Data Rates - **S. Pordes 9/16/08**

The signals from the sense wires are digitized continuously to 12 bits at a rate of say 5 MHz. The Liquid Argon TPC generates a continuous stream of 12 bit numbers, one stream for each of the 10,000 wires (total) of the TPC. Each number is a `sample' and the collection of one sample at the same time from the complete set of wires is a `frame'. The information from a single interaction is spread over many frames. I assume 4 milliseconds readout so 20,000 frames make an `event'.

There will be certain signals external to the TPC wires (I want to avoid the word `trigger') whose timing can be used to define the frames that constitute some of the events. These signals are `markers'. Examples are the beam-spill or a cosmic ray seen by a scintillator. Other markers may be derived from the wire-data themselves either in-line (ie as the data come from the wires) or off-line (by examining archived data). The data collection is expected to be able to run without regard to the external markers which will be used as flags.

There are 5 x 10^10 samples per second coming from the detector. An event (4 milliseconds) is about 2 x 10^8 samples, most of which are pedestals. It would be useful to be able to record several milliseconds of raw data at the full rate but that should be enough. Any sensible system for normal conditions will implement pedestal suppression and probably some form of compaction.

Cosmic rays are the main source of non-pedestal signals on the wires. Their rate into the detector is about 6 kHz and each cosmic ray can be expected to generate signals in a total of 2000 wires with about 100 useful samples per signal per wire. A single 4 millisecond event will contain 24 cosmic rays generating a total of 4.8 x 10^6 samples. Fully live there will be 1.2 x 10^9 samples (12 bits) from cosmic rays per second.

There are several ways to reduce the amount of data written without losing information. The ICARUS people tested a scheme that records the differences between successive samples on a given wire. With 12 bits per sample we would probably use 5 bits for the differences and may achieve a reduction of a factor 2, giving 4.8 x 10^6 x 6 bits or 3.6 x 10^6 bytes per event and 9 x 10^8 bytes per second for a fully live system. Of course, a sensible aim would be to characterize a hit by processing the samples in-line. As an example of the compression achievable, a hit could be characterized by 8 parameters with a total of 80 bits.[1] This would effect a reduction of 1200/80 = 15, giving a rate of 1.2 x 10^8 bytes

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[1] The 8 parameters could be: – wire no., pulse-height, time, pulse-width, rise-time, inferred angle, chi-square of fit to single pulse, is there another hit entangled. The wire number requires 12 bits (within a plane) and the time 16 bits bits. I think 62 bits are enough for the other parameters.

per second for a fully live system. In the table, I am conservative and assume an ICARUS style reduction.

On-line Analysis and Storage

It is not necessary or useful to archive 6 kHz of cosmic rays for the whole life of the experiment. At some stage, the reconstruction program needs to be able to identify and reject cosmic rays at the same rate as the data are collected. This requirement sets the scale for the online computing. We plan to learn this from on-going simulations and from the ArgoNeuT test.

The scale of the amount of long-term data storage can be set by the requirement to archive all beam-spill events for one year. A typical Booster year has 4 x 10^7 spills. Taking the conservative compaction factor of 2 from above, this will require 1.4 x 10^14 bytes. This suggests that storage of about 0.1 to 0.2 petabytes is appropriate.

Table of Numbers for MicroBooNE Data

	Parameter	**Value**	**Comment**
1	No. of Wires (channels)	10,000	*Approximate*
2	Digitizing Rate	5 MHz	*Approximate*
3	Bytes per Sample (12 bits)	1.5	*Approximate*
4	Total Samples per second	5 x 10^10	*1 x 2*
5	Readout duration = Event	4 x 10^-3 seconds	*Approximate*
6	Samples per event	2 x 10^8	*4 x 5*
7	Cosmic ray rate	6 kHz	*Approximate*
8	Wires hit per cosmic ray	2,000	*Estimate*
9	Samples per wire per cosmic ray	100	*Approximate*
10	Total samples per cosmic ray	2 x 10^5	*8 x 9*
11	Cosmic rays per event	24	*7 x 5*
12	Non-pedestal (n-p) samples per event	4.8 x 10^6	*10 x 11*
13	Compaction - ICARUS style	2	*Approximate*
14	Bytes (n-p) per Event	3.6 x 10^6	*3 x 12 / 13*
15	Beam spills per second (maximum)	10	*Approximate*
16	Beam-only n-p bytes per second (maximum)	3.6 x 10^7	*14 x 15*
17	Fully live n-p bytes per second	9 x 10^8	*14 / 5*
18	Beam spills per year	4 x 10^7	*Approximate*
19	Storage for 1 years Beam Events (bytes)	1.4 x 10^14	*14 x 18*