8.812 Graduate Experimental Laboratory
MIT Department of Physics
Aug.2009 U.Becker

1. **Exp. #5** Angular distribution of cosmics

Measure the angular rates by two methods, using time differences. or tilting the two counter setup.
Supplement both measurements by Monte Carlo predictions and compare to data. Learn acceptance calculations, coincidence measurements, (a bit about air showers).

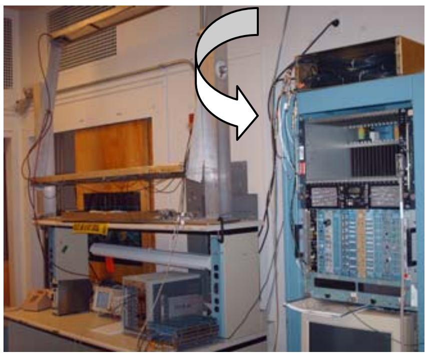


Fig.1 Double ended modern counters for dual measurement of cosmic angular distribution in 44-007

Preparation

1. How and where are the muons generated? Estimate a cross section and determine the height and roughly the energy spectrum in the region 1-10 GeV
2. a)Give the muon spectrum more detailed assuming the incident protons are ~ $E^{-2.75}$ in the interval 2-200GeV. b) Are their directions isotropic? Consider the acceleration mechanism and magnetic fields of 5 μgauss. c) Compare your estimate with the literature.
3. Using the PDG estimate the energy loss of muons in: i) the atmosphere ii) 1m concrete of the roof, iii) 100m of water.
4. Consider the earth atmospere as 1bar exp(-height/8km) to predict the angular distribution
5. The earth magnetic field can be modeled as an 150kn offset dipole[ref IGRF] It will deflect incoming primary protons so they may not interact with the atmosphere. Estimate the “Cut off energy” by not allowing them to get closer than 20km to the earth surface for i) at the magnetic equator, ii) boston, iii) the magnetic south pole (where?)
6. Can you give reasons, why there might be “tails” at 0, 180 degrees?

Physics

By sending up a balloon with a counter V.Hess discovered cosmic rays.Deceived by Yukawa's estimate of a particle (pion) interacting with nuclear matter in the vincinity of 100MeV/c^2 mass muons were first mistaken for the pion. However then it should have interacted before it reached sea level, or there should have been an incredible amount going up with the balloon, which was not the case. Accepting that this was not the hadronic pion but a leptonic muon with spin 1/2 the question arose for the neutrino partner with spin 1/2. Demanded again also by missing energy in pion decays generated by accelerators this muonic neutrino was discovered at Brookhaven [   ] by re-creating a muon from a neutrino beam of decayed pions. This processes in cosmic atmospheric neutrinos play an important role in today's neutrino oscillation experiments[ ].

Measurements

1. Attenuation along the counters
   Scintillator also absorbs the light. Having photomultipliers at both ends the signal heights will be usually different and may allow a rough determination where the muon went through. A source will be moved to do this.
2. Using a third counter the plateau-voltage for each counter and photomultiplier end will be determined and set to an efficient, but not too high value.

3 Determination of timing differences. Moving a collimated source along the counter similar to point 1. the arrival times can be compared. This will measure the speeed of light in the scintillator for averaged over different paths ,including reflections and light collection.

4 Measure the coincident rates of two different counters spaced a distance d and compare to estimates.

5 Take time and pulse height distributions for two settings of d.

6 Obtain the angular distribution by rotating the frame in ~10 degree increments

7

Schedule

The net time depends on your scheduling/speed of initial evaluation, which we recommend to do immediately in the log book for example for the "Set Voltages" but also for the other measurements 1-3..

Day 1 Get familiar with the setup. Explore the measurements 1 and 2.

Day 2 Complete the setting voltages of the gain, tracking the discriminator thresholds and the "single rates..

Day 3 Set the counter to a close distance and obtain coincidence rates which compare to your calculations Take overnight runs if possible

day4 Choose another d distance and record times and pulse heights for all four channels. Take overnight runs if possible

Day 5 Use a large d and measure the rates by tilting the frame.

