# COMPARISON OF TWO DATA ACQUISITION AND PROCESSING SYSTEMS OF MOLLER POLARIMETER IN HALL A OF JEFFERSON LAB

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Two data acquisition and processing systems are used simultaneously to measure electron beam polarization by Moller polarimeter in Hall *A* of Jefferson Lab (Newport News, VA, USA). The old system (since 1997) is fully functional, but is not repairable in case of malfunction (system modules are not manufactured anymore). The new system (since 2010) based on flash-ADC is more accurate, but currently requires more detailed adjustment and further improvement. Description and specifications of two data acquisition and processing systems have been given. The results of polarization measurements during experiments conducted in Hall *A* from 2010 to 2012 are compared.

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## 1. MOLLER POLARIMETER

The Moller polarimeter of Hall *A* was designed in NSC KIPT jointly with Jefferson Lab [1, 2]. The polarimeter is intended for measuring electron beam polarization in energy range 0.8…11.0 GeV in Hall *A* of Jefferson Lab.

The polarimeter consists of polarized electrons target, magnetic spectrometer and detector (Fig. 1). Moller electrons, emerging due to interaction of electron beam and target, are analyzed by magnetic spectrometer. The spectrometer comprises four quadrupole (Q1, Q2, Q3, Q4) and one dipole magnets. Scattered electrons are focused by quadrupole magnets in horizontal plane at the input of dipole magnet. The dipole magnet reflects these electrons down to detector.

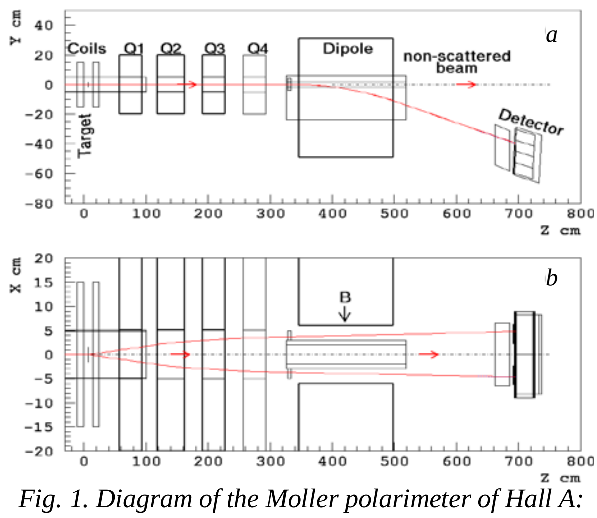


*Fig. 1. Diagram of the Moller polarimeter of Hall A: side view (a), top view (b)*

The electrons detector consists of two total absorption calorimeters, which allow to detect Moller events in coincidences. Each calorimeter has four channels. Photomultipliers are fastened at the output ends of calorimeter units. Before each calorimeter there is an aperture detector made of plastic scintillator and divided into four sections.

Detection of Moller event is carried out by coincidence of signals from left and right detectors; this allows reducing the impact of background events.

Typical load of the detector during measurements is 100…200 kHz in one arm and 50 kHz in coincidences. The quantity of coincidence events for different signs of electron beam polarization and known value of target polarization allow to determine electron beam polarization.

## 2. THE OLD DATA ACQUISITION SYSTEM OF THE POLARIMETER

The Moller polarimeter of Hall *A* has two data acquisition and processing systems:

1. The old system (Fig. 2) is based on CAMAC, VME, NIM modules and has operated since 1997.
2. The new system is based on VME module flash-ADC F-250 designed in Jefferson Lab, and was introduced in 2009.

