The HPS SVT

Tim Nelson - SLAC

SVT/SVT DAQ Review

November 5, 2013

Outline

- SVT design elements
- HPS Test SVT → HPS SVT
  - L1-L3 module support and cooling
  - All-new L4-L6 modules
  - Large-scale detector support and services
- SVT schedule, budget and organization

Optimizing Acceptance

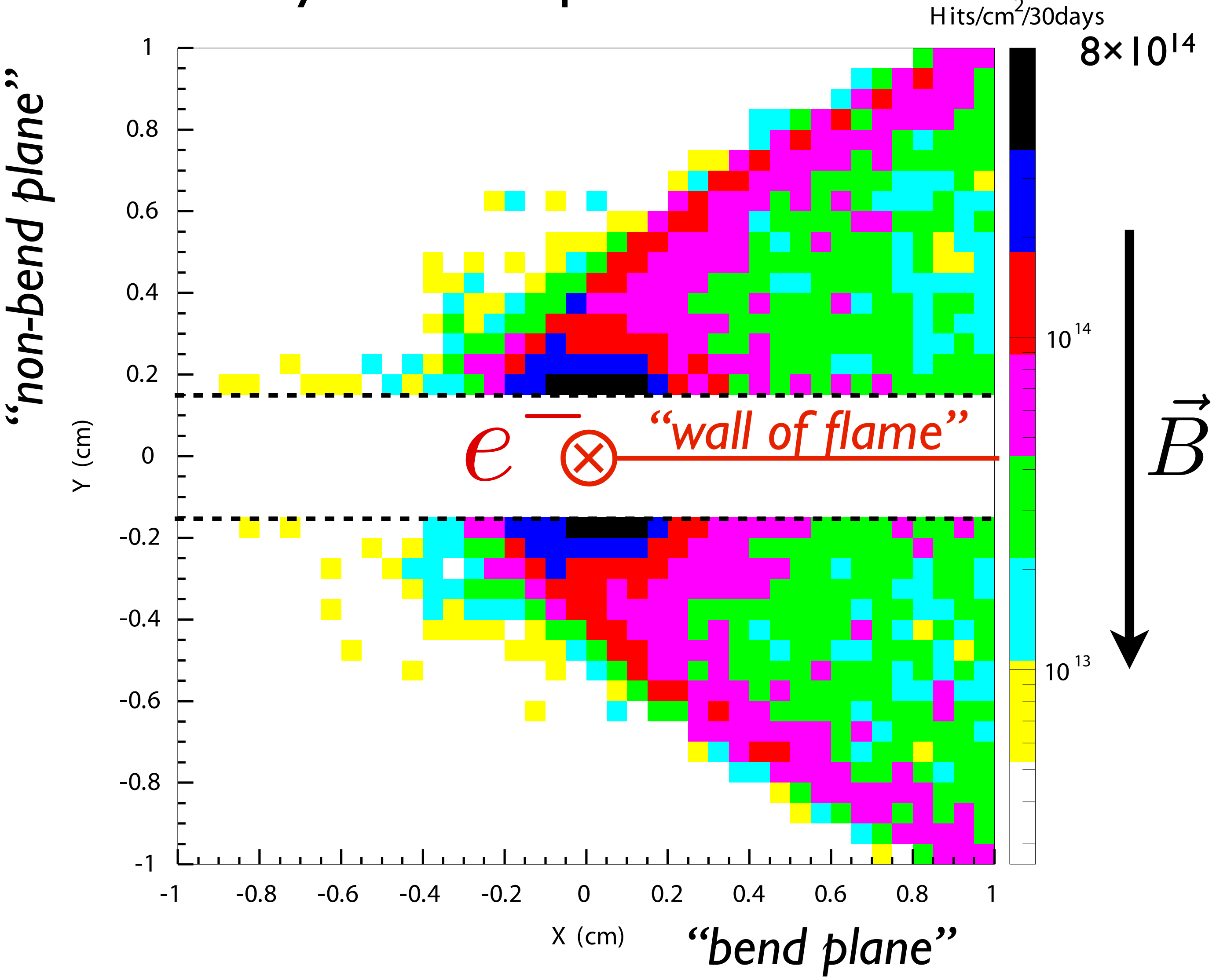
High-mass is simple in principle:
build it as big as you can afford!

Low-mass is harder:
requires acceptance very close to beam

At 15 mrad, 10 cm from target (L1):

- Active detector ~1.5 mm from beam
- Peak occupancy ~4 MHz/mm^2
- Fluence 4.8×10^{15} e^- $\cong$ 1.6×10^{14} neq. in 6 months of running

Layer 1 e^- exposure / month



Sensor Selection

Also need...

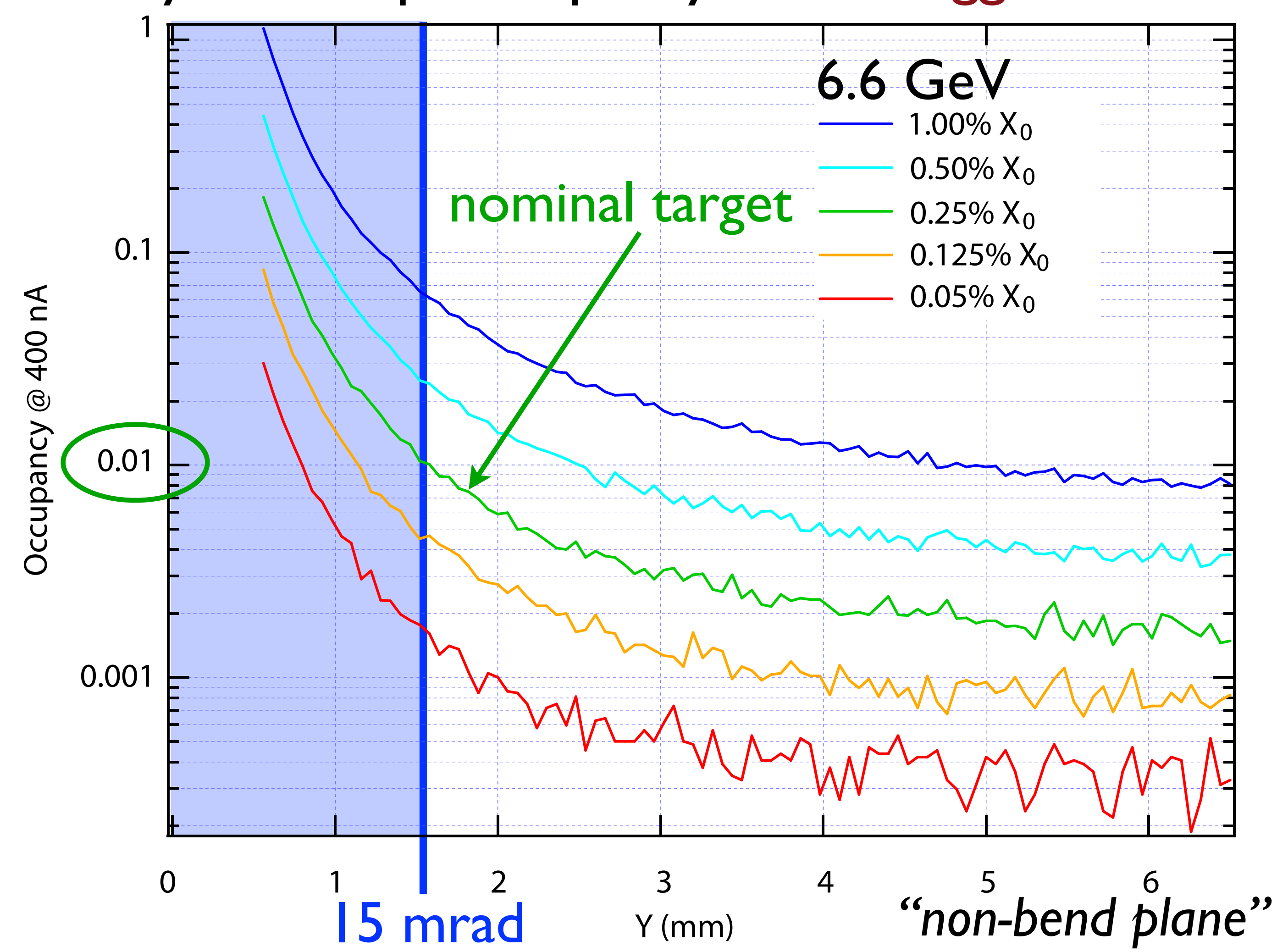
- < 1% X_0 per layer
- ≲ 50 μm single-hit resolution in both measurement coordinates
- < $1M for a complete system, soon!

~~MAPS~~?

~~Hybrid pixels~~?

➡ *Strip sensors (edges 500 μm from beam!)*

Layer 1 strip occupancy / 8 ns trigger window

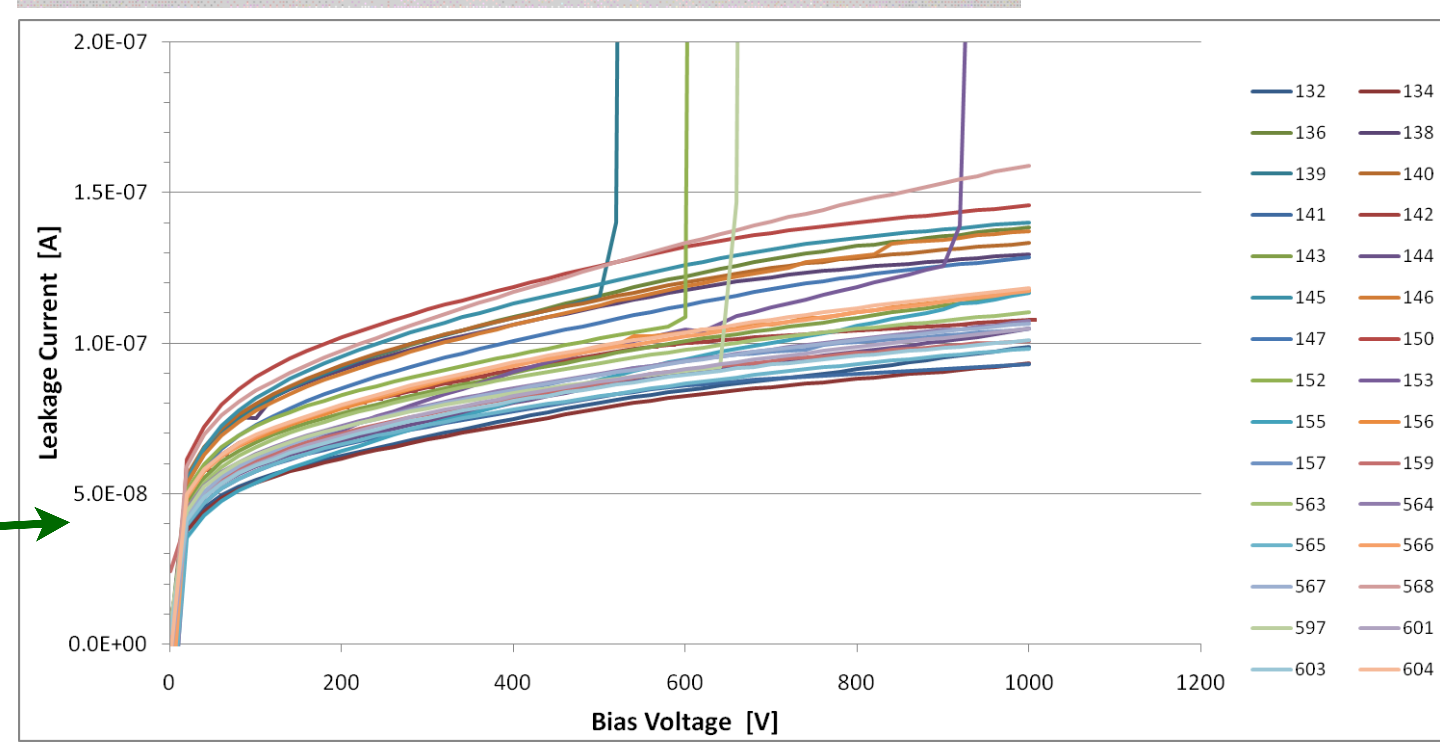


Silicon Microstrip Sensors

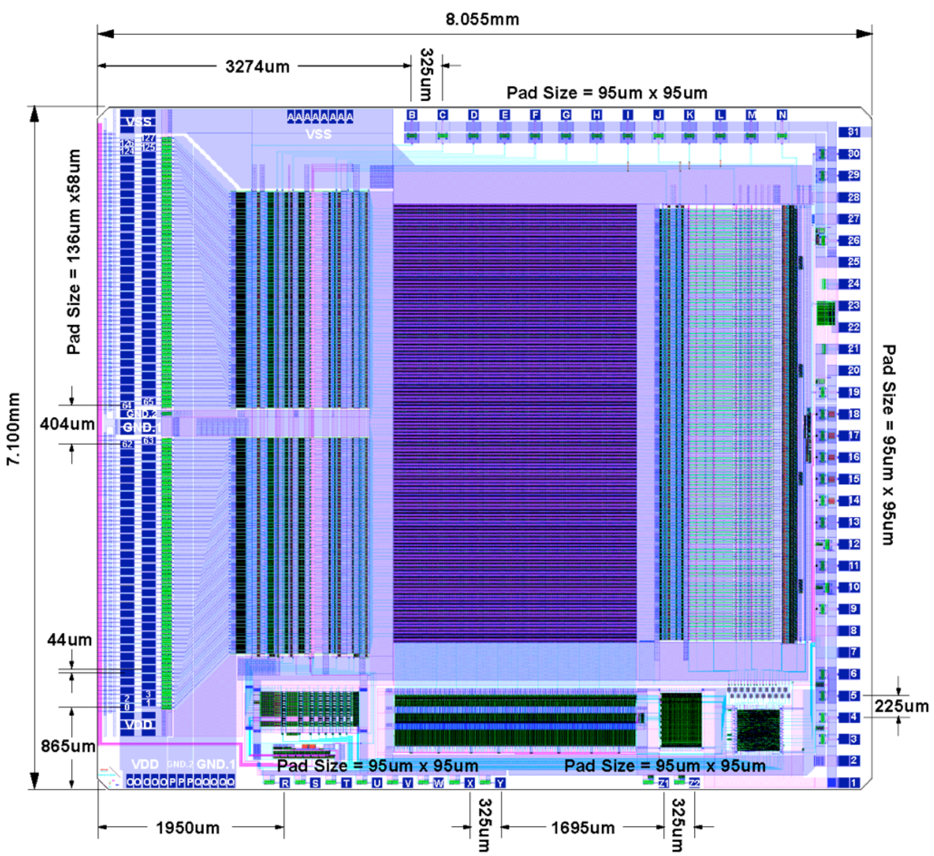
Production Tevatron RunIIb sensors (HPK):

