MUON LIFETIME AND COUNT EXPERIMENTS
S.C.I.P.P. INTERNSHIP
PROGRAM SPECIFICATION

July 2007

assembled for

the Santa Cruz Institute of Particle Physics
University of Santa Cruz, California

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Working Draft

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PREFACE

This document specifies the structure and requirements for the Muon Lifetime experiment and the Muon Altitude Counts Experiment. The Counts experiment may be referred to as Atmospheric Experiment, Aerial experiment, and ADOM. SHALL, MUST, SHOULD specify mandatory courses, actions, and logic. CAN, OPTIONAL, MIGHT are to be treated as suggestions. When not stated, treat as highly recommended.

1. INTRODUCTION

1.1 Motivation

The Muon Lifetime experiment and Atmosphere counts are assigned programs given out by Fermilab with the express concept of building a world map of Muon intensity at different altitudes and locations. Groups are supplied with the equipment to build a four panel muon scintillator and a light, one-panel scintillator for suitable for flight in the atmosphere. The programs for an analyzing the data are specified within this document, and must follow the specified objectives.

1.2 Scope

The scope for the two programs are not very large. Although the initial raw data will exceed over 1,500 lines, the finished data will either allow one to, or in later versions, compose one bar graph and two line charts (ground data and sky data).

2. OVERVIEW

2.1 Relation to other projects

The Muon Lifetime experiment and Atmosphere counts are the most common projects for non-Fermilab personnel involved with Quarknet. Quarknet is tasked with managing the finished data from participating institutions into a database. The data analysis programs described are related only in usable output they produce, and should be considered separate from other analysis programs.

Quarknet, at this time of writing, is attempting to compile a geographical database of muon counts in the atmosphere. Along with altitude, one may be able to compute in the future what the world looks like in particle distributions.

2.2 Objectives

The primary objectives this document hopes to achieve is the formation of working data analysis programs that interpret and prepare data for human interaction and exceed the level of accuracy accomplished with manual data conversion.

3. SPECIFICATION

3.1 Data Format

Raw data is 16 Hexadecimal encoded DWORDS. The raw format is as follows:

ticks	ch0s	ch0e	ch1s	ch1e	ch2s	ch2e	ch3s	ch3e	pps	time	date	state	sats	stat	alt

Legend:
Ticks: Hex encoded, time between tick is 24ns.
Ch (0,1,2,3)s: First half of channels (0-3). Only channel 0 can "trigger" an event.
Ch (0,1,2,3)e: Second half of channels (0-3).
pps:Pulse per second. Not understood fully by author at this time.
time: GPS onboard time, accurate to the second. DAQ time is achieved through adding time offset to gps time.
date: encoded as month/day/year. Example: 080803 is August 8, 2003
state: GPS status. In all cases this should be 'A'.
sat(ellite count): number of GPS satellites communicating with DAQ
daq (status):

- 0: no 1PPS pulse pending
- 1: trigger interrupt pending
- 2: GPS data OK
- 3: CPLD frequency OK

Should be at either 2 or 3.

alt: GPS altitude

EXAMPLE DATA SET:

```
          0 0  1  1  2 2 3 3 <- scintillators
----------------------------------------------------------------------------------------------------
80EE0049  80 01 00 01 38 01 3C 01 7EB7491F 202133.242080803 A 04 2 -0389
80EE004A  24 3D 25 01 00 01 00 01 7EB7491F 202133.242080803 A 04 2 -0389
80EE004B  21 01 00 23 00 01 00 01 7EB7491F 202133.242080803 A 04 2 -0389
80EE004C  01 2A 00 01 00 01 00 01 7EB7491F 202133.242080803 A 04 2 -0389
80EE004D  00 01 00 01 00 39 32 2F 81331170 202133.242080803 A 04 2 +0610
```

The trigger for the start of the event is here:

80EE0049 **80** 01 00 01 38 01 3C 01 7EB7491F 202133.242 080803 A 04 2 -0389

Ch 0s must be equal to or greater than 80 (decimal value 128) to be a start tag.

