

Overview of the FC-Endwall Production for the ProtoDUNE Single-phase LAr Detector

Thomas Kutter,
LSU
for the FC Endwall production team

PRR at LSU
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The Team

LSU machine shop:

Brandon Amos, Donnie Olano, Vince Vaughn

LSU electronics shop:

Brad Ellison, Marcus Nauman, (Doug Smith)

LSU Students:

Bryce Bowlsbey, Zach Bradshaw, Hunter Meyer,
Brandon Roberts, Nicholas Welsch

Part of our campus network:

Chem. E. machine shop: Joseph Bell

LSU ESH: Jason Lejeune

Engineering and design at BNL: Rahul Sharma, Andres Ruga

Outline

- FC design overview
 - FC production of parts
 - QC procedure and documentation
 - Status of module zero
 - Schedule
-
- Resistive divider chain production

ProtoDUNE-SP Field Cage (FC) Geometry

Major mechanical units:

Top + bottom FC:

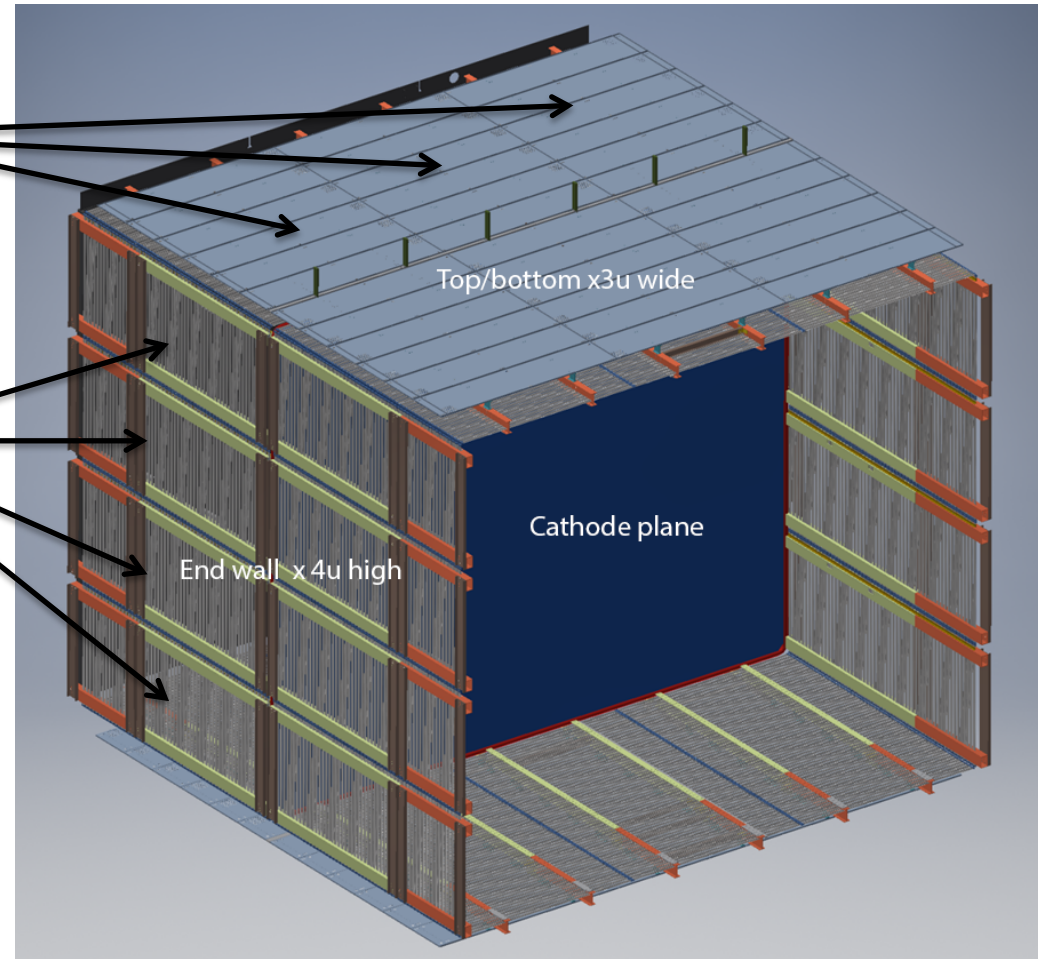
3 panels wide per drift volume
with mounted ground plane

