

# FD1-HD and FD2-VD FC workshop

*Nov. 18, 2023*

*1<sup>st</sup> DUNE FC Workshop*

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# Workshop Fundamentals

- Goals : To train all group members with DUNE field cage module QC, tooling and assembly procedure
- Tasks to complete in the workshop
  1. Understand the scope and tasks involved in the project
  2. Complete construction of the HDFC assembly table, including the motor drive and operate
  3. Go through the module assembly procedure hands-on and finish constructing one HDFC module
  4. Go through the module parts QC procedure and exercise recording them into the QC iPADS

# 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  $L/E_\nu$ )

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

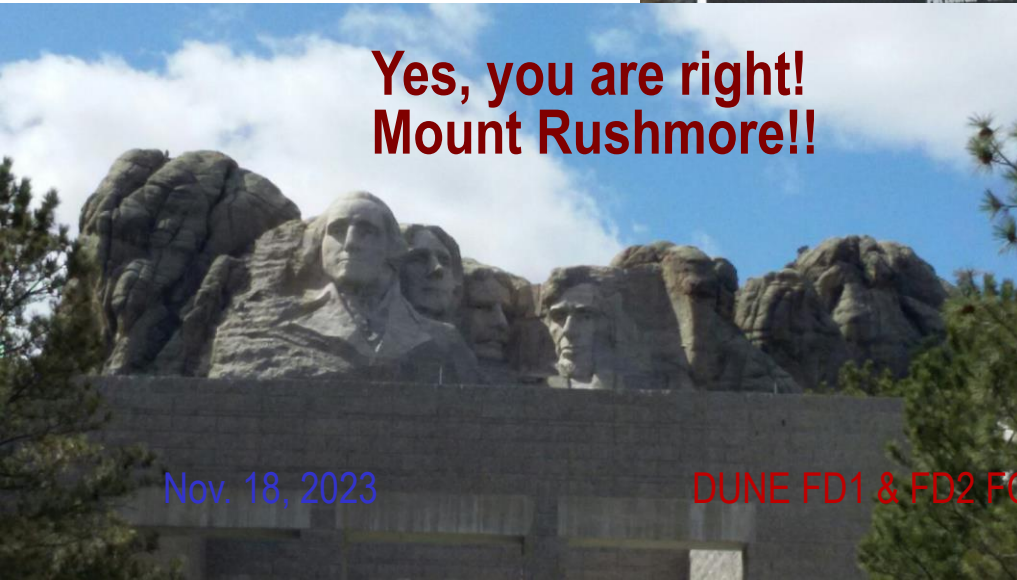
- Neutrinos have mass!  $\rightarrow$  SM in BIG trouble!

# The DUNE Experiment

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



**Yes, you are right!  
Mount Rushmore!!**

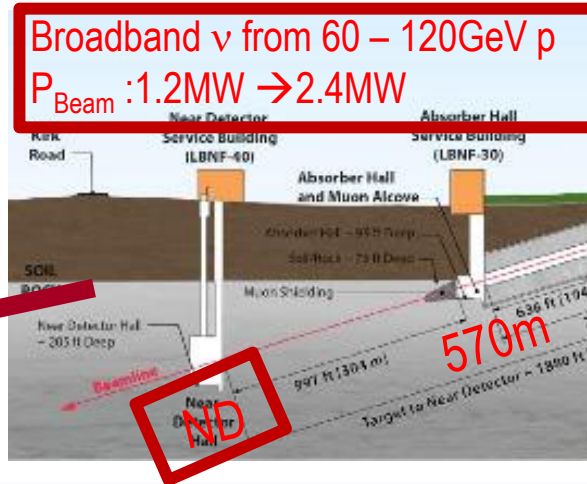


- 2002 Nobel Winning solar  $\nu$  detection by Ray Davis
- Many DM experiments
- New DUNE area being excavated (>60%)

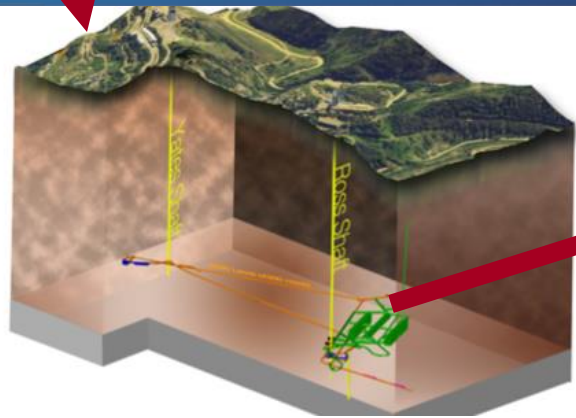
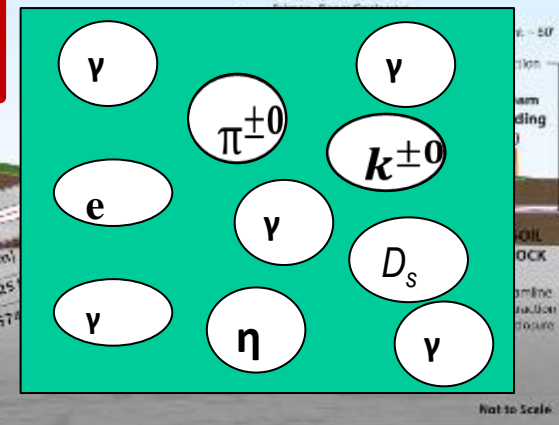
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DUNE FD1 & FD2 FC Workshop

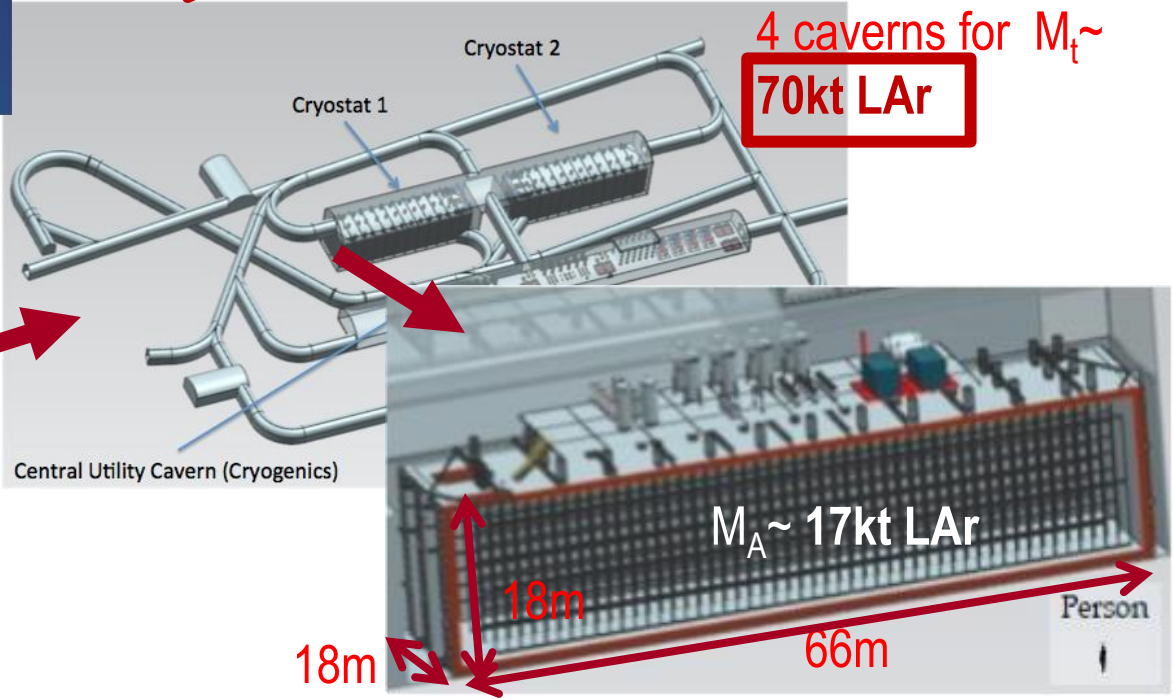
# Anatomy of DUNE



## LBNF $\nu$ Beam



LBNF Far Detector Site, SURF  
 1500m underground

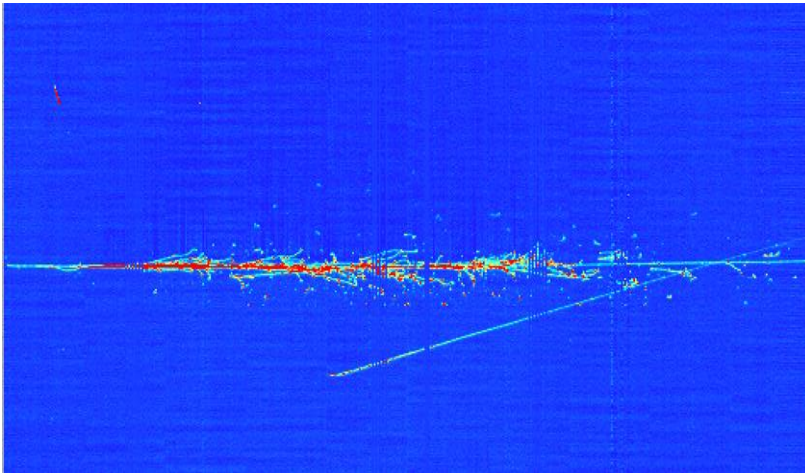


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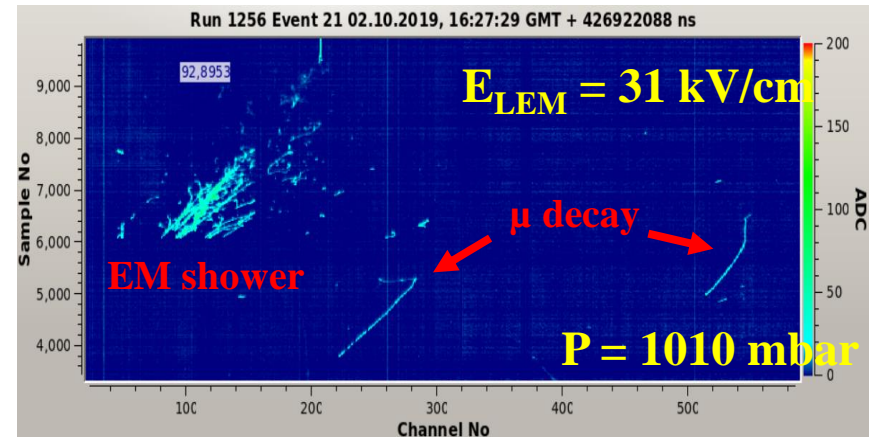
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# Images in DUNE LAr-TPC Prototypes

