TRIUMF Experiment E614: TWIST

Report on Energy Loss Analysis in the Proportional Chambers near the Target, From Real Data

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Introduction

Technical note 22 describes a means of identifying and rejecting events in which muons stop in PC 6 instead of the target. Figure 1 shows how we could, with good enough resolution, distinguish where the muon stops on a plot of energy loss in PC 6 vs. energy loss in PC 5.

Post amp charge to time converters (PACT) were installed to read the output of the target PC ADC's and tested during summer 2002. Data was then taken to investigate if the Monte Carlo simulation results could be reproduced. This report shows that the needed resolution in ADC pulse width is not achieved in the current data. It should be noted that the simulations were done with 100% resolution.

Algorithm

Once we have the data from the ADCs, we still need to do a few manipulations to get a good value for the energy loss in each plane. The first concern is whether each wire threshold is set high enough to cut the pedestals. Figure 8 shows a few wires with low thresholds, displaying a lot more hits than surrounding wires because pedestals are detected. To avoid this, the pedestal file must be well calibrated and each considered hit must have positive energy. Negative energy would be an indication that the thresholds used during the run were lower than a more recent pedestal calibration file.

Secondly, if the particle goes through two cells in one plane, the energy measured in both is added. Since there are low levels of crosstalk and noise measured in the PC ADCs, the code currently rejects events with two non-adjacent wide hits or three or more hits (even if

adjacent). The fraction of events rejected is small[1] and this avoids cases where we would use the wrong hit. Note that we dismiss a second non-adjacent hit that has a small width, as it could be a pedestal hit, noise or crosstalk.

To further increase our confidence in the hits we use, we require that there be a TDC hit on the same wire and within 100 ns from the ADC gate. Hits will be rejected if there are no such hits or more than one.

Stops in PC 6

Another part of the algorithm tries to find some events where the muon stopped in PC 6. For this code to work, we need to use windowing (dividing the hits in time windows) and trackrange (finds the range of hits in a window in u, v, radius and z). To know that the muon stopped in PC 6, the last muon hit must be in PC 6 and the first decay hit must also be in PC 6, with the decay going downstream. If the decay was upstream, we could not distinguish if it stopped in PC 6 or in the target. In order to find the range of the muon and positron tracks, they need to be in different time windows. This implies that we only look for decays that occur at least 1.05 μs after the muon enters the detector.

The code currently finds very few such events. Most events are rejected because there isn't a decay window (only 3 windows) or because the muon goes past the target PC radius. Perhaps this could be corrected for by beam tuning. Also, the magnetic field would focus the beam, reducing the second effect considerably. Another reason for not finding many of these events could be that a small region of the wire in the cell the muon stops in can be dead[2] for some time after the muon hit. The first decay hit is then not detected in PC 6 but in PC 7 and we can't distinguish this type of event from a stop in the target.

Also note that the code requires window 2 to be the trigger window. This will be the case for most events by adjusting dc_mintdc_cut and pc_mintdc_cut to get rid of windows before the trigger. We don't want these cuts to be too close to zero so events with particles going through the chambers just before the trigger will be rejected (-200 ns works well).

Mofia usage

The PACT analysis code only depends on windowing and trackrange. Therefore, the analysis can be quick when turning off clustering, tracking and first guess. A few namelist variables can be modified, but default values should be adequate for most runs.

PACTanalyze (F) Turn on to analyze pact data.

[1] At this point, we were only studying the distribution of energy loss in PC 6 vs. PC 5 to see if we had enough resolution, so the fraction of events rejected does not matter as long as we keep clean events and we have enough statistics. If we did, we would need to minimize the number of events rejected.

[2] When electrons accelerate towards the wire, they cause some ionization that is slow to recombine. Thus a small region of the wire can be dead for up to 100 μs.

EnergyCut (100) When more than one hit in a plane, hits with smaller TDC width will be dismissed as noise, pedestals or crosstalk.
PACTDebug (F) Prints ADC hit wires and energy on screen for debugging.
PACT_gate (200) PACT gate width (ns).
HighE (33000) High bound for energy in histograms. Needed for different gas gains.

One should also turn on namelist hist variables FillPACTHist to get the analysis results and FillRawHist for raw ADC hit data.

Results

Figure 2 shows a typical energy loss spectrum for each target PC when the muon stops near the target. The first peak close to zero is from beam positrons. The muon peak is well resolved when adding the energy of double cell hits.

Figure 3 is an attempt at reproducing figure 1 from the data. The upper left plot contains all events where hits were well identified as described above. The beam positron peak near the origin dominates the muon peak so the latter appears lighter. The upper right plot shows events where the muon is believed to have stopped in PC 6. Although the statistics are very low, we don't see these events as being in a separate region than the others. The two lower plots show the events separated on whether there are no hits in PC 7 and PC 8 (left) or there are (right). The beam positron peak almost completely disappears from the left plot and we see the muon peak much better. However, from these plots, we can only conclude that we do not have high enough resolution to see the same shape as in figure 1.

Figure 4 shows the energy loss in PC 6 vs. PC 5 for different stopping distributions.[3] Starting more upstream on the upper left plot with 40% He and 60% CO_2, the following plots move the stopping distribution progressively downstream with 60% He, 75% He and 90% He. We see the expected effect, that the muons lose less energy in PCs 5 and 6 when stopping further downstream. However, none of these plots show any resolution improvement.

Spread in ADC vs. TDC

While trying to get a better resolution, a few anomalies were found when comparing the ADC and TDC pulses. Plots of energy loss vs. TDC pulse width for each target PC are shown in figure 5. Note that all ADC hits where there is only one matching TDC hit on the same wire are used here, even those that were rejected while trying to find the energy loss. There is a definite correlation between the ADC and TDC widths. A two-dimensional cut was imposed to study events outside the main band shown in figure 10.

Among these, we first notice a second curve in PCs 5 and 6. These are due to a shift in TDC width in 8 wires in each planes (see figure 6). There is also a smaller third curve in PC 5, due

[3] To control where the muons stop, we vary the mixture of helium and CO_2 in a volume at the entrance of the detector called the gas degrader. Muons interact more with heavy atoms and lose more energy so their range will be shorter when we increase the CO_2 fraction.

to a shift in ADC width for wires 58 and 59 in that plane (see figure 7). There is most probably a contact between these channels as they always have hits together. Figure 8 shows they have about twice as many hits as other wires which is expected if both fire when any one of them have a hit. The details of the ADC distribution for these wires as well as a typical wire (90) and a wire with too low a threshold (91) are found in figure 9. Such wires will detect the pedestals and have a lot more hits. This is seen in the projections in figure 8. Note that the thresholds have been adjusted since then.

