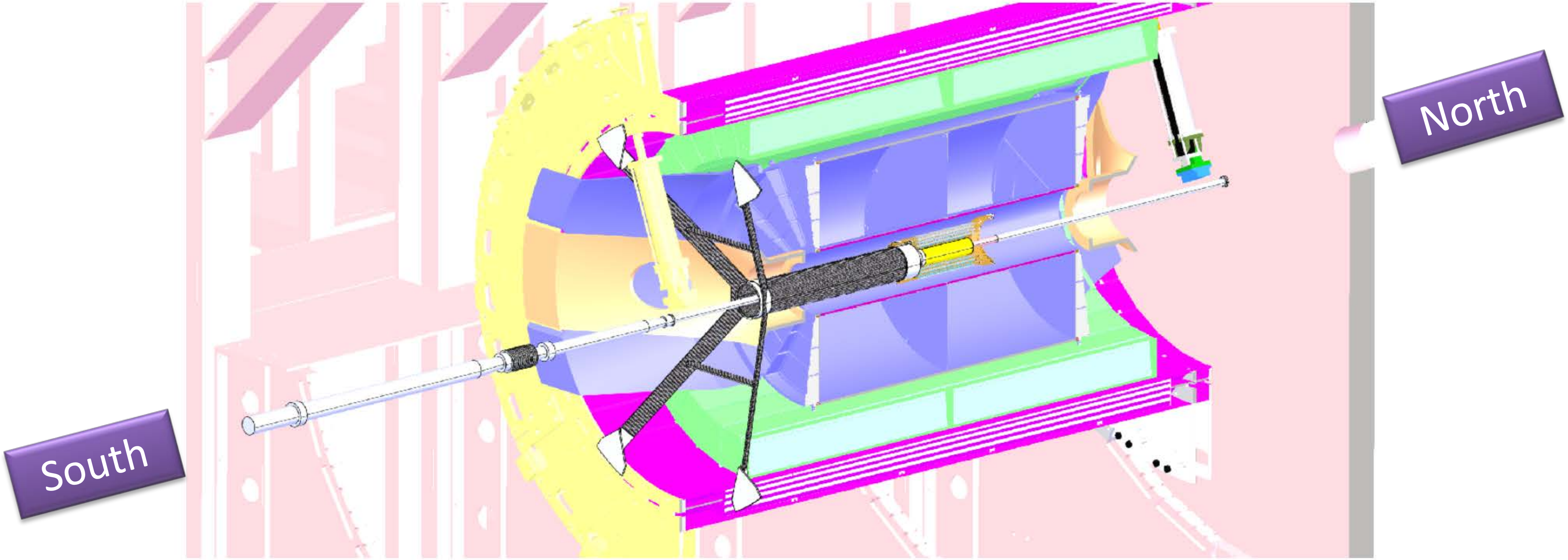
MVTX PRR Mechanics

15 DEC 2020

Jason Bessuille (MIT)

Overview

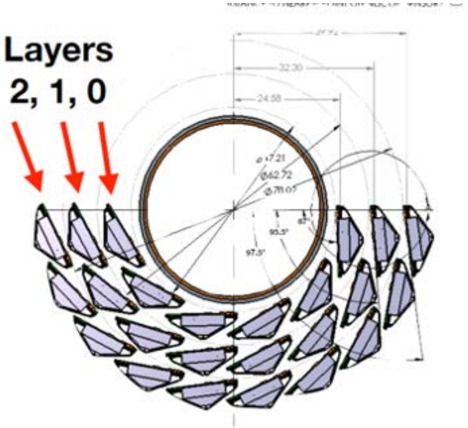
1. Comparison of MVTX to ALICE design
2. Leveraged ALICE work
3. Mechanical analyses
4. Production progress

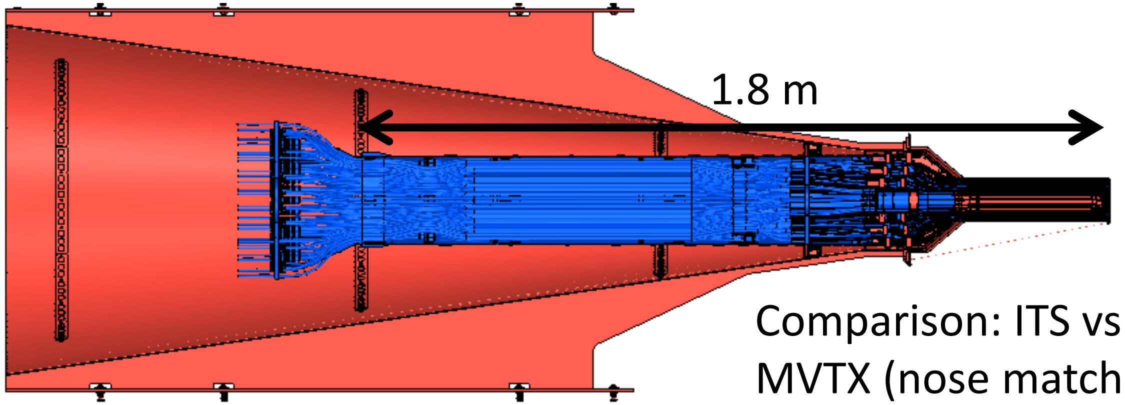


ITS vs. MVTX

Changes driven by:

1. **Beam pipe**: wider and closer in sPHENIX
   → snugger fit, and stave positions modified to keep hemeticity

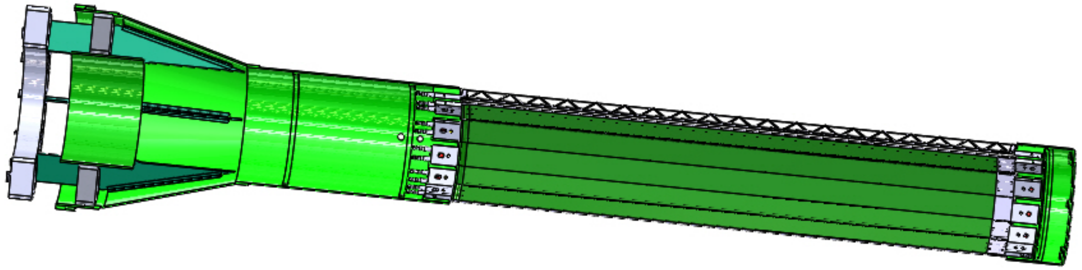




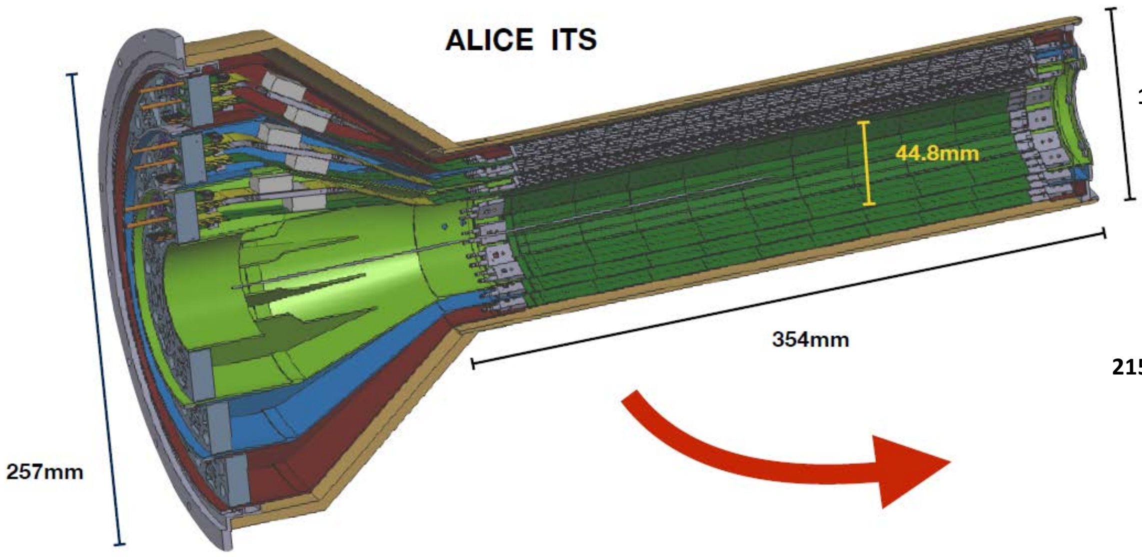
Comparison: ITS vs MVTX (nose match)

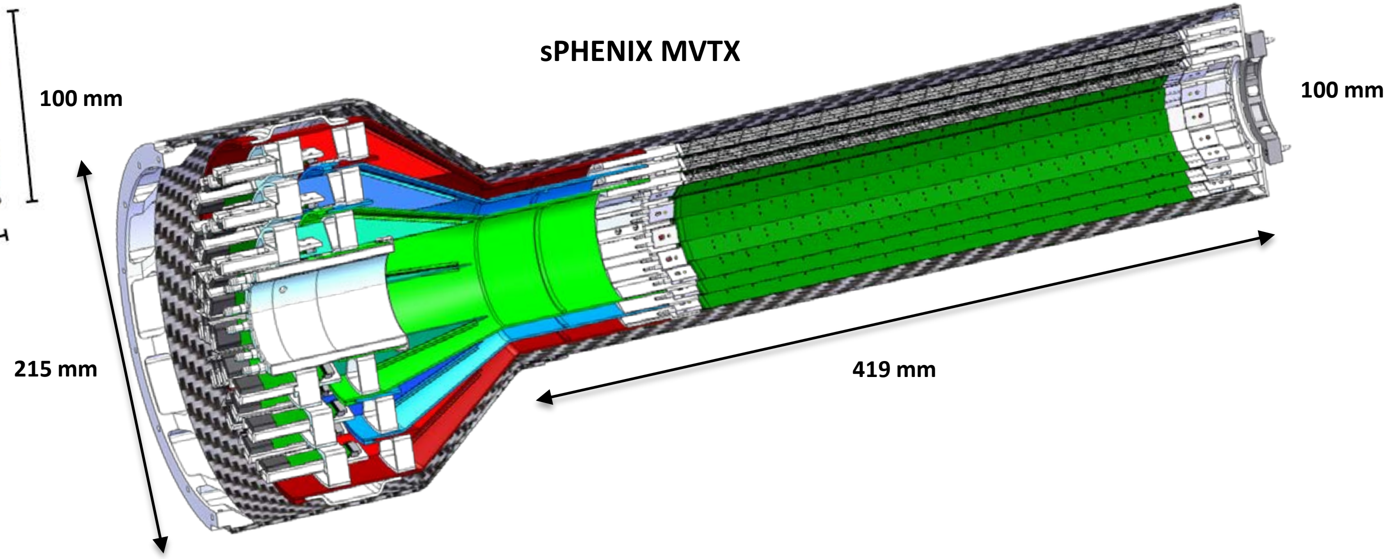
	ALICE ITS	sPHENIX MVTX
# Staves	48 (inner barrel)	48
Cantilevered Length (support-to-IP)	~1.0 m	~1.5 m
Beampipe radius	19.0 mm	20.76 mm (Be) / 21.7 mm (Al)
Inner Layer sensors radius	22.38 mm	24.61 mm
Beampipe clearance (to sensors)	3.38 mm	3.85 mm (Be) / 2.91 mm (Al)
Beampipe clearance (to nose flange)	3.38 mm	2.07 mm (Be) / 1.125 mm (Al)
Primary structural construction	Foam core carbon fiber	Carbon fiber
Split configuration	Top / Bottom	Left / Right
Total radiation dose	2700 kRad	< 100 kRad

2. **The next detector** specifics (INTT in sPHENIX): envelope longer than MVTX staves → MVTX has to flare out the cables later

