A multi-parameter data acquisition system for the collision research platform at Shanghai EBIT

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Abstract In this work we describe a multi-parameter data acquisition system (DAQ) which has been developed for the Shanghai EBIT. This system is operated at the collision research platform which includes a recoil-ion momentum spectrometer (RIMS). We have employed DAQ based on the VME system, which is a very fast developing system within the RIMS community, and with which we can reach data transfer rates of up to 160 Mb·s^{-1}. The software developed for DAQ based on UnisDX-XP is also described.

Key words Data acquisition system, VME, Shanghai EBIT, TDC, ADC

1 Introduction

Electron Beam Ion Trap (EBIT)[1] is a device capable of acting both as light source and ion source for highly charged ion research. Before the development of EBITs, ions of charge states above 30 could be produced at just a couple of very expensive high energy accelerators scattered around the world, while with EBIT one can produce ions of basically any charge state of any element in the periodic table. It is a small machine suitable for a normal scale laboratory, with only a fraction of the running costs of large accelerator facilities.

As the first EBIT in China and the 8th cryogenic EBIT in the world, Shanghai EBIT at Institute of Modern Physics, Fudan University was built in 2005[2,3], as a project started in 2002. A spectroscopic platform was subsequently established with various detectors/spectrometers, covering a continuous wavelength range of 0.1–1000 nm[4]. And a collision research platform, including a recoil-ion momentum spectrometer (RIMS)[5] for studying the interaction between highly charged ions (HCIs), with atoms/molecules or photons, is close to its completion.

Interaction of HCIs with atoms and molecules is an ideal way to study atomic many-body system and dynamics and to understand atomic collision processes, atomic structures, and the underlying physics[6]. In the past few years, the interaction between HCIs and atoms and molecules was revolutionized by recoil-ion momentum spectroscopy (RIMS) and other advanced experimental imaging and projection techniques. RIMS enables one to measure the vector momenta of almost all fragments in a collision process with an unprecedented large solid angles, often reaching almost 4π. On top of this high angular coverage, very high energy resolutions of sub-meV for slow electrons and of μeV[7] for ions have been achieved.

A pre-requisite for obtaining good resolution in fragmentation experiments of atomic collisions are fast electronic systems, and high performance data acquisition (DAQ) systems. Such systems collect information from all the detectors, combines the data into a complete event, and writes to a data file which stores the experimental result for post analysis. Like most systems of the kind, the DAQ part is based mainly on CAMAC. However, the data scale for such full information collision studies is usually very large

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and increasing as the experiments become more detailed. In fact the data size requirements are increasing faster than the development of new CAMAC modules.

In this paper, we report a VME DAQ system, which is a pioneering system in RIMS collision systems worldwide. With the system's data transfer rate of up to 160 Mb/s, the collision research platform will enable us to perform very fine collision dynamics studies.

2 The structure of DAQ system

VME64x systems[8] are more favorable for handling problems related to the huge amount of data and data acquisition rate in current RIMS instrumentation. The most important information to record and register is the arrival time and the amplitude of signals. The main modules to achieve this purpose include TDC (Time to Digital Converter), ADC (Analog to Digital Converter) and different scalers.

The Model V1290N is a 1-unit wide VME 6U module that houses 16 independent multi-hit/multi-event TDC channels developed by CAEN[9]. The unit consists of two 21 bit HP-TDC (High Performance TDC) chips, with 25 ps LSB (Least Significant Bit), 52 μs full scale range and 5 ns double hit resolution. The module accepts the NIM input signal. The TDC can be programmed by a microcontroller, which acts as a high-level MMI (Man Machine Interface) for masking the TDC hardware. Two different module setups are selectable *via* software for different acquisition scenarios, namely: continuous storage mode and trigger matching mode. It is possible to switch from one operation setup to the other by simply reprogramming. In the continuous storage mode, data are directly forwarded to the output buffer of the TDC, where they await readout. In the trigger matching mode, trigger matching is performed as a time match between a trigger time tag and the channel time measurements themselves. All data belonging to an event are written into one pack. In this way, the data are clearer and more correlated to the events.

Another important module is the Model V785 of CAEN, which is a 12 bit (4096 channels) ADC[10], with 16 independent analog to digital convert channels and 4V full scale range.

Multi-coincidence measurements were performed in event by event mode and all data were recorded in list mode by a 6U VME bus embedded computer VP9 developed by SBS[11]. This computer offers a package called UniSDK-XP, which enables the access to VME modules. The data acquisition system software is based on this package.

3 DAQ software

The function of the DAQ software is to control the VME modules, record the measured data and show the necessary spectra for online analysis. It works according to the following steps:

First, it initializes all the modules, i.e., sets the fixed parameters, such as the operating mode, the channel enable pattern of the TDC, the error enable pattern, the best resolution, etc. These parameters are saved as default, and the modules load the parameters automatically at the next boot-up.

