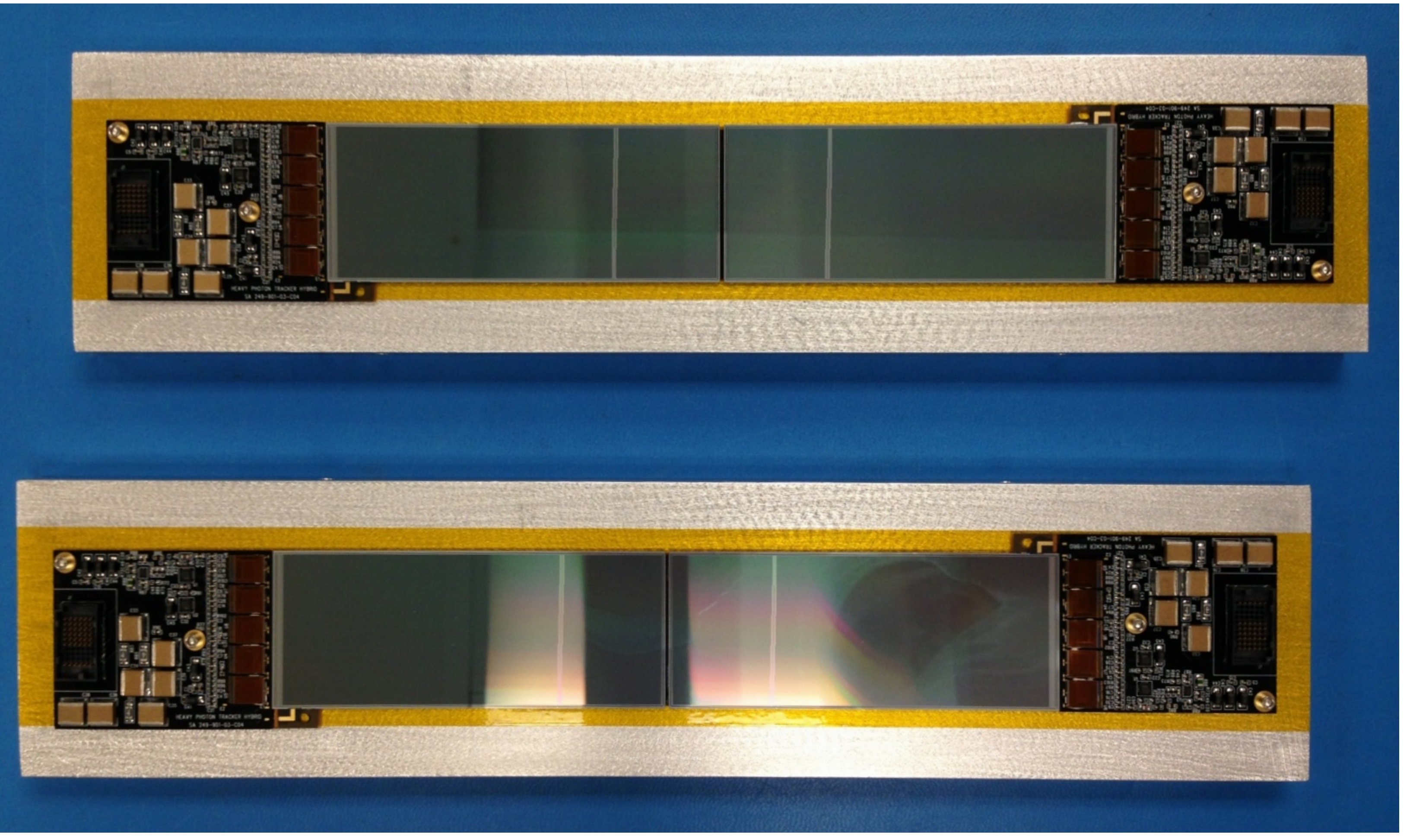
SVT Overview



Tim Nelson - SLAC

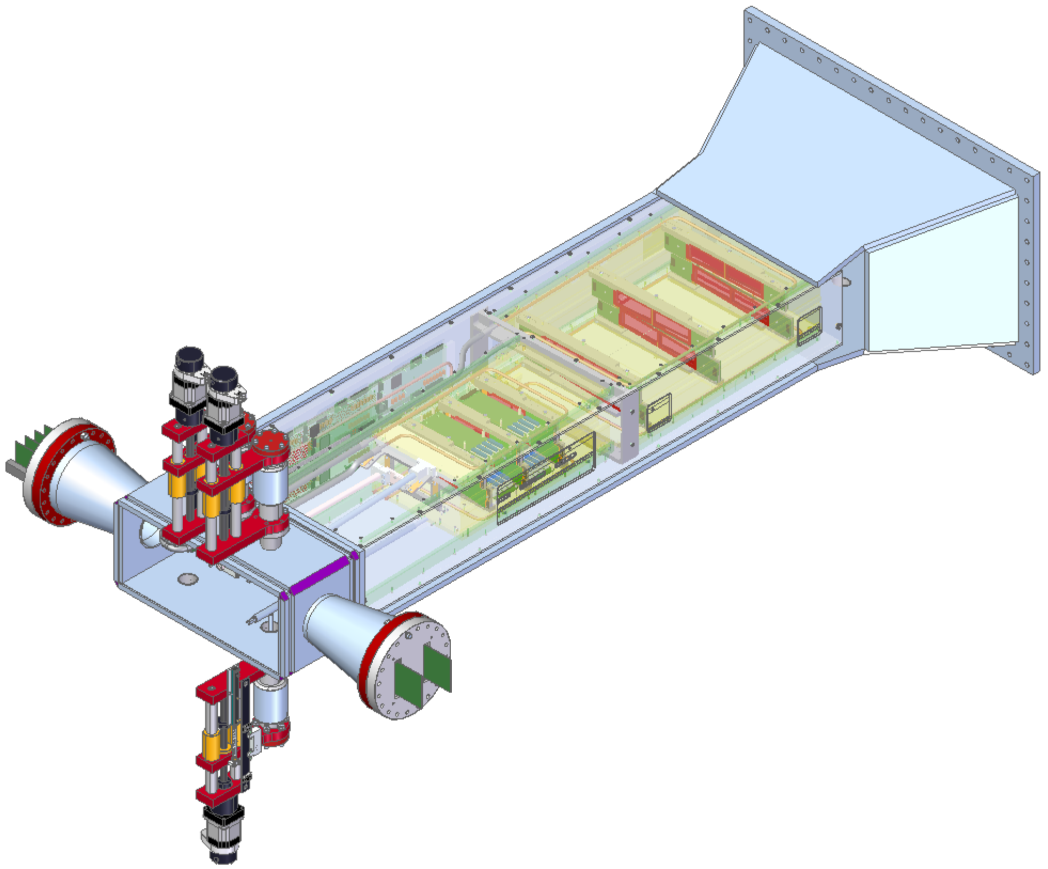
HPS Collaboration Meeting

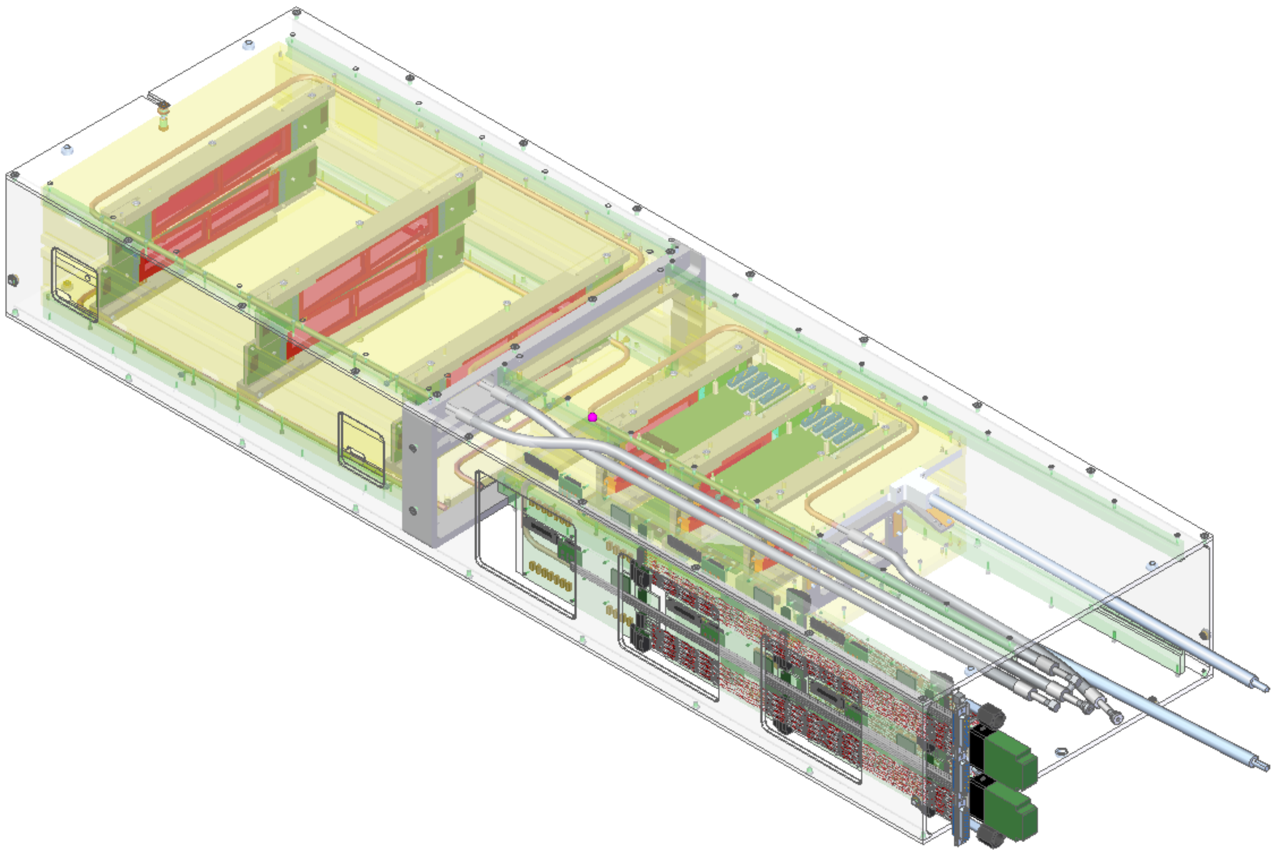
June 16, 2014

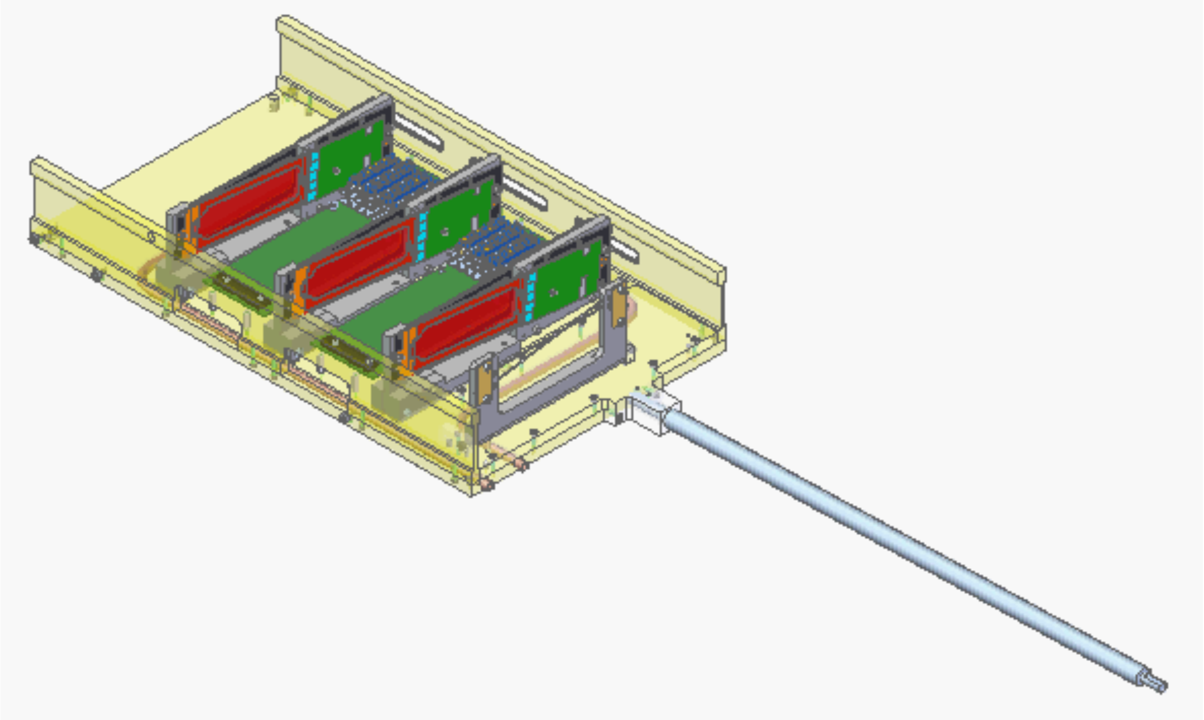
Outline

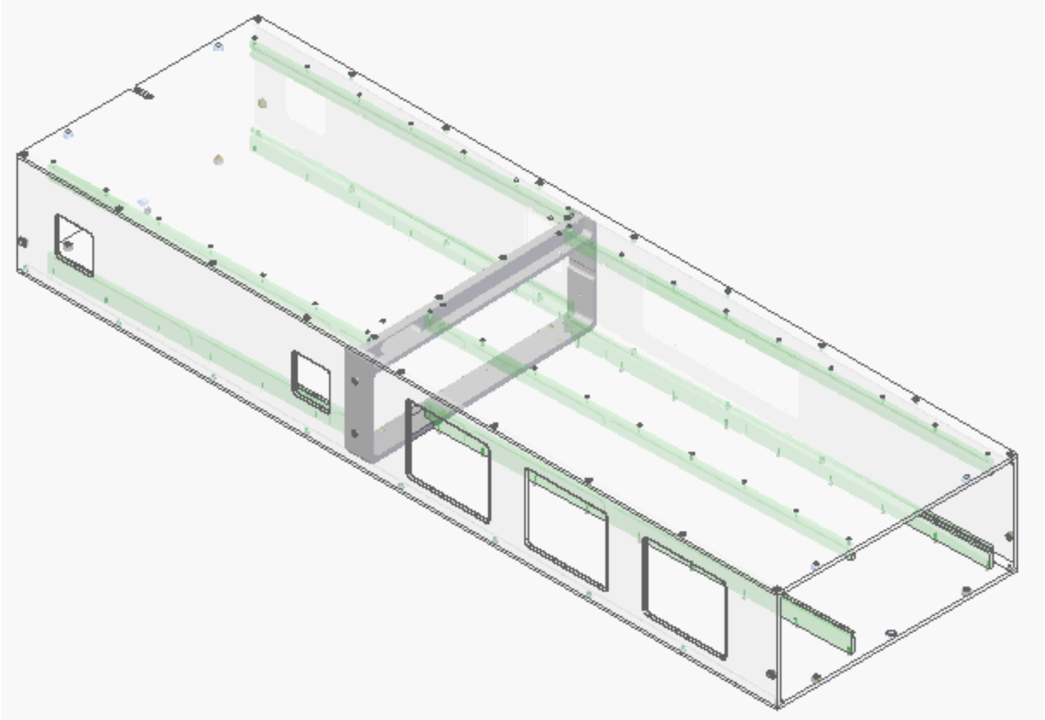
- Design Overview
- Module Status
- Mechanical Support Status
- Services Status
- Survey and Alignment
- Installation and Commissioning
- Schedule and Budget
- Documentation