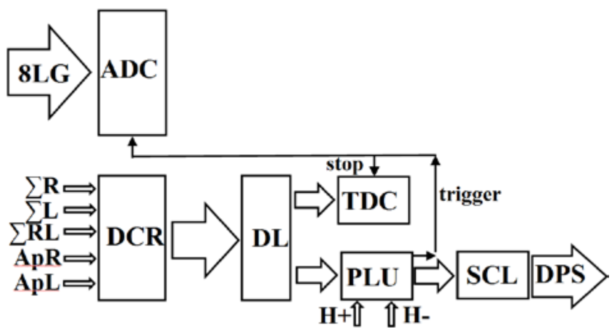


*Fig. 2. Electronic circuit of the old data acquisition system: 8LG – signals of 8 blocks of lead glass; ADC – analog to digital converter; ∑L – total signal from 4 left blocks; ∑R – total signal from 4 right blocks; ∑LR – total signal from 8 blocks; ApL – signal from left aperture counter; ApR – signal from right aperture counter; DCR – discriminator; DL – delay lines; TDC – time to digital converter; PLU – programmable logic unit; H+, H- – signals of + and - helicity; SCL – scalers; DPS – data processing system*

The old system is fully functional for all polarimeter targets. It is time-tested and well-studied, but it has low events recording speed; the system modules occupy several crates, and its great number of interunit connections and cables reduces system reliability. Besides, some system modules went out of production and are not replaceable in case of malfunction.

The CODA system remotely controls the data acquisition system and records data from the Moller polarimeter [5]. CODA is an online data acquisition system for physical experiments, designed at Jefferson Lab. Data analysis and processing is carried out by special software on the basis of PAW package. PAW is a package of programs and libraries designed in European Organization for Nuclear Research (CERN) in FORTRAN programming language.

The values from scalers are recorded for every “window” of beam helicity state (electron beam impulse with polarization value “+” or “-” corresponding to logic signal value 1 or 0). The trigger for a “window” cessation is a signal produced by another beam helicity value coming from polarized electrons injector of accelerator [4].

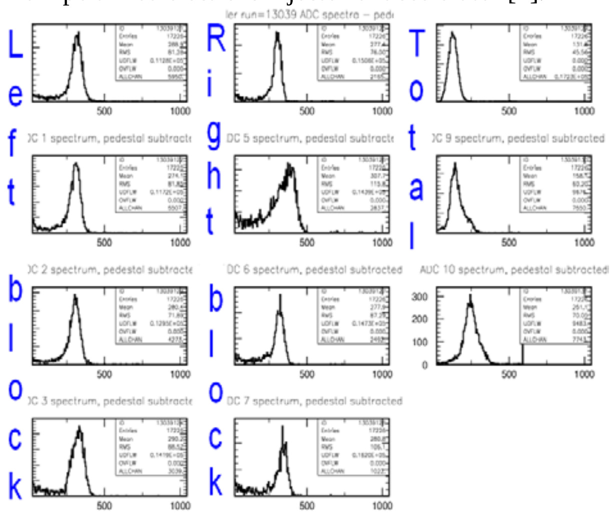

*Fig. 3. Spectrums of energy from detector units of the old system*

Fig. 3 shows energetic spectrums of electrons from lead glass units of the Moller polarimeter detector. The left column shows spectrums from four lead glass units of detector’s left channel. The middle column shows spectrums from four lead glass units of detector’s right channel. Two upper spectrums of the right column show total spectrums from four lead glass units in detector’s left and right channels. The third spectrum from the top of the right column shows coincidence spectrum of right detector’s channel with left channel. The signals of the right column are used directly for calculation of electron beam polarization value; other values are used for various checks and calibrations.

After normalization of total quantity of coincidence events with certain helicity state (polarization direction) to “windows” quantity and beam current value, and after subtraction of random coincidences the beam asymmetry value is calculated.

### 2.1. THE OLD SYSTEM RECONSTRUCTION

The basic electronic modules are replaced by more contemporary ones with higher bandwidth in order to reduce dead time, and due to the impossibility of replacing certain modules that gone out of production.

The main objectives of reconstructing the old data acquisition system (DAQ) are:

- increase bandwidth (up to 200 MHz);
- reduction of readout time from ADC and TDC modules;
- replacement of programmable logic unit (PLU) gone out of production;
- getting rid of CAMAC as an outdated and slow standard.

