ProtoDUNE-SP CE Mechanicals

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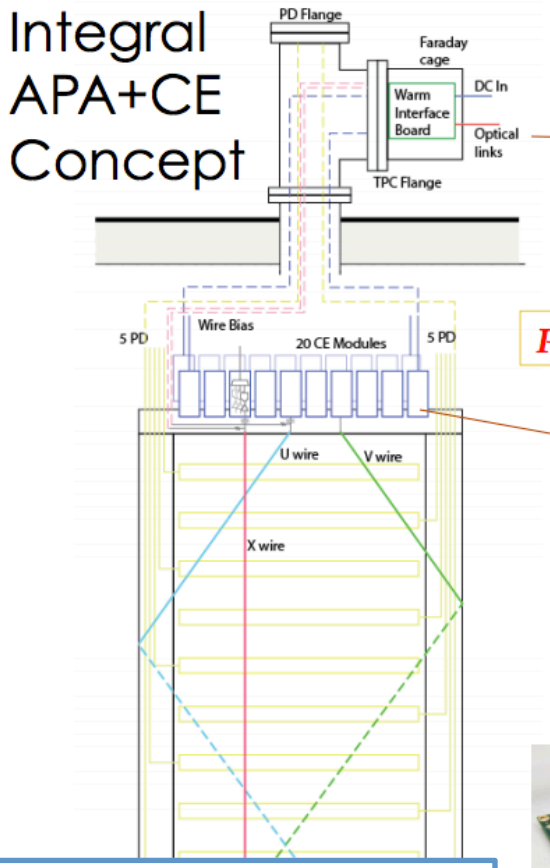
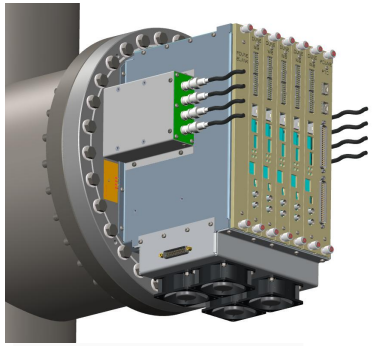
ProtoDUNE-SP Cold Electronics Production Readiness Review
March 28, 2017

Outline

- Cold Electronics introduction
- Mechanical components
  - CE Box
  - Signal feed-through
    - Tee pipe
    - Crossing Tube Cable (CTC) support
  - CE warm components
    - Warm flange
    - Flange PCB
    - Warm Interface Electronics Crate (WIEC)
  - Cold Cable
- Schedule
- Conclusion

LArTPC Cold Electronics

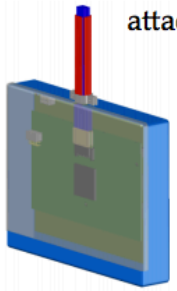


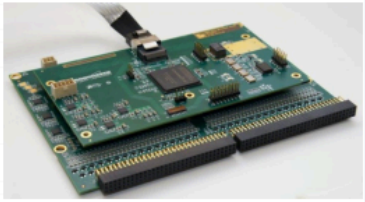


Warm Interface Electronics Crate: interface between CE and DAQ with local real-time diagnostics.

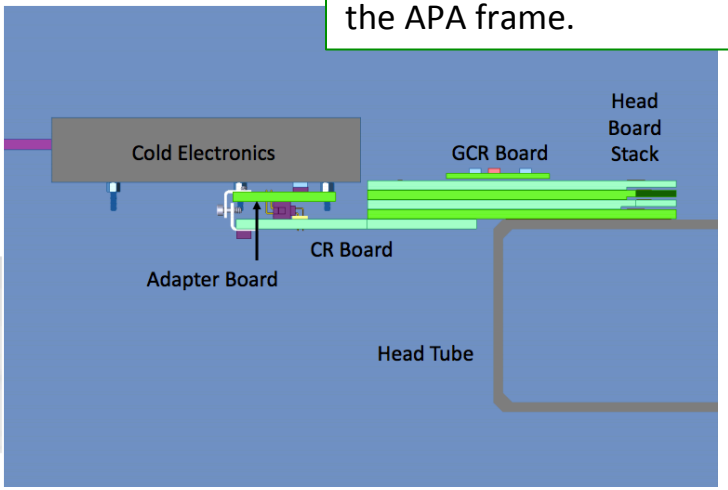
ProtoDUNE-SP

Cold electronics module and its attachment to the APA frame





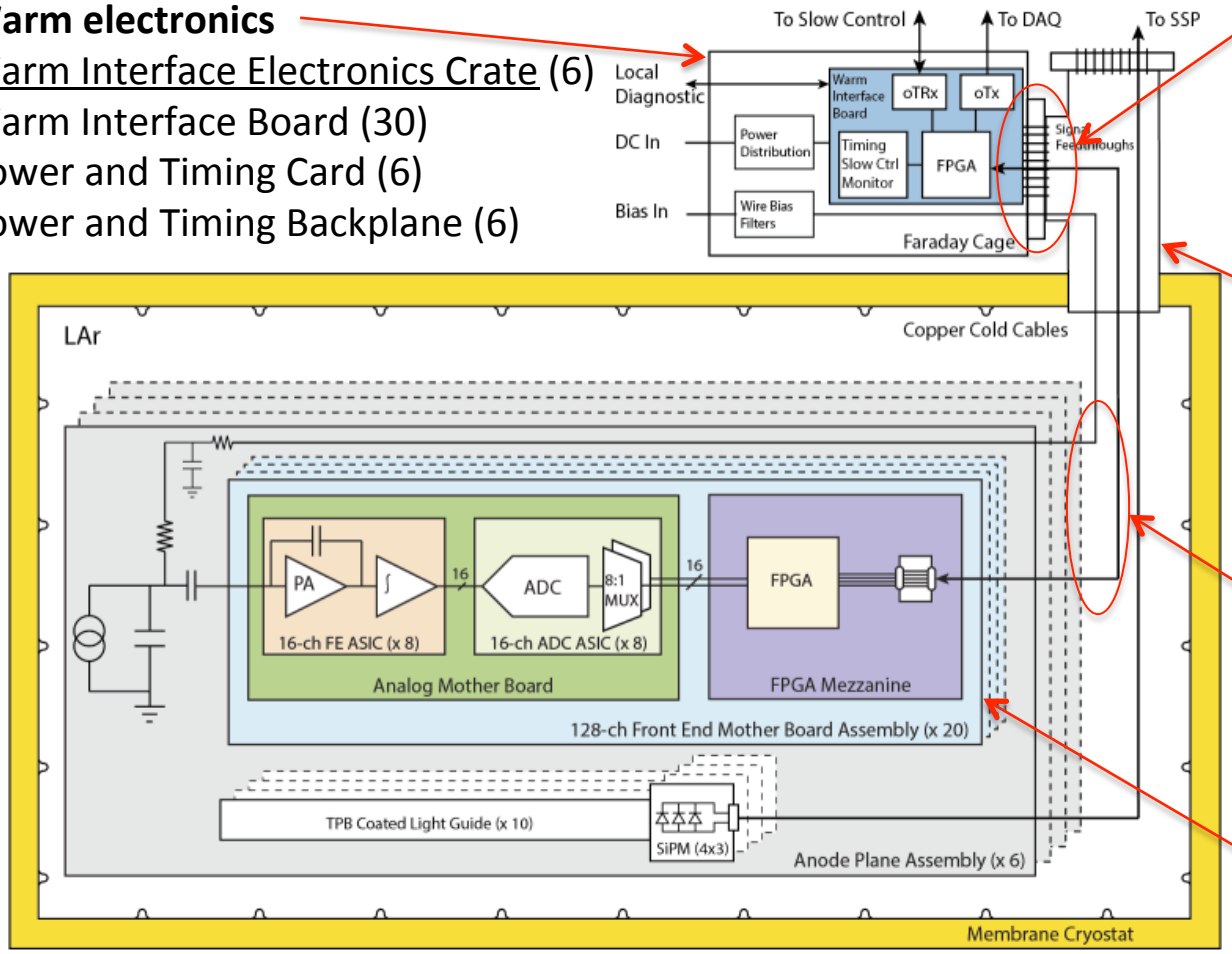
Common plane of all cold electronics must make low impedance connection to the APA frame.



Each APA must be isolated inside the cryostat and only connected to detector ground at the flange.

ProtoDUNE-SP Cold Electronics

Warm electronics
Warm Interface Electronics Crate (6)
Warm Interface Board (30)
Power and Timing Card (6)
Power and Timing Backplane (6)



CE flange
Flange assembly with cable strain relief and flange PCB for cable/WIB connection (6)

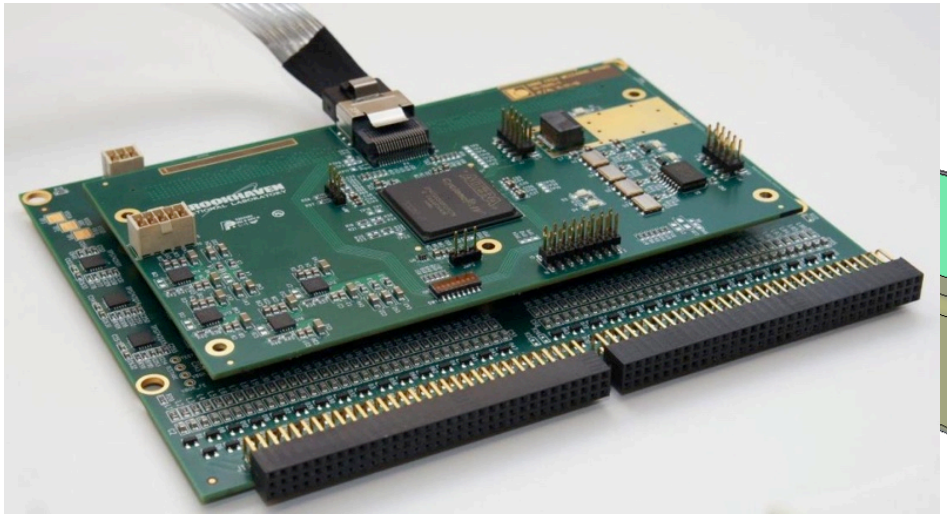
Signal feed-through
Tee pipe with 14" Conflat flanges and crossing tube cable (CTC) support (6)

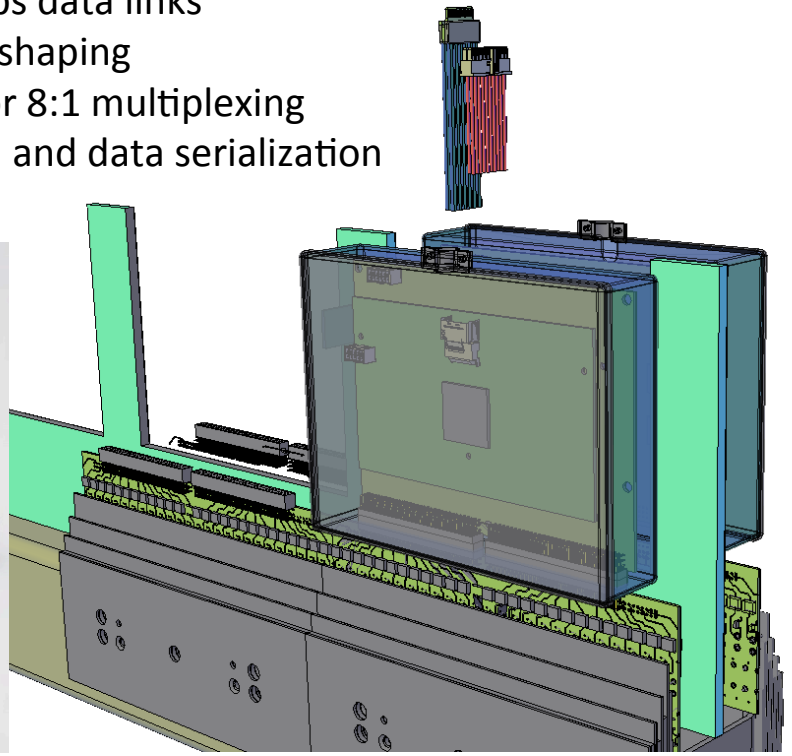
Cold cable to FEMB
LV and data cable (120+120) and APA wire-bias SHV cable (48)

Front End Motherboard (FEMB) 128 channels of digitized wire readout enclosed in CE Box (120)

FEMB

- 128 channels of digitized wire readout, 4x1 Gbps data links
- 8 16-channel FE ASICs: pulse amplification and shaping
- 8 16-channel ADC ASICs: digitization and 16:1 or 8:1 multiplexing
- FPGA mezzanine for ASIC control/configuration and data serialization



