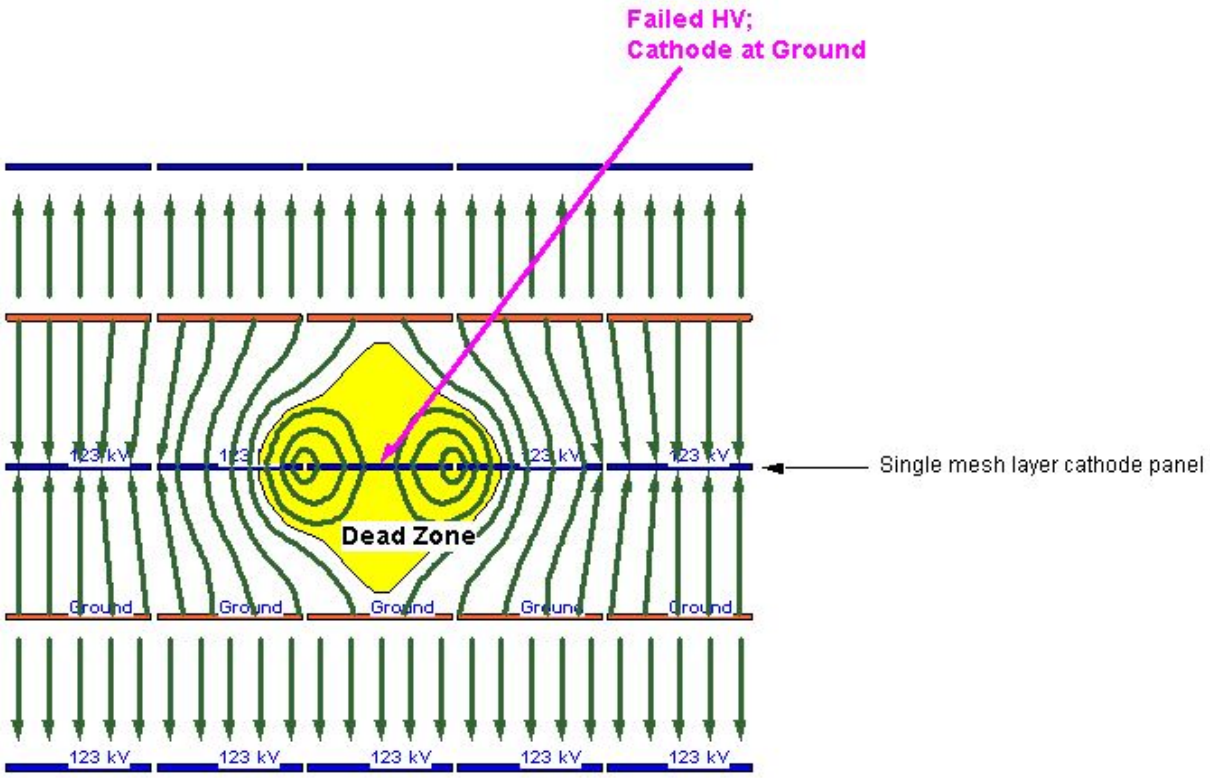
Segmentation Trade-Off

The lowest cost solution would be to daisy-chain all cathodes together, and use a single HV feed. This is also the configuration most vulnerable to a breakdown event, rendering the whole detector inoperable.

In the other extreme, supplying each plane separately, is more complex and costly.

What happens if a Cathode has failed?

