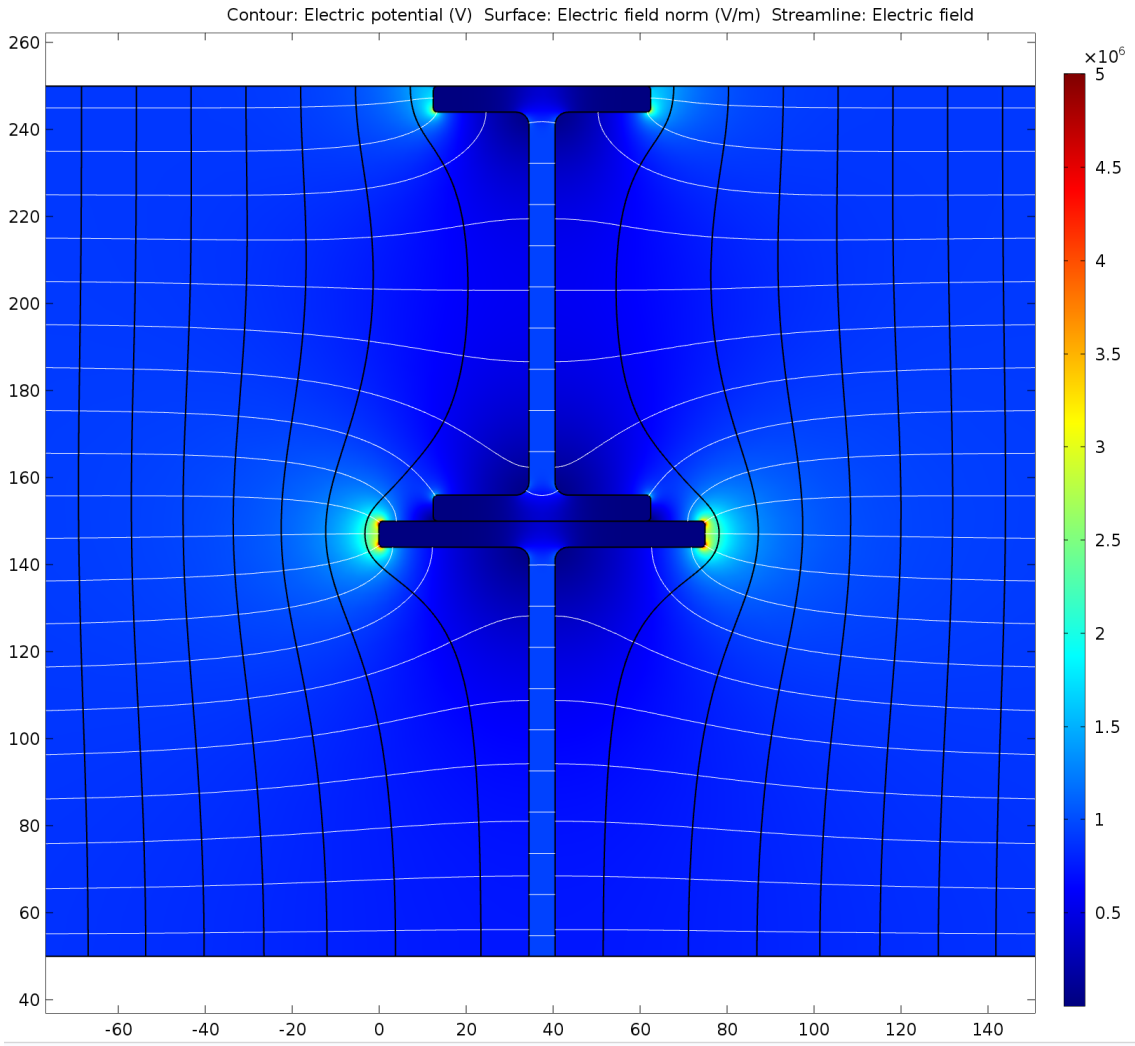
Answers to Reviewer Questions

- The committee has pointed out several times the concern of unknown field in regions where insulators such as G10/FR4/FRP, that can charge up, are used in the vicinity of high field regions. Can you review and tell us the current knowledge and positive experiences from other experiments, detectors, lab tests? Will this issue be still tested in the 35ton test?
  - Answered

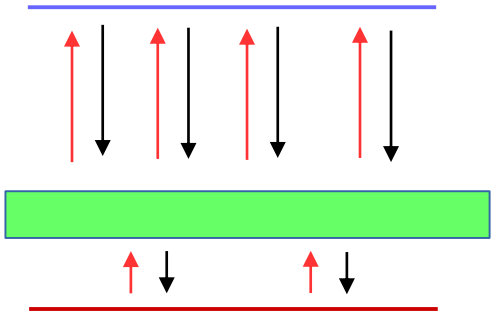
Charge build up

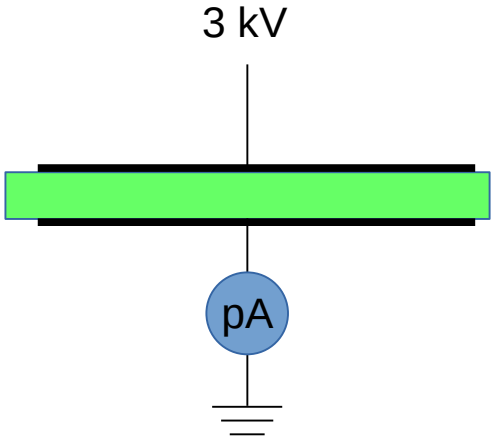
- FEA with “zero perpendicular field” boundary condition on all surfaces of the I-beams except at top and bottom.
- This is the condition when surfaces have charged just enough to repel any further incoming charge.
- White contour lines: V
- Black contour lines: E
- High fields at corners.
- Charge-up rate depends on volume adjacent to surface.



