Grounding and Testing L0 (L1)
--- noise studies ---

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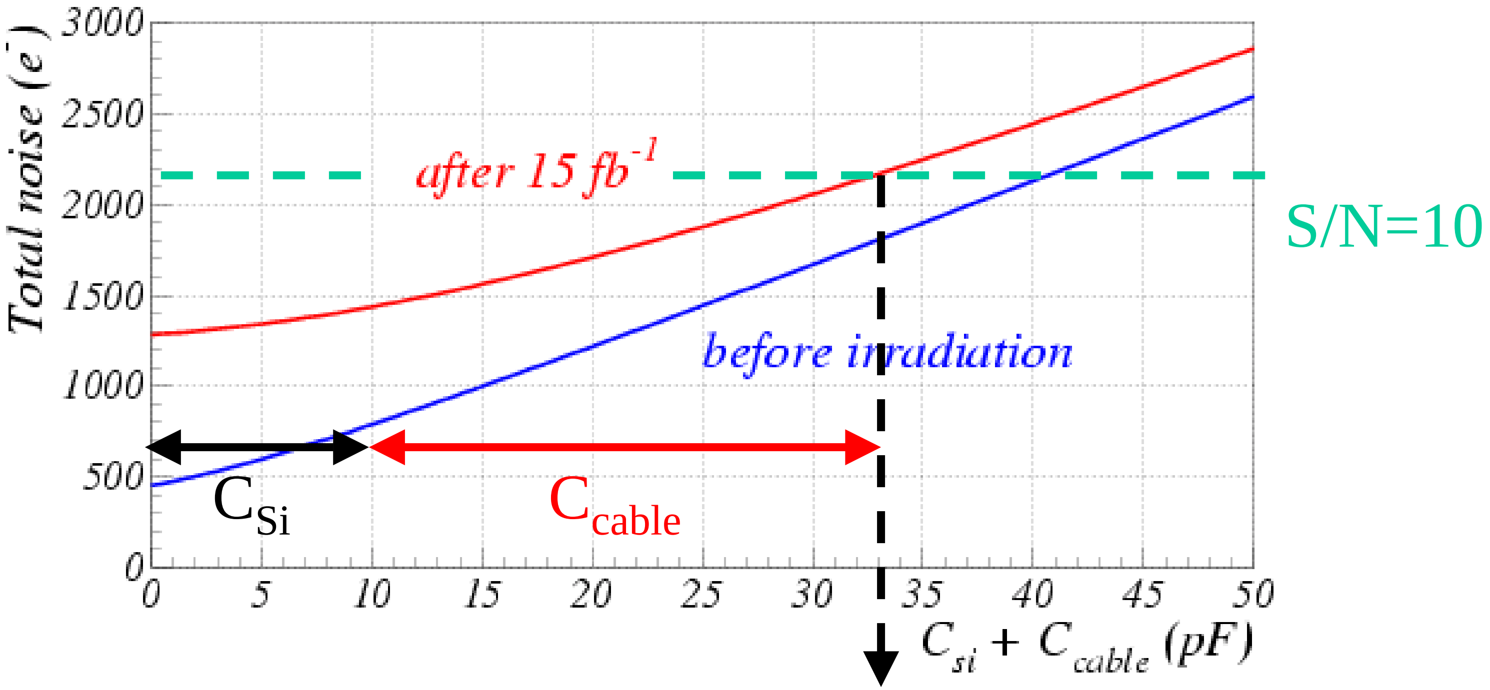
- Introduction of noise issue
- What is going on the other side of the ring (CDF).
- Noise studies using L0 prototypes
- Results for the L1 prototype module
- Grounding studies (done by Marvin, Breese, Mike M)
- Plan
- Conclusions

Introduction of Noise issues for L0

- Goal: S/N>10 after 15(6.5-11?) fb^{-1}.
- Internal contribution: capacitive load by the long analog flex cable.
- External contribution: RF pickup, capacitive coupling… 🡐 unfortunately the analog cable works as antenna.
- A few slides to show the current CDF situation.

Noise in terms of Capacitive Load

Total noise estimates VS total capacitance (C_{si} + C_{cable})

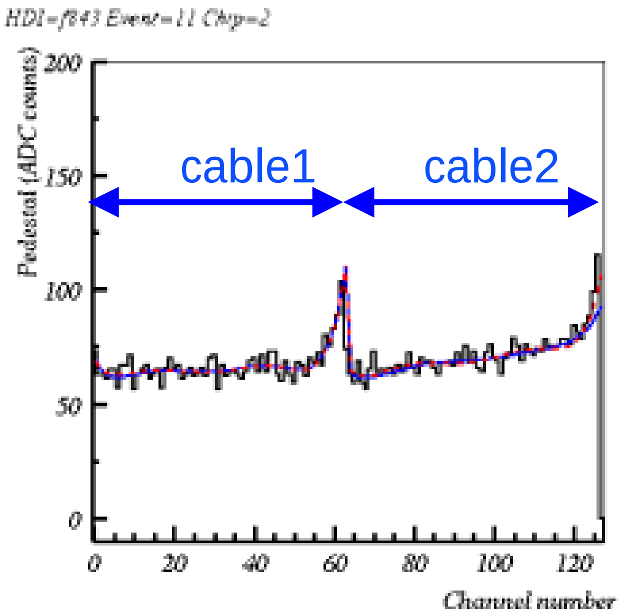


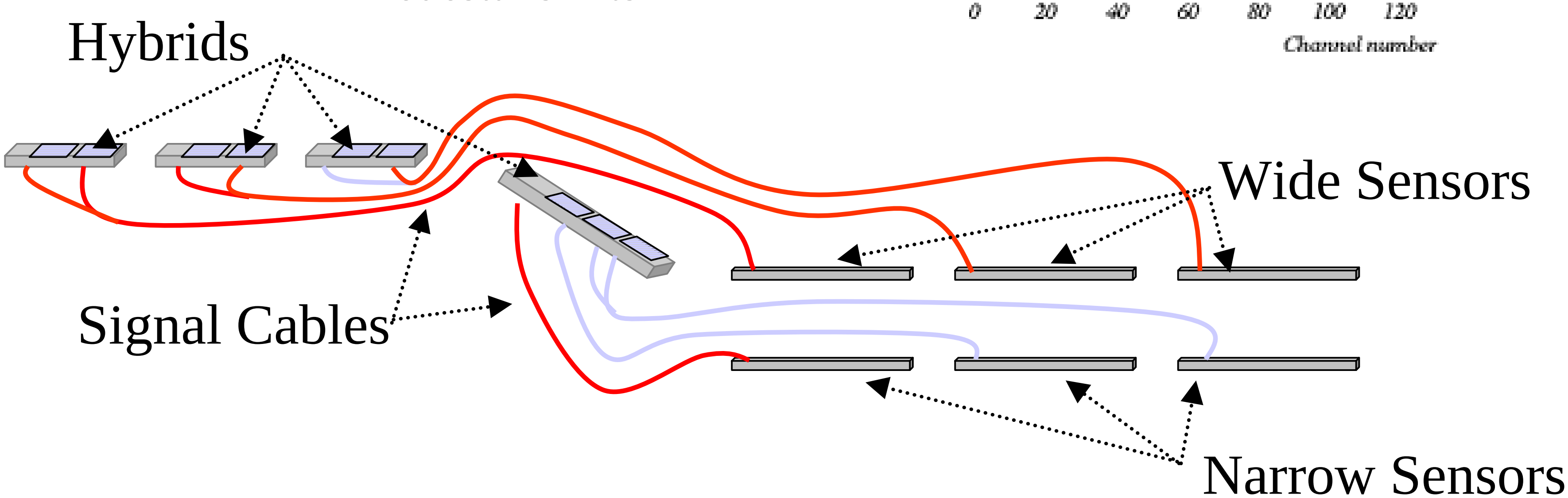
S/N=10 after 15fb^{-1} ➔ C_{cable} < 23pF for 43.5cm long cable

➔ C_{cable} < 0.53pF/cm

Lesson from CDF (Pickup on Signal Cables)

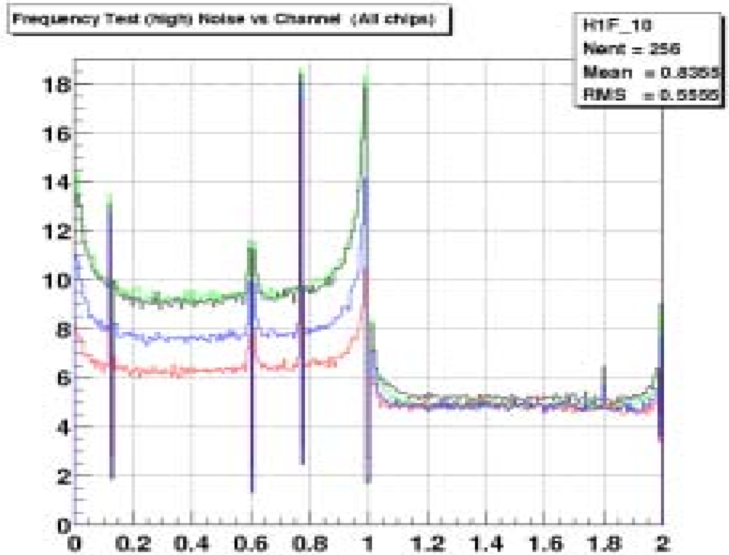
- Noise picked up by analog signal cables
  - Effects are seen at edges of cables, within one sensor
  - Both coherent and incoherent sources
    - Noise shapes
    - Pedestal shifts





Lesson from CDF (Study of Pickup)