The end for the event is more complicated.

80EE004D 00 01 00 01 00 **39 32 2F** *81331170* 202133.242 080803 A 04 2 +0610

When channel 3e drops to 0 after spiking, that is the end for an event.

3.2 Muon Lifetime

3.2.1 Rules

There are several rules that must be met.

For the Muon Lifetime experiment:

1. Valid Muon instances must have a life time greater than or equal to three microseconds and less than or equal to ten microseconds.
2. An instance is the time distance between the end of the first event and the start of the next.
3. Counters keep track of similar life time events, e.g. 500 instances of muon events with a similar life time of 8 μs adjust the counter for 8 μs to a value of 500.
3. A counter is defined by if the criteria (in this case, time) is met by a particular data event, then said counter is adjusted to reflect the occurrence of said event.
4. Data must be 'binned' for integration into spreadsheets and graphs.
5. For every valid event, two values must be produced: the time frame of the muon decays (the counter object itself) and number of muon decays (the numerical value of the counter).

3.2.2 Methods

The experiment measures the death time between "single" events. A single event is defined by a pulse spike in one, and only one, start channels. Channel 0 will most commonly be featured, with it's special >80 spike in Ch 0s. One and only one channel can be excited with a charged particle. Very rarely, the scintillator will see two or more channels excited simultaneously. In this case, it is not one muon, but two, and shall not be counted.

The logic must function as follows:

- Muon passes through scintillator 1.
- Search for trigger
  - If more than one complete channel shows a pulse, then search for next start trigger.
  - If only one channel is excited and event ends, then record the end trigger for that event and look for next trigger.
    - If next start trigger is more than .5μs away from previous events end trigger and less than 10μs from it, add one to counter value, whose name corresponds to the time.
    - If start trigger is less than .5μs away from previous trigger or greater than 10μs, then use the current events end trigger and judge the distance to the next start trigger.

In a sample scenario, Muon A hits scintillator 0, and excites it. A doesn't excite any other panel in our ideal experiment. The length of the data must be greater than a user defined time (in this case, .5μs). 5μs later after A ended, Muon B hits panel 3. We take the time (5μs), make the counter "5μs" variable, and add +1 to it. Ironically, after the user defined time is passed from Muon A, Muon B can excite any panel, but like A, can only excite one, and only one, channel.

3.3 Atmosphere counts

3.3.1 Rules for Atmosphere counts

For the Atmosphere counts:

1. The measurement is events per two minute.
2. An event is merely a start trigger.
3. Two minutes of time is $2 * 60 * 10^9$ nanoseconds.
4. One tick is 24ns.
5. Every 2^{32} ticks, the tick timer resets to 0. After every reset, the program must add $(x)*2^{32}$ ticks to the tick timer after each sucessive reset, where x is the current count of resets.
6. The program must be able to “ignore”a set amount of seconds in the beginning to compensate for start time offsets as a run time option.
7. The user must be able to change the interval time and the counter roll over variables within the program.

3.3.2 Methods

The program must read the program line by line. With each line, it must pass the data through a hexadecimal to decimal converter, and feed that data into an array. While the program reads and converts lines of data, it must at a specific tick count set the interval counter to reflect the interval of time it has read, therefore it must be able to express to the user the muon counts for each successive two minute interval.

GLOSSARY:

DAQ: Data AQuisition Unit
ns: nanosecond

REFERENCES:

DAQ Manual - http://scipp.ucsc.edu/outreach/internships/2006Internship/Resource/Qnet2-daq-manual-2b.pdf

WALTA/DAQ Specs:
http://neutrino.phys.washington.edu/~berns/WALTA/Qnet2/misc/DAQ_output_format.txt

Specification guide - ftp://ftp.rfc-editor.org/in-notes/rfc791.txt