

Searching for Lorentz Violation at TRIUMF and J-PARC

Jiro Murata

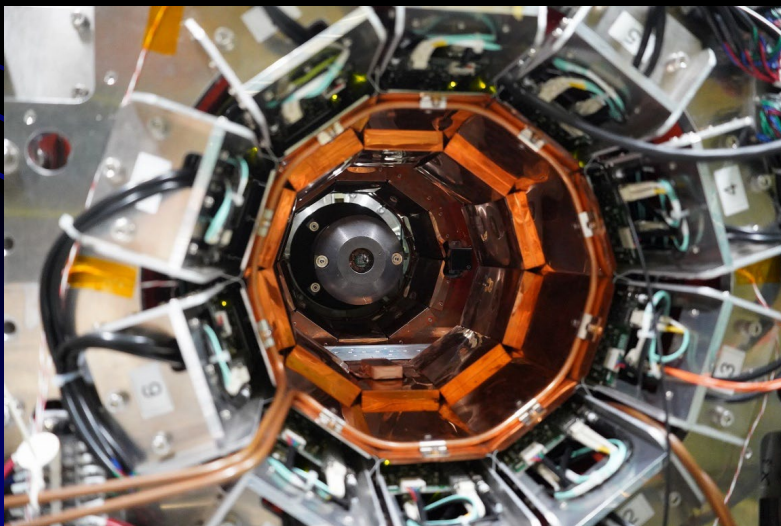
Rikkyo University

ARIEL Science Workshop 2026

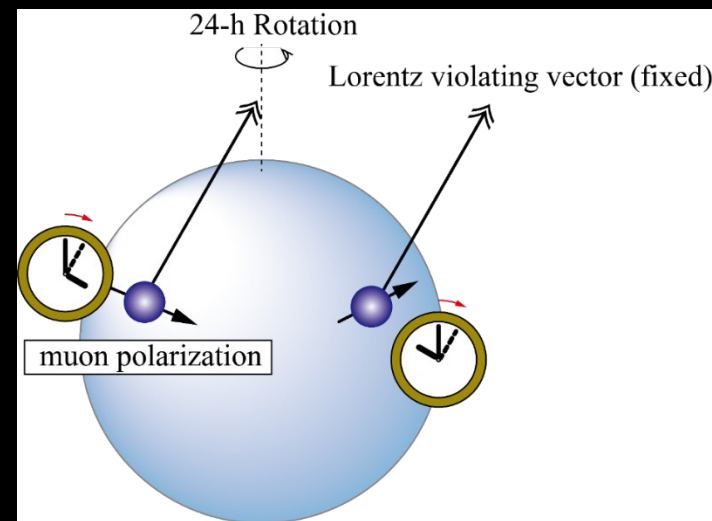
20-23 April, 2026, TRIUMF

4/22 11:00-12:30

Future directions in exploring fundamental symmetries with rare-isotopes



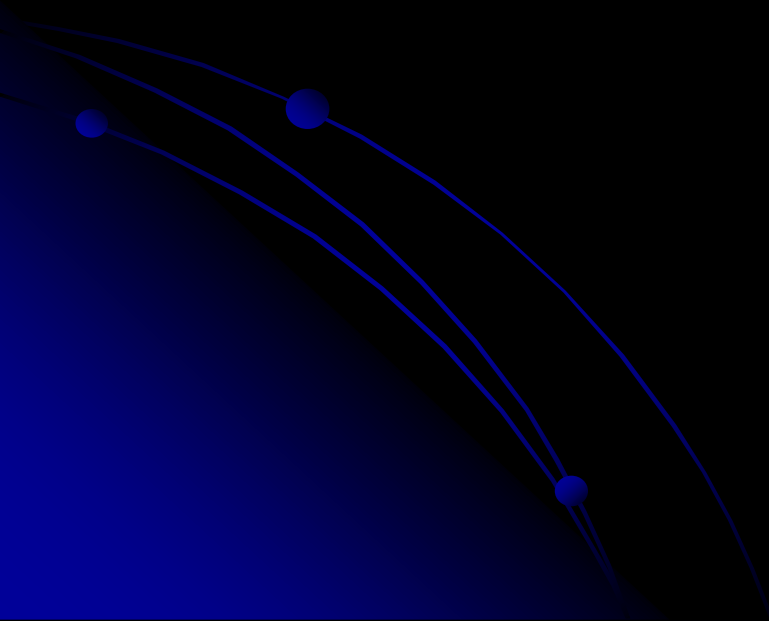
μ LV @ J-PARC in lepton sector



qLV @ ISAC in quark sector

Crazy Dream:

Make a breakthrough towards Quantum Gravity



Towards Quantum Gravity and Force Unification

Experimentally Testable ?

Solution-A : String, Extra-Dimensions

- strong gravity at short scale?

ADD, RS models

Solution-B : Gravity = Residual Interaction of XX

- weak gravity at short scale?

like nuclear force

Solution-C : Symmetry breaking

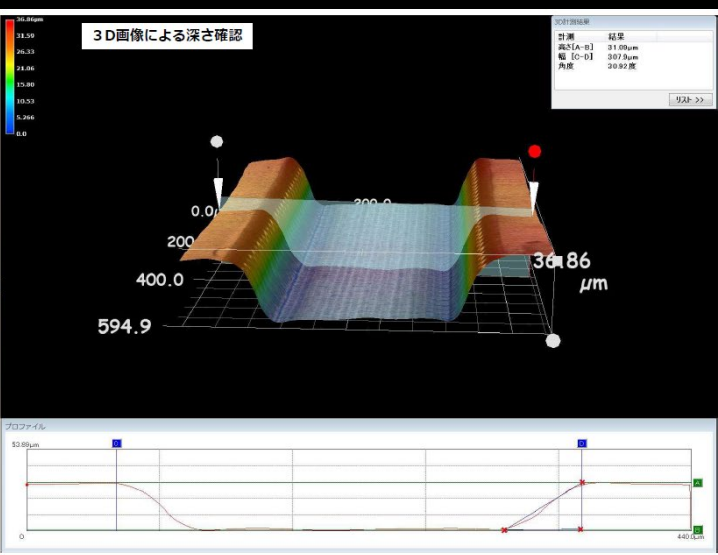
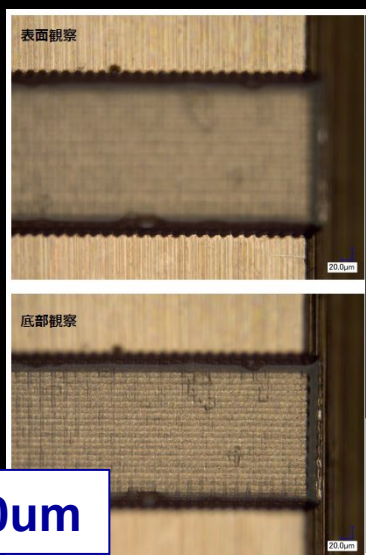
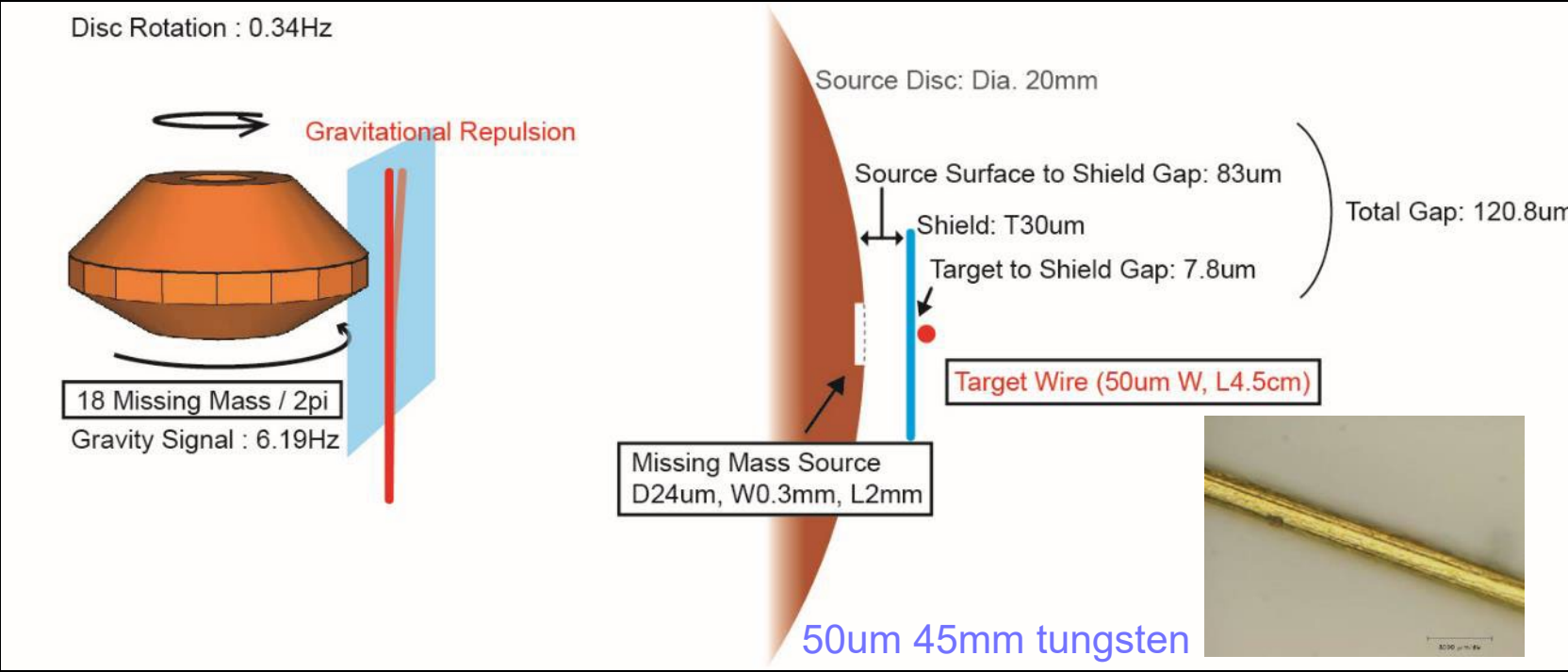
- **Lorentz violation** at short scale?

Harlow-Ooguri, Hořava-gravity

Gap 10um, Wire Dia. 50um

Newton-V status

Solution-A & B



Kajihara 2019

missing mass Depth 24um, Width 300um

Matsushiro

Secret UG Fortress for WWII, 1945



Towards Quantum Gravity and Force Unification

Experimentally Testable ?

Solution-A : **String, Extra-Dimensions**

- strong gravity at short scale?

ADD, RS models

Solution-B : Gravity = **Residual Interaction** of XX

- weak gravity at short scale?

like nuclear force

Solution-C : **Symmetry breaking**

- **Lorentz violation** at short scale?

Harlow-**Ooguri**, **Hořava**-gravity

LV (preferred frame) Tests: Time Variation of "constants"

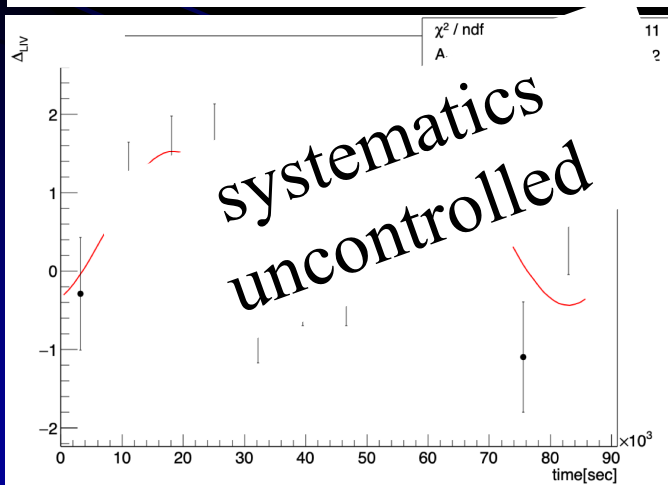
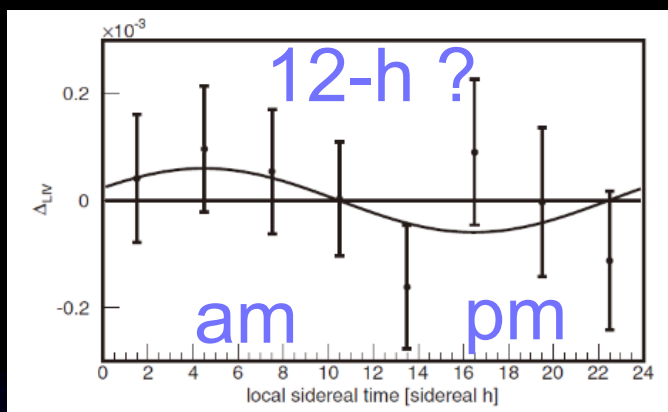
Weak

Sytema (KVI) PRC 2016

Na-20 beta decay :

nuclear clock

60ppm

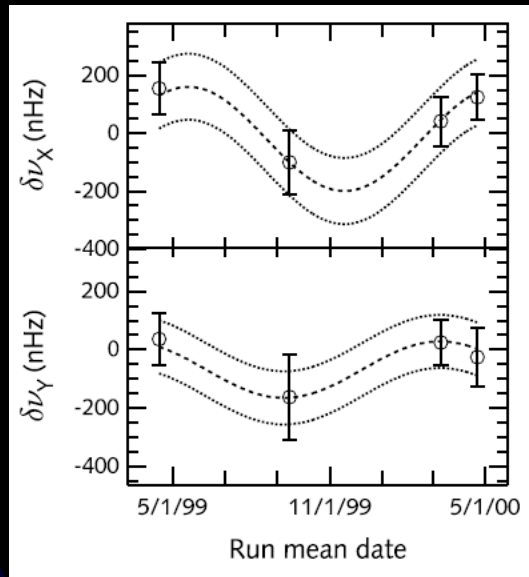


MTV Li-8 beta decay 2017



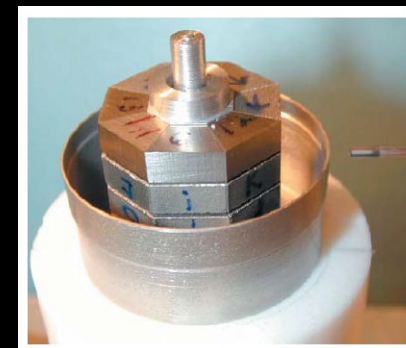
EM

atomic/nuclear clock

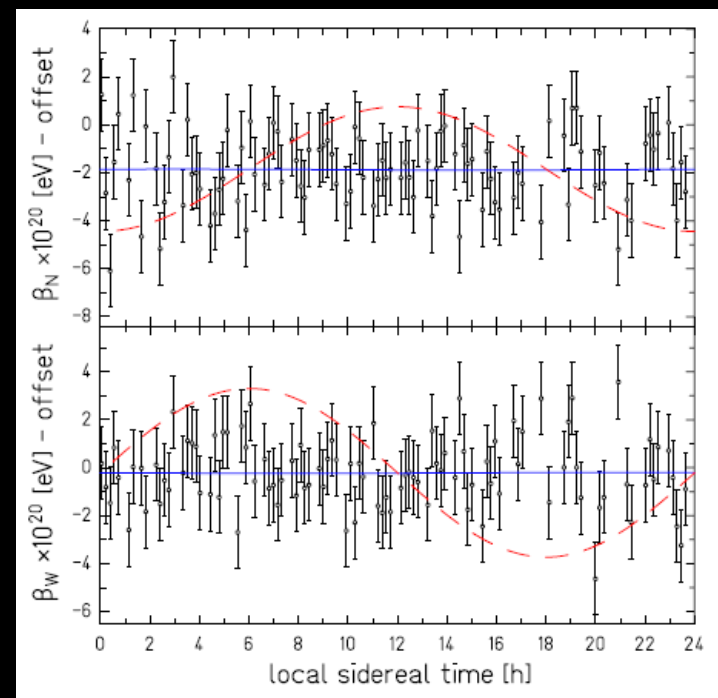


Cane PRL 2004

Gravity



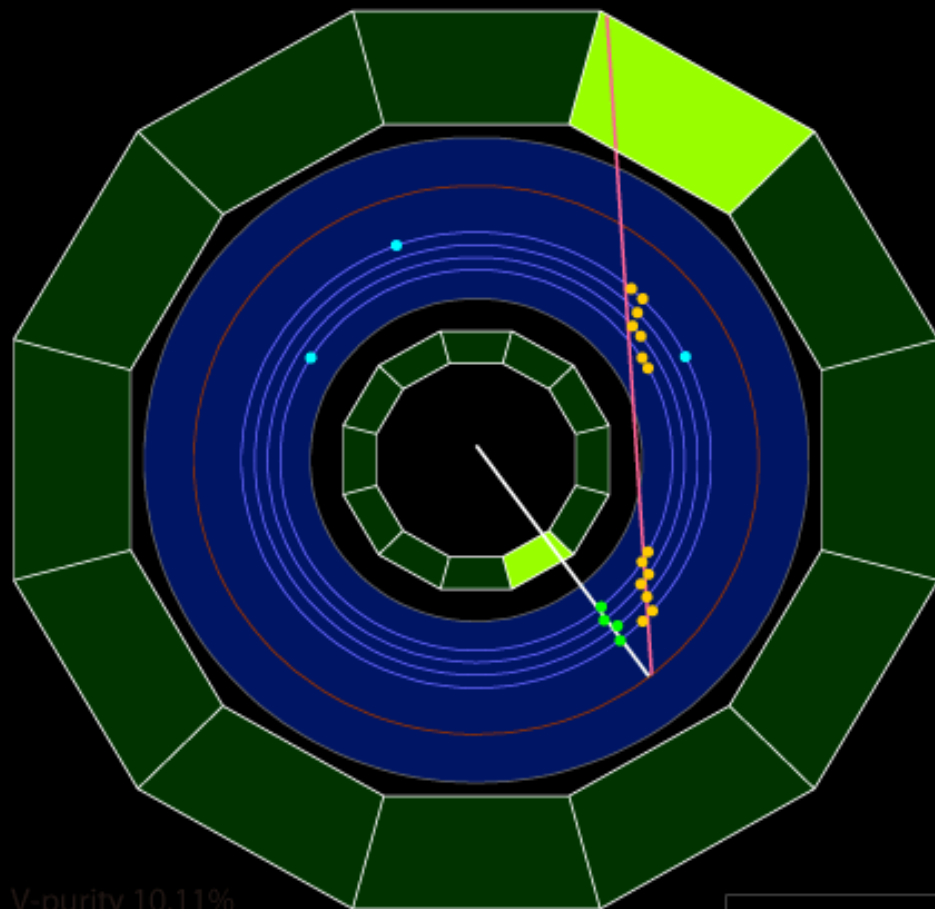
Heckel (UW) PRL 2006



am

pm

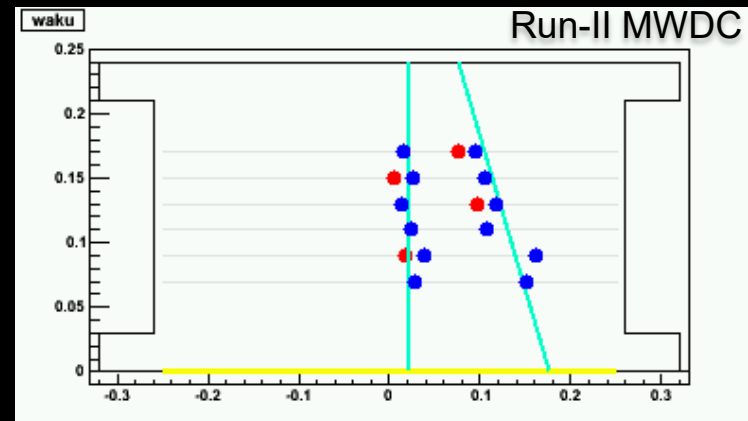
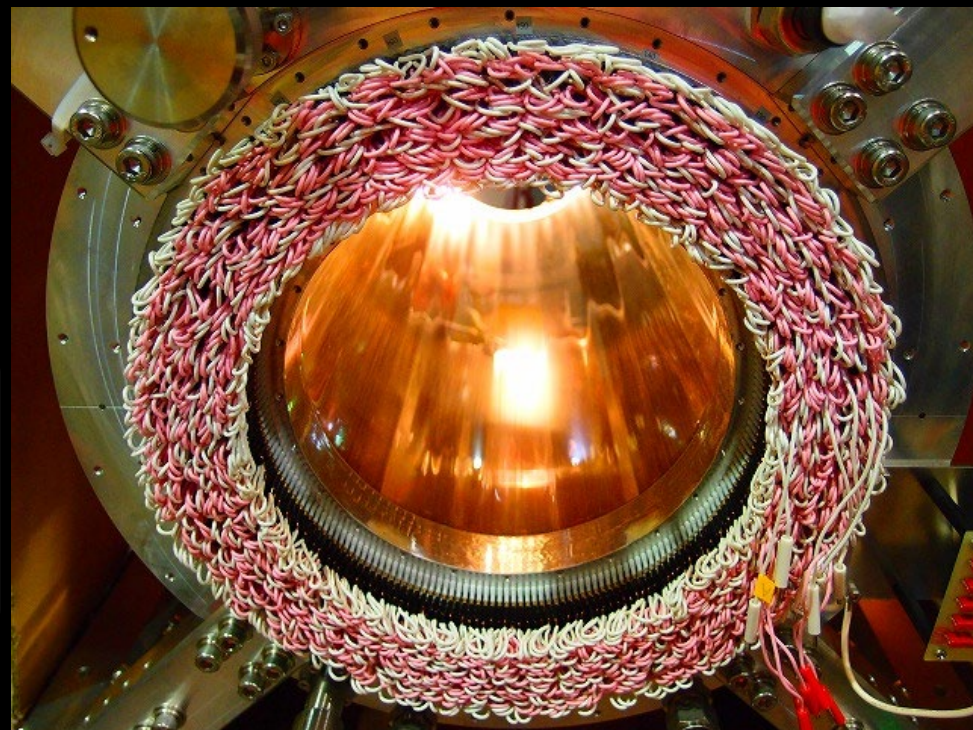
Run-IV 2012



V-purity 10.11%

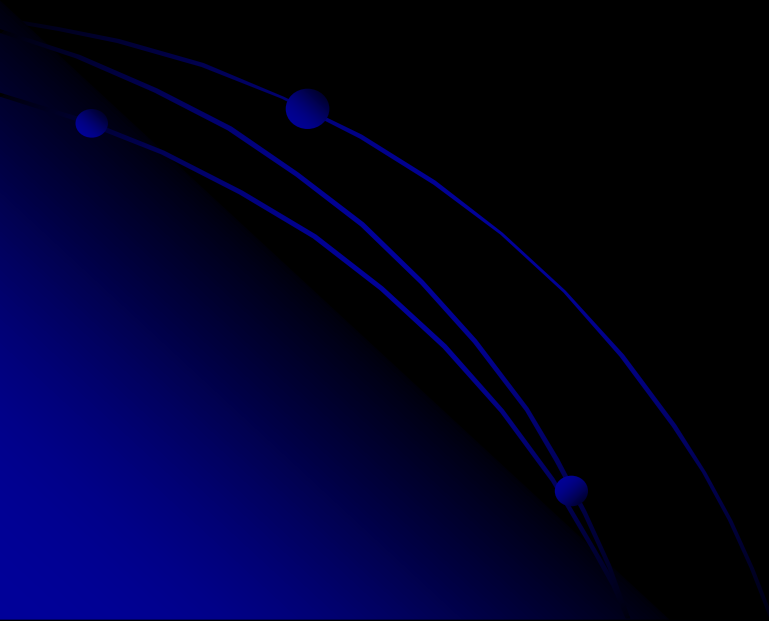
event #89
run# 20123066

[m]



V-tracking using CDC

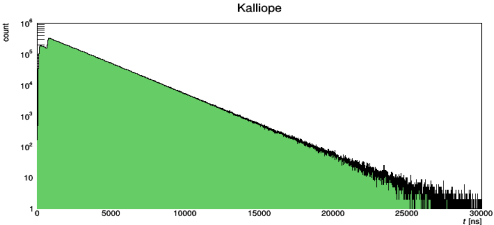
Michelson-Morley experiment in Weak Interaction.






Lorentz Violation μ LV/qLV

Searching a special direction in the universe



morning

24-h Rotation




Lorentz violating vector (fixed)

daily variation of lifetime

24-h / 12-h ?

Yearly variation of the phase?
Solar origin or LV?



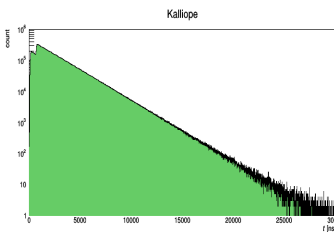
muon polarization

10-100 Mpps @ 100% pol.

Li-8 polarization

~10 Mpps @ ~70% pol.

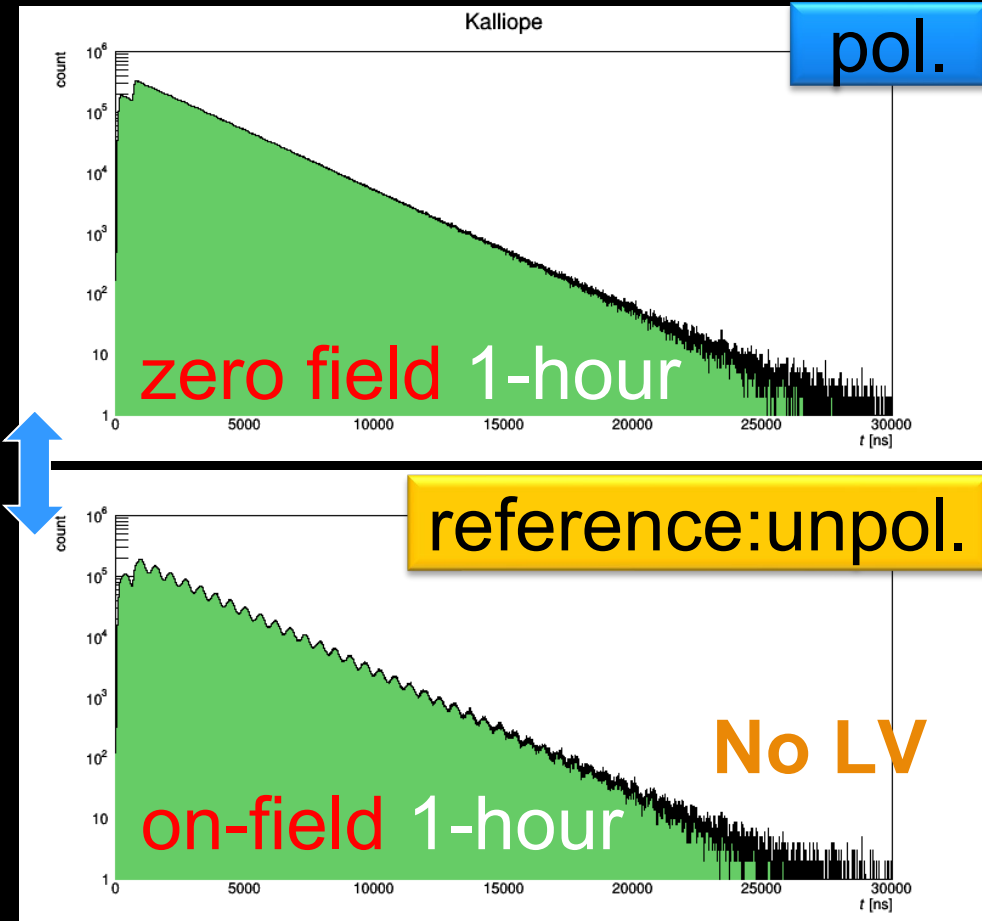
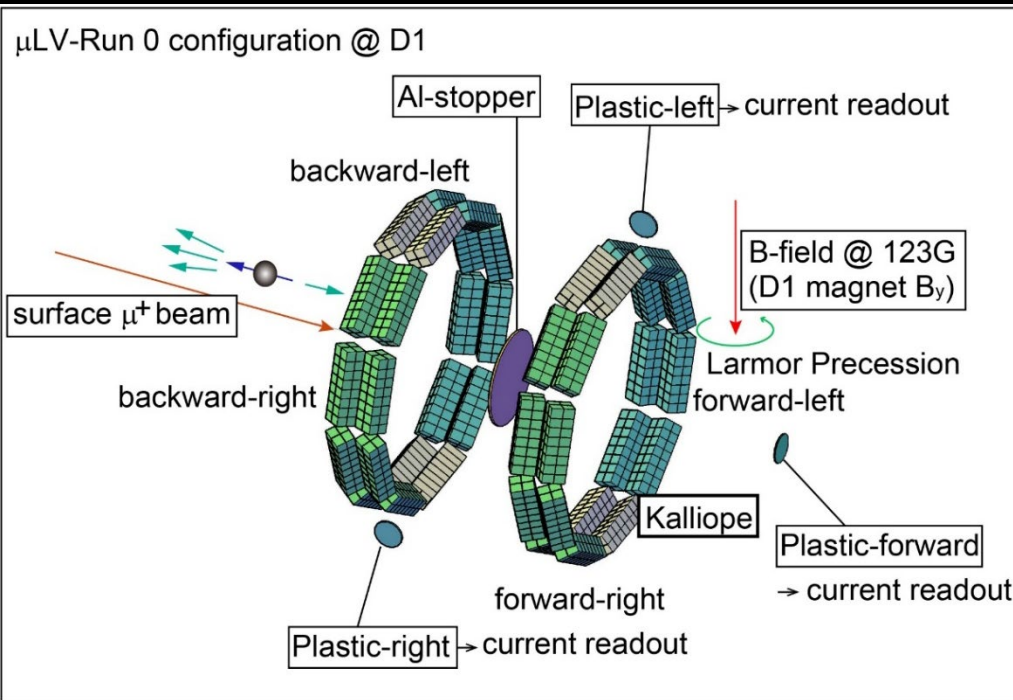
noon



timing measurement is the most precise

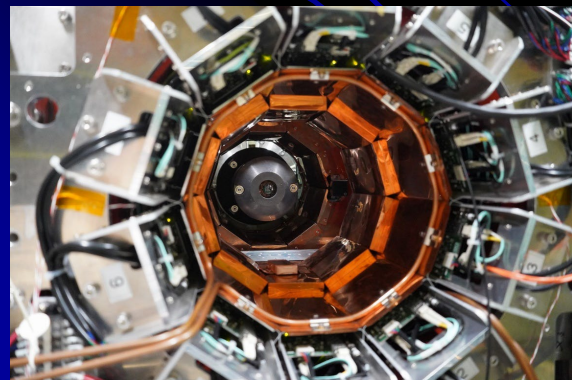
particle-size clock : 1/1000 fm (smallest clock w direction¹⁰)

J-PARC μ LV experiment



1280 ch PL-MPPC array

K. M. Kojima, J. Phys.: CS 551 (2014) 012063.

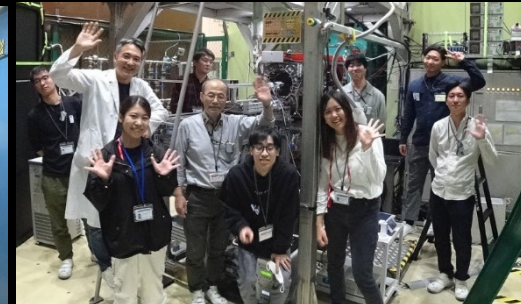
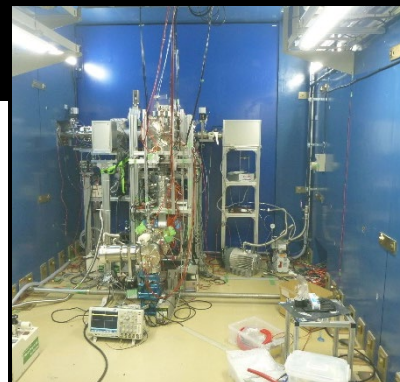
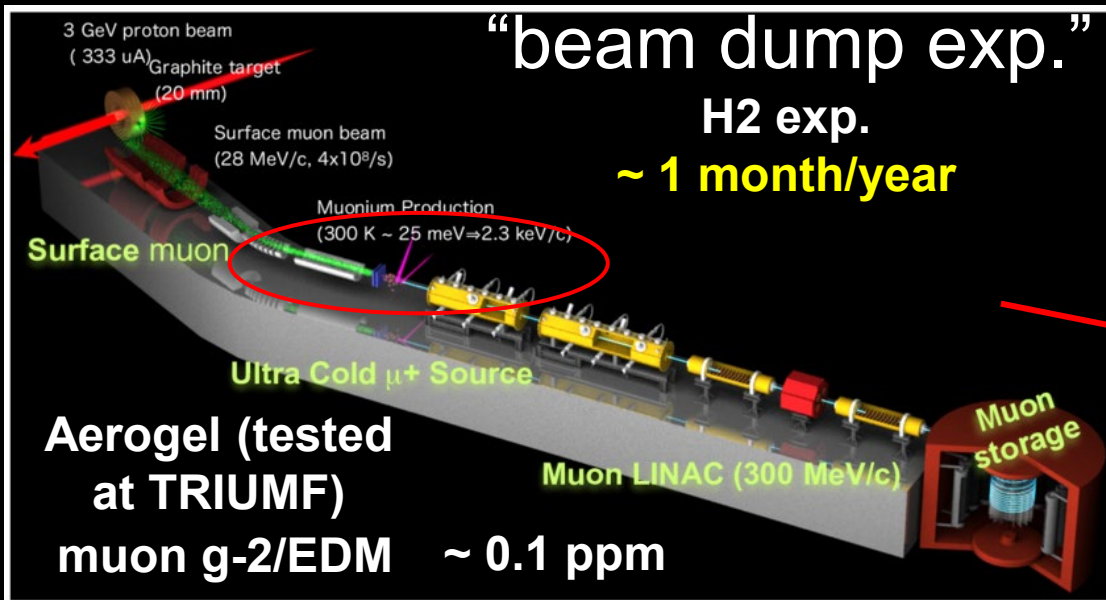


Common Systematics on Temperature, Clock

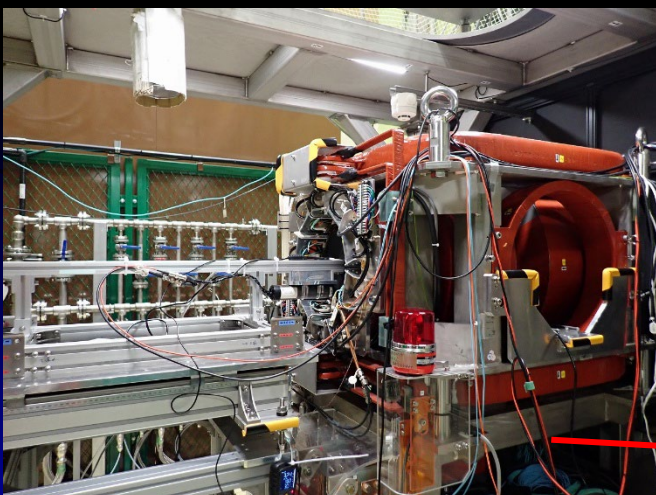
$$\sigma_{\text{variation}}(\tau_{\text{POL}} - \tau_{\text{reference}}) \sim 10 \text{ ppm}$$

$$\sim 10^{12} \text{ muon decays}$$

polarized muon decay



I-PARC MLF 100% polarized muon



D1 dedicated exp.

~ 1 week/year

~ 10 ppm



H1 dedicated exp.

~ 1 week/year

~ 1 ppm

muon g-2/EDM experiment

J-PARC

JAPAN PROTON ACCELERATOR RESEARCH COMPLEX



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Contact: [Karen McNulty Walsh](#), (631) 344-8350, or [Peter Genzer](#), (631) 344-3174

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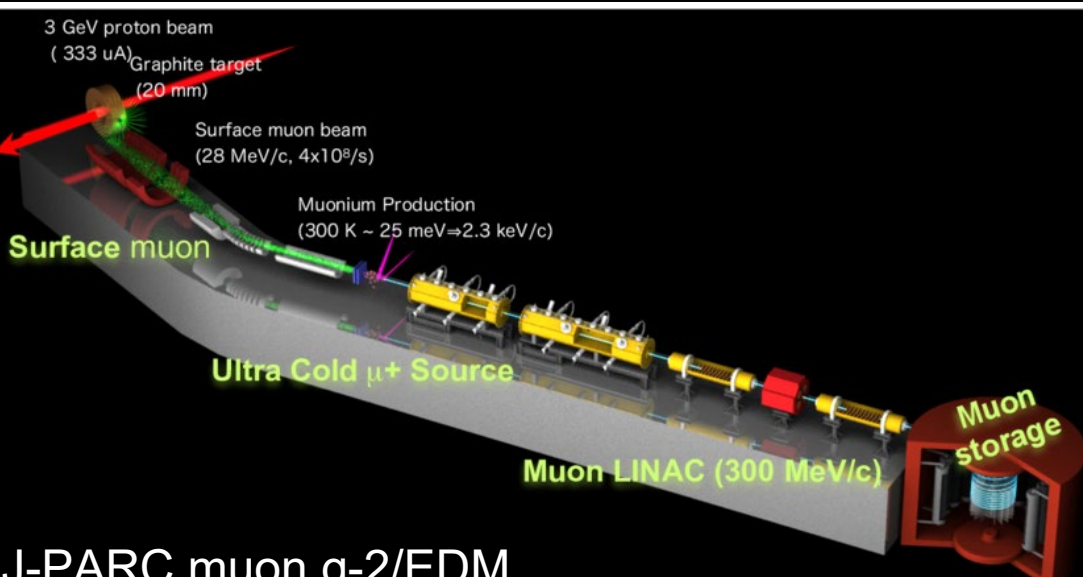
Muon g-2 Experiment Pioneers Win Breakthrough Prize in Fundamental Physics

Recognition honors experiments and scientific collaborations at three institutions that explored the subtle wobble of a subatomic particle

April 18, 2026



Just some of the members of the Brookhaven Lab Muon g-2 experiment collaboration circa 2001, when the first results were published, posing with the exquisite storage magnet used for the experiment. (Brookhaven National Laboratory)



J-PARC muon g-2/EDM

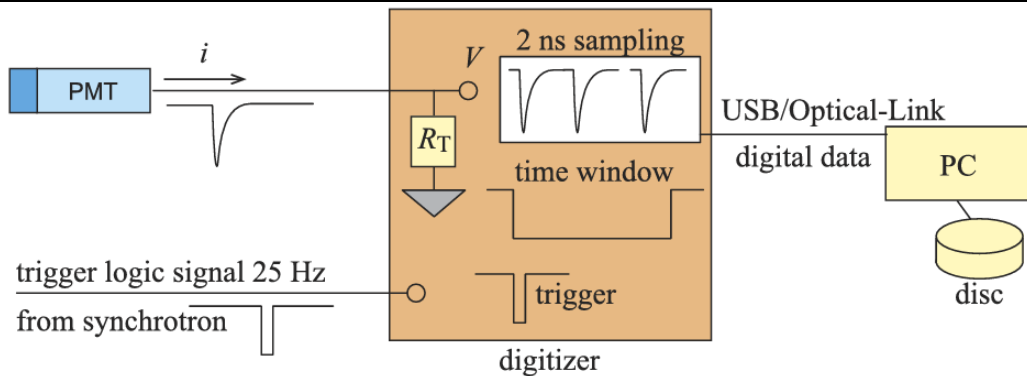
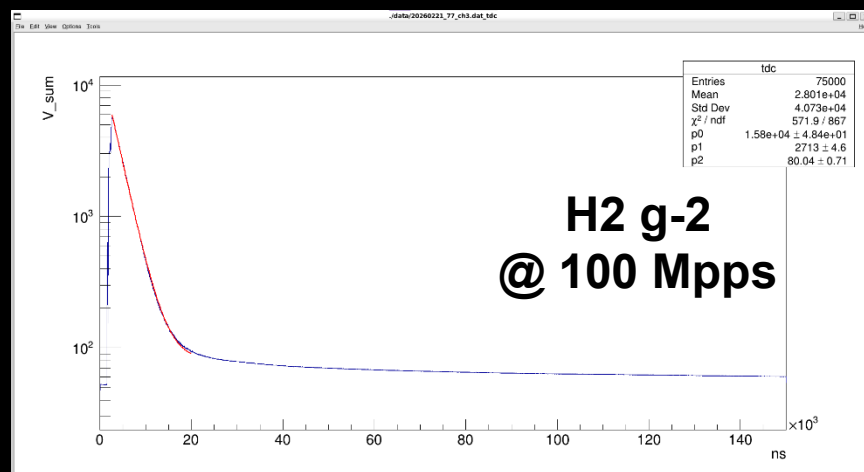
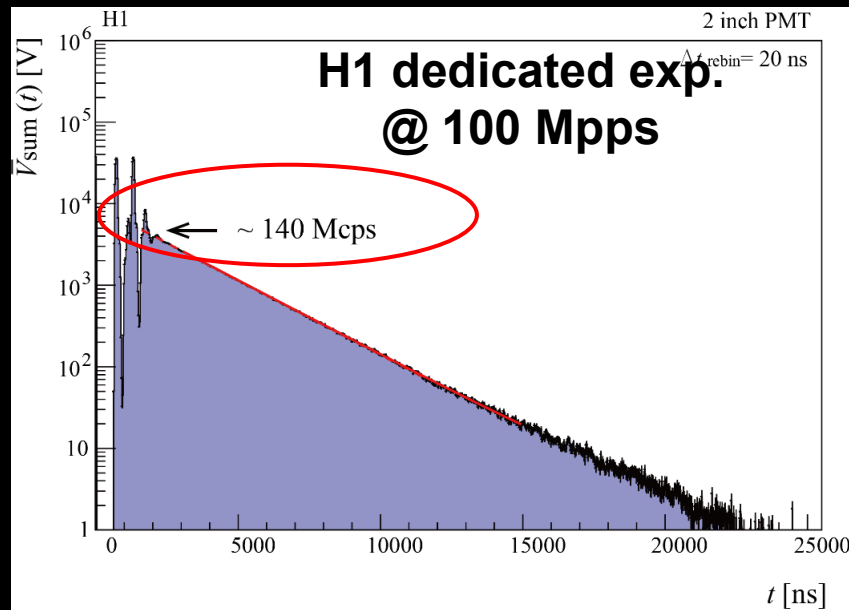


Fig. 3. Block diagram of the data-taking system using a digitizer.

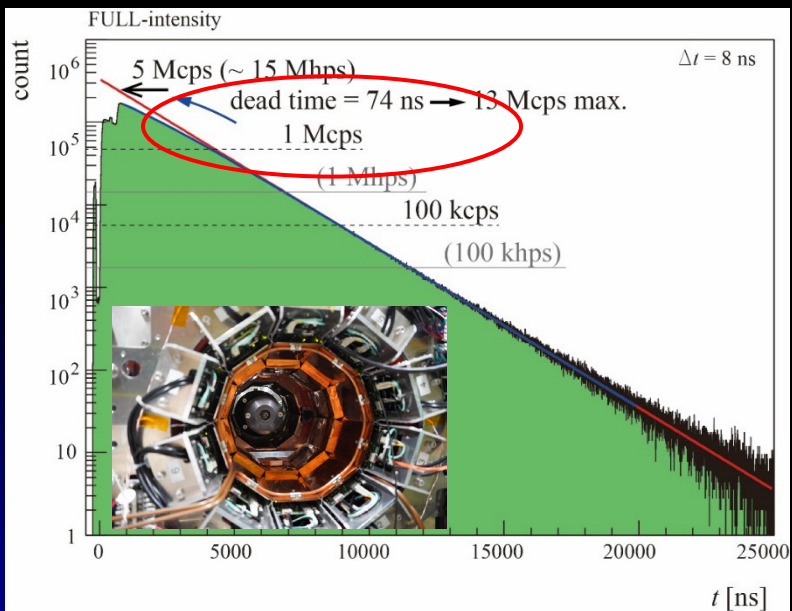
R&D current readout

No saturation

Negligible deadtime < 1 ns

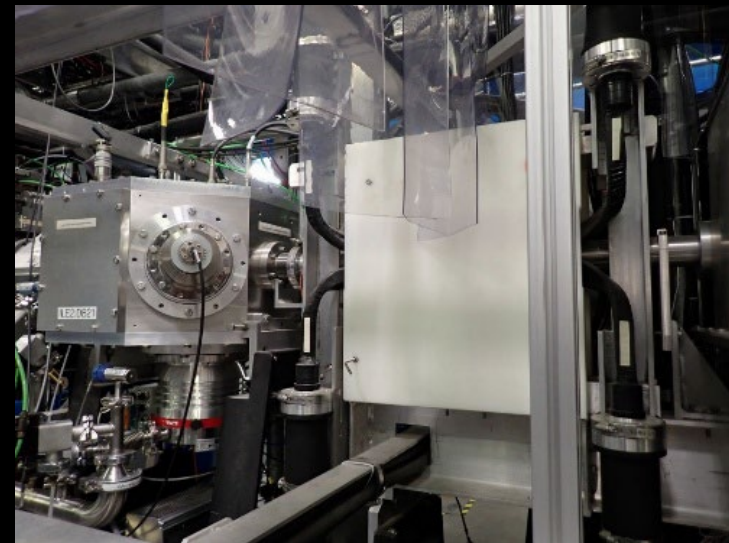
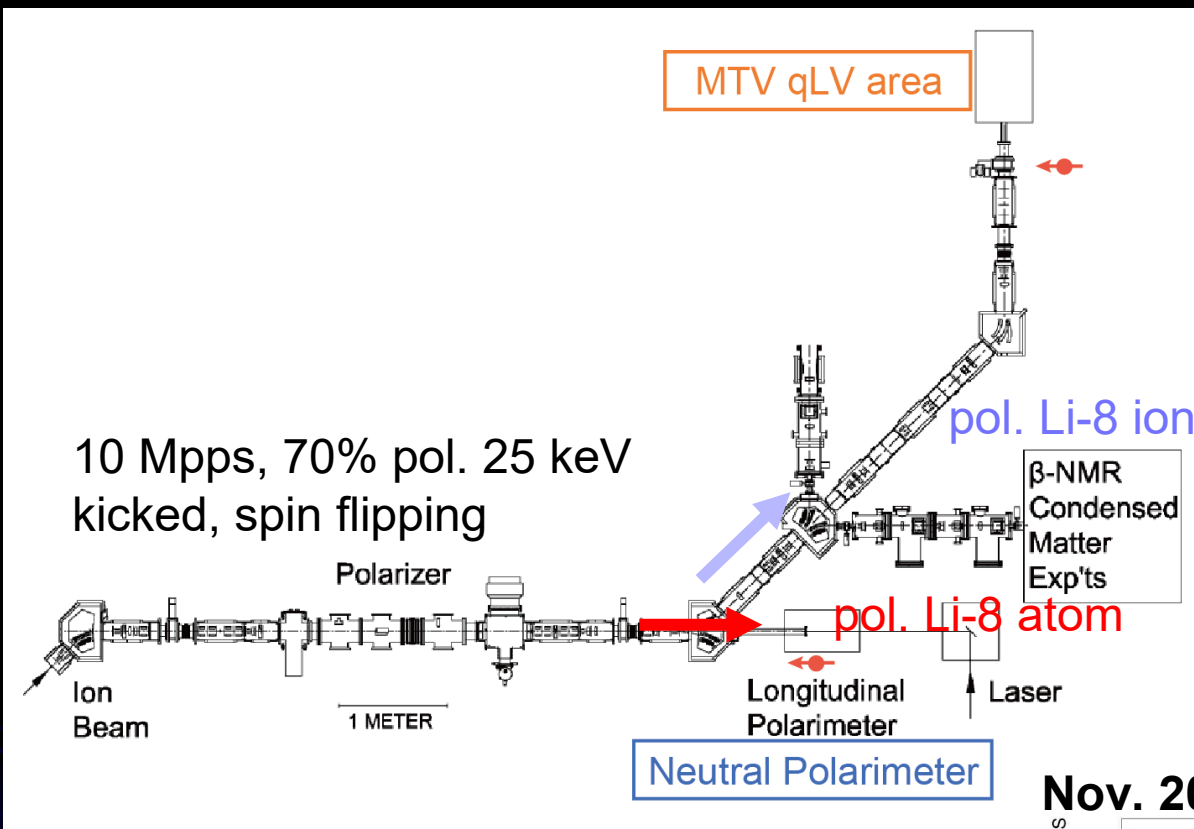


Wakata, Prog.Theor.Exp.Phys. 2025 023H01



D1 dedicated exp. @ 10 Mpps
4.1MeV surface muon

Science using existing NBM



~ 2 months/year

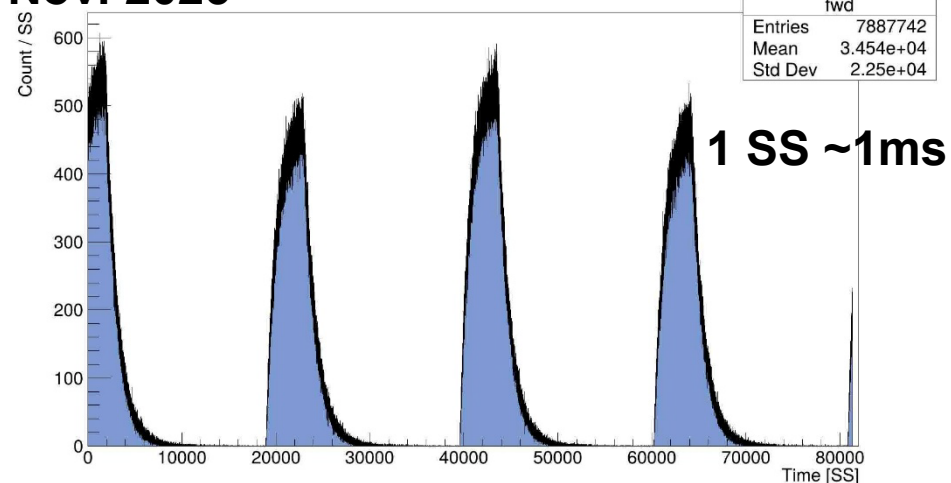
Test Run 2025 ~ 3 weeks
100 G decay observed
~ 3 ppm expected

Pd stopper @~100G
8 Plastic R=54mm, L Fwd+Bwd 254mm

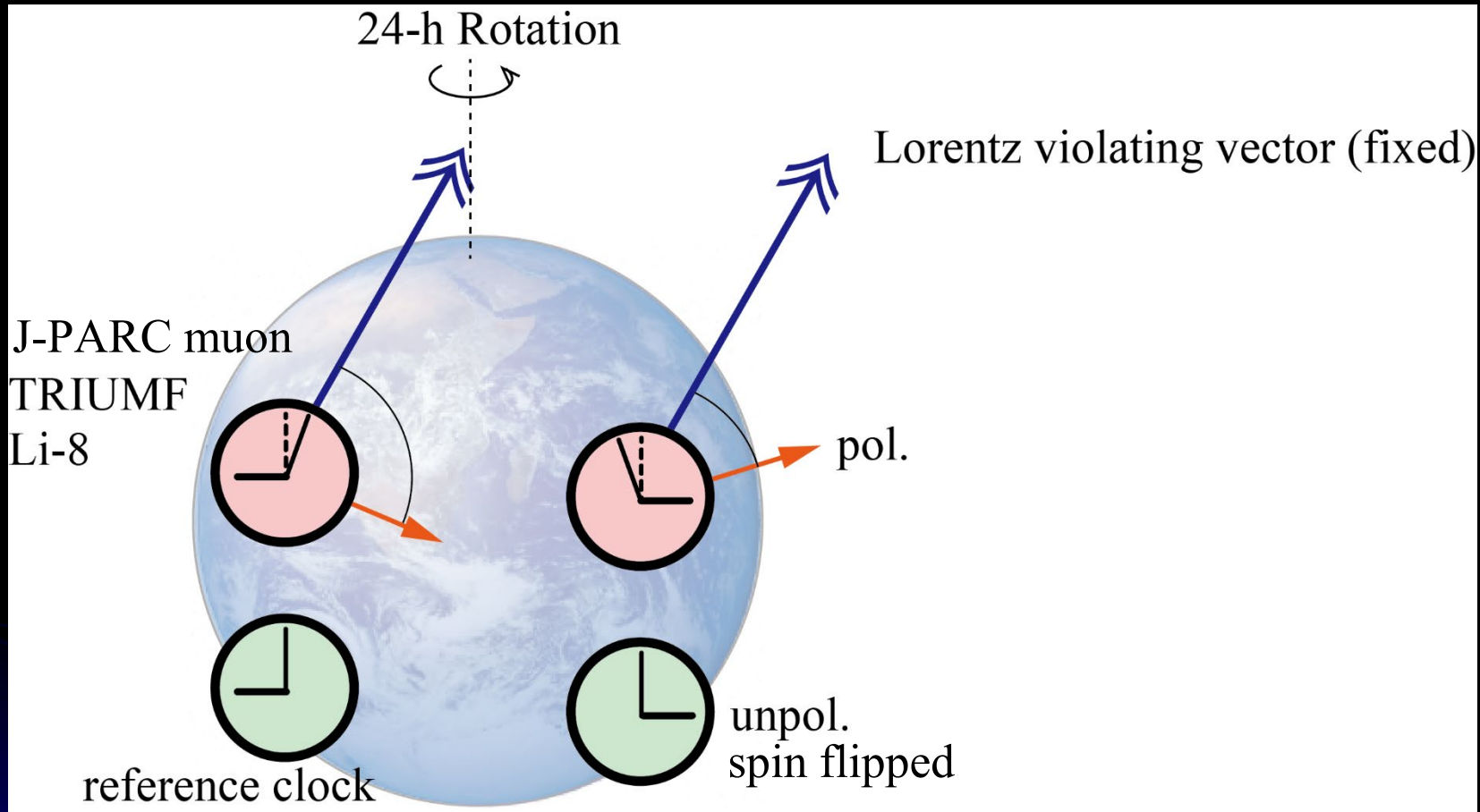
Better to have Temperature
CTRL of stopper/electronics

Nov. 2025

fwd pico SS



Systematic Errors



Time-Variation of system clock, purity, BG, kicker-off temperature (gain, threshold): common with reference clocks
Depol. (relaxation) T1 temp. variation: Spin-Rotation
->Analytically Cancel

YITP long-term workshop

Gravity and Cosmology 2024

January 29–March 1, 2024

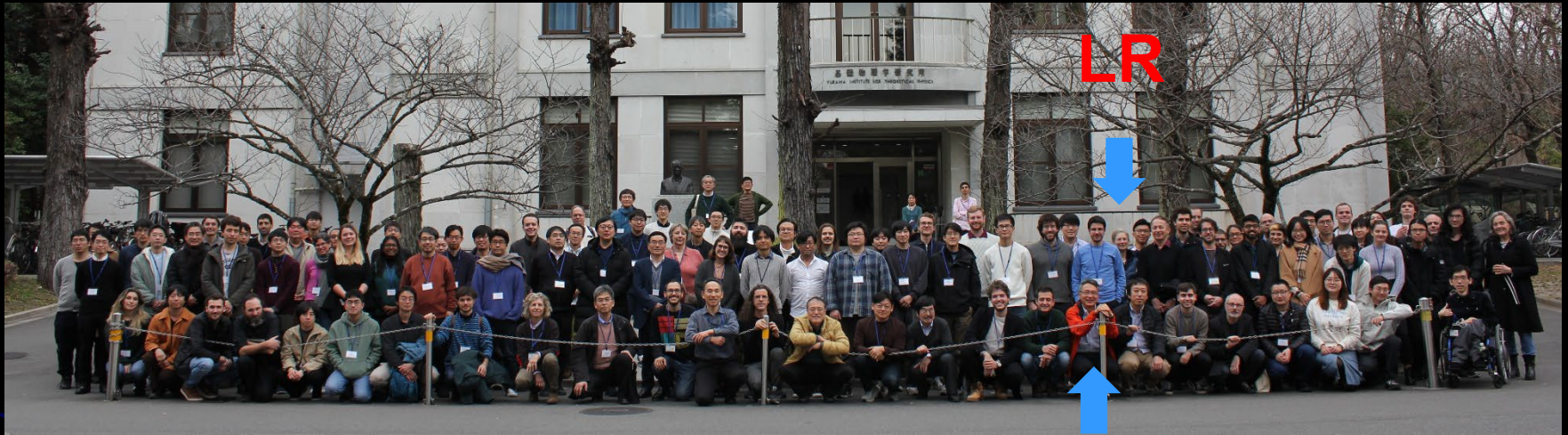
Yukawa Institute for Theoretical Physics, Kyoto University

Nishinomiya-Yukawa Symposium

"General Relativity and Beyond"

February 12–February 16, 2024

Yukawa Institute for Theoretical Physics, Kyoto University



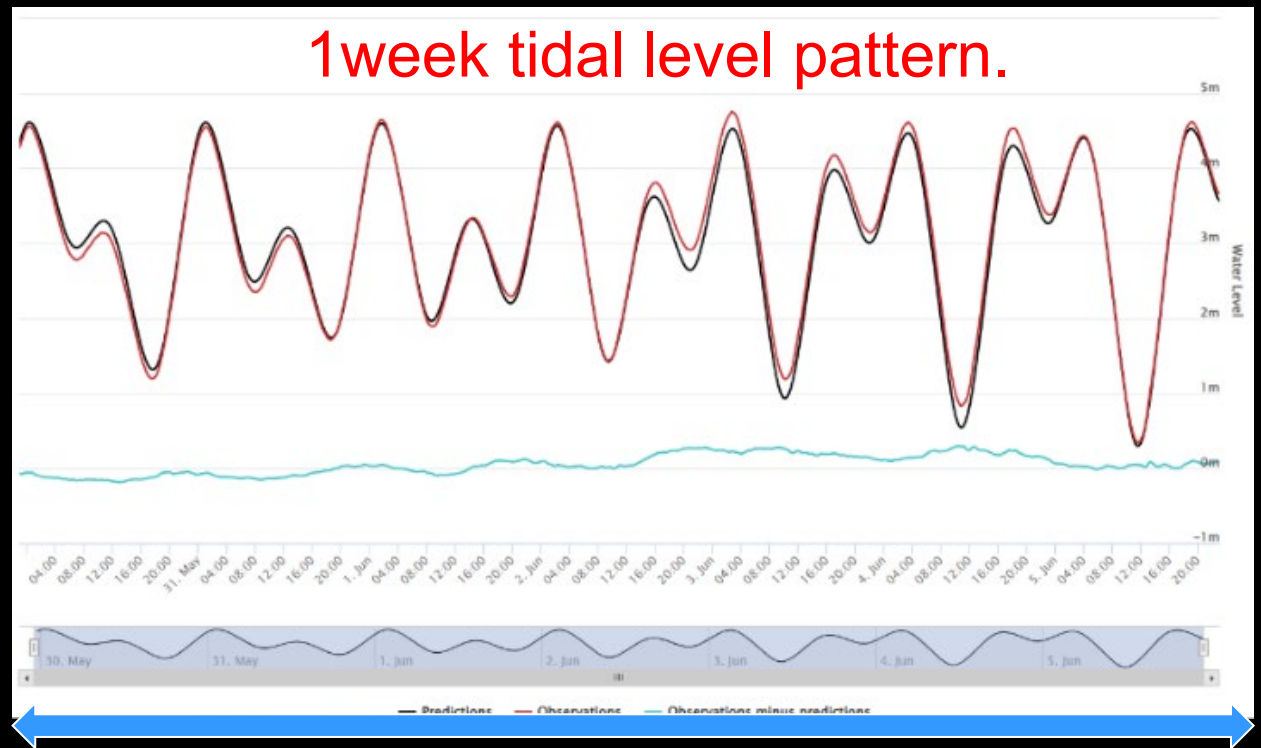
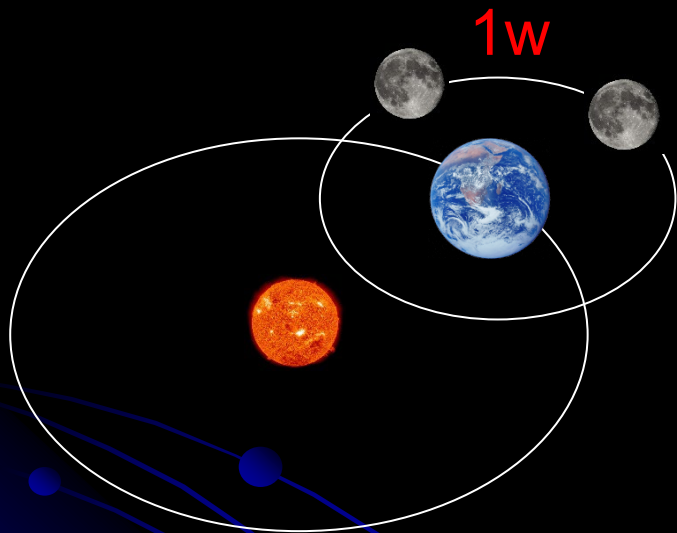
Question to theorists.

LV may open the window for QG, Y/N?

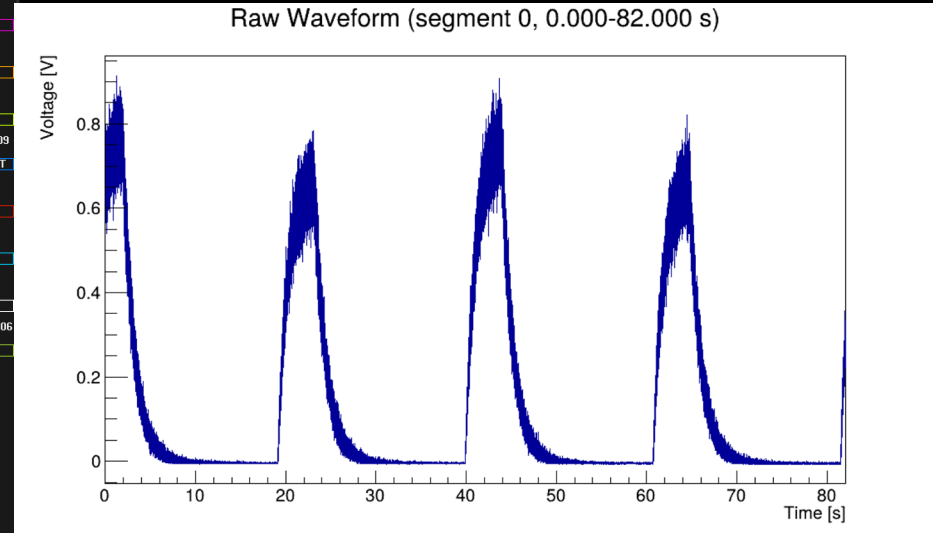
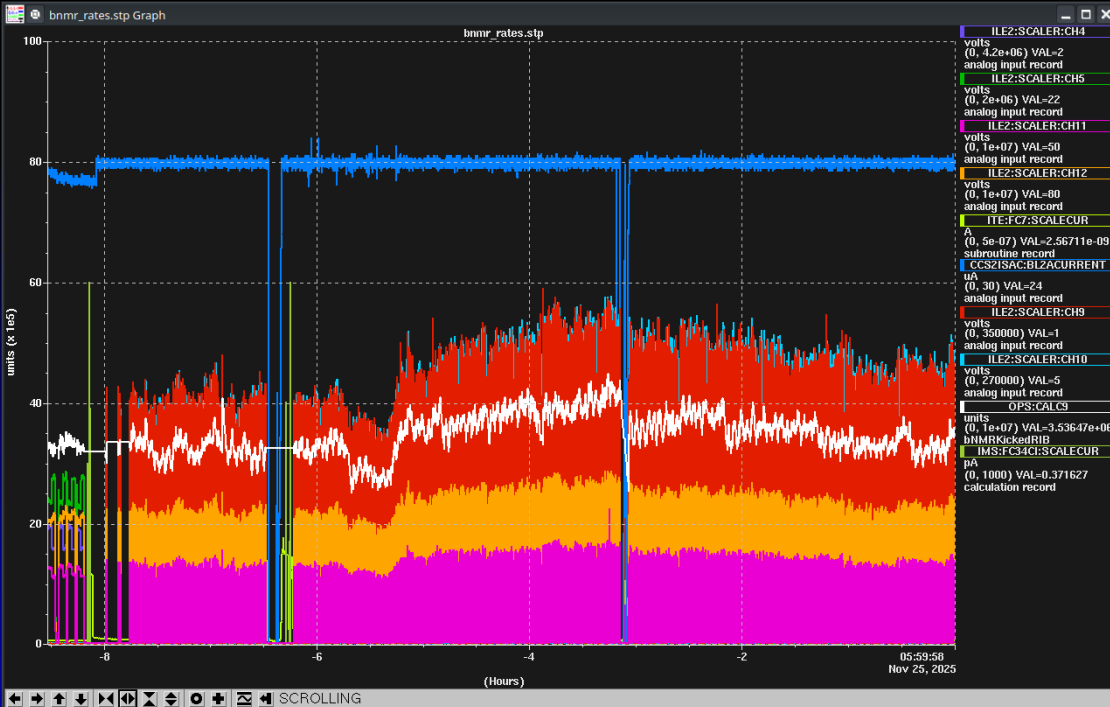
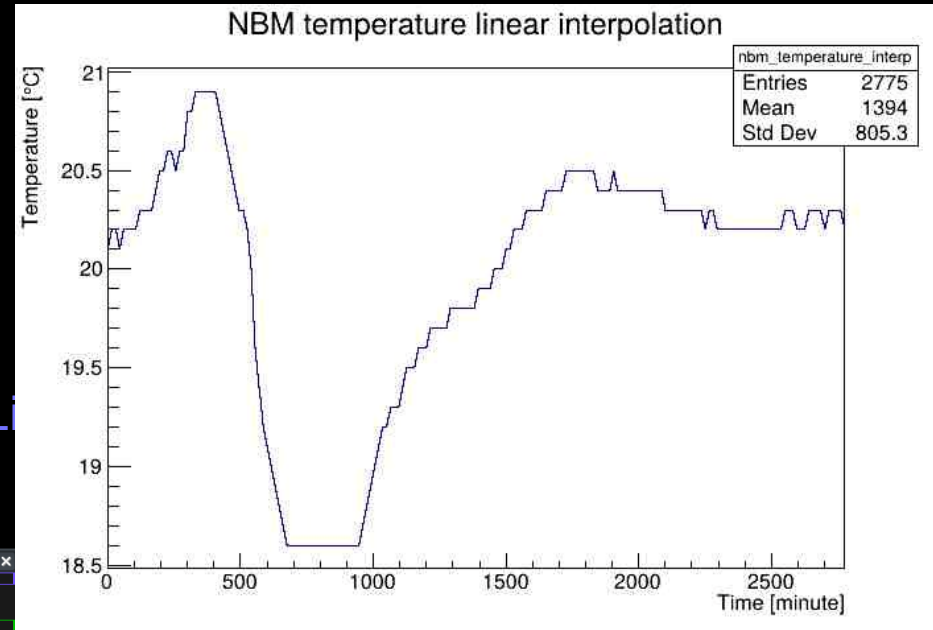
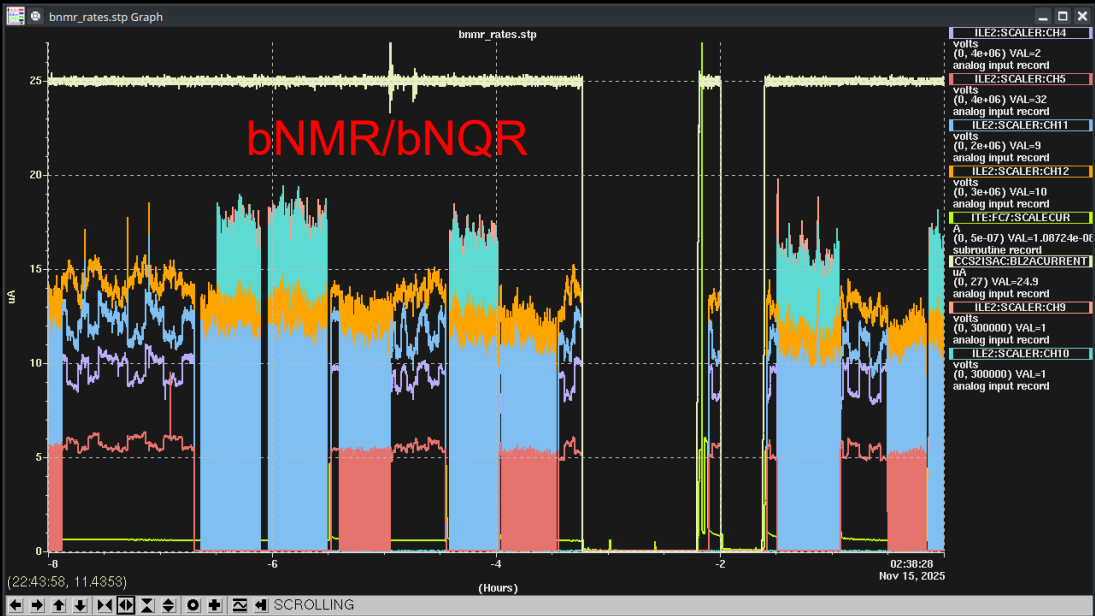
24/12-hour systematics

24-hour variation: check on/off-**phase from solar clock time** at 0:00 (temperature variation -> canceled in the PQR method)

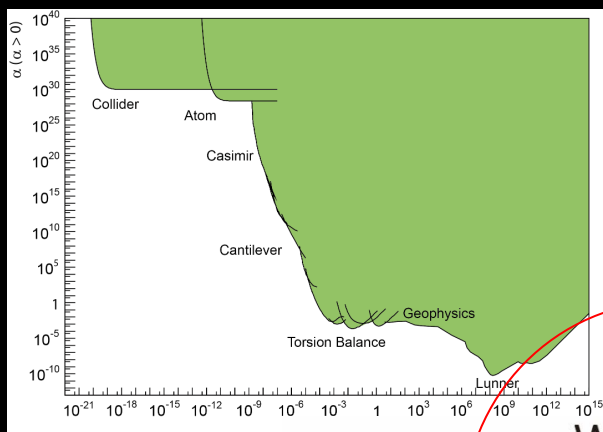
12-hour variation: More robust but **tidal change** may cause sys. err. e.g. Gravitational Red-Shift



Not a pure 12-h oscillation, revealing a **characteristic pattern**.
Essential to check ~ quarter month = 1w duration.



