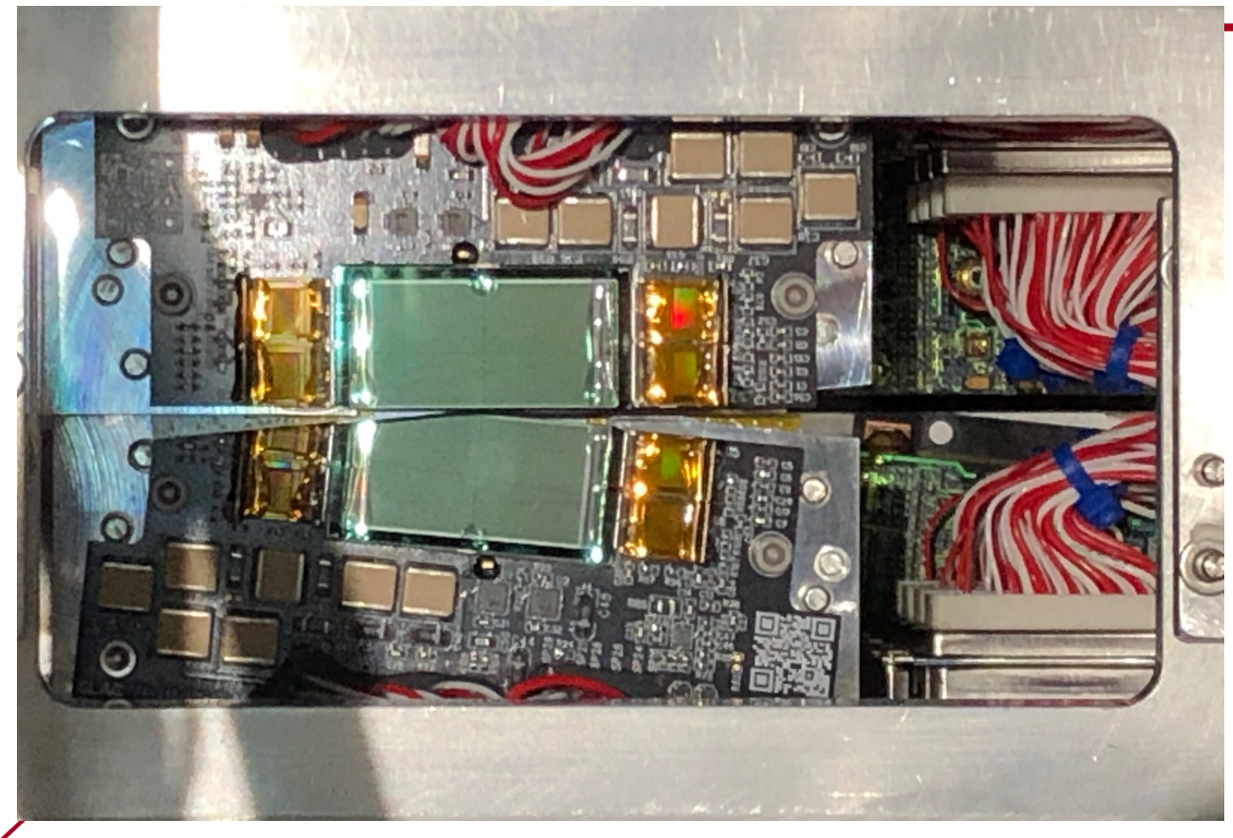
Preparing the SVT for Future Operations

Tim Nelson - SLAC

HPS Collaboration Meeting

JLab - May 15, 2020



U.S. DEPARTMENT OF ENERGY
Office of Science

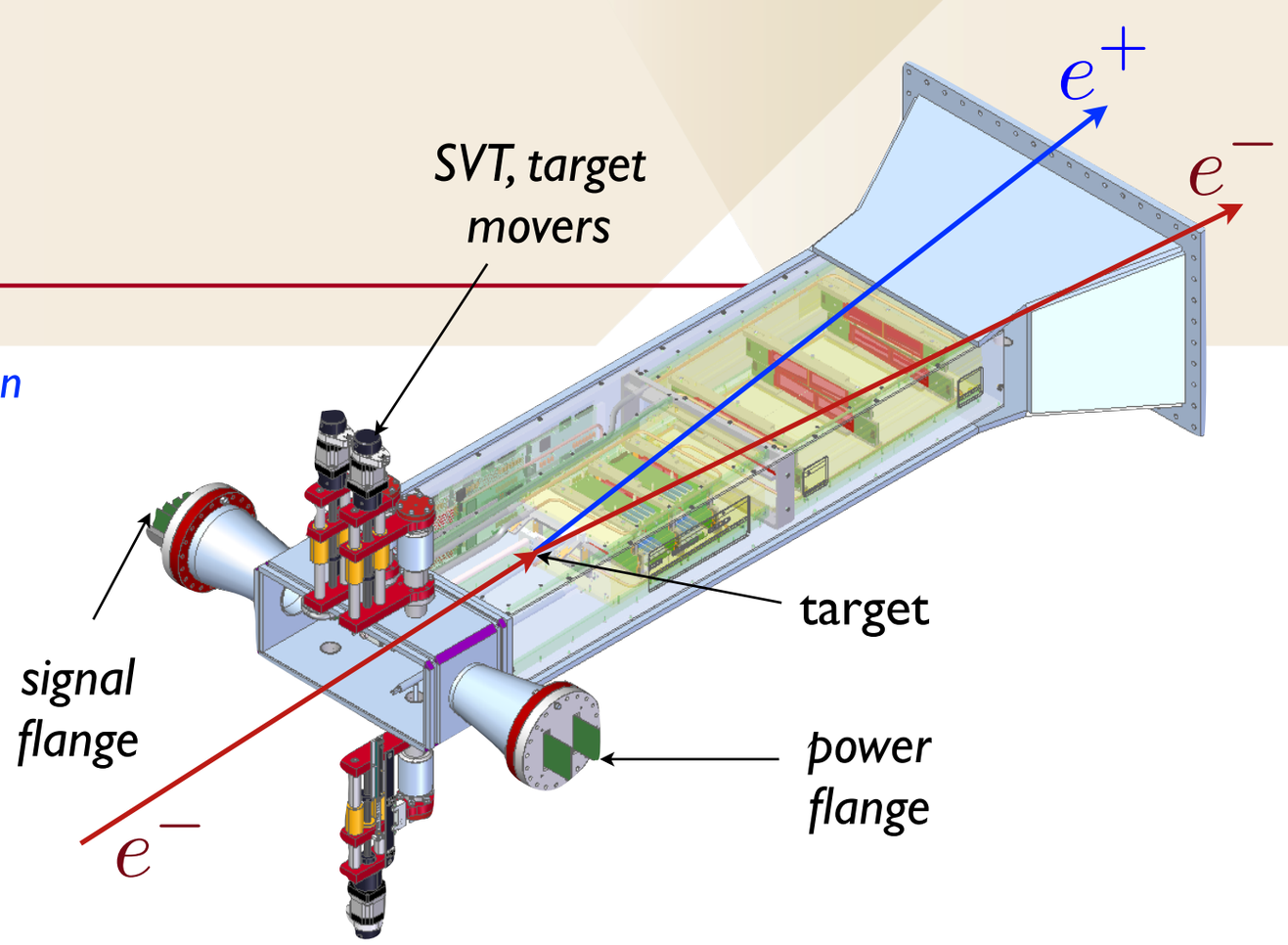
SLAC NATIONAL ACCELERATOR LABORATORY

