# Carbon Fiber Grounding Issues in the DØ Run IIb Silicon Detector Design

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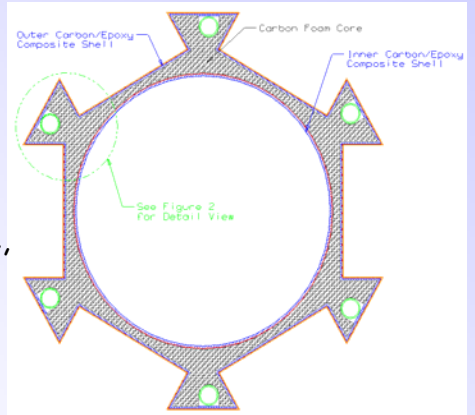
# Carbon Fiber Issues

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

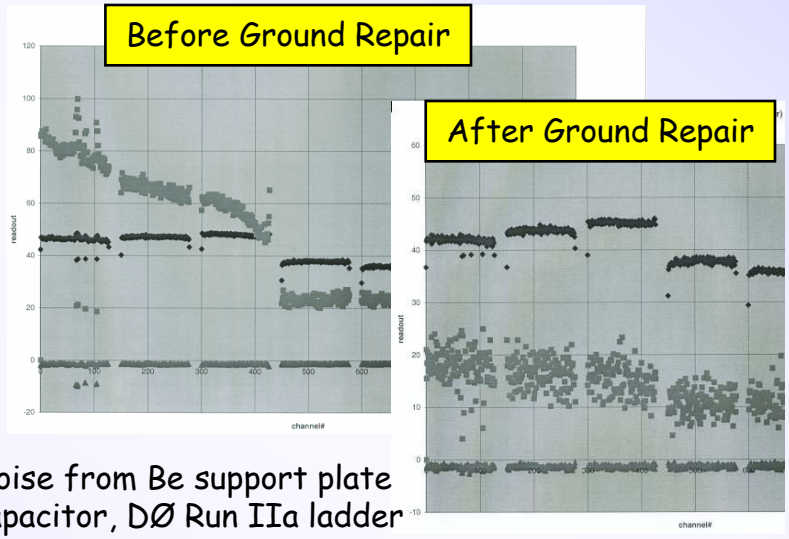
- **Mechanical support**
- **Cooling tubes**