Apart from these extra curves, there is also a spread in ADC width. This is mostly visible on the muon peak centered near 350 ns (TDC width). It is not clear what causes this spread. There is no correlation with wire as displayed in figure 11 (apart from the 8 wires in PC 5 and 6 already discussed). There is however a correlation with the time of the matching TDC hit. Figure 12 shows details of the TDC hit distribution around the peak at time zero. The first plot is for all hits as a reference. The second plot is for hits inside the band and the third plot for hits outside the band in figure 10. The two last plots clearly differ. The second peak in the third plot indicates that some hits are late and the ADC pulse recorded is only a fraction of the whole hit. These hits are found below the band, as the ADC width is smaller but the TDC width unaffected. The rest of the hits outside the band are almost all very close to zero.

Other attempts to increase resolution

Among other tests done to try and increase the resolution, we tried restricting the events by choosing only those with one ADC hit per PC (figure 13 top right), only accepting hits that match the ADC vs. TDC band in figure 10 (figure 13 lower left) or accepting all hits, but correcting the ADC width according to the matching TDC width (figure 13 lower right). Although the lower plots in figure 13 are less spread, the expected shape is still not seen. Furthermore, we need to understand the spread before we know we can remove these hits without introducing a bias.

Another important test was to replace the gas in the PCs. We tried a mix of argon and isobutane instead of CF_4/isobutane. It is a slower gas, but was supposed to have a better resolution. The same plot of energy loss in PC 6 vs. PC 5 for this gas is shown in figure 14. We first notice that the gain is much higher with this gas (same uncalibrated scale as before). The shape also seems different, but not at all like the one figure 1 suggests.

Stopping distribution and efficiency

The last PC ADC hit in the muon window is plotted on the left in figure 15 for the case with 75% helium in the gas degrader. Bin one represents events with no ADC hit, where the muon stops before the target PCs or is too far in radius to be detected. The fact that PC 8 has more hits than PC 7 can be explained by the presence of beam positrons that will go through the entire detector. The right plot counts the number of time a PC has no hit while there are some in PCs downstream from it. This gives us a relative efficiency for the first three target PCs and it seems to show that PC 5 misses a lot more hits than the others.

Conclusion

The data analyzed indicates we do not have the required resolution to identify muon stops in PC 6 by a cut on the plot of energy loss in PC 6 vs. PC 5. All attempts to restrict the data analyzed to clean events and good hits did not result in better resolution. Although there was a difference in shape with argon/isobutane, we still don't get the simulated result.

Although it is unlikely we will be able to use the target PC ADCs as intended, it would still be useful to try the same analysis with magnet on. Also, understanding the spread in ADC vs. TDC width could indicate a cause of bad resolution.

We might also want to add a resolution function in the simulation software. If it reproduces the observed results, it would show that we cannot identify the muons that stop in PC 6 individually and reject them. If we reach that conclusion, we will need to find a way of measuring the fraction of muon stops in PC 6 so we can correct our results statistically.

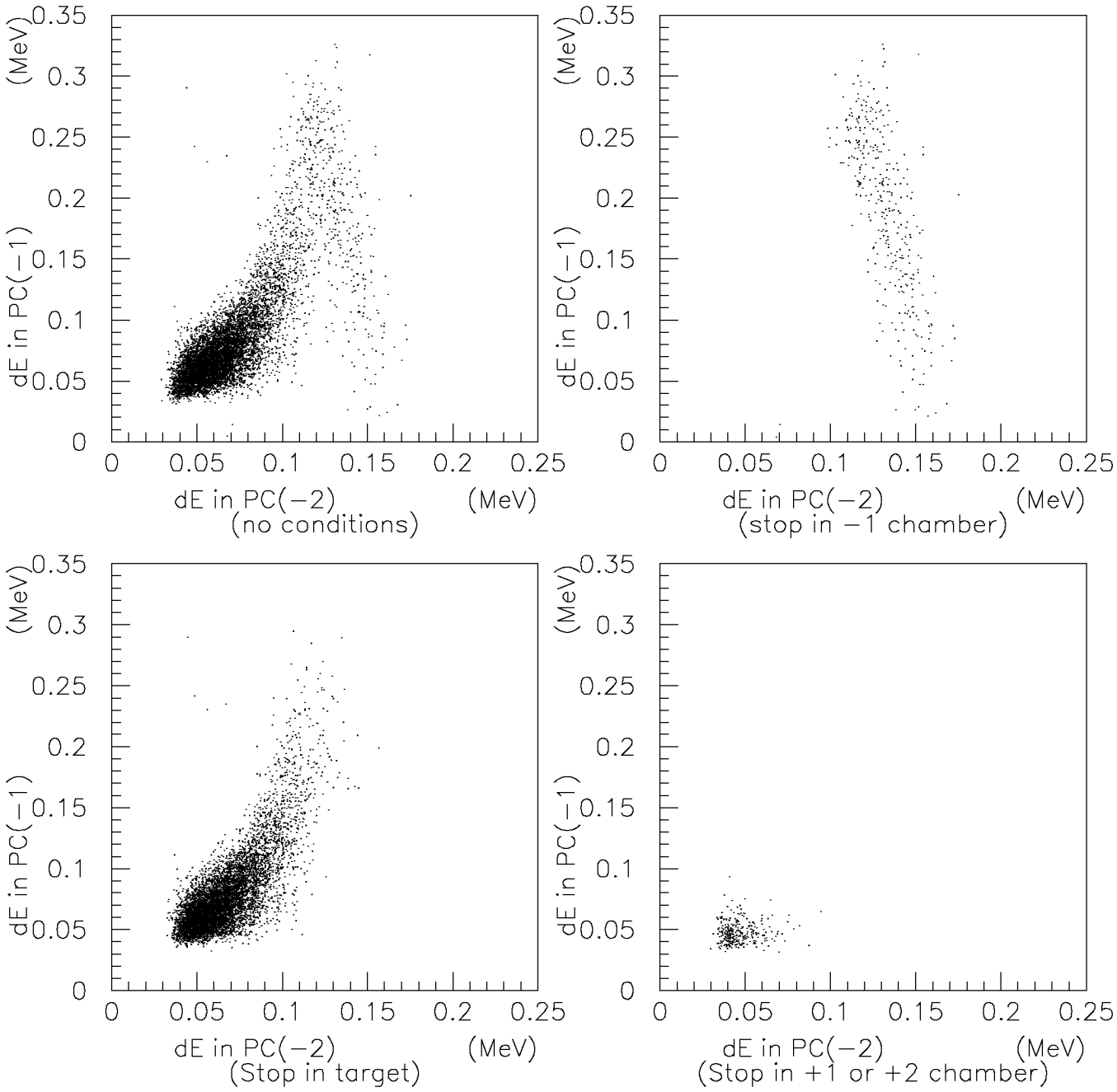

Figure 1 *(figure 3 from tech. note 22)* : Simulated energy loss in PC 6 (-1) vs. PC 5 (-2) for various muon stopping conditions. Top left to bottom right: all, stops in PC 6, stops in target, stops in PC 7 or 8.