We look at a case where a single cathode plane's HV has failed (i.e. each cathode is supplied independently), and where the failed cathode is now at ground potential:



Consequence of a single Cathode Panel Failure

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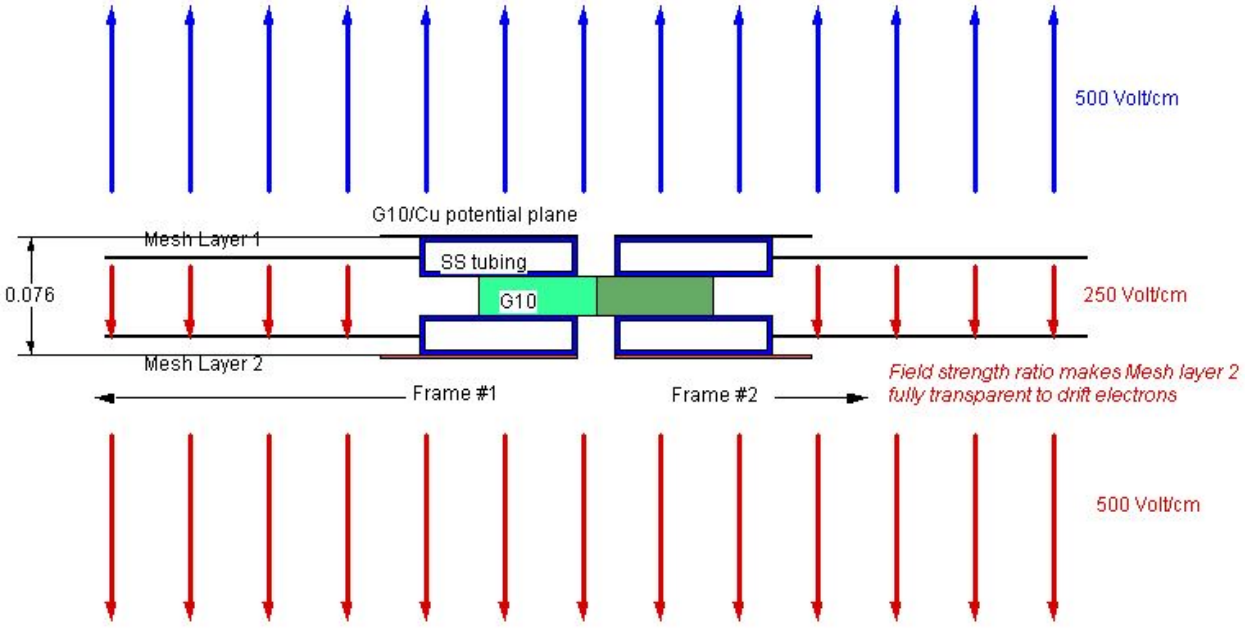
Roughly speaking, the drift spaces on **both** sides of the failed cathode will no longer be sensitive to tracks.

The adjacent drift spaces will be sensitive, but with significant geometric and time distortions. The data may be usable. Two panels away there will be significant distortion, but at a level that should be fully recoverable.

The Double Mesh Cathode

It is possible to make cathodes with two mesh layers. These cathodes will support good HV on one face, while the other face has suffered a discharge failure. Here is a cross section of the double frame:



Double Mesh Cathode

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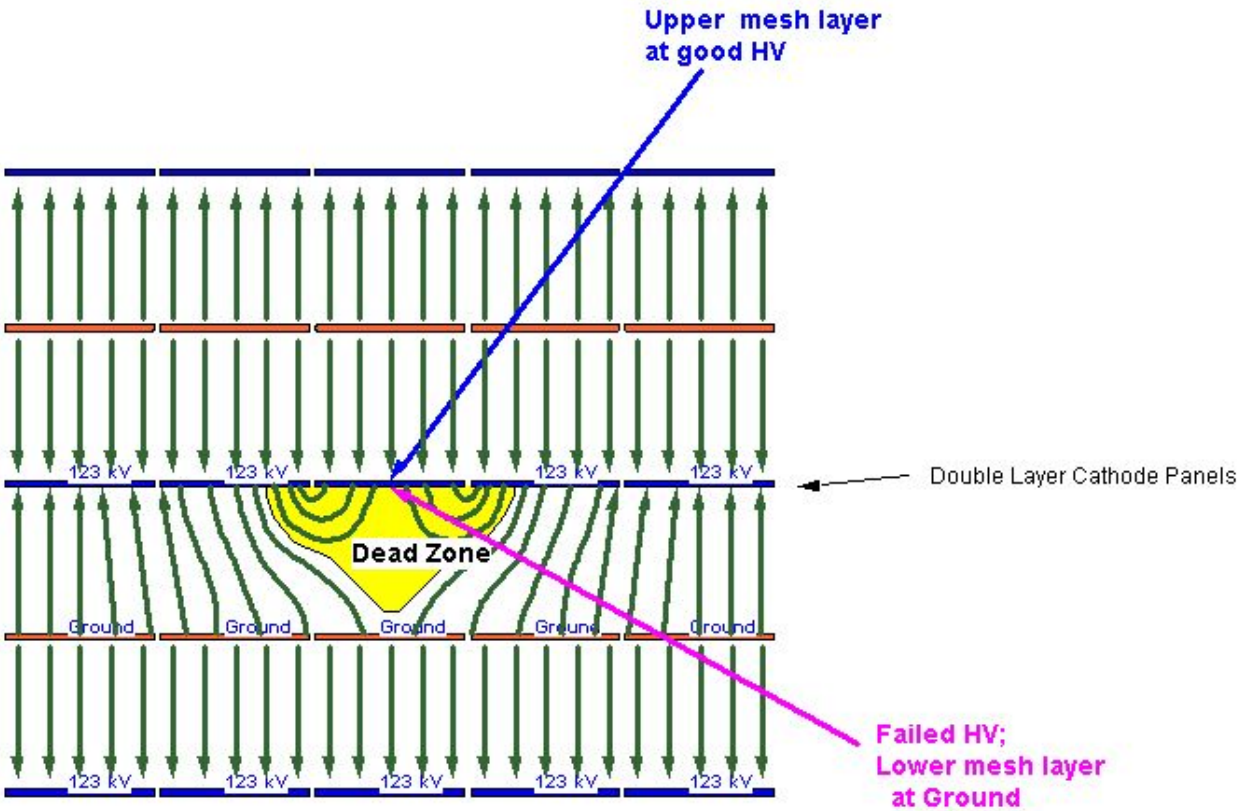
The two SS tubular frames are electrically separate by, but mechanically connected to G10 spacers.

The spacers are 1" thick and subject to an electric field of 50 kV/cm, well below their rated dielectric strength of 200 kV/cm, and also well below the LBNE specification of 100 kV/cm in liquid Argon.

The two faces are biased slightly differently, by about 2 kV, to create an electron drift field between the mesh planes. The field is chosen low (250 V/cm) to provide full transparency to the electrons through the second mesh.

We see that the lost and distorting detector volumes are now only to one face of the cathode plane, a reduction to half the damage:



HV failure with Double Mesh Cathode Panel

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Proposed Architecture

We propose to feed each single faced cathode (vertical) pair, and each face of a double mesh cathode pair via its own separate feed through. This will require 168 HV feed throughs. This is a large number.

Let us look at the cost:

I have made several feed throughs of the Icarus variety. They have tested at 150 kV, but one would like to beef them up to hold 200 kV. The cost , including labor, was around $ 1000.- for the feedthrough itself, not counting the cost of the nozzle. We need to add contingency, but may also realize savings due to scale of production. In addition the internal distribution piping may add another $ 1000.- per lead.

Let us use $ 5,000 per lead to be conservative. The total cost of this highly segmented HV system would be $ 840,000 . This must be compared to the potential benefit.

Summary

We are proposing a highly segmented HV distribution system, with 168 separate feedthroughs and lines. Note that this system can be operated with just a few power supplies, each connected to a group of cathodes in normal operation. The system cost guess is $ 840,000.-

If the cost is deemed too high, there are several intermediate segmentations that can be chosen. One option is to stay with single mesh cathodes. Additional reductions could be realized by connecting pairs of cathode-pairs to each lead, or by even larger groupings.

These decisions can be made fairly late in the project, and the cost can be part of the scope contingency budget.