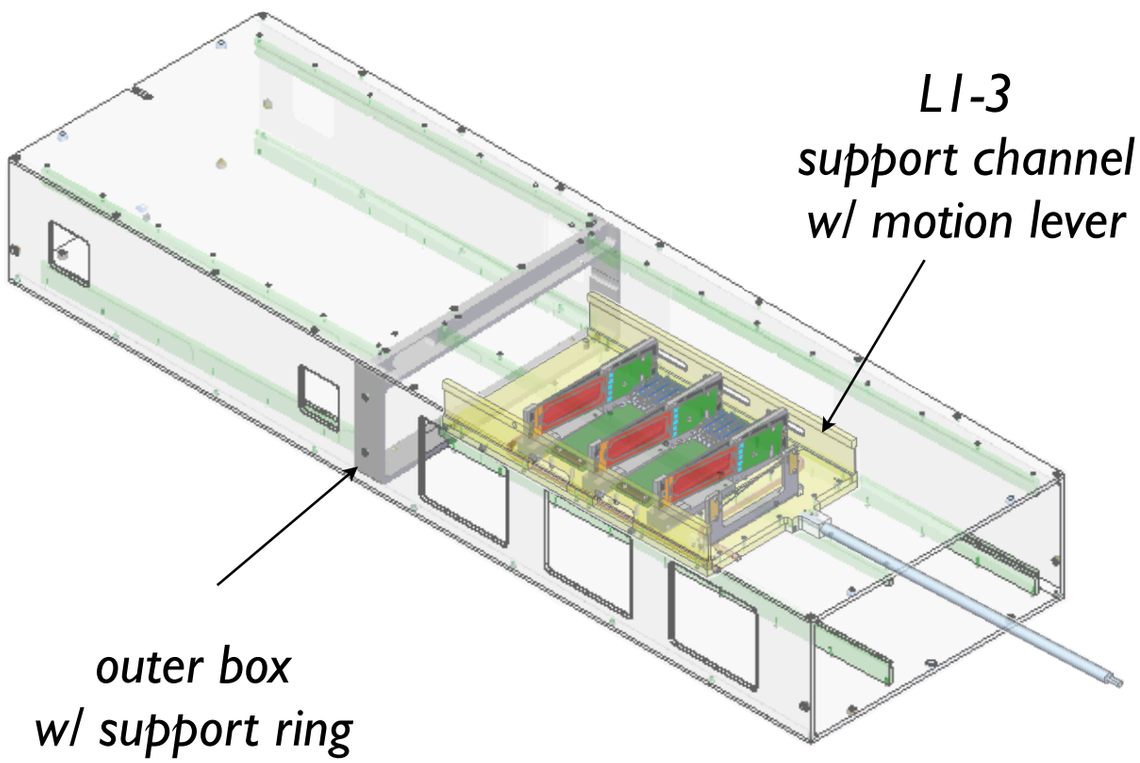
The HPS SVT

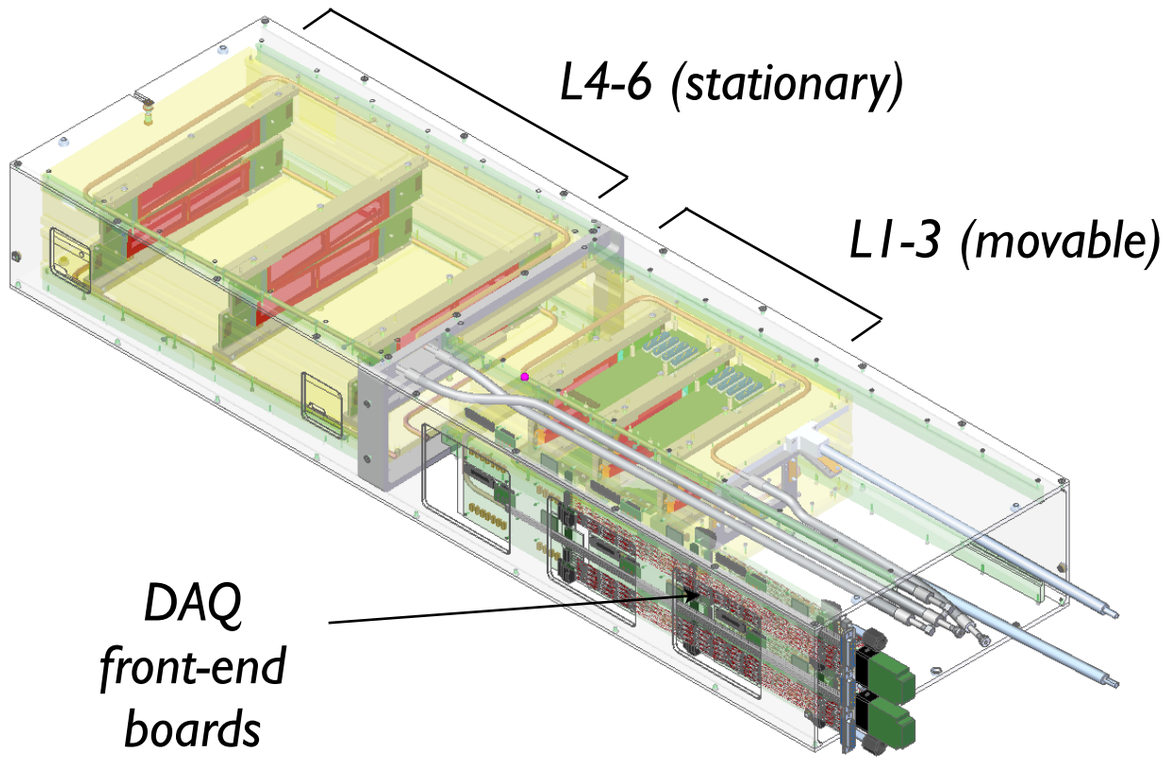
7 double-layers of silicon strips, each plane measures position (~6-10 μm) and time (~2 ns) with ~0.2% – 0.35% X_0/hit.

Operates in an extreme environment:

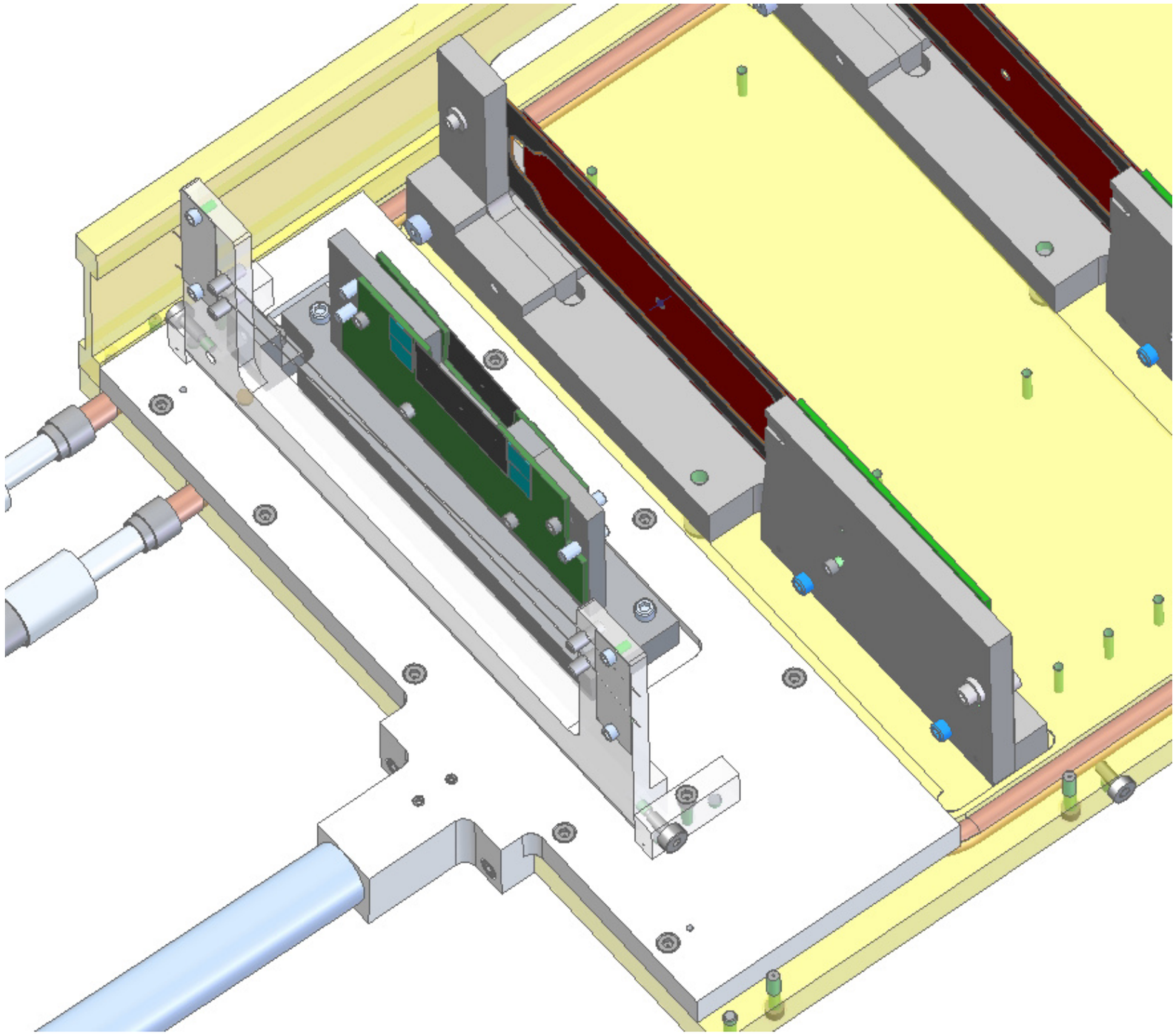
- beam vacuum and 1.5 Tesla magnetic field
  ⇒ constrains materials and techniques
- sensor edges 0.5 mm from electron beam in L1
  ⇒ must be movable, serviceable
- sensors see large dose of scattered electrons
  ⇒ must be actively cooled to -20 ˚C
- 24528 channels can output >100 gb/sec
  ⇒ requires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







Changes for 2019: addition of new L1… and L2



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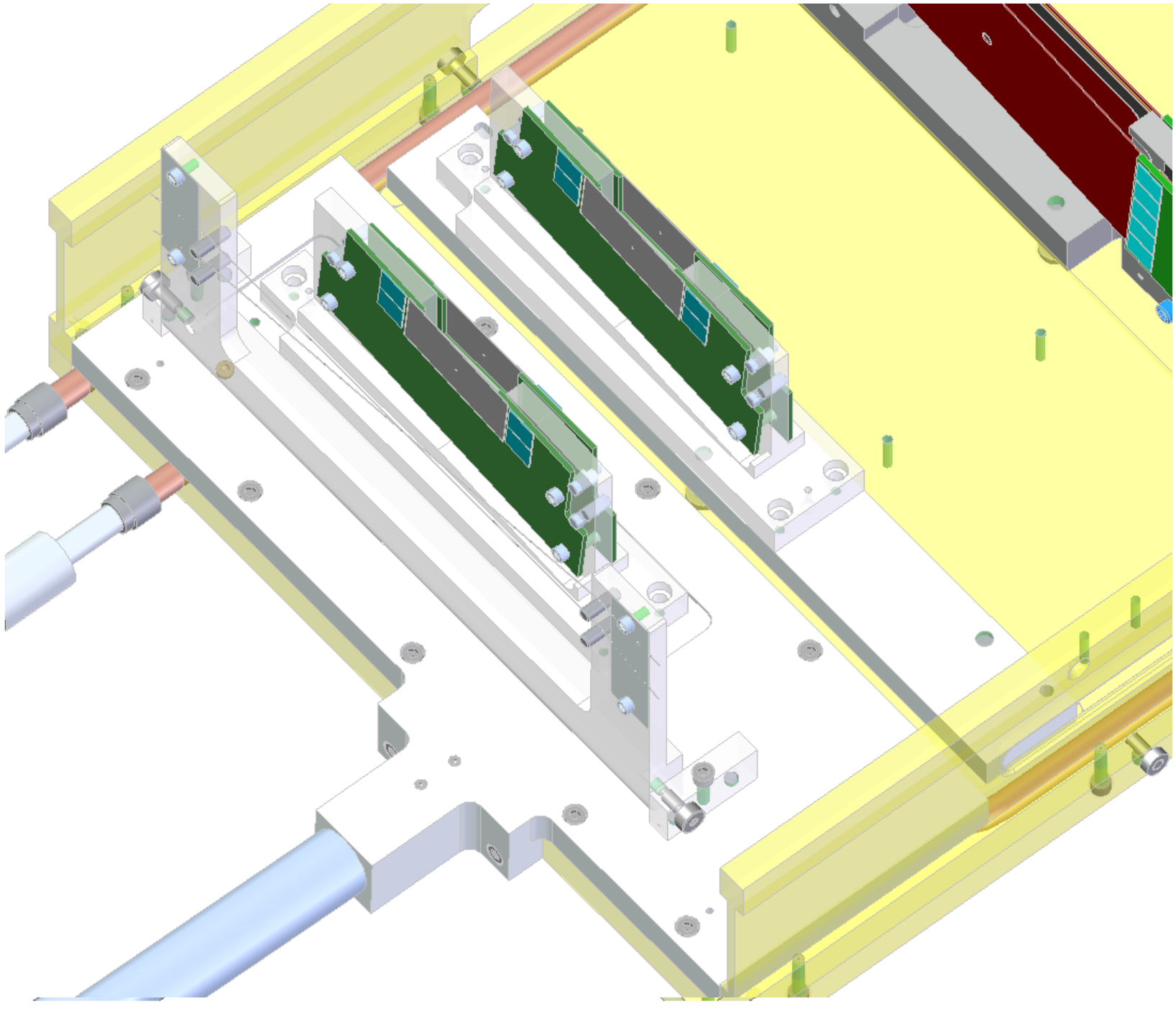

