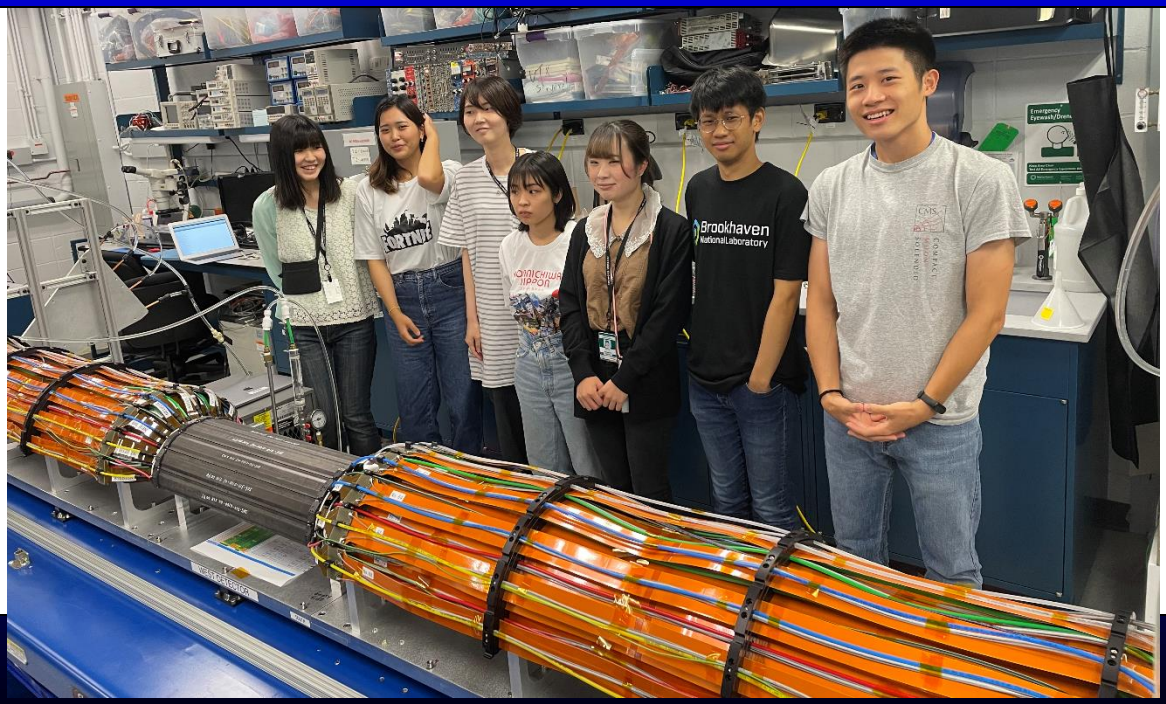
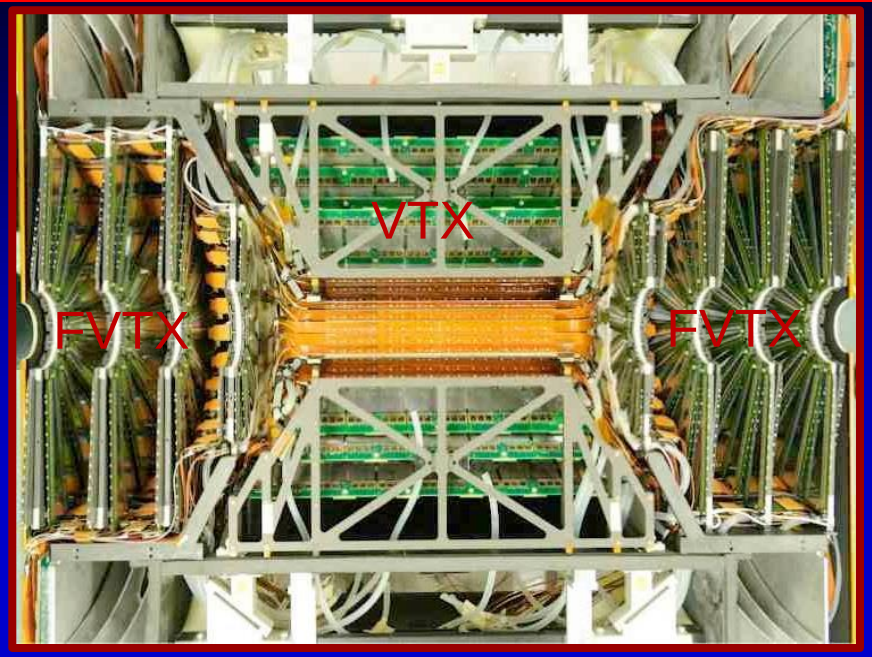
Intermediate Silicon Tracker (INTT)

