Analysis of Supermodule Prototype Data

Draft

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Introduction

To quickly check the consistency of data taken with the supermodule prototype I wrote a simple event display and analysis C program on my Macintosh without using any of the existing code on the HERA-B computers. Some results concerning hit distribution, cross-talk and data consistency are presented in this note.

Processing of Raw Data

I used the raw binary data files produced by the RICH prototype FED system. The data contain a header (for HERA-B runs) and a fixed 144 byte long block for each event. Each block contains 96 bytes (48 data words) representing the 48 ASD08 cards used. The mapping of bits in the data words to cells of each PMT is done in four steps. 1) Base-board: on the M16 base-board each of the four ASD08 cards reads out a column of 2×4 anodes from the upper and lower PMT. The M4 base-board is read out by only one ASD08 card. 2) Each base-board is located in one of the 6×16 square holes in the supermodule. 3) Each ASD08 card is connected by a cable to one of the 8 inputs of a FED daughter card. 4) The daughter cards in the FED crate are read out top (input) to bottom, left (slot) to right. The two bytes in the ASD08 data word get swapped.

Display of Hits in a Supermodule

After applying the four mapping steps described above hits in a single event or hits accumulated over time could be displayed in their proper position with the option of turning lenses on or off. Figure 1 shows an event taken at the radiator tank in testbeam 24. The beam penetrating the uppermost M16 leaves a cluster of hits in this PMT and produces a fair number of hits approximately one ring radius away. All hits from this run accumulated — displayed as if lenses were used — are shown in Figure 2.

The supermodule, with a set of Plexiglas sheets as a radiator, was later moved into the HERA-B experiment. The module was tilted by 45° so that Čerenkov light, produced by particles in the Plexiglas, can hit the PMTs. The photon yield was estimated to be 2–3 photons per track. The accumulated number of hits for two runs of 500,000 events, one at 4 MHz and one at 38 MHz target rate, is shown in Figure 3.

