Possible Noise Sources in the PS Modules

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Detector Noise

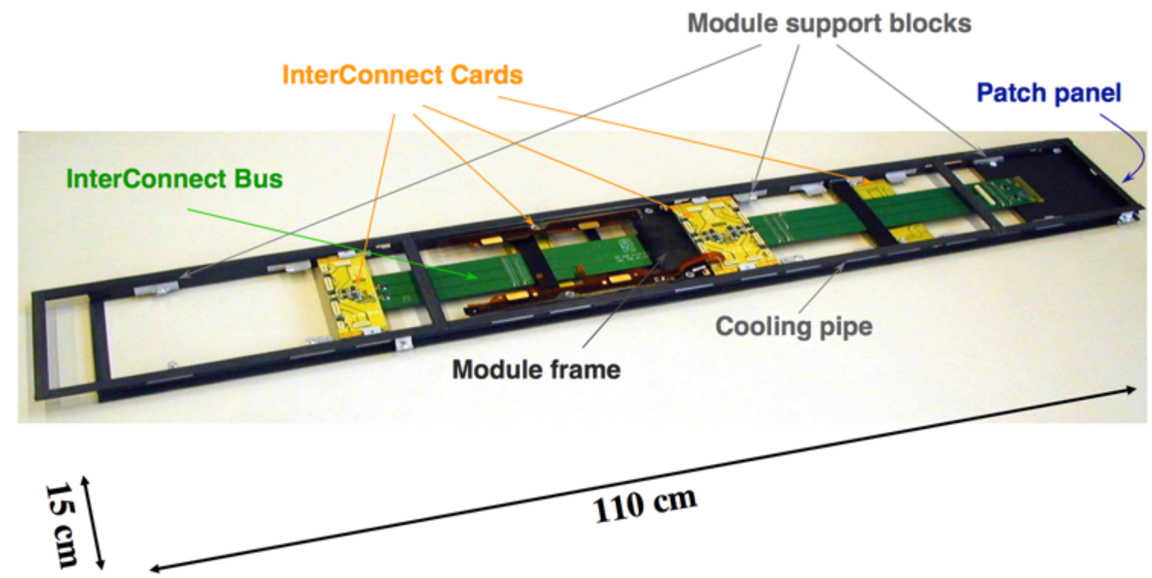
- Two main sources
    - Front end chips and associated components
    - Mechanical structures interacting with the electrical components
- This talk will concentrate on the second category
- There can be both magnetic and electric field coupling
- The first part will discuss coupling through the magnetic field and the second part will cover electric field coupling
- The last section will suggest some small changes in the current design to reduce the possibility of excessive noise

