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A Study of Life & Death

of the AMANDA Detector

by

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1 Introduction

In all the different analysis in AMANDA we are often interested in the overall normalization and thus need to know the live-time corresponding to a certain sample. We also have to correct for dead-time for events occurring too close in time for the trigger system to cope.

This is certainly done my many Amandians already but since we did not easily find any detailed information on this subject we made a small investigation on these matters. The start point for this investigation was a raw-data sample of one day (94) from the year 2000 data for which we wanted to determine the dead-time correction as well as the live-time. A small fast procedure was developed to cope with many (compressed) data files in f2k-format in an efficient way.

Later we tested some data samples from different years and recently all raw data from 2000 and 2001 has been analyzed. We should admit that in the first round we had an error, described below, in our technique but we hope and think that the analysis is correctly done now.

Finally we have managed to make web tools by which live- and dead-time for any run/file selection may be determined in 2000 or 2001 data.

Note that what we call dead- and live-time may be combined to an overall dead-time of the detector but we have chosen to split the two effects in this analysis.

2 Live-time

In the first approximation the live-time T is calculated as the sum over all files of the difference between the time of the last and first event.

$$T = \sum_{\text{files}} t_i^{\text{last}} - t_i^{\text{first}}$$

This is, of course, the simple basis of evaluating live-time *but* there are a few effects, normally minor, that we want to, or must, correct for.

2.1 Interval correction

One obvious but minor correction is that given n_i events we observe only $n_i - 1$ intervals thus a small bias is corrected by

$$T = \sum_{\text{files}} \frac{n_i}{n_i - 1}(t_i^{\text{last}} - t_i^{\text{first}})$$

where n_i is the number of events in file i.

In reality data tested shows that the time difference between subsequent files is of the same order as between events and thus we could have neglected the summation and as well as the bias-correction. However, there are runs where changes occurr within the run and we want to possibly be able to make a selection not only on run level but also on file level in the future. The correction above takes care of the effect and is even more imporant if the technique is used on a data sample where the rate is low.

2.2 GPS readout problem

In our detailed investigations of the full 2000 and 2001 raw data samples we extracted each individual time for each event. In doing this we could investigate thoroughly the event timing. In doing this we found some problems concerning the GPS clock(s), or probably rather the GPS readout system. This implied *e.g.* that in the beginning of each run in 2000 data, in the file with index `000` the first 1350 events or so were unreliable and even drastically wrong.

Minor similar problems occurred in some other, but very few, cases. To deal with this we introduced a lag, ℓ, usually equal to 1 to indicate which event to use as the first reliable time for a file. In doing this we modify our formula above to read

$$T = \sum_{\text{files}} \frac{n_i}{n_i - \ell_i}(t_i^{\text{last}} - t_i^{\text{first}})$$

For instance in the case mentions about we use $\ell = 1350$ for those files and in some other cases $\ell = 2$. In most cases, however, $\ell = 1$.

2.3 Artificially long time gaps

If longer intervals occur between events within a file or raw data something fishy is going on. This was the case in 1997. Although 1997 data is not in focus in our present investigations there are occurrences of artificially longer Δt's also in those samples. Since, as we will se, we use a maximum likelihhod estimate of the slope of the exponential distribution we are sensitive to ignore out-liers in the far tail and thus we need a technique to avoid this.

Although somewhat arbritarily we adopted a small algorithm which separately adds times longer than a certain value (0.1 was used for 1997 data and 0.2 s turned out to be a not too bad choice for 2000 as well as 2001 data). This may sometimes select a few events just above the limit and we even make a final check after a sample (a file) has been processed where, if the number of such occurrences are below 5 and the average of those is less than 1.5 times the limit used (*i.e.* 0.3 here), we merge those observations with the normal sums. If, however, this is not the case we regard the effect as due to some arificial hick-up where the read-out was hang-up for short time periods. With m such too long intervals having a total time T_{high} we finally get

$$T = \sum_{\text{files}} \frac{n_i}{n_i - \ell_i - m}(t_i^{\text{last}} - t_i^{\text{first}} - T_{\text{high}})$$

i.e. we subtract T_{high} and correct the number of gaps correspondingly.

It should be noted that corrections to the live-time from the simple-minded formula is small except for some really spurious GPS times which are handled by the lag correction.

3 Dead-time

The distributions in Δt for raw-data, at least for some samples from 1998 to 2000 which we first tested were in perfect agreement with an exponential distribution except for a region at small values. See *e.g.* Fig. 1 for a plot of 2000-data. Above a certain value where dead-time losses are negligible (for the raw data shown a value of 10 ms seems adequate but we have tried the robustness of our method for different values of this value as shown below) the distribution is a perfect exponential without any losses in the variable $x = \Delta t - t_{\text{cutoff}}$.

