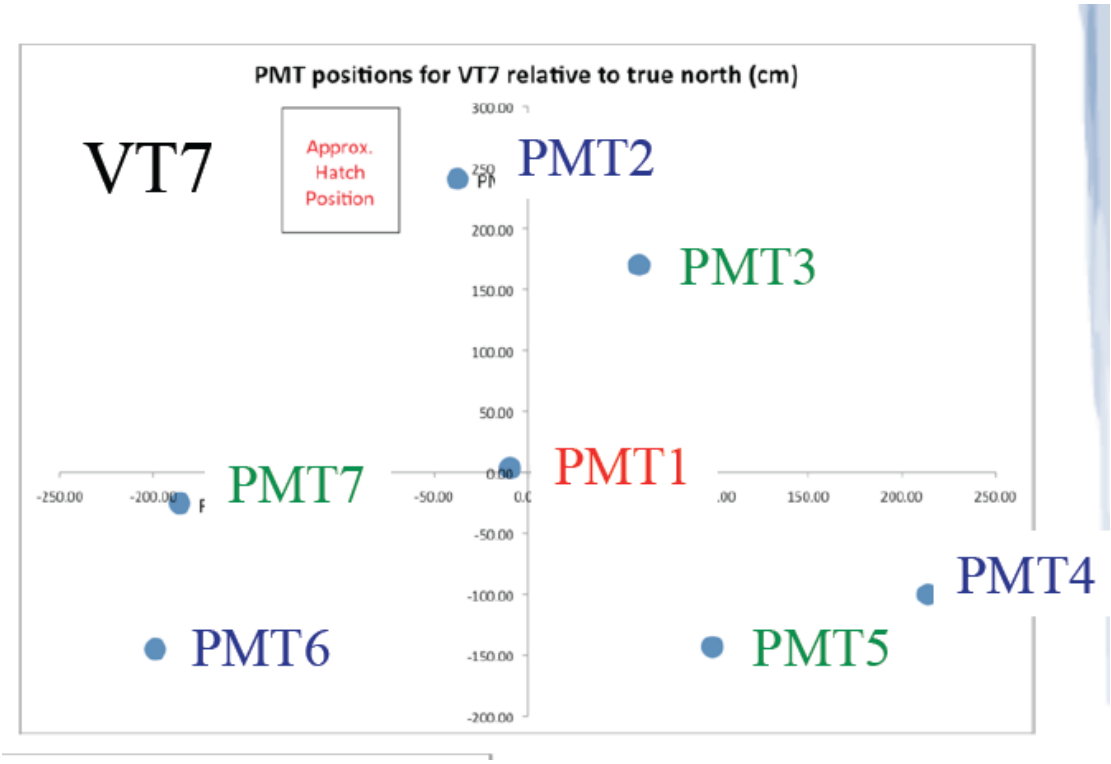
Muon measurements in VAMOS

V. Grabski, A. Sandoval

On April 4-6 2012 we took data with a FADC system of 4 PMTs of the VAMOS VT7 water Cherenkov detector.

Selected were the central PMT (PMT1) and the three PMTs in the inner triangle: PMT3, PMT5 and PMT7.