Rachid Nouicer

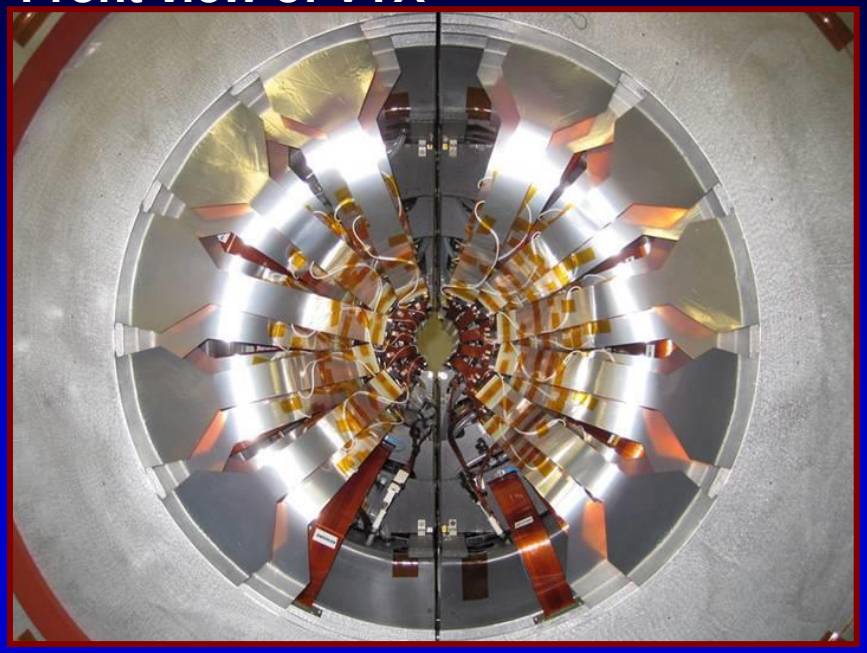
Brookhaven National Laboratory



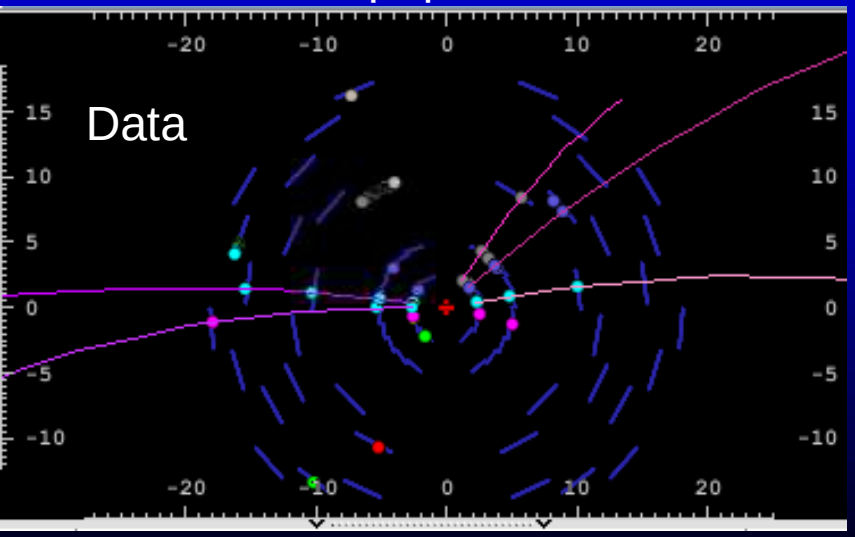
Silicon Vertex Tracker for PHENIX



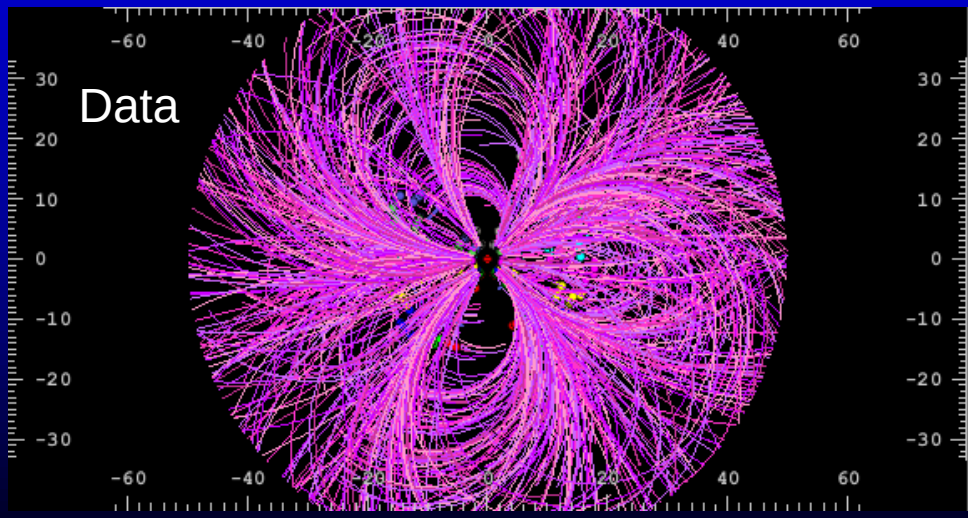
Front view of VTX



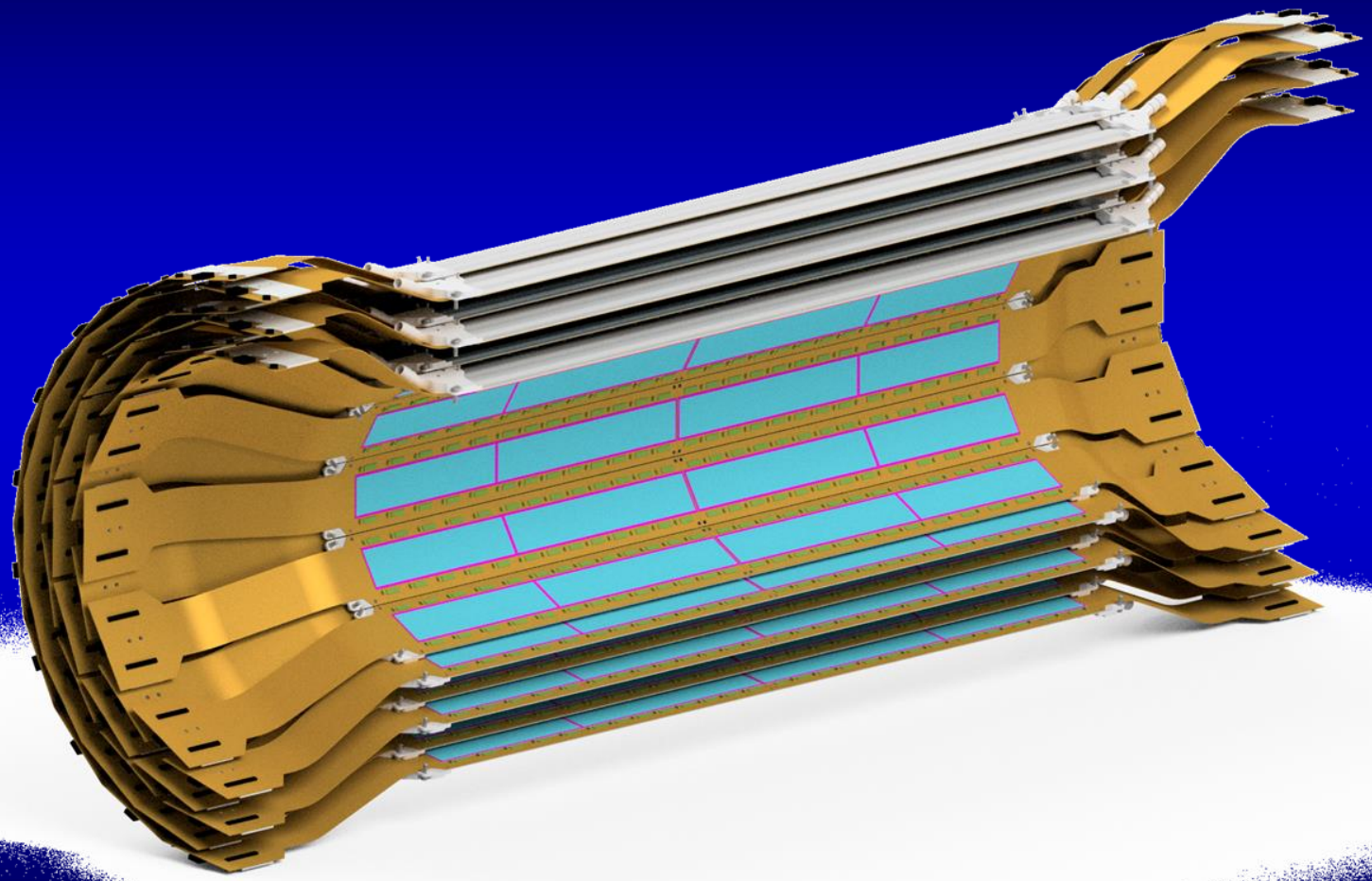
RUN-12: p+p at 200 GeV



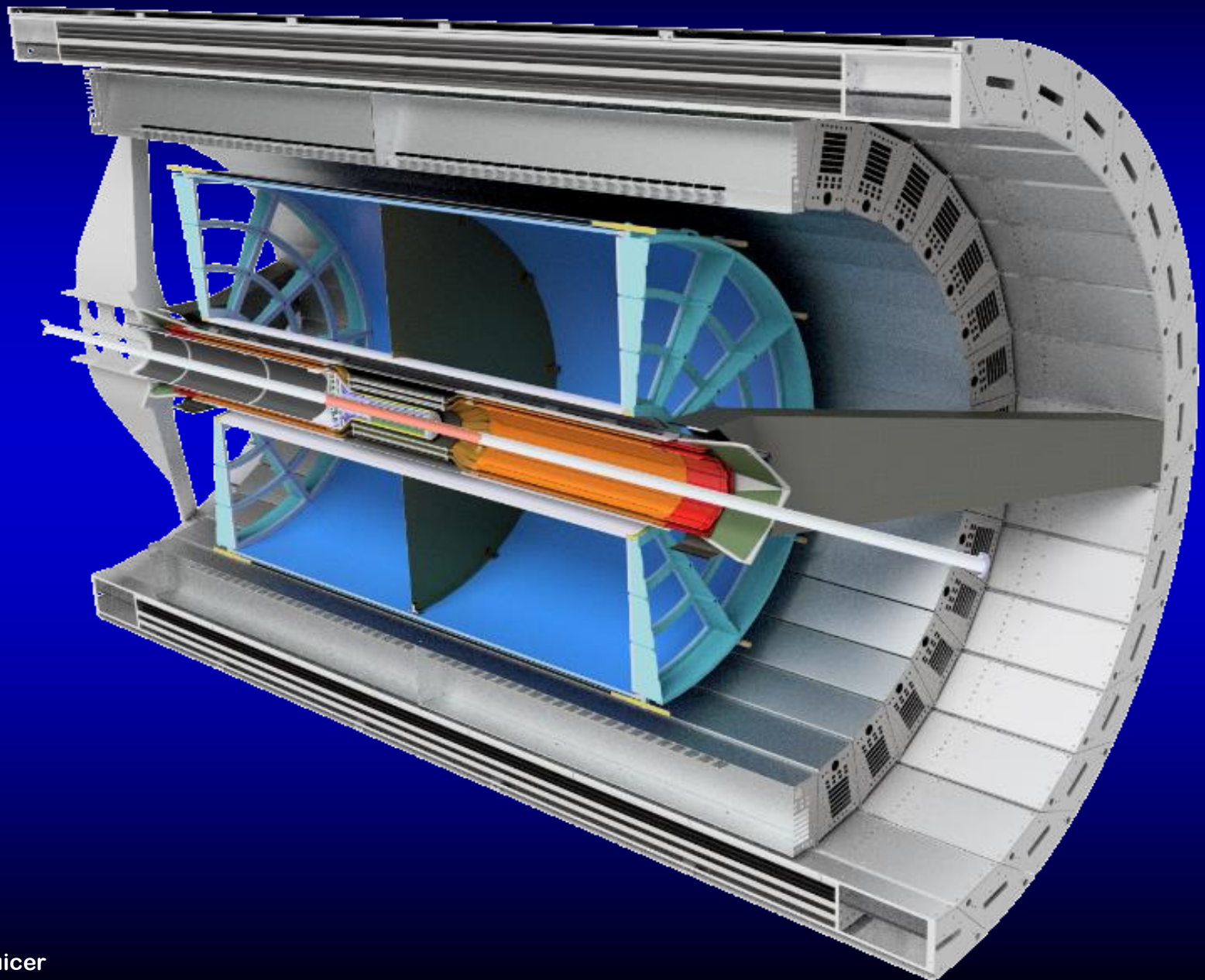
VTX RUN-11: Au+Au at 200 GeV



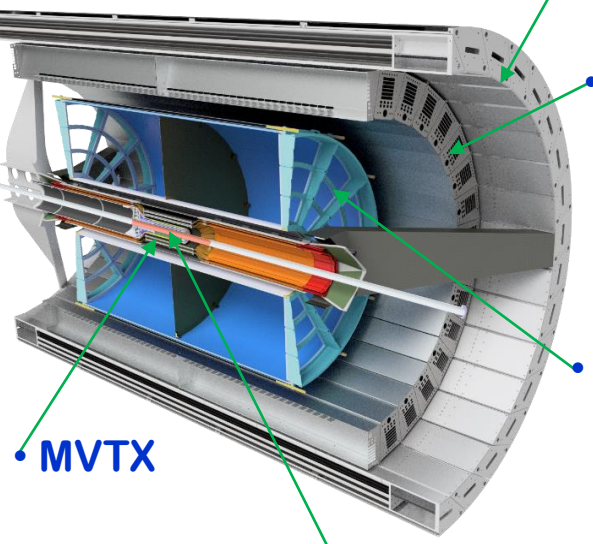
Intermediate Silicon Tracker (INTT)



sPHENIX Detector

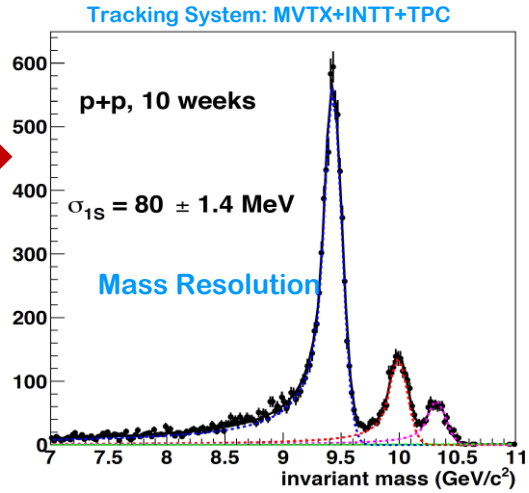


sPHENIX Intermediate Silicon Tracker

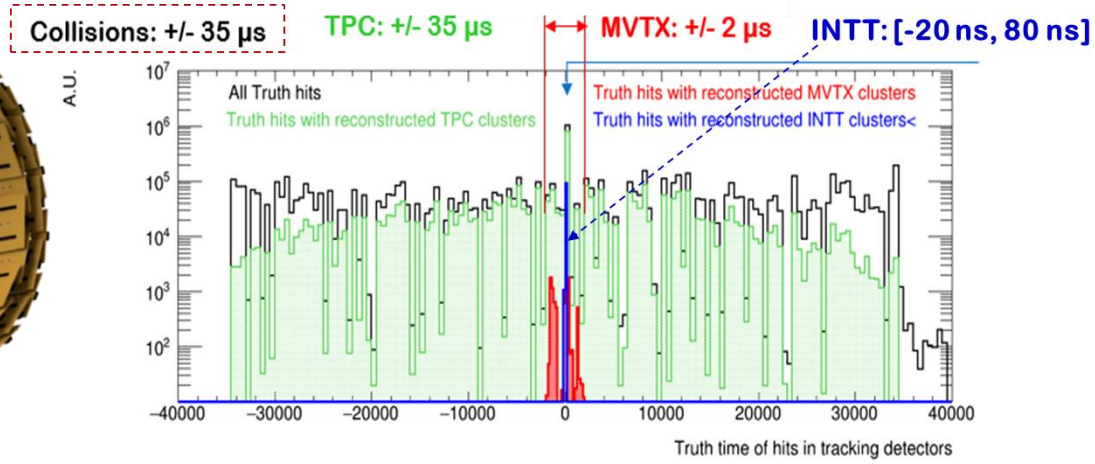


- Charged Tracking in sPHENIX:
  - MVTX provides vertexing
  - TPC provides p-resolution
  - INTT provides matching

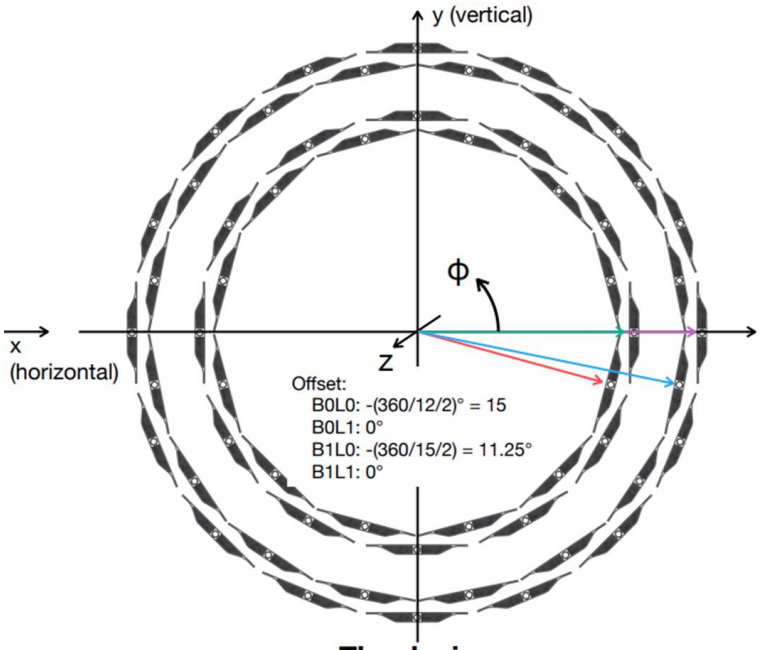
- INTT has a unique role in the sPHENIX tracking system being the only detector with sufficiently fast time response to be able to associate individual tracks and events.



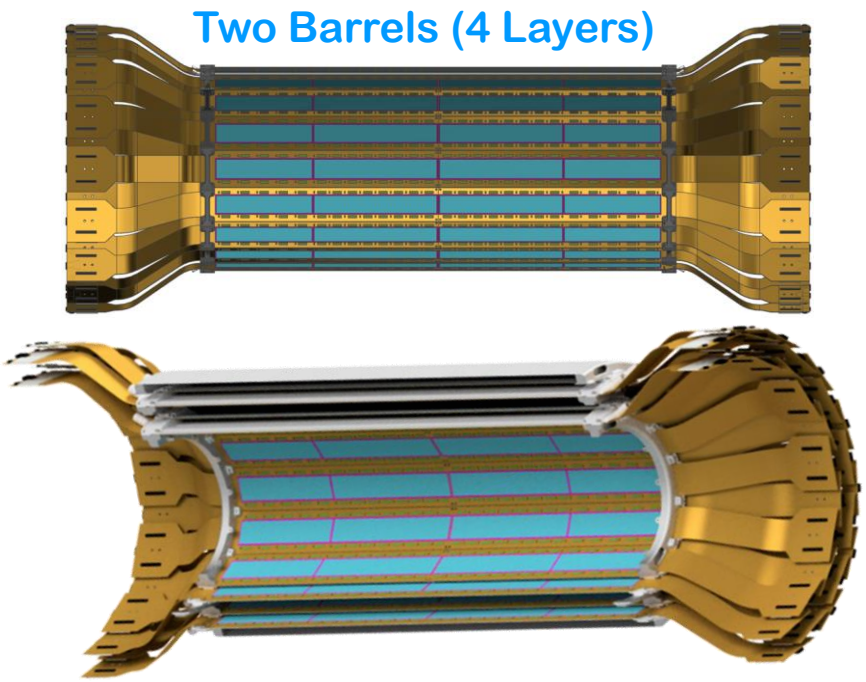
Event generator (simulated data): event pile up



INTT Technical Overview: Two Barrels Specification



The design
(provided by Dan)