L0 Support Structure, DØ Run IIb Silicon

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



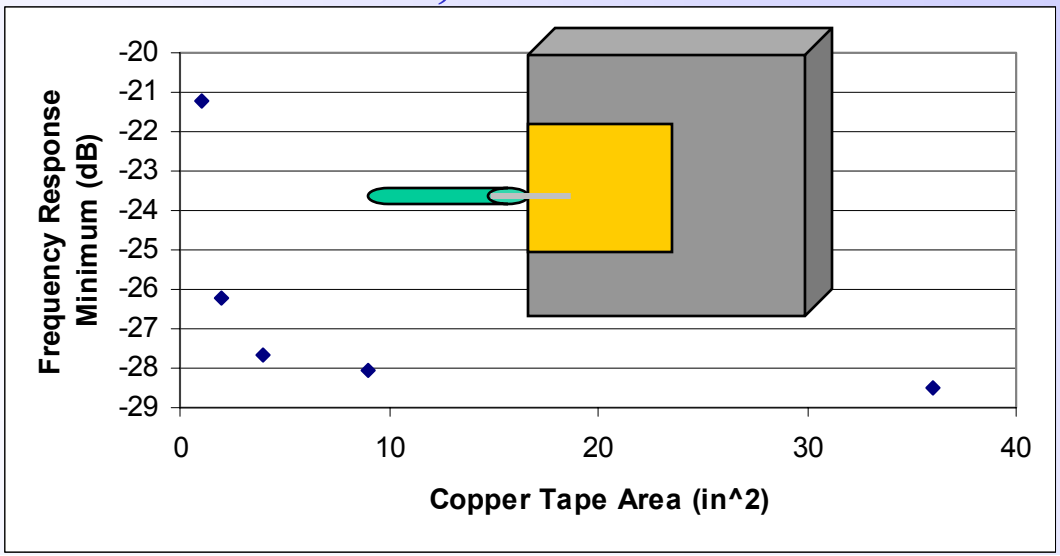

Noise from Be support plate capacitor, DØ Run IIa ladder

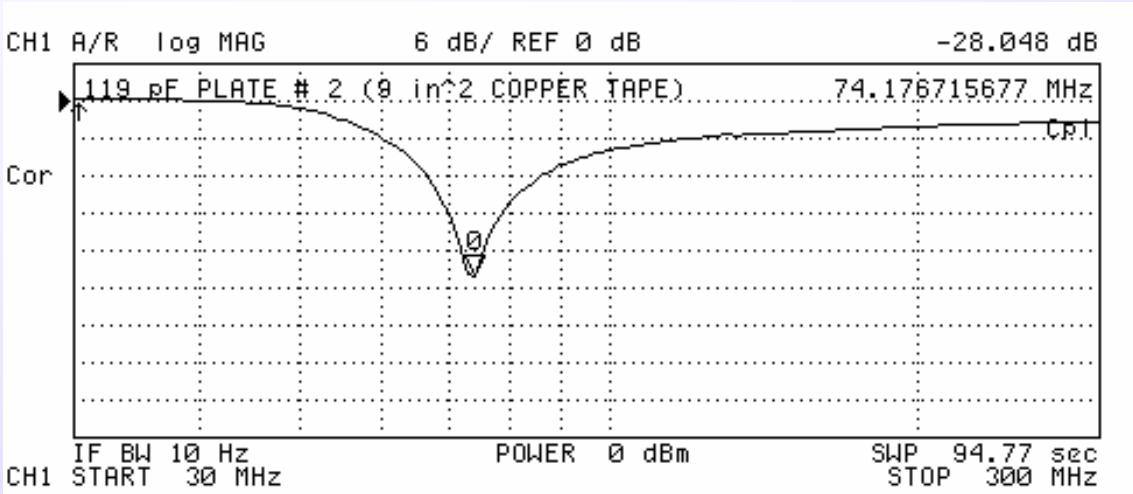
**Effective grounding of all carbon fiber elements is *essential* in producing a low-noise environment for silicon detectors**

# Coupling to Carbon Fiber

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

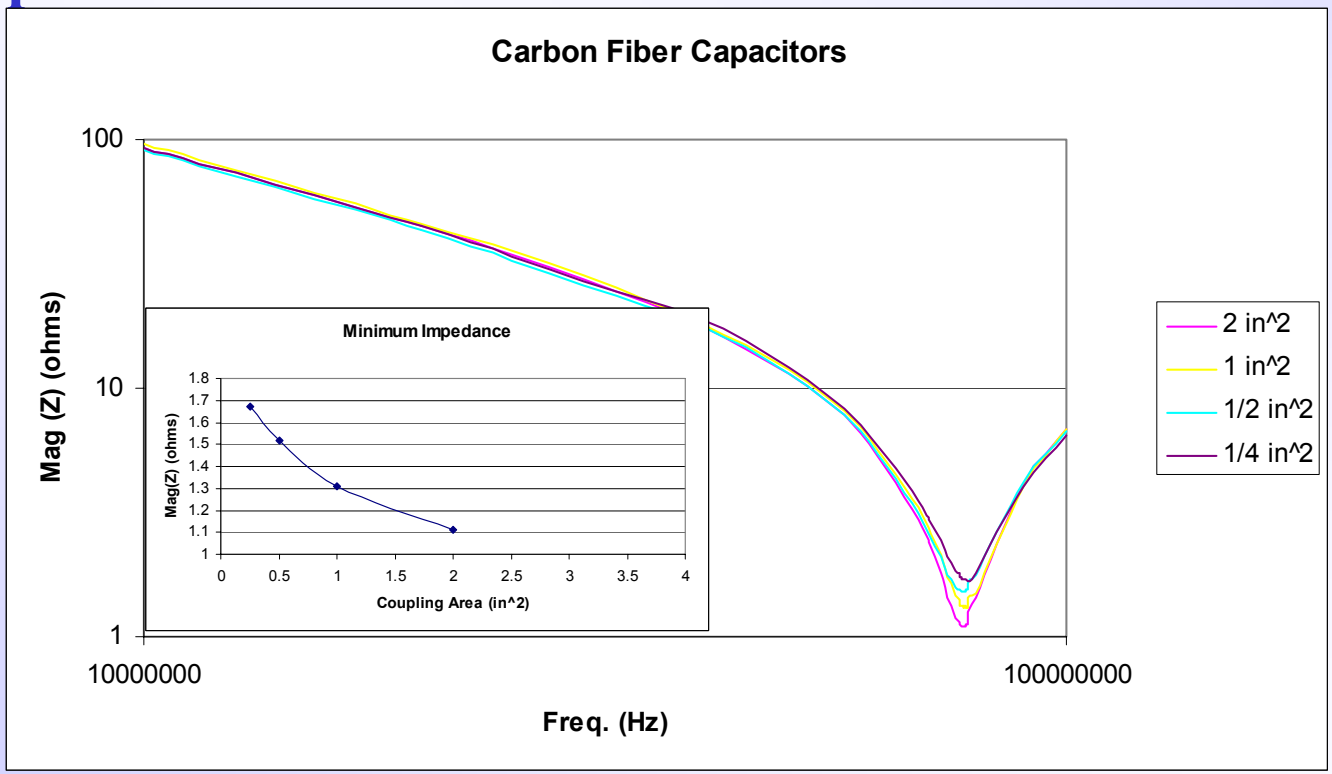
- Tested coupling to carbon fiber (K13C) with copper tape
- Measured the attenuation of a network analyzer input at the bandstop resonance
- Saturation at ~10-15% coupling area



