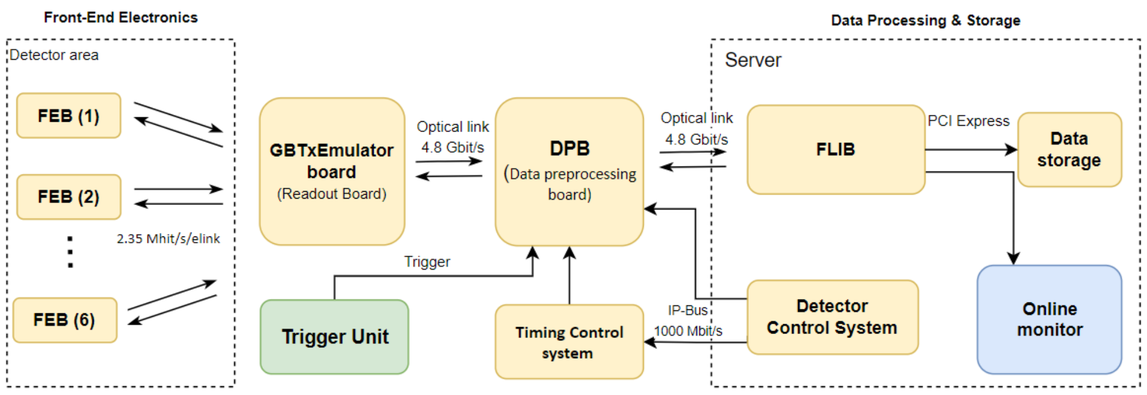
Free-Streaming Data Acquisition System for the Modernized Silicon Tracking System of the BM@N Experiment

Shitenkov Mikhail, Veksler and Baldin Laboratory of High Energy Physics, JINR, Dubna, Russia
shitenkov@jinr.ru

Free-Streaming Data Acquisition System Concept

The results of the development of the high-speed free-streaming data acquisition system to be used for the upgraded silicon tracking system of the BM@N experiment are presented.
The first element of the readout chain is a front-end board (FEB) with eight STS-XYTER ASICs of 128 channels each with a self-triggering architecture for readout from CBM/BMN modules located inside the tracking station in the radiation and magnetic fields. GBTxEmulator board based on FPGA serializes the data received from up to 3 modules for its further transmission through 4.8 Gbps optical link to remote online server. Data Processing Board (DPB) based on Kintex-7 FPGA receives data from GBTxEmulator, sorts it with regard time, providing control and synchronization for the front-end electronics. The First Level Interface Board (FLIB) based on a commercial PCIe board provides a server-node back-end interface for up to 8 DPBs.

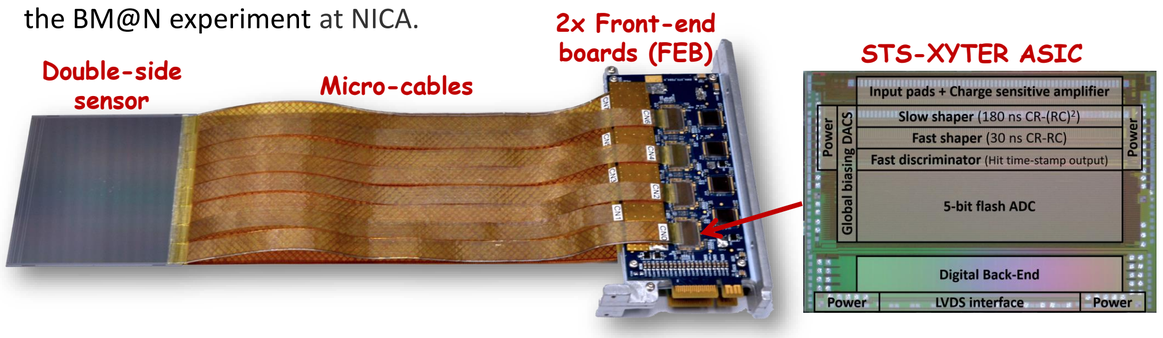


Block diagram of the free-streaming data acquisition (DAQ) system

- Self-triggering front-end electronics;
- Optional trigger operation mode (trigger rate up to 78 kHz);
- Detector occupancies up to 360 kHz/cm²;
- Concentration of 6 144 detector channels into a single high-speed optical GBT-link;
- A fully synchronous 40 MHz reference clock for TDC operation and time-based sorting.