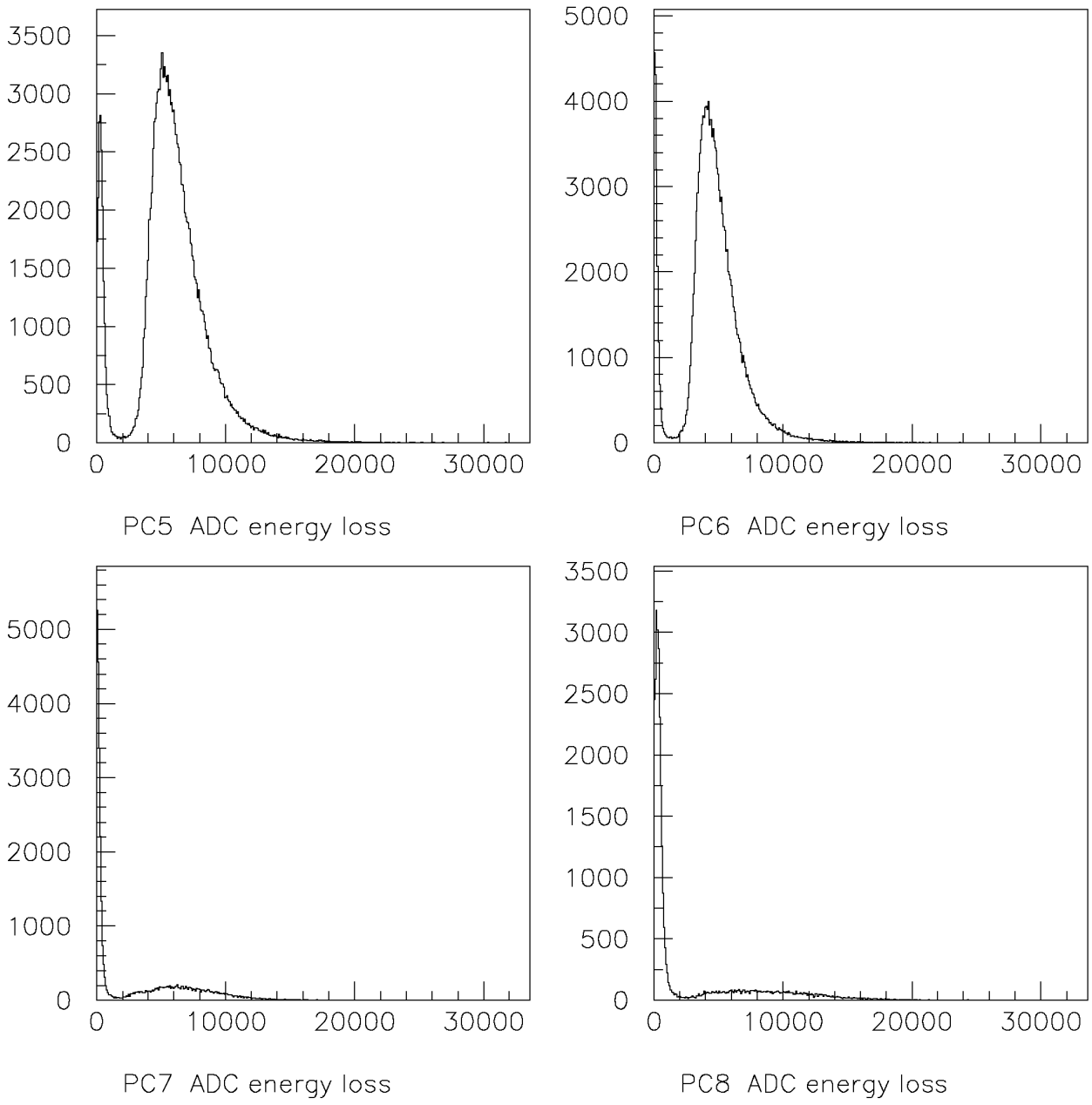

Figure 2: Measured energy loss in each target PC (uncalibrated scale).