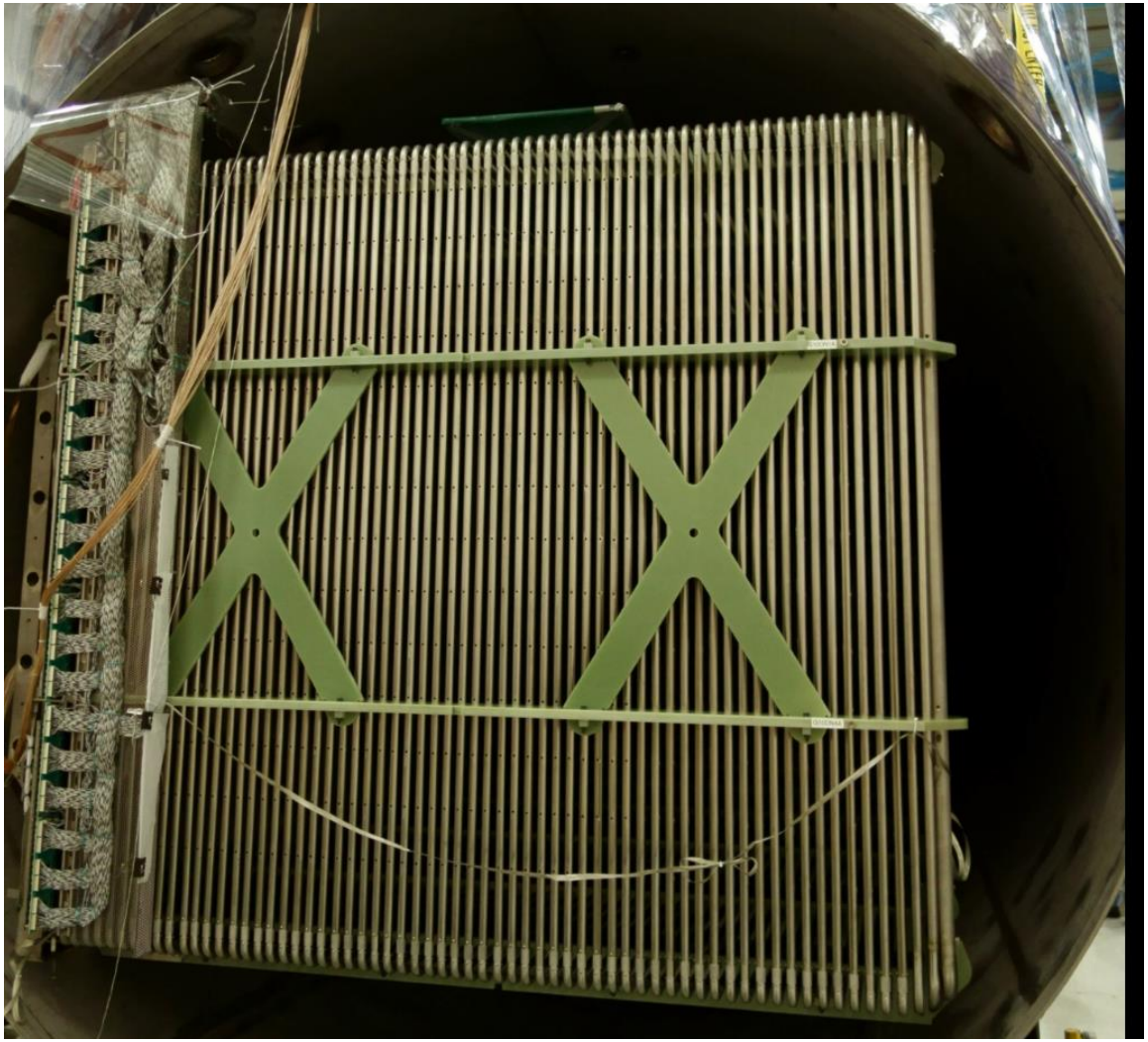
Currents, time constants, and effect of bulk resistance

- Charging of two sides can be asymmetric if volume on one side is different from the other.
- E.g., for box beams holding field cages, roughly 20 pA/m^2 on one side, 30 pA/m^2 on the other.
- Approximate analytic calculation gives **~2 day** time constant to charge one side only if no current on other side, **~2 wks** for both sides to charge, for 1/4" thick material.
- **A non-infinite bulk resistance would mitigate charging**: internal E = J ρ.
- E.g., if ρ = 10^{18} ohm-cm, then
- E < (30 pA/m^2) (10^{16} ohm-m) = 3000 V/cm.
- Attempted to measure resistivity of 12" x 12" x 1/4" FRP plates at K-State at E = 4.7 kV/cm. Saw long, increasing time constants of hours then days, slow "self-recharge" after applied voltage zeroed or reversed. Done in air at room temp.
- **Need test at full HV and E scale, in LAr.**





Similar wide insulating structure in MicroBooNE



- Present plans for the 35ton test. The committee would like to understand if the foreseen tests and setup can reply on time to the open issues and risks that have been identified in the presentations and discussions.
  - Answered by QA/QC talk

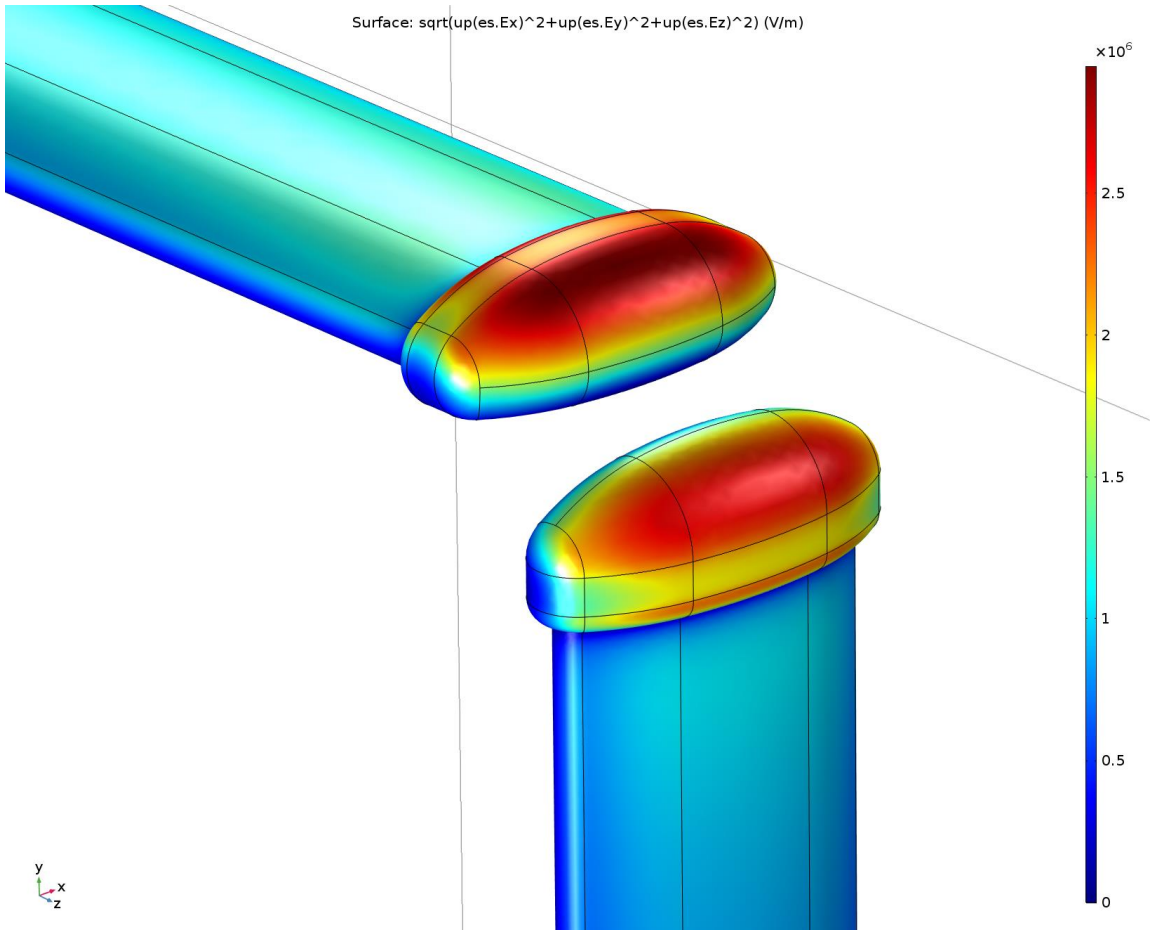
- Could you make a short summary of the test results of the effect of discharges in the resistive kapton laminated panels? What current do you expect in each plane?
  - Answered by QA/QC talk

- Have the project discussed alternative designs to the profile caps of the FC Al profiles? The committee believes these parts may pose a significant risk if they degrade.

