HVPS, Cable, FT, and Extender and Related R&D

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DUNE HV CDR

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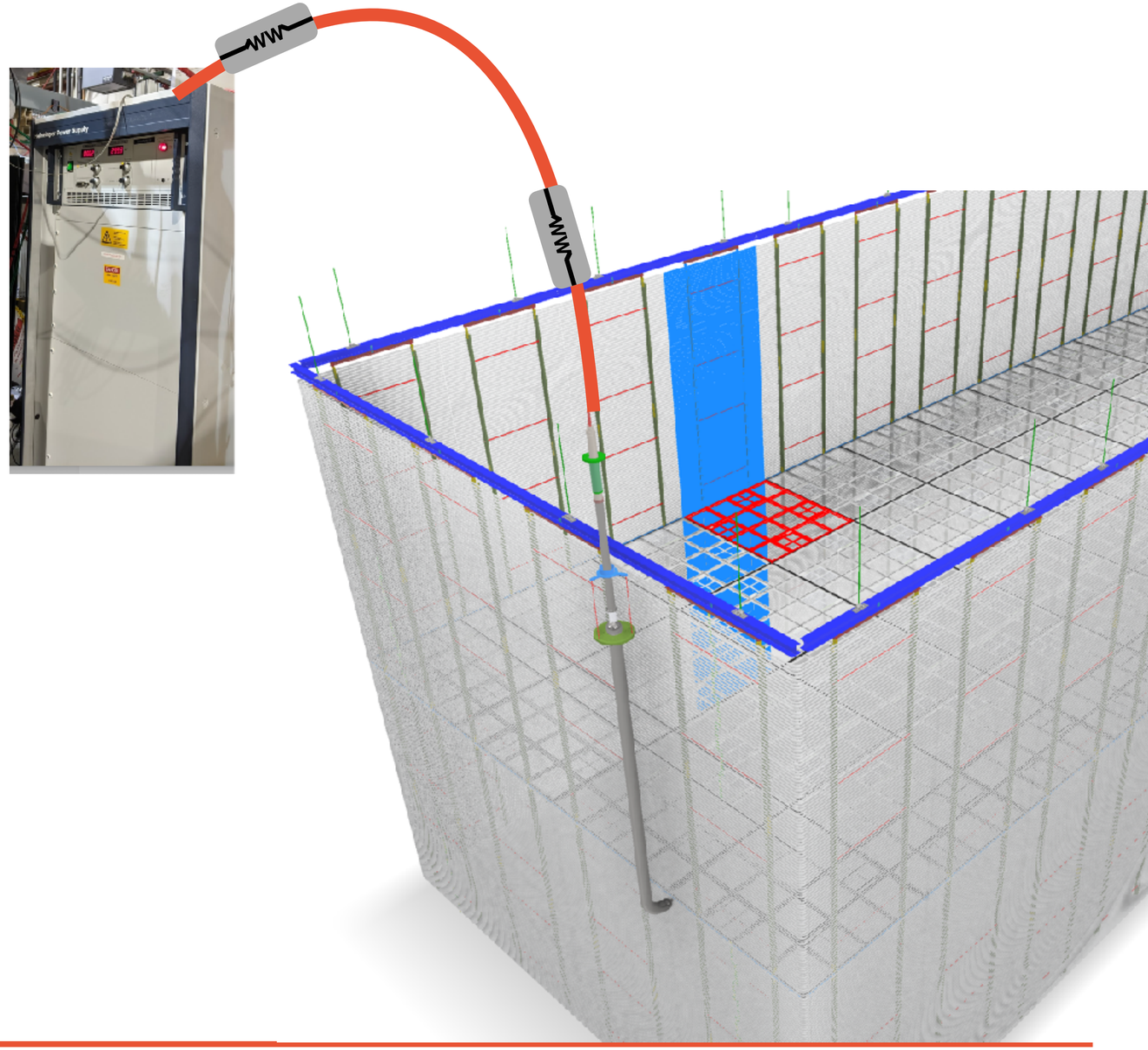
Scope

- Delivery of HV to the cathode:
  - High voltage power supply (HV PS)
  - Cable & ripple filtering
  - HV Feedthrough
  - HV Extender
- Institutions: CERN and FNAL



