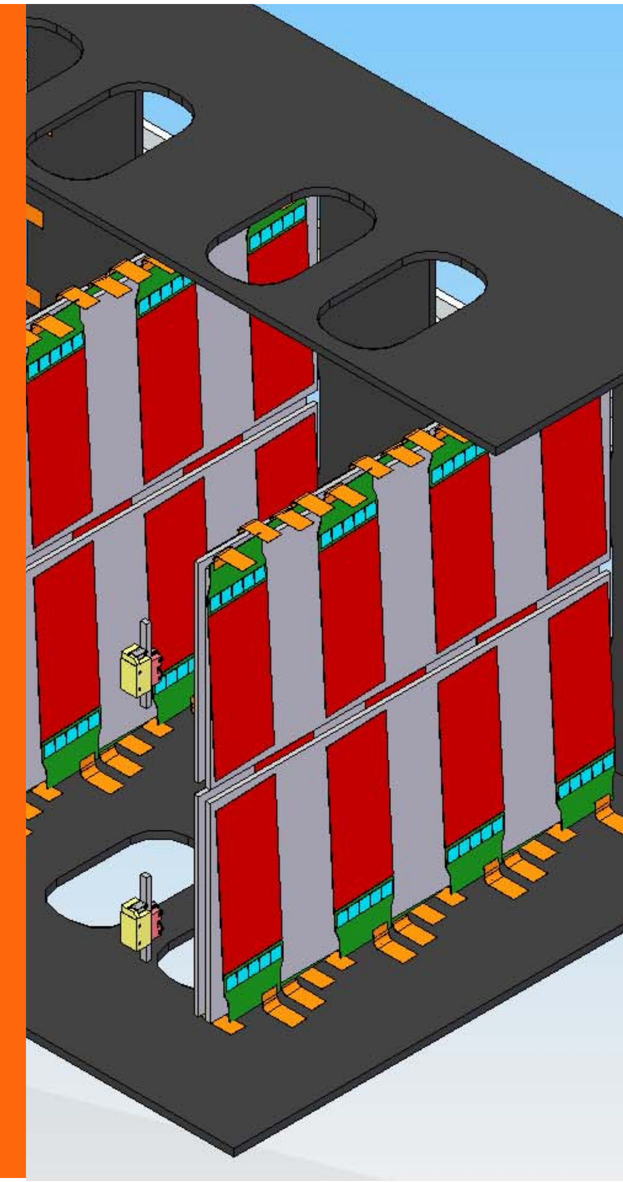
Tracking and Vertexing



Tim Nelson - SLAC

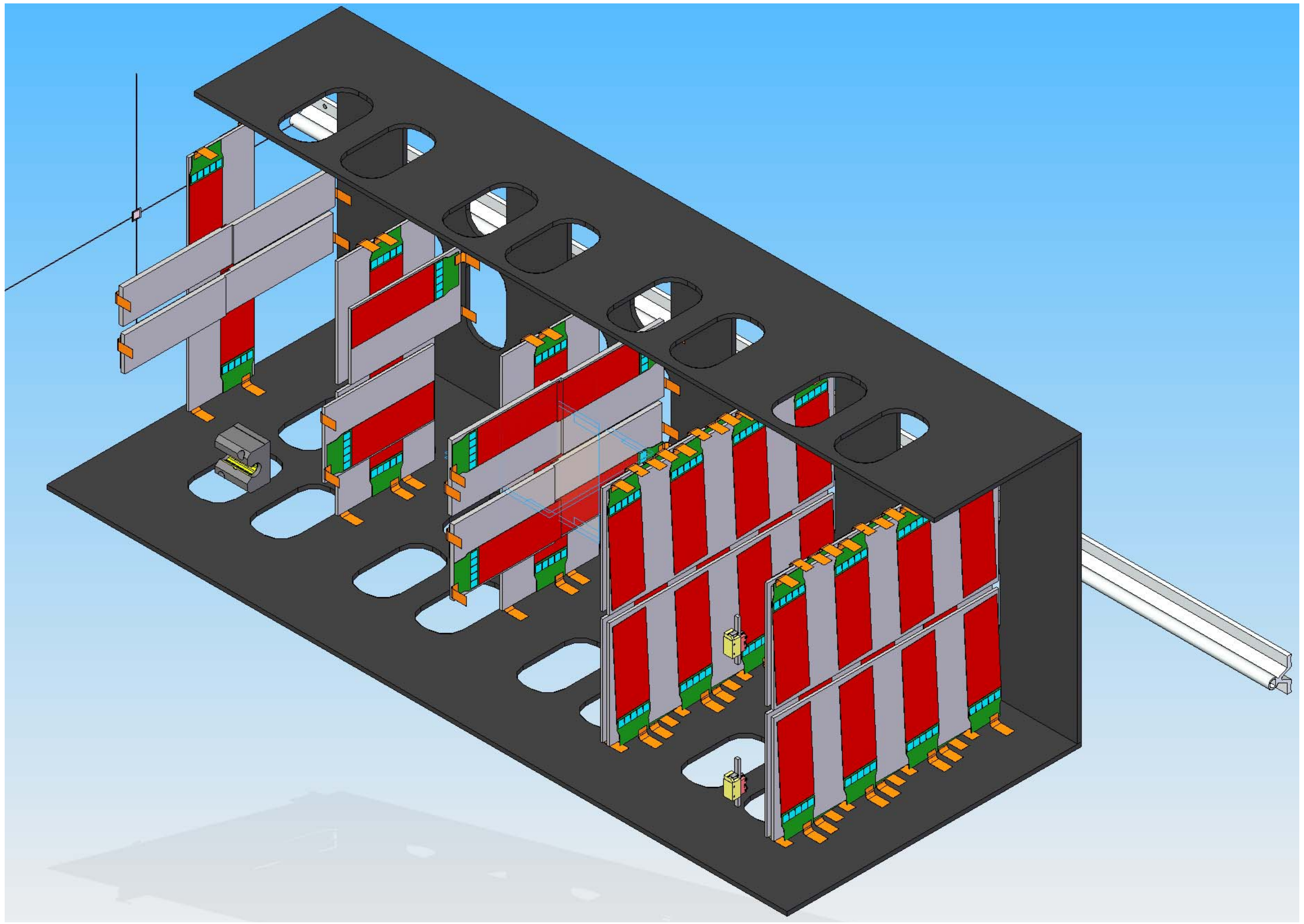
Massive Dark Photon eXperiment

MaPhoX

June 1, 2010

Design Considerations

- Mass and vertex resolution
  - low-mass construction
- Backgrounds and radiation
  - robust sensors / electronics
  - movability / replaceability
  - operation in vacuum
- Acceptance/Purity
  - optimized sensor layout
