Performance of the DZero Layer 0 Detector

Marvin Johnson

For the DZero Silicon Group

Outline

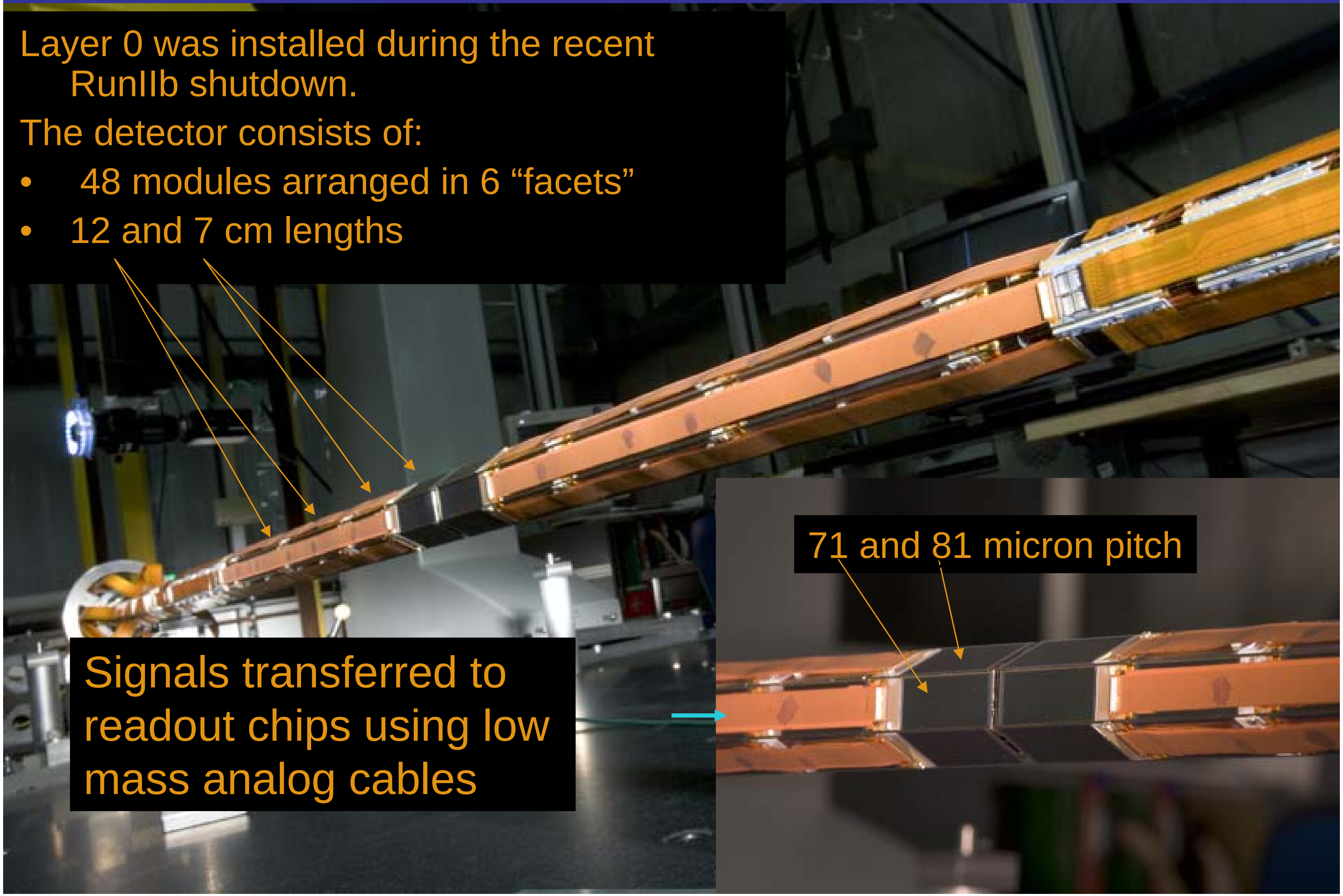
- Description of the detector
- Noise and tracking performance
- Low noise design techniques
- Implementation in layer 0
- Conclusion

Layer 0 Performance

Layer 0 was installed during the recent RunIIb shutdown.

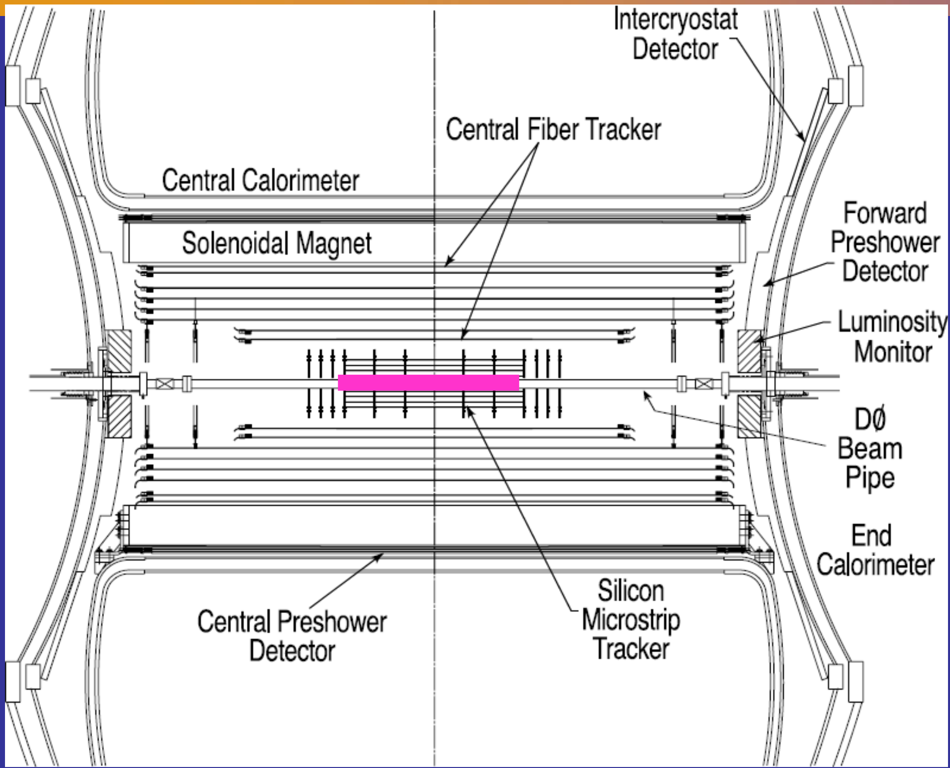
The detector consists of:

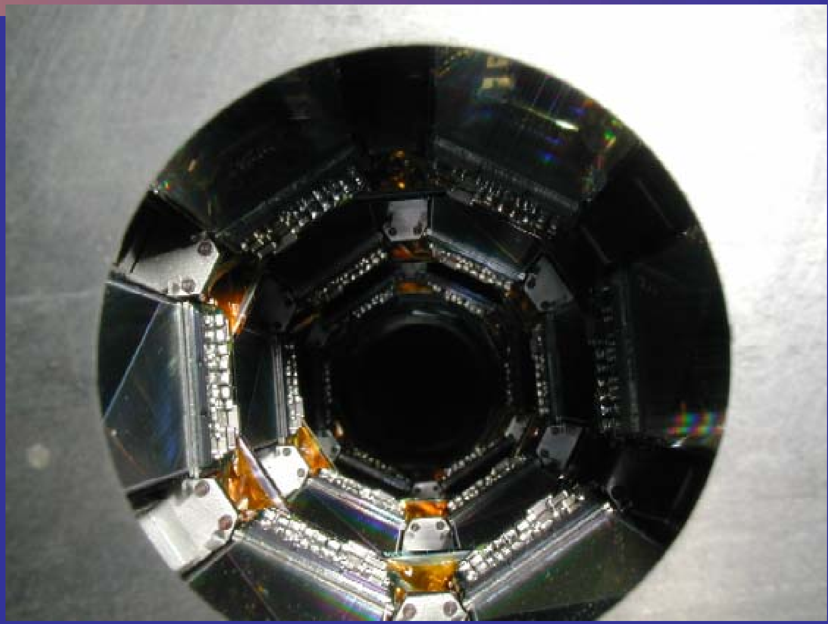
- 48 modules arranged in 6 “facets”
- 12 and 7 cm lengths

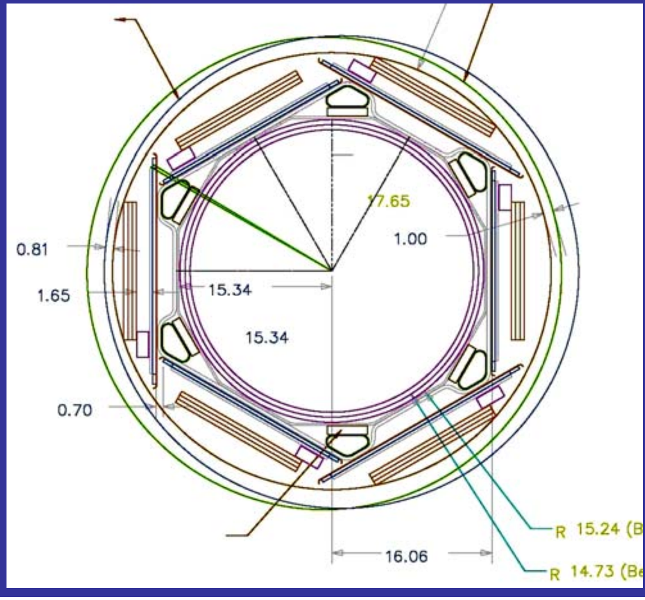


Signals transferred to readout chips using low mass analog cables

Where does L0 go?







