# RICE DAQ 2003 manual

We, who wrote it

December 10, 2004

**Abstract**

This document describes RICE DAQ in reasonable detail, including overview of the detector array, DAQ electronics at depth (hardware, connections, performance) and DAQ Labview software. Some system performance studies are given, as well as operating instructions for South Pole operators.

**WARNING! This version of the manual is not self-consistent. I have started modified it from 2002 to 2004 version in Jan 2005 but did not have time to finish. Therefore it only partially reflects the 2004 DAQ design. The DAQ diagrams are new and the text is updated only around sections 1-4. -Ilya**

# Contents

# 1 Introduction

In this manual, we describe in some detail the online DAQ hardware and software, as it has evolved with time. The receiver design, performance, etc., are described in the companion document "RICE Receiver Design" [1]. The fate of the data after they are saved to HD is described in the online analysis manual [2].

Note the following important URL's:

- http://kuhep4.phsx.ukans.edu/~Evan is the main KU RICE page.
- http://kuhep4.phsx.ukans.edu/~iceman/misc contains DJ/Eben's work from the summer of 2000.
- http://rice.physics.fsu.edu is george's webpage at FSU, and also contains the raw data.
- http://kuhep4.phsx.ukans.edu/~soeb contains several plots relating to Monte Carlo generation, and also contains the draft of a GEANT/ZHS comparison document.

# 2 The RICE environment

RICE experiment is located at the Geographic South Pole. The sensitive detector elements, receivers, are submerged into the ice at the depth of several hundred meters. The Polar Icecap at the South Pole is approximately 2400m deep and consists of a very pure and transparent ice with temperature about -50 C. The ice transparency qualities, index of refraction and the stability of the temperature vary with depth. The top 10s of meters of the Icecap are called "fern" and are characterized by the presence of air bubbles in ice, index of refraction varying with depth and ice temperature varying with time. By the depth of 100m and below, the ice reaches stable index of refraction and temperature, and bubbles of air are gone. The receivers of the RICE experiment are mostly deployed to the depths 150-250 meters in a 3D array.

One of the most important characteristics of ice, is RF transparency. There have been measurements of the antarctic ice properties in the past, for example, at Vostok station. Thus we know that at radio frequencies (200 MHz - 1 GHz), the attenuation length of the electromagnetic waves is about 1 km. Within the RICE experiment various studies of rice properties have been performed, for details see [1].

# 3 RICE receivers and detector array

This section provides a short overview. Longer version with more details, studies, etc., can be found in [1].

## 3.1 Receiver/Transmitter design

There are two types of modules used by RICE, receivers ("Rx") which perform signal detection and transmitters ("Tx") which are used for calibration of the array. Since 1997-98, RICE receivers have followed the "fat dipole" design indicated in Figs. 1(a)-(d).

(Higher resolution versions of these drawings can be found in:

```
http://kuhep4.phsx.ukans.edu/~dzb/superdb_ant1.jpg,
http://kuhep4.phsx.ukans.edu/~dzb/superdb_ant2.jpg,
http://kuhep4.phsx.ukans.edu/~dzb/superdb_ant3.jpg,
http://kuhep4.phsx.ukans.edu/~dzb/superdb_ant4.jpg.
```

)

A fully assembled receiver consists of a copper dipole antenna (Fig. 1(c)) placed inside a nylon pressure vessel (cylinder in Fig. 1(a) and top/bottom caps in Fig. 1(d)). Inside the pressure vessel there is also an amplifier (further referred as "in-ice amplifier"), with several nylon pieces (Fig. 1(b) thrown in to hold assembly together.

**Receiver design** The antennas are half-wave dipoles with central frequency in the air approximately 415 Hz, and 242 MHz in ice; the real part of the antenna impedance is expected to be close to 50 Ω. This design is likely to change somewhat in the future as our understanding of antennas and ice environment improves.

Surface receivers are "TEM horns", fabricated by the Moscow Institute of Nuclear Research (MINR). At low frequencies, the horns have very poor reception below 200 MHz, however, at higher frequencies, the horns show good reception up to 3 GHz. Performance characteristics of dipoles vs. horns will be discussed in subsequent sections.

**Transmitter design** Dipole transmitters deployed to date are identical to receivers, save for the absence of the receiver amplifier. Transmitter can be always differentiated from receivers according to their DC resistance, as measured with an ohm-meter: The DC resistance of the receivers is approximately 1170 Ω, whereas the transmitters present infinite DC resistance (an open circuit) to an ohm-meter.

**In-ice amplifiers** The in-ice amplifiers located in pressure vessels with antennas [1] are +36 dB gain MITEQ amplifiers with the bandwidth of 0-1 GHz. The noise figure of these amplifiers is from 1.6 to 1.8 and they have a 1 dB compression point of 8 dBm. Amplifiers take DC power from the same coaxial cable that carries away the signal from the antenna. A more detailed description of the specs and their meaning can be found in [1].

A normal receiver plus amplifier system operates at the voltage of 12 V and draws approximately 60 mA of current. There are **voltage** regulators inside the deep amplifiers, so the voltage to the deep-ice amps should **never** exceed 12 V. If the current draw at 12 V is significantly above 60 mA, notify DZB (dzb@lns.cornell.edu) immediately.

[1] Actually, our older pressure vessel design had amplifiers located outside of antenna pressure vessel, in a special aluminum casing (96-97 receivers, 97RxG, 98Rx3 and 98Rx5). All other receivers starting from 97-98 season and up to present time have amplifiers inside the antenna pressure vessel.

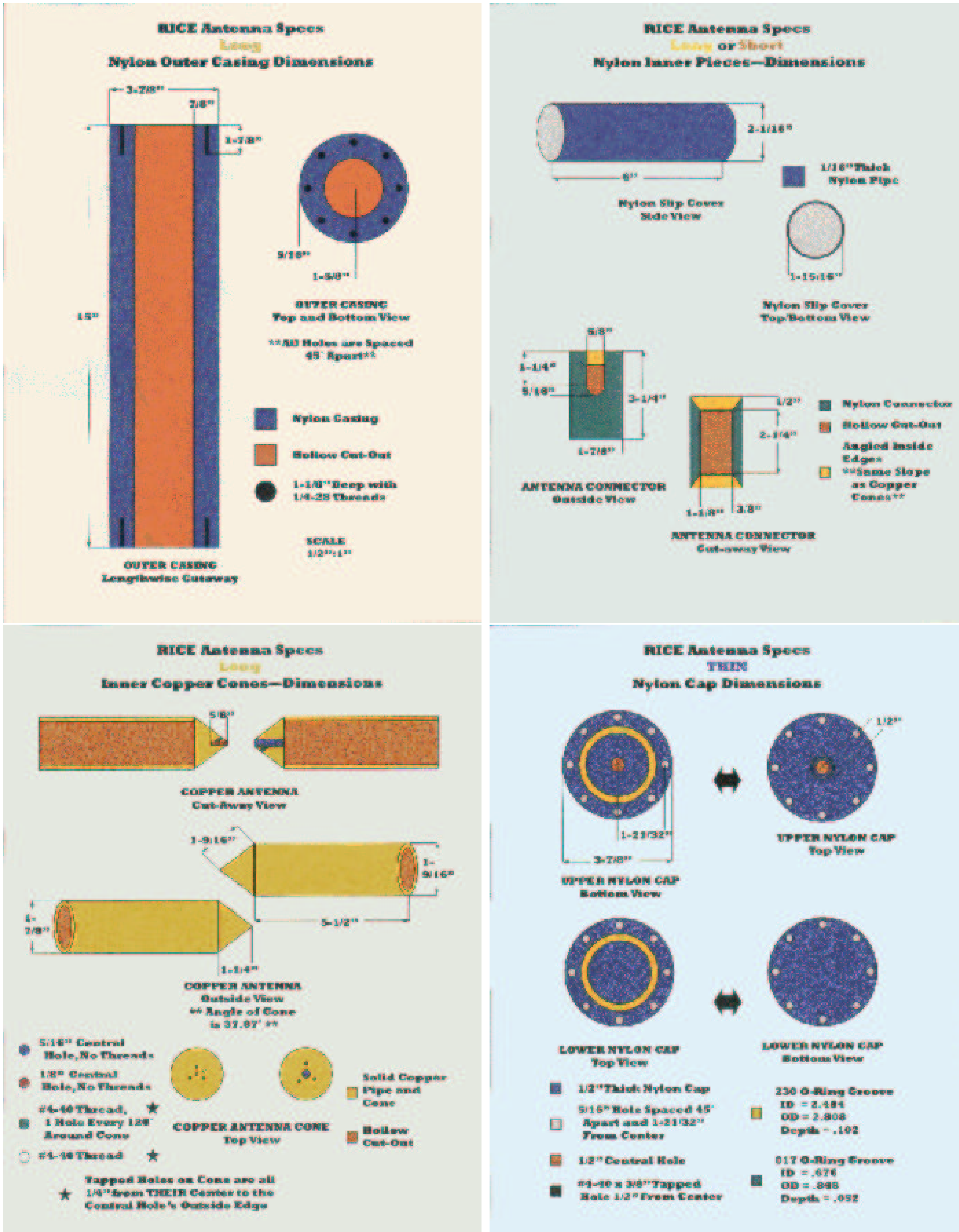


Figure 1: Dipole Antenna schematic: a) top-left: Outer Casing; b) top-right: Nylon inner pieces; c) bottom-left: Inner Copper Cones; d) bottom-right: Nylon Caps.

| Type | TESSCO SKU# | $v_{\text{propagation}}/c$ | Attenuation 150 MHz/450 MHz |
|---|---|---|---|
| Intercomp RG-8U | 57147 | | 2.3 dB / 4.7 dB (/100') |
| LMR-500 | 48279 | 0.86 | 1.22 dB/2.17 dB (/100 ') |
| LMR-600 | 86672 | 0.87 | 0.964 dB/1.72 dB (/100') |
| Cablewave FLC12-50J | 70393 | 0.88 | 0.845 dB/1.51 dB (/100') |
| Andrews LDF4-50A | (Hutton) | 0.88 | 0.73 dB/1.41 dB (/100') |
| Andrews LDF5-50A | (Hutton) | 0.88 | 0.46 dB/0.83 dB (/100') |

Table 1: Specs for RICE coaxial cables

**Pressure vessel** Receivers are housed within a nylon (doped with molybdenum disulfide, aka "MDS-60", for additional mechanical strength) cylindrical pressure vessel, as indicated in the antenna Figures. The pressure vessels are designed to withstand a rather high pressure. Already dropping a receiver into a hole filled with water to the depth of about 200 meters causes about 20 atm of pressure, and when the whole freezes this pressure goes up significantly as the ice expands. After testing various models in a pressure chamber the cylindrical design shown in Figure 1 has been chosen. Receiver nylon has been ordered from AIN Plastics of Michigan. Connections with the coaxial cable are made through a bulkhead SMA-to-N adapter (mfr. Pasternak Industries of Irvine, CA).

### 3.2 Detector array

Figure 2 shows the scheme of present deployment of both receivers and transmitters. The mnemonics for the modules are: NNXXI, where NN indicates the year of the polar summer when the module was deployed (e.g., 98 for the 98-99 summer), XX indicates whether the module is a receiver ('Rx') or a transmitter ('Tx'), and the final integer is the number of that season's receiver or transmitter. The holes are drilled for AMANDA in the vicinity of the building MAPO housing DAQ electronics of AMANDA, RICE and several other experiments. Coaxial cables run between the deployed RICE antenna and MAPO.

### 3.3 Cables: types, specifications, etc.

Several types of coaxial cables connect under-ice RICE hardware to DAQ electronics in MAPO. With current detector geometry it takes approximately 600-1000 feet of cables. A summary of the cable types and their specs is specified in Table 1.

In addition to the essential characteristics given in the table, one has to be concerned about the dispersive effects. The magnitude of the dispersive effects have been tested by sending a 1ns pulse through 1000 feet of LMR-500 cable and the resultant shape have been compared to that at the input. The scope traces of both pulses are shown in Fig. 3-4. The figures indicate that the signal is spreading by approximately 1ns through 1000 feet of this cable, and LMR-500 is the poorest-quality cable used in RICE, at present. Thus the dispersive effects are not considered significant.

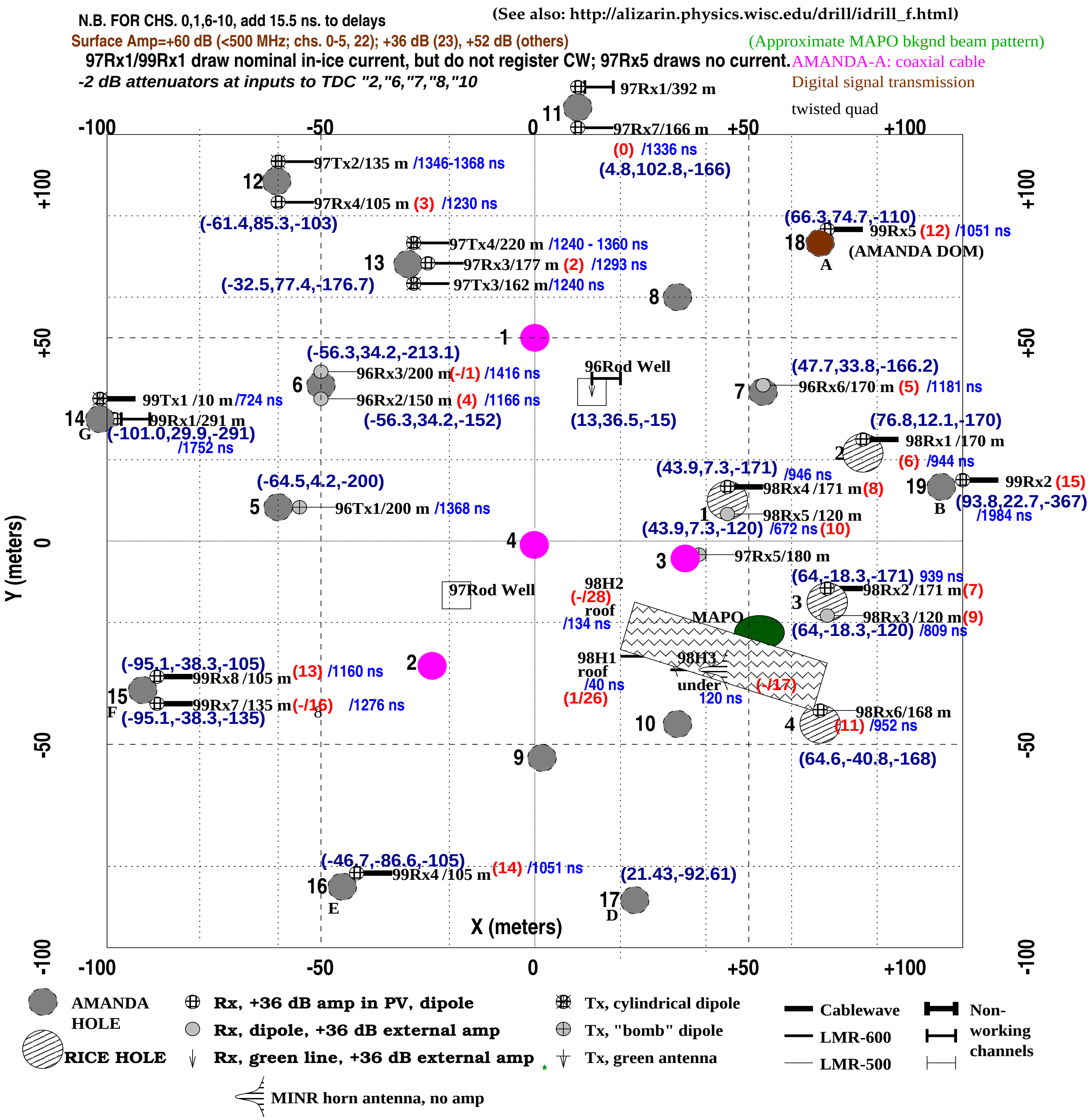


Figure 2: The RICE modules; also indicated are channel number and time delay of the cable relative to the MAPO DAQ.

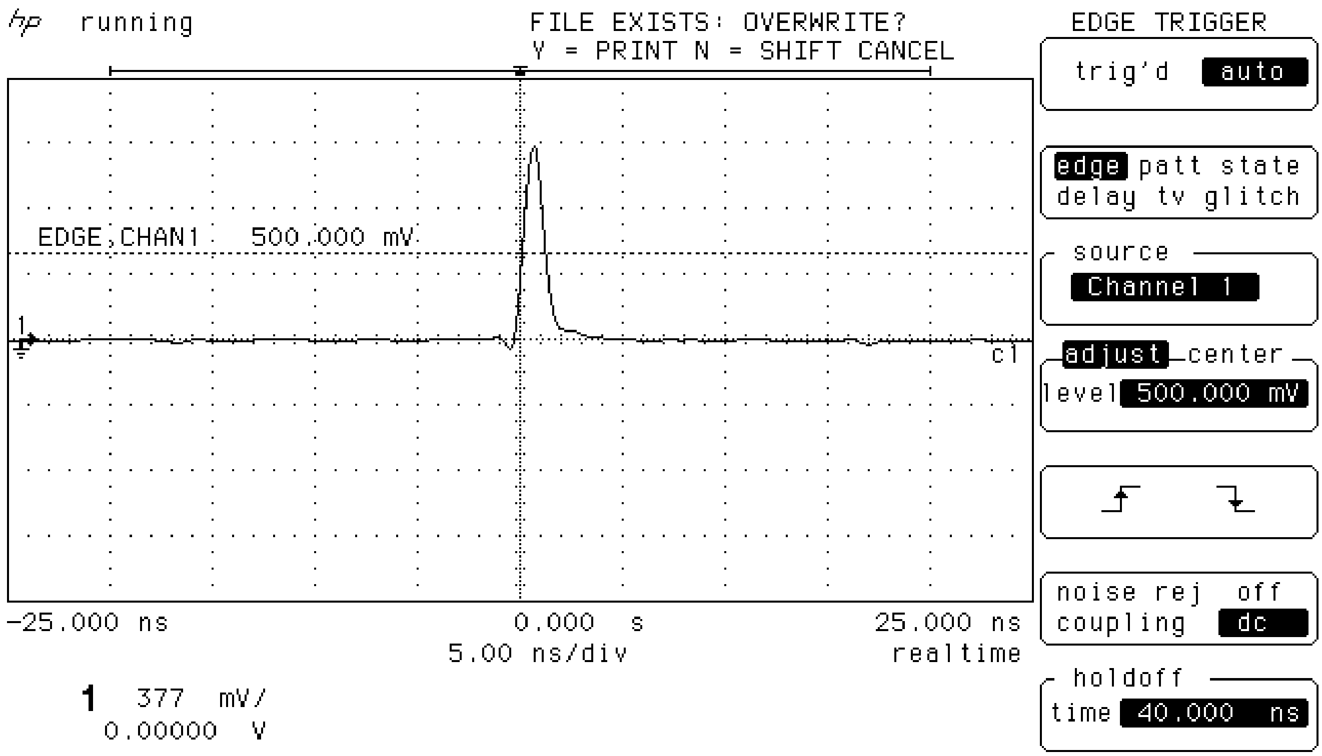


Figure 3: 1 ns signal from pulse generator, fed directly into digital scope

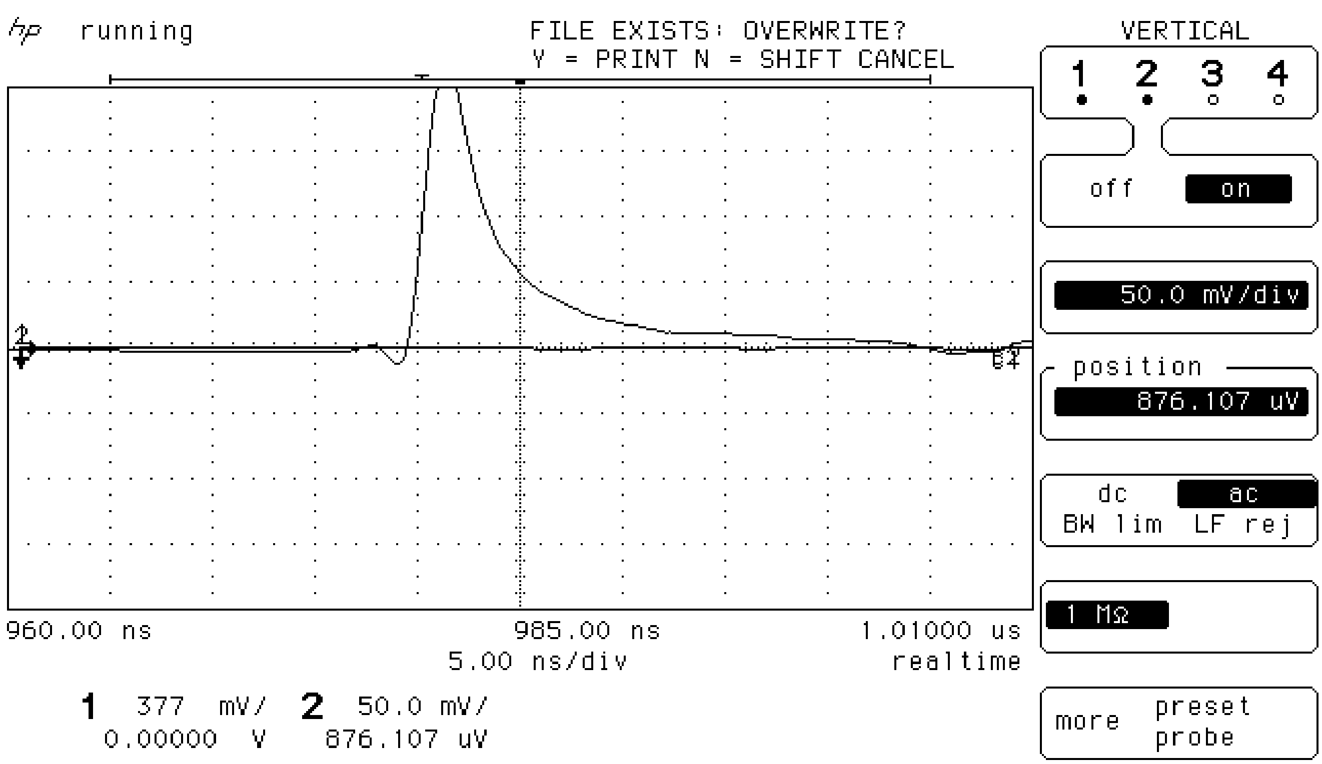


Figure 4: 1 ns signal from pulse generator, as in previous figure, but passed through 1000 feet of LMR-500 cable

# 4 DAQ electronics: hardware

## 4.1 Analog section

Analog section of the DAQ on the surface includes power supplies and power distribution system and also amplifying and filtering components to prepare the signals from antennas for the scopes and digital electronics of the DAQ. In this section every component is described.

### 4.1.1 Power distribution box, bias tees and filters

After being led through a conduit into MAPO, the signal cables are then plugged into the power distribution boxes (PDB). At present we have two of these. Each power distribution box is a rack mounted aluminum structure that is capable of holding 12 channels of electronics. The correspondence between the underground channels and the channels of the power distribution boxes is shown in Figure 2, and also presented in the Table below. The three surfaces horns are ganged together using N-type tees and take one channel of the second PDB (000101).

| 3412 "Channel/PDB | set $I_{surface}$ (mA) | set $I_{deep}$ (mA) |
|---|---|---|
| "0 96Rx3/1 | 232/3 | 70 |
| "1 97Rx7/1 | 232/3 | 72 |
| "2 97Rx3/1 | 232/3 | 18 |
| "3 97Rx4/1 | 256/3 | 16 |
| "4 96Rx2/1 | 256/3 | 70 |
| "5 96Rx6/1 | 256/3 | 70 |
| "6 98Rx1/1 | 82/3 | 60 |
| "7 98Rx2/1 | 82/3 | 60 |
| "8 98Rx4/1 | 82/3 | 56 |
| "9 98Rx3/1 | 100/3 | 50 |
| "10 98Rx5/1 | 100/3 | 40 |
| "11 98Rx6/1 | 100/3 | 58 |

Table 2: Channel routing and current draws. Data for chs. 0-11 are taken from Bai (990918). Settings were obtained by modifying $I_{surface}$ and $I_{deep}$ until measured peak-to-peak voltage for each scope channel was ~200 mV (using infinite persistence mode; while LES-9 was OFF). According to Bai, the first two channels were determined to be "flaky". In fact, it is known that scope 1, channel 2 has a loose connector.

These currents are not uniform in order that each channel be equally likely to contribute to a true signal event trigger. Since some channels have higher noise levels than other, the surface amplifier gains are adjusted so that the thermal noise, at the scope, be approximately equal (we should not lower the currents for the in-ice amps for this, since this will only have the effect of reducing the S:N). Currents and bias voltages were again adjusted by Mike Boyce and Darryn Schneider June 17, 2000 to accommodate the new under-ice channels added in the 99-00 astral summer. Updated voltages/currents are:

| PS# | PB | 3412 | Scope | name | surface amp | I(surface) (mA) | Voltage (V) | deep amp | I(deep) (mA) | Voltage (V) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.1 | 1E | 1.1 | 96Rx3 | dB | \ | | dB | 71 | 14.8 |
| 2 | 1.2 | 2E | 1.2 | 97Rx7 | dB | )- 221 | 9.6 | dB | 72 | 14.6 |
| 3 | 1.3 | 3E | 1.3 | 97Rx3 | dB | / | | dB | 18 | 5.6 |
| 4 | 1.4 | 4E | 1.4 | 97Rx4 | dB | \ | | dB | 12 | 4.9 |
| 5 | 1.5 | 5E | 2.1 | 96Rx2 | dB | )- 237 | 14.7 | dB | 67 | 14.1 |
| 6 | 1.6 | 6E | 2.2 | 96Rx6 | dB | / | | dB | 64 | 13.6 |
| 7 | 1.7 | 7E | 2.3 | 98Rx1 | dB | \ | | dB | 57 | 12.1 |
| 8 | 1.8 | 8E | 2.4 | 98Rx2 | dB | )- 81 | 7.5 | dB | 57 | 12.2 |
| 9 | 1.9 | 9E | 3.1 | 98Rx4 | dB | / | | dB | 50 | 10.7 |
| 10 | 1.10 | 10E | 3.2 | 98Rx3 | dB | \ | | dB | 46 | 10.4 |
| 11 | 1.11 | 11E | 3.3 | 98Rx5 | dB | )- 106 | 8.8 | dB | 36 | 8.8 |
| 12 | 1.12 | 12E | 3.4 | 98Rx6 | dB | / | | dB | 54 | 12.1 |
| 13 | 2.1 | 2 | | 99Rx1 | dB | 43 | 12.1 | dB | 51 | 12.3 |
| 14 | 2.2 | 14E | 4.2 | 99Rx8 | dB | 44 | 12.1 | dB | 57 | 12.3 |
| 15 | 2.3 | 15E | 4.3 | 99Rx4 | dB | 54 | 11.8 | dB | 54 | 11.8 |
| 16 | 2.4 | 16E | 4.4 | 99Rx2 | dB | 41 | 11.8 | dB | 53 | 11.8 |
| 17 | 2.5 | 1 | | 99Rx6 | | Amplifiers not powered | | | | |
| 18 | 2.6 | 13E | 4.1 | 99Rx5 | dB | 61 | 12.3 | db | 63 | 12.0 |
| 19 | 2.7 | 3 | | 99Rx7 | dB | 82 | 12.3 | db | 56 | 12.0 |

Adjusted

| PS# | PB | 3412 | Scope | name | surface amp | I(surface) (mA) | Voltage (V) | deep amp | I(deep) (mA) | Voltage (V) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.1 | 1E | 1.1 | 96Rx3 | 60dB | \ | | 36dB | 64 | 13.3 |
| 5 | 1.5 | 5E | 2.1 | 96Rx2 | 52dB | )- 80x2=243 | 15 | 36dB | 64 | 13.7 |
| 6 | 1.6 | 6E | 2.2 | 96Rx6 | 52dB | /max out at 240* | | 36dB | 64 | 13.6 |
| 7 | 1.7 | 7E | 2.3 | 98Rx1 | 52dB | \ | | 36dB | 64 | 13.3 |

```
 8  1.8    8E  2.4    98Rx2  52dB    )- 80x3=240    14.6  36dB       64     13.3
 9  1.9    9E  3.1    98Rx4  52dB   /                     36dB       52     12.5*

10  1.10   10E 3.2    98Rx3  52dB   \                     36dB       64     13.3
11  1.11   11E 3.3    98Rx5  52dB    )- 80x3=240    14.6  36dB       64     13.3
12  1.12   12E 3.4    98Rx6  52dB   /                     36dB       54     12.2*

13  2.1     2         99Rx1  52dB       77*         14.9  36dB       64     14.4
14  2.2    14E 4.2    99Rx8  52dB       77*         14.9  36dB       64     13.3
15  2.3    15E 4.3    99Rx4  52dB       77*         14.5  36dB       64     13.5
16  2.4    16E 4.4    99Rx2  52dB       78*         14.5  36dB       64     13.5
17  2.5     1         99Rx6             Amplifiers not powered
18  2.6    13E 4.1    99Rx5  52dB       66          12.7**36dB       64     13.6
19  2.7     3         99Rx7  52dB       80          10.0  36dB       64     13.3
----------------------------------------------------------------------------------
```

PS# : Power supply number. The power supply leads for the 99 season are labeled 13-19I (deep) and 13-19S (surface).

* Increasing the voltage further did not result in higher current drawn. Power supply not current limited.

** Power supply at maximum voltage

| Run Name | Surface | Deep | Comment |
|---|---|---|---|
| 061700a | on | on | original settings |
| 061700b | on | on | spec'ed settings |
| 061700c | on | off | spec'ed settings |

Each channel of the PDBs contains: Bias T, attenuator(s), surface amp, and a power splitter. The inputs to the box (from the rear of the box) are the cables from the underground antennas and the power cables from the power supplies.

The large LMR and Cablewave cables from the underground antenna should be mounted in the back of these boxes (or attached via jumpers) and, if desired, secured with the cable ties provided through the cable tie holes, plugging into the Bias T.

**Bias T** (made by MITEQ) component allows us to put power and signal on the same cable for the underground antenna receivers. It is powered with a 12V supply through the BNC connector. It is a 1 inch square device with part number M/N AM 15233-6622 for FREQ 1-1000MHz. The Bias T for each channel is mounted in its slot and secured by two screws from the bottom. The top of the Bias T has a BNC connector that is connected to a short (2 ft) cable that snakes through a hole in the aluminum and connects to the bottom set of BNC feedthroughs on the back side of the front panel. The Bias T is connected at the front to the attenuator(s), and the attenuator(s) is in turn connected to the surface amp. (If the order of the bias-T/attenuator is reversed, voltage for the in-ice amps would never reach the in-ice amplifier.)

Figure 5: Mini-circuits filter efficiency as a function of frequency.

We use Mini Circuits **attenuators** which are blue tubes about 3 inches long. The model used is NHP 250, which is a high pass filter with the 3dB loss point at 200MHz. The purpose is, obviously, to remove frequencies below 200 MHz from the signal which eliminates a lot of noise. The bandpass filter efficiency, as a function of frequency, is shown in Figure 5.

The **surface amp** derives its power by a soldered wire connection to the top row of BNC feedthroughs on the front panel. There are three amps ganged together on each one of these power supply connections. The surface amp protrudes through the front panel hole and is connected to the $50\Omega$ (50/50) power splitter.

**Power Splitter** is the Mini Circuits 15542 model ZFSC-2-2, 0 9747. It divides the signal evenly [2] between two outputs and assures no reflections by matching impedances. It is a square box approximately 1.5 inches per side with three N female connectors. The numbered connectors are for the outputs and the input should be attached to the side with the S. One signal from the power splitter runs down to the first element of the crate-based DAQ, (the LeCroy 3412E discriminator); the other signal runs directly to the scopes.

At present (000101), all 12 channels in PDB1 and 4 channels of PBD2 have the full assembly described above, feeding the 16 channels of the scopes and 16 channels of the discriminator 3412E. The rest of the channels have no power splitters and are connected to the discriminator 3412 directly. The 3412E and 3412 seem to be functionally identical, with the exception of a lower discriminator threshold for the 3412 (10 mV vs. 15 mV; note that both discriminators trigger on negative excursions).

[2] A direct check with two scopes shows that the accuracy of such power splitters is about 10%

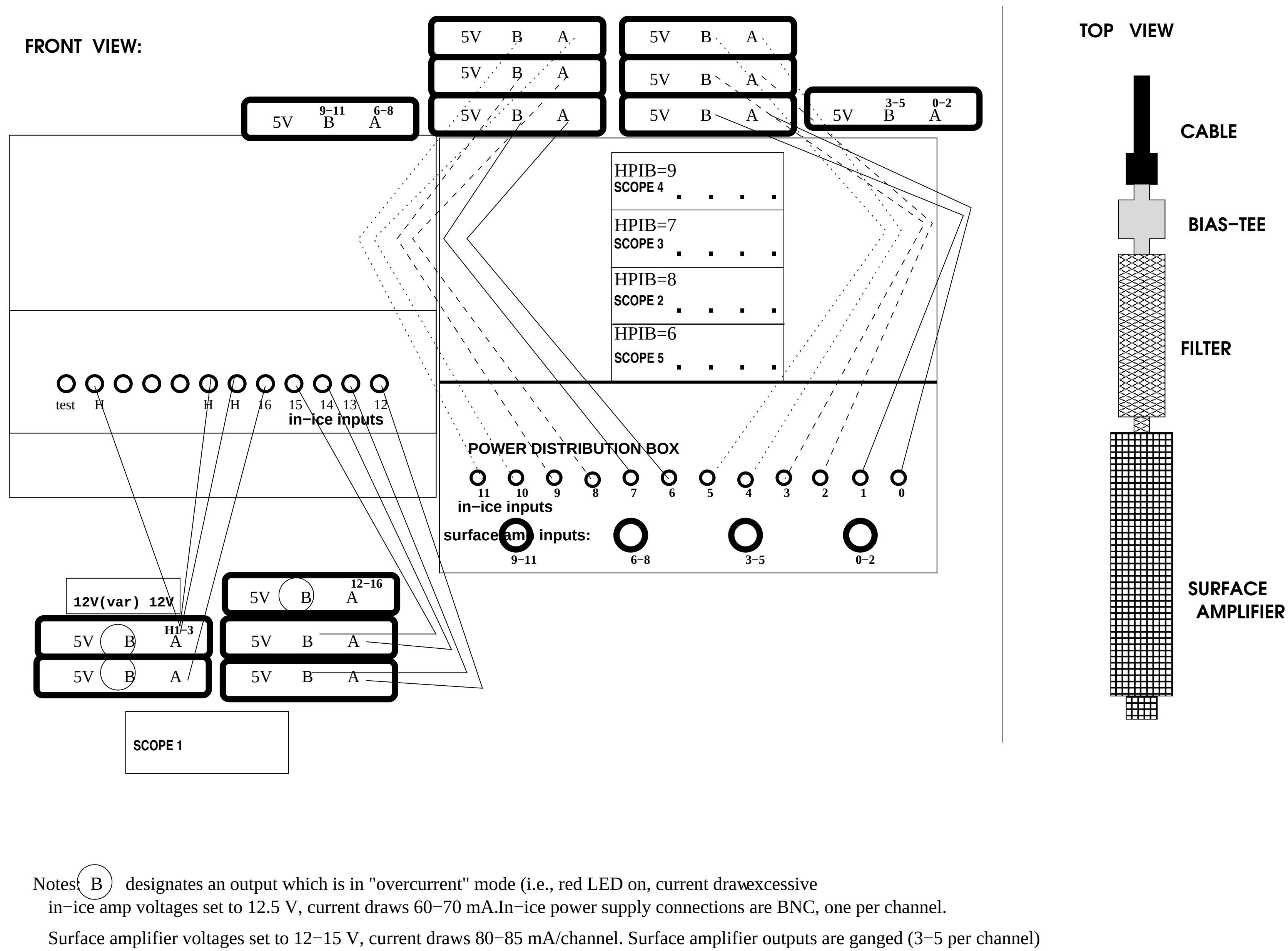


Figure 6: The RICE power distribution box (PDB). WARNING! Do not trust GPIB addresses of the scopes indicated in this picture, they are likely to be wrong.

