HMS Calorimeter "Wiggles" Observation in Normalized Track Energy vs. X-track

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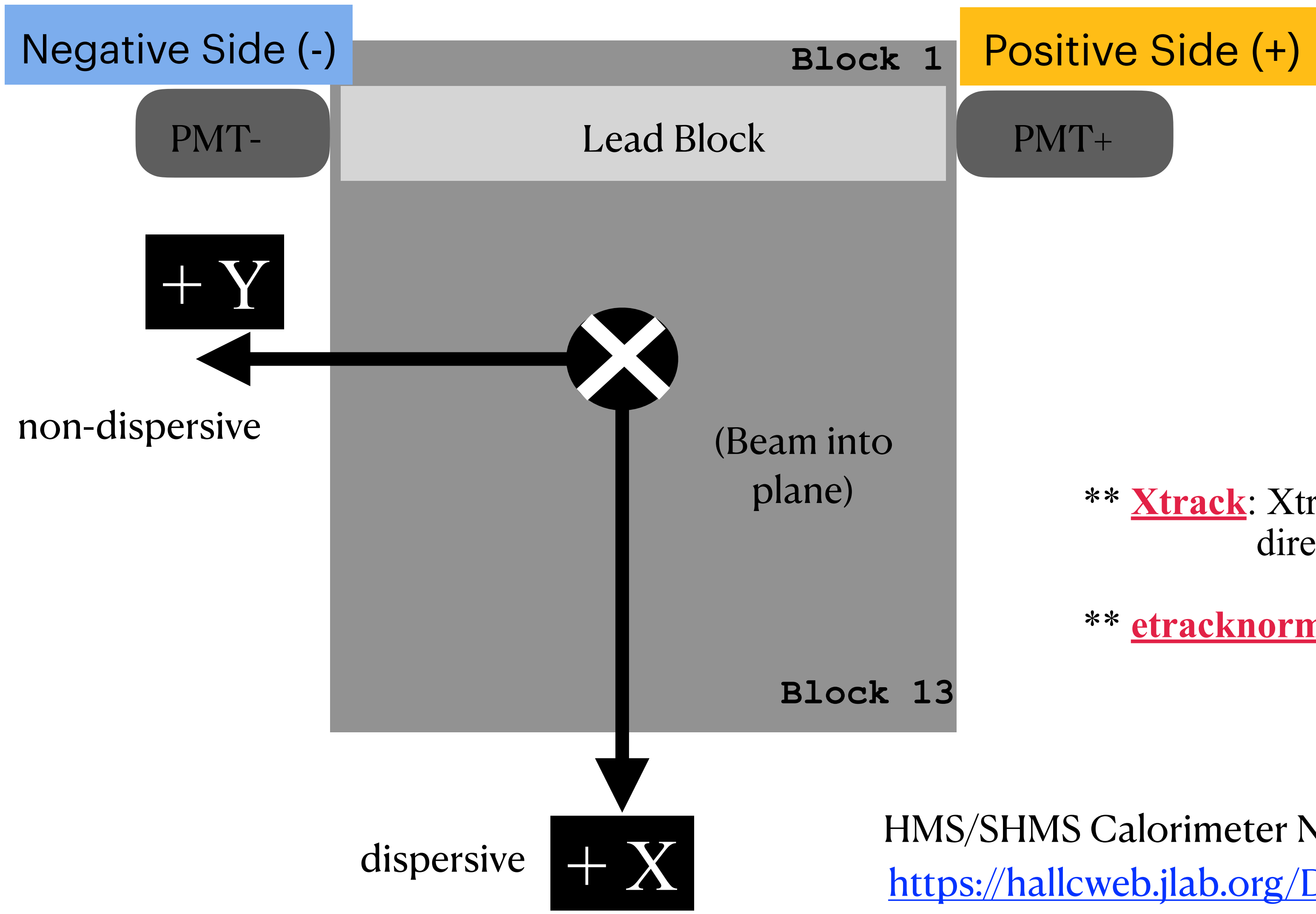
HMS Calorimeter Coordinate Definition



NOTE: **The sign of the HMS Calorimeter PMTs is actually opposite to that of the Hut horizontal coordinates.**

First 2 layers have PMTs on both Sides
Last 2 layers have PMTs ONLY on Positive Side(+)

DEFINITIONS:

** **Xtrack**: Xtrack is the X position [cm] (vertical, in dispersive direction) of the track which matched the layer cluster