- Fine readout granularity
- most capable of 1000V bias:
  fully depleted for 6 month run.
- Available in sufficient quantities
- Cheapest technology
  (contribution from FNAL)

Technology	**<100>, p+ in n, AC-coupled**
Active Area (L×W)	**98.33 mm × 38.34mm**
Readout (Sense) Pitch	**60μm (30μm)**
Breakdown Voltage	**>350V**
Interstrip Capacitance	**<1.2 pF/cm**
Defective Channels	**<0.1%**



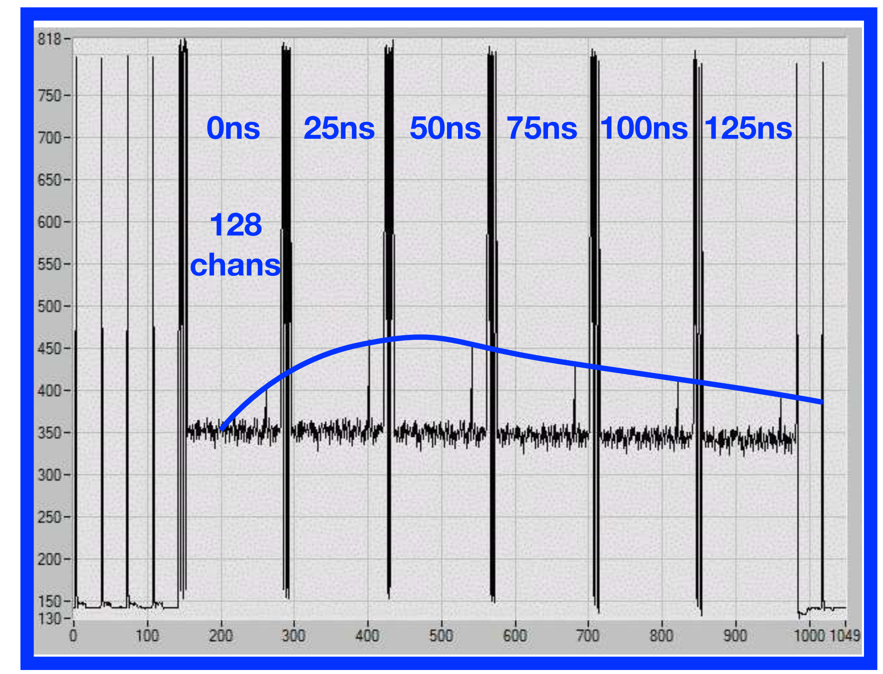
Front-end Electronics: APV25

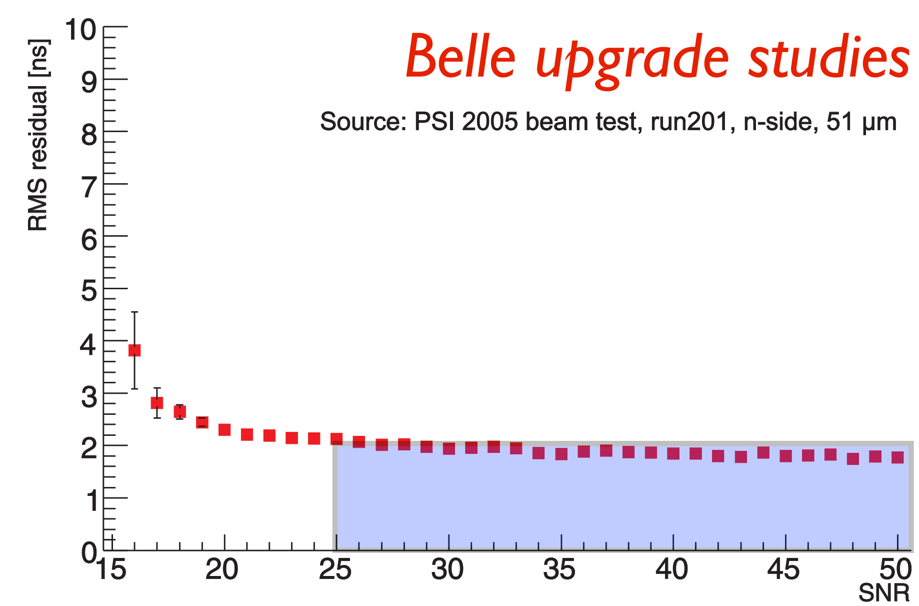


# Readout Channels	128
Input Pitch	44 μm
Shaping Time	50ns nom. (35ns min.)
Noise Performance	270+36×C(pF) e^- ENC
Power Consumption	345 mW

Developed for CMS

- available (~~28~~ CHF/ea.) *15!*
- radiation tolerant
- fast front end (35 ns shaping time)
- low noise (S/N ≅ 25)
- "multi-peak" readout
- ~2 ns t_0 resolution!





Optimizing Detector Layout

Using SLIC/lcsim framework for simulation and reconstruction of both MC and data

- Detailed model of detector response for MC
    - Silicon charge deposition/collection
    - Time response and multi-peak readout of APV25 front end
    - Time-sequenced overlay of backgrounds
- Same hit and track reconstruction tools for both MC and data
    - Amplitude, time reconstruction, and clustering of hits
    - Track finding and fitting
    - Can produce MC using constants established with data

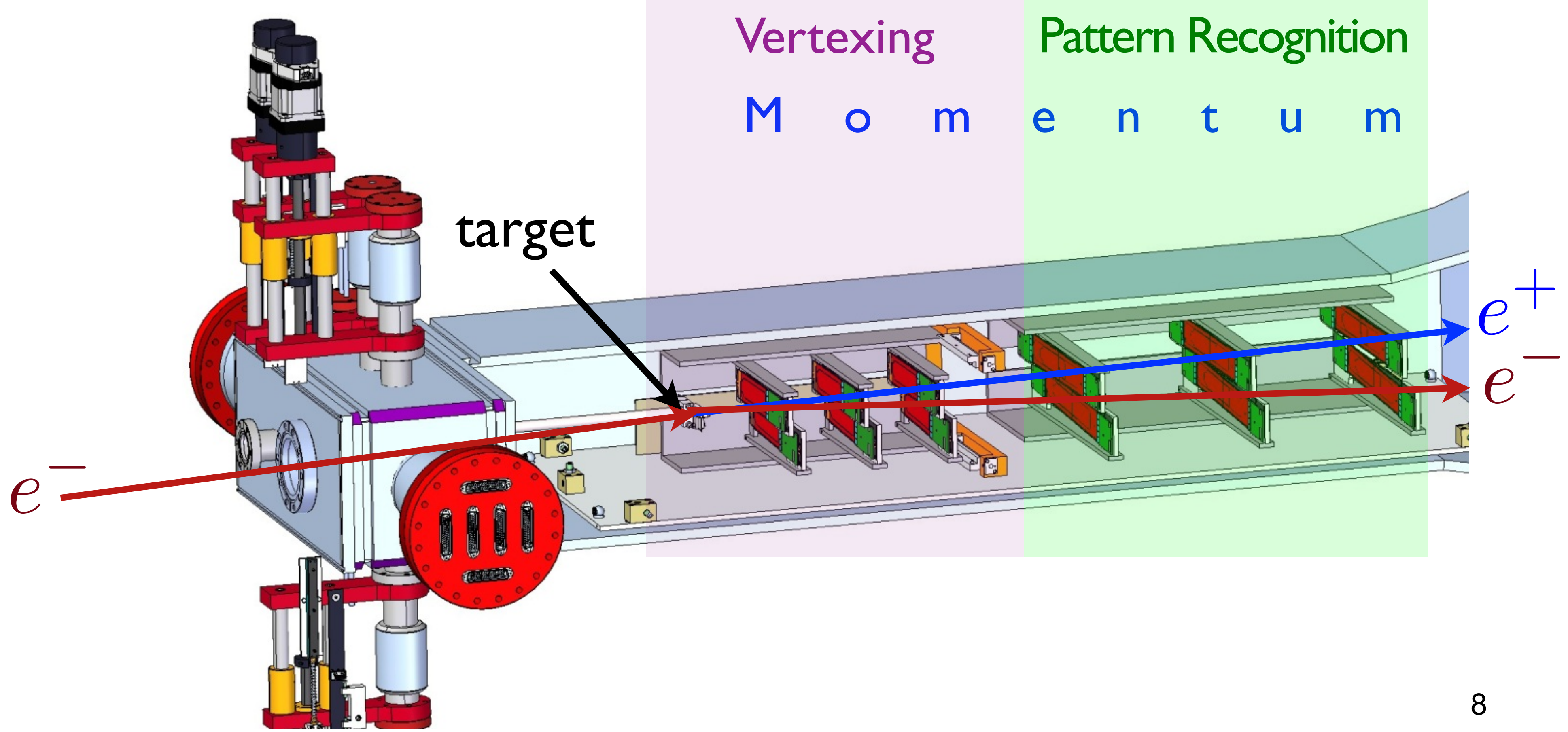
This high level of detail is critical for establishing vertex reach (10^{-7} prompt rejection!)

HPS SVT Layout

Evolution of HPS Test SVT

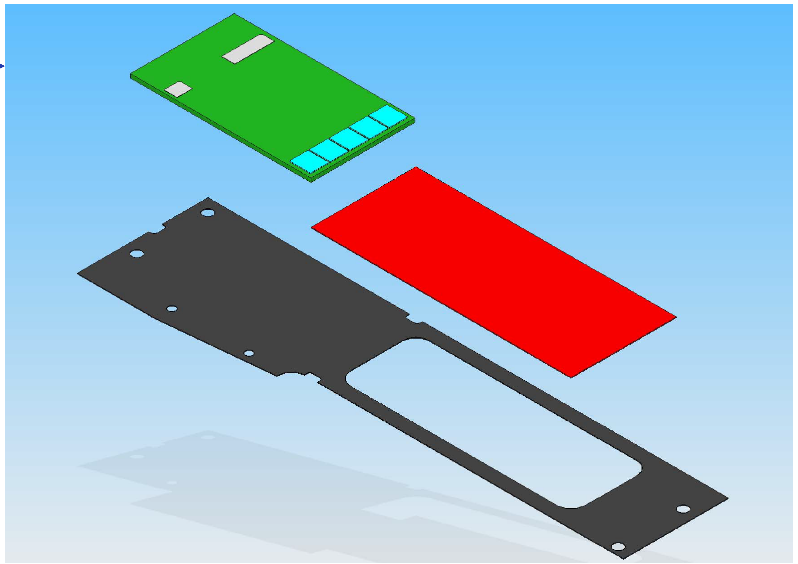
- Layers 1-3: same half-modules and layout as HPS Test SVT
- Layers 4-6: double width to match ECal acceptance and add extra hit.
- 36 sensors & hybrids
- 180 APV25 chips
- 23004 channels

