

VD FC Module-Assembly Workshop

FC Overview and DUNE Timeline

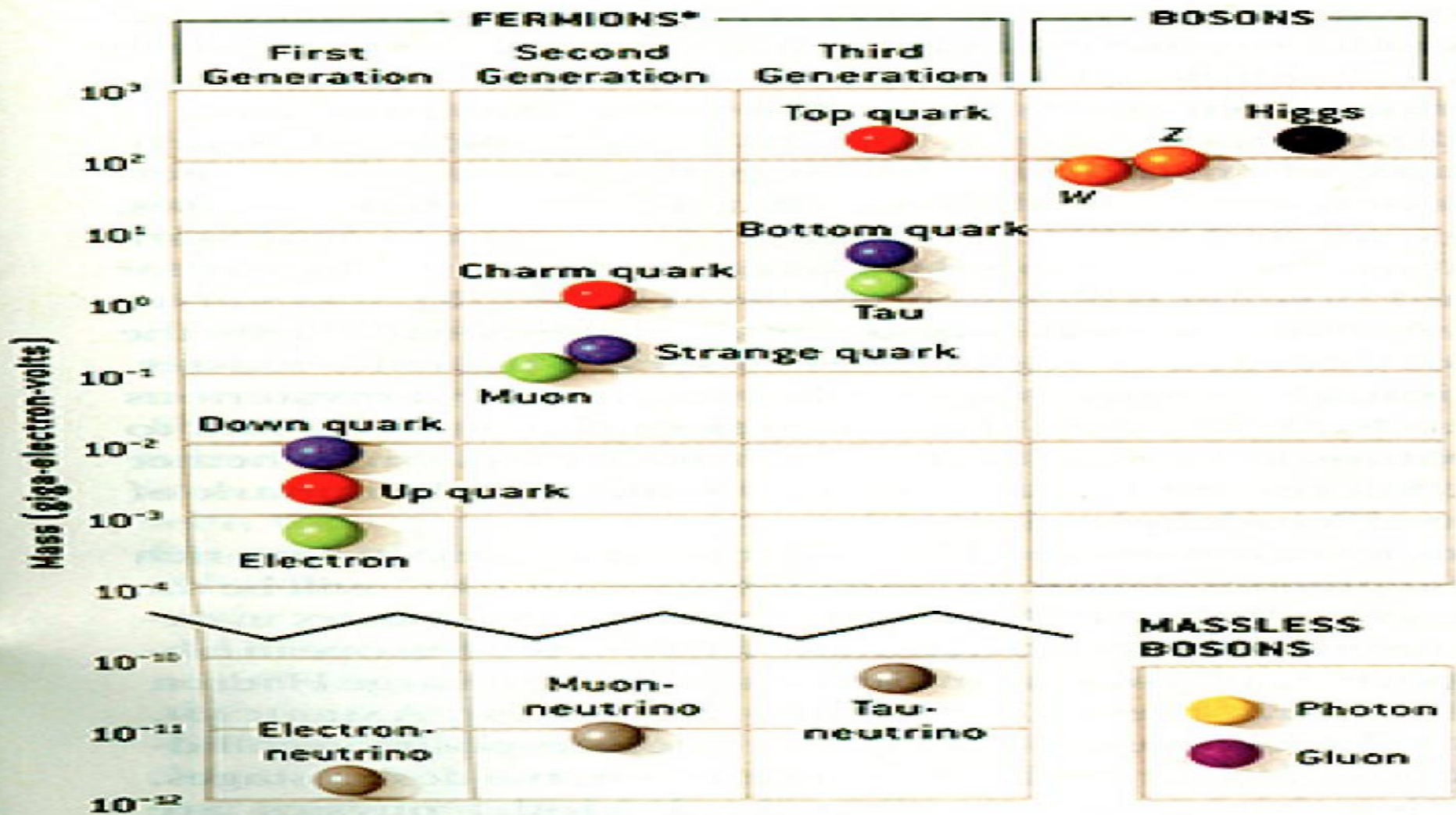
November 2, 2024

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University of Texas at Arlington

Workshop Fundamentals

- Goals : To learn the VD FC module assembly and QC procedure and to decide on the assembly table height
- Tasks to complete in the workshop
 1. Understand the scope and the tasks involved in FC assembly and the module QC
 2. Hands-on training of the module assembly procedure and complete the procedure documentation
 3. Exercise the module QC procedure, exercise recording them into the QC iPADS and complete the QC procedure documentation

The SM Fundamental Particle Table



- Total of 12 particles, 4 types of force mediators and the Higgs make up all the visible matter in the universe! → Simple and elegant!!!

Periodic Table of the Elements

118 Elements!

1 H Hydrogen 1.008	2 He Helium 4.003											13 B Boron 10.811	14 C Carbon 12.011	15 N Nitrogen 14.007	16 O Oxygen 15.999	17 F Fluorine 18.998	18 Ne Neon 20.180
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.99	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.789
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [286]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]

Lanthanide Series

57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
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Actinide Series