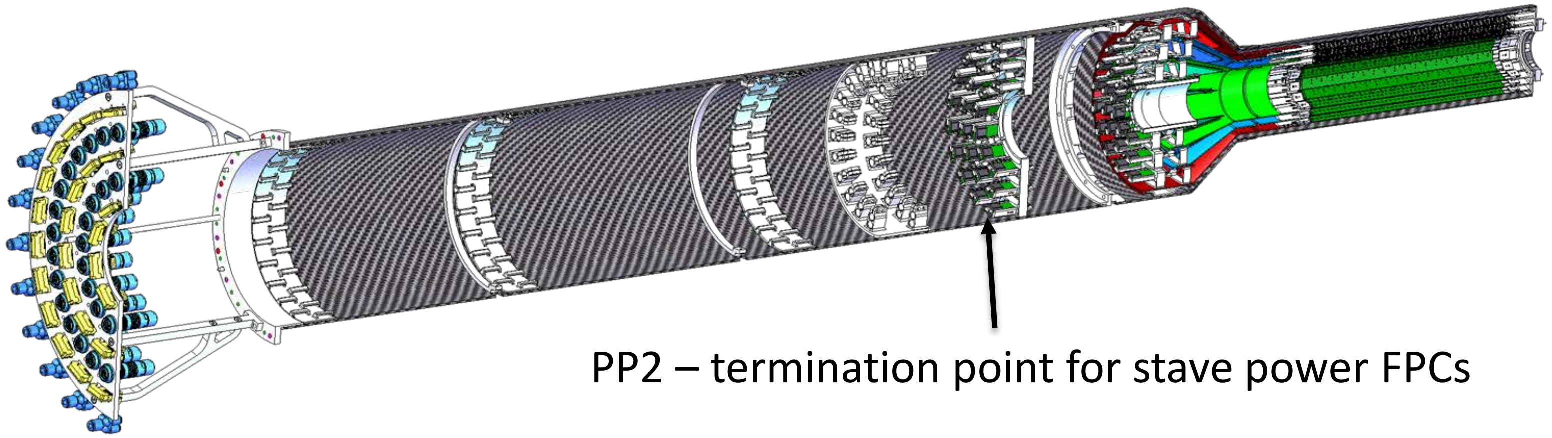


ITS vs. MVTX





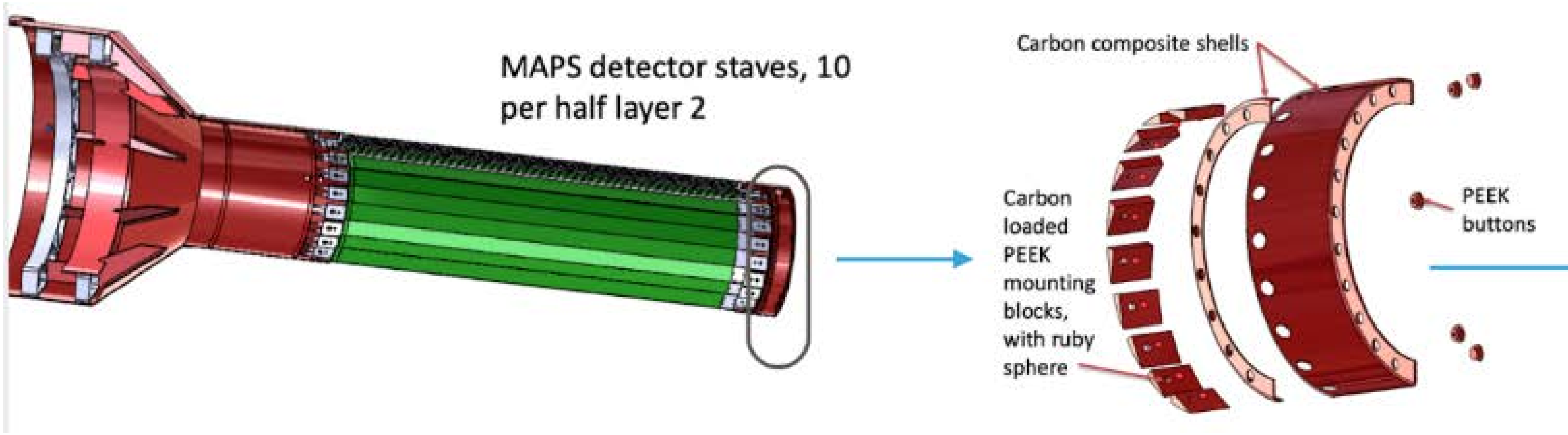
- Different envelope dimensions complicate cable routing
- Whereas ITS had sufficient radial space to terminate all signal and power cables for each layer in a single plane, MVTX staves have been modified so that power cables can terminate further down the service barrel

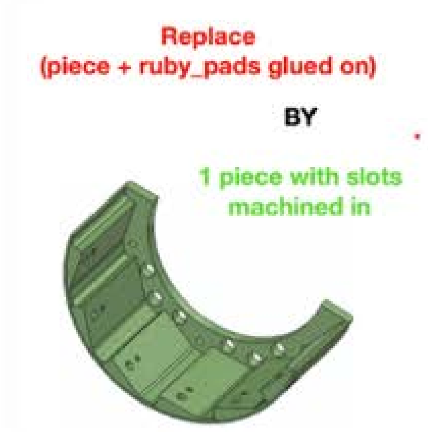


ITS vs MVTX

Changes driven by:

3. Convenience/practical aspects : the EndWheel change → simpler design (also cheaper)





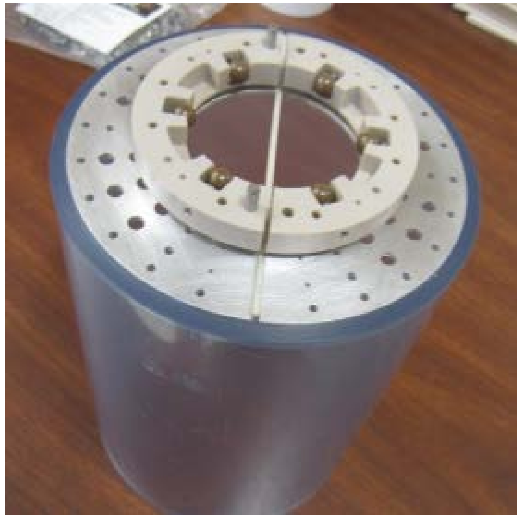
ITS: MANY tiny pieces

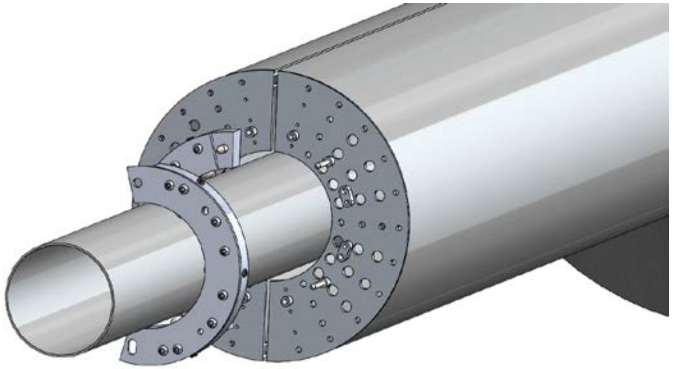
MVTX: 1-piece

ITS vs MVTX

Changes driven by:

4. Final Design Review (January 2020) → Added a "nose roller" assembly to protect the beam pipe
   Uses spring-loaded PEEK balls whose inner radius is smaller than the staves inner radius





Leveraged ITS Work

	Directly Applicable	Needs some modification	Useful as baseline
Fabrication tooling design		X	
Assembly tooling		X	
Stave mfg tolerances and FEA studies	X		
Design of many small parts	X		
Achievable assembly tolerances	X		
Spring-finger connection scheme	X		
Signal cable strain relief	X		
Materials selection for patch panels and CF components		X	
Potential vendors			X
Static and frequency-domain FEA			X

Bottom line: most of the ITS work/knowledge was directly applicable to MVTX

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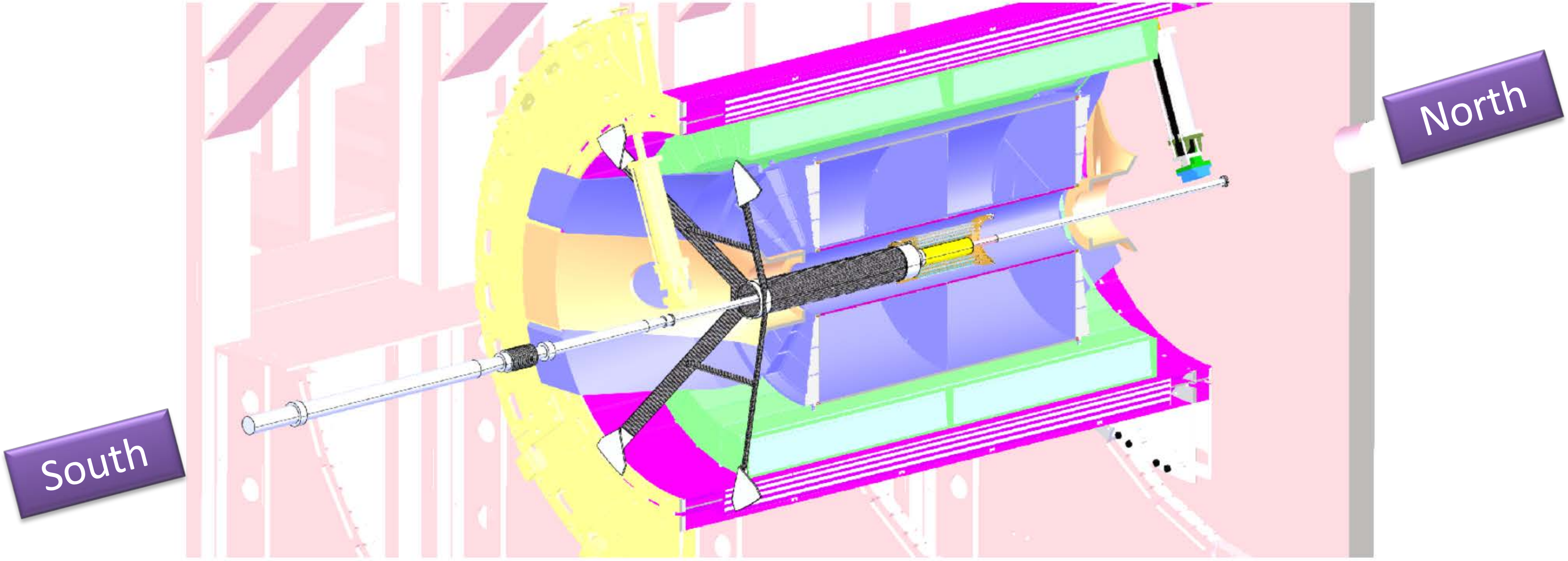
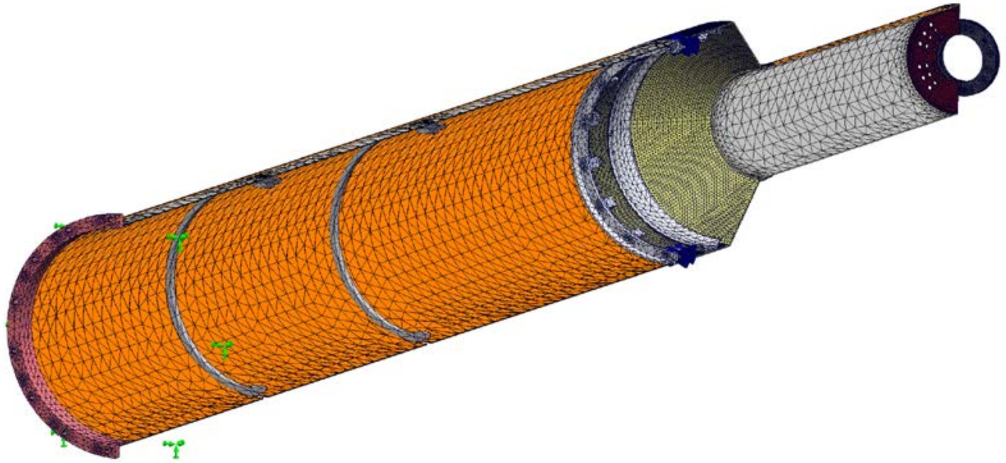


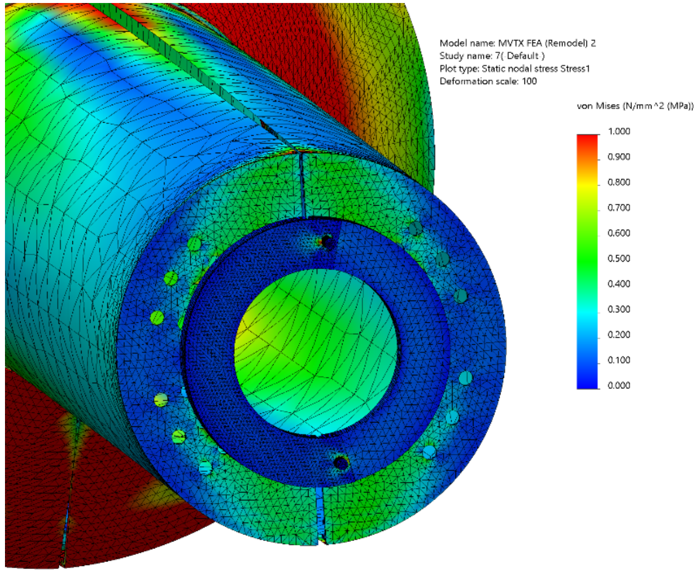
FEA Studies

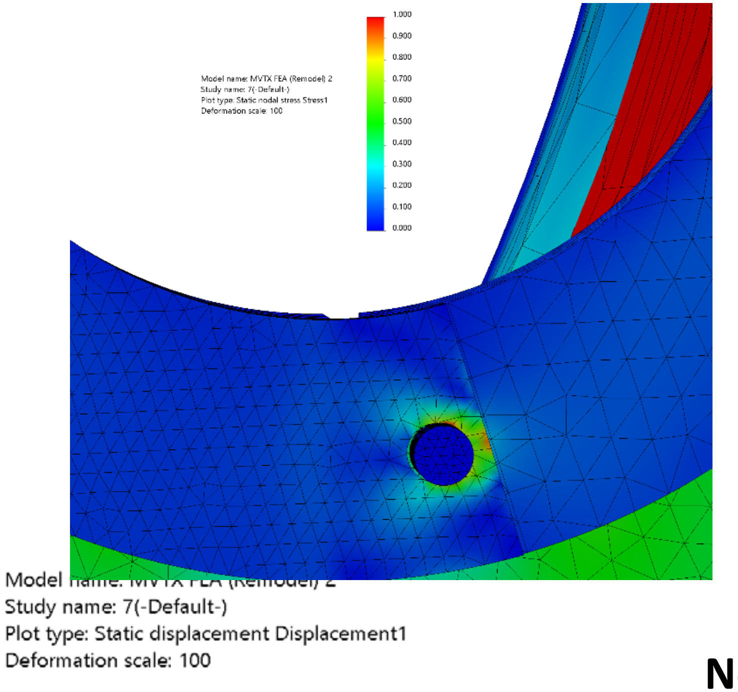


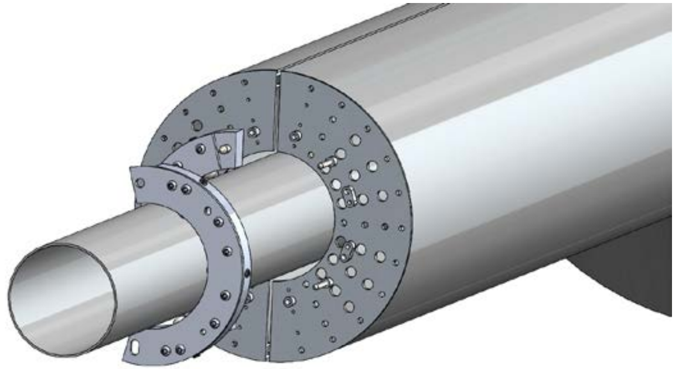
Load	Value	Type	Location
Gravity	-9.81 m/s^2	Global free body	Everywhere
Signal Cables	2226 g	Distributed Force, per side	SB inside face
Power Cables	3612.3 g	Distributed Force, per side	SB inside face
L0	261.26 g	Remote mass, per side	CYSS Clamp ring and Nose Plate
L1	312.9 g	Remote mass, per side	CYSS Clamp ring and Nose Plate
L2	418.9 g	Remote mass, per side	CYSS Clamp ring and Nose Plate
water 4mm + Air Tubes	1122.1 g	Distributed Force, per side	SB Inside face
Nose rollers	Self weight / or 30 g per side	Mass / Distributed Force	Self / On nose plates

