Design Concepts of a More Transparent Field Cage

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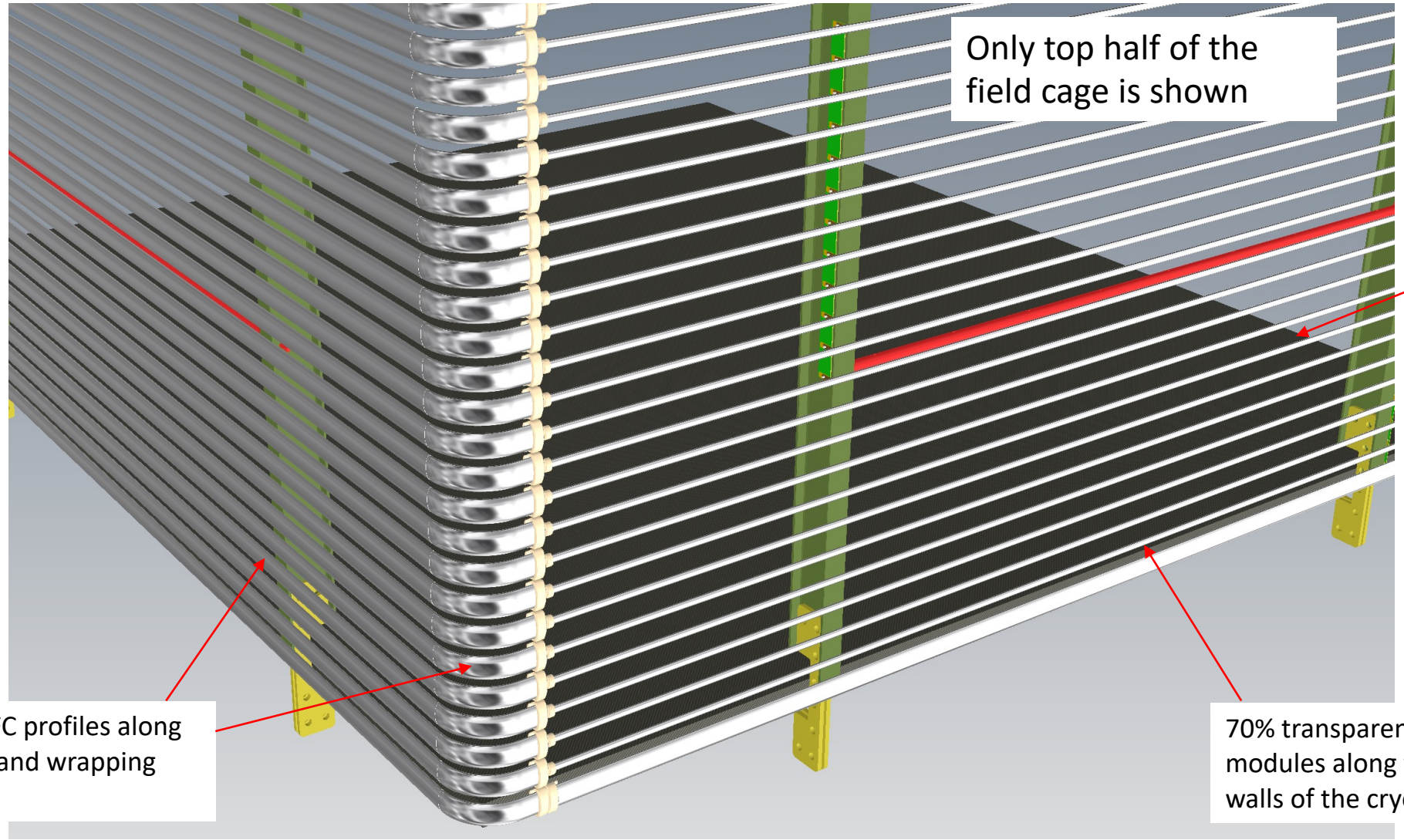