- UHMW PE is the material used in nearly all cryogenic HV feedthroughs.
- The caps are expected to shrink ~2% in LAr. This is accounted for in the opening of the caps. No significant stress is expected from the attachment of the caps to the profiles
- The caps are locked onto the profiles with two nylon rivets. The locking of the cap is tested in LN2 with ~ 14kg of pulling force (force gauge limit)
- Since the small higher field test was successful, we are fairly confident that we have a viable solution and have not discussed alternatives.
  - But, other interesting configurations are available

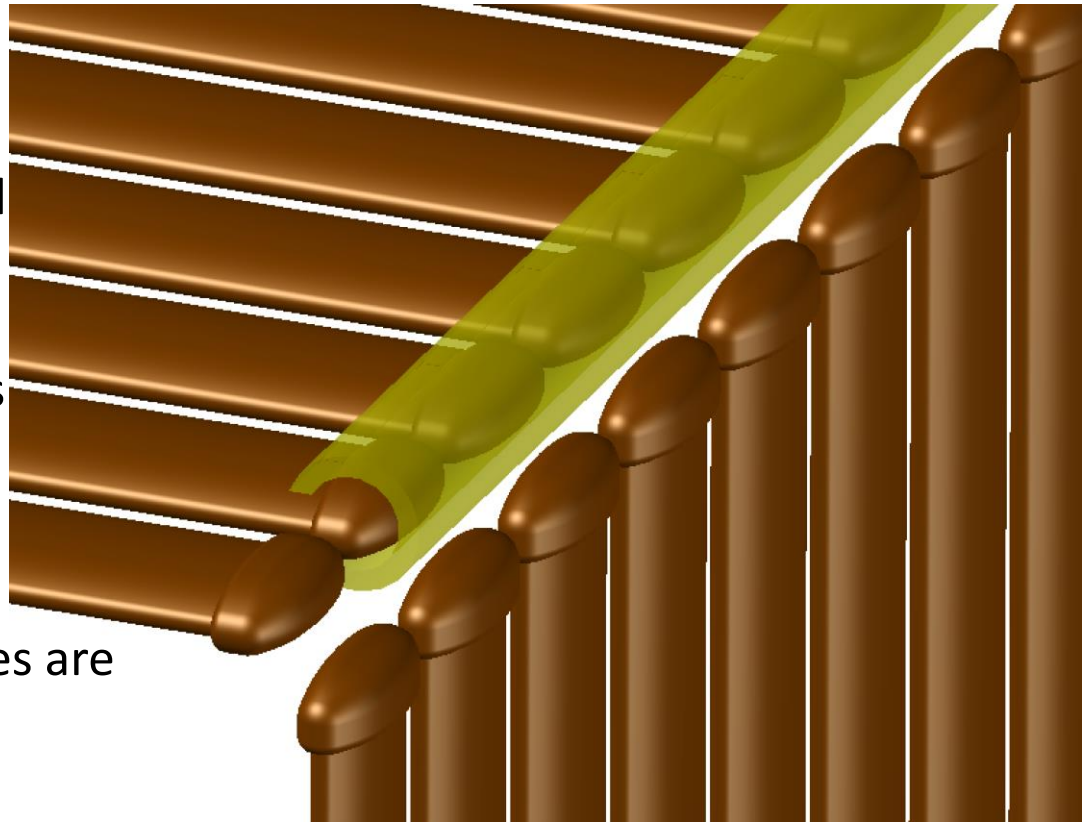
Conductive Caps on the Profiles

- Caps (plugs) are 3mm thicker than the profiles.
- Max E: 29.5kV/cm
- CNC or casted metal plug screwed into the profile ends

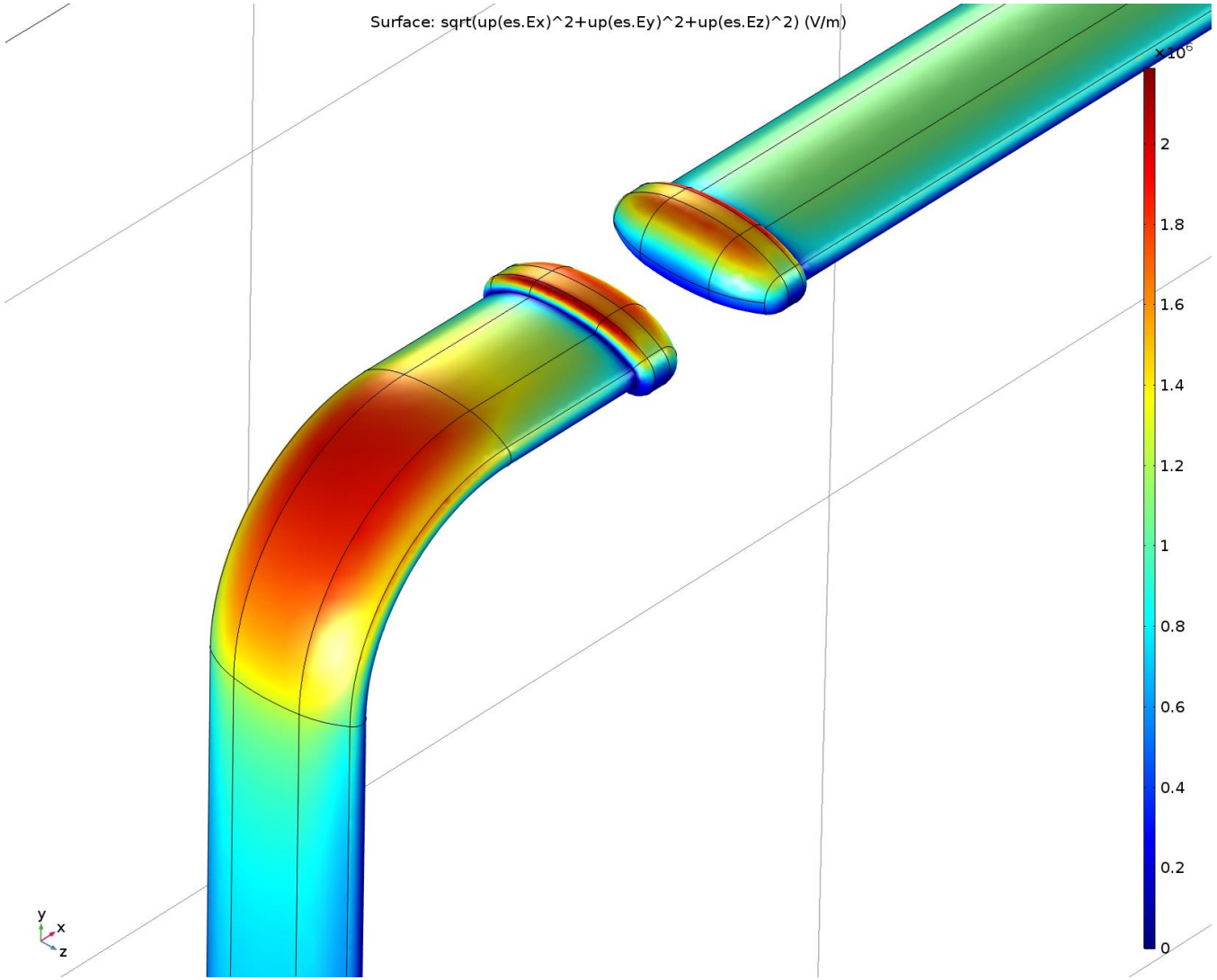


Conductive Caps with PE Edge

- The exposed caps/plugs would allow direct arching across the caps to adjacent FC modules in a discharge.
- To achieve HV isolation, we can encase the caps in a polyethylene tube (with one side slotted). This tube should be locked on the CPA side, and allow shrink on the APA side.
- The tube length does not need to exceed 2m.
- With this scheme, the metal electrodes is safe during normal operation without the PE tube. The tube helps to maintain HV isolation.
- If the tube is damaged, only this gap can arc through, while the rest of the modules are still protected.