Total Mass: 24 kg (both sides combined) <->~53lb

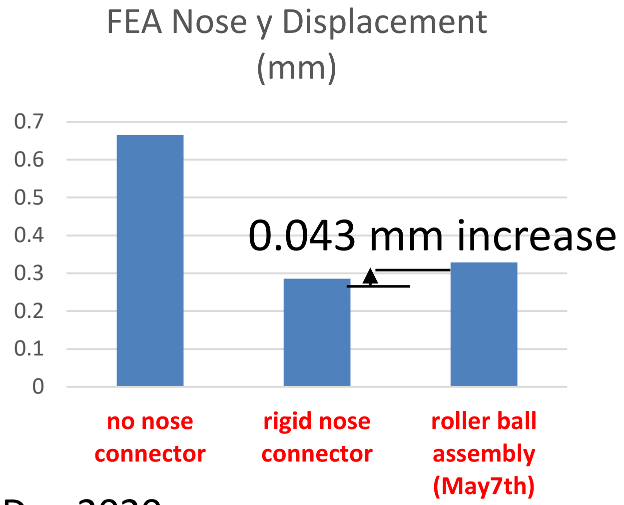
FEA Studies – Nose Roller

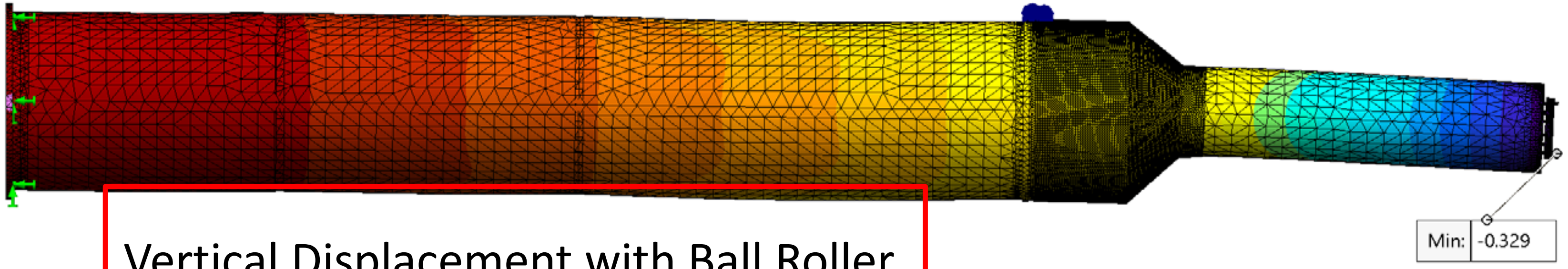






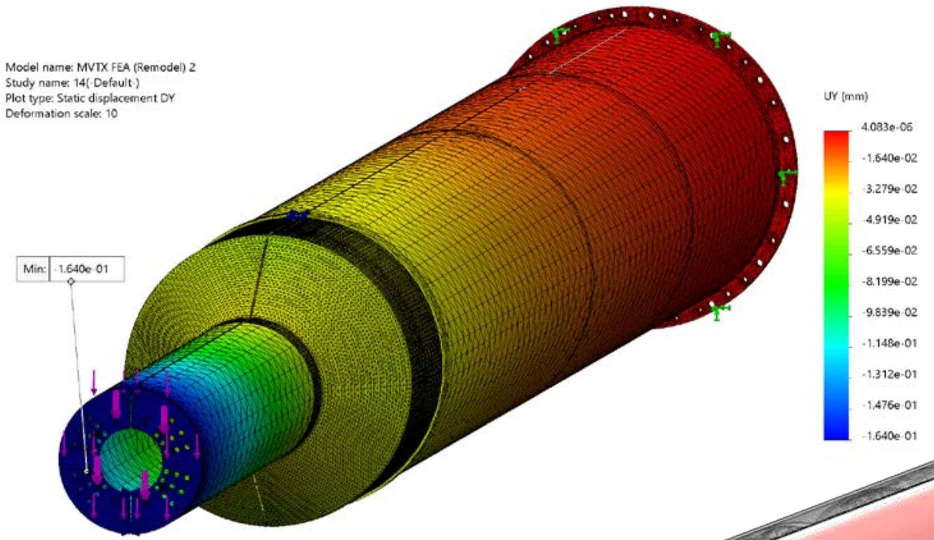
Nose Roller that interconnects ends of MVTX halves effectively reduces sag by over 0.3 mm



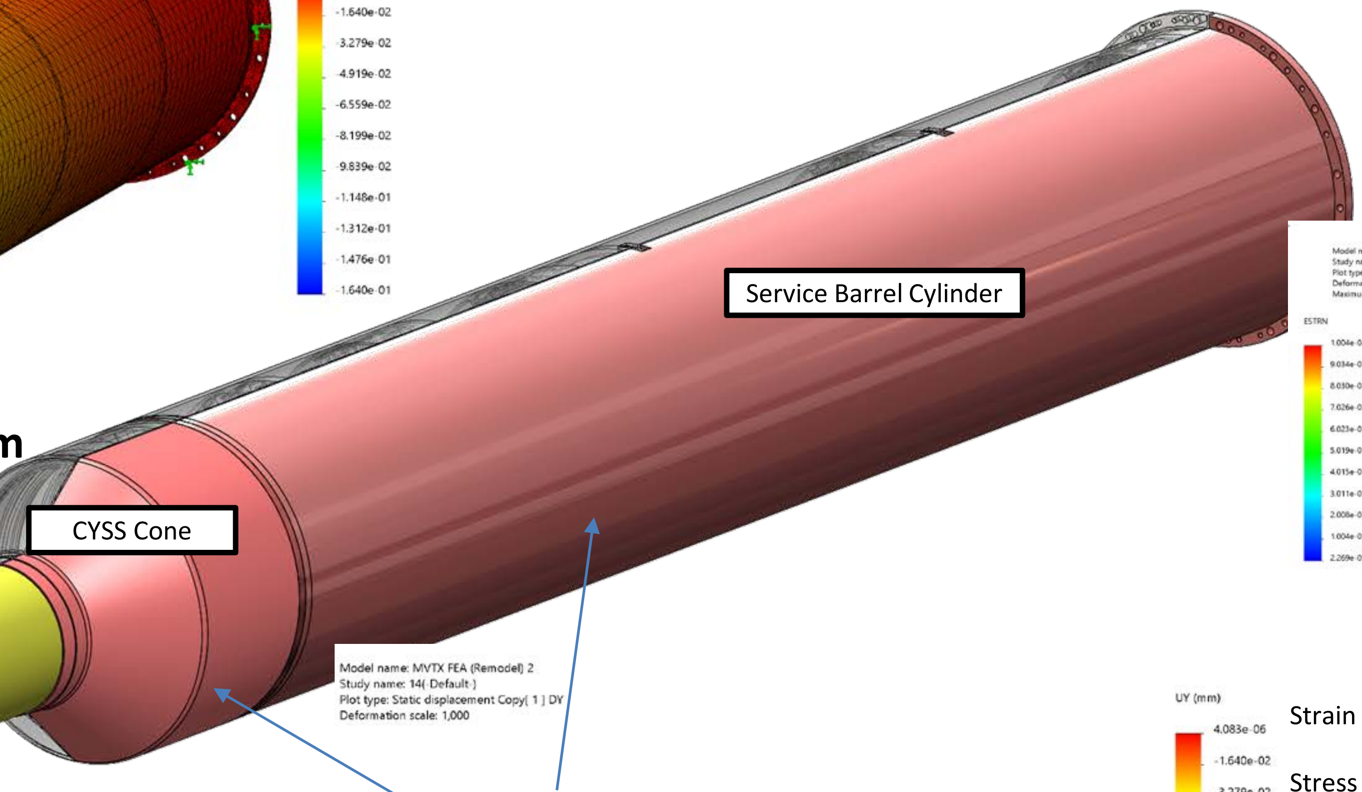


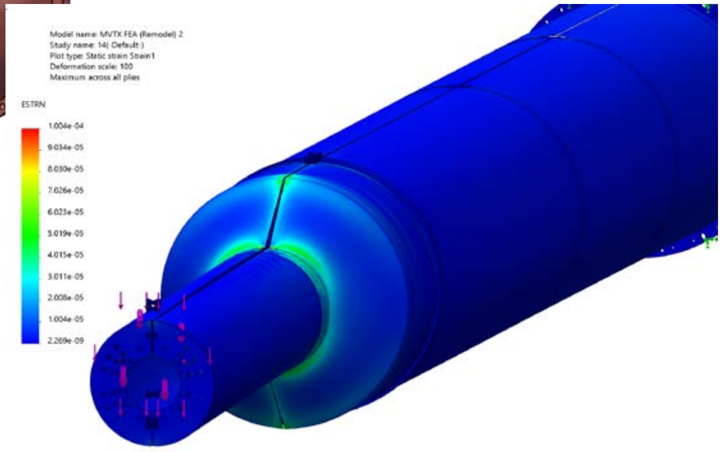
Vertical Displacement with Ball Roller

Study 14 Results (12 JUNE 2020)



Deflection max = 0.164 mm





Strain Plot (max across plies)

Stress max = 9.8 MPa near a sharp corner of a cutout

16 layers [0/90, 0/90, 0/90, ±45, ∓45, 90/0, 90/0, 90/0] 2.24 mm

8 layers [0/90, ±45, ∓45, 90/0] 1.12 mm

However, in this model it was modeled as a 1 mm Ti solid

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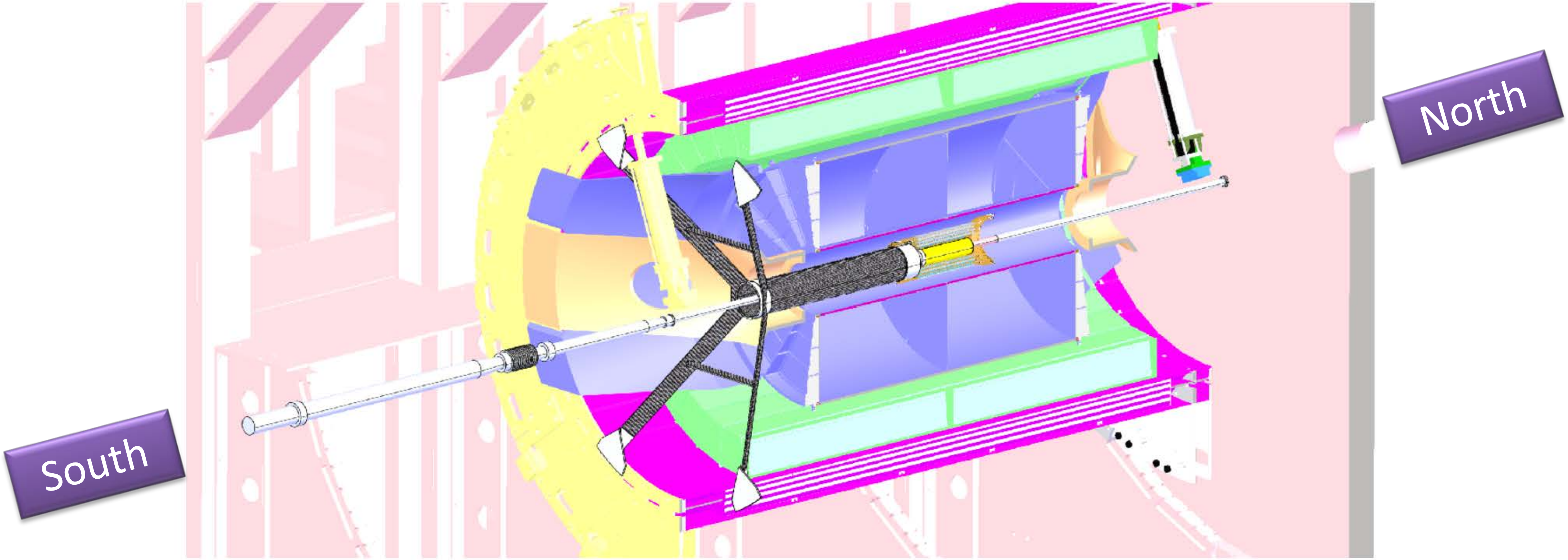
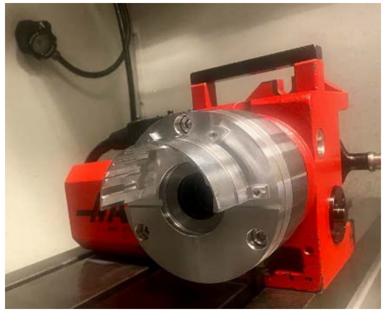
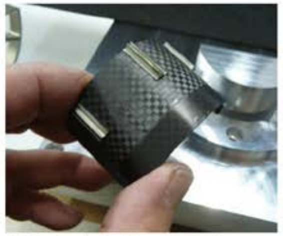


Production

1. Discussion of endwheel manufacturing hurdles
2. Latest results from End Wheel CMM



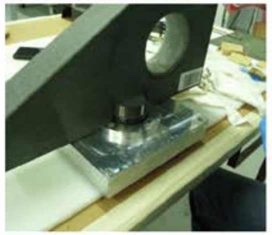


C-ring is sanded, and protected with some Teflon tape. It is then degreased.

