

HVS Planning for FD Integration/Installation

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Outline

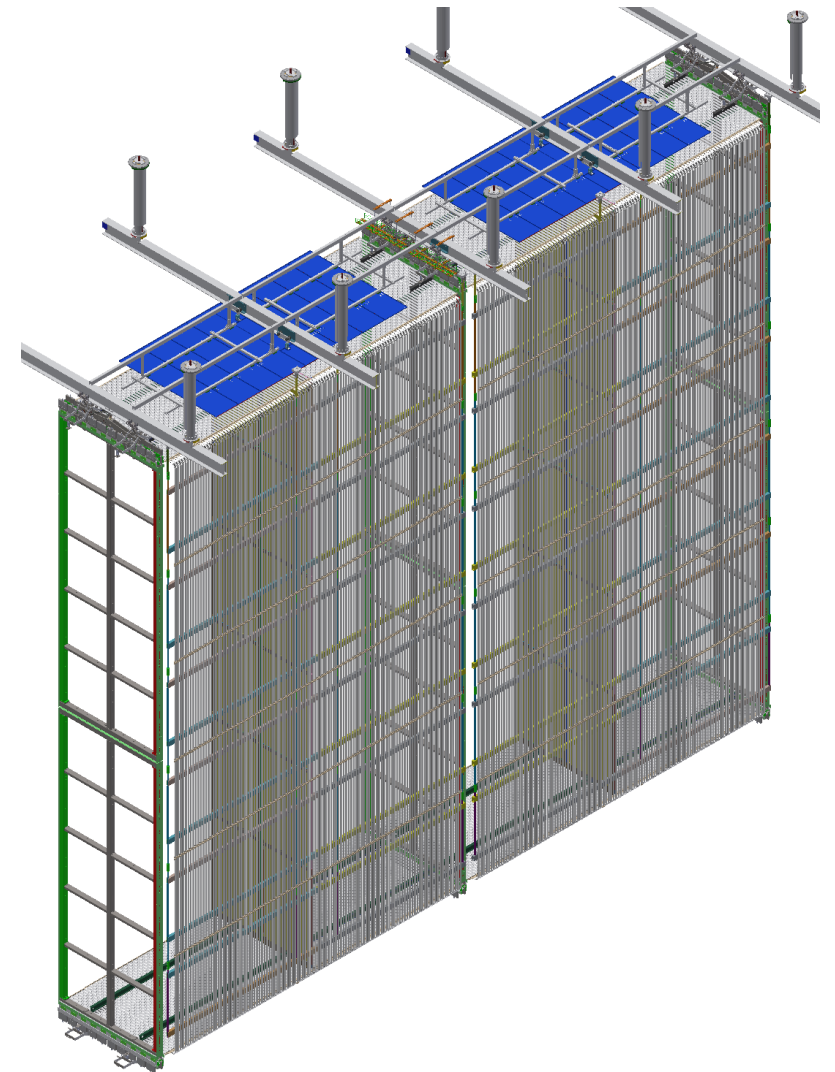
- Parts Breakdown Structure, including the list of deliverables & tooling, items that require special handling
- Personnel requirements during installation & integration
- QA & testing plans
- Expectations about services provided by detector installation team and facility services team

Foreword

- After the HVS preliminary Design Review held in June and following the Committee recommendations, the HVS Consortium is now (for the last two months) focusing on the HVS design evolution aiming at:
 - Improving the HV stability
 - Simplify the construction and installation phases
 - Optimizing costs
- Main changes are:
 - Decoupling of the Top Ground Planes from the Field Cage module
 - No Bottom GP (only local grounding on cryogenic instrumentation if required)
 - No Insulation elements exposed to the High field outside of the field cage
 - Bent profiles at End Wall edges to better define the E-Field
- A full HVS design is quite advanced but still not final:
 - This presentation is based on the present status of the HVS design

The new HVS design

- 2 End Wall FC's each made of:
 - 24 EW identical modules (2m x 3.5m), with top/bottom modules hosting bent aluminum profiles
- 25 ~ identical CPA/TBFC/GP rows, each made of:
 - 2 CPA's: 6 basic unit (1.15m x 4 m)
 - 8 Top/Bottom FC module (3.5m x 2.3m)
 - 4 Top Ground Planes (4 units each: 2.3m x 0.5m) hanged independently to the DSS beams
- Assembly & Installation of FC modules:
 - Performed fully underground (NP02 experience on FC)
 - about 1 month for EW
 - 1 week for each CPA/TBFC/GP slice: deploying of FC (and CP) can be performed during installation or at the end of installation (preferred)

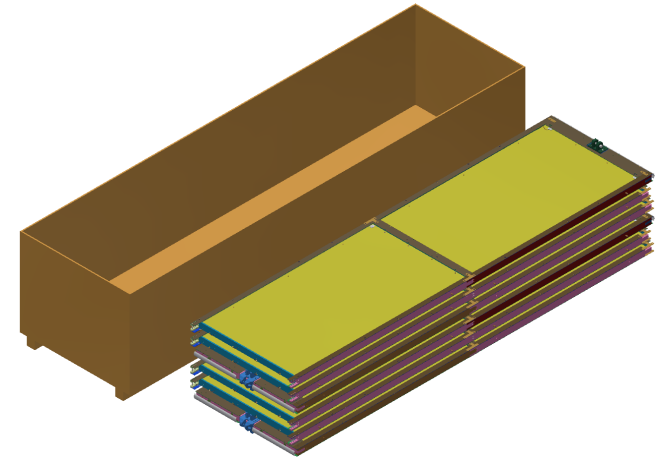


HVS Integration/Installation Plan

- CPAs are pre-assembled at factories in 1.2m x 4m panels and shipped to cleanroom in crates holding 6 panels each. It seems possible that these crates can fit in the Ross cage with some special handling. 2 crates are needed per week.
- EWFC parts are shipped in crates through Ross cage to cleanroom. Modules are assembled at two stations in ~ 2 weeks at a rate of about 2 per shift. 6 modules are then linked into a column and raised to the DSS beam. Need to build 2 pairs of these columns in the rest of 2+ weeks. 4 large crates per endwall.
- TBFC parts are shipped in crates through Ross cage to cleanroom. Modules are assembled at one or two stations in the cleanroom at a rate about 2 per station per shift. Completed modules are linked to the CPA. Need to assemble 4 top + 4 bottom per week. 3 large crates are needed every 2.5 weeks.
- Parts for the upper ground planes and their DSS support structure are sent through Ross cage in crates. They are assembled in either the cleanroom or the cavern at a rate of about 2 person-hours per module.

CPA

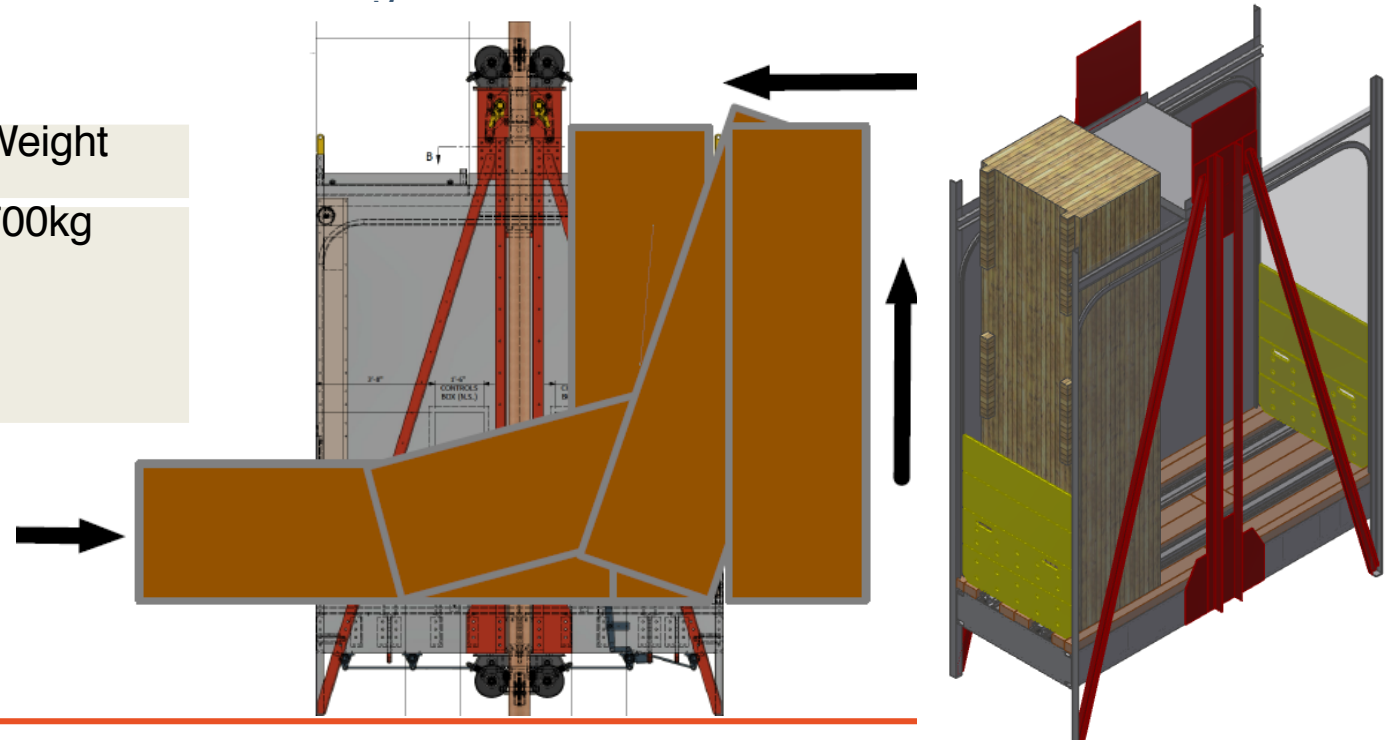
- 2 CPA Arrays:
 - 25 CPA Planes (50 CPA Planes)
 - 2 CPA Panels (100 CPA Panels)
 - 3 CPA Units (**300 CPA Units**)
 - 2 CPA modules (600 CPA RPs)
- Production rate: 2 Panels/week/factory -> 2 factories ~ 6 months
- Shipping Unit : 2 connected modules (1 CPA Unit)
- Shipping crate : 6 CPA Units (2 CPA Panels -> 1 CPA Plane)
- Shipping crate includes all fixtures and tooling needed to assemble the CPA Plane (as in ProtoDUNE)
 - Inclusion of diffuser (and Reflector foils???) at production site
- 50 Crates are required to ship 300 CPA Units
- **2 crate per week required underground during installation**