Clearance

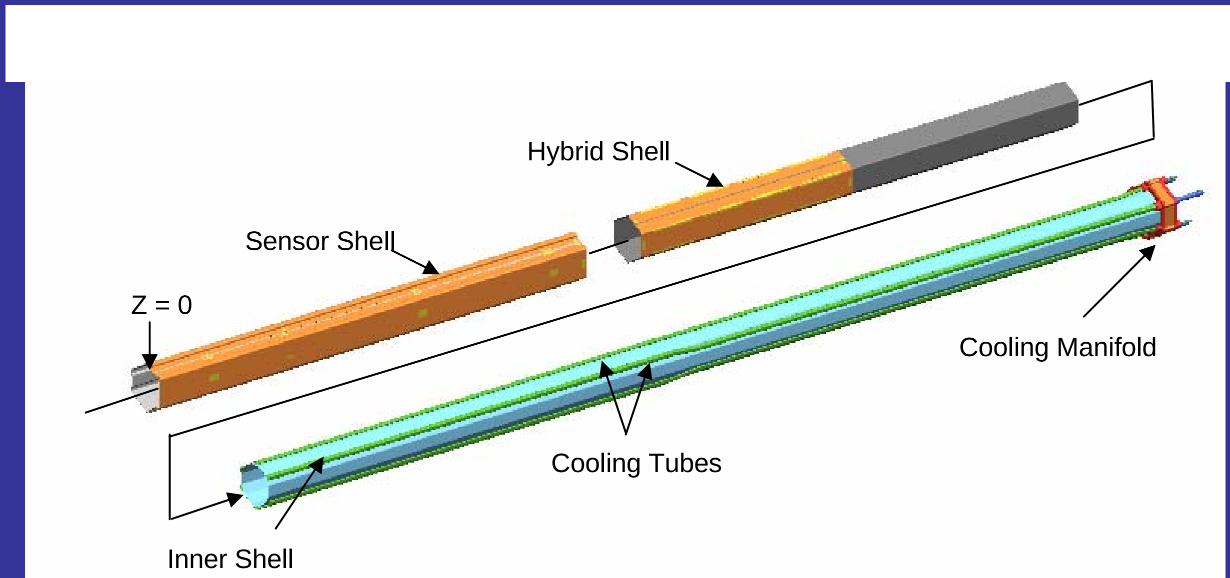
outer radius ~23mm

inner radius ~15mm

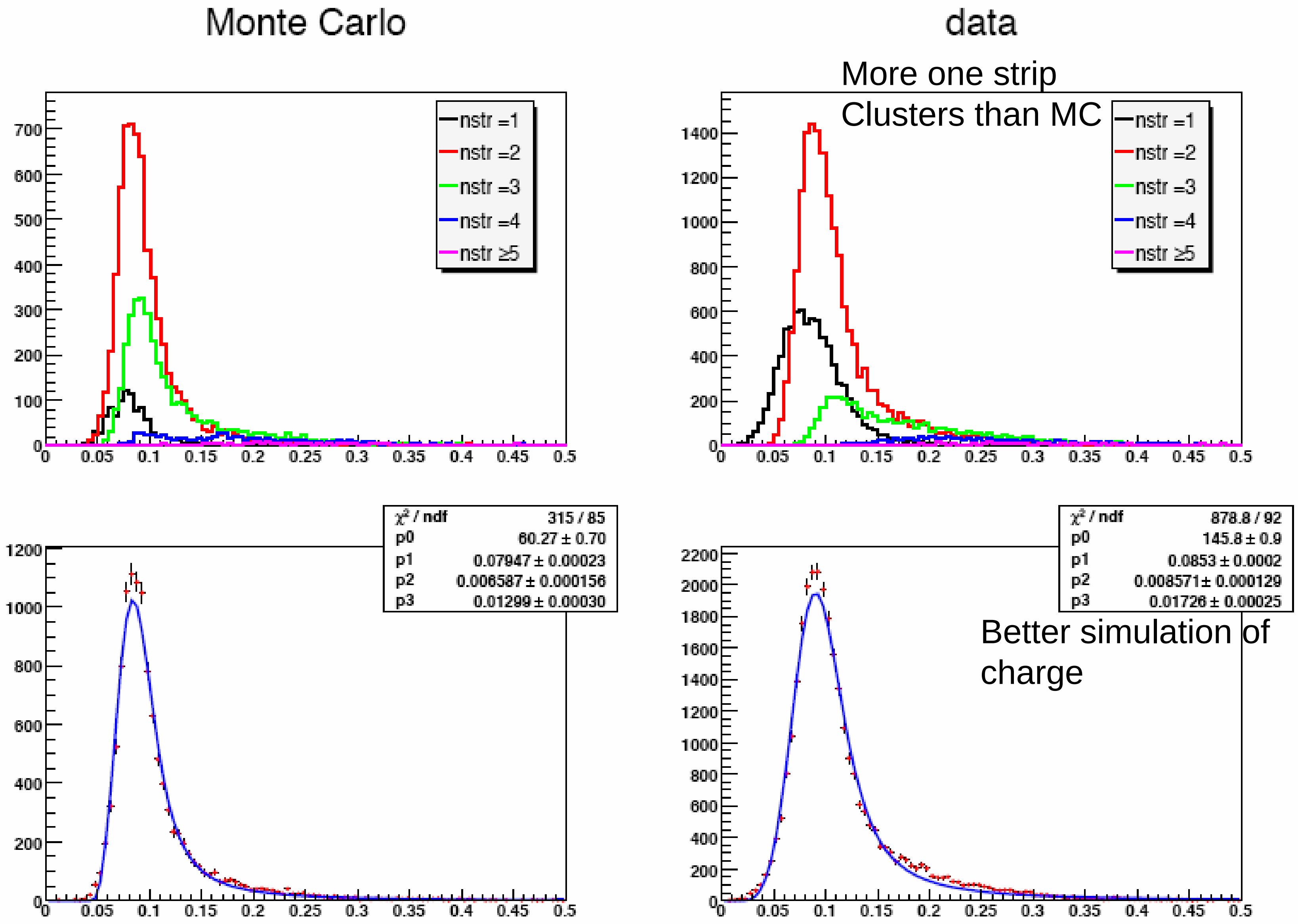
➔ very tight!

Layer 0 Structure

- All Carbon fiber structure
- 3 main pieces but no separation for electrical isolation



Performance - Charge Distributions



Noise

- Challenging noise design because of long cables between silicon and amplifier.
- SVX 4 has good noise performance

$$Q_{noise}^{SVX4} = 700 + 48C_D$$

- Challenge is to reduce common mode noise as much as possible

Noise Theory

- We define noise for channel a as $\sigma_a^2 = \overline{a^2} - \overline{a}^2$
- To investigate common mode noise we define differential noise as

$$\left(\sigma_a^{diff}\right)^2 = \frac{\overline{(a-a')^2} - \overline{(a-a')}^2}{2}$$

- We also assume that the noise is equal in the two channels. Then

$$\left(\sigma_a^{diff}\right)^2 = \frac{\sigma_a^2 + \sigma_{a'}^2}{2} - \overline{aa'} + \overline{a}\,\overline{a'} = \frac{\sigma_a^2 + \sigma_{a'}^2}{2} - \rho\sigma_a\sigma_b = \sigma_a^2(1-\rho)$$

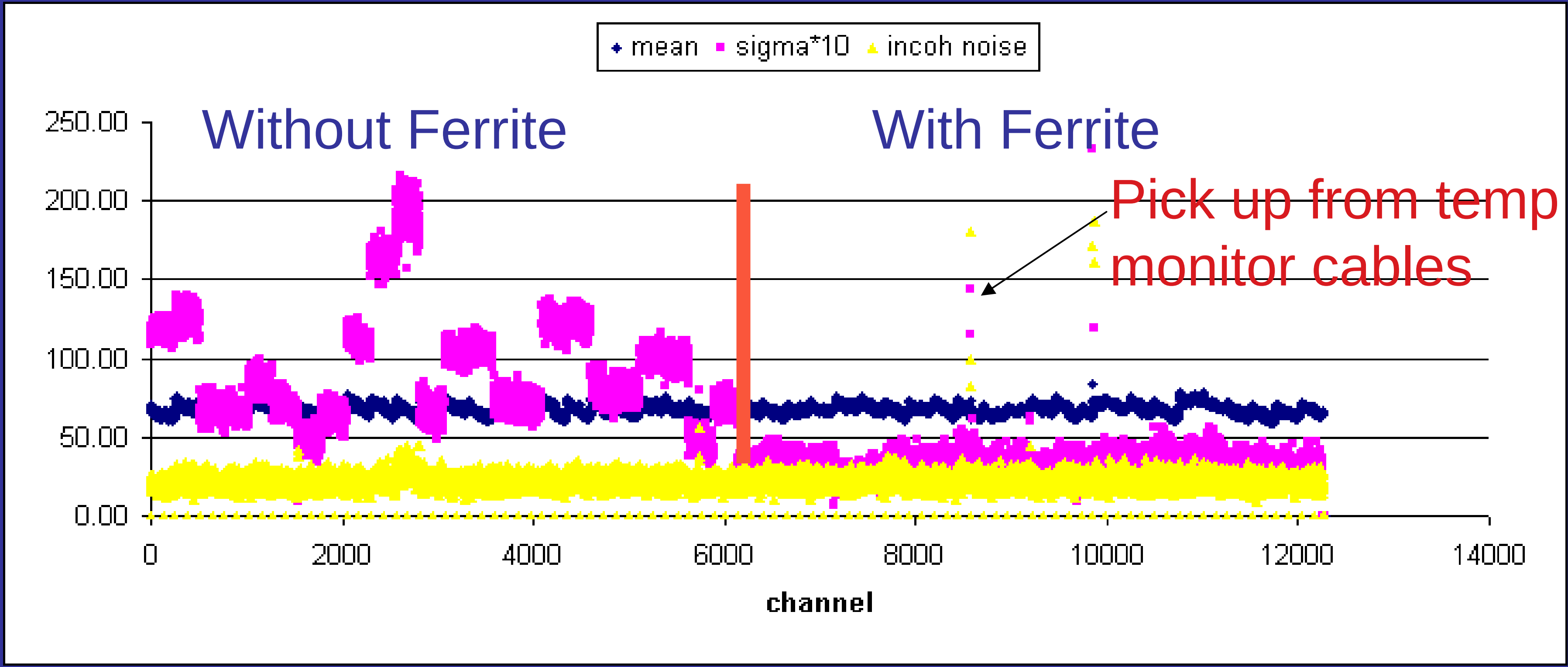
$$\rho = \frac{\mathrm{cov}(a,a')}{\sigma_a\sigma_{a'}}$$