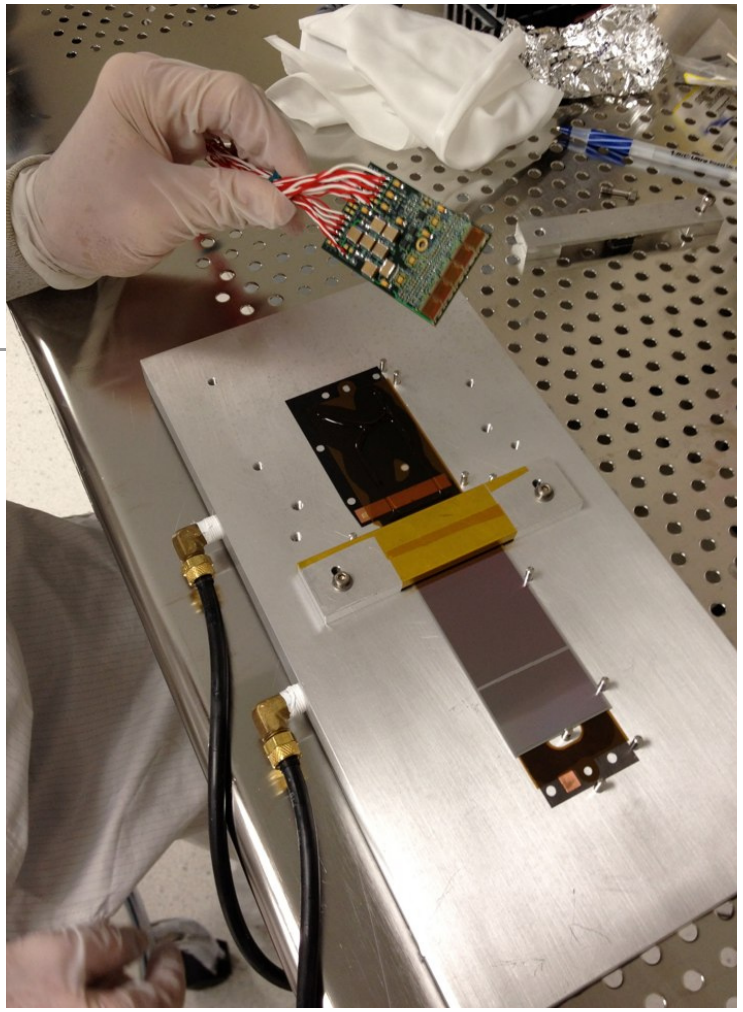
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
z position, from target (cm)	10	20	30	50	70	90
Stereo Angle (mrad)	100	100	100	50	50	50
Bend Plane Resolution (μm)	≈ 60	≈ 60	≈ 60	≈ 120	≈ 120	≈ 120
Non-bend Resolution (μm)	≈ 6	≈ 6	≈ 6	≈ 6	≈ 6	≈ 6
# Bend Plane Sensors	2	2	2	4	4	4
# Stereo Sensors	2	2	2	4	4	4
Dead Zone (mm)	±1.5	±3.0	±4.5	±7.5	±10.5	±13.5
Power Consumption (W)	7	7	7	14	14	14



Test SVT Modules

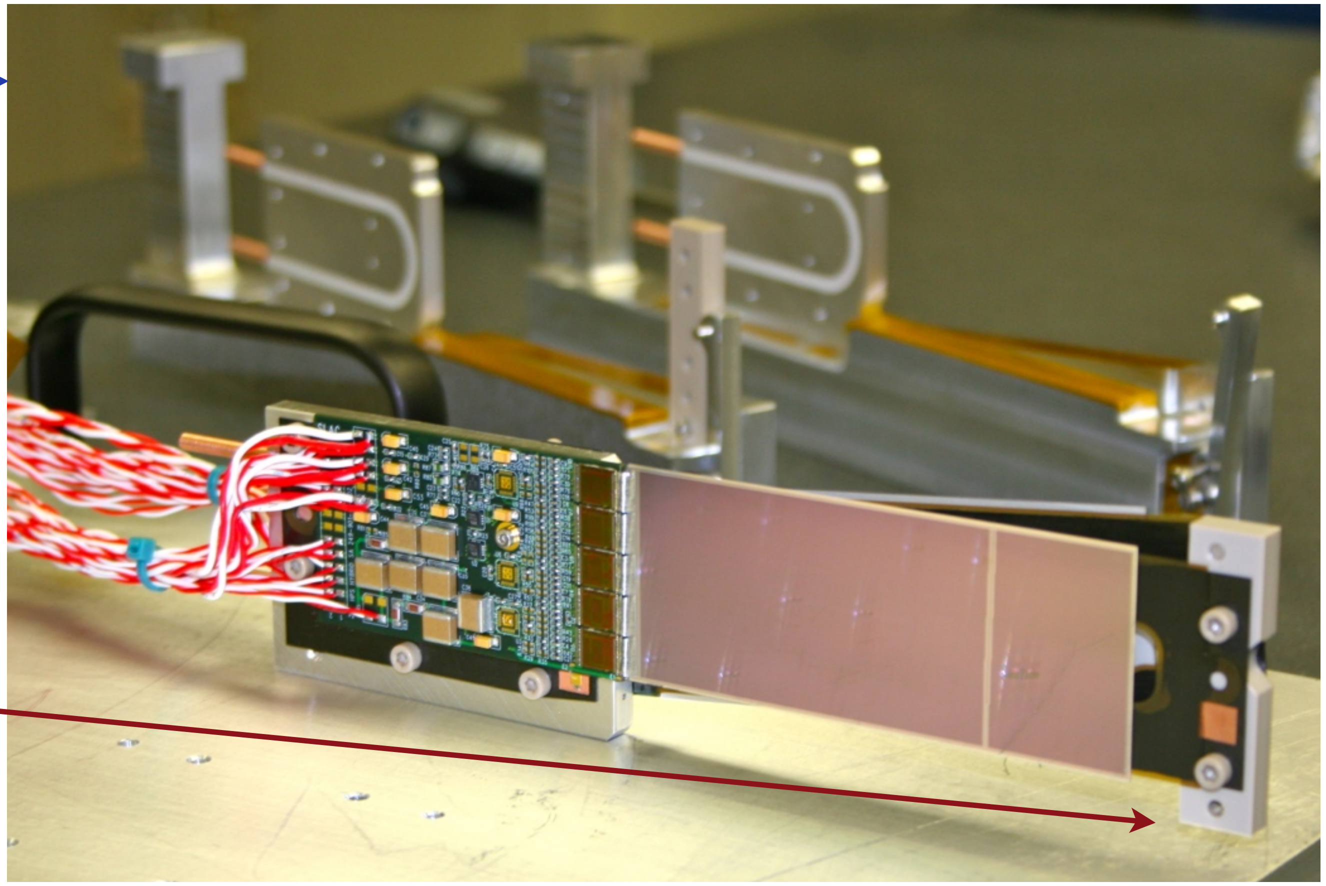
Half Module





- 0.17 mm thick CF frame (FE grounded, HV passivated)
- FR4 hybrid with 5 APV25, short twisted-pair pigtail cable
- single sensor

Full module



- Two half-modules back-to-back on Al cooling block w/ Cu tubes
- glue-less assembly with PEEK spacer block and hardware

➡ *0.7% X_0 average per layer*

➡ *Limits flatness of Si to ~200 μm*

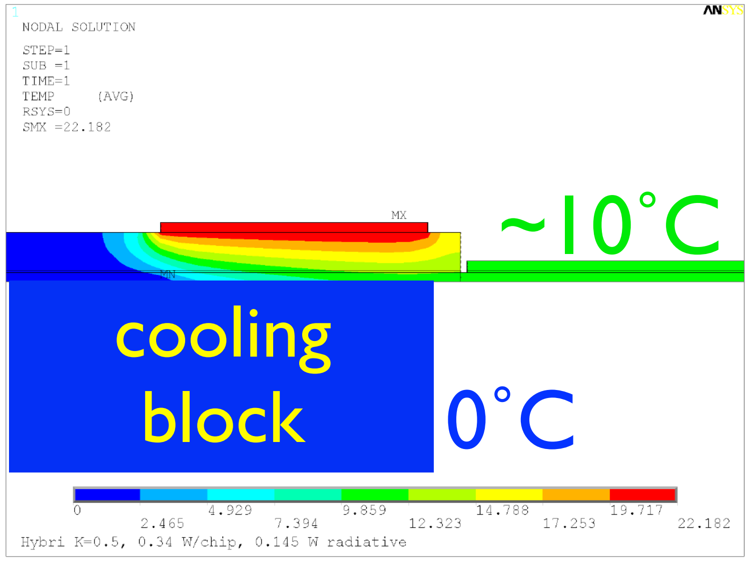
➡ *Compromised cooling limits radiation tolerance*

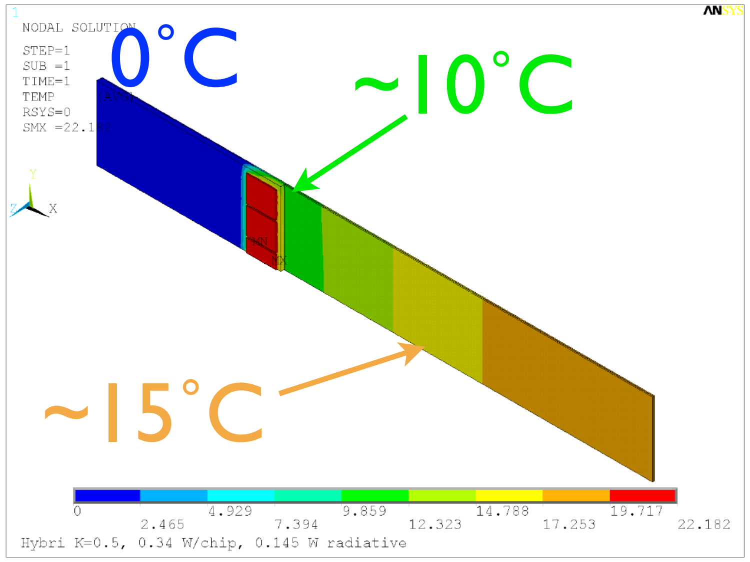
Layer 1-3 Modules

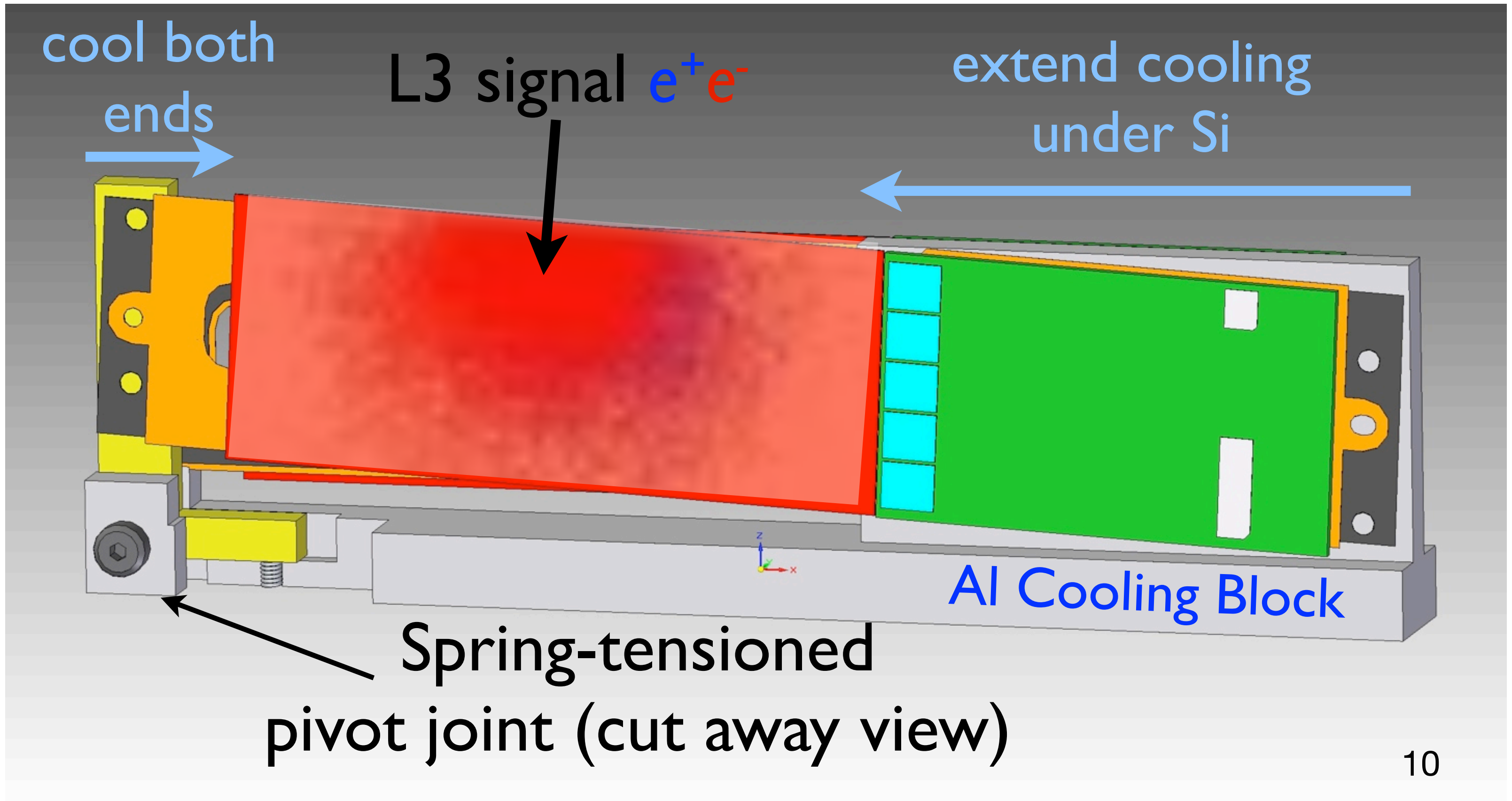
Reuse half-modules from HPS Test, but design better module supports: tension CF between cooled uprights.

- better cooling and cooling at both ends of sensor reduces Δt to "hot spot" by ~80%
- support at both ends ensures overall straightness
- spring pivot with low-viscosity thermal compound keeps CF under tension:
    - stiffens/flattens half module
    - absorbs 60 μm differential contraction during 30˚C cooldown

HPS Test Sensor Cooling



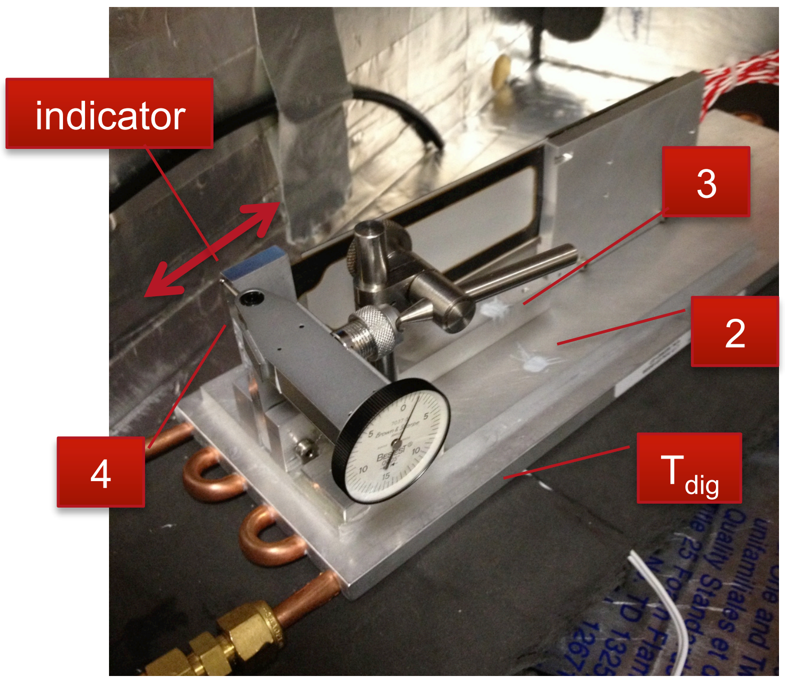


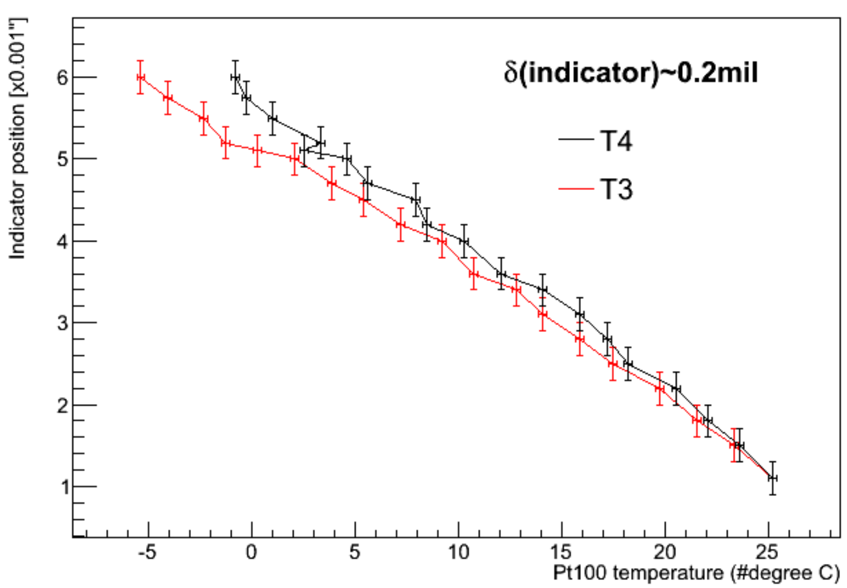


Layer 1-3 Modules

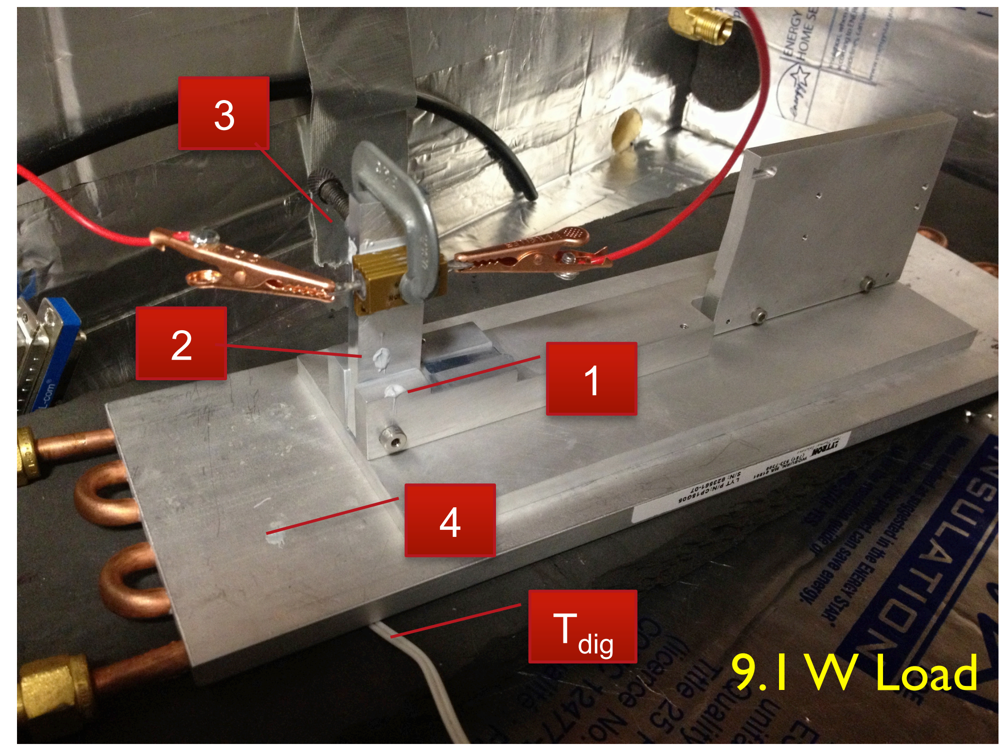
Layer 1-3 Module Status

Pivot operates smoothly during cool-down





Heat flow through pivot is sufficient



Point	1st meas.	2nd meas.
3	30	30
2	20	20
1	16.3	16.5
4	11.5	11.5
T_{dig}	10.2	10.6

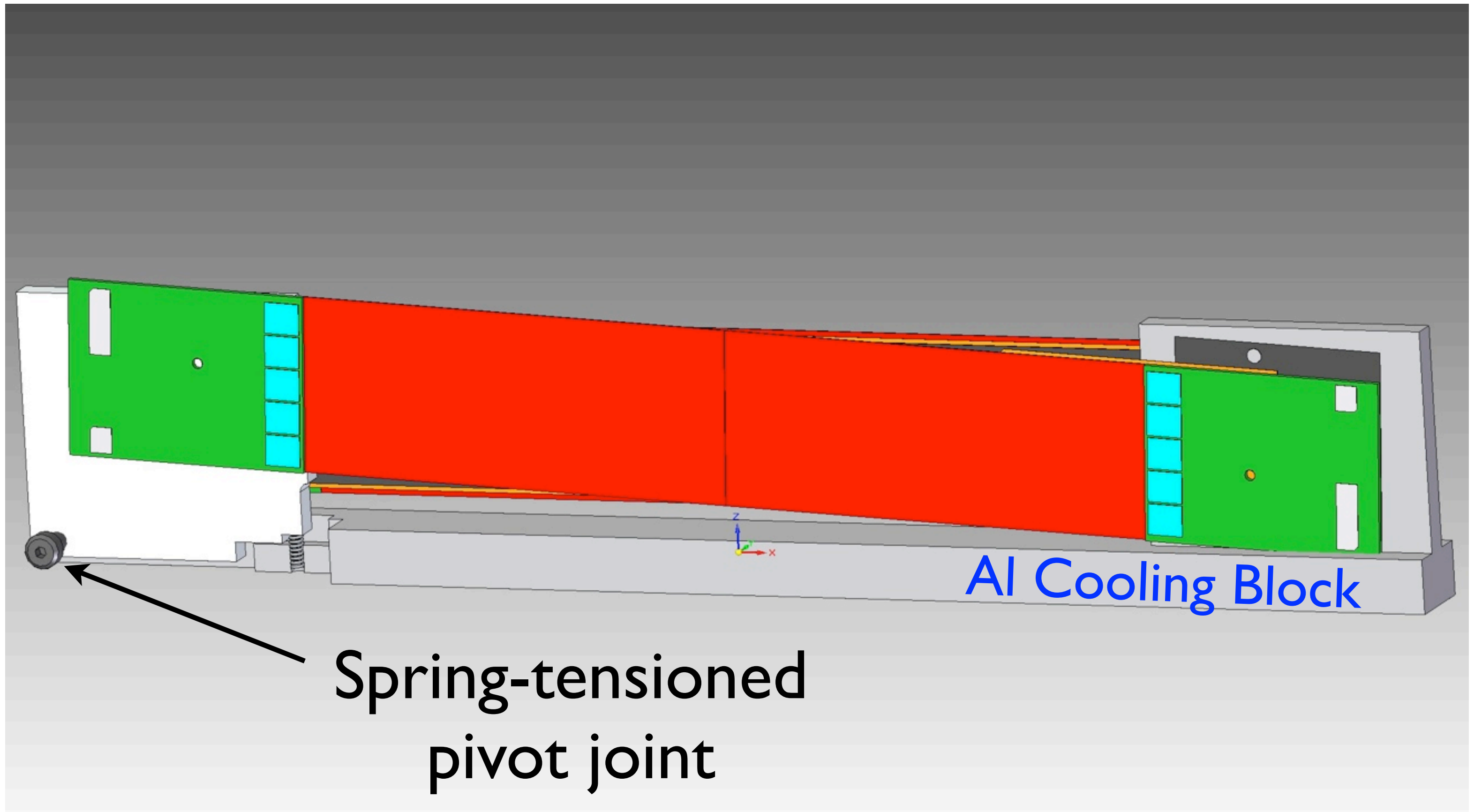
Module support concept is sound for both L1-3 and L4-6

Layer 4-6 Modules

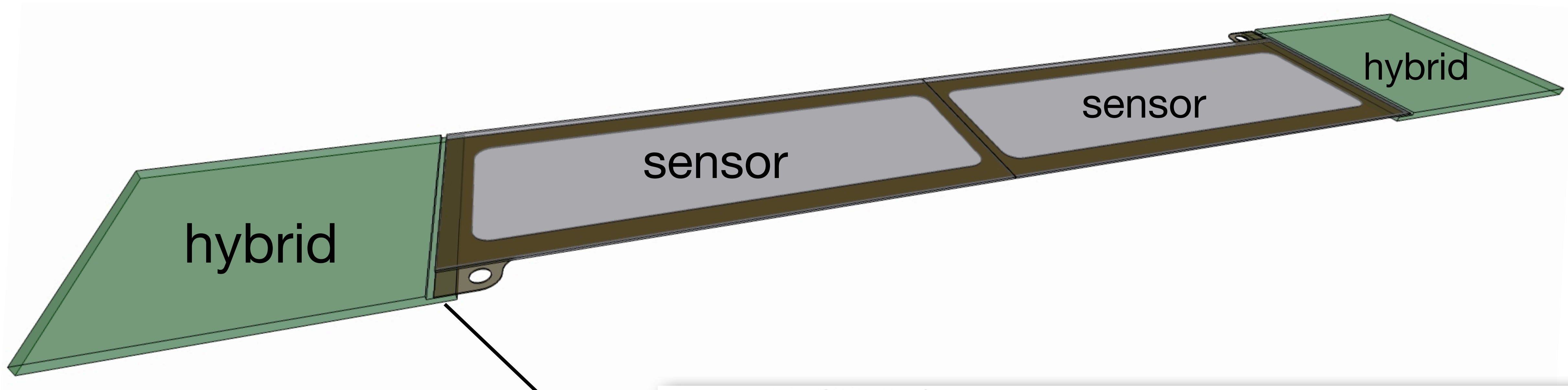
Extending concept to L4-L6 allows same material budget for long modules.