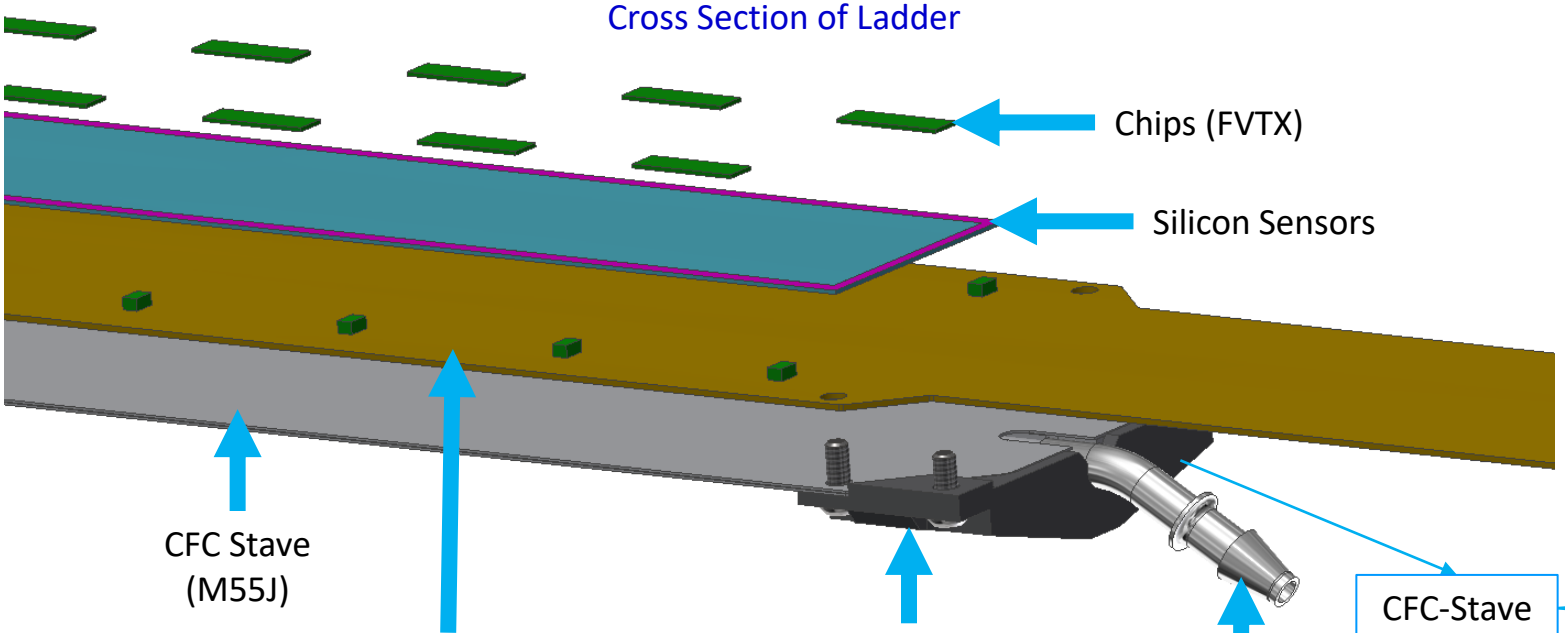


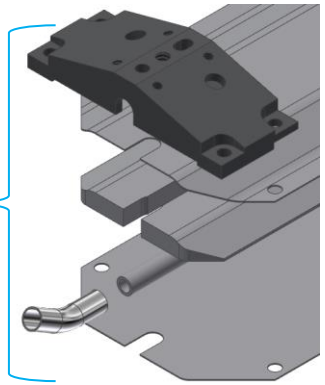
Barrel	Center of Sensor Tangent Radius (mm)	Pseudo rapidity	QTY of Ladders	Angle (deg)	Coverage (PHI) (%)	Overlap (%)	Clearance (mm)	Chip Power Dissipation (W)	Stave Rad Length (%)	Barrel Rad Length (%)
1	-	-	24	-	100	1.8	2.0	79.88	0.50	2.16
1a (Inner)	71.88	1.37	12	0	52.7	0	0.6	39.94	0.25	1.08
1b (Outer)	77.32	1.31	12	0	49.4	0	3.4	39.94	0.25	1.08
2	-	-	32	-	100	1.8	2.0	106.50	0.50	2.16
2a (Inner)	96.80	1.12	16	0	52.4	0	0.6	53.25	0.25	1.08
2b (Outer)	102.62	1.07	16	0	49.4	0	2.8	53.25	0.25	1.08
Total	-	-	**56**	-	-	-	**11.88**	**186.38**	**1.00**	**4.32**

INTT Technical Overview – Ladder Components and Assembly

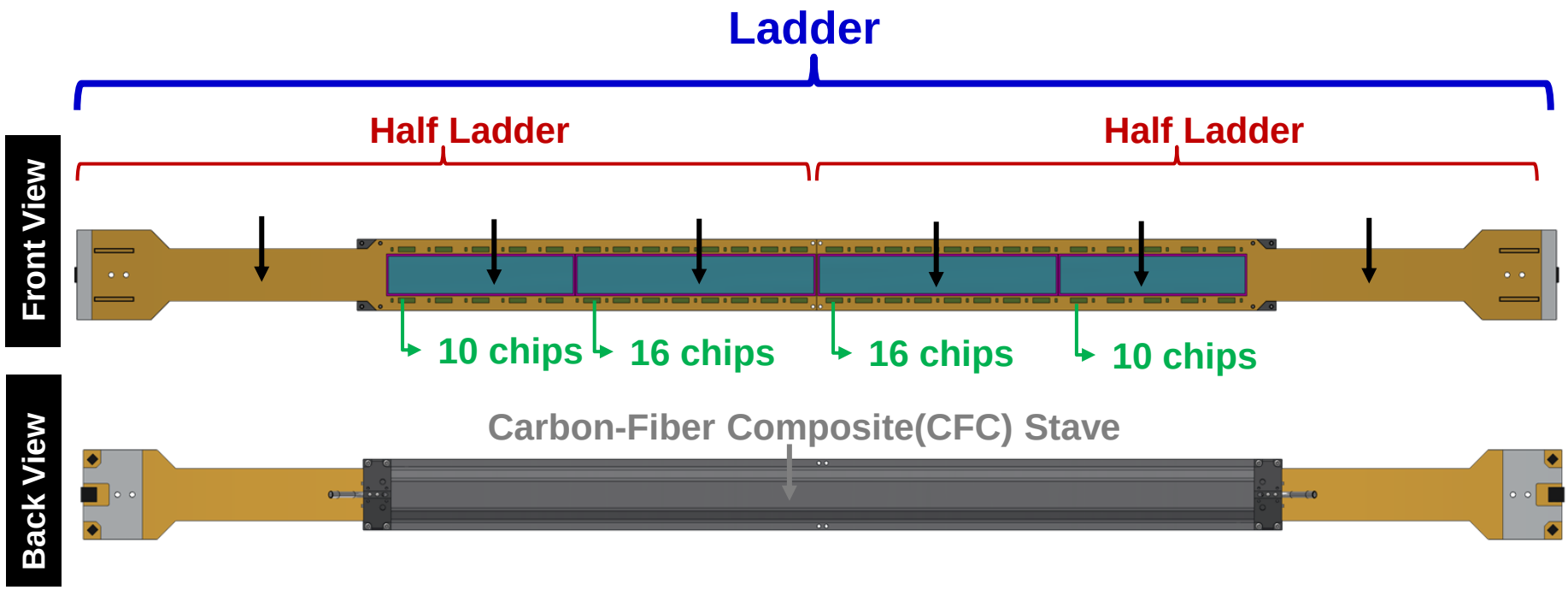
Ladder = 1 CFC Stave + 2 HDIs + 52 Chips + 4 Silicon Sensors

Cross Section of Ladder





INTT Technical Overview



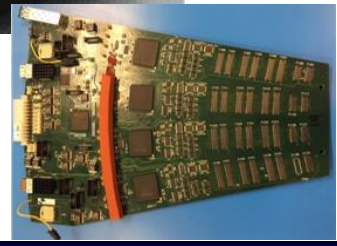
HDI Cable

Silicon Sensors

FPHX Chip

CFC Stave

ROC



1.11 m Bus Extender

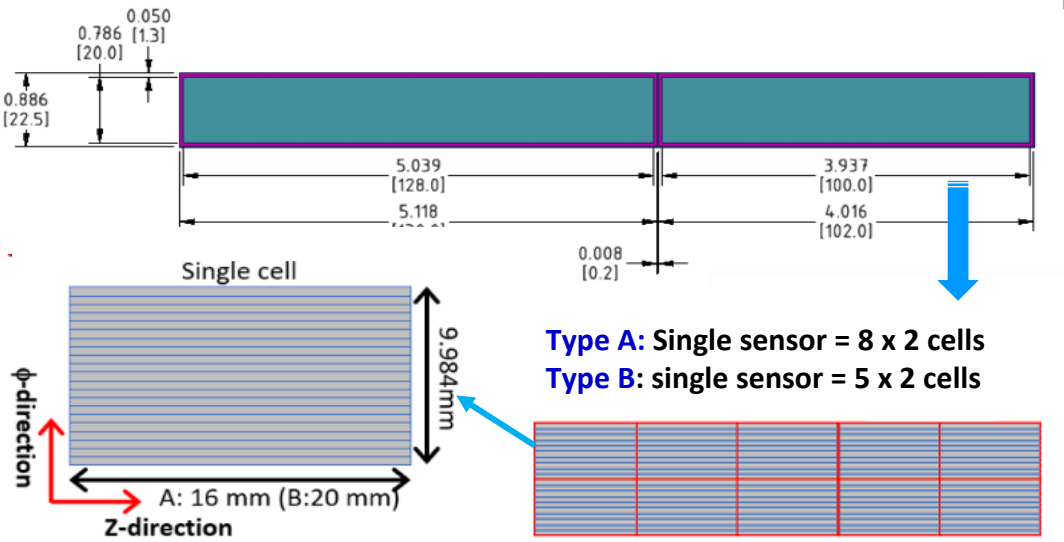
Conversion Cable Prototype

INTT: Silicon Sensors Geometry

Silicon Strip Sensor:

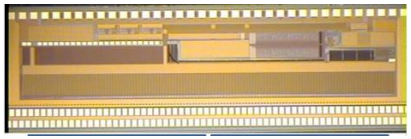
- Very fine pitch (9.984/128 = 78 μm in ϕ), for good spatial resolution
- High efficiency (>99%) and low noise for excellent tracking
- Excellent time resolution [-20 ns, 60 ns], for no pileup
- Thin-sensor/low mass, 320 μm (~0.34% X_0), for less multiple scattering

Type A **Type B**



Type A: Single sensor = 8 x 2 cells
Type B: single sensor = 5 x 2 cells

FVTX Chip:

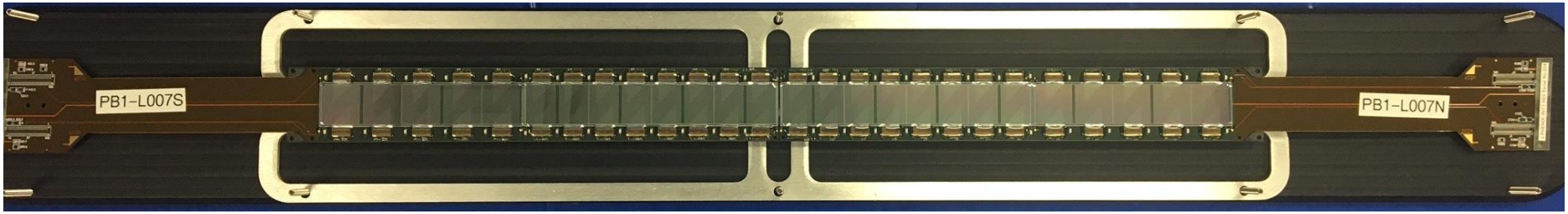


128 channel
46 to 200 mV/fC
60 ns peak time (programmable)
3—bit ADC (programmable)
Optimized for 1 to 2.5 pf
115e + 134e/pf
~ 70 to 140 uW/ch (Bias current)

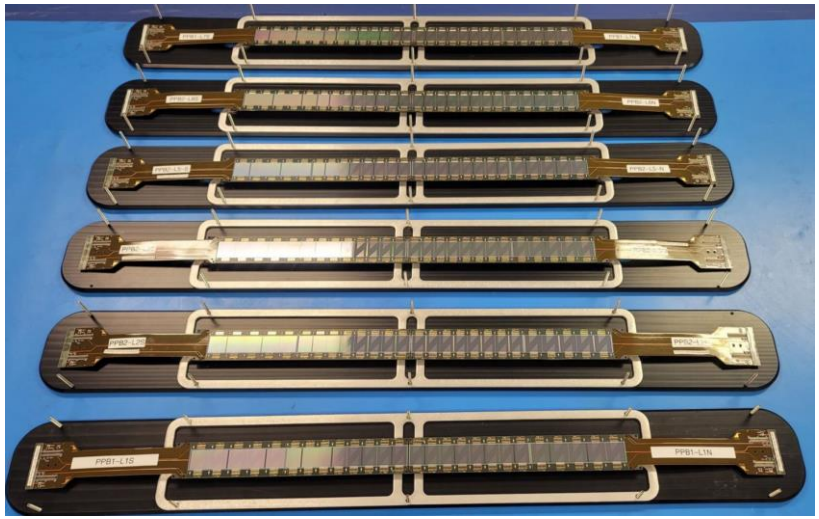
Data push architecture
10 MHz beam clock (BCO)
200 MHz data clock
Zero suppressed
Output 4 hits/chip in one BCO
Approx. 300 uW/ch

- ✓ p-implant on n-bulk, Ac-coupled, 1.5 MΩ polysilicon resistors
- ✓ Depletion voltage < 100V, Resistivity 3 to 5 kΩ-cm
- ✓ Single cell geometry (active region):
- ✓ 128 strips (better resolution in ϕ-direction)
- ✓ Strip width = 78 μm
- ✓ ϕ-length = 78 μm x 128 strips x 2 cells =19.968 mm
- ✓ z-length = A: 16 mmx 8=128 mm (B: 20 mm x5=100 mm)

INTT Ladders Assembly



Ladders assembled successfully



Draft INTT Ladder Assembly Steps (ver. 12/16/2020)

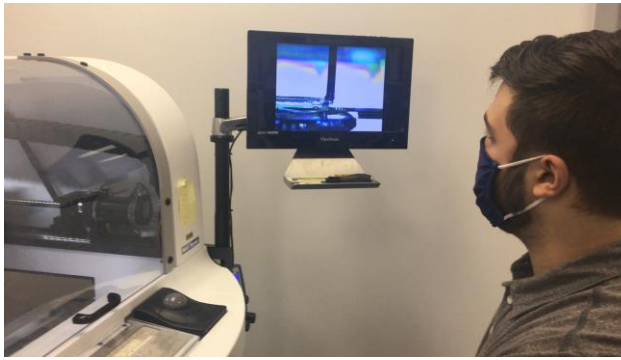
A. Carbon Fiber Flatness Inspection Steps

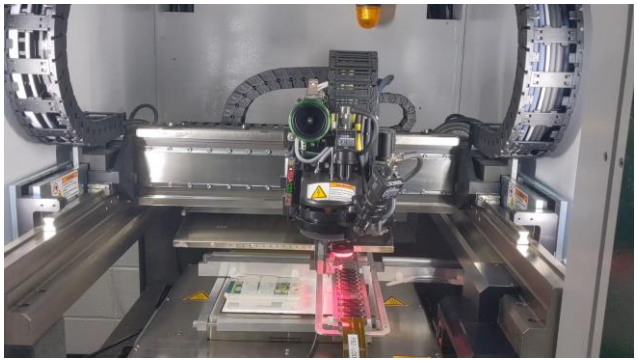
1. Remove all fixtures from the OGP platen, except for the Base Fixtures and the Pickup Base Fixture.
2. Clean all debris from the OGP platen and base fixtures.
3. Power on the OGP system and open MeasureMind 3D Multisensor.
   a. Go through the OGP initialization process.
   b. File->Open: C:\INTT\Prod Routines\INTT-CF-Flatness.RTN
   c. Navigate to System - > Configuration -> Safe Zones and enable Safe Zones 1 and 2.
4. Open MeasureFit
5. Open SmartReport
   a. File->Open: C:\Prolink\QC-CALC 3.2\Data\INTT-CFStave-Flatness.mfp, INTT-CF-Flatness_Report.Qcc
   b. This file should already be open upon SmartReport startup. Check the top border to verify this.
6. Place Carbon Fiber Stave on Base Fixture (top fixture meaning located towards the wall) and remove the lower left (towards you), and lower right (towards you), pins to expose the small thru-holes in the fixture. (Pins closest to the operator when standing in front of the OGP machine).
7. Engage the vacuum pump.
8. Run the routine on the OGP.
   a. When prompted, save the output as C:\INTT\Prod Data\INTT-CF-Flatness.DAT
   b. After the OGP routine is completed, go to C:\INTT\Prod Data\ and save a time stamped copy of the DAT file in the Archive subfolder. (MeasureFit will delete the original when it generates the report).
9. In MeasureFit, play the INTT CF Flatness Inspection under the Macros tab.
10. Once the report file is generated, save the file under C:\INTT\Prod Reports\
    a. Save the file with the following timestamp format:
    INTT_SNXXXX_205-310-0100-XX_Report.pdf
    &
    INTT_SNXXXX_205-310-0100-XX_VAC_Report.pdf
11. Repeat these steps. Once with the Vacuum on and once with the vacuum off.