Total quantity: 12

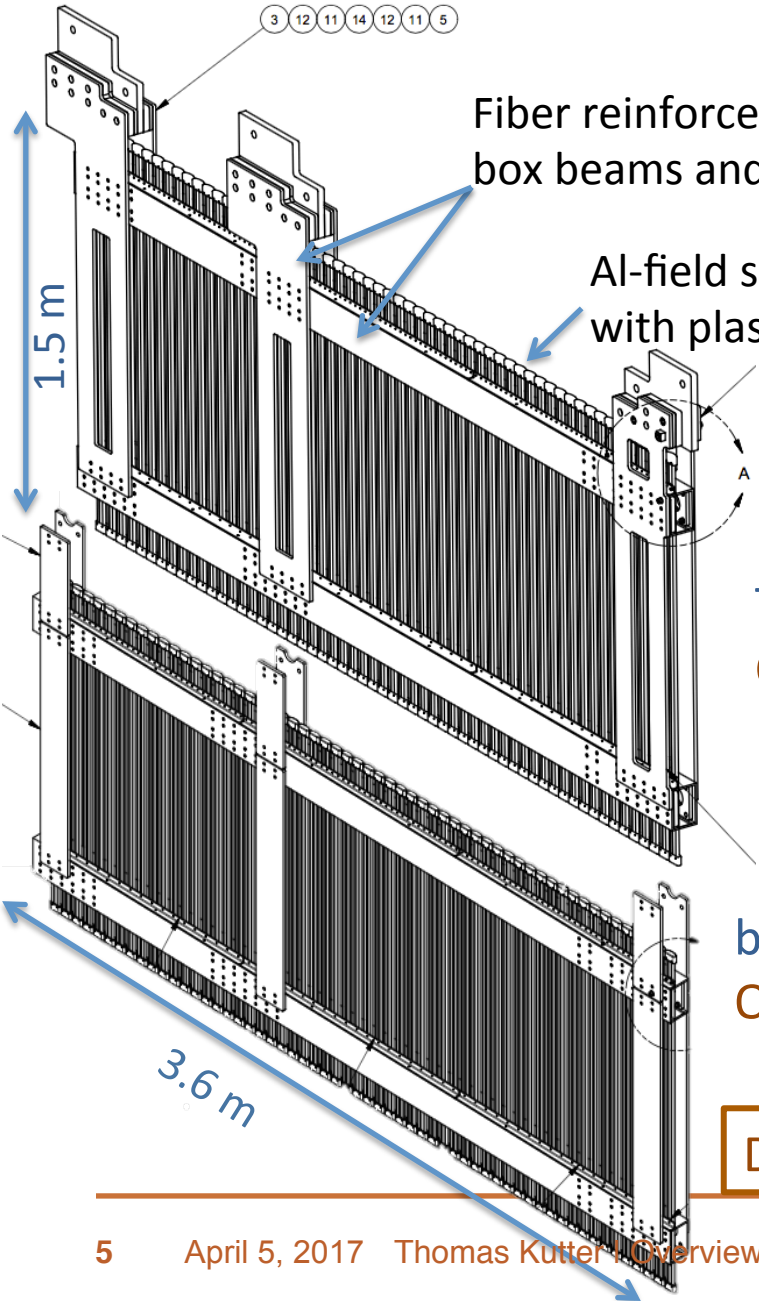
Endwall FC:

4 panels high per drift volume

Total quantity: 16



ProtoDUNE-SP Field Cage Endwall Panels



Fiber reinforced plastic (FRP)
box beams and plates

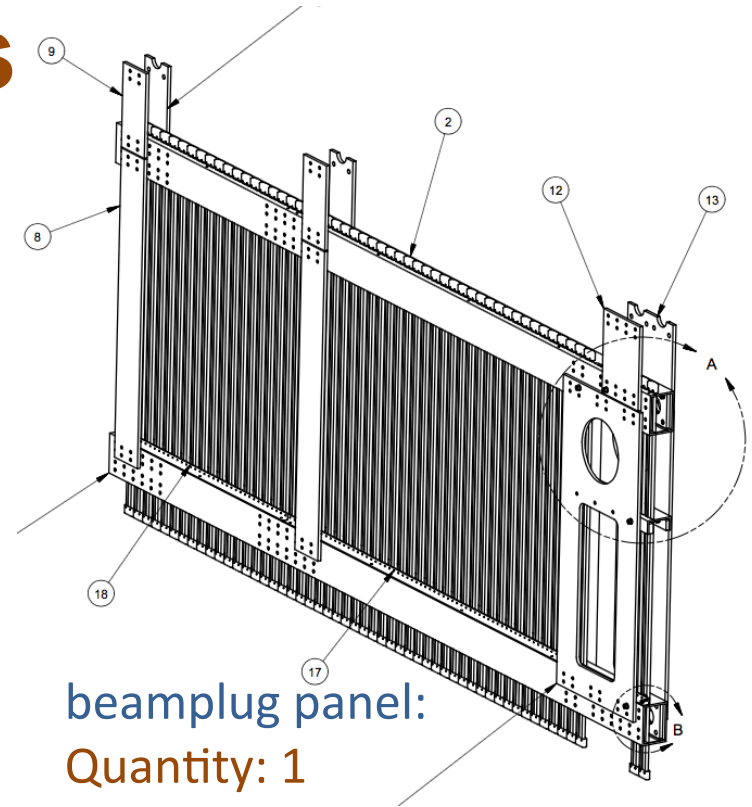
Al-field shaping profiles
with plastic endcaps

