

## DUNE Far Detector Parameters Spreadsheet

Anode Planes on Outside, One "10 kton" detector, **lbne-docdb 3383**

11-Aug-15

11.6 kton fiducial mass

Parameter	Input value	Units	Value at 88 Kelvin	Units	Quality	Notes
	calculated					
	10 kton 4850 1x2Hx3Wx25L 3.6 m drift					
<b>Anode Plane Assembly (APA)</b>						
	<b>2.3 x 6m APA</b>					
Wire spacing - X plane	4.79	mm		mm	***	Should be <5 mm for good tracking resolution and e-pi0 separation. Doc #266
Wire spacing - U plane	4.667	mm		mm	***	Should be similar to X plane. Exact size chosen to have an integral number of readout cards (multiples of 128) on an APA
Wire spacing - V plane	4.667	mm		mm	***	Should be similar to X plane. Exact size chosen to have an integral number of readout cards (multiples of 128) on an APA
Wire plane gap	4.76	mm		mm	***	Should be ~same as the wire spacing
Wire angle, u	35.710	deg		deg	***	Optimized for beam neutrino interactions. Doc #2836. Angle is with respect to x direction.
Wire angle, v	35.710	deg		deg	***	Optimized for beam neutrino interactions. Doc #2836. Angle is with respect to x direction.
num Grid wires per board	48				***	
num U wires per board	40				***	
num V wires per board	40				***	
num X wires per board	48				***	
number of boards across top, one side	10				***	On both sides
width boards at top	230	mm		mm	***	they are slightly less for clearance
APA active width	2.2944	m		m	***	Distance between outermost x wires.
Num grid wires	960				***	Grid wires have same orientation as the X plane
Num U wires	800				***	
Num V wires	800				***	
Num X wires	960				***	
thickness of boards along top	4.7625	mm		mm	***	3/16", should be about equal to wire spacing
width of boards along sides	296	mm		mm	***	they are slightly less for clearance
thickness of boards along sides	3.175	mm		mm	***	1/8", sides have U&V, bottom have X,U,V,grid
thickness of cover along sides and at bottom	1.5875	mm		mm	***	1/16" cover over sides and bottom
APA overall width	2.3159	m		m	***	APA frame width plus side boards plus cover
number of boards along side	20				***	
Wire diameter	150	micron		micron	***	copper-beryllium wire. Standard chamber wire
Wire tension	5.00	N		N	***	Hardened Cu-Be has 30 N break strength
APA num readout wires	2560				***	
Num readout channels per APA	80				**	Divide by MUX level & redundancy factor
APA total num wires	3520				***	
APA active height	5.9	m		m	***	Chosen for ease of transport and cryostat depth. This is the active height, not the total height
APA frame height	6.060	m		m	**	Side tube length
APA electronics mounting fin	0.228	m		m	**	
APA total height	6.302	m		m	**	Top of fin to outside of bottom cover
APA tube thickness	76.2	mm		mm	**	3"x 4"x 3/16" tubing
APA thickness grid plane to grid plane	114.3	mm		mm	***	grid plane to grid plane
APA thickness X plane to X plane	85.725	mm		mm	***	X plane to X plane
APA weight	258	kg		kg	**	Includes frame, printed circuit boards, readout boards, covers
U Wire length	7.29	m		m	***	
V Wire length	7.29	m		m	***	
Wire capacitance (in air)	15	pF/m		pF/m	**	H. Jostlein measurement of prototype
U,V wire capacitance (in LAr)	164	pF		pF	**	Apply dielectric constant for LAr
<b>Cathode Plane Assembly (CPA)</b>						
CPA thickness	5.1	cm		cm	***	2" tubing
Cathode plane weight	50	kg		kg	***	
number of CPA's per APA size	2				*	CPA panel size 2.3 m x ~3 m vertical. CPA's are half the size of an APA
CPA extension beyond APA	10.2	cm		cm	*	CPA extends past APA by 4" at end of row and at top and bottom.
<b>Detector Modules</b>						
Num Vertical APA's	2				***	Chosen to balance construction, installation and cryostat design factors
Arrangement of Anode & Cathode planes	A C A C A				**	Anode Planes on outside, closest to wall
Number of APA rows	3				***	Chosen to result in a moderate span
number of CPA rows	2				***	
Number of Longitudinal APA's in a row	25				**	Chosen to achieve minimum fiducial mass requirement
Total number of APAs per detector	150				**	
Total number of cathode planes per detector	200				**	CPA panel size 2.3 m x ~3 m vertical. CPA's are half the size of an APA
Centerline Distance between APA & CPA rows	3.637	m	3.631363	m	**	Set to be something less than 3.7 m
Drift distance	3.594	m		m	**	Distance from APA X plane to center of cathode plane
Detector Active Width	14.377	m		m	**	
Detector APA row Length	58.089	m	57.930	m	**	Outside of APA to Outside of APA
Detector CPA row length	58.292	m		m	**	Outside of CPA to Outside of CPA

