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Muon and electron g-2, proton and cesium weak charges implications on dark Z_d models

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Theoretical Introduction

Recent measurement of muon anomalous magnetic moment a_μ by the Muon g-2 Collaboration [1-2], and recent rehevaluation of α_{EM}^{th} from the measurement of the recoil velocity on rubidium atoms[3]

The two anomalies now point in the same direction:
$\Delta a_\mu = 251(59)\times10^{-11}(4.2\sigma)$ [2]
and
$\Delta a_e = 0.48(30)\times10^{-12}(1.6\sigma)$ [3]

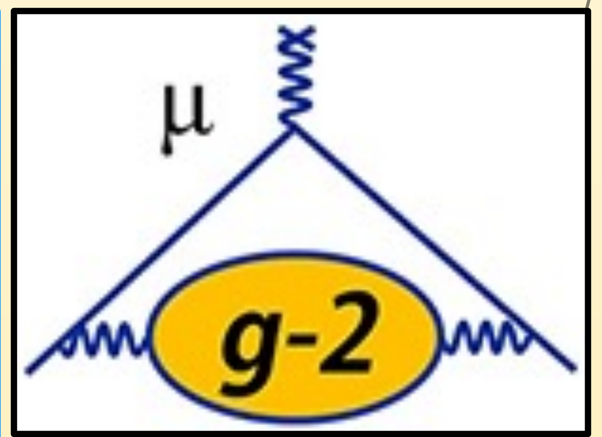
New boson which couples to the SM bosons via kinetic mixing ε and $Z - Z_d$ mass matrix mixing δ [4]. $U(1)_d$ extension of the SM with an interection Lagrangian:

$$\mathcal{L}_{int} = \left(-e\varepsilon J_\mu^{em} - \frac{g}{2\cos\theta_W}\frac{m_{Z_d}}{m_Z}\delta' J_\mu^{NC}\right) Z_d^\mu$$

New source of low energy parity violation

For polarized electron scattering and atomic parity violation experiments:

- $G_F \to \left(1+\delta f\left(\frac{Q^2}{m_{Z_d}^2}\right)\right) G_F$
- $\sin^2\theta_W(Q^2) \to \left(1 - \varepsilon\delta\frac{m_Z}{m_{Z_d}}\cot\theta_W f\left(\frac{Q^2}{m_{Z_d}^2}\right)\right)\sin^2\theta_W$



Additional contribution to the magnetic moment [4]:

$$a_{l,vector}^{Z_d} = \frac{\alpha}{2\pi}\left(\varepsilon + \frac{m_{Z_d}}{m_Z}\delta\frac{1-4\sin^2\theta_W}{4\sin\theta_W\cos\theta_W}\right)^2 F_V\left(\frac{m_{Z_d}}{m_l}\right)$$