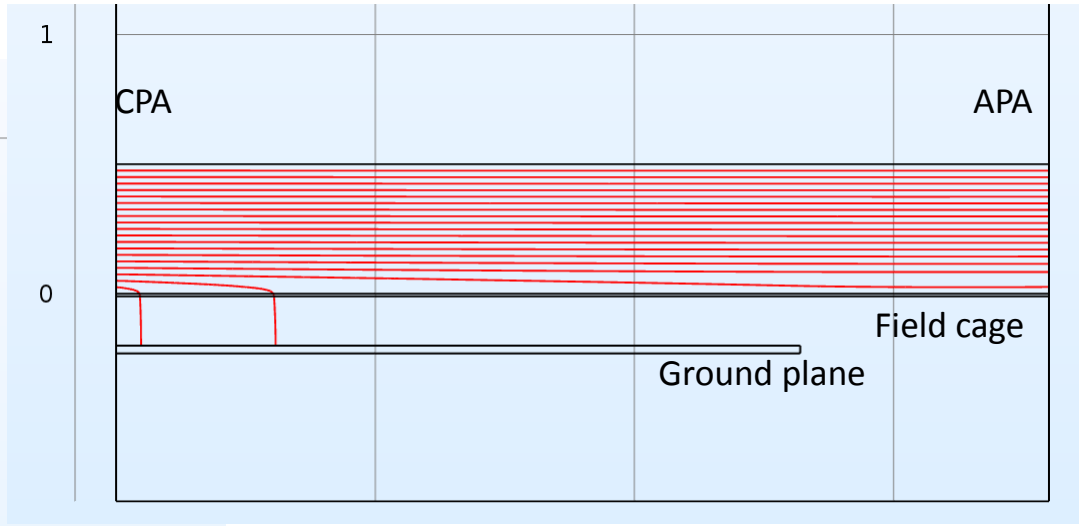


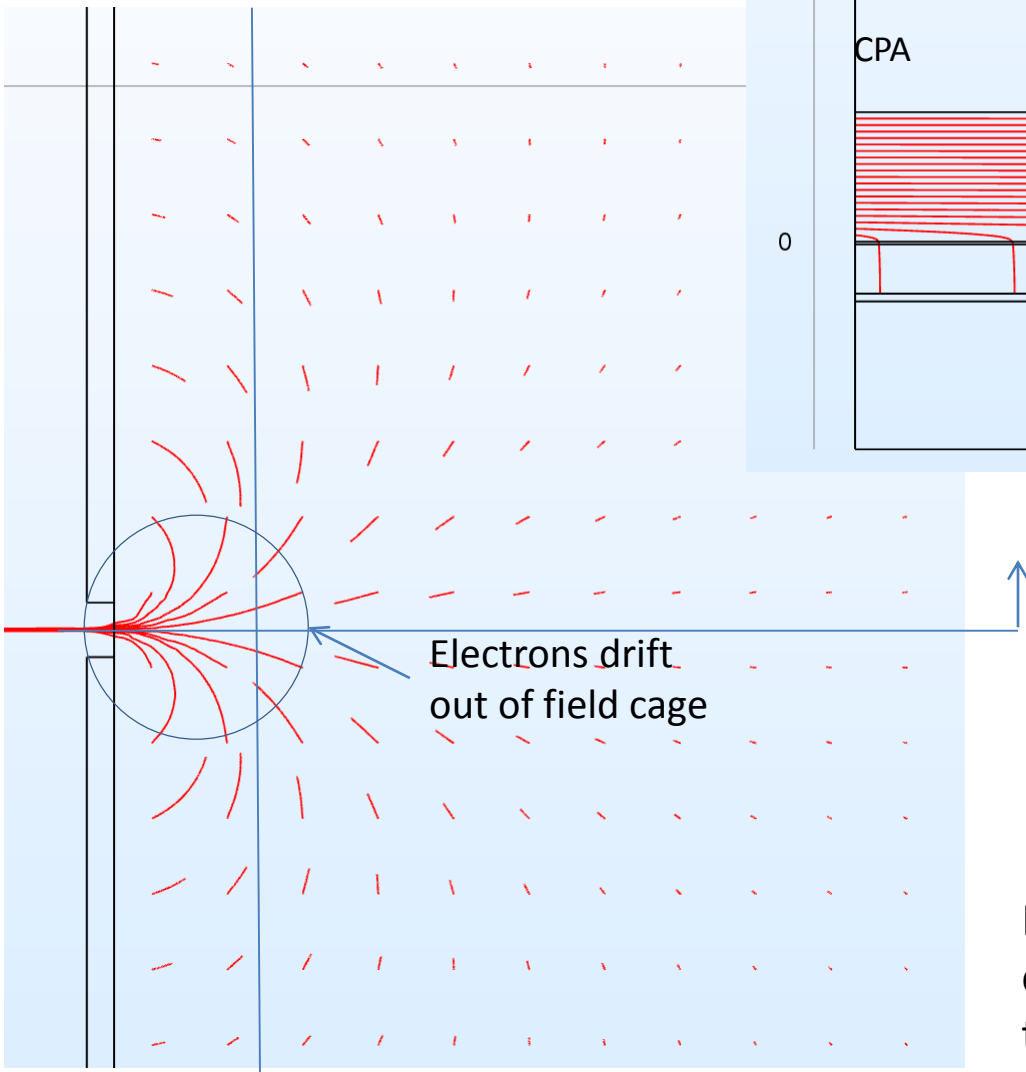
End wall to top/bottom arrangement



- The mechanical properties of the proposed FC Aluminum profiles are well defined. Can you show the mechanical requirements (alignment, planarity, etc) when they are together in assembled panels, and when adjacent panels are joined together? Is there a value of how possible deformations after assembly will affect the electric field?