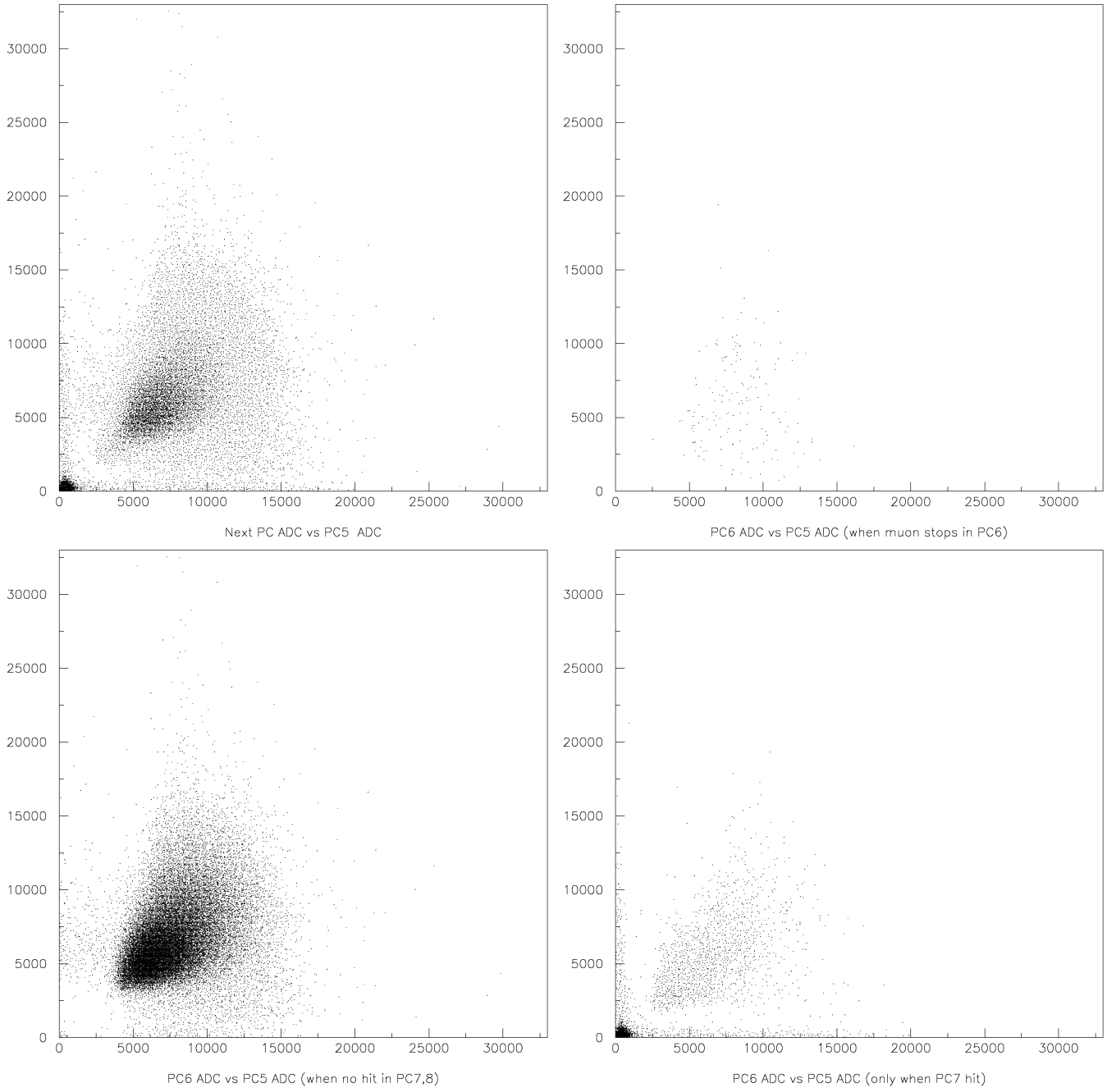

Figure 3: Energy loss (uncalibrated) in PC 6 vs. PC 5. Top left to bottom right: all, stops in PC 6, no hit in PC 7 or PC 8, hit in PC 7.

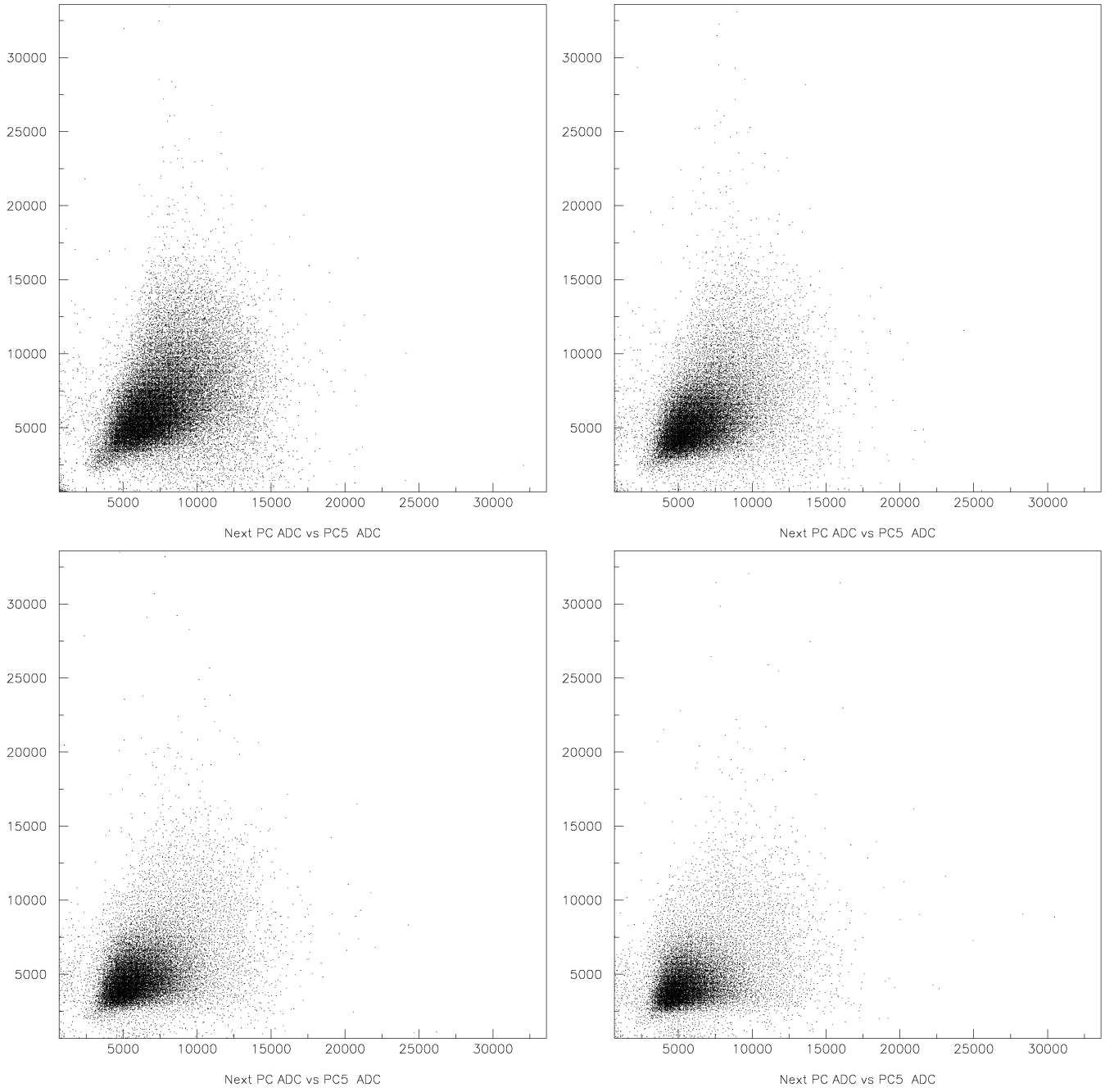

Figure 4: Energy loss (uncalibrated) in PC 6 vs. PC 5 for various gas degrader settings. Top left to bottom right: 40% He, 60% He, 75% He, 90% He.