- Limited Time/Budget
  - reuse and recycle components and techniques



“Parts is Parts”

- silicon sensors
- readout electronics
- support and cooling
- vacuum chamber
- magnet

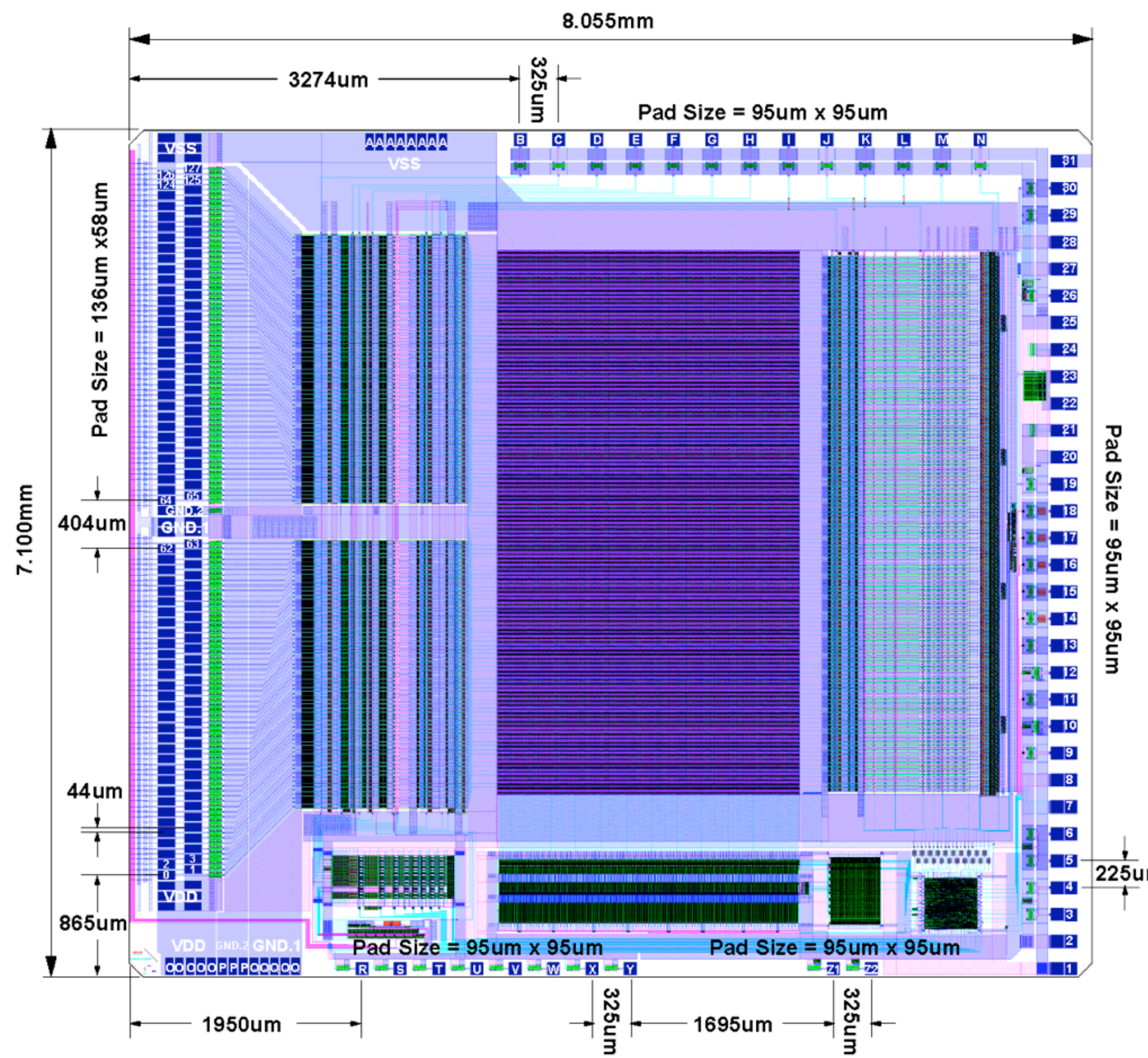
Silicon Sensors

- pixels too massive, costly: microstrips are the simple, lightweight option
- DØ RunIIb Sensors
  - Many capable of 1000V bias
  - Fine readout granularity
  - Free!

