Sensor and Module Design

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Goals for 2006

KPiX-T

- Working 2X32 chip delivered and tested
- Submission of full-sized chip

Sensors

- **Develop detailed design for sensors**
- Obtain prototype sensors from Hamamatsu

Cables

- **Develop detailed design for pigtails**
- Obtain quotes for pigtails

Module Assembly

- **Develop fully designed/engineered sensor supports**
- **Develop fully designed/engineered module mounting scheme**

Sensor Design

Much of design can be derived from existing devices

- Double-metal & bump bonding issues from ECAL sensors
- 50(25) readout(sense) geometry from HPK Layer 00 sensors

What’s Left?

- Optimize double-metal layer for strip geometry
  - Minimize capacitance and balance with trace resistance
  - Equalize trace capacitance/resistance over entire sensor
- Details of vias in dense 50/25 geometry?
- AC/DC coupling decision?

Design Requirements

Want S/N > 20. Following work at Oregon by David Strom:

- **Limit capacitance to 40 pf**
- **Limit total trace resistance to 500 ohms**

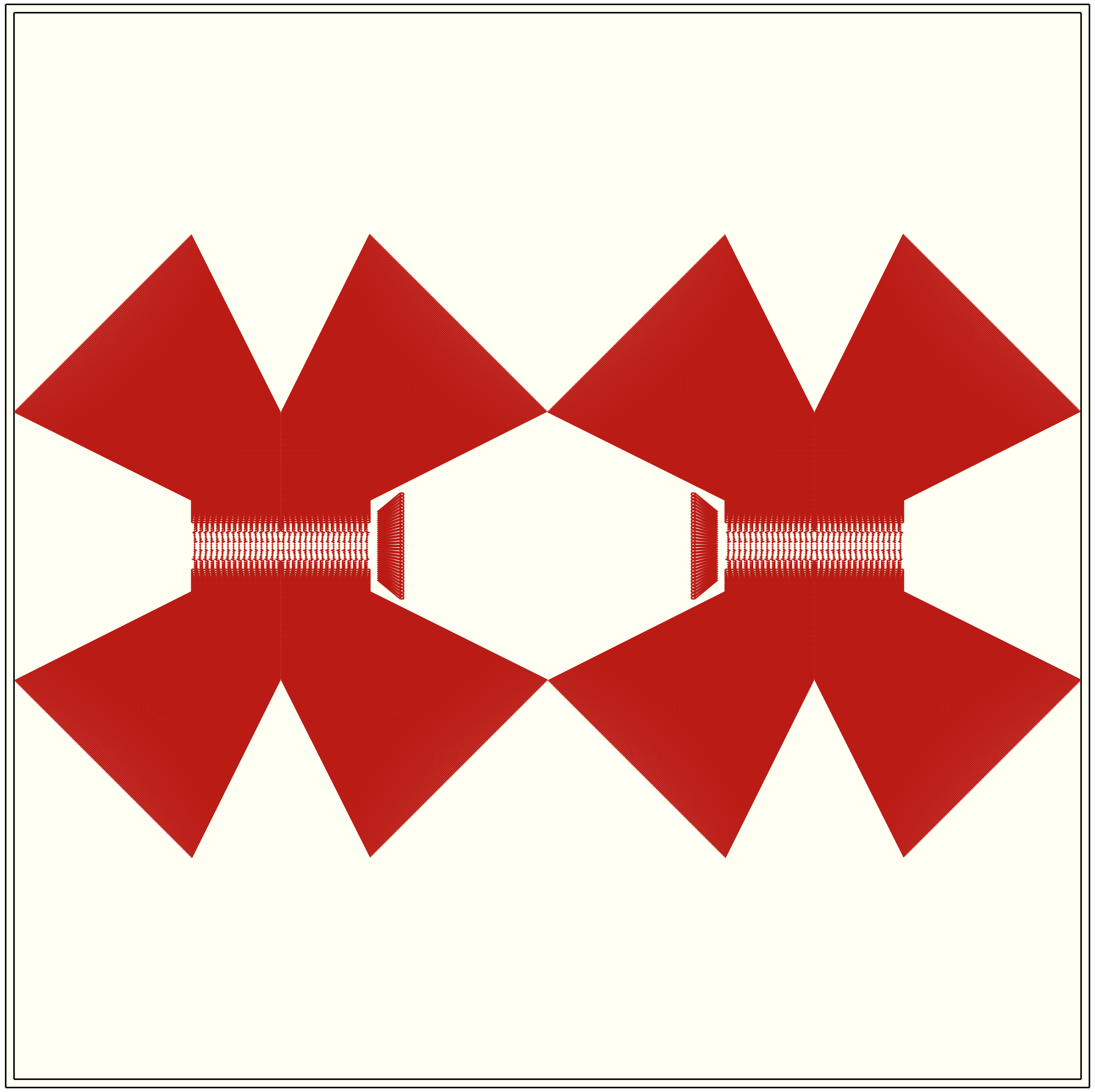
➡ **These result in S/N = 25: depends on still-unknown transconductance of input FET (assumed here to be 2mS)**

Want resistance of power supply/return < 1 ohm (including cable!)

➡ **Detector must minimize the resistance of these double-metal traces.**

Preliminary Sensor Design

- 9.75cm square
- 0.75 mm bias/guard area
- 1920 channels (64X30)
- Two readout chips!

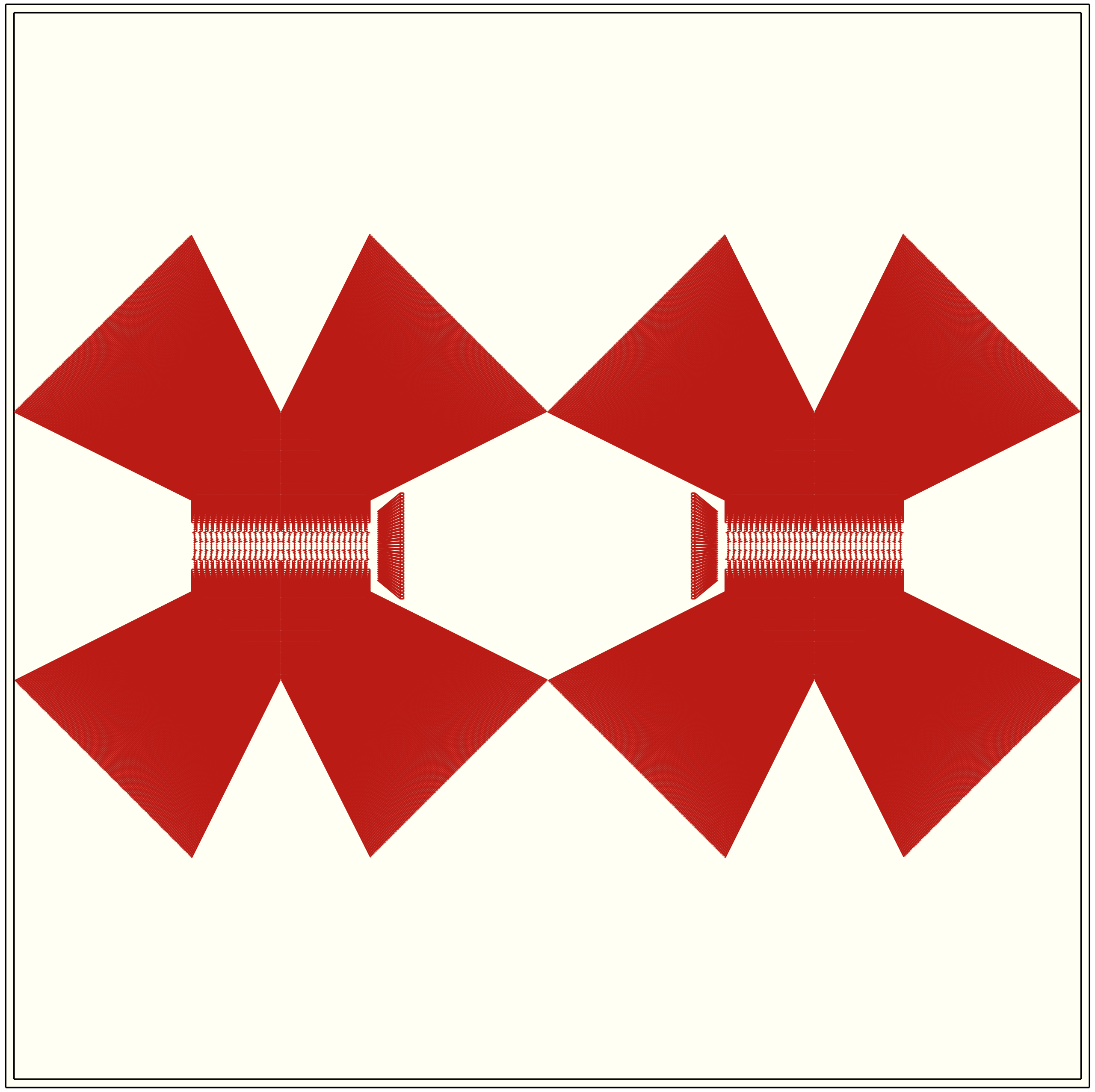


Two Chips vs. One?