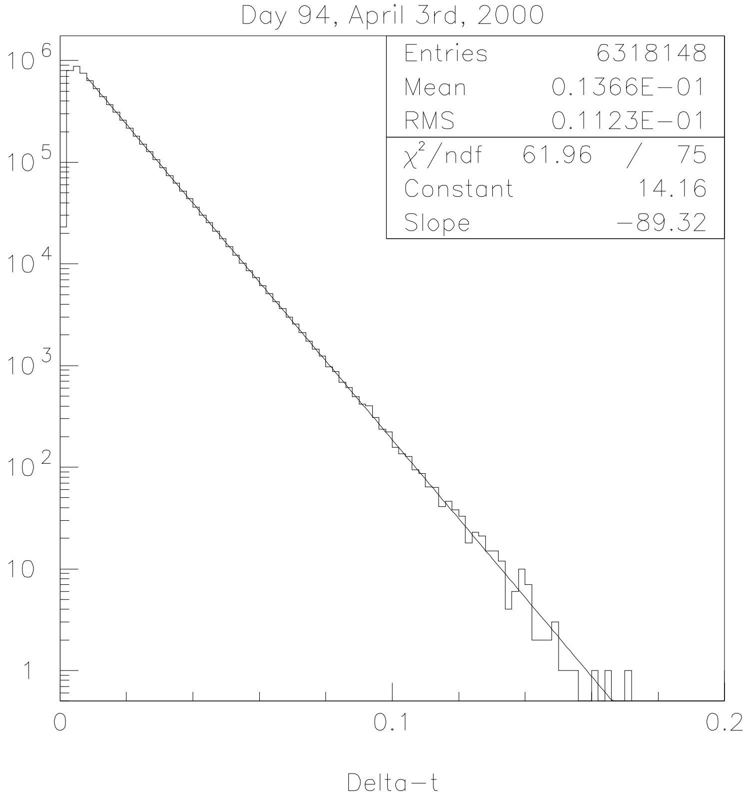

Figure 1: Raw data from day 94 in 2000.

The parameter of the exponential distribution, the average τ in x, may be obtained by

$$f(x;\tau) = \frac{1}{\tau} e^{-x/\tau}$$

which is a properly normalized probability function for the exponential distribution (note that sometimes the slope $1/\tau$ is used as the parameter instead of τ).

The maximum likelihood estimator of τ is easily shown to be equal to the sample mean *i.e.* we get the best estimate of this parameter by

$$\hat{\tau} = \frac{1}{n_{\text{above}}} \sum_{i=1}^{n_{\text{above}}} x_i$$

where the sum runs over all n_{above} events with $\Delta t > t_{\text{cutoff}}$ *i.e.* with $x > 0$. The variance of this estimator is given by

$$V(\hat{\tau}) = \frac{\hat{\tau}^2}{n_{\text{above}}}$$

3.1 The old faulty technique

In the first attempt we did something which turned out not to be correct. This may be slightly embarrising but since many bright people did not seem to be aware of a trap in this case it may be worthile to make a point on how this happened.

In a process following an exponential distribution, but with losses at low values, it is visually very tempting to extrapolate, in log-scale, the exponential back to the axis and look at the missing integral between this ideal exponential and the observed spectra.

This is completely correct in a process where events are simply lost *not* affecting other entries which sometimes is the case. And this is what we first did for several reasons *e.g.* to be independent of the live-time estimate. However, in our case a missing event creates a longer Δt to the next event (or sometimes even more events are missing inbetween). This implies that our final distribution will be a superposition of exponentials, some of which are shifted, up to the point where losses are negligble. Each exponential has the same slope such that our determination of the exponential parameter still is correct. However, what fooled us is the normalization. Especially with the unfortunately sizeable dead-times we have a substantial amount of events are added in the tail besides the ideal tail from the unaffected events. This leads to overestimating the dead-time effect if we calculated the missing area under the exponential curve.

3.2 Classical method

When we realized the problem described above we did not try to find ways to rescue such a method. Indeed it seems far from trivial to correct for arbitrary dead-time scenarios. Instead we turn to what is probably the classical method namely to estimate, from the slope of the exponential, the ideal rate by

$$R_{\text{true}} = \frac{1}{\hat{\tau}}$$

which we compare to the observed rate

$$R_{\text{obs}} = N_{\text{obs}}/T$$

where N_{obs} is the observed number of events and T our live-time estimate.

The dead-time becomes

$$\mathcal{D} = \frac{R_{\text{true}} - R_{\text{obs}}}{R_{\text{true}}} = 1 - \frac{R_{\text{obs}}}{R_{\text{true}}} = 1 - R_{\text{obs}} \cdot \hat{\tau}$$

4 Data

Although the main focus is on 2000 and 2001 data we started to look at small samples we had available also for the previous years from 1997 to 1999. Also we started to analyze selected files being brought from the South Pole for the present 2002 data.

4.1 1997 data

For a day of 1997 raw data we had available unfortunately the ideal situation is far from fulfilled. This is well known and is sen *e.g.* in Ped's web-pages

`http://grimm.berkeley.edu/~ped/datastat/dead/plots.html`

and is there for all runs. As is seen in Fig. 2 after a normal exponential drop in the Δt-distribution we observe a sizeable bump at about 150 ms. On top of that, but outside the graph, a smaller bump at around 1 s and an even smaller at 6 s is observed.

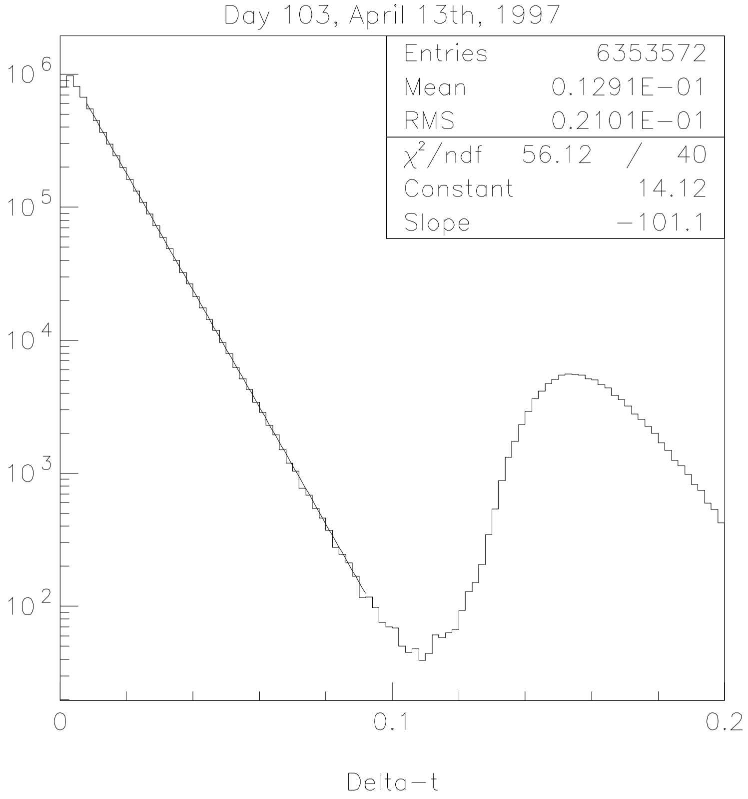

Figure 2: Raw data from day 103 in 1997.