Cut Dimensions (L×W)	100 mm × 40.34mm
Active Area (L×W)	98.33 mm × 38.34mm
Readout (Sense) Pitch	60μm (30μm)
# Readout (Sense) Strips	639 (1277)
Depletion Voltage	40V < V_{dep} < 300V
Breakdown Voltage	>350V
Total Detector Current at 350V bias	<16 μA
Bias Resistor Value (both ends of strips)	0.8 ± 0.3 MΩ
AC Coupling Capacitance	>12 pF/cm
Total Interstrip Capacitance	<1.2 pF/cm
Defective Channels	<1%

Readout Electronics

- Silicon readout for high rate environment: **LHC**
- Of these, APV25 is best for us.
  - Low noise: S/N ≈ 34
  - Radiation tolerant
  - Chips, DAQ infrastructure, knowledge all widely available
  - Flexible in operation

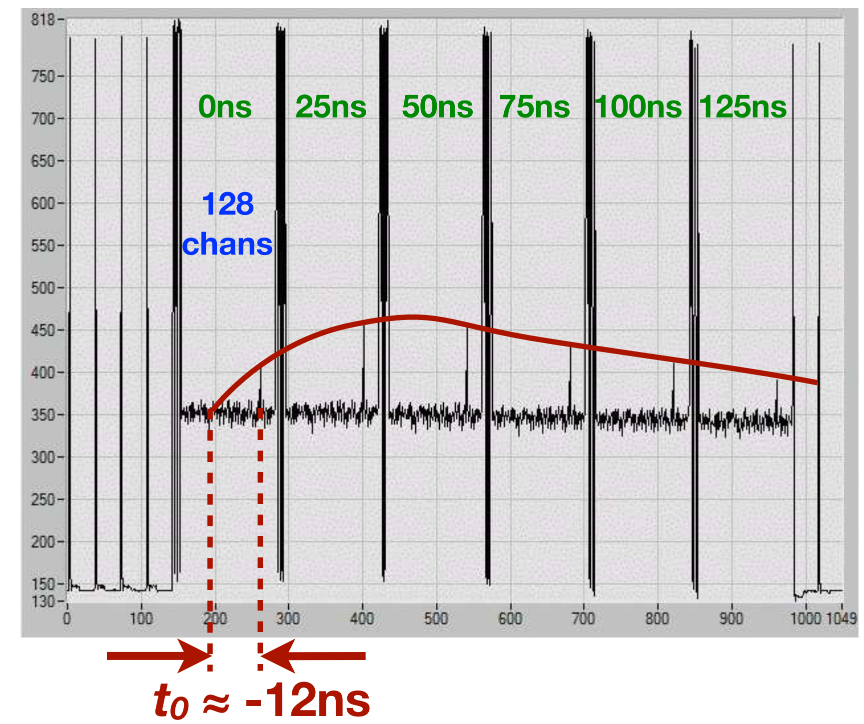


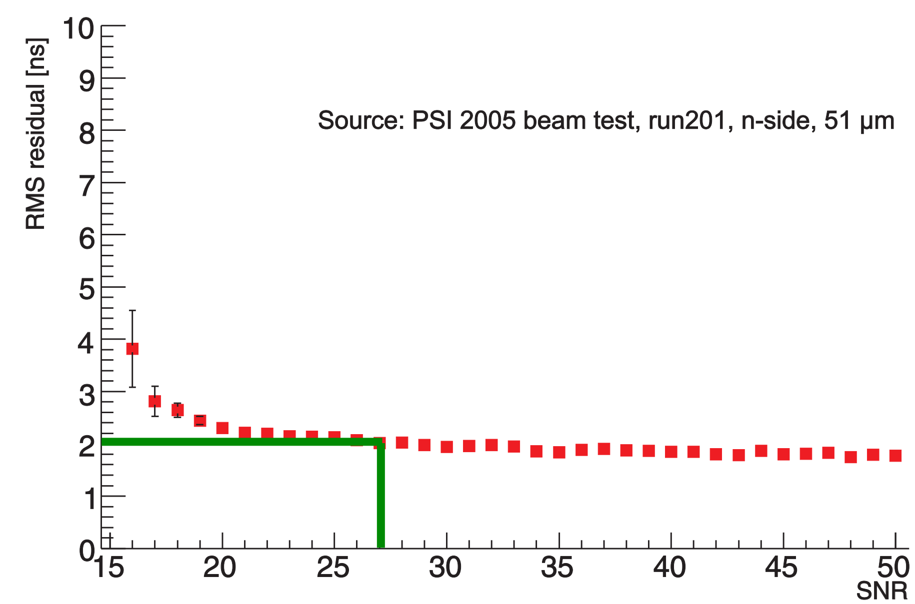
Timing Information

***Multi-peak readout mode*:**

- sample shaper output every 25ns in multiples of three snapshots
- Fit to shaping curve determines hit time with RMS of 2 ns or better for S/N > 27
- 6-sample readout helps at high occupancy
- For simulation studies, simply assumed a 3-pulse time window for hits (7.5ns).

➡ Fitting hits in both space *and* time will further assist pattern recognition and track selection.



