Calibration of the calorimeter signal waveform in the SND detector

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Abstract

The new spectrometric channel for the SND electromagnetic calorimeter (EMC) is described. It provides measurement of the calorimeter signal arrival time and amplitude with 1 ns and 250 keV resolutions, respectively. The new electronics is useful for reliable detection of low-speed anti-neutrons from the e+e- -> n anti-n reaction near threshold and needed for increasing the EMC operation rate. The algorithm of determination of signal parameters (time, amplitude) is based on invariability of the signal waveform. We present the procedure of the waveform calibration using generator signals, and signals from cosmic rays and Bhabha scattering events.

Introduction

The Spherical Neutral Detector (SND, Fig. 1) is one of the two detectors operating at VEPP-2000 e+e- collider, which is located at Novosibirsk, Russia

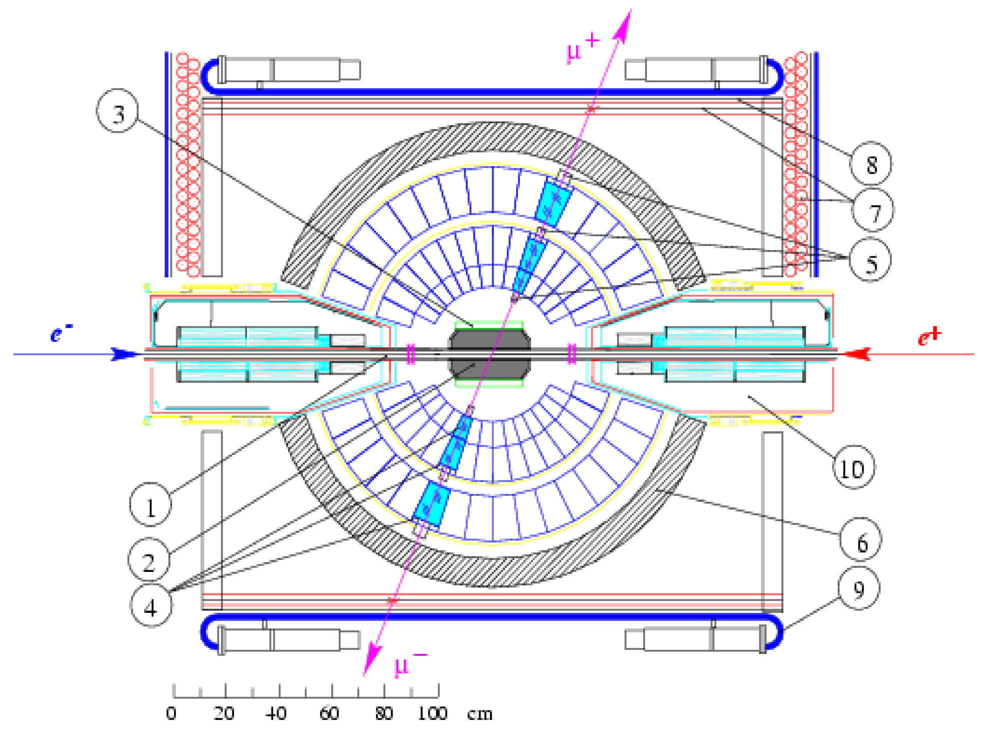

Figure 1 The Spherical Neutral Detector layout.. *1 – VEPP-2000 beam pipe, 2 – tracking system, 3 – aerogel Cherenkov counter, 4 – NaI(Tl) counters, 5 – vacuum phototriodes, 6 – absorber, 7-9 – muon system, 10 – VEPP-2000 superconducting focusing solenoids*

The main part of the SND is a three-layer electromagnetic calorimeter (EMC, Fig 2, 3), which consists of 1640 NaI(Tl) counters. Each counter includes NaI(Tl) crystal, vacuum phototriode, and charge-sensitive preamplifier.