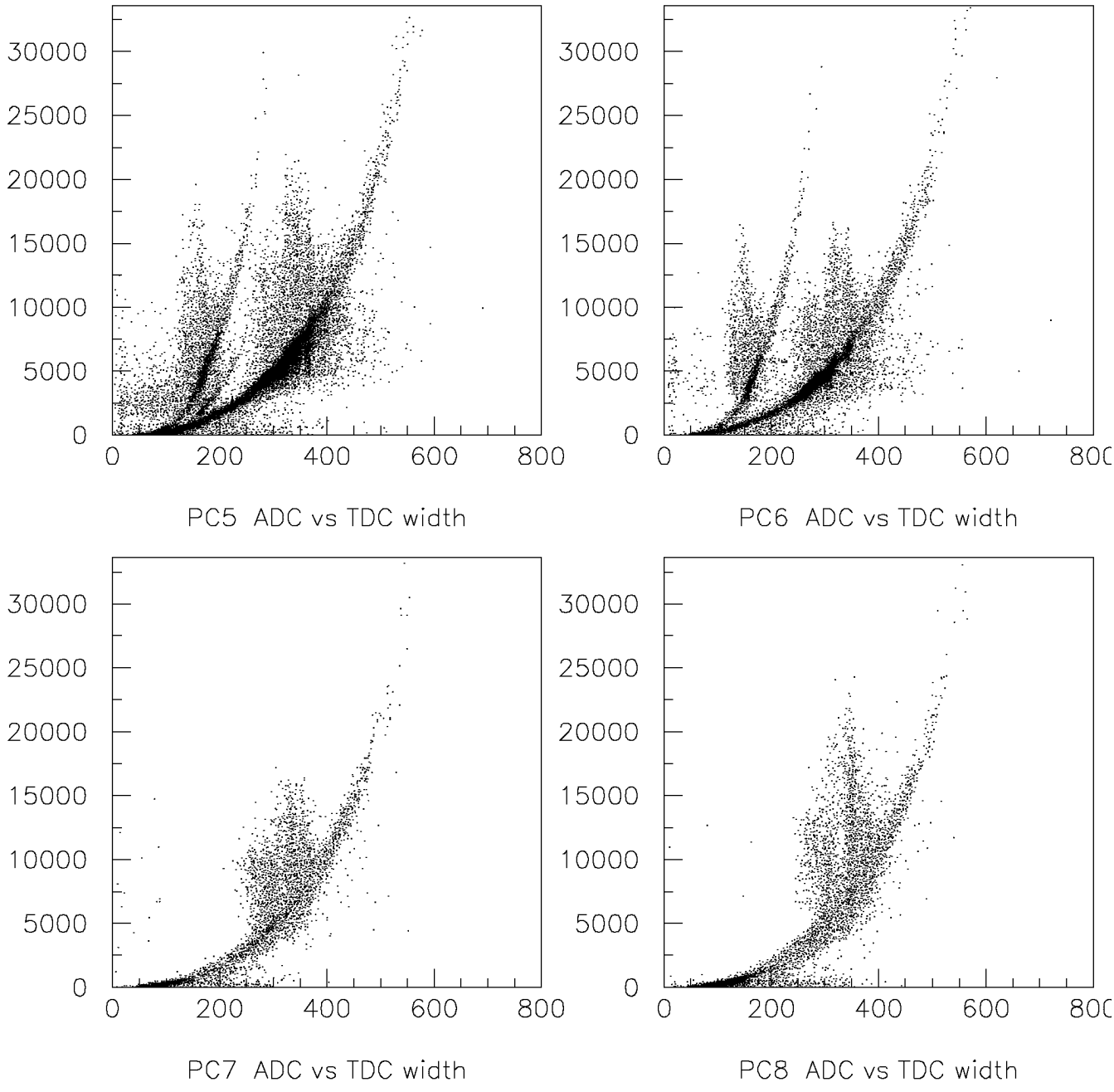

Figure 5: Energy loss (uncalibrated) vs. TDC pulse width (ns) for each target PC.

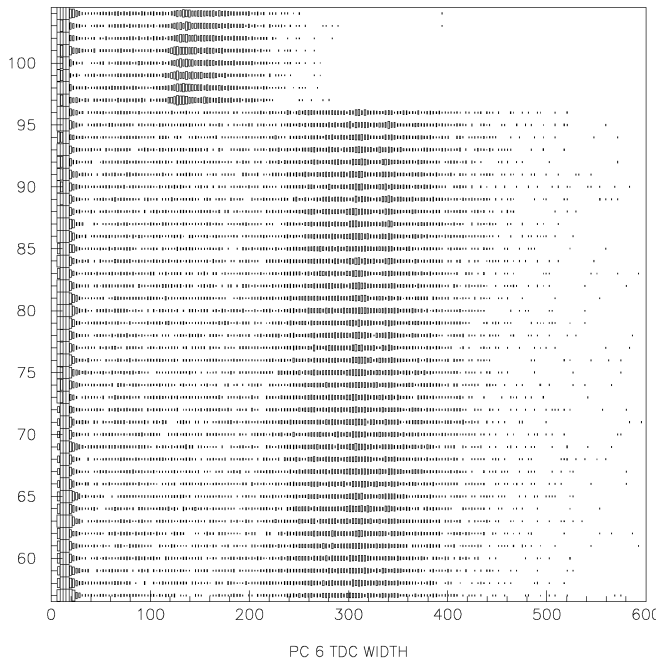

Figure 6: TDC pulse width (ns) per cell for PC 6.

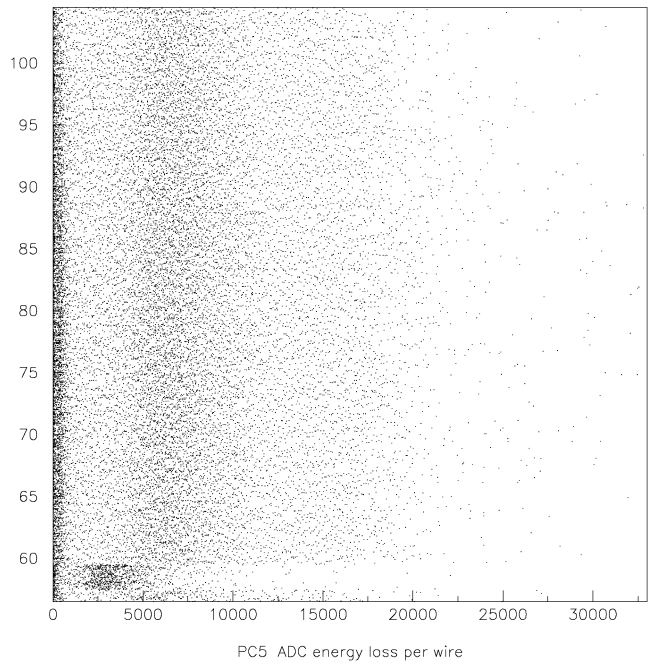

Figure 7: Energy loss (uncalibrated) per wire for PC 5.

