

Carbon Fiber Grounding Issues in the DØ Run II b Silicon Detector Design

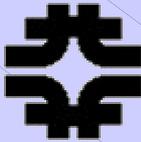
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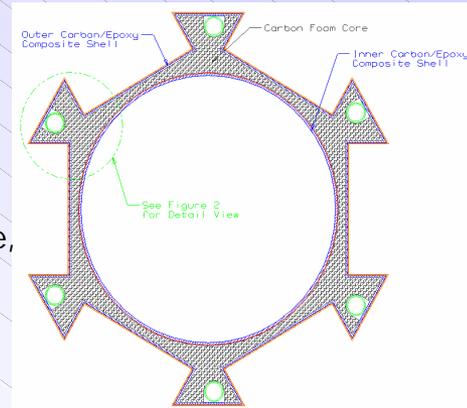
Carbon Fiber Issues



Carbon fiber (CF) has become ubiquitous in silicon detector design because of its high modulus and low mass.

- Mechanical support
- Cooling tubes

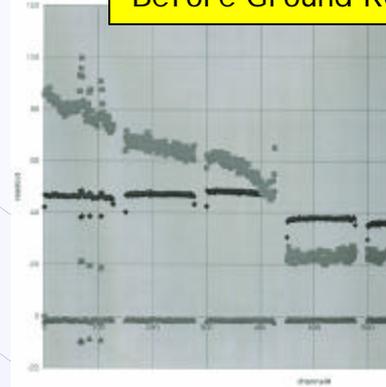
L0 Support Structure, DØ Run II b Silicon



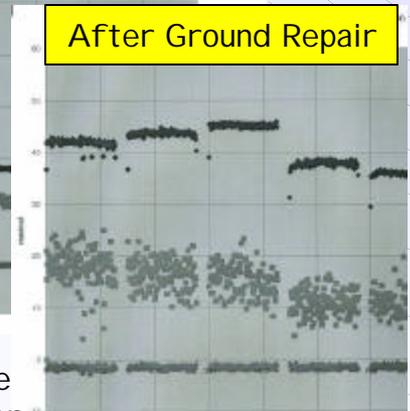
However, the current pitch fabrication techniques that produce carbon fiber with ultra-high modulus (~1000 GPa) also yield very low resistivity (~100 mΩ•cm)

- Floating conductors present the potential for strong capacitive coupling to silicon sensors
- Can result in a very troublesome source of noise, especially in close-packed L0 structures

Before Ground Repair



After Ground Repair

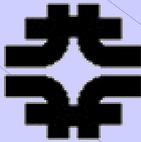


Noise from Be support plate capacitor, DØ Run II a ladder

Effective grounding of all carbon fiber elements is *essential* in producing a low-noise environment for silicon detectors

