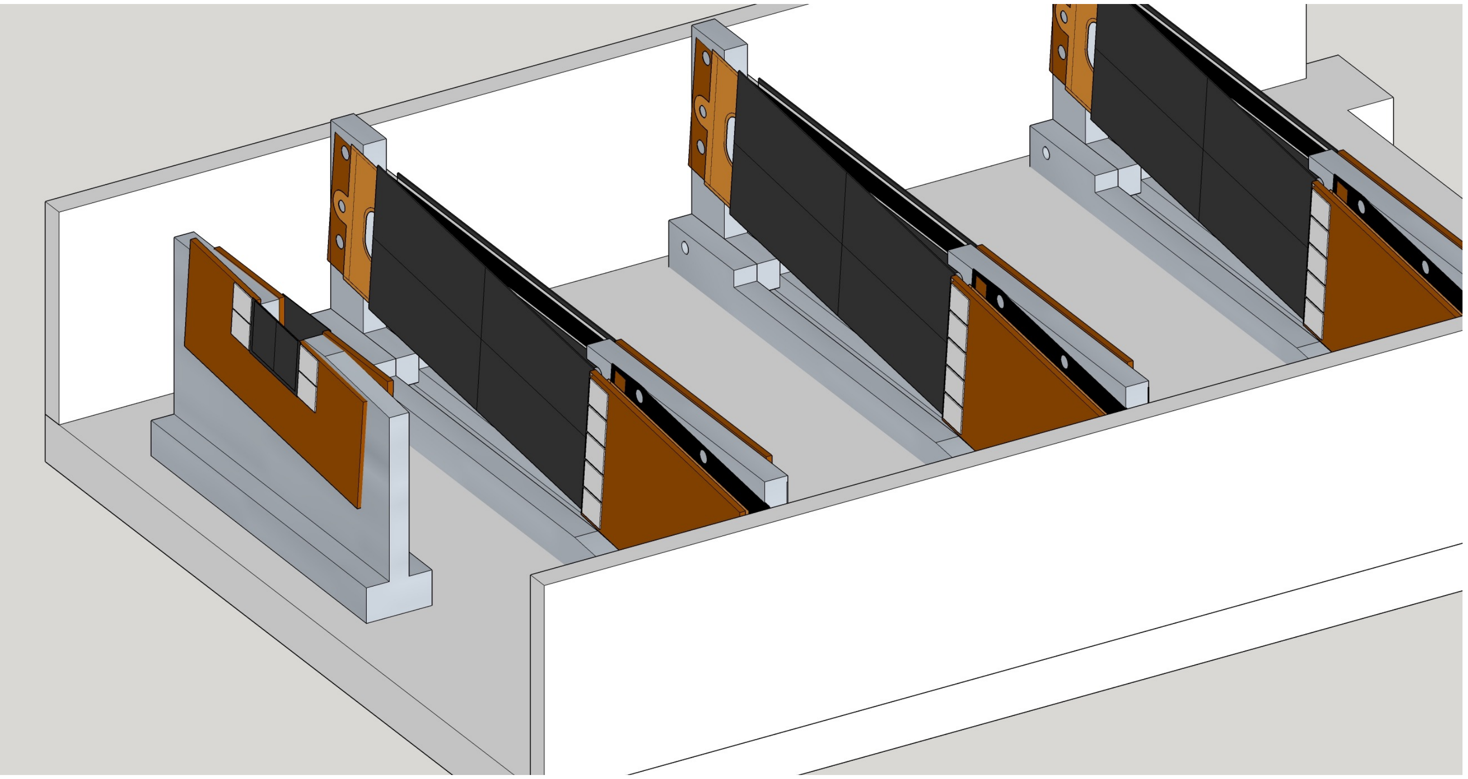
Upgrade to the HPS SVT



Tim Nelson - SLAC

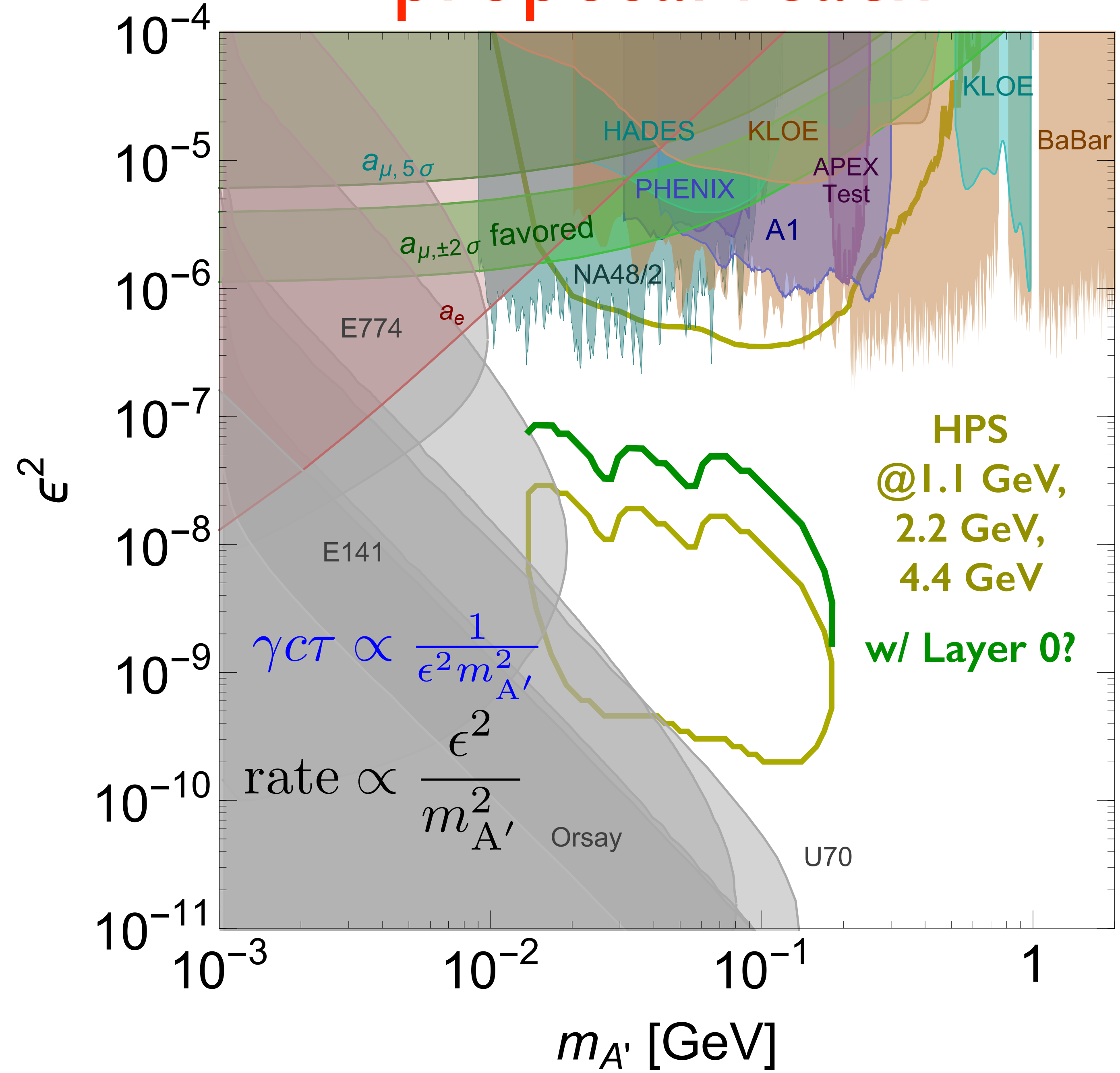
JLab ERR - June 12, 2017

Motivations

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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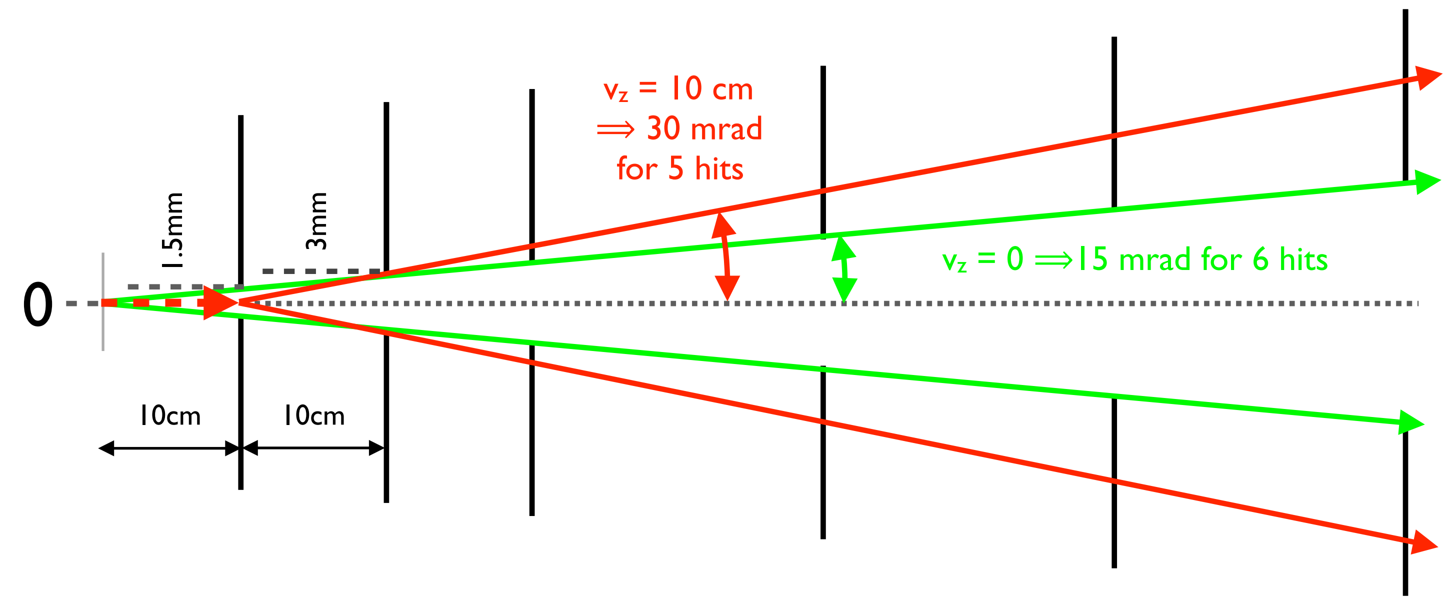

Move of Layers 2 and 3

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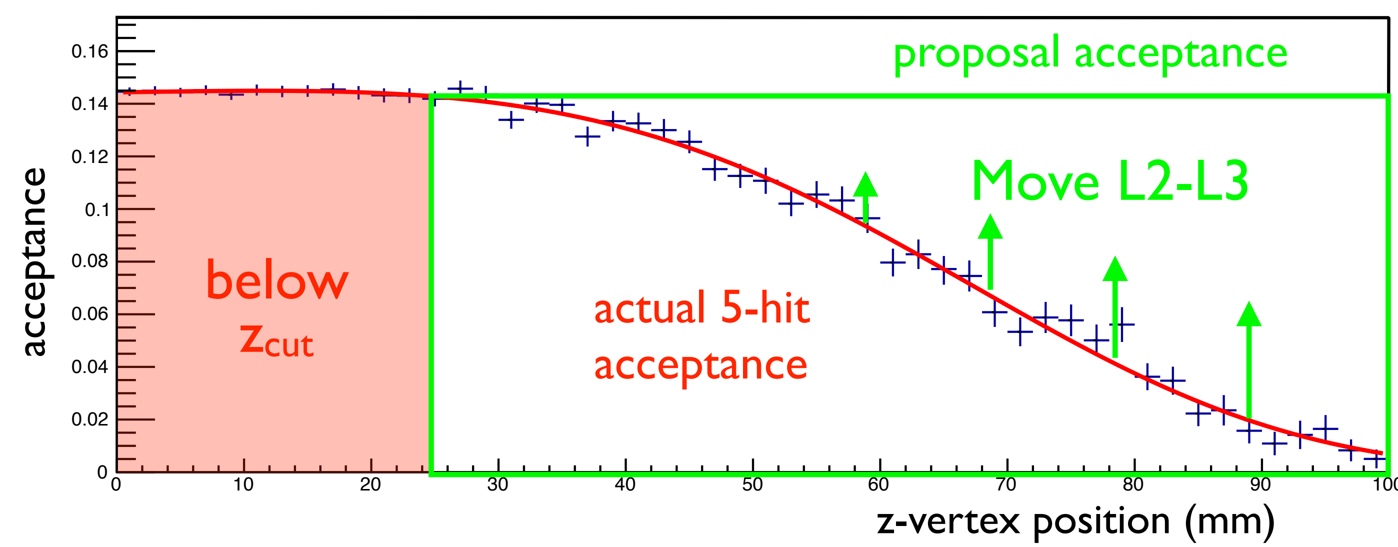
- Moving Layers 2 and 3 towards y=0 recovers some of the lost acceptance.



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Move of Layers 2 and 3

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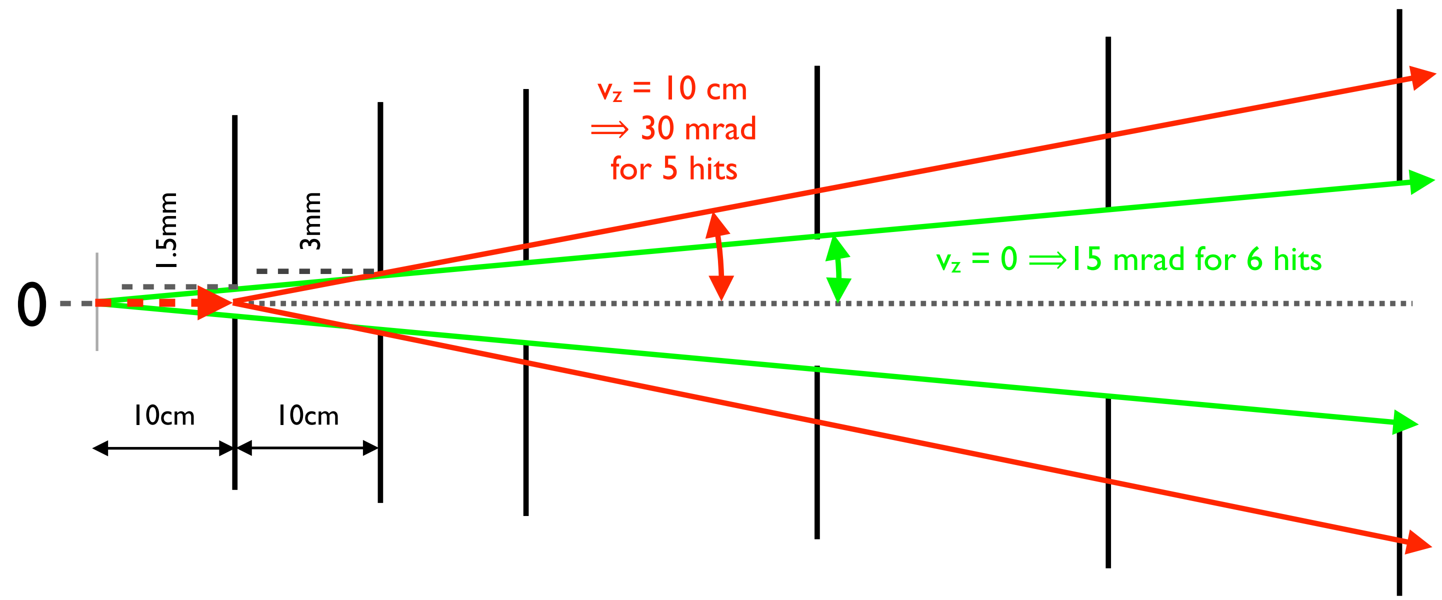
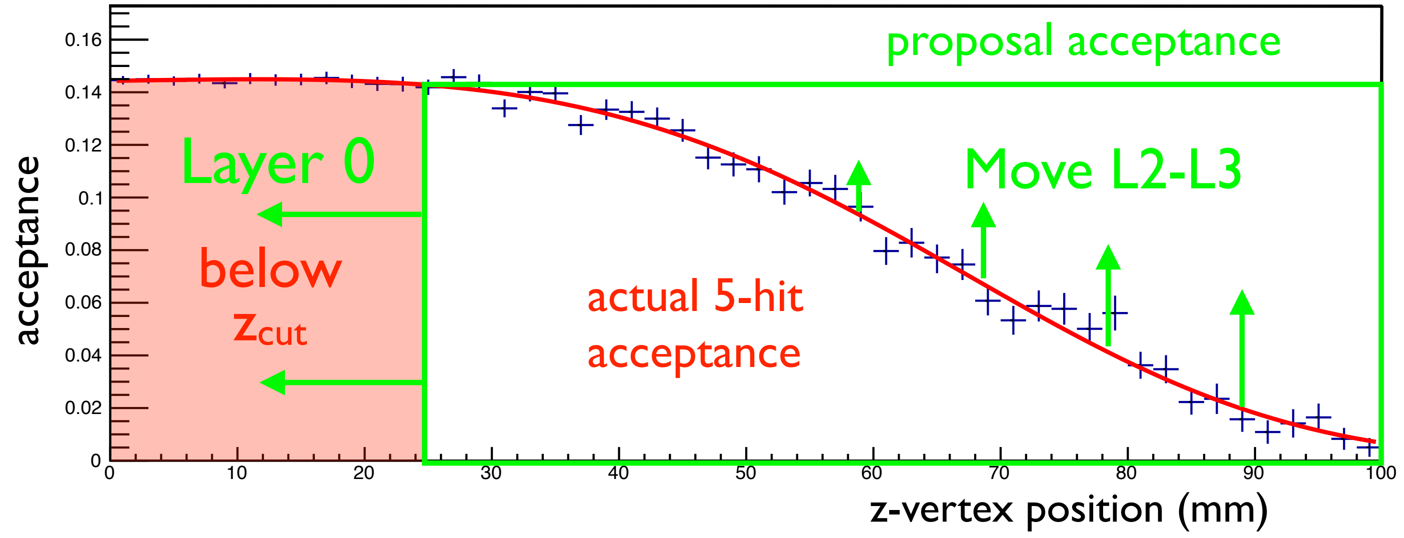
Addition of Layer 0 takes on new importance in light of corrections to reach estimates.

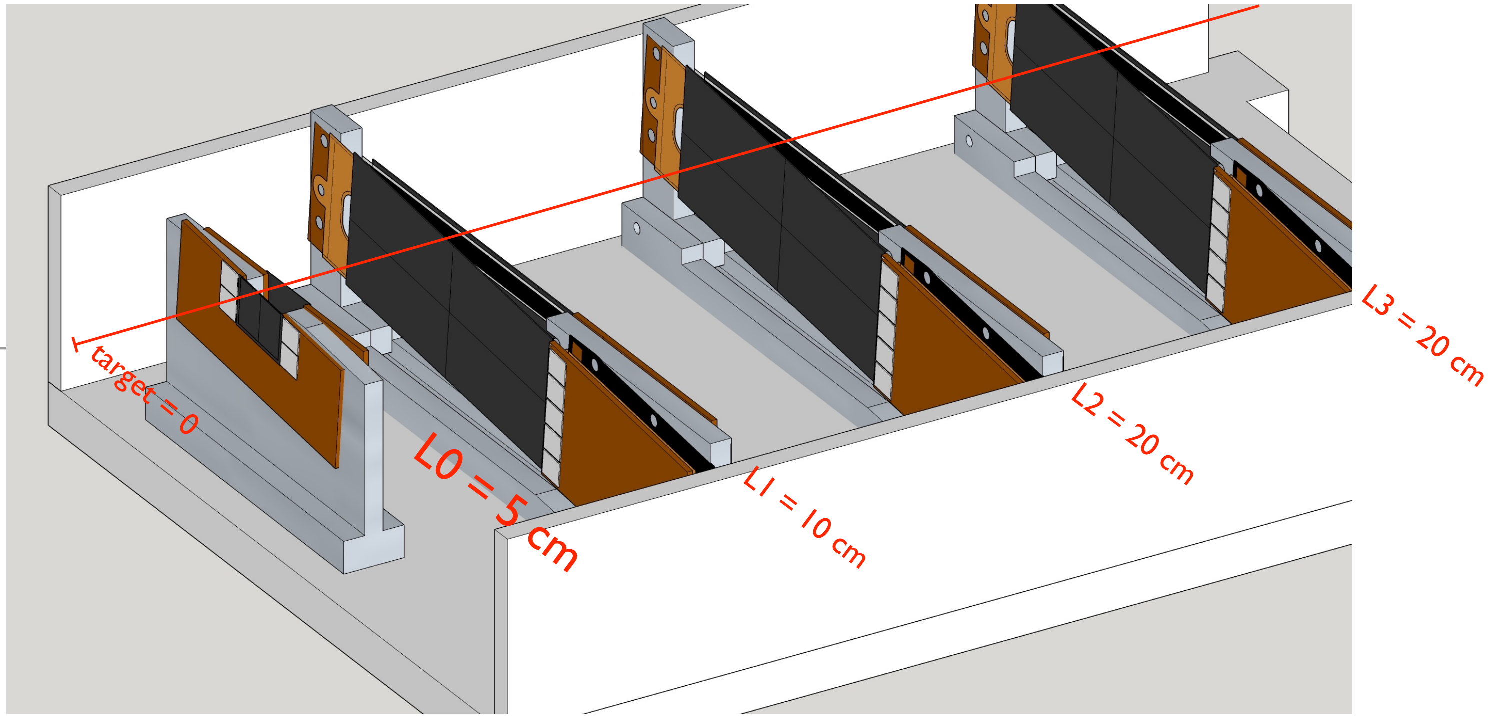




Proposed Design

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)



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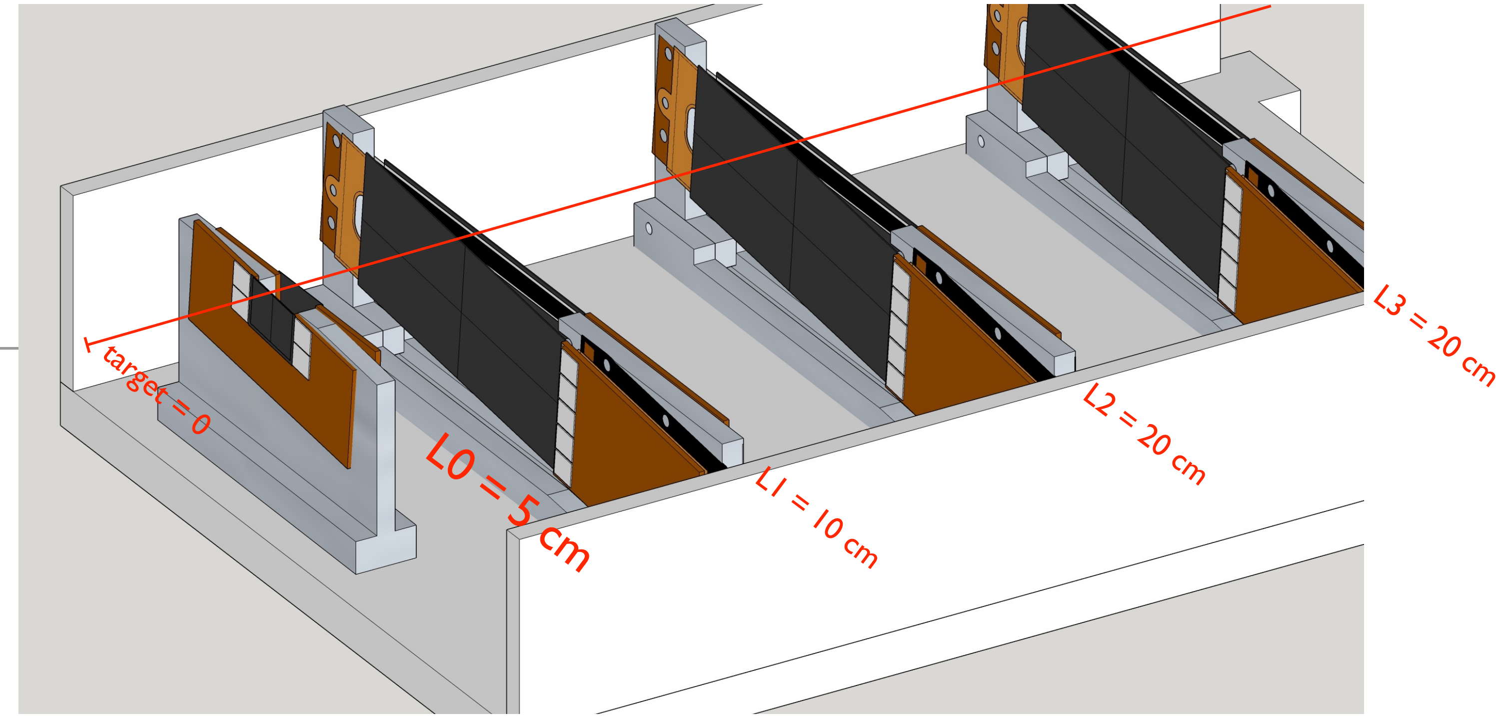

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Negative impacts of thinner sensors and proximity to beam appear manageable:

- thinner sensors have reduced signal
- being closer to target increases backgrounds and radiation
- L-shell x-ray sensitivity from lower thresholds creates additional occupancy
- Proximity of active region to beam means greater sensitivity to beam tails.
- Worst-case risk is extra material if Layer 0 doesn't work as designed.