# Impedance Measurement

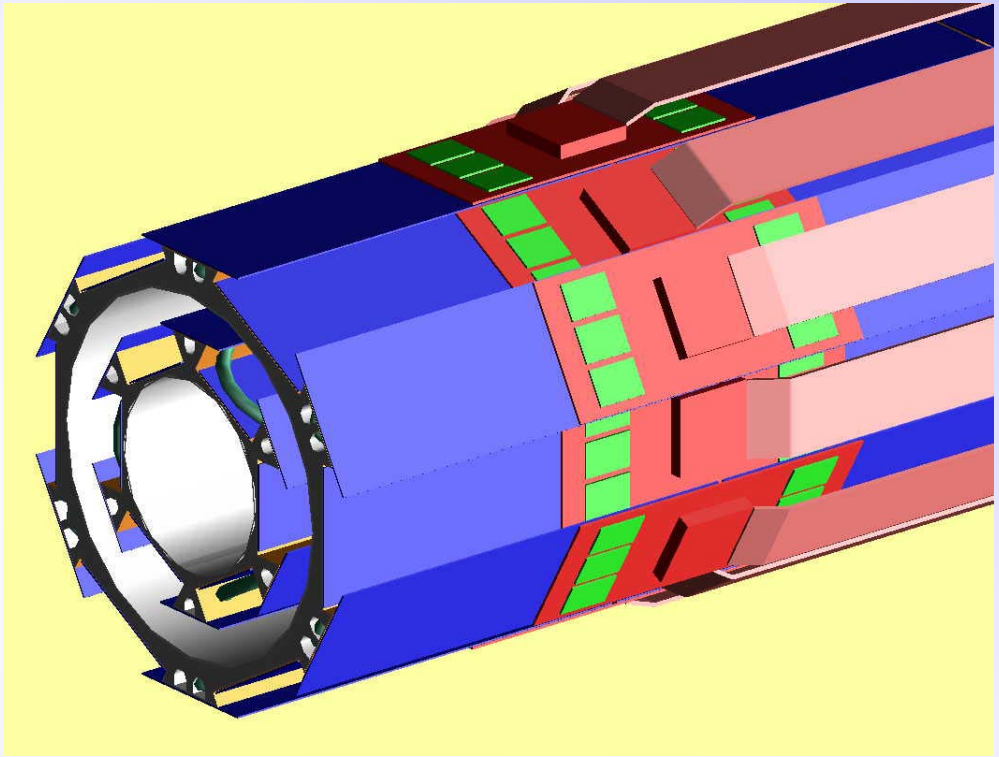
- Power transfer functions measured with the network analyzer were complemented with manual, analog impedance measurements