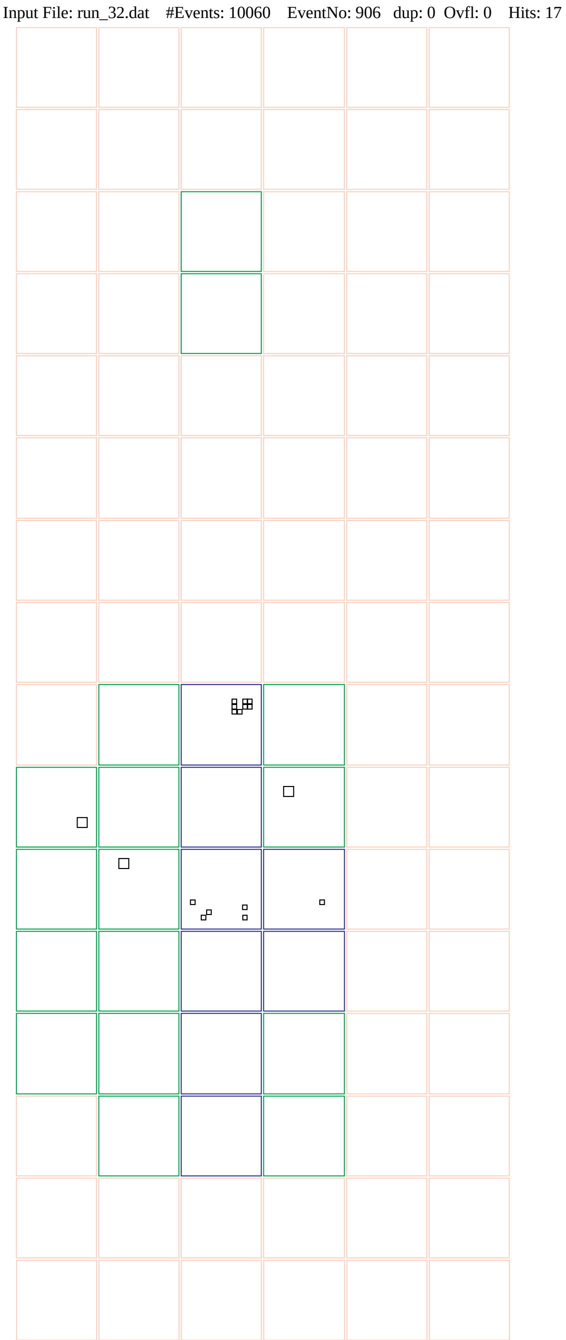

Figure 1. Display of hits in an event taken at the C_4F_{10} filled radiator tank at testbeam 24. No lens modules are present and hits are displayed at their true position. The green squares indicate fully equipped M4, the blue M16 baseboards. The orange squares are the unused baseboard mounts of the supermodule.

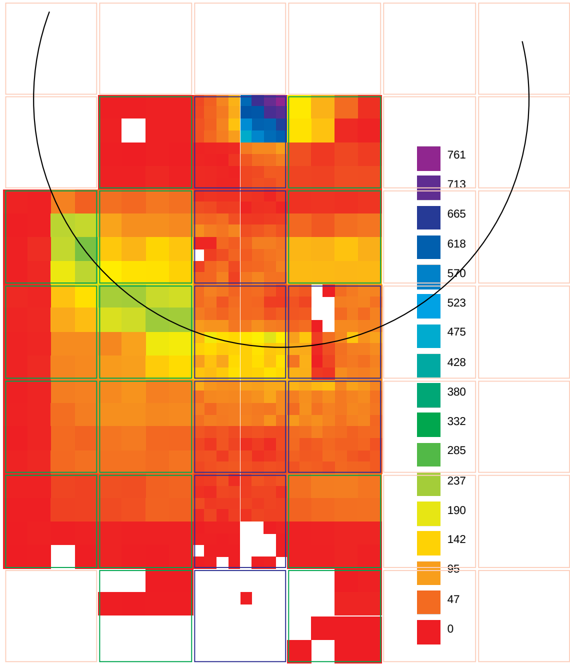

Figure 2. Accumulated hits for the same run shown in Figure 1. The entries are color coded according to the legend at right and corrected for the larger area of the M4 PMTs. For easier viewing, all hits are displayed as if lenses were used.

Hit Distributions

The data taken at the test beam 24 radiator show clearly a segment of the imaged Čerenkov ring. The signal to background rate is low enough for ring segments to be seen on an event by event basis.

The passing of a charged particle through a PMT is clearly visible and produces more than one hit in the PMT, probably due to showering or emission of secondary electrons in the dynodes. The electron in Figure 1 most likely showered before it hit the PMT resulting in close-by tracks producing multiple rings.

The hit distributions for 500,000 events taken at two extreme HERA-B target rates of 4 MHz and 38 MHz (Figure 3) show no significant differences besides the higher number of entries for the 38 MHz run. The distribution of hit multiplicities for several target rates is shown in Figure 4, the mean is proportional to the target rate and rises from about 2 to 5.2 hits/event.

Other patterns, visible in Figure 3 that are not caused by the expected drop of occupancy from lower right to the upper left, can be divided into four groups

1. M16 PMTs seem to have a lower number of entries than the M4s.
2. White space (2×4 cells for M16 and 4×2 cells in M4) is caused by a stuck last byte in each FED daughter, affecting four M16 and the two bottom M4 base-boards.
3. The threshold of some ASD08 cards on the M16 base-boards seems to be too high (reddish bands of 2×8 cells).

