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Determination of the effective observation time

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Abstract

Contents

1 Introduction

For measuring absolute fluxes of cosmic rays particles the effective observation time T_{eff} has to be known. Due to the dead time of the detector T_{eff} is not identical to the total observation time T_0. In this note it is shown how T_{eff} can be determined.

2 Distribution of time differences in a Poisson process

The distribution of cosmic ray events in time follows a Poisson distribution. In a Poisson process, the probability for observing no events in the time interval $(0,\ t+\mathrm{d}t)$ is equal to the probability for observing no events in $(0,\ t)$ and no events in $(t,\ t+\mathrm{d}t)$:

$$P_0(0,\ t+\mathrm{d}t) = P_0(0,\ t)\cdot P_0(t,\ t+\mathrm{d}t) \ = \ P_0(0,\ t)\cdot[1-P_1(t,\ t+\mathrm{d}t)] \tag{1}$$

$$= P_0(0,\ t)\cdot[1-\lambda\cdot\mathrm{d}t] \tag{2}$$

where λ is the intrinsic rate at which the probability of a single event increases as the length of $\mathrm{d}t$ increases.

It follows

$$\frac{dP_0(0,\ t)}{\mathrm{d}t} \ = \ -\lambda\cdot P_0(0,\ t) \tag{3}$$

or $P_0(0,\ t) \ = \ A\cdot\exp(-\lambda\cdot t)$. The normalization condition $\int_0^\infty P_0(0,\ t)\cdot\mathrm{d}t \ = \ 1$ yields

$$P_0(0,\ t) \ = \ \lambda\cdot\exp(-\lambda\cdot t) \tag{4}$$

$P_0(0,\ t)$ is the probability distribution for time differences t between successive events, where the average event rate is λ. For convenience $P_0(0,\ t)$ will be denoted by $P(t)$.

3 Distribution of time differences in an experiment

3.1 Ideal detector

In the ideal case of a detector with vanishing dead time the distribution of time differences t between successive events is, according to (4),

$$\frac{\mathrm{d}N_{id}}{\mathrm{d}t} \ = \ N_0\cdot\lambda\cdot\exp(-\lambda\cdot t) \tag{5}$$

where λ is the ideal average event rate and N_0

$$N_0 \ = \ \int_0^\infty \frac{\mathrm{d}N_{id}}{\mathrm{d}t}\cdot\mathrm{d}t \tag{6}$$

is the total number of events (see Fig. 1). The total observation time is

$$T_0 \ = \ \int_0^\infty t\cdot\frac{\mathrm{d}N_{id}}{\mathrm{d}t}\cdot\mathrm{d}t \ = \ \frac{N_0}{\lambda} \tag{7}$$

3.2 Real detector with fixed dead time

A real detector, which in principle could record all those events which are recorded by an ideal detector, will often not record an event because the detector is still busy processing the data from the previous event. This phenomenon is important at high event rates and is called 'dead time'.

If the detector has a fixed dead time d then after occurence of an event which is recorded all events that happen within the time d after that will not be recorded. Therefore, and because the average event rate is λ, the average loss of events per recorded event is (λd). If the total number of recorded events is denoted as $N_{d,0}$ it follows that

$$\frac{N_0 - N_{d,0}}{N_{d,0}} = \lambda d \qquad \text{or} \qquad N_{d,0} = \frac{N_0}{1 + \lambda d} \tag{8}$$

Because of the loss of events also the distribution of time differences between successive events is altered. In Fig. 2 four successive events are plotted on the time scale, of which only events 0 and 3 are recorded whereas events 1 and 2 are lost due to the dead time. In this example the 3 time differences t_1, t_2 and t_3 are replaced by the single time difference t.

The probability $R(t) \cdot \mathrm{d}t$ of getting a time difference t in the interval $(t,\ t + \mathrm{d}t)$, if the dead time is d, can be written as a sum of the contributions $\widetilde{P_n}(t)$ corresponding to the cases where in the time interval d n events $(n = 0, 1, 2, 3, ...)$ happen :

$$\begin{aligned}
R(t) \quad &= \quad \sum_{n=0}^{\infty} \widetilde{P_n}(t) \qquad (9) \\
&= \quad P(t) \\
&\quad + \int_0^d P(t_1)\mathrm{d}t_1 \cdot P(t - t_1) \\
&\quad + \int_0^d P(t_1)\mathrm{d}t_1 \int_0^{d-t_1} P(t_2)\mathrm{d}t_2 \cdot P(t - t_1 - t_2) \\
&\quad + \ ..... \\
&\quad + \int_0^d P(t_1)\mathrm{d}t_1 .... \int_0^{d-\sum_1^{n-1} t_i} P(t_n)\mathrm{d}t_n \cdot P(t - \sum_1^n t_i) \\
&\quad + \ .....
\end{aligned}$$

