Composites Capabilities at LBNL

Joe Silber (mech engineer) ...the one talkin' at ya

Lead engineer at composites shop: **Eric Anderssen**
Technicians at shop: **Mario Cepeda, Tom Johnson, Ken Wilson, Eric Phillips**

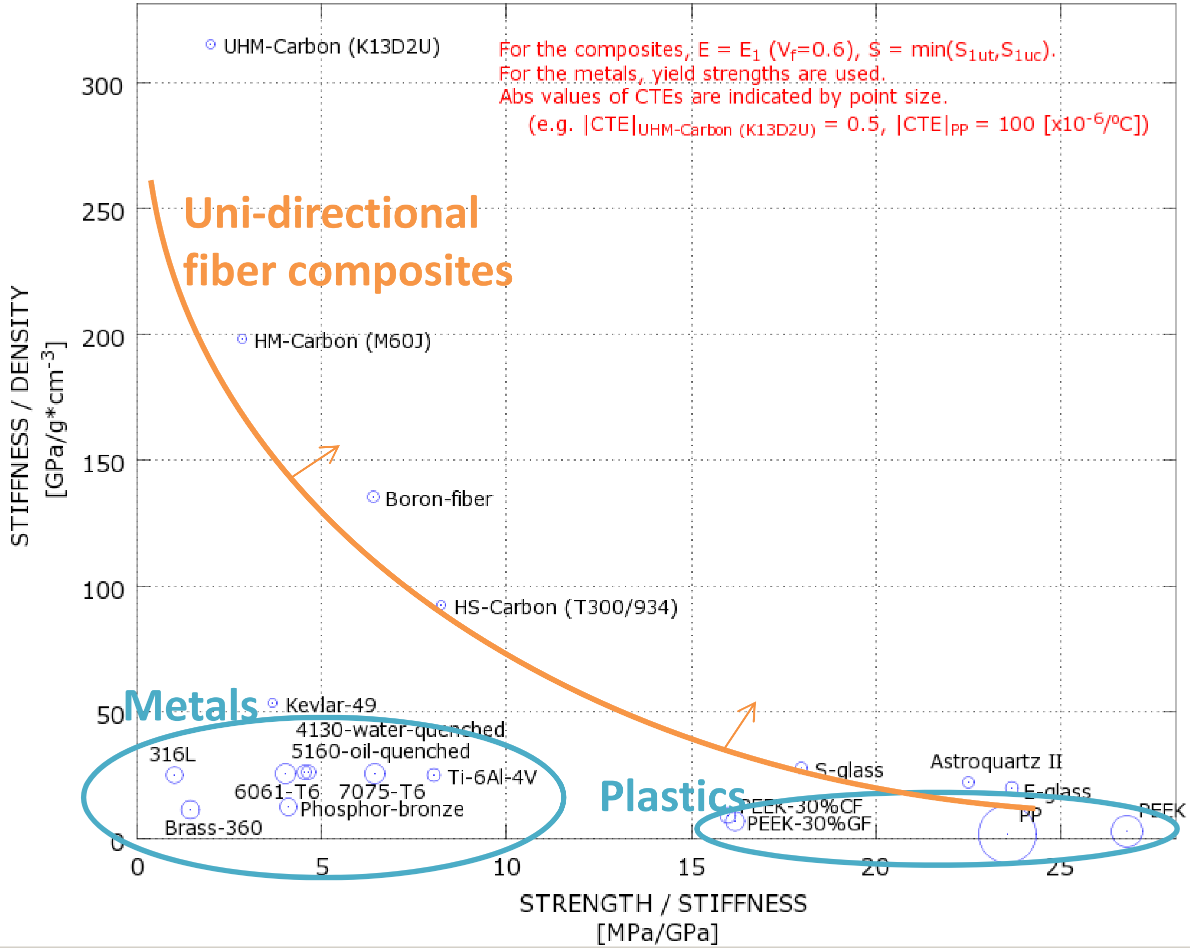
2011-12-16

Overview

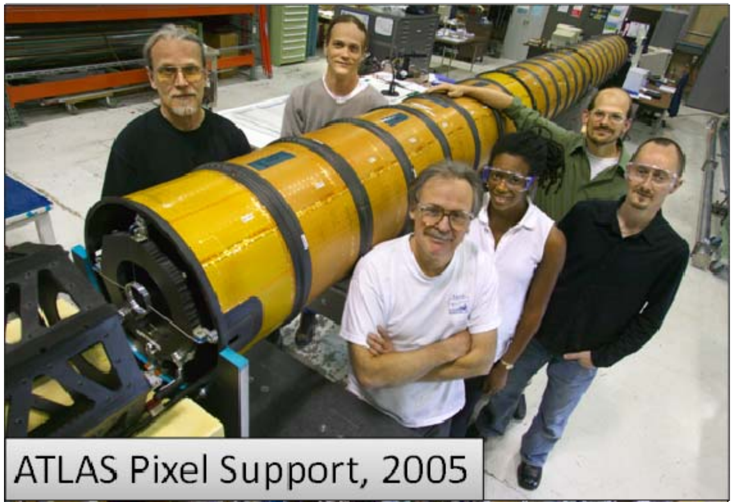
- Composites shop is at 77-101, located across street from main shops
- Composite laminates and precision bonding
- Large autoclave capacity for prepreg cures
- Walk-in freezer -40C for storing prepregs
- High speed CNC ply cutter with continuous feed
- Inventory of expired-but-still-good-for-prototyping carbon and glass fiber prepregs
- Mostly using high to ultra-high modulus fibers (500 – 900 GPa); some lower modulus stuff also
- Also do wet layups, some mold making, etc.

Materials comparison

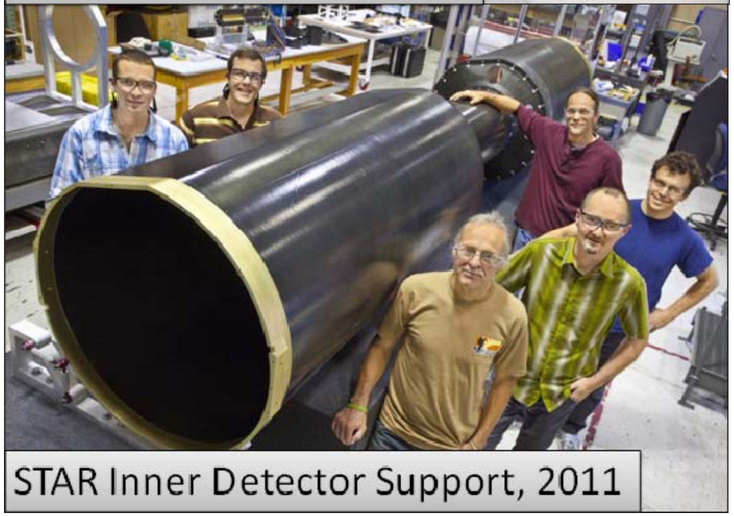
(this plot was for a flexure mechanism)



History (as I know it)…

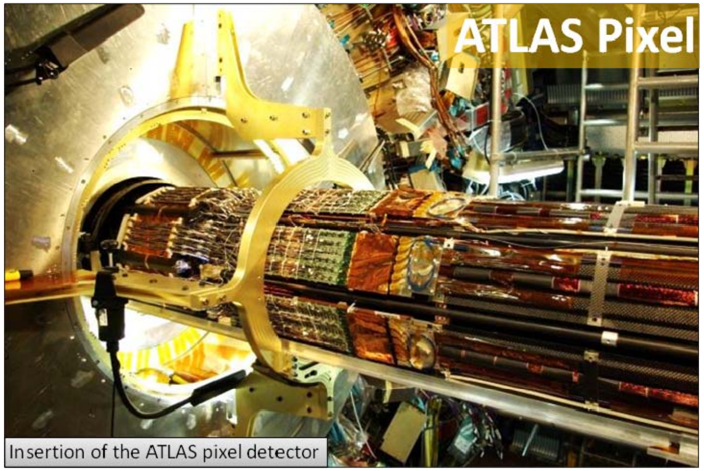


ATLAS Pixel Support, 2005



STAR Inner Detector Support, 2011

- Composites shop was built up by Eric Anderssen and Neal Hartman in the mid 2000s largely to build inner support structures for ATLAS (largest detector at LHC)
- Built inner supports for PHENIX (a detector at RHIC)
- Currently building for STAR (another detector at RHIC)
- Steady stream of prototype parts for other sorts of instruments, but shop's main focus has been making the large and complex structures for particle detectors at the big colliders

