13 SNMP and GRB system

13.1 The Supernova and Monopole System

13.1.1 Introduction

The idea to search with the AMANDA detector for the low energy neutrino bursts emitted during supernova (SN) explosions was first pointed out in [5]. The array is operated as a counting rate monitor for each individual PMT, searching for a sudden increase of the rates from all PMTs over a time window of the order of 10 secs. These signals could be due to Cerenkov light from positrons, generated in the reaction $\bar{\nu}_e + p \rightarrow e^+ + n$. For $E_{\bar{\nu}_e} \approx 4$MeV, the generated positrons are almost istropically emitted and have a path length of about 12 cm in ice, emitting $\sim$3000 photons.

The effective detection volume V_{eff} at the single photoelectron level for each optical module is a function of the maximum absorbtion length L_{abs} of the medium and the absorbtion spectrum. It is not influenced by the scattering length. For a single PMT and L_{abs} =310 m (AMANDA-A) one finds $V_{eff} \approx 970\text{m}^3$, for AMANDA-B with $L_{abs} \approx 90$ m, the effective vloume comes up to $V_{eff} \approx 410\text{m}^3$ [6]. For a SN of the same luminosity as SN1987A, located at the center of our Galaxy (8 kpc), this yields about 160 counts per PMT in AMANDA-A and 110 counts per PMT in AMANDA-B.

The background to this signal is determined by the noise fluctuation of all PMTs. For the ideal experimental situation of uncorrelated and purely poissonian noise of the PMTs, the fluctuation of noise hits N_{HIT} per 10 secs, is given as $N_{HIT} = (10\text{sec} \cdot R_{noise} \cdot n_{PMT})^{1/2}$, with n_{PMT} being the total number of PMTs. Under this assumption, a SN1987A-type supernova at the galactic center would yield a 15σ effect for 60 PMTs in AMANDA-B4, each with the typical noise rate of R_{noise} =320 Hz. The above assumption simplifies the experimental situation, the most dramatic change being non-poissonian single PMT noise fluctuations.

The upgrade of AMANDA to a supernova watcher required only a moderate extension of the existing setup. Given the very low rate of SN-bursts in our Galaxy ($10^{-1} - 10^{-2}\text{yr}^{-1}$ [7]), and the few existing SN-detectors, a continuous monitoring seems to be an interesting task for a neutrino telescope. First results have been presented in [2].

13.1.2 The SNMP-DAQ

The Supernova-and-Monopole (SNMP) System is a separate Data Aquisition System build by the Zeuthen group, as show in figure 1. A first setup was installed in 1994/95 for AMANDA-A, it was upgraded in 1996 and 1997 to the needs of AMANDA-B.

The system runs independently of the muon-DAQ, taking the output of the 1 pe-discriminators used in AMNAD-A and -B, as given in fig.**??**. It is based on custom-made 'Supernova&Monopole' CAMAC boards which are read out via a Jorway-73A CAMAC controller into a PowerMacintosh. Data are transfered via the South Pole LAN to the AMANDA DEC-Alphas and Linux-PCs for fast offline data extraction and DAT-tape storage (150 MB/day).

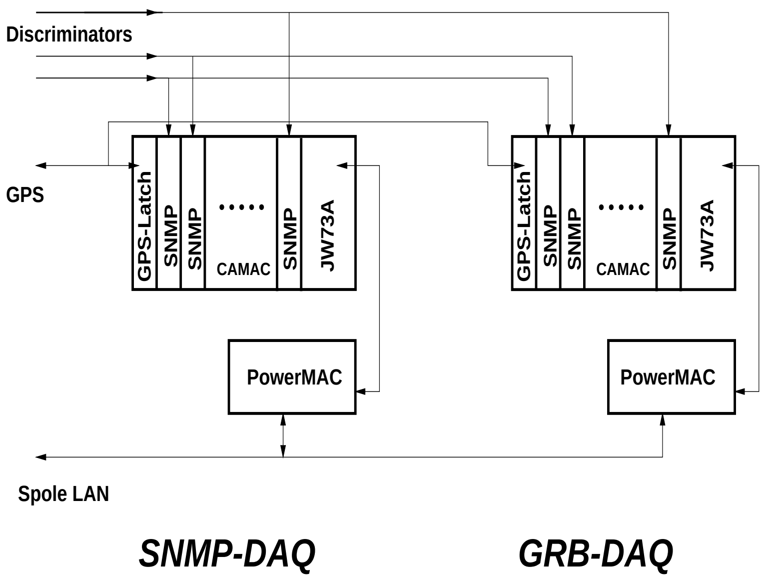


Figure 1: Sketch of the SNMP- and GRB-DAQ, connected to the AMANDA-A and AMANDA-B 1-pe-discriminator outputs, see fig.??.

