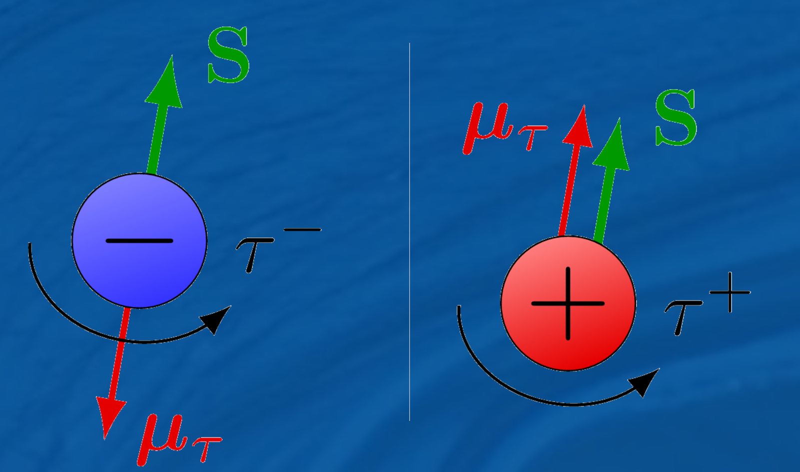
Probing τ lepton dipole moments at future Lepton Collider

Introduction



$$\mu = g\frac{e}{2m}\mathbf{S}$$

Δa_τ refers to the deviation of the measured anomalous moment of the SM prediction:

$$\Delta a_\tau = a_\tau^{\text{exp}} - a_\tau^{\text{SM}}$$

•Significance: The anomalous magnetic moments (g-2) of leptons are crucial for probing the Standard Model and Potential New Physics.
•Focus: Investigation of τ lepton g-2 at future colliders like FCC-ee or a Muon Collider.
•Challenge: The short lifetime of the τ lepton has prevented precise measurements of its g-2, unlike the muon and electron.

The Lagrangian of SMEFT

The relevant effective Lagrangian of leptonic g-2 up to one-loop order, at a scale Λ larger than the electroweak scale: $E \ll \Lambda$ by an effective Lagrangian containing non-renormalizable $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ invariant operators.

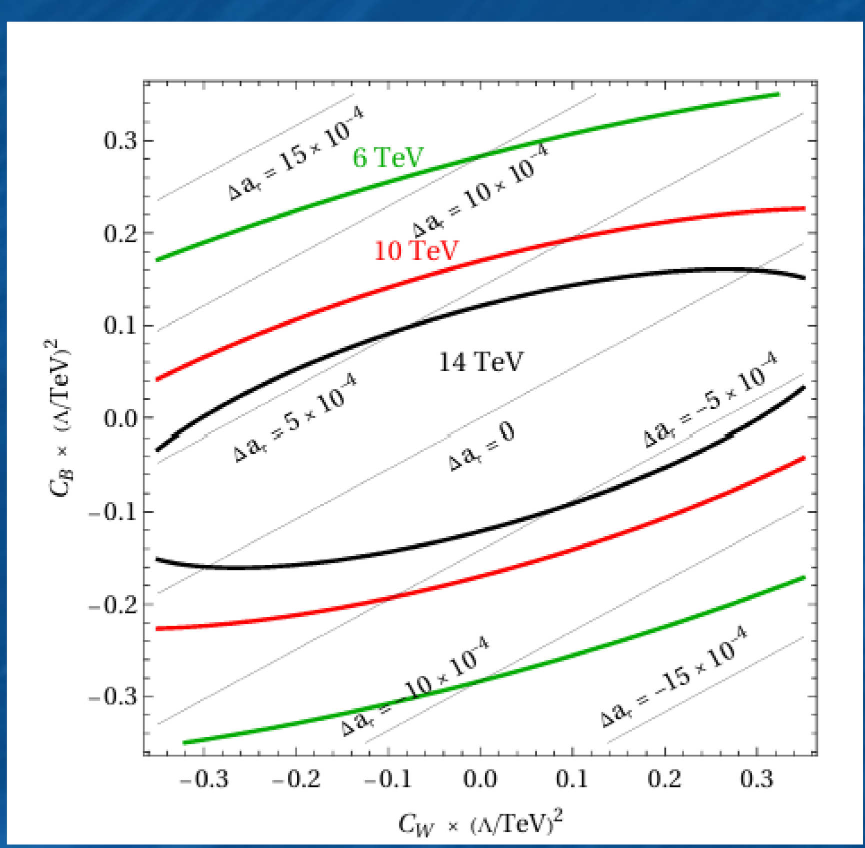
$$\mathcal{L} = \frac{C_{eB}^{\ell}}{\Lambda^2}\left(\bar{\ell}_L \sigma^{\mu\nu} e_R\right) HB_{\mu\nu} + \frac{C_{eW}^{\ell}}{\Lambda^2}\left(\bar{\ell}_L \sigma^{\mu\nu} e_R\right) \tau^I\, HW_{\mu\nu}^I + \frac{C_T^{\ell}}{\Lambda^2}(\bar{\ell}_L^a \sigma_{\mu\nu} e_R)\varepsilon_{ab}(\bar{Q}_L^b \sigma^{\mu\nu} u_R) + h.c$$