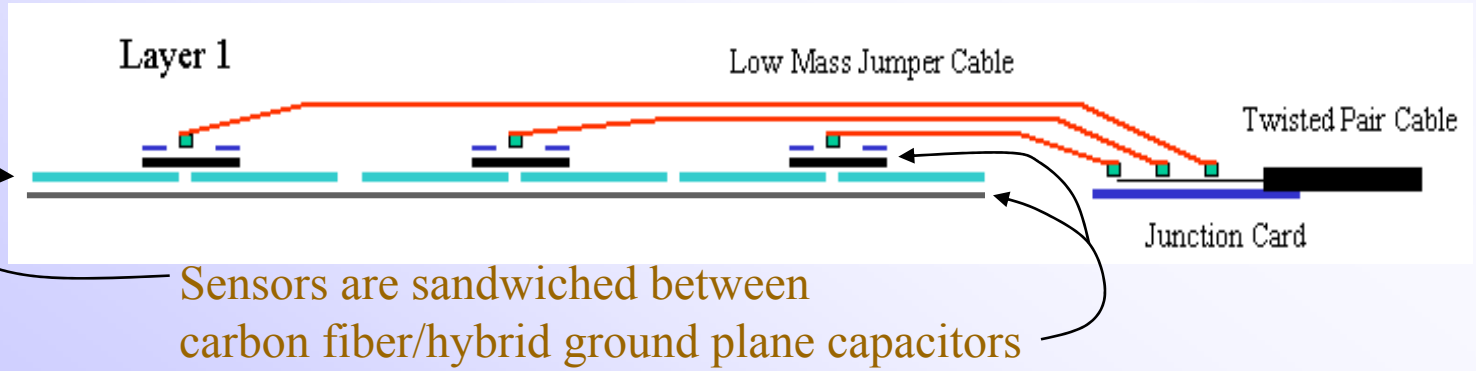



- Inverse relationship between impedance (and thus power throughput) and coupling area was verified