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	calculated					
	10 kton 4850 1x2Hx3Wx25L 3.6 m drift					
Detector Active Height	11.873	m		m	**	Active height, Not total height of APA
Detector CPA Height	12.076	m		m	**	Outside of CPA to Outside of CPA
Detector Vertical APA gap	3.2575	cm		cm	***	2*(4 x 3.175mm FR4)+cover) + 4mm of clearance. Space between APA frames vertically
Detector Longitudinal APA gap	8	mm		mm	***	For inter-APA connection. Distance between G-10 covers.
Number of readout wires per cryostat	384,000				**	
Number of readout channels per cryostat	12000				**	
Number of grid wires per cryostat	144,000				**	
total APA+CPA+grid wire length per cryostat	3455	km		km	**	
APA Transverse Fiducial cut	0.3	m		m	*	Approx value for neutrino oscillation physics. Basis - MicroBooNE and ArgoNeuT studies
CPA Transverse Fiducial cut	0.01	m		m	*	exclude events with vertex within 1 cm of CPA centerline
Detector Longitudinal fiducial cut	1.5	m		m	**	Approx value for neutrino oscillation physics. 10 cm upstream, 140 cm downstream. Basis: ArgoNeuT events and simulations
Longitudinal fiducial fraction	97%				*	
Transverse fiducial fraction	91%				*	30 cm cut at APA and 1 cm cut at CPA
Vertical fiducial fraction	95%				*	
Detector fiducial fraction	85%				*	
Liquid Argon Density	1.389	gm/cm <sup>3</sup>		gm/cm <sup>3</sup>	***	At ullage pressure, 0.100 MPa + 0.013 MPa = 0.113 MPa absolute
Liquid Argon Temperature	88.3	K	88.3	K	***	At ullage pressure, 0.100 MPa + 0.013 MPa = 0.113 MPa absolute
Field Cage Area	2012	m <sup>2</sup>		m <sup>2</sup>	**	
Detector Fiducial Mass	11.6	kton		kton	*	
Detector Active Mass	13.8	kton		kton	**	Ignores vertical and longitudinal gaps between APA's

