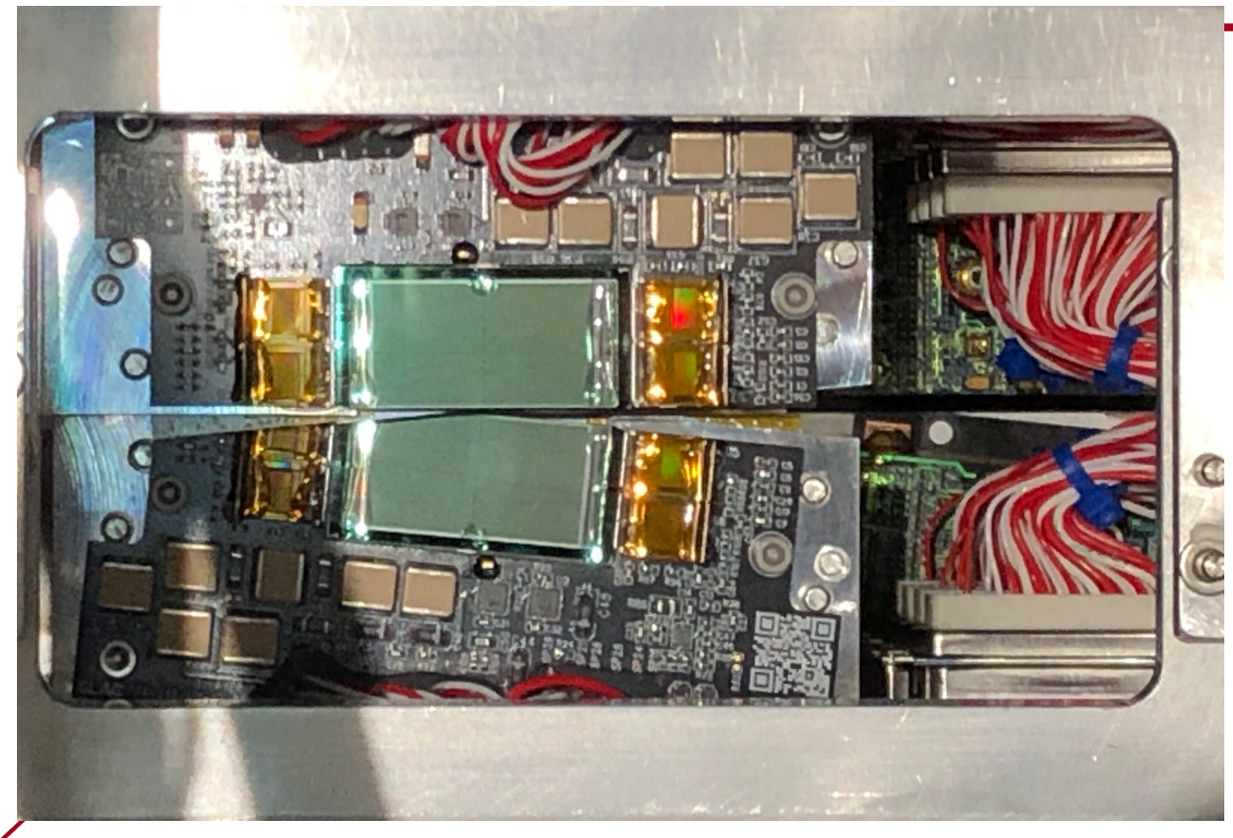
Preparing the SVT for Operations in 2021

Tim Nelson - SLAC

HPS Collaboration Meeting

JLab - November 20, 2020



U.S. DEPARTMENT OF ENERGY
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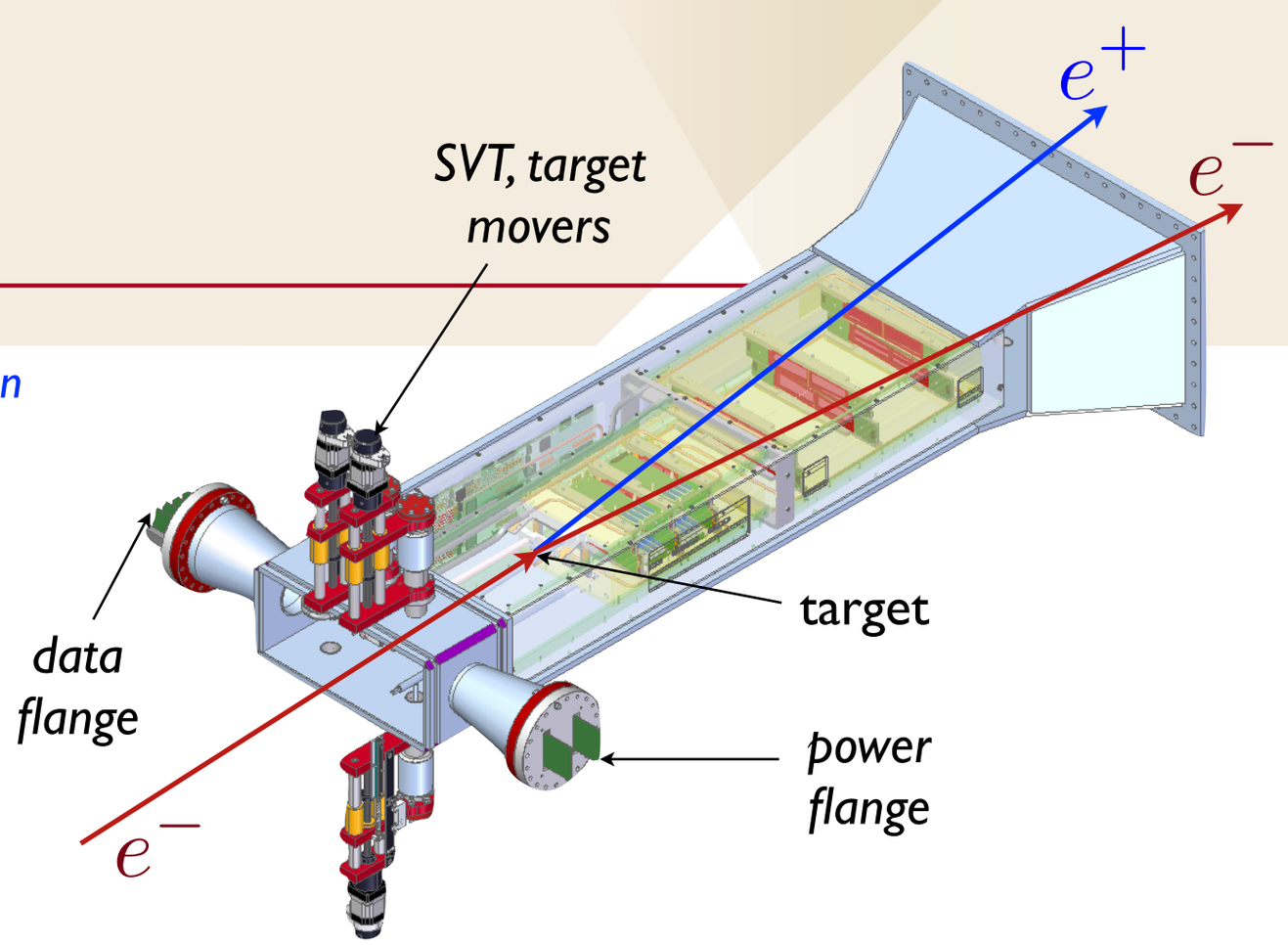
SLAC NATIONAL ACCELERATOR LABORATORY