89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]
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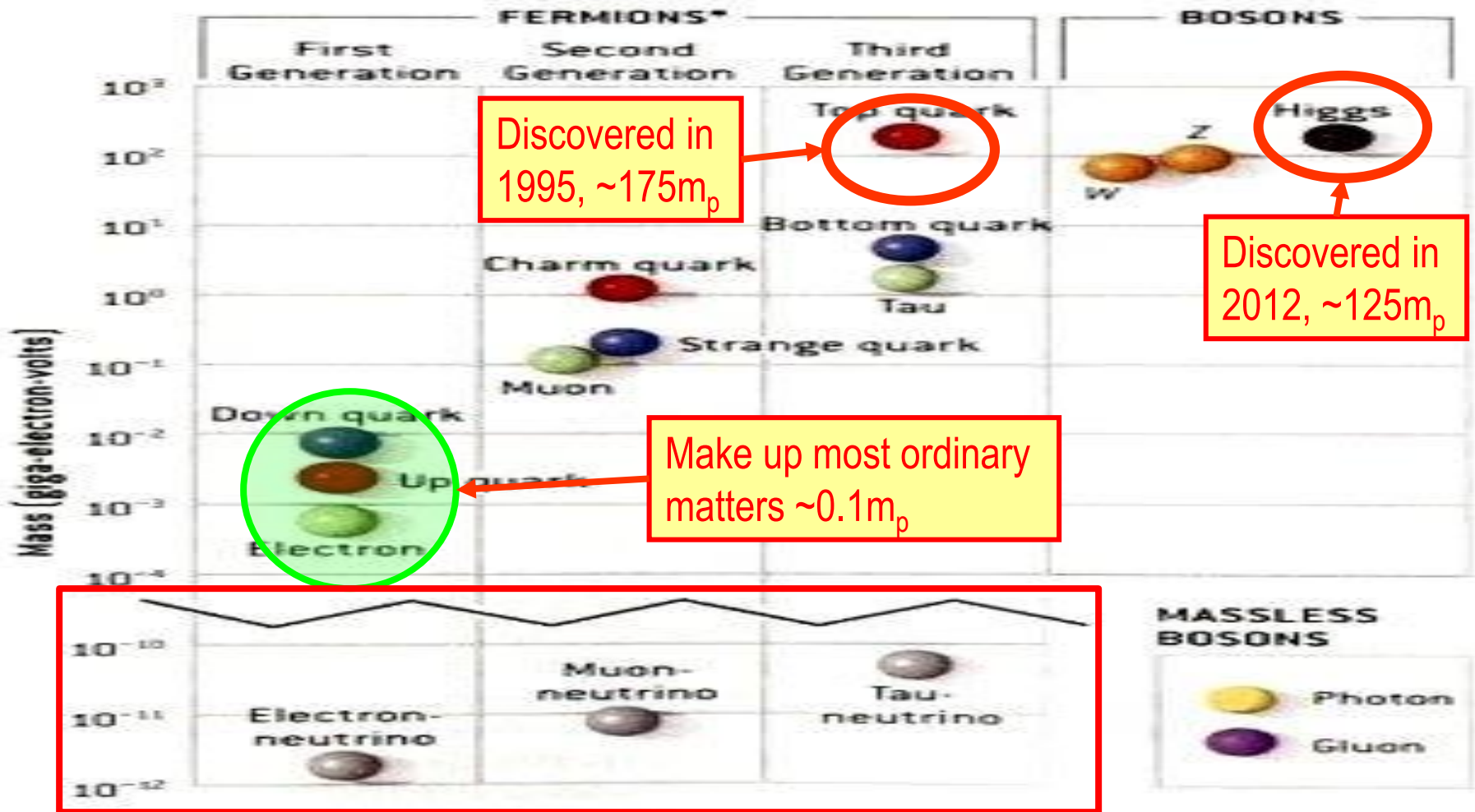
Nov. 2, 2024

Alkali Metal	Alkaline Earth	Transition Metal	Base Metal	Semimetal	Nonmetal	Halogen	Noble Gas	Lanthanide	Actinide
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DUNE VC FC Module Assembly

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HEP and the Standard Model



- Total of 12 particles, 4 types of force mediators and the Higgs make up all the visible matter in the universe! → Simple and elegant!!!
- Tested to a precision better than 1 part per million!

Neutrino fundamentals – 1

- Postulated in 1930 to explain the nuclear β -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 (ν_e – **2002 Nobel**), muon (ν_μ – **1988 Nobel**), and tau (ν_τ) 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 (ν_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_ν)

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

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

The Next Big Thing - DUNE Experiment

- Stands for Deep Under Ground Neutrino Experiment
- \$3.5B US flagship long baseline (1300km) experiment
 - 1500m underground in an old South Dakota gold mine