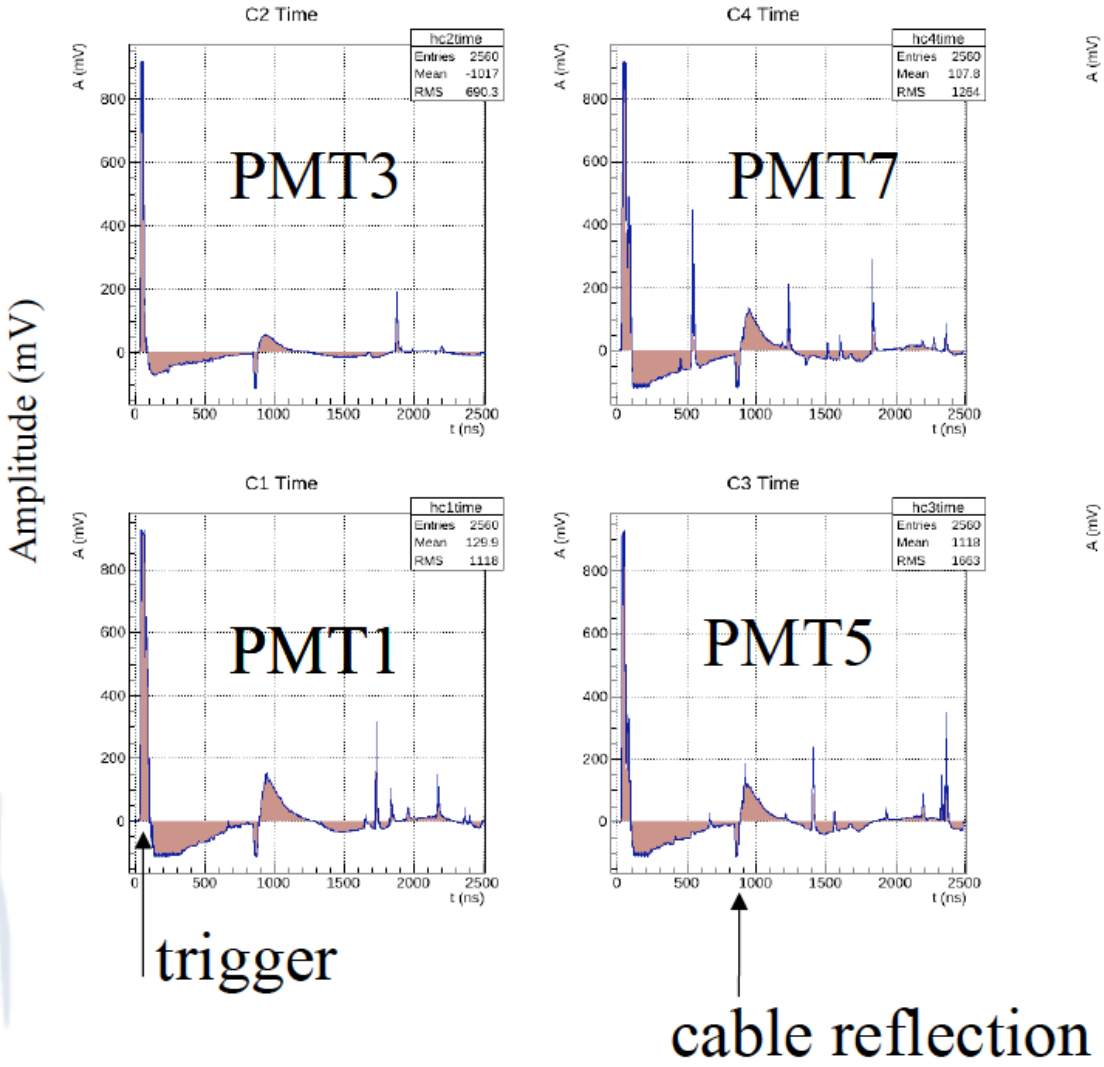


The FADC system with 4 channels samples the shape of the analog signals every 1 ns in a time window of 2.5 μs. The system is sampling continuously in a circular buffer and a trigger signal initiates the readout of all 4 buffers. A variable delay between the start of the readout and the trigger signal allows the system to initiate the sampling of the signals a fixed time before the trigger. The polarity of the signals is inverted by the FADC.

In this tests the 4 PMTs had the same voltage of 1830V but different gains. The trigger signal was provided by the central PMT1 with a threshold of 5 mV, well below the 1 pe (photo electron) pulse height. The sampling is setup to start 30 ns before the trigger signal arrives. We introduced a deadtime of 5 ms in order to take 200 Hz of data and stored it to disk.

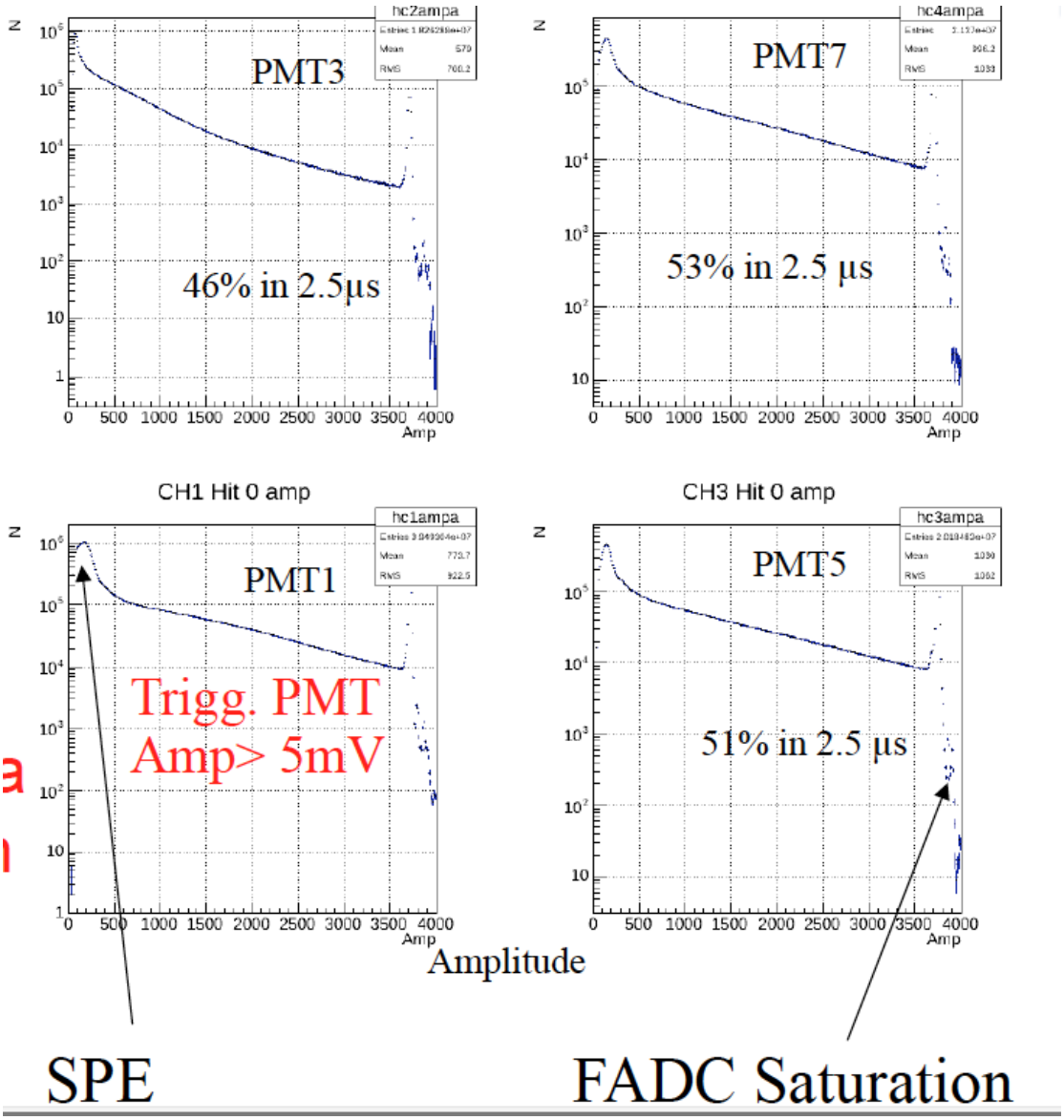
The signal shapes of the 4 PMTs for one event that we think is a vertical muon are shown in the figure. They start with the signal from the Cherenkov light produced by the particle in the water of the tank. It is followed by an overshoot

(here negative) for ~600ns that balances the charge, then by a reflection of the signal due to the mismatch of the impedances of the anode signal and the FADC. The arrival time is given by twice the cable length. This is followed by an overshoot in this case positive. There are also afterpulses arriving at random times.