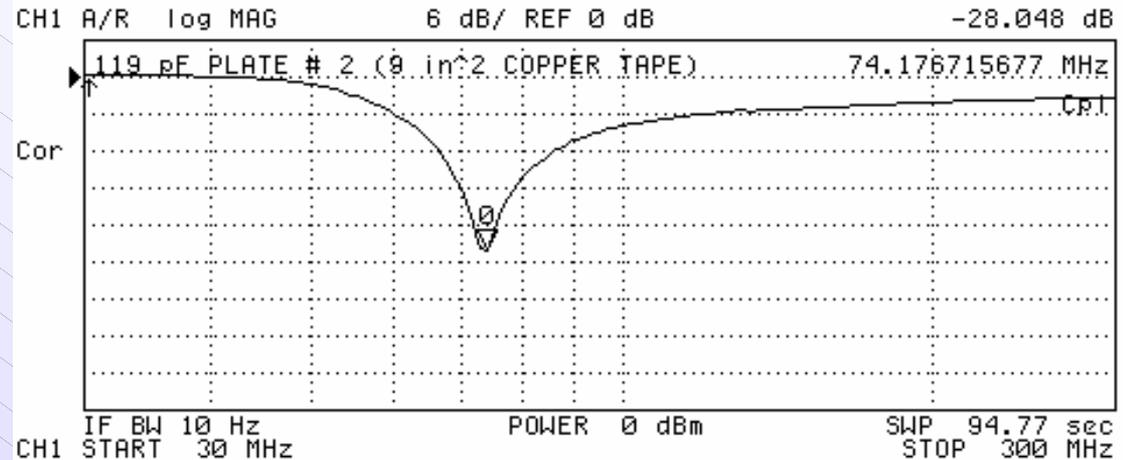
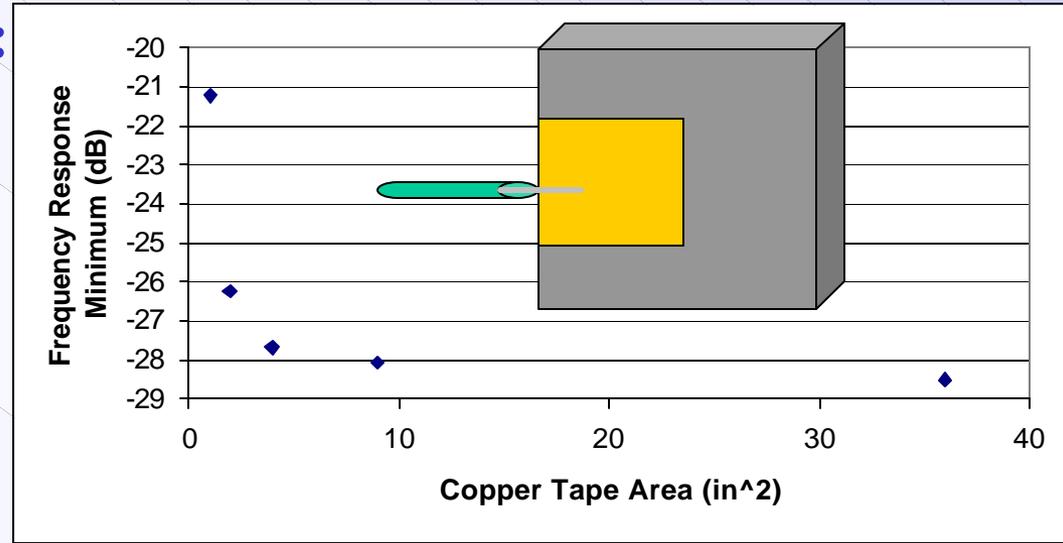


Coupling to Carbon Fiber



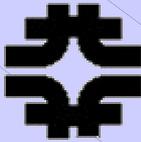
To effectively ground a piece of carbon fiber, one must ensure excellent electrical coupling:

- Tested coupling to carbon fiber (K13C) with copper tape
- Measured the attenuation of a network analyzer input at the bandstop resonance
- Saturation at ~10-15% coupling area

