Median Filtering Algorithms for the Multichannel Detectors

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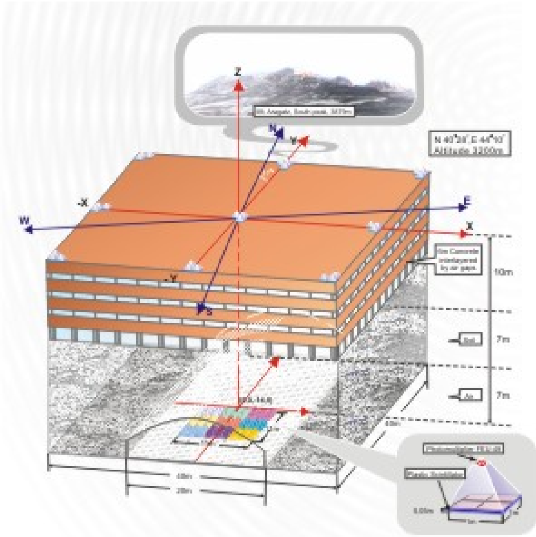
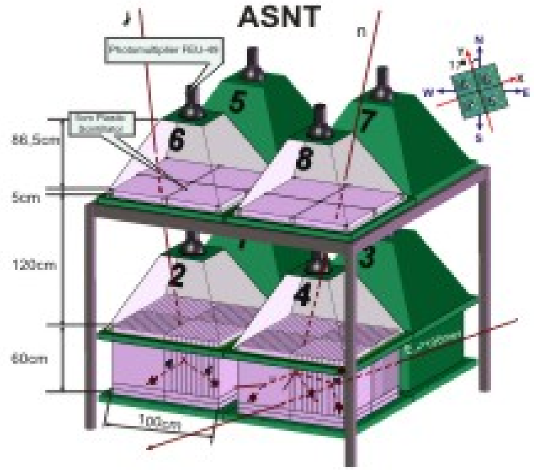
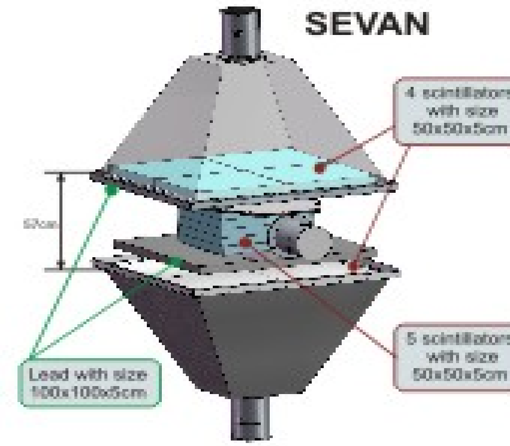
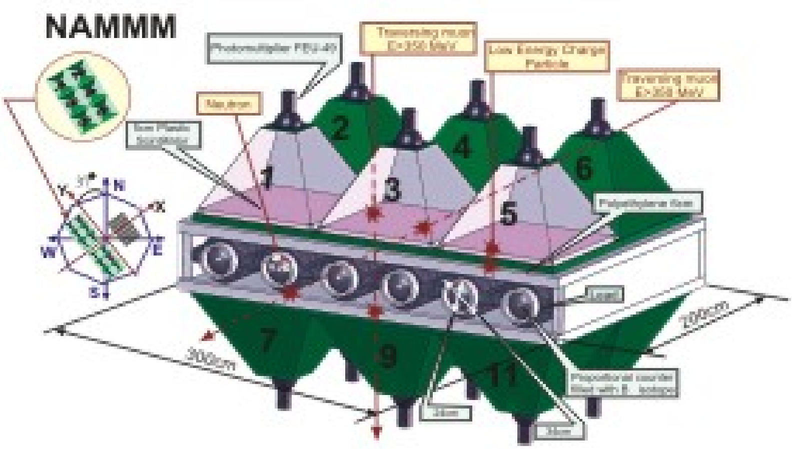
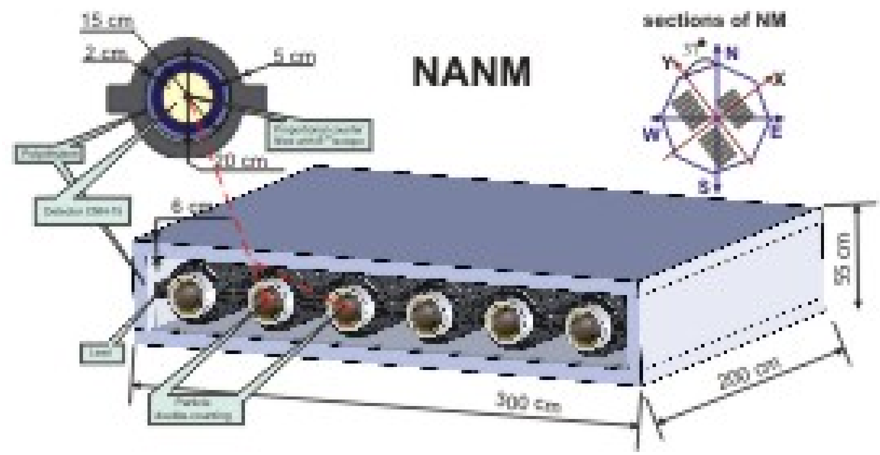
ASEC Monitors