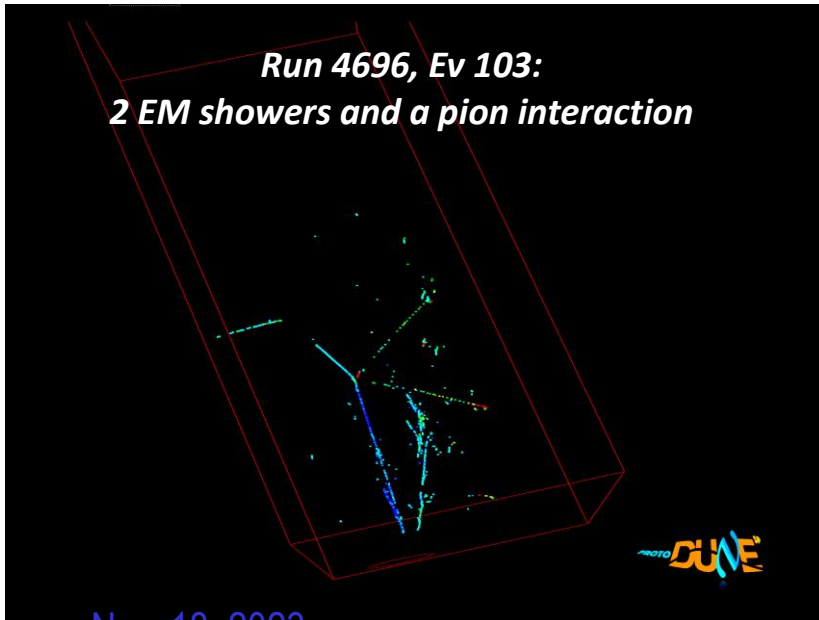
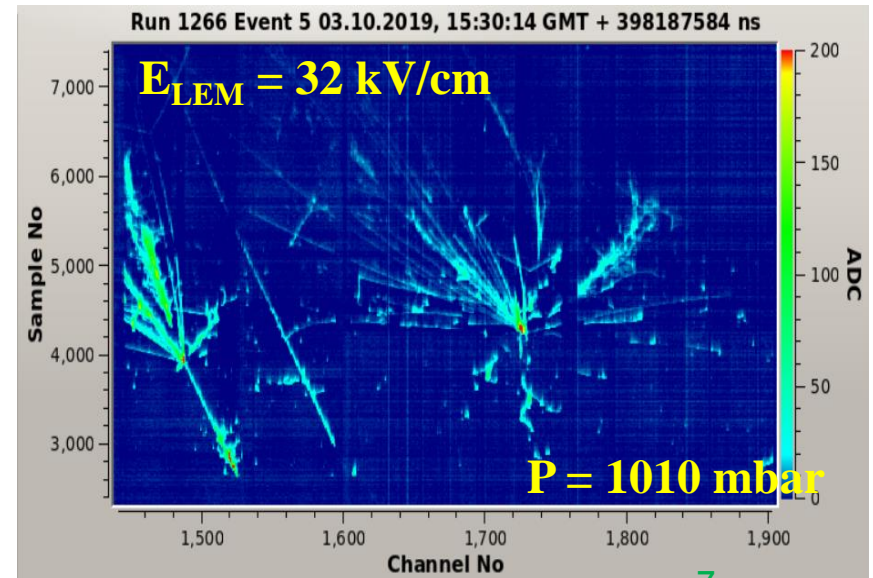
*Throughgoing  $\mu$*



*Electromagnetic shower + two muon decays*



*Multiple hadronic interactions in a shower*



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DUNE FD1 & FD2 FC Workshop 1

# Latest news on DUNE

- Both ProtoDUNE HD and VD cryostats to close by the end of Nov. → LAr fill to follow in Jan. 2024
  - Need to have someone (most likely grad students) out at CERN to help with the fill and the subsequent data taking operation
- FD2 VD installation mechanical mock-up testing in Summer 2024 at CERN
- UTA is expected to undergo 2 production readiness reviews (PRR) successively in summer (FD1 HD done w/ UMN) and fall 2024
- CPB120 renovation progressing well → floor painting to be done over the winter break
- Need to procure necessary tools and parts for tooling and build them



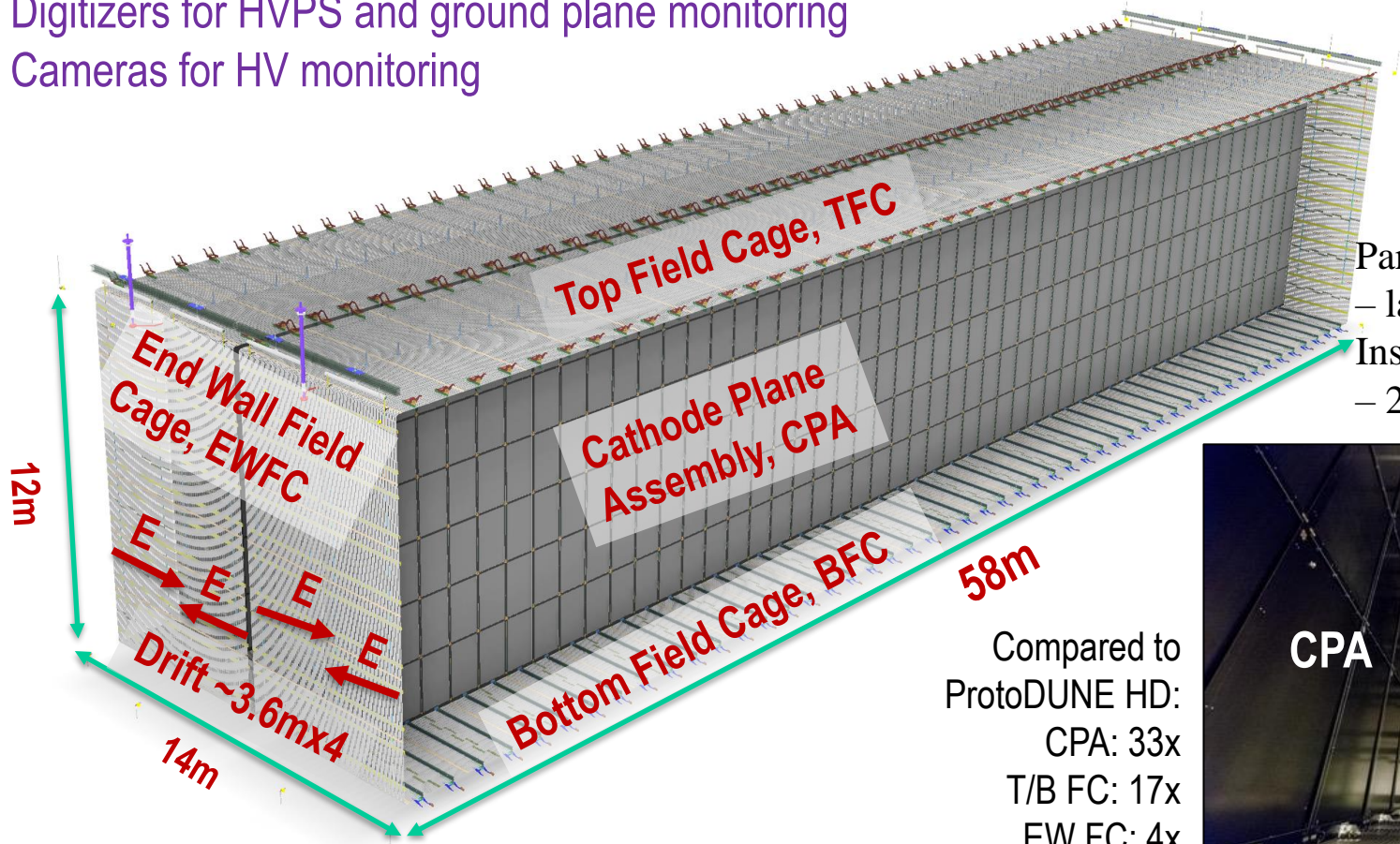
# LArTPC HVS Overview

- HVS provides a uniform E field to the active volume for the ionization electrons to drift to anodes
- Consists of three primary components

<ul style="list-style-type: none"> <li>- <b>HV Delivery</b> <ul style="list-style-type: none"> <li>• HV PS</li> <li>• HV Cable</li> <li>• HV Ripple Filter</li> <li>• HV Feedthrough</li> </ul> </li> </ul>	<p>warm</p>
<ul style="list-style-type: none"> <li>• <u>HV Extender (VD only)</u></li> <li>- <b>HV Distribution</b> <ul style="list-style-type: none"> <li>• Cathode Plane</li> <li>• HV Divider Boards</li> <li>• Field Cage</li> </ul> </li> <li>- <b>HV Return and Monitoring</b> <ul style="list-style-type: none"> <li>• HV Return</li> <li>• HV Monitoring</li> </ul> </li> </ul>	<p>cold</p>