SVT Design



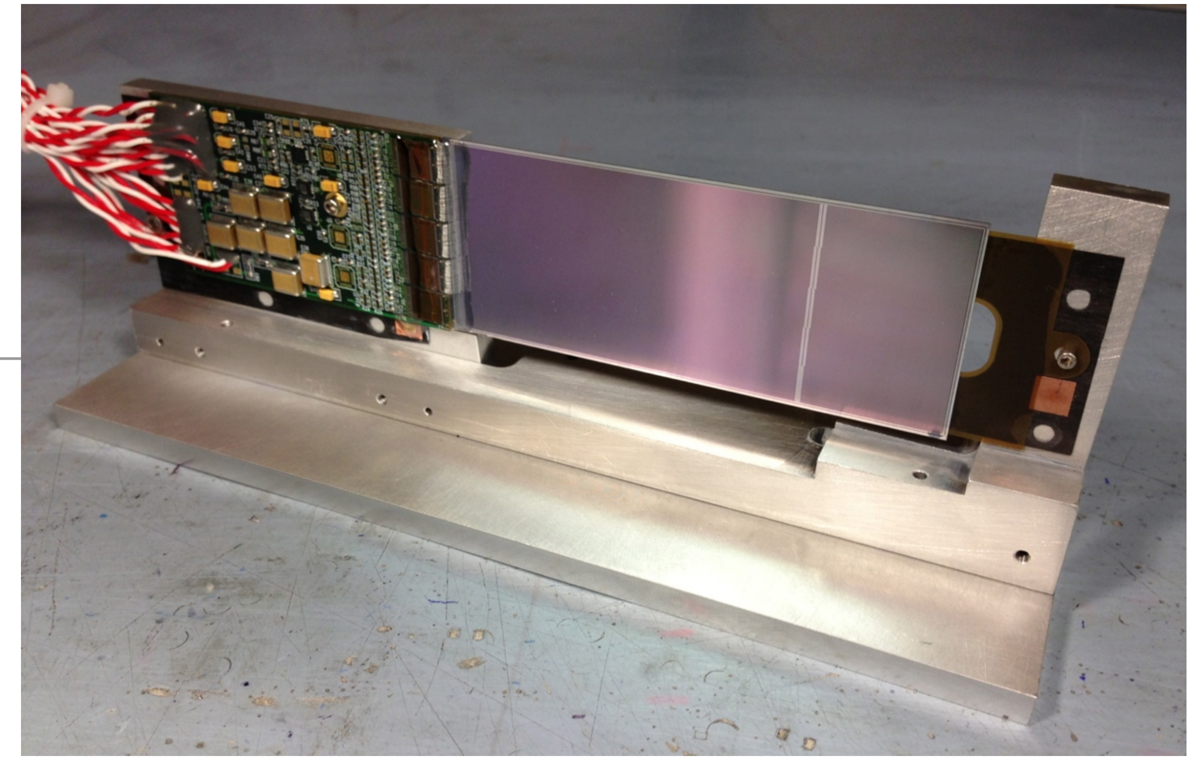


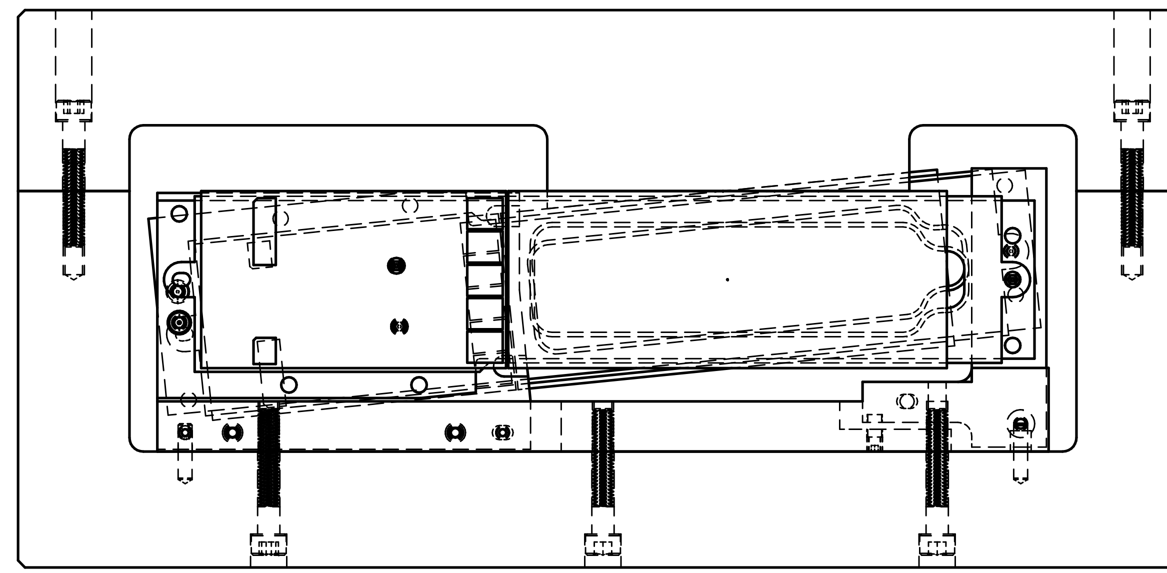


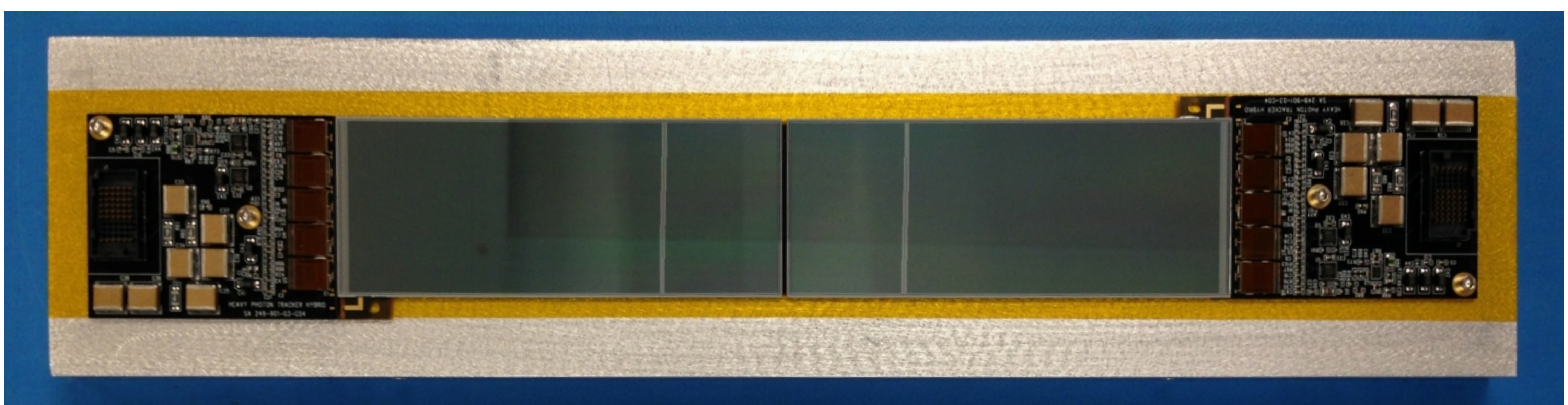


Module Design/Status

- HPS Test disassembled, most L1-L3 half-modules tested and ready for assembly. (Sho)
- Complete set of L4-L6 half-modules ready for assembly, still building spares. (Omar)
- Module supports were delayed in fabrication: expect at the end of the week.
- Module alignment tools almost ready for fabrication.







Mechanical Support Status

- Most parts in hand or expected in ~1 week:
  SVT outer box, support ring, support channels, drawer guides, alignment/survey hardware, etc...
- Key R&D and testing has been completed (e.g. drawer insertion of supports.)
- Down to last few % of design work.
- Most remaining fabrication will be odd jobs/ modifications required as we build up the detector. Exceptions: motion levers, wire scanner supports.

The next ~2 weeks will mark a major shift from fabrication to final assembly of the SVT.

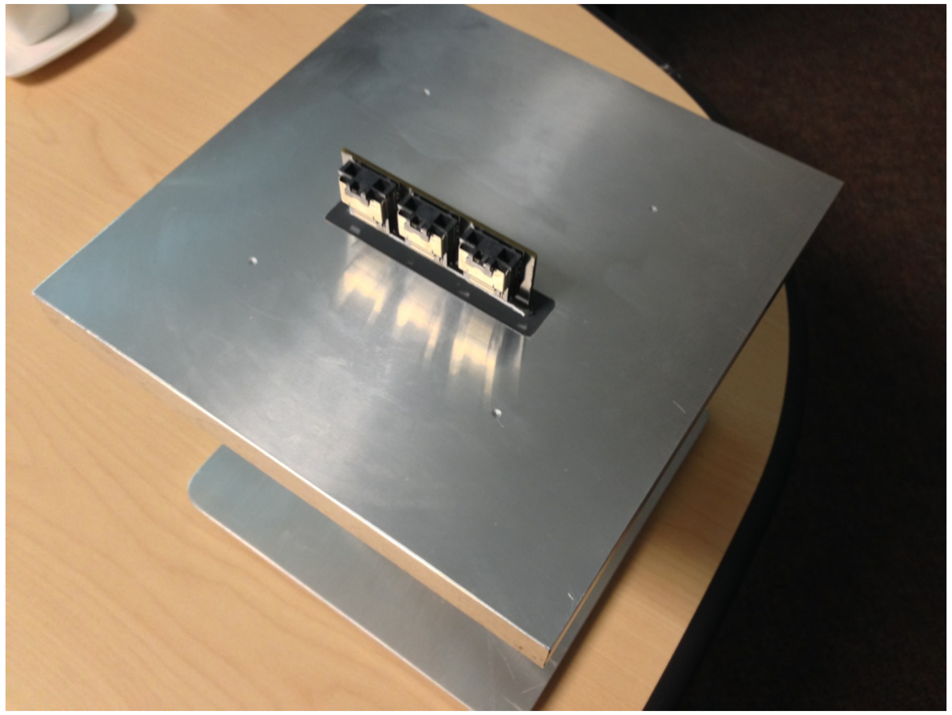
Services Status

Cooling

- SVT chiller delivered.

Power & DAQ

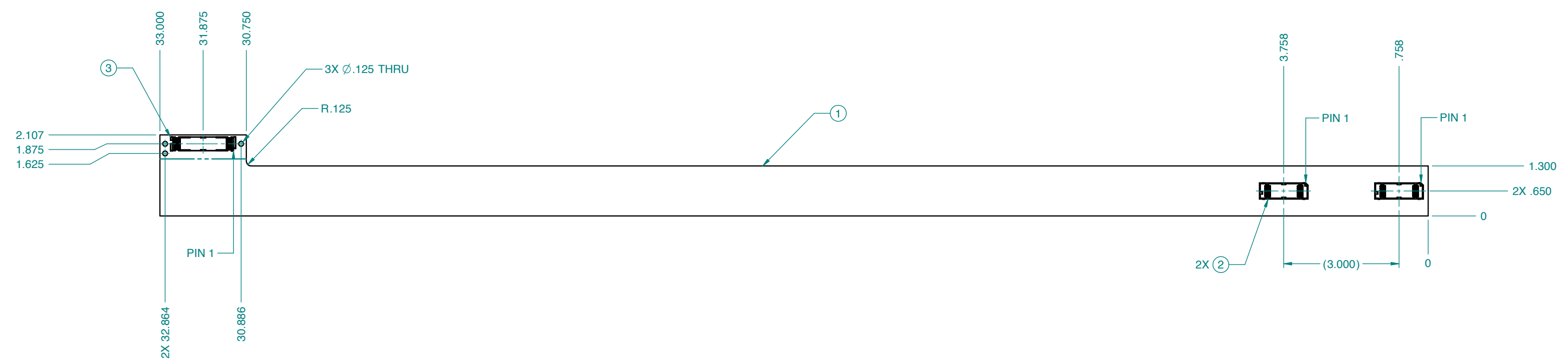
- Power supplies delivered.
- Vacuum flanges and flange boards (both power and DAQ) are ready for potting.
- Rough machining of FEB cooling plate underway to allow mockups of cable routing.
- *Most cabling in-hand with one major exception...*



Module to FEB Cables (DAQ)

Kapton flex cables are not a good fit:

- Too wide/thick (power requirements)
- Very long = high risk
- Impedance control is difficult

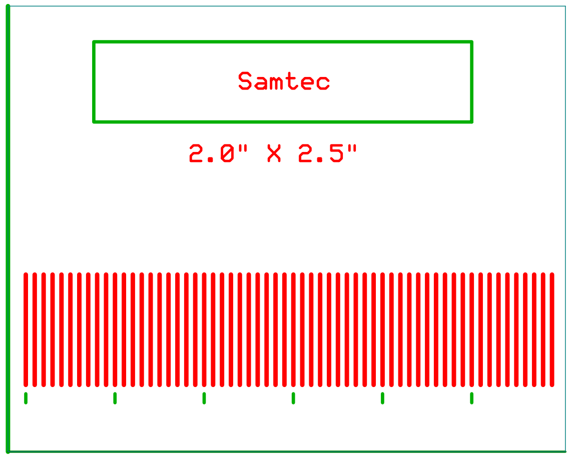


SLAC has experience with another solution for ATLAS: enameled, solid core magnet wire soldered to small "mezzanine board" housing the connector.

- Twisted pair with 100 Ohm impedance for analog/digital signals (custom)
- Plain wire for power (off the shelf)

Need the right enamel to simplify the task (~1000 conductors):

- ATLAS used polyimide: requires stripping with concentrated sulfuric acid at 100-130 C.
- Instead, we will use Polyester-imide (MW77 "Solidex")
  - Radiation tolerant to 10^7 Gy.
  - Vacuum compatible (NASA + SLAC testing).
  - Solderable (enamel becomes flux for solder process).



Survey and Alignment

All survey/alignment features are incorporated in the design to enable complete survey:

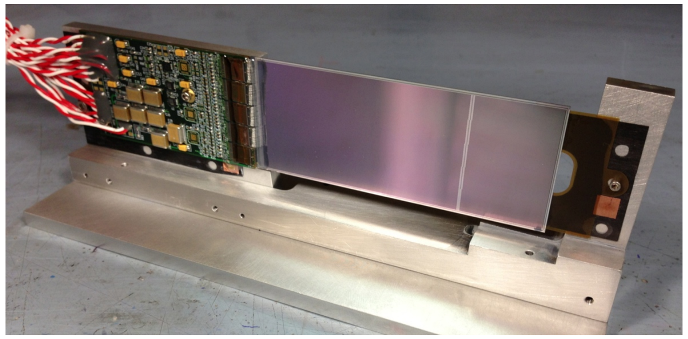
1. Face of modules surveyed optically to determine position, flatness of each sensor relative to the module support (~few μm)

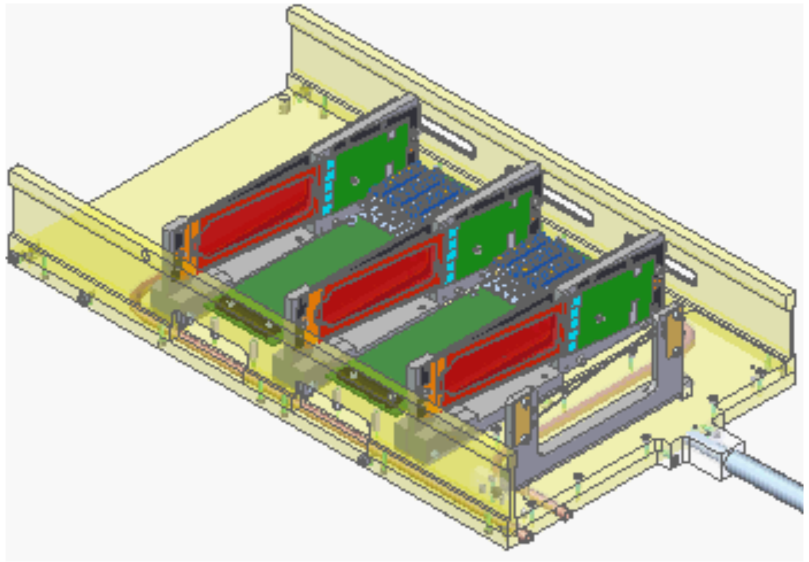
2. Edges of sensors surveyed after mounting support plates to determine sensor/module positions relative to support plates (~few μm)

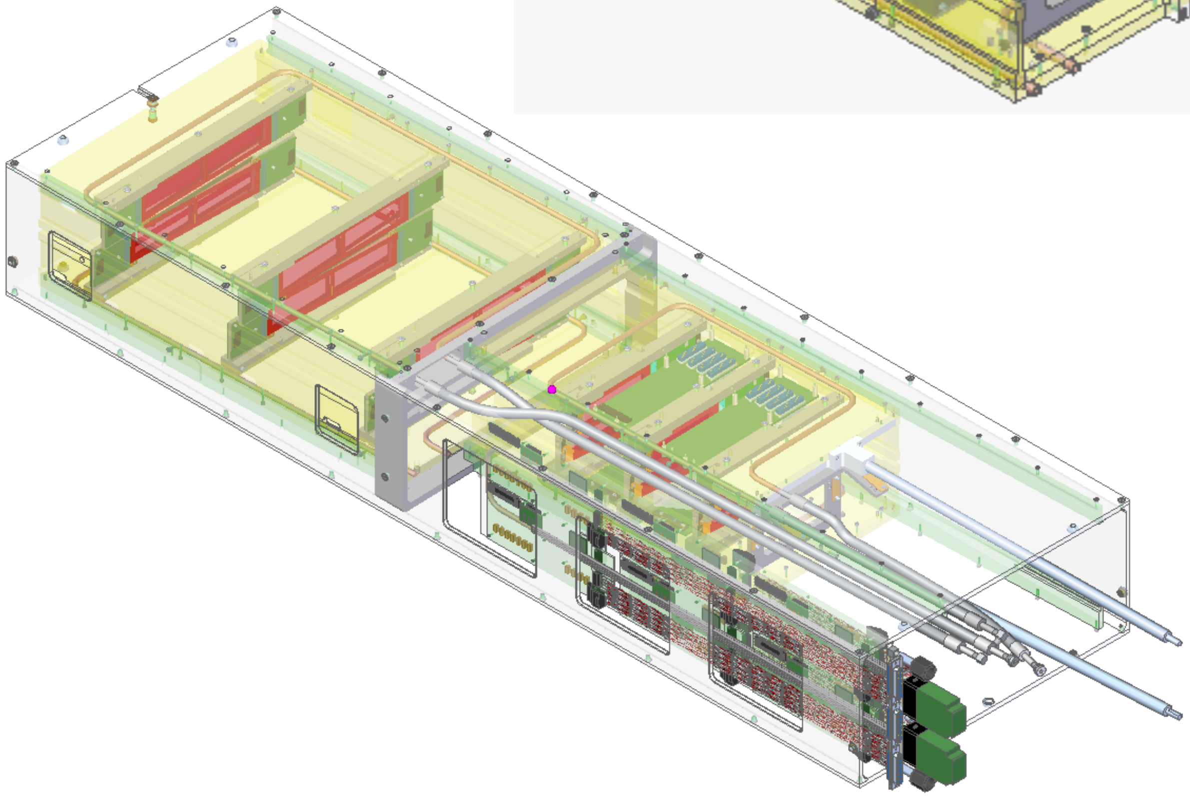
3. Support plates surveyed after installation on vertically adjustable kinematic mounts in support box to adjust/determine location of sensor groups relative to box. (~10 μm)

4. Support box surveyed after installation in PS vacuum chamber and adjusted to desired position relative to beamline. (100 μm?)

Have met with SLAC metrology and OGP (multi-sensor CMM) vendor to design the fiducials and get assistance with measurements.







Installation and Commissioning (Takashi)

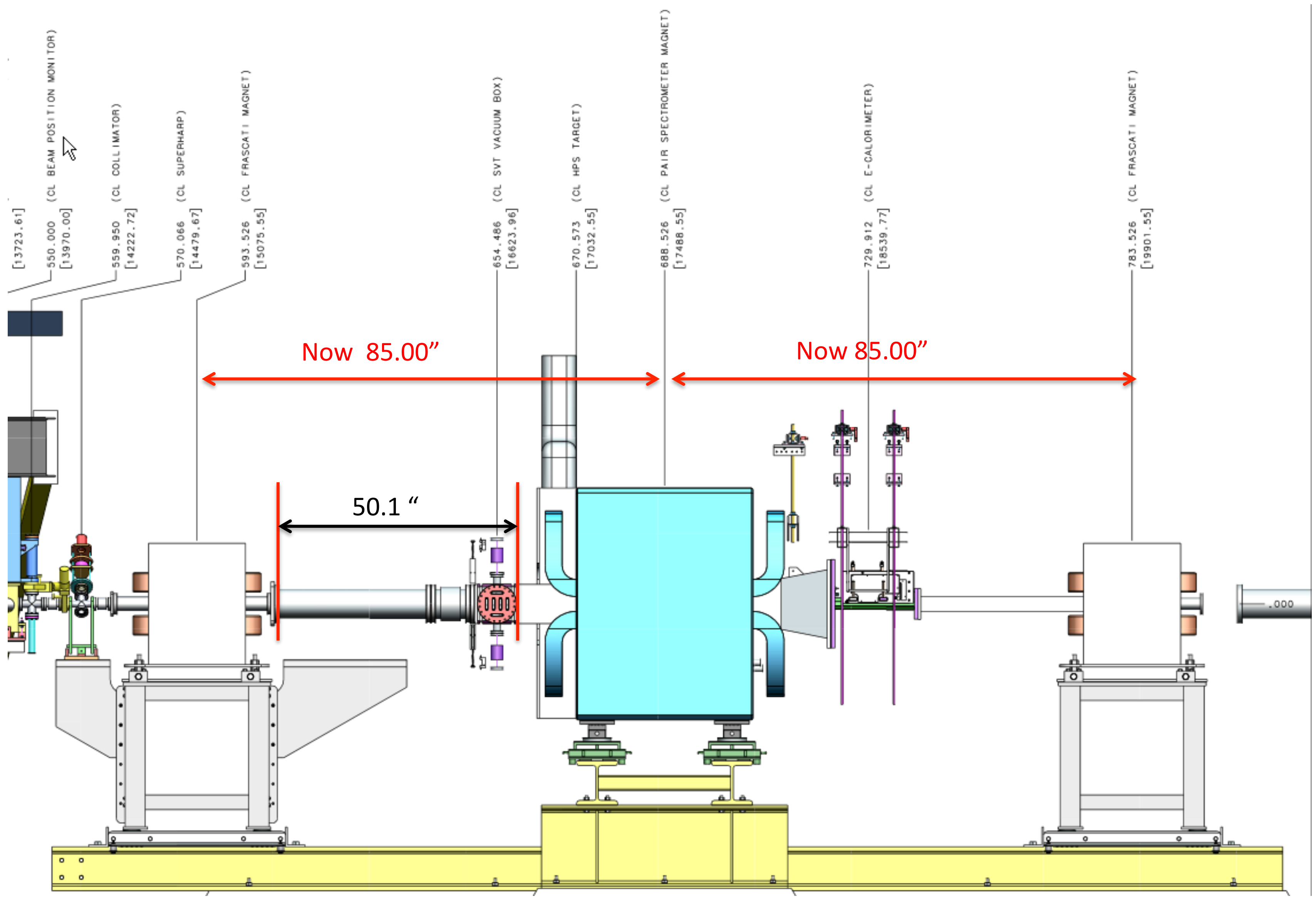
Installation for SVT is well understood:

- Length of SVT box requires move of upstream Frascati
- Survey requires access at both ends (and removal of ECal)
- SVT components serviceable without removal of box

Critical issues for commissioning are well understood:

- SVT motion safety
- Beam safety
- Alignment and calibration

These issues have been mostly discussed in other groups (beamline, analysis).
Needs coordination.



