ProtoDUNE-HD Geometry

This page describes the geometry and channel numbering conventions of the ProtoDUNE-HD LArTPC. For ProtoDUNE-SP, which ran from 2018 to 2020, please see ProtoDUNE geometry. Much of the information below is a modified version of what is on the ProtoDUNE-SP page.

Contents

Detector Geometry

The ProtoDUNE-HD LArTPC has four APAs with a row of two on either side of the beam line. The APAs each have four wire planes on either side: one collection plane with vertical wires on either side and two induction planes with wires that wrap around both sides. An uninstrumented grid plane of vertical wires is the farthest from the center of the APA. The side of each APA facing away from the beam (cryostat side) is very close to the cryostat wall and is called the "B" side. The side facing the beam (TPC side) collects signals from the TPC volume and is called the "A" side.

The wires on the beam-right APAs ("Saleve", "South", "Rack") are read from the top, and the wires on the beam-left APAs ("Jura", "North", "DAQ") are read out from the bottom. There are 20 Front-End Motherboards (FEMBs) per APA, each with 128 channels, of which 40 are connected to U-plane wires, 40 are connected to V-plane wires, and 48 are connected to X-plane (collection) wires. There are ten FEMBs on each side of each APA, and each FEMB reads out wires that are anchored in close physical proximity to the FEMB.

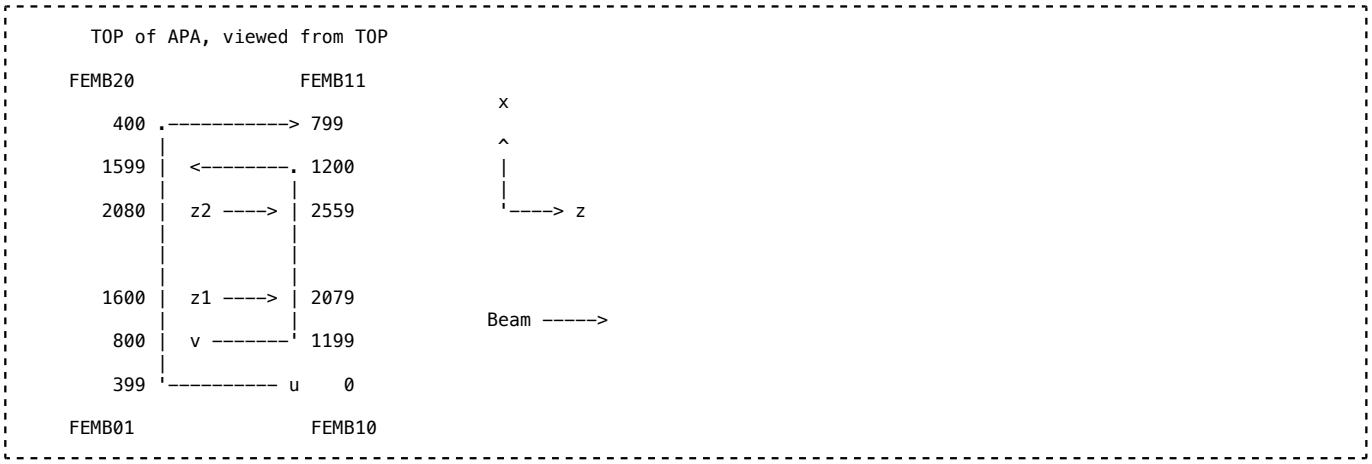
Table listing APA and TPC-set numberings. Viewed from above. The beam enters from the left-hand side. FEMB numbers are Local. This has been updated November 21, 2022 with final APA numbering from Roger Huang.

