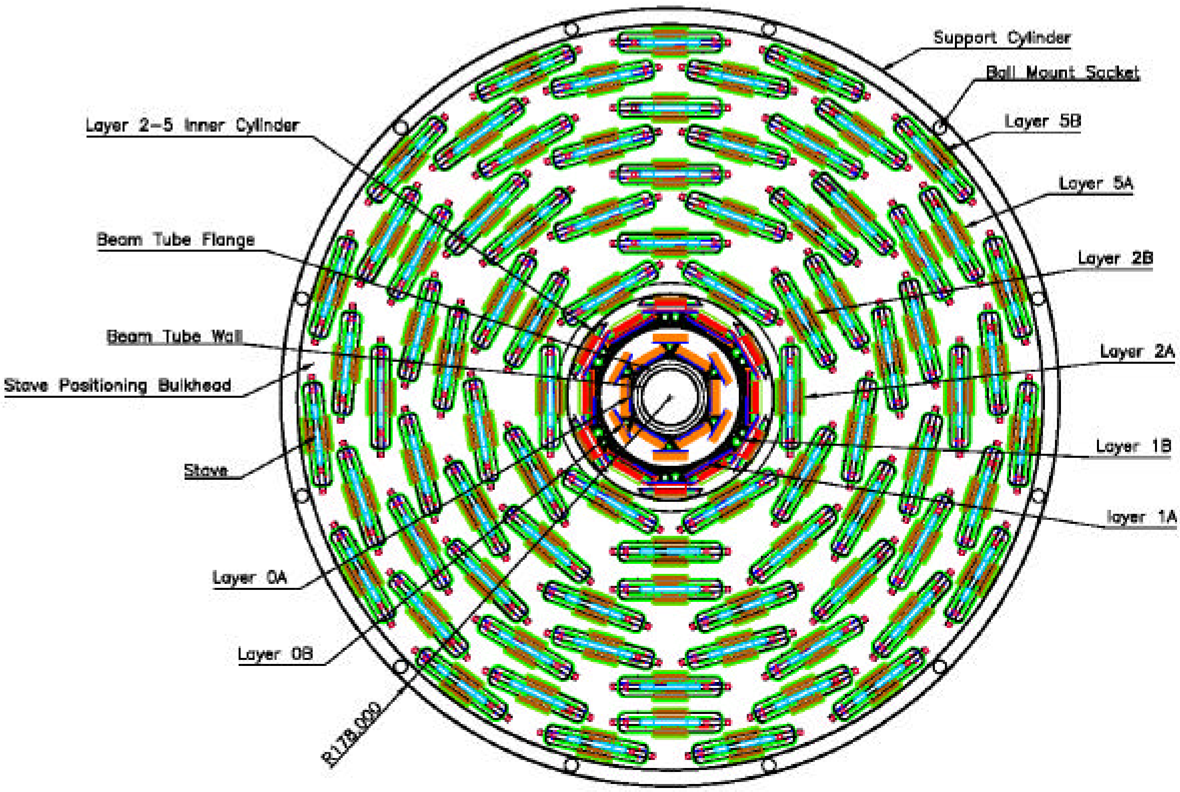
Run 2b Silicon Mechanical Design and Progress

Bill Cooper
April 16, 2002

Outline

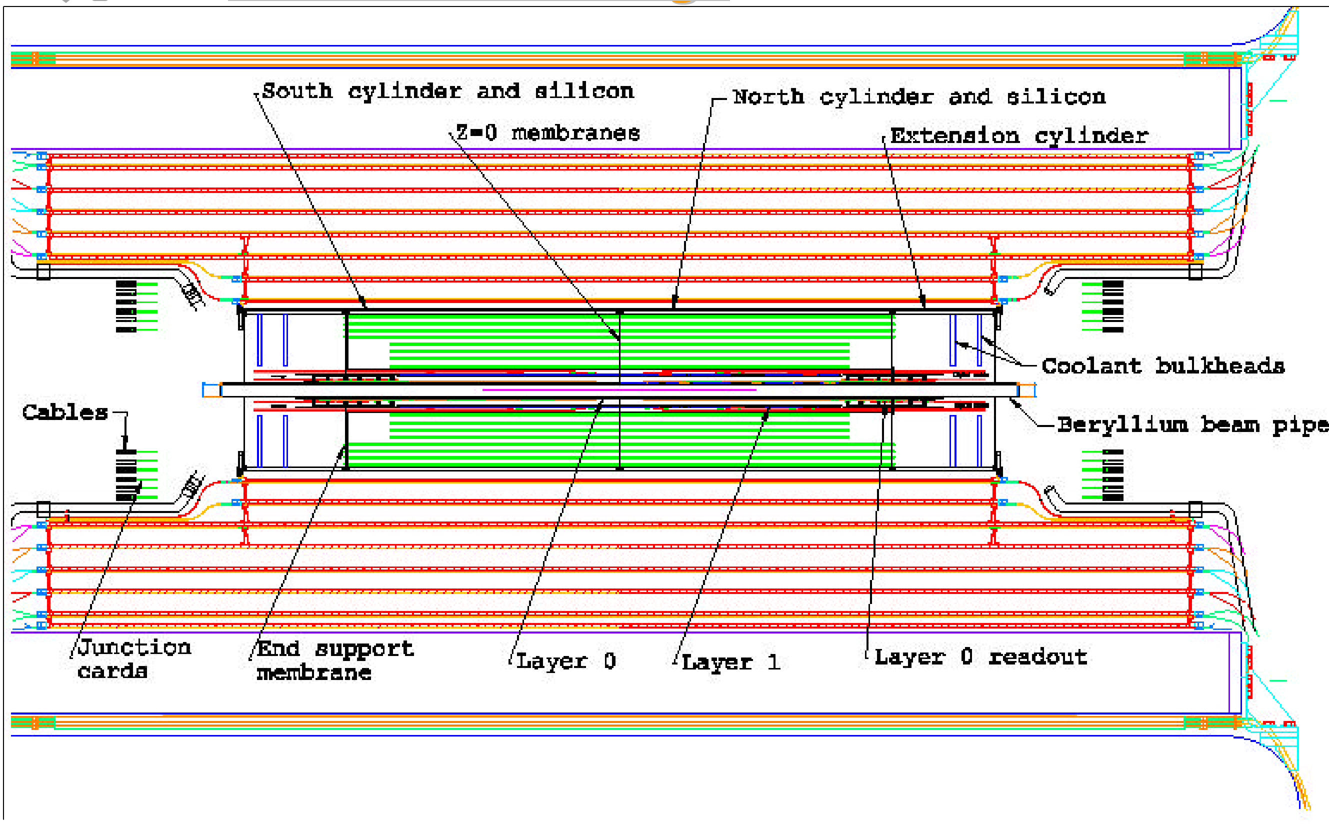
- Overview of design
- Sensors
- Layers 0 and 1
- Layers 2 through 5
- Recent progress
  - Material studies
  - Designs
  - Prototyping
  - Beam tube
- Mechanical tasks
- Resources: people
- Summary

Overview of design



- Identical north and south assemblies are mated at z = 0.
- Each assembly comprises six layer radial layers.
- Layers 0 and 1 are assembled separately and then joined into an inner silicon assembly.
- Outer layers 2-5 are assembled as a unit.
- Radial and azimuthal positions have been chosen to ensure adequate overlap between sensors of a layer.
- The outer radius of the support structure is 178 mm.

