

Muon g-2 Experiment

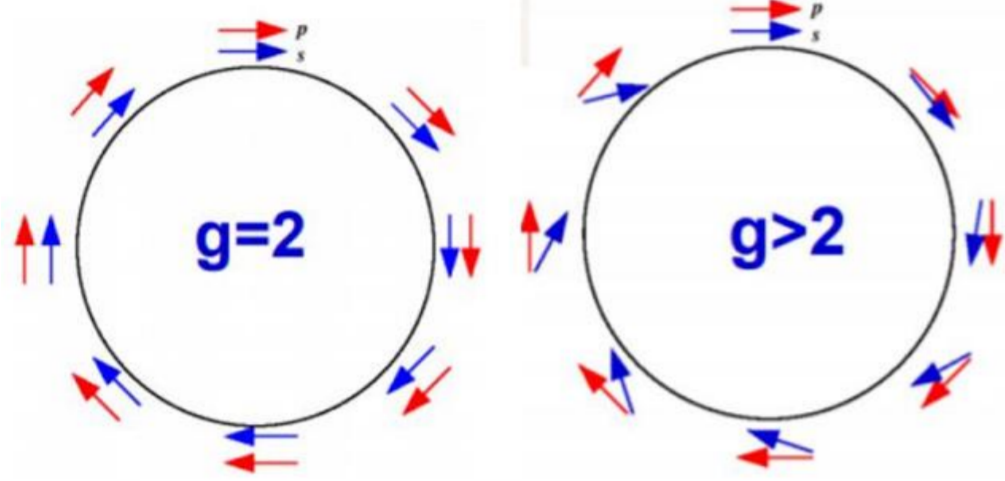
- Both muons' momentum and spin rotate in storage ring.

$$\vec{\omega}_c = -\frac{q\vec{B}}{m\gamma}$$

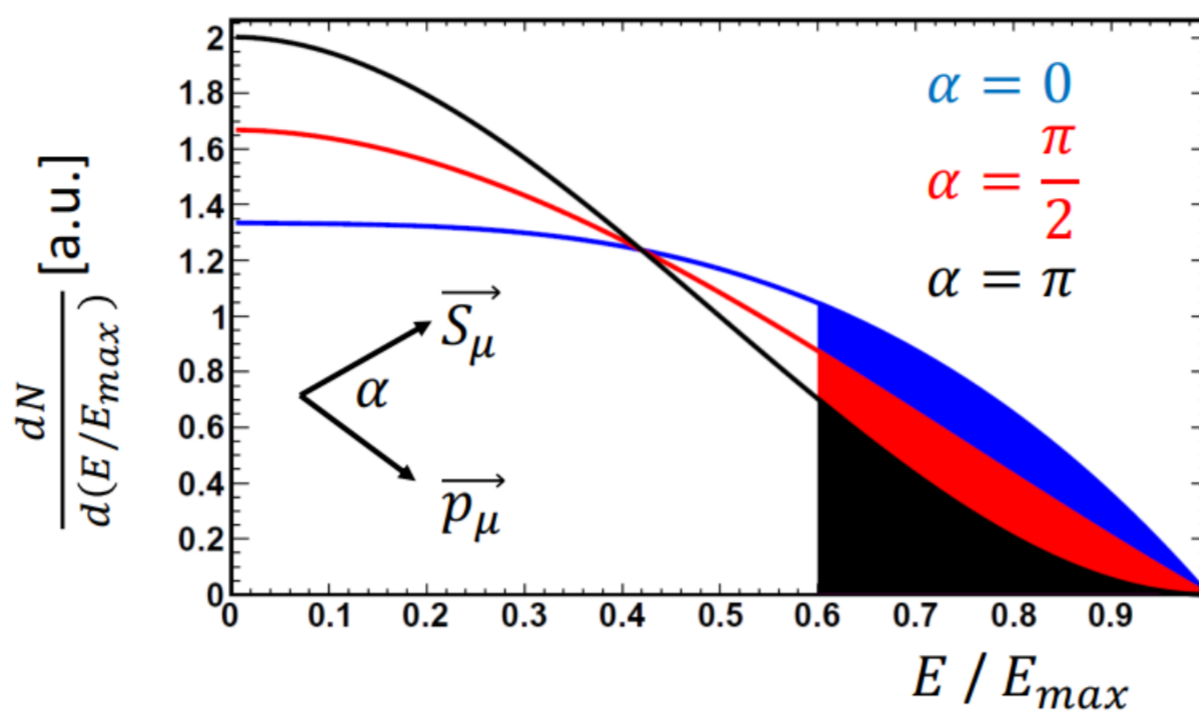
$$\vec{\omega}_s = -g\frac{q\vec{B}}{2m} - (1-\gamma)\frac{q\vec{B}}{m\gamma}$$

$$\vec{\omega}_a = \vec{\omega}_s - \vec{\omega}_c = -\left(\frac{g-2}{2}\right)\frac{q\vec{B}}{m}$$

