

# VD FC Production Workshop

*May 17, 2024*

*Jaehoon Yu*  
*University of Texas at Arlington*

# Workshop Fundamentals

- Goals : To learn the QC procedure and start processing FD2 (VD) box beams and plug pieces
- Tasks to complete in the workshop
  1. Understand the scope and tasks involved in the project
  2. Hands-on training of the module parts QC procedure and exercise recording them into the QC iPADS
    - To the level everyone knows how to process each part and QC them
  3. Process as many parts as possible and measure time needed to process and QC each one

# Neutrino fundamentals – 1

- Postulated in 1930 to explain the nuclear  $\beta$ -decay and detected experimentally in 1956 (1995 Nobel)
- Fundamental particles of matter in the current Standard Model of Particle Physics
  - Makes up a quarter of the whole particle table in TSM as massless particles
  - Have three flavors – electron ( $\nu_e$  – 2002 Nobel), muon ( $\nu_\mu$  – 1988 Nobel), and tau ( $\nu_\tau$ ) types
  - Charge neutral and only interact via the weak force → do not interact often in matter

# Neutrino fundamentals – 2

- Large numbers of low E neutrinos ( $\nu_e$ ) produced in the Sun (**2002 Nobel**) and in reactors
  - $\rightarrow 65 \times 10^9 \nu_e / \text{s/cm}^2$  (FFT: how many passes throughout your body/sec?)
- Neutrino flavor oscillation (change their flavors in flight!) discovered & confirmed throughout late 1990 and early 2000 (**2015 Nobel**)
  - Happens because flavor and mass eigenstates differ (oscillation probability dependent on  $L/E_\nu$ )

$$P(\nu_\mu \rightarrow \nu_e) = \sin^2 2\theta \sin^2 \left( \frac{1.27 \Delta m^2 L}{E_\nu} \right)$$

- Neutrinos have mass!  $\rightarrow$  SM in BIG trouble!

# The Next Big Thing - DUNE Experiment

- Stands for Deep Under Ground Neutrino Experiment
- US flagship long baseline (1300km)  $\left\{ \right.$  experiment
  - 1500m underground in an old South Dakota gold mine



**Yes, you are right, again!  
That Sturgis is right next door!**

May 17, 2024

DUNE FC Workshop 4

on Jan. 25, 2024

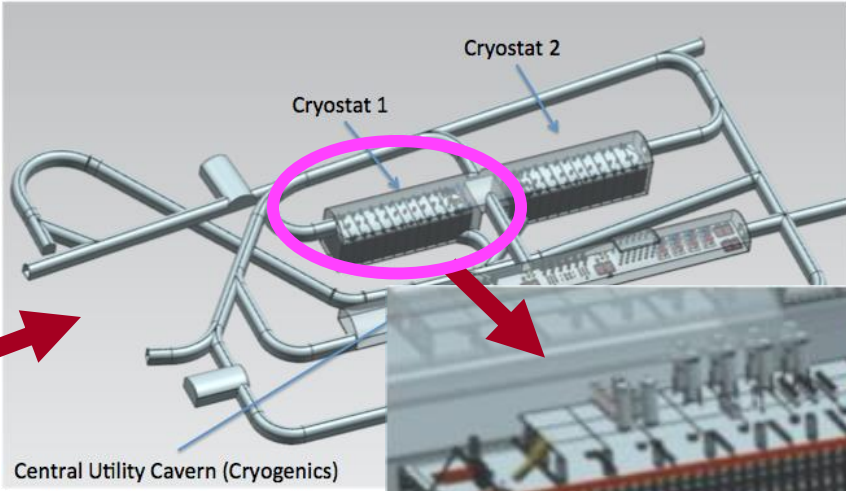
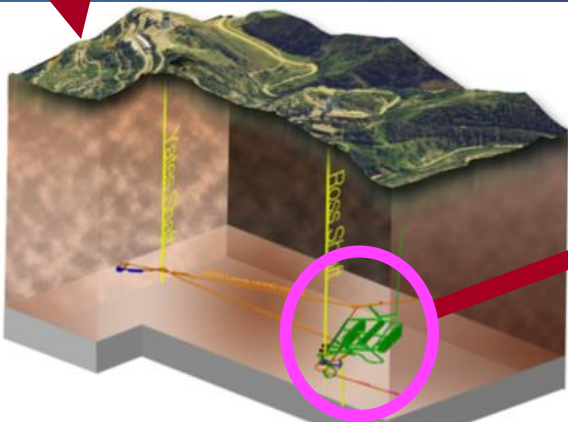
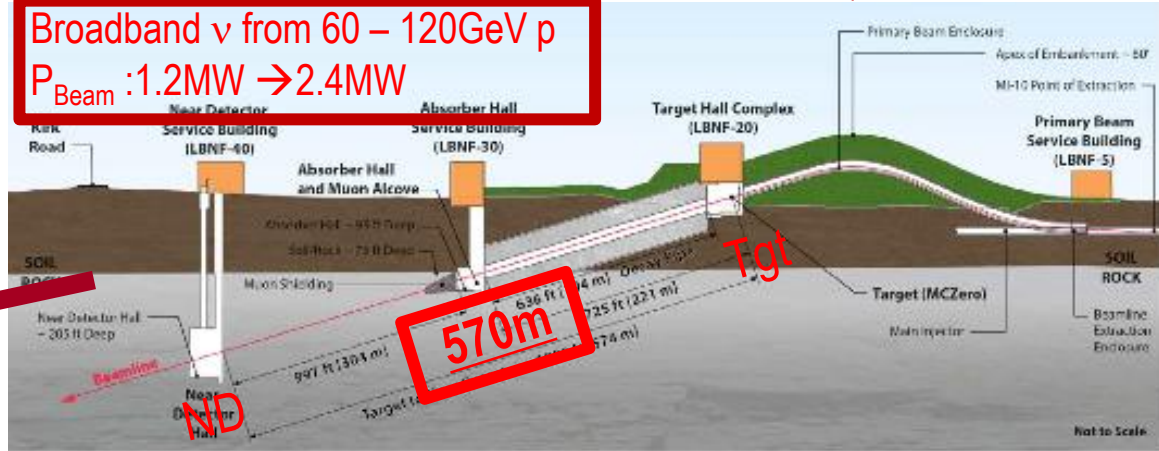
Experiment infra work begun

# Anatomy of DUNE



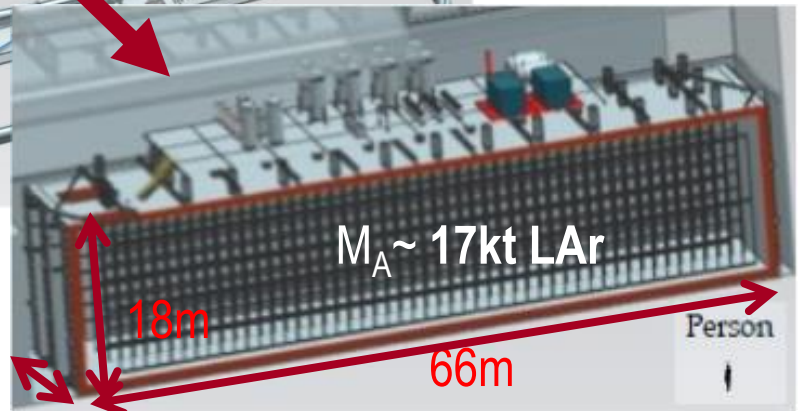
Broadband  $\nu$  from 60 – 120 GeV  $p$   
 $P_{\text{Beam}} : 1.2 \text{ MW} \rightarrow 2.4 \text{ MW}$

