SND DAQ system evolution

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Abstract. The spherical neutral detector (SND) takes data at the e+e− collider VEPP-2000 in Novosibirsk. We present here recent upgrades of the SND DAQ system which are mainly aimed to handle the enhanced events rate load after the collider modernization. To maintain acceptable events selection quality the electronics throughput and computational power should be increased. These goals are achieved with the new fast digitizing electronics and distributed data taking. The data flow for the most congested detector subsystems is distributed and processed separately. We describe the new distributed SND DAQ software architecture, its computational and network infrastructure.

1. Introduction

The SND detector is a general purpose nonmagnetic detector placed at the e+ e− collider VEPP-2000 in BINP (Novosibirsk, Russia). At present, VEPP-2000 is the only e+ e− machine operating at the center-of-mass energy range from 0.3 to 2.0 GeV. The physics program of experiments at SND includes measurements of hadronic cross sections, studies of dynamics of hadron production, search for rare and forbidden processes, and other researches [1].

SND collected data in 2010-2013. Then experiments were stopped for collider modernization [2]. Data taking will be resumed in the beginning of 2017. During the modernization the injection subsystem was significantly changed to achieve higher luminosity performance. With increased luminosity the peak loads of SND electronics are expected to increase up to 10 times. The DAQ system did not have sufficient power reserves to process the data stream without compromising the quality of the event selection. In order to prepare the online system to sustain expected high loads, the DAQ architecture was redesigned, computational and network infrastructures were upgraded, a sequential replacement of electronics in the digitization subsystem was started. In this paper the new design, last updates and current state of the DAQ system are presented.

2. VEPP-2000 collider

The VEPP-2000 electron-positron collider operates in the center-mass-energy (c.m.) range from 0.3 to 2.0 GeV. Two detectors, SND and CMD-3 (Cryogenic Magnetic Detector), are located in two beam collision points, opposite each other, and take data simultaneously.
Figure 1. The layout of the VEPP-2000 accelerator complex in the experiments of 2010-2013.

Figure 2. The snapshot of the VEPP-2000 collider.

The layout of the VEPP-2000 accelerator complex during experiments of 2010-2013 and the snapshot of the VEPP-2000 collider are presented on figures 1 and 2, respectively.

Figure 3. VEPP-2000 luminosity in experiments 2010-2013.

In the 2010-2013 experiments VEPP-2000 had the following parameters:

- Energy (c. m.): \( E = 0.3-2.0 \text{ GeV} \)
- Circumference: 24.4 m
- Round beam optics
- Beam energy spread: 0.6 MeV at \( E=1.8 \text{ GeV} \)
- Luminosity at \( E=1.8 \text{ GeV} \): \( 2 \times 10^{31} \text{ cm}^{-2} \text{ sec}^{-1} \)

The collider luminosity was limited by the deficit of positrons at the beam energies near the upper energy limit of the collider. The maximum luminosity \( 2 \times 10^{31} \text{ cm}^{-2} \text{ sec}^{-1} \) was achieved (figure 3).
During the collider upgrade a new electron/positron source, VEPP-5 injector, was connected to the VEPP-2000 complex as shown in figure 4, in order to achieve projected luminosity $\times 10^{32} \, \text{cm}^2 \, \text{sec}^{-1}$ at $E=2\text{GeV}$. This will lead to a significant increase in the load of SND front-end electronics and an increase in the frequency of background and experimental events in comparison with previous experiments.

3. DAQ

3.1. Data processing system

The DAQ architecture and the main data flows before the last upgrade are presented in figure 5. The hardware trigger is implemented in CAMAC modules. A dedicated computer is used for reading and processing data from SND electronics. Process Readout collects event data from the digitizing electronics KLUKVA (internal institute standard of boards and crates for data acquisition), builds events and puts them in containers in the shared temporary storage for further software trigger processing. Software triggers concurrently grab containers, read and parse events, and provide online full events reconstruction to select interesting and calibration events. Interesting events go to the long-term storage for offline processing, calibration events go to the short time storage for further processing by calibration and control processes.
3.2. **Online processes**

Online software provides interactions with SND electronics, data gathering, event building and processing, multiple support services and user interfaces.

Activities concerning electronics configuration, digitized data reading, events building and events storage are performed by the process Readout. Reading of electronics triggering counters are performed by the process Scalers. Slow control of electronics parameters (e.g. high voltages) is performed by the process Slow Control.

Online event processing is implemented by the distributed software trigger L3, which utilizes parallel procedure of events selection after full software reconstruction. The process Control uses selected events and provides automatic statistical control of detector channels and calibration on events.

Different auxiliary software services are used for data acquisition management and event acquisition consistency: notification service (messages, emails and sound alarms), external information exchange service (VEPP and CMD-3), online processes manager and context recovery service.

