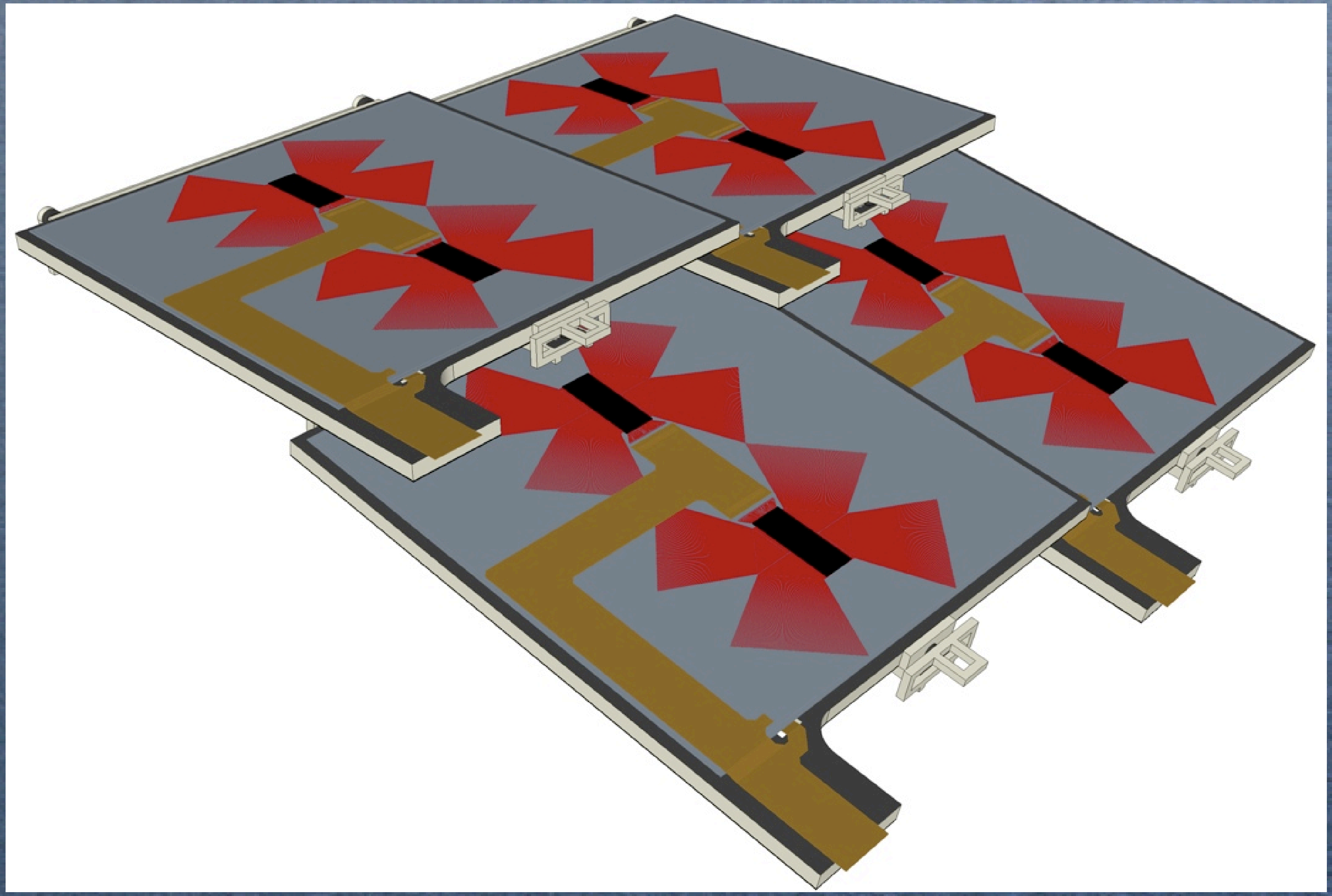
ILC Tracker R&D at SLAC



Tim Nelson

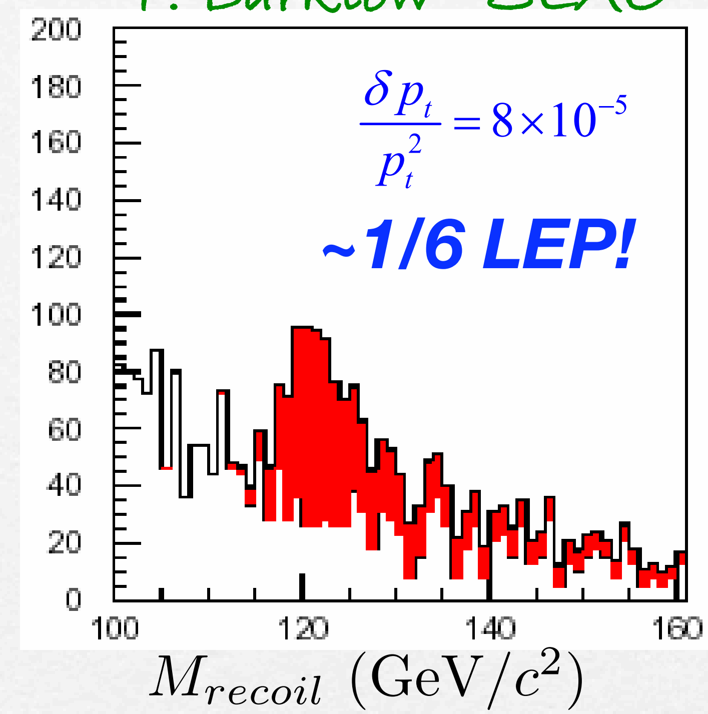
ILC Tracking Requirements

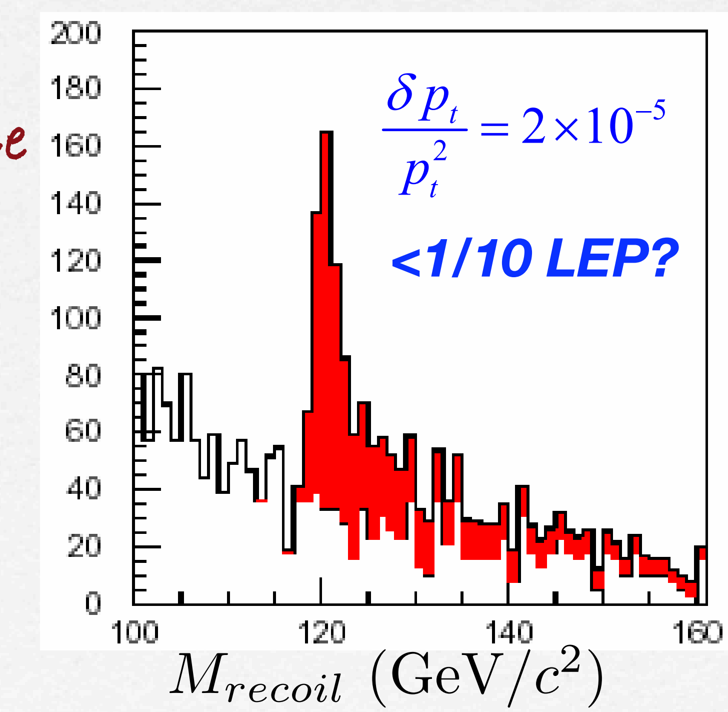
T. Barklow - SLAC

Superior P_T resolution:

- $e^+e^- \rightarrow Z^0 H^0 \rightarrow \mu^+\mu^- + X$

  Given $\sqrt{s}, M_Z, M_{\mu\mu} \Longrightarrow M_H$





Fast readout:

- Long readout times add background to signal events
- Signal collection/readout time ≪100ns

Low mass:

- Production of secondaries threatens calorimeter performance
- goal: average < 1% X_o / layer

Mass producible / low cost:

- Roughly same scale as LHC trackers
- Production of components must be simple

Possible Solutions

Superior P_T resolution:

- Large radial span ⇒ SiW ECAL gets large, expensive
- Large magnetic field ⇒ CMS-type solenoid of maximal field
- Smallest single-hit resolution ⇒ Silicon, optimized for precision

Fast Readout:

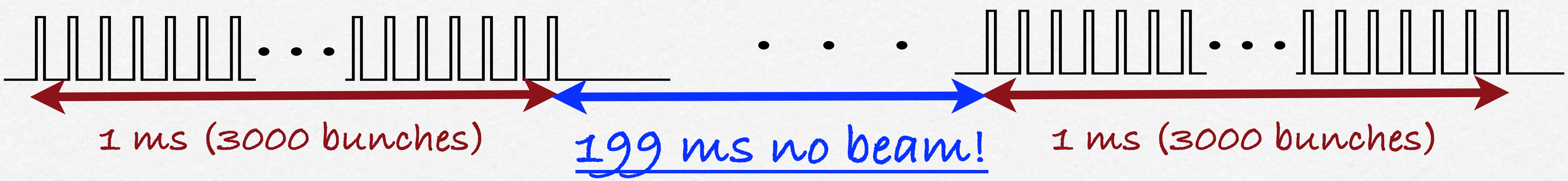
- Solid state sensors ⇒ Silicon with beam-crossing time stamp

Low mass vs. Mass producible:

- LHC did mass-producible silicon but NOT low-mass
- BaBar did low-mass silicon but NOT mass-producible

  ⇒ Need a design that shatters this dilemma

Use ILC Machine Attributes



During collisions (0.5%):

- Noisy digital functions of chip can be turned off
  - Need readout chip that stores analog signals during train
  - Simplifies isolation/filtering generally requiring a hybrid

    ⇒ Mass reduction AND assembly simplification

Between collisions (99.5%):

- Power-consuming front-end can be powered down
  - Need readout chip that can be "power pulsed"
  - Eliminates need for active cooling

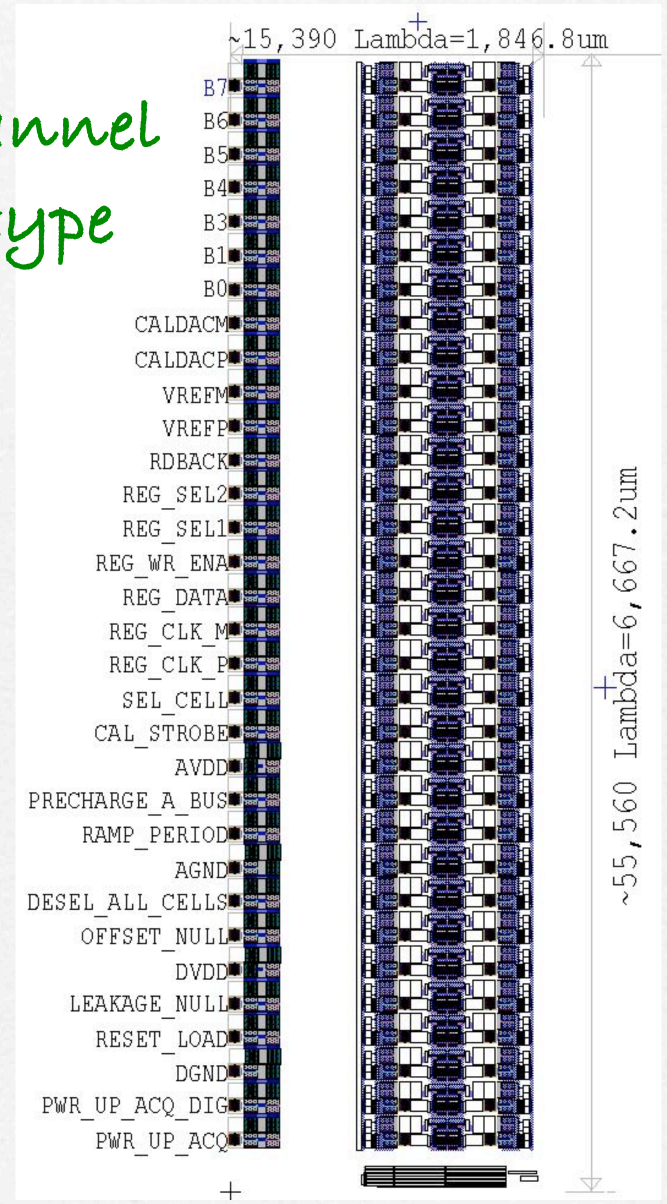
    ⇒ Mass reduction AND assembly simplification

KPiX Readout Chip

Already under development at SLAC for SiD ECAL!

- 1024 Channels
- Power-pulsed, average power ~20mW
- 4 time-stamped analog buffers for readout between trains
- Designed for bump-bonding directly to silicon - no hybrid
- Dual-range logic is only extraneous component

64-channel prototype



All the basic attributes we require

Optimizing Single-hit Resolution

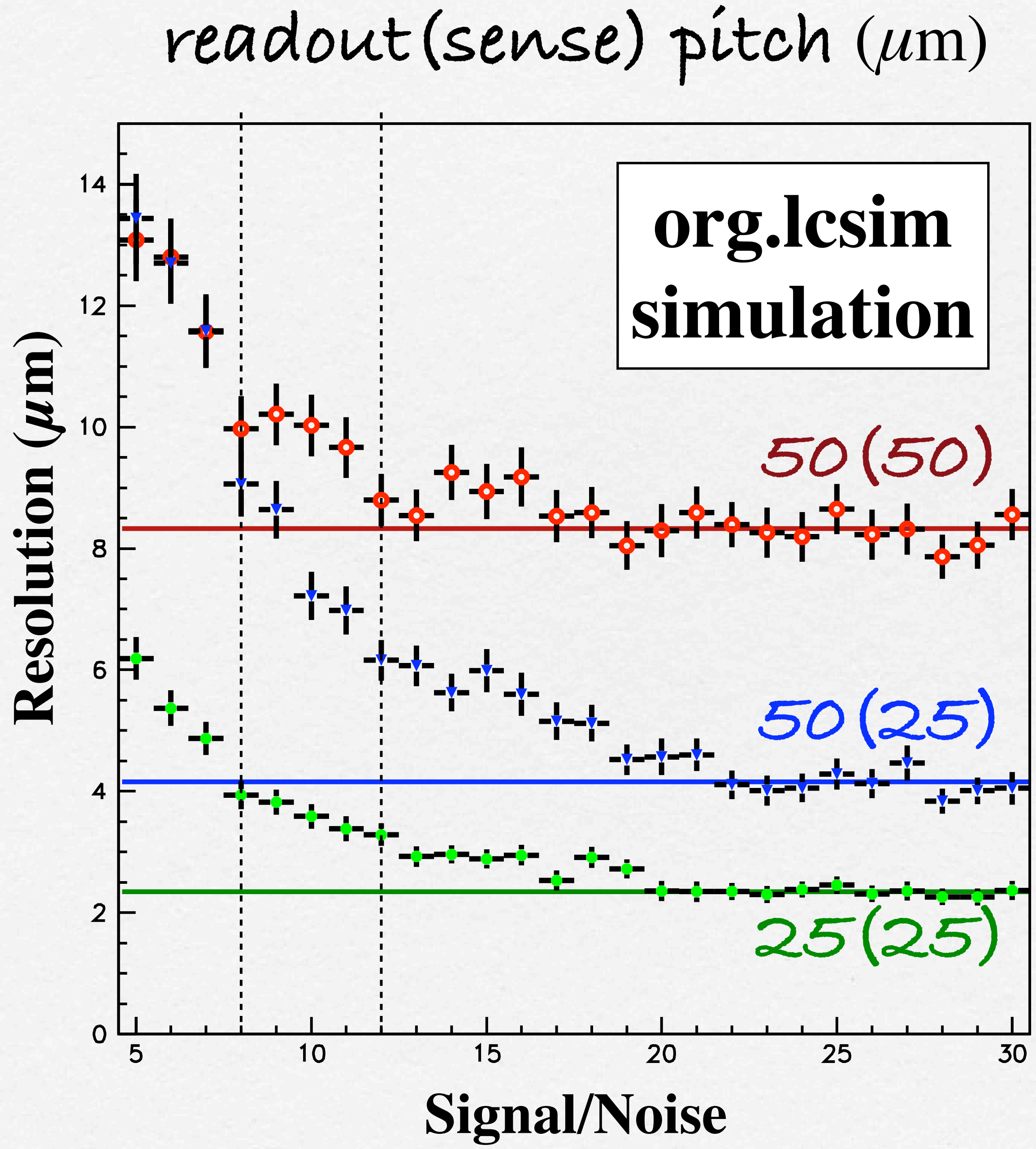
Reduce sense pitch (>25 μm)