In this case we estimate the dead-time correction from the first exponential part of the distribution in a similar way as above. We could (should perhaps) make a proper fit in this case but the exponential part extends to about 100 ms where the distribution has fallen a factor > 10000 so for the moment we use the part up to this Δt-value in the same manor as above as a first order approximation.

We also correct live-time as mentioned above by reducing the total live-time by the longer Δt's subtracting τ as the normal average value.

4.2 1998 data

As mentioned already the 1998 data looks perfect, see Fig. 3. Here, however, the trigger rate was high and the dead-time correction quite big with an overall correction factor of 1.4380 ± 0.0012. The uncorrected rate was 120 events per second and both the rate and the correction factor was the same for all files within errors.

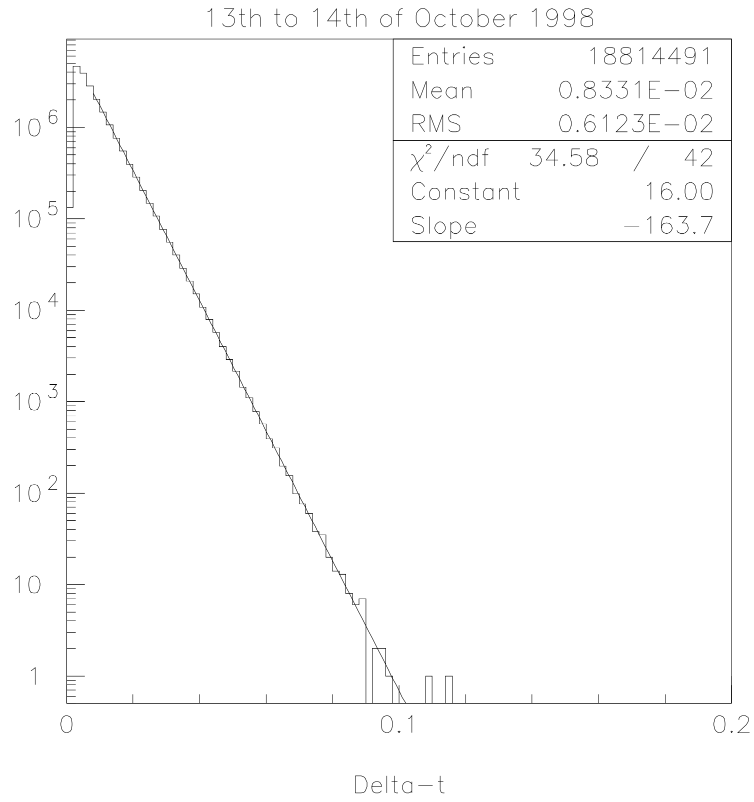

Figure 3: Raw data from days 287 and 288 in 1998.

4.3 1999 data

We found some raw data for 1999, corresponding to about a fifth of a day in live-time (about one million events) on our disks. This enabled us to make a first test also for 1999 data. Indeed, as 1998 and 2000 data, this data follows a perfect exponential as may be seen in Fig. 4.

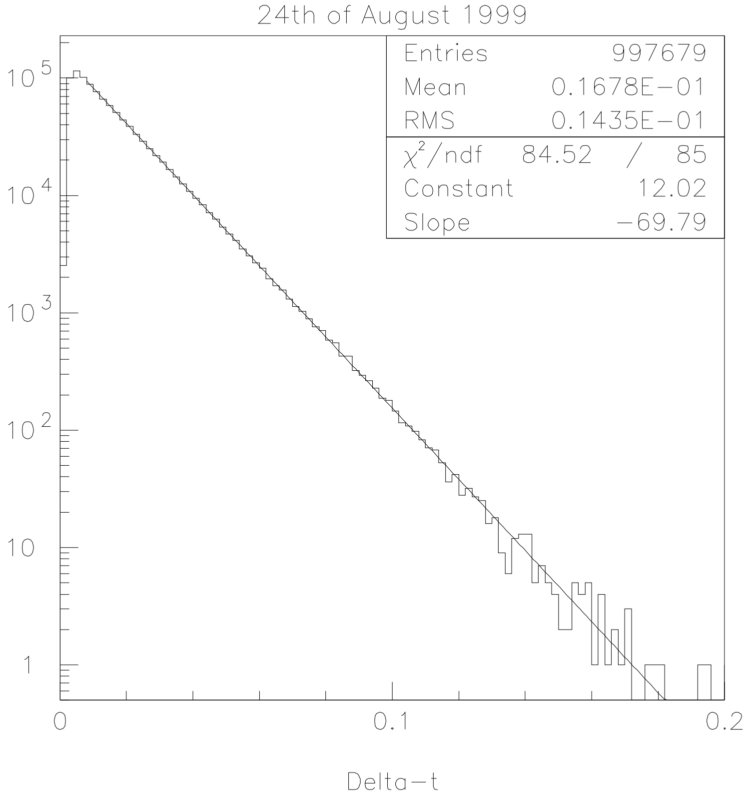

Figure 4: Raw data from 24th of August 1999.

4.4 2000 data

The data for day 94 year 2000 was shown earlier in Fig. 1. Here the uncorrected rate was 73 events per second and the dead-time 18.0 %. As for 1998 and 1999 data the situation looks very stable over time.

