FR-PHENO-2026-XXX

Imprint of the anomalous magnetic moment of the τ-lepton in the $\tau^+\tau^-$ production via ultraperipheral heavy-ion collisions at the LHC.

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Abstract

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Contents

1 Introduction

2 Features of the calculation

2.1 Form-factor approach

- Keep this section for a general lepton and focus on the τ-lepton in the numerics to emphasize that the same analysis can be done for e and μ as a check of the method(?).

2.1.1 Form-factor decomposition of the $\gamma\bar{\tau}\tau$ vertex function

- Mention the problem of the off-shell τ in the standard approach.

- Outline the way how the general form-factor decomposition is obtained.

- Give the general form-factor decomