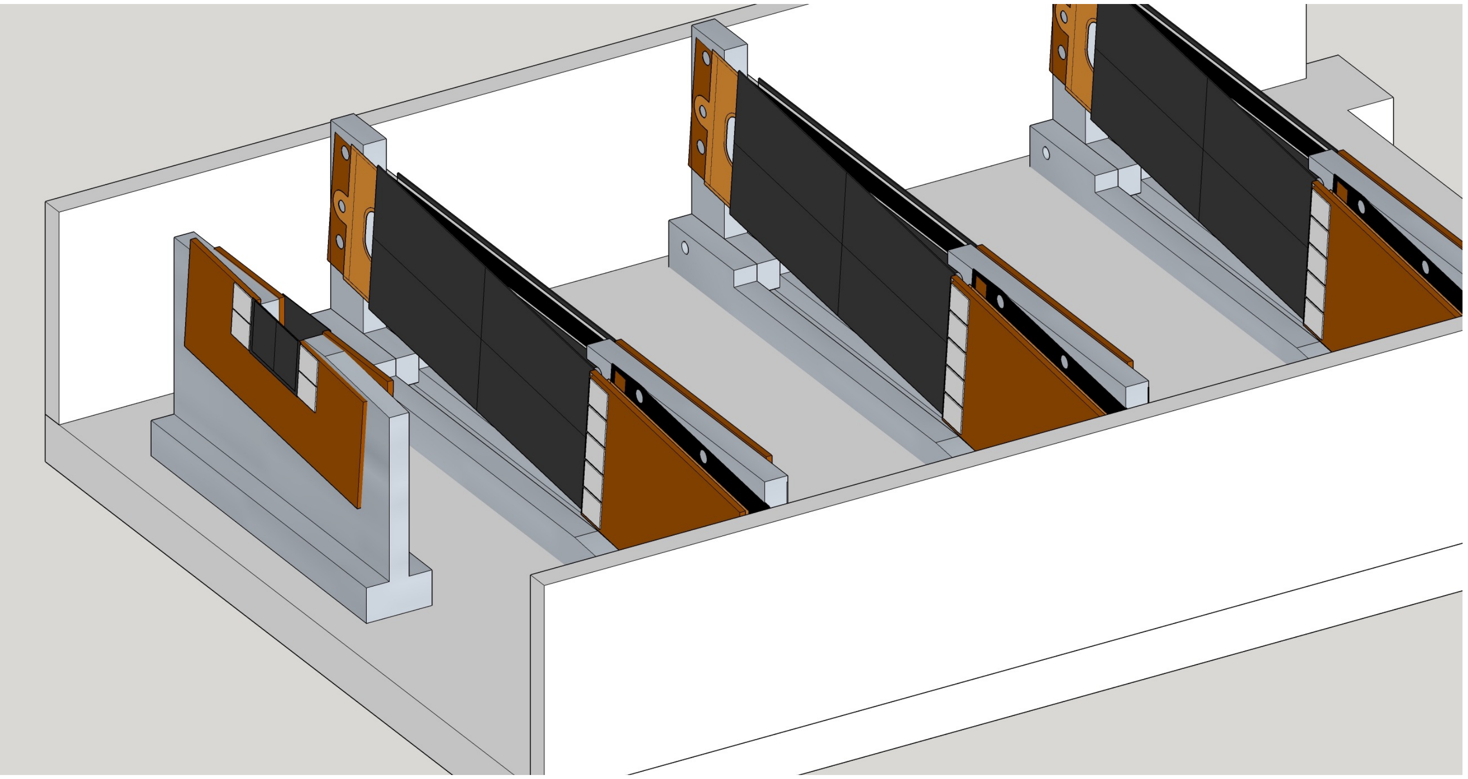
SVT Upgrades

Tim Nelson - SLAC

May 4, 2016



Upgrade Approval

From 4/13/17 EC Meeting (JJ proposal)

What process should EC establish for approving the SVT and Trigger/DAQ Upgrades for HPS? Here's a proposal:

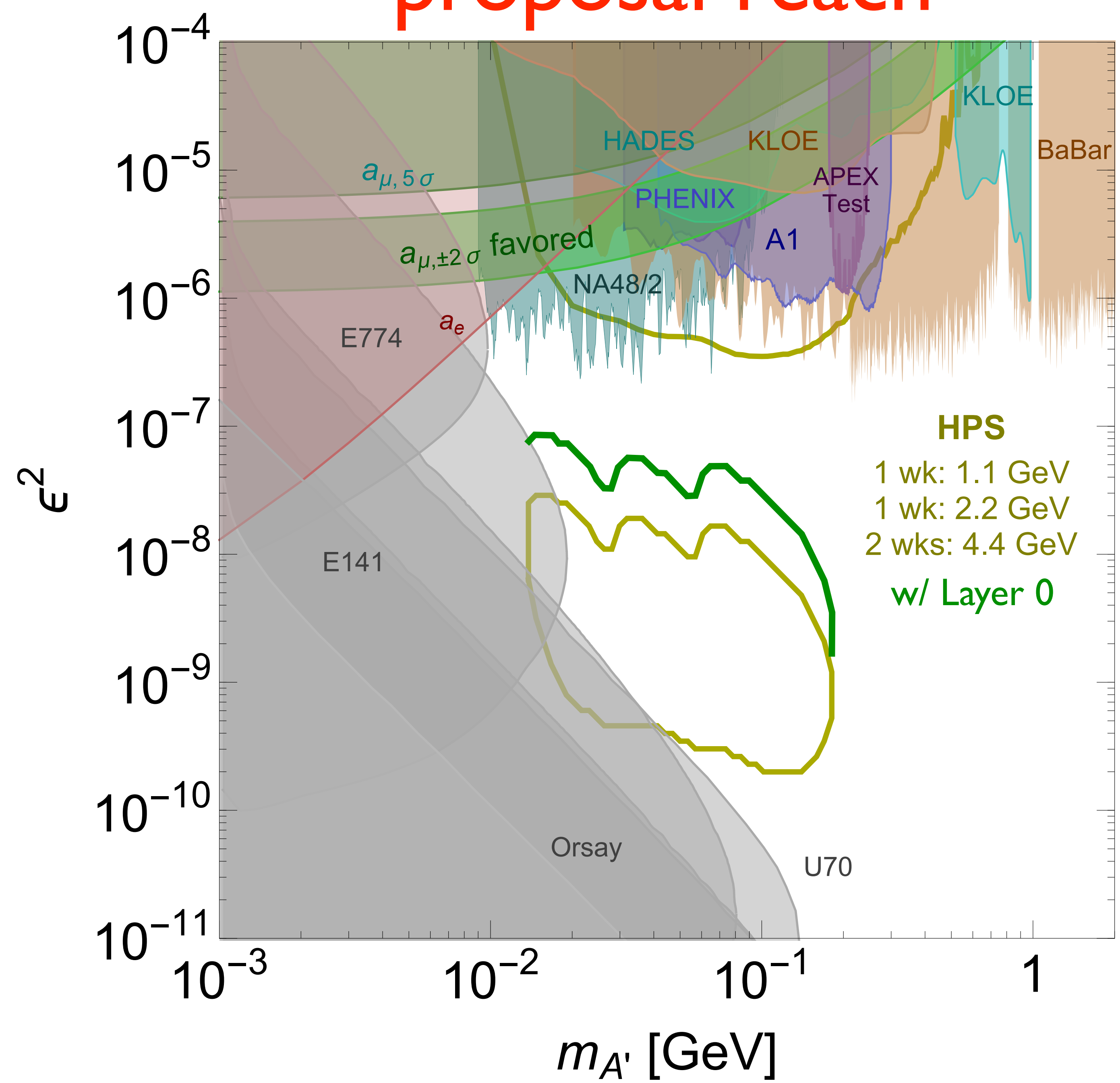
- **Presentation to Collaboration**
  Physics justification
  Simulated performance improvements
  Proposed Design
  Cost, schedule, manpower and resource availability
  Commissioning Plan (time and effort required)
- **Technical Review**
  ½ day review with local experts to judge technical feasibility, cost, and schedule once actual design is completed
- **Regular Progress Updates for EC**
  Quarterly? *Monthly (SS proposal)*
- **EC "Readiness" Review before installation**

Physics Justification

Addition of Layer 0

- conceived and largely designed before errors in proposal reach were uncovered.
- purpose was to expand vertex reach, especially upwards into Mont's Gap.

proposal reach



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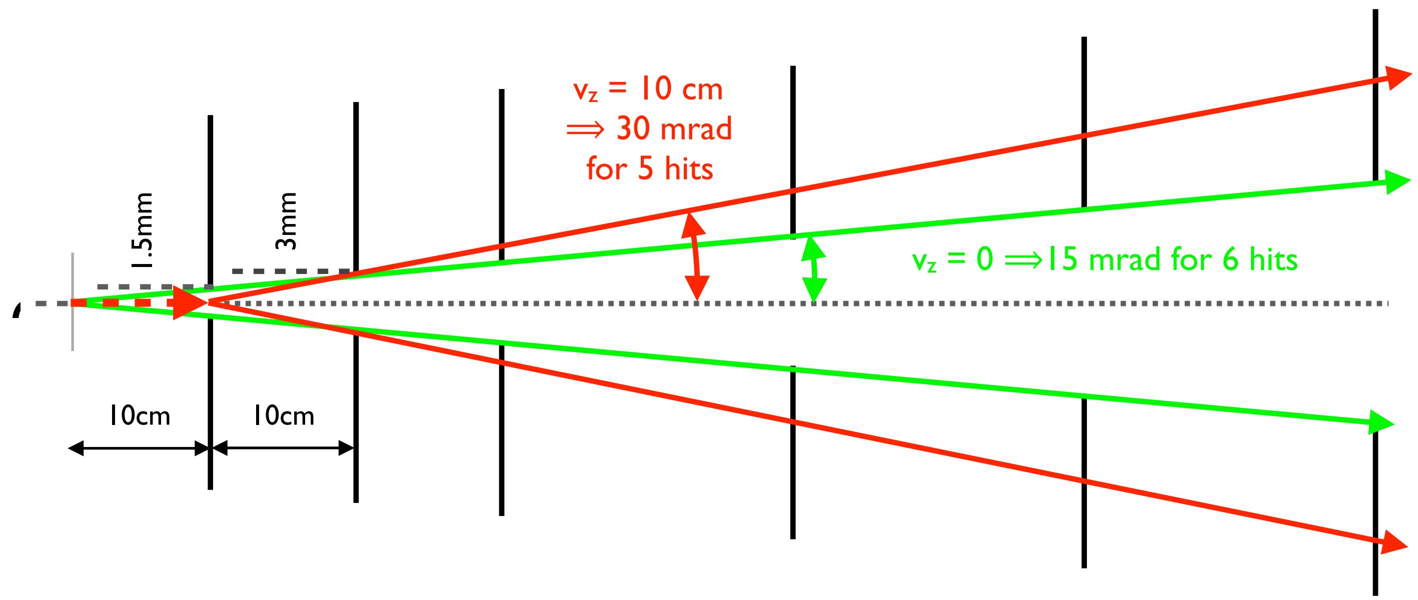
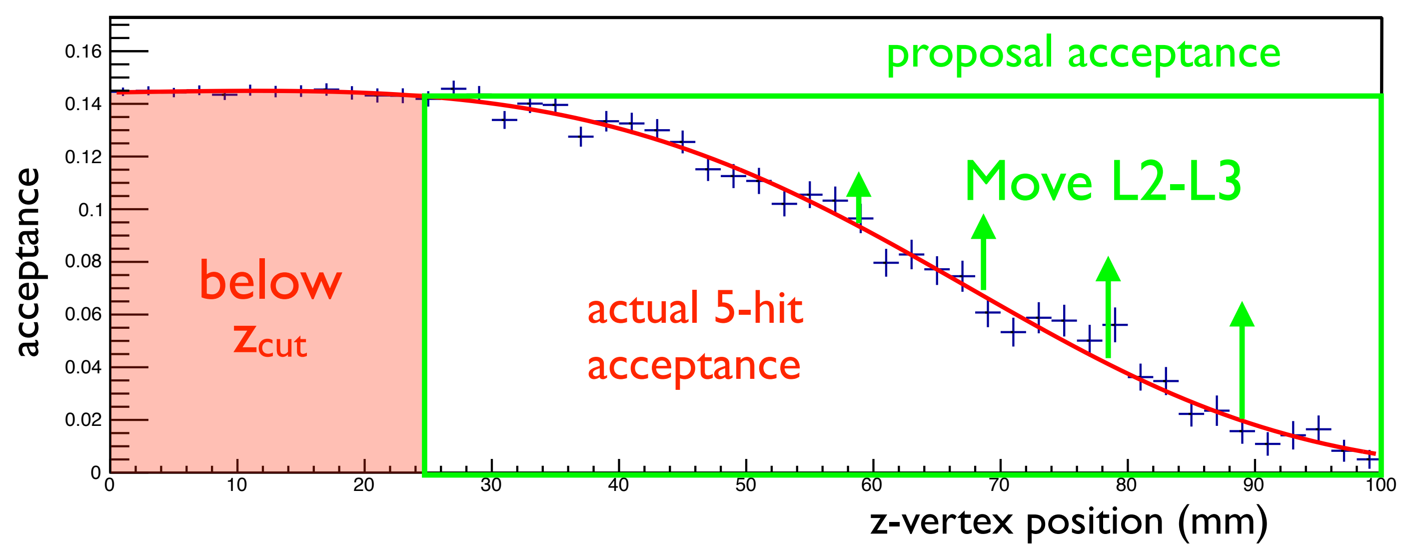


