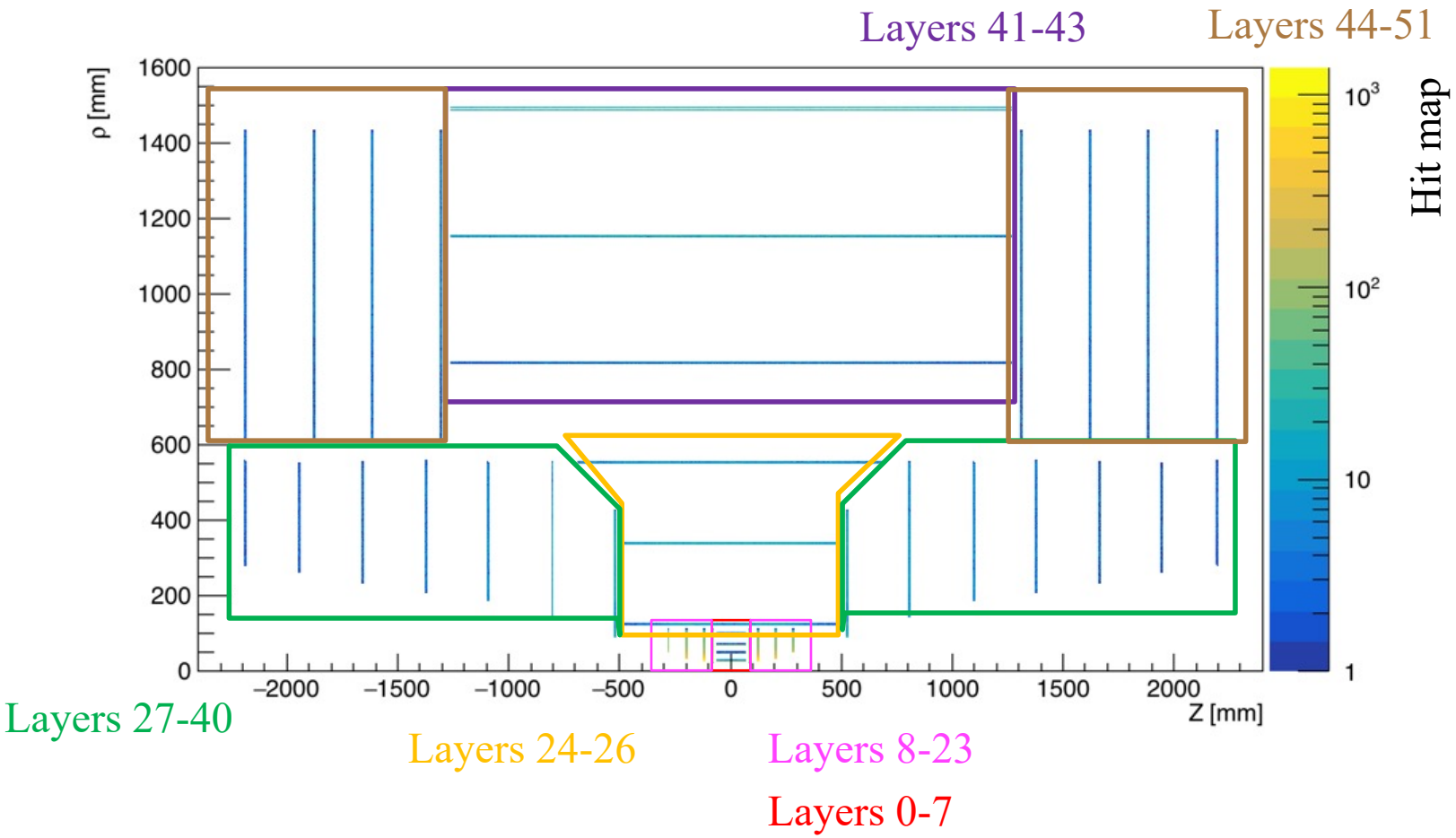
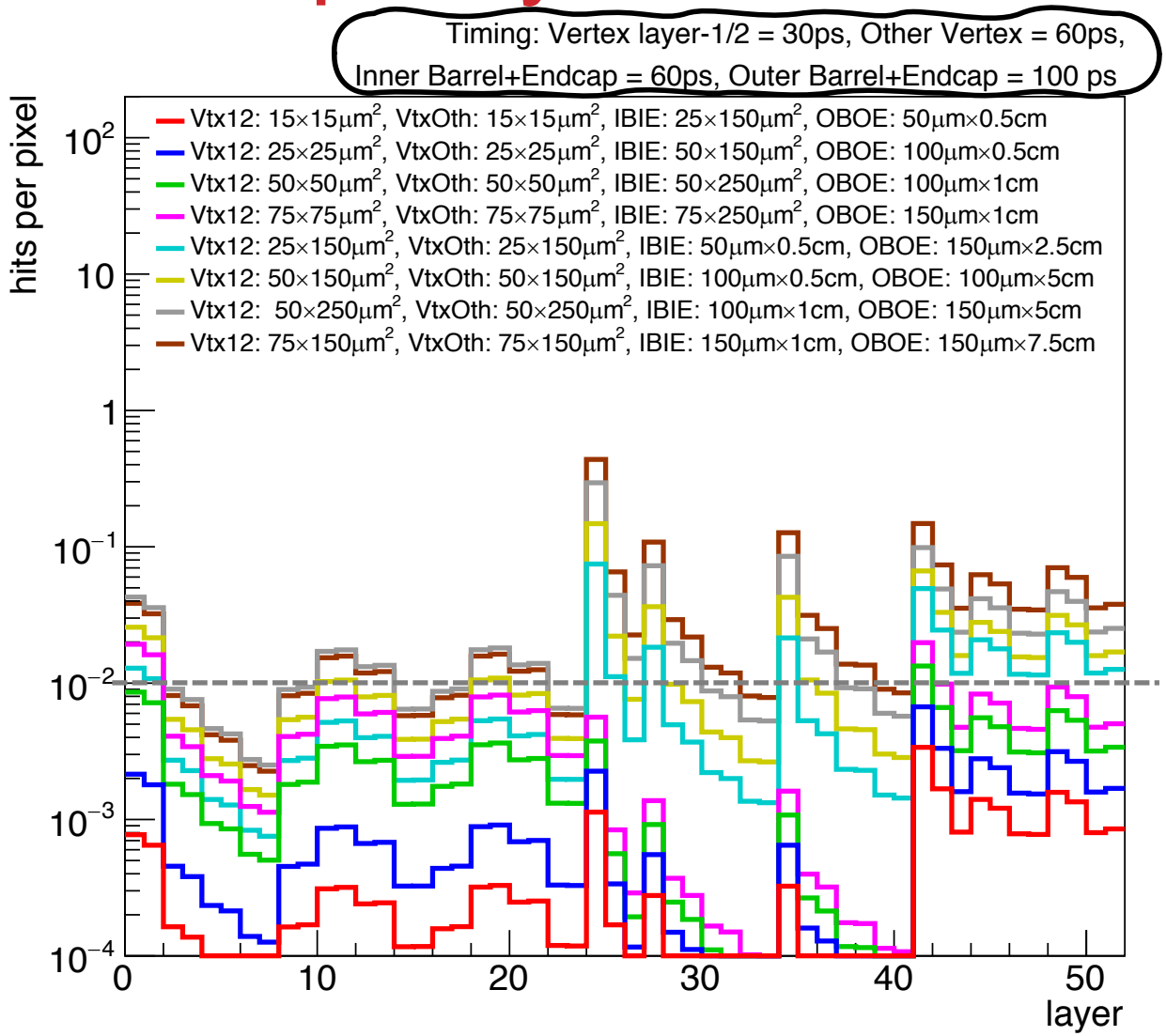
Study on Tracker Occupancy – Update after Losing upper Timing Cut