2cm Gap between Modules

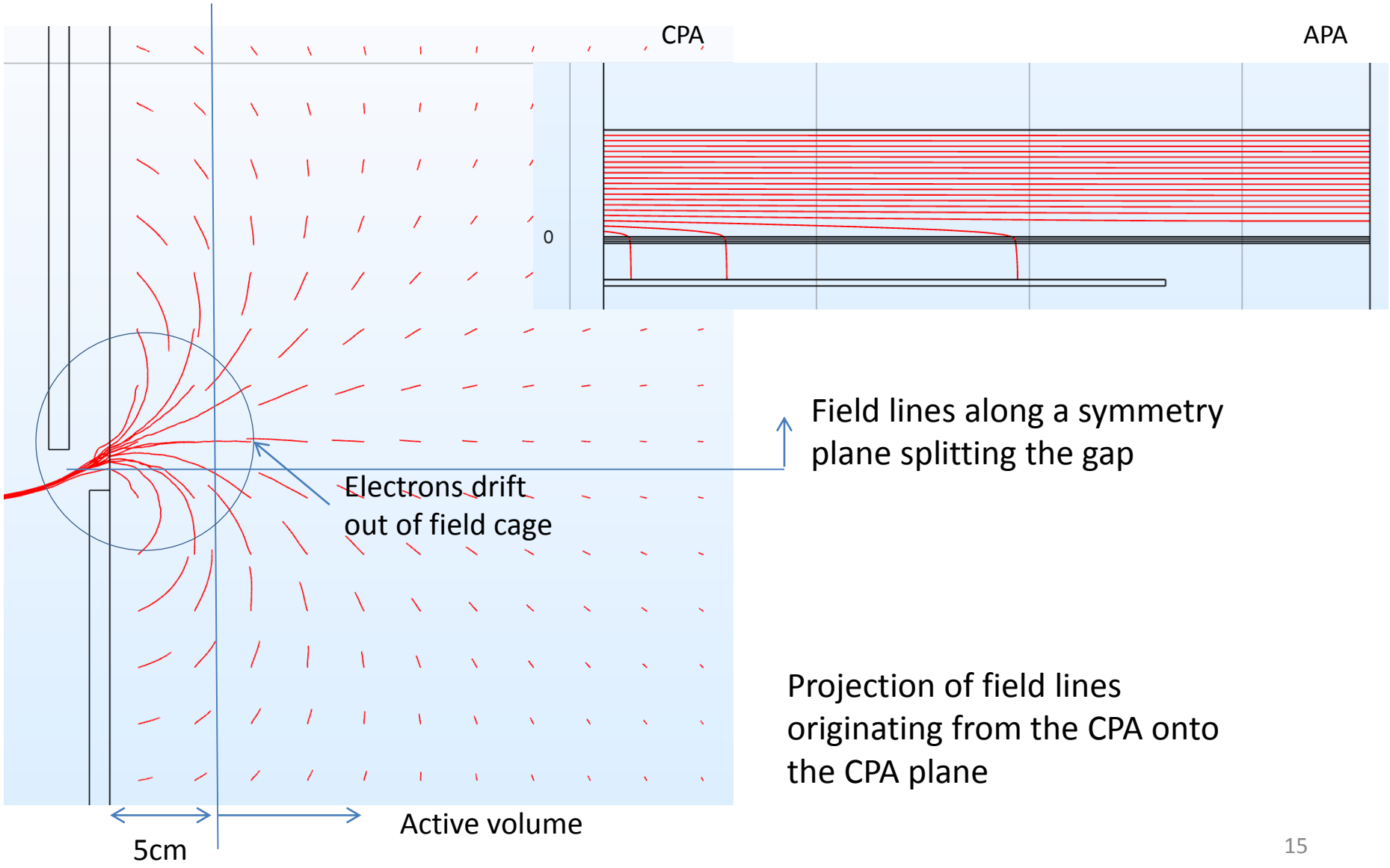




Field lines along a symmetry plane splitting the gap

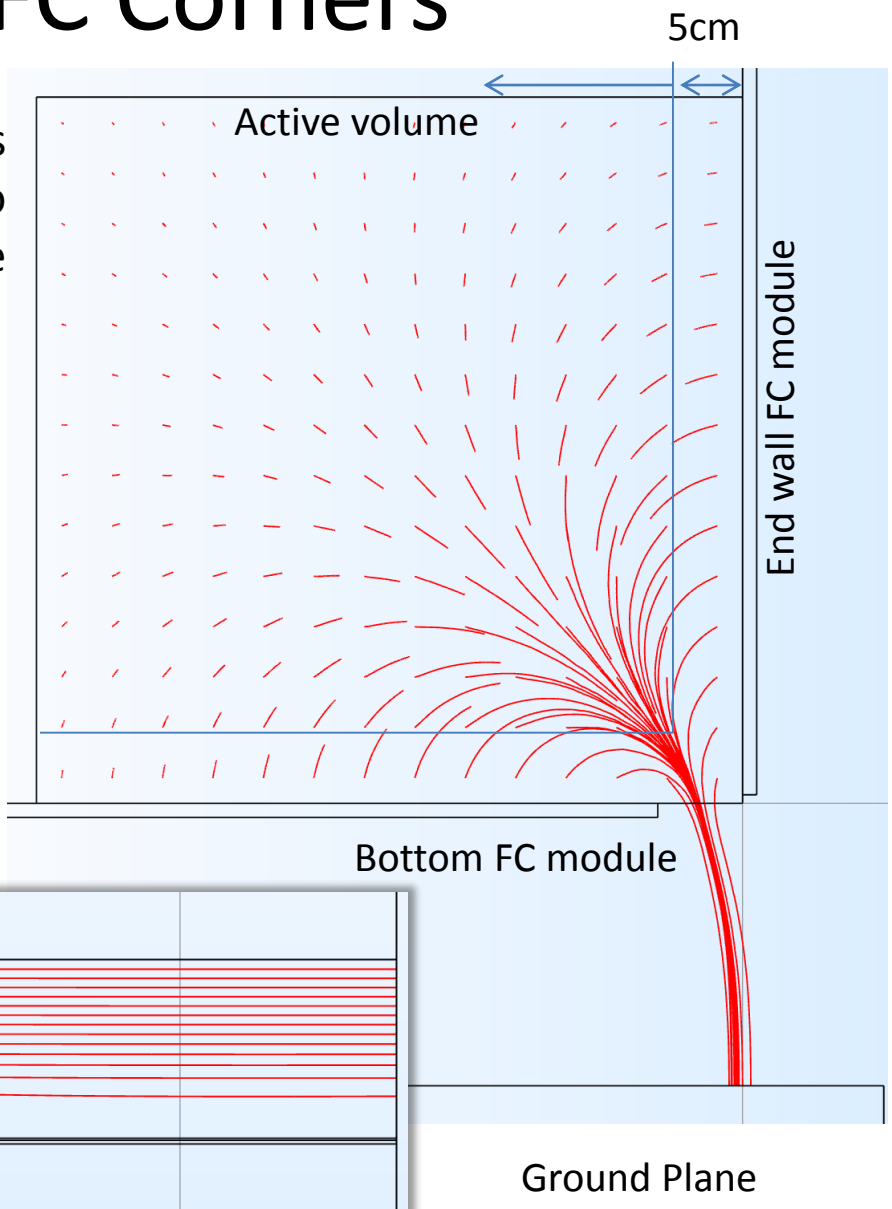
Projection of field lines originating from the CPA onto the CPA plane

