Nuclear Inst. and Methods in Physics Research, A 899 (2018) 43–48

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Application of the Generic Electronics for Time Projection Chamber (GET) readout system for heavy Radioactive isotope collision experiments

T. Isobe [a,*], G. Jhang [b], H. Baba [a], J. Barney [b], P. Baron [f], G. Cerizza [b], J. Estee [b], M. Kaneko [d,a], M. Kurata-Nishimura [a], J.W. Lee [c], W.G. Lynch [b], T. Murakami [d], N. Nakatsuka [d], E.C. Pollacco [f], W. Powell [e], H. Sakurai [a], C. Santamaria [b], D. Suzuki [a], S. Tangwancharoen [b], M.B. Tsang [b]

[a] RIKEN Nishina Center, RIKEN, 2-1 Hirosawa, Wako, Saitama 356-0198, Japan
[b] National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA
[c] Department of Physics, Korea University, Seoul 136-701, Republic of Korea
[d] Department of Physics, Kyoto University, Kyoto 606-8502, Japan
[e] Department of Physics, University of Liverpool, Liverpool, Merseyside L69 7ZE, UK
[f] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France

ARTICLE INFO

Keywords:
Time projection chamber
Readout electronics
Radioactive isotope
Heavy ion collision

ABSTRACT

We have implemented the Generic Electronics for Time Projection Chamber (GET) in a SAMURAI Pion Reconstruction and Ion-Tracker (SπRIT) readout system for heavy radioactive ion collision experiments at RIKEN-RIBF. The SπRIT experiment is designed for heavy ion collision experiments with radioactive ion beams, where a Time Projection Chamber (TPC) with 12096 pixelized readout pads is employed as the main device. Since the TPC is located on the beam line, the readout electronics must handle small signals from pions as well as very large signals from beam or large fragment particles. Operation of the GET electronics during experiment functioned well using 270 time-bucket readout with 25 MHz sampling at an event Data acquisition (DAQ) rate of 60 Hz. Using the slope information of acquired signals it is possible to extend the dynamic range of dE/dx information compared to using the peak height information. However, huge signals arising from energetic δ-rays produced by un-interacted projectiles induce dead channels, which can be recovered after 70 μs on average.

1. Introduction

The nuclear Equation of State (EoS) is fundamental to understand the bulk property of nuclear matter. It describes the relationships between the parameters of a nuclear system, such as energy, density and temperature. For an asymmetric system, the nuclear EoS depends on the nuclear asymmetry term, which is often expressed as the value $\delta = (N - Z)/(N + Z)$, where N and Z are the number of neutrons and protons, respectively. The asymmetry term of the nuclear EoS is also important in astrophysics to describe highly asymmetric objects such as neutron stars. Much efforts have been made to constrain the asymmetry term of the nuclear EoS especially below the normal nuclear density region.

Heavy-ion collisions provide a unique experimental probe to study the nuclear EoS in the laboratory at densities exceeding normal nuclear density. To perform heavy-ion collision experiments at the Radioactive Ion Beam Facility (RIBF) in RIKEN, Japan, a time projection chamber (TPC) was constructed as the main device for SπRIT experiments [1]. At high density, the charged pion spectral ratio has been predicted as most sensitive to the asymmetry term of the nuclear EoS [2,3]. The SπRIT TPC is designed to measure charged pions as well as proton, deuteron and other light nuclei. By installing the SπRIT TPC inside the SAMURAI superconducting dipole magnet [4], charged particles can be identified using the trajectories measured inside a magnetic field of 0.5 T.

2. Readout electronics for TPC: GET

The SπRIT TPC employs the Multi-Wire Proportional Chamber (MWPC) type readout with an array of 108 (wire direction) × 112 (beam direction) pads as shown in Fig. 1. The size of a pad is 8 mm × 12 mm. The effective detection area of the TPC is 864 mm (wire direction) × 1344 mm (beam direction) × 530 mm (drift direction). The capacitance between a pad and the detector ground is estimated to be 15 pF.

* Corresponding author.
E-mail address: isobe@riken.jp (T. Isobe).

https://doi.org/10.1016/j.nima.2018.05.022
Received 2 February 2018; Received in revised form 9 May 2018; Accepted 11 May 2018
Available online 17 May 2018
0168-9002/

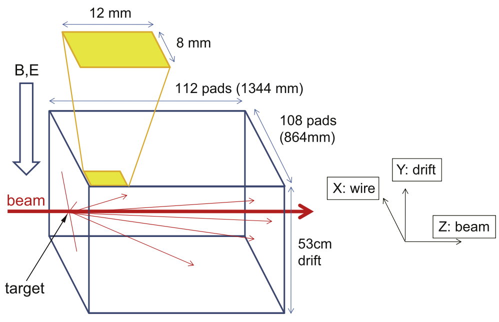

Fig. 1. Schematic view of SπRIT-TPC.

