

MTV-S1183  
Beam Time Report

**Test of Time Reversal Symmetry Using Polarized Unstable Nuclei**

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**for the MTV collaborators.**

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Final Test Run for Physics production in 2014  
Schedule: Beam Time 11/15-11/16

TRIUMF-ISAC Science Forum (20. Nov. 2013)

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# INTRODUCTION

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## MTV : Mott Polarimetry for T-Violation experiment

### $\beta$ decay rate function

$$\omega(\langle \vec{J} \rangle, \vec{\sigma} | E_e, \Omega_e) dE_e d\Omega_e = \frac{F(\pm Z, E_e)}{(2\pi)^4} p_e E_e (E_0 - E_e)^2 dE_e d\Omega_e \times \xi \left( 1 + b \frac{m}{E_e} + \frac{\vec{p}_e}{E_e} \left( A \frac{\langle \vec{J} \rangle}{J} + G \vec{\sigma} \right) + \vec{\sigma} \cdot \left( N \frac{\langle \vec{J} \rangle}{J} + Q \frac{\vec{p}_e}{E_e + m} \left[ \frac{\langle \vec{J} \rangle}{J} \cdot \frac{\vec{p}_e}{E_e} \right] + R \frac{\langle \vec{J} \rangle}{J} \times \frac{\vec{p}_e}{E_e} \right) \right)$$



OSAKA@ISAC-I

### T transform

$$R \vec{\sigma} \cdot \frac{\langle \vec{J} \rangle}{J} \times \frac{\vec{p}_e}{E_e} \longleftrightarrow -R \vec{\sigma} \cdot \frac{\langle \vec{J} \rangle}{J} \times \frac{\vec{p}_e}{E_e}$$

$\vec{J}$  : Parent Nuclear Pol.

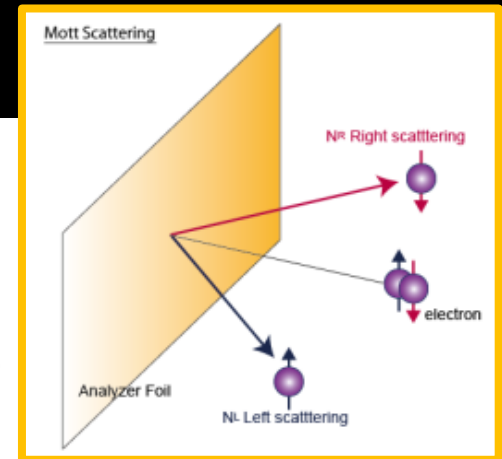
$\vec{\sigma}$  : Electron Pol.

$\vec{p}_e$  : Electron momentum

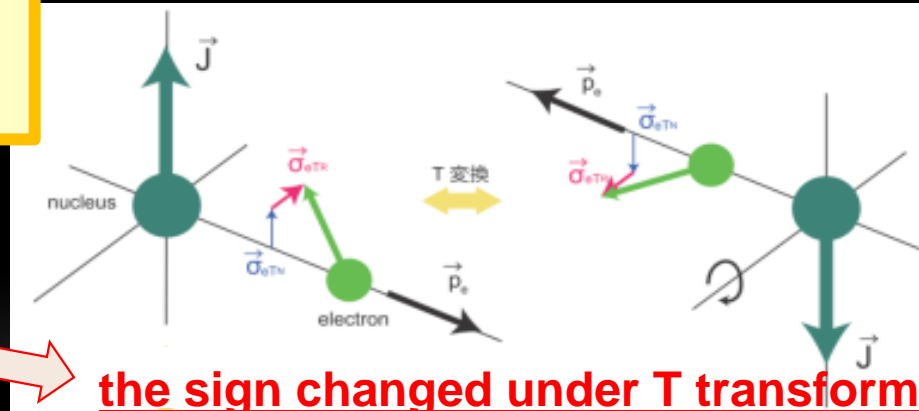
$R=0$  ? or  $R \neq 0$  ?

$R \neq 0 \Rightarrow$  T-Violation !

### Backward Mott scattering



Left-Right Asymmetry



the sign changed under T transform

### R correlation 3 components

1. Pol. Nuclei. produced @ISAC
2. Electron momentum

### 3. Electron Trans. pol.

Evidence for New Physics beyond the Standard Model

## Previous MTV Experiment

2008. 4 : Unpol. Test Exp.

2008. 9 : Physics Run : 10% precision

Main detector: **planer MWDC** **178keV/u @  $10^5$ pps**  
@KEK-TRIAC JAPAN **8% polarization**

$$R = -0.020 \pm 0.41_{\text{sta}} \pm 0.024_{\text{sys}}$$

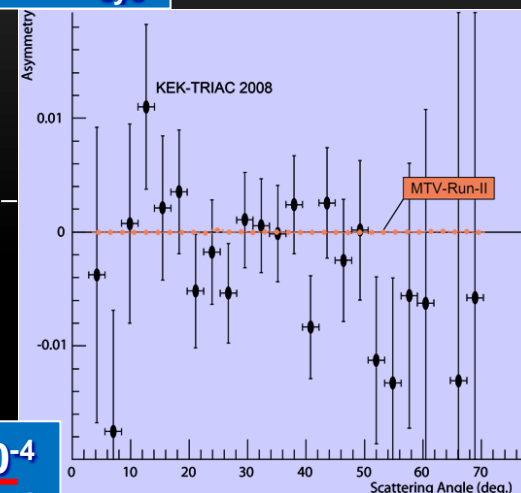
2009. 11 : Run-I Test Exp. : 1% precision

2010.11 : Run-II Physics Run : 0.1% precision Exp.

Main detector: **planer MWDC** **28keV @  $10^4$ - $10^7$ pps**  
@TRIUMF CANADA **80% polarization**

three orders of magnitude improvement !

$$\text{Asym.} \sim (0.2 \pm 2.1) \times 10^{-4} \text{ (preliminary)}$$



high beam intensity & polarization required.

Main detector : planer MWDC

2011. 11 : Run-III Unpol. CDC Commissioning

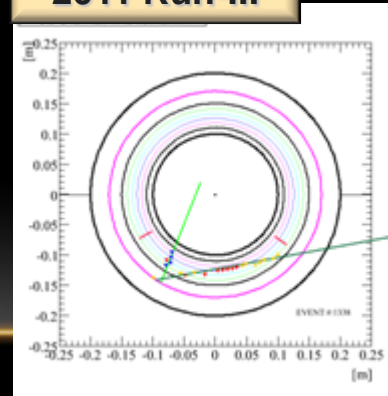
Goal : checking V-track event using a part of CDC.

2012. 11 : Run-IV Trigger Detector & DAQ full setup Test

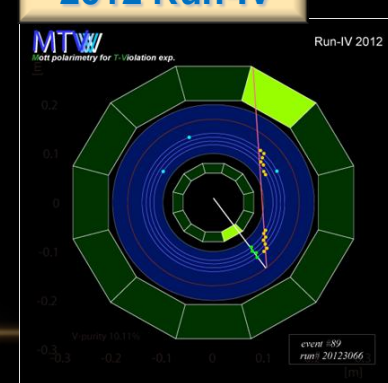
Goal : Installing trigger detector and DAQ for CDC & obtaining V-track rate using full setup.

2013. 11: Run-V Final Demonstration Exp.

2011 Run-III



2012 Run-IV



Main detector : Cylindrical Drift Chamber

## Schedule: 11/15-11/16 (original) —> 11/16 – 11/17 (actual)

- Beam time actually started from 11/16(12:00) to 11/17(12:00). → 2 shifts.
- It's because tuning of  $^7\text{Li}$  for MTV/ $\beta\text{NMR}$ / $\beta\text{NQR}$  took long time due to Faraday Cup trouble.

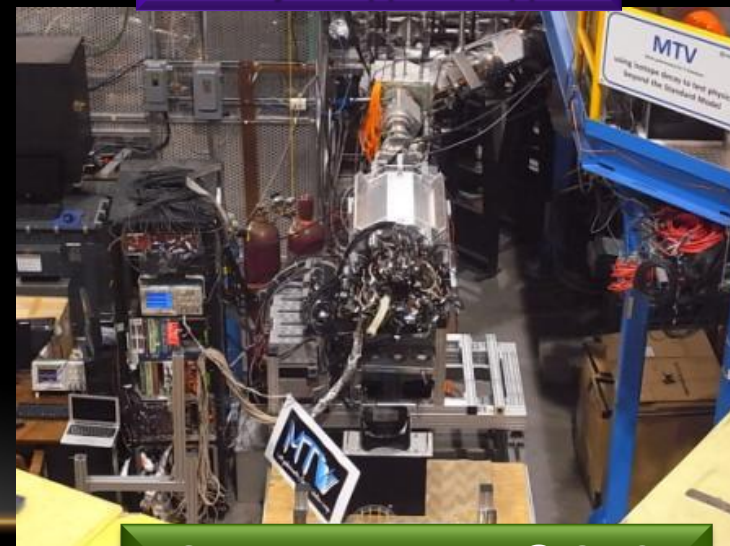
## Motivation

- Studying systematic effect for Physics Run using CDC scheduled in 2014.