Overview of design



- Populated lengths
  - Layers 0-1: 96 cm
  - Layers 2-3: 100 cm
  - Layers 4-5: 120 cm
- North and south support structures are aligned at SiDet before silicon installation. They will be joined into a single unit during installation at D0.
- Extension cylinders connect the main cylinders to the ends of fiber tracker barrel 1.
- Reproducible ball mounts join cylinder sections.

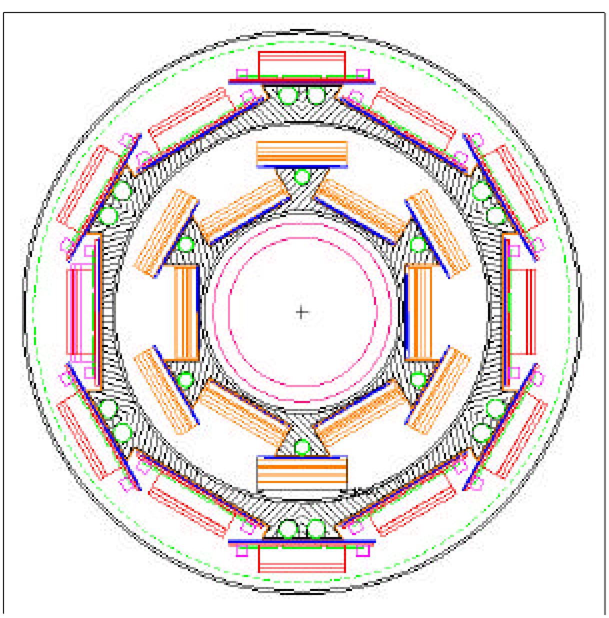
Sensors

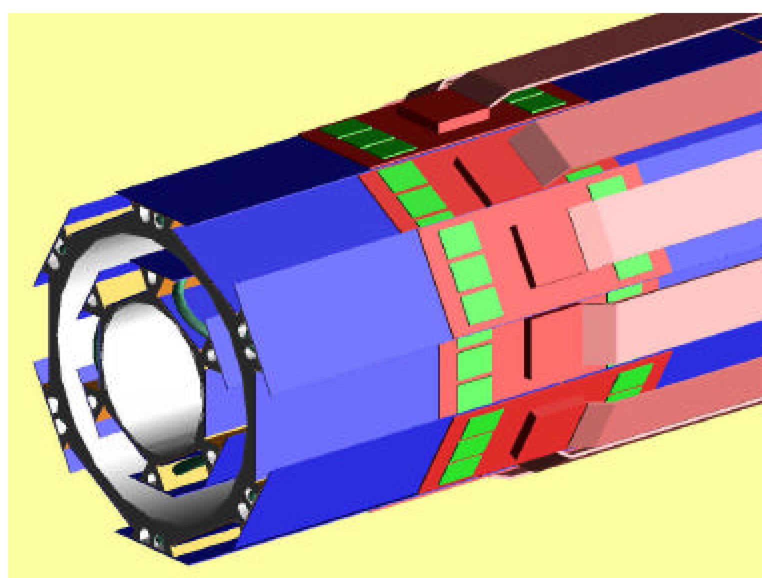
Three types:

- Layer 0:
  - 2-chip wide x 79.4 mm long sensors
  - 25 µm trace pitch, 50 µm readout pitch
  - Hybrids at the end of silicon region
  - Two SVX chips per sensor
  - Axial readout only
  - Design will be based upon modification of that of Layer 1
- Layer 1:
  - 3-chip wide x 79.4 mm long sensors
  - 29 µm trace pitch, 58 µm readout pitch
  - Hybrids on-board
  - 6-chip hybrid readout services two sensors
  - Axial readout only
  - Design complete
- Layers 2 through 5:
  - 5-chip wide x 100 mm long sensors
  - 30 µm trace pitch, 60 µm readout pitch
  - Hybrids on-board
  - 10-chip hybrid readout services two to four sensors
  - Axial and small angle stereo readout
    - Sensors are rotated to obtain the stereo angles
  - Design complete except for vendor-specific features

Layers 0 and 1

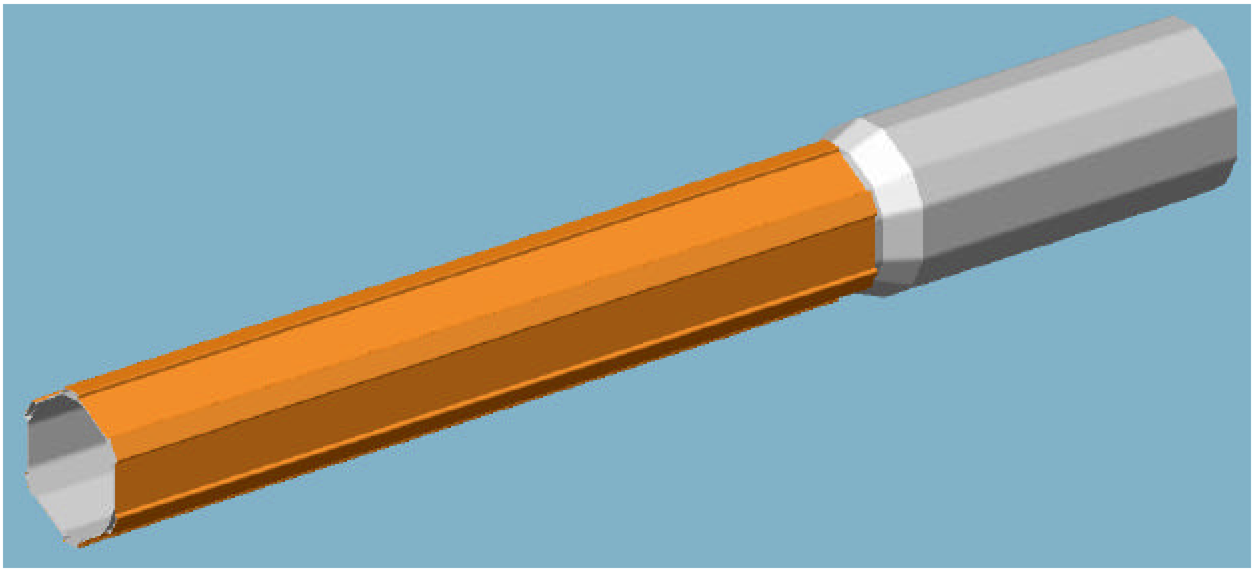
- Sensors at twelve azimuthal positions and two radii for each layer
- Support is via carbon fiber reinforced epoxy cylinders
- The outer cylinder of each layer is castellated to provide the two radii
- The inner cylinder is either round or hexagonal
- Support for the cylinders is at z = 0 and z = 61 cm
- The hybrids at the end of layer 0 are cooled with liquid
- Gas cooling is under investigation for the layer 0 sensors
- Liquid cooling will be used for layer 1 sensors and their on-board hybrids

