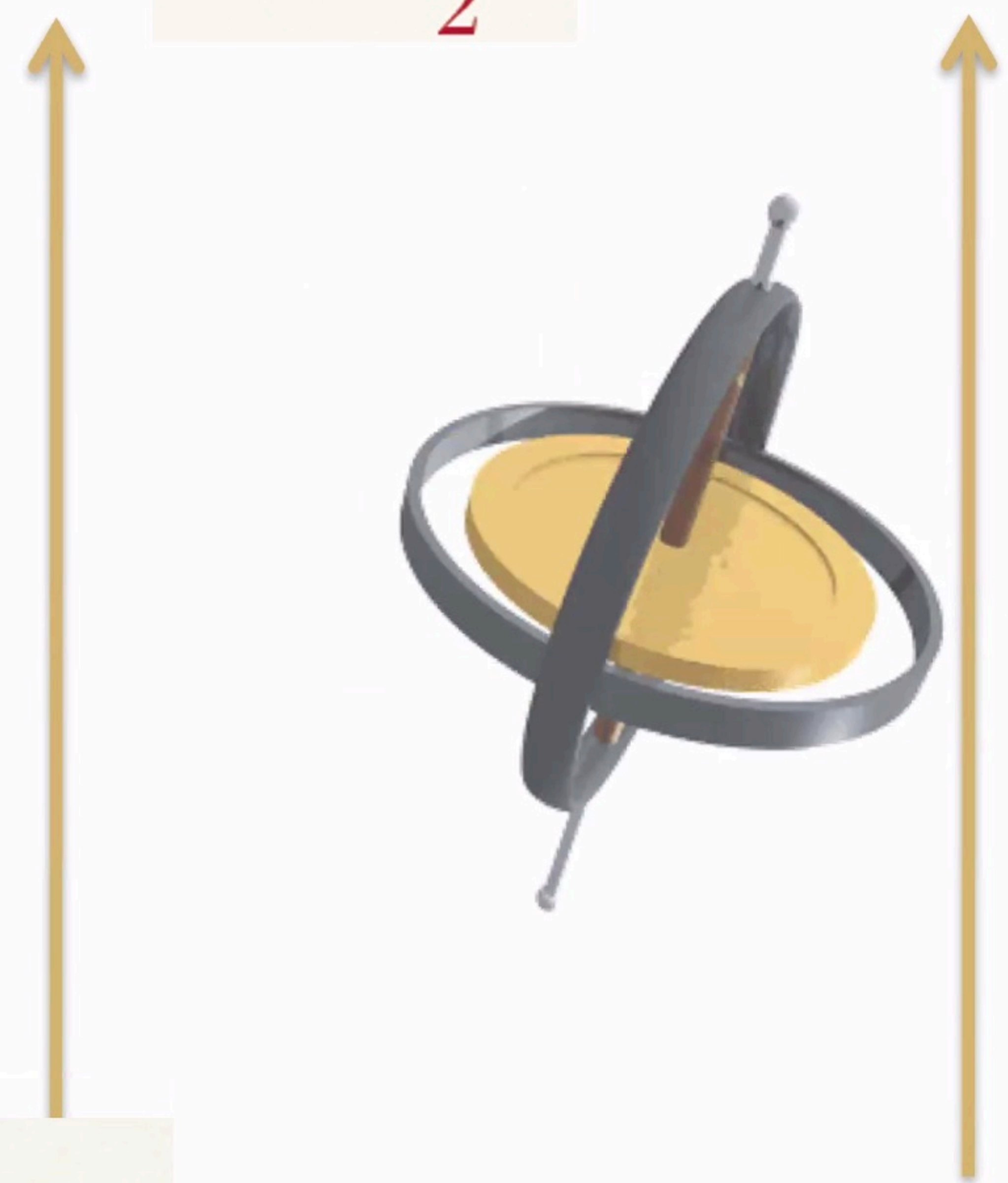
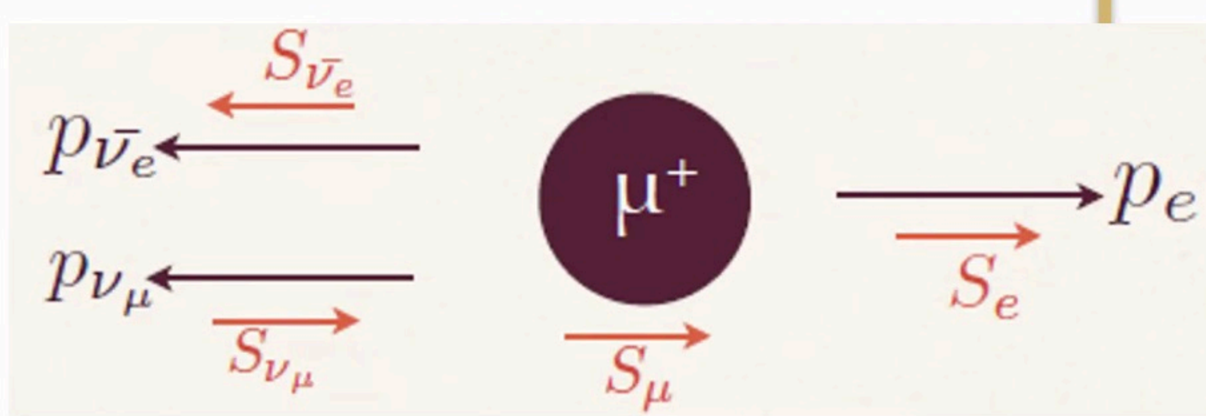
Experimental Principle