2cm gap + 2cm offset

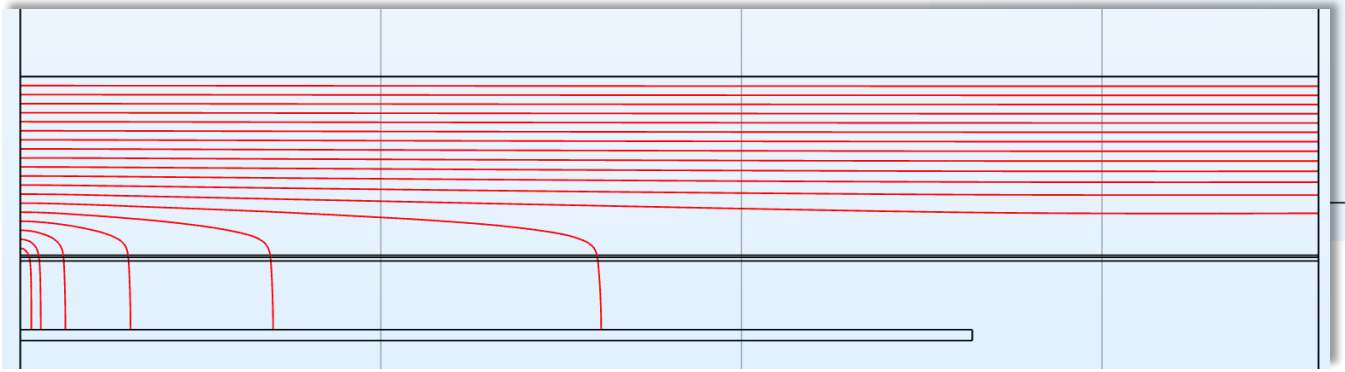


6cm Gap at FC Corners

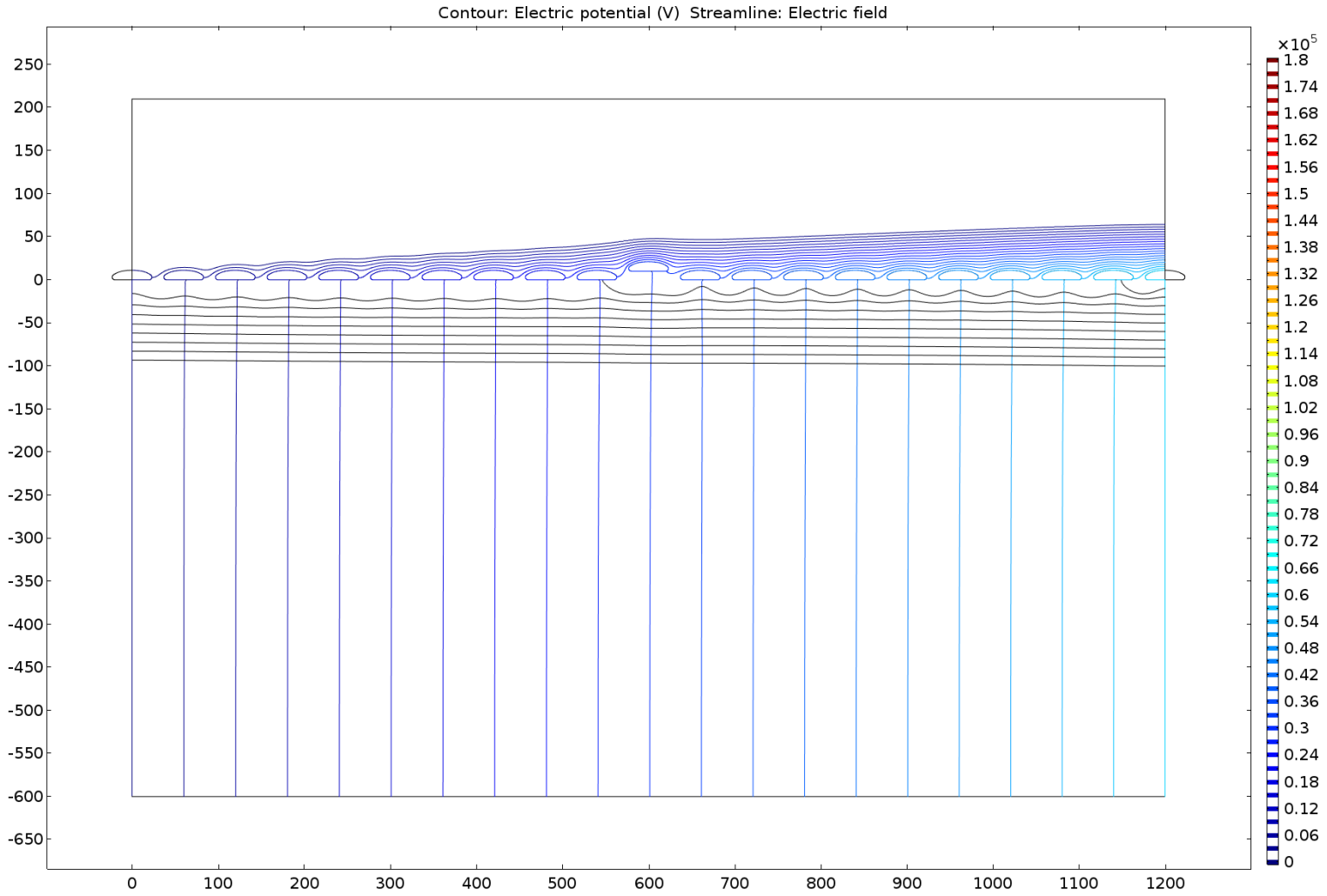
Projection of field lines originating from the CPA onto the CPA plane



Field lines along a diagonal plane splitting the gap and viewed in the beam direction

