EPJ Web of Conferences 66, 05017 (2014)
DOI: 10.1051/epjconf/20146605017

T-Violation experiment at TRIUMF-ISAC using polarized ^{8}Li

J. Murata[1a], H. Baba[2], J.A. Behr[3], T. Iguri[1], M. Ikeda[1], H. Kawamura[4], R. Kishi[1], C.D.P. Levy[3], Y. Nakaya[1], R. Narikawa[1], K. Ninomiya[12], J. Onishi[1], R. Openshaw[3], M. Pearson[3], E. Seitaibashi[1], S. Saiba[1], S. Tanaka[1], R. Tanuma[1], Y. Totsuka[1] and T. Toyoda[1]

[1] Department of Physics, Rikkyo University, Tokyo 171-8501, Japan
[2] Nishina Center, RIKEN, Saitama 351-0198, Japan
[3] TRIUMF, Vancouver, BC V6T 2A3, Canada
[4] Cyclotron and Radioisotope Center, Tohoku University, Miyagi 980-8578, Japan

Abstract. Motivated by a search for a new physics beyond the standard model, the MTV experiment (Mott Polarimetry for T-Violation Experiment) is intended to achieve the highest precision test of time-reversal symmetry in polarized nuclear beta decay by measuring a triple correlation (the *R*-correlation). The first physics run of the MTV experiment was performed in 2010 at TRIUMF-ISAC. This paper gives preliminary results and describes the next generation setup, which involves a cylindrical drift chamber.

1 Introduction

To explain the large matter-antimatter asymmetry observed in our universe, the MTV experiment is intended to search for a large time-reversal symmetry violation outside of the CKM mechanism. Because CKM predictions for up-down quark systems are negligible compared to current experimental sensitivities, all searches for a T-Violation in normal nuclear systems are regarded as searches for the physics beyond the standard model. In this study, we measure the *R*-correlation, which is defined as a triple vector correlation in nuclear beta decay for polarized ^{8}Li beta decay processes. This triple vector correlation occurs in the following decay rate equation [1].

$$\omega dE_e d\Omega_e = \left\{ ... + \vec{\sigma} \cdot \left[...N \frac{<\vec{J}>}{J} + R \frac{<\vec{J}>}{J} \times \frac{\vec{p}_e}{E_e} \right] \right\} \tag{1}$$

Here, $\vec{J}$ and $\vec{\sigma}$ are parent nuclear and electron's polarization vectors, while $\vec{p}_e$ and E_e are the electron's momentum vector and energy. In this experiment, the existence of non-zero transverse electron polarization is examined by utilizing the analyzing power of Mott scattering from a thin metal foil ("analyzer foil"). Backward scattering electron tracks, called V-tracks, are measured using a planar multi-wire drift chamber (MWDC) [2]. The first physics data taken in the MTV experiment were obtained at TRIUMF-ISAC in 2010 using an 80% polarized ^{8}Li beam at 10^{7}pps, which achieved the highest statistical precision on the order of 0.1% on the *R*-parameter. The obtained result is better than that in a previous study performed at PSI [3].

[a] Corresponding author: jiro@rikkyo.ac.jp

2 MTV Run-II Experiment

The MTV experiment was originally started at KEK-TRIAC in 2008 [4], and was moved to TRIUMF-ISAC in 2009. In 2010, the first physics data-taking was performed as the MTV Run-II experiment. The experimental setup is shown in Figure 1. To measure backwardly scattered V-tracks, the MWDC was set between the beam stopper and lead analyzer foil. In total 250Mevents were recorded as V-tracks by applying an intelligent triggering system. In Figure 2, the statistical precision achieved in this run is shown as a function of experimental run numbers.

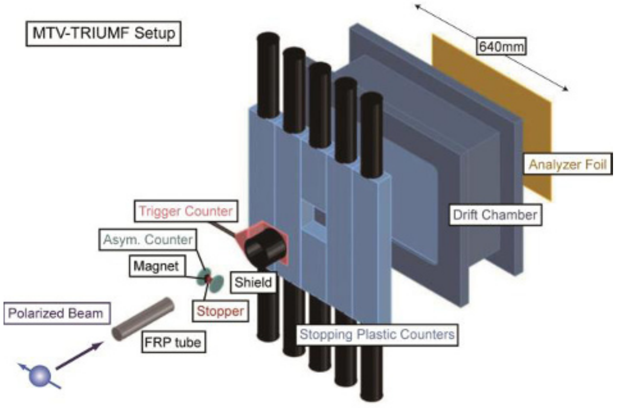

Figure 1. Experimental setup of MTV Run-II.

