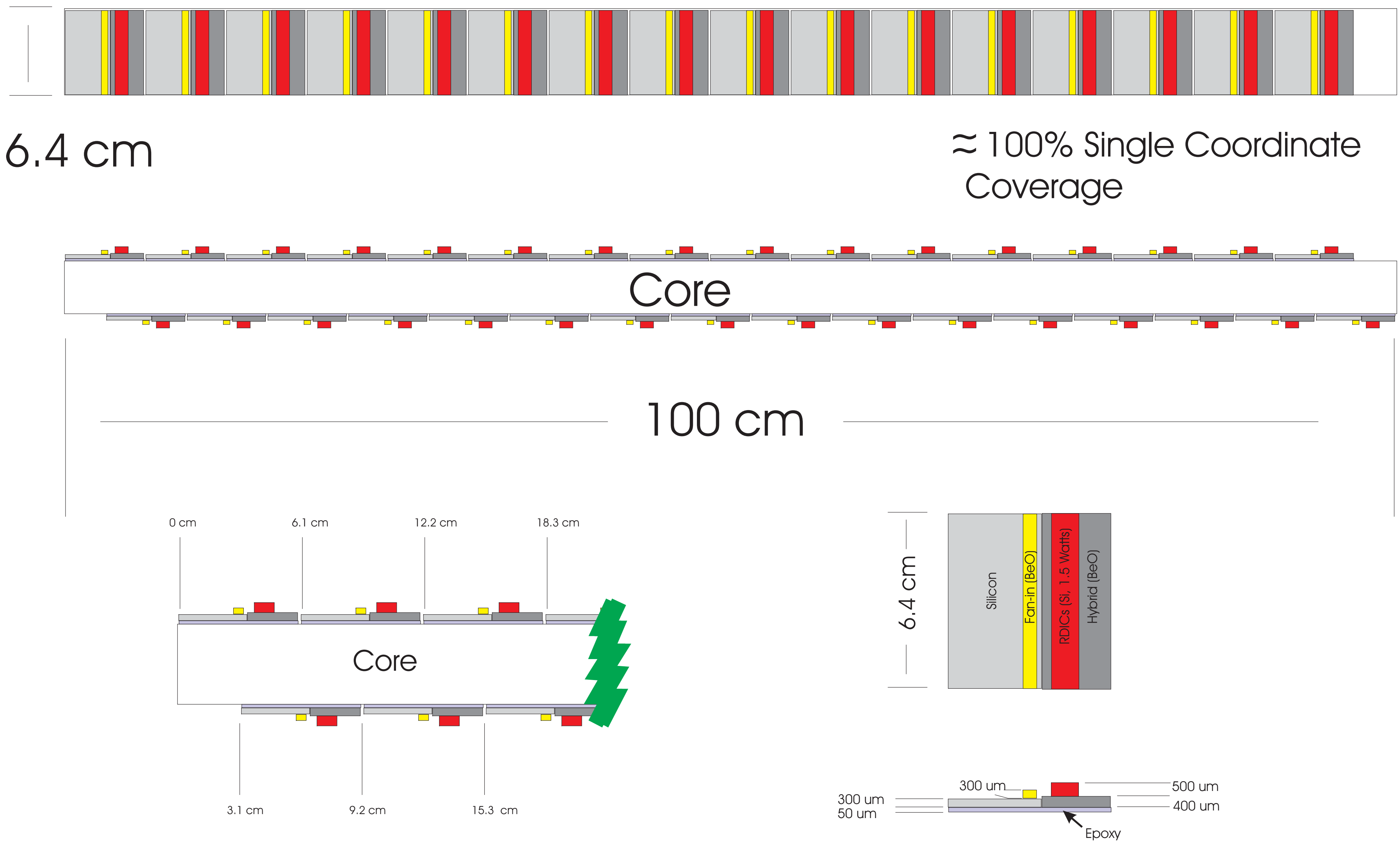
Short Strip Stave Issues

- Alternative Staves
- Radiation Length Issues
- Cooling
- Specifications

Emphasis on discussion and exhange of ideas

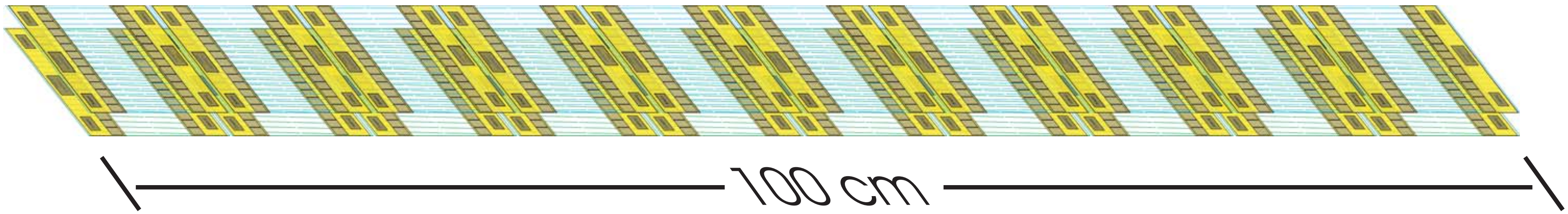
D. Lynn

1-d SS Stave Model

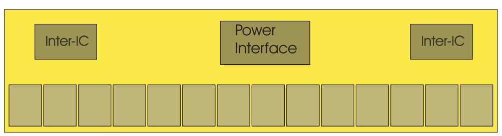


2-D SS Stave Model

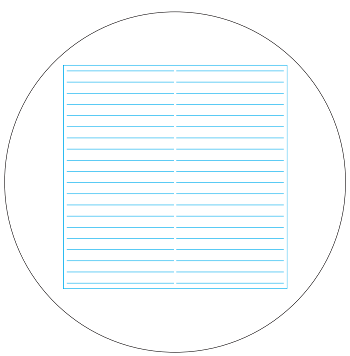
Reduce pitch to 50 um to increase strip length