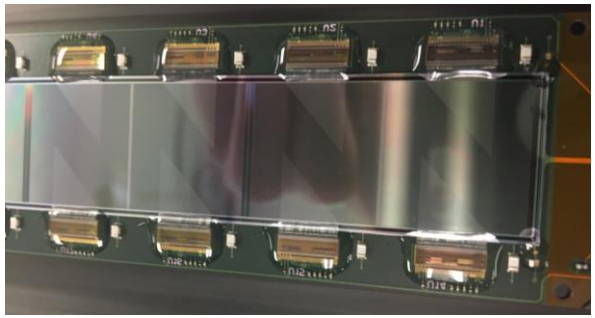
B. High Density Interconnect (HDI) Gluing Steps

1. Install the Carbon Fiber Stave on the Base Fixture (mounted to the OGP platen located towards the wall) in the same fashion as [Section A | Step 6].
2. Verify that all 2mm locating pins are installed in the Base Fixture and are captured by the Carbon Fiber Stave.

Wire bonding and Encapsulation

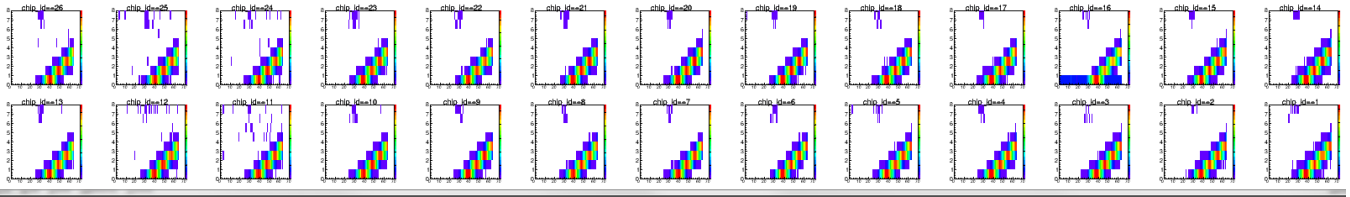


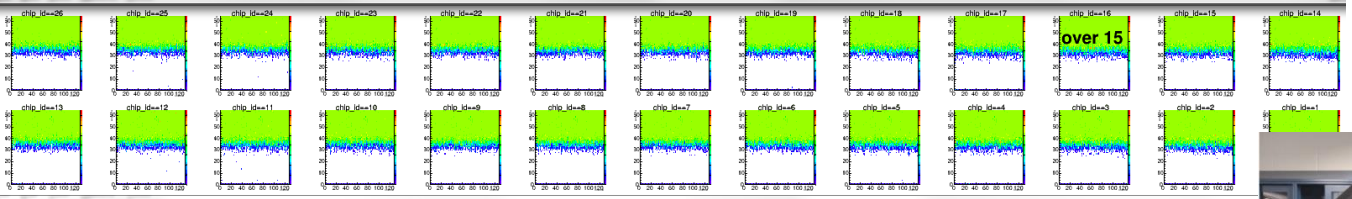


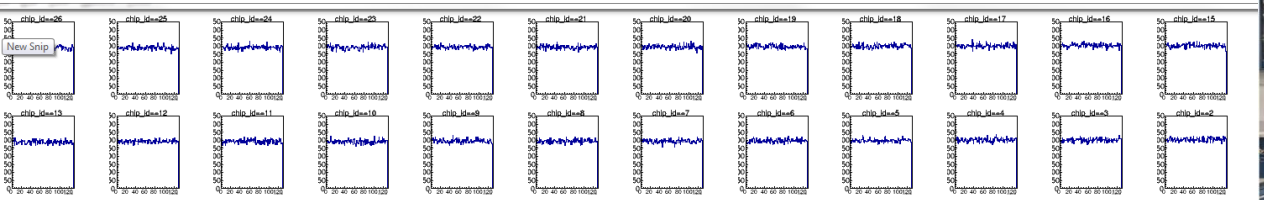


INTT Ladders Performance

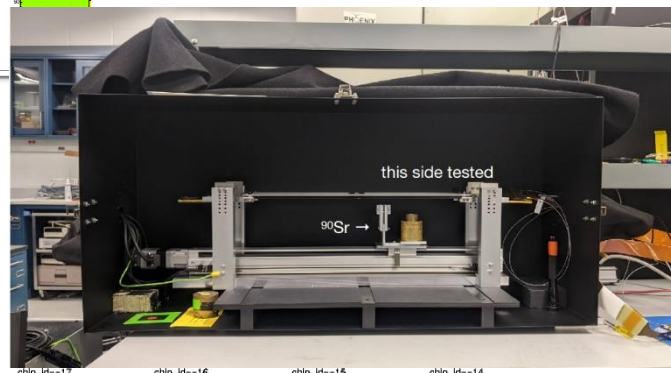
Calibration Test (Pulse test for each channel)

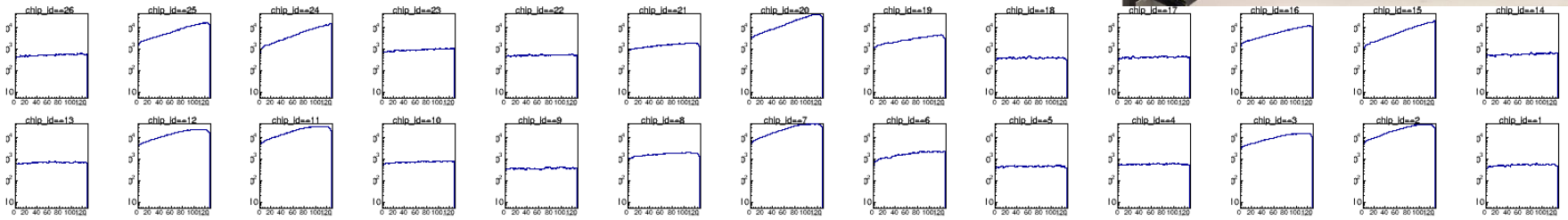


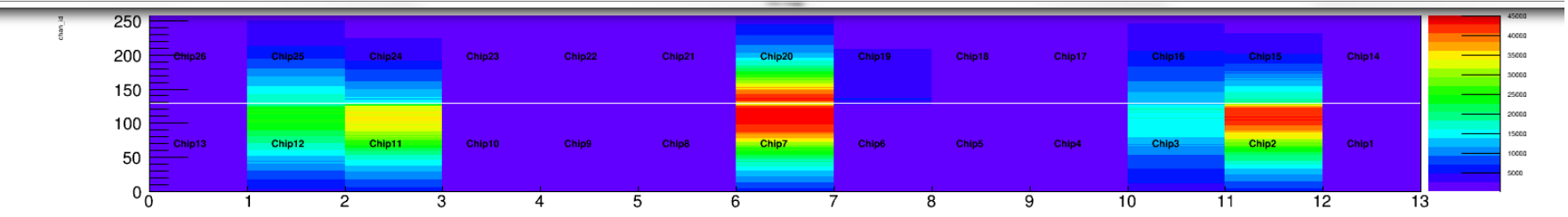




^{90}Sr Source Test





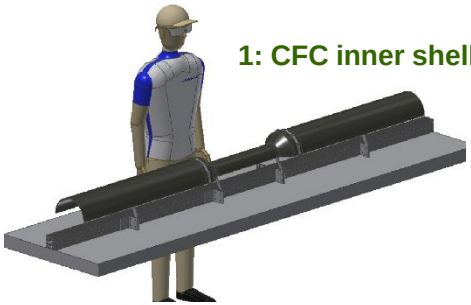


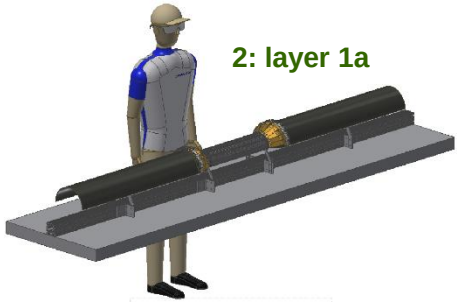
Barrels Assembly

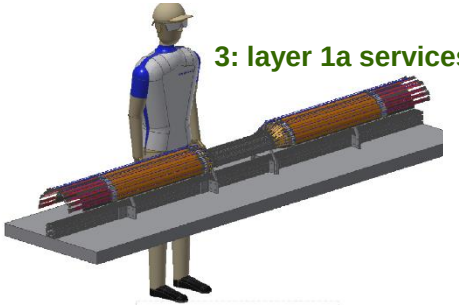
We built ladders what next? → Build barrels

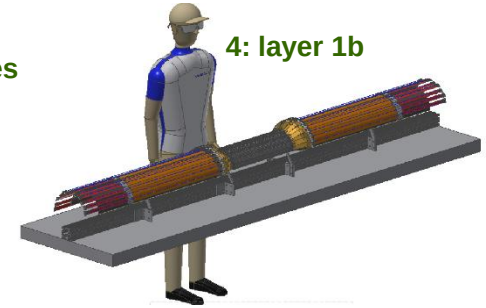
Barrel Assembly Concept

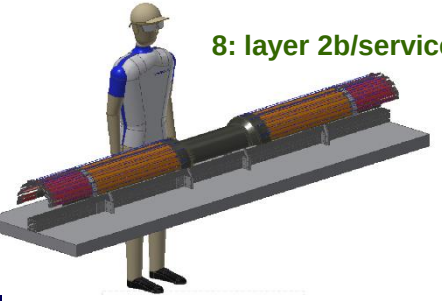
- Dimensions
  - **120 x 30 inch Platform**
  - **Elevates from 31 inches to 48 inches (Span of 17 inches)**
  - **$2,026**
- Hardware holes can be added to the cart for fixturing.
- Cart will host the half barrel assembly and will safely transport the assembly.
- Global Industrial Item # WBB54093

