Electronics Issues for LBNE

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Introduction

- First, it is too early to commit to any particular design
  - Many areas need R and D to validate design options
  - Need to study impact of design choices on rest of detector
  - Need to understand long term reliability

Warm Electronics

- Really just a study of how to get the signals out of a cryostat with minimum capacitance
- Main issues are
  - Need good estimate of detector capacitance
  - Methods to bring signals to the top and bottom of TPC
  - Capacitance of commercial cables
  - Possible feedthrough designs

TPC Capacitance

- Analytic model
  - 2 parallel wires
    - D=wire separation
    - R=wire radius

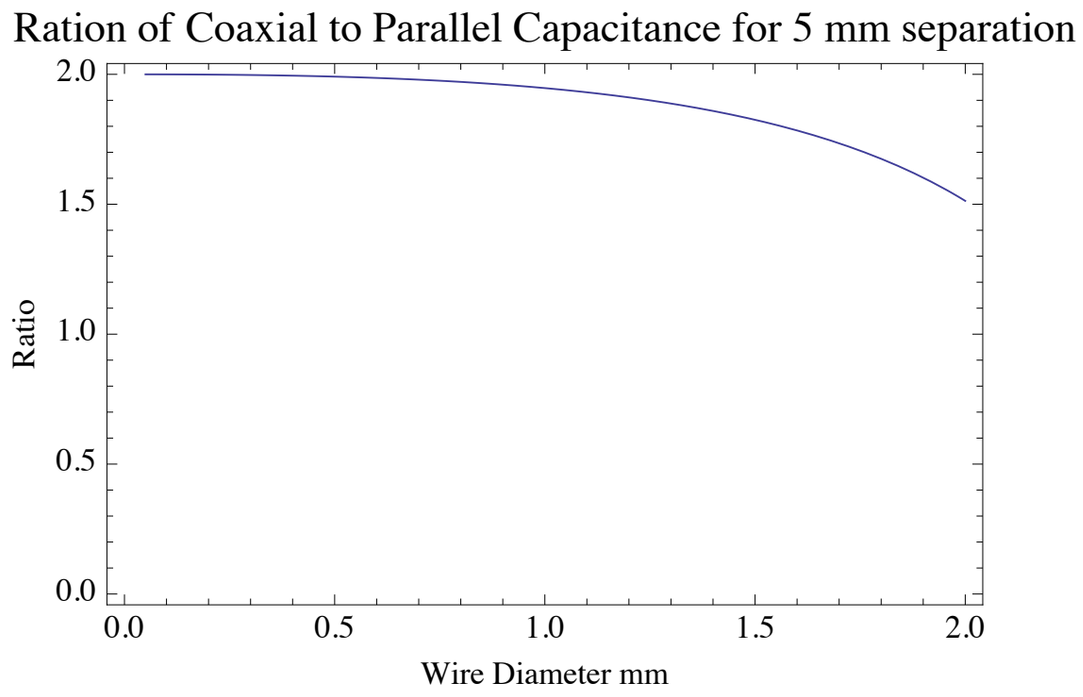
$$C = \frac{2\pi\varepsilon}{Cosh^{-1}\left[\frac{D^2 - 2R^2}{2R^2}\right]}$$

  - Coaxial Cable
    - R_1=outer radius
    - R_2=inner radius

$$C = \frac{2\pi\varepsilon}{Cosh^{-1}\left[\frac{R_1^2 + R_2^2}{2R_1R_2}\right]}$$