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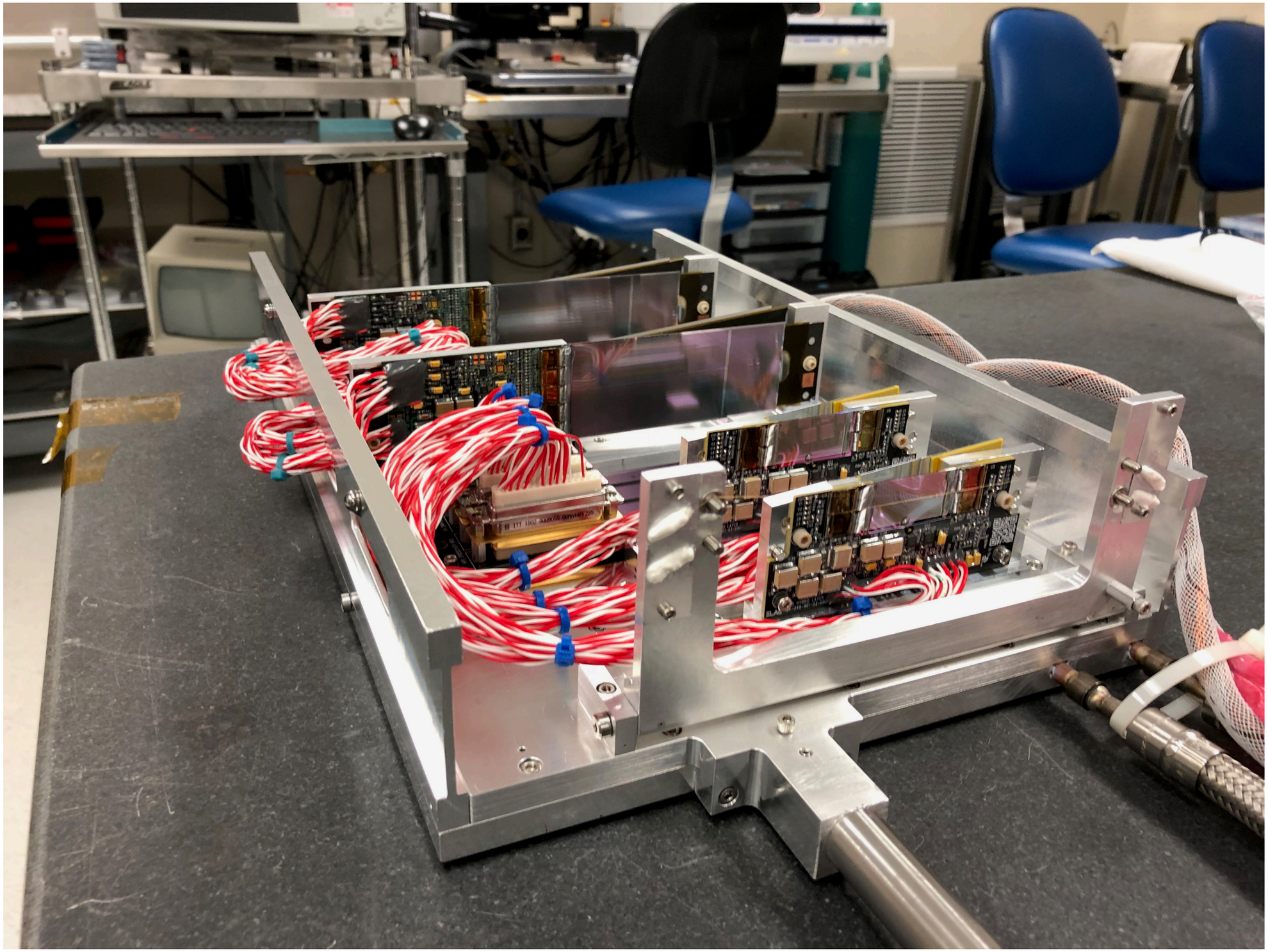
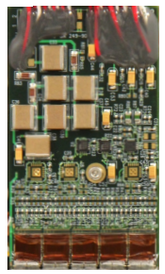
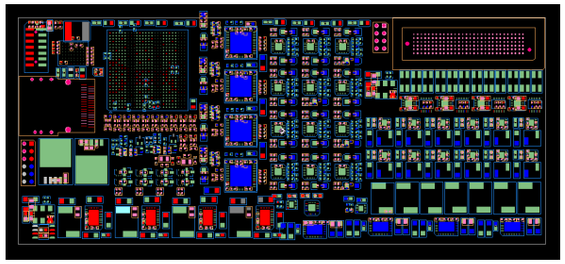


HPS SVT DAQ

- 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

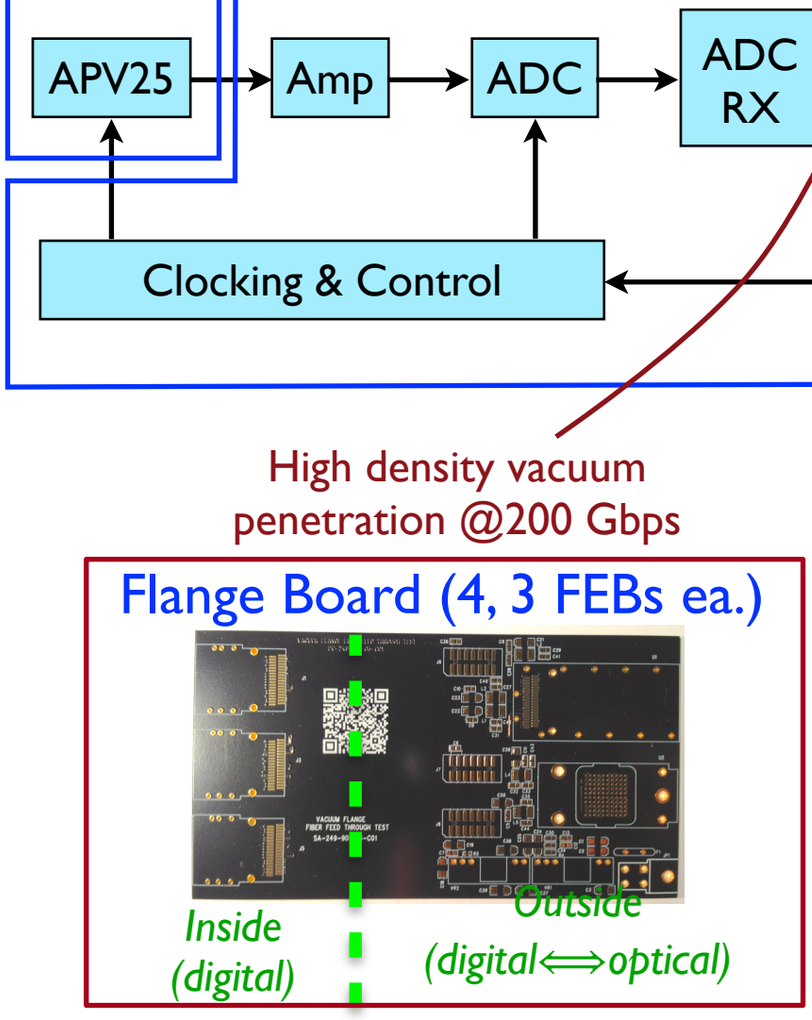


Hybrid (40)



Front End Board (10, 4 Hybrids each)

RCE Platform



Outline of SVT Maintenance and Repair

Repair and/or replacement of radiation damaged FEBs

- Investigation and diagnosis
- 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 *(Sergey/Ryan)*
- Odd jobs

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

FEB Damage During 2019 Operations

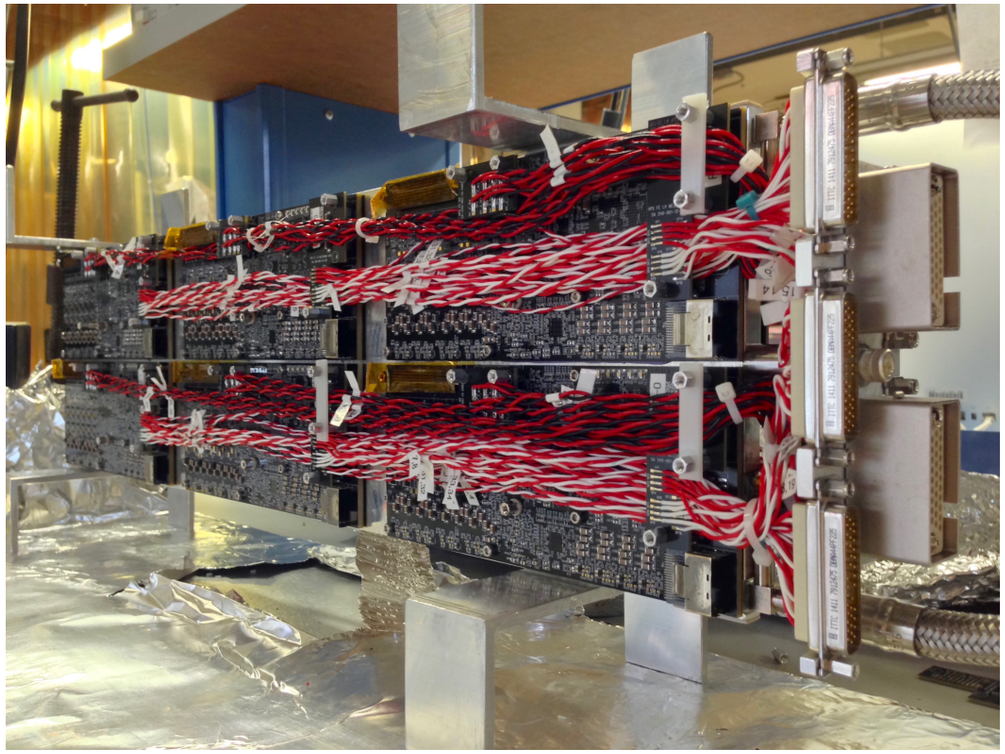
FEB degradation manifests as drooping 5V / 500 mA regulator, which supplies:

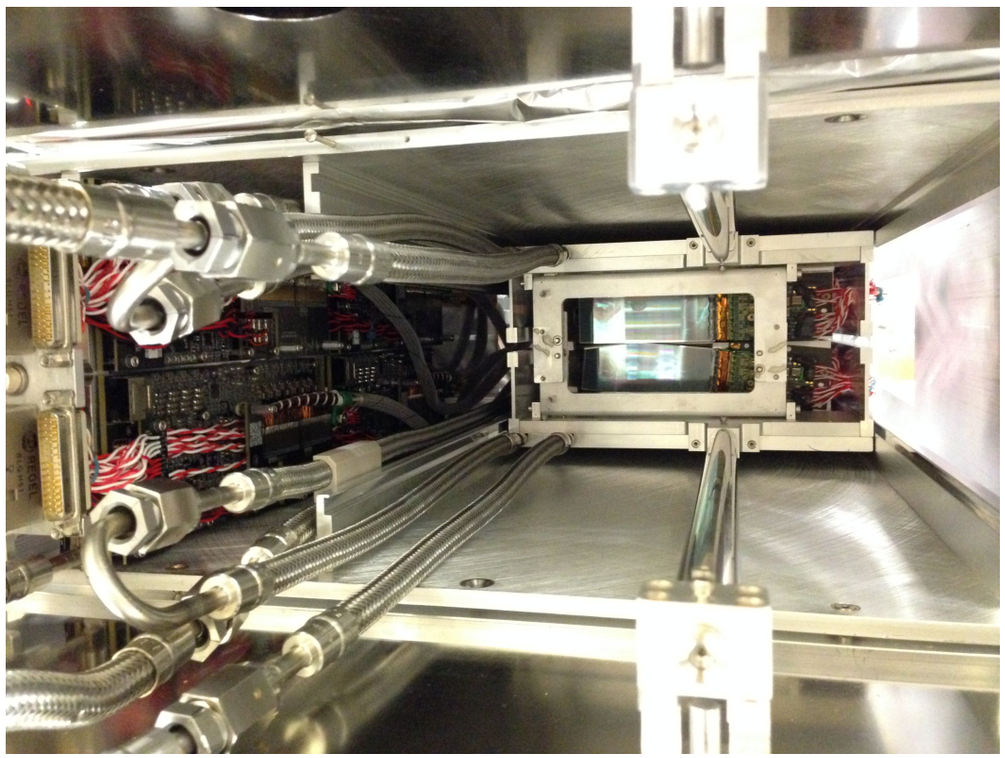
- 24 preamps for APV before ADCs (~10 mA each)
- bias voltage for 12 regulators that supply voltages to the hybrids (~5 mA each)

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

- With only 3/10 symptomatic, geographically diverse, numerology favors problem w/ current draw.
- Temperature sensitivity favors a regulator problem. (known susceptibility of LDO control/monitoring).

Damage meant loss of L7T and one hybrid in L5B.





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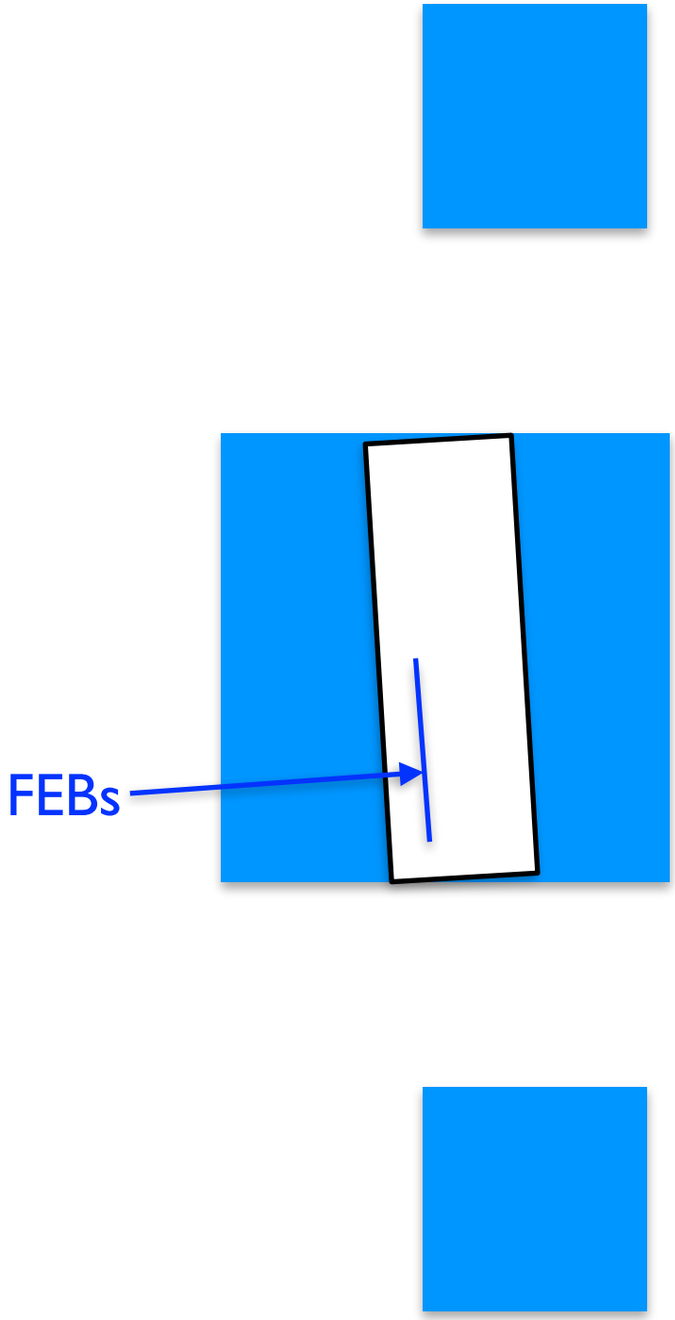

