Stave Mechanics

Outline

1. Previous R&D
2. Near Term R&D
3. Questions/issues
4. Some current work
5. End Insertion
6. Schedule

D. Lynn, BNL (with Yale, LBNL)
Santa Cruz, Aug 12, 2008

Previous R&D--LBNL

Fabricated 5 stave prototypes

- Lengths 1/3-1 meters
- Narrow 7 cm width (was previous baseline)
- Various tube sizes/shapes

Extensive FEA

- Thermal modeling
- Mechanical modeling

Measurement on Prototypes

- IR Measurements (room temperature)
- Stave deflection/sag
- Thermal cycling

Previous R&D--Some Mechanical Conclusions

Stave Philosophy

Originally "stiff stave" with cantilevered space-frame support at each end. Goal to minimize stave sag(must maximize stave design for stiffness)

Evolved to stave with multipoint support (to minimize sag) on cylinders. (maximize design for thermal performance and minimal mass)

Flatness

Question remains on what spec should be on flatness (would be good to loosen this specification if it is not justified).

One stave achieved min–max < 200 um, rms~30 um

Flatness dependent upon uniformity of honeycomb thickness...must precision machine honeycomb if greater flatness required

Sag

Deflection of "non-stiff" staves less than 75 um if supported every 50 cm

Deflection agrees with FEA to within ~20%

Previous R&D--Some Thermal Conclusions

Cooling tubes

Not large difference between three options (in terms of ΔT/watt)

1. Flattened tube in direct contact with facing
2. 4.8 mm tube in carbon foam (diamter for C_3F_8)
3. 2.8 mm tube in carbon foam (CO_2)

Coolant

CO_2 preferred to give more margin from thermal runaway

Facings

Not large difference in ply thickness (but ply orientation only briefly checked)

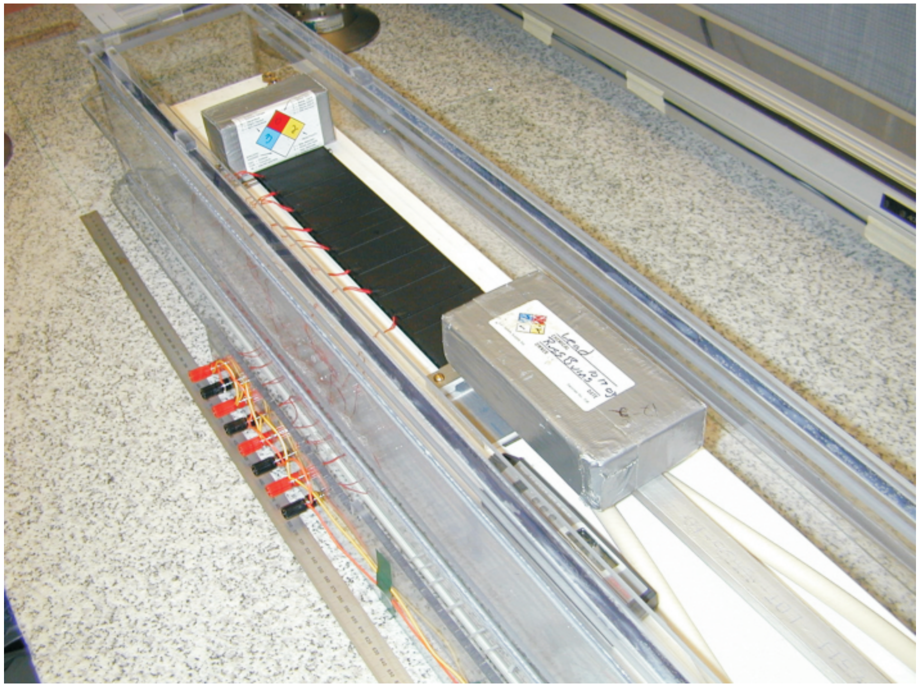
FEA

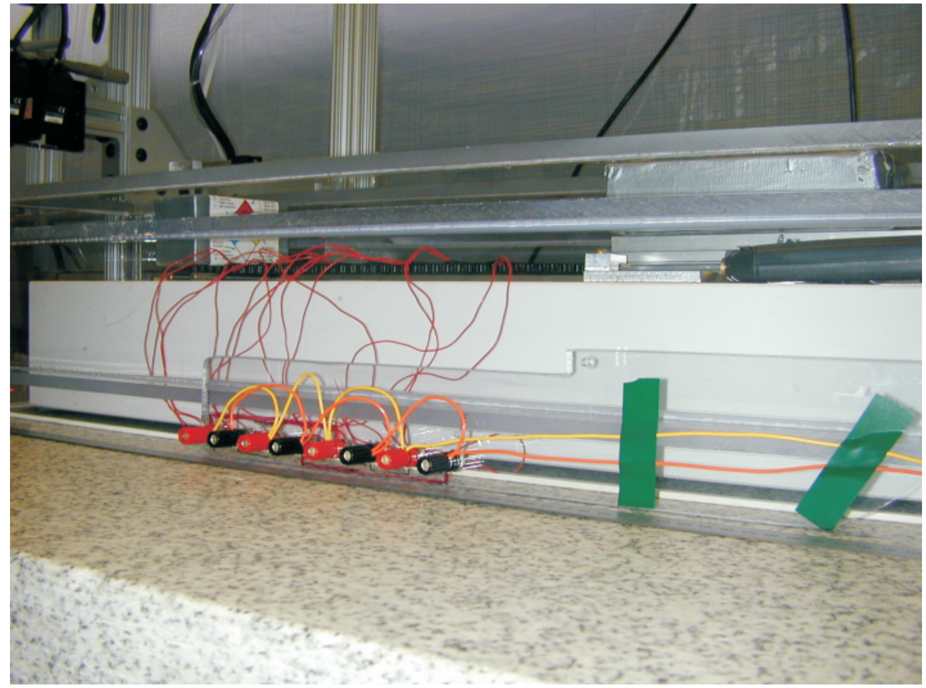
Agrees with measurements to ~1-2 °C, within uncertainties of material properties