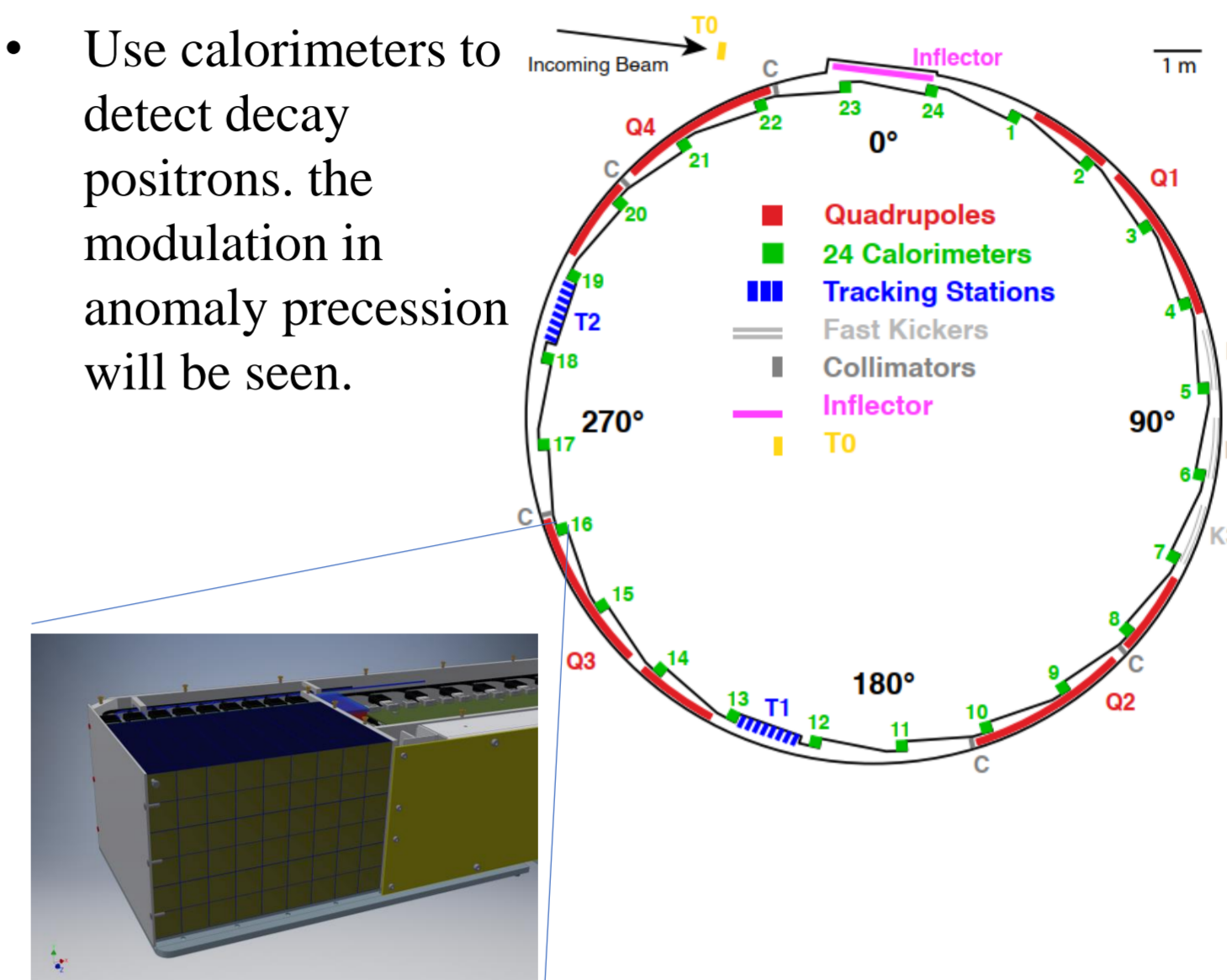
- Because $g > 2$, the polarization of muons will rotate too, which is called anomaly precession.