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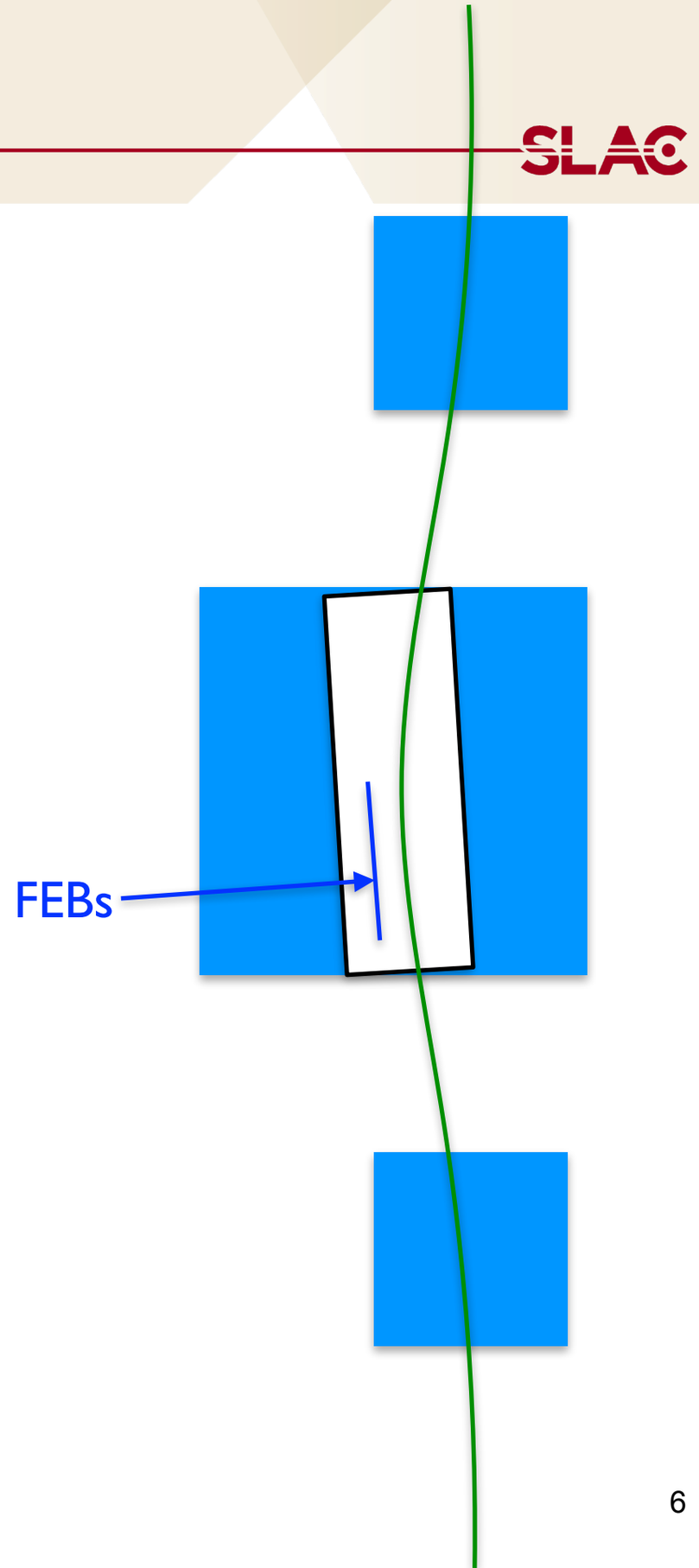

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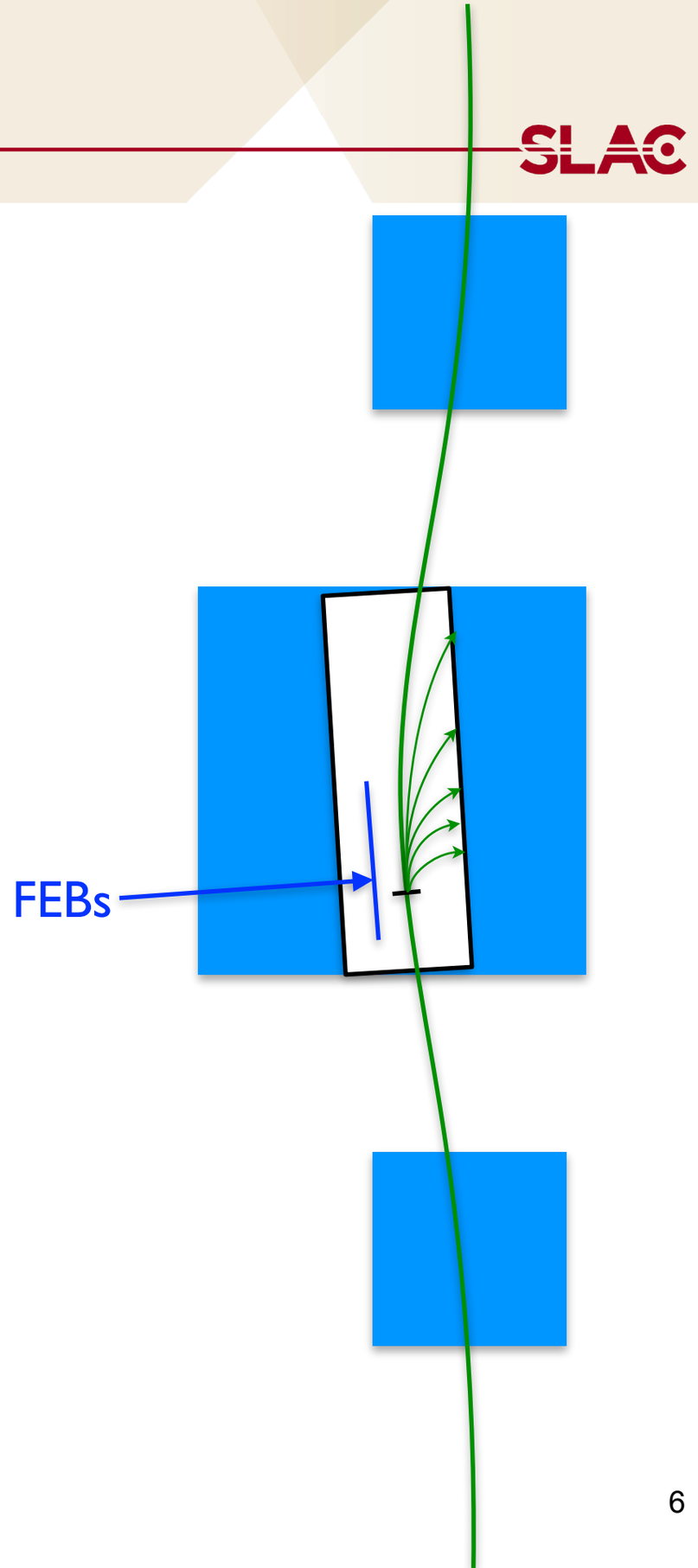