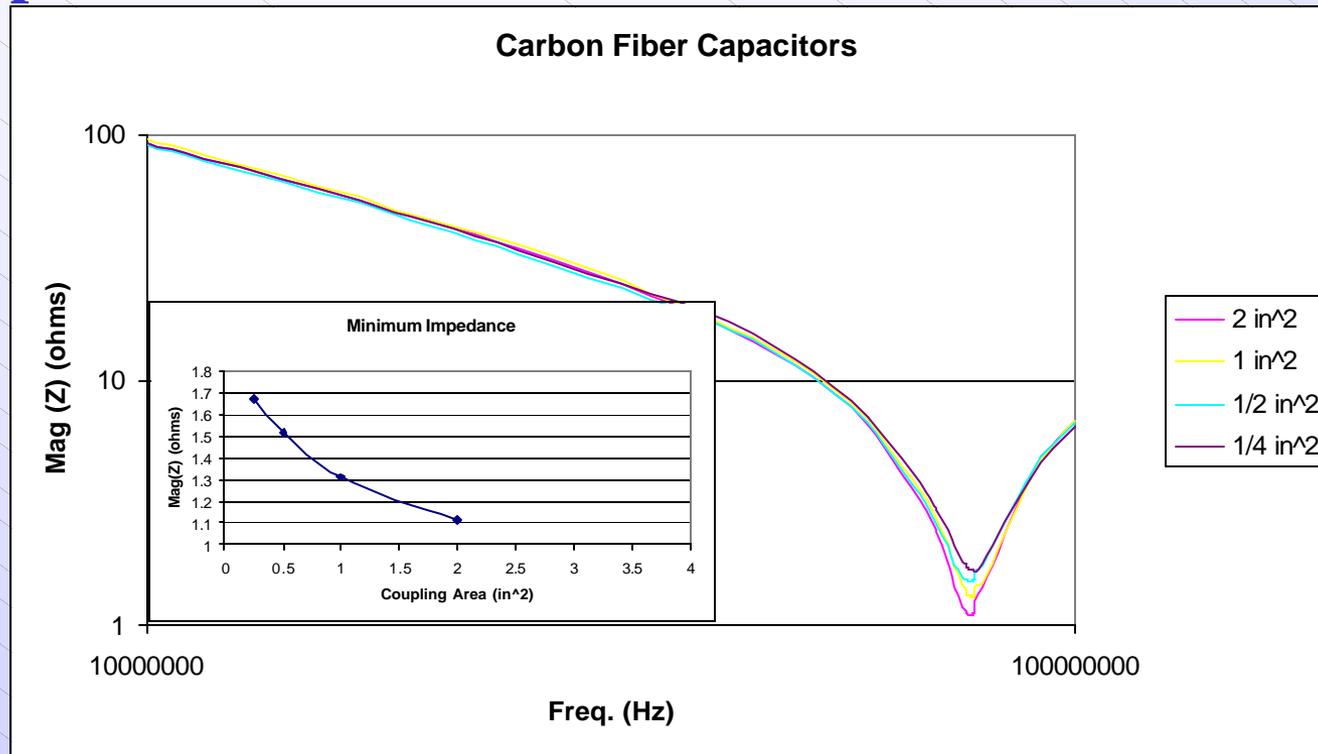




Impedance Measurement



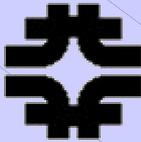
- Power transfer functions measured with the network analyzer were complemented with manual, analog impedance measurements



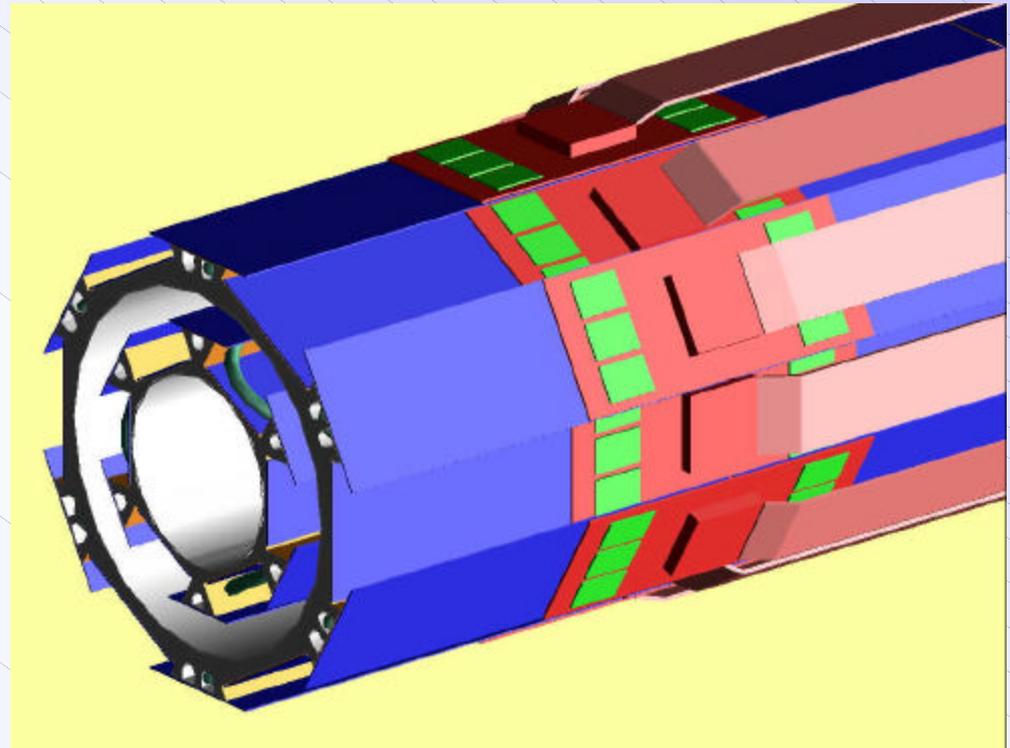
- Inverse relationship between impedance (and thus power throughput) and coupling area was verified