## LBNF $\nu$ Beam

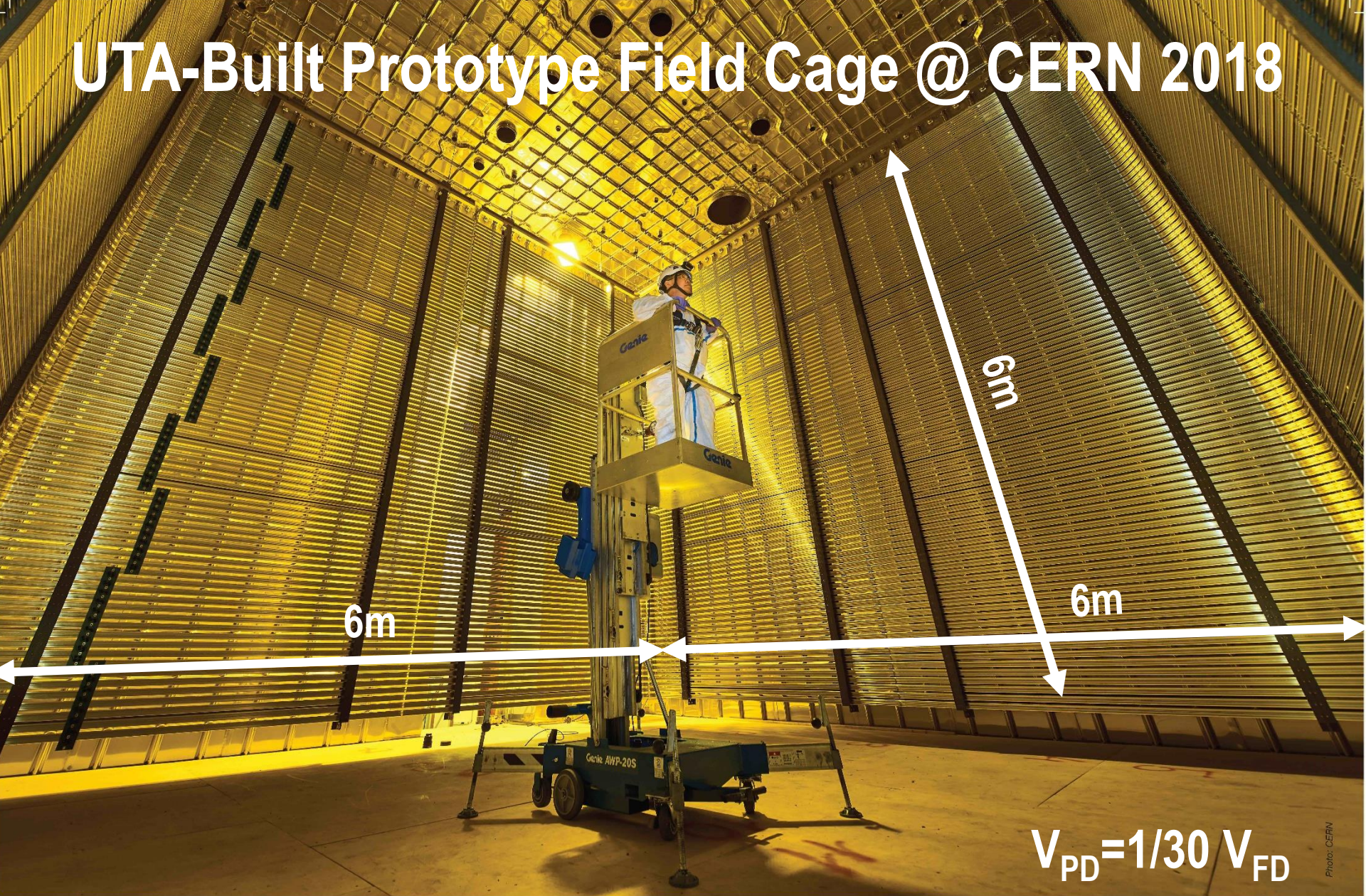


4 caverns for  $M_t \sim 70 \text{ kt LAr}$   
 (>85% complete)

