L0 TRIGGER ELECTRONICS FOR THE BM@N SETUP IN RUN MARCH 2017

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The BM@N facility is a fixed target experiment based on heavy ion beams of the Nuclotron-M accelerator. The aim of BM@N is to study nucleus – nucleus collisions at energies up to 4.5 GeV per nucleon. The L0 trigger system of BM@N consists of fast beam and target area detectors, fast amplifiers, discriminators, a trigger processor unit, power supplies and interface modules. The concept of the L0 trigger system and test results obtained in run March 2017 are discussed.

Keywords: Trigger electronic, L0 trigger, detector control system, trigger detector system, trigger detector, trigger logic, fast preamplifier, barrel detector, beam trigger, trigger signal, trigger generation, front-end electronic,

1. Introduction

The BM@N facility is a fixed target experiment based on heavy ion beams of the Nuclotron-M accelerator. The aim of the BM@N experiment is to study of nucleus – nucleus collisions at energies up to 4.5 GeV per nucleon [1,2]. The BM@N run in March 2017 was performed with beams of deuterons and carbon ions with an energy of 3.5 GeV/nucleon.

The beam line and target area detectors are an important part of the BM@N setup and are used for: (i) active transportation of the beam ions to the target, (ii) beam monitoring, (iii) start pulse generation with picosecond precision for the TOF detector, (iv) effective triggering of the collisions in the target by generation a L0 trigger signal.

2. Detector system

A scheme of the trigger detector system is shown in Fig. 1.

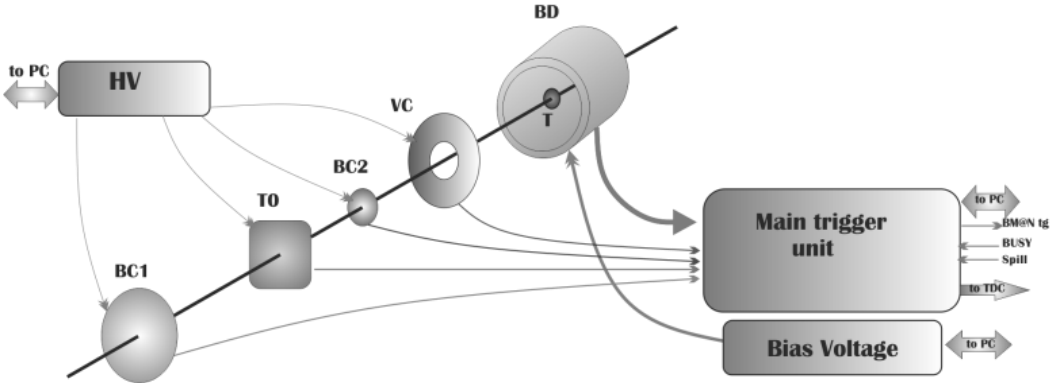


Figure 1. Scheme of BM@N trigger detectors

The detector system consists of beam counters BC1, T0, BC2, a veto counter VC, and a 40-channel scintillation barrel detector BD. The BC1 is based on a 5-mm thick plastic scintillator and PMT FEU87; the T0 is a Cherenkov detector with a 4-mm quartz (46° to the beam axis) connected with MCP-PMT PP0365G by Photonis. The BC2 is equipped with a plastic scintillator 20diam.× 0.8 mm3 with an Al-mylar light guide (45° to the beam axis) and MCP-PMT PP0365G. The VC is based on a plastic scintillator 100diam.× 10 mm3 with a hole diameter of 28 mm, the scintillation light is collected on a photocathode of MCP-PMT XP85012 (Photonis) using the Al-mylar light-guide housing. The BD has 40 scintillation strips BC-418 with dimensions 150 × 7 × 7 mm3 and wrapped by Al- mylar, the scintillation light is detected on one end of the strips by SiPMs Micro FC-60035-SMT, 6 × 6 mm2 by Sensl. Two detectors - the T0 and BC2 were used for the start signal production for the detectors TOF400 and TOF700.

The transverse dimensions of the small scintillator of the BC2 define the size of the beam spot on the target.

The barrel detector, BD, is used for selection of the nucleus - nucleus collisions on centrality by fast determination of the number of fired scintillation strips detecting charged particles at large angles to the beam direction. The target is placed inside of the strip array. The strip assembly with SiPM's board is shown in Fig. 2a. A view of the BD in the BM@N setup 2017 is shown in Fig. 2b.

The beam trigger (BT) signal was generated by the coincidence of the beam counter pulses BC1 × BC2 × T0 × VC, and the collision trigger (CT) signal was generated by the coincidence BT × BD (*N*>bias) where *N* is the number of fired channels.