Some glue is applied on the C-ring, then the part is placed in the main bonding jig.

3. Discussion of CF procurement
4. CMM results for test article

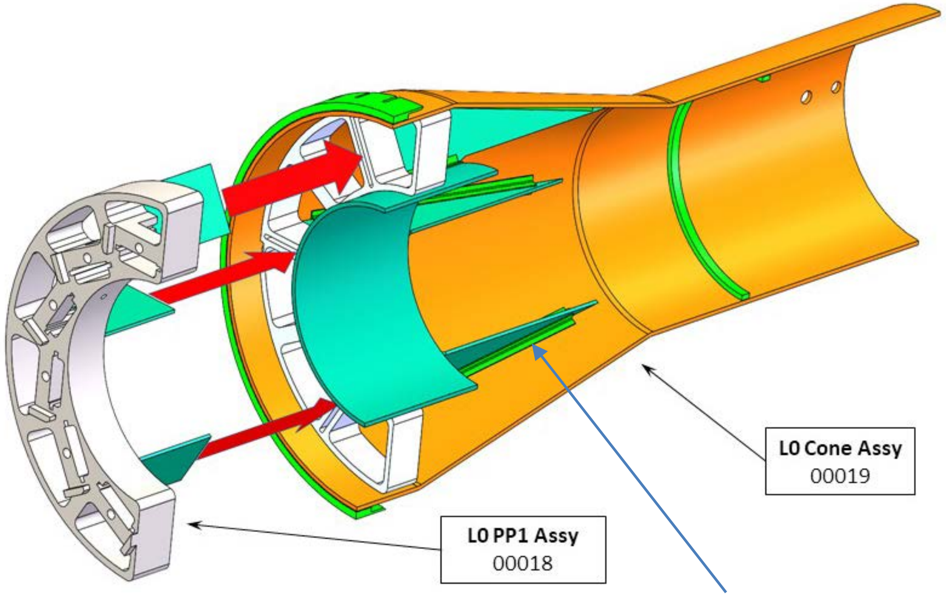
Passthrough is degreased as well.

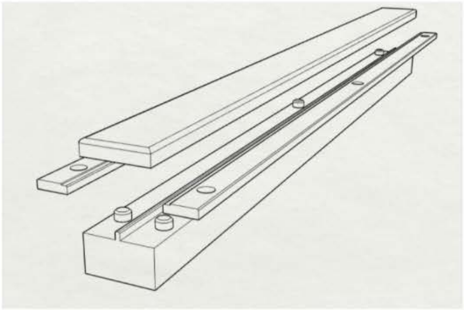


Changes during production

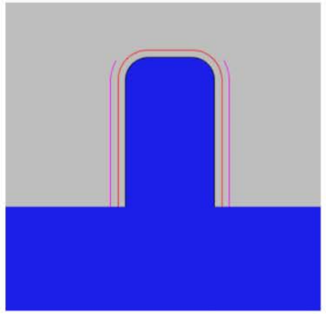
1. Test Article:

1. Divider mounts: aluminum --> carbon fiber

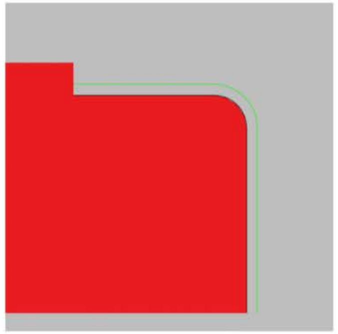




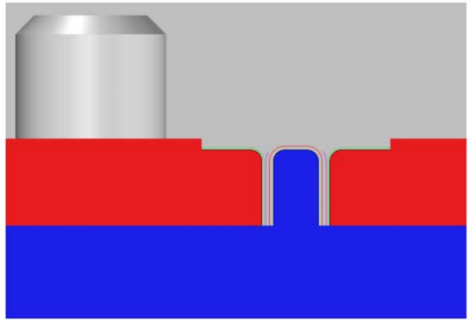
Step 1: we mill a 4 parts mould in aluminium.



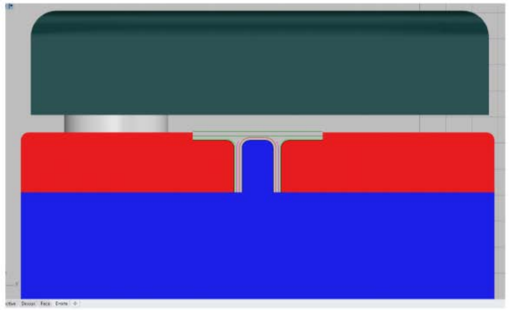
Step 2: we lay-up the 2 first plies as describe on this picture



Step 3: we lay-up 1 ply on the side parts of the mould



Step 4: we put the side parts of the mould in place, and secure them with pins



Select an area to comment on

Step 5: we put the last 2 plies on top, and then close the mould. We can now cure the part. Mould is long enough (260mm) to allow us to manufacture the divider mounts for 1 MVTX layer each autoclave cure.

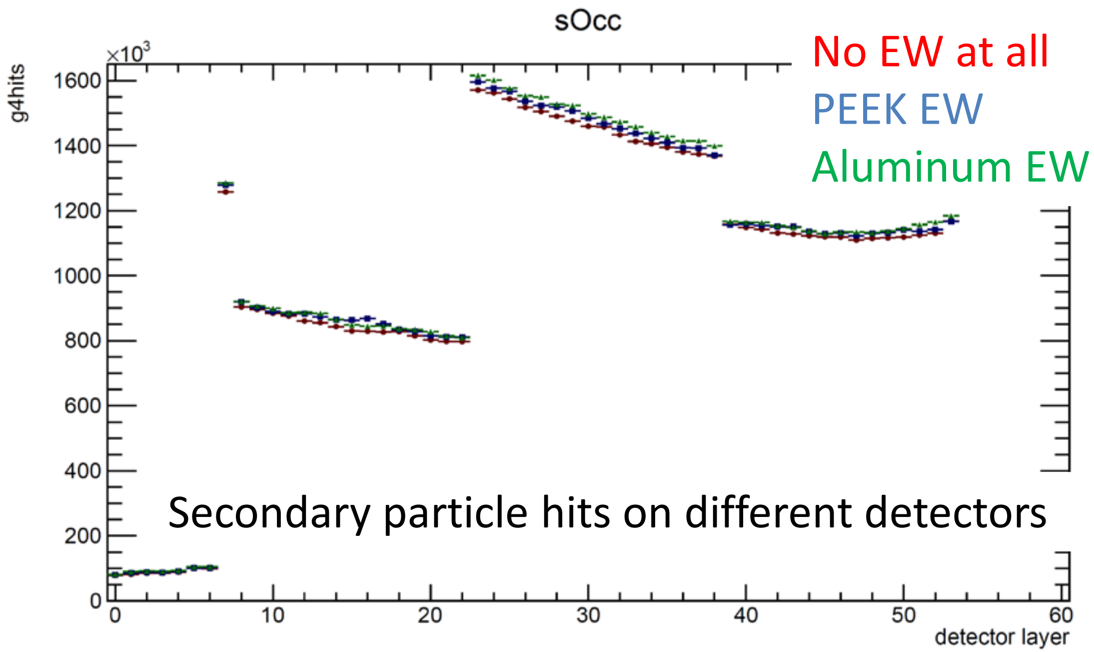
WORK SHAPE
conception . prototypage

Changes during production

2) **Lengthened / enlarged end flange**: we start working on the mock-up, we realized we would like a larger flange (near PP3) for more clearance to support structure and for additional installation bracket mounting holes

3) **EndWheel material**:

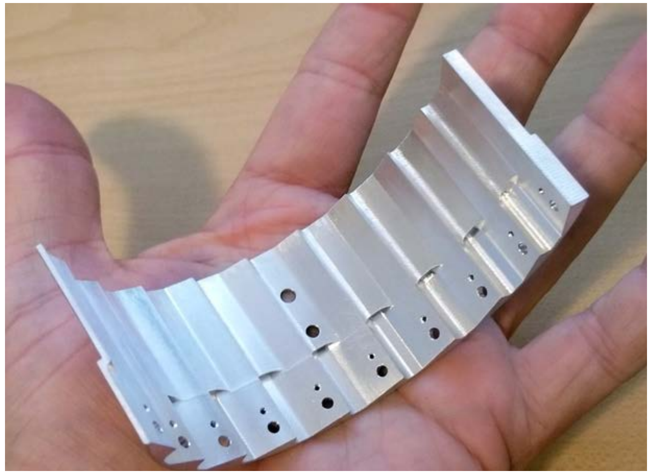
- started with PEEK (2 tries, both failed), we switched to Al
- <u>No impact on physics</u>

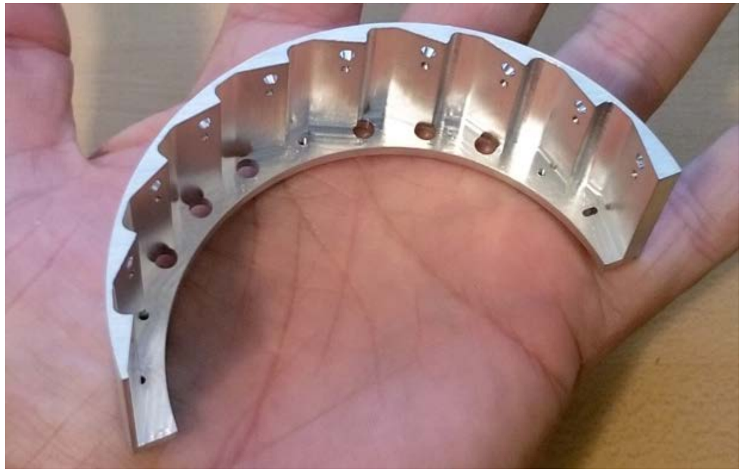


Secondary particle hits on different detectors

Endwheel production

- The endwheels were made of a single piece each to simplify production
- Initial plan was to produce using 30% carbon fiber filled PEEK
  - 2 shops made 3 total attempts at this, without success
  - Different methods of stress relieving were tried, including heat-annealing and vibration (tumbling)
- Ultimately, it was decided to use aluminum
- Measurements were confirmed using 3rd party CMM shop
- **Results of aluminum end wheel test pieces are good**

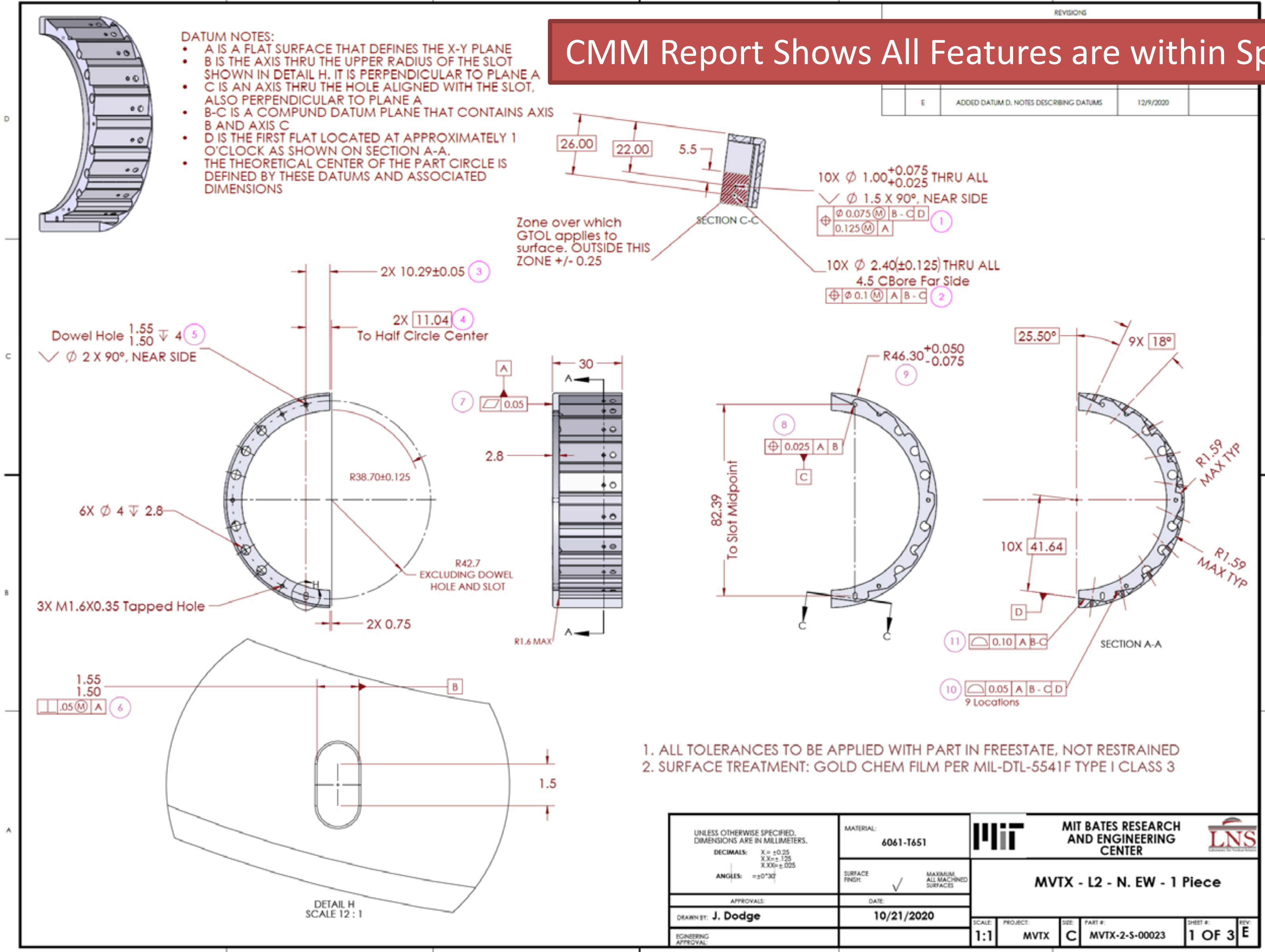




EndWheel CMM Reports
Test Article Reports (Mfr)
Test Article Reports (3rd Party)

North Aluminum End Wheel

CMM Report Shows All Features are within Spec!