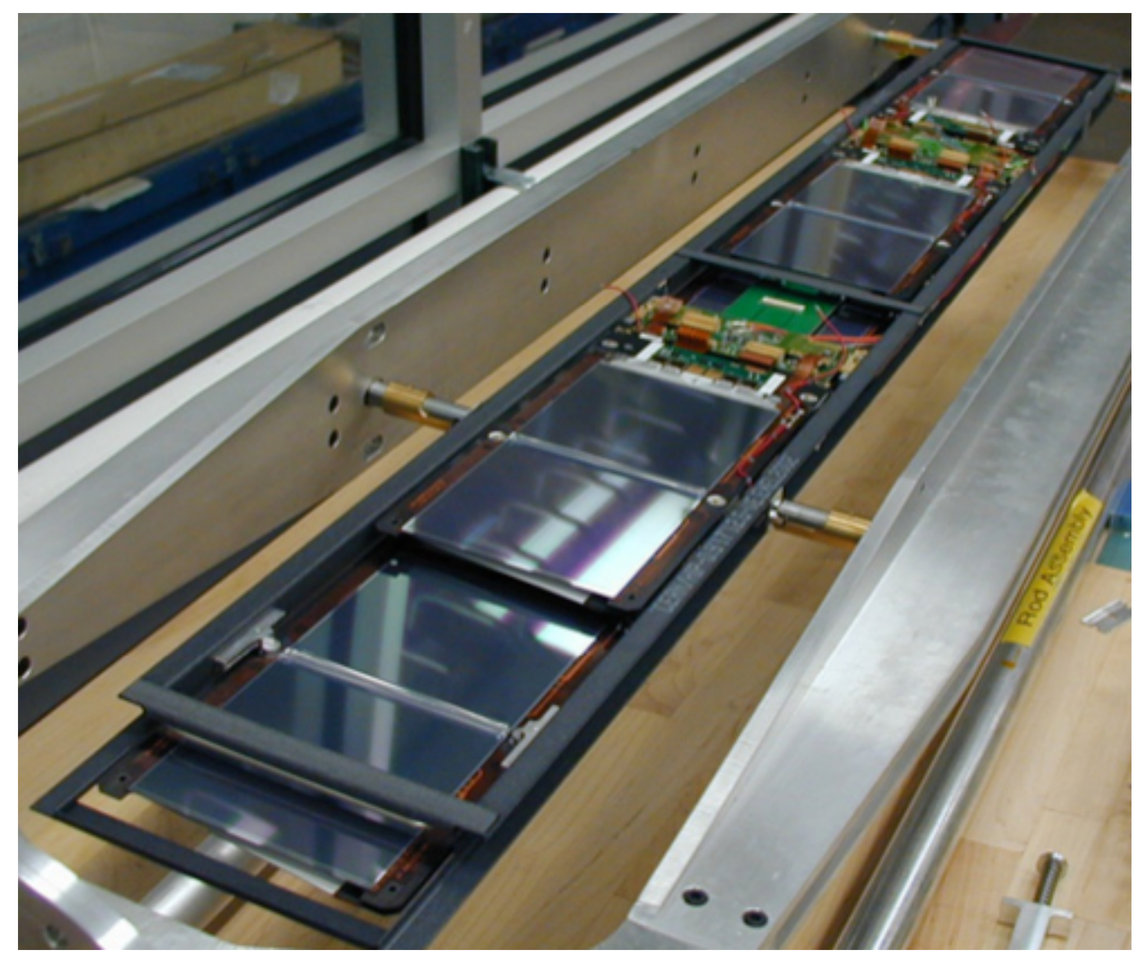
Examples

- Examples are very useful to educate people about grounding and shielding
- Choose examples from work I did on the current CMS detector
- Two examples of magnetic coupling from the current tracker
- One example of electric field coupling from the ECAL detector

Tracker Outer Barrel

- Rod based design somewhat similar to the PS design
- Rod is a multi layer PC board with 1.25 volt power bus on one side and 2.5 volt bus on the other side
    - Power return is on an inner layer
- 12 modules per rod with 6 on either side
    - Strips run parallel to the long axis of the rod for one side and tilted on the other side