Advantages

- Same die size as ECAL

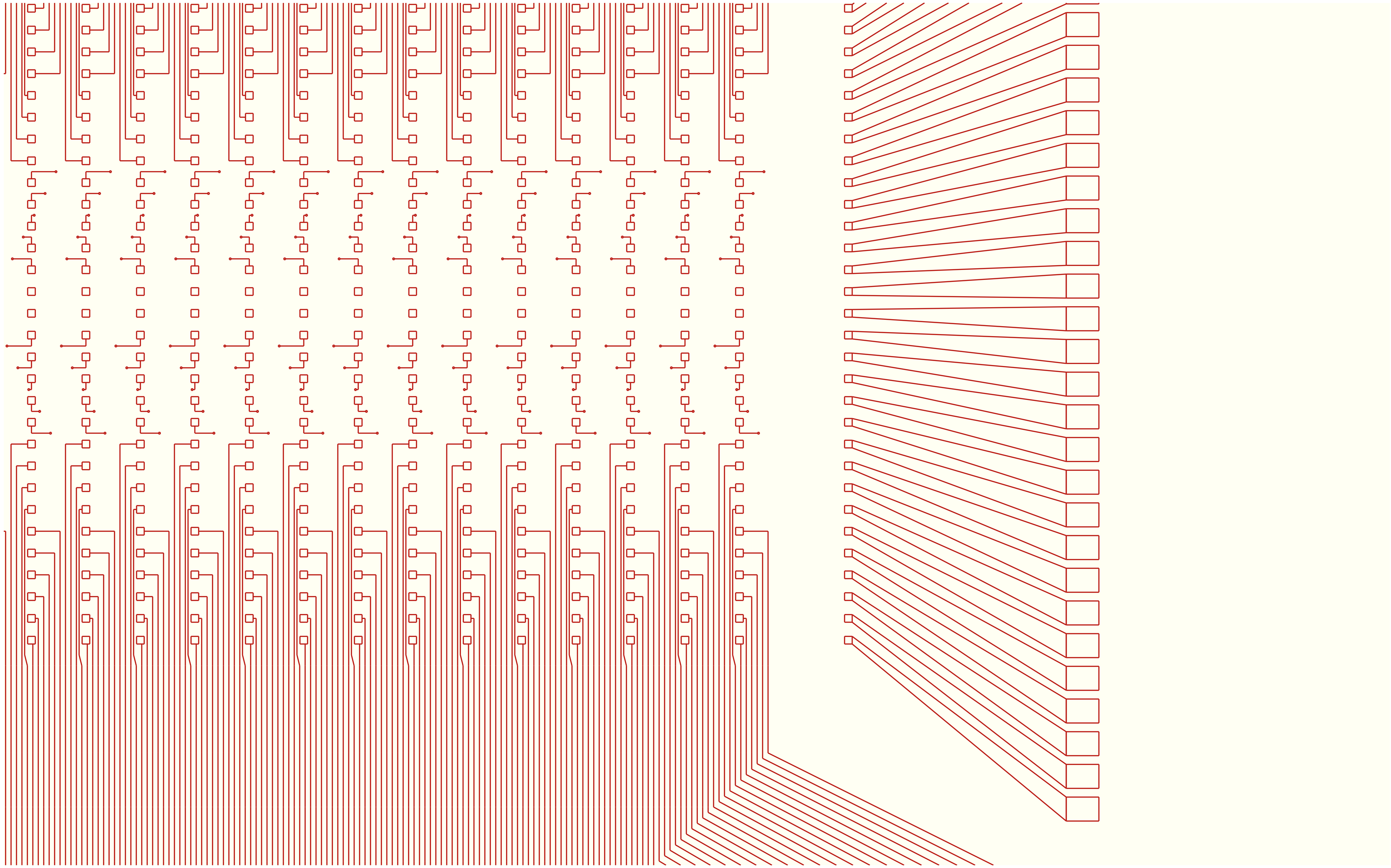
  Dieter: "1024 already quite large."
- Average double-metal trace reduced in length by factor of 2
  - ➡ Reduces both capacitance and trace resistance
- Range of double-metal trace lengths reduced by factor of 2
  - ➡ Equalizes both capacitance and trace resistance