$$\begin{aligned}
&= \lambda \cdot \exp[-\lambda t] \cdot \left\{ 1 \ + \ \lambda d \ + \ \frac{(\lambda d)^2}{2!} \ + \ \frac{(\lambda d)^3}{3!} \ + \ ... \ + \ \frac{(\lambda d)^n}{n!} \ + \ ... \right\} \\
&= \lambda \cdot \exp[-\lambda(t - d)] \qquad\qquad (\text{with } t > d) \qquad (10)
\end{aligned}$$

$$\int_d^\infty R(t) \cdot \mathrm{d}t = 1 \tag{11}$$

The relative loss of events due to the dead time d can be calculated as

$$\frac{N_0 - N_{d,0}}{N_{d,0}} = \int_d^\infty \sum_{n=0}^{\infty} n \cdot \widetilde{P_n}(t) \cdot \mathrm{d}t \ = \ \lambda d \tag{12}$$

which is identical to (8).

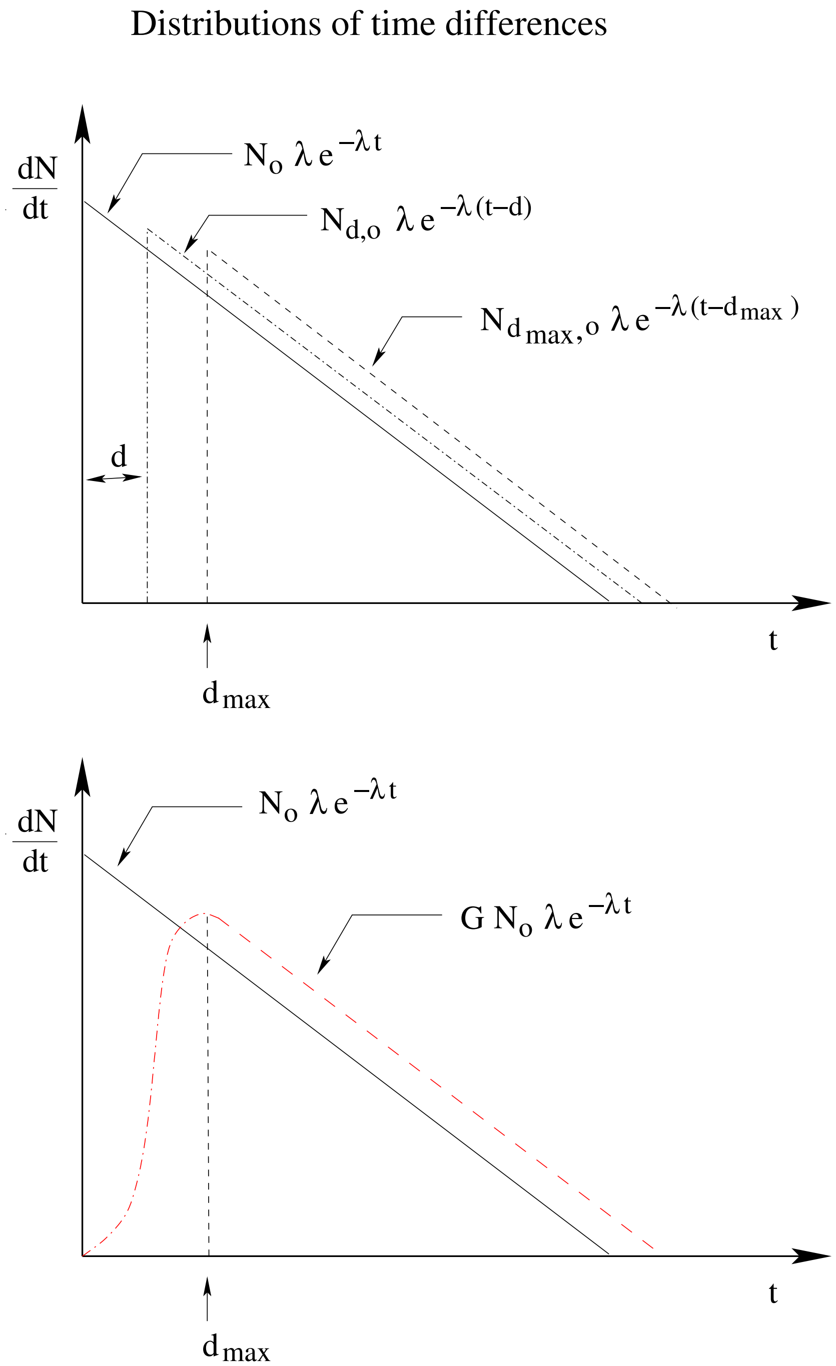

Figure 1: Distributions of time differences t between successive events. Upper plot : The solid line represents the ideal distribution expected for an ideal detector with zero dead time. The dashed lines are the distributions for fixed dead times d and d_{max} respectively. Lower plot : The solid line represents again the ideal distribution expected for an ideal detector with zero dead time. The dashed curve is an example of the distribution for a real detector, with a distribution of dead times d which extends up to $d = d_{max}$. λ is the ideal event rate, N_0 is the number of events an ideal detector would observe.

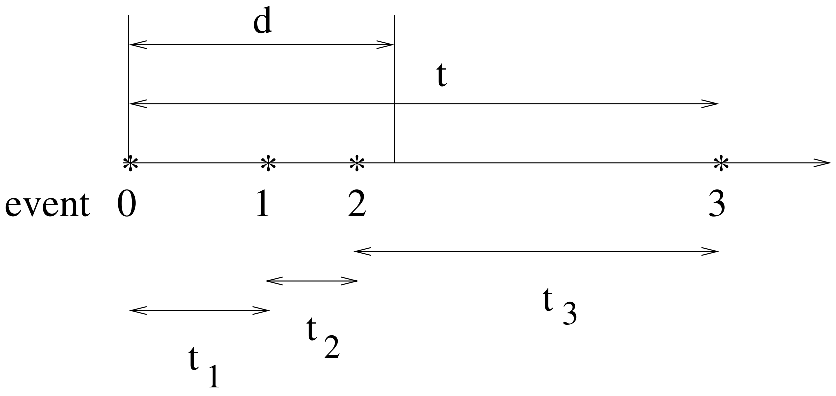

Figure 2: Four events are plotted on the time axis, of which events 0 and 3 are recorded, whereas events 1 and 2 are lost due to the dead time d of the detector. The probability density for this situation to occur is given by $\widetilde{P_2}(t)$ (see eq. (9)).

The new distribution of time differences thus reads (see Fig. 1, upper plot)