Next, the software opens channels for access to the VME modules, establishes a new file for data storage, and sets and checks other parameters necessary for a special experiment.

After this the data acquisition procedure begins, i.e. read and analyze the data in the modules and write to a data file in event-mode. The selected information for online analysis can then be sent to different arrays, so as to show, for example, a TOF spectrum, or a 2-dimensional position spectrum according to the analysis requirements (Fig.1).

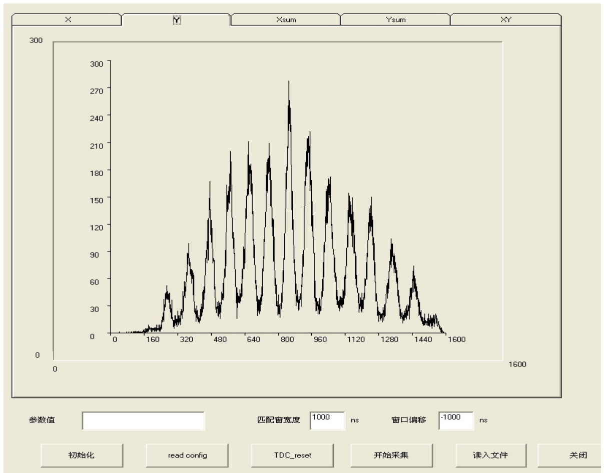

Fig.1 A working space of the software. The abscissa is the time of flight, and the ordinate is the counts. It can show the TOF spectrum of each channel, or 2-dimensional position information.

Post data analysis can be done with the software, which reads the data files, shows the spectra from selected projection along different axes or of different variables, compares the spectra shown in a single figure, and performs spectra algebra, such as adding many spectra or subtracting a spectrum from others.

Finally, the DAQ software ends by closing the access channel, closing any open data files and saving the current parameters as default.

4 Tests with delay-line detector

The DAQ system was tested by checking the individual modules and their integration using a delay line anode position sensitive detector.

The NIM signal from a gate generator is split into two parts. One is sent to the TDC trigger as a common start, while the other is delayed by a GG8020 module and sent to the TDC. In this way, six groups of data can be obtained. As shown in Fig.2, the TDC's time resolution is 50 ps (FWHM).

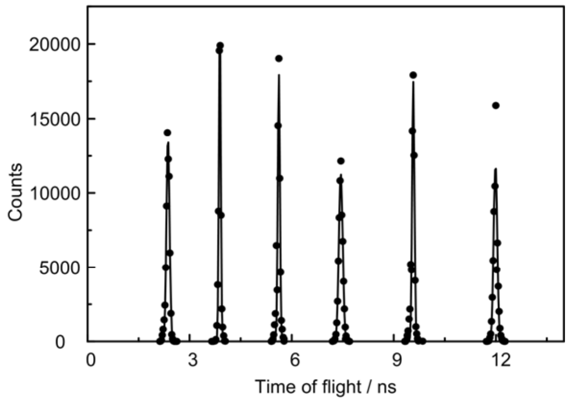

Fig.2 Results of TDC. The time resolution of the TDC is 50 ps (FWHM).

Similar tests were done for the ADC, the signal from the generator is amplified to different amplitudes, and measured by the ADC, and the results show that the ADC works fine.

After testing the individual modules, the microchannel plate (MCP) position sensitive detector was tested with the DAQ. The principle of this kind of position sensitive detector is as follows. When charged particles hit the MCP, an electron avalanche along the MCP channels occurs. The electron cloud will finally hit the anode, which is an encoder for position information of the different events. Among various kinds of anodes for MCP positions sensitive detectors, delay line anodes[12,13] and resistive anodes[14] have been used. With the delay line anodes, the position information is obtained from the time interval of the X_{t1}, X_{t2}, Y_{t1} and Y_{t2} signals from the end of delay lines, respectively. The time signals are processed by standard electronic modules and finally transformed to digital numbers by the TDC. With the resistive anode, the position information is obtained from the amplitudes of the X_{q1}, X_{q2}, Y_{q1} and Y_{q2} signals from each corner, respectively, and the analog signals are transformed by an ADC.

Currently we use the MCP with a delay-line. The four signals from the delay-line are amplified and discriminated by fast amplifier and constant fraction timing discriminators respectively. The signals are sent to the TDC as start signals. The MCP signal is employed as the common stop signal. Fig.3 shows the distribution of ^{241}Am α particles passing through a mask with Φ0.4 mm holes in 5 mm intervals. The distribution pattern agreed well with the array of the mask. This indicates that there is no distortion image introduced by the delay-line detector. The signal rate in the inner part of the image is somewhat higher than in the outer part. This is because the solid angle for the holes is not constant and also the homogeneity of the MCPs may not be high enough.