LBNF Far Detector Site, SURF  
 1500m underground



# UTA-Built Prototype Field Cage @ CERN 2018



$$V_{PD} = 1/30 V_{FD}$$

Photo: CERN

ia @ CERN, June 2022

Eric Garcia, Gajendra Gurung & Atharva Dange @ CERN, March 2023



May 17, 2024

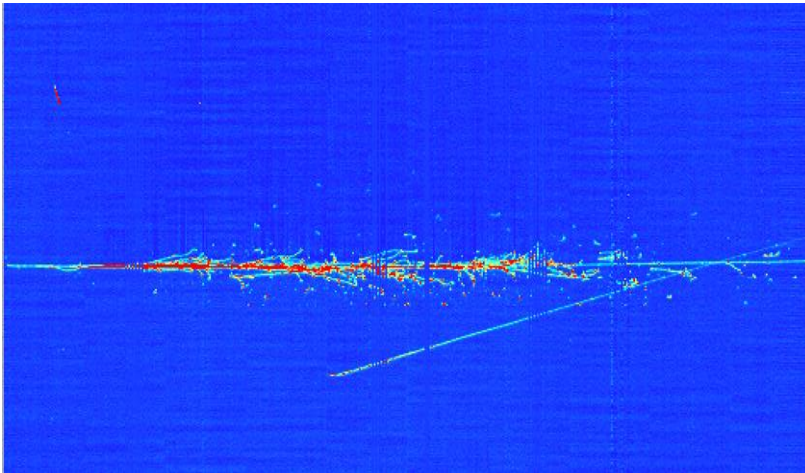
DUNE FC Workshop 4

8

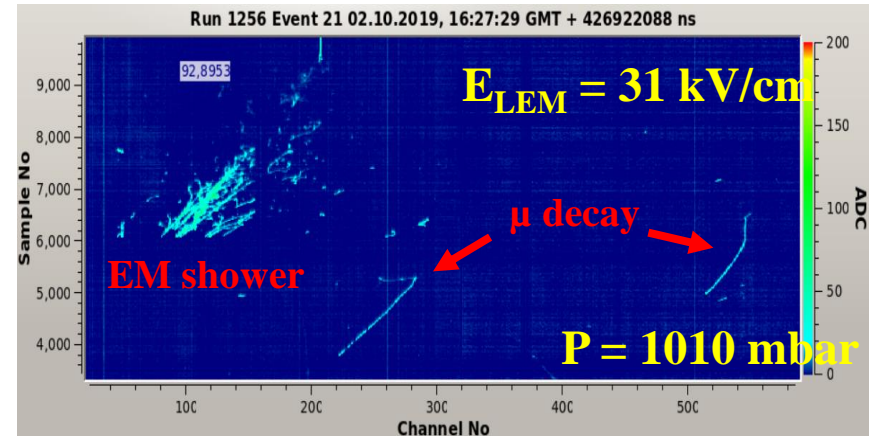


# Images in DUNE LAr-TPC Prototypes

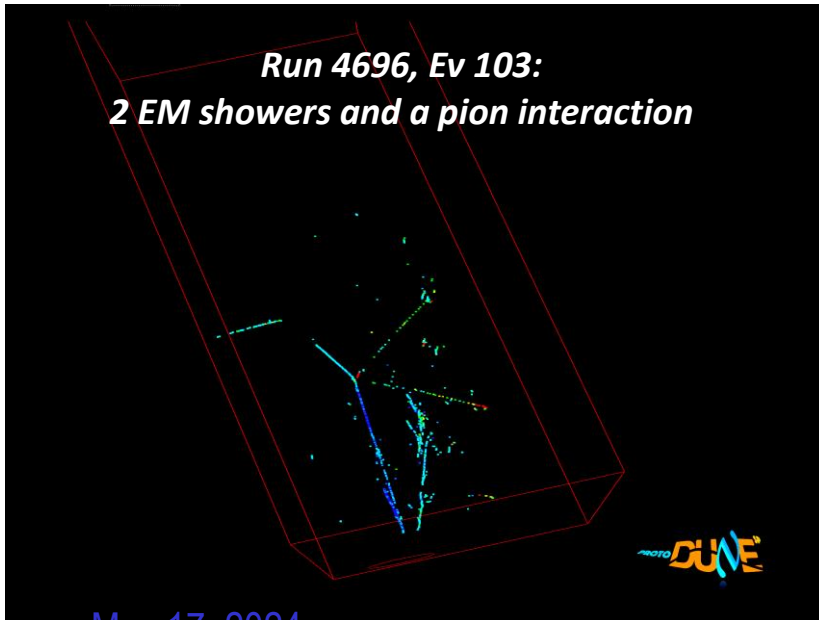
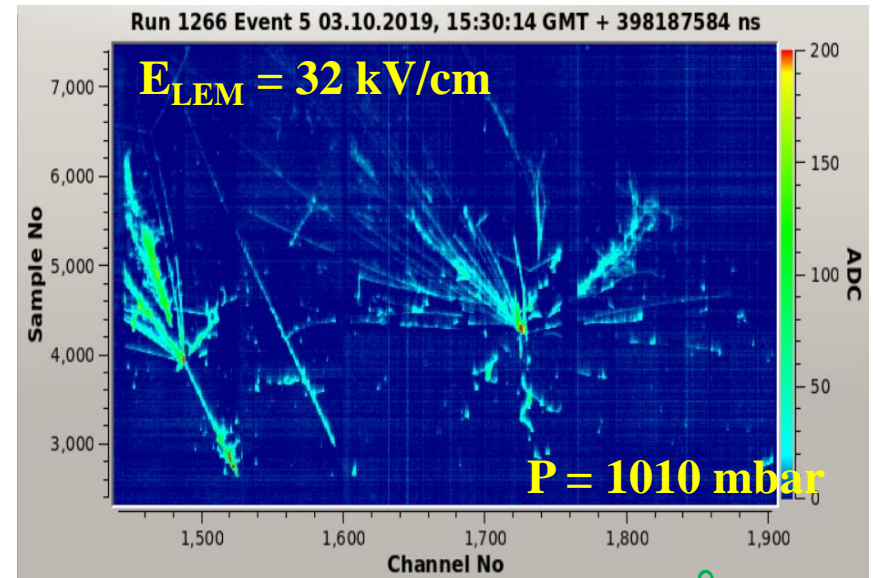
*Throughgoing  $\mu$*



*Electromagnetic shower + two muon decays*



*Multiple hadronic interactions in a shower*



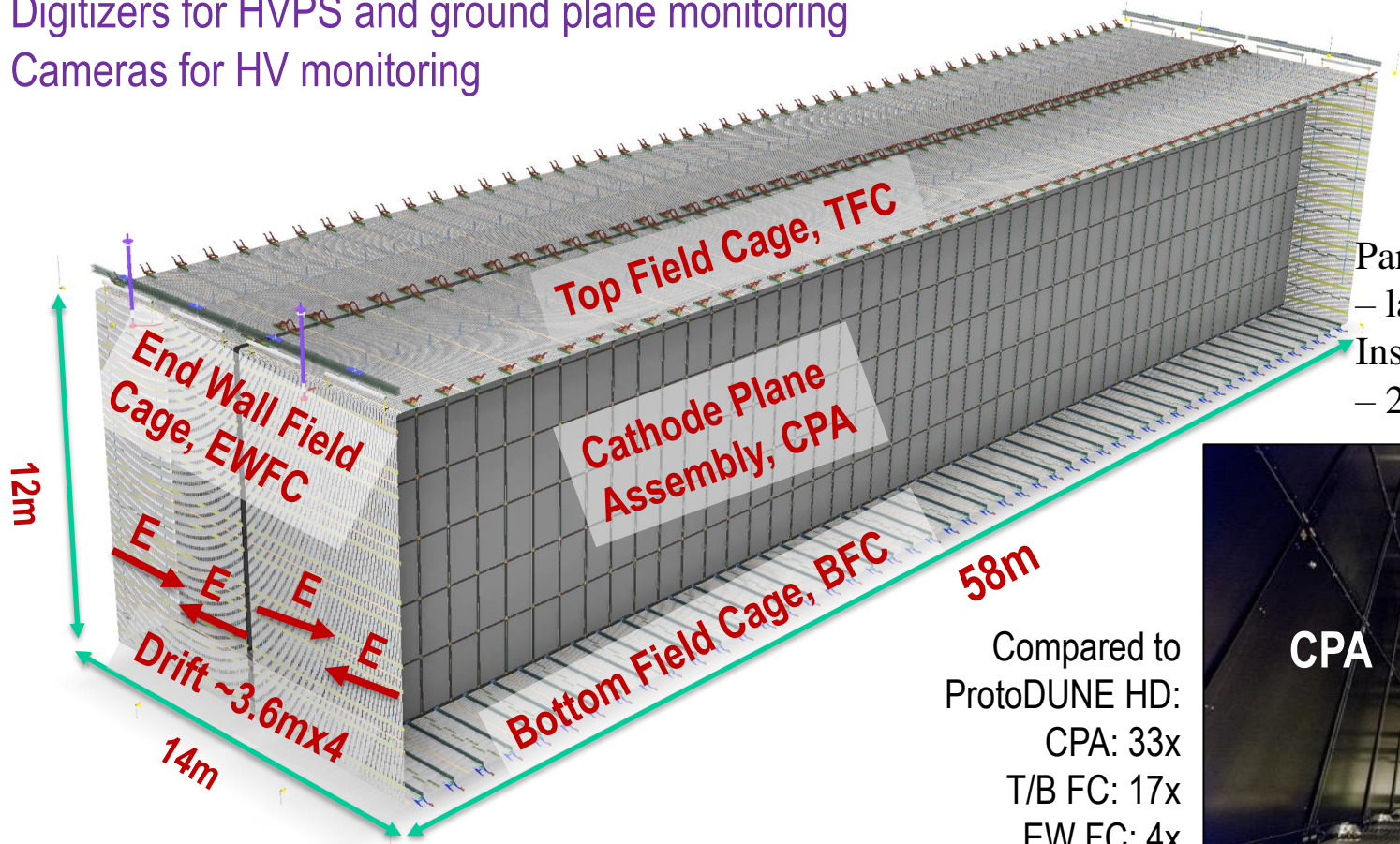
May 17, 2024

# Latest news on DUNE

- DUNE far detector cavern excavation completed Jan. 25 and the first set of steel parts for FD cryostat left Spain and to arrive in June
- Both ProtoDUNE HD to take beam in June and allotted a couple of weeks more of beam time
- ProtoDUNE VD PDS replacement work ongoing
- FD2 VD installation mechanical mock-up testing in this summer at CERN
  - Mock-up mechanical structure delayed due to safety calculations
  - Will have 3 members staying at CERN in July 22 – Aug. 9 for the module assembly and other related tasks
  - Will need 1 – 2 students for 2 – 3 weeks in the fall for installation exercise

# HVS Consortium Scope - FD1-HD TPC

- Design, fabricate, test and assemble:
  - 100 CPA resistive panels forming two cathode arrays (1400m<sup>2</sup>)
  - 100 top + 100 bottom field cage modules, 48 End Wall field cage modules (1728m<sup>2</sup>)
  - 2 sets of HV power supplies, cables, ripple filters, and feedthroughs
  - Digitizers for HVPS and ground plane monitoring
  - Cameras for HV monitoring