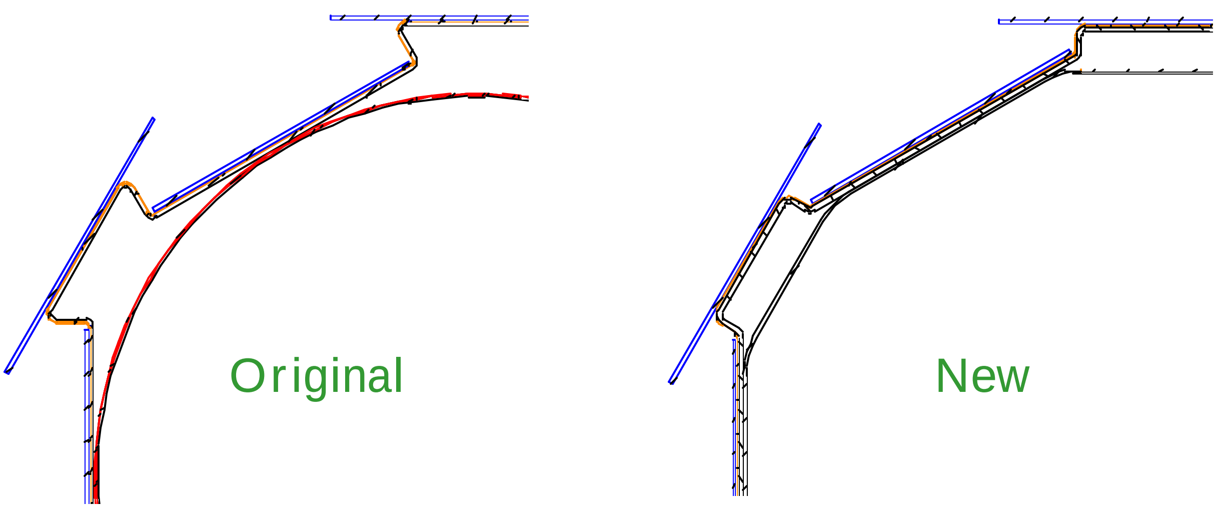




Layers 0 and 1

- Layer 1 support with "hexagonal" inner cylinder

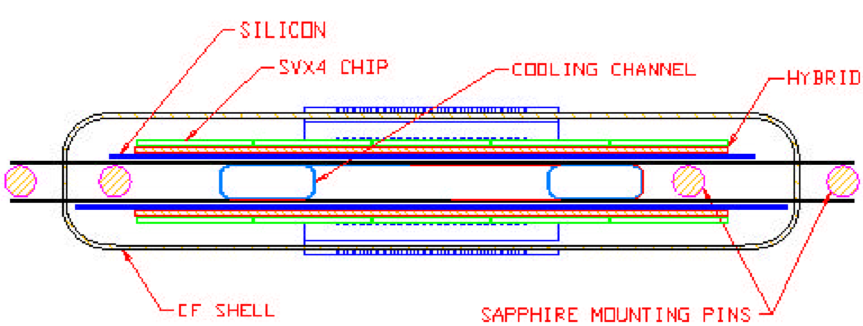




Layers 2-5

- 12, 18, 24 and 30-fold geometry

- Staves
  - Readout modules are assembled into staves
  - Staves are populated with five sensors in layers 2-3 and six sensors in layers 4-5.
  - Staves are positioned by and supported from bulkheads at z = 0 and z = 600 mm
  - Each stave carries axial sensors on one surface of cooling tubes and small angle stereo sensors on the other



Kurt Krempetz,
Dave Butler, Lab 8

Recent Mechanical Progress

- Material studies
  - Carbon fiber
    - D0 has substantial experience with carbon fiber gained from its use in Run 2a structures (silicon support structures, fiber tracker cylinders).
    - Material studies specific to higher modulus fiber for Run 2b are essentially complete.
  - Radiation hardness
    - Studies have been completed of the radiation hardness of candidate tubing and epoxies for Run 2b.
- Designs
  - Mechanical designs integrating sensors with their readout structures have been completed for all layers
  - Sensor designs are ready for submission to potential vendors
    - Fabrication is ready to begin on layer 1 prototypes
  - Hybrid mechanical designs have been completed for all layers
    - Fabrication of Layer 1 prototypes is nearly complete
  - Cooling and dry gas systems will be based upon those of Run 2a, which have performed well.
- Prototyping
  - Layer 0 castellated cylinders have been fabricated and are good.
  - Successful prototypes of stave components (support structures and cooling tubes) have been built to test each of two Layer 2-5 stave designs. It appears that either design would work.
  - The choice between the two designs will be based upon grounding and shielding requirements, cooling and structural performance, and manufacturability.

Recent Progress: Material Studies

- Unidirectional properties of cured K13C carbon fiber prepreg have been measured by the University of Washington and used to predict the properties of multi-layer lay-ups. The agreement of predictions with measurements was excellent.

Summary of Measured Unidirectional Properties and Predictions for a $[0/20/-20]_s$ Laminate

- Summary of measured unidirectional properties:
  - $E_1 = 59.5$ Msi $\nu_{12} = 0.39$
  - $E_2 = 0.806$ Msi $G_{12} = 0.595$ Msi
- Predicted properties for a $[0/20/-20]_s$ laminate:
  - $E_x = 38.4$ Msi $\nu_{xy} = 3.0$
  - $E_y = 1.08$ Msi $G_{xy} = 4.55$ Msi

Summary of Measured and Predicted Material Properties for K13C2U/Epoxy Prepreg

- Unidirectional Properties (measured):

E_{11} (GPa)	E_{22} (GPa)	ν_{12}	G_{12} (GPa)	α_{11} (μm/m-°C)	α_{22} (μm/m-°C)
410	5.6	0.39	4.1	-3.7	38.0

- $[0/20/-20]_s$ laminate:

	E_{xx} (GPa)	E_{yy} (GPa)	ν_{xy}	G_{xy} (GPa)	α_{xx} (μm/m-°C)	α_{yy} (μm/m-°C)
Predicted	265	7.45	3.0	31.4	-5.9	24.7
Measured	301		3.1		-5.5	25.4

- $[0/90/0]_T$ laminate (predicted):

E_{xx} (GPa)	E_{yy} (GPa)	ν_{xy}	G_{xy} (GPa)	α_{xx} (μm/m-°C)	α_{yy} (μm/m-°C)
276	141	0.015	4.1	-3.3	-2.5

Recent Progress: Material Studies

- Photomicroscopy examinations were made of the carbon fiber of castellated cylinders to understand whether voids or fiber breakage were significant.
  - Void fraction was acceptable.
  - Fiber breakage was negligible.
- Measurements were made of cylinder dimensions relative to the dimensions of mandrels on which the cylinders were made. The measurements will allow fine-tuning of mandrel dimensions.
- The use of an autoclave was implemented as part of the cylinder fabrication process and led to good results.
- A small (~1.5" x 2") sample of TPG laminated as the outer layer of a carbon fiber coupon had been prepared. This is under consideration as an alternative to carbon foam for heat transfer to the cooling tubes. The TPG came from Panasonic's US representative, Digikey. It is supposed to be listed as a normal item in their catalogue starting this May.