Move of Layers 2 and 3

- dependence of acceptance on z-vertex position was not included in proposal estimates and therefore never explored
- Moving Layers 2 and 3 towards y=0 recovers some of the lost acceptance.



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Move of Layers 2 and 3

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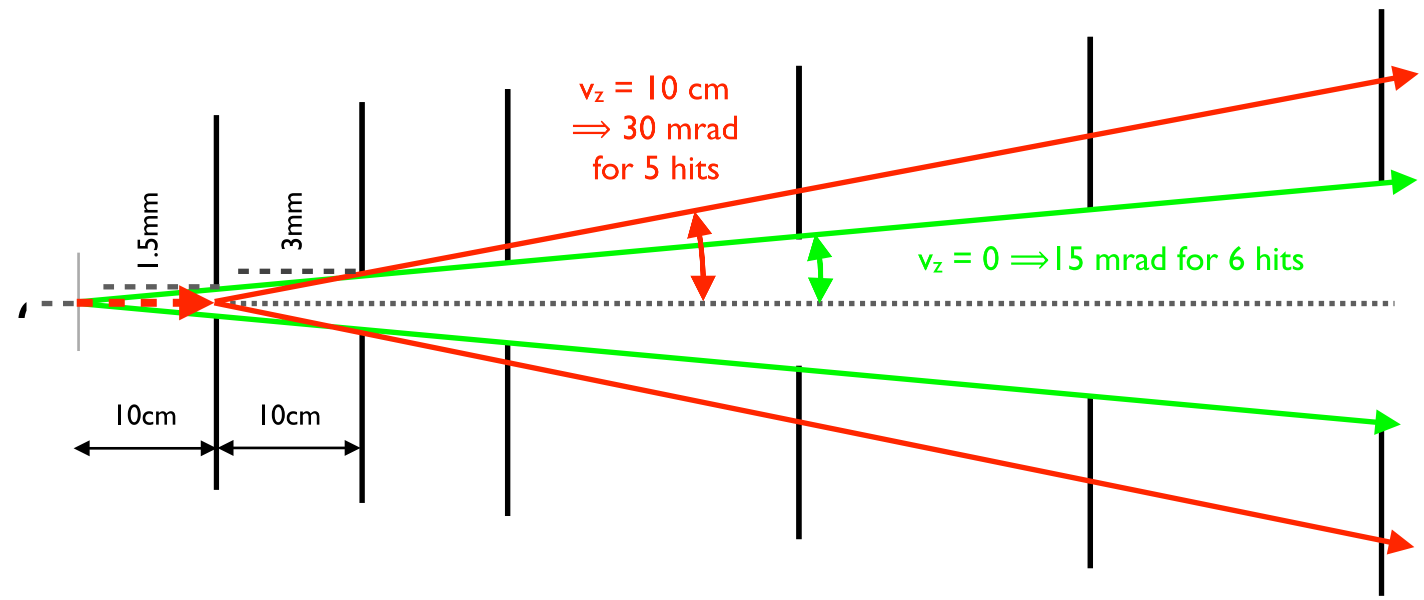
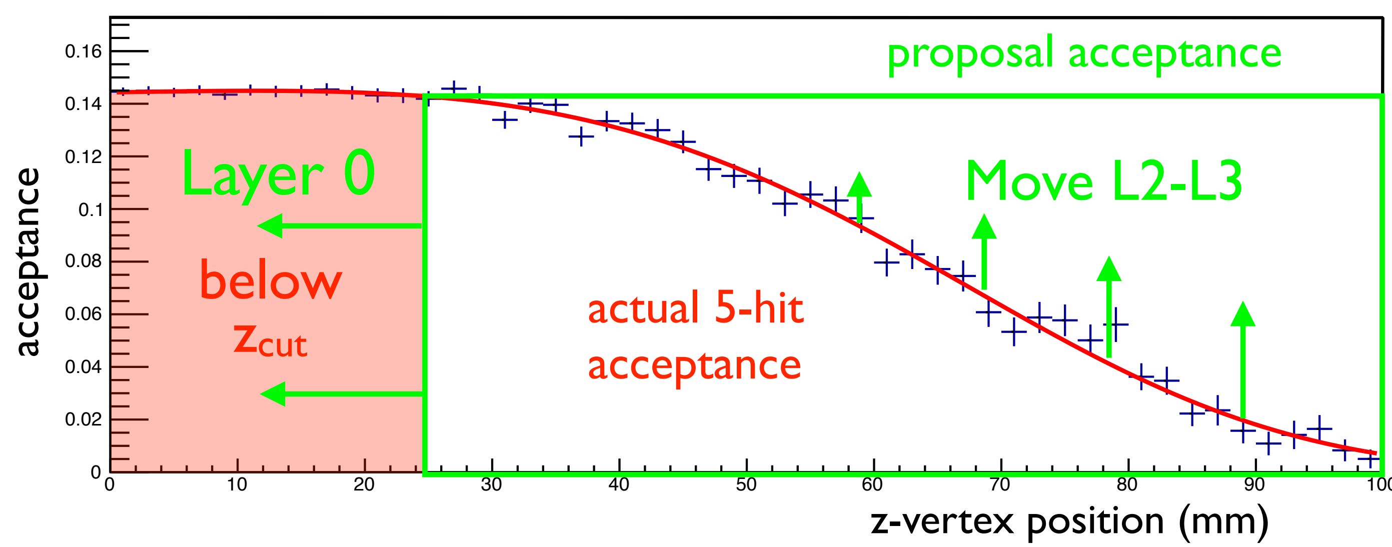
- Moving Layers 2 and 3 towards y=0 recovers some of the lost acceptance.

Addition of Layer 0 takes on new importance in light of reduced acceptance.





Simulated Performance Improvements

Matt Solt has been working very, very hard on this, with help from Bradley, Omar and Matt Graham.

Fundamentals

- acceptance and efficiency
- resolutions (mass and vertex)
- backgrounds (esp. WABs)

Reach estimates

- z cuts
- nominal vs. upgraded reach
- 1.06 GeV (have developed analysis and clear benchmark from data)
- 2.3 GeV
- 4.4. GeV