- The energy distribution of decay positrons depends on polarization of muons.



- Use calorimeters to detect decay positrons. the modulation in anomaly precession will be seen.

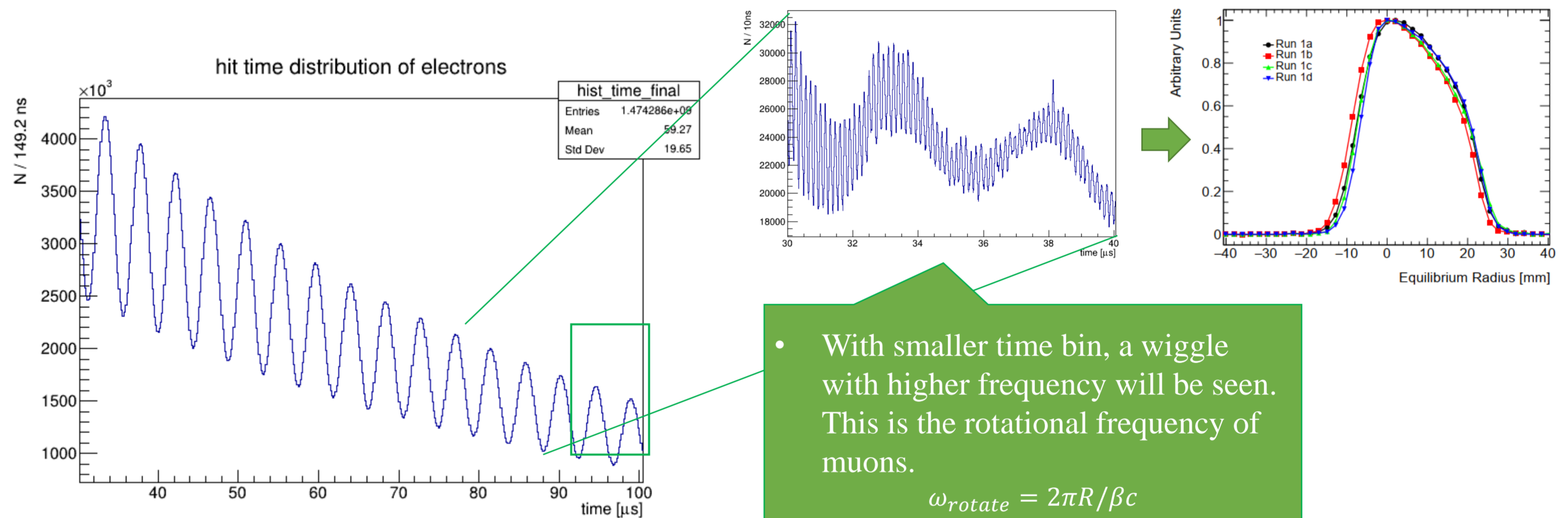


Muon Lifetime Measurement

- The hit time distribution of electrons with energy over a threshold has a module as wiggle + exponential decay.

$$N e^{-\frac{t}{\tau_{boosted}}} [1 + A \cos(\omega t + \phi)]$$

- However, muons rotates in storage ring with energy about 3.1 GeV, the lifetime here is Lorentz boosted.