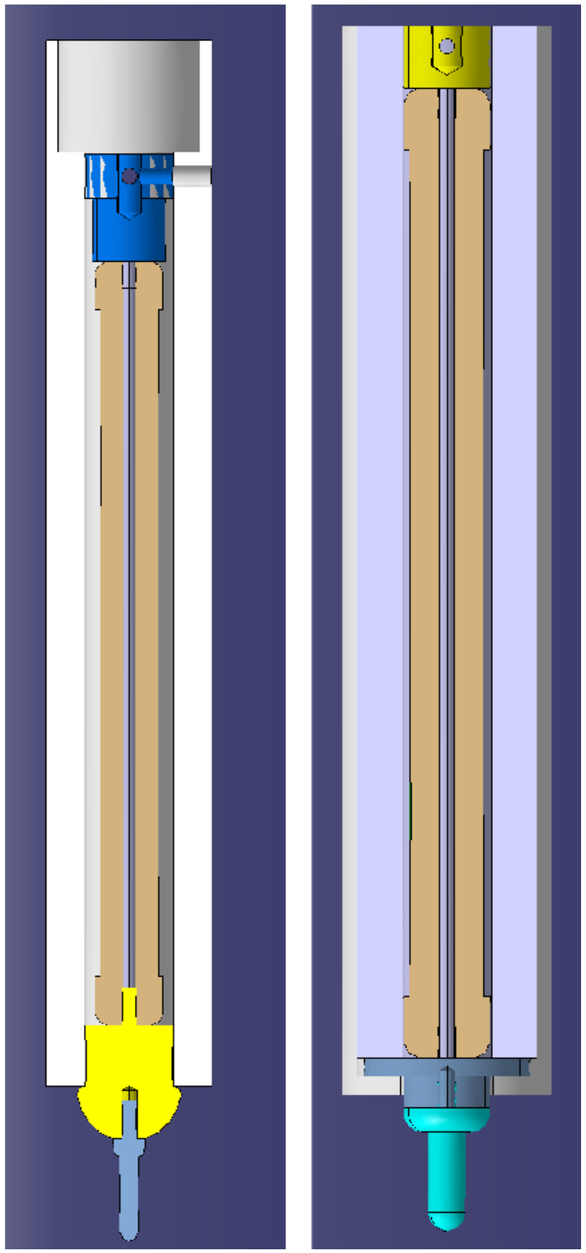
Related Requirements

ID	Subsystem	Name	Values	Comments
1	HVS	Minimum drift field intensity	**>300 V/cm (goal: 500 V/cm)**	The minimum E-field requirement for the vertical drift (VD) is set at 300 V/cm (5.2 ms maximum drift time in VD) based on the experience of the protoDUNE-SP; the goal is set at 500 V/cm as in the horizontal drift (HD) and dual-phase(DP) far detector requirements. This gives a 4.2 ms maximum drift time in the VD. In protoDUNE-SP, a value of 500 V/cm was routinely maintained. In the last days of operation, the E- Field was increased to 650 V/cm and kept stable for several days.
3	HVS	HV Power supply ripple	**better then 10^{-5}**	Same as for HD. The HV ripple requirement on the cathode is dV < 1mV at 10-100 kHz, comparable to that of the HD. This is achieved by appropriate RC filtering along the warm cable from the HV-Power Supply to the HV Feed-through (HVFT) as demonstrated with NP04. For the 2-view configuration, the 1st view strip length is about ¼ of the HD wire length, but there is no shielding from the grid plane wires. A more stringent requirement (by a factor of ~3) is expected for the 3-view configuration compared to the HD due to the wider strip width and longer lengths.

- Drift field: 300 (500) V/cm over a 6.5 m drift implies 195 (325) kV at the cathode
  - 2-300 kV low-noise power supplies are readily available from industry. PSs capable of > 300 kV are more challenging to come by (F. Pietropaolo's talk)
- 10^{-5} peak to peak V_{nom} is the specified voltage ripple of the low-noise units
  - Further filtering down to the sub-millivolt level is accomplished by a low-pass filter between the PS and HV FT
  - Filtering can use similar methods to other installation (synergy with HD)

Ripple Filter

- HV PSs typically have a ripple (~10^{-5} V_{out}) in the ~30 kHz range
  - This is in the range of sensitivity to the anode readout electronics
- A low-pass filter is employed to reduce the ripple
  - It also limits the energy dissipated into the PS or cryostat in the event of a loss of voltage
- A design is being worked on at CERN where the filter resistors are incorporated into the PS and FT connections
  - Removes the need to “break” the cable midway — there would be a continuous cable between the supply and the FT

