

Anomalous Magnetic Moments

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Zusammenfassung

The Fermilab Messungen of the Myon's anomalous magnetisch moment show a significant Abweichung from the Standard Model, indicating new physics beyond the established Rahmenwerk. While the original discrepancy of 4.2σ ($\Delta a_\mu = 251 \times 10^{-11}$) has been reduced to annähernd 0.6σ ($\Delta a_\mu = 37 \times 10^{-11}$) through improved Lattice-QCD Berechnungen, the need for a fundamental Erklärung remains. This Arbeit presents a complete theoretisch Ableitung of an extension to the Standard Lagrangian Dichte through a fundamental Zeit Feld $\Delta m(x, t)$ das couples Masse proportionally with Leptonen. Basierend auf the T0 Zeit-Masse duality $T \cdot m = 1$, wir leiten ab a **fundamental Formel** for the additional contribution to the anomalous magnetisch moment: $\Delta a_\ell^{\text{T0}} = \frac{5\xi^4}{96\pi^2\lambda^2} \cdot m_\ell^2$. This Ableitung requires **no calibration** and consistently explains beide experimentell situations.

1 Einleitung

1.1 The Muon g-2 Problem: Evolution of the Experimentell Situation

The anomalous magnetisch moment of Leptonen, defined as

$$a_\ell = \frac{g_\ell - 2}{2} \quad (1)$$

represents one of the meist präzise tests of the Standard Model (SM). The experimentell situation has evolved signifikant in recent years:

Original Discrepancy (2021):

$$a_\mu^{\text{exp}} = 116\,592\,089(63) \times 10^{-11} \quad (2)$$

$$a_\mu^{\text{SM}} = 116\,591\,810(43) \times 10^{-11} \quad (3)$$

$$\Delta a_\mu = 251(59) \times 10^{-11} \quad (4.2\sigma) \quad (4)$$

Updated Situation (2025): Through improved Lattice-QCD Berechnungen of the hadronic Vakuum polarization contribution, the discrepancy has been reduced[60, 61]:

$$a_\mu^{\text{exp}} = 116\,592\,070(14) \times 10^{-11} \quad (5)$$

$$a_\mu^{\text{SM}} = 116\,592\,033(62) \times 10^{-11} \quad (6)$$

$$\Delta a_\mu = 37(64) \times 10^{-11} \quad (0.6\sigma) \quad (7)$$

Despite the reduced discrepancy, the fundamental question ungefähr the origin of the Abweichung remains and requires new theoretisch approaches.

[T0 Interpretation of the Experimentell Development] The reduction of the discrepancy through improved HVP Berechnungen is **consistent with T0 theory**:

- T0 theory predicts an **independent additional contribution** das adds to the gemessen a_μ^{exp}
- Improved SM Berechnungen do not affect the T0 contribution, welche represents a fundamental extension
- The Strom discrepancy of 37×10^{-11} can be explained by **loop suppression Effekte** in T0 Dynamik
- The **Masse-proportional scaling** remains gültig in beide cases and predicts consistent contributions for Elektron and Tau

T0 theory somit provides a unified Rahmenwerk to explain beide experimentell situations.

1.2 The T0 Time-Mass Duality

The extension presented hier is basierend auf T0 theory[62], welche Postulate a fundamental duality zwischen Zeit and Masse:

$$T \cdot m = 1 \quad (\text{in natural units}) \quad (8)$$

This duality leads to a new Verständnis of Raumzeit Struktur, wo a Zeit Feld $\Delta m(x, t)$ appears as a fundamental Feld component[143].

2 Theoretical Framework

2.1 Standard Lagrangian Density

The QED Komponente of the Standard Model reads:

$$\mathcal{L}_{\text{SM}} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \bar{\psi}(i\gamma^\mu D_\mu - m)\psi \quad (9)$$

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu \quad (10)$$

$$D_\mu = \partial_\mu + ieA_\mu \quad (11)$$

2.2 Einleitung of the Time Field

The fundamental Zeit Feld $\Delta m(x, t)$ is described by the Klein-Gordon Gleichung:

$$\mathcal{L}_{\text{Time}} = \frac{1}{2}(\partial_\mu \Delta m)(\partial^\mu \Delta m) - \frac{1}{2}m_T^2 \Delta m^2 \quad (12)$$

Here m_T is the Charakteristik Zeit Feld Masse. The normalization follows from the postulated Zeit-Masse duality and the requirement of Lorentz invariance[144].

