Anomalous Photon Self-Couplings in Born-Infeld Theory: Implications for the Muon Magnetic Anomaly

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1. Introduction

Basics of the anomalous magnetic moment

- For spin 1/2 particle, the magnetic moment μ_{orb} is

$$\mu_{orb} = I \cdot \overrightarrow{A} = g\frac{Q}{2m}\vec{S}$$

- Dirac's equation in the non-relativistic limit predicts g=2
- **The Lamb Shift experiment (1947)** revealed that **g** is slightly **greater than 2!**
- Anomalous magnetic moment: $a = \dfrac{(g-2)}{2}$

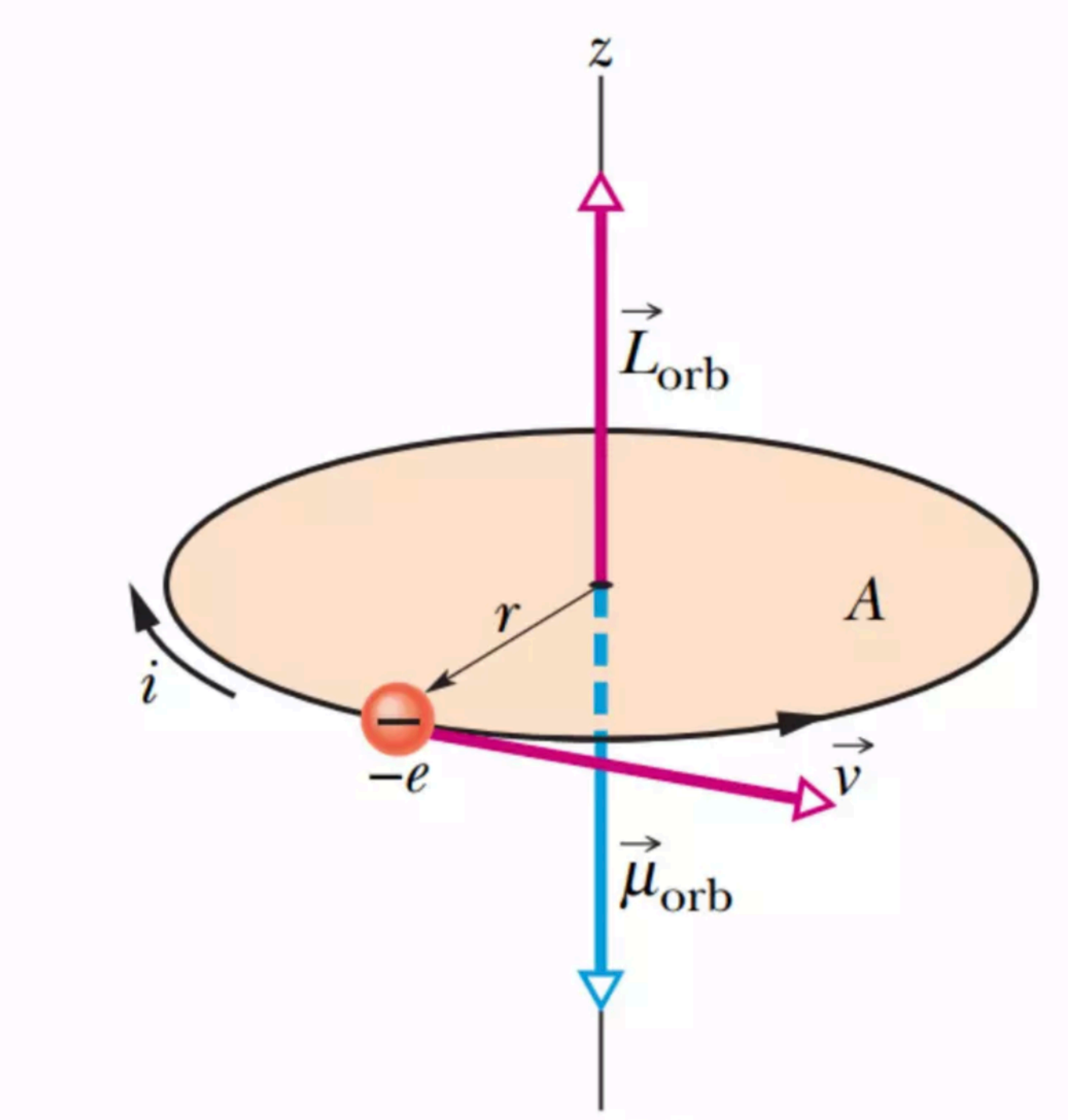
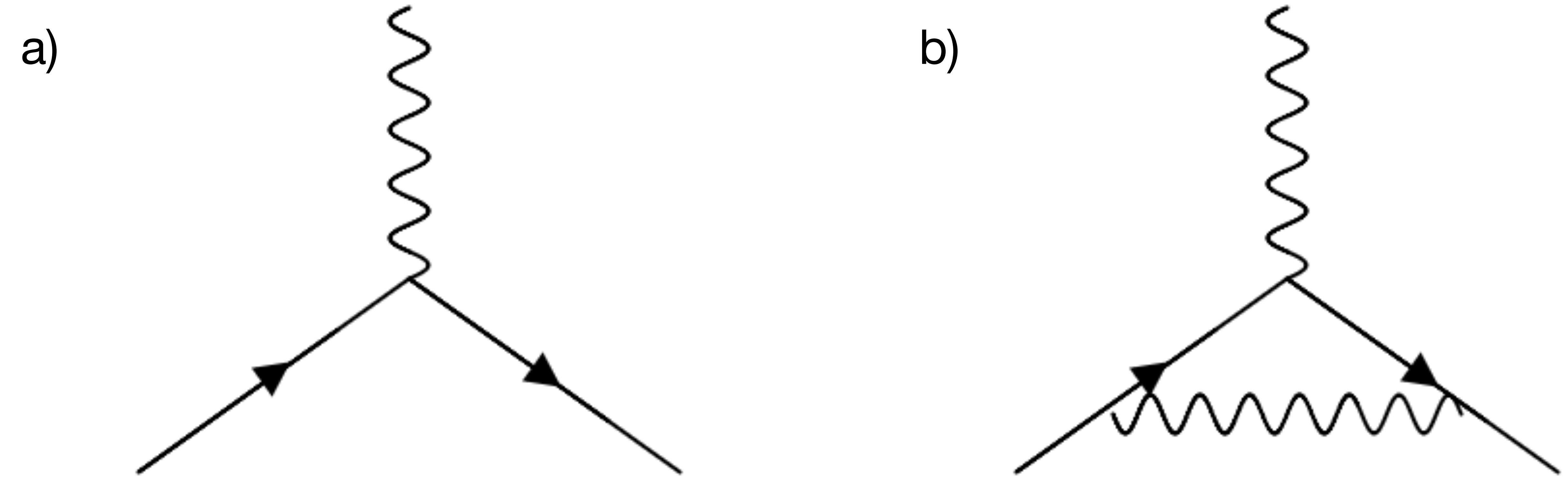