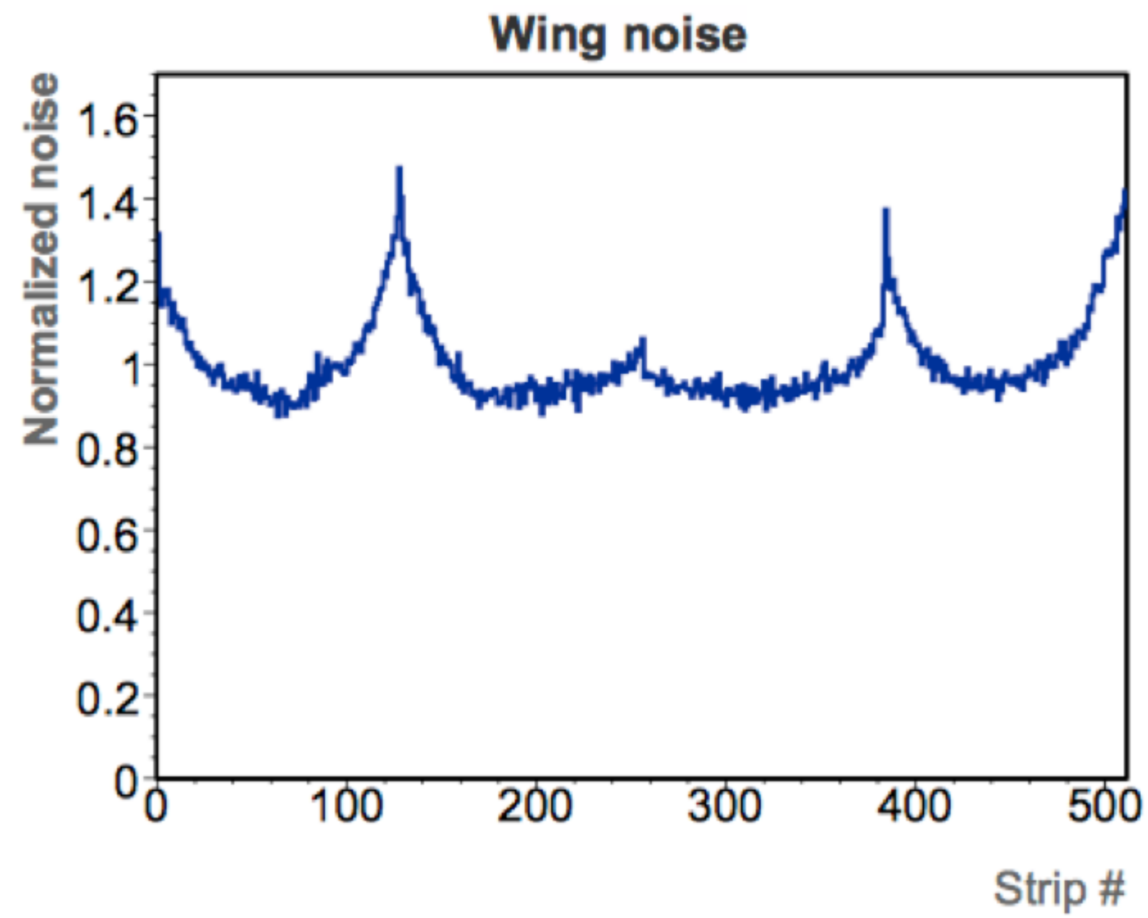


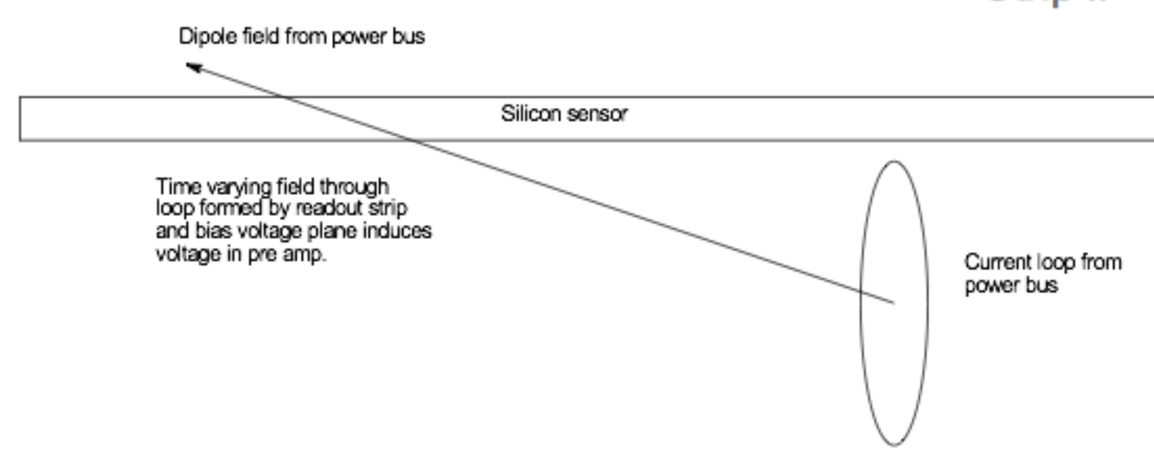


“Wing” Noise in 4 Chip Sensor

- Noise is concentrated on the 2 outer chips and the outer edges of the 2 center chips