3.3. **New online requirements**

New requirements have been imposed on the online system. This was caused by changes in the accelerator complex and new digitizer electronics:

- The performance improvements of the collider should lead to significant increase of the events rate (up to 10 times) in the upcoming experiment.
- New types of digitizing boards were developed in order to improve the accuracy of signals measurement and to provide extra facilities of particle separation. They produce more data: the average size of events has increased in two times.

As a result, the expected data flow from the detector electronics in upcoming experiments will increase up to 20 times: from 6 KB and 1 KHz up to 12KB events at 10 kHz.

The increase of the event rate impacts badly on the performance of the DAQ due to the presence of SND electronics dead time. The event lost fraction (unregistered/total events ratio) may be described by the approximate formula $f^*\tau / (1+f^*\tau)$, where $f^*$ is the average event frequency and $\tau$ is a dead time per event.

![Figure 6](image1.png) **Figure 6.** Lost event fraction over event frequency (Hz) dependency in experiments 2010-2013.

![Figure 7](image2.png) **Figure 7.** Lost event fraction over event frequency (Hz) after the upgrade.

In experiments 2010-2013 the dead time of digitizing electronics was about 120 microseconds per event. The experimental measurements of lost events fraction with formula fitting are presented in figure 6. Events lost fraction becomes fairly high and unacceptable at high events frequencies. For example, more than 20% of events remain unregistered at event frequencies above 2 kHz.
The reasons for the existence of dead time are as follows:

- The digitizing boards are paused on the period of data transfer. The longer event data reading time leads to the longer period, when the DAQ system remain unprepared for new event registration.
- Reading of the digitizing boards is sequential in one crate. So, the transfer dead time is summarized for every crate and depends on the distribution of the event data over crates.
- Electromagnetic calorimeter boards digitizing takes about 40 µs after triggering, when the boards are not ready for data transmission.

4. DAQ upgrade

4.1. Computing and network infrastructure

Figure 8. New computing and network infrastructure.

The DAQ computer network infrastructure after SND DAQ upgrade is presented in figure 8. New elements are indicated by the dashed-line box. Two new online subsystems were deployed: online computer farm for data processing and network digitizing modules.

4.2. Digitizing and event collection

In order to reduce the dead time, improve data collection performance and quality, the consistent replacement of the digitizer boards was started. Digitizing boards are replaced by the new ones which can digitize and transfer data simultaneously, thus, do not have dead time at all.
DC strips and Cherenkov counters detector digitizing subsystems were upgraded the first. The current architecture is show in figure 9, where new digitizing modules are circled with a dashed line. All new digitizing boards have network interfaces, presentation of signals in the form of arrays of digitized samples. After this update, the dead time per event was decreased from 120 to 50 µs (see figure 7). It allows to work at the frequency, which is approximately two times higher than it was in the experiment 2010-2013, at the same percentage of the lost events.

4.3. Software pre-processing
Event data flow was significantly increased after the integration of the net boards, which record signal form as array of amplitudes.

In order to reduce incoming data, the software for online pre-processing of digitizing arrays was implemented. The scheme of the data pre-processing is presented on the figure 10. Readout may be configured to read net boards through the Proxy processes running on the online farm. Proxy uses specific converter plugins to perform the online data preprocessing to extract and transfer the most
important information only. Proxy passes data in an extraction format. Such conversion significantly reduces the data transfer size (100-200 times). For Readout process, reading through Proxy looks in such a way as if Readout reads the different type of the net board.

4.4. Upcoming upgrades

The upcoming updates are presented in figure 11. Old digitizing electronics will be replaced by the new boards with network interfaces, zero dead time on high frequencies and improved measurements accuracy.

The upgrade of the digitizing subsystem of the electromagnetic calorimeter will be the next [4]. The projected board Z24 will have extra time measurement facilities, which should help to suppress event pileup. The Z24 board prototype, which is based on the system-on-chip with Linux operating system inside (Xilinx PetaLinux) and Flash ADC, was developed. ADC and data transfer features of the board were examined and tested successfully. A very good throughput (> 500Mbps) was achieved on the prototype in simulation of events reading. The firmware and driver development works was started. This project seems very promising due to the software flexibility, and if its viability and reliability will be proved, it may be taken as the basis for the further upgrades of all digitizing boards.

![Figure 11. Upcoming updates.](image)

Concerning data processing we plan to separate the events reading from interaction with CAMAC and other Readout functionalities, in order to use the online farm not only for selection but also for events reading.

5. Conclusions

The SND DAQ system underwent the upgrade to meet the needs of processing higher electronics load. The next major updates were made:

- New online network infrastructure and computer farm were deployed.
- The network digitizing boards for drift chamber cathode strips and Cherenkov counters were developed, tested, manufactured and integrated into DAQ.
- Readout & EB were upgraded to support heterogeneous digitizing electronics.
- Online quick software-processing of digitizing data was implemented.
In total, DAQ performance was increased 2 times by frequency and 4 times by volume of processing data. The further upgrades are coming.

References
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