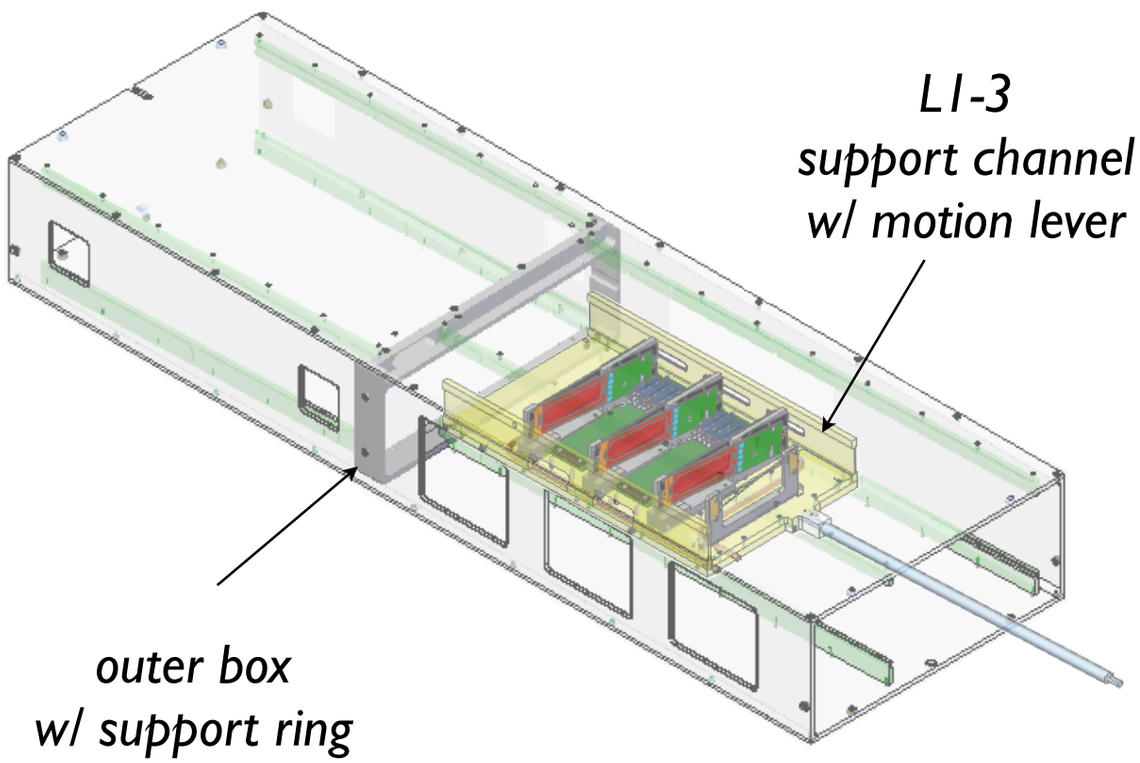
The HPS SVT

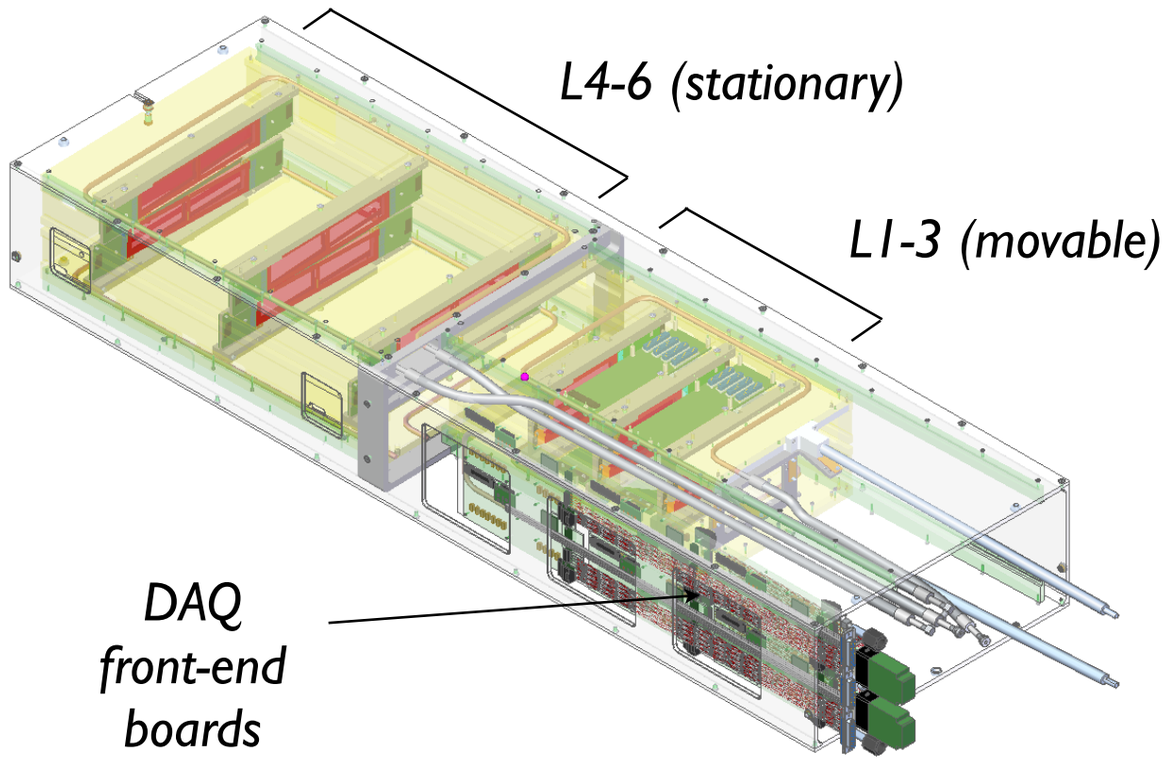
7 double-layers of silicon strips, each plane measures position (~6-10 μm) and time (~2 ns) with ~0.2% – 0.35% X_0/hit.

Operates in an extreme environment:

- beam vacuum and 1.5 Tesla magnetic field
  ⇒ constrains materials and techniques
- sensor edges 0.5 mm from electron beam in L1
  ⇒ must be movable, serviceable
- sensors see large dose of scattered electrons
  ⇒ must be actively cooled to -20 ˚C
- 24528 channels can output >100 gb/sec
  ⇒ requires fast electronics to process data