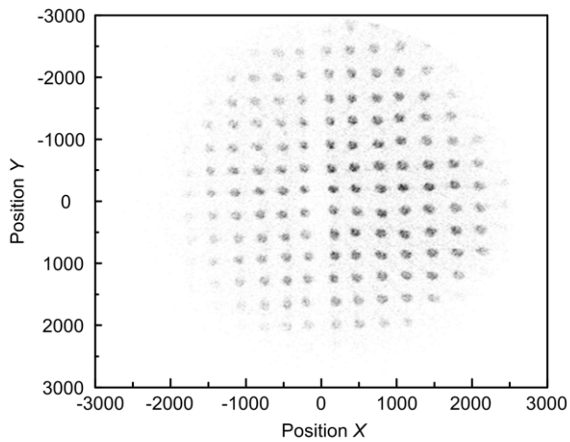

Fig.3 Image of a shadow mask with an MCP detector of 75-mm active diameter.

The homogeneity of the MCP and reliability of the DAQ system were tested with two rows of spots in X and Y directions. With the defined region of X from 700 to 1000 in Fig.3, the projection of Y is shown in Fig.4a, while the projection of X is shown in the region of Y from –700 to –400. The density of the peaks shown in Fig.4 is quite different. This may be attributed to the homogeneity of the MCP and/or extended by the holes across the mask. From the fact that the profile of the peaks in Fig.4a is not Gaussian indicates that the homogeneity of the MCP has not yet been optimized. This may be the reason for the different signal rates between inner and outer parts of the image shown in Fig.3. Similar inhomogeneity problems were reported in Ref.[13]. On the other hand, the ^{241}Am source was maybe not far enough away from the MCP in the current experiment, hence the solid angle was different from hole to hole. The solid angle is then, a function of the detector radius, which can also give rise to the Gaussian profiles shown in Fig.4b.

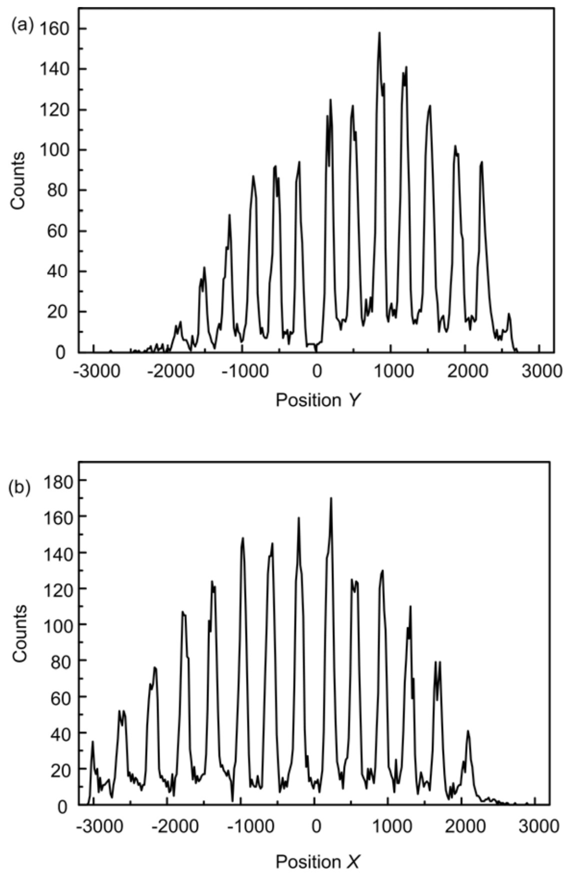

Fig.4 Row spots in regions of Y=–700～–400 projected to X (a) and X=700～1000 projected to Y (b).

Despite these minor problems of the MCP detector, the DAQ is ready for experiments, while the software can conveniently display and analyze the data on line.

5 Conclusion

A VME DAQ system for the collision research platform at Shanghai EBIT has been established and the performance of the 2-dimensional position sensitive MCP detector with a delay line anode has been tested. The TDC's time resolution is shown to be 50 ps. Since fast electronics has been used, the total time resolution for the system is better than 1 ns and the dead time is shorter than 10 ns. It has been shown that the resolving power of the MCP detector is better than 0.1 mm. The tests show that the DAQ system can reach a data transfer rate of 160 Mb/s, which is among the fastest DAQs running at any RIMS collision research platform worldwide. With the help of this fast developing system, our collision research platform will give us the capability to do very fine collision dynamics studies in the near future.

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