# L0/L1 Design

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

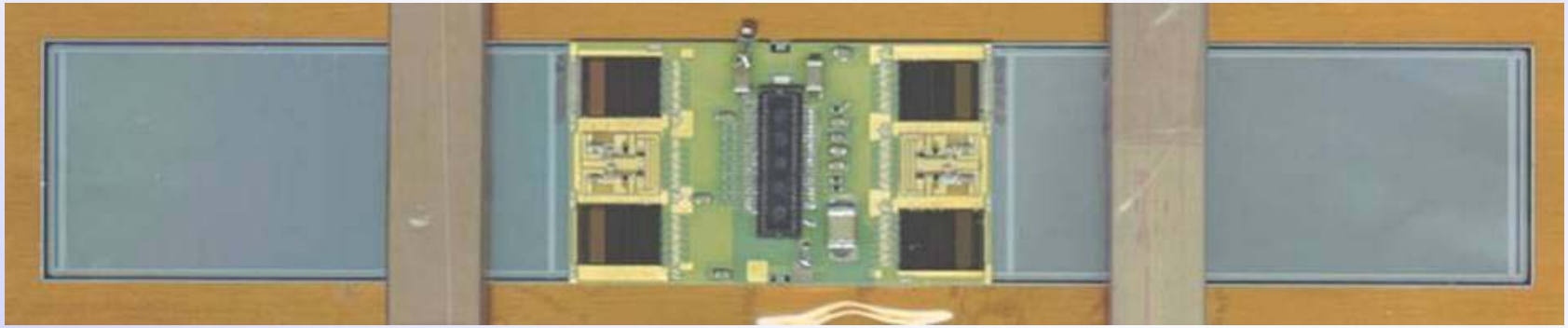





Sensors are sandwiched between carbon fiber/hybrid ground plane capacitors

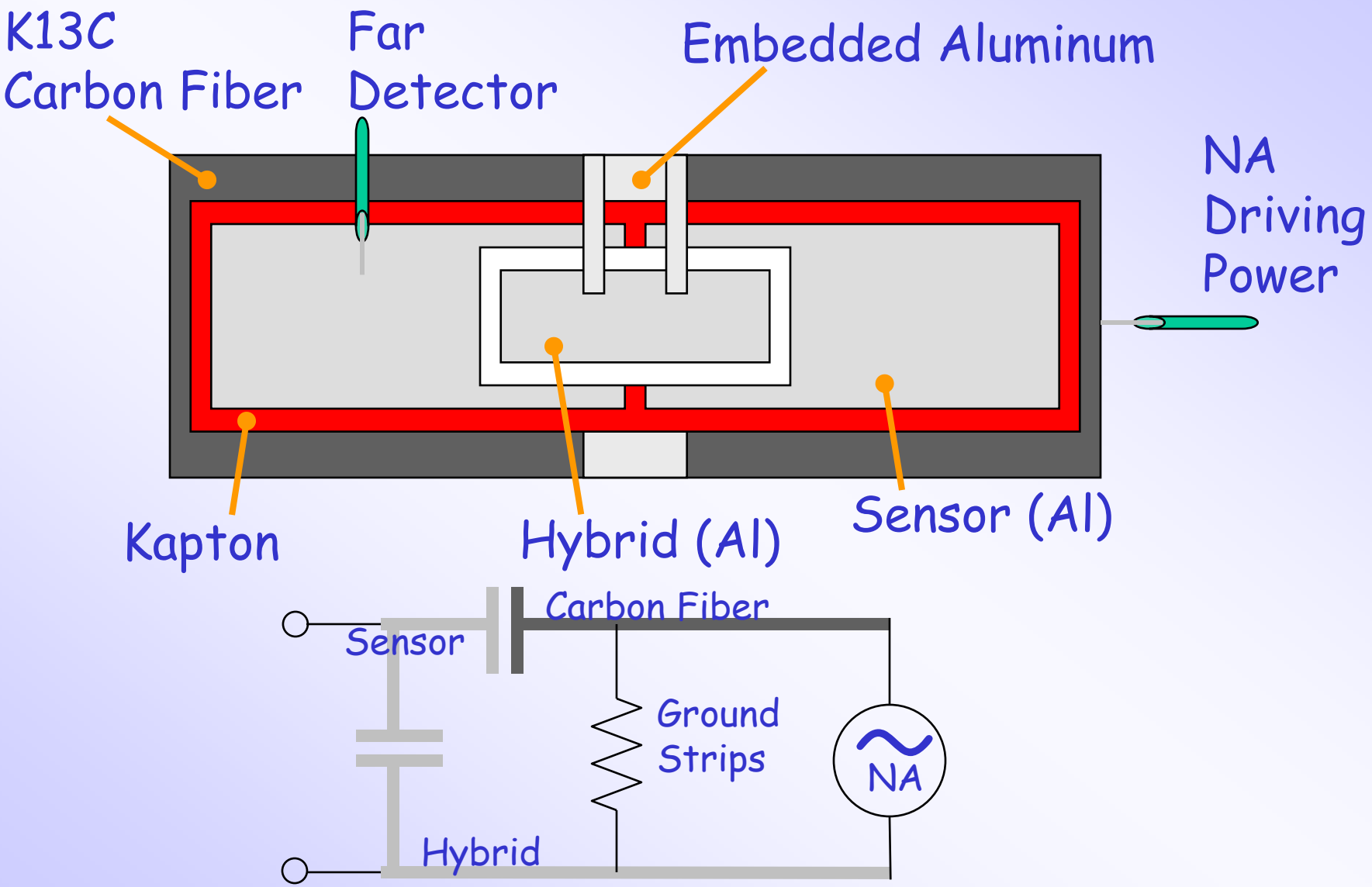
# Shorting the Carbon Fiber

- **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**



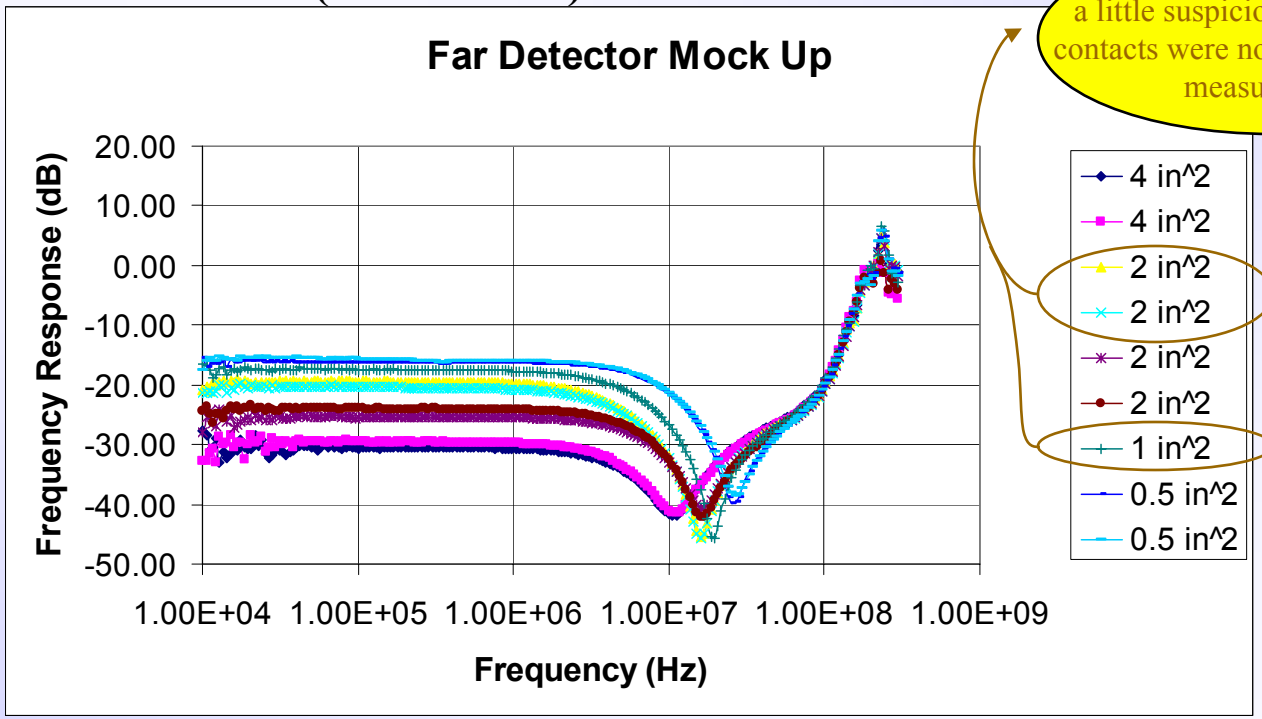
- **Try aluminum foils embedded onto the carbon fiber surface**
  - **Narrow aluminum strips folding up and over to the ground pads**

# L0/L1 Mock-up


K13C
Carbon Fiber
Far
Detector
Embedded Aluminum
NA
Driving
Power
Kapton
Hybrid (Al)
Sensor (Al)
Carbon Fiber
Sensor
Ground
Strips
NA
Hybrid

# L0/L1 Mock-up

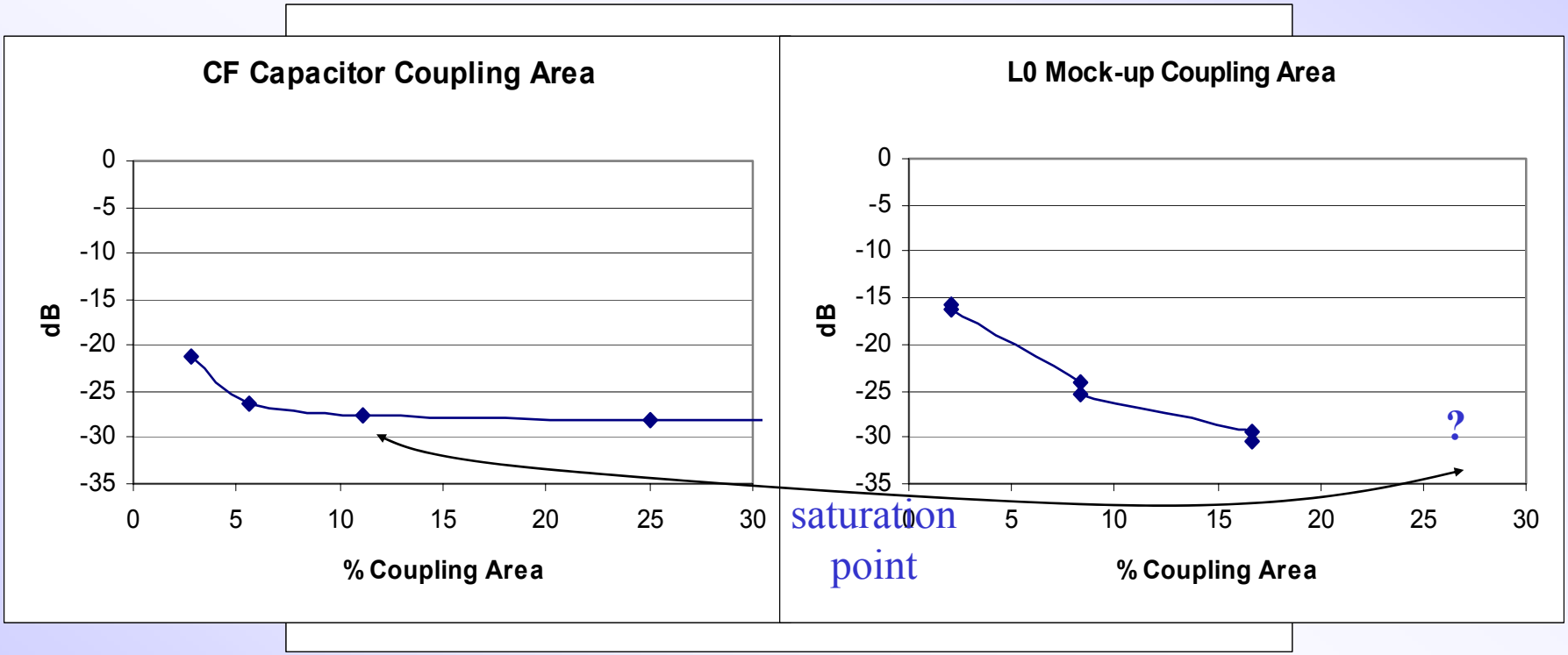
- **Studied transfer functions from the C fiber to the "sensor"**
  - **Varied the amount of C fiber area covered by embedded aluminum**
    - **0.5 in² → 4 in² (2% → 17%)**