PART NAME :	MVTX-2-S-00023		December 03, 2020	17:43
REV NUMBER :	R2	SER NUMBER :	STATS COUNT :	1

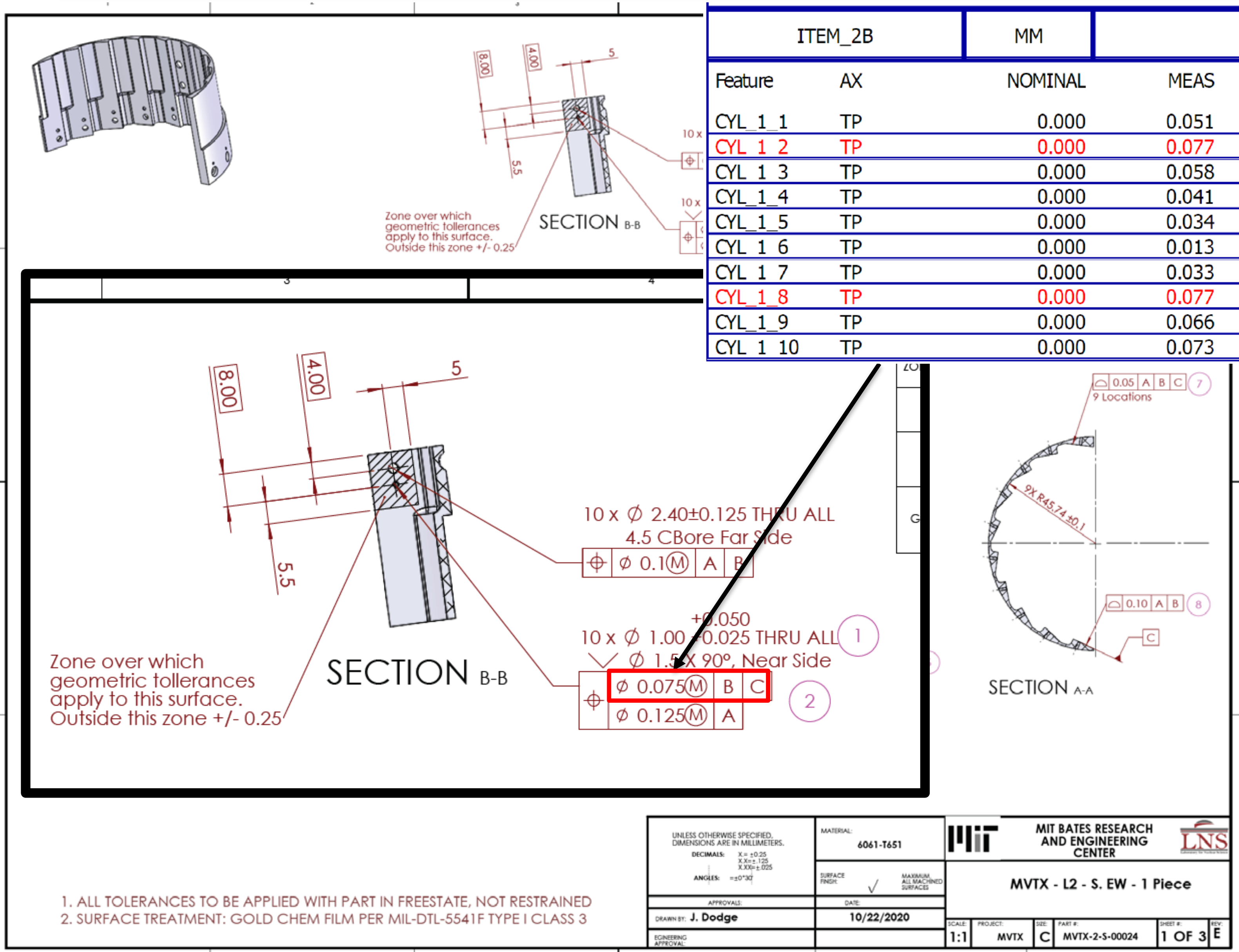
AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
MM ITEM_1_1 - CYL_1_1						
D	1.000	1.038	0.075	-0.025	0.038	0.000
MM ITEM_1_2 - CYL_1_2						
D	1.000	1.038	0.075	-0.025	0.038	0.000
MM ITEM_1_3 - CYL_1_3						
D	1.000	1.039	0.075	-0.025	0.039	0.000
MM ITEM_1_4 - CYL_1_4						
D	1.000	1.039	0.075	-0.025	0.039	0.000
MM ITEM_1_5 - CYL_1_5						
D	1.000	1.039	0.075	-0.025	0.039	0.000
MM ITEM_1_6 - CYL_1_6						
D	1.000	1.040	0.075	-0.025	0.040	0.000
MM ITEM_1_7 - CYL_1_7						
D	1.000	1.042	0.075	-0.025	0.042	0.000
MM ITEM_1_8 - CYL_1_8						
D	1.000	1.042	0.075	-0.025	0.042	0.000
MM ITEM_1_9 - CYL_1_9						
D	1.000	1.042	0.075	-0.025	0.042	0.000
MM ITEM_1_10 - CYL_1_10						
D	1.000	1.042	0.075	-0.025	0.042	0.000

ITEM_2B Position — MM — ∅0.05 BC

Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CIR_1_1	0.000	0.006	0.050		0.006	0.000	0.000
CIR_1_2	0.000	0.018	0.050		0.018	0.000	0.000
CIR_1_3	0.000	0.035	0.050		0.035	0.000	0.000

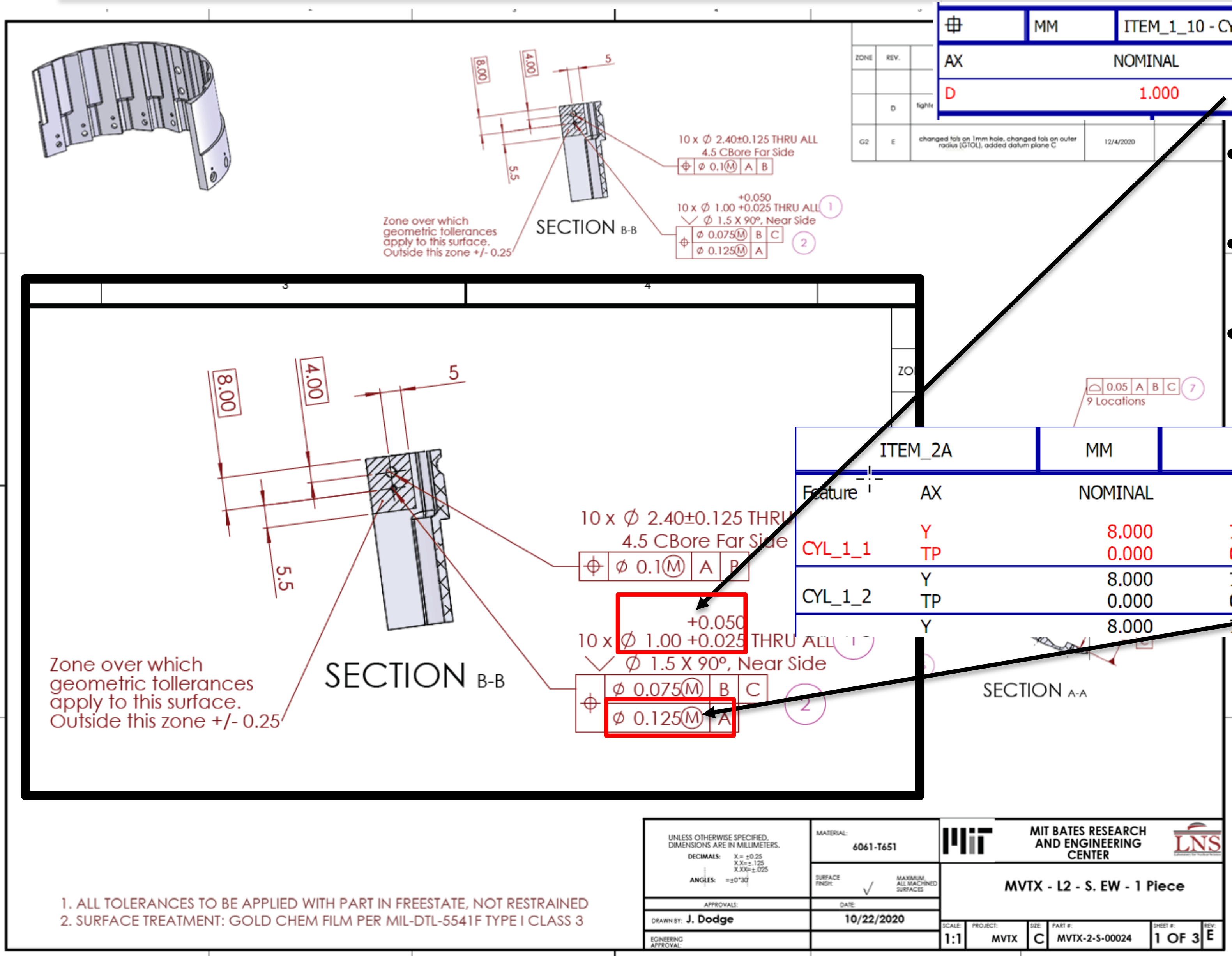
South Aluminum End Wheel

ITEM_2B	MM	⌖ 0.075 B		LSQ		ASME Y14.5		
Feature	AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_1_1	TP	0.000	0.051	0.075	0.000	0.051	0.000	0.000
CYL_1_2	TP	0.000	0.077	0.075	0.000	0.077	0.002	0.000
CYL_1_3	TP	0.000	0.058	0.075	0.000	0.058	0.000	0.000
CYL_1_4	TP	0.000	0.041	0.075	0.000	0.041	0.000	0.000
CYL_1_5	TP	0.000	0.034	0.075	0.000	0.034	0.000	0.000
CYL_1_6	TP	0.000	0.013	0.075	0.000	0.013	0.000	0.000
CYL_1_7	TP	0.000	0.033	0.075	0.000	0.033	0.000	0.000
CYL_1_8	TP	0.000	0.077	0.075	0.000	0.077	0.002	0.000
CYL_1_9	TP	0.000	0.066	0.075	0.000	0.066	0.000	0.000
CYL_1_10	TP	0.000	0.073	0.075	0.000	0.073	0.000	0.000



- True position error of two pin holes out by 2 um (r - ϕ)
- **Small enough to not be a concern, but we will continue to monitor production of these features**

South Aluminum End Wheel



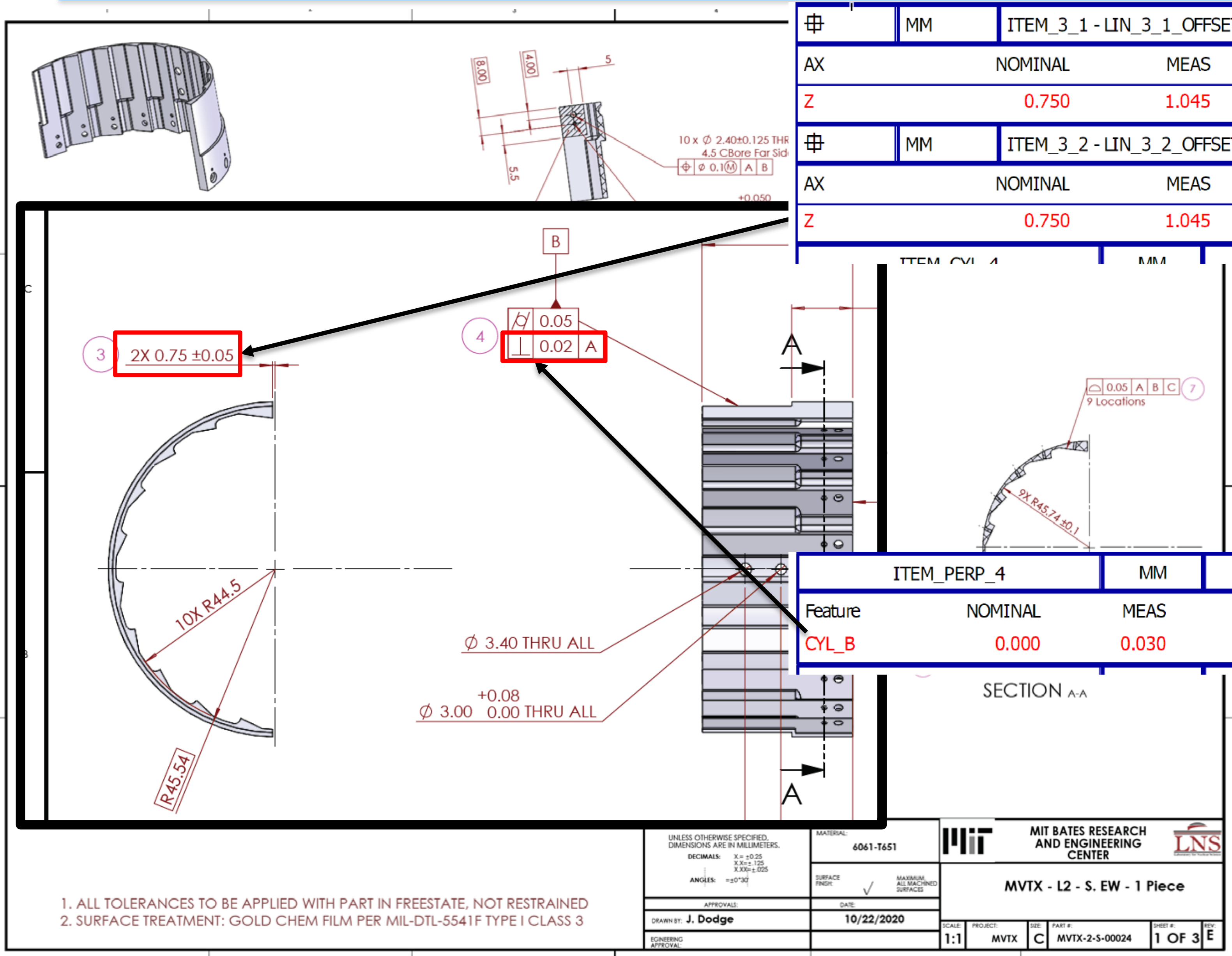
⌖	MM	ITEM_1_10 - CYL_1_10				
AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
D	1.000	1.021	0.050	0.025	0.021	0.004