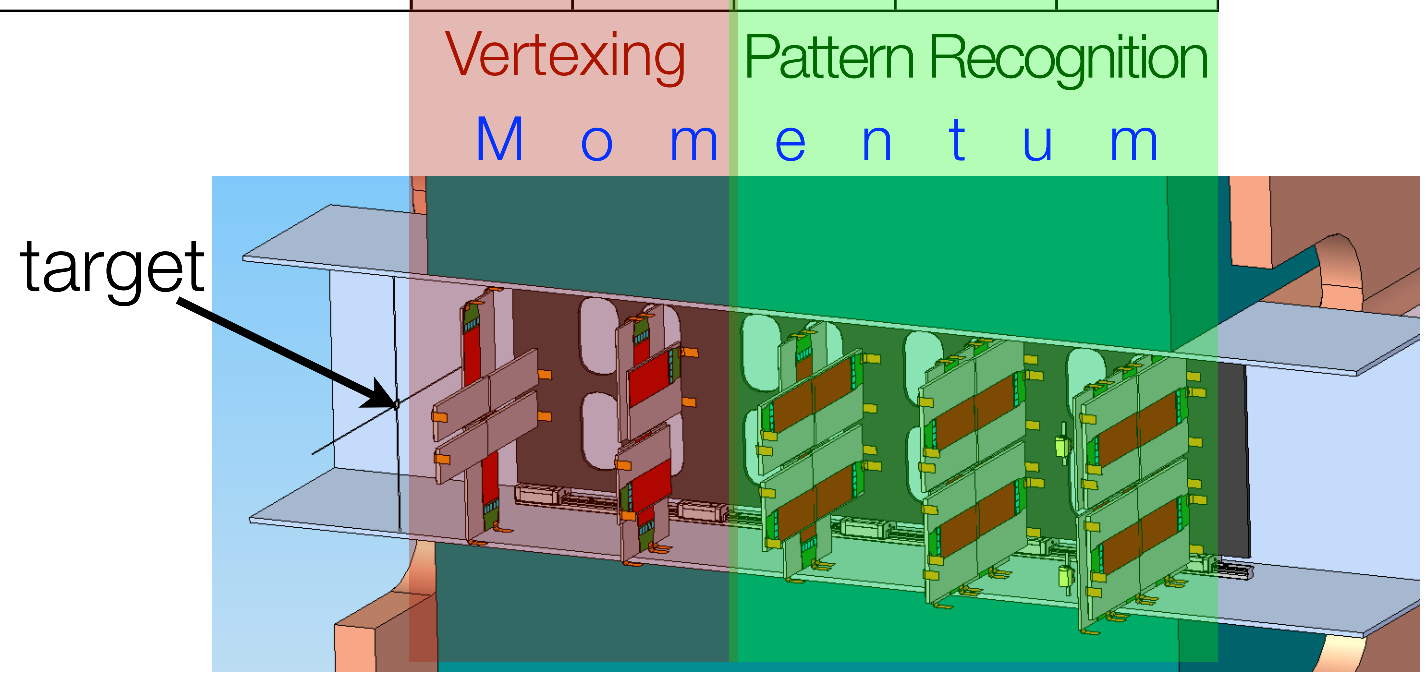


Detector Layout

Nominal Layout:

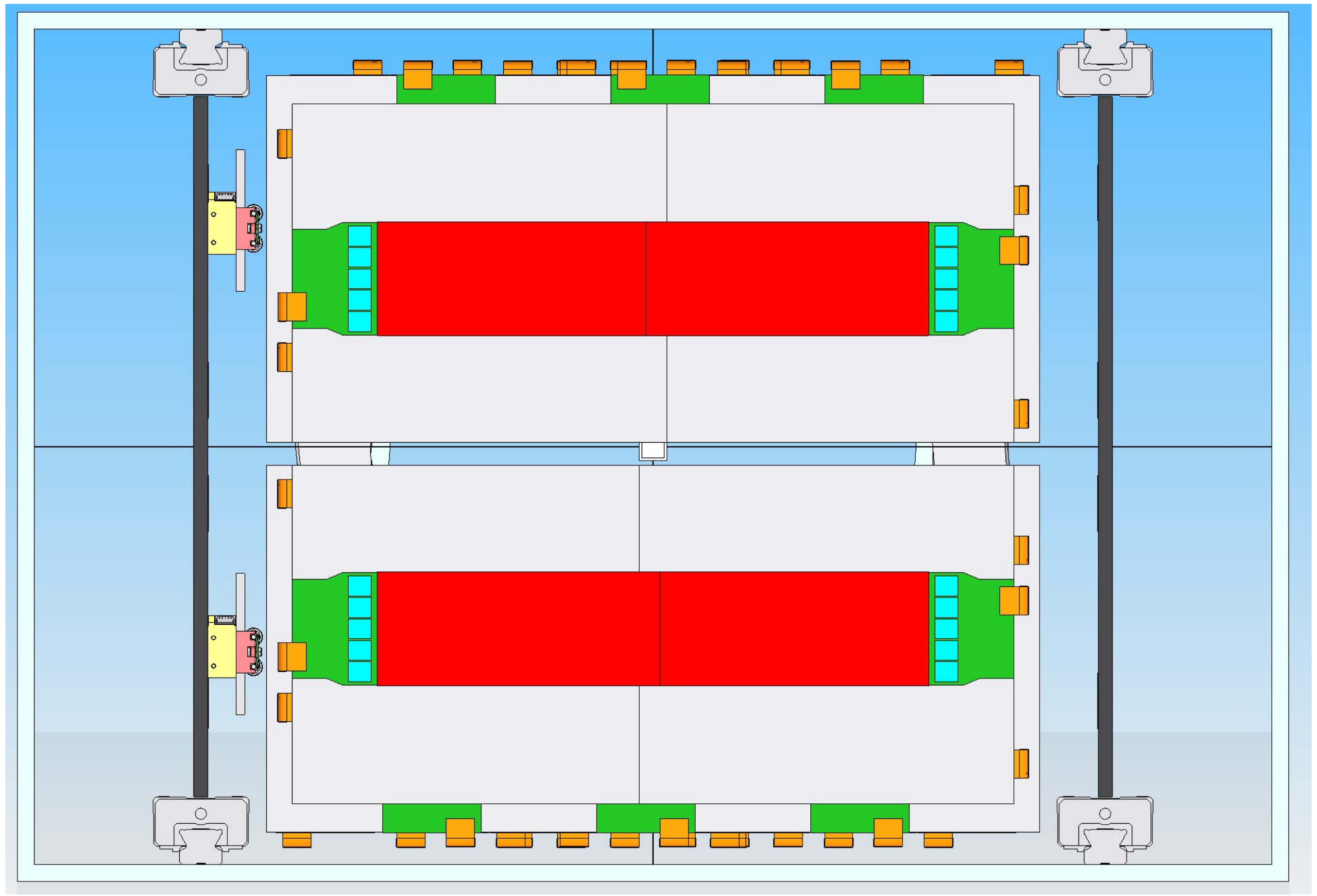
- Layers 1-2: vertexing
- Layers 3-5: pattern recognition with adequate pointing into Layer 2.
- Bend plane measurement in all layers: momentum
- 96 sensors/hybrids
- 480 APV25 chips
- 61440 channels