L0/L1 Design



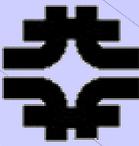
- Silicon sensor/hybrid assemblies are mounted on crenellated carbon fiber support tubes



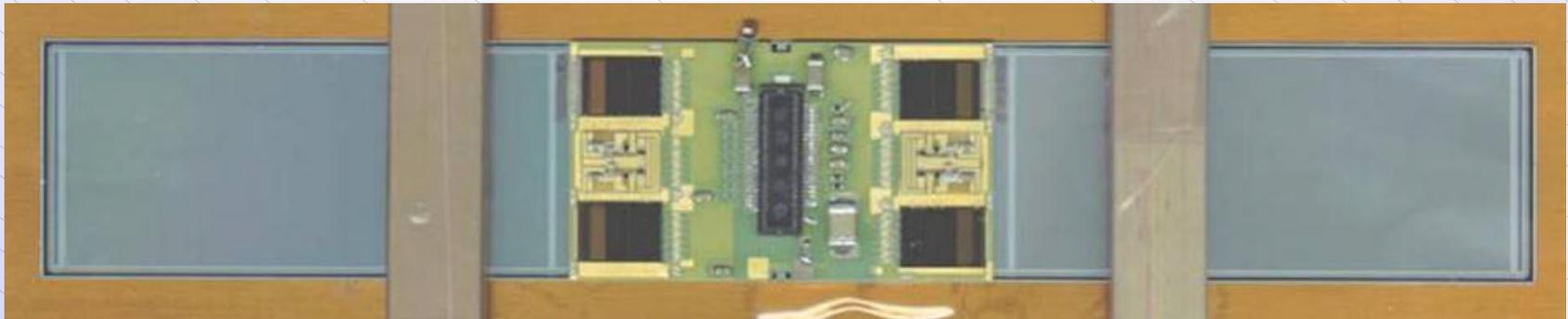
Sensors are sandwiched between carbon fiber/hybrid ground plane capacitors



Shorting the Carbon Fiber



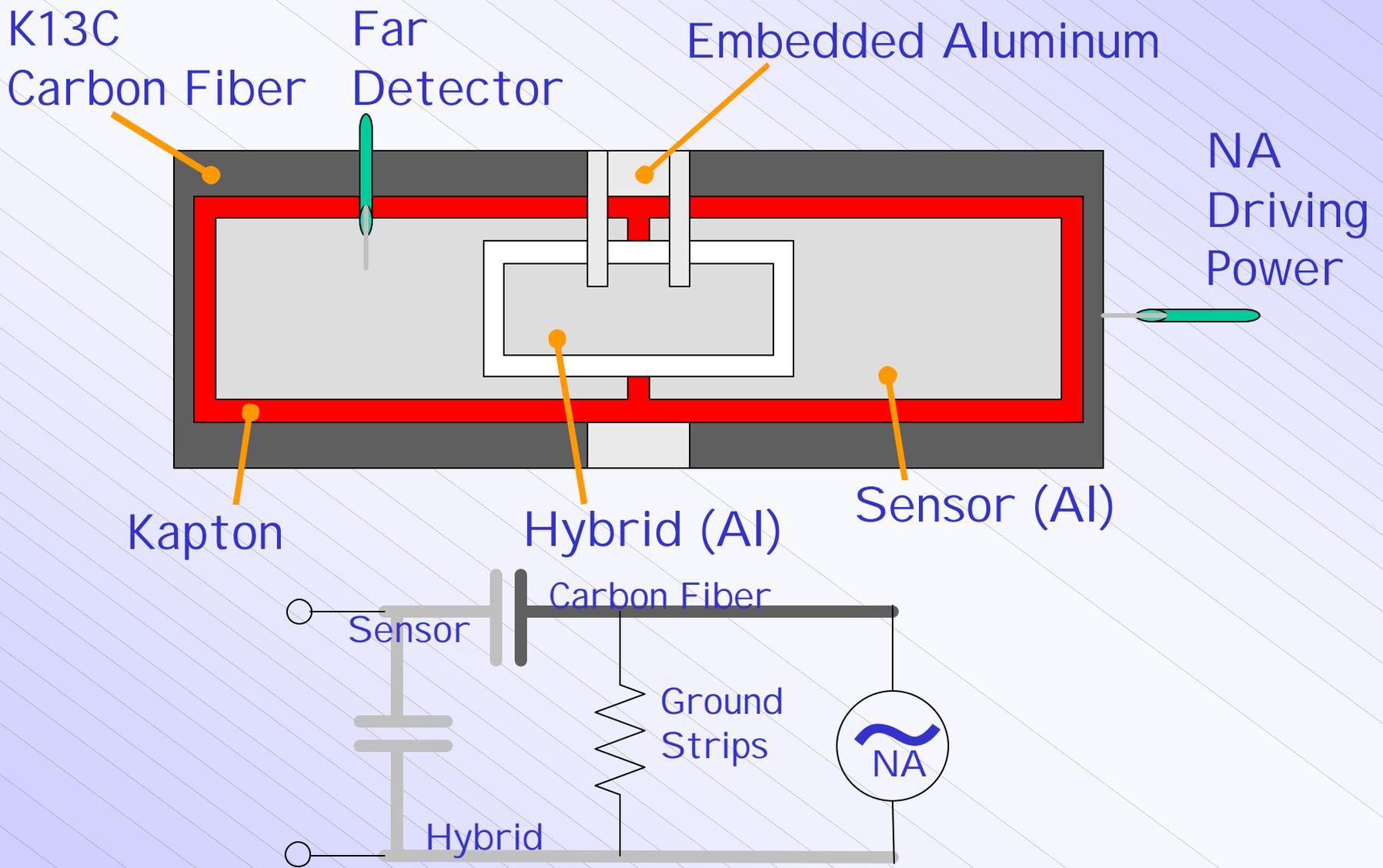
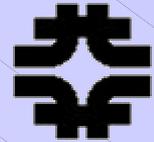
- **The carbon fiber support underneath the silicon sensors must be shorted to small pads on the hybrid ground plane**
 - ◆ **Need low-mass coupling to the carbon fiber**
 - ◆ **Need small attachments to 2 mm ground pads on the hybrid**
 - ◆ **Need to be effective over a frequency range from ~ 4.5 kHz – 10 MHz**
 - **Determined by integration time and 8-bit ADC dynamic range**



- ◆ **Try aluminum foils embedded onto the carbon fiber surface**
 - ◆ **Narrow aluminum strips folding up and over to the ground pads**