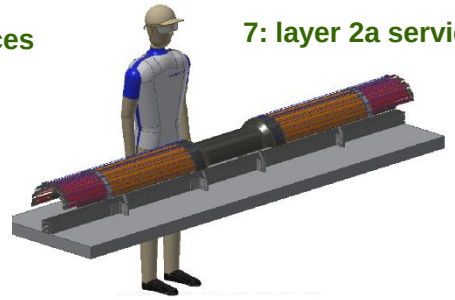


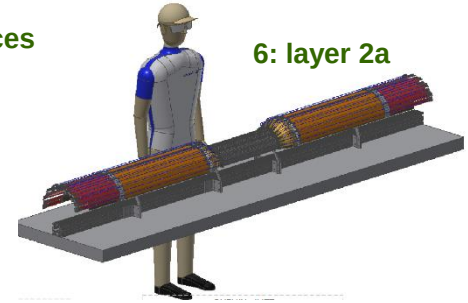


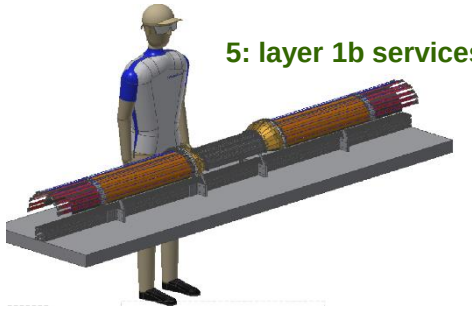




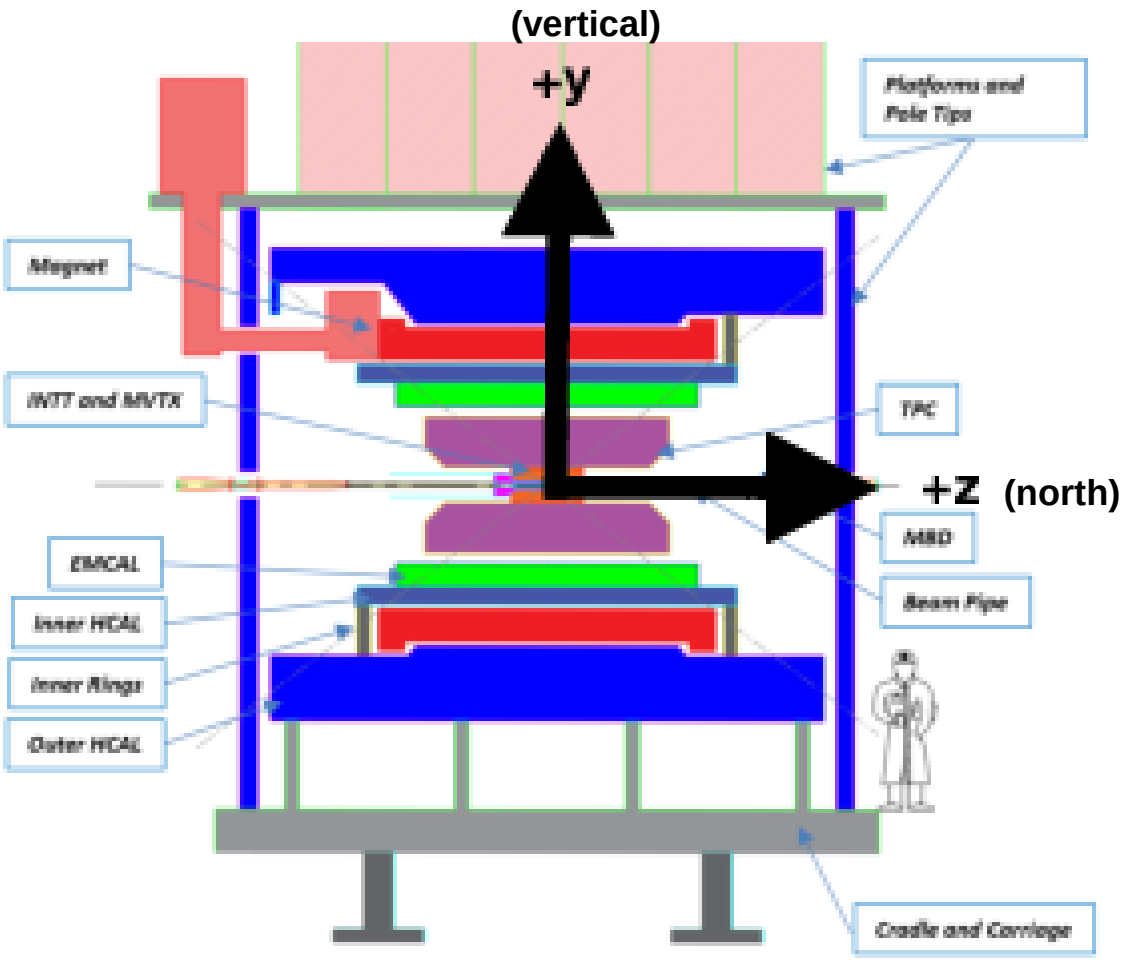






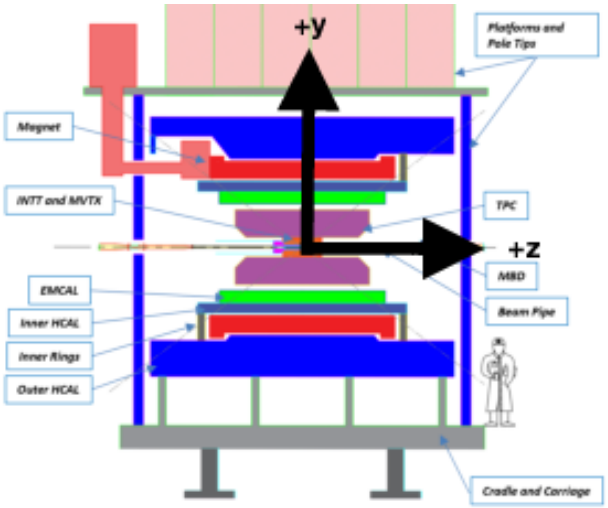


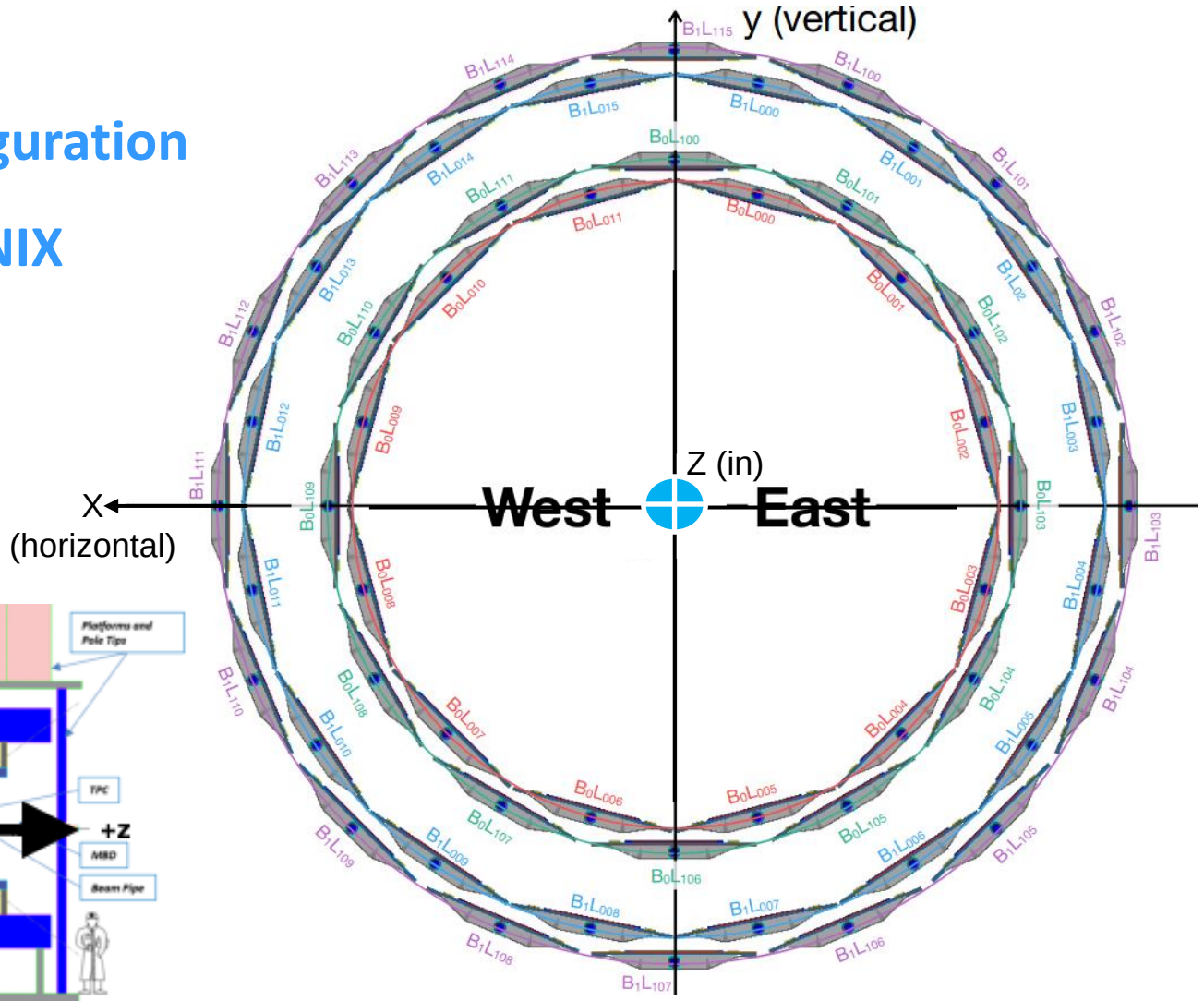
Barrels Assembly: sPHENIX Coordinates



Barrels Assembly: sPHENIX Coordinates

Barrels Configuration in sPHENIX





Barrels Assembly

Step 1: CFC Support Structure for Barrels (Inner Shell)

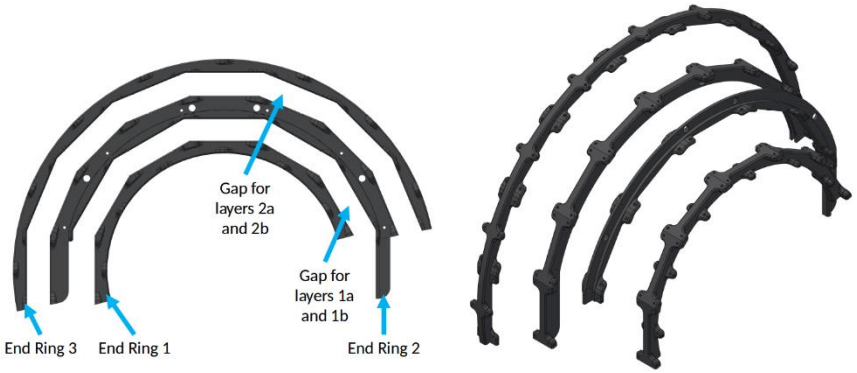
Done

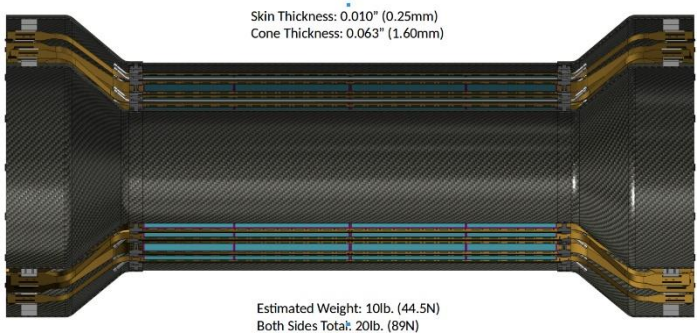
Barrels Assembly

We built ladders what next? → Build barrels

Barrels Assembly: FEA Analysis

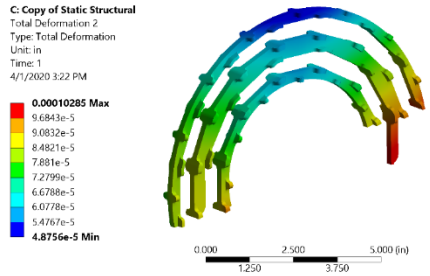
We built ladders what next? → Build barrels



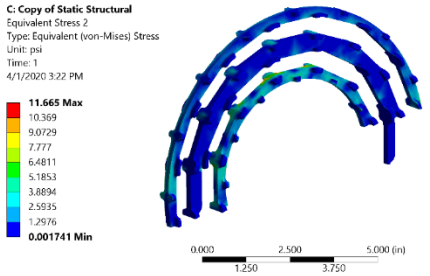


Barrel barrels concept design and FEA done successfuly

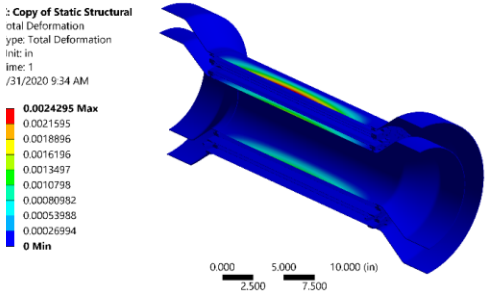
Deflection – MAX: 0.0002 in (5 um)



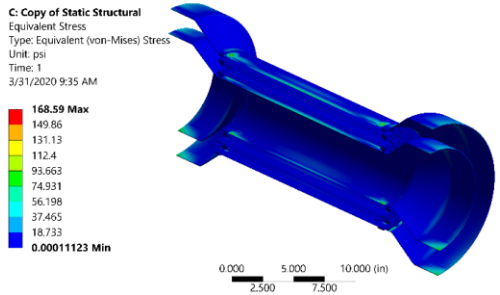
Stress – MAX: 12 psi (0.08 MPa)



Deflection – MAX: 0.0025 in (63.5 um)



Stress – MAX: 170 psi (1.17 MPa)



Boundary Conditions: Carbon fiber cones fixed-fixed, HDI weight added

Barrels Assembly: B0L0

Order Built	Name	Layer	South Leakage A+B	North Leakage A+B	Class	Number Dead	Average Current (S+N)/2	Source Test File
16	PB1-L010	1	420	440	1	10	430	1
19	PB1-L013	1	570	880	1	11	725	1
62	PB1-L031	1	254	233	1	12	244	1
23	PB1-L017	1	700	500	1	12	600	1
58	PB1-L027	1	240	228	1	14	234	1
12	PB1-L006	1	360	280	1	14	320	1
11	PB1-L005	1	440	510	1	14	475	1
51	PB1-L020	1	259	264	1	15	262	1
15	PB1-L009	1	440	850	1	15	645	1
65	PB1-L034	1	363	220	1	16	292	1
52	PB1-L021	1	311	284	1	16	298	1
14	PB1-L008	1	518	413	1	16	466	1
20	PB1-L014	1	500	500	1	16	500	1
54	PB1-L023	1	359	311	1	17	335	1
17	PB1-L011	1	330	490	1	17	410	1
59	PB1-L028	1	283	750	1	17	517	1
53	PB1-L022	1	482	552	1	17	517	1
63	PB1-L032	1	220	216	1	18	218	1
57	PB1-L026	1	277	348	1	18	313	1
21	PB1-L015	1	200	500	1	18	350	1
4	PB1_L001	1	330	340	1	20	335	1
22	PB1-L016	1	200	700	1	20	450	1
64	PB1-L033	1	253	567	1	21	410	1
60	PB1-L029	1	1181	413	1	21	797	1
55	PB1-L024	1	294	243	1	22	269	1
24	PB1-L018	1	200	300	1	24	250	1
18	PB1-L012	1	650	300	1	24	475	1
13	PB1-L007	1	270	490	1	25	380	1
56	PB1-L025	1	267	468	1	28	368	1
9	PB1-L004	1	320	290	1	33	305	1
50	PB1-L019	1	303	284	4	140	294	4
8	PB1_L003	1	420	300	4	149	360	4
6	PB1_L002	1	960	690	4	153	825	4
61	PB1-L030	1	20	20			20	

