

HV connections and distribution options in DUNE FD

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DUNE FD SP HV review
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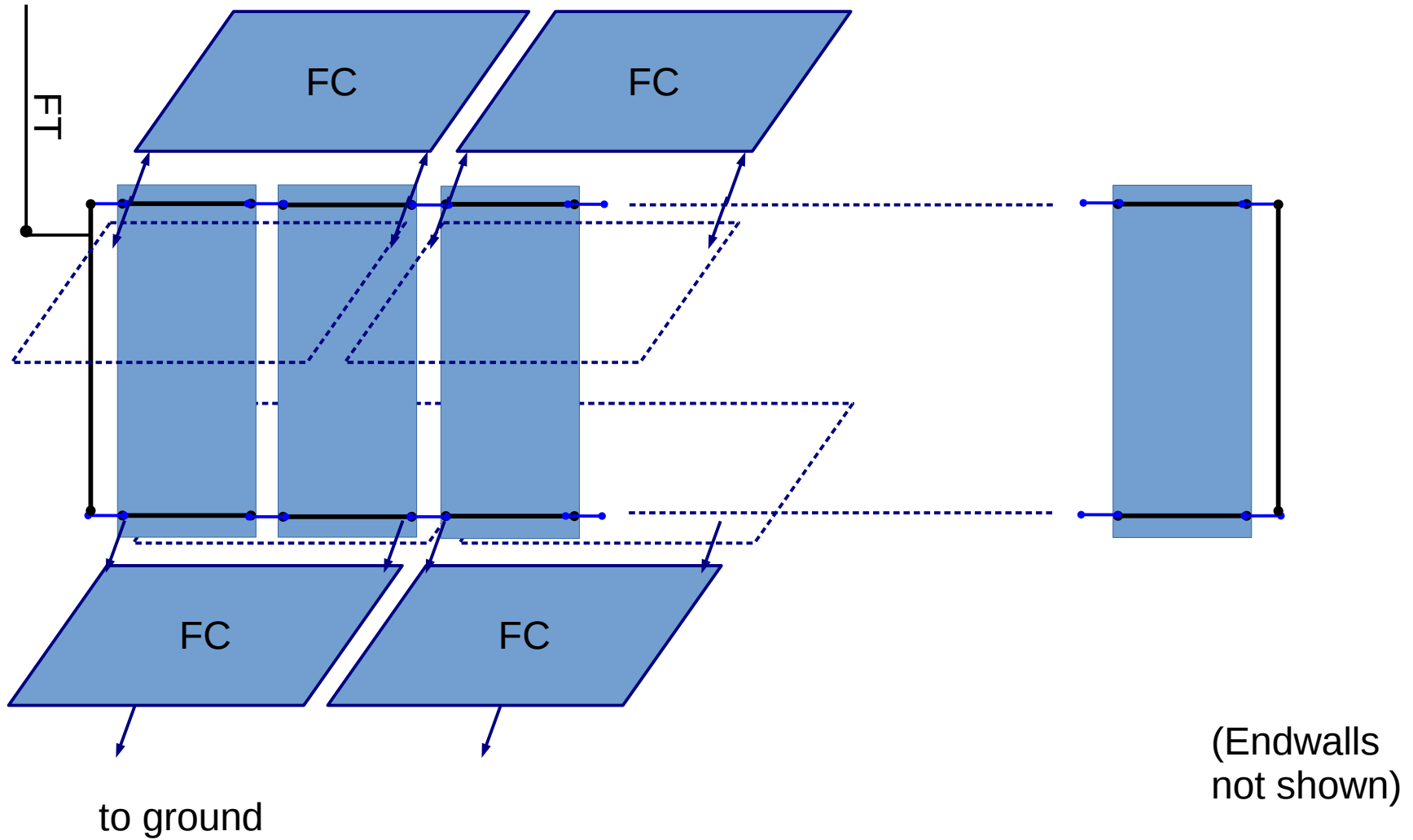
(updated version of talk from 2017-03-21)

Basic topology

used in HVtest in 35t, ProtoDUNE

- HV comes in to cryostat via one HV feedthrough (FT) per overall cathode plane (1 in ProtoDUNE, 2 in DUNE), connects to cup mounted on end cathode plane array (CPA). (Spare feedthrough port in DUNE SP is normally unpopulated.)
- HV bus distributes current to cathode plane arrays and to resistive voltage divider on endwall field cages (FC).
- Voltage divider on CPA biases field shaping strips on CPA frames and distributes current to top and bottom FC.
- **2 CPA longitudinally for every 2 top and 2 bottom FC transversely.**
- FC divider chains terminate in a resistive divider to ground with a pickoff point that allows monitoring FC current, optionally biasing the last FC element.