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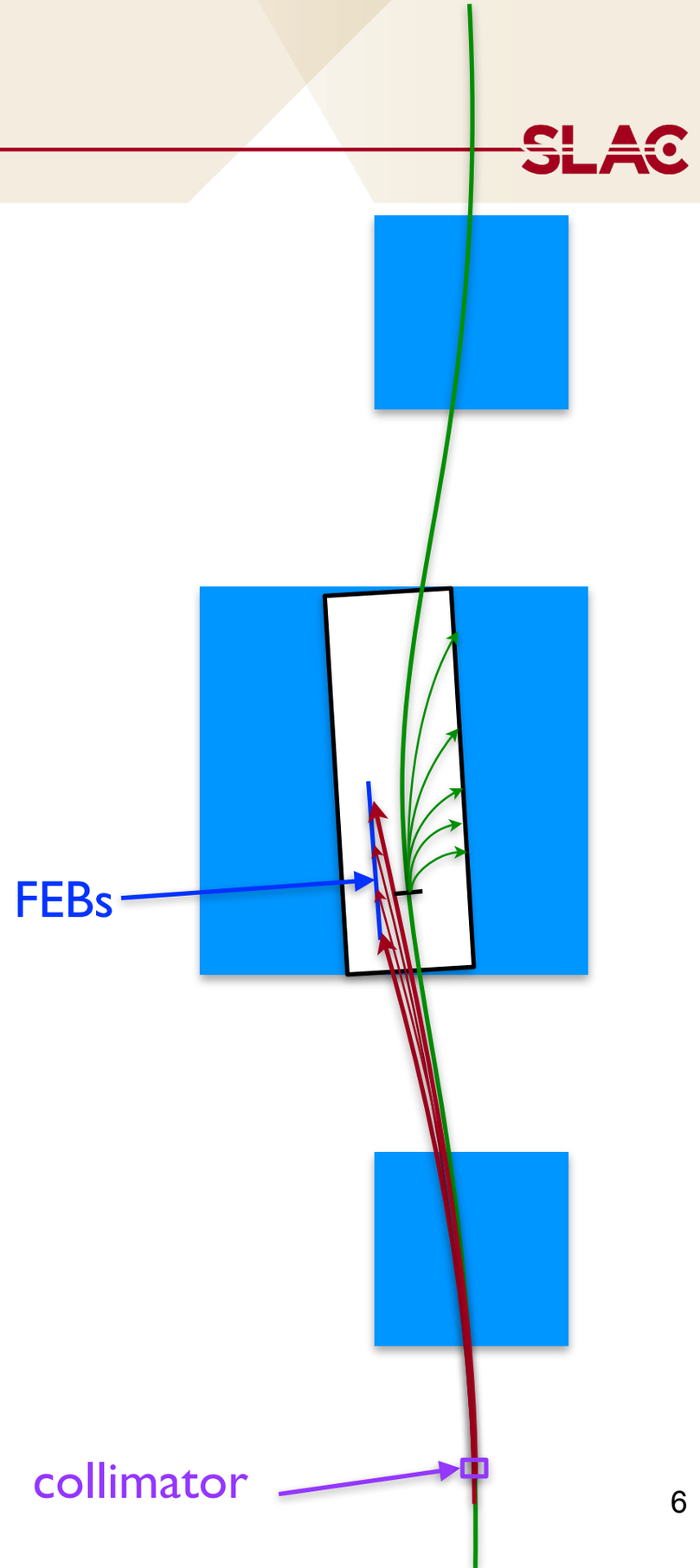

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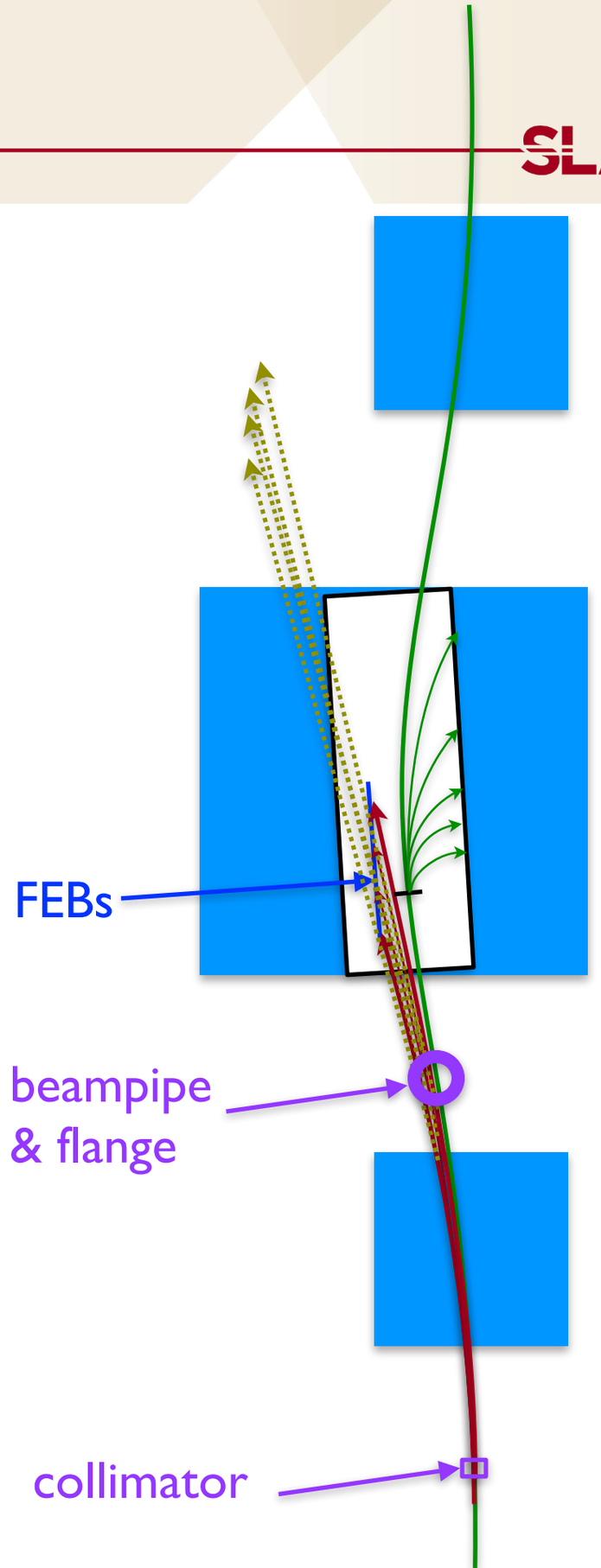


FEB Damage Investigation

Extended operation of 2019 run emptied our coffers: no resources to investigate FEB damage.

Lauren Tompkins (Stanford), interested in Dark Sectors already, bailed us out.
Engineer Marcelo Vicente, with setup assist from Cameron, investigated FEB8 (most damaged)

- With FEB8 powered, 5V reads 0V (temperature not clear, but probably 30-40 C)
- 5V regulator removed, FEB 5V connected to external supply:
  FEB5V draws 215 mA (300 mA) with all hybrids off (on). 240 mA / 300 mA is expected.
- Resistivity of 5V rail on is the same on both good and bad FEBs.

Seems to indicate that the LDO regulator is the problem, but intend to check other damaged FEBs also. Work interrupted by pandemic.

Plan to move forward:

- investigate replacement components (LHC colleagues have some relevant experience)
- choose replacement with significant current overhead, probably requires larger package
- begin layout process assuming no other major changes

We may be able to work on site again to complete testing before layout work needs to begin.

FEBs: Repair or Replace?

FEB Status:

- 15 built, 10 needed. After replacements during installation no perfect spares.
- 3 show symptoms of damage in 5V supply
- 1 has some kind of damage to V125 control for one hybrid
- possible damage to ADCs? (bad temperature data, but no other signs.)