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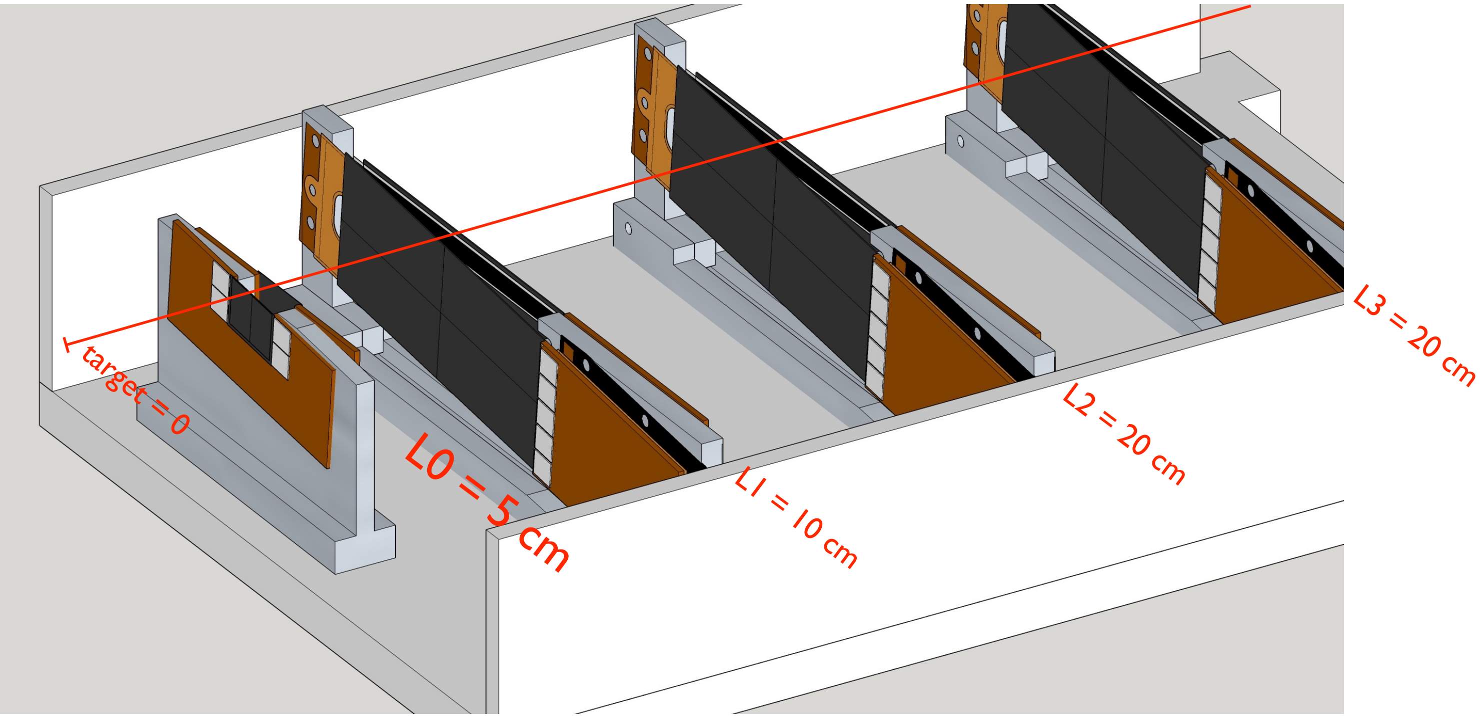

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Moving L2 and L3 is completely independent and very low impact.

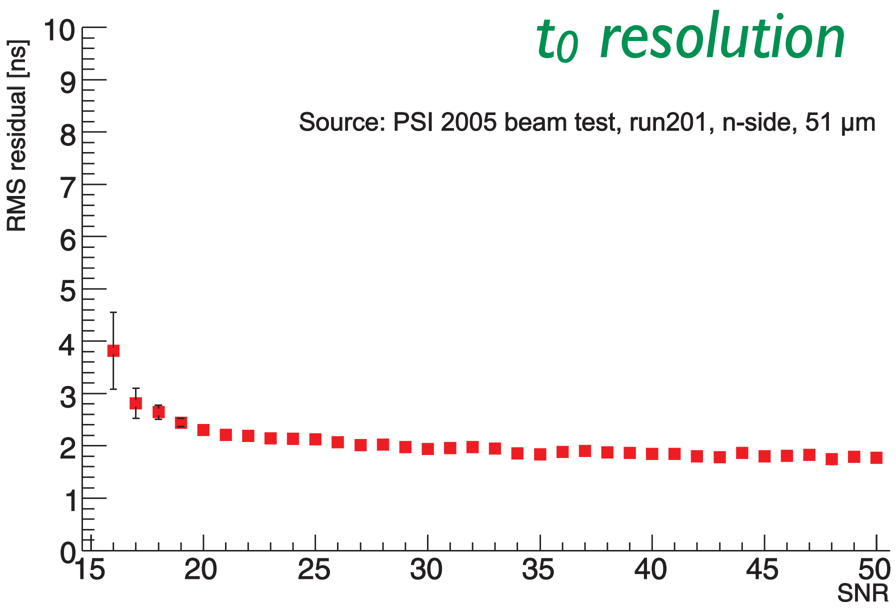
- Thin shims under module supports move L2 and L3 by 0.8 mm towards y=0.
- Adding these when modules are remounted for L0 modifications is trivial.
- no major risks.

Reduced Signal Primarily Impacts t_0 Resolution

Currently S/N ~ 25 for 300 μm Si. Assume ⟹150μm:

- Structure is negligible, so material/2 means signal/2.
- To maintain t_0 resolution, must have S/N>20.

➡ need noise/2



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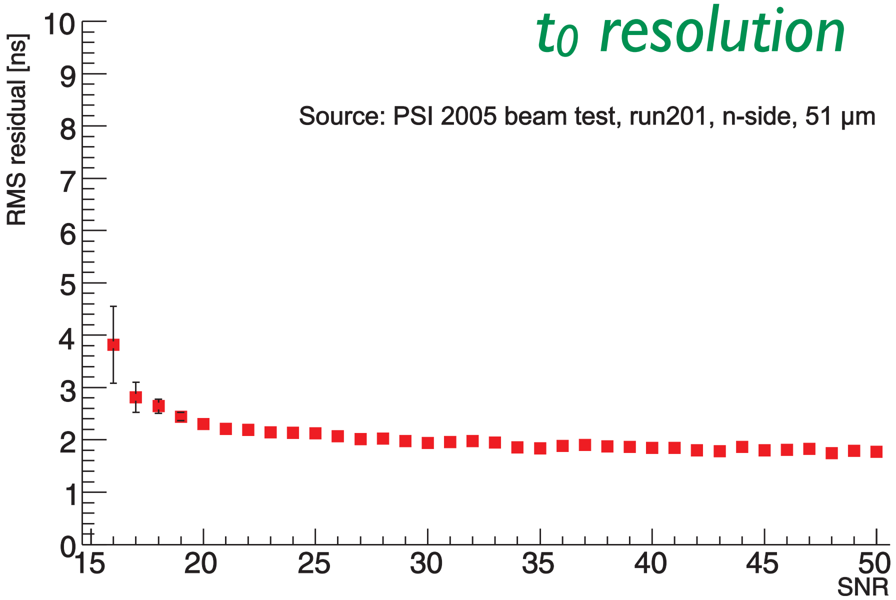

Noise characteristics of our sensors w/ APV25:

$$ENC \simeq 250+36C \oplus \alpha C(R_s)^{1/2} \ e^-$$

- currently C=12pf ⇒ ENC = 950 (C ≃1.2 pf/cm)
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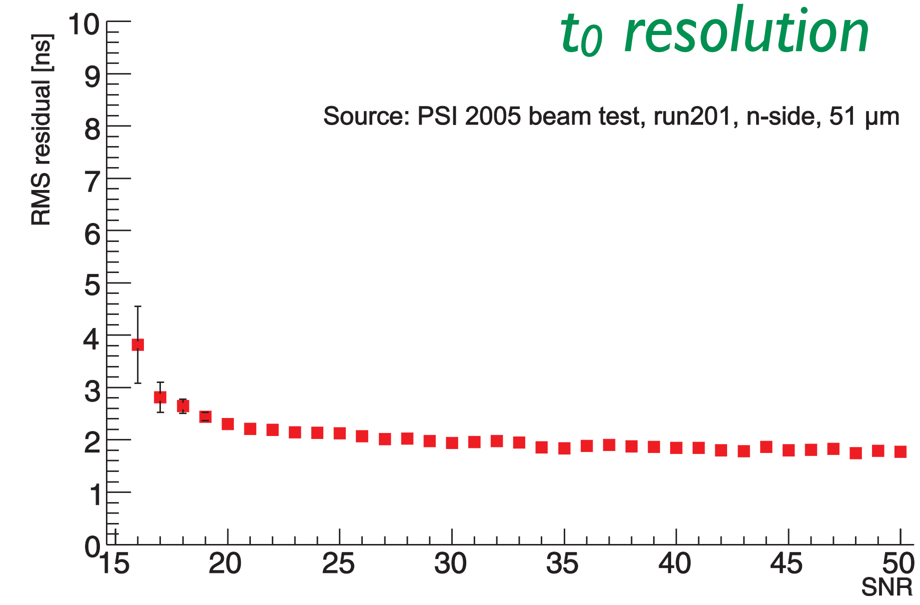
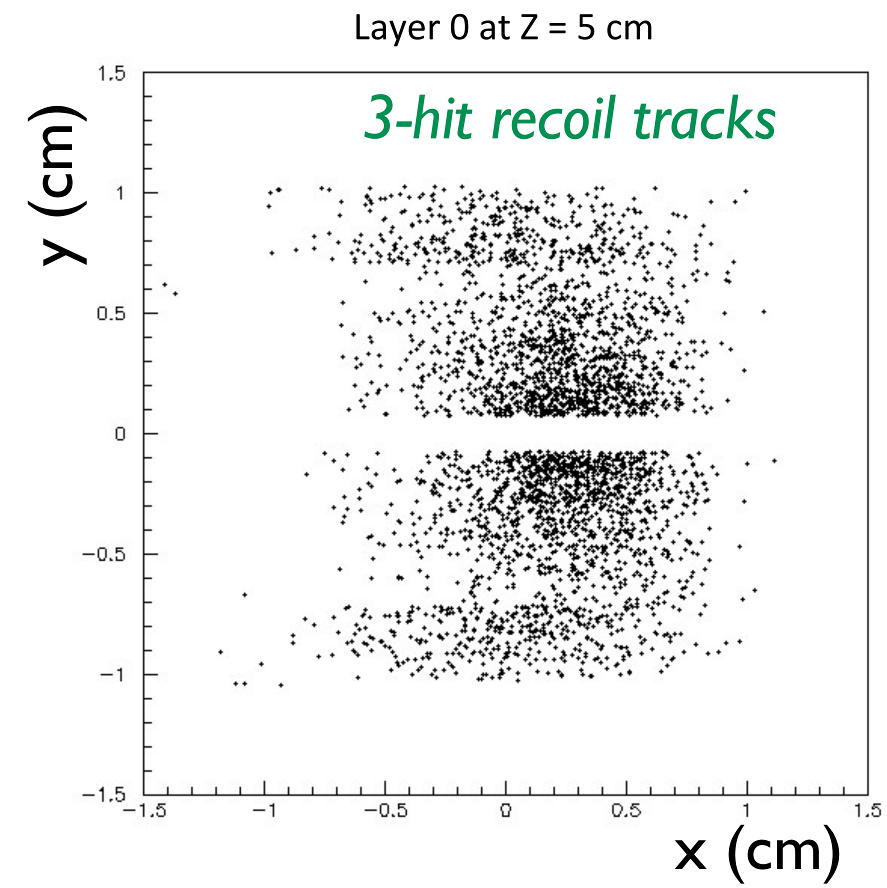
Full acceptance for A′ daughters allows very short strips. Conservatively assume we want largest acceptance we could imagine for any purpose: 3-hit tracks from recoils.

⇒ Requires silicon only ~2 cm long: OK





Physics Backgrounds/Radiation

Must match 15 mrad coverage of Layer 1

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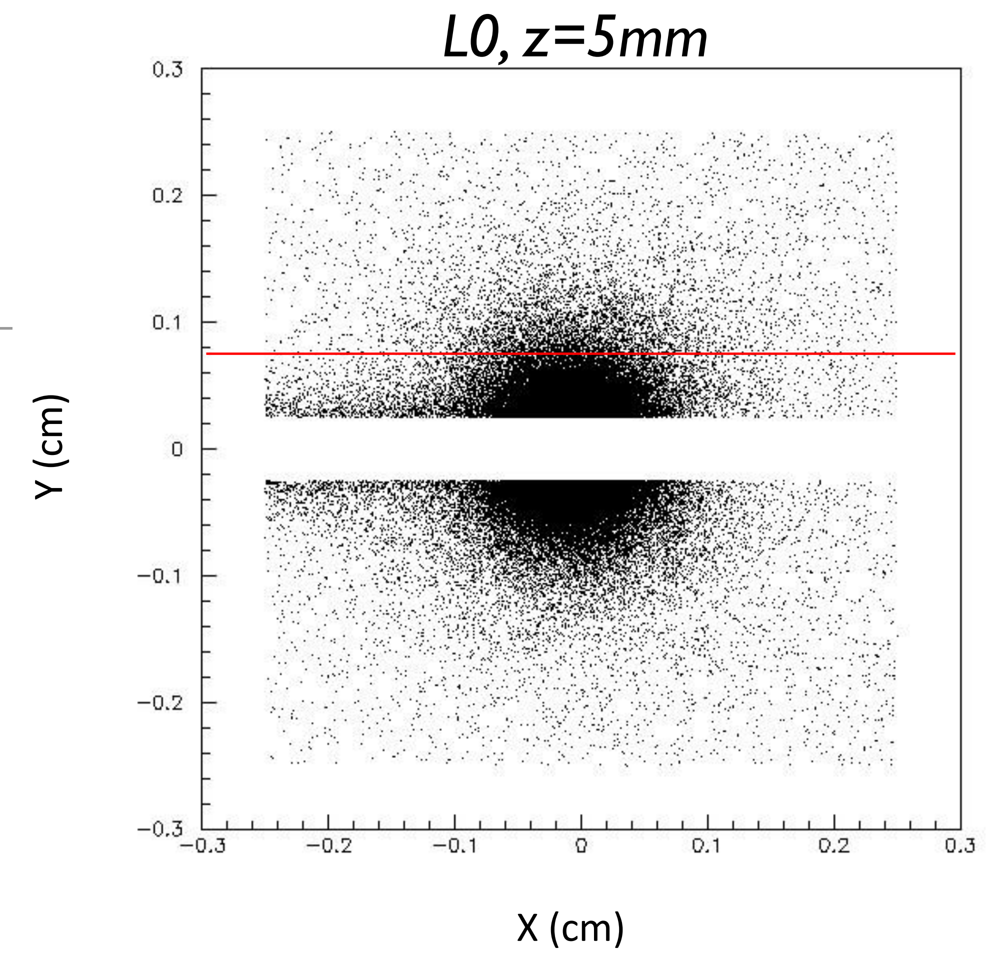

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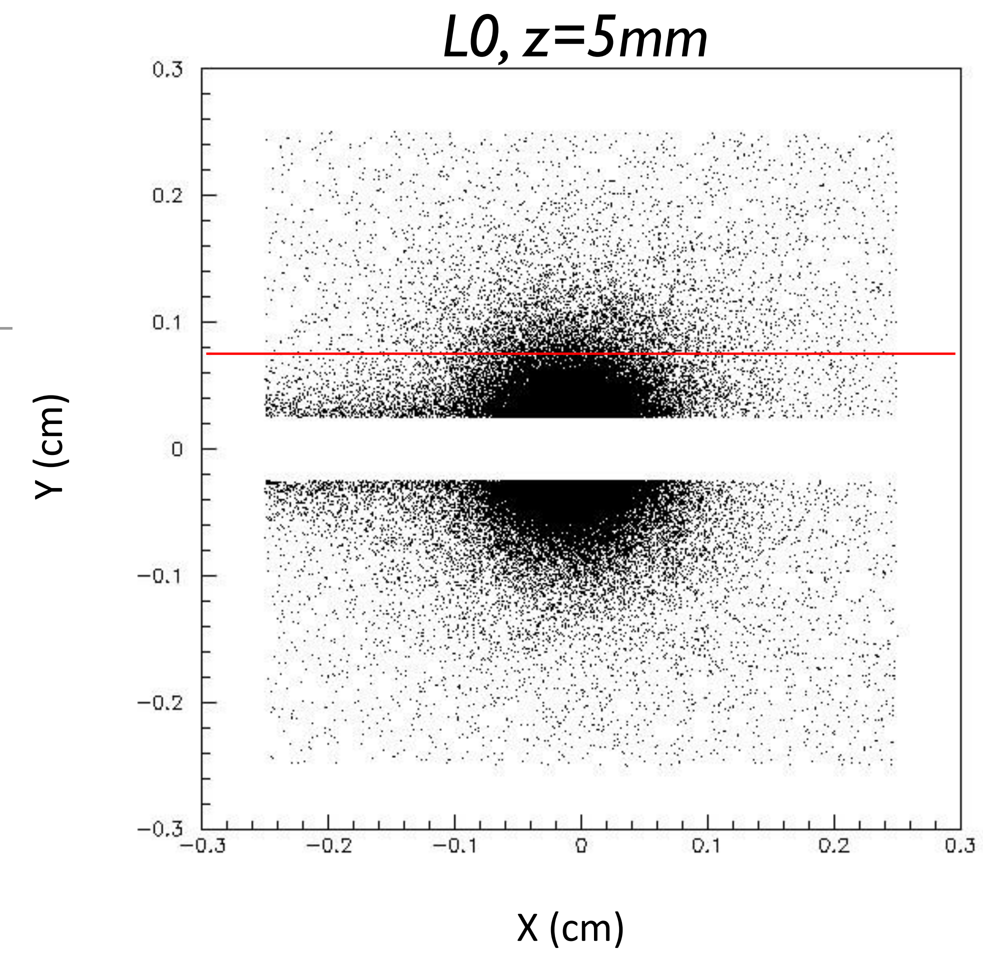
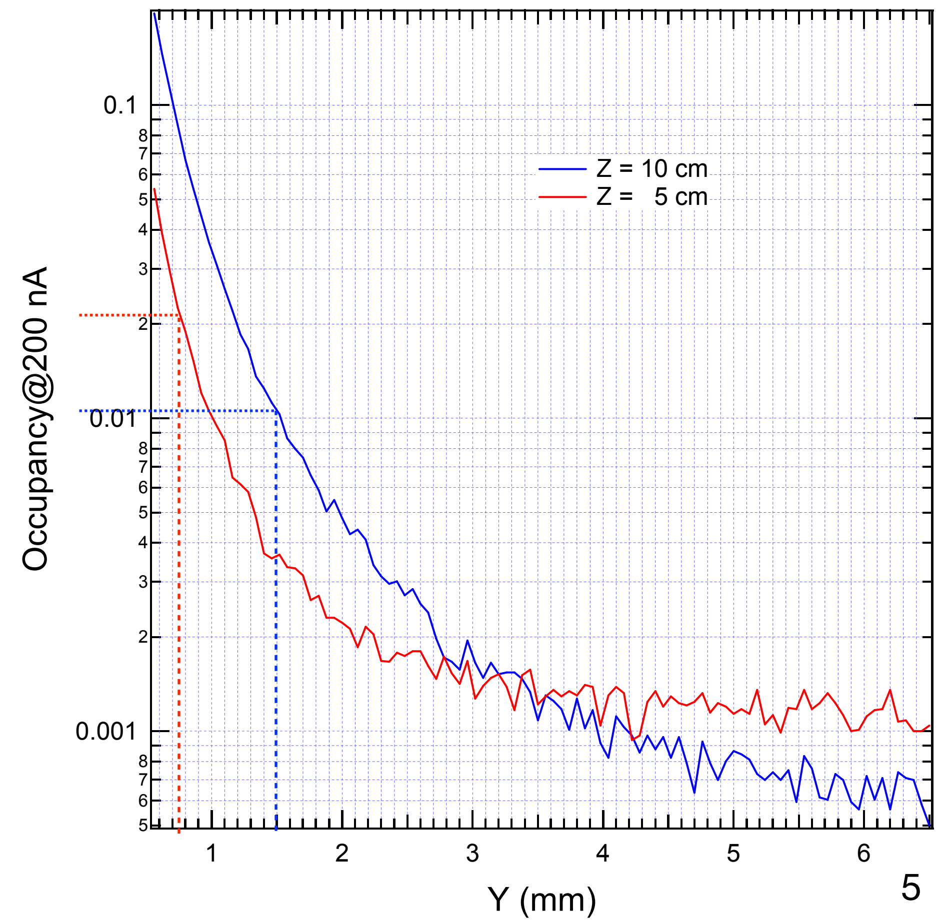
  Split the strips on the sensor in half electrically, reading out sensor from both ends. Cuts occupancy in half: OK.

  For extra headroom on strip occupancy, eliminate capacitively-coupled sense strip present in other layers. (resolution is limited by multiple scattering anyway).

  These changes further reduce noise.