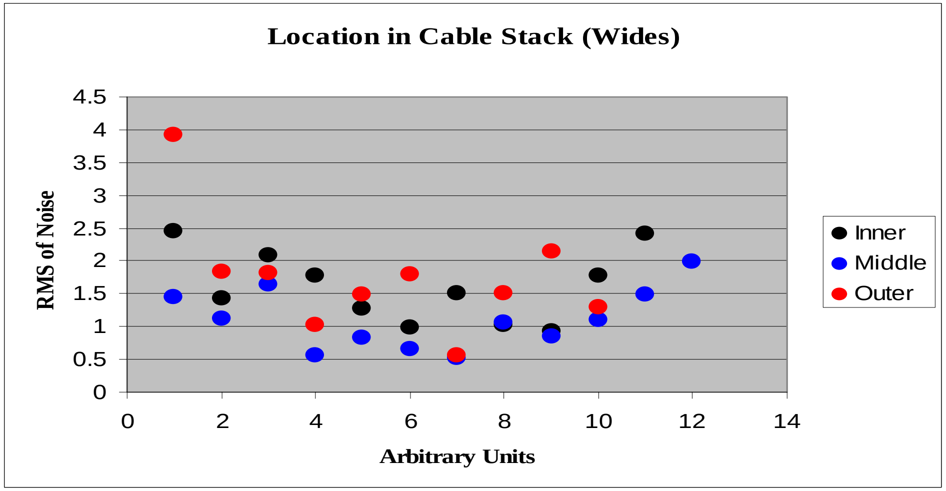
- L00 module in a well-grounded faraday cage
- Insert a noise source (waveform generator)
- Vary amplitude, frequency, geometry, grounding, shielding, state of SVX3D chips when acquiring, etc.

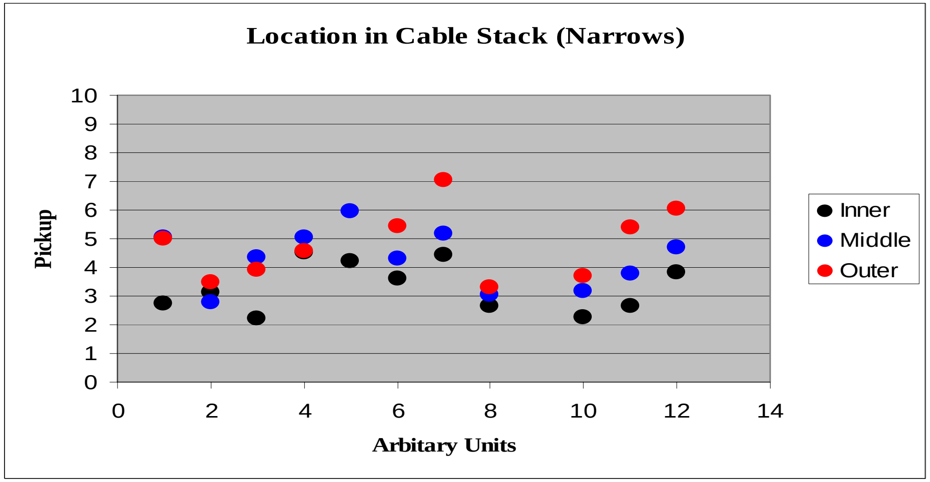


- Conclusions:
  - Cables are the antennae
  - Cables shield one another
  - Pickup increases with frequency
  - Large pickup in some dead-timeless operations, but common-mode
  - Hybrid electronics cables couple to signal cables, depending on geometry
    - Coherent pickup from in-time signals
    - Increased noise due to increased capacitance seen by front-end electronics
  - Properly grounded shield eliminates problem

Lesson from CDF (Correlations in Data)

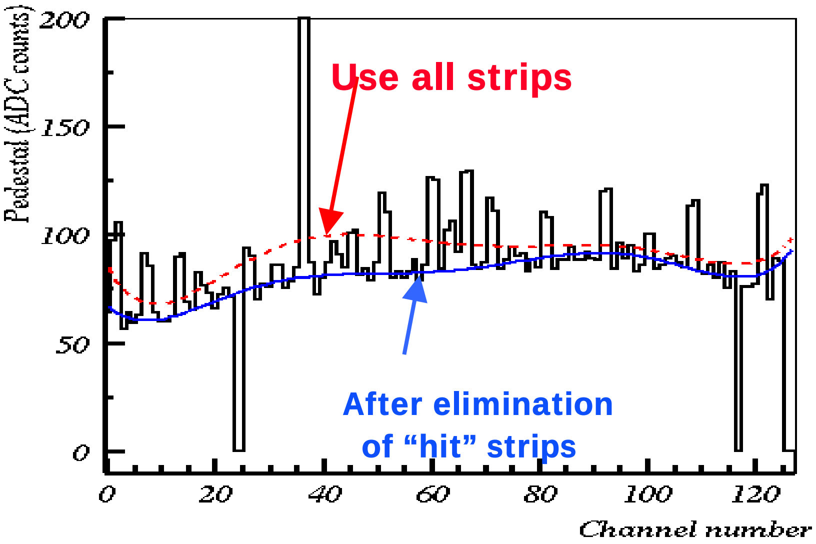
- CDF data exhibits patterns consistent with bench studies
  - Location in cable stack important
    - Wide modules with cables in the middle of stack have least pickup
      - Noise from above & below
    - Narrow modules chip's with innermost cable have least pickup
      - Noise source is above
        - » Beam-pipe, C-fiber support not source of noise
    - Less pickup on west than east
      - Shield grounded on west
- Has other structures not yet understood

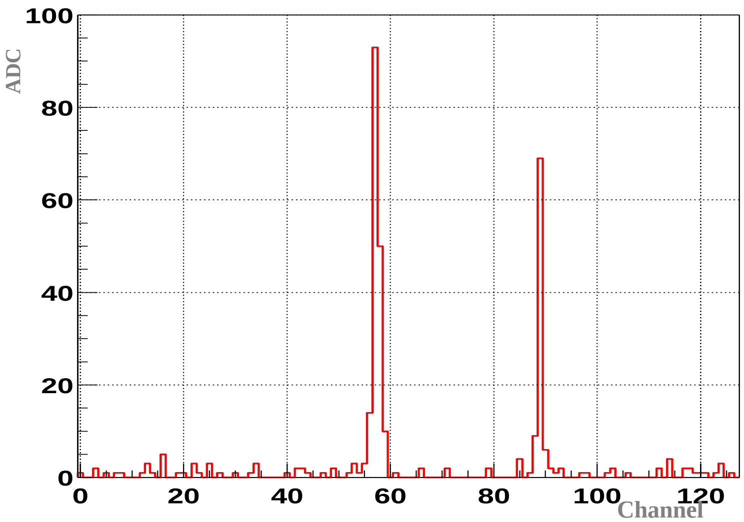




Lesson from CDF (Solution: Fit for Pedestal)

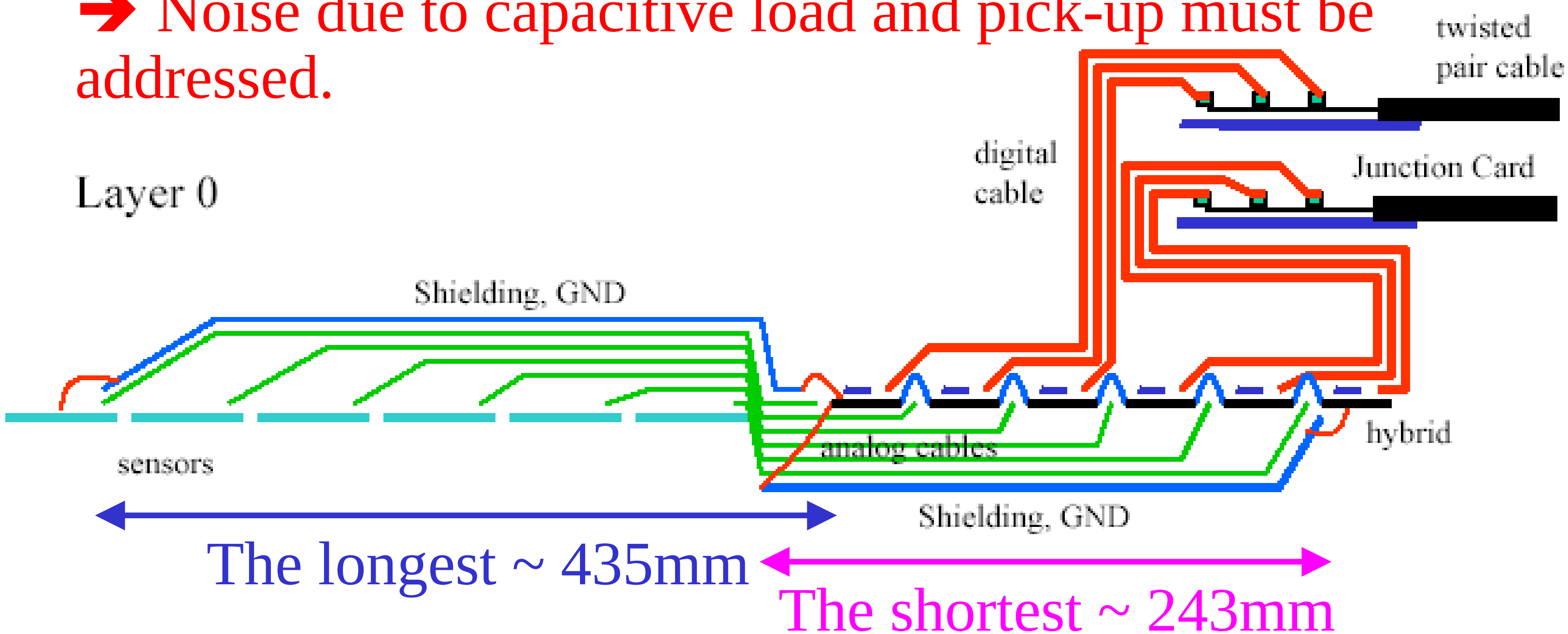
- Problem solved offline
  - Readout all strips in L00
  - Use this information to fit for an event-by-event pedestal
    - χ^2 fit to Chebyshev polynomials
  - Tested by embedding MC clusters in data
    - 95% efficiency with 95% purity
    - No impact on cluster size or centroid resolution
  - Implications for CDF
    - L00 can't be in online track trigger
    - Readout time may be a bottleneck