Figure 7: Typical current draw vs. gain for 36 dB amps.

### 4.1.2 Surface amplifiers' specifications

There are two different models of surface amplifiers currently used in the system. Channels 1-4 of the PDB1 have older kind of 60dB amplification for the frequency range 1-500 MHz. Channels 5-12 of the PDB1 use the newer model MITEQ, M/N AM-4A-000110-7227 that work in the frequency band 1-1000 MHz. These latter ones are approximately 5 inches long powered with 15 V.

The current draw for the surface amplifiers and the ice amplifiers, as a function of applied voltage, is given in Figure 7. These curves were obtained simply by taking network analyzer transmission traces at different operating voltages/currents for each amplifier. It is important to note that the amplifiers will saturate whenever the output power exceeds $\sim$10 mW. Saturation was also checked by putting a 1 ns signal into each amplifier indicated, and observing the height of the amplified signal on a scope. The results of that test are consistent with the results of the network analyzer test depicted in Figure 7.

A study of the saturation voltage as a function of the input voltage was carried out by Eben for three different bias voltages (7 V, 12 V and 15 V). A 3 ns pulse was sent in through an amplifier (plus an attenuator; the results given below have been corrected for the attenuator). The following is a table of $V_{in}$ vs. $V_{out}$:

We note the following:

- At nominal bias voltage (12 V), the expected gain of the amplifier is +36 dB (a factor of +18 dB, or $\times$63 in voltage). At nominal voltage, this is preserved up to an output voltage of 4 V.

Is saturation happening at the Pole? Since the settling time is 100$\mu$sec, this is a potential concern. However, the fact that 100 Tx pulse signals look essentially identical (i.e., there is no evidence that the transmitters are in the shadow of a very large transient pulse) argues against this.

| $V_{bias}$=7 V | | | $V_{bias}$=12 V | | | $V_{bias}$=15 V | | |
|---|---|---|---|---|---|---|---|---|
| $V_{in}$ | $V_{out}$ | $V_{out}/V_{in}$ | $V_{in}$ | $V_{out}$ | $V_{out}/V_{in}$ | $V_{in}$ | $V_{out}$ | $V_{out}/V_{in}$ |
| .0158 V | .515 V | 32.6 | .0155 V | 0.968 V | 62.4 | .015 V | 1.203 V | 80.2 |
| .022 V | .765 V | 34.7 | .0223 V | 1.375 V | 61.7 | .022 V | 1.703 V | 77.4 |
| .0478 V | 1.578 V | 33.01 | .023 V | 1.437 V | 62.5 | .044 V | 3.43 V | 76 |
| .0538 V | 1.609 V | 30.0 | .028 V | 1.906 V | 68.1 | .051 V | 3.75 V | 73.5 |
| .061 V | 1.562 V | 25.6 | .035 V | 2.343 V | 66.9 | .057 V | 4.156 V | 72.9 |
| .068 V | 1.5 V | 22.1 | .042 V | 2.781 V | 66.2 | .063 V | 4.5 V | 71.4 |
| .074 V | 1.468 V | 19.8 | .0494 V | 3.218 V | 65.1 | .074 V | 5.187 V | 70.1 |
| .079 V | 1.43 V | 18.1 | .056 V | 3.593 V | 64.2 | .081 V | 5.56 V | 68.7 |
| .080 V | 1.421 V | 17.7 | .063 V | 3.937 V | 62.5 | .084 V | 5.62 V | 63.2 |
| .087 V | 1.39 V | 15.9 | .070 V | 3.968 V | 56.7 | .097 V | 5.56 V | 57.3 |
| .093 V | 1.39 V | 14.9 | .078 V | 4 V | 51.2 | .102 V | 5.56 V | 54.5 |

Table 3: Saturation study of 36 dB amplifiers

In fact, we have checked possible saturation explicitly using pole data in the following way: the waveform for a surface-generated event was divided into a “pre-pulse”, “pulse” and “post-pulse” region in the time domain. If saturation effects are present, then the post-pulse gain should be smaller than the pre-pulse gain. In Figure 8, such a study has been performed. We see no evidence for saturation in our data.

#### 4.1.3 Power supplies

We use the Tektronix CPS250 **power supplies**. Each has two variable supplies 0-20V (max output 0.5A) that can supply power through banana plugs. There is also a 5V (max output 2A) connection available with these. As of this writing (AOTW), the in-ice amplifier power supplies are sitting on top of the main RICE rack which also houses PDB1. This is rack #6; the leftmost rack (rack #4) houses PDB2. The power supplies for PDB1 are sitting on top of the rack #6. The power supplies for PDB2 are located inside of rack #4 itself, just below PDB2. These latter power supplies provide the operating current for all of the receivers deployed in the 99-00 campaign, as well as the horn antenna channel and 97TxG.

The in-ice amplifiers should draw 60 mA at the nominal operating voltage of +12 V (as mentioned before, do NOT exceed this value, since these amplifiers are not voltage regulated); the surface amplifiers will each draw ~85 mA at the nominal operating voltage of 12 V (these amplifiers are voltage regulated, so exceeding this voltage by a volt or two will not increase the current draw into the amplifier). The net current draw for each of the outputs from the surface-amp power supplies should therefore be approximately 3 x 85 mA, or ~250 mA, when they are fully powered. However, in order to maintain equal acceptance through the array as a function of incident neutrino angle, and also to ensure that we are far from saturation, the currents were selectively lowered in some of the channels (Table 2).

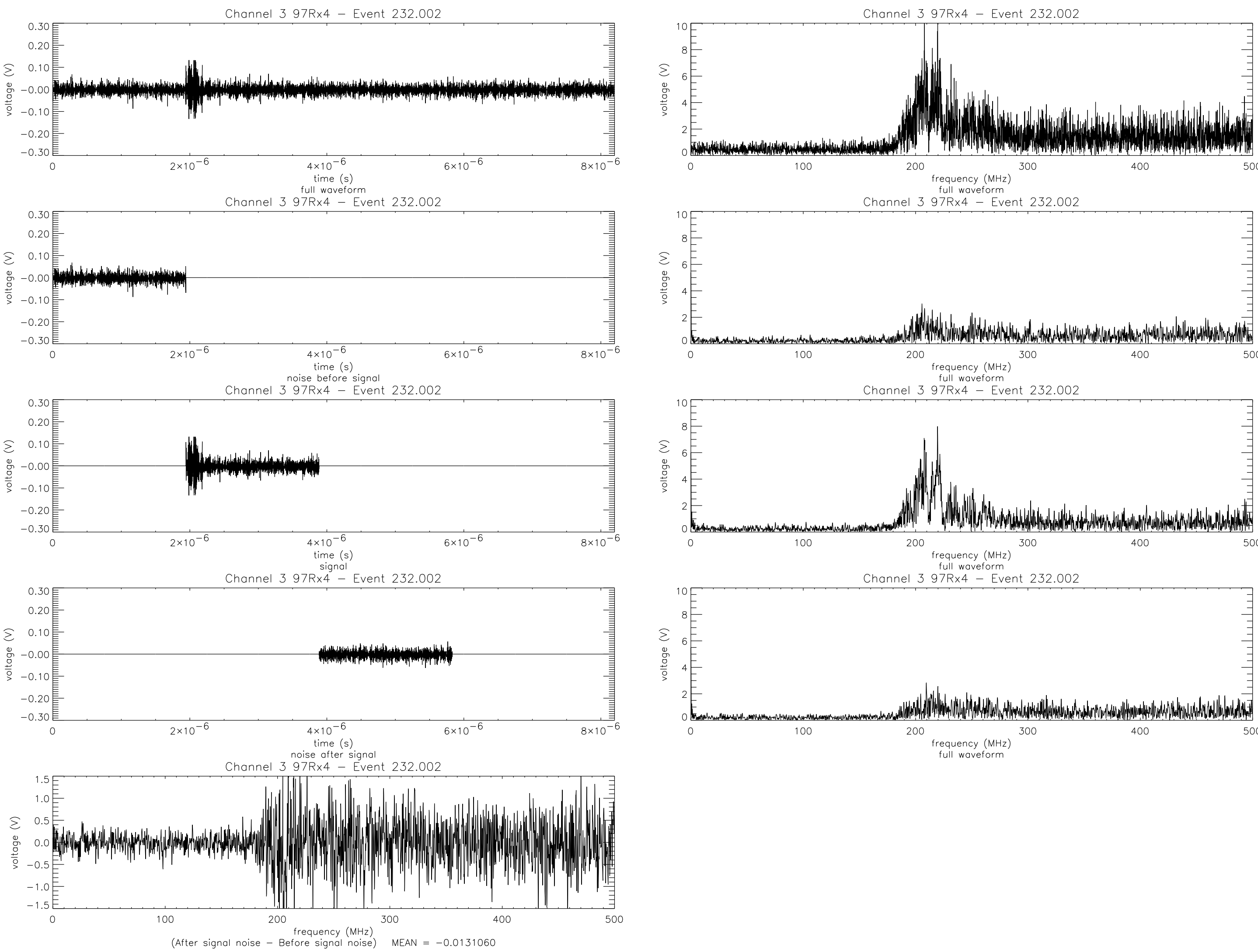


Figure 8: Pre-pulse, pulse, and post-pulse FFT's showing no evidence for saturation in data.

In 1999-2000, with the addition of more channels, the currents were re-adjusted once again, as indicated in Table **??**. In the table below, the mapping for chs. 13 - 19 is:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Channel | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Receiver | Rx1 | Rx8 | Rx4 | Rx2 | Rx6 | Rx5 | Rx7 |

Voltages and current for Surface and in ice amps, as of 3/12/00 are given in Table 4.

| | Surface amplifiers | | | In ice amplifiers | | |
|---|---|---|---|---|---|---|
| | PS | V | I mA | PS | V | I mA |
| 1 | 8A | 9.6 | 219 | 7A | 14.8 | 71 |
| 2 | 8A | 9.6 | | 7B | 14.6 | 71 |
| 3 | 8A | 9.6 | | 6A | 5.1 | 18 |
| 4 | 8B | 14.7 | 236 | 6B | 4.9 | 12 |
| 5 | 8B | 14.7 | | 5A | 14.1 | 67 |
| 6 | 8B | 14.7 | | 5B | 13.6 | 64 |
| 7 | 1A | 7.9 | 85 | 4A | 12.0 | 56 |
| 8 | 1A | 7.9 | | 4B | 12.1 | 57 |
| 9 | 1A | 7.9 | | 3A | 10.7 | 50 |
| 10 | 1B | 8.8 | 102 | 3B | 10.4 | 46 |
| 11 | 1B | 8.8 | | 2A | 8.7 | 35 |
| 12 | 1B | 8.8 | | 2B | 12.0 | 54 |
| 13 | 13A | 12.1 | 43 | 12A | 12.3 | 52 |
| 14 | 13A | 12.1 | 44 | 12B | 12.2 | 58 |
| 15 | 13B | 11.8 | 54 | 11A | 11.9 | 55 |
| 16 | 13B | 11.8 | 41 | 11B | 12.0 | 55 |
| 17 | NC | | | NC | | |
| 18 | 14 | 12.3 | 61 | 9B | 12.0 | 54 |
| 19 | 15 | 12.3 | 82 | 10A | 12.0 | 56 |

Table 4: Amplifier voltages and currents and power supplies (PS).

**Power Supply cables**: In PDB1, there are two sets of cables with BNC connectors on each end. The first set is ~8ft long and should be used from the banana-BNC adapter on the power supply to the front panel of the PDB. The second set is 2ft and is used to connect from the Bias T to the back of the front panel. The second set is presently obscured from view.

## 4.2 Digital section

### 4.2.1 HP scopes

Waveform information is captured on the digital oscilloscopes. At the moment we have five similar scopes: three of the type HP54542A and two HP54542C (color). Scope locations are shown in Fig. 6. All scopes have a maximum sampling rate of 2GHz. Note that HP scopes of 54XXB type do not work with the current DAQ executable (different commands and Labview drivers).

The signal inputs to these scopes are through BNC connections on the front. The trigger is supplied through the BNC connection on the back labeled "aux. trig. input". The oscilloscope readout is controlled through the HPIB (GPIB) bus by the PC. Each scope should have a GPIB cable connected to the back which is daisy chained. The user needs to verify on each scope that the HPIB address is set correctly using the utility menu. The five scopes should have addresses of 6, 8, 7, 9 and 10 respectively.

#### 4.2.2 Channel numbering convention

DAQ has total 20 scope channel inputs and 32 TDC channel inputs.

Table 5 summarizes channel numbering convention currently used in RICE DAQ. It also shows correspondence to scope and TDC channels as well as connections to Power Distribution Boxes. Note that channels 30 and 31 are reserved for recording external triggers from AMANDA and SPASE, and the channels 26-29 are for capturing event information from the HSV board, none of these needs power, of course, and they do not need their waveforms to be saved. Waveform information for the DAQ channels 17-31 is not recorded.

See also the drawing of the antenna array in Fig. 2 for antenna/channel physical locations.

#### 4.2.3 CAMAC modules

There is a full-width 25 slot CAMAC crate in the system. The modules in this crate are found in the table below:

| Module | Notation | slot # |
|---|---|---|
| Discriminator 3412-A | 3412E | 2 |
| Discriminator 3412-B | 3412 | 5 |
| MALU 4532 | MALU | 8 |
| HSV board | HSV | 11-12 |
| UCI Delay | UCI Del A | 15 |
| UCI Delay | UCI Del B | 17 |
| GPS module | GPS module | 21 |
| TDC 3377 | TDC | 19 |
| Dual Gate and Delay 2323A | Gate 2323A | 22-23 |
| CAMAC controller | same | 24-25 |

The connection between these modules and also those in the NIM bin are shown in Fig. 9-10. Some of the CAMAC modules are not in an operational state when the crate power is turned on and have to be initialized through GPIB interface. The description of each module is given below.

- **Discriminators (LeCroy, 3412E and 3412)** There are two discriminators of the type 3412 sitting in slots 1 and 2 of the CAMAC crate. Each discriminator has 16 input channels (LEMO) and 16 outputs (ECL). Discriminators are programmed through GPIB-Labview. There are 3 items to be set - threshold, output pulse width and dead time. Threshold lies in range –15 mV to –1.0 V in steps of 5.5

| DAQ channel | Receiver ID | Scope and channel | TDC channel | PDB number and channel |
|---|---|---|---|---|
| 0 | 97Rx7 | sc 1 ch 0 | 0 | box 1 ch 0 |
| 1 | 96Rx3 | sc 1 ch 1 | 1 | box 1 ch 1 |
| 2 | 97Rx3 | sc 1 ch 2 | 2 | box 1 ch 2 |
| 3 | 97Rx4 | sc 1 ch 3 | 3 | box 1 ch 3 |
| 4 | 96Rx2 | sc 2 ch 0 | 4 | box 1 ch 4 |
| 5 | 96Rx6 | sc 2 ch 1 | 5 | box 1 ch 5 |
| 6 | 98Rx1 | sc 2 ch 2 | 6 | box 1 ch 6 |
| 7 | 98Rx2 | sc 2 ch 3 | 7 | box 1 ch 7 |
| 8 | 98Rx4 | sc 3 ch 0 | 8 | box 1 ch 8 |
| 9 | 98Rx3 | sc 3 ch 1 | 9 | box 1 ch 9 |
| 10 | 98Rx5 | sc 3 ch 2 | 10 | box 1 ch 10 |
| 11 | 98Rx6 | sc 3 ch 3 | 11 | box 1 ch 11 |
| 12 | 99Rx5 | sc 4 ch 0 | 12 | box 2 ch 0 |
| 13 | 99Rx8 | sc 4 ch 1 | 13 | box 2 ch 1 |
| 14 | 99Rx4 | sc 4 ch 2 | 14 | box 2 ch 2 |
| 15 | 99Rx2 | sc 4 ch 3 | 15 | box 2 ch 3 |
| 16 | 99Rx7 | sc 5 ch 0 | 16 | box 2 ch 4 |
| 17 | ? | sc 5 ch 1 | 17 | ? |
| 18 | ? | sc 5 ch 2 | 18 | ? |
| 19 | ? | sc 5 ch 3 | 19 | ? |
| 20 | ? | none | 20 | ? |
| 21 | ? | none | 21 | ? |
| 22 | ? | none | 22 | ? |
| 23 | ? | none | 23 | ? |
| 24 | ? | none | 24 | ? |
| 25 | ? | none | 25 | ? |
| 26 | HSV: Nhit met | none | 26 | ? |
| 27 | HSV: veto | none | 27 | ? |
| 28 | HSV: EENF | none | 28 | ? |
| 29 | HSV: UEF | none | 29 | ? |
| 30 | AMANDAB | none | 30 | N/A |
| 31 | SPASE | none | 31 | N/A |

Table 5: DAQ channel numbering

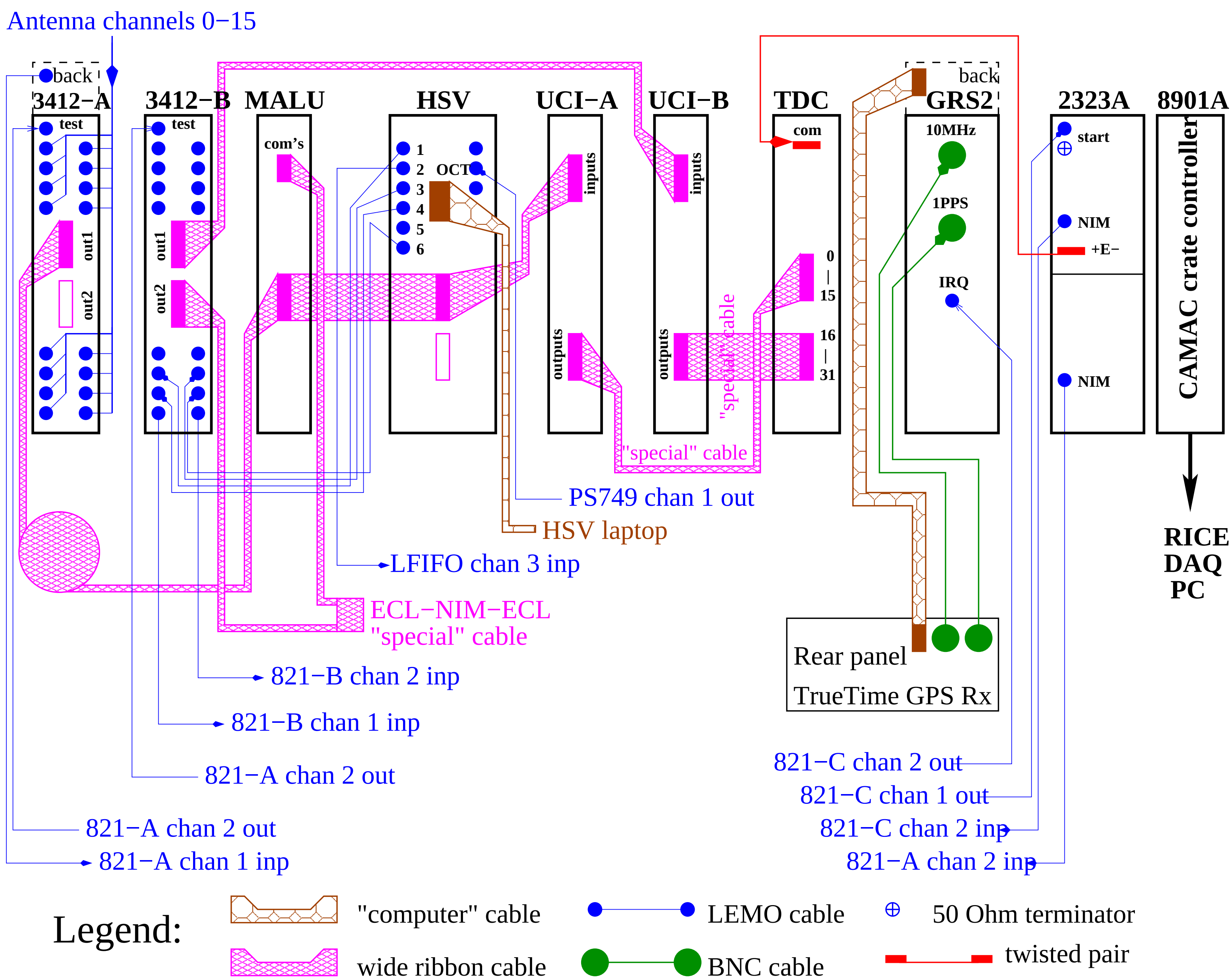


Figure 9: The RICE DAQ hardware, CAMAC section, as it appears in the RICE SPICE rack (Rack #6 in the AMANDA-A set of racks in MAPO).

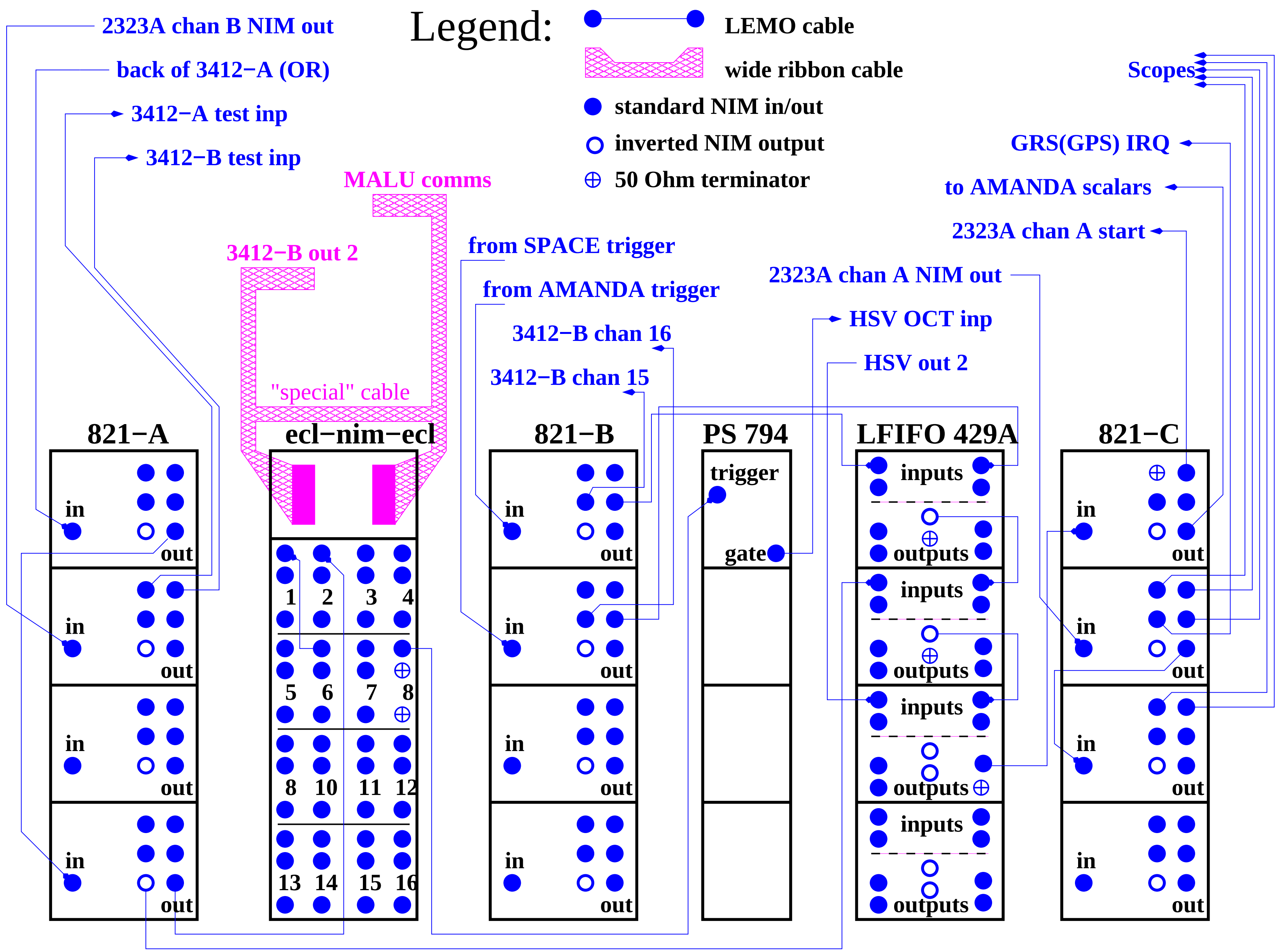


Figure 10: The RICE DAQ hardware, NIM section, as it appears in the RICE SPICE rack (Rack #6 in the AMANDA-A set of racks in MAPO).

mV. It is recommended not too set it too low, at thresholds smaller than –20 mV discriminator fires from internal noise.

XXX-DZB: The following is yours. Can you revise it? *At thresholds smaller than –300 mV, the background rate from surface generated noise will probably be prohibitive. A 'typical' value for the threshold should be something like –500 mV – –800 mV.* Input signals greater than 5 V in amplitude may potentially do damage to this unit.

All 16 channels of the discriminator 3412-A are used. The signals come from one half of the power splitters. The outputs are sent to MALU, HSV board and the UCI Delay unit through a long 34 pin twisted pair cable. The cable is about 36.6 feet long from the discriminator to the MALU (22 sections), 20 inches long from MALU to HSV, and another 20 inches long from HSV to UCI delay board.

In addition, the "Current Sum Output" from the rear panel is used. The amplitude of this output signal depends on the number of hits at the input, and is equal to $N_{hit} \times -50$ mV. Using a LEMO cable, the output of the .AND. (i.e, current sum) should be connected to the input of channel 1 of the DISC 821 A.

The discriminator 3412-B of the CAMAC crate currently has only several input channels connected (counting from 1): channels 11-14 are connected to HSV debug output in order to monitor the performance of the HSV board. The connections are 11,12,13,14 of the discriminator to 1,3,4 and 6 of the HSV, respectively, via LEMO cables. Channels 15 and 16 of the discriminator are connected to AMANDA-B and SPASE trigers via discriminator 821-C outputs of channels 1 and 2 respectively. This year (2004), we have dropped the horn antennas that were connected to this discriminator in the past.

Each of the discriminators 3412 has two outputs per channel. In the past (prior to year 2004) we used the second set of outputs of 3412-B in order to implement Hardware Surface Veto. According to DZB's observations, the old HSV system did not give us any gain and is currently abandoned in favor of the new HSV board. However the connection from the 3412-B second set of outputs to ECL-NIM-ECL converter is not removed.

Both 3412 discriminators have test input connected to the output of the discriminator 821 A module channel 2. These are needed to trigger Unbiased events.

The output width of the discriminator channels is tunable from <5 ns to >100 ns; the time structure of the output directly follows the number of inputs which are hit (i.e., there is no "gating", per se). The dead time of this unit ranges from 25 ns to 250 ns with default 250 ns. Dead time means that after the end of the pulse on the output of each individual channel of the discriminator there will be no other pulses within the dead time no matter what is on the input of this channel. We set the dead time to the maximum possible value in order to prevent event pile-up. Both the width and the dead time counting start at the same time, so if they are set to equal values, there is no dead time.

Note that input pulses must be negative in order to trigger the discriminator. E.g., it does not trigger from the pulses from the signal generator HP8110A which are always positive, unless you flip polarity (or use the "complement on" mode).

In the first version of the DAQ, we used a LeCroy constant fraction discriminator (CFD 3420), this had the advantage of channel-to-channel thresholds that were independently tunable. However this module had the drawback that the double pulse resolution (or, alternately, it's internal clock speed) was much too slow for the signals that we expect to observe. Consequently, this 3420 was replaced with a faster 3412E discriminator, which requires that signals be over threshold only for $\sim$3 ns.

- **MALU 4532**

  This module is used to determine whether $\geq N$ underground antennas are coincident in the gate width. We assume the gate width to be 1.25 $\mu$sec and the number N is adjustable using the threshold voltage setting, typically it is equal to 4. We are not programming this module from software so all settings are done manually.

  On the side of this module are three switches. The memory enable switch should be enabled. According to the LeCroy manual for this module, if the memory enable switch is disabled, then the 4532 is "completely transparent with respect to inputs and outputs". The cluster enable switch should be disabled and the LAM enable switch should be disabled. There are two LEMO connectors at the top of the module labeled AMIO which should have 50$\Omega$ terminators attached to them. Above these AMIO connectors is a probe point for testing the threshold level. The threshold level should be determined and then is set using the screw driver adjustment under the AMIO connectors which is labeled MATHR (majority threshold). This adjustment happens in 80mV steps and can be examined using the probe point at the top of the module. For a trigger of $\geq$4 antenna, the threshold value, as read by the voltage on a voltmeter should be set to 280 mV (i.e., 40 mV + (N-1)$\cdot$80 mV). Note that the actual voltage reading is ten times the threshold value (i.e., to set the internal threshold to 280 mV, set the voltage as read on a voltmeter at 2.8 V). The gate width of this module is determined using the two pin twisted pair connector labeled GAI. For the two pin cable, red is + and black is –. The black connector should be to the left for the GAI connection which comes from Channel 2 ECL out of the NIM-ECL module. We are using an internal reset so using another 2 pin cable, the STO and RTI channels should be connected. At some point in the past we have switched from 2-pin cables to specially made wide ribbon cable. It will be described further in the text. See Fig. 11.

  The input for this unit comes from the 34 pin twisted pair ribbon cable from the output of the DISC 3412E. The connection happens at the second junction of this long cable, 36.6 feet or 22 sections after the discriminator. After about 20 inches the third junction of this cable plugs into the HSV board. One should check the termination of the connection and remove the resistor pack on the inside of the MALU module if needed.

- **Hardware Surface Veto (HSV) board**

This CAMAC module has been designed at KU and introduced into the system in January 2004. The board takes input from the Phillips gate generator PS794 chan 1 gate output that is connected to the OCT input of the board via a LEMO cable. Also, the output of the discriminator 3412-A reaches this board via the long 34-pin ribbon cable. The HSV is the third module connected on this long cable that proceeds on to the UCI delay unit A. There are several outputs of the HSV conected via LEMO cables. The output # 3 goes to the NIM module Logic FIFO 429 channel 3 input carrying the decision of this trigger/veto board. The outputs # 1, 3, 4 and 6 carry the various useful information to the channels 11-14 of the discriminator 3412-B to be recorded as TDC hits.

The DIP switches on the side of this board are set so that the LEDs of this board blink at the lowest possible duration. Only the first three DIP switches are needed for that. Under the daughter card on the main board antenna inputs can be terminated by resistor packs. Currently the first 16 inputs are connected to the antenna signals with the 34-pin connector and therefore do not carry resistor packs. The inputs 17-32 are not connected and *are* terminated with the resistors.

- **UCI DELAY**

  There are two such modules in the system. First, start with the UCI Delay A. This module delays signals that come from the output of the discriminator 3412E. There is a long 34 pin twisted pair ribbon cable between 3412E and this module with intermediate 34 pin connections at the MALU and the HSV board. All four connectors on this long cable must be connected for proper termination. Another 34 pin ribbon cable connects the output of this module to the input of the TDC 3377. The polarity of the output of the UCI Delay is opposite to the polarity of the input of the TDC so this last cable is specifically made for this connection and reverses + and - for each of 17 pairs.

  The UCI Delay module B takes its input from the output of the discriminator 3412 connected by a short 34 pin twisted pair ribbon cable. The output of this module goes to the TDC as well through a similar custom-made 34 pin cable with inverted +/-.

  Such module provides a 1.6$\mu$s delay for each of the possible 16 input channels. Functionally, it holds the signals long enough to give the hardware an opportunity to make a trigger decision so that hits come to TDC after the Start pulse. The delay value varies from channel to channel of the order of tens of nanoseconds (data provided later in this document).

- **TDC (LeCroy, 3377)**

  This is a 32 channel TDC made by LeCroy. It is programmed via CAMAC protocols through the Labview program. The object of this module is to give us the times of all of the hits which are above the (common) 3412E threshold. We are operating this module using the COMMON start so times are registered from the start signal.

  The common start signal comes through the 2pin twisted pair cable from the GATE 2323A +E- output to the COM input. This signal is not delayed, and represents the

$t_0$ of the event. Notice that the red wire should be on the left in the COM input. The first set of the underground signal inputs come in through the 34pin twisted pair cable into IN (1-16). This cable is from the UCI Delay output in slot 3. The second set comes to IN (17-32) from the UCI Delay in slot 4. The last two channels of the TDC always correspond to AMANDA-B and SPASE signals, respectively.

The TDC module operates in Common Start mode. The settings are made through GPIB from Labview, there are no controls on the module. The settings are set in the form of 6 words, written into six Control Registers (CR0-CR5). The values are:

$$\mathrm{CR0} = 0$$

$$\mathrm{CR1} = 3072$$

$$\mathrm{CR2} = 0$$

$$\mathrm{CR3} = 15$$

$$\mathrm{CR4} = 80$$

$$\mathrm{CR5} = 0$$

The Common Start mode is set separately by programming the chip in the TDC, on the front panel of main DAQ executable it corresponds to value 3 for Start Mode control. The meaning of the settings:

- Mode - Common Start Double Word
- CR0 sets Single Buffer mode (1 event is saved), leading edge only is recorded, CAMAC readout, header always, module ID is zero.
- CR1 - 3.2 microsec Measure Pause Interval (dead time after Common Start timeout); event number starts at zero.
- CR2 - The maximum number of hits per channel is 16.
- CR3 - request delay setting. Ilya has set it to 30 microsec, but it is evidently not used anywhere.
- CR4 - Common start timeout. 0 is 25 ns, maximum is 32767.5 ns, with 50 ns steps. Ilya set it to 4 microseconds.
- CR5 - zero means test mode disabled.

There is a TDC manual in MAPO for more details (AMANDA also uses these modules). After turning the crate power on, the TDC is initially disabled. The main DAQ program needs to be run to enable acquisition and initialize the TDC. There is an LED indicator at the top of the 3377 which blinks when the TDC is addressed (e.g., when data are read by Labview).

COM input is for common start pulse. There are 32 channels total, as mentioned. We use the first 16 and the last two at the moment. The pins are a little bent and this seems to cause problems sometimes; make sure you connect the 34-pin connector carefully. The sign of the problem is that the DAQ runs normally, however, in the hit list indicator only chan 0 and time 0.0 appears.

The TDC has a bug in its main chip. If there is another hit on the COM input, it stops data acquisition. Because of this, we use the 'Gate' to send the start pulse to TDC and not the OR output of discriminator; the gate width is larger than Common Start Timeout.

Note that, in principle, the 3377 can be used to make a Time-Over-Threshold (TOT) measurement. At present, that feature is not being used.

There are noticeable channel-to-channel timing variations in the TDC 3377. Given a signal at t=0 ns at the input of the 3412E produced by the signal generator, the following TDC times were recorded by Bai in his test report of 990719 (more recent measurements of all 32 channels are also given in this document):

| 3412E Channels | TDC channel | TDC readout |
|---|---|---|
| 1 | 0 | 1406 |
| 2 | 1 | 1437 |
| 3 | 2 | 1418–1424 |
| 4 | 3 | 1406–1408 |
| 5 | 4 | 1439–1434–1433 |
| 6 | 5 | 1418–1423–1422 |
| 7 | 6 | 1451–1457–1456 |
| 8 | 7 | 1439–1442–1442 |
| 9 | 8 | 1398 |
| 10 | 9 | 1432 |
| 11 | 10 | 1451–1454 |
| 12 | 11 | 1421–1423 |
| 13 | 12 | 1433–1427 |
| 14 | 13 | 1413–1415–1420 |
| 15 | 14 | 1421–1423–1423 |
| 16 | 15 | 1447–1435 |

Note the channel-to-channel jitter in the TDC's. This is either the result of channel-to-channel T0 offsets (e.g., through the UCI delay, which contributes the bulk of the typically 1400 ns delay, or differences in slopes, e.g.) In a "test" TDC 3377 that Ilya uses at Fermilab, the T0 typically varies less than 5 ns and the slope varies within 10%.