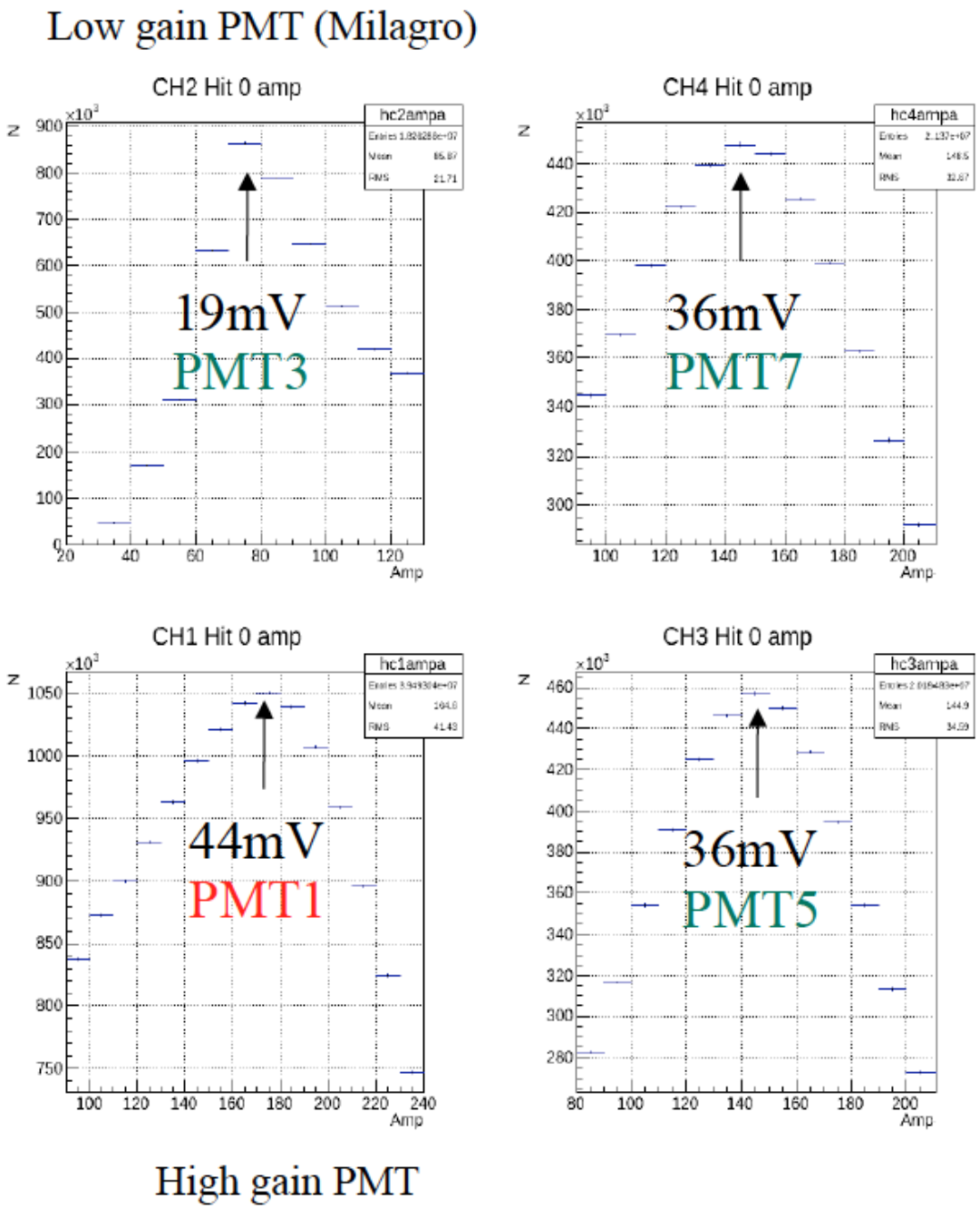


From the pulse shape we determine the arrival time, the amplitude and the charge, this by integrating the amplitude over the width of the signal. The FADC is calibrated in mV.

The most probable signal we observe is a single pe. This is shown in the amplitude spectra with no other bias than a pulse >5mV in PMT1.