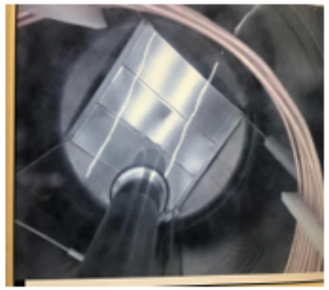


Feedthrough Development

- **NP04/NP02 feedthroughs were demonstrated to work at -300 kV**
  - Ice formation was seen in the cable receptacle that could have led to degradation seen at 234 kV
  - **This feature can be addressed by designing the receptacle to end higher in the warm section.**
- At CERN currently there is a UCLA version of a feedthrough similar in design but ~1 m longer
  - Cable terminates in a warmer section of the FT
  - Interchangeable with the NP04/NP02 FTs
  - Earlier tested to -200 kV (limit of available UCLA supply), and planned to be tested to 300 kV at CERN (next slide
  - Quote available to build an additional FT if the test is successful

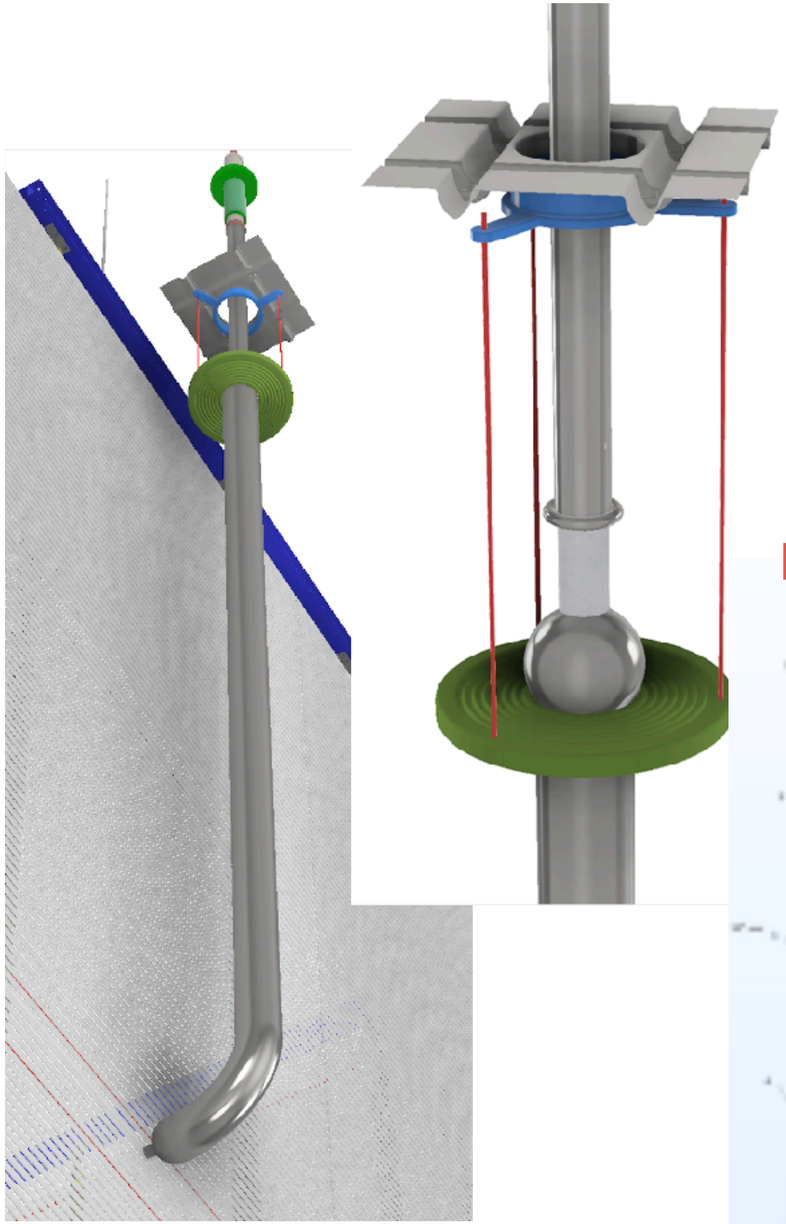
Prototyping and R&D: External Chain to FT