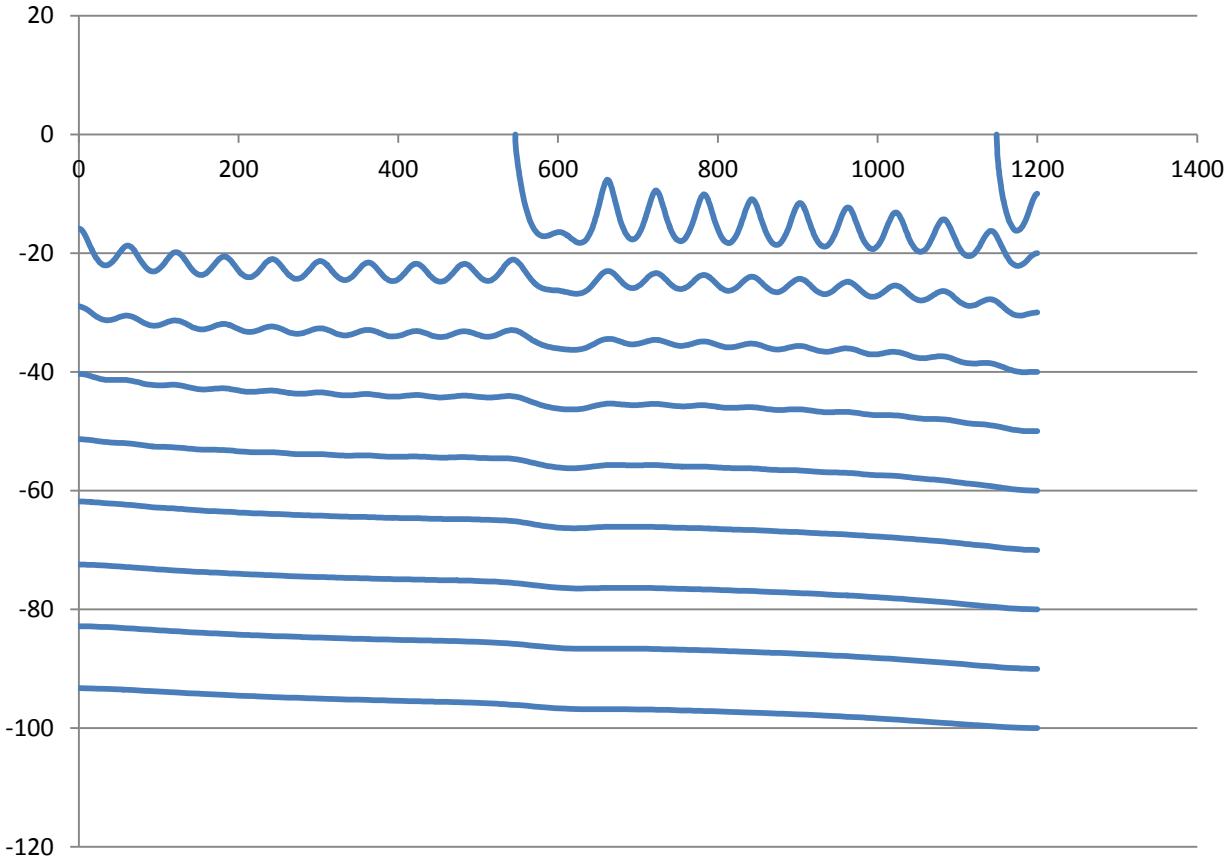


FC profile off plane by 10mm

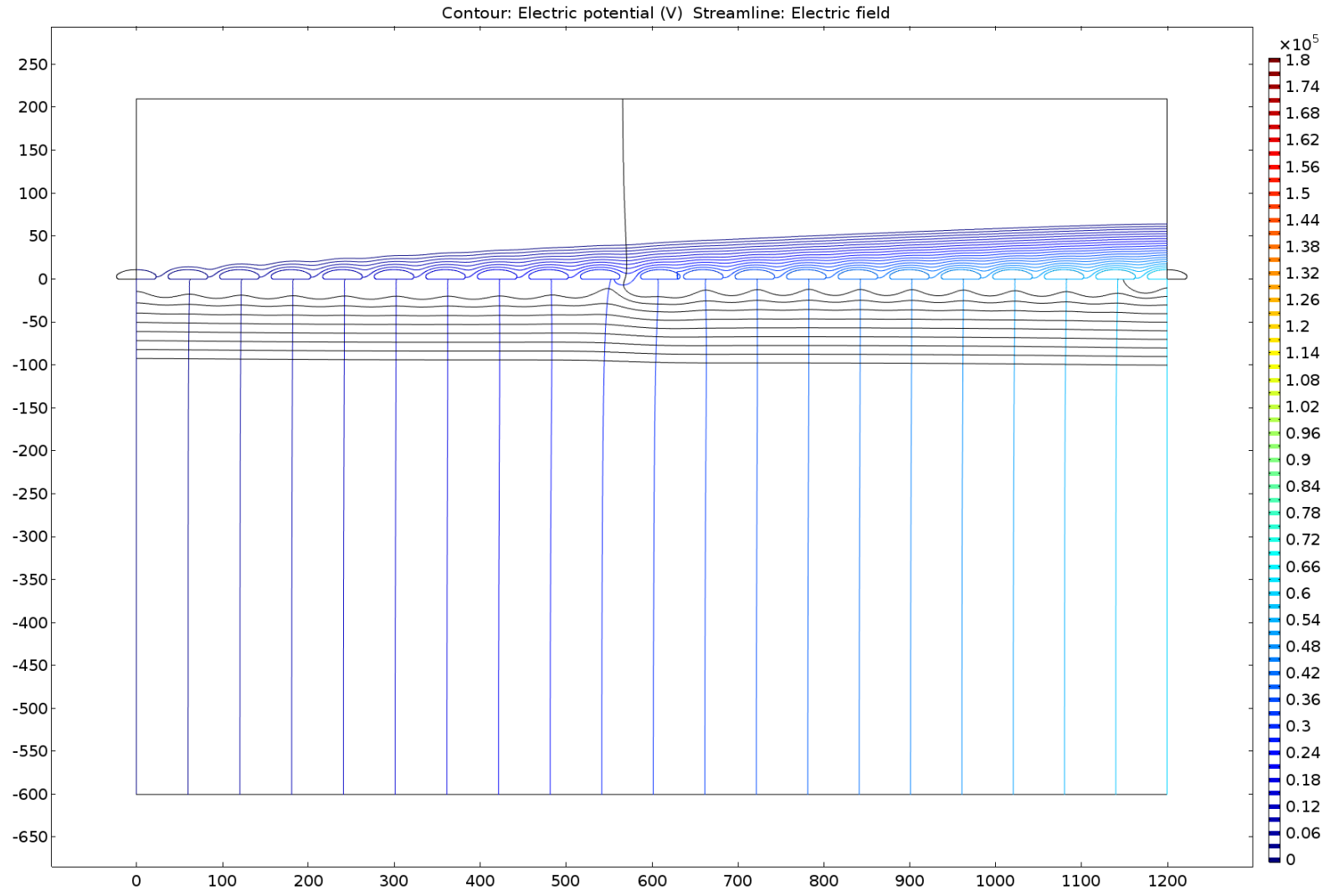


180kV differential between the displaced profile and the “ground plane” on top. This should be the worst case.