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
z position, from target (cm)	5	25	45	65	85
Stereo Angle	90 deg.	90 deg.	50 mrad	50 mrad	50 mrad
Bend Plane Resolution (μm)	≈ 6	≈ 6	≈ 6	≈ 6	≈ 6
Stereo Resolution (μm)	≈ 6	≈ 6	≈ 120	≈ 120	≈ 120
# Bend Plane Sensors	4	6	10	14	16
# Stereo Sensors	2	4	10	14	16
Dead Zone (mm)	1.5	7.5	13.5	19.5	25.5
Power Consumption (W)	10.5	17.5	35	49	56



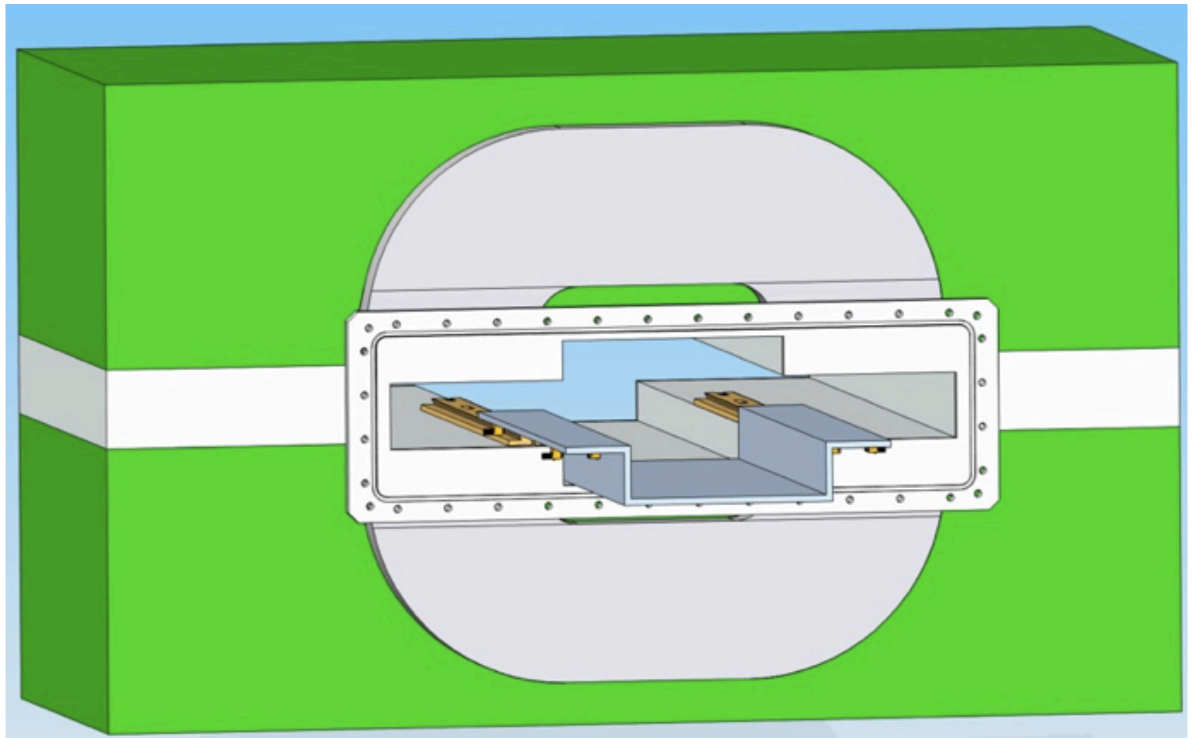
Support and Cooling

- silicon support planes with integrated cooling
- motion of planes via piezo movers
- planes slide into and out of vacuum chamber on rails