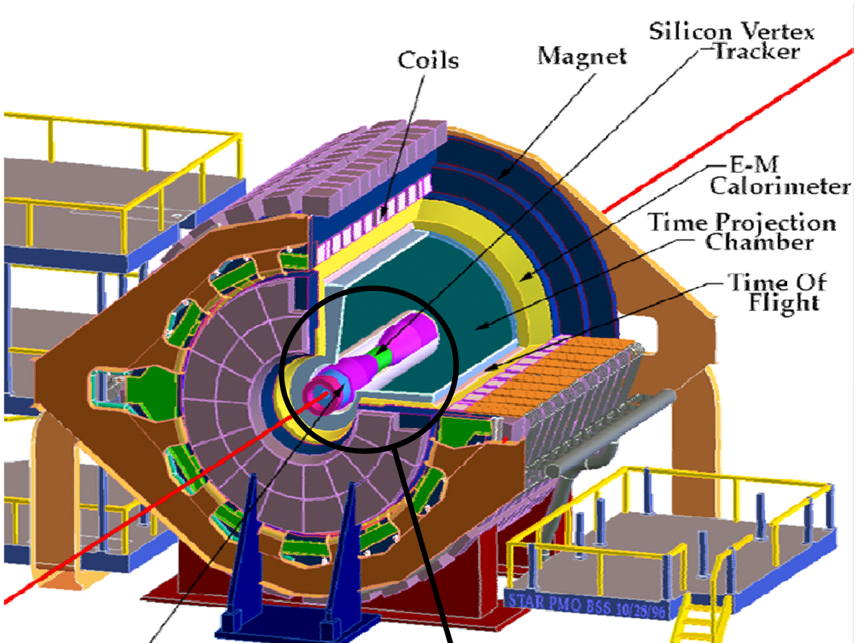


Insertion of the ATLAS pixel detector

Current large projects…

STAR Heavy Flavor Tracker

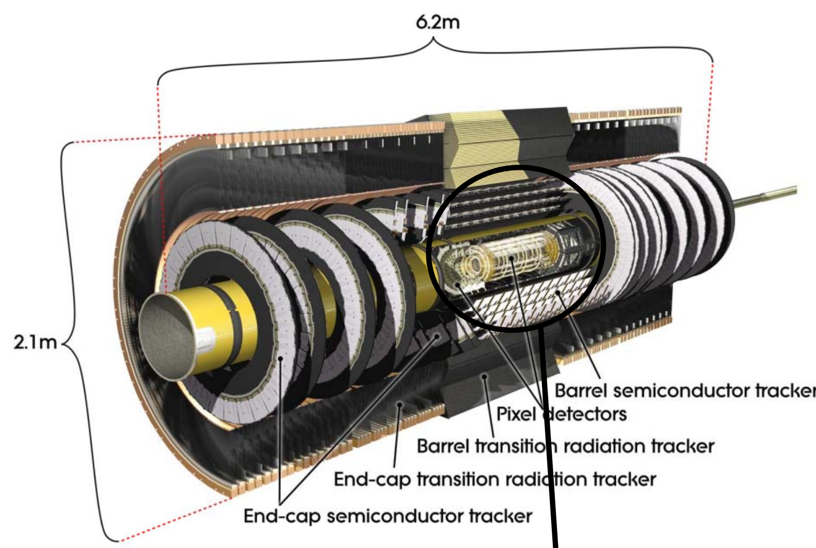
Relativistic Heavy Ion Collider (RHIC) in Brookhaven



LBL currently building the entire inner detector structure. First stage of installation was in Nov 2011, second stage in 2013.

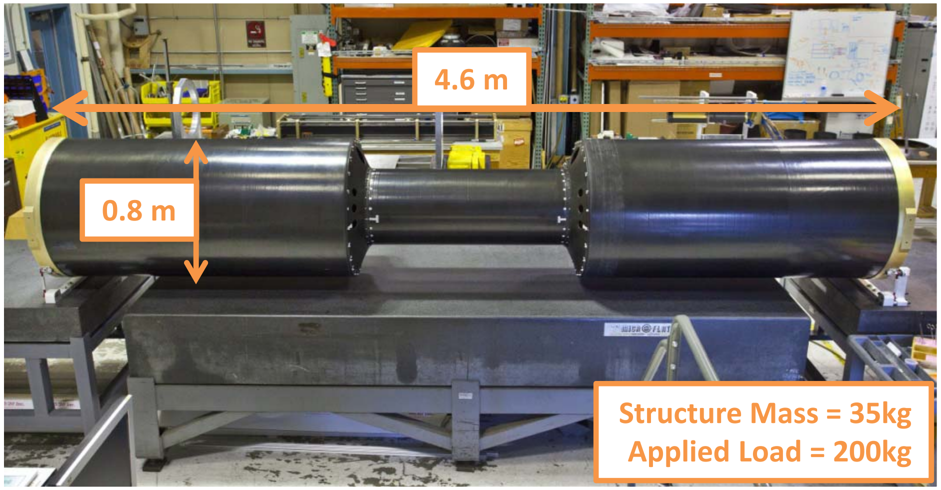
ATLAS Upgrade

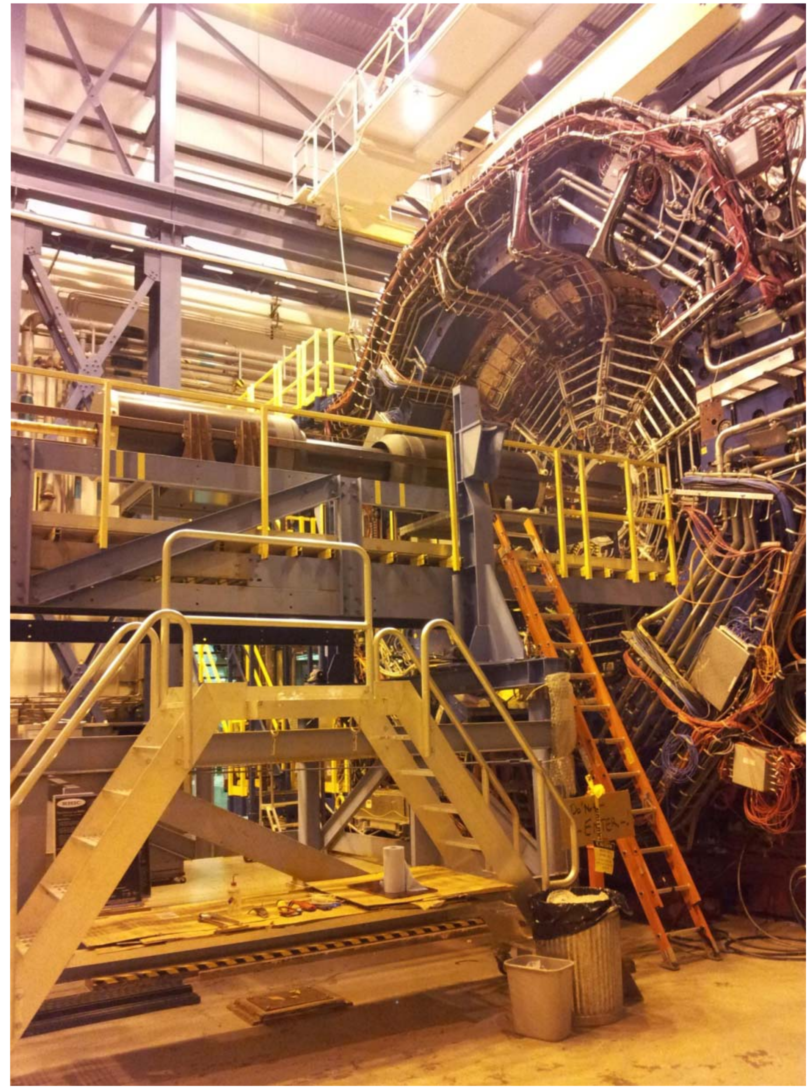
Large Hadron Collider (LHC) in Geneva



LBL involved heavily in current pixel and barrel upgrades R&D. Likely to be building key structures in the future (a few years).