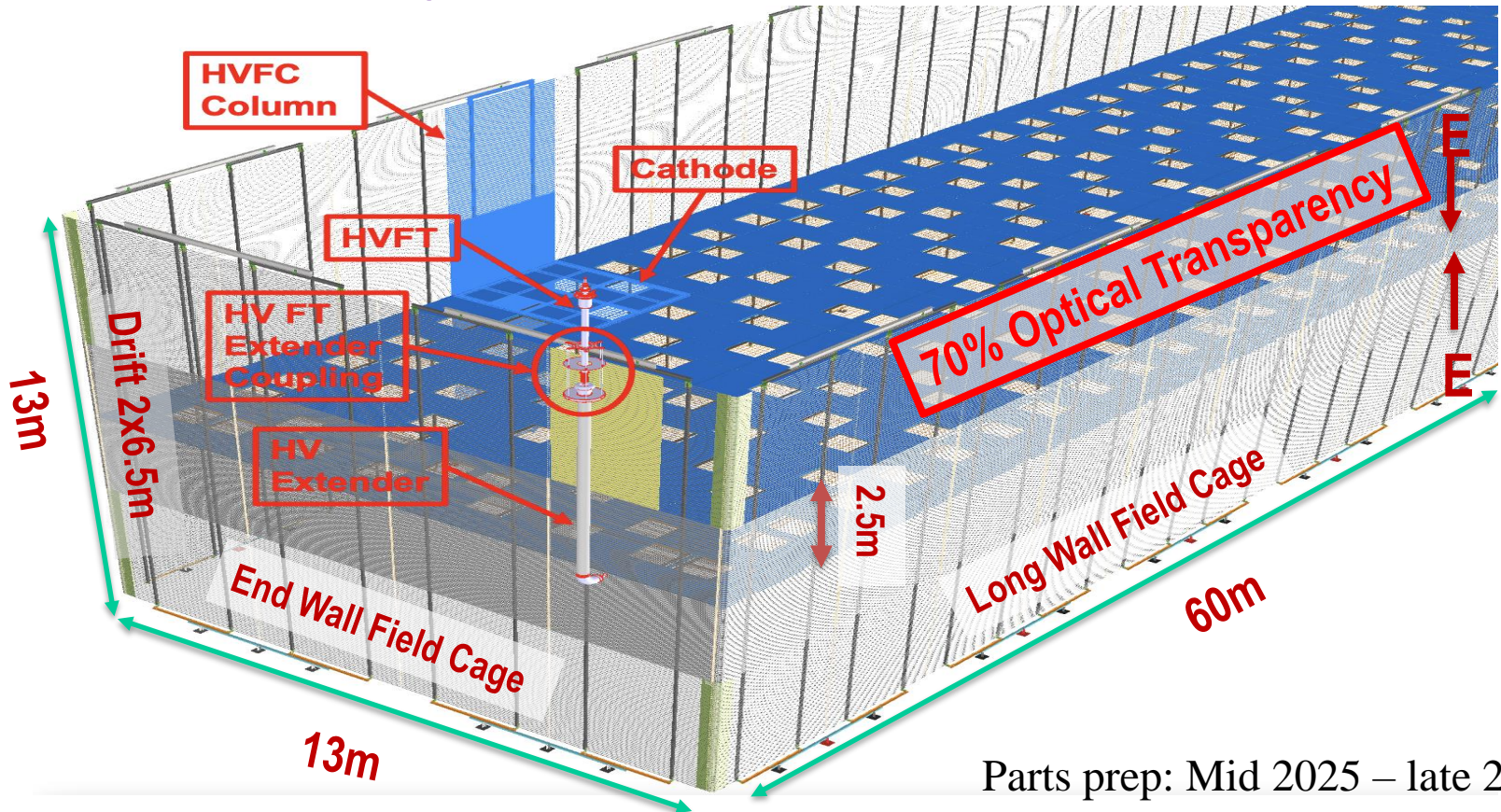
Parts prep: 2025  
– late 2025  
Installation: 2026  
– 2027 @SURF

Compared to  
ProtoDUNE HD:  
CPA: 33x  
T/B FC: 17x  
EW FC: 4x



# HVS Consortium Scope - FD2-VD TPC

- Design, fabricate, test and assemble:
  - 80 Full Unit Cathode Planes (780m<sup>2</sup>) with embedded PD
  - 192 field cage modules – 160 Long Wall and 32 End Wall modules (~1781m<sup>2</sup>)
  - One set of HV power supply, cable, ripple filter, and feedthrough
  - Digitizers for HVPS and current monitoring
  - Cameras for HV monitoring



Parts prep: Mid 2025 – late 2026  
Installation: 2027 – 2028@SURF

# What do we need to do?

- Exercise, learn and adhere to the QA/QC procedures
- Procure all FRP and other parts
- Construct all tools for module assembly and installation
- Train for profile bending
- Train and get used to the different types of parts
- Exercise the parts preparations, along with the QA/QC procedure and the use of the QA/QC tool
- Construct the HD and VD assembly tables and exercise module constructions for training
- Exercise the 3D printing of necessary QC jigs
- Prepare for production readiness review (PRR) for both HD and VD parts production → end of 2024 for VD and early 2025 for HD (driven by UMN?)

# Field Cage Installation Test Configuration

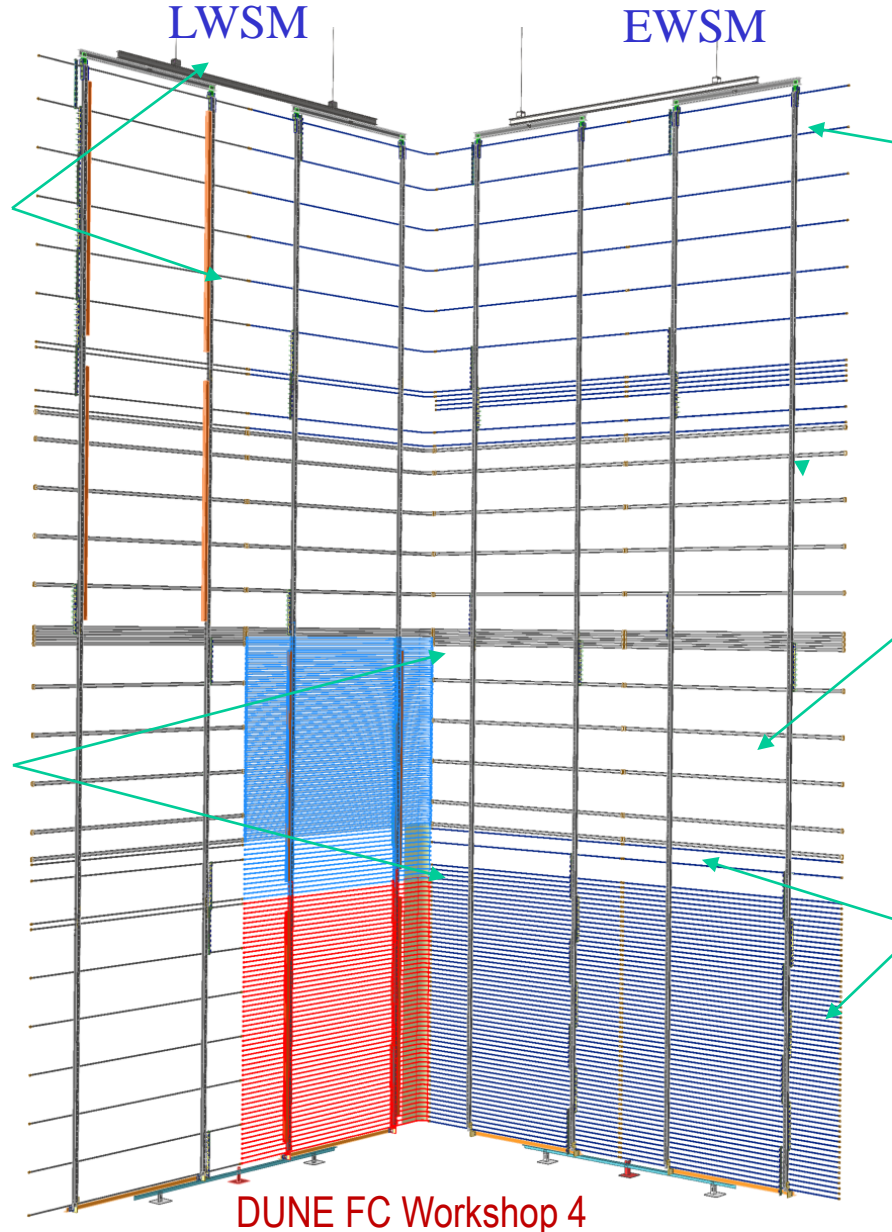
Two dummy LW modules with fiber conduits, and top profiles to demonstrate new fiber connection scheme

Make cathode/HV bus connections

Two full(?) LW modules with fiber conduits to demonstrate old fiber connection scheme.