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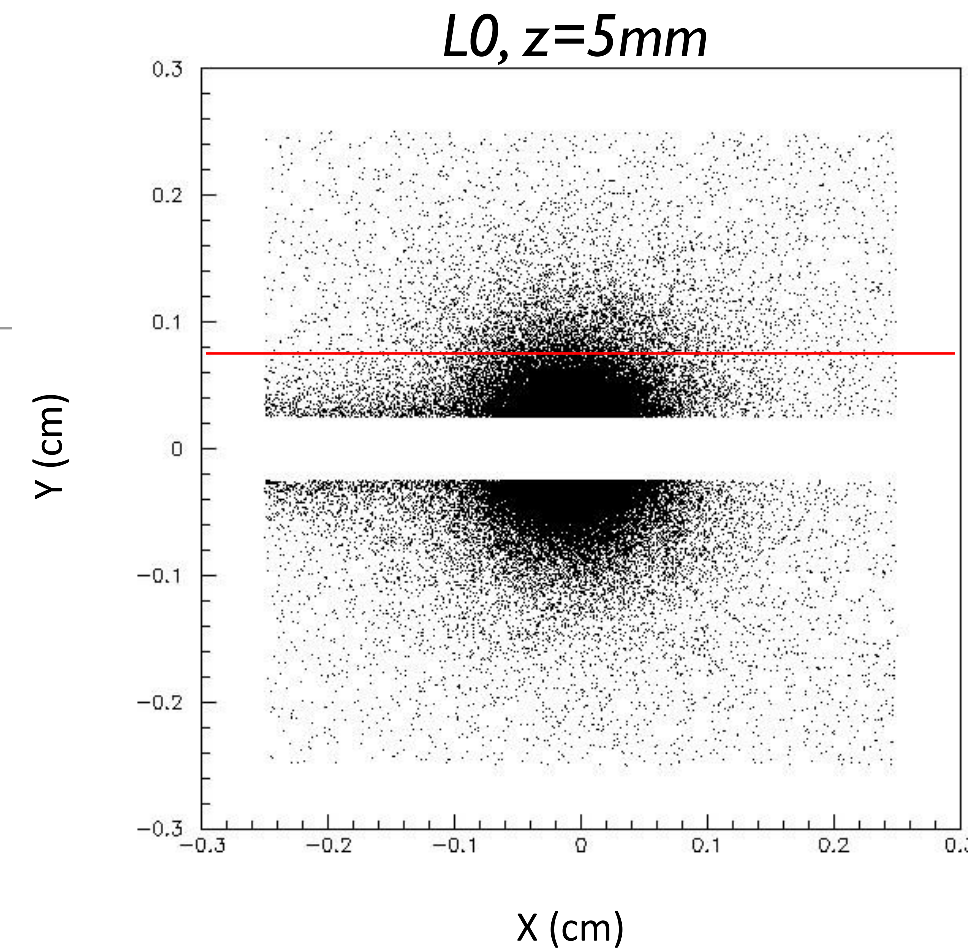
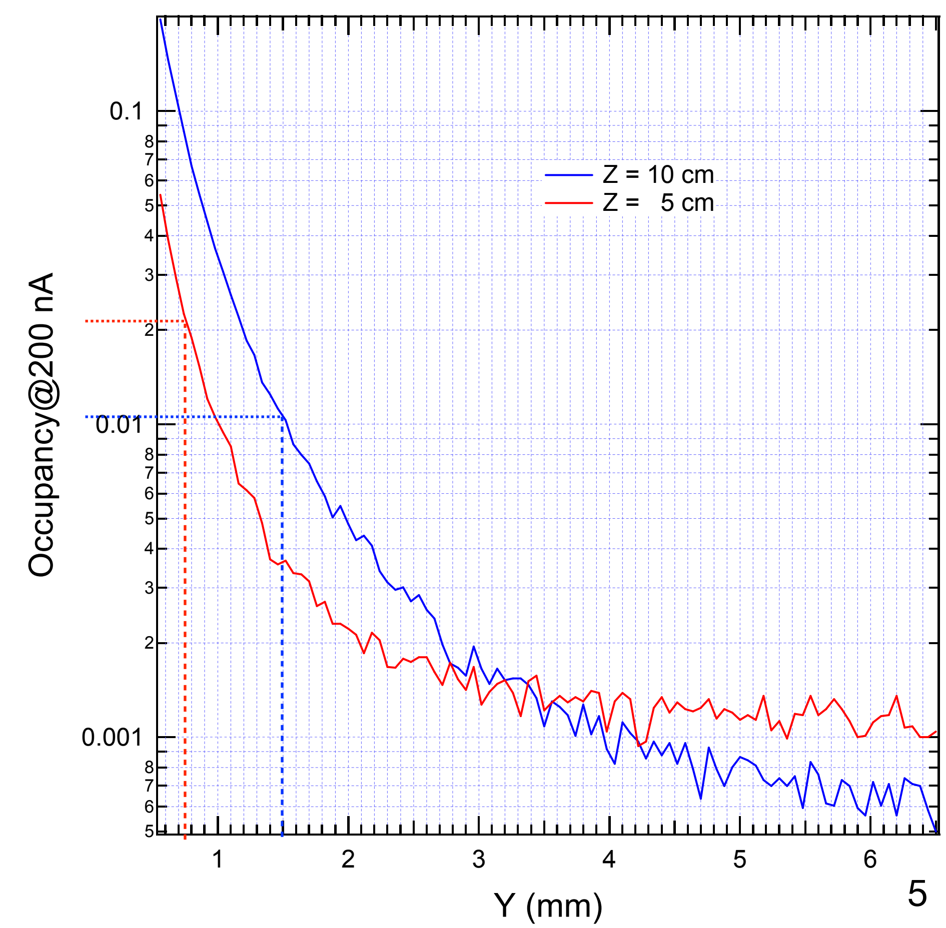
- Principal source of our radiation damage. Layer 0 could require replacement in as little as 3 months.

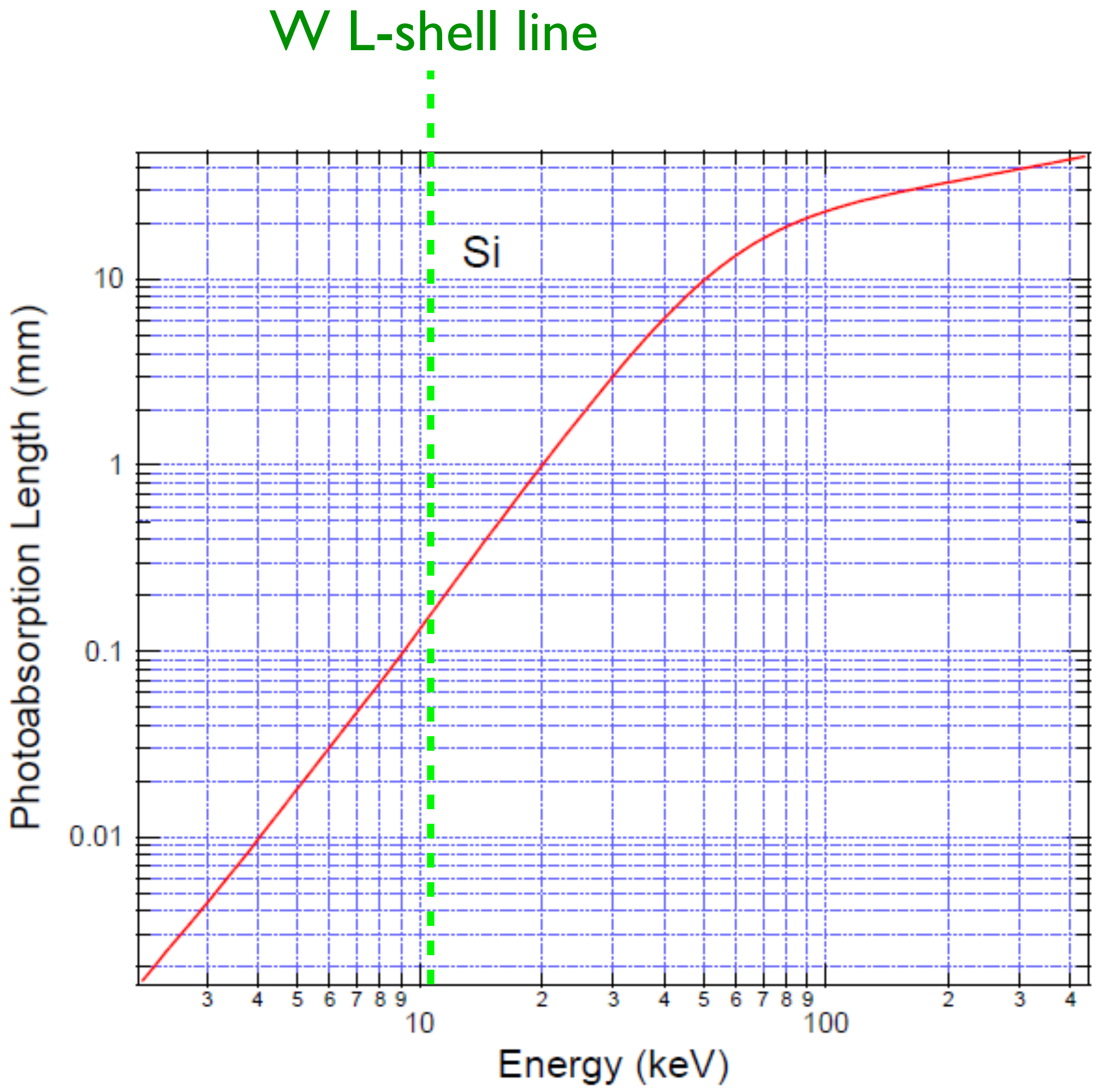
  Layer 0 can be easily replaced between runs.





X-rays

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



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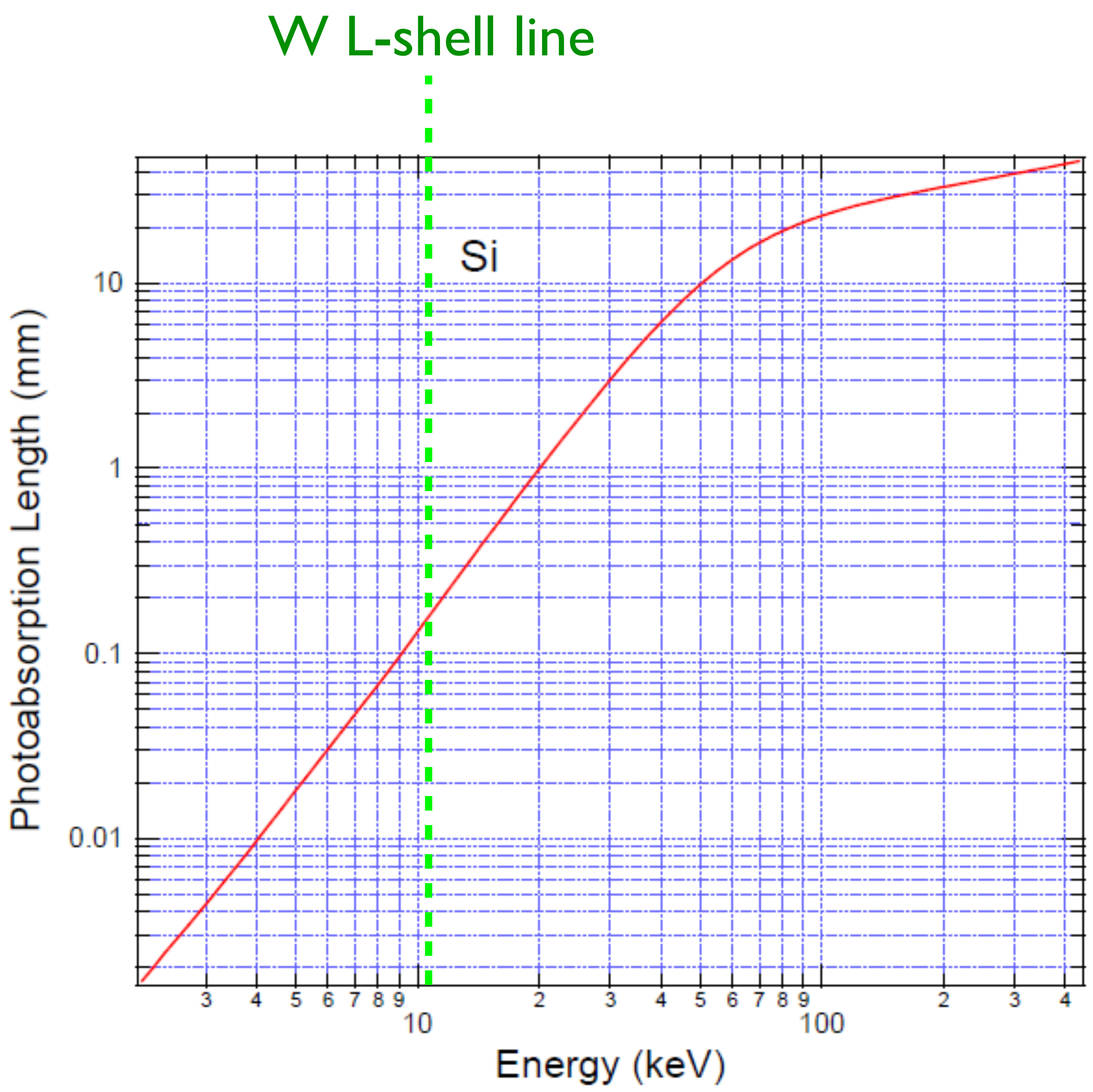

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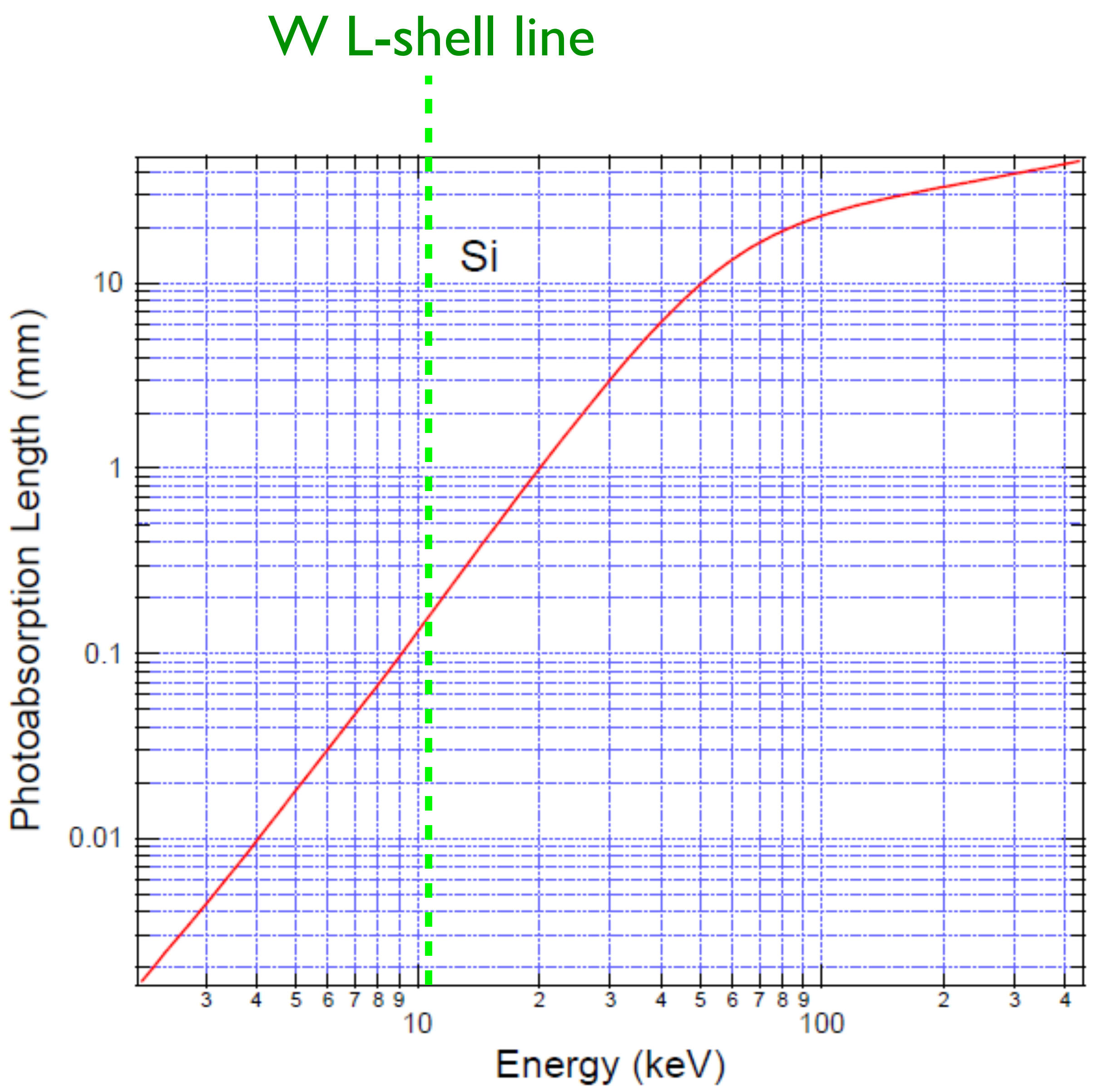
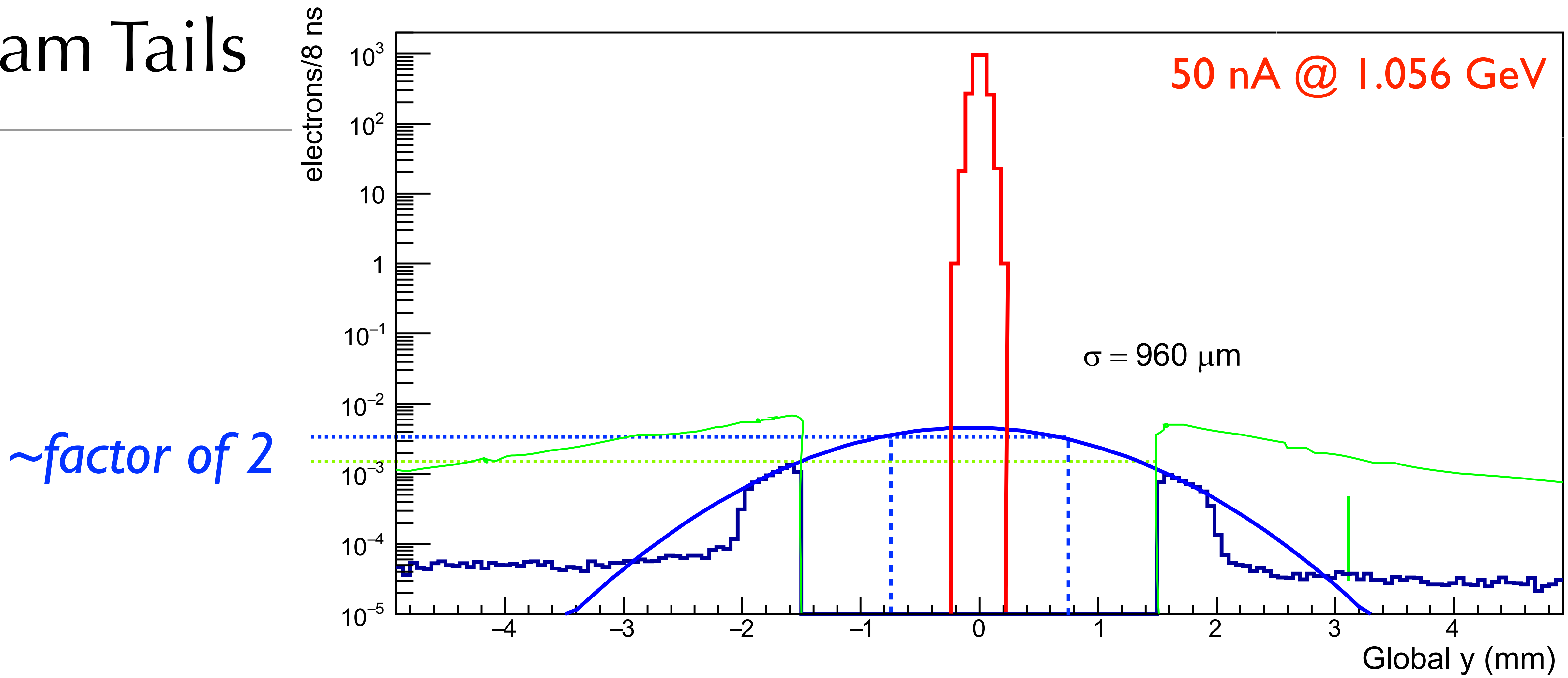
- Small sensor means sensor actually has smaller solid angle than Layer 1.
- Thinner sensor means only about 2/3 of L-shell x-rays with be absorbed in sensor.
- Studies find that x-ray occupancy will be ~0.4 hits/sensor
  ⇒ 0.07% occupancy: OK



Beam Tails



- With innermost strip at 0.75mm, beam tails could be a more serious problem.
- Profile of tails measured in engineering run would predict roughly 2× tails at 0.75mm.
- Like physics occupancy, splitting readout strips in half cuts this in half. *OK.*
- *At 300 nA (4.4 GeV running), expect roughly 1% occupancy / 8 ns in both L0, L1.*
- *Expect that tails generated by beam-gas in poor vacuum through tagger will be improved.*

Full Simulations of Upgrade Performance

HPS has been busy re-estimating reach with full simulation given lessons learned from analyzing 2015 data.

The same techniques are being used, in parallel, to estimate reach for both current (AKA "Nominal") and upgraded (AKA "L0") detector configurations.

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- occupancies
- acceptance/efficiency
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Fundamentals

- occupancies
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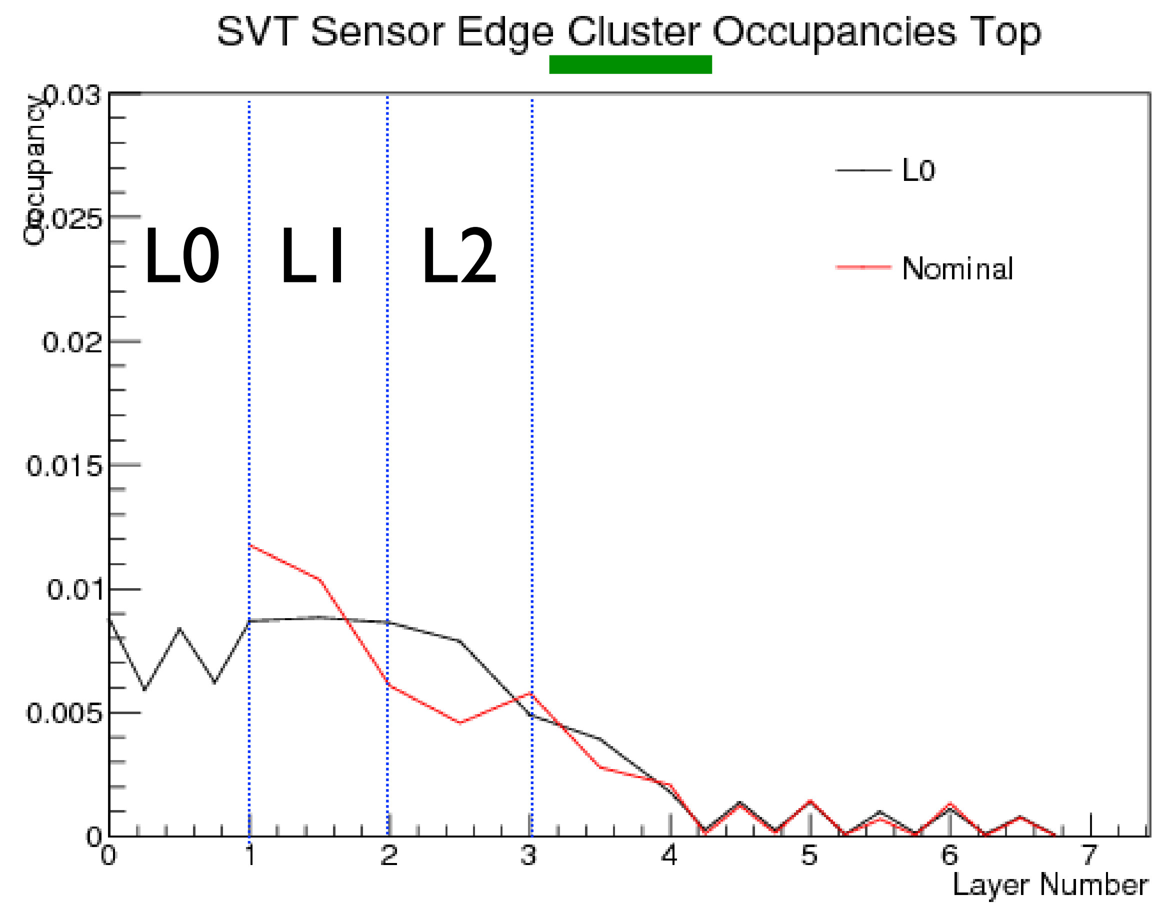
Reach estimates

