Electron Transverse Polarimeter for the MTV experiment at TRIUMF

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Abstract. A new experimental project called MTV(Mott Polarimetry for T-Violation Experiment)-S1183 has started at TRIUMF, aiming to achieve the highest precision test of time reversal symmetry in polarized nuclear beta decay. In this experiment, existence of T-violating transverse polarization of electrons emitted from polarized nuclei is examined, using a multi-wire drift chamber (MWDC) as an electron tracking detector in order to measure Mott scattering asymmetries. The Mott polarimeter, MWDC, consists of six sense layers. In order to improve the real backward scattering event purity, a new intelligent triggering system using FPGA module to perform on-line hit pattern recognition was developed. The new triggering system was installed for the first commissioning experiment in November 2009 at TRIUMF-ISAC. In addition to the triggering system, a new buffering DAQ system was also developed in order to achieve the needed high triggering rate at ISAC. Details of their performance are also described.

1. Introduction

The MTV experiment measures electron backward scattering angle at a thin metal foil using a multi-wire drift chamber (MWDC), in order to search T-violating electron transverse polarization in polarized nuclear beta decay utilizing the analyzing power of Mott scattering [1,2].

The first test experiment using polarized $^9$Li beam was performed at KEK-TRIAC in 2008. The aim of this commissioning run was to test the feasibility of the MTV detector, which was designed to have sensitivity to electron transverse polarization. After successful data taking at KEK-TRIAC, the whole experimental setup was shipped to TRIUMF from KEK-TRIAC. We have performed the first test
experiment at TRIUMF, called MTV-Run I, in November 2009. We have confirmed about 3% statistical precision on the $R$-correlation using 70% analyzed data from MTV-Run I. Physics data taking run, called MTV-Run II, is scheduled in late 2010 and 2011. A brief overview of the MTV detectors, principle of the measurement and development status of MTV-Run II are described in the following.

2. Detectors

The MTV experiment is going to measure backward scattering “V-tracks” at a thin metal foil in order to extract Mott scattering angular asymmetries. The V-tracks are measured using the MWDC event-by-event. The tracking measurement has advantages compared to the previous counter type experiment in acceptance, background rejection, and systematic effect reduction, due to beta asymmetric emission which cannot be canceled by beam polarization flipping.

![Figure 1. Comparison between counter type experiment and tracking experiment.](image1)

Overview of the experimental setup is described in [1], which consists of the MWDC as the beta tracking chamber, stopping scintillation counters for electron energy measurements, and asymmetry plastic scintillation counters for beam polarization measurements.

| Asymmetry Counter       | Plastic Scintillator (Dia.5cm x T1mm) | 4 (PMT H7415 D33mm x 8ch) |
|-------------------------|--------------------------------------|----------------------------|
| Stopping Counter (Full) | Plastic Scintillator (L40cm x W10cm x T7cm) | 4 (PMT H7195 D60mm x 8ch) |
| Stopping Counter (Half) | Plastic Scintillator (L14cm x W10cm x T7cm) | 2 (PMT H7195 D60mm x 2ch) |
| Electron tracking detector | Drift Chamber (W64cm x H51cm x T24cm) | Anode 104ch |

**Table 1. MTV Detectors**

The MWDC is a planar drift chamber with XX’-UU’-VV’ six sense planes, with total 104 anode channels. Details of the MWDC are listed in Table 2. The anode signals are fed into ASD [3] boards with 64 channel analog inputs and LVDS outputs. The LVDS output signals are split to TDCs (CAEN...
V1192A 128ch) and FPGA trigger boards (GND GN-0324/270 with XILINX XCV150 200MHz FPGA).

|                          |                           |
|--------------------------|---------------------------|
| **Size**                 | 640mm x 510mm x 240mm     |
| **Window Size**          | 480mm x 330mm             |
| **Effective Area**       | 440mm x 300mm             |
| **Wire Configuration**   | XX’ UU’ VV’              |
| **Sense Wire**           | 20micron Au-W wire, 0 degree, ± 15.9 degrees directions, 104 wires |
| **Field Wire**           | 100micron Au-BeCu wire, parallel with sense wires, 110 wires |
| **Anode-Field Wire Pitch** | 1cm spacing            |
| **Sense-Cathode Gap**    | 1cm spacing               |
| **Cathode Wire**         | 100micron Au-BeCu wire, 90 degrees direction, 413 wires |
| **Cathode Pitch**        | 5mm spacing               |
| **Bias Voltage**         | Cathode: -2.1kV, Field: -2.1kV, Anode: GND level |
| **Gas Window**           | Aluminized Mylar (single side) 25micron |
| **Chamber Gas**          | 90% Argon + 10% Methane   |
| **Gas Pressure**         | Atmospheric Pressure      |
| **Gas Flow Rate**        | 30 cc/min                 |
| **Gas Volume**           | 37 litters                |