Time and motion study on assembly speed.

Remaining LW modules are dummies with sparse profiles



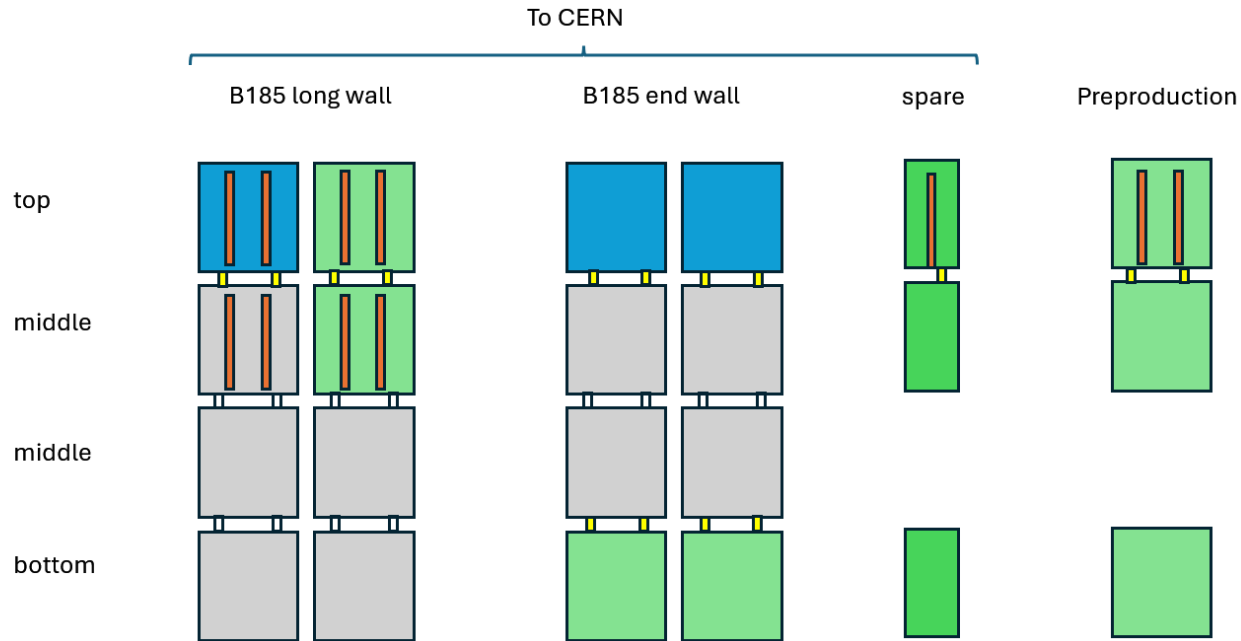
4 FC support flanges with lift rods

Six dummy EW modules with subset of profiles:

- Demonstrating cathode connection
- Demonstrating row 3 to row 4 interconnects

Two full EW modules to demonstrate final FC closing (one split in 2 half modules?)

# Mock-up Test and PreProduction Plan?



- Real beams and profiles
- Real beams and dummy profiles
- Spliced beam and dummy profiles
- Fiber conduit
- Plug, middle
- Plug, Al, slotted

Parts	Quantity to CERN
FRP beam, top	9
FRP beam, middle	3
FRP beam, bottom	5
FRP beam, spliced	14 middle, 4 bottom
Fiber conduit	9 + 2 struts channels
Plug, top	9
Plug, middle	13
Plug, Al, slotted	12

# What do we need to build for Mock-up?

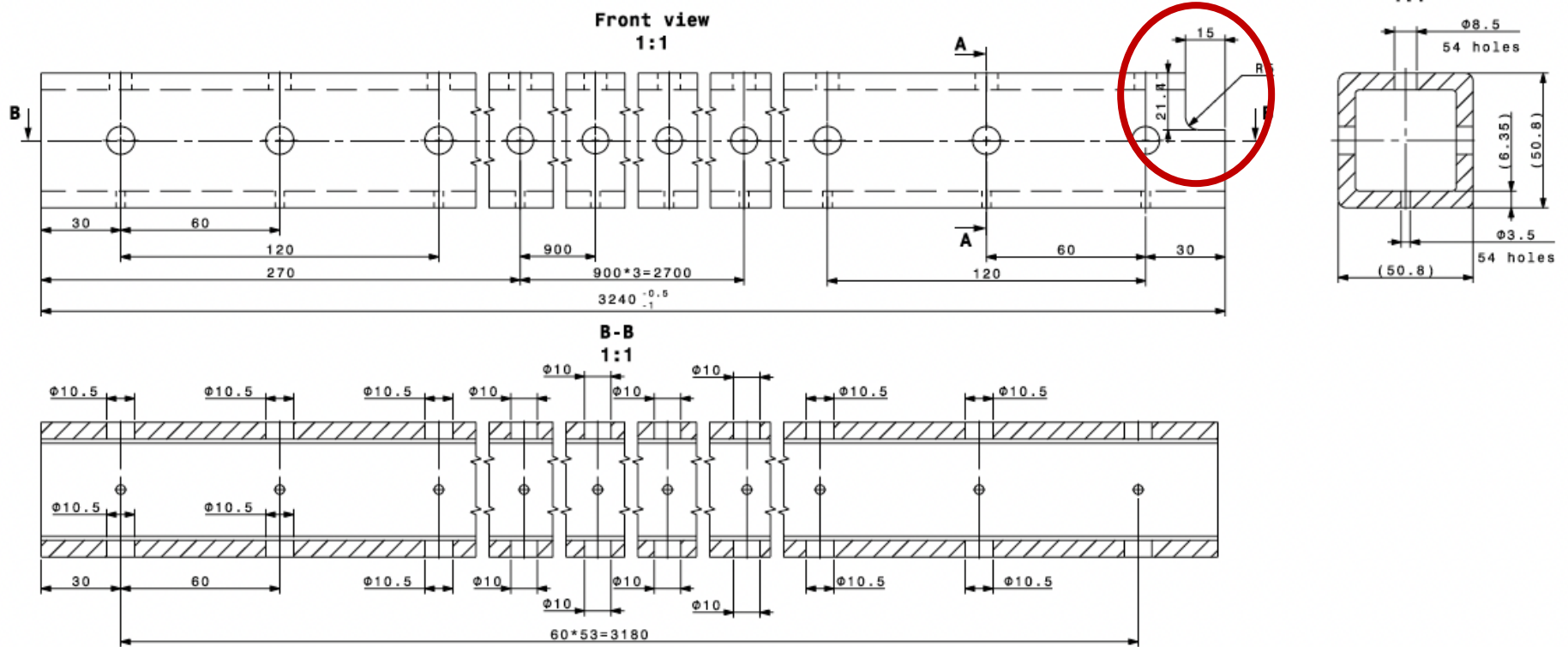
- Process and QC
  - FRP full size box beams from Liberty = 23 of which 19 out to CERN
    - TFC Box beams:  $4*2 + \text{Spare} = 11$  (9 out to CERN, 2 @UTA)
    - MFC Box beams:  $1*2 + \text{spare} = 5$  (3 out to CERN, 2 @UTA)
    - BFC Box beams:  $3*2 + \text{spare} = 7$  (4+1=5 out to CERN, 2@UTA)
  - Optical fiber conduit :  $16 + \text{spare} = 18$  (8+1=9 @CERN, 9@UTA)
  - Inserts
    - 6 hole mid box beam inserts:  $6*2 + \text{spare} = 15$  (12+1=13 @CERN, 2@UTA)
    - 3 hole top box beam inserts:  $4*2 + \text{spare} = 11$  (9@CERN, 2@UTA)
  - Custom made beams for dummy modules
    - UTA machine shop will make 18 each of 2.7m and 0.54m (14 mid+4bot) box beams + aluminum bx beam plugs of 18 two-hole pieces → these make up 14 TFC and 4 BFC beams for dummy modules
      - need to splice the two box beams with the Al box w/ the epoxy glue (all out to CERN)
    - 12 Al inserts for dummy module interconnect