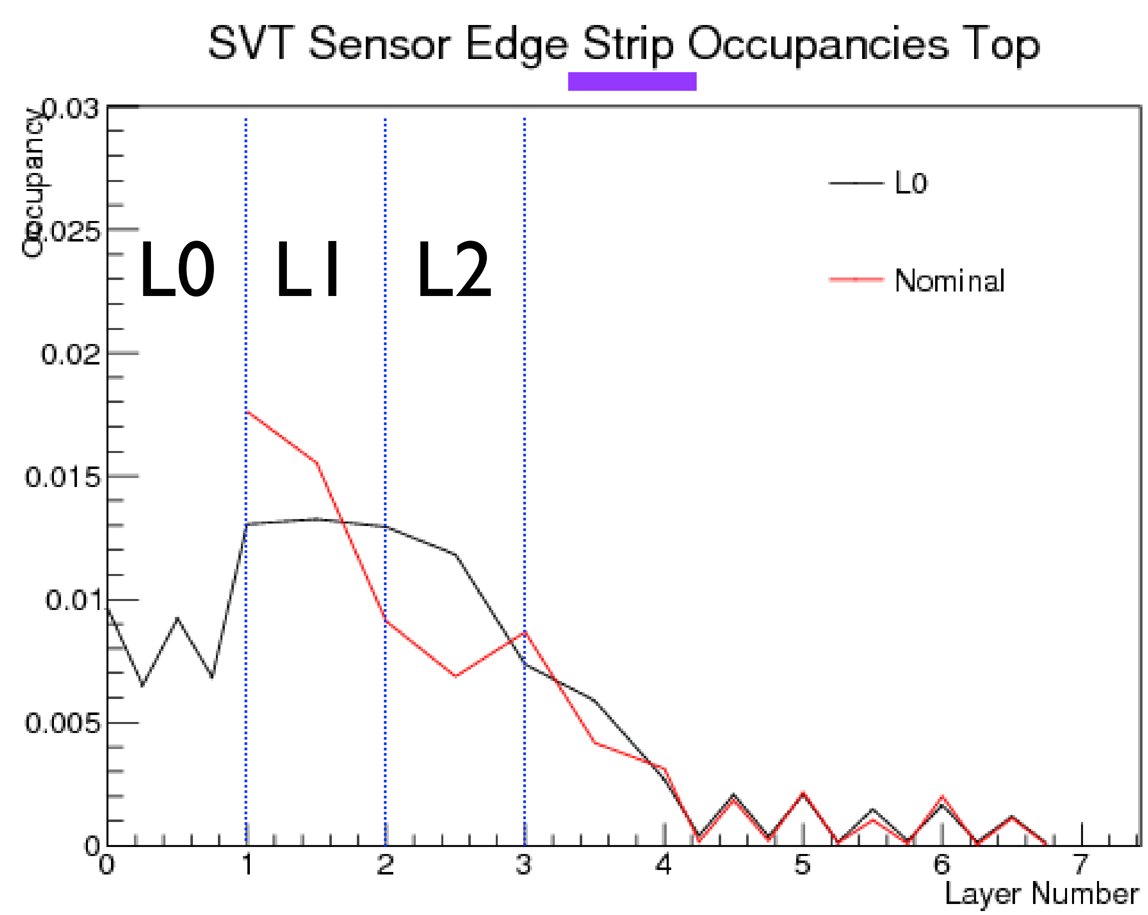
- z cuts required to achieve 0.5 background events
- Reach with/without SVT Upgrade @ 1.1 GeV, 2.2 GeV, 4.4 GeV

Occupancies

Nominal (current detector)

- L1 > L2





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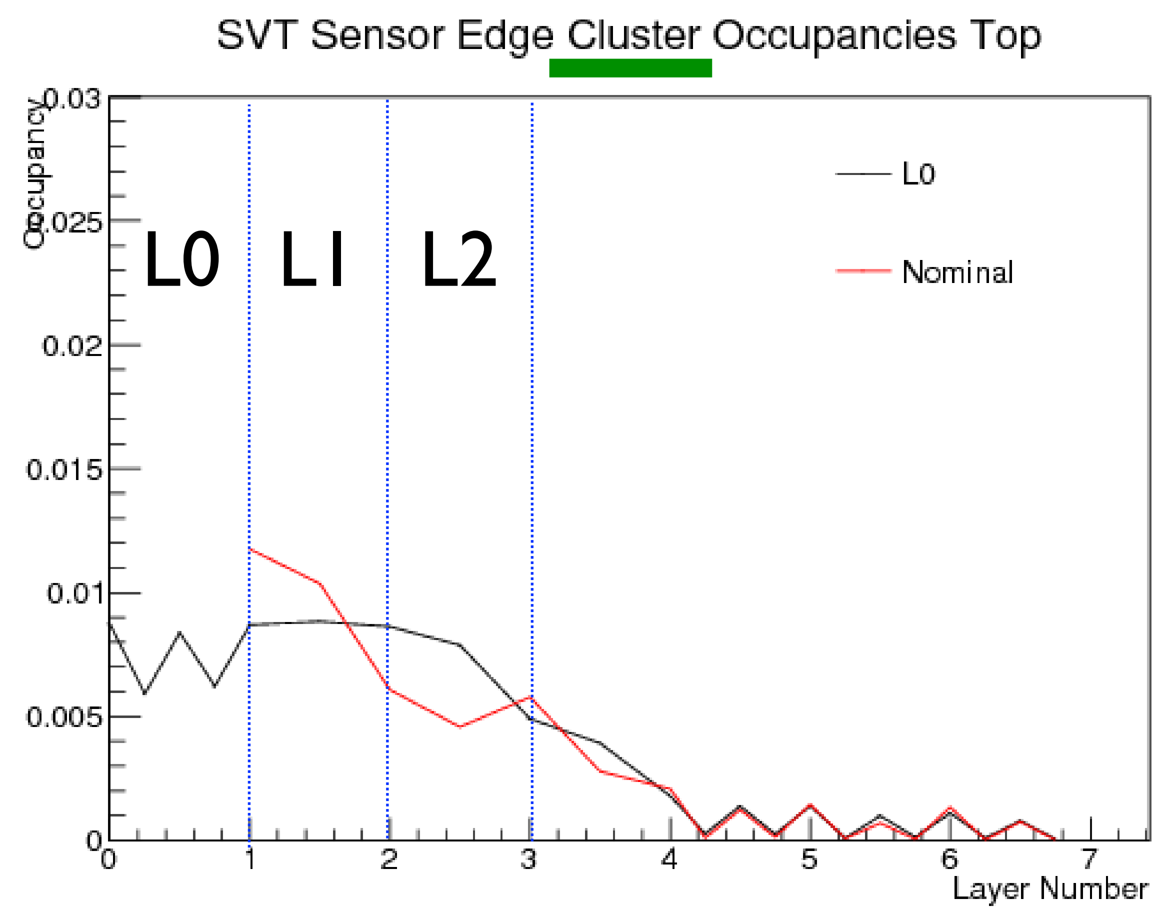
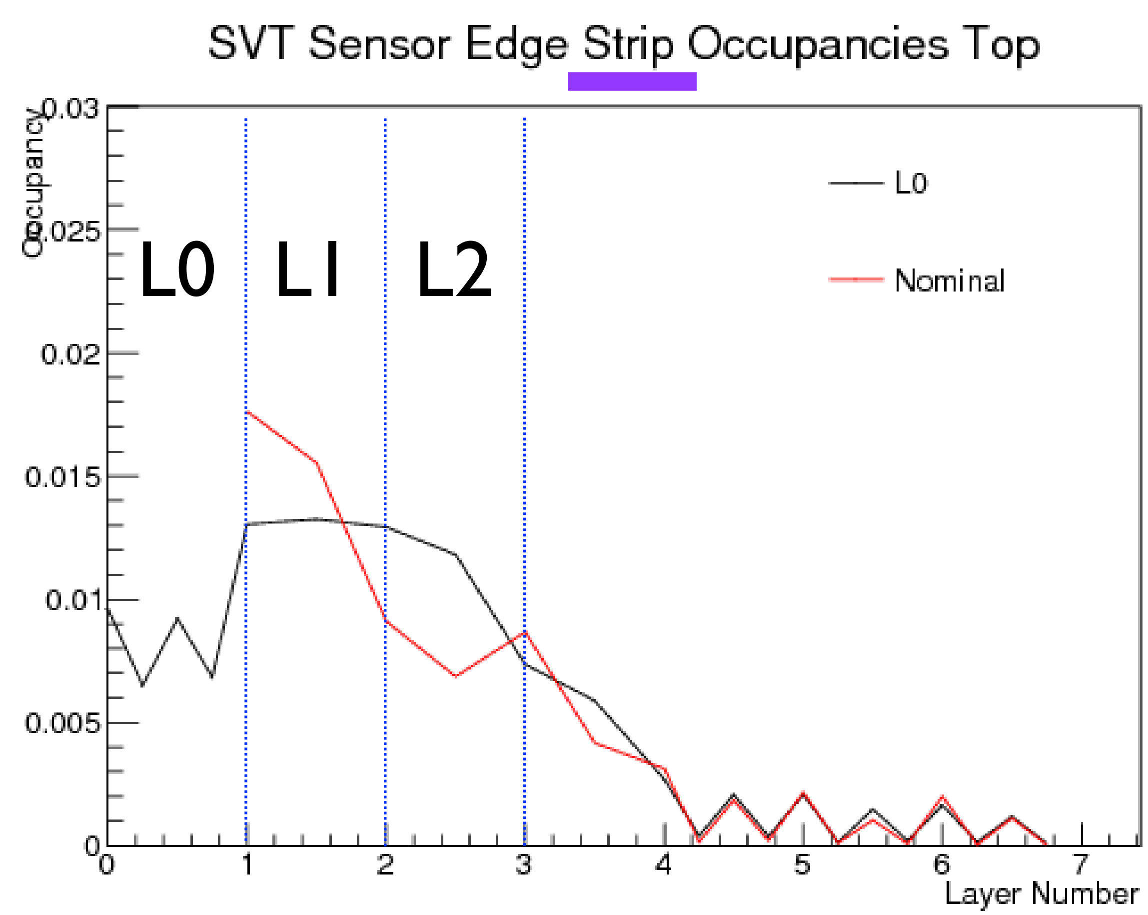
- L1 ~ L2 (by design)





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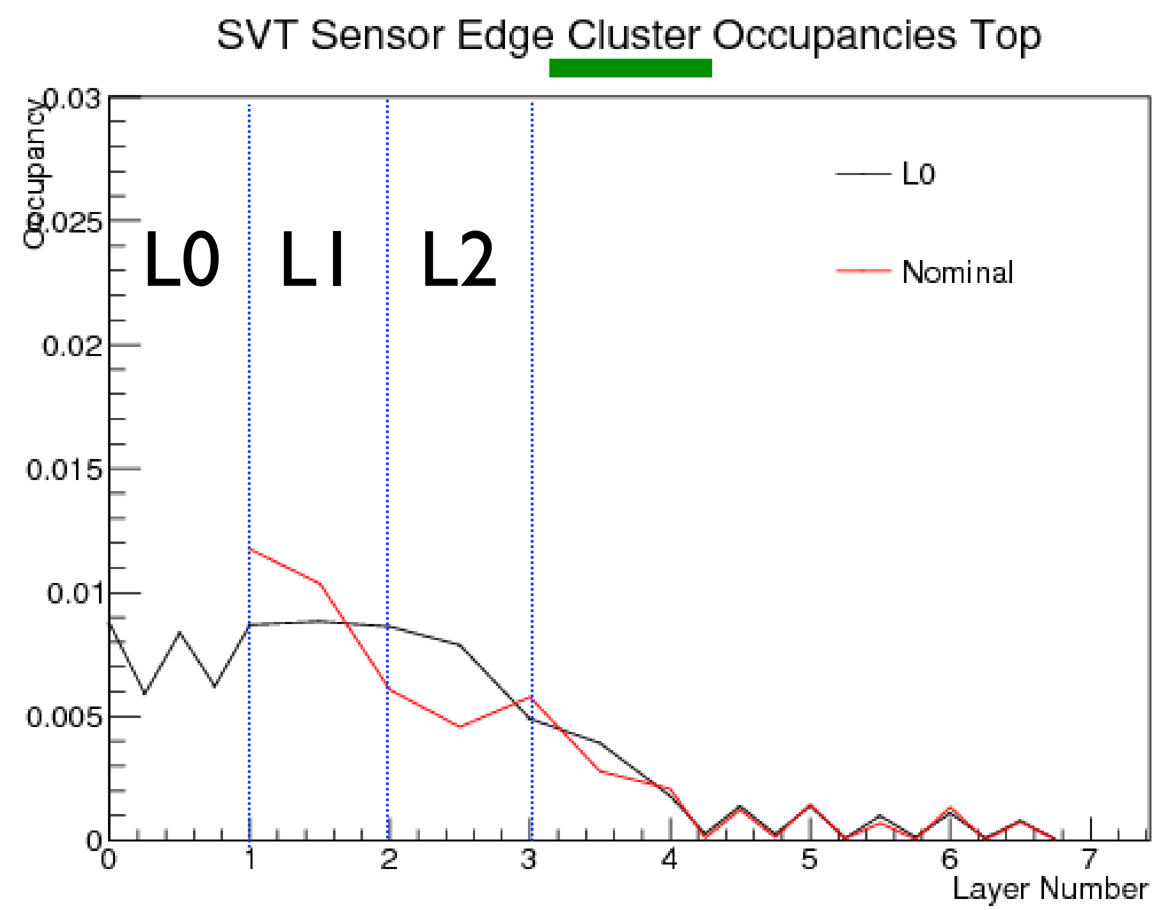

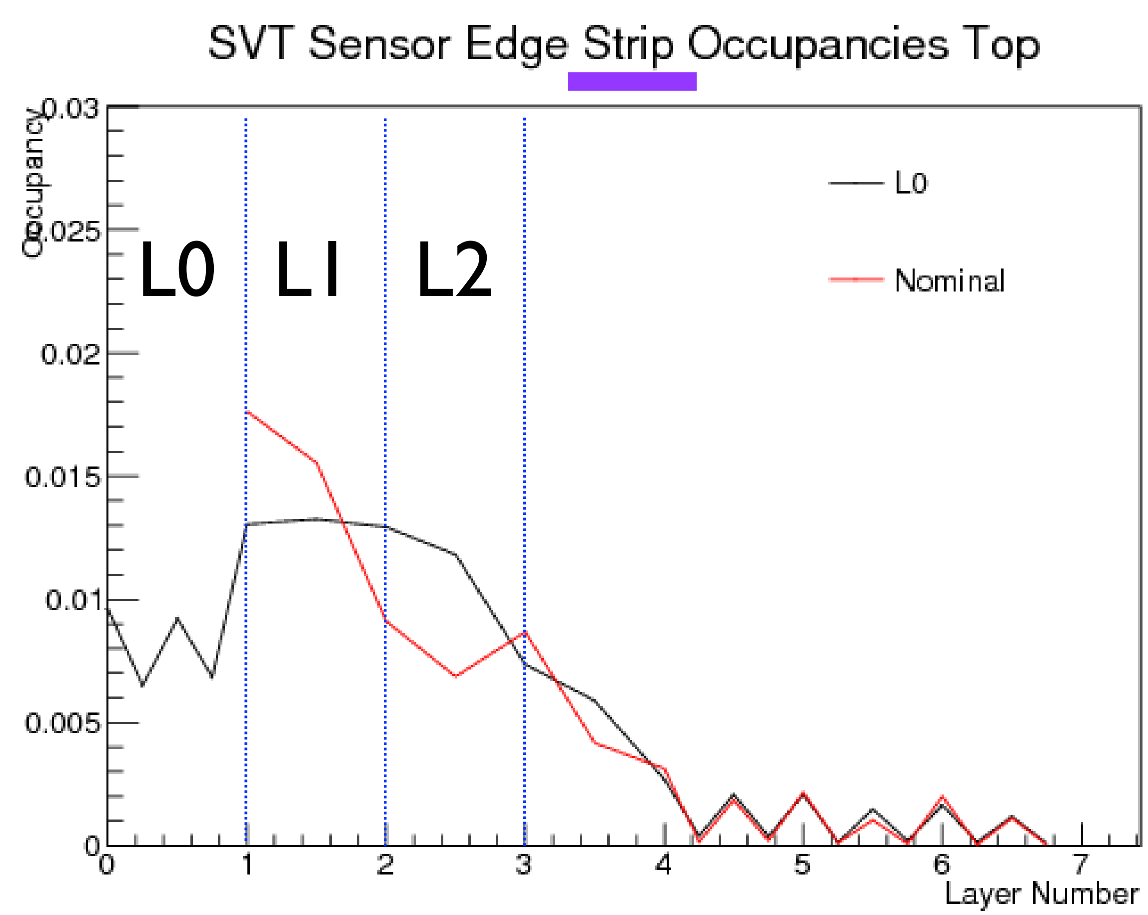

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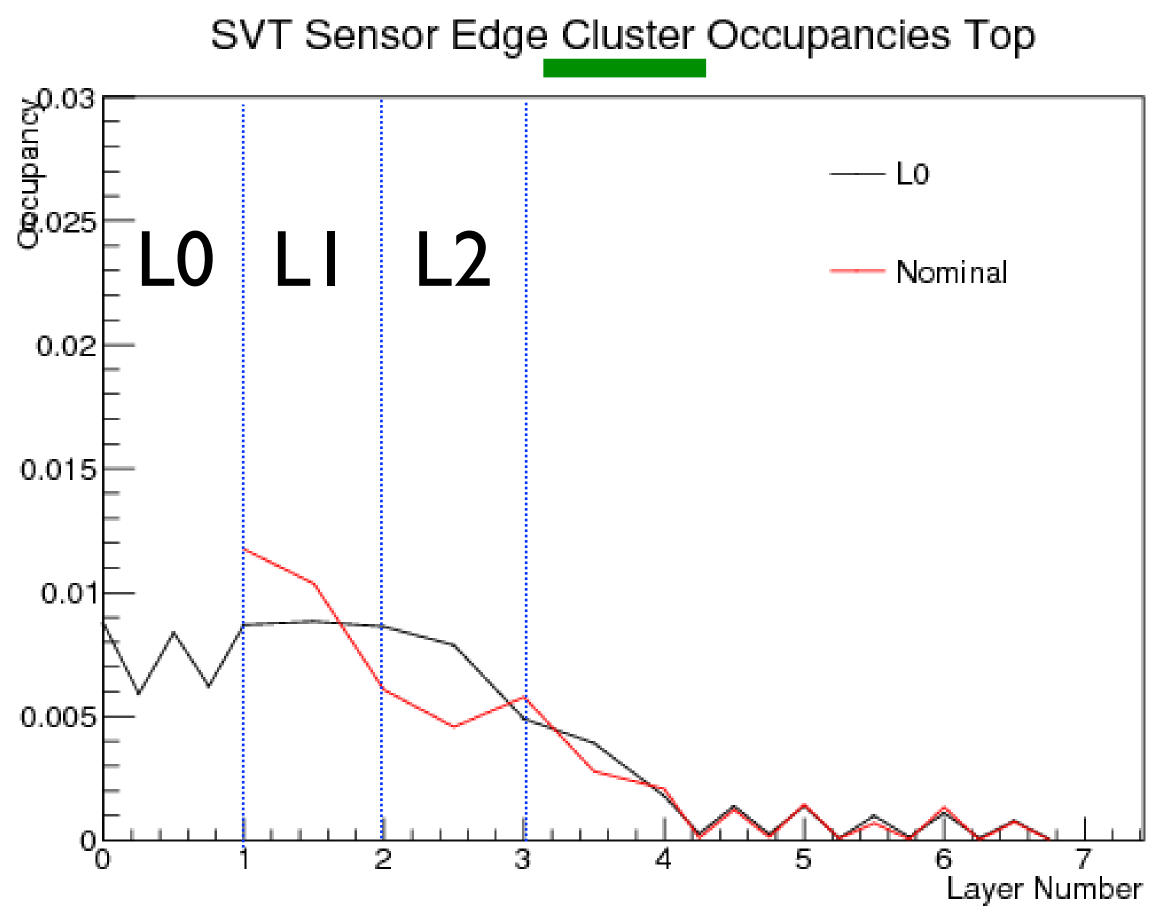
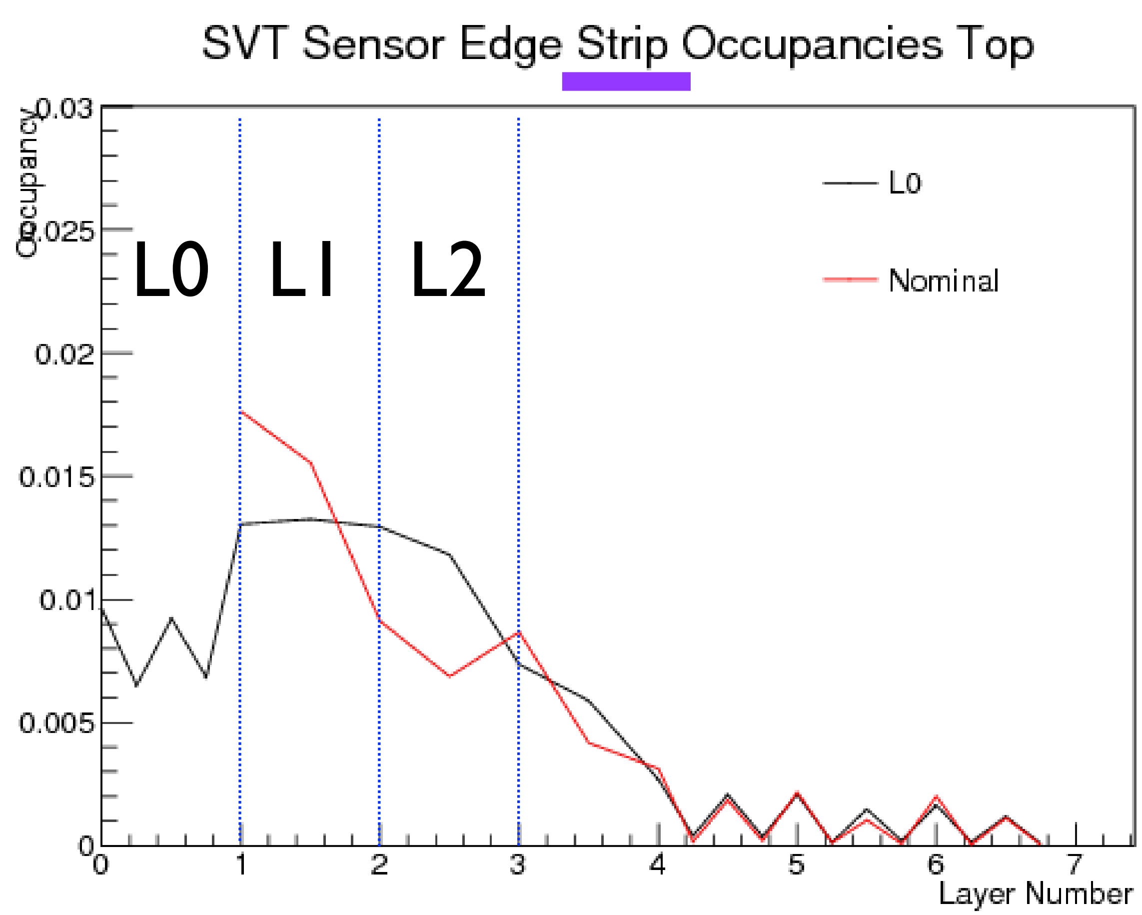
L0 (upgraded detector)

- L1 ~ L2 (by design)
- Particle occupancy (cluster occupancy) of L0 ~ L1 (by design)
- Strip occupancy of L0 < L1 (by design) because no capacitively-coupled sense strips
    - Mean cluster size in L0 is ~1.1 strips
    - Mean cluster size in L1 is ~1.6 strips





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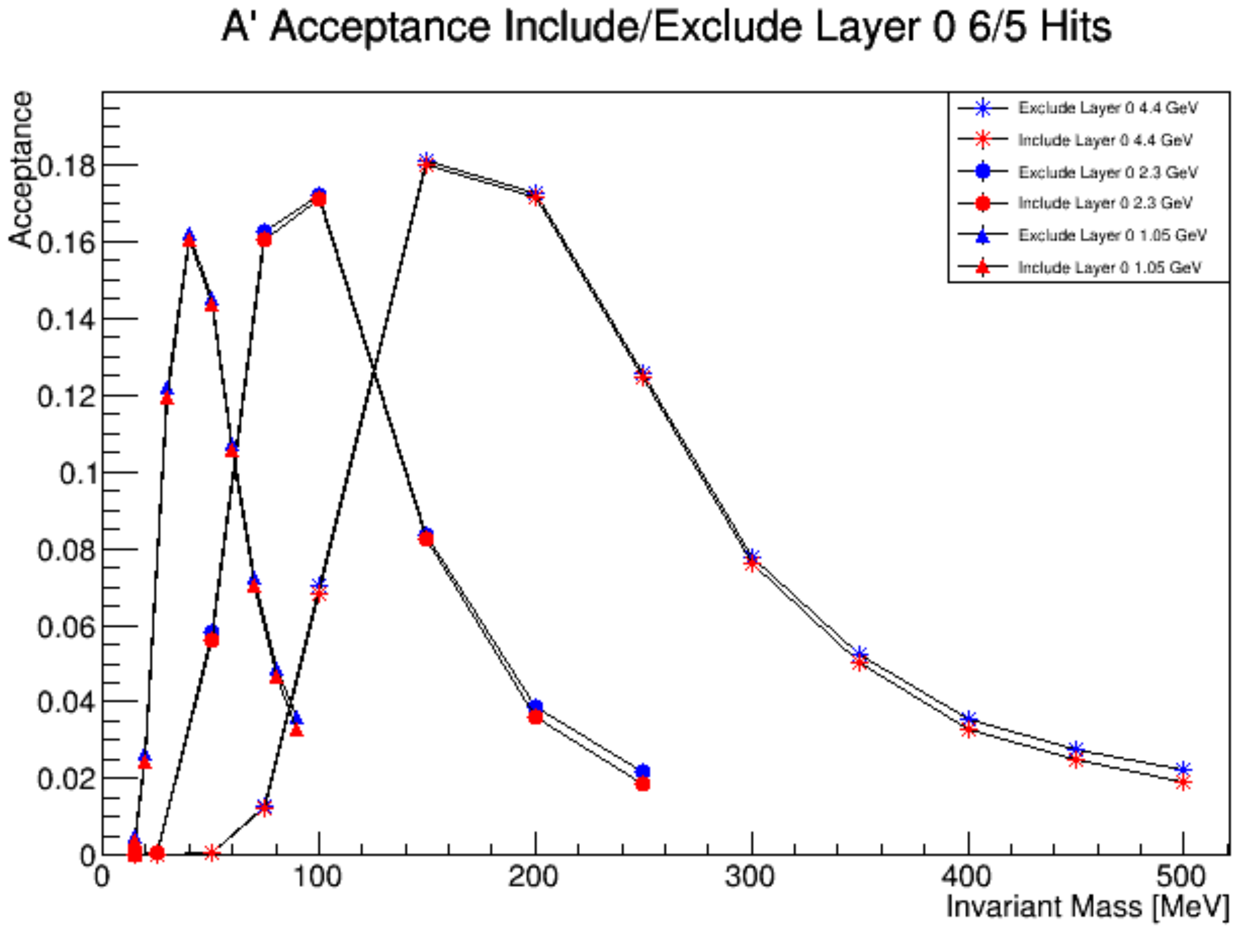
Layer 0 has full acceptance and good efficiency for tracks accepted by the rest of the tracker.