Tests conducted 12/99 and 01/01 verified that the primary source of jitter in this system was the UCI delay board.

The TDC delays can be measured using the following procedure:

1. Take a signal from the Signal Generator, short pulse, standard height (~800-1000mV), make two copies out of it.
2. Delay one of them.
3. Convert both of them to ECL using ECL-NIM-ECL.

4. Connect undelayed to TDC start (called "COM") and delayed to TDC stop of any channel ("IN")
5. Setup TDC - go to the directory with DAQ Labview code (any version), open camac.llb, choose "TDC setup.vi". Choose there correct settings. Numbers for RegisterX should be taken from DAQ front panel.
6. Take a single TDC measurement - open camac.llb, get "TDC output.vi" set parameters "GPIB address" and "TDC station number" (the slot of the TDC within the crate), run it once. It should return TDC values in ns and channels hit.
7. Possibly you will need to reset TDC. To do it, open camac.llb, open "CAMAC command.vi", enter parameters, including F=9, A=0
8. Measure expected delay with the scope
9. Repeat for different delays.

To do this, one can just put additional TDC (the RICE spare one) into the CAMAC crate, and use free channels of ECL-NIM-ECL, so there is no need to rearrange connections of the real DAQ.

- **Dual Gate and Delay Generator (LeCroy, 2323A)**

  This is a double width LeCroy unit. There are two channels of gate/delay on this module. Both channels are used and both are programmed by DAQ during initialization stage.

  Channel A is set in the latch mode. The input of this channel is taken from 821 C(1) and the output is sent through 821 C(2) discriminator to the external trigger input of the four scopes and through a twisted pair cable to TDC start (COM input).

  Channel B is used to generate Unbiased events. Its pulse is set to 1.5us by DAQ and it is connected to the input of the 821 A(2).

  There are several switches on the module. The "Trigger on" switches must be set to "-" for each channel and the "CAMAC" switch should be "ON".

- **GPS CAMAC**

  This is the Wisconsin board. This can provide timing accuracy to approximately 100 ns. Note that the GPS board is latched by a TTL input; the TTL signal is sent to the GPS board at a time approximately (few tens of ns ) corresponding to the middle of the full waveform. See more in Sec. 4.2.5.

- **Crate controller with GPIB interface 8901A**

  This is a double-slot module. The GPIB cables are daisy-chained on the outside to the computer and scopes.

  This module contains two important items. The GPIB address is set here (a row of small white switches); default is one, as it is on the front panel of the main DAQ executable. Also, the GPIB cable from the PC is connected here. LED indicators show when CAMAC is communicating with PC.

### 4.2.4 NIM modules

None of the modules in NIM bin is programmable. They are operational when power is turned on (unlike the CAMAC modules). The following modules are found in the NIM bin, from left to right. The exact slot numbers are not important.

| Module | Notation |
|---|---|
| Discriminator 821 | 821 A |
| ECL-NIM-ECL converter | same |
| Discriminator 821 | 821 B |
| PS Gate and Delay 794 | PS 794 |
| Logic FIFO 429 | LFIFO |
| Discriminator 821 | 821 C |

The arrangement of the modules is also given in Fig. 9-10. In this figure, the connections are shown; these are described in more detail below for each module. For modules with multiple channels, the channel numbering is assumed to start from the top.

- **ECL-NIM-ECL module**

  It is used just for that, ECL inputs are converted into NIM outputs and also there are ECL outputs.

  At present this module is mostly needed to interface MALU. It converts NIM to ECL to provide Gate input (coming from 821 A(4)) and converts MDO (N-hit coincidence) output of ECL type into NIM (sent to LFIFO (3)). In addition, it is used to connect Strob output (STO) to Reset output (RTI) of the MALU. Due to the different polarity of MALU and the converter the connectors are flipped. See Fig. 11.

  There is also a connection of the last 8 channels of the CAMAC discriminator 3412 B to the input of ECL-NIM-ELC. Three of these channels have been used in the past (pre-2004) for the old style Hardware Surface Veto. Now these are not used, but the cable remains in place.

- **Quad discriminators**

  There are a total of 3 of these 821 DISC's giving us, in principle, 12 total channels. The discriminators can provide an output pulse up to 1.25 microsec long. The width for each channel is set by a small screw on the front surface, it is at maximum unless noted otherwise. The 821 DISC's are triggered by an input edge which exceeds threshold for at least ~5 ns.

  The 821 DISC's have two modes of operation: "updating" and "burst guard". According to the LeCroy documentation, in "update" mode, two pulses separated by a time $DPR < t < t_{out}^{821}$ (DPR=double pulse resolution, ~5 ns for this unit) will extend the width of the 821 output signal ($t_{out}^{821}$, adjustable from 5 ns to 600 ns) by one unit of $t_{out}$. Note that this is potentially dangerous - a train of 10 input pulses 10 ns apart will produce an 821 DISC signal $10t_{out}^{821}$ long. In "burst guard" operation, the output signal is either equal to the time-over-threshold of the input

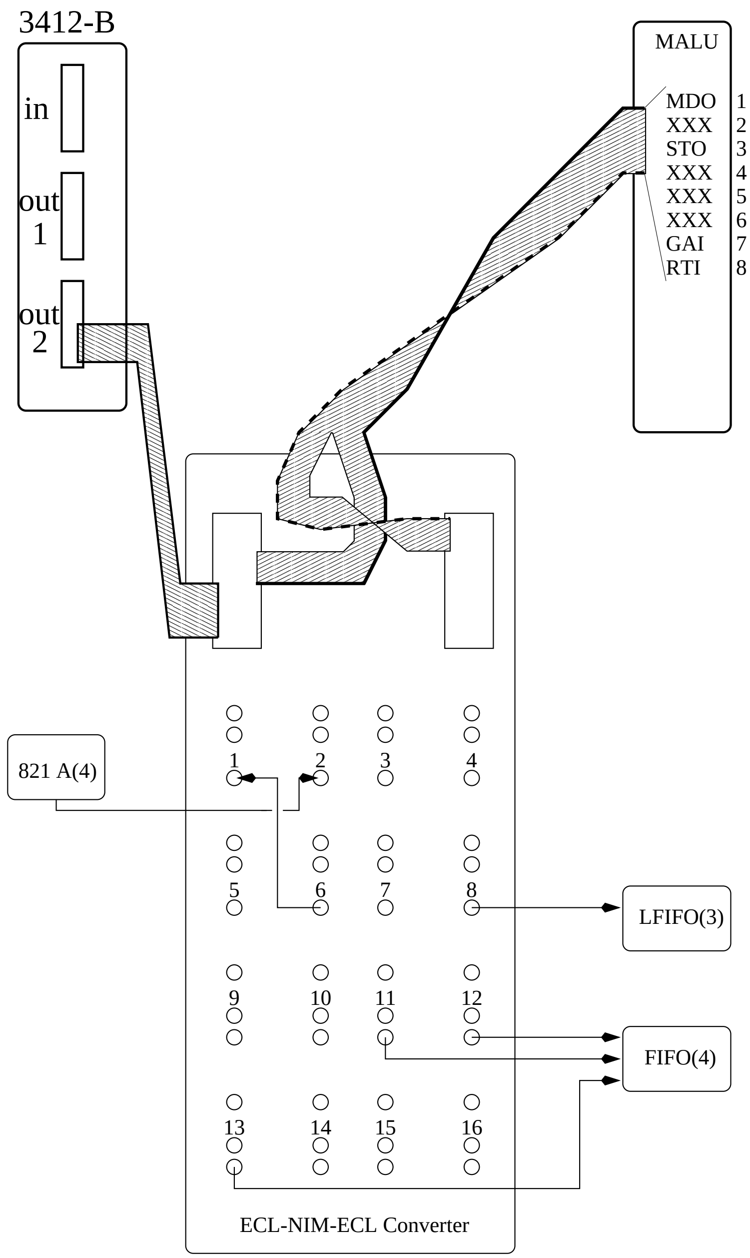


Figure 11: Connections between MALU and ECL-NIM-ECL converter.

signal or equal to the preset duration, whichever is greater. For input burst rates greater than the DPR of the unit, the output is equal to the duration of the burst. The default mode of operation of our discriminators is therefore "burst guard".

In Table 6 for all currently used channels the values of thresholds and widths are listed. Those numbers that are in bold must be exactly as specified. For others the only requirement is that the channel triggers on standard NIM signal.

| Discriminator channel | Used? | Threshold | Width |
|---|---|---|---|
| 821 A(1) | Yes | **30mV** | **1.25$\mu$s** |
| 821 A(2) | Yes | ~400mV | any |
| 821 A(3) | No | - | - |
| 821 A(4) | Yes | ~400mV | **1.25$\mu$s** |
| 821 B(1) | Yes | ~400mV | 1.2$\mu$s |
| 821 B(2) | Yes | 48mV | 1.2$\mu$s |
| 821 B(3) | No | - | - |
| 821 B(4) | No | - | - |
| 821 C(1) | Yes | ~400mV | 1.05$\mu$s |
| 821 C(2) | Yes | ~400mV | any |
| 821 C(3) | Yes | ~400mV | any |
| 821 C(4) | No | - | - |

Table 6: Threshold and width settings for all channels of 821 discriminators.

Each discriminator has two coupled pairs of NIM outputs, one single NIM and one $\overline{NIM}$. In case when only one output of a coupled pair is used, the other must be terminated.

DISC 821 A -

Channel 1 of this discriminator derives its input from the "Current Sum Output" of the CAMAC DISC 3412E on the back of that module. The output of this channel goes to 821 A(4).

Channel 2 is needed to get two copies of the unbiased trigger out of one. The input comes from the Gate-Delay 2323A chan 2 NIM output and two outputs are connected to the "Test" inputs on the front panels of 3412 A and B.

Channel 4 receives input from the output of the channel 1 of the same module as mentioned above. Two outputs of the channel 4 are used. One, the inverted output $N\bar{I}M$, should go to one of the inputs of the channel 2 of the Logic FIFO 429 NIM module. The other, normal output $NIM$, of channel 4 should go to a LEMO channel 2 connector of the ECL-NIM-ECL module.

DISC 821 B -

Channels 1 and 2 are used for inputs from the external triggers, i.e. AMANDA-B and SPASE. The AMANDA-B signal is a standard NIM pulse. The shape of the

SPASE signal is peculiar and the signal is attenuated before connecting to the input of this discriminator. One should be aware that this output can be changed by the SPASE experiment, e.g., adding or subtracting modules to the SPASE output signal. Note that this SPASE output is taken from a line which leads from the SPASE building. One output for each of these channels (AMANDA and SPASE) should be connected into one of the inputs of the the channel 1 of the Logic FIFO NIM module. Another output of 821 B(1) and (2) are sent to the input channels 15 and 16 of the 3412 B.

DISC 821 C -

Channel 1 gets input from the inverse NIM output of the channel 4 of the Logic FIFO NIM module, and sends output to the Start of the channel 1 of the Gate 2323A in the CAMAC crate. Another output should, in principle, be forwarded to AMANDA VME scaler: SIS3808 - VME 200MHz counter.[3] These rates are monitored online by AMANDA in:

`http://jordgubb.spole.gov/~amanda/online_stat/.`

and mirrored at:

`http://area51.berkeley.edu/amanda-private/online_stat/html.`

Channel 2 receives input from a NIM output of the channel 1 of the Gate 2323A and sends three outputs to the trigger inputs of three scopes, one output to the IRQ input of the CAMAC GPS module, and the fifth output triggers channel 3 of this same discriminator module.

Channel 3 gets its input from one of channel 2 outputs of the same discriminator and sends its two outputs to trigger the remaining two scopes.

Channel 4 is not used in normal datataking mode, but sometimes is employed for transmitter tests.

- **Logic FIFO 429**

  This logic unit has 4 channels of logic OR. Each channel has 4 inputs and 3 output pairs, one of the pairs is inverted. Whenever one output of a pair is used, the other one should be 50 Ohm terminated. The switch at the top has to be set to 4x4 (middle position). We also use this unit as an AND exploiting the identity $A.or.B = C => \bar{A}.and.\bar{B} = \bar{C}$.

  The first channel takes input from channels 1 and 2 of 821 B discriminator, and its inverted output is sent to one of the inputs of this Logic FIFO channel 2.

  The second channel of this unit takes in the inverted output of channel 1 of this unit and in addition the inverted output of 821 A(4). The output, inverted again, goes to the input of Logic FIFO channel 3.

[3] Although this was partially operational in 1999, this was disconnected in Dec., 1999, so the raw rates are not accessible for data taken in 2000.

The third channel takes as input the inverted output of channel 2 of the same unit and in addition the output # 2 of the HSV board carrying the trigger/veto decision. The regular NIM output of this channel is sent to the input of the channel 1 of the discriminator 821 C.

The forth channel is currently unused.

- **Gate Generator 794**

  The first channel of this module is used to shape the logic pulse coming from MALU to the desired duration before sending it to the HSV board. The input comes from the NIM channel 8 output of the ECL-NIM-ECL converter in the NIM crate, it is connected to the "trigger" LEMO soceket. The "gate" output is connected to the OCT input of HSV via a LEMO cable. The width of the gate is adjusted with a screwdriver to be 100ns long.

  Other comments on module operation: the 794 unit requires a certain amplitude of the input signal so that it can output a "delayed, rewidthed" signal. According to the measurement by the scope, the "threshold" is $\sim -500$mV, not so accurate though. This means if we use a smaller amplitude signal there will be no output from the 794 unit. With a screwdriver, one can adjust the threshold on that module. The important thing is that it is a logic yes/no module, i.e. the output of it will be delayed NIM signal of standard magnitude and the input amplitude information will be lost. You can adjust the amplitude of the output of 794 by using attenuators. Or, for simple timing studies you can use the basic NIM signal as it comes out from 794.

#### 4.2.5 GPS system

The GPS system allows us to obtain a time stamp for each event with the accuracy of $\sim$100 ns. The system contains GPS antenna located on the roof of MAPO, TrueTime receiver and a CAMAC module. The diagram of the system is shown in Fig. 12. The meaning of all the inputs to the CAMAC GPS module can be found in the manual for this board (see the reference below). DAQ executable obtains current time from the GPS CAMAC module. The IRQ input to the GPS CAMAC module freezes time until buffers are reset. This IRQ input is taken from our main trigger that stops the scopes. After buffer is cleared and no IRQ signal comes, reading out the modules provides current time. More on the GPS CAMAC module can be found on the web page of F. Halzen:

`http://pheno.physics.wisc.edu/~halzen/`

(I have not been able to view his postscript with my GV, but it is human-readable in any ASCII text editor).

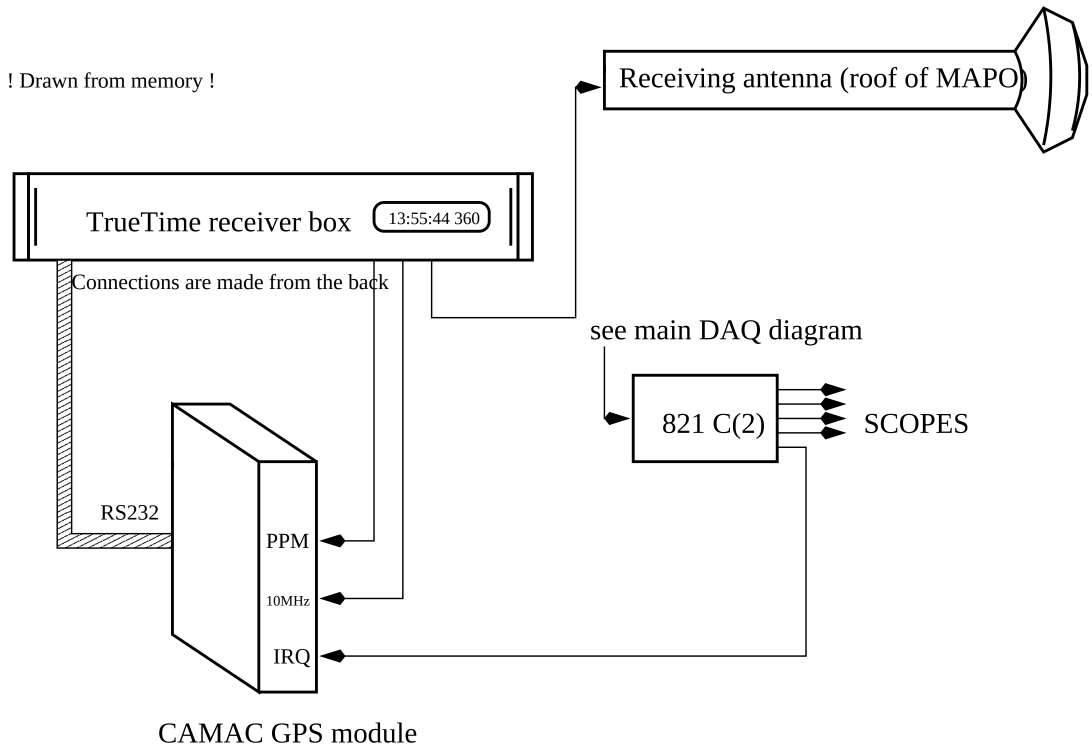


Figure 12: Diagram of the RICE GPS circuit.

# 5 DAQ electronics: Theory of operation

## 5.1 Input signal: expected and real

The expected coherent radio pulse from a neutrino-initiated electromagnetic shower in ice was initially derived from the Monte Carlo simulation work of Zas, Halzen and Stanev (ZHS, 92) and more recently explored using a GEANT simulation by Razzaque, Seunarine, McKay and Besson at KU. Both simulations develop the cascade as it develops in a semi-infinite medium (ice) and calculate the number of atomic electrons swept into the forward-moving cascade. These atomic electrons therefore endow the shower front with a net negative charge. From that, one can determine the expected net Čerenkov electric field signal strength at an arbitrary observation point $\vec{R}$ by summing the Čerenkov electric field vectors $\vec{E}(\vec{R},\omega)$ for each particle participating in the forward-moving shower. Both simulation efforts give the same qualitative conclusion - at large distances, the signal at the antenna is a symmetric pulse, approximately 1-2 ns wide in the time domain. The power spectrum as a function of frequency is linearly rising with frequency, as expected in the long-wavelength limit. In that limit, the excess negative charge in the shower front can be treated as a single ("coherent") blob of charge emitting Čerenkov radiation with an energy per photon: $E = \hbar\omega$, i.e., $E(\omega) \sim \omega$, and $dE/d\omega$ ~constant.

For perfect signal transmission (no cable signal losses, >GHz bandwidth), the signal induced in a broadband bicone (on the Čerenkov cone) due to a 1 PeV neutrino initiating a shower at 1 km from an antenna is $\sim 20\mu$V. This is comparable to the 300 K thermal noise over that bandwidth in the same antenna, prior to amplification.

Due to the finite bandwidth of our experiment, however, the time domain signal is broadened ($\Delta t \sim 1/B$, where $B$ is the bandwidth of the experiment). Finite bandwidth is introduced by: a) finite response of the antenna (~800 MHz), b) cable losses as a function of frequency, which tend to attenuate the high-frequency signal components, c) filtering in the PDB, which removes $f$ <200 MHz by fiat. The resulting pulse is therefore stretched in the time domain to ~5 ns. Specifics of signal shape is work currently in progress and being studied.

## 5.2 Trigger scheme overview

There are three possible conditions that can produce a RICE trigger:

1. The main RICE trigger is a "self-trigger", which is formed if ≥N underground antenna receivers fire over threshold within the 1.25 microsecond gate. At present we use 4-fold coincidence. These are our primary physics events.

2. AMANDA-B or SPASE coincidence trigger happens if at least one underground antenna is hit within ±1.25us from the trigger signal received from the "big" AMANDA-B or SPASE. The "big" AMANDA-B trigger signal is derived from the AMANDA-B racks and corresponds to a 30-fold AMANDA multiplicity trigger (courtesy of Steve Barwick).

3. Random noise trigger, or so called Unbiased events, is the trigger forced by DAQ periodically (described in more detail later).

While Fig. 9-10 represent all electronics from location/connections point of view, it is easier to understand how the DAQ works using a functional diagram from Fig. 13.

The figure is divided into logical sections by a dotted line. First, consider the **Main Rice Trigger**. Analog data from antennas come to CAMAC discriminators 3412E and B.

Once any channel is long enough over threshold, at the output of this channel a NIM pulse appears. The "Current Sum Output" of the 3412E is converted into the NIM pulse of 1.25us long by means of two discriminators 821 A(1) and 821 A(4).

Transformed into ECL signal, it opens the gate of the MALU 4532 module. While the gate is open, MALU is counting rising edges coming to its channels 0-15 from the 3412E (only one hit per channel is counted). In case, if the number of pulses seen by MALU is greater or equal to some preset value N (by default, 4), the trigger pulse is produced by this module.

Second, the **Noise Events Trigger** producing the Unbiased events. The chain for this trigger starts at the Gate 2323A (2) that is at appropriate moments is triggered by the DAQ executable from the PC through GPIB interface. The two copies of this signal created using the 821 A(2) module are connected to the "Test" inputs of both discriminators 3412E and B. A pulse appearing at the "Test" input produces hits in all channels of the discriminators' outputs. Afterwords, the events develop as described for the Main Rice Trigger.

Last trigger line is **External Trigger** that is AMANDA-B and SPASE trigger. At first, we make sure that AMANDA and SPASE triggers are standard NIM signals using the discriminators 821 B(1) and 821 B(2). Next, we form a logic OR of AMANDA and SPASE

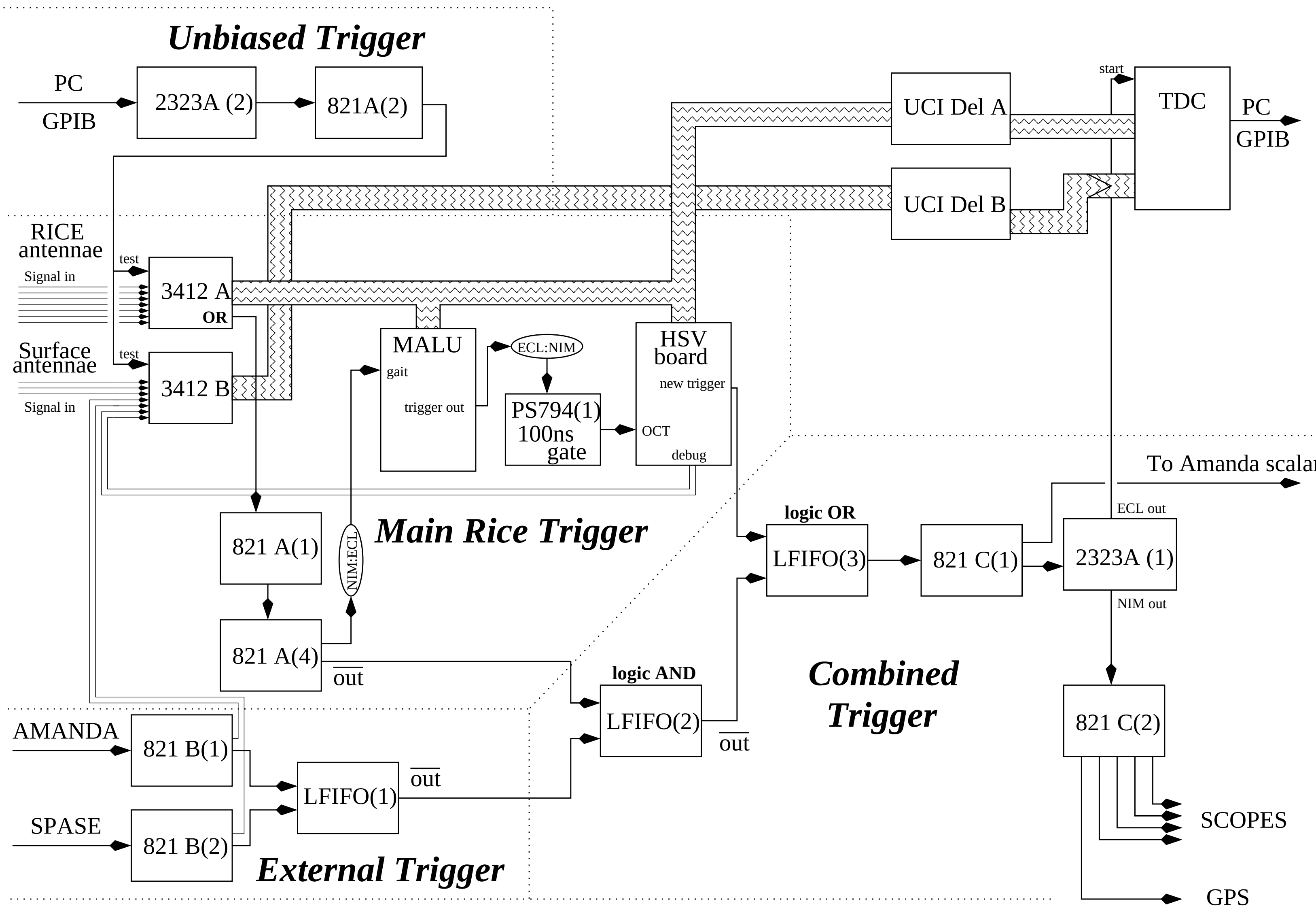


Figure 13: Functional diagram of the DAQ electronics.

by means of the Logic FIFO (1) module. Then, we want to build a condition $A.and.B = C$ where A is detection of AMANDA or SPASE and B is at least one underground hit while C is the result. Our LFIFO has only OR logic in it. We know that if $A.and.B = C$ is equivalent to $\bar{A}.or.\bar{B} = \bar{C}$. This is what is done in Logic FIFO (2). We send into it inverted AMANDA.or.SPASE logic signal and inverted "at least 1 underground hit" logic signal. Then we take an inverted output that is our desired "C", External Trigger.

There is an additional branch: **Hardware Surface Veto**. The surface antennas signals are connected to dedicated channels of 3412 B (currently channels 11-14 counting from 1). The ECL outputs of 3412 B of these channels are converted into NIM and connected to the input of the module FIFO(4), output of which is run through 821 B(3). These last two modules are needed only to form a logic OR of three inputs (we have run out of channels in LFIFO so we have to use non-direct solution). Then we also delay the result by $1\mu s$ and make it $3.2\mu s$ wide using Phillips Gate-Delay module.

These three chains form input for the **Combined Trigger**. The Main RICE trigger is ORed with the External Trigger in Logic FIFO (3). To use Hardware Surface Veto, we want to form the following logic: $A.and.\bar{B} = C$, where A is a valid trigger, B is the veto pulse and C is the final trigger. As we do not have an AND module, we use a trick again. $A.and.\bar{B} = C$ is equivalent to $\bar{A}.or.B = \bar{C}$. Thus, we combine inverted result of LFIFO(3) with the plain output of the veto branch in Logic FIFO(4) and take the inverted output of it. This output is finally run through 821 C(1) to get constant duration logic pulse. The result is the "raw" RICE trigger. One copy of this is used to monitor the raw trigger rates, connected to AMANDA scalar. The other copy trigger the gate unit 2323A (1); the output of it is the final RICE trigger. The last unit is needed as it latches the system and preserves the event until it is read out.

The discriminator 821 C(2) produces 5 copies of the final trigger that stop the scopes and freeze the event time in GPS module. The TDC also receives its "Start" from the final RICE trigger, while data inputs come from the discriminators 3412E and 3412 delayed by 1.5 $\mu$s in the UCI Del A and B.

Once triggered, the system is ignoring any other possible valid triggers and keeps the data in TDC and the scopes until cleared and enabled again.

## 5.3 Trigger timing details

Timing diagrams for main RICE trigger and External trigger will possibly be added by Dave.

**Hardware Surface Veto timing.** Our goal is to reject events generated by surface noise. In such events, radio wave propagates from the surface into the ice as a spherical or perhaps almost plane wave. In any case, surface antennas will be hit first. Then, it will take some time for the pulse to go through the ice and reach underground antennas. And some more time will elapse while the signal detected by the receivers propagates back to MAPO through some length of cable. If we assume that the scale of distance from surface antennas around MAPO and underground antennas is 300m, we get about 600m of round trip or $2\mu s$ of time difference between pulses appearing on the scope from the surface and underground antennas.

The timing diagram in Fig. 14 illustrates how HSV works. After a pulse from a surface

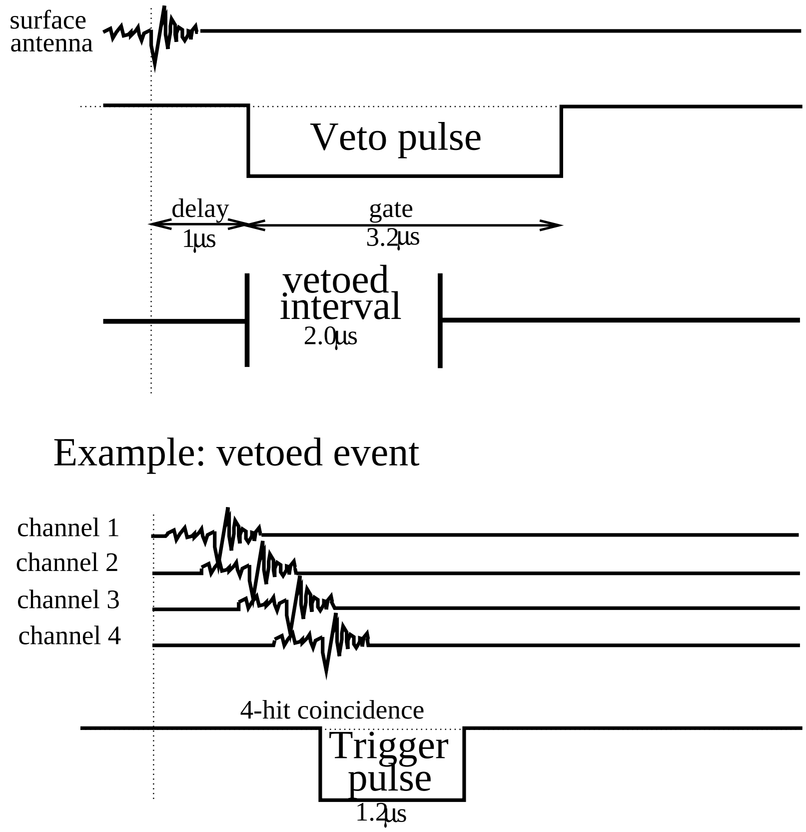


Figure 14: Timing diagram, showing two possible trigger routes.

antenna triggers discriminator, there is a delay of $1\mu s$ followed by the veto pulse of $3.2\mu s$ inhibiting the RICE trigger.

If there is a 4-hit coincidence that happens in time interval between the beginning of the veto pulse and the time instant of $2\mu s$ after the beginning of the veto pulse (marked as "vetoed interval" in Fig. 14), then this 4-hit coincidence will not trigger the DAQ.

The system will trigger normally, if:

- there is no surface hit in the vicinity
- the 4-hit coincidence happens in less than $1\mu s$ after the surface hit
- the 4-hit coincidence happens in more than $3\mu s$ after the surface hit

In this way we tuned our delays to veto all 4-hit events that follow a surface hit in $2\pm1\mu s$.

We have checked that the HSV does not produce an inordinately large amount of deadtime. This is done by using unbiased event waveforms, and plotting the maximum voltage for each waveform. That distribution is shown in Figure 15. As can be seen from the figure, the maximum voltage is observed to never exceed the discriminator 2 threshold (-200 mV) in these unbiased waveforms. Correspondingly, we can set an upper limit on the amount of deadtime incurred by the HSV at <0.25% (95% C.L.).

## 5.4 Calibration and constants

To achieve level of accuracy of 1ns and less for TDC measurement it is important to measure the actual differences between the channels in our electronics. In this section we

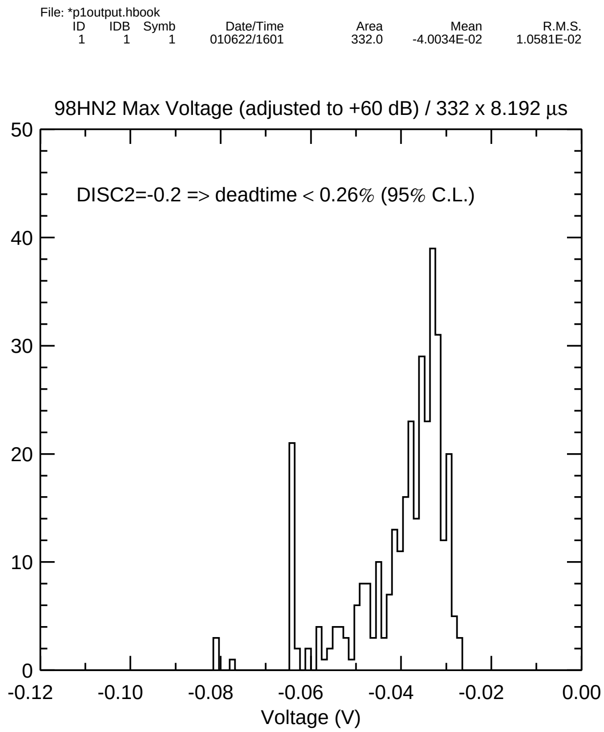


Figure 15: Distribution of maximum voltages within a waveform, for many waveforms of surface horn channel, for data taken on 1/11/01.

describe calibration and time constants obtained for different components.

The measurements are done typically sending one NIM pulse as a trigger to the scope and the other through a given DAQ component to another channel of the scope, measuring the time delay between the two signals.

Note, that in time measurements in this section we count time from a moment that is fixed in all the measurements but is defined by the setup we used (i.e. cable lengths). Also, in some cases we had to use ECL-NIM-ECL converter, introducing some delay as well.

**1. Discriminators 3412E and B**. These modules are fairly precise. Jitter is of the order of 200ps. The observed pulse timing relative to the trigger pulse is given in Table 7 and shows little (<1ns) variation between the channels. Such differences can be ignored.

| | Channel Number | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| A | 14.6 | 14.8 | 14.4 | 14.9 | 14.6 | 14.9 | 14.8 | 15.0 | 14.9 | 15.5 | 15.0 | 16.2 | 14.9 | 15.3 | 15.0 | 15.4 |
| B | 14.6 | 15.0 | 14.8 | 15.2 | 14.8 | 15.2 | 14.9 | 15.2 | 15.2 | 15.6 | 15.1 | 15.4 | 14.9 | 15.3 | 15.0 | 15.5 |

Table 7: Time of test signal arrival relative to the standard trigger, ns, for the discriminators 3412E and 3412.

When all channels are triggered through the "Test" input, the variation of delay between channels is slightly larger, but still stays within 1ns.

**2. Measurements for 3412E + 30' ribbon cable**. Adding a long 34-pin ribbon cable is not expected to change anything. Still, we provide the numbers (Table 8). Unlike the previous measurement, in this one channel-to-channel variation of the ECL-NIM-ECL module contributes to the total variation. The total variation stays small although the difference between Min and Max is now 2.9ns. The contribution of ECL-NIM-ECL should be taken out of these numbers if they are to be used as constants for analysis.

| Channel | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Time | 75.3 | 76.6 | 76.8 | 76.9 | 76.4 | 78.2 | 77.4 | 77.5 |
| Channel | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Time | 76.8 | 78.0 | 77.8 | 76.5 | 76.6 | 77.8 | 78.0 | 78.4 |

Table 8: Time of test signal arrival relative to the standard trigger, ns, for the discriminator 3412E plus 30 feet of ribbon cable. Note that the time delays imply a signal propagation velocity of roughly v=0.5c, typical of twisted pair cable.

**3. The ECL-NIM-ECL converter** is used in the test 2 (although, not in the test 1), so we give corresponding table for it as well (Table 9). Note, that setup up is practically identical to the test 1, only here we use the same channel of 3412E and different channels of ECL-NIM-ECL while for the test 1 it was the opposite.

| Channel | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Time | 14.6 | 14.6 | 15.0 | 15.2 | 14.7 | 14.6 | 15.2 | 15.2 |
| Channel | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Time | 14.8 | 15.0 | 15.3 | 15.3 | 14.8 | 15.0 | 15.4 | 15.4 |

Table 9: Time of test signal arrival relative to the standard trigger, ns, for the ECL-NIM-EL test.

