A Small Data Acquisition System for the KOALA Experiment in Jülich

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***Abstract*—For the KOALA detector a small data acquisition system mainly consisting of VME modules was designed and installed at COSY in Jülich. Main focus was the test of the detector and the DAQ system itself. This paper will show the chosen DAQ concept and describe some difficulties we had to deal with.**

I. Introduction

KOALA (**K**ey experiment f**o**r P**A**NDA **L**uminosity determin**a**tion) will be an independent experiment at HESR (Darmstadt) to measure antiproton-proton elastic scattering in order to gain the differential cross section which is a crucial input for the PANDA luminosity determination. The KOALA experiment will measure the elastically scattered beam particles in forward area and recoil protons from the target near 90 degrees. One of the recoil detectors has been designed and built. It was installed and commissioned by measuring proton-proton elastic scattering at COSY in Jülich. The data acquisition system is currently running with a small amount of channels (240 ADC, TDC and scaler channels, plus trigger and synchronisation logic).

II. Detector

The detector itself is not in the focus of this paper, therefore only a few facts are mentioned here: The detector part for the recoil protons consists of two silicon strip detectors with 1 mm thickness and 1.2 mm pitch and two germanium strip detectors with 5 and 11 mm thickness and 1.2 mm pitch. These detectors can be cooled within a range of 70–300 K. Fig. 1 shows the germanium and silicon detectors of the one existing arm of KOALA.

At HESR the PANDA luminosity monitor detector (high-voltage monolithic active pixel sensors) could be used as forward detector. For the tests at COSY plastic scintillators had been used instead.

The detector setup was installed at the ANKE experiment place and used the ANKE hydrogen cluster target.

Further information can be found in [1].

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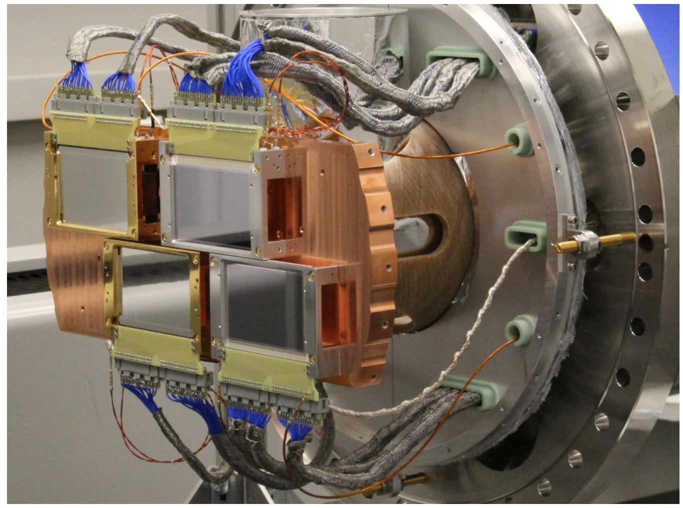

Fig. 1. Strip detectors of KOALA (H. Xu, 2013)

III. Acquisition hardware

We chose to use MESYTEC electronics for the analog and digitising part of the DAQ system. MPR16 (multichannel preamplifier) and MSCF16 (shaping / timing filter amplifier with constant fraction discriminator) were used to readout the silicon and germanium detectors.

As digitisation modules we used six VME modules of type MADC-32 (32 channel peak sensing ADC), one MTDC-32 (32 channels TDC) and one MQDC-32 (32 channel charge integrating ADC with individual gates) [4].

For the trigger handling and the synchronisation of the modules we used a general purpose FPGA board: CAEN V1495 [5]. Its purpose is explained in section V.

It is always a good idea to count important signals using a scaler, we used a SIS3820 [6]. It is common standard, not mentioned here further.

And last but not least we needed a VME controller. The standard controller for us is a SIS3100/SIS1100 or SIS3104/SIS1100 combination [7], also not explained further.

IV. Acquisition software

About 20 years ago we began to develop a data acquisition software called EMS (Experiment Message Specification) [2]. It is still alive and actively enhanced. New modules or bus concepts are integrated. It was developed for experiments with thousands of channels and dozens of crates, but it is well suited for small test systems also.