Recent Progress: Material Studies

- Through plane thermal conductivities of K13C and K139 carbon fiber reinforced epoxy were measured at Fermilab (Dan Olis).

Coupon Material	Cure Pressure	Sample No.	Measure-ment	Thickness [mm]	Conductivity [W/m-K]	Measure-ment Date
K13C	vacuum	1	a	1.943	**0.79**	12/21/01
K13C	vacuum	1	b	1.943	**0.82**	1/8/02
K13C	vacuum	2	a	1.006	**0.79**	12/26/01
K13C	vacuum	2	b	1.006	**0.80**	1/9/02
K13C	clamped	3		1.489	**1.94**	12/13/01
K139	vacuum	4	a	0.965	**0.81**	1/7/02
K139	vacuum	4	b	0.965	**0.82**	2/5/02
K139	vacuum	5	a	2.454	**0.64**	1/17/02
K139	vacuum	5	b	2.454	**0.64**	1/25/02
K139	vacuum	6		2.484	**0.59**	1/23/02
K139	clamped	7		1.692	**1.00**	1/18/02

Recent Progress: Material Studies

Radiation hardness tests: tubing

Radiation Hardness Test of Plastic Tubes Pressurized to Failure
Samples Irradiated to 18 Mrad

	Tyogon 2275 1/4 OD x 1/8 ID Bulge/burst press. [psi]		PEEK 1.58"ID x .004 wall Bulge/burst press. [psi]		Cilran 5/16 OD x 3/16 ID Bulge/burst press. [psi]	
	Control	18 MRad	Control	18 MRad	Control	18 MRad
	240	260	570	525*	52	54
	240	265	550	570	54	53
	240	265	520*	540	54.5	53
	240	270	560	555	51.5	55*
	240	265	600	530	55	52.5*
			625	530		44
AVG.	240	265	571	542	53	52

* Tubing burst or bulged at 'irradiated' region. All others failed at fittings.

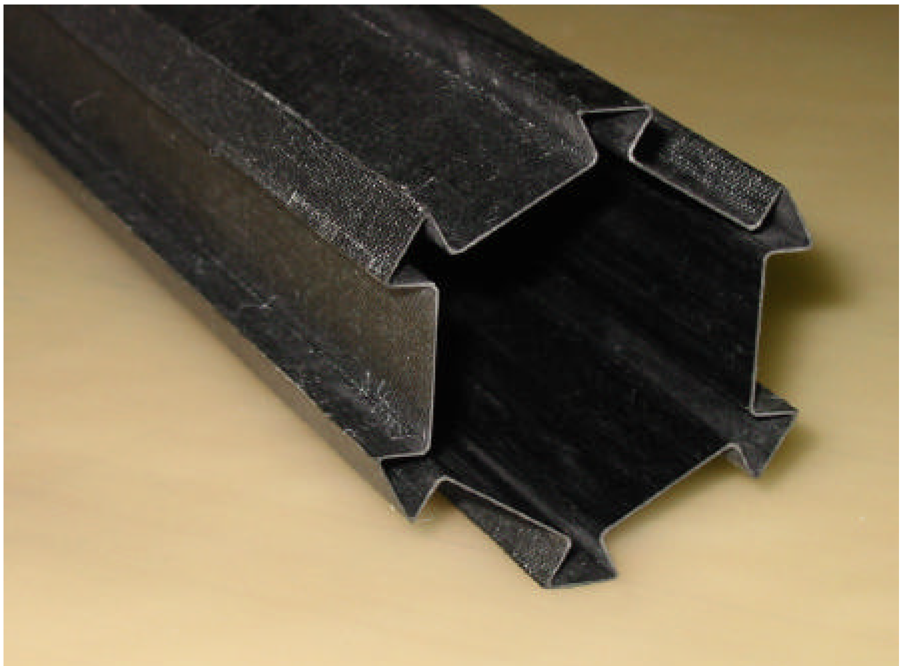
Radiation harness tests: adhesives

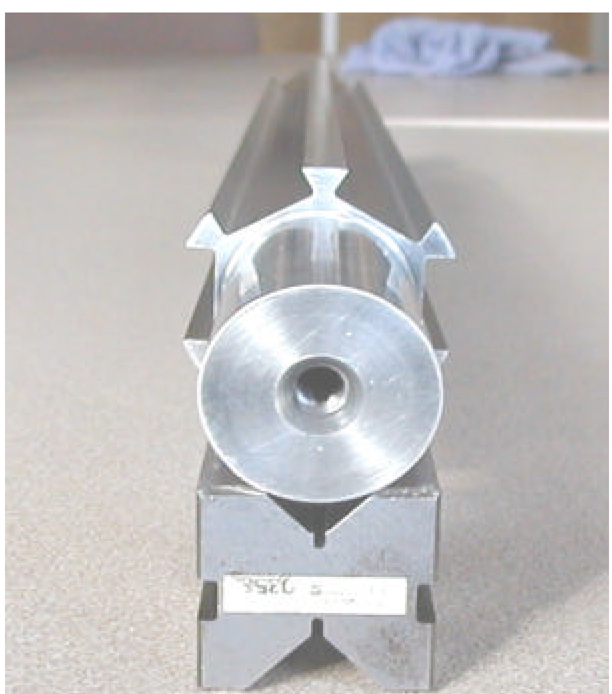
Radiation Hardness Test of Adhesives in Overlap Shear
Samples Irradiated to 18 Mrad

	3M DP110 Epoxy				Epolite 5313 with Epicure 3234				EPO-TEK H20E Epoxy (thermally cond.)			
	Control		18 MRad Irradiation		Control		18 MRad Irradiation		Control		18 MRad Irradiation	
	Disp. [in]	Force [lb]		Force [lb]	Disp. [in]	Force [lb]	Disp. [in]	Force [lb]	Disp. [in]	Force [lb]	Disp. [in]	Force [lb]
	0.107	601	0.119	598	0.001	478	0.101	602	0.075	357	0.069	353
	0.094	530	0.098	479	0.109	623	0.108	681	0.065	356	0.065	349
	0.084	463	0.128	811	0.100	572	0.110	627	0.071	326	0.062	329
	0.136	924	0.133	850	0.092	492	0.106	648	0.067	323	0.081	363
	0.122	805	0.106	508	0.073	342	0.104	609	0.070	341	0.070	353
	0.128	863			0.065	335			0.079	349		
average ->	0.112	698	0.117	649	0.073	474	0.106	633	0.071	342	0.069	349

