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Scintillation Light DAQ and Trigger System for the ICARUS T600 Experiment at Fermilab

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Abstract

ICARUS T600 will operate at shallow depths as far detector for the Short Baseline Neutrino (SBN) program at FNAL taking data from the BNB and NuMI beams. The entire apparatus will be exposed to the huge cosmic background which can mimic genuine neutrino interactions. To distinguish the signals related to the neutrino beams from those induced by cosmic rays, the detector will be provided with a trigger system that will exploit the coincidence of the prompt signals from the liquid argon scintillation light, detected by 360 Photomultiplier Tubes (PMTs), with a beam gate window generated in correspondence to the expected arrival time of neutrinos in the T600.

Keywords: Front End, Trigger, DAQ and Data Management

1. Introduction

ICARUS T600 is the largest Liquid Argon Time Projection Chamber (LAr-TPC) ever built for neutrino oscillation studies. The apparatus is being installed at FNAL after three years of data taking at LNGS followed by an extensive overhauling carried out at CERN. It will be exposed to BNB and NuMI neutrino beams in the framework of the SBN program for the ultimate search of sterile neutrinos [1].

ICARUS at FNAL will take data at shallow depths, facing more challenging experimental conditions than at LNGS, by being exposed to the huge cosmic background which can mimic genuine ν_e interactions. Therefore, it will be fundamental to distinguish the signals related to the neutrino beams from those induced by cosmic rays. The trigger system will exploit the coincidence of the prompt signals from the LAr scintillation, detected by 360 Photomultiplier Tubes (PMTs), with a beam gate window generated in correspondence to the expected arrival time of neutrinos in the detector.

2. The ICARUS T600 scintillation light detection system

ICARUS T600 detector is made of two identical cryostats, each housing two TPCs with a common cathode. Charged particles interacting in liquid argon produce both scintillation light (λ = 128 nm) and ionization electrons. These latter are drifted by an electric field ($E = 500$ V/cm) to the anode, made by three parallel wire planes. Photons are detected by a light detection system based on large area PMTs mounted behind the wire planes [2].

The T600 scintillation light detection system was significantly upgraded at CERN with the adoption of 360 Hamamatsu PMTs R5912-MOD deployed behind the 4 wire chambers. Each device is made sensitive to VUV photons by means of a 200 μg/cm^2 Tetra-Phenyl Butadiene coating deposited on the sensitive windows by means of a thermal evaporation [3, 4].

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3. Trigger logic design

The trigger system of the ICARUS-T600 detector will exploit the coincidence of the prompt signals from the scintillation light in the LAr-TPC, with a beam gate window generated in correspondence to the expected arrival time of neutrinos in the T600 from an “early warning” information on the proton spill extraction, both for BNB and NuMI beams. The trigger system is based on two parallel logics (figure 1).

PMT Trigger Logic
A *PMT-TRIGGER* signal is generated in correspondence of each interactions in the TPC volume as recorded by the PMT system according to defined majority/coincidence patterns. This signal will enable the digitizers for the PMT signal recording and will serve as an input for the subsequent Global Trigger Logic and to enable the PMT signal waveform recording.

Global Trigger Logic
A *GLOBAL-TRIGGER* signal is generated every time a previous *PMT-TRIGGER* signal occurs in coincidence with the proton spill extraction from BNB and NuMI beams. This will be sent to the different sub-detectors to enable the event read-out as stop of data acquisition in one or in both two T600 modules.

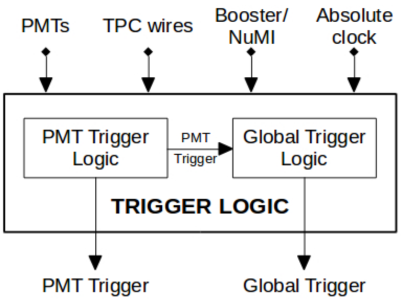

Figure 1: The General Trigger Logic layout.