# 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



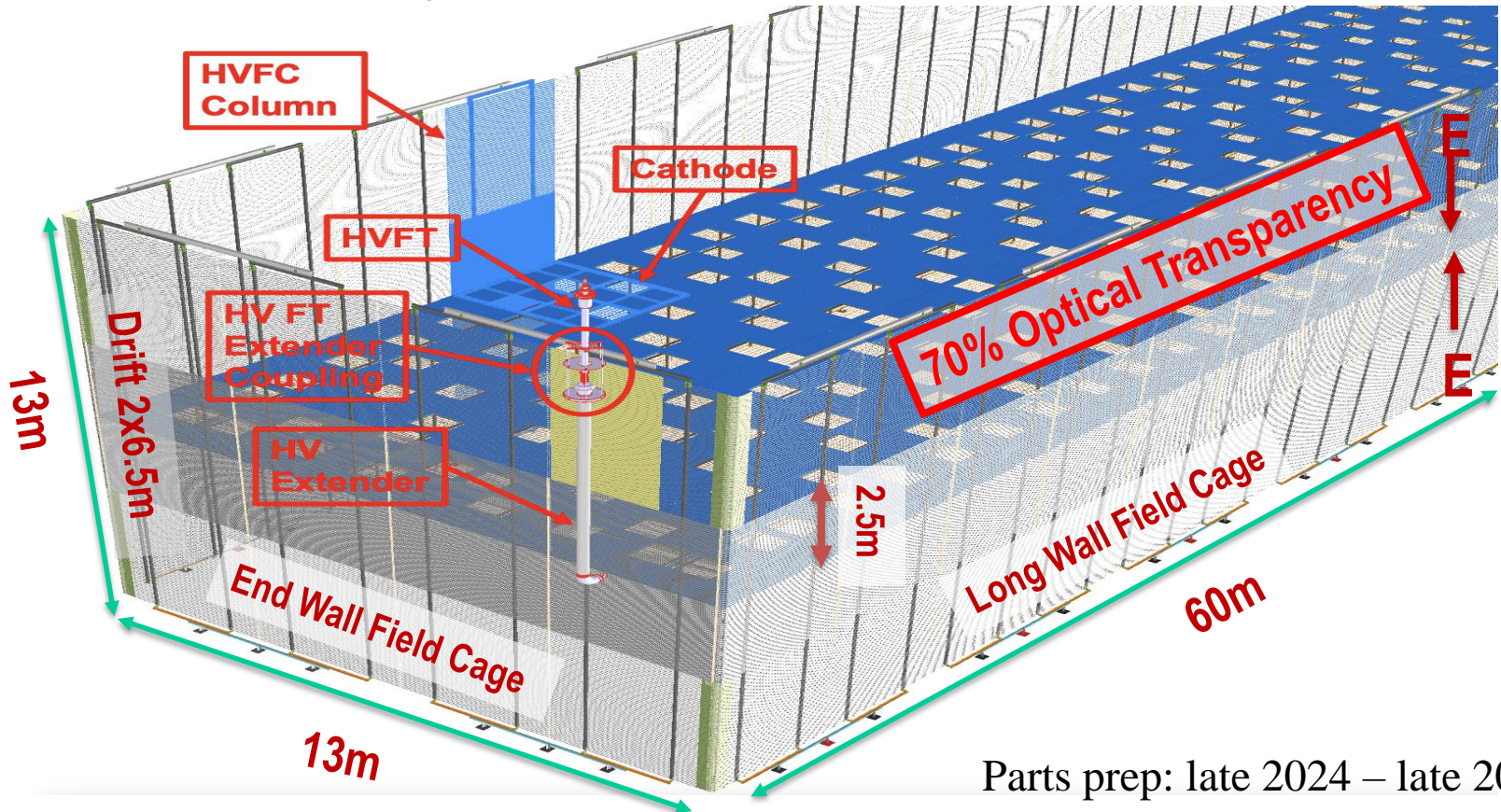
Parts prep: 2024  
– late 2025  
Installation: 2026  
– 2027 @SURF

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: late 2024 – late 2026  
Installation: 2027 – 2028@SURF

# Field Cage & the Scope of the Work

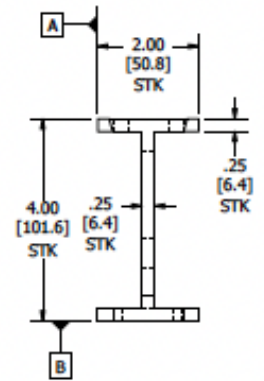
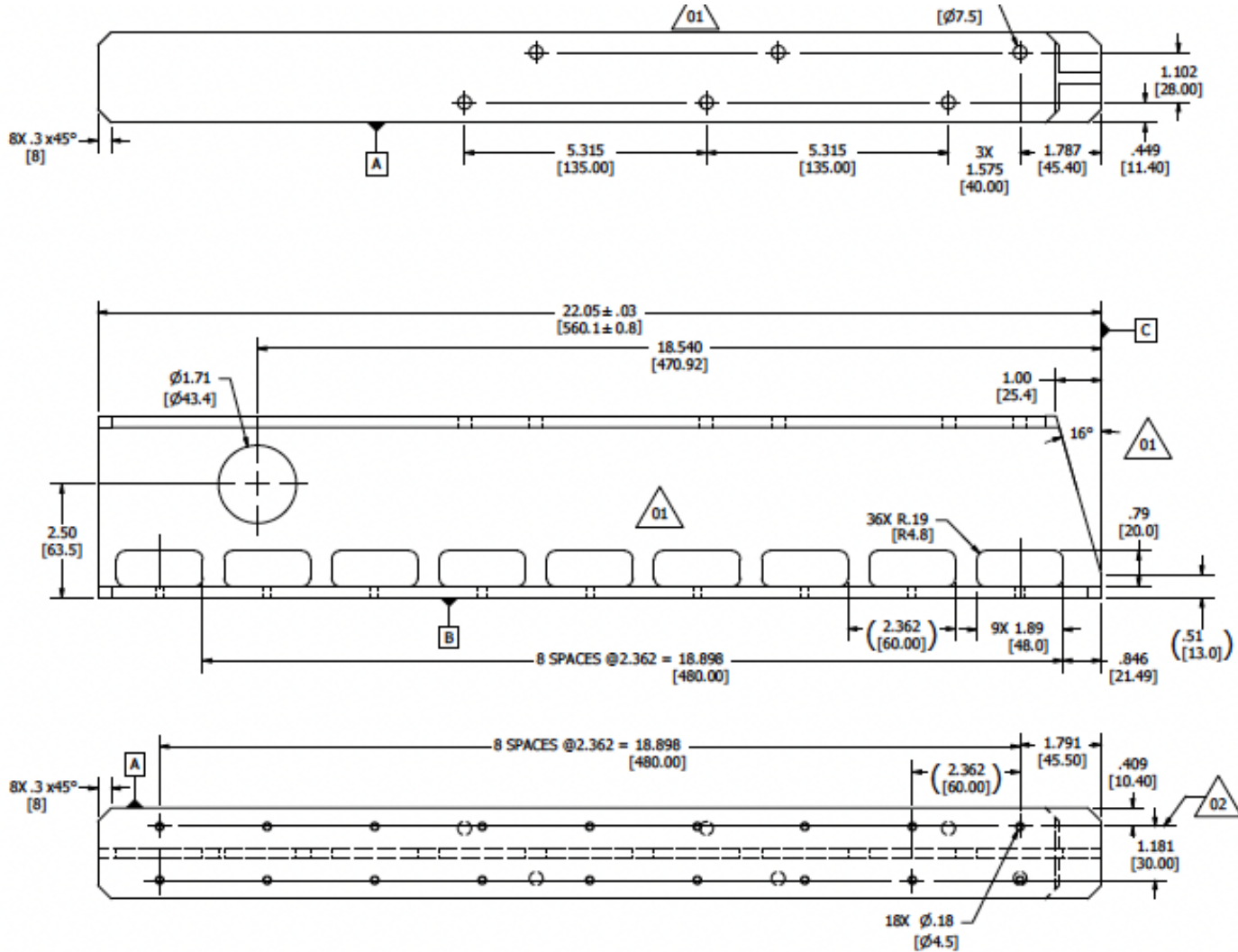
- FC surrounds the active volume and help provide a uniform E field
- The Scope: Construct the field cage (FC) for the FD1-HD and FD2-VD, integrate it into the HVS
- Teams
  - FD1-HD: UT Arlington, U. of Minnesota, LSU and CERN
  - FD2-VD: UT Arlington, William & Mary and CERN
- This entails to
  - Procure all the FC parts and devise the necessary tools
    - CERN is responsible for design and the aluminum profile electrodes
    - UTA is responsible for FRP and other parts
  - QC the FC parts
  - Package and ship QCed parts to SURF at least 6mo prior to the start of the construction
  - Assemble FC modules, including the HVDB mounting underground at SURF
  - Install FC into FD1-HD (Mar. 2027 – Dec. 2027) and FD2-HD (Feb. 2028 – June 2028)
  - Commission the HV system