A zoom on the peak is shown. It turned out that at the same voltage PMT1 had a higher gain, which was confirmed by the Milagro data sheet for this PMT. Also PMT3 was known to have lower gain.



With the trigger on PMT1 we found that PMT3 had 46% of the time a signal >5mV, PMT5 in 51% of the time and PMT7 in 55% of the time.

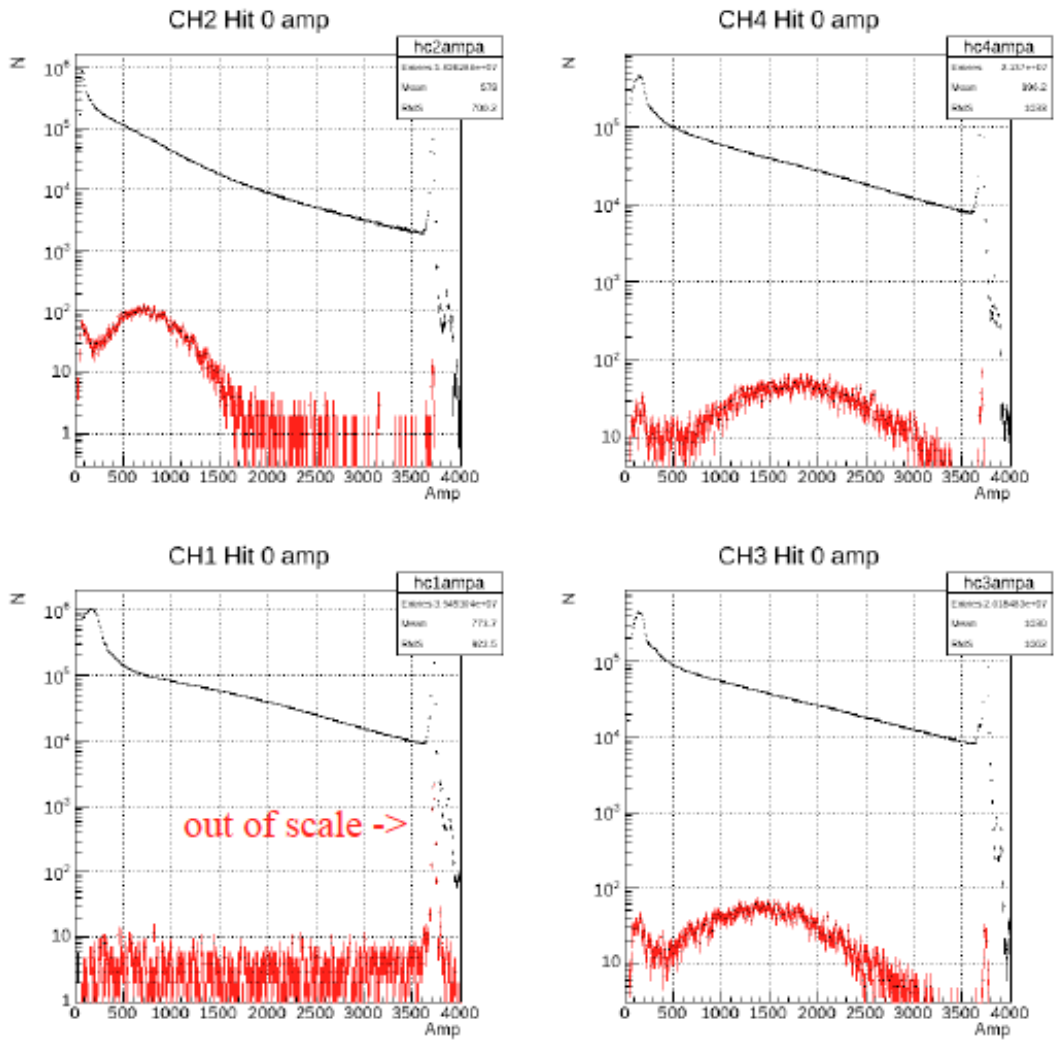
Vertical Centered Muons

If on this data we select a 4-fold coincidence and request that the time between the signals to be less than 2 ns we expect to select vertical centered muons. (This cut is actually abs(time difference)<2ns, so the time spread is 4ns)

We observe a clear muon peak in PMT3, PMT5 and PMT7 while the amplitudes in PMT1 are mostly saturated, what would be expected if the muon passes nearby.