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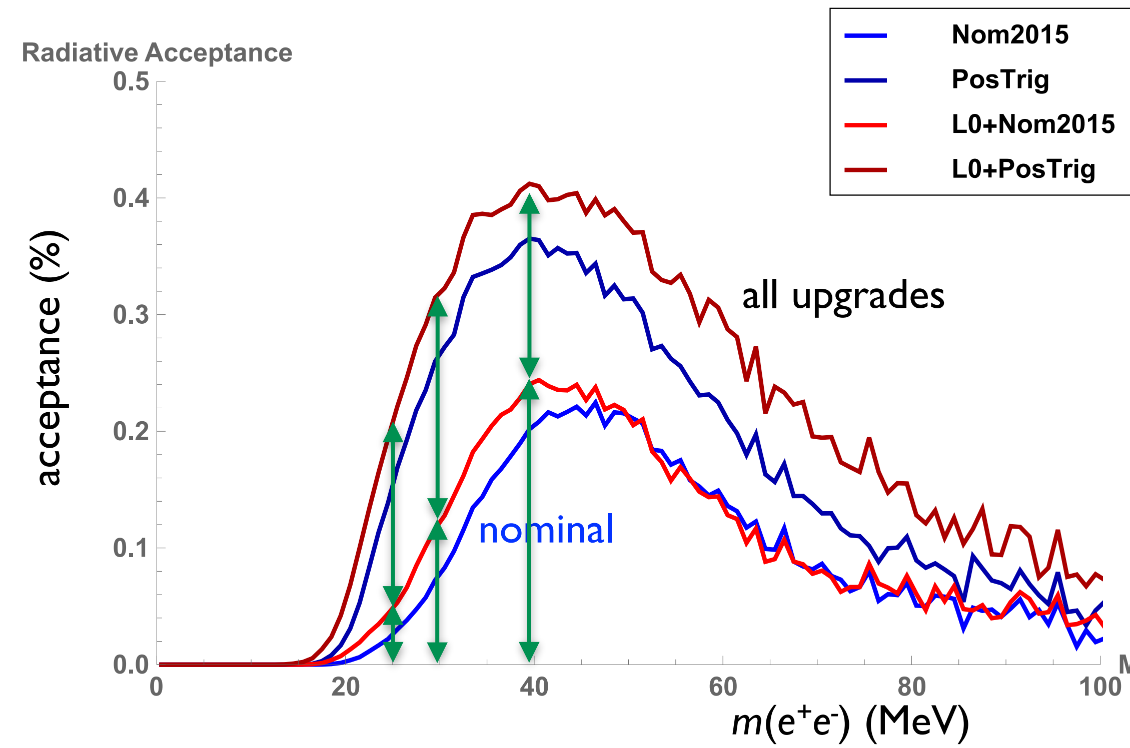
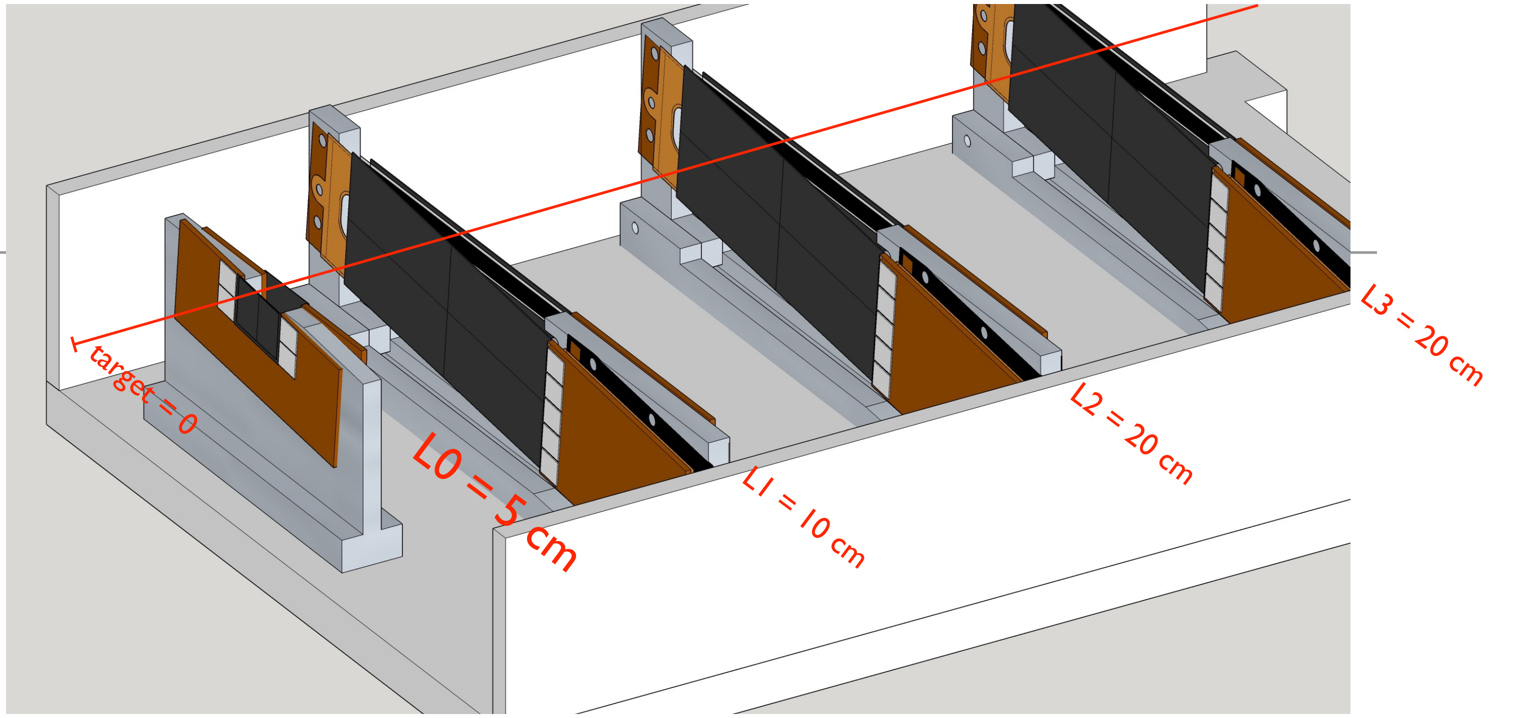
geometric acceptance for radiative events



New estimates don't include effect from positron only trigger. Based on rough studies performed by Matt, positron-only trigger is likely to expand the reach considerably to lower masses.

Proposed Design



Addition of Layer 0, similar in concept to other layers, but…

- half the distance to target (5 cm)
- half the material (0.35% X_0)

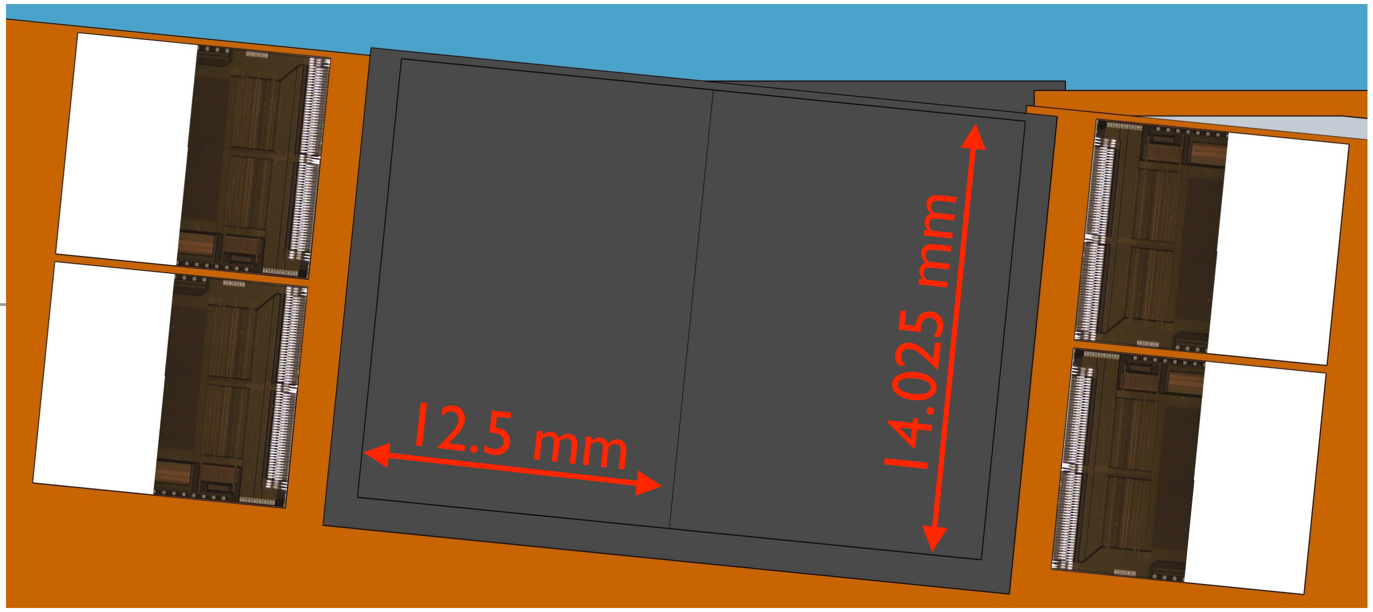
Negative impacts of thinner sensors appear manageable:

- reduced signal compensated by lower noise from short strips
- L-shell x-ray sensitivity from lower thresholds compensated by smaller solid angle of short strips
- Proximity of active region means greater sensitivity to beam tails. This is an area where further work is called for.

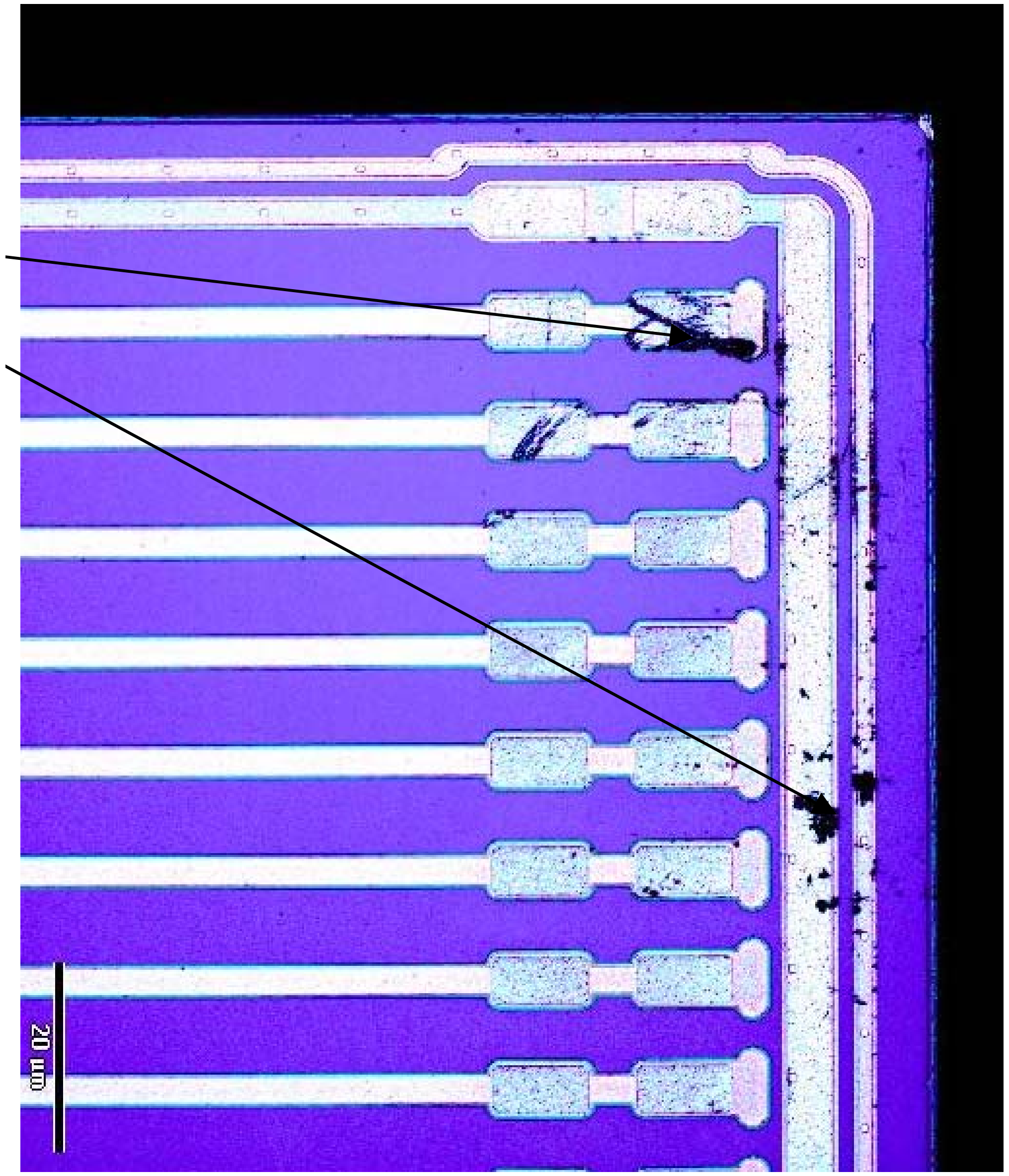
Moving L2 and L3 is completely independent and very low impact.

- Thin shims under module supports move L2 and L3 towards y=0.
- Adding these when modules are remounted about L0 modifications is trivial.