Correlations

- Adjacent channels are correlated through interstrip capacitance (G. Lutz, NIM A 309 (1991) 545)
- Must include analog cable
- Measured capacitance of cable but…
  – Cable has ~ 20 ohms of resistance
  – Cable has variable spacing from ground
- Best estimate is .35 ADC counts of common mode noise (MIP signal is ~30 counts)

Early Test Stand Data

Ferrites refer to filters on the power supply lines



Detector installed in D0

Design Goal was S/N=15

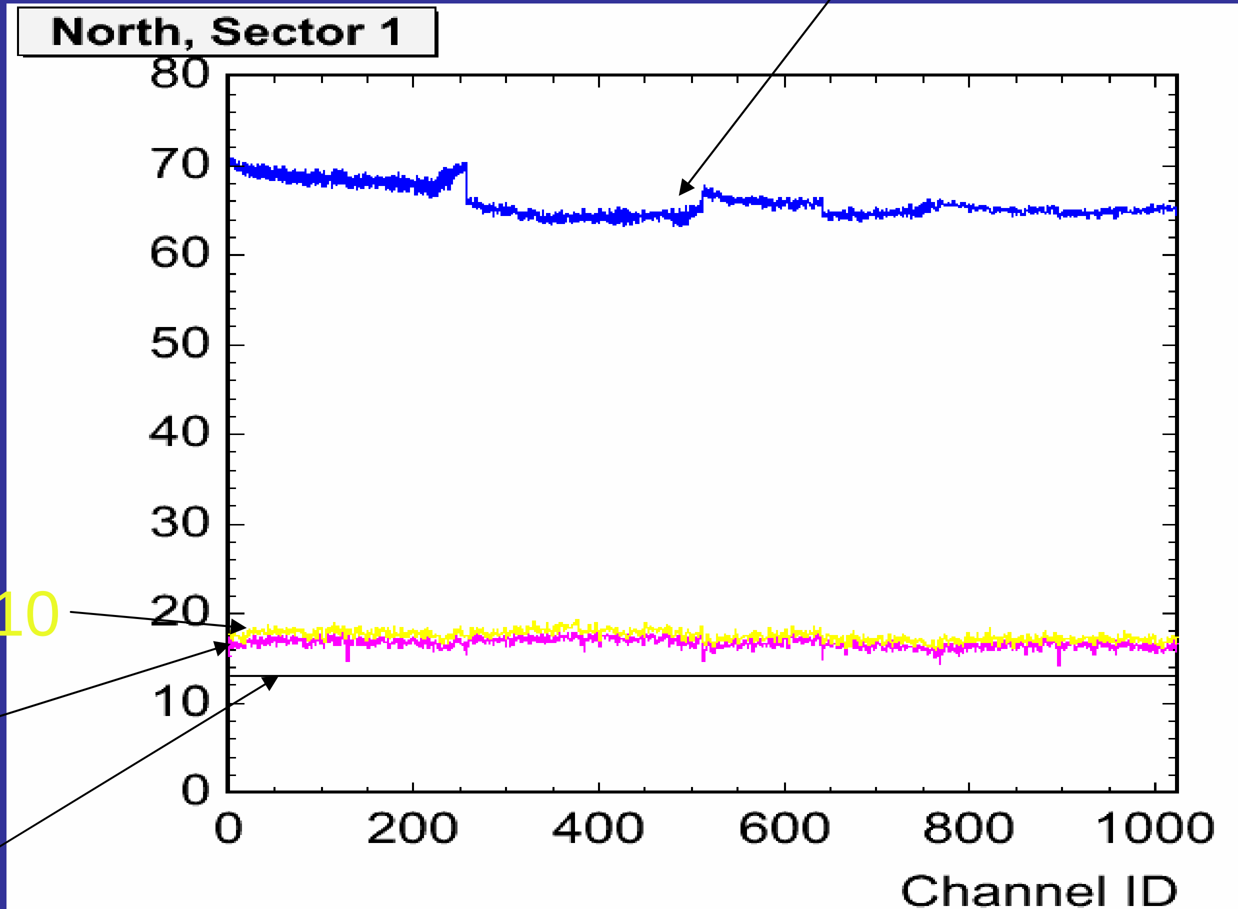
Measured S/N=18

Pedestal

Differential noise X 10

Total noise X 10

Calculated Noise



No real time pedestal subtraction

Noise Sources

- Ground Loops
- Power Supply Noise
- Other Noise conducted into the Detector
  - Capacitive coupling is very important
- Radiated Noise (broadcast) is usually NOT a source
  - Radiators are usually the size of the wavelength
  - Radiated wave needs ~ wavelength to develop

Detector Grounding Principles

- Isolate the input lines from capacitive coupling to the rest of the world.
- Keep the entire detector at the same potential as the ground of the SVX 4 chip.
  - No noise will be measured even if the ground is oscillating.
  - Minimizing inductance is crucial
- Eliminate ground loops - especially ones through the detector structure

Ground Loops

- Small diameter of detector required a continuous carbon fiber support tube
- Carbon fiber is conductive at high frequencies (W. Cooper et al, NIM A 550 (2005) 127)
- Electronics at each end so if they are grounded, there is a ground loop
  - Magnetic fields cutting this loop will cause currents in the carbon fiber => noise in the readout.