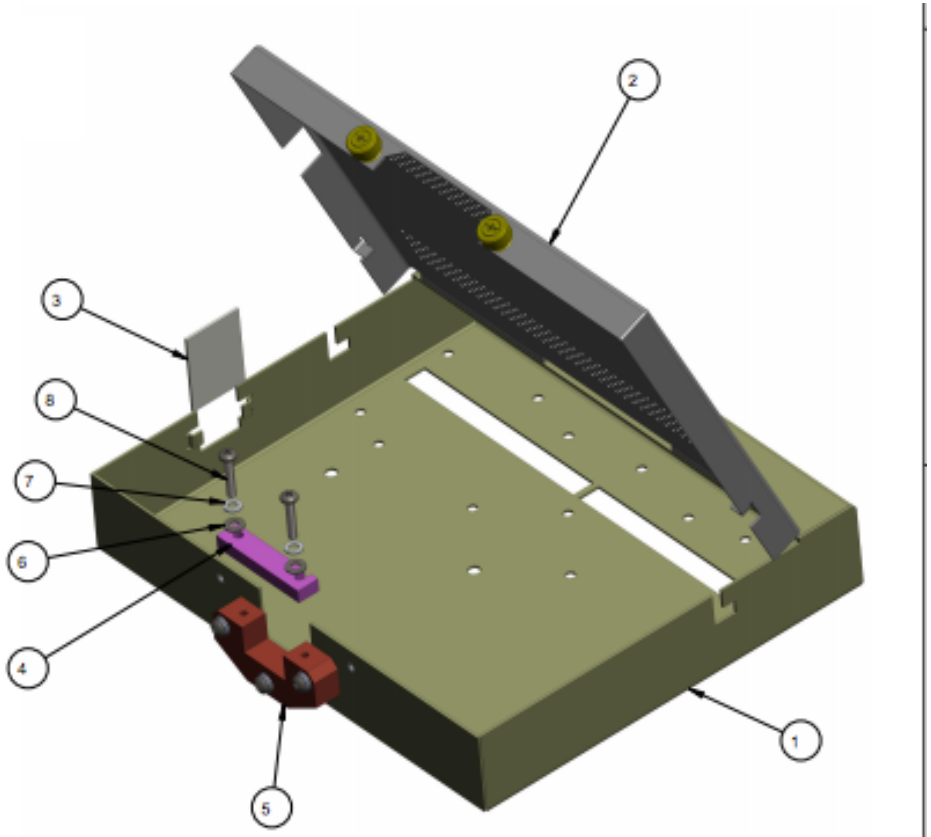


FEMB individually enclosed in CE Box: 20 FEMB/APA

- ESD protection for ASICs and FEMB circuitry and Faraday shield
- Attaches to PSL APA adapter and built-in cable strain-relief
- Low impedance connection from FEMB ground to APA frame

CE Box

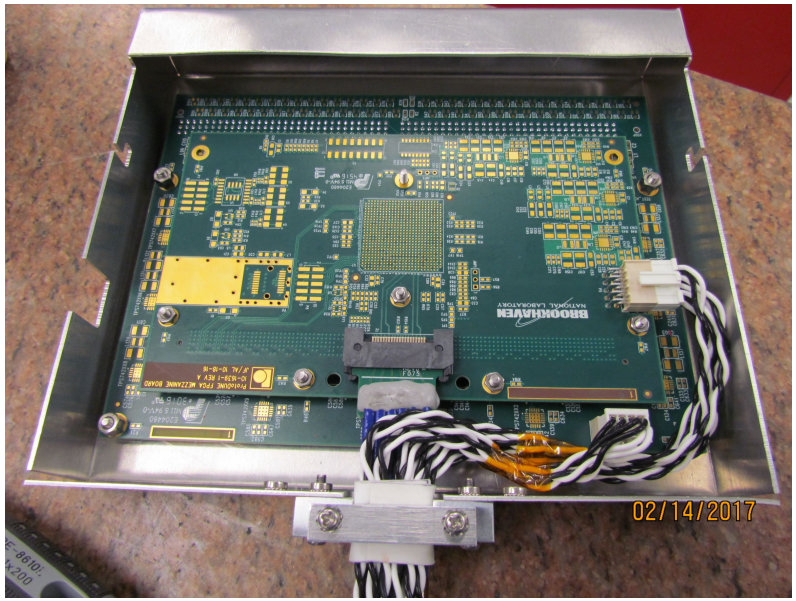
- Mechanical and assembly drawings in [DUNE DocDB 2611]
- Current status
  - 1 prototype machined at BNL
    - Six slow cold cycles into LN2 and one cold SHOCK, with no continuity issues at the data connector
  - Attachment holes to mount PSL APA adapter agreed to between BNL and PSL and checked
  - Order for 3 prototypes submitted to Zober Industries for fabrication
  - Delivery expected on 4/21
- Production plan
  - Submit final order of 150 on 5/5
  - 4 weeks lead time
  - 2-3 days assemble first 20 boxes to be ready for APA1 FEMBs in mid June
  - 2 weeks check and assemble remaining boxes at BNL
- Ready for final FEMB QC in July 2017
  - ASIC production is FEMB schedule driver



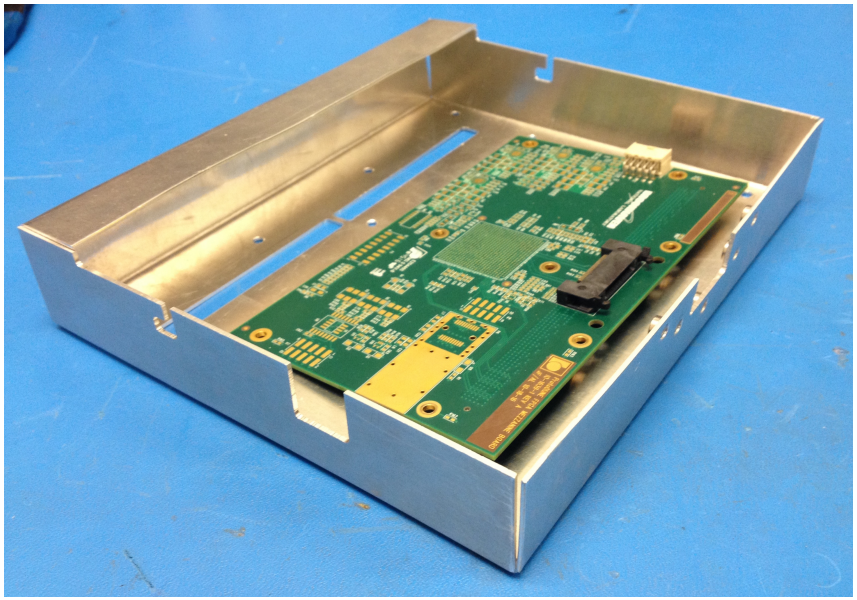
ITEM	QTY	PART NAME / DESCRIPTION	TYPE	MATERIAL	MASS [kg]	DRAWING / PART NUMBER
8	5	PAN_PHILLIPS_SCREW_M3X0_5X16LG	PART	18-8_SST	0.001	MCMASTER_92000A126
7	5	SPLTLK_WASHER_M3X0_7LG	PART	18-8_SST	0.000	MCMASTER_92148A150
6	5	FLAT_WASHER_M3X3_2IDX7ODX0_6LG	PART	18-8_SST	0.000	MCMASTER_93475A210
5	1	CLAMP_BLOCK_BASE	PART	304_SST	0.057	PDUNE-400-5
4	1	CLAMP_BLOCK_TOP	PART	304_SST	0.013	PDUNE-400-4
3	1	CE_BOX_OPENING_COVER	PART	18-8_SST	0.005	PDUNE-400-3
2	1	CE_BOX_COVER_ASSY	ASSEMBLY		0.767	PDUNE-400-2
1	1	CE_BOX_BASE_ASSY	ASSEMBLY		0.432	PDUNE-400-1

CE Box Prototype

CE Box prototype machined at BNL
- Complete box assembly with cable clamp
- FEMB installed with cold cable
- Cable connectivity and mounting hardware passed tests in LN2

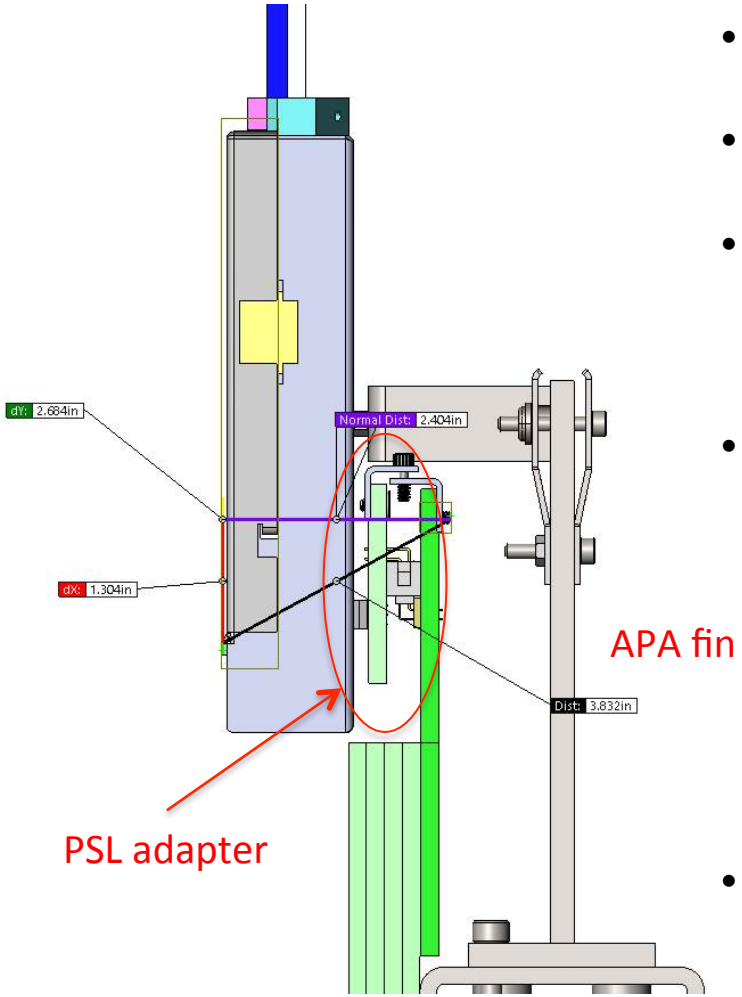


Box with cable clamp containing full FEMB assembly for cable routing and testing



Bare box containing FEMB FPGA mezzanine PCB

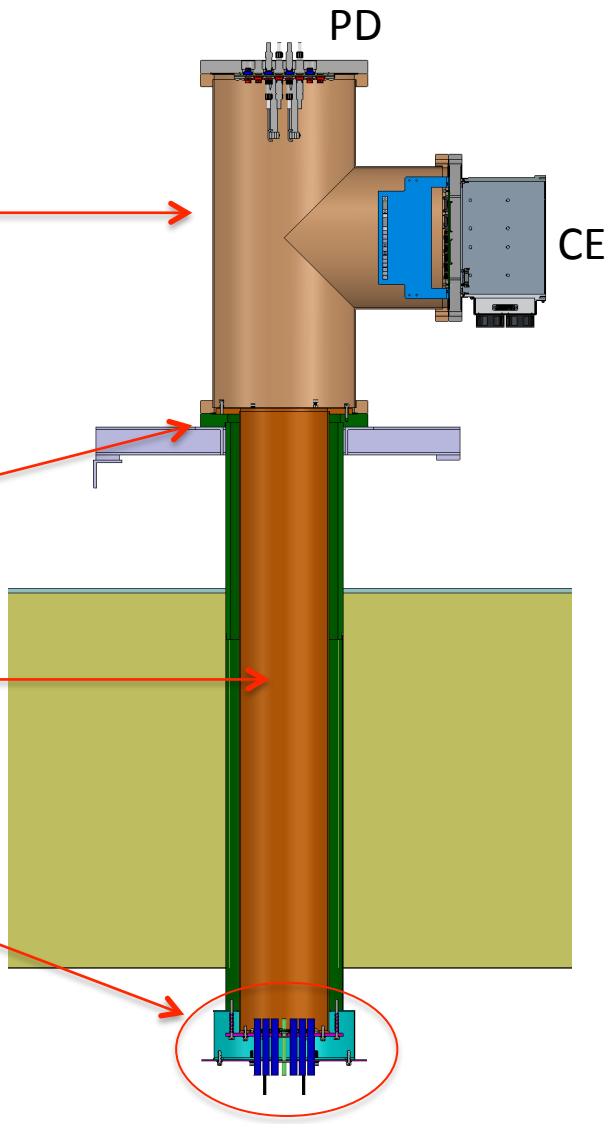
CE Box QC Plan



- Upon delivery to BNL, boxes will be visually inspected and clamps assembled onto bases
- All FEMB will be pre-tested in LN2 to reject/ replace bad components
- Tested FEMB will be “dressed”
  - Installed in CE Box with mounting hardware
  - Cold cables clamped and cover closed
  - PSL adapter board attached
- FEMB + cable + adapter are final unit and each one will be individually retested in LN2
  - Connection from adapter socket to FEMB input checked with toy TPC (150 pF load)
  - Criteria to pass QC:
    - Full suite of FEMB QC passed: functionality, noise characterization, ADC response (DUNE DocDB 1809)
    - No visible stress damage or loose hardware after return to room temperature
  - Results stored in QC database for comparison at CERN
- Final units shipped from BNL to CERN
  - Custom shipping crates to be designed and built at BNL
  - Electronics can be stored in shipping crates until installation