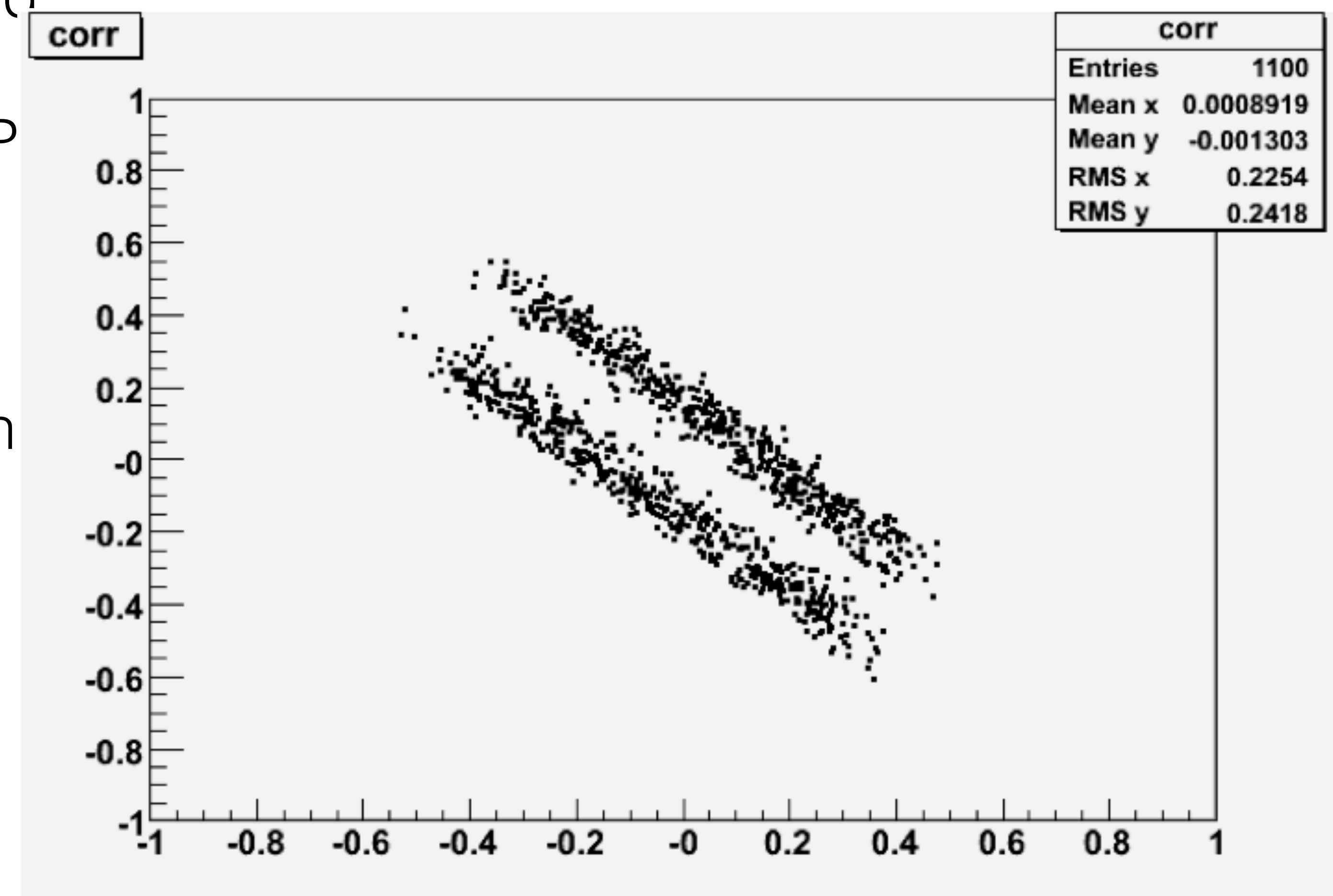
- Model is that the noise is from magnetic coupling of the dipole field created by source and return current on the two power buses





Noise Signal on left and right edge chips is highly correlated

- Plot is from the 6 chip sensor located next to the flange: the Y axis is the APV6 signal and the X axis is the AP 1 signal
  - Positive signal onAPV6 corresponds to negative signal on APV1
- If the signal were from capacitive coupling, then the signal should be the same sign on both sides of the sensor
- The two signals correspond to dipole fields from the 2.5 and 1.25 volt busses