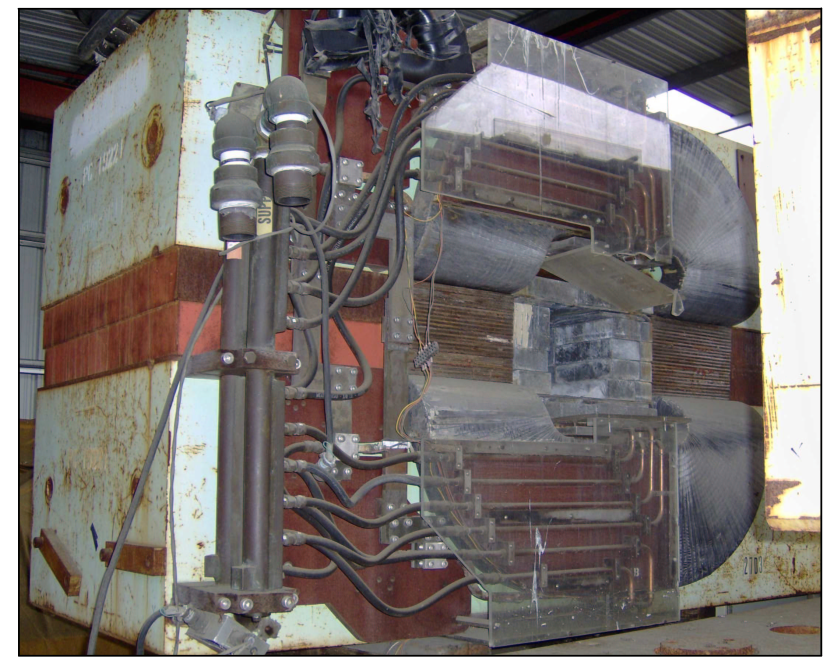
Vacuum Enclosure

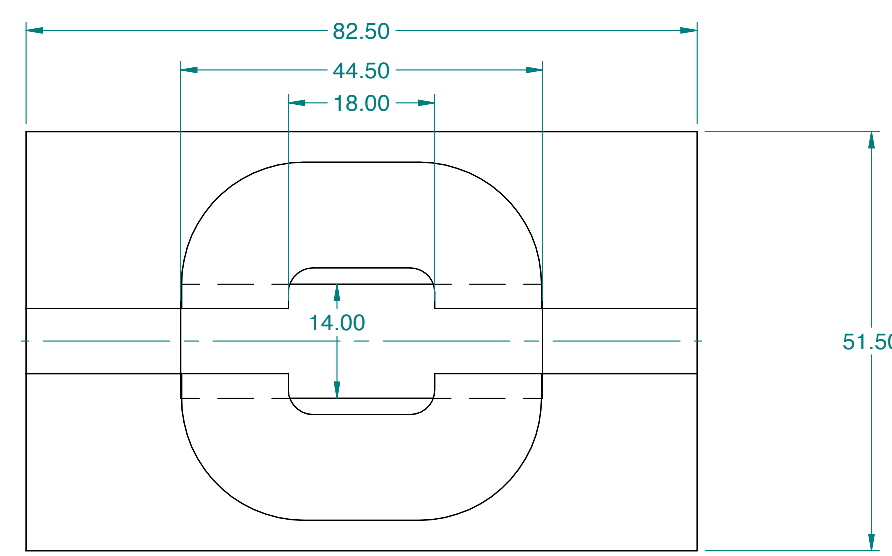
- stainless(?) vacuum enclosure
- slides into magnet on rail system to allow quick installation and removal
- will have patch panel for cables and cooling at or near front face.



Magnet

- “new” magnet with 14”X18” bore resolves vertical clearance issues
- B = 1T
- Woefully ignorant of other details!

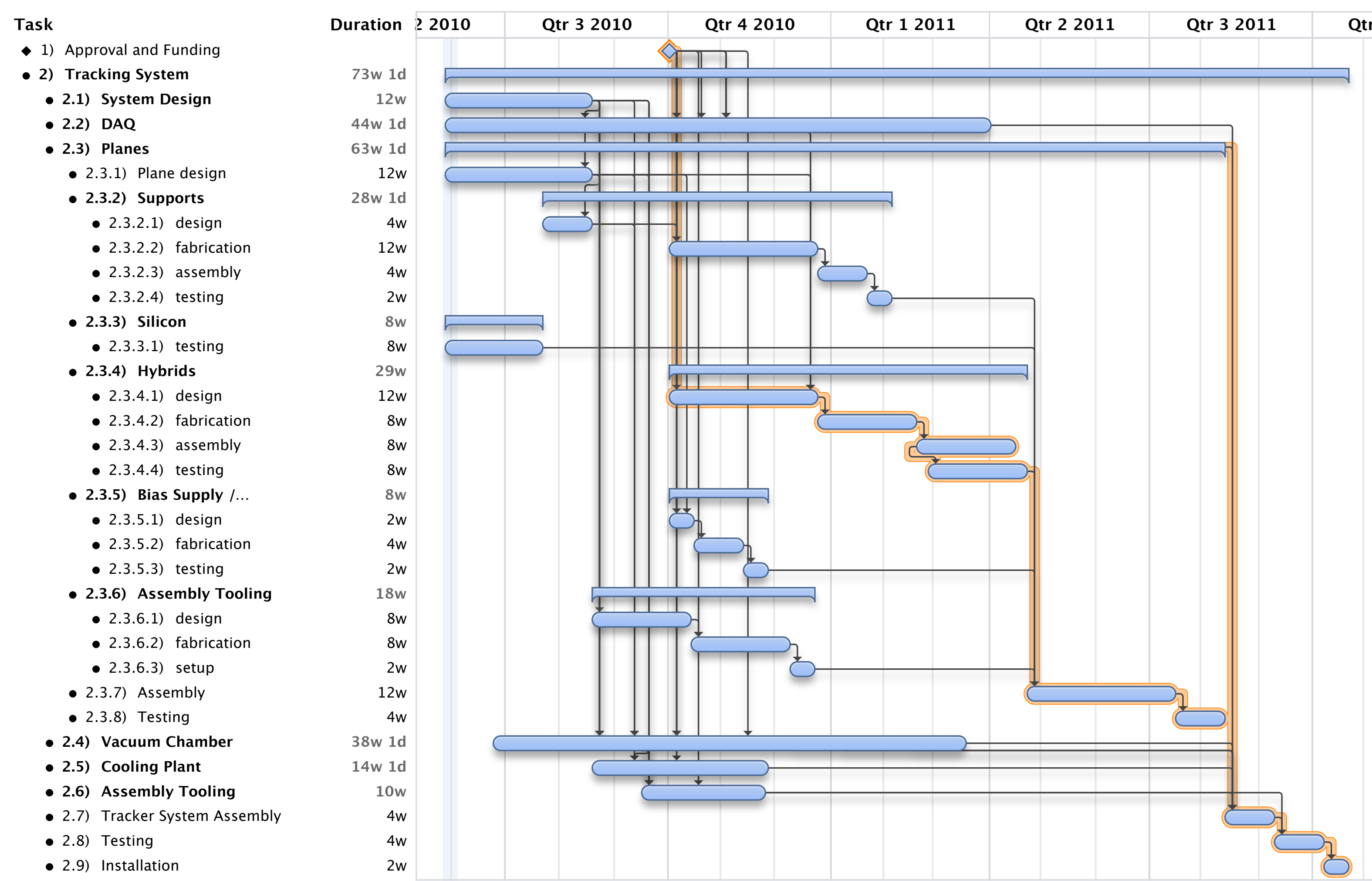




18D36 MAGNET

Schedule (not completed)

- Making a serious attempt at understanding the schedule
- Many design elements are still in flux
- The largest efforts are coming into focus
  - hybrid electronics: must get design under way ASAP.
  - silicon support/mounting are a big project with large uncertainties at current.