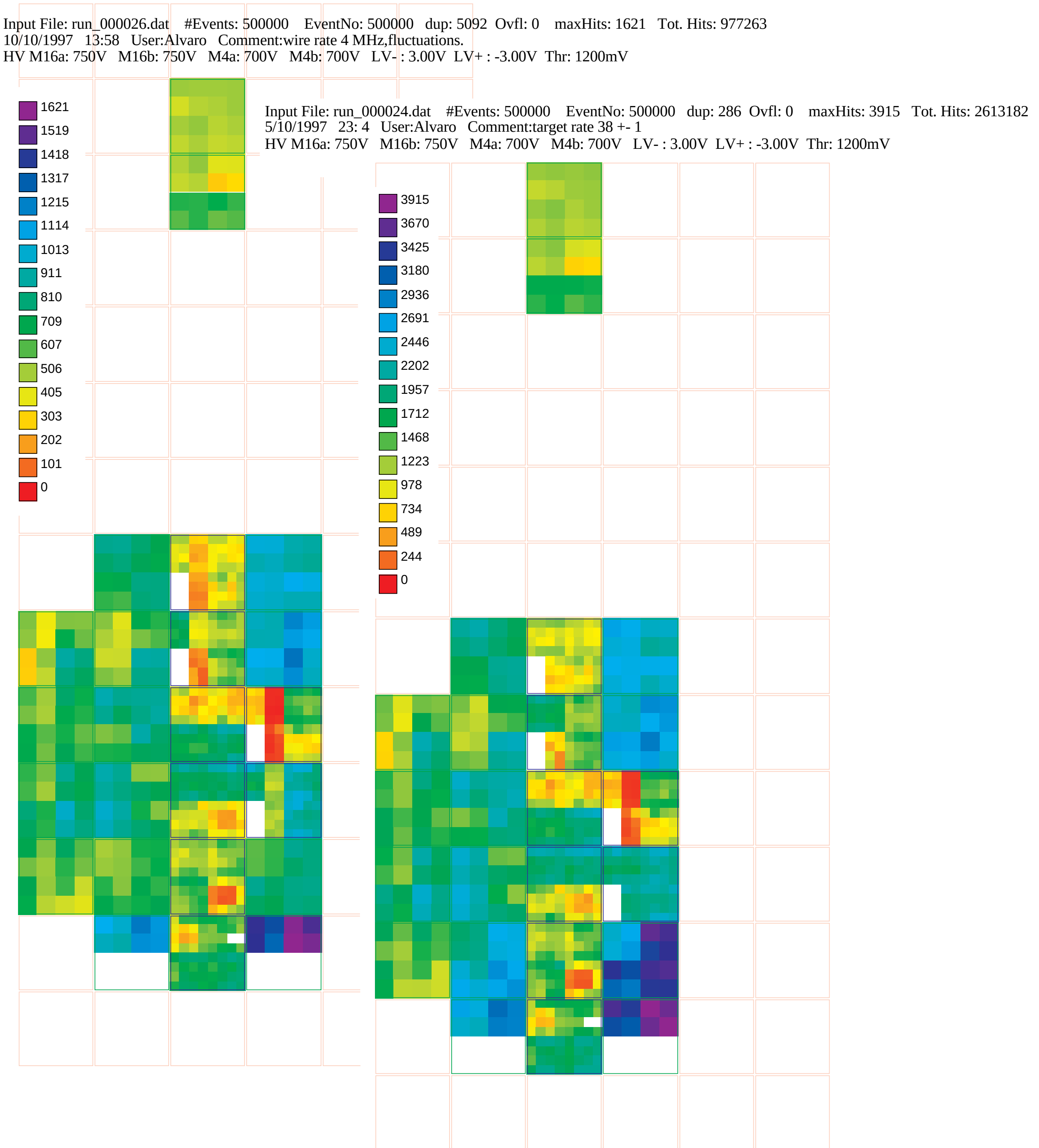

Figure 3. Comparison of accumulated hits for two HERA-B runs. 4 MHz target rate (left) and 38 MHz (right).