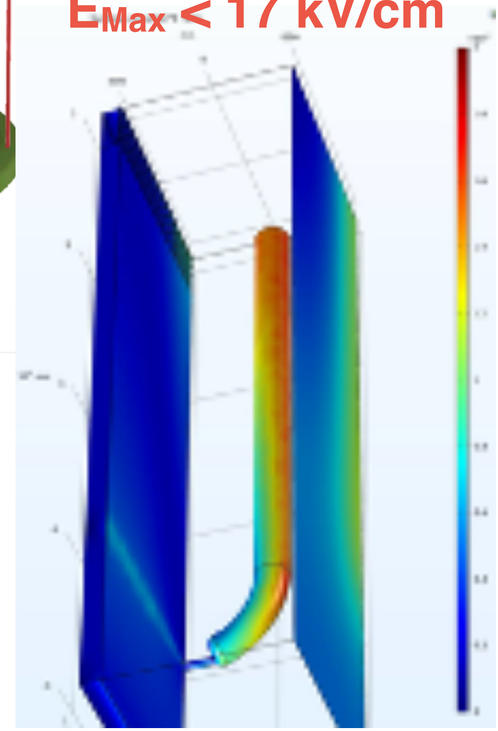
- The HV chain including the 300 kV PS, cables & filter, and HV feedthrough are planned to be tested using a 2 ton cryostat at CERN (bldg 182) with access to pure argon (ms-type lifetime)
  - FT is UCLA feedthrough previously tested to 200 kV
- Current monitoring, cryogenic cameras, and temperature probes will monitor the performance and behavior of the components for a month



HV Extender

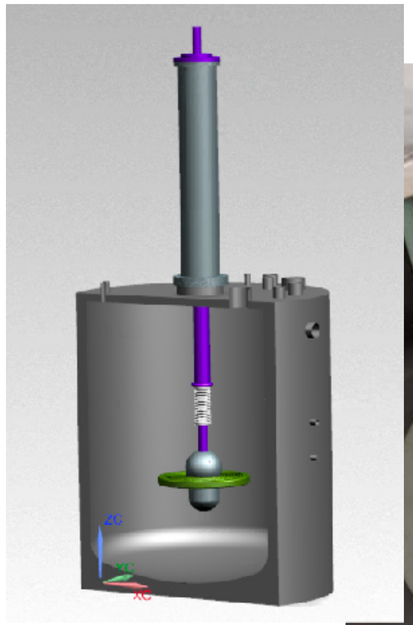
- The HV extender is a new design
  - Original extender used a graded field design: rings separated separated by g10 insulator defined the field along the length of the extender
    - Issue was related to a manufacturing defect
    - The complexity of extender design introduced more uncertainty on the HV performance/stability than the expected advantages on the E-field uniformity.
  - The new design is a long stainless steel piece delivering the voltage from the feedthrough to the cathode.
    - It is planned to be supported by a G10 disk suspended by G10 rods
    - In this design, the surrounding liquid argon provides the electrical insulation (which is also the case for the field cage)