Layer 0 Sensor Design



- thickness: 150 um
- sense/readout pitch: 55 um
- active areas: 2×(12.5 mm × 14.025 mm)
- # channels: 510 (2×255)
- slim edge: ≲200 um
- max bias voltage: 500V (will test/select)



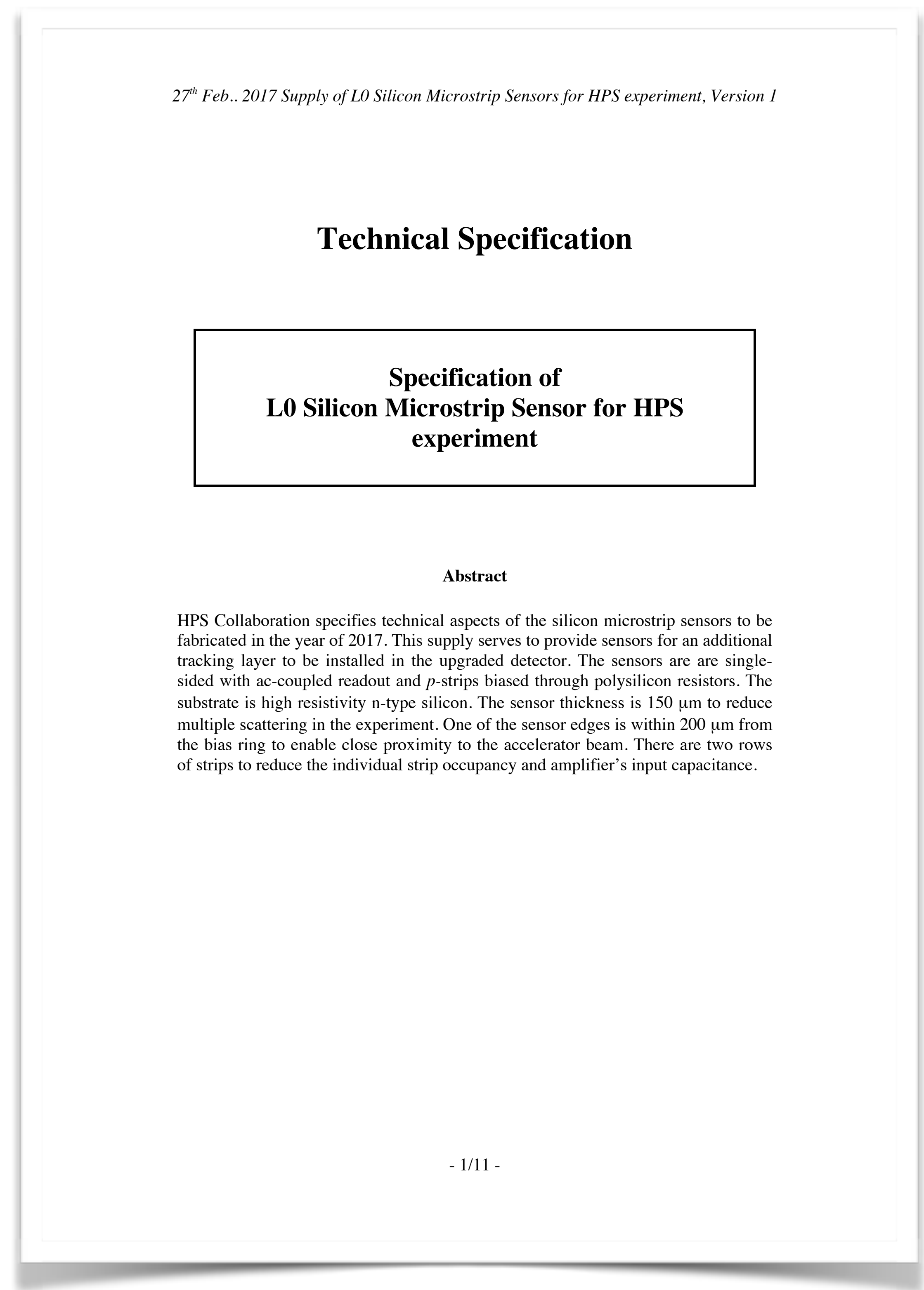
Layer 0 Sensor Design

The vendor, D+T CNM, has quoted the project and technical specifications are ready

Discussions regarding the design are largely complete.

Lead time is 6 months, plus slim-edge processing.

Need to decide on approving the project so that we can place this order ASAP.



27th Feb.. 2017 Supply of L0 Silicon Microstrip Sensors for HPS experiment, Version 1

Technical Specification

Specification of
L0 Silicon Microstrip Sensor for HPS experiment

Abstract

HPS Collaboration specifies technical aspects of the silicon microstrip sensors to be fabricated in the year of 2017. This supply serves to provide sensors for an additional tracking layer to be installed in the upgraded detector. The sensors are are single-sided with ac-coupled readout and *p*-strips biased through polysilicon resistors. The substrate is high resistivity n-type silicon. The sensor thickness is 150 μm to reduce multiple scattering in the experiment. One of the sensor edges is within 200 μm from the bias ring to enable close proximity to the accelerator beam. There are two rows of strips to reduce the individual strip occupancy and amplifier's input capacitance.

- 1/11 -

Layer 0 Hybrid Design

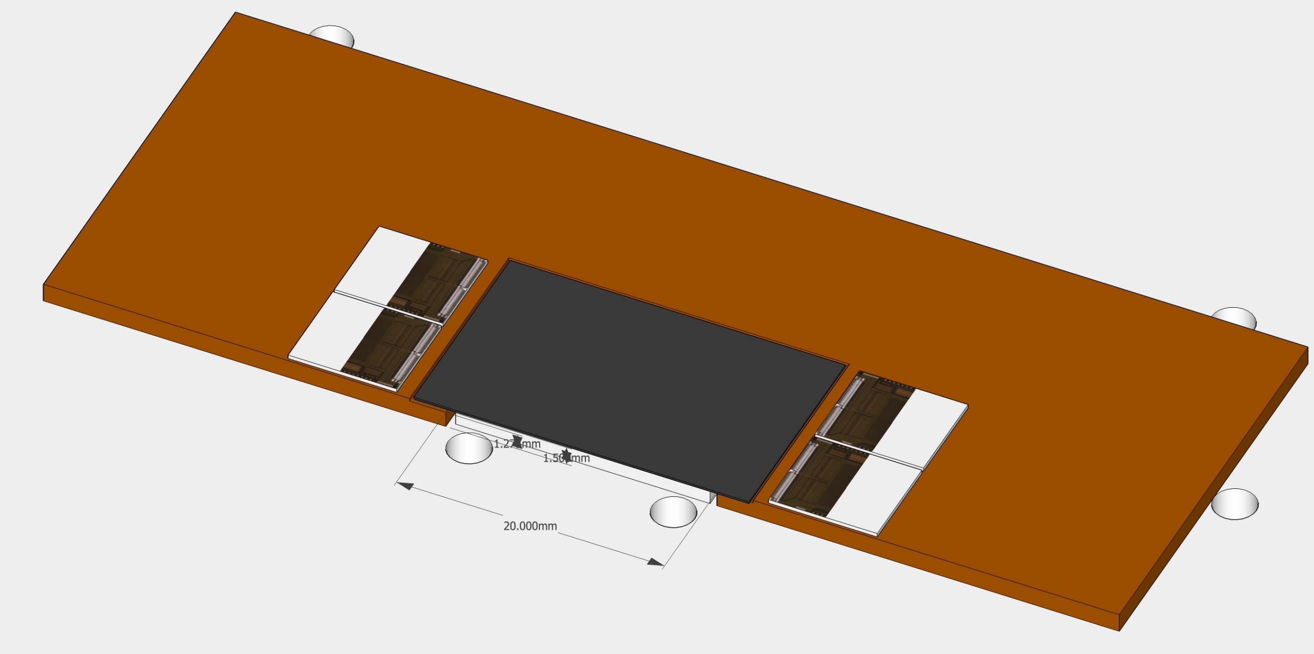
Schematic identical to previous hybrids, with one fewer APV25

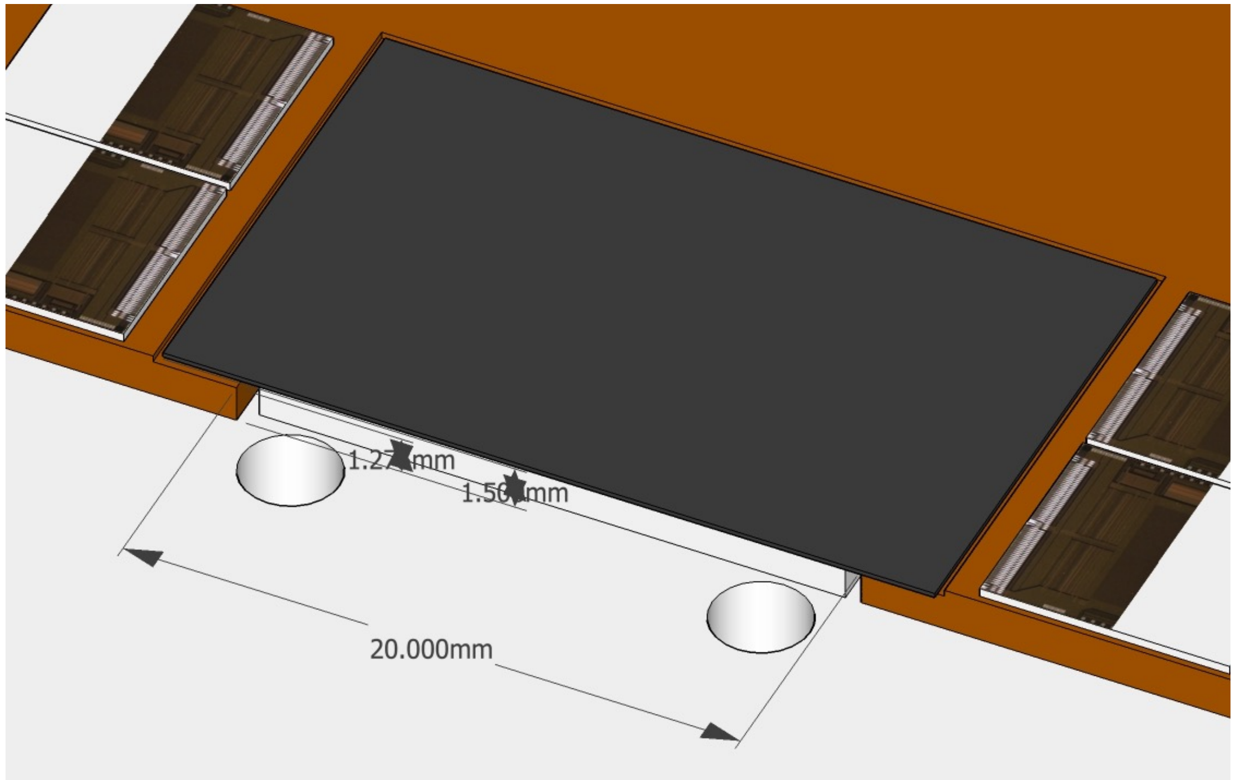
Layout very different, sensor placed in a window along one edge.

No CF support, but heat path to long edge of sensor is very short.

Currently testing with vendor to ensure that small step and sharp inside corners for window aren't an issue.