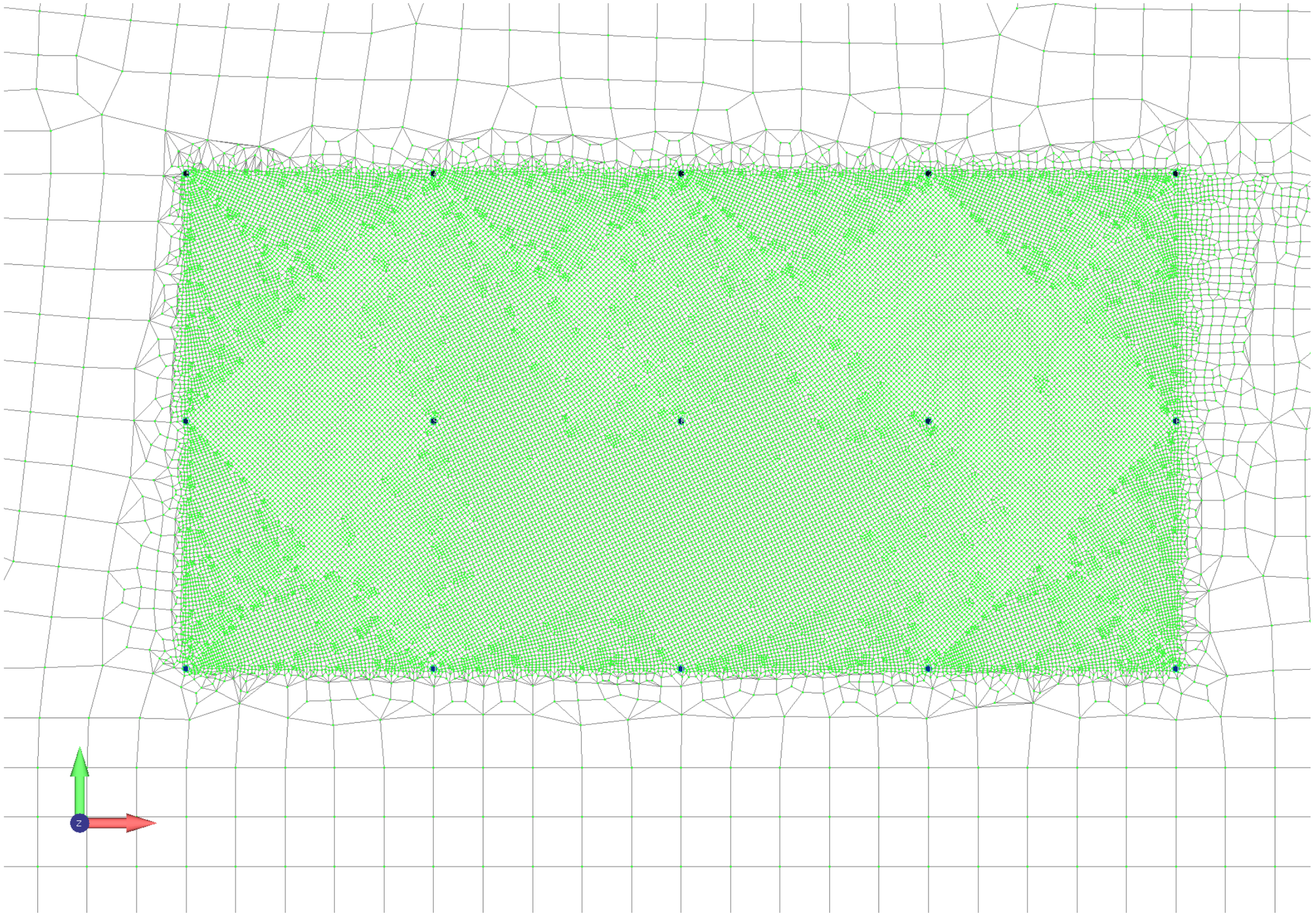
TPC Capacitance

- For radii much less than separation coaxial capacitance formula with R_{outer} =D is 2 times that for 2 parallel wires



FEA Model

- Actual case is several parallel wires
- Build a FEA model
  - Heat transfer is the same as electrostatics
  - 2 D only