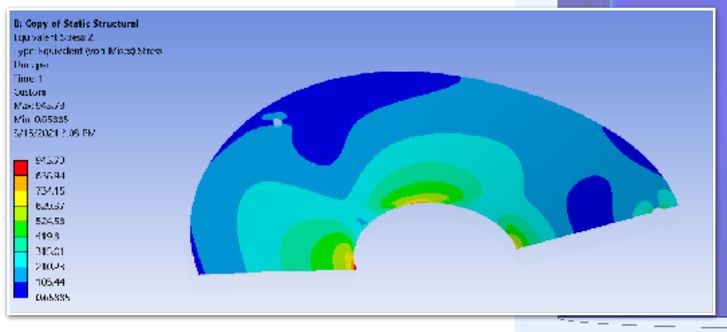


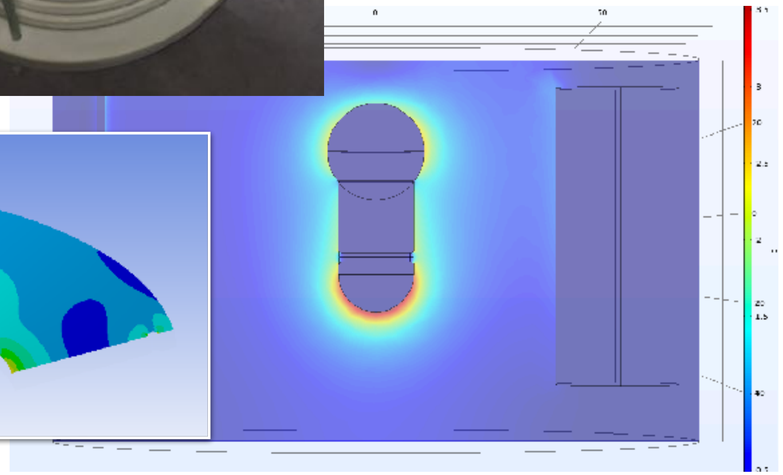


Prototyping and R&D: HV Extender

- A first test of the HV extender is taking place in the Iceberg cryostat at Fermilab
  - E-Field analysis — showed filter & level probe are safe
  - Mechanical stress analysis done — within many safety factors
- Testing “critical” features of the extender design: Sphere & G10 interface
  - These are identical the the pieces to be used in the NP02 test
  - Lower welds of test piece are similar to the welds on the NP02 lower extender
- Pieces for NP02 are planned to be sent to CERN this month.