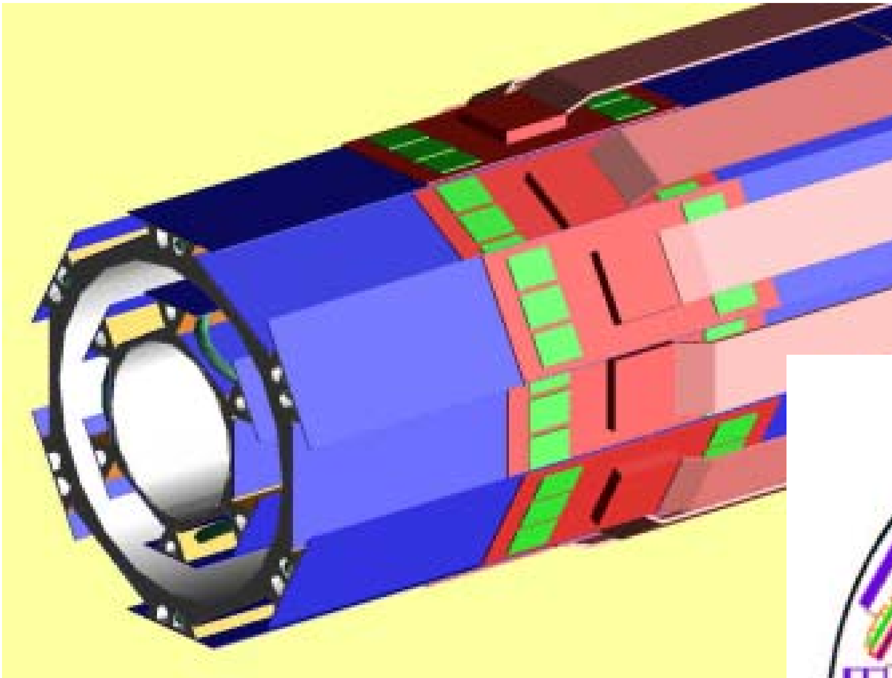


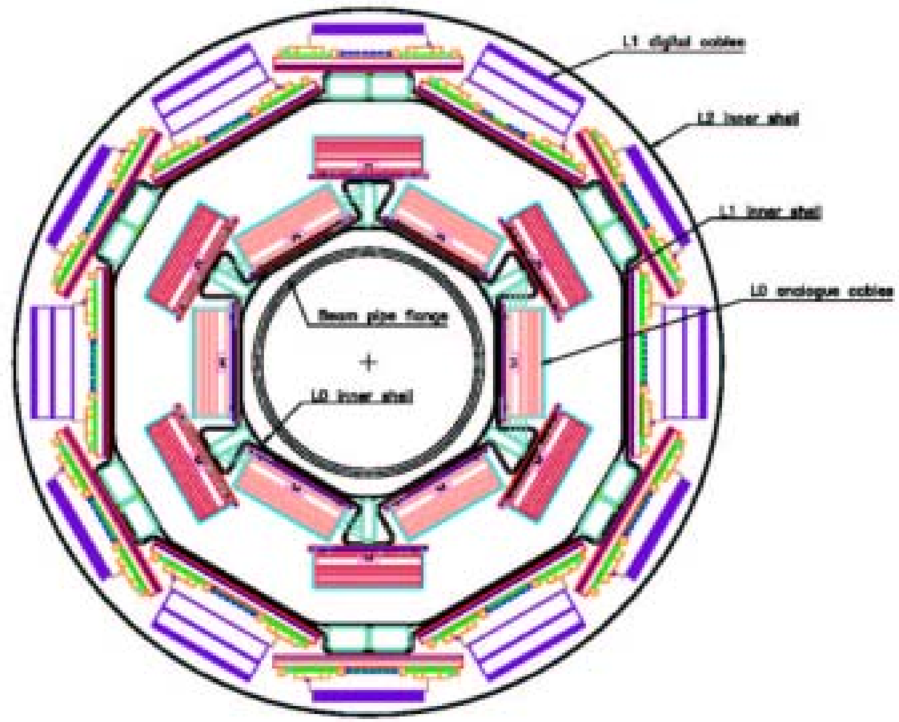
Conceptual Design of L0

- SVX4 chip cannot sit on the sensors because of the cooling and space issues.
  ➔ Signal must be read out from the sensor to the chip. Also bias voltage and its return must be provided.
  ➔ Low mass analog flex cable.
  ➔ Noise due to capacitive load and pick-up must be addressed.



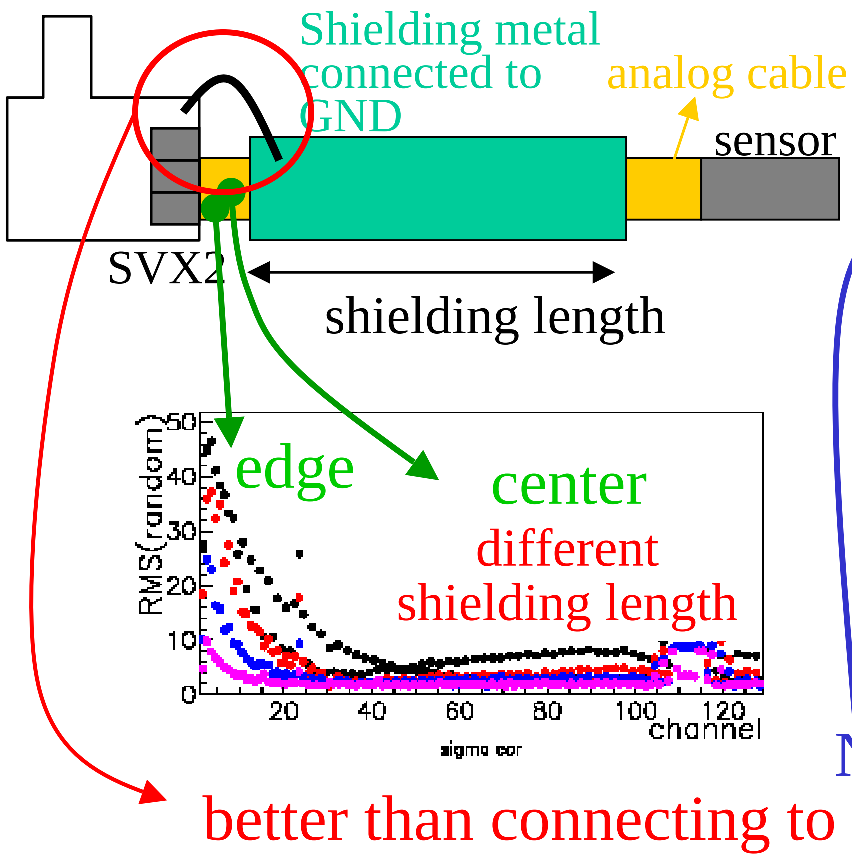
L0/L1 Design

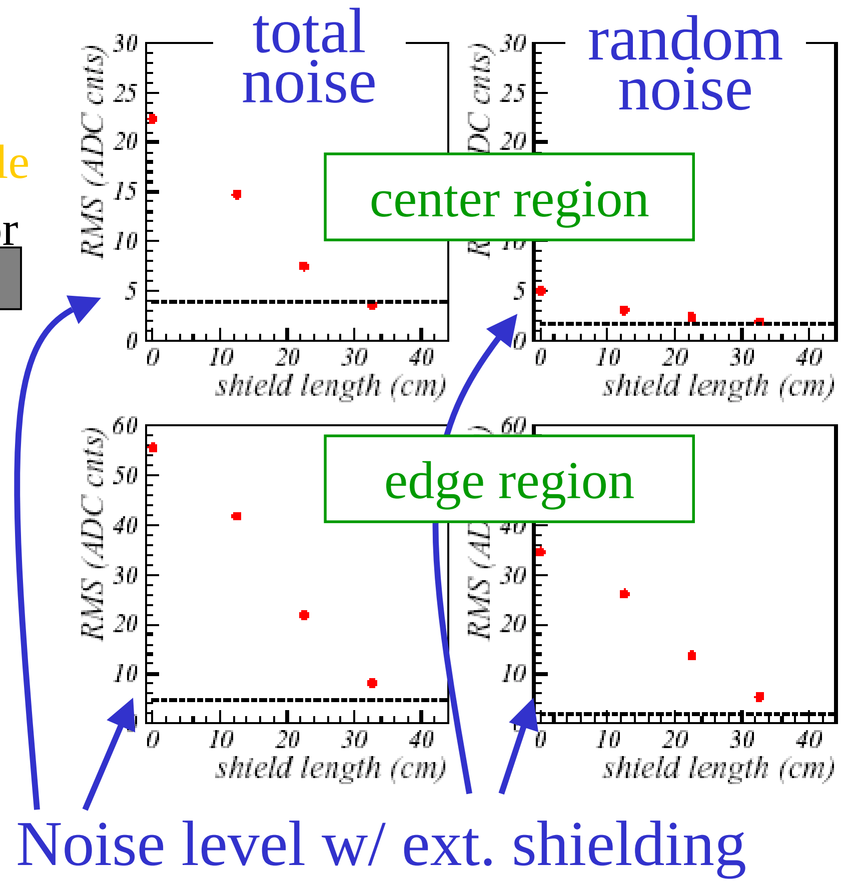



L1 digital cables
L2 inner shell
L1 inner shell
L0 analogue cables
Beam pipe flange
L0 inner shell