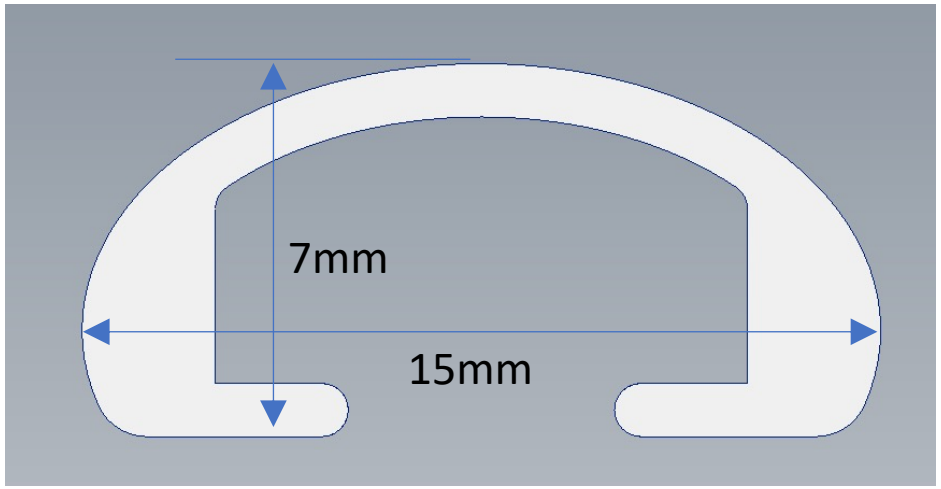
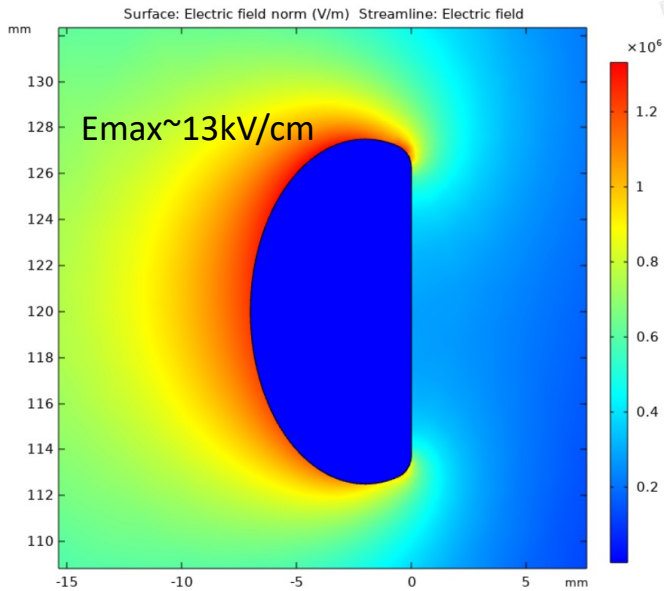
Conceptual Design of a 70% Transparent Field Cage