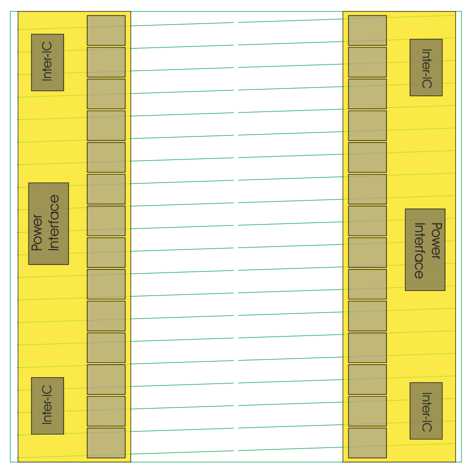
Hybrid



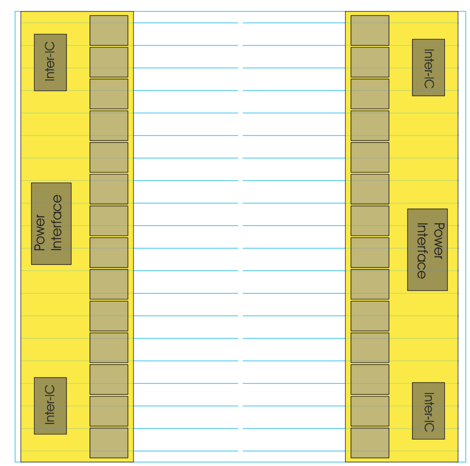
6” wafers, 10 x 10 cm detector,
4.9 cm long strips



U-Strip Module



Y-Strip Module



Rough Comparison 1d vs 2d

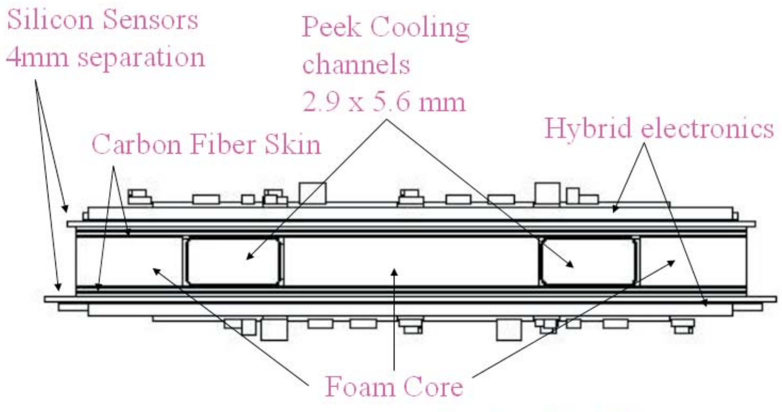
	1-d Stave	2-d Stave
Prob 1 hit	≈ 100%	>97%
Prob 2 hit	0%	>94%
Radiation Length	Less	More
Difficulty to Fab	Easier	Harder
σ_z	8.7 mm	↓ (see below)