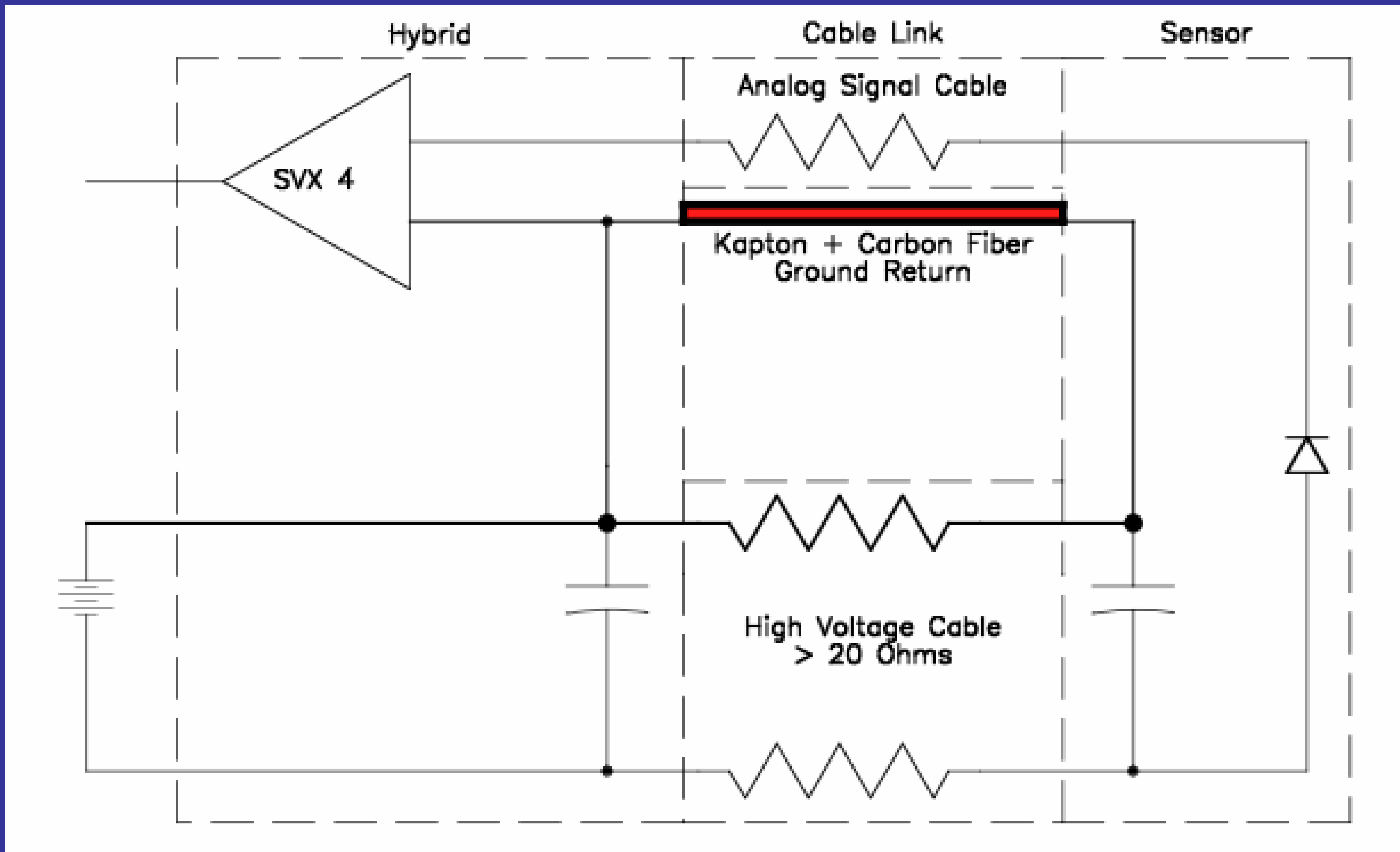
Our Solution

- Electronically create an isolated ground on the detector
  - Use ground isolated power regulators near the detector
  - All signals sent differentially across the barrier
  - Minimize capacitive coupling in the mechanics
  - Isolated high voltage ground with 10K resistor
- We achieved about 60 ohms at 1 MHz
  - Run the SVX 4 at lowest bandwidth to minimize coupling
- Isolated ground needs reference to the outside world
  - This is provided by the high voltage ground resistor

Filters

- Regulators did not have enough common and differential noise rejection for power supply noise and cable pick up
  - Added CLC filter before regulators
    - Filter both source and return for common mode noise.
- Tested this system by shorting the grounds together
  - Overall affect was small.
  - Implies rest of grounding design was working exceptionally well