The list of replaced modules:

- to increase bandwidth:

1. PLM LeCroy-2365 (frequency <75 MHz, crate CAMAC) was replaced by PLM based on CAEN V1495 (frequency 200 MHz, crate VME) (Fig. 4).

2. Discriminator Ortec-TD8000 (frequency < 150 MHz, crate CAMAC) was replaced by discriminator P/S 708 (frequency < 300 MHz, crate NIM).

- To reduce readout time:

1. ADC LeCroy 2249A (12 channels, crate CAMAC) was replaced by ADC CAEN V792 (32 channels, crate VME).

2. TDC LeCroy 2229 (crate CAMAC) was replaced by TDC CAEN V1190B (64 channels, 0.1 ns, crate VME).

The new modules have been tested and the software is being developed for the reconstructed data acquisition system.

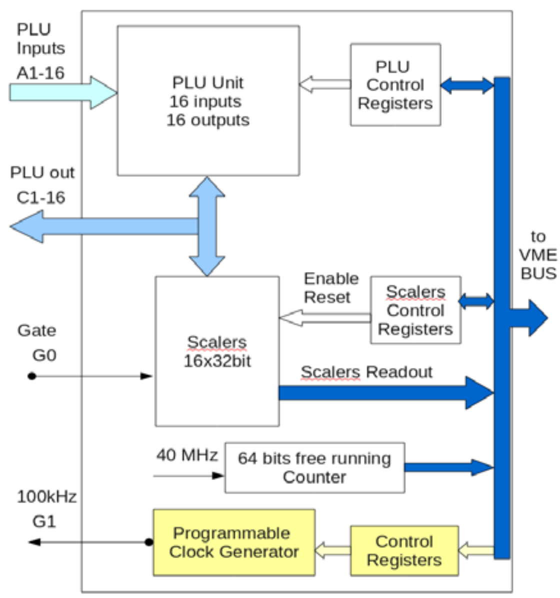

*Fig. 4. Diagram of programmable logic unit based on module type of CAEN V1495*

It is planned to use the old system after reconstruction at least up to the moment when the new system based on flash-ADC is fully functional for operation with two targets of the Moller polarimeter. It should be noted that the new system was created for operation with new target (with high magnetic field) and its software is not intended for operation with old target (with low magnetic field). As a result, while operating with old target, the old system is mandatory whereas the new one is optional. Moreover, the simultaneous use of two systems allows to study systematic errors.

## 3. THE NEW DATA ACQUISITION SYSTEM OF THE POLARIMETER

The main objective of introducing the new data acquisition system is to reduce systematic errors in polarization measurement. One of the components of measurement systematic error is the impact of dead time of events rerecord system. While polarization measuring the dead time of data acquisition system depends upon detectors loading or upon beam current. One of the ways to reduce the impact of dead time is to increase events rate registration and record speed by data acquisition system. While developing the new system, it was suggested to use module flash-ADC of F250 type, designed in Jefferson Lab, with corresponding programmed record algorithm and event processing from the polarimeter [6]. A block diagram of data acquisition system on the basis of flash-ADC is shown in Fig. 5.

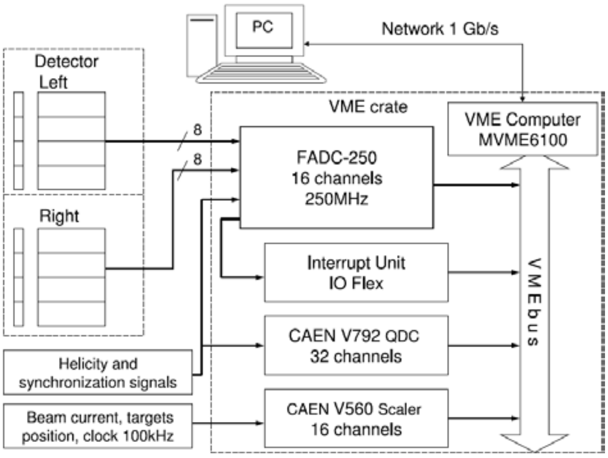


*Fig. 5. New data acquisition system of the Moller polarimeter*

Data acquisition system comprises:

- flash-ADC F250;
- interrupt unit IO Flex;
- additional QDC module CAEN V792;
- scalers module CAEN V560;
- VME controller MVME6100;
- NIM crate and modules for ECL/NIM levels conversion (not shown in the figure);
- Gigabit Ethernet network;
- controlling PC.