- Build new "double-ended" half-modules using same techniques as HPS Test.
  - similar CF frame, kapton passivation
  - shorter hybrid design omits unnecessary components, uses flex pigtails

A redesign of existing half-modules



Layer 4-6 Half-Module Concept



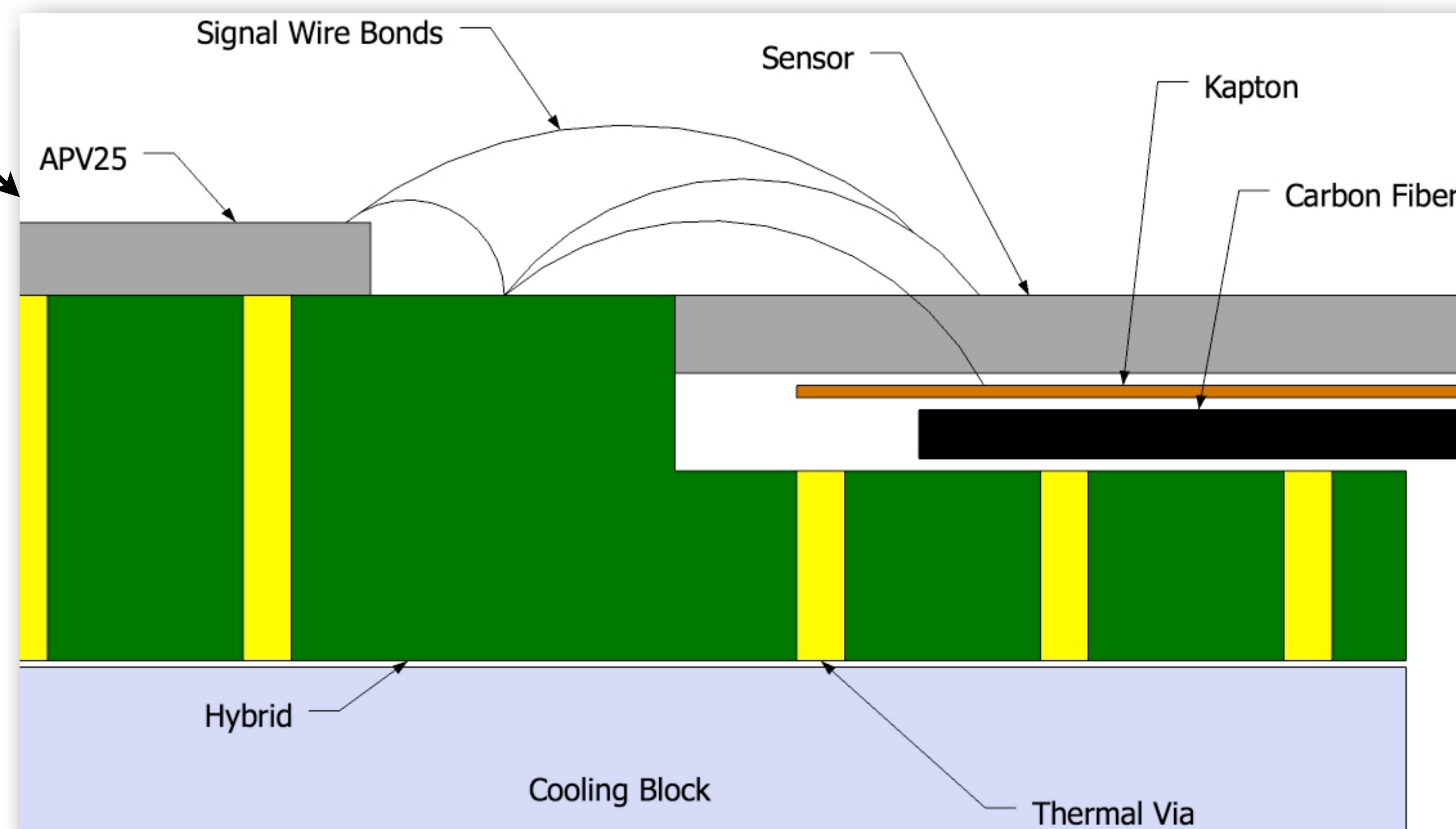
Similar to L1-L3 design, but...

- ends of CF/Si supported by hybrid
- bias supply on Kapton passivation layer
- Silver epoxy between Cu pad on CF and thermal vias provides ground

➡ *simplifies assembly process*

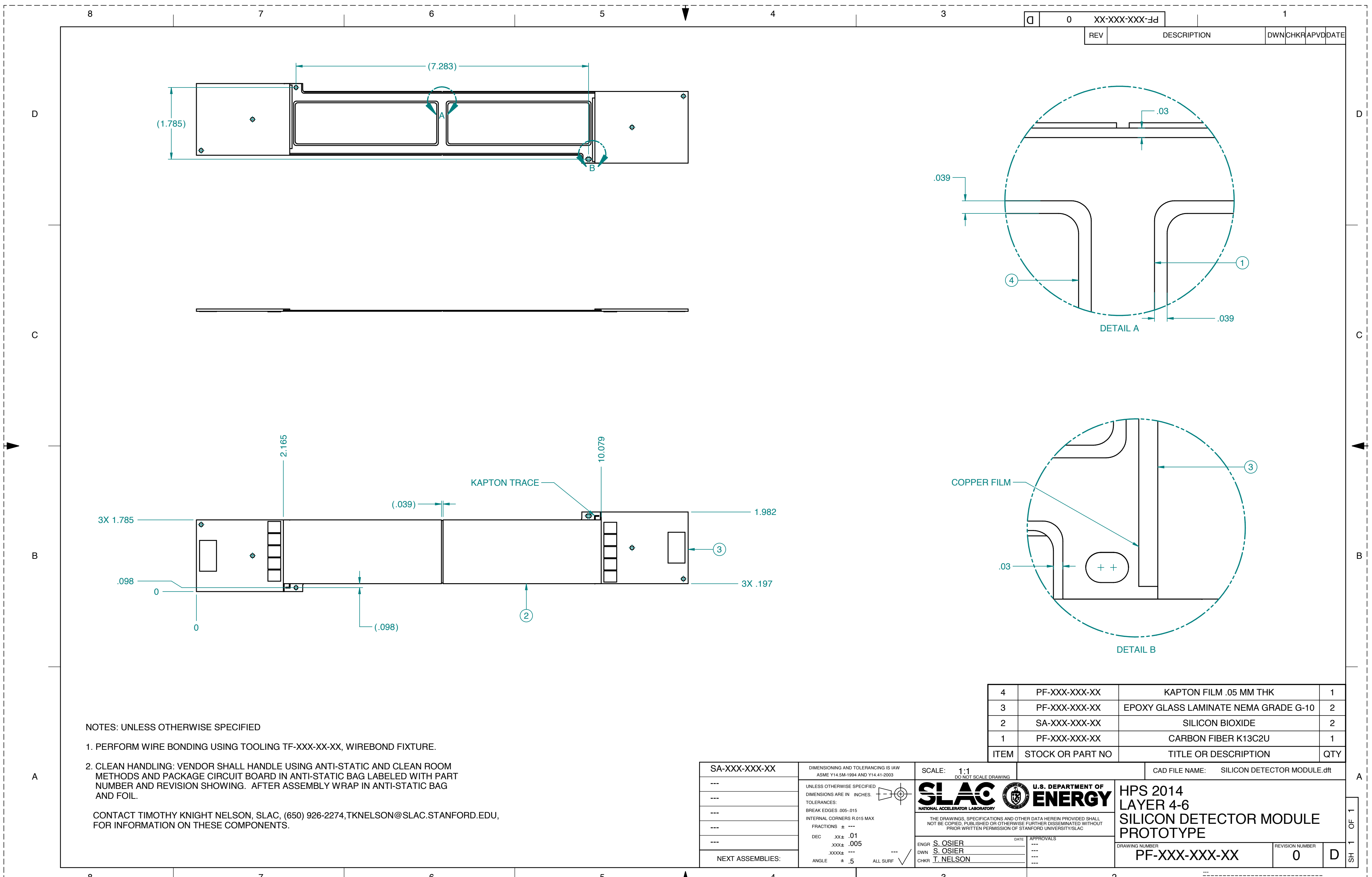
➡ *separates heat path for silicon from APV heat loads*

➡ *easier wirebonding geometry and better support under bonds*



Layer 4-6 Half-Module Design

Design complete for all components



Layer 4-6 Module Status

Sensors

- 40 received from FNAL
- Testing at UCSC complete, QA passed

Hybrids

- schematic and layout complete
- internally reviewed along with half-module design and grounding scheme.
- ready for submission after small changes
- all APV25 (including mechanicals) in hand

Kapton

- mechanical design and trace layout complete
- internally reviewed along with half-module design and grounding scheme.
- ready for submission with hybrid

Carbon Fiber

- mechanical design complete
- reviewed, approved by Bill Cooper
- ready to submit to FNAL for fabrication

New materials

- Silver epoxy passed vacuum test
- New structural epoxy passed vacuum test
- New hybrid connectors passed vacuum test

Supports

- Design of module supports underway based upon successful L1-L3 design

Fixtures

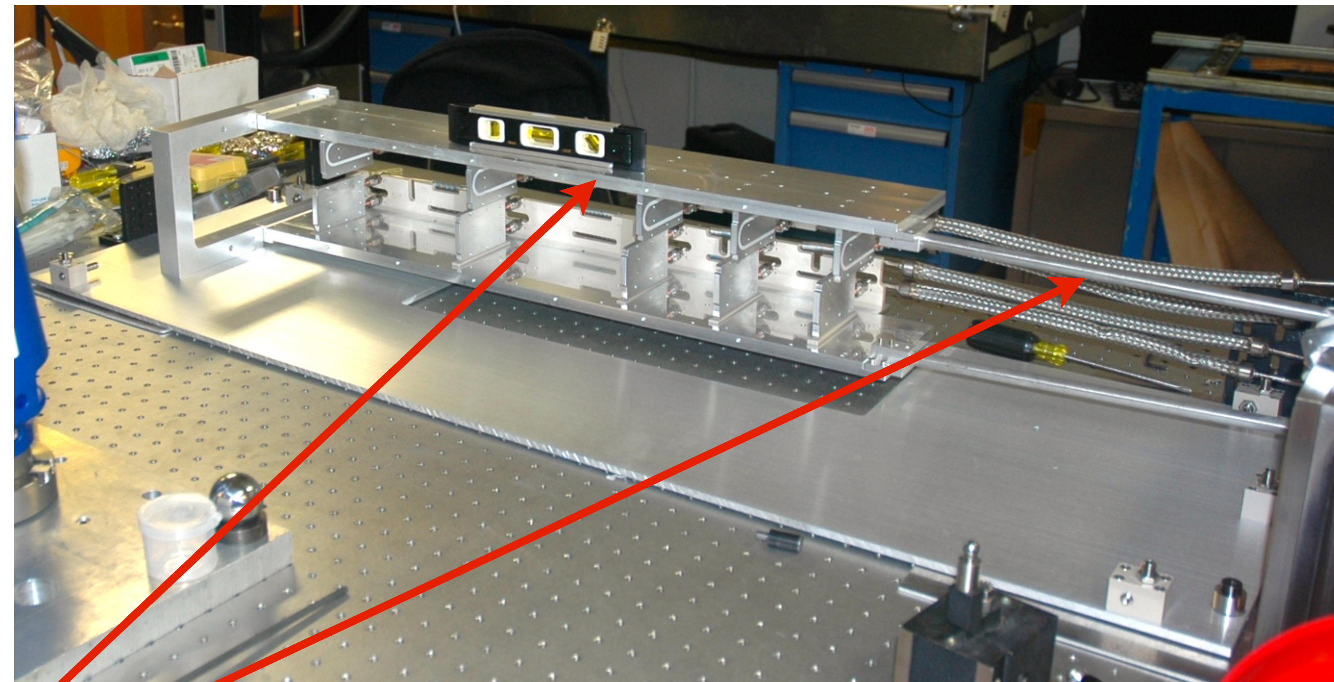
- Design of assembly, wirebonding, testing/transport/storage fixtures underway based upon similar designs from L1-L3 production.

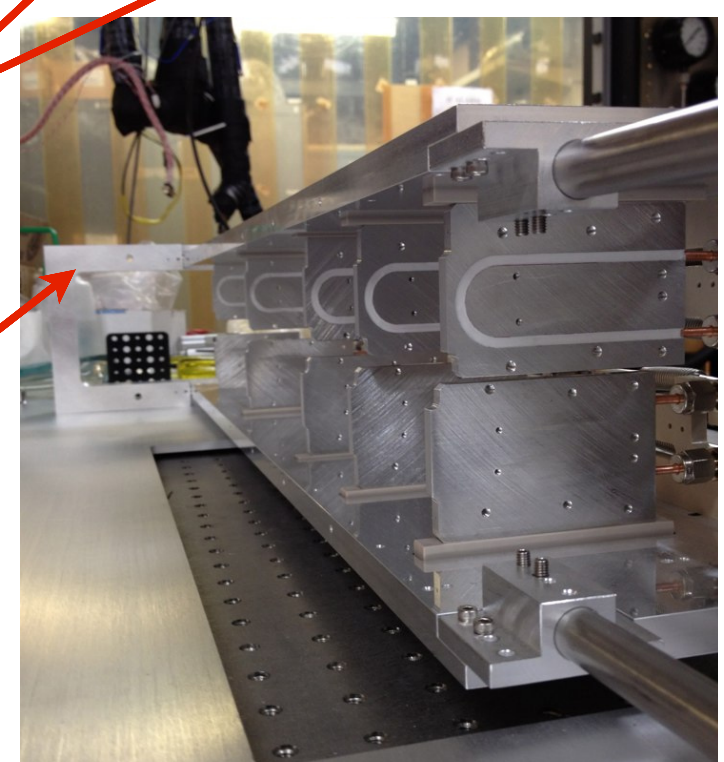
Test SVT Mechanics

Cooling blocks mount on Al support plates with hinged "C-support" and motion lever

- Provide solid mounting for modules, routing for services, and simple motion for tracker
- PEEK pedestals create 15 mr dead zone, provide some thermal isolation
- Support plates + motion levers ~1.5 m long: sag dominates x-y imprecision (300 μm)
- Load on C-support introduces small roll in top plate.