# VD Top Module Parts

11 Liberty TFC FRP Box beams → 9 to CERN & 2 @ UTA

Position 01

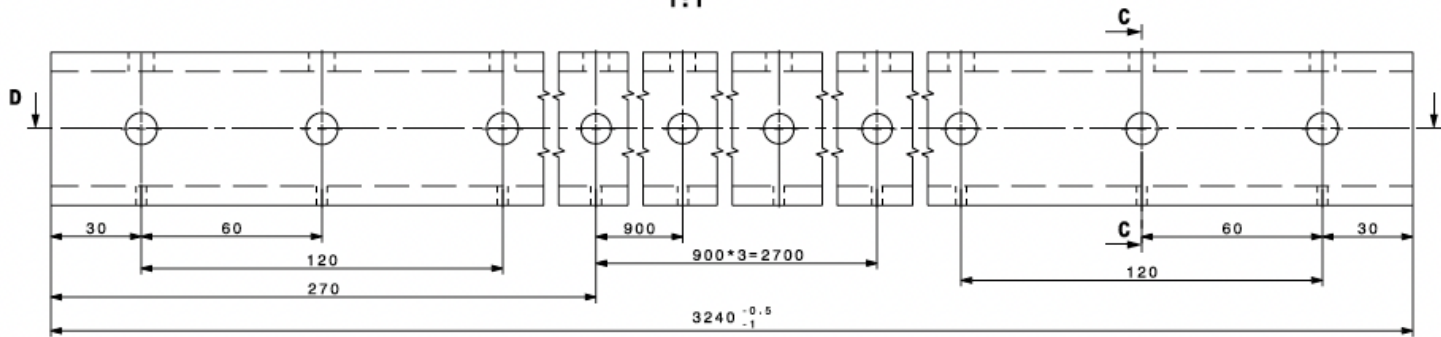


# VD Mid FC Module Parts

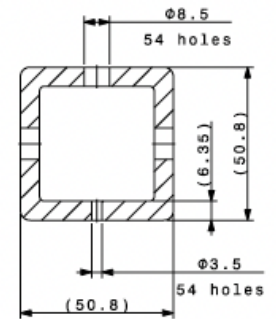
5 Liberty MFC FRP Box beams + 14 additional spliced MFC beams : Total 19  
➔ 3 Liberty + 14 spliced MFC to CERN & 2 Liberty MFC beams @UTA

Position 02

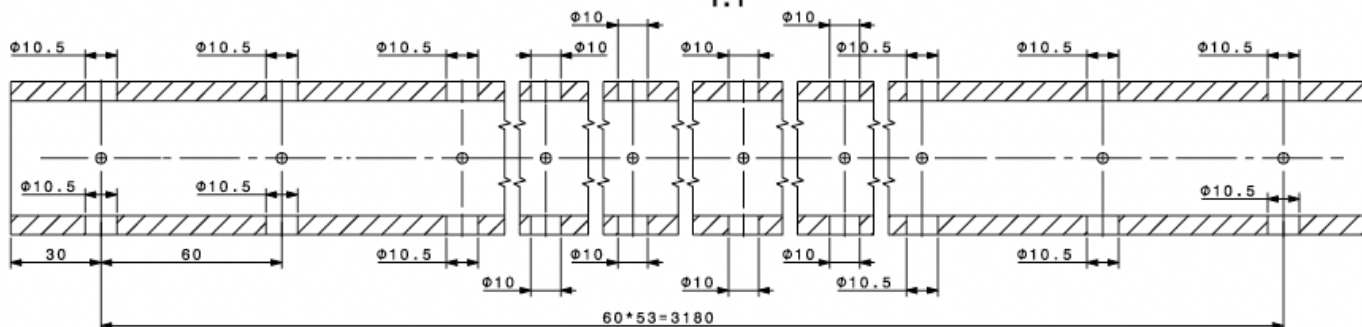
Front view  
1:1



C-C  
1:1



D-D  
1:1



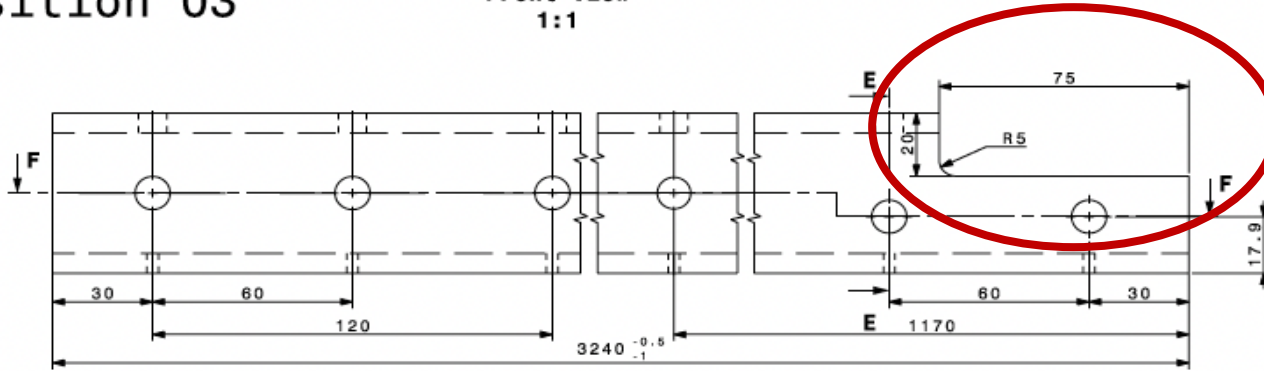
# VD Bottom FC Module Parts

7 Liberty BFC FRP Box beams + 4 Spliced BFC beams: Total 11

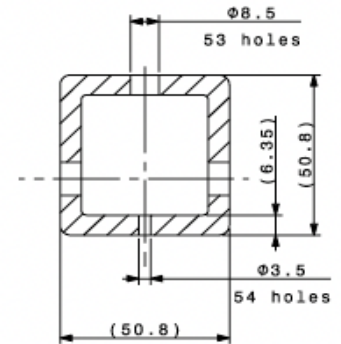
➔ 5 Liberty + 4 Spliced BFC beams to CERN, 2 Liberty BFC @UTA