completed on Jan. 25, 2024

- Experiment infra work ongoing

Recent Photos from SURF

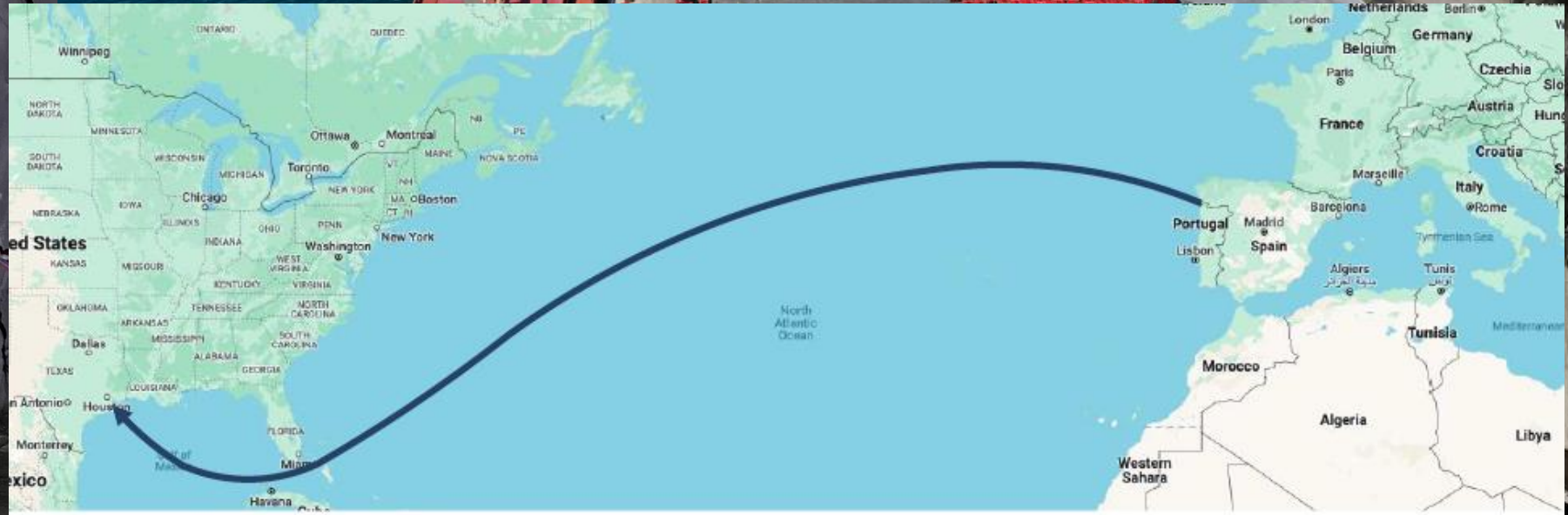
Early 2023

Jan 2024

Cryostat parts are arriving and being delivered to SURF

Total weight > 2500 tons/cryostat

Total number of components > 150,000/ cryostat

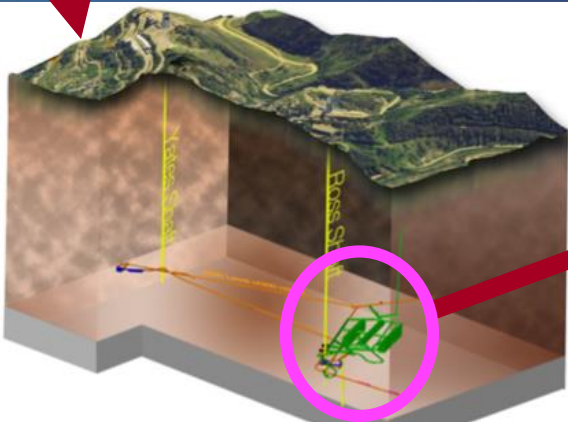
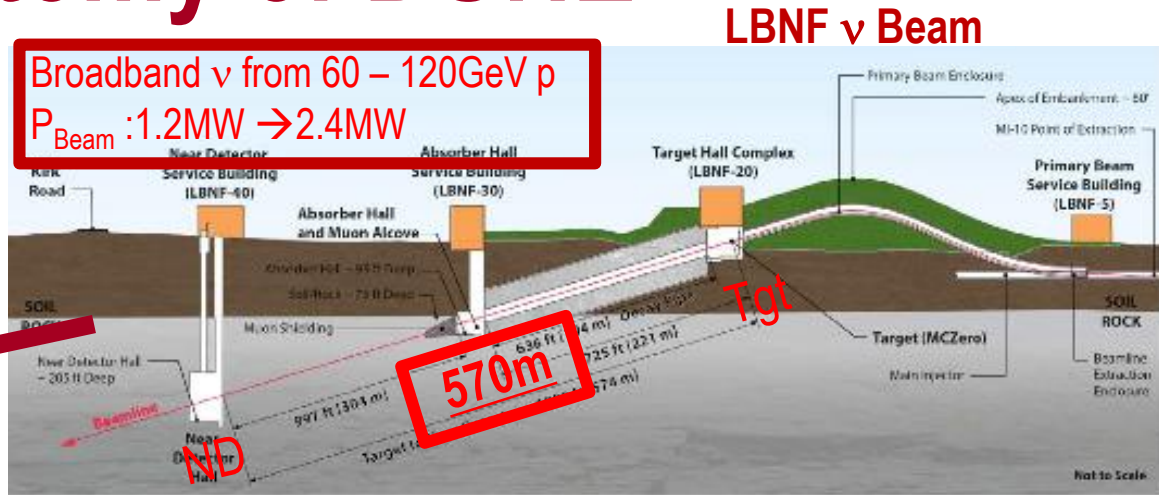