Costing (not completed)

- The key elements of the modules; chips, hybrids, cables, etc.; are the largest material costs: **very roughly** $65K
- Other major costs
  - Tooling for fabrication of supports and assembly of detector planes
  - Fabrication, assembly of vacuum chamber and detector mounting system
    - ➡ These are difficult to estimate without a more detailed design. Will make a guess.
- Big human efforts are hybrid design/assembly/testing; design/fabrication of support planes; assembly/testing/installation of detector planes: **very roughly** 8 FTE years for entire project.

Outstanding Questions

Stereo angle in Layer 3:

- 50 MRad: better pattern recognition
- 90-degree: better vertexing for decay lengths of order 5cm or longer

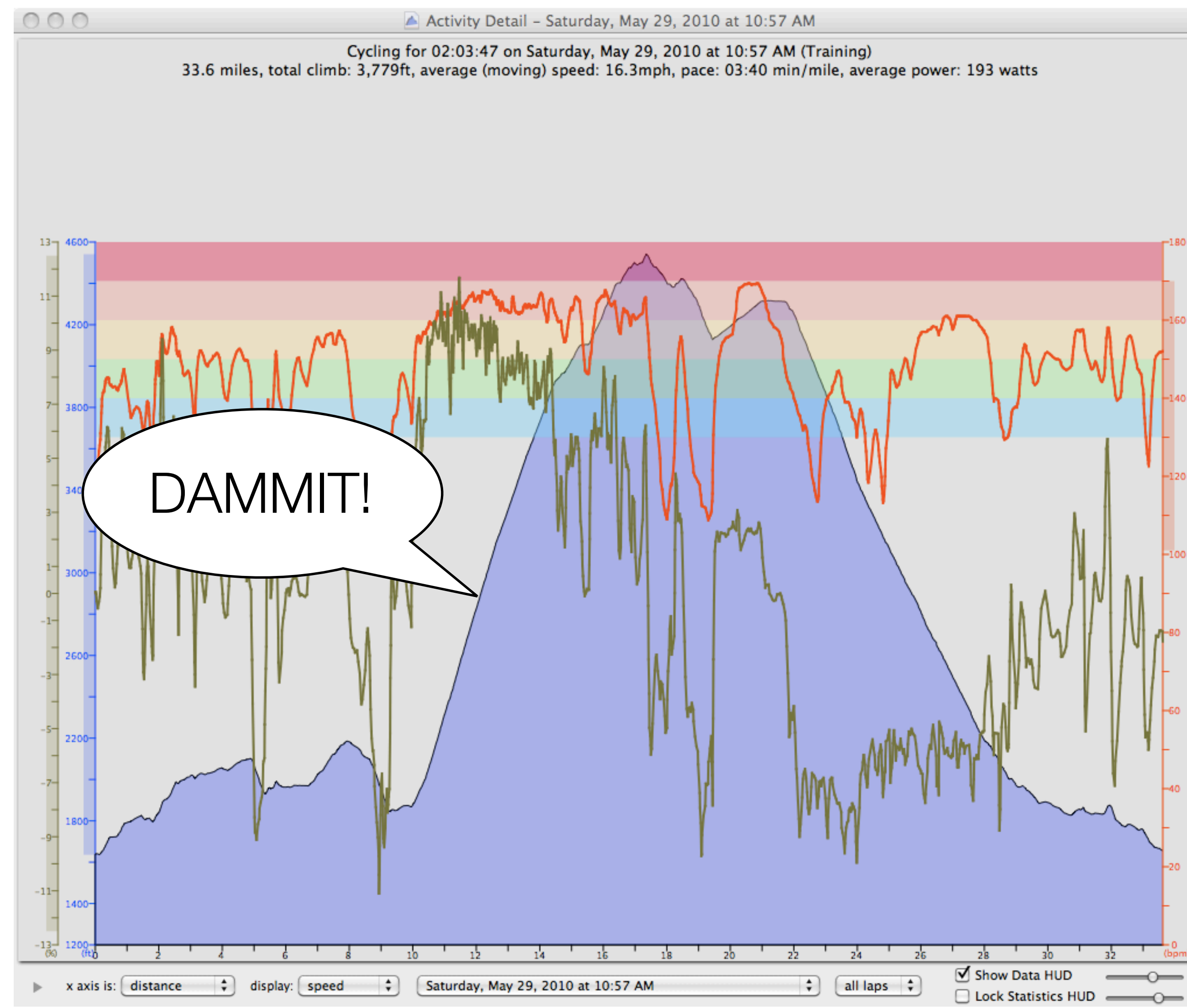
Have proposed a study to Matt to settle the issue:

- 50 MRad: Eliminate L1 and shift all planes by -5cm, -10cm in z to test vertexing performance for late decays.
  If close but no cigar, try 75mrad and 100 mrad in L3 instead.
- 90-degree: Test according to usual pattern recognition measures.
  If there are problems, are they isolated to cases where we miss Layer 5?
  If so, can we expand Layer 5 to enough to demand acceptance there?