Module CBM/BMN

The double-sided silicon microstrip sensor module based on the STS-XYTER ASIC [1] developed collaboration between CBM and BM@N to modernize the tracking system for the BM@N experiment at NICA.

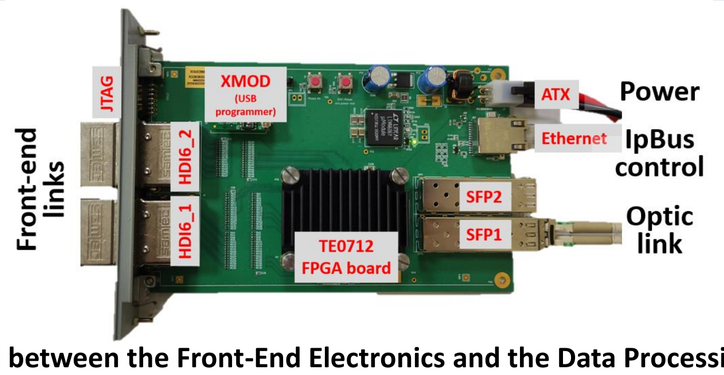


- Size of silicon sensor 62 × 62 mm;
- Readout channels – 2048 (128 ch. per ASIC);
- STS-XYTER ASIC per module – 16 pcs;
- Length of analog cable: 115 – 360 mm;
- Self-triggering for each channel;
- Adjustable in-channel 5-bit flash ADC + 8 Hit digital buffer;
- Dynamic range up to 15 fQ (typ. signal – 3.6 fC);
- Individual channel dead time ≈ 1 µs;
- Calibration and diagnostic functionality;
- Noise level ≈ 0,15 fC;
- Hit spatial resolution ≈ 17 µm;
- 14-bit TDC with resolution ≈ 12,5 ns;
- AC-coupled LVDS links (80 Mb/s);
- Energy consumption – 12 W.

References

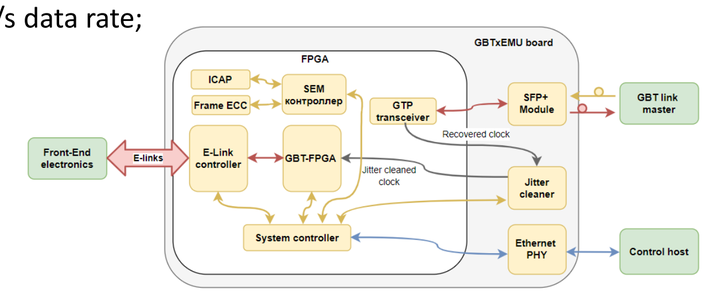
[1] Kasinski K., Zabolotny W., Szczygiel R., et al, SMX2.0, SMX2.1, SMX2.2 Manual.
[2] Shitenkov, M. O. Radiation Tests of the Data Concentrator Board Based on Artix-7 FPGA for the Silicon Tracking System of the BM@N Experiment // Instruments and Experimental Techniques. 2024. T. 67. № 4. – C. 691-699. doi:10.1134/S0020441224701136
[3] Dementev D. V., Shitenkov M. O. et al. Characterization of Tracking Modules Based on DSSD Sensors at the SC-1000 Accelerator for the BM@N Project // Physics of Particles and Nuclei Letters. 2024. T. 21. № 4. – C. 919-927. doi:10.1134/S1547477124701000.