Electronic modules are in crate VME, which is in experimental Hall *A* behind a shielding wall 10 meters away from the detector. The computer is in experiment control room 100 meters away from crate VME. The additional module ADC V792 is used with flash-ADC for supplementary record of levels of polarization sign signals and synchronization signals. Scalers module V560 is used for record of beam current, target location on beam and signals of 100 kHz reference generator [3].

### 3.1. MODULE FLASH-ADC

Module flash-ADC is an integration of 16-channel 12-bit ADC of conveyor type with conversion frequency 250 MHz and programmable logic array FPGA in one VME unit. From detector's outputs of photomultipliers analog signals, with amplitude up to +1 volt and duration 30…35 ns, are sent to module's input and digitized in ADC. The use of programmable logic array allows to construct the whole logic circuit of events record and to process digitized signals from ADC with clock frequency 250 MHz directly in the module. Functions of discriminators, delay lines, coincidence circuits, scalers and events record logics are programmed in FPGA (Fig. 6).

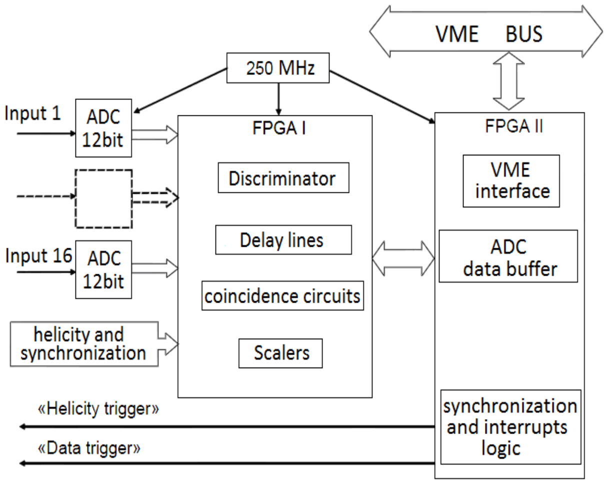


*Fig. 6. Module flash-ADC*

After digitizing in ADC, signals from detector are summarized for each calorimeter arm, and then total signal is discriminated by level. If the level of total signal exceeds the preset discriminating threshold, then this event (digitized signals of all channels) is recorded to inner data buffer of the module; logic signals are formed at the inputs of coincidence circuits.

Parameters of ADC operation are programmed and downloaded to module when starting data acquisition system on measuring [3].

The software for analyzing and processing measuring data is designed on the basis of ROOT package (a package of object-oriented programs and libraries designed in European Organization for Nuclear Research (CERN)) [7].

Data acquisition system based on flash-ADC, generates 2 types of triggers (events):

1. Helicity trigger, when scalers values are read;
2. Data trigger, when inner buffer is filled with data from ADC.

At interrupt signals, the data of inner scalers and ADC buffer are read into overall data flow of CODA system and are transmitted via network to controlling computer. The computer operates under Linux Red Hat Enterprise and contains quad-core processor with frequency 3.2 MHz and 2 TB of disk space. On PC the data are written into files for further analysis and processing. This system allows detecting and recording data flow at speed up to 50 MB/s when speed of events record in coincidence of left and right arms of the detector equals 160 kHz.

The ability of flash ADC to record every signal from detector (data trigger) allows to study systematic errors. Analysis of this information will improve the polarimeter GEANT model, increase the accuracy of measuring average analyzing power, take into account such effects as "pile-up events" (Fig. 7), Levchuk effect, etc. In operation of flash-ADC data trigger certain errors have been found, which prevent from using this universal instrument in full measure. The errors are being eliminated and software for data analysis is being developed.