## Beam Menu

- Rate Stability using beam  $10^7\text{pps}$
- Systematic Study
  - ✓ taking unpolarized beam data as UP-DOWN-UNPOL sequence
  - ✓ comparison high and low rate beam intensity.
- Relaxation time measurement
  - ✓ Beam Stopper Upgrade

Beam : Pol. /Unpol.  $^8\text{Li}$   
Energy : 28keV  
Intensity :  $10^4\text{pps} \sim 10^7\text{pps}$

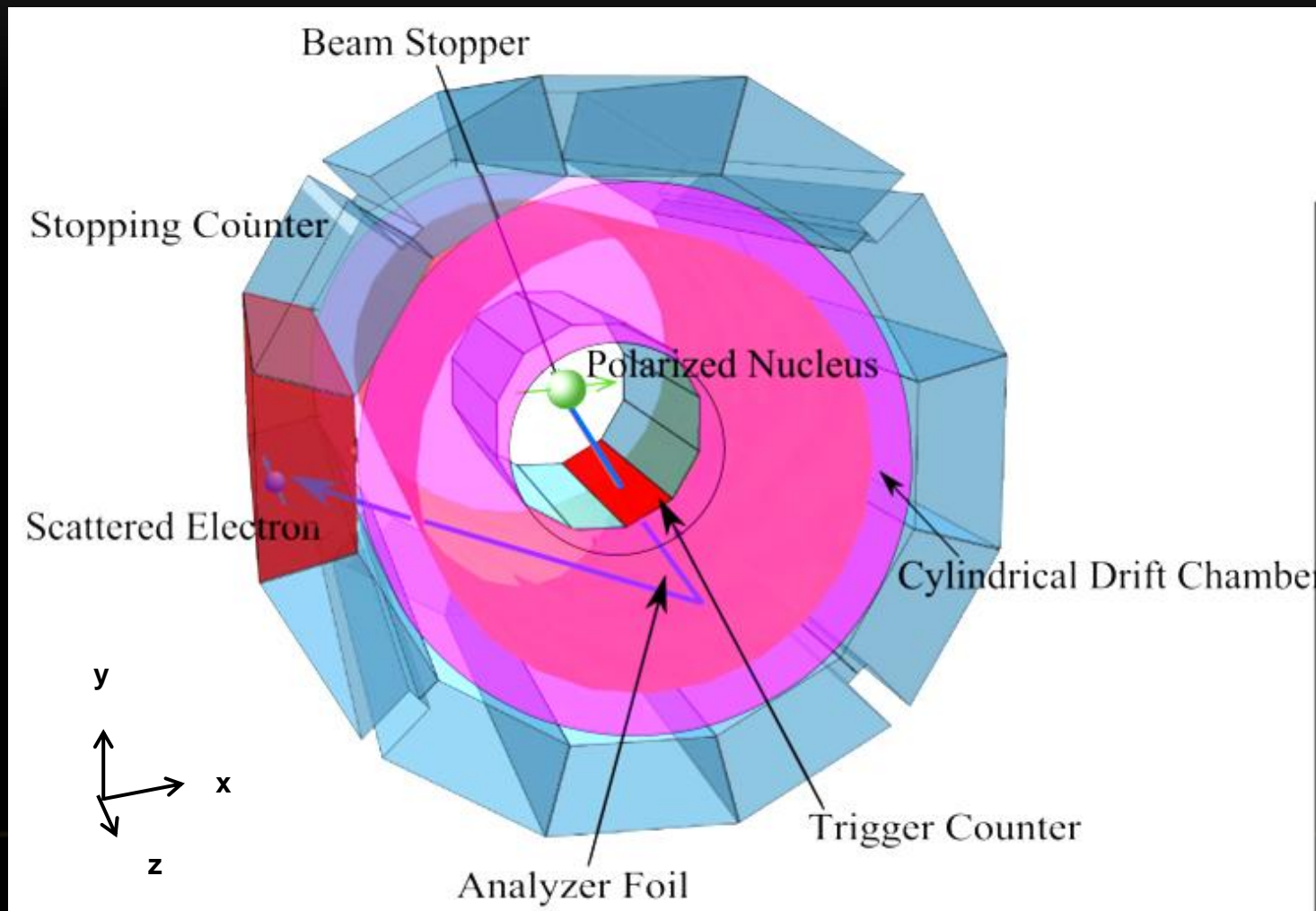


OSAKA beam line @ISAC-I

# DETECTOR SETUP & DAQ

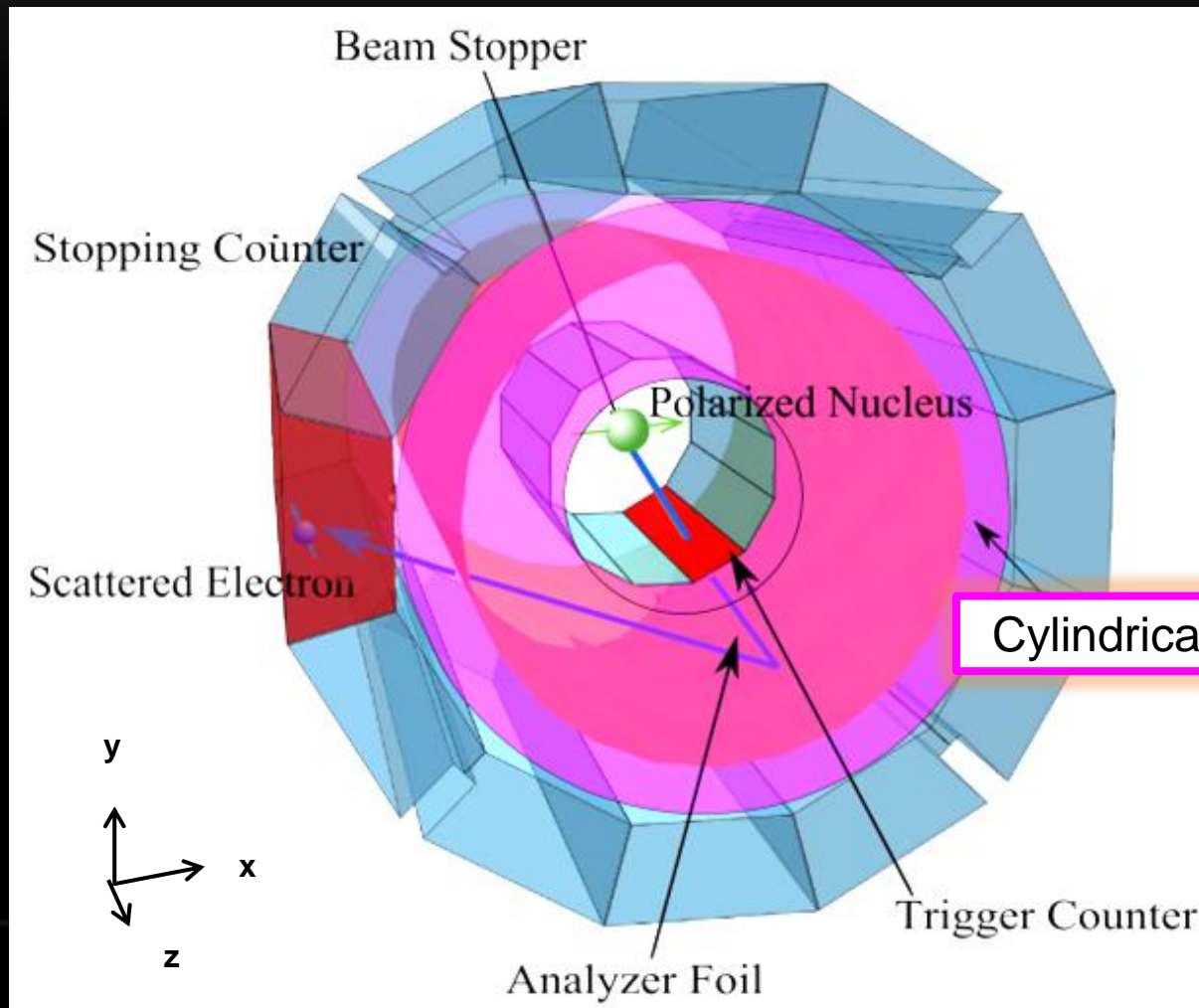
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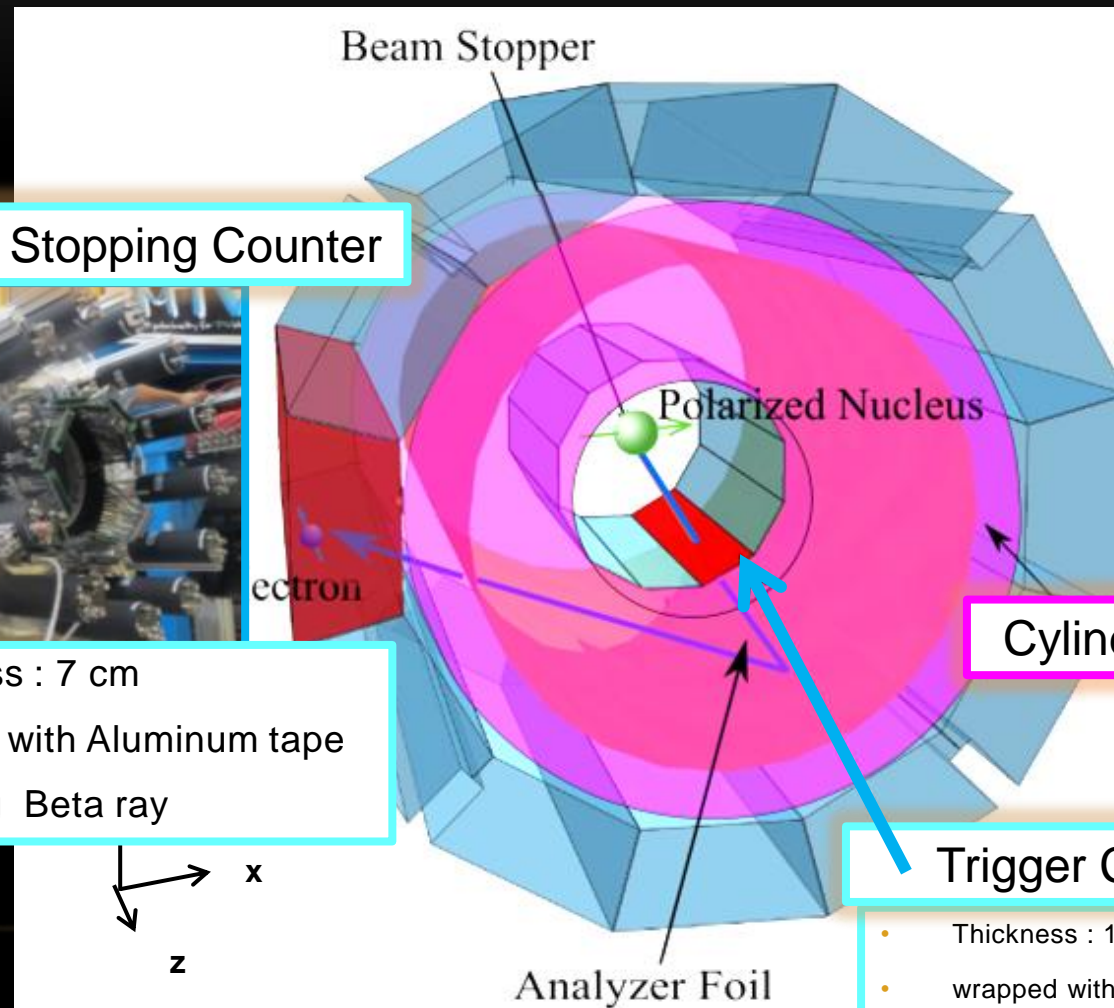