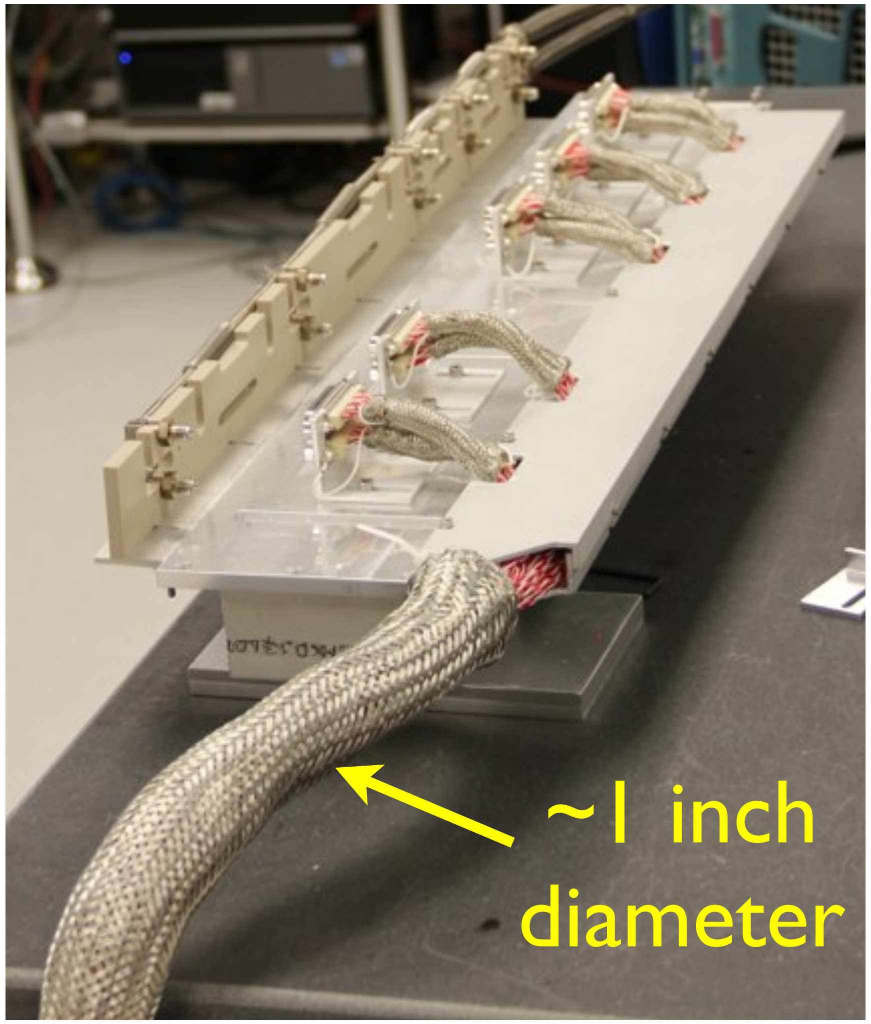
Works, but can be improved upon

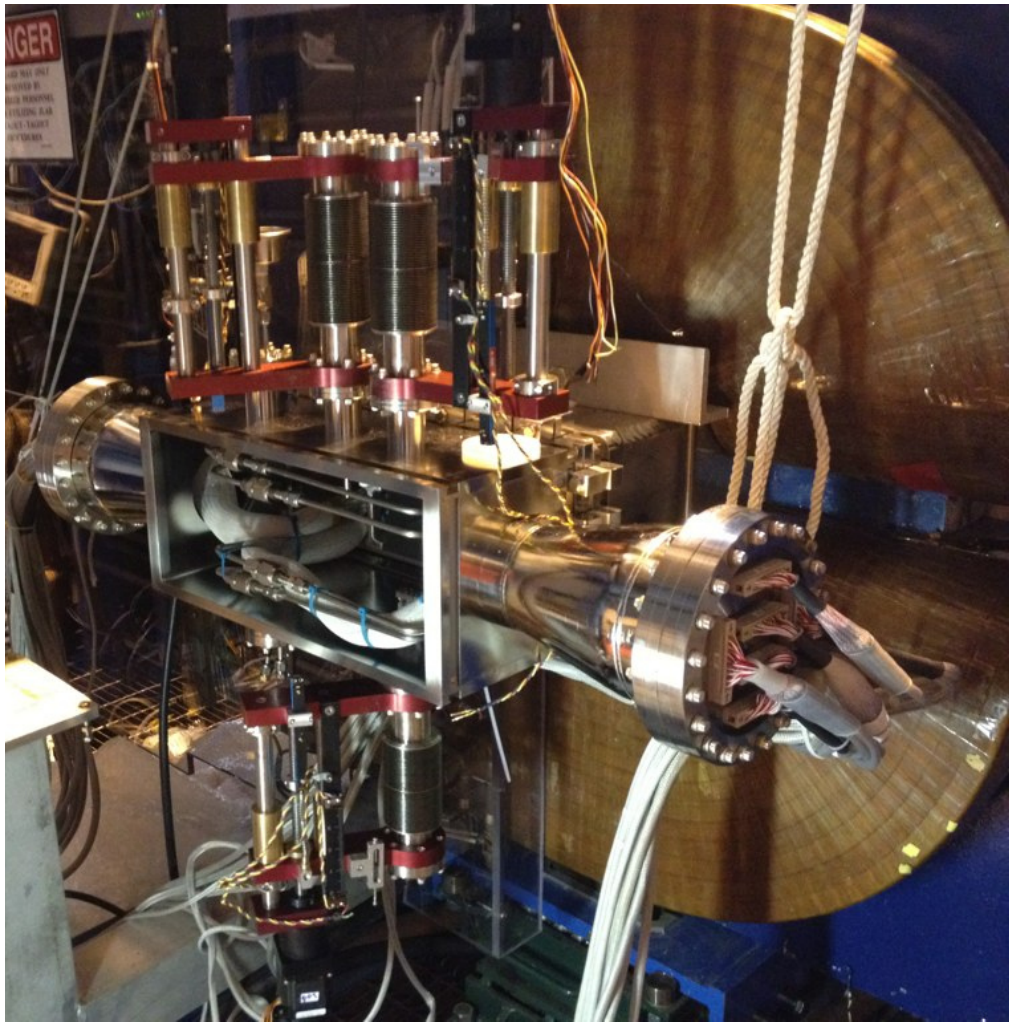




Test SVT Services

- Borrowed CDF SVXII power supplies (very crufty) and JLab chiller (limited to > 0˚C)
- Intricate welded cooling manifolds with 2 compression fittings/module
- 600 wires into vacuum chamber for power and data (3600 total pairs of connector contacts): recovered three sensors with internal connectivity problems after assembly/installation at JLab





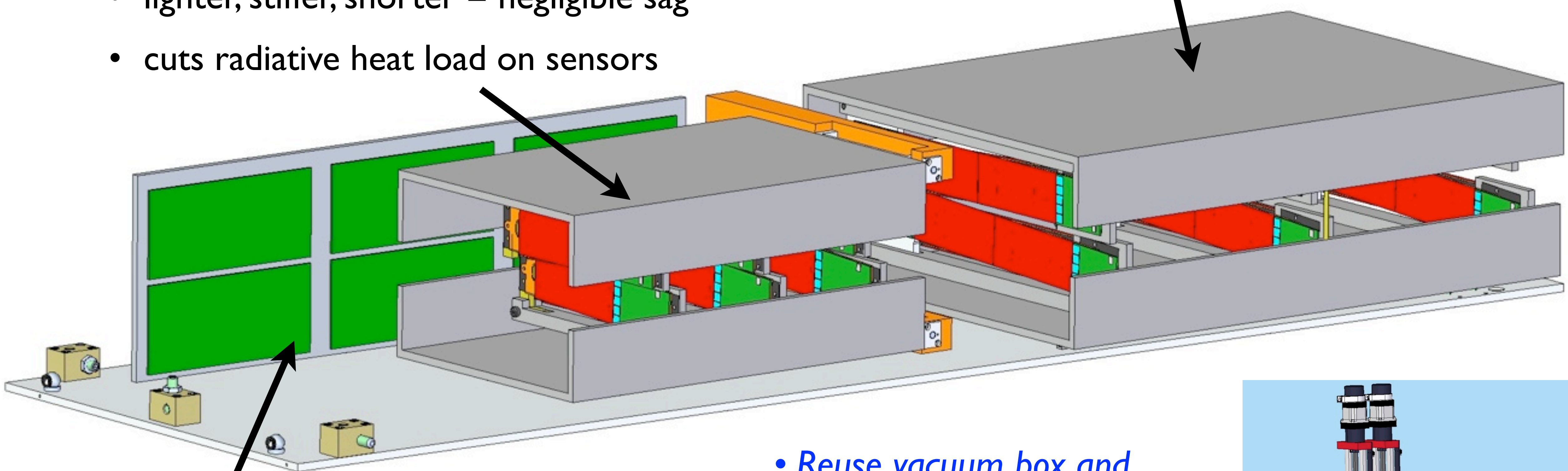
We got away with this, but it doesn't scale well to a larger detector.

SVT Support, Cooling and Services

Cooled support channels for L1-L3

- *reuse c-support, motion levers*
- lighter, stiffer, shorter = negligible sag
- cuts radiative heat load on sensors

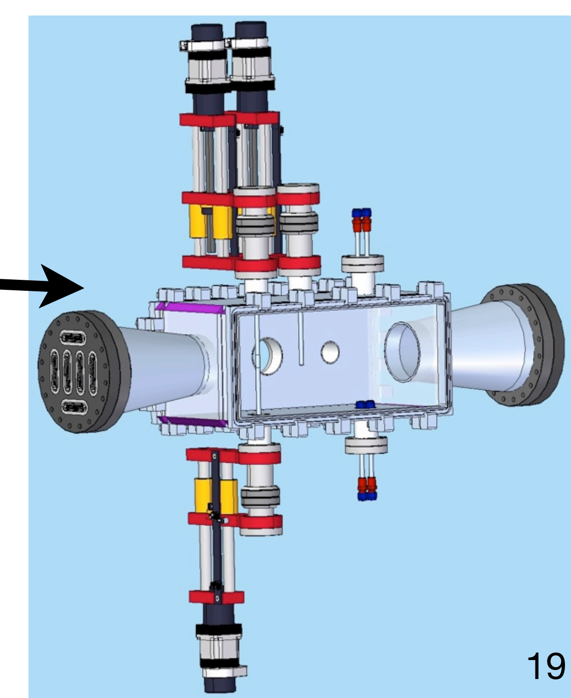
Cooled support channels for L4-L6 are stationary



DAQ/power inside chamber on cooling plate

- Reduces readout plant
- Low-neutron region (upstream, e^+ side)
- Board spacing minimizes flex cable designs

- *Reuse vacuum box and linear shifts with new vacuum flanges*
- *New chiller operable to -10°C with 1°C stability.*
- *Use new Wiener MPODs for power*



SVT Support, Cooling and Services Status

Ready to detail design of remaining components

- u-channels
- new baseplate
- c-support modifications
- motion lever modifications
- cooling plate for front end boards
- polyimide readout cables (pigtail + 4 longer cables)

...and place critical orders

- new power supplies
- new chiller

Roles and Responsibilities

Same tasks and personnel as Test SVT

SLAC - Hansson, Jaros, Maruyama, McCulloch, Nelson, Oriunno, Osier, Swift, Uemura, SLAC Techs

UCSC - Fadeyev, Grillo, Martinez-McKinney, Moreno, UCSC Techs

FNAL - Cooper, FNAL Techs

CF frames
- Fabrication
- Machining
- Passivation

Hybrids
- Loading
- APV25 attach
- Wirebonding
- *QA testing*

Sensors
- *QA testing*

Half Modules
- Hybrid attachment
- Sensor attachment
- HV Wirebonding
- Signal wirebonding
- *QA testing*

fail = discard

Modules
- Module assembly
- *QA testing*
- Survey

Module Supports
- Fabrication
- Assembly

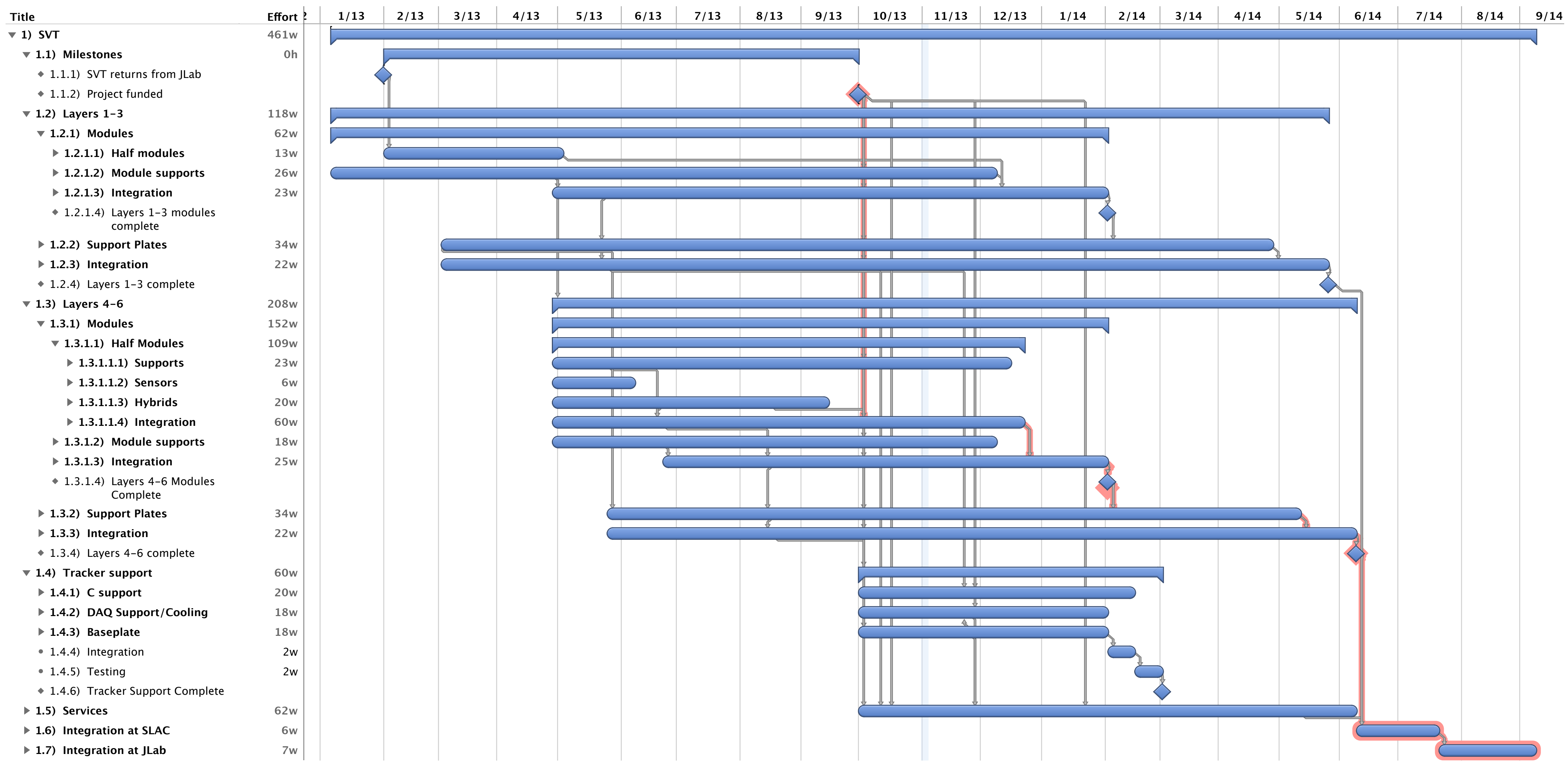
Support Channels
- Machining
- Assembly
- Cooling installation
- Cable installation
- *Survey*