*Amiquity based upon occupancy at R=24 cm

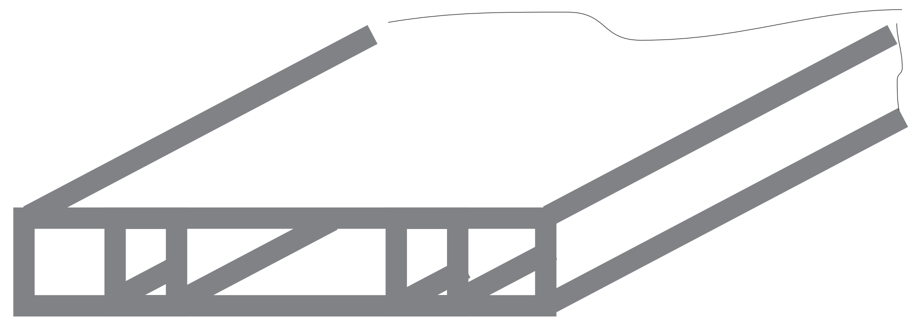
=> Would build 1-d if physics allows

θ [mRad]	σ_z [mm]	Ambiguity(%)*
40	0.7	56
20	1.4	28
10	2.8	14

Stave Core Variants

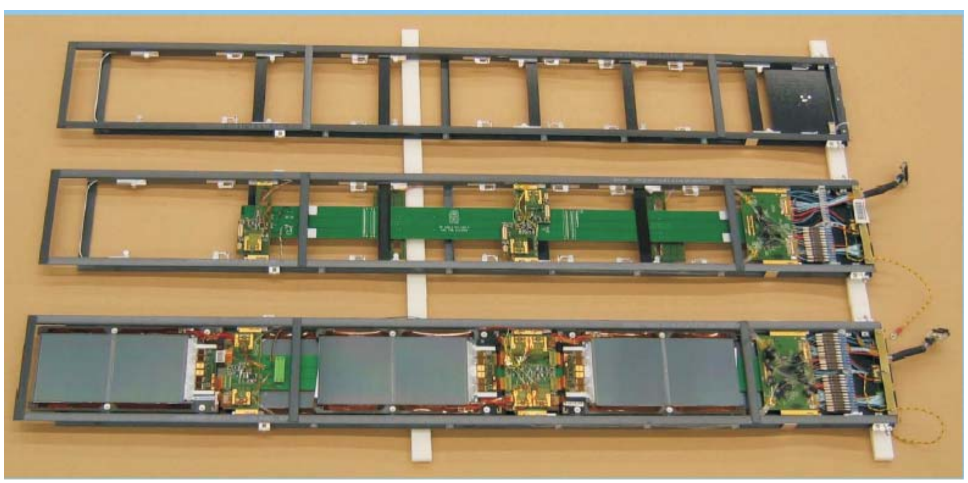


CDF Style Foam Core Sandwich



One Piece Carbon Fiber

CMS Style (Rad length?)



Scaffold Style

Radiation Length

Table 3-9 SCT barrel material.

Item	Material	Size	Radiation Length (%)	
			no overlap	with overlap
Detectors (wafers)	Silicon	6.36×12.82 cm^2 $\times$ 600 µm	0.64	0.70
Hybrid[a]	Copper	2.14×11.0 cm^2 $\times$ 0.6% X_0	0.35	0.38
Mounting Block	Carbon	1 cm wide $\times$ 0.19 cm thick		0.17
Support cylinder	Carbon			0.30
Services (cooling, cables)	Copper	0.128 cm thick at η=0		0.61 at η=0 (0.950 at end)
Total				2.16 at η=0

a. Allows for hybrid, chips, fan-ins, glue, printing, washers and connectors.

Total=2.16%/layer. Includes cooling fluid? How accurate is it?

Radiation Length--coolant

Chart below from an Atlas document

Components	Material	Pipe OD (mm)	Pipe ID (mm)	Area (mm2)	Length (mm)	Volume (each) (mm3)	Density (g/mm3)	Mass (each) (g)	No. On Disc	Total Volume (mm3)	Total Mass (g)	Radiation Length (mm)	t	Percentage Radiation Length (%)
Outer Cooling Circuit	CuNi	3.74	3.6	0.81	2856	2305.0	8.95E-03	2.06E+01	4	9220.0	8.25E+01	14.4	0.011981	0.083
Inner Cooling Circuit	CuNi	3.74	3.6	0.81	2069	1669.8	8.95E-03	1.49E+01	4	6679.4	5.98E+01	14.4	0.00868	0.060
Middle Cooling Circuit	CuNi	3.74	3.6	0.81	3098	2500.3	8.95E-03	2.24E+01	4	10001.3	8.95E+01	14.4	0.012996	0.090
Coolant	C3F8	3.74	3.6	10.18	8023	81664.2	4.50E-05	3.67E+00	4	326656.8	1.47E+01	7778	0.424477	0.005

? We assume cooling tube is half liquid on average. Is this correct?