CPA Transport underground

- The 6 panel shipping crate for the CPAs seems to fit in the Ross cage with the roof section removed. Ladia shared a loading concept for such a crate. His estimate is that the loading time is similar to a slung-load, but the cage travel is faster so it is still a time saver. In either cases, the crates will be designed to tolerate handling in various orientations.

Crate content	Size	Weight
6 CPA panels, installation hardware, jumper wires, PDS diffuser fibers	4.5m x 1.4m x 1m	700kg

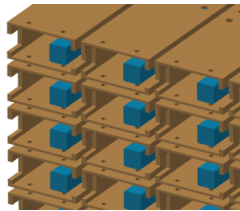


EndWall FC Modules

- 24 EWFC Modules per assembly run (~1 month installation)

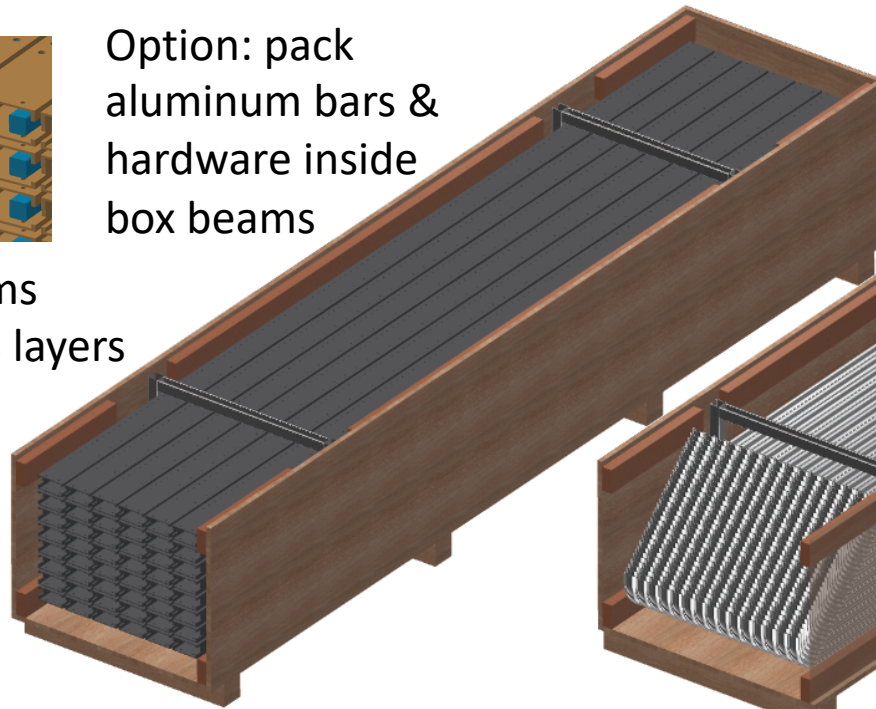
Items	Dimensions [cm]	Weight [kg]	Count with spares	Total Weight [kg]
Bent profiles	200 x 5 x 15	0.5	480	240
Straight profiles	200 x 5 x 1	0.5	960	480
FRP box beams	355 x 10 x 5	7.5	48	360
Aluminum bars	200 x 2.5 x 2.5	3.4	48	163
Slip nuts	4 x 2 x 0.3	0.02	4320	90
PE caps	6 x 2 x 3	0.02	2880	60
Hardware				50

EW FC Parts Shipping

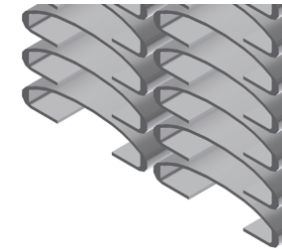
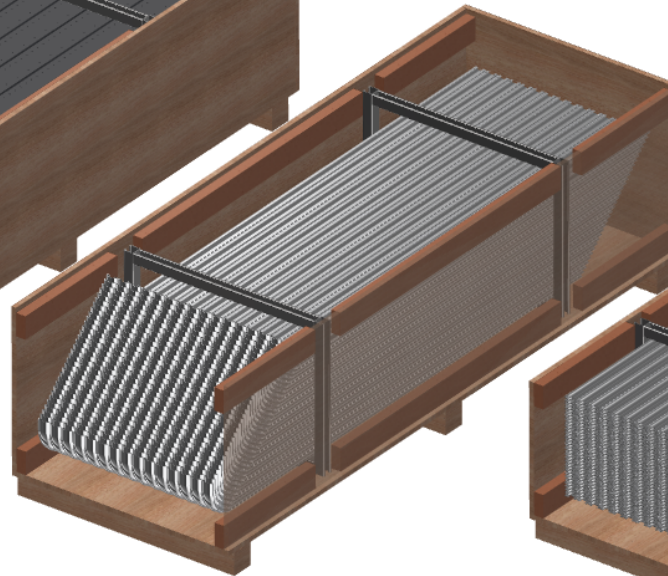


FRP beams
6 wide, 8 layers

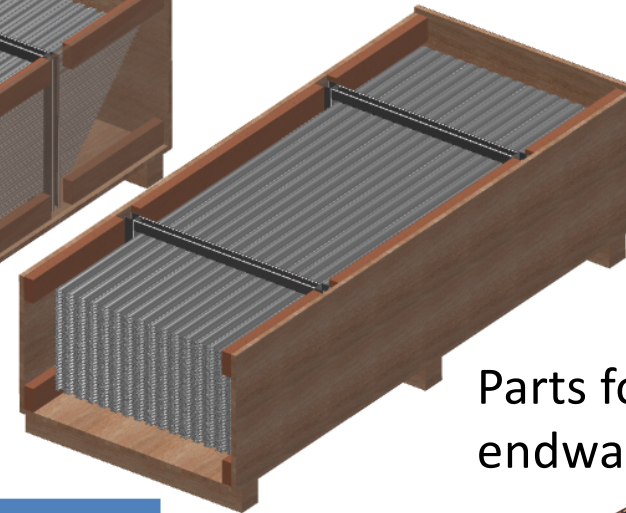
Option: pack
aluminum bars &
hardware inside
box beams