Schedule and Budget

- A number of big milestones in June and July on current schedule:
  We are at or ahead on all of them except...
  - fabrication delay on module supports
  - module to FEB cables

  Neither creates an overall delay.

- PM schedule shows SVT shipping in late September (2 week delay.)
  However, we are still working to be ready to ship in early Sept.

- SVT Mechanics currently under budget on both labor and M&S.
  - However, with project end date pushing forward, assuming we will need additional labor.
  - Requesting contingency funds from DOE according to conservative estimate of additional effort.

Documentation

- Have solid drafts of SVT ESAD and OSP for installation and operation.
- Have some text for Operations Manuals and have assigned authors, but these are not ready yet. Hope to get a good draft by early next week.

```
\chapter{SVT Controls, Monitoring and Alarms}
      \section{SVT Power Supplies}
            \subsection{System Description}
                  Pelle
            \subsection{Control}
                  Pelle, Omar
            \subsection{Monitoring, Alarms and Interlocks}
                  Pelle, Omar
      \section{SVT Cooling}
            \subsection{System Description}
                  Marco
            \subsection{Control}
                  Marco, Takashi
            \subsection{Monitoring, Alarms and Interlocks}
                  Sho, Pelle
      \section{SVT Position}
            \subsection{System Description}
                  Takashi
            \subsection{Control}
                  Takashi
            \subsection{Monitoring, Alarms and Interlocks}
                  Takashi, Sho
      \section{SVT Beam Conditions}
            \subsection{System Description}
                  Takashi
            \subsection{Monitoring, Alarms, and Interlocks}
                  Takashi, Sho
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Installation and Operation of the HPS SVT

1 Description of the Silicon Vertex Tracker

The SVT uses 6 layers of silicon extending from 10 cm to 90 cm downstream of the target inside of the PS vacuum chamber to measure charged particle trajectories. To accommodate the passage of the beam, the SVT is built in two halves, top and bottom, so that each layer consists of a pair of modules, one above and one below the beam plane. Each module uses silicon microstrip sensors placed back-to-back with a small stereo angle between sides to provide 3-d space points for the hits in a module. Modules for layer 1-3 have a single sensor on each side with readout at one end, while those for layers 4-6 are longer, with a pair of sensors on each side and readout at both ends.