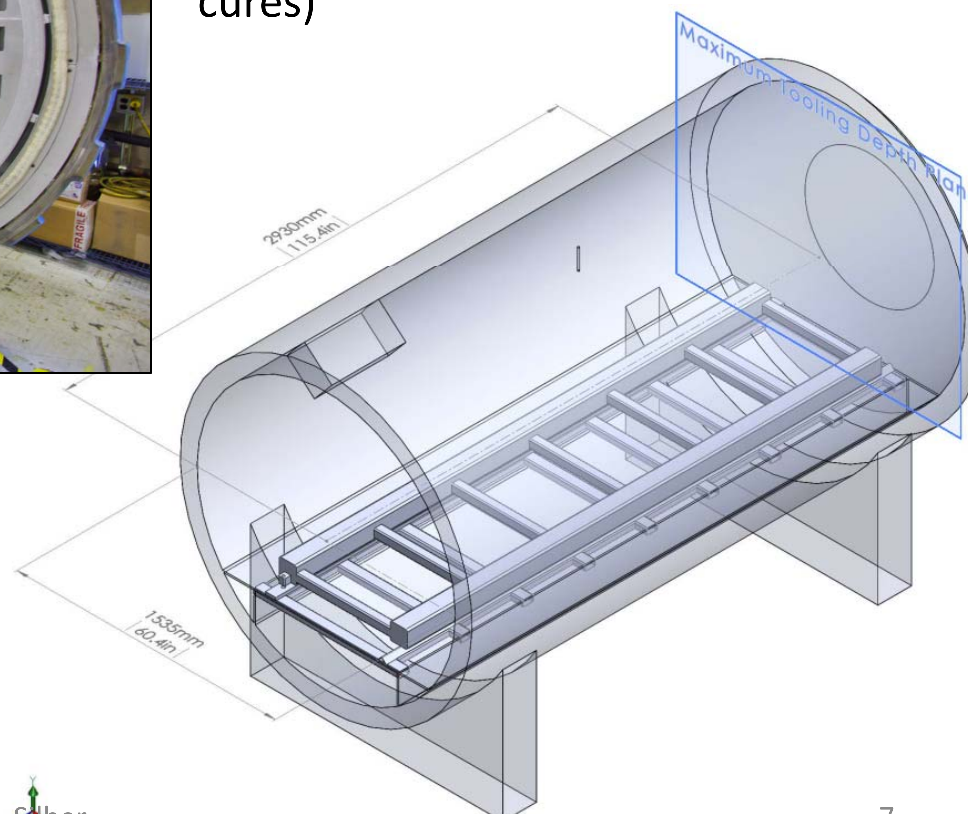
STAR HFT Inner Detector Support





Autoclave

Autoclave is essential for high-quality laminates with low void-fraction (need external pressure to overcome vapor pressure of water as laminate cures)



- Temp / pressure control with multiple sensors at all stages of cure cycle
- 60” x 115” capacity
- Rail system to slide in/out any large tooling

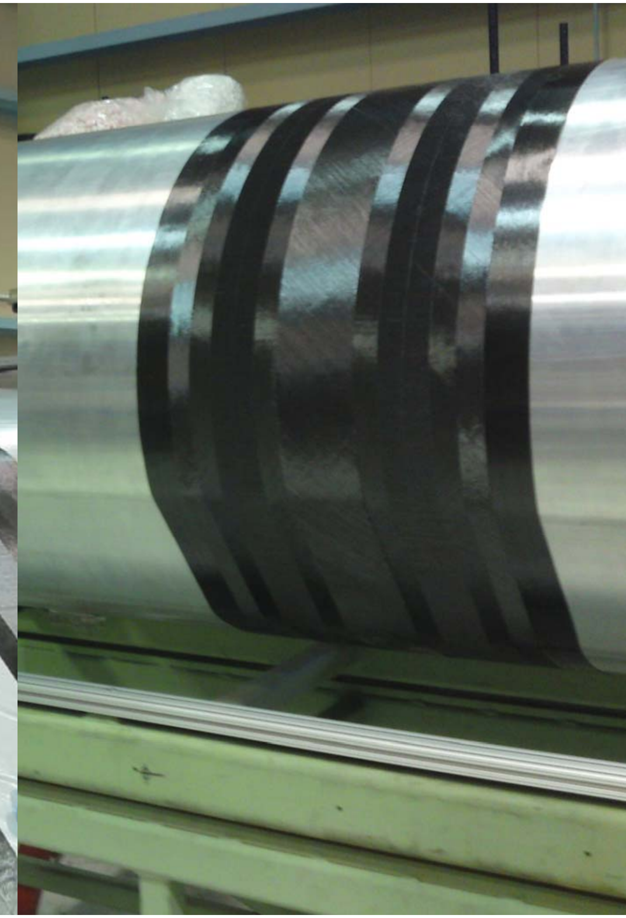
Equipment for large composite parts


- 5X10 Autoclave, chordal duct
- Part Lengths up to 8.5', diameters up to 40"
- Fully Computer controlled
  - Controls PART Temp—ramps air faster to achieve part temp ramp
  - Internal Pressure and Vacuum bag probes controlled by program
- All sensor data recorded to disk for QC, correlated with Part DB
- Tool and part shown are from ATLAS, 2.4m length

STAR IDS – WSC tube Layup

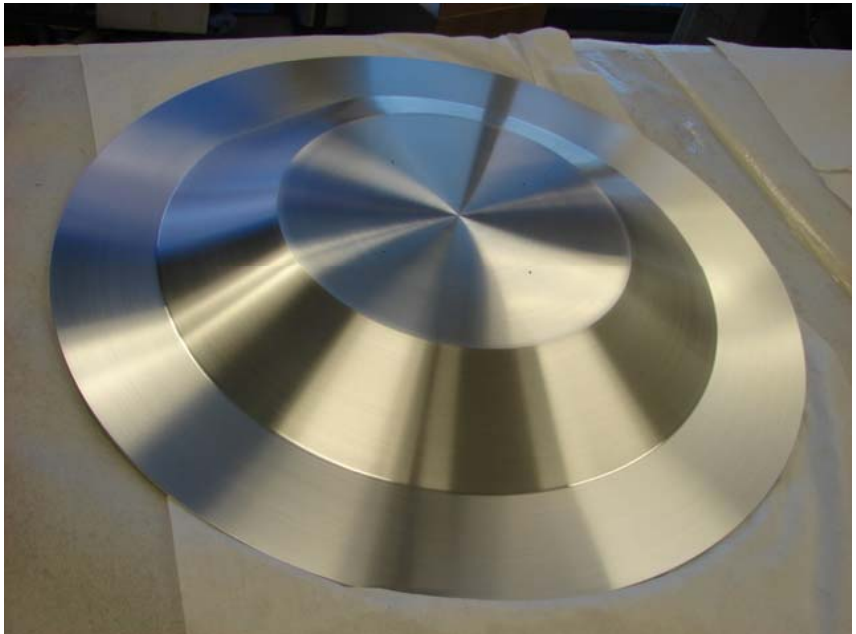
“Bricking” of ply stack to ensure good overlaps and correct fiber orientations