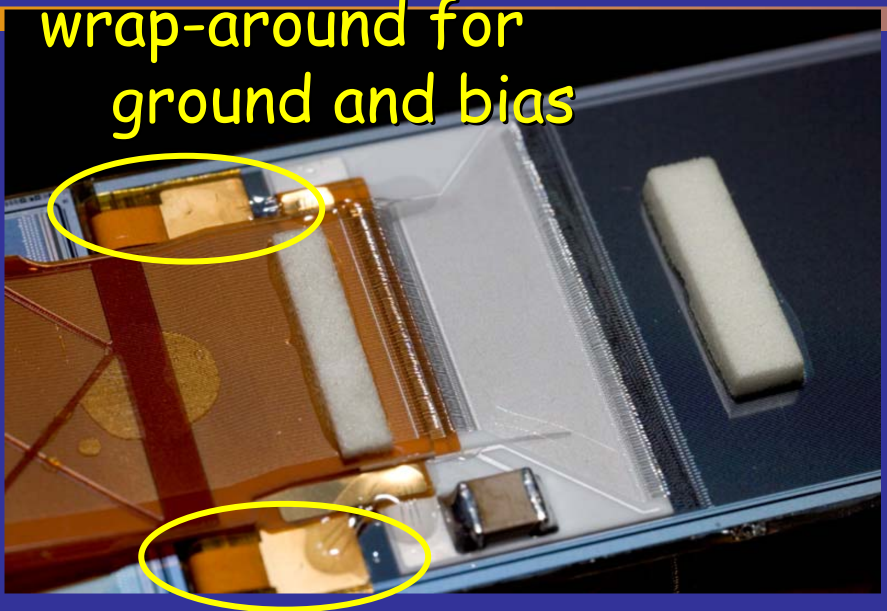
Detector Schematic

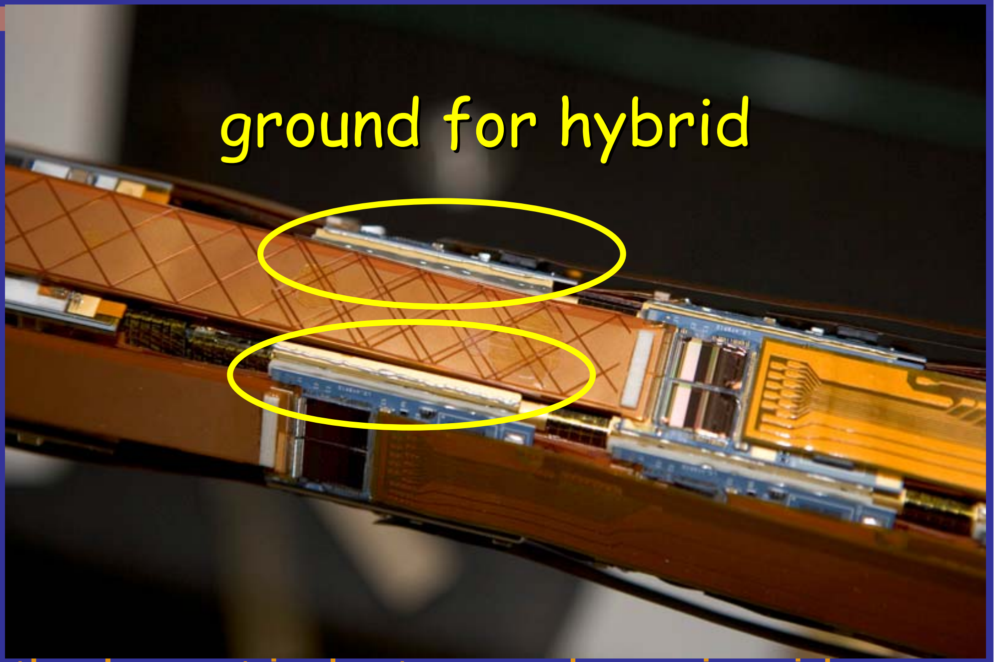


Some Detector Design Features

- Carbon fiber is conductive but needs 10%-20% coverage by copper or Aluminum to make a good connection (see NIM article)
- Want even better conductivity to minimize potential differences across the detector
- We developed a process where we co cured a copper clad Kapton sheet onto the outside of the carbon fiber
  - 5 µ copper etched as a mesh with 30% coverage
  - Kapton thickness is 25 µ
  - Copper is next to the carbon fiber. Vias with gold plated contacts are used to connect to to the circuit.

Other Tricks





- For a given amount of material, the lowest inductance shape is wide and thin.
- Wrap-around to connect sensor GND to support (as well as bias voltage to backplane)
- Mesh (to minimize capacitance) spacer between analog cables
- Large area for hybrid ground connection

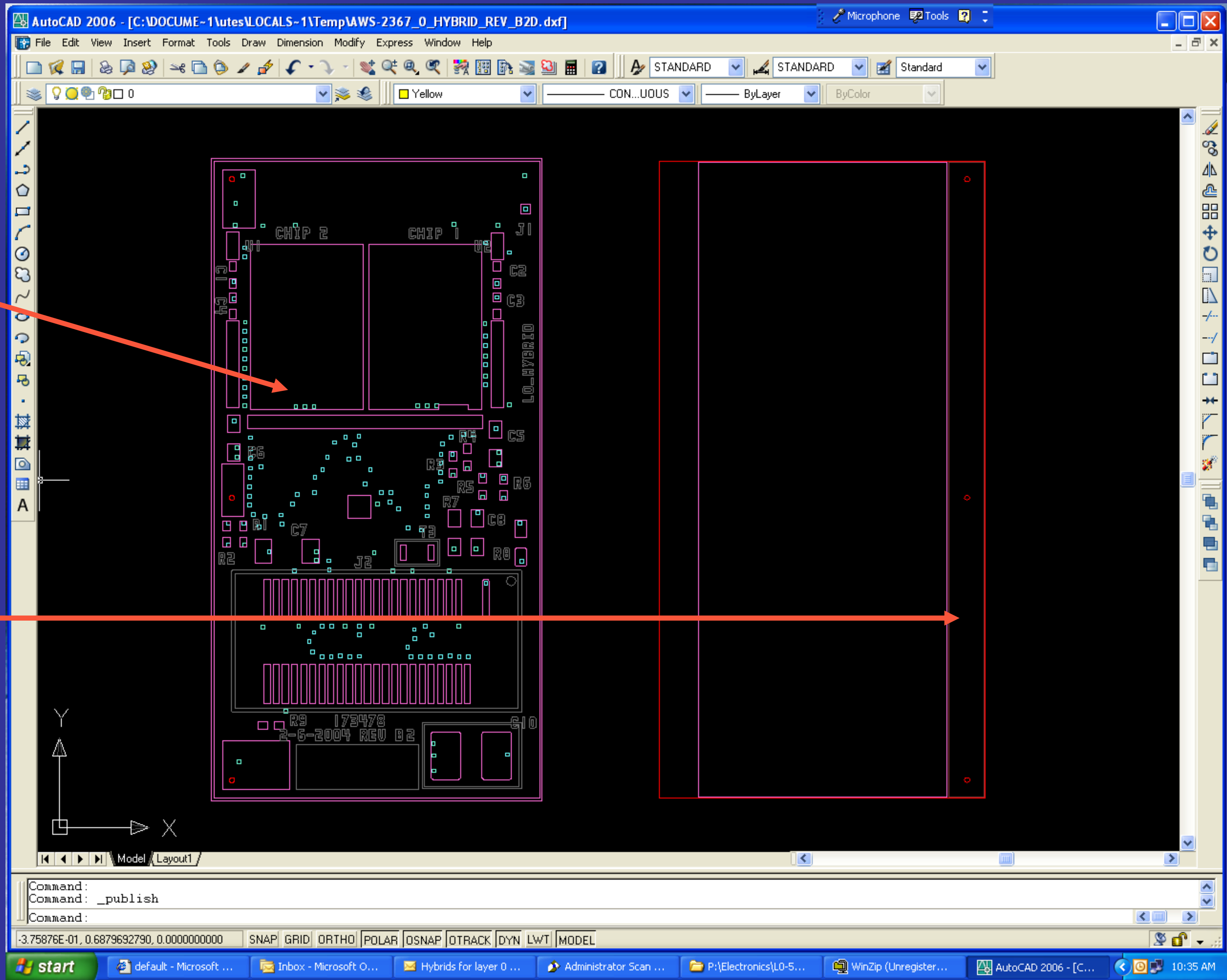
Hybrid grounding

- Tried wire connections to connect to carbon fiber
  - Tried 1 to 4 wires about 2 cm long
- The larger the number of wires, the less noise.
- Switched to gold strip on back of hybrid
  - Provided the very lowest noise.
- SVX 4 set up as single point ground
  - Minimize ground currents inside chip

