Trigger System of the NA61/SHINE Experiment at the CERN SPS

Oskar Wyszyński

Abstract—**NA61/SHINE (SPS Heavy Ion and Neutrino Experiment) is a large acceptance hadron spectrometer designed for comprehensive studies of hadron production in hadron-proton, hadron-nucleus and nucleus-nucleus collisions at the CERN Super Proton Synchrotron. The NA61/SHINE physics programme requires measurements of a large number of reactions recorded using different trigger conditions. This motivated a flexible solution for the NA61/SHINE trigger system. The trigger uses signals from scintillation, Cherenkov and calorimeter detectors. In total up to 16 signals have to be processed for a trigger decision. The core of the system is based on a single field-programmable gate array (FPGA), running with a 120 MHz clock which offers a resolution of 8.3 ns. Moreover, it is capable of selecting in parallel events which satisfy up to four trigger definitions. Events corresponding to these trigger definitions are recorded with relative frequencies which can be selected using 12 bit prescalers. The working parameters of the trigger, such as coincidences and delays, are set up remotely via a Java application, designed to be handled by non-expert users. The performance parameters are monitored by Python based monitoring software, which is capable of displaying values of beam counters and beam time structure. Furthermore, the monitoring software calculates summary information, such as trigger probabilities, which are crucial from a user's point of view. It also detects pre-failure states of the trigger system, such as false scaler counts, and gives the opportunity to prepare the necessary repair procedure before the state of irrecoverability. This paper describes technical aspects and details of the trigger system of NA61/SHINE experiment.**

I. Introduction

THE SPS Heavy Ion and Neutrino Experiment (SHINE) is one of the Super Proton Synchrotron (SPS) experiments, located in the North Area of CERN. A large acceptance hadron spectrometer [1] allows us to study the properties of the hadron production in collisions of particle beams (pions, protons, beryllium, argon and xenon) with a variety of fixed nuclear targets. NA61 reuses the main tracking system of its predecessor, the NA49 experiment, with important upgrades.

II. Detector overview

NA61/SHINE facility [1], Fig. 1, consists of time projection chambers (TPC), namely Main TPC, Vertex TPC immersed in homogeneous magnetic field and Gap TPC. In order to extend identification abilities to low momentum particles, Time Projection Chambers are supplemented by Time of Flight detector walls and Low Momentum Particle Detector (LMPD) [5]. Recently installed calorimeter, the Projectile Spectator Detector (PSD), is used to select central collisions at the trigger level.

The beam position detectors located upstream of the target, as well as scintillation and Cherenkov counters, provide precise position measurement and timing references of particle beams. The Trigger system uses set of counters along with PSD calorimeter to determine time of appearance of desired events. Afterwards it sends main trigger signal to Busy Logic, where decision is made whether electronics is ready to record a new event.

III. Trigger

The CMC206 CAMAC [8] Module [3] provides the Xilinx Spartan-3 FPGA [4] running at 120 MHz to host the trigger logic. It is capable of selecting events from different reactions using a variety of beams and targets foreseen by NA61/SHINE physics programme. CAMAC is used for backward compatibility with the legacy NA49 electronics.

A. Trigger logic

The design, Fig. 2, is aimed to handle 16 input signals derived from the beam counters in a flexible and robust way. The signals are distributed to the four coincidence logic, which provides ability to select four different kind of events. Each coincidence logic is prescaled accordingly to our needs, afterwards signals are combined by OR gate, in order to produce the Main Trigger signal. Before the trigger signals can leave the module, they are synchronized with delayed S1 signal. This procedure is required in order to have the right timing between subsystems.

B. Coincidence logic

As it is shown in Fig. 3, the coincidence logic is divided into three main blocks in order to handle signals with different time of appearance:

- Beam logic - fast signals from scintillation counters
- Beam particle identification - signals from Cherenkov detectors
- Interaction logic - signals from PSD calorimeter

Afterwards the signals from the blocks are sent to the corresponding prescaler.