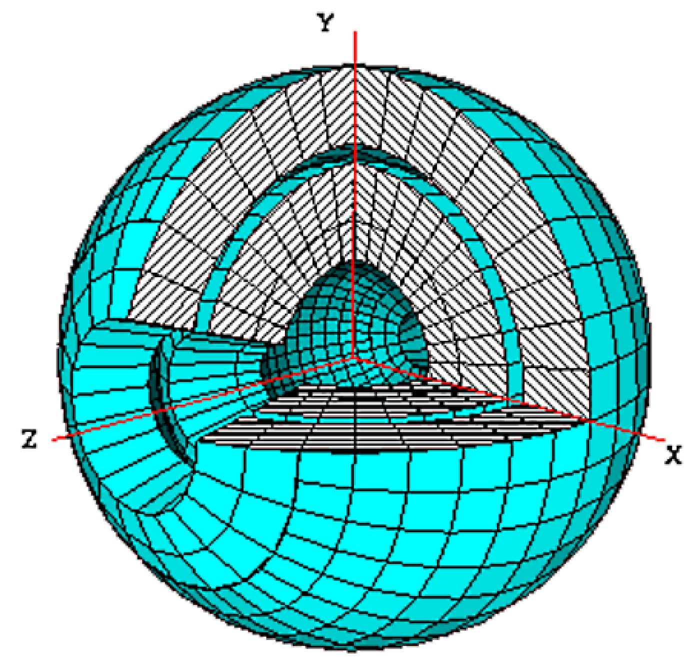

Figure 2. *The EMC layout. SND calorimeter general parameters: total weight of NaI - 3.5 tons, 1632 crystals, VPT readout, 13.4 X_0NaI=(2.9+4.8+5.7)X_0 (34.7 cm), 0.9·4π solid angle, angular size of the counter $\Delta\varphi=\Delta\theta=9°$*

Energy resolution $4.2\%/\sqrt[4]{E(GeV)}$

Angular resolution $0.82°/\sqrt{E(GeV)} \oplus 0.63°$

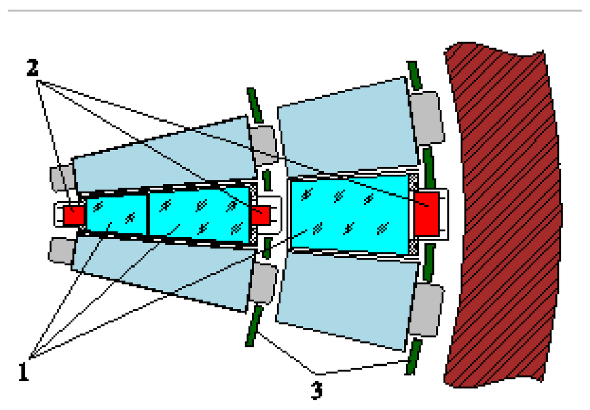

Figure 3.*The segment of the EMC:NaI(Tl) crystals (1), vacuum phototriodes (VPT) (2), aluminum supporting spheres (3).*

New spectrometric channel

The layout of the new spectrometric channel is shown in Fig. 3. The signal from the vacuum phototriode (VPT) installed on the NaI(Tl) crystal goes to the charge-sensitive preamplifier (CSA) and then to the input of the shaper module (F12M). After that, the signal is digitized by the Z24 module. The calorimeter pulse recorded in Z24 is read out after the arrival of a first-level trigger (FLT) signal.

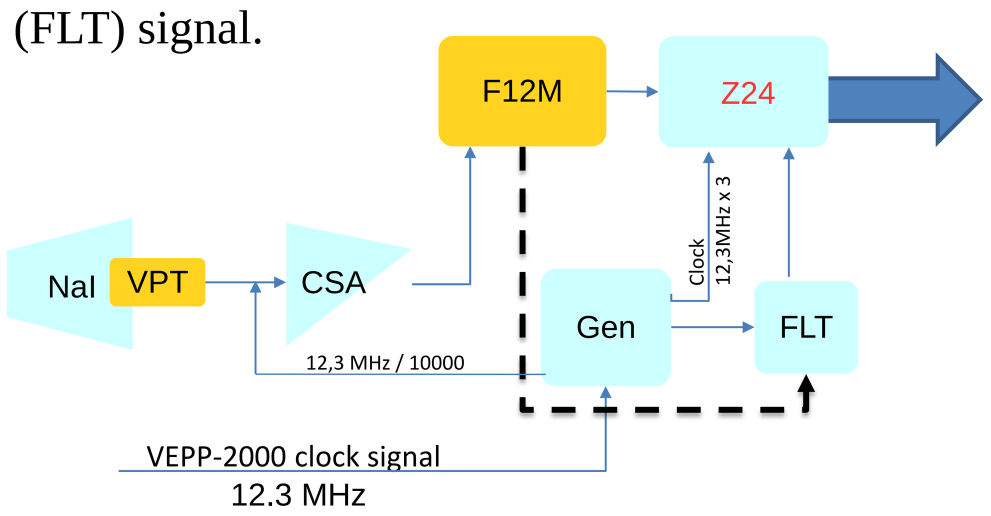

Figure 4*. The layout of the spectrometric channel*

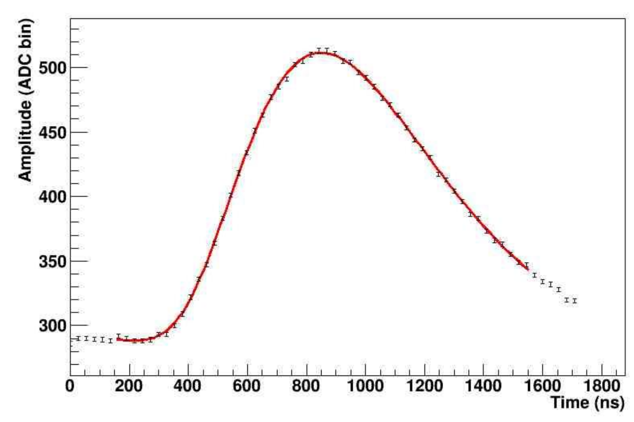

Figure 5*. The calorimeter pulse*

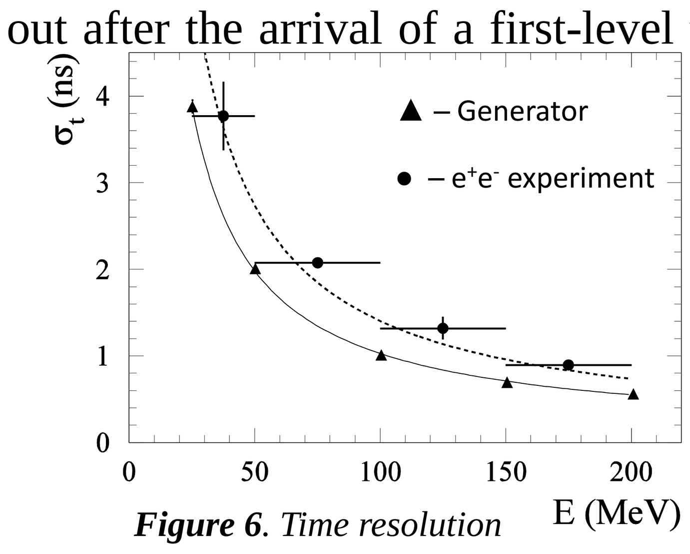

Figure 6*. Time resolution*

The digitized pulse (Fig. 5) is fitted with the function ***U(t)=A•F(t – Δt) + P***, where F(t) is a function describing signal waveform equal to unity in the maximum (cubic B-spline), A is the signal amplitude, P is the pedestal, Δt is the shift of the arrival time.

Figure 6 shows comparison between the time resolution obtained with the calibration generator (Gen in Fig. 4) and time resolution in data recorded during experiment at the VEPP-2000 e^+e^- collider.

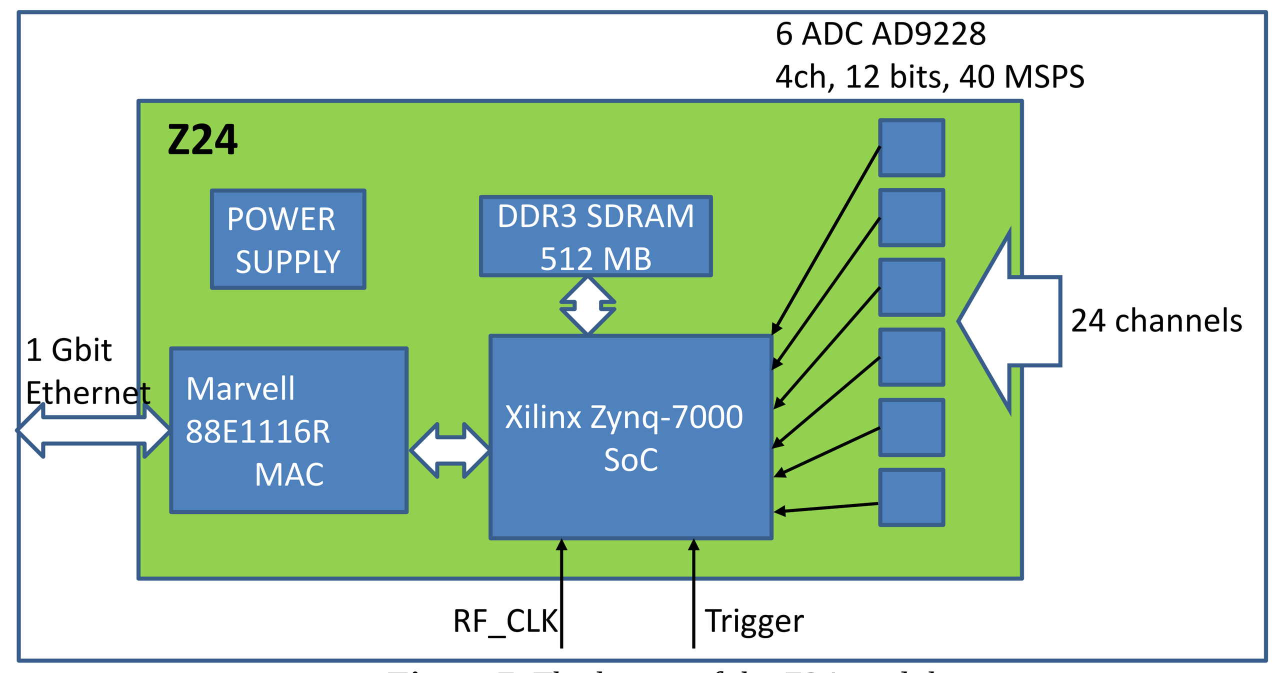

Figure 7*. The layout of the Z24 module.*

Z24 module

We performed optimization of F12M shaping parameters to reduce the level of noise. The Z24 design has an aim to determine parameters A,P, Δt inside of the Z24 module. The algorithm used in Z24 minimizes $\chi^2=(u_i - AF(t_i - \Delta t) - P)S^{-1}_{ij}(u_j - AF(t_j - \Delta t) - P)$, where u_i is the signal sample, and S_{ij} is the noise covariance matrix. The algorithm has been tested and was adopted for implementation in System-on-Chip (SoC) Zynq-7000.

The Z24 board digitizes 24 analogous inputs from two F12M shapers (see Fig. 7) . This digitization is performed by 6 ADCs AD9228BCPZ-40 (4 channel, 12 bits, 40 MBPS) and the data go in serial from to the SoC. This SoC is basically a combination of FPGA programmable logic and ARM processor. The use of this SoC allows flexibility of the design approaches. We use programmable logic for ADC data deserialization and buffering. And we use the CPU with Linux system running on it for the reconstruction algorithm and interface with DAQ system over Ethernet. But we can use the SoC programmable logic also for fast data processing.