Small circles are 150 μm wires spaced 5 mm

FEA Results

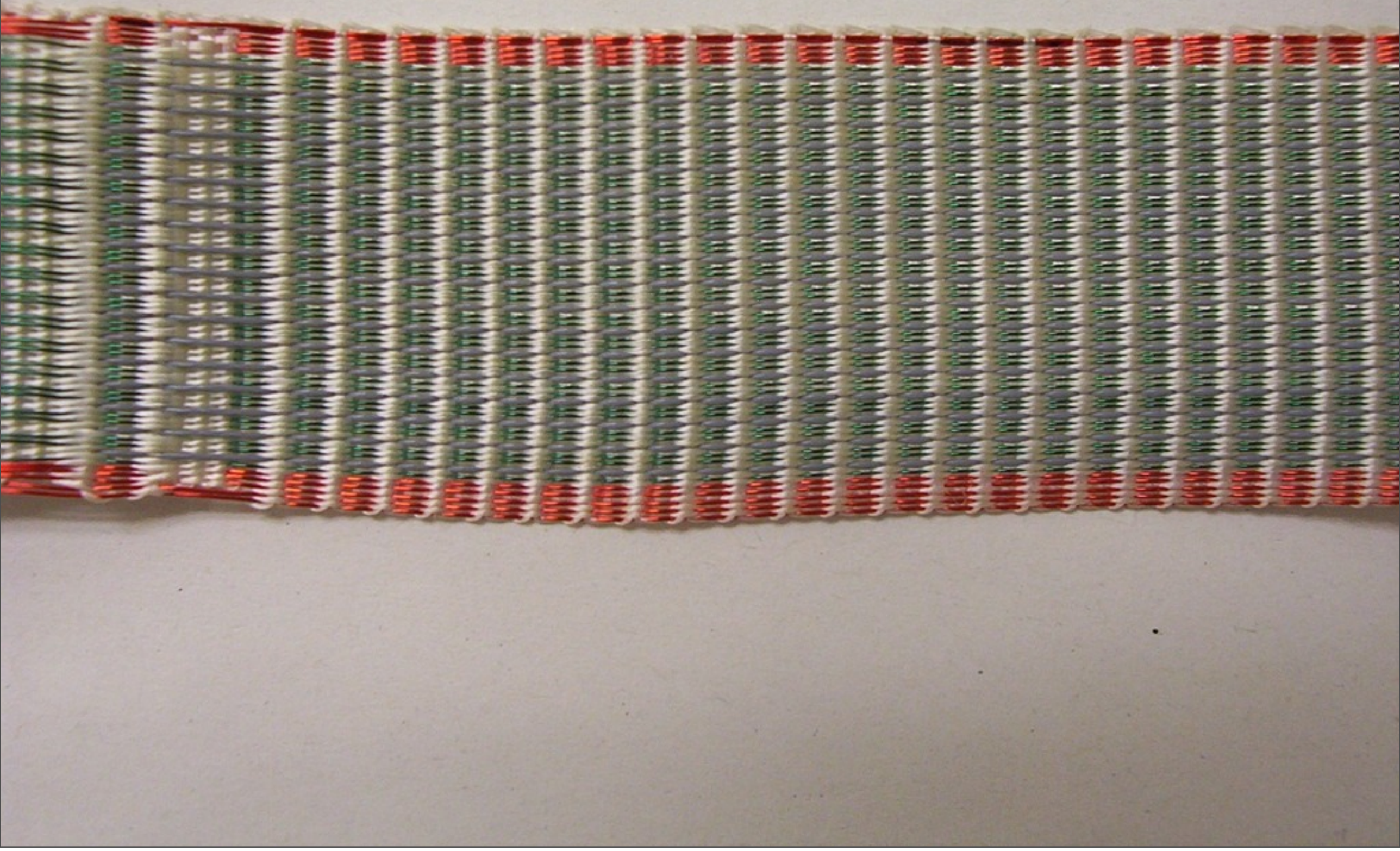
- Wire surrounded by 4 wires is 90% of coaxial (19.2 pF/meter)
- Wire with wires on 3 sides is 87% of coaxial (18.4 pF/meter)
- Actual case has wires at an angle but using nearly the coaxial value is likely to be a good estimate
- Use 20 pF/meter for design
- Can easily extend this method to cables