- Diameter of one alignment pin hole is 4 um under spec
- This dimension is oversized already (to allow slip-fit of pin and pond gap)
- **Pin diameters have a range of O(10um) so a smaller pin will be matched with this hole**

ITEM_2A	MM	⌖ 0.125 A				LSQ	ASME Y14.5	
Feature	AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_1_1	Y TP	8.000 0.000	7.936 0.128	0.125	0.000	-0.064 0.128	0.003	0.000
CYL_1_2	Y TP	8.000 0.000	7.970 0.059	0.125	0.000	-0.030 0.059	0.000	0.000
	Y	8.000	7.982			-0.018		

- True position error of one pin hole out by 3 um (*z*)
- Very small error
- **This is the direction along which the stave slot is oriented, so actually has much more room for error than the given tolerance of 0.125 mm**

South Aluminum End Wheel



⌖	MM	ITEM_3_1 - LIN_3_1_OFFSET				
AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
Z	0.750	1.045	0.050	-0.050	0.295	0.245

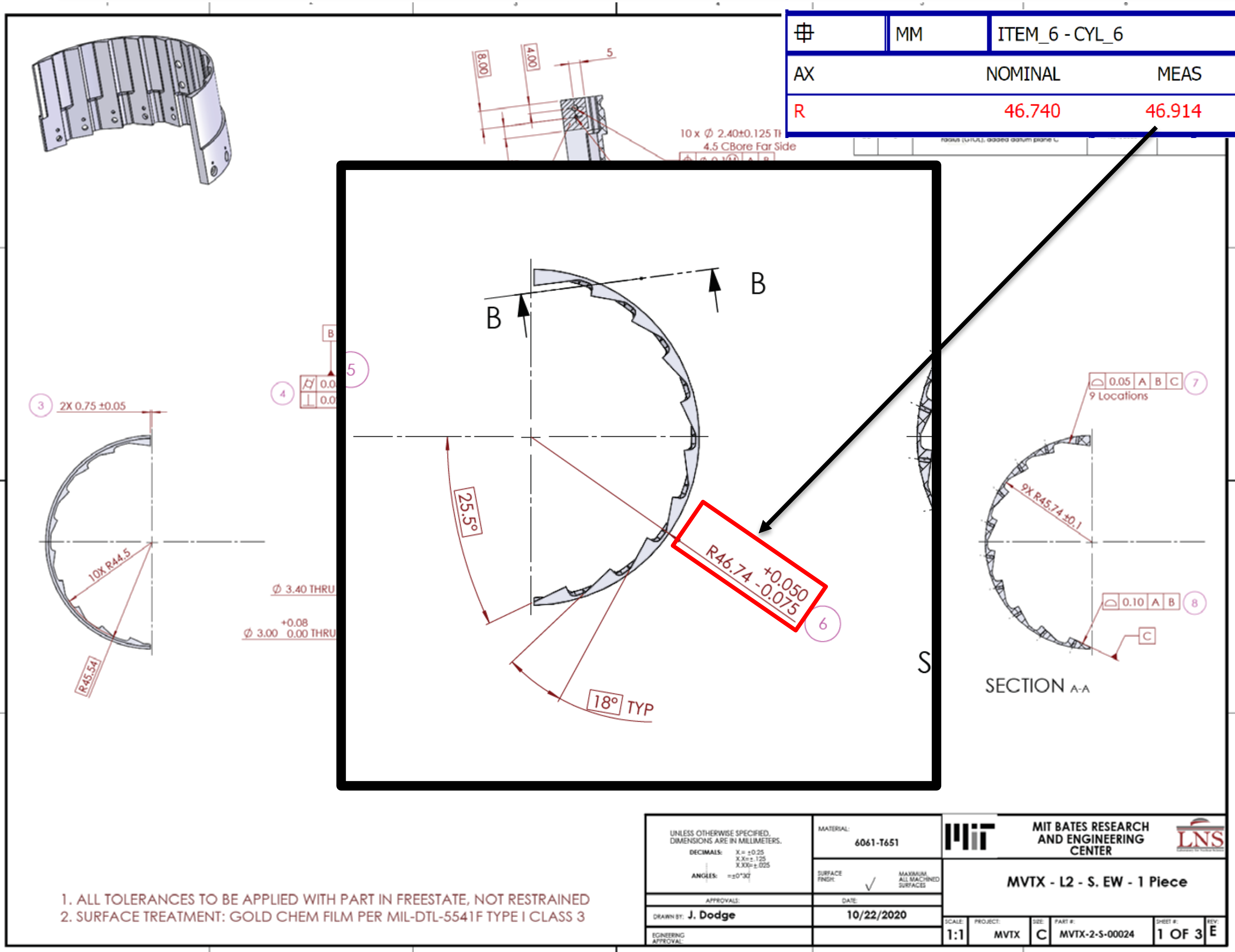
⌖	MM	ITEM_3_2 - LIN_3_2_OFFSET				
AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
Z	0.750	1.045	0.050	-0.050	0.295	0.245

- Half-gap to vertical z-r plane is larger than spec
- Error is in the right direction
  - If it were under-size, this would be fixable.
- **Does not affect function of part**

ITEM_PERP_4	MM	⊥ Ø 0.02 A		LSQ	ASME Y14.5		
Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_B	0.000	0.030	0.020	0.000	0.030	0.010	0.000

- Bond surface cylinder perpendicularity out by 10 um
- Originally had a larger tolerance; was asked by machine shop to tighten it to better qualify datum
- **Still well within geometric envelope for bonding**

South Aluminum End Wheel

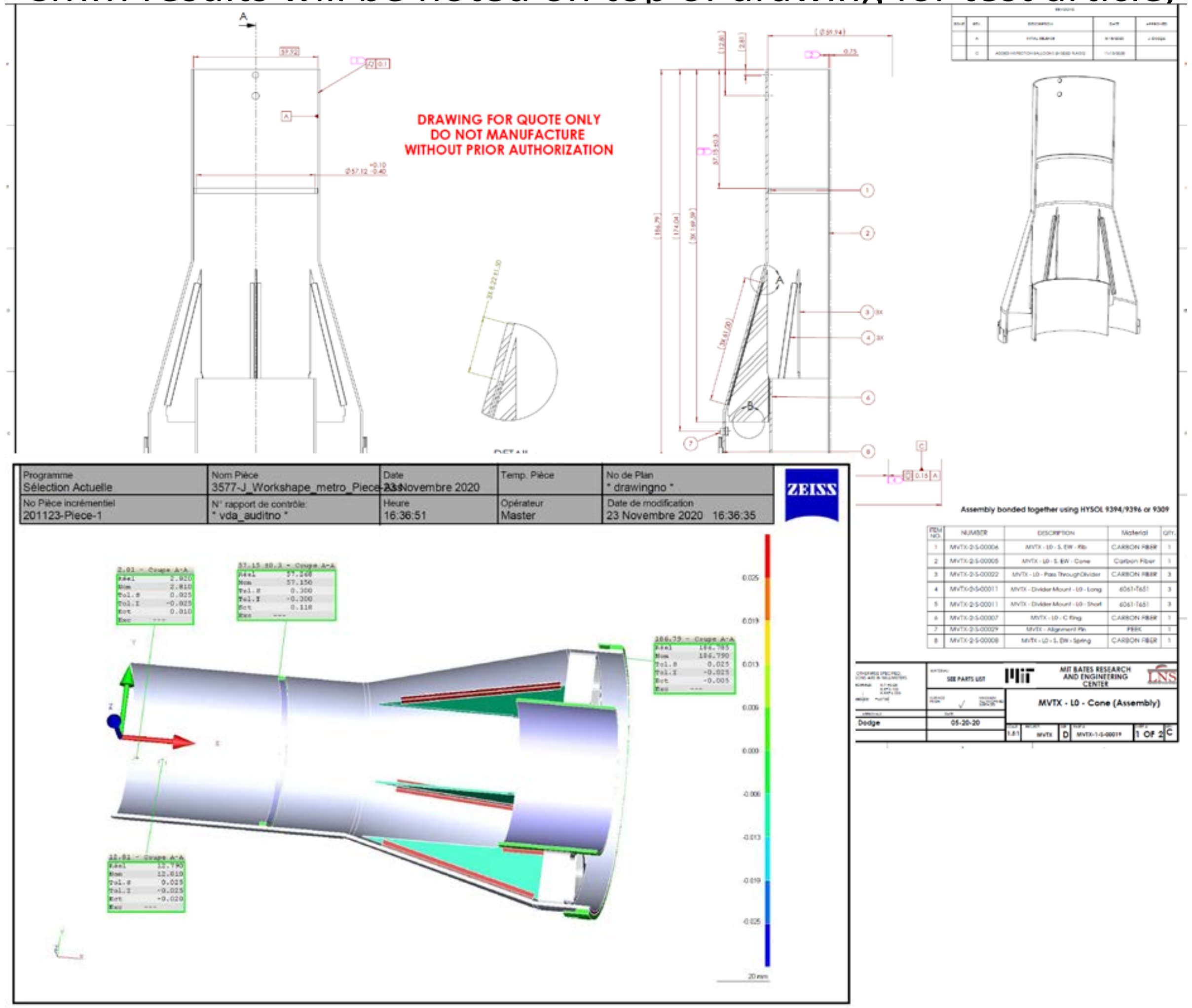


	MM	ITEM_6 - CYL_6				
AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
R	46.740	46.914	0.050	-0.075	0.174	0.124

- Largest radius oversized by 174 um
- **Because this is the outer layer, there is nothing beyond the end wheel for it to interfere with.**
- **Inner layer End Wheels with similar issue would be re-machined to correct**

Test Article

CMM results will be noted on top of drawing for test article,



PART NAME :	MVTX-1-S-00019 REV C	December 10, 2020	14:59
REV NUMBER : R2	SER NUMBER :	STATS COUNT :	1

Current Temperatures: X=71.644 Y=71.2 Z=70.901 P=None
Temperature Compensation is ON

ITEM_1 — MM — ⌭ 0.1

Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_A	0.000	0.059	0.100		0.059	0.000	

⌖ MM — ITEM_2 - PLN_B

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
Z	0.750	0.693	0.025	-0.025	-0.057	0.032

↔ MM — ITEM_3 - PLN_3 TO PNT_TOP (YAXIS)

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
M	57.150	57.294	0.300	-0.300	0.144	0.000

ITEM_4 — MM — ◎ Ø0.15 A

Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_C	0.000	0.050	0.150		0.050	0.000	

∠ DEG — ITEM_5 - PLN_5 TO XAXIS

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
A	30.000	29.558	0.500	-0.500	-0.442	0.000

∠ DEG — ITEM_6 - PLN_6 TO XAXIS

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
A	90.000	90.052	0.500	-0.500	0.052	0.000

∠ DEG — ITEM_7 - PLN_7 TO XAXIS

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
A	150.000	150.368	0.500	-0.500	0.368	0.000

ITEM_8 — MM — ◎ Ø0.1 C

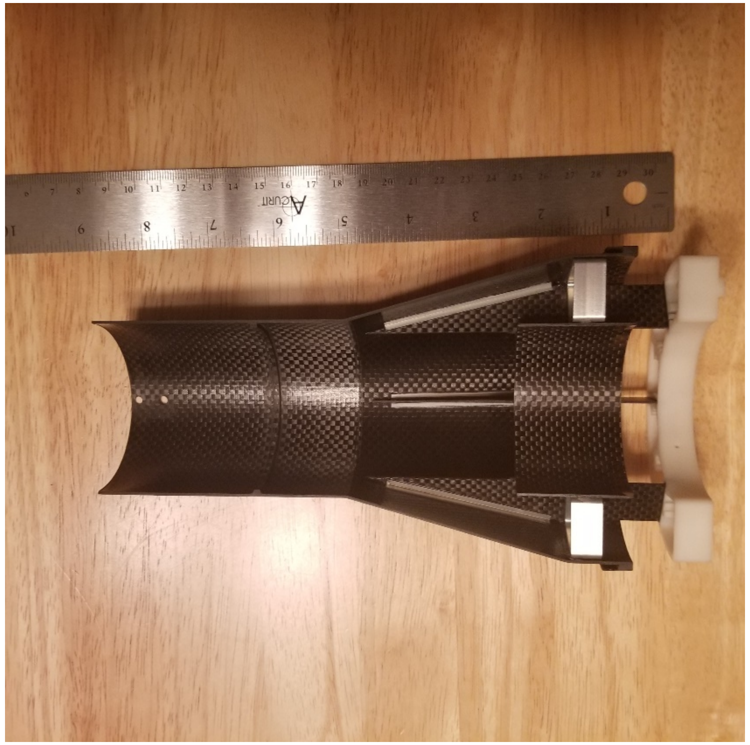
Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_8	0.000	0.017	0.100		0.017	0.000	