$$\frac{\mathrm{d}N_d}{\mathrm{d}t} = \begin{cases} 0 & \text{for} \quad t < d \\ N_{d,0} \cdot \lambda \cdot \exp[-\lambda(t-d)] & \text{for} \quad t > d \end{cases} \qquad \text{with } N_{d,0} \; = \; \frac{N_0}{1+\lambda d} \tag{13}$$

One sees that in the region $t > d$ the distribution $\frac{\mathrm{d}N_d}{\mathrm{d}t}$ is greater than $\frac{\mathrm{d}N_{id}}{\mathrm{d}t}$ by the factor $\frac{\exp(\lambda d)}{1+\lambda d}$.
The total observation time is given by

$$T_d = \int_d^\infty t \cdot N_{d,0} \cdot \lambda \cdot \exp[-\lambda(t-d)] \cdot \mathrm{d}t \; = \; \frac{1+\lambda d}{\lambda} \cdot N_{d,0} \; = \; \frac{N_0}{\lambda} \; = \; T_0 \tag{14}$$

As expected, the total observation time, which is the sum over all time differences, is not altered by the dead time. The constraint $T_d \; = \; T_0$ could also have been used to determine the normalization (8).
The effective observation time, defined as the time in which $N_{d,0}$ events would be recorded by an ideal detector, is

$$T_{eff}^d = \frac{N_{d,0}}{\lambda} \tag{15}$$

The relative loss of events is equal to the relative loss of observation time, which is

$$\frac{N_0 - N_{d,0}}{N_0} = \frac{T_0 - T_{eff}^d}{T_0} \; = \; \frac{\lambda d}{1+\lambda d} \tag{16}$$

The average time difference between successive recorded events becomes

$$\overline{t_d} = \frac{\int_d^\infty t \cdot \frac{\mathrm{d}N_d}{\mathrm{d}t} \cdot \mathrm{d}t}{\int_d^\infty \frac{\mathrm{d}N_d}{\mathrm{d}t} \cdot \mathrm{d}t} \; = \; \frac{T_d}{N_{d,0}} \; = \; \frac{1+\lambda d}{\lambda} \; = \; \frac{1}{\lambda} \; + \; d \tag{17}$$

