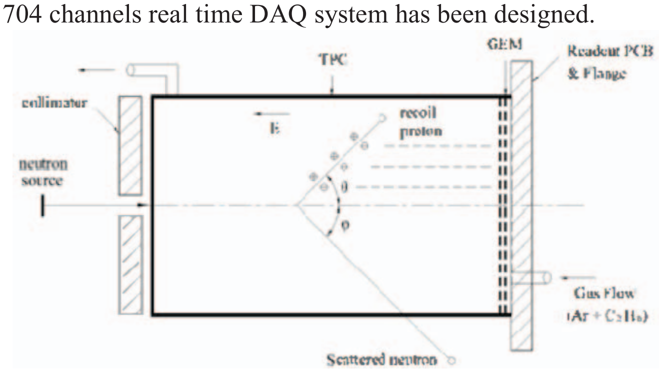
The Intelligent Front End Real Time DAQ System for GEM-TPC Fast Neutron Spectrometer Based on Recoil Proton

Xiaolei Cheng, Peipei Yao, Xiaoping Ouyang, *Member, IEEE*

***Abstract*–A new fast neutron spectrometer based on recoil proton has been designed. The recoil angle and the energy of the recoil proton will be acquired by a 704 channels GEM-TPC. To read out the signals from each of the 704 pads of that TPC, an intelligent front end real time DAQ system has been designed. With the 40Ms/s sampling rate and the 12 bits resolution of each channel, this DAQ could operate with over 8MHz input bandwidth and over 60dB dynamic range required by the spectrometer. With the intelligent design in its main FPGA, this 704 channels DAQ could be self-pre-triggered by each recoil event and transmit the data of over 1000 events per second through only one universal Ethernet interface.**

I. Introduction

A new fast neutron spectrometer based on recoil proton has been designed by Tsinghua Univ. We hope to improve the energy resolution of fast neutron spectrometer with a 704 channels GEM-TPC. As shown in Fig.1, the readout PCB with 704 pads could collect the drifting electrons and record there drifting time, deposition charge and locations to calculate the recoil angel and energy of the recoil protons. To read out and transmit remotely the signals generated by the GEM-TPC, a 704 channels real time DAQ system has been designed.



Manuscript received April 3, 2014. This work was supported by "the Fundamental Research Funds for the Central Universities (2014MS49) and National Natural Science Foundation Of China (11275109).

Xiaolei Cheng, Peipei Yao, Xiaoping Ouyang are with the Nuclear Science and Engineering School, Beijing Key Laboratory of Passive Safety Technology for Nuclear Energy, North China Electric Power Univ., Beijing, China (telephone: +86-10-61773165, e-mail: dampfarmer@163.com).

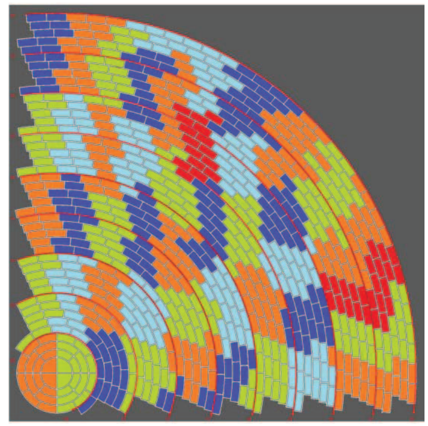


Fig. 1. The readout pads of GEM-TPC fast neutron spectrometer

II. Principle

Limited by the space of layout, each 32 pads must share one 32 channels connector. The DAQ system is constituted by 21 slave boards and one master board to match the 22 output connectors of this GEM-TPC. As shown in the Fig.2, each of the 22 boards could sample 32 channels signals from GEM-TPC with a 32 channels charge amplifier (CASA). All of the sampled data from 704 channels would be gathered by one master board and transmitted to the computer with only one universal Ethernet interface.