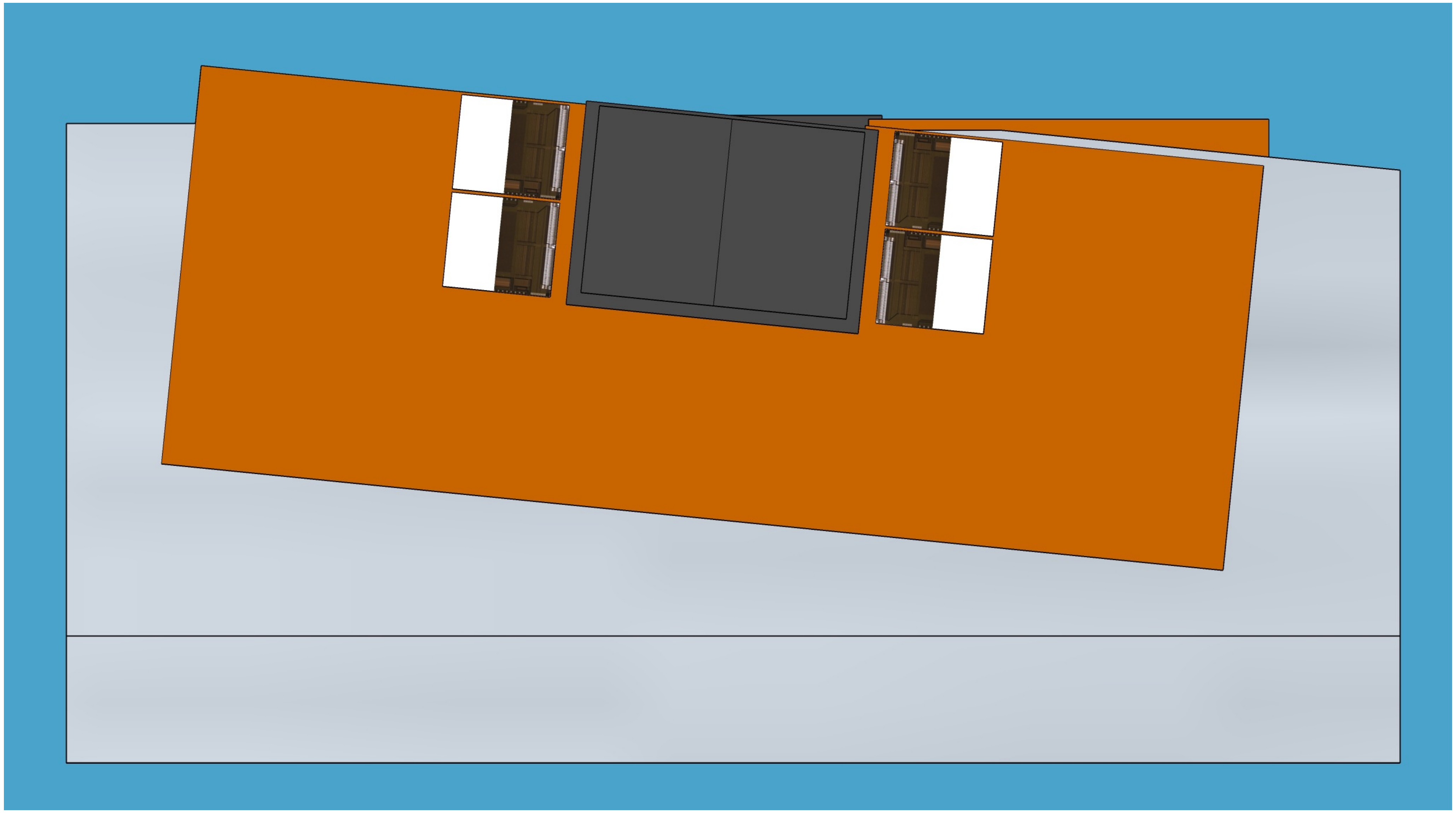
Small dimensions: expect CTE mismatch won't require stretched-silicon approach used in other modules. However, testing may tell use we need flexible adhesive.





Layer 0 Module Design

Similar to, but simpler than other layers: a solid Al cooling block.



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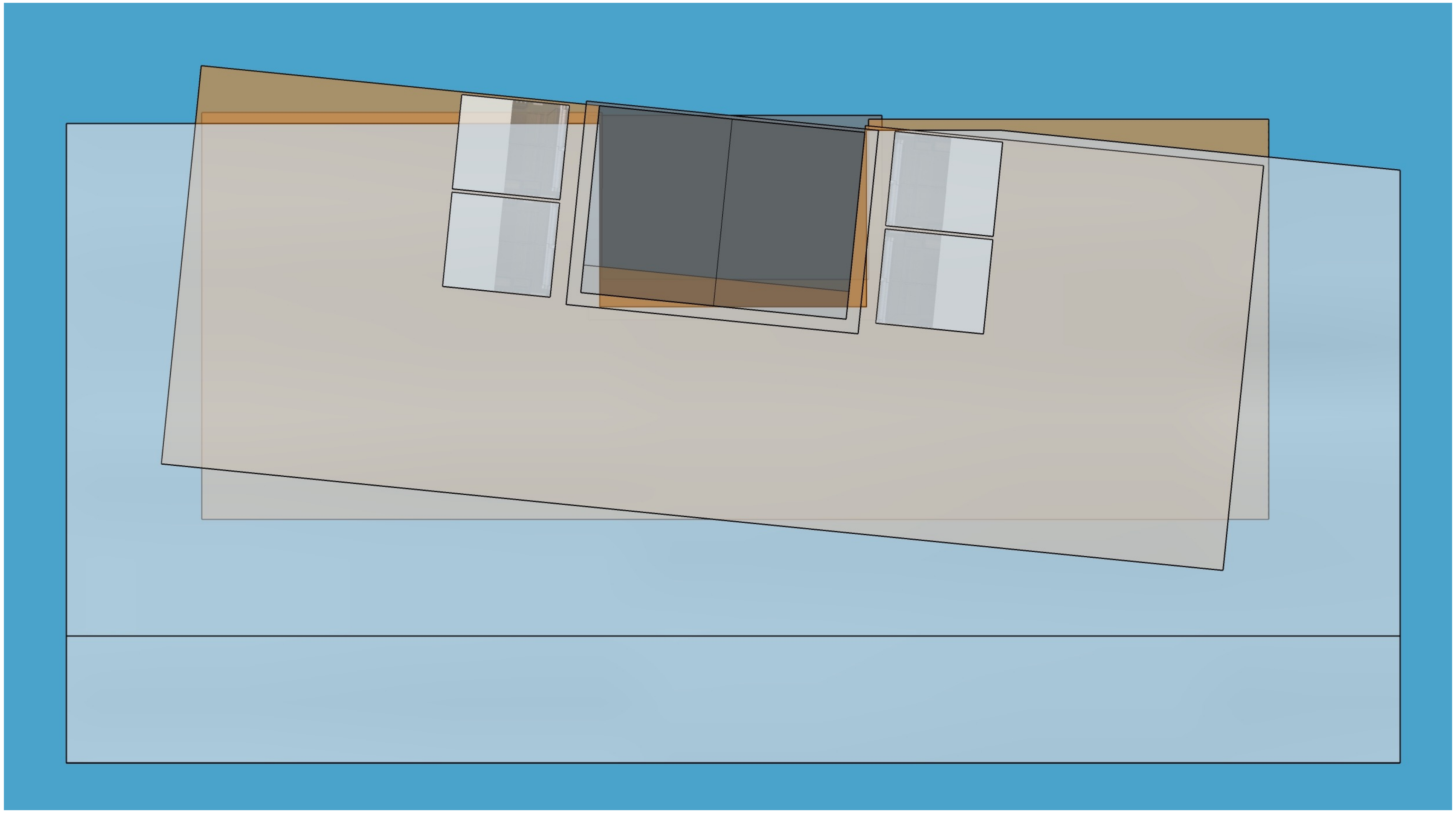


Angular acceptance of cooling block begins at 200 mrad. Is this acceptable?

Layer 0 Support and DAQ

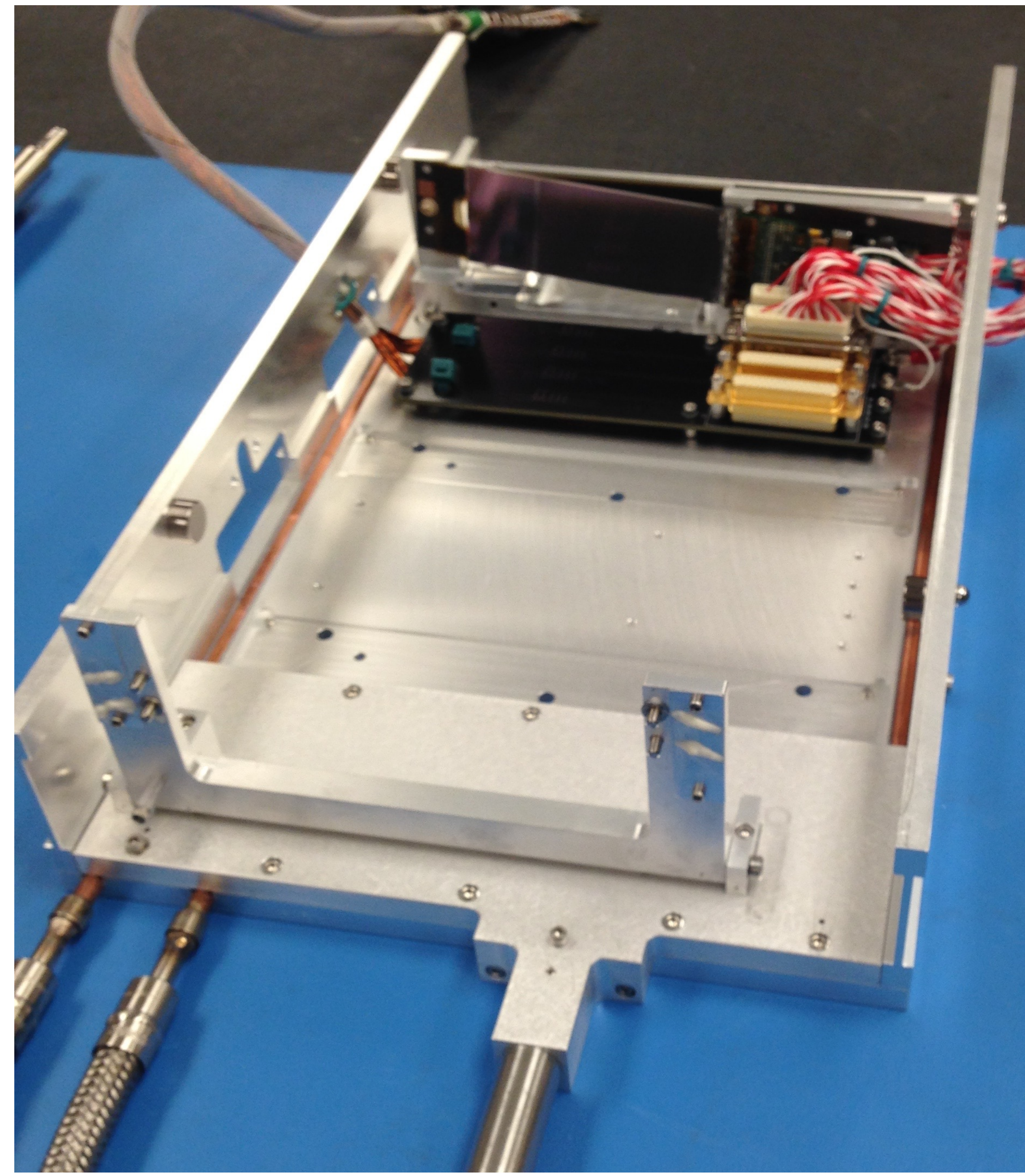
Layer 0 goes just downstream of the current SVT scan wire supports.

Current lever blocks will be replaced with new blocks, probably slightly longer, that will accommodate both the Layer 0 module supports and the current SVT scan wire frames.