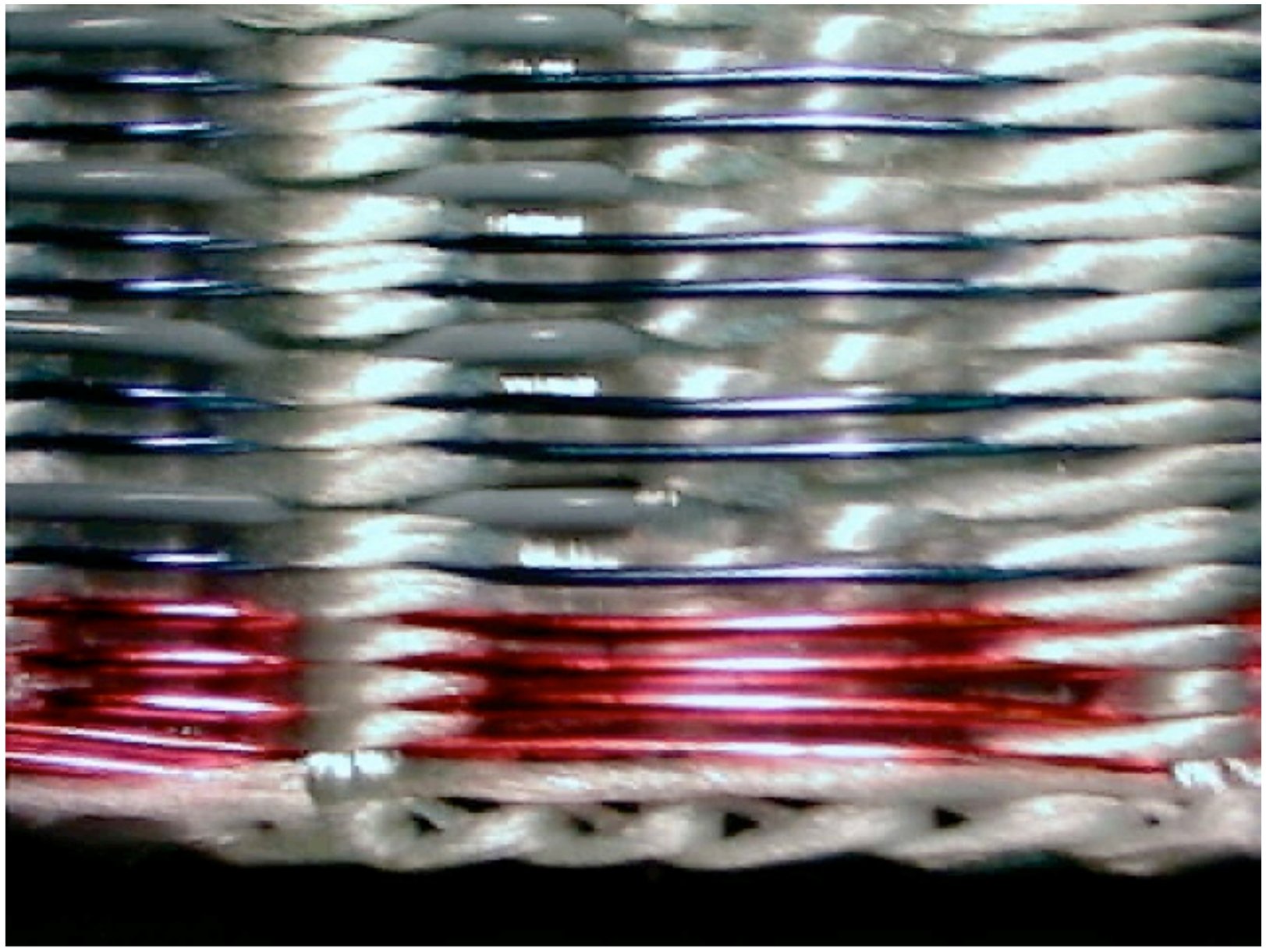
Woven Cables

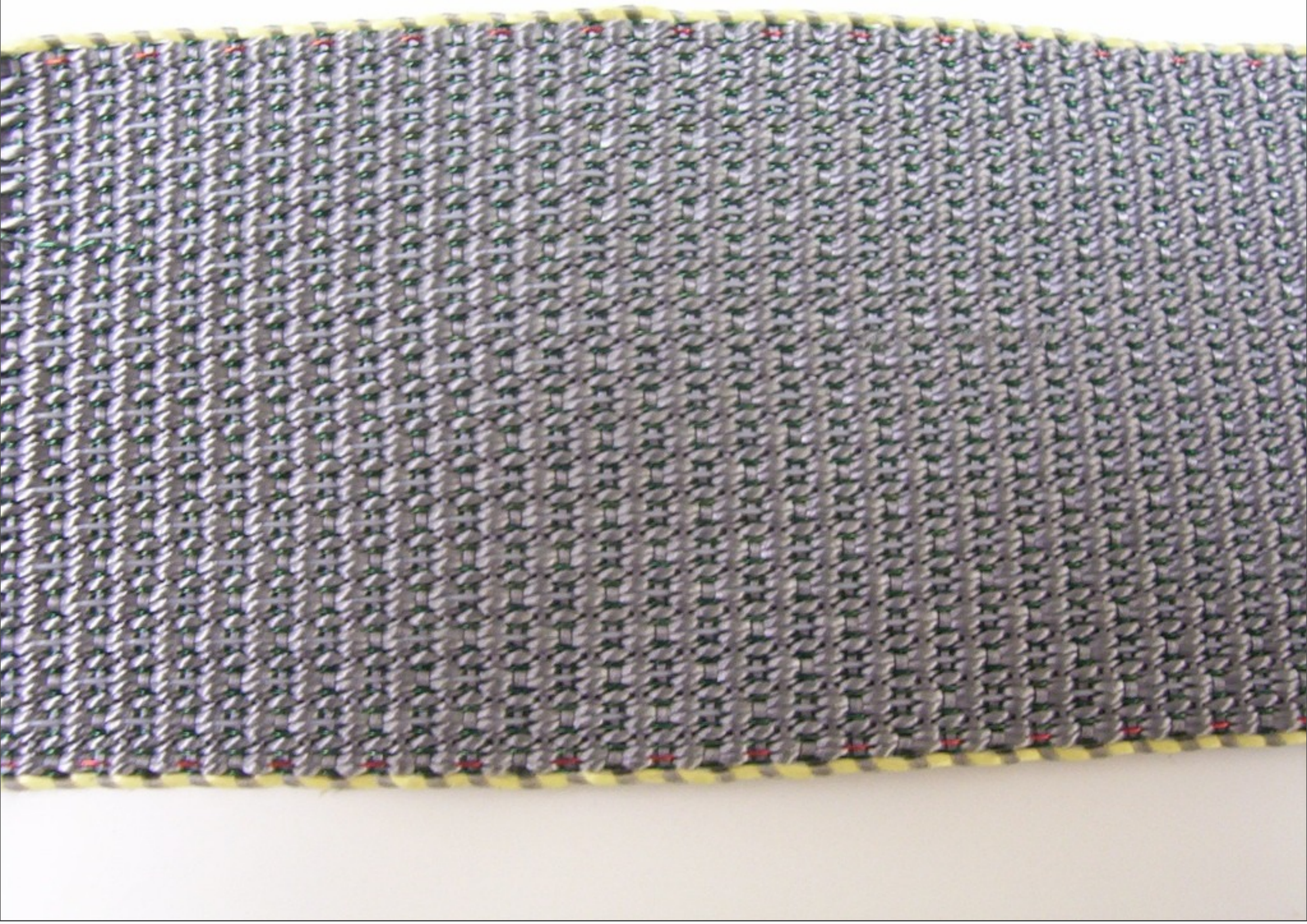
- Spin off of garment industry
- Many different cables in a single harness
- Very flexible in type of wire, spacing, weave etc.
- Can have different weave at end for connectors