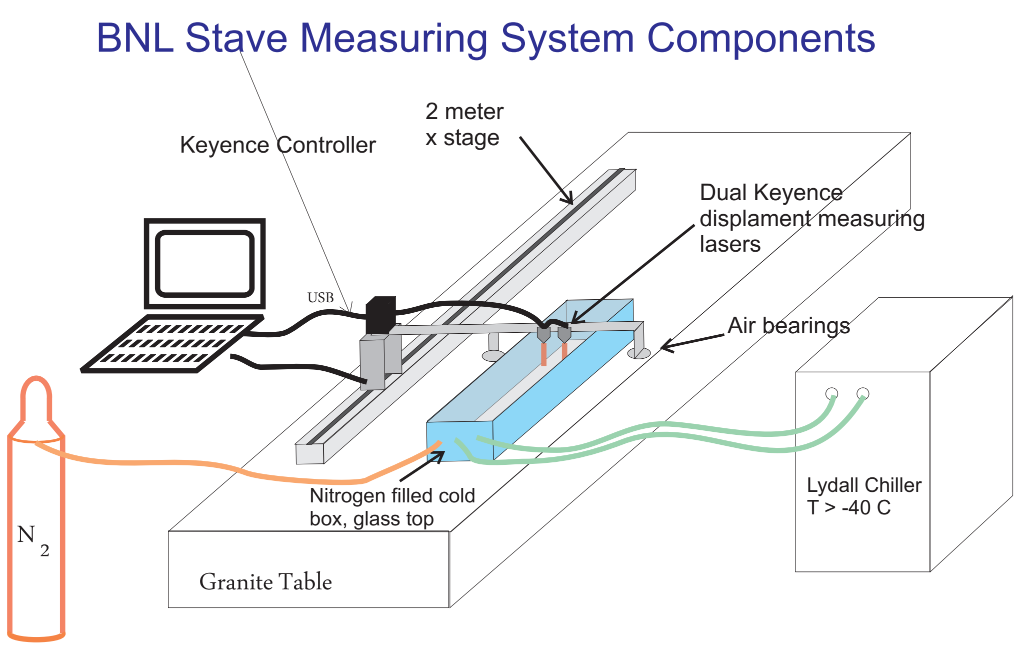
Thermal Cycling

No change in thermal performance after 50 cycles from -35 °C to 20 °C

Recent Measurements on LBNL Stave at BNL



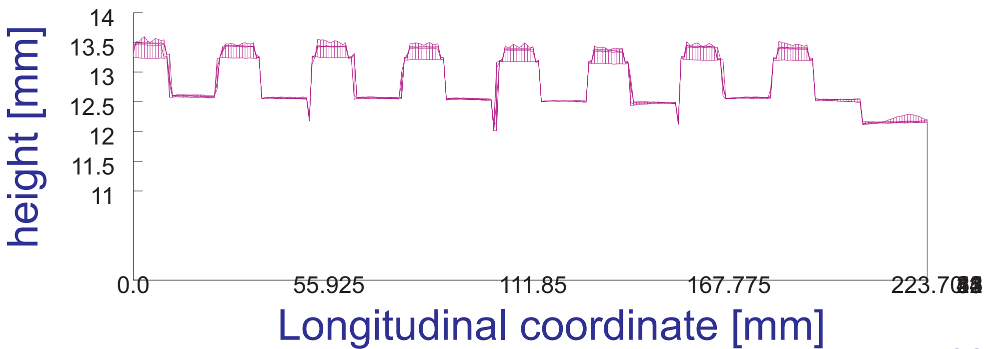


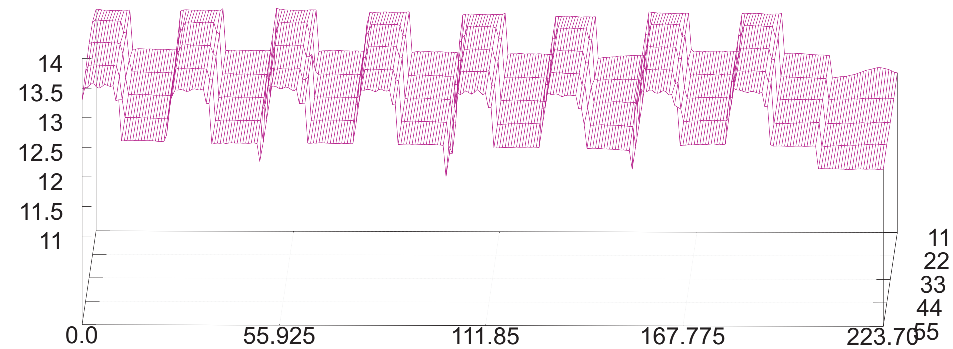


Short Stave
4.8 mm pipe
Heaters one side only
Silicon one side only

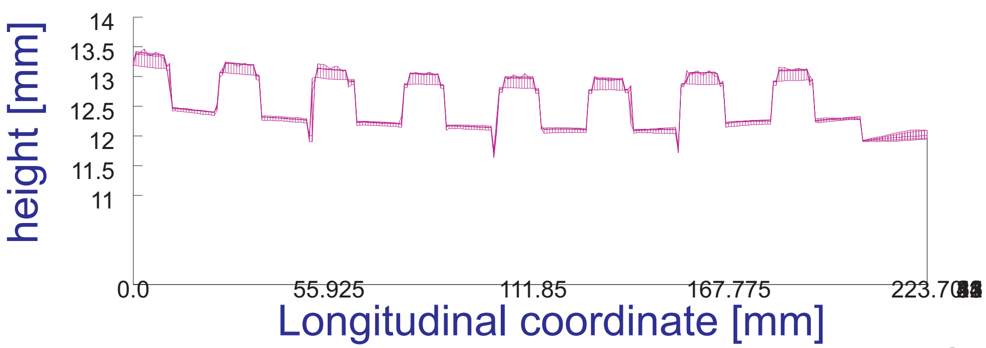
Stave Deformation Measurements

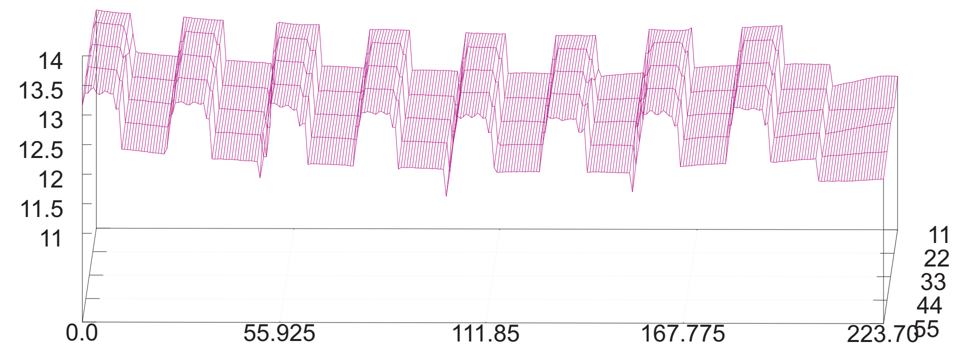
coolant = 25 C



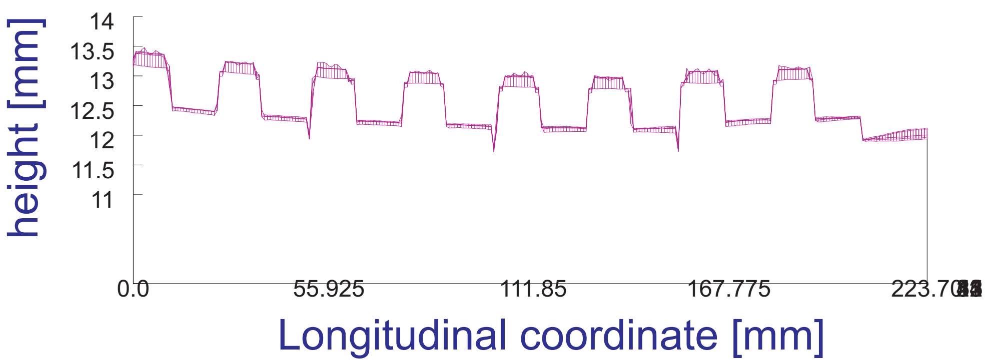


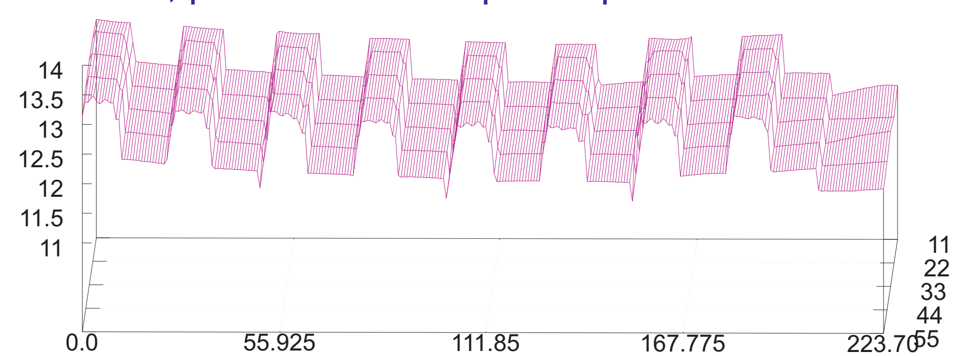
coolant = -30 C





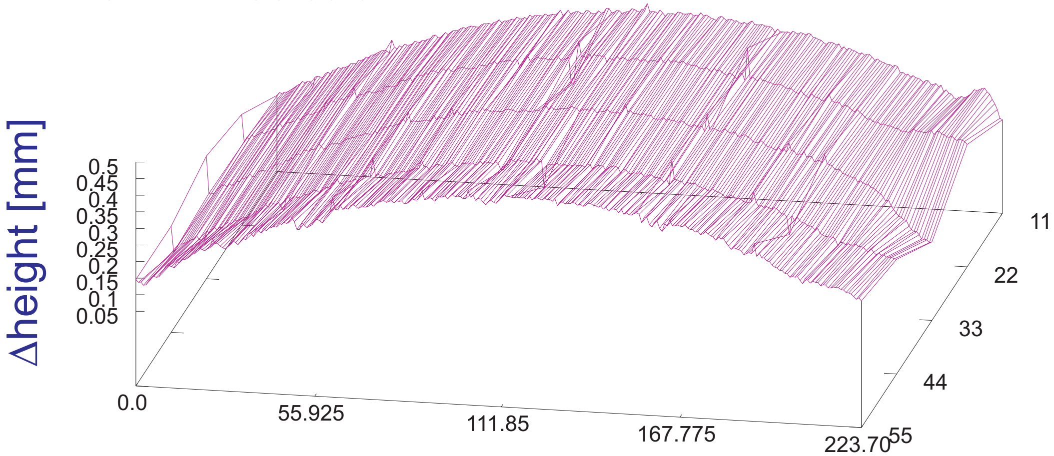
Coolant = -30 C, power =1/4 watt per chip