The cooling line (supply end) runs directly beneath the lever blocks.

Hybrids will use soldered pigtails terminated in non-magnetic D-sub connectors, as in L1-L3 modules originally built for the HPS Test Run.

Open channels on crossover boards fully serviced by existing DAQ.



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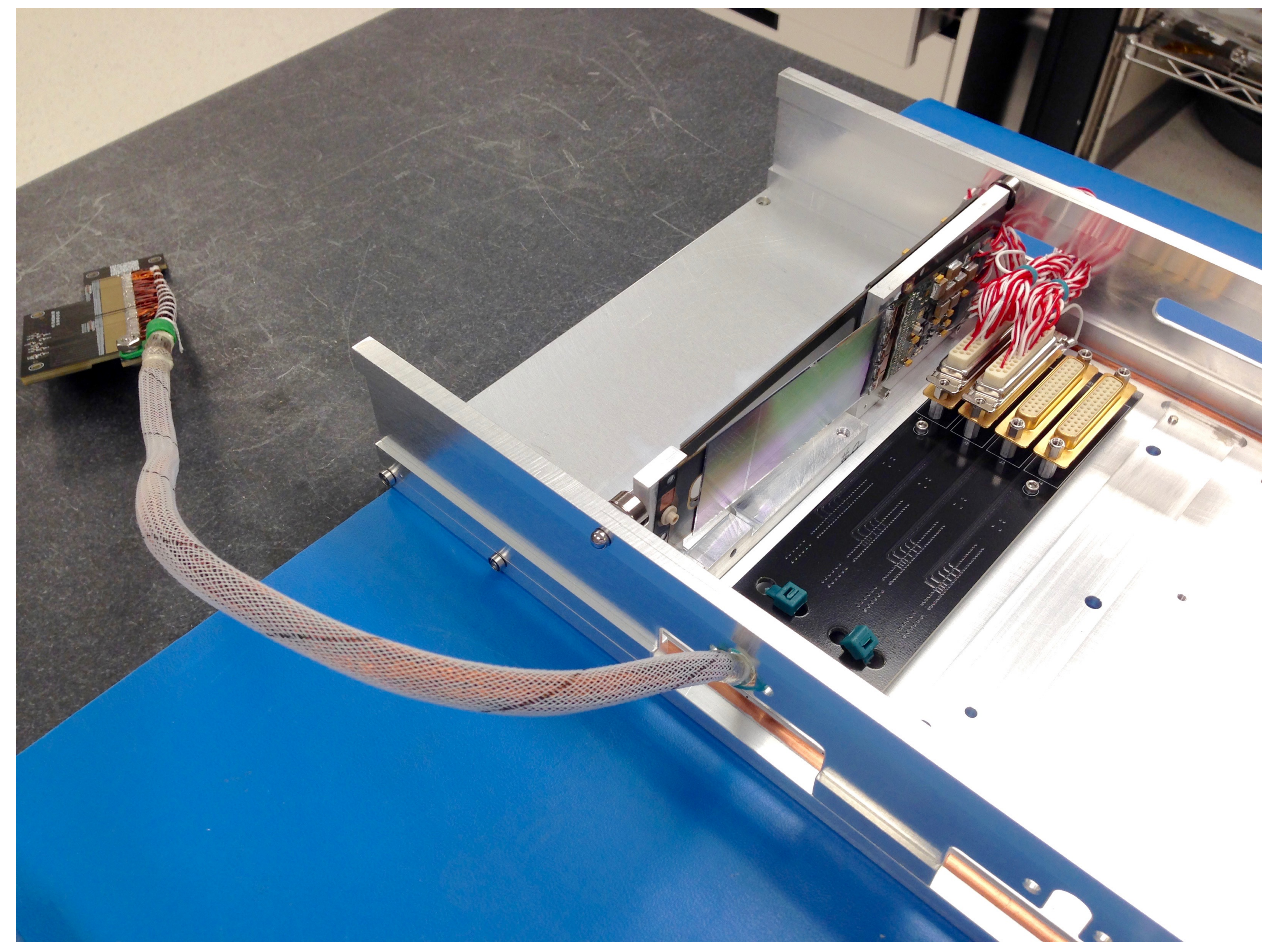


Cost

New Sensor: $43K

- Labor
  - Processing: $5K
- M&S: : $38K

New Hybrid: $75K

- Labor
  - Design: $29K
  - Assembly: $19K
  - Testing: $17K
- M&S: : $10K

New Modules: $84K

- Labor
  - Design: $33K
  - Assembly: $34K
  - Testing: $17K
- M&S: $10K

Modifications to mechanical support (includes L2 and L3 Move): $83K

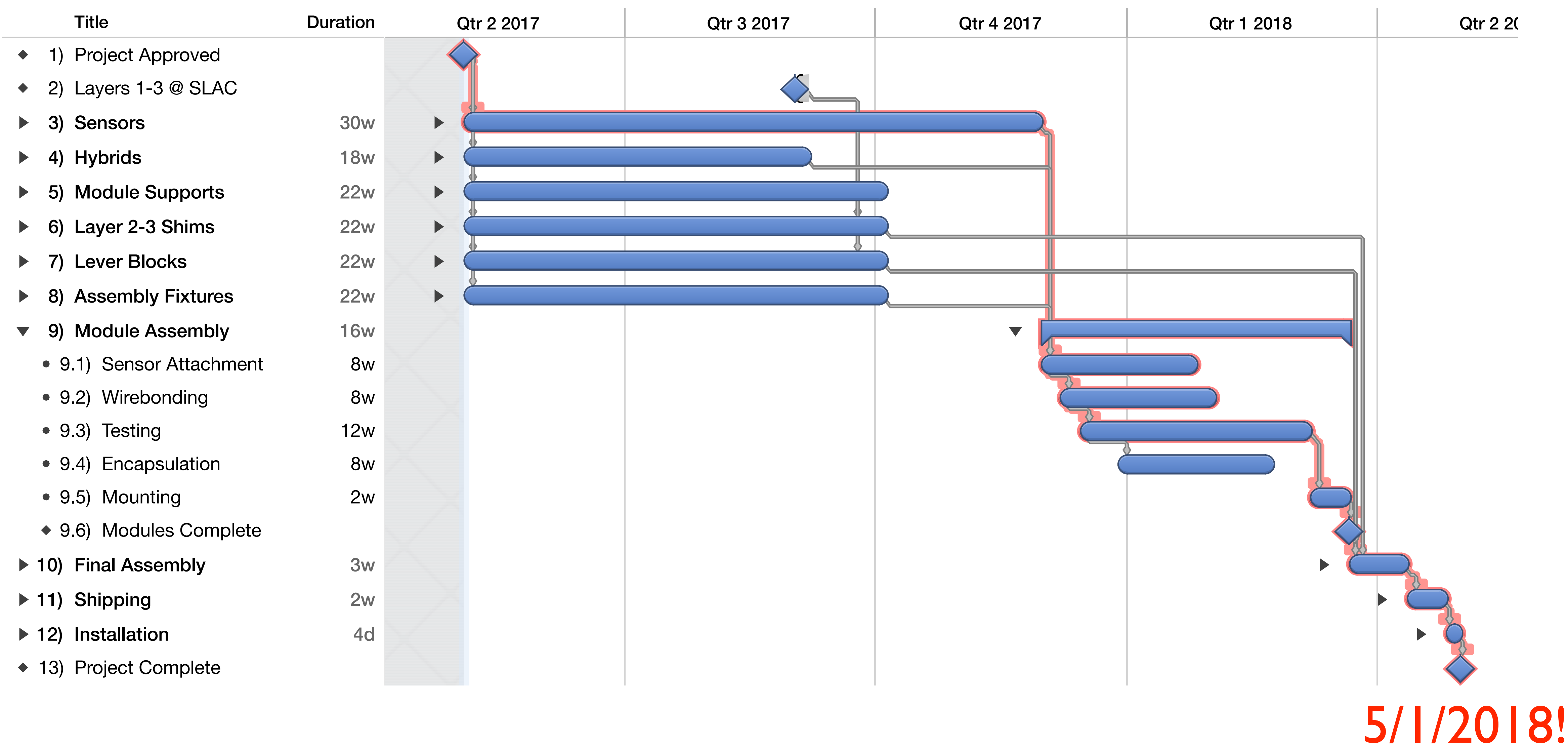
- Labor
  - Design: $33K
  - Assembly: $20K
  - Testing: $20K
- M&S: $10K

Shipping and Installation: $10K

GRAND TOTAL: $295K (not included: DAQ software updates — range from $16K - $66K depending on who does the work)

Schedule

Target completion *was* Summer 2018. Do we need it earlier? Is that even possible?



Single long lead time item, sensors (6 months), drive the schedule.

$\implies$ *Need to finish making upgrade case and approve as soon as possible.*

Manpower and Resources

Labor for hybrids, module electronics and DAQ

- SLAC EE and tech for design, assembly and testing easily handled by TID AIR
- UCSC technician support and student labor (Mike!) available for assembly and testing

Labor for mechanics

- An experienced ME has been identified at SLAC with time to work on the project under the supervision of Shawn Osier.
- Nominal amount of tech support available from Matt McCulloch

Facilities

- L1-3 U-channels are small enough to do work in Building 84 cleanroom, but appears that these should come back to SLAC in order to work most efficiently.

Commissioning Plan

Entire SVT will need to be tested after installation to ensure that everything works as expected.

We will want to leave time to inspect the downstream side of Layer 6, where we see sections of abnormal (dead?) channels in all the sensors that fact the ECal (these changed state between the end of 2015 running and when we next tested the detector before 2016 running.) Affects ~5% of channels. Replacement of these modules is possible without detector removal.

With first beam, we will want to undertake careful scanning and running before moving the SVT in completely. Previous experience will help us do this safely and quickly. Probably, this will not look very different from 2016 running, unless we see something unusual along the way.

One item that needs special attention is beam halo and how to identify the source and mitigate it if turns out to be an issue.

Summary

- SVT upgrade will significantly improve the vertexing reach of HPS
- Together with positron-only trigger, reach from future runs will be dramatically improved.
- project is well-defined in scope, design and resources required.
- it’s a small project, but our resources are very limited, so we have to proceed very carefully…
- but not so carefully as to slow us down: we need to get started soon and work efficiently.
- Hopefully we can soon be ready to approve the project. Complete proposal draft in coming days.