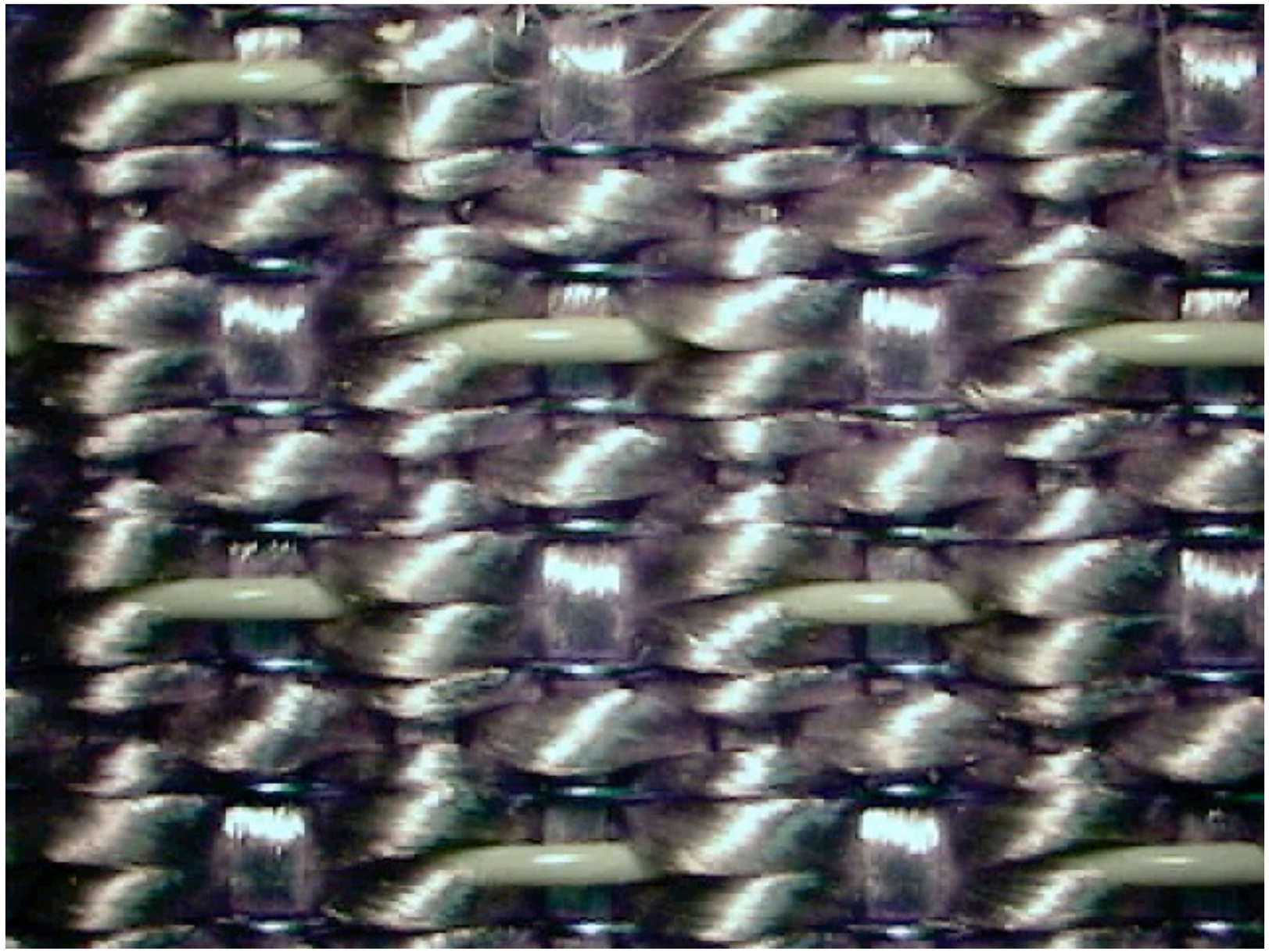
Woven Options

- Can use magnet wire down to 40 gauge (75 μm)
  - Copper wire covered with few microns of insulator