- Huge channel count/density: readout becomes difficult

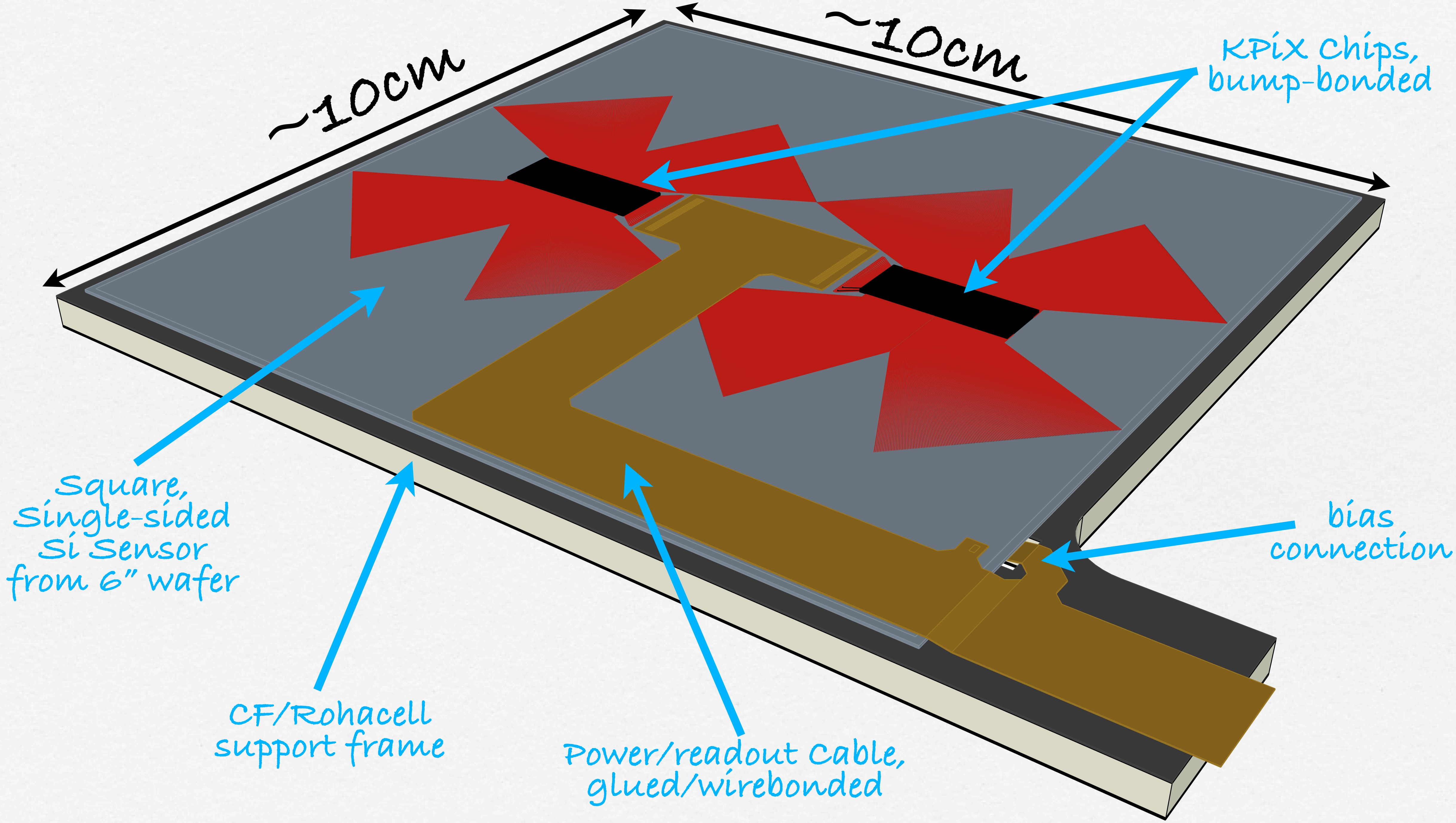
  ⇒ Read out every-other channel

  - Delivers resolution that approaches full 25 micron readout for high S/N
  - Requires high S/N to deliver best performance

⇒ Short strips for small input capacitance on amplifier



Short Module Design



Sensor Design

- Single-sided p-in-n silicon
- 50(25) micron readout(sense) pitch
- Double-metal carries digital signals and power between cable and KPiX
- Double-metal readout carries signals to KPiX bonding array: 1856 channels
  - Shortest trace: 15pf, 225 ohms
  - Longest trace: 21pf, 490 ohms