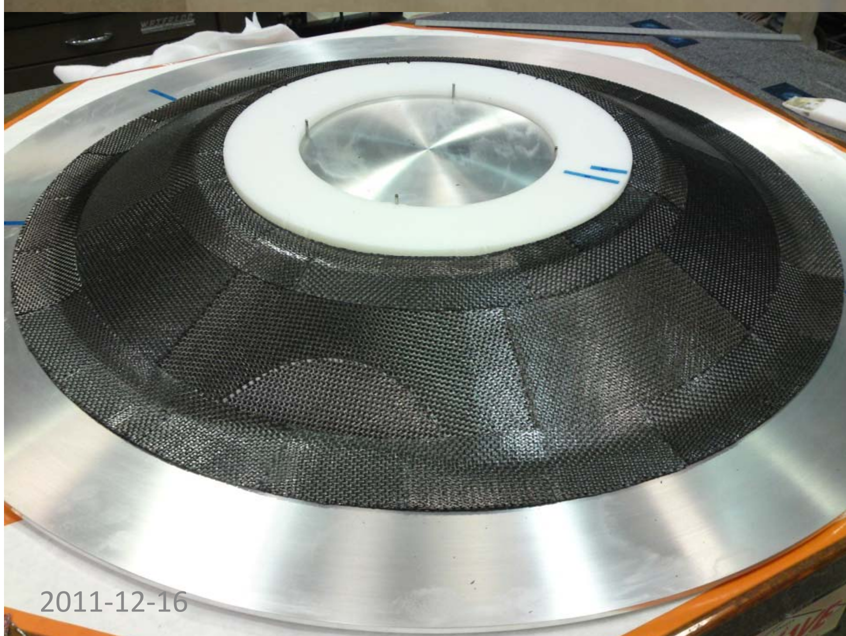
Pre-compacted ply stack goes on mandrel under tension at precise angle



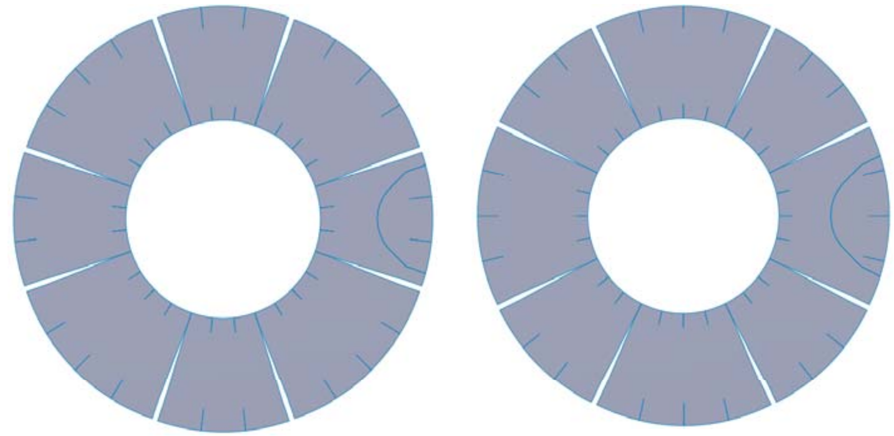
Bottom ply stack on mandrel. Another stack (flipped over) will mate to this one

STAR IDS – Carbon fiber cone layup





Ply shape design…



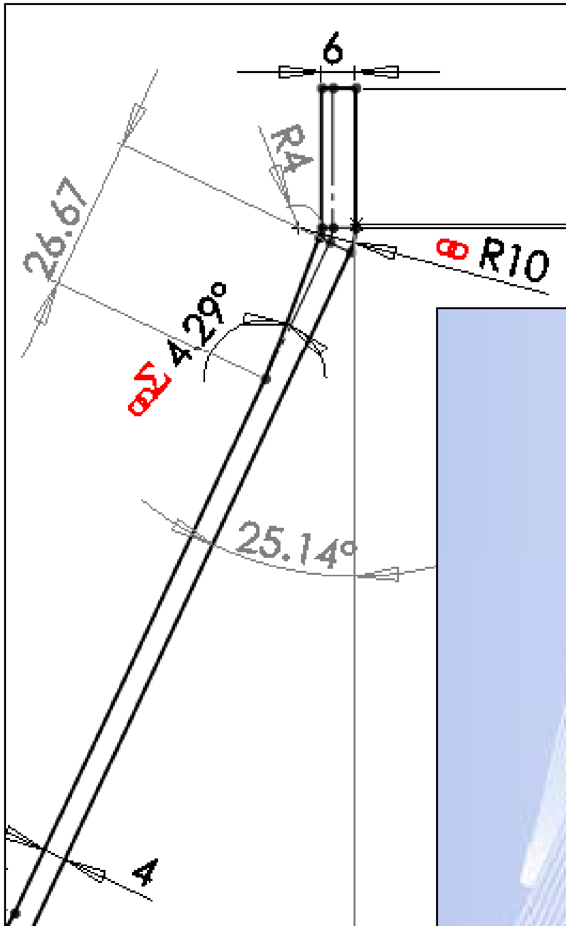
Stackup and Plies To Cut Out

STACKUP				PLIES TO CUT OUT									
Ply Number	Layout / Ply Shape	Fiber Angle (As Cut)	Flange Ply Clocking	A			B			inner and outer radius pieces all flanges			
				Wedge	*WedgeMinusFlat*	*Flat*	*Wedge*	*WedgeMinusFlat*	*Flat*	*Flange 1*	*Flange 2*	*Flange 3*	*Flange 4*
0 ?	Glass+Resin?												
1	Layout 1	±45		3	1	1	4						
2	Flange 4	±45	~0.0°							8			
3	Layout 1	0/90		3	1	1	4						
4	Layout 2	±45		4			3	1	1				
5	Flange 4	0/90	~0.0°							8			
6	Layout 2	0/90		4			3	1	1				
7	Layout 1	±45		3	1	1	4						
8	Flange 3	±45	~3.5°								8		
9	Layout 1	0/90		3	1	1	4						
10	Layout 2	±45		4			3	1	1				
11	Flange 3	0/90	~3.5°								8		
12	Layout 2	0/90		4			3	1	1				
13	Layout 1	0/90		3	1	1	4						
14	Flange 2	0/90	~7.0°									8	
15	Layout 1	±45		3	1	1	4						
16	Layout 2	0/90		4			3	1	1				
17	Flange 2	±45	~7.0°									8	
18	Layout 2	±45		4			3	1	1				
19	Layout 1	0/90		3	1	1	4						
20	Flange 1	0/90	~10.5°										8
21	Layout 1	±45		3	1	1	4						
22	Layout 2	0/90		4			3	1	1				
23	Flange 1	±45	~10.5°										8
24	Layout 2	±45		4			3	1	1				
25	Antistatic												

Totals to Cut for One Cone Part:

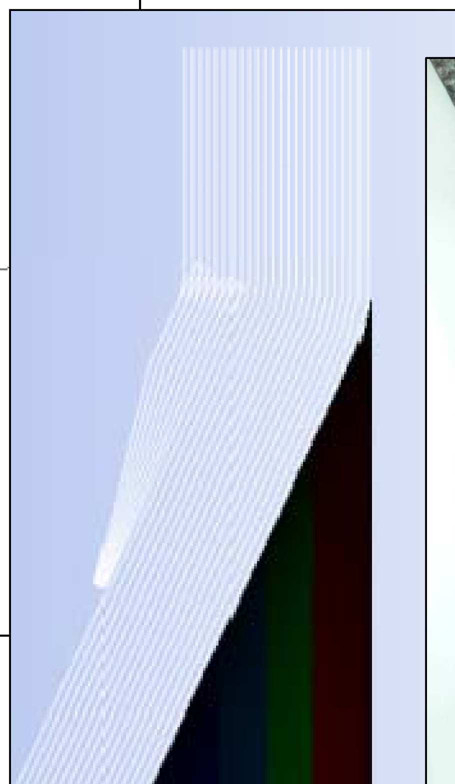
Wedge A	28x @ 0/90 and 28x @ ±45
Wedge B	28x @ 0/90 and 28x @ ±45
WedgeMinusFlat A	4x @ 0/90 and 4x @ ±45
WedgeMinusFlat B	4x @ 0/90 and 4x @ ±45
Flat A	4x @ 0/90 and 4x @ ±45
Flat B	4x @ 0/90 and 4x @ ±45
Flanges	8x (inner flange) and 8x (outer flange) @ 0/90 in all four sizes
Flanges	8x (inner flange) and 8x (outer flange) @ ±45 in all four sizes
Filler	8x @ 0/90 and 8x @ ±45
FlangeFiller	For both inner and outer flange pieces, 4x @ 0/90 and 4x @ ±45