4.4.1 GPS problem in 2000 data

In our investigation we came upon a problem for 2000 data inasmuch as GPS-times at the start of each run was concerned. In the data from day 94 which we investigated amongst the first 1336 events we found 713 events for which $\Delta t = 0$ *i.e.* the GPS-clock has not moved at all from the previous event. Also, as a consequence, a few large Δt-values were observed the maximum being Δt =13.684 between the two last events (1335 and 1336) after which things looks perfectly normal.

We tried to use the latest reader-version (version 2.2.1 from `http://reader.icedaq.com/` as opposed to version 2.1.8 which was used previously) to see if the problem had been solved but without success. A closer look using reader-options to reveal two alternative GPS-clocks shows that these seems more reasonable besides having a strange step for the first event (*cf* effect seen in 2002 data below). This may be a known roll-over bug where we first get the last time from the previous run.

When we finally transferred all the data from Zeuthen we found this problem was a true, and very stable, feature all through the year and we therfore have to adopt a lag of 1350 for all files with index `000`.

During the fulll 2000 data taking we had 15 occurrences of a day-roll-over bug where the day is update before the seconds roll-over to low values. This gave rise to a $\Delta t = 86400 + \epsilon$ s followed by a $\Delta t = -86400 + \epsilon$ s with ϵ typically a few ms. This was corrected by brute force but we give below a table with details. The last column shows the time left to midnight, judging from the seconds, when the date was updated *e.g.* in the first line day 51 came 234 μs too early.

Day roll-over bug in 2000 data

Run	File	Event	Day	μs to midnight
201	075	3532336	51	234
204	084	3989135	54	51
233	086	3887493	83	702
266	009	427813	112	578
304	110	4534330	146	107
308	094	4273026	150	991
318	089	4099976	156	85
326	073	3588817	181	715
379	011	492176	207	588
390	093	4406179	217	887
435	027	253869	231	1366
464	012	443082	235	127
476	009	402588	247	1218
480	009	380252	251	351
501	124	5020978	272	144

4.5 2001 data

In the summer of 2002 when all raw data from 2001 was still available in Wisconsin we manged to extract files for the full sample. Detailed investigations showed that the GPS readout problems had disappeared except in one odd case (run 3212) where the Δt between event 0 and 1 in file `000` was -595737 seconds!

However, quite frequently we encounter artificially high values of Δt which we treat by the technique outlined above, correcting the live-time (and disregarding in the determination of the exponential parameter which could be affected by out-liers).

A few occurrences of $\Delta t = 0$ and a few cases of negative Δt's we currently ignore as a higher order negligible effect.

4.6 2002 data

Data from the 2002 season was stored in Wisconsin and is avilable at

`http://amanda.physics.wisc.edu/data/`

Here we find mimimum bias raw data for a selection of files which we have analyzed. This is a more heterogenous sample than the ones we have looked at earlier and may need some reconsideration when it comes to calculating dead-time for the full sample but we have calculated rates and dead-times per file to start with. Also note that it is not yet as thoroughly checked as the 2000 and 2001 data samples. In Fig. 5 we show very preliminary plots on the uncorrected rate and the dead-time calulated for each data file and plotted against time.

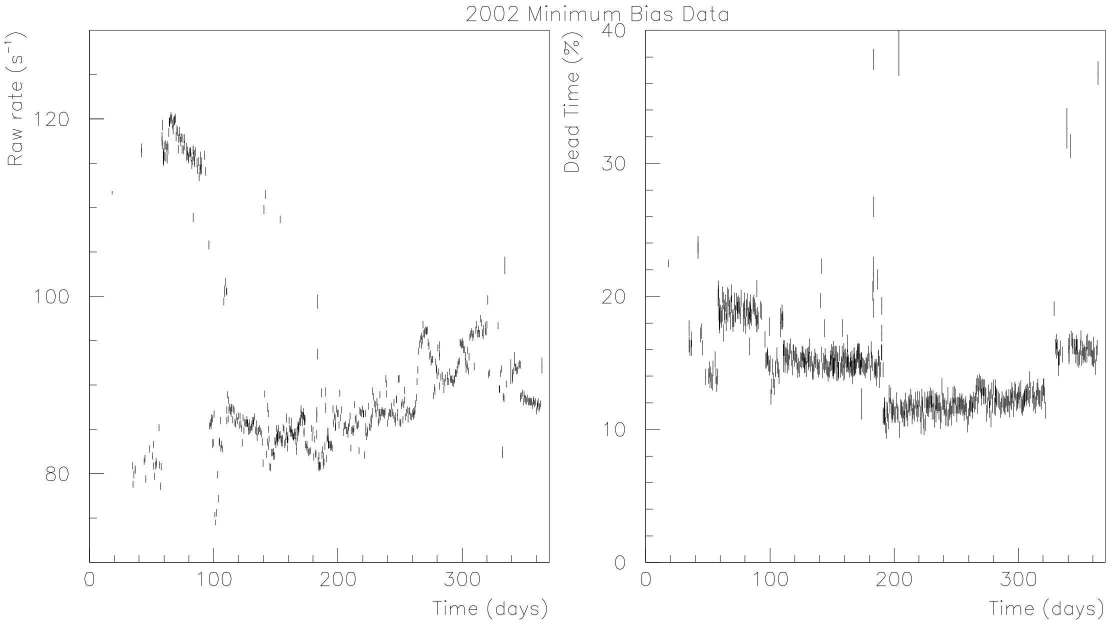

Figure 5: Rate and dead-time for minimum bias raw data from 2002.