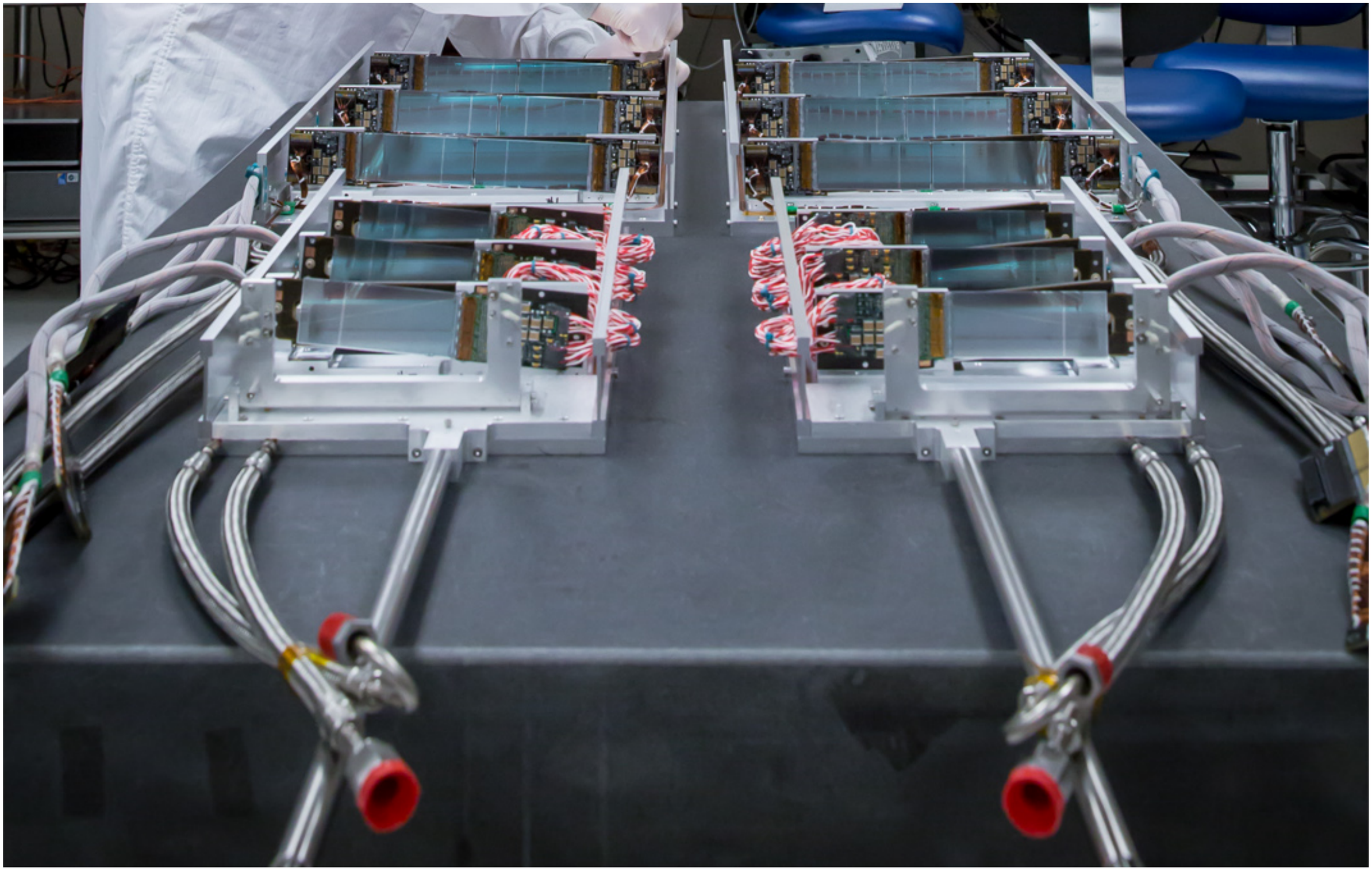






Changes for 2019: addition of new L1 and replacement of L2

SLAC



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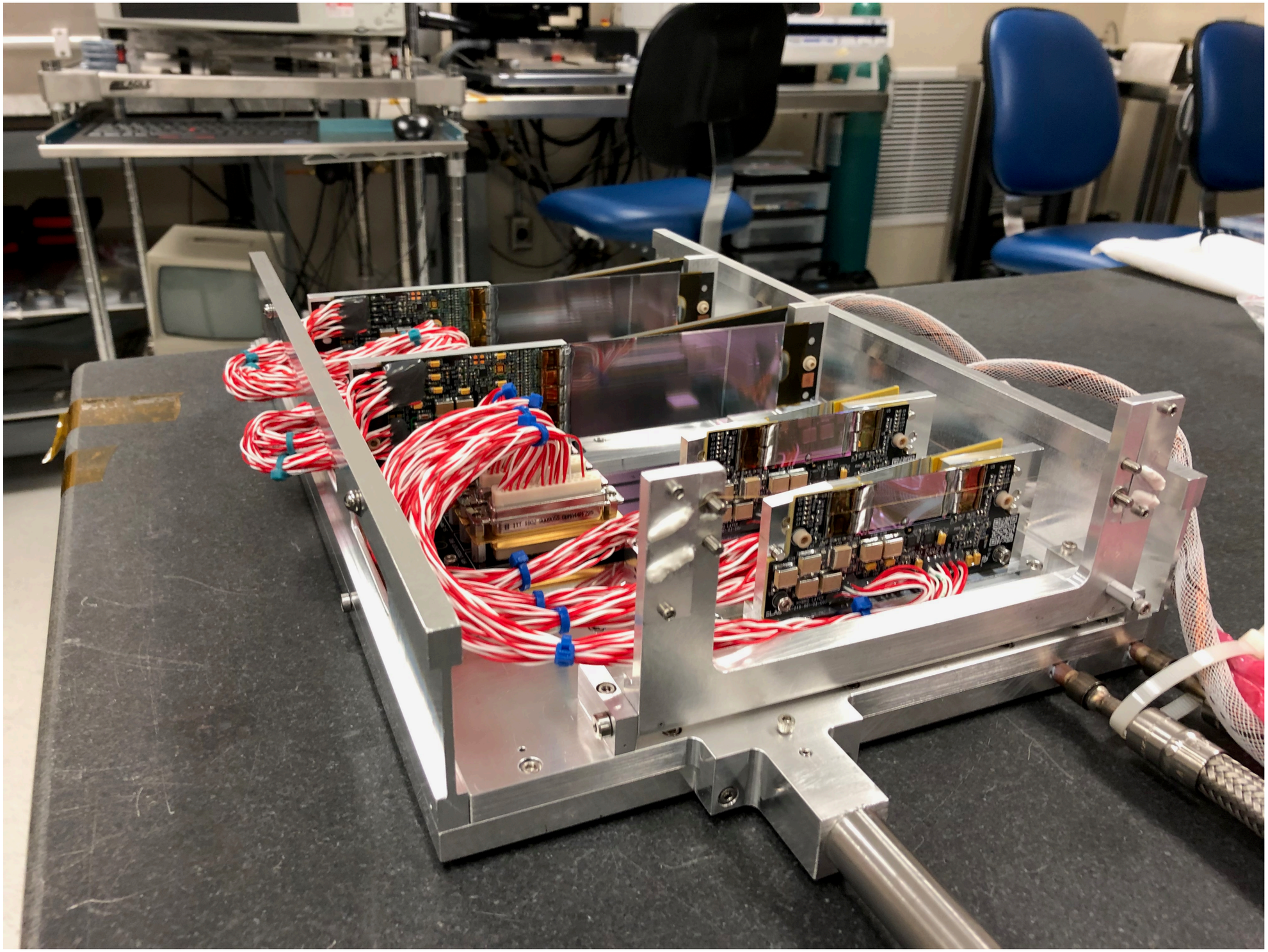
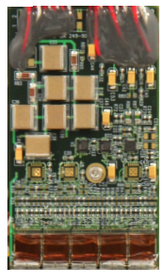
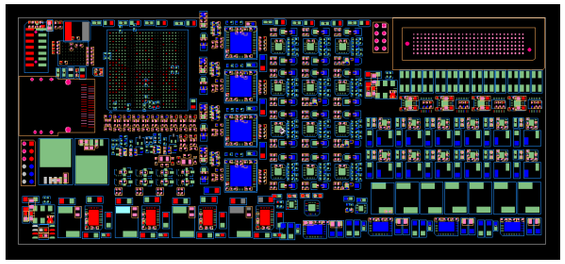


HPS SVT DAQ

- Hybrids hosting 5 CMS APV25 each
- In-vacuum ADC, voltage generation and power distribution/control on Front End Boards
- Penetration for digital signals via high-density PCB through flange. Optical conversion on outside of flange.
- Firmware support for APV25 burst trigger mode (50 kHz trigger rate for 6 samples)
- Wiener MPOD power supplies

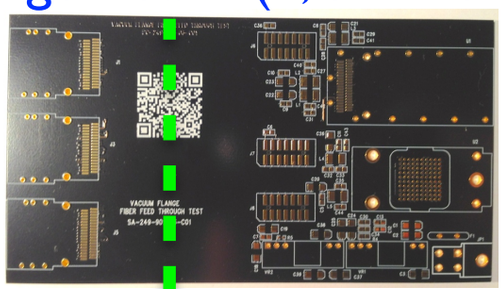


Hybrid (40)



Front End Board (10, 4 Hybrids each)

RCE Platform



Flange Board (4, 3 FEBs ea.)

High density vacuum penetration for 200 Gbps

Outline of SVT Maintenance and Repair

Repair and/or replacement of radiation damaged FEBs

- Investigation and diagnosis of damage
- Design improvements and repair or replacement

Replacement of damaged modules, now three types:

- L1, L2: serious damage, sensor quality issues leave only one spare
- L3, L4: not much damage and have spares (built in 2011 for test run!)
- L5-L7: some wirebond damage in L7. With few spares and no easy path to more, may have to live with some (few %) dead channels in L7.

Maintenance of SVT Infrastructure

- SVT chiller problems and cooling system integrity
- DAQ updates *(see Sergey's talk)*
- Odd jobs

Status and plans for work at SLAC and JLab in the COVID era

FEB Damage During 2019 Operations

FEB degradation manifests as drooping 5V / 500 mA regulator designed to supply ~300 mA total:

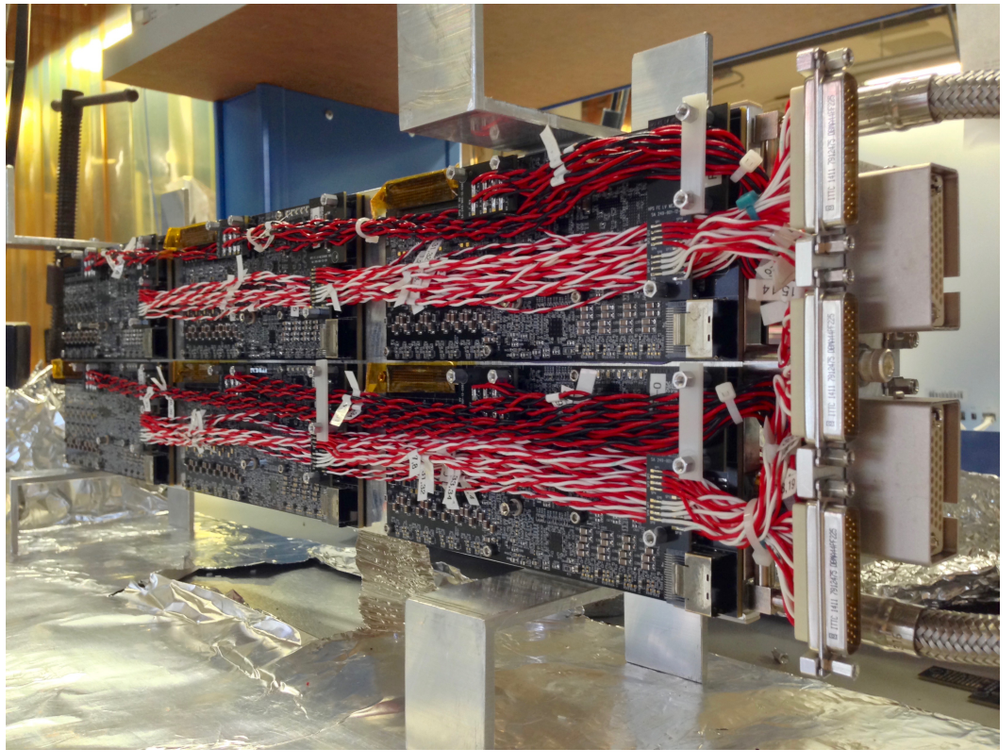
- 24 preamps for APV before ADCs (~10 mA each)
- bias voltage for 12 regulators that supply voltages to the hybrids (~5 mA each)

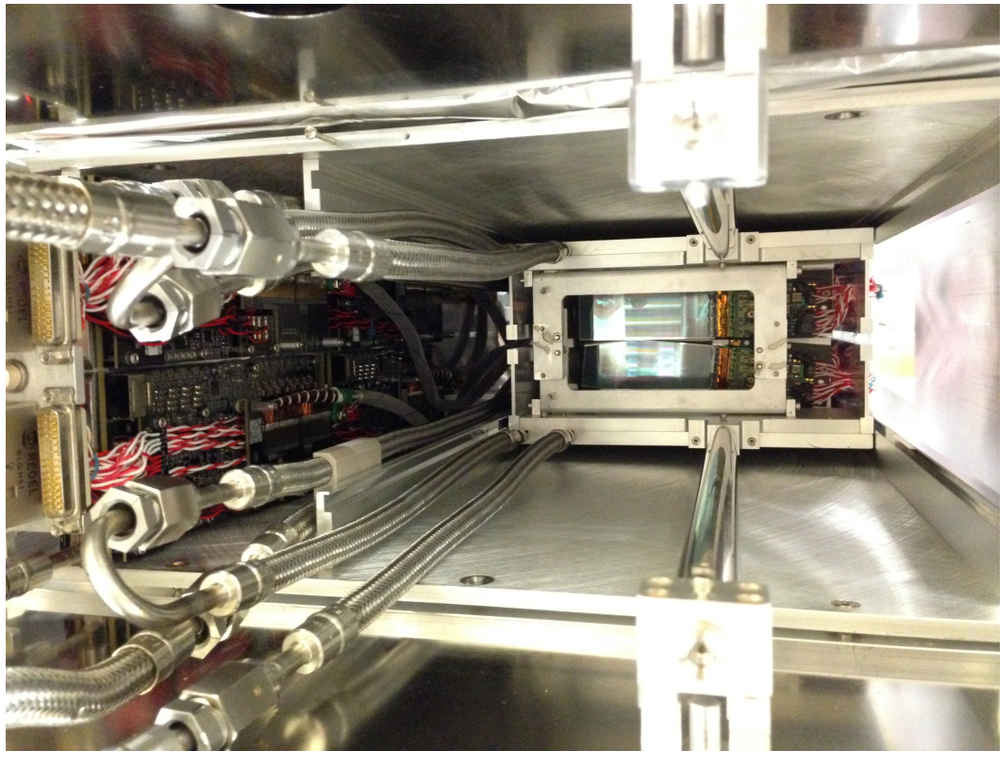
No current monitoring, so mechanism has been unclear, but lowering temperatures improved overhead.

Damage meant loss of data from L7T, one of four hybrids in L5B for most of the run.

Once recognized, we improved monitoring and were more careful with the beam to limit further damage.

See Marcelo Vicente's talk next!





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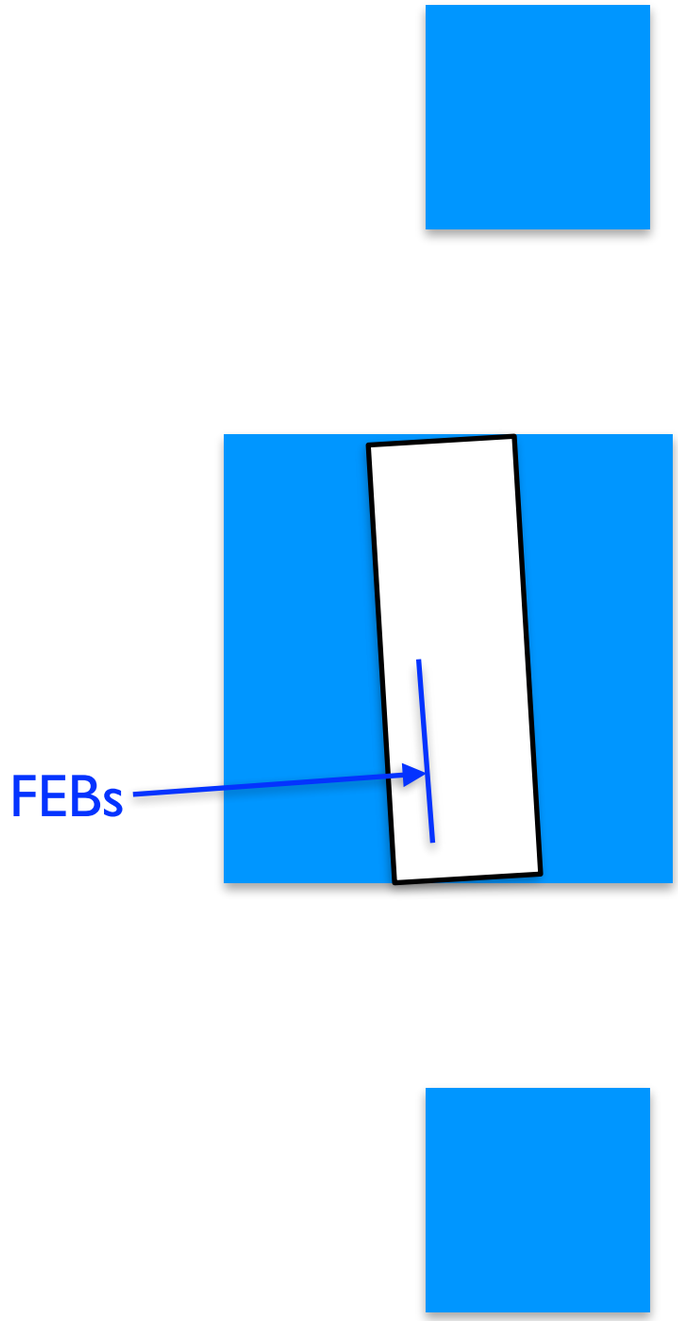

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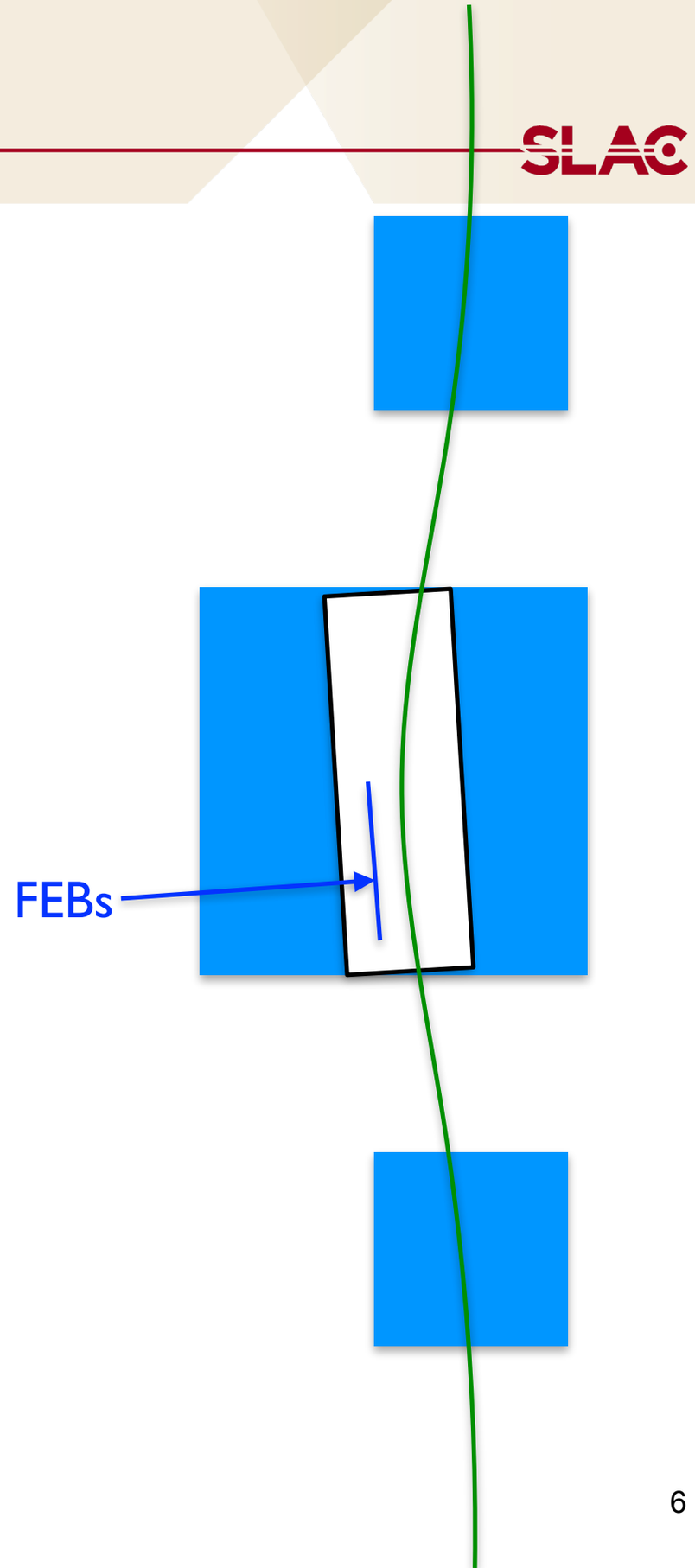

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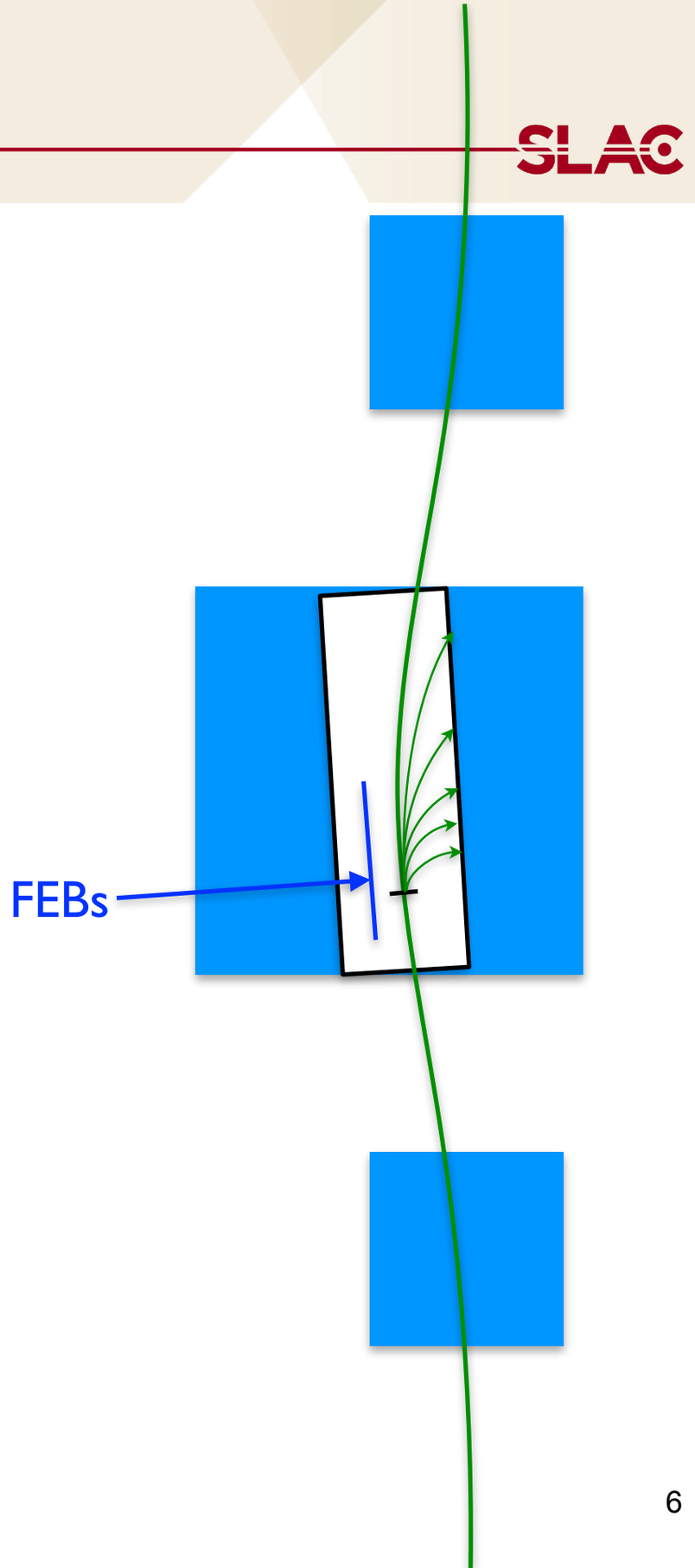

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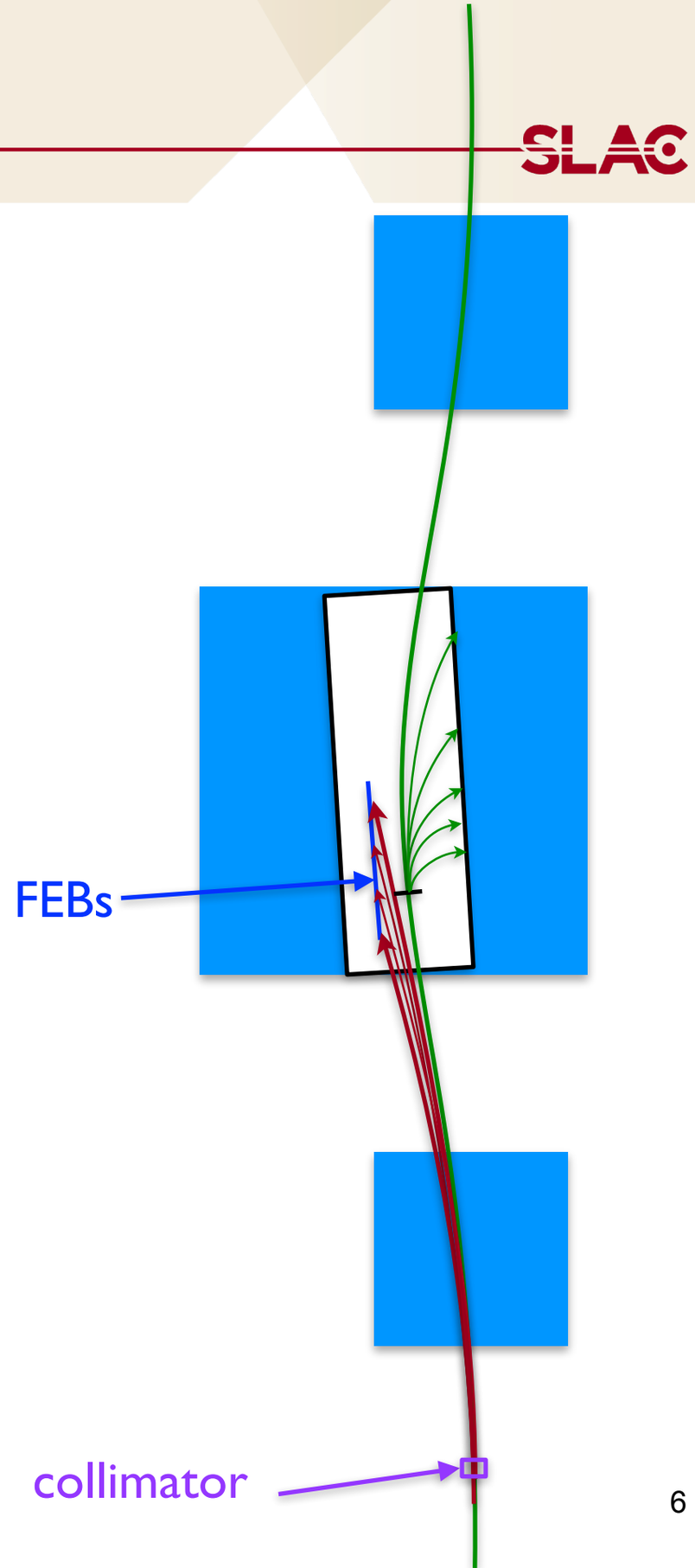