Recent Progress: Prototyping

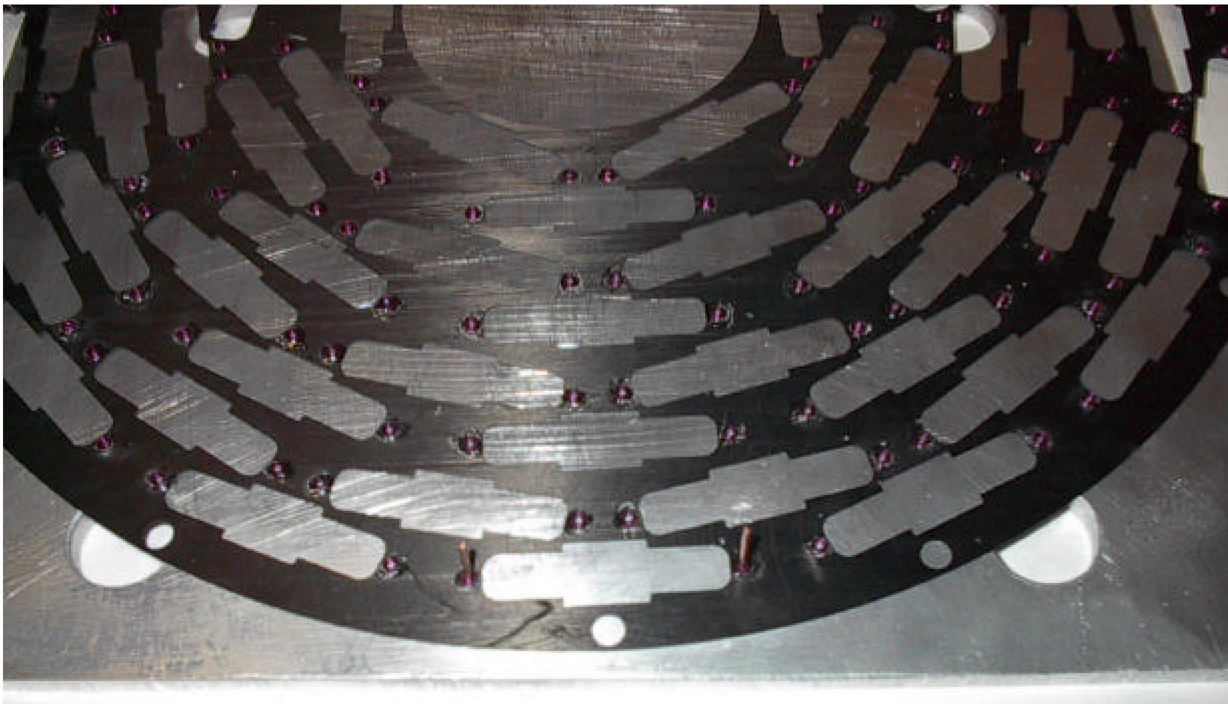
- Prototype L0 castellated cylinder and fabrication mandrel