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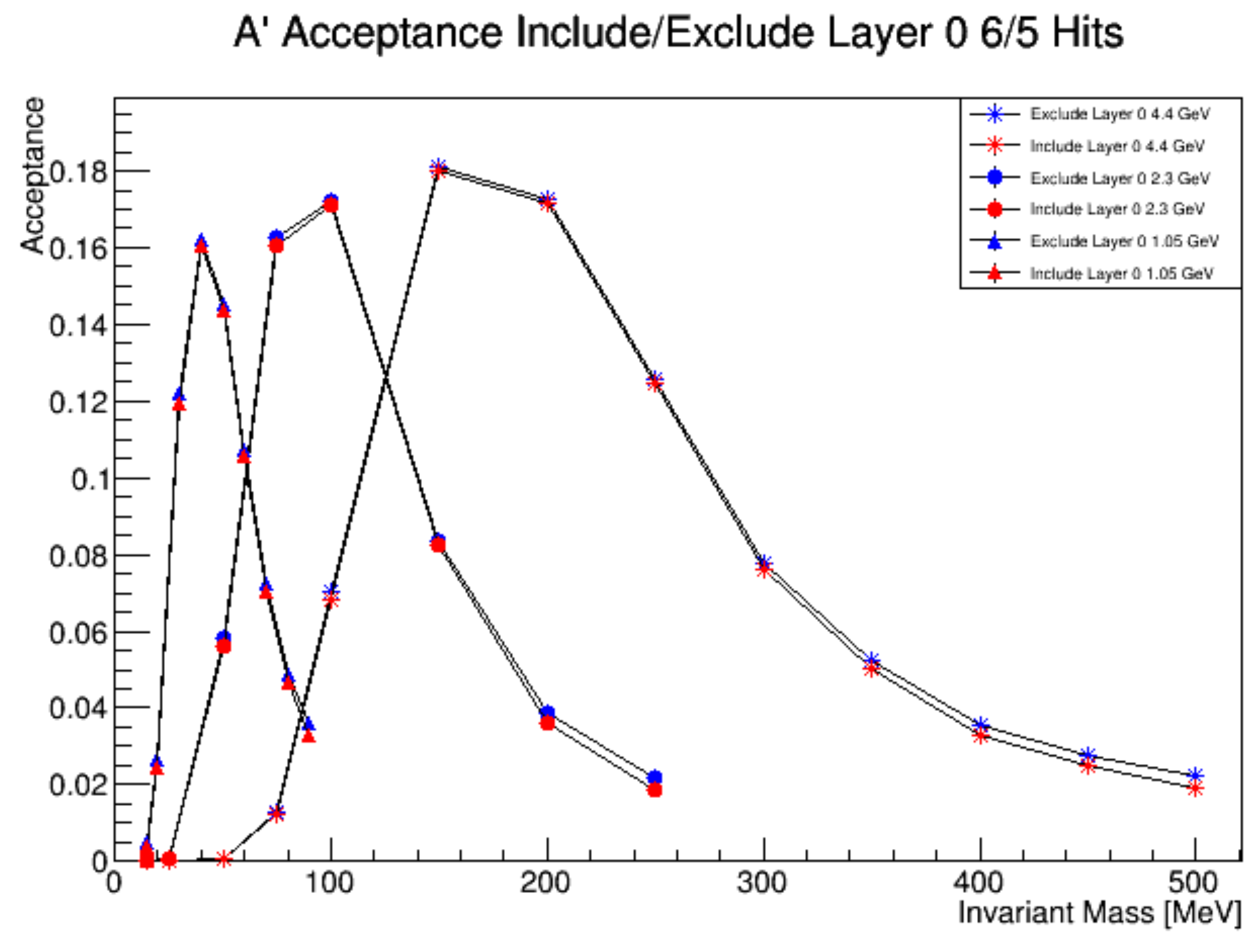
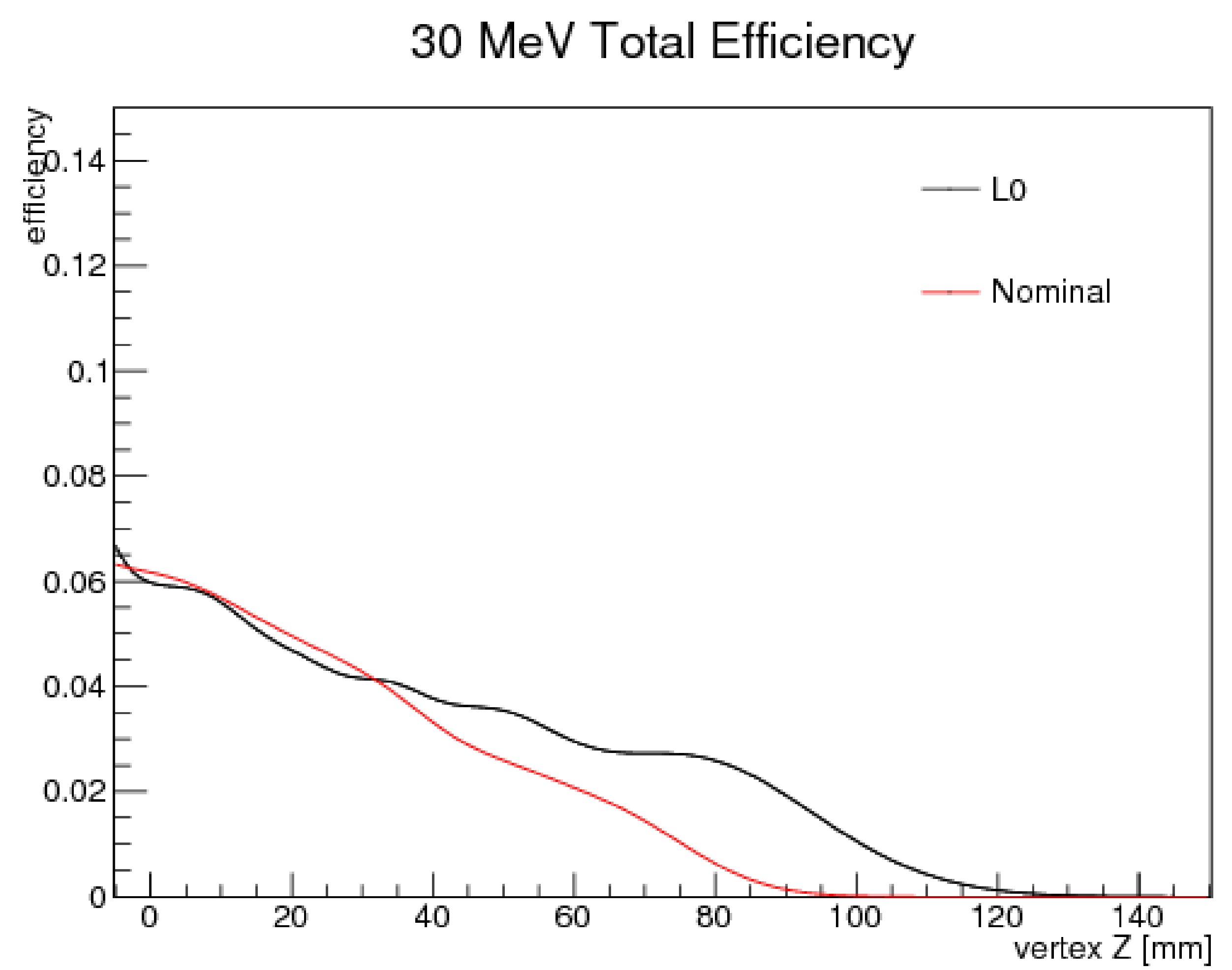
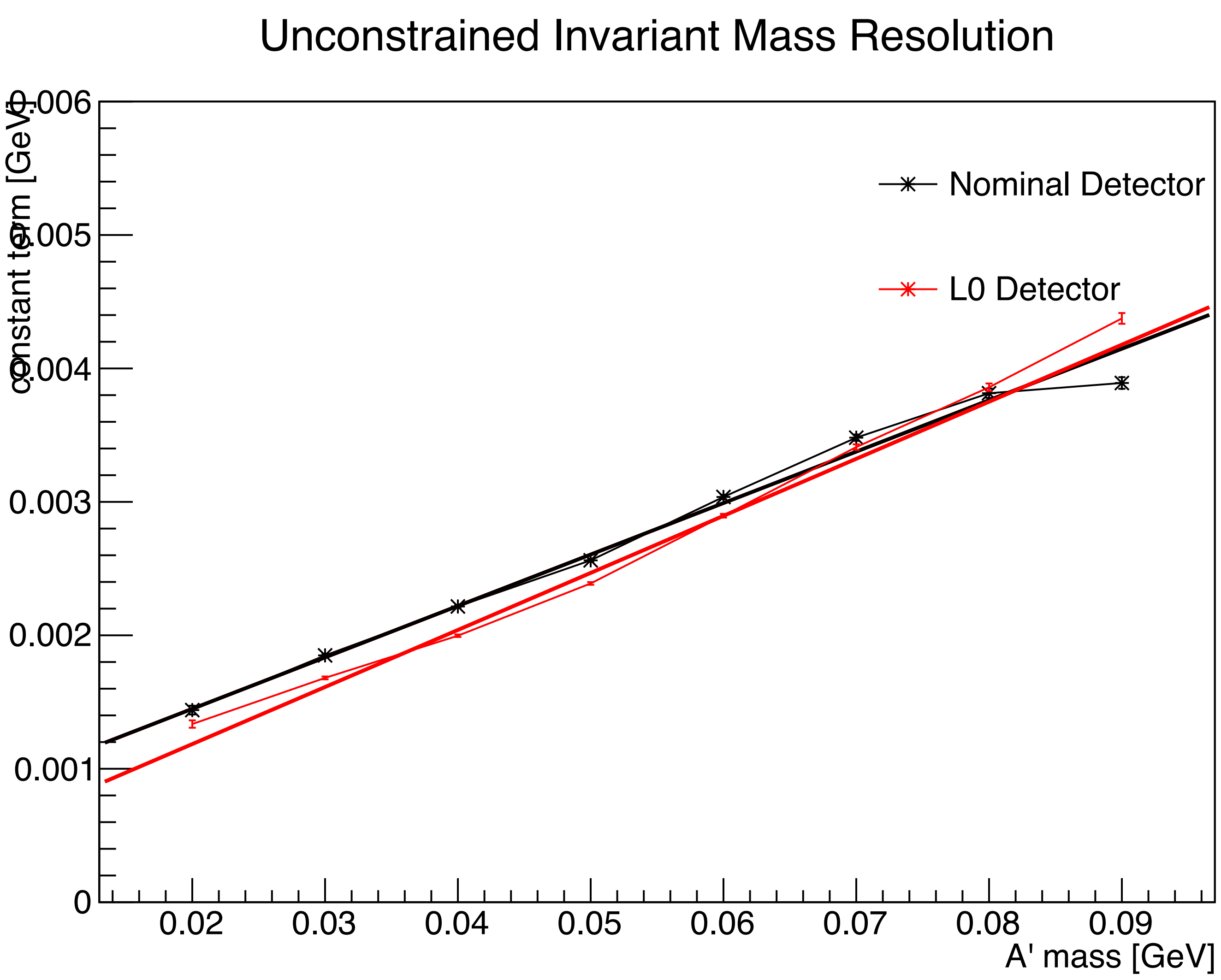
Moving Layers 2 and 3 inwards increases acceptance for long-lived A′ daughters as expected.





Resolutions



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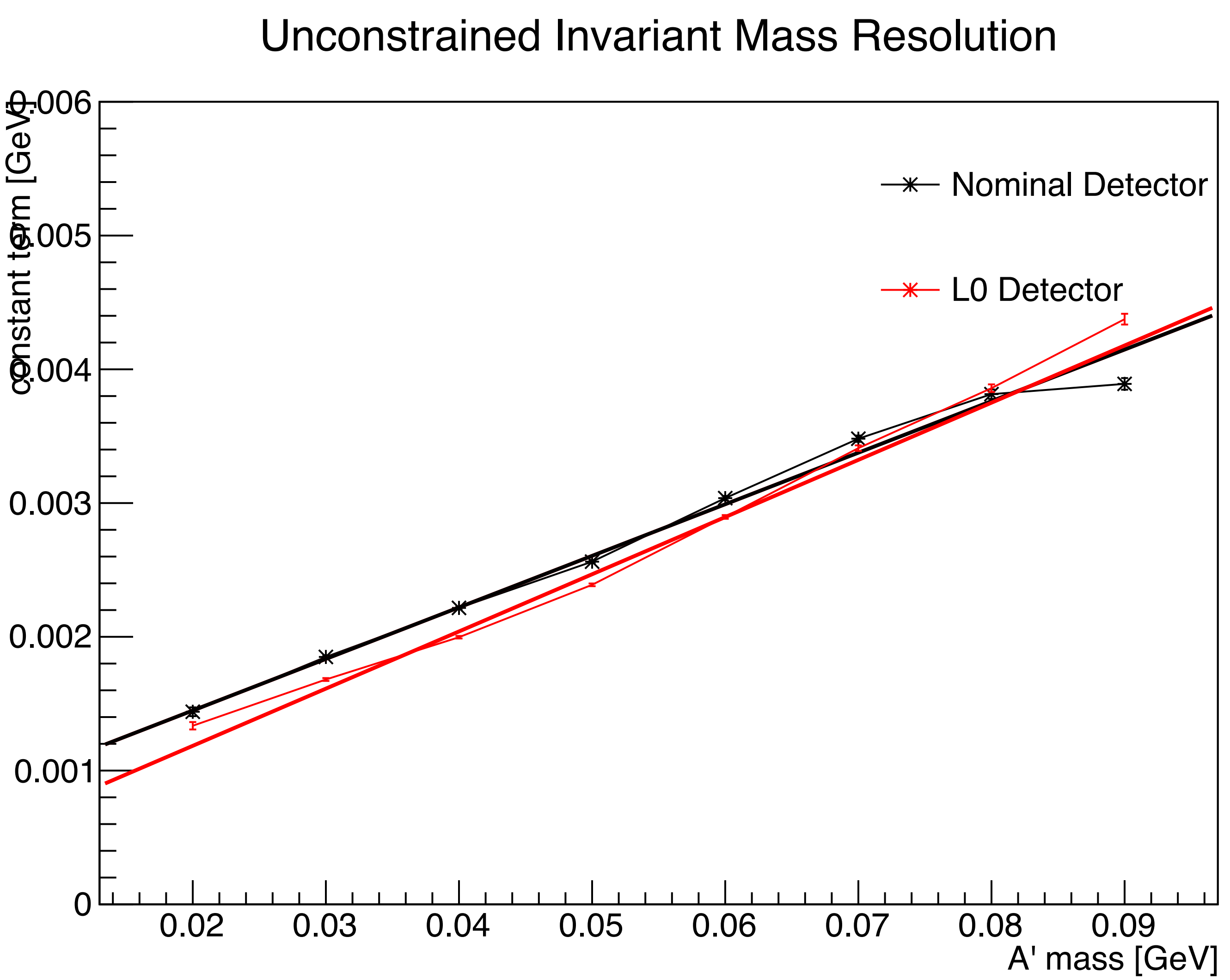

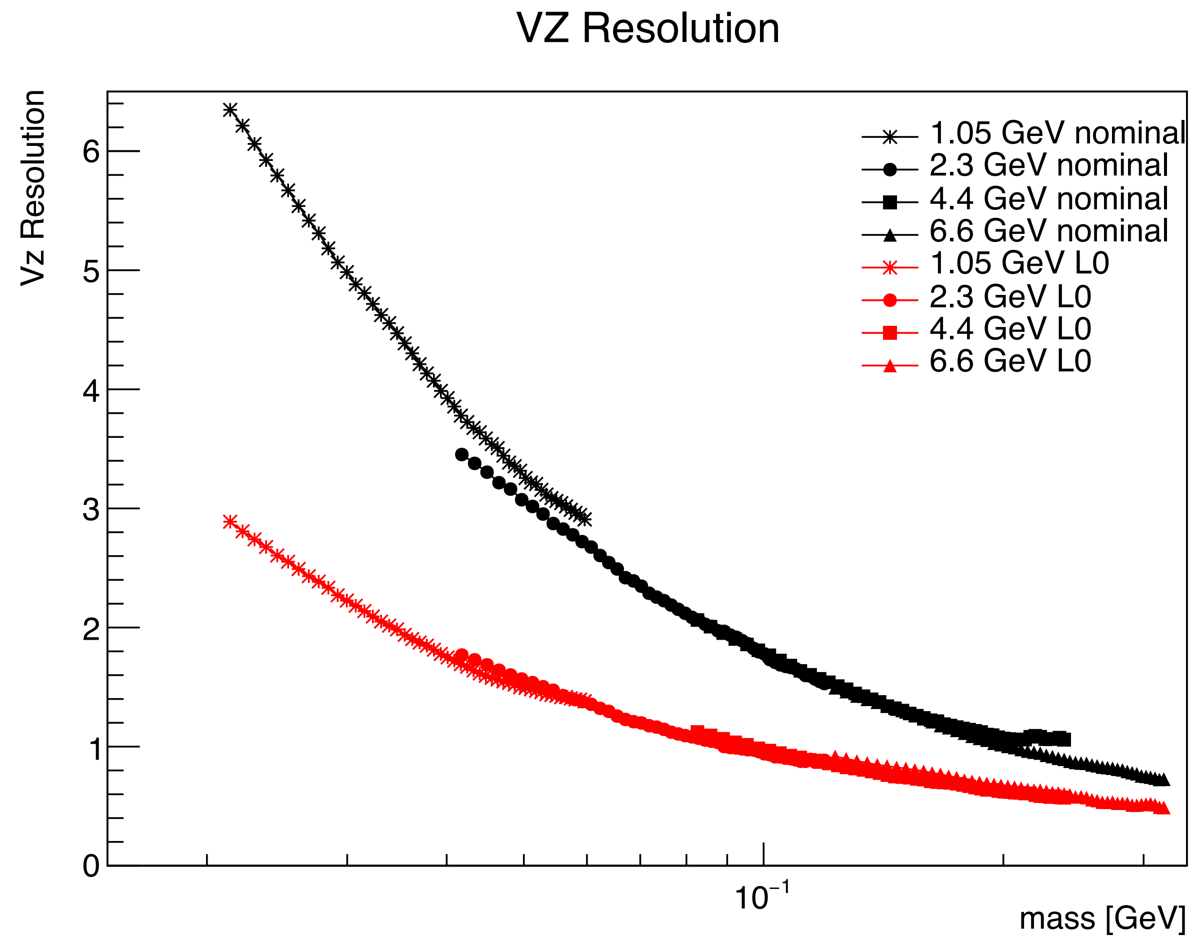

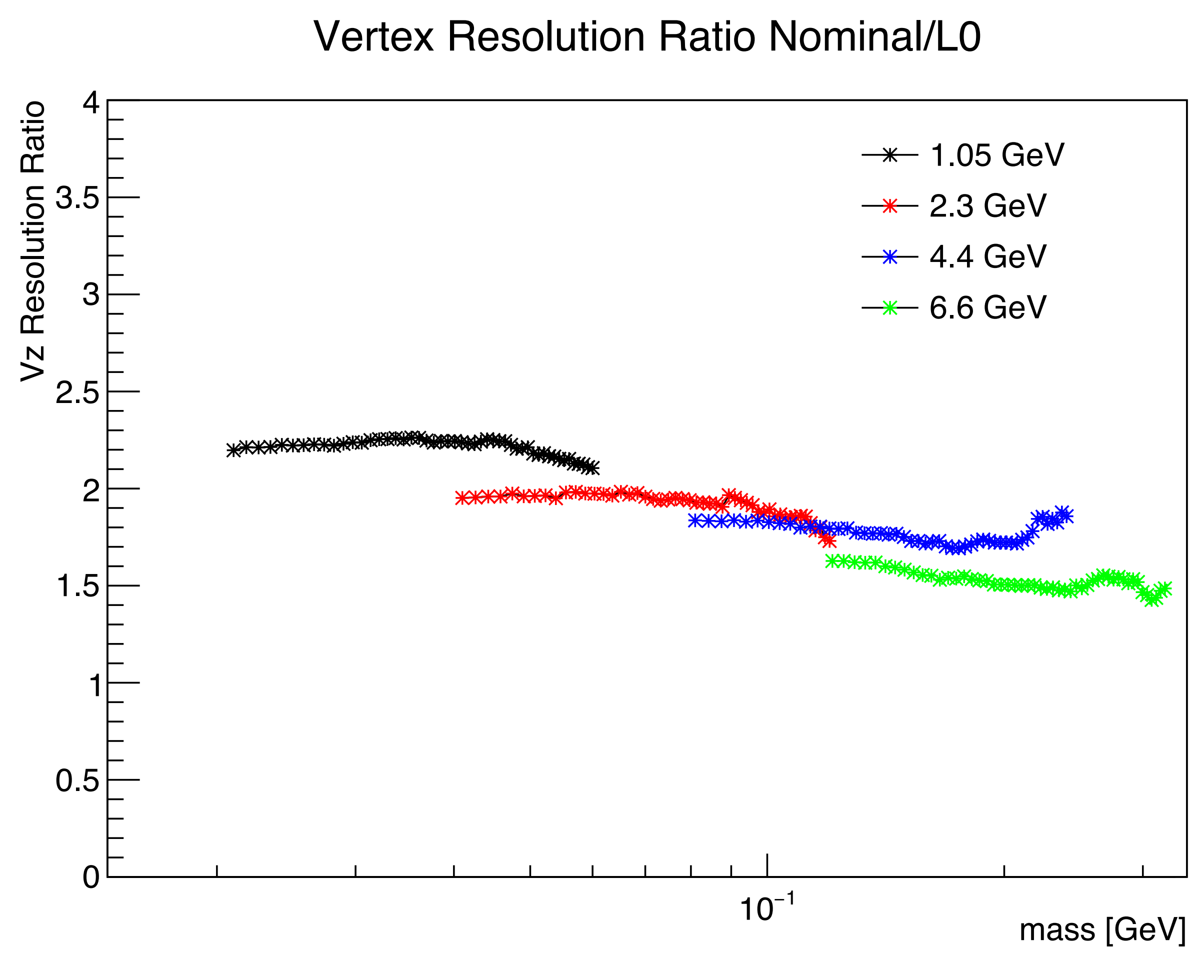

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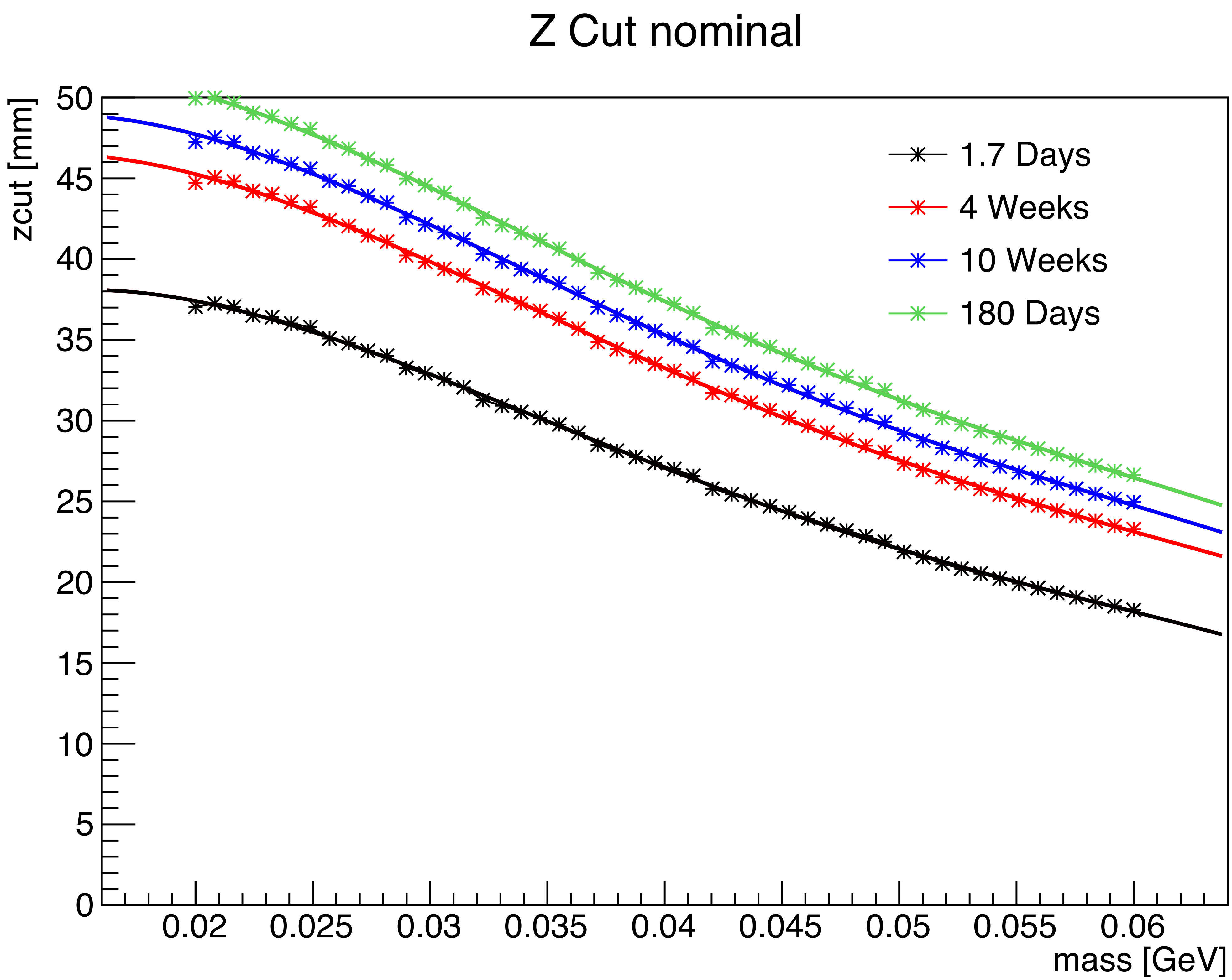
Vertex resolution improves roughly a factor of two, with some momentum dependence.