** **etracknorm**: Calorimeter track energy normalized by the track momentum (Etrack / Ptrack)

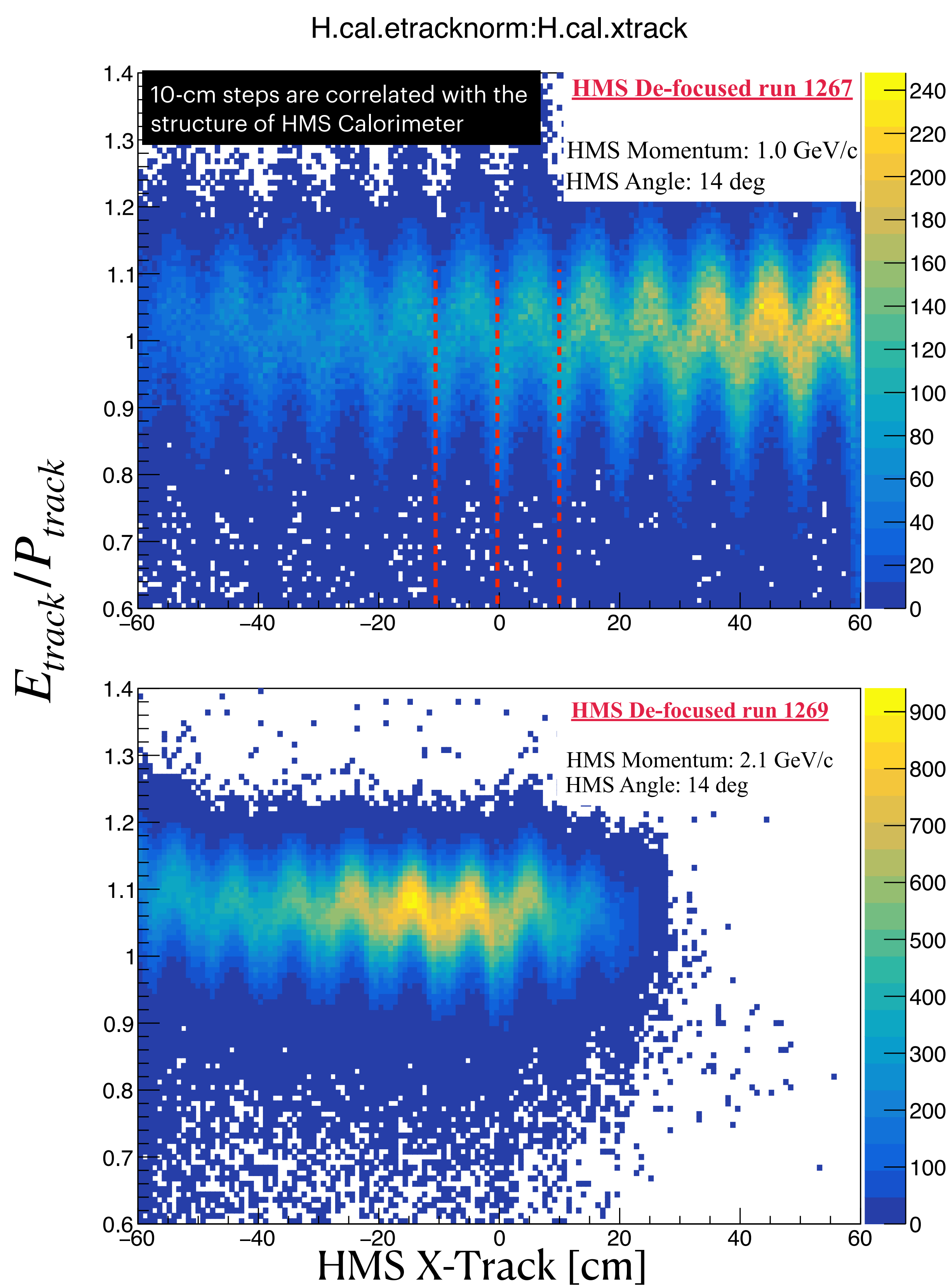
HMS/SHMS Calorimeter NIM Article Reference:
https://hallcweb.jlab.org/DocDB/0008/000809/001/NIMarticleOverview.pdf

PROBLEM: The 2D histogram of “etracknorm vs. xtrack” exhibits a characteristic “wiggle” along the xtrack coordinates. We are trying to determine what could be the cause and whether this could be a potential problem.

This observation has been made in HMS de-focused runs 1267 and 1269, were the spectrometer was stationed at 14 deg, and the central momentum was set to 1 GeV and 2.1 GeV, respectively.
In the next slide we compare the “wiggly” structure for the two runs.

“This (“wiggles”) is an issue noted several years ago by the Yerevan group, who did not see this in the 6 GeV era.”

HMS Defocused Tune (Q2 Magnet +25%)



Email snippet from Vardan T. (July 04, 2018):

thanks for pointing to the X-dependence. I also noticed that some time ago. It is also seen in the delta dependence, at high delta-s. The 10 cm step and positions are correlated with the structure of the HMS calorimeter. I would naively assume tracks passing through or close to the cracks between the lead glass blocks. But the problem is that I don't remember that kind of effect in the simulations and in the 6 GeV data. More studies are needed to pin down the cause of that.

Email snippet from Hamlet M. (March 29, 2021):

Yes, this phenomenon has been observed before, but in a slightly weaker way. This is not energy or shower leak, but just lost of collected light. As you know we have "y-coordinate" correction for the calorimeter signal in the analysis code, but not any correction for x dependence. We proposed this correction would be very small.

If this wiggling comes bigger with time then probably surface reflectivity of the modules have been changed. (For example there no any air gap between Mylar and lead-glass or reflection quality of wrapping material changed).

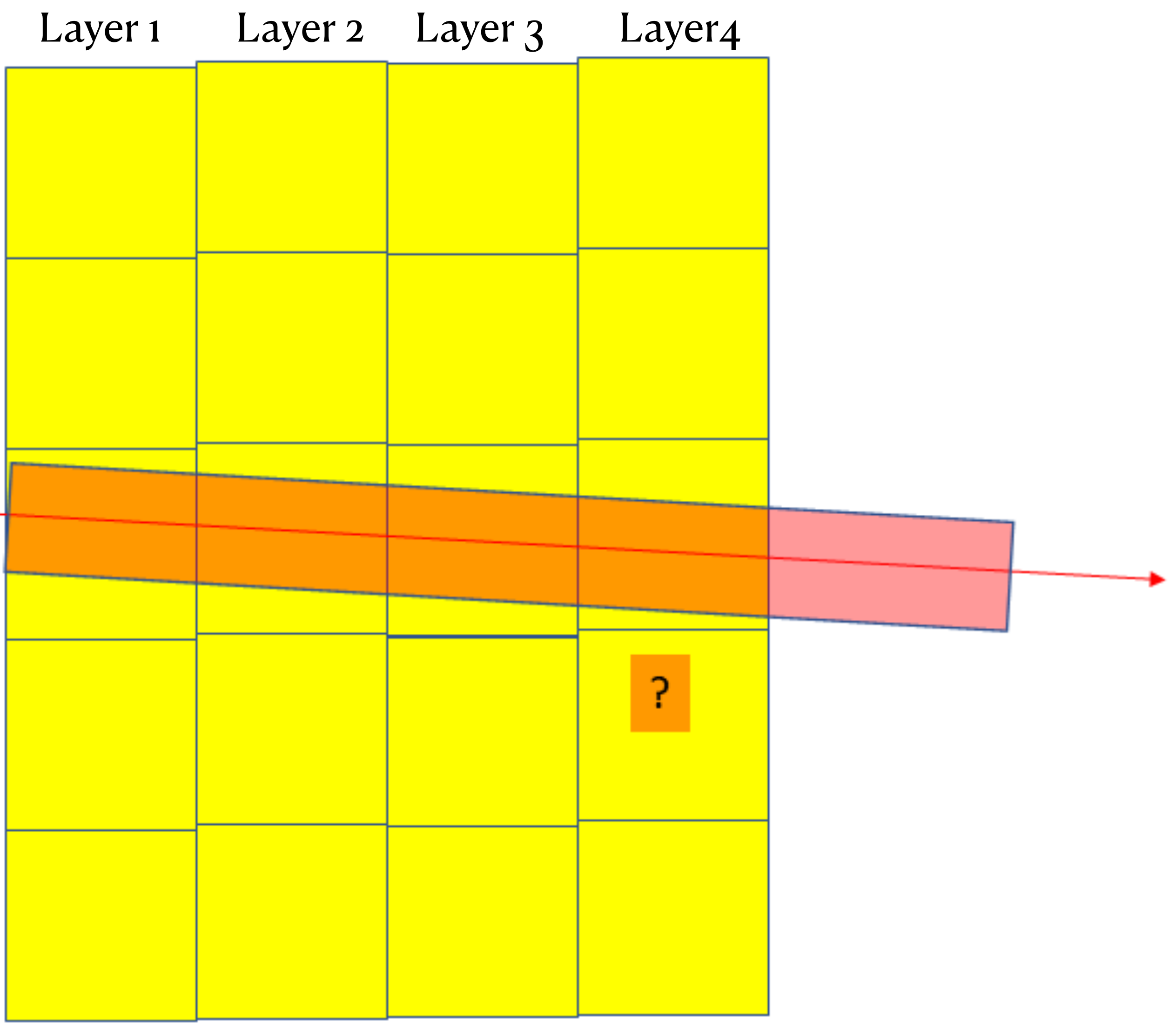
☑ NOTE: The HMS Calorimeter fADC thresholds / block for these runs were determined to be 10 MeV (from plots of pulse amplitudes for each block)

Hypothesis to Explain Calorimeter Structure

Stack is tilted 5deg wrt central ray at P0. (I tilted the ray.)
The Moliere radius (90% of energy) is shown in red.
Most of the energy is deposited in the 1st 3 layers.
The shower energy is only 1 GeV which has two implications:

1) shower fluctuations are relatively large, and
2) the FADC threshold of very roughly 50 MeV is a BIG quantum.

SIDE VIEW OF HMS CALORIMETER



Track hits center of block in 1st layer:
yields 4 relatively large energy deposits in 4 blocks.
(There could be a small amount of energy below FADC threshold in the adjacent block in layer 4 which I marked with "?", but probably only 0-1% .)

<u>Moliere radius:</u> By definition, it is the radius of a cylinder containing on average 90% of the shower's energy deposition (Wikipedia)

Hypothesis to Explain Calorimeter Structure

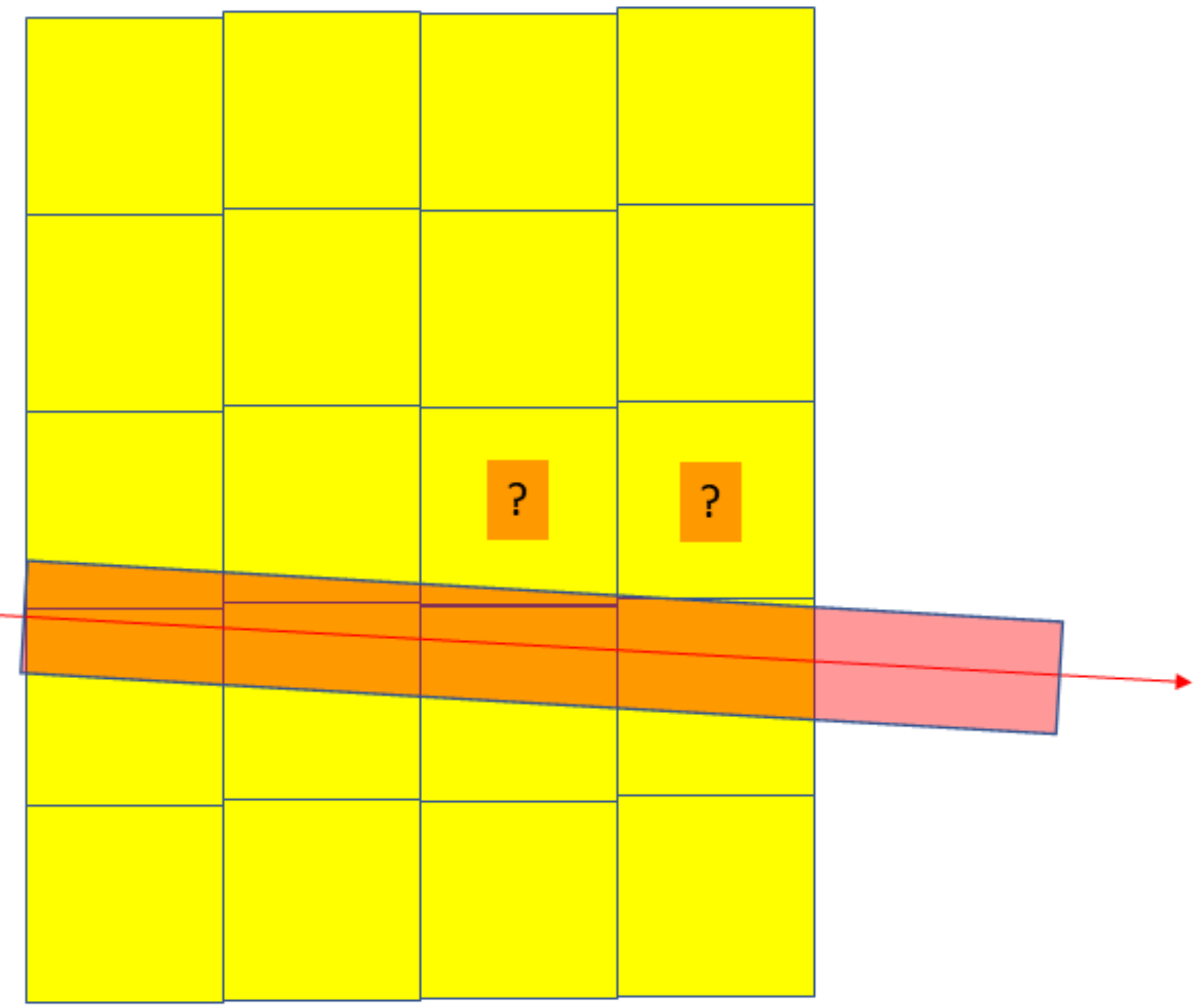
Track hits boundary between blocks on the 1st layer:
yields 8 relatively small energy deposits in 8 blocks.
One could easily end up with 30+20 MeV in the blocks marked with "?" which is below both FADC thresholds and gets ignored.