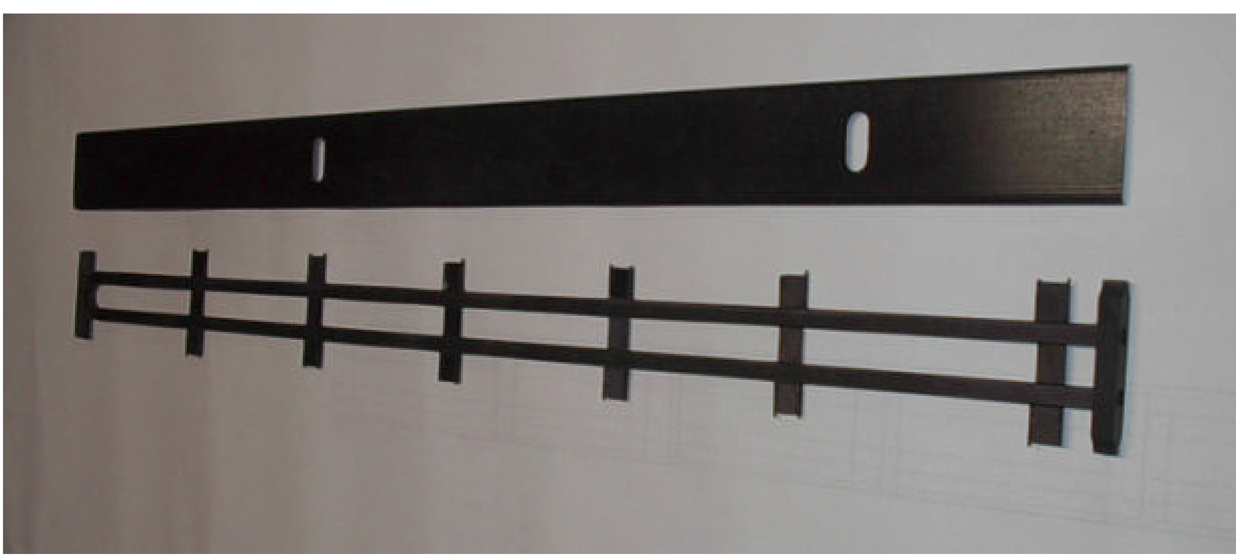


Recent Progress: Prototyping

- Positioning bearings glued to carbon fiber bulkhead



- Stave cover and cooling tubes



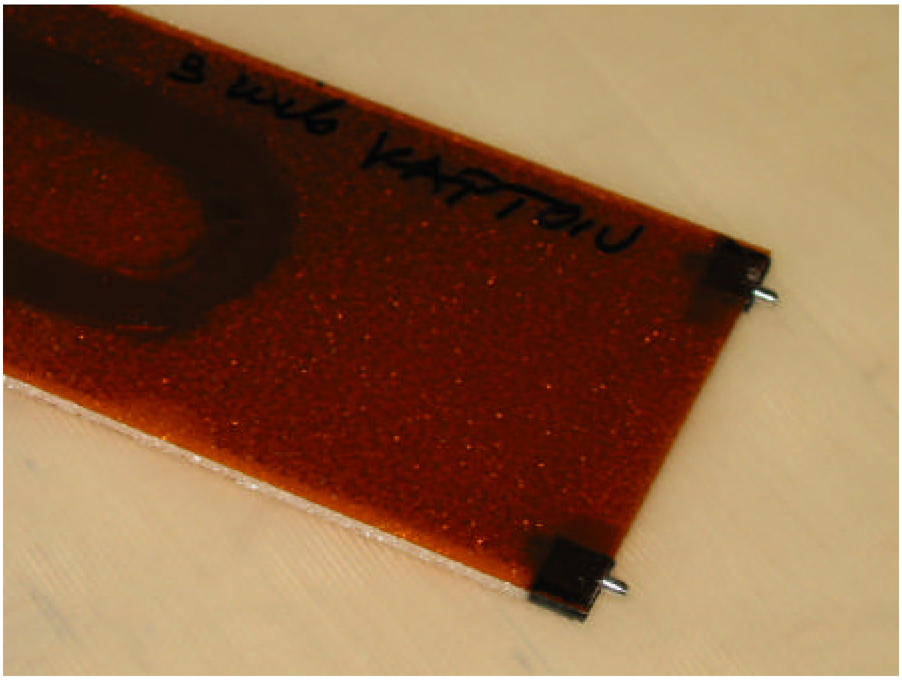
Recent Progress: Prototyping

- Bend in formed PEEK tubing

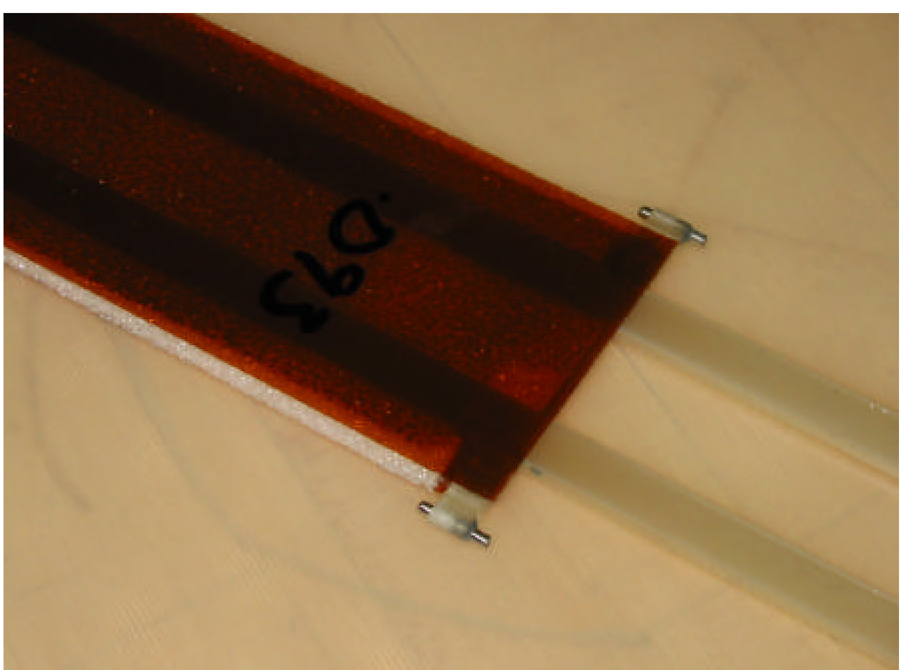
- Bend in molded carbon fiber tube

Recent Progress: Prototyping

- Z = 0 end of dummy stave core with PEEK tubing



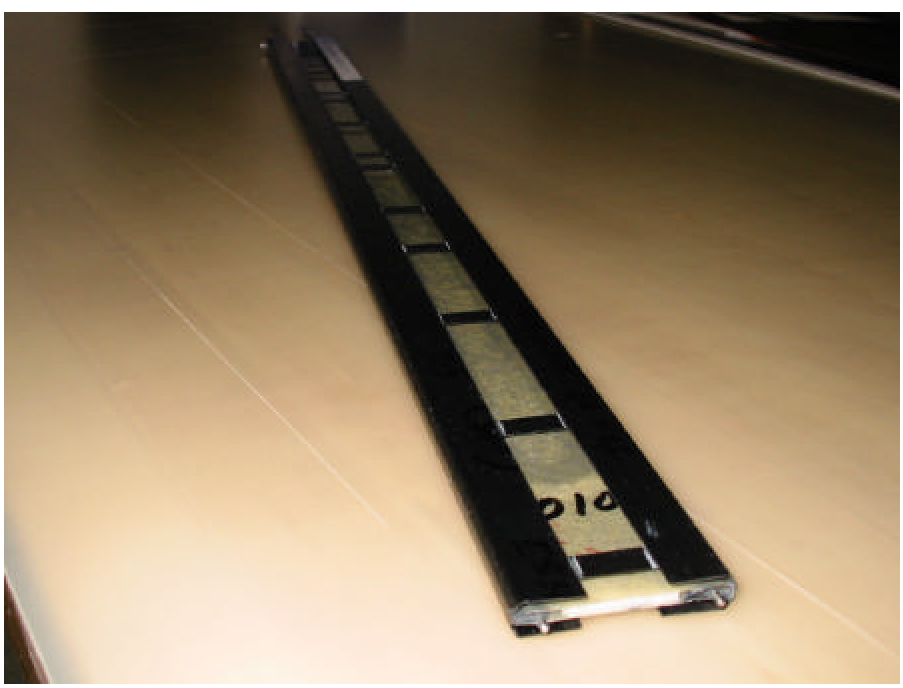
- Outer end of dummy stave core with PEEK tubing