4. Adjacent PMTs have different numbers of entries. The outside cells on some M16s have more hits than the inside cells.

The reason for the patterns mentioned in 1 and 4 are the differing sensitivities of PMTs which were not selected according to their optimal high voltage. Only two high voltage values for the four HV channels employed were used, 700V for M4 and 750 for the M16. Additionally, M4s have less dead space per unit cathode area and also use UV extended glass. The outer cells of M16 PMTs are more efficient than the inner cells due to the continuous photo cathode.

The last byte of each FED daughter card, which in the HERA-B readout setup was found to be always on, was not counted as valid hit. The same effect was observed by the Muon group which uses a similar FED setup.

While scanning events, consecutive duplications of the same event were observed. The duplications existed already in the raw data. The number of duplications were counted when analyzing the data. Figure 5 shows the mean hit multiplicity and the percentage of event duplicates plotted against the target rate. The multiplicity can be fitted nicely to a straight line,

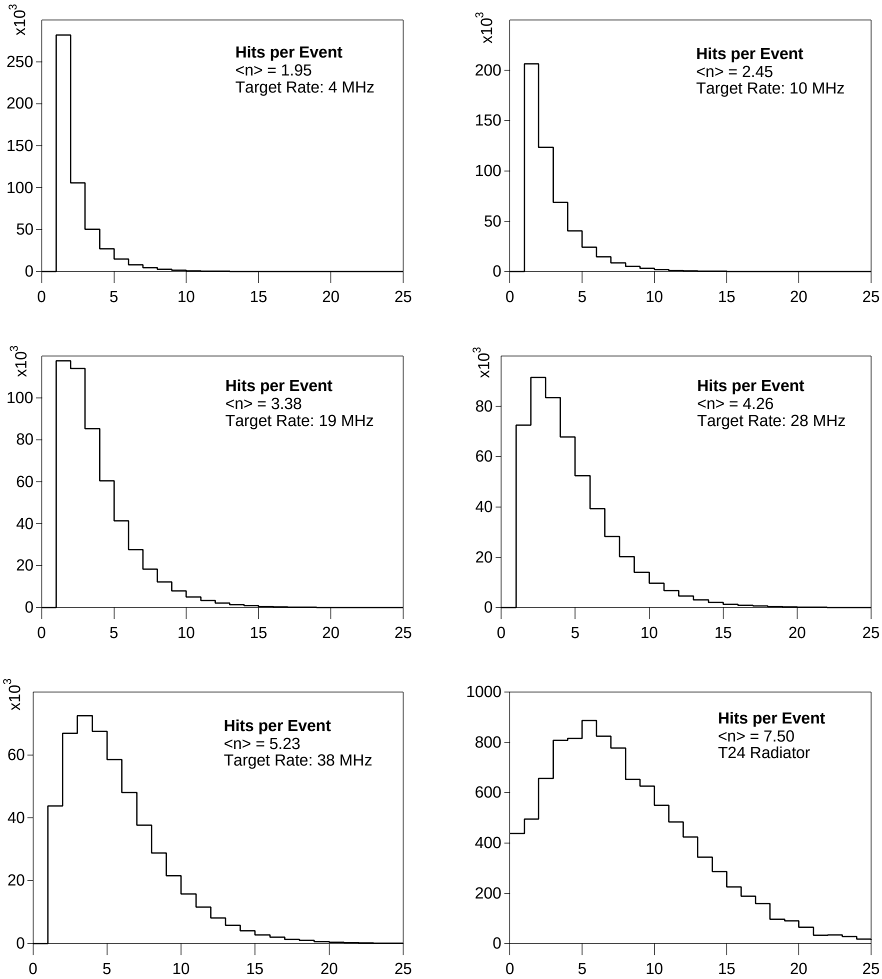

Figure 4. Distribution of hit multiplicities for data taken at various HERA-B target rates and at the radiator of testbeam 24 (lower right). ⟨n⟩ is the mean of the hit multiplicity.