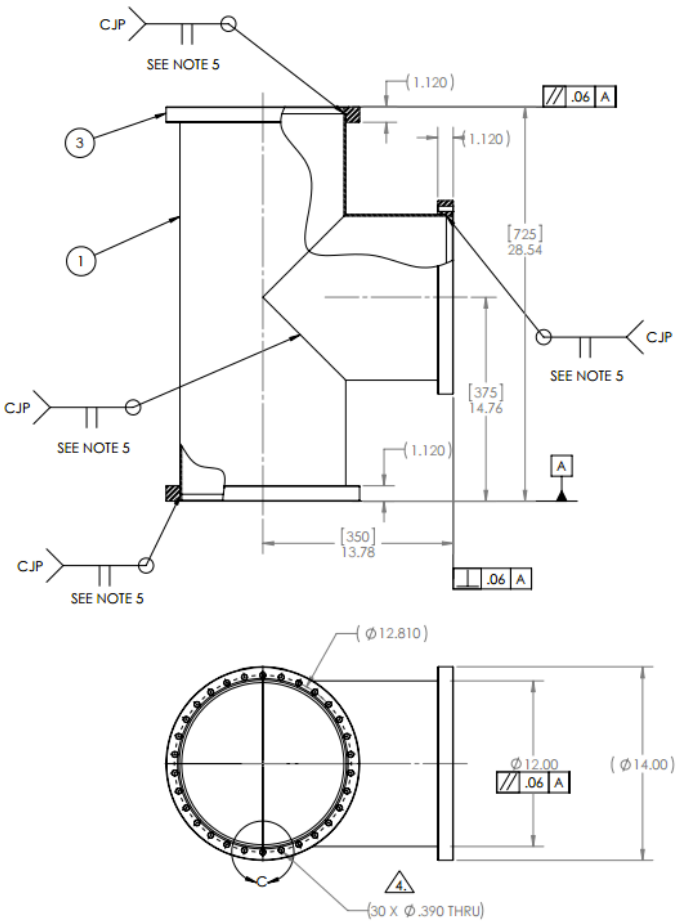
Signal Feed-through

- ProtoDUNE-SP signal feed-through has two major parts
  - Tee pipe with 14” Conflat flanges to attach CE and PD flanges
    - PD cables will be routed to the top flange
    - CE cables will be routed to the side flange
  - Crossing Tube Cable (CTC) support
    - Attaches the top of 14” Conflat flange of crossing tube from CERN
    - Additional support from L-brackets under the crossing tube flange
    - Thin inner tube also controls GAr flow in ullage
    - Provides cable strain relief at lower end of cryostat crossing tube without touching tube
- One signal feed-through per APA: 6 total

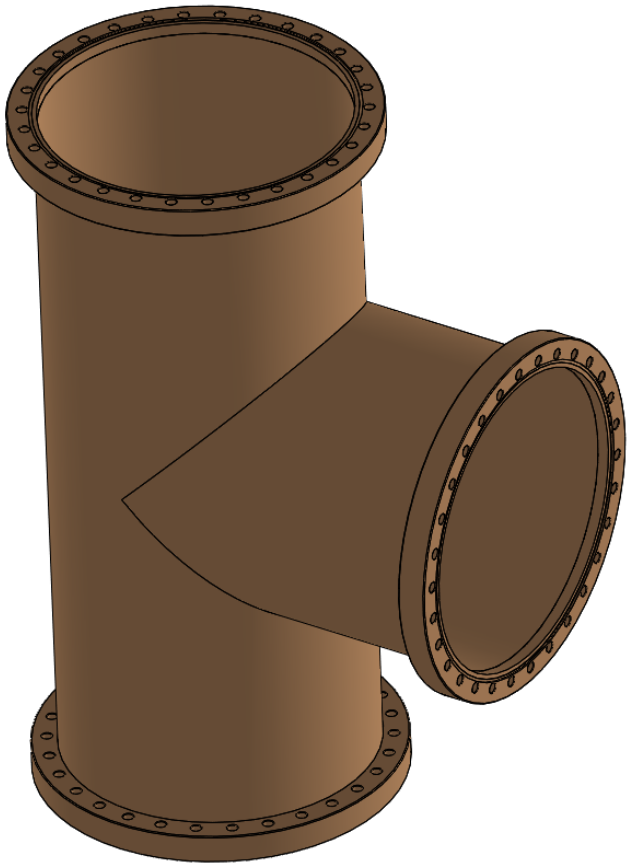


Tee Pipe

- Mechanical drawing in [DUNE DocDB 2126]
- Current status
  - 1 prototype built by MDC Vacuum Products and to be delivered to BNL
  - Will be tested on 40% APA teststand with prototype CE flanges and electronics at BNL
- Production plan
  - Submit final order of 8 on 4/21
  - 6 weeks lead time
  - 2 weeks for QC at BNL
- Ready for assembly onto cryostat top in August 2017
  - One will be shipped to CERN for Cold Box integration test in July
    - If necessary ship current prototype



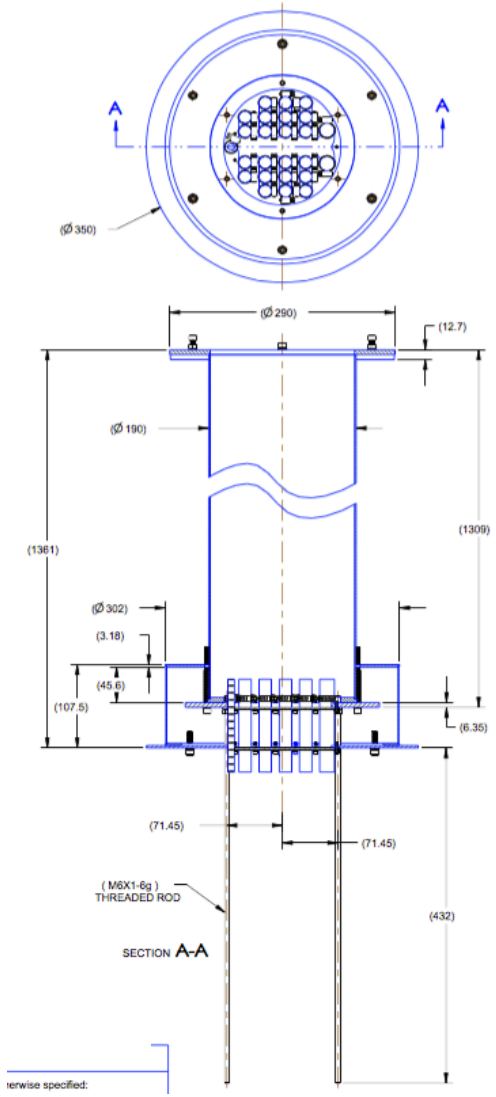
Tee Pipe QC Plan



- Manufacturer will provide certification of leak check
- Tee pipes will ship to BNL
- 2 weeks for QC
  - Visually inspect and check label upon receipt
  - Ensure fit to flanges and CTC:
    - Attach 14” flange blank to both CE and PD Conflat flanges
    - Fit top of CTC inner tube into lip of bottom Tee pipe Conflat
- Final units shipped from BNL to CERN
  - Custom shipping crates to be designed and built at BNL
- 1 week for acceptance at CERN
  - Recheck mechanical assembly
  - Store in shipping containers until installed on cryostat

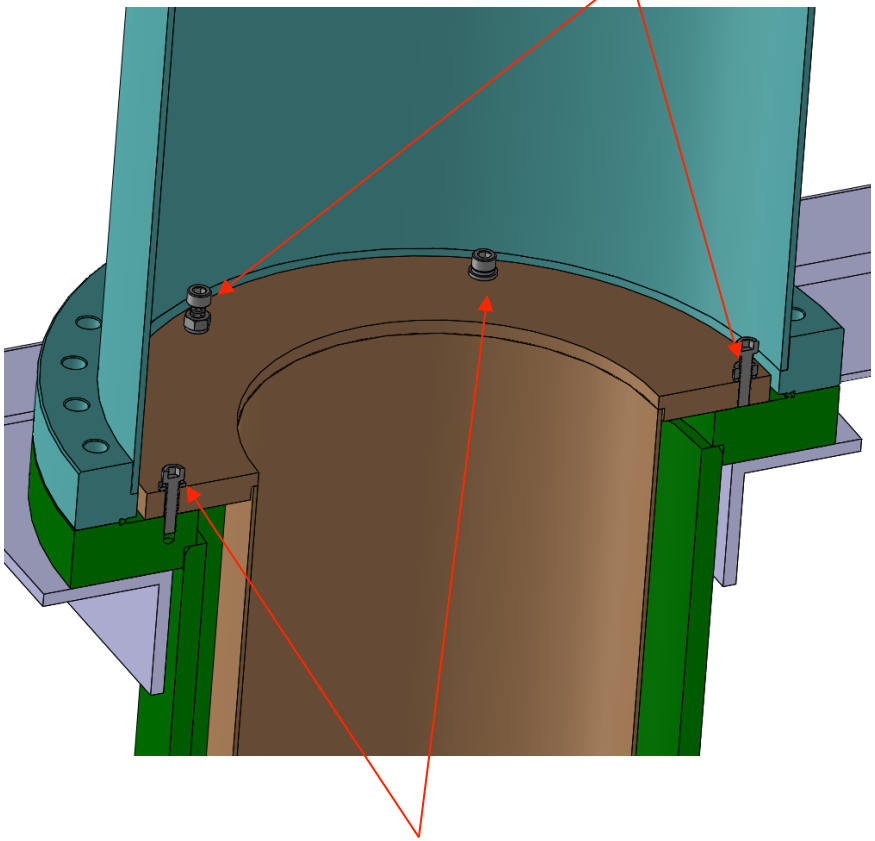
CTC Support

- Mechanical and assembly drawings in DUNE DocDB 2883
- Current status
  - 2 prototypes will be ordered on 3/31
- Production plan
  - Submit final order of 8 on 5/12
  - 4 weeks lead time
  - 2 weeks for QC at BNL
- Ready for assembly onto cryostat top in August 2017
  - CTC not needed for cold box testing