The Next Big Thing - DUNE Experiment

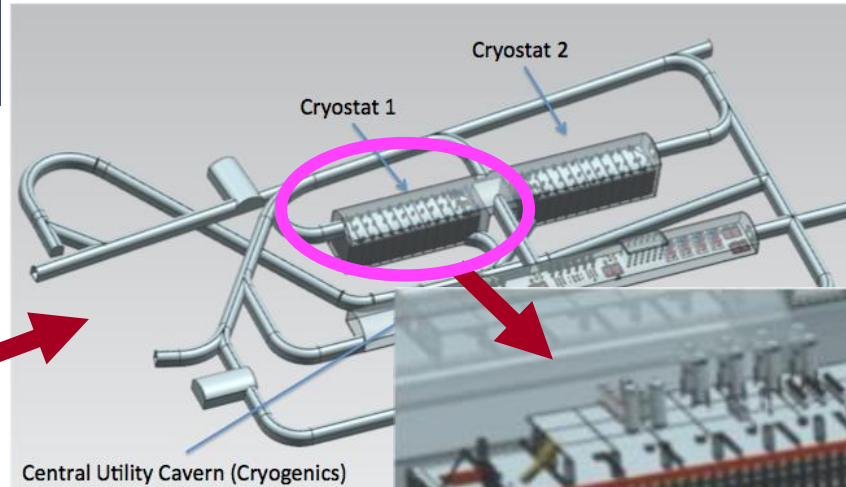


- Stands for Deep Underground Neutrino Experiment
- \$3.5B US flagship long baseline (1300km) ν experiment
 - 1500m underground in an old South Dakota gold mine
- Needs a very high intensity proton beams (1.2MW \rightarrow 2.4MW!)
 - Result in a large number of ν for precision measurements
 - Great potential for Dark Matter search and other BSM phys.
- Large mass (~70kt! total) **LArTPC** Far Detectors at SURF
- Powerful near detector complex to control systematics
- Was born March 2015!
 - Combination of LBNE (US) and LBNO (EU)
- >1500 collaborators from >209 institutes in >36 countries
+ CERN

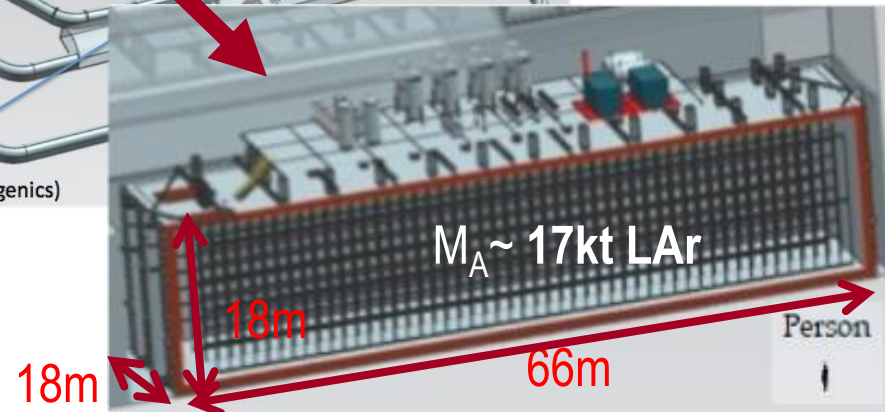
Anatomy of DUNE



LBNF Far Detector Site, SURF
1500m underground



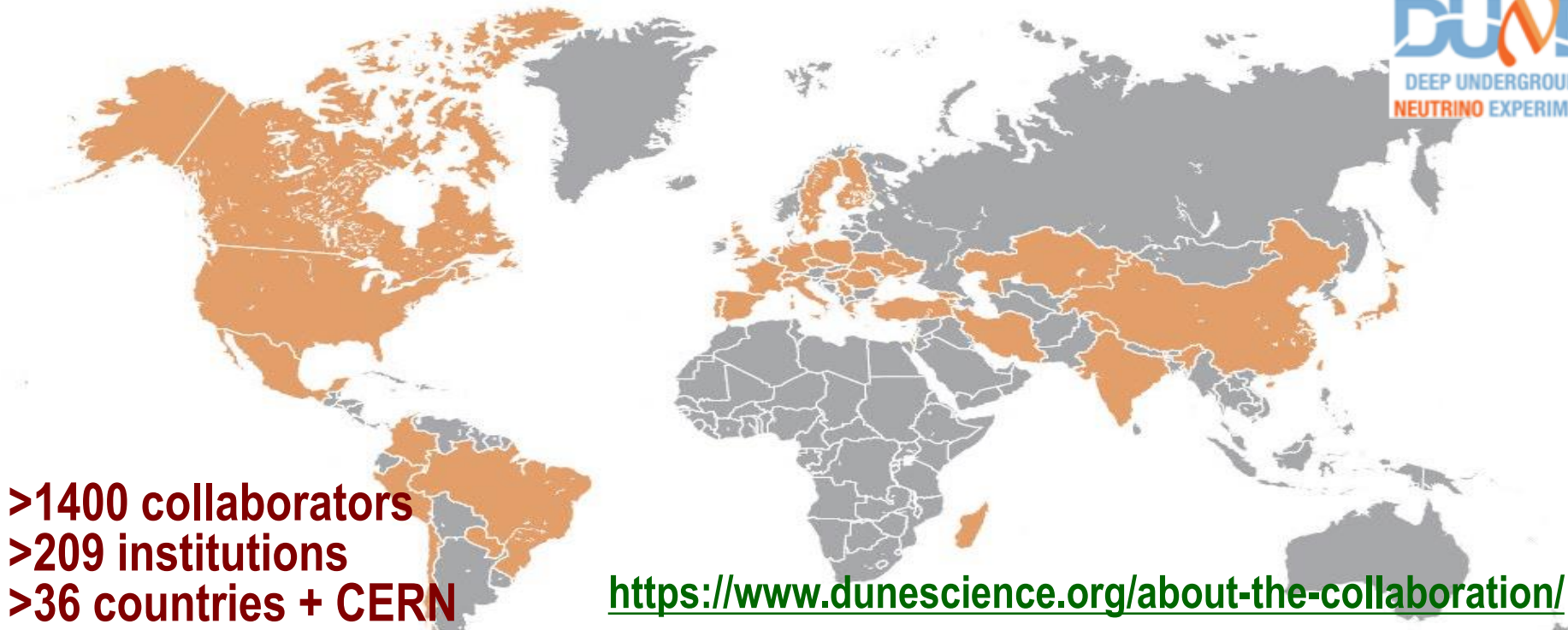
4 caverns for
 $M_t \sim 70 \text{ kt LAr}$
($>85\%$ complete)