Topology



Connection points

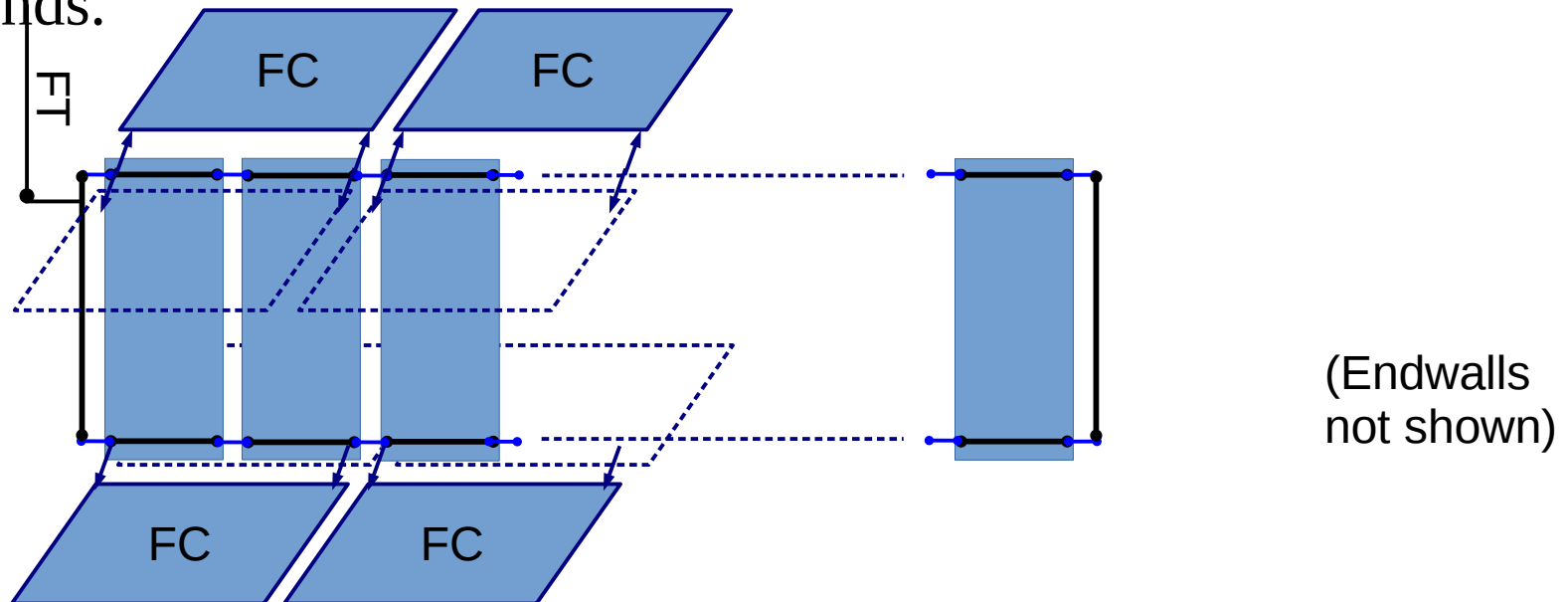
- FT connects to HV cup on frame.
- Relatively small hook-up wire passes through frame to connect between CPAs, necessary due to how everything is assembled.
- Also wire connections from HV bus to FC and from FC to final ground connection, necessary because of swinging FC design.

Many connections. What could go wrong?

- HV FT contact issues – have experienced in uB, fixed by small mechanical adjustment of FT. **New FT tip design in DUNE based on ProtoDUNE experience.**
- HV FT failure – e.g., damage to tip or insulator due to unexpected accident or seismic scenario, mechanical issue, unanticipated decade-long effect of ultra-pure argon (?) **Now have spare FT port.**
- Loss of connectivity of HV bus at one or two CPA-to-CPA connections – e.g., due to unexpected long-term failure of spring washer, crimp, or solder, or unexpected scenario causing mechanical stress breaking wire, or ... (?)
- Loss of connectivity of CPA to FC.
- Loss of connection of low voltage end of FC to ground.