And also a negligible axial contribution given by δ

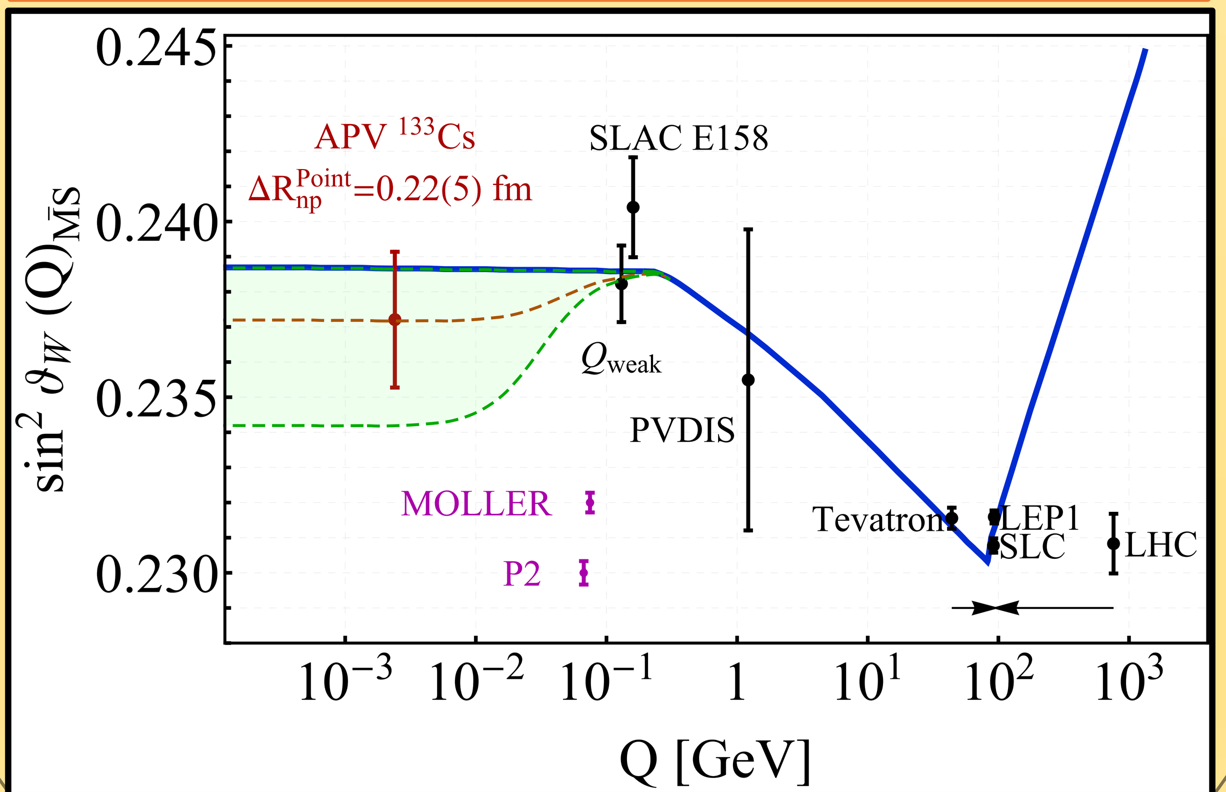
Other Effects

The Weinberg angle running changes in presence of such a boson, according to the substitutions

$$\sin^2\theta_W(Q^2) \to \left(1 - \varepsilon\delta\frac{m_Z}{m_{Z_d}}\cot\theta_W f\left(\frac{Q^2}{m_{Z_d}^2}\right)\right)\sin^2\theta_W.$$

We showed the curves for the best fit values and their 1σ variations

To highlight the need for low-energy measurements of the weak mixing angle, as these will play a key role in future searches for U(1) extensions of the SM.
Such as the Z dark boson that we consider, or the Dark Photon and the Z prime models.