**4. The UCI Delay modules** cause major variations between the channels, being not very precise. The setup used for this test includes 3412 + 30" ribbon cable + UCI Delay. We use 3412E and the long ribbon cable to test and compare the response and propagation time of both UCI Del A and B. This test is also subject to channel-to-channel variations in ECL-NIM-ECL which are, however, negligible on overall scale. The delay times are given in Table 10.

The difference between Min and Max is now increased up to 55ns. The $T_0$ time constants should be derived from these measurements and the TDC data should be corrected before using them in event reconstruction.

**5. TDC measurements**. Table 11 contains an example of an unbiased event (such an event has hits in all channels generated simultaneously). Note, that the first 16 channels are different from the last 16 by time shift of approximately 50 ns. This shift is due to the difference in the length of the 34-pin ribbon cable that goes from the discriminators

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| UCI Del A | Channel | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Time | 1.616 | 1.606 | 1.602 | 1.603 | 1.600 | 1.561 | 1.610 | 1.580 |
| | Channel | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | Time | 1.616 | 1.584 | 1.599 | 1.589 | 1.602 | 1.582 | 1.605 | 1.614 |
| UCI Del B | Channel | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Time | 1.607 | 1.606 | 1.595 | 1.622 | 1.597 | 1.614 | 1.613 | 1.602 |
| | Channel | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | Time | 1.609 | 1.611 | 1.627 | 1.603 | 1.597 | 1.591 | 1.600 | 1.603 |

Table 10: Time of test signal arrival relative to the standard trigger, us, for the UCI Delay modules.

to the UCI delays. The first group has about 30 feet of such cable and the second only 1.5 foot. The table also contains the time difference between the observed arrival time from Table 10 and the TDC measurement for each channel ($T_{uci} - T_{TDC}$). This number allows us to check if the TDC adds any more to channel-to-channel variation. As one can see, the additional variation is $\pm 6$ ns for the worst cases.

**6. Calibration constants**. As seen from the above studies, in order to use the TDC timing information, we need to take out time shifts introduced by electronics (and primarily by the UCI delay modules). The most simple way is to calculate the corrections from the measurements in Table 11. Using channel 0 as a reference point, for the $i$th channel the correction is found as $T_0 = T_{ch.0} - T_{ch.i}$ and is also given in Table 11. Now one can find the real (corrected) time from the measured time as follows:

$$T_{real} = T_{meas} + T_0$$

It is possible to do such a calibration remotely by simply looking at any Unbiased event. It might be a good idea to monitor $T_0$ over the year.

**7. Jitter**. It was reported that noticeable jitter (30ns or so) in TDC timing had been observed by Bai and George. In our direct tests the jitter for every component of the system has not exceeded 1 ns so the earlier results remain puzzling. Please, send any new info about this problem to Ilya or DZB.

# 6 DAQ software

The DAQ is written in Labview, a file containing the executable has .vi extension, library files are .llb. Both types are needed to run DAQ, so don't move files from directories without need. THE LABVIEW CODE SHOULD NEVER BE MODIFIED AT THIS POINT WITHOUT THE AUTHORITY OF ILYA.

## 6.1 Main DAQ executable

The main DAQ executable has the name (as of now): "RiceDaq2002_v2.2.vi". The libraries are

| TDC Channel | TDC time | $T_{uci} - T_{TDC}$ | $T_0$, ns |
|---|---|---|---|
| 0 | 1.450 | 166 | 0 |
| 1 | 1.440 | 166 | 10 |
| 2 | 1.437 | 165 | 13 |
| 3 | 1.442 | 161 | 8 |
| 4 | 1.438 | 162 | 12 |
| 5 | 1.399 | 162 | 51 |
| 6 | 1.446 | 164 | 4 |
| 7 | 1.420 | 160 | 30 |
| 8 | 1.450 | 166 | 0 |
| 9 | 1.418 | 166 | 32 |
| 10 | 1.433 | 166 | 17 |
| 11 | 1.416 | 173 | 34 |
| 12 | 1.438 | 164 | 12 |
| 13 | 1.421 | 161 | 29 |
| 14 | 1.442 | 163 | 8 |
| 15 | 1.452 | 162 | -2 |
| 16 | 1.380 | 227 | 70 |
| 17 | 1.378 | 228 | 72 |
| 18 | 1.366 | 229 | 84 |
| 19 | 1.393 | 229 | 57 |
| 20 | 1.367 | 230 | 83 |
| 21 | 1.380 | 234 | 70 |
| 22 | 1.382 | 231 | 68 |
| 23 | 1.370 | 232 | 80 |
| 24 | 1.380 | 229 | 70 |
| 25 | 1.381 | 230 | 69 |
| 26 | 1.398 | 229 | 52 |
| 27 | 1.374 | 230 | 76 |
| 28 | 1.370 | 227 | 80 |
| 29 | 1.362 | 229 | 88 |
| 30 | 1.372 | 228 | 78 |
| 31 | 1.374 | 229 | 76 |

Table 11: Time of test signal arrival relative to the standard trigger, us, TDC times and calibration constants.

- camac.llb - low-level CAMAC Vis
- veto-decision.llb - software veto implementation
- 303-decision.llb - 303-rejection mechanism
- hp545xx.llb - Vis dealing with HP scopes
- RiceDaq.llb - everything else

The code is located in

`‘‘c:\Rice\Software\Daq\RiceDaq2002_v2.2’’`

Note: the location of the code changes as new versions appear. Normally, the latest and best version is linked to an icon on the DAQ PC desktop.

### 6.1.1 General structure of event flow

First, the concept of the system state has to be introduced. At any given moment the DAQ can be in one of several possible states and there are certain allowed transitions between the states. DAQ main framework operates with states and transitions while low-level subroutines do the actual work.

The state machine is shown in Fig. **??**. The description of the states follows:

- **Idle** Once the main DAQ executable is started, it waits for the input doing nothing. No communication with DAQ electronics. The system also returns to this state when the run is ended.
- **Configured** All internal variables, modes, etc are filled. However, there is no communication with DAQ electronics yet.
- **Initialized** DAQ electronics is initialized, including CAMAC modules and the scopes.
- **Calibration Loop** DAQ is taking a calibration run.
- **Event Loop** DAQ is in running mode, taking data.
- **End Run** Equivalent to Idle. Run has terminated normally.
- **Session finished** as the name says

The transitions allowed are obvious from the Fig. 16. For the operator **Configure** and **Initialize** are not separated, second follows the first immediately. For “Initialized” state the options are to **Finish**, start calibration run, **Start Run** and **Configure** again. Once the DAQ is running in the event loop the only allowed option is **Stop Run** transition. Once the run is ended the new one can be started through **Configure** or one can **Finish** the session.

The **Abort** transition can be done from any state stopping the executable by clicking on the red stop button on the Vi menu bar. When aborted, the End of Run summary is not written to the log file, so normal End of Run is preferable.

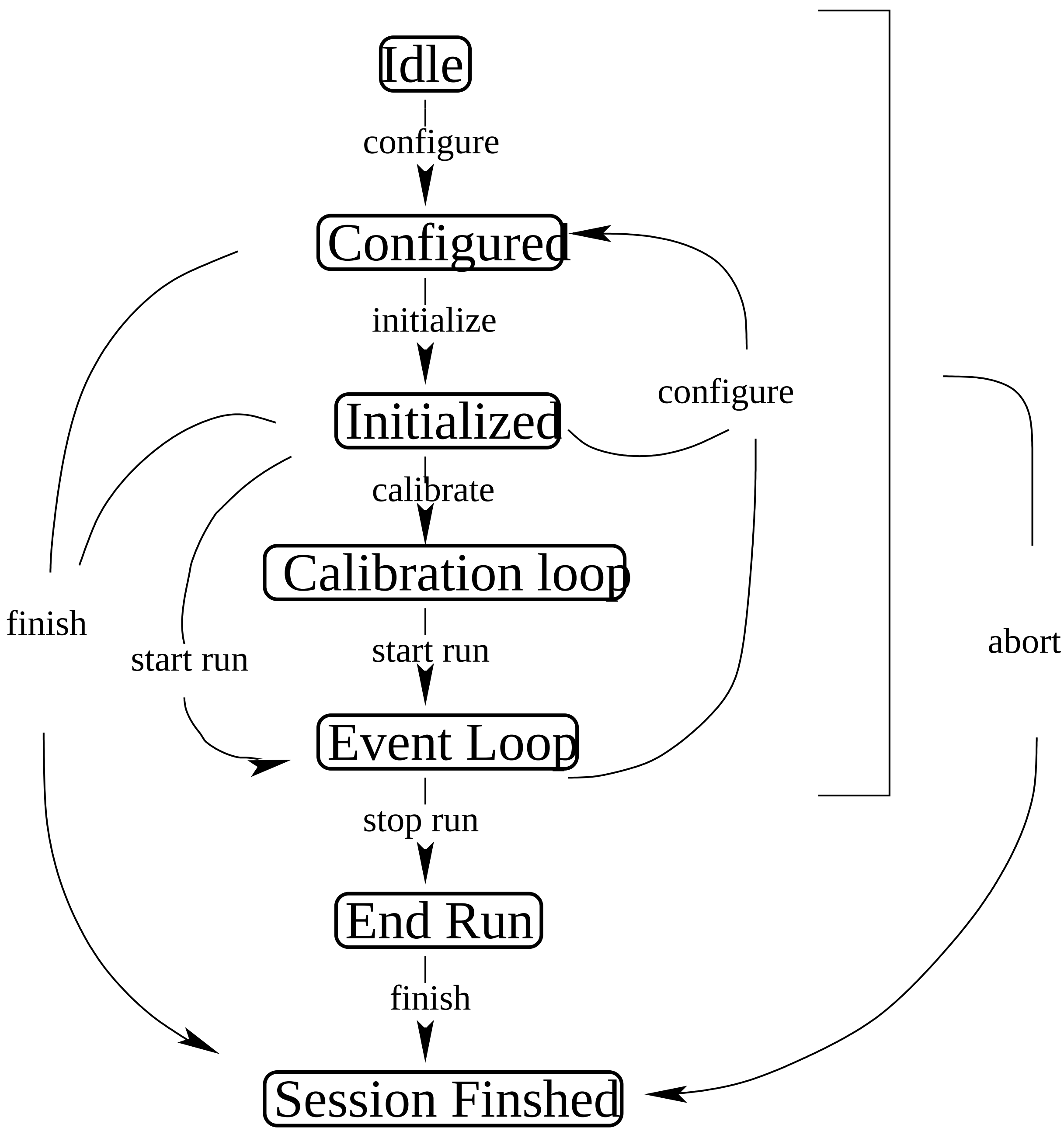


Figure 16: DAQ state and transition diagram

### 6.1.2 Event loop

Once the run is started, DAQ spins in the event loop, as the diagram in Fig. 17 shows. The meaning of each step is explained below.

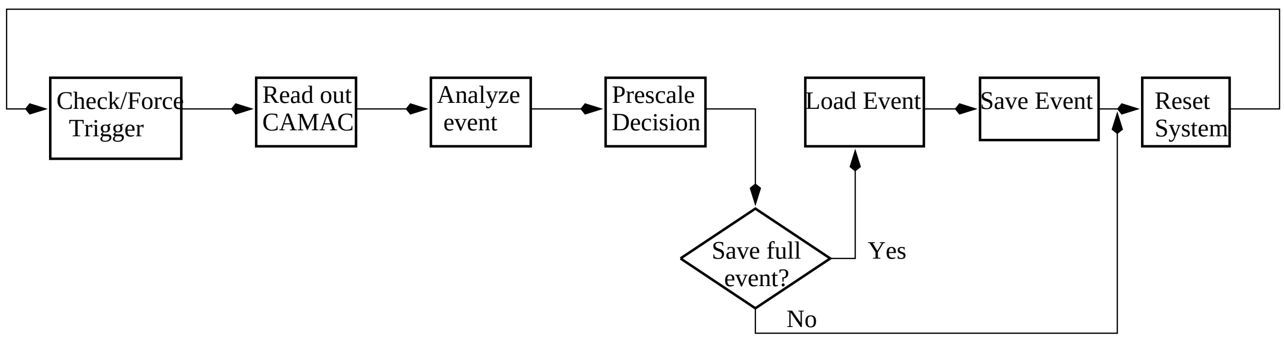


Figure 17: Event Loop diagram

- **Check/Force Trigger:** The executable waits for an event to arrive polling the CAMAC every 2-10 milliseconds. The check consists of sending "Event Ready?" query to the TDC module and then checking the "Q" response on CAMAC controller. This part of the Event Loop also forces the event when the circumstances are right.
- **Read out TDC:** Once the new event is detected, the TDC data are read.
- **Analyze Event:** The event type is determined based on TDC information (see Sec. 6.2, 6.8)
- **Prescale Module:** Decides whether the event should be saved or not based on the event type. For example, we do not want to save every event that is classified as a background (i.e., "Veto" event). Thus, we set prescale factors during configuration step of the run for each event type.
- **Load event:** The waveforms are loaded from the HP scopes and saved into "Current Event Buffer". This step is skipped when running in "Scalar" mode (see Sec. 7.1.1) or when Prescalar Module decides to skip this event.
- **Waveform Analysis:** for every loaded event one can do a quick analysis of the waveforms. Right now every event is checked for presence of the 303 MHz background in order to decide whether to save it or not.
- **Save Event:** The event data from the Current Event Buffer are formatted and saved to HD. Save Event is not run if Load Event is not run.

- **Reset System:** Clears TDC data and re-enables the trigger. For Unbiased events (see 6.2) adjusts Y range of the scopes.

This modular structure will hopefully make it easier to upgrade and maintain from US.

### 6.1.3 Event Time Stamp

In general, we have two methods to obtain current time. One is GPS system, described in Sec.4.2.5 accurate to 100ns. The other one is internal PC clock. At present we are running AboutTime client on the PC at all times. This utility logs in to one of the Internet time servers every 2 hours end resets the internal PC clock (provided network is reachable). Currently we are using two Amanda time servers as primary time hosts. There are also several US hosts (that are used only if both Amanda servers are not responding). The internal PC time is expected to be accurate up to 10-20 milliseconds.

The exact time of each event is obtained from GPS. The time is frozen in the GPS module in CAMAC crate by the same pulse that starts the TDC and triggers the scopes and is accurate up to several hundred nanoseconds (100ns is the resolution of TrueTime receiver). Begin Run and End Run time stamp written into the log file is also obtained from the GPS system. The "Time of the Run, sec" variable displayed during the run and also saved into log file is taken from the PC internal clock.

The date format is yy/xxx where yy is the year and xxx is the day (0-365 or 366). Hours in the time record go from 0 to 24 without PM/AM.

## 6.2 Event classification, prescaling and noise level

Defined event types are the following: General, Veto, External trigger 1, External Trigger 2 and Unbiased event. Related topics are discussed in the trigger section (Sec. 5.2).

General event corresponds to 4-hit coincidence trigger based on the signals from underground antenna array, that is accepted by the "Analyze Event" module. These are events that are mostly useful for physics.

Veto events are those 4-hit coincidence trigger events that were rejected by the "Analyze Event" module, failing some veto criteria (see Sec. 6.8).

External trigger 1 and 2 events are coincidence events between at least one underground RICE antenna and AMANDA-B and SPASE trigger, respectively. These are identified by DAQ executable by the presence of the hits in channels 30 and 31 of the TDC.

Unbiased events are forced by DAQ itself and with some luck contain only noise without any outstanding pulses. This event type is taken periodically in order to monitor the noise level and also make sure that Y range of the scopes is neither too large nor too small. At present, after each unbiased event RMS is calculated for each channels and the scopes are reinitialized to have Y range equal to $32 * RMS$ volts. The value 32 is changeable during the configuration step of the run. In some cases, when the trigger rate is too high, an event expected to be Unbiased can contain a normal (General/Veto/Ext. type) event if it happens just before "Force trigger" action happened. *One can tell if an event denoted as Unbiased is the true Unbiased event by looking at the number of TDC* *hits, which should be 32, and at TDC values that should be around 1350-1450 ns. Note, that the second event saved in any run is an Unbiased event.*

When the event type is determined, the precedence is the following: Unbiased, External 1 External 2, Veto, General in descending order.

As mentioned before, we determine fraction of events saved by prescale factors. Handling of Unbiased events is different from the other types. Every Unbiased event is saved. Unbiased events are taken based on two criteria:

a) every NN events

b) if more than TT seconds passed since the last unbiased event

where NN and TT are set during configuration step of the run.

## 6.3 User interface and main windows

The **main** run control window is shown in Fig. **??**. This is the first window that opens once the executable is loaded. Its content is fairly obvious. Some details are given in Sec. 7.

**Run Statistics** window (Fig. 19) displays constantly updated variables such as numbers of events of each type, total events in run and run time. Time of the run shows how much time passed from the moment when "Start Run" button was pressed to the present moment if data taking is in progress or to the moment when data taking was turned off by user or "Maximum number of events" condition is reached.

When DAQ is reading out an event and/or resetting the scopes, the time of the run variable is not updated. The numbers in the Run Statistics window are updated once per second. This window is open automatically once the system is initialized.

Some explanations on the meaning of non-obvious numbers and switches:

*303-detects:* total number of 303 events detected in this run

*303-rejects:* total number of cases when an event was supposed to be saved but due to the fact of the 303 presence was rejected

*303 alert:* if red, the last event had 303 line in it

*HSV On/Off:* current state of Hardware Surface Veto (enabled/disabled) This is an indicator, the switching On/Off is done automatically.

*Interrupt:* operator can stop the run by clicking on this button in special cases, when DAQ is waiting for an event but nothing comes (Stop Run might not work in this case)

*Raw event counter:* this counter is incremented every time a valid triger has been detected regardless of the event type and the save status. It is added for convinience so that during 303-background prediod one can see the rate of veto events that otherwise do not increment any other counter.

**Current Event Buffer** window (Fig.20) contains event display for the latest event. This window opens only if the option is selected during Configure System dialog. The following information is available:

- Most important group:

  **Number of hits in the event** recorded by TDC.

  **Hit list from TDC** - channels and TDC times. Only 4 hits are displayed but one can scroll using mouse through the arrays.

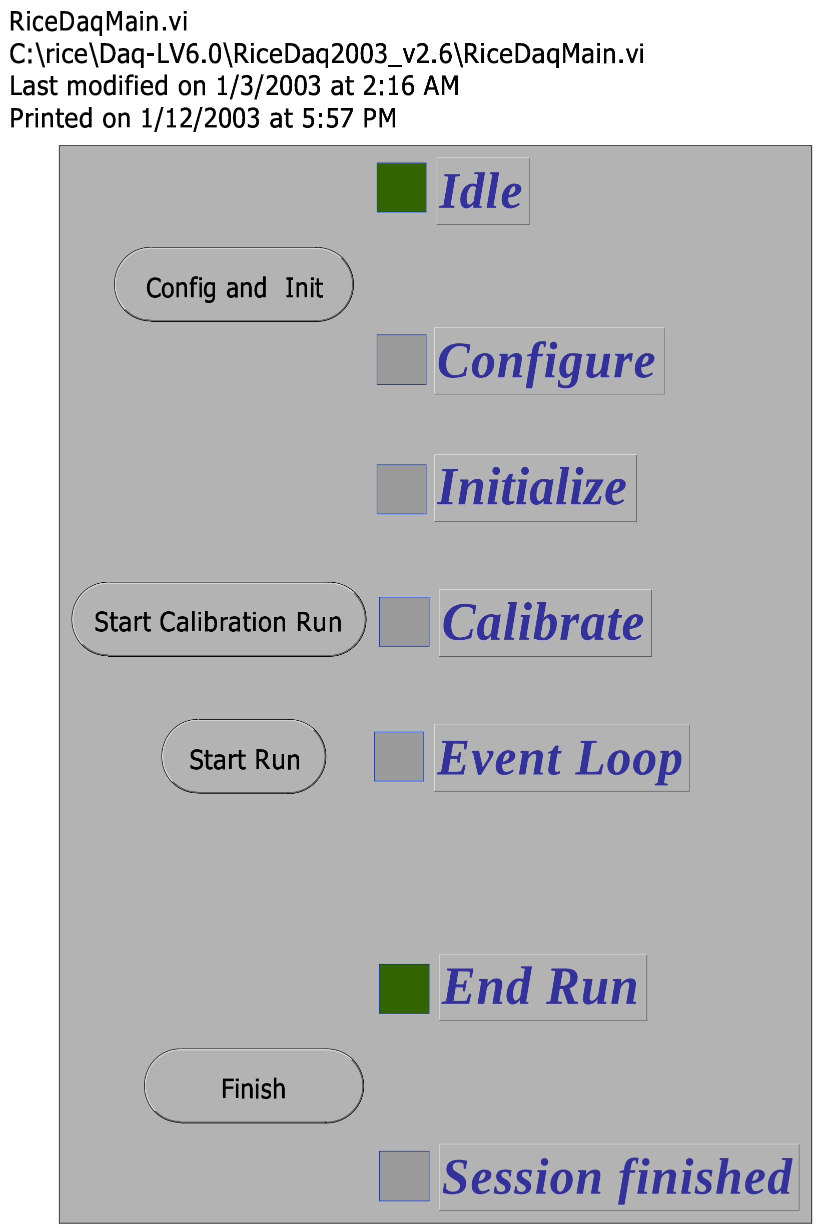


Figure 18: Main window of the DAQ executable

Run Statistics Display
C:\rice\Daq-LV6.0\RiceDaq2003_v2.6\RiceDaq.llb\Run Statistics Display
Last modified on 12/30/2002 at 2:16 AM
Printed on 1/3/2003 at 3:13 AM

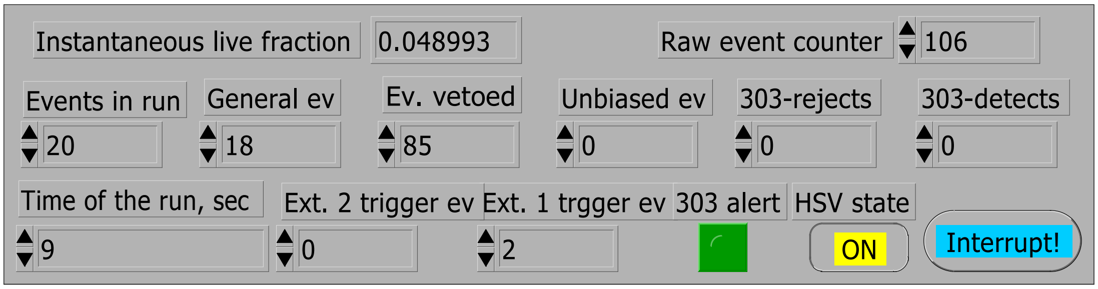


Figure 19: Run Statistics window of the DAQ executable.

**Waveform** corresponds to the first channel of the first scope recorded in the last event.

**Event Type** is the result returned by "Analyze Event" procedure.

**This event will be saved?** is the result returned by "Prescale Module".

- Others:

  **Date and time** obtained from GPS

  **Progress Marker** indicators show where exactly in the event loop the execution is at this moment.

  **Max and RMS** arrays correspond to the last Unbiased event taken in this run.

  **Data Array** shows waveform data from the last saved event.

For the events that are not saved to disk only the information on the number of hits, event type and the hit list is updated, while the rest remains from the last saved events. Marker and date/time are always updated.

There are two more windows, **Configure System** and **Configure System Advanced** that are opened during configuration stage (Fig. **??** and **??**). The detailed description is given in Sec. 6.4.

Any window can be closed at any time during the run except for the main window of run control. Windows can be open as well by opening the appropriate Vi from RiceDaq.llb They will always contain up-to-date information.

Current Event Buffer
C:\rice\Daq-LV5.0\RiceDaq2002_v2.2\RiceDaq.llb\Current Event Buffer
Last modified on 1/1/2001 at 4:37 AM
Printed on 2/2/2002 at 7:20 PM

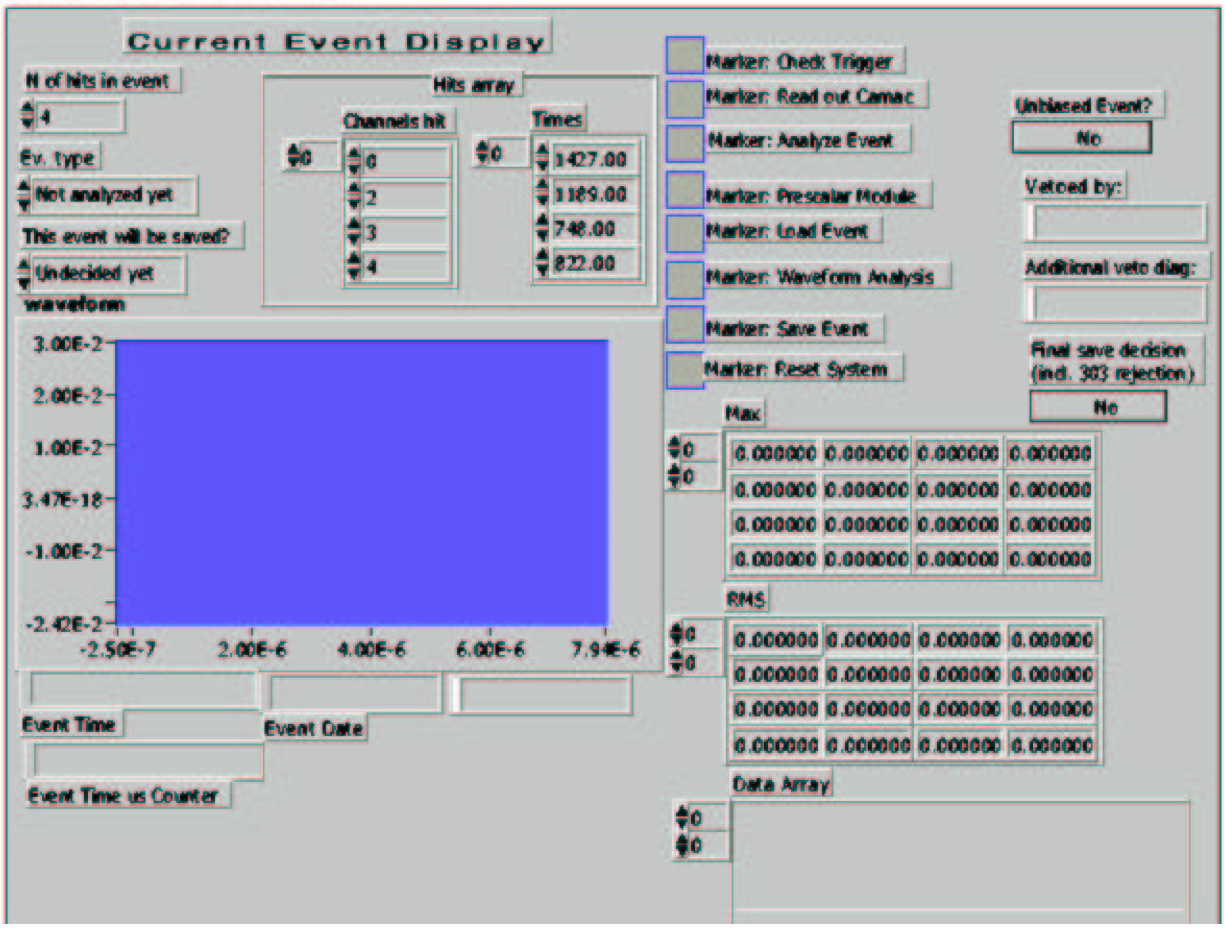


Figure 20: “Event Display” window of the DAQ executable.

Page 1 Config action

Configure System Action
C:\rice\Daq-LV6.0\RiceDaq2003_v2.6\RiceDaq.llb\Configure System Action
Last modified on 12/29/2002 at 7:44 PM
Printed on 1/3/2003 at 3:17 AM

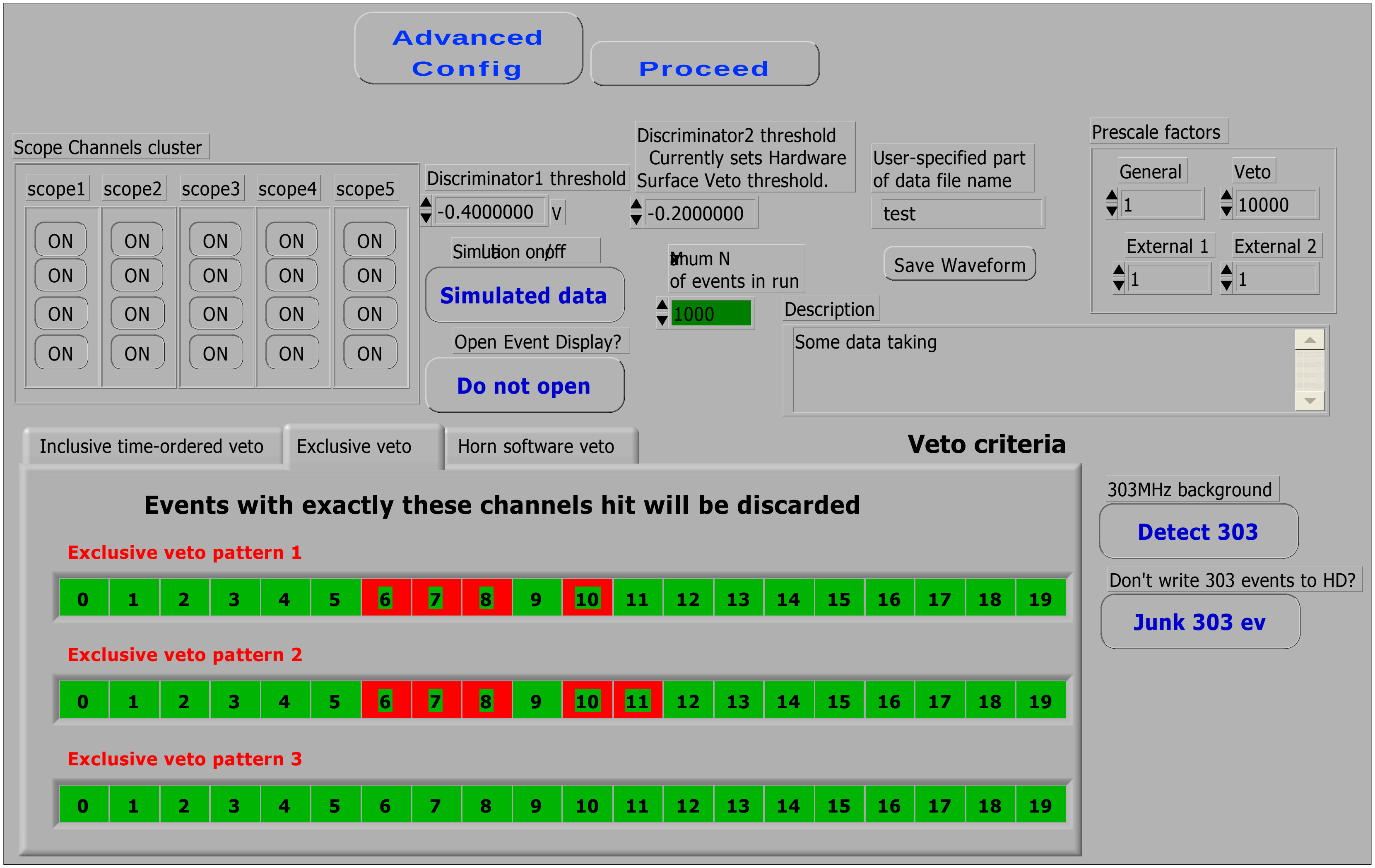


Figure 21: Configure System window of the DAQ executable.

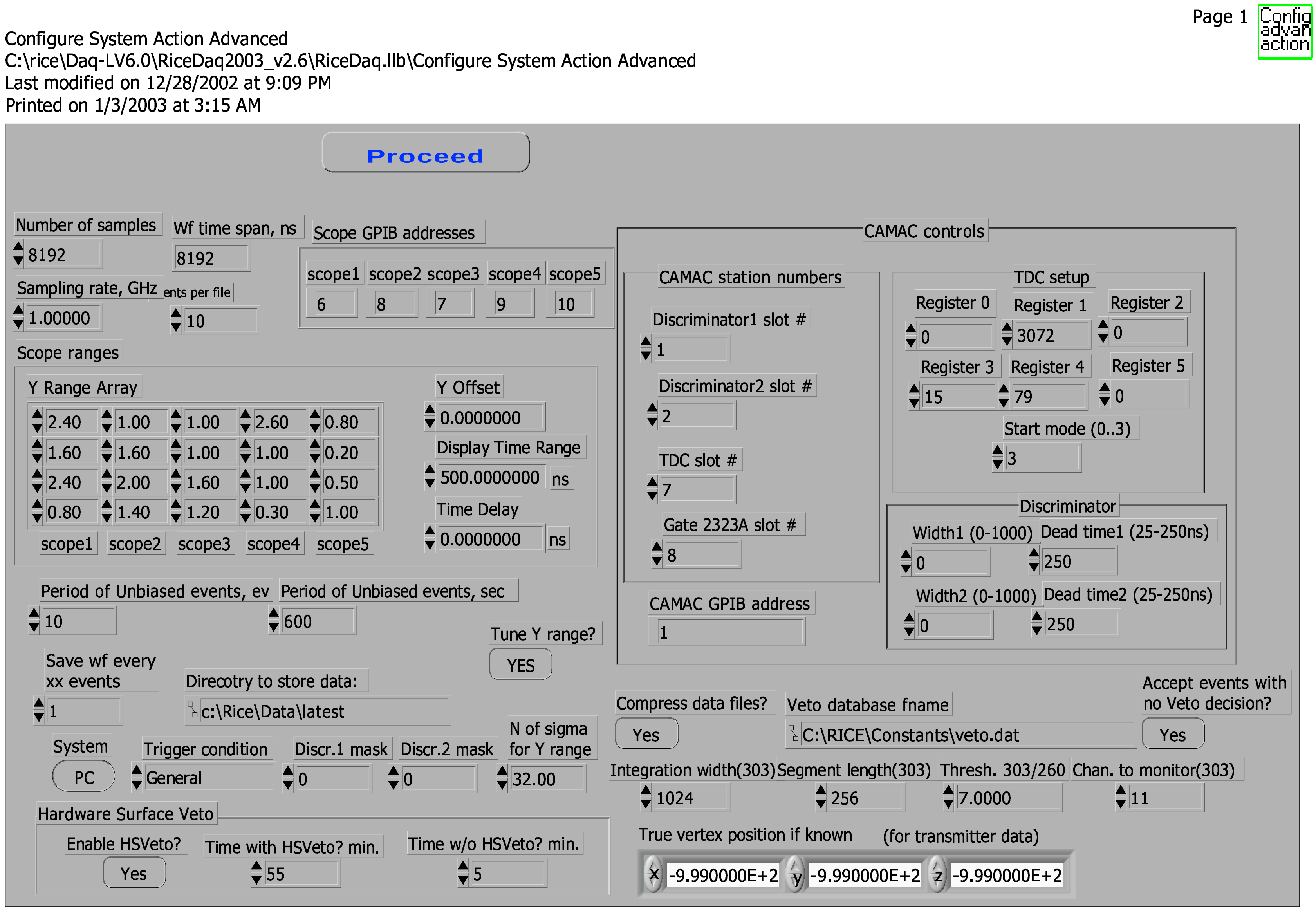


Figure 22: Configure System Advanced window of the DAQ executable.

## 6.4 System configuration controls

There are two windows that open during "Configure" transition that contain all the entities that need to be set to run the system (see Fig. ?? and ??). We can subdivide them into logical groups: Scope, CAMAC, Data Logging, Modes of Operation, etc. In the list below they are subdivided into Basic and Advanced corresponding to "Configure" and "Configure Advanced" windows. Also, see Sec. 7.

- Scope Controls

  - *Basic* -

  **Scope Channel Cluster**: a set of "On/Off" buttons defines which waveforms will be saved. The default value is all

  - *Advanced* -

  **Scope Ranges/Y range array**: sets the vertical size (maximal possible voltage measured is Y/2), and also resolution for each channel. Scopes' digitizers divide Y into 8 segments, 8 bit resolution per v segment.