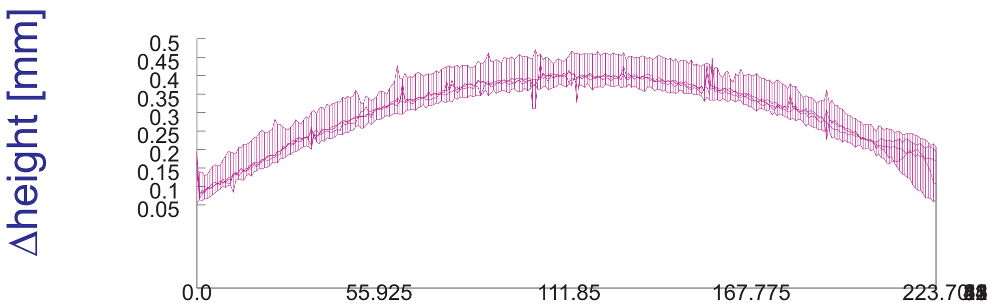


Deformation measurements – Differences

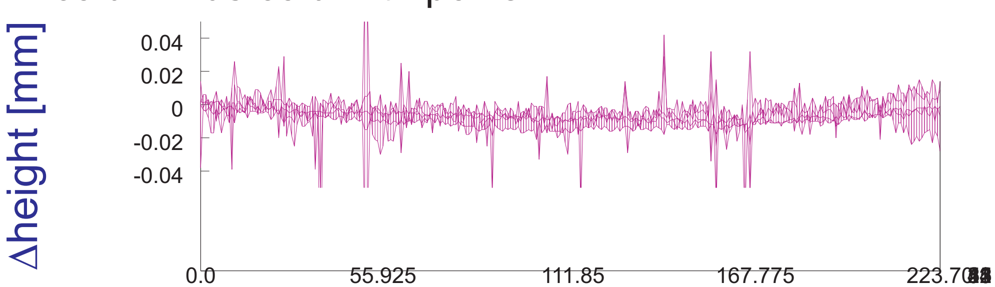
warm minus cold



warm minus cold



cold minus cold with power



Longitudinal coordinate [mm]

These measurements done on side of stave without silicon or heaters

~ 300 um bow between room temperature and -30 C

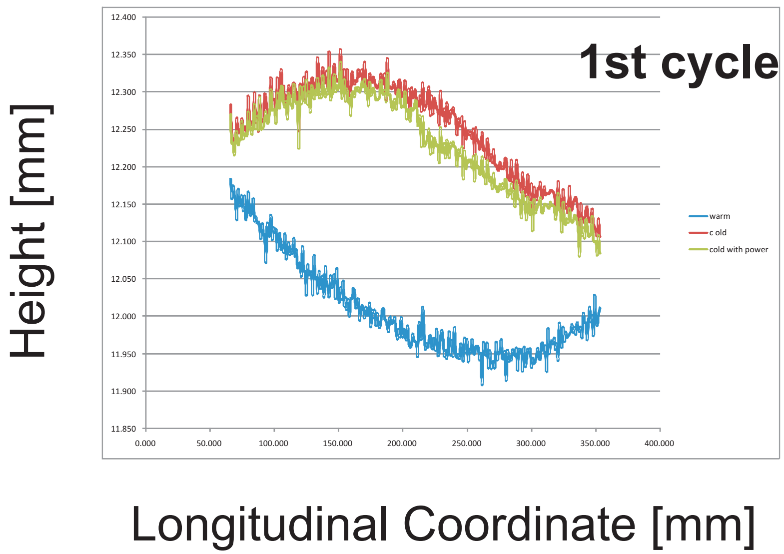
Not surprising as this stave was a thermal model, and so has silicon and heaters only on one side

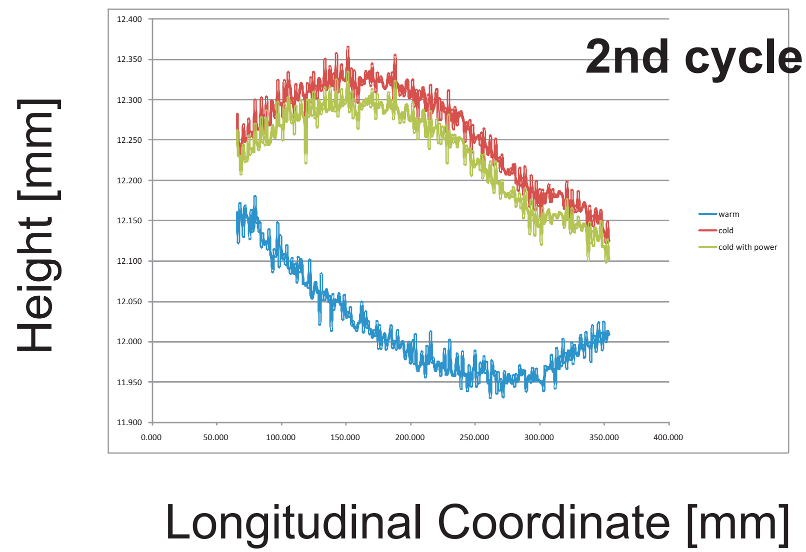
Of more interest is change in bow between power on and power off. Change in bow is less that 15 um.

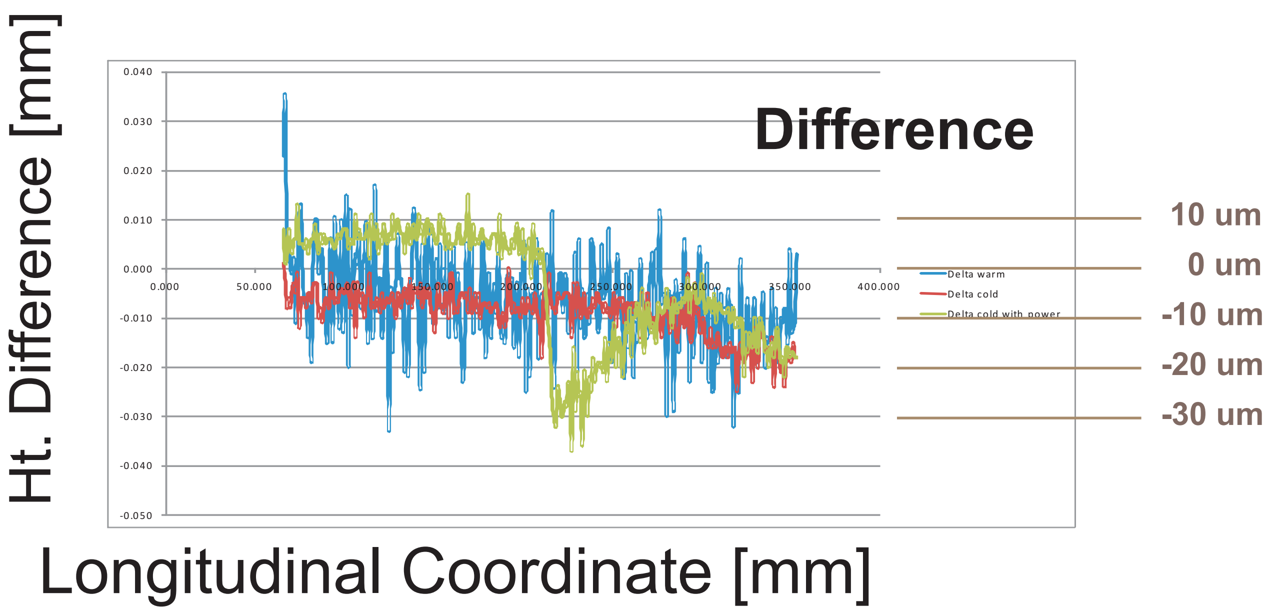
Deformation measurements – Differences

Repeatability Measurement on LBNL Stave

= warm
= cold, no power
= cold with power







Warm-to-war and cold-to-cold repeatability is better than 20 um

Cold-to-cold with power repeatability better than 30 um

These measurements will be needed to be done with mahy more cycles with future staves, and results understood.

Near Term R&D Activities/Resposibilities

LBNL

- Petal Prototyping
- Foam/pipe shear studies (also relevant to pixels)
- $C0_2$ cooling (working with SLAC)
- Honeycomb for next generation of 11 cm wide staves (also for petals)
- Expertise on stave mechanics

Yale

- Foam/pipe shear studies
- Foam machining
- Tube R&D
- Provide Foam-Tube units for next generation of 11cm wide staves
- Thermal FEA

Near Term R&D Activities/Resposibilities

BNL

- Assemble next generation of 11 cm wide staves
- FEA-- Mechanical and Thermal
- Deformation measurements (Room temp to -30C)
- Thermal Imaging (down to -30C: NYU provides thermal imager)
- End insertion with bracket prototyping

Other Institutions (US and non-US)

- Much work to do.
- How do we engage and organize?

Prototype Plan--Stave Variants

Note: Which staves to build still under discussion. One possible plan is presented. Uncertainties partly due to available materials

Short composites 0 and 00.

~ 35 cm long, 10.7 mm wide

5 mm and 3mm honeycomb (BNL 2pcf honeycomb or LBNL supplied honeycomb)

Purpose: Measure core properties, CTE, and CME

Short Staves 1 and 2

~ 35 cm long, 10.7 mm wide

5 mm and 3mm honeycomb (BNL 2pcf honeycomb or LBNL supplied honeycomb)

Existing (BNL) K13C2U 3-ply facings, 420 um thick, or other

5 mm CF side rails

Poco foam--stainless steel tubing assembly (Yale)

Purpose: Test assembly technique

Measure: Mechanical distortion, flatness, CTE, CME,
thermal performance under varying conditions of
temperature (25C to -30C), humidity, power, etc

Compare to FEA

Prototype Plan--Stave Variants

Short Staves 3 and 4 (if necessary), or...

Long (i.e. full length) stave 1.

Should have hopefully made decision on thickness

Should have preferred choice of facing material

Should have preferred choice of honeycomb

Should have end close-outs

Purpose: Last stave to be made before making full length stave for module mounting

Testing: Full round of testing and comparison to FEA as with short staves

Long stave 2.

Stave to be mounted with modules. Must satisfy requirements of the collaboration

Prototype Plan--Questions to be Answered and Issues (List not comprehensive)

Optimizations

- Carbon Foam Type (Poco, Koppers, Other)
- Carbon Foam Size (thermal performance vs mass)
- Facing layup, orientation (stiffness vs thermal performance)
- Honeycomb thickness, density (stiffness)

Machining

- How much thicker does carbon foam have to be than tube?
- Can we grind 1.2 m honeycomb to < 50 um flatness

Support

- Are CF tubes for side rails sufficient with various end-insertion concepts?
- Is carbon dust generated during inserstion? Is this a concern

Stainless Steel Tubes

- Is electrical isolation required? Corrosion issues? (From electrical standpoint, I don't think isolation is required).

Prototype Plan--Questions to be Answered & Issues(Con't)

Stiffness

- What now drives stiffness requirement? Sag is minimized via supports
- Does end insertion drive stiffness requirement?

Stability

- Need FEA frequency analysis, eventually coupled to support
- Measure stability with accelerometers with next generation stave? What use as excitation?

Glues

- Se4445 have any impact on detector performance (before and after irradiation)
- Glue for bus cable, glue for honeycomb-facing
- Tube-foam glue
- Gluing on silicon question

Assembly technique

- Need to refine assembly technique. Must be transferable to large scale production.

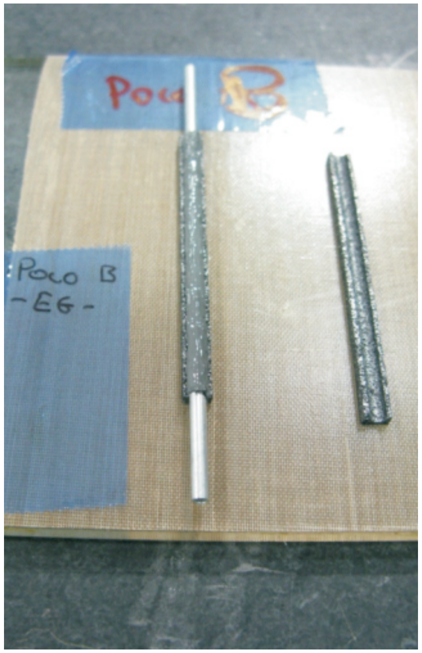
Some Current Work--LBNL

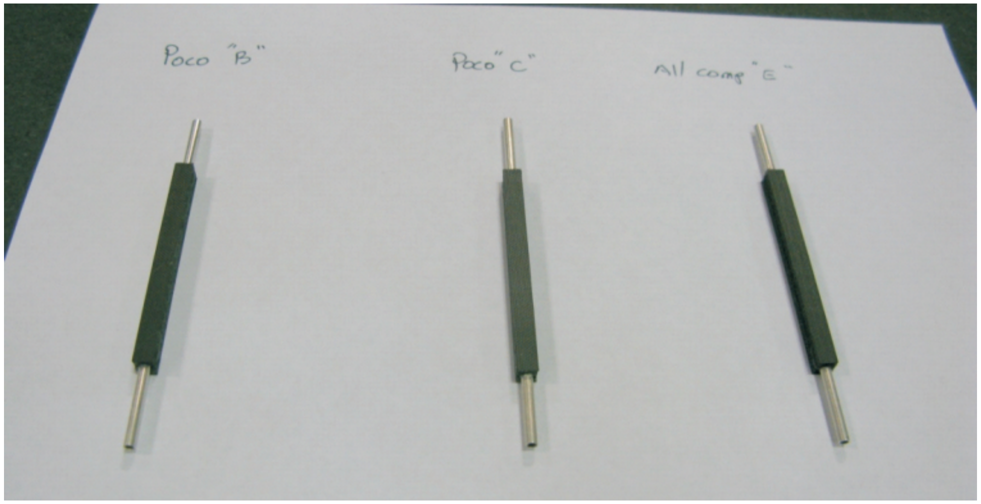
LBNL Working to Answer Question of Reliability of Tube-Foam Interface

Shear Stress Samples

- Made 5mmx5mmx6cm foam/Al tube samples to thermal cycle and look for foam cracks visually at the moment. This is for both POCO and a candidate pixel foam. Curing. Results next week.

Sample	Priority	Tube Type	Foam Type	Tube/Foam Adh	Foam/Facing Adh	Facing
A	7	Al (2.85mm OD)	POCO	CGL	9396/30%BN	90 - 0 - 0 - 90 K13D2U
B	1	Al (2.85mm OD)	POCO	EG7658	9396/30%BN	90 - 0 - 0 - 90 K13D2U
C	3	Al (2.85mm OD)	POCO	9396/30%BN	9396/30%BN	90 - 0 - 0 - 90 K13D2U
D	6	Al (2.85mm OD)	Allcomp2	CGL	9396/30%BN	90 - 0 - 0 - 90 K13D2U
E	2	Al (2.85mm OD)	Allcomp2	EG7658	9396/30%BN	90 - 0 - 0 - 90 K13D2U
F	4	Al (2.85mm OD)	Allcomp2	9396/30%BN	9396/30%BN	90 - 0 - 0 - 90 K13D2U