# Detector Setup

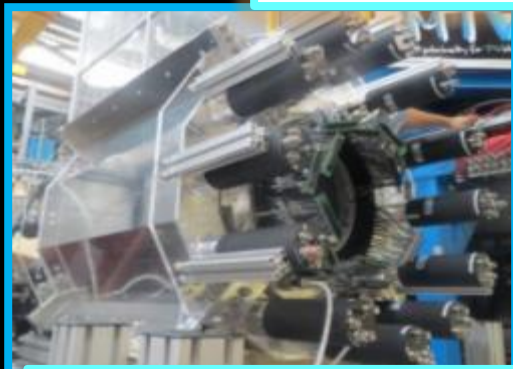


- Readout : 400ch
- gap: 4 mm
- Ar:CF4=160:80

Cylindrical Drift Chamber



Stopping Counter



- Thickness : 7 cm
- wrapped with Aluminum tape
- Stopping Beta ray



- Readout : 400ch
- gap: 4 mm
- Ar:CF<sub>4</sub>=160:80

Cylindrical Drift Chamber

Trigger Counter

- Thickness : 1 mm
- wrapped with aluminu-vapored tape
- Triggering Event



**New FPGA-based system is developed with General Purpose VME board.**



2009 Run-I

2010 Run-II

2011 Run-III

2012 Run-IV

2013 Run-V

## Trigger part

- ✓Lv.1 trigger (Plastic Scintillation Counter)  
OR logic circuit of 12 Trigger Counters.
- ✓Lv.2 trigger (CDC + Counters)  
Counter circuit for hit wires for setting lower limit to the count number of hit wires.

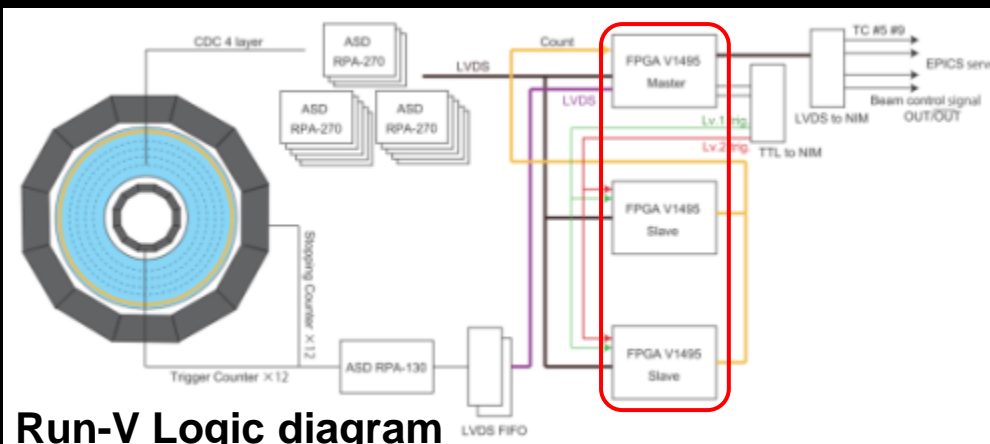
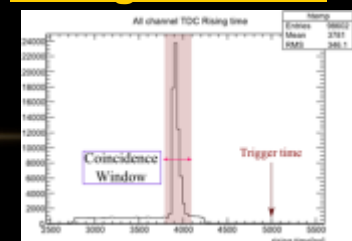
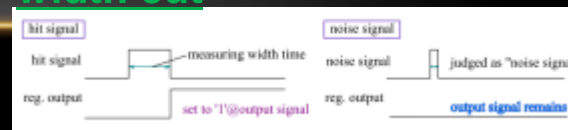
## DAQ part

### Coincidence Register

- ✓Hit pattern is recorded.  
—> No TDC information
- ✓Fixed data size in each event

**Speeding Up !** **rising time cut**

### width cut



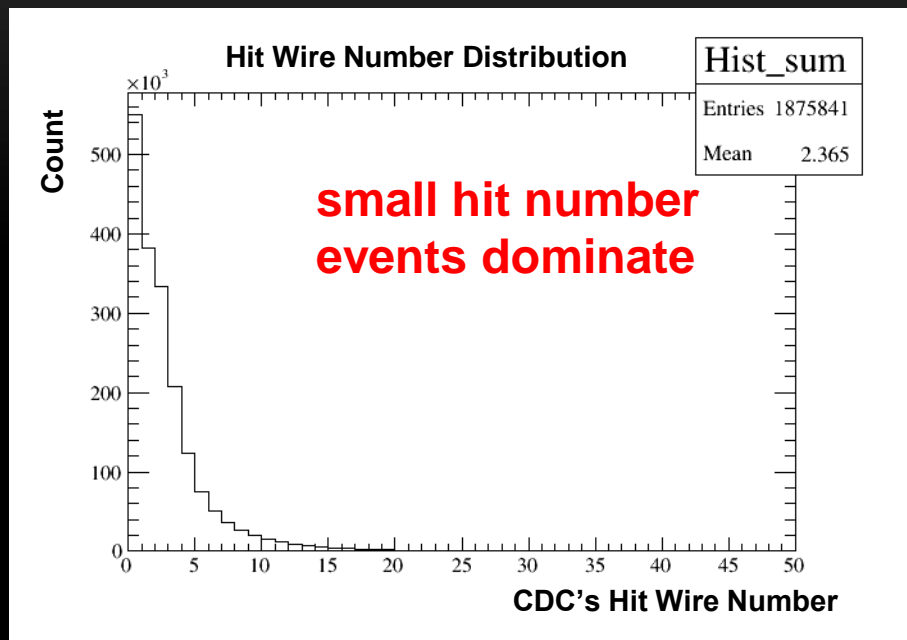
Run-V Logic diagram

**Master-Slave System using 3 FPGA Board**

# RESULTS

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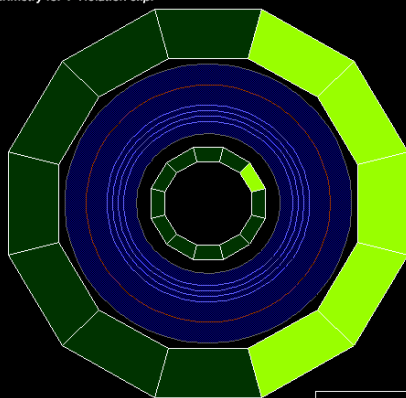
## Lv.1 (Scintillation Counter)



## Lv.2 (Counter + CDC)

MTV  
Mott polarimetry for T-Violation exp.