Each SNMP board takes the AMANDA leading edge discriminator output signals from 16 PMTs and acts

(1) for the *supernova search* as 16 frequency counters with a time window of 0.5 sec and a dynamic range of 8 kHz, to permanently record the counting rates of every PMT, and

(2) for the *monopole search* as a trigger for high noise fluctuations in any of the PMTs above a trigger threshold of $N_{hit} = 1$–16 noise hits within a time window of $\delta t = 10\,\mu$sec–8 msec (both programmable).

The boards are single-width CAMAC modules with 16 ECL input channels, each hosting five Field Programmable Logic Array chips (XILINX XC3x64 family) and a FIFO data output buffer of $16\,\mathrm{k} \times 16\,\mathrm{bit}$.

A second generation of SNMP modules had been produced for the 1996 and 1997 upgrades of the DAQ. They allow for afterpulse suppression (via a programmable artificial deadtime at module input up to $12.8\,\mu$sec) to reduce the effective PMT dark counting rate and their fluctuations. Also, they offer an optional extention of the dynamic range from 8 kHz up to 2 MHz (used for the DC-light source measurements described in sect.??). Absolute time synchronisation is given by a GPS clock, interfaced with a CAMAC-GPS latch module.

Since its first installation in 1995, the system has been running stable, interrupted only by station power failures, for detector maintenance and for upgrade during the expeditions. Extracted SNMP data (3 MB/day compressed) are send via satellite on a weekly basis, to allow for monitoring the PMT performance as well as a preliminary SN-search. The full set of data is, as for the muon data, once per year shipped back to the home institutes.

In 1995, all 80 AMANDA-A PMTs were connected to 10 first generation SNMP modules. In

1996, the newly deployed 86 AMANDA-B4 PMTs were incorporated into the 11 board setup (2nd generation SNMP modules, dead time set to 10 μsec). With the old SNMP modules, a GRB trigger was set up (see below). In 1997, a full CAMAC crate with 22 SNMP boards (max. 352 channels) was set up to monitor all PMTs of AMANDA-B10 and the 48 most stable from AMANDA-A (6 twisted pair AMANDA-B4 PMTs not connected).

Since mid 1996, the monopole trigger option on all SNMP boards has been switched off, since scattering and the high PMT afterpulse rate masks Monopole signatures. This reduced the data rate and improved stability against short term PMT noise glitches.

13.1.3 Results for AMANDA-B and AMANDA-A

Average noise rates for the AMANDA-A PMTs (EMI 9353) are 1.7 kHz (at $\sim$0.2 p.e and without afterpulse suppression, 1995). The AMANDA-B4 array (Hamamatsu-R5912) shows much improved noise performance. The average counting rate for the array was about 370 Hz in 1996 (10 μsec deadtime). We attribute this to better PMT performance and afterpulse suppression. In 1997, the average rate drops down to $\sim$320 Hz, after recalibration and threshold adjustion. The AMANDA-B PMTs deployed in 1996/97 at strings 5-10 have with $\sim$1.1 kHz a higher by $\sim$3.4 noise rate as compared to string 1-4. This is shown in fig.2, giving the noise rate, R_{noise}, as function of PMT number. This is due to lower PMT quality, since similar differences were observed for these PMTs in laboratory measurements. Note, that the twisted pair PMTs deployed in 1995/96 showed the same low rates as the coax modules.