APA3 APA_P02NL FEMBs 1-20 TPS1 TPC 2 (3) 1st channel: 2560	APA4 APA_P01NL FEMBs 1-20 TPS3 TPC 6 (7) 1st channel: 7680
APA1 APA_P02SU FEMBs 1-20 TPS0 TPC 1 (0) 1st channel: 0	APA2 APA_P01SU FEMBs 1-20 TPS2 TPC 5 (4) 1st channel: 5120

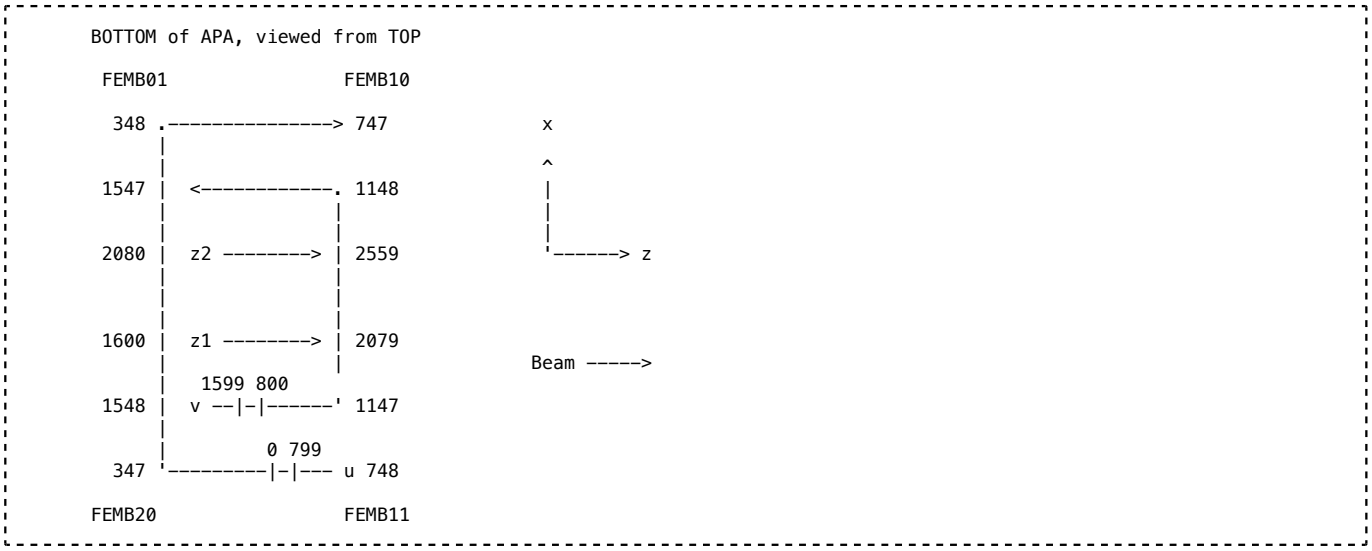
The table shows the offline convention for numbering TPC sets (TPS), FEMBs and channels, as well as listing the installation numbers which ought to match the crate numbers and geographical names of the APAs. The geographical names of the APAs follow this convention: APA_P[nn][N,S][U,L] Where "P" means ProtoDUNE, nn is the row number (01 or 02), N: North, S: South, U: Upper, L: Lower

The label TPS from the offline geometry meaning "TPC set" is used in place of APA to try to reduce confusion with the installation label which should correspond to the crate number. An offline "TPC" is a drift volume corresponding to one side of an APA. Cryostat-side TPCs' numbers are listed in parentheses in the table. Each APA has 2560 channels numbered contiguously from the indicated value (1st channel). From an offline channel number one may obtain the corresponding offline APA/TPS index by doing an integer division: channel/2560.

The figure below shows the offline channel numbers for wires that are anchored on the top of the upright APAs, separately for each plane. The first and last channel numbers in a plane on a side of an APA are given. The numbers of the FEMBs in the four corners are also listed.



The figure below shows the offline channel numbers for the wires that are anchored at the bottom of the APA. Due to the symmetry of the APA construction, the inverted APAs have the same channel numbering convention as the upright APAs, though the electronics mapping is different from that of the upright APAs. Due to the fact that the wrapping is incomplete, the numbering of the U and V channels has a discontinuity 52 channels from the end on one side of the APA.