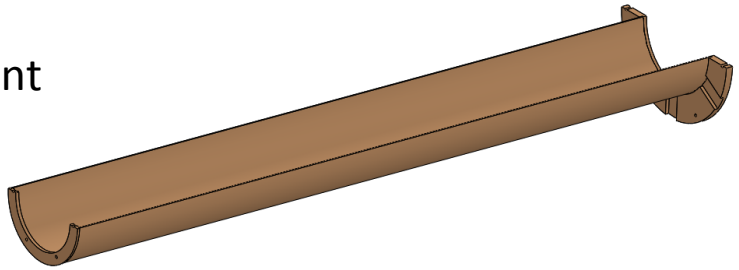


CTC Upper End

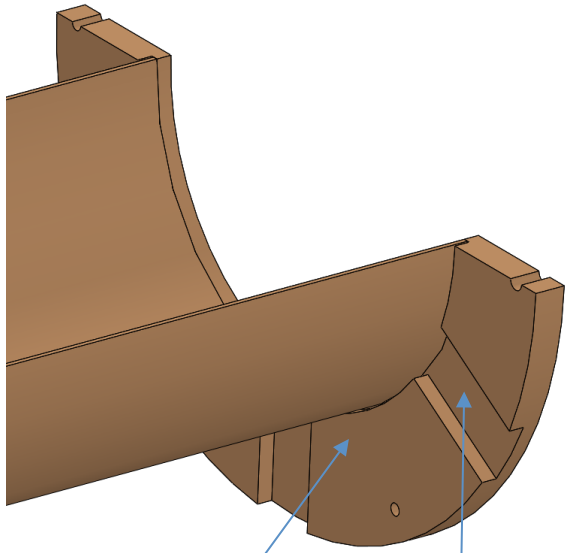
Three screws for concentric alignment



Three screws for Inner tube tightening



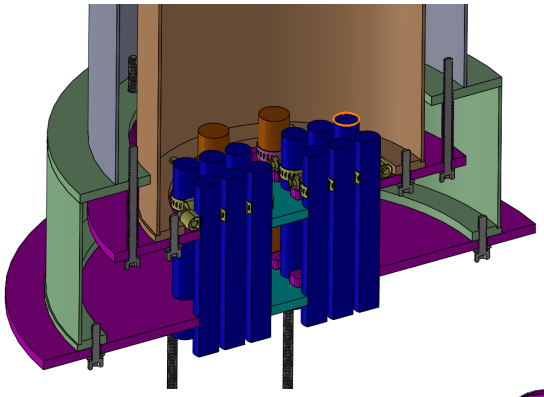
Inner tube



Higher flange

Grooves for gas flow

CTC Lower End

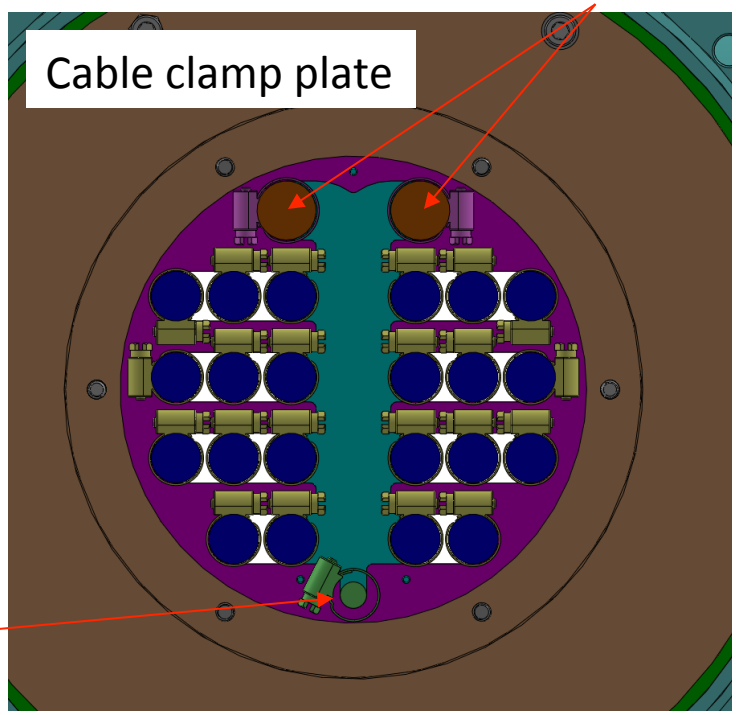


Assembled view

Exploded view of the lower end of the feed-through chimney

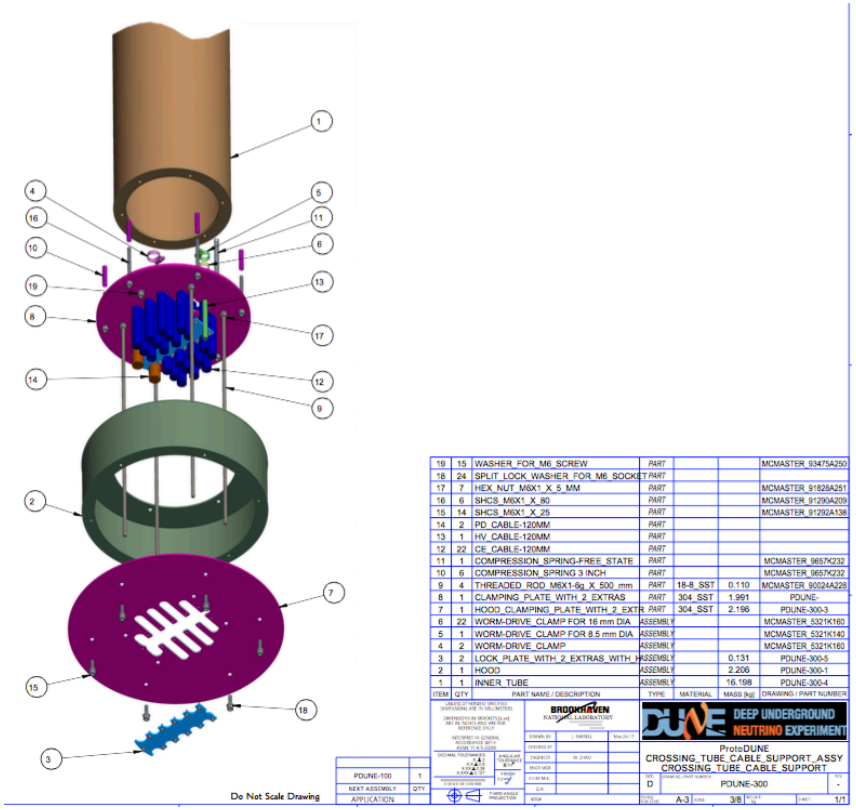
Looking down through Inner Tube at Clamping Plate:

PD cable bundles



HV cable bundle

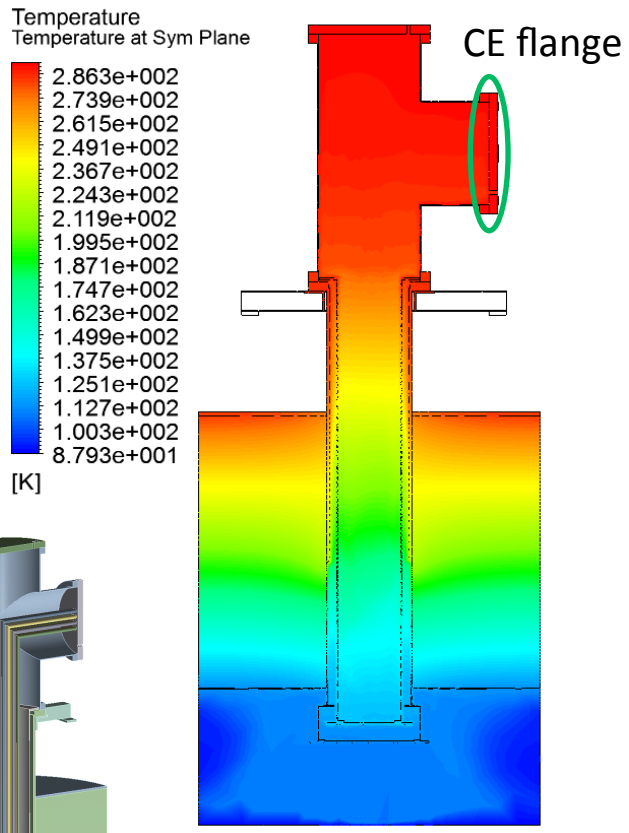
CTC QC Plan

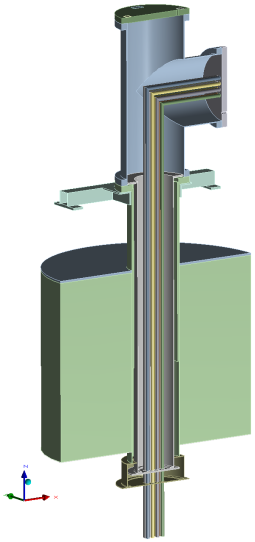


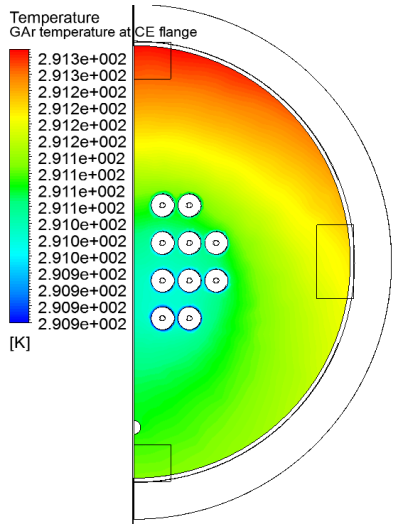
ITEM	QTY	PART NAME / DESCRIPTION	TYPE	MATERIAL	MASS [kg]	DRAWING / PART NUMBER
19	15	WASHER_FOR_M6_SCREW	PART			MCMASTER_93475A250
18	24	SPLIT_LOCK_WASHER_FOR_M6_SOCKET	PART			
17	7	HEX_NUT_M6X1_X_5_MM	PART			MCMASTER_91828A251
16	6	SHCS_M6X1_X_80	PART			MCMASTER_91290A209
15	14	SHCS_M6X1_X_25	PART			MCMASTER_91292A138
14	2	PD_CABLE-120MM	PART			
13	1	HV_CABLE-120MM	PART			
12	22	CE_CABLE-120MM	PART			
11	1	COMPRESSION_SPRING-FREE_STATE	PART			MCMASTER_9657K232
10	6	COMPRESSION_SPRING 3 INCH	PART			MCMASTER_9657K232
9	4	THREADED_ROD_M6X1-6g_X_500_mm	PART	18-8_SST	0.110	MCMASTER_90224A228
8	1	CLAMPING_PLATE_WITH_2_EXTRAS	PART	304_SST	1.991	PDUNE-
7	1	HOOD_CLAMPING_PLATE_WITH_2_EXTR	PART	304_SST	2.196	PDUNE-300-3
6	22	WORM-DRIVE_CLAMP FOR 16 mm DIA	ASSEMBLY			MCMASTER_5321K160
5	1	WORM-DRIVE_CLAMP FOR 8.5 mm DIA	ASSEMBLY			MCMASTER_5321K140
4	2	WORM-DRIVE_CLAMP	ASSEMBLY			MCMASTER_5321K160
3	2	LOCK_PLATE_WITH_2_EXTRAS_WITH_H	ASSEMBLY		0.131	PDUNE-300-5
2	1	HOOD	ASSEMBLY		2.206	PDUNE-300-1
1	1	INNER_TUBE	ASSEMBLY		16.198	PDUNE-300-4

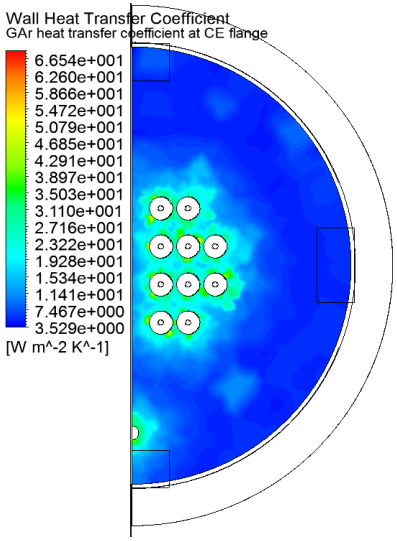
- CTC assemblies will ship to BNL
- 2 weeks for QC
  - Visually inspect and check label upon receipt
  - Ensure fit to Tee pipe
    - Fit top of CTC inner tube into lip of bottom Tee pipe Conflat
  - Assemble lower end of each CTC structure
- Final units shipped from BNL to CERN
  - Custom shipping crates to be designed and built at BNL
- 1 week for acceptance at CERN
  - Recheck mechanical assembly
  - Store in shipping containers until installed on cryostat