# Parts for UTA to Process – FD1-HD

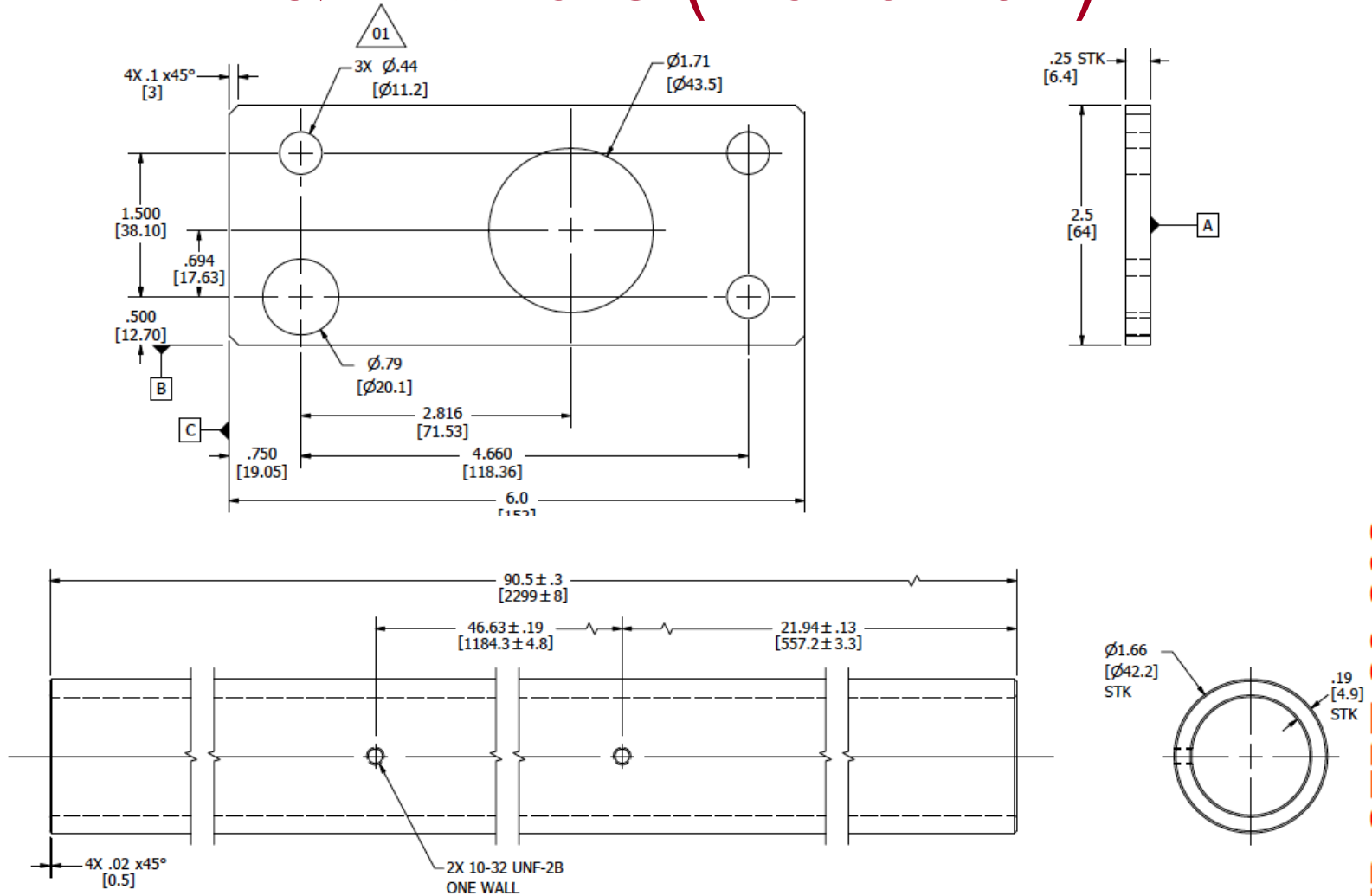
- Process parts for 100 BFC w/ 10% spare & deliver by 11/1/26
- Parts and numbers to process
  - For BFC Modules
    - FRP I-beams: 2/BFC + 10% spare → 200+20 = 220
    - FRP Latch Beams: 2/BFC + 10% spare → 200+20 = 220
    - G10 Reinforcement plates: 4/BFC + 10% spare → 400+40 = 440
    - BFC Lifting Bar: 1/BFC + 2% spare → 100+2 → 102
    - Lifting Plates: 2/FC → 8 total (already in hand)
    - All necessary hardware : screws, lock washers, flat washers, nuts
  - Tooling
    - 2 FC assembly tables : One to be shipped to SURF
    - Any tools for installation



# FD1-HD Latch – Beam (process 220)



# FD1-HD Reinforcement Plates (process 440) & Lift Bars (make 102)

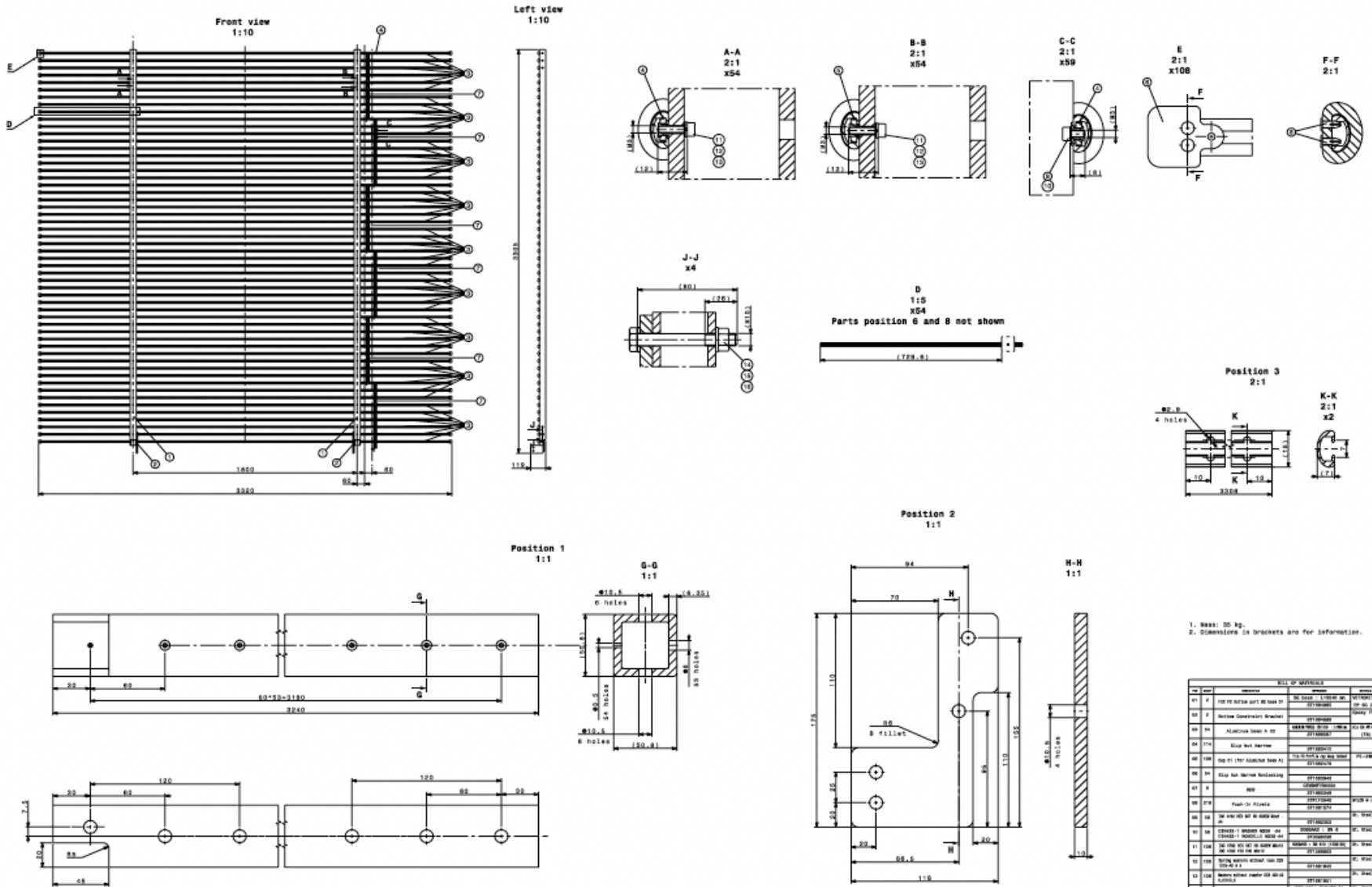




# Parts for UTA to Process – FD2-VD

- Process parts for 192 FC w/ 10% spare & deliver by 9/1/27 → 2\*3 different types of modules , long wall/end wall \* top/middle/bottom
- Parts and numbers to process
  - FC Module
    - FRP Box-beams: 2/FC + 10% spare →  $384 + 38 = 422$
    - FRP Box beam insert for inter-module connection :2/FC+10% spare →  $384+38$
    - Bottom stabilizers : 2/FC column + 10% spare:  $2*48*1.1=106$
    - Top stabilizers: 2/FC column + 10% spare:  $2*48*1.1=106$
    - Top yoke: 1/FC column + 10% spare:  $1*48*1.1=53$
    - Top SM I-beams: 1/SM + 10% spare:  $1*24*1.1=26$
    - All necessary hardware: screws, lock washers, flat washers, nuts, etc
  - Tooling
    - 2 profile bending tools: stay at UTA
    - 3 FC assembly stands : Two to be shipped to SURF, 1 at UTA
    - 28 FC Storage carts: all to be shipped to SURF
    - 3 scaffolding structure for module assembly: 2 to be shipped to SURF
    - 4 installation tripods: all to SURF
    - 1 gantry crane for completed module lifting and insertion into the storage cart
    - 4 module installation carts: all to SURF




# FD2-VD Long-wall Bottom Module (48)



BILL OF MATERIALS					
NO	DESCRIPTION	QUANTITY	UNIT	REMARKS	REF. NO.
01	FOR PC LONG WALL BOTTOM PART	1	PC		
02	ALUMINUM BRACKET A 10	2	PC		
03	ALUMINUM BRACKET A 10	2	PC		
04	ALUMINUM BRACKET A 10	2	PC		
05	ALUMINUM BRACKET A 10	2	PC		
06	ALUMINUM BRACKET A 10	2	PC		
07	ALUMINUM BRACKET A 10	2	PC		
08	ALUMINUM BRACKET A 10	2	PC		
09	ALUMINUM BRACKET A 10	2	PC		
10	ALUMINUM BRACKET A 10	2	PC		
11	ALUMINUM BRACKET A 10	2	PC		
12	ALUMINUM BRACKET A 10	2	PC		
13	ALUMINUM BRACKET A 10	2	PC		
14	ALUMINUM BRACKET A 10	2	PC		
15	ALUMINUM BRACKET A 10	2	PC		
16	ALUMINUM BRACKET A 10	2	PC		
17	ALUMINUM BRACKET A 10	2	PC		
18	ALUMINUM BRACKET A 10	2	PC		
19	ALUMINUM BRACKET A 10	2	PC		
20	ALUMINUM BRACKET A 10	2	PC		
21	ALUMINUM BRACKET A 10	2	PC		
22	ALUMINUM BRACKET A 10	2	PC		
23	ALUMINUM BRACKET A 10	2	PC		
24	ALUMINUM BRACKET A 10	2	PC		
25	ALUMINUM BRACKET A 10	2	PC		
26	ALUMINUM BRACKET A 10	2	PC		
27	ALUMINUM BRACKET A 10	2	PC		
28	ALUMINUM BRACKET A 10	2	PC		
29	ALUMINUM BRACKET A 10	2	PC		
30	ALUMINUM BRACKET A 10	2	PC		
31	ALUMINUM BRACKET A 10	2	PC		
32	ALUMINUM BRACKET A 10	2	PC		
33	ALUMINUM BRACKET A 10	2	PC		
34	ALUMINUM BRACKET A 10	2	PC		
35	ALUMINUM BRACKET A 10	2	PC		
36	ALUMINUM BRACKET A 10	2	PC		
37	ALUMINUM BRACKET A 10	2	PC		
38	ALUMINUM BRACKET A 10	2	PC		
39	ALUMINUM BRACKET A 10	2	PC		
40	ALUMINUM BRACKET A 10	2	PC		
41	ALUMINUM BRACKET A 10	2	PC		
42	ALUMINUM BRACKET A 10	2	PC		
43	ALUMINUM BRACKET A 10	2	PC		
44	ALUMINUM BRACKET A 10	2	PC		
45	ALUMINUM BRACKET A 10	2	PC		
46	ALUMINUM BRACKET A 10	2	PC		
47	ALUMINUM BRACKET A 10	2	PC		
48	ALUMINUM BRACKET A 10	2	PC		