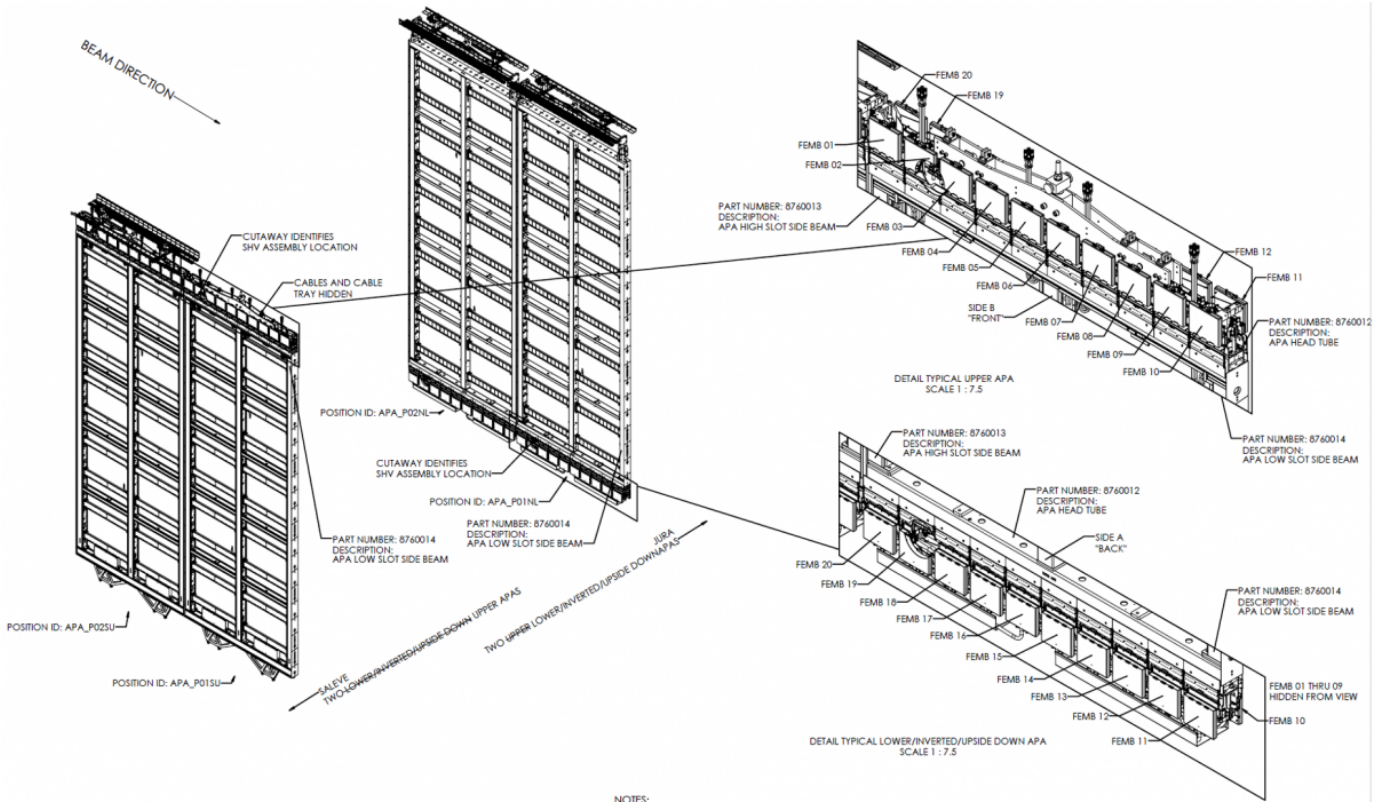
These numbers have been determined from the [wire dumps (https://cdcvs.fnal.gov/redmine/projects/dunetpc/wiki/_ProtoDUNE-SP_Wire_Dumps_)] for ProtoDUNE-SP, using APA 3 (TPS 0).

FEMB Numbering

The numbering of the FEMBs is described in a [talk (https://indico.fnal.gov/event/50217/contributions/241714/attachments/155294/202169/CE_Installation_May-2022.pdf)] by Vladimir Tishchenko at the May 2022 DUNE collaboration meeting.