Outstanding Questions

Riding in the Jura under the hot sun on Saturday, I was pondering radiant heat load on our larger planes and the cruelty of Stefan-Boltzmann's T^4 ...

- Assuming:
  $T_{chamber} = 293K$, $T_{silicon} = 263K$, $\varepsilon=1$;
  ≈5W radiant load
- Current structure is more than 50% void to achieve <0.2% X_0:
  not enough heat path for a uniform 5W load.



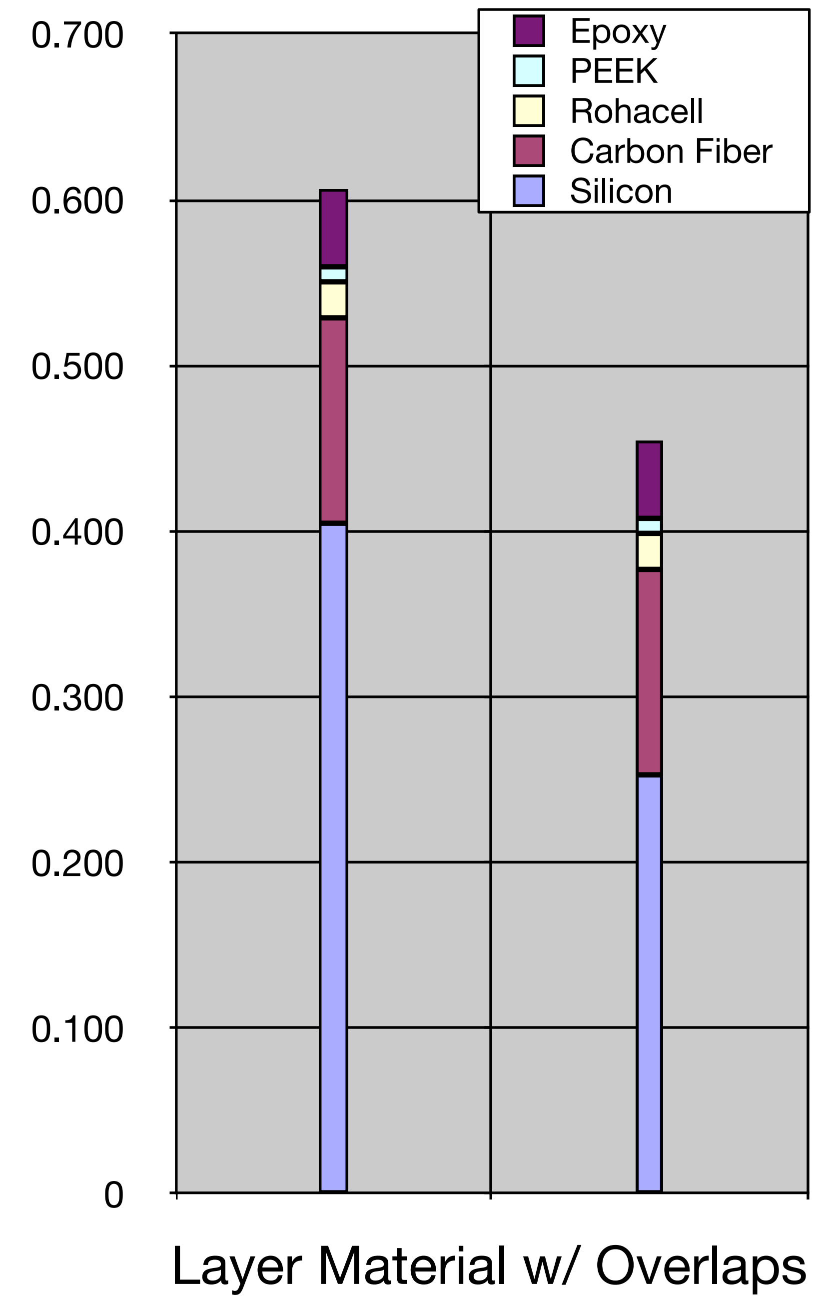
Outstanding Questions

- 3 mm Allcomp carbon foam: 50 W/m-K at 0.3 g/cc
  - $\Delta T = 4.9C$, 0.21% X_0 with no passivation, glue or facings (lacks structure)
- 3 mm Rohacell with 0.225 mm K1100 facings (600 W/m-K), no voids
  - $\Delta T = 5.4C$, 0.19% X_0 with no passivation or glue
- 3mm Rohacell with 0.150 mm K1100 facings, no voids, with Panasonic PGS for passivation: self adhesive, pyrolytic graphite sheet (>750 W/m-K) with PEEK passivation rated at 2kV.
  - $\Delta T = 3.8C$, 0.20% X_0, complete (better, but marginal)
- Even partial heat shielding would improve matters greatly. Incorporate cooling in CF support walls around silicon planes?

Outstanding Questions

Advocate thin silicon in Layer 1?

- Reduces material budget by 0.15% X_0, 25-30% of total.
- S/N still ~22: timing resolution degrades by only ~10%.
- Cost: $37.5k for silicon
- Should be possible to use same hybrids, partially populated, with a pitch adapter
- Additional risk for parts not in hand. Risk in working with Micron, but minimal for such a small production of single-sided sensors.



Odds and Ends Still Needed

- From Takashi
  - Need to make sure radiation dose/pattern is correct for current assumptions
- From Marco
  - Drawings showing final layout, cooling, “final” plane mounting
- From Deiter/Marco
  - Details of vacuum chamber, shown consistently in drawings. Patch panel?
- From Dieter
  - Details and text / table for magnet

Conclusions

- Things are falling into place for a believable design.
- Many details still fuzzy for proposal, but we are doing the best we can.
- Costing and scheduling are particularly difficult, but will have something ready by next week. Will get input from experts at our disposal.
- Need input on a few key issues in order to make some crucial decisions.