The name of game: a → ω

- **Put (polarized) muons in a magnetic field and measure precession f.q.**
- **Get muon spin direction from decayed electrons**

$$a = \frac{g-2}{2}$$





$$\omega_s = g\frac{eB}{2mc}$$

Frequency Measurements

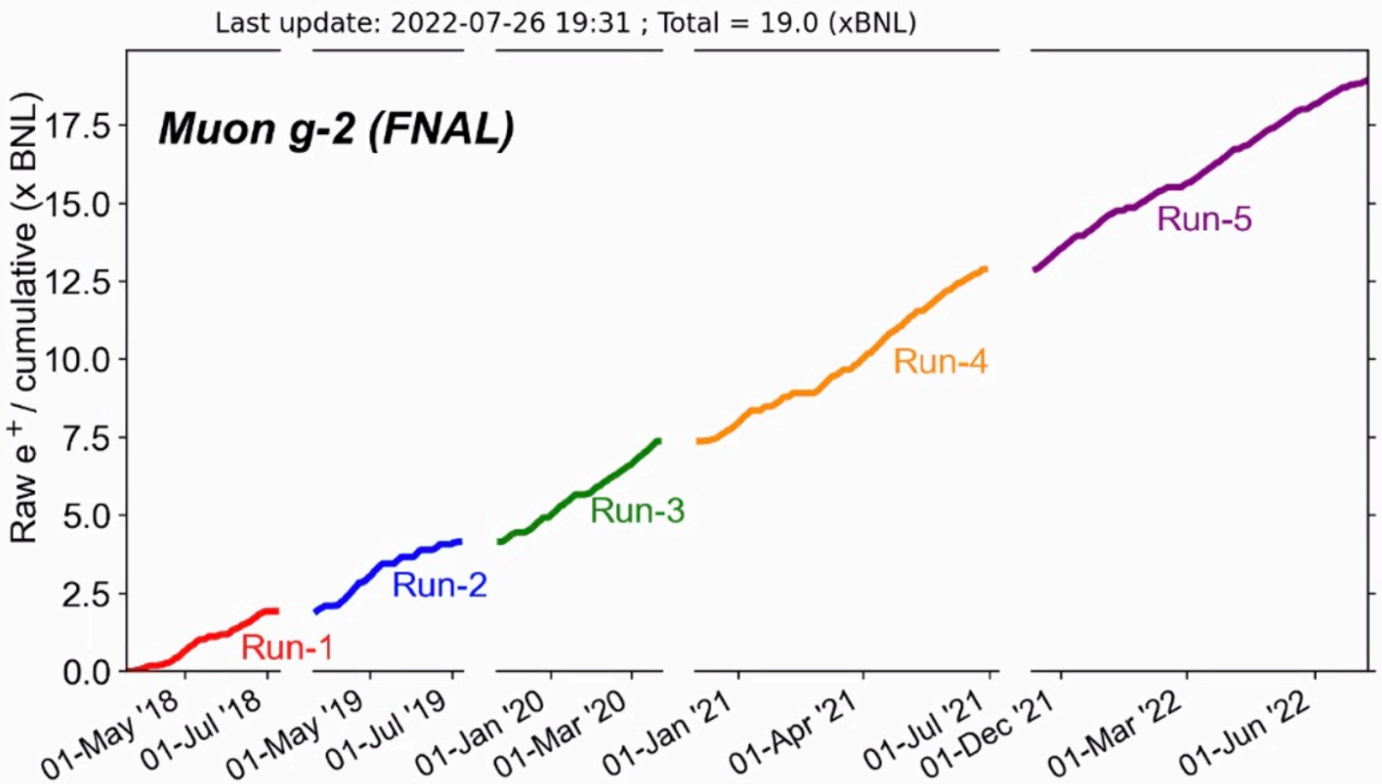
Frequency measurements can be done in very high precision