Figure 1: Classical representation of the magnetic moment, μ_{orb}, of a spin 1/2 particle.

Basics of the anomalous magnetic moment

- **Schwinger, Tomonaga, Feynman** and **others** started developing **Quantum Electrodynamics (QED).**
- Feynman developed his diagramatic method that simplified super-complicated calculations of QED.
- Schwinger, obtained the first order correction (1-loop).



$$\boxed{a_\mu = \frac{\alpha}{2\pi} + \mathcal{O}(\alpha^2)}$$

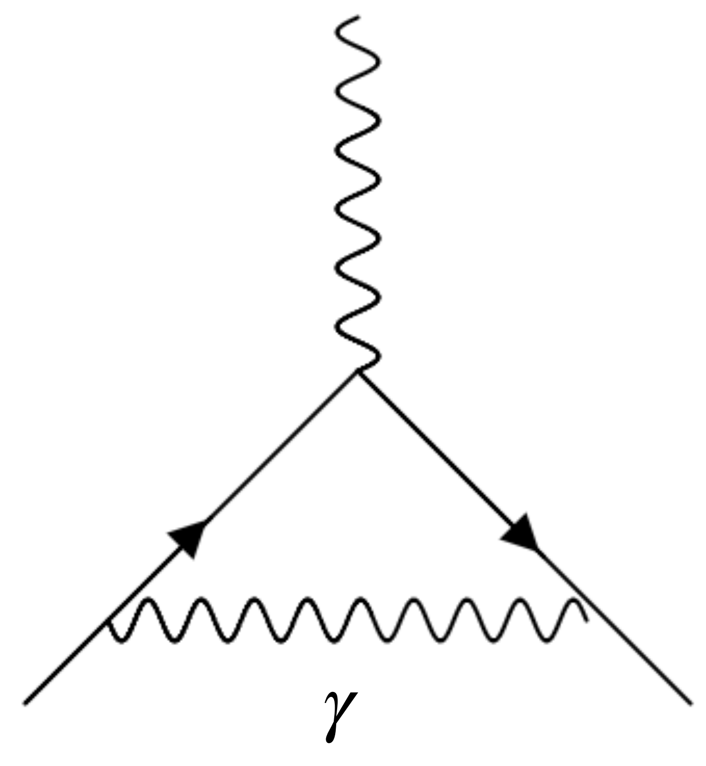
Figure 2: Feynman diagram representing the magnetic moment of a spin 1/2 particle at tree level (a) and next leading order (NLO) (b).

Basics of the anomalous magnetic moment

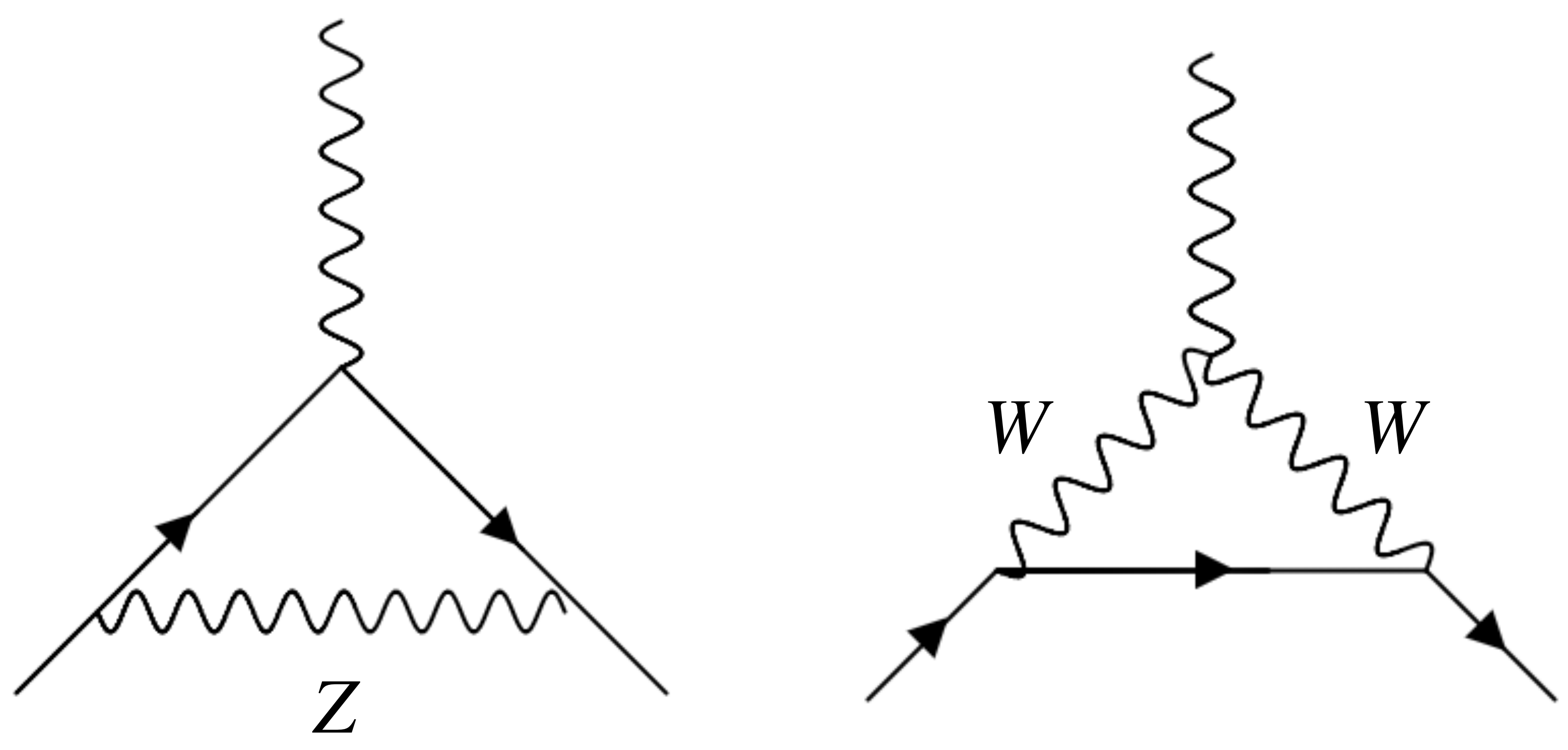
- The total anomaly (taking into account the Standard Model) can be written as