4.6.1 GPS problems for 2002 data

Compared to what was seen in 2000 data the GPS problems in 2002 data are negligble but on the other hand somewhat worse than for 2001 data. However, we see one effect that consistently affects the first GPS-time in each run. This implies that the Δt between event with number 0 and number 1 is wrong. From the minimum bias data available at `http://amanda.physics.wisc.edu/data/2002-data.shtml` with a selection of files we find 21 such files (with file index `000`):

file	Δt_{01} (s)
`ab_2002_019_4536_000.data.mu.min_bias.gz`	0.017359
`ab_2002_035_5303_000.data.mu.min_bias.gz`	661.409523
`ab_2002_035_5304_000.data.mu.min_bias.gz`	77302.475867
`ab_2002_036_5338_000.data.mu.min_bias.gz`	289.222558
`ab_2002_037_5353_000.data.mu.min_bias.gz`	1104.675507
`ab_2002_064_5561_000.data.mu.min_bias.gz`	251.130683
`ab_2002_084_5603_000.data.mu.min_bias.gz`	530.804357
`ab_2002_085_5604_000.data.mu.min_bias.gz`	67.401810
`ab_2002_152_5729_000.data.mu.min_bias.gz`	14428.726054
`ab_2002_170_5754_000.data.mu.min_bias.gz`	215.462504
`ab_2002_185_5798_000.data.mu.min_bias.gz`	10619.987703
`ab_2002_192_5805_000.data.mu.min_bias.gz`	1270.442279
`ab_2002_210_5825_000.data.mu.min_bias.gz`	50.535754
`ab_2002_230_5846_000.data.mu.min_bias.gz`	50.465118
`ab_2002_329_5960_000.data.mu.min_bias.gz`	71520.076949
`ab_2002_333_5971_000.data.mu.min_bias.gz`	7942.405168
`ab_2002_340_6313_000.data.mu.min_bias.gz`	615.647011
`ab_2002_342_6436_000.data.mu.min_bias.gz`	1256.252712
`ab_2002_343_6482_000.data.mu.min_bias.gz`	64.845540
`ab_2002_350_6552_000.data.mu.min_bias.gz`	67.904292
`ab_2002_360_6562_000.data.mu.min_bias.gz`	21209.971971

These values should be compared to an average Δt of around 0.1 s with a tail for the exponential distribution which rarely extends beyond 0.2 s. The first run was a big one made already during the austral summer in 18th of January and here the Δt is normal while for all others it is competely insensible. Once again this may be caused by a known roll-over bug giving the time from the end of the last run for the first event. This problem is cured by putting the lag to 2 for all files with file index `000` in the live-time determination.

Besides this marginal but annoying effect the only small problems seen is two longish Δt-values for the third file in the table where we find Δt=0.844565 between events 508 and 509 and Δt=1.02667 between events 565 and 566. This is odd but we regard it as a minor problem which does not affect our estimates of dead-time for this file significantly and which was only seen for this file. Also we may handle it with the correction to the live-time for artificially long intervals which is described above.

4.7 2003 data

Data from the 2003 season is currently brought to Wisconsin and is available at

`http://amanda.physics.wisc.edu/data/amanda/2003/mu-daq/`

Here we find mimimum bias raw data for a selection of files which we have analyzed. Sofar this is mostly runs from the periods when work still was carried out at the South Pole and there may be many tests runs later to be excluded from the analysis. As for 2002 data of the same kind note that 2003 data is not yet as thoroughly checked as the 2000 and 2001 data samples. In Fig. 6 we show very preliminary plots on the uncorrected rate and the dead-time calculated for each data file and plotted against time.

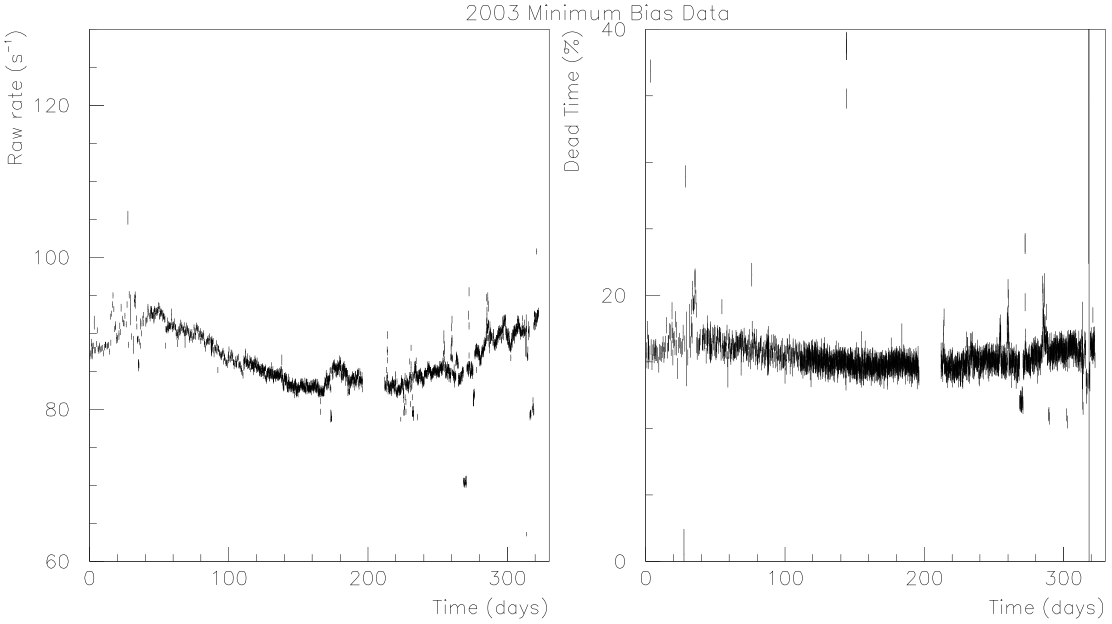

Figure 6: Rate and dead-time for minimum bias raw data from 2003.