C. Busy signal handling

All trigger signals such as Fast Strobe, S1_1 and S4 are distributed in order to be validated against the Busy signal. If the Busy signal is not present, these signals are forwarded to the corresponding subsystems. The detailed implementation is shown in Fig. 4.
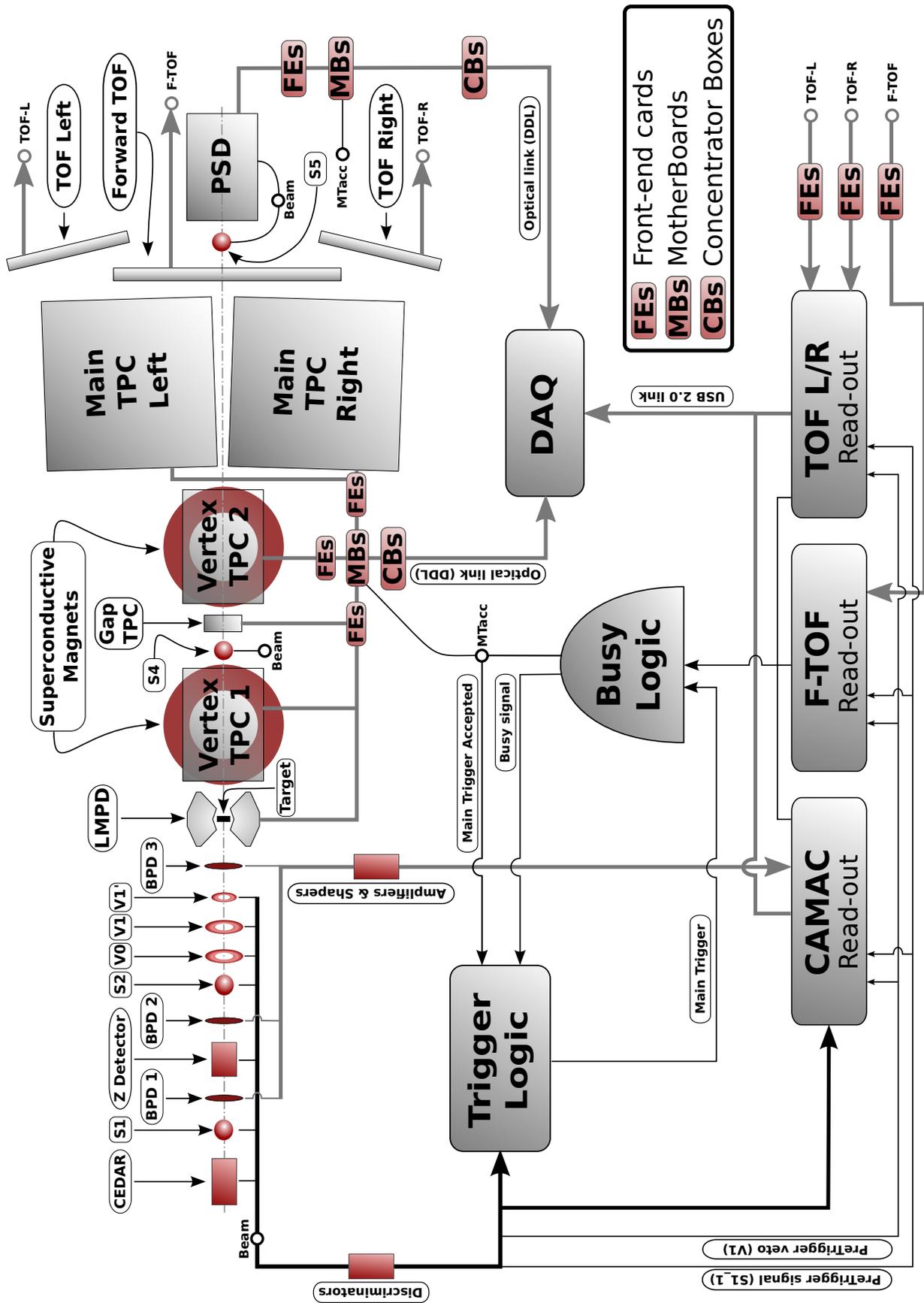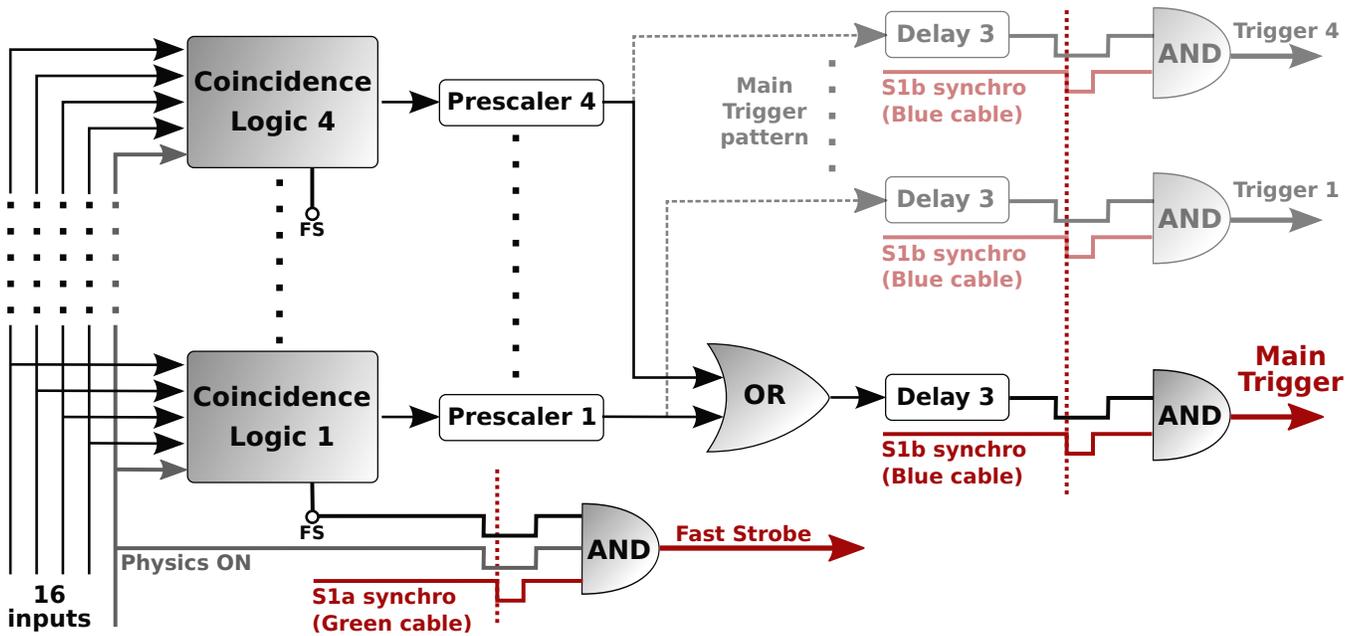
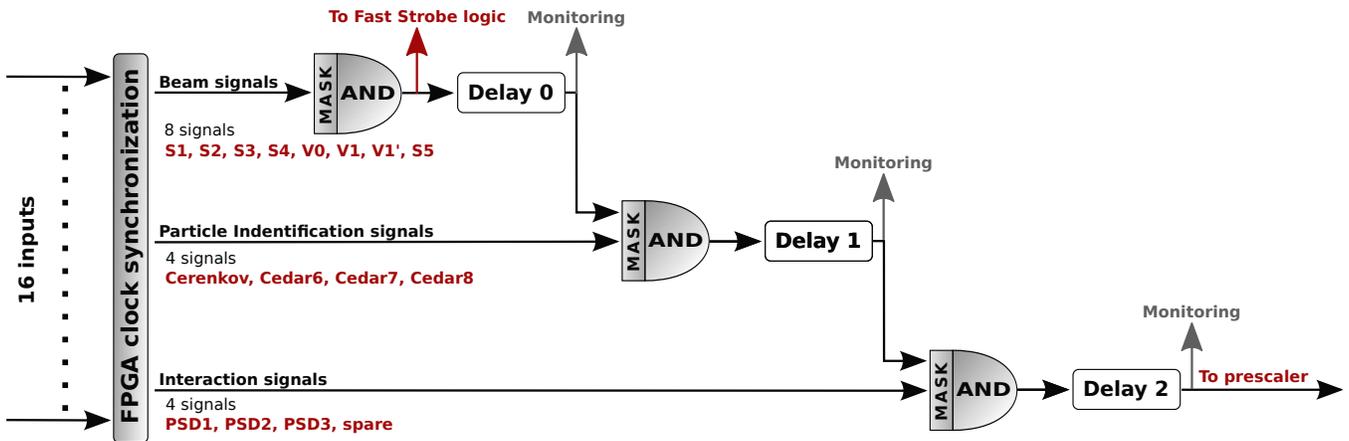Fig. 1.   General overview of readout system