Tracker Halves
- Module installation
- Service dressing
- *System testing*
- *Survey*

Base Plate
- Plate machining
- C-support fab./inst.
- Lever fab./inst.
- Fiducial fab/inst
- *Survey*

fail = replace faulty component

Schedule



- Comfortable relative to schedule for HPS Test, but still quite busy
- Critical tasks begun during "keepalive" period before October 1:
  - Design and prototyping of new module supports for Layers 1-3
  - Design and prototyping of new half-modules for Layers 4-6
- Approximately 6 weeks behind schedule for L4-6 production.
  Working concurrently on unnecessarily serialized tasks can erase slippage.

SVT Budget

- *SVT "upgrades" have been designed around scope we understand; scope of the Test SVT*
- *Budget includes significant contingency beyond actual spending on similar items for Test SVT*

	Labor (w/ cont.)	Material (w/ cont.)	Total (w/ cont.)	Capital Eq.
Layers 1-3	$66K	$37K	$103K	$103K
Layers 4-6	$107K	$86K	$193K	$175K
Support, Cooling, Vacuum	$143K	$20K	$163K	$107K
Testing, Shipping, Integration	$136K	$61K	$197K	$154K
Total	$452K	$204K	$656K	$539K

+ 173K to UCSC in FY2013-FY2014

Biggest items are completely new modules for Layers 4-6 and testing/integration at SLAC.

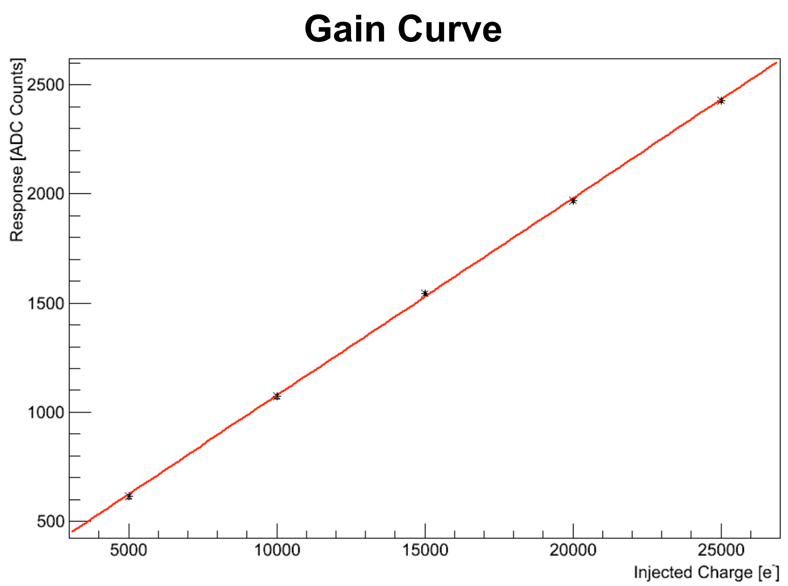
Summary

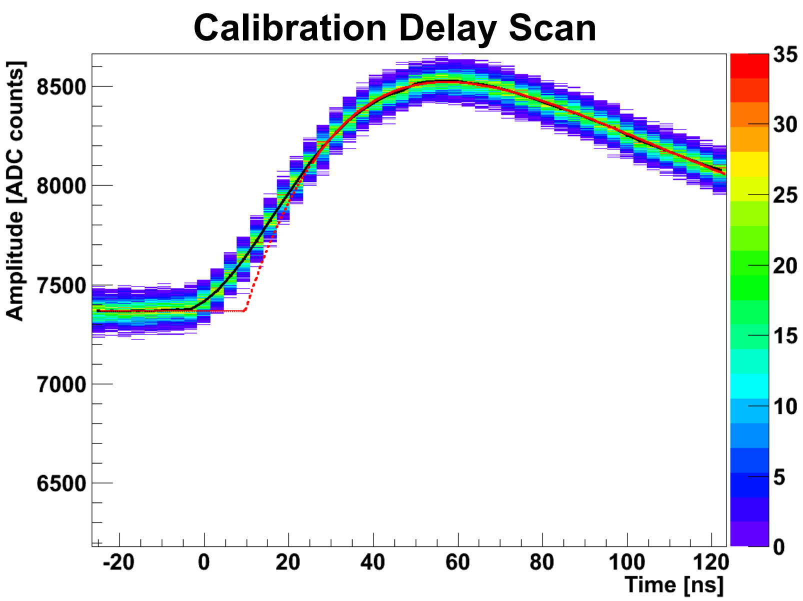
- The HPS Test SVT got most things right and performed well
  - Met key performance goals for material, efficiency, position and time resolution.
  - *Acceptance, redundancy, mechanical precision, and cooling could be improved.*
- *Modest upgrades to the Test SVT address these*
  - Project scope is, by design, very similar to that for HPS Test SVT.
  - Minimal budget risk, which is generous relative to Test SVT actual costs.
  - Schedule risk is modest if new L4-6 module production begins as planned

Test SVT Assembly, Commissioning, Operation

At SLAC:

- Began with 165 APV25 (enough for 33 hybrids)
- 29/30 hybrids passed QA
- 28/29 half-modules passed QA
- Good noise, linearity, uniformity
- Assembly precision at cooling block: x-y ~10 μm, z ~ 25 μm
- Flatness (z) along sensor ~200 μm

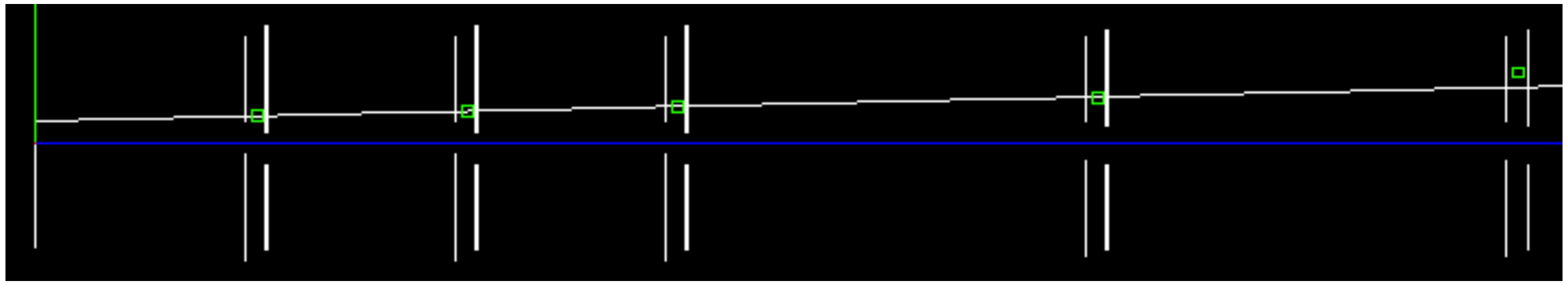




At JLab:

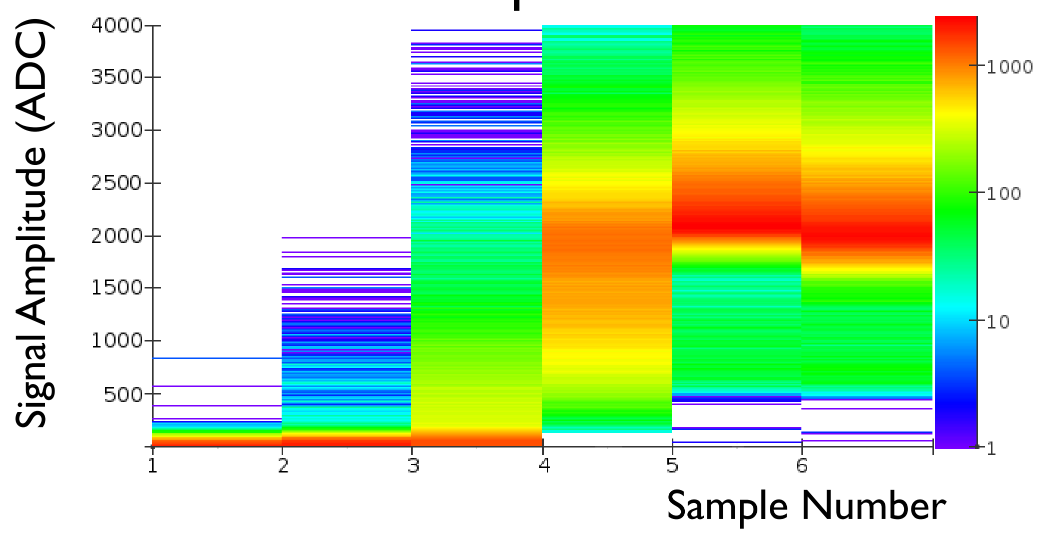
- Installed in Hall B on April 19 for parasitic photon run
- all chips responding
- no problems with vacuum

From: Graham, Mathew Thomas <mgraham@slac.stanford.edu>
Subject: tracks, I think...
Date: May 3, 2012 3:10:54 PM PDT