Z Cut for 0.5 Events Expected Background



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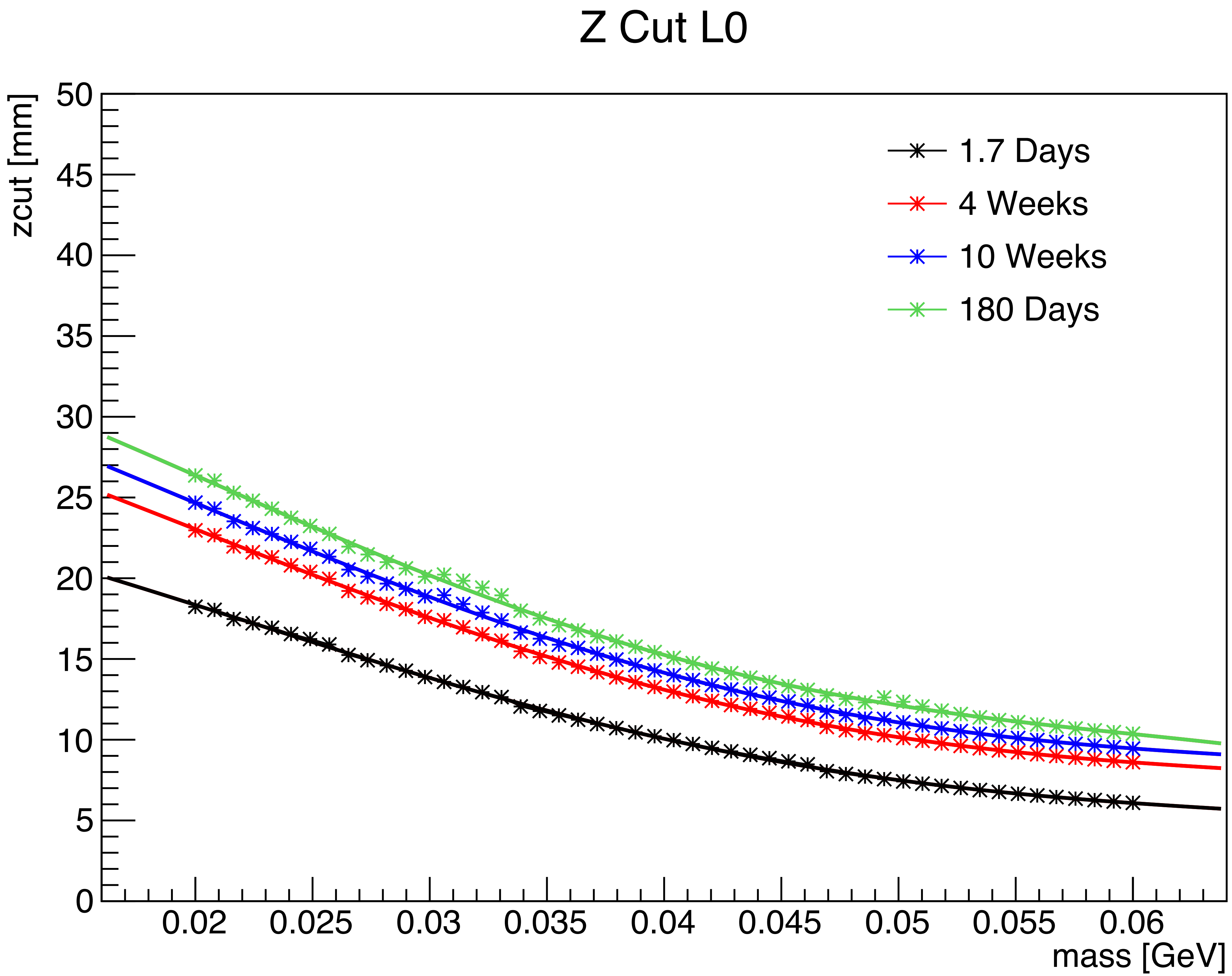
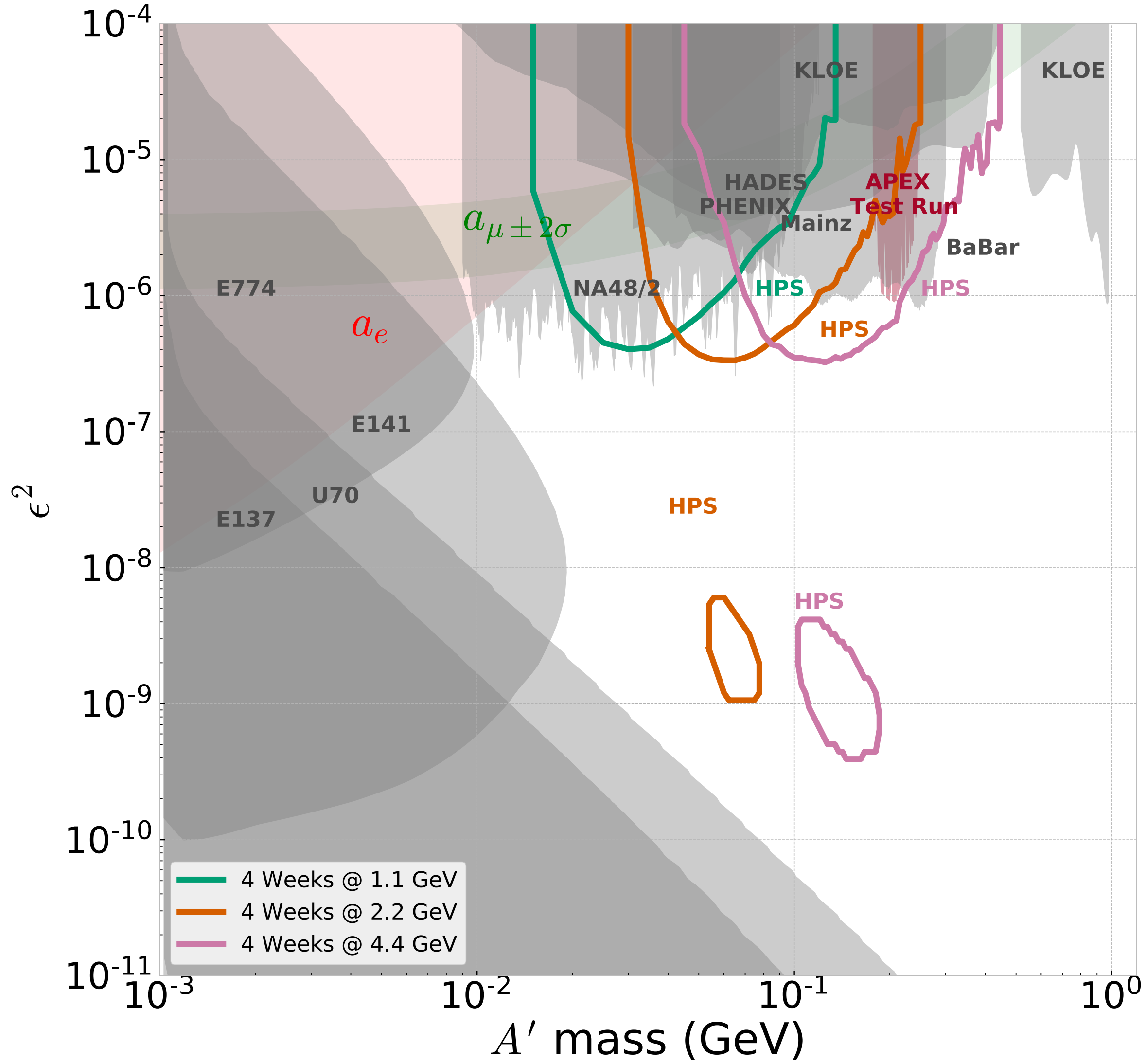
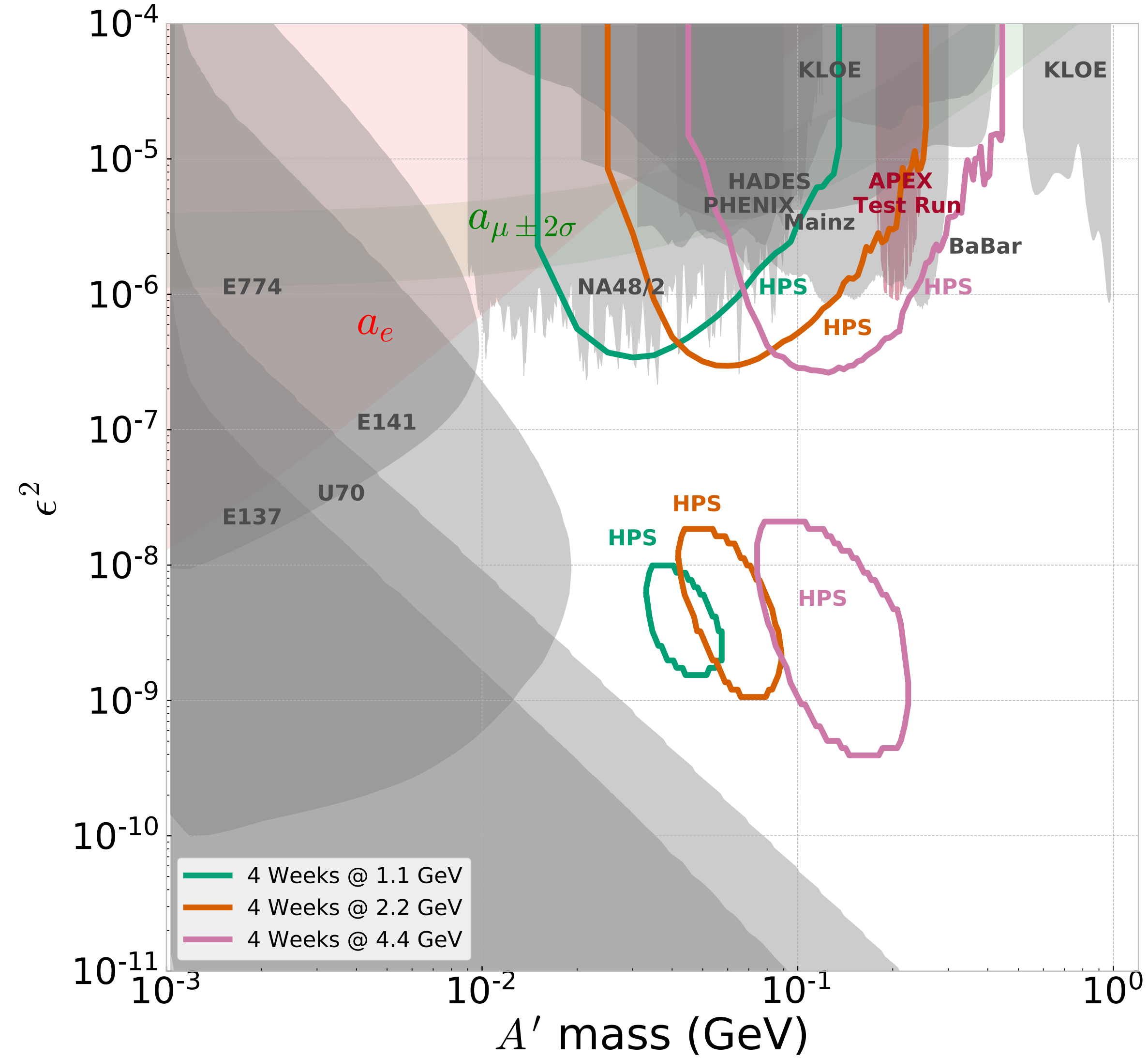


Impact on Reach

w/ positron hodoscope

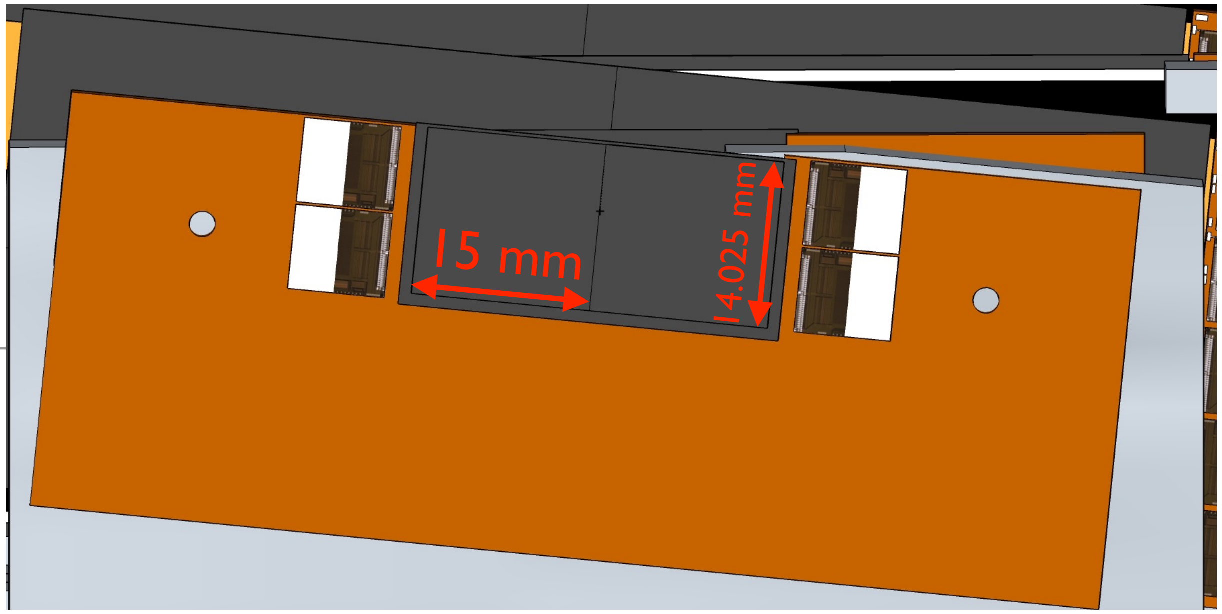


+ SVT upgrade

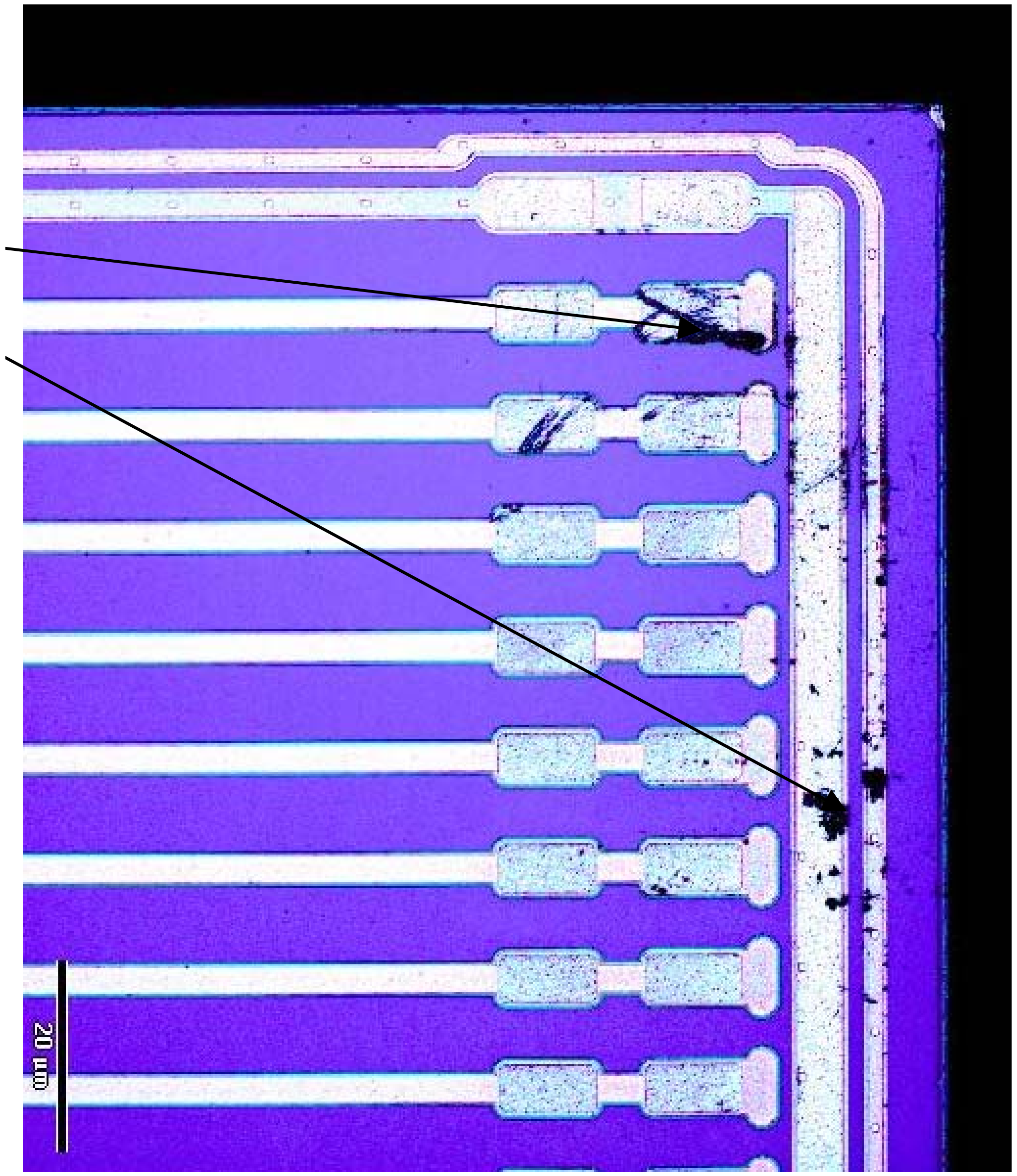


The majority of the SVT improvement is from adding Layer 0

Layer 0 Sensor Design



- thickness: 150 um
- sense/readout pitch: 55 um
  (no capacitively coupled intermediate strip: reduces occupancy, improves two-hit resolution, reduces capacitance and strip resistance)
- active areas: 2×(15 mm × 14.025 mm)
- # channels: 510 (2×255)
- slim edge: ≲200 um, similar to sensors already processed this way by UCSC.
  (means edge of sensor will be further from beam than current Layer 1)
- max bias voltage: 500V *(will test/select for 1000V operation as with current sensors)*

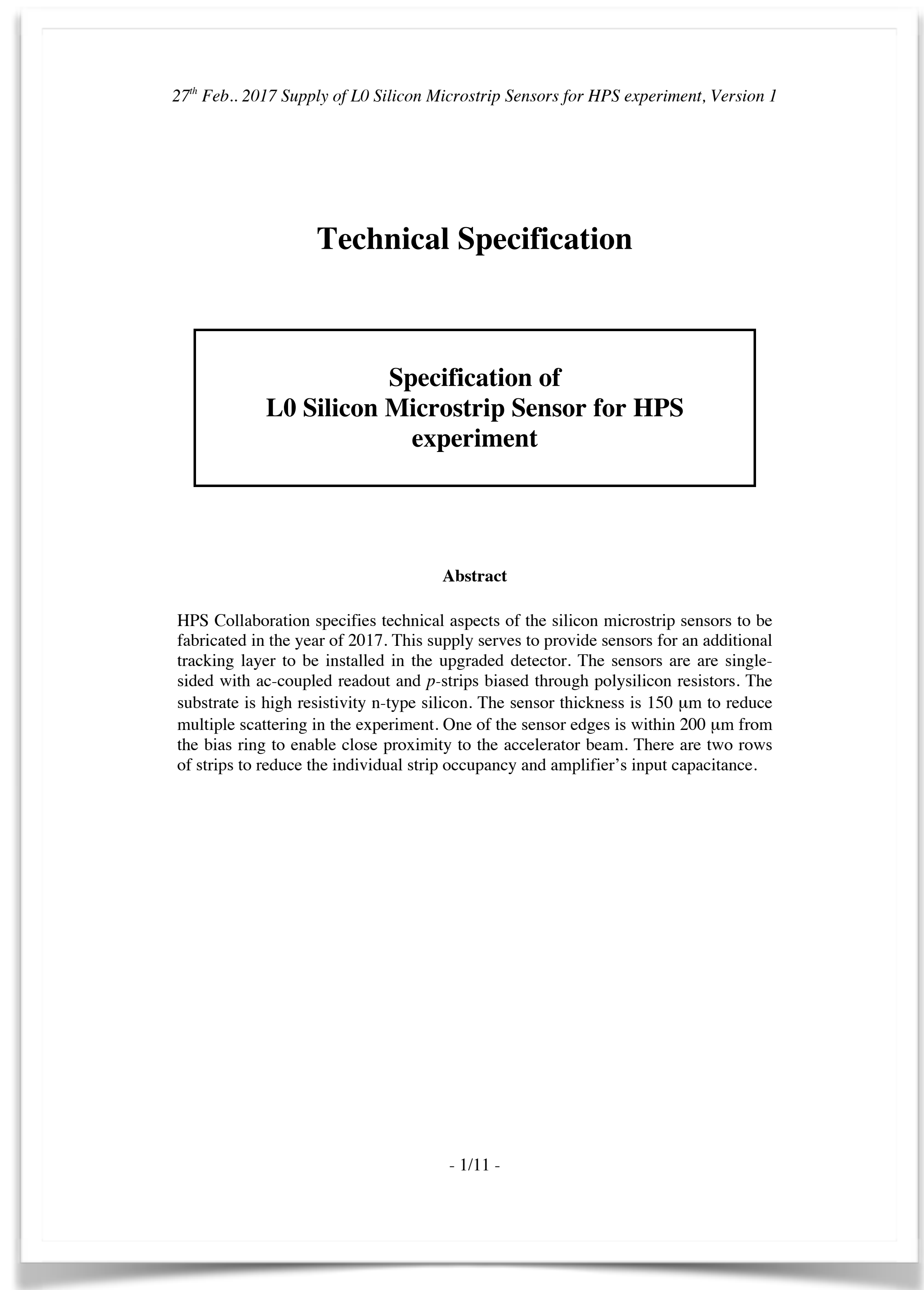


Layer 0 Sensor Procurement

The vendor, D+T CNM (with which UCSC has long working relationship) has quoted the project and technical specifications are ready.