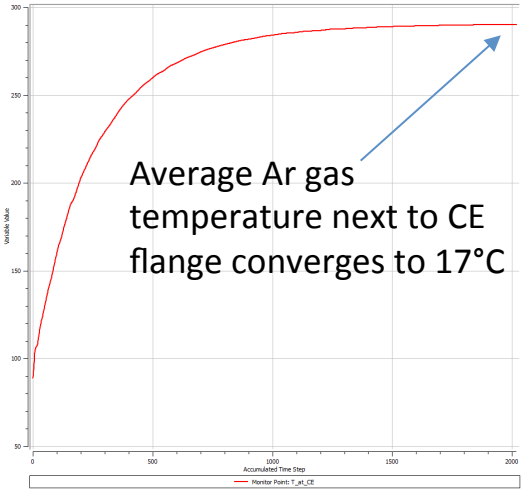
Signal FT Thermal Simulation

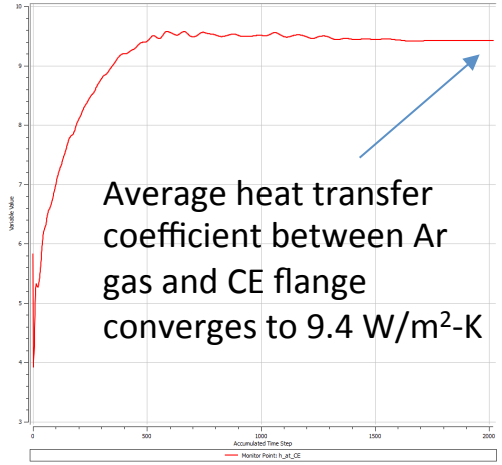




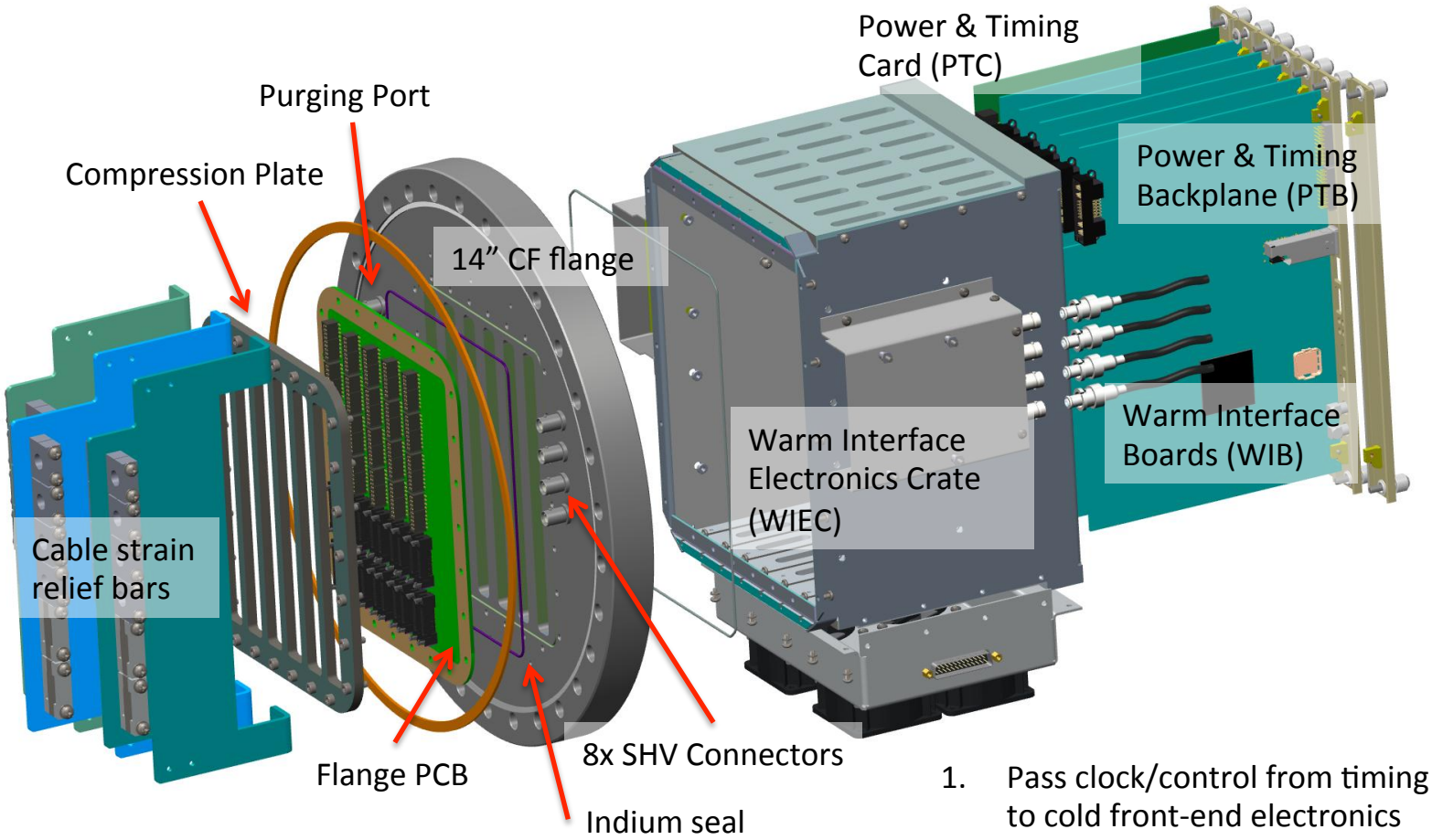






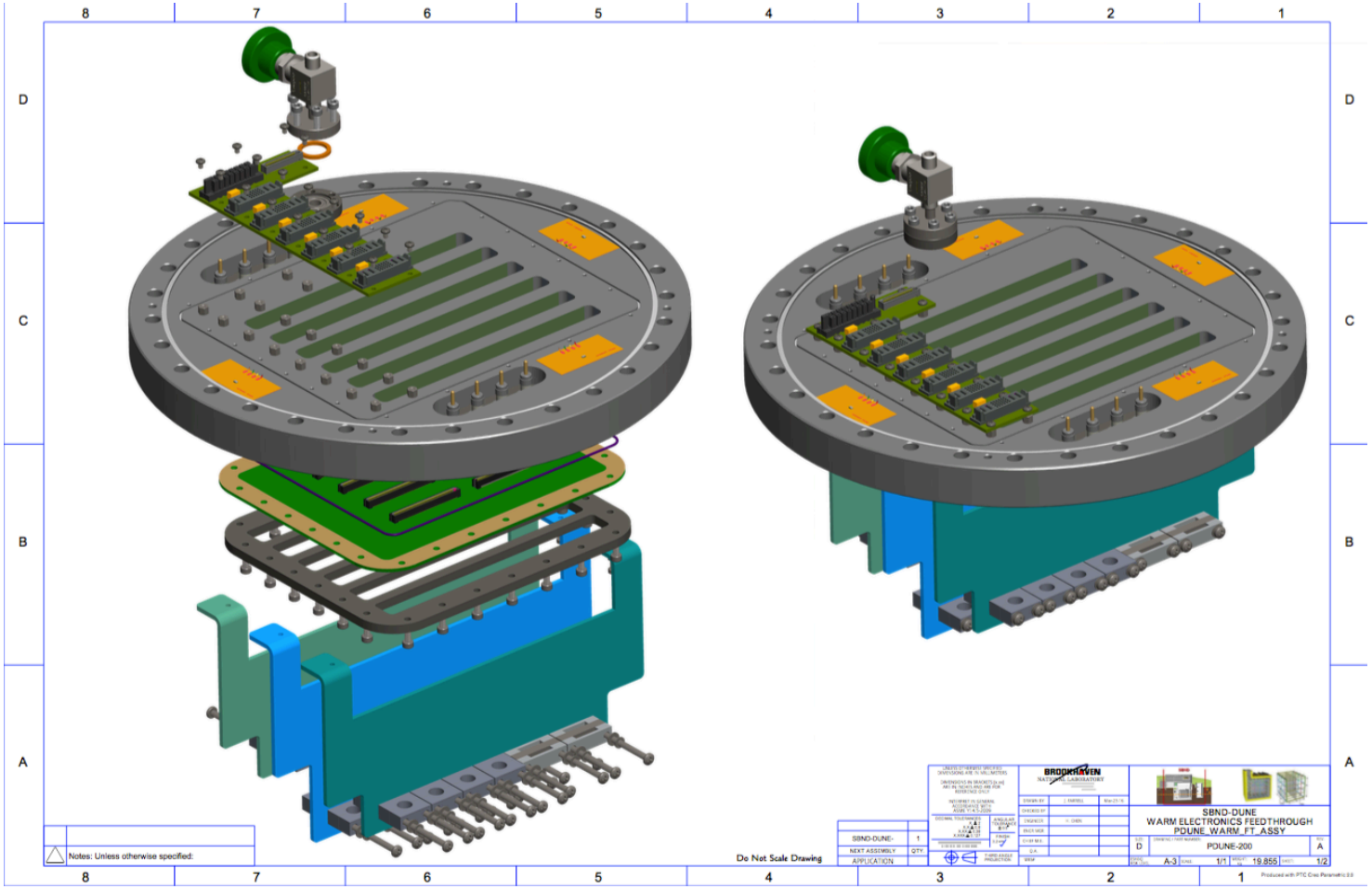


CE Warm Components



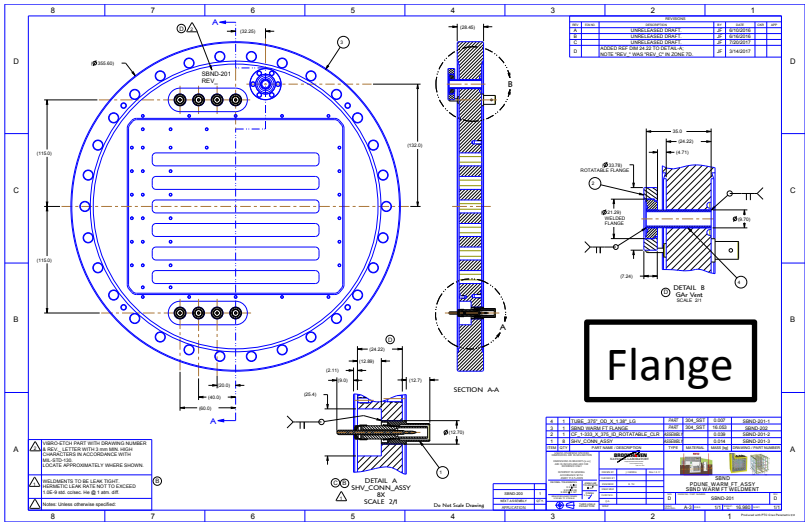
1. Pass clock/control from timing system to cold front-end electronics
2. Deliver high-speed TPC wire data from cryostat to DAQ
3. Connection to detector ground at CE flange
4. Pass wire-bias and FC HV to cryostat

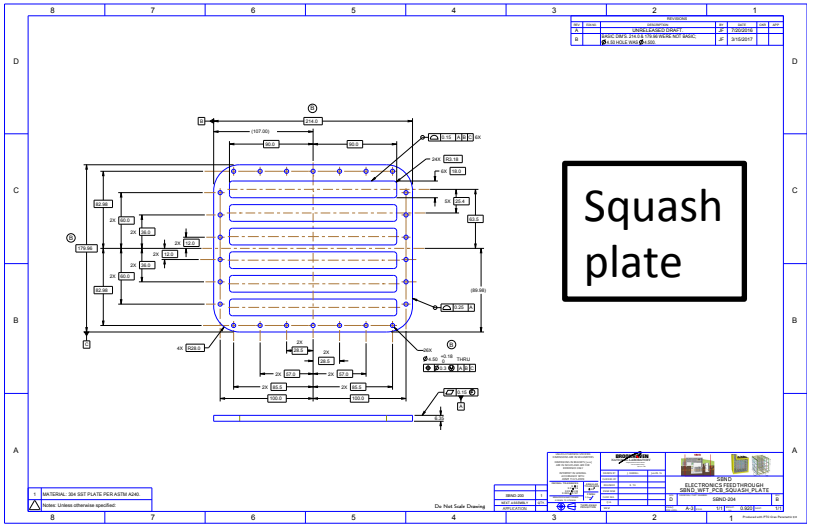
CE Warm Flange



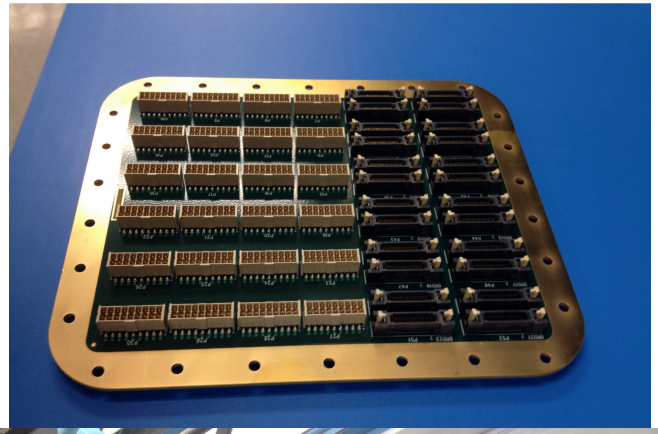
CE Warm Flange

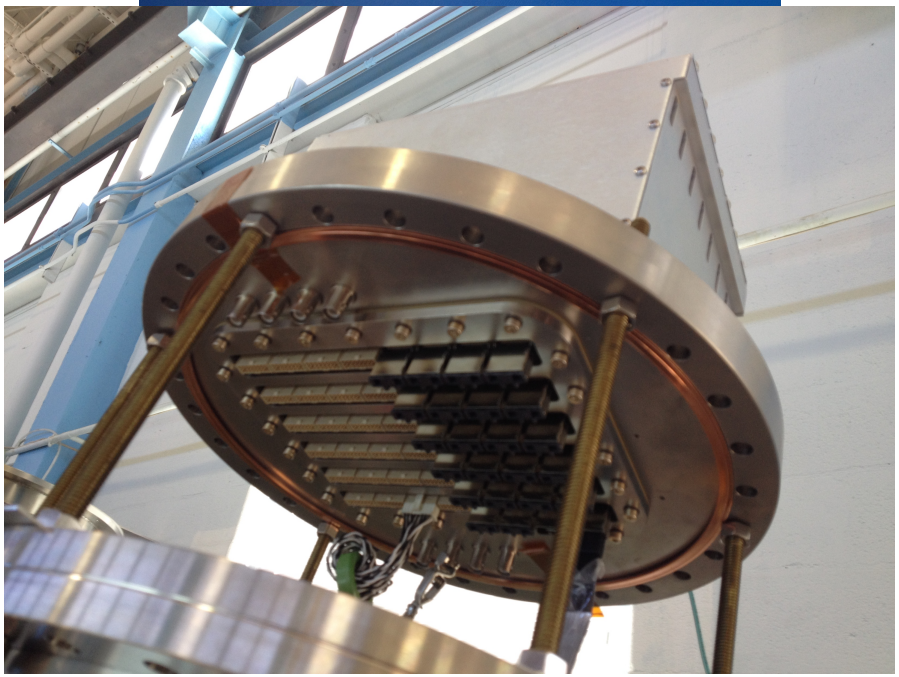
- Mechanical and assembly drawings in DUNE DocDB 2771
- Current status
  - 2 prototypes machined by MDC Vacuum Products and assembled and tested at BNL
  - Leakage tests passed up to 10^{-9} leakage rate with 5 PSI differential pressure applied to GAr side of the flange: DUNE DocDB 1809
  - 2 final prototypes will be ordered 3/31
- Production plan
  - Submit final order in 05/12
  - 6 weeks lead time
  - 1 week to assemble with flange PCB and squash plate
- Ready for QC testing at BNL in July 2017
  - One of final prototypes will be shipped for cold box tests





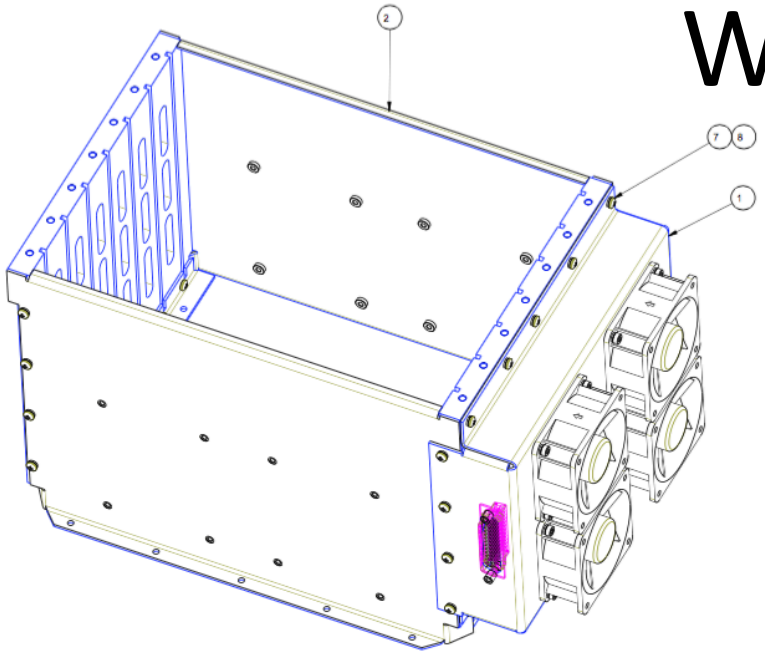
CE Flange PCB

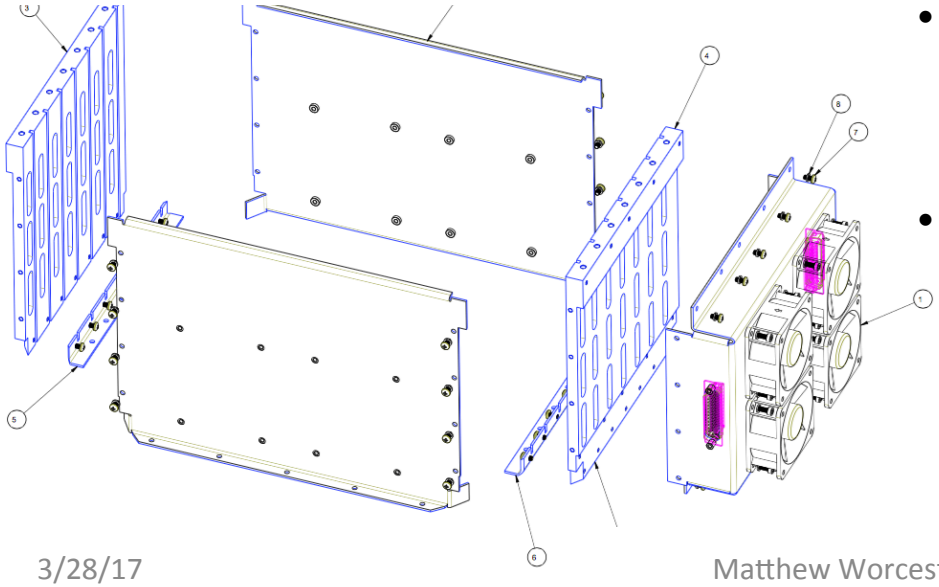




- Schematics, layout, and BOM in DUNE DocDB 2777
- Current status
  - 2 prototypes with nearly final version of connectors at BNL
    - Passed flange pressure tests
    - Tested with prototype PTC, WIB in prototype WIEC
  - 20 PCBs with final connectors ordered, due 03/31
- Production plan
  - Submit final assembly order in 05/12
  - 2 weeks lead time
  - 1 week for QC validation of electrical connectivity
- Ready prior to assembly onto CE flange assemblies in July 2017
  - Final QC done on CE flange