Waveform calibration

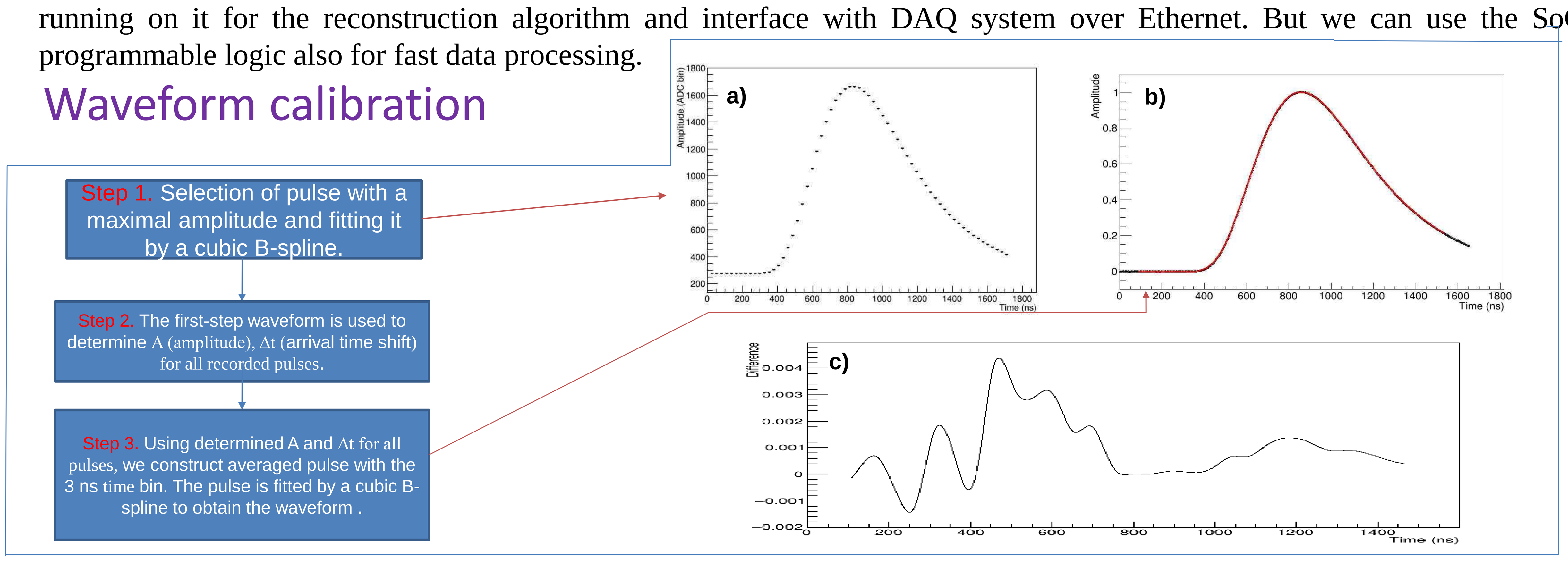

Figure 8. *Waveform calibration procedure. a) The typical pulse with a digitization step of 27.12 ns. b) The averaged normalized pulse with the 3 ns bin. The pulse is fitted by a cubic B-spline c) The difference between the waveforms obtained on Bhabha and cosmic events.*

As mentioned above, the algorithm of pulse-parameters determination (time, amplitude) is based on invariability of the signal waveform. It is planned to use two procedures for waveform calibration. The first is to construct averaged pulse from cosmic muons and fit it. The procedure is described in Fig.8. All collected pulses have amplitude more then 25 MeV. This energy deposition provides optimal signal/noise ratio for obtaining waveform. The procedure converges after several iterations over steps 2 and 3. The pulse is fitted by cubic B-spline. The second procedure constructs the averaged pulse for Bhabha scattering events, which is then fitted to obtain a waveform. Comparison of the waveform obtained on Bhabha events with the waveform obtained on cosmic muons is shown in Fig.8.

Conclusion

The new spectrometric channel for the electromagnetic calorimeter of the SND detector taking data at the VEPP-2000 e^+e^- collider has been tested. The time resolution about 1.3 ns and the amplitude resolution about 0.25 MeV have been obtained at the 100 MeV energy deposition in the calorimeter crystal. The algorithm of fitting the calorimeter pulse has been designed. The algorithm was tested in hardware and now we finished the production of more than 80 Z24 boards. The waveform calibration procedure was designed and verified. The waveforms obtained on cosmic muons and Bhabha events are in good agreement.