Discussions regarding the design and implementation are complete.

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


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

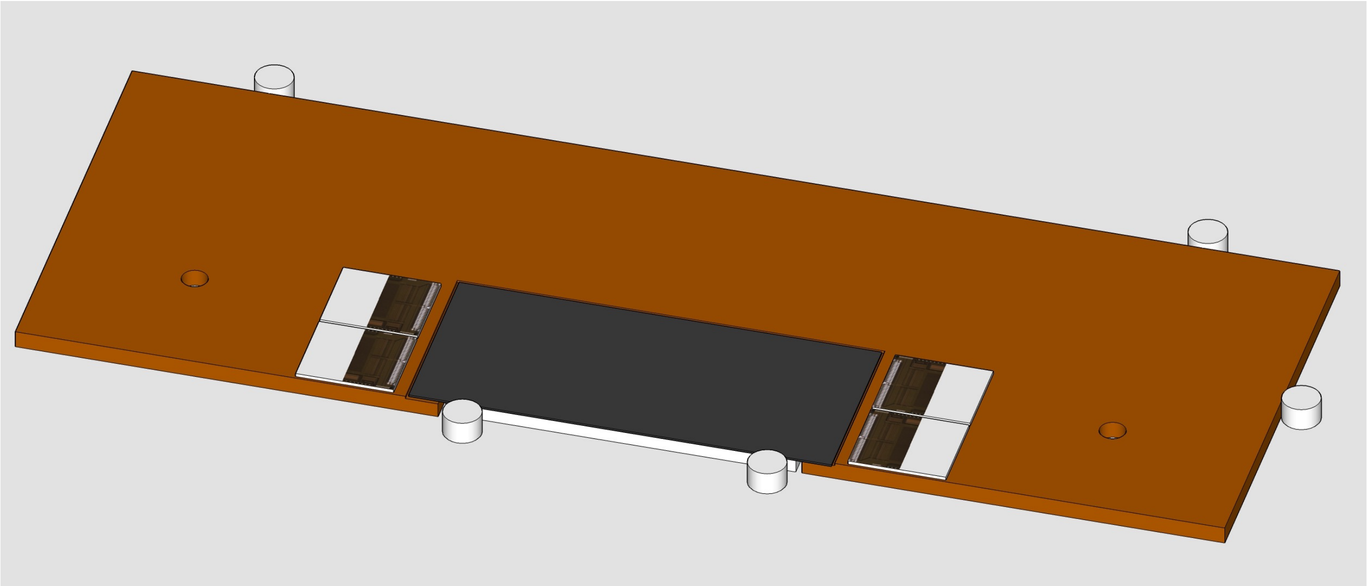
Schematic identical to previous hybrids, with one fewer APV25 chip.

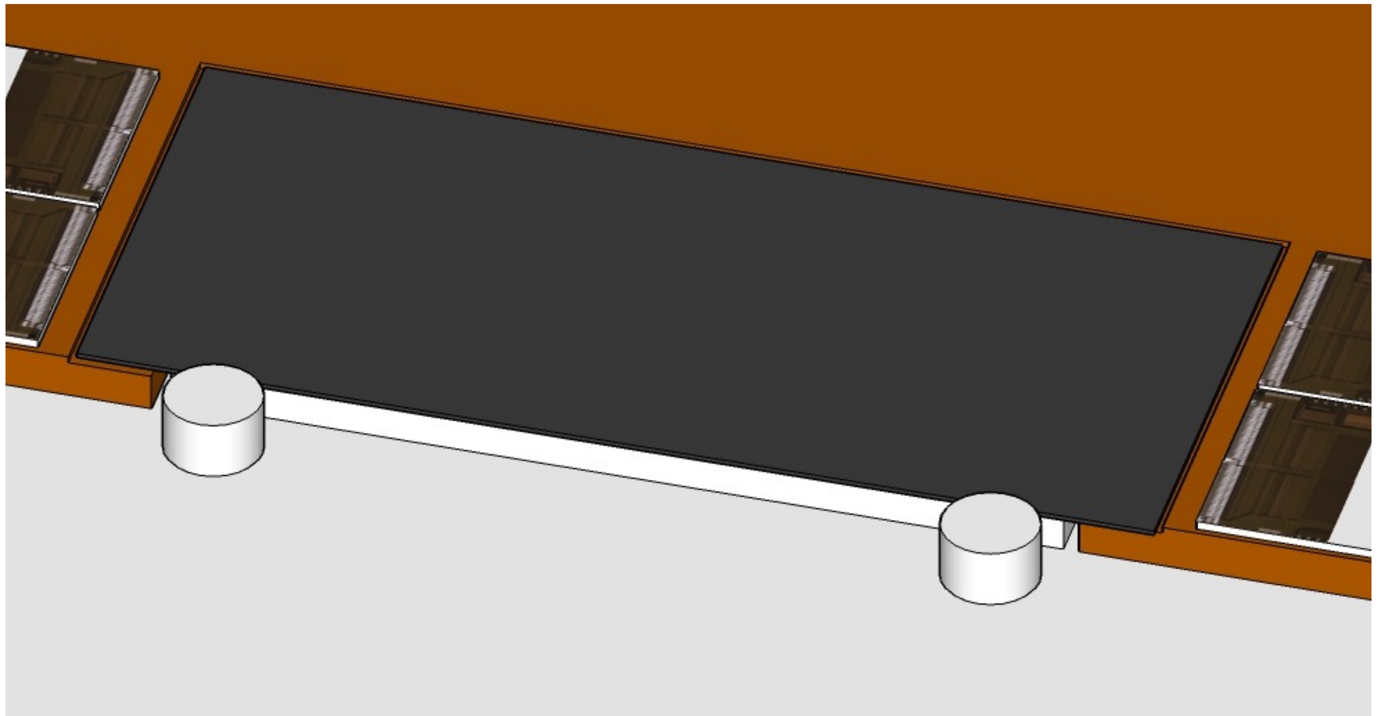
Layout very different, sensor placed in a window along one edge.

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 used in LCLS-II detectors.





Layer 0 Module Design

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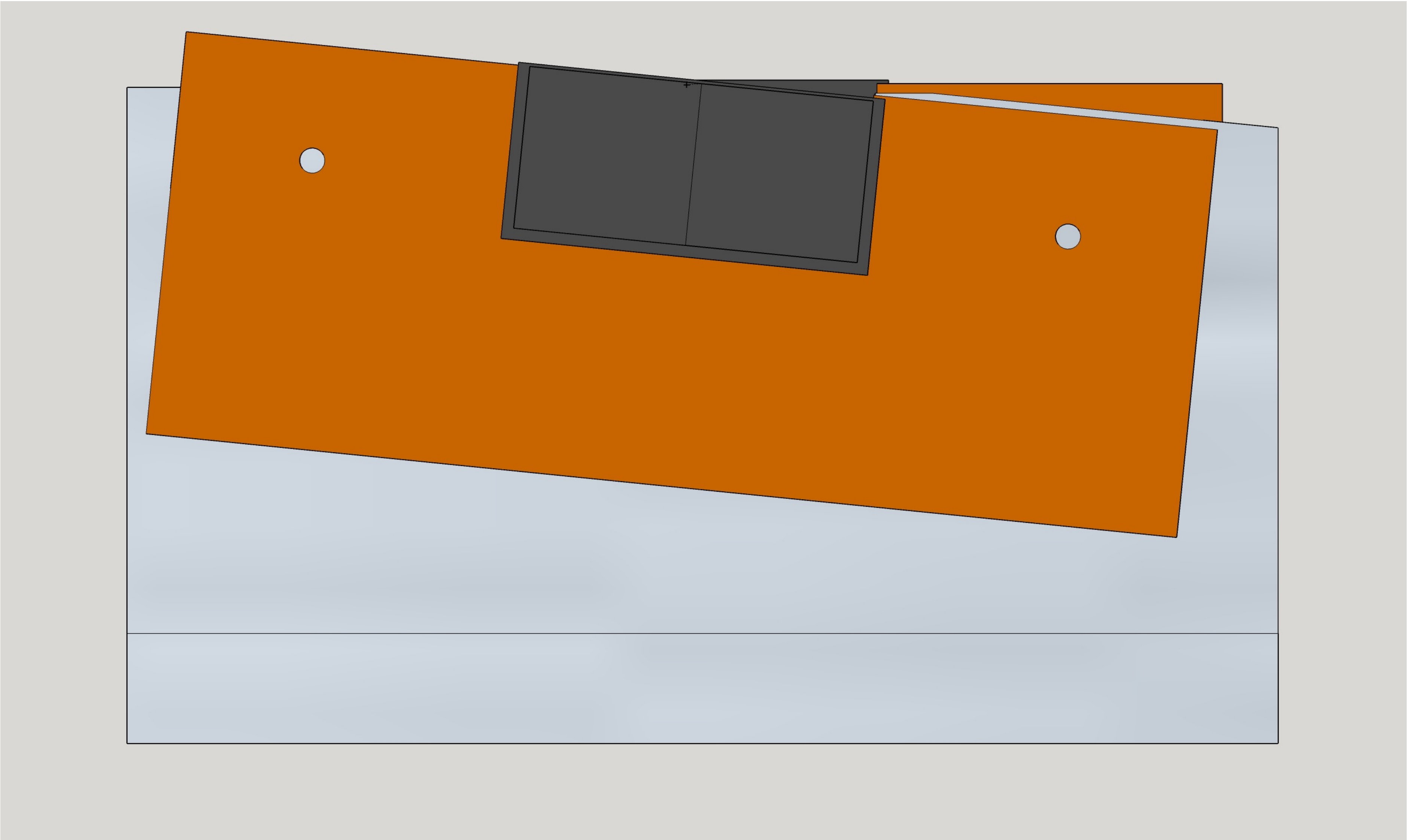
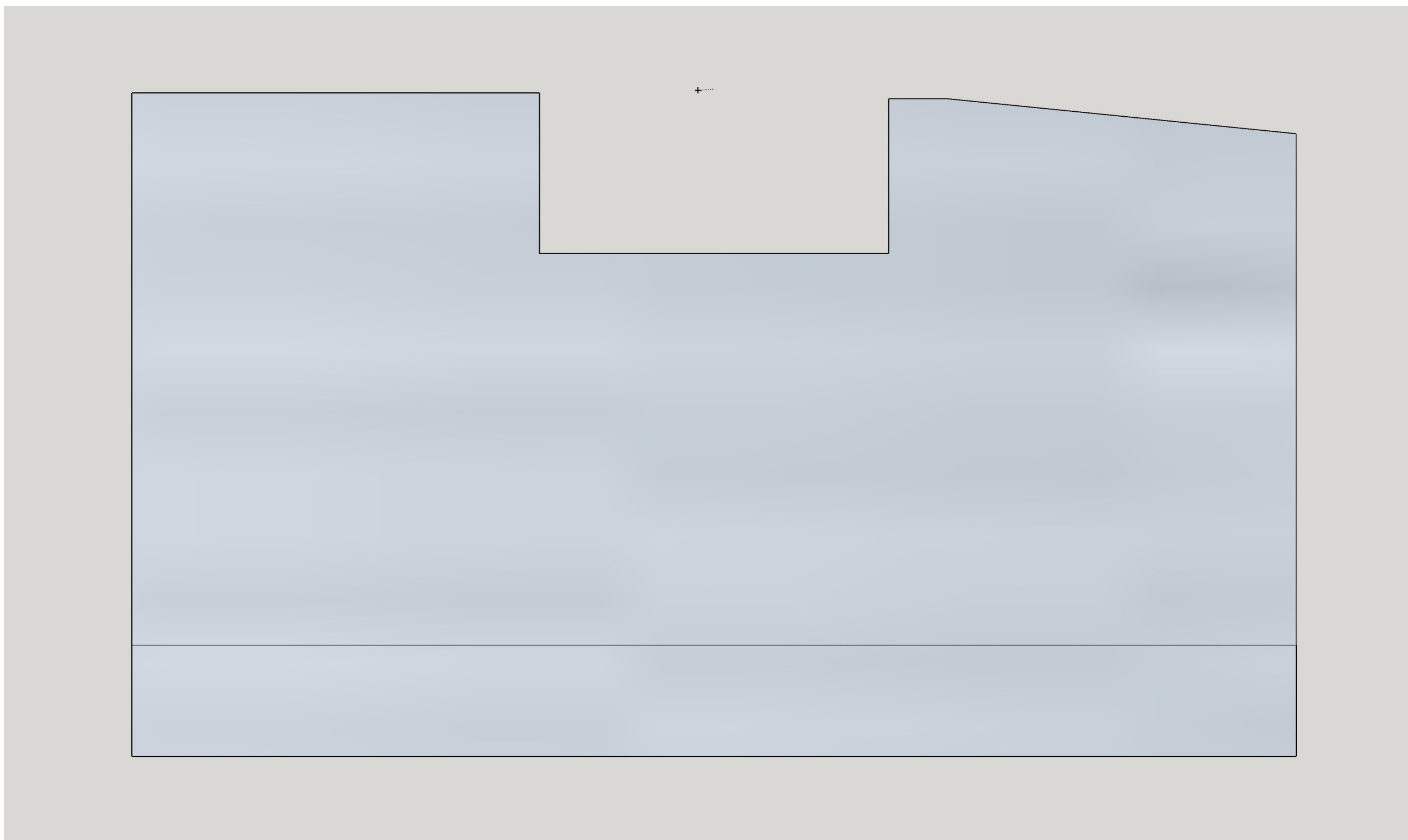


Layer 0 Module Design

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



Angular acceptance of cooling block begins at 300 mrad, outside of SVT acceptance and where rate of brems is suppressed by >6 orders of magnitude.

Layer 0 Support and DAQ

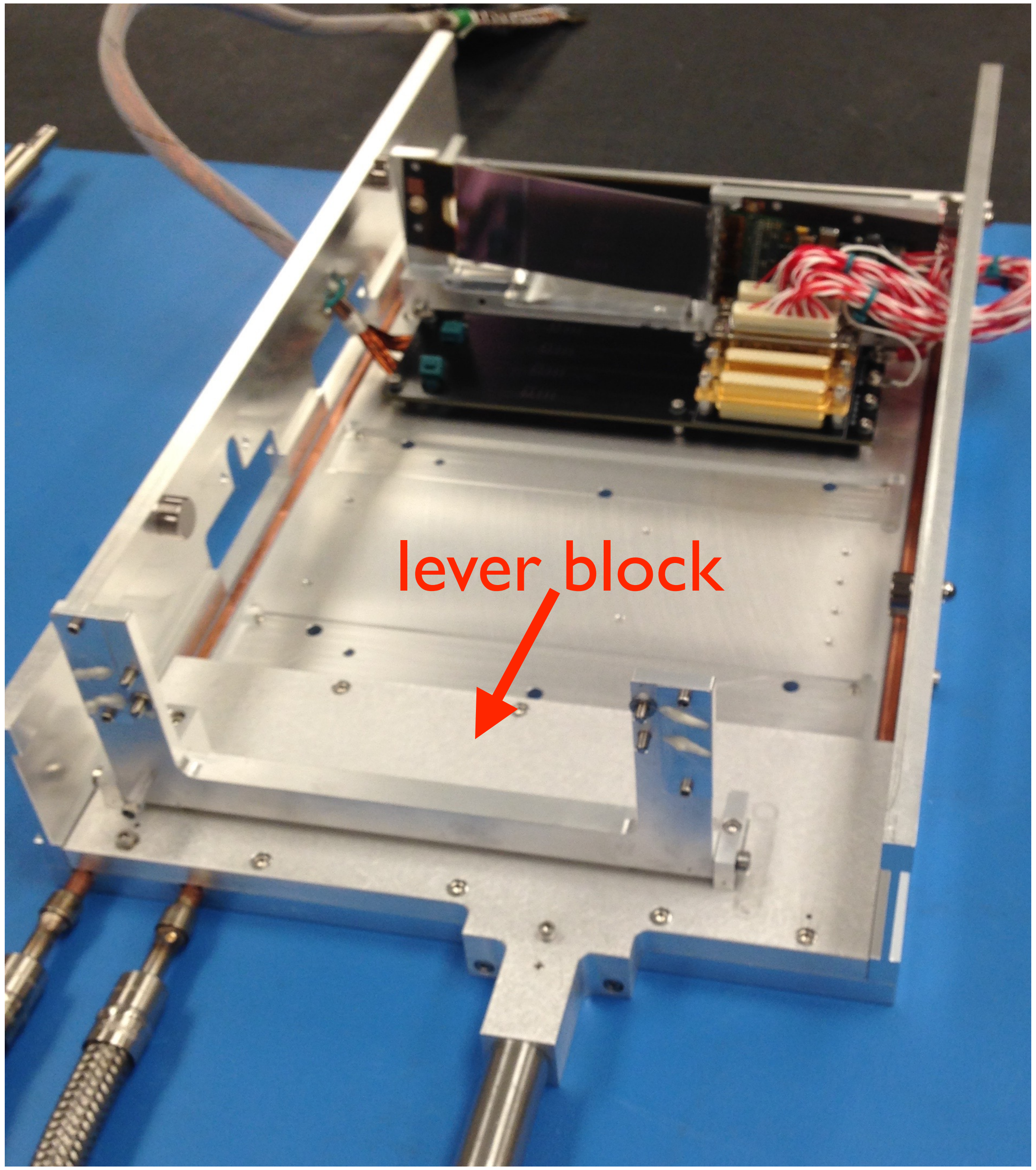
Layer 0 goes just downstream of the current SVT scan wire supports.

Current lever blocks will be replaced with new blocks 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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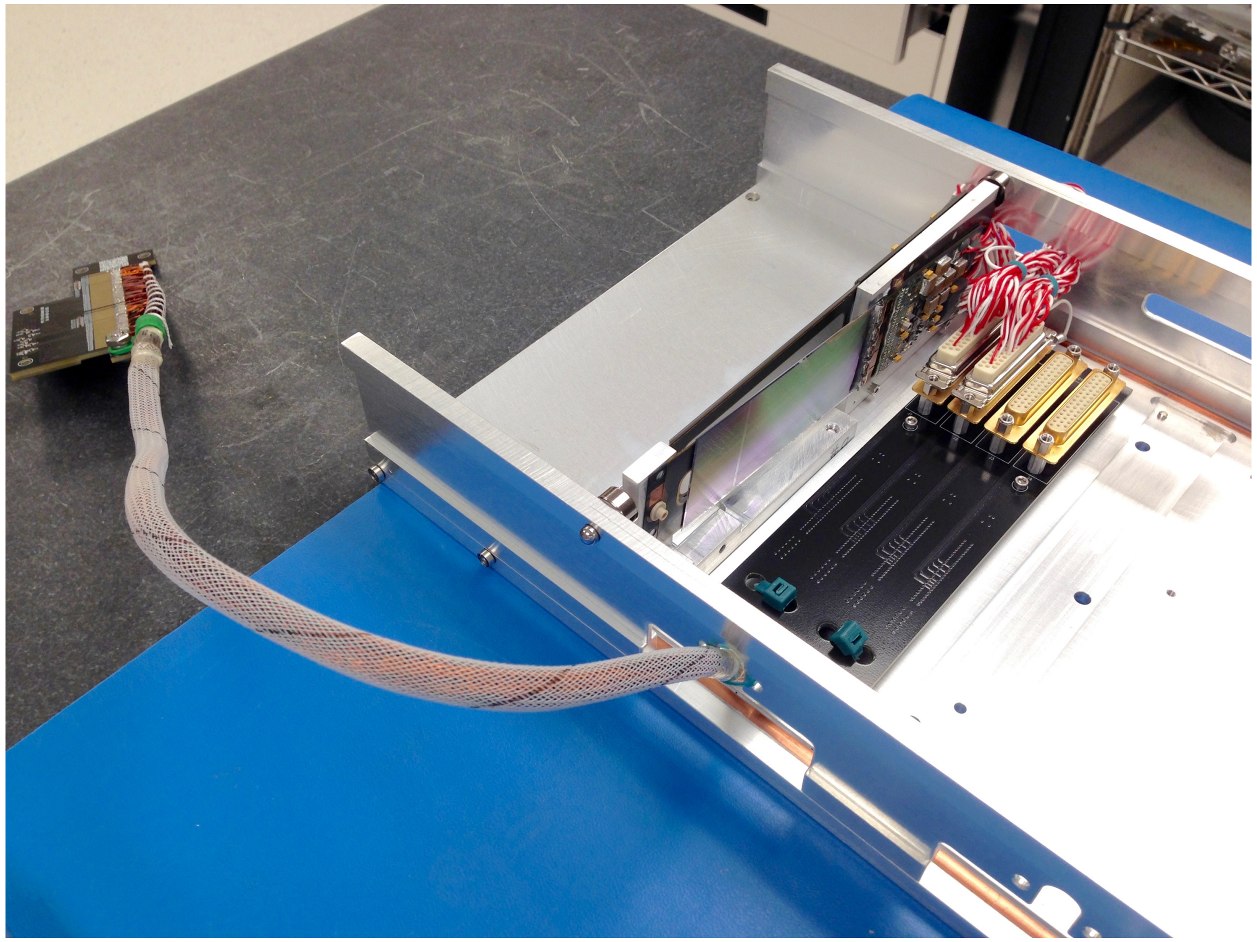

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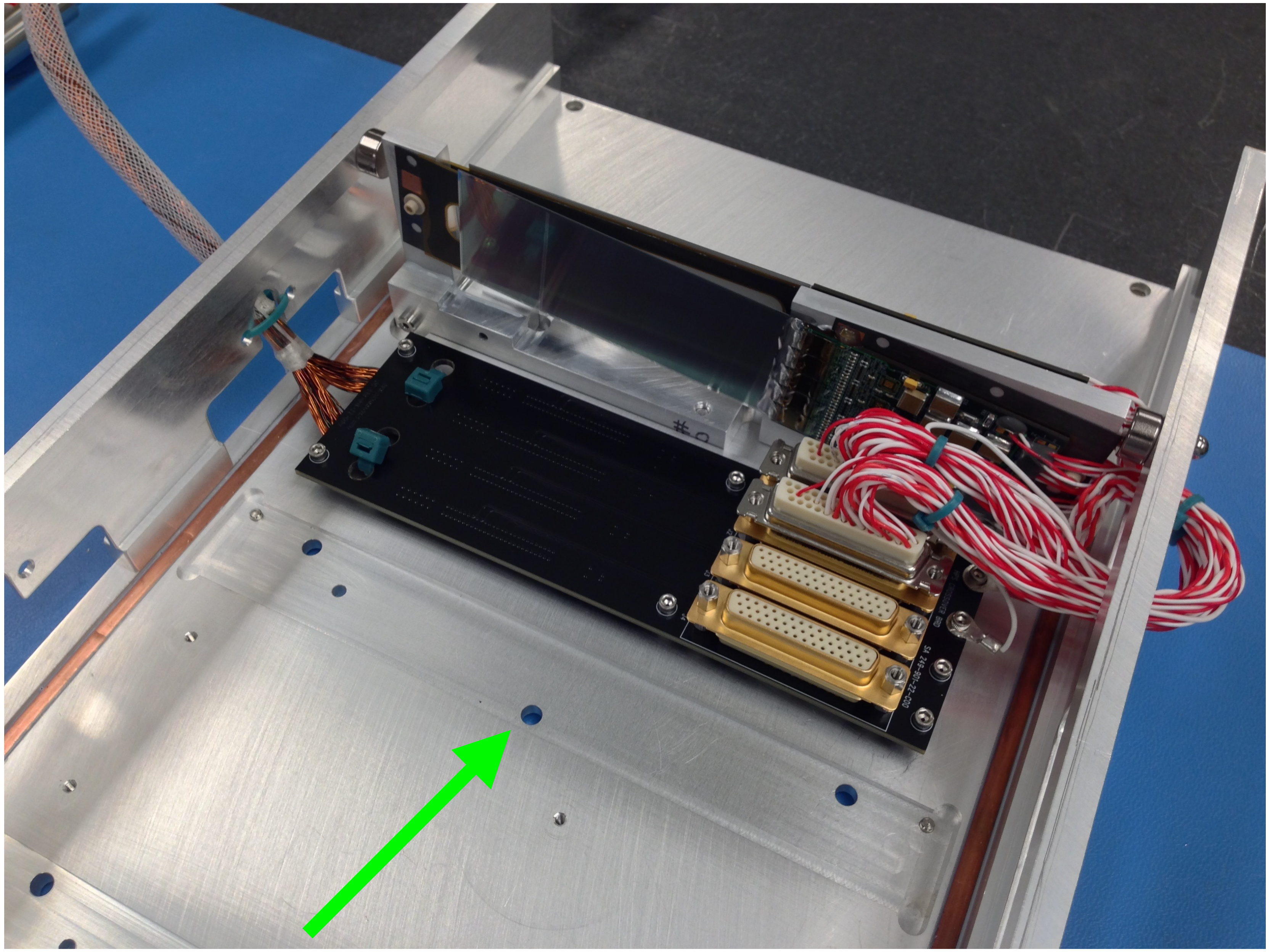
Open channels on crossover boards fully serviced by existing DAQ.