DUNE VC FC Module Assembly

Nov. 2, 2024

The Map of the DUNE Experiment



- >1400 collaborators
- >209 institutions
- >36 countries + CERN

<https://www.dunescience.org/about-the-collaboration/>



UTA-Built Prototype Field Cage @ CERN 2018

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

6m

6m

6m

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

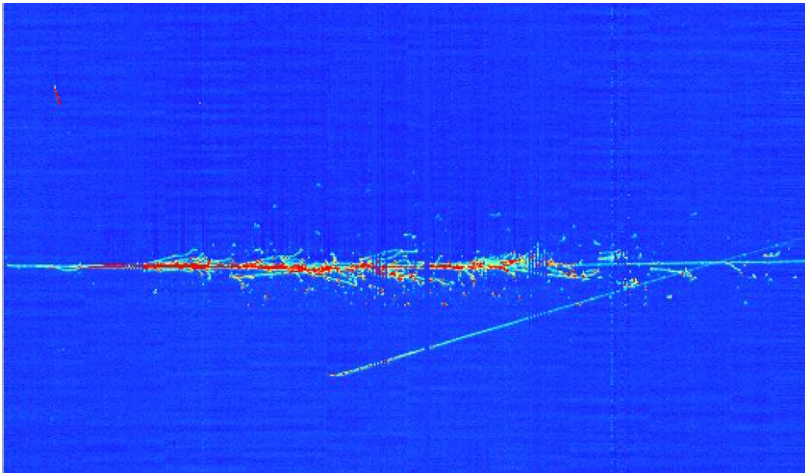
Eric Garcia @ CERN, June 2022

Akash Behanan, Sam Blanchard, Brad Brown, Gajendra Gurung & Rohit Raut @ CERN, Summer 2024

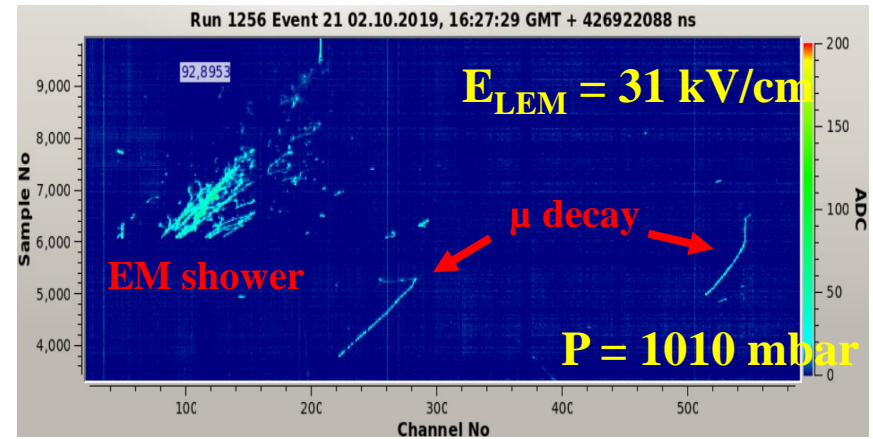


Images in DUNE LAr-TPC Prototypes

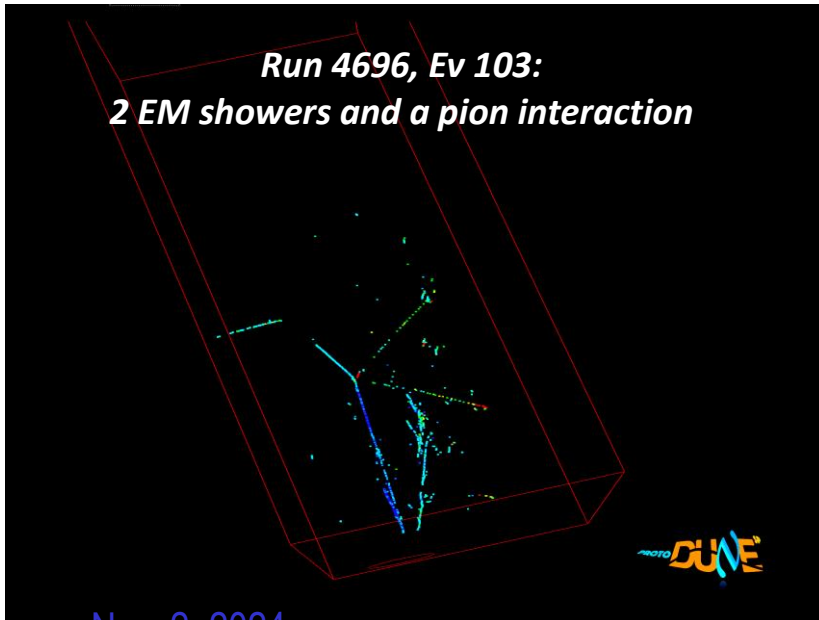
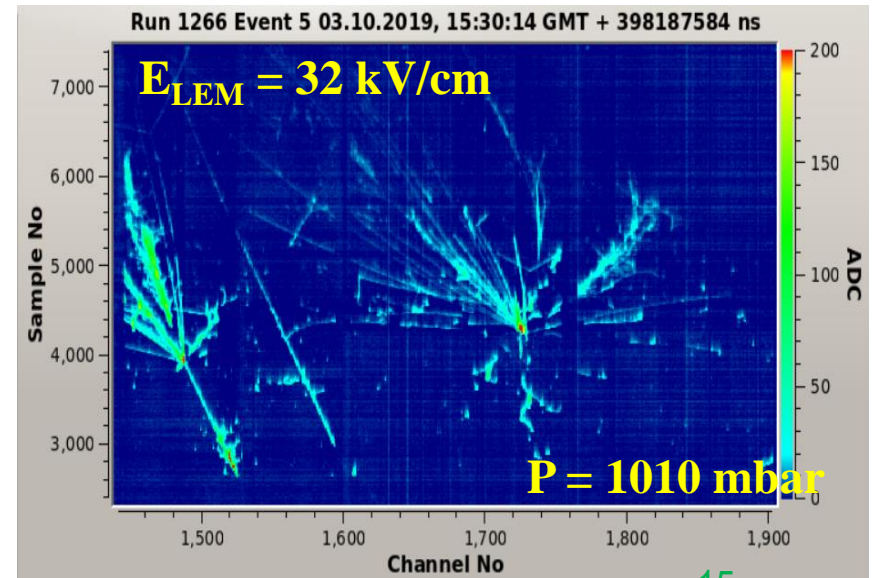
Throughgoing μ



Electromagnetic shower + two muon decays



Multiple hadronic interactions in a shower



Nov. 2, 2024

DUNE VC FC Module Assembly

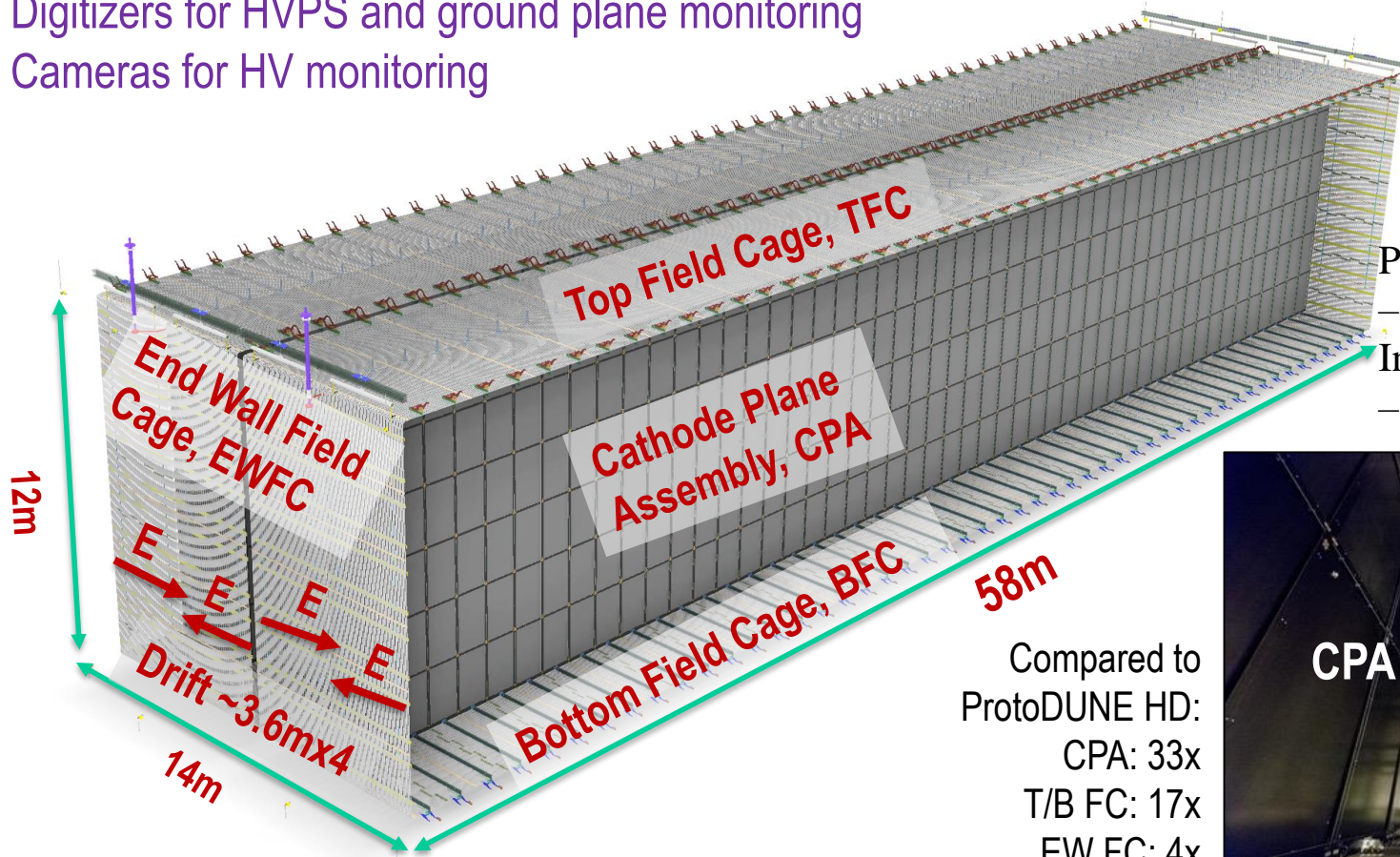
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Latest news on DUNE