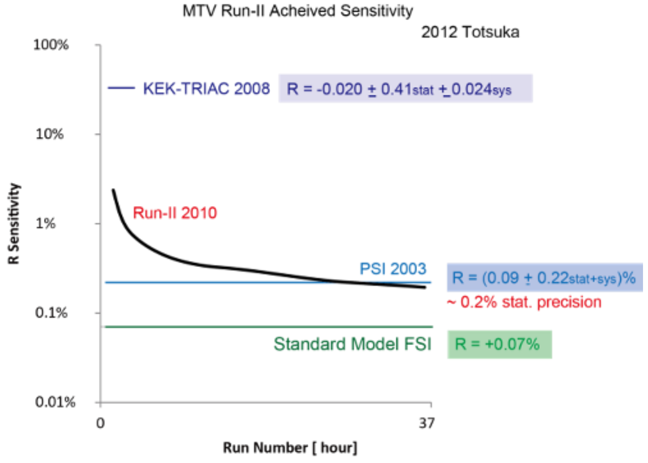

Figure 2. Statistical precision achieved in MTV Run-II.

The statistical precision achieved in Run-II was 0.2%, which is the best precision obtained among past measurements. The main systematic errors arise from the following points listed below;

1. Beam polarization tilting with the *N*-correlation,
2. Detector asymmetric geometry with the *A*-correlation,
3. Efficiency non-conservation.

The N-correlation is defined as the transverse polarization of an electron being parallel to the initial parent nuclear polarization direction (see (1)). This N-correlation should not contribute to our measurement provided we set the nuclear polarization direction perpendicular to the Mott analyzer; however, in practice, a small tilting cannot be avoided. To subtract this standard model contribution, a dedicated beam polarization direction monitor was developed, giving a tilt of 6.1 ± 0.3 mrad. This corresponds to a contribution of $0.024 \pm 0.029\%$ contribution to the R-parameter. The second systematic effect arises from combination of parity-violating asymmetric beta-emission angular distribution (the A-correlation) with the detector's asymmetric geometrical acceptance. This effect cannot be canceled by flipping the beam spin. To remove this effect, we developed a "two-dimensional" analysis method, using the beta emission angle and the Mott scattering angle, to extract the double ratio without incurring the systematic errors. The last systematic effects come from instabilities in the detector's efficiency during spin-flipping processes. To remove this effect, a conventional double-ratio method, combining two left-right scattering ratios for spin up and down configurations, cannot be used. We developed an analysis algorithm to extract the real asymmetry using un-polarized data. After evaluating these effects in offline analyses, preliminary analysis results are obtained, which will be published elsewhere. The overall systematic effects are of the same order as the statistical precision.

3 MTV CDC

To reduce the remaining systematic effects on the MWDC measurements, a cylindrical drift chamber (CDC) has been built; this chamber has axial symmetry which enables us to cancel the systematic effects that arise from the detector's asymmetry, and to measure the R and the N correlations independently. In addition, a larger solid angle can be obtained. Figure 3 shows the experimental setup of MTV-CDC and a sample event display obtained from a test measurement in 2012. The CDC was built in 2011, and the final setup test was performed in 2012 at TRIUMF [5].