Features like tapered cross-section (useful at bolt flange) are natural to do

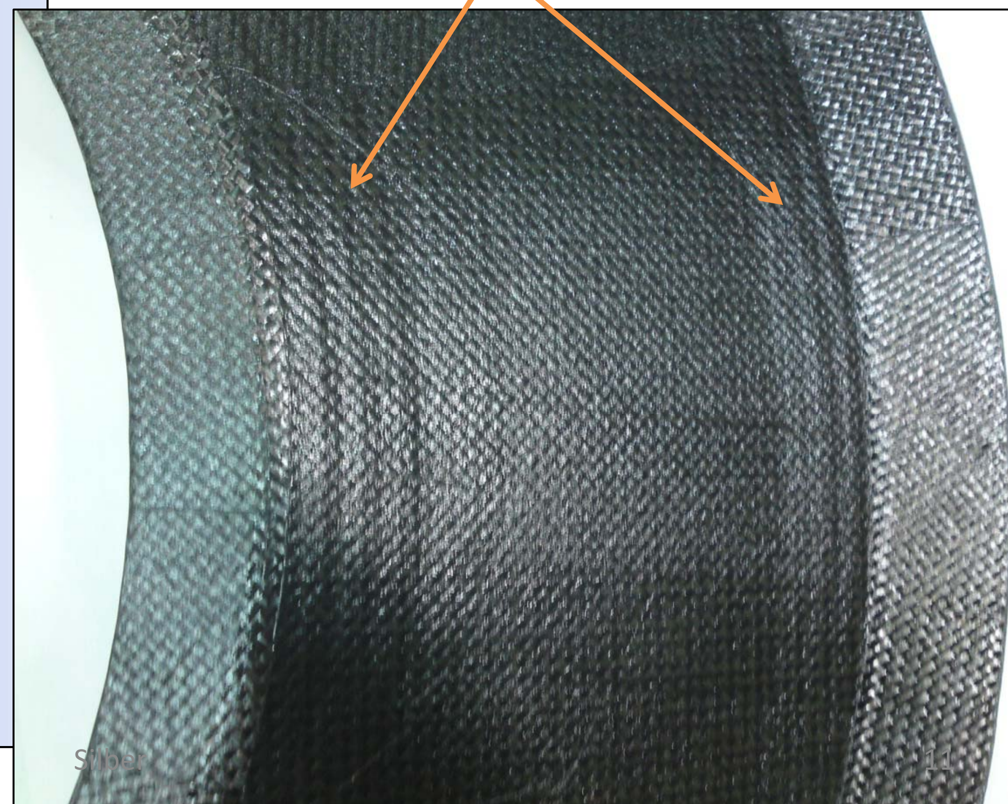


Design the geometry envelope

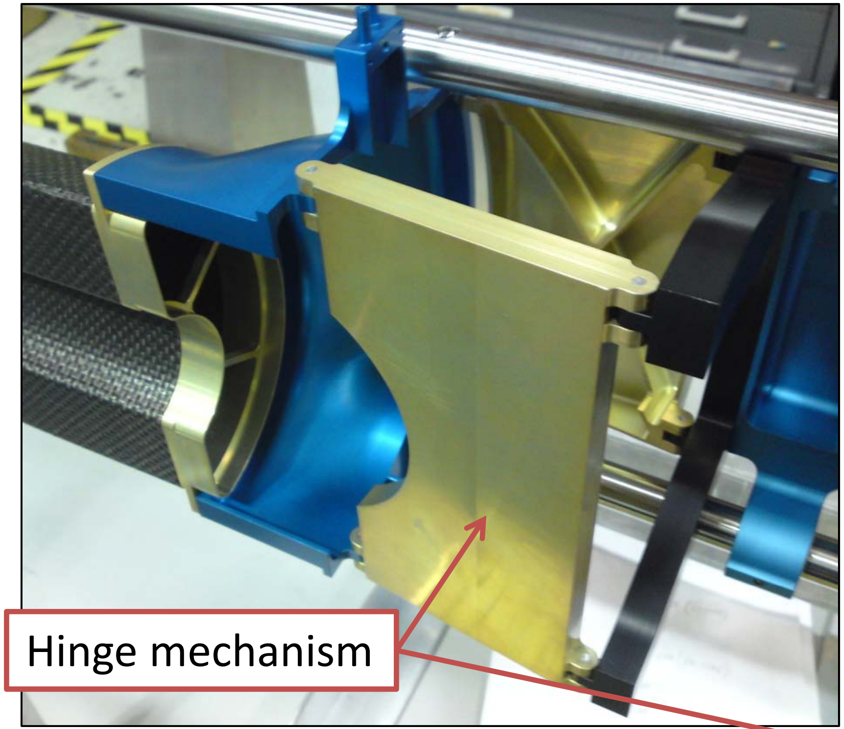
Design the ply stacking to match

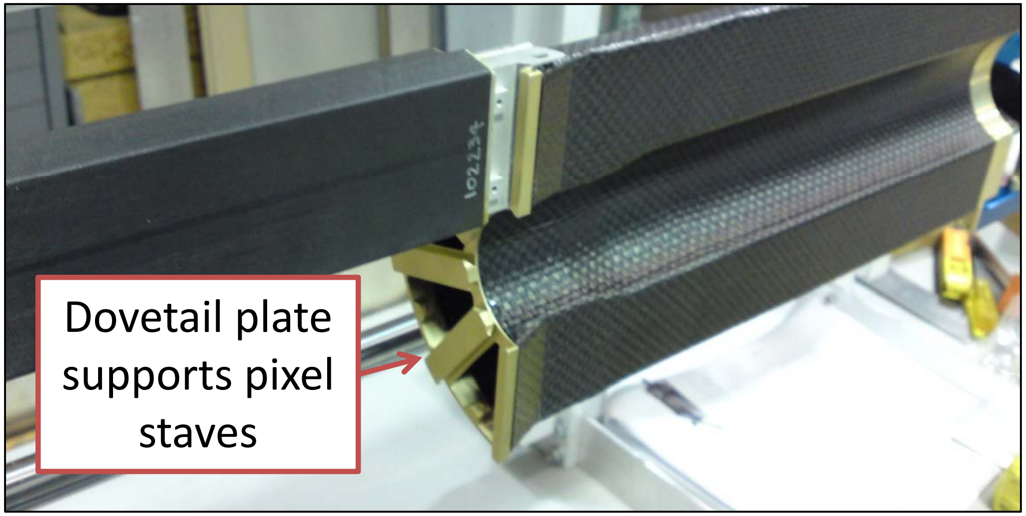


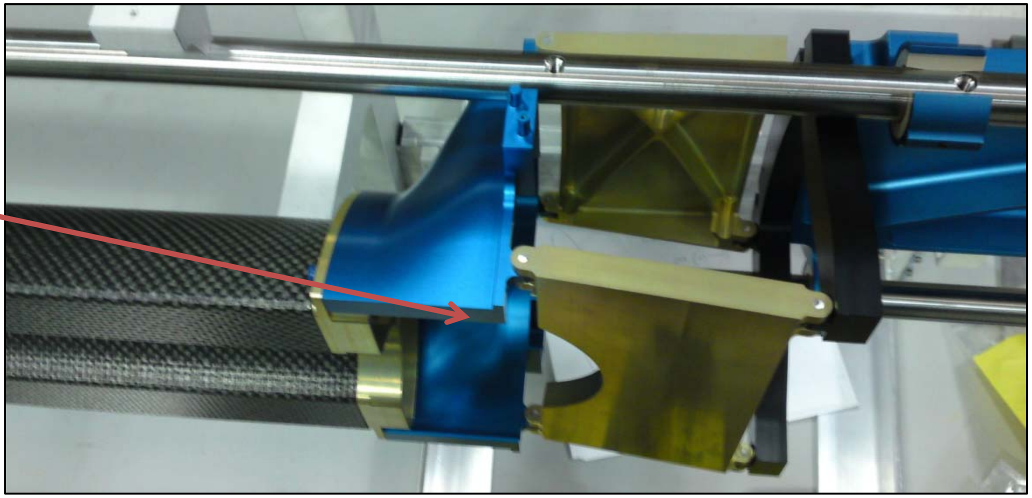
Layup (notice tapering steps)

