1-Introduction

This document summarizes the discussion that occurred on October 11th 2016 between trigger and timing experts of protoDUNE, the beam instrumentation group and White Rabbit experts, in order to establish a consistent clock, timing and trigger system for protoDUNE. A previous meeting was held on August 26th

The discussion here did not include the data/trigger from the FNAL pLAPPD ToF system that will be addressed in a separate document.

A description of the Beam instrumentation can be found in the ProtoDUNE TDR[1]. To summarize here, it will be composed by two Cerenkov counters, three monitors for momentum measurement, two monitors for beam tracking, one ToF system. The monitors will be composed by planes of scintillating fibres [2], each plane including 192 fibres with 1mm square section, so covering the full width of the beam line. The monitors for momentum measurement will consist of one plane only, the tracking devices will have two planes with orthogonal fibres, for a total of 7 planes. Evaluation of the triggering capabilities of these beam monitors is ongoing in the BI/EA groups, the possibility to add flat scintillators, 2mm thick, for triggering purposes is open. The two solutions will be almost identical for what concerns data acquisition and trigger on the PD side. For what concerns the ToF, it will be again provided by two scintillating fibres devices for low beam momenta (below 2 GeV/c, and by the pLAPPD ToF system presently under development at FNAL for higher beam momenta.

2-Location of BI DAQ

The BI DAQ will be located in a barrack separated from the PD one. The present plan is to locate two VME crates (one for H2 and one for H4) in HNA394, which is located at the downstream limit of the old North Area building. A barrack 30-40 meters further downstream could also be considered in order to gain 100 ns on the time delay between the two DAQs

3- Trigger

The primary trigger will come from the BI as a coincidence of beam scintillators or fibre trackers. The choice is left to the BI and EA group, depending on their monitoring needs. The trigger will be in the form of a NIM signal on BNC connectors. These will be essentially asynchronous signals. More signals can be delivered in a similar fashion (e.g. Cerenkov).
For physics, PD requests all the signals that can be used. At low beam energies, the signal from the Cerenkov identifying electrons will be used as a veto trigger. Other counters might be inserted in the trigger to select only particles whose trajectory can be fully reconstructed. Even if not inserted in the trigger, a full trigger mask can be useful offline.

The maximum number of logical (trigger) signals from BI is 10 (one master trigger, 7 fibres planes, two Cerenkovs). To this, one should add 3 signals from the pLAPPD ToF.

The ProtoDUNE trigger box will sit in PD barracks in same rack as timing system.

Warning Extraction (WE) and End of Extraction (EE) which we can provide on a Lemo00 patch panel in PD barrack.

4- BI DATA

For reliability reasons, the Technical Network (TN), in which the BI crate resides, is not accessible from the General Network (GN). ProtoDUNE will have no access to data during buffering, will have to access data once published to the General Network.

BI will readout data from each fibre with SiPM and dedicated boards. Data will be buffered in the BI crate and transferred to the CERN DIP and DIM [3] servers at the end of each SPS cycle. Duration of the SPS cycle is of the order of 40 seconds, each cycle containing from zero to a few spills to the ProtoDUNE beam line. The same data will also be recorded in the CERN logging system[4] for medium and long term storage.

The ProtoDUNE DAQ will need to merge PD data with BI data offline, due to the delay in data publishing. A nearline merger will be needed, so that PD data will be written on local storage, and merged with BI data in the first, prompt, offline processing. Complete events will be then sent to offline storage. This procedure is already in use by the MicroBoone experiment at the BNB.

BI data will be aggregated to PD data based on timestamps, as described in the following section.

pLAPPD data, instead, could be directly read out into the PD DAQ .

For what concerns data size, BI data will include separate bit-wise signals from each of the scintillating fibres. Conting 200 fibres on 7 planes will results in 1400 bits. Headers will have to be added, as well as a few words from Cerenkov counters and ToF, for a totalof about 200 Bytes/event plus headers.

pLAPPD foresee waveform readout, reading 16 ADC samples + 1 TDC per channel. A few non-zero channels are expected per event, summing up to about 200 values in 400Bytes/event

In summary, 600 Bytes/event are expected from the beam instrumentation, equivalent to 60kB/s at 100 Hz trigger rate.