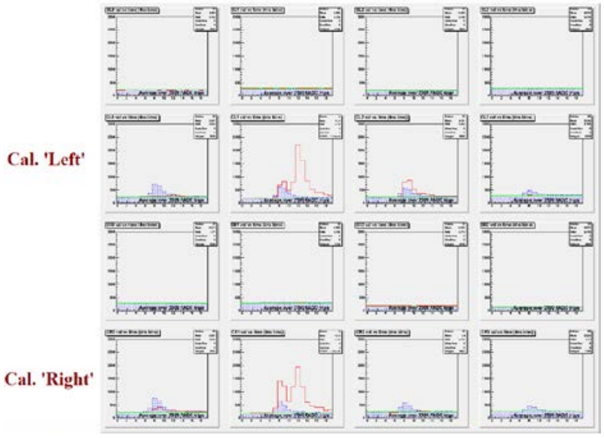


*Fig. 7. Example of data trigger (pile-up events)*

Program package comprises program of data acquisition online monitoring and programs of offline processing. Program of monitoring allows to control the quality of incoming information by displaying current values of coincidence scalers, digitized analog signals from each detector's unit, amplitude spectrums of signals from the detector. Fig. 8 shows an example of displayed information by program of online monitoring. The programs of offline processing allow to convert data files from CODA into ROOT, to process and analyze data, and to obtain the results of beam polarization measurement.

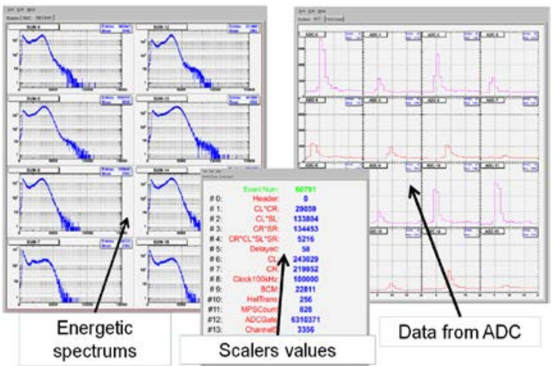


*Fig. 8. Data from online monitoring program*

## 4. COMPARISON OF MEASUREMENTS RESULTS OF TWO SYSTEMS

To measure electron beam polarization it is necessary to know the value of reaction analyzing power, target polarization and beam asymmetry. As the two first parameters are the same for both systems, the asymmetry values measured by both systems are compared.

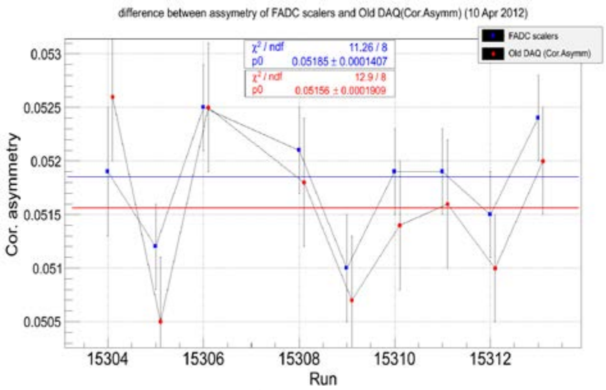


*Fig. 9. Results of asymmetry measurement by two systems*

Fig. 9 shows the results of comparison of asymmetry values measured by both data acquisition systems.

Blue dots are measurement results on the new system based on flash-ADC, red dots are measurement results on the old system. Horizontal straight lines are averaged values of beam asymmetry. It is seen that the difference in measurements by two systems is less than 1% and is not beyond the statistical error limits.

## CONCLUSIONS

The Moller polarimeter of Hall *A* has two data acquisition and processing systems operating simultaneously. The systems are based on different element bases with different types of triggers (events).

The old system is fully functional, several modules have been replaced, for the old ones are not subject to repair in case of malfunction (gone out of production) and in order to increase bandwidth frequency of the system.