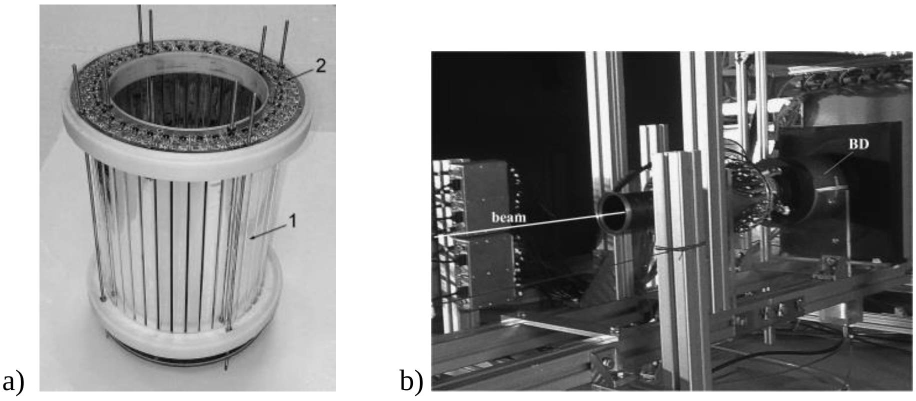


Figure 2. a) A view of the strip assembly with SiPM's board of the barrel detector: 1 – the scintillation strip covered by Al-mylar, 2 – the SiPM's board; b) a view of the barrel detector at the BM@N beam line in March 2017

3. L0 trigger electronics

Special electronic modules were developed to provide trigger generation for the 2017 BM@N run. The L0 trigger electronics consists of front-end electronics (FEE), power supplies for the FEE and SiPM, fast discriminators and a T0U module with programmable trigger logic providing output signals for DAQ and main readout electronics.

The fast amplifiers and discriminator of the FEE are placed into the detector of the T0, BC2, and VC. A block diagram of the FEE is shown in Fig. 3. The performance of this FEE was discussed in [3,4,5]. Each channel has both analog and digital output (time over threshold comparator with an LVDS output). Both signals and LV power were fed via a HDMI cable connected to the T0U module.

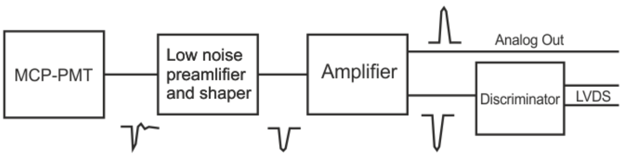


Fig 3. Block diagram of the FEE board of beam detectors T0, BC2, and VC

The barrel detector FEE has a similar structure. This detector has 40 SiPM's mounted on a PCB board (Fig. 4a). The first stage of the amplification was implemented at the detector PCB. The fast amplifier with a shaper and comparator was performed as a standalone module (Fig. 4b). This module has 10 input channels. The output signals go to the T0U via HDMI cables. The whole barrel detector has four preamplifier modules.

The power supply modules for the FEE provide three independent voltages to supply the T0 detector FEE. These voltages are controlled and monitored with high precision. The structure of the LV power supply is described in [6].

The power supply module of SiPMs (Fig. 4c) provides bias voltage for the barrel detector photosensors. This module is controlled and monitored with high precision. Every channel could be switched On or Off independently, the channel voltage range is 0 to 36 V with 1 mA current per channel and the output voltage could be adjusted with 0.5 mV step. The channel output voltages are read back by 12-bit ADC. The communication to the detector control system is done via USB 2.0, Ehternet or RS serial link. This power supply module is assembled in one unit NIM module.

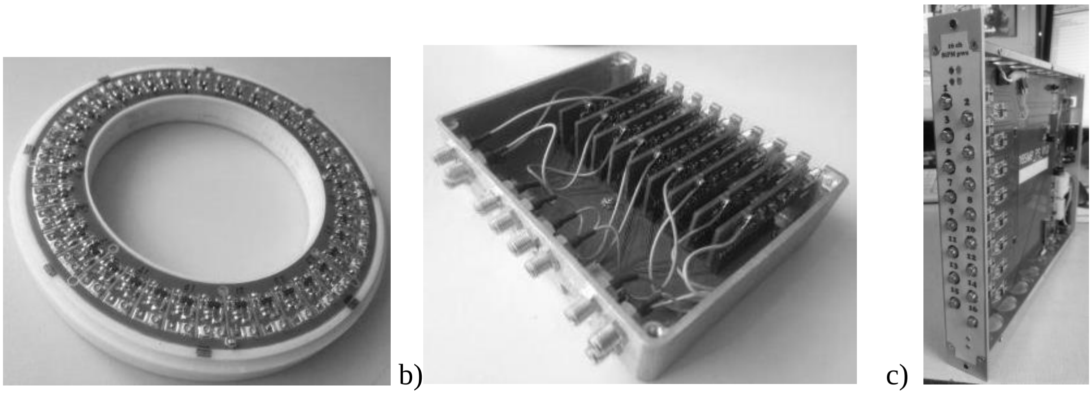

b) c)

Figure 4. a) The SiPM's board of the barrel detector, b) FEE module of the barrel detector c) the power supply module of SiPMs.

The T0U module is the heart of the BM@N L0 trigger system. The main tasks of the T0U module are: the beam line and target area detector signal processing, monitoring of the beam conditions and detectors operation, L0 trigger logic with a convenient and flexible graphical interface, and a stable low voltage power supply for the detector FEE channels.

The T0U generates a trigger pulse, which is output signal of a programmable logic based on FPGA with a suitable trigger interface. This module also provides control and monitoring of the front-end electronics power supplies. The T0U can process 76 input signals in total, 60 of them arrive from the T0 FEE and up to 16 signals could be taken from other detectors or units.

The T0U shown in Fig. 5 has a modular structure. It has a motherboard and 4 different type mezzanine boards.

a)
b)
c)

Figure 5. Different views of the T0U: a) top, b) front, and c) back sides

The motherboard performs the following jobs:

- distribution of the input signals to the external readout electronics (TDC72VL) and theL0 trigger processor;
- L0 trigger generation by the trigger processor built on Altera Cyclone V GX FPGA,

- powering, monitoring, and control of mezzanine cards: power supply boards, TTL-NIM, TTL-TTL50 Ohm and TTL-LVDS convertors, discriminator boards;
- accumulation of the trigger monitoring information;
- generation of calibration pulses and a signal for the chamber heating;
- generation the trigger information for the DAQ system.

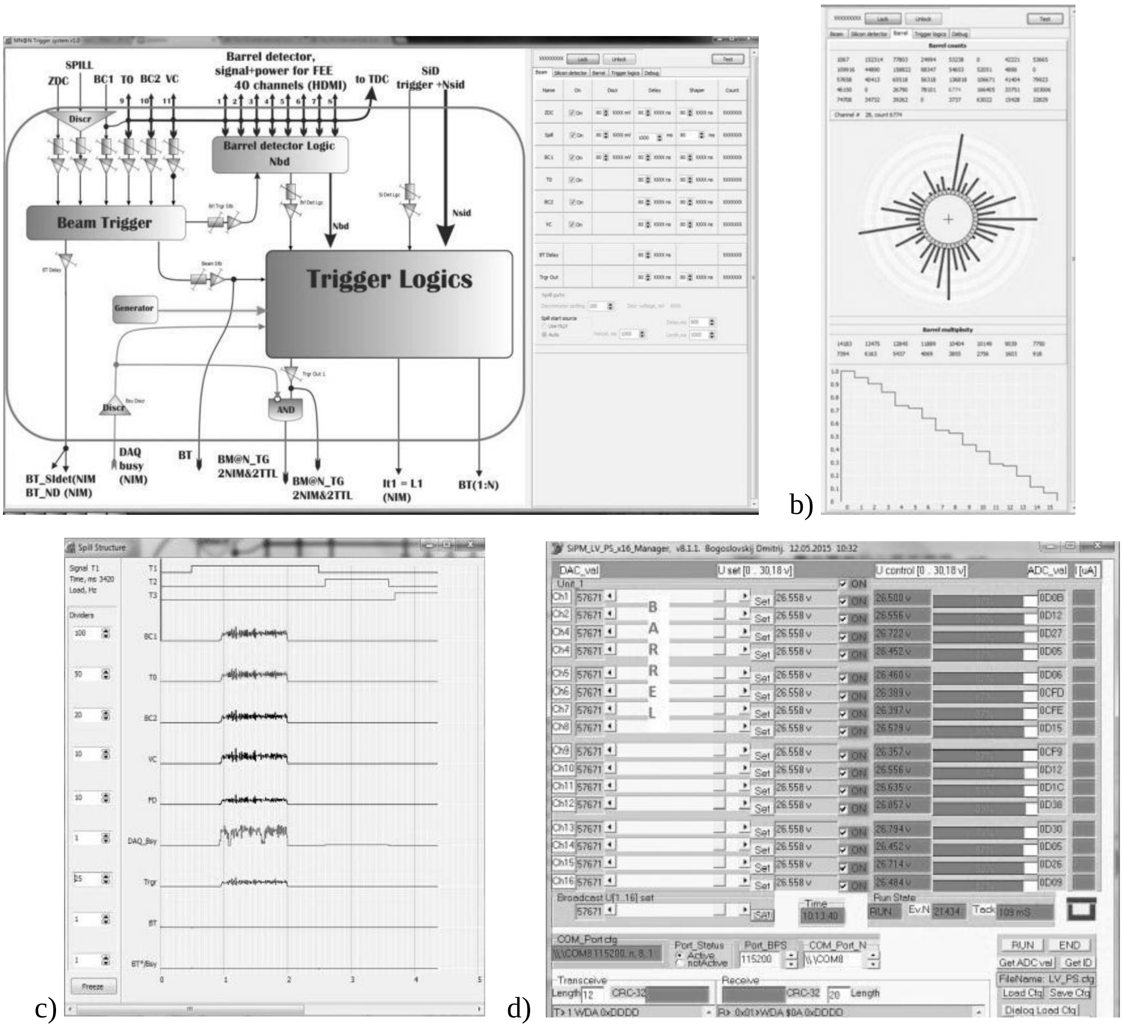
The control and L0 trigger monitoring are performed using special PC connected with the T0U module via an optical link or USB 2.0.