Hannsjörg Weber (Fermilab)

Reminder: muon collider tracker labeling



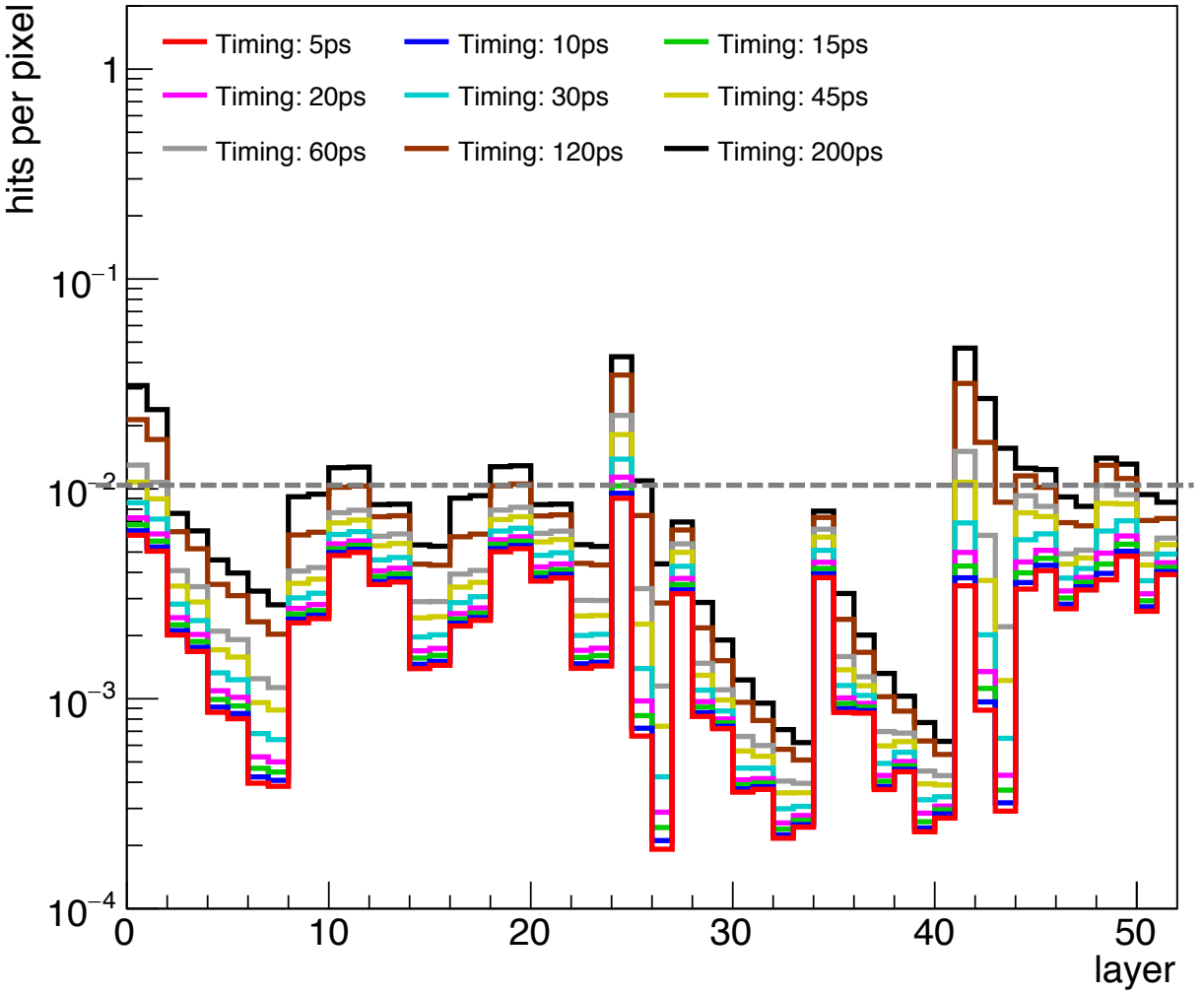
Reminder of original results: Pixel occupancy with fixed timing



- We find that we need:
  - Small square pixel in innermost layers.
  - Macropixels O(50 μm × 1 mm) for the inner tracker.
  - Short strips O(100 μm × 1 cm) for the outer tracker.

Reminder of original results: Pixel occupancy with fixed pixel size

Position: Vertex = 50×50μm^2/75×75μm^2, Inner: 75μm×1mm, Outer: 100μm×2cm



- If we can afford small pixels/strips, most of the detector can use "modest" timing resolution if ~60ps.
- For innermost vertex/inner barrel layer, we will benefit for better timing of 20-30ps.
- However, as all hits shown here are unwanted hits, a very good timing would be very beneficial.