Disadvantages

- Two chips to connect

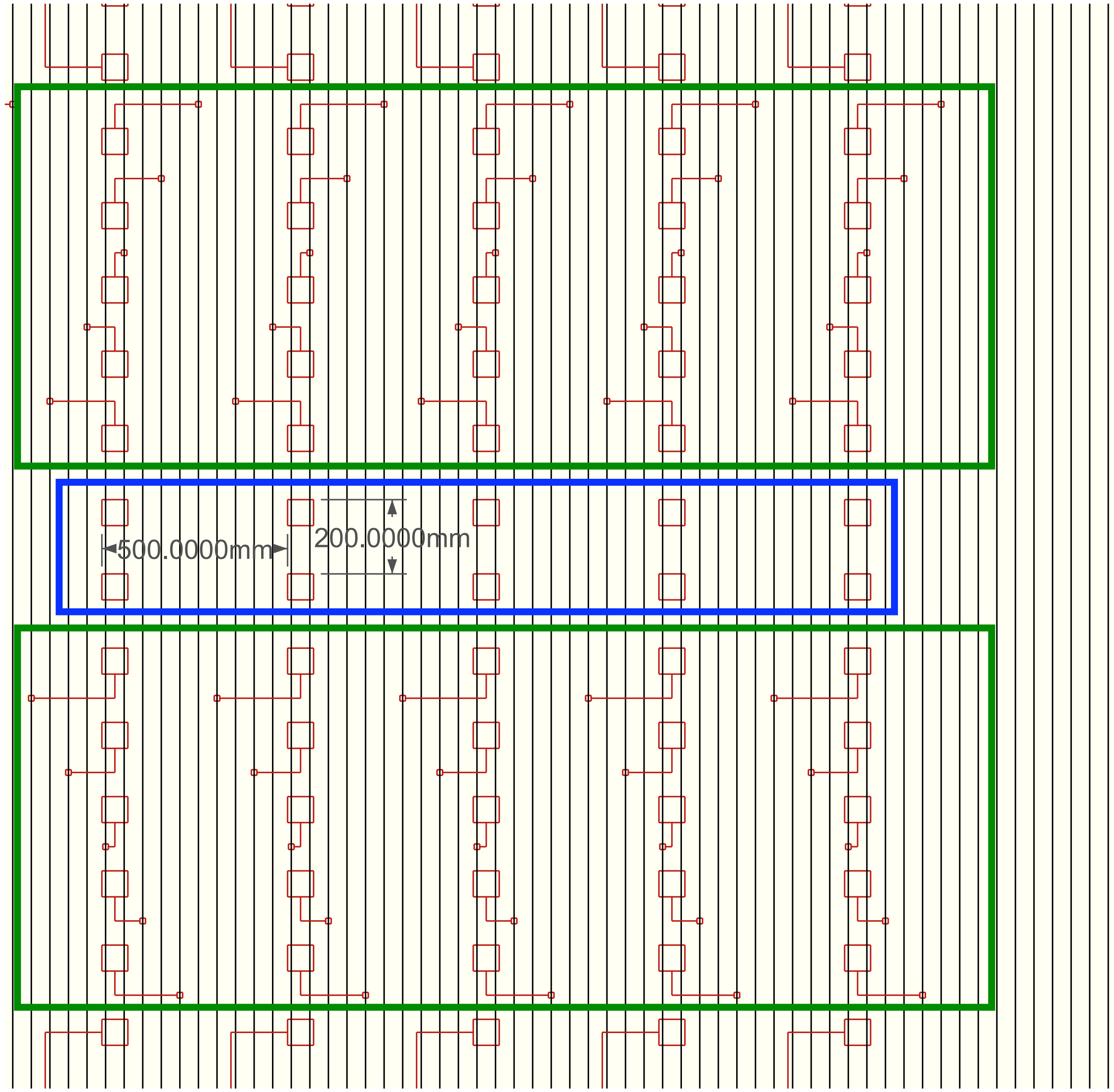
Double-Metal Layout



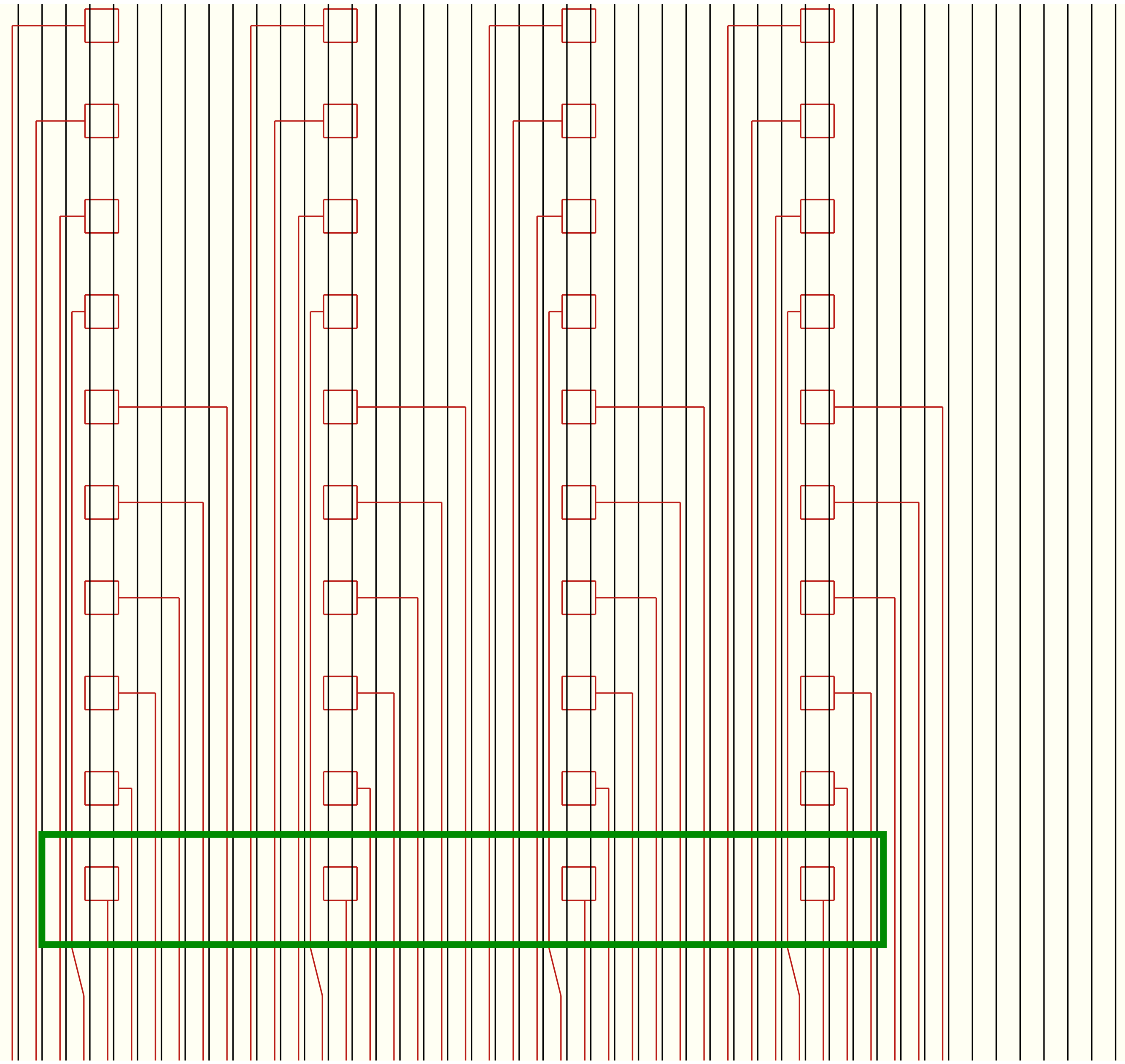
Double-Metal Layout

Easier than ECAL

- Only use 30/32 KPiX-T rows
- 10/30 rows can connect directly underneath the chip
- 20 traces left to route from each column: 10 on each side
- With 500 micron column spacing, ten readout strips to route out between each column:
  - ➡ leaves 9 spaces between strips



Double-Metal Layout



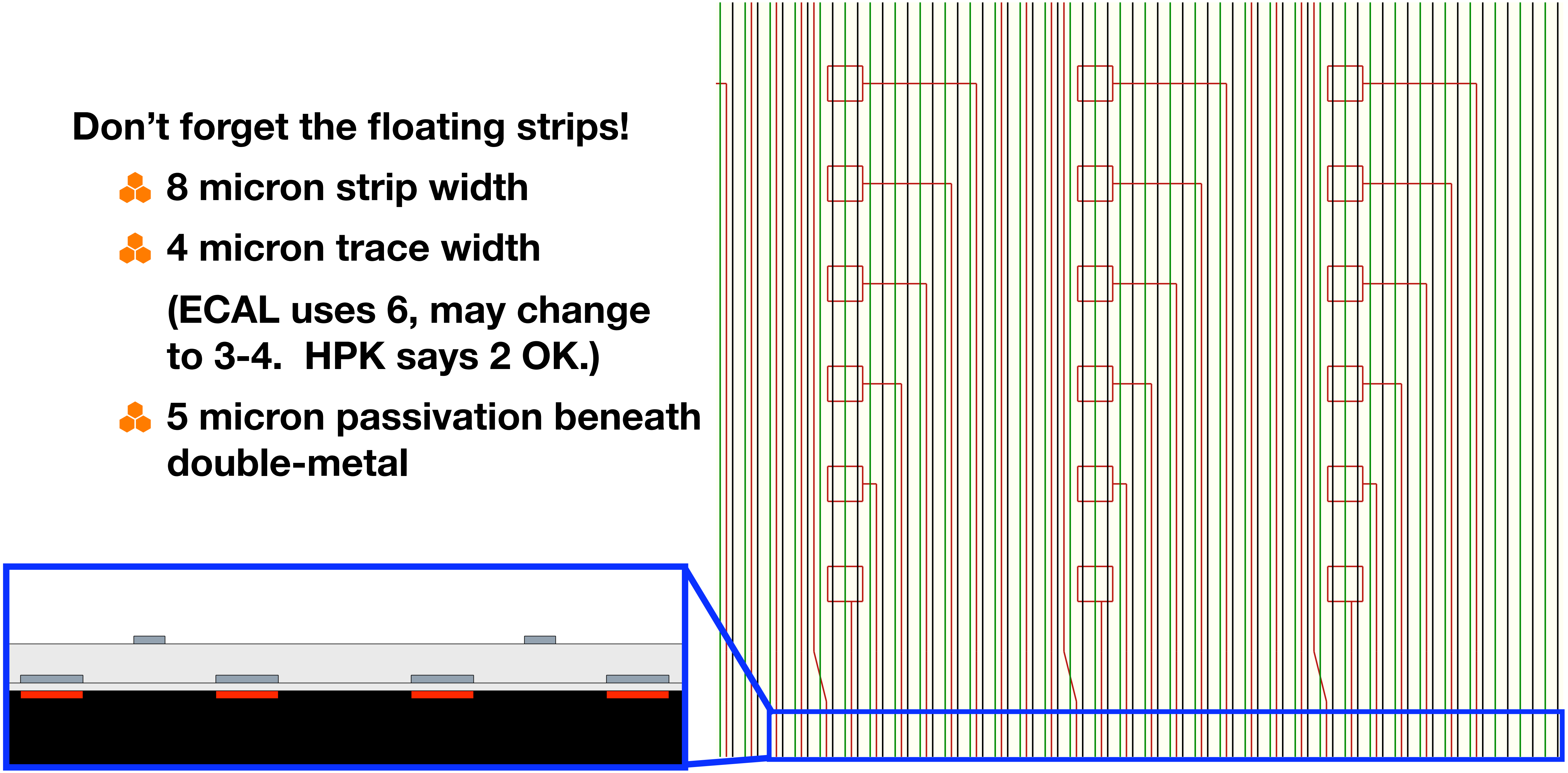
- One trace comes for free: directly from edge of array!
- Leaves a trace for each gap between readout strips.