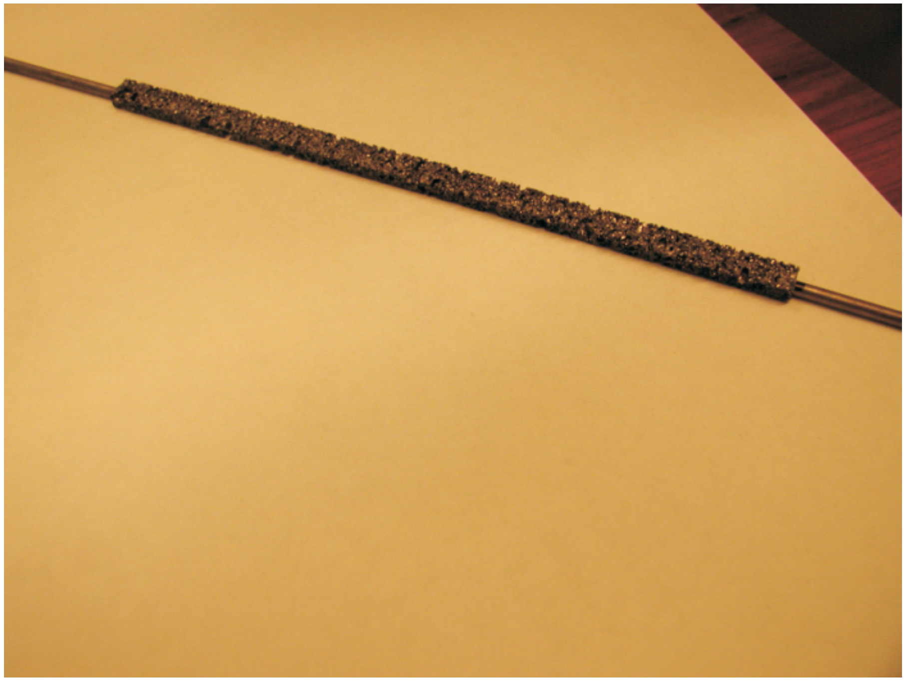


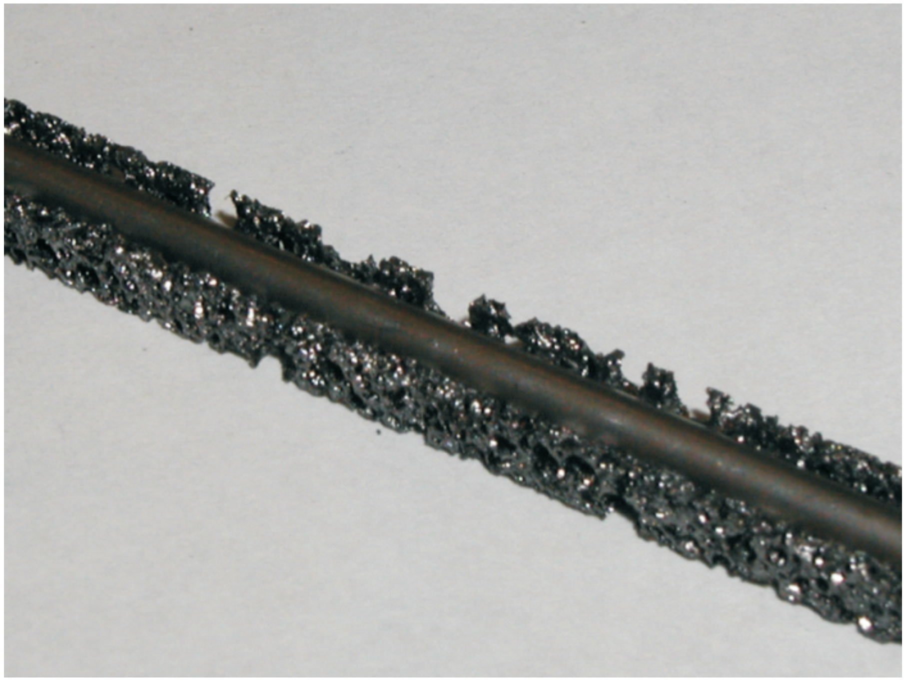


Some Current Work--Yale

Graphite Foam

- Samples procured from two sources:
  - Poco
  - Koppers
- Poco has much more uniform porosity
- Both machine easily…however, Koppers is very fragile due to pore size variability.

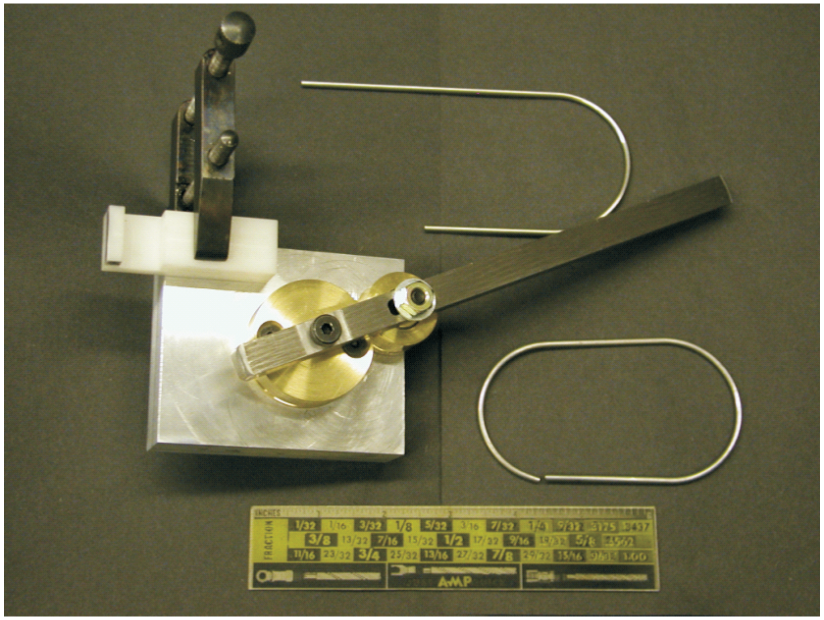




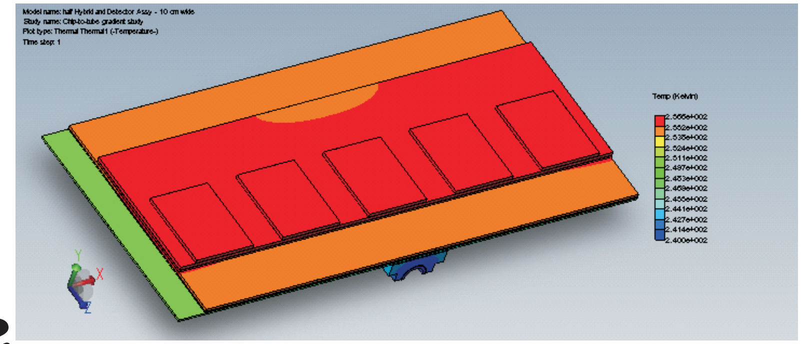
Some Current Work--Yale

Tubing R&D

- Tubing samples procured from two sources:
  - Small Parts Inc (seamed and drawn) 2.76 mm OD x 2.16 mm ID
  - McMaster Carr
- Tube bending fixture developed and in use
- Two sources for <3 meter lengths identified:
  - Superior Tube (Thanks, David Lynn…)
  - New England Small Tube
- Next step: order tubing lengths sufficient for prototype