Shielding

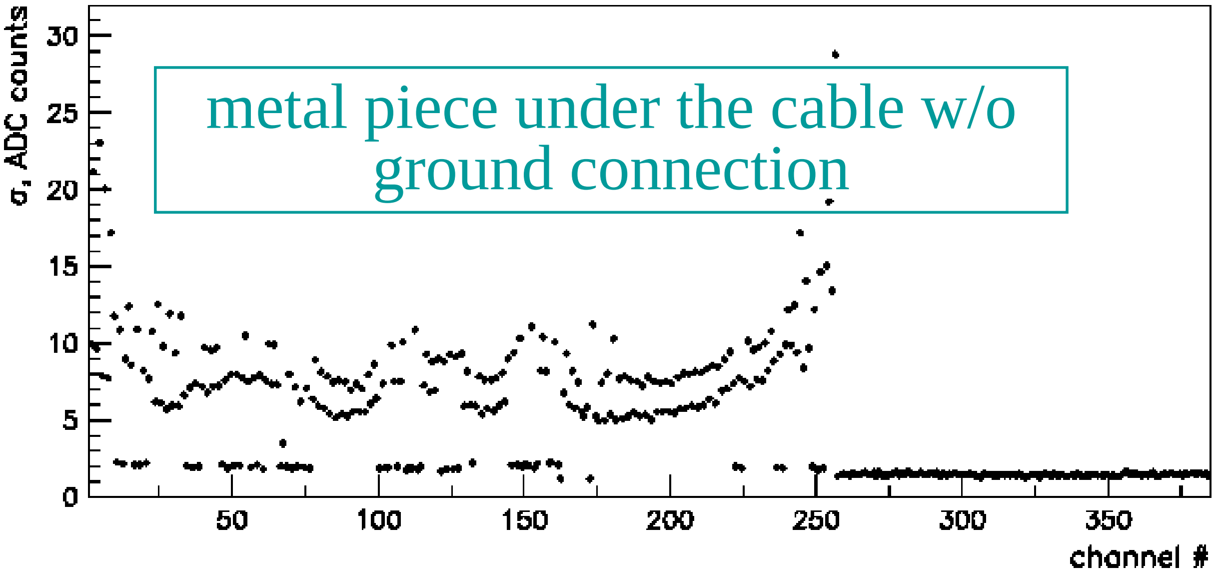
- RF pick-up by the analog cable.
- No external but shielding (= aluminum foil) only around the analog cable.

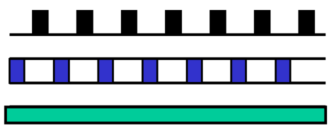




Shielding (cont'd)

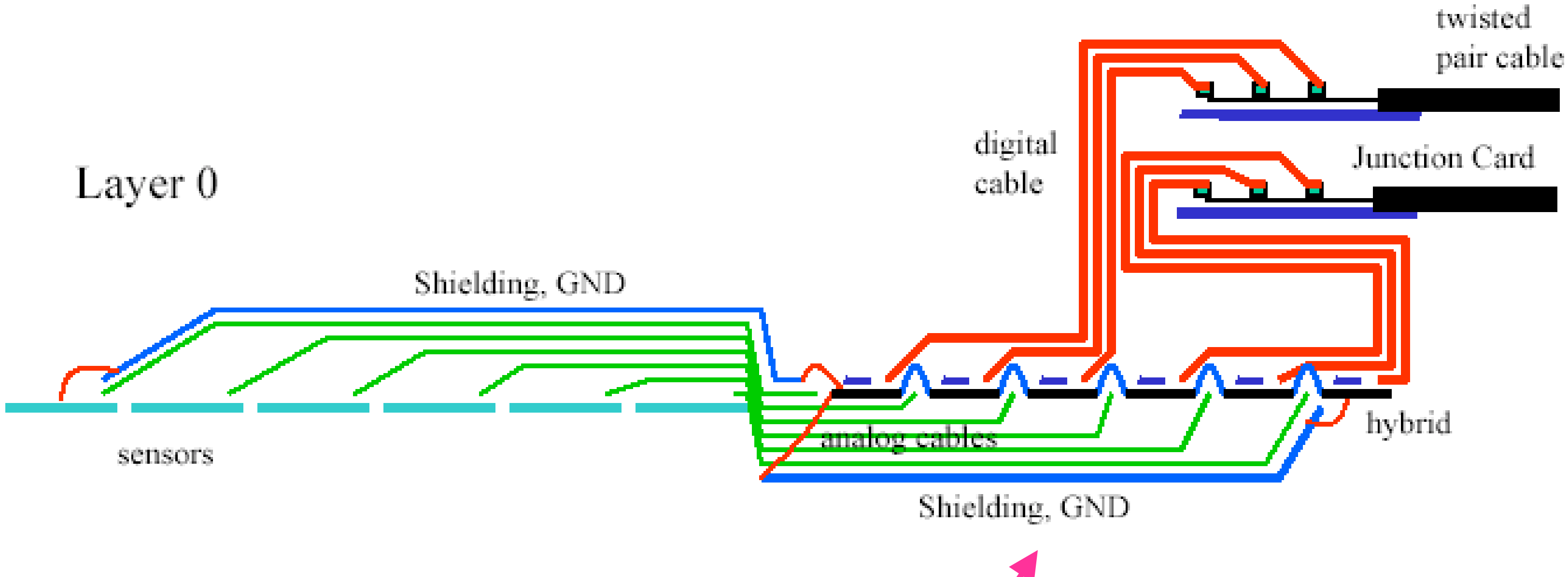
- Must be careful about capacitive coupling to nearby floating metal.





- Clear even-odd effect indicates capacitive coupling to the analog cable. 🡸 Distance between the traces to the metal; top-metal ~ 100μm, bottom-metal ~ 50μm.

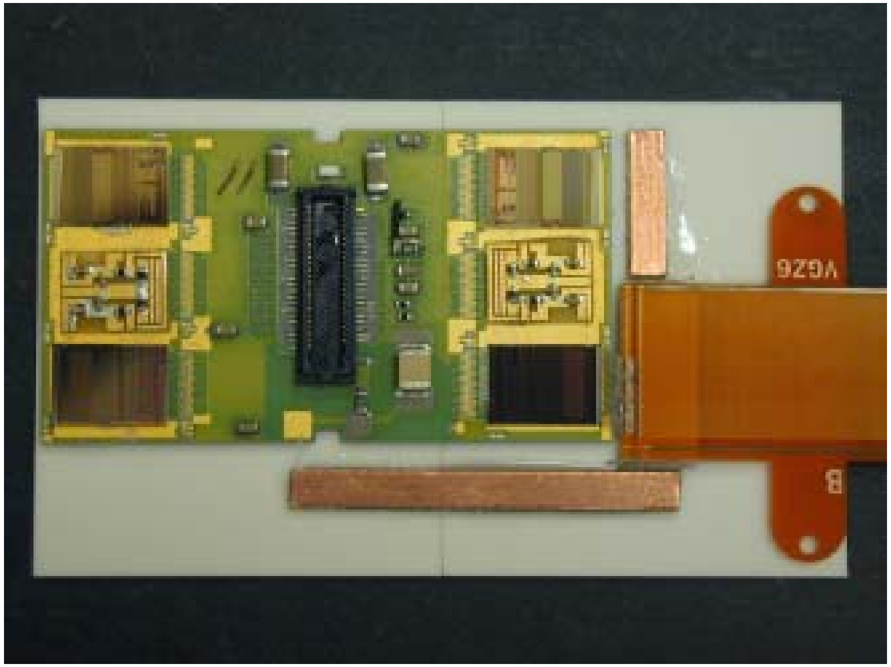
Shielding (cont'd)

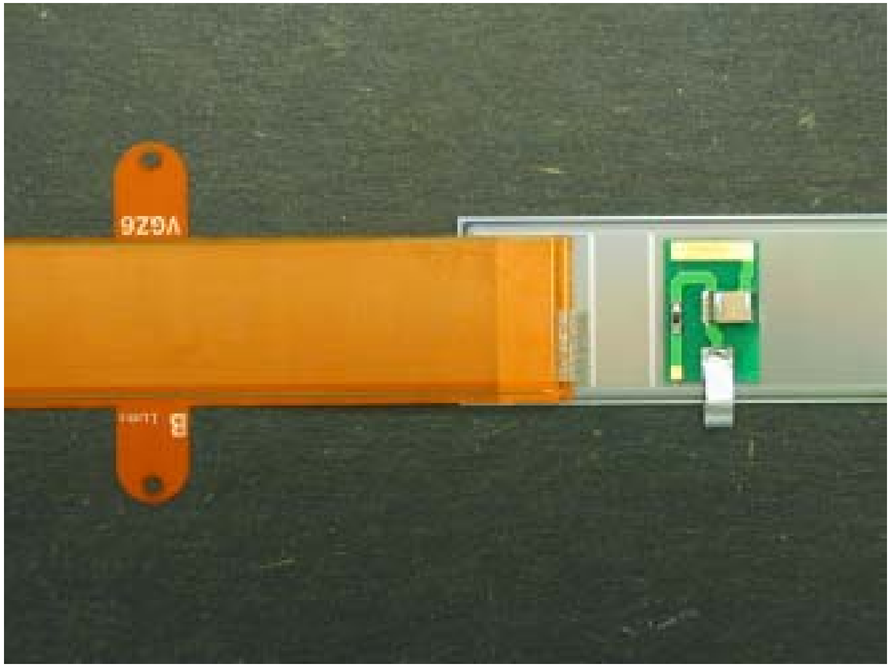


- Shielding on the bottom.
- Is there space? How do we connect?