GBTxEmulator



Provide interface between the Front-End Electronics and the Data Processing board
Features:

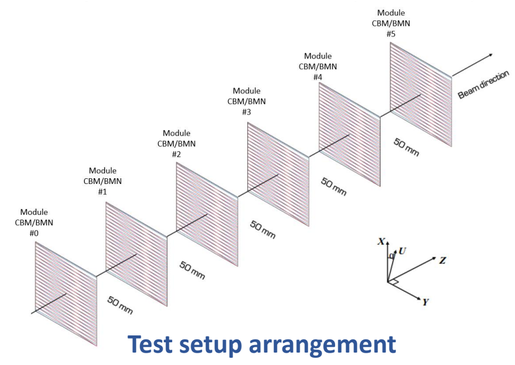
- Provides GBTx ASIC (CERN) functionality:
  - fast time deterministic transport of downlink massages (control and monitoring);
  - high-speed transmission of hit data in the uplink direction;
- Platform: Trenz TE0712-02-100-2C with Artix-7 FPGA from Xilinx;
- 4.8 Gb/s optical links connecting to the Data Processing board (DPB);
- Control interface: GBT-link and IPbus via 100 Mb/s Ethernet;
- E-Link interface (for communication with Front-end electronics):
  - 48 LVDS links with 80 Mb/s data rate;
  - 6 E-Link clock – 40 MHz;
  - 6 downlink;
- Single Event Upset (SEU) control and mitigation [2];



Block diagram of the Firmware GBTxEMU

Results of the in-beam tests

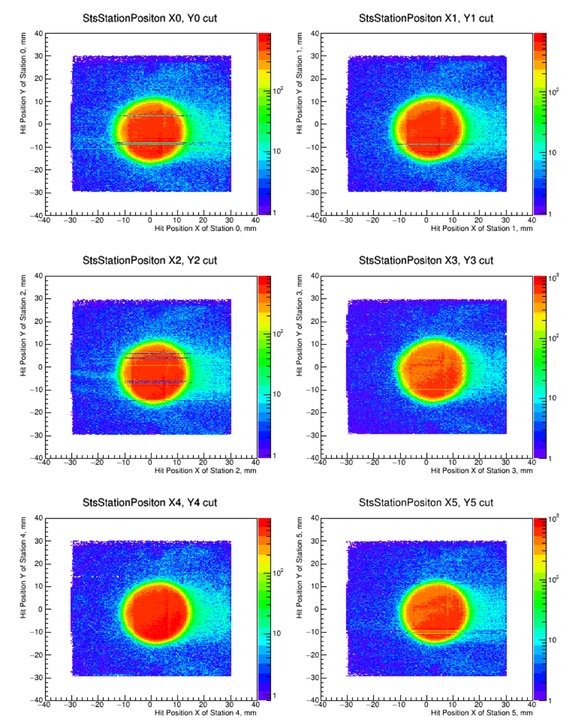
The DAQ system with 6 modules CBM/BMN was tested in a telescope configuration with 1 GeV proton beam at PNPI (Gatchina).



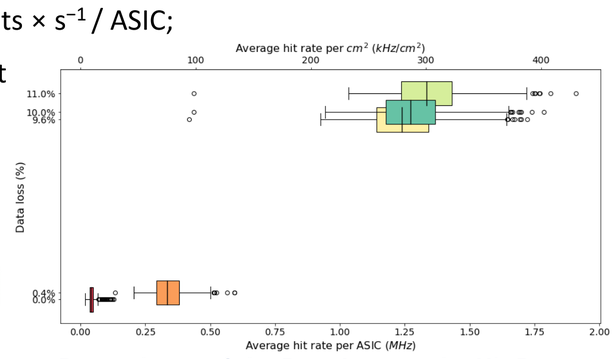
Test setup arrangement

Results [3]:

- Signal/Noise > 24;
- Thresholds 4600 – 6300 e-;
- Spatial resolution 15.4±0.4 µm;
- Maximum data throughput ≈ 2.35 MHits × s^{-1} / ASIC;
- Efficiency > 99% (for the areas without nonworking channels);
- TDC resolution σ = 0.79 ts (9.9 ns);
- Endurance test ✔
- Integration with triggered readout ✔



Beam profiles for six modules



Dependence of the Data Loss on the Hit Rate

Silicon vertex plane for the BM@N Upgrade

The silicon high-granulated plane of 6 CBM/BMN modules equipped with the streaming readout system is being installed at the BM@N setup. The major final goal of the upgrade is a drastic decrease of the dead time for the silicon tracking system data readout eventually making the rare events studies with BM@N setup feasible.