For the upright APAs, the FEMBs are numbered in an order that increases in the counterclockwise direction when viewed from the top. For the inverted APAs, the FEMBs are numbered in an order that increases in the clockwise direction when viewed from the top.

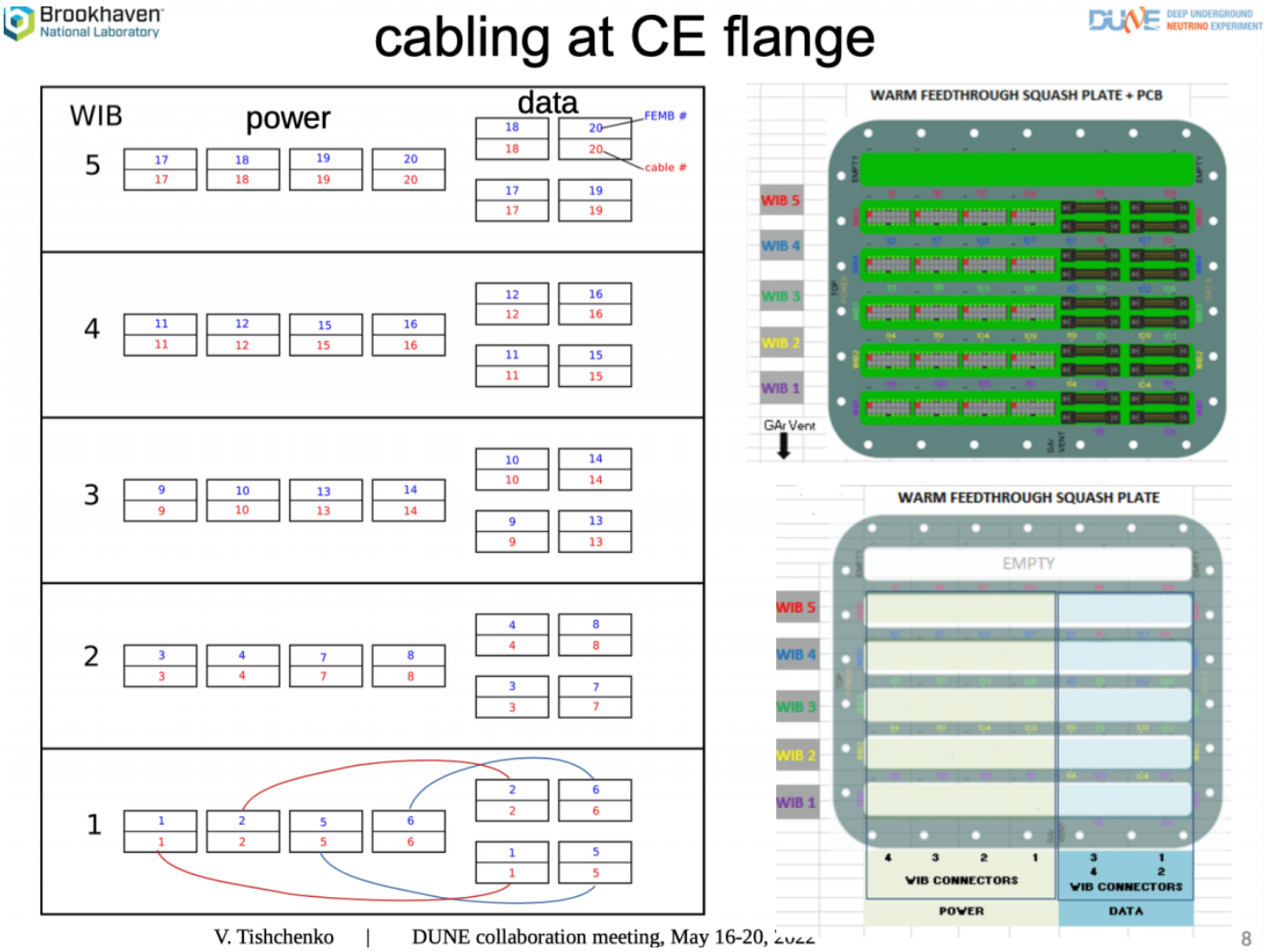
FEMBs are numbered from 1 to 20. Due to the choice of numbering, the channels are numbered within an FEMB increasing in the opposite direction to the FEMBs.