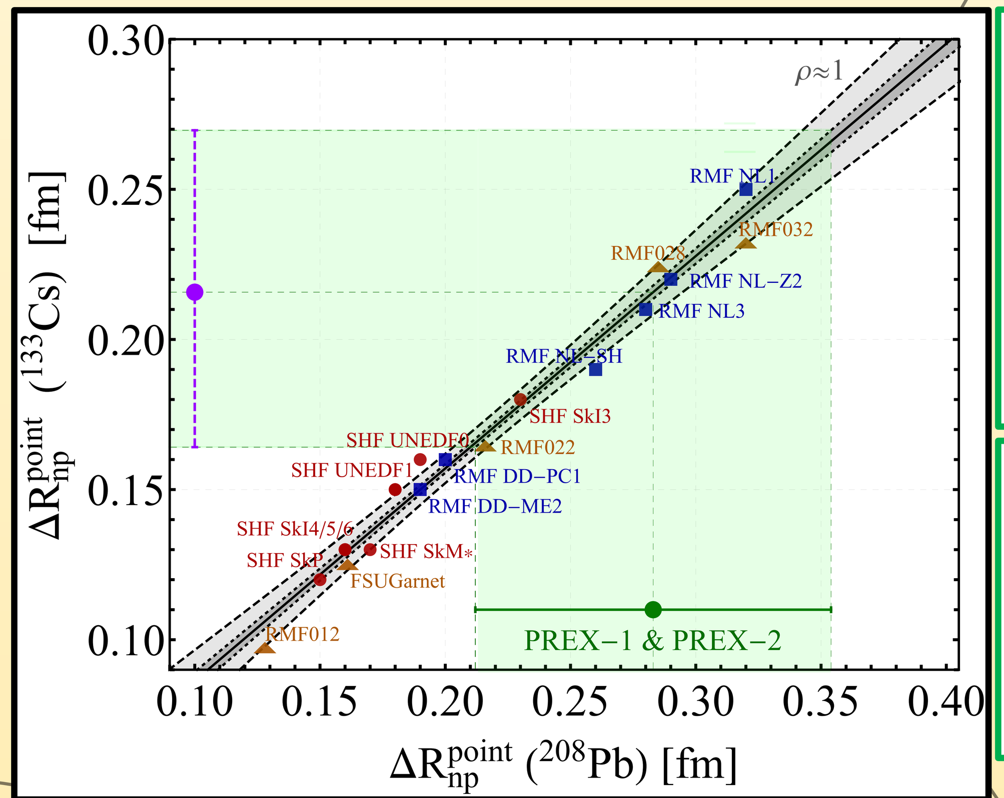


Experimental Measurements

Thus we concentrated our attention on weak charges measurement experiments, that are sensitive to this new boson.

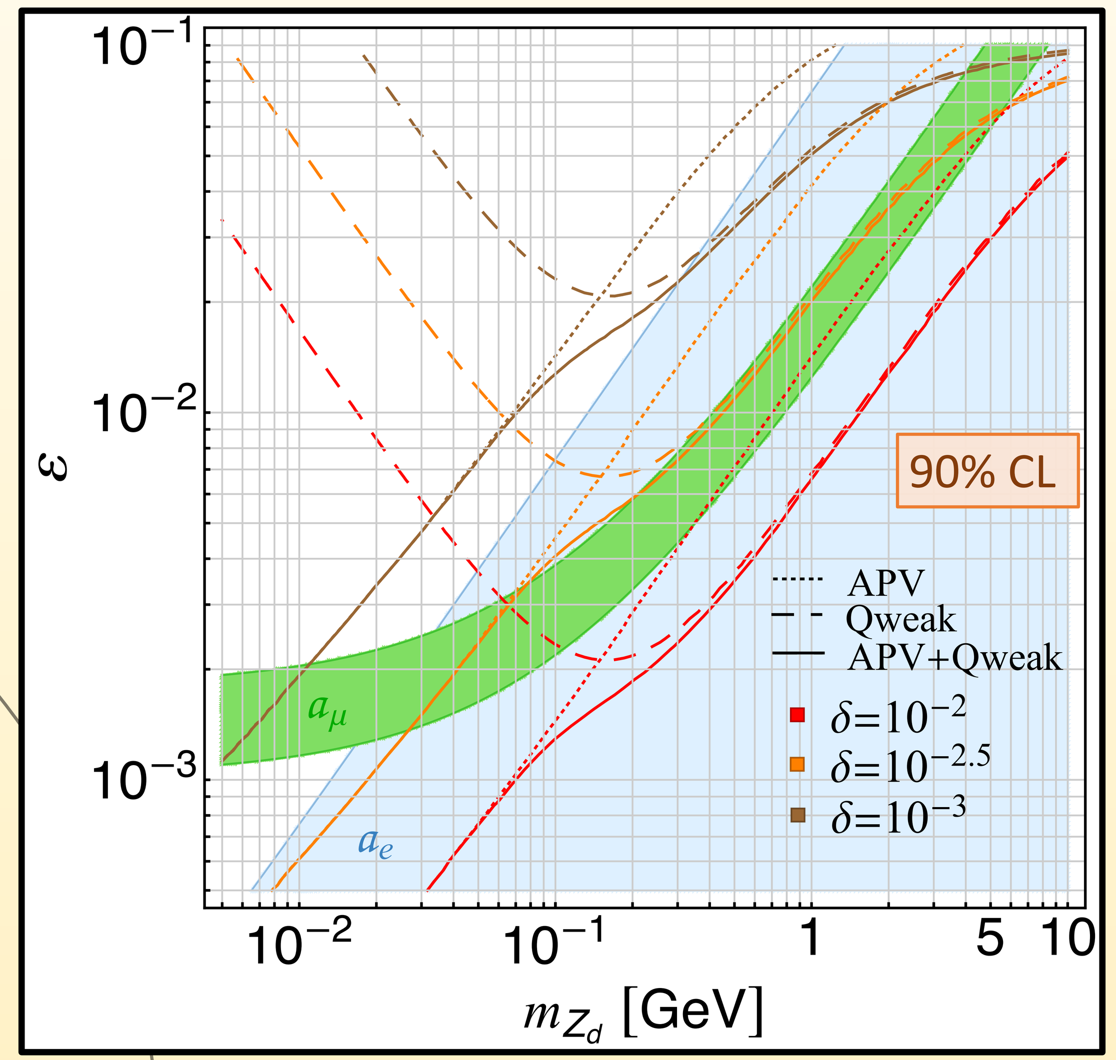
- Qweak experiment [5]: measurement of the proton weak charge using polarized electron-proton scattering
- $Q_W^{th}(p) \approx -2g_{ep}^{AV}(\sin^2\theta_W)$
- APV Cs experiment [6]: extraction of the Cesium nucleus weak charge by measuring parity violating atomic transitions
- $Q_W^{th}(Cs) \approx -2[Z\, g_{ep}^{AV} + N\, g_{en}^{AV}]$