- **Measure frequency ratio and extract from several measurements**

$$a_\mu \sim \frac{\omega_a}{<B>} = \frac{g_e}{2}\frac{\omega_a}{\varpi_p}\frac{m_\mu}{m_e}\frac{\mu_p}{\mu_e}$$

  - ω_p is the proton precession frequency ($\omega_p \sim |B|$)
  - ϖ_p is the weighted magnetic field folded with muon distribution
  - All other values from Committee on Data for Science and Technology (CODATA), uncertainty < 25 ppb
    - E.g. muon-to-electron mass ratio by muonium hyperfine structure experiment
- **Final measurements done in three steps**
  - Inject muons into a ring with uniform magnetic field
  - Measure muon frequency difference ω_a
  - Measure proton precession frequency ω_p and muon distribution
  - Blind analyses: measurements and correction factors done *before* simultaneously and independently *before* final answer

Beyond Run1



Run 1 results ~6% of full stats:
434 ppb stat $\oplus$ 157 ppb syst errors

- **Analysis of Run2/3 ongoing, expect a factor of two improvement in precision**
- **Run 5 finished a few weeks ago and brought us very close to the TDR goal of ~ 20x BNL**
- **Run 6 under discussion**
  - **Projected precision ~ 120ppb**
  - **CPT and Lorentz Violation Effects**
  - **Sidereal Oscillation**
- **With improved experiment and theory precision, expect significance of deviation > 5σ with latest BMW calculation**

J-PARC g-2/EDM

Comparison of various parameters for the Fermilab and J-PARC $(g-2)$ Experiments

Parameter	Fermilab E989	J-PARC E24
Statistical goal	100 ppb	400 ppb
Magnetic field	1.45 T	3.0 T
Radius	711 cm	33.3 cm
Cyclotron period	149.1 ns	7.4 ns
Precession frequency, ω_a	1.43 MHz	2.96 MHz
Lifetime, $\gamma\tau_\mu$	64.4 μs	6.6 μs
Typical asymmetry, A	0.4	0.4
Beam polarization	0.97	0.50
Events in final fit	1.8×10^{11}	8.1×10^{11}

No magic momentum!