$$a_\mu = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{hadron}$$

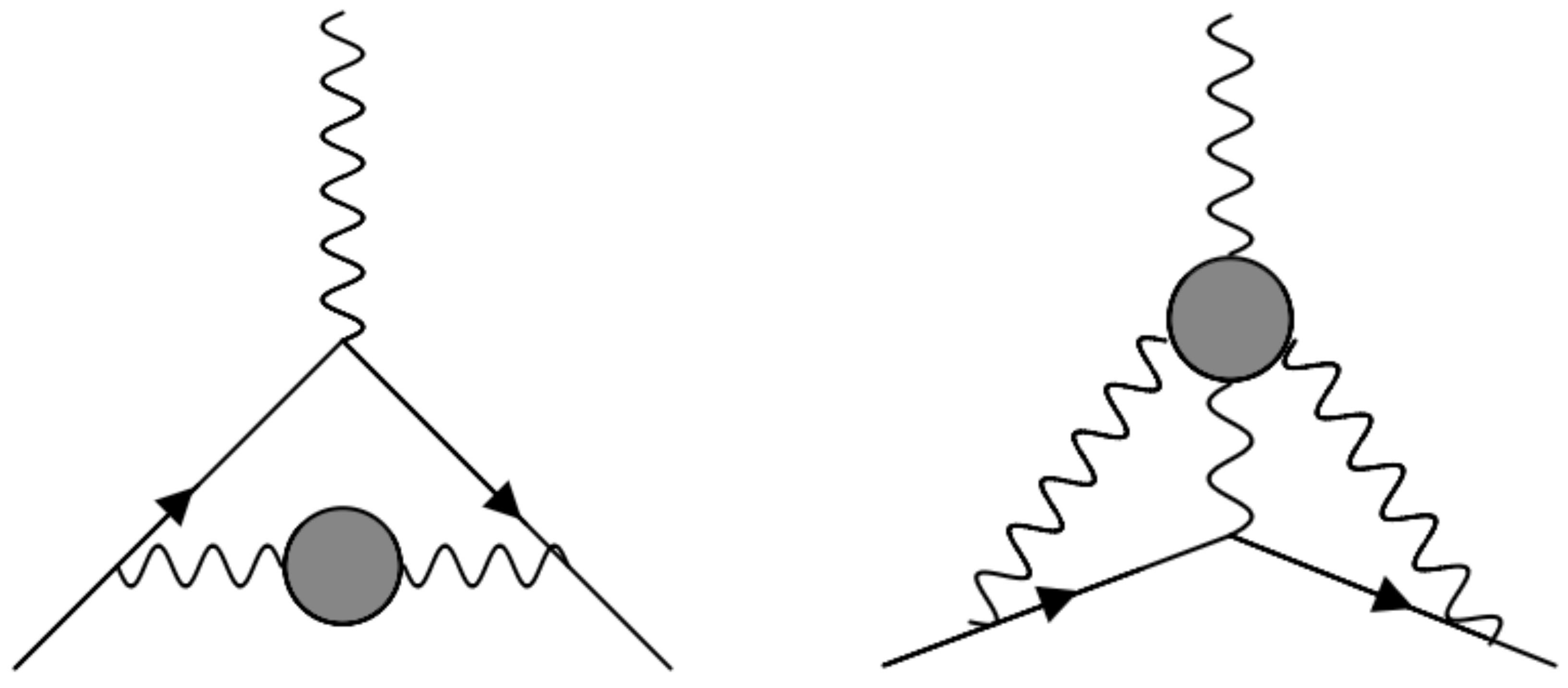
LO QED



LO ELECTROWEAK



LO HADRONIC



Basics of the anomalous magnetic moment

- Does the Standard Model tell the whole story or it is an incomplete picture?

$$a_\mu^{SM(WP)} = 116591810(43) \times 10^{-11} \quad [37]$$

$$a_\mu^{exp.(2023)} = 116592059(22) \times 10^{-11} \; [39]$$

DISCREPANCY OF >5σ

- Is this a window to new physics (BSM) or do we need more theoretical precision?