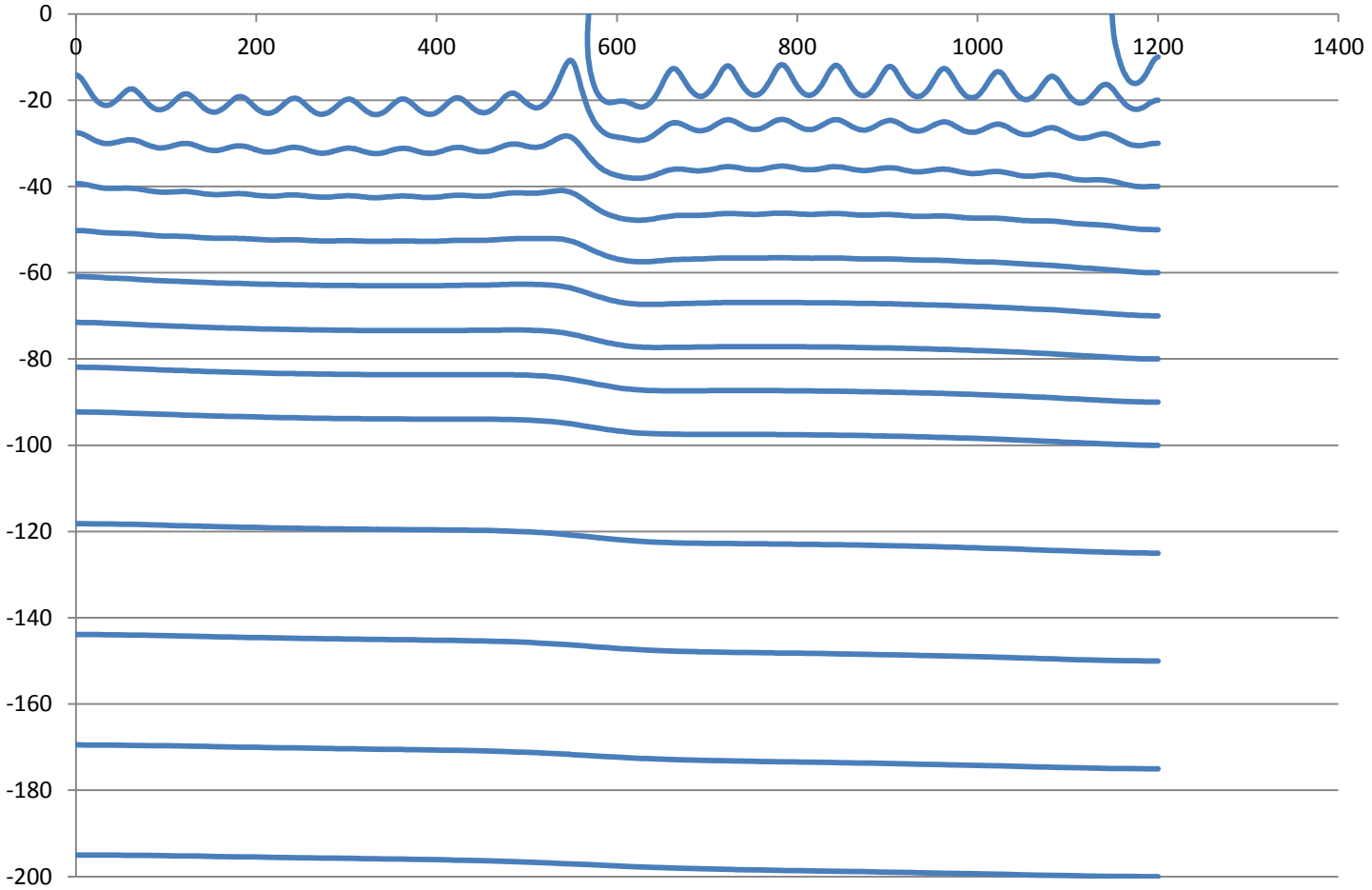
FC profile off plane by 10mm



FC profile shift on plane by 10mm



FC profile shift on plane by 10mm



- Currently, the design of the HV feedthrough is mostly in hands of ETHZ. Does the Single-Phase team have a plan to move timely from the current design and validation phases to production?
  - Our understanding is that we'll receive one of the 3 identical HVFT constructed and tested from DP.
  - We'll work with the DP team to implement the spring loaded tip and validate it.

- A safety factor of 3.75 has been agreed. Minor changes to the design will be made to raise the factor of safety of all components below 3.75 in all loading scenarios. Is it possible to get a table that summarizes and explains uncertainties on which the 3.75 safety factor will apply on top. Have all the components of the design, as known today, be included in the baseline calculations carried out till today? Has the worst case scenario been considered?
  - All of the load carrying components have been examined and considered. During the analysis all of the worst case scenarios were considered (ie during installation; 200 lbs worker)

- At which point in time will you include CERN HSE (Safety unit) to validate key aspects of the design and the described assembly and installation scenarios? Their input (to aspects such as co-activity, electrical risks, work on coffined spaces, etc) may have a severe impact on the procedures being worked out now.
  - Example: It is planned that the construction and assembly of CPA modules, FC modules and installation in the detector will be performed according to a set of Work Planning and Control (WPC) documents. Who validates WPC?

- CERN HSE has been involved since the beginning, we are in close contact with them and working with them to develop the installation procedures that will occur at CERN. Installation procedures are being developed based on the experience at Ash River and these will be reviewed and approved by HSE.
- The WPC for the construction/assembly of CPA/FC at institutions in the US will be approved by each institutions safety organization.

- Can you show a full team organization chart? Are responsibilities well defined for the different phases of the project? How will the project management guarantee that the knowledge acquired by the current team is available during production, assembly and integration? Succession planning?
  - Answered by Vic's talk

- Is there already a safety matrix resulting of a global risk analysis and how this will for instance translate in the safety/monitoring interlock strategy for the different systems? What kind of revision/validation are you planning to perform on this global risk analysis? Do you have already a preliminary global risk assessment?
  - Need clarification

Example of HA Form

Hazard Analysis Form

This form can be used by UMN Far Detector Building Employees, Supervisors, Visitors, and Construction Subcontractors. This is a dynamic document which may require modification as the project moves from start to finish and should be readily available at the site where the work is being performed.

Note: Not all sections of the first page are applicable to every job or task, complete what is necessary for your specific job or task.

Job Title HA Hanging a CPA

Job Location NOvA Far Detector Building

Contract/Work Order #

TO BE COMPLETED FOR WORK INVOLVING SUBCONTRACTORS

Subcontractor (if applicable)	UMN Far Detector Building
Company	Project Leader
Project Manager	Phone (218) 374-2400
Phone Page	Organization
ESH Rep.	ES&H Rep.
Phone Page	Phone Page

AT LEAST TWO SIGNATURES ARE REQUIRED

☐ Prepared Date
Print Name

☐ Accepted Date
Print Name

☐ Accepted as noted Date
Print Name

Description of Work: This is an open ended document for Proto Dune. Assembling CPA's and attaching them to a beam trolley.

HA

Personal Protective Equipment: (Check protective equipment required for the job.)

√ Safety glasses ☐ Side shields	☐ Chemical splash goggles
☐ Hearing Protection	√ Hard Hats
☐ 3.0 Brazing goggles	☐ Impact goggles
☐ Face shield	☐ Rubber apron
√ Leather gloves	☐ Hot/Cold thermal protective gloves
☐ Chemical resistant gloves (specify type):	√ Respirators
	√ Steel Toe Footwear
☐ Other required PPE (specify):	☐ Fall protection equipment (specify):

Environmental Aspects (check one):

☐ Yes, I have thought about the environmental aspects of this job and will document such aspects and mitigation steps within this document.

Yes, I have thought about the environmental aspects of this job and no such credible aspects exist and therefore do not need to be written in this document.

Equipment required for the job: (List the tools needed to perform the job.)

Overhead crane, lifting straps, D rings, spreader bars, scissor lift, wrenches, L channel, C- Clamps, small soft face hammer

Work Plan History Information: (List any lessons learned incidents from this job, tips from previous jobs)

Improvement/Feedback: At the conclusion of the job, the Task Manager, Supervisor and/or Project Leader shall work with those involved to consider lessons learned and receive feedback in order to improve future work plans.

Check One:

Yes we have considered lessons learned and accepted feedback on this job and will communicate such information so that future work plans may be improved.

☐ **Yes** we have considered lessons learned feedback and determined that future work plans do not need to be improved.

- Can you describe in more detail how is the mass cut from the HV cable into the HV feedthrough made? What's the electrical stress in that specific region?
  - Franco

- Can you clarify the difference between results in Fig59 in Design Doc V25 and Fig50 of V20, where a factor of 20 in terms of displacement appears? How has this number been improved?
  - The analysis was done months ago and the original figure was a mistake that has been corrected.

- When will you be ready to review the beamplug? This part as it is very innovative an critical, it needs careful revision. Is any test foreseen for validating the design? Would you consider making a full sized test at 1.3 times design voltage in a N_2 atmosphere and with an appropriate beam?
  - Tim

- Entire part will be immersed in LAr and will have open ends. Test will be at ~60 kV (30 kV per section).
- In-beam high voltage test of full-scale beam plug at ~150 kV. Beam plug interior at nitrogen gas environment, entire beam plug immersed in oil. Test will isolate performance of interior nitrogen volume of beam plug.
- High voltage test of full-scale beam plug at nitrogen gas environment, entire beam plug immersed in LAr.

- The assembly/installation procedure is not fully mature, have you considered the implications on schedule and cost if input from the trial assembly at ash river has an impact on parts that are already fabricated at that time?

- The full assembly process will not start until ~August 2017.
- We believe that the majority of the issues and problems will be understood by the end of the December 15-16 workshop at Ash River and this would be resolved by the time we meet with the CERN HSE (Safety Team) early next year.
- We do not expect and major changes to the main parts (APA,CPA,FC) but there will be refinement of the installation tooling and interface connections (latches and connections) to allow safe access and minimize and danger to both the detector and personnel.

- Have you studied and documented the implication on detector performance and physics if you are forced to operate at lower HV (space charge may increase and hence the field distortions…)?
  - Glenn

- While the design of the different parts seems sound, which is the foreseen validation process for the overall design?

- Validation of the overall design is being done with the 3d solid model and a detailed beam FEA model of the entire detector