Definitions of the term “Dead-time”:

a) Detector dead-time (ddt)

The registration of an individual particle hit on a detector with recovery of all generated signal pulses requires a certain time period, here called ***detector dead-time (ddt)***, before the next particle hit shall occur.

A *single hit (event)* is defined as a particle detection event consisting of 1 impacting particle and which has

condition 1) no preceding particle hit within the *detector dead-time* and
condition 2) no later particle hit within the *detector dead time*.

The *detector dead-time* for our position sensitive detectors is mostly determined by the maximum propagation time of signals on the delay-lines, typically ranging from 40ns 110ns (detail depending on the detector’s actual active area).

In a *multi-hit (event)* condition 2 is not given. As a consequence information (position, arrival time) at least for one of the hits can get lost or distorted when a standard *delay-line detector* (***DLD***) is employed.

If *multi-hit events* enter into a data set unrecognized they can ruin this event’s information content. <u>All</u> of our delay-line detectors can distinguish *single hit* (“good”) events from *multi-hit* events and can disclose those during data analysis (e.g. for filtering out). Using a ***Hexanode*** *delay-line detector* it is (under favorable conditions) even possible to recover information on some or all individual particle hits within a *multi-hit event.* Our software uses a special reconstruction algorithm to recover lost signals by using the information from other signals. Since this algorithm consumes a considerable amount of CPU-processing power it is recommend to us it only during off-line data analysis.

This is, however, restricted to *multi-hit* events when not more than 2 particles are closer in time than the detector dead-time limit, even then, resolution may be affected for certain relative time/position coordinate combinations of the individual particles. However, in most cases **the Hexanode detector’s dead-time for a <u>pair</u> of particles (2 hits only) may even be as low as zero.** A true zero dead time however will onyl be achieved if the 2 particles are well separated in space (> 15mm).

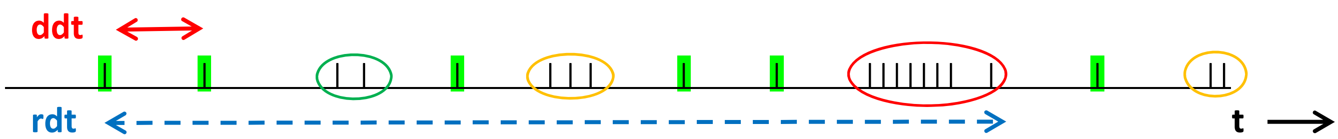

Figure: all green shaded hits are classified as “good” single hit events because they are separated by > ddt (see red double-arrow) from other hits and thus can be easily processed by a DLD. From the circled multi-hit sequences such like the green-marked require a Hexanode readout for complete information recovery for each particle. In case of triple hits or very close double hits (yellow circled) event recovery may not always be perfect, not work at all for “dense” high-multiplicity events (red circled).

b) Read-out dead-time (rdt)

While the *detector dead-time* is solely determined by detector properties (which include certain front-end electronic circuits) a *data throughput limit R* of the digital read-out devices (ADC or TDC) may introduce an additional ***read-out dead-time (rdt)*** so that some of the detected particles will not be registered. R is typically about 1 MegaCounts/s and not only determines the maximum event detection rate (speed of measurement) but introduces effectively a (mean) *read-out dead-time* of 1/R (typically 1 µs). This can be significantly larger than the *detector dead time* and will especially affect experimental situations when particles arrive in "bunches". The detector's own capability of recovering information of several particles arriving within this mean *read-out dead-time* window (see blue double-arrow in the figure above) may get lost.

However, modern read-out devices usually feature internal short-term data buffering. So information for several particles can be recorded with very low or no dead-time. **Assuming sufficient buffering capability and low-enough <u>mean</u> particle rate (< R) the *detector dead-time* will remain the only limiting parameter for the experiment.**

c) Electronic dead time (edt)

A delay line detector produces 5 signals for each impacting particle. The Hexanode produces 7 signals. These signals are amplified and processed either in a CFD unit or (if sampled with a fast digitizer) processed by software in a similar way how a CFD does it. Identifying 2 signals becomes difficult if the signals come so close to each other so that they begin to overlap. Typical dead times of CFDs are 8 ns to 25 ns. Since these times are significantly shorter than the detector dead time (ddt) they do not affect the detector dead time. However, in multi-hit events the electronic dead time (edt) plays an important role. A short edt is desirable because this reduces the required minimum distance between 2 simultaneous hits (dead time hole). If only single hits shall be measured then the edt does not need to be considered.