Setup:

2 AMS scintillators 136x11cm^2 and 2 AMS scintillators 72x11cm^2 all are 10mmm thick [10]

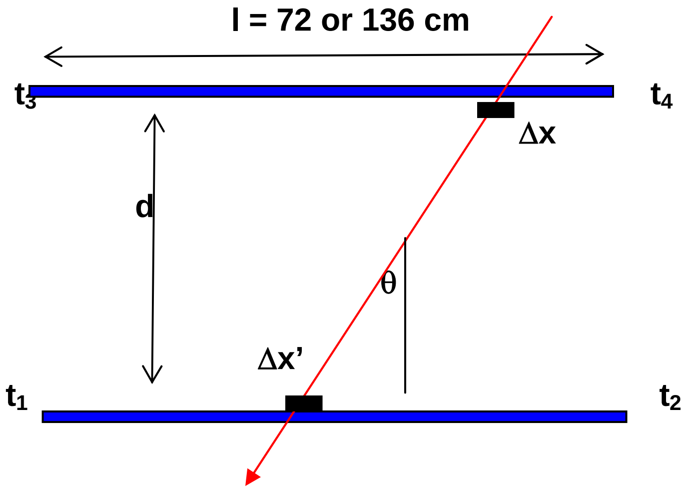


Fig.2 Setup for method 1. θ is measured by time differences and confirmed by amplitude data

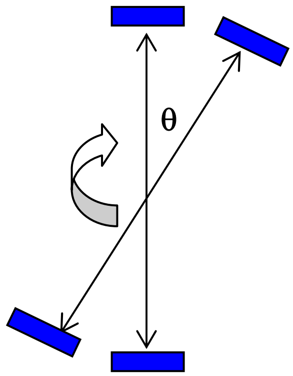


Fig. 3. Setup for method 2. Simply rotate the frame by θ

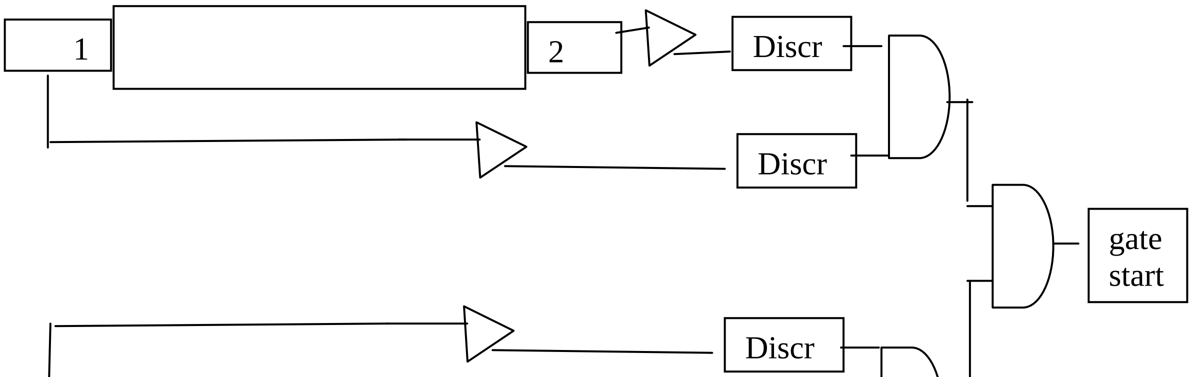


Fig.4 Trigger logic . The fourfold coincidence initiates a “start or stop” signal for CAMC recording. Note; it fires when the last of four signals comes in.

The “high Z” LRS discriminators have the **input** either terminated to 50Ω or send to a device wit 50Ω termination. Here we send the analog signal further to the ADC unit for amplidude recording. The discriminator has three outputs. One of each is used as shown in fig.4, another is send to the CAMAC TDC , see Fig.5, and the third you can use for oscilloscope monitoring.