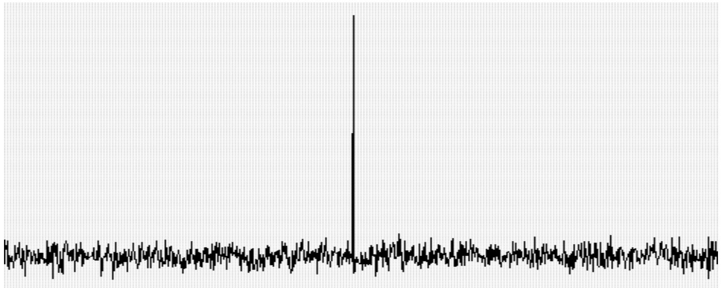




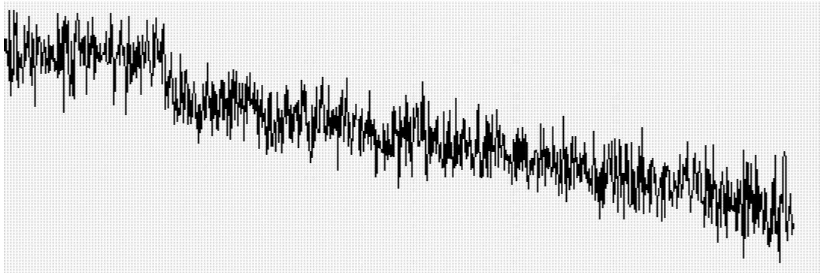


Errors in time-series

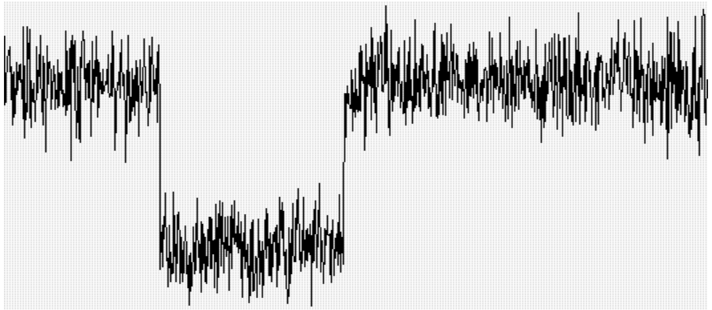
1 Spike



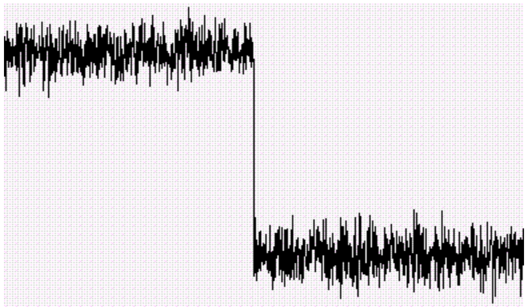
2 Slow Drift



3 Abrupt change of mean with recovering



4. Abrupt change of mean without recovering

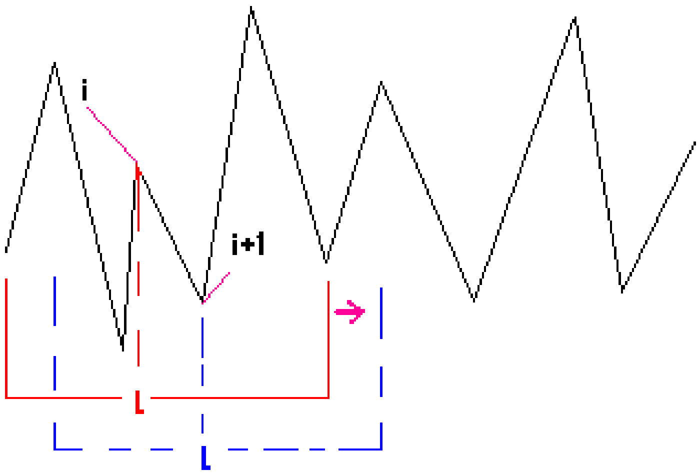


Moving Median Filter(MMF)

- Window of size L is “moving” from beginning to end of time series with unit step and continuously calculating the median of count rates within window. If difference of the current time series and median falls out of pre-chosen limits several actions are triggered:
- the outlier can be substituted by the median value;
- the outlier can be substituted by the special code;
- execution of program stops and an request to operator is send.
- Also MMF perform operation of time series smoothing with variable smoothing window.
- All time series are substituted by the corresponding moving median values (smoothing of time series) .
- If number of outliers exceed pre-choser

limit another filtering algorithm

described in the next section is invoked



MMF (2)

- 1. Select time series from database with N elements;
- 2. Start algorithm operation from the first of time series, assign $i = 0$;
- 3. Define $L = L_{min}$; if $i < N$, then assign $i = i+1$ and continue;
- otherwise write filtered time series into data base; calculate length of periods when algorithm substitute the time series by the median value, send to operator all messages and stop.
- 4. Select L-1 elements of time series to the right; calculate the median value M;
- if its value is in the limit of the predetermined values $M \varepsilon (P_{min} - P_{max})$ then continue;
- otherwise check if $L < L_{max}$ enlarge L by 2 and repeat steps 3,4;
- otherwise report about algorithm failure at point i and store algorithm parameters for i_{th} time series: (i, v_i, L_{max}); then go to 3
- 5. Check if $abs(v_i - MED) < D_{max}$ then continue;
- otherwise report erroneous i-th time series, store algorithm parameters $(I, v_i,)$
- and assign $v_i = MED$; then go to 3

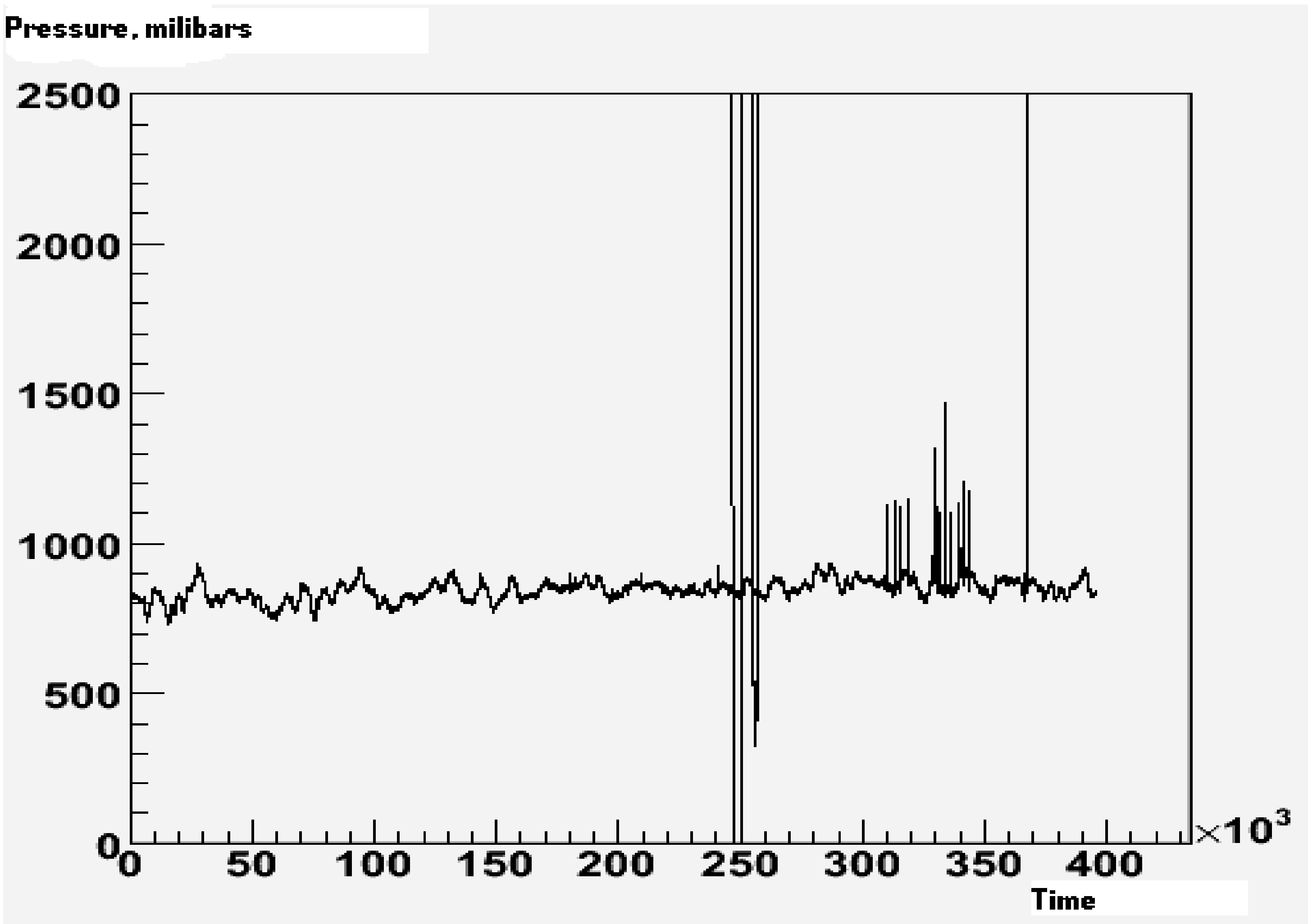
Relational Median filter for multichannel measurements (RMF)

- Let's suppose that detector consists of M identical channels, however due to individual characteristics of sensors used (photomultipliers, proportional counters, etc…) the mean count rates of channels , i=1, M - are dispersed within definite (not very large) limits. Below are RMF parameters:
- M – number of channels of the monitor;
- <ni> - mean value of j-th channel;
- N_{total} – sum of mean values of all channels (detector mean count rate);
- MEDi – Median value of M channels at i-th time series (i-th minute);
- Fj - the equalizing coefficient of j-th channel;
- vi,j- i-th time series of j-th channel; V_i – total detector count rate at moment i.
- At the start of detector operation by assigning to each channel the appropriate coefficient ; j=1, M it is possible to equalize the mean count rates to use stabilizing properties of the median filtering:
- $$F_j = \frac{\bar{n}_j * M}{N_{total}}, \; j = 1, M$$
- And the detector total count rate at moment I can be calculated according:
- $$V_i = med\{F_j v_i^j\} \; j = 1, m$$
-