Should achieve S/N > 25

➡ Preparing detailed design and specs for HPK with FNAL

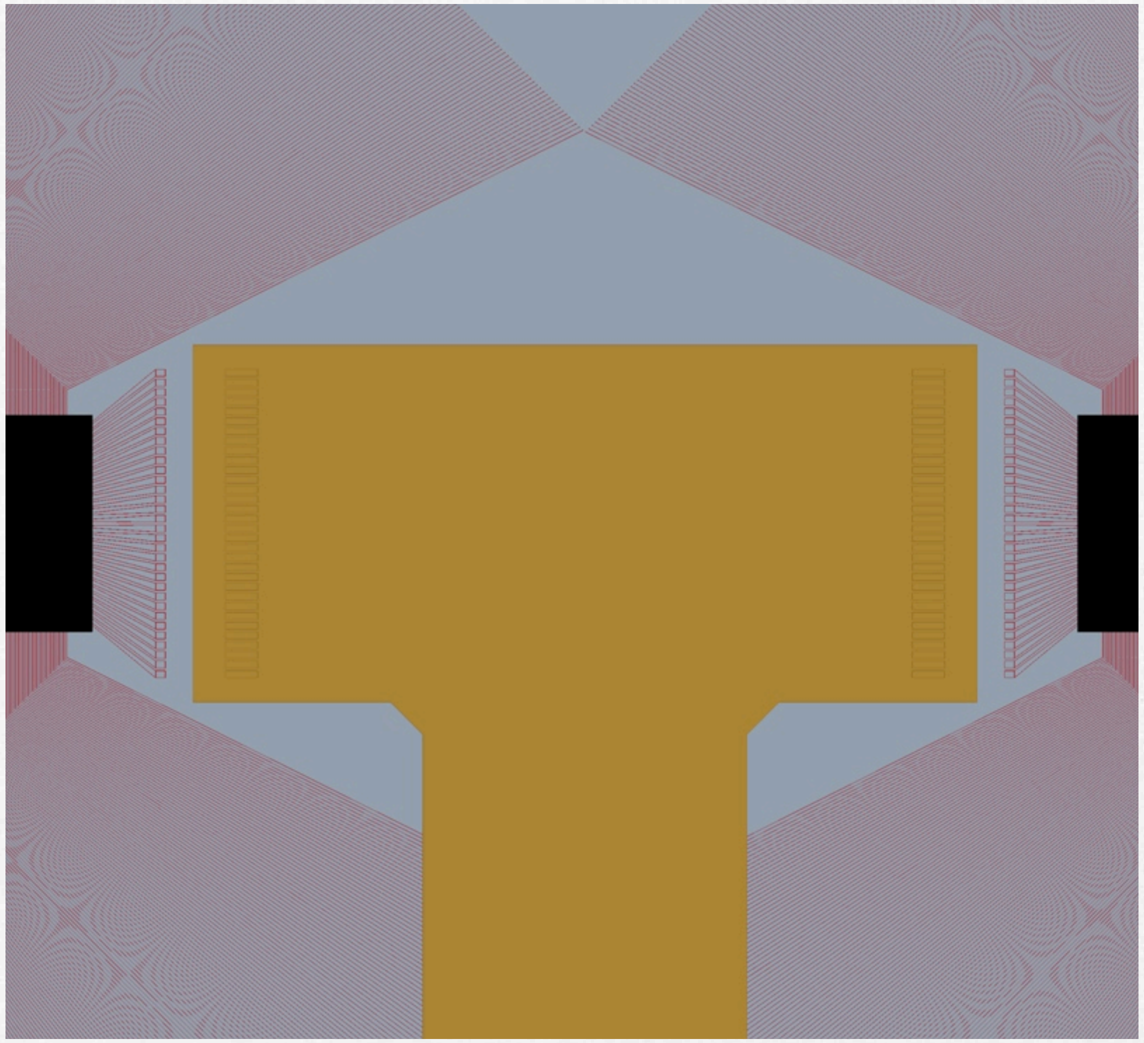
➡ Submit this fall (w/ ECAL)

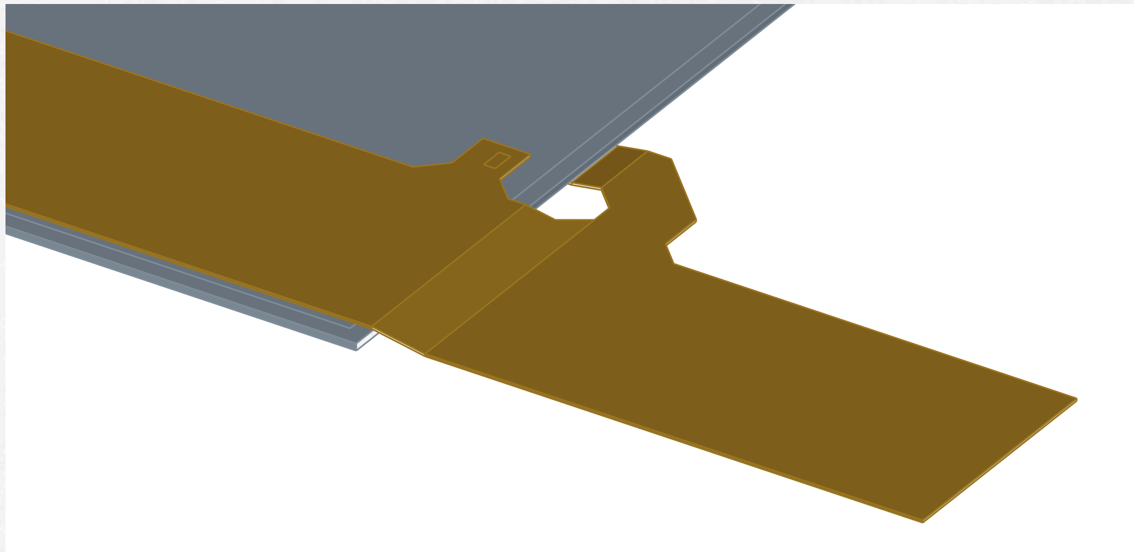
Cable Design

- pigtail glued & wirebonded to sensor
- very simple extension cable to electronics at ends of barrel cylinders
- will follow the lead of similar ECAL cable design underway now
- no group currently covering cable design

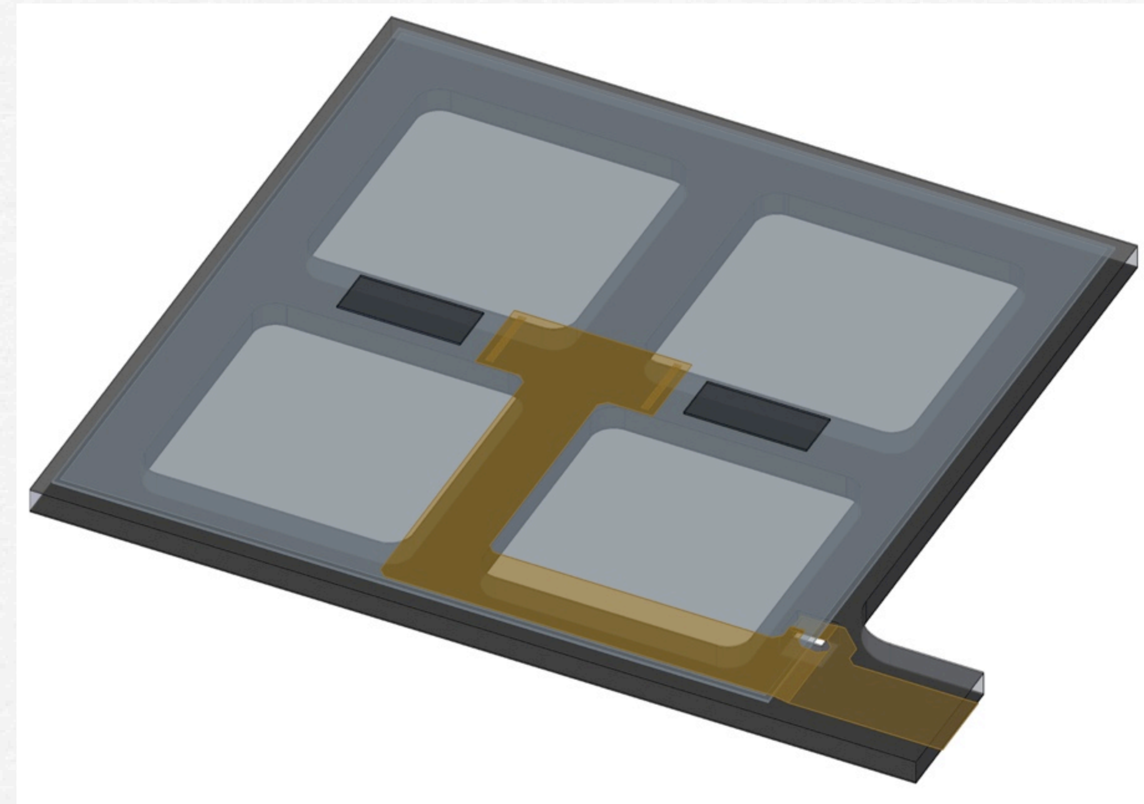
➡ Need to develop design for pigtail cable