By the dead time d the average time difference $\frac{1}{\lambda}$ of the ideal distribution is increased by d. The rate of recorded events is

$$\lambda_d = \frac{1}{\overline{t_d}} \; = \; \frac{\lambda}{1+\lambda d} \; = \; \frac{1}{d+\frac{1}{\lambda}} \tag{18}$$

3.3 Real detector with a distribution of dead times

Because the time needed for recording an event is not constant, there will be a distribution of dead times $g(d)$ in a range $0 < d < d_{max}$. In this case the observed distribution of time differences is (see Fig. 1, lower plot)

$$\frac{\mathrm{d}N}{\mathrm{d}t} = \int_0^{d_{max}} g(d) \cdot \frac{\mathrm{d}N_d}{\mathrm{d}t} \cdot \mathrm{d}d \qquad \text{with} \qquad \int_0^{d_{max}} g(d) \cdot \mathrm{d}d \; = \; 1 \tag{19}$$

In the region $t > d_{max}$, where the contribution from each d is proportional to $\exp(-\lambda t)$, $\frac{\mathrm{d}N}{\mathrm{d}t}$ can be written as

$$\frac{\mathrm{d}N}{\mathrm{d}t} = G \cdot N_0 \cdot \lambda \cdot \exp(-\lambda t) \; = \; G \cdot T_0 \cdot \lambda^2 \cdot \exp(-\lambda t) \tag{20}$$

$$\text{with} \quad G \; = \; \int_0^{d_{max}} g(d) \cdot \frac{\exp(\lambda d)}{1+\lambda d} \cdot \mathrm{d}d \; > \; 1 \tag{21}$$

This means that in the region $t > d_{max}$ the distribution $\frac{\mathrm{d}N}{\mathrm{d}t}$ has the same slope as $\frac{\mathrm{d}N_{id}}{\mathrm{d}t}$ and $\frac{\mathrm{d}N}{\mathrm{d}t}$ is greater than $\frac{\mathrm{d}N_{id}}{\mathrm{d}t}$ by the factor G. For reasonable values of λd ($\lambda d \lesssim 1$) G is between 1 and 1.36. The total number of recorded events is

$$N_m = \int_0^{\infty} \frac{\mathrm{d}N}{\mathrm{d}t} \cdot \mathrm{d}t \; = \; \int_0^{d_{max}} g(d) \cdot \mathrm{d}d \int_0^{\infty} \frac{\mathrm{d}N_d}{\mathrm{d}t} \cdot \mathrm{d}t \; = \; N_0 \cdot \int_0^{d_{max}} g(d) \cdot \frac{1}{1+\lambda d} \cdot \mathrm{d}d \tag{22}$$

Due to the loss of events N_m is always less than N_0. The total observation time, however, remains unchanged :

$$T_m = \int_0^{\infty} t \cdot \frac{\mathrm{d}N}{\mathrm{d}t} \cdot \mathrm{d}t \; = \; \int_0^{d_{max}} g(d) \cdot \mathrm{d}d \int_0^{\infty} t \cdot \frac{\mathrm{d}N_d}{\mathrm{d}t} \cdot \mathrm{d}t \; = \; \int_0^{d_{max}} g(d) \cdot T_0 \cdot \mathrm{d}d \; = \; T_0 \tag{23}$$

For the average time difference between successive recorded events one finds

$$\overline{t_m} = \frac{T_m}{N_m} \; = \; \frac{T_0}{N_0 \cdot \int_0^{d_{max}} g(d) \cdot \frac{1}{1+\lambda d} \cdot \mathrm{d}d} \; = \; \frac{1}{\lambda} \cdot \frac{1}{\int_0^{d_{max}} g(d) \cdot \frac{1}{1+\lambda d} \cdot \mathrm{d}d} \tag{24}$$

The rate of recorded events is

$$\lambda_m = \frac{N_m}{T_m} \; = \; \frac{1}{\overline{t_m}} \; = \; \lambda \cdot \int_0^{d_{max}} g(d) \cdot \frac{1}{1+\lambda d} \cdot \mathrm{d}d \tag{25}$$

3.4 Experimental determination of the effective observation time

In the experiment the distribution $\frac{\mathrm{d}N}{\mathrm{d}t}$ of time differences t can be measured, and thus also N_m and T_m by the integrations (22) and (23) respectively. The ideal event rate λ can be determined by fitting the experimental distribution with the expression $[B \cdot \lambda \cdot \exp(-\lambda \cdot t)]$, in the region $t > d_{max}$, where $\frac{\mathrm{d}N}{\mathrm{d}t}$ exhibits an exponential behaviour. d_{max} can be found as the time difference above which $\frac{\mathrm{d}N}{\mathrm{d}t}$ behaves like an exponential. B and λ are free parameters to be determined in the fit. According to (20) B can be interpreted as $B = G \cdot N_0 = G \cdot \lambda \cdot T_m$. With the known values of B, λ and T_m the value of G can be derived.