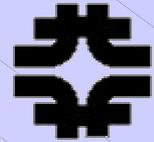


L0/L1 Mock-up

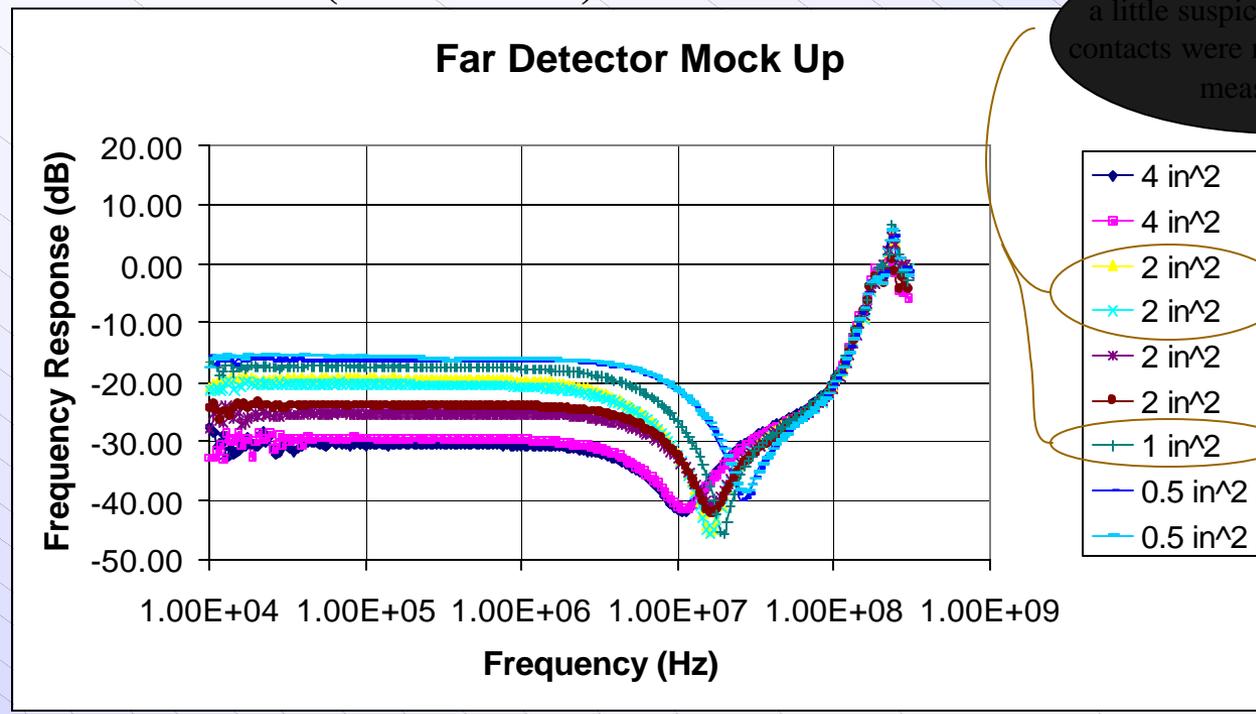




L0/L1 Mock-up



- Studied transfer functions from the C fiber to the “sensor”
- Varied the amount of C fiber area covered by embedded aluminum
 - 0.5 in² → 4 in² (2% → 17%)

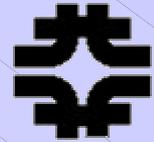


Data curves look a little suspicious –copper tape contacts were not “fresh” for these measurements

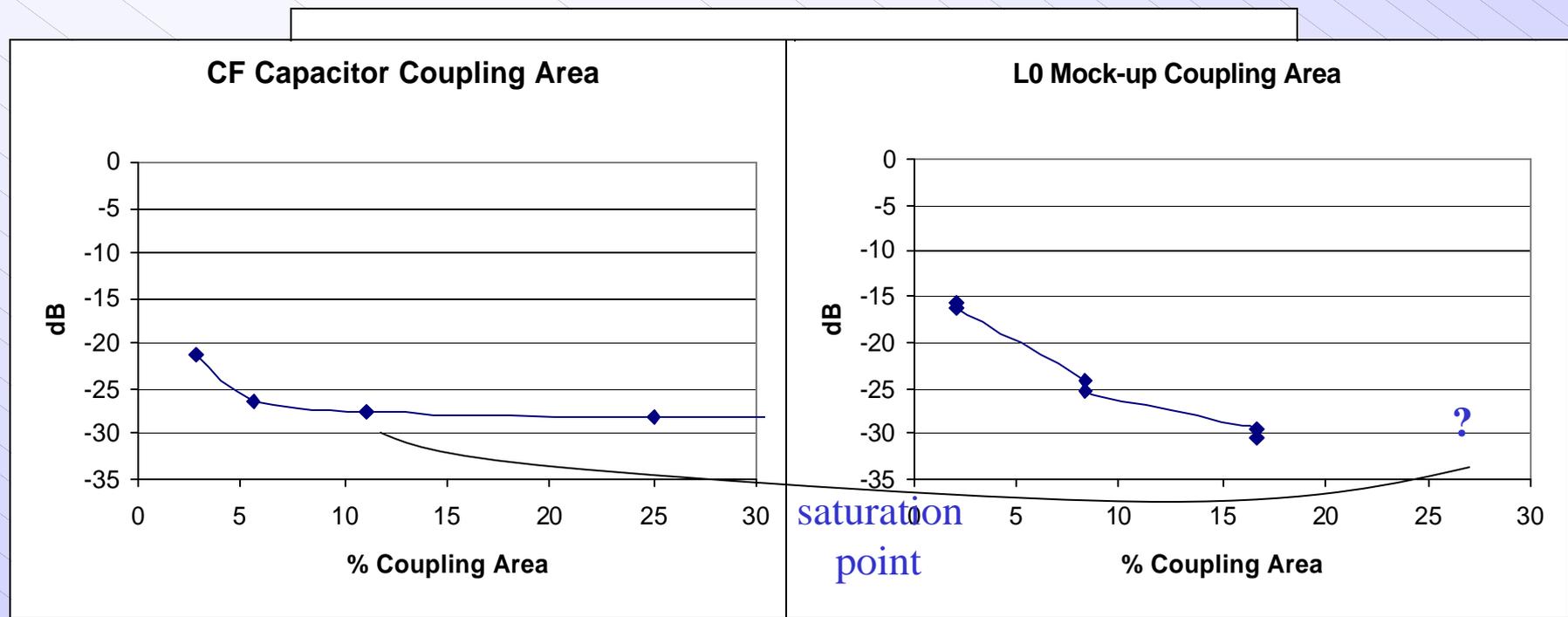
- Quality of the electrical contact is crucial
- Varying the number and size of shorting strips had no significant effect