4. Electronics Trigger Scheme

A basic scheme of the PMT read-out and trigger electronics is shown in figure 2. The PMT DAQ and trigger layout is based on CAEN and National Instrument PXIe instrumentation.

For each TPC, the 90 PMTs are directly connected to 6 CAEN V1730B boards, 16 channels each. The boards will provide the sampling of the PMT signals (500 MS/s, 14 bit resolution) which will be available through dedicated CONET2 optical links. The V1730B boards will generate a set of discriminated output signals (Low Voltage Differential Signaling, LVDS) in term of OR/AND of 2 by 2 adjacent PMT channels, which will be available for triggering purposes. Thresholds (order of photoelectrons) will be set to guarantee the full detection efficiency of neutrino interactions and cosmic events with energy down to 50 MeV in the full T600 LAr active volume.

The 45 signal outputs from a single TPC will be processed by a programmable logic unit FPGA (NI-PXIe 7820, one for each T300 module) to generate the *PMT-TRIGGER* signal inside 2 ms wide windows around a foreseen BNB/NuMI beam gate. This allows to record all the PMT activity during the TPC time drift window (1 ms). Each PMT waveform is recorded by considering a 10 μs sampling size. The presence of a *PMT-TRIGGER* pulse in coincidence of a BNB (1.6 μs) od NuMI (8.6 μs) spill gate will also generate the *GLOBAL-TRIGGER* signal to enable the event read-out.

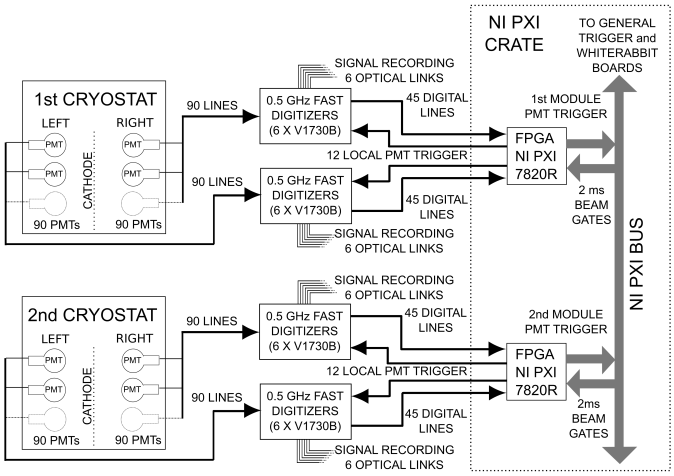

Figure 2: Basic PMT trigger system scheme.

The electronics is completed by a Real Time (RT) controller (NI PXIe-8135) and one SPEXI board by Incaa Computers for the generation of the clock signal and the beam coincidence windows for an “early warning” information distributed by the White Rabbit protocol.

5. Conclusions

The trigger system of the ICARUS-T600 detector will allow the selection of genuine neutrino interactions while rejecting the cosmic background. Implemented on programmable FPGA units, it will exploit the coincidence of the prompt signals from the scintillation light in the LAr-TPC, with a beam gate window generated in correspondence to the expected arrival time of neutrinos in the detector.

The features of the trigger system can be further extended including information of the charge collected on TPC wires and the timing information from an external Cosmic Ray Tagger.

References

[1] SBN Collaboration, A proposal for a three detector short-baseline neutrino oscillation program in the fermilab booster neutrino beam, FNAL Proposal P-105 https://arxiv.org/abs/1503.01520

[2] A. Falcone, Performance study of the new light collection system for the ICARUS T600 detector, Journal of Physics: Conf. Series 888 (2017) 012093

[3] M. Bonesini et al., Realization of a high vacuum evaporation system for wave-length shifter deposition on photo-detector windows, J. Vac. Sci. Technol. B 36 (2018) 01A101

[4] M. Spanu, Study on TPB as wavelength shifter for the new ICARUS T600 light collection system in the SBN program, Journal of Physics: Conf. Series 956 (2018) 012016