Knowing N_m, T_m and λ, and using $T_m = T_0 = \frac{N_0}{\lambda}$, the observed event rate λ_m, the effective observation time T_{eff} and the fraction r_{dead} of lost observation time can be computed :

$$\lambda_m = \frac{N_m}{T_m} \tag{26}$$

$$T_{eff} = \frac{N_m}{\lambda} \tag{27}$$

$$r_{dead} = \frac{T_0 - T_{eff}}{T_0} = \frac{N_0 - N_m}{N_0} = \left(1 - \frac{\lambda_m}{\lambda}\right) \tag{28}$$

T_{eff} is defined as the time within which N_m events would be recorded by an ideal detector.

4 Subsamples

In the previous section the distributions were derived for time differences between **all recorded** events. The distributions are different if subsamples of the recorded events are considered.

A subsample A_α (B_α) of a sample A (B) of recorded events may be defined by applying certain cuts on the events of sample A (B). These cuts are assumed to cause a random selection of events as far as the event time is concerned. The cuts may very well select special types of events, for example high energies, low impact parameters, long events, protons, etc. The probability that a recorded event of sample A (B) belongs to sample A_α (B_α) is denoted by α, the probability that it does not belong to sample A_α (B_α) is denoted by $\beta = 1 - \alpha$.

4.1 Zero dead time

In the case of zero dead time (ideal detector) the probability distribution of time differences between events of sample A_α is

$$Q(t) = \alpha\lambda \cdot \exp[-\alpha\lambda \cdot t] \tag{29}$$

because the events of sample A_α follow a Poisson distribution with the average event rate $(\alpha\lambda)$. The total number of events of sample A_α, recorded in the time T_0, is $N_{\alpha,0} = (\alpha N_0)$.

4.2 Finite dead time

For the case of a finite fixed dead time d, the distribution of time differences between events of a subsample B_α of the total sample B of recorded events is derived from the distribution (10) of all recorded events. The probability density $S(t)$ of getting a time difference t between two successive events of sample B_α is written as a sum of contributions $\widetilde{R_n}(t)$ corresponding to the cases where in the time interval t there are n recorded events, all of which do not belong to sample B_α (see Fig. 3) :

$$\begin{aligned} S(t) = & \sum_{n=0}^{\infty} \widetilde{R_n}(t) \qquad (30) \\ = & \alpha R(t) \\ & + \int_d^{t-d} \beta R(t_1)\mathrm{d}t_1 \cdot \alpha R(t-t_1) \\ & + \int_d^{t-2d} \beta R(t_1)\mathrm{d}t_1 \int_0^{t-t_1-d} \beta R(t_2)\mathrm{d}t_2 \cdot \alpha R(t-t_1-t_2) \\ & + \ldots\ldots \\ & + \int_d^{t-nd} \beta R(t_1)\mathrm{d}t_1 \cdot \int_d^{t-t1-(n-1)d} \beta R(t_2)\mathrm{d}t_2 \ldots\ldots \int_d^{t-\sum_1^{n-1} t_i - d} \beta R(t_n)\mathrm{d}t_n \cdot \alpha R(t - \sum_1^n t_i) \\ & + \ldots\ldots \end{aligned}$$

$$\begin{aligned} S(t) = & \alpha R(t) \cdot \Theta(t-d) \\ & + \alpha R(t) \cdot (\beta\lambda) \cdot \exp(\lambda d) \cdot (t-2d) \cdot \Theta(t-2d) \\ & + \alpha R(t) \cdot (\beta\lambda)^2 \cdot \exp(2\lambda d) \cdot \frac{(t-3d)^2}{2!} \cdot \Theta(t-3d) \\ & + \ldots\ldots \\ & + \alpha R(t) \cdot (\beta\lambda)^n \cdot \exp(n\lambda d) \cdot \frac{[t-(n+1)d]^n}{n!} \cdot \Theta[t-(n+1)d] \\ & + \ldots\ldots \end{aligned}$$