➡ Need to develop design for extension cable





Module Support



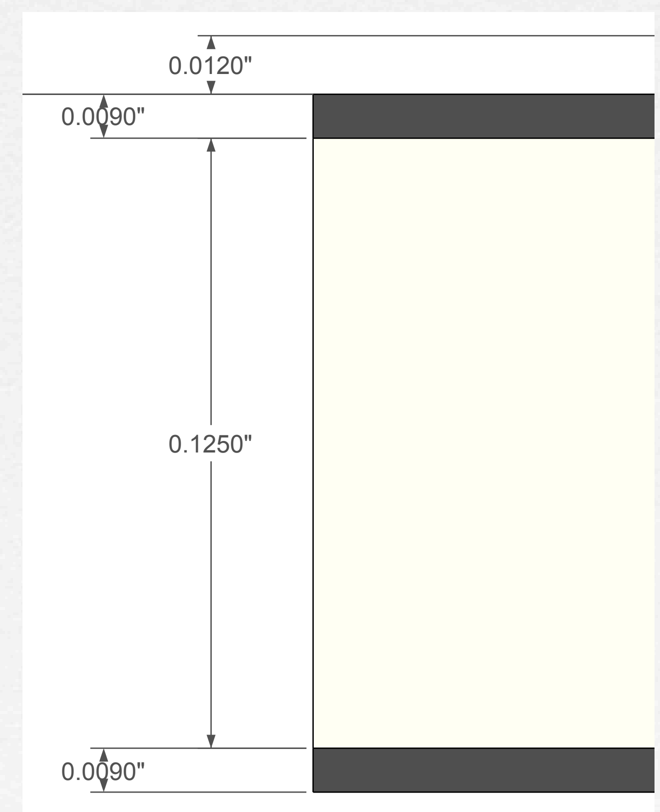
Low-mass, mass producible

- Two, 60°-60°-60°, 0.009" thick, high-modulus CF sheets
- 0.125" Rohacell foam sheet
- 50% void, but CF directly under KPiX
- Only enough mass to hold silicon flat: ~0.15% X_0
- tab for handling, cable strain relief

➡ FEA to see if it is enough/too-much: FNAL / U Wash.

➡ Investigate cost of production by industry

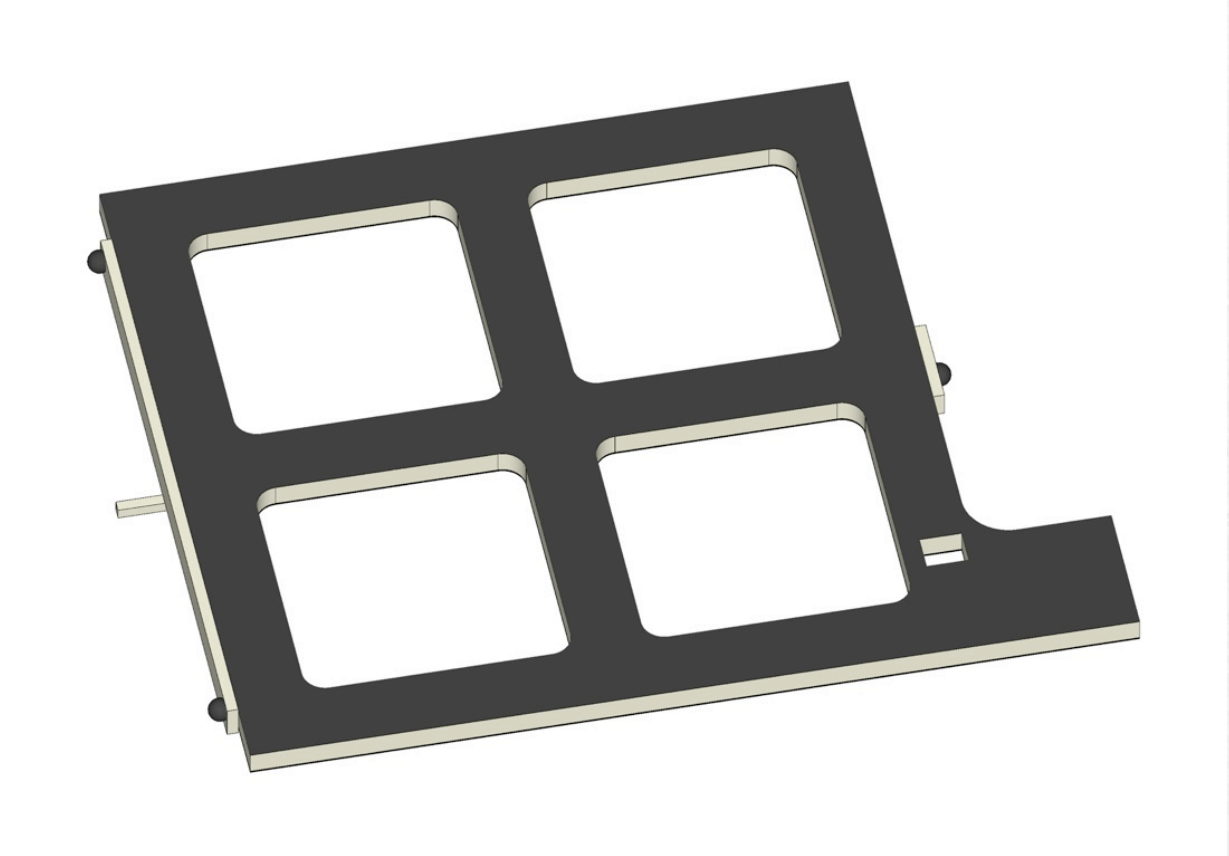
➡ prepare tooling for prototypes

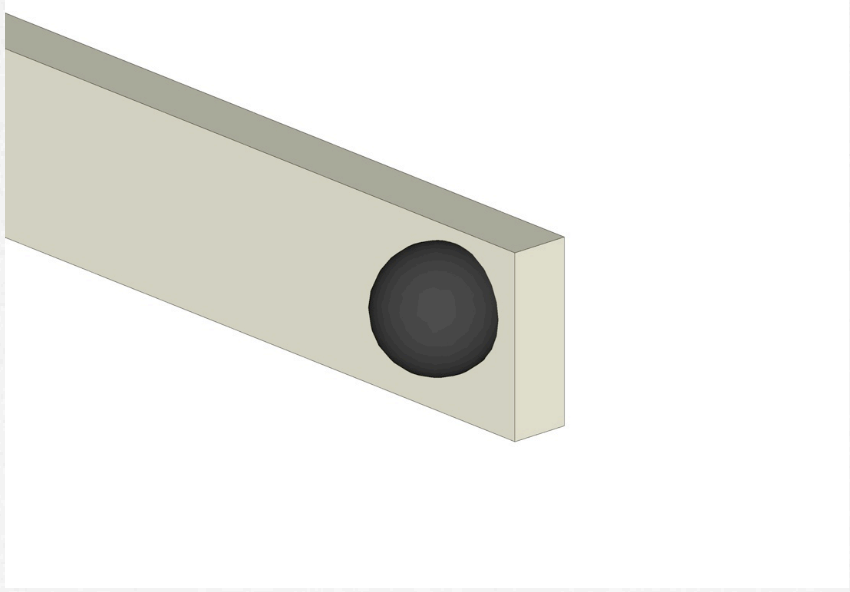


Module Mounting

High-precision, low-mass, mass-producible mounts

- CF-filled, PEEK or Torlon (working with Victrex, Solvay)
  - high modulus
  - low CTE (near Si)
  - Can be injection molded
- Insert-molded silicon-nitride mating parts (input from Ceradyne)
  - long radiation length (~Si)
  - high-precision (< 1 micron)
  - very hard, low friction