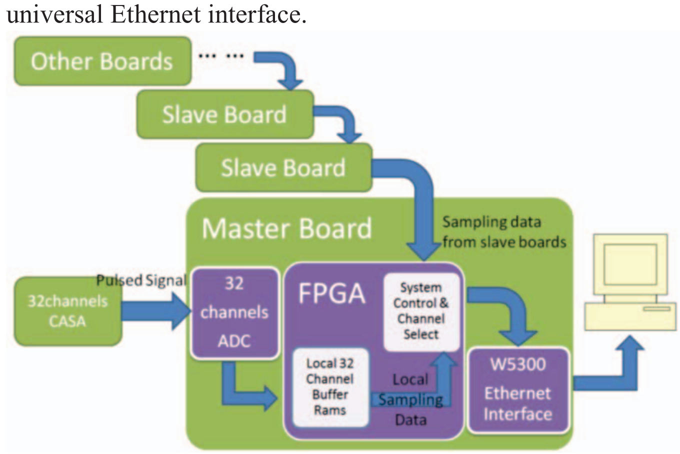


Fig.2 Functional Diagram of DAQ system

The rising edge of the pulsed signals shaped by the CASA is over 40ns, and the prospective energy resolution of this fast neutron must be better than 10%. To meet those requirements (over 8MHz input bandwidth and 60dB dynamic range), the sampling rate and digit should be design as 40MHz and 12bits.

Even if the intensity of fast neutron beam is stable, the time and location of the recoiling and the recoil angel of the proton

978-1-4799-3659-5/14/$31.00 ©2014 IEEE

are all random. The number of the hit pads in one event would vary from 1 to 120, and the width of each pulsed signal from GEM-TPC through CASA would vary from 200ns to 3us.

There are two difficulties to design the DAQ, based on upper mentioned. The first one is to distinguish which signals are generated by the same recoil event. Although we could record each random pulsed signal with a self-pre-trigger design in FPGA, it is hard to get the relationship between all the signals without external unified event trigger. To solve this problem, an intelligent function has been design in the FPGAs. When power-on, the DAQ will be waiting for the input pulsed signals. If any channel is triggered by the first arrived electronic cluster of one event, a 6.4us time window will be opened to wait for the last arrived cluster. All the channels triggered in 6.4us (it's the very time length to acquire all the signals of one same event and keep out the accidental event effectively) would be seen as hit by the clusters of one same recoil event, then the acquisition data would be collected event by event, the recoil angel and the recoil proton's energy of each event would be calculated out reliably.

The second one is to improve the average event sampling rate of this DAQ system. As mentioned above, the max data size acquired from one event is 3000ns×704×12/25ns =1,013,760bits. Limited by the cost and spot technology, those data should be transmitted to computer with one universal Ethernet interface. The transmitting would last over 10ms and the event sampling rate would be down to 100/s. In fact, most of the 1,013,760bits data is '0'. Thus an intelligent function has been designed to assure that only the significative data of the 1~120 triggered channels in the 6.4ns time window would be transmitted to the computer, the '0' data from other channels would be ignored. Calculated with the probability distribution of the recoil angel, the average number of hit pads per event is nearly 72, and the average width of pulsed signals is nearly 1.24us. The average data size acquired per event is changed to 42,854.4bits, and then the event sampling rate would become over 2k/s.

III. Conclusion

With the intelligent design in the FPGA of the real time DAQ system, the GEM-TPC could get the energy spectrum of fast neutron more accurately. That's very useful in the fast burst reactor and general pulsed reactor.

References

[1] Cheng, X. ; Ouyang, X.; Liu, F. A Multi Channel High Accuracy Real Time DAQ System For Fast Neutron Spectrometer Based On GEM-TPC . IEEE Nuclear Science Symposium Conference Record, p 1028-1030, 2012. .

[2] 2. Meng Huang; Yulan Li; Zhi Deng; Xiaolei Cheng; Jin Li; Libo Niu; Yuanjing Li. A Fast Neutron Spectrometer Based On GEM-TPC. 2012 IEEE Nuclear Science Symposium and Medical Imaging Conference Record (NSS/MIC 2012) & Workshop on Room-Temperature Semiconductor X-Ray and Gamma-Ray Detectors, p 146-8, 2012.

[3] Igor Jovanovic, Michael Heffuer, Directional Neutron Detection Using A Time Projection Chamber, IEEE Transactions on Nuclear Science, June 2009, Volume:561ssue:3.