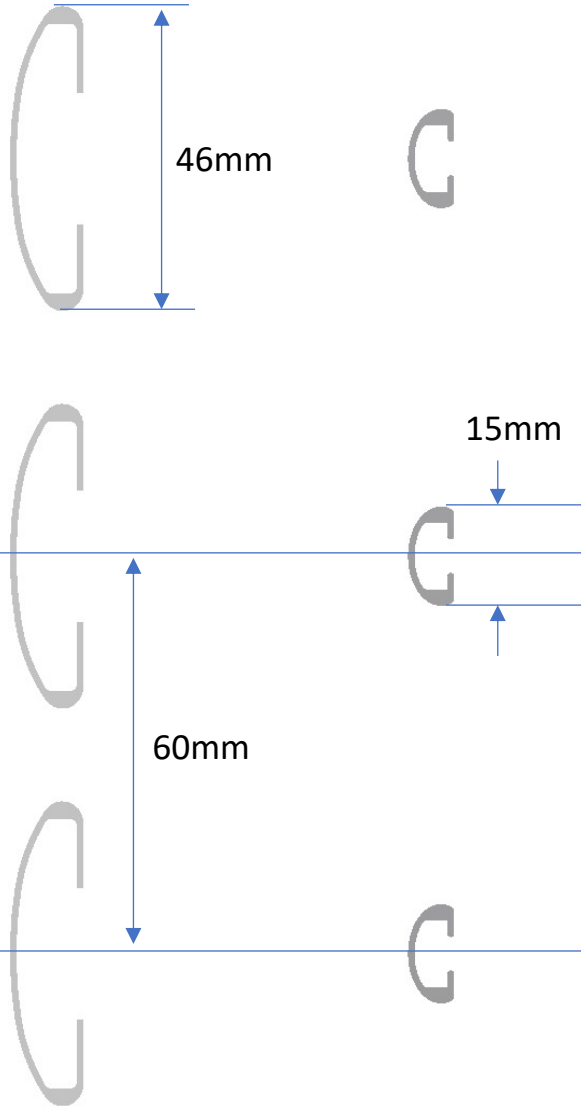
A Narrower Elliptical FC profile

- An ellipse with 3:2 aspect ratio gives a lower surface E field compared to circle of the same diameter, and also has a better transparency at larger incident angles.
- This ellipse is flattened on the side facing the active volume as a potential design of extruded aluminum profiles.
- The profiles are mounted on the FC modules with the 60mm pitch used in the ProtoDUNE TPCs, providing a 75% maximum transparency at normal incident angle.