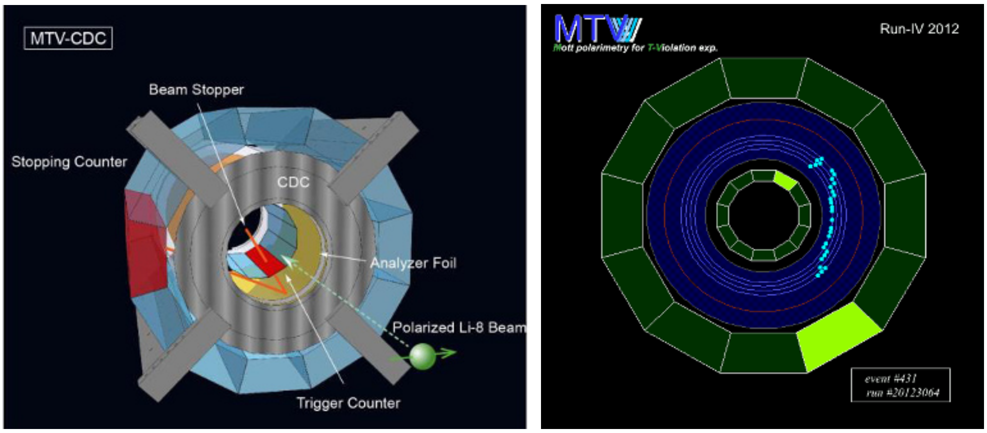

Figure 3. MTV-CDC experimental setup and the event display showing a V-track event.

Figure 4 shows the data-taking rate for the past MTV measurements and for the final test, Run-IV, performed in 2012. Note that although the beam intensity was only 1/100 of Run-II, the V-track sampling rate using the CDC setup was almost the same for Run-IV. This means we can reduce the beam intensity, i.e. the radiation penetrating the detectors. This test result assures us that not only can we expect better statistics than in Run-II at the increased beam intensity but also the efficiency instability problem should be reduced because of the small hit rate on each detector.

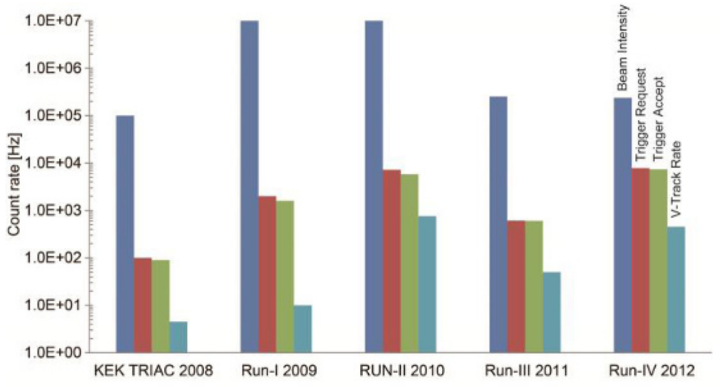

Figure 4. Event taking rates. Run-III and IV were performed with the CDC.

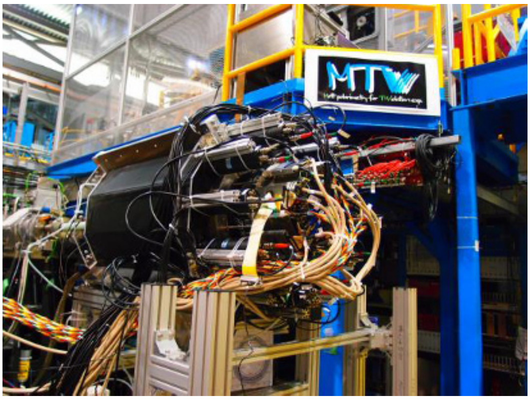

Figure 5. MTV-CDC setup in 2012.

We have developed the final experimental setup using the CDC and tested it in 2012. The first physics data-taking using the CDC is scheduled to occur in autumn 2013. This experimental setup is also used for a different experiment, MTV-G aiming gravity physics using an un-polarized Sr(Y)-90 source, partially as a final check and calibration for the MTV experiment [6]. The highest statistical precision data with reduced systematic effects are expected to be obtained for finding the T-violating *R*-correlation.

References

1. N. Severijns *et. al.*, Rev. Mod. Phys. **78**, 991 (2006)
2. J. Murata *et. al.*, J. Phys. CS **312**, 102011 (2011)
3. R. Huber *et. al.*, Phys. Rev. Lett. **90**, 202301 (2003)
4. H. Kawamura, Doctor Thesis, Rikkyo University (2010)
5. J. Murata *et. al.*, Hyp. Interact. DOI 10.1007/s10751-013-0897-3 (2013)
6. S. Tanaka *et. al*, J. Phys. CS **453,** 012018 (2013)