L0 Prototype with SVX4

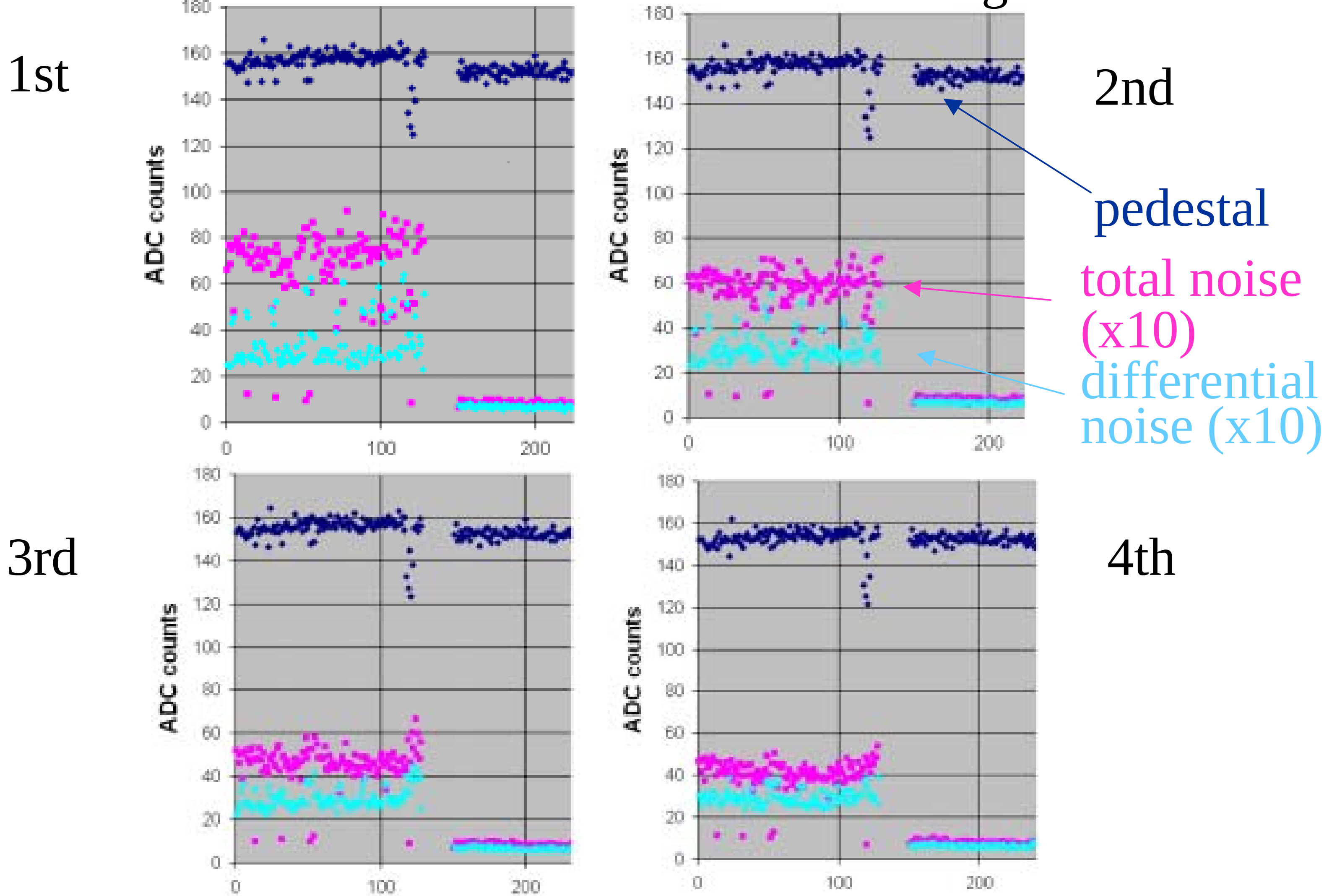
- First prototype using new SVX4 chip.
  - Large capacitive load
  - Long analog cable ← signal transmission
- L1 prototype hybrid with SVX4.





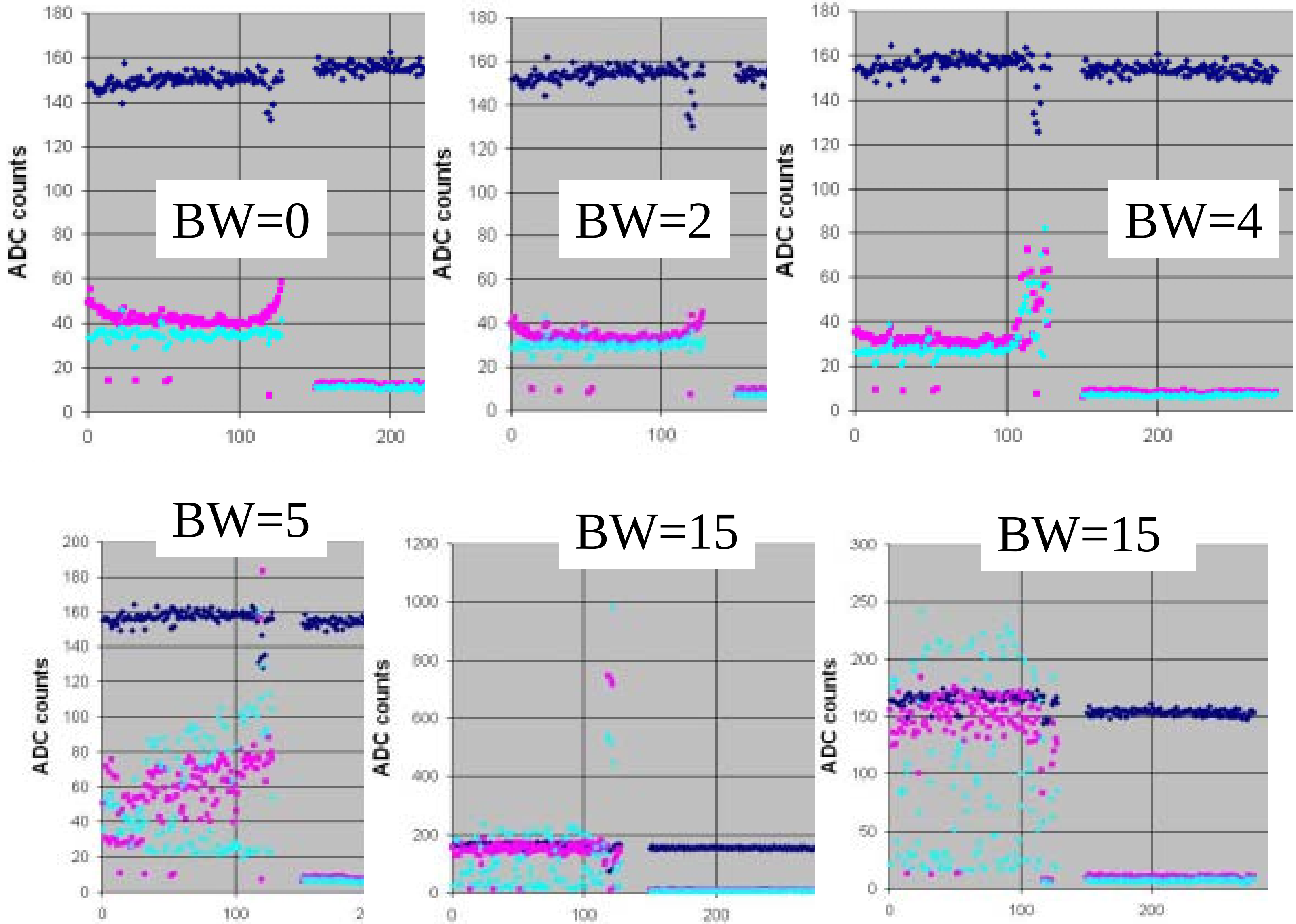
Noise stability

It takes > 5minutes to be stable after turning HV on.