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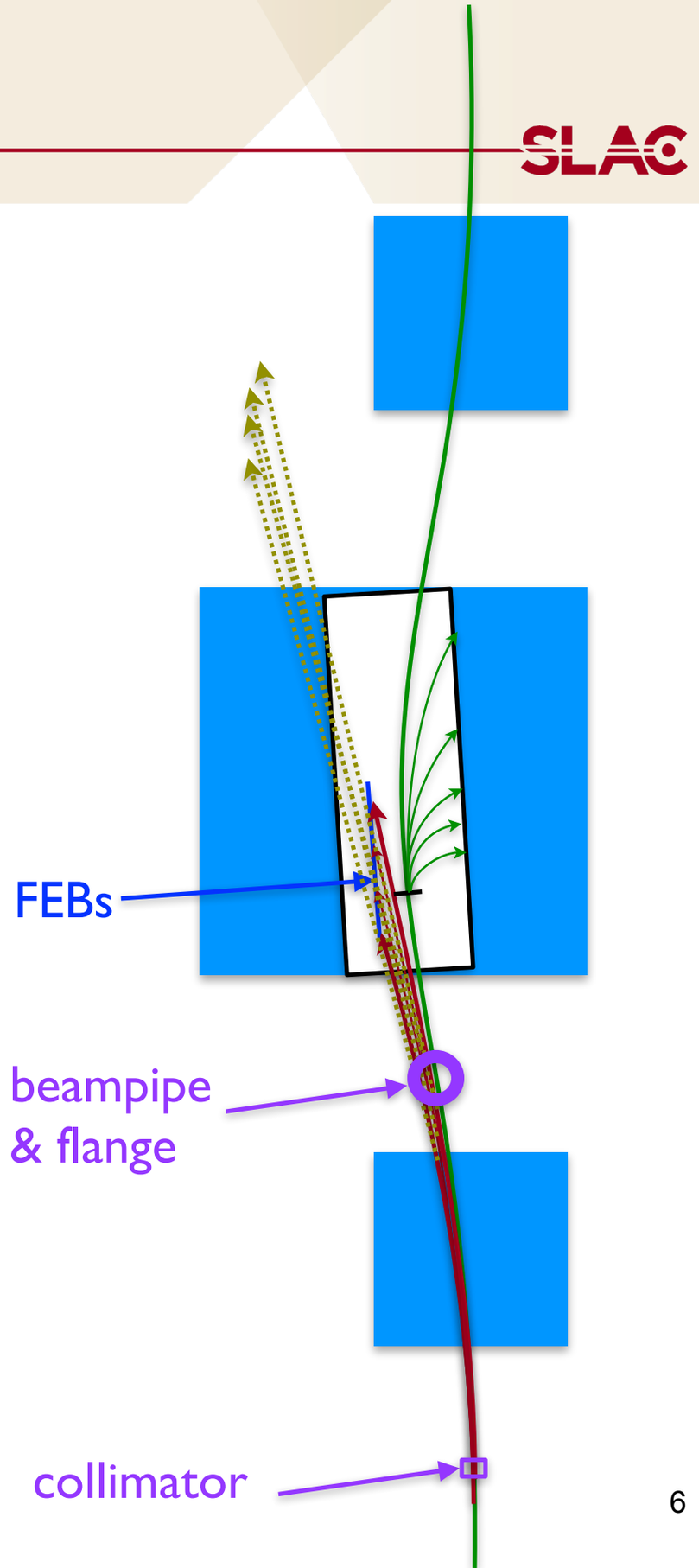


FEBs: Repair or Replace?

Current Status of FEBs

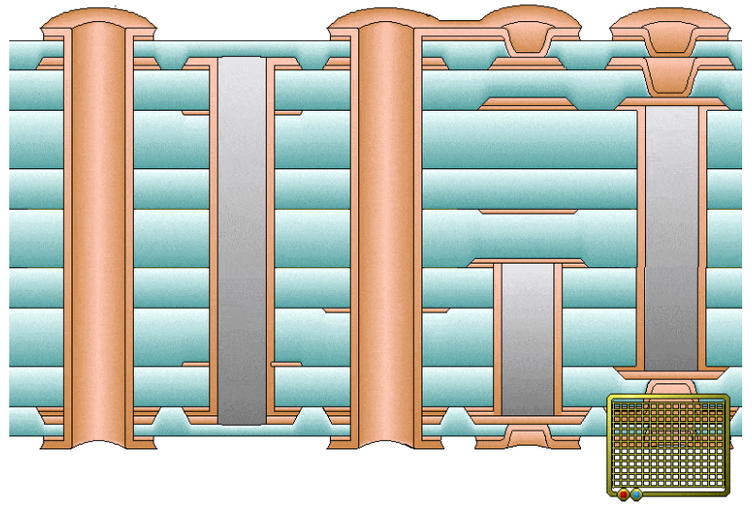
- 15 built, 10 needed. After replacements during 2019 installation, no perfect spares left.
- 3 show symptoms of damage in 5V supply
- 1 has some kind of damage to V125 control for one hybrid, set by AD5144 digital potentiometer (50 in the system). Possibly a fluke, but are discussing how to study this.

There are many issues with the repair scenario:

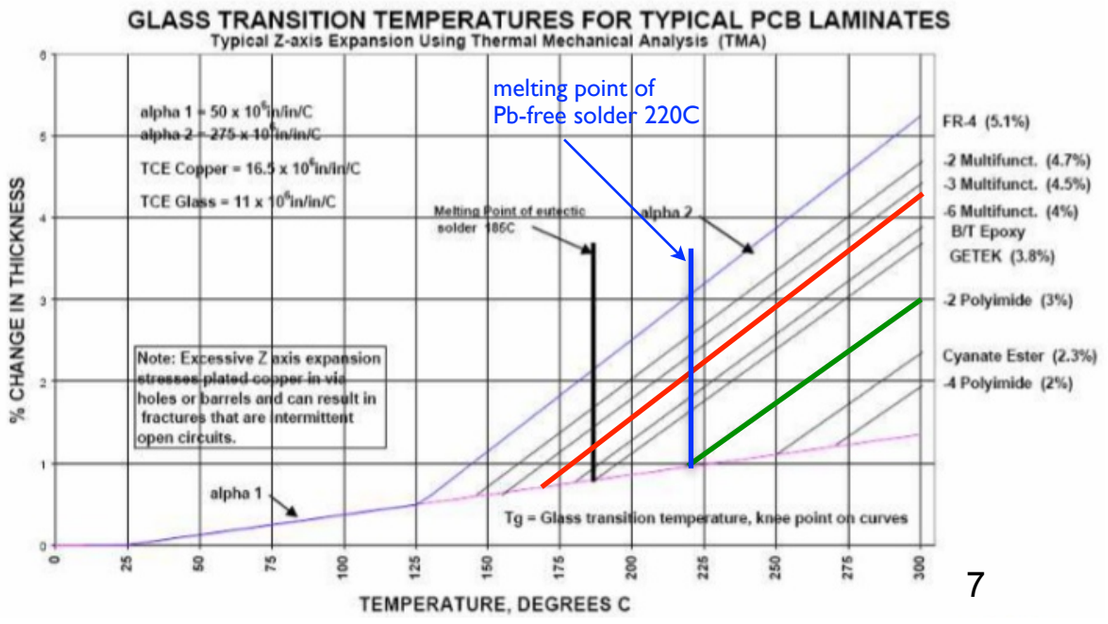
- Not clear how to accommodate component changes (e.g. larger regulator) with a repair.
- Repairs have often created new problems due to CTE stresses
- Repairing these complex boards has proven to be a time sink. Labor costs for repair likely exceed M&S for new boards by a large factor, even for improved board construction.
- Given historical problems with these boards, possible that there were initial quality problems or material issues resulting in cracked vias that a new spin gives us opportunities to solve.

Replacement allows opportunity to mitigate observed failure modes and obtain a proper pool of spares at reasonable cost.