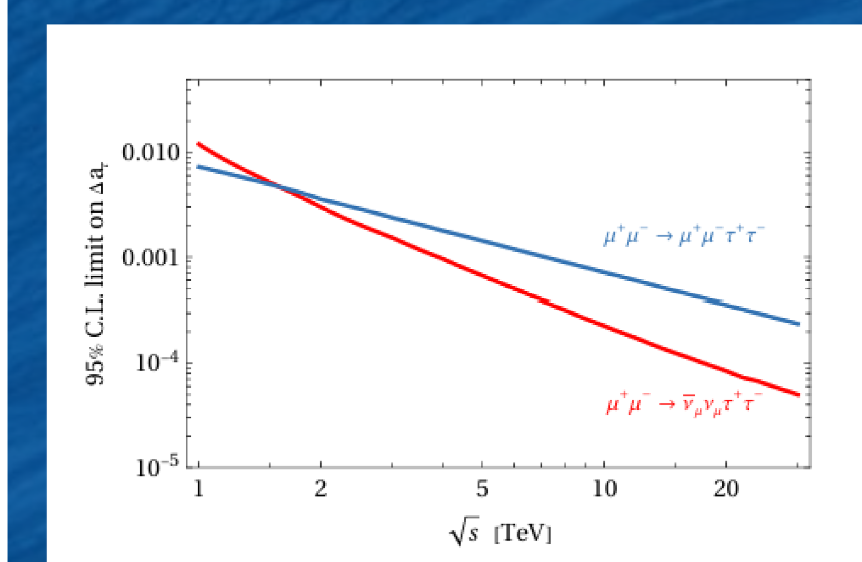
The resulting expression for Δa_τ at one-loop order is given by

$$\Delta a_\tau \simeq \frac{4m_\tau v}{e\sqrt{2}\Lambda^2}\left(C_{e\gamma}^{\tau} - \frac{3\alpha}{2\pi}\frac{c_W^2 - s_W^2}{s_W c_W} C_{eZ}^{\ell}\log\frac{\Lambda}{m_Z}\right) - \frac{4m_\tau m_t}{\pi^2}\frac{C_T^{\tau t}}{\Lambda^2}\log\frac{\Lambda}{m_t}$$

The example of Results

Analysis cuts and efficiencies effectively reduce backgrounds, improving the reach on dipole operators at high-energy muon colliders.
Higher collider energies provide stronger constraints on Wilson coefficients.





The example of $\mu^+\mu^- \to \mu^+\mu^-\tau^+\tau^-$

The calculation performed with MadGraph in this case considers the imposed cuts, as well as the efficiency of tagging and the background.

Left: 95% CL limits on the Wilson coefficients C_{eW} and C_{eB} from $\mu^+\mu^- \to \mu^+\mu^-\tau^+\tau^-$ at muon colliders of different energies; Right: Showing the reach on Δa_τ as a function of center-of-mass Energy.

Conclusion

*Examining tau g−2 sensitivity at future high-energy muon colliders, which have the advantage of higher c.o.m. energy, corresponding higher luminosity, and larger cross-sections compared to FCC-ee.

*The NP responsible for $\Delta a_\tau < 10^{-4}$ can be also tested indirectly through the rare higgs decay $h \to \tau^+\tau^-\gamma$ and the high-energy processes $\mu^+\mu^- \to \tau^+\tau^-(h)$, $\mu^+\mu^- \to \mu^+\mu^-\tau^+\tau^-(\bar{\nu}\nu\tau^+\tau^-)$ where the latter process enjoys a very large cross-section driven by vector-boson-fusion.

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