Bent profiles
15 wide, 32 layers

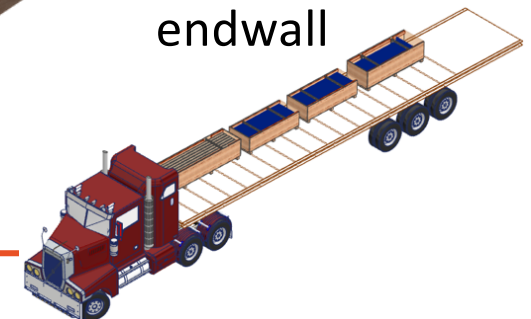


Straight profiles
15 wide, 32 layers, 2 boxes



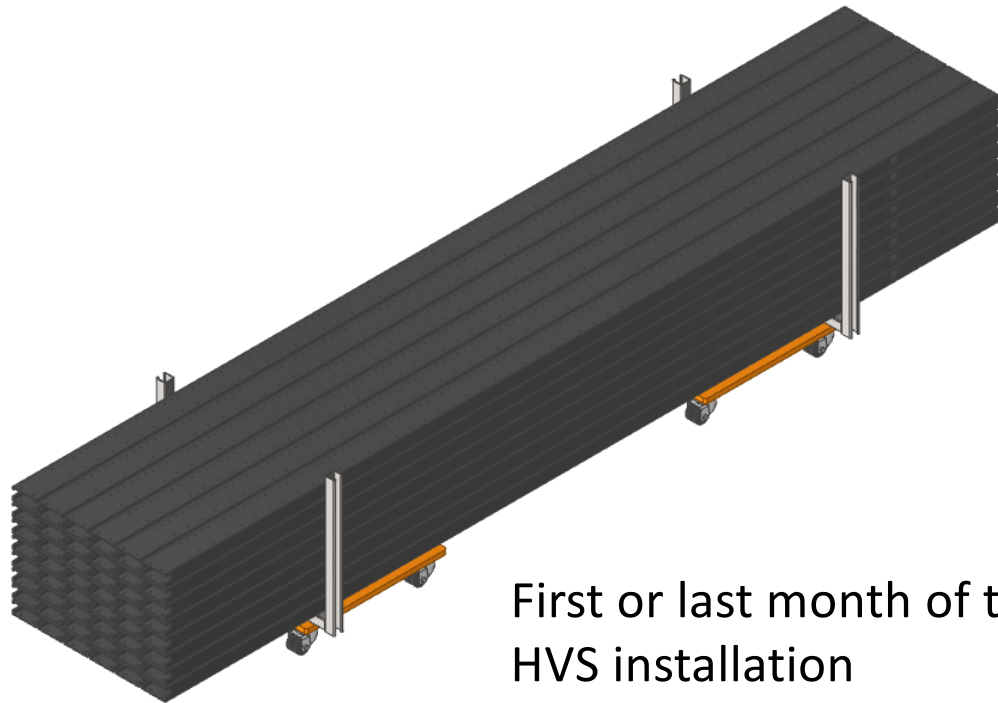
Parts for one
endwall

Box #	Dimensions [m]	Weight [kg]	Notes
1. Bent profiles	2.5 x 0.9 x 0.8	350	+ PE caps & rivets
2. Straight profiles x 2	2.2 x 0.9 x 0.7	350	
3. Box beams	3.7 x 0.9 x 0.7	530	
4. Aluminum bars	2.3 x 0.4 x 0.3	350	+ slip nuts & hardware

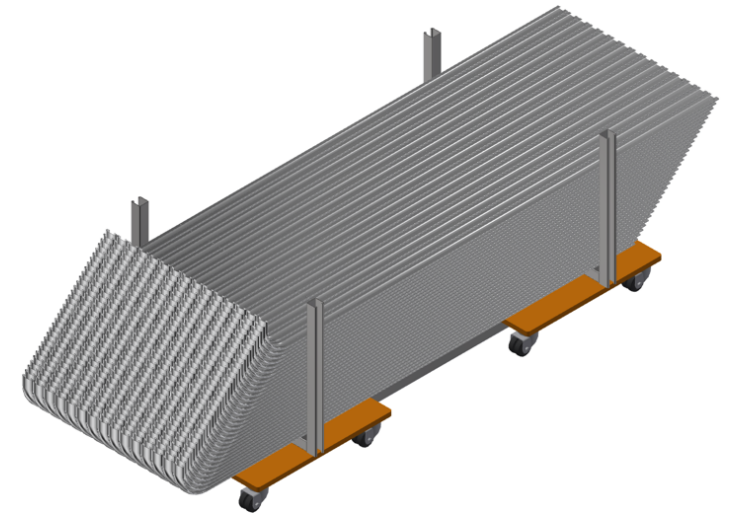


Inside Cleanroom

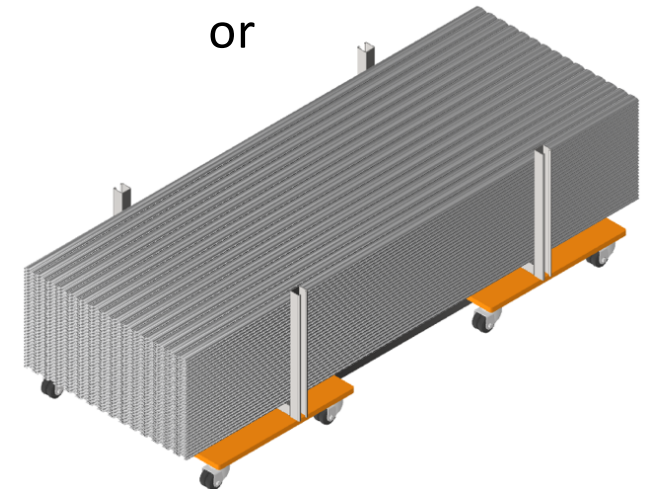
- Assuming that the shipping crates are not allowed into the cleanroom, their contents can be transferred to a dollie in the SAS and rolled into the cleanroom.



First or last month of the
HVS installation



or

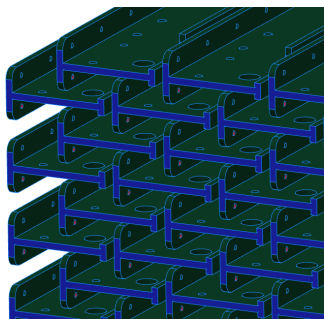


Top/Bottom Field Cage Modules

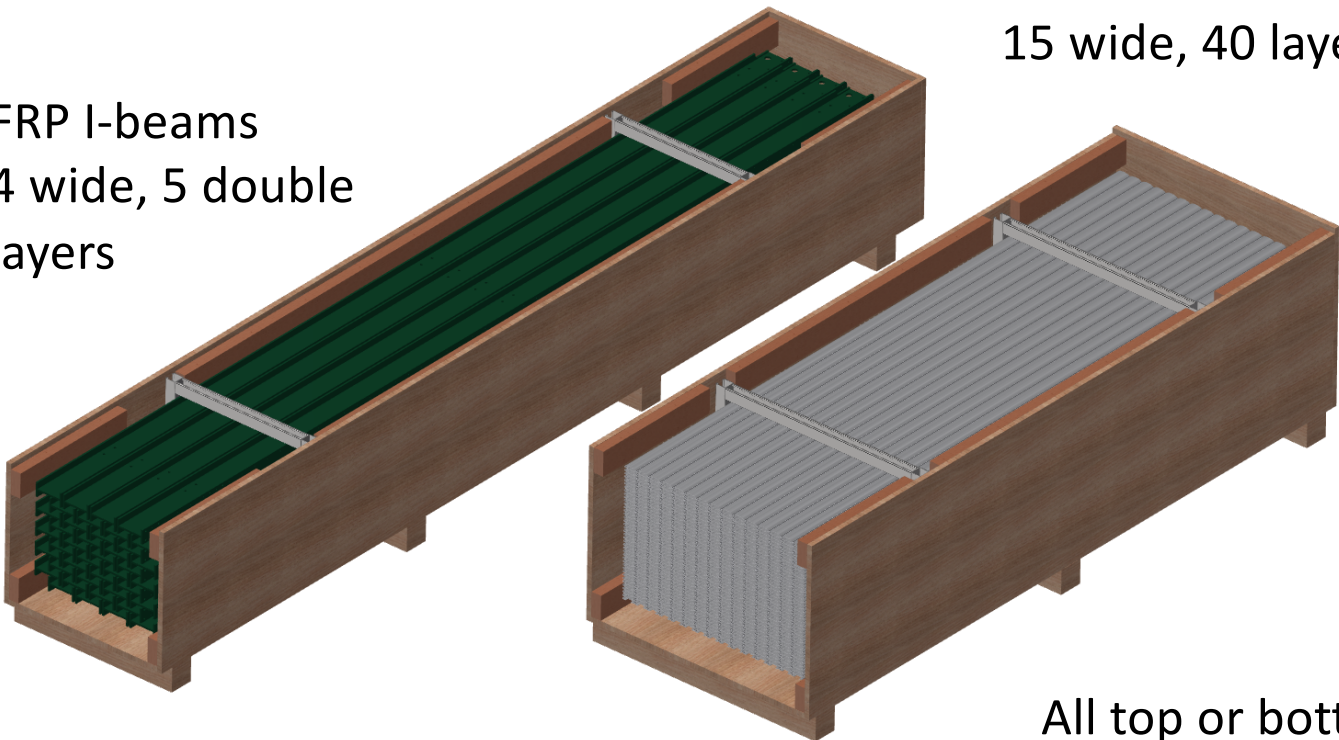
- 20 TFC + 20 BFC modules per 5 weeks installation