At the same time the new system based on high-speed multichannel flash-ADC has been developed and tested. This system allows to record events up to 160 kHz in coincidence and data acquisition up to 50 MB/s without significant increase of system dead time; this allows to increase the accuracy of measuring electron beam polarization by means of the Moller polarimeter [6].

The new system is more accurate but currently requires more detailed adjustment and further improvement.

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## REFERENCES

1. A.V. Glamazdin, V.G. Gorbenko, L.G. Levchuk, et al. Electron Beam Møller Polarimeter at Jlab Hall *A* // *Fizika*. 1999, B8, p. 91-95 (in Russian).
2. E.A. Chudakov, A.V. Glamazdin, V.G. Gorbenko, L.G. Levchuk, R.I. Pomatsalyuk, P.V. Sorokin. Moller polarimeter for electron beam in Hall A Jefferson Lab // *Problems of Atomic Science and Technology. Series «Nuclear Physics Investigations»*. 2002, №2(40), p. 43-48.
3. R.I. Pomatsalyuk. Data Acquisition System of Moller Polarimeter Hall A Jefferson Lab // *Problems of Atomic Science and Technology. Series «Nuclear Physics Investigations»*. 2012, №3(79), p. 101-104.
4. A.V. Glamazdin. *The interaction of polarized electron beams with polarized electron target:* PhD dissertation. Kharkov, 2002, p. 90-91.
5. JLAB CODA Group. Coda. http://coda.jlab.org.
6. B. Sawatzky, Z. Ahmed, C-M Jen, E. Chudakov, R. Michaels, D. Abbott, H. Dong, E. Jastrzembski. Moller FADC DAQ upgrade // *Internal Review. Jefferson Lab*, December, 2010, p. 7.
7. R. Brun, F. Rademakers, P. Canal, et al. ROOT – An Object-Oriented Data Analysis Framework // *Users Guide 4.04*. Geneva, 2005, p. 293.

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## СРАВНЕНИЕ ДВУХ СИСТЕМ СБОРА И ОБРАБОТКИ ДАННЫХ МЁЛЛЕРОВСКОГО ПОЛЯРИМЕТРА ЗАЛА А ЛАБОРАТОРИИ им. ДЖЕФФЕРСОНА

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Для измерения поляризации пучка электронов мёллеровским поляриметром зала А лаборатории им. Джефферсона (Ньюпорт-Ньюс, Вирджиния, США) параллельно используются две системы сбора и обработки данных. Старая система (работает с 1997 года) полностью функциональна, но не подлежит ремонту в случае выхода из строя (модули системы сняты с производства). Новая система на базе флэш-АЦП (введена в эксплуатацию с 2010 года) предоставляет больше возможностей для улучшения точности измерений, но на данный момент требует более детальной настройки и дальнейших доработок. Представлены описание и характеристики двух систем сбора и обработки данных. Сравниваются результаты измерений поляризации во время экспериментов, проведенных в зале А с 2010 по 2012 годы.

## ПОРІВНЯННЯ ДВОХ СИСТЕМ ЗБОРУ ТА ОБРОБКИ ДАНИХ МЬОЛЛЕРІВСЬКОГО ПОЛЯРИМЕТРУ ЗАЛУ А ЛАБОРАТОРІЇ ім. ДЖЕФФЕРСОНА

*В.В. Верещака, О.В. Гламаздін, Р.І. Помацалюк*

Для вимірювання поляризації пучка електронів мьоллерівським поляриметром залу А лабораторії ім. Джефферсона (Ньюпорт-Ньюс, Вірджинія, США) паралельно використовуються дві системи збору та обробки даних. Стара система (працює з 1997 року) повністю функціональна, але не підлягає ремонту в разі виходу з ладу (модулі системи зняті з виробництва). Нова система на базі флеш-АЦП (введена в експлуатацію з 2010 року) надає більше можливостей для покращення точності вимірювань, але на даний момент потребує більш детального налаштування і подальших доробок. Представлено опис та характеристики двох систем збору і обробки даних. Порівнюються результати вимірювань поляризації під час експериментів, проведених в залі А з 2010 по 2012 роки.