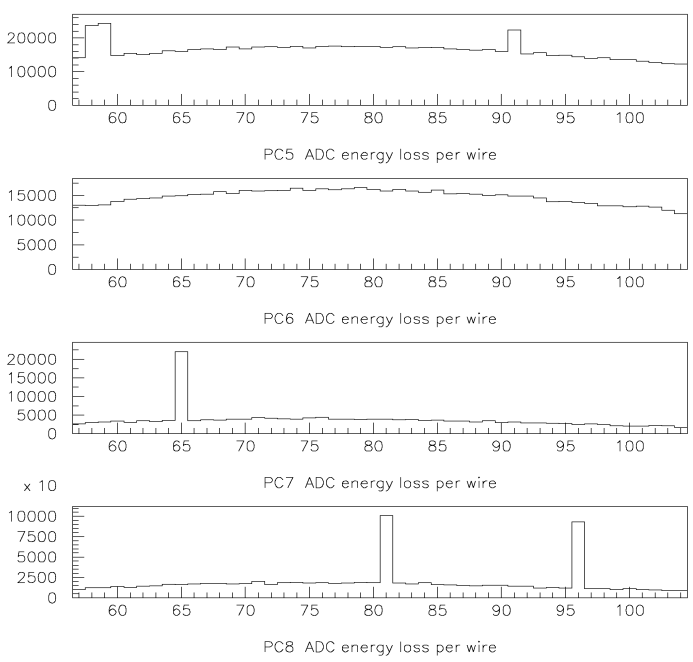

Figure 8: ADC hits per wire for each target PC (projection of energy loss per wire histograms).

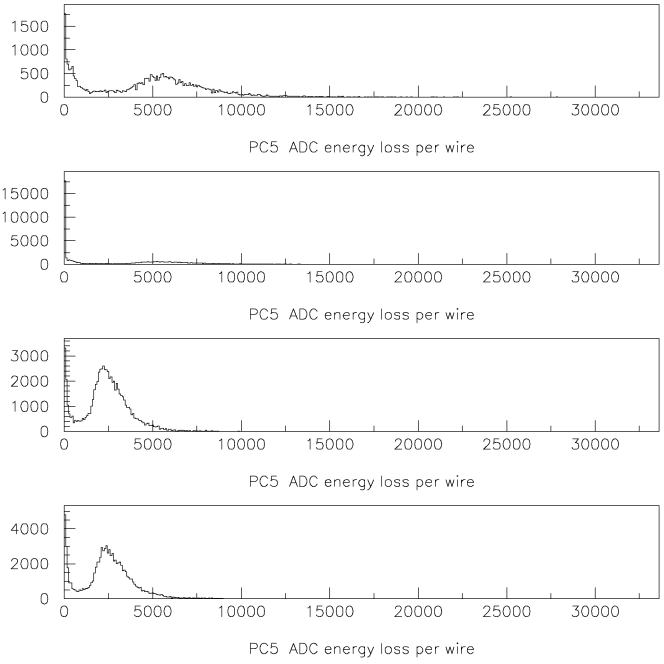

Figure 9: Energy loss for wires 90 (typical), 91 (pedestals being measured) and 58-59 (short between them: peaks shifted).

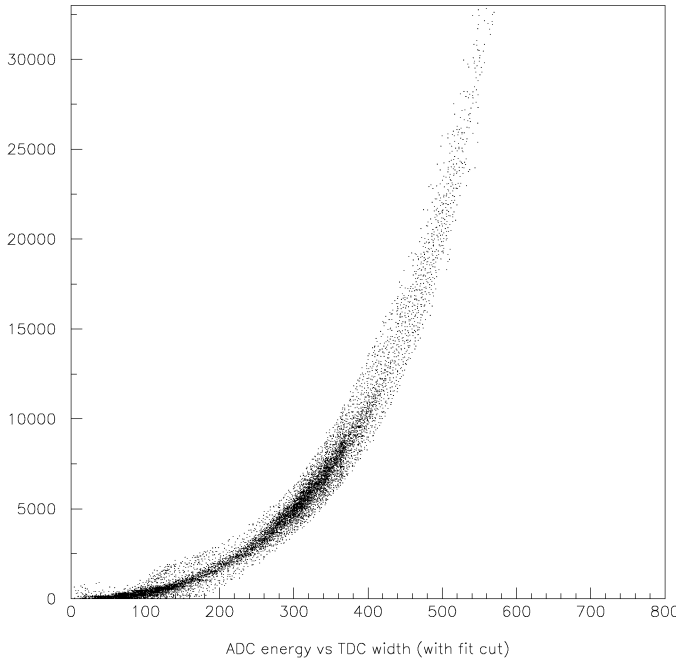

Figure 10: Energy loss vs. TDC pulse width for all target PC hit that is close to a polynomial fit of the main curve.

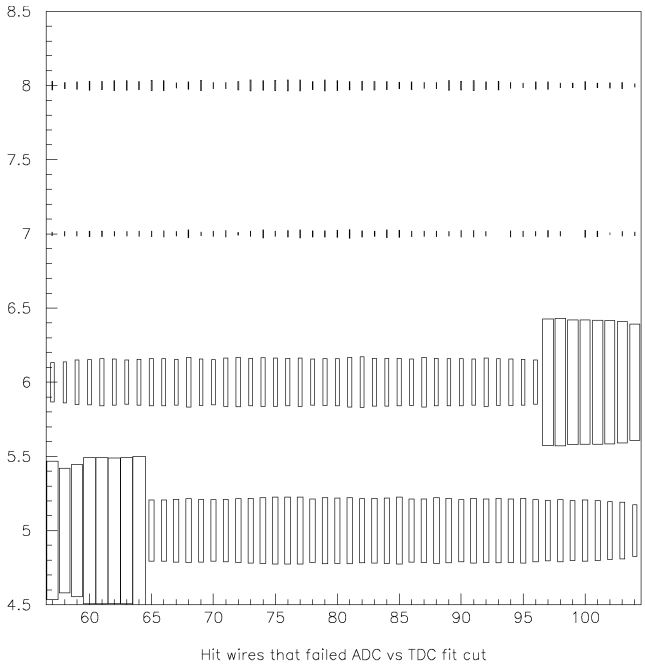

Figure 11: Number of ADC hit per plane and wire that failed the ADC vs. TDC band cut (figure 10)

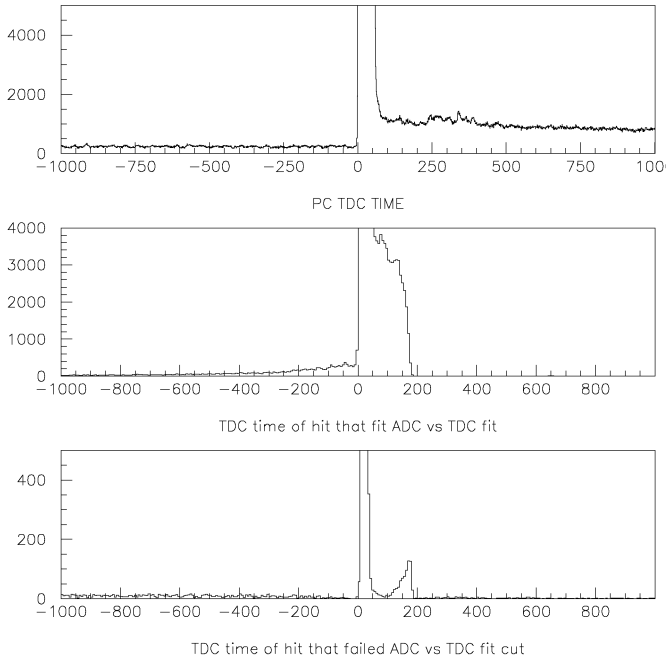

Figure 12: TDC time hit distribution. Top to bottom: all target PC TDC hits, TDC hits with matching ADC hit close to the fit, TDC hits with matching ADC hit far from the fit.