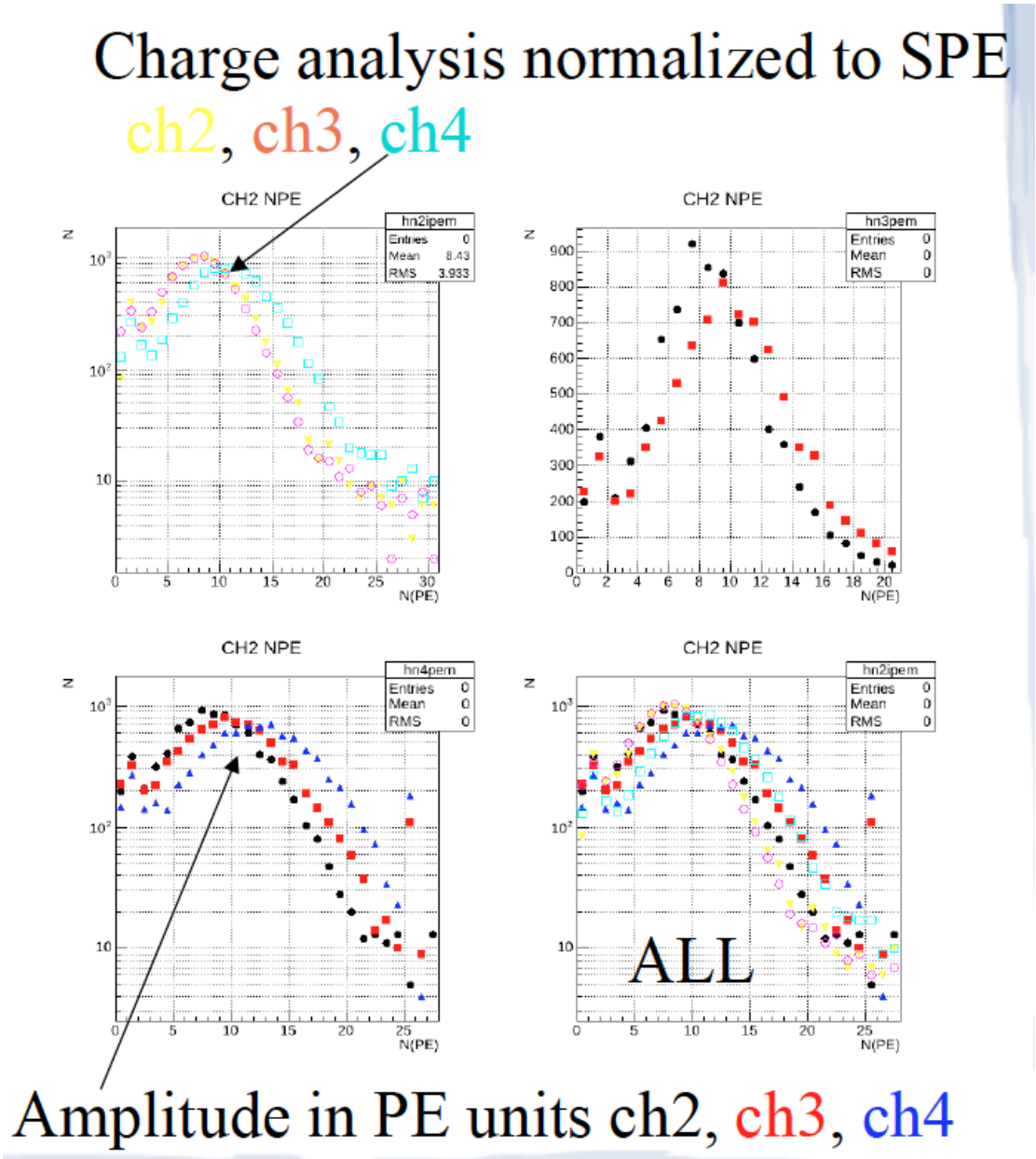
— Amplitude spectra

— 4-Coincidence in 2ns window



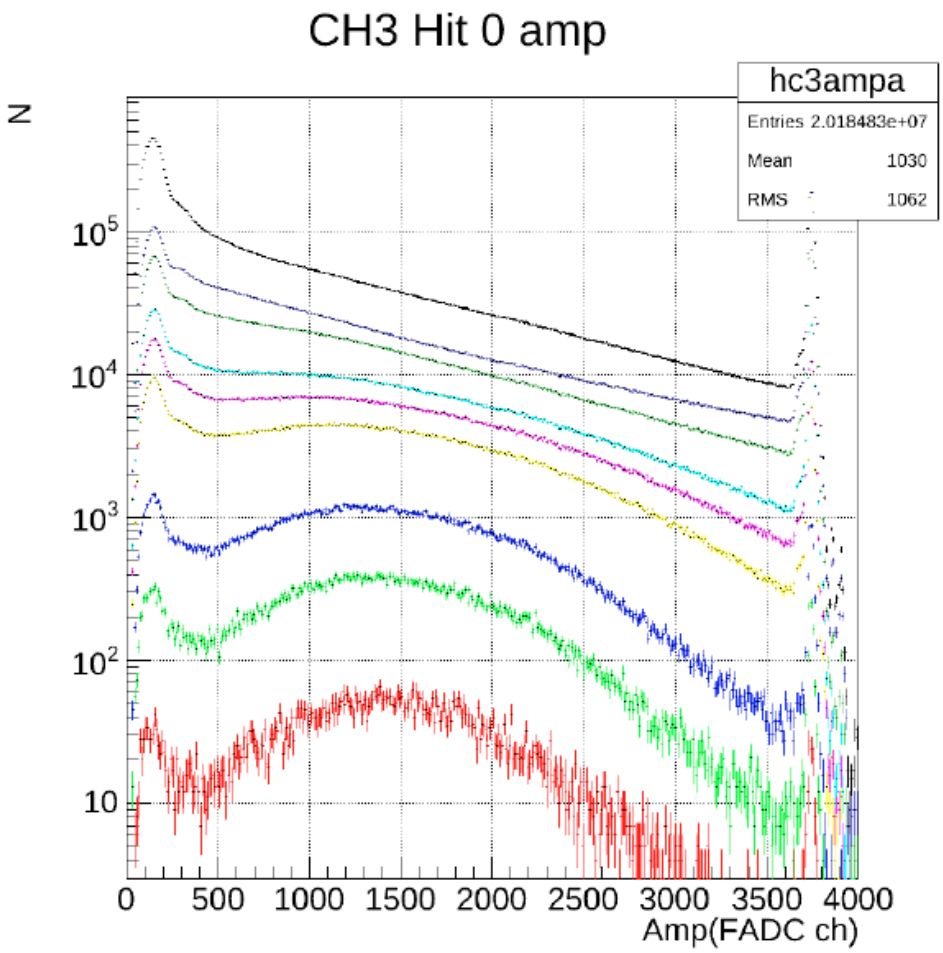
As we know where the single pe peak is, both in amplitude and in charge, we can transform the spectra of the outer PMTs to a pe scale. On the top left it is shown for the analysis using the integrated charge, on the bottom left using the amplitude information. The top right is the charge spectra is shown in a linear scale and the bottom right shows the spectra of both the charge and amplitude analysis together.

We see that central vertical muons produced 10 pe in the PMTs of the inner triangle.