Some Current Work--Yale



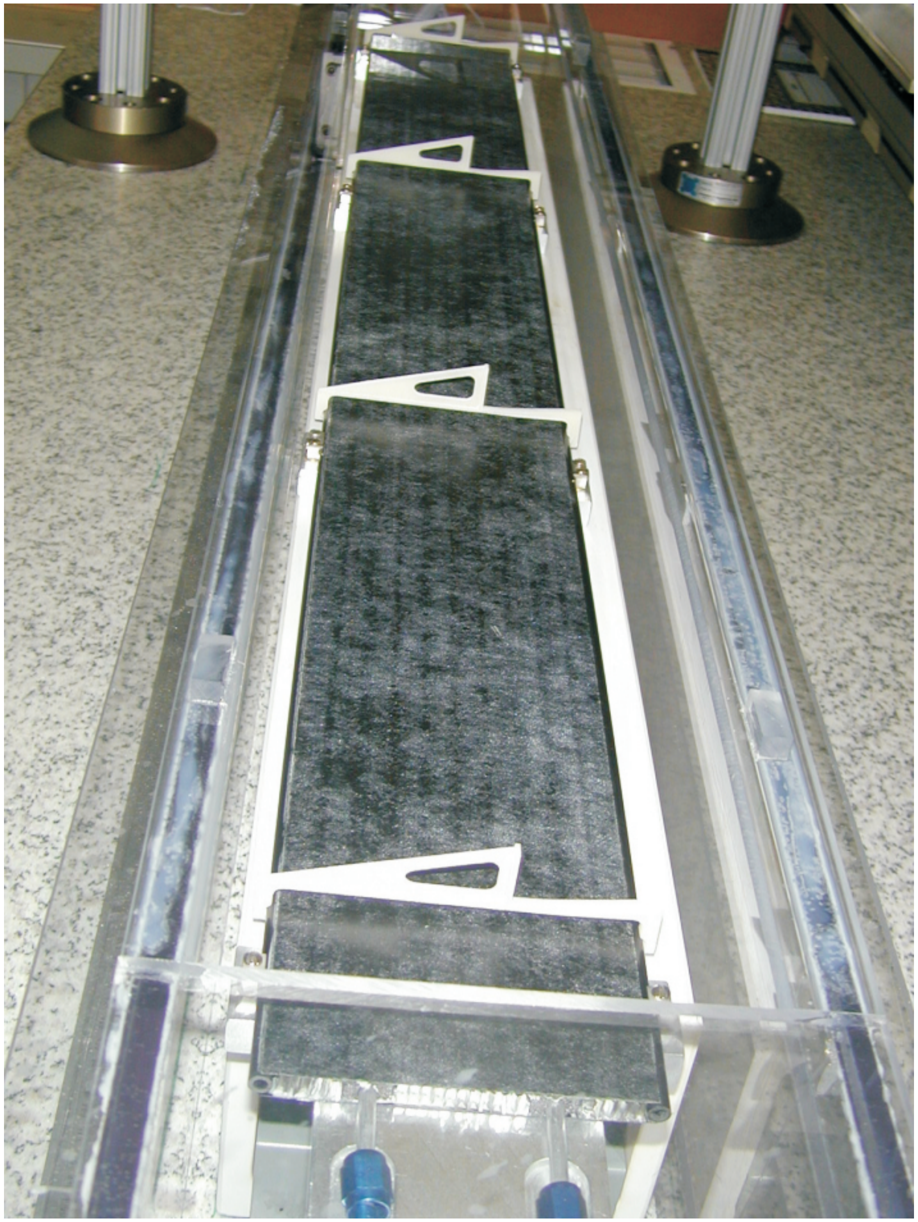
0.3 watts/chip, $T_{tube\ wall}$ held at 240 °K
-Top View

Prototype Stave Thermal Mode

- As a starting point, I attempted to duplicate results from M. Cepeda et al. Mechanical and Cooling Design Studies for an Integrated Stave Concept for Silicon Strip Detectors for the Super LHC, 18 June 2008.
- Specifically, I looked at the model presented on p.17.
- Modeled ¼ of stave cross-section using CosmosWorks
- Maintained tube inner wall at –35 °C
- 0.3 watt generated at each of five chips
- Used conductivity information from table 5 of study
- Result: temperature rise at detector surface of 13°C vs 8°C from fig.20
- No obvious modeling or mat'l property errors at this point, but still looking…
- I'm currently developing a simple SINDA (finite differencing) model to check my results.
- Next: simple two-phase thermo-fluid model of tube
- After that: full-scale thermo-fluid model of current design

Some Current Work – BNL

Last Aluminum Honeycomb Stave Prototype Before Attempting All CF Prototype

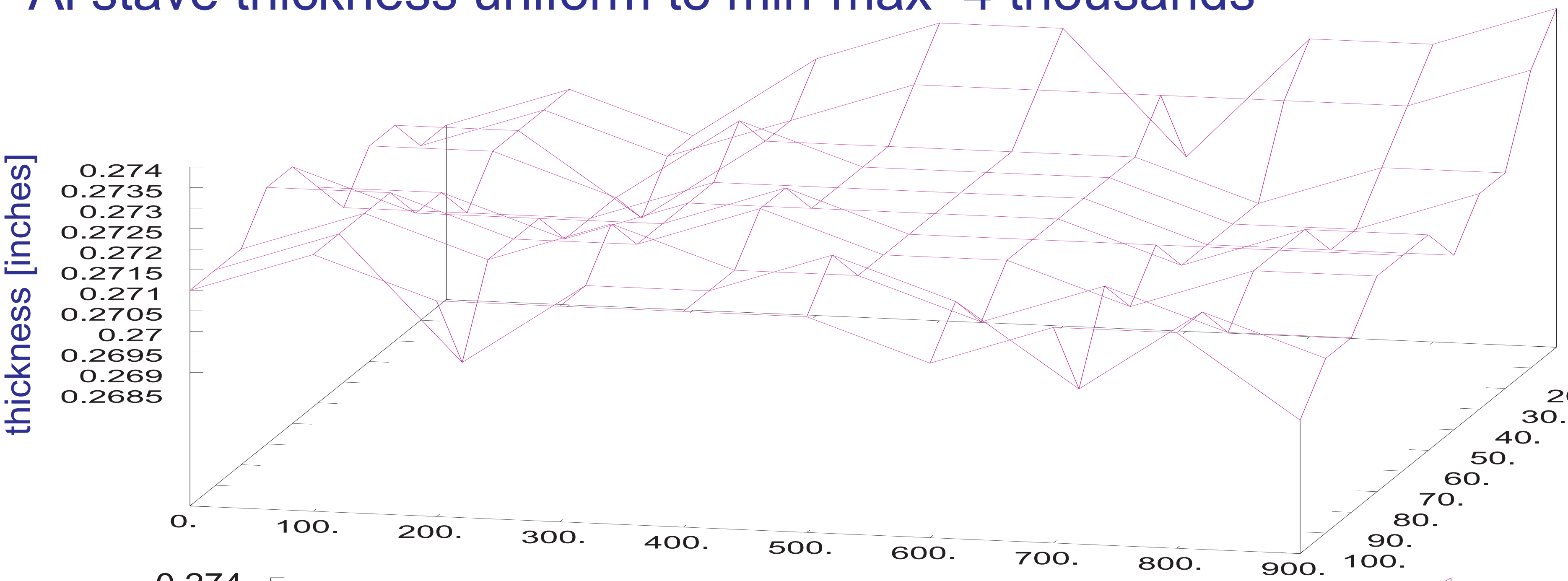


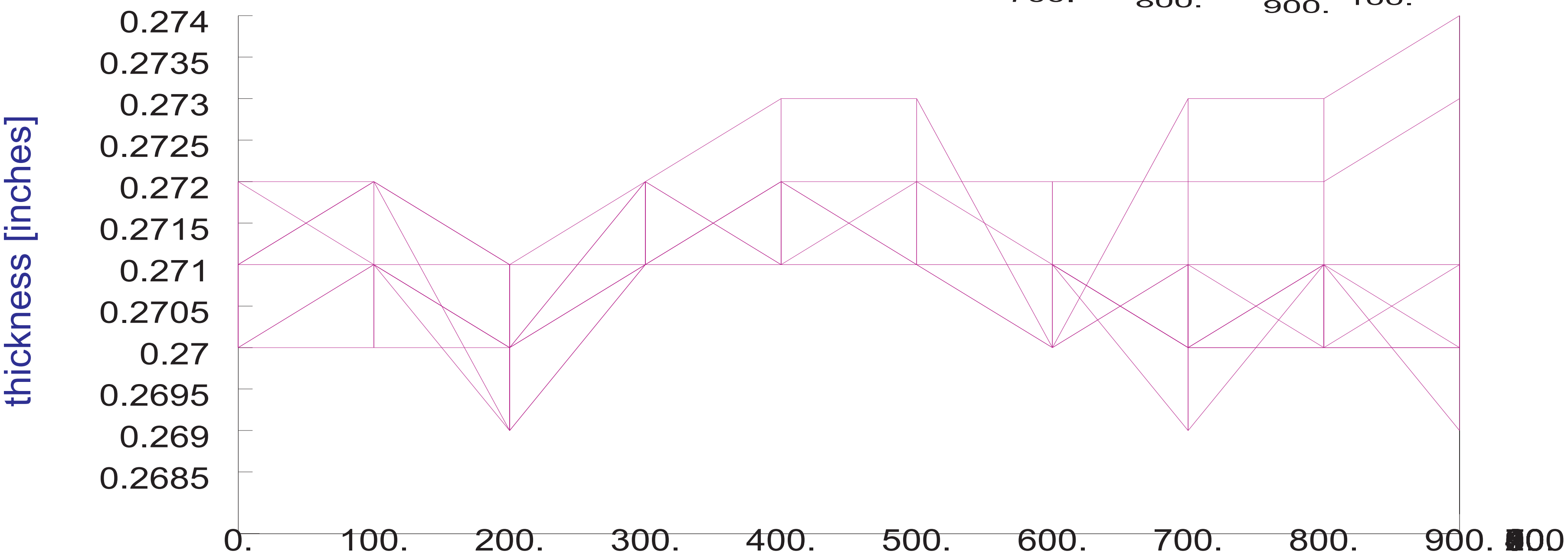
Purpose:

- Refine assembly technique
- Use for end-insertion tests

Some Current Work – BNL

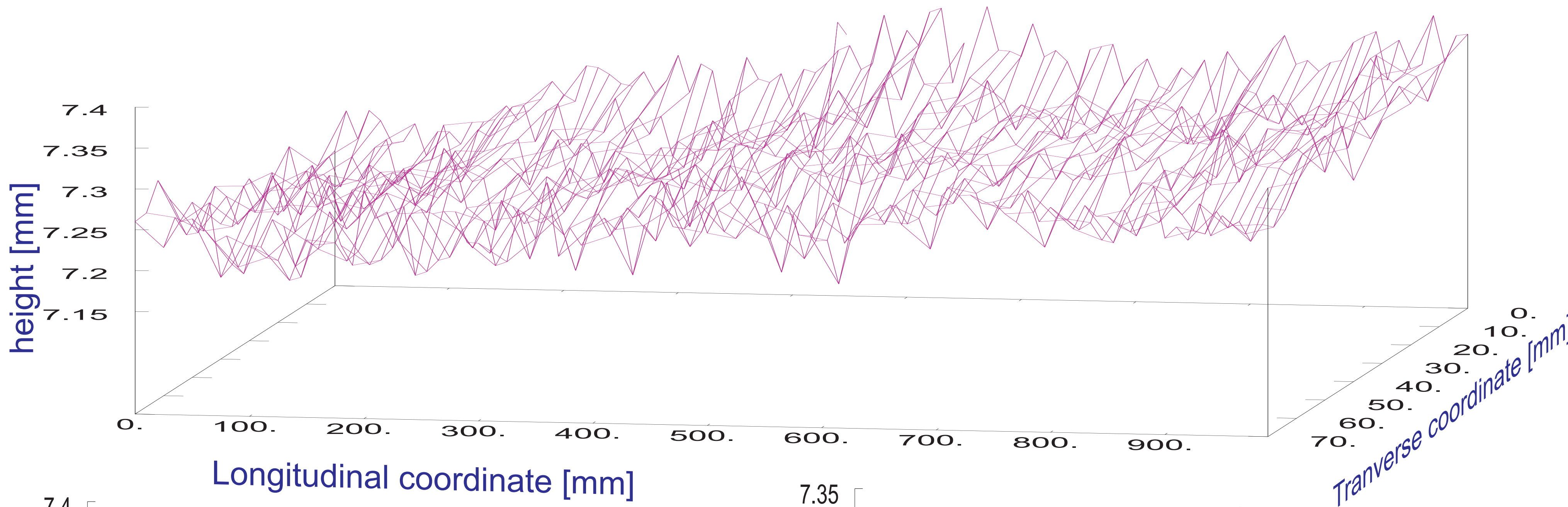
Al stave thickness uniform to min-max=4 thousands