- DUNE far detector cavern excavation completed Jan. 25 and the steel parts for FD cryostat getting delivered to SURF
- ProtoDUNE HD beam data taking completed yesterday
- LAr to be transferred from HD to VD along with some additional LAr for ProtoDUNE beam run spring 2025
- FD site infrastructure construction on going!
- FD2 VD installation to go first in 2026 before the HD
- Expect significant overlap in VD and HD parts production and a few months on installation work

HVS Consortium Scope - FD1-HD TPC

- Design, fabricate, test and assemble:
 - 100 CPA resistive panels forming two cathode arrays (1400m²)
 - 100 top + 100 bottom field cage modules, 48 End Wall field cage modules (1728m²)
 - 2 sets of HV power supplies, cables, ripple filters, and feedthroughs
 - Digitizers for HVPS and ground plane monitoring
 - Cameras for HV monitoring



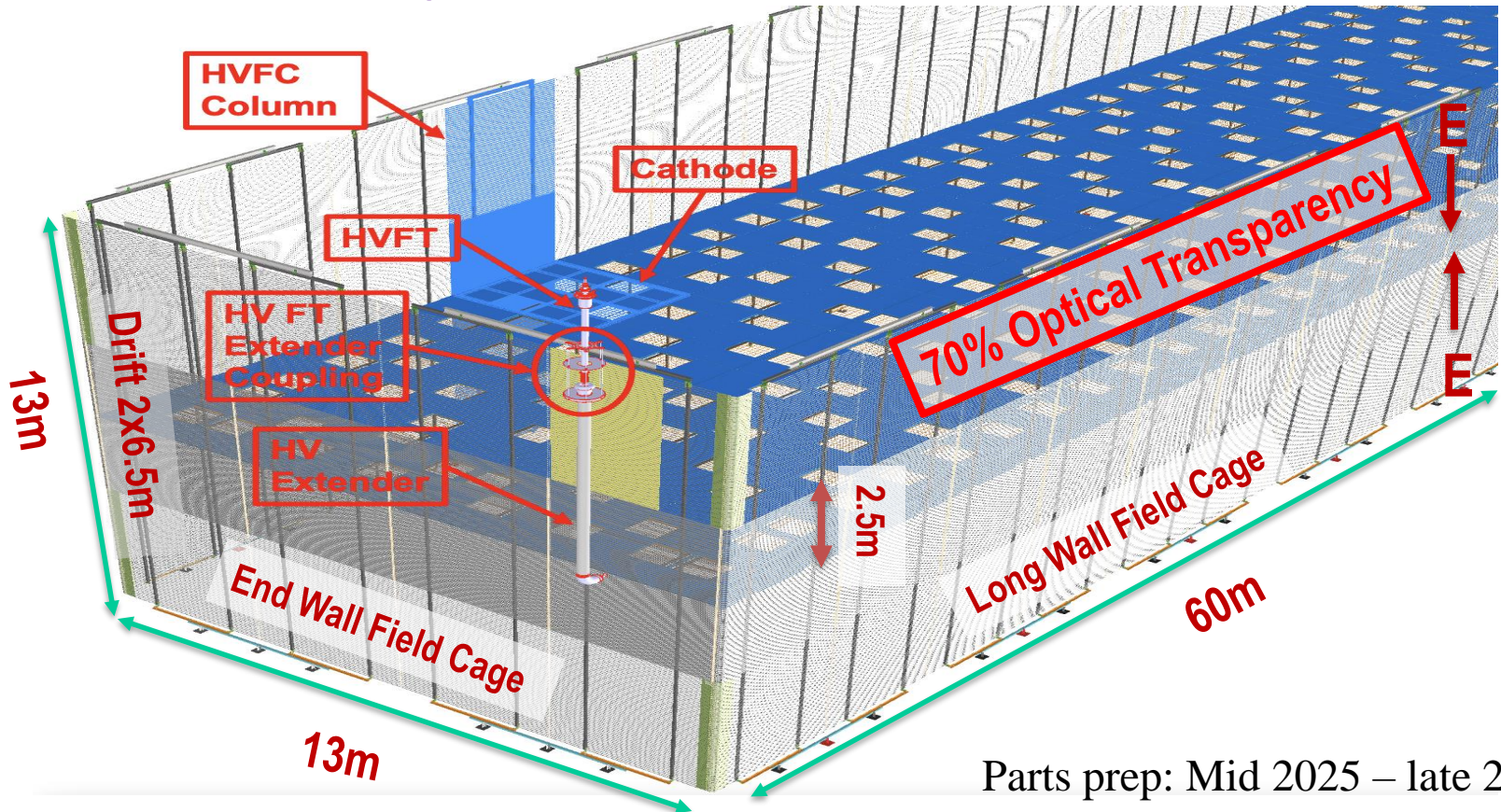
Parts prep: 2026
– late 2027
Installation: 2028
– 2029 @SURF