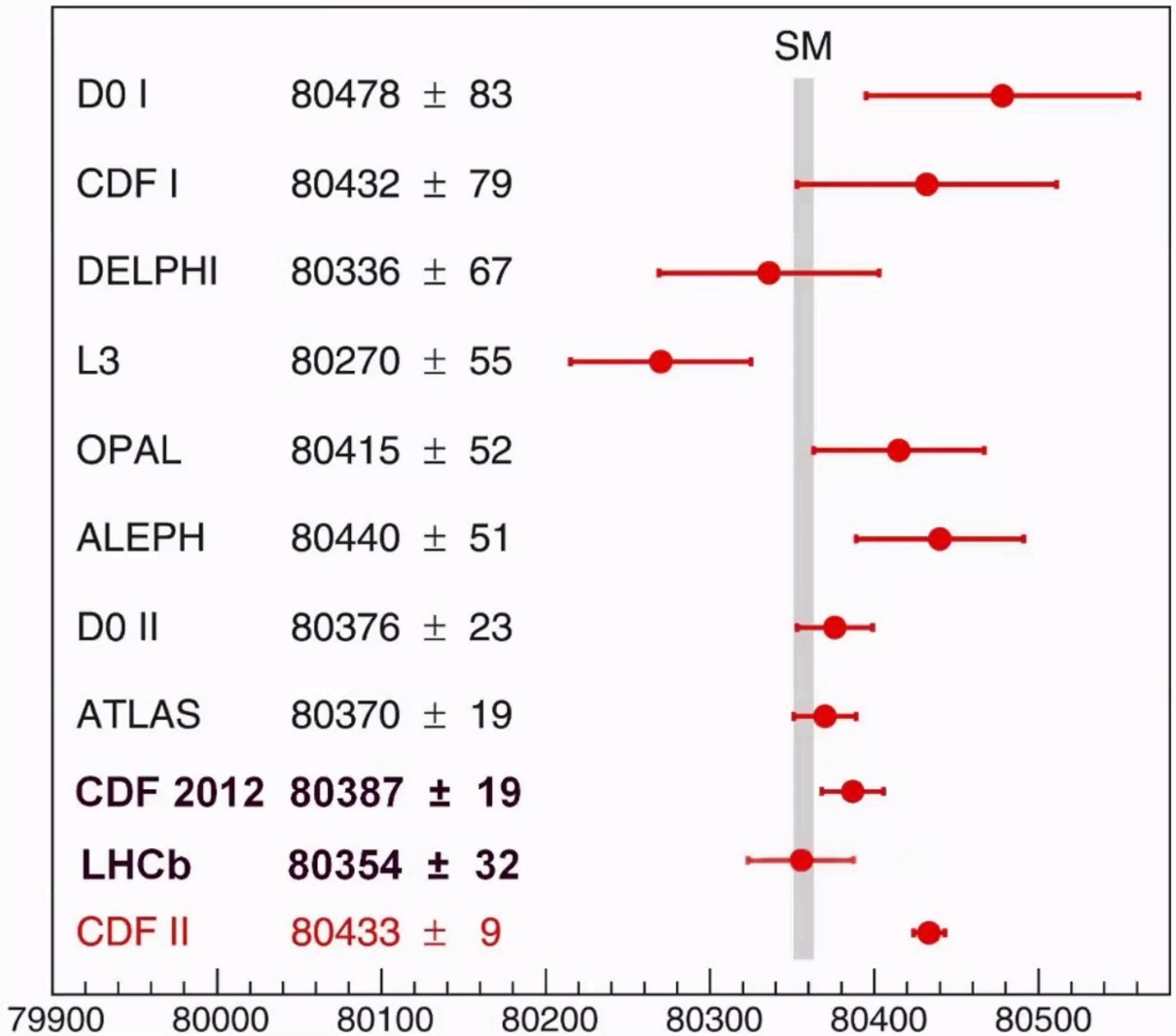
- **No strong focusing**
- **Super-low emittance muon beam**
- **Compact storage ring**
- **Full tracking detector**

Anomalous spin precession (ω_a)		Magnetic field (ω_p)	
Source	Estimation (ppb)	Source	Estimation (ppb)
Timing shift	< 36	Absolute calibration	25
Pitch effect	13	Calibration of mapping probe	20
Electric field	10	Position of mapping probe	45
Delayed positrons	0.8	Field decay	< 10
Differential decay	1.5	Eddy current from kicker	0.1
Quadratic sum	< 40	Quadratic sum	56

Statistical uncertainty dominated

- $\delta\omega_a$ = 0.45 ppm including $\delta\omega_{a\_sys}$ < 0.1ppm
- δEDM = $1.5 \cdot 10^{-21}$ e·cm

What about W Mass?



$$\Delta\alpha^{(5)}_{\text{had}}(q^2) = \frac{q^2}{4\pi\alpha^2}\int_{m_\pi}^{\infty} ds\ \sigma_{\text{had}}(s)\frac{q^2}{(q^2-s)}$$

Global EW fits: predict M_W, M_H,…

$$a_\mu^{\text{had, VP}} = \frac{1}{4\pi^3}\int_{m_\pi}^{\infty} ds\ \sigma_{\text{had}}(s)\,K(s)$$