  - **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**

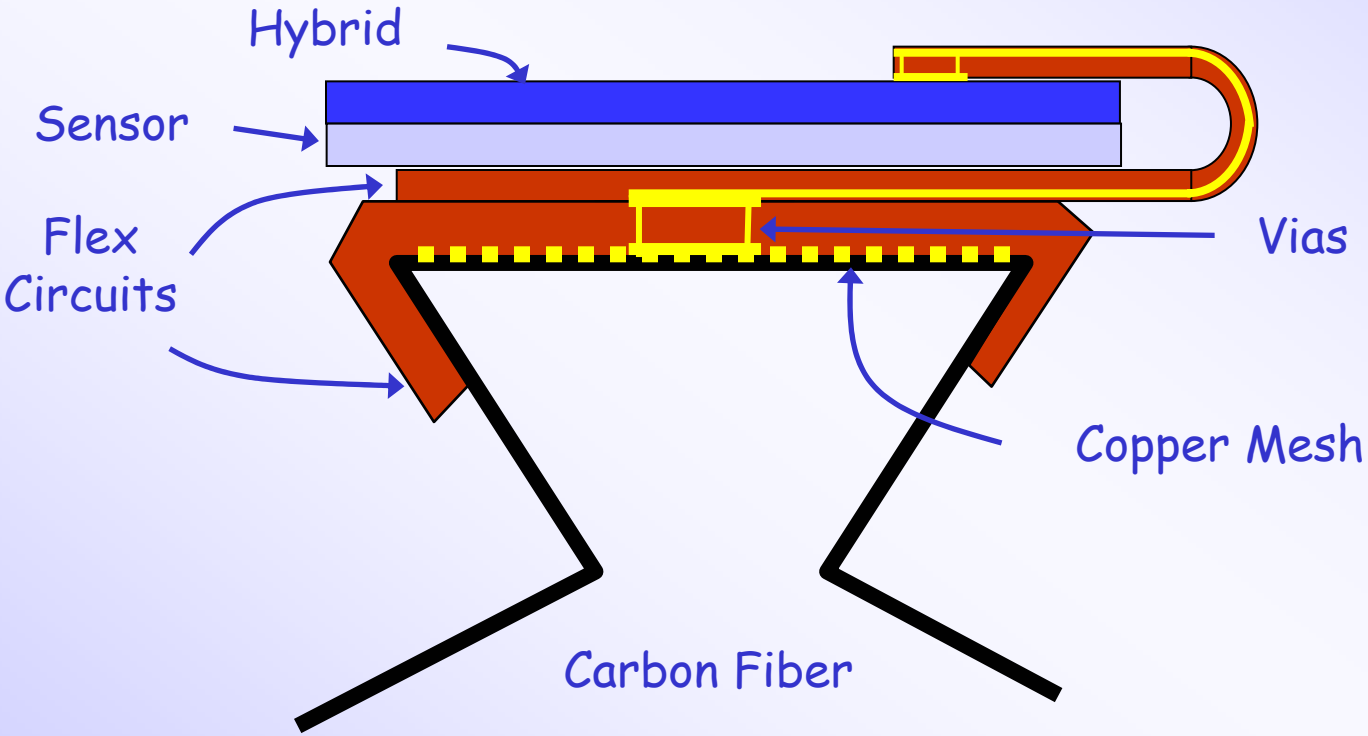



- **Estimate 25-30% coverage by embedded Al is needed for maximum attenuation**

# Ongoing Studies

- **A significantly more complicated, though considerably more robust coupling concept…**

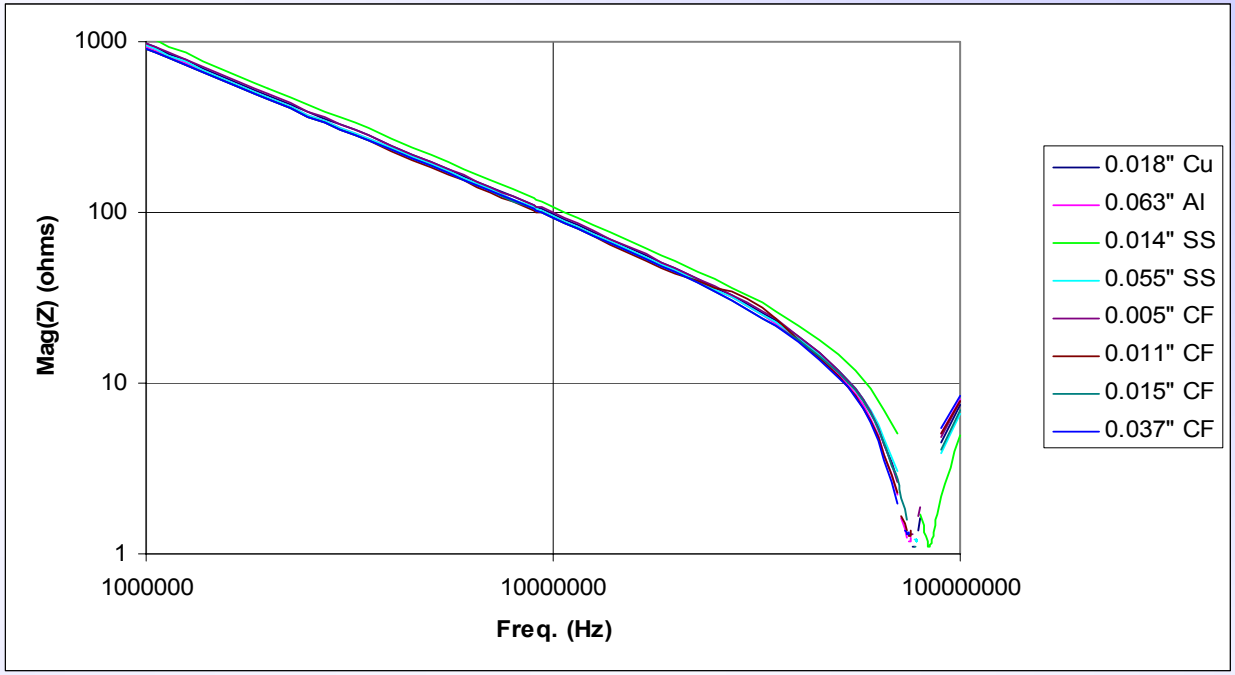
**(not even close to scale…)**




- **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**