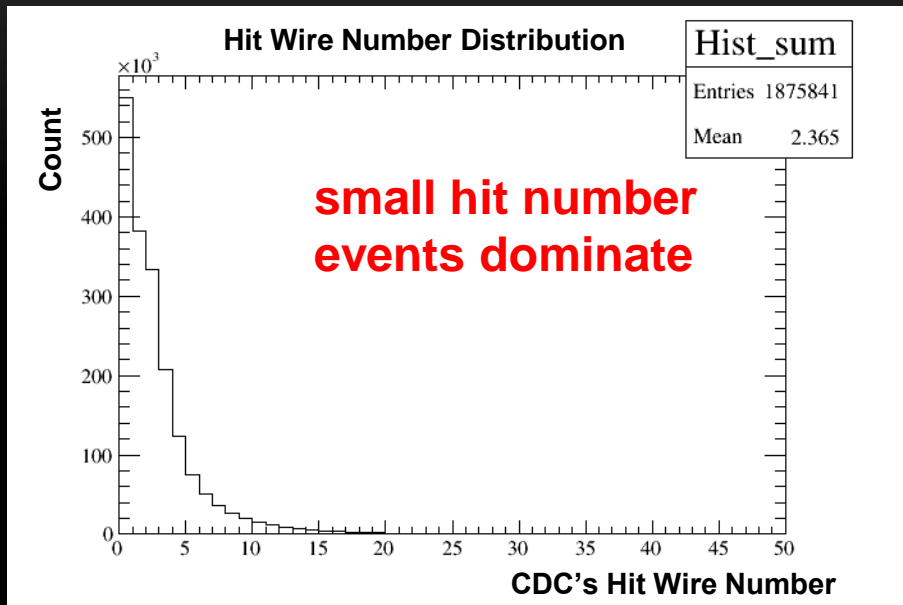
2013 MTV



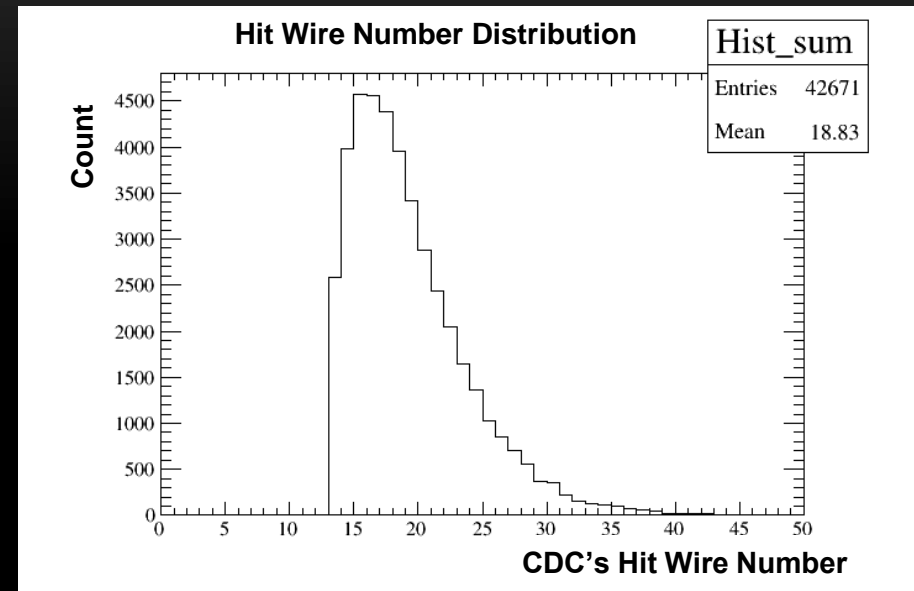
event #:0  
run #:20133154



## Lv.1 (Scintillation Counter)

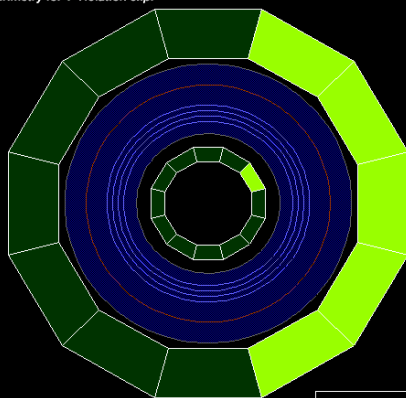


## Lv.2 (Counter + CDC)



MTV  
Mott polarimetry for T-Violation exp.

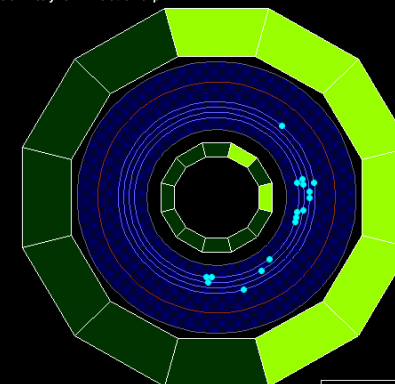
2013 MTV



event #:0  
run #:20133154

MTV  
Mott polarimetry for T-Violation exp.

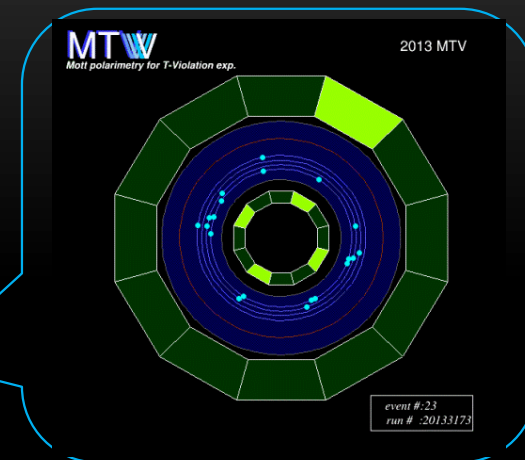
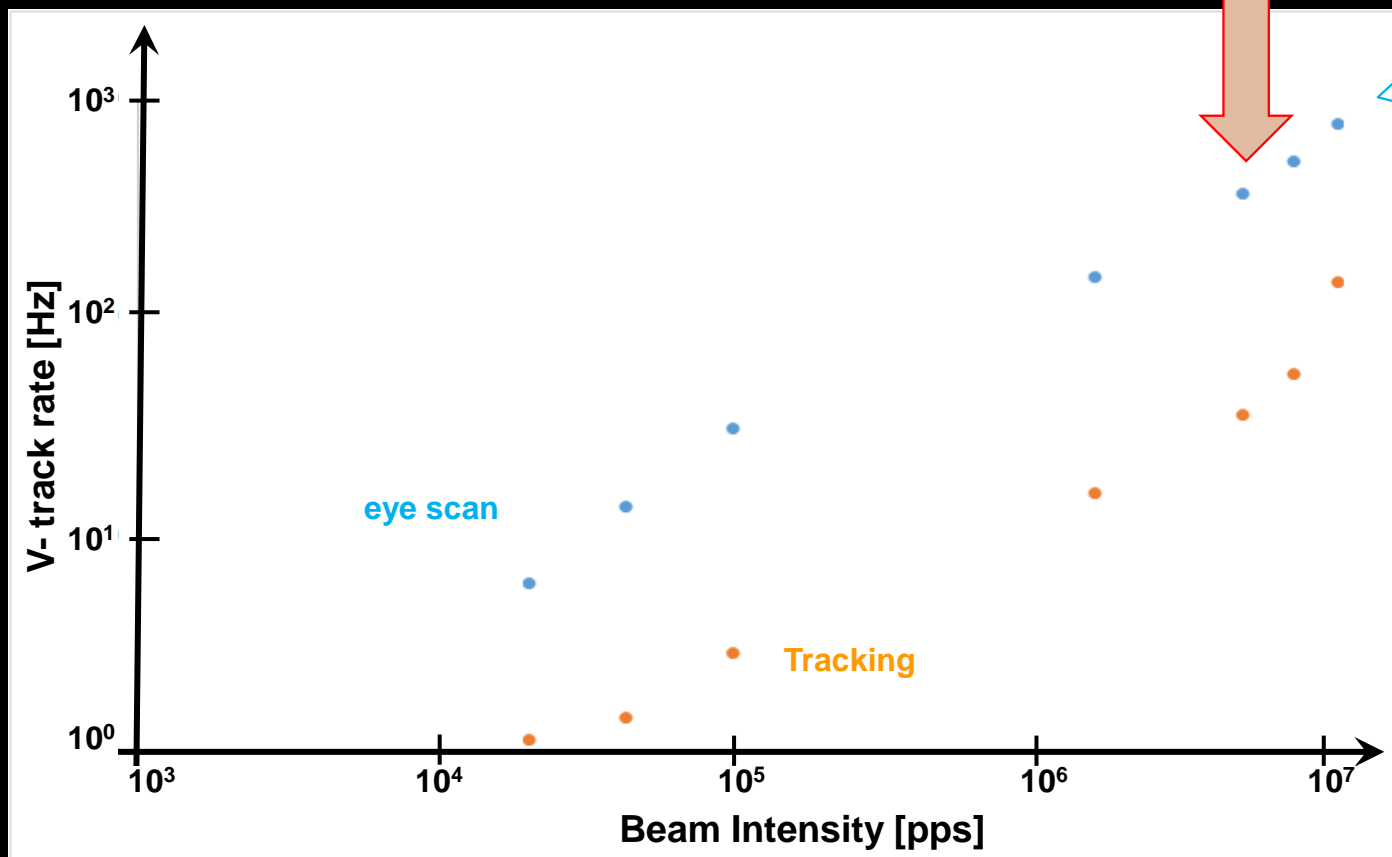
2013 MTV