Recent Progress: Prototyping

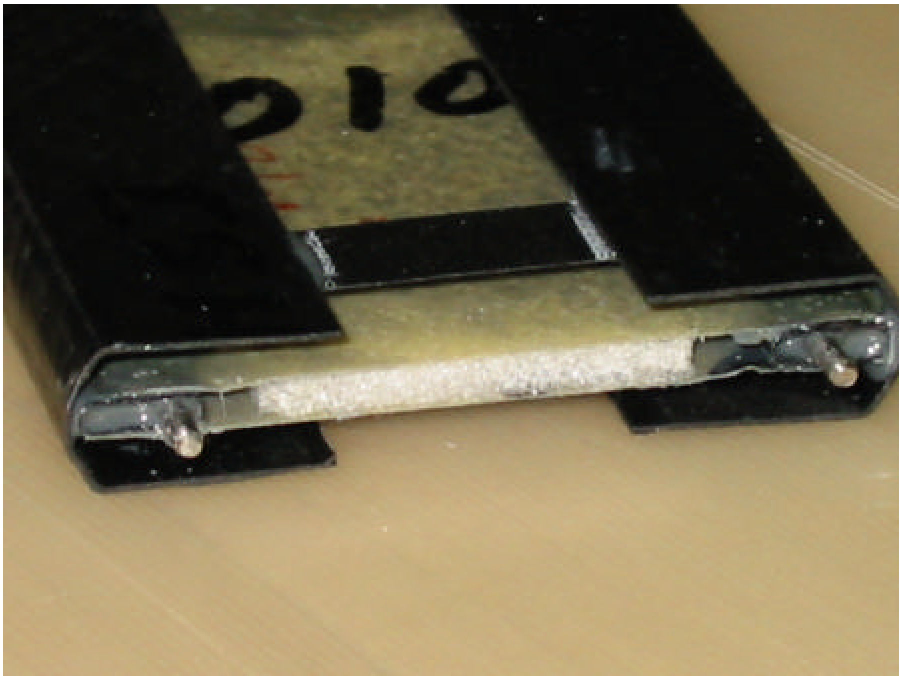
- C-channel to provide stave stiffness

- Completed dummy stave support structure

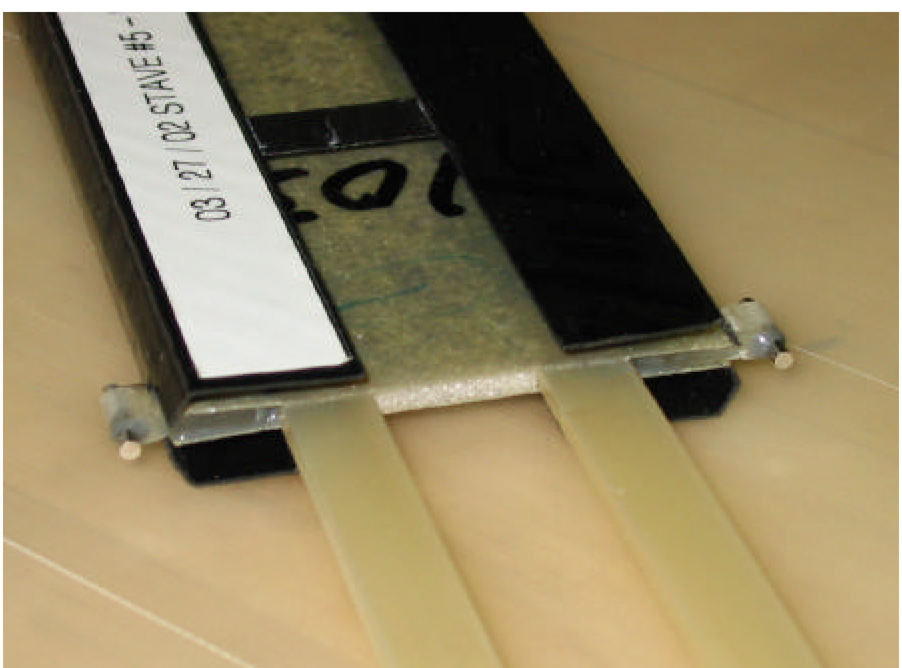


Recent Progress: Prototyping

- Inner end of dummy C-channel stave

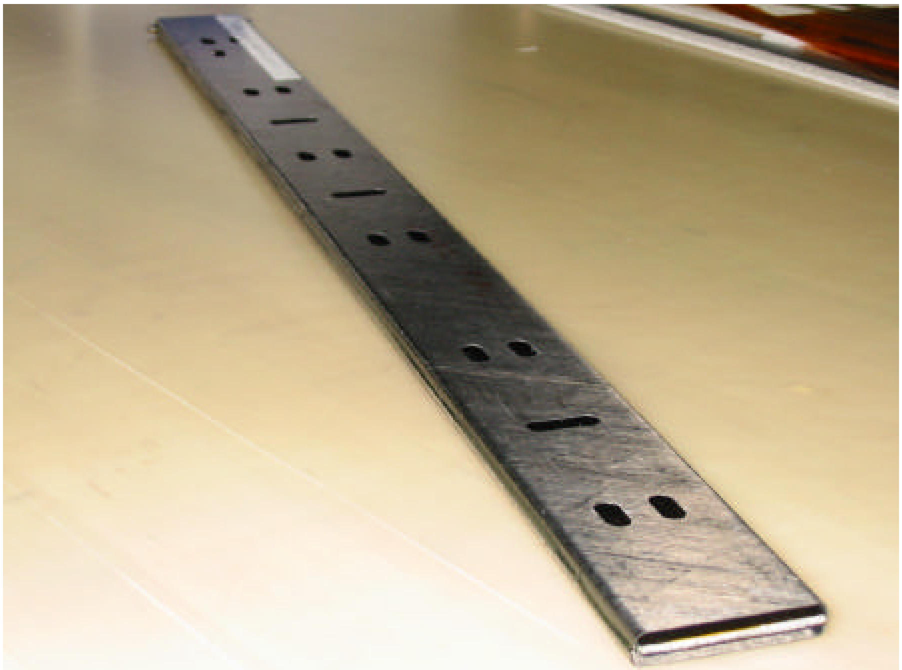


- Outer end of dummy C-channel stave

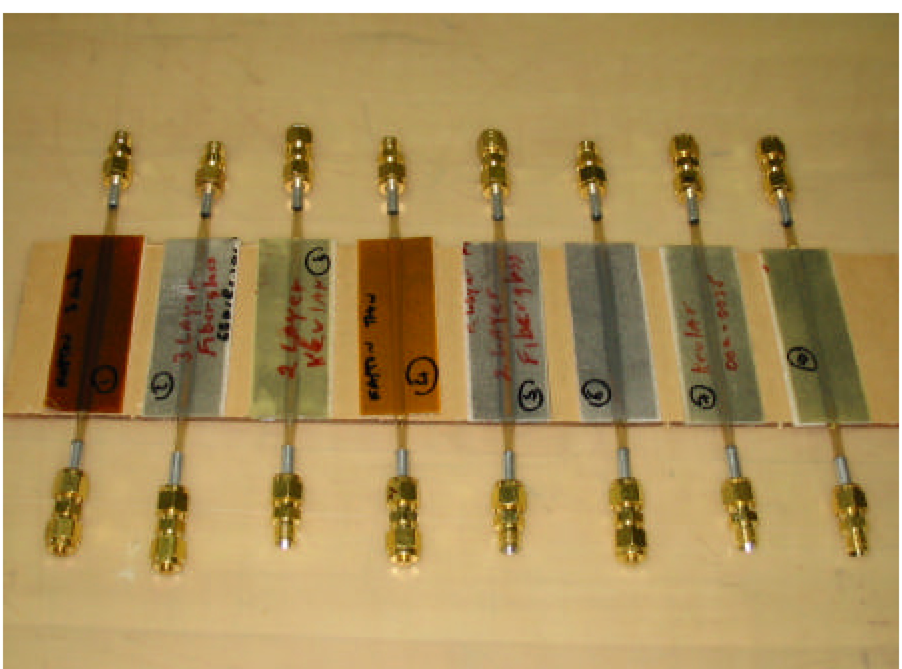


Recent Progress: Prototyping

- Dummy stave support structure with cover



- Test samples to study stiffening of PEEK tubing against collapse



Recent Progress: Beam Tube

- Order placed with BrushWellman Electrofusion 3/26/02.
- Cost = $98672. A 15% discount will apply to that if CDF orders a pipe utilizing the same construction within the 180 day period of quote validity.
  - Run 2a cost was $110487
- Quoted delivery = 36 weeks ARO.
  - Run 2a procurement through acceptance duration was 78 weeks.
- Requisitions for coupling parts and flanges (which Fermilab is to supply) were submitted 3/28/02.

Recent and Near-term Mechanical Tasks

- People have been matched with tasks.
- Most tasks have been completed on schedule.