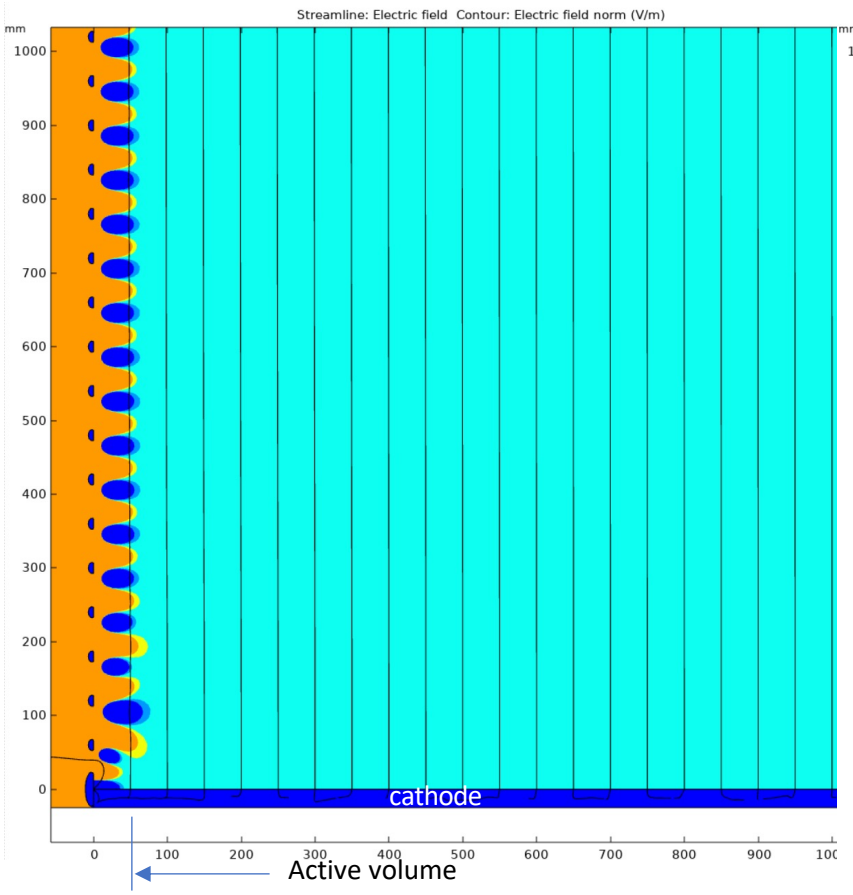
FD1 profile narrow profile



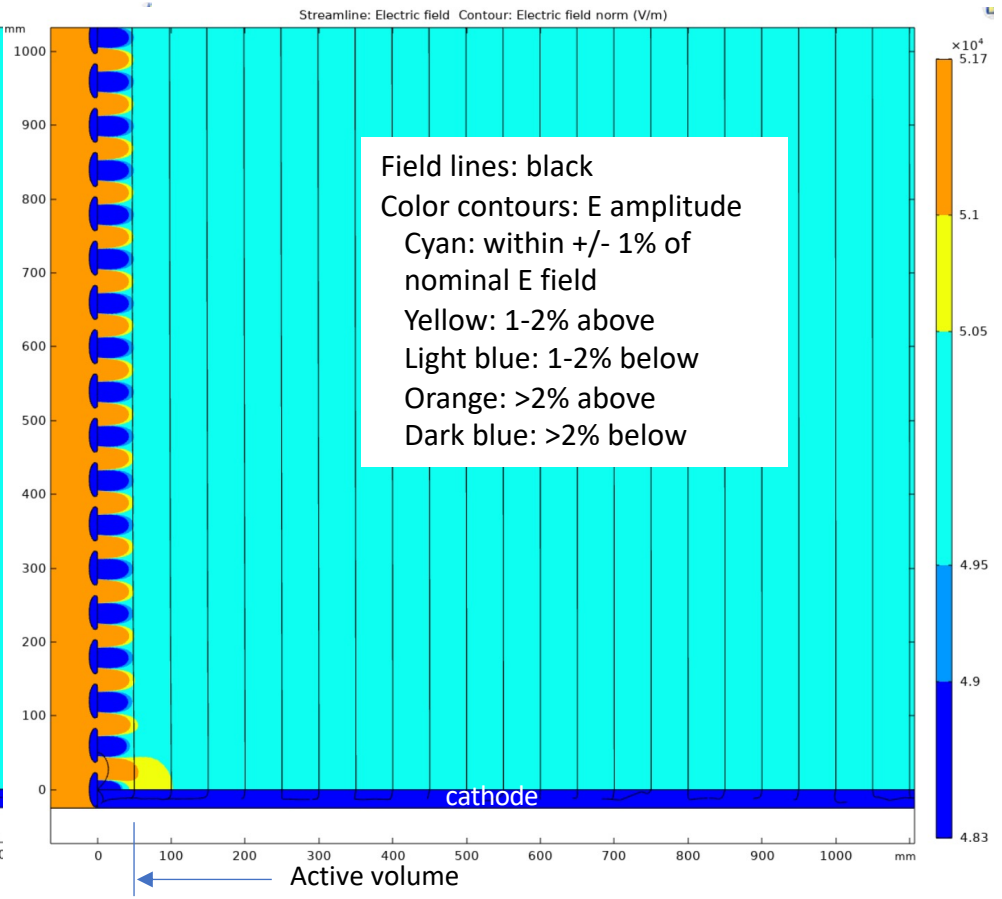
Simple and Effective Correction to the Drift Field Distortion

- If the thinner FC profiles are biased with a constant voltage drop between profiles and on a constant pitch, a significant fraction of the active volume has drift field deviating from the nominal value by more than 1%, and the field lines diverge as electrons leaving the cathode.
- A simple and effective correction to the non-uniformity can be achieved by adjusting the bias voltages on the first 3 FC profiles near the cathode surface while maintaining a constant voltage drop on the rest of the profiles.
- This correction requires a set of resistive divider boards with non-standard values at the 3 gaps.