Position 03

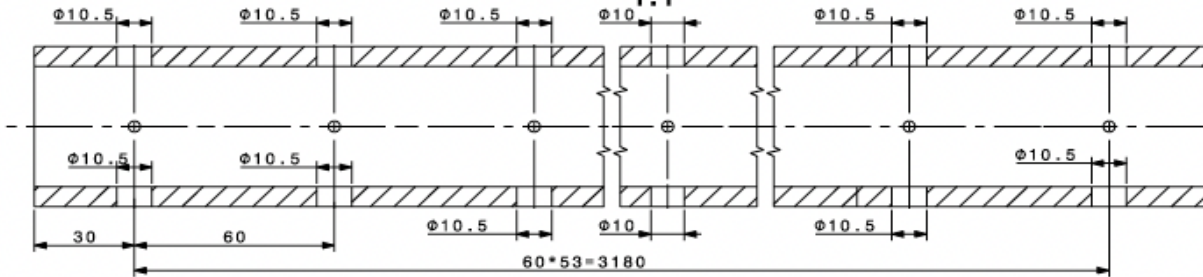
Front view  
1:1



E-E  
1:1



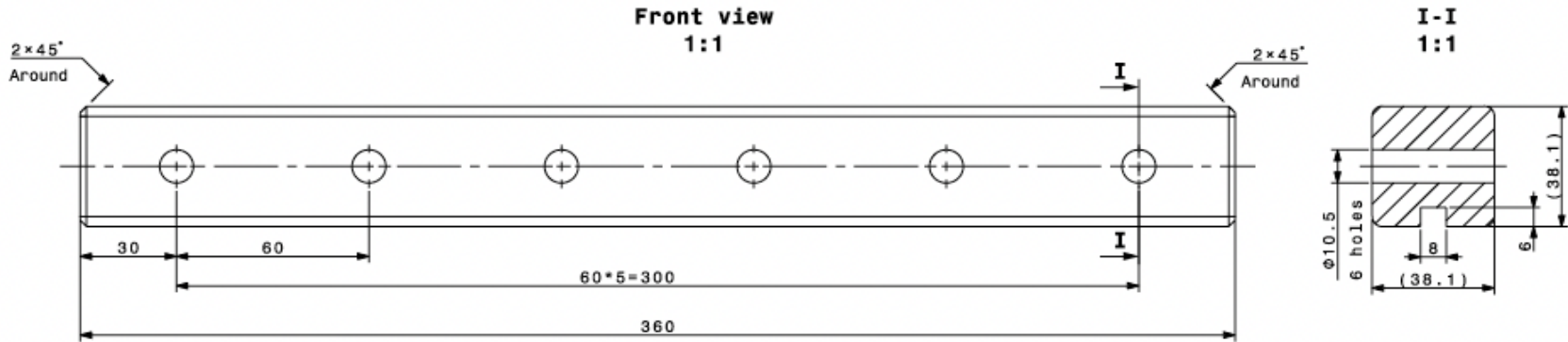
F-F  
1:1



# VD Inter-module Connections

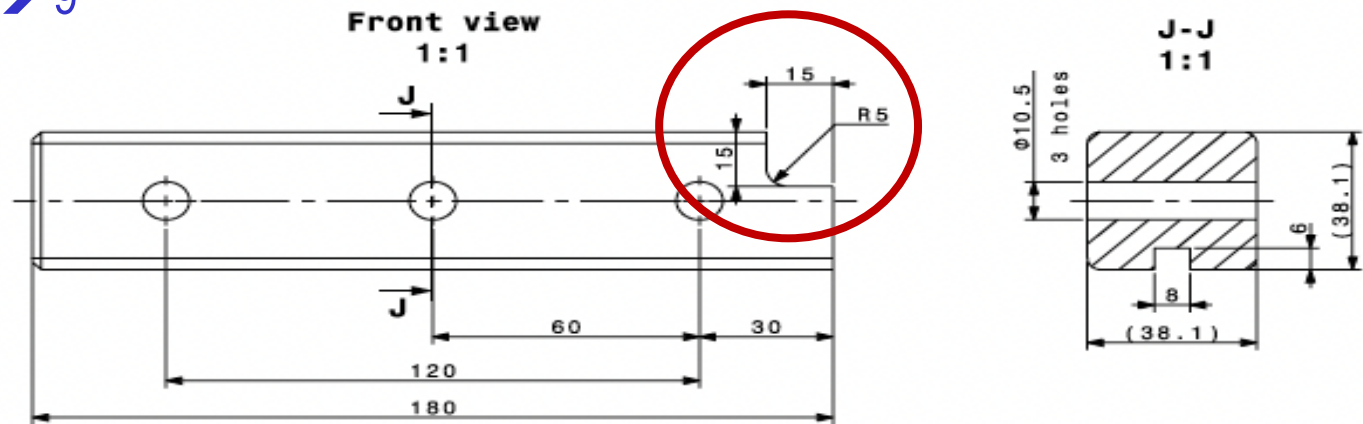
15 Liberty 6-hole FRP interconnect Insert + 12 Slotted Al from UTA machine shop: Total 17  
➔ 13 Liberty + 12 Slotted Al to CERN, 2 Liberty @ UTA

## Position 05



## Position 06

11 Liberty 3-hole FRP  
Insert top connection ➔ 9  
to CERN, 2@UTA



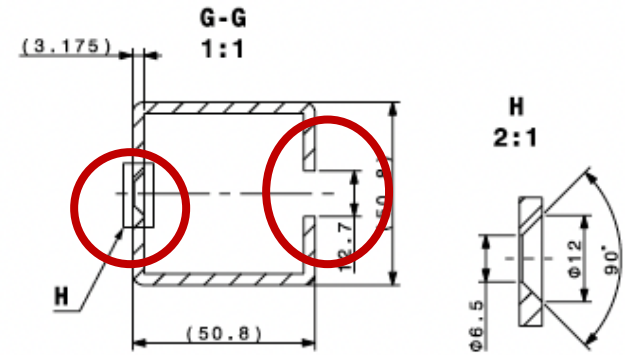
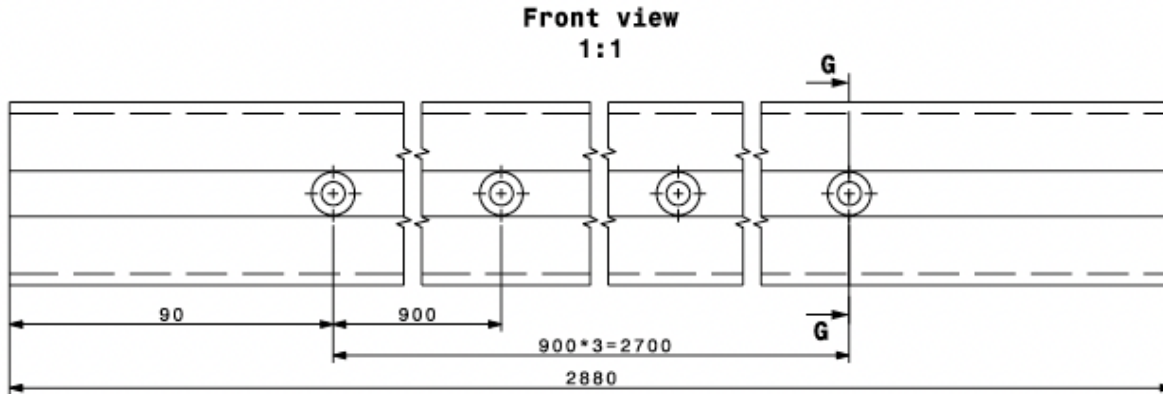
May 17, 2024

# VD Optical Fiber Conduit

Fiber conduit: full size from Liberty → 16 to CERN, 2@UTA)

Box beams with the slot cut out through the entire length and with four dish head screw holes for mounting on the FC frames