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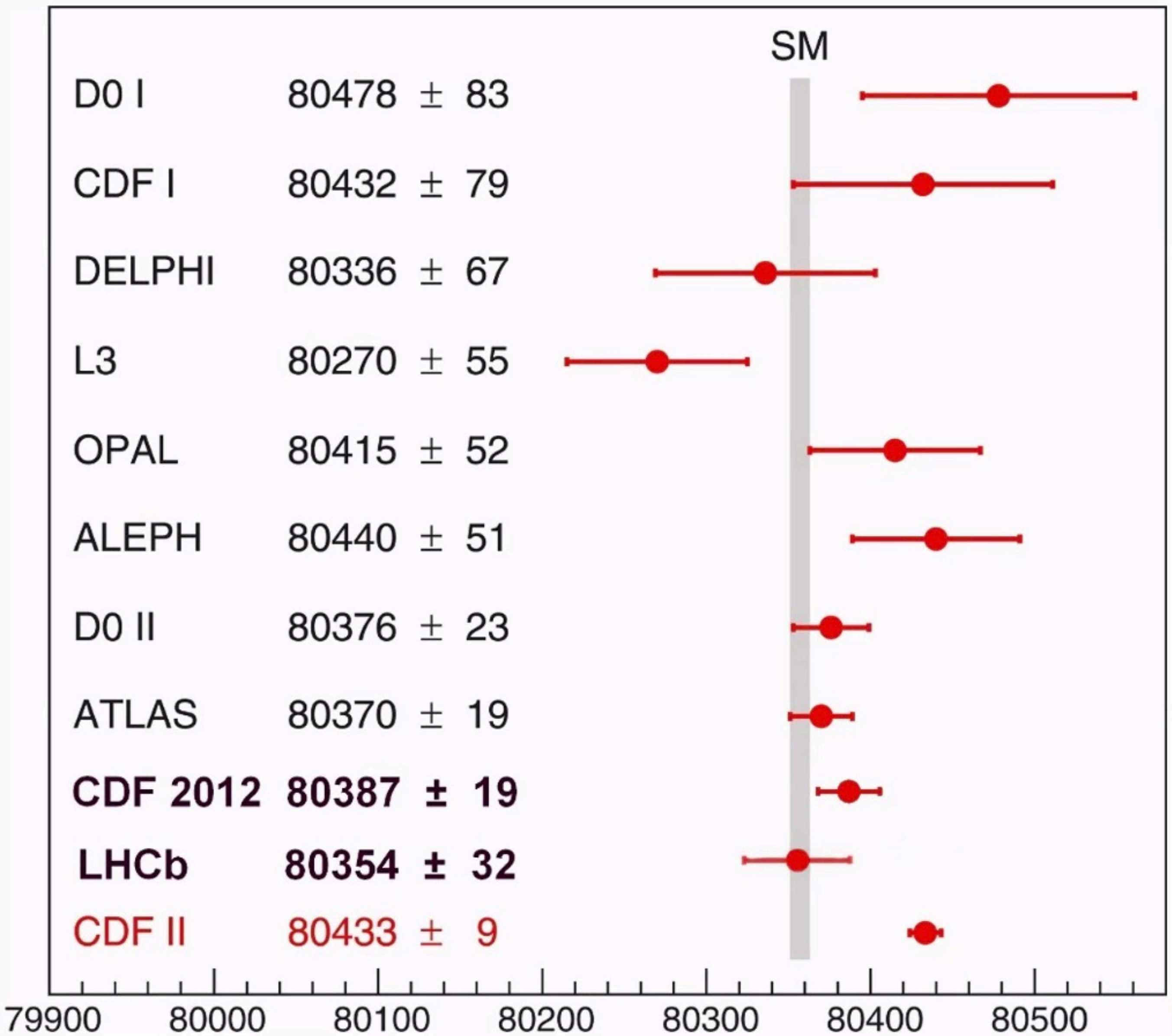