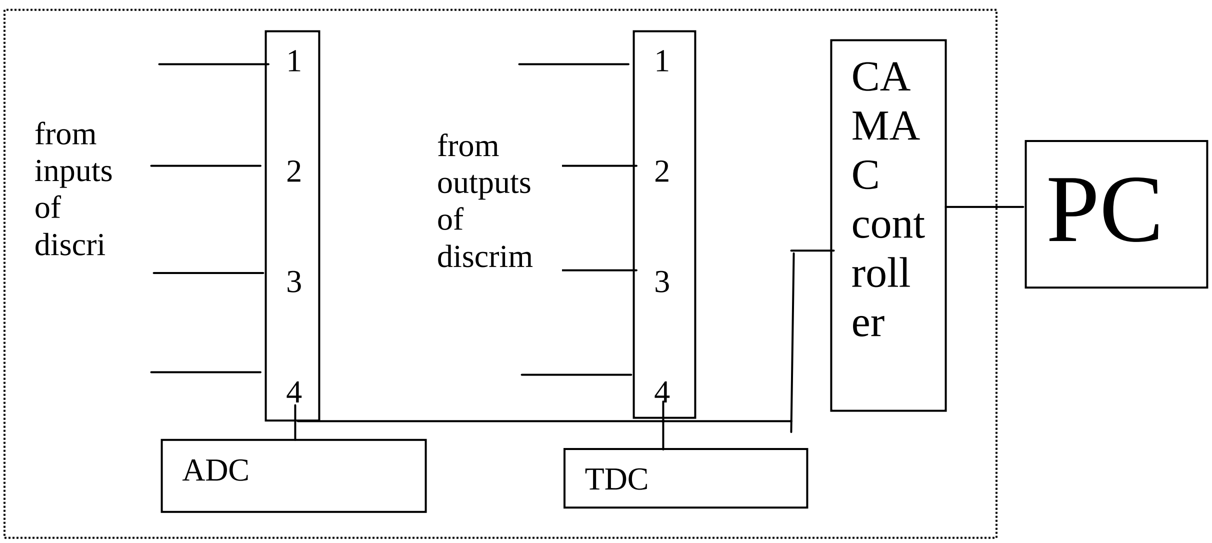


Fig.5 Data aqusition located in a CAMAC crate

Results aimed for

Determination of Δt to Δx conversion, compared to amplidude differences
Recording of cosmics in absolute rate.
Proper acceptance calculations in comparison with actual measurements.

The TOF resolution which can be obtained with state –of the-art scintillation counters.
The angular distribution according to method 1.
The angular distribution according to method 2.

Guide to analysis

Start with calibrations:

Are the counters well plateau-ed? see non ideal fig. 9.Given the geometrical size a rate estimate was done beforehand expecting ~500 counts in the time interval. Rising the voltage of the counter under question in coincidence with another ,independent one underneath with fixed voltage

the curve was obtained. Whereas the rate at the knee is ok it keeps rising, which is assign that “accidentals” due to increased noise come in and after 900V increase exponentially.
For a better procedure see appendix A.

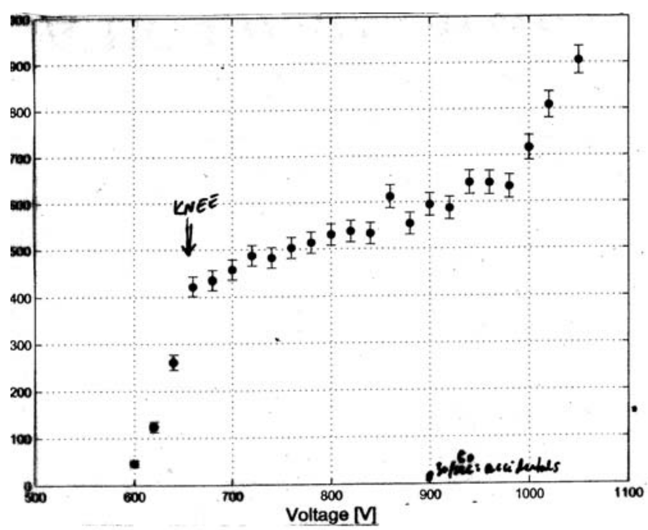


Fig.6 Not-so- good example of a plateau determination, but sufficient

In method 1 you will demonstrate the correctness of your acceptance calculations for different spaceings d (104.52.12 cm or your choice) by showing the angular distribution agrees in overlap region. and absolute rate fig.10 shows an early measurement using the smaller counters 14.5 cm apart.

Fig.7 gives a sample experiment. Notice that the horizontal error bars Δx were converted into vertical errors by the local slope and added in quadrature to the counting errors. Other error evaluation can be used, for example convolution with the spatial resolution.