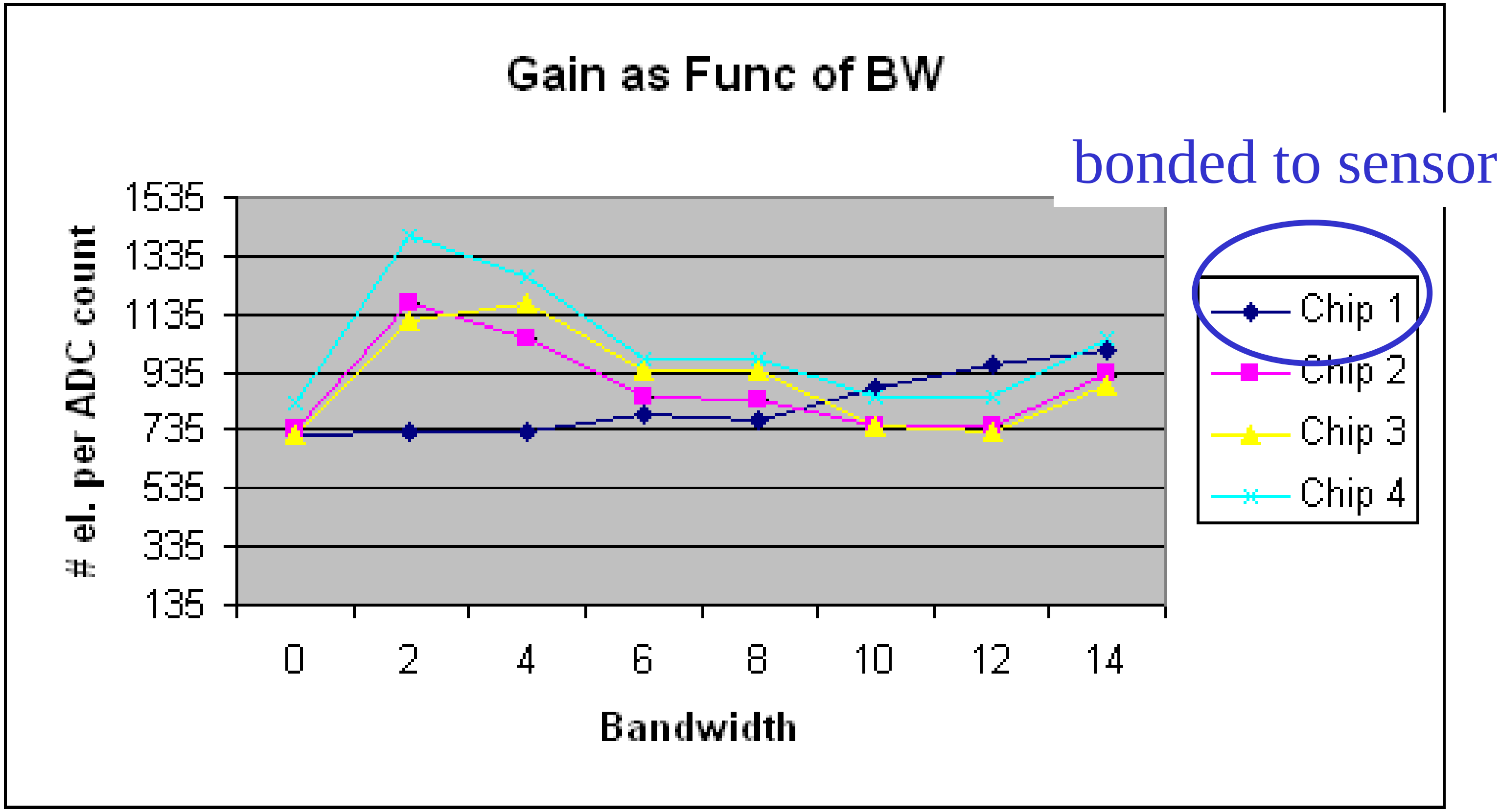
Nothing changed. Just wait order(1minute) each.

BW or Rise Time Dependence



Gain measurement by L0 Prototype

by Sara



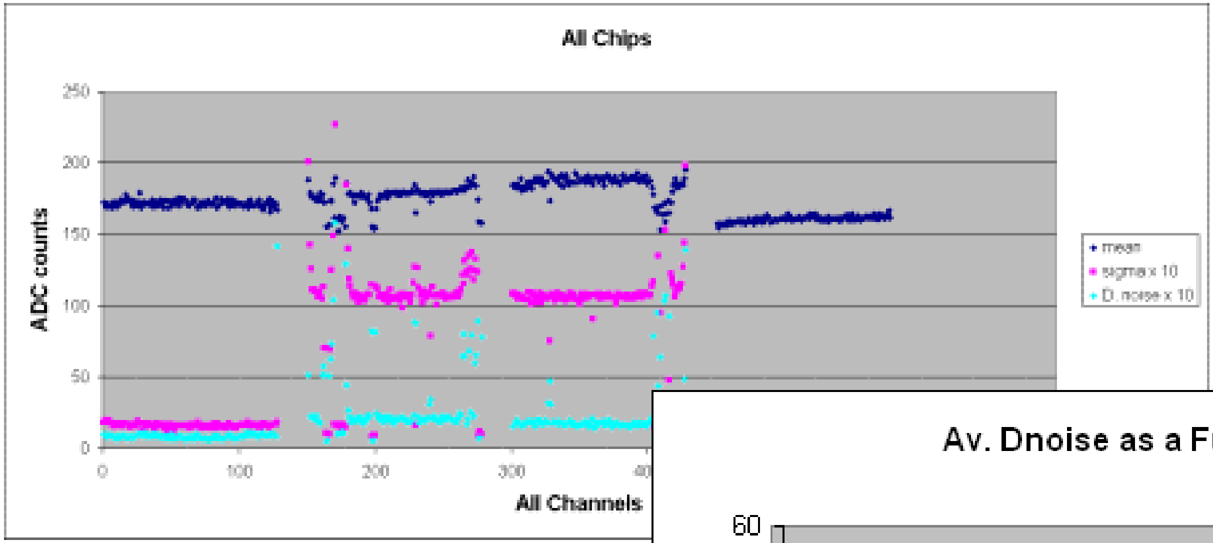
- Consistent with bare chip measurement with ~30pF load.

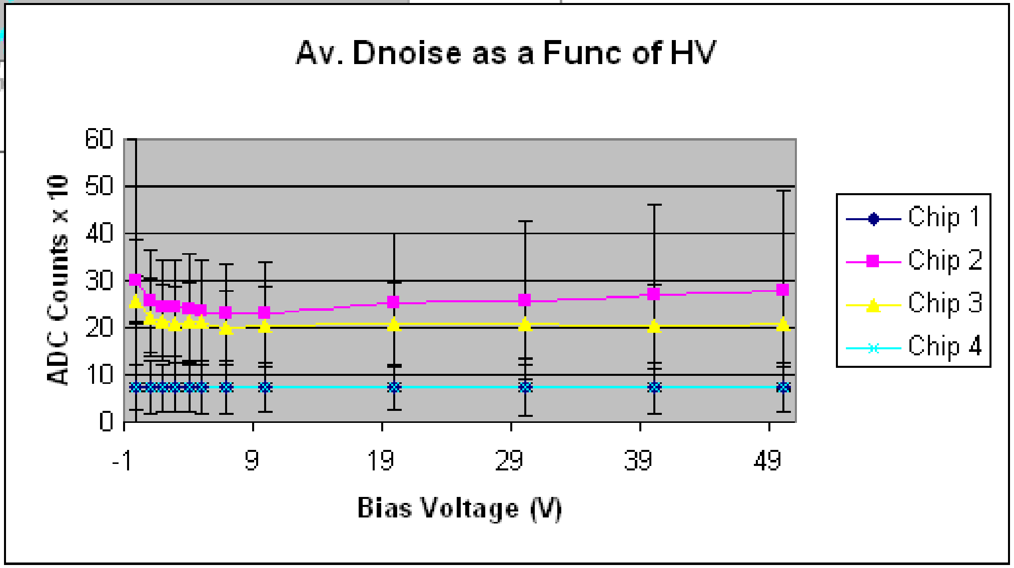
Noise Level of L0

- BW=4 as a baseline; the rise time is close to 70ns for 33pF of external load.
- SVX4 front end performance;
  ENC = 300 + 41C (pF) @ fixed rise time of 70ns.
- #electrons / ADC count is measured as ~ 700.
  Gain measurement with external charge injection (33pF load) consistent with the measurement for the actual L0 prototype with cal_inject by Sara (assuming 25fF of C_{cal}).
- Random noise for non-loaded chip ~ 0.7ADC count = 500e.
- ENC = 500 + 41C (pF) is, thus, good reference.
- C(sensor)=10pF, C(analog cable)=15pF → C(total) = 25pF
  → expectation = 1500e.
- Measured random noise ~2.7ADC count = 1900e.
- 1900 = 500 + 41C → C(total) = 34pF

L1 Prototype Module

by Sara



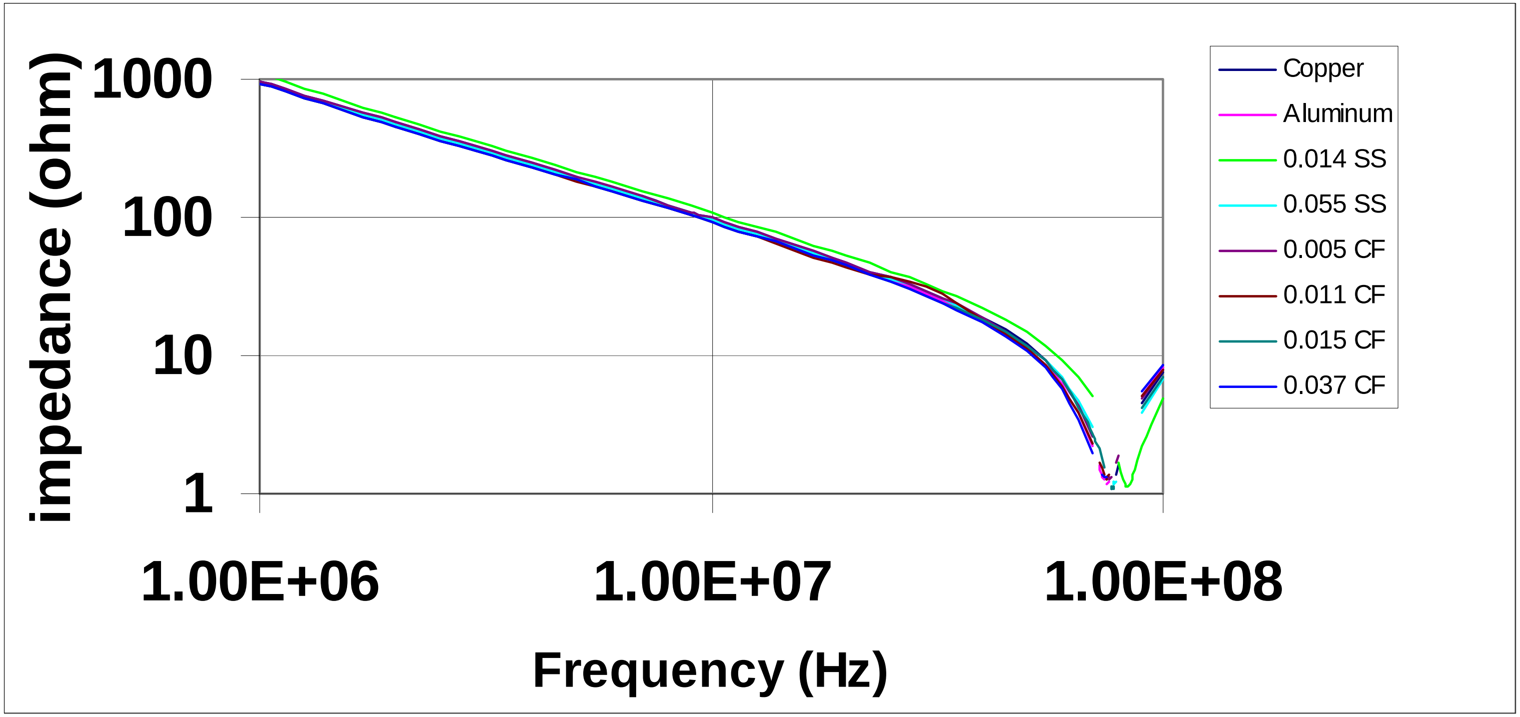


- Depleted at only 10V?
- Huge common mode noise for the chips bonded to sensor.