event #:1  
run #:20133156

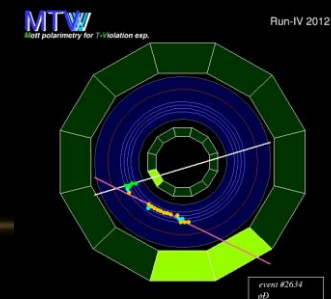
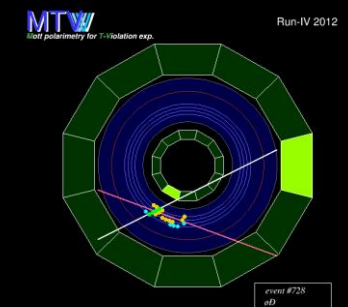
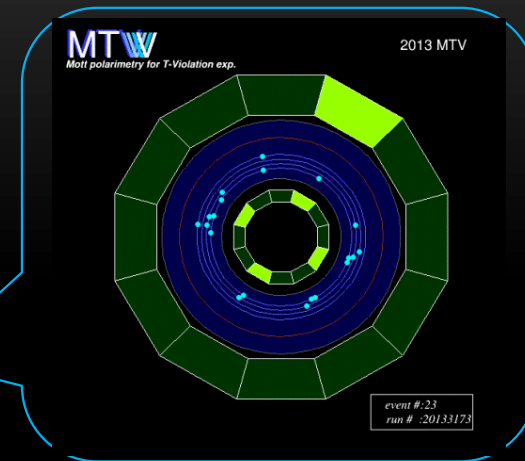
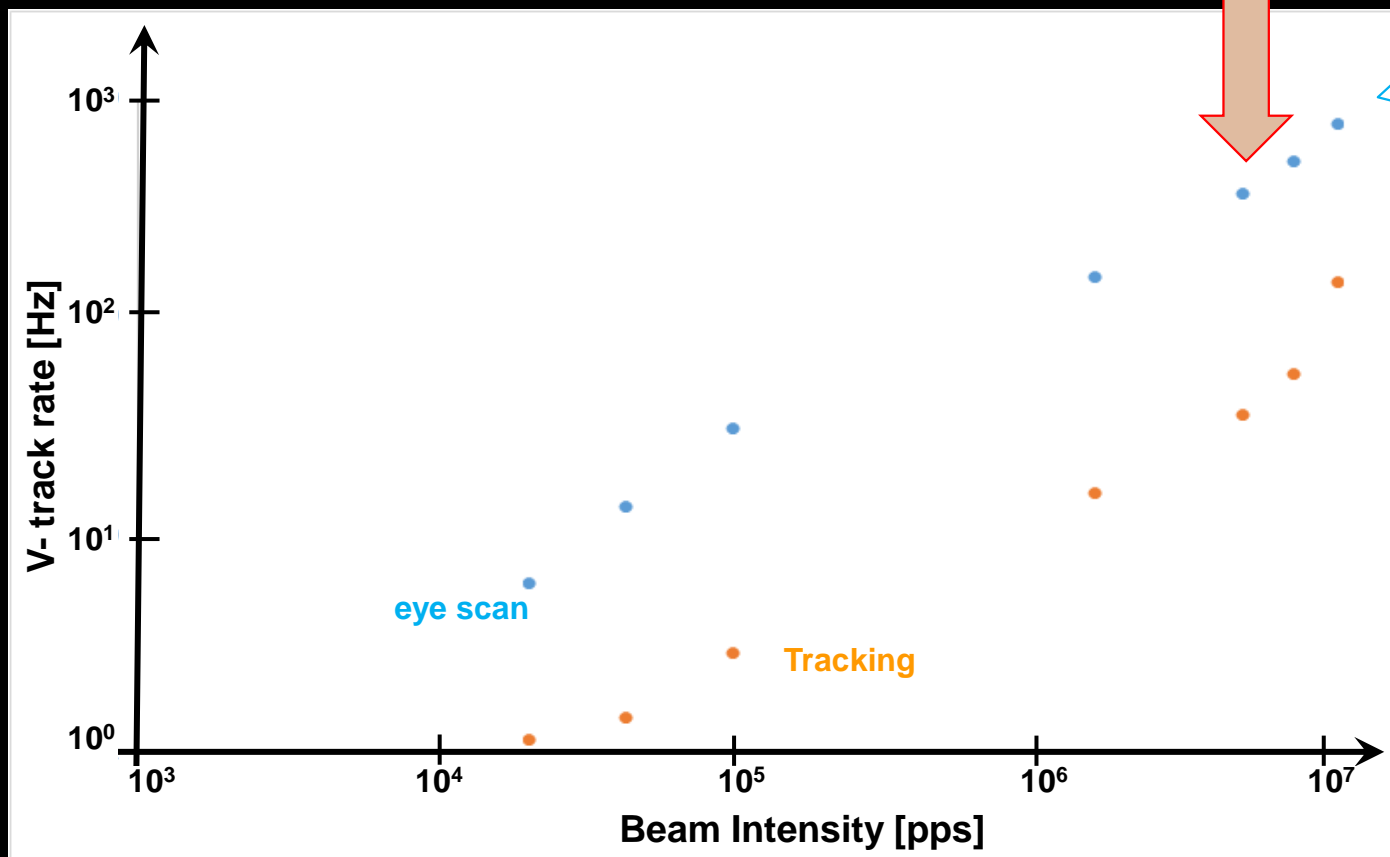
**Suppressed small hit number event.**

# Result —Rate Stability—





# Result —Rate Stability—



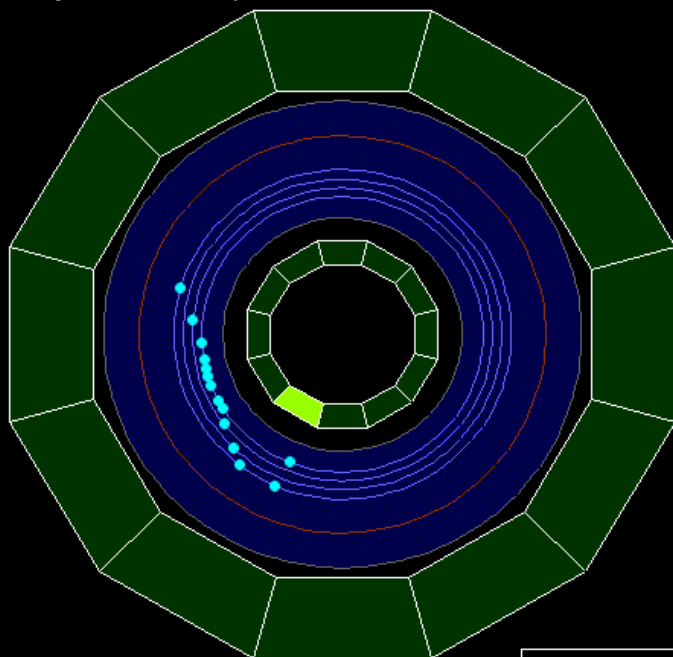
## Event Display

1 shift was used for tuning setup.  
Another 1 shift was used for Physics run

**MTV**

Mott polarimetry for T-Violation exp.

2013 MTV



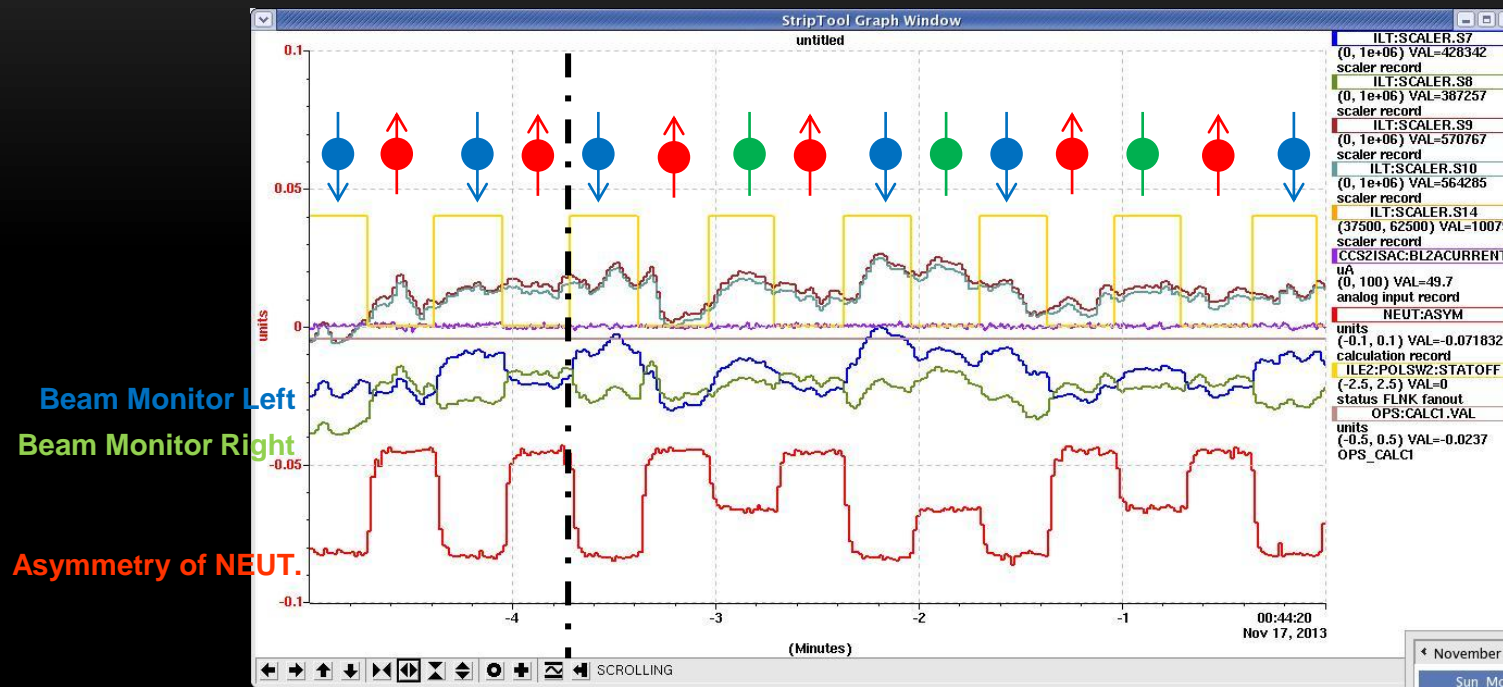
event #:130  
run # :20133219

Run	Obtained event #
High intensity	70 M events
Low intensity	6.3 M events
Unpol. run	3.9 M events