Evidence for Magnetic Coupling

- Ungrounded Kapton sheet with 17 μ copper coating eliminates the noise
- Noise is also eliminated by added filtering on the power supply
- Noise is largest on sensor next to the power input and is nearly gone at the far end of the rod
    - Voltage is the same but current decreases along the rod
- Noise is nearly zero at the sensor center; dipole field is also 0 at 90 degrees
- Correlation plot shows 2 signals which correspond to the 2 power busses
- Symmetric shape of noise distribution for each chip results from the FED subtracting the median signal for that chip from each channel of the chip

Eliminating the Noise

- Wing noise was eliminated from most of the detector by adding capacitors on the powerlines at PP1 to sink the noise to the CMS magnet and also grounding the cooling pipes to the magnet at patch panel 1

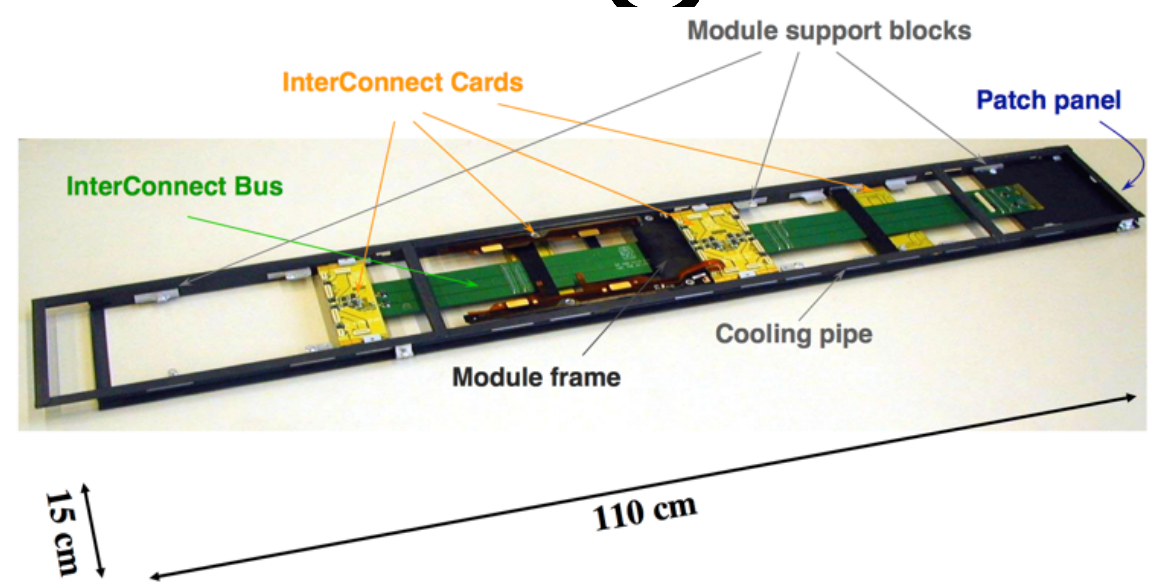
- This fixed all but 7 of 569 rods

- The capacitors and grounding were checked to be correct on the 7 failures

- This indicates that the grounding to these 7 rods was incorrect and also that grounding was a very important part of the fix