Double-Metal Layout

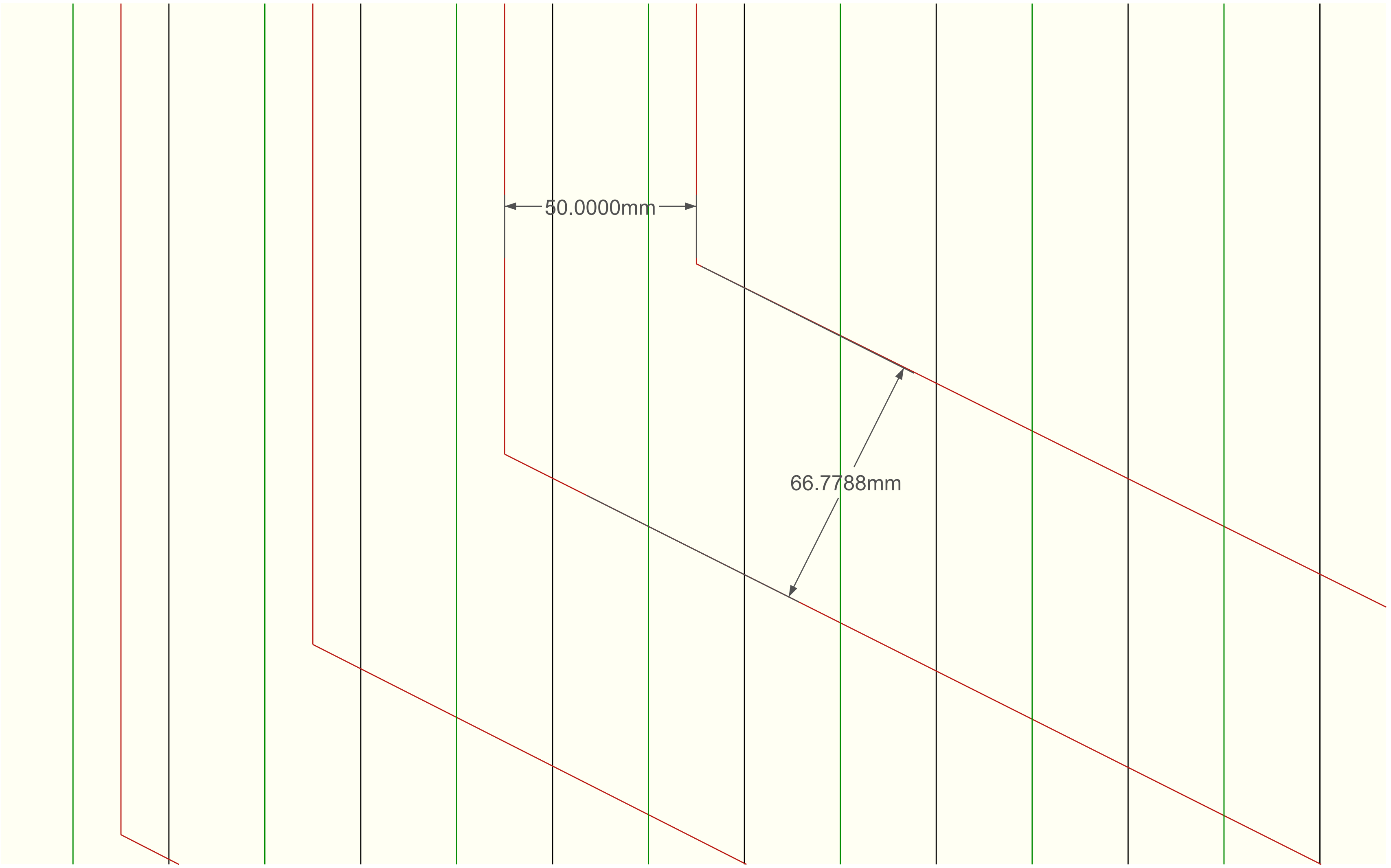
Don’t forget the floating strips!

- 8 micron strip width
- 4 micron trace width

  (ECAL uses 6, may change to 3-4. HPK says 2 OK.)
- 5 micron passivation beneath double-metal

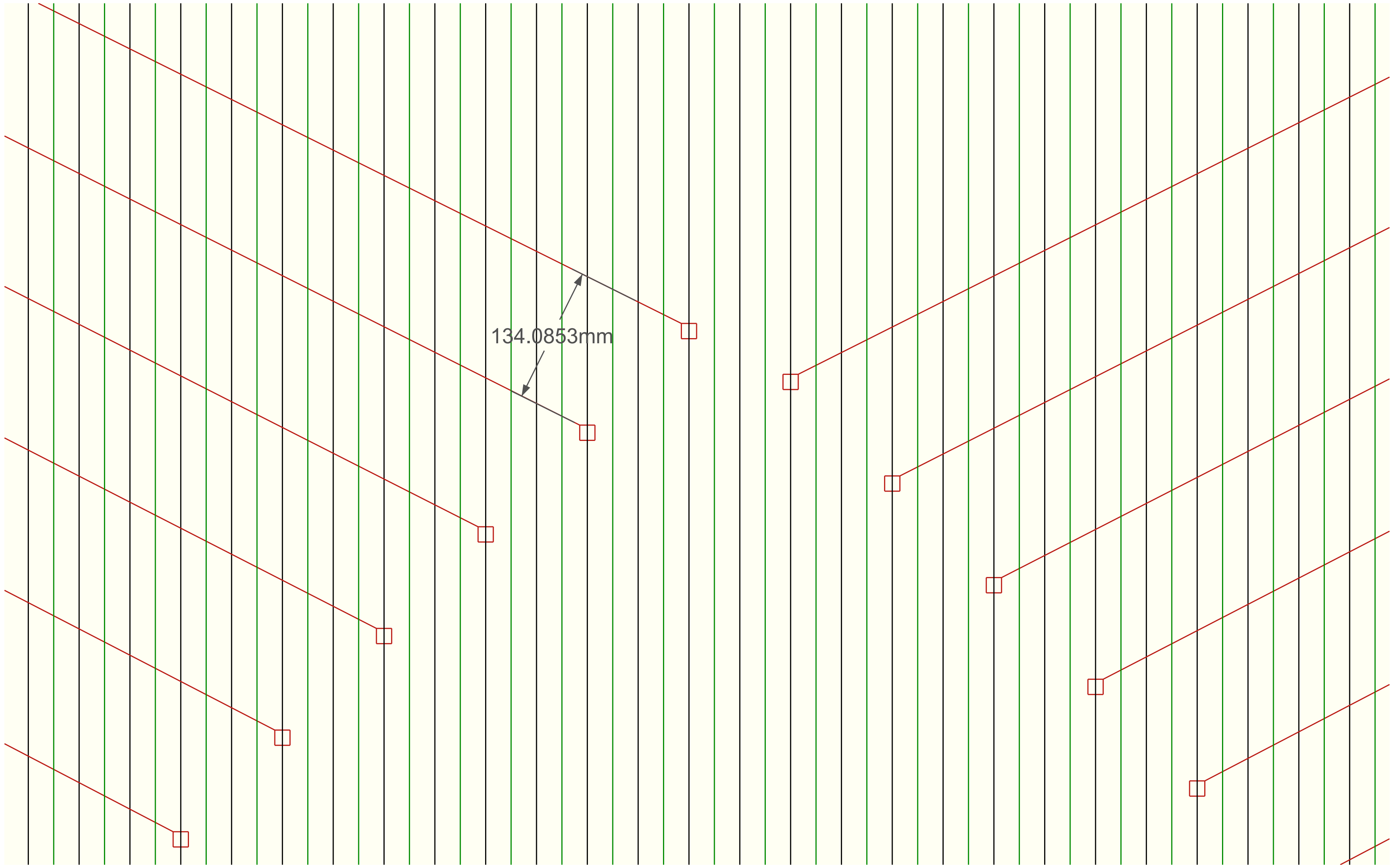


Double-metal Details



Change from 4 to 6 micron trace width at fanout.