WIEC

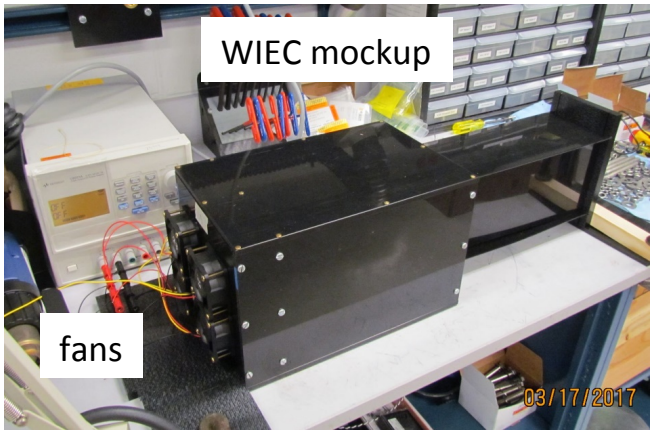


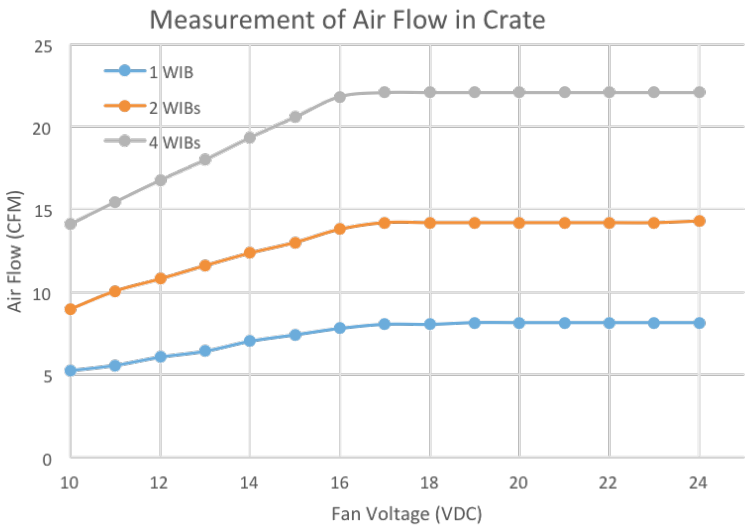


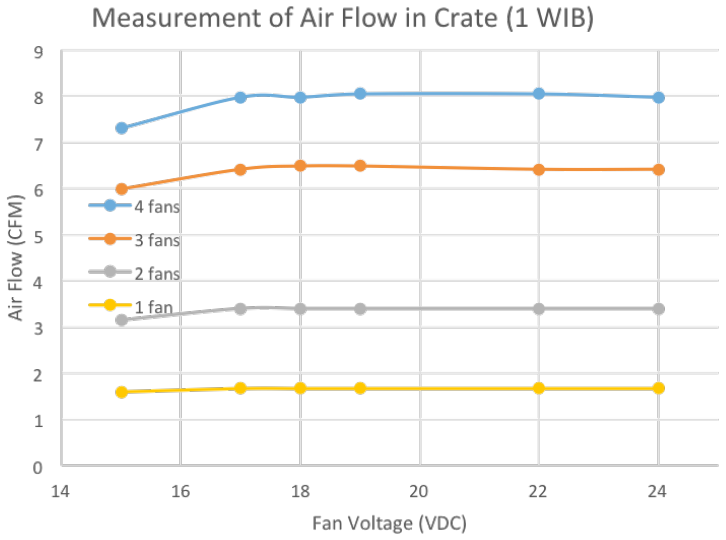
- Mechanical and assembly drawings in [DUNE DocDB 2774]
- Current status
  - 1 prototype machined by Zober Industries and assembled and tested at BNL
  - System tests ongoing with full CE flange assembly and FEMB on the PSL 40% APA
  - 2 final prototype to be ordered on 3/31
- Production plan
  - Submit full order in 5/12
  - 4 weeks lead time
  - 2 weeks inspect and assemble
- Ready prior to installation onto CE flange assemblies in July 2017
  - Final QC done on CE flange
  - One of final prototypes will be used for cold box test at CERN
  - Schedule driver of flange assembly is the warm flange

WIEC Fans

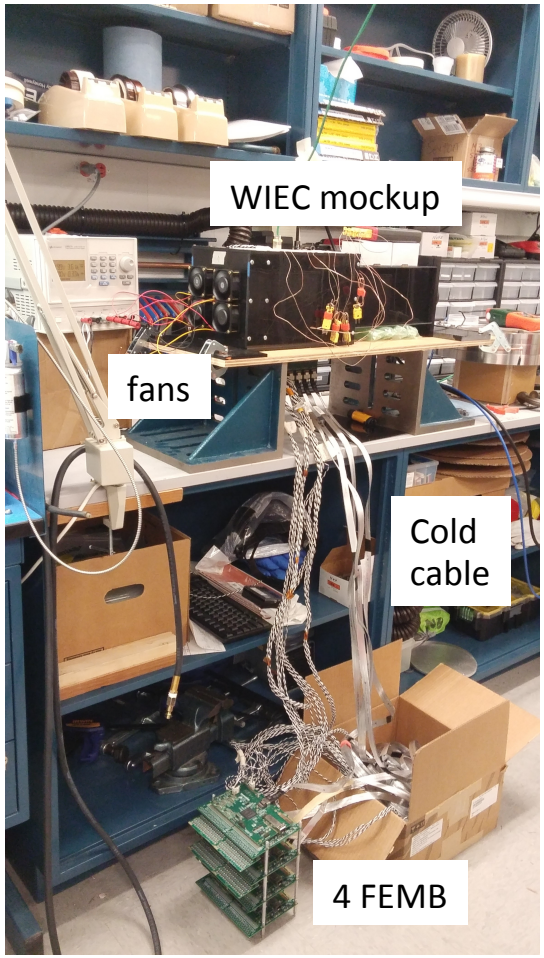
- Each WIEC is cooled by 4 brushless fans supplied by a variable power supply up to 24V
  - Aavid PEAD26025BH (data sheet)
  - Each fan independently powered and monitored by CERN DCS slow control
  - Interlock at a Weiner PL506 48V channel to each signal feed-through if a WIEC fan is disabled
- Air flow measured with mock WIEC and WIBs
  - Test results in DUNE DocDB 1809



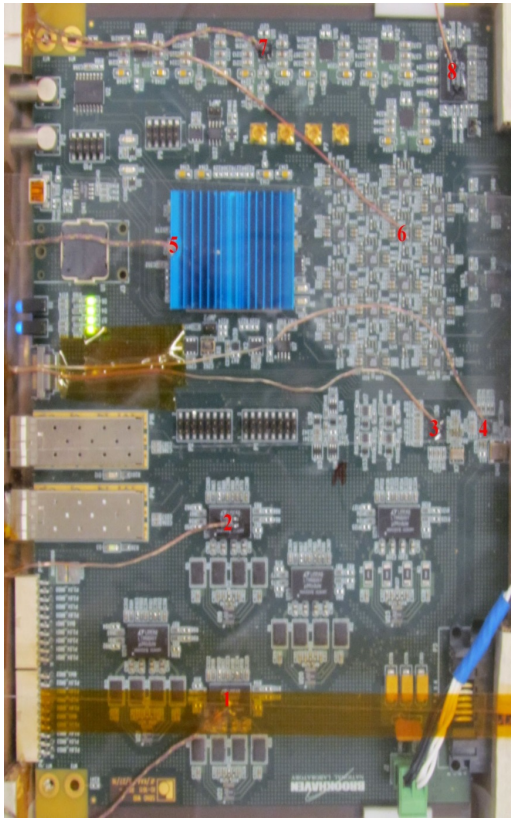




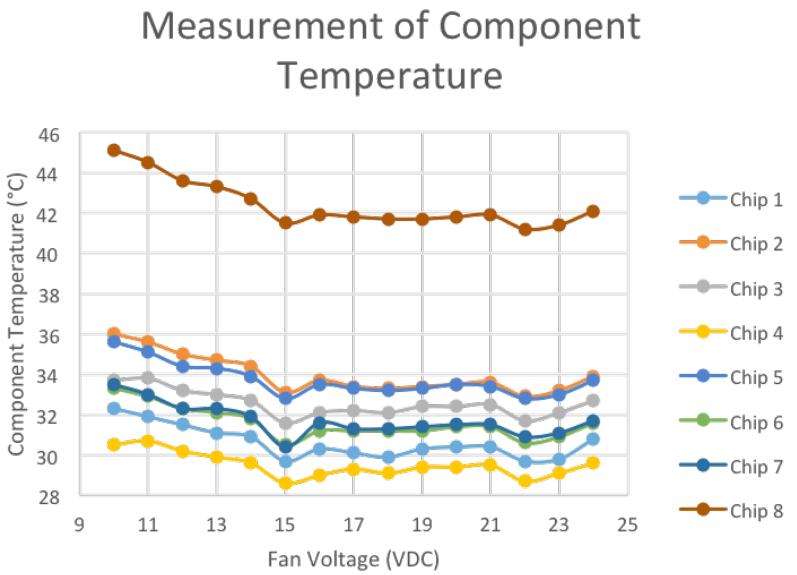
WIEC Temperature



WIB

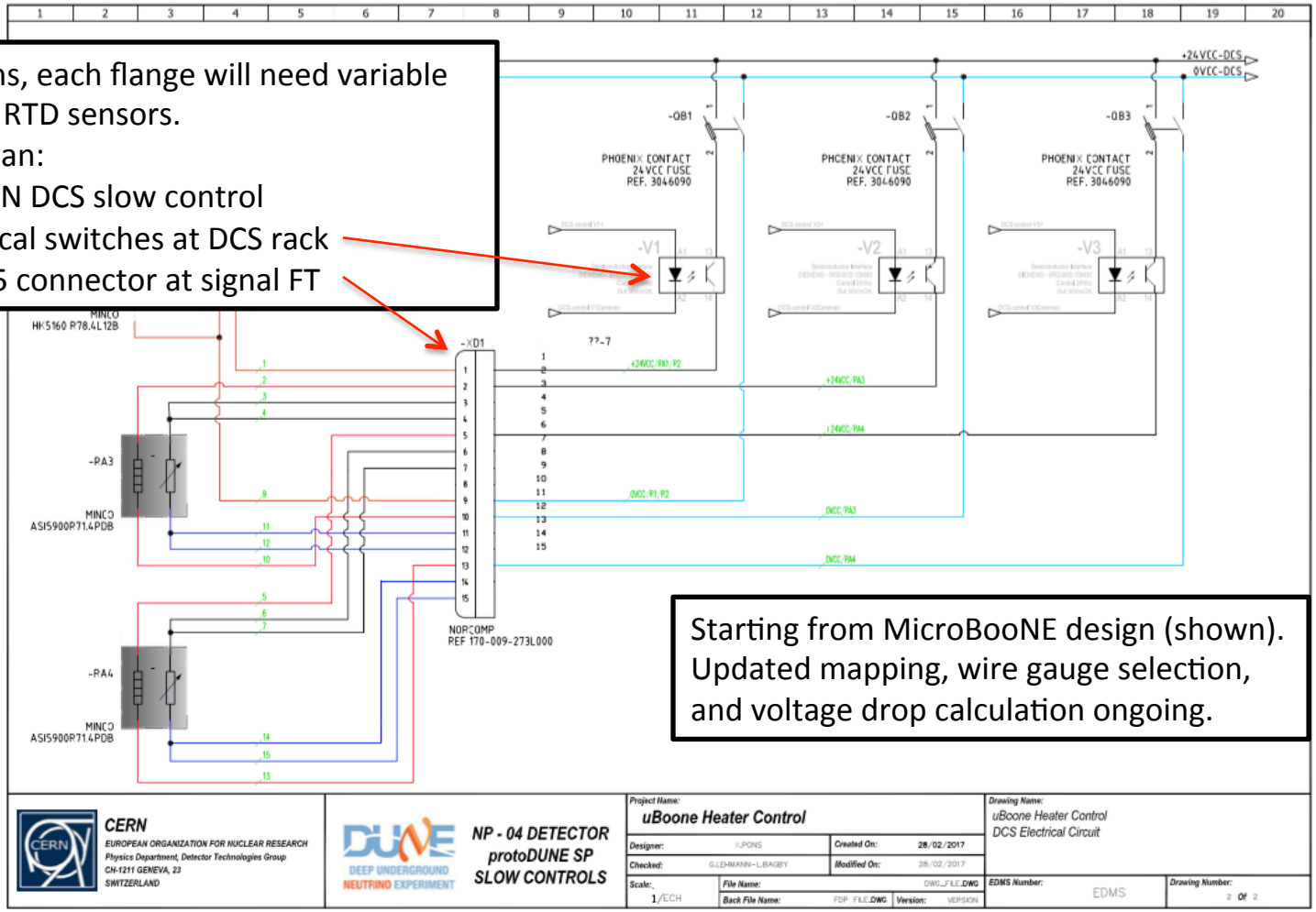


- In addition to airflow, thermal measurements were made on a WIB reading out 4 FEMB (fully loaded)
  - Temperature sensors on 8 components on WIB
  - Test results: DUNE DocDB 1809