Modules are supported in groups of three by a set of four support plates. The top and bottom support plates for the back half of the SVT (layers 4-6) are stationary. However, the supports for layers 1-3 can be opened and closed vertically around the beam, rotating around hinges behind layer 3 and moved by levers extending upstream to a pair of linear shifts outside of the magnet. The support plates are kinematically mounted inside a support box that installs into the PS vacuum chamber.

The first stage of readout electronics is located on a hybrid circuit board at the end of each sensor. Multiplexed analog signals from these boards are digitized by a set of 10 Front End Boards (FEBs) mounted to a separate cooling plate inside the SVT support box. Each FEB can control 4 hybrid/sensor units: a single module in layers 4-6 and either one or two modules in layers 1-3. The FEBs also control the hybrids, provide regulated low-voltage power from a single input, and pass externally generated bias voltages (HV) through to the sensors. The FEBs communicate with a set of 4 Signal Flange Boards (SFB), up to three per SFB, which transmit digital signals through the vacuum penetration. The exterior side of each flange board converts digital to optical signals for communication with the RCE DAQ. Power to

Summary

- SVT is transitioning from design/fabrication to final assembly
- SVT and SVT DAQ are separately in good shape. *The big question is time required for final integration.*
- We have scrambled to deal with some integration setbacks, especially the module cables. We are working hard to ensure this doesn't delay final SVT/DAQ integration.
- If module cables and FEB services come together quickly, we could have the SVT fully assembled by early August for early September shipping.
- Plans for alignment/survey, installation and commissioning are in good shape, with only a few questions remaining.
- We will probably need some contingency money for SVT Mechanics (and almost certainly for SVT DAQ.) Making a conservative request to ensure we can complete the project on time.
- Documentation for the readiness review will soon be complete.

Backup

SVT Requirements