Our budget covers 20 new FEBs in polyamide, which greatly reduces CTE stresses during loading/rework heat cycling



Type	Description	Glass transient temp. Tg	Dielectric constant Dk	Main suppliers
FR4	FR stands for Fire Retardant. FR4 is a glass fiber epoxy laminate. It is the most commonly used PCB material.	135°C	3,8-4,7	Shengyi, Isola, Nanaya, KB, Goldenmax
FR4 High Tg, FR5	These laminate types have excellent performance in Pb-free soldering.	170°C	3,8-4,6	Nanya, Nelco, Panasonic
Polyimide	Material for the production of flexible and rigid-flex PCB	195-220°C	3,4	Dupont, Taiflex



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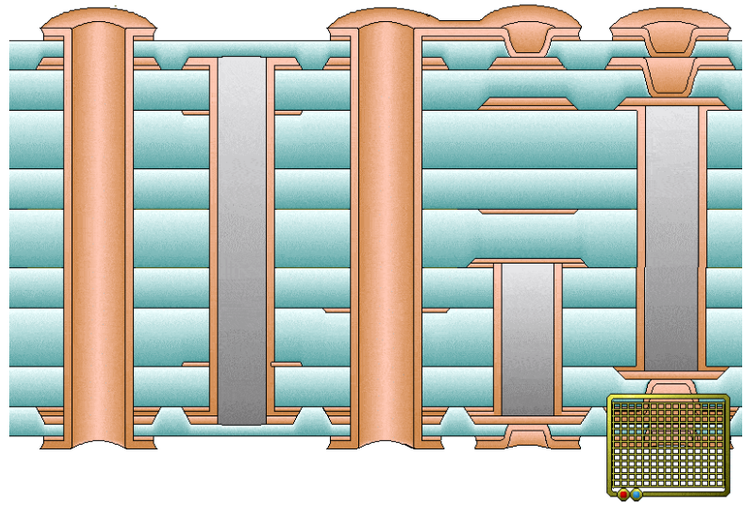

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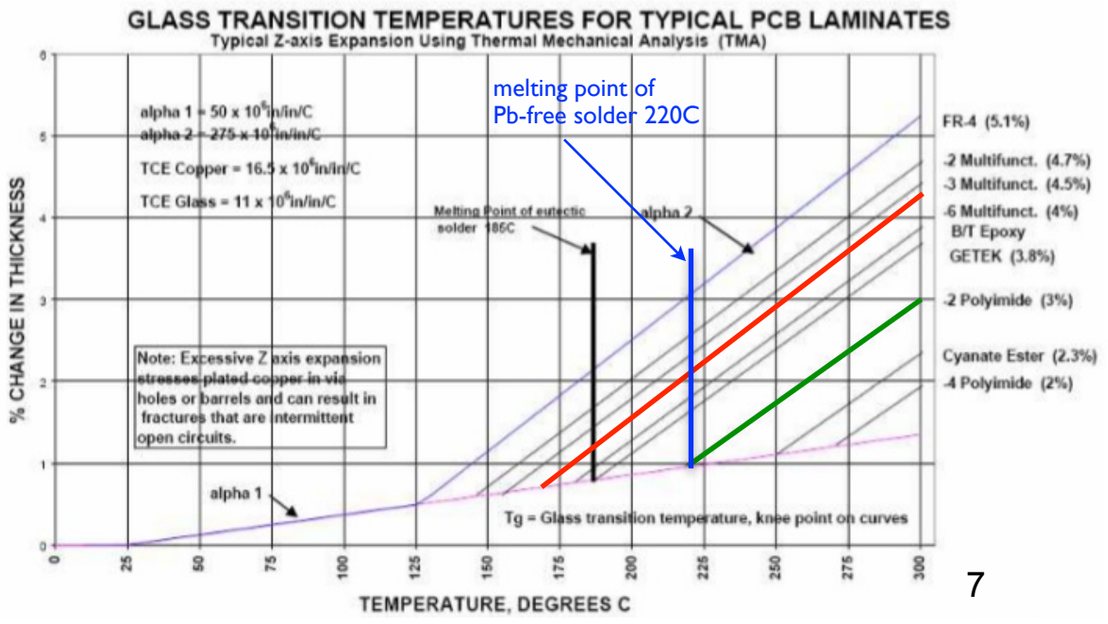
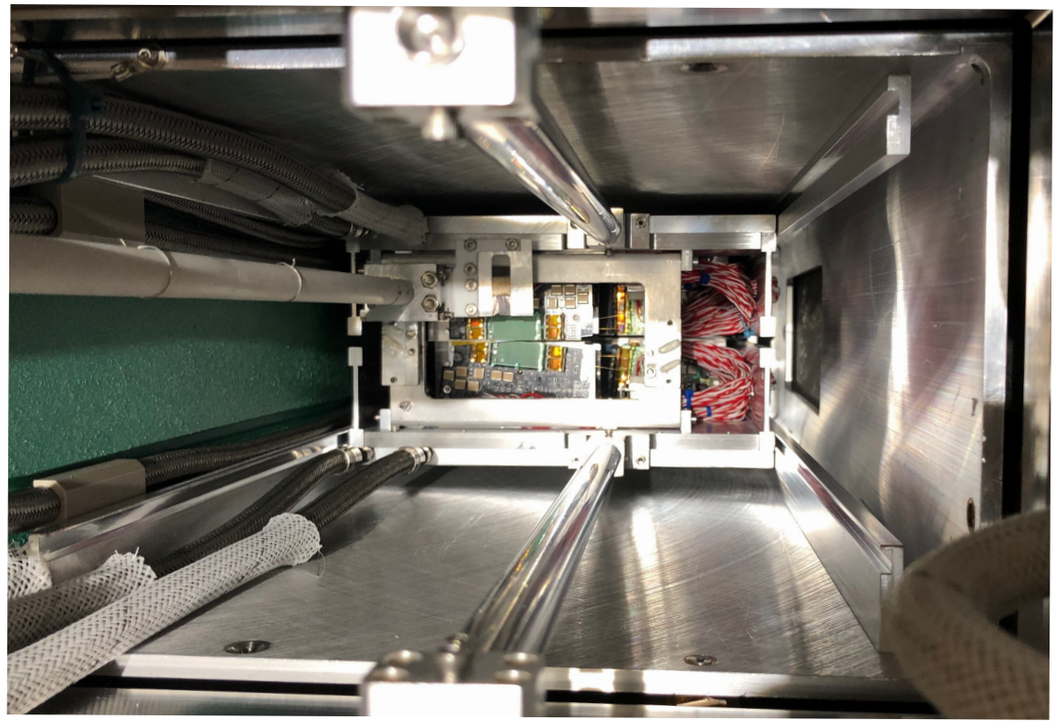
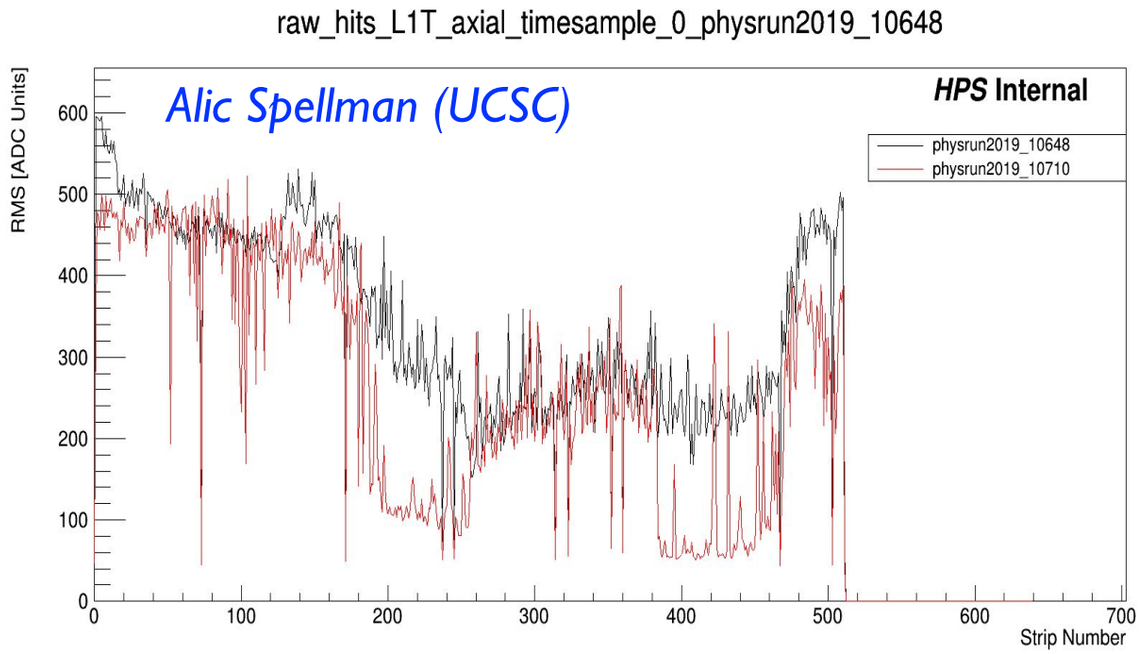


Damage to L0/L1 Modules

HV trips in the SVT were rare in previous runs, but much more common in 2019.

