Development of front end electronics for the Time Projection Chamber at SPring-8

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A Time Projection Chamber (TPC) was constructed as the 4π detector for hadron photoproduction experiments at SPring-8/LEPS[1]. The basic performance of TPC was studied on 64 pads by prototype readout electronics in year 2001. Main progress in year 2002 is the improvement of these modules and mass production for 1055 channels. A good noise performance and linearity of front end electronics are required for precise measurements of momenta of particles. The spatial resolution required for the study of hyperon resonance, especially $\Lambda^*(1405)$, is 350 μm and 700 μm in the pad plane and in the drift direction respectively. An accuracy of 1.5 % on the measurement of induced charges on the pad plane is crucial for achieving the required 350 μm spatial resolution.

The signal readout system of TPC consists of preamplifiers, shaping amplifiers and flash ADCs (FADCs). The charge integrating preamplifiers are the most important component with regard to noise performance and dynamic range. Operational amplifier chips (LMH6655) are used for the preamplifier and shaping amplifier. The preamplifier is designed to deal with signals from both of cathode pads and anode wires. The polarity of output can be chosen by a switch on the card. An important role of a shaping amplifier is to shape signals suitable for sampling by a FADC. The shaping amplifiers is CR-$(RC)^4$ pseudo-Gaussian type with a pole cancellation circuit eliminating undershoot of signals. All time constants of band pass filters are 20 nsec. A FADC module with 10 bits resolution and 40 MHz sampling has been newly designed at the institute of Physics, Academia Sinica in Taiwan. A detailed report on this FADC can be found in another contribution of this issue.

Mass production of readout electronics has finished in March 2003. The basic performance of whole electronics such as noise level, linearity and gain variation was studied. Figure 1 shows a typical noise structure measured by one channel of FADC. The typical RMS noise including TPC is 3300 e_{RMS} corresponding to 0.6 % of dE/dx by a minimum ionizing particle. Figure 2 represents a typical result of a linearity measurement. A good linear correlation can be seen. The integral nonlinearity obtained as an average of all 1055 channels is 0.4 %, good enough for our specification. The performance of front end electronics is summarized in table 1.

The spatial resolution in the pad plane has much improved by development of front end electronics. The spatial spread of an avalanche along a wire was reduced by a lower gas multiplication on a wire together with a higher gain preamplifier. The position resolution in the pad plane is 280 μm, which is about twice better compared to the one by old readout modules. The further performance study for whole active volume of TPC is underway, and physics experiment will start in year 2003.

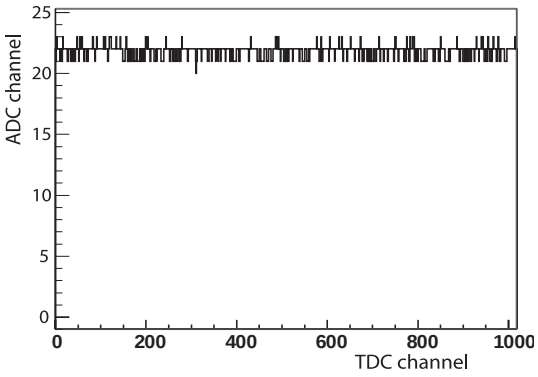

Figure 1: A typical noise structure of whole detector system including TPC measured by a FADC. X and Y axis are time in unit of TDC channel (25 nsec/channel) and voltage in unit of ADC channel (2 mV/channel). A typical RMS noise was 1.2 mV corresponding to 0.6 % of dE/dx by a minimum ionizing particle.

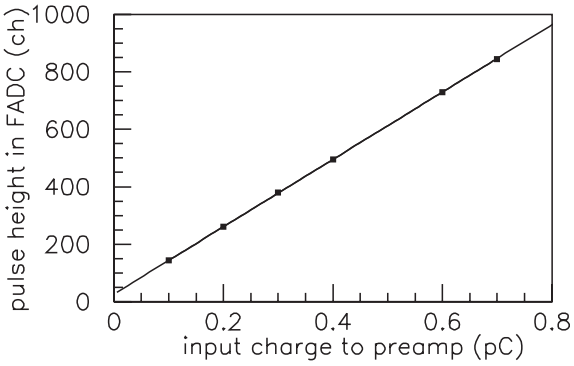

Figure 2: A plot of pulse height measured by a FADC as a function of input charges to a preamplifier. The error bars are hidden under the markers. A good linear correlation can be seen. The integral nonlinearity was 0.4 % as an average of 1055 channels.

Table 1: The performance of TPC readout electronics

performance of TPC readout electronics	
Number of channels of a preamp. and a shaping amp.	16
Gain of preamplifier	0.75 V/pC at 50 Ω load
Integration time of preamplifier	1.32 μs
Maximum input charge to preamplifier	4.0 pC
Shaping time constant (RC constant)	20 nsec
FWHM of signal from shaping amplifier	200 nsec
Total gain of whole readout electronics	2.3 V/pC
Channel by channel variation of total gain	1.1 %
Integral nonlinearity of whole readout electronics	0.4 %
Equivalent noise charge of whole readout electronics	3300 e_{RMS} with TPC

Reference

1. M.Niiyama et al., RCNP Annual Report 2001, p119.
2. W.C.Chang et al., in another contribution of this issue, RCNP Annual Report 2002