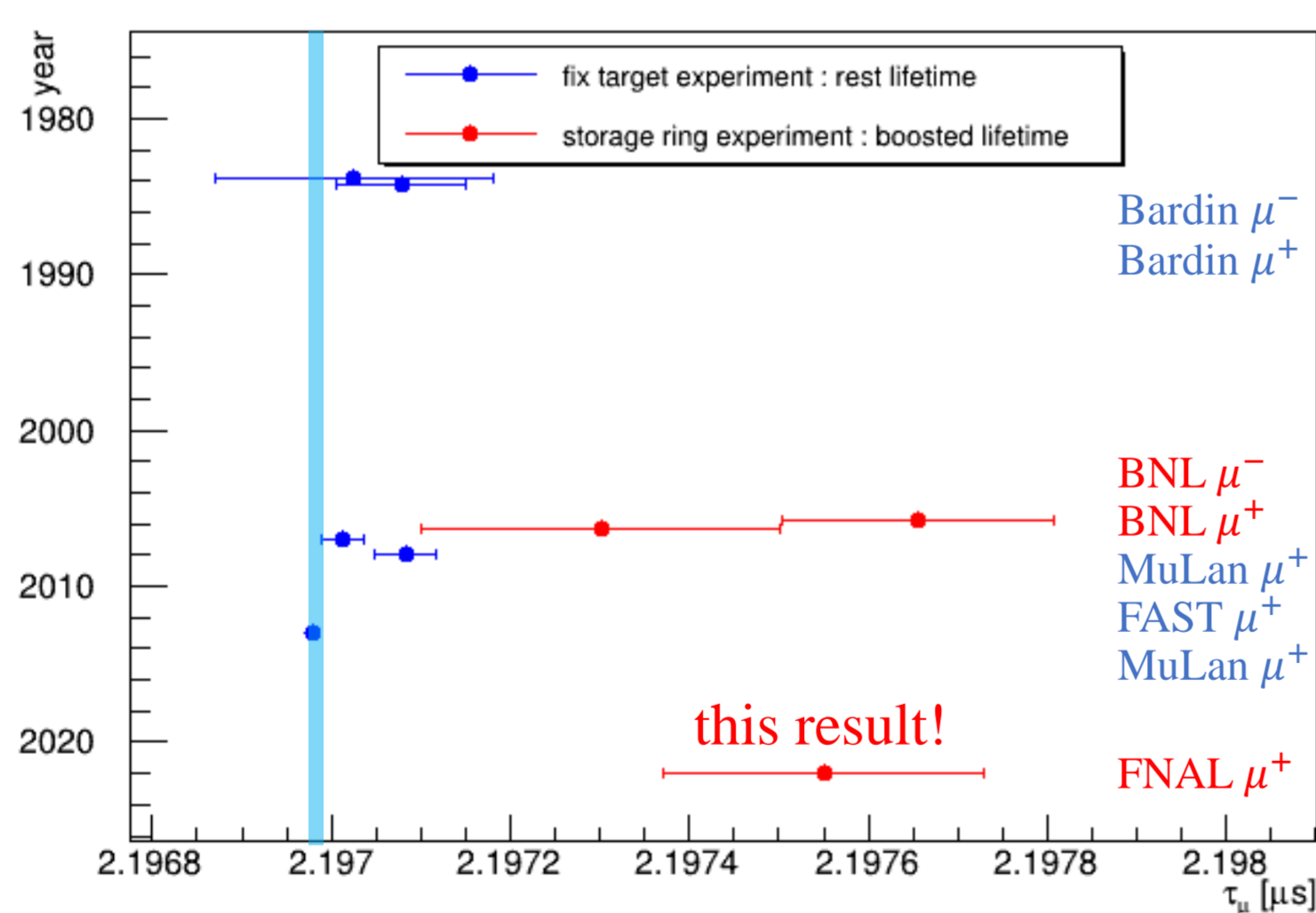
- With smaller time bin, a wiggle with higher frequency will be seen. This is the rotational frequency of muons.