Tasks through 6/02

						WBS	Start	Finish
1		Complete beam tube coupling design	Krempetz	Cooper		1.1.3.1.1	9/4/01	4/12/02
2		Material R&D in conjunction with L0 and L1				1.1.3.2.1.1.2.1	8/6/01	1/18/02
		structures	UW			1.1.3.2.1.3.2.1	8/6/01	12/12/01
	a	K13C	UW	Fast				
	b	Thinner carbon fiber	UW	Krempetz				
	c	TPG	UW					
	d	Thermal conductivity	UW	Olis				
	e	Other material R&D	UW					
3		L0 structures						
	a	Design sensor supports	UW			1.1.3.2.1.1.2.2	1/21/02	4/19/02
	b	Design support fabrication tooling	UW			1.1.3.2.1.1.2.3	4/22/02	7/23/02
	c	Design cooling tubes and connections	UW	Krempetz	Cooper	1.1.3.2.1.1.2.4	3/25/02	4/19/02
	d	Design support of readout	UW	Krempetz	Jostlein	1.1.3.2.1.1.2.5	2/11/02	4/19/02
	e	Design connection to L1	UW	Krempetz	Fast	1.1.3.2.1.1.2.6	4/22/02	7/1/02
4		L1 structures						
	a	Design sensor supports	UW			1.1.3.2.1.3.2.2	12/13/01	3/22/02
	b	Design support fabrication tooling	UW			1.1.3.2.1.3.2.3	3/25/02	6/24/02
	c	Design cooling tubes	UW	Krempetz	Lanfranco	1.1.3.2.1.3.2.4	2/25/02	3/22/02
	d	Design cooling tube connections	UW	Olis		1.1.3.2.1.3.2.5	1/14/02	3/22/02
	e	Design connection to L2	UW	Krempetz		1.1.3.2.1.3.2.6	3/25/02	5/24/02
	f	Procure prototype fabrication fixtures	UW			1.1.3.2.1.3.2.7	5/28/02	8/20/02
	g	Prototype connection to layer 2	UW			1.1.3.2.1.3.2.11	3/25/02	4/19/02
5		L2-L5 readout module fixtures						
	a	Design fixtures	Fast			1.1.3.2.5.1.2	3/4/02	5/24/02
	b	Procure initial layer 2-5 readout module fixtures	Fast	McConologue		1.1.3.2.5.1.3	5/28/02	8/20/02
6		L2-L5 stave cores						
	a	Design cooling tubes	Lanfranco	Krempetz	Fast	1.1.3.2.5.2.4.1.1	11/1/01	2/5/02
	b	Conduct cooling analyses and tests	Lanfranco	Olis	Schultz	1.1.3.2.5.2.4.1.2	2/6/02	4/2/02
	c	Obtain chiller	Fast	Demarteau				
	d	Set up system for cooling test	Lanfranco	Olis	Schultz			
	e	Design stave hybrid mounting	Fast	Krempetz		1.1.3.2.5.2.4.1.3	3/4/02	4/12/02
	f	Design stave core fiducial and locating features	Fast	Krempetz		1.1.3.2.5.2.4.1.4	11/1/01	2/5/02
	g	Procure stave core prototype fixtures	Fast	Krempetz		1.1.3.2.5.2.4.1.5	2/6/02	4/30/02
	h	Procure carbon fiber prepreg and other materials for core prototypes	Fast	Krempetz	Cooper	1.1.3.2.5.2.4.1.6	1/9/02	4/30/02
	i	Fabricate core prototypes	Olis	Lanfranco		1.1.3.2.5.2.4.1.7	5/1/02	5/29/02
	j	Design and procure stave core QC fixtures	Olis	Krempetz		1.1.3.2.5.2.4.1.8	4/17/02	5/29/02
	k	QC prototype stave cores				1.1.3.2.5.2.4.1.9	5/30/02	6/12/02
	l	Conduct cooling tests	Olis	Lanfranco	Schultz	1.1.3.2.5.2.4.1.10	6/13/02	6/26/02
7		L2-L5 stave core/hybrid modules						
	a	Design core/hybrid fabrication fixtures	Fast	Krempetz	Jostlein	1.1.3.2.5.2.5.1	4/15/02	7/9/02
8		L2-L5 stave shells						
	a	Design stave shells	Fast	Lanfranco		1.1.3.2.5.2.6.1	10/1/01	3/28/02
	b	Design and procure shell QC fixtures	Fast	Lanfranco		1.1.3.2.5.2.6.2	3/29/02	5/9/02
	c	Procure shell fabrication fixtures	Fast	Lanfranco		1.1.3.2.5.2.6.3	3/29/02	7/22/02
	d	Procure carbon fiber prepreg for shell prototypes	Krempetz	Fast	Cooper	1.1.3.2.5.2.6.4	3/29/02	7/22/02
	e	Procure carbon fiber prepreg for shells	Krempetz	Fast	Cooper	1.1.3.2.5.2.6.6	4/25/03	8/19/03
9		South support cylinder assembly						
	a	Prototype cylinder	Jostlein	Krempetz		1.1.3.8.1.1	4/15/02	7/9/02
	b	Prototype stave positioning bulkhead	Jostlein	Krempetz		1.1.3.8.1.2	4/15/02	5/24/02
	c	Prototype z = 0 membrane	Jostlein	Krempetz		1.1.3.8.1.3	5/28/02	6/24/02
	d	Prototype reproducible ball connections	Jostlein	Krempetz		1.1.3.8.1.4	4/15/02	5/24/02
10		South extension cylinder						
	a	Prototype z = 830 membrane	Jostlein	Krempetz		1.1.3.8.2.1	4/15/02	5/10/02
	b	Protoype mounts to CFT barrel 1	Jostlein	Krempetz		1.1.3.8.2.2	5/13/02	6/24/02
	c	Protoype reproducible ball connections	Jostlein	Krempetz		1.1.3.8.2.3	6/25/02	7/9/02
11		Support structures within CFT barrel 3						
	a	Design support structures	Cooper	Olis		1.1.3.9.1	6/17/02	8/12/02
12		Develop cable routing plan	(Nomerotski)			1.1.3.10	12/13/01	3/15/02

Other Mechanical Tasks

- Ongoing efforts
  - FEA
  - Hand calculations (thermal and mechanical performance)
  - Drawing preparation
- Mechanical support for other D0 Run 2b efforts
  - Sensors
  - Hybrids
  - Readout modules
  - Junction cards
  - Cables
- Future support tasks
  - Temperature monitoring (Rice)
  - Radiation monitoring (NIKHEF)

Resources for mechanical efforts: People

- Principal University of Washington physicists and engineers working on the Layer 0-1 design
  - Lubatti
  - Daly
  - Kuykendall
  - Tuttle
  - Wang
  - Zhao
- Principal Fermilab physicists, engineers, and designers working on the Layer 2-5 design and the overall mechanical design
  - Cooper
  - Fast
  - Jostlein
  - Kowalski
  - Krempetz
  - Lanfranco
  - Mateski
  - McConologue
  - (Nomerotski)
  - Olis
  - Schultz
- It's a good thing we can draw upon prior experience. The effort from a modest number of people is substantial.

Summary

- Excellent progress
- The overall geometry has been specified.
- Material studies necessary for the designs have been completed.
  - Studies of K13C for layers 0-1
  - Studies of K139 for layers 2-5 and other structures
  - Studies of radiation hardness of materials
- Successful prototypes have been made of:
  - Layer 0 cylinders
  - Layer 2-5 cooling tubes
  - Layer 2-5 stave cores
  - Layer 2-5 stave shells
- Mechanical designs have been completed sufficiently to allow procurement of prototype sensors, hybrids, and cables.
- Cooling studies continue for all layers.
- The beryllium beam pipe has been ordered.
- Most tasks have been completed on schedule.
- Fermilab support has been provided at the approximate levels promised. D0 is tracking progress carefully to help ensure that support will be adequate to maintain the schedule (OK so far, but some worries).