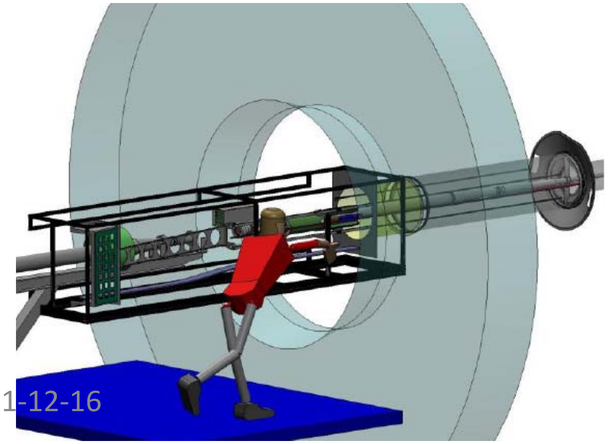


STAR: PXL Insertion Testbed

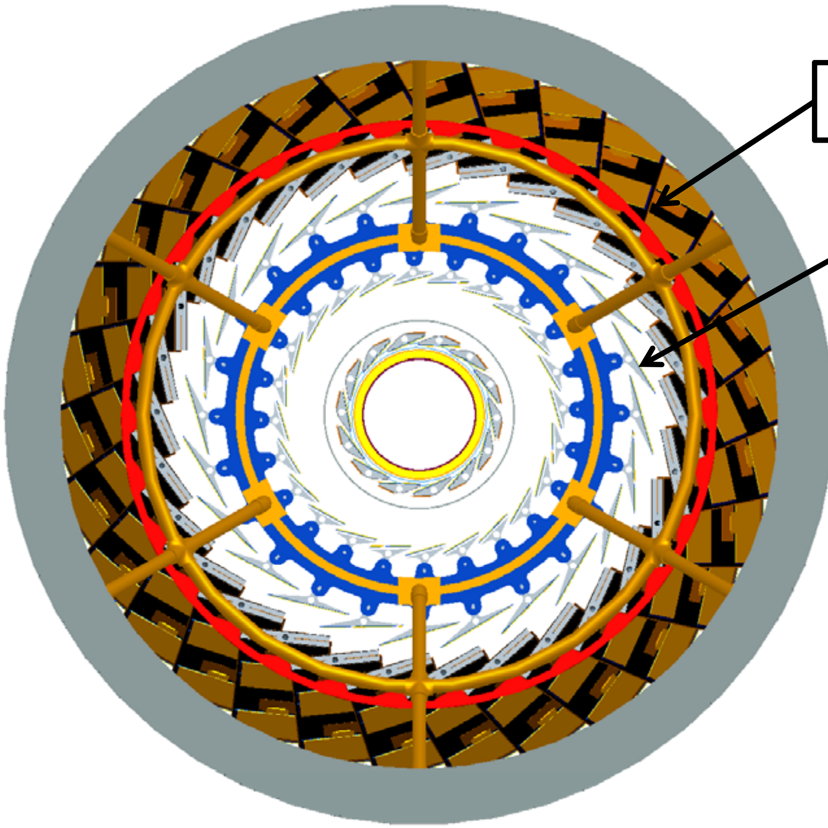


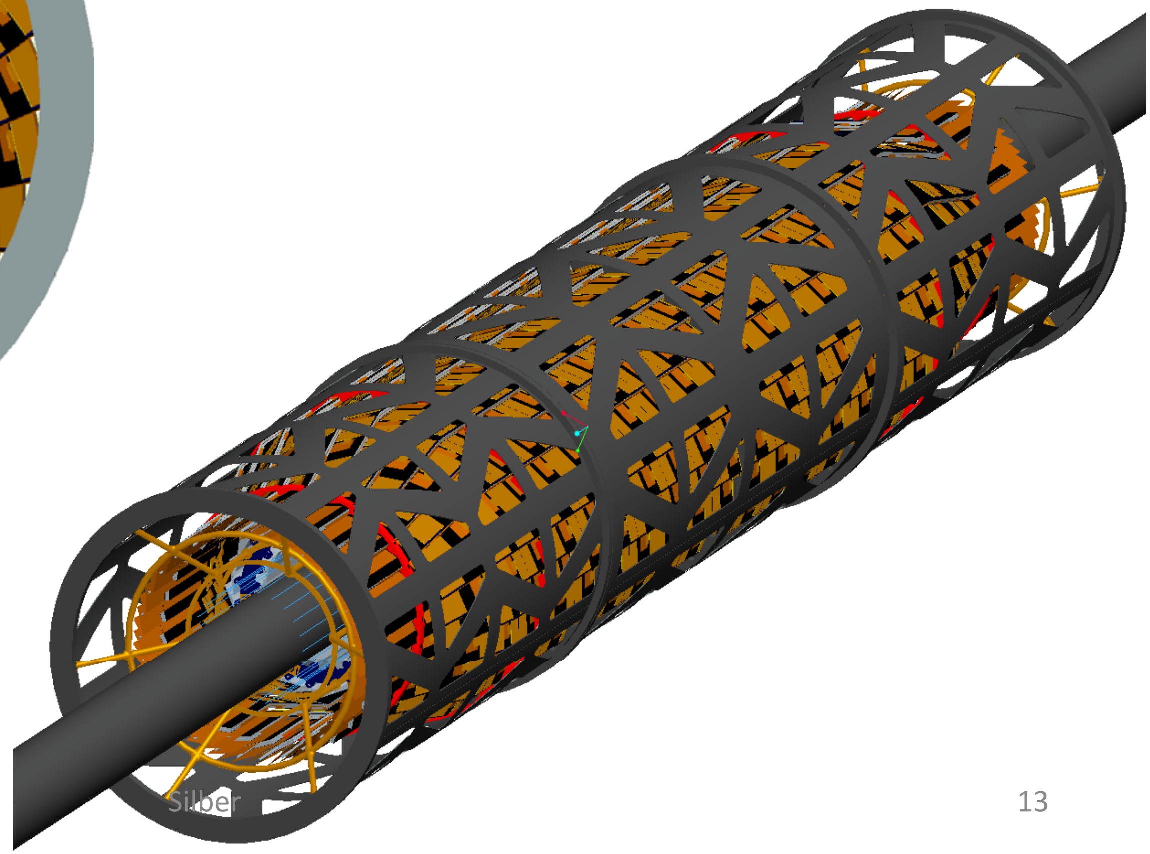




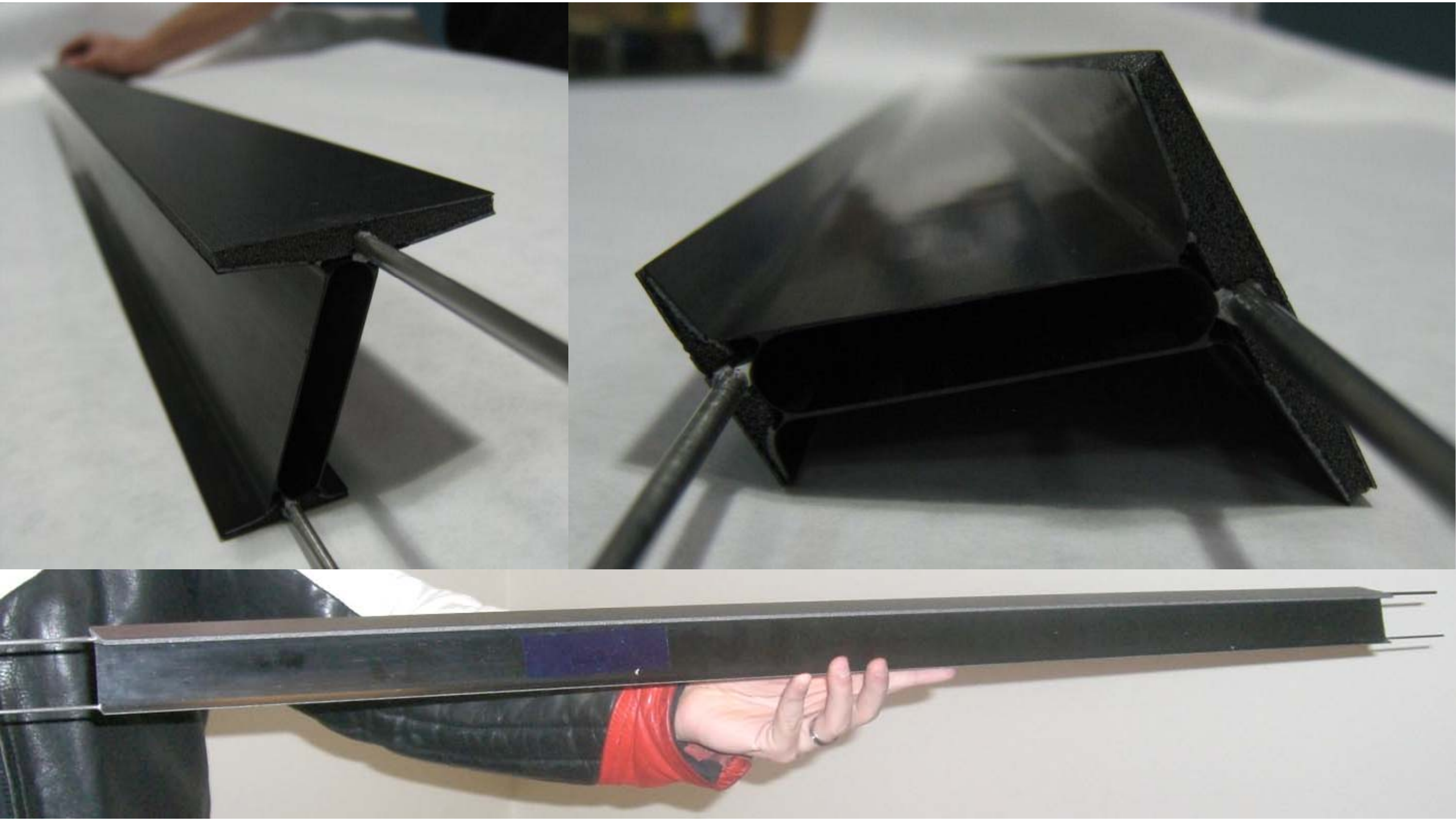


ATLAS Upgrade: Pixel Layout

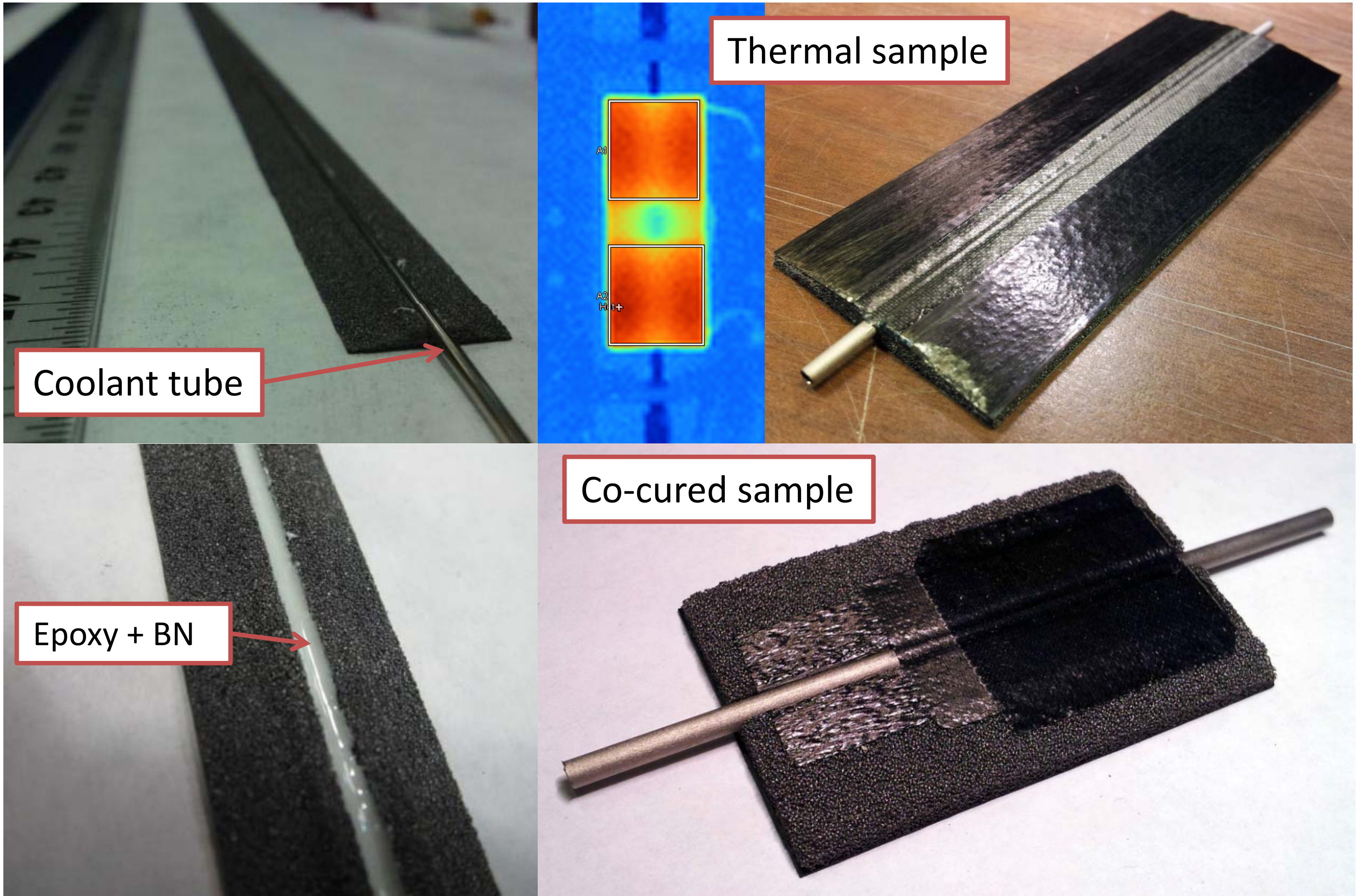




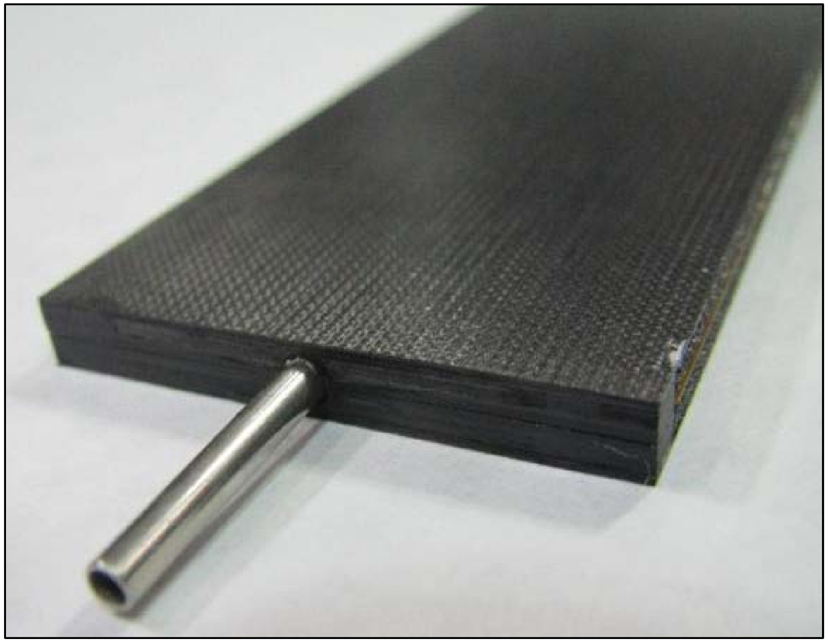
ATLAS Upgrade: 1m I-Beam

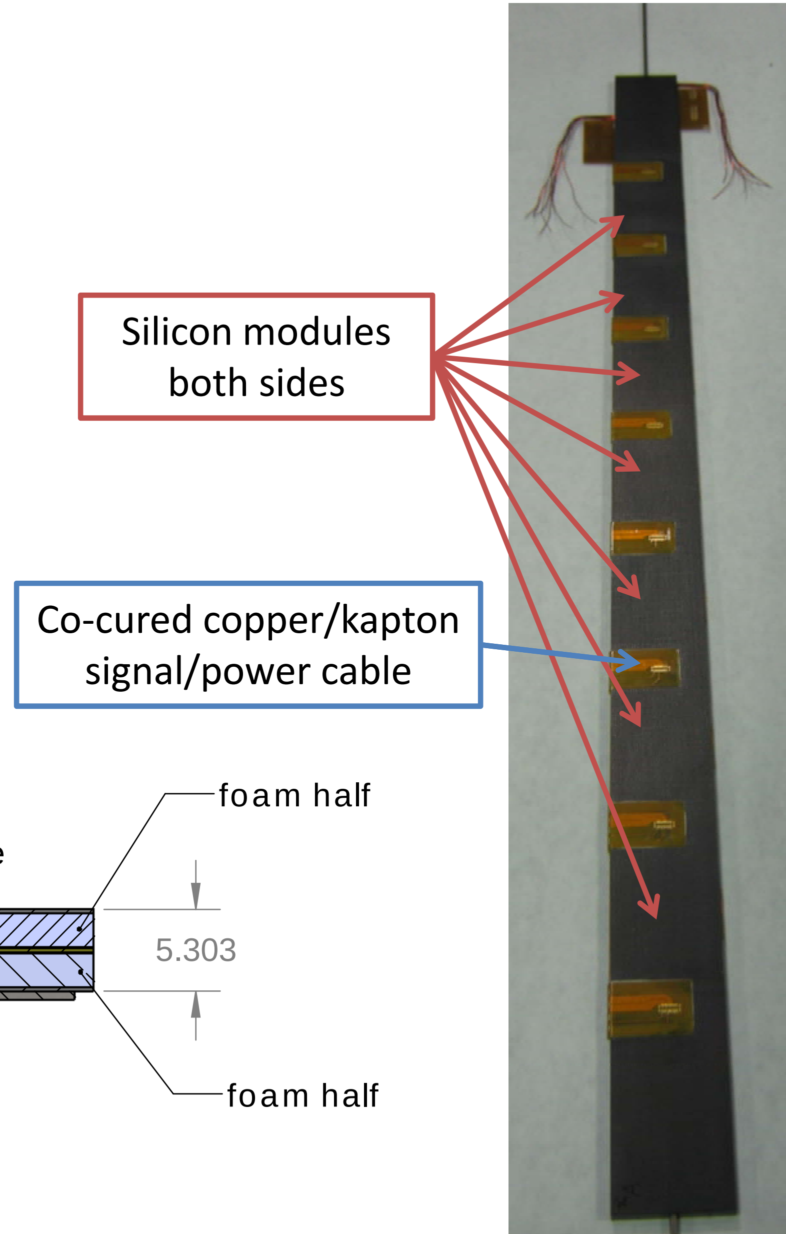


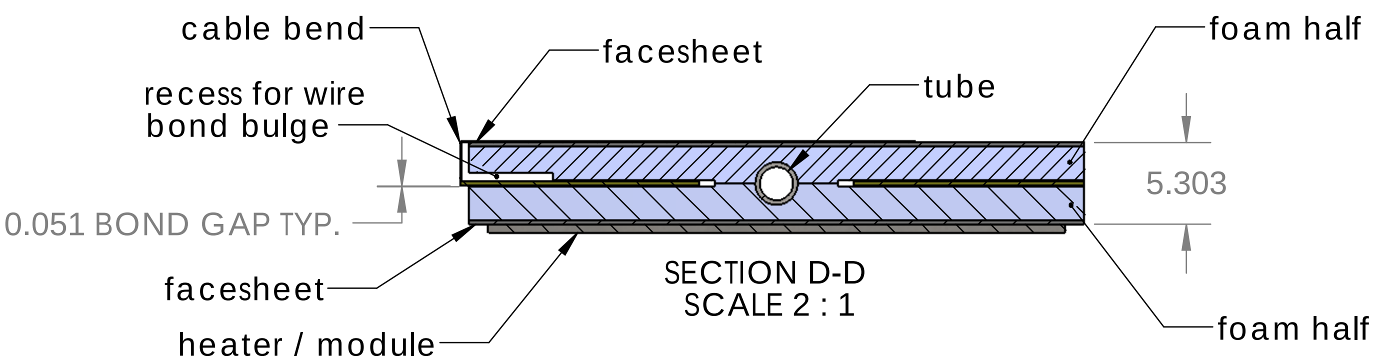
ATLAS Upgrade: I-Beam Fabrication



ATLAS Upgrade: Outer Stave







When considering composite materials…

- Thin walled, stiff & stable parts are the bread & butter – especially if you're making several+ parts, such that the tooling gets amortized
- Post machining is no problem
- Often we use a bonding jig to locate precise inserts, especially for threaded features. Typical insert material is CF-filled PEEK.