  **Tune Y range**: if measured voltage is higher than Y Range, it will be set to Y Range, if it is much smaller the resolution will be poor. Therefore it is important to have Y range set properly for current noise/signal level. The DAQ will always try to adjust Y Range as time advances based on the RMS voltage it measures in Unbiased events. The default is "Tune Y Range"=ON. When OFF is chosen, the settings from the Y range array will be used throughout the run.

  **N of sigma for Y range**: after an unbiased event is taken, Y ranges for all the scopes are set to this number times the unbiased waveform RMS for the corresponding channel. The default is 32.

  **Scope Ranges/Y offset**: is for taking out DC components, it is usually zero as we set the scopes to do it for us.

  **Scope Ranges/Display Time Range**: this setting is redundant. It is overwritten by the Sampling Rate setting.

  **Scope Ranges/Time Delay**: the time between the trigger instant and the middle of the waveform.

  **Sampling rate** sets the sampling rate of the scopes. If it is set to a rate higher than possible for a given scope, the rate set will be highest possible. The default setting should be 1 GHz. The Time Range for a scope (i.e., time range of a waveform displayed on the screen of the scope) corresponds to the time interval of 500 samples. For 1GHz it is 500ns.

  **Number of samples in waveform** is a power of 2 and ranges from 1024 to 32768. This number together with Sampling Rate determines length of waveforms in time. The default value should be 8192.

  **Wf time span, ns**: this number is calculated by DAQ executable and is not used for anything in particular.

- CAMAC Controls

  - *Basic* -

  **Discriminator Threshold** 1 and 2: the thresholds for the $16x2$ discriminator channels. The default is 0.057V. The thresholds should be between 0 and -1.0 V. From zero to approximately -25mV threshold discriminator starts to trigger on internal (crate) noise. The values should be tuned to give an event rate (Events-in-run/Time-of-the-run, sec) appropriate given our dead time (see Sec. 8.2).

  - *Advanced* -

  CAMAC GPIB address: should be the same as set on the front part of the GPIB controller module in CAMAC crate. The default is 1.

  Discriminator **Width** and **Dead Time** 1 and 2: can be set from 25 to 250ns; defaults are 250ns for both. This is the width of the output pulse and dead time after this pulse for individual channels. "Sum" output of the discriminators is a simple AND of all channel outputs without its own dead time.

  **Discriminator slot #** 1 and 2: is the slot number in CAMAC crate, where Discriminators are located. Usually in the slots number one and two.

  TDC **Start Mode**: sets the mode of TDC, default is 3 which means "Common Start Double Word".

  TDC **Registers 0-5** set parameters for Common Start mode, see details in Sec. 4.2.3, the numbers are not supposed to be changed, the Register 4 establishes Common start Timeout which is calculated as $(25 + R4 * 50)ns$. So $R4 = 80$ means $Timeout = 4025ns$. The defaults are $R0 = 0$, $R1 = 3072$, $R2 = 0$, $R3 = 15$, $R4 = 80$, $R5 = 0$.

  **TDC slot #** is currently 7 - the slot number in the crate where the TDC module is put.

  **Gate 2323A slot #** is currently 8.

- Data Logger

  - *Basic* -

  **User-specified part of data file name**: user can add any sequence of characters to data file name (except for "_" symbol). Note, that current date is added automatically".

  **Description**: a string(text) control that allows user to type any text that will be added to the event header (to each event in each file). Every new run should have some description added to it indicating running conditions, any changes in channel connections, etc.

  - *Advanced* -

  **Directory to store data**: the default area should be $D : \backslash Rice \backslash Data$.

  **Events per file**: determines how many events each data file will contain. It is better not to write files several tens of Mb big - it is more difficult to process data in such case. Depending on the size 5-10 events per file is ok.

**Compress data?**: this yes/no switch allows to select whether gzip will be run on each data file right after DAQ is finished writing into it.

**True Vertex Position**: the 3 numbers define the position of the source in X, Y abd Z in case it is known in real data (such as when transmitter data are taken), otherwise it is (-999,-999,-999). Monte Carlo events contain the true generated vertex in this field.

- Veto/Prescale/Trigger

  - *Basic* -

  **Veto Criteria**: this tab control defines three types of veto criteria, spread over thres pages. All pages of the tab veto selection control are shown in Fig. 23. The first page sets inclusive time-ordered veto patterns, the second sets exclusive arbitrary-time patterns, and tje third is an old-style inclusive arbitrary-time pattern based on the horn hits. The final fourth veto type, TDC/Geometry, does not have a dedicated page for its settings, it only needs a constants file the location of which is set in the Advanced window and which is typically found in: $C:\backslash Rice\backslash Constants\backslash veto.dat$.

  **Prescale factors**: set frequency for saving events of different types. E.g. Prescale Veto 100 means that only one out of a hundred events will be saved.

  **Period for Unbiased events**: there are two of these controls, one is specified in the number of events and the other in the number of seconds. Both cycles are used.

  - *Advanced* -

  **Trigger Condition**: can be General or Masked Channels. The second allows to turn off some discriminator channels so that they are excluded from the trigger.

  **Discriminator Mask** determines which channels are active and which are disabled. Decimal number is converted into the 16 bits where 0 means channels enabled and 1 means channel disabled. Bit 0 is channels 0 and bit 15 is channel 15, setting this control to 0 enables all the channels (0000000000000000), setting it to 65535 disables all channels (111111111111111), or, e.g. 8 means 0000000000001000 that disables channel 3 (counting from zero).

  **303 veto settings**: these are explained at length in Sec. 6.10.3.

  **Hardware Surface Veto cluster**: one can turn HSV on/off, and, when it is on, one can specify time in minutes of HSV on and off (see Sec. 6.9).

- Modes of Operation

  - *Basic* -

  **Real data/Simulated data**: turns on/off simulation. Default is Real data.

  **Open event display?** switches between fast (Do not open) and slower (Open) modes, see Sec. 7.1.1.

  **Scalar/Save waveform**: obvious, see Sec. 7.1.1.

  - *Advanced* -

Untitled 1
Last modified on 1/3/2003 at 3:25 AM
Printed on 1/3/2003 at 3:25 AM

Page 1

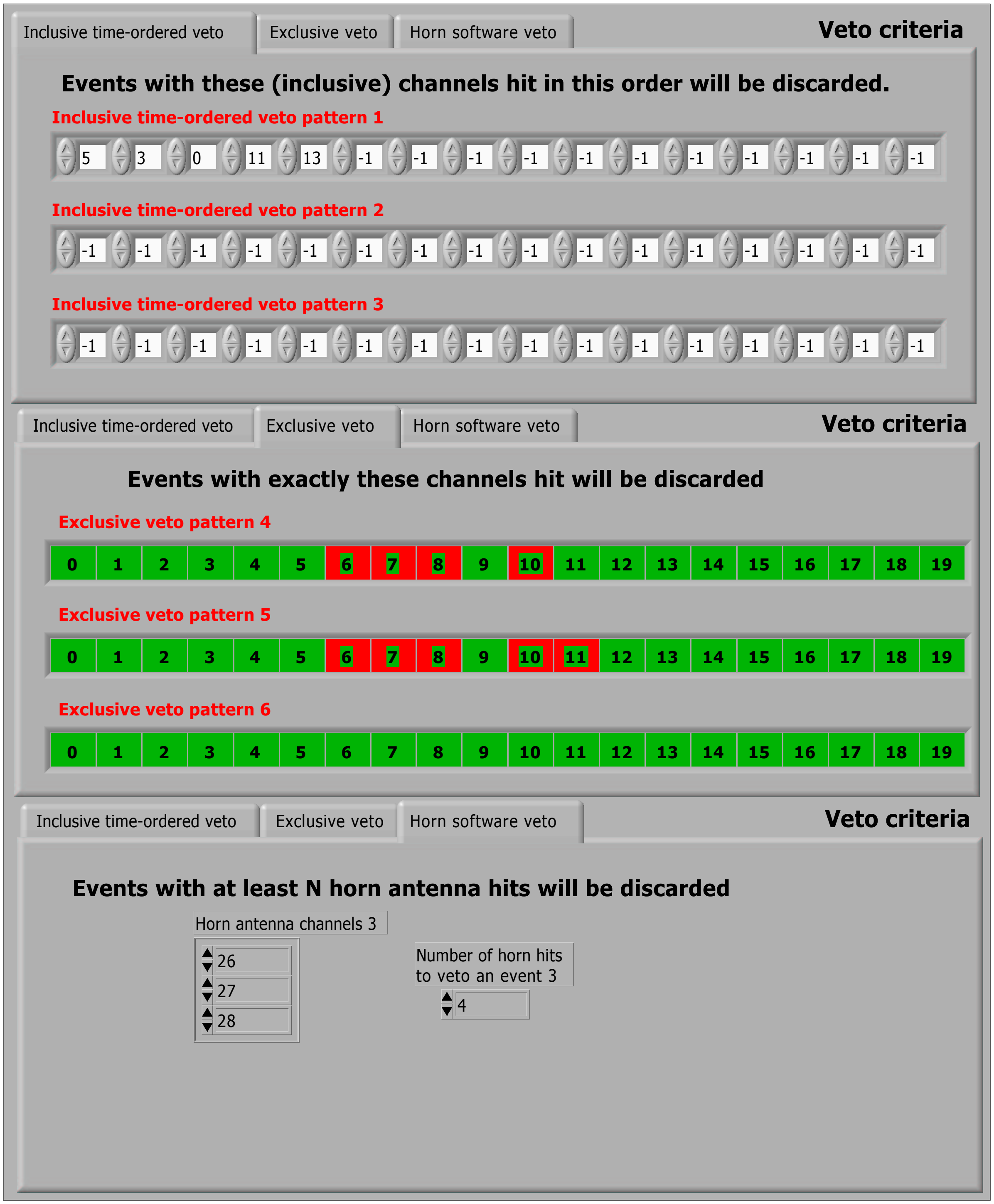


Figure 23: All pages of the veto controls tab from the System Config window.

- General

  - *Basic* -

  **Maximum N of events in run**: allows one to limit the number of events taken after "Start run" button is pressed. When the number of events in run reaches this value, the run is automatically stopped.

  - *Advanced* -

  **System** is the switch between PC and Mac file formats.

## 6.5 Calibration Run

### 6.5.1 General idea

The setting of the primary discriminator threshold for the first 16 channels that are fed into the RICE trigger is obviously very important. Our current guidliness is to set this threshold to such a value that keeps our livetime fraction at about 85-90%. Too high threshold gives livetime close to 100%, but real neutrino events are not likely to go through such a high threshold, while too low threshold gives poor livetime. In the past the winterover responsible for running RICE DAQ typically would select threshold based on the observations of thresholds and livetimes of the previous days.

Now we have introduced a "Calibration Run" to help with selecting the threshold. This run is actually a sequence of several mini-runs (called "segments" below), each at a different threshold lasting about a minute. After sampling the rates at different thresholds, the software attempts to approximate the results with a smooth curve and finds the threshold that corresponds to a desired livetime fraction.

### 6.5.2 Implementation details

**Configuring the run** Calibration runs are initiated by clicking on the "Calibratation Run" button on the main Rice DAQ window (see Fig. XX). The configuration dialog shown in Fig. 24 comes up. This dialog allows to set the most basic parameters, such as the number of segments to be taken and the time duaration of each segment. Obviously, the longer the segment is, the more precise is the livetime estimate for that segment. It is not advisable to make the segment duration less than 30s. About 1-2min is optimal. The defaults are 10 segments 1 minute each. One also sets the range for threshold value (the default is from -1V to -100mV) and the target livetime (the default is 90%).

Calibration runs have to be taken during time of the day when there are no 303 background, obviously, so there is a button "Abort if 303 present?", when set to "Yes" it will cause the calibration run to abort if 303 is found.

Calibration strategy control is currently redundant. It allows to choose between several strategies of selection of the threshold of individual segments, however only a single strategy is currently implemented: the uniform sampling of threshold values within the given min-max range.

There are also four controls that set time associated with different steps of event readout. These are not supposed to be changed. These numbers are taking into account by the calibration procedure while calculating livetime fraction for each run segment.

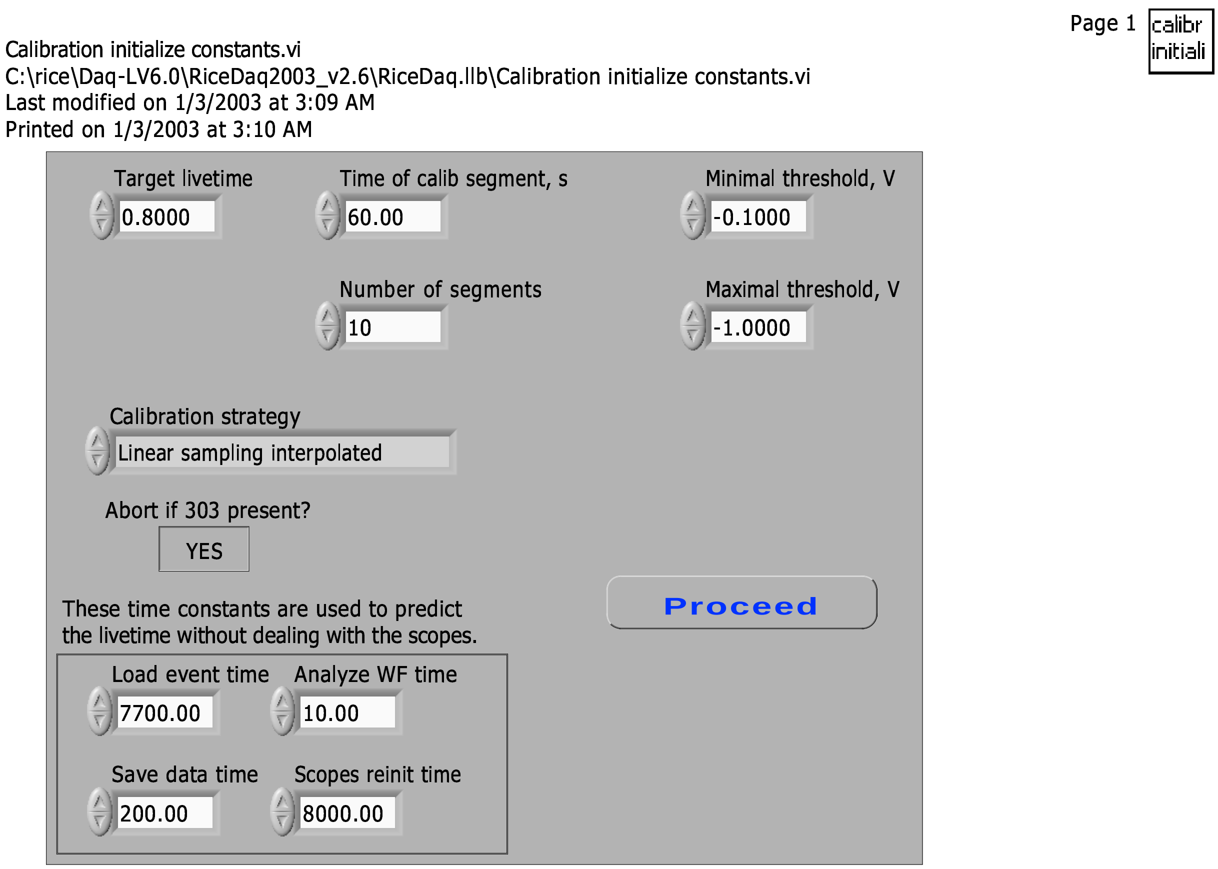


Figure 24: Calibration run configuration dialog.

**303-background test** Before starting with the threshold sampling, the DAQ takes one unbiased event right away and performes the standard test for the presense of the 303-background, unless this test is disabled in the previously-described configuration dialog. If 303-background is found, the calibration run is aborted and the final threshold selection dialog is opened for the operator (see the description below).

**One segment** One segment, again, is an interval of datataking with threshold set to a certain value. During each segment the DAQ waits for an event and calssifies it according to the TDC readings just as it is done in a normal run. However, there is no readout of the scopes regardless of the event type. Also no unbiased events are taken. The software just keeps counting events of all types. At the end of the segment, the total accumulated run time and total accumulated live time are known just like for a normal run. These numbers are further corrected. For each general, external or veto event that would have been saved to HD if this were a normal run, the expected dead time is added to the total accumulated run time, the expected dead time being the sum of the time intervals associated with "load event", "analyze waveform" and "save event" operations, total of about 7-8 seconds. There are also two corrections associated with the unbiased events. For every 9 events[4] that would have been saved we know that an unbiased event should be added, so the total accumulated run time is increased by the appropriate amount of dead time: the sum of "load event", "analyze waveform", "save event" and "reinitialize the scopes", total of about 15 seconds per event. The livetime fraction is then calculated in the usual way as the ratio of the accumulated live time to the accumulated run time. The livetime is also corrected for the unbiased events taken every 10 minutes. One unbiased event (15s) taken every 10min adds about 2.5% of dead time.

The current state of the calibration run is reflected on the "Calibration state array" window shown in Fig. 25. This window also contains the "Abort" button that allow to interrupt calibration runs at any time. This window opens automatically when calibrations are taken for the first time, and then stays open until killed manually.

**Threshold selection for a segment** For the segment $i$ the threshold is set to be $V_{min} + i(V_{max} - V_{min})/(N-1)$ where $[V_{min}, V_{max}]$ is the threshold scan range, $N$ is the number of segments and $i = 0, 1, .., N-1$.

**Fitting the threshold scan** The result of the calibration run when all the segments are taken is a set of threshold values and associated with them livetime fractions. These data are fitted with two different models: a threshold function and a 5-th order polynomial. The formula for the polynomial is standard. The formula of the threshold function is the following:

$$f_{live} = 1 - 0.5 \tanh\left(a(V-b)\right) + 0.5 \tanh\left(c(V-d)\right)$$

where a,b,c and d are the fit parameters. The first tanh in the formula above describes the expected step-function-like behaviour with livetime being zero at low thresholds and close to one at higher thresholds. The second tanh describes an effect sometimes observed in the real system: when threshold becomes too small, the DAQ stops triggering because of too frequent narrow oscillations over threshold (a feature of our current 3412 discriminator). This second tanh thus allows to describe a rise in livetime fraction at lower (closer to

[4]More precisely, the period for unbiased events is set in the Configure dialog, but it is almost always is set to 10.

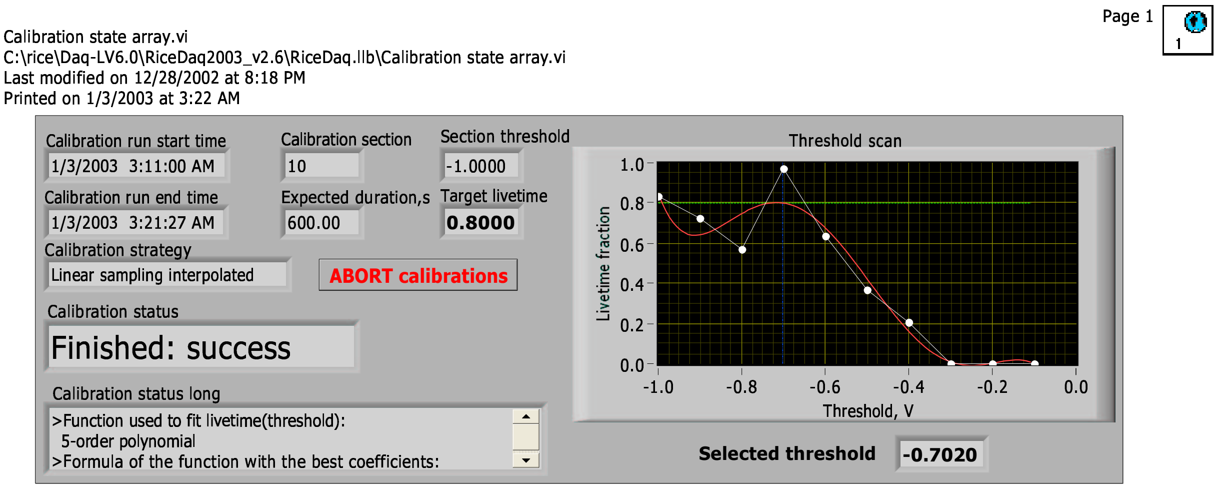


Figure 25: Calibration state array window shows the current status of calibration run.

zero) thresholds.

Fitting in LabView is not too advanced. It is a min $\chi^2$ fit with all data points having equal weight (no individual errors). The threshold function above is a well-motivated model, but due to the fitting specifics in LabView the fit fails often. On the other hand, the polynomial fit almost always succeeds, but typically does not look as good visually as the threshold function fit.

**Determining the threshold** After the fitted curve $F_{fitted}(V)$ is established, the DAQ attempts to find the threshold that would yield the desired livetime. To find the threshold, an equation is solved to find all points of intersection between $y = f_{live}^{target}$ and $y = F_{fitted}(V)$. Three casses are possible: no solutions, single solution and multiple solutions. In case of multiple solutions the optimal one is defined as the one with the smallest absolute value that also has a negative derivative. This method allows to avoid problems with livetime rising again at very low thresholds due to discriminator problems.

**Threshold selection dialog**

At the end of a calibration run the operator is presented with the final threshold selection dialog shown in Fig. 26. The window contains a graph with the threshold scan data points and an attempted fit to it. Using radio-buttons to the left of this graph one can select the fit model to approximate the data. In case if fit fails there is no continuous curve overlaying the data points. The fit status is also explained in the text field in the middle titled "Calibration Run Status". In addition to the data points and the fit, the graph also has a horizontal line: the target livetime, and the vertical line: the selected threshold.

The bottom part of the window contains radio-buttons for the final threshold selection. The three choices presented are: the optimal threshold found in the calibration run, the original threshold set in "Configure System" dialog window, and the "custom" threshold allowing it to be set to an arbitrary value. Only the last two options are available in case

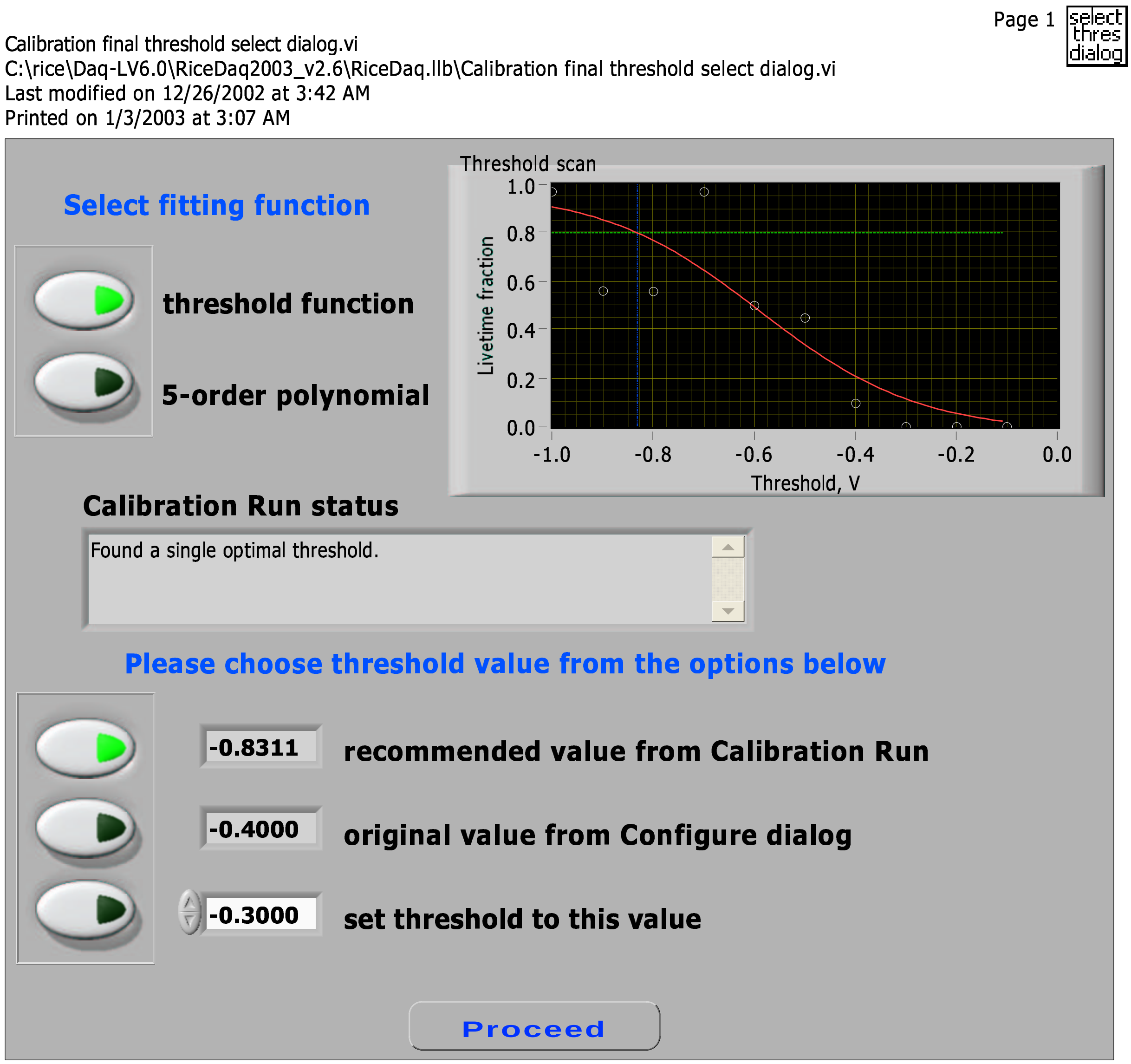


Figure 26: Threshold selection dialog window opened at the end of a calibration run.

if the calibration run has not been completed properly (due to either Abort action or due to the presence of the 303 background), or if the fit of the threshold scan has failed or if there are no solution for the target livetime value. In such cases, the optimal threshold button is grey and disabled.

After selecting the desired threshold option the “Proceed” button at the bottom allows to continue with the datataking.

**Abort options**

A calibration run can be interrupted at any time by pressing the “Abort calibrations” button found on the state display window (Fig. 25). After run was aborted, the DAQ still attempts to find the optimal threshold based on the data that have been collected up to this point, which may or may not be successful. Subsequently, the final threshold selection dialog described above is opened.

**Log file**

For each calibration run a log file is created. For more details see Sec. 6.7.8.

**Final remarks** The usefulness of the calibration runs is still questionable. The problem is that it is difficult to extrapolate the rates observed within 10-20 minute time for the whole 24 hours. There may be background sources on the surface and come on and off over 24 hours. It remains to be seen how close the suggested threshold values to what we really want.

## 6.6 Event Simulation

DAQ software can simulate simple noise events. A simulated event has the structure of a normal event once saved to disk. It contains appropriate number of samples and channels as well as normal event header. Waveforms are simulated using Gaussian white noise generator with sigma equal to 50. The constants T0, dT, Y resolution, Y offset are all set to 1. The hit list contains always 4 hits with fixed TDC numbers that correspond to a veto event.

In the future if needed this simulation can be made arbitrarily complex, e.g. generating events with hits according to some distribution and corresponding waveforms with pulses superimposed on white noise.

The main reason the simulation is implemented is to be able to run, test and develop DAQ software with no access to the external electronics.

## 6.7 Data logging

PC drive D: (on RICE3) is reserved for data, the capacity of it is approx. 16GB. The directory used is usually $D:\backslash Rice\backslash Data$ . One can also store data in $C:\backslash Rice\backslash Data$ where there is about 1GB of space.

As explained in Sec. 7.2, RICE datataking is restarted daily. The data are normally written into the $D:\backslash Rice\backslash Data\backslash Latest$ directory and subsequently moved to $D:\backslash Rice\backslash Data\backslash Transfer$.

Data from multiple runs can be stored in the same directory because all output files have unique file names.

### 6.7.1 Data format and data files

Each run is provided by a unique RunID generated by DAQ software. The RunID for a given run is based on the time of the beginning of the run. The format is YYDDDHH-MMSS, here YY is year (02 for year 2002), DDD is the day number (1 to 366), HHMMSS are hours minutes and seconds. This RunID is used in file names of all output files.

Data file names contain several parts. First part is the name of the mode (*data* or *simu*), then after "-" the RunID is added, next comes the "User part of file name" and last part takes the form "*_xx.dat*" where xx is the number of data file, incremented automatically when previous file contains maximum number of events allowed per file (set during Advanced Config step). An example: $data - 02029200808 - test\_1.dat$ - data taken Jan 29, 2002 with user comment "test".

Event size is approx. 620 kB for 16-channel configuration with the new data format. Compressed, it becomes approx. 6-8 times smaller. Without compression, for example, 6GB of data will contain about 10000 full events which is approx. 20 hours of running provided events are saved one right after another.

Each file contains data from several events. Each event consists of the event header, followed by the waveform data for one or several channels.

Event header can have different length for different events since it contains "Description" section which will change from event to event as well as the length of the hit list. An example of event header is given here.

```
Event number: 1
Year 01 Day 2 Universal  Time 05:02:09  mksec count   915263.4
Run type: Hardware Trigger Measurement
Description:Testing DAQ 1.4
***Scope Parameters***
Trigger source: Auxiliary
Trigger type: hardware
Y-range: 1.000000E+0
Y-offset: 0.000000E+0
T-range: 5.000000E-7
T-delay: 0.000000E+0
Active channels:
1st scope: =1111
2nd scope: =1111
3d scope: =1111
4th scope: =1111
Number of samples: 8192
***Trigger, veto and prescale settings***
Trigger mode: General
Discriminator #1 level: -3.000000E-1V
Discriminator #2 level: -2.000000E-1V
Trigger conditions: Generic
Veto conditions:  A .or. B .or. C
       A: exactly following channels (0:12):  0000000000000000
```

```
       B: exactly following channels (0:12):  0000000000000000
       C: suraface veto:    at least 4 of the channels 13   14   15
Prescale factors:
       General events         20
       External trigger 1       2000
       External trigger 2       100
       Veto events              100
303 analysis: yes
303 save option: do not save 303 events
303 analysis channel 11
303 analysis segment length 3
303 analysis integration width 1024
303 analysis threshold 7.000000E+0
Hardware Surface Veto is enabled
HSV ON time in munites: 10
HSV OFF time in munites: 10
***Event Summary***
Event is classified as General
303 analysis results:No 303 detected
Number of hits in event (from TDC): 4
Full hit list:
Channel 6  time 1444.5 ns
Channel 7  time 1326.0 ns
Channel 8  time 1445.0 ns
Channel 11  time 1230.0 ns
HSV is ON
***RICE DAQ version*** v1.8, Labview 5.0 , Dec 2000.
------------------------------
```

We explain the meaning of some of the above (most are obvious). Active channels - 0 indicates channel is off, 1 is on, 1st channel of each scope is the left-hand number, 4th is the right-hand number.

The hit list may contain hits on channels that are not active in the scopes or may not have hits on the channels that are active, depending on event and DAQ settings.

At the end of event header there is a separator in form of 30 “-” (minus) symbols.

The data section contains several sections of identical structure - waveform sections. Only for active channels of the scopes some data are present. Each waveform section starts with “——————Waveform from channel 1” with corresponding channel number. For channels of the scopes 2-5 add scX to this line, where X is the scope number.

The first 4 data words are $T_0$ (seconds), $dT$ (seconds), $Y_{off}$ offset (V) and $Y_{res}$ resolution (V). The rest of the numbers in the section are ADC counts of individual samples. The number of data points is equal to the number of samples set for this run (also found in the event header). The data points are integers in the range from -2048 to 2048. For data point number $i$ having number of counts $C_i$ the voltage $V_i$ and time in the waveform

$T_i$ are calculated as follows:

$$V_i = C_i * 8 * Y_{res} + Y_{off} \tag{1}$$

$$T_i = N * dT + T_0 \tag{2}$$

The time offset $T_0$ has no particular meaning, the middle of waveform corresponds to the trigger time unless Time Delay setting is not equal to zero.

After the last number in a waveform section there are either data from the next channel in the same format or the end of the event line which is as well 30 "-" symbols.

### 6.7.2 TDC information in hits-<RunID>.dat file

This file(also called hits log) contains the listing of all the TDC hits which produced for an event (e.g., 6/1444.5 means that channel 6 of TDC had a hit at 1444.5ns after the "Start").

It also gives the time of the event as well as the event classification the event, as either a general trigger (i.e., a trigger resulting from ≥4 RICE antennas firing), a veto trigger, etc, as shown below:

```
   Run ID     303  HSV    event     date    time     time,   Nhit   1st        2nd
             markers    type                         mksec          TDC hit
01002050141, 000, HSV1, gnrl,     01/2, 05:02:09, 915263.4,   4,  6/1444.5,  7/1326.0,...
01002050141, 000, HSV1,     unbi, 01/2, 05:02:17, 348411.6, 32,  0/1448.0,  1/1437.5,...
01002050141, 000, HSV1, gnrl,     01/2, 05:03:01, 695270.7,   4,  6/1445.0,  7/1325.5,...
01002050141, 000, HSV0,    veto,  01/2, 05:14:35, 703393.2,   7,  6/1540.0,  7/1420.5,...
01002050141, 000, HSV1, gnrl,     01/2, 05:50:47, 915171.0,   4,  6/1446.0,  7/1313.0,...
01002050141, 000, HSV1,     unbi, 01/2, 05:50:55, 341220.3, 32,  0/1448.5,  1/1438.0,...
01002050141, 000, HSV0,    veto,  01/2, 05:51:50, 835362.8,   7,  6/1536.0,  7/1420.5,...
01002050141, 000, HSV0, gnrl,     01/2, 05:52:34, 943425.4,   4,  6/1444.5,  7/1325.5,...
01002050141, 000, HSV0, gnrl,     01/2, 05:53:38, 724689.3,   4,  6/1444.5,  7/1325.0,...
```

Run ID is constructed as YYDDDHHMMSS, where YY-year, DDD-day (3-digit, 1-366), HH-hour, MM-minutes, SS-seconds. 303-marker can be 303 (303 is detected), 000 (no 303 detected), — (detection is not run). HSV marker can be HSV0 (currently HSV is disabled) and HSV1 (HSV is enabled).

### 6.7.3 rms-<RunID>.dat file

This file (a.k.a. rms log ) contains the readings of the rms values of the voltage, channel-by-channel. This is extremely useful for two reasons: a) it allows us to monitor the gain of the amplifiers over a long time baseline, b) it allows the calculation of the appropriate y-scale, channel by channel. There are 16 columns containing RMS values for each event. If an event has a channel of a scope off, that column contains value 0.0

```
  Run ID      date    time    -  0th channel  1st channel  2nd channel
                                     RMS          RMS          RMS
01002050141, 01/2, 05:02:17, ,   6.895E-3,   1.301E-3,   6.334E-2, ...
01002050141, 01/2, 05:07:17, ,   1.801E-2,   5.222E-4,   6.462E-2, ...
01002050141, 01/2, 05:07:33, ,   1.586E-2,   6.009E-4,   6.493E-2, ...
01002050141, 01/2, 05:12:32, ,   1.718E-2,   6.638E-4,   6.492E-2, ...
```

### 6.7.4 Run Summary information and stat-<RunID>.dat file

This file (a.k.a. stat log) contains run configuration, settings for all the scopes and CAMAC. An example is given below:

```
*******************************************************
********************** New Run ********************
*******************************************************
----------Start of the run   Run Identifier: 01002050141
Year 01 Day 2 Universal  Time 05:01:41
Run type: Hardware Trigger Measurement
***Scope Parameters***
Trigger source: Auxiliary
Trigger type: hardware
Y-range: 1.000000E+0
Y-offset: 0.000000E+0
T-range: 5.000000E-7
T-delay: 0.000000E+0
Active channels:
1st scope: =1111
2nd scope: =1111
3d scope: =1111
4th scope: =1111
Number of samples: 8192
***Trigger, veto and prescale settings***
Trigger mode: General
Discriminator #1 level: -3.000000E-1V
Discriminator #2 level: -2.000000E-1V
Trigger conditions: Generic
Veto conditions:  A .or. B .or. C
       A: exactly following channels (0:12):  0000000000000000
       B: exactly following channels (0:12):  0000000000000000
       C: suraface veto:    at least 4 of the channels 13   14   15
Prescale factors:
       General events         20
       External trigger 1       2000
       External trigger 2       100
       Veto events              100
303 analysis: yes
303 save option: do not save 303 events
303 analysis channel 11
303 analysis segment length 3
303 analysis integration width 1024
303 analysis threshold 7.000000E+0
Hardware Surface Veto is enabled
```

```
HSV ON time in munites: 10
HSV OFF time in munites: 10
***RICE DAQ version*** v1.8, Labview 5.0 , Dec 2000.
***End of Run Statistics***
Time of the run (sec):   3124
General(undegr.  ant.) events: 1180
Vetoed events: 20917
External 1 trig. events: 22
External 2 trig. events: 0
Unbiased events: 15
303-detected events: 0
303-rejected (and not saved) events: 0
Total events saved: 84
Total time with Hardware Surface Veto ON: 1800 seconds
  The event rates, events/second:
    General         0.322
    Veto            6.447
    External 1      0.007
    External 2      0.000
    Unbiased        0.005
    303-detects     0.000
    Saved to HD     0.023
Total time with Hardware Surface Veto OFF: 1322 seconds
  The event rates, events/second:
    General         0.455
    Veto            7.044
    External 1      0.007
    External 2      0.000
    Unbiased        0.005
    303-detects     0.000
    Saved to HD     0.032
Live time statistics:
   Average Live Fraction for this run: 0.702627
   accumulated run time, s: 3123.5,  accumulated live time, s:2194.7
     Average time per saved event, ms:                          7417.57
     Average time per rejected (veto/prescale) event, ms:          8.11
     Average time per unbiased event, ms:                      15881.60
Estimated 303 ON time: 0s, fraction of 303 ON to total time: 0.000
Average RMS for this run calculated from all unbiased events
   RMS of channel  0:   1.418E-2 +/- 6.143E-3 V
   RMS of channel  1:   7.157E-4 +/- 1.936E-4 V
   RMS of channel  2:   8.175E-2 +/- 5.147E-2 V
   RMS of channel  3:   6.711E-2 +/- 4.235E-2 V
   RMS of channel  4:   6.864E-2 +/- 6.659E-2 V
   RMS of channel  5:   7.914E-2 +/- 1.075E-1 V
```

```
   RMS of channel  6:   1.040E-1 +/- 1.103E-1 V
   RMS of channel  7:   1.054E-1 +/- 1.122E-1 V
   RMS of channel  8:   1.072E-1 +/- 6.692E-2 V
   RMS of channel  9:   4.619E-2 +/- 3.367E-2 V
   RMS of channel 10:   9.269E-2 +/- 9.883E-2 V
   RMS of channel 11:   6.413E-2 +/- 7.037E-2 V
   RMS of channel 12:   9.770E-2 +/- 1.157E-1 V
   RMS of channel 13:   6.618E-2 +/- 3.555E-2 V
   RMS of channel 14:   5.185E-2 +/- 1.666E-2 V
   RMS of channel 15:   1.564E-2 +/- 1.164E-2 V
--------End of the run Year 01 Day 2 Universal  Time 05:53:46
```

In the beginning of the run the settings for the scopes and Trigger/Veto settings are written to this file. At the end of the run, the statistics information is calculated and written, including numbers of events of every kind, event rates, live fraction, 303 statistics, average RMS of all channels, etc.

#### 6.7.5 Amplifier gain calculations and gains-<RUNID>.dat file

The amplifier gain calculations are done for every unbiased event and saved to gains log file. The calculation returns the total gain of the in-ice and surface amps, corrected for the losses. The algorithm is described below.

For each waveform the first 1024 samples are used. The FFT is calculated. The frequency interval for the gain calculation is $225 - 275$MHz.

We find the total gain as

$$G = 10 \log_{10} (P_{ob}/P_{th}) + K$$

The power of thermal noise in the frequency interval $\Delta f$ is taken to be $P_{th} = kT\Delta f$, where T is approximately 300K, k is the Boltzman constant, $\Delta f = 50$MHz. The correction factor K is added to account for the loss in cables and also includes 3dB attenuation in the power splitters (see Table 12). The cable loss is calculated at frequency 250 MHz.

The power observed in the waveform $P_{ob}$ for the mentioned frequency region is found (using Parcevale theorem) as follows:

$$P_{ob} = \frac{1}{R}\frac{1}{N^2} 2 \sum_{i=i_{min}}^{i_m ax} |Y_i|^2$$

in this expression, R is the 50 Ohm impedance, N is the number of samples (i.e., 1024), $Y_i$ is the $i$th FFT component. The summation is performed from $i_{min} = 225MHz/df$ to $i_{max} = 275MHz/df$ where $df = f_s/N$, $f$ being the sampling rate of the scopes. The factor of two in the expression for $P_{ob}$ is added to account for the FFT components that have identical amplitude and opposite phase.

In such a way, the gains are calculated and saved into the file gains log An example of such file is given below:

| Channel | Receiver | Correction K, dB |
|---|---|---|
| 0 | ?bad? | 0.0 |
| 1 | ?bad? | 0.0 |
| 2 | 97Rx3 | 16.29 |
| 3 | 97Rx4 | 15.63 |
| 4 | 96Rx2 | 18.47 |
| 5 | 96Rx6 | 18.67 |
| 6 | 98Rx1 | 11.34 |
| 7 | 98Rx2 | 11.30 |
| 8 | 98Rx4 | 11.36 |
| 9 | 98Rx3 | 13.73 |
| 10 | 98Rx5 | 11.91 |
| 11 | 98Rx6 | 15.63 |
| 12 | 99Rx5 | 13.29 |
| 13 | 99Rx8 | 13.25 |
| 14 | 99Rx4 | 13.29 |
| 15 | 99Rx6 | 20.53 |

Table 12: Correction K: cable loss plus power splitter loss

```
Run ID       Date    Time           Gain ch.0   Gain ch.1   Gain ch.2 ...
01002050141, 01/2, 05:02:17, ,      96.438,     93.105,     94.664,   ...
01002050141, 01/2, 05:07:17, ,      95.617,     93.418,     94.062,   ...
01002050141, 01/2, 05:07:33, ,      96.317,     93.947,     95.286,   ...
01002050141, 01/2, 05:12:32, ,      96.658,     95.027,     94.688,   ...
01002050141, 01/2, 05:12:48, ,      95.452,     93.899,     94.400,   ...
```

The expected gains currently are about 88-93dB. The accuracy of gain calculation is dependent on the voltage resolution. Thus, the result will be in-accurate for the first unbiased event in the run, or when the noise level suddenly changes. In particular, when 303 line turns on, the next unbiased event is likely to have wrong gain. Sudden changes can be found by checking RMS voltages from RMS file or by checking 303 on/off info from 303-log file. The error on the result in such cases can be as large as 50%.

#### 6.7.6 Online Live Time monitoring and livet-<RunID>.dat file

The Live Time of the DAQ is calculated during data taking. Each event cycle can be roughly broken into two pieces: waiting for event and processing event, as shown in Fig. 27. When the new event arrives, DAQ does not respond instantly, but with a certain delay. In the process of waiting, the executable stays within a "while" loop, checking for a trigger every cycle as well as performing some other actions. One waiting cycle takes approx. 4-5ms, about 1.2ms of which is actual checking for the trigger occurrence. The definition of the dead/live time is illustrated in Fig. 27. Out of the full time that one event takes, the first "waiting for event" cycle and full "handling event" part is counted

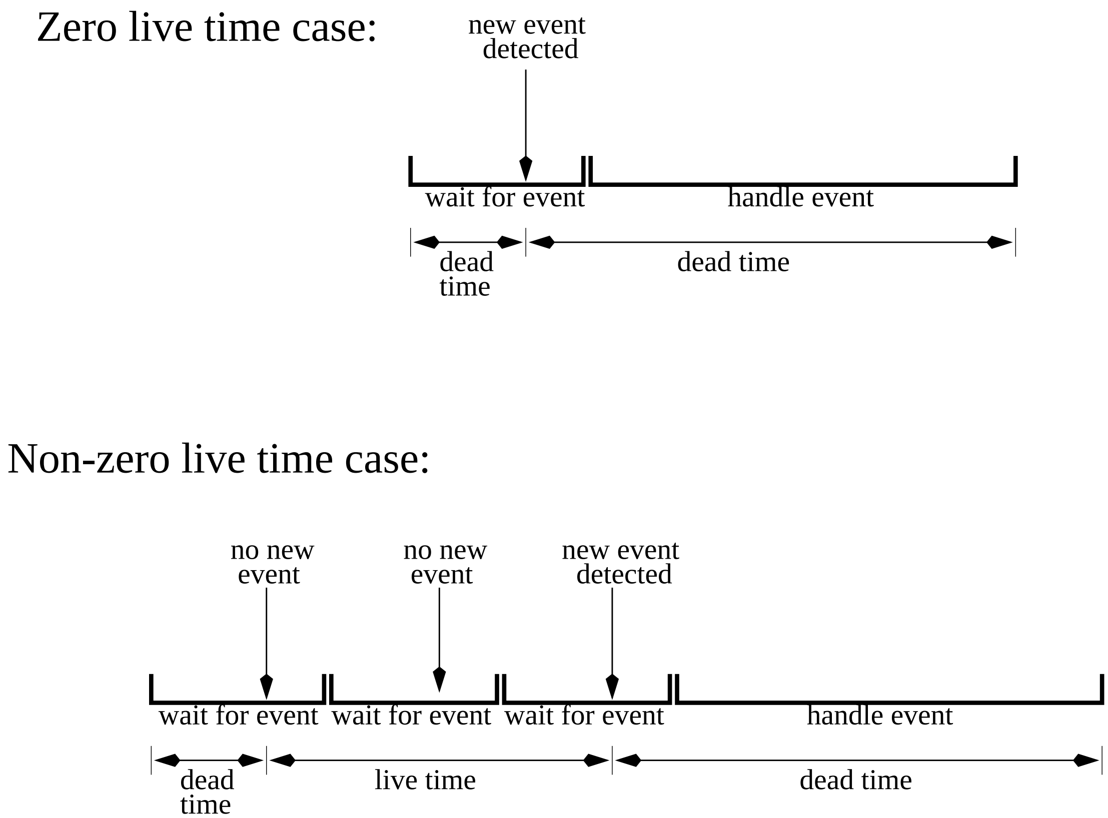


Figure 27: Live/dead time definition

as a dead time, while the extra (above 1) "waiting for event" cycles are counted as a live time. Live fraction is then defined as Live Time divided by the total event time for this event.

The total live fraction for the run can now be calculated as the total live time for all events detected divided by the total run time. In "events detected" we include normal saved events, vetoed/prescaled events and unbiased events.

The above algorithm is simple, but the complications arise from the 303 line interference. When running in Detect 303 and Junk 303ev mode (the default way), the run is effectively paused when the 303 line comes on. To account for this, DAQ keeps track of several entities: total live/run time, instant live/run time and instant live/run time with no 303.

The total live/run times DO NOT include 303 ON time. These numbers are saved into the run summary file, i.e. stat log as well as the live fraction for the run calculated from them.

The instant live/run time is accumulated over the period of 5 min, then reset and accumulated again, regardless whether 303 line is on or off. The corresponding live fraction is saved every 5 min into the livet log along with the live/run times in ms.

The instant live/run time with no 303 is also recorded with the same 5min periodicity and the numbers are saved into the livet log file.

In the livet log file we also give the 303 marker that says 303 if the 303 line was detected for any fraction of the 5 min period, 000 if no 303 was observed and — if no 303 detection was requested.

An example of the gains log file is given here (time is in ms):

```
  Run ID      Date    Time      full t  live t  Live Frac   303   no 303  no 303  no 303
                                                           marker full t  live t  Live Frac
01002050141, 01/2, 05:06:41, 299955, 224387, 0.748069,   000,  299955, 224387, 0.748069,
01002050141, 01/2, 05:11:41, 299818, 196097, 0.654053,   000,  299818, 196097, 0.654053,
01002050141, 01/2, 05:16:41, 300047, 187833, 0.626012,   000,  300047, 187833, 0.626012,
01002050141, 01/2, 05:21:41, 299834, 212638, 0.709186,   000,  299834, 212638, 0.709186,
01002050141, 01/2, 05:26:41, 299797, 224558, 0.749034,   000,  299797, 224558, 0.749034,
01002050141, 01/2, 05:31:41, 299965, 226678, 0.755681,   000,  299965, 226678, 0.755681,
01002050141, 01/2, 05:36:41, 300008, 169205, 0.564002,   000,  300008, 169205, 0.564002,
```

In the example above, 303 marker shows no presence of 303, so times and live fractions with and without 303 are equal.

One has to be careful interpreting the live time numbers. Here are some examples.

If every time when we check for the new event, we find it, the live time and live fraction are both zero, obviously.

The 303 line presence is detected only when an event is read out from the scopes as it requires waveform analysis. While processing events that are vetoed or prescaled (no waveform is fetched from the scopes) the DAQ has no way of knowing if the 303 is on or off. For example, if we start the run while 303 is on and have a high prescale value for surface veto, we might start vetoing events at high rate for 10 min. until it is time to take a new unbiased event, and only then the beginning of the 303 section will be recorded. Alternatively, after the 303 section ends, the DAQ can be vetoing events and only when the next good event is saved, the end of 303 section will be recorded.

The live fraction during the 303 time can be dependent on chance. An example: we just detected 303 on a general event and now it is time to take an unbiased event. The DAQ will start taking event after event and reject all because of 303 sign. The life time will be zero. Alternatively, if during the 303 period events come mostly as a veto and, rarely, as general, the life time might be significant, coming mostly from the vetoed events.

#### 6.7.7 303-<RunID>.dat file

Information about every 303 event detected is saved into the 303 log file. The format of this file is given in the following example.

```
   Run ID     303    event   date     time       time,     1st TDC    2nd TDC
            marker   type                        mksec       hit         hit
01002050141, 000, gnrl,     01/2, 05:02:09, 915263.4,  6/1444.5,  7/1326.0,...
01002050141, 000,     unbi, 01/2, 05:02:17, 348411.6,  0/1448.0,  1/1437.5,...
01002050141, 000, gnrl,     01/2, 05:03:01, 695270.7,  6/1445.0,  7/1325.5,...
01002050141, 000,    veto,  01/2, 05:14:35, 703393.2,  6/1540.0,  7/1420.5,...
```

#### 6.7.8 Calibration run logs calib-<RunID>.dat

Each time a calibration run is taken (see Sec. 6.5) an accompanying log file is created. This log file contains all configuration settings of the calibration run. It also contain all points of the threshold scan, the fitting function, the results of the fit and the selected threshold option. The calibration log files adhere to the standard naming convention: calib-<RunID>.dat

An example of a calibration run is given below, it is rather self-explanatory.

```
*******************************************************
****************** Calibration Run ********************
*******************************************************
Start of the run GPS time Year 99 Day 999  Universal  Time 3:11:01
DAQ PC time: 1/3/2003  3:11:01 AM
Run ID 9999931101
*** Starting parameters***
Target livetime: 0.800
Calibration strategy: Linear sampling interpolated
Range to tune the threshold: from -0.1000  to  -1.0000 V
Number of calibration segments: 10
Time of a calibration segment: 60.0 s
Assumptions about time necessary for varios steps:
  Load event time: 7700.00 ms
  Analyze WF time: 10.00 ms
  Save event time: 200.00 ms
  Scopes reinit time: 8000.00 ms
***Threshold scan data points***
  Threshold, V   Livetime fraction
  -0.1000          0.0000
  -0.2000          0.0000
  -0.3000          0.0000
  -0.4000          0.2063
  -0.5000          0.3659
  -0.6000          0.6344
  -0.7000          0.9710
  -0.8000          0.5695
  -0.9000          0.7238
  -1.0000          0.8329
***Fit status and threshold selection***
>Function used to fit livetime(threshold):
  5-order polynomial
>Formula of the function with the best coefficients:
(-3.943877E-1)+(-8.018189E+0)*x+(-5.453985E+1)*x^2
   +(-1.543010E+2)*x^3+(-1.765101E+2)*x^4+(-6.997335E+1)*x^5
>Fit status:
Found multiple optimal thresholds.
Selected the smallest with negative
derivative.
Optimal threshold from the fit: -0.7020
```

```
>Threshold choice:
  Operator selected tuned threshold.
***Selected threshold***
Threshold is -0.7020
End of the Calibration Run (DAQ PC) time: 1/3/2003  3:21:27 AM
```

## 6.8 Veto

Events that trigger the scopes and TDCs are further analyzed by DAQ software and many are rejected by veto criteria. There are two parts of event that are read out by DAQ executable: TDC hits and waveform information. The first is very fast and the second is fairly time consuming. The purpose of veto is to make a decision whether the event is interesting based on fast TDC information and if it is not, reset the system discarding the waveforms and move to the next event.

There are four veto kinds implemented: inclusive time-ordered paattern veto, exclusive pattern veto, horn pattern veto and TDC/Geometry.

**Inclusive time-ordered veto patterns** These patterns allow to reject events in which a defined group of channels is hit in a predetermined time sequence. In the matching of the observed pattern to the veto pattern, all channels not present in veto pattern are ignored.

For example, suppose the veto pattern is (5, 6, 0, 11, 13) in exactly that order (as configured on the top page in Fig. 23). A few example of veto decisions are listed below for different observed time-ordered hit patterns:

- (5,6,0,11,13) event rejected, the pattern matches exactly
- (7,5,6,2,0,11,13,15,14) event rejected, after removing channels not mentioned in the veto pattern we are left with the sequence matching veto pattern exactly
- (6,5,0,11,13) event is accepted, even though the hit channels are the same in the veto pattern and the current event, the time order is different

There are currently three different inclusive time-ordered veto patterns available. If the position in the time sequence (Fig. 23 top) is filled with "-1", it is ignored.

**Exclusive pattern veto** simply vetoes the events that contain exactly specified pattern of hits. These patterns are set during configuration stage (middle part of Fig. 23). It is useful in rejecting events in which only known noisy/hot channels are on. In particular, if there are certain configurations of hit patterns in events which are coming every ten seconds or more often, these are almost certainly background, and should be excluded from data-taking. To do this, one needs to scan the hits log file and take note of which hit antenna patterns are most common. E.g., if in the hits log file, one notices that there is an enormous number of events for which channels (6, 7, 8, 10) and (6,7,8,10,11) fire the trigger, then the veto pattern should be set as shown on the middle page in Fig. 23. Note that these veto patterns refer only to cases where the underground antennas exactly satisfy the indicated hit pattern.

**Horn Veto Pattern** settings are also defined during configuration stage (bottom page in Fig. 23. If at least N out of 3 specified channel numbers have a hit, the event is vetoed. Originally, this veto has been designed to be used with surface horns, but can be used with any channels. The default is setting $N = 4$ that effectively disables the veto.

Beginning in February, 1999, a **TDC/Geometry** was installed to reject events with a TDC hit pattern consistent with surface-generated noise (note that it is independent of waveform information). George generated a large sample of surface noise Monte Carlo events and compared the receiver-to-receiver relative time distributions with those expected from a sample of under-ice events. Ilya subsequently instituted a software veto of events which satisfy the TDC pattern expected for surface generated noise. This was done using an overall $\chi^2$ criterion (I.e., we can have veto events with ten TDC times consistent with surface noise, and one TDC time which is inconsistent with surface noise, as long as the overall $\chi^2$ is sufficiently low) based on the spread of TDC values obtained from George's distributions.

This veto obtains constants from the file $C:\backslash Rice\backslash Constants\backslash veto.dat$. Note, that if this file is in wrong format, the TDC/Geometry veto might do weird things. Currently, the constants file contains entries for 32 channels. However, in DAQ software all TDCs for channel 24 and above are set to zero at the input to the veto subroutines because we have Amanda/SPASE/surface antennas at those inputs.

## 6.9 Hardware Surface Veto control and monitoring

Event though Hardware Surface Veto happens in the Trigger Logic outside of the PC (see Sec. 5.2), it is controlled from DAQ software. The surface antennas participating in HSV are connected to predefined channels of the discriminator 3412 B, these channels can be disabled at will thus disabling the HSV.

In Configure Advanced dialog window one can select whether to enable or permanently disable HSV. If it is enabled, one can select the number of minutes of HSV on and the number of minutes of HSV off. The cycle will repeat itself indefinitely, the current state being indicated on the yellow switch indicator on the Run Statistics Display.

In the beginning it is advisable to run with HSV on and off comparable amounts of time (e.g., 10 min. ON and 10 min. OFF). Once the effects of HSV are understood, a default number could be order of 55 min ON and 5 min OFF.

For each event saved in data and various log files the HSV on/off state is always saved. One can monitor the HSV performance by comparing the event rates for each event type that are summarized at the end of the run in stat log file.

## 6.10 303 line veto / suppression

### 6.10.1 The 303 detection mechanism

One of major interferences with Rice DAQ data taking has been the satellite communication uplink on the 303MHz frequency. Everyday there is a period when the 303 background is on. This background has amplitude of up to several hundred millivolts and is higher than normal noise. Until now we were forced to set DAQ thresholds rather high so that we do not fill the disk with data during 303 periods. Thus, during the quiet periods we save very little amount of data since thresholds are very high, while during 303 period a lot of data is saved which are mostly noise on top of 303 modulation.

The 303 mechanism allows us to turn the DAQ off automatically during the 303 periods. As a consequence, we can set threshold values that make more sense in terms of physics that we are looking for: to values that are slightly above the thermal noise floor. The usefulness of the data for analysis is expected to be greatly increased.

It is desired to have an instant reaction to the presence of the 303 background so that no useless data are written to disk. Therefore, for every event a 303 detection algorithm is run. The algorithm tests the presence of 303 component in the waveform data. The presence of 303 MHz background is determined from the FFT analysis of a waveform segment from one of the channels.

### 6.10.2 The detection algorithm

The calculation starts with a segment of a waveform, from the beginning and up to a sample $N$. The FFT transformation is done for this segment. Denote the FFT coefficients $Y_i$. The frequency resolution is $df = 1/(dt \cdot N)$ where $dt$ is the time resolution of the waveform. The frequency range covered is $0 < f < N \cdot df/2$.

In order to see if 303 line is present in the FFT spectrum, the sum of FFT amplitudes in the short vicinity of 303 region is compared to the sum near 260 MHz, where no unusual background is expected. The indicies of FFT elements at these frequencies are calculated as

$$j_{303} = (int)0.3035 \cdot 10^9/(df + 0.5)$$
$$j_{260} = (int)0.2600 \cdot 10^9/(df + 0.5)$$

The width of the region over which these sums are performed is set by parameter K as follows:

$$j_w = (int)\frac{0.0020 \cdot 10^9}{df}\frac{K}{N}$$

The characteristic figure is the ratio between the sums of FFT amplitudes near 303 and at 260:

$$P = \frac{P_{303}}{P_{260}}$$

and

$$P_{303} = \sum_{j=j_{330}-j_w}^{j_{330}+j_w} Y_j \qquad P_{260} = \sum_{j=j_{260}-j_w}^{j_{260}+j_w} Y_j$$

The 303 is found whenever $P > P_{thresh}$ where $P_{thresh}$ is a tunable parameter.

For the year 2000 the described algorithm used to be run only on the beginning part of each waveform. The performance was further examined at the Pole. It was found that the 303 sections registered by the DAQ tend to be short and numerous while we expect them to be long. Often, 303 section would consist of 1 event only. Looking through the events, we would see that there are many events marked as good in which the "fish tail" pattern appeared. The beginning of such a waveform looks like thermal noise and then 303 turns on in the middle (i.e. low frequency-modulated 303). Such events are obviously not usable. To improve efficiency of the 303 detection, the DAQ is changed to run 303 detection twice. First on the beginning of a waveform and second on the tail of it, if either shows sign of 303, the event is declared to be a 303 event. The constants (segment length, 303/260 power ratio, ...) are the same for either of the two segments.

This change had a strong impact on the length of 303 sections recorded in stat log and on event classification in, say, hits log file. It also affects our life time calculations.

In addition, stat log file contains total time with 303 on and fraction of 303 on over the run time.

#### 6.10.3 Operating instructions and features

In short: 303 algorithm can be run or not, 303-events can be saved or not, log files keep track of 303 events. The first 303 event detected after a normal event defines a beginning of a "303 run section", and the first non-303 event marks the end of the 303 run section. More detailed description follows.

- We can choose "Detect 303" or "Ignore 303" on the "Configure" window before run begins. No 303 analysis is done in "Ignore 303" mode.

- For "Detect 303" runs we run 303 analysis on every event that passes surface veto and that is loaded into the memory of the DAQ PC. The time spent on 303 analysis is negligible relative to the time of loading waveforms.

- The analysis is run on the short segment of a single waveform. the parameters of this analysis are set in "Advanced Config" window:

  | | |
  |---|---|
  | Channel on which to run analysis | (default 0) |
  | Wf segment length | (default 256 samples) |
  | Integration width | (default 1024, the effective is 1024/256) |
  | Threshold 303/260 | (default around 7, AFAIR) |

- One can choose "Save 303" or "Reject 303". In the first case the events are saved normally with appropriate 303 comments added to the event headers.

  If "Reject 303" is chosen, only the first 303 event after a non-303 event is saved to disk, subsequent 303 events are completely ignored, regardless of the type. (E.g., if it is time to take an unbiased event, it will not be taken and unbiased time counter will be reset to zero). The first non-303 event to appear will define the beginning of the normal run section, and everything will come to normal.

- Indicators: in the Run Statistics window there is "303 Alert" red/green light. Red value means that the run currently in the middle of 303-section, while green means that no 303 is currently found.

  Also, there are two numbers in the same window: "303-rejects" (events with 303 that were not written to disk) and "303-detects" (total number of 303 events). These two numbers are also saved to stat log at the end of each run.

#### 6.10.4 303 info in log and data files

In the hits log file, there is a marker for each 303 event. It says "—" if 303 is not tested, "000" and "303" if it is tested and not found or tested and found, respectively.

In data files, event header contains the results of 303 analysis and all 303 settings.

In stat log for each run 303 settings are saved. Also, the 303 run sections are defined, with the times of the first and the last 303 event in each 303 section saved. The total 303 ON time is calculated for each run as well as the fraction of it over the full time of the run. The 303 time is calculated as a sum of all 303 time intervals between the first 303 event and the first non-303 event (note, that this is slightly different from the 303 section entries in the same file which use the last 303 event to define the end of the section).

Additional file is created: 303-<RunID>.dat log file, in this file date/time/type and hit information is saved for every 303 event, regardless whether it was written to disk or not.

### 6.11 Event Viewer

There is an event viewer, which is useful for diagnostics and checking events. It displays waveforms for all 16 channels and event header. In addition it runs a simple peak finder for each channel, displays time for each channel and the time difference between TDC (if available) and waveform time.

The Event Viewer can be invoked simply by clicking on the "Event Viewer 2003" icon that is found on the desktop. To use the event viewer, one needs only specify the directory where the data in question is stored, and the name of the data file one wishes to view. When viewing the first event in a file the button "New file?" has to be on. If the file name is not specified, the file dialog window is opened so the file can be selected. It is allowed to select/enter a gzipped file, the Event Viewer will unpack this file automatically.

### 6.12 Debugging Tools

There are several convenient debugging tools available in current DAQ software.

The variables and data are stored in global data structures. These can be opened as a separate windows at any time of execution or when not running, they always contain the latest information. The configuration structures are filled during "Configure System" stage of the run, event related variables are constantly updated. To open them one needs to go into RiceDaq.llb and double click on needed structure. The names are self-explanatory.

- Trigger Config Globals
- Scope Config Globals
- CAMAC Config globals
- Data Logger Config Globals
- System Config Globals

- Run Statistics

- Current Event Buffer

Another useful Vi is "DAQ State Array", it contains information on which stage the executable is at when queried, as well as the time in milliseconds spent at each stage. It is therefore a useful dead time diagnostic tool.

# 7 Operating procedures

The main DAQ executable currently has the name: "Rice Daq 2002 v2.2"[5]. To open(load) an executable just double click on its icon on desktop of the computer, it will start Labview (if it is not already started) and will load the code into it. A window that appears is the "Front panel" of the main VI (Virtual Instrument). The program when just loaded is not running.

## 7.1 Normal data taking

Here is the algorithm how to run DAQ software and take data:

1. Start DAQ executable by clicking on the → icon of the Labview menu on top of the RiceDaqMain window. The system is Idle as indicated by the green light.

2. Configure the system:
   a) click on *ConfigAndInit* button
   b) "Configure System" window pops up. Enter your settings or leave the default. All settings here are important. For details refer to Sec. 6.4 and 7.1.1. Make sure that the mode of operation is selected properly. Usually it will be "Normal running fast mode". Do not forget to put some comments into the "Description" field. [6]
   c) if needed, click on "Advanced Config'. This can be done for the first run after the system was loaded, and later only if changes are needed. A new window "Config System Advanced" appears. After finishing changes (or even if you change nothing) click on "Proceed" button.
   d) you are back to "Configure System". You can still do any changes you need, then click on "Proceed".
   e) the "Configure" windows disappear. Now you have RiceDaqMain window, Run Statistics window and possibly Event Display window. Wait until both green lights of Configure and Initialize are lit on the RiceDaqMain window. It will take of the order of 10 seconds.

[5] The version number will possibly go up if there are code update throught the year

[6] Parameters are changed either by clicking on up/down arrows of controls or by clicking with the "hand" cursor on the number and typing in the new one. After typing new text into string control (i.e. text variable like description) one can press 'Enter' icon that appears at the top left-hand corner of the window (to the left from the arrow icon), or simply $< CR >$.

3. Take a Calibration Run to find a recommended threshold for the discriminators. Push "Start Calibration Run" button. The configuration dialog window will appear. After configuring the important parameters (or leaving all at the default settings) click on "Proceed" button and the calibration run will start. At the end of the calibration run a new dialog window will open itself displaying the outcome of the calibrations. Select the desired threshold value and click "Proceed" again. For details on the pop-up windows and the idea of calibrations refer to Sec. 6.5.

4. Start the run: push "Start Run" button. When a run is in progress, the green light near the "Event Loop" is on. You will see some updating statistics in the "Run Statistics" window and "Current Event Buffer" window if it is open.

5. Stop the run: push Stop Run button. After DAQ finishes processing the last event and writing into log files, the green light "End Run" lights up.

6. Now you are in the Idle state. You can start the next run by going through "Configure", etc again, or stop the DAQ by clicking on "Finish Session" button.

### 7.1.1 Primary modes of operation

**Normal running fast mode** and **Normal running with Event Display mode** are the modes that take useful physics data. The difference between them is whether the Event Display window is closed or open. With Event Display open the maximum possible rate is approx. 40 Hz (see Sec. 8.2), slowed by the constant update of the event information for vetoed events. When run through RapideRemote it is even slower, 5-10 Hz as observed at the SP. Without the Event Display is the fast mode that is capable of up to 125 Hz maximum veto rate. Note, that if you started with the Event Display open, it is always possible to close it by choosing "Close" in the file menu, the data taking will not be affected.

To choose Normal-fast mode in configuration select "Real data", "Save waveforms" and "Do not open" for Event Display.

The Normal w Event Display is same as above, only select "Open" for Event Display.

**Scalar mode** is used to estimate trigger rates. It is selected by "Scalar/Save waveforms" button during configuration stage of the run. In this mode TDCs are read for each event, the event type is determined but the waveform information is always ignored. No data files are created. Nothing is written to rms and hits log files. This mode is best to use with Event Display closed.

**Simulation mode** is selected by the switch "Real data/Simulated data". More details about simulated data are found in Sec. 6.6. While running, a new event is simulated every 2 seconds.

### 7.1.2 Important! Read this.

**Main process** DAQ executable must be the primary process on the PC. This means that the main DAQ window must be highlighted. If it is not, it will almost freeze at the point of fetching waveforms from the scopes. It does not freeze while waiting for events or while vetoing events, so it may be confusing. Here are several "bad" examples:

You start the run, then open Netscape window or even a notepad window and leave it on foreground. DAQ will freeze once it detects the first good event to save.

You start the run, open notepad window, close it and leave. Bad again. When the notepad (active) window is closed, no window is active. DAQ freezes.

You log in to the rice PC at the Pole using RapideRemote. During logging in all windows on the target PC become inactive. You have to click on the main DAQ window. Logging out does not affect it. This happens because during login there is a window on the target PC asking whether to allow login. It is an active window and than it disappears, leaving everything inactive.

Screen saver on the PC from which you access RICE DAQ PC does not seem to matter, but screen saver on RICE DAQ PC must be disabled (it is now).

In addition to screen saver, one has to disable power management that might decide to switch computer to standby after a while.

BUTCH/IAN: If someone is expert on PCs, advice would be appreciated, for now the rule is to make sure that the main DAQ window is always active and highlighted.

**Avoid run abort** It is best to stop run by clicking on "Stop Run" button. If the run is aborted by clicking on the red stop button on the menu bar, the run summary information is not saved to stat log file. Although, the data files are ok. If you are having problem to stop run with "Stop Run" button, click on the "Interrupt" button of cyan color and wait for at least 20 seconds before deciding to Abort.

**Do not save Labview**. When closing DAQ or exiting from Labview it may ask if you want to save changes. DO NOT save unless you know what you are doing. Also, avoid loading different DAQ versions at the same time.

### 7.1.3 PC configuration

At present DAQ software is compatible with Windows NT/95/98. Currently running NT 4.0 and using Labview 5.0, probably will upgrade next year.

GPIB card is from National Instruments and can do 7MB/s.

Data taking normally is done from Administrator or Rice account. Logging in to this account allows you to see icons "Rice DAQ 2002" and "Event Viewer 2002". In addition, three programs are started automatically and are running on background. These are RapideRemote, FTP daemon and AboutTime time correcting program.

Here is the check list of all components that can be used for a new Windows PC:

1. Create rice account.

2. Install time synchronization client (e.g., AboutTime).

3. Install ftp daemon (such as wftpd).

4. Install remote access software (such as VNC or RapidRemote) and add several accounts to it.

5. Make all daemons (ftp, time, remote) start automatically when the computer is rebooted.

6. Add necessary utilities: WinZip, gzip.exe, ssh (e.g. putty). Make sure gzip.exe is in the system path.

7. Install GPIB card and NI DAQ software that comes with it

8. Install Labview.

9. Copy DAQ software (DAQ and EventViewer).

10. Make DAQ icons appear on desktop.

11. Disable screen saver and power management.

### 7.1.4 Modification of the default parameter values

To update the default configuration settings:

1. Load/open RiceDaqMain, as normally done to prepare to start the run. It is also currently aliased to the desktop icon "Rice Daq 2000 v1.3".

2. Start the run normally, click on "Config and Init" button. The window "Configure System Action" will open. In this window click on big "Advanced Config" button. Another window will be opened: "Configure System Advanced Action". Now click on the "Abort Execution" icon at the top-left of this window. The run preparation and everything will stop, all windows will remain open.

3. There are two windows that contain all settings, both should be open by now: "Configure System..." and "Configure System Advanced ...". To change the default settings of any control: click on it, type in a new value, then click anywhere else or at the left-top most icon in this window that says "Enter". Check that the value appears in the window. The numeric values also can be changed using up-down errors right next to their controls. Now these settings need to be saved. Click and hold right mouse button on the control that you want to save. There will be a pop-up menu. Move to "Data Operations", another menu will appear. Finally, select "Make current values default". After this, Labview considers this program modified so it needs to be saved to disk. Choose File-¿Save from the menu in this window. The windows "Configure System ..." and "Configure System Advanced ..." are independent programs, so they have to be modified and saved separately.

4. Close these two windows. Now DAQ is ready to start another run.

### 7.1.5 Measuring DAQ dead time explicitly

There is a special program that allows to measure time intervals associated with each step in the event processing in DAQ software. Click on RiceDaqMain window and go to File→Open. In the file dialog box double-click on RiceDaq.llb VI Library. In the list of files, choose "DAQ State Array Globals".

This will open the window containing several indicators that show time spent for each step in the event loop. Note, that Load and Save event times are not updated when event is vetoed. The times are different for events of different types.

For general events: Set Veto and General prescale factors to 1, Ext. 1 and 2 to a high number. Set run to be stopped after 3-4 events, or stop it manually at some points. Read out the time values in the "DAQ state array globals". Make sure that the last event was not "Unbiased".

For veto events: Set prescale factor for veto and general events high. Stop run manually after a few events vetoed. Record the time values.

For unbiased events: Select period of unbiased events to be very often - time-wise or event number-wise and run the system, stop after several events.

General advice: check the results, veto events should have total times (seen in the "Event Loop Timer" of the "DAQ State Array") <100ms, general events are about 7 seconds and unbiased events are about 15 seconds. These numbers are true for the full 16-channel operation.

There is event-to-event spread in timing results. One might want to measure each event type several times and find the averages. To get a feel of the spread in values one can start the run and watch "DAQ State Array" values changing as it is updated in real time.

The time measurements will be different if the "Event Display" option is selected on or off. Out default mode of operation is with "Off", this is the fast mode.

## 7.2 Daily procedures and checklist

Currently RICE requires a little of attention every day with its semi-automatic data transfer. Also, hardware needs to be checked regularly for failures. Therefore, this checklist.

- q See that the RICE PC is okay. This means: it is up, no error message windows, screen saver is not running, the DAQ windows are highlighted, mouse responds

- q Check that RICE rack generally looks ok (power lights on RICE CAMAC and NIM crates, on power supplies).

- q Stop current run by clicking once "Stop Run" on RiceDaqMain window. Wait until "End Run" lights up. If it does not happen for 30s, click on "Interrupt" button of "Run Statistics" window. That should bring you to the End state within 10 s or so. If that fails, please send email to rice people. with the description.

- q Check whether the directory $D:\backslash Rice\backslash Data\backslash Transfer$ is empty. If it is not, and if it has been more than 12 hours since the data movements, something is wrong. AMANDA system polechomper is supposed to move anything found in there to the Linux cluster every 8 hours. If "Transfer" is not empty, please send panic email to AMANDA winterovers and rice people.

- q Move all data from $D:\backslash Rice\backslash Data\backslash Latest$ to $D:\backslash Rice\backslash Data\backslash Transfer$ regardless of the current state of "Transfer".

- q Start the next run. Keep an eye on the threshold settings during configuration stage. If the rates of the previous several days have been too high (say, more than 5000 events taken over 24 hours), limit the maximum number of events in this run to 2000 and send email to the rice crew.

- q Check amplifier current draws. These should not exceed 60mA and should not show "overload" light on any channels. For locations see Fig. 2

The most important items here are restarting the run and moving the data from Latest to Transfer. This we would really like to be happening every 24 hours if possible. Logging in to RICE DAQ PC from the Dome can be easily arranged by AMANDA winterovers.

Visual check of DAQ hardware and amplifier gains does not have to be done every day, 2-3 times a week is sufficient.

Emails of RICE people: ikrav@fnal.gov and dzb@lns.cornell.edu

## 7.3 Running with transmitter

XXX DAVE: feel free to correct/add to the text in this section.

*The description below is mostly correct, however it is slightly different this year, Jan. 2001. We have been successfully running with transmitter from Avitech pulser while triggering on underground antennas. The pulses were more than clear. No special triggering arrangements were needed.*

*Another detail, we do not have FIFO(3) anymore, as described below. Instead, if one wishes to do a similar trigger from Avitech, the best way is to replace temporarily the SPASE input with the Trigger Out of the Avitech and connect another copy of it to any of the free channels of 3412 B, thus simulating an external trigger. The thresholds of 3412 A-B will have to be set high, to 750mV or so.*

Taking data from a transmitter in a known location helps us to understand and calibrate the system. To just check whether a particular receiver is 'alive', the transmitter can be operated in Continuous Wave mode (either the HP8110A, capable of generating CW signals at 166 MHz or the Wavetek Model 3000-200 signal generator, capable of generating CW signals at 512 MHz). When transmitter operates in Continuous Wave mode, DAQ may be run in any way of Normal running with sufficiently low threshold or with Period of Unbiased events set to 1ev/1sec.

The results from a comprehensive study of channel-to-channel responses to CW signals by Darryn and Mike (3/12/00) are presented below. What is shown is the CW signal (dBm) measured using a 250 MHz, 2V source into the indicated transmitter

If we want to study detection of a single pulse, it is a bit more complicated. The pulse picked up by receiver might have rather small amplitude and be buried under noise, so it is difficult to trigger on the received signal. To deal with this problem, we trigger using essentially the same set-up as the one causing Unbiased event to happen. The following steps have to be done (also, see Fig. 28).

First, the signal generator should be set up properly and connected to the transmitter. It is best to use AVITECH pulser. It can send ≈5ns pulses with the amplitude up to 350 V. The frequency is not important as long as it is less than 10 MHz. Normally 5kHz is used.

The Signal output is connected to the transmitter, the trigger switch is in "internal" position and trigger output is connected to FIFO (3) (see Fig. 28). WARNING: if 350V signal output is connected directly to any electronics module or a scope, **the scope will be damaged** (although it is possible to look at the signal with the scope using 40dB

| | 96Tx1 | 97Tx2 | 97Tx3 | 99Tx1 |
|---|---|---|---|---|
| Rx ch. | 250MHz/floor | signal/floor | signal/floor | signal/floor |
| 1 | +1.6/-50 | -13/-50 | -0.9/-50 | -8/-50 |
| 2 | -28/-70 | -17/-60 | -17/-60 | -23/-70 |
| 3 | -7.5/-50 | -5.3/-50 | -5/-60 | -8/-50 |
| 4 | NM/-50 | +2.5/-50 | -5/-50 | -5/-50 |
| 5 | -20/-50 | -8/-40 | 0/-50 | -24/-45 |
| 6 | -15/-55 | -25/-55 | -7/-60 | -25/-55 |
| 7 | -18/-55 | -11/-50 | -5/-50 | -8/-50 |
| 8 | -25/-55 | -8/-60 | -6/-60 | -5/-60 |
| 9 | -5.3/-50 | -5.3/-50 | -5/-50 | -13/-55 |
| 10 | -11.9/-50 | -1.7/-50 | -3.4/-50 | -3.8/-50 |
| 11 | -17.5/-50 | +0.3/-50 | -8/-50 | +0.3/-50 |
| 12 | -16.6/-50 | -4.1/-50 | +0.3/-50 | -1.3/-50 |
| 13 | NM/-60 | NM/-60 | -45/-60 | -50/-60 |
| 14 | -15.3/-45 | -3.4/-45 | -3.1/-45 | -4/-50 |
| 15 | -22/-50 | -0.3/-50 | -2.8/-45 | -5/-50 |
| 16 | -25/-60 | -31/-60 | -19/-60 | -25/-60 |

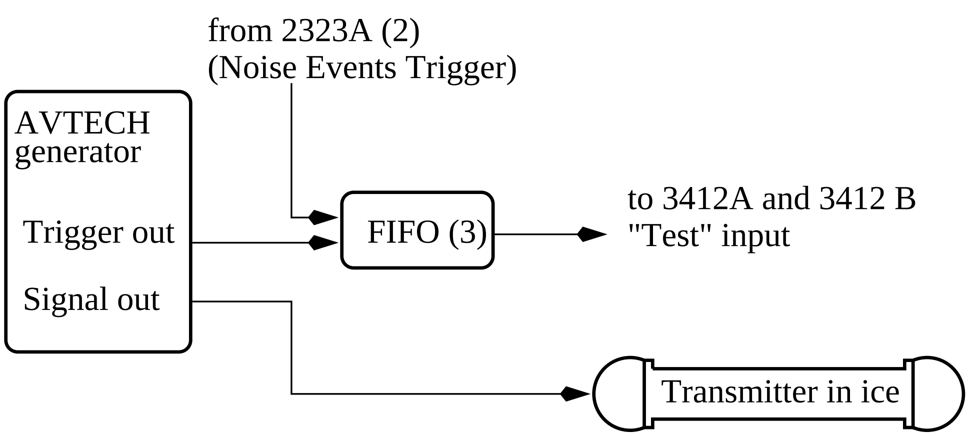


Figure 28: Connecting transmitter to the system.

attenuators to reduce the signal voltage to 3.5 V peak-to-peak). Also: All AVITECH outputs must be 50Ω terminated and set to off or their minimum output settings in order to safeguard against high power reflections.

Threshold of all discriminators (3412E and B) should be set to 0.9-1V during configuration stage of the run. The trigger happens when the pulse from "Trig. out" of the generator reaches 2 Test inputs of the discriminators 3412.

One can also use HP8110A generator for such test, however, its output amplitude is limited to 10V and it is difficult to tune it. Otherwise, algorithm is the same as before.

Similarly, transmitter tests can be done using short pulses (there is, for instance, some uncertainty about the contributions of reflections off of the metallic side of MAPO to the Rx signals received. I.e., the received signals for a CW transmitter can be the sum of the direct plus the MAPO-reflected signal). Such a set of tests were done sending pulses through 97Tx3 and 97Tx4.

pulsed w/ 97Tx3:

| Rx/ch. (0-11) | V(amplitude) | V(DC, rms) | $\Delta$t |
|---|---|---|---|
| 96Rx3/(0) | 515 mV | 81 mV | 397 ns |
| 97Rx7/(1) | 760 mV | 43 mV | 173 ns |
| 96Rx2/(4) | 350 mV | 38 mV | 0 |
| 96Rx6/(5) | 453 mV | 39 mV | 260 ns |
| 98Rx1/(6) | 206 mV | 28 mV | 230 ns |
| 98Rx2/(7) | 243 mV | 27 mV | 264 ns |
| 98Rx4/(8) | 210 mV | 41 mV | 76 ns |
| 98Rx3/(9) | 76 mV | 37 mV | 173 ns |
| 98Rx5/(10) | 55 mV | 39 mV | -135 ns |
| 98Rx6/(11) | 232 mV | 36 mV | 386 ns |
| | pulsed w/ 97Tx2 | | |
| Rx/ch. (0-11) | V(amplitude) | $\Delta$(t) | |
| 96Rx3/(0) | 79 mV | 509 ns | |
| 97Rx7/(1) | 520 mV | 309 ns | |
| 96Rx2/(4) | 239 mV | 0 | |
| 96Rx6/(5) | 140 mV | 411 ns | |
| 98Rx1/(6) | 58 mV | 387 ns | |
| 98Rx2/(7) | 45 mV | 403 ns | |
| 98Rx4/(8) | 83 mV | 228 ns | |
| 98Rx3/(9) | 34 mV | 249 ns | |
| 98Rx5/(10) | 21 mV | -78 ns | |
| 98Rx6/(11) | 158 mV | 508 ns | |

Comments:

- V(amplitude) is peak-to-peak voltage obtained by averaging 64 measurements
- V(rms) is "V(DC rms)" as measured by the scope - accdg. to the manual: V(DC rms)=$\sqrt{(\Sigma(V_i^2))}$. The similarity of these values, of course, is a result of the gain-

tuning that bai did around August. I'm sure there is a precise numerical prescription for converting these values into the magnitude of the background voltage that needs to be subtracted in order to determine the true signal strength; by eye, the factor is something like 0.3 (i.e., V(background)=0.3*V(DC, rms), V(signal) = V(amplitude) - 0.3*V(DC, rms)).

- $\Delta$(t) is determined by scope wrt to 96Rx2 trigger, uncorrected for cable delay Voltages are raw, and uncorrected for amplifier gain, cable losses, $cos^n\theta$ factor of Rx or Tx, or different intrinsic efficiencies of Rx w/ external amps vs. Rx w/ contained amps. (this efficiency is the thing that ryan measures).

- note that I have not included data from 97Rx4 or 97Rx3, as those channels are on the same cable as the transmitters.

For extracting transparency measurements from these, it is perhaps best to compare channels that are on identical cables, since their signal attenuation should simply scale (in power) with length of cable.

Another important detail is the "Time Delay" setting. It takes time for the signal to propagate from the signal generator through cable to the transmitter, then through ice to antenna, then through cable back to MAPO. It may take 3-6 microseconds, so one has to make sure that the expected signal is within the waveform range by delaying the scope or making waveform wider. E.g. if we expect signal to appear in a receiver channel 5 microseconds after the pulse was sent, the following parameters can be set: Time Delay to 4000ns and number of samples to 8192 (meaning 8192 ns waveform length @ 1 GSa/sec), then the trigger will occur at approximately 200ns from the beginning of waveform (you may see a glitch from pick-up, normally middle of waveform, 4096ns in our example, corresponds to trigger moment) and the expected signal will be around 5000ns.

Before taking data you can try to see antenna response on the scope directly using "Average" option. About 512 to 1024 waveforms in averaging is typically enough to kill noise.

After finishing runs with the transmitter be sure to turn off the generator and disconnect cables between the generator and other electronics.

## 7.4 Testing DAQ with HP8110A Pulse Generator

*Again, the description below is generally correct, except that we have taken HP8110A back to the States this year for repairs. Also, two channels of the Phillips Gate-Delay module are used now in the DAQ, so one would be restricted to the remaining channels.*

Many aspects of the performance of the DAQ can be studied using a pulse generator. In particular, dead time can be measured and response of the DAQ to various hit patterns. The generator that we have is capable of sending fairly complicated patterns of pulses as well.

Typically, a detailed request is made by George or Ilya with specifications of the hit patterns, frequency and what to look for from DAQ software side. Here are some instructions how to set up hardware. The diagram in Fig. 29 shows all the modules and

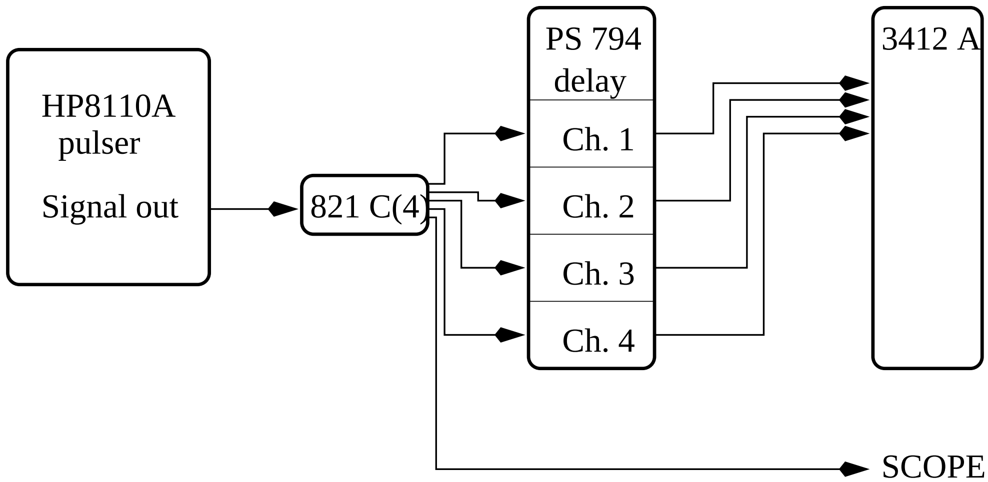


Figure 29: Testing DAQ with a pulser.

connections. Basically, we substitute the signal generator signals for the antenna signals themselves to force a trigger of the DAQ at a prescribed frequency.

1. Setting up HP8110A pulse generator. This is fairly straightforward through menu except that the generator is damaged, its offset is often not what is set by the knobs. Nevertheless, it is usually possible to achieve desired pulse by tuning it with the scope. The problem appears to be only with the signal/zero level of the pulse. Once this is tuned, the frequency can be changed without checking again with the scope. For test purposes, we typically use standard NIM level of about 0.8 V, unless specified otherwise.

2. After tuning the pulse and frequency the signal is sent to the input of the 4th channel of 821C. This module is used to produce 4 copies of the signal.

3. These 4 copies are connected to the 4 channels of the black PS 794 gate and delay generator in the NIM bin. (The yellow lights on this module should be flashing with the expected frequency). The "Delay" output should be used and the delay should be set as desired. The delay is set by the knobs and fine-tuned by the screw, has to be checked with the scope for each case.

4. The delayed outputs of the 4 channels of the PS 794 unit form our pattern. Now one has to disconnect 4 signal channels of the discriminator 3412E and replace them by the 4 generated signals. If the other channels cause the trigger to happen more often than simulated signal, those have to be disconnected too. The threshold of the discriminators should be set fairly high, to approximately 0.7 V, from the configuration window of the DAQ program to reduce triggers from underground antennas. (WARNING: be careful and connect back the original antennas correctly after you are done with the tests).

Now the system is ready for the tests. Most of the connections described above are likely to be already made.

### 7.5 Code Updates (since 1/10/00)

1. Precision of the TDC times that go into the tdc-log file is now 0.1ns (times are really measured to 0.5ns).

2. Veto and other prescale factors have no limitation of 32xxx, I have switched to unsigned 32-bit integers.

3. File compression is installed. Now by default all data files are gzipped. One can switch this feature on and off by appropriate button in "Advanced Config".

4. There were other modifications since the above entries, too many to name.

5. Really, see ChangeLog.txt.

The full detailed list of the changes is found in the file ChangeLog that accompanies the RICE DAQ software package.

## 8 DAQ performance studies

A fair amount of time was invested in attempting to assess the dead time intrinsic in forming the event trigger, and also associated with making the software veto decision described above as well as maximum rates that DAQ is capable of. Some measurements were done by Bai at the Pole (990730) followed by more studies in Dec. 99. The measurements were revised in Dec. 00.

There are two areas that are investigated: the maximum rate at which DAQ can consider events and decide whether to accept or reject them with associated dead time; and dead time occurring when a good event is being saved.

### 8.1 Maximum trigger rate

First, we measure the maximum DAQ veto rate and veto dead time. The setup is identical to that described in Sec. 7.4. A four-fold copy of signals coming out of the signal generator is sent into the 3412E. The time spacing between the signals is set (using appropriate delays from the PS 794 unit) so that the event should constitute a four-fold coincidence, but the timing pattern should be consistent with a veto event. The frequency of the Signal Generator output is then varied, and the trigger rate through the DAQ recorded. If the dead time were zero, then the trigger rate through the DAQ would exactly track the input signal generator rate. The results of this test are given in Table 13.

| Generator frequency, Hz | Fast mode Event Rate, Hz | Fast mode Live fraction | Slow mode Event Rate, Hz | Slow mode Live fraction |
|---|---|---|---|---|
| 10 | 10.1 | 0.918 | 9.9 | 0.800 |
| 20 | 20.3 | 0.838 | 19.7 | 0.580 |
| 30 | 30.2 | 0.758 | 30.2 | 0.294 |
| 40 | 39.8 | 0.679 | 39.9 | 0.157 |
| 50 | 50.4 | 0.599 | 40.1 | 0.165 |
| 60 | 60.5 | 0.517 | - | - |
| 70 | 69.1 | 0.440 | 34.6 | 0.228 |
| 80 | 79.4 | 0.357 | - | - |
| 90 | 89.3 | 0.279 | - | - |
| 100 | 99.4 | 0.194 | 44.2 | 0.092 |
| 105 | 105.3 | 0.155 | - | - |
| 110 | 109.9 | 0.117 | - | - |
| 115 | 114.2 | 0.078 | - | - |
| 120 | 113.7 | 0.084 | - | - |
| 125 | 112.0 | 0.093 | - | - |
| 130 | 105.1 | 0.148 | - | - |
| 135 | 93.2 | 0.256 | - | - |
| 140 | 78.0 | 0.368 | - | - |
| 150 | 80.8 | 0.346 | 43.2 | 0.044 |
| 160 | 79.3 | 0.356 | - | - |
| 170 | 84.3 | 0.316 | - | - |
| 200 | 99.9 | 0.194 | - | - |
| 300 | 100.9 | 0.188 | - | - |
| 400 | 100.8 | 0.188 | - | - |
| 500 | 118.3 | 0.037 | - | - |
| 1000 | 123.4 | 0.000 | - | - |
| 5000 | 124.9 | 0.000 | 48.3 | 0.000 |

Table 13: Veto rate as a function of the input frequency of the simulated signal. Slow mode is different from fast mode by the presence of Event Display window.

Conclusions:

- Saturation of the rate happens at about 125 Hz indicating dead time of 0.008 seconds.
- Event rate is independent on how many scopes/channels are in the system, as expected (the numbers in the table correspond to runs with 16 channels used, the runs with a single channels active give the same result).
- In the Table 13 some numbers are missing - those were not measure considering the picture clear.

- Event rate does not rise monotonically but goes up and down before reaching saturation. This is likely to be caused by the interference between the cycles with different time constants: frequency of the generator and DAQ polling rate. Naturally, this does not affect the dead time of the system which should be calculated at the rate saturation point.

- Note that dead time might(will) change in the future, if the software changes or faster PC is used. For data analysis new dead time constants will have to be requested when software/hardware is modified.

## 8.2 Direct dead time measurements

To measure dead time directly we simply use millisecond tick counter available in Labview and see what time is spent for each operation. The Event Loop and its stages are described in Sec. 6.1.2. The time spent by DAQ at each stage is measured for all the basic event types. The relevant types are: rejected veto event, accepted event (regardless of classification) and unbiased event. The differences between these events regarding time are listed below and the exact time measurement can be found in Table 14. The scopes are set to 8192 sample waveforms.

For the **vetoed events** "Load Event" and "Save Event" steps are obviously omitted. Most of the time spent in checking CAMAC for trigger. The measured time per rejected event, 8 ms, is in agreement with the maximum observed rate of 125 Hz.

Saved **normal events** take much longer. For the full configuration with 16 channels it takes approximately 7.4 seconds. As seen in the Table 14, >6 seconds is spent on data transfer from the scopes.

Let us look at the "Load Event" step. GPIB interface of the PC is capable of transferring 7MB/s. The scopes used at the moment have maximum data transfer rate of 120 kB/s and DAQ reads them out sequentially. A waveform of 8192 corresponds to approximately 16k of data transferred to the PC. Therefore, we expect that the time spent is 130ms. However a direct measurement of the simplest Labview code that retrieves such a waveform yields 370ms. With all additional operations with data arrays the time per waveform is increased to approximately 400ms. The dependence of "Load Event" and "Save event" time interval on the number of active channels is shown in Table 15.

**Unbiased events** take longer time. For these events we do not run "Analyze Event". The load and save time are similar to the normal saved events. As it is seen in Table 14, the "Reset System" time is significant. This time is spent on a) tuning Y range, b) reinitializing the scopes. These steps are done for every Unbiased event.

Note: the numbers in Tables 15 and 14 are measured in 2000-2001 season. In 2001-2002 SP visit we have added the fifth scope. This has slightly increased Load Event and Save Event time, and we have now 20 channels to be read out from the scopes. However, the increase is not significant (we are still under 9s/event).

# 9 Known problems and emergency procedures

Questions - send e-mail to ikrav@fnal.gov or dbesson@ukans.edu.

| Stage in Event Loop | Time spent for given event type | | |
|---|---|---|---|
| | Vetoed | Saved normal (16ch) | Unbiased (16ch) |
| Check/Force Trigger | 4 | 5 | 21 |
| Read out Camac | 1 | 1 | 2 |
| Analyze Event | 2 | 2 | 0 |
| Prescale Module | 0 | 0 | 0 |
| Load Event | 0 | 6975 | 6992 |
| Waveform analysis | 0 | 11 | 10 |
| Save Event | 0 | 423 | 458 |
| Reset System | 1 | 2 | 8353 |
| Event Loop Total | 8.1 | 7418 | 15882 |

Table 14: Time spent in different steps of the Event Loop

| Active Channels, ms | Load Event time, ms | Save Event time, ms | Total time, ms |
|---|---|---|---|
| 1 | 415 | 44 | 485 |
| 2 | 872 | 45 | 942 |
| 4 | 2062 | 69 | 2155 |
| 6 | 2759 | 132 | 2914 |
| 8 | 3664 | 165 | 3854 |
| 10 | 4234 | 196 | 4453 |
| 12 | 5009 | 318 | 5350 |
| 14 | 5824 | 418 | 6266 |
| 16 | 6987 | 430 | 7439 |

Table 15: Time spent saving and loading normal events as a function of the number of channels.

## 9.1 DAQ

Why does it not work? You start the DAQ and see no events. Here is a list of simple cases.

- Symptom: you are watching DAQ front panel for 10 seconds but nothing is happening, event timer does not increment. Possible cause: DAQ is taking an Unbiased event that may be longer than 15 sec. Wait a bit.
- Symptom: You click on one of the buttons on the main DAQ window, it says "Processing" but nothing is happening. Explanation: there are no interrupts in this software, each button is checked at the appropriate place of the execution line/loop. For example, if you are in the Event Loop and press "Finish" button, nothing will happen. First you have to "Stop Run" and then "Finish". Or, for example, you click on "Config and Init" when DAQ executable is not started yet. Naturally, nothing

will happen. If this bothers anyone, a proper disabling of buttons can be installed. Also note, that when you click on “Stop Run” it might take some number of seconds to process the last events before DAQ will go into End/Idle state. Another similar event occurs when DAQ is waiting for a new trigger. If there is nothing coming at all one might have to “Abort” run because “Stop Run” condition is not checked in the Check Trigger loop.

- Symptom: DAQ appears to be frozen or running extremely slow. Possible cause: see Sec. 7.1.2 and make sure that DAQ window is always highlighted.

- Symptom: waveforms from different scopes look identical. Possible cause: after **power failure** scopes reset their internal GPIB addresses. Will have to set them manually as described in Sec. 4.2.1

- Symptom: when started, DAQ sees no events although time counter increments every second. Possible reasons:
  a) discriminator thresholds are too high. Set them lower.
  b) discriminator thresholds are too low. The discriminator outputs are always in the HIGH state, and there is no rising edges for trigger logic. Set them higher.
  c) antenna amplifiers are not getting correct power so there is no signal coming to the DAQ. Check all power supplies.

DAQ still does not work and nothing obvious is wrong: more serious debugging is needed.

- Software side: see where the DAQ spends all its time. For this start a run with open Event Display and look at the green Marker lights. Chances are you will see it always in Check Trigger state.

- Hardware side: first, look at the red LEDs on the electronics modules. Here is the list of important once:

1. LED of the top channel of the Gate 2323A in CAMAC crate. Constantly ON means that trigger has occurred and event is ready for readout, OFF means the opposite. Changing ON-OFF means that events are being read out by the DAQ.

2. LED of the discriminator 821 C(1) flashes every time when there is a valid trigger.

3. Check if there are 4-fold coincidences. For this connect one of the NIM outputs of channel 8 on ECL-NIM-ECL module in the NIM bin to oscilloscope. You expect to see a square pulse of approx. 500-800mV, After this test, disconnect the cable and restore 50Ohm terminators if there were any originally.

4. LED of the discriminators 821 A(1) and A(4) flash every time when there is at least one hit from underground antenna above threshold.

5. LED of AMANDA and SPASE are on the discriminators 821 B(1) and B(2).

If some of these items do not behave normally then you have to go through the whole signal chain with the timing diagram described in Sec. **??**.

## 9.2 Power Supplies

The Tektronix CPS-250 power supplies have had an alarmingly high failure rate of late. (For some reason, this is always output "B"). The symptom is that the current draw always becomes very large and the red "OVERCURRENT" LED comes on. The overcurrent limiting knobs have been tuned so that the current draw is very close to nominal, so sometimes these LED's may also come on as the voltage output of the supply ripples. The large failure rate is evidenced by the fact that a few of these power supplies have outputs for which the LED's are always on, even though there is no cable connected to the power supply. If a red LED which has a cable connected to it comes on, try tweaking the overcurrent limiter knob beneath the voltage knob slightly (keep in mind that the in-ice amps should draw a nominal 60 mA and the surface amps should draw nominal 80 mA or so. Because of the ganging of the surface amps, the total current draw of the surface amps is, for three-fold ganging, approximately 250 mA) and see if this fixes the problem. If it does not, then the channel is probably bad and the power supply will have to be replaced. First, take out the input to the power supply and, using another, good power supply, make sure that the current draw for that channel really is nominal and that the problem is in the power supply rather than the antenna. If so, then you can use the Energy One XP-4 power supplies for the bad Tektronix power supply (unfortunately, these power supplies do not have current regulation, so we discourage their use). In either case, make sure you send mail to dbesson@ukans.edu detailing the problem, etc.

# 10 Deployment procedures

## 10.1 Preparation at KU

## 10.2 Preparation at the South Pole

## 10.3 Deployment

As of this writing, there have been two modes of deployment – deployment of antennas into "dry" holes (bored by PICO using a 12 cm caliber mechanical drill, as in the 98-99 campaign) and "wet" holes (bored by PICO for AMANDA using a hot-water drill). "Wet" holes are typically 60 cm in diameter, and up to 2400 m. deep.

Before deploying either Rx or Tx, modules should be checked for functionality. Tx should be put up on the network analyzer in MAPO and their VSWR measured. A good Tx has a VSWR of two or less over the frequency range 100 MHz - 600 MHz, and should show infinite DC resistance. Receivers should first have their DC resistance measured (1140 $\Omega$ = nominal). Next, they should be attached to a bias tee and their FFT measured. A loose connection in the interior of the receiver will result in an unstable measured DC resistance, and also an FFT which may show characteristic harmonic oscillations of the amplifier. In Dec. 1999, this evidenced itself as oscillations with fundamental $f$=125 MHz.

Dry hole deployment (98-99) is the most straightforward, due to the lack of a time constraint imposed by water freezing, and also the retrievability of the modules. The cable spool is hoisted onto the crossbar of a jack stand, the module attached and then lowered to the desired depth. Cable (LMR-600 and also Cablewave) is marked with foot markings, so the desired depth can be easily "dialed in".

Wet hole deployment has been, in the past, more problematic of the two procedures. Receivers and transmitters to be deployed in wet holes should be well sealed with silicone caulking before deployment. It is essential that the Rx/Tx be duct-taped to the main AMANDA cable during deployment – when the wet hole re-freezes, it re-freezes from the sides in. As re-freeze occurs, water is therefore pushed up to the open top, resulting in vertical fluid flow. In order that the module be as insensitive to the fluid flow (which can result in a tilted receiver, possibly bending the top connector and also making the broadcast/reception pattern something other than $cos^n\theta$ and/or up-down asymmetric), the module should be well-attached to the AMANDA cable. After deployment, the DC resistance should again be measured. Water penetration into the cap of a receiver will result in a reduction of the DC resistance from nominal (1140 $\Omega$) by approximately 50-60 $\Omega$. This is believed to be due to metal which flakes off during connector attachment, which result in some non-zero conductivity between lead and ground. However, after re-freeze, the resistance should again return to nominal value. It is recommended that power not be supplied to the receivers until re-freeze is complete (however, a good receiver should draw nominal current even when there is water penetration inside the connector. This was tested simply by taking cupfuls of snow at Pole, and filling the connector prior to attachment).

During the 1999 deployment, there were two instances in which receivers performed nominally up until re-freeze ($\sim$3 days after deployment). However, during re-freeze, the DC resistance of the module suddenly dropped to $\approx$500$\Omega$, and thence rapidly (time scale of hours to 250$\Omega$; specifically for 99Rx1, the DC resistance was measured to be 575 $\Omega$ at 11 pm and 278 $\Omega$ at 10 am the next morning). This resulted in a very large current draw for the module. We note that a standard, ohmic response to a DC resistance of 1140$\Omega$ would be a current draw of I=12/1140=10.5 mA. Of course, since the amplifier response is non-ohmic, the actual current draw is 60-90 mA for a healthy amplifier. However, for one of the receivers deployed in 1999 (the first one in hole G2, which subsequently failed), the DC resistance at t=5 days was measured to be R=46$\Omega$, which gave a current draw of 120 mA. I.e., behavior is now ohmic, suggesting that the problem is not in the amplifier. Verification of this awaits a test wherein a "naked" amplifier is frozen into a container of water and it's resistance measured as freeze-in occurs. The fact that there have also been compromised transmitters suggests that the failure is not occurring in the amplifier itself. The symptom of a failed transmitter is similar to a failed receiver - the DC resistance drops (for a healthy transmitter, $R_{\rm DC} = \infty$). For the first deployed module of 1999, a transmitter was mistakenly lowered rather than a receiver. The DC resistance was subsequently measured to be 300 $k\Omega$, suggesting water penetration to the connector. This transmitter was pulled back out of the hole. However, a later transmitter, deployed on 991227, was measured to have a DC resistance of 15.3 $k\Omega$ on 991230 (and "dropping in real time"). This is clearly a non-amplifier failure.

An interesting case is that of 97Rx1, which was deployed to a depth of approximately 392 meters. This channel draws nominal current (60 mA) at nominal voltage (12 V), however, it fails to detect either the 303 MHz line or any of the buried transmitters (in principle, this could be the result of an unfavorable combination of $cos^2\theta$ plus high signal attenuation). Assuming that the receiver is, indeed, failed, we conclude that the failure of this module was somewhere $after$ the in-ice amplifier. Since this receiver used the "old" design of an amplifier in a separate pressure vessel above the antenna, it is, of course, possible that the point of failure is (again) above the antenna, but below the amplifier. (The same failure mode was noted for 99Rx1, although 99Rx1 appeared to be functional for $\sim$1 month prior to failure. Oddly, this receiver failed during trenching, which is suspicious).

After deployment, cable must be "dragged" back to MAPO. In order to prevent twisting of the cable, the simplest way to do this is to pull the cable from behind the hole and unspool all of the cable in an orderly fashion, on the snow. Then lead the freed "back" end of the cable back to MAPO, or to whatever jumper is being attached to the cable. Note that all cables have a characteristic bending radius, which is the minimum radius that the cable can be bent back on itself without doing permanent damage to the cable. This value is typically $\sim$10 cm.

## 10.4 Trenching, cables length and jumpers

After deployment, cables should be run back to MAPO along a route which has been pre-arranged with ASA support (the "trenching" path). There have been two types of trenching done in the past – for the 1998-99 "dry" holes, a dedicated mechanical trench (basically, a swordfish which runs through the ice like a jigsaw) was employed. For the AMANDA holes, hot water trenching (considerably less dangerous and less likely to cut cables) is used. In both cases, a groove approximately 5 cm wide and 1 m deep is cut into the ice and the cables subsequently lowered into the groove.

## 10.5 Failures and causes, hints and tips

Some of the observed failure modes have been described above. We have made some effort to reproduce those failures in the lab. In the simplest test, an amplifier was frozen in a cup of water in a freezer. Prior to freeze-in, the current draw and resistance of this amplifier were nominal (63 mA and 1140 Ohms, respectively). After approximately 4 hours, but prior to freezing, the resistance of the amplifier was observed to begin to fluctuate. Over the next 6 hours, during freeze-in, the resistance varied between 600 $\Omega$ and 1500 $\Omega$, however, the current draw remained nominal (60 mA). During the course of freeze-in, and 10 hours after being placed in the freezer, the current draw began to climb; concurrently, the DC resistance of the amplifier continued to fluctuate over the aforementioned range. The next morning (24 hours after first placed in the freezer), the DC resistance was observed to be approximately 100$\Omega$, and the current draw$\sim$200 mA. When freeze-in was finally noted to be complete, the DC resistance was approximately 1140-1200 Ohms, however the current draw settled at a value of $\sim$180 mA. 24 hours later, when we were sure that freeze-in was, in fact, complete, the response of the amplifier was measured on the NWA, and the gain determined to be essentially zero above 200 MHz (i.e, the amplifier was broken).

0) speak to U Wisconsin people about getting a RICE ROM breakout for ICECUBE

cables. Accdg. to karl heinze-sulanka, signal comes up on twisted pair, goes into a pcibus and is read out directly w/in PC. sounds like hard stuff is done already; what comes into the pc is a digitized waveform presumably with a t0 stamp.

1) add HV and amp cards (camac) to electronics next year

2) get a twin-prop twin otter flight out to siple dome to braodcast down into clow (gary) hole and measure ice transparency - use optical fiber for this or some onter ICECUB technology?

3) talk to charlie bentley (U Wisconsin or washington about GPR.

4) re-do freeze-in tests - why did checker's tests "fail" (no water penetration) but there is indication of water penetration at holes at ple? perhaps ice froze first on outer edge of RX in checkers tests, which formed protective coating (perhaps we can make an ice coating at pole before lowering hardware, similarly). At pole, ice freezes in from sides first. look at pattern of freeze-in with checker's tests and see if this is the case.

# 11 Future task list

## 11.1 Hardware going down to pole

1. repaired HP8131A signal generator, Need 10 V output p¡-¿ for transparency measurement (or higher).
2. Dedicated CAMAC HV board w/ current/voltage readback to replace all power supplies.
3. 02-03: install two radio DOMs and two radio Optical fiber channels.

   Assess what we need and don't need from waveform information

   assess if we can just get by with hit information
4. DDS3 (or 4, if we can get them) tapes for DDS4 tape drive.
5. SPARE MALU for ilya
6. 3420 CFD for HSV
7. GPIB controlled HV with current readback
8. Alice's new CAMAC crate
9. Two New ¿833 MHz PC's (must be loaded with software)
10. Some more jumpers
11. more power supplies
12. long cables.

    more power splitters (01)

    52 dB amps, amps of all kinds

adapters

repaired scope (to repair channel "0 of scope 1)

13. Variety of filters high/low-pass.
14. Two notch filters per channel. (programmable/tunable)
15. Braaten GPS system for surface surveying?

## 11.2 Hardware coming back

1. BRING BACK HIGH GAIN LCF AMPLIFIER TO KU.
2. ECL cables
3. Lemo cables

## 11.3 ON-SITE work, 01-02

1. optimize L0 cuts
2. take new rrtx data to replace lost 00-01 data
3. make online scripts look like offline scripts
4. make sure that unbiased events are not taken while 303 is on, so that rms-noise is "good".
5. Collect events where antennas are disconnected to study noise generated in MAPO itself.
6. Use signal generator to track down why ch. "8 seems to have 6 ns resolution; all other channels have 1-2 ns resolution.
7. Tune horn surface veto window - IK starts 1 us after horn gets hit; should we narrow that time delay to make the veto gate start sooner?
8. install backup PC.
9. Determine why unbiased events are not really unbiased. Ilya: One interesting test would be to set the threshold really high for the discriminator, say to 1V, then only unbiased events will be recorded in the run. I wonder, how many of those would have exactly-lined up pulses, and what would be the magnitude of such pulses? If we think about it, the possibilities probably are: 1. Old good event is somehow not cleared from the scopes and read out at the unbiased trigger time 2. Something makes coincidence of a real event and an unbiased pulse 3. There is a bad crosstalk somewhere Unfortunately, the easiest way to debug this is by working with the real system, either on site or with the test system that we don't have currently at Kansas. If we ever get some money, it might be worth trying to recreate it, with one scope but all CAMAC/NIM modules.

10. Re-calibrate all channel t0's by following method: 1) assume Tx and Rx positions are well-known so that signal propagation speed from Tx to Rx is well-determined, 2) take output from AVTECH pulser through a filter, next to a splitter. One side goes to scope, other side goes to Tx. Side to scope provides a trigger. On that channel, should see signal directly from scope plus reflected signal from Tx. This reflected signal arrives at twice the cable propagation distance and directly gives us the cable delay. We therefore now know the time at which the Tx is producing the signal. Run same trick with receivers (with amplifiers off) to determine total cable delay through receivers.

11. Determine max voltage on-line and do surface veto using some combination of TDC's plus times-of-max-voltages.

12. Use unbiased events to actually send a digital pulse to scopes.

13. At end of every run, calculate upper limit to neutrino flux, or some parameter indicating total exposure...

14. More cross-talk studies, send pulse into one channel; look for return pulse in another channel (also Tx$\rightarrow$Tx).

15. Do transparency over long baseline, beaming using horn from surface.

    Use generator to power signal out of network analyzer? or optical fiber?

    Drop Tx in mark battle holes? and/or holes E/F?

    Lessons for 02-03 from 01-02 attempts:

    Need higher power signal generator.

    Take data in unbiased events.

    Use SPRESO holes to try to measure attenuation - will need more cable?

    Use SPASE; also check out clean air sector ahead of time.

    Do measurements with both dipoles and horn antennas.

    Make sure that Tx is entirely submerged in snow to prevent refractive effects from being problematic at air/snow interface.

    Should be at least a couple of wavelengths from metal (Fraunhofer zone); do redundant measurements at different locations.

    Need to think through issue of saturation - we observed that NWA saturated amps when we swept a 0 dbm signal too quickly from 0-¿1 GHz when doing absolute gain calibration. Similarly, if output signal from surface amp is >1 V, we are likely to be saturating surface amp. This will happen for 1V (e.g.) signals close to array.

16. *** Reflection coefficient for transmitter in and out of ice/snow.

17. Do experiment in which dipole dropped into an AMANDA hole, and look at response as a function of azimuth, when dipole in ice is broadcasting, to test shielding explicitly.

18. Should we increase the minimum multiplicity to 5? (conf. call issue)

19. for 01-02, need to take network analyzer data from the surface from the horns, to all in-ice receivers. knowing the relative locations and assuming uniform response of the antennas, can derive the ice attenuation information, need to record orientation of horn plane.

20. BUY NOTCH FILTERS FOR 149 AND 303? (DEFINITELY 303...)

21. optimize SPASE/AMANDA coincidences for reconstruction of stopping showers.

22. NEED systematic study of what filtering region is best - this requires one channel w/o filter... construct one dipole receiver and stick in the snow and attach to TDC.

23. Systematize study fraction of times there are 1, 2, 3, or 4 random TDC hits overlapping with a pulser t0 signal as a function of disc threshold to determine random occupancy, etc.

24. take out GPIB controller from old crate controller and use one from 7-slot crate.

25. Play with AMANDA-A and see what we can do/learn (DZB/IK/DS)

26. Put version number of DAQ into .log files.

27. Plug in RICE trigger so that it gets read in AMANDA Strück scalar. (IK)

28. Locate 2 100' jumpers sent down this year. (DZB)

29. Check of gain equalization/optimize reception (DS)

    Compare butch-calculated gain in lab with gains on screen, verify that 52 dB amps seem to measure 10 dB lower gain at pole. Take data with AMANDA off, do deep-ice amps give 36 dB gain? are deep-ice amps saturating due to AM noise? Take one of the 00Tx's and measure thermal noise, then attach amplifier to antenna and see if we get back 36 dB (we'll get less if we saturate on low frequency noise). Now attach filter at input to amplifier and see if we get back 36 dB (we hopefully will now suppress low frequency background). (DS)

30. See what signals look like (FFT's) w/ no filter, and w/ amanda on/off.

31. Bring spectrum analyzer to pole to check the gain w/ a 36 dB amp on and with 52 dB amp out of circuit. Find one at Pole (DS)

32. Determine what TDC times get recorded if there are overlaps.

    This would be first hit, no?

33. Fix advanced config bug. (IK)

34. Set scopes' screens off when data not being taken. (IK)

35. Disable control buttons at appropriate moments. (IK)

36. Is there any meaningful way to use surface horns? One pointing up, one pointing down? (DB/All)

37. Background survey of MAPO while no drilling/deployment (All)

38. As much Tx data as possible, possibly using the 1998-99 holes. (All).

39. Extend the MALU gate to more than 1.25 microseconds?

40. "Tholian Web" (DB/All.)

41. Install newer, faster PC (DS)

42. Possibly change ganging of surface amps, etc. (incl. mods to PDB?) (DB/All)

43. Figure out why unbiased events have signals in them (IK)

44. RICE KANDI code (Labview) (IK)

    (a) *Figure out a way to monitor the t0 jitter online.

    (b) What is the best algorithm for getting the "true" signal time?

    (c) monitor number of hits as a function of time

    (d) hit pattern as a function of time - 2D histogram of time/eventN vs channel hit - do triggers always show up at the same time with same amplitude?

    (e) event rate vs time

    (f) A 2-dim plot of $< V >$ separately for $f$ <200 MHz, 300< $f$ <306 MHz, and $f$ >200 MHz, without the 303 line would allow us to separately monitor the in-ice vs. the surface amps. Butch has code that does this, over a long time baseline. Can we see sun?

    (g) Closely related, at the end of the run, a 2 dimensional plot of $< V >$ vs. FFT frequency (the sorts of plots that George makes)

    (h) A plot showing the integrated number of triggers, as a function of time, for: i-iv) each possible trigger (general ev., vetoes, ext. 1 evt, ext. 2 evt), v) cases where $t(i) < t(j) < t(k) <$..., where i, j, and k are successively larger integers. This would, e.g., allow us to monitor the rate of surface triggers (actually, since 98Rx6 has replaced 97RxG, we have to make allowance for the different time delay of that channel vs. what we had before with 97RxG).

    (i) A true DAQ Monte Carlo, which simulates the timing (do this in Labview) and deadtime. among other things it would be good to see here calculation of the following: if a signal appeared T times after/before the trigger, what are the times on the waveform and on TDC?

    (j) $N_{hit}$ as a function of time, where $N_{hit}$ is the total number of TDC hits in an event.

(k) $y_{max}$ as a function of time for each channel, where $y_{max}$ is the maximum amplitude of the waveform for events that we trigger on (not the events that we take for the rms measurements).

(l) A two-dimensional correlation plot of the number of times that channel i fires for an event compared to channel j. This would help identify cross-talk channels.

(m) A two dimensional scatter plot of the bit-encoded 'event integer' (for 12 active underice channels, this would have to go up to $2^{11}$=512) vs. time. In addition to giving perhaps the most direct monitor of the event trigger vs. time, this would also be *very* useful in allowing us to define event vetoes, at least for the underground antennas.

(n) Note that Ilya started some of this, and has code that:

   i. has LabView tools to read an event from the standard data file

   ii. extracts TDC time from the event header

   iii. scans waveforms, do a kind of signal analysis and extract the time of the signal

   iv. the main program then takes these dT and plots them as a histogram. (Ideally, we should always have dT=const, say, 2000 ns if every signal found by me in waveforms matches correctly to corresponding TDC measurement

45. Calibrate antennas by measuring solar BB emission power. (DB)

46. See bottom echo using pulser with horns, but with Faraday shield around horns to prevent sideways leakage? (DB)

47. Debug ch. 2 of 1st scope (DB)

48. Install and readout ADC's (IK/DB)

49. Automate 303 MHz avoidance; make sure working properly (IK)

50. *** Should we wrap PDB's in aluminum foil????

51. Can we construct a crude testing range out by SPASE? Need non-metallic scaffolding. Ideally, some absorber on ground. (DB)

52. Tx measurements in 98-99 dry holes (DB).

53. Can we transmit from Mark Battle's holes and see transparency? (DB)

54. Put in low-pass filter to take out high frequency noise components and thereby lower threshold? try this on a couple of channels next year. (DB)

55. Suppose amplitude spectrum of background MAPO noise is always the same, can we use two discriminators together so that we don't trigger on stuff which is too large in amplitude? (IK, with spare DISC board)

56. More Tx tests at pole to study occupancy. (DB/DS)

57. individually power all amplifiers (01-02)

58. Use CHANNEL 2 of scope to monitor one channel which has had filter removed.

59. Figure out why "unbi" events in hits-log.dat record TDC's that look like general or veto events.

60. Add a trigger line which has RICE, delayed by 16 microseconds, in coincidence with AMANDA - bring down a separate scope for this? allow us to see downcoming stuff in both RICE and AMANDA? To do this right, we would need:

    (a) Time structure of all AMANDA hits, and access to their data. (They do NOT filter their data online, so this is, in principle, doable)

    (b) Complete waveform information from all RICE receivers, in order to see: a) downcoming stuff in the same RICE hole (so that we can see the time structure of one RICE hit, then the next), b) maximal overlap with AMANDA and maximal coverage...

## 11.4 Hardware Tasks OFF site, 00-01

1. Finish Ledford board; add summing board to suppress noise backgrounds.

2. Try out Nygren digitizers in EDL.

3. Consider: Is breakage at the pole due to the fact that the antenna cables are shrinking as the ice is expanding? look up coefficient of thermal expansion of antenna cable, Young's modulus of cable, stress-strain relation for cable.

4. Re-design PDB to allow: a) access to any component: add/remove easily; e.g., if an amp goes bad, we slip it in or slip it out.

5. Antenna attachments closer to the rear of the PDB

6. Box/enclosure for LCF amplifier.

7. Checker's tests, but monitor current draw during freeze-in.

8. Look at dipoles next-to-each-other for coincidence studies.

    ONLY TAKE HITS IF TDC's FOR ADJACENT CHANNELS ARE CLOSE!

9. Construct dipole antennas that have very poor response below 200 MHz, so we can eliminate band-pass filtering.

10. To check effect of semi-infinite AMANDA cable, ground cable and then test shielding response. More systematic study of AMANDA cable effects.

11. We see a 1 microsecond ring time in an Rx when signal is sent into a Tx which is in the same hole. Is this due to amplifier saturation or is this due to the AMANDA cable "ringing"? check in the lab by saturating an amp using a brief duration signal (use Avtech for this).

12. DO MORE DETAILED MODELING OF SATURATION - WHAT ARE TOLERANCES FOR, E.G., PULSER TESTS? set up plan for George's Tx tests.

13. John study of noise as a function of integration time - does S:N improve with longer integration time? Technique: a) with unbiased events, determine distribution of Vtot(dt), where Vtot is the total voltage obtained by summing over a total integration time dt, b) with signal events (surface noise with a pulse or fast Tx events that don't saturate), determine Vtot(dt) for signal. Take the ratio as a function of dt. Can also probably model this without data, taking a simple model of ringing (take an RLC circuit here) and noise...

14. Update pressure vessel testing and figure out what the failure mode is during refreeze. (MRI/Plamen Doynov)

15. Development of analog Electro-Optical modules for the Radio amplifiers, optical fiber readout

16. Test digitization in-ice and transmission of digital signal through coax.

17. verify that shielded coax does not have an effect on Rx reception.

18. Design and test of broad-band dual polarization radio antennas (Lucio/CTA). Note that, if we have both polarizations, we can determine the distance and orientation of the C-cone based on just two measurements. Calibrate using polarized signals from dipoles.

19. Put GPS receivers into the RICE antennas so that we can monitor ice drift?

20. Having shown that we can extract the phase information by doing an NWA sweep with a fixed length of cable, and verifying the magnitude of the phase info, measure the phase of —h— by doing the same measurement on the range - note that, if we have actually calibrated to the end of the Rx and Tx cables, the phase diff. when cable ends are joined should be zero. (Eben/Tim)

21. Suppose we rectify and integrate signals into the 3412 at 10 ns intervals rather than 1 ns intervals, then we will see more of "true" signals and integrate out noise. ergo, less spurious triggers. Things to look at: try in software, also consider using two discriminators with different time-scales (or else use a TOT criterion, in software?)

22. Measure VSWR's/Gamma's, etc. at some remote site in western KS? (Eben/Tim)

23. determine the trigger efficiency by sending a pulsed signal from AVTECH→Yagi→dipole. Generate plot of $\epsilon_{trig}(Signal\ Strength)$. (Eben/Tim)

24. Measure VSWR on testing range and make sure that it is same as inside 2068. Also, measure VSWR on a remote site, away from metal environment, and make sure that VSWR is constant. (Eben/Tim)

25. Determine if cable loss is a function of temperature – do an insertion loss measurement (transmission) on an NWA with a small jumper, then a small jumper in dry ice. (Eben/Tim)

26. Check the impedance function (complex) of the antennas in ice and verify that they shift as expected. (Eben/Tim)

27. Re visit issue of Mini-Circuits baluns - my impression is that these transformers have specified turns ratios and therefore require that we know the input impedance relative to 50 Ohm to work. Check this. (Eben/Tim)

28. Check the dipole response to an axial feed vs. a perpendicular feed. (Eben/Tim)

29. Construct and test a small horn receiver for testbeam. (XX)

30. Use Dave Becker plastic module to test transmission through water. Corn oil?

31. Spec out and fix long cable; ship to pole way in advance. (XX)

32. Can we downshift the signal through heterodyning and save money? (XXXX)

33. Receiver antennas on the same cable with tee breakouts. Saves cable, but need to associate pulse X with Rx X. (XX)

34. Test deep pressures in Big Springs hole. 5 inch hole is in Big Springs, 10.2 m. past the McDonalds on 6th St. (40W), just past the Big Springs, unincorporated sign on the right, and parallel to I70.

35. Learn baluncing technology from DDP. (Eben/Tim)

36. Construction of a system that multiplexes the waveform information into the four digital scopes. Since, beginning in '99-'00, we will have considerably more channels of information than our digital oscilloscopes can accommodate, and since these scopes are so expensive, we would like to assemble a system which will route those channels having 'hits' into the oscilloscope to preserve waveform information. (XXXX)

37. testing range - test using short duration pulse into YAGI, and see response of antenna (Rx). Is response consistent with what we expect given the measured receiver characteristics of the Rx? (Eben/Tim)

38. Adjustable power splitter that will split power according to a dial so that we can 'equalize' signals into DAQ/scope. (XXXX)

39. Wrap AMANDA cable in aluminum in vicinity of Rx? (this may do more harm than good). Test on Range. (Eben/Tim)

40. Antennas that can be run in Tx or Rx mode (see RxTx_0002.xfig). (or use circulator, alternately known as an “RF bridge” – HP makes such devices.) Alternately, Ken Filardo suggests using a TO-5 DPDT relay wired so that application of a voltage opposite that used to power the amplifier engages the relay to bypass the amplifier. These relays provide reasonable isolation and VSWR below 1 GHz, and have been widely used in commercial attenuation products. Total power handling of the relay is about 5 Watts. This configuration will require manually disconnecting the feedline from the measurement rack to reconnect to transmitter mode. (XXXX)

41. John Ralston idea - construct ”mask” that will allow us to do signal rectification at input to discriminator, and ”cheap” pattern recognition. (XXXX)

42. Hardware trigger that does surface veto - some primitive CAMAC board to do this. (XXXX)

43. john’s inverter+multiplier delay scheme - need 2 splitters, and 1 inverter. (XXXX)

44. Altera chip that will come after TDC and do hardware veto after TDC? (XXXX)

45. “matched-filter”? (XXXX)

46. Spark test of system. (Eben/Tim)

47. Use 1 ns pulser: braodcast Yagi to Yagi, then Yagi to dipole, then dipole to dipole then take to pole to test dipole to dipole at pole. (Eben/Tim)

48. Figure out a way to improve S:N so that TDC’s are more reliable (52 dB amps, in-ice??) (XX)

49. Study cross-talk between two antennas in the lab, also study saturation effects in the lab. (*)

### 11.5 Analysis Tasks

1. Convert all of george’s IDL code to C++

2. Make simulated data really look like real data, at the input to hitLoc_L0.cc

3. If we make gridsize 5 m rather than 10m, does the spatial resolution improve? Want plot of rms of reconstructed vertex as f(gridsize)

4. set up surface source n(z) correction, do this as a three-dimensional array correction (tcorr[zsource][zrx][theta])

5. Determine efficiencies of various L0 cuts, for simulation, and Tx events:

   double-pulse veto

   Fails BOTH 4-hit and grid-fit z<-60

   Fails cone-$chi^2$ cut

6. Study veto events' waveforms to see how often we see clean surface events (Done - vertexed veto events, which passed prescaler. Find the fraction of veto events vertexing to the source, and fraction vertexing below the source).

7. Find fraction of unbiased events containing "good" events.

8. Modify first steps of reconstruction code so as to be compatible with both 1999 and 2000 data.

9. Install suruj's upgrades/mods to sim.cpp.

10. Butch's study of occupancy in the unbiased events generated some interest (we should also do this separately for unbiased events which come every 10 minutes vs. unbiased events which directly follow a true trigger), although we'll have to start at a threshold voltage of 20 millivolts or so rather than 100 mV. On the former subject, do the t0's in general triggers always show up at the same place, while t0's of unbiased events which have signals in them show up with a different t0? (accdg. to george, this latter class of events is reproducible, from event to event). Along the same lines, how often are there two events superimposed in the same event? (*)

11. Analyze unbiased events separately for $\Delta t$ events vs. every-N-trigger events. (*)

12. Make hit correlation plots and look for correlated noise. (*)

13. Monitor $t_0$'s from TDC values in unbiased events. (XX)

14. plot $t_0$'s for waveform data.

15. For raw trigger rate: use the method AMANDA apply for any amanda-trigger: plot the time difference DT_EV between all pairs of neighbouring events that have been readout. This distribution should be exponential (if teh statistics is poissonian), apart from your deadtime-region (¡ 0.5sec). If you fit the exponential part, you'll get your TRUE rate. (At least some rough estimation). Also, you check by this easily for possible conatmination by periodic signals (e.g. like a 'pulser' at xx Hz that would show up in the plot as a delta-function at DT_EV_pulser=1/(xx Hz)), as well as for other effects, like a larger deadtime that occurs sometimes rarely (we had this e.g. in the old (97) Amanda-daq). (XX)

16. Figure out mechanics of downloading george's data from web, and analyzing with L0 cuts.

17. Automate data analysis routines.

18. figure out if double-pulses are the result of ringing within the same hole.

### 11.6 Software Tasks

1. Run vertex reconstruction, eliminating single channels one-by-one to see pulls (set weight to -1 in antennaloc.dat).
2. Examine file sent by steffen for correlation between wind speed and rice trigger rate.
3. Include total number of data files written in stat-log.dat file.
4. List channels in waveform and TDC explicitly in stat-log.dat file.
5. Use event-viewer to scan events during 2000 (noise-dominated) and 2001 (surface-dominated). Can we use pattern recognition to differentiate the two?
6. RICE data structure is not optimal - If I knew how to fix it I would, but I don't :( I think this fix will have to occur in subsequent major revisions of the DAQ software (which for the moment is done by Ilya at MIT). I'll make sure it gets on the "to do" list.
7. Can we quote a vertex resolution with an error? Ditto angular resolution? (*)
8. Using PDG formulae for Cerenkov radiation, verify that GEANT excess charge "blob" gives expected electric field at C-angle. (*)
9. Use Balanis .for files to study antenna response characteristics (/home/dzb/rice) (*)
10. 303 detection on unbiased events?
11. Do filtering of data online, as it comes in? (i.e., run something like a level3 filter?) Need C++ on some machine there.
12. butch - determine fraction of times that voltages in one of the horn-veto waveforms exceeds a given value to tell us what is firing rate of a horn-veto at a particular threshold.
13. take master disk and re-do cable delay measurements. (*)
14. Need someone to daily monitor hits-log.dat file / rms-log.dat file / scan ten events. (*)

    Trace back to jan. 1999; for each discriminator threshold, calculate an effective volume, knowing amplifier gains and cable losses. Multiply effective volume by livetime to get detector sensitivity.
15. use only chs. "6-"11 for surface veto to prevent being thrown off by spurious hits
16. track channel-to-channel jitter in pulser data files (*)
17. look at TDC's and TDC correlations of surface horns in order to locate source of surface noise.

18. To determine fraction of times that horn veto is working:

    Determine observed gains for horn channels "0 and "1. (will be lower than nominal)

    Assuming nominal gain, scale each voltage point in waveform up by appropriate scale factor (nominal/observed).

    Histogram 8192 (corrected) points; integrating histogram above some threshold gives the fraction of times that horn sample exceeds threshold.

19. LabView interface to network analyzer to automate data-taking.

20. Determine saturation of deep-ice and surface amplifiers; how often is dynamic range saturated? (*)

21. Work with Suruj's old monte carlo and add in vertexing from vertex.f, also examine multiplicity distribution for signal.

22. What sets the t0?

23. Why don't veto events reconstruct to surface if they are dominated by true MAPO-background?

24. Get the book by Kraus on antennas (McGraw-Hill)

25. Determine optimized $N_{hit}$ vs. $V_{thresh}$ for maximal effective volume.

26. During skimming of neutrino candidates by waveforms, retain some figure-of-merit telling us how many sigma above noise event is (in toto).

27. Determine absolute $t_0$ for pulser tests. (XXXX)

28. Is there any way that we can prevent the signals from saturating the vertical scale on the scope?

    Set tunable N(sigma)

29. CHANGE FRONT PANEL TO UPDATE HORN VETOES TO CHS. "26, "27, "28, "29 (vs. old "13, "14, "15).

30. Study of efficiency as a function of coincidence time window, so that we can lower 1.2 us trigger window and thereby lower noise backgrounds. (*)

31. Play with h*(omega). Given data for —h—, use different models for variation of phase with angle to determine how different the signal might look at 3412E. (DJ/transfer function)

32. analyze Tx data and also surface noise - is the azimuthal dependence consistent with shielding by AM cables? (Butch)

33. analyze Tx data - do amplitude analysis on pulser data, using measured effective heights, etc. (Butch)

34. Merge MC signal and unbiased background events. Generate a channel-to-channel efficiency to use in MC, determine change in efficiency by merging background. (*)

35. Add hadronic shower to shower simulation and C-pulse signal strength. (soeb)

36. Need event reconstruction, per se, in data and MC. Need to make data and MC look identical prior to event reconstruction. (XXXX)

37. Determine how often we would veto true neutrino events by incorrectly classifying them as surface noise. (lori?)

38. Look at FFT's before and after a signal comes through and see if there is any sign of saturation. (*)

39. Determine occupancy in unbiased events. (*)

40. TDC/waveform correlations. Are times of TDC hits consistent with our model of the DAQ timing? (XX)

41. Correlations with GRB's/auroral discharges/ion trails (after calibration) (XXXX)

42. Amplifier gains - day vs. night; do we see the sun? (*)

    "Quiet" sun: S/$N_{\mathrm{thermal}} \sim .05$. Compensate by using dish behind dipole.

43. Look at correlations between receivers on the same string, and noise levels thereof - measure correlations in the lab. (XX)

44. figure out what's happening with relative scope/tdc timing; (XX)

45. Systematic study of channel-by-channel response Alternately - use George's monte carlo as input to model of antenna+cable+etc. See whether we match data with our model. (George/Butch)

46. Finish event viewer (IDL). Or can we steal the AMANDA event viewer and adapt it to our needs? (XX; requires C++)

    Option to change axes on event viewer to automatically take into account propagation time through cable; change scale of event viewer to automatically take into account losses through cable. (craig?)

47. Transparency issues: Analyze the CW surface horn data taken on jan. 13, 1999 to get direct information on transparency through the firn (and n(z)) (XX)

    Pick up radio work from UT, Austin to give more information on firn transparency. also, get in touch with joan fitzpatrick and finally use density data, etc. to extract n(z) at pole. (XX)

    Transparency using pulser data. (XX)

    Transparency using UT data, Greenland data.

## 11.7 Monte Carlo Modeling Issues

1. Need to install full MC at KU (XX)
2. What is our directional resolution? (XXXX)
3. Determine which channels should be trigger channels, which should be TDC channels, which have waveform information, what 3412 and 3412E thresholds should be. (XXXX)
4. Additional Monte Carlo simulation studies which estimate the sensitivity of the upgraded RICE detector to neutrino mass oscillations, in the $\Delta M^2 - sin^2\theta$ plane ($\Delta \equiv$mass difference between mass eigenstates; $\theta \equiv$mixing angle between different weak eigenstates). (XXXX)
5. Study of Monopole sensitivity (as per Weiler/Wick hep-th preprint). (XXXX)
6. Testbeam Monte Carlo (XXXX)
7. For RICE MC, plot efficiency as f(energy), i.e., yield for a power-law spectrum as a function of energy. array optimization for 99-00, and beyond, via Monte Carlo. (GMF)
8. Response of current detector/event rates for different models, AGN, stopping showers (XXXX)

   Francis claims a rate of $10^4$ per km2 per year for downcoming showers stopping in the ice. Can we separate this pulse (1-3 per day) from MAPO noise? (XXXX)
9. Optimized AMANDA overlap. What Delta t is best? Should we put in a delay? Ditto for SPASE. What are expected overlapping signals (particularly cascades and tau neutrinos). (XX)
10. Overlap with auroral discharges? (ion trail - peter gorham idea; can we see the radio echo from cascades?) (XX)
11. What is the ideal/optimal trigger rate vs. veto rate vs. prescale rate (get a UG to model this), given the amount of time required to write an event out (c. 0.75 sec/scope). (XX)
12. What is the potential for salt domes? (XX)

### 11.8 Known instances where Monte Carlo sensitivity estimated conservatively

13. trigger efficiency lower since does not include noise.
14. Used GEANT rather than ZHS power estimates
15. Signal from neutrinos only from upper half-hemisphere.

I just tried calling you, but to no avail. I don't quite understand your model of how this works, but I'd like to. For my own edification, I've tried to summarize where we are below. Hopefully, butch can fill in the blanks and correct my errors.

a) scope-52 dB amp-terminator gives 54.8 dB amplifier gain. I believe this is flat as a function of frequency, consistent with the flat spectrum expected for thermal noise. The fact that we get something larger than 52 dB is, I think a result of the noise figure of these amps. According to MITEQ, these amps have a noise figure of about 1.8, which means that they generate about 80% more noise above thermal at the output. This is about a 2 dB effect. GOOD.

b) scope-52 dB amp (open ended) gives 49 dB amplifier gain. The amplifier evidently amplifies it's own internally generated noise, although "nominal" gain at spec evidently corresponds to something attached at the input end of the amp.

c) scope-52 dB amp-36 dB attenuation-36 dB amp (on) gives 55 dB gain, consistent with a). GOOD.

d) scope-52 dB amp-filter-cable-36 dB amp (on) gives 65 dB gain, inconsistent with a). George's model is that the 36 dB amp is amplifying thermal noise, and that the heat energy somehow makes it to the surface amp. However, why don't we see this in c)? If this is true, somehow the filter+cable is behaving differently than the attenuators. Additionally, the heat energy must be changing its frequency spectrum somehow, in order to get past the filter (have we checked that this filter does, indeed, work? Eben has spec'ed out one filter; we should check this one, also).

However, it is suggestive that, when the gain of the deep amp plus the surface amp is calculated in a higher frequency bin, that the total gain of deep+surface amp comes out to be 65 dB + 23 dB = 88 dB, which is, remarkably the sum of the spec'ed gains for the amplifiers (52 dB + 36 dB). This is an intriguing coincidence; there is probably some clue buried here. It isn't clear to me how this jibes with George's model. NOT UNDERSTOOD.

e) scope-52 dB amp-filter-cable-36 dB amp (off) returns us to nominal gain.

f) Darryn runs a test at the Pole, where he turns off the deep ice amps and then takes data (unbiased triggers, correct, george?) with only the surface amps. This should be similar to configuration e) above. However, George only measures 42 dB gain or so, for all channels. (ARE WE SURE THAT DARRYN RAN THE SURFACE AMPS AT THE PROPER CURRENT FOR THE SURFACE AMPS AND NOT THE DEEP-ICE AMPS?). The gain is, however, remarkably flat for the 52 dB amp channels. NOT UNDERSTOOD. BUTCH SHOULD REPEAT GEORGE'S ANALYSIS WITH HIS (BUTCH'S) SOFTWARE AND VERIFY THAT HE GETS 42 dB GAIN. CERTAINLY, BUTCH SHOULD REPEAT THIS ANALYSIS AT THE POLE THIS YEAR. Another dumb question - the calculated gain is insensitive to the sampling rate of the scope, correct? I just want to make sure, since it very well may be different between the lab here and the situation at the pole.

So the big outstanding questions are: i) where the extra 12 dB of gain is coming from when we use filter+cable rather than attenuators (George has a model for this; I would like to understand it better), ii) why do we measure only 42 dB of gain for the surface amps at the Pole?

Other comments -

g) from George's studies, it seems like the impedance mismatch between the antenna and the amplifier doesn't matter in calculating the thermal noise at the pole - his thermal noise frequency spectrum is claimed to be flat (we would expect to see the frequency dependence of the impedance mismatch here, I think). However, from butch's study b) above, even if the antenna were disconnected, we would still expect to see something like almost nominal gain, so this is not very troublesome (not yet).

h) the 52 dB amps will saturate, according to their specs, when the output power gets to about 8 mW. If we look at a V(t) plot, this corresponds to something like $< V^2 >/50$ Ohm=.01, or $< V_{out} >\sim 0.7$ V, or $V_{in}\sim .0015$ V. We can go one step further and compare this to the output of the 36 dB amplifiers, for a 300 K thermal noise input, and 1 GHz bandwidth: $4kTB \sim< V >^2/50$ Ohm, or about $31\mu V$ (George and butch have done this calculation a million times, I'm sure). If we add the noise figure of the 36 dB amp, and then amplify this thermal noise by 18 dB in voltage (x80), we are at 37 mV. If there were no cable between the two amplifiers, we would saturate the 52 dB amplifier with thermal noise. It is, on the other hand, very likely that for the large "fishtail" events, we are almost certainly saturating these amplifiers... In general, saturation is obviously a bigger effect than we had previously considered (as hopefully, DJ will tell us more tomorrow, since this is the only way I can understand some of the plots he made today.).

One more comment, to george, who asked about how to handle random noise yesterday. The usual approach in HEP is to take Monte Carlo signal events and merge them with unbiased triggers from data, to see how a superposition of MC signal with background will affect our efficiency/etc. One then goes ahead and makes something like a table of signal reconstruction efficiency with and without noise, as a function of neutrino energy and distance from the array. So, although this is a laborious procedure, and probably much more intricate than I have depicted it here, I think it is a plausible procedure...

a typical surface-generated noise event at pole generates a signal with a typical voltage of 1 V, peak-to-peak, and a decay time of 15 ns (I'm recalling this from memory, if anyone has better numbers, that would be good). I'll assume that the transient which generates this signal at the input to the deep amp is a very narrow ($\sim$1 ns) pulse, and that the surface amp sees the smeared 15 ns pulse.

Given that, the total power output the back end of the amplifier is given by the integral of $< V_{out}(t) >^2$/R over that 15 ns period. I'll take $V_{out}(t)\ 1V exp(-t/15ns)$ (the effect of the power splitter and taking $V_{peak}$ rather than $V_{rms}$ cancel each other), and the total energy output from the amplifier $int(< V(t) >^2\ /50dt) = 150x10^{-12}$J; dividing by 15 ns, we find the average power at the amplifier output is then 10 mW, which is almost exactly the saturation point of the surface amps. It may therefore be that the true signal strengths get larger than 1 V, but we only see 1 V maximum voltages due to amplifier saturation.

Note that this is even after filtering noise below 200 MHz. For the in-ice amps, which have no 200 MHz filter, the situation is more difficult to estimate. We can work backwards, optimistically assuming that the surface amps are not saturating, and taking an average cable loss of  22 dB, so that the signal at the output of the deep-ice amps is then 30 dB lower than 10 mW, or .01 mW. Two factors can potentially get us the factor of 100 that we would need to put the in-ice amps into the saturation regime: a) inclusion of the noise power below 200 MHz (including the 149 MHz line, which I recall was quite large and which I think was one of the primary motivations for installing the surface filters), b) we have always attributed the shape of the observed V(t) signal to the finite bandwidth of the antennas, however, it may be that some of the "ringing" that we observe may be due to the amplifiers themselves - i.e., the signal that the in-ice amp sees at its input may be narrower than 15 ns. If it is, e.g., 1.5 ns, then the power into the deep-ice amp scales up by a factor of ten. (I'm not sure what definition of "bandwidth" here to use; there are, unfortunately, different ones found in the literature - defined relative to a power reflection coefficient, the bandwidth is narrower than defined relative to the gain, for which the antennas are, according to Eben and DJ's measurements, $\sim$700 MHz in bandwidth. I *think*, although I'm not sure, that the latter definition is the convention)

If my math is correct (very possibly not, although I've checked it), then my conclusion is that we may be saturating both amplifiers on transients. What I don't know is how often transients come (the fact that we are vetoing at about 25 Hz with a discriminator threshold of -0.15 V indicate that we aren't seeing 1 V signals more often than 25 Hz.) If the recovery time of the amplifiers is something like 100 us - 1 ms, then if booming transients are coming at 100 Hz, we are in a saturation regime somewhere between 1-10

Again, three studies that would be very helpful would be to take data with an "unfiltered" channel (97RxG is simplest for this), to look at the occupancy in unbiased events and to look at the power/amplitude spectrum in transient events.

# References


[1] "RICE Receiver Design 2002" document.

[2] "RICE Online Analysis Manual" document.

[3] C. W. Harrison and C. S. Williams, IEEE Trans. Anten. Prop., **AP-13**, 236 (1965)