- On a few specific days, experienced a large number of HV trips in new Layers 1/2.
- No obvious problems with beam, but there *was* unusual activity /tuning for other halls
- On one occasion, a section of channels damaged in Layer 1, mostly outside acceptance.
- Late in the run (during field-off run), a Layer 2 sensor severely damaged.





Layer 1/2 sensors no longer hold bias voltages required for operation to much higher doses.

Will need access to modules to study these issues further and explore mitigations.

More modules will be needed to run again.

Layer 0/1 Module Replacement

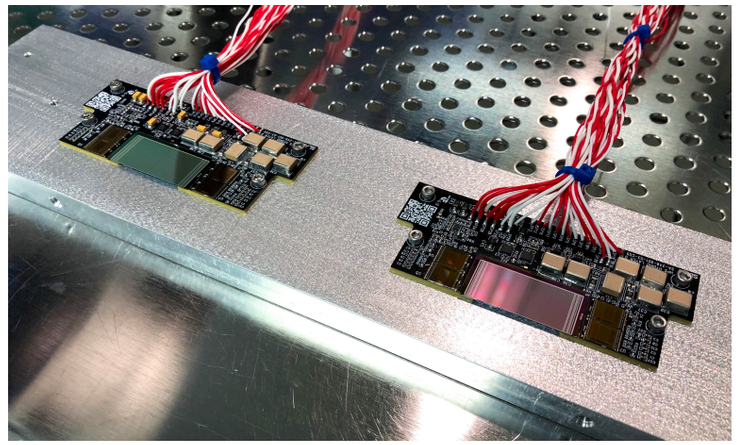
New modules are relatively simple and inexpensive to build.

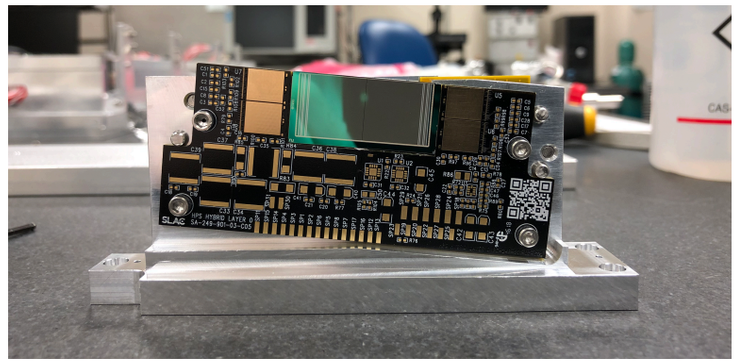
- Hybrids: no design changes
- APV25 ASICs: Purchased *last* 185 APV25 chips in world last December
- Other components: On hand or orders placed
- Support structures: Spares ordered during first run
- Assembly infrastructure: Still in place in cleanroom
- Sensors: Opportunity to address quality issues with a new run, which *may* also make the sensors more robust to damage.

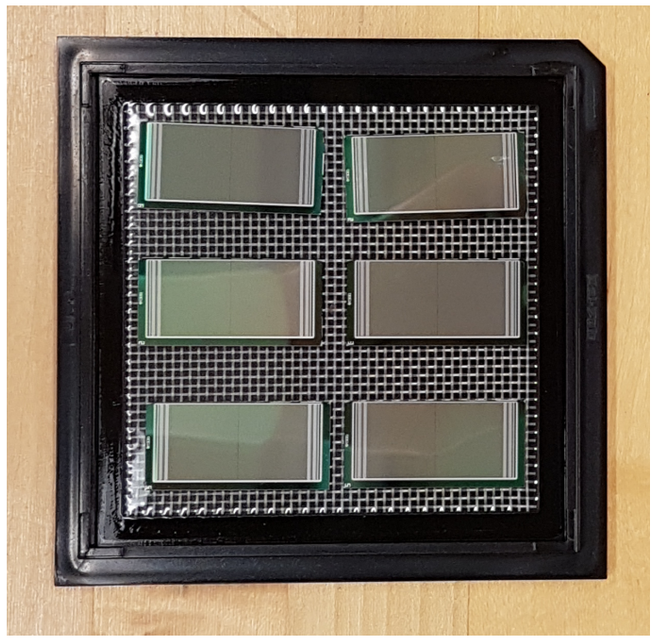
Sensor lead time is a key issue

- COVID disruptions at CNM (Barcelona) through early summer. Design was finalized late July, including double-oxide coupling capacitor process (eliminates pinholes) and features to improve cleaving (slimmer edges and higher breakdown voltages)
- CNM had difficulties with vendor qualification (recently worked out) but they agreed to begin fabrication in September without contract.
- Processing is ongoing. Current estimate is delivery in May, where COVID impacts are obviously still uncertain.

The strategy is complete as much assembly as possible, along with other tasks, so minimal work is required once we receive sensors.







SVT Infrastructure Maintenance and Repair

Cooling System:

- SVT chiller has become grumpy. Chiller has been moved to EEL for service.
- Loss of HFE during 2019 run indicates a leak in chiller or lines external to the detector. Will need to carefully test.

Odd Jobs:

- Proper modification of FEB "octopus" wiring harness to gang bias voltage for extra sensors in upgraded SVT.
- Addition of features to solidly lock SVT into place in case of magnet trip.
- Possible repairs of SVT motors, damaged by work in the alcove.
- Installation of thin sheet of shielding material on back of SVT Support Box to mitigate physical damage to wire bonds on sensors facing downstream.

FEBs and DAQ can be fully tested at SLAC but the rest of the SVT needs testing and repair also if we want to deliver a fully refreshed SVT to Hall B for next run.

SVT must be removed to EEL for this work, including the DAQ, power supplies, and cable plant. Plan to do module installation and survey at JLab also.

Current Outline of Work Plan

FEBs

- (– 12/20) testing of old FEBs *(mostly complete)*
- (11/20 – 1/21) parts selection, modifications to schematic, layout, and board specifications. *(in progress)* funds arrived in Sept.
- (1/21 – 3/21) procurement and testing. Requires FY21 funds still pending.
- (2/21) modifications to octopus. Requires FY21 funds still pending.
- (3/21 – 5/21) re-assemble and test cooling plate prior to arrival of sensors. Requires FY21 funds still pending.

Sensor Modules

- (– 9/20) design changes completed and approved. sensors ordered and in fabrication. *(complete)*
- (11/20) order components for new hybrids. *(in progress)*
- (12/20) order new run of hybrids. *(in progress)* funds arrived in Sept.
- (2/21 – 3/21) hybrid assembly at SLAC. funds arrived in Sept.
- (2/21 – 5/21) APV25 mounting, wirebonding, and testing at UCSC
- (5/21 – 7/21) sensor testing, gluing, wirebonding, and module testing

JLab integration and testing

- (12/20) Schedule chiller service. DOE funds arrived in Sept.
- (1/21) Develop design for locking SVT in place. (have some ideas)
- (1/21) Develop design for downstream SVT shield. (have some ideas)
- (5/21?) Remove SVT and set up in EEL with DAQ and new FEB cooling plate. Requires FY21 funds still pending.
- (8/21?) Install and survey new sensor modules, install and test new FEB cooling plate. Requires FY21 funds still pending.
- (9/21?) Installation. Requires FY21 funds still pending.

We expect more curveballs, so we want to beat these dates where possible and be continually adjusting the plan.

Summary

- The SVT requires some work to get back into shape for 2021.
- The pandemic introduces additional schedule uncertainty and reduces float, depending how the JLab schedule develops.
- All we can do is plan for success and keep pushing.
- Keep on thinking! To our credit, we've rarely suffered from the same issue more than once, but that means we have to plan for the unknown, unknowns in operation, because next time it will be something else!