Carbon Fiber Coupling



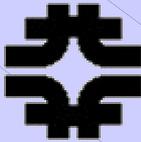
- Comparison of coupling to the simple CF capacitor with a somewhat subjective selection of L0 Mock-up coupling data



- Estimate 25-30% coverage by embedded AI is needed for maximum attenuation

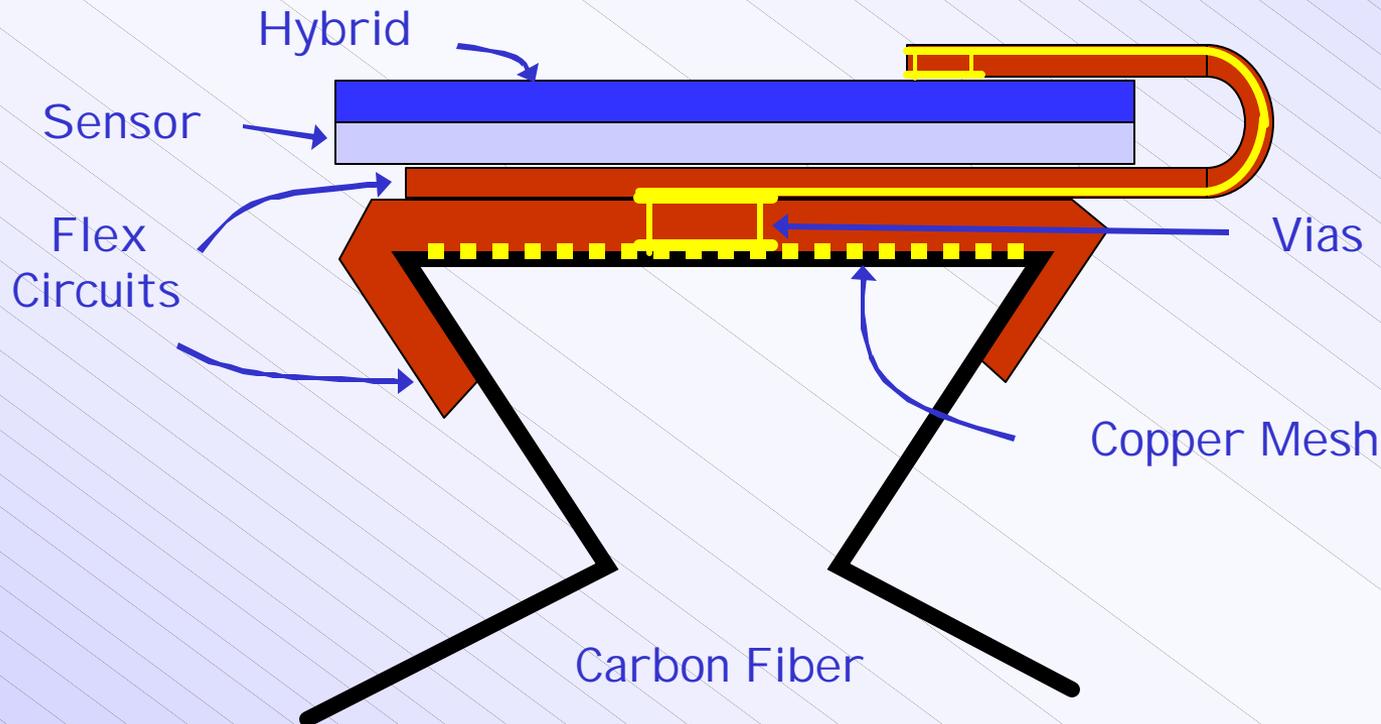


Ongoing Studies



- A significantly more complicated, though considerably more robust coupling concept...