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



HVS Consortium Scope - FD2-VD TPC

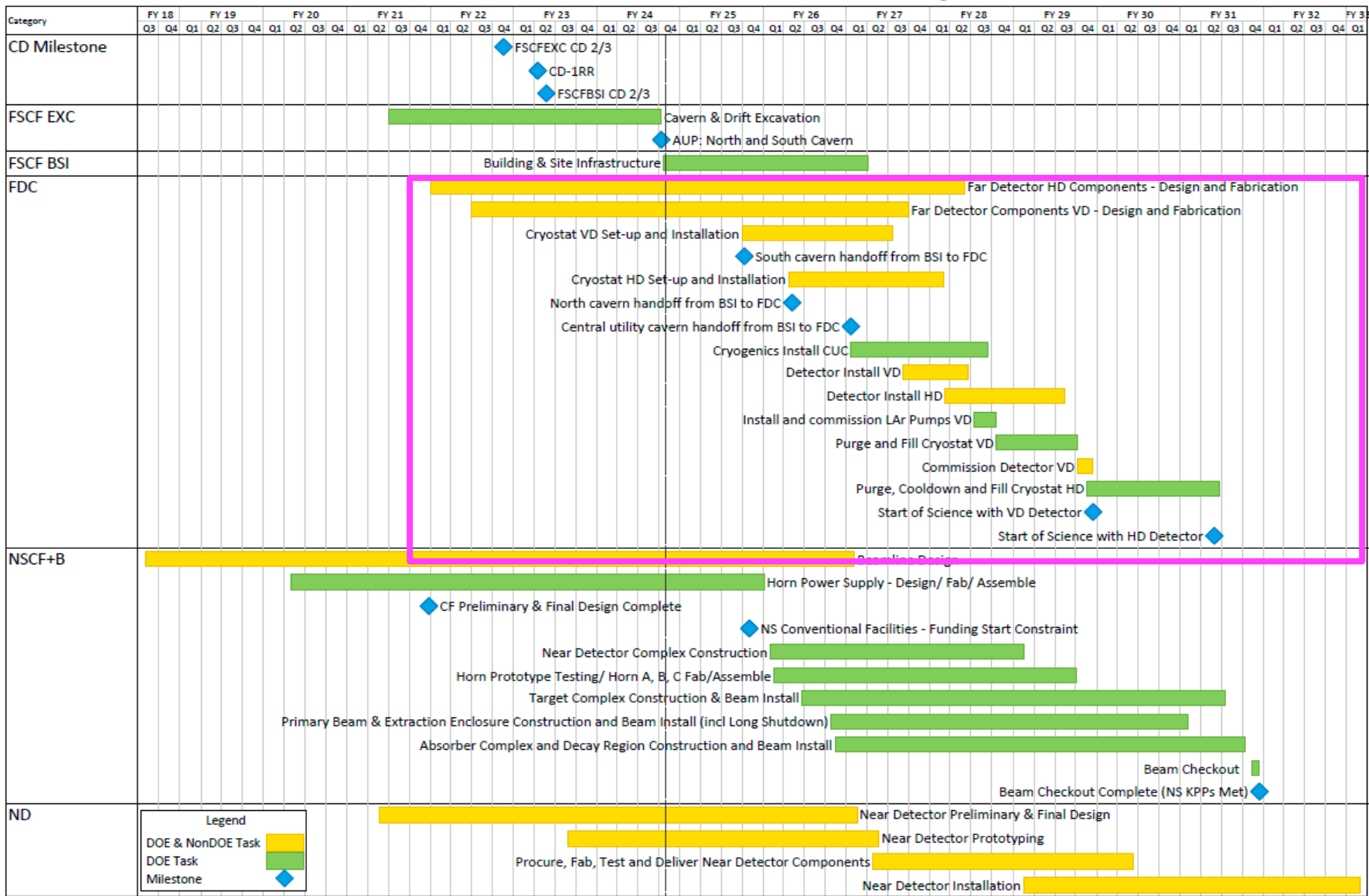
- Design, fabricate, test and assemble:
 - 80 Full Unit Cathode Planes (780m²) with embedded PD
 - 192 field cage modules – 160 Long Wall and 32 End Wall modules (~1781m²)
 - One set of HV power supply, cable, ripple filter, and feedthrough
 - Digitizers for HVPS and current monitoring
 - Cameras for HV monitoring



DUNE VC FC Module Assembly

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

DUNE Detector and Facility Timeline



LBNL-DUNE Summary Schedule.xlsx

Snapshot Date: 8/1/2024

Created in OnePage® Express

DUNE Far Detector Timeline

- VD Installation goes first
- VD Timeline
 - Q4/26: VD Cryostat Installation Complete
 - **Now – Q2/26 : VD Detector component production**
 - Q4/26 – Q2/27 : VD Detector installation
 - Q3/27 : VD LAr pump and other cryo-infra installation
 - Q1/28 – Q4/28 : VD LAr purge, cooldown and fill
 - Q1/29: VD Commissioning
 - Q2/29 : VD Start of science
- HD Timeline
 - Q3/27 : HD Cryostat Installation Complete
 - **Now – Q4/27: HD Detector component production**
 - Q2/27 – Q1/29 : HD Detector installation
 - Q2/29 : HD LAr pump and other cryo-infra installation
 - Q3/29 – Q4/30 : HD LAr purge, cooldown and fill
 - Q1/31: HD Commissioning
 - Q2/31 : HD Start of science

What do we need to do today?

- Exercise, learn and familiarize the VD FC module assembly and QC procedure
- Complete the documentation for the assembly procedure
- Train and familiarize yourself to the different types of parts, including all hardware and tools
- Exercise both laying down on the creeper and sitting on a chair for the assembly and clearly understand the advantages and disadvantages of the two heights of the assembly tables
- Prepare for production readiness review (PRR) for both HD and VD parts production → late 2024 for HD (led by UMN) and early 2025 for VD (UTA only)

Group's 3E Motto

Demand Yourself Excellence!

Demand Each Other Excellence!

Help Each Other Become Excellent!