I think this could explain several observations:

1) In a 1 GeV shower, ignoring 50 MeV immediately puts the event in a tail 5% below the nominal E/p = 1.

2) The Yerevan group didn't see this issue with the 6 GeV electronics (ie, Fastbus ADCs with pedestal suppression at 3x the noise limit.)

3) Vardan's simulation in the NIM article includes the dead layers, and he saw no such obvious "dead layer" effect. However, his simulations stopped after counting pe's produced in the pmt and did not explore digitization blind spots like an FADC threshold.



It's a testable hypothesis:
the wiggles in E/p vs Xcal will be 4x smaller at 4 GeV/c.
(We may have dropped the FADC thresholds in the calorimeter later. I know we talked about it.)

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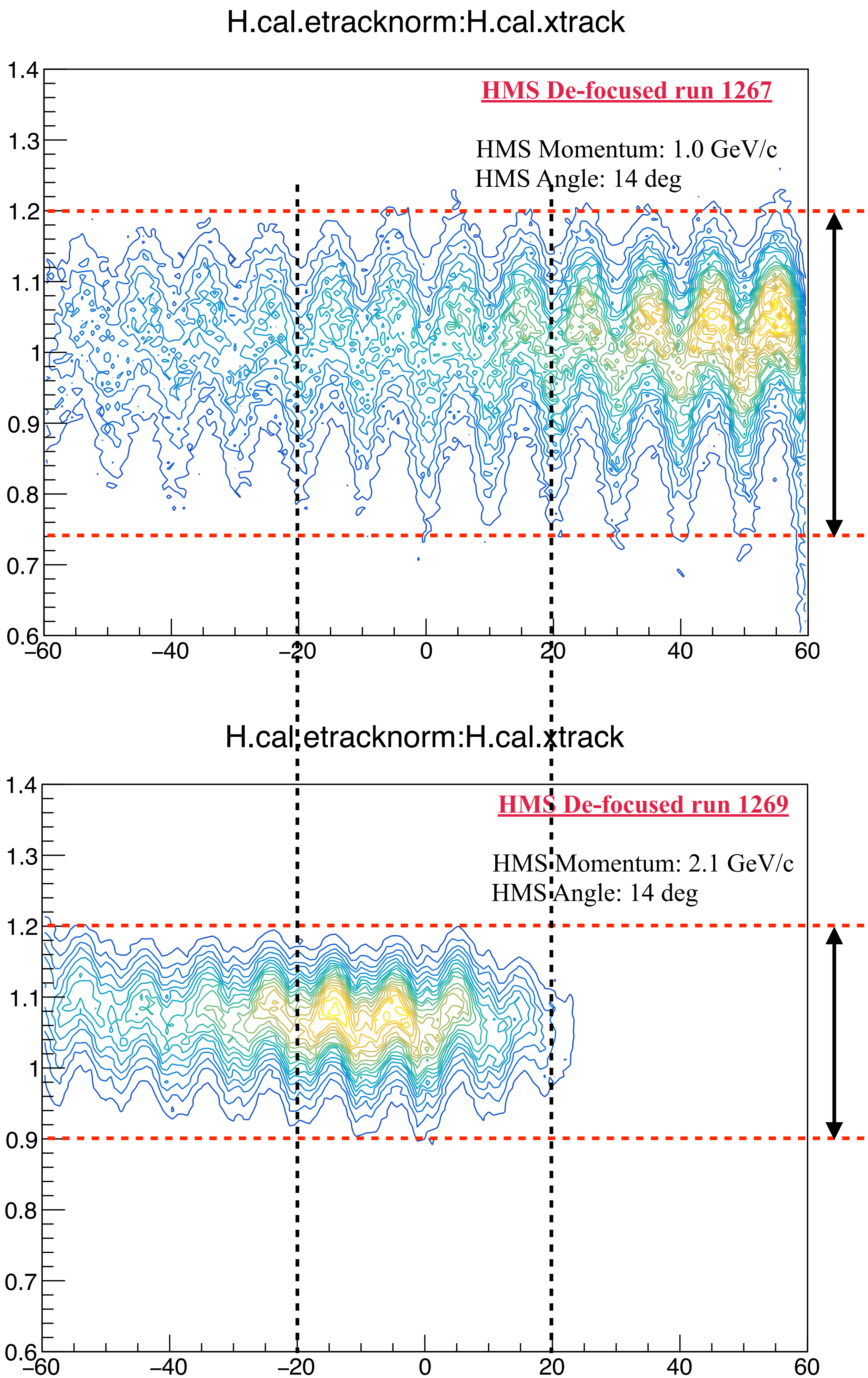
** To test this hypothesis, we looked at the two defocused runs shown in the previous slide. As can be seen from those slides, the wiggles are indeed smaller for a larger momentum. In this case, we expect the wiggles to be ~2.1x smaller at 2.1 GeV (run 1269) as compared to 1.0 GeV (run 1267). To check this, I plotted the contour of the 2D histograms, which enhance the minima/maxima regions and can be more accurately measured. See NEXT SLIDE