Noise Level of L1

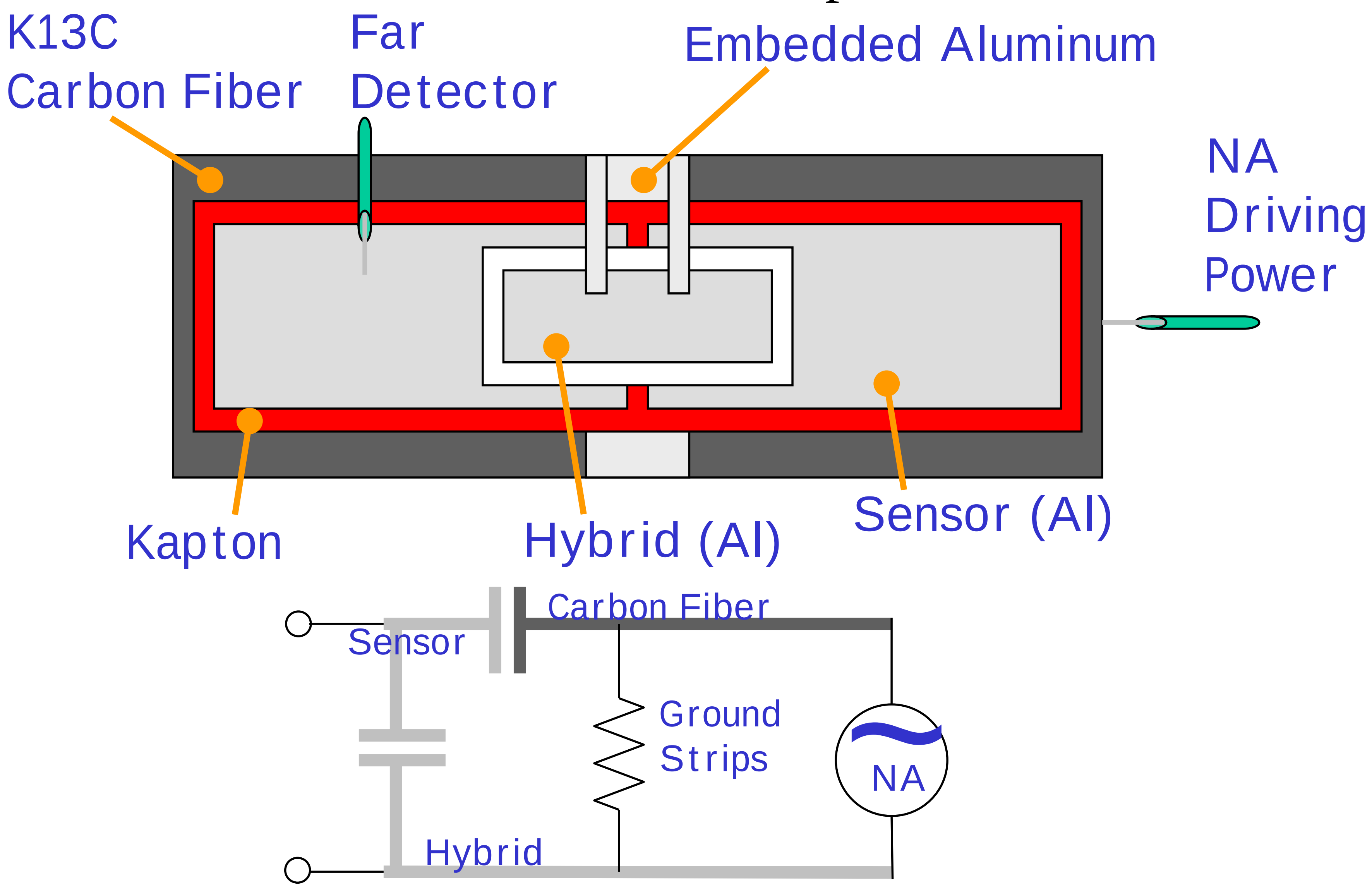
- Differential noise = 2.2 ADC counts
- 2.2 ADC counts ~ 1500e
- Non-loaded chip has similar noise level as L0.
  ➔ use the same reference formula for ENC.
  ENC = 500 + 41C(pF) = 910 e --- expectation
- Measured noise level is larger than expectation by 40%.
- $\sqrt{(N_{obs}^2 - N_{expect}^2)}$ = 1200e for L1
- $\sqrt{(N_{obs}^2 - N_{expect}^2)}$ = 1200e for L0
  ➔ accidental coincidence? Or common source?
- Note: argument here is for differential noise.

Impedance of Carbon Fiber



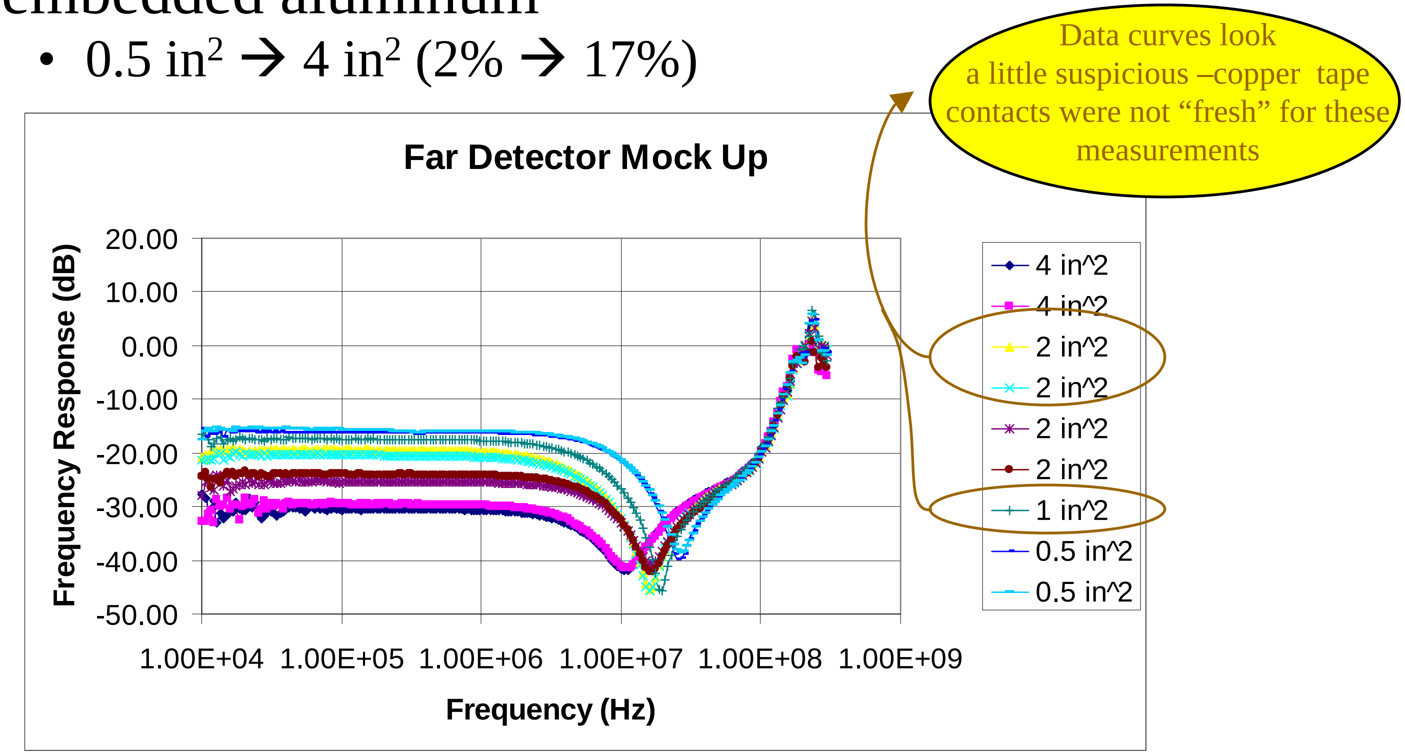
- Carbon Fiber (CF) support structure is regarded as a conductor for high frequency.