Top panel:
Quantity: 4

baseline panel:
Quantity: 11

beamplug panel:
Quantity: 1

Drawings for all parts final



FC Endwall Parts Production at LSU

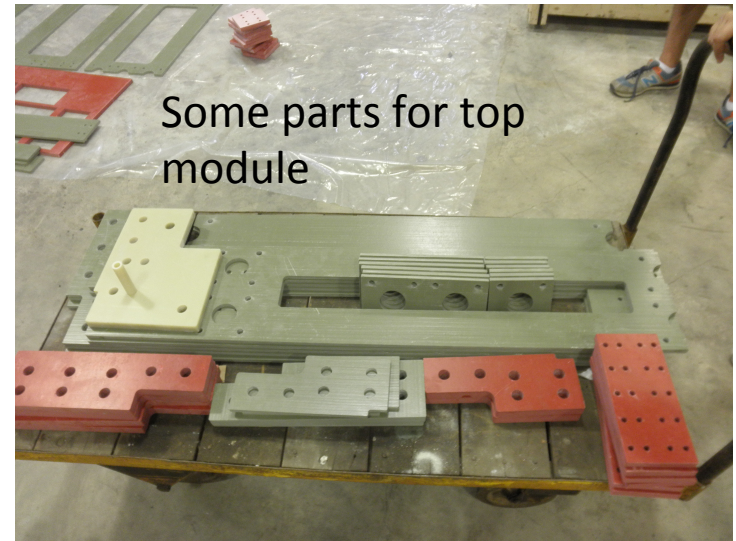
LSU shop:

- Cut rectangular FRP beams to length
- Reaming of holes and rounding of edges
- G10 bushings and angle
- All SS parts (three types of nuts)
- Al parts for lifting jig
- Small part water jetting

Waterjet cutting (local outside company):

- Cut shapes in rectangular FRP beam
- Cut large components from FRP plates

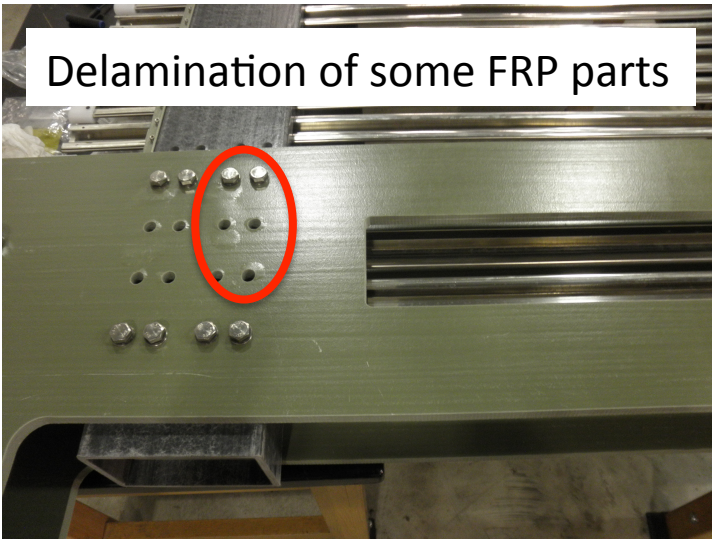
- Parts manufacturing + QC checks
- assembly of each endwall panel in high bay area (alignment QC)
- hanging of panels to test interconnects
- Hazard Analysis for connecting and hanging panels
- dis-assemble panels + clean components + QC checks + coating
- Final assembly in controlled area