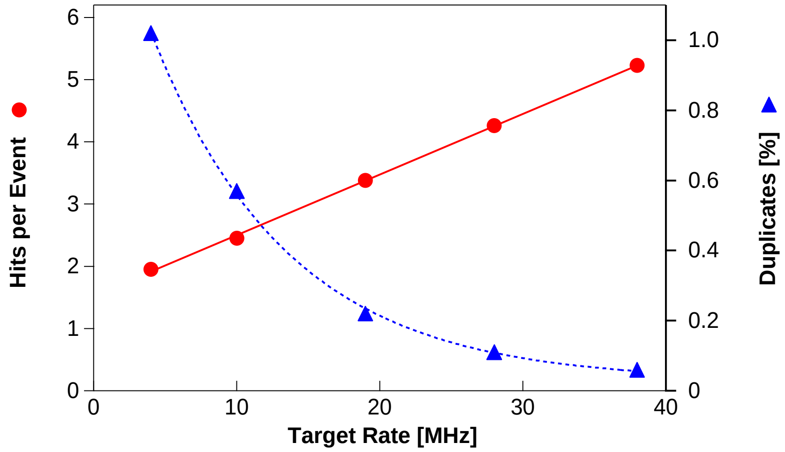

Figure 5. Mean number of hits per event (circles, left axis) and percentage of duplicate events (triangles, right axis) as a function of the HERA-B target rate. The solid line is a linear fit to the hit multiplicity, the dashed line an exponential fit to the duplicate fraction.

the fraction of duplicate events *drops* with target rate and follows an exponential. This behavior indicates that the event duplication happens at some fixed random rate, so the probability to find duplicates in the same number of events recorded at a shorter and shorter interval drops exponentially.

The distribution of hits on an event by event basis in the HERA-B data shows no particular pattern and hits from the charged particle and the correlated Čerenkov photons cannot be distinguished because they can happen everywhere on the detector.

Cross Talk

Cross talk from single photons can be produced at different stages of signal generation and propagation. It can take place inside the PMT, during analog signal propagation on the base-board from the PM socket to the ASD08 card, inside the ASD08 card, and on the 5m long unshielded twisted pair cable from the ASD08 output to the FED receiver. The first kind of cross-talk should be limited to 16 or 4 channels of each PMT. Cross talk on the base-board can be generated between adjacent signal traces, not necessarily from the same PMT. On the ASD08 card cross-talk is most likely limited to one of the two ASD chips on the card. The cable could cause cross-talk between adjacent wires, but also between the same channels on two cables stacked on top of each other.

To analyze cross talk using data one can look for correlations between multiple hits in the same event. To do so I accumulated in 2D histograms (one for each of the 768 cells in the supermodule) the distribution of secondary hits. To increase statistics, I only used the 64 (16) 2D histograms representing all cell locations inside an M16 (M4) base-board.

Figure 7 shows cross talk for four typical M16 base-board channels. The data are from the 38 MHz target rate HERA-B run. Hits for all M16 base-boards have been added to enhance statistics. Results do not change significantly for the runs with a lower target rate.