# FD2-V

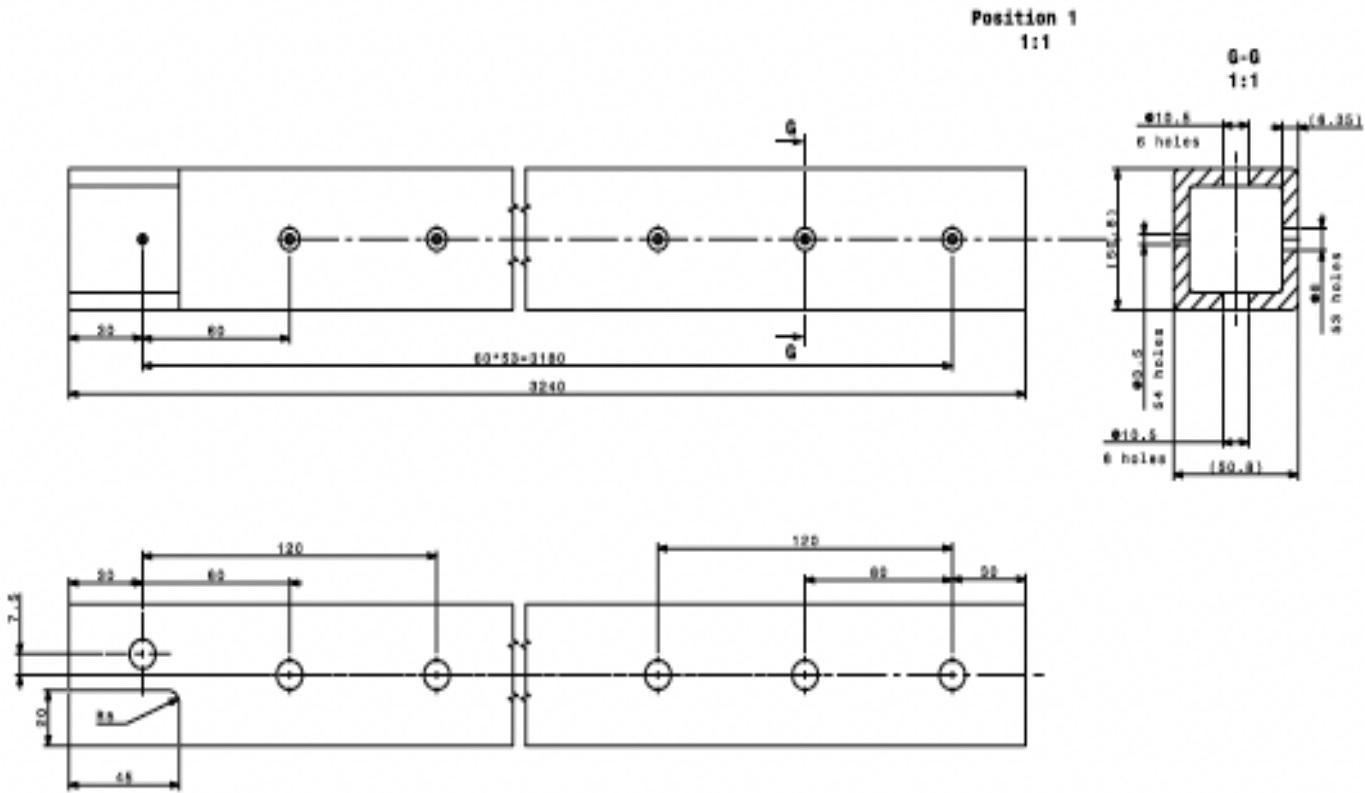
# om FC

BILL OF MATERIALS					
POS	QUANT	DESIGNATION	REFERENCE	MATERIAL	EDH SCEN
01	2	FD2 FC Bottom part SQ beam 01	SQ beam : L=3240 mm	VETRONIT ®	
			ST1684965	EP GC 201	
02	2	Bottom Constraint Bracket		Epoxy FR-4	
			ST1684889		
03	54	Aluminum beam A 03	ALUMINIUM PROFIL 3013133 : L=3308 mm	Alu EN AW-6061	
			ST1688567	(T6)	
04	114	Slip Nut Narrow			
			ST1683412		
05	108	Cap 01 (for Aluminum beam A)	Thin FC Profile cap deep tabbed	PE-UHMW	
			ST1682479		
06	54	Slip Nut Narrow Nonlocking			
			ST1683948		
07	6	RDB	CENBNFVD0005		
			ST1690348		
08	216	Push-In Rivets	27PIF0045	NYLON ® (PA)	
			ST1681574		
09	59	ISO 4762 HEX SKT HD SCREW M3x6 - A4		St. Steel A4	
			ST1682302		
10	59	DIN433-1 WASHER M3X6 -A4 DIN433-1 RONDELLE M3X6-A4	BOSSARD : BN 6	St. Steel A4	
			ST0399238		
11	108	ISO 4762 HEX SKT HD SCREW M3x12 ISO 4762 VIS CHC M3x12	BOSSARD : BN 610 (1233130)	St. Steel A2	
			ST1568803		
12	108	Spring washers without nose DIN 127B-A2 B 3		St. Steel A2	
			ST1681945		
13	108	Washers without chamfer DIN 433-A2 3,2/6/0,5		St. Steel A2	
			ST1681951		
14	4	HEX HD screw M10x80 Vis Tete Hexa M10x80	ISO 4014_M10x80-A4	St. Steel A4	OLD 47.62.82.371.2
			CAN BE HEAD SIZE DIN 933		
15	4	HEX NUT STYLE1 GRADE A M10 ECROU H STYLE1 GRADE A M10	ISO 4032_M10-A4	St. Steel A4	47.43.77.100.6
16	8	NORMAL PL WASHER 10X20 RONDELLE PLATE NORMALE 10X20	ISO 7089_10x20-A4	St. Steel A4	47.78.15.010.4
WHERE USED			CENBNFVD0002	[Last checked at 2023-03-20 11:18]	
DESIGNATION FD2 FC Long wall Bottom part			DESIGNED	E. SELETSKAYA	FORMAT A0
			CHECKED		
			RELEASED		SCALE 1:20
			APPROVED		
EQUIPMENT CODE CENBNFVD Vertical Detector			DESIGNED 2023-03-20		
	REFERENCES	Doc No: ST1688678_02	INDEX	LABEL	GAC
	CENBNFVD0013			NOT VALID FOR EXECUTION	-
					SHEET 1/1

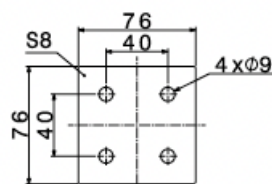
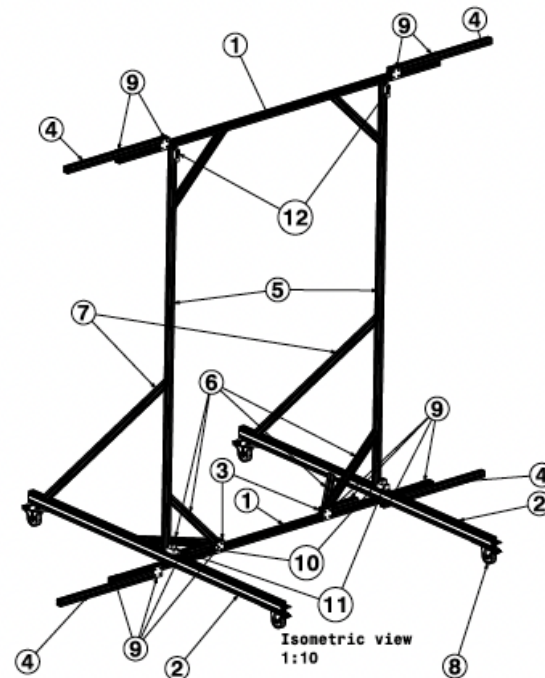
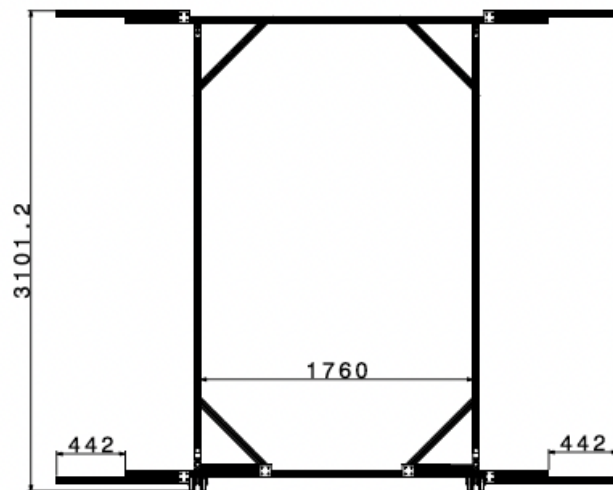
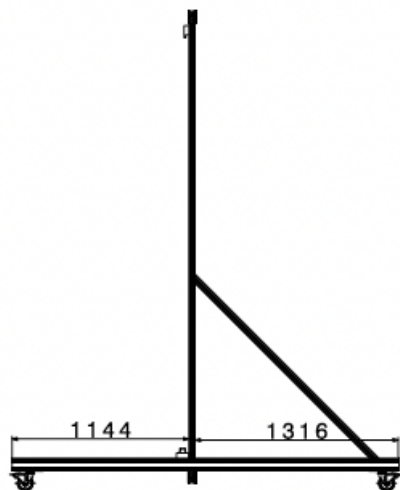
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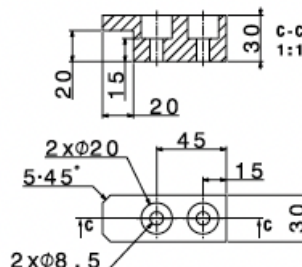
# FD2-VD Box Beams (process 422)