Redundancies we have in current design

- HV bus is a loop, two low-resistance paths from FT to any connection to bus. Completely mitigates any single break in HV bus.
- Two resistive paths to any top or bottom FC from HV bus. Mostly mitigates any loss of a single CPA-to-FC break, some field distortion near top and bottom edge.
- More than one connection to each FC (T/B and endwall) at HV and APA ends.



Redundancies we have given second FT port on each CPA

- Only one feedthrough per cathode, failure disconnects TPC, or makes large noise from intermittent contact. **Switch to other FT port if cup damaged, remove and replace bad FT otherwise.**
- Two breaks on HV bus could completely or partially disconnect a large portion of the TPC, depending where they occur, likely large noise from corona/breakdown across bad connection. **Would need to have a FT in both ports for this CPA to address.**

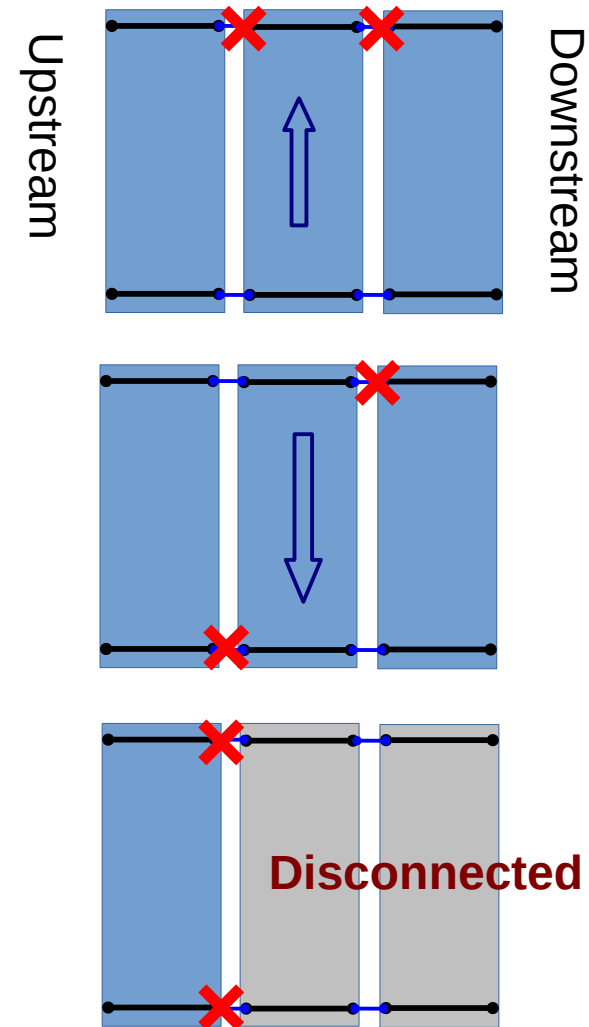
Spare or redundant feedthrough options

1. Adopted: Keep one or more spare feedthroughs on hand, not in service. Design so FT replacement is possible: make sure to preserve enough headroom above flange, concept how to keep argon contained, cold, and pure without ODH.
2. Considered and not adopted: Actually install two FT per cathode.
Advantage: might not need to replace broken one, just switch.
Disadvantage: redundant feedthrough would be subject to same conditions as first, over same amount of time, might fail at same time depending on cause.
 - a) Install at same end. No change to TPC placement.
 - b) Install one at opposite end. (Made possible by centered TPC placement.) Also mitigates HV bus double-break scenario.

Adopted a variant of 2.b where there is a FT receptacle (“HV cup”) at each end, but FT is installed on only one end.

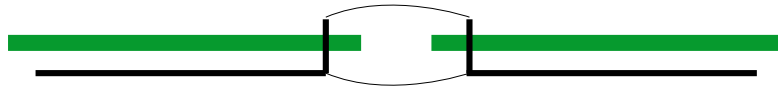
HV bus double-break scenarios

- In most cases, a resistive connection of some Mohms would still exist through the cathode surface. FC resistance is Gohm.
- Only in case of break at top and break at bottom on same CPA-CPA interface would downstream CPAs be completely disconnected.
- Motion of CPA-CPA is mechanically restricted by design.



Additional mitigation of double-break scenario

- We could make the HV bus connection on both sides of the CPA. (Suggested by Steve Magill.)



- Pro: whatever the probability is of one connection becoming disconnected might be, this would reduce the probability of both becoming disconnected by a lot.
- Con: Doubles the number of connections to make at height. Approximately doubles the chance of at least one disconnected, potentially loose wire.