Items	Dimensions [cm]	Weight [kg]	Count with spares	Total Weight [kg]
Top profiles	230 x 5 x 1	0.56	1200	672
Top FRP I-beams	355 x 10 x 5	7.4	40	300
Top slip nuts	4 x 2 x 0.3	0.02	3600	72
Top FRP standoffs	60 x 10 x 5	1.2	40	50
Bottom profiles	230 x 5 x 1	0.56	1200	672
Bottom I-beams	355 x 10 x 5	7.4	40	300
Bottom slip nuts	4 x 2 x 0.3	0.02	3600	72
Bottom FRP standoffs	60 x 10 x 5	1.2	40	50
PE caps	6 x 2 x 3	0.02	4800	100
APA latches		5?	80	400?
Hardware				120

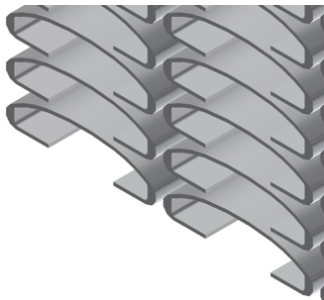
TBFC Parts Shipping



FRP I-beams
4 wide, 5 double
layers

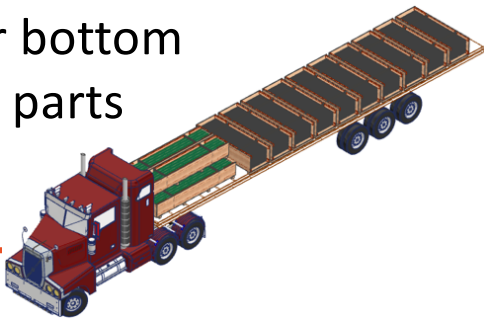


Profiles:
15 wide, 40 layers, 2 boxes



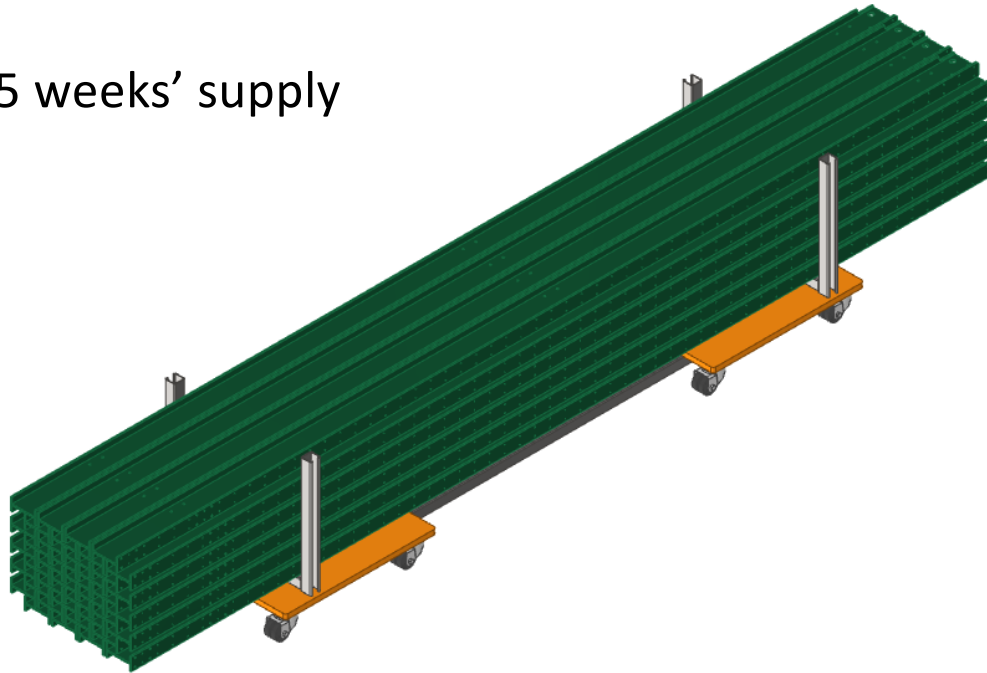
Box #	Dimensions [m]	Weight [kg]	Notes
1. Top profiles x 2	2.5 x 0.9 x 0.8	473	
2. Top I-beams	3.6 x 0.6 x 0.6	440	+ short riser I-beams
3. Bottom profiles x 2	2.5 x 0.9 x 0.8	473	
4. Bottom I-beams	3.6 x 0.6 x 0.6	440	+ short riser I-beams

All top or bottom
FC major parts

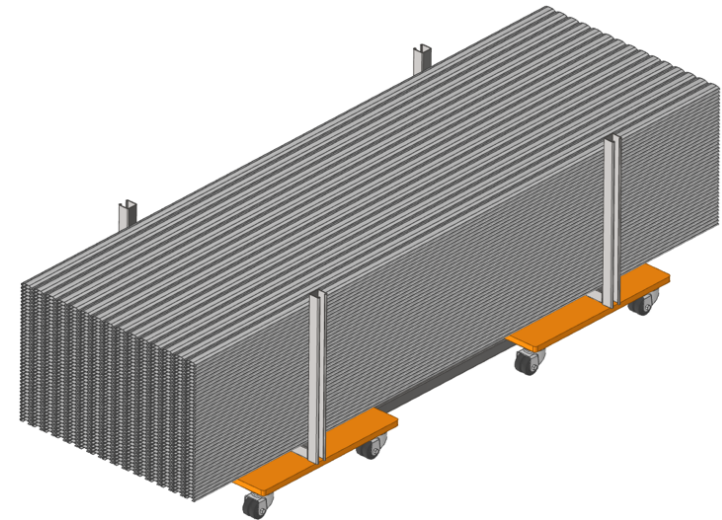


TBFC Inside Cleanroom

2.5 weeks' supply



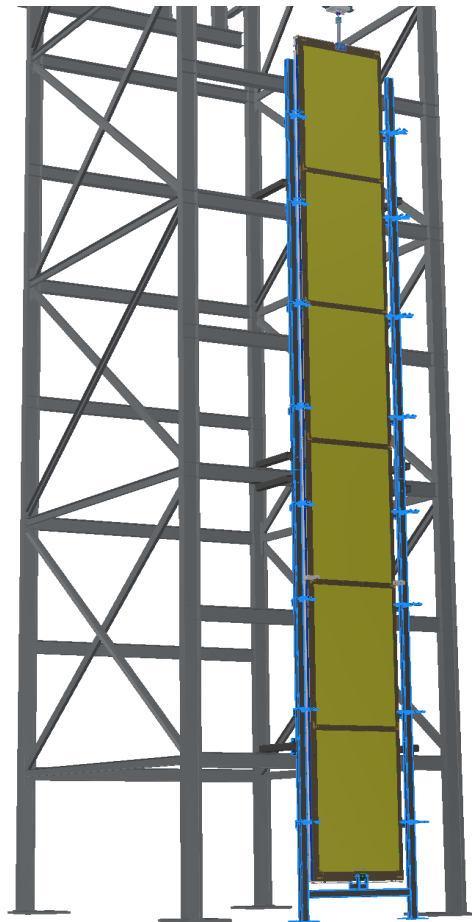
1.25 weeks' supply



- Alternative: move 4 beams from the crate in the cavern into the cleanroom every shift. Leave them on a shelf in the clean room to save floor space in the cleanroom.
→ This leads to the option of packing more beams in the shipping crate

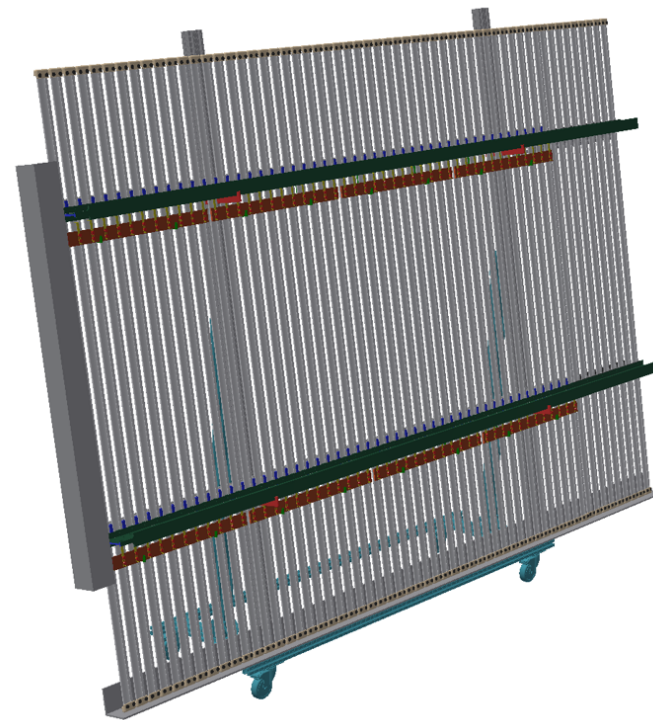
Main assembly tooling required

- CPA assembly tower



- FC assembly station

- Can be the same for EW and TB (under study)
- Possibly two station can be installed back-to-back



Parts Breakdown Structure, 1 of 2

- <https://indico.fnal.gov/event/20775/session/3/contribution/23/material/0/0.xlsx>