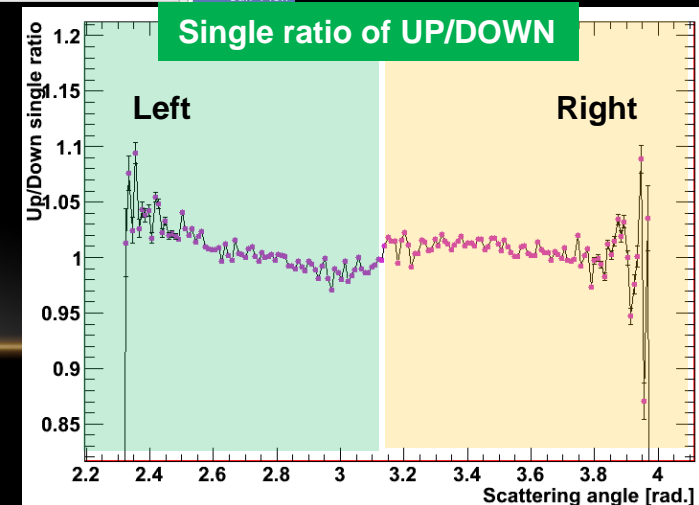
V- track event rate: Max. 100Hz (purity:16% )

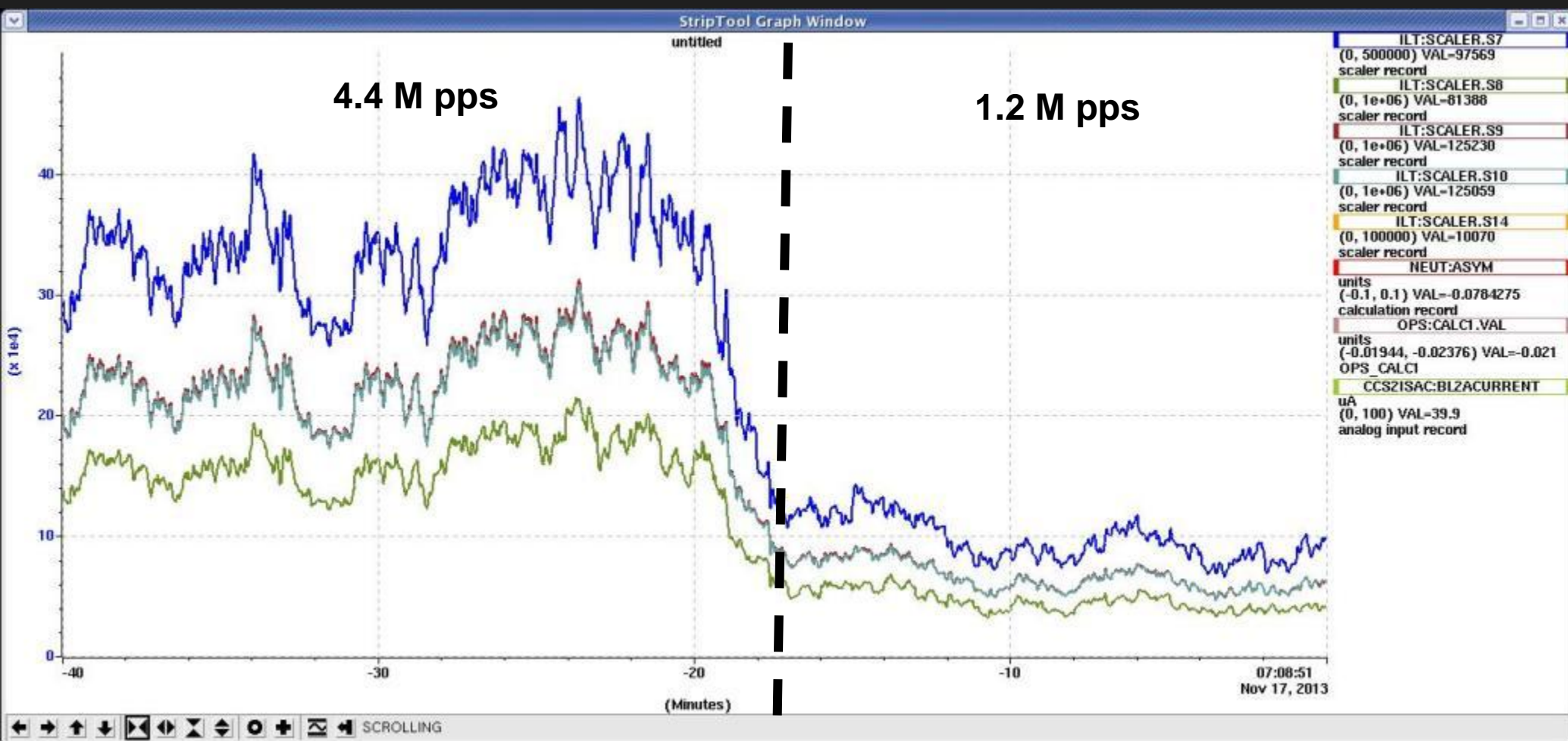
We achieved to collect enough number of events for systematic study.

## UP-DOWN-UNPOL sequence



**Unpol. data** is required from Run-II analysis.  
It's found that the left-right efficiency of the detector doesn't conserve during spin-flip and that we can correct the systematic effect using Unpol. data.

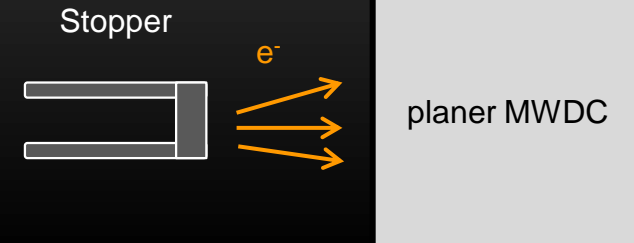
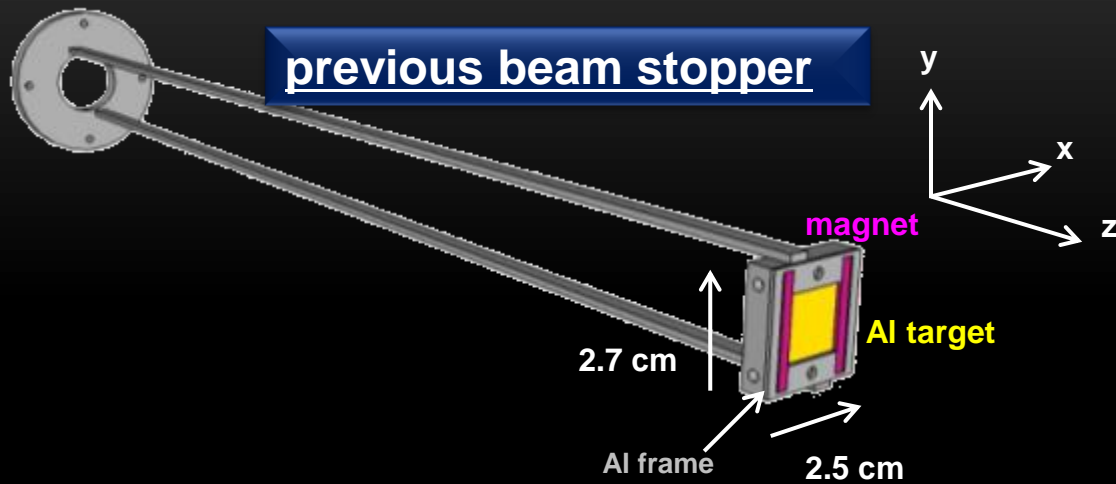




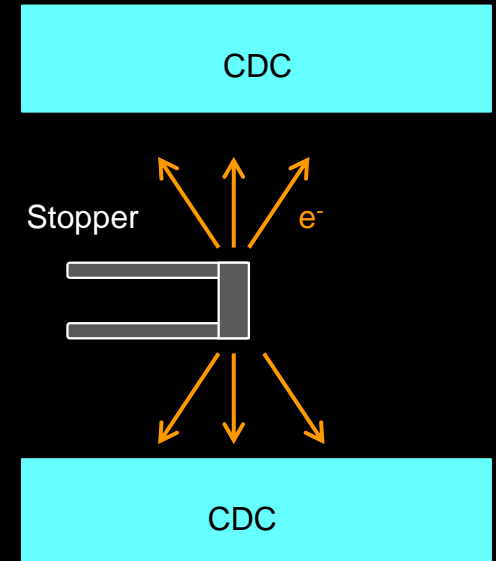
whether the fluctuation become systematic effect should be checked.