Possible Cable

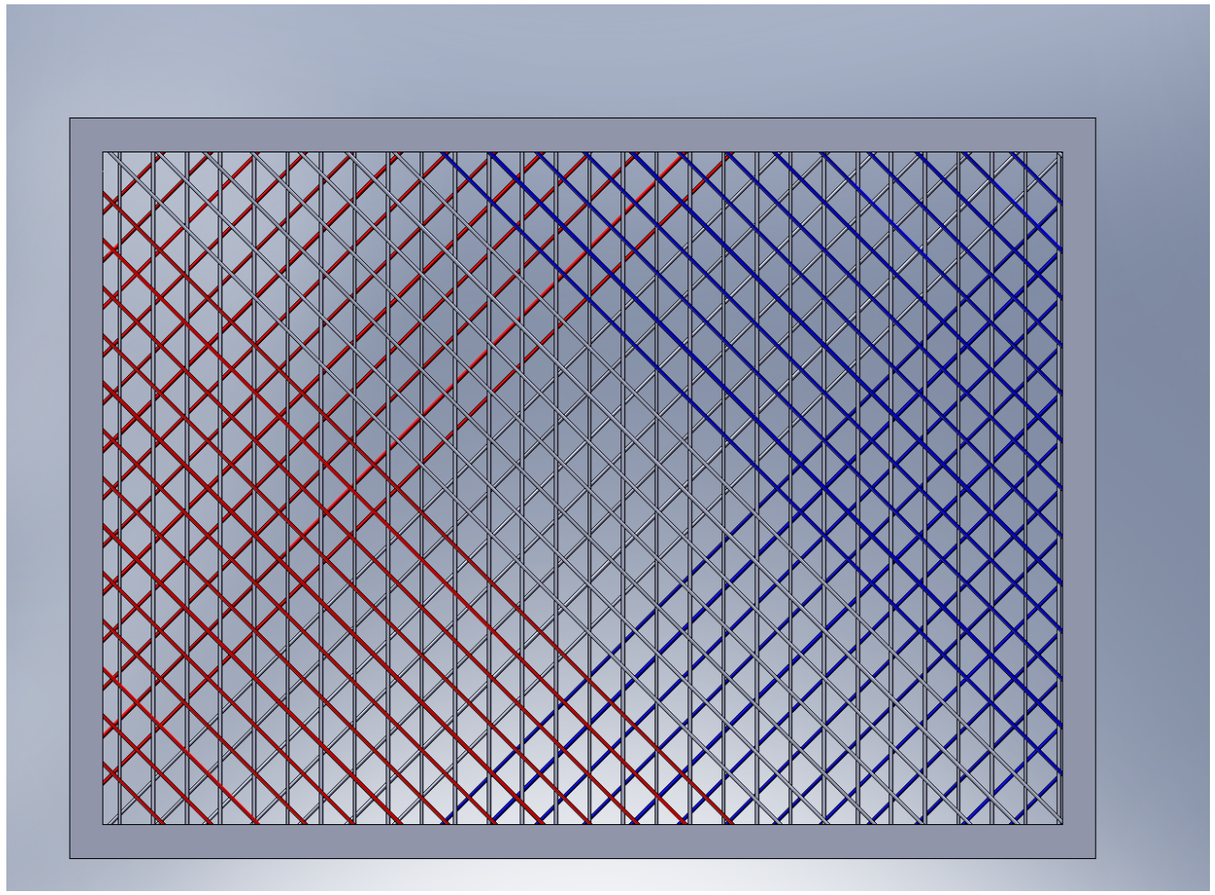
- 200 μm magnet wire
- Spacing of 4 mm
- Coaxial value is 24 pF/meter
- With loose weave, guess 33 pF/meter (~50% increase)
  - Cable has no grounds - not needed for low freq.
- Need to test cable for C, purity etc.