It is a client-server system written in C, C++ and TCL/TK. The servers, written in pure C, are running at the front-end

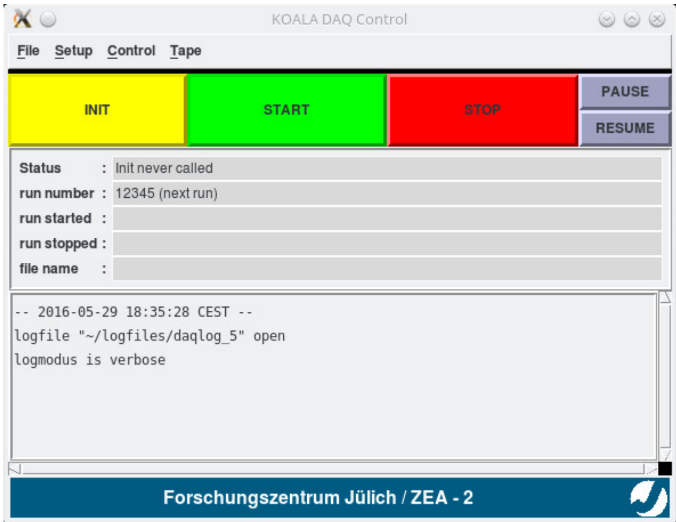

Fig. 2. EMS control window

computers and there are one or more client programs (possibly with graphical user interface). The servers contain code to access all buses and modules we used in the past 20 years. We never used the MESYTEC modules before, therefore some code for these modules had to be added. But all the 'infrastructure' (VME bus access, trigger procedures, storage management, user interface) already existed. Fig. 2 shows the main window of the EMS control client.

V. Synchronisation

In a system with a common trigger and more than one acquisition module some synchronisation is needed. In small systems the synchronisation is often done implicitly by the sequential readout of all modules and blocking the trigger during this readout. This is organised by the readout software itself.

In larger systems with parallel readout of many crates doing this in software would be very slow. For our larger COSY experiments (TOF, WASA, ANKE) we developed our own synchronisation hardware [3]. But this hardware can only be used together with our proprietary LVDS system and not with VME.

KOALA is a small system with one VME crate only. Nevertheless, synchronisation by software is not suitable. The MESYTEC modules use buffers (several kBytes) to store many events before a VME readout is required. This means that the readout software does not see single triggers, but only the buffer-nearly-full interrupts and can not be used for synchronisation.

As all other known acquisition modules the MESYTEC modules have a busy output. Busy means either the conversion of a single event or a blocked trigger input because of a full event buffer. So the solution is simple: A logical OR of the trigger itself and the busy signals of all modules blocks following triggers until the last busy becomes inactive. The busy signals are activated about 100 ns after the trigger (internal logic of the modules), therefore the trigger itself (extended to more than 100 ns, if necessary) has to be included in this OR. This simple logic was realised using the V1495 FPGA module.

VI. Problems and Solution

The logic above guarantees that a trigger is only accepted if all modules are ready for the next trigger. Each module generates a timestamp for each event. During the offline analysis in theory we should be able to collect complete events from the subevents of all modules just by comparing the timestamps.

Unfortunately, this is not true. Each module generates its own timestamp. They use the common VME clock (16 MHz), so the internal time counters are running synchronously. But they need a common reset. Because we ordered the modules too late and had not enough time for testing, we did not realise that a synchronous reset via software (using VME multicasts) was not working. Thus we reset the counters with simple VME commands one after each other. The result is that the counters are running with identical speed but with an offset. This offset is of course different from run to run.

In addition the TDC behaves different than the other modules: if it has no hit for one trigger it does not even generate an empty event. Therefore the timestamps of all the modules cannot be directly matched.

But there is a solution: Our data files are not very large (a few GBytes), so we can read a complete file before processing it in memory. We use the list of timestamps of one module as a reference and for each subevent we look up the nearest time stamp for each other module and compute the time offsets. These matches are correct in almost all cases, but not in all. The next step is to find the median value of the offsets for each module. Because the offsets (for the correct matching subevents) are constant during each run (+- one clock cycle) collecting the complete events is now possible.

VII. Conclusion

We built a simple data acquisition systems for test measurements of the KOALA detector at COSY. Our main fault was to order the modules not early enough and thus we could not test the whole system thoroughly in the laboratory.

The resulting problems made the analysis of the data more complicated than necessary, but the issues could fortunately solved by software.

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