- Our shop is a leader in co-curing things like plumbing, signal and power cables directly into structures
- A big benefit of bonded-up assembly is a one-step tolerance (no chain buildup).
- When bonding large assemblies, typically:
  - 100um absolute accuracy of placement over distances of several meters pretty easy
  - 50um takes a bit more effort, but still reasonable
- Anything planar is basically cheap and easy (waterjetting works fine)
- Talk to Eric or I early on in your design process. We can save you a lot of time or talk you out of composites if it's the wrong choice for you.
- Paul Perry is another good contact for composites questions / design help.

Material properties:

- Typical non-optimized layup with our standard fibers is "Black Titanium":
  - Quasi-isotropic (homogeneous properties in-plane)
  - E = 110 GPa (same as Ti)
  - ρ = 1650 kg/m³ (2.7x lighter than Ti)
  - α = -0.1 ppm/°C (much lower than Ti, and *slightly negative*)
  - S = 660 MPa (0.75x of Ti)
  - These are rough approximations of in-plane properties, good for getting a feel and initial design concepts, as well as basic FEA inputs.
  - Depending on which property you care about, we can tune the laminate – i.e., you could design specially for CTE = 0 ppm/°C, or for 4x tensile stiffness = 485 GPa, 3x strength = 2000 MPa in a particular direction…

Typical precision bonding jig for large structure

End

- Joe Silber (me): jhsilber@lbl.gov
- Eric Anderssen: ecanderssen@lbl.gov
- Paul Perry: peperry@lbl.gov
- These slides: http://www-eng.lbl.gov/~jhsilber/slides