Detailed simulation of physics performance for proposal determines requirements

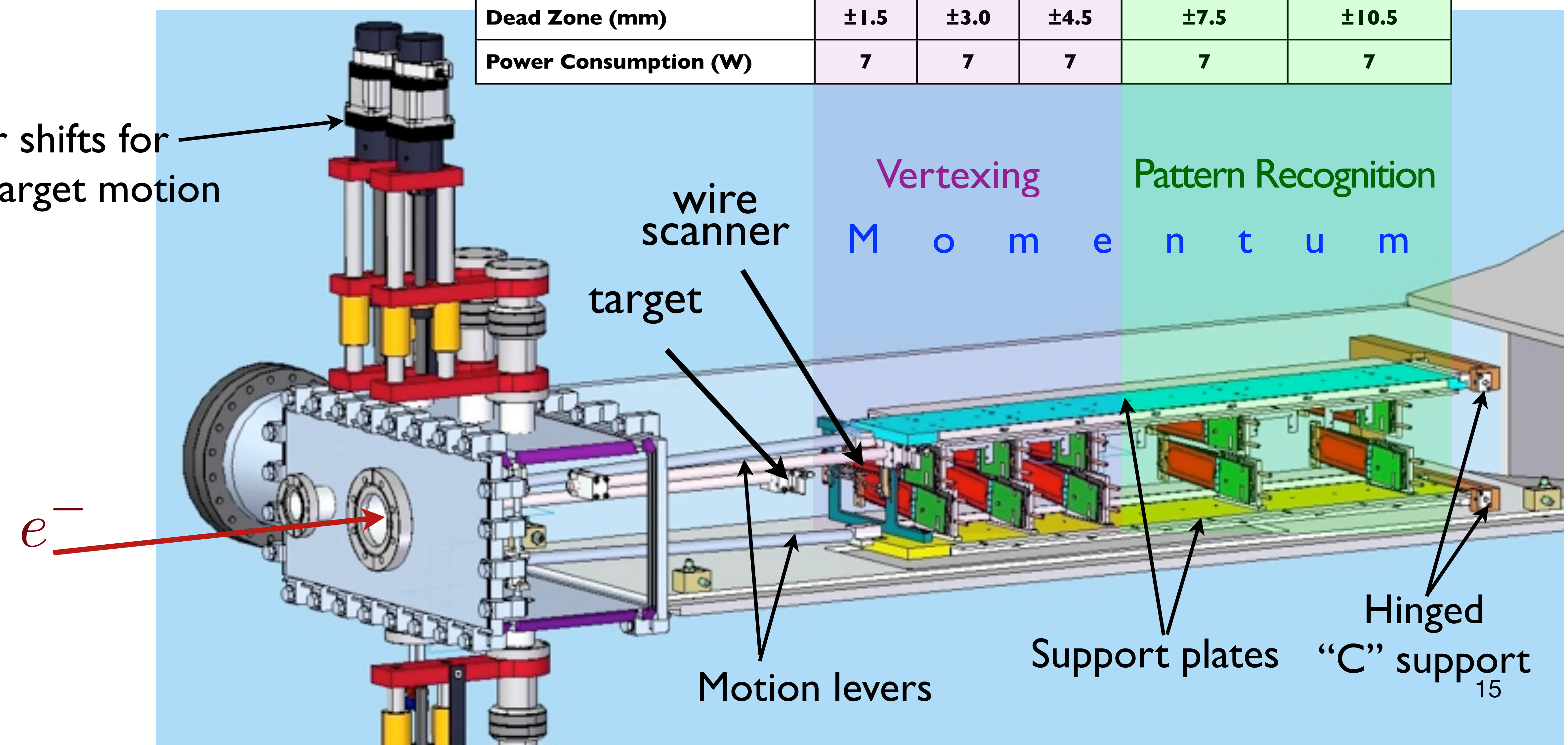
- Material budget
  - 0 material along beamline (detector in vacuum)
  - 0.7% X_0 / 3d measurement in tracking volume
- Acceptance
  - >15 mr from beam axis
- Hit efficiency and resolution
  - >99% single-hit efficiency
  - position: $\sigma_x < 125\ \mu\text{m}$, $\sigma_y < 10\ \mu\text{m}$ (performance limited by multiple scattering / beam size)
  - time: $\sigma_{t0} \approx 2$ ns
- Occupancy / speed
  - trigger rate > 20 kHz
  - peak occupancy ≈ 4 MHz/mm^2
- Radiation
  - Bulk damage from electrons equivalent to > 1×10^{14} 1 MeV neq.
  - Neutrons from backscattered beam
  - X-rays from target

HPS Test SVT

Proposed 3/11, Installed 4/12

- Develop technical solutions
- Prove operational principles
- Capable of A′ physics

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

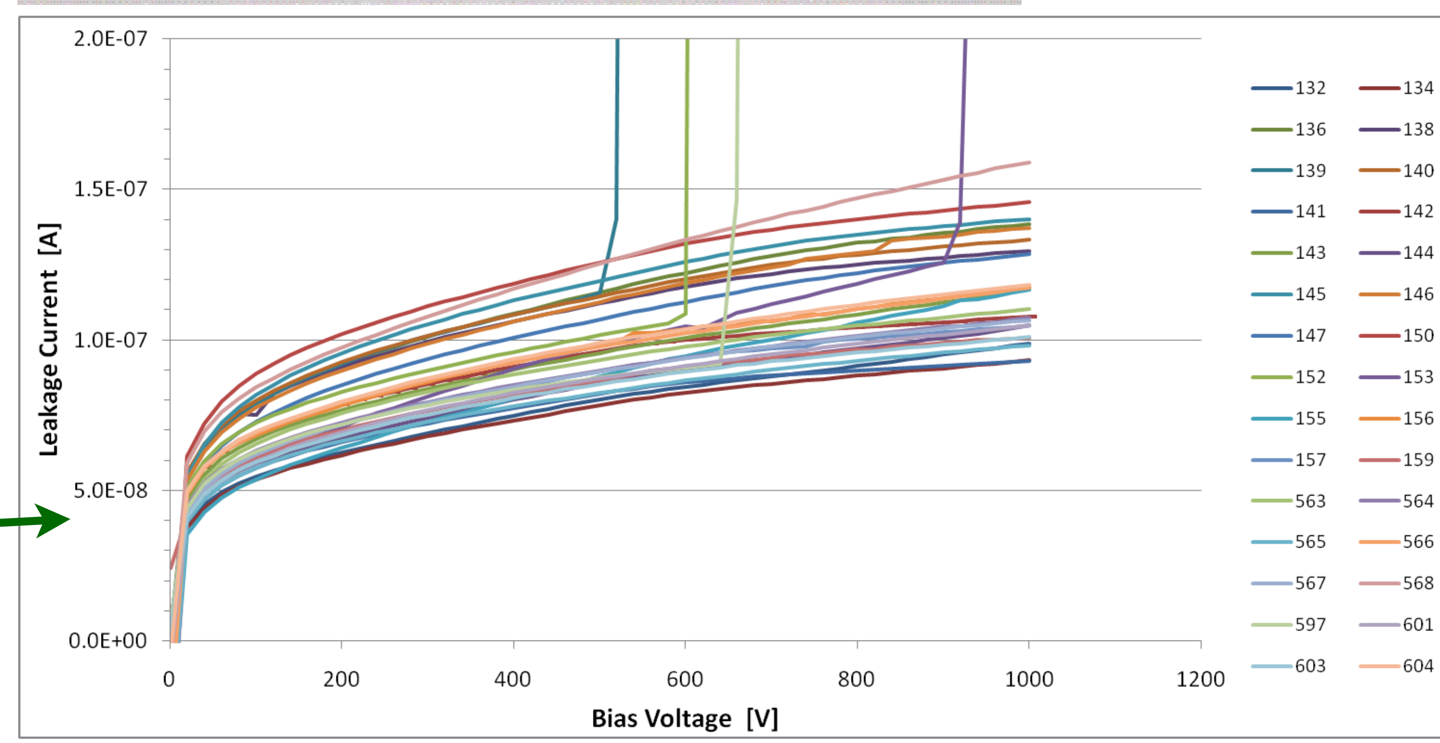


Silicon Microstrip Sensors

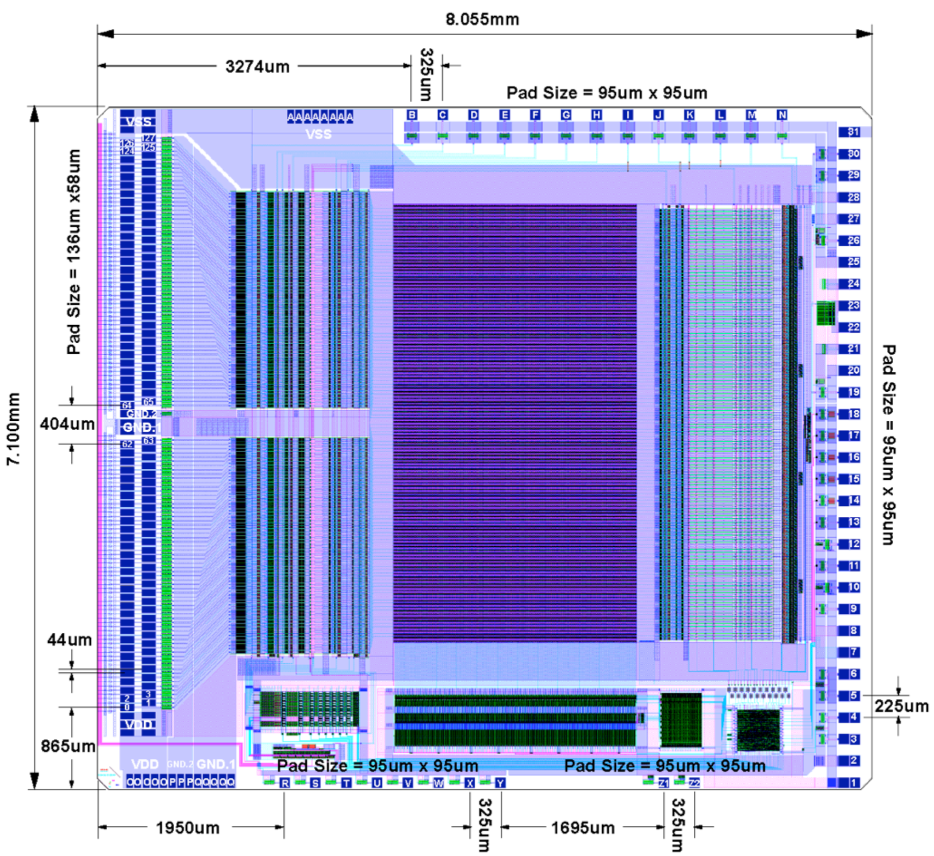
Production Tevatron RunIIb sensors (HPK):

- 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%**



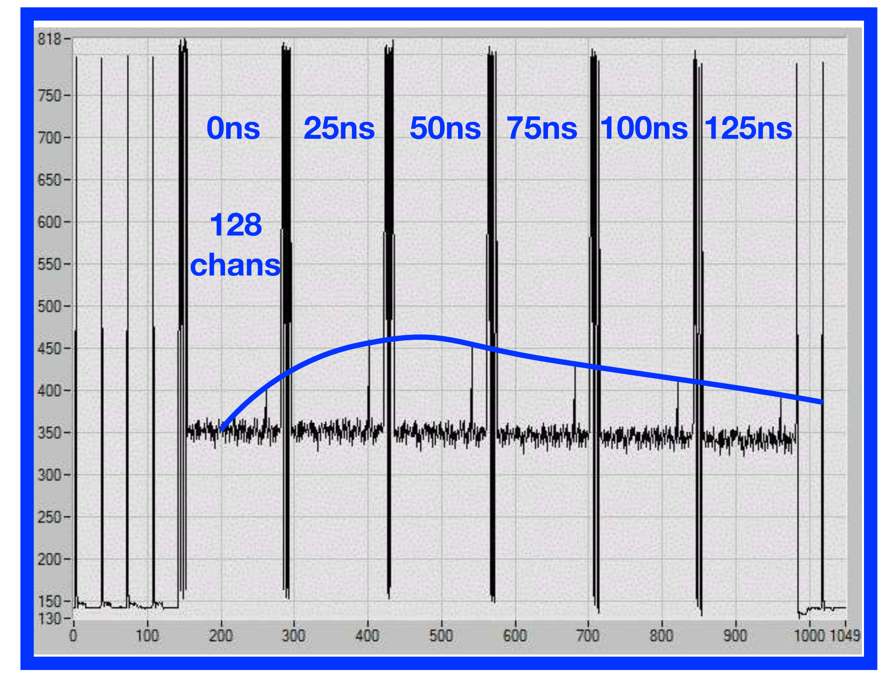
Front-end Electronics: APV25

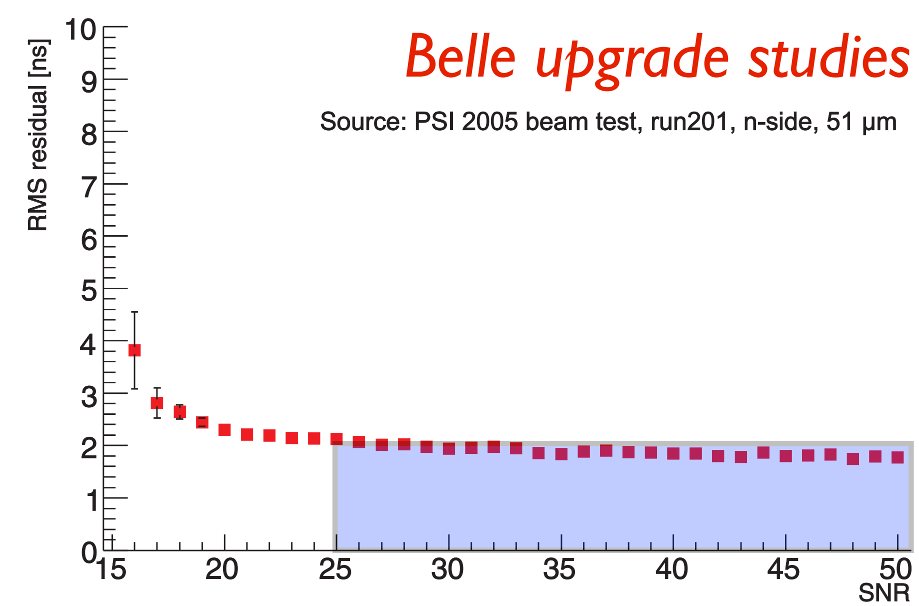


# Readout Channels	128
Input Pitch	44 µm
Shaping Time	50ns nom. (35ns min.)
Noise Performance	270+36×C(pF) e⁻ ENC
Power Consumption	345 mW

Developed for CMS

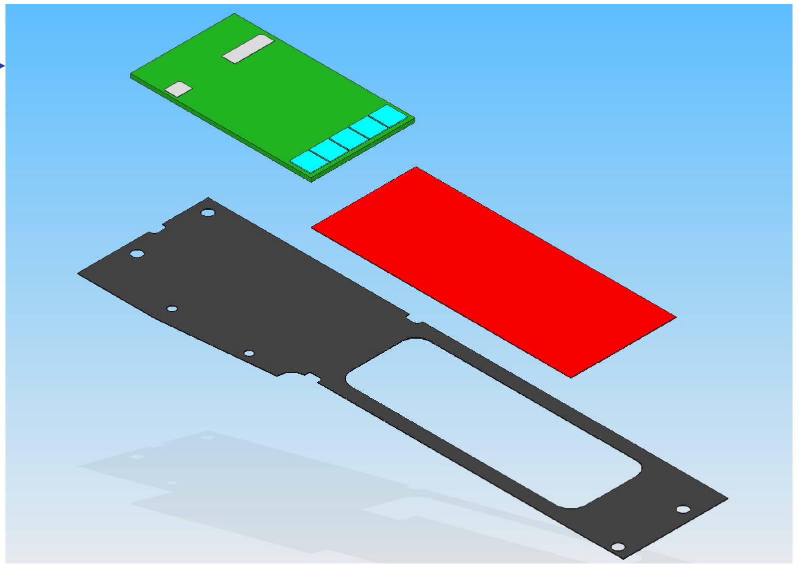
- available (~~28~~ CHF/ea.) *15!*
- radiation tolerant
- fast front end (35 ns shaping time)
- low noise (S/N ≅ 25)
- "multi-peak" readout
- ~2 ns t_0 resolution!

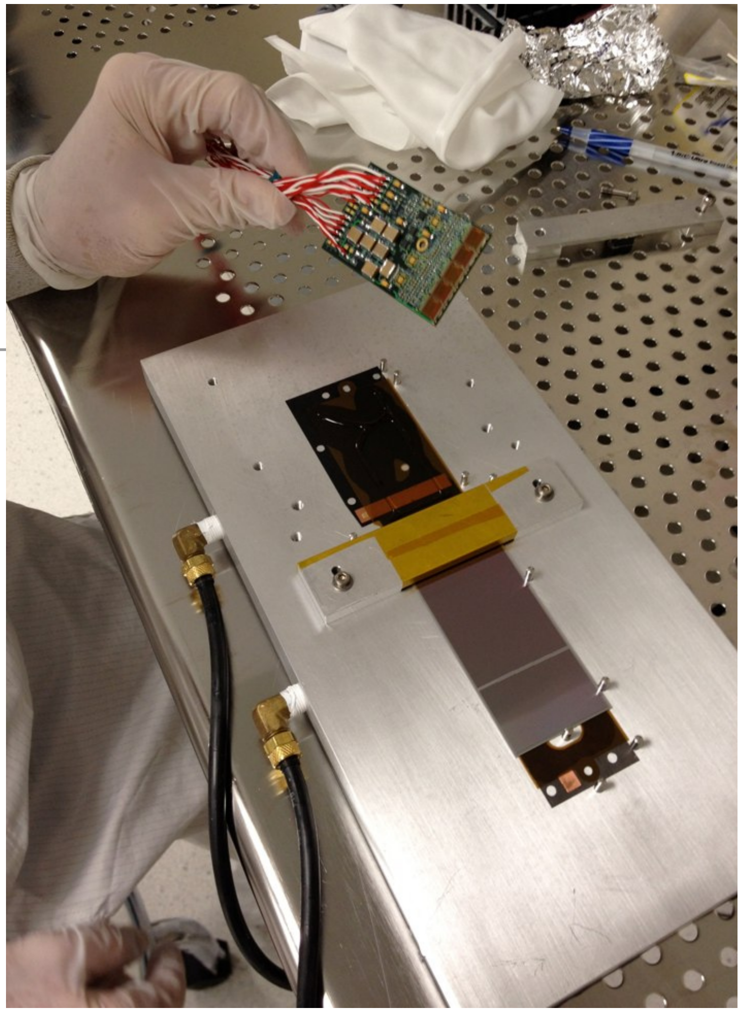




Test SVT Modules

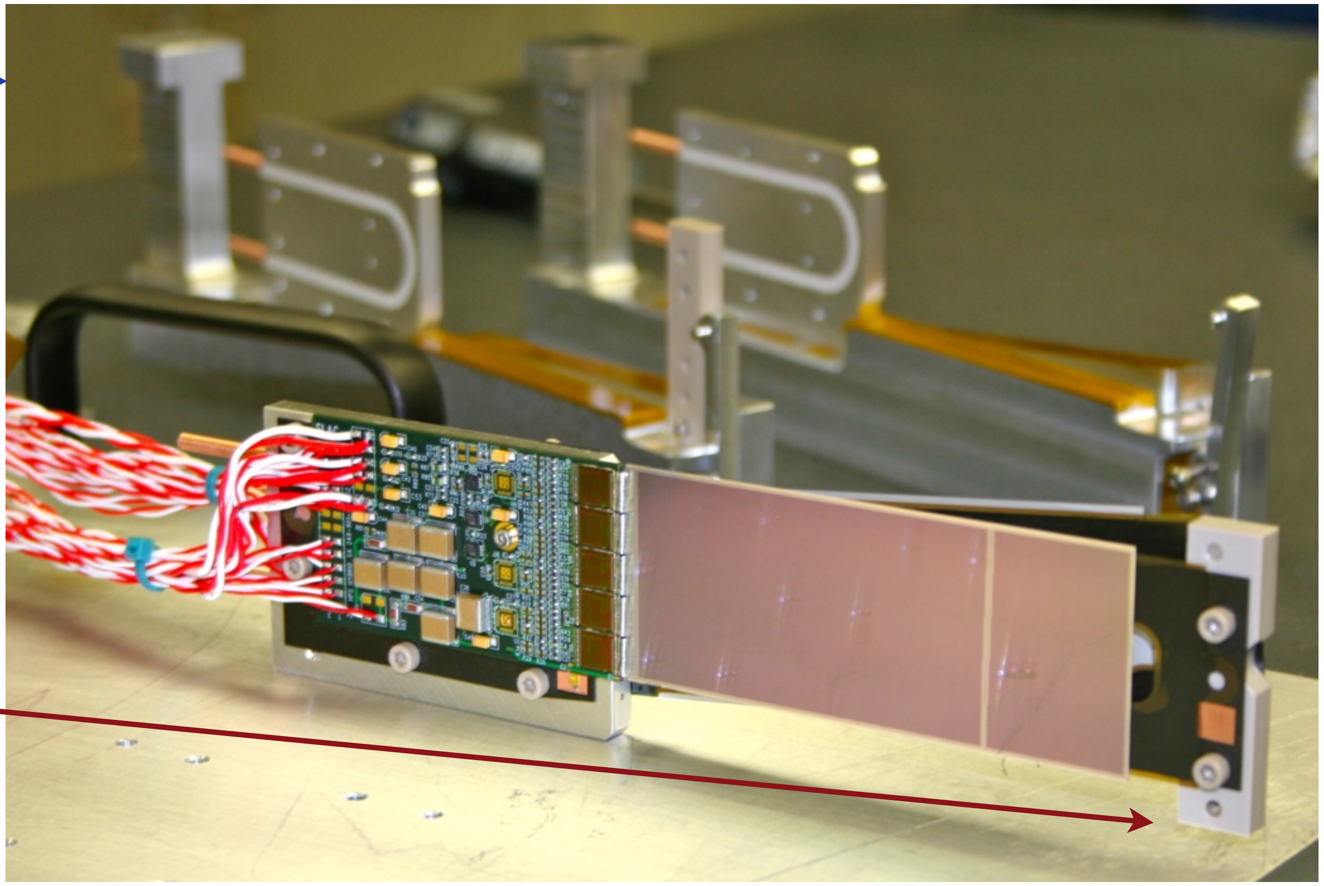
Half Module





- 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*

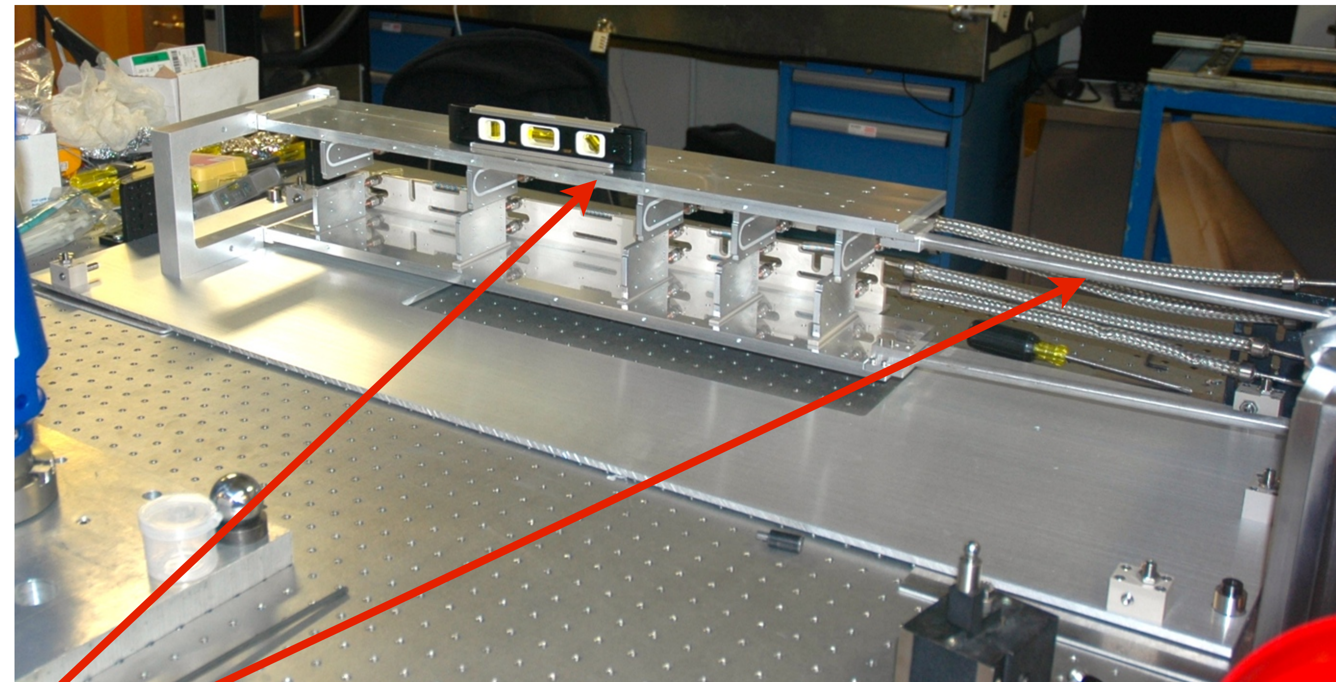
➡ *Compromised cooling limits radiation tolerance*

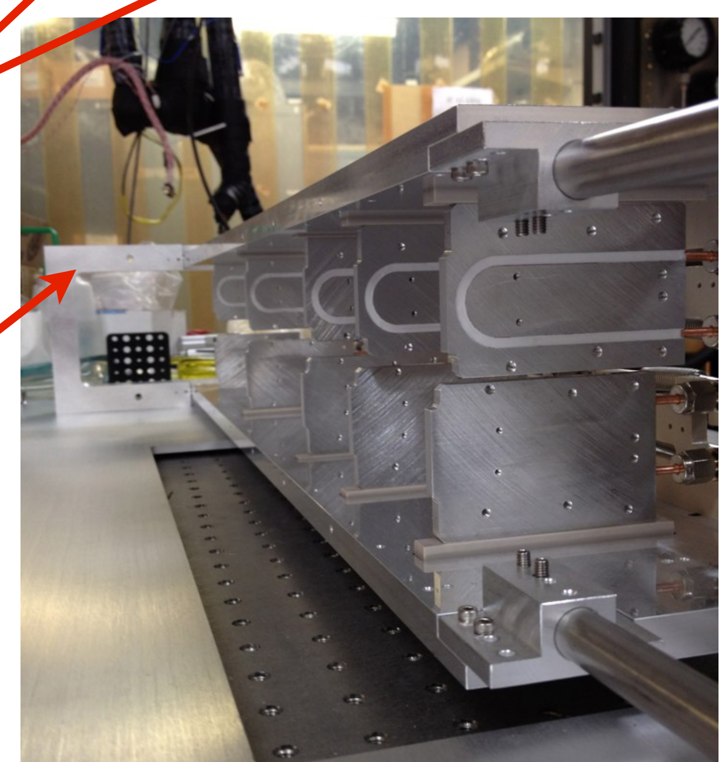
Test SVT Mechanics

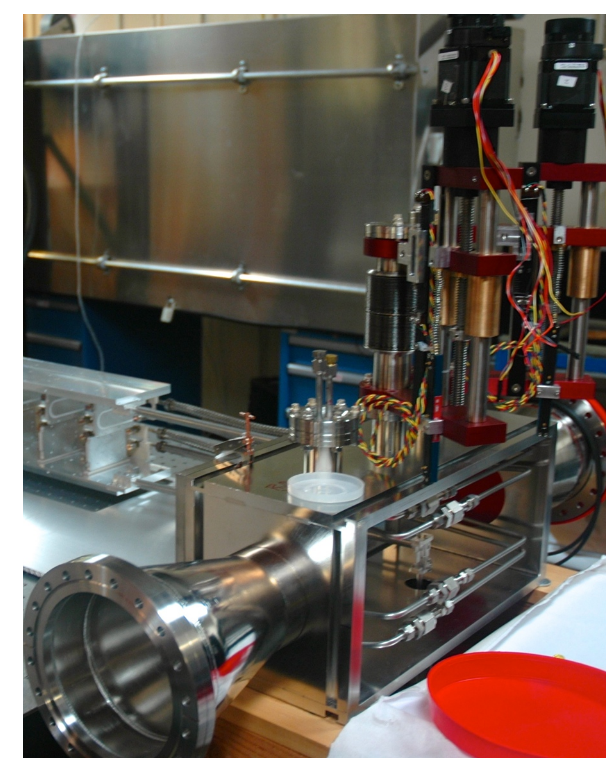
Cooling blocks mount on Al support plates with hinged “C-support” and motion lever

- 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 significant roll in top plate.

Works, but can be improved upon

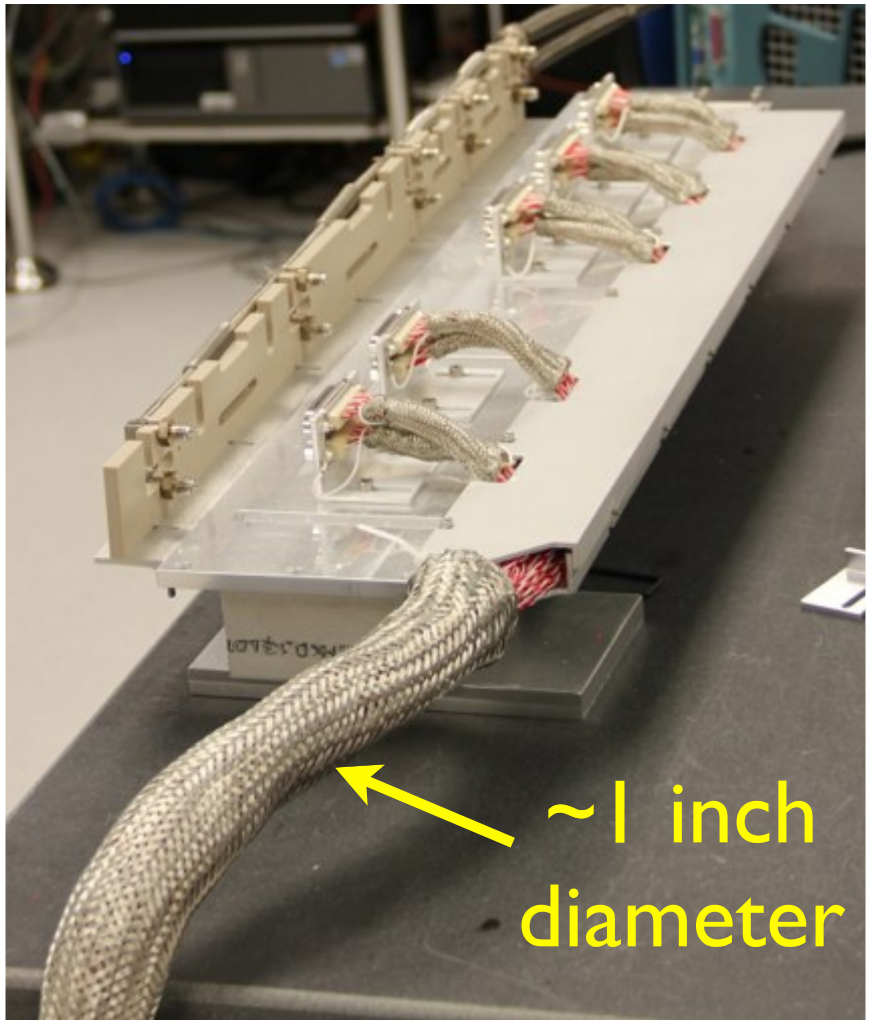


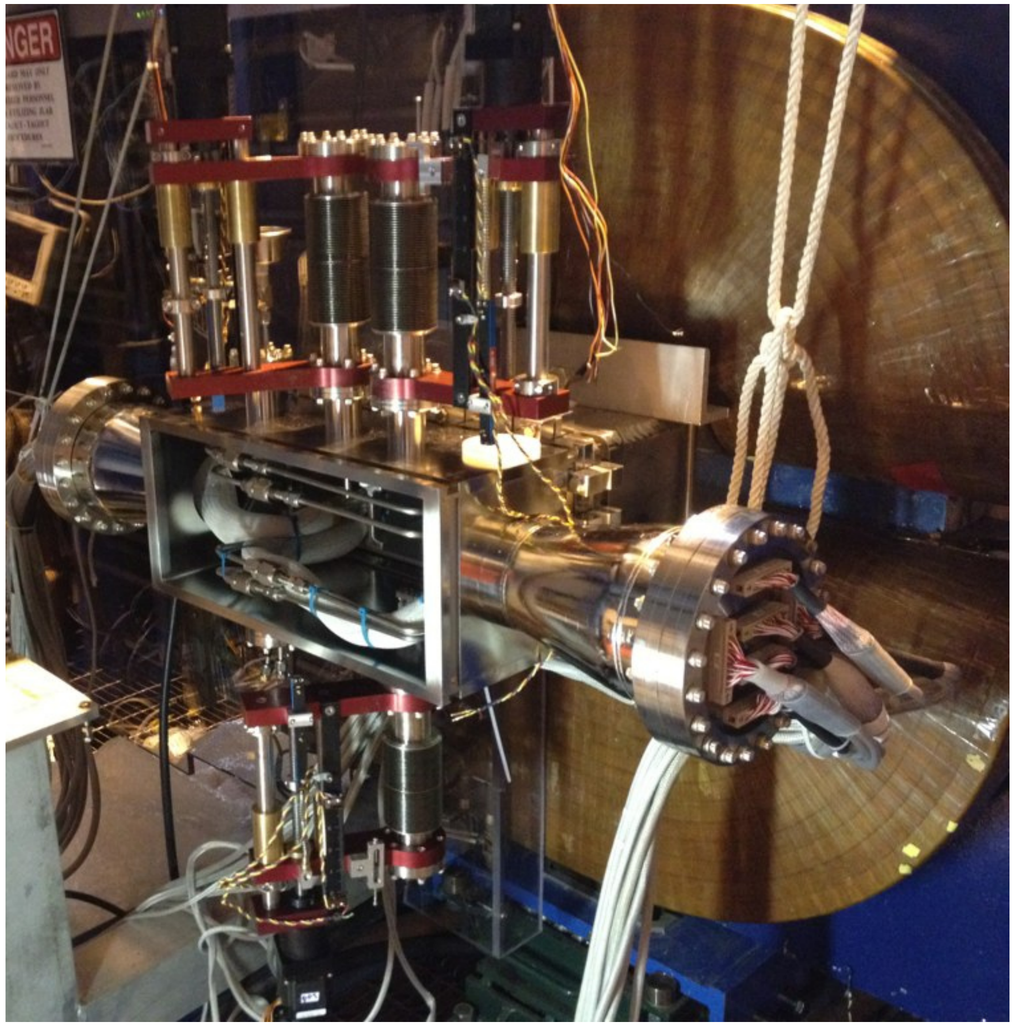




Test SVT Services

- 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 Requirements: Test Run

Due to JLab Hall B schedule constraints, test run did not include high intensity electron beam:

- Material budget
  - 0 material along beamline (detector in vacuum)
  - 0.7% X_0 / 3d measurement in tracking volume
- Acceptance
  - >15 mr from beam axis (compromised by support rigidity)
- Hit efficiency and resolution
  - >99% single-hit efficiency
  - position: $\sigma_x < 125\ \mu m$, $\sigma_y < 10\ \mu m$ (performance limited by multiple scattering / beam size)
  - time: $\sigma_{t0} \approx 2$ ns
- Occupancy / speed
  - trigger rate > 20 kHz (limited by DAQ)
  - peak occupancy ≈ 4 MHz/mm^2
- Radiation
  - Bulk damage from electrons equivalent to > 1×10^{14} 1 MeV neq. (limited by sensor cooling)
  - Neutrons from backscattered beam
  - X-rays from target

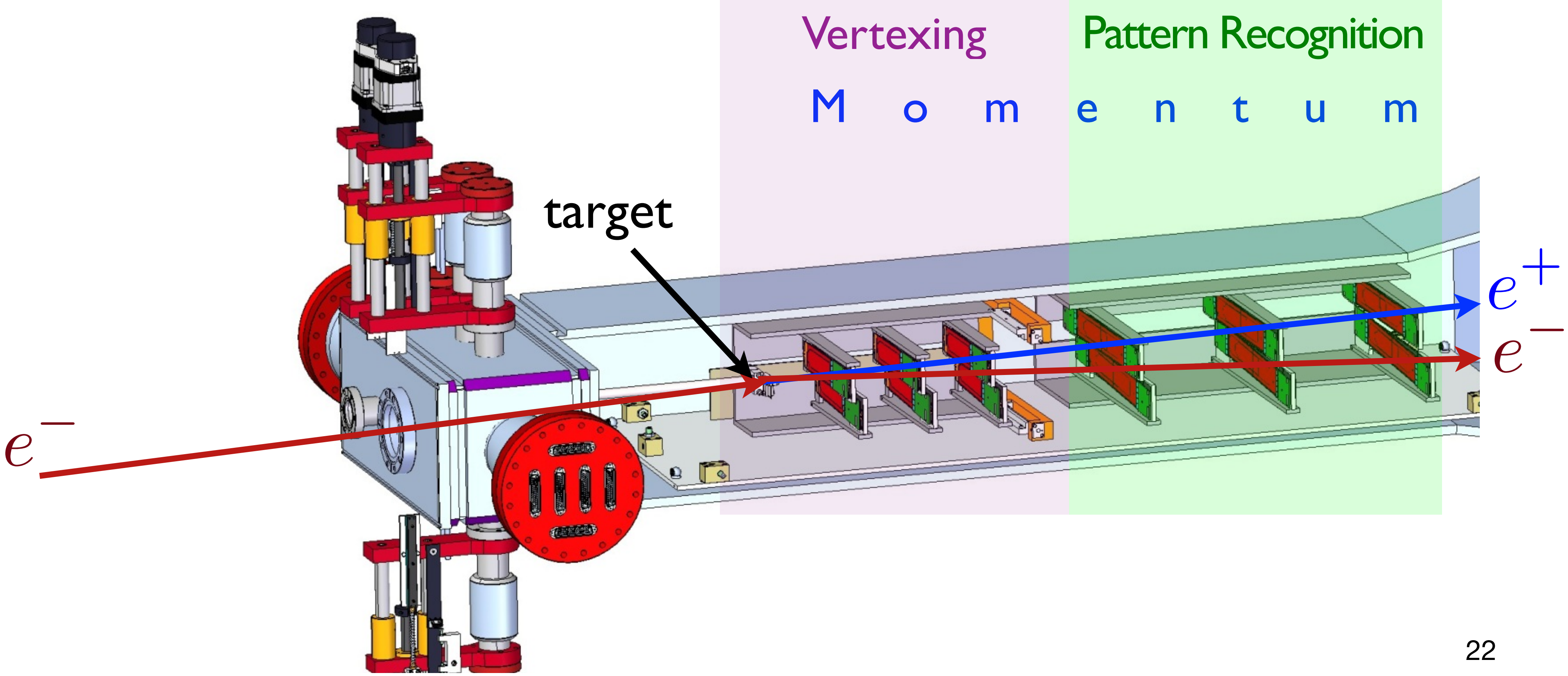
Met and verified
Met, not verified
not met by design

HPS SVT Layout Changes

An evolution of Test SVT Layout

- Layers 1-3: same layout as 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



Key SVT Improvements

- New modules for L1-L3 to improve cooling and alignment
  - Reuse existing half-modules with new module supports.
- New, longer modules for L4-L6
  - New, double-length half-modules
  - Longer module supports with new support design
- New support structure for detector modules with improved rigidity
- Move DAQ / power distribution inside of vacuum chamber on new "Front-End Boards" to reduce vacuum penetrations.
  - Cooled support structure for new Front End Boards (FEB)
  - New flanges with high-density feedthroughs for data and power

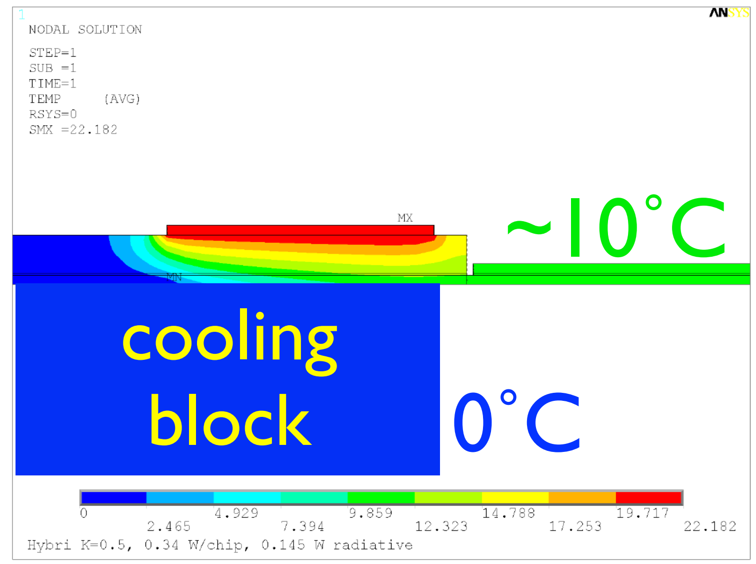
+ SVT DAQ improvements

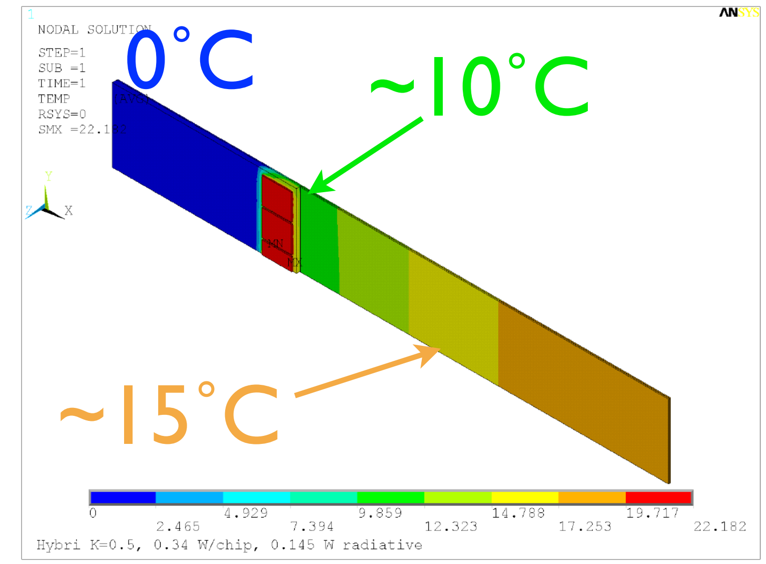
New Layer 1-3 Modules

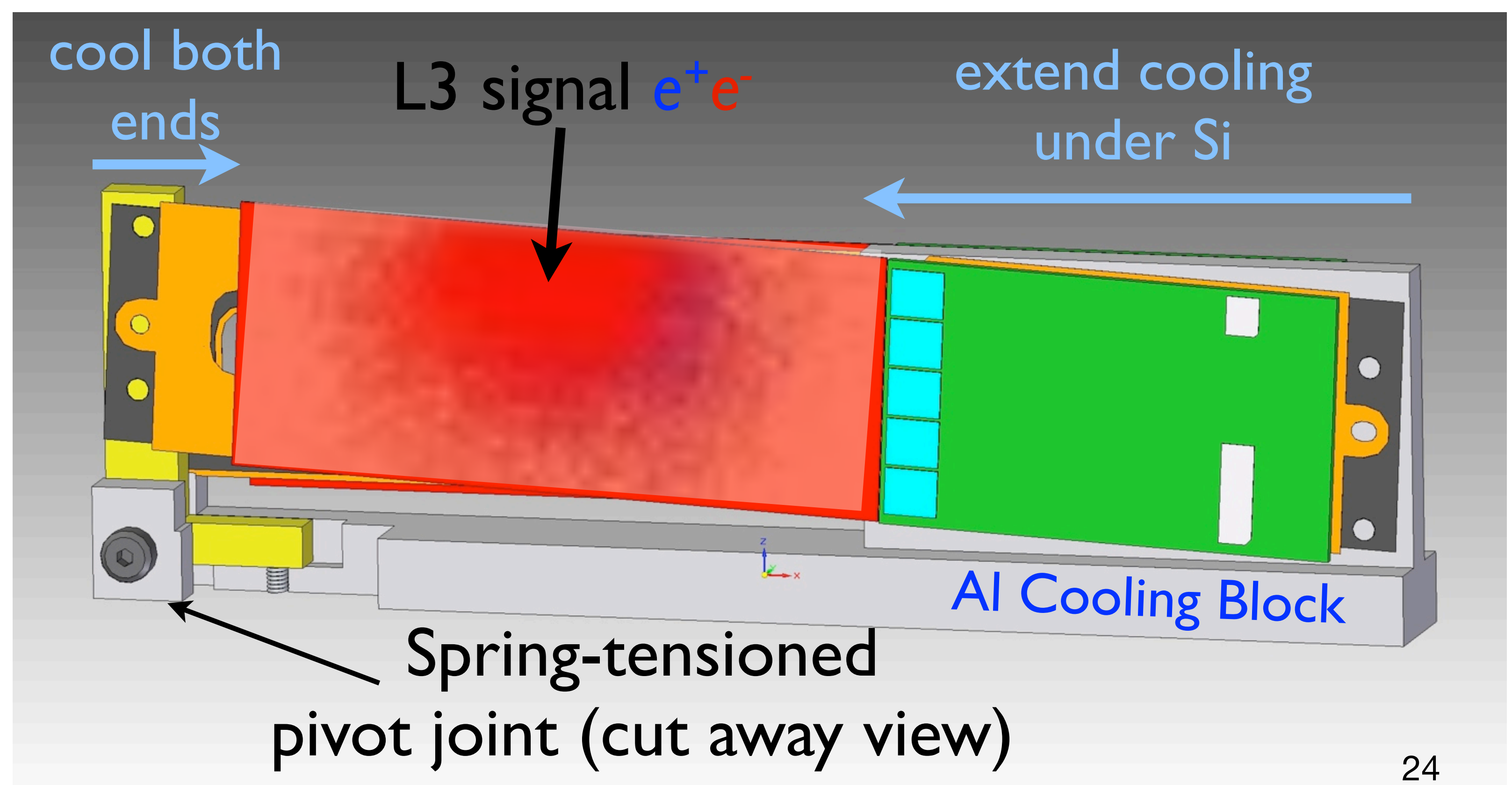
Reuse half-modules from HPS Test, but with improved module supports: tension CF between cooled uprights.

- 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



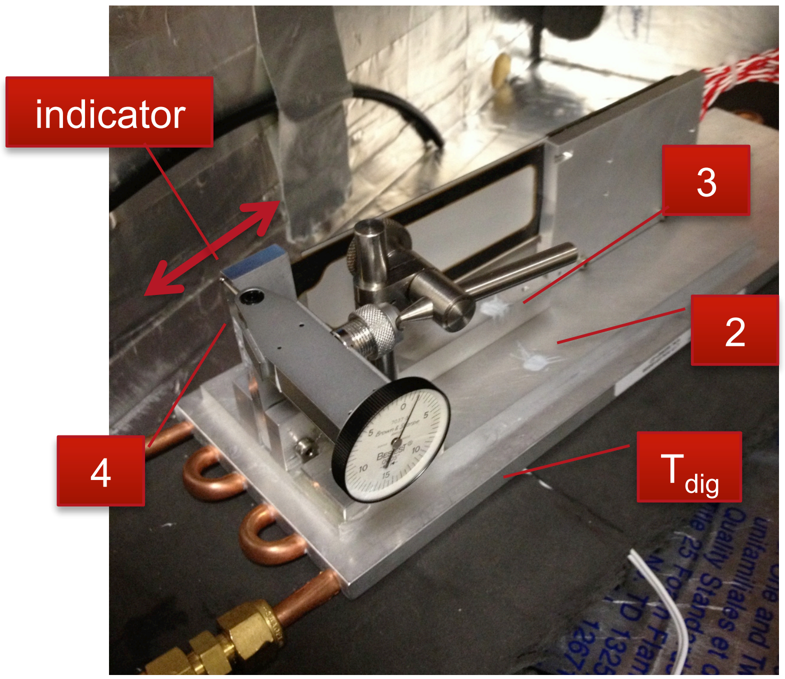


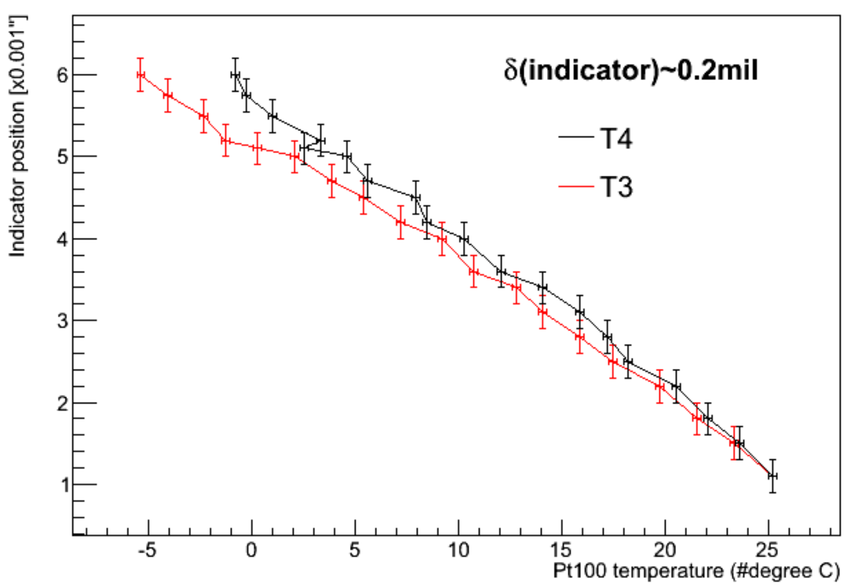


New Layer 1-3 Modules

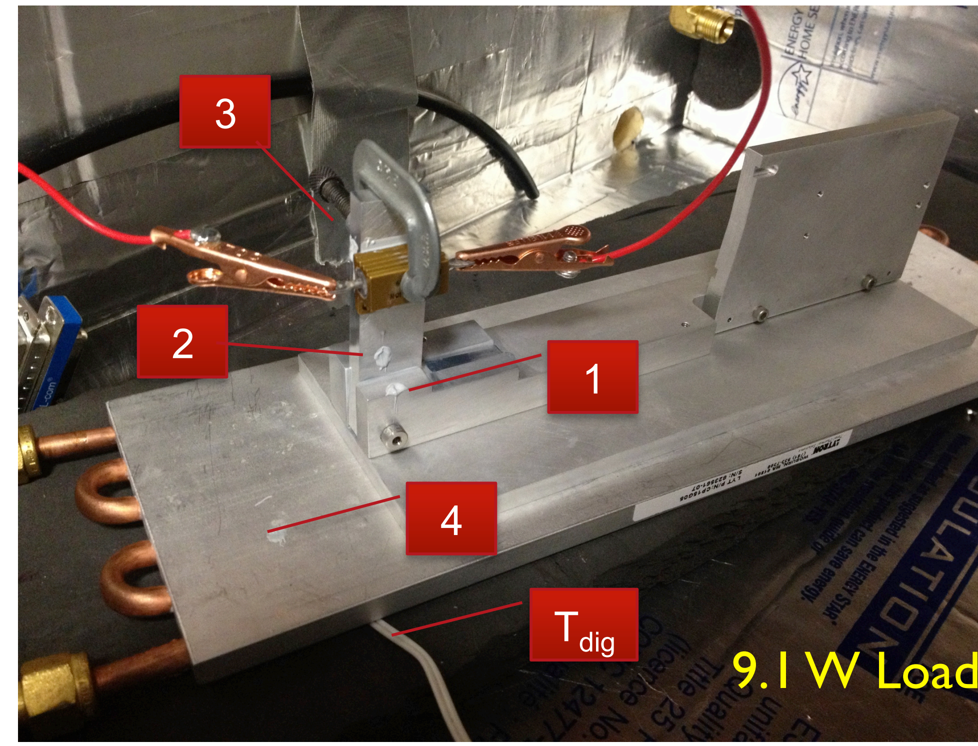
Layer 1-3 Module Status

Pivot operates smoothly during cool-down





Heat flow through pivot is sufficient



Thanks to Pelle!

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

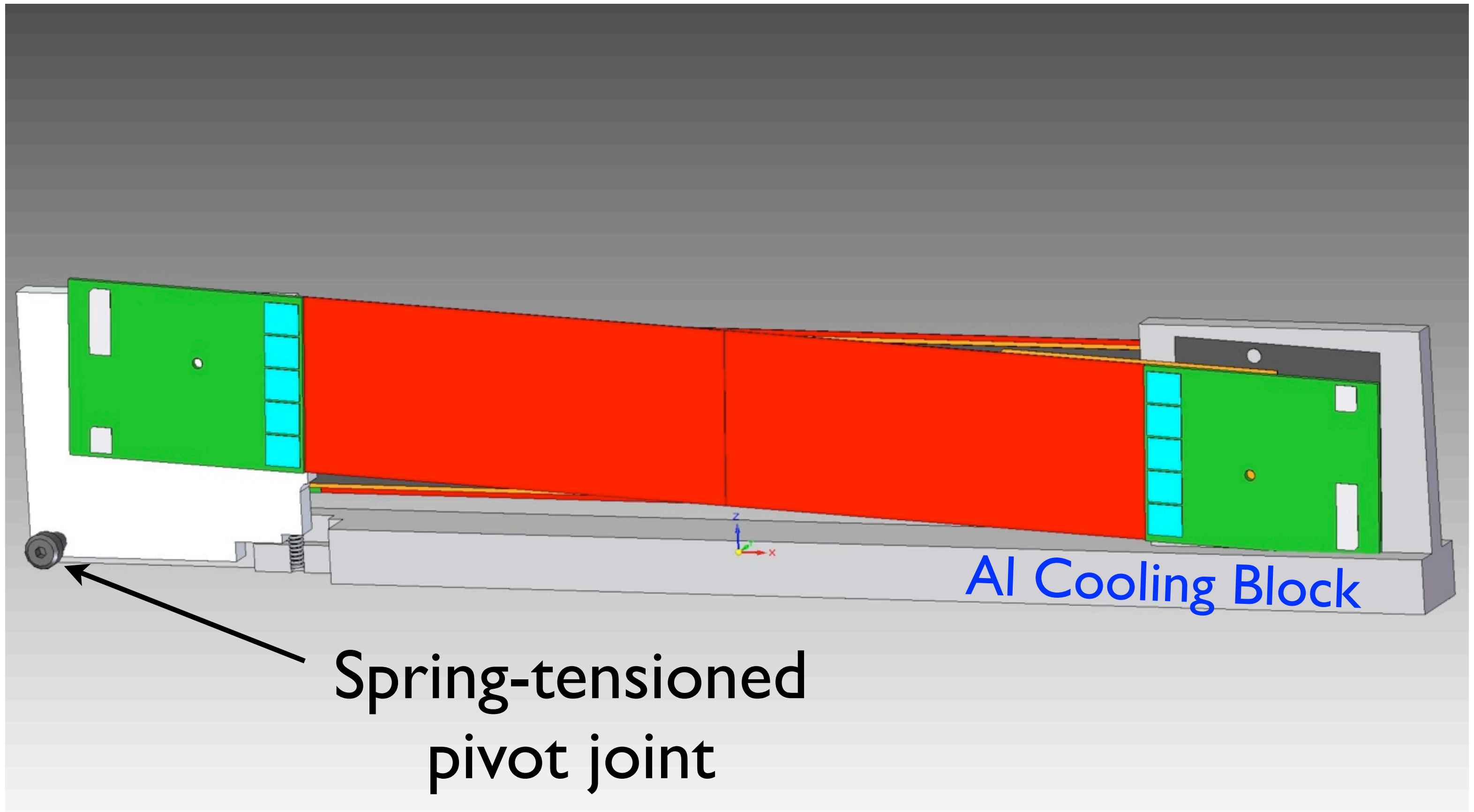
Module support concept is sound for both L1-3 and L4-6

Layer 4-6 Modules

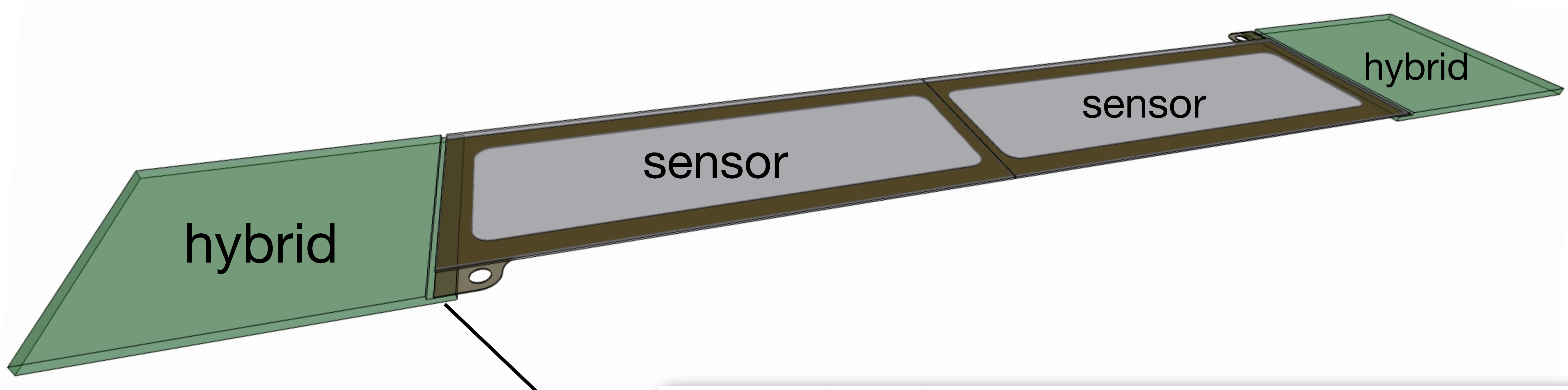
Extending concept to L4-L6 allows same material budget for long modules.

- 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



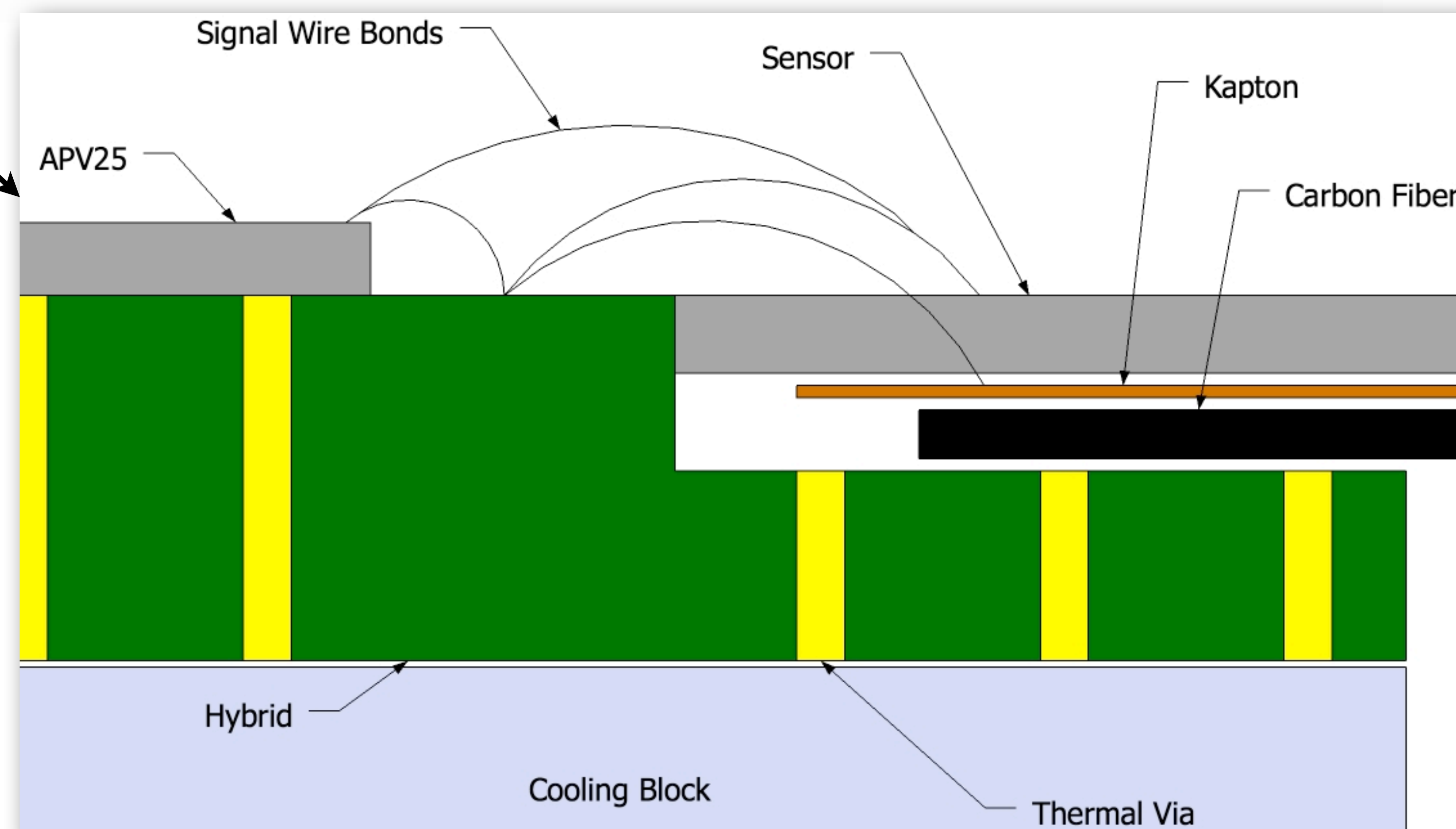
Similar to L1-L3 design, but...

- 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 Module Status

Sensors

- Received from FNAL
- QA testing at UCSC complete

Hybrids

- Received from fabrication
- Temperature sensor error requires re-spin
- DAQ qualification completed w/o temp. sensor
- V2 now on order

Carbon Fiber

- Received from FNAL
- a few have problems, we will need more to make planned spares

Kapton

- Received from fabrication
- quality is good

New materials

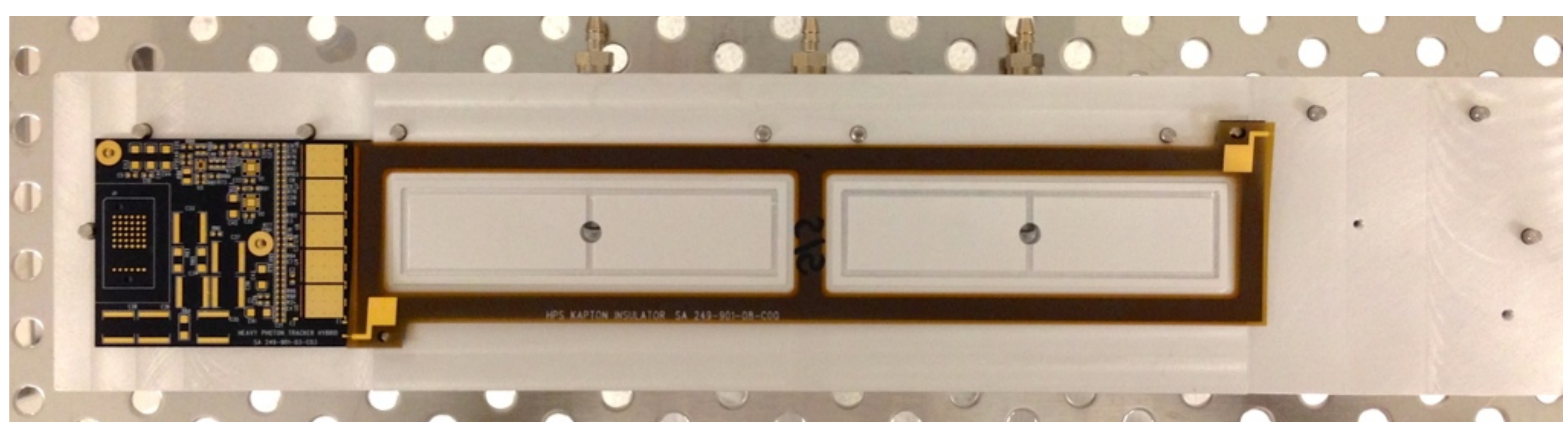
- Silver epoxy passed vacuum test
- New structural epoxy passed vacuum test
- New hybrid connectors passed vacuum test

Supports

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

Fixtures

- All assembly, wirebonding, testing/transport/storage fixtures are in hand.
- Currently dry-fitting parts to identify issues

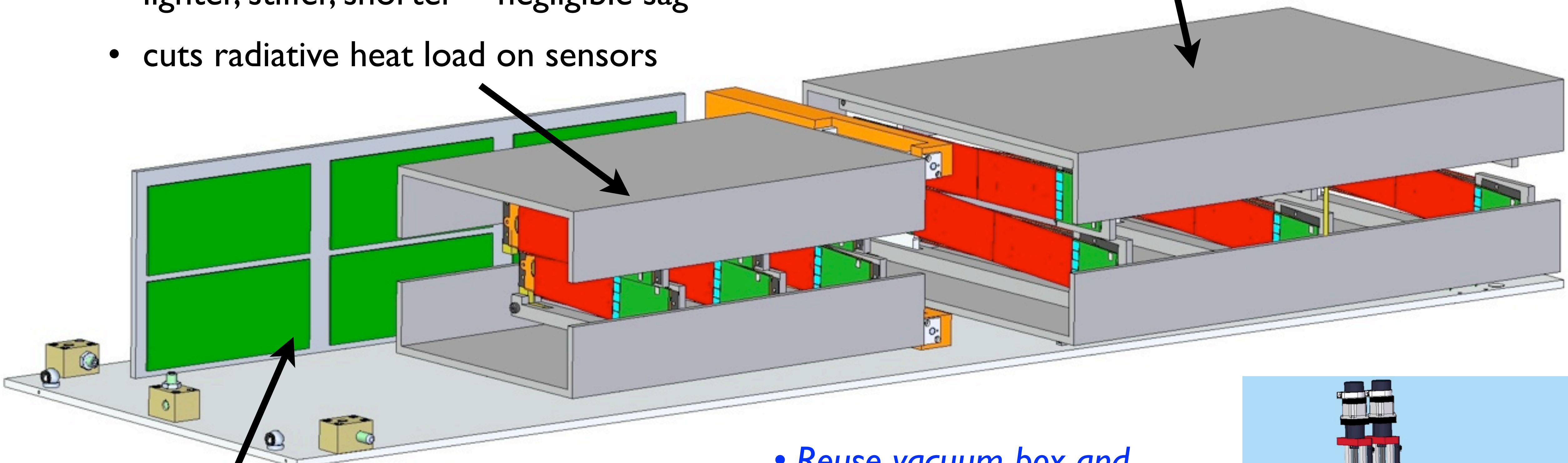


SVT Support, Cooling and Services Changes

Cooled support channels for L1-L3

- reuse pivot concept for motion
- lighter, stiffer, shorter = negligible sag
- cuts radiative heat load on sensors

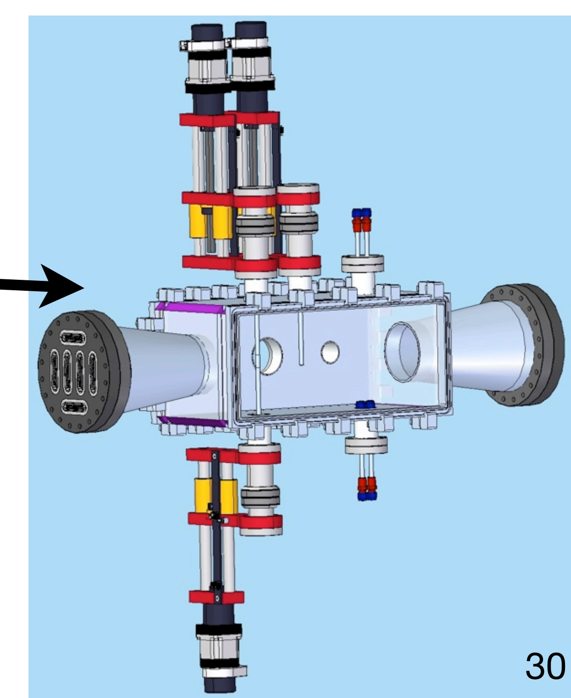
Cooled support channels for L4-L6 are stationary



DAQ/power inside chamber on cooling plate

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

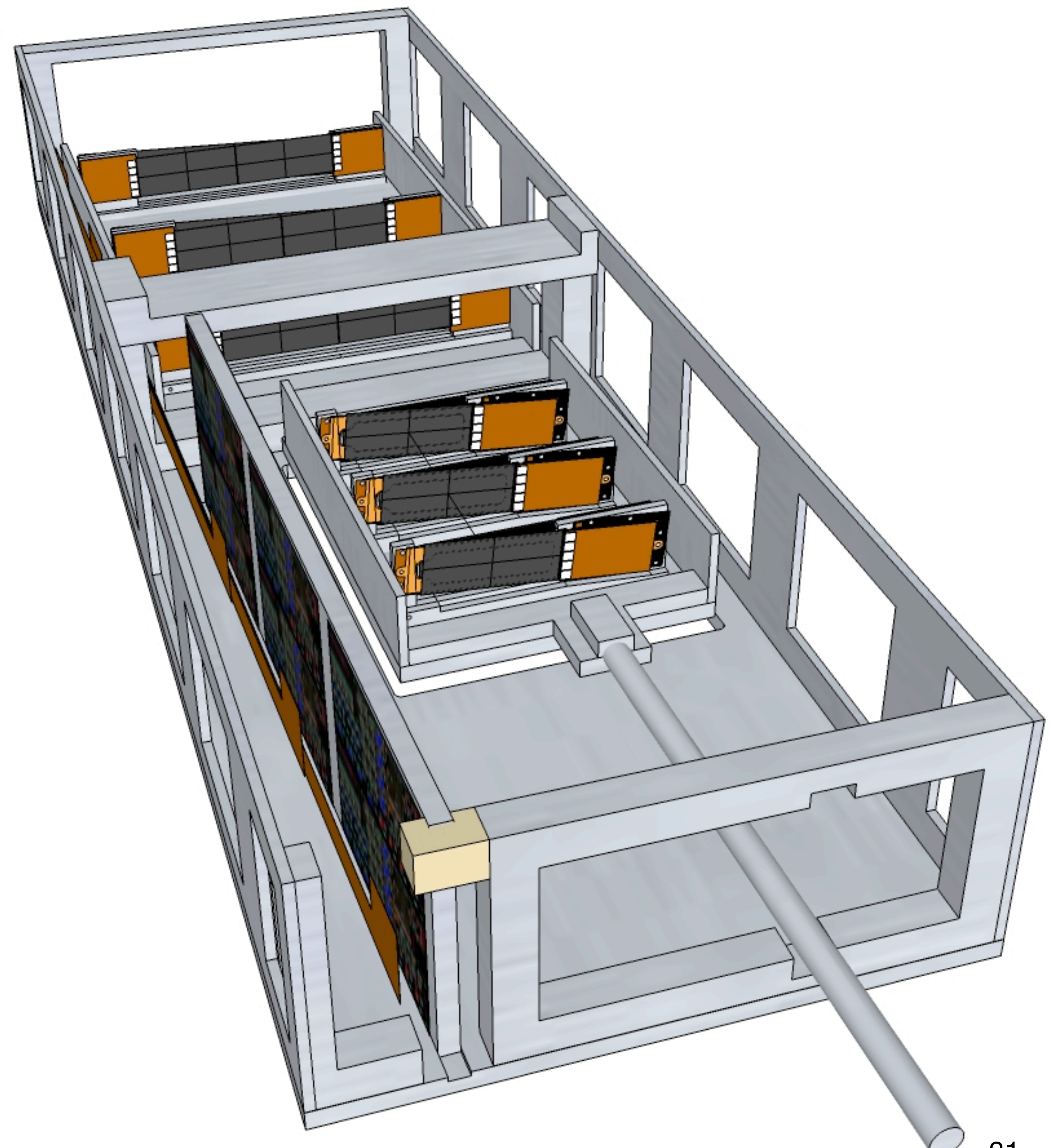
- *Reuse vacuum box and linear shifts with new vacuum flanges*
- *New chiller operable to -10°C with 1°C stability.*
- *Use new Wiener MPODs for power*



SVT Support Box Design

Developing detailed designs

- Rigid SVT support box
- adjustable, 3-point, kinematically mounted u-channels slide in like drawers, are removable from ends
- Survey features on box and each channel at kinematic mount points
- FEB cooling plate slides out from upstream end
- polyimide flex cables for data and power (1 pigtail + 4 longer cable designs)



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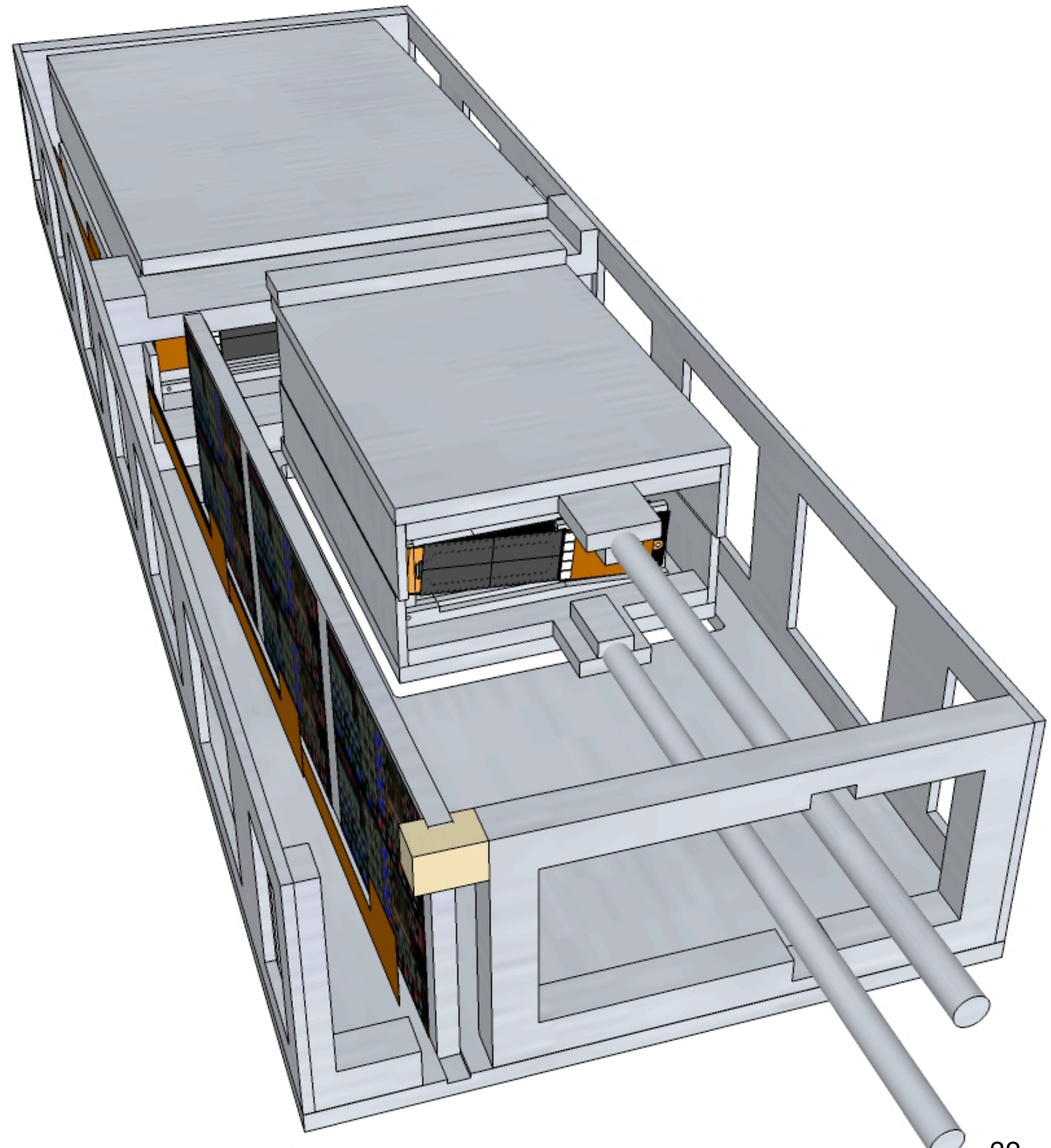
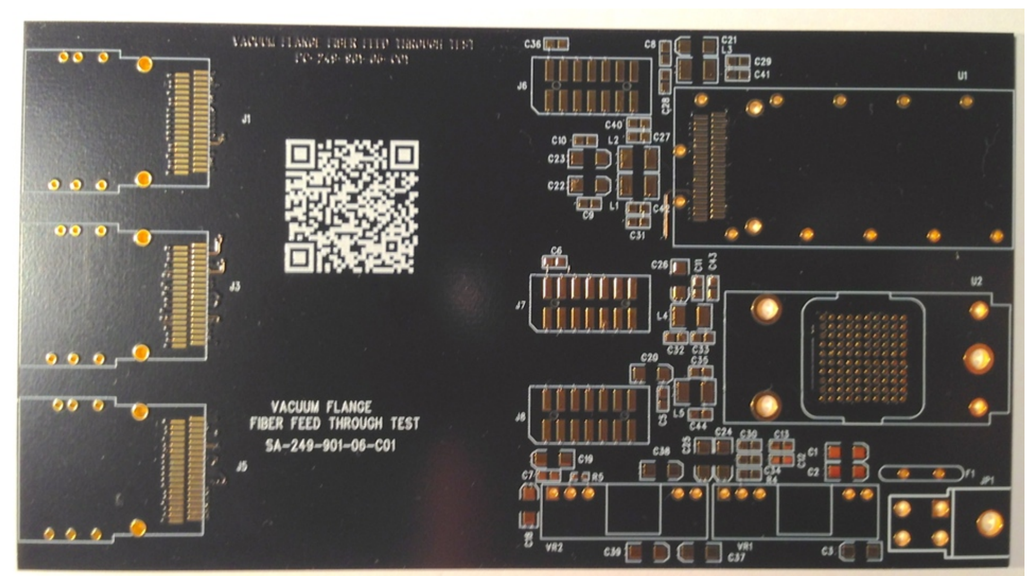


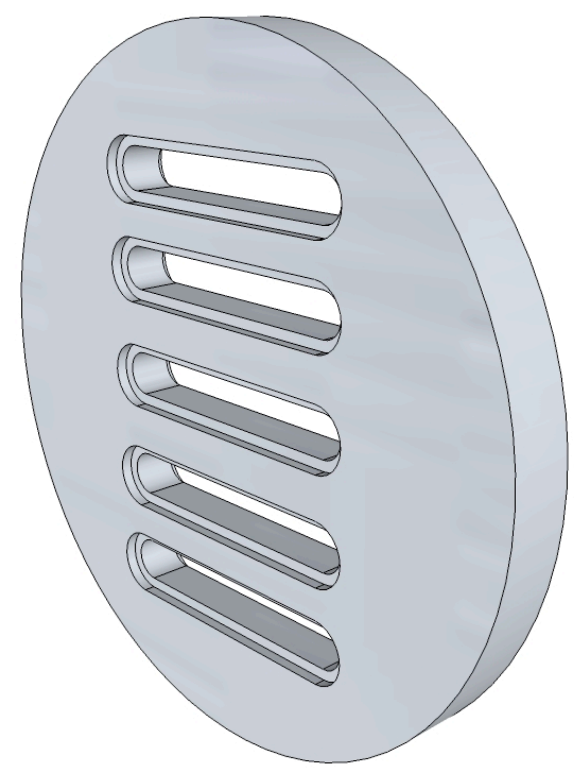
New Vacuum Feedthroughs, Services

Flange Boards

- DAQ version in hand
  (also need versions for LV and HV)
- Out for component loading
- Preparing to test flange assembly technique
- Detailing design of flange and strain reliefs for boards

Inside (digital) *Outside (digital□ optical)*





Detector Services

- new power supplies ordered