Proposed Mechanicals Ground Plan

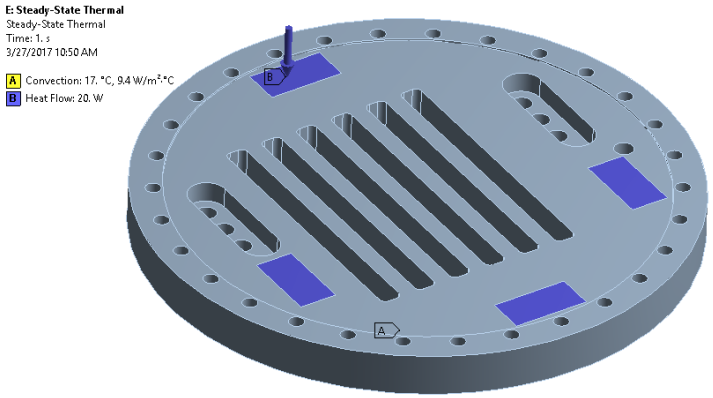
In addition to WIEC fans, each flange will need variable 24V for 4 heaters with RTD sensors.
Proposed grounding plan:
- 24V provided by CERN DCS slow control
- isolate 24V with optical switches at DCS rack
- isolate shield of db25 connector at signal FT

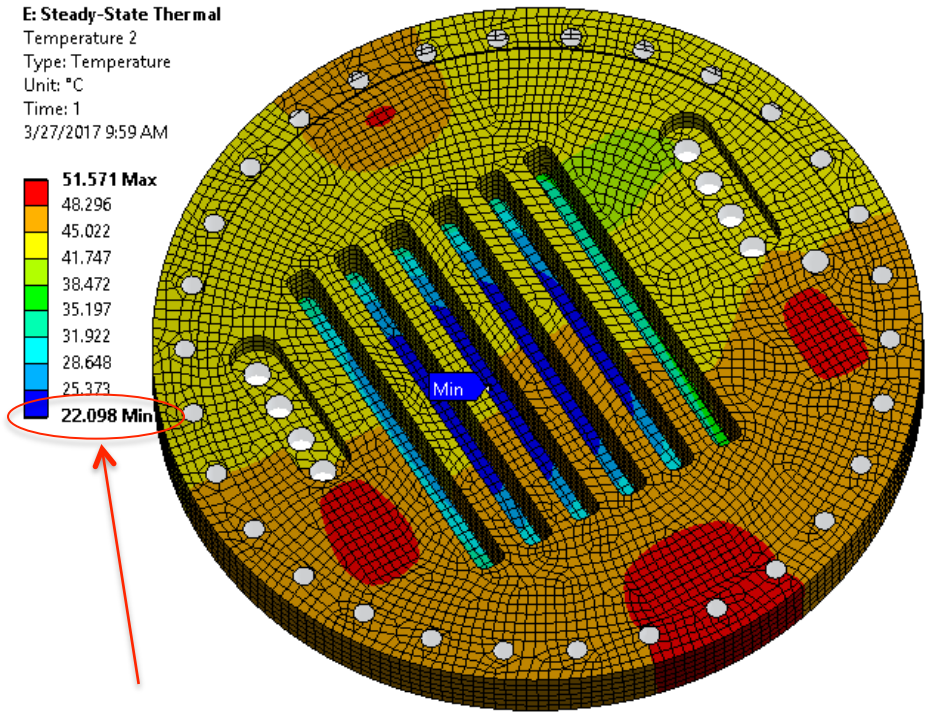


Starting from MicroBooNE design (shown). Updated mapping, wire gauge selection, and voltage drop calculation ongoing.

Flange Heaters

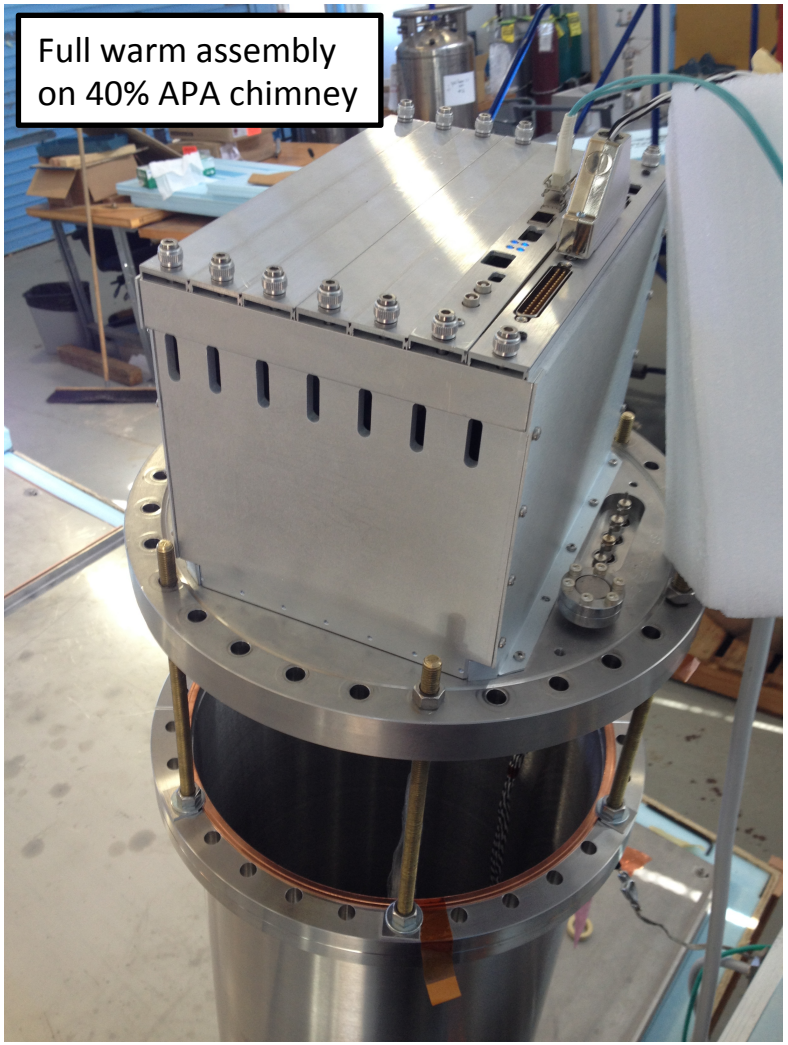
- When WIEC electronics are off, require that we can warm the CE flange above the dew point at CERN
  - Highest dew point at Geneva in last 6 years is 21°C
  - 4 Minco ASI5900R16.9PDB (DS) heaters attached to warm side of flange
    - Capable of up to 35W at 24V





4 heaters, 20W total output (0.5A/heater)
22°C at minimum point

Warm Components QC

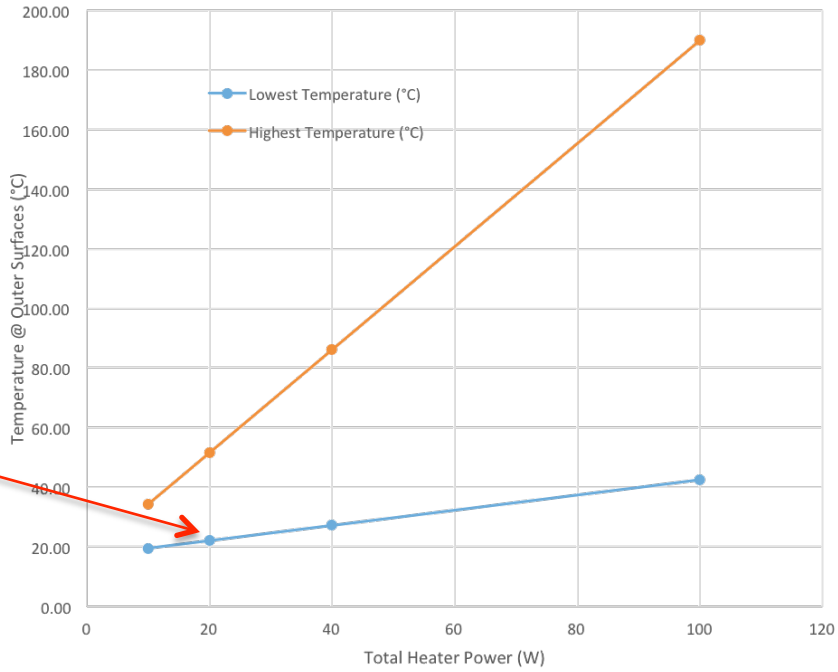


- Upon delivery to BNL, warm flanges will be visually inspected and assembled
- QC tests for warm flange
  - Full set of pressure tests done per DUNE DocDB 1809 for each flange: leakage rate < 10^{-9} mbar L/sec with 5 PSI positive pressure differential applied to cold side
  - All 8 SHV connectors tested with up to 3 kV of HV
  - 3 weeks to pressure/HV test all flanges
- Flanges which pass the QC testing will be assembled with a WIEC
  - Flanges with WIEC are the final units and will not be disassembled
  - 1 week to assemble all units

Warm Components QC

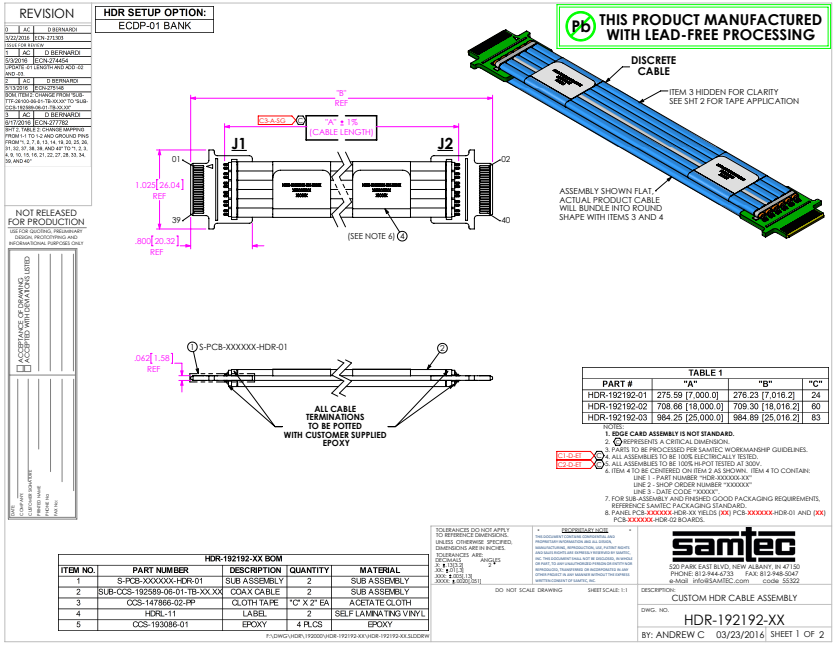
- Once complete flange + WIEC assemblies are ready, full suite of flange QC tests done:
  - Read out 4 FEMB via a WIB in all slots
    - Criteria to pass: no dead channels or excess noise above bench tests of FEMB
  - Measure air flow and WIB surface temperatures with all 4 fan units per DUNE DocDB 1809
    - Criteria to pass: all surface temperature readings within operational limits of WIB electronic components
  - Attach Minco heaters and measure minimum total power to achieve >21^{0}C at lowest point, applying 17^{o}C to cold side: verify temp at high points
  - 3 weeks to test all units
- Final units shipped from BNL to CERN
  - 1 week acceptance tests at CERN
  - Custom shipping crates to be designed and built at BNL
  - Units can be stored in shipping crates until installed on cryostat

Lowest and highest temperature based on thermal simulation of flange heaters



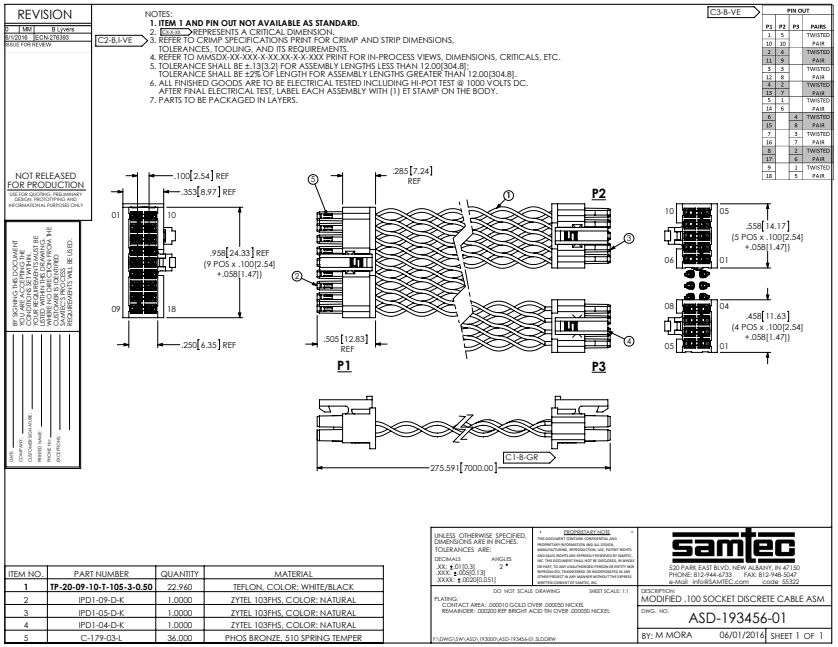
Cold Data Cable

- Mechanical and assembly drawings in [DUNE DocDB 1755]
- Current status
  - 4 prototype bundles manufactured by Samtec
    - 1 set being used for FEMB + CE Box testing
    - 1 set being used for installation mock ups at Ash River
  - 50 bundles ordered
- Approved for use at SURF, FNAL and CERN
  - Passed FNAL fire safety burn test
- Production plan
  - Order remaining 100 in early April
  - 8 weeks lead time
  - 4 weeks for QC
- Ready for installation onto FEMB and CE Box assemblies in July 2017