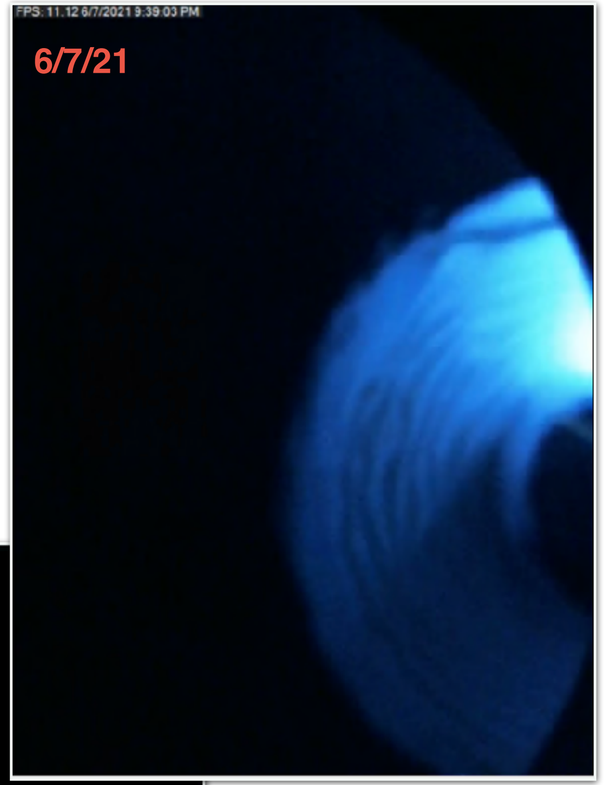


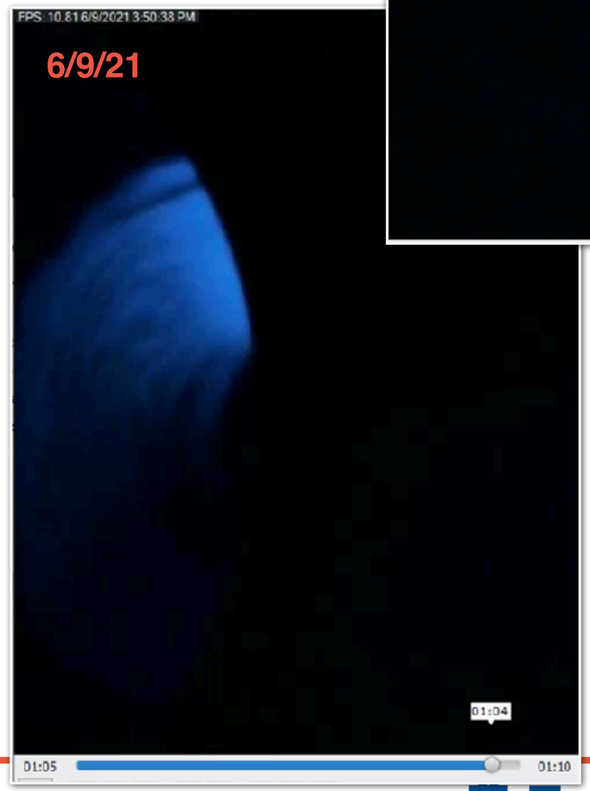




Current Extender Testing Status

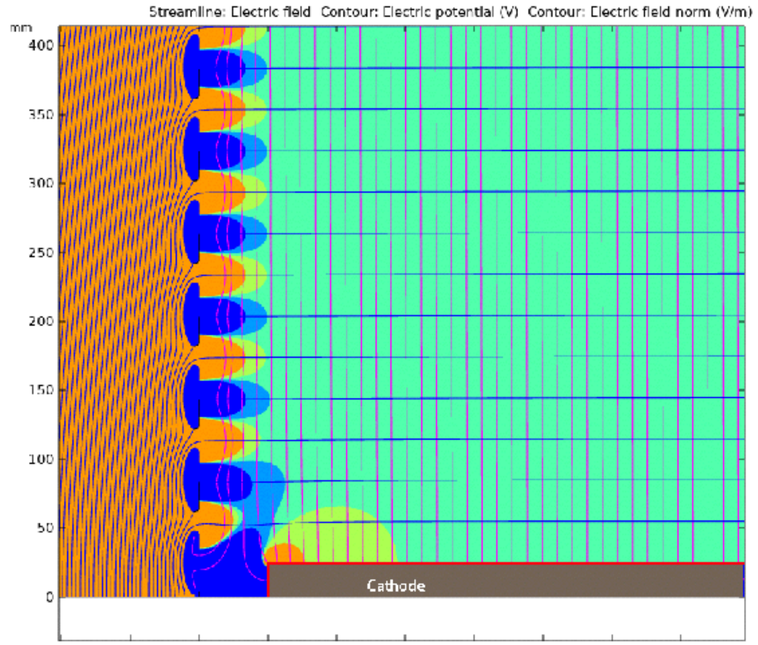
- Just after filling, achieved 300 kV in ~250 us argon
- After purification to 3-400 us argon, held 300 kV for ~10 hours then tripped.
- Cable attachment investigated (purge added) and a camera was added to the view port. Tripped again.
  - Some coincidence with pressure changes due to the internal filter. “Some” because 300 kV is not currently held with the filter off
  - Question on if it was the FT — increased the liquid level and saw no effect
    - Feedthrough at CERN has vent holes to inhibit bubble formation at the base of the ground tube (where the highest field in the system is)
  - Issue may be in the same place (and unfortunately just outside of the view of the viewport)
  - Will look for “scarring” when opened
- Holding -250 kV since Thursday evening. (Have only tried 300 kV and 250 kV).
- Purity never got above 3-400 us. Operating theory is an issue with a seal on the internal filter degrading and an impurity source unrelated to the test.

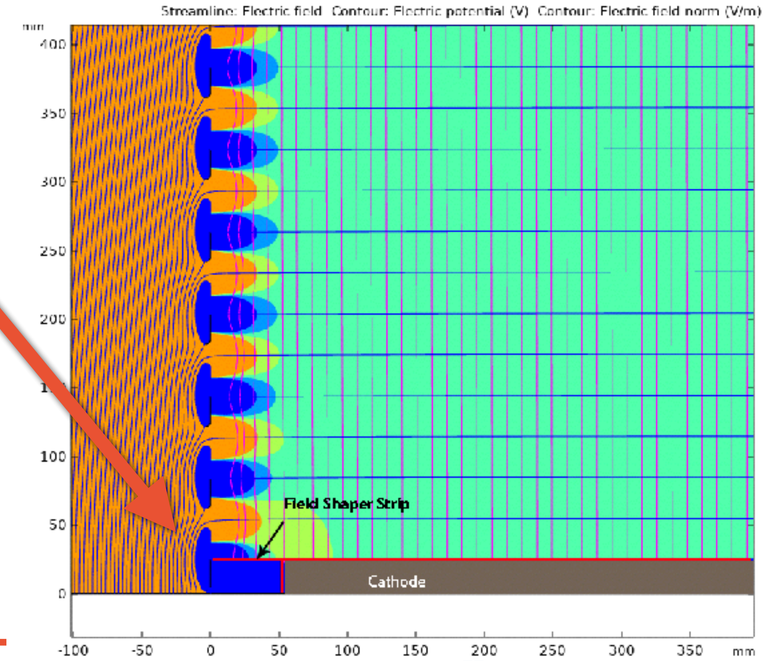




HV Bus

- Delivering the voltage to all vertical segments of the field cage is accomplished via an HV bus
  - Similar to the (successful!) HD design, the design uses segments of HV cable
  - The HV bus will be placed in a cavity behind the aluminum sheet at the edge of cathode that serves to help define the corner drift field





Near-Term Plans

- Parts for extender are finishing now (today?), and will be polished and shipped out as fast a possible.
- CERN is preparing to test the warmer-cable FT to 300 kV (within the next few weeks)
  - Test will use the full chain (PS, cable, filtering)
- The upcoming HV demonstration run in the NP02 cryostat will evaluate the full chain including the extender (& interface to field cage).