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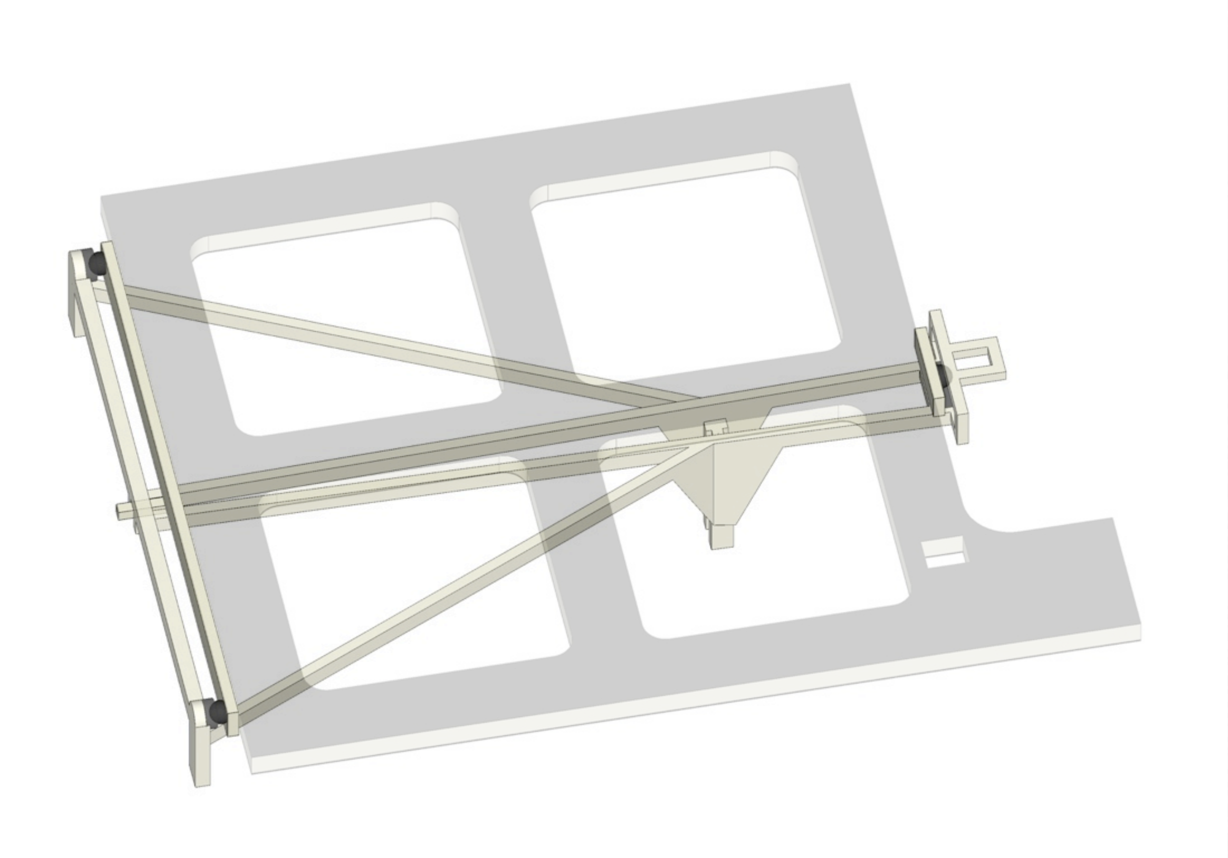
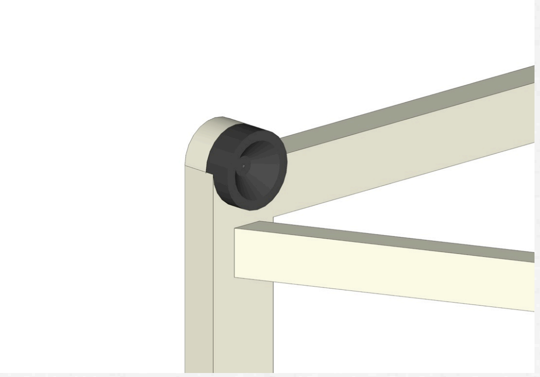
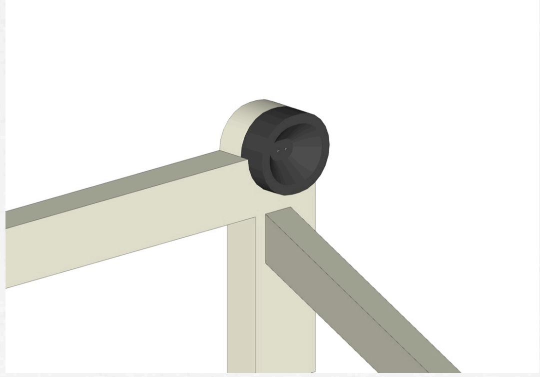
➡ FEA of mounting clip: FNAL/UW