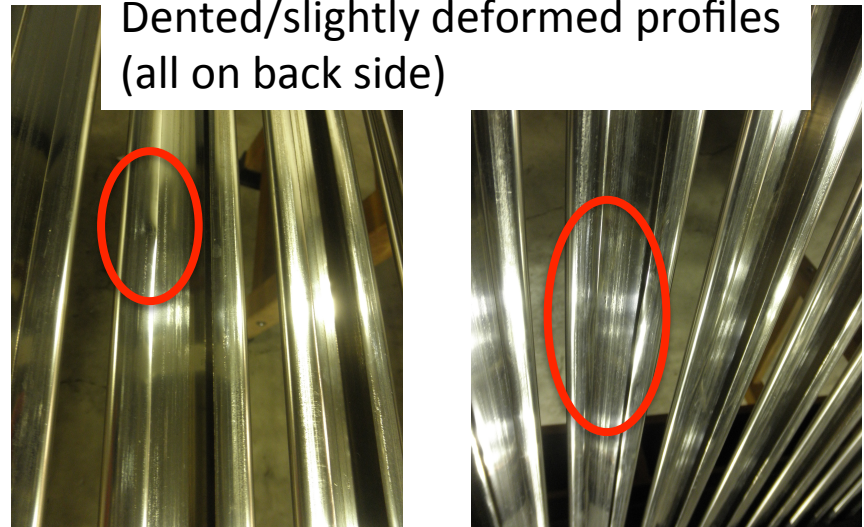
Sample QA/QC Issues

Visual inspection: some defects noticed during *Ash River mech. mock-up* production

Delamination of some FRP parts



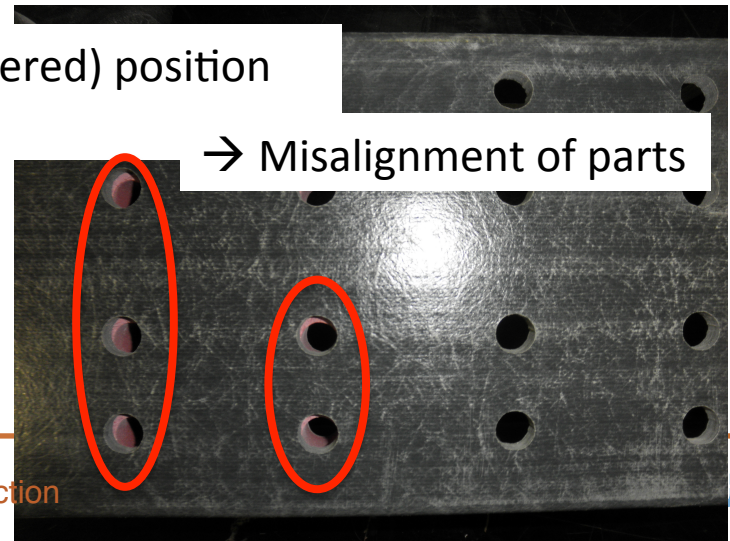
Dented/slightly deformed profiles
(all on back side)



Hole pattern off-set from nominal (centered) position
→ due to deformation of FRP beam



→ Misalignment of parts



FC Production/Assembly Site:

- FC endwall panels requires access from both sides
- panel turntable in controlled area
 - Nearly complete

Status of Module zero:

- All parts in hand
- Module assembled in high bay area and taken apart
- All major components cleaned

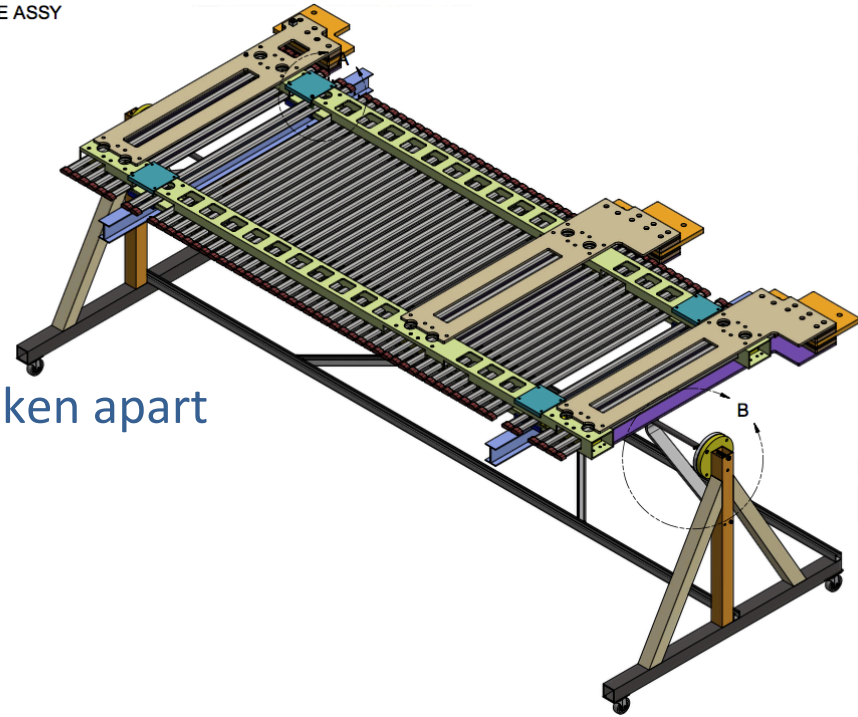
In progress:

- clean small components in ultrasound bath

Next steps:

- Coat FRP parts
- Profiles: inspect, drill holes, clean
- Assemble panel zero in controlled area
- Double bag and prepare for shipment to PSL

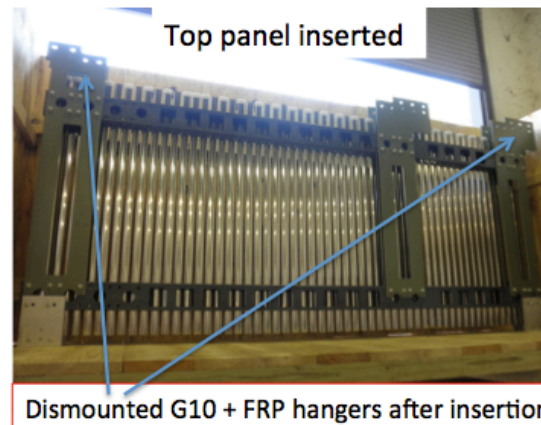
BASE ASSY



Crating/Shipping Preparations

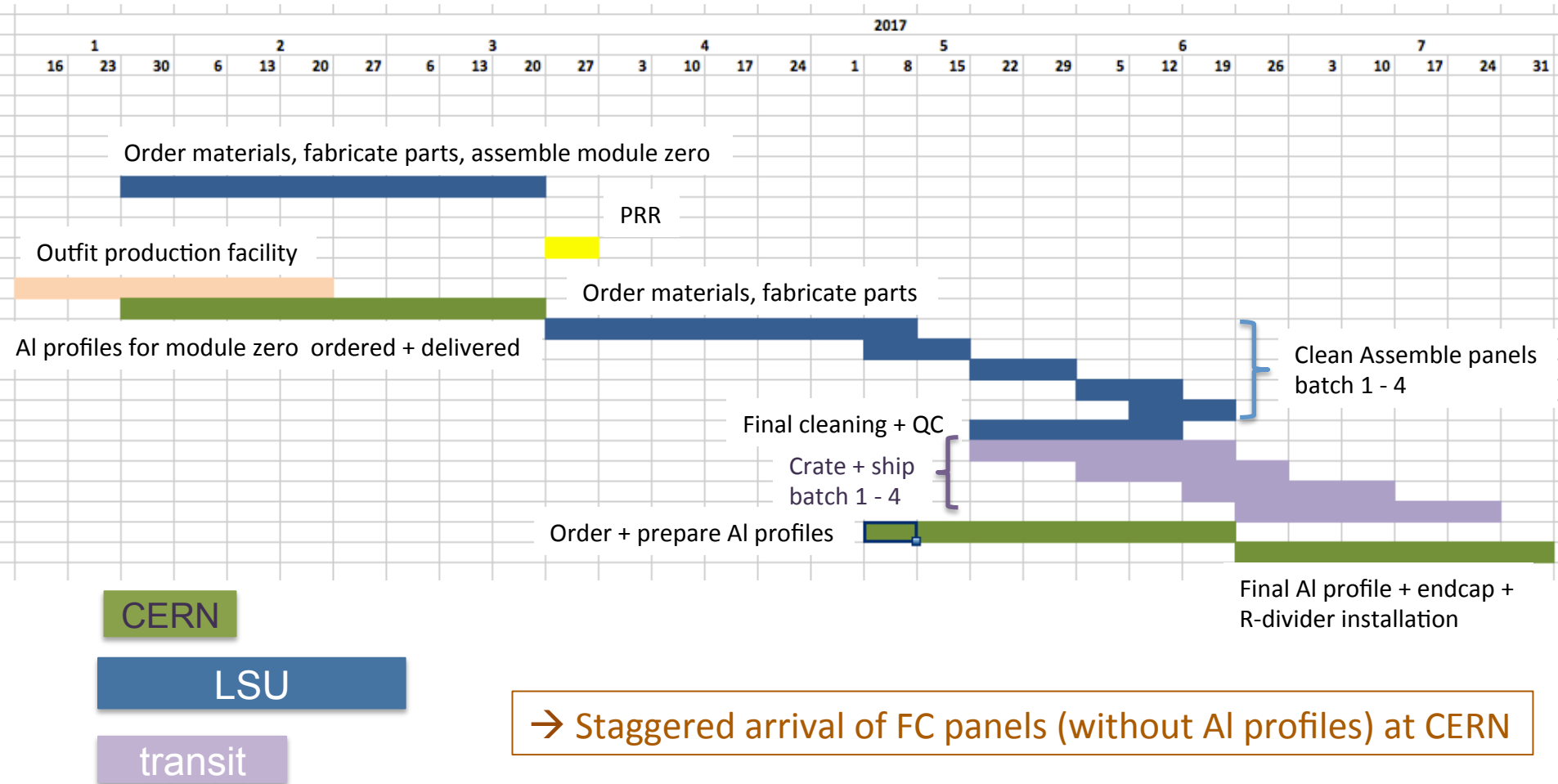
- Plastic double bagging of panels in controlled area
→ crating and shipment to CERN