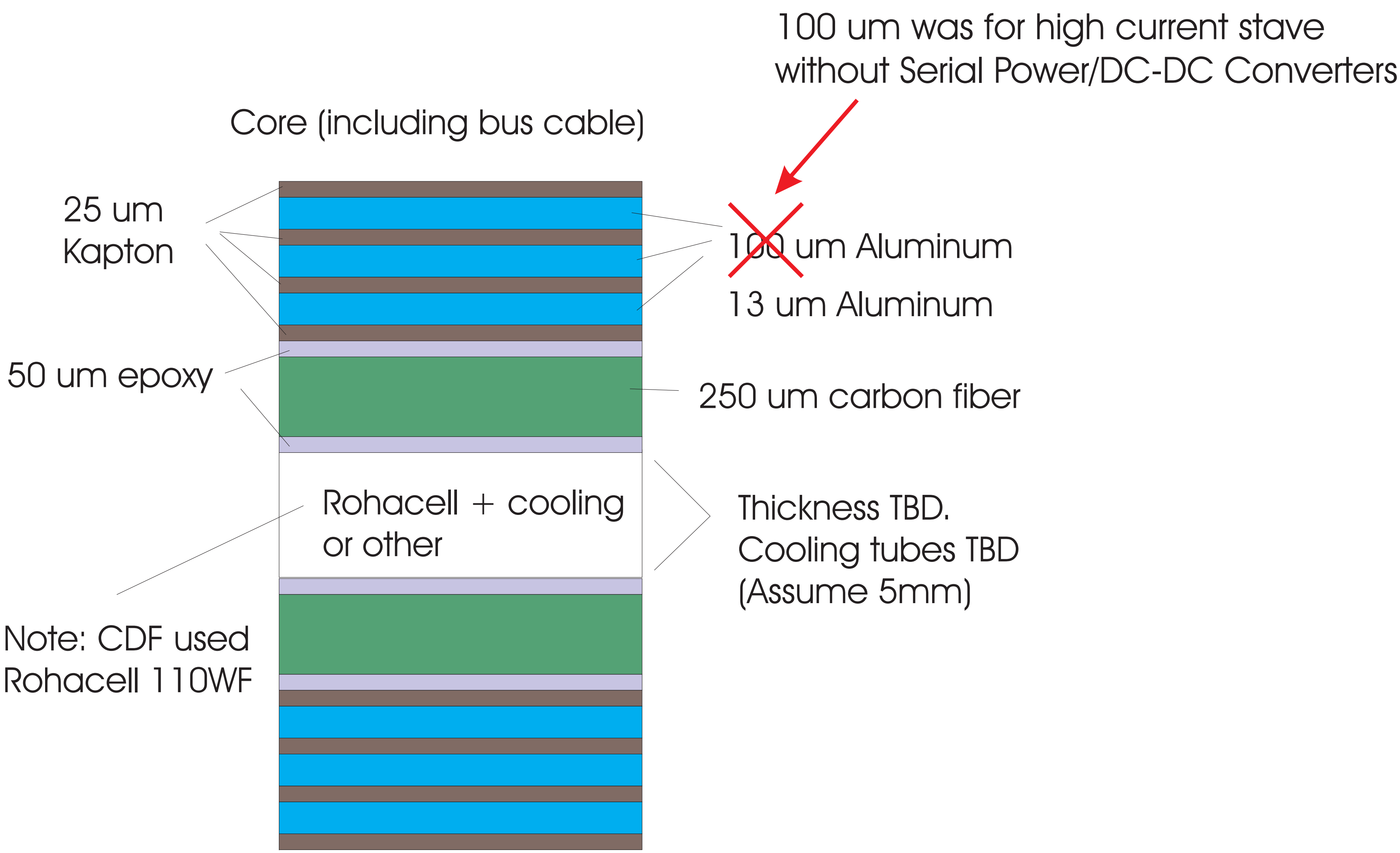
Liquid $C0_2$ $X_0 = 36$ cm

If two pipes/stave, 100 um Cu-Ni walls, diameter 4mm, then get "effective thicknesses":