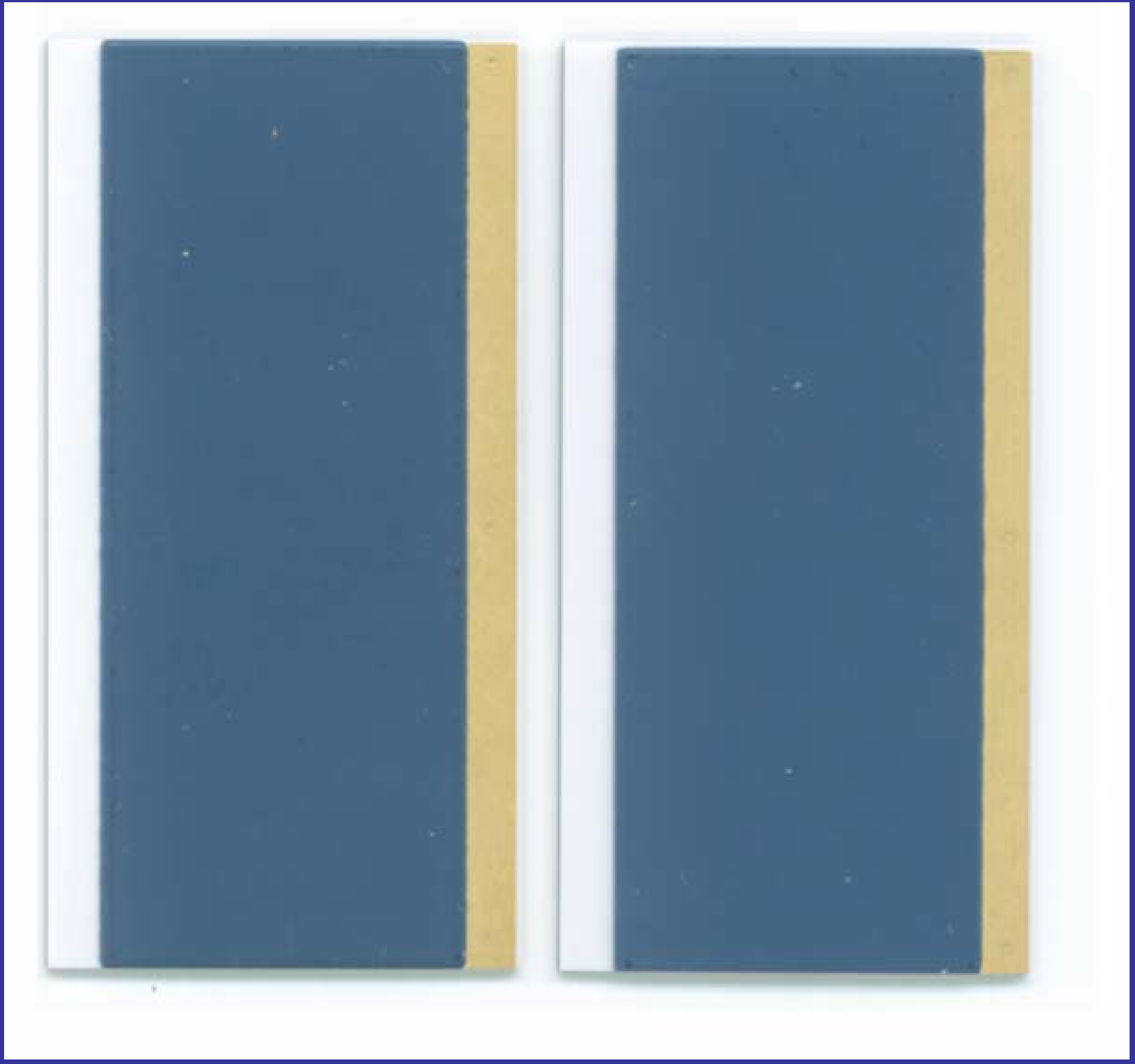
Hybrid Schematic

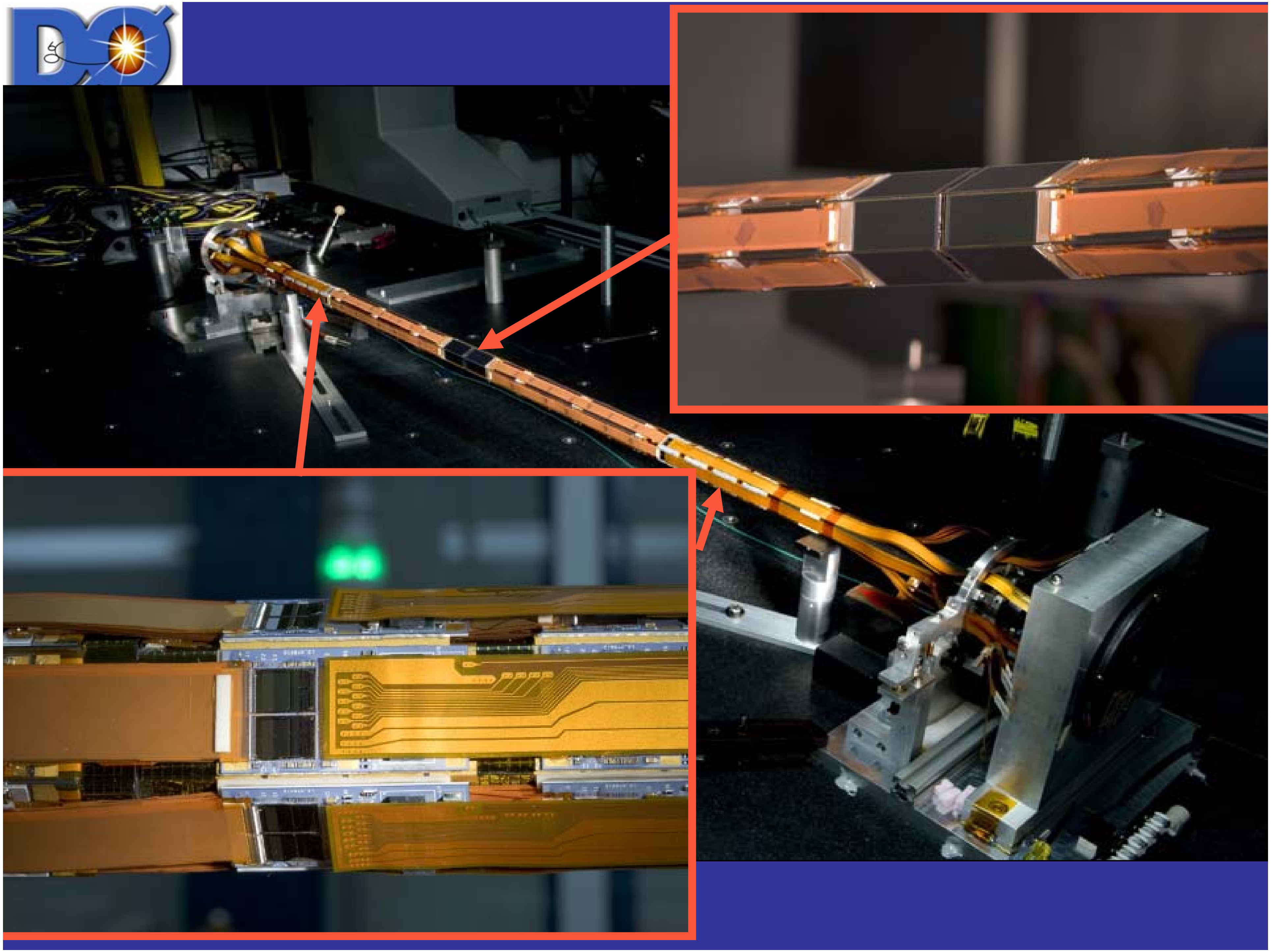
Single Point chip ground

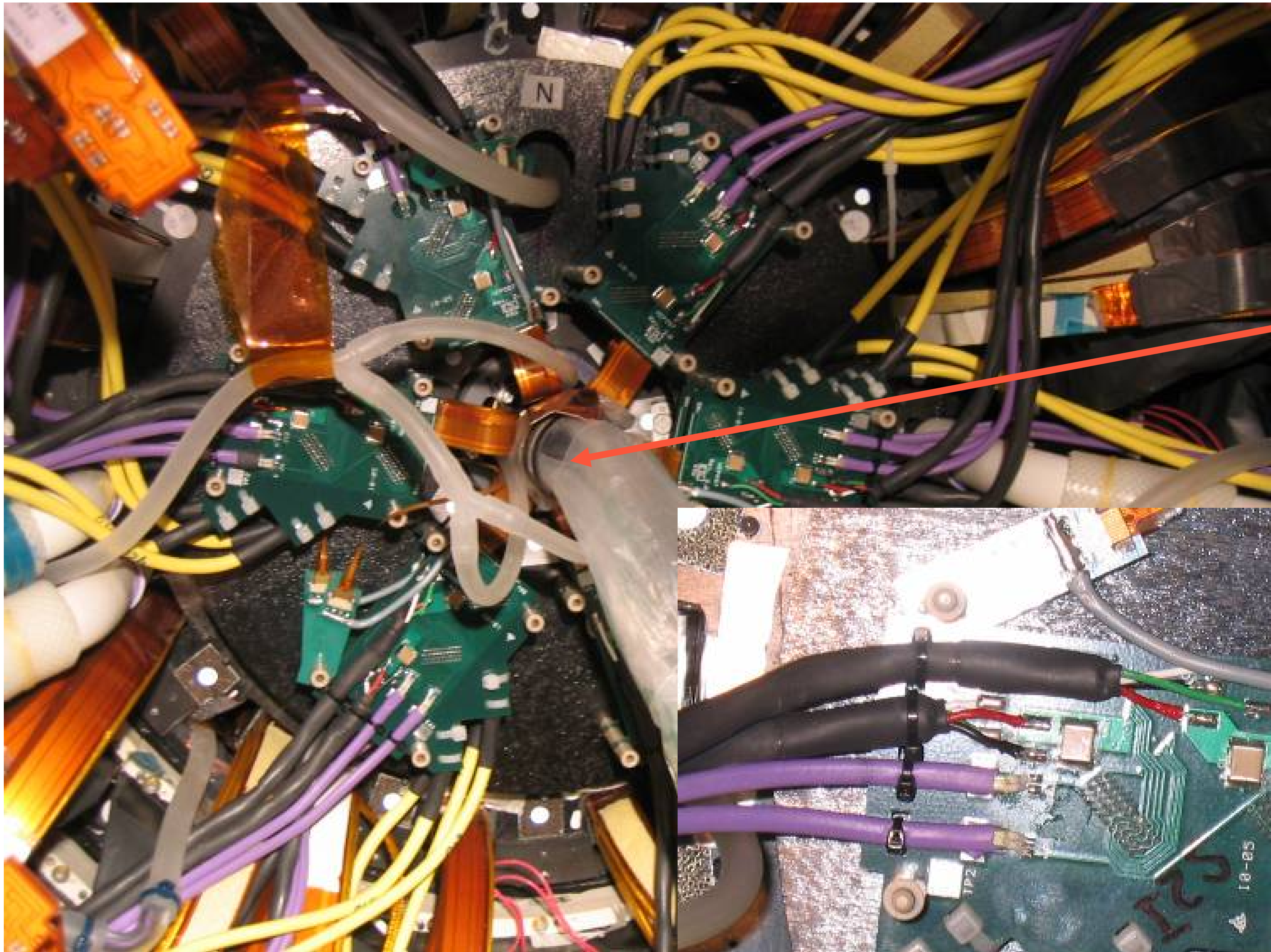
Strip on back of hybrid



Hybrid






N
Layer 0


S

Other Considerations

- There is no metallic shield around the detector
  - Radiated noise is almost never a problem
  - The large number of cable penetrations make an RF shield almost impossible
- Capacitive coupling is minimized by keeping layer 0 separated from nearby conductors
  - Beam pipe is an important issue
  - Separation is ~1 mm
  - Careful mechanical installation
  - Verified separation by measuring the capacitance between the beam pipe and layer 0

Conclusions

- Layer 0 has ~.3 ADC counts of common mode noise
- Isolated ground is useful but does not make a major contribution
- Good power supply filtering is important
- Single point ground for chip is likely to be useful
- Most important is overall detector design
  - Kapton mesh for connection to carbon fiber and low impedance ground
  - Hybrid to detector ground attachment
  - Bias voltage attachment at sensor