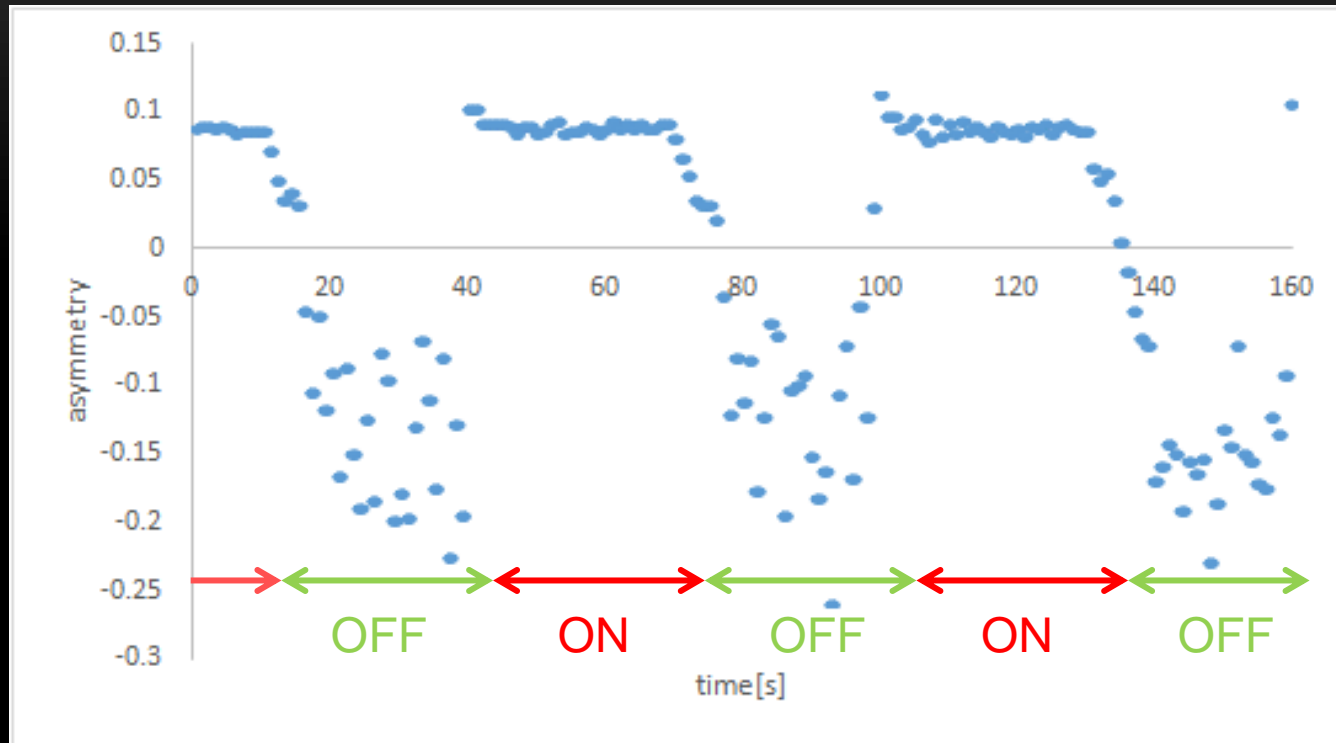


# Beam Time Result —Relaxation time—



- ✓ previous beam stopper was designed for planer MWDC.
- ✓ There are Al frame and magnet at the emission angle of electron.





previous beam stopper

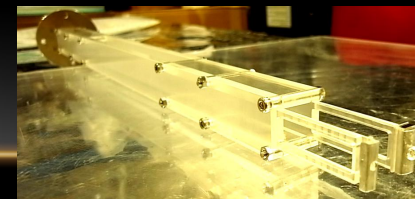


~ 2.0 sec.

improved



new beam stopper



~ 4.0 sec.

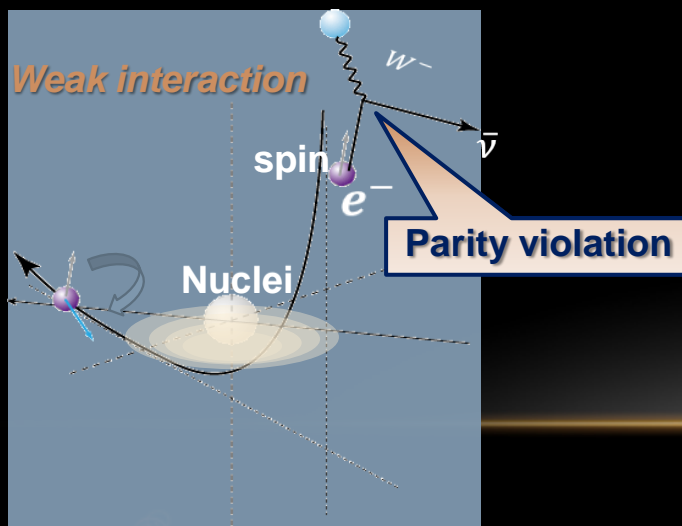
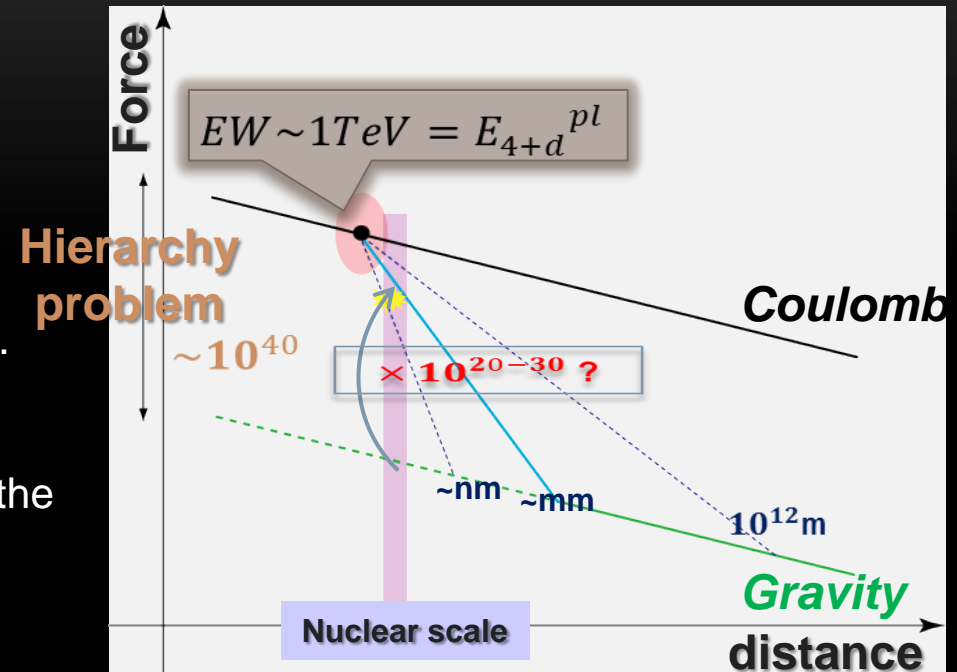
MTV-G EXP.



**MTV-G exp. is the test of Inverse square law by Newton at Nuclear scale** and search for Large-extra dimension model (called ADD model).

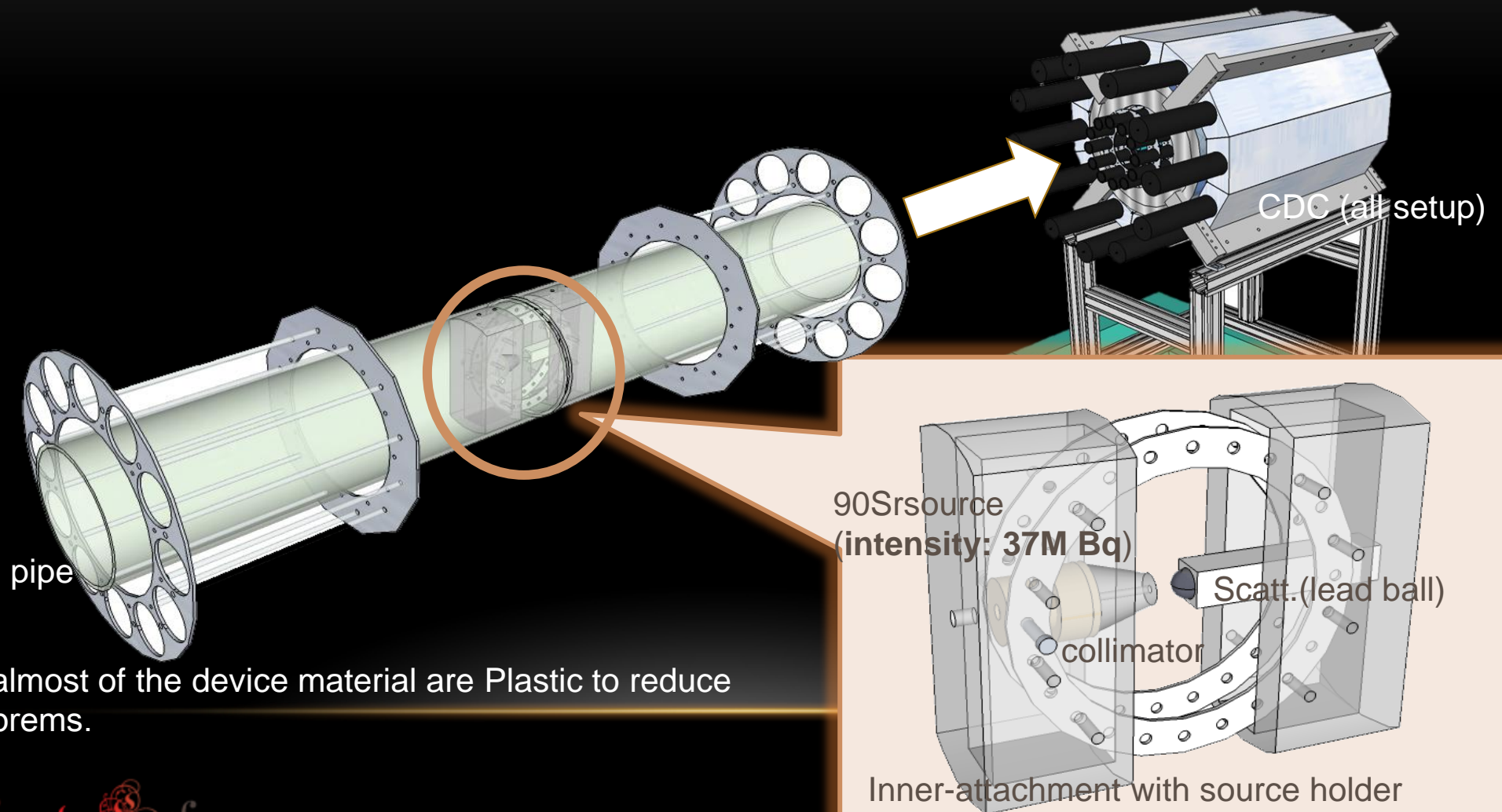
We will **search short-range gravitational field around atomic nucleus** using MTV detector, and test the tilting from Longitudinal polarization of electron spin by analyzing power of Mott scattering.