- new chiller ordered
- will use JLab chiller for front end boards

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

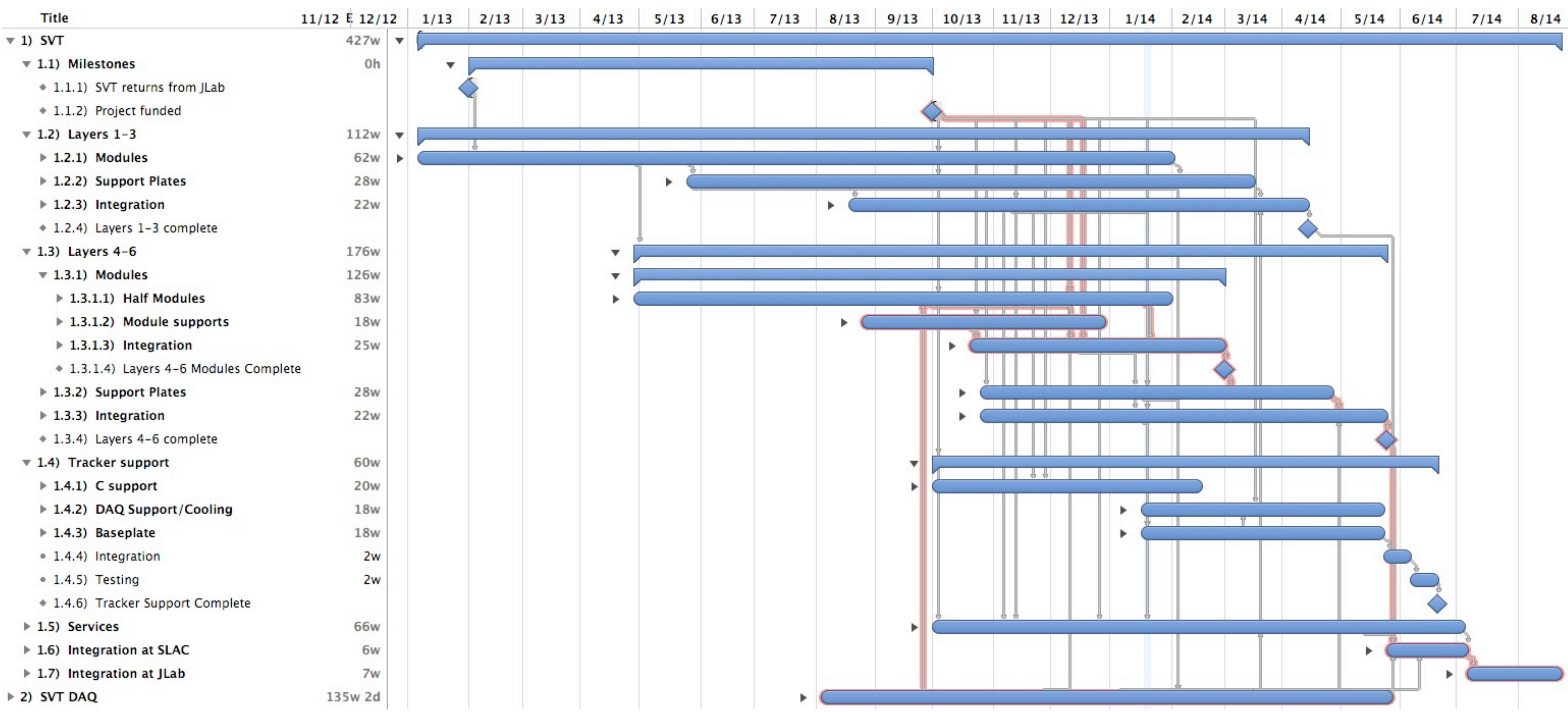
Support Channels
- Machining
- Assembly
- Cooling installation
- Cable installation
- *Survey*

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 and Budget



- Approximately 6 weeks behind schedule for L4-6 production.
  Working hard to catch up with 3/1 completion date for modules.
- Roughly on schedule with support, cooling and services.
- Under budget on some items, over on others. Expect to require at least some contingency funds.

Summary

The SVT is an evolution of Test SVT that got most things right and performed well

- *Acceptance, redundancy, mechanical precision, and cooling will be improved for SVT.*
- Somewhat behind schedule, but trend is positive and still within planned float.
- Most R&D risks mitigated: new module supports, new materials, new hybrids. Have yet to produce first L4-L6 half-module, but components look good.

Some remaining issues are still under investigation

- Sensor/APV25 damage mechanism for beam accidents (studied in SLAC beam tests)
- Extreme radiation of bias structure (device simulations done at SLAC look OK: plan beam test if time allows)

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

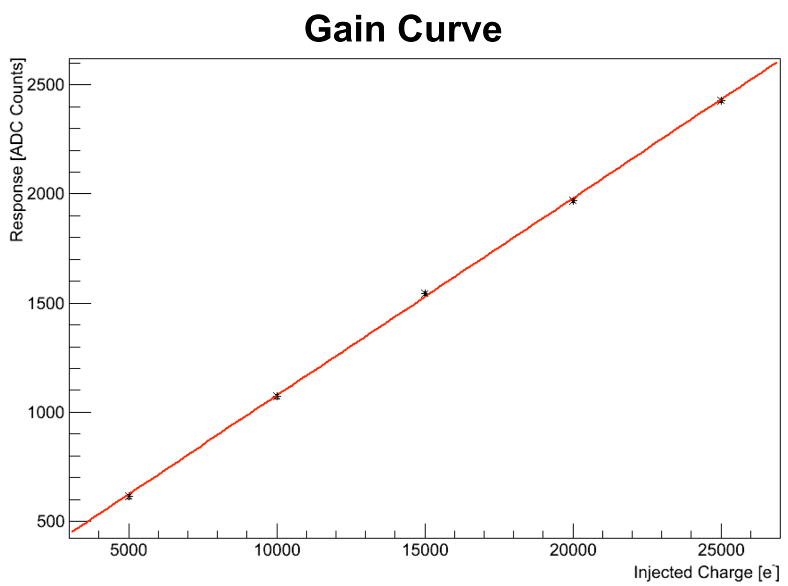
+ 173K to UCSC in FY2013-FY2014

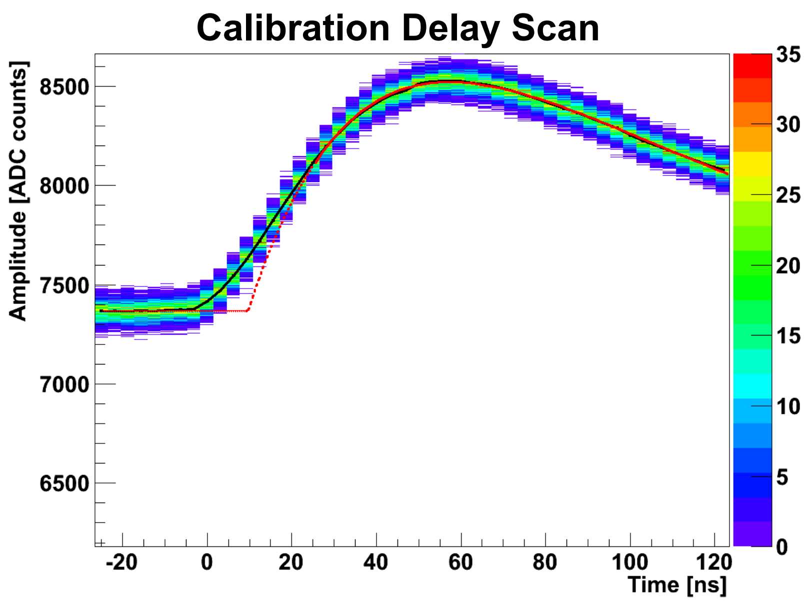
Biggest items are completely new modules for Layers 4-6 and testing/integration at SLAC.

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

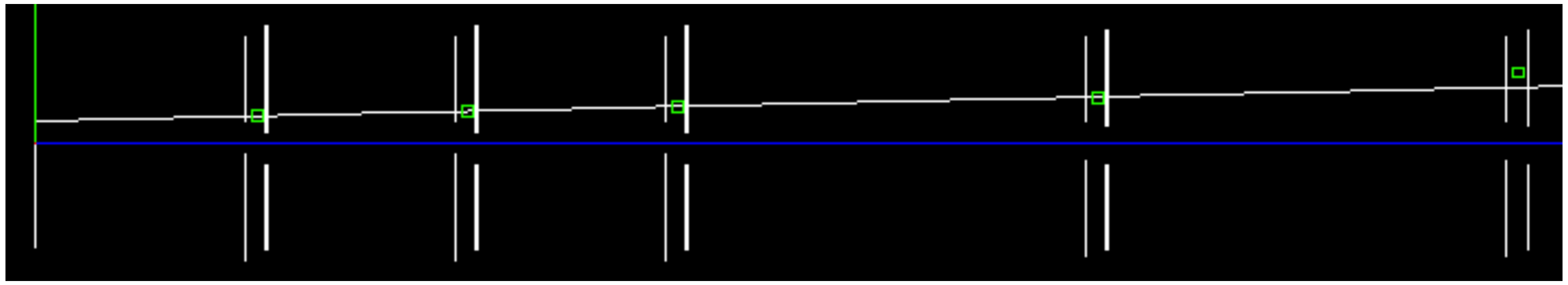




At JLab:

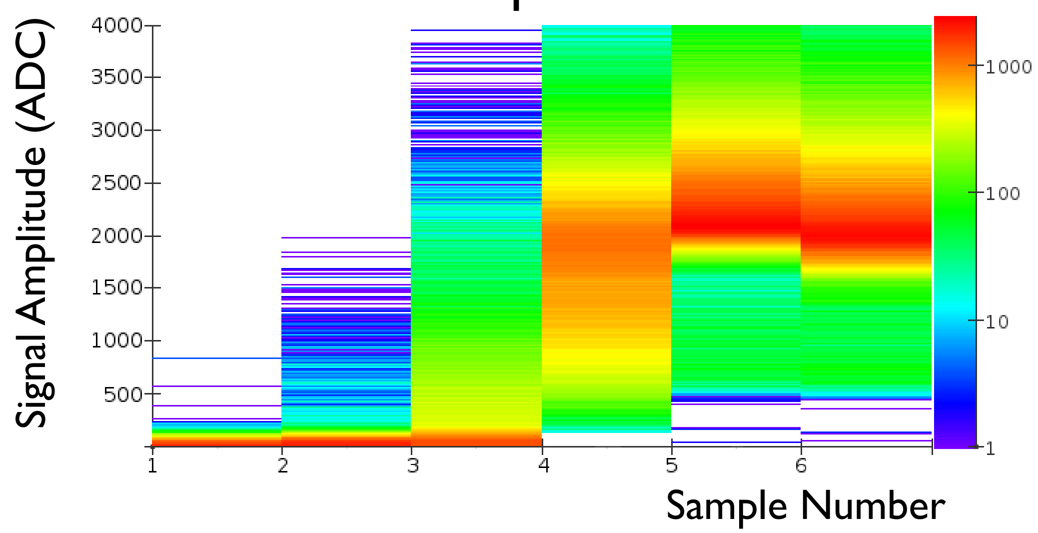
- Installed in Hall B on April 19 for parasitic photon run
- all chips responding
- no problems with vacuum

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

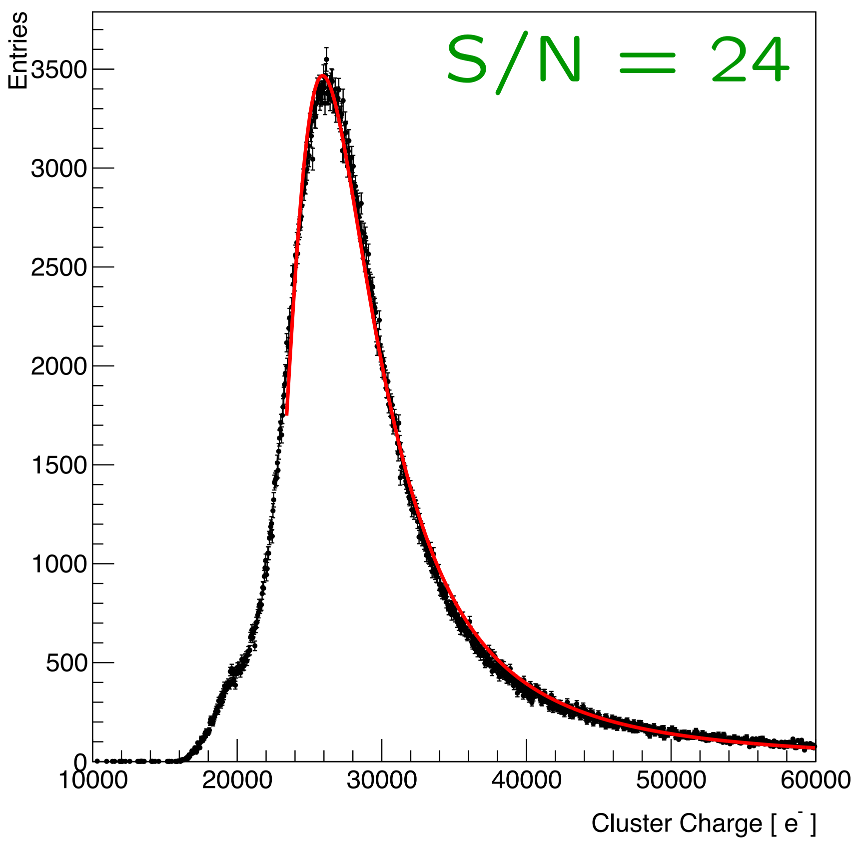


Test SVT Amplitude and Time Reconstruction

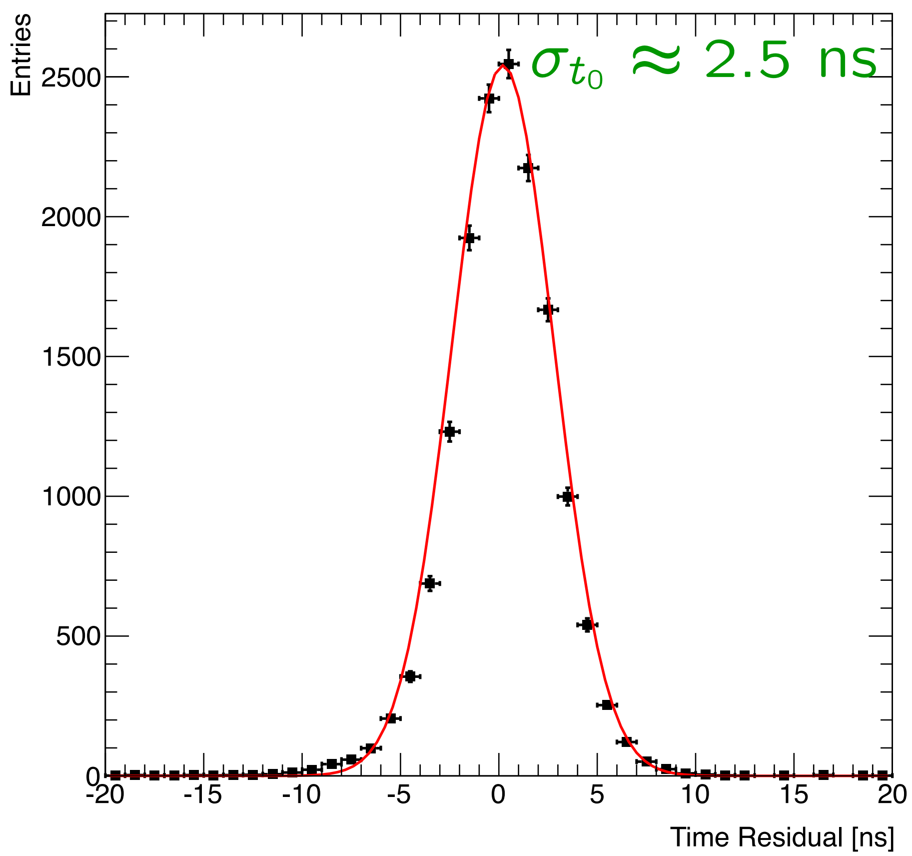
Raw Amplitude Data



Cluster Charge Reconstruction

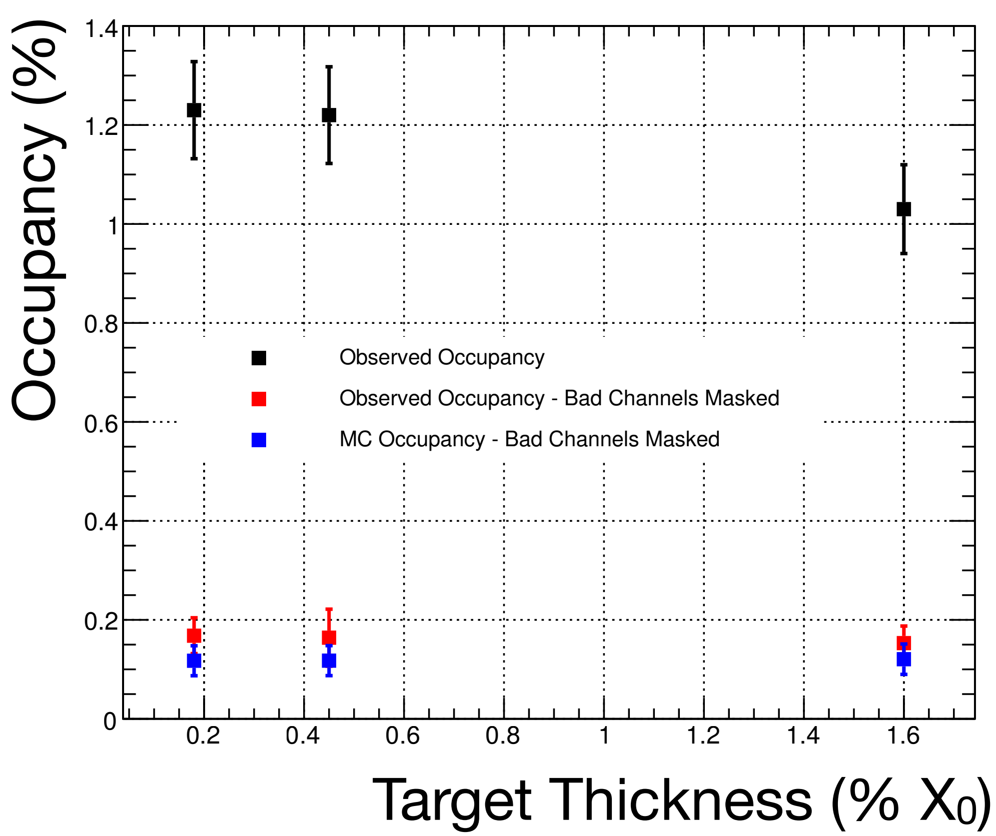


Hit Time Reconstruction

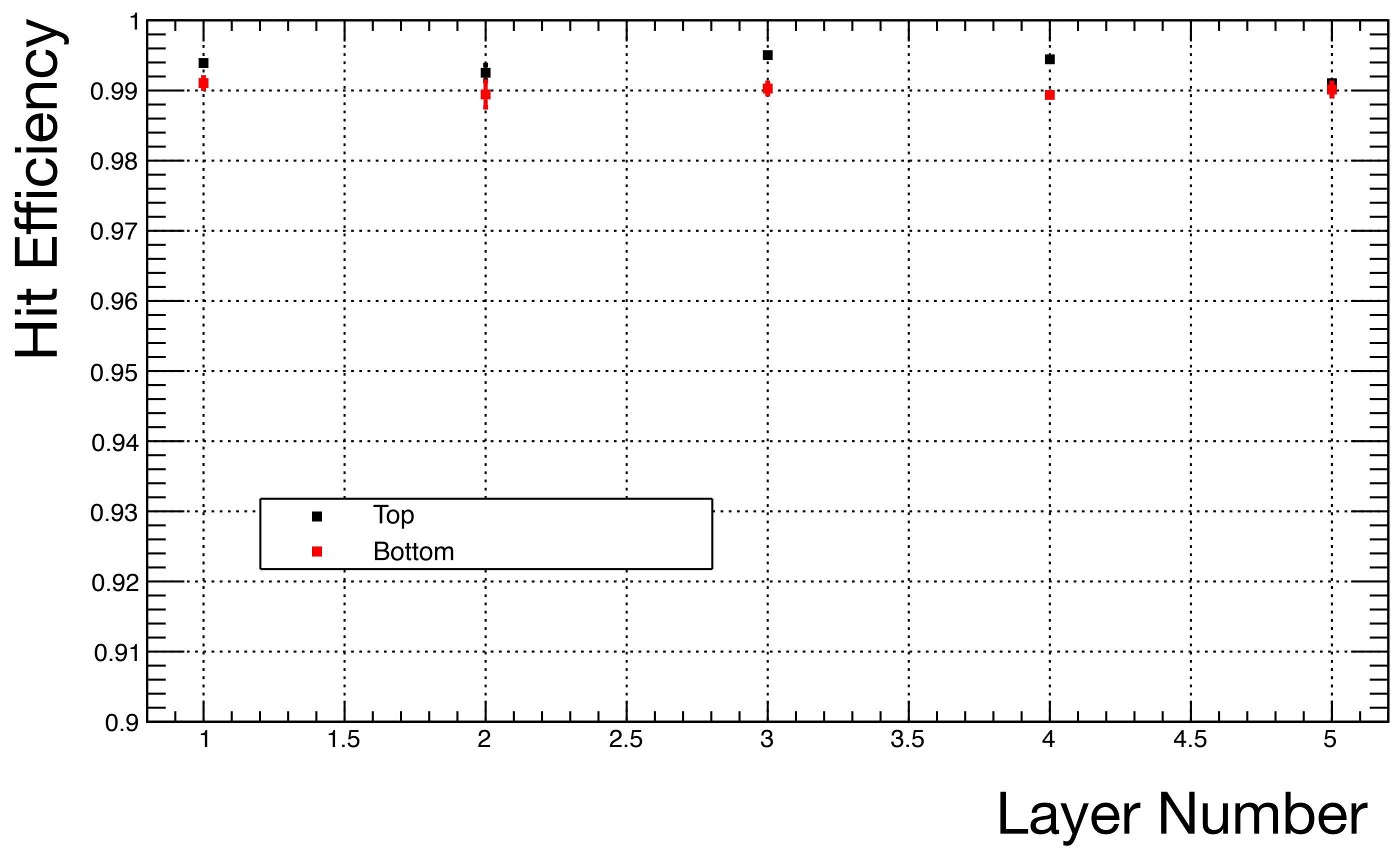


Test SVT Hit Occupancy and Efficiency

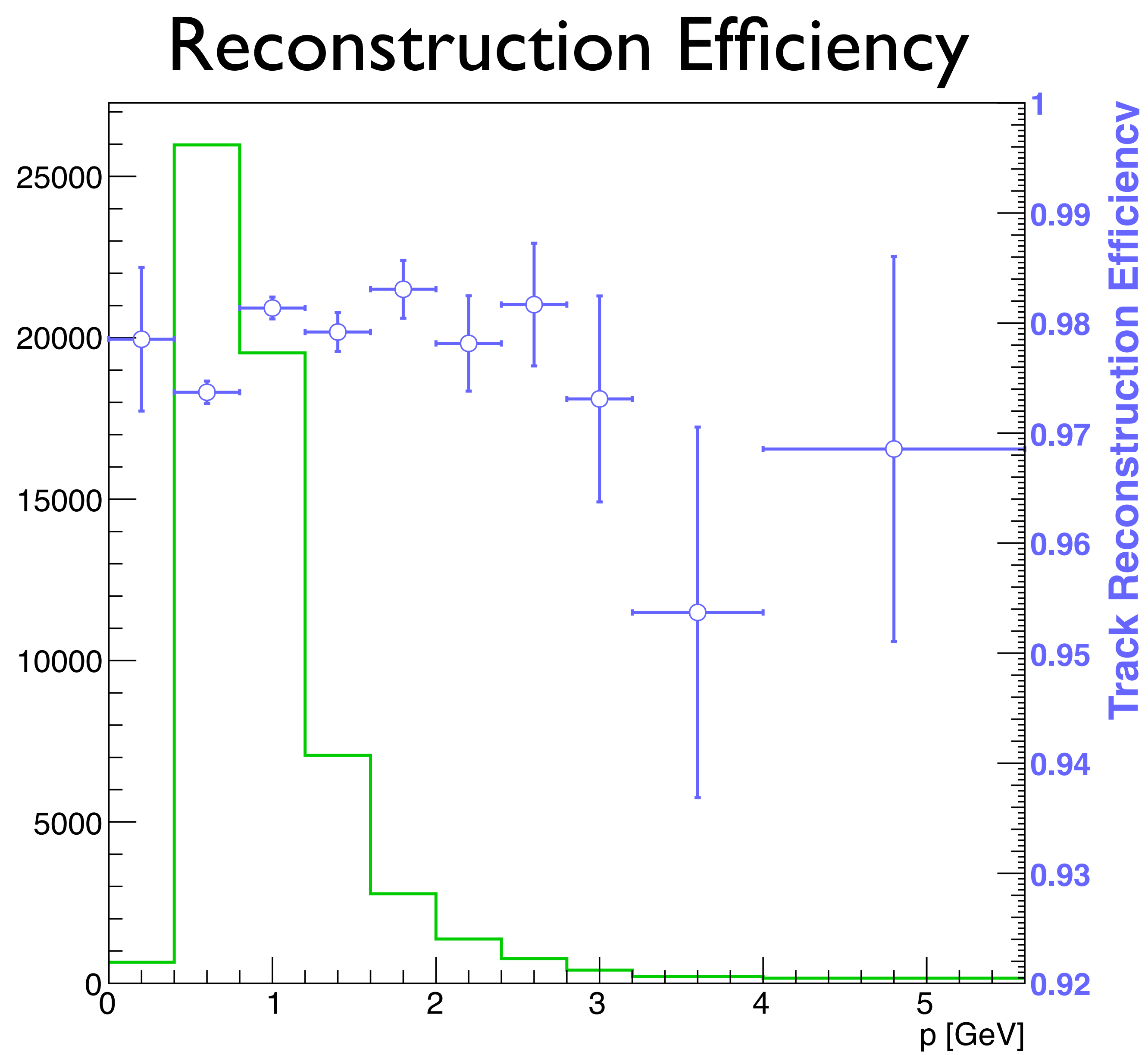
With noisy channels masked, occupancy is as expected...



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



Track Reconstruction Efficiency



Good reconstruction efficiency
even without full alignment