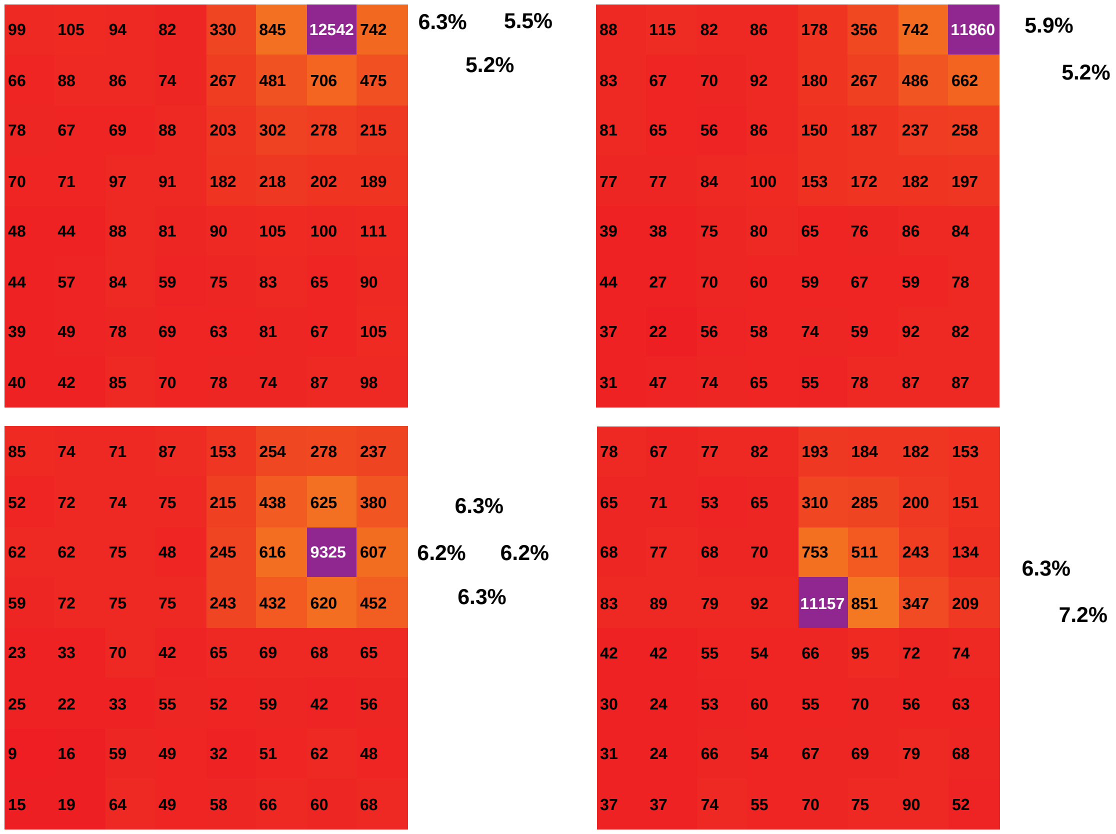

Figure 7. Cross talk for selected channels (violet) of M16 PMTs. Counts for all M16 base-boards have been added to enhance statistics The percentage numbers are background corrected. Data are from the HERA-B run with 38 MHz target rate.

Above a background of about 50 uncorrelated counts in the three non-hit PMTs, the outline of the hit PMT is clearly visible showing 2–3% of the maximum counts. The cells adjacent to the selected one show about 5–7% of the maximum. The percentage number shown in Figure 7 have been corrected for the uncorrelated background.

Because all correlated hits seem to lie inside the same PMT, one can exclude significant contributions from cross-talk on the base-board and the ASD08 card. It is more likely that