Four individually bagged panels per crate

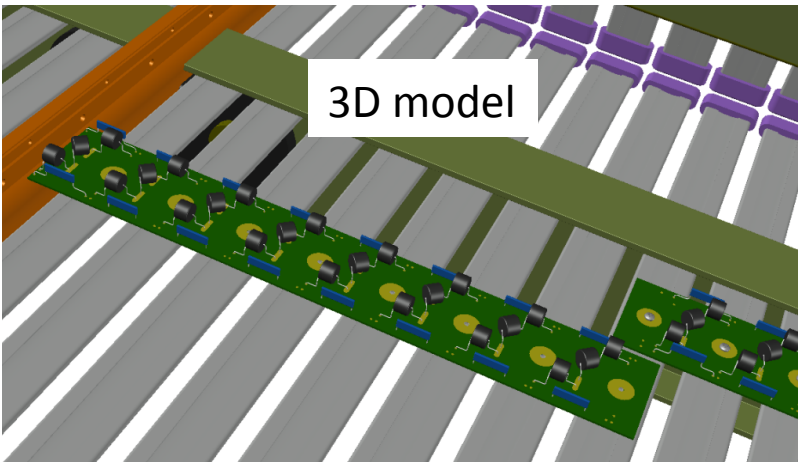


FC Production/Assembly Schedule

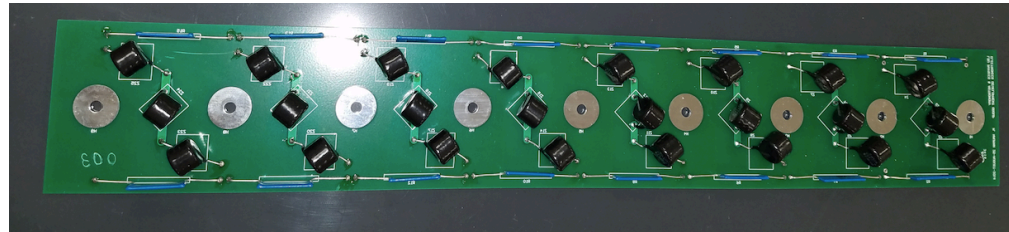
Approximate schedule for FC endwall:



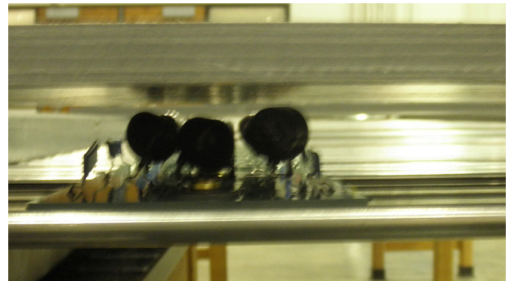
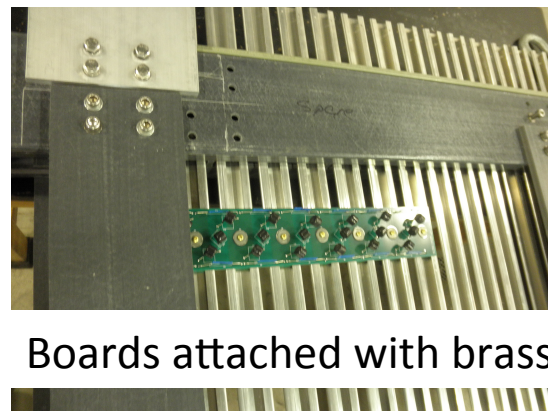
Resistive Divider Chain Production at LSU



Divider boards can be mounted at different positions along the metal profiles. They are staggered to provide a continuous chain.