70% transparent field cage



Standard (HD) field cage



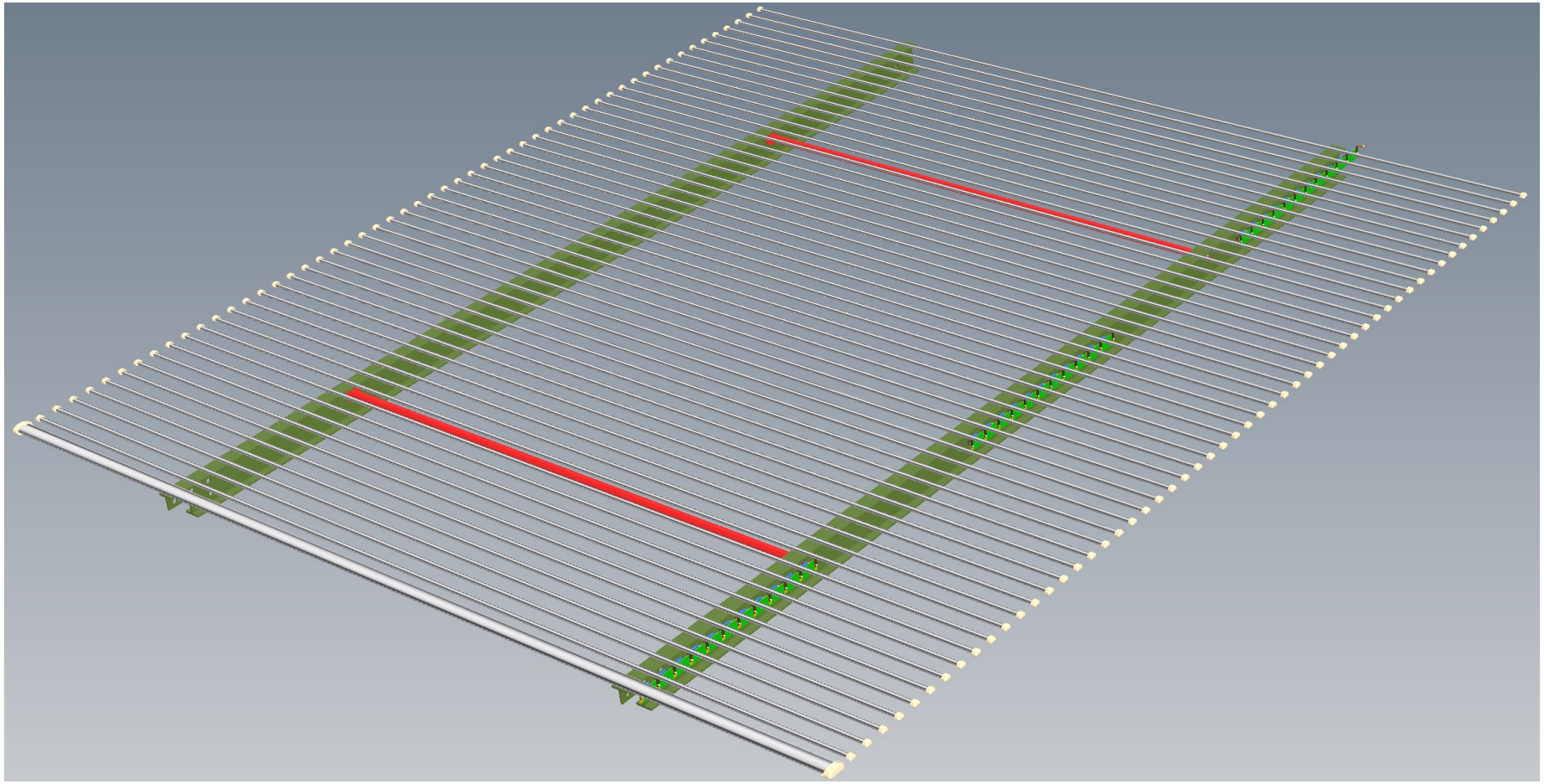
Field lines: black
Color contours: E amplitude
Cyan: within +/- 1% of nominal E field
Yellow: 1-2% above
Light blue: 1-2% below
Orange: >2% above
Dark blue: >2% below

The voltage drop across the first gap (cathode to FC #1) is 900V
The voltage drop across the 2nd gap is 1650V
The voltage drop across the 3rd gap is 3520V
The voltage drops between profiles from #3 and up is 3023V.