➡ Mold design and quotes for plastic and ceramic components



~0.1% X0





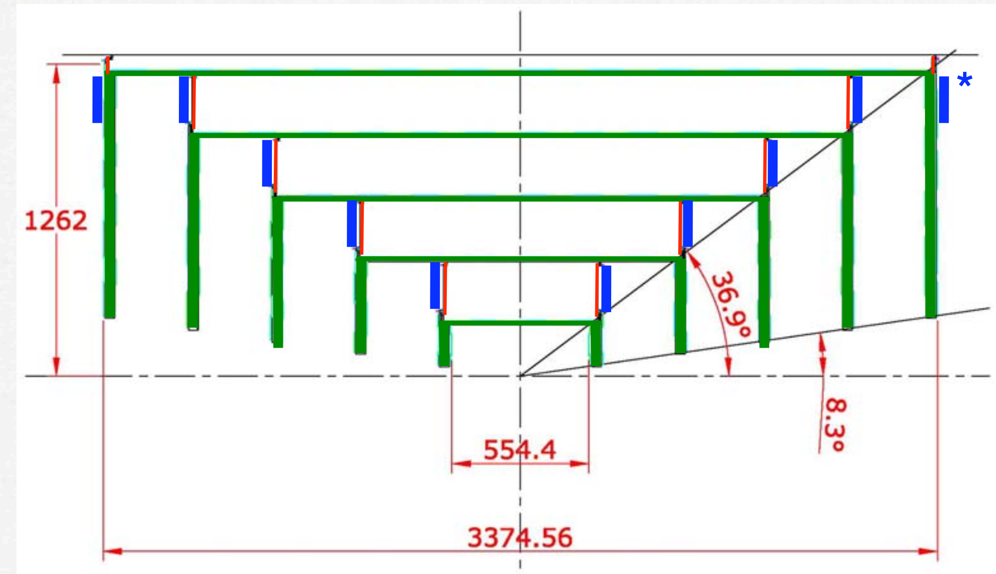
Overall Support

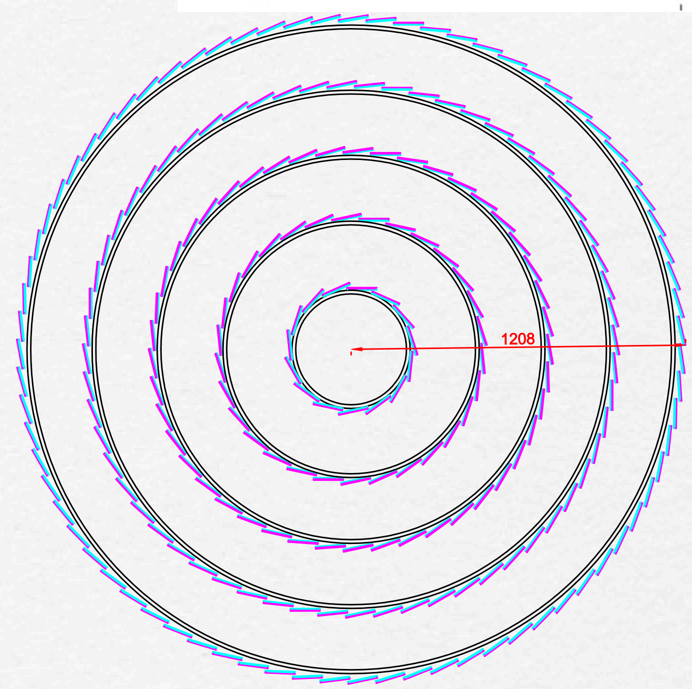
Short modules need many mount points:

- CF/Rohacell cylinders (D0 CFT and ATLAS SCT)
  - very low mass (~0.25% X_0)
  - maximally rigid single unit

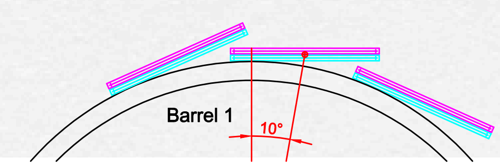
FNAL engineering of cylinders, tiling design encouraging

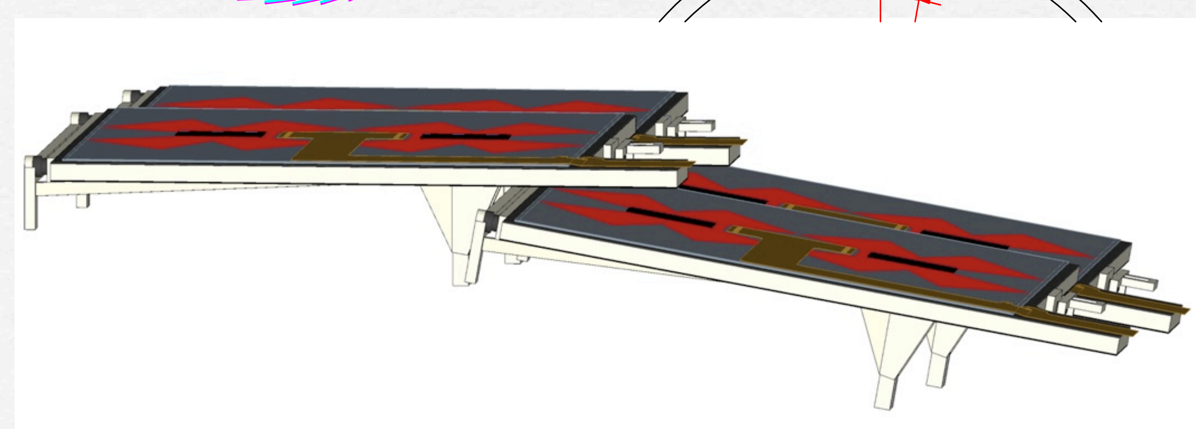
- Work closely with FNAL on module mounting
- Develop realistic power/readout distribution system





Sensors:
Cut dim's: 104.44 W x 84 L
Active dim's: 102.4 W x 81.96 L
Boxes:
Outer dim's: 107.44 W x 87 L x 4 H
Support cylinders:
OR: 213.5, 462.5, 700, 935, 1170
Number of phi: 15, 30, 45, 60, 75
Central tilt angle: 10 degrees
Sensor phi overlap (mm):
Barrel 1: 5.3
Barrel 2: 0.57
Barrel 3: 0.40
Barrel 4: 0.55
Barrel 5: 0.63
Cyan and magenta sensors and boxes are assumed to be at different Z's and to overlap in Z.
Within a given barrel, cyan sensors overlap in phi as do magneta sensors.





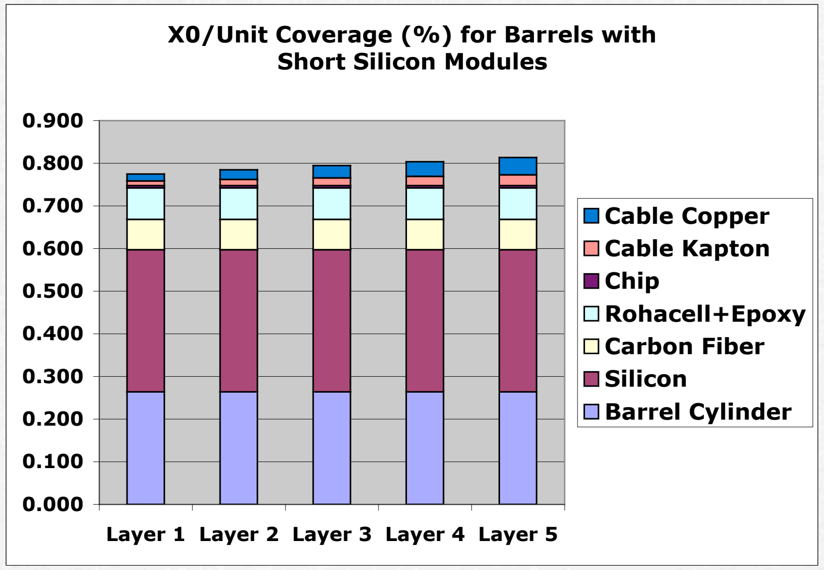
Tracking Studies

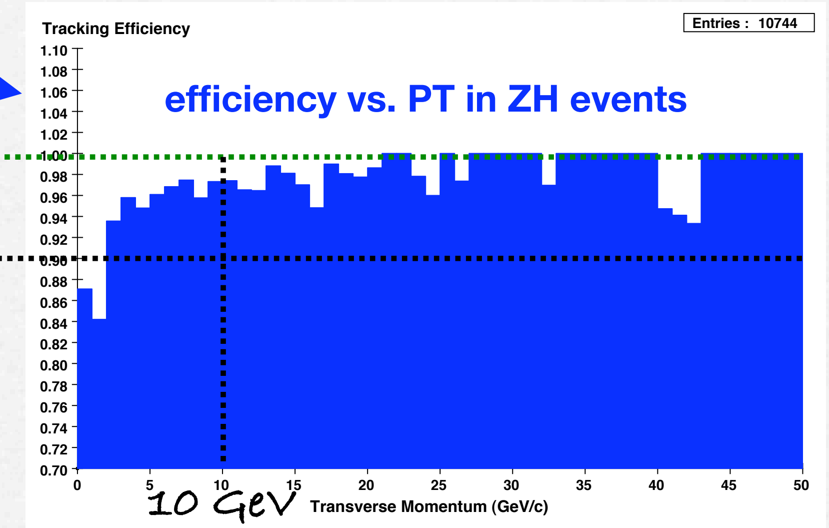
Model of tracker in simulation:

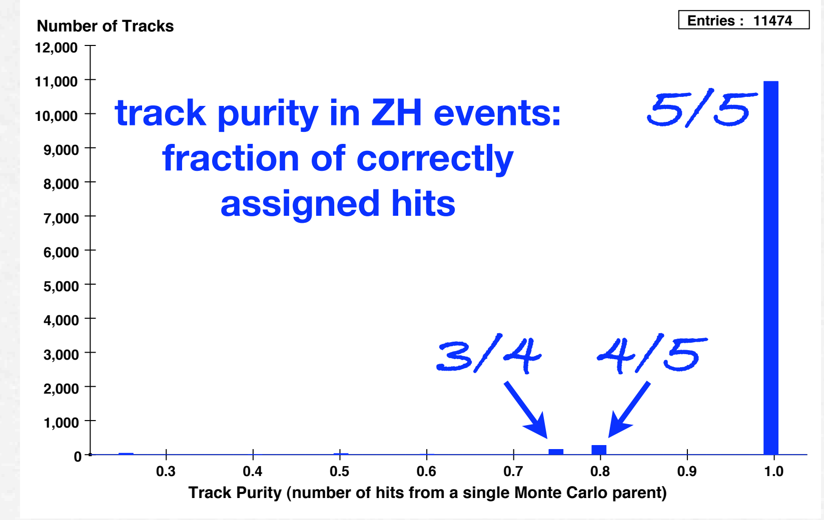
- Are 5 layers enough?
- How much material is too much?
- Does tracker need standalone capability? (drives assembly precision)
- Do we need double-sided layers? (N.B. studies show short modules provide useful z-information!)
- What do the endcap modules need to look like?

➡ A detailed simulation and complete reconstruction toolkit are required

a big job...more manpower needed







SiD Tracker R&D Roadmap

2006

- Obtain prototype silicon, begin probing and testing with KPiX
- Design prototype pigtail cables (needs new effort)
- Produce fully engineered module design incl. costing
- Produce fully engineered module mounting scheme incl. costing

2007

- Obtain prototype pigtails, testing/assembly/wirebonding with sensors
- Obtain/fabricate prototype module supports, mechanical testing
- Develop module assembly fixtures and assemble first prototype module
- Develop design for endcap modules (needs tracking studies)
- Develop power distribution system

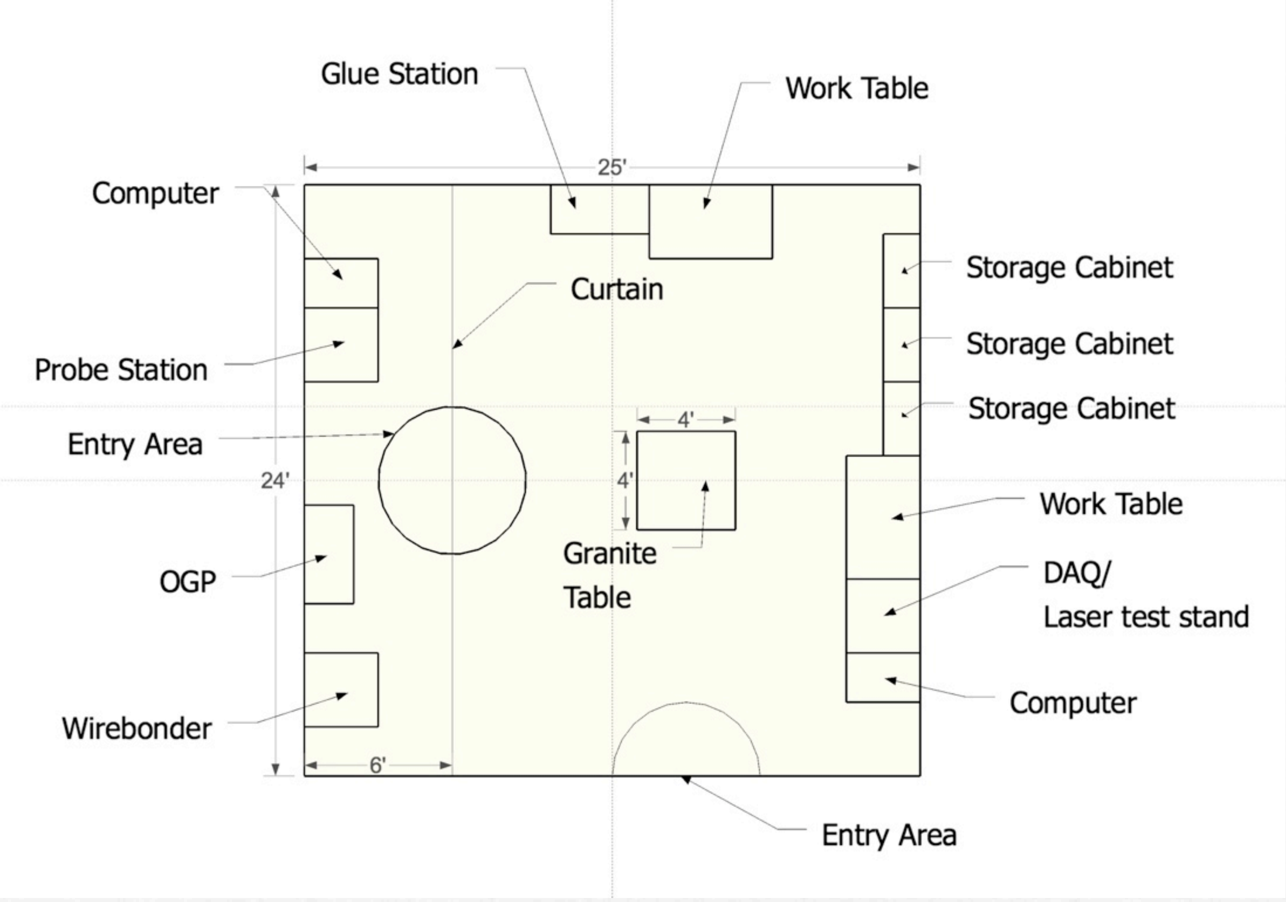
2008

- Assemble telescope of ~10 prototype modules for beam test
- Begin prototyping of endcap modules

Laboratory Facilities

Need small silicon lab:

- Laboratory space (in hand?)
- Probe station (in hand)
- Wirebonder (in hand)
- Small "clean area"
- OGP (optical/touch-probe measuring & inspection)
- Granite table
- Full DAQ/Laser test stand



Small facility can serve both tracker and ECAL work at SLAC throughout R&D phase for ILC detectors

Summary

- Silicon appears to be best answer to ILC tracking requirements
- Some novel ideas needed: KPiX is key
- SLAC is leading development of tracker modules
  - Sensor design
  - Mechanical design
  - Readout design
  - Mounting design: interface with FNAL where support cylinders being developed
- Plan to prove concept with prototype modules in next 1-2 years

  ⇒ Small silicon lab needed to do any of this work at SLAC
- Need more simulation to optimize layout, design forward disks

SLAC playing a central role in ILC detector R&D efforts