Current tracker configuration for muon collider physics studies

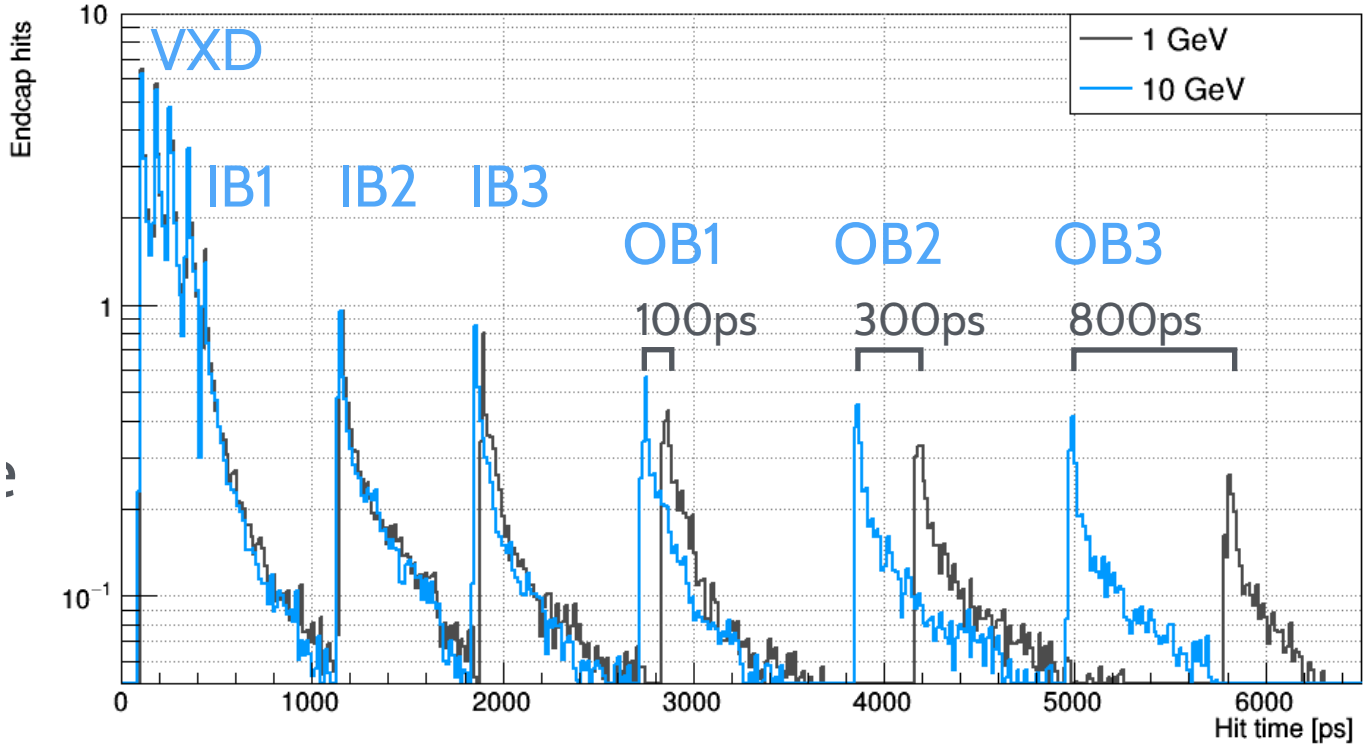
- Based on these and other studies, we fixed the tracker configuration for the snowmass physics studies. For more details, see this presentation by Massimo Casarsa.

		cell size	sensor thickness	time resolution	spatial resolution	number of cells
VXD	B	25 μm × 25 μm pixels	50 μm	30 ps	5 μm × 5 μm	729M
	E	25 μm × 25 μm pixels	50 μm	30 ps	5 μm × 5 μm	462M
IT	B	50 μm × 1 mm macropixels	100 μm	60 ps	7 μm × 90 μm	164M
	E	50 μm × 1 mm macropixels	100 μm	60 ps	7 μm × 90 μm	127M
OT	B	50 μm × 10 mm microstrips	100 μm	60 ps	7 μm × 90 μm	117M
	E	50 μm × 10 mm microstrips	100 μm	60 ps	7 μm × 90 μm	56M

Sum: 1.6B

New development: upper timing cut

- As shown now several times, slow particles arrive much later at pixel layer especially for the outer tracker.



Nazar Bartosik

- I looked into this.