Built R-divider boards for HV test at PC4



Boards attached with brass screw to SS nut in profile

- Developed and commissioned component test stand
- Automated measurement procedure and data logging
 - UG Students can perform measurements and analyze data
- Defined QC criteria

Large Scale Component QC Test Stand

Need to test ~ 8000 MOV and ~ 4000 resistors

- Can stack up to 5 PCBs high, each with 16 MOVs or resistors → 80 devices per setup
- have multiple mechanical mounts

Status:

- 7000 MOVs in hand; 1500 resistors in hand

Started production mass testing in shift modus

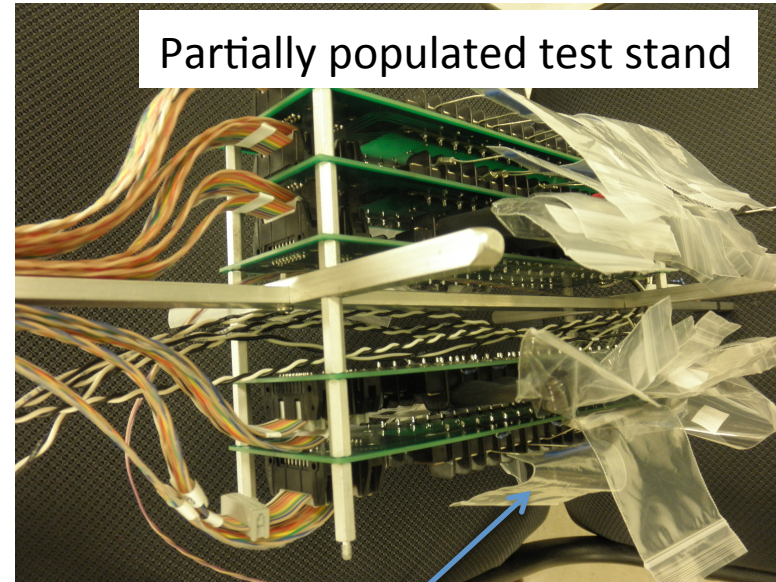
- ~ 240 devices per day (warm and cold)

In progress:

Assemble boards and perform final QC

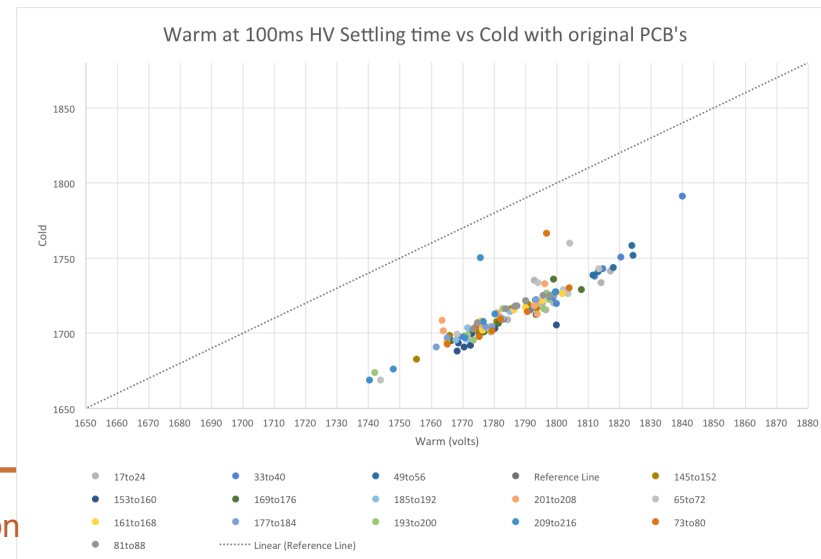
Discharge tests of assembled divider boards starting at Yale (joint with SBND effort – Serhan Tuflani)

- test several boards



Partially populated test stand

Components are individually bagged and serialized



Final QC measurements + documentation

Each test circuit consists of two 1 GΩ resistors in parallel connected to a 100.0 KΩ pickoff resistor.
 A DMM with a 10 MΩ input impedance is connected in parallel with the pickoff resistor
 The equivalent circuit from above consists of two resistors in series: $R_a = 500M$ and $R_b = 99.0099K$

A test voltage of 1 kV (V_i) is applied across R_a and R_b .