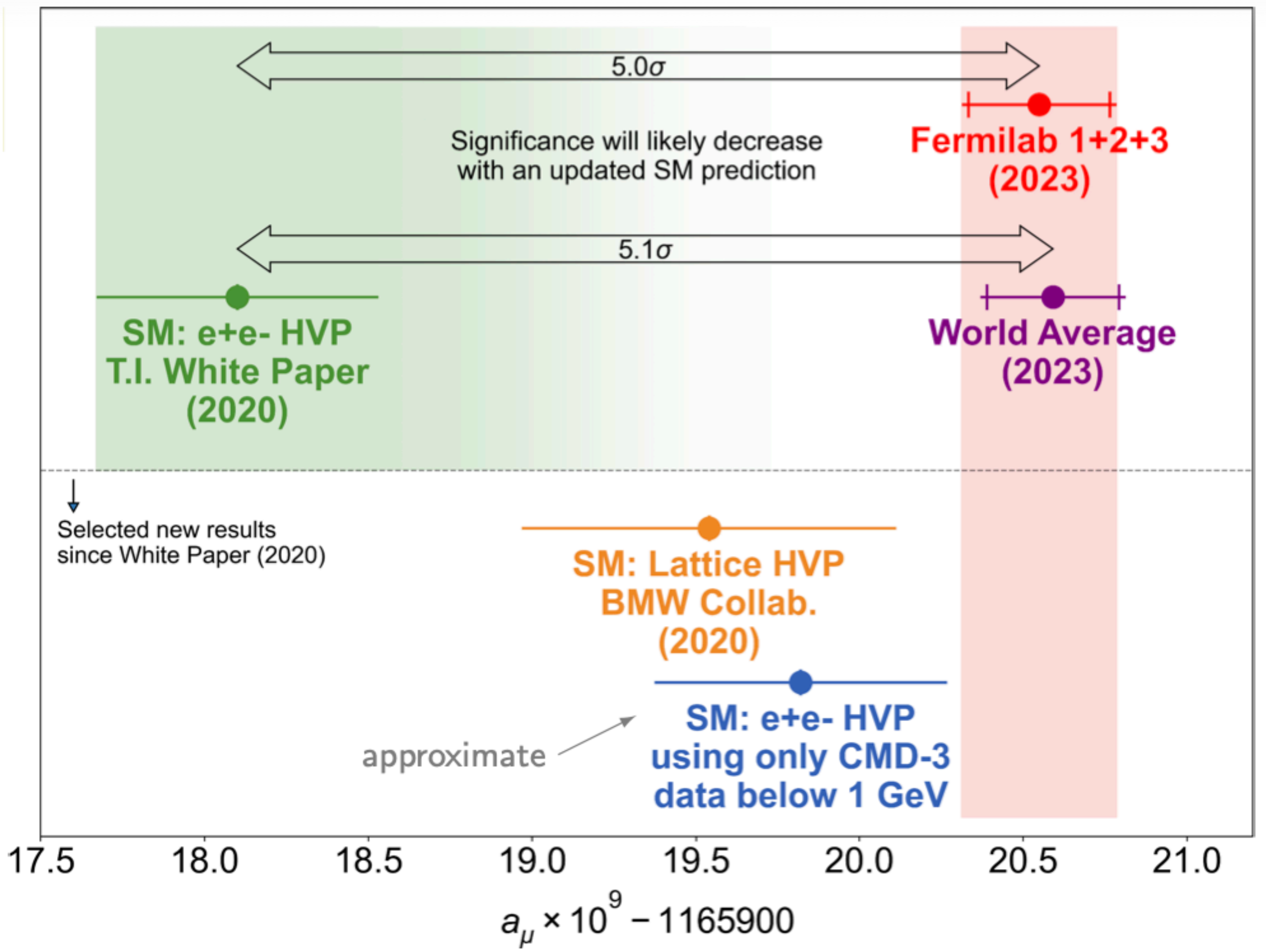


Figure 3: The present discrepancy between experimental results and the SM prediction for the a_μ [38].