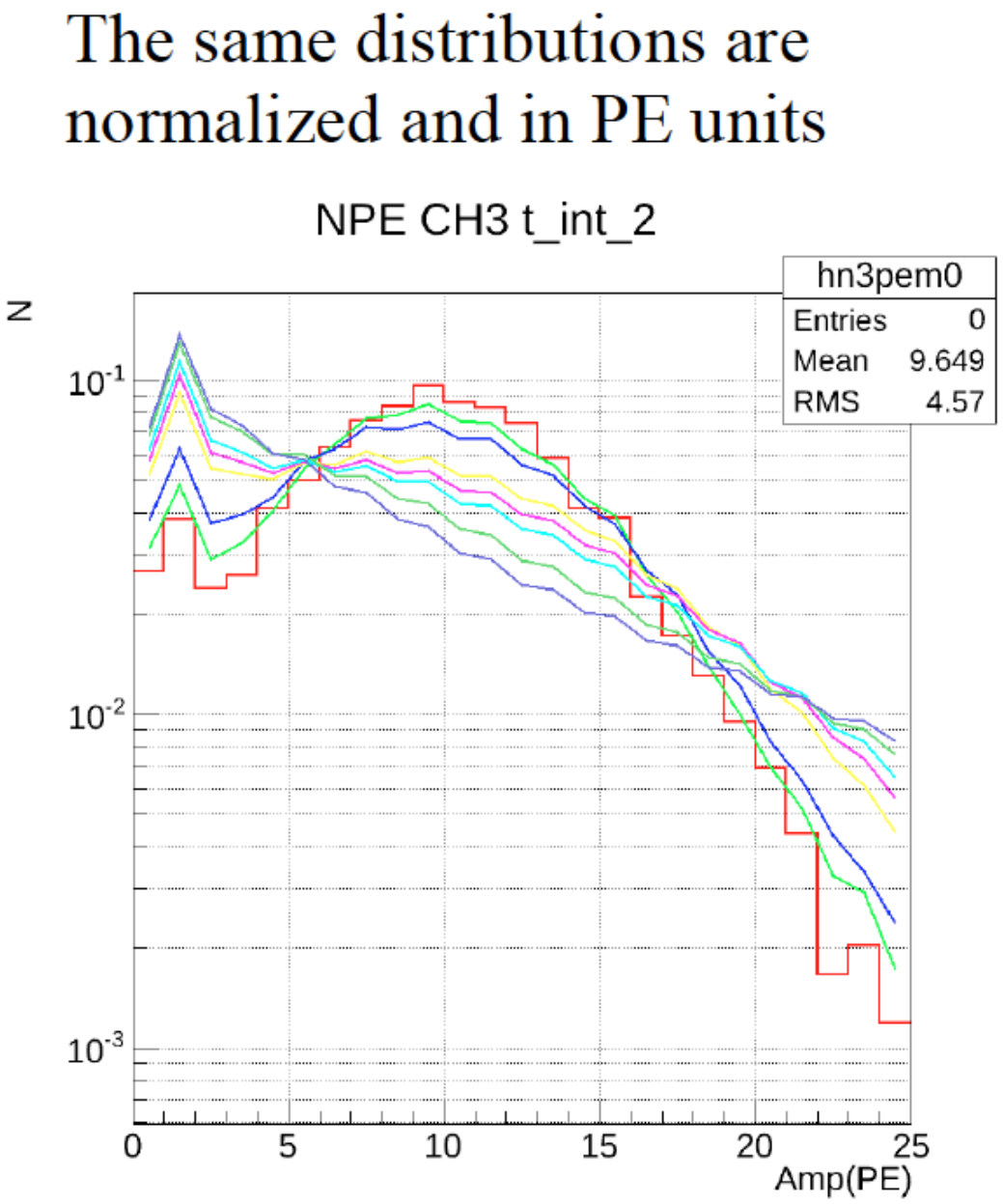


We studied how the signals change with the time with of the coincidence window. This is shown for PMT3 in the amplitude spectra in the figure. We see that the muon peak starts appearing at a time diference of 8 ns. The peak does not move as the window becomes shorter.

4 fold coincidences
Time window 40,20,14,10,8,6,4,2, ns



These spactra can be transformed to a pe scale and they are shown normalized in the figure.



Summary

Data was taken with a FADC system of 4 channels for the VAMOS VT7 detector. It is shown that vertical, centered muons can be selected by requiring a 4 fold coincidence between the central PMT and 3 outer PMTs with the signals arriving within a short time of each other (< 8 ns). In this case the outer PMTs have a clear muon peak of 10 photo electrons while the central PMT has a saturated signal.