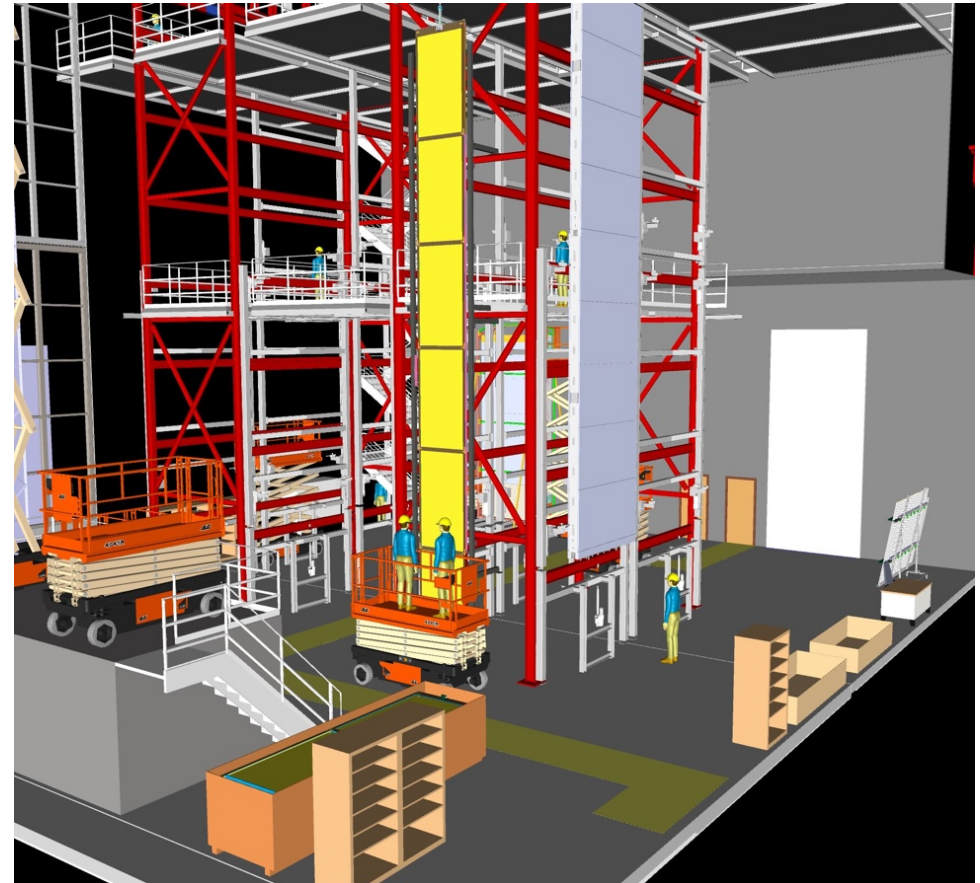
Package Type	Quantity	Contents	Dimensions	Weight	Origin
FD1.HV.CPA.Panels	50	6 CPA panels, installation hardware, jumper wires, PDS diffuser fibers	4.5m x 1.4m x 1m possible in Ross cage	700kg	TBD
FD1.HV.CPA.Tower	1	Parts for CPA assembly frame	6.2m x 1.7m x 0.7m	900kg	TBD
FD1.HV.CPA.Tools	1	one tool chest with tools			TBD
FD1.HV.CPA.Hangers	1	100 CPA hanger+trolley assemblies			TBD
FD1.HV.CPA.Cups	1	6 HV cups			CERN
FD1.HV.TFC.Beams	5	40 FRP long I-beams, 40 riser beams, installation hardware	3.6m x 0.6m x 0.6m	440kg	SBU
FD1.HV.TFC.Profiles	10	600 TBFC profiles	2.5m x 0.9mx 0.8m	470kg	SBU
FD1.HV.BFC.Beams	5	40 FRP long I-beams, 40 riser beams, installation hardware	3.6m x 0.6m x 0.6m	500kg	UTA
FD1.HV.BFC.Profiles	10	600 TBFC profiles	2.5m x 0.9mx 0.8m	470kg	UTA
FD1.HV.TFC.Tools	1	one tool chest with tools			
FD1.HV.TFC.Caps	5	6000 UHMWPE caps, locking rivets		150kg	BNL
FD1.HV.TFC.RDBs	3	600 long RDBs, 80 short RDBs			LSU
FD1.HV.FC.Term	1	240 FC termination boards and cables			BNL
FD1.HV.TFC.CIBs	1	420 CPA interconnect boards			KSU
FD1.HV.TFC.Winches	1	2 sets of TFP deployment winch bars, BFC deployment fixtures			SBU

Parts Breakdown Structure, 2 of 2

Package Type	Quantity	Contents	Dimensions	Weight	Origin
FD1.HV.TFC.Latches	5	40 sets of top APA latches			SBU
FD1.HV.BFC.Latches	5	40 sets of bottom APA latches			UTA
FD1.HV.TFC.Braces	1	10 sets of FC temporary bracing, wheels and attachment plates			SBU
FD1.HV.GP.Panels	5	90 ground plane tiles	2.5m x 1.2m x 1m		W&M
FD1.HV.GP.Frames	5	20 sets of top GP frame and beams			W&M
FD1.HV.GP.Shields	??	Bottom GP shield tiles			W&M
FD1.HV.GP.Pickoff	1	110 GP pickoff boards and cables			KSU
FD1.HV.EFC.Beams	2	48 sets of box beam, Al bars, hardware	3.7m x 0.9m x 0.7m	530kg	LSU
FD1.HV.EFC.BentP	2	480 bent profiles	2.5m x 0.9m x 0.8m	350kg	LSU
FD1.HV.EFC.StrtP	4	480 straight profiles	2.2m x 0.9m x 0.7m	350kg	LSU
FD1.HV.EFC.Guides	1	Endwall to APA/CPA guiding plates			LSU
FD1.HV.EFC.Support	1	Endwall DSS support fixtures, lifting bars			LSU
FD1.HV.EFC.TransCart	1	Endwall module storage/transport cart			LSU
FD1.HV.EFC.AsmCart	3	FC module assembly cart kit			CERN x2, UTA
FD1.HV.HVC.FT	2	2 HVFT			CERN
FD1.HV.HVC.Cables	2	2 sets of HVPS cables			CERN
FD1.HV.HVC.Filters	1	4 HV filters			CERN
FD1.HV.HVC.HVPS	2	one 300kV HVPS			CERN

HVS installation: Assembly areas

- The main storage for FC components will be outside in the main cavern and boxes will be moved via fork truck or motorized pallet jack
- Boxes sized in the model match what is needed for profiles and FR4 beams and one tool cabinet and one work desk
- CPA assembly tower allows to put together the CPA units to make a full panels and attach TBFC module
- Details of assembly sequence under evaluation. Test in Ash River foreseen



HVS Integration/Installation Plan

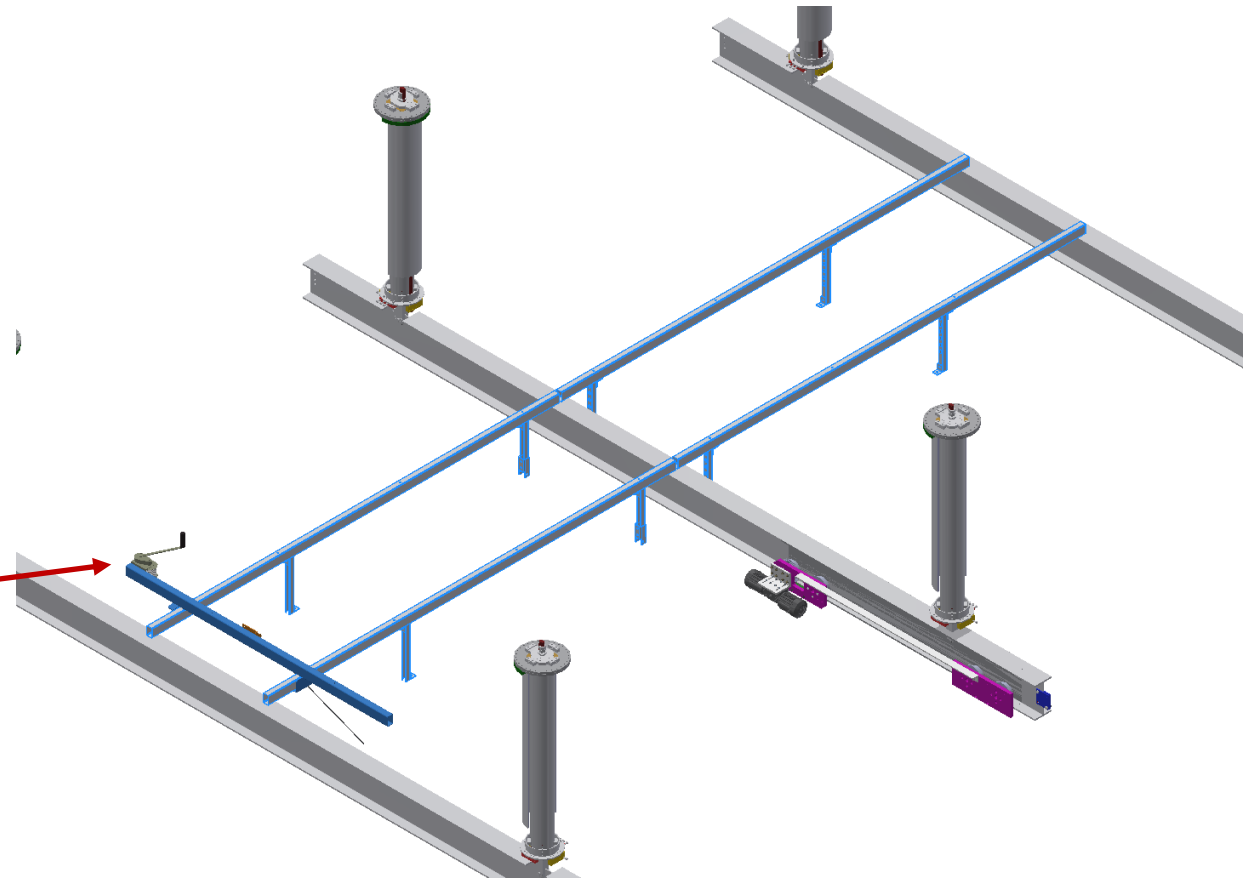
- We are developing a new CPA/TBFC installation sequence that should allow a more steady pace of FC module assembly, less storage need, faster final deployment:
 - Attach the bottom FC modules to the CPA similar to what we did in ProtoDUNE NP04
 - Move the CPA+T/B FC module super assembly into the cryostat, and connect to the HV bus. This step can be decoupled with the APA installation.
- Some time before the installation of the 2nd endwall, start the deployment of the FC modules:

Row by row, deploy the top FC modules, remove the floor panels, clean the membrane, deploy the bottom FC modules in pairs using the top FC beams as lift points, check electrical connections. Repeat 25 times @ 1 row /day rate.
- Install the 2nd endwall

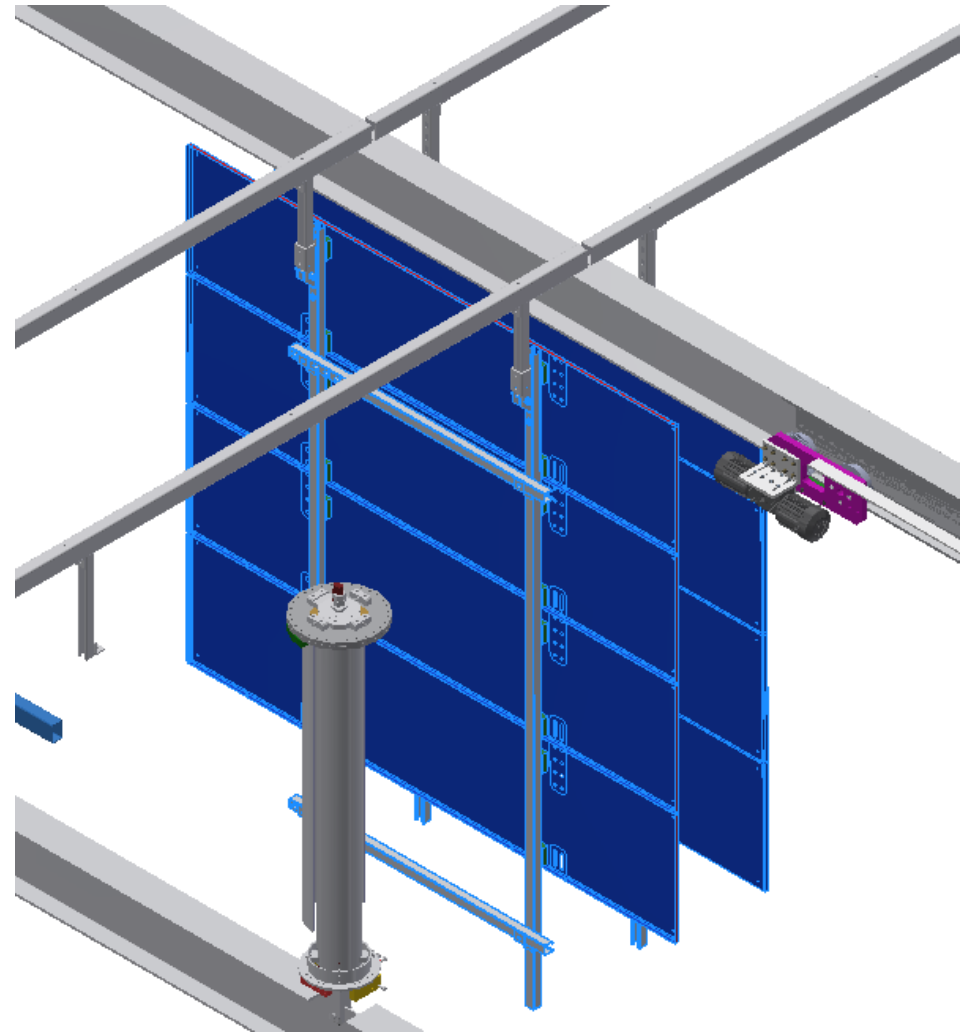
CPA-TBFC-GP Integration/Installation Steps

- Install the ground plane support beams over the DSS beams.
- At some rows, the support beams need to shift to avoid the CE feedthrough ports