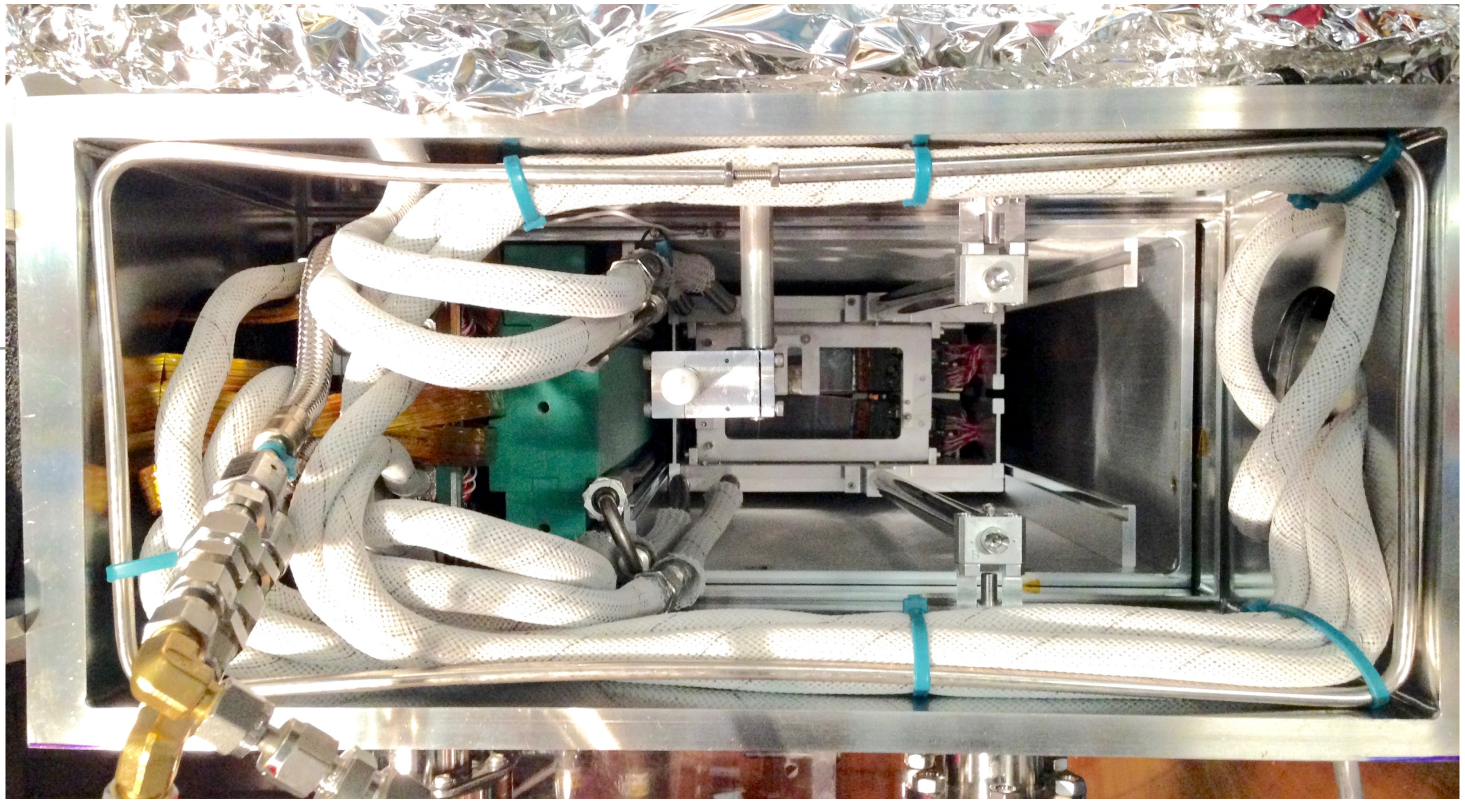
Moving Layers 2 and 3

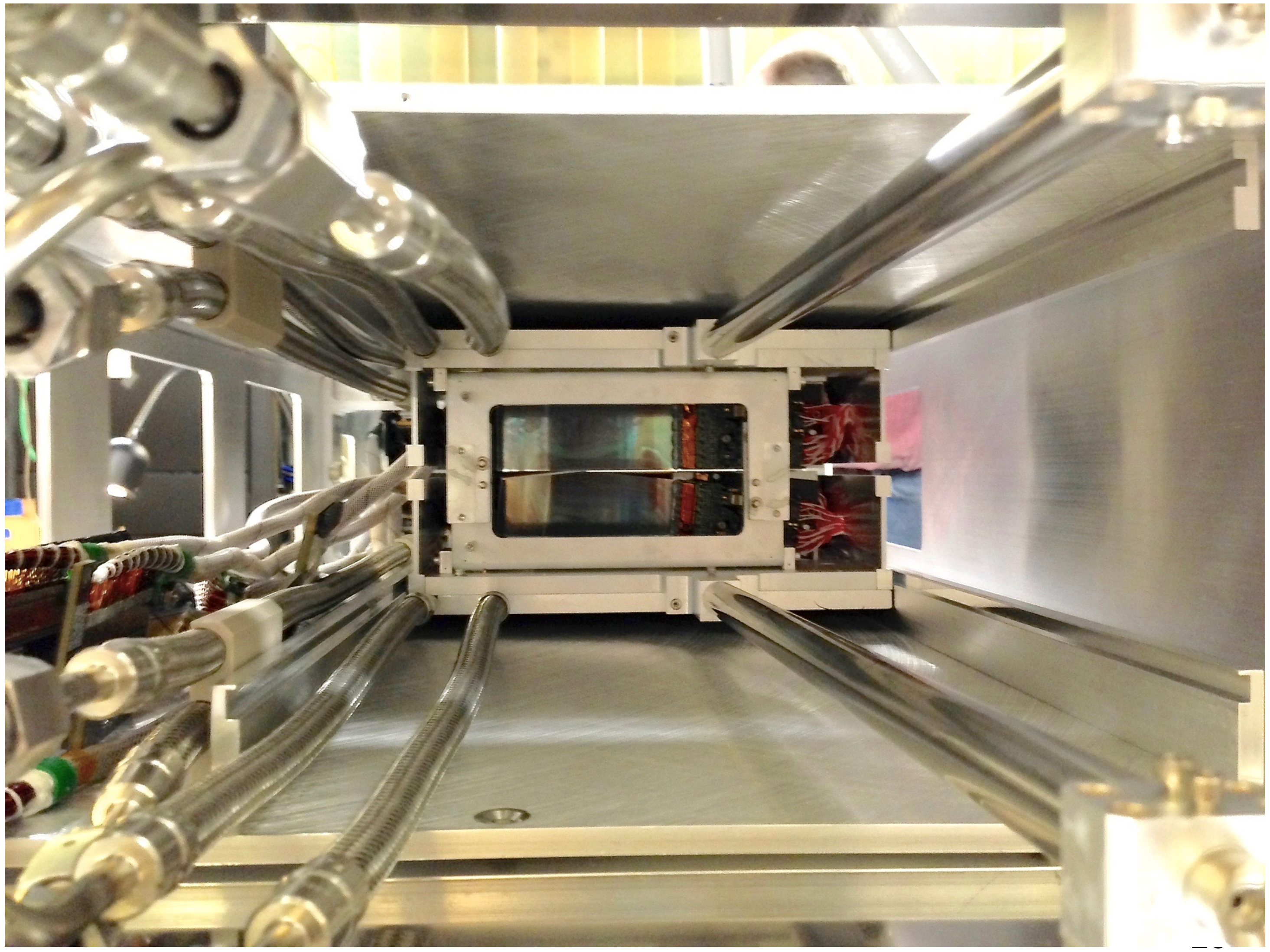
- Modules will be removed from U-channels for addition of Layer 0
- Shims can be added when modules are re-installed
- Requires only machining of standard shim stock of desired thickness with clearance holes
- Shims are thin enough that no changes to module mounting hardware are required
- We can easily decide at a very late date whether, and how much, to move L2 and L3.



Removal, Installation and Serviceability

- Layer 1-3 U-channel designed for extraction without removing entire SVT (<1 day)
- If necessary, Layer 0 could be removed or replaced in alcove.
- Will extract U-channel for shipping back to SLAC in Aug.





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Budget

New Sensor: $43K

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

New Hybrid: $74K

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

New Modules: $86K

- Labor
  - Design: $33K
  - Assembly: $34K
  - Testing: $8K
- M&S: $10K

Modifications to mechanical support (includes L2 and L3 Move): $72K

- Labor
  - Design: $33K
  - Assembly: $20K
  - Testing: $8K
- M&S: $10K

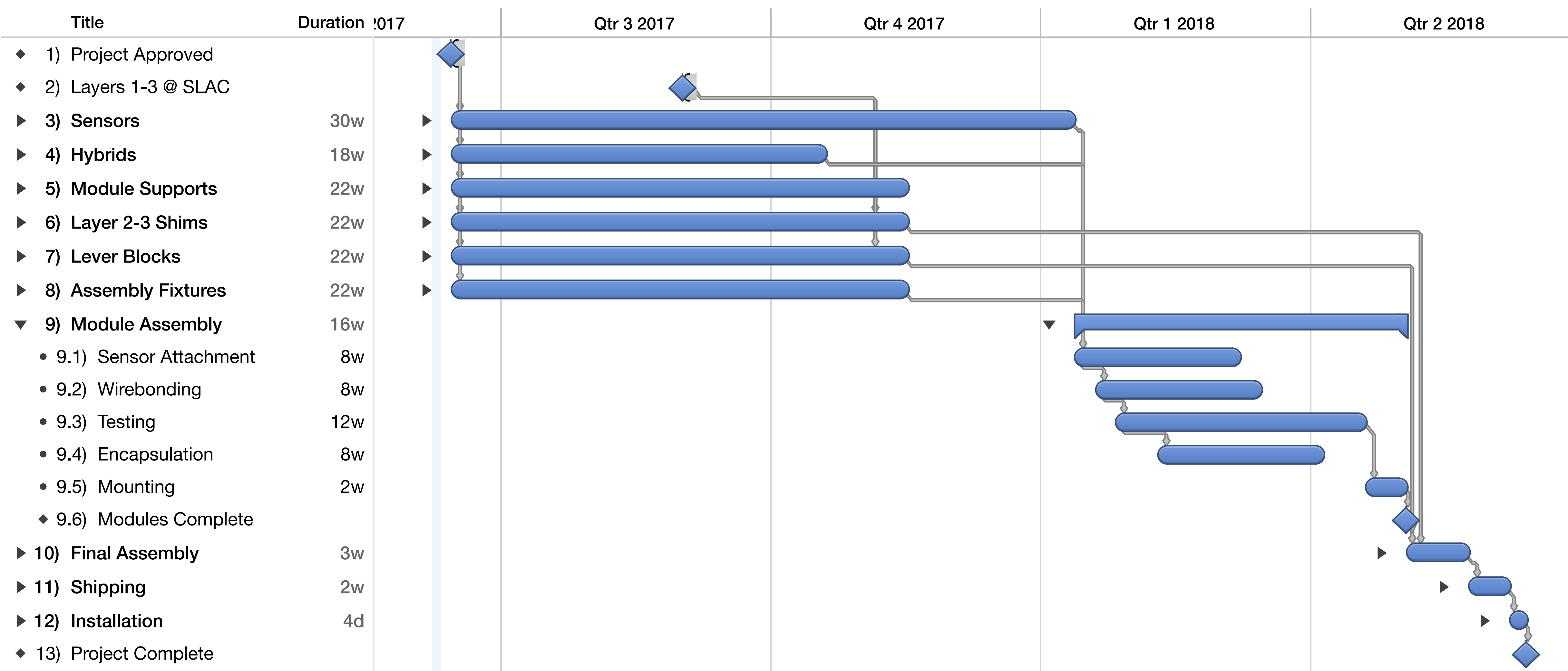
Shipping and Installation: $10K

GRAND TOTAL: $284K

	Labor	M&S	Totals
Sensors	$5000	$37500	$42500
Hybrids	$64360	$10000.00	$74360.00
Modules	$75640	$10000.00	$85640.00
U-channels	$61640	$10000.00	$71640.00
Misc	$5000	$5000.00	$10000.00
TOTALS	**$211640**	**$72500.00**	**$284140.00**

Schedule

Target completion is Summer 2018.



6/13/18

Single long lead time item, sensors (6 months), drive the schedule. Other design and assembly work lives in the shadow of sensor procurement with >25% contingency

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 and student labor 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, who designed the HPS SVT.
- Technicians available to assist with assembly.

Facilities

- L1-3 U-channels are small enough to do work in Building 84 cleanroom at SLAC.

Commissioning Plan

Entire SVT will need to be tested after installation to ensure that everything works as expected. (must be done anyway after 2 years down!!)

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 we will want to give attention to measuring beam halo with some ideas of how to identify the source and mitigate if larger than expected: not unique to Layer 0… Layer 1 has similar susceptibility.

Miscellaneous Items

Things that the upgrade Layer 0 does not change significantly:

- The materials inside the vacuum chamber
- The cooling envelope for the detector
- Any operational procedures for the detector
- Any equipment in Hall B (outside of the vacuum chamber)
- The data volume produced by the detector
- The software and techniques used to reconstruct the data

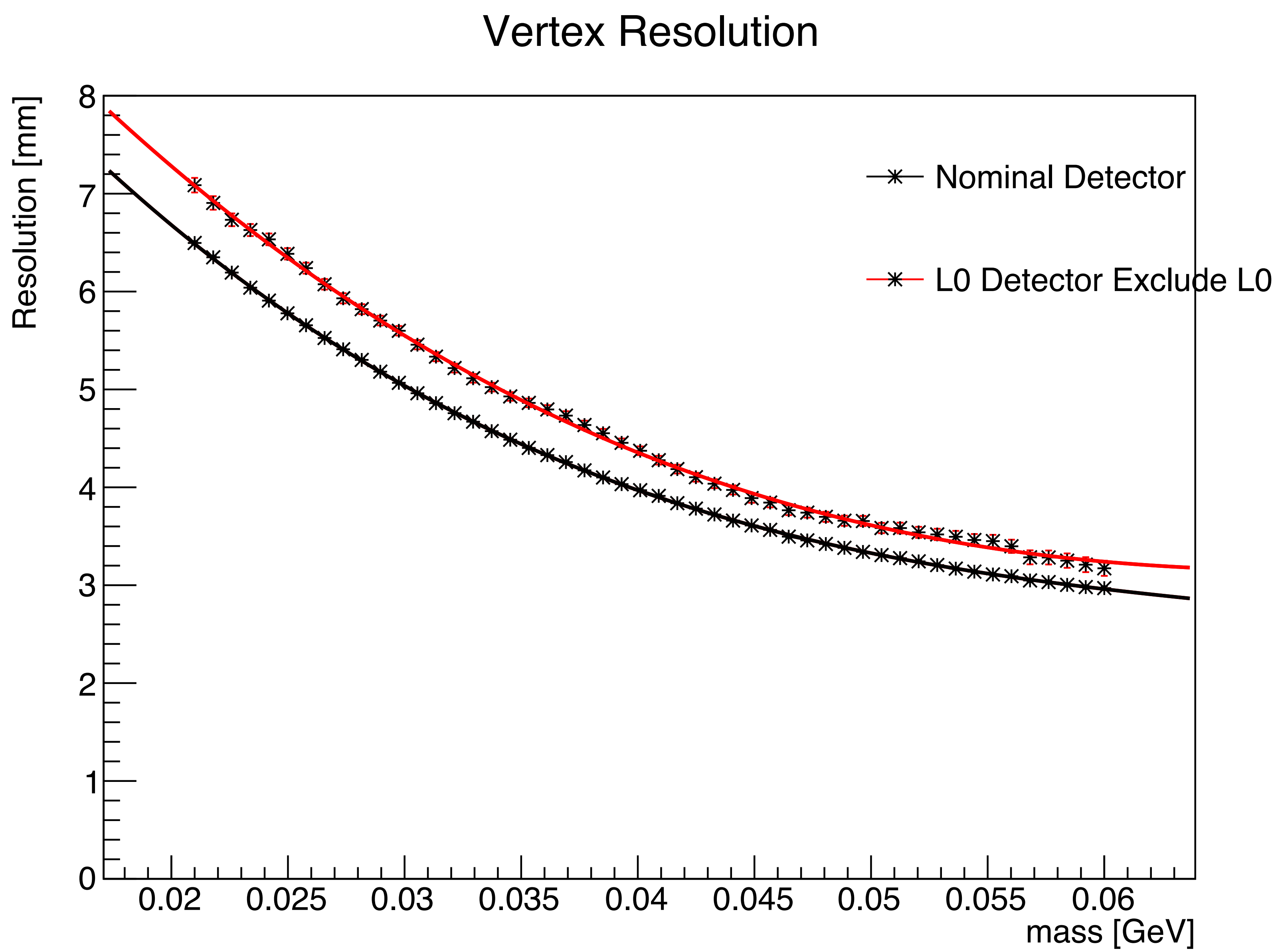
Contingency Plans

Layer 0 worst case scenario: it doesn't work

- Degradation in vertex resolution is ~5%
- Layer 0 can be removed in 1 day down.

Layer 2-3 worst case scenario: strips closest to the beam have occupancies high enough to create rare pattern recognition failures

- Those strips could be ignored in analyzing the data



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.
- Project is ready to proceed to final design and construction phase. Expect release of funds at SLAC to begin in next 2 weeks.

An Upgrade for the HPS Silicon Vertex Tracker

M. Diamond, N. Graf, M. Graham, J. Jaros, T. Maruyama, J. McCormick, O. Moreno, T. Nelson*, M. Solt
SLAC National Accelerator Laboratory, Menlo Park, CA 94025

V. Fadeyev, R. Johnson, M. Testa
University of California, Santa Cruz, CA 95064

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University of New Hampshire, Department of Physics, Durham, NH 03824

(Dated: June 10, 2017)

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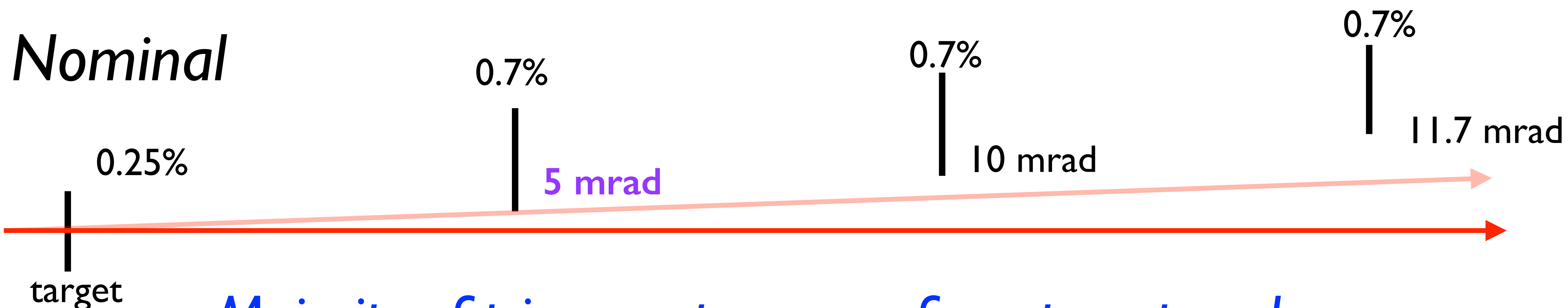
Contents

SVT proposal document on Wiki

Extra Slides

Material Distribution: Upgrade vs. Nominal

Nominal



Majority of trigger rate comes from target, and…

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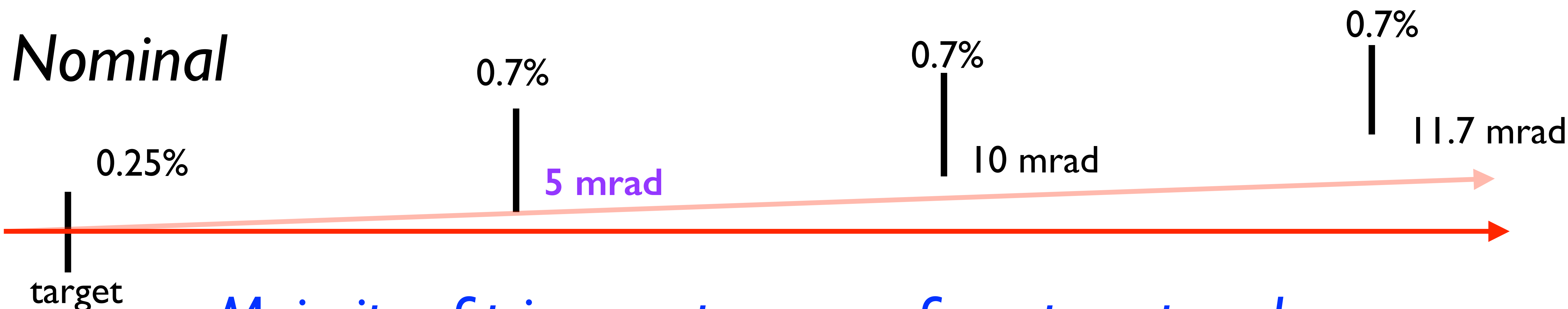

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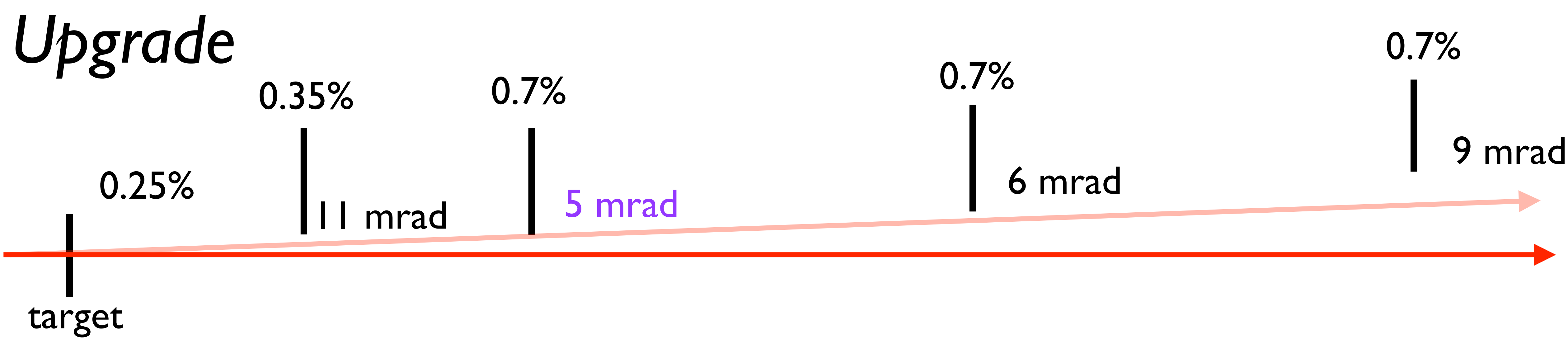

*upgrade does **not** add material at smaller scattering angles.*