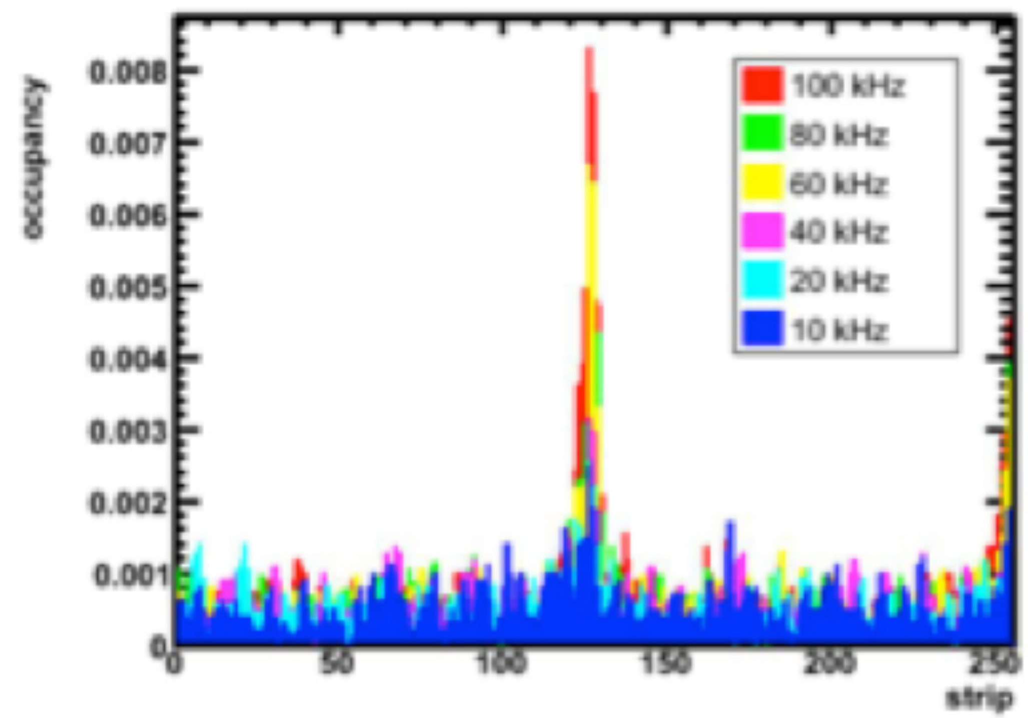
Rod Grounding

- Rod is grounded by a wire at the patch panel end
- Also grounded through the cooling pipe
- Ground failure could be a damaged or broken wire or resistance at the cooling pipe to rod connection
  - Important to test ground connections during production



APV25 Wire Bonds

- Plot shows edge channel noise on APV25 chips as a function of trigger rate
- APV25 2.5 volt power bonds were next to channel 127 and the ground bonds were next to channel 0
- When a second trigger event occurred at the same time as the start of readout of the current event, there was a small switching current generated on the power bus
- This current coupled magnetically from the wire bonds
  - We removed the pitch adapter and sensor connections on channel 127 and we still saw about 1/3 of the noise signal
  - The noise signal disappeared when we removed the wire bonds



E Field Coupling in ECAL

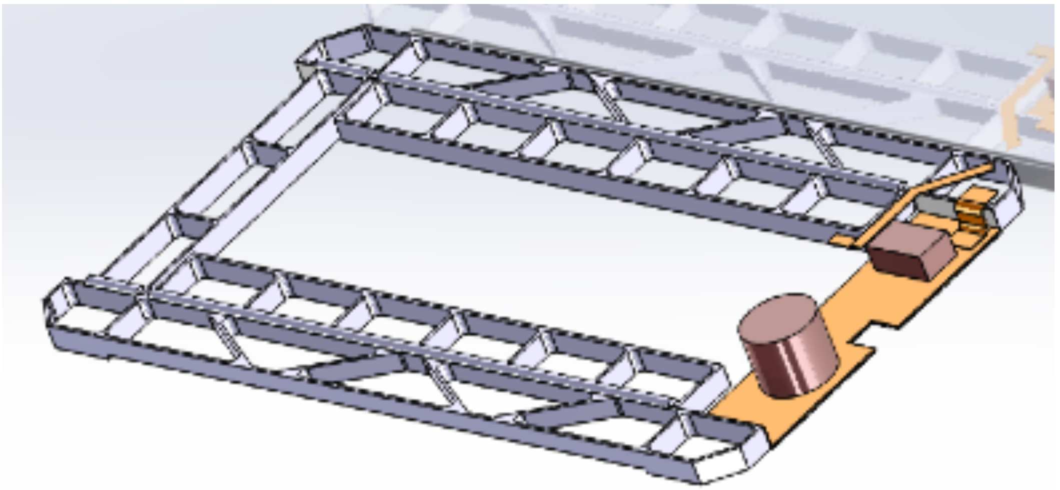
- The ECAL system consists of a photo diode viewing a lead tungstate crystal
- Diode is connected to main electronics module by a short cable
- System temperature control is crucial so all components are mounted on a large aluminum cooling plate
- Mechanical design avoided the use of mechanical fasteners; the entire structure relied on interlocking pieces
  - Most of these pieces were also made out of aluminum
- No effort was made to remove the aluminum oxide from the surface
  - All the Aluminum pieces were ungrounded