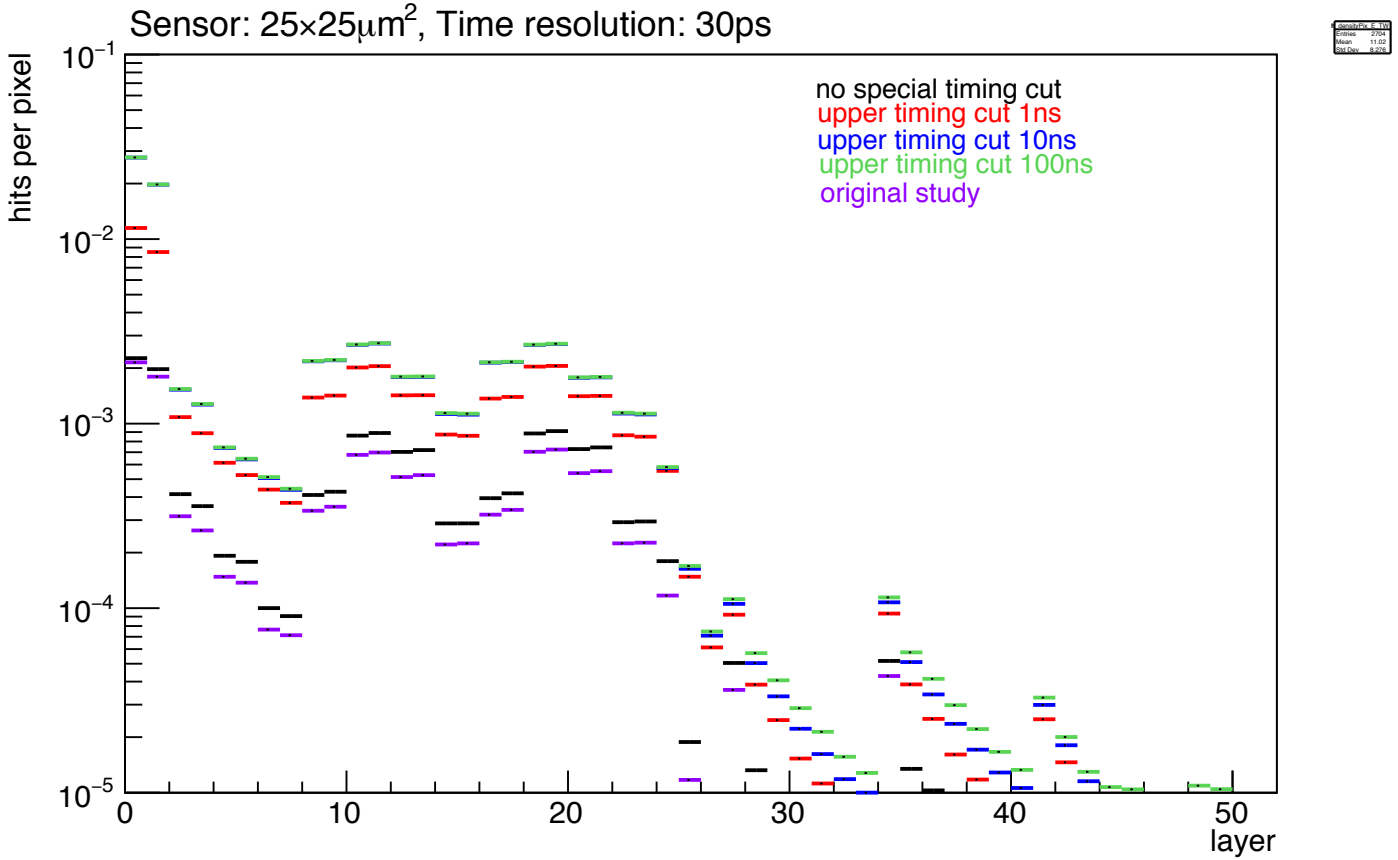
New development: upper timing cut

- As shown now several times, slow particles arrive much later at pixel layer especially for the outer tracker.

- Take new ntuples I obtained from Nazar (thank you), reran my study first, i.e. take spatial and time resolution as before, cut on 3σ for time resolution.
- Then open up upper timing cut, place it at 1, 10, or 100 ns.
- Also add on plot the number I got from the previous ntuples from Massimo (which used reco hits not sim hits) – just for comparison.