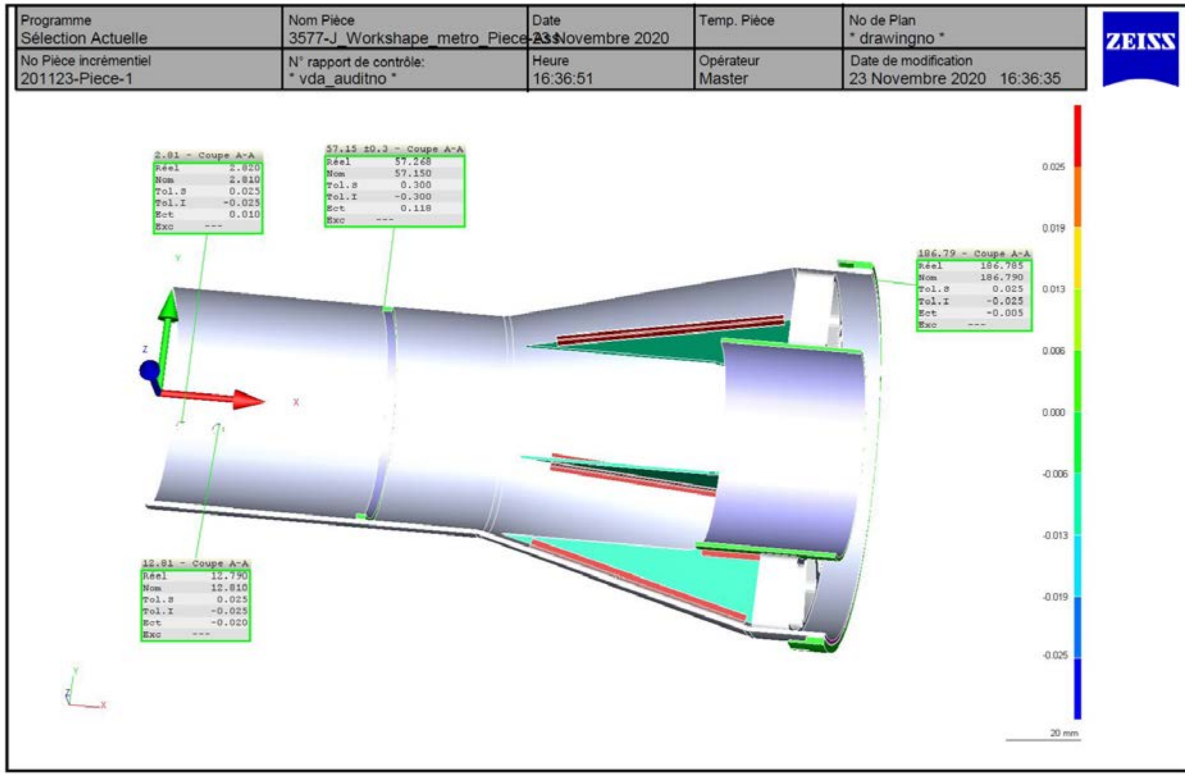
ITEM_9 — MM — ◎ Ø0.1 A

Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_8	0.000	0.077	0.100		0.077	0.000	

Test Article

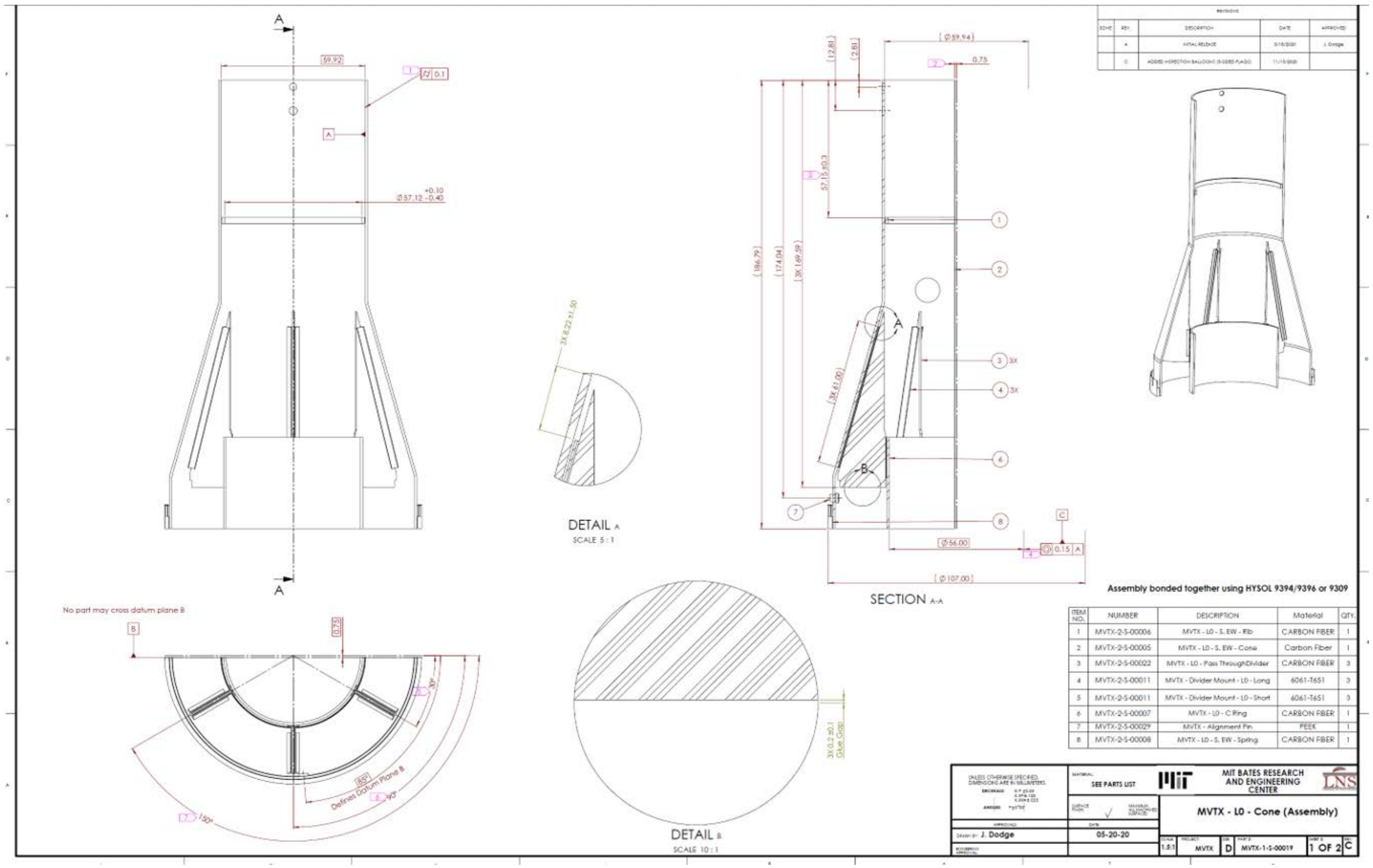
- Layer 0 Cone was produced at Workshape (FR) and delivered to MIT earlier this month
- 3rd-party inspection confirms results from manufacturer
- Layer 0, 1, and 2 cones are the most complex components with the tightest tolerances. Layer 0 was chosen because it is the smallest of these





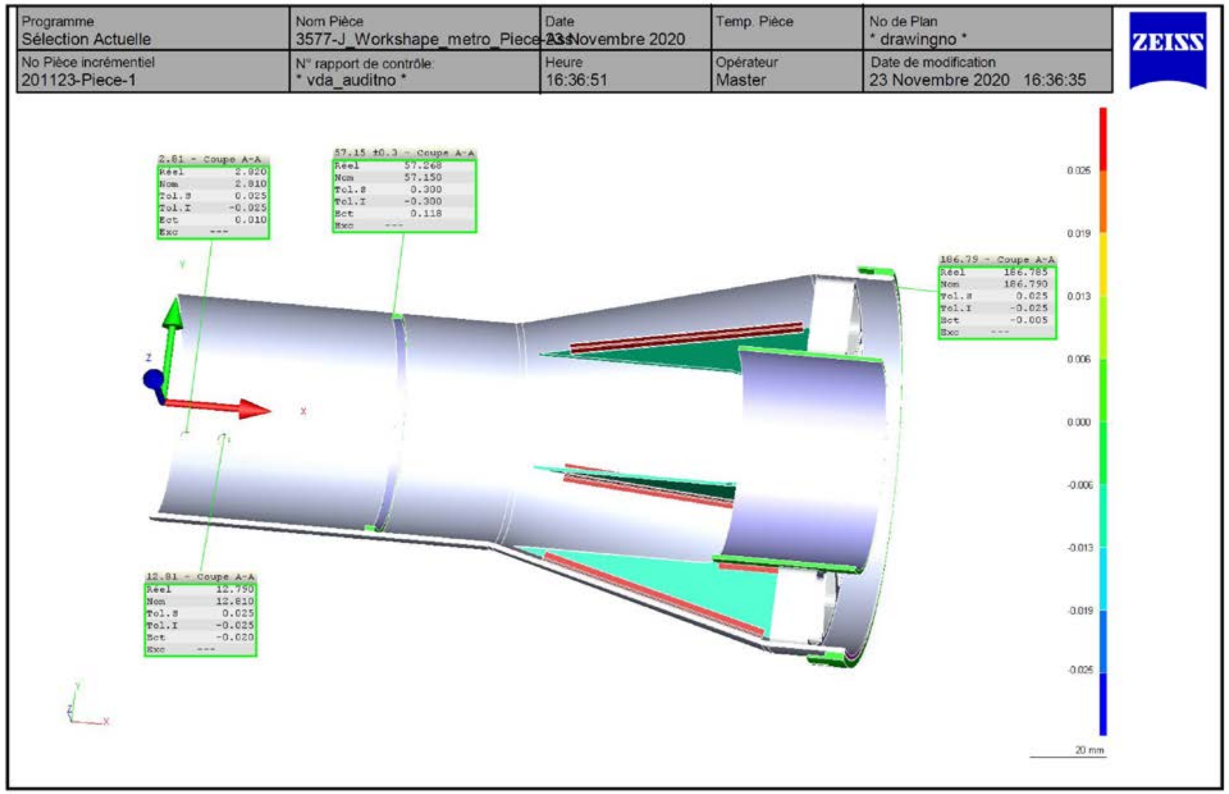
Test Article

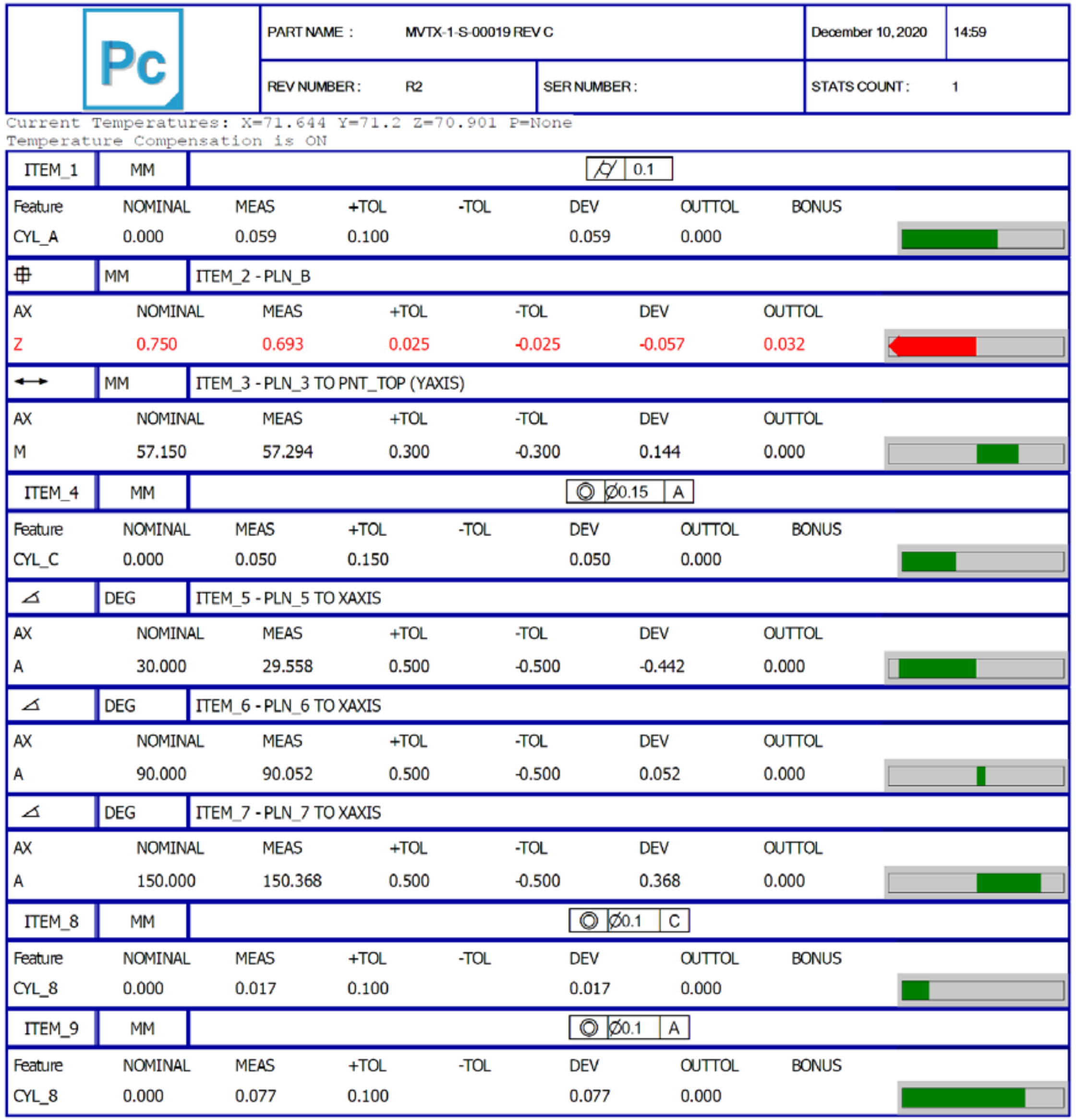
Drawing for layer 0 cone which we used as a Test Article for checking production at WorkShape in France.