$\Delta_{p=1.0} = 1.2 - 0.75 = 0.45$

$$R_{ratio} = \frac{\Delta_{p=1.0}}{\Delta_{p=2.1}} = 0.45/0.3 = 1.5$$

Not the factor of 2 we naively expected, but in the right direction. The shower statistics are very different at 2.1 GeV and 1 GeV, so a simulation with FADC thresholds would be needed.

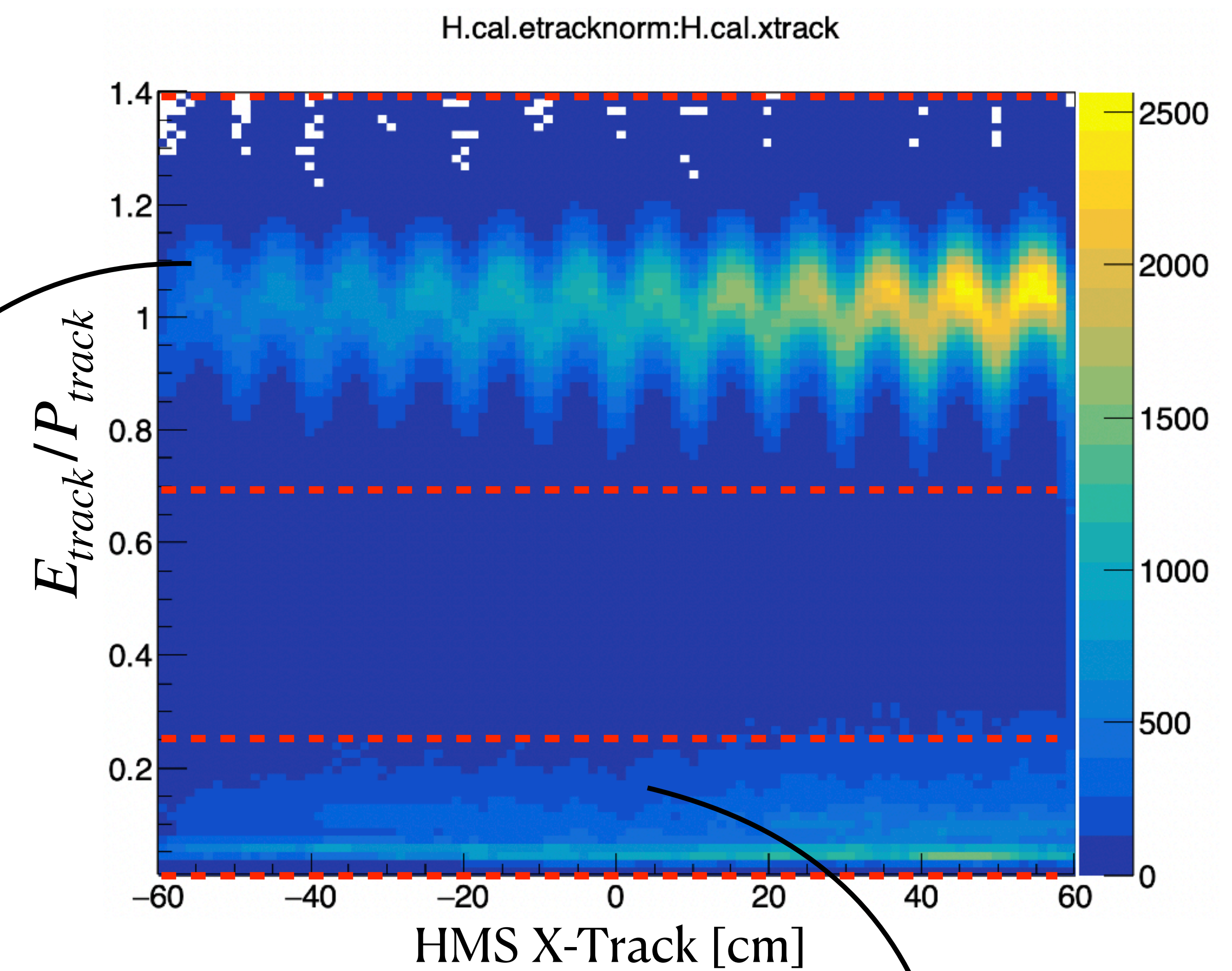
$\Delta_{p=2.1} = 1.2 - 0.9 = 0.3$

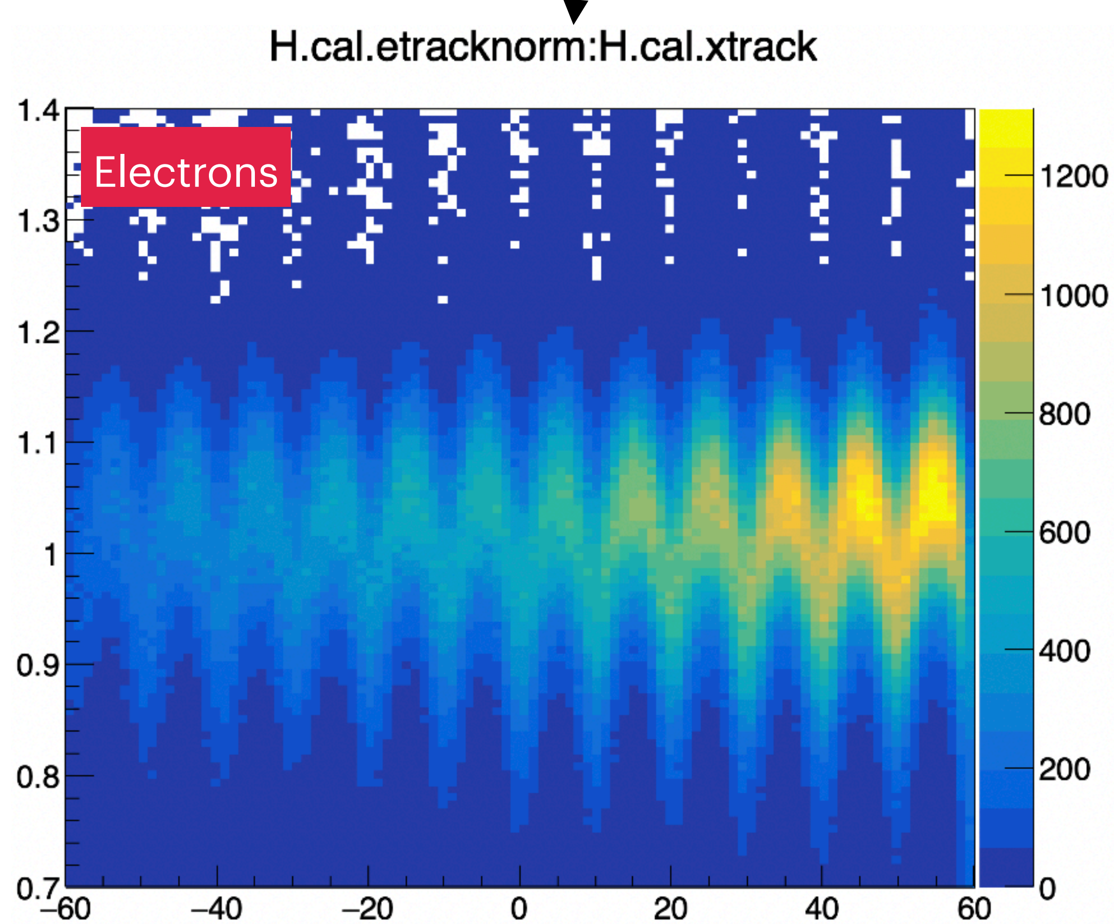