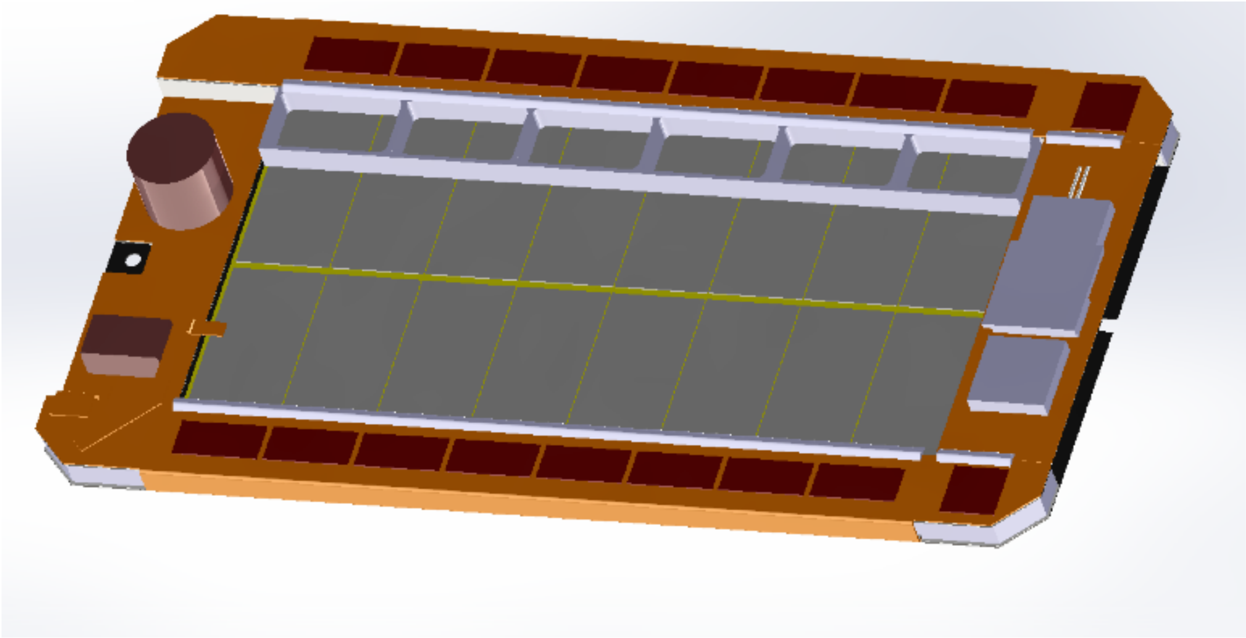
ECAL

- The noise source was a classic output to input feed back
- Since the AL cooling plate was ungrounded (because of the oxide layer), the output of the preamp induced a voltage on the cooling plate by capacitive coupling
- This signal appeared on the entire plate via Gauss's law
- The voltage was picked up on the photodiode output and returned to the preamp input.
    - The coupling was not strong enough to generate stable oscillations but valid pulses generated a lot of extra noise pulses
- Solution was to remove the oxide layer and coat the AL with a conducting coating

PS4 Design

- Aluminum Carbon Fiber material has good electrical conductivity
  - Resistivity is ~4 times CU
  - Capacitance to GBT frame is ~11 pF with 50μ gap (140 Ohms at 100 MHz)
  - Capacitance between side frames is ~.12nF with 50 μ gap (13 ohms at 100 MHz)
  - If the frames touch, the C is determined by praline thickness and R could drop to a few ohms even at the end connection
- Depending on trace locations, adhesive thickness etc, C from Kapton to frame can also be large
- Very small currents can cause noise





Possible Noise Sources

- Digital signals from Strip chip to Pixel chip
  - ~3/4 of a turn so there is a dipole moment
  - Side frames have some components at angles and dipole field is only normal to the coil at the center so induced currents are possible
- Signals to the concentrator chip
  - Possible direct coupling from the B field
  - Possible induced currents in the frames

More Sources

- Power supply and return to both the strip and pixel chips may also run parallel to the frame
- Power line between the DC to DC and the GBT
    - The abort gap and other beam structures could cause high frequency pulses on this line
    - Capacitors can reduce this but experience with the current detector indicate that a lot of C is needed and that large C might not be adequate
    - The best solution is good shielding
- There are likely other sources that I have not yet identified