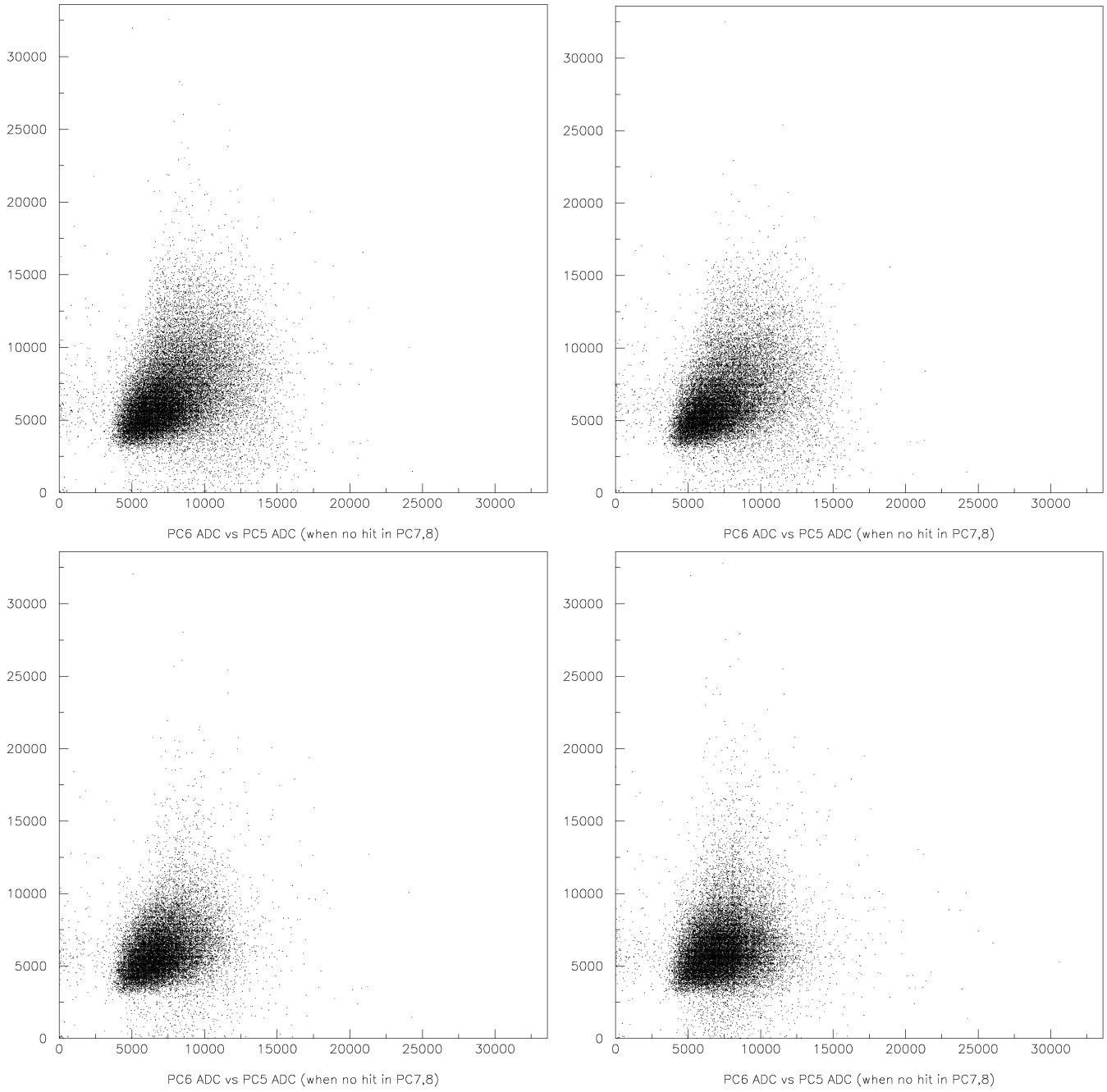

Figure 13: Energy loss (uncalibrated) in PC 6 vs. PC 5 for various restrictions. Top left to bottom right: require a matching TDC hit in time with each ADC hit, only one ADC hit per plane, require that the energy loss and TDC width be close to the fit, modified energy loss to match the TDC width according to fit.