Used

Not Used

B0L0 Layer

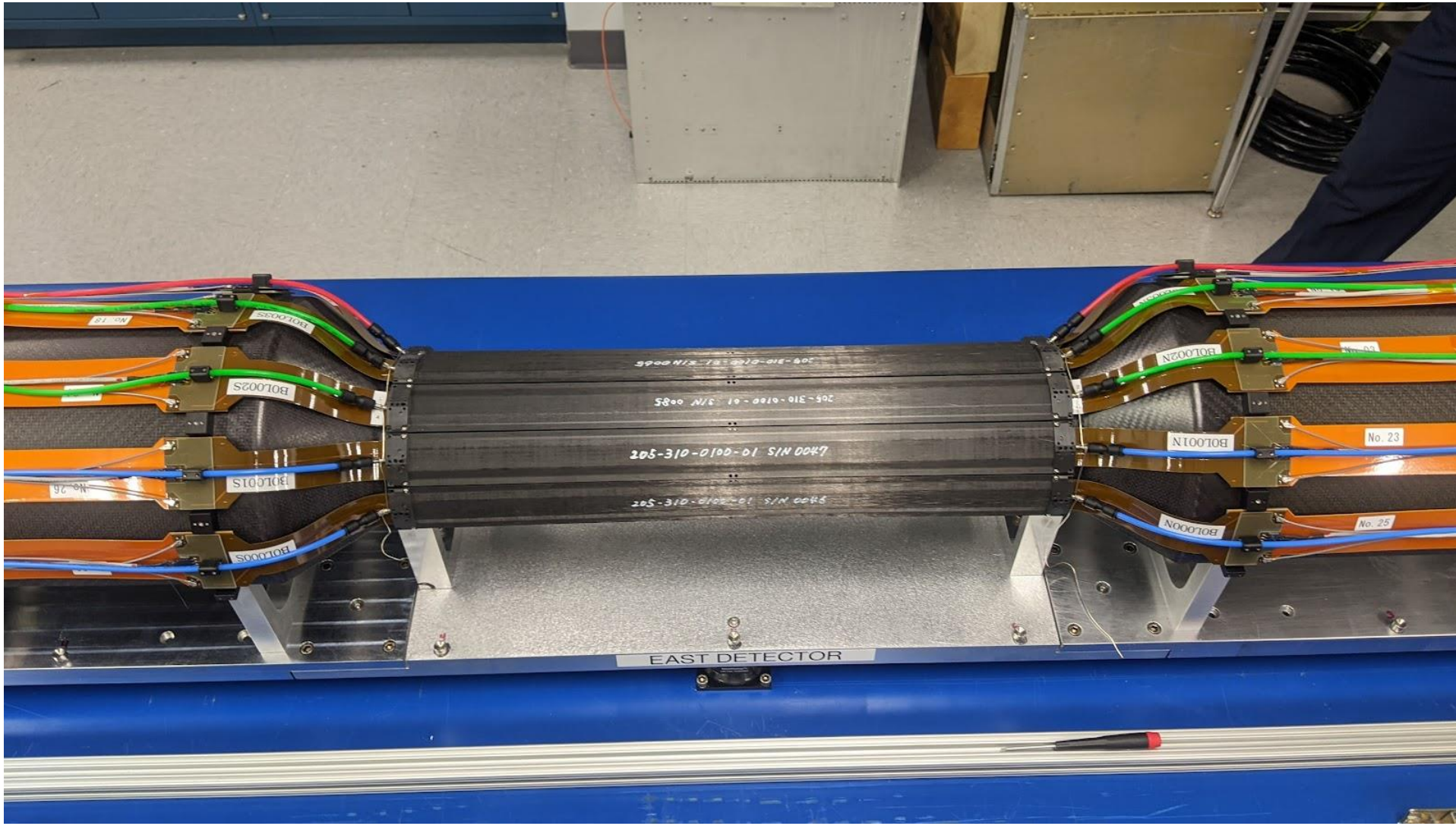
INTT Layer 1a	Position	Ladder Name
EAST	B0L000	PB1-L008
	B0L001	PB1-L005
	B0L002	PB1-L031
	B0L003	PB1-L010
	B0L004	PB1-L027
	B0L005	PB1-L009
WEST	B0L006	PB1-L034
	B0L007	PB1-L020
	B0L008	PB1-L017
	B0L009	PB1-L013
	B0L010	PB1-L006
	B0L011	PB1-L021

Barrels Assembly: layer B0L0

Assembly Team: Assembly of First Layer B0L0

Barrels Assembly: layer B0L0

Assembly Team: Assembly of First Layer B0L0

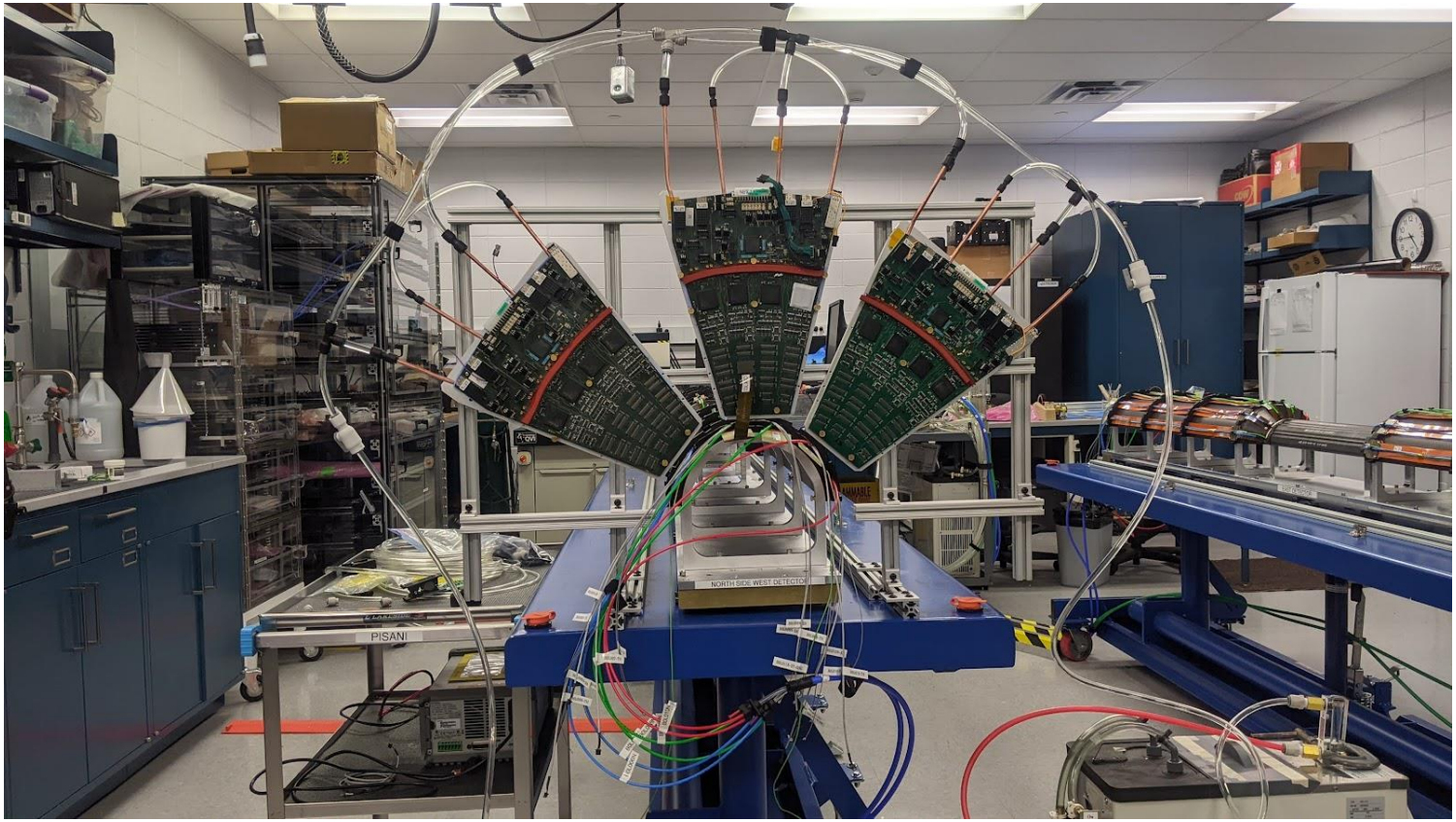


Barrels Assembly: B0L0 Services

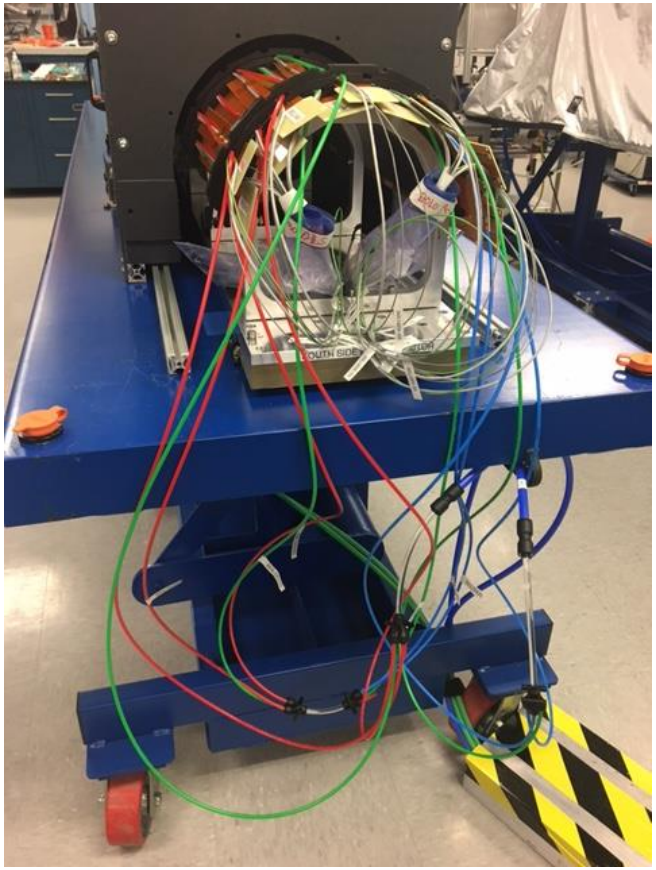
Assembly Team: Assembly of First Layer B0L0