Repair issues:

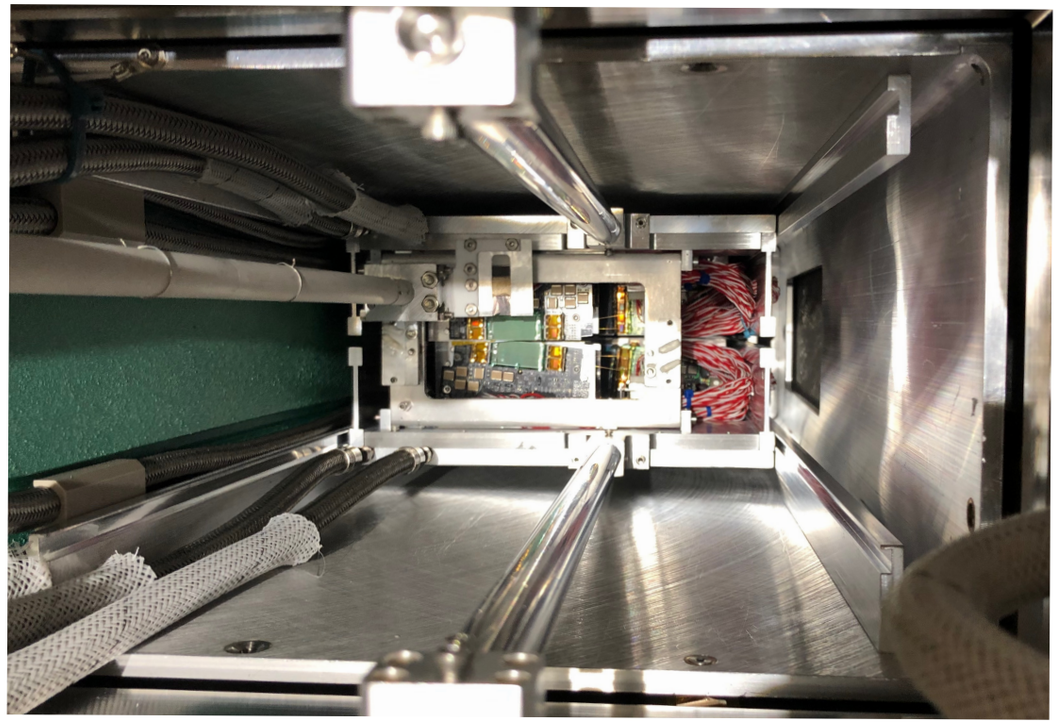
- Not clear how we would accommodate a larger regulator with a repair.
- Repairs have often created new problems: whack-a-mole
- Repairing these complex boards has proven to be a time sink. Labor costs for repair likely exceed M&S for new boards by a large factor.
- Given historical problems with these boards, likely that there were initial quality problems or material issues (resulting in cracked vias) that a new spin gives us opportunities to solve.

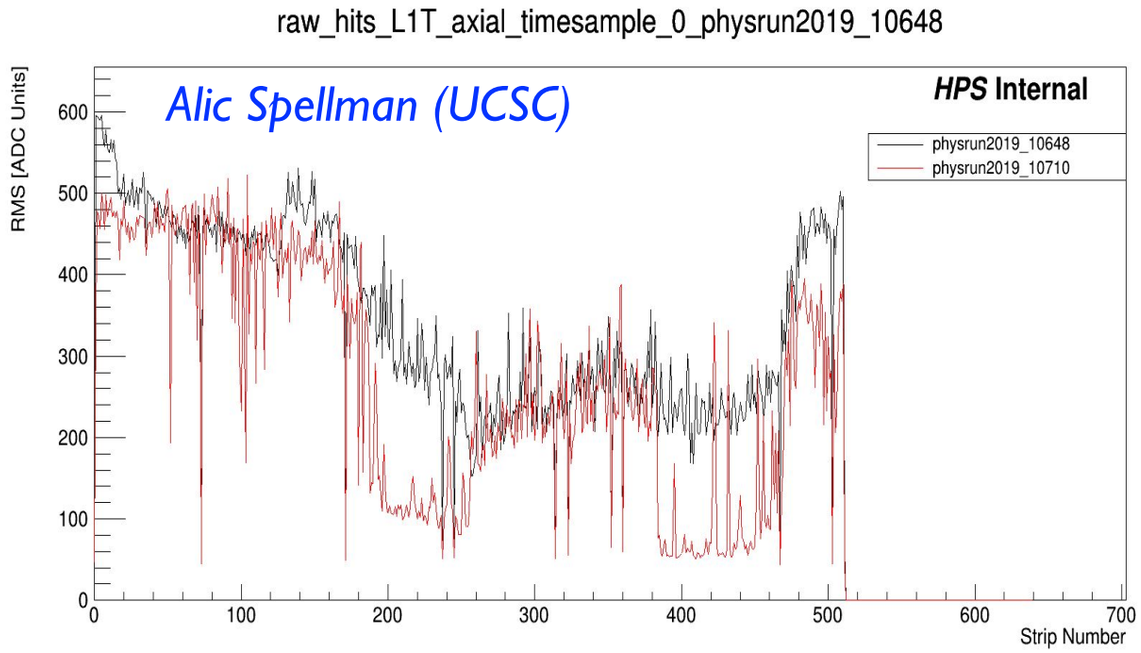
Replacement allows opportunity to mitigate risk of observed failure modes and obtain a proper pool of spares at reasonable cost.

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 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 straight-throughs?), 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

The modules for L1, L2 are very simple and inexpensive to build

- Hybrids and passive components are inexpensive
- Have spare support structures
- Assembly infrastructure still in place
- Need more APV25. Immediately after the run, purchased *last* 185 APV25 chips from stocks
- Need more Sensors. Opportunity to address quality issues with a new run, which *may* also make the sensors more robust to damage (impossible to predict).

Sensor lead time is the key issue

- Estimated delivery is 5.5 months after design acceptance
- D+T CNM is in Barcelona: processing line is down and takes weeks to restart.
- Want to get order placed and design work done before line is back up
- With help from Vitaliy, sensor specification has been settled, including double-oxide coupling capacitor process (eliminates pinholes) and features to improve cleaving (slimmer edges and higher breakdown voltages)
- Quote received yesterday: $29K for 20 sensors (also asking for quote on 30).

Must push hard now even if run is in second half of 2021 to preserve float.

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 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.

Working at SLAC and JLab in the COVID-19 Era

Work plan must accommodate current closures at SLAC/JLab, and anticipate how on-site work will begin again.

At SLAC, "On-site Recovery Task Force" plans to bring work back in stages:

- Stage 0 – now – essential work and "construction" (e.g. LCLS-II)
- Stage 1 – 6/1? – priority tasks (MIE/Ops where DOE milestones at stake)
- Stage 2 – 7/1-8/1?? – phased start of other on-site work (not office work)
- Stage 3 – ??? – return of some office work
- Stage 4 – ??? – new "normal"

Work at JLab carries additional uncertainties

- Travel
- Access for users
- Interaction with Hall B schedule for SVT removal

Wild card: trajectory of pandemic at both sites, localized outbreaks, restrictions.

General Outline of Work Plan

FEBs

- begin parts selection, modifications to schematic, board specifications. DOE funds already at SLAC.
- complete testing of old FEBs when Stage 2 work at SLAC begins. DOE funds already at SLAC.
- complete FEB design and layout late FY20. Requires FY20 funds still pending.
- fabrication and testing early FY21, along with modifications to octopus
- ready to re-assemble FEB cooling plate by Jan. 2021

Sensor Modules

- place order for sensors ASAP, approve sensor design for fabrication before fab is back online aiming for early CY2021 delivery. DOE funds already at SLAC.
- order hybrids ASAP when Stage 2 work at SLAC begins. Requires FY20 funds still pending.
- hybrid loading at SLAC late FY20. Requires FY20 funds still pending.
- loading and testing at UCSC early FY21, ready to build modules in Jan. 2021, before sensors arrive.

JLab integration and testing

- Have chiller serviced ASAP. Requires FY20 funds still pending.
- When travel, HALL B plans allow, remove SVT and set up in EEL. Requires FY20 funds still pending.
- Two subsequent trips to install and survey new sensor modules, install and test new FEB cooling plate, and then do full system testing prior to installation.

Summary

- The SVT requires work to get back into shape for 2021.
- Plans were well underway before COVID pandemic struck.
- The pandemic introduces additional schedule uncertainty and probably reduces float, depending on JLab schedule.
- All we can do is plan for success and keep pushing. DOE has been supportive in this.
- 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!