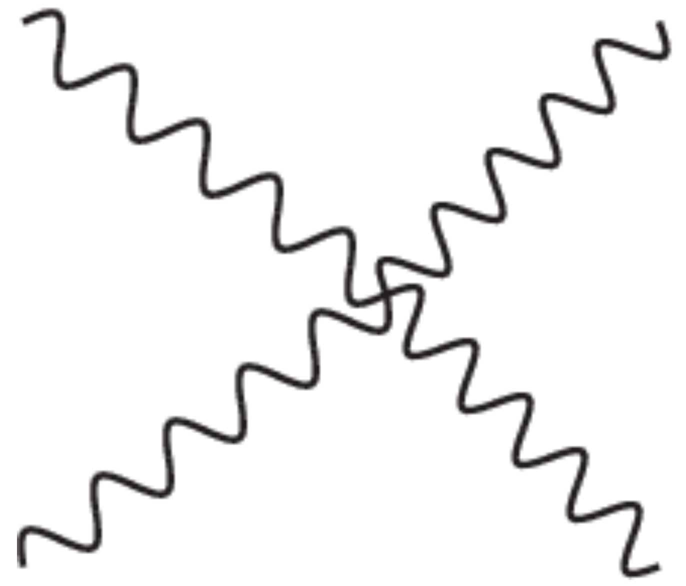
2. Born-Infeld Theory

Born-Infeld Theory

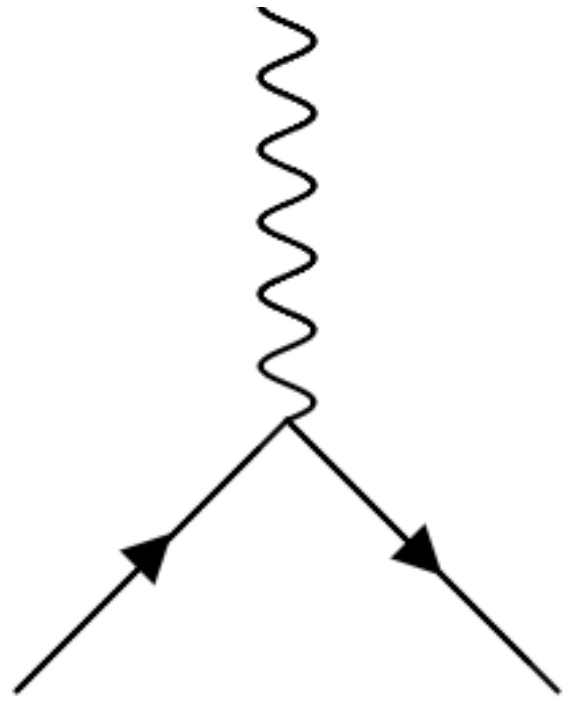
- The **Born-Infeld lagrangian** [48] incorporates non linearities

$$\mathscr{L}_{BI} = \beta^2 \left(1 - \sqrt{1 + \frac{1}{2\beta^2} F_{\mu\nu}F^{\mu\nu} - \frac{1}{16\beta^4} (F_{\mu\nu}\tilde{F}^{\mu\nu})^2} \right)$$

$$= -\frac{1}{4} F_{\mu\nu}F^{\mu\nu} \boxed{- \frac{1}{32\beta^2} (F_{\mu\nu}F^{\mu\nu})^2 + \frac{1}{8\beta^2} (\tilde{F}_{\mu\nu}F^{\mu\nu})^2} + \mathcal{O}(1/\beta^4)$$



- In the limit $\beta \to \infty$, we recover the kinetic term of the ordinary Maxwell Lagrangian.
- $[\beta] = M^2$



3. Born-Infeld: implications to the g-2

Born-Infeld: implications to the g-2

- At 3rd order: LbL extra contribution to the g-2.
- At 4th order: 13 LbL extra contributions to the g-2.

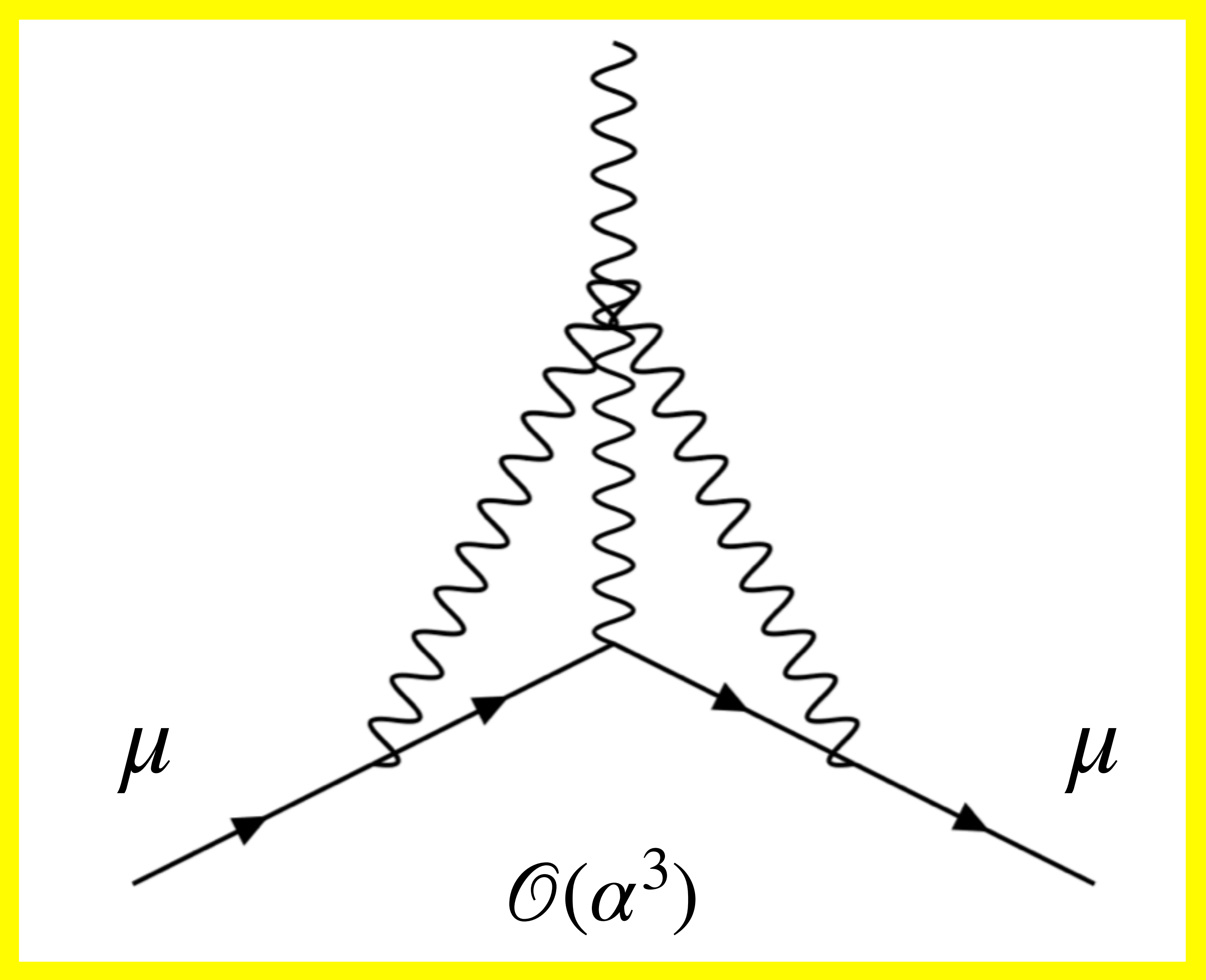


Figure 4: Light-by-light Born-Infeld contribution to the anomalous magnetic moment of the muon at order $\mathcal{O}(\alpha^3)$.