4.7.1 GPS problems for 2003 data

For the first runs with file index `000` we see the same "roll-over" bug as for 2002 data. However, as the table below indicate the problem disappeared for a long period before reappearing (see text below).

file	Δt_{01} (s)
`ab_2003_016_6606_000.data.mu.min_bias.gz`	96.485918
`ab_2003_023_6622_000.data.mu.min_bias.gz`	67.268171
`ab_2003_028_6665_000.data.mu.min_bias.gz`	83894.039955
`ab_2003_032_6691_000.data.mu.min_bias.gz`	0.015334
`ab_2003_034_6697_000.data.mu.min_bias.gz`	0.005679
`ab_2003_035_6704_000.data.mu.min_bias.gz`	0.012020
`ab_2003_037_6730_000.data.mu.min_bias.gz`	0.011452
`ab_2003_038_6746_000.data.mu.min_bias.gz`	0.014466
`ab_2003_041_6839_000.data.mu.min_bias.gz`	0.004817
`ab_2003_042_6869_000.data.mu.min_bias.gz`	0.003849
...	...
`ab_2003_191_7201_000.data.mu.min_bias.gz`	1049.098335
`ab_2003_195_7205_000.data.mu.min_bias.gz`	68.247569
`ab_2003_223_7241_000.data.mu.min_bias.gz`	68.706340
`ab_2003_229_7247_000.data.mu.min_bias.gz`	68.832267
`ab_2003_240_7266_000.data.mu.min_bias.gz`	2532.723075
`ab_2003_242_7269_000.data.mu.min_bias.gz`	68.388539

Due to turning of data-taking to avoid interference from the operation of a VLF antenna we have some very long breaks far outside the exponential which we treat with a correction to the live-time as usual.

Amanda has more than one GPS clock and the reader program uses one as default. In 2003 data a new roll-over bug was found where microseconds roll over to low values before seconds are incremented. This creates time differences of -1 s followed by +1 s for the next event gap.

However, special checks revealed that the GPS clocks were not coinciding as well as they should differing by microseconds in a scheme with up to four discrete values comparing two of them. Those problems led to several changes in the DAQ-system at the South Pole. One effect was that we cured some but also got back some of our old problem such as the effect above for the first events of a run and even the day roll-over bug seen in 2000 data appeared at least once again.

Also occasionally there are negative times probably due to switching between different GPS-clocks. Both 2002 and 2003 data awaits a thorough check of GPS-times as was done for 2000 and 2001 data once the full data sets are available.

5 Check for robustness in cutoff

The t_{cutoff} above which we assume a perfect exponential behaviour (except for 1997 data) may seem somewhat arbitrarily chosen. However, for the first data-set we tested (raw data from day 94 in 2000) we checked the robustness in this variable. Indeed, the situation is very close to ideal and in Fig. 7 we see that changing from the nominal value of $t_{\text{cutoff}} = 10$ ms over a wider range do not change the final correction at all unless we move down to about 5 ms or less. Note that points are highly correlated in this plot. In this particular case the nominal choice at 10 ms leaves 51.1% of the data above the cutoff whereas 25 ms leaves only 13.4% (at 5 ms 79.8% is analyzed but here we begin to see a small bias from going too low in the cutoff). Of course, errors become larger in the 25 ms case but essentially the result is very stable in the whole range 6-25 ms.

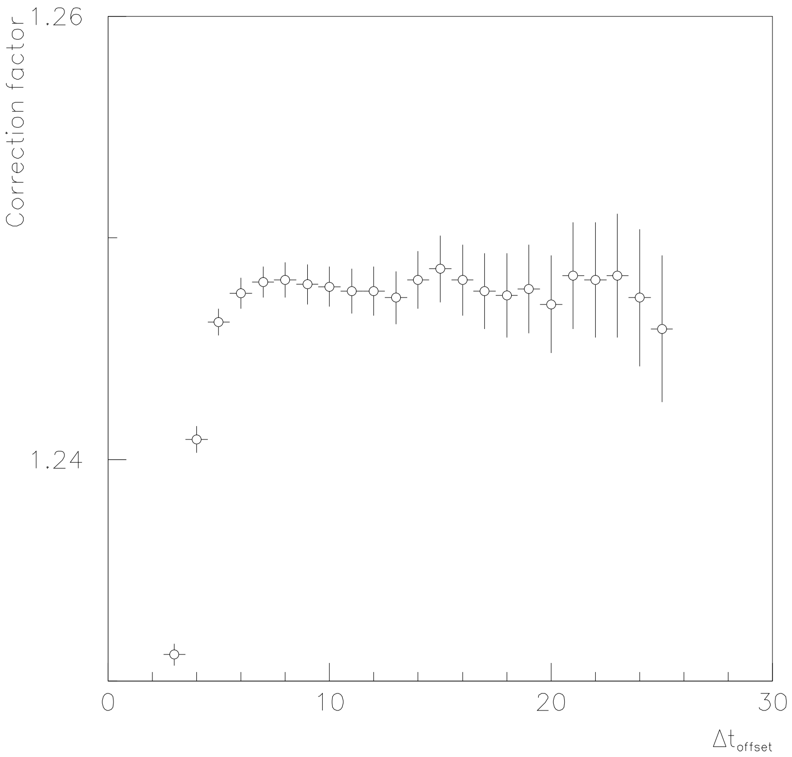

Figure 7: The dead-time correction factor vs the cutoff chosen for the estimation of the exponential parameter (*i.e.* the mean).

6 Selected Results

In this section we give preliminary summaries from an analysis of live- and dead-time for the data from 1997 to 2000 used above. The analysis was done by a small simple program developed for the ideal case (which seems sufficient for 1998 to 2000 data) but later modified in order to cope with the special features seen in the spectra for 1997 data. Not everything written in this summary output is explained in detail but hopefully is understandable anyway.