By using the electron which have Transverse polarization, it could be checked the principle and the set up of MTV exp.



If a strong gravitational field around Nuclei exist, **an electron spin is getting more changed the direct by Geodetic precession** than without the effect (only Thomas precession and Coulomb scattering).

With change the incidence angle of Sr source to the scattering lead ball, we take the spin change angle by angle.



+++++ Scaler Information(c

Master(Slave)	Master	Slave 1
Trigger Counter 1(E(12))	2,466 ( 613,529)	170 (
Trigger Counter 2(E(13))	2,406 ( 599,141)	175 (
Trigger Counter 3(E(14))	5,601 ( 1,382,100)	179 (
Trigger Counter 4(E(15))	3,036 ( 768,665)	172 (
Trigger Counter 5(E(16))	5,815 ( 1,413,660)	197 (
Trigger Counter 6(E(17))	5,564 ( 1,333,080)	186 (
Trigger Counter 7(E(18))	2,249 ( 559,395)	194 (
Trigger Counter 8(E(19))	2,345 ( 583,227)	174 (
Trigger Counter 9(E(20))	2,226 ( 546,616)	183 (
Trigger Counter 10(E(21))	2,361 ( 584,269)	166 (
Trigger Counter 11(E(22))	3,524 ( 882,762)	181 (
Trigger Counter 12(E(23))	3,082 ( 757,695)	167 (
Lv.1 trig. w/o veto	35,778 ( 8,805,109)	0 (
Lv.1 trig. with veto	34,285 ( 8,438,943)	34,285 ( 8
Coincidence window	34,285 ( 8,438,944)	34,285 ( 8
Lv.2 trig. w/o veto	48 ( 11,201)	0 (
Lv.2 trig. with veto	48 ( 11,165)	48 (

Time: 20

Polarization Control: 1

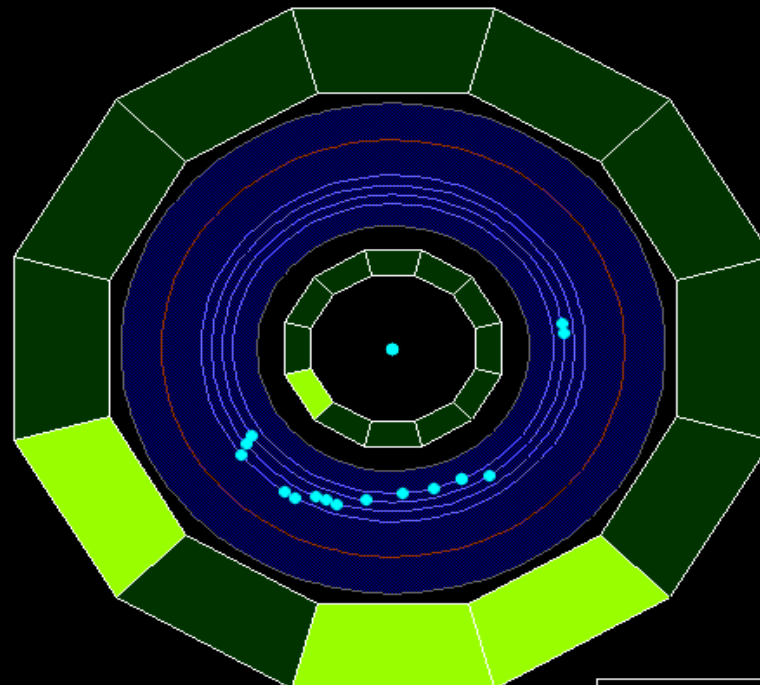
Lv.1 trig. Acc./Req. =0.9583

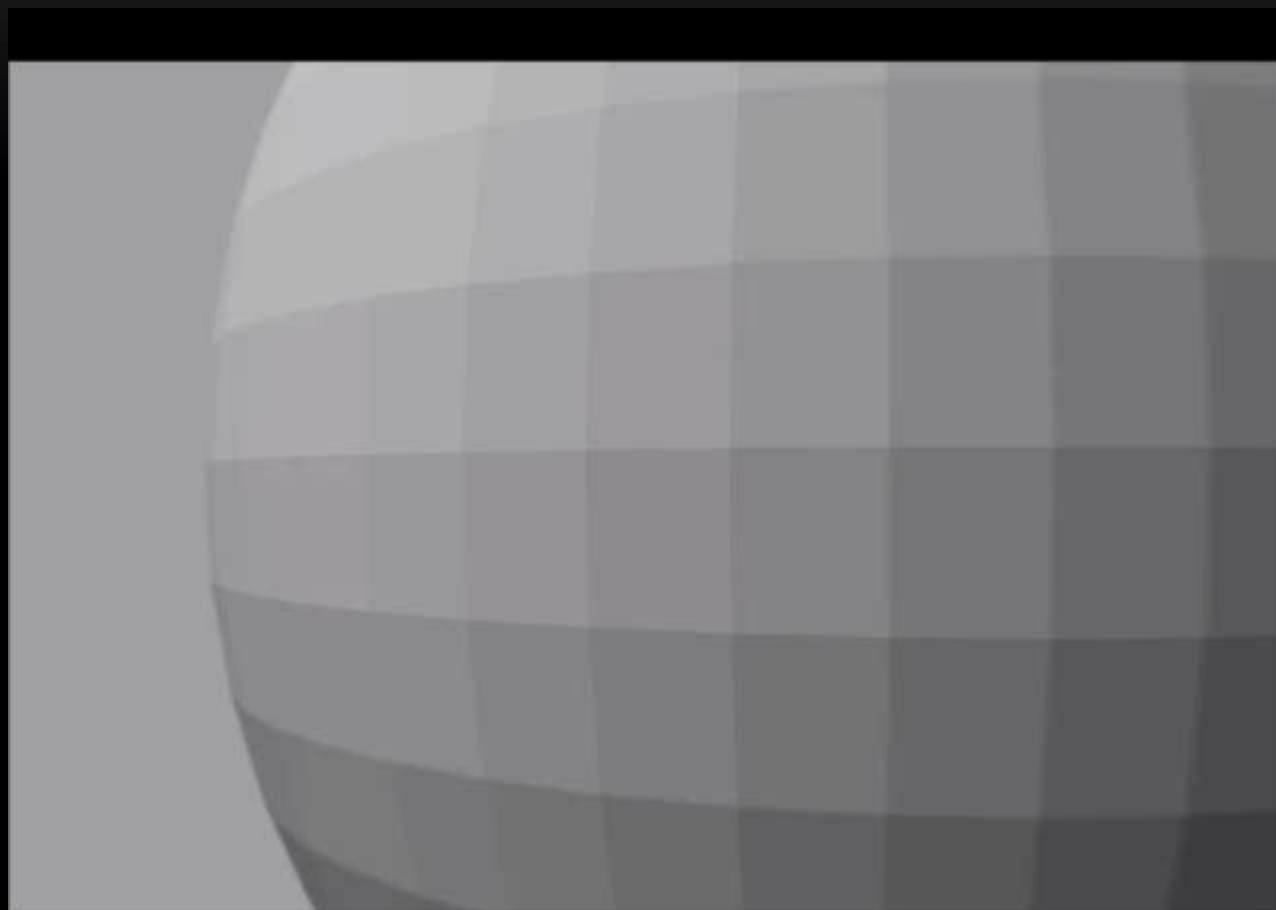
Lv.2 trig. Req./Lv.1 Acc. =0.0014

Lv.2 trig. Acc./Req. =0.9949

w/ scatt. Rate : 100~200Hz

w/o scatt. Rate : 40~50Hz


event #1  
run #20131142



## Summary

- ✓ The MTV experiment is aiming to search non-zero T-violation in nuclear beta decay by measuring electron transverse polarization.
- ✓ The electron transverse polarization is measured as left-right scattering asymmetry in Mott scattering.
- ✓ Final test experiment for physic run was performed on 11/16 – 11/17
- ✓ We check the rate stability of CDC setup using  $10^7$ pps
- ✓ We developed new beam stopper and measured relaxation time.

## Future Plan

- ✓ Offline tracking analysis
- ✓ Systematic Study
- ✓ First physics run using CDC will performed in 2014.

THAT'S ALL  
THANK YOU FOR LISTENING

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