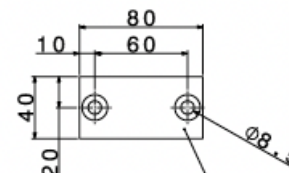
# FD2-VD Assembly Stand (make 3)



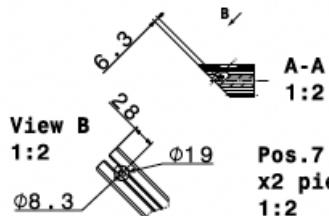
Pos. 9  
x12 pieces  
1:1



Pos. 12  
x2 pieces  
1:1



Pos. 11  
x2 pieces  
1:1

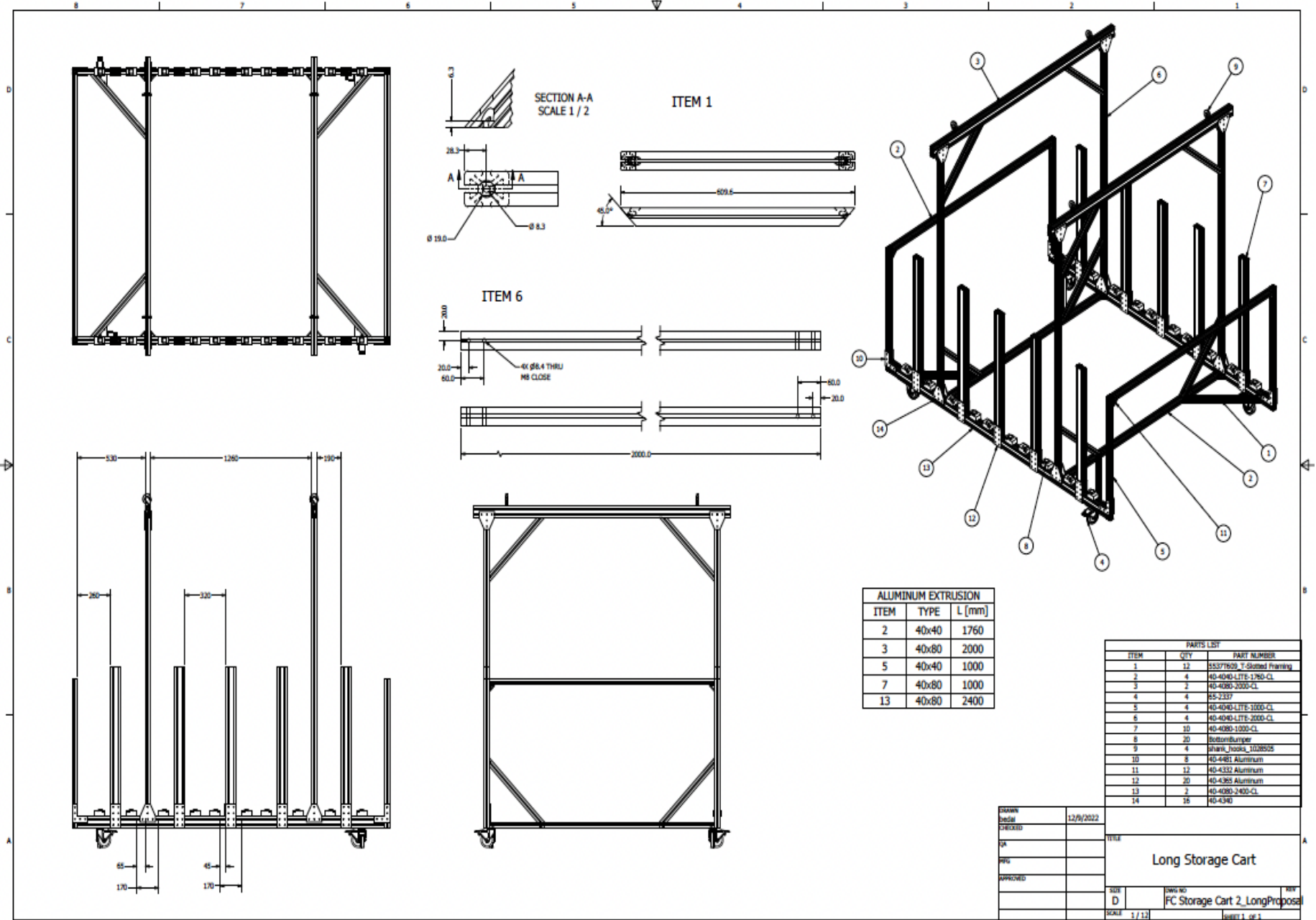


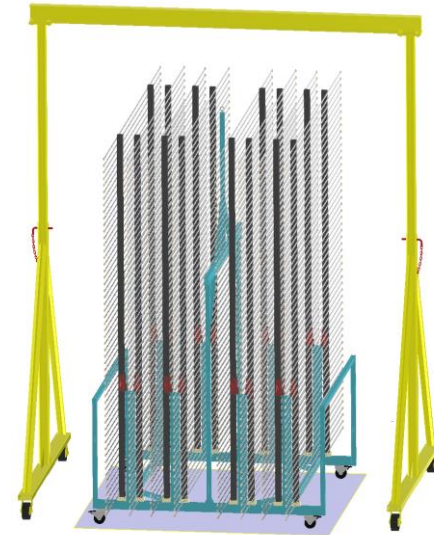
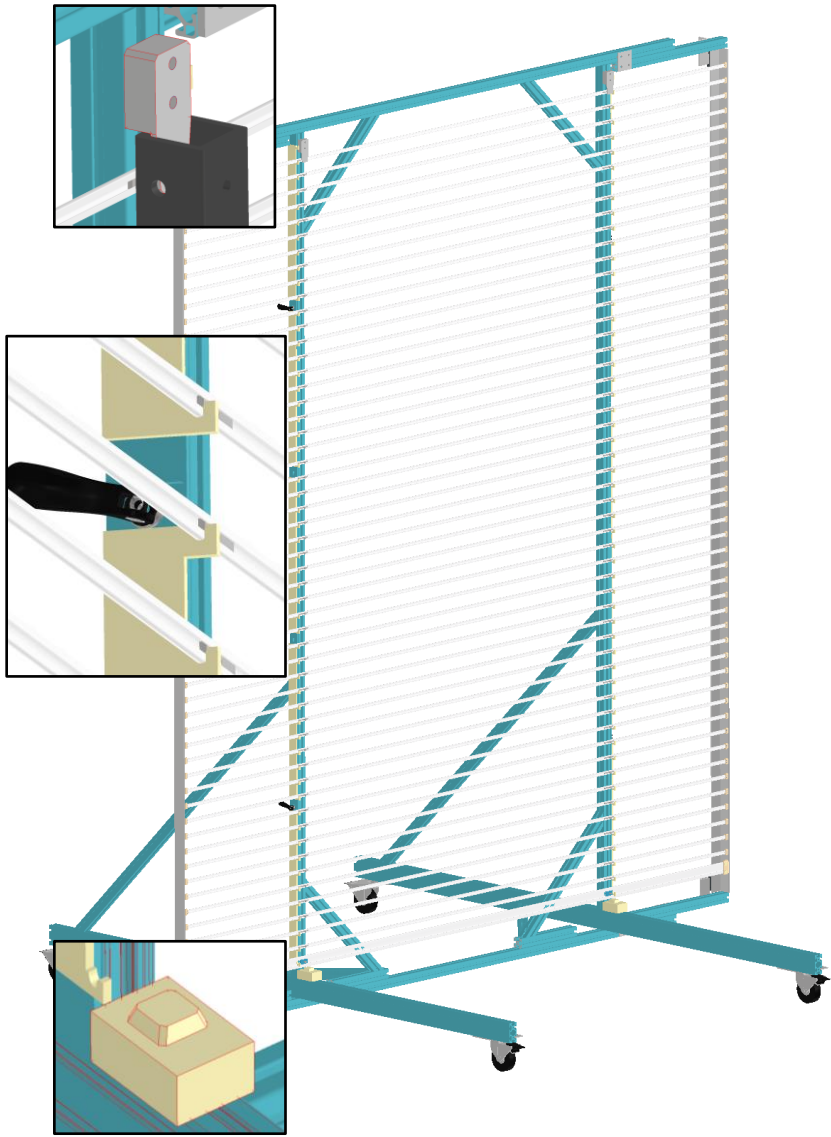
Pos. 7  
x2 pieces  
1:2

Pos.	L (mm)
1	2740
2	2500
3	305
4	860
5	2776

LIST OF MATERIALS			
NO	DESCRIPTION	UNIT	QTY
01	PROFILA 40x40	STANDARD	
02	PROFILA 40x40	STANDARD	
03	PROFILA 40x40-1	STANDARD	
04	PROFILA 40x40-2	STANDARD	
05	PROFILA 40x40-3	STANDARD	
06	PROFILA 40x40x40-1	STANDARD	
07	PROFILA 40x40x40-2	STANDARD	
08	ROD (Ø8.3)	STANDARD	
09	ROD (Ø8.3) 2000	STANDARD	
10	ROD (Ø8.3) 2000	STANDARD	
11	ROD (Ø8.3)	STANDARD	
12	ROD (Ø8.3)	STANDARD	