Pipes: $t_{eff} =$ (2 pipes x pi x 4 mm / 6.4 cm)* 100 um=40 um

CO_2: $t_{eff} =$ 2 pipes x pi x $2mm^2$ * ½ full/ 6.4 cm =200 um

Model of 1-d Stave Core + Busses



Quick Radiation Length Estimate of 1-d Foam core model

Poorly defined number

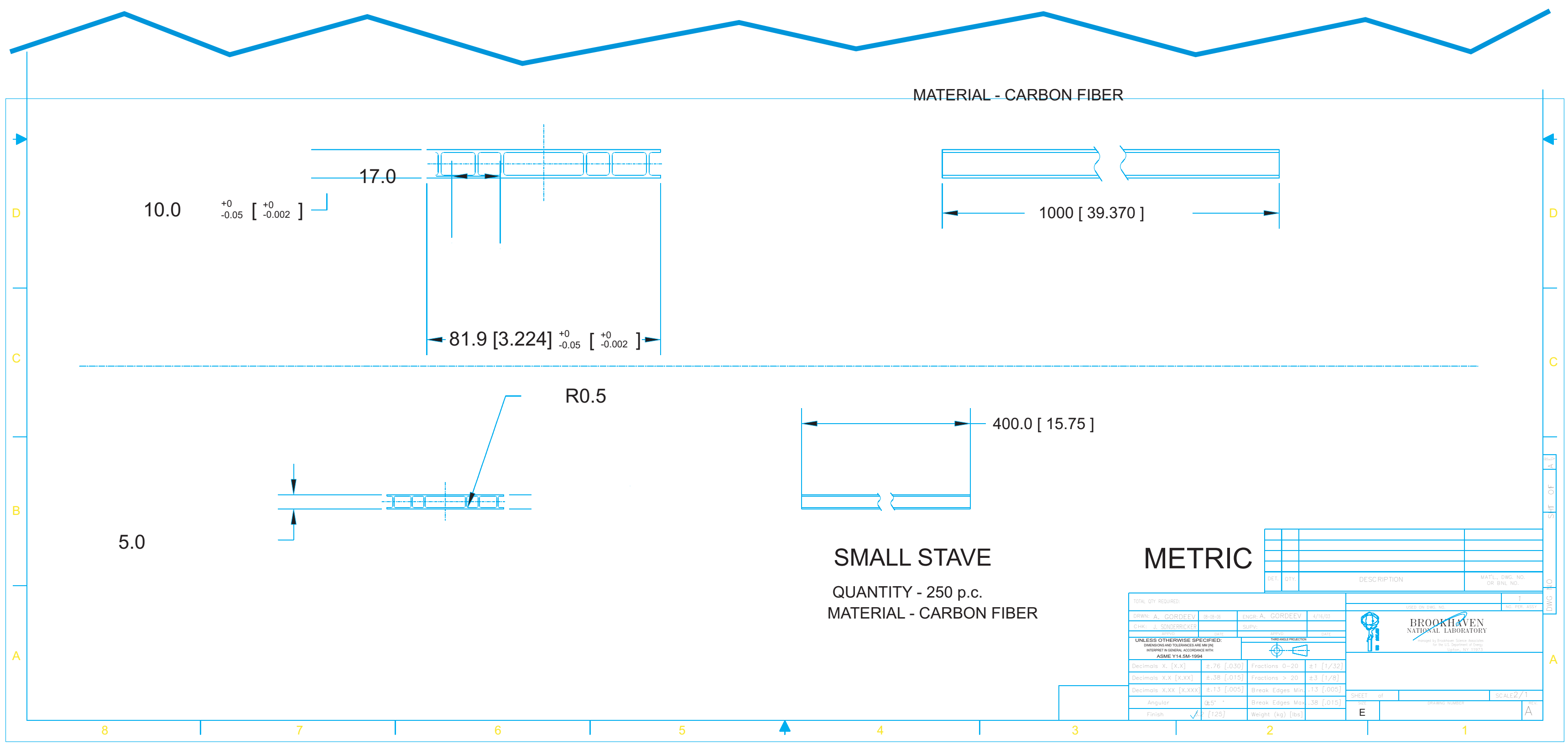
? Implies use kapton circuit on CF ala present atlas