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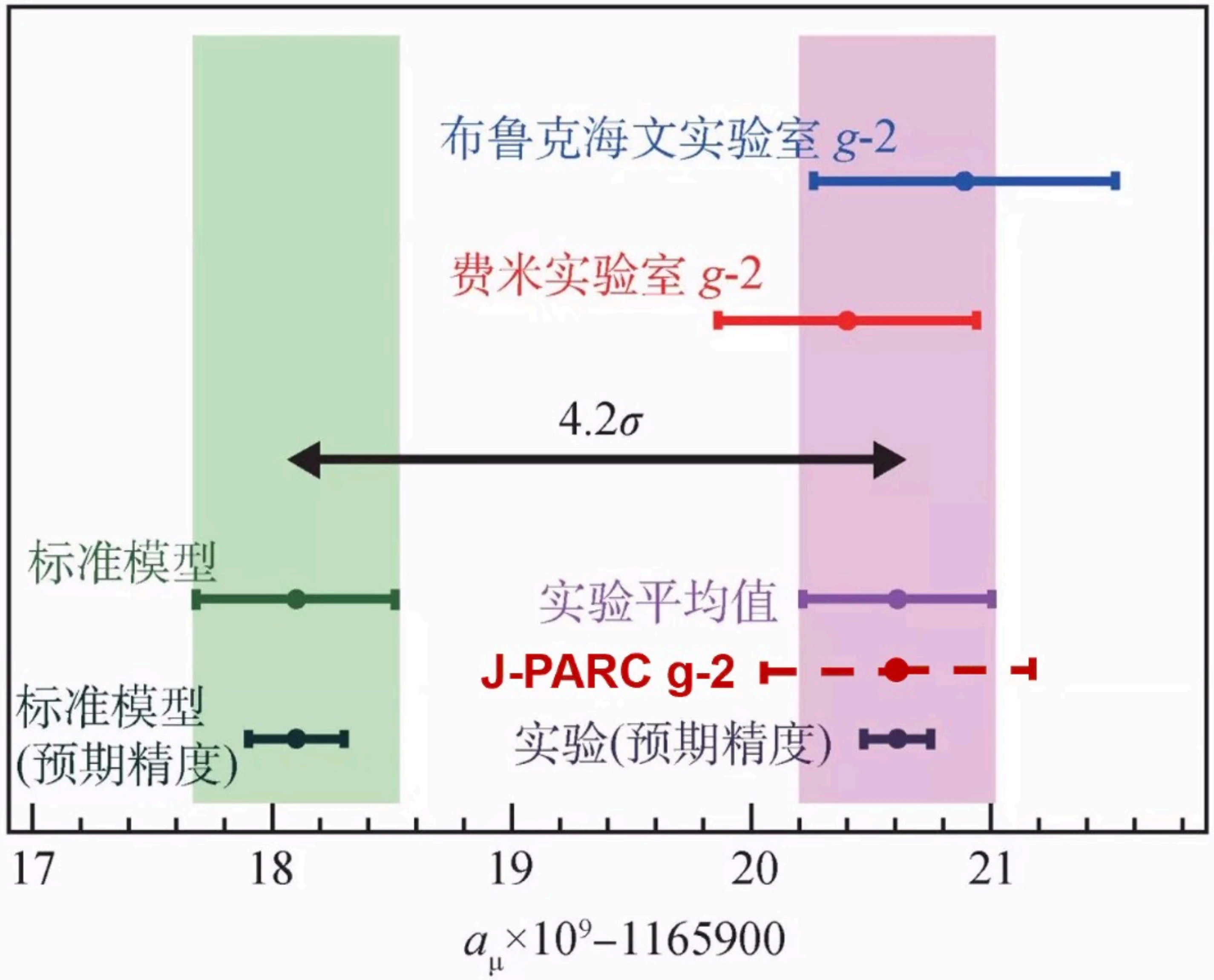
From A. Keshavarzi:

The new CDF M_W measurement makes the situation worse:

- It pushes $\Delta\alpha^{(5)}_{had}(M_Z^2)$ even further away from FNAL g-2 and lattice HVP.
- From EW fit predictions, it results in 4.9σ discrepancy for $\Delta\alpha^{(5)}_{had}(M_Z^2)$, 9.5σ discrepancy for M_H.
- There is no scenario that accommodate Muon g-2 discrepancy and CDF CDF M_W.