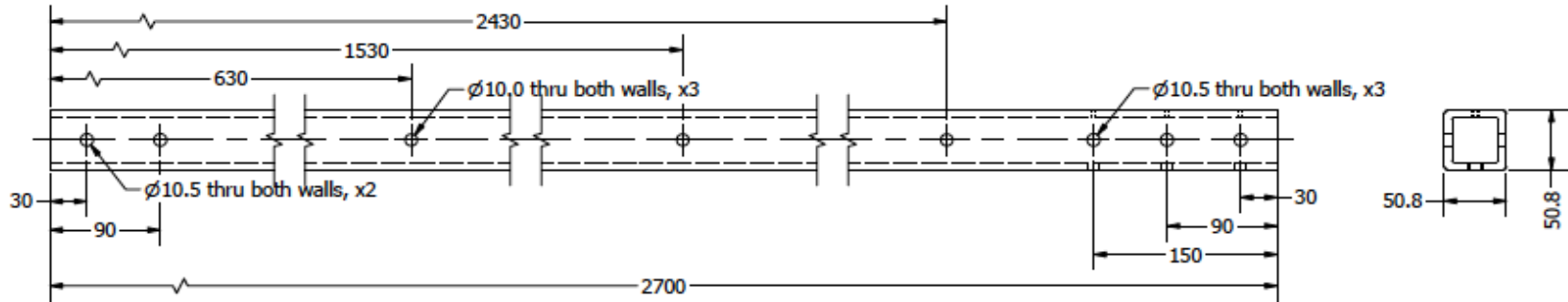
## Position 04



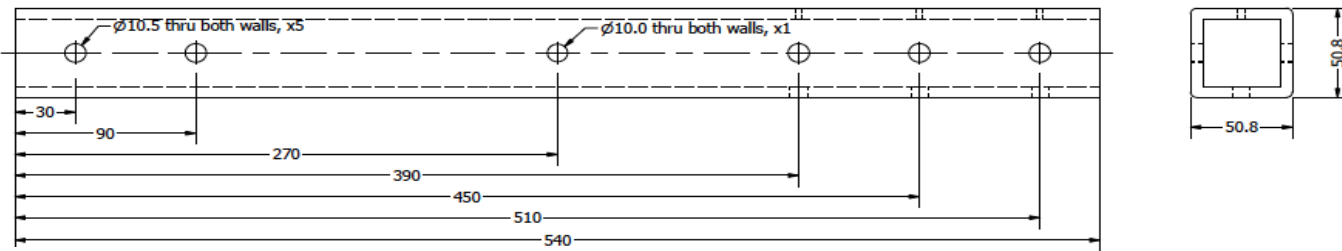
# Box beams for dummy modules

One each of long and short box beams with 2-hole Al box beam splicing the two with the epoxy (3M DP190 – McMaster 7467A72) and screws.

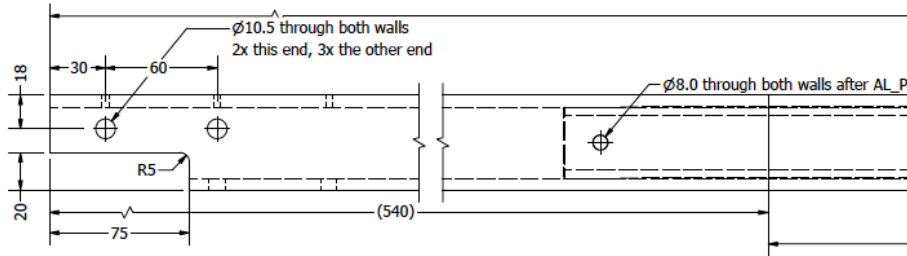
Long  
(2.7m)



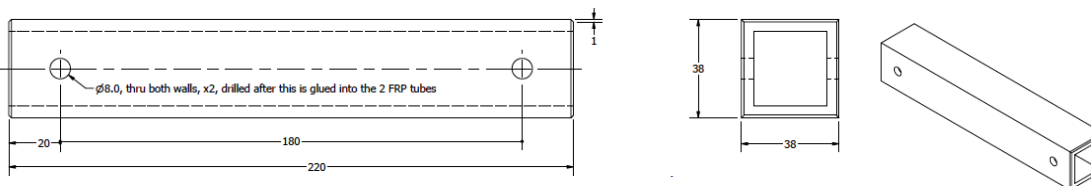
Short MFC  
(14x0.54m)



Short BFC  
(4x0.54m)



Al plug  
(18x0.22m)



# DUNE FD2-VD Parts Distribution Plan (5/17/24)

<b>Parts</b>	<b>Origin</b>	<b>Total</b>	<b>Send to CERN</b>	<b>Keep at UTA</b>
TFC Beams	Liberty	11	9	2
	UTA Spliced	0	0	0
	<b>Total</b>	<b>11</b>	<b>9</b>	<b>2</b>
MFC Beams	Liberty	5	3	2
	UTA Spliced	14	14	0
	<b>Total</b>	<b>19</b>	<b>17</b>	<b>2</b>
BFC Beams	Liberty	7	5	2
	UTA Spliced	4	4	0
	<b>Total</b>	<b>11</b>	<b>9</b>	<b>2</b>
Fiber Contuits	Liberty	18	9	9
	McMaster	4	4	0
	<b>Total</b>	<b>22</b>	<b>13</b>	<b>9</b>
6-hole Insert	Liberty	15	13	2
	UTA Slotted Al	12	12	0
	<b>Total</b>	<b>27</b>	<b>25</b>	<b>2</b>
3-hole Insert	Liberty	11	9	2
	UTA Produced	0	0	0
	<b>Total</b>	<b>11</b>	<b>9</b>	<b>2</b>

# Mock-up Test Timeline

- May 15: FRP Parts delivered & Visual Inspection
- May 16: Deliver the 23 drop pieces to Scott at the engineering machine shop for additional machining → return by the week of June 10
- May 31: Complete Liberty FRP Parts processing and QC
  - Further develop and refine the QC procedure (Sam C.)
  - Pick up the machined parts from the engineering machine shop and process them
- June 10: All machined drop pieces delivered from Engineering machine shop
- June 21: Complete splicing the parts to put together 18 full size MFC box beams and QC
- June 24: Crate and ship all parts to CERN
- By July 12: crate to arrive at CERN
- July 20: 3 UTA members depart to CERN
- July 22 – Aug. 10: 3 UTA students at CERN to participate in the Mock-up installation process, developing installation and module QC procedures



# Who's available?

- Gajendra Gurung
  - @FNAL: 5/24 – 6/7
  - @UTA: 6/8 – 6/20
  - Depart to CERN: 6/20
- Rohit Raut
  - @UTA : through 6/6
  - @CERN: 6/7 – 8/31
- Eric Garcia
  - @UTA: through 6/6
  - @INFN, Italy: 6/7 – 8/15
- Everyone else should be here through the end of June to finish preparing the parts and ship
- Each and everyone of you should take responsibility on getting these parts processed to highest quality and ship in a timely fashion

# Member Availability and Task Matrix

Weeks		wk 5/20	wk 5/27	wk 6/3	wk 6/10	wk 6/17	wk 6/24	wk 7/1	wk 7/8	wk 7/15	wk 7/22	wk 7/29	wk 8/5	wk 8/12	wk 8/19	wk 8/26	
Team Members	Gurung	UTA	FNAL	UTA	CERN												
	Raut	UTA	UTA		CERN						CERN						
	Garcia	UTA	UTA		INFN, Italy				CERN			CERN		UTA			
	Brown	UTA				UTA		CERN			CERN		UTA				
	Blanchard	UTA				UTA		CERN			CERN		UTA				
	Hernandez	UTA?								CERN							
	Chakraborty	UTA?								CERN							
	Vavilla	UTA?								CERN							
	Behanan	UTA?								CERN							
	Parris	UTA?								CERN							
Available members	UTA	10	9	9	8	8	7	7	7	7	5	5	5	7	8	8	
	CERN	0	0	0	2	2	2	2	2	2	5	5	5	2	2	2	
Tasks	Liberty QC	UTA															
	Splice QC				UTA												
	Crate&Ship							UTA									
	CERN Arrival										CERN						
	FC module Assembly												CERN				
Weeks	wk 5/20	wk 5/27	wk 6/3	wk 6/10	wk 6/17	wk 6/24	wk 7/1	wk 7/8	wk 7/15	wk 7/22	wk 7/29	wk 8/5	wk 8/12	wk 8/19	wk 8/26		

# Who's available?

- Gajendra Gurung
  - @FNAL: 5/24 – 6/7
  - @UTA: 6/8 – 6/20
  - Depart to CERN: 6/20
- Rohit Raut
  - @UTA : through 6/6
  - @CERN: 6/7 – 8/31
- Eric Garcia
  - @UTA: through 5/30
  - @INFN, Italy: 6/7 – 8/15
- Everyone else should be here through the end of June to finish preparing the parts and ship
- Each and everyone of you should take responsibility on getting these parts processed to highest quality and ship in a timely fashion
- Listen and fully adhere to the safety rules of the lab (Eric & Brad)

# Group's 3E Motto

**Demand Yourself Excellence!**

**Demand Each Other Excellence!**

**Help Each Other Become Excellent!**