An Upgrade for the HPS Silicon Vertex Tracker

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(Dated: May 4, 2017)

DRAFT

Contents

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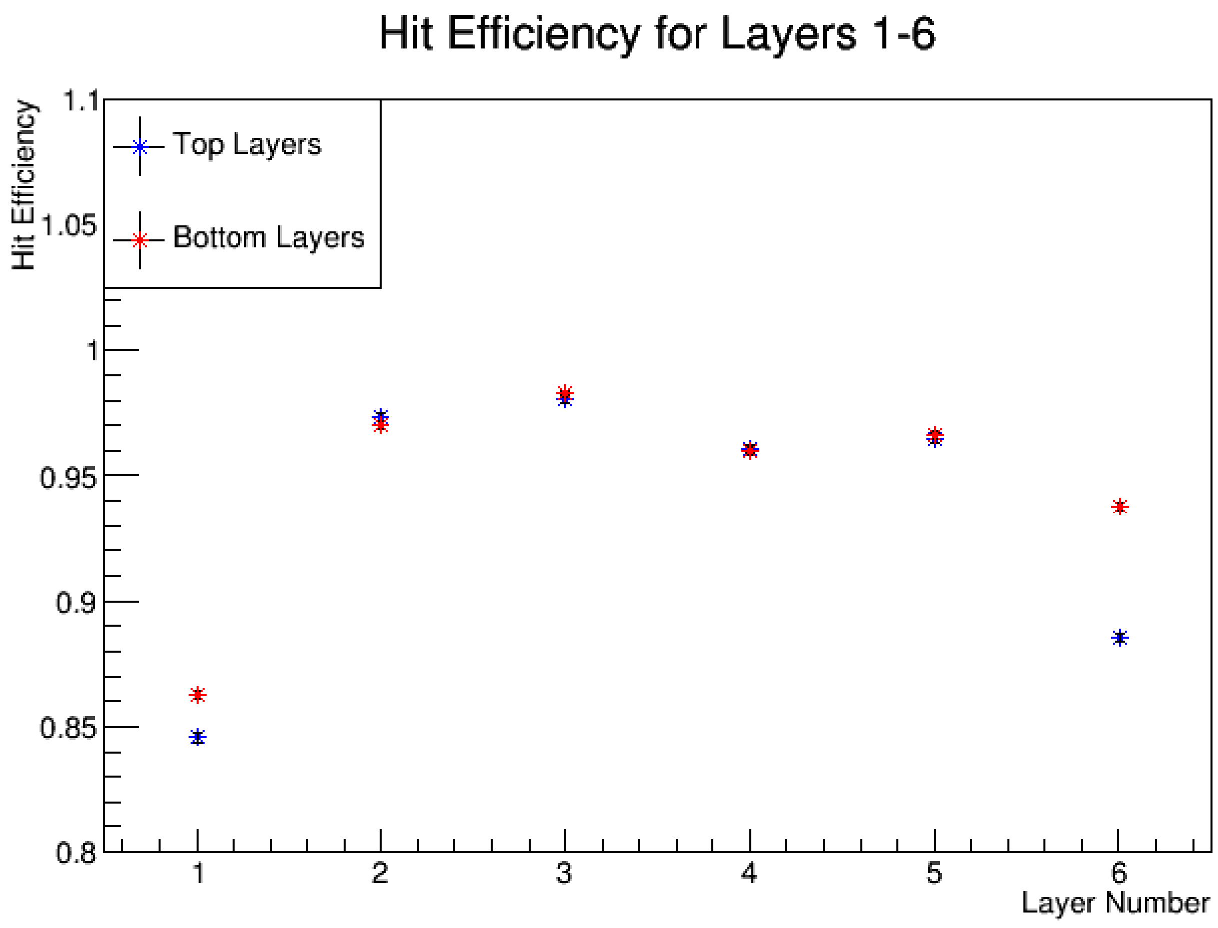
Extra Slides

Hit Efficiency 2016

- Hit efficiency as a function of layer for 2016 data



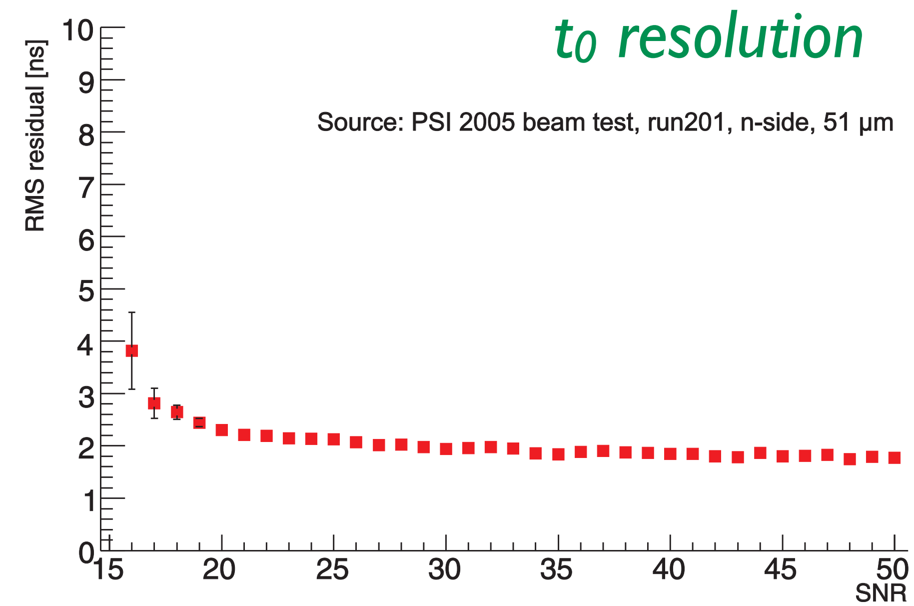
t_0 Resolution

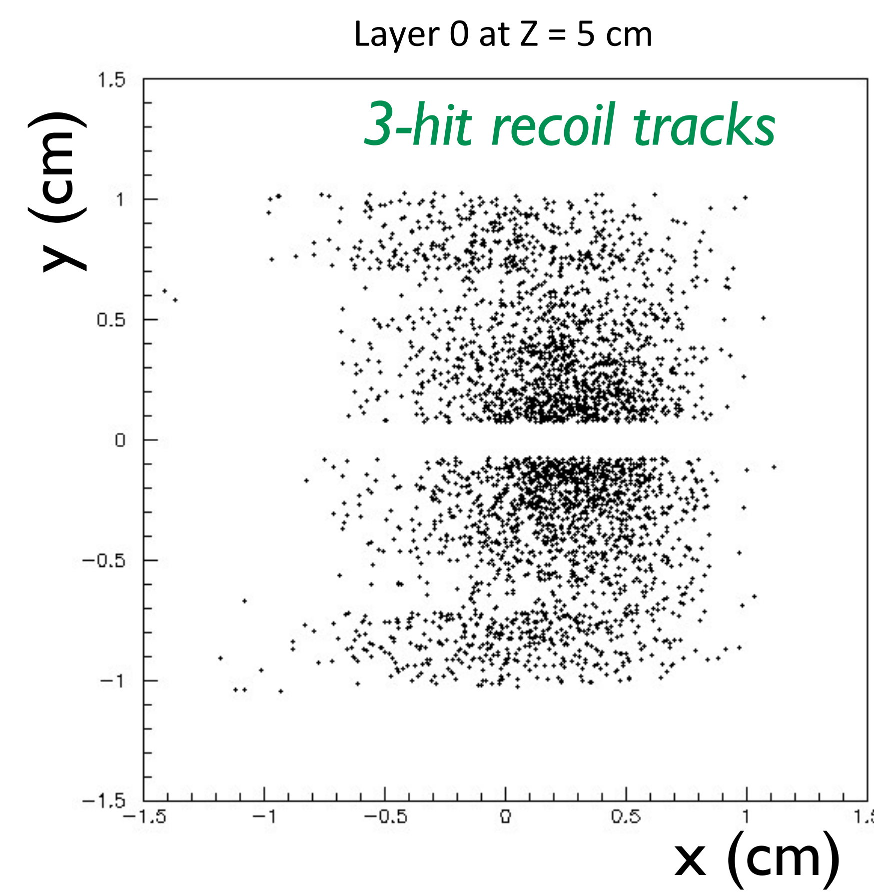
- Structure is negligible, so material/2 means signal/2.
- If we want to maintain t_0 resolution,
  S/N>20 must be maintained.

➡need noise/2

- noise characteristics of our sensors w/ APV25:
  $\mathrm{ENC} \simeq 250+36C \oplus \alpha C(R_s)^{1/2}\ e^-$
  - Currently C=12pf ⇒ ENC = 950 (C ≃1.2 pf/cm)
  - Need ENC ≲ 450 ⇒ strip length ≲ 3.5 cm.

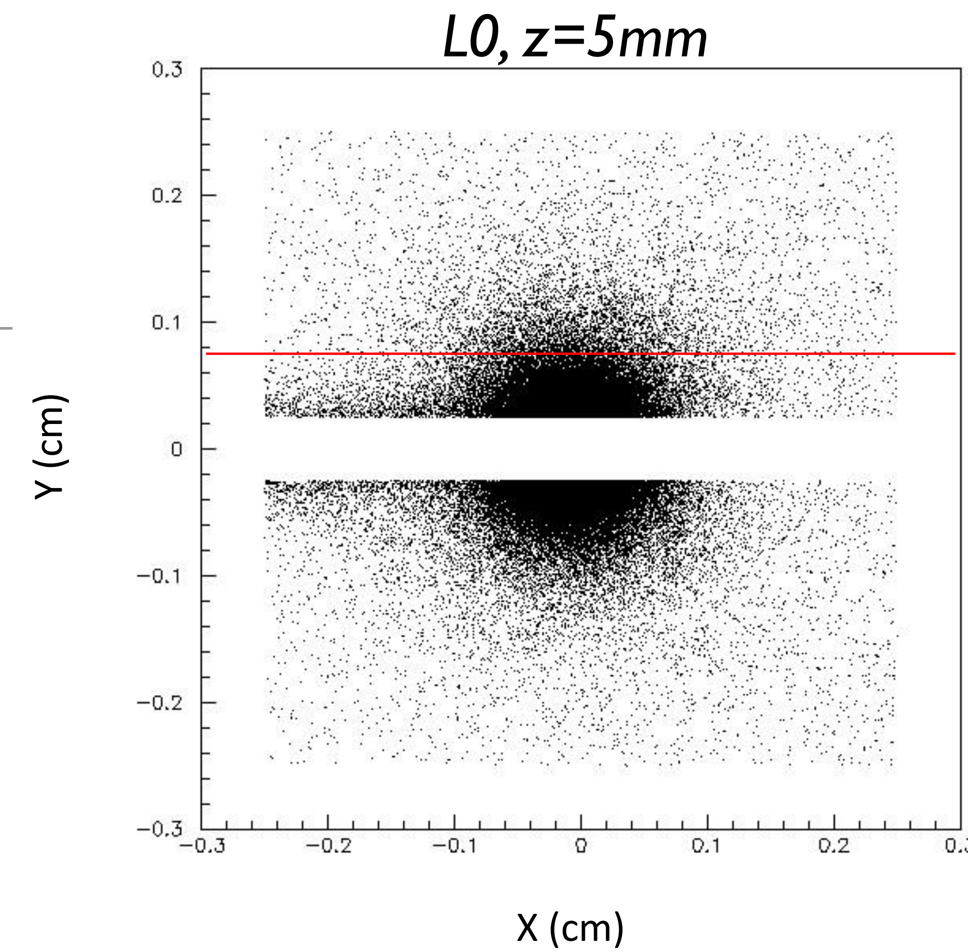
⇒ Takashi shows silicon can be 2 cm in x.