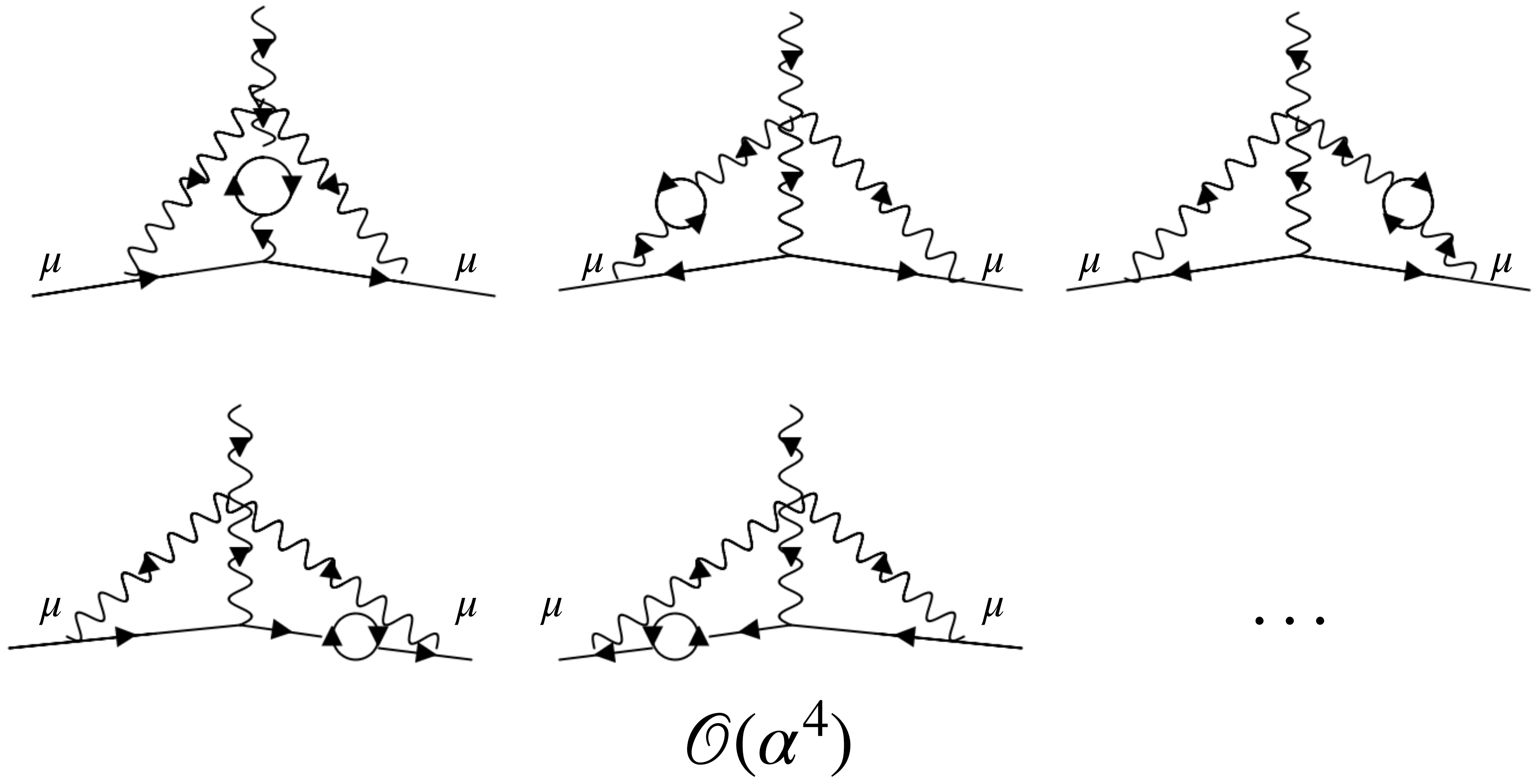


Figure 5: Light-by-light Born-Infeld contribution to the anomalous magnetic moment of the muon at order $\mathcal{O}(\alpha^4)$.