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<b>Electronics</b>						
Mux level	128				**	
Readout redundancy	4				**	
Front end amplifier shaping time	1.0	micro-sec		micro-sec	***	Choices are 0.5, 1 and 2 micro-sec
Readout electronics board power	8	W/board		W/board	**	Preliminary from LBNE-docdb-9047
Electronics power per detector	23.7	kW		kW	**	
ENC @ 90K	403	electrons		electrons	***	BNL ASIC measured
ENC @ 300K	833	electrons		electrons	***	BNL ASIC measured
dE/dx (1 MIP)	2.1	MeV/cm		MeV/cm	***	
W ion (ionization energy)	23.6	eV		eV	***	
Recombination factor @ 500 V/cm	70%				***	NIM A523, 3 (2004)
Ionization 1 MIP - min	29836	electrons		electrons	**	
Electron drift velocity	1.6	mm/micro-sec		mm/micro-sec	***	Drift velocity for 500 V/cm electric field
Electron drift time	2.25	ms		ms	***	
Electron lifetime assumption	3.00	ms		ms	NA	Set to achieve minimum S/N = 9, revised 5/13/15.
Equivalent O2 contamination	107	ppt		ppt	**	ICARUS, A. Bettini, et al., NIM A305 (1991) 177.
Signal to noise ratio - max	74				*	For 1 MIP
Signal to noise ratio - min	35				*	For 1 MIP
Diffusion coefficient - Long	5.3	cm <sup>2</sup> /s		cm <sup>2</sup> /s	**	
Diffusion coefficient - Trans	12.8	cm <sup>2</sup> /s		cm <sup>2</sup> /s	**	at 500 V/cm (IEE Trans. on Dielectrics 5 (1968) 450)
Long diffusion rms at max drift	1.5	mm		mm	**	
Trans diffusion rms at max drift	2.4	mm		mm	**	
ADC sampling rate	2	MHz		MHz	**	Same as ICARUS, MicroBooNE and ArgoNeuT
Num MIP dynamic range	15				**	15 MIP ionization is a reasonable maximum value
ADC resolution - min	11	bits		bits	**	Minimum value required
<b>High Voltage</b>						
Drift field	500	V/cm		V/cm	***	Same as ICARUS, MicroBooNE and ArgoNeuT
Cathode high voltage	180	kV		kV	***	
Num cathode HV feedthrough	2				**	One supply on each CPA row
Minimum Distance between High Voltage & ground	0.359	m		m	*	HV to ground, 5 kV/cm nominal. Consider 40 kV/cm as breakdown field.
LAr depth above CPA	0.509	m		m	*	HV to GAR, 5 kV/cm nominal + 15 cm
Grid bias voltage	-665	V		V	***	Adjust to achieve transparency. Doc #2833
U plane bias voltage	-370	V		V	***	Adjust to achieve transparency. Doc #2833
V plane bias voltage	0	V		V	***	Adjust to achieve transparency. Doc #2833
Collection plane bias voltage	820	V		V	***	Adjust to collect electrons. Doc #2833
<b>Other</b>						
Dimensional change 293K to 88K, stainless steel	0.00274	mm/mm		mm/mm	***	
Dimensional change 293K to 88K, structural fiberglass	0.00155	mm/mm		mm/mm	**	4.23E-6 in/in-F, room temp to LN2 temperature
Dimensional change 293K to 88K, G-10 warp direction	0.00212	mm/mm		mm/mm	**	warp direction, in sheet plane
Dimensional change 293K to 88K, G-10 thickness direction	0.00626	mm/mm		mm/mm	**	normal to the sheet
<b>Detector Depth</b>						
Vertical rock cover	4706	ft		ft	**	
	1434	m		m	**	
Longitudinal axis of the LAr cavern	N80W +/-10	degrees		degrees	***	Beam direction from Fermilab
Rock formation	NA				*	
Rock density	2.82	g/cm <sup>3</sup>		g/cm <sup>3</sup>	***	
Effective shielding depth	4045.0	mwe		mwe	**	
Cosmic ray average energy	300	GeV		GeV	**	
Cosmic ray rate	0	Hz/m <sup>2</sup>		Hz/m <sup>2</sup>	**	
Cosmic ray rate - detector module top	0	kHz		kHz		
Cosmic ray rate - APA drift cell top	0.0	kHz		kHz		
Cosmic ray rate - APA drift cell all sides		kHz		kHz		
<b>Radioactive Backgrounds</b>						
Ar39 decay rate - beta	1	Hz/kg		Hz/kg	**	NIM A574 , 83 (2007)
Ar39 decay rate > 500 keV threshold	0.28	Hz/kg		Hz/kg	**	doc #3018
Average Ar39 decay energy	200	keV		keV	***	
APA cell Ar39 decay rate in one APA drift cell	38	kHz		kHz	*	
Kr85 decay rate - beta	0.2	Hz/kg		Hz/kg	*	NIM A574 , 83 (2007)
Kr85 decay rate > 500 keV threshold	0.06	Hz/kg		Hz/kg	*	doc #3018
Average Kr85 decay energy	251	keV		keV	***	doc #3018
APA cell Kr85 decay rate in one APA drift cell	8	kHz		kHz	*	doc #3018
Max allowable Co60, Th, U rate	TBD					No requirement set on this parameter (yet)
<b>Photon Detector</b>						
Num paddles per APA	10				**	
Num SiPM's per paddle	12				**	
Paddle acrylic thickness	0.48	cm		cm	*	4 - 1" x 3/16" bars

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Paddle acrylic width	10.16	cm		cm	*	4 - 1" x 3/16" bars
Paddle acrylic length	209.12	cm		cm	*	
Total num paddles cryostat	1500				**	
Total num SiPM's per cryostat	18000				**	
Number of SiPM's per readout channel	3				*	gang 3 SiPM's together
Number of PD readout channels	6000				*	
Sensitivity at 3.7 m	0.1	PE/MeV		PE/MeV	*	For a MIP (doc #4134)
Maximum N2 contamination	1.9	ppm		ppm	*	2 ppm nitrogen contamination will start interfering with 3 m to 4 m photon transmission in LAr
DAQ						
DAQ readout mode	Continuous				***	
DAQ samples/hit	12				**	
APA data rate: Ar39	10.9	MBytes/s		MBytes/s	**	
APA data rate: Kr85	2.3	MBytes/s		MBytes/s	*	
APA data rate: Co60, Th, U	0.5	MBytes/s		MBytes/s	*	
APA data rate: Cosmic rays	3.E-08	MBytes/s		MBytes/s	*	
APA data rate total	13.8	MBytes/s		MBytes/s	*	

Quality

Meaning

\*\*\*

Stable, well understood parameter

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Reasonably well defined parameter

\*

Rough estimate

red font

possible issue with the value