# FD2-VD FC Storage Cart (make 28)





# 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 the thin profile caps and the necessary QA/QC jigs
- Prepare for production readiness review (PRR) for both HD and VD parts production



# Field Cage Installation Test Configuration

LWSM

EWSM

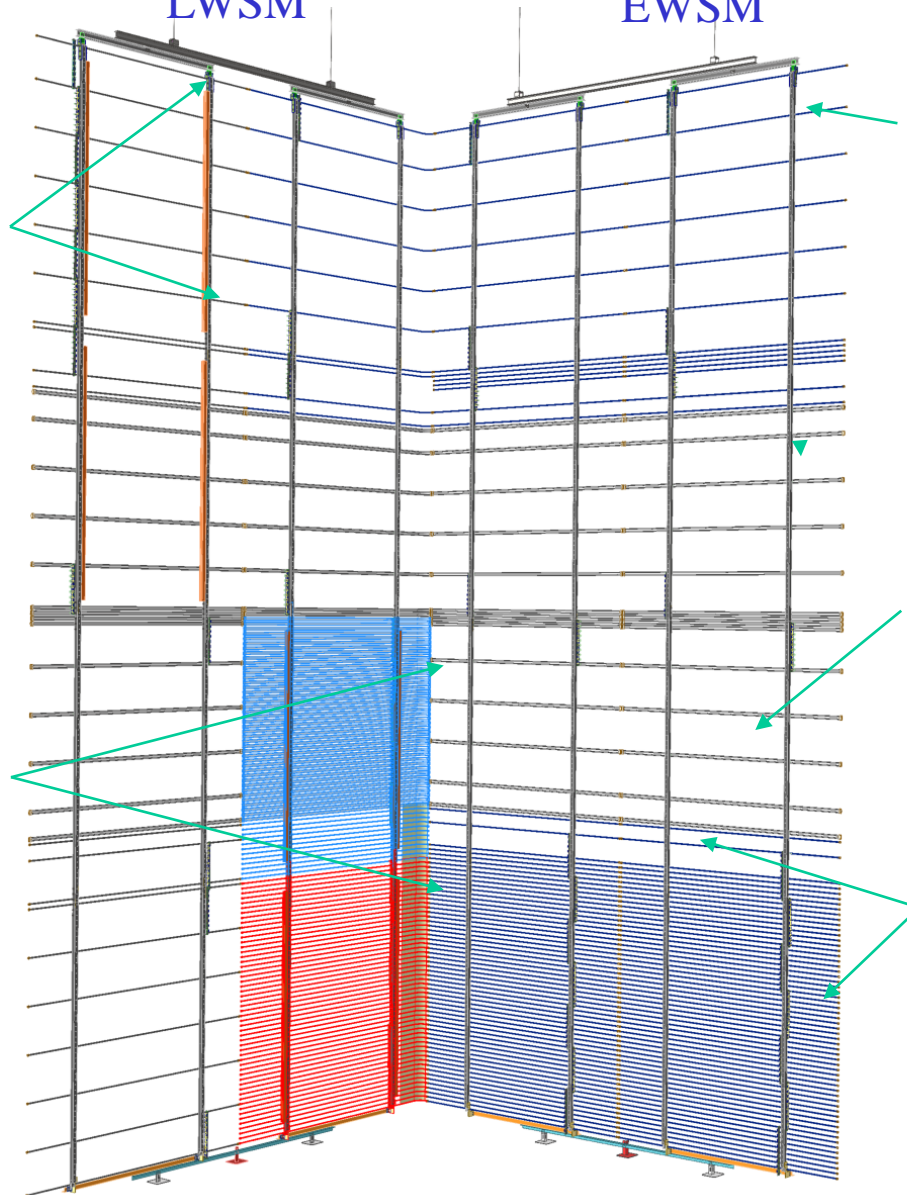
Two dummy LW modules with fiber conduits, and top profiles to demonstrate new fiber connection scheme

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?)

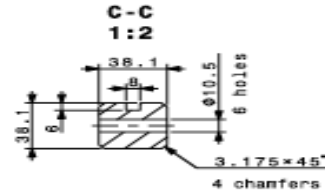
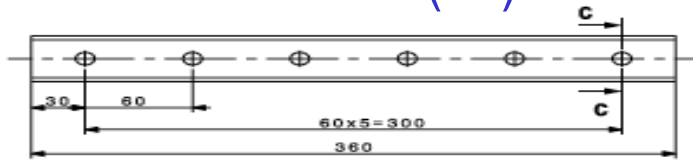
# What do we need to build for Mock-up?

- Process and QC
  - FRP Box beams:  $2 \times 16 + \text{spare} = 40$ 
    - TFC Box beams:  $2 \times 4 + \text{spare} = 10$
    - MFC Box beams:  $2 \times 8 + \text{spare} = 20$
    - BFC Box beams:  $2 \times 4 + \text{spare} = 10$
  - FRP Box beam inserts:  $3 \times 2 \times 4 + 10\% = 24 + 2 = 26$
  - Al FC Column box beam top connector:  $2 \times 4 + 10\% = 8 + 2$
  - SS FC Column yoke connector:  $1 \times 4 + 10\% = 4 + 1$
  - TFC support plates:  $2 \times 2 \times 4 + \text{spare} = 20$
  - BFC constraining bracket:  $1 \times 2 \times 4 + \text{spare} = 10$
  - Steel Bottom stabilizer structure :  $1 \times 4 = 4$
  - Module installation cart: 1

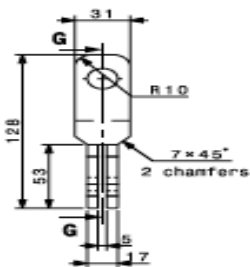
# Top VD FC Structures and Inserts

Position 4  
1:2

FRP Insert (14)

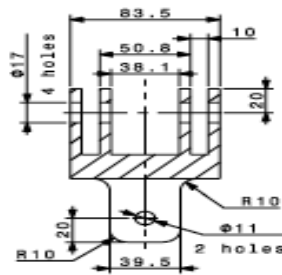


Position 5  
1:2

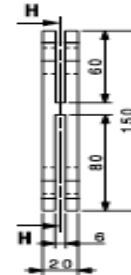


Aluminum top box  
beam connector (10)

G-G  
1:2

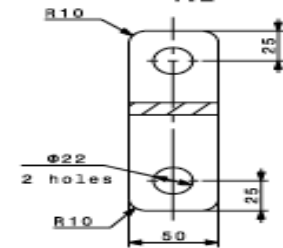


Position 6  
1:2



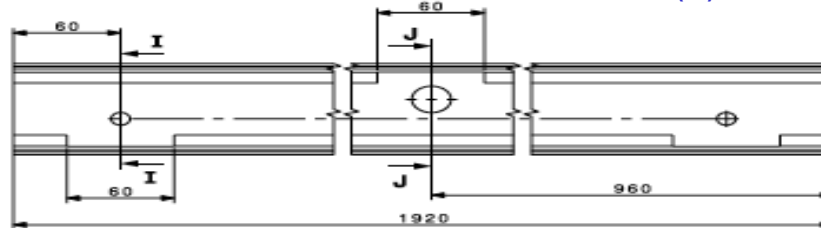
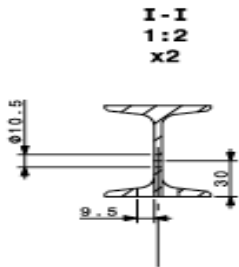
SS top yoke  
connector (5)

H-H  
1:2

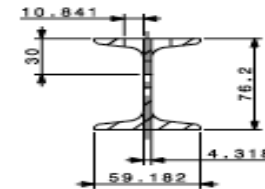


Position 7  
1:2

Aluminum FC column I-beam (5)

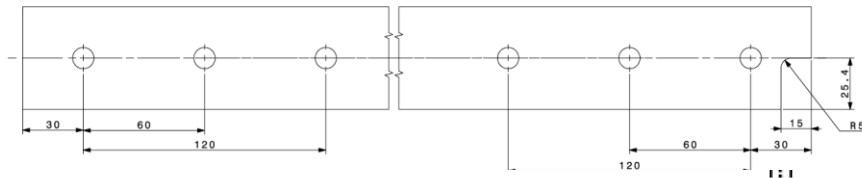
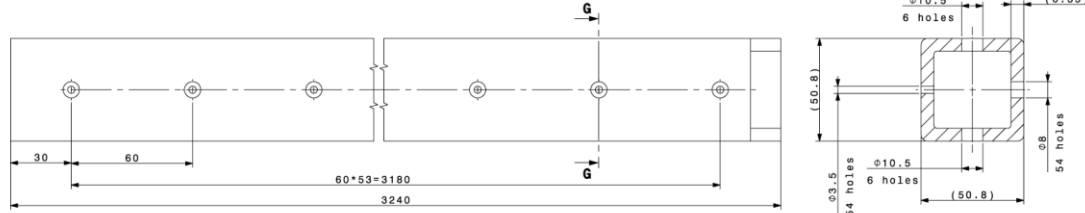


J-J  
1:2

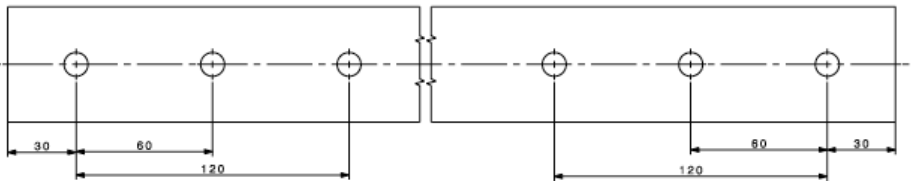
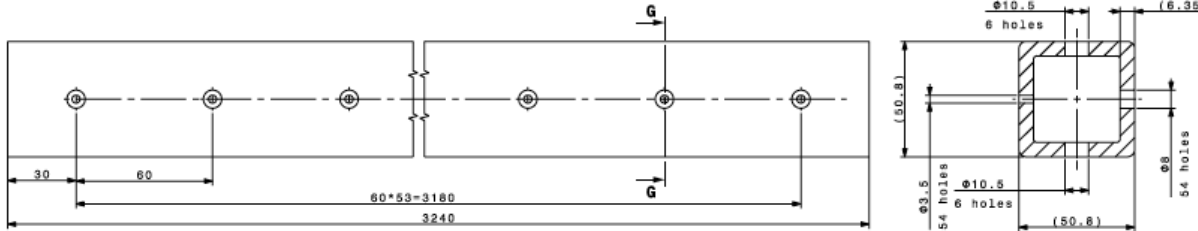