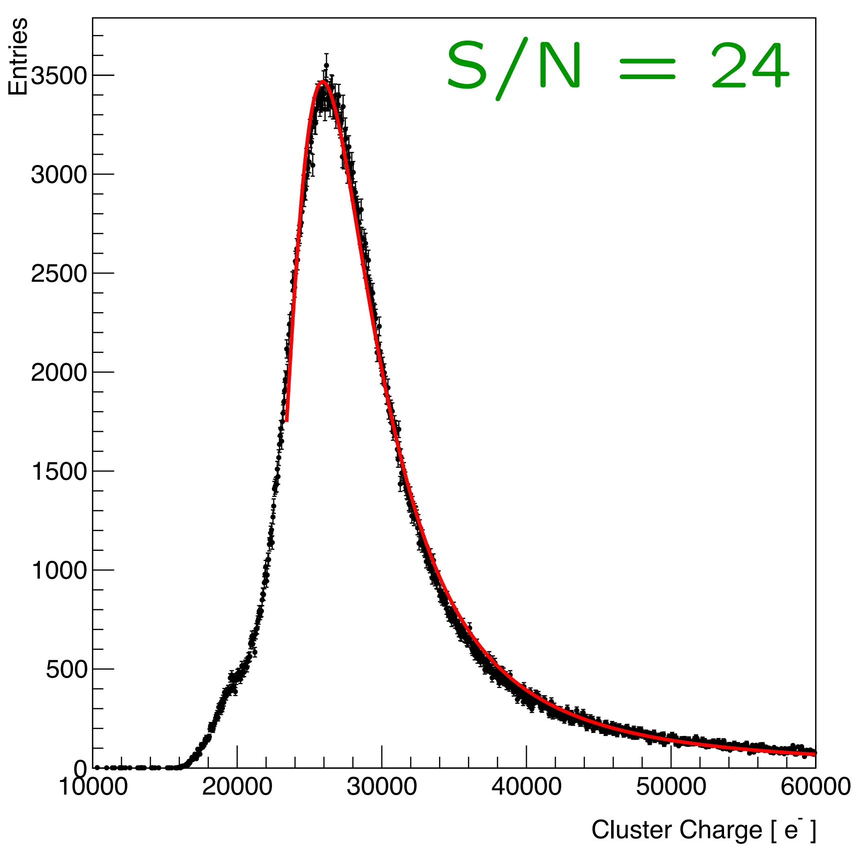


Test SVT Amplitude and Time Reconstruction

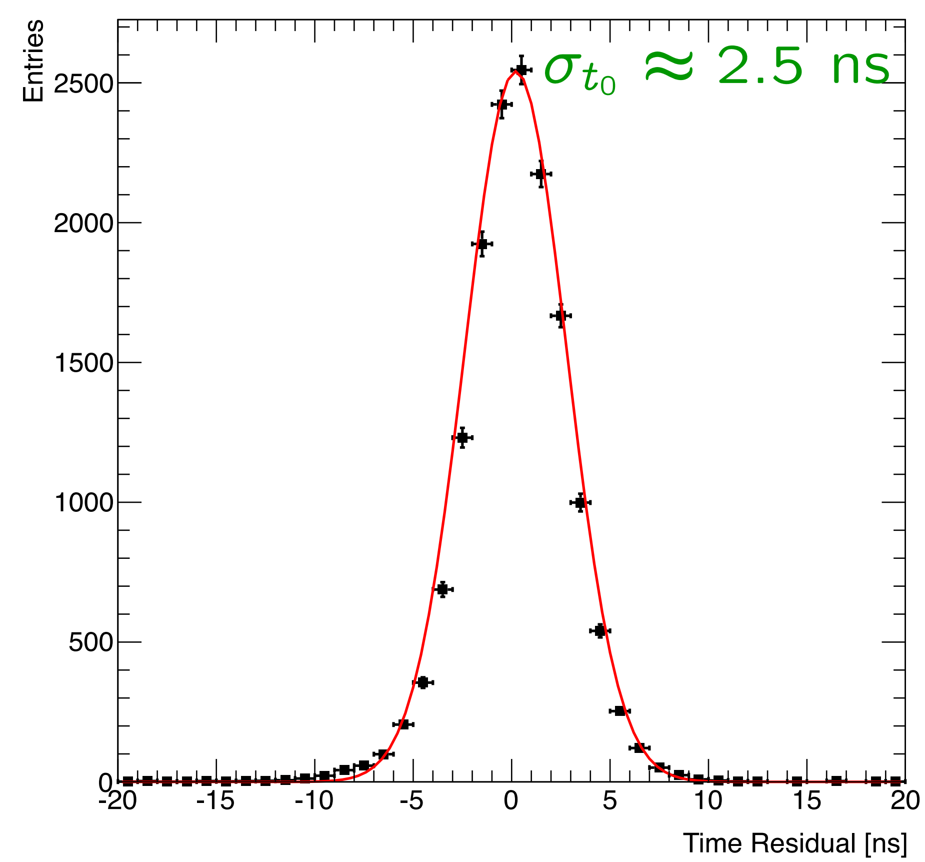
Raw Amplitude Data



Cluster Charge Reconstruction

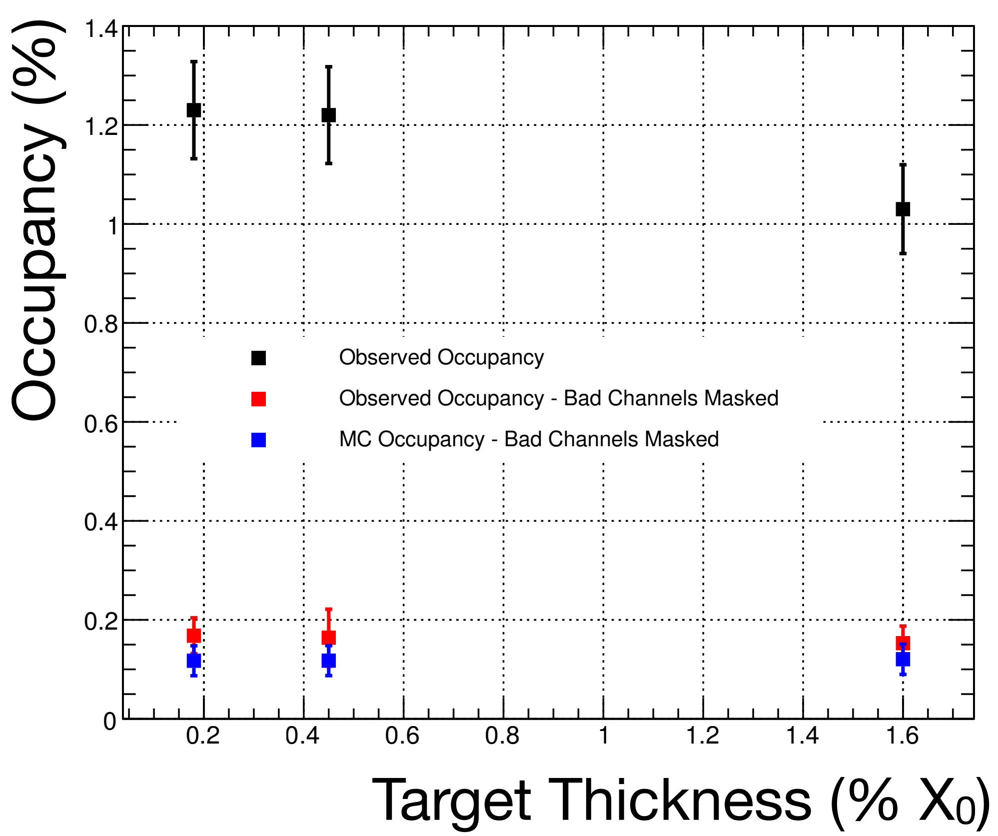


Hit Time Reconstruction

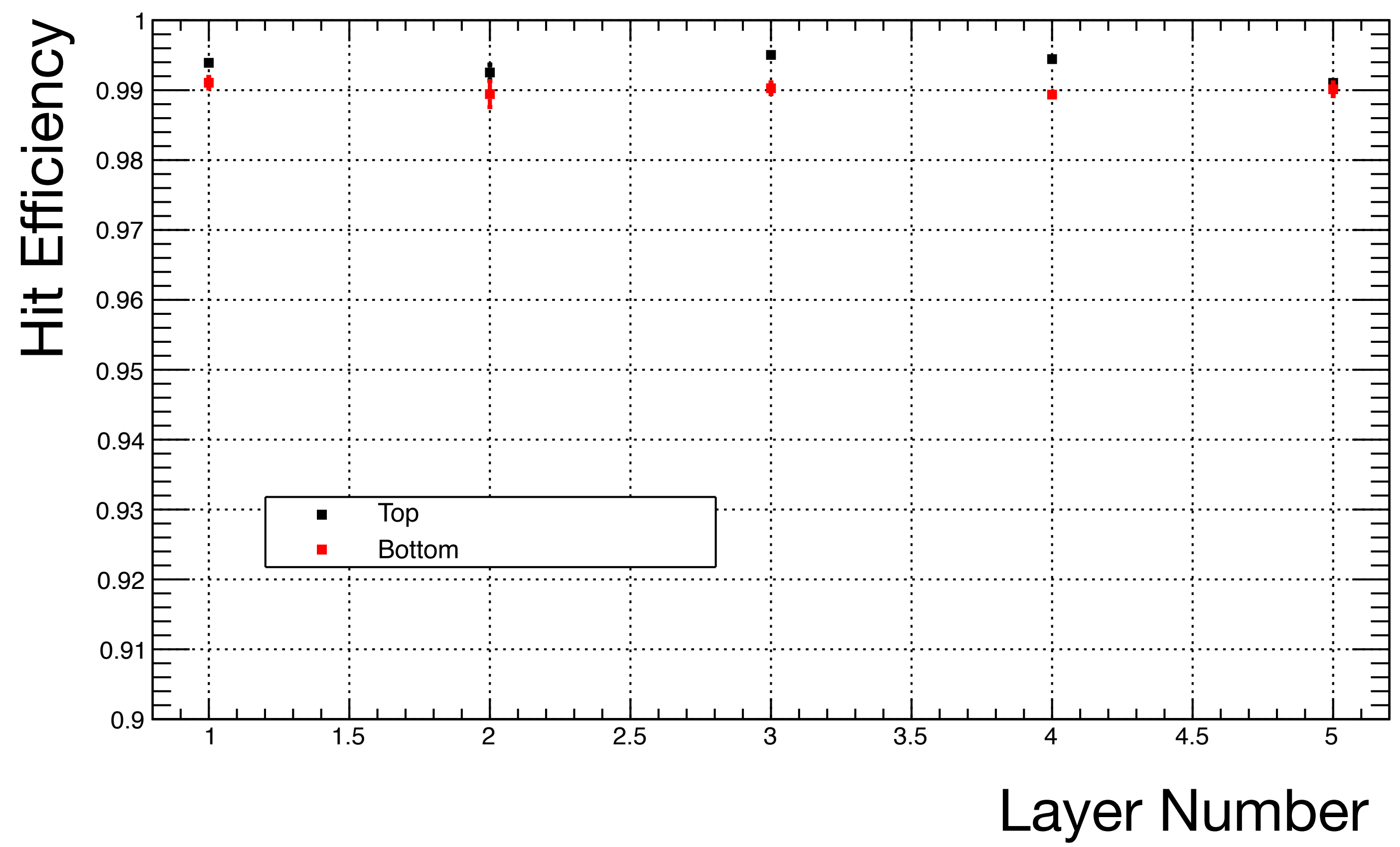


Test SVT Hit Occupancy and Efficiency

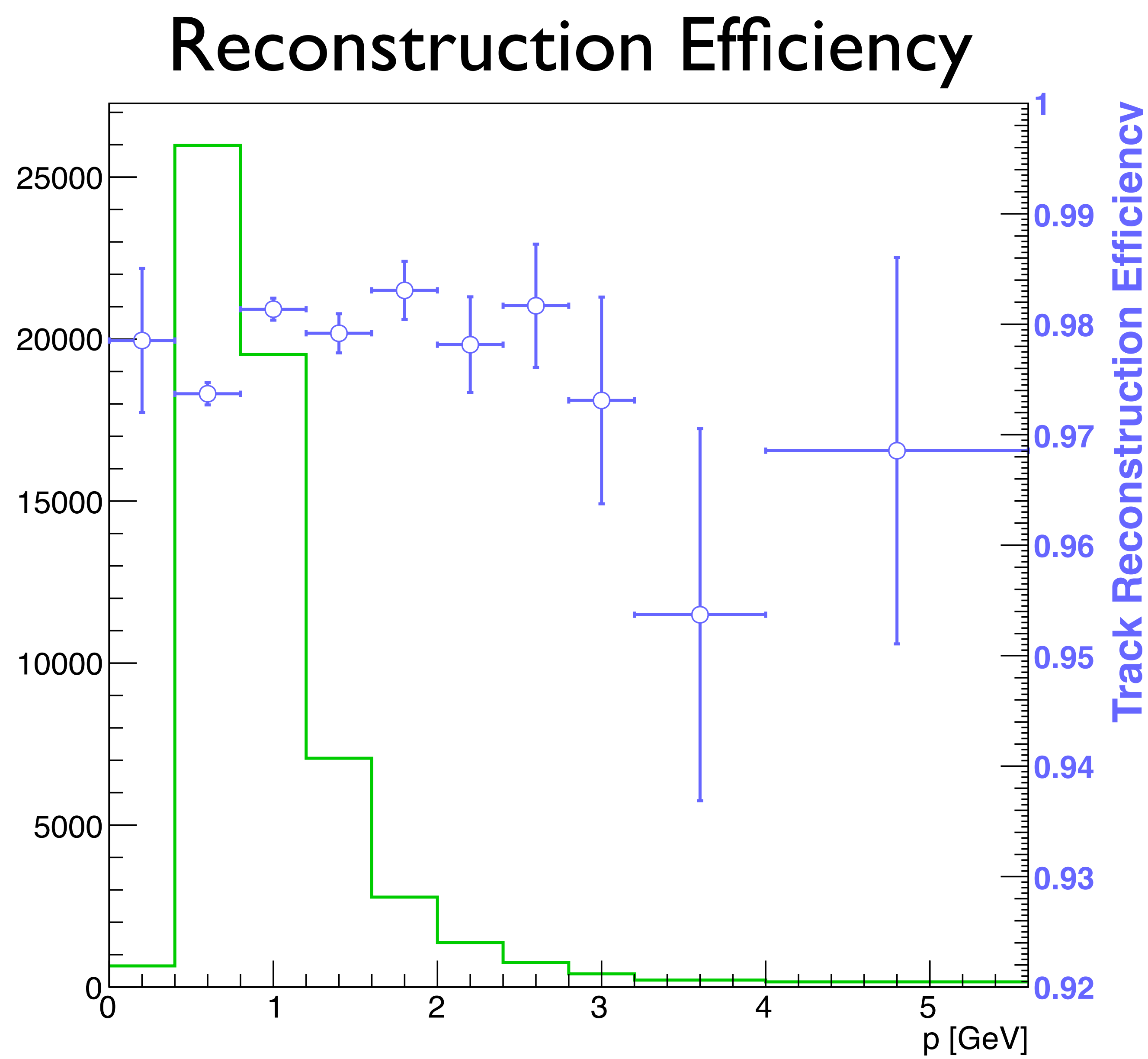
With noisy channels masked, occupancy is as expected...



and efficiency for finding hits on tracks is >99%.



Track Reconstruction Efficiency



Good reconstruction efficiency
even without full alignment

HPS Test SVT Lessons Learned

- We can build a movable, liquid cooled tracker that operates in beam vacuum
- We can build tracker with 0.7% X_0 per 3-d measurement
- We can build a tracker with required efficiency, spatial and time resolution
- We can integrate SVT DAQ with JLab ECal DAQ and trigger
- *We can do better for the HPS SVT,*
  - Larger acceptance and better redundancy
  - Modules with flatter, colder sensors
  - Improved support rigidity
  - More reliable interconnect strategy
  - Fully tested and debugged DAQ

but it would be foolish to start from scratch!!