**Table 2. Description of the Drift chamber**

![Figure 2. Left: Sense wire design in xy-plane. Right: Cathode wire design in yz-plane](image)

3. **Trigger and Data acquisition system**

A simple plastic counter logic is used as Level-1 trigger. It has become clear that only about 0.2% of the Level-1 triggered events survive after offline tracking analysis as real V-tracking events. In order
to improve the V-track purity in the online triggering system, a new FPGA triggering system is installed in KEK-TRIAC test experiment, generating Level-2 trigger using 104 channels of analog signals from the MWDC. In addition, upgrade on the triggering logic is also performed as Level-3 trigger, in order to further improve the rejection power at TRIUMF.

Level-1 trigger is a simple OR signal from all the stopping counters. Both Level-2 and Level-3 reads hit pattern from the drift chamber anode signals. Level-2 trigger requests at least two anode hits for each of the six sense planes. Level-1 signal is used as a trigger for the Level-2 logic starting. The Level-3 logic consists of counter logic circuits, which count the hit numbers of the anode signals for each sense plane. The Level-3 sets not only minimum number of the anode hits, but also maximum number of them, in order to reject multiple scattered events which request large data size restricting data transfer rate for the real events.

The data acquisition system (DAQ) consists of VME-TDCs. In KEK-TRIAC experiment and MTV Run-I, AMSC AMT-TDC modules are used in event-by-event reading cycle mode. In this system, event trigger generated from the trigger board was also used as the DAQ reading trigger. For the KEK-TRIAC experiment, the trigger request is lower than the maximum DAQ bandwidth using this event-by-event readout system. At TRIUMF, however, requested event triggering rate is over 10kHz, which is larger than the DAQ bandwidth of 2kHz. Figure 4 shows the triggering rate obtained at KEK-TRIAC and MTV-Run-I at TRIUMF. Here W (V) track means events which contain double straight line tracks before (after) applying vertex cut etc.

![Figure 3. Triggering System](image)

![Figure 4. Rate dependence of the Triggering Rate at KEK and TRIUMF](image)
In order to remove the DAQ limit, we have developed a new TDC readout system after Run-I. To avoid frequent VME actions, TDC buffering readout is applied. By this development, data transfer rate is improved from 0.3MByte/sec to 20MByte/sec, which corresponds to event taking rate of 1kHz to 50kHz. The New system consists of TDC (CAEN V1190A 128ch multi-hit TDC), PCI VME controller (CAEN V2718), Scaler (SIS 3803) and I/O Register (REPIC RPV-130).

The Maximum capacity of the TDC buffer is 32k long word (long word = 4byte). Data transfer in DMA mode is set to start when the buffer exceeds 30k long word. We use CAEN-V2718 PCI-bridge for VME controller which has IRQ waiting function which can reduce the CPU load. Figure 6 shows the DAQ performance for the original event-by-event system and the new buffering system.

**Figure 5.** DAQ diagram

**Figure 6.** DAQ performance for the original and new readout system.
In addition to this DAQ upgrade development, we have also performed re-wiring of the MWDC, developed fine triggering timing tuning using delay functions in FPGA. We are almost ready to start the physics data taking owing to these developments, in late 2010 aiming to achieve highest statistical precision experiment.

As for systematics effects, measurement of electron energy becomes a key measurement in order to distinguish final state interaction and new physics signals. For that reason, ADC readout of the stopping counter is necessary. In order to avoid reduction of data transfer rate by adding ADC readout, we are going to measure pQTC (pseudo-Q to Time Convertor) information combined with the ASD and the TDC, by recording leading and trailing edge of the analog signal after sufficient time shaping.

By combining above developments, we will perform the finest precision measurement on the R-correlation very soon.

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References
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