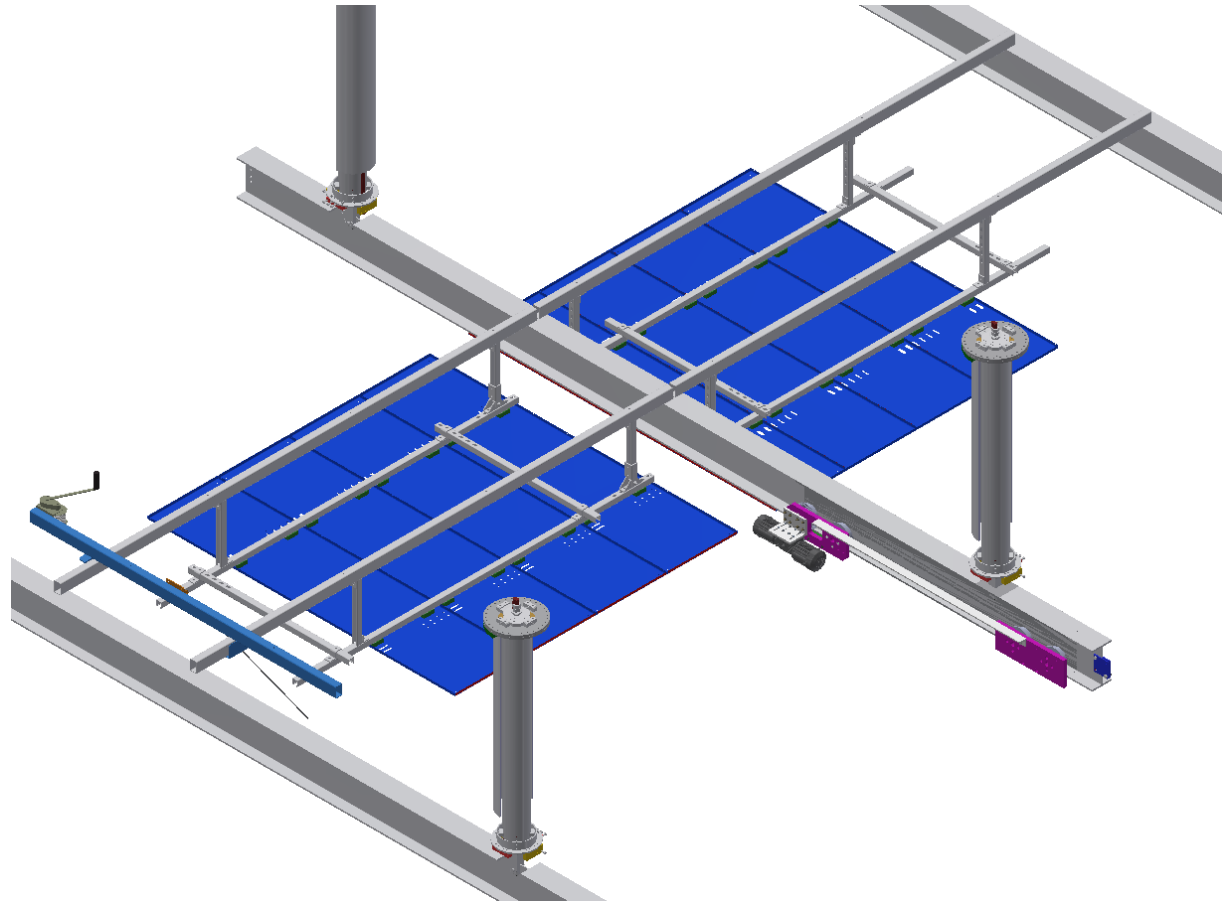
Temporary upper FC
deployment winch



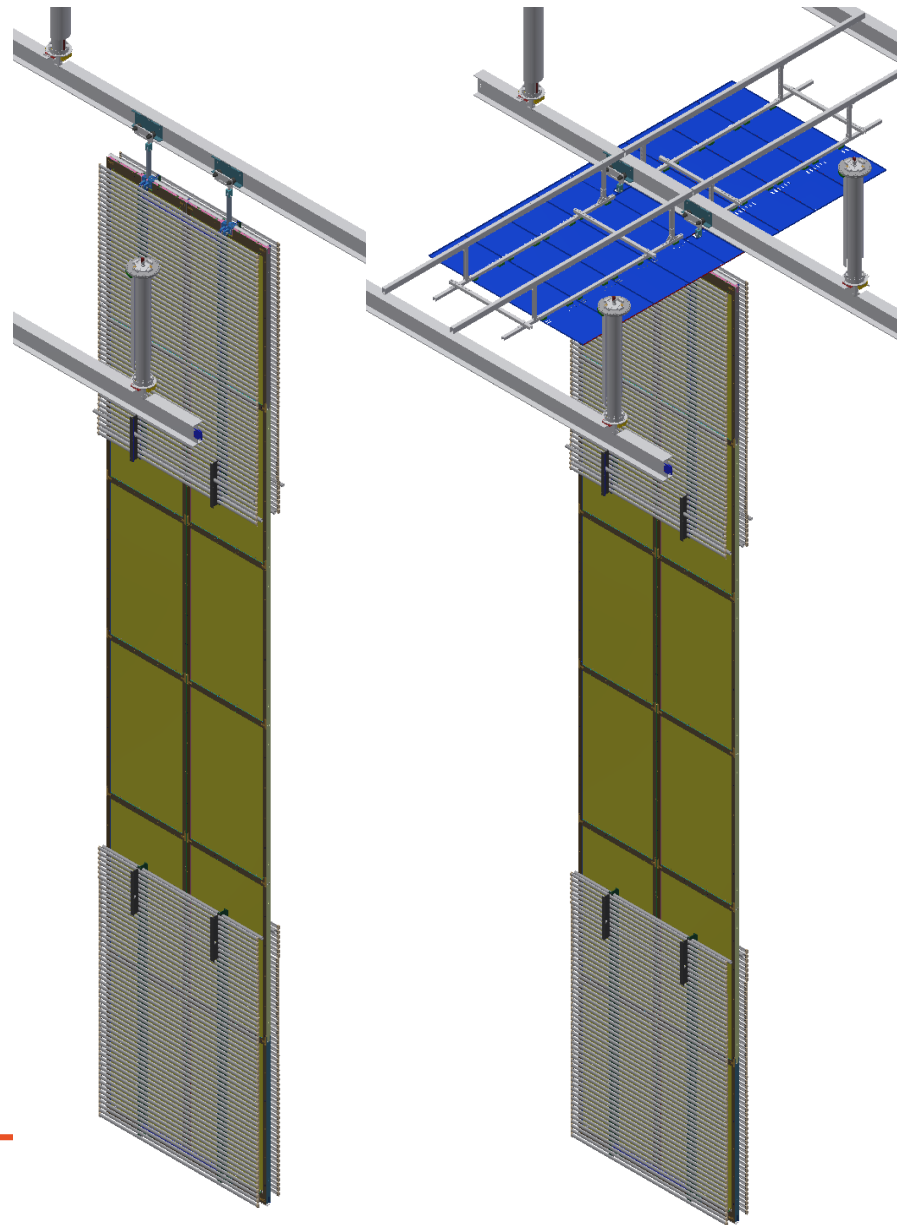
- Raise the ground plane modules and attach to the support beams



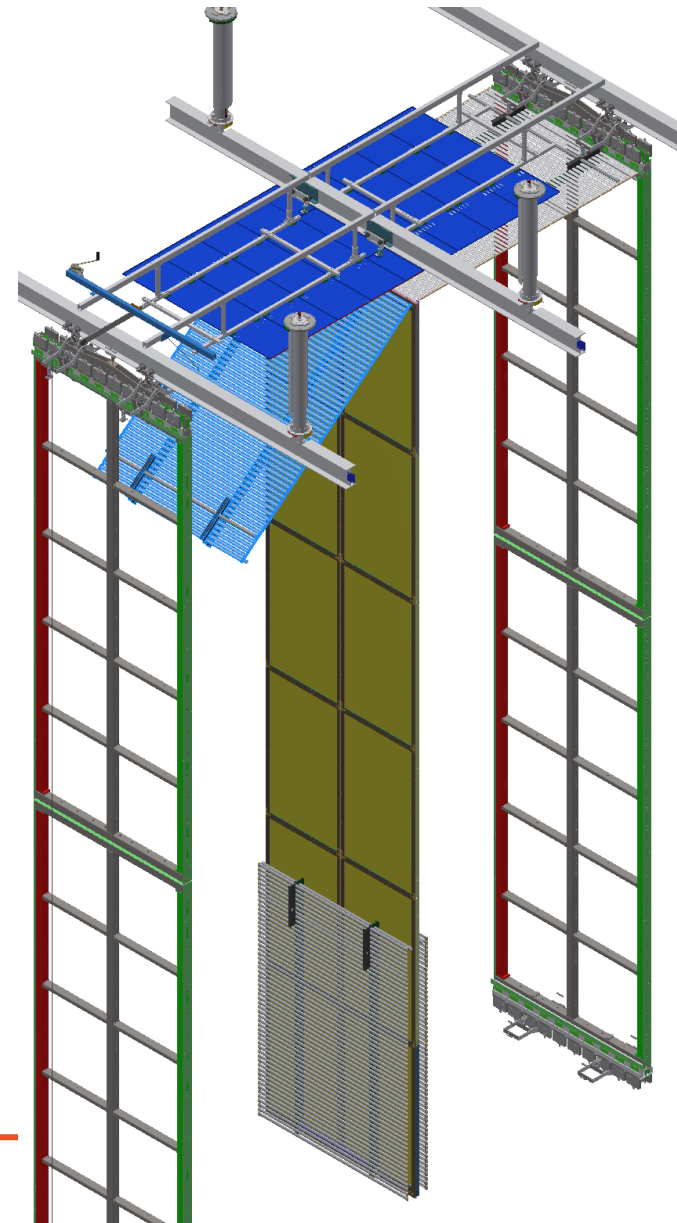
- Rotate the ground plane modules and attach to the support beams.
- Connect the GP monitoring wires.
- This step needs to be done after the CE cables are routed through the feedthroughs.