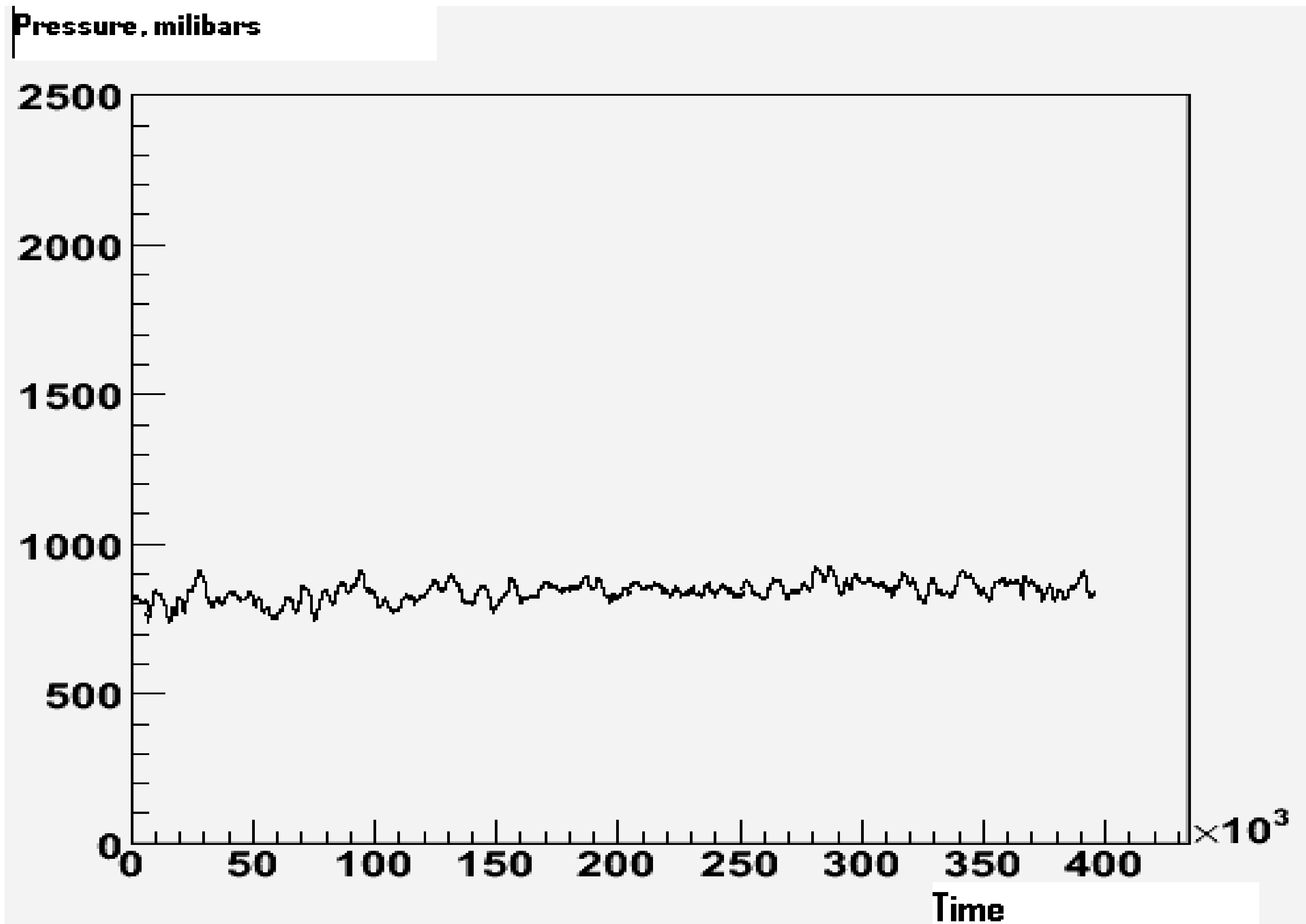
Possible scenario of implementation of algorithms

- For some initial period without errors the mean count rates and coefficients are calculated and stored.
- Each day data all channels of detector are filtered with algorithm 1;
- If some channels operate unstable according to the first algorithm second one turns on, it reads the stored means and coefficients.
- Channel means and appropriate coefficients are renewed and stored.
- If second algorithm didn't correct the data (which means that all or nearly all channels have been corrupted or detector was switched of due to some overall failure) send an e-mail to operator.
- By automatically implementing both filtering algorithms each day and storing renewed mean values of channels and appropriate coefficients it will be possible to correct all mentioned channel failures. The time history of the equalizing coefficients will help to outline non-stable channels and repair them.

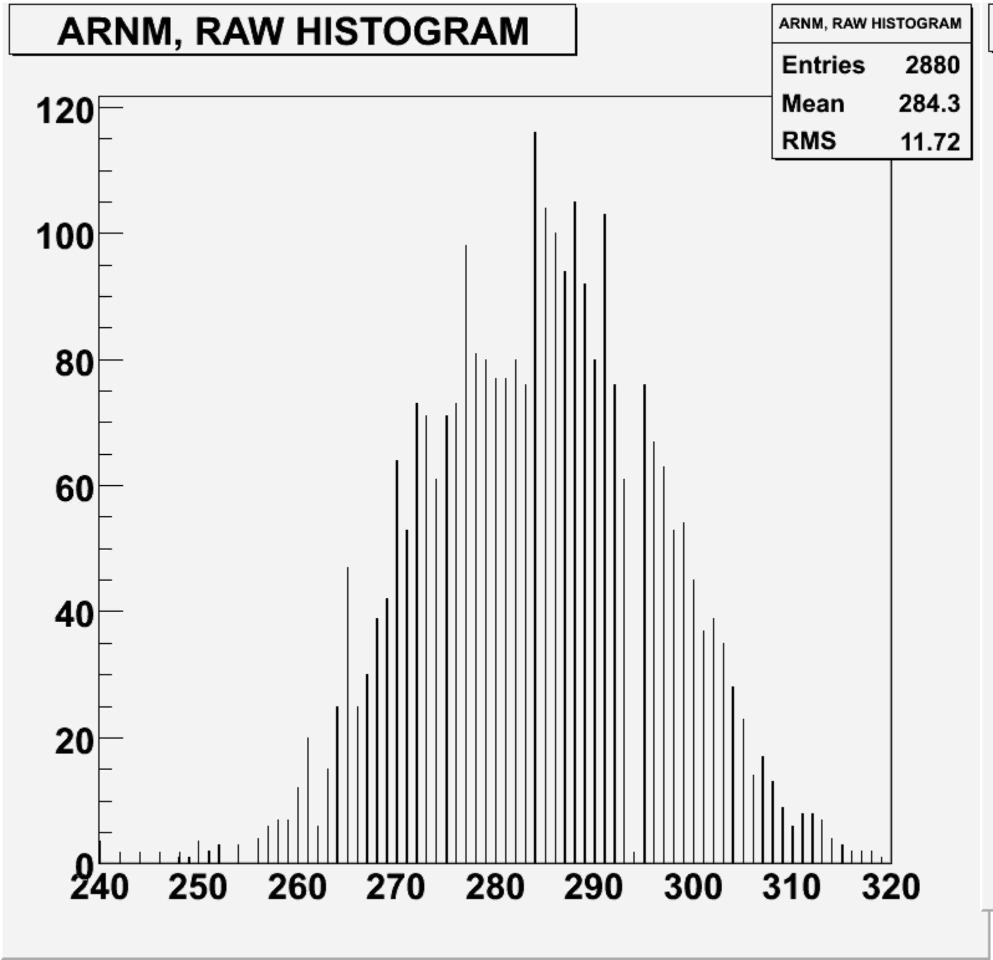
Atmospheric Pressure, Nor-Amberd Station, Period – 6 Months