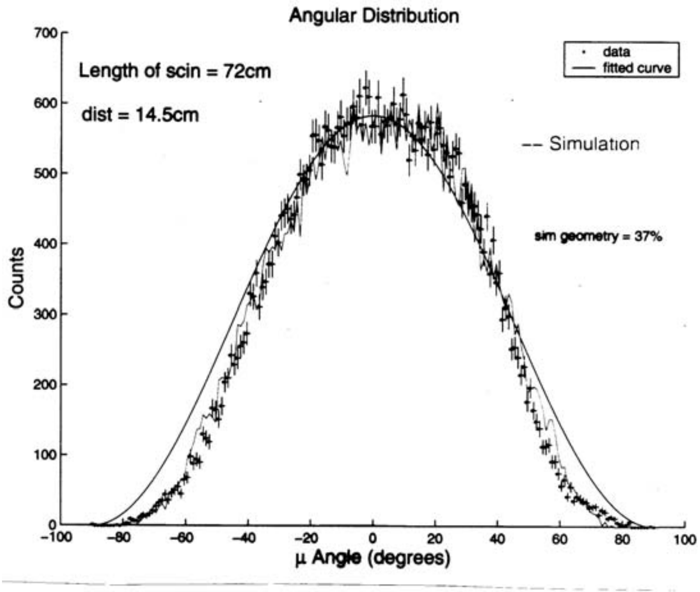


Fig.7. Measured cosmic rates with data as points, A Monte Carlo calculation is given by the jagged curve connecting statistically fluctuating points with an assumed angular distribution.

Your paper

Try to stay within 8 pages figures included. Latex recommended, but not required. Close to PRL format. We recommend the classical sequence:

- WHY this experiment (Physics)
- WHAT was done (this paper's experimental approach)
- WHICH accuracy was achieved (errors)
- WHAT was learned?

In other words, a WWW(W) approach.

References

[1] PDG C.Amsler et al.Phys.Lett. B 667, chapter 24,(2008)
[10] The Alpha Magnetic Spectrometer (AMS) Phys.Report Vo; 366,#6,aug.2002, p 333-401

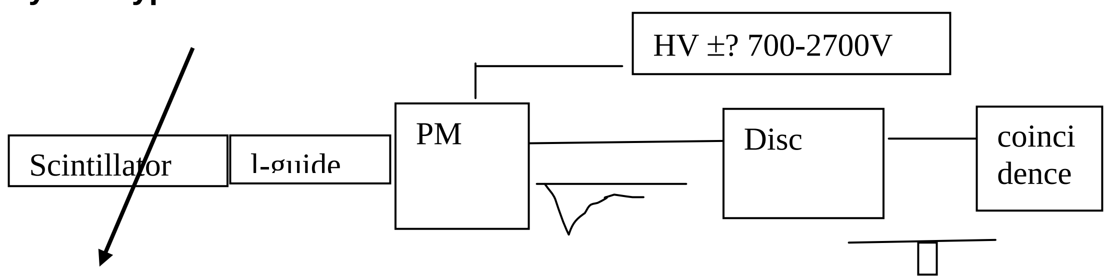
Appendices

A. How to plateau a scintillator and determine the efficiency

scintillation counters are used to detemine that a charged particle passed through them at a given time. This is in form of a digital signal “yes” = a standard pulse from a discriminator. Several features determine whether the signal is large enough to create a logic signal:

a) The dE/dx by traversing the counter ie the thickness
b) The efficiency of the scintillaror – ie the ability to avoid self absorption, see PDG
c) The collection of the shifted light – absorption length in the scintillator, light guide
d) Cathode efficiency for photoelectrons 5-24%
e) Threshold of the discriminator

Anatomy of a typical counter:



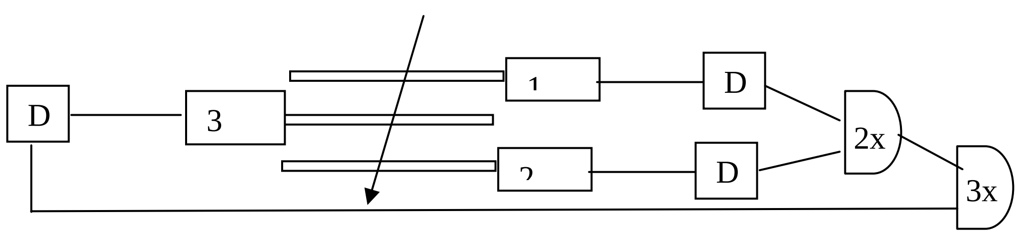
dE/dx = 2 MeV/cm glue joints 2^n .1-1V .03 –1V NIM -.8V

$5x10^5$ hν 10^{-2}hν’ 10^{-1} 10^{-1} = **50** ± **7** 50Ω Thresh. logic

photons scint.- transmit–photocath- PM gain termination .

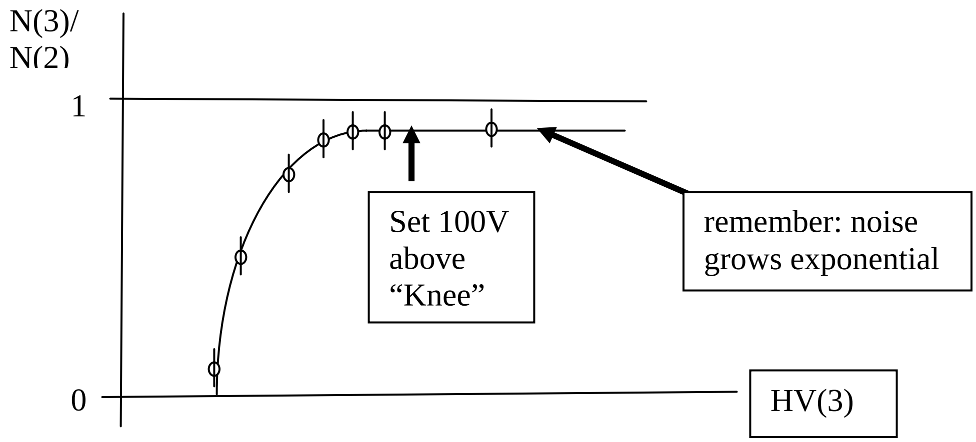
Plateau

Vary the HV until the counter is efficient - is easy to say, but may be obscured by noise. Noise may come from the thermal liberation of electrons from the photo-cathode, the resulting pulse height spectrum will fall exponentially. The presence of a particle is best sensed by two (not necessarily optimized) counters 1,2 located above and below the counter 3 which is to be tested.



Typical setup with coincidences, assuming you checked the correct overlap of the logic pulses. Discriminators usually let you adjust the output width.

As a function of the HV of 3 we see a plateau in the ratio N(3x)/N(2x):