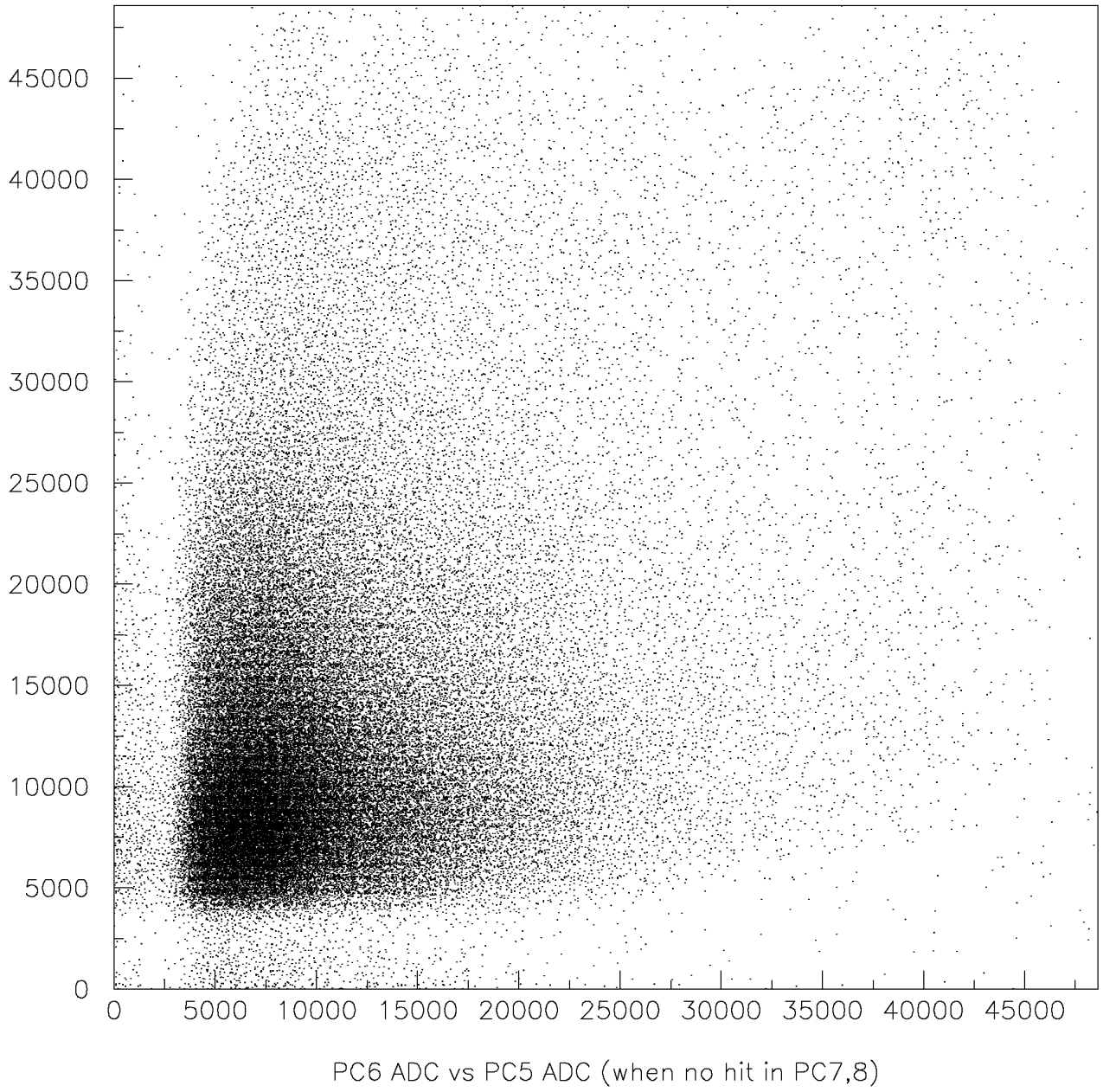

Figure 14: Energy loss (uncalibrated) for PC 6 vs. PC 5 with argon/isobutane gas instead of CF_4/isobutane in the PCs.

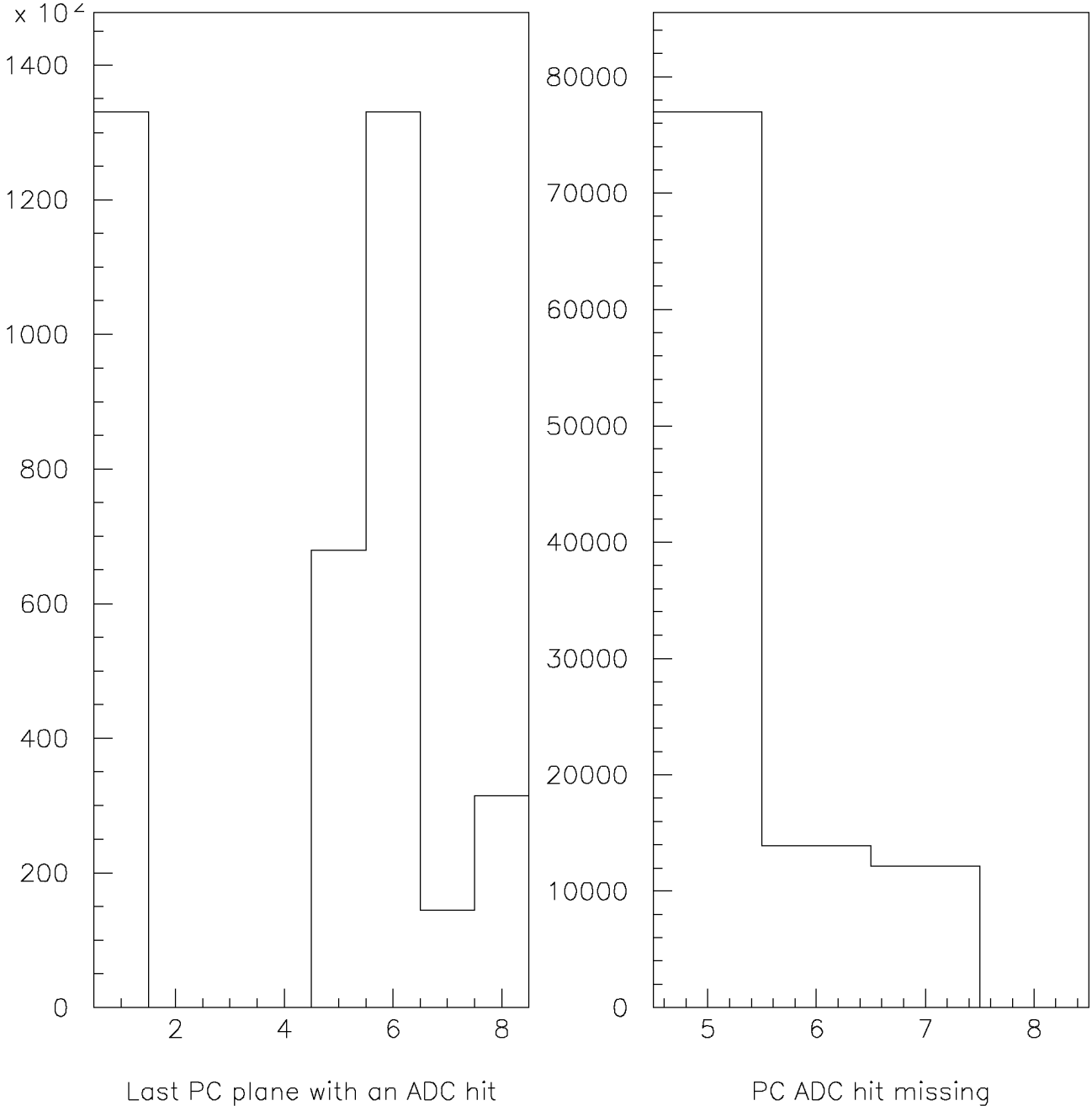

Figure 15: Left: Indication of where the muon stops from the last PC with an ADC hit. Column 1 is for events with no ADC hits in any target PC. Right: Number of times a hit is not found in a target PC ADC but one or more is found in the following planes, indicating the hit was missed.