To read out the 12,096 channels of SπRIT TPC, a state-of-the-art readout system, Generic Electronics for TPC (GET) [5], is employed. Fig. 2 shows the overview of the GET system for the SπRIT-TPC. The AsAd (ASIC and ADC) board is the front-end board for the amplification, shaping and digitization of an analog signal. Each AsAd board contains 4 AGET ASIC chips, FPGA and 4 channel ADC (ADS6422) and is connected to the TPC pads via an interface board, which is described later. The AGET is the ASIC chip specially developed for the GET system [6]. The dynamic range (120 fC to 10 pC), charge polarity (positive or negative), signal peaking time (50 ns to 1 μs) and sampling rate (1 to 100 MHz) are configurable through slow control. Each AGET chip can read out 64 channels. However, for the SπRIT-TPC, 63 channels are connected to $7 \times 9 = 63$ TPC pads. The unconnected channel serves as a fixed pattern noise (FPN) line which is used for the evaluation of baseline noise and cross talk signal through the cables and interface board. For each channel of the AGET chip, a 512 switched capacitor array is integrated as analog memories. The charge stored in the analog memories is converted to digital data when a trigger is made. Each AsAd board is connected to $9 \times 28 = 252$ readout pads out of 108×112 total readout pads. In total, 48 AsAd boards with 192 AGET chips are mounted on top of SπRIT-TPC, directly above the pad plane. The configuration of 25 MHz sampling rate, 120 fC dynamic range and shaping time of 117 ns was employed for the SπRIT-TPC during the experiment.

Digitized data in AsAd board are sent to the CoBo (Concentration Board) board which has DDRAM for event buffering. The functionality of the CoBo board includes receiving the trigger, and controlling the AsAd. The data buffered in the CoBo-DDRAM are sent to a DAQ computing cluster as described in a later section.

3. Installation of GET Front End Electronics

The AsAd boards can fully function under a magnetic field of at least up to 0.6 T. To minimize distortion of the SAMURAI magnetic field, we avoid using any magnetic component except for the IEEE1394 type 2 connector mounted on AsAd. Two μ-TCA crates (Vadatech VT893-123-000-000 with the MCH module of Vadatech UTC002-210-400-010), one with eight and one with four CoBo boards are located outside the SAMURAI magnet to minimize the effect of magnetic field. Each CoBo board is connected to four AsAd boards on the TPC via 8 m long commercial VHDCI cables with very weakly magnetic connectors (CS-VHDCIMX200-008).

3.6 V is supplied to AsAd boards on the TPC via 10 m long cables with μD-SUB connectors (Nihon Maruko Int., JMCK-L-9S4C3-400, AWG24 wire) using WIENER OMPV8016 module. The voltage and current value supplied to AsAd is continuously monitored with web based PHP scripts through SNMP.

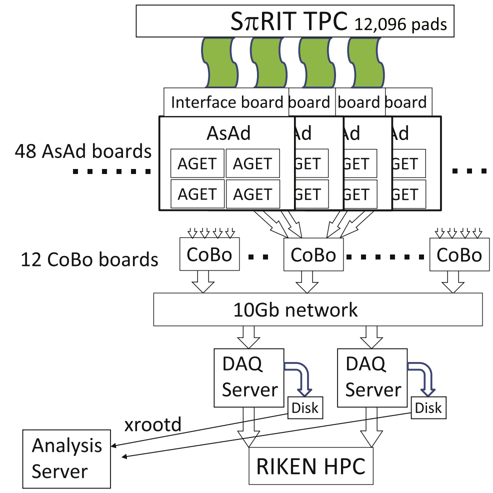

Fig. 2. Overview of readout system for SπRIT-TPC. 48 AsAd boards are mounted on TPC. 12 CoBo boards are located outside the SAMURAI magnet. Each CoBo board is connected to four AsAd boards. The data buffered in CoBo are continuously sent to data acquisition servers (DAQ), which have 100 TByte cache disk space in total. The data are copied to RIKEN high performance computing clusters through 10 Gbps intranet.

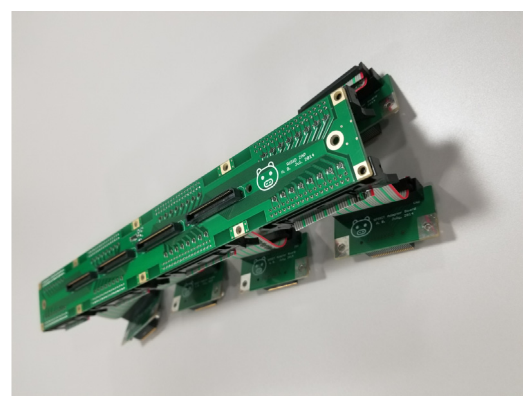

Fig. 3. Interface board between TPC and AsAd board. It is composed of two types of rigid boards connected through eight flat cables so that AsAd board can be tilted to be mounted in the limited space.

3.1. Interface board for GET on TPC

As the GET system itself was developed for general use, an interface board to connect the GET electronics to SπRIT-TPC is needed. The board serves as an adaptor–connector between the GET electronics and the TPC, as well as provides protection against huge signal caused mainly by discharge. The low-capacitance (1.5 pF) back-to-back diode array of TPD4E001 (Texas Instruments Inc.) is employed as the component for protection. The supporting structure and all of the readout components, including interface boards and cooling components, are designed to fit on top of the TPC within 17 cm of vertical space available after installation of the TPC inside the SAMURAI chamber during experiments. The interface board is composed of two types of rigid boards connected through 8 flat cables as shown in Fig. 3. The AsAd board can be tilted when mounting in the limited space. The size of the larger part of the interface board is 31×4 cm^2. The push type connector of FSI-125-10-L-D-A (SAMTEC Co. Ltd.) is employed to make the connection between TPC readout pads and the smaller part of interface board.

The board was designed to minimize the additional noise, which is essential for maximizing the dynamic range. Each channel of the AGET has an individual signal discriminator, which can be used for generating