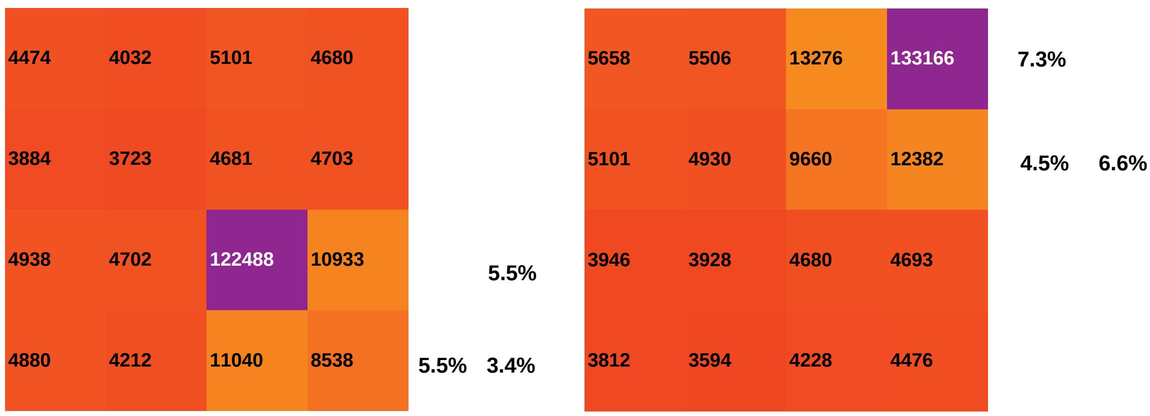

Figure 6. Cross talk for selected channels (violet) of M4 PMTs. The percentage numbers are background corrected.

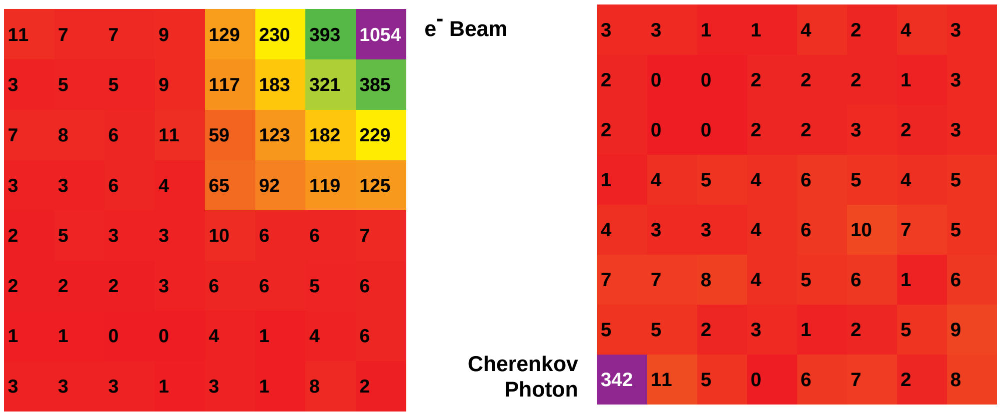

Figure 8. Cross talk using data from testbeam 24. The top-right cell of the 4xM16 base-boards is dominated by the traversing 3 GeV electrons. The lower-left cell is hit mostly by Čerenkov photons.

nearby hits are generated by charged particles transversing the PMT or showers of close electrons.

Figure 6 shows cross talk for two selected M4 base-board channels. The correlated hit pattern agrees with the M16 numbers if one takes the larger cell size into account.

An enhancement of hits in the same channel in a neighboring base-board, caused by cross-talk on the readout cable, could not be detected when analyzing the 2D histograms from each individual base-board.

A similar cross-talk display (Figure 8) produced from data taken at the RICH in testbeam 24 illustrate the difference between hits caused by transversing charged particles and true single photons. The beam electrons, which pass near the top right M16 PMT (see also Figure 2) clearly produce correlated hits in a radius of about 20 mm around the beam spot. The cell diagonally opposite of the beam spot can only be hit by single Čerenkov photons. The adjacent cells don't show any access hits over background.

Conclusions

The three sets of test runs (testbeams 21 and 24, HERA-B) showed that the RICH PMT read-out system can work reliably in different environments. The photons produced in the Plexiglas radiator sheets are too few to be useful for a more detailed analysis. The HERA-B data, due to their high statistics, are helpful to detect differences in PMT and ASD08 response.

We need to understand and fix the observed variations in response in the PMTs and the ASD08 cards. We probably don't have to worry much about cross-talk in the readout chain.

The repetition of events which was found in both setups, HERA-B and testbeam, seems to occur randomly and needs to be investigated. The stuck last byte in each FED daughter card was a problem in the HERA-B setup where a longer SHARC link was used.

The next logical step is to continue the tests at electron test-beam 24, using our partially C_4F_{10} filled radiator and also incorporate the three lens modules we have from NU. Using this setup we should try to improve our estimate on the photon yield we expect at HERA-B.