6.1 1997

```
Start time               : 1997-04-12 23:59:17.115141 UTC/GMT = MJD 50549.999504
End time                 : 1997-04-13 23:59:17.177150 UTC/GMT = MJD 50550.999504
Cutoff in dt             : 0.01000 s
Minimum value for dt     : 0.00028 s
Maximum value for dt     : 152.01146 s
Total number of events   : 6353602
dt-values less or equal 0: 0
dt-values >0.20 s        : 2749
Fraction above offset    : 39.09 %
Overall correction factor: 1.07082±0.00069 (dead-time 6.61±0.06 %)
Weighted average corr.   : 1.07083±0.00069 (dead-time 6.61±0.06 %)
Bias corrected rate      : 94.543±0.038 / s
Uncorrected live-time    : 83010.274060 = 23:03:30.274060 = 0.961 d
Corrected live-time      : 67203.265161 = 18:40:03.265161 = 0.778 d
Total time span          : 86400.062009 = 1-00:00:00.062009 = 1.000 d
Live-time efficiency     : 96.08 %
Exponential mean         : 0.00988±0.00001 s
Breakpoint for tail bumps: 0.1 s
Events in tail-bumps     : 102695
Excess live-time in bumps: 15879.161803 s
```

Comment: The 1997 data needed, as stated above, some special treatment regarding the bumps seen in the spectra. However, another puzzling effect is that although we expected, from all our 1997 data analysis, a dead-time correction of about 32% the raw data we had at hand gave a surprisingly low dead-time correction of only 6.6%. Indeed, comparing the graphs shown above for the different years the 1997 data has much less of a dip in the lowest bin in agreement with a smaller dead-time correction. We have inspected the low Δt region of the plot without observing any obvious problems (*e.g.* no peak or special structures at or around $\Delta t = 0$). With the 19.0% loss in live-time, however, the total dead-time for this sample is about 24.4% if we combine the two effects.

6.2 1998

For 1998 we had almost two days of raw data. Here the trigger rate was higher than in 1997 and in 2000 and consequently the dead-time correction was high (almost 44%). If this is representative for the full year we do not now yet. Anyhow the situation is close to ideal as concerns a single exponential distribution describing the Δt-distribution.

```
Start time               : 1998-10-14 00:16:30.494781 UTC/GMT = MJD 51099.011464
End time                 : 1998-10-16 01:12:02.480413 UTC/GMT = MJD 51101.050029
Cutoff in dt             : 0.01000 s
Minimum value for dt     : 0.00123 s
Maximum value for dt     : 0.11429 s
Total number of events   : 18814780
dt-values less or equal 0: 0
dt-values >0.20 s        : 0
Fraction above offset    : 27.96 %
Overall correction factor: 1.36077±0.00059 (dead-time 26.51±0.03 %)
Weighted average corr.   : 1.36078±0.00059 (dead-time 26.51±0.03 %)
Bias corrected rate      : 120.355±0.028 / s
Uncorrected live-time    : 156324.951364 = 1-19:25:24.951364 = 1.809 d
Corrected live-time      : 156327.352582 = 1-19:25:27.352582 = 1.809 d
Total time span          : 176131.985632 = 2-00:55:31.985632 = 2.039 d
Live-time efficiency     : 88.75 %
Exponential mean         : 0.00611±0.00000 s
```

Comment: Here we started with reconstructed files in f2000-format rather than real raw data. The life-time efficiency is low because some files are missing in the data-set we have been using. It is unclear why this is so and it does not necessarily reflect what may be achieved ideally.

6.3 1999

A small sample for 1999 corresponding to a fifth of a day or about one million events was investigated showing a dead-time of about 16%.

```
Start time               : 1999-08-25 08:40:35.515987 UTC/GMT = MJD 51414.361522
End time                 : 1999-08-25 13:20:11.984277 UTC/GMT = MJD 51414.555694
Cutoff in dt             : 0.01000 s
Minimum value for dt     : 0.00145 s
Maximum value for dt     : 0.19451 s
Total number of events   : 997697
dt-values less or equal 0: 0
dt-values >0.20 s        : 0
Fraction above offset    : 59.11 %
Overall correction factor: 1.17111±0.00152 (dead-time 14.61±0.11 %)
Weighted average corr.   : 1.17111±0.00152 (dead-time 14.61±0.11 %)
Bias corrected rate      : 59.5870.060 / s
Uncorrected live-time    : 16743.285494 = 04:39:03.285494 = 0.194 d
Corrected live-time      : 16743.587570 = 04:39:03.587570 = 0.194 d
Total time span          : 16776.468290 = 04:39:36.468290 = 0.194 d
Live-time efficiency     : 99.80 %
Exponential mean         : 0.01433±0.00002 s
```

6.4 2000

The raw data used for 2000 had a lower rate than the 1998 data and the dead-time correction came out at about 17%. As for the 1998 data the situation is ideal with the full sample in perfect agreement with an exponential distribution besides the losses at low values of Δt. Listed here is the summary output for the first test sample for run 244.

```
Start time               : 2000-04-03 02:14:03.771295 UTC/GMT = MJD 51637.093099
End time                 : 2000-04-04 02:12:19.761964 UTC/GMT = MJD 51638.091895
Cutoff in dt             : 0.01000 s
Minimum value for dt     : 0.00135 s
Maximum value for dt     : 0.17021 s
Total number of events   : 6318436
dt-values less or equal 0: 0
dt-values >0.20 s        : 0
Fraction above offset    : 51.10 %
Overall correction factor: 1.21969±0.00068 (dead-time 18.01±0.05 %)
Weighted average corr.   : 1.21974±0.00068 (dead-time 18.02±0.05 %)
Bias corrected rate      : 73.202±0.029 / s
Uncorrected live-time    : 86294.177883 = 23:58:14.177883 = 0.999 d
Bias corrected live-time : 86314.598434 = 23:58:34.598434 = 0.999 d
Total time span          : 86295.990669 = 23:58:15.990669 = 0.999 d
Live-time efficiency     : 100.00 %
Exponential mean         : 0.01120±0.00001 s
```

For determination of live- and dead-time for the 2000 sample we now refer to the web-tool (see next section) at

`http://www.physto.se/~walck/amanda/livedead/2000/ld00.php`

For the complete sample, without any quality cut we find a total live-time of 248.238 days and a dead-time of 17.326±0.003 %.

Details investigations of the sample and lists for each run may be found from the basic web-page

`http://www.physto.se/~walck/amanda/livedead/`

6.5 2001

For the complete 2001 sample, without any quality cuts, the total live-time is 257.660 days and the dead-time 21.580±0.003 %.

For determination of live- and dead-time for the 2001 ample we refer to the basic web-page or directly to the web-tool (see next section) at

`http://www.physto.se/~walck/amanda/livedead/`
`http://www.physto.se/~walck/amanda/livedead/2001/ld01.php`

7 Tools for Live- and Dead-time Determinations

7.1 Extraction of EM-lines

From harvest and monitoring efforts one may probably find histograms of Δt which may be used to find the dead-time by fitting an exponential.

It seems, however, quite nice to use the methods described in this note to find good estimates of dead- and live-time simultaneously. At the same time one may investigate non-exponential behaviour as well as GPS-clock problems as observed above.

In order to achieve this we have extacted summary files with the EM-cards (well for future possible extention we also selected TRIG-cards) from the raw data in f2000-format. From this we could run our program and collect information per file as well as per run and globally. We extract special files by *e.g.* a unix/Linux-script like

```
#!/bin/tcsh
@ n=1
foreach file ($1)
   echo "fil $n: $file " ‘date +"%Y-%m-%d %T"‘
   setenv NYFIL ‘echo $file | sed ’s/.gz/.em.gz/’ | awk -F ’/’ ’print $NF’‘
   gzip -cd $file | grep EM | gzip > $NYFIL
   @ n++
end
```

In most cases we have to use (gzipped) raw-data in which case a more lengthy procedure involving the reader must be used

```
#!/bin/tcsh
@ n=1
foreach file ($1)
   echo "fil $n: $file " ‘date +"%Y-%m-%d %T"‘
   setenv NYFIL ‘echo $file | sed ’s/.gz/.em.gz/’ | awk -F ’/’ ’print $NF’‘
   gzip -cd $file | ˜walck/amanda/reader -r 2000 -f- | grep EM | gzip > $NYFIL
   @ n++
end
```

Those scripts (which could have been simpler by using the dirname and basename directives) creates one output file per input file adding an `.em.` into the original file name. The reader can take gzipped files as input but we found a feature/bug that, in such a case, the last event in each file is lost. Here we must, of course, find an appropriate reader for the data being processed. In the above example the reader was a copy of version 2.1.8 for Amanda-II used on 2000-data. (See `http://reader.icedaq.com/` for the newest readers.)

Not to ship terabytes of raw data in order to make this extraction we were able to execute scripts similar to the one above in Zeuthen (for all 2000 data) and in Wisconsin (for 2001 data). Still the resulting data-bases were quite large being 17 Gb for 2000 data and 32 Gb for 2001 data.

7.2 Web Tool

The data-bases created for 2000 and 2001 data are still big and after carefully investigating, and correcting for, different problems in the data we finally created smaller data-bases with just enough information per file to redo the calculations of live- and dead-time as well as determining those quantities for big, possibly inhomogeneous, samples. Those files became 4 Mb and 5 Mb, respectively, for 2000 and 2001 data.

To facilitate calculations on selected samples we managed to make two web tools already mentioned above

`http://www.physto.se/~walck/amanda/livedead/2000/ld00.php`
`http://www.physto.se/~walck/amanda/livedead/2001/ld01.php`

by which one may determine live- and dead-times given a run, and file, selection. The syntax given as input is basically a run list (or $*$ for all runs) delimited by commas or with hyphens for intervals *e.g.* `340-360,400,420-431`. Selection at file level is supplied on any such argument, delimited by a comma, by adding, in parentheses a file index list as *e.g.* in `340-360,400(1:7+9:*),420-431` where we for run 400 have deselected file index `000` and `008`.

8 Bad file deselection

The above syntax may at some stage become inconvenient in which case we may have to supply this information in other ways. Especially when dsetailed investigation has produced long lists with file sto be excluded in the default analysis. For 2000 data vad file deselection has now been introduced as the default using the list of Mathieu Ribordy

`http://www-zeuthen.desy.de/ ribordy/files2remove.dat`

9 Summary

Detailed investigations of live- and dead-time in Amanda data from 1997 and onwards have been performed. Especially for 2000 and 2001 data the complete samples have been thoroughly investigated and web tools designed to determine those quantities.

Although only small samples from 1997-1998 and selected files from 2002 and 2003 we summarize in the table below the results for the different years. Note that for 2000-2002 we do se sizeable variations in dead-time over the year due to *e.g.* changes in the trigger.

Year	# runs	# files	# events	live-time	dead-time
1997	1	30	6 353 602	0.778 d	6.61 %
1998	6	293	18 814 780	1.809 d	26.51 %
1999	2	18	997 697	0.194 d	14.61 %
2000	343	33 919	1 411 437 151	248.238 d	17.33 %
2000[1]	343	31 333	1 364 254 419	236.832 d	17.24 %
2001	312	44 065	2 099 386 442	257.660 d	21.58 %
2002	325	620	30 558 775	3.900 d	15.02 %
2003	416	2395	119 746 592	16.095 d	16.20 %

Note that test runs at the end of 2003 artificially increases the overall dead-time. A reasonable cut before this period gives approximately 15.3 %.
This manuscript and some text files with details of this investigation exist at

`http://www.physto.se/~walck/amanda/livedead/`

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[1] Bad files removed according to the list by Mathieu Ribordy