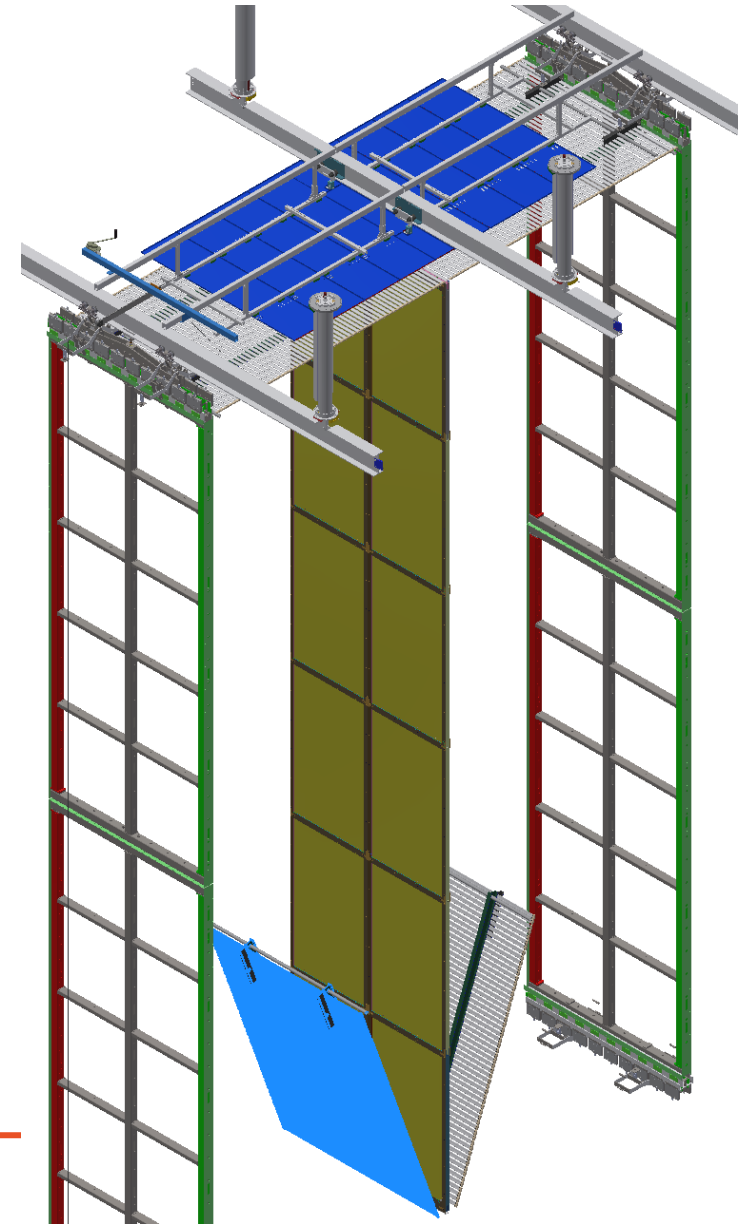
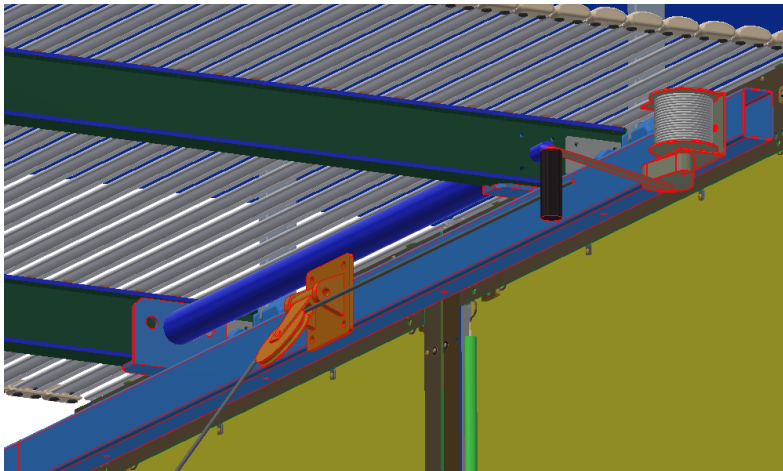
- Fold the 2 top FC and 2 bottom FC modules with the two CPA columns in the clean room, push into the cryostat along the CPA DSS rail.
- Once in position, install the small GP filler pieces above the CPA



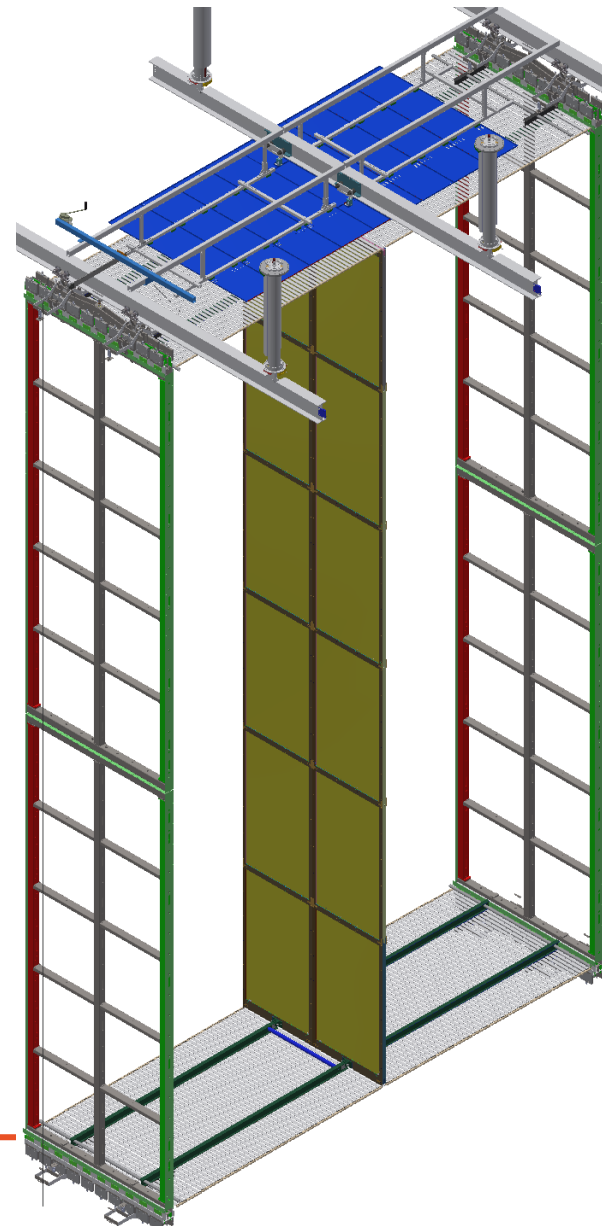
- Deploy the top FC modules using winch bars on the GP support beams.
- Connect top FC termination wires
- This action (and the following ones) can be performed during the insertion of the row in the cryostat or when the full CPA/TBFC rows are inserted.
- In the latter case insertion rate could decoupling from that of the APA



- Deploy the 2 bottom FC modules, preferably symmetrically to minimize the lateral swing of the CPA.
- The bottom FCs are lowered through a temporary winch bar attached to the CPA side of the top FC I-beams



- Connect bottom FC termination wires, final check all electrical connections.
 - Move on to next row.
-
- *The installation and deployment of the 2nd end-wall is more complex due to the limited accessibility inside the TPC for electrical and mechanical connections.*
 - *A conceptual deployment sequence is presently under study.*



Underground Labor and Activities

- Detailed schedule of assembly and installation is under definition assuming:
 - an HVS provided crew up to 6 workers + 1 physicist supervisor.
 - 1 CPA workstation
 - 2 FC assembly stations (allowing assembly of 1 or 2 modules) for both the TBFC and the EWFC
- Schedule foresees 2 shifts/day and 4 days/week to complete a CPA/TBFC/GP slice:
 - Day#4 is dedicated to FC deploying electrical connection and QC: it can be moved at the end of installation in parallel with floor removal and cleaning (for a total of 3 to 4 weeks)
 - 1 months per EW

Underground Labor and Activities

Day #1 Shift 1 (& 2)

	Hours	FTE
Open CPA Crates -- QC Receiving checklist	0.5	2
CPA Panel #1-Remove bottom 4m CPA and rotate vertical -- secure to fixture on tower	1	4
CPA Panel #1 (#2)-Remove middle 4m CPA and rotate vertical -- secure to bottom 4m and to fixture on tower	1	4
CPA Panel #1 (#2)-Remove top 4m CPA and rotate vertical -- secure to bottom 4m and to fixture on tower	1	4
Transfer to TCO beam #1	1	4
Remove CPA top lifting shackle assembly	1	4
Final CPA Panel QC, Cleaning	1	4
TFC #1:place profiles, 1st end caps	0.5	2
mount beams, install screws	1.5	2
install divider boards	0.5	2
install 2nd end caps	0.5	1
install riser block	0.5	1
QC	0.5	2
remove from fixture	0.5	2
TFC #2:place profiles, 1st end caps	0.5	2
mount beams, install screws	1.5	2
install divider boards	0.5	2
install 2nd end caps	0.5	1
install riser block	0.5	1
QC	0.5	2
remove from fixture	0.5	2

Day #2 Shift 1

Assemble 4 top GP module	4	2
Install 4 top GP module	4	2
Pair Panels to make CPA Plane - Complete Plane Assembly QC checklist	0.5	4
FC Crate opened -- FC Inspection	0.5	4
Mount bottom FC1	1	4
Mount bottom FC2	1	4
Mount top FC1	1	4
Mount top FC2	1	4
CPA/FC HV Connections, Top and Bottom	1	4
CPA/Top FC QC checklist	0.5	4
CPA/Bottom FC QC Checklist	0.5	4
Insert through TCO - QC checklist	1	4

Day #2 Shift 2 and Day #3: repeat above operation for the next CPA/TBFC

Day #4 Shift 1 (& 2)

Deploy Top FC1 and FC2, HV Bus connection, install BFC deployment fixture	2	4
CPA/Top FC QC Checklist	0.5	4
Deploy Bottom FC1 and FC2 - HV Bus Connection, remove deployment fixtures	2	4
CPA/Bottom FC QC checklist	0.5	4
CPA/FC DSS Position checklist	1	4

In our scheme where deploying is done after installation of the CPA/FC rows: day #4 are compacted at the end of the TPC installation (25 days).

QA testing plans, required services

- QA Testing:
 - Visual inspection for integrity on material arriving in the crates:
 - Damage and scratches of CPA resistive surface
 - Scratches, deformation of the FC aluminum profiles
 - Electrical checks of Voltage divider boards: resistor value, continuity.
 - Before mounting on the FC modules
 - After mounting
 - After assembly of FC's on CPA and electrical connection
 - After deploying in the cryostat
 - 1+1 High resistivity Multimeters to be provided by the consortium
- Request to Detector Installation & Far Site teams:
 - No special requests: only riggers to move crates and assembled FC modules
 - Integration of a HVS expert into the installation/deploying team