TPC Parameters

- 150 micron wire
- 5 mm spacing for planes and wire spacing
- 45 degree U and V planes
- Two 7 meter frames in vertical direction
- Four 10 meter frames along beam
- Four rows of double TPC's across cryostat

TPC Routing

- Route wires that end at the edge to the top or bottom (H. Jostlein's suggestion)



Little Affect on Pattern Recognition

- Vertical wires are independent on the two sides
- Get precise timing from vertical wires
- Common point on one side does not give common point on the other
  - 2 hits at same time are not a problem
- Need more than 2 hits at same time and position
  - Still likely to be OK

Bottom signals

- ~965 signals/meter for double TPC plane
- Atlas feedthrough has 1940 signals + grounds (3880 total I think)
- Need a feedthrough every 2 meters (4 if no ground) 20 or 10 feed throughs per row
- 3 meters of cable to preamp should be good enough

Top Feedthrough

- Could be used in combination with bottom feedthrough or all signals could be on top
- Gas at top so little pressure
  - Don't need Atlas feedthrough
  - Use feedthrough similar to D0 fiber tracker
    - Simple polyimide cable feedthrough
    - 9 kelvin to room temp in ~40 cm

Top Feedthrough

- If cables only from top TPC (of 2), then 3 meters of cable are probably OK (100 pF)
- If both TPCs go through the top, then bottom TPC has additional 7 meters of cable (additional 233 pF)

Noise

- 45 deg wires are 10 meter -> C=200 pF
- 10 total meters of cable -> C=333pF
- Noise (Paul Rubinov) $\sigma_N = 125e + 2.6C\frac{e}{pF}$
- S/N: 11000/1510= 7.2 or 22000/1510=14.4
  - Low signal is a problem
    - Concern is margin for less than perfect detector

Summary

- Feed throughs at top and bottom of cryostat could give good signal/noise
- Atlas feed throughs are nearly good enough for bottom
- Feed throughs only at the top are problematic with low signal amplitude
  - Concern is reduced margin for impurities

Cold Electronics

- Discuss a few system issues
  - reliability
  - amplifiers only
  - everything through multiplexor is cold
  - Discuss continuous read out only
    - Much easier if only accelerator based physics

Analog Multiplexing

- Choose ICARRUS design for ADC
  - 10 bit
  - 2.5 MHz (400 ns)
- Likely to need 50 to 100 ns settling time
  - Rules out large analog multiplexing
  - Multiplex by a factor of 4 or so
  - Big reduction in cables but need control cables etc

Digital Multiplexing

- SVX 2 requires 15 cables for 8 bit data
- 10 bit so need 17+2 grounds=19
- Need ~20:1 just to stay even on cable plant

Data Transmission

- D0 uses both edges of clock for readout
- 53 MB/sec
- 26 MHz on cable
- 3M pleated foil cable ~ 25 meters
- Difficult to get working without errors

Digital Multiplexing

- Very difficult to get a factor of 2
- Might get 80 MB/s (32 to 1 MUX)
- Could go to serial but requires code for clock recovery (8B 10B)
  - May not save much cable

Zero Suppression

- Zero suppression can be useful but requires channel ID which increases cable plant by several bits
- Also only useful if it increases the data rate beyond the cable capacity.
  - But need to read all channels for calibration, testing etc.
    - not impossible: divide readout into smaller units
    - One needs a complete design

Cables and Pickup

- Above analysis is for single ended drive
- CDF found that could not read out and take data with out differential drive
  - nearly doubles cable count
- Very important not to have output to input feedback
  - TPC is a great antenna!

Reliability

- D0 has had a lot of power wire bond failures
- Double wire bond some power pads (no failures)
- Add second power bus with a diode
  - D0 has done this with over voltage diodes!
- Might consider separating preamp from digital processors and doubling digital section
  - both chips on same cable with enable line

Summary

- Optimizing a cold digital design is complex
- Need to asses reliability, cable plant size, affect of failures on the physics performance etc.
- Cold design potentially is the cheapest solution with the lowest noise
  - History of silicon detectors is that they have a high failure rate (10-20% after a few years)
  - Chips designed for HEP often have errors that show up later