Double-metal Details



Crossing capacitance will dominate in fanout: ~6-8 fF / crossing.

Performance Guesstimates

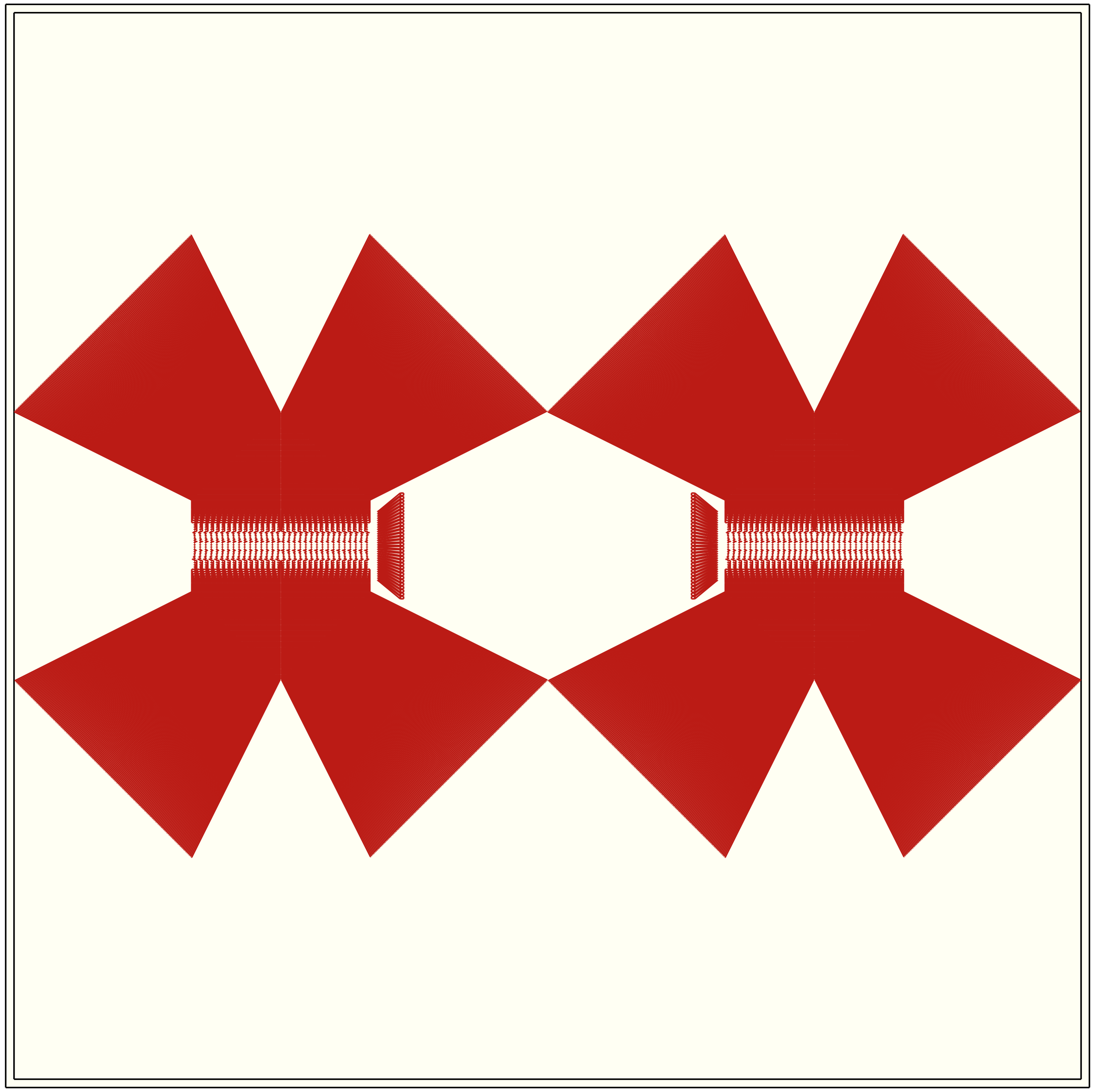
Shortest Trace

- 15 pF
- 225 ohms

Longest Trace

- 21 pF
- 490 ohms

Should easily achieve S/N = 25



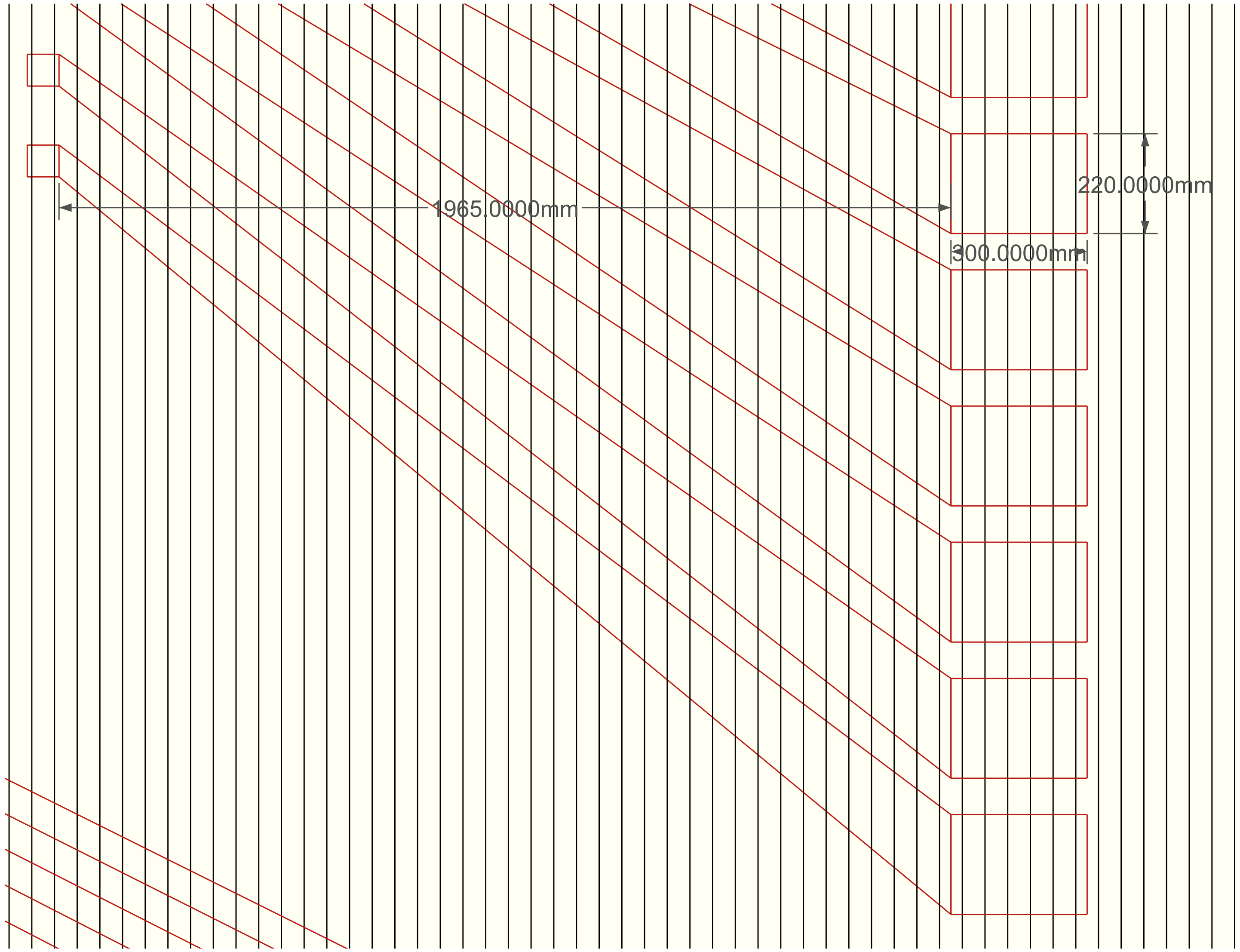
Power Connections

Chip layout has a full column of connections (32) at edge

Current generation uses many of these for test signals: most will ultimately serve power

  - Each double-metal power trace is ~0.5 ohms
  - Several ganged together can achieve required power+return resistance

Strips underneath these traces pick up about 3 pF additional capacitance.



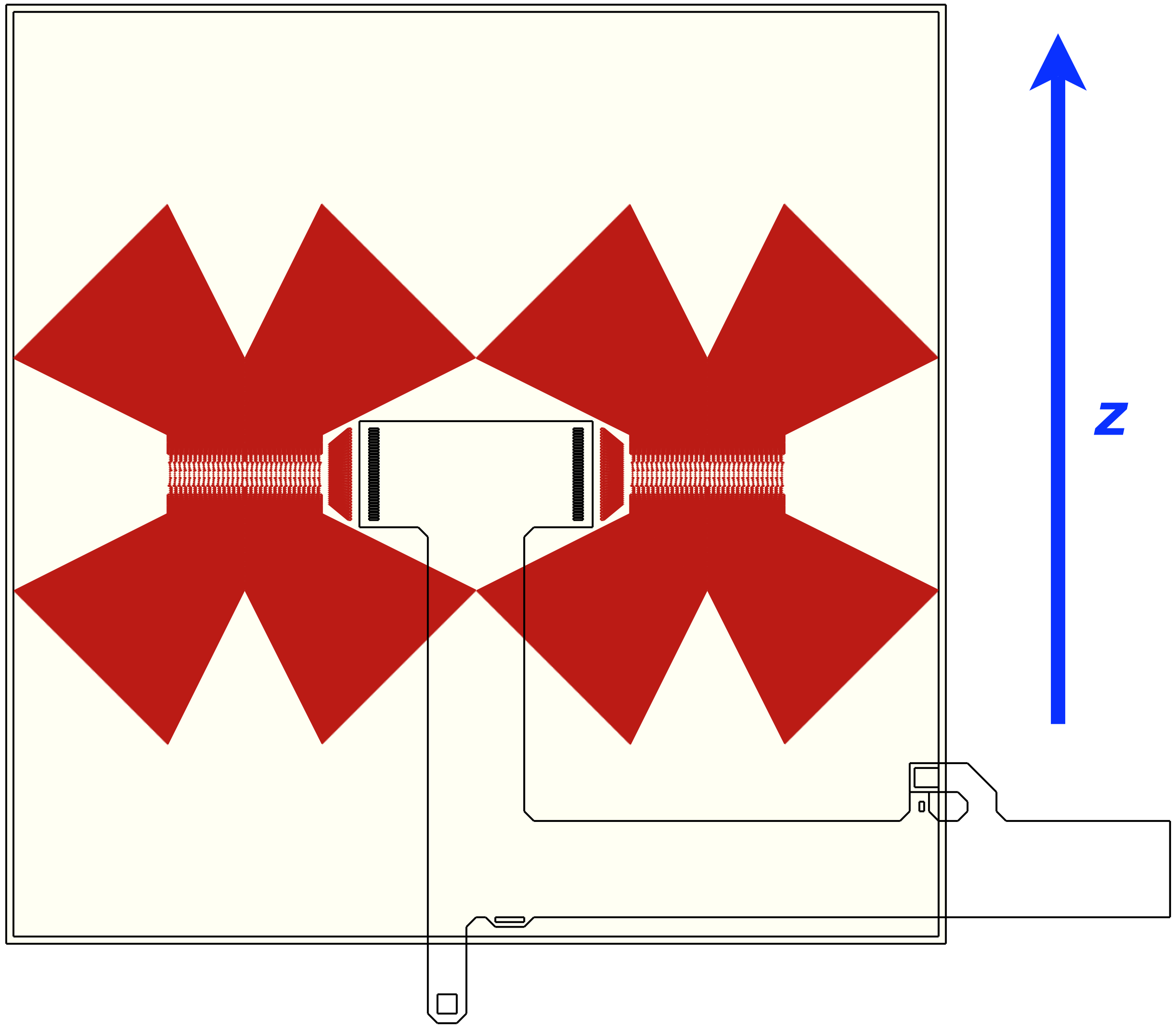
Cable Connection

Proven solution: glue & wirebond cable to face of sensor

- 1mm gap from edge of cable to bond pads on sensor
- 2-2.5mm bond length

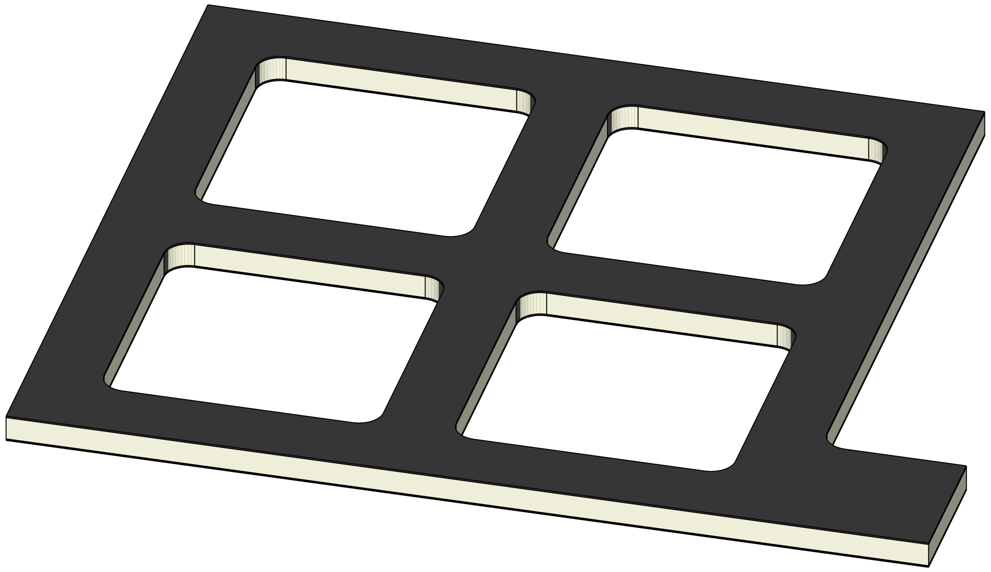
Two biasing schemes shown: arrangement at right preferred.