$$S(t) = \alpha\lambda \cdot \exp[-\lambda(t-d)] \cdot \sum_{n=0}^{N(t,d)} \frac{[\beta\lambda \exp(\lambda d)]^n}{n!} \cdot [t-(n+1)d]^n \cdot \Theta[t-(n+1)d] \qquad (31)$$

$$\text{with} \quad N(t,d) = \left[\frac{t}{d}\right] - 1$$

Using

$$\int_0^{\infty} x^m \cdot \exp(-\lambda x) \cdot \mathrm{d}x = \frac{m!}{\lambda^m} \cdot \frac{1}{\lambda} \qquad \text{for } m \geq 0 \qquad (32)$$

$$\sum_{\nu \geq 0} \beta^\nu = \frac{1}{1-\beta} \qquad \text{for } \beta < 1 \qquad (33)$$

$$\sum_{\nu \geq 0} (\nu+1)\beta^\nu = \frac{1}{(1-\beta)^2} \qquad \text{for } \beta < 1 \qquad (34)$$

$$\sum_{\nu \geq 0} \nu\beta^\nu = \frac{\beta}{(1-\beta)^2} \qquad \text{for } \beta < 1 \qquad (35)$$

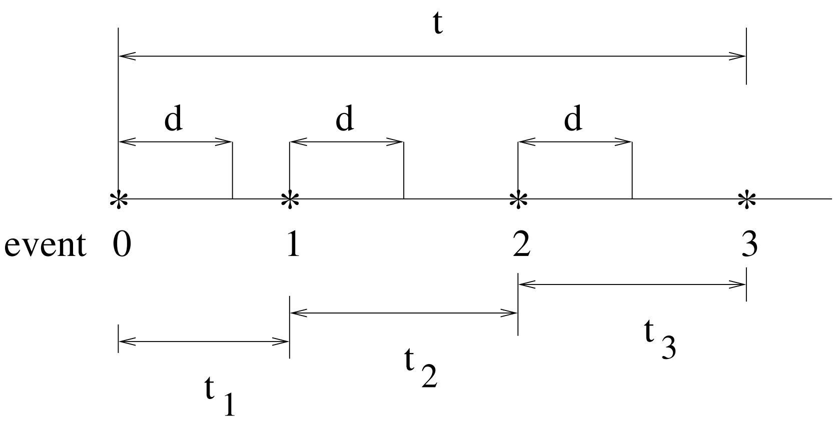

Figure 3: Four events are plotted on the time axis, all of which are recorded by a detector with fixed dead time d. Events 0 and 3 are assumed to belong to subsample B_α, whereas events 1 and 2 are assumed not to belong to subsample B_α. The probability density for this situation to occur is given by $\widetilde{R_2}(t)$ (see eq. (30)).

one finds

$$\int_d^\infty S(t)\cdot \mathrm{d}t \quad = \alpha \cdot \sum_{n\geq 0} \beta^n \;=\; 1 \tag{36}$$

$$\int_d^\infty t\cdot S(t)\cdot \mathrm{d}t = \alpha\cdot\left(d+\frac{1}{\lambda}\right)\cdot\sum_{n\geq 0}(n+1)\cdot\beta^n \;=\; \frac{1}{\alpha}\cdot\left(d+\frac{1}{\lambda}\right) \;=\; \frac{1}{\alpha\lambda}\cdot(1+\lambda d) \tag{37}$$

The total number of events of sample B is $N_{d,0}$. The total number of events $N_{d\alpha,0}$ of sample B_α can be derived from the number of recorded events not belonging to sample B_α, which is given by

$$N_{d,0} - N_{d\alpha,0} = N_{d\alpha,0}\cdot\int_d^\infty \sum_{n=0}^{\infty}(n\cdot\widetilde{R_n})\cdot \mathrm{d}t \;=\; N_{d\alpha,0}\cdot\alpha\cdot\sum_{n\geq 0}(n\cdot\beta^n) \;=\; N_{d\alpha,0}\cdot\frac{1-\alpha}{\alpha} \tag{38}$$

This gives

$$N_{d\alpha,0} = \alpha\cdot N_{d,0} \;=\; \frac{\alpha N_0}{1+\lambda d} \tag{39}$$

The same result is obtained by the constraint that the total observation time

$$N_{d\alpha,0}\cdot\int_d^\infty t\cdot S(t)\cdot \mathrm{d}t = N_{d\alpha,0}\cdot\frac{1}{\alpha\lambda}\cdot(1+\lambda d) \tag{40}$$

has to be equal to $T_0 \;=\; \dfrac{N_0}{\lambda}$.