# VD Top and Mid FC Module Parts

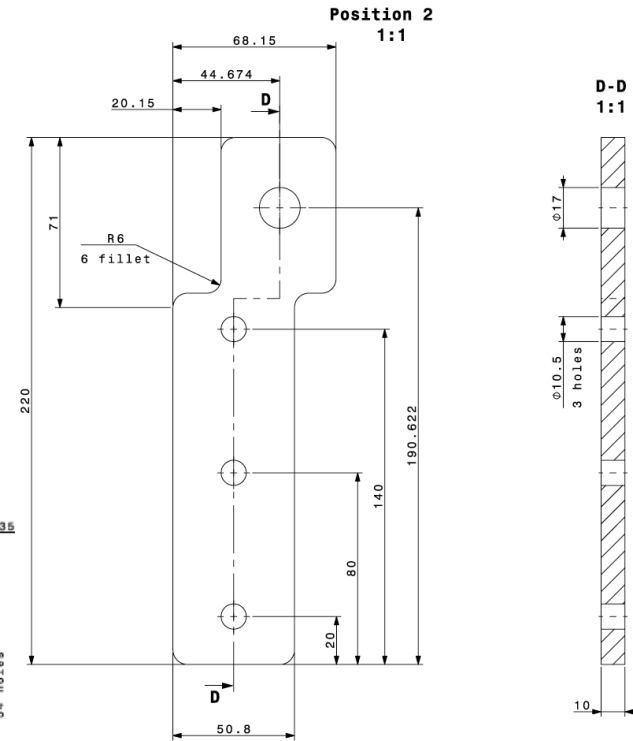
TFC FRP Box beams (2\*4+spare=8+2)



MFC FRP Box beams (4\*4+spare=16+4)

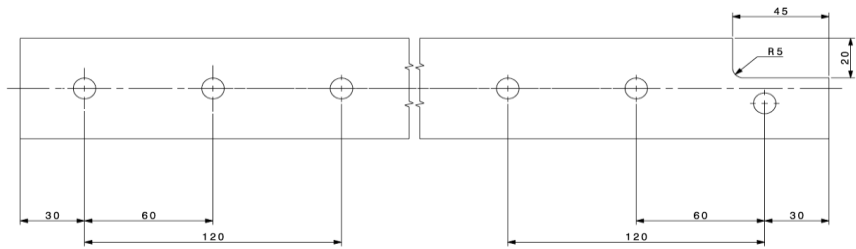
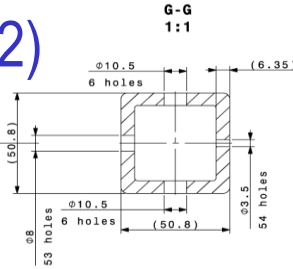
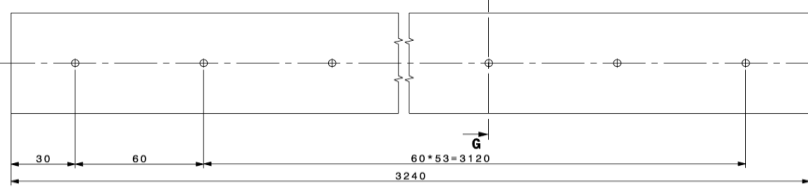


G10 Top FC support plates  
(2\*2\*4+20% = 16+4 = 20)

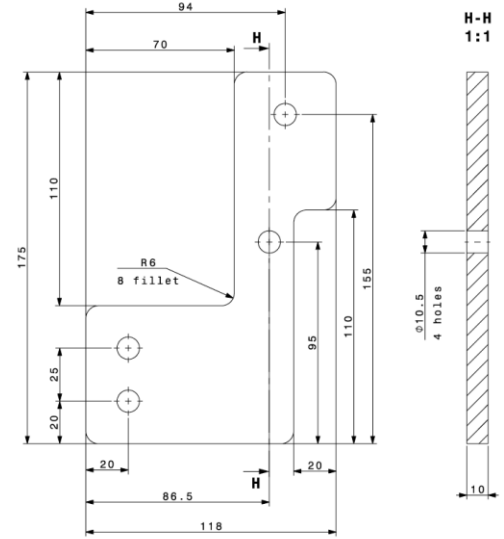


# VD Bottom FC Module Parts

BFC FRP Box beams (2\*4+spare=8+2)

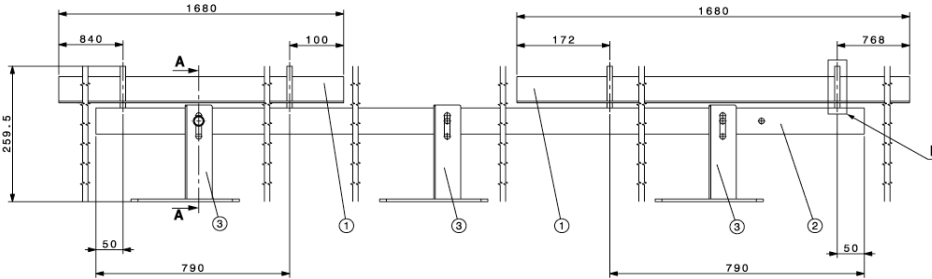


G10 Bottom constraining bracket (1\*2\*4+20% = 8+2 = 10)

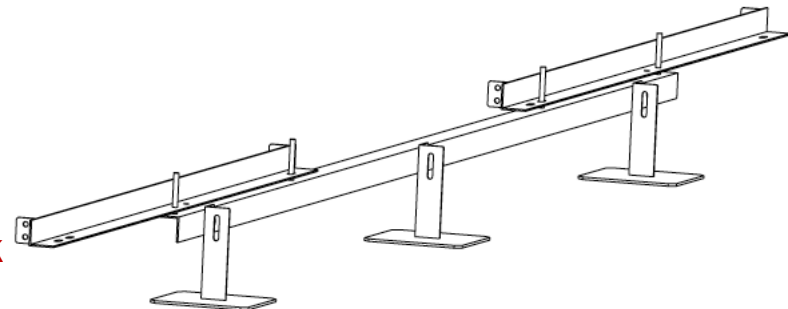
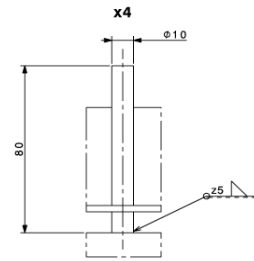
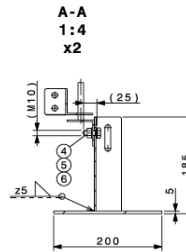
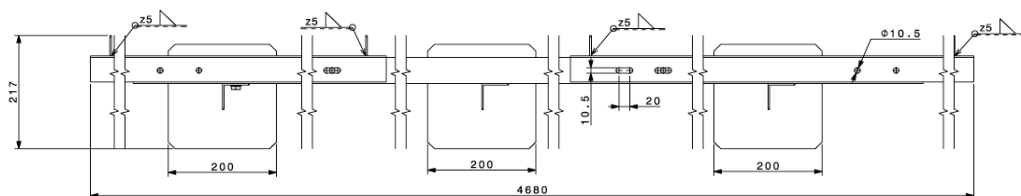


Bottom stabilizer (1\*4=4)

Front view  
1:4



Top view  
1:4



Nov. 18, 2023

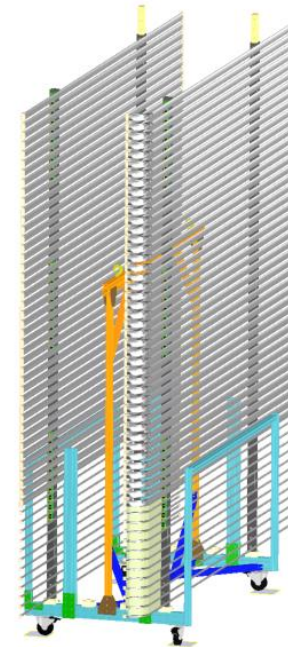
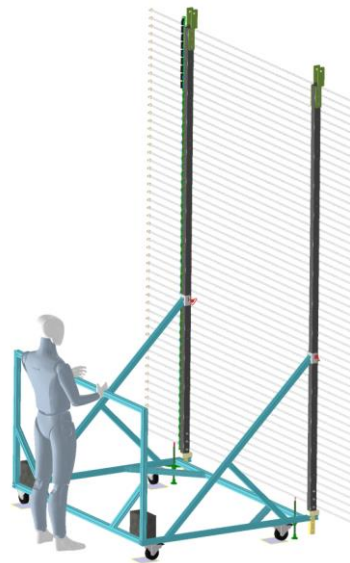
DUNE FD1 & FD2 FC Work

# VD Field Cage Tools

One assembly station  
Modified NP02 version @  
CERN

One installation  
cart → UTA to  
build one and  
ship to CERN

2 storage carts  
Available @  
CERN with  
minor updates



# Summary Table

Deliverable	Earliest Available Date	Relevant PRR Date
Full size FC assembly station	April 2024	June 2024
FC installation cart	May 2024	June 2024
FC storage cart	April 2024	June 2024
2 EW bottom FC modules	May 2024	June 2024
One middle corner FC module	May 2024	June 2024
One bottom corner FC module	May 2024	June 2024
12 dummy FC modules	June 2024	
4 sets of FC support FT	April 2024	June 2024
2 sets of FCSM beams	May 2024	June 2024

# Group's 3E Motto

**Demand Yourself Excellence!**

**Demand Each Other Excellence!**

**Help Each Other Become Excellent!**