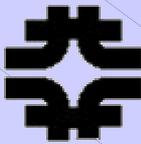
(not even close to scale...)



- Potentially less integrated mass than the embedded aluminum option
- Less susceptible to oxidation, tears, silver epoxy

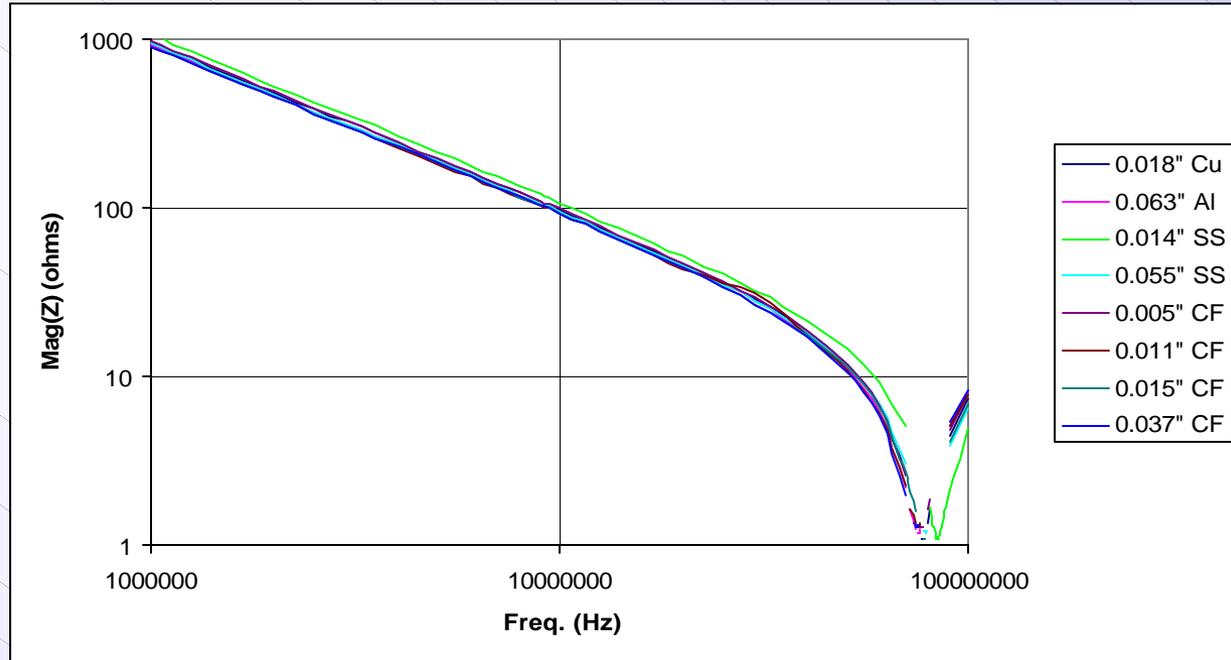


Ongoing Studies



Why is the C fiber so conductive?

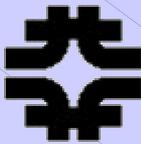
- Impedance measurements of capacitors made of different materials and thicknesses
- Virtually indistinguishable from copper



- Thin stainless steel is the only metal with significantly different impedance
 - Thinnest plate (14 mils), and largest skin depth (~ 2 mils at 75 MHz)
- C fiber has larger skin depth (~ 3 mils) and some plates were thinner (→ 5 mils)
 - Other effect at work – graphene layer-plane characteristics, eddy currents?



Conclusions



- Today's ultra-high modulus types of carbon fiber are highly conductive, and demand careful attention to proper grounding when used in silicon vertex detectors.
- Effective electrical coupling to the carbon fiber is the critical issue involved in designing a grounding scheme.
 - **Thin aluminum foils embedded into the carbon fiber yield excellent ground connections**
 - ~ 25-30% coverage of the carbon fiber is optimal for the DØ Run IIb inner layer geometry
 - However, oxidation and fragility of thin Al foils are major concerns
 - **Kapton/copper flex circuits together with an embedded copper mesh is a promising solution**
 - Low-mass and robust
- Open questions remain concerning the nature of carbon fiber conductivity