The probability distributions of time differences for the different samples are compared in Table 1. In the limit $\alpha \to 1$ the distribution $S(t)$ (eq. (31)) tends to $R(t)$ (eq. (10)) , in the limit $d \to 0$ to $Q(t)$ (eq. (29)), as expected. Whereas $R(t)$ and $Q(t)$ are functions with t independent slopes, the distribution $S(t)$ has a slope which is a complicated function of t.

	name of sample	total no. of events	$\overline{\Delta t}$	probability distribution
ideal detector (full sample)	A	N_0	$\frac{1}{\lambda}$	$P(t) = \lambda \cdot \exp(-\lambda t)$
fixed dead time (full sample)	B	$N_{d,0} = \frac{N_0}{1+\lambda d}$	$d + \frac{1}{\lambda}$	$R(t) = \lambda \cdot \exp[-\lambda(t-d)] \cdot \Theta(t-d)$
ideal detector (subsample)	A_α	$N_{\alpha,0} = \alpha N_0$	$\frac{1}{\alpha} \cdot \frac{1}{\lambda}$	$Q(t) = \alpha\lambda \cdot \exp(-\alpha\lambda \cdot t)$
fixed dead time (subsample)	B_α	$N_{d\alpha,0} = \frac{\alpha N_0}{1+\lambda d}$	$\frac{1}{\alpha} \cdot \left(d + \frac{1}{\lambda}\right)$	$S(t)$

Table 1: Comparison of different probability distributions for time differences t between successive events. λ is the average event rate an ideal detector would observe. d is the dead time and α is the probability that an event of sample A (B) belongs to the subsample A_α (B_α). $\overline{\Delta t}$ is the average time difference.

The question arises how the effective observation time can be determined from the sample B_α. From the fact that $\frac{N_{d,0}}{N_0} = \frac{N_{d\alpha,0}}{N_{\alpha,0}}$ it follows that all subsamples B_α are affected by the dead time in the same way, implying that also the effective observation time is independent of the subsample considered and thus independent of α :

$$T_{eff} = \frac{N_{d,0}}{\lambda} = \frac{N_{d\alpha,0}}{\alpha\lambda} = \frac{N_0}{\lambda} \cdot \frac{1}{1+\lambda d} = \frac{T_0}{1+\lambda d} \tag{41}$$

In order to calculate T_{eff} from sample B_α one has to divide $N_{d\alpha,0}$, which is known, by $\alpha\lambda$, which has yet to be determined. Unfortunately, the slope of $S(t)$ is in general different from $\alpha\lambda$, even at large t, as can be seen from Fig. 4. From (31) it follows that at high t the slope of $S(t)$ is equal to $\lambda \cdot [1 + (\alpha - 1)\exp(\lambda d)]$, which is close to $\alpha\lambda$ only if $\lambda d \ll 1$. Therefore, in order to determine T_{eff} from a subsample B_α one has in general also to measure higher moments of the probability distribution $S(t)$.

5 Remarks concerning the experimental determination of the effective observation time

5.1 Variation of λ with time

If the ideal event rate λ changes during observation, both $\frac{\mathrm{d}N_{id}}{\mathrm{d}t}$ and $\frac{\mathrm{d}N}{\mathrm{d}t}$ (for $t > d_{max}$) will no longer be simple exponential functions of the time, and the procedure described in section 3 is no longer

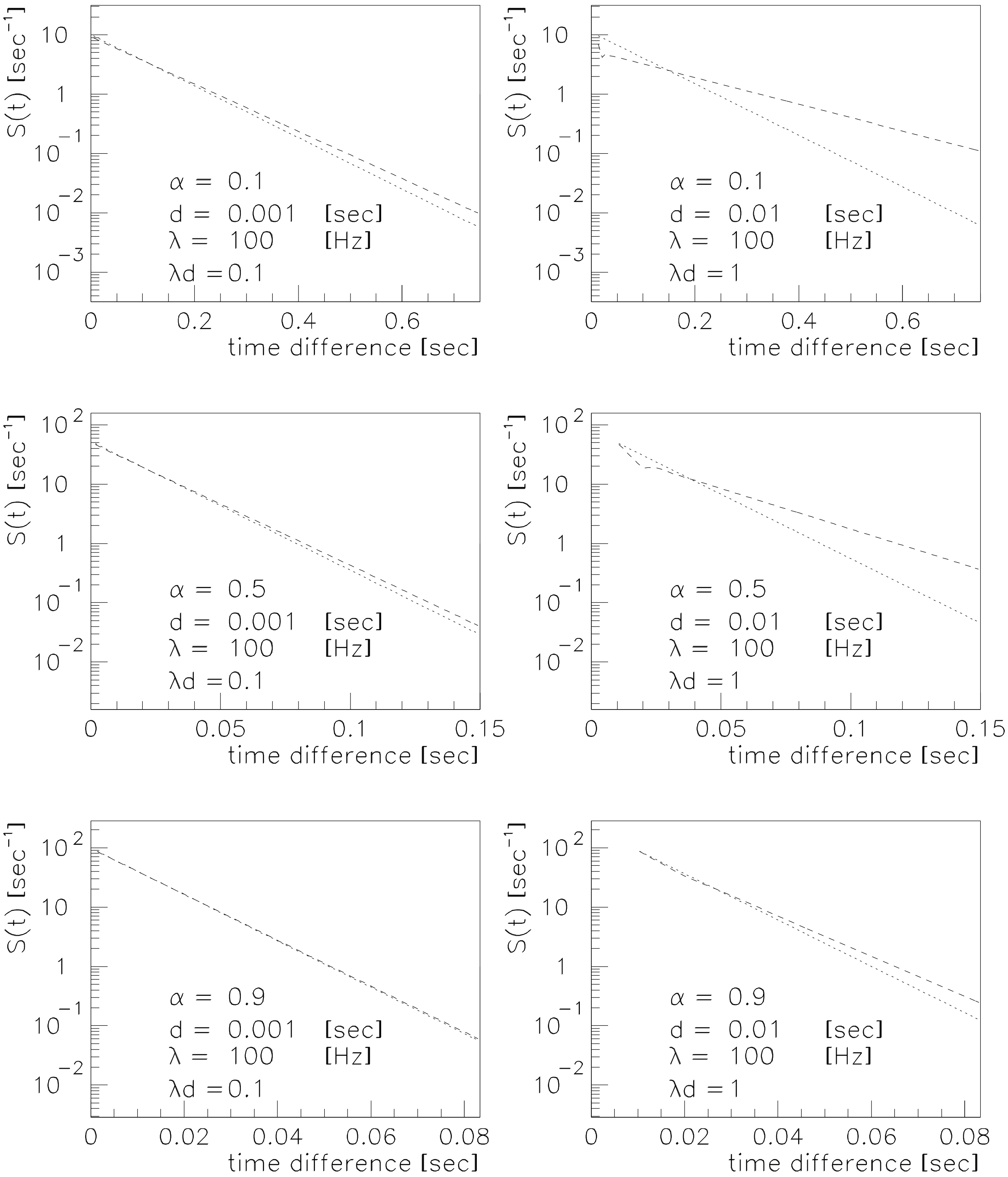

Figure 4: Probability distribution $S(t)$ for different values of α and λd (dashed curves). For comparison the distributions $\alpha\lambda \cdot \exp[-\alpha\lambda \cdot (t-d)]$ are shown as dotted curves.

applicable. Therefore the experimental data sample has to be subdivided into periods, within which λ is approximately constant. T_{eff} has to be determined for each period separately.

Since point sources of photons often show strong time variability, only event samples should be used in which the contribution of these photons is negligible, i.e. event samples which consist practically only of the cosmic ray background events.

However, even with this choice of event samples, λ will change with time because λ is a function of the zenith angle θ, which changes with time. For this reason the data sample has to be subdivided into bins of θ. For practical reasons it may be useful to choose a binning which is compatible with the choice of θ values at which MC events are generated.

Other reasons for a time variability of λ may be changes in the hardware of the detector or in the data acquisition system.

5.2 Interruptions of the observation

Apart from the ordinary breaks in data taking, there will be interruptions of the observation (due to hardware or software problems) which are rather short but still much longer than the average time difference between successive events. These interruptions can be easily identified in the experimental distribution $\frac{\mathrm{d}N}{\mathrm{d}t}$ as entries at large t which clearly don't follow a simple exponential behaviour.

In determining N_m and T_m from $\frac{\mathrm{d}N}{\mathrm{d}t}$ one should therefore perform the integrations in (22) and (23) only up to a value t_{max} of t, up to which $\frac{\mathrm{d}N}{\mathrm{d}t}$ is consistent with an exponential behaviour. Also the fit of λ should extend from d_{max} to a value of t which doesn't exceed t_{max}.

5.3 Dependence on cuts

While the effective observation time T_{eff} can be easily determined from the sample of **all recorded** events (see Sect. 3.4), this is in general not the case for subsamples of the recorded events (see Sect. 4.2).