Appendix A

Behavior of a Constant Fraction Discriminator

Constant Fraction Discriminators (CFD) were used for PM3 and PM4 in order to reduce time walk. Looking at the time walk of PM4 in Figure 5.8, a clear time walk (Δt_{PM4}) shows up for low ADC values, while for ADC values larger than 200 the Δt_{PM4} is almost independent of the ADC value. The CFD seems to behave like a normal discriminator for ADC values smaller than 200. Note that the time walk for ADC > 200 is less than 100 ps (apart from the last point), which is within specification of the Ortec type 934 CFD [125] (150 ps).

The dual behavior can be explained by looking in some detail at the operation of a CFD. Figure A.1 shows the basic functionality of an Ortec type 934. The input signal

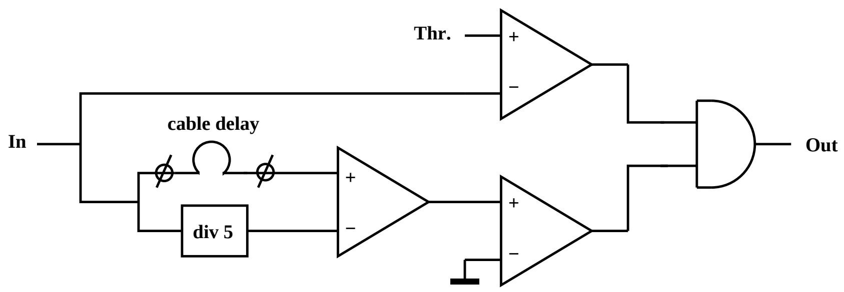

Figure A.1: *Basic functional diagram of a constant fraction discriminator.*

from the photomultiplier is supplied to two circuits, a normal (threshold) discriminator and a constant fraction discriminator. An output pulse is produced from the logic AND of the normal discriminator and the CFD. The output timing of the normal discriminator shows time walk and it should only act as enable for the CFD-output.

The operation of the CFD part is explained with the help of Fig. A.2. The input signal is split in two parts. One part is attenuated by a factor 5 and subtracted from the delayed input pulse. The amount of delay is selectable by cable. Figure A.2 shows that the resulting bipolar signal crosses the baseline at a fixed, but selectable, time with respect to the start of the pulse. The operation principle of the CFD part does not depend on the selected cable delay. However, the cable delay should be chosen such that the output of the CFD determines the timing of the logic AND. If the cable delay is

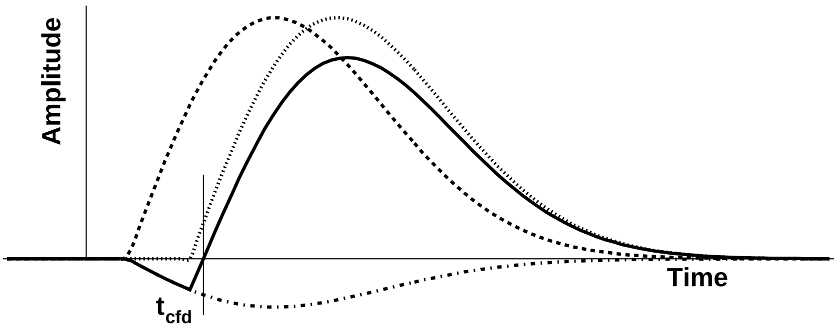

Figure A.2: *Operation of the* CFD*. The input pulse (dashed curve) is delayed (dotted) and added to an attenuated inverted pulse (dash-dot) yielding a bipolar pulse (solid curve). The output of the* CFD *fires when the bipolar pulse changes polarity which is indicated by time* $t_{\rm cfd}$.

too short, the unit will work as a normal discriminator for signals with a low amplitude because then the output of the normal discriminator fires later than the CFD part. This effect is depicted in Figure A.3. The two dashed curves are the signals going into the

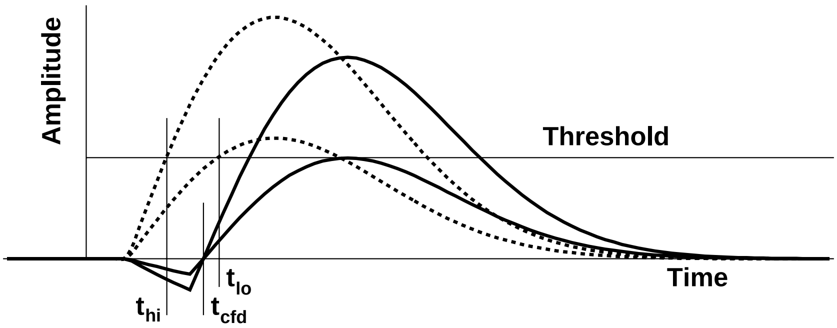

Figure A.3: *The moment at which the threshold discriminator fires depends on the amplitude of the pulse. If the cable delay of the* CFD *is too short, the* CFD *fires too early* ($t_{\rm cfd}$)*. For small input pulses, the timing is determined by the threshold discriminator and not by the* CFD *part.*

threshold discriminator whose output exhibits time walk. For a small input pulse, the threshold discriminator fires at $t_{\rm lo}$ which is later than $t_{\rm cfd}$, and as a result the output of the CFD unit shows time walk. For large input pulses, the threshold discriminator output fires earlier than $t_{\rm cfd}$, and no time walk will occur.

Hence, the observed behavior of PM3 and PM4 is probably caused by a too short cable delay. Selection of the cable delay for the CFD was done *before* the experiment with the help of a radioactive source using short coaxial cables for the connection of the photomultiplier to the CFD. At CERN long coaxial cables ($>$ 50 meter) were used which give rise to dispersion of the signals. Dispersion will increase the peaking time of the signals which should have been compensated by increasing the length of the delay cable. This retuning of the delay cables was accidentally omitted.