Barrels Assembly: Testing

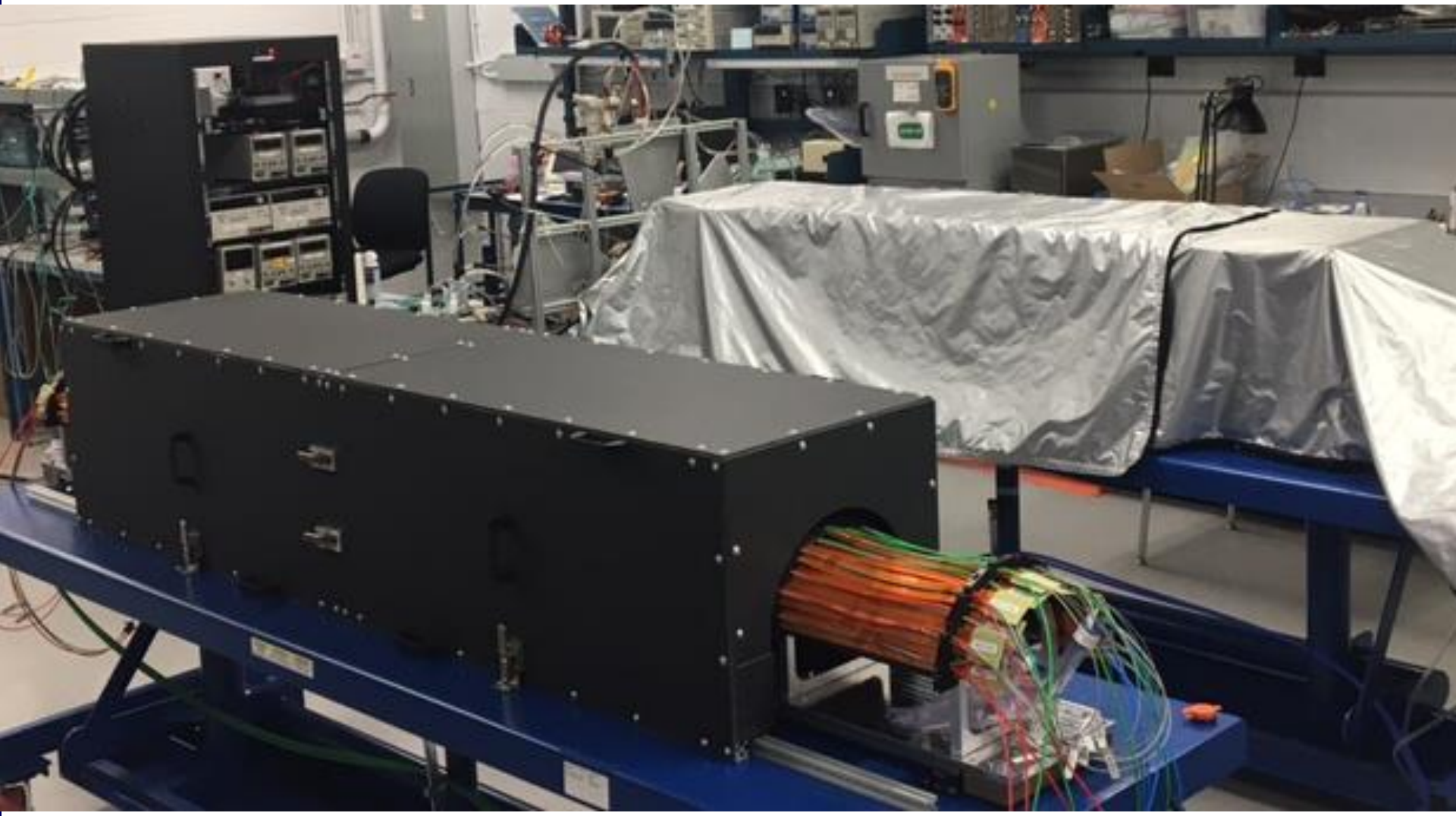
First Layer B0L0: Fully Tested



Barrels Assembly: Cooling



Barrels Assembly: Testing



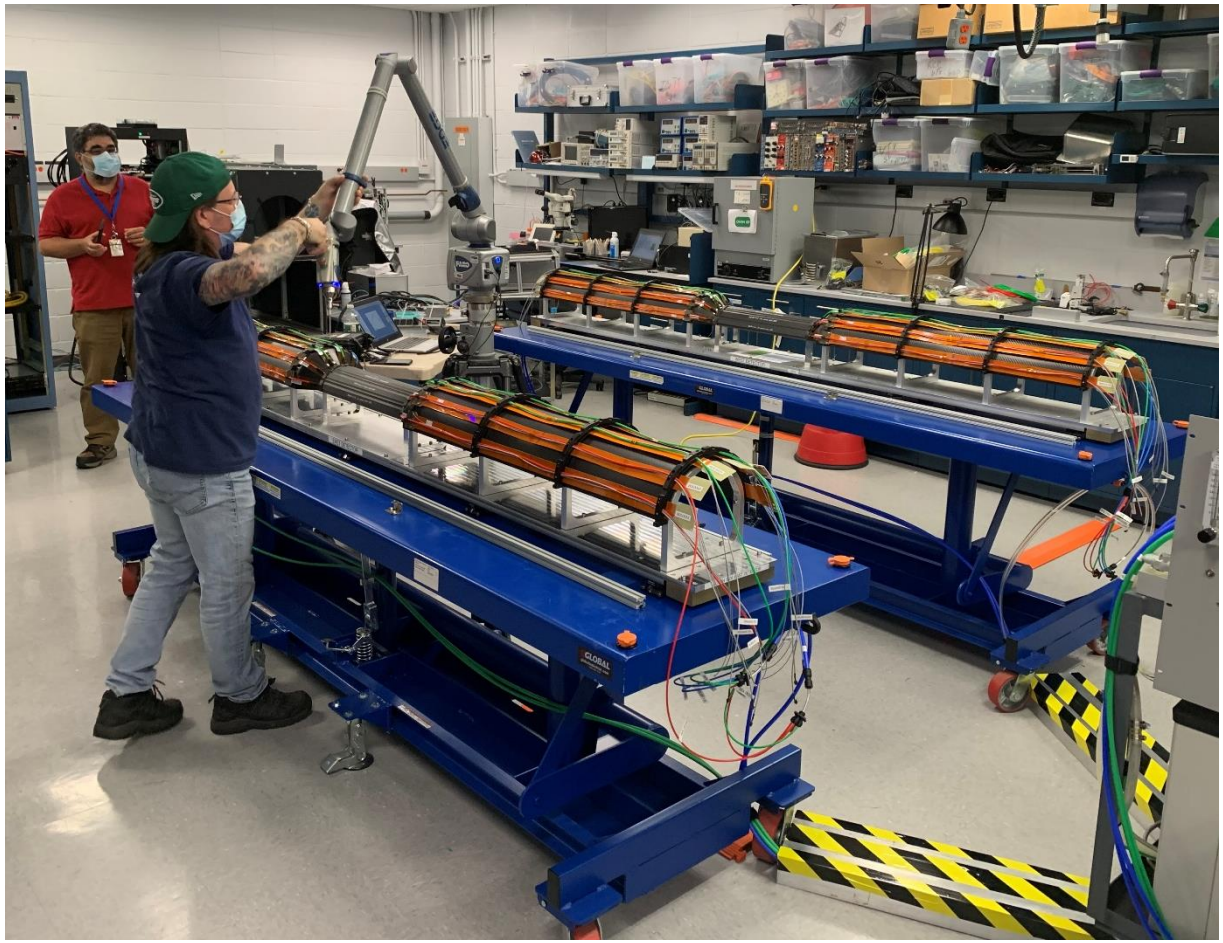
Barrels Assembly: Testing

Final Layer B0L0 Status

B0L1			Hardware Componenents				Calibration Test								Survey, Cooling, and Grounding						Final	
							South				North											
ID	ID	Ladder Position	Ladder Name	HDI South/North	BEX South/North	Conversion Cable S/N	Current SA/SB [nA]	TA/TB [Celsius]	File Name	Status	Current SA/SB [nA]	TA/TB [Celsius]	File Name	Status	Survey Status	GND Wire Stave	Glue TC Connector	Cooling Test	Silver Epoxy	Grounding Confirmed	Pulse Test	Barr Statu
1	EAST	B0L000	PB1-L008	201/202	028/025		116/257	20.6/20.7	20220613-1616,	1	115/96	21.0/20.5	20220613-1338,	1	1	1	1	1	1	1		
2		B0L001	PB1-L005	038/039	026/023		115/89	20.5/20.8	20220613-1659,	1	112//100	20.5/20.3	20220613-1351,	1	1	1	1	1	1	1		
3		B0L002	PB1-L031	281/288	004/003		135/102	20.7/20.5	20220613-1546,	1	130/87	20.8/20.3	20220613-1215,	1	1	1	1	1	1	1		
4		B0L003	PB1-L013	217/218	018/019		150/90	24.0/25.0	20220613-1530	1	129/101	21.3/20.8	20220613-1157,6	1	1	1	1	1	1	1		
5		B0L004	PB1-L027	279/280	022/005		108/93	20.6/20.4	20220613-1715,	1	123/89	21.0/20.5	20220613-1325,	1	1	1	1	1	1	1		
6		B0L005	PB1-L009	199/200	024/021		122/88	19.3/19.4	20220613-1733,	1	125/86	21.1/20.7	20220613-1316,	1	1	1	1	1	1	1		
7	WEST	B0L006	PB1-L034	302/307	016/017		175/133	23.4/x	20220614-1217,	1	197/87	20.9/20.4	20220610-1158,6	1	1	1	1	1	1	1		
8		B0L007	PB1-L020	282/283	014/015		129/94	23.3/23.0	20220614-1142,	1	125/115	20.7/20.3	20220610-1127,6	1	1	1	1	1	1	1		
9		B0L008	PB1-L017	213/214	010/011		120/84	20.7/20.7	20220614-1050,	1	128/91	22.3/21.8	20220610-1012,5	1	1	1	1	1	1	1		
10		B0L009	PB1-L010	197/198	006/007		120/350	20.9/19.3	20220614-1027,	1	132/91	21.1/20.8	20220610-1025,5	1	1	1	1	1	1	1		
11		B0L010	PB1-L006	040/206	008/009		149/125	22.6/22.4	20220614-1134,	1	118/133	20.8/20.6	20220610-1041,	1	1	1	1	1	1	1		
12		B0L011	PB1-L021	284/285	012/013		132/93	21.2/21.0	20220614-1107,	1	118/105	20.9/20.5	20220610-1214,	1	1	1	1	1	1	1		