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

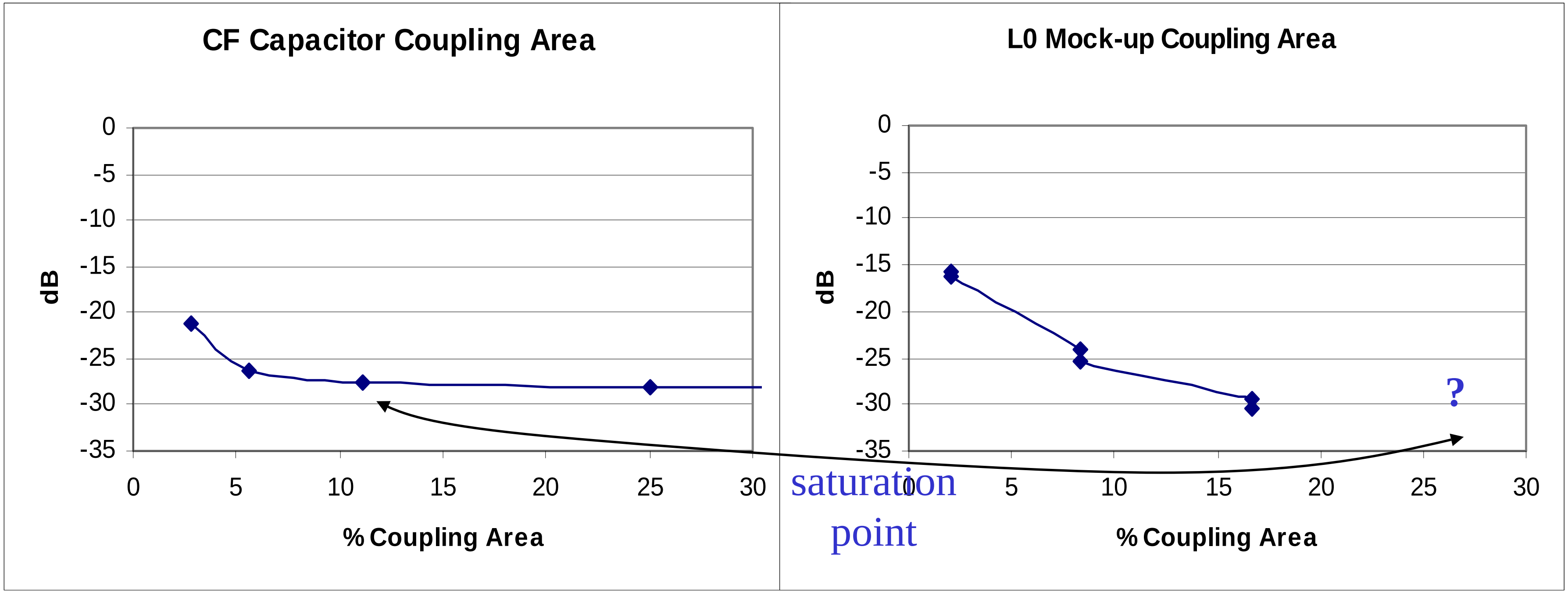
- Studied transfer functions from the C fiber to the “sensor”
  – Varied the amount of C fiber area covered by embedded aluminum
    - 0.5 in^2 → 4 in^2 (2% → 17%)



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

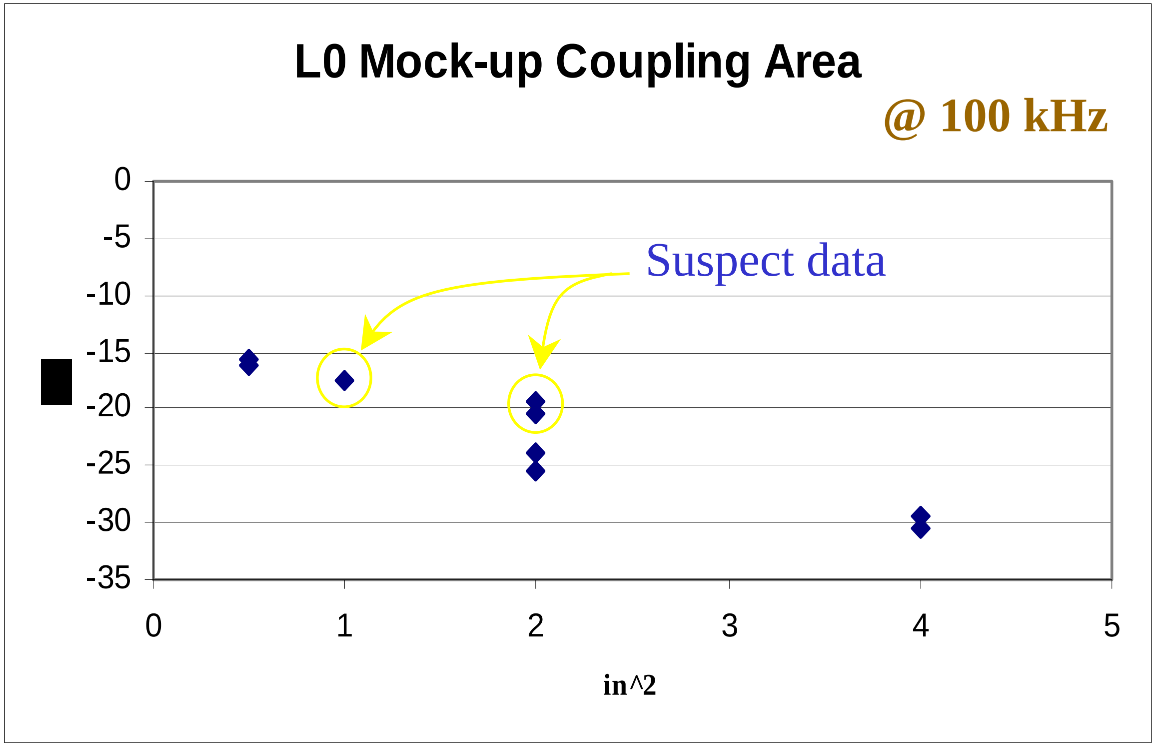
Carbon Fiber Coupling

- 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

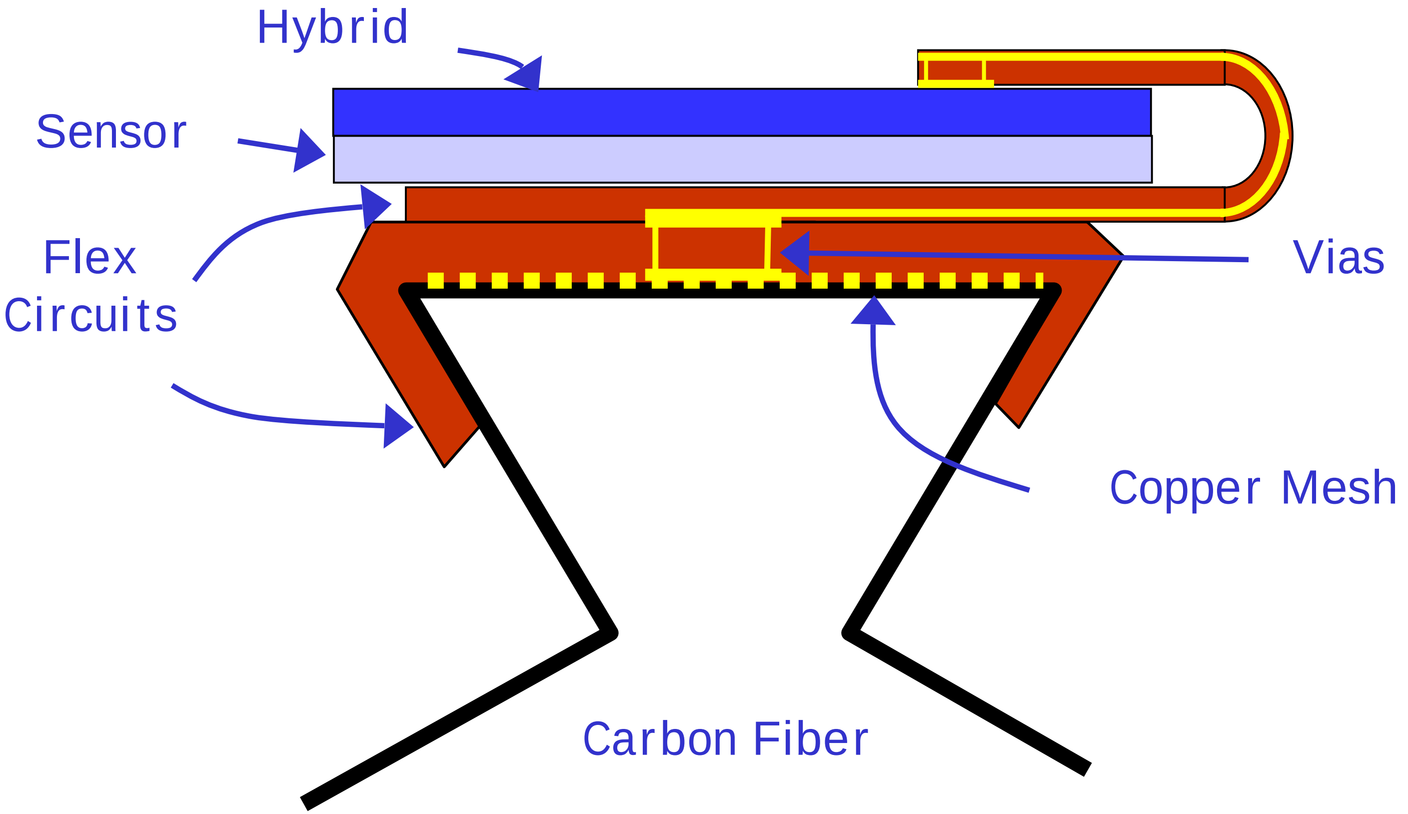
CF Coupling (cont'd)



- Not only a fraction of area to be covered, but also the absolute area may be matter.

Conceptual Design of Grounding

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



Conclusions

- Both L0 and L1 prototype works.
  ← confirmation of baseline design (except L0 hybrid).
- Gain of the L0 prototype consistent with the expectation by SVX4 performance.
- L0 noise higher than expectation.
- L1 module also has high noise.
- Noise behavior must be addressed in both L0 and L1 prototypes.
  → crucial for advance studies, such as frequency dependence study to decide shielding material/way.
- Grounding scheme is proposed by Marvin et al.