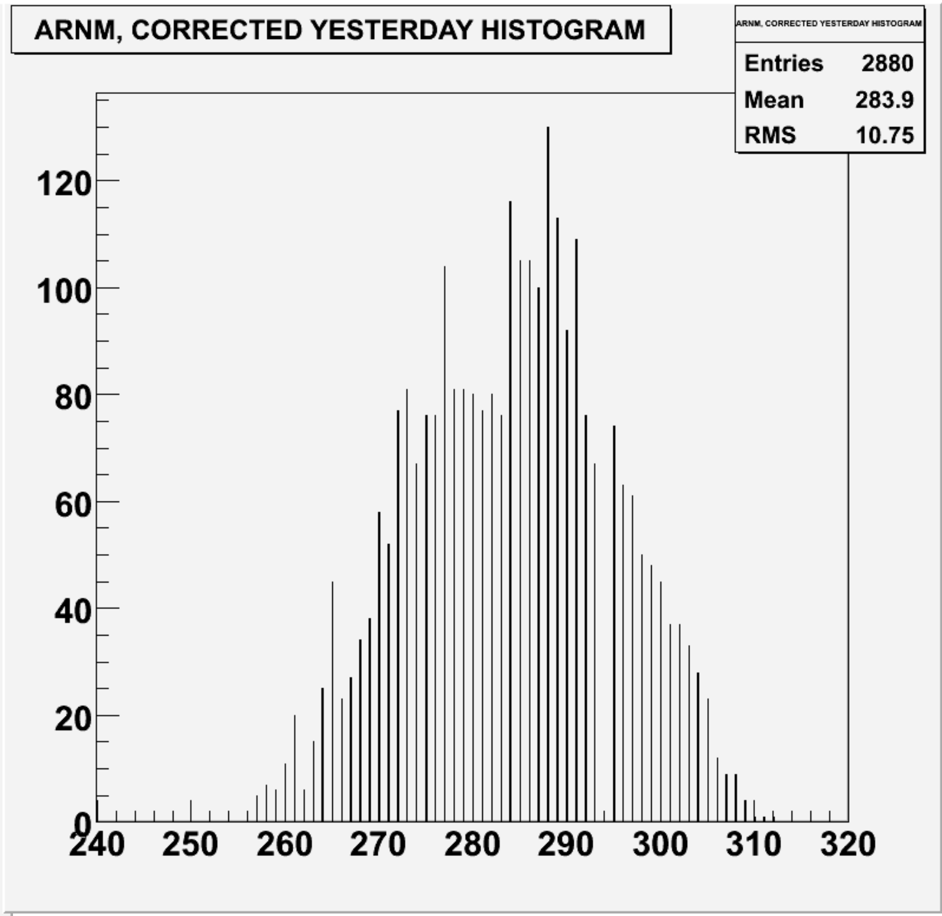


Atmospheric Pressure - Corrected

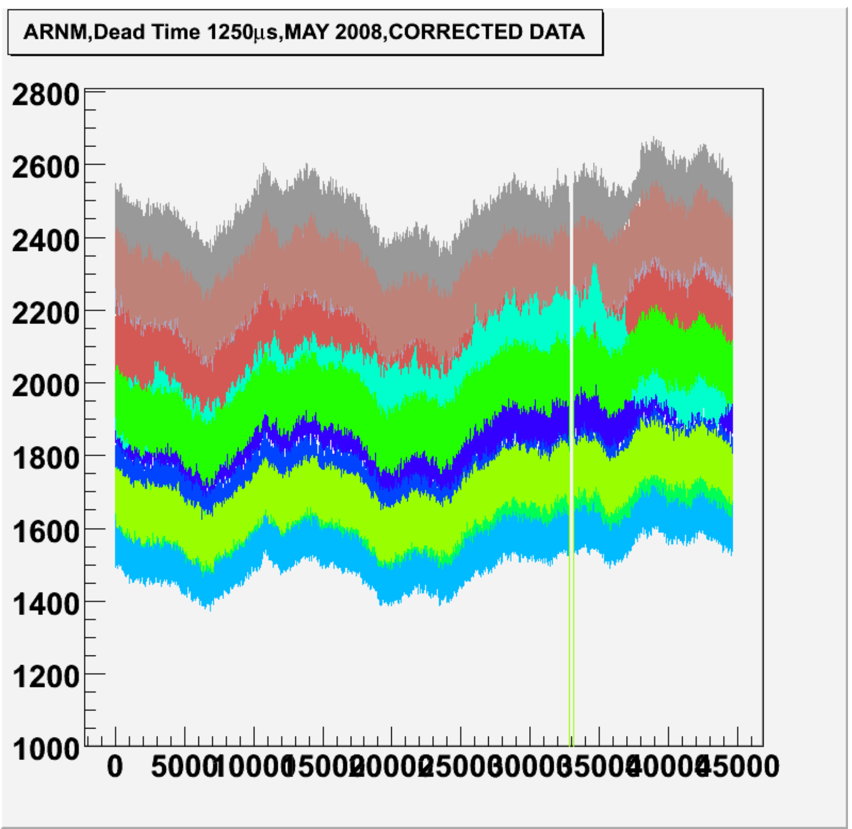


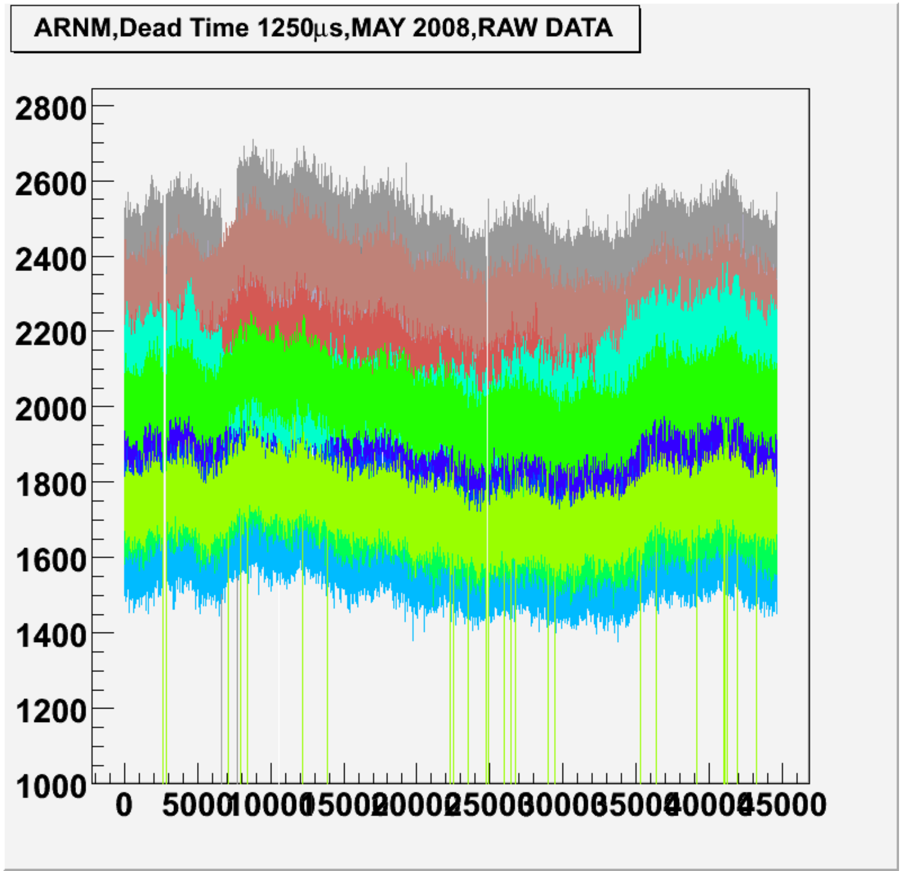
Cutting outliers





Filtering time-series

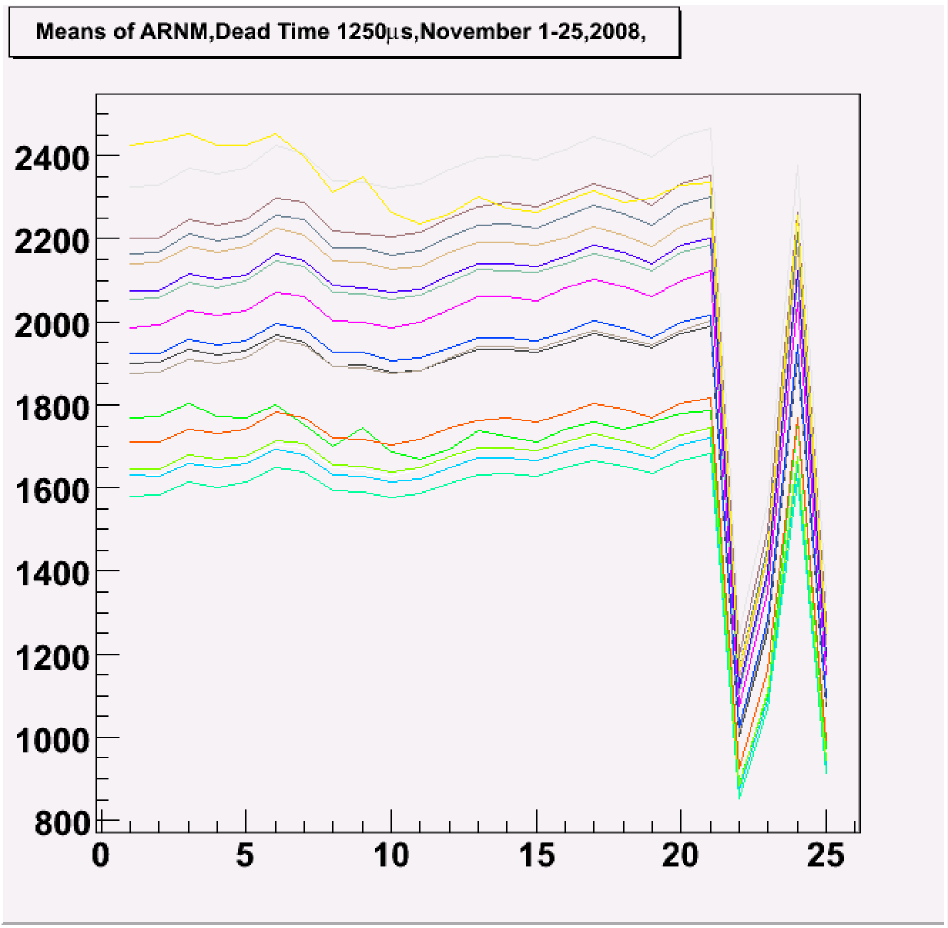


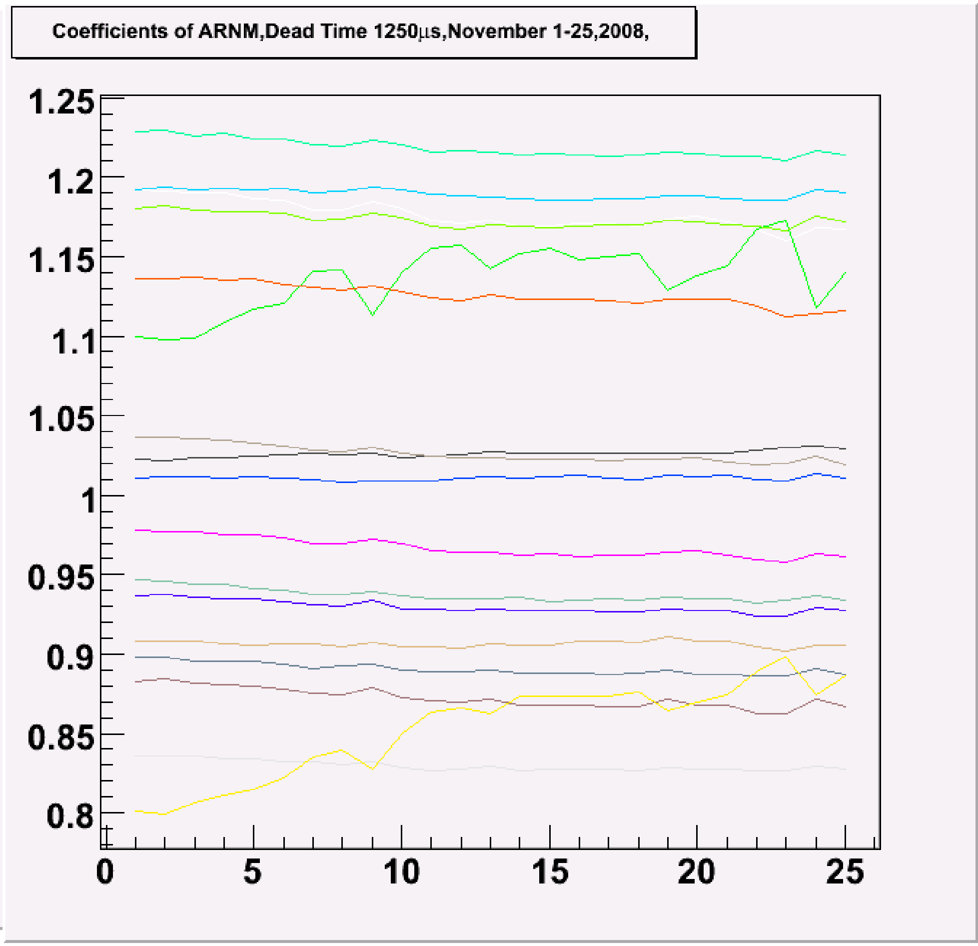


Mean, Variance, Relative Error for first channel of NANM before and after filtering

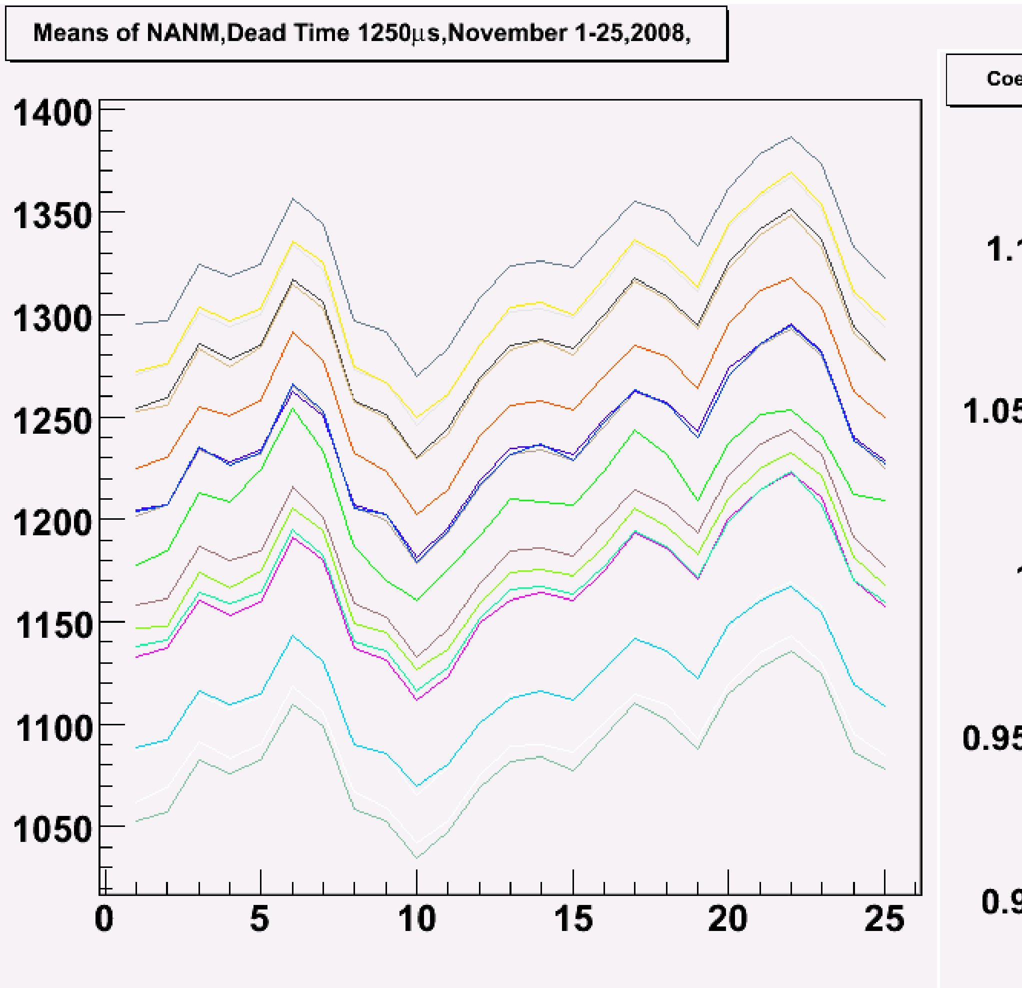
	MEAN	Relative error	RE
BEFORE FILTERING	1730	42	0.024
AFTER FILTERING	1731	19	0.010

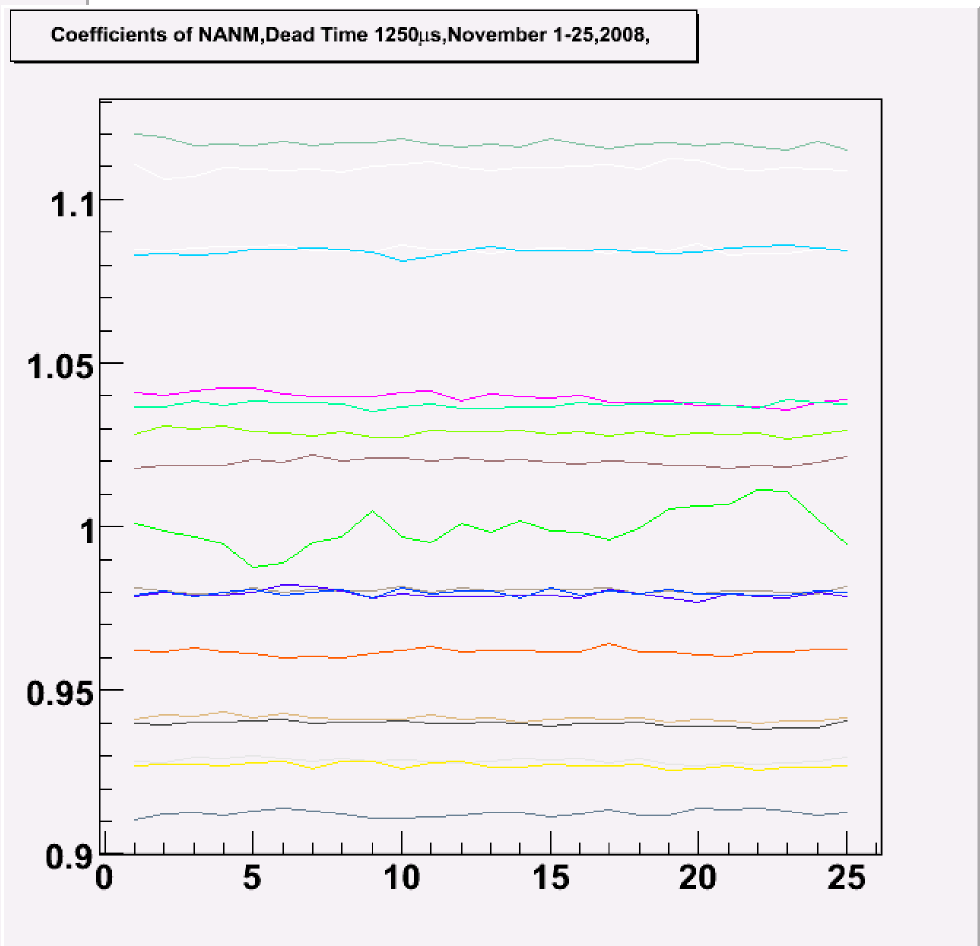
ARNM: means and coefficients



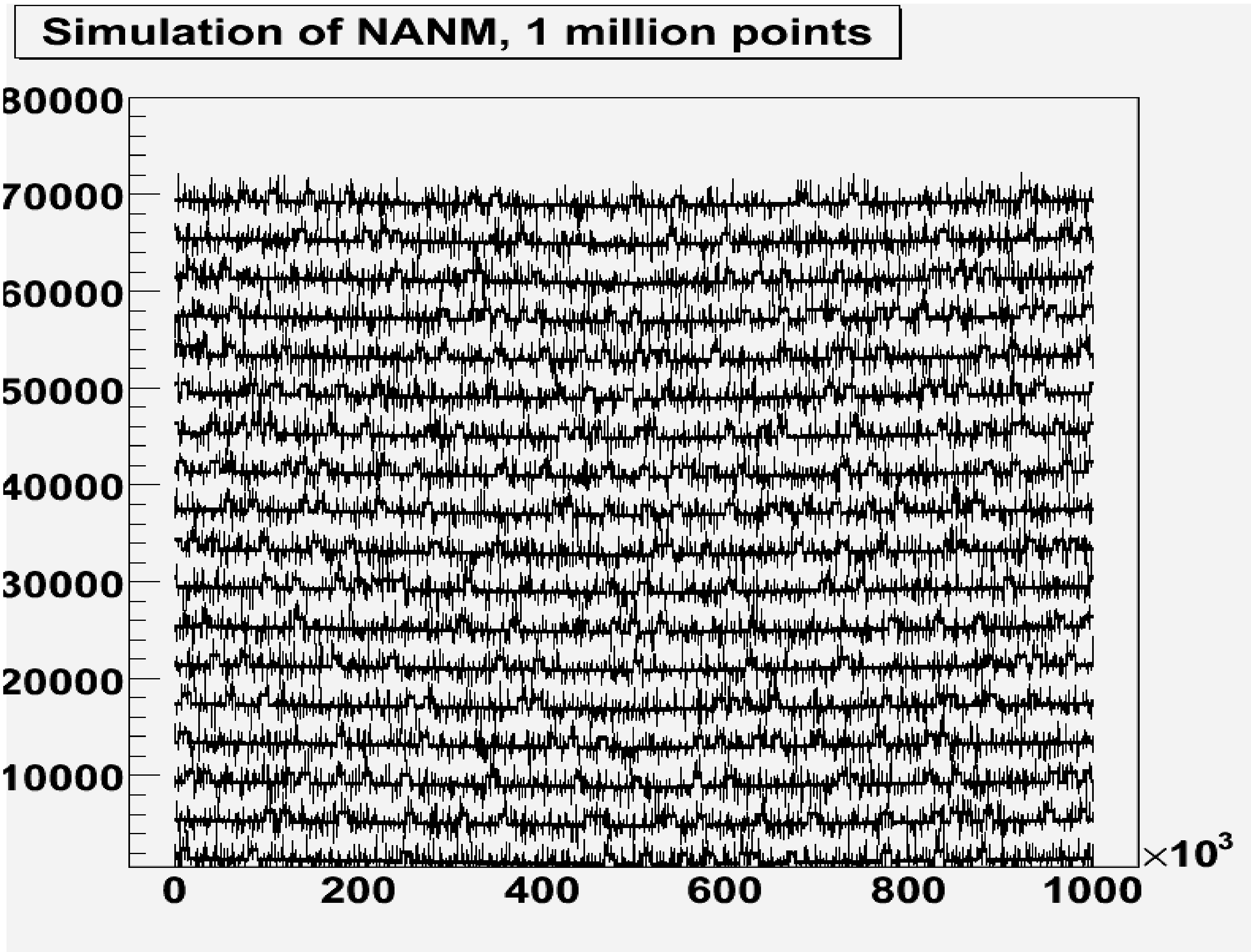


NANM: means and coefficients

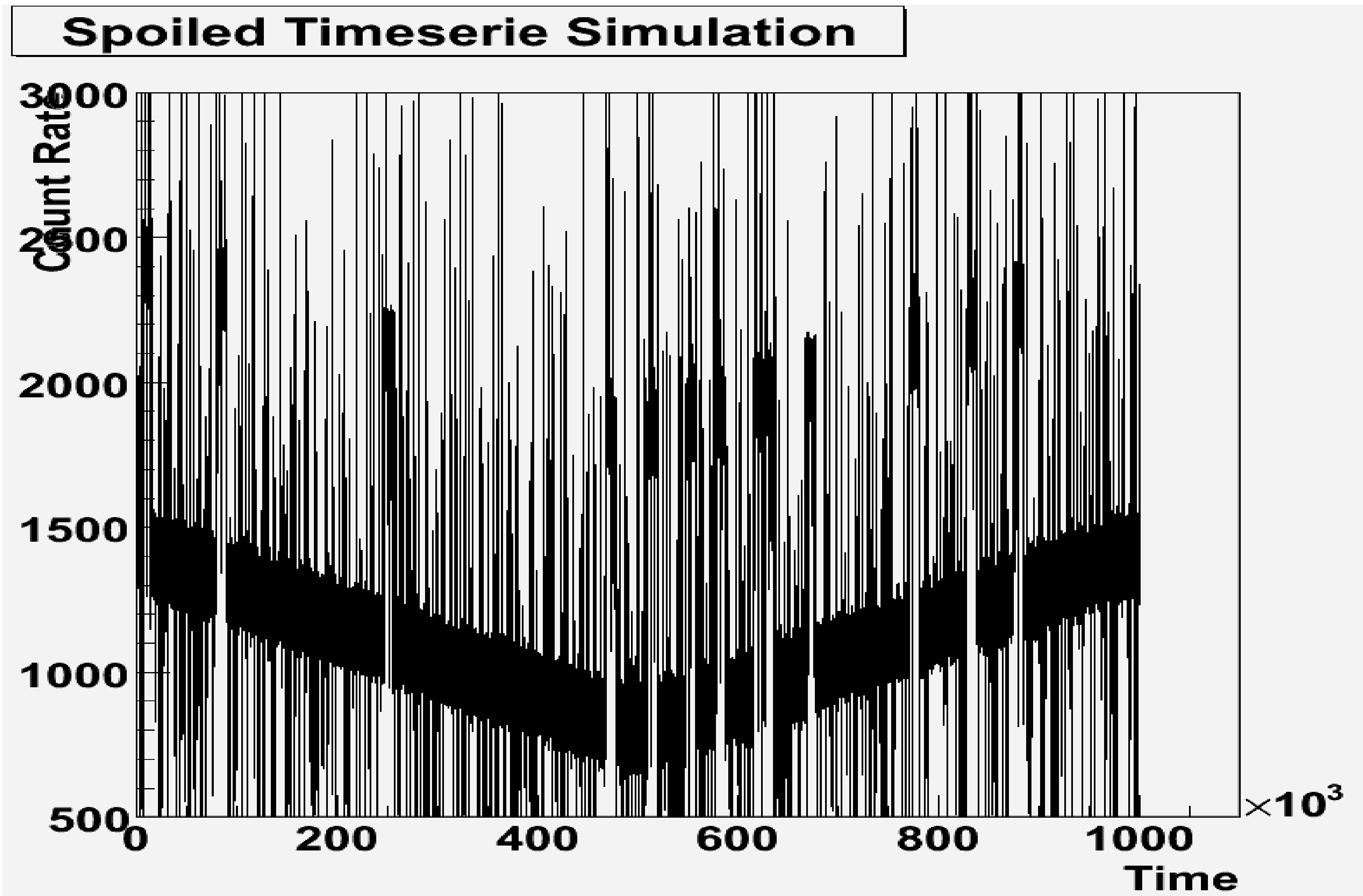




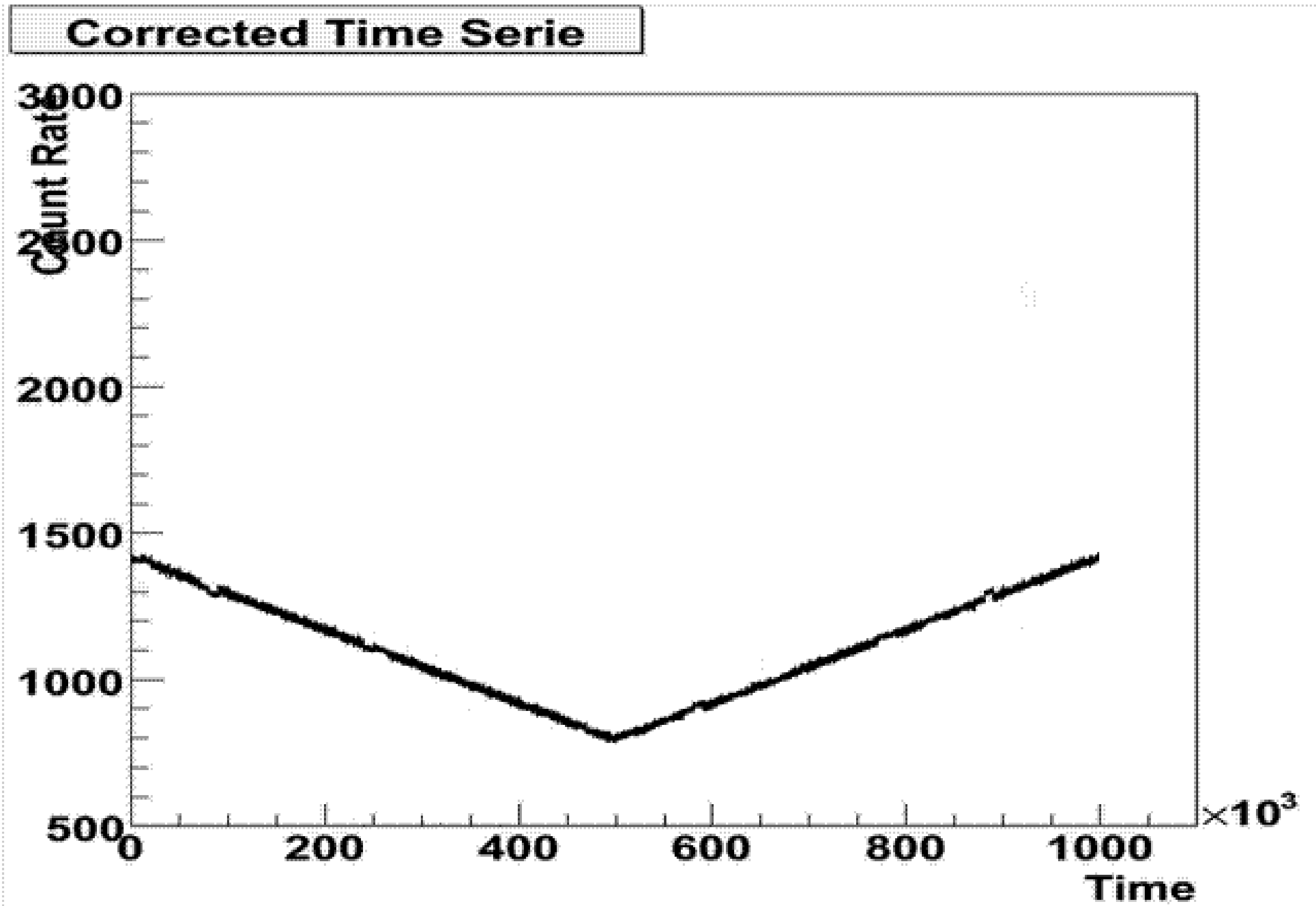
Simulation of Data For NANM



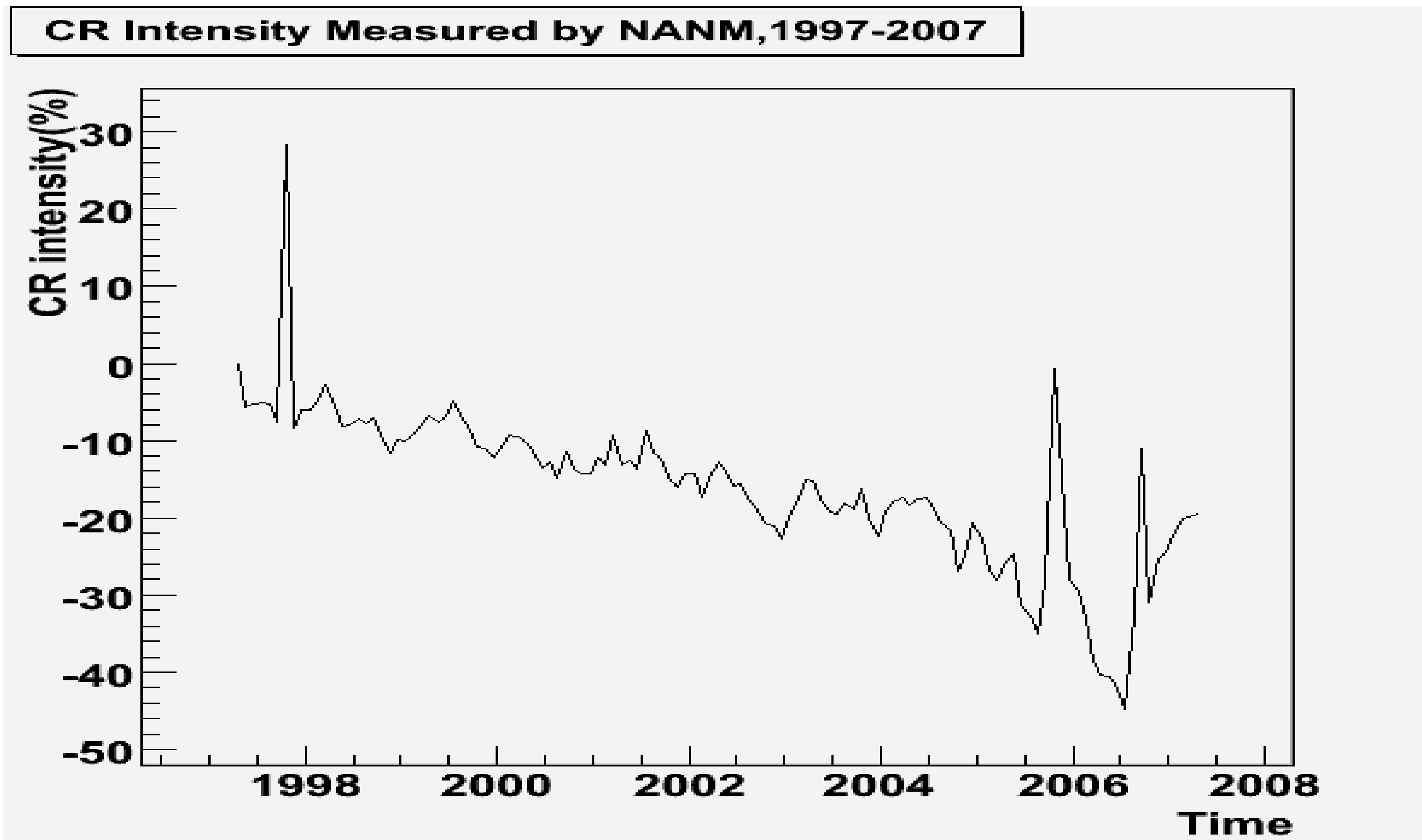
Simulation of Spoiled Timeserie



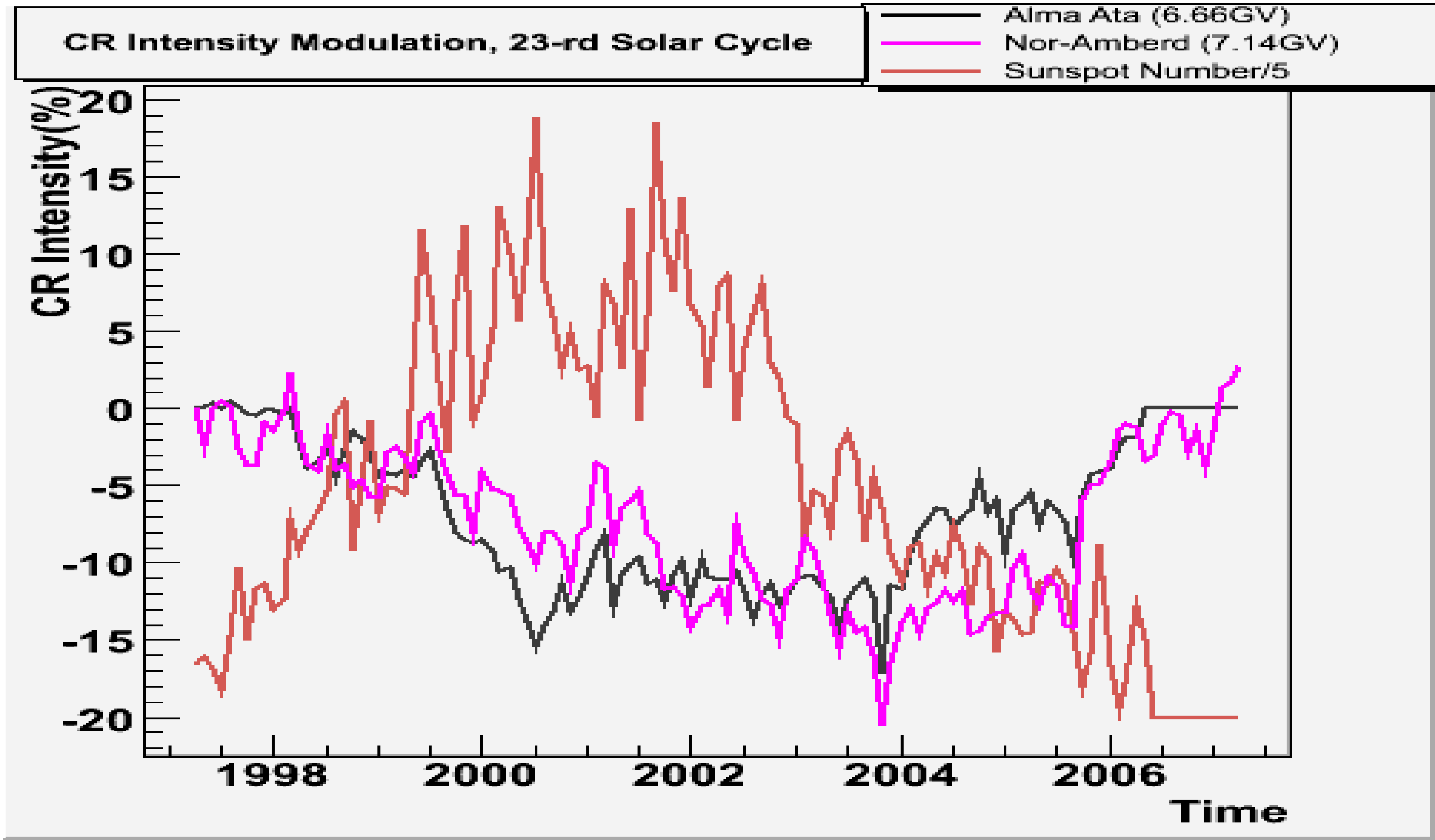
The Same Timeserie After Correction



CR Intensity Modulation during 23th solar cycle, Measured by NANM



Comparison of Corrected Data of NANM with Alma-Ata Data



Conclusion

- Filtering of the multichannel data of particle detectors operated many years for detection of the solar modulation effects and, may be sidereal modulation effects, is of upmost importance. During multiyear measurements characteristics of detector undergo critic changes due to aging effects of sensors and discrete elements of electronics. Overabundance of the information allows introducing correction algorithms using stabilizing properties of the median of time series. Continuous storing and monitoring of the mean values of all channels along with their equalizing coefficient allows archiving of time-history of the behavior of all channels. Examining the relative behavior of channel means and coefficients during multiyear operation it became possible to distinguish the physical effects from instrumentation failures