	Eff thickness(um)	Rad Length(cm)	% RL	
Core+busses				
rohacell	5000	500	0.10	
TC Epoxy	200	20	0.10	
AL	80	9	0.09	
Carbon Fiber	500	20	0.25	
Kapton	200	29	0.07	
			0.61	
Silicon	300	9.4	**0.32**	
Be0 Hybrid				6.4 cm x 2 cm
Be0	400	14.4	0.28	
Ag-Pd	38	0.85	0.45	two 15 micorn layers
chips	150	9.4	0.16	500 um thick, area 6 x 6.4 mm x 10 mm,
…				normalized to hybrid area
Dielectric	150	10	0.15	3 layers, 50 um, radlength of glass
Subtotal			1.03	
Normalized subtotal			**0.69**	Hybrid covers only 2cm of 3cm strips
Cooling				
C02	200	36	0.06	two 4mm dia pipes, 50% full of liquid
Cu pipes	40	1.4	0.29	Cu-Ni used in present atlas ~ 100 um thick walls
Subtotal			**0.34**	
Total			1.96	

Note: If we wish to compare to present Atlas in terms of radiation length, the support structure is not included and information is only 1-d.

Integrated Carbon Fiber/Cooling Stave

- Integrated cooling provide lower thermal resistance
- May be able to make in one piece via pultrusion process
- There was concern about stability of rohacell core



Integrated Carbon Fiber/Cooling Stave

– Pultrusion does not seem to be a viable option. 5 vendors contacted. Wall thickness a difficulty even though original drawing had 1mm walls that are unacceptable from radiation lenght point of view.

– Comparison of foam core and intergrated carbon fiber radiation length

Foam core rad length (rohacell+skin)+Cu tubes =.1+.25+.29=**.64 %**

Integrated CF stave (5mm height) with 500 um walls gives effective thickness of 500 um (top) + 500 um (bottom) +2/6 *500 um (cooling walls)=1.2 mm. Rad length = 1.2 mm/20 cm = **0.60%**.

– Not yet CF clear walls could handle high pressure necessary.

Integrated Carbon Fiber/Cooling Stave

– Looking into alternative production techniques

Hi Augie - I have had the chance to review your request for the Atlas Stave Detector. The parts pose some interesting challenges that we would be eager to tackle. What we would propose is a co-molded part using a Rohacell core in the large cells and an extractable core for the smaller cooling channels. This will make the tooling more versatile and remove a bit of the complexity as well. Because the parts are so thin, we do have some concern with the overall flatness requirement along the length of the part and some investigation would be required to determine how attainable those tolerances are.

For the sake of planning my estimate on the costing is as follows:

Description	Cost Estimate
Tooling and NRE for all three sizes	$8K to $10K total*
Large Stave, qty 200 pieces	$500 each
Medium Stave, 350 pieces	$300 each
Small Stave, 250 pieces	$125 each**

* includes process refinement, equipment modification, all tooling and expendable cores, for all three sizes
** There is a possibility of "gang-molding" this particular part, which could have a favorable impact on pricing. An investigation would need to be conducted.

These might be a bit on the conservative side, not knowing all of the parameters or much about the end use. We can certainly refine these once it has been determined that you have interest. Please let me know if I can get you any additional information on this. We appreciate your consideration and hope to be working with you in the future.

Sincere regards,

Jeff Allott

Rohacell

– Is it stable
– Are there problems with CTE matching to -25C?
– Is it rad hard?

More information was found on the internet. The IU Atlas project at CERN had conducted tests on Rohacell 31. They found that at exposures above 9.2 Mrad rohacell "completely gave out and could not hold any more weight." This only happened after they subjected the exposed rohacell sample to over 400 grams of weight. [Radiation test on Transition Radiation Materials, H. Orgen, et. al., February 29, 1996, needmore.physics.indiana.edu/~fred/iu_atlas/iu_atlas.html]

– Are there better foam alternatives?
(e.g. better thermal conductivity?)

– Was LBNL considering something else?

K-Foam an alternative Rohacell?

	Kfoam L1	Rohacell 110Wf
Thermal Conducivity (w/mK)	70	.031 A
Tensile Modulus(MPa)	310	180
Radiation Length(cm)	110 B	500 C

A. Source M. Rehak (not sure it is 110)

B. Rad Length of graphite adjusted for density

C. Needs verification. From a CDF note.

But Rad Length probably would require a ~ 2-3 mm thick foam core for K-foam

Properties	Unit	ROHACELL® 51 WF	ROHACELL® 71 WF	ROHACELL® 110 WF	ROHACELL® 200 WF
Density	kg/m^3 lbs./cu.ft.	52 3.25	75 4.68	110 6.87	205 12.81
Compressive strength	MPa psi	0.8 116	1.7 246	3.6 522	9.0 1,305
Tensile strength	MPa psi	1.6 232	2.2 319	3.7 536	6.8 986
Flexural strength	MPa psi	1.6 232	2.9 420	5.2 754	12.0 1,740
Shear strength	MPa psi	0.8 116	1.3 188	2.4 348	5.0 725
Elastic modulus	MPa psi	75 10,875	105 15,225	180 26,100	350 50,750
Shear modulus	MPa psi	24 3,480	42 6,090	70 10,170	150 21.750