Mitigating Factors

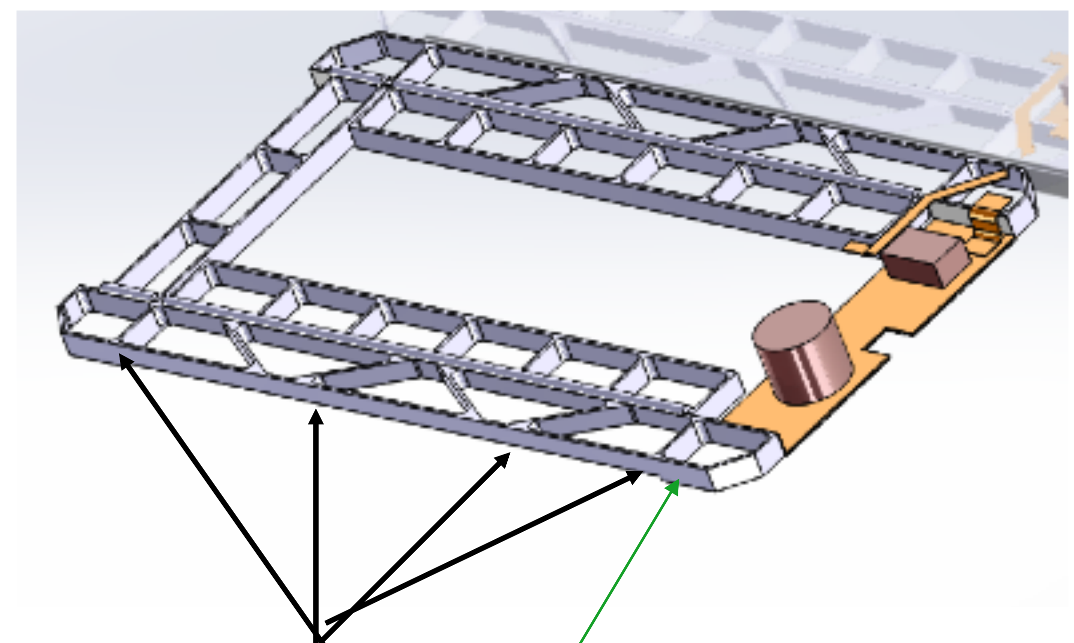
- If the currents are parallel to the side frames, the B field cuts across the strip in the PS 4 design rather than along the strip in the current detector.
    - This almost certainly reduces the magnetic coupling
- High modulus carbon fiber is conducting and the rods will be properly grounded so connecting the PS CF substructure to the rod should provide some additional grounding

DC to DC

- Converter itself may not be a problem
  - It appears to be well shielded
  - It is mounted directly on CF plate so it can be grounded to the rod
  - Still needs careful testing

Possible Improvements

- Ground all conductive material
  - Parylene coating will need to be removed
  - Aluminum Oxide will also need to be removed and the bare Al coated with a conductive coating
- Make sure that all Kapton grounds pieces are connected together with low inductance couplings
- Run the power bus between the GBT and DC-DC along outer edge of frame



Testing

- Experience with the current detector indicates that realistic testing is essential
  - APV25 problem was rather easily found once we tested it at the planned operating rate
  - Design change would have been easy but the problem was found after the detector was built
- Testing must not only be done at design rates but it must also include things like the effect of the abort gap in the beam structure
- This should include the rod structure

Testing Cont.

- The present detector had many components made before the component could be tested in the entire system
- It appears that we are pursuing the same path with this detector
- I believe tha we should have a complete rod test BEFORE committing to manufacturing any of the components
  - The trigger makes this design much more complex than the current tracker so kludges may not be possiblecs

Summary

- This design may work but it has features which substantially increase the risk of unwanted noise
- This device is a trigger so one cannot do things like CDF did for there layer 00
    - They fitted a polynomial to the chip data on an event by event basis in order to suppress the noise back ground.
- Testing may expose problems which require design modification
- Design modifications after construction has started look to be very complicated if not impossible
- I am somewhat surprised that there has not been an outside review that raised some of these issues