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Memorandum

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Approximation of real detector rates from measured rates

At high detector rates in the MHz-range detector dead times and pileup lead to a reduction of the measured rate. If the detector hits are randomly distributed in time at a constant rate R, the measured rate R_m with the detector electronics in "updating mode" is given by [1, 2]

$$R_m = R \cdot \exp^{-R \cdot \Delta t}, \tag{1}$$

where Δt is the pulse length of the detector. The "real" rate R can not be simply calculated from the measured rate R_m, since Eq. 1 cannot be converted to give a simple expression for R. However, if R/R_m deviates less than 25% from unity R can be approximated to better than 3% by following simplification. We begin with taking the logarithm of Eq. 1:

$$\begin{aligned}
\ln R_m &= \ln R - R \cdot \Delta t \\
&\Longrightarrow \\
R &= \frac{\ln R - \ln R_m}{\Delta t} = \frac{\ln \frac{R}{R_m}}{\Delta t} = \frac{\ln(1 + \Delta R)}{\Delta t} \\
&\simeq \frac{\Delta R}{\Delta t} = \frac{R - R_m}{R_m} \cdot \frac{1}{\Delta t} \\
&\Longrightarrow \\
R &= \frac{R_m}{1 - R_m \cdot \Delta t}.
\end{aligned} \tag{2}$$

Equation 2 can be rewritten to give the approximated expression for the measured rate:

$$R_m = \frac{R}{1 + R \cdot \Delta t}. \tag{3}$$

Table 1 gives examples for detector rates in the MHz-range and a detector pulse width of 10 ns.

References:

[1] W.T. Eadie, D. Drijard, F.E. James, M. Roos and B. Sadoulet, *Statistical Methods in Experimental Physics*, North Holland, Amsterdam and London (1971)

[2] T. Prokscha, E. Morenzoni, M. Meyberg, T. Wutzke, B. E. Matthias, A. Fachat, K. Jungmann and G. zu Putlitz, *Muonium formation by collisions of muons with solid rare-gas and solid nitrogen layers*, Phys. Rev. **A58**, 3739 (1998).

Table 1: For a given rate R the measured rate R_m is calculated using Eq. 1 with $\Delta t = 10$ ns. With this R_m the rate R is approximated using Eq. 2, and denoted R_a here.

R [MHz]	R_m [MHz]	R_a [MHz]	R/R_a
1.0	0.990	0.9999	1.0001
5.0	4.756	4.9935	1.0013
10.0	9.048	9.9481	1.0052
12.5	11.031	12.398	1.0082
15.0	12.911	14.825	1.0118
17.5	14.690	17.220	1.0163
20.0	16.375	19.581	1.0214

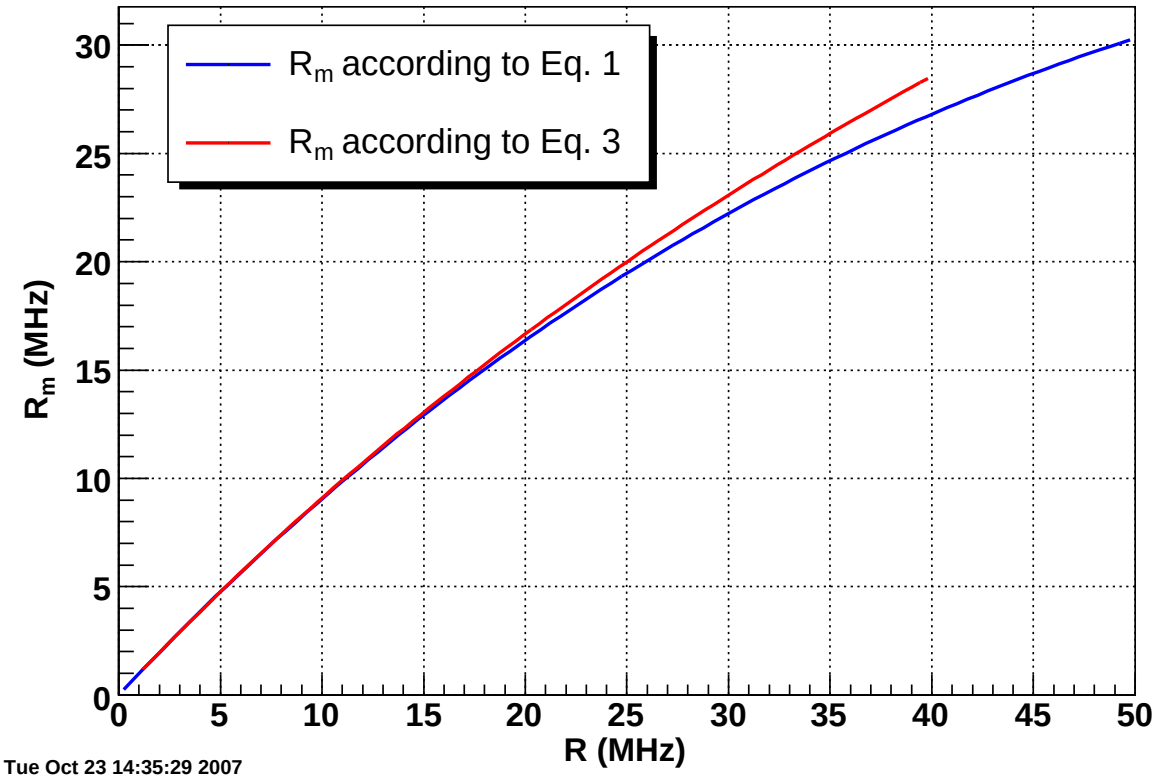

Figure 1: Comparison of measured rate R_m as a function of "real" rate R, calculated according Eq. 1 and the approximation Eq. 3.