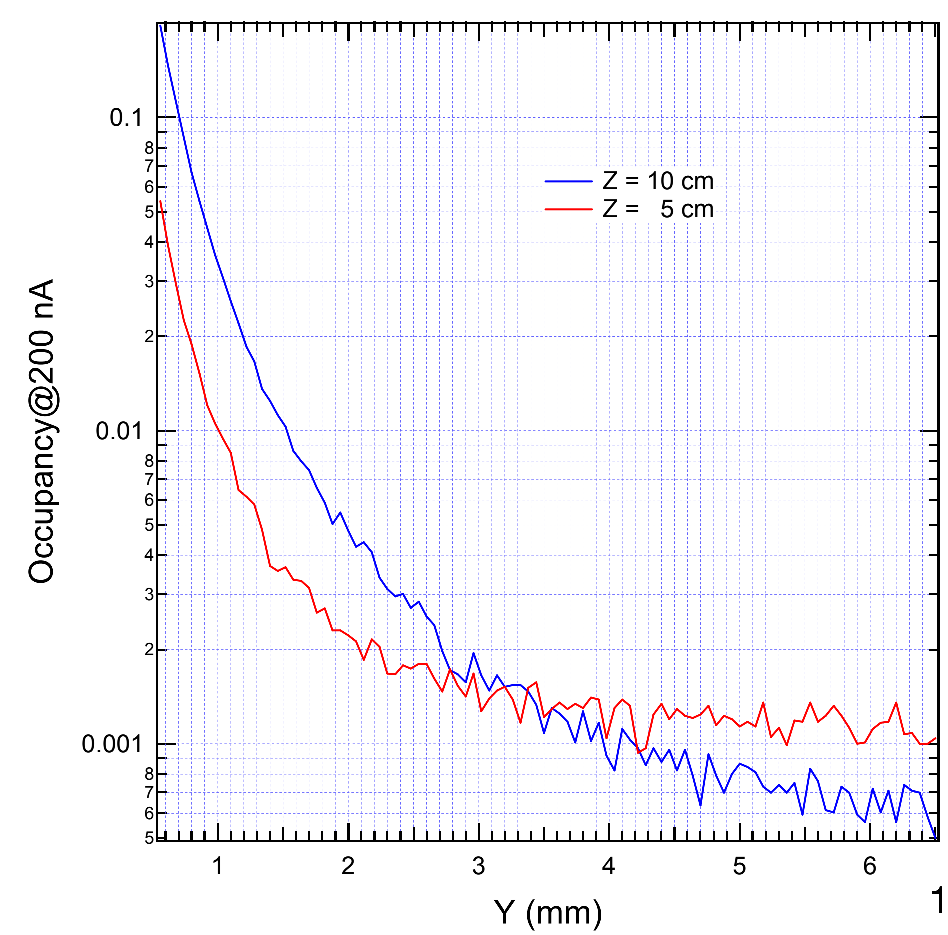




Physics Backgrounds

- 15 mrad coverage means first strip @ 0.75mm from beam for z = 5 cm.
- Naively, background flux at 15 mrad for z=5 cm will be 4× backgrounds at current L1 at 10 cm ($1/r^2$).
  However, strips don't sample areal density!
- Takashi finds that background occupancy in first strip for Layer 0 only 2.5× current Layer 1.
- *If we split the strips on the sensor in half and read out from both ends, we can cut this in half: OK.*





X-rays

- Thresholds in current detector are roughly at the L-shell line from the tungsten target.

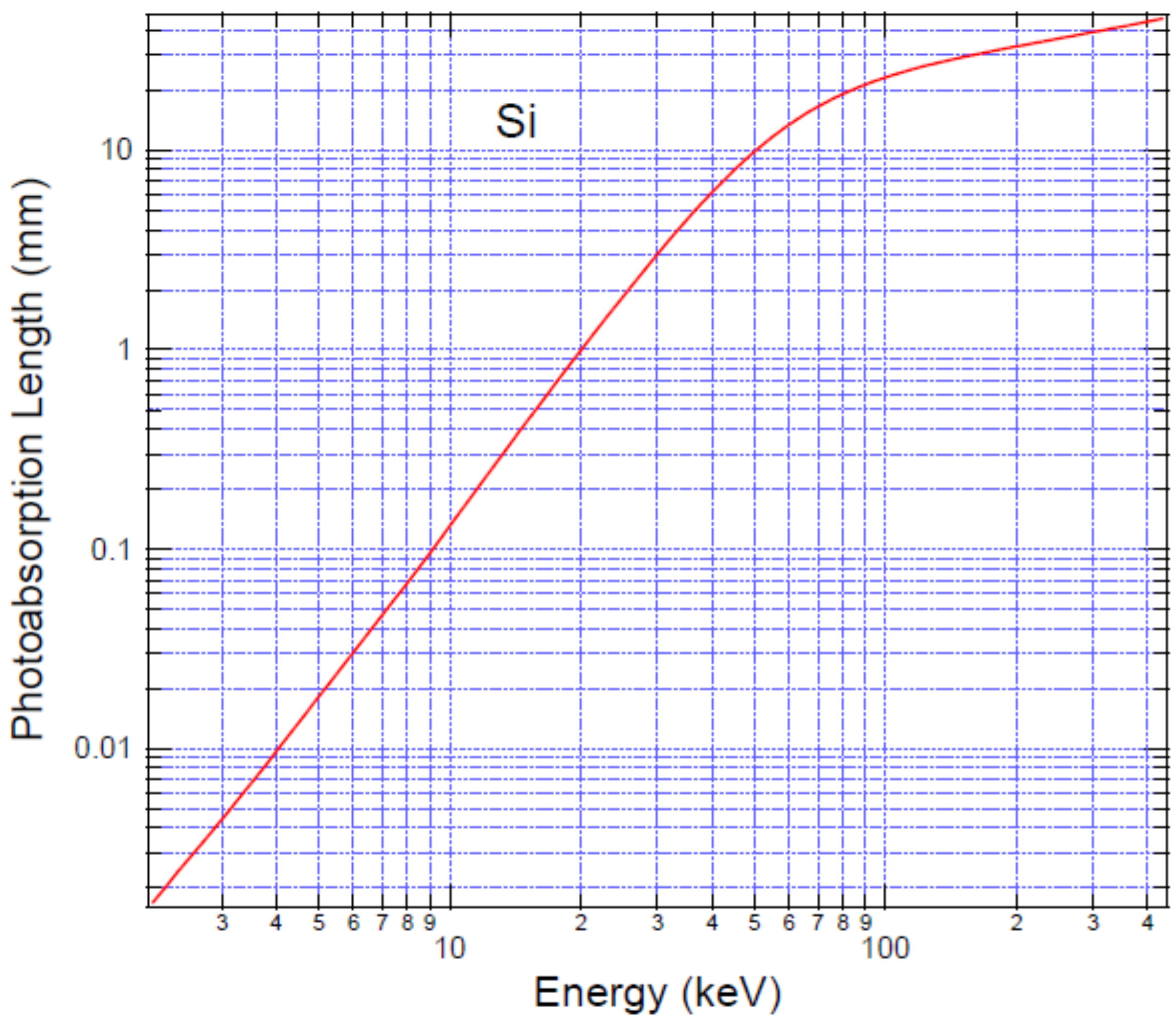
- signal/2 ⇒ ~threshold/2

➡All L-shell x-rays that absorbed in Si will be above threshold.

- Small sensor means sensor actually has smaller solid angle than Layer 1.

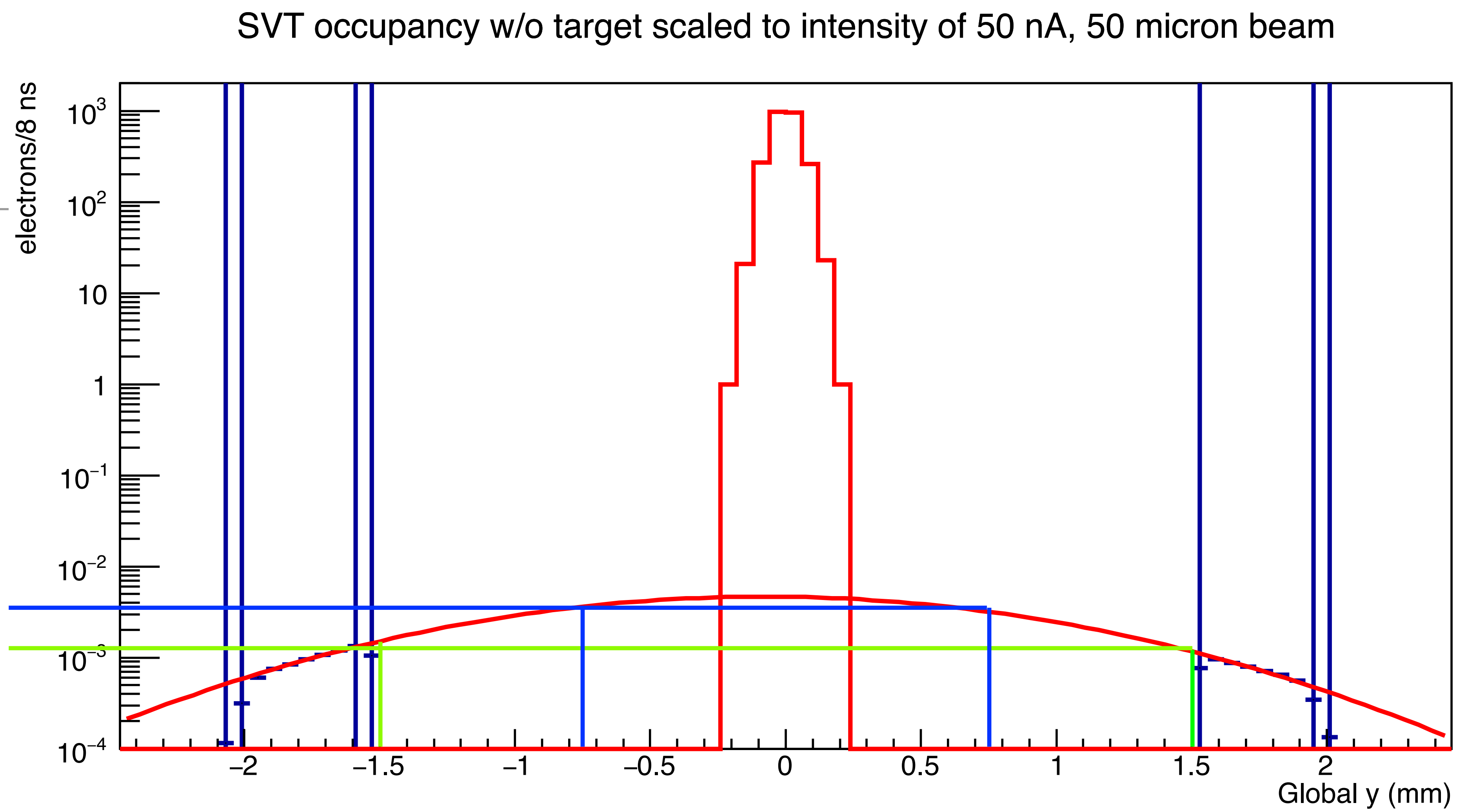
- Thinner sensor means only about 2/3 of L-shell x-rays with be absorbed in sensor.

- Takashi finds that x-ray occupancy will be:
  ~0.4 hits/sensor
  ⇒ 0.07% occupancy/channel: OK



Beam Tails

~factor of 3



- With innermost strip at 0.75mm, beam tails will be a more serious problem.
- Profile of tails measured in engineering run would predict roughly 3× tails at 0.75mm.
- A 200 nA, one then expects roughly 1% occupancy. What about 6.6GeV/400 nA??
- Splitting readout strips in half cuts this in half: *maybe OK.*
- *Doesn't seem realistic to imagine a collimator that eliminates this.*