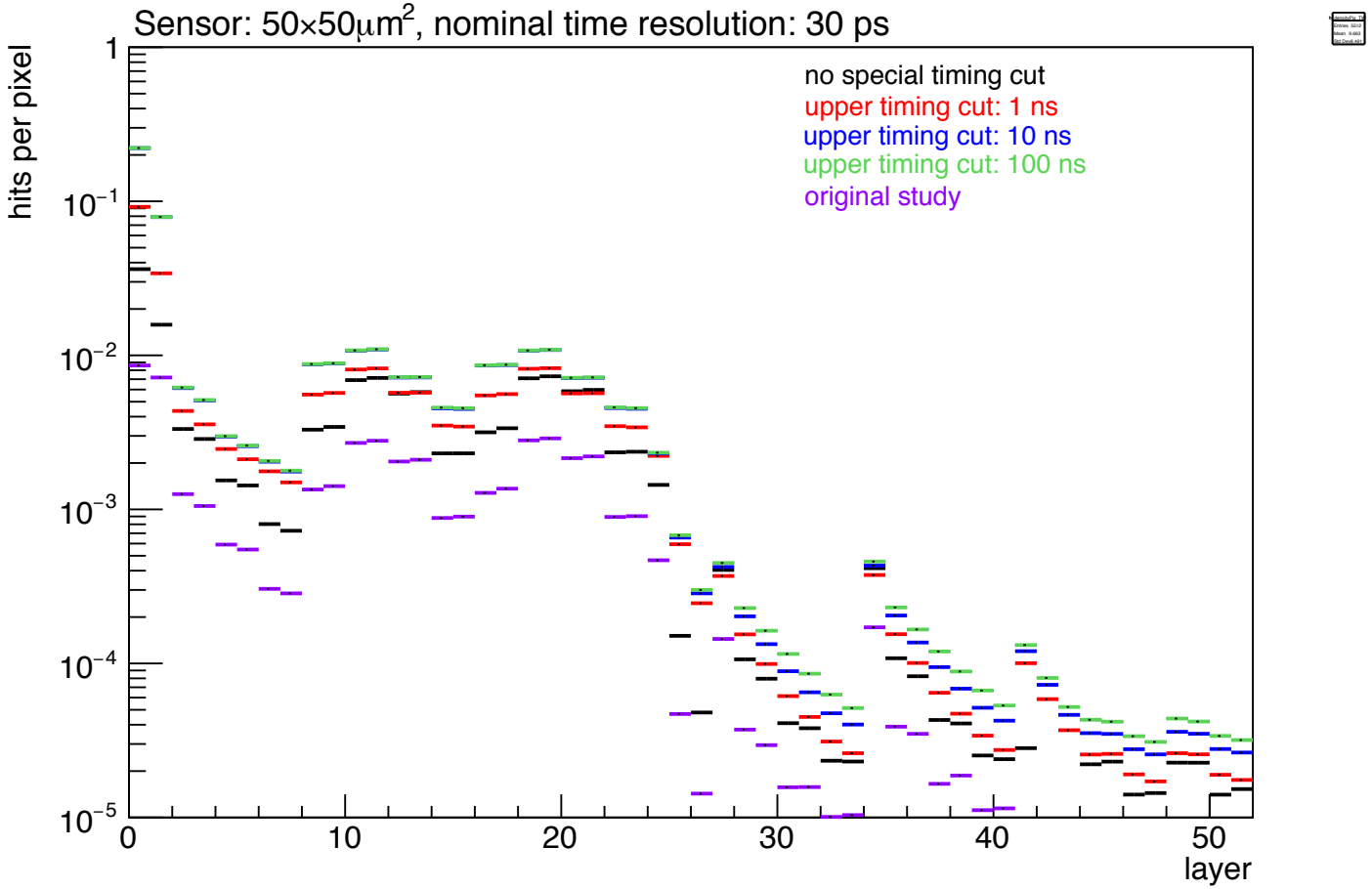
- See impact on per pixel occupancy – as reminder: goal is ≤1-3%.