The Discriminator board (DIB) consists of 4 input channels having fast discriminators with a 1.5 GHZ equivalent input rise time bandwidth and 700 ps propagation delay. The threshold could be set in a range from – 2 V to +3 V with a step around 5 mV.

The Convertor boards are used to convert the trigger processor output TTL signals to NIM signals and TTL-50 Ohm, which could be sent to the external subsystems. Also, we have a TTL-LVDS convertor which is used to send trigger flag information to the DAQ system in a parallel code.

4. Detector control system

The T0U Slow Control is built using client/server architecture on Windows platform and it provides connection to the TANGO system [6]. The expert client runs only on the T0U Slow Control PC. The user GUIs, partly shown in Fig. 6, perform following jobs: detector and selected trigger counting rate monitoring, adjustment of the duration and delay of spill gate signal, selection of the trigger logic scheme, monitoring and control of the FEE and SiPM power supplies.



b)

c)

d)

Figure 6. T0U interface pannels: a) and b) - the views of the T0U manager GUI, c) – the SpillView for control of the beam conditions, d) - the GUI of the SiPM power supply

Specific software was developed for online counting rate monitoring. Spill summary data are published using a web server and the beam intensity and detector counting rates are published with a TCP/IP server with corresponding clients running under Windows.

5. Operation during run 2017

The T0U operation was tested during the first BM@N run in 2017 with beams of deuteron and carbon ions. Detector signals were transported to the T0U module by 5-m long cables. The LVDS signals of the detectors were fed to TDC72VHL modules placed in the VME crate of the TOF400 detector. These data together with the data from other BM@N detectors were read out and stored during a global run.

The T0,BC2,VC, and BD trigger detectors operated in a strong magnetic field of the main BM@N magnet with B up to 0.9 T without any visible degradation of characteristics.

The TOF peak measured with a carbon ion beam and two detectors T0 and BC2, Cherenkov and scintillation, measured with TDC72VHL is shown in Fig. 7. It corresponds to the time resolution of a single detector of σt = 30 ps.

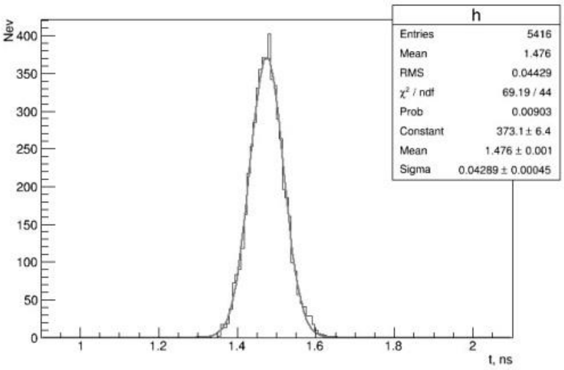


Figure 7. The TOF peak obtained with the T0 and BC2 detectors with a beam of 3.5- GeV/n C ions

6. Conclusions

The trigger system developed for the BM@N experiment was successfully tested during the BM@N run 2017. The time resolution of 30 ps. was obtained for the start pulse provided by the T0 and BC2 detectors. The obtained experience will be used in farther development and upgrade of the trigger detectors, the electronics, and the control system. Nowadays a new trigger system is being prepared for the next BM@N run in March 2018.

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