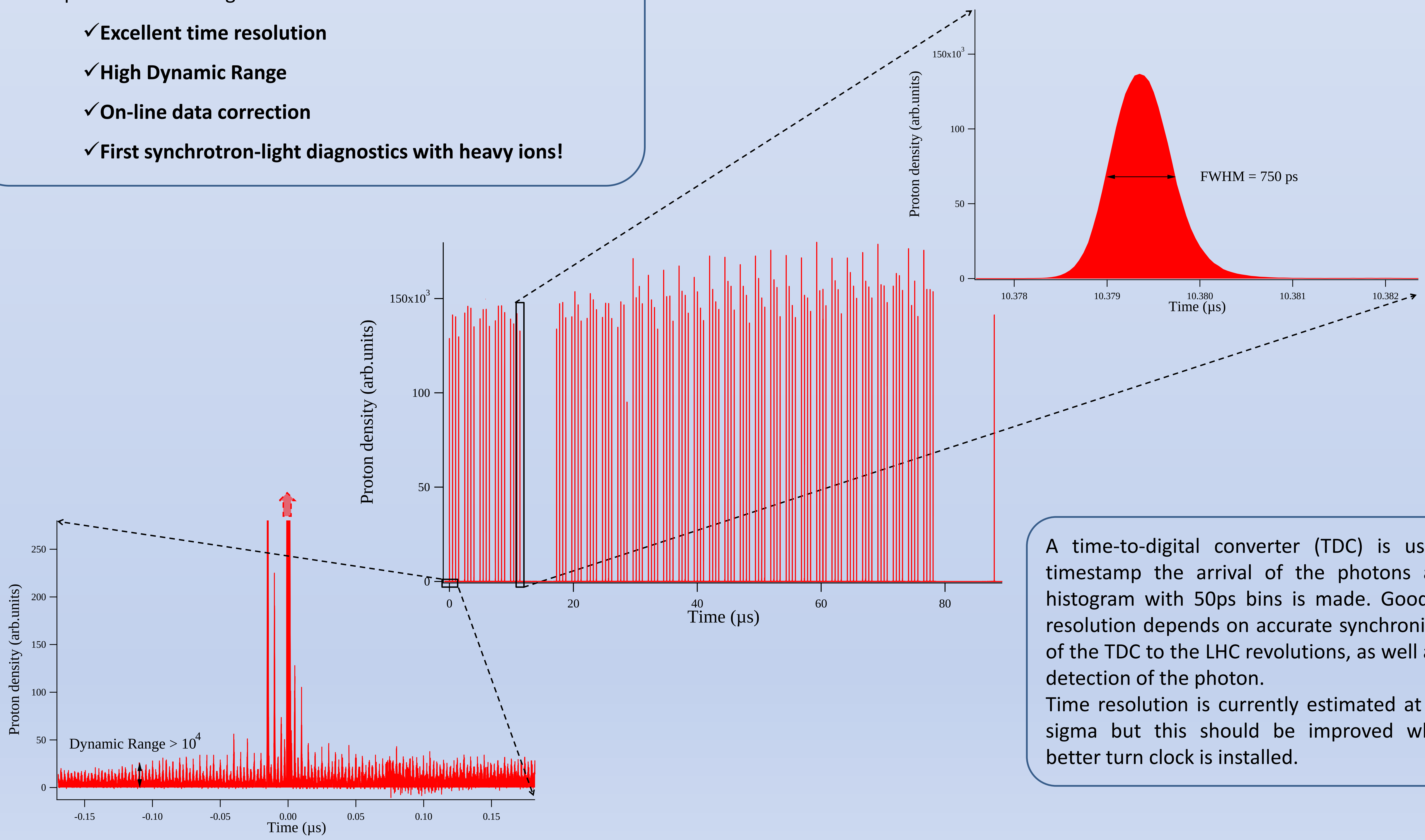
Longitudinal Profile Measurements for the LHC

A. Jeff (CERN & University of Liverpool)
A. Boccardi, E. Bravin, T. Lefevre, A. Rabiller, F. Roncarolo (CERN)
C. Welsch (Cockcroft Institute)

Longitudinal profile measurements allow measurement of bunch shape and length as well as the characterization of ghost bunches.

The Longitudinal Density Monitor (LDM) for the LHC is based on single-photon counting of synchrotron light by an avalanche photo-diode operated in the Geiger mode.

- ✓**Excellent time resolution**
- ✓**High Dynamic Range**
- ✓**On-line data correction**
- ✓**First synchrotron-light diagnostics with heavy ions!**



A time-to-digital converter (TDC) is used to timestamp the arrival of the photons and a histogram with 50ps bins is made. Good time resolution depends on accurate synchronisation of the TDC to the LHC revolutions, as well as fast detection of the photon.
Time resolution is currently estimated at 90 ps sigma but this should be improved when a better turn clock is installed.

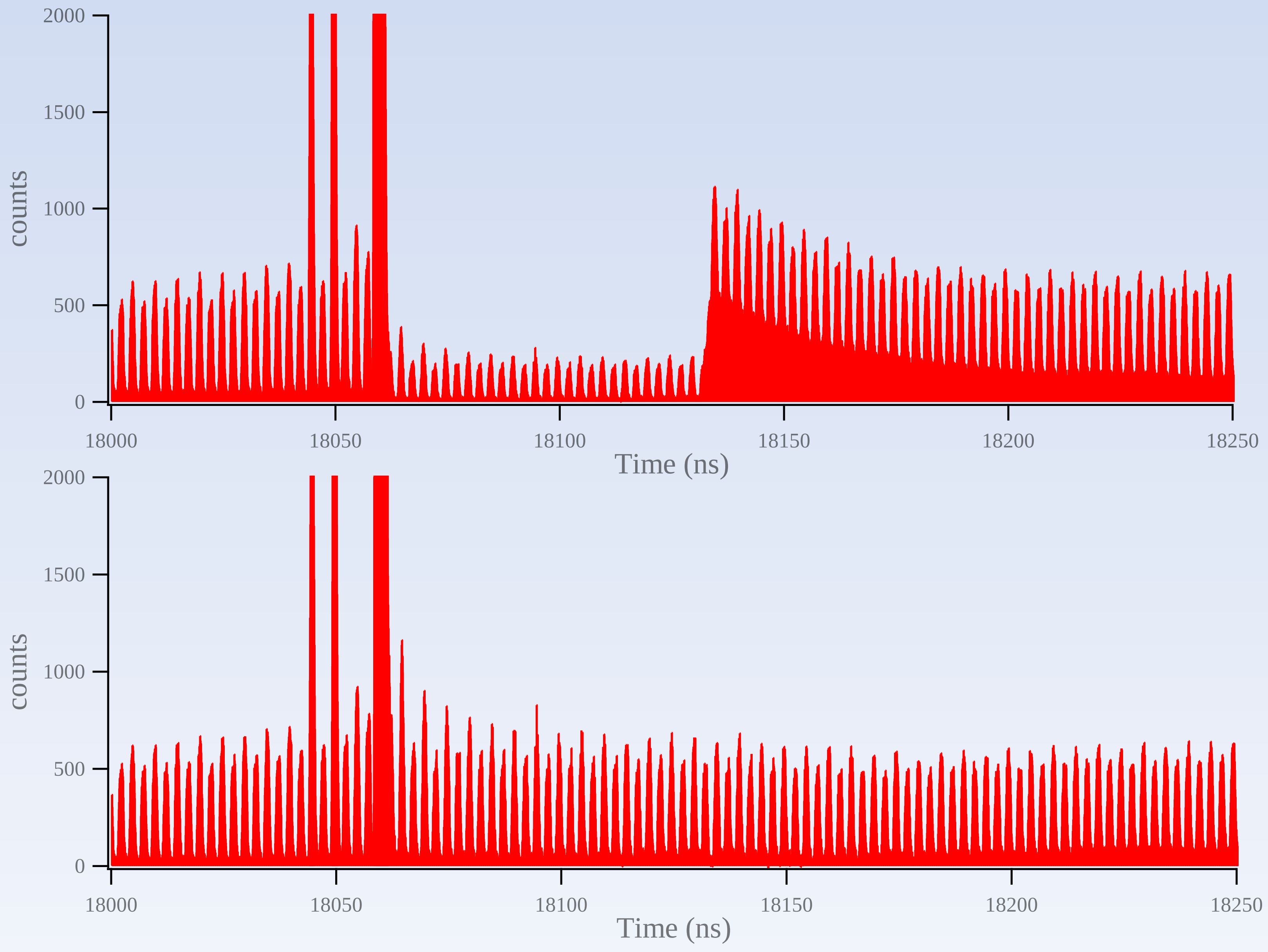
The use of APDs in Geiger mode gives sufficient sensitivity and good time resolution, but also leads to some problems. The APD has a certain deadtime after each count during which it is not sensitive; at the end of this deadtime it can also generate a false count (afterpulse). These factors limit the dynamic range achievable because they limit the maximum count rate and introduce noise.
Since the deadtime is longer than the bunch length, the detector is more likely to be ready to receive a photon at the start of the bunch than at the end, as the detector will be in its deadtime if a photon has been received at any time earlier in the bunch. This causes a skewing of the signal towards the front of the bunch. However, it can be corrected. The number of photons C_i counted by an ideal detector (i.e. one with no deadtime) would be

$$C_i = \frac{x_i}{P(up)_i} = x_i \frac{N}{N - \sum_{j=i-d}^{i-1} x_j}$$

where x_i is the number of counts given by the non-ideal detector in bin i over N turns.
A second correction must then be carried out to account for the possibility of two photons arriving in the same bin. The emission of synchrotron radiation is a stochastic effect involving a very large number of particles, each with a very small chance of emitting a photon within the acceptance of the detector, the photons can thus be considered to have a Poissonian distribution. The expected number of photons, which is now directly proportional to the proton density, is then given by

$$\lambda = -\ln\left(1 - C_i/N\right)$$

Afterpulsing is found to follow a double exponential decay and can thus be eliminated by subtraction of two infinite impulse response (IIR) filters. The weights and time constants of the two IIRs are found by experiment.



An example profile taken with ions at 3.5 Z TeV, showing the effects of deadtime and afterpulsing (above) and after correction (below)

adam.jeff@cern.ch