Occupancy for VTX dimensions/timing



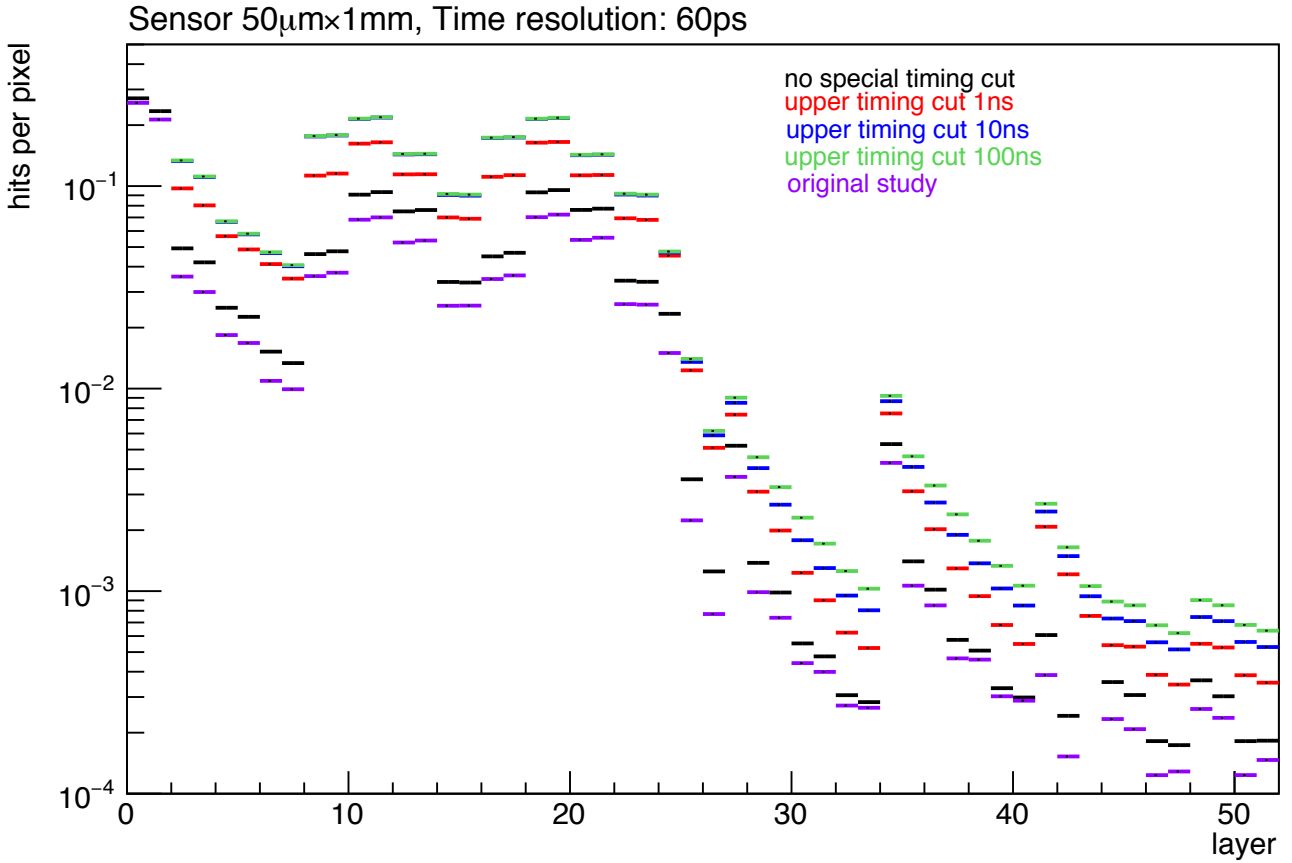
- For 25×25μm² and σ_t = 30ps, opening up upper cut would work, especially for all but two innermost layers.

Occupancy for VTX dimensions/timing



- Simone suggested to look at $50\times50\mu m^2$ and $\sigma_t = 30ps$, because digitization might show clusters of >1pixels per hit. Now two innermost layers cannot live with opened cut.