Email snippet from Vardan (March 29, 2021):

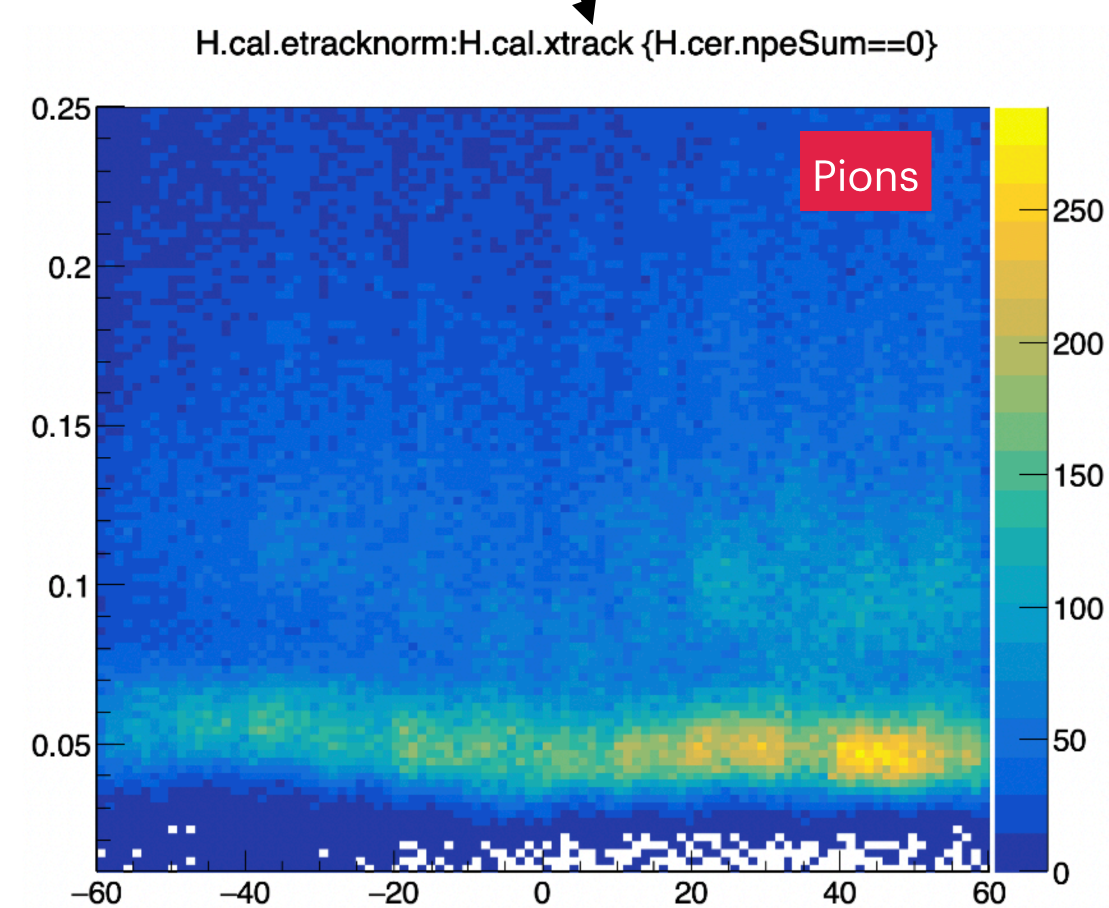
thank you for paying attantion to that problem, and for the study. We agree that Dave's hypothesis can be checked by simulations. Besides that, we think something can be done with data analysis:

1) Look in the same distributions by choosing m.i.p. pions/muons (if any) in the gas Cherenkov. The effect should be much less pronounced.