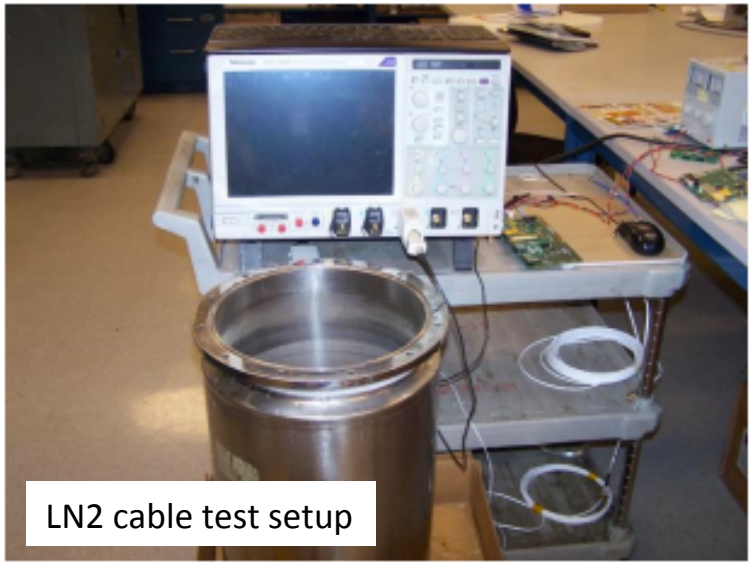
Cold LV Cable

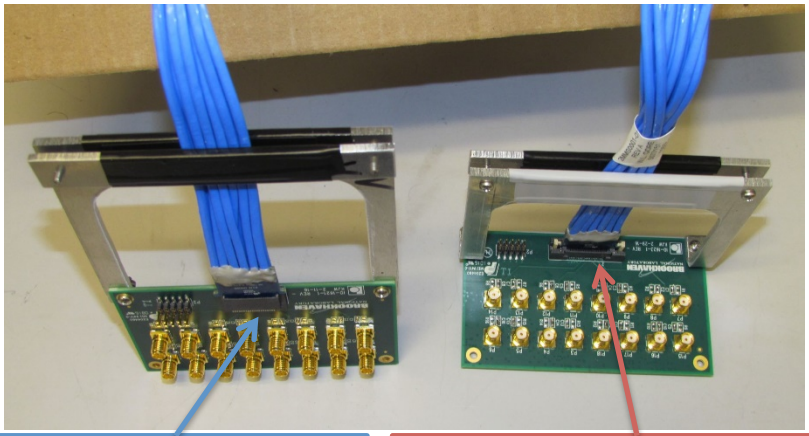
- Mechanical and assembly drawings in [DUNE DocDB 1755]
- Current status
  - 10 prototype bundles manufactured by Samtec
    - 1 set being used for FEMB + CE Box testing
    - 1 set being used for installation mock ups at Ash River
- Approved for use at SURF, FNAL and CERN
  - Passed FNAL fire safety burn test
- Production plan
  - Full order of 150 bundles placed
  - Expect delivery in late May
- Ready for installation onto FEMB and CE Box assemblies in July 2017



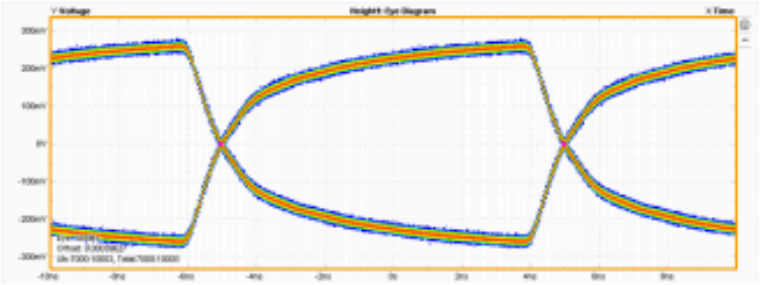
Cold Cable QC

- Cable continuity at room temperature certified by Samtec
- At BNL, test 10% of the data cables in LN2 to ascertain yield
  - Eye diagram must be recovered
  - Criteria to pass is BER test up to 10^{-13} without loss after active equalization
  - 1 month to cold test cable
- Assemble data and LV cable with FEMB and CE Box for final FEMB QC testing
- All bundles tested cold with FEMB
  - Same QC tests and acceptance criteria as described for CE Boxes
- Wire-bias SHV cables (8 APA)
  - Verify that connectors can hold up to 3 kV in GAr

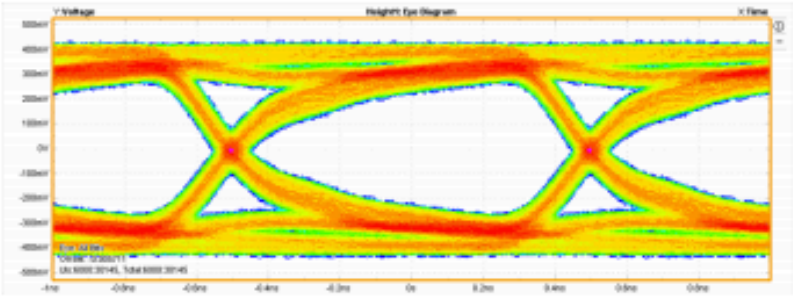

LN2 cable test setup



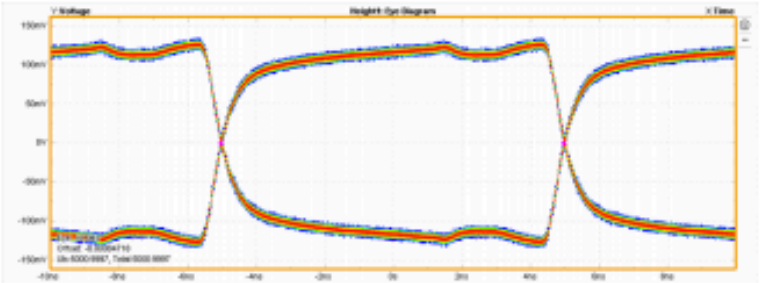
Samtec Cable Eye Diagrams



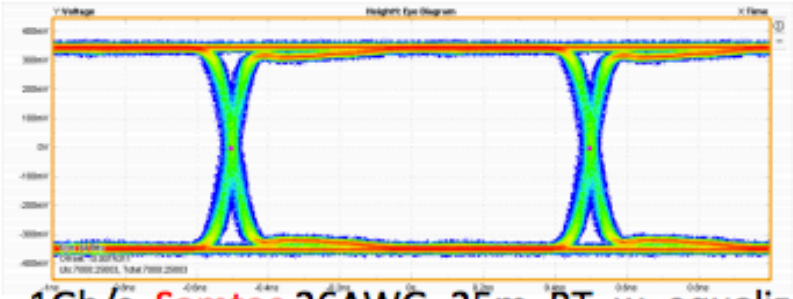
50MHz, Samtec 26AWG, 25m, RT
Height = 415mV, Tj = 180ps



1Gb/s, Samtec 26AWG, 7m, RT, w/o equalizer
Height = 429mV, Tj = 152ps



50MHz, Gore 24AWG, 25m, RT
Height = 218mV, Tj = 107ps

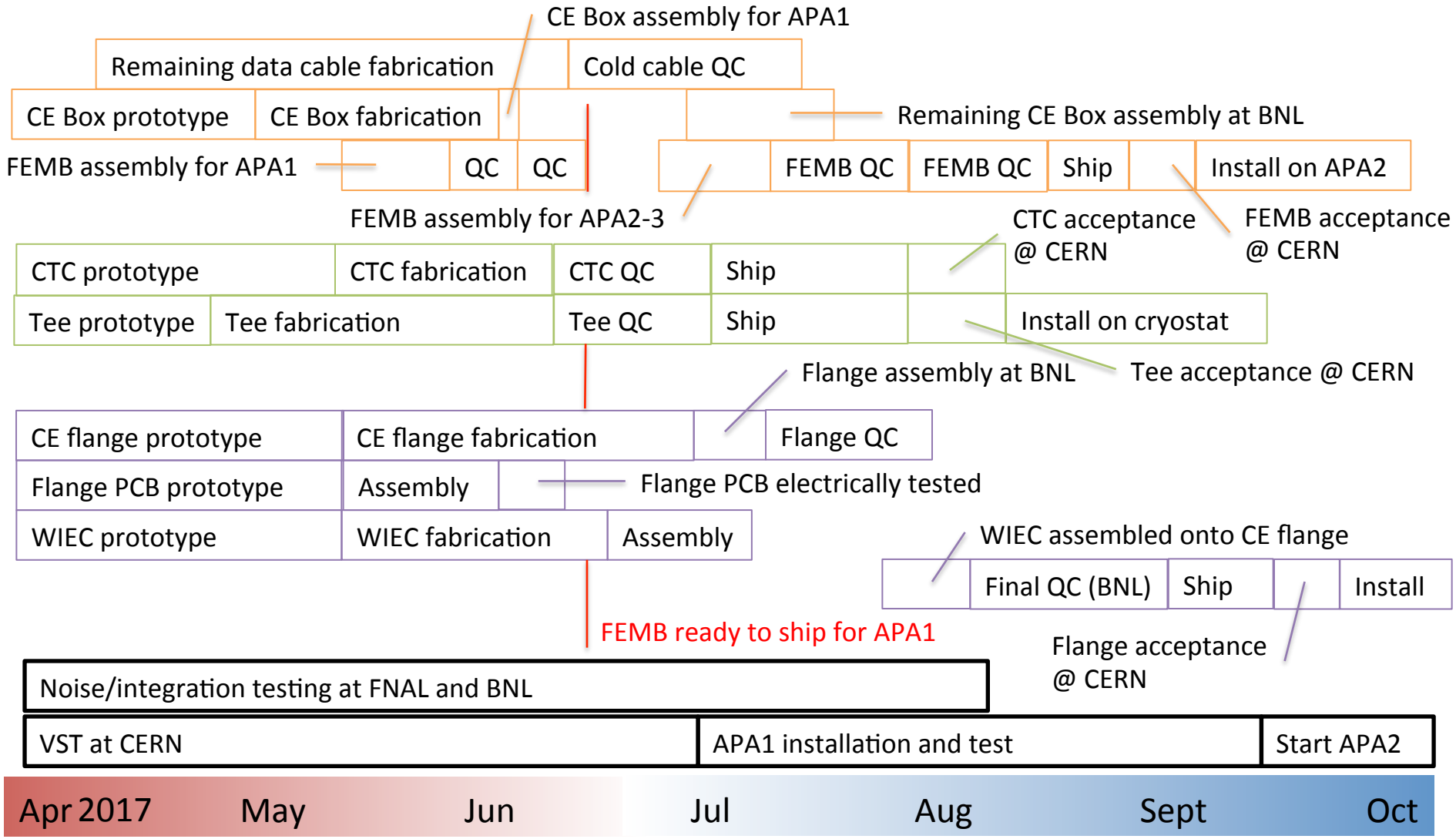


1Gb/s, Samtec 26AWG, 25m, RT, w. equalizer
Height = 628mV, Tj = 113ps

50 MHz encoded system clock for configuration and control
BER test passed at 10^{-13} with and without active equalizer

CE installation (as of March 17)
- APA1: 6/28
- APA2: 9/8
- APA3: 10/26

Schedule



Labeling

- Each major unit (FEMB, flange, signal FT) will have a primary label for identification at CERN
  - FEMB: have vendor etch ID onto CE Box
    - ASICs and FEMB will have individual IDs for QC testing at BNL
    - Once installed in CE Box, box ID becomes the final label for QC tests and tracking
    - QC database will allow for reporting test results from box ID back to each individual ASIC
  - Flange: have vendor etch ID onto stainless steel flange
    - Flange PCB and WIEC will be QC tested on flange and follow flange ID
  - Signal FT: have vendor etch ID onto Tee pipe
    - CTC support will follow Tee pipe ID
- All major units will all be tracked by a hardcopy traveller
  - Receiving and assembly history
  - Sign off on QC results
- Cables will be labeled at each end after FEMB pass final QC tests
  - Once FEMB are installed on APA and cable routed, label at box end will be removed

Conclusions

- All mechanical drawings complete
- Final prototypes in process of being obtained
  - Will place orders for CE flange & WIEC final prototypes, remainder of production cold data cable following review
- Process for labeling and tracking being developed
  - Travellers will be part of QC database
- Shipping to CERN
  - Handled by Interfreight, an experienced broker, to CERN directly
  - Done for ATLAS LAr Calorimeter electronics for 10+ years
  - Custom packaging for FEMB and CE flange units will be designed and built by BNL team that installed MicroBooNE
- Production orders can be placed to meet installation schedule