$Q_W^{exp}(Cs)$ depends strongly on $R_n(Cs)$



We exploited the model-independent correlation between ΔR_{np}^{point} of cesium and lead, to translate the PREX result [7] $(\Delta R_{np}^{point}$ (Pb)=0.283(71) fm) into a determination of $R_n(Cs)$=5.03(5) fm, to be used as an input to determine the APV Cs experimental result

We showed the sensitivities of the APV and Qweak experiments compared to the favored regions for the explanations of both the muon and electron anomalous magnetic moments, at fixed values of the mass mixing parameter.

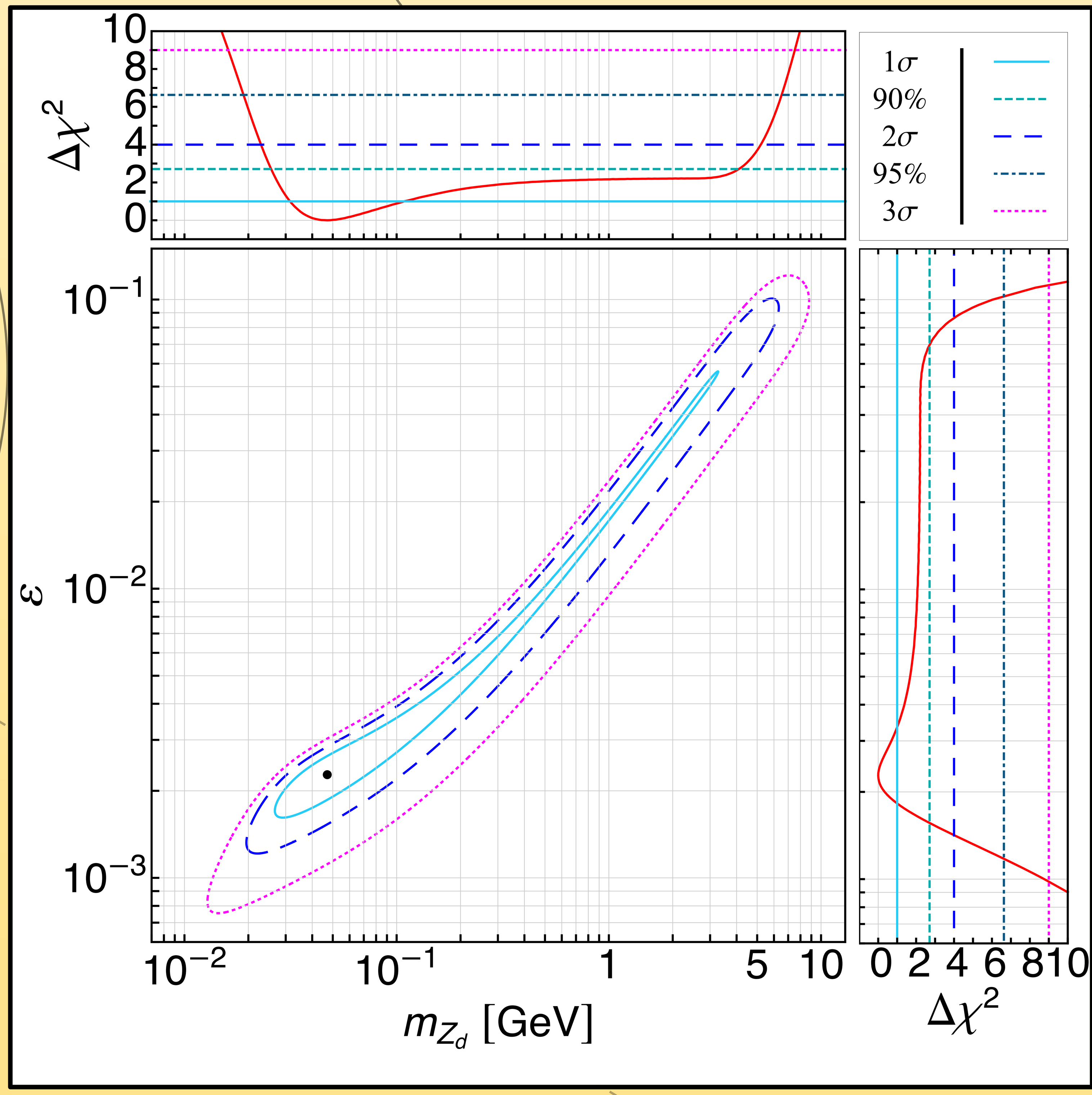


Main Result

We performed a combined fit of all the mentioned experimental results: Qweak, APV Cesium, muon and electron g-2, and marginalized over the δ parameter.

Suggestion of an appealing evidence of a Z_d boson

$$m_{Z_d} = 47_{-16}^{+61}\ MeV$$
$$\varepsilon = 2.3_{-0.4}^{+1.1}\times10^{-3}$$
$$\delta < 2\times10^{-3}$$