The standard field cage design uses the wider aluminum profiles designed for FD1. The profiles have a constant voltage drop of 3000V.

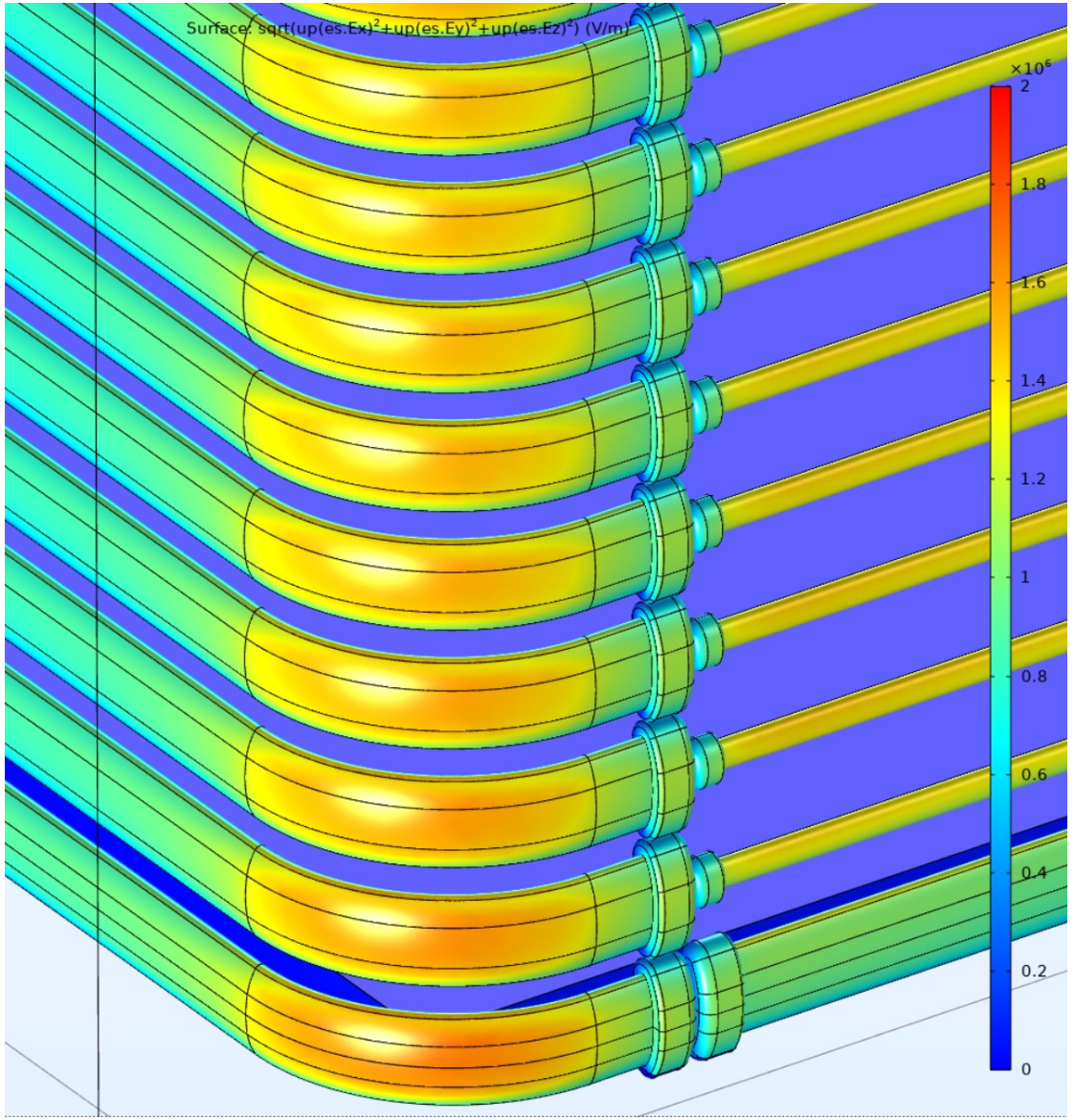
FC module construction (3m x 3.3m nominal size)

- The estimated weight of a typical FC module with the 70% transparency is about 35kg, while a standard FC module of the same size weighs about 70kg.