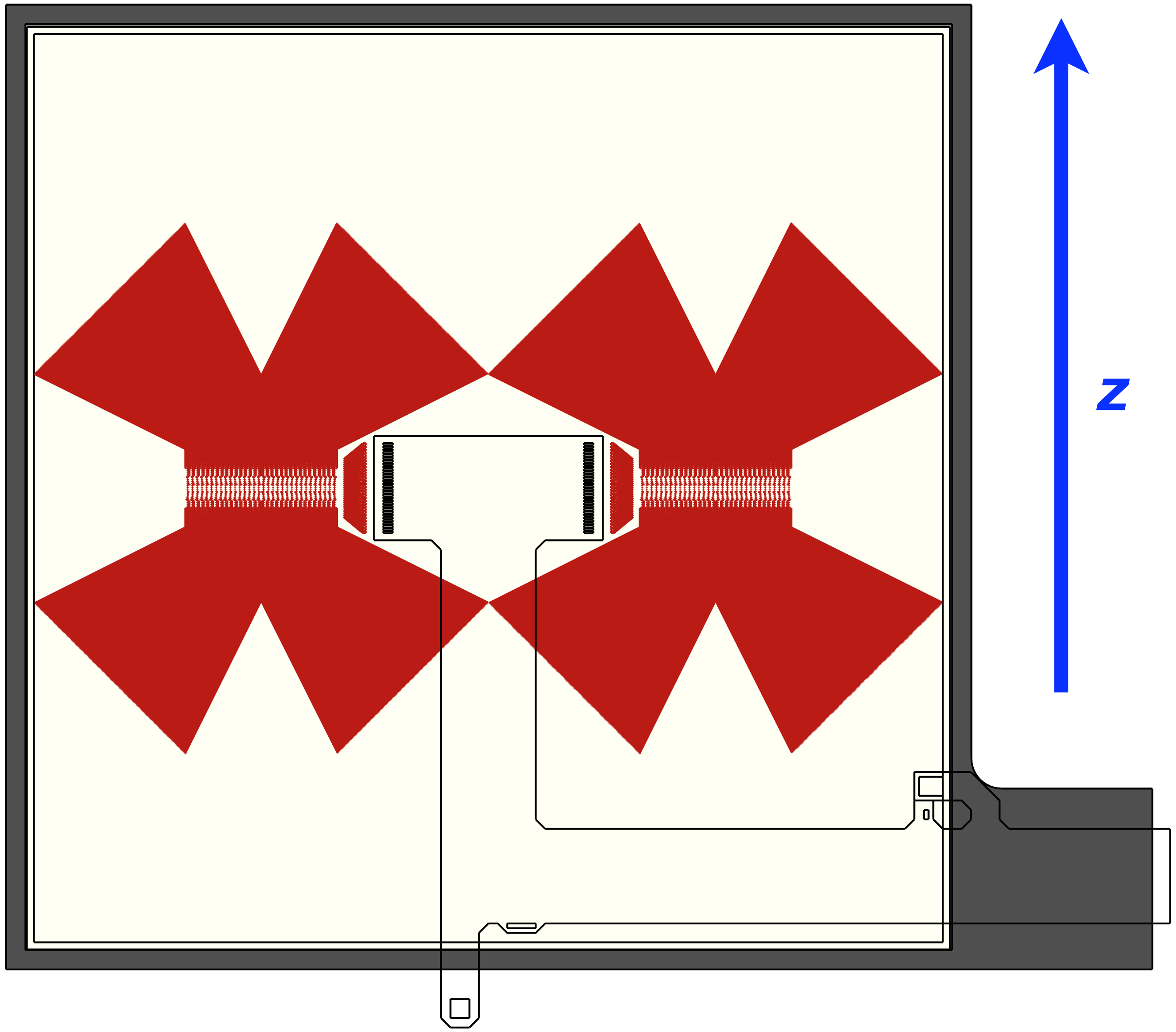
- Left tab glued to top of sensor and wirebonded to bias ring
- Right tab glued to bottom of sensor with conductive epoxy
- Nearby space on cable can host bias-filtering components



Sensor Support - V0.2

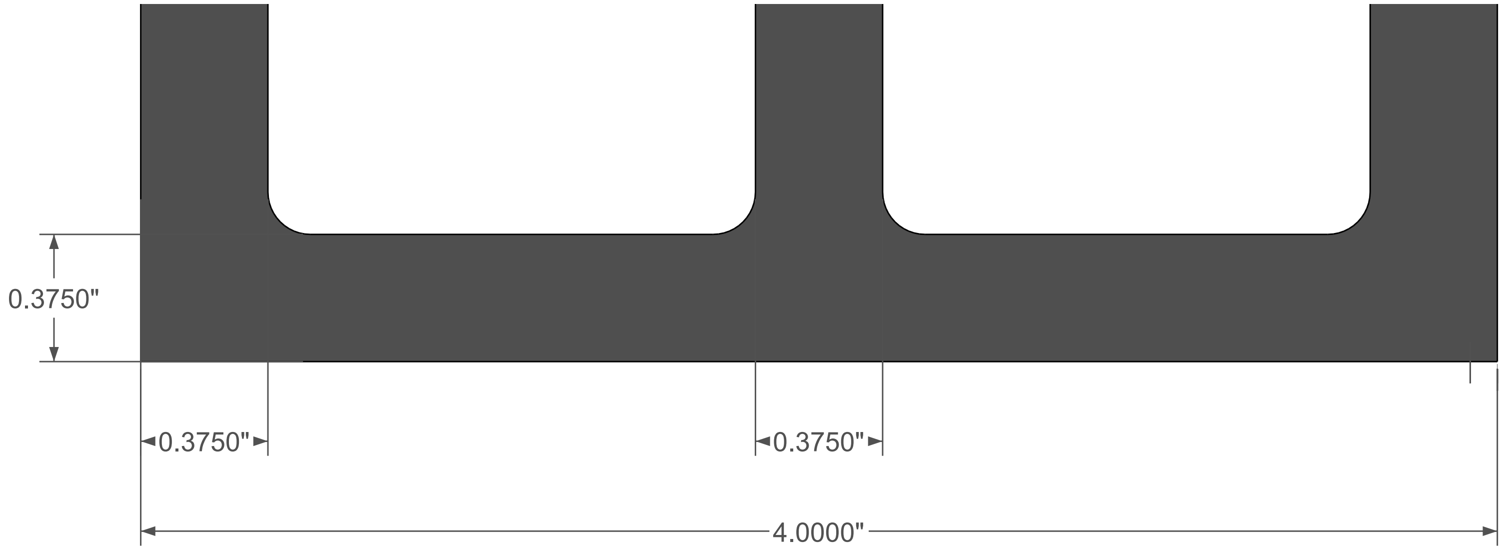
- Completely different structure
- “Handle” at right to strain relieve cable and provide support for bias filtering circuit
- CF directly underneath chips for thermal conductivity in any possible axial or stereo sensor orientation