2) Raise threshold on the energy depositions in the modules above 50 MeV in the analysis, let say to 100 MeV. The effect should become stronger.



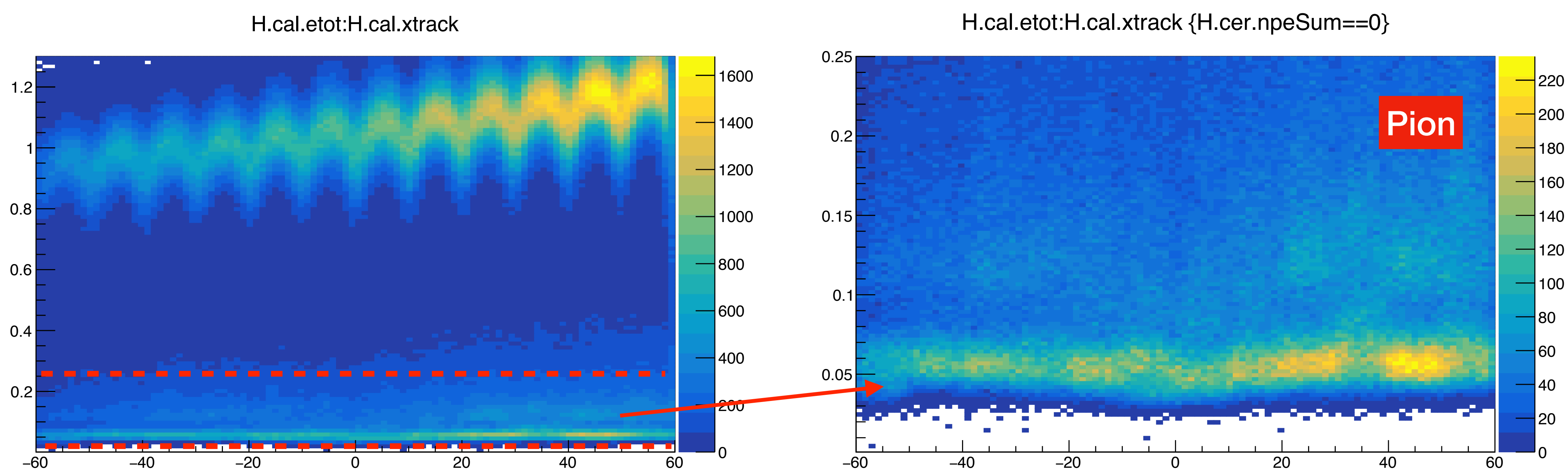




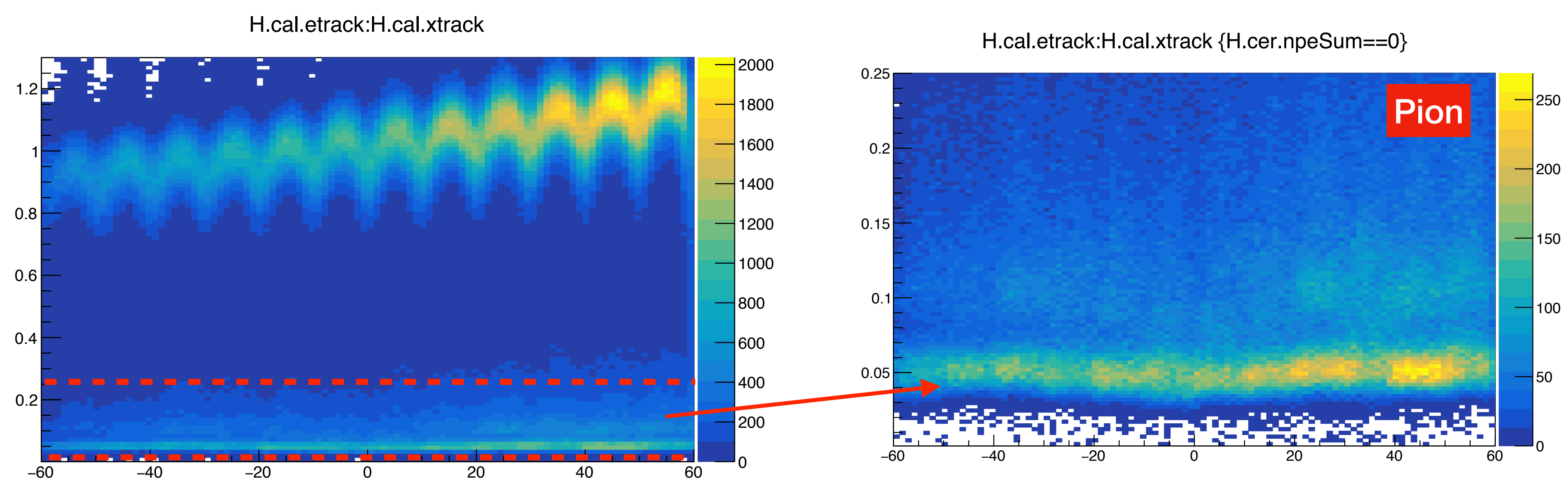
Email snippet from D. Mack (March 30, 2021):