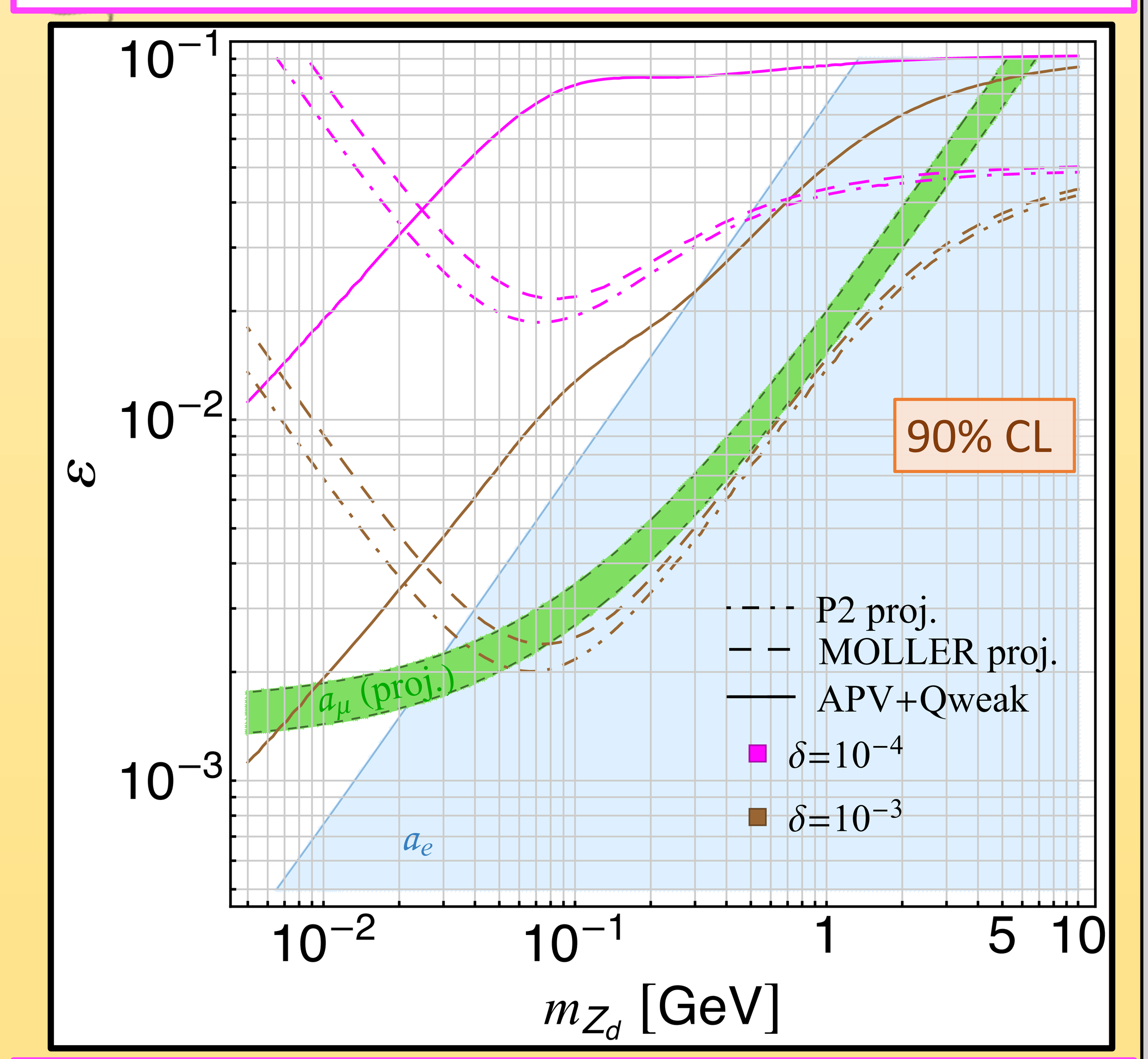
Near Future Projections

We then considered the projected sensitivity of near future measurements such as P2 [8] and MOLLER[9] , and also the expected uncertainty for next Muon g-2 runs.

The P2 experiment is going to measure the weak charge of the proton with expected precision of the order of 1.5%.

The MOLLER experiment is going to measure the weak charge of the electron with a precision of 2.4%.

For the Muon g-2 we considered the recent experimental value, but half of the uncertainty.



With such precisions, P2 and MOLLER could exclude the g-2 explanation region for smaller values of δ.

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[5] Nature 557, 207–211 (2018)
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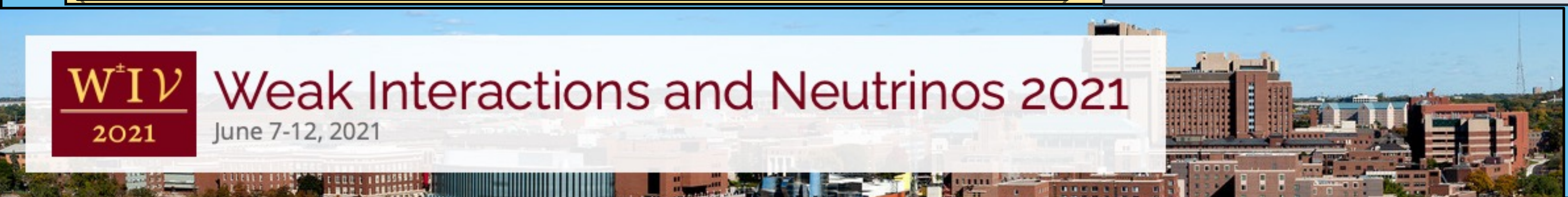

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