4. Constraining Born-Infeld parameter

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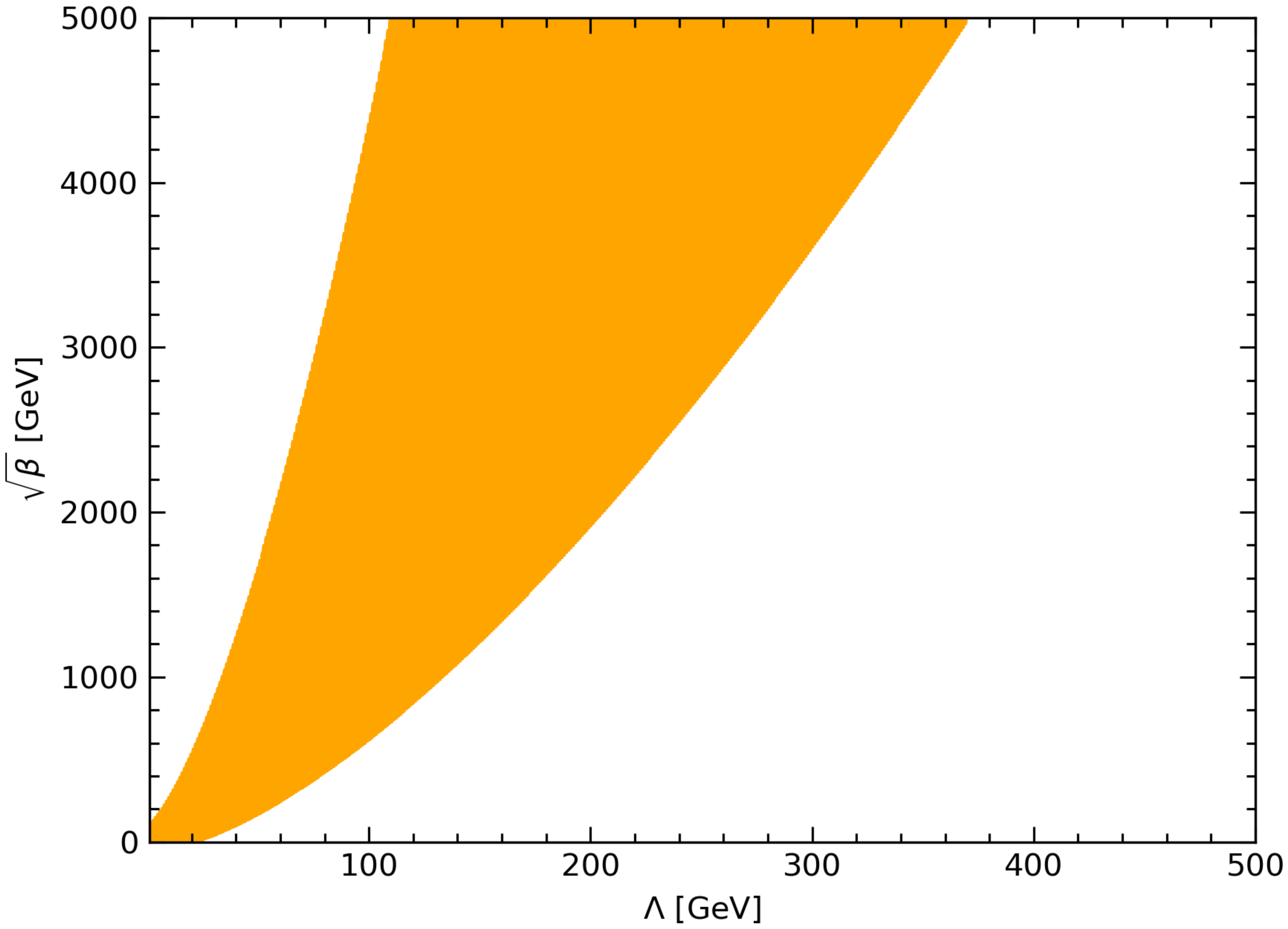
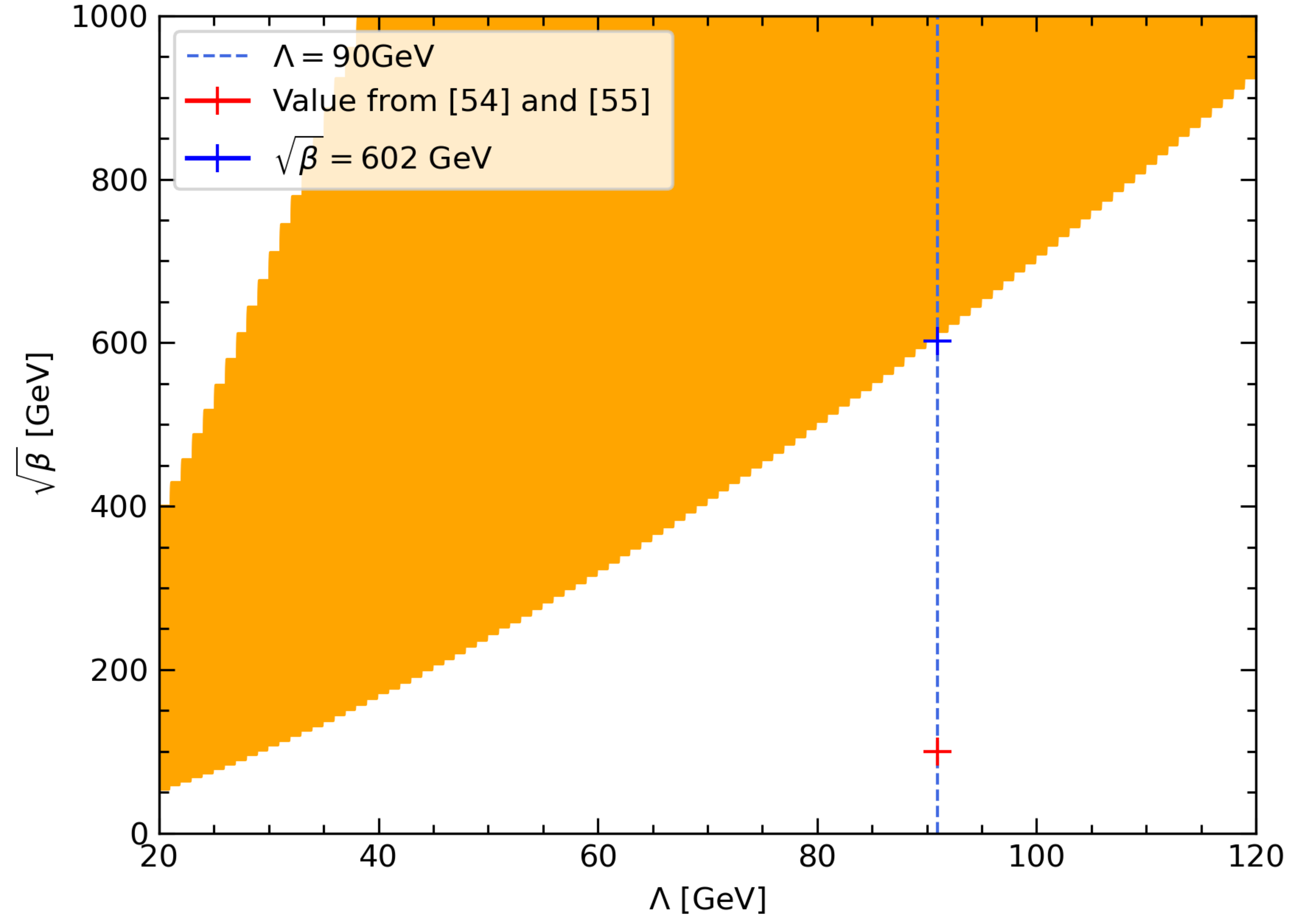