Property	Units	Carbon Foam Grade L1	Carbon Foam Grade L1a	Carbon Foam Grade D1
Density	[g/cc]	0.38	0.34	0.48
Compressive Strength	MPa	3.4	1.7	2.5
Compressive Modulus	GPa	0.31	0.15	0.4
Tensile Strength	MPa	7.95	4.4	6.8
Tensile Modulus	GPa	0.31	0.19	0.31
Flexural Strength	MPa	3.2	2.1	2.5
Flexural Modulus	GPa	0.26	0.12	0.34
Shear Strength	MPa	0.67	0.54	0.89
Shear Modulus	GPa	0.09	0.06	0.16
Coefficient of Thermal Expansion	E-6/C @ 650°	3.0	1.72	0.69
Thermal Conductivity -Z	W/m·K	70	55	110
Electrical Resistivity -Z	µΩ·m	47.6	40.8	31.5
Average Pore Size	µM	600	500	650
Average Pore Volume	%	70	78	72

Stave Core Discussion

– Is a single piece all-CF core a viable option?

– Is rohacell a problem? Are there suitable replacements

– Stave concept vs present Atlas barrel support in terms of radiation length

- Present barrel support has RL of .30 %
- Foam core stave (CF+Rohacell) has RL of .35 %

==> Not much difference ? Are there other missing items?

Other Stave Specifications

This Chart from Carl

Table I: Basic Stave Specifications (nominal)

Property	Short stave	Long Stave
Width	6.4 cm	12.8 cm
length (nominal)	98 cm	192 cm
detector width	6.4 cm	12.8 cm
detector length	3 cm	10-12 cm
detectors per side*	15-18	12-16
gap between detector along the stave	2.4 cm	3 mm
detector thickness	280 microns	300 microns
number of strips	768	768
strip pitch	80 microns	160 microns
Power in front end chips (per hybrid)	3 watts	3 watts
Power in silicon – no dose (per crystal)	1 milliwatt	2 milliwatt
Power in silicon – high dose (per crystal)	1 watt	2 watt
Maximum temperature at silicon	-25 C	-10 C
Maximum temperature variation	<5 C	<5C
Max detector position shift from nom Dy	30 microns	30 microns
Max detector position shift from nom Dx	30 microns	30 microns
Survey accuracy Sy	5 microns	5 microns
Survey accuracy Sx	10 microns	5 microns
Survey accuracy Sq	0.13 mRad	0,13 mRad
Ladder sag maximum**	60 microns	60 microns
Ladder sag stability***	25 microns	25 microns

Stave Flatness Considerations

C:\home\atlas\stave\flatness.doc

Some considerations that may influence flatness specification:

1. ΔZ, the error in z measurements

2. ΔX, the error in x measurements (here x is taken to be in the plane of the silicon but

perpendicular to direction of the strips).

3. wafer warp

4. Mounting

5. $\Delta F/\Delta S$, S = Sag, ΔF = flatness spec

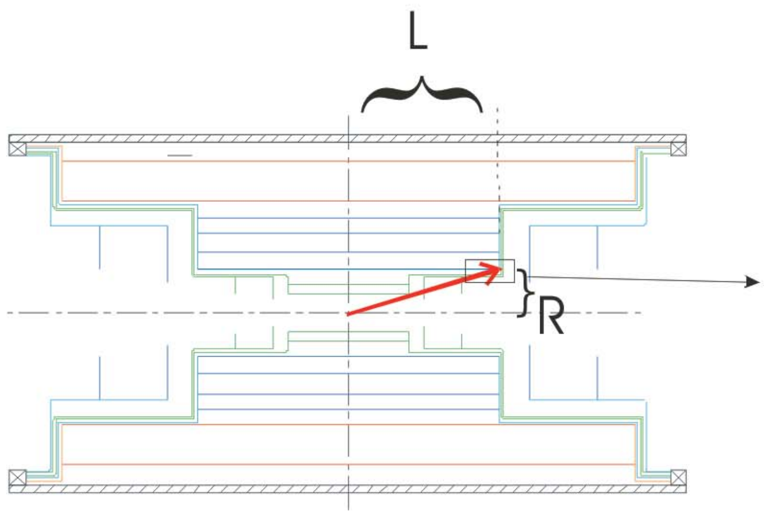
6. Alignment.