A vector-graphic PDF version of this drawing is available [here (https://wiki.dunescience.org/w/img_auth.php/f/f4/8765016_Interface_pDUNEII_APA_CE_POSITIONS_v3.PDF)].

Cabling at the Cold Electronics Flange

The figure below gives the numbering of cables from the FEMBs to the WIBs. Each WIB sends data on two fiber links to the FELIX cards. Data are formatted in WIB frames that are sent along the links. Each WIB frame consists of data from two FEMBs, or 256 channels, on one time sample ("tick"). The WIB frames contain the crate number (= APA number, running from 1 to 4), the slot number (= the WIB number minus 1), and the Link number (0 or 1). The FEMB within a link also runs from 0 to 1. The first FEMB on Link 0 corresponds to WIB data connector 1 and the second FEMB on Link 0 corresponds to WIB data connector 2. Link 1 has data from connectors 3 and 4 in that order.



Channel Maps

The channel map service and associated files are [available (https://indico.fnal.gov/event/55149/contributions/245059/attachments/156640/204540/trjchanmapjune2022.pdf)] in github, along with a README.txt file describing what they are. They map a set of four numbers available in each WIB2 frame, crate:slot:link:wibframechan, to and from the offline channel number. The several versions correspond to different WIB firmware revisions used for the HD coldbox in 2022 and 2023, which re-ordered the ASIC numbering. Also included are "rotated" channel maps. These account for the fact that the wires run under the head boards for a distance before emerging into the active volume. The U-plane and V-plane wires are offset by three wires between where they are soldered and where they emerge from the head boards. The offline channel numbering assumes that the channels are active until their ends in the geometry, and so the rotated maps are to be used for physics. This effect was present in ProtoDUNE-SP as well, but as all six APAs were upright, it only corresponded to a vertical displacement of the detector. ProtoDUNE-HD has a mixture of upright and inverted APAs, and so matching the active volume on both sides of the cathode requires accounting for this effect. Details and pictures are available in this [presentation (https://indico.fnal.gov/event/55149/contributions/245059/attachments/156640/204540/trjchanmapjune2022.pdf)] on the ProtoDUNE-HD channel maps.

Offline Optical Channel Numbering

The schema for optical channel number is similar to ProtoDUNE-S. The lowest channel number is the optical detector positioned highest in x, y, and z (in other words, uppermost and farthest downstream on the Jura-side APAs). The number then increases first moving down in y, then down in z. The figure below shows this ordering.

	APA 3				APA 4			
	70	60	50	40	30	20	10	0
	71	61	51	41	31	21	11	1
	72	62	52	42	32	22	12	2
X > 0	73	63	53	43	33	23	13	3
Beam Left	74	64	54	44	34	24	14	4
Jura Side	75	65	55	45	35	25	15	5
	76	66	56	46	36	26	16	6
	77	67	57	47	37	27	17	7
	78	68	58	48	38	28	18	8
	79	69	59	49	39	29	19	9

Beam direction
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	APA 1				APA 2			
	150	140	130	120	110	100	90	80
	151	141	131	121	111	101	91	81
	152	142	132	122	112	102	92	82
	153	143	133	123	113	103	93	83
X < 0	154	144	134	124	114	104	94	84
Beam Right	155	145	135	125	115	105	95	85
Saleve Side	156	146	136	126	116	106	96	86
	157	147	137	127	117	107	97	87
	158	148	138	128	118	108	98	88
	159	149	139	129	119	109	99	89

ProtoDUNE-HD Coldbox

The coldbox is a temporary test stand and is read out by Crate 0. For offline processing of coldbox data, the crate number used is 2, which has the lowest-numbered offline channels. In case other crate numbers are used, any crate number that is not between 1 and 4 inclusive is interpreted to be 2 in order to map channels to the lowest-numbered offline channels.