The current is calculated by dividing the DMM voltage across the pickoff resistor by R_b . ($I_c = V_p/R_b$)

For the tables below, columns 1-8 are referenced to the first stage at R1/R2 on the left side of the PCB and move sequentially to the right.

DMM voltages (V_p) measured across 100.0 KΩ pickoff resistor. Unit = mV

Board #	V-1	V-2	V-3	V-4	V-5	V-6	V-7	V-8	Measurement
010	196.2	196.1	196.0	196.8	196.5	196.0	196.4	196.1	Bench
010	196.0	195.6	195.6	195.6	196.2	195.6	196.0	***	Profile

Calculated current from above pickoff voltages $I_c = V_p * 1000 / 99009.9$ Unit = μA

Board #	i-1	i-2	i-3	i-4	i-5	i-6	i-7	i-8	Measurement
010	1.982	1.981	1.980	1.988	1.985	1.980	1.984	1.981	Bench
010	1.980	1.976	1.976	1.976	1.982	1.976	1.980	***	Profile

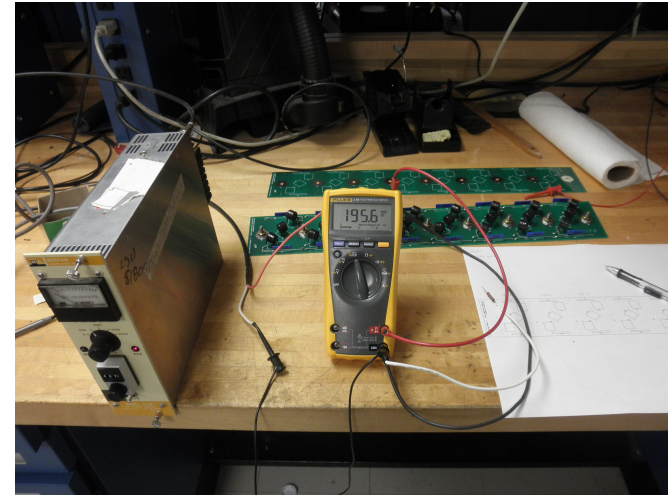
Calculated resistance from I_c $R_a = (V_i - V_p) / I_c$ Unit=MΩ

Board #	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8	Measurement
010	504.5	504.8	505.1	503.0	503.8	505.1	504.0	504.8	Bench
010	505.1	506.1	506.1	506.1	504.5	506.1	505.1	***	Profile

*** - No measurement made due to shorting of profiles at positions 7 and 8 when AI bracket is mounted !

*MOV pos measured from left to right of each group
 *Resistor pos measured from top to bottom on each group

LSU	Resistor pos 1 (R1)	Resistor pos 1 (R3)	Resistor pos 1 (R5)	Resistor pos 1 (R7)	Resistor pos 1 (R9)	Resistor pos 1 (R11)	Resistor pos 1 (R13)	Resistor pos 1 (R15)	
physics & Astronomy	MOV pos 3	MOV pos 3	MOV pos 3	MOV pos 3	MOV pos 3	MOV pos 3	MOV pos 3	MOV pos 3	
	MOV pos 2	MOV pos 2	MOV pos 2	MOV pos 2	MOV pos 2	MOV pos 2	MOV pos 2	MOV pos 2	
	MOV pos 1	MOV pos 1	MOV pos 1	MOV pos 1	MOV pos 1	MOV pos 1	MOV pos 1	MOV pos 1	
	Resistor pos 2 (R2)	Resistor pos 2 (R4)	Resistor pos 2 (R6)	Resistor pos 2 (R8)	Resistor pos 2 (R10)	Resistor pos 2 (R12)	Resistor pos 2 (R14)	Resistor pos 2 (R16)	board #
	group 1 (-1)	group 2 (-2)	group 3 (-3)	group 4 (-4)	group 5 (-5)	group 6 (-6)	group 7 (-7)	group 8 (-8)	



QC procedure:

Measure voltage drop for each individual stage, convert to current, calculate equivalent resistance R_A (nominal: 500 MΩ)

Results: see spreadsheet on left

→ For all R-divider boards and steps