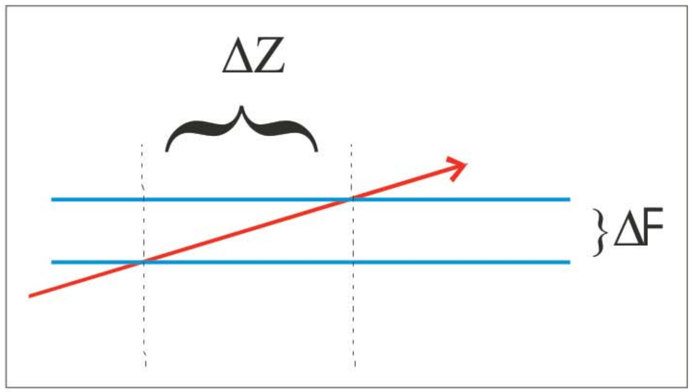
7. Epoxy filler

8. Non straight (low momentum)tracks

1. ΔZ, the error in z measurements.

Largest error should occur at first short strip layer at very end, i.e. with R = 27 cm and L = 100 cm. For calculational simplicity, let
R ≈ 25 cm.



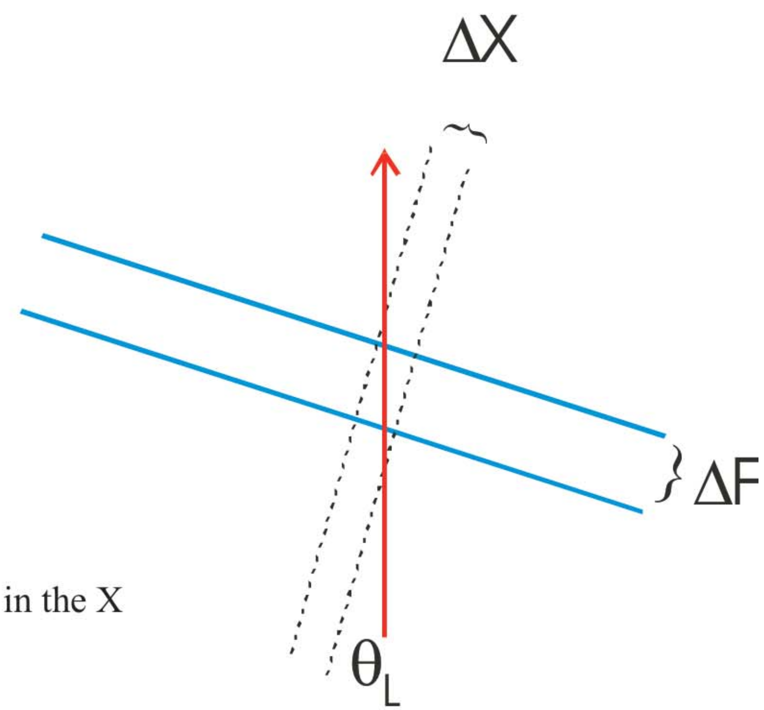


R/L=ΔF/ΔZ, or ΔZ = L ΔF/R = 4 ΔF.

Thus with a flatness specification of .002" = 50 um per 3 cm of length of stave (the length of a silicon detector), we would get

ΔZ = 200 um. (This compares to current Atlas Z resolution of 1.2 mm; what is the new required Z resolution?)

2. ΔX, the error in X measurements (here x is taken to be in the plane of the silicon but perpendicular to the direction of the strips).



The sketch shows the error for a straight (high momentum) track in the X direction due the rotation of the silicon by the Lorentz angle θ_L.

$\theta_L \approx 17°$ (for a 2 Tesla field).

$\tan \theta_L = \Delta X/\Delta F$, or

$\Delta X \approx 0.3\ \Delta F$.

We are aiming for resolutions on the order of 80 um/$\sqrt{12} \approx 23$ um. If we want the error to be less than the resolution (to avoid calibrating on a finer scale then a detector, then we want)

$\Delta F < 23$ um/.3 ≈ 75 um.

Other Details

Wafer Warp

– Hamamatsu quotes +/- 100 um. Seems large

– Are detectors “flattened” in current back-to-back gluing process?

Sag

– Carl notes 60 um. Is this necessary? How determine?

– We assume stability more important, and local flatness (Carl notes stability of 25 um.) How define stability?

Lorentz Angle

– Lorentz angle will increase from current 3.5° for electrons to about 17° for holes. Must we tilt staves this amount?