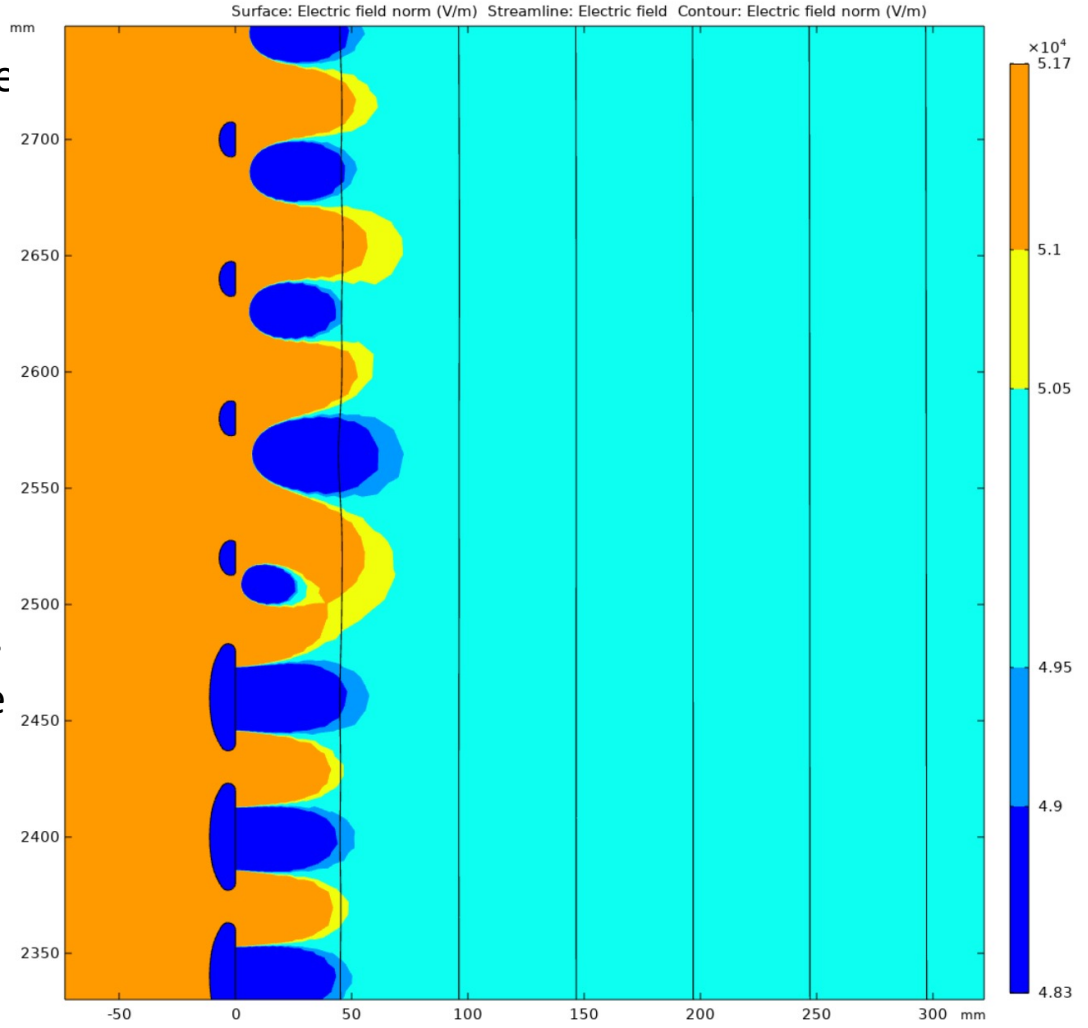
Avoid high E field at corners

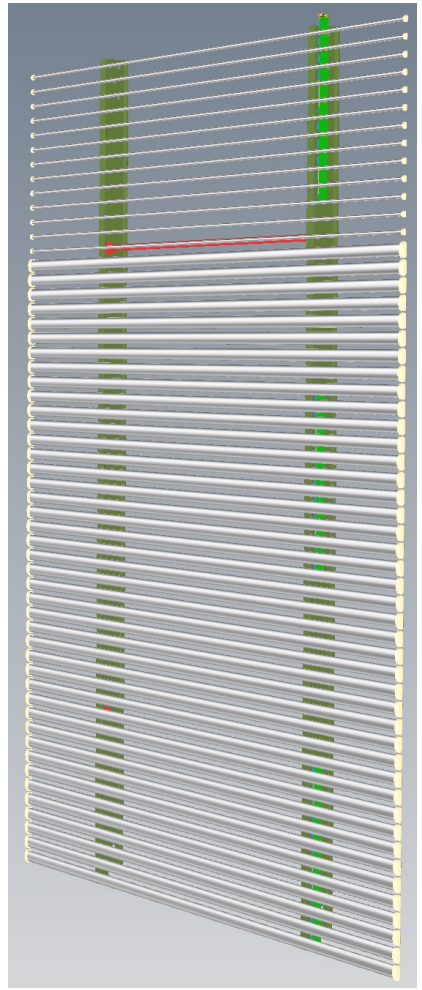
- Since PDS only plan to install PDs on the long walls of the cryostat, the FC modules along the short walls can remain the same construction as the reference design using the wider profiles.
- The 90° bent profiles at the corners of the FC have a lower E field (17kV/cm) than narrow profiles would have (29kV/cm).



To Further Reduce the Higher E Field on the Thin Profiles

- If we want to reduce the higher E field on the thin profiles to the level comparable to that of the standard profiles, we can use the wider profiles up to ~ 2.5m away from the cathode, and leave the rest of the profiles to the anode planes with the thin profiles.
- To maintain good E field uniformity, some adjustment on the voltage distribution among the profiles are needed:
  - The voltage drop between the wide profiles is 3000V.
  - The voltage drops at gaps 42,43,44 are set to 2000V, 1900V, 3400V respectively.
  - The voltage drop between the rest of the thin profiles is 3023V.
- The 7.7% change in the divider resistance may be difficult to implement for a large quantity of divider boards. We might have to look into changing profile pitch instead.





Summary

- A conceptual design of a field cage with ~70% transparency is being developed.
- Compared to the baseline field cage design, the FC with narrower profiles will have ~50% higher surface E field. To avoid the high surface field at the corners of the field cage, the standard wider FC profiles are used at the corners. The highest E field on the field cage is determined by the wide profiles at the FC corners, which would have been the same for the standard field cage design.
- To further reduce the E field on the thin profiles to the values comparable to that of the the wider profiles, we can replace all of the thin profiles with E field higher than that of the wide profiles within ~ 2.5m of the cathode. To maintain uniform drift field inside the field cage, additional tuning of voltage distribution must be made.
- A special voltage distribution arrangement on the field cage profiles appears to be very effective in compensate for the drift field distortion introduced by the much open field cage electrodes. Simulations show the drift field uniformity is nearly identical to that of a standard HD style FC.
- Because of the thinner profiles, the weight of the more open field cage module is about half of that of the standard FC module
- We have the options of building a 70% transparent field cage along the entire long walls of the TPC, with slightly increases the risk of HV instability due to the higher surface E field, or restrict the 70% openness to the outer 62% of the long walls with no elevated HV risk.