$$3.80807 \times 10^{-9} \leq a_\mu^{LbyL;BI} \leq 3.83076 \times 10^{-6}$$

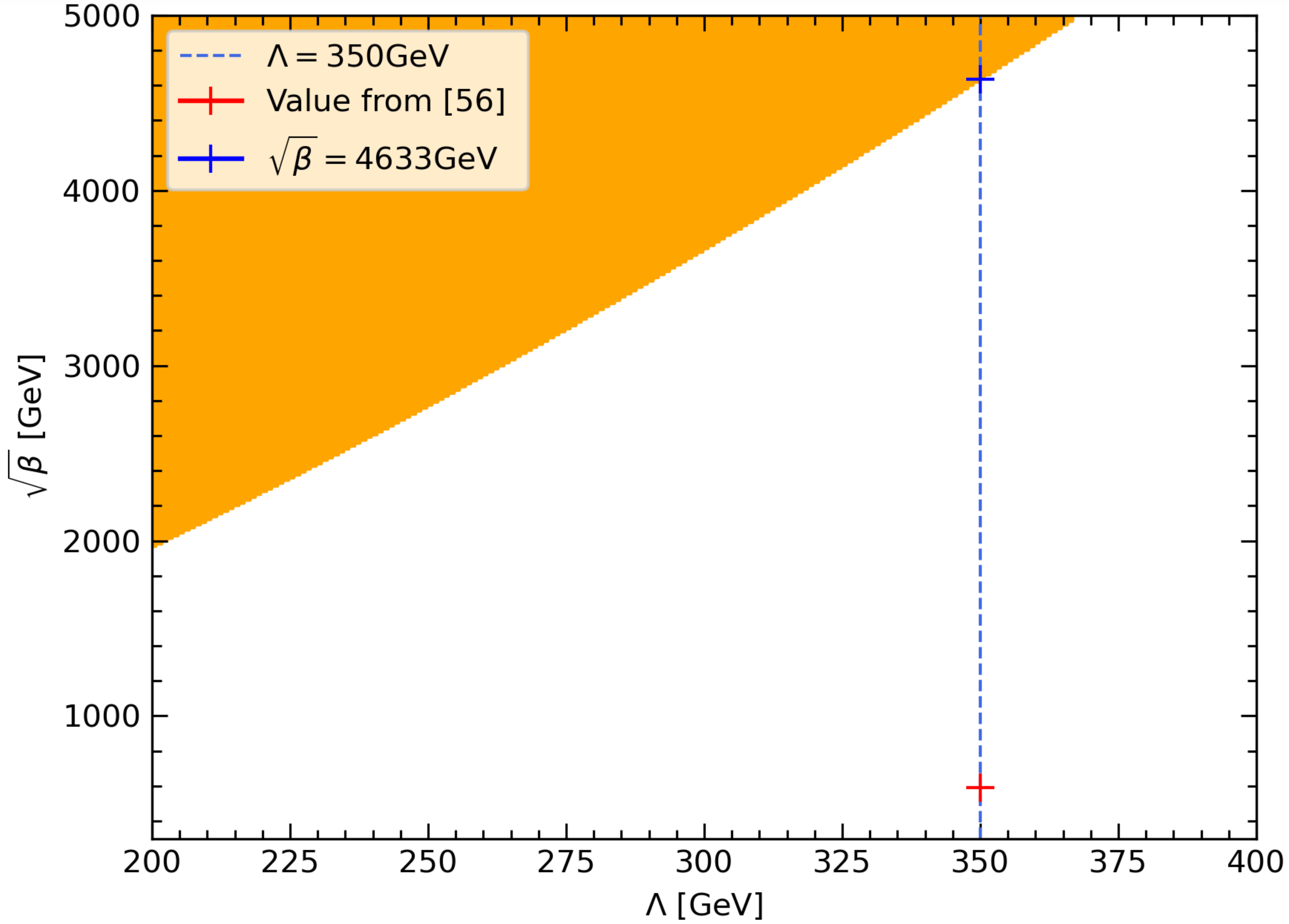
$$a_\mu^{LbyL;BI} \leq (a_\mu^{exp.(2023)} - a_\mu^{SM(WP)})$$ [28]

Figure 6: The Born-Infeld parameter, $\sqrt{\beta} = M$, as a function of the cutoff. The orange color represents that the combination of values for $(\sqrt{\beta}, \Lambda)$ fullfill the restriction of $a_\mu^{LbyL;BI}$ lying within the range 3.83076×10^{-6} to 3.80807×10^{-9}.

Constraining Born-Infeld parameter



a) Cut off Λ ranging from 20 to 120 GeV.



b) Cut off Λ ranging from 200 to 400 GeV.

Figure 7: Comparison of QED Born-Infeld scale $\sqrt{\beta}$ limits fro \(\sqrt{\beta}\) m literature [54] ,[55] and [56] and our results.

Thank you!

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6. References

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