Summary and Outlook



- ✓ **The first results of Fermilab Muon g-2 measurement at 0.46 ppm with μ^+**
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  - ✓ **Expect a factor of two improvement in precision from Run2-3 data and more from Run4-5**
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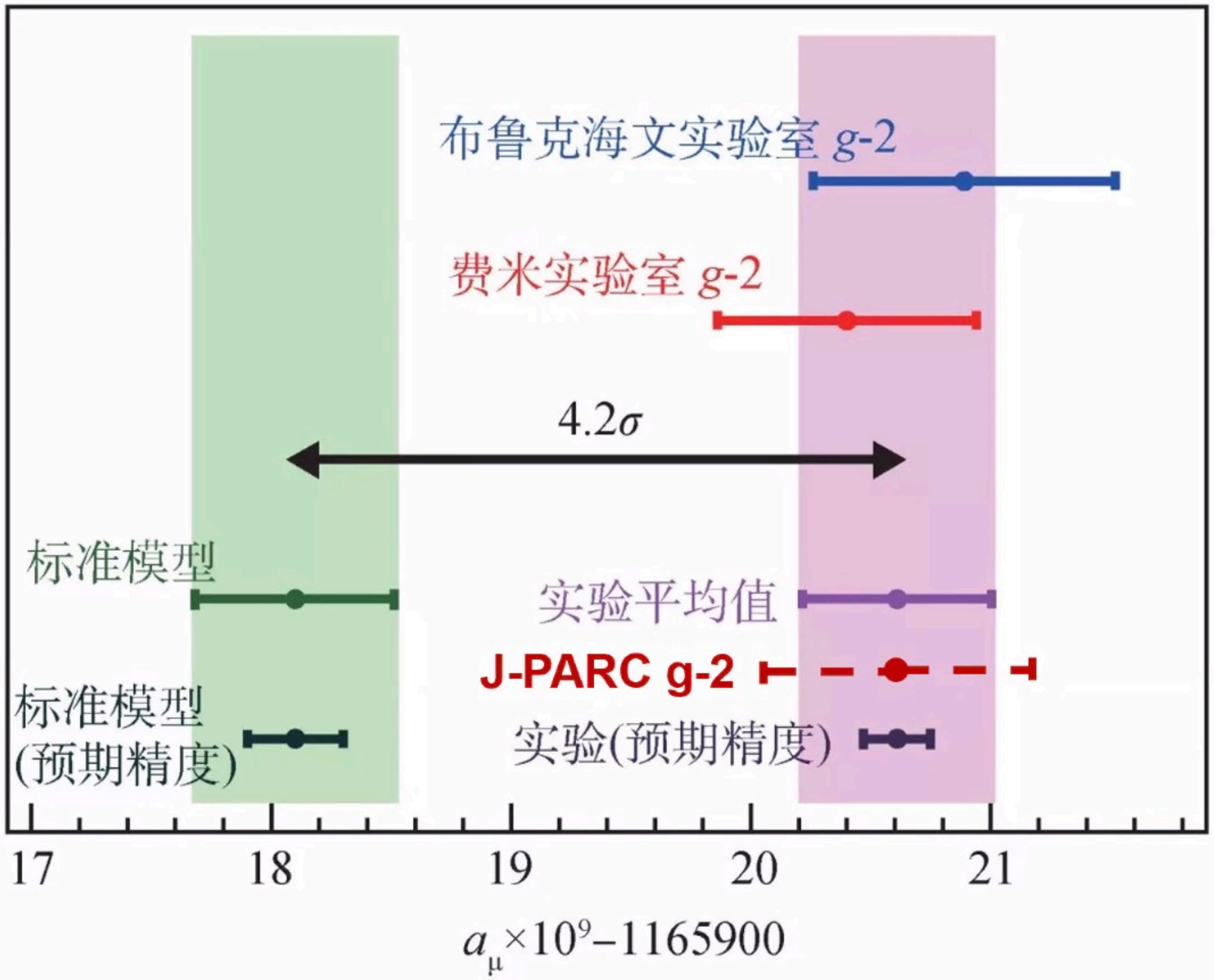

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- ✓ **Looking forward to J-PARC result and possible Muon g-2 Run6!**