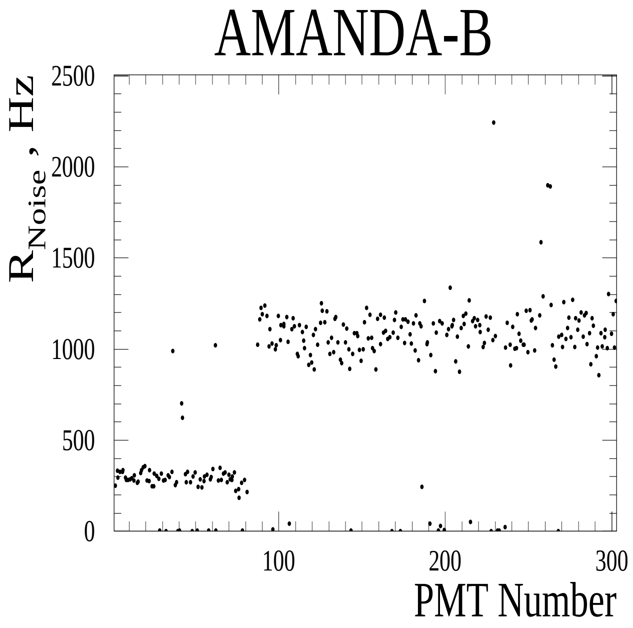


Figure 2: The average noise rate, R_{noise}, for AMANDA-B PMTs in 1997. AMANDA-B string 1-4 are PMT 1-86 (81-86 not shown), strings 5-10 are PMT 87-302. Dead modules are set to $R_{noise} = 0$.

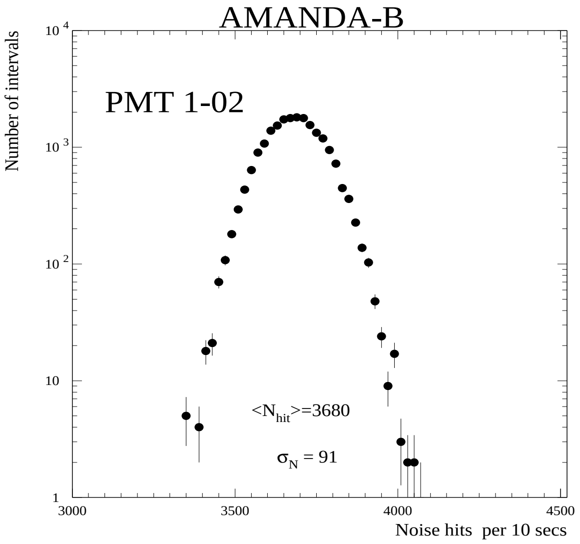
The **width of the noise distribution**, σ_N, for all PMTs is clearly above the poisson expectation $\sigma_{pois} = \sqrt{N_{HIT}}$. For AMANDA-A we find for the ratio $r_{pois} = \sigma_N/\sigma_{pois}$ ~2.7 (without afterpulse suppression). For AMANDA-B we find r_{pois} ~1.6 and ~1.8 for strings 1-4 and 5-10, respectively. Figure 3 displays the noise rate distribution of a typical AMANDA-B4 PMT ($r_{pois} = 91/\sqrt{3680} = 1.5$). For all AMANDA-B PMTs, the measured dependence of σ_N as function of number of hits for 10 sec intervals, N_{HIT}, is presented in fig.4. The two large cluster at N_{HIT} ~3000 and ~11000 correspond to strings 1-4 and strings 5-10.

SN-signal: The distribution of noise hits, summed over all stable operating PMTs in the AMANDA-B4 array for adjacent 10 sec intervals, is given in fig.5. The counting rate is normalized to a moving average window of 1000 secs to account for slow drifts. A total of 64 very stable PMTs has been selected for the 1996-run period, 21.7 days of stable life-time have been analyzed from satellite extracted data, see fig.5(left). Arrows indicate the signal expected for a SN1987A type event occuring at 8 kpc and 6 kpc distance, respectively. For a SN-detection efficiency of 90 %, a cut at $\sim 1.3\sigma_N$ below the average signal position has to be made. For a detailed analysis, oversampling of the time interval starting positions has to be done.

The 1997 runs are more stable for strings 1-4, as compared to 1996. A first analysis of satellite data gives a rate of ~95 % stable runs. This is shown in fig.5(right) for 60 selected PMTs and a life time of 21.4 days. A rough estimation of the fake SN signal rates at 90 % efficiency is $\approx 1yr^{-1}$ for 8 kpc, assuming that run conditions remain as stable as for the investigated time interval. Routine analysis of AMANDA-B string 5-10 data is in preparation [8]. We expect, assuming the same long-term stability as string 1-4, a signal to noise roughly equal to the AMANDA-B4 data ($\sqrt{(200/60)}/\sqrt{1100\,Hz/320\,Hz} \sim 1.$).

For AMANDA-A, the distribution of noise hits in 10 sec intervals, summed over 60 PMTs for a selected life time of 81.9 days (1995), is given in figure 6 (normalized as for fig.5, arrows indicate the 8 kpc and 6 kpc signals). The SN signal is buried in a huge rate of fake signals. We note, that the same data set had been presented before [2] [1], where the old signal predictions ($V_{eff} = 1700\mathrm{m}^3$ [4] compared to $970\,\mathrm{m}^3$) resulted in a calculated fake trigger rate as low as $\leq 10\,\mathrm{yr}^{-1}$ for a 6 kpc signal.

To summarize, for AMANDA-B a detection or confirmation of supernovae from our galactic center at a reasonable background rate seems feasible. The operation of 3 different 'sub-detectors' (AMANDA-B string 1-4, string 5-10 and AMANDA-A) with their different systematics allows for additional background suppression. For an AMANDA-II array with 500 new PMTs (assuming same low noise as for string 1-4), we expect an improvement in signal-to-noise ratio compared to AMANDA-B4 of about $\sqrt{500/86} \sim 2.4$.



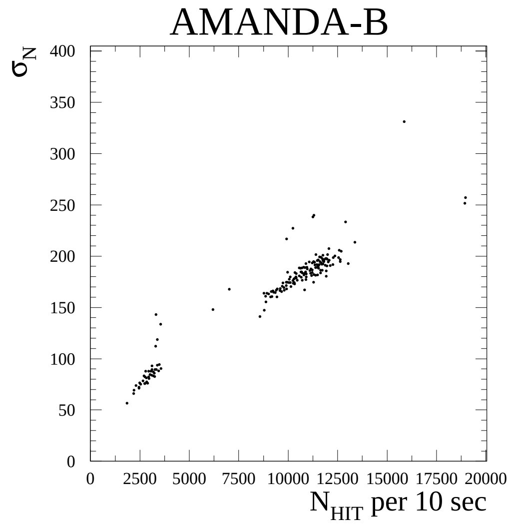


Figure 3: (Left) Distribution of number of hits of a typical AMANDA-B4 PMT, taken for 10 sec time intervals for a total of 51 hours (1996).

Figure 4: (Right) Width of the noise hit distribution, σ_N, as function of the average number of hits N_{HIT} in 10 sec intervals for AMANDA-B. Strings 1-4 are clustered at N_{HIT} ~3200 (320 Hz), Strings 5-6 at ~11000 (1.1 kHz).

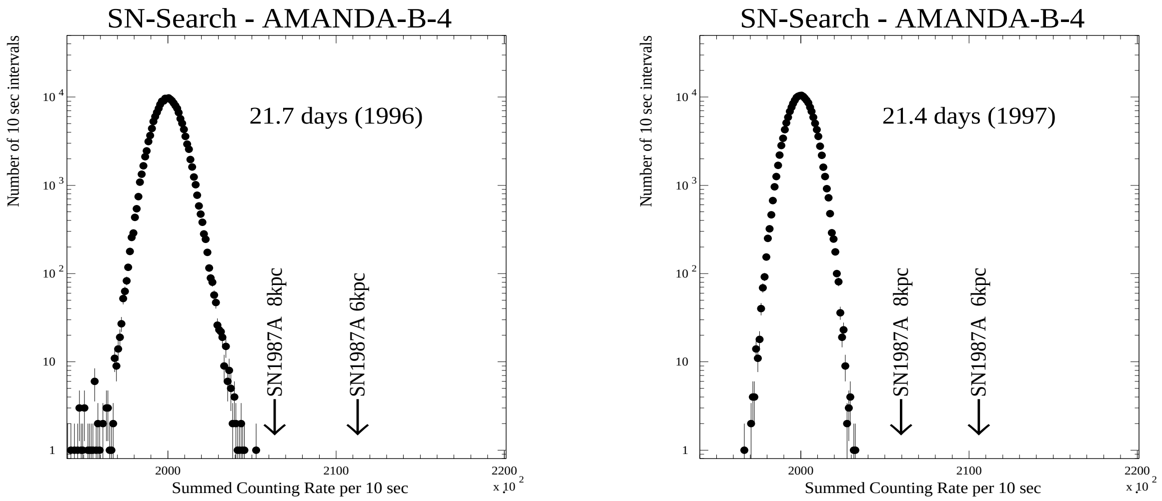


Figure 5: Left: Distribution of summed number of hits for 64 PMTs of AMANDA-B4, taken for adjacent 10 sec time intervals and a selected life time of 21.7 days in 1996. Indicated are the average signals expected for SN1987A-type Supernova at 8 kpc and 6 kpc.
Right: Same distribution for AMANDA-B4 for 60 PMTs in 1997, and a selected life time of 21.4 days. Absolute rates are normalized to $2{\cdot}10^5$ counts.

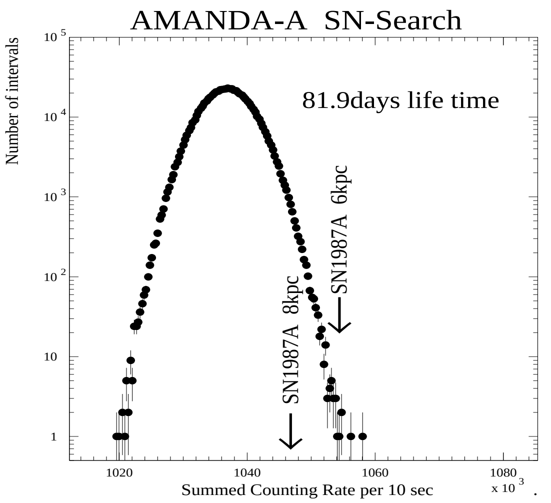


Figure 6: Distribution of summed number of hits for 61 PMTs of the AMANDA-A array, taken for adjacent 10 sec time intervals and a selected life time of 81.9 days in 1995.

13.2 The GRB-system

As pointed out in sect.**??**, AMANDA might act as a detector searching for neutrino signals correlated with Gamma Ray Bursts (GRB's). Predictions for the different GRB models vary over orders of magnitude with respect to the energy spectrum and flux and the time scale of a possible neutrino signal. Some models predict neutrino bursts on the msec scale.

During the 1995/96 expedition, a separate trigger system to search for signals from GRB's had been installed. The system consisted of 11 first generation SNMP boards. They run at maximal readout speed, corresponding to a 5 msec sampling window. The summed array rate is online watched for large fluctuations, only events above a 4σ-cut are stored on disk.

Fig.7 gives the raw distribution of summed counting rates in 5 msec bins, for all selected AMANDA-B PMTs. From this plot, the 4σ-cut was determined to be 270 counts, resulting in a 0.3 Hz trigger rate. An investigation of the sources of this rate, which is much above the total GRB rate of $\sim 0.3\,\mathrm{day}^{-1}$, is under way.

Since 1997, a setup with 14 second generation SNMP boards with a total of 224 channels is running, being connected to all AMANDA-B4 PMTs, to 96 PMTs of string 5-7 and 48 stable AMANDA-A PMTs.

We regard the current setup as a first step towards understanding of the experimental detection capabilities of pulses from msec to sec duration correlated with the satellite GRB data. A dedicated GRB system should monitor the array rate fluctuations simultaneously at different timescales, down to the few 10 μsecs, which is not accessible with the current SNMP DAQ-design.

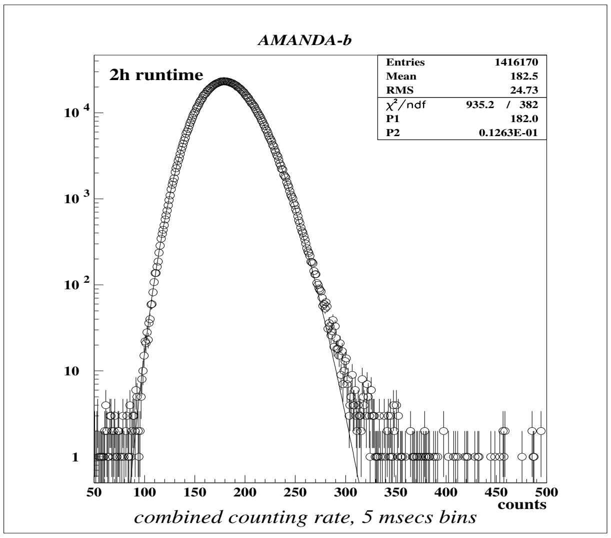


Figure 7: Raw distribution of PMT noise rate summed over the AMANDA-B array for a 5 msec time window and a total of 2 hours (1996). The implemented online "GRB"-trigger threshold is set to 270 counts (4σ).

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