$$\omega_{rotate} = \frac{2\pi R}{\beta c}$$

$$R = \frac{p}{qB}$$

$$\tau_{rest} = \tau_{boosted} / \gamma$$

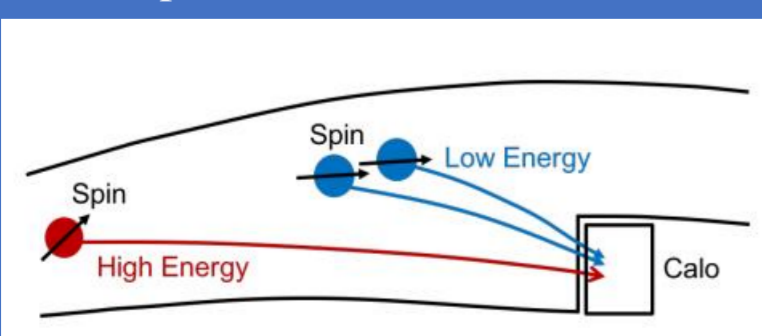
Experiment Result Comparison



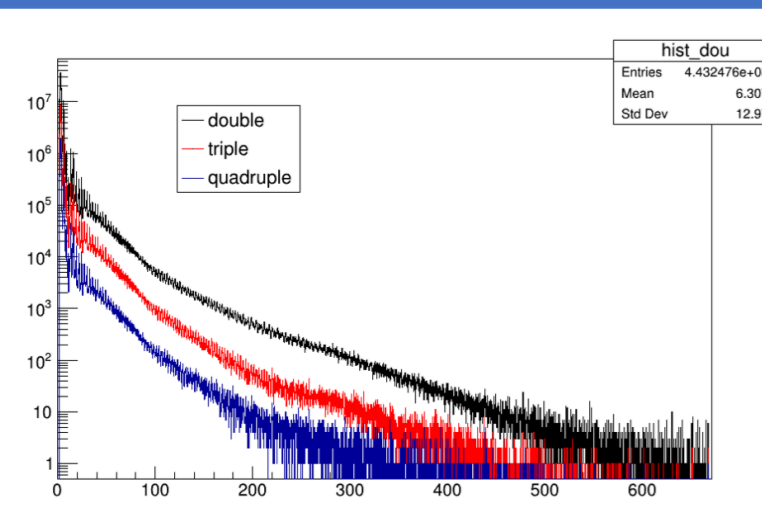
- The result of measured muon lifetime of Run-1 dataset is $\tau_{\mu^+} = 2.19755 \pm 0.00018 \mu s$
- An independent measurement of muon lifetime other than fix target experiments. A test on general relativity.
- $> 3\sigma$ deviation between storage ring and fix target experiment results. Further study is needed.
- Potential precision improvement with μ^- lifetime measurement compared to fix target result.
- CPT violation test.

Systematics Uncertainties

pileup Pileup happens when two or more positrons are reconstructed as one.

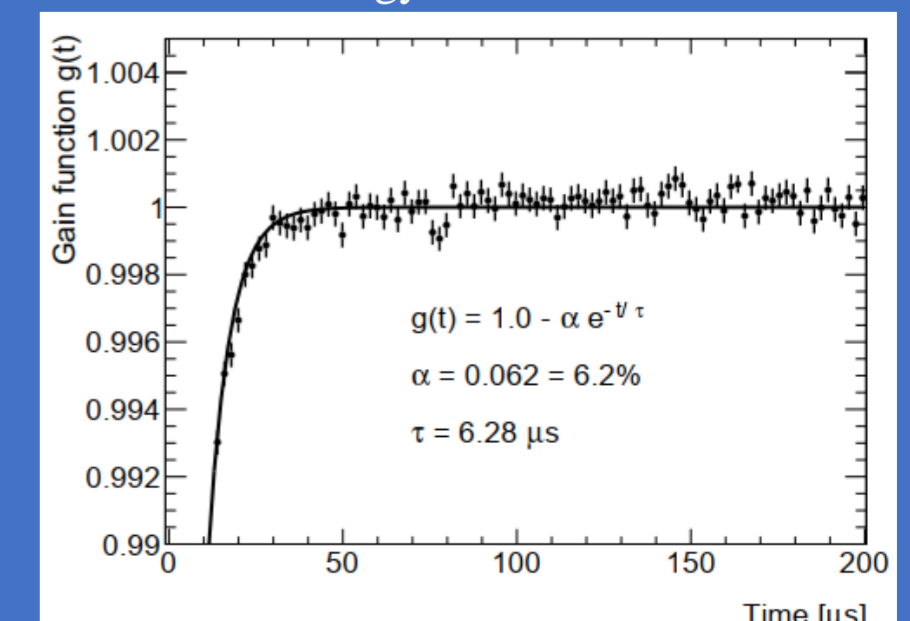


lost muon Muons lost during period of measurement biases lifetime.



sub dataset	Run-1a	Run-1b	Run-1c	Run-1d	
fast rotation analysis uncertainty on γ (Fourier Method) ^[1]	150	150	150	150	
statistics from τ	46	37	30	29	
systematics	time randomization	2	1	1	1
	gain	69	66	73	17
	pileup	6	9	8	3
	loss muon	3	2	1	1
	beam oscillation	2	1	3	3
total	173	168	168	155	

gain Gain recovery from injection flash affects energy reconstruction.



* Uncertainties in ppm.

[1] Physical Review Accelerators and Beams 24.4 (2021): 044002.