Fig. 2. Trigger logic

Fig. 3. Coincidence logic

IV. Adjusting configuration

Using the Java application, the trigger internal configuration can be created, stored and finally sent to the module by the Ethernet-CAMAC bridge [2].

The application provides the extended set of options organized into several tabs as follows:

- General Settings tab provides means to choose number of coincidence logics as well as the prescaling factors.
- Trig 1 to Trig 4 tabs are meant to be used in order to configure coincidence logics. One can choose signals which should be enabled and a type of signal - positive or veto.
- Signal delays tab may be used to adjust delays of the first 16-Channel Programmable Logic Delay Fan-Out CAMAC module [6] used to adjust input signals.
- Input advance tab provides the method to change delays of the second 16-Channel Programmable Logic Delay Fan-Out CAMAC module [6] as well as thresholds and

signal width of input and output signals of the 16 Channel Leading Edge Discriminator [7]
- Trigger advance tab contain settings for internal delays of the Trigger and coincidence logics.

Such software is suitable for both, the non-expert users, to whom the first five tabs are dedicated, and experts, who wish to have a remote control on internal signal delays and input thresholds.

V. Monitoring system

For monitoring purpose the client-server architecture was implemented in order to distribute in real time all the necessary information. There are two types of clients available. The Python and QT4 [11] based rich client is used to monitor state of particle beam such as intensity, time structure and interaction probabilities as well as the trigger performance parameters. Furthermore it provides all necessary readings of raw data registered by scalers, giving opportunity to detect
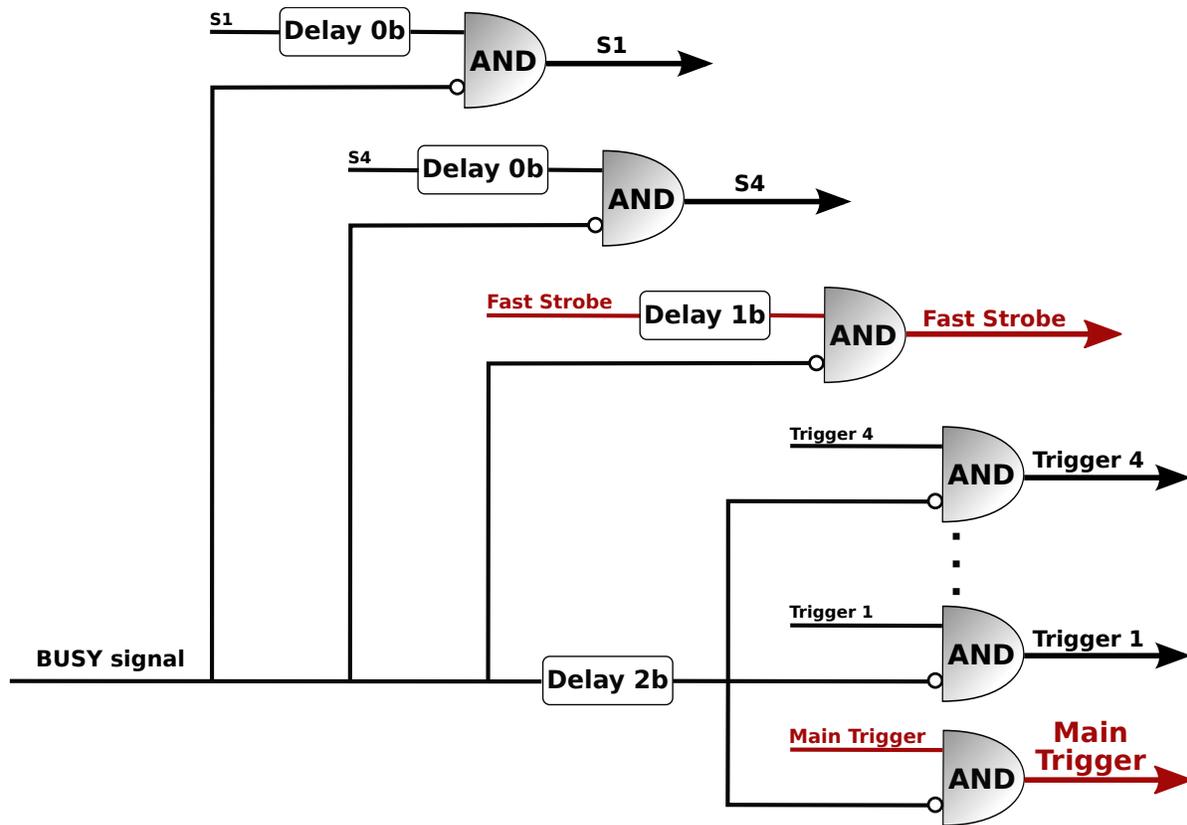
Fig. 4. Busy signal handling

pre-failure states of the trigger system. The rich client can be used either by a users inside of the facility or by a users inside of the CERN laboratory. For those who are outside the local network or use mobile devices, the poor client was prepared. It is a passive web based application which provides the most important statistics based on data registered by the scalers [9]. The Django [10] framework was used as it fulfills all conditions such as the way to incorporate a python code and separation from the framework by providing the mechanism of plugins. The JavaScript was introduced in order to enhance the presentation manner of the data for instance automatic refreshment.

VI. PERFORMANCE

The maximum event rate of the Central Data Acquisition system is around 83Hz, determined by the deadtime of the TPC readout Front-End Electronics (12ms). In order to saturate the DAQ, a Main Trigger rate of about at least 600Hz is needed. Thus, with the interaction probability of about 1% of a typically applied experimental setting, one needs at least about 60kHz rate for valid beam particles. Typically, secondary beams are used where the yield of useful beam particles (with proper particle identification) is about 10-50%. Therefore, up to 100-600kHz of total raw beam rate can be needed for DAQ saturation. Due to the safety limits and in order to keep the contribution of off-time events low, the rate of 100kHz is never exceeded in practice. This means that the trigger system must be able to handle signals with deadtime better than $10\mu s$, which is just the case: the trigger deadtime is 100ns.

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