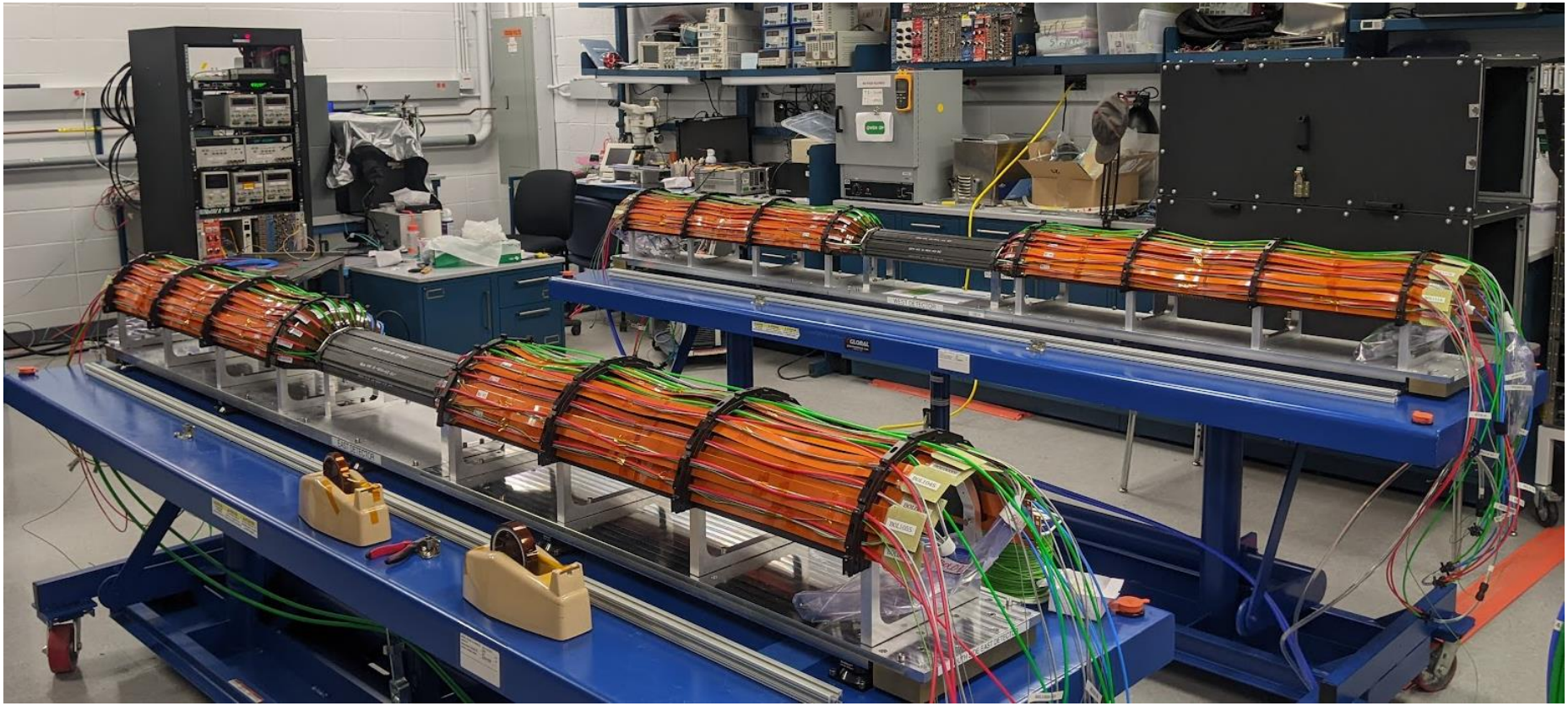
Barrels Assembly: Survey

First Layer B0L0: Fully Surveyed



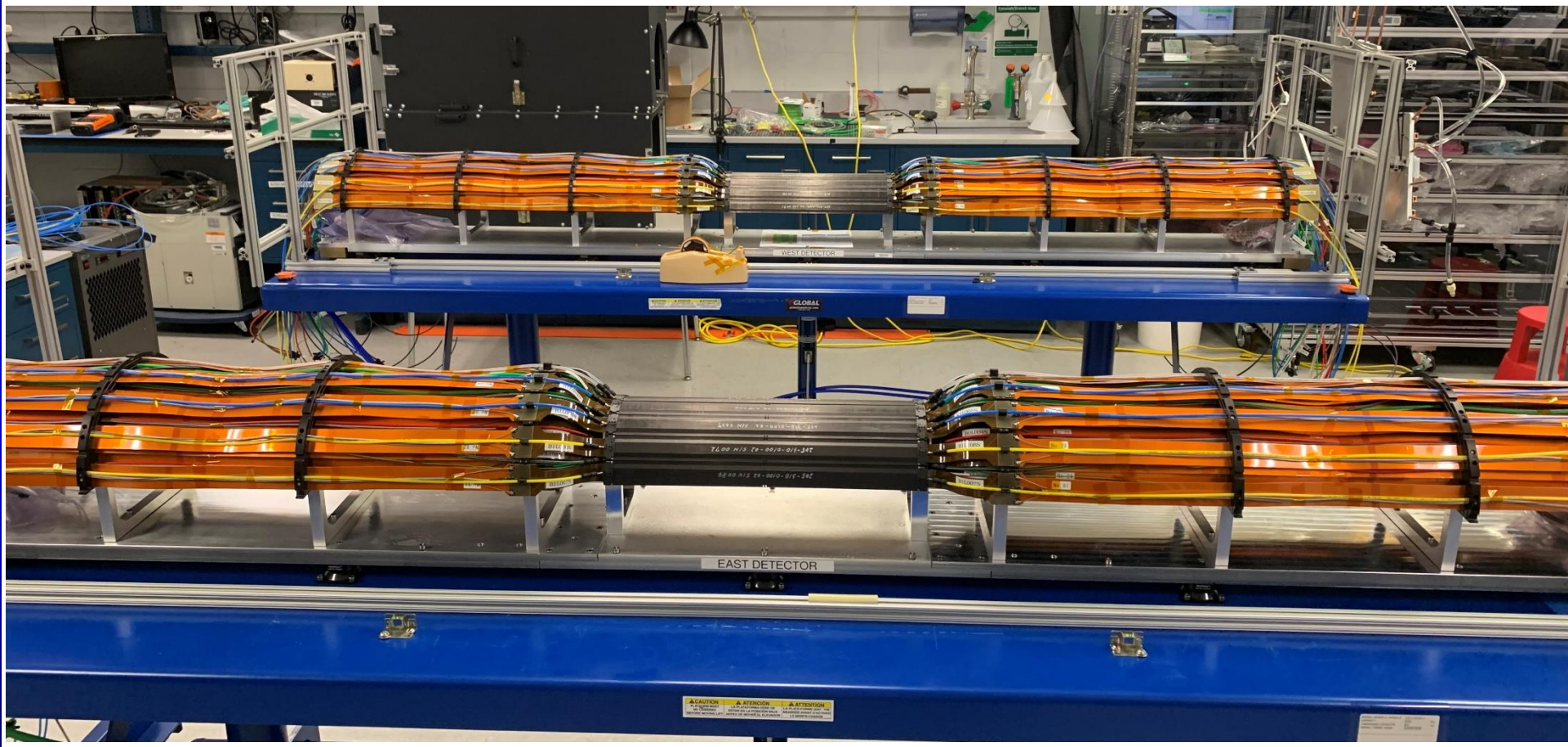
Barrels Assembly: B0L1

Assembly Team: Assembly Second Layer B0L1

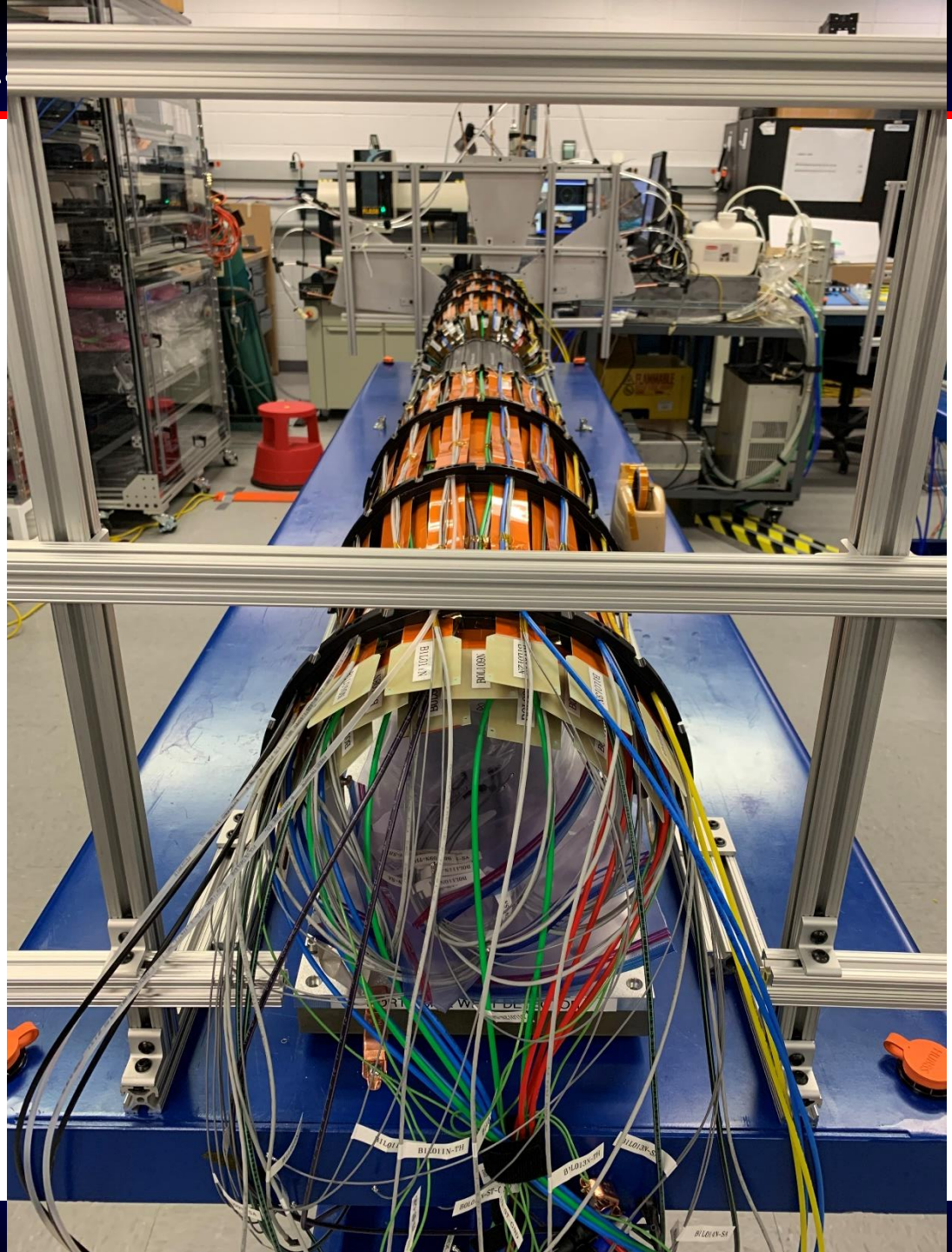


Barrels Assembly: B1L0

Assembly Team: Assembly of Third Layer B1L0

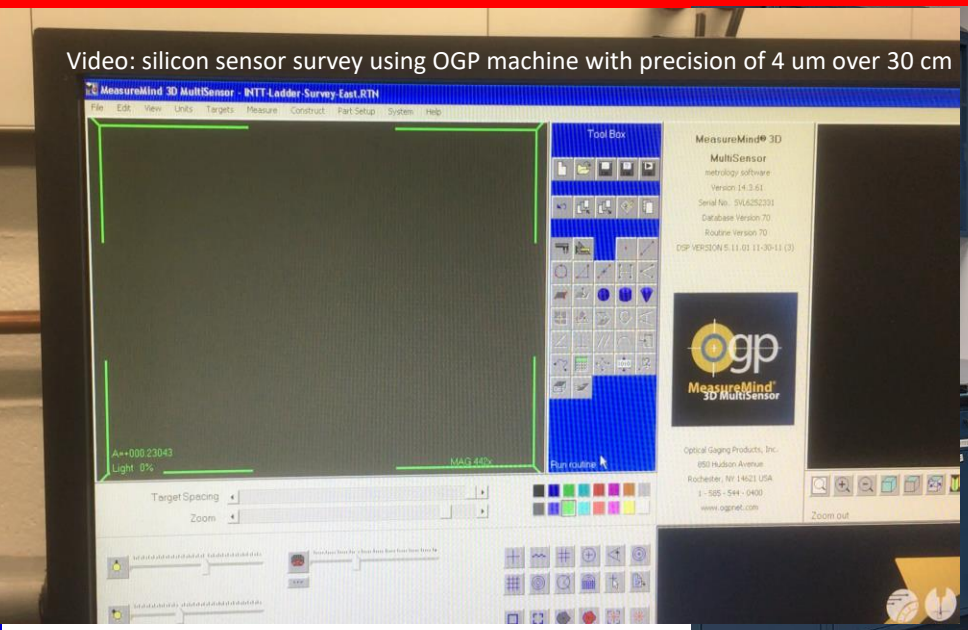


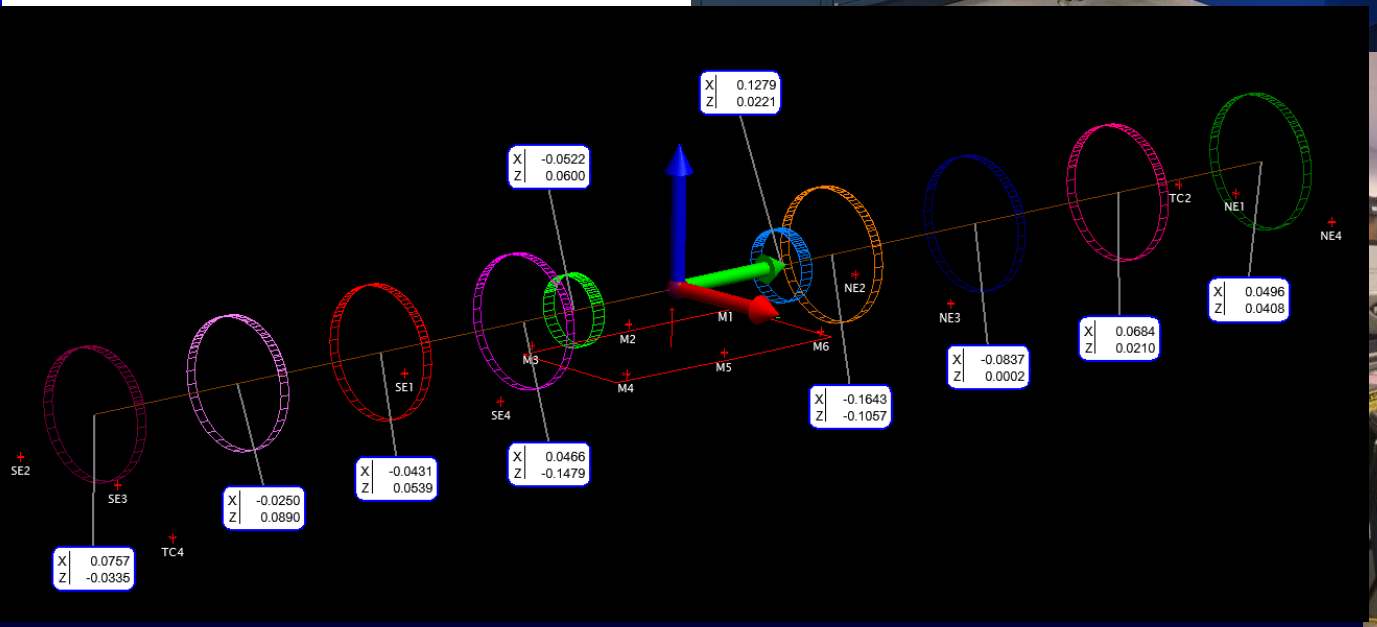
Barrels A



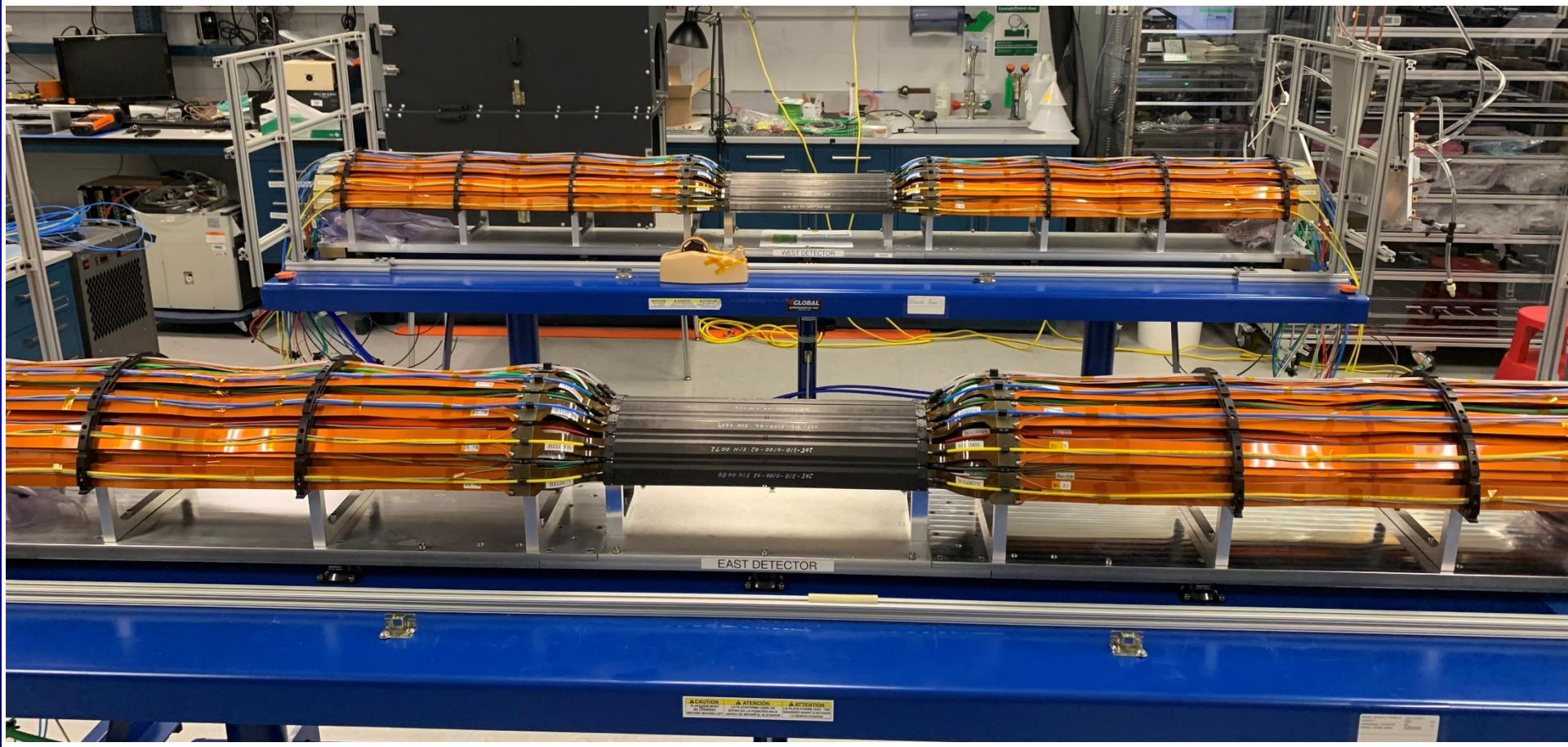
Barrels Assembly: Ideal Geometry for Physics

Video: silicon sensor survey using OGP machine with precision of 4 um over 30 cm





Barrels Assembly: Two Halves INTT



Barrels Assembly: INTT Halves Assembly

Barrels Assembly: INTT Halves Assembly

Summary

sPHENIX INTT Tracker is on his prime time of construction

May tasks need to be done such as :

- Finishing barrels assembly
- Survey and analysis data to make Ideal Geometry for physics analysis
- Barrels Testing
- Installation, and commissioning wo/w Beam
- Many other tasks

This is excellent timing for students to join INTT and gain expertise in the silicon detector construction, knowing that silicon detectors open many job opportunities in the NP and HEP.