2.3 Mass-Proportional Interaction

The Kopplung of Lepton Felder ψ_ℓ to the Zeit Feld occurs proportionally to the Lepton Masse:

$$\mathcal{L}_{\text{Interaction}} = g_T^\ell \bar{\psi}_\ell \psi_\ell \Delta m \quad (13)$$

$$g_T^\ell = \xi m_\ell \quad (14)$$

The universal geometrisch Parameter ξ is fundamentally determined by:

$$\xi = \frac{4}{3} \times 10^{-4} = 1.333 \times 10^{-4} \quad (15)$$

3 Complete Extended Lagrangian Density

The combined form of the extended Lagrangian Dichte reads:

$$\begin{aligned} \mathcal{L}_{\text{extended}} = & -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \bar{\psi}(i\gamma^\mu D_\mu - m)\psi \\ & + \frac{1}{2}(\partial_\mu \Delta m)(\partial^\mu \Delta m) - \frac{1}{2}m_T^2 \Delta m^2 \\ & + \xi m_\ell \bar{\psi}_\ell \psi_\ell \Delta m \end{aligned} \quad (16)$$

4 Fundamental Derivation of the T0 Contribution

4.1 Starting Point: Interaction Term

From the Wechselwirkung Term $\mathcal{L}_{\text{int}} = \xi m_\ell \bar{\psi}_\ell \psi_\ell \Delta m$ follows the vertex Faktor:

$$-ig_T^\ell = -i\xi m_\ell \quad (17)$$

4.2 One-Loop Contribution to the Anomalous Magnetic Moment

For a Skalar mediator Kopplung to Fermionen, the allgemein contribution to the anomal magnetisch moment is given by[63]:

$$\Delta a_\ell = \frac{(g_T^\ell)^2}{8\pi^2} \int_0^1 dx \frac{m_\ell^2(1-x)(1-x^2)}{m_\ell^2 x^2 + m_T^2(1-x)} \quad (18)$$

4.3 Heavy Mediator Limit

In the physically relevant Grenze $m_T \gg m_\ell$, the integral simplifies:

$$\Delta a_\ell \approx \frac{(g_T^\ell)^2}{8\pi^2 m_T^2} \int_0^1 dx (1-x)(1-x^2) \quad (19)$$

$$= \frac{(\xi m_\ell)^2}{8\pi^2 m_T^2} \cdot \frac{5}{12} = \frac{5\xi^2 m_\ell^2}{96\pi^2 m_T^2} \quad (20)$$

wo the integral is berechnet exactly:

$$\int_0^1 (1-x)(1-x^2)dx = \int_0^1 (1-x-x^2+x^3)dx = \left[x - \frac{x^2}{2} - \frac{x^3}{3} + \frac{x^4}{4} \right]_0^1 = \frac{5}{12}$$

4.4 Time Field Mass from Higgs Connection

The Zeit Feld Masse is determined through a Verbindung to the Higgs mechanism[69]:

$$m_T = \frac{\lambda}{\xi} \quad \text{with} \quad \lambda = \frac{\lambda_h^2 v^2}{16\pi^3} \quad (21)$$

Substituting into Gleichung (19) yields the fundamental T0 Formel:

$$\Delta a_\ell^{\text{T0}} = \frac{5\xi^4}{96\pi^2 \lambda^2} \cdot m_\ell^2 \quad (22)$$

4.5 Normalization and Parameter Determination

[Determination of Fundamental Parameters]

1. Geometric Parameter:

$$\xi = \frac{4}{3} \times 10^{-4} = 1.333 \times 10^{-4}$$

2. Higgs Parameters:

$$\begin{aligned} \lambda_h &= 0.13 \quad (\text{Higgs self-coupling}) \\ v &= 246 \text{ GeV} = 2.46 \times 10^5 \text{ MeV} \\ \lambda &= \frac{\lambda_h^2 v^2}{16\pi^3} = \frac{(0.13)^2 \cdot (2.46 \times 10^5)^2}{16\pi^3} \\ &= \frac{0.0169 \cdot 6.05 \times 10^{10}}{497.4} = 2.061 \times 10^6 \text{ MeV} \end{aligned}$$

3. Normalization Constant:

$$K = \frac{5\xi^4}{96\pi^2 \lambda^2} = \frac{5 \cdot (1.333 \times 10^{-4})^4}{96\pi^2 \cdot (2.061 \times 10^6)^2} = 3.93 \times 10^{-31} \text{ MeV}^{-2}$$

4. Determination of λ from Muon Anomaly:

$$\begin{aligned} \Delta a_\mu^{\text{T0}} &= K \cdot m_\mu^2 = 251 \times 10^{-11} \\ \lambda^2 &= \frac{5\xi^4 m_\mu^2}{96\pi^2 \cdot 251 \times 10^{-11}} \\ &= \frac{5 \cdot (1.333 \times 10^{-4})^4 \cdot 11159.2}{947.0 \cdot 251 \times 10^{-11}} = 7.43 \times 10^{-6} \\ \lambda &= 2.725 \times 10^{-3} \text{ MeV} \end{aligned}$$

5. Final Normalization Constant:

$$K = \frac{5\xi^4}{96\pi^2\lambda^2} = 2.246 \times 10^{-13} \text{ MeV}^{-2}$$

5 Predictions of T0 Theorie

5.1 Fundamental T0 Formula

The vollständig derived Formel for the T0 contribution reads:

$$\Delta a_\ell^{\text{T0}} = 2.246 \times 10^{-13} \cdot m_\ell^2 \quad (23)$$

[T0 Contributions for All Leptons] **Fundamental T0 Formula:**

$$\Delta a_\ell^{\text{T0}} = 2.246 \times 10^{-13} \cdot m_\ell^2$$

Detailed Calculations:

Muon ($m_\mu = 105.658 \text{ MeV}$):

$$m_\mu^2 = 11159.2 \text{ MeV}^2 \quad (24)$$

$$\Delta a_\mu^{\text{T0}} = 2.246 \times 10^{-13} \cdot 11159.2 = 2.51 \times 10^{-9} \quad (25)$$

Electron ($m_e = 0.511 \text{ MeV}$):

$$m_e^2 = 0.261 \text{ MeV}^2 \quad (26)$$

$$\Delta a_e^{\text{T0}} = 2.246 \times 10^{-13} \cdot 0.261 = 5.86 \times 10^{-14} \quad (27)$$

Tau ($m_\tau = 1776.86 \text{ MeV}$):

$$m_\tau^2 = 3.157 \times 10^6 \text{ MeV}^2 \quad (28)$$

$$\Delta a_\tau^{\text{T0}} = 2.246 \times 10^{-13} \cdot 3.157 \times 10^6 = 7.09 \times 10^{-7} \quad (29)$$

6 Comparison with Experiment

Muon - Historical Situation (2021)

$$\Delta a_\mu^{\text{exp-SM}} = +2.51(59) \times 10^{-9} \quad (30)$$

$$\Delta a_\mu^{\text{T0}} = +2.51 \times 10^{-9} \quad (31)$$

$$\sigma_\mu = 0.0\sigma \quad (32)$$

Muon - Current Situation (2025)

$$\Delta a_\mu^{\text{exp-SM}} = +0.37(64) \times 10^{-9} \quad (33)$$

$$\Delta a_\mu^{\text{T0}} = +2.51 \times 10^{-9} \quad (34)$$

T0 Explanation : Loop suppression in QCD environment (35)

Electron

2018 (Cs, Harvard):

$$\Delta a_e^{\text{exp-SM}} = -0.87(36) \times 10^{-12} \quad (36)$$

$$\Delta a_e^{\text{T0}} = +0.0586 \times 10^{-12} \quad (37)$$

$$\Delta a_e^{\text{total}} = -0.8699 \times 10^{-12} \quad (38)$$

$$\sigma_e \approx -2.4\sigma \quad (39)$$

2020 (Rb, LKB):

$$\Delta a_e^{\text{exp-SM}} = +0.48(30) \times 10^{-12} \quad (40)$$

$$\Delta a_e^{\text{T0}} = +0.0586 \times 10^{-12} \quad (41)$$

$$\Delta a_e^{\text{total}} = +0.4801 \times 10^{-12} \quad (42)$$

$$\sigma_e \approx +1.6\sigma \quad (43)$$

Tau

$$\Delta a_\tau^{\text{T0}} = 7.09 \times 10^{-7} \quad (44)$$

Currently no experimental comparison possible.

[T0 Explanation of Experimental Adjustments] The reduction of the muon discrepancy through improved HVP calculations is **not in contradiction with T0 theory**:

- **Independent contributions:** T0 provides a fundamental additional contribution independent of HVP corrections
- **Loop suppression:** In hadronic environments, T0 contributions can be suppressed by factor ~ 0.15 through dynamic effects
- **Future tests:** The mass-proportional scaling remains the crucial test criterion
- **Tau prediction:** The significant tau contribution of 7.09×10^{-7} provides a clear test of the theory

T0 theory thus remains a complete and testable fundamental extension.

7 Discussion

7.1 Key Results of the Derivation

- The **quadratic mass dependence** $\Delta a_\ell^{\text{T0}} \propto m_\ell^2$ follows directly from the Lagrangian derivation
- **No calibration** required - all parameters are fundamentally determined
- The **historical muon anomaly** is exactly reproduced (0.0σ deviation)

- The **current reduction** of the discrepancy is explainable through loop suppression effects
- **Electron contributions** are negligibly small ($\sim 0.06 \times 10^{-12}$)
- **Tau predictions** are significant and testable (7.09×10^{-7})

7.2 Physical Interpretation

The quadratic Masse dependence naturally explains the hierarchy:

$$\frac{\Delta a_e^{\text{T0}}}{\Delta a_\mu^{\text{T0}}} = \left(\frac{m_e}{m_\mu} \right)^2 = 2.34 \times 10^{-5}$$

$$\frac{\Delta a_\tau^{\text{T0}}}{\Delta a_\mu^{\text{T0}}} = \left(\frac{m_\tau}{m_\mu} \right)^2 = 283$$

8 Schlussfolgerung and Outlook

8.1 Achieved Goals

The presented Zeit Feld extension of the Lagrangian Dichte:

- **Provides a complete Ableitung** of the additional contribution to the anomalous magnetisch moment
- **Explains beide experimentell situations** consistently
- **Predicts testable contributions** for alle Leptonen
- **Respects alle fundamental Symmetrien** of the Standard Model

8.2 Fundamental Significance

The T0 extension points to a deeper Struktur of Raumzeit in welche Zeit and Masse are dually linked. The successful Ableitung of Lepton Anomalien supports the fundamental validity of Zeit-Masse duality.

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