Can you make another version of the passing pion plot using the other energy variable which is not normalized to momentum? That might take out some of the curvature since the beta of the passing pions is high enough to ~saturate their Cerenkov light emission. (beta ~0.99)

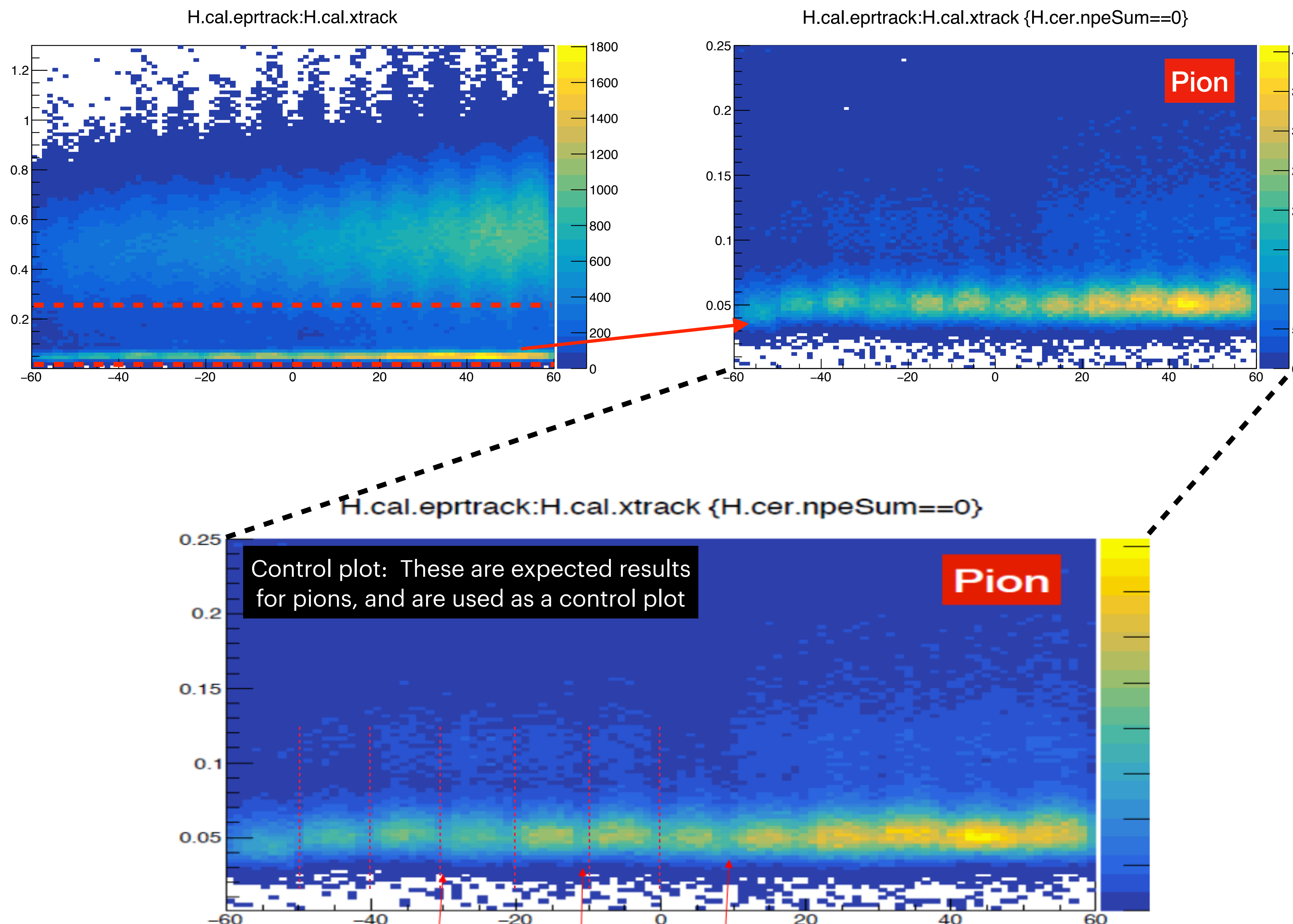
Total shower (all layers) energy vs. X-track



Total shower (all layers) track energy vs. X-track



Pre-shower (layer 1) track energy vs. X-track



<u>Comments by D. Mack</u>

Nice. This is what I was looking for: you can see we're losing the "grazers" on the boundaries between blocks because they for example only go thru 5cm of lead glass in each block. (This would be crisper at higher momentum due to reduced multiple scattering in the hodoscopes.)

Optimistically, it looks like the preshower FADC thresholds are OK away from the top and bottom edges of the block (at least in an average sense; this plot averages over the Y coordinate 70cm length of the blocks).

Summary

- ☑ Dave Mack's hypothesis was tested using using HMS defocused runs a 1 and 2.1 GeV and the results, although not exact, seem to be in the right direction, with a reduction in the "wiggles" by a factor of 1.5 when going from 1 to 2.1 GeV/c in central momentum

- ☑ The "wiggles" for pions, in the low end of the calorimeter energy spectrum are significantly reduced compared to electrons near ~1.

- ☑ Vardan confirmed that D. Mack's hypothesis can be tested by doing an energy-dependent simulation ** Need to confirm with Vardan when the simulation will be done.

- ☑ From Hamlet, no X-Track correction was done for the calorimeter as these were small at the time the calorimeter analysis code was written. These corrections may be more significant, and thus a more detailed study of the x-dependence of the calorimeter energy is needed.

- ☑ NOTE: The HMS fADC thresholds for these run were determined to be 10 MeV (from plots of pulse amplitudes for each block)