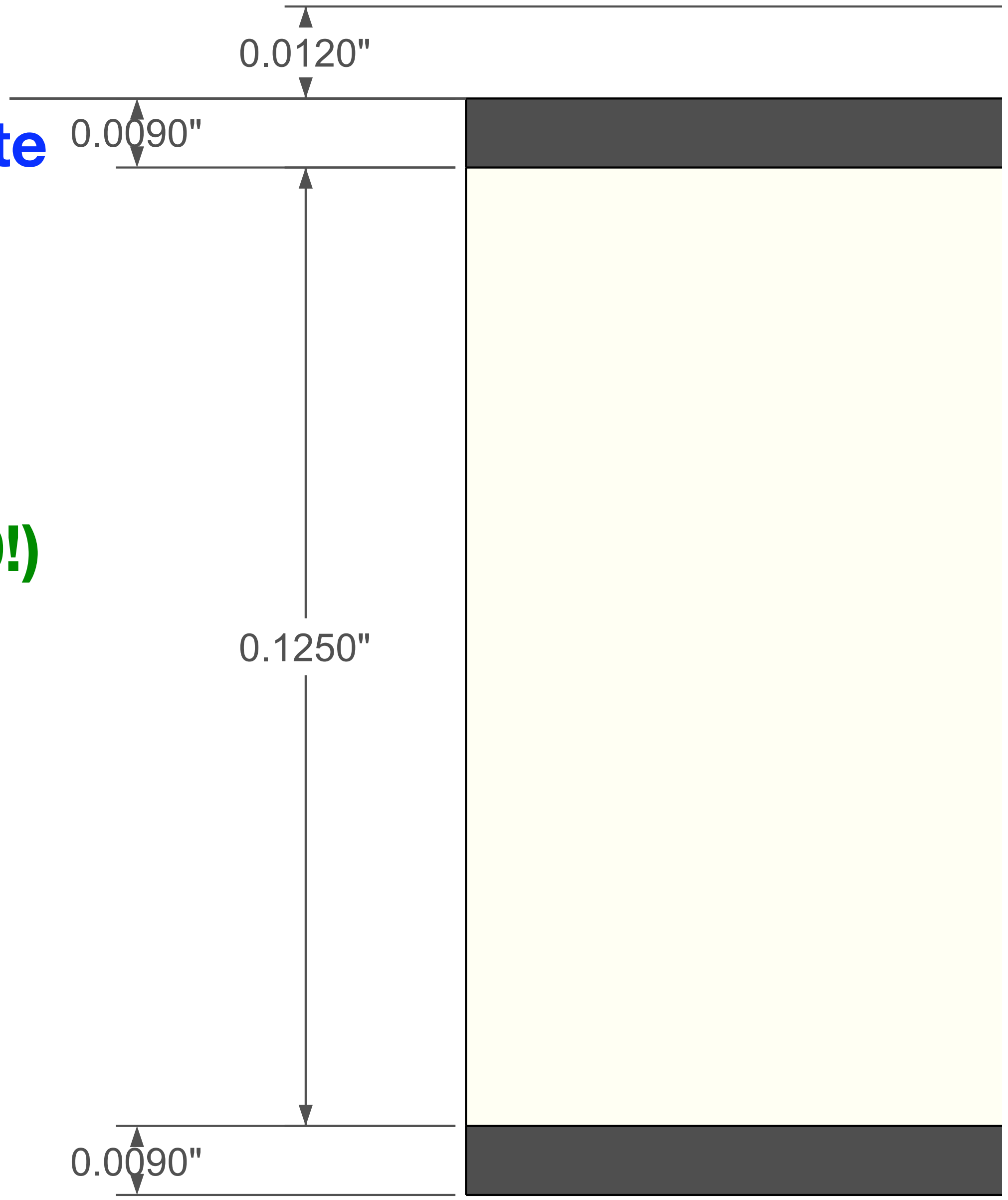




Sensor Support - V0.2

- 0.125” rohacell between two 0.009”, 60-60-60 sheets of high-modulus CF composite
  - ➡ Overall thickness < 4mm
- >50% void
  - ➡ Less material than previous design
- As mass producible as CF can be (need ~5000!)

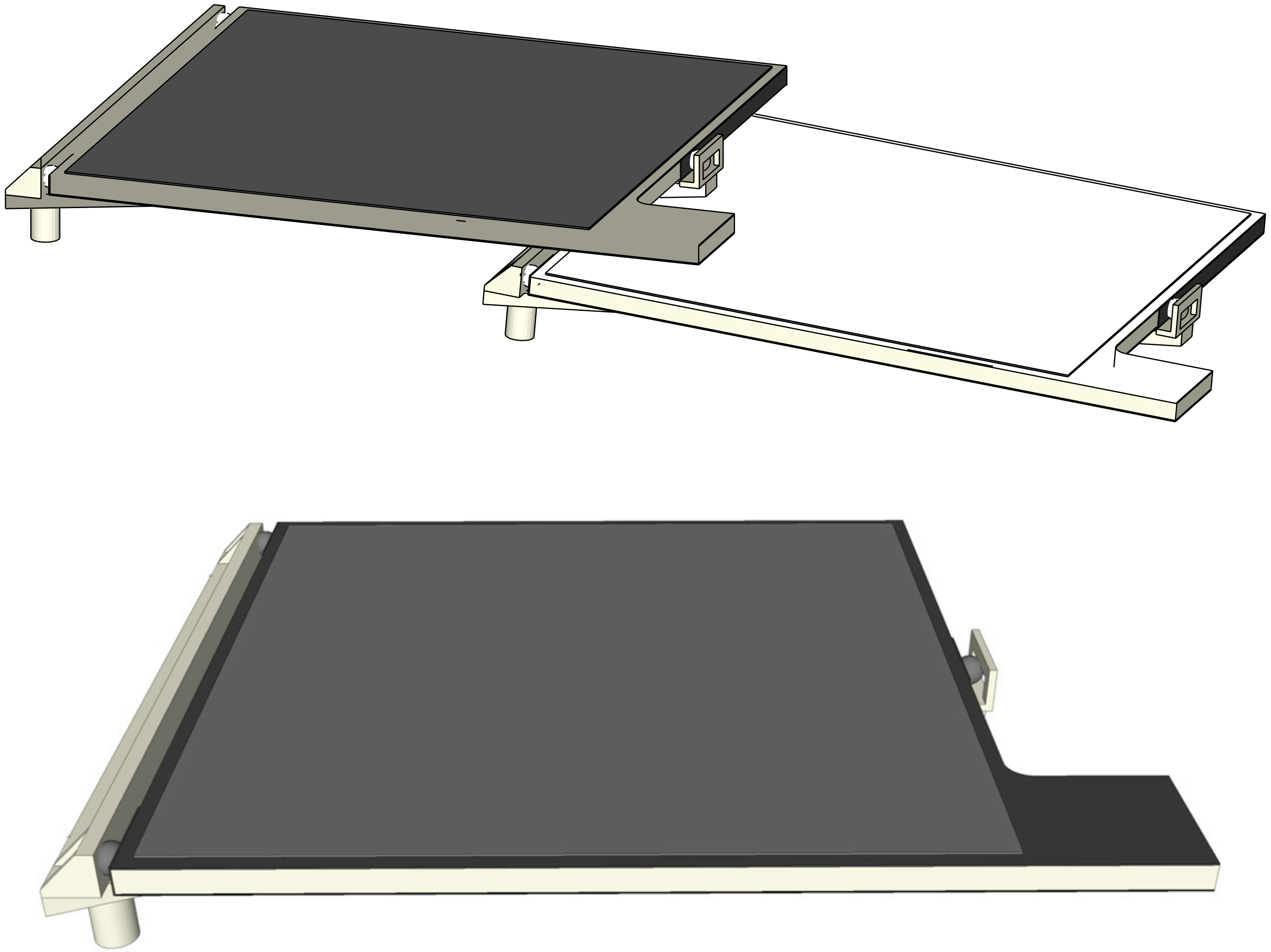




Module Mounting

- Developing a serious design for module mounting
  - First concept could not provide required z overlaps
  - Precision questionable for standalone momentum measurement in an axial-only design
- Working on three-point ball-and-cup design

➡ Can design be such that repeatability of tooling limits precision?



Material for Mating Surfaces

- **Plastic**
  - Light
  - Even for high-performance plastics: not precisely or repeatably machinable (CTE issue)
  - Subject to wear
- **Metal**
  - Precisely & repeatably machinable
  - good wear properties
  - Massive
- **Sililcon nitride (Si_3N_4)**
  - Precision meets or exceeds similar metal parts
  - Harder than bearing steel, extremely resistant to wear & fracture
  - Dry coefficient of friction <0.1 (similar to ice-on-ice) ideal for repeatable mating surfaces
  - Relatively inexpensive in standard shapes (balls, sheets, etc.): 0.125” grade-10 ball = $0.18
  - Radiation length nearly identical to that of silicon (expect parts to total <0.05% X_0 avg.)
  - May be possible to injection mold directly into PEEK (extraordinary adhesion to PEEK)

Feedback from Ceradyne to understand processing and optimize design

Material for Mounting Clip

- Carbon Fiber
  - Ideal CTE match for modules
  - Light and rigid (10-40 msi)
  - Difficult to fabricate part with necessary complications - making 5000 could be problematic
- High-performance, semi-crystalline plastic (PEEK)
  - Easily fabricated and mass producible
  - Good injection molding tolerances (500 ppm ⇒ 50 microns for 10 cm span)
  - Light and reasonably rigid (0.5 - 1 msi)
  - Poor match for CTE of modules: 3.6×10^{-5} /°C ⇒ 3.6 microns/°C for 10 cm part
- Carbon Fiber Filled PEEK
  - Molding requirements only slightly more restrictive than unfilled PEEK
  - Same molding tolerances as for unfilled PEEK
  - Light and rigid (3-5 msi)
  - Reasonable CTE match for modules: 1.5 microns/°C for 10 cm part (30% filled, 50% available): effects can be minimized with careful design

Feedback from Victrex to understand processing and optimize design

Next Steps

- **Sensors**
  - Resolve remaining issues (bias scheme, AC vs. DC coupled)
  - Generate complete set of formal drawings for HPK - FNAL
  - Perform more detailed analysis of trace capacitance and resistance - SLAC, FNAL, Tokyo?
  - Take to HPK for quote
- **Cables**
  - Create detailed pigtail design - SLAC? Davis?
  - Quotes and costing for prototypes and production
- **Sensor Support**
  - Create FEA model of support and test under mechanical and thermal loads - FNAL
  - Finish detailing design (modifications for biasing scheme, mounting details) - SLAC
  - Generate complete set of formal drawings - FNAL
  - Quotes and costing for prototypes and production
- **Module Mounting**
  - Finish conceptual design / engineering of mounting clip - SLAC
  - Create FEA model of mounting clip and examine thermal effects - FNAL
  - Generate complete set of formal drawings - FNAL
  - Quotes and costing for prototypes and production

Another talk in next few weeks on sensor support and module mounting