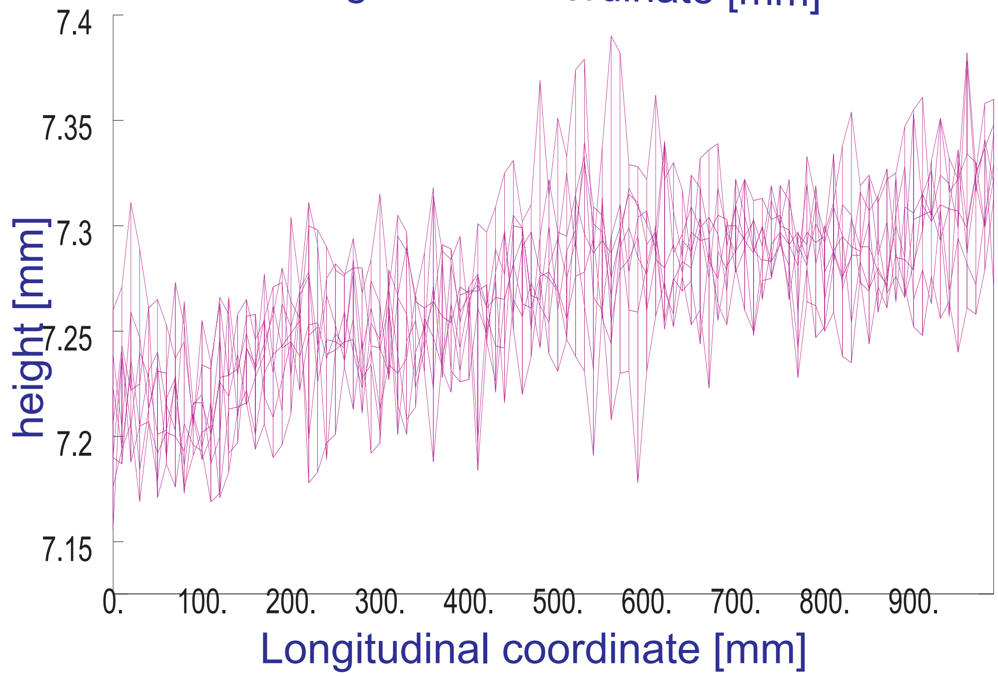


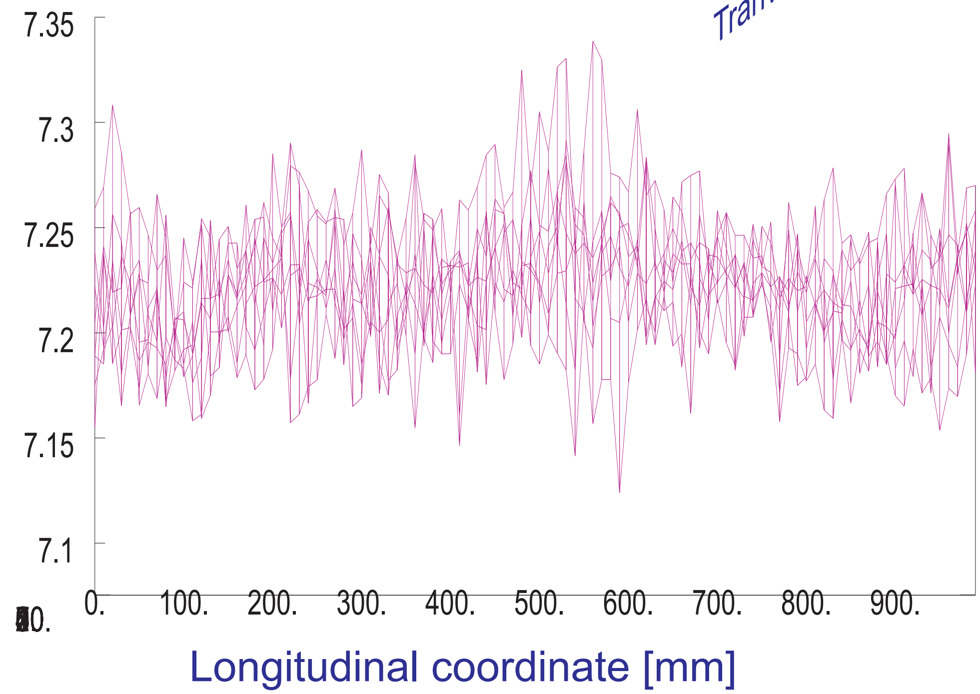


Some Current Work – BNL

Stave flatness rms=30 um, Min-Max=215 um







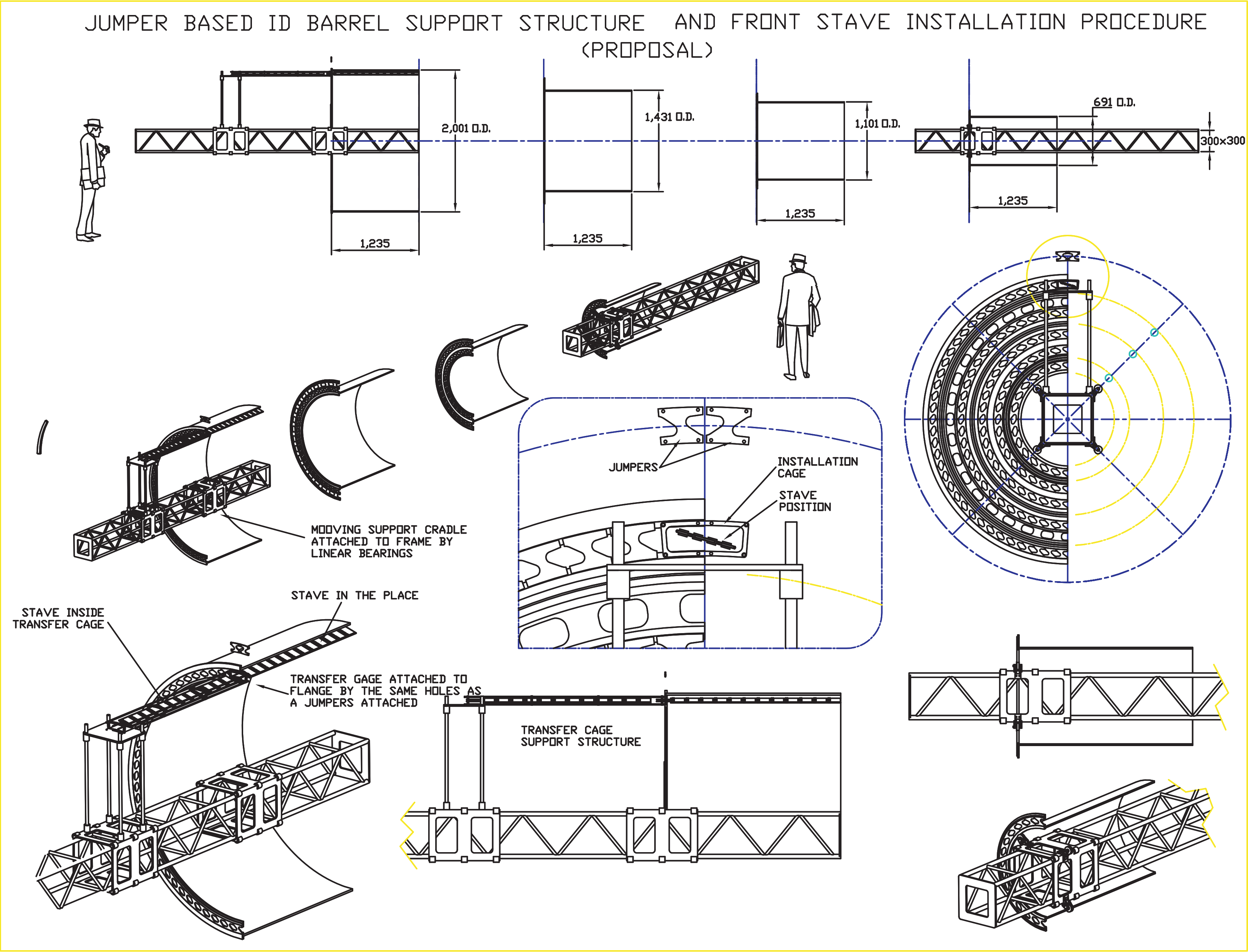
End Insertion Bracket

Recently prototyped in thermoplastic one version of bracket (lacked sufficient stiffness)

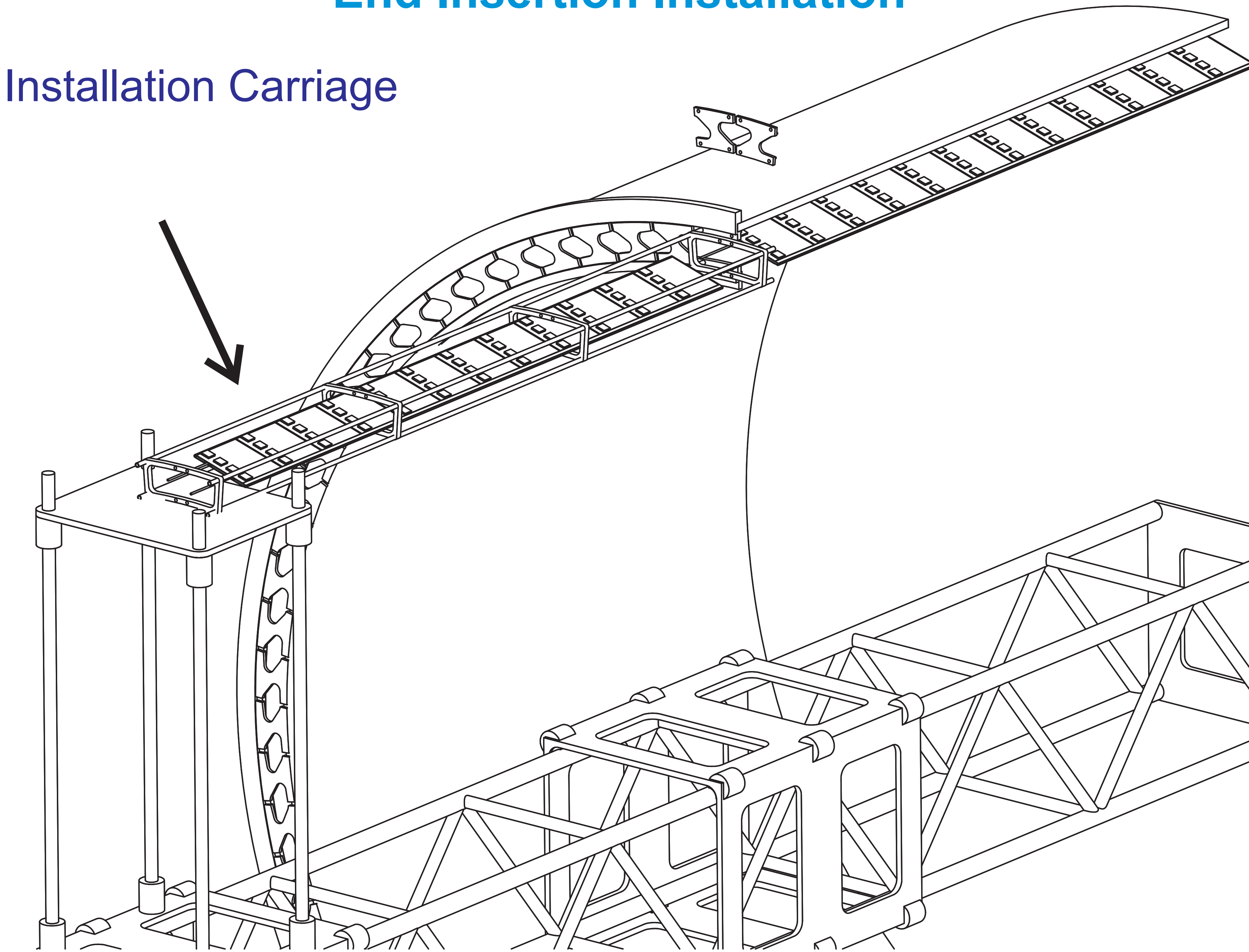
Version below is being designed for sufficient stiffness in thermoplastic (Gordeev). Will be used with existing long stave at BNL

Like to prototype in carbon fiber for long stave 1

End Insertion Installation



End Insertion Installation



Stave Prototyping--Schedule

Sept 08	Composite Staves 0 and 00	
Oct Nov 08	Short Staves 1-2	Need dummy silicon, bus cable, heaters
Mar-Apri 09	Long Stave 1	Need preferred facings, closeouts-end insertion
Aug 09	Long Stave 2	Could be used with real modules

Above schedule is my own first pass and needs discussion, agreement.

Note that in Allport's MIWG schedule, a short stave is fabricated by Jan 09, and a long stave suitable for module mounting is ready in May 2010.