Test Article

CMM results for the test article. One OOT which we deemed acceptable. WorkShape authorized to continue.





PART NAME :	MVTX-1-S-00019 REV C	December 10, 2020	14:59
REV NUMBER : R2	SER NUMBER :	STATS COUNT :	1

Current Temperatures: X=71.644 Y=71.2 Z=70.901 P=None
Temperature Compensation is ON

ITEM_1 MM 0.1

Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_A	0.000	0.059	0.100		0.059	0.000	

MM ITEM_2 - PLN_B

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
Z	0.750	0.693	0.025	-0.025	-0.057	0.032

MM ITEM_3 - PLN_3 TO PNT_TOP (YAXIS)

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
M	57.150	57.294	0.300	-0.300	0.144	0.000

ITEM_4 MM Ø0.15 A

Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_C	0.000	0.050	0.150		0.050	0.000	

DEG ITEM_5 - PLN_5 TO XAXIS

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
A	30.000	29.558	0.500	-0.500	-0.442	0.000

DEG ITEM_6 - PLN_6 TO XAXIS

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
A	90.000	90.052	0.500	-0.500	0.052	0.000

DEG ITEM_7 - PLN_7 TO XAXIS

AX	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL
A	150.000	150.368	0.500	-0.500	0.368	0.000

ITEM_8 MM Ø0.1 C

Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_8	0.000	0.017	0.100		0.017	0.000	

ITEM_9 MM Ø0.1 A

Feature	NOMINAL	MEAS	+TOL	-TOL	DEV	OUTTOL	BONUS
CYL_8	0.000	0.077	0.100		0.077	0.000	

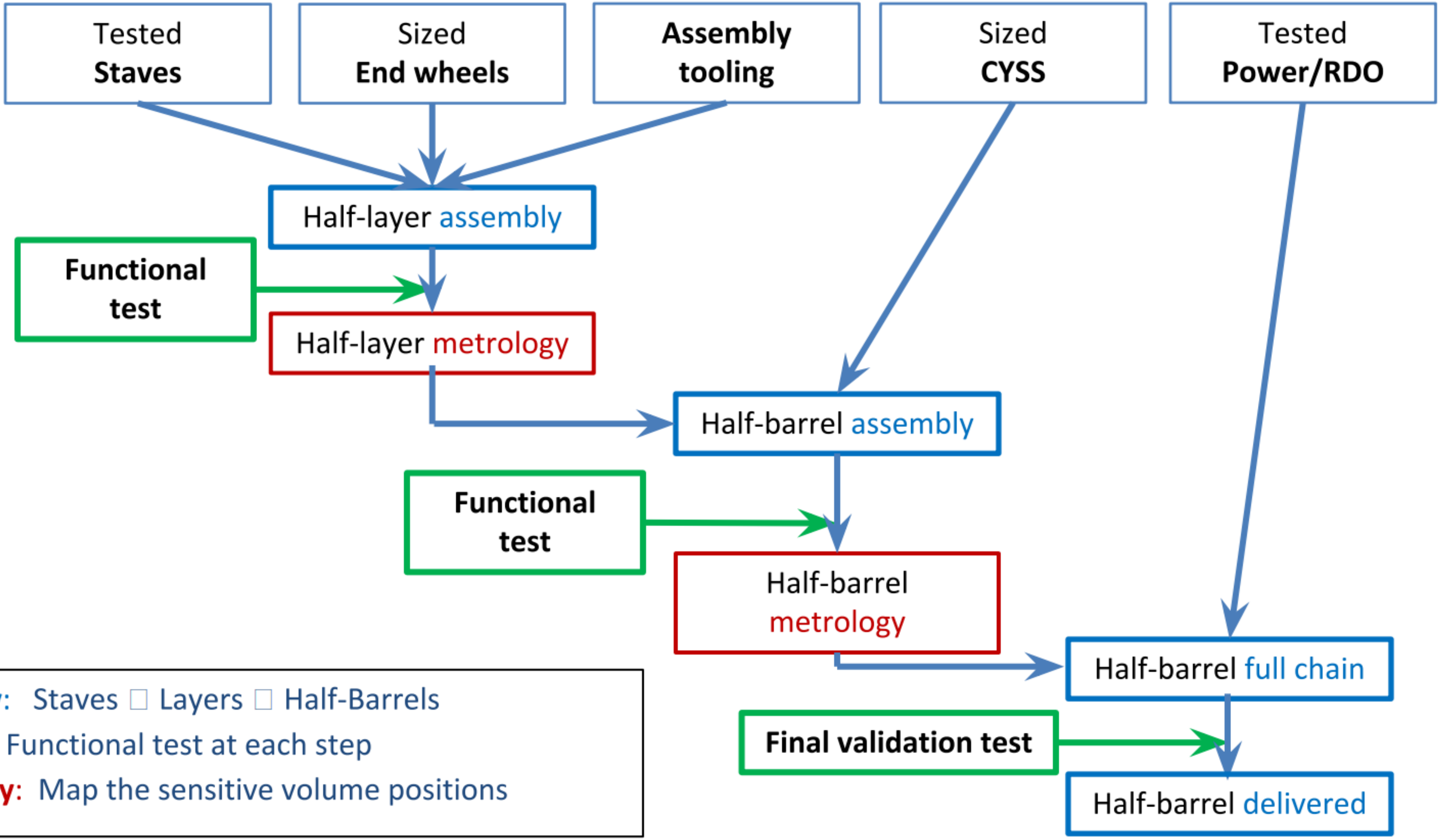
4.1 Metrology

1. Staves being produced at CERN, electrical testing and pressure / flow / cooling testing done
2. Staves will be shipped to LBNL where they will be installed to CF end wheels
3. Stave position will be measured w.r.t. end wheels for future transfer to fiducials on CYSS
4. Assembled Half-detector (including CYSS) will be delivered by LBNL

Taken from ALICE ITS

LBNL facility for testing, assembly, metrology, etc.

4.1 Metrology

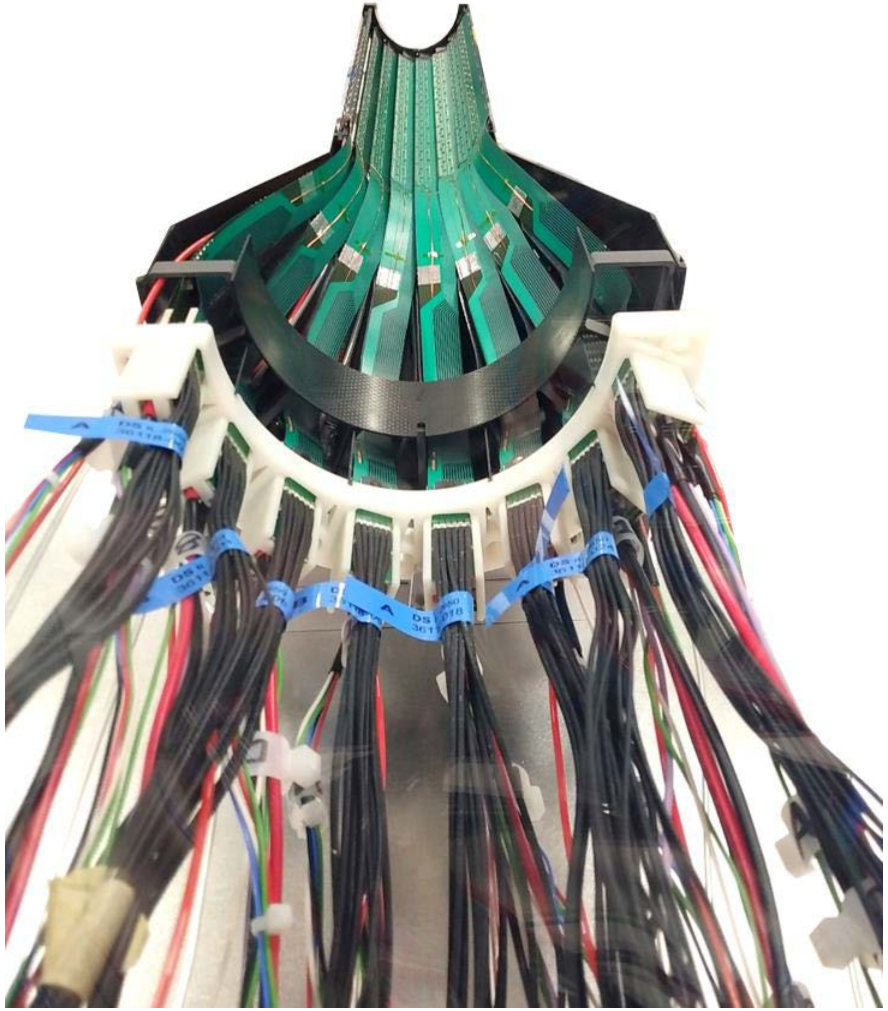


- **Assembly**: Staves □ Layers □ Half-Barrels
- **QA**: Functional test at each step
- **Metrology**: Map the sensitive volume positions

Summary

- Changes to proven ITS design have been designed and analyzed
- Production on longest lead-time parts (composite structures) is underway
- We have examined critical test pieces (layer 0 carbon and layer 2 end wheels) and determined that they are satisfactory

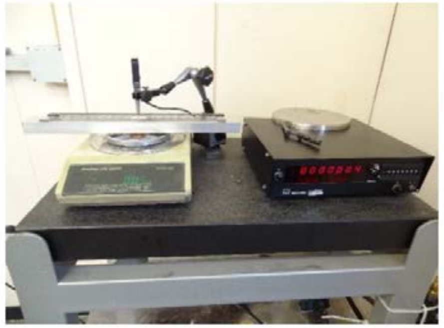
2.2 Leveraged ITS Work



ITS Inner Barrel layer model

Bending test

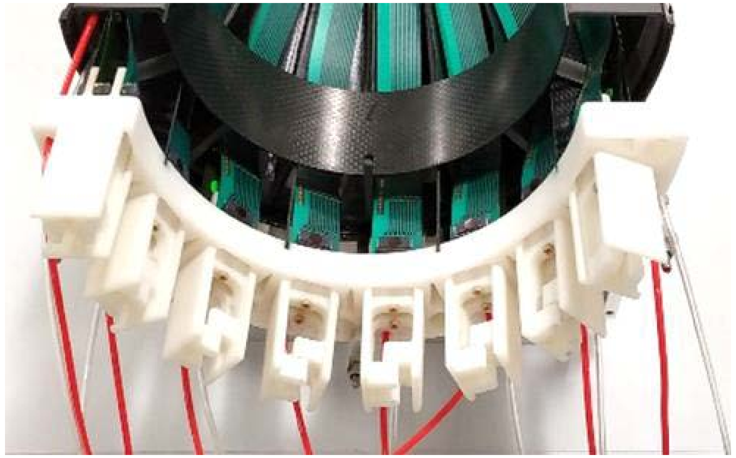
Flexural stiffness EIx~0.3Nm^2



Flexural stiffness EIy~1.41Nm^2

Torsion test

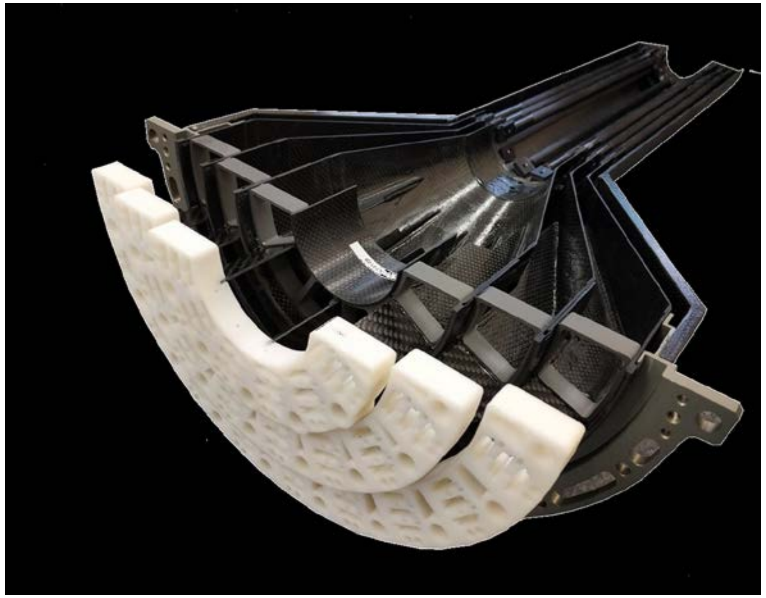
Torsional stiffness GIp~0.33Nm^2



ITS Inner Barrel patch panel and strain relief model

ITS vs. MVTX

CYSS
Service Barrel (SB)
Layer 2 (L2)
Layer 1 (L1)
Layer 0 (L0)
“End Wheels”



Nose Roller