5- Timing

Common time-stamping will be achieved by the use of the White Rabbit protocol[5] The same will happen for the DualPhase Protodune NP02.
A common GPS signal, same as for LHC, will be delivered from a WR master switch in the CCR (CERN Control Room). This will be propagated to WR slave nodes, one for BI and one for PD.
This will provide a 10 MHz clock and a 1 PPS output to both systems. PD will derive its primary 50 MHz clock from this 10 MHz.

Front-end digitizers of each BI and PD detector will time-stamp their buffer recording, corresponding to the time of the received trigger, with their internal clock, which is freestreaming. Synchronisation is then ensured by time-stamping of trigger signals distributed to these detectors with the respect to the common GPS timeframe.

6-Grounding

BI will not sit on detector ground, but likely building ground. Indeed, BI often have detectors floating with grounding only in the barrack.

Appendix 1 : WhiteRabbit stamping

- Time stamping of TTL signals can be performed using the FMC TDC mezzanine [6] plugged onto a VME64x [7] or PCIe [8] WR-enabled carrier.

- These timestamps have a precision of +/-700 ps.

- With one mezzanine, you get 5 input channels. You can plug one mezzanine on the PCIe carrier or two mezzanines on the VME64x carrier.

- The time for a timestamp is stored in three 32-bit registers, as described in page 9 of the gateware guide for the FMC TDC [9]. WR is a compatible extension of the Precision Time Protocol (IEEE 1588) and will soon be part of the standard. Therefore we chose to have the first 32-bit register represent the number of seconds since midnight 1 January
1970 (the same epoch as that used for UNIX time). However, UNIX time is based on UTC, whereas PTP time (and therefore WR time) is based on International Atomic Time (TAI). The difference between UTC and TAI is a number of so-called "leap seconds" which are introduced in UTC from time to time to make sure UTC midday is "when the Sun is at its highest".
I.e. TAI is really the number of seconds since 1/1/1970, whereas UTC isn't because it tracks the imperfect oscillator the Earth rotation represents. Conversion to UTC can be done easily in software if needed, by subtracting the appropriate offset from the TAI count (36 currently,
37 after 1/1/2017). The second register holds a count of 125 MHz ticks within the second, i.e. one bit of that register represents 8 ns. One bit of the third register represents a 81.03 ps step within the 8 ns window. These two last registers are implementation-specific. There is to our knowledge no standard way of representing the fractions of the second in timestamps.

- The boards come with Linux device drivers, a C/C++ library and a test program.

Appendix 2: CERN servers and databases

DIP and DIM

The DIP and DIM service is managed by CERN EN/ICE and is used by BI for data exchange with other experiments in the North Area

The DIP service is composed of :

- A Central Name Server that provides the list of available publications
- An API (Application Programming Interface) that allows to publish and receive information.
- A PVSS extension (PVSS API Manager) that allows to publish and receive DIP data in PVSS.
- A LabVIEW extension that allows to publish and receive DIP data in NI LabVIEW.

DIP name servers are operated as a critical service, aiming for 100% availability through server redundancy

The CERN Logging System

The CERN-wide Accelerator Logging Service persists data of signals coming from heterogeneous sources. These signals range from data related to core infrastructure such as electricity, to industrial data such as cryogenics and vacuum, to beam related data such as beam positions, currents, losses, etc.

The logging service provides access to logged data for more than 700 registered individuals, >100 registered custom applications from around CERN, and even offsite access for purposes such as the CNGS experiments in Gran Sasso Italy.

Data is persisted in Oracle RAC databases, via a custom Java data-loading infrastructure. Approximately 2TB of data per week are written to the short-term measurement database (MDB) and around 1TB or data per week is stored online in the long-term logging database (LDB).

Data extraction is performed using a Java API, and optionally a generic Graphical User Interface (called TIMBER) to visualize the data. The entire Java infrastructure is based on the Spring framework, and pure JDBC for database interactions.

PL/SQL is extensively used for a variety of operations, including filtering and transfer of data from the short-term to long-term database.

References

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