Preferred-frame tests



Sensitive to un-isotropy on Higgs / EW field

$$\tau_\mu \propto \frac{m_W^2}{m_\mu^5 g^2}$$

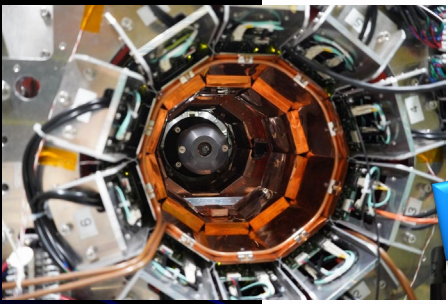
Higgs field EW field

Weak/Higgs
 β -decay

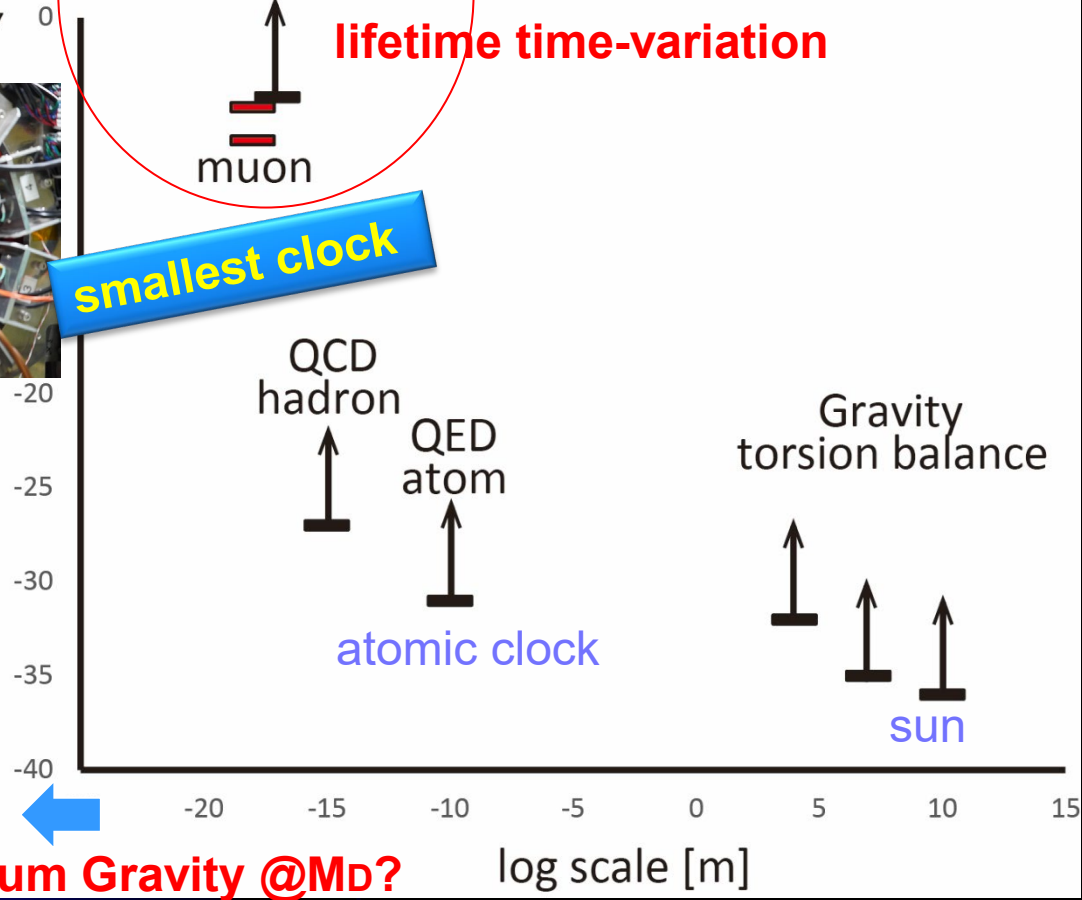
lifetime time-variation



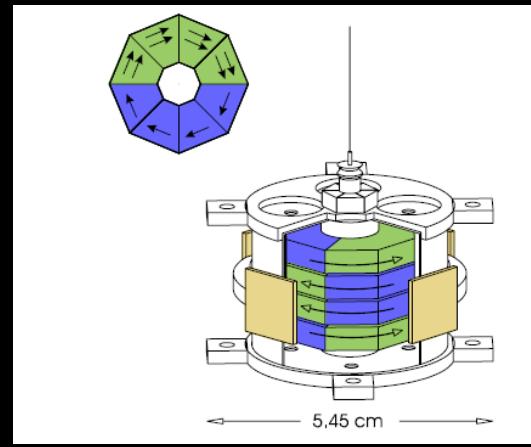
smallest clock



not scaled



Quantum Gravity @Md?



Heckel (UW) PRL 2006

Physics of Run-1 (1w measurement : 2022 Nov.)

Statistics : Run-1 Total 21G observed decays -> 7ppm

Systematics:

P-run: Polarized & Physics (Long. Holding Field)

Q-run: Pseudo Unpol. & Reference (Trans. pi Rotating Field) 1st – 2nd

R-run: Env. Monitor (Trans. 2pi Rotating Field) 1st + 2nd

→ $\alpha\beta\gamma$

Expected : Stat. $\sqrt{3}$ × Err.Prop. $\sqrt{2}$: **17ppm** expected.

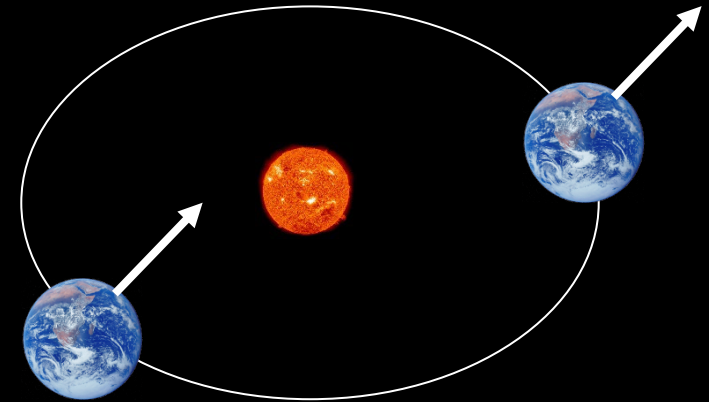
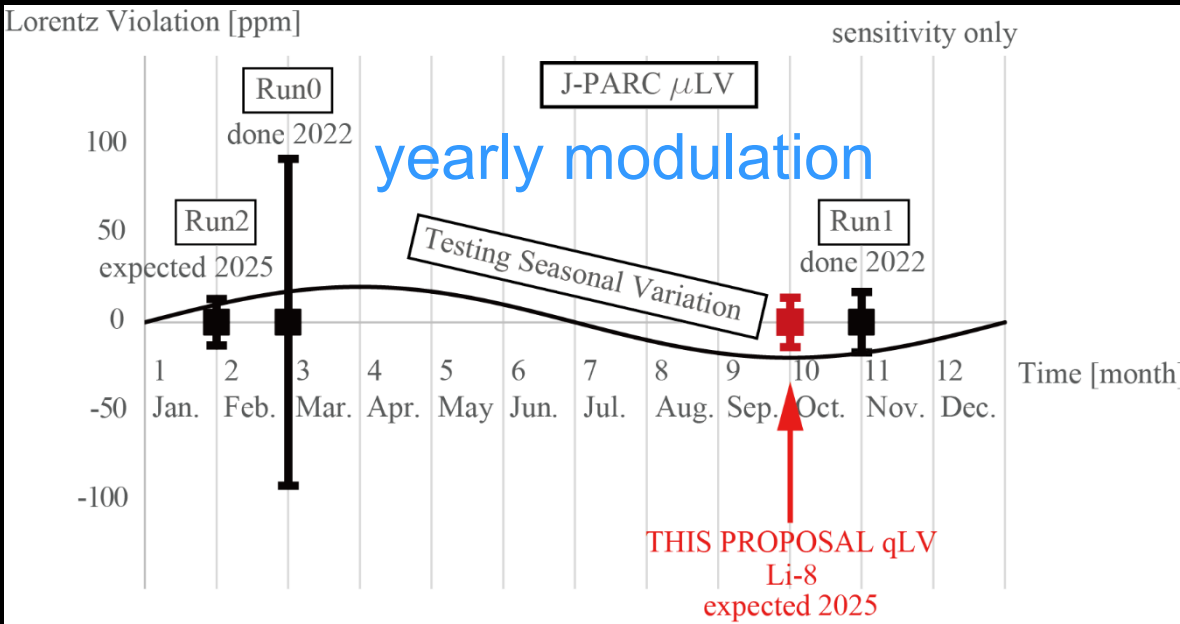
< KVI Na-20 : **60ppm** (MuLV Run-0 **92ppm**)

$$\alpha = \frac{\epsilon_F}{\epsilon_B}, \beta = \frac{\eta_F}{\eta_B}, \gamma = \frac{1}{\cos \delta}$$

Forward-Backward efficiency ratio, ratio, mis-phase

Ex : Depolarization, Gain, Polarization variation due to temperature etc.

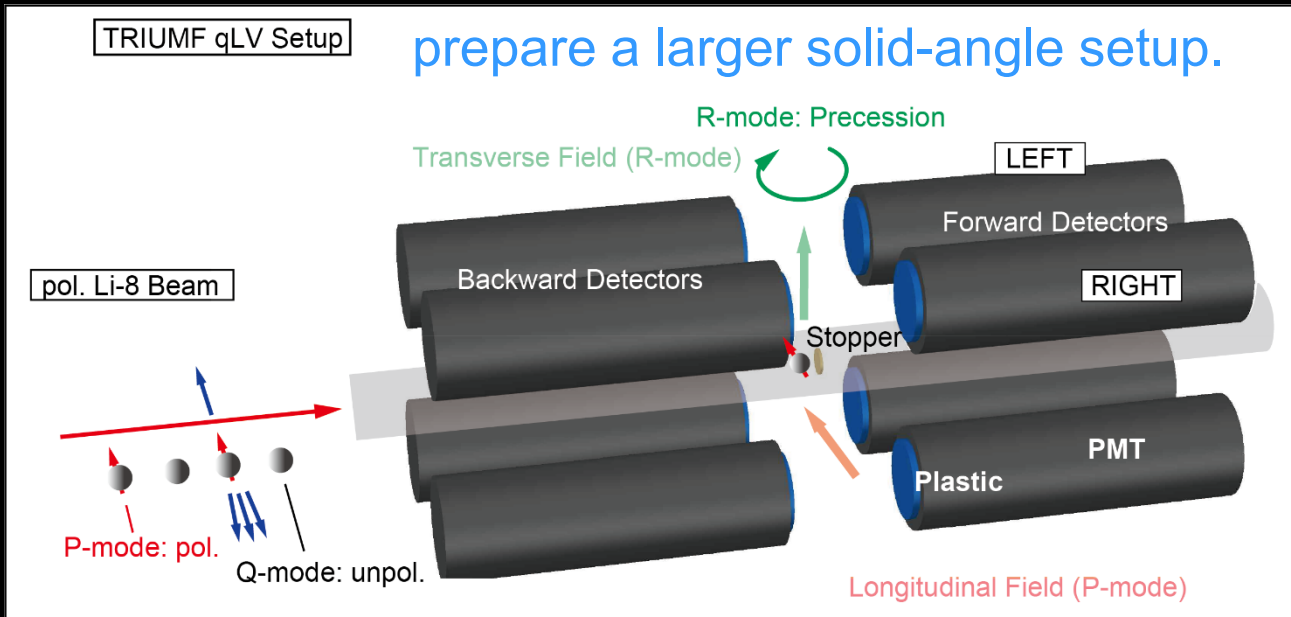
J-PARC μ LV to qLV @ TRIUMF ISAC



daily + yearly variation

Same precision ~ 10 ppm expected.
System: lepton to quark.

12-h oscillating? :KVI, MTV



prepare a larger solid-angle setup.