Occupancy for IT dimensions/timing

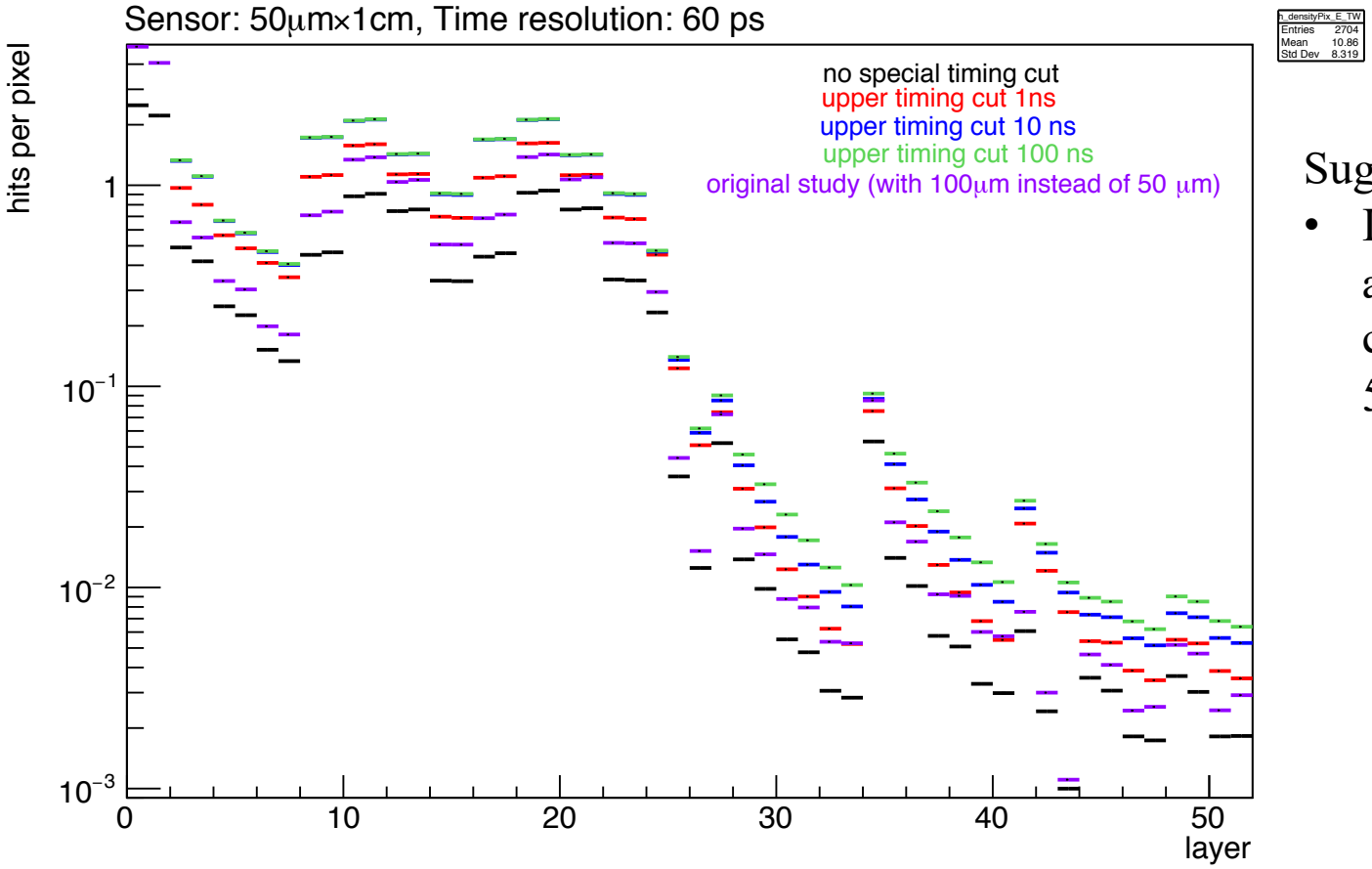


Suggestion:

- Change IT dimensions to asymmetric pixels: $50\times200\mu m^2$
- If it is acceptable, could do this only for the barrel.

- IT is layers 24-27: For the IT barrel, opening cut to 1ns would lead to 4-8% occupancy for barrel. What to do?

Occupancy for OT dimensions/timing



Suggestion:

- If we don't feel good about it, we could change OT barrel to 50μm×5mm.

- IT is layers 28-51: For the *T barrel, opening cut to 10ns would lead to 3% occupancy for barrel. Is this acceptable?

Summary

- I showed a simple study, studying how many hits can be reconstructed depending on the pixel size and pixel time resolution.
- Yet it was shown, that slow particles arrive much later for the outer layers, need to account for that.
  - Extended study to take that into account.
- Conclusions:
  - For vertex tracker, besides two innermost layers, opening up upper timing cut should be fine. Since those two layers are closest to interaction point, I don't think any action is needed.
  - For inner tracker, the barrel would suffer if opening up upper timing cut to 1 ns. Probably need smaller pixel size, e.g. $50\times200\mu m^2$ should work. Does this sound reasonable? Should it be done only for the barrel or all of the inner tracker.
  - For outer tracker, it looks generally fine, but innermost barrel layer is borderline at 3% occupancy. So maybe also reduce pixel size for outer barrel?