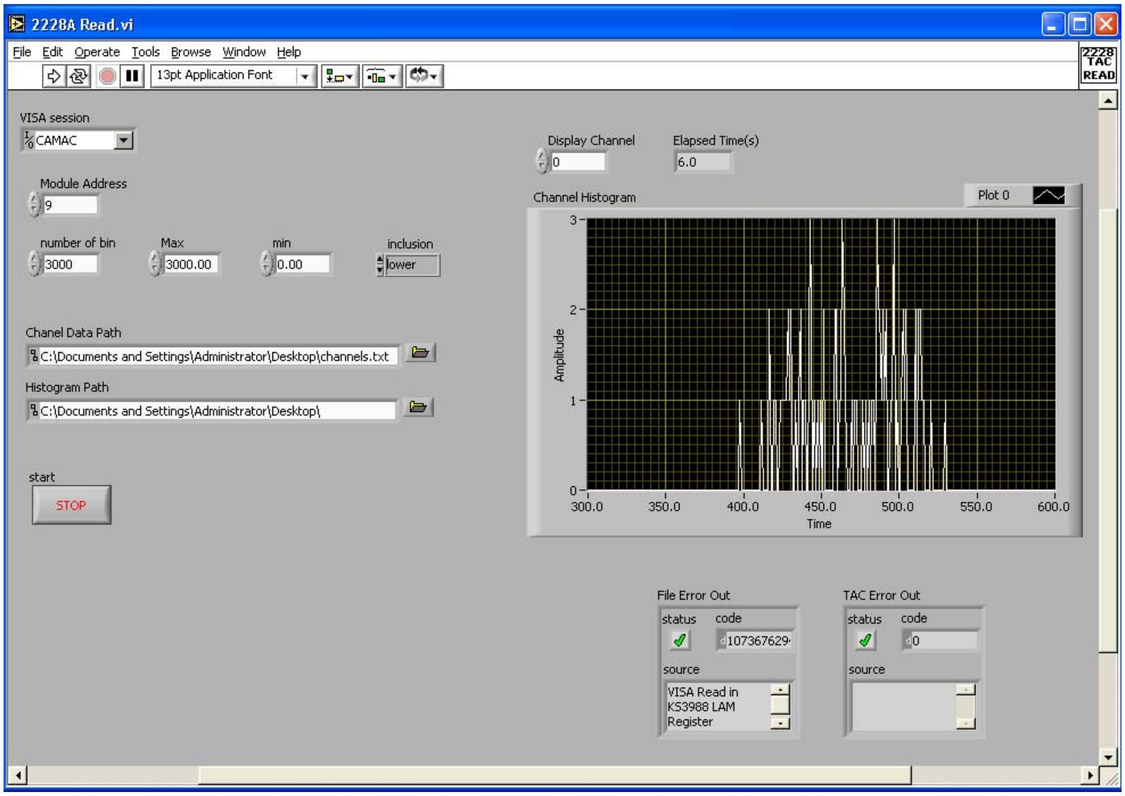


Good plateau curve, if the inefficiency (deviation from 1) can be explained by mismatched geometrical overlap.
Small error bars at the “knee” are mandatory. The set voltage conveniently should be written on the counter. If it changes the counter is damaged.
If counters 1 and 2 trigger only particles which **Must** go through 3 the ratio should be 0.999 unless the inefficiency can be attributed to lack of statistic. Example: If the counter produces on average 9 photoelectrons the inefficiency is e^{-9} very small. However at the far end of, say a 2m long counter with attenuation length of 2m we would have e^{-3} = 5% inefficiency.

B. Computer time recording

Computer
Username: administrator
Password: amorphous

2888A TAC Readout Program
Program Path: Desktop/8.812/2228A Read.vi
Front Panel



Functionality:

This program is used to read the data from a 2888A TAC module in a CAMAC crate. The program will read the data after the digitization completes, clear the data registers in the TAC, and then is ready for next readout. The program will run and extract the data continuously and display the data in a histogram. The user can choose which channel to be displayed by changing the field "display channel." The elapsed time will also be displayed on the panel. Once the STOP button is pressed, the program will stop reading the data from TAC, and will ask the user to save the data. The file paths can be specified in the data path fields. Two files will be saved. The first one, the channel data, will contain all the raw data from all 8 channels of the module. Eight columns represent the 8 channels of the TAC. Another one, "histogram", will contain the histograms of all 8 channels. The data file will be a text file, which can be imported into matlab for further analysis. Histogram will have 8 rows, representing 8 channels of TAC.

Notice that the program will read all eight channels of the TAC, whether the channel is connected or not. Unconnected channel will cause overflow, and the data reading from that channel will be a large number. Because of the nonlinearity in the range larger than 3000, the user should keep the measurement in the range less than 3000. Therefore, the user can simply limit the range of interests to be less than 3000 and discards all the data larger than 3000, and thus the data from unconnected channel will be discarded.

There are a few input parameters of this program.

VISA session: The GPIB address of the instrument, or CAMAC crate controller in this experiment. Default is "CAMAC", which is a alias of "GPIB::0::0::INSTR".

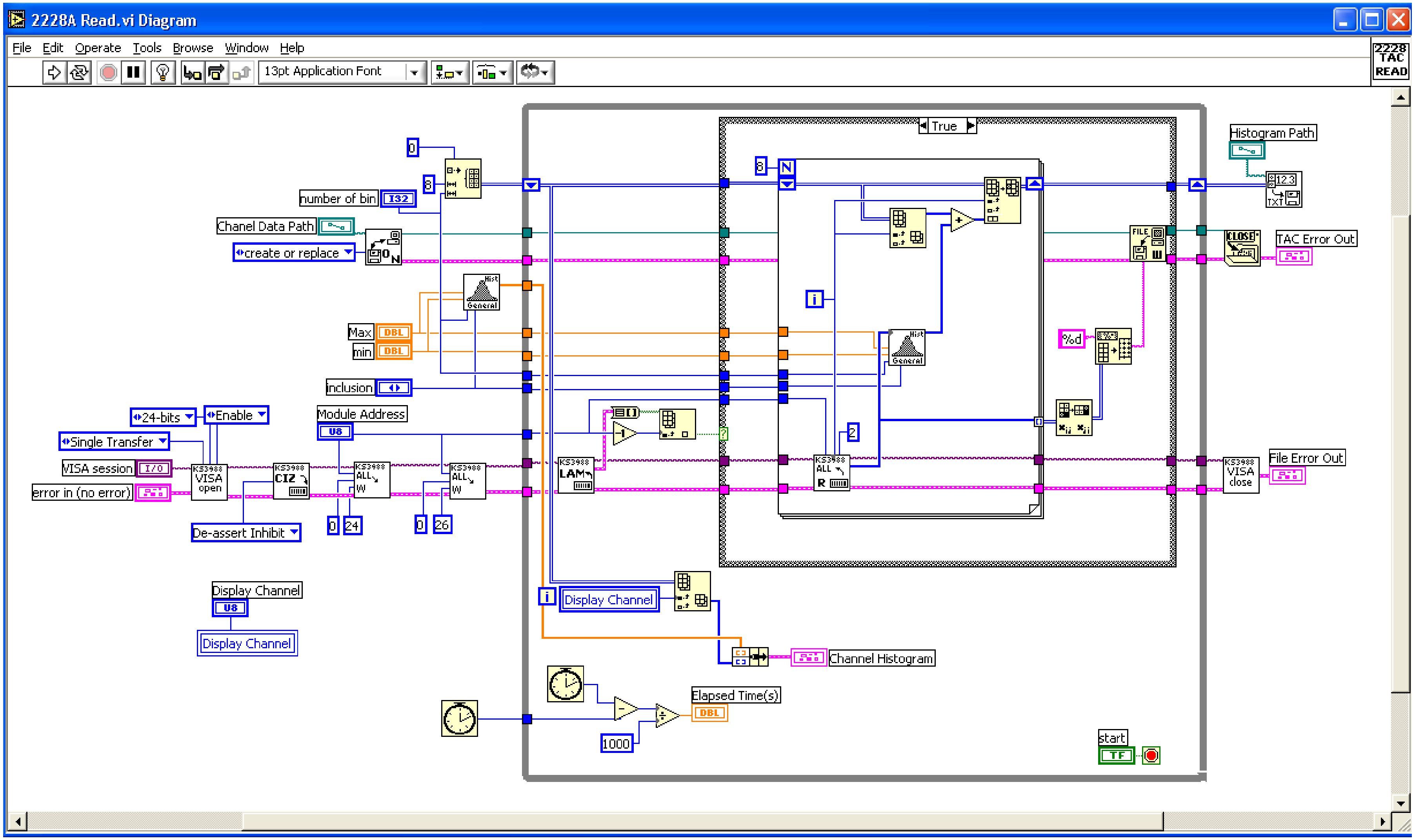
Module Address: The address of TAC module in the crate.

Four of the parameters are used to control the histogram: number of bins, max, min, inclusion.

Number of bins: how many of bins in the histogram
Max, min: the range of histogram
Inclusion: if the bins should include the upper or lower boundary

Notice that after the program starts, changing of these four parameters will not have any affect.

When you close the program please **DO NOT choose "save the program."** The backup program can be found at Desktop/8.812.zip.


2228A Read.vi Diagram
File Edit Operate Tools Browse Window Help
13pt Application Font
2228 TAC READ
number of bin
Chanel Data Path
create or replace
Max
min
inclusion
Module Address
24-bits
Enable
Single Transfer
VISA session
error in (no error)
De-assert Inhibit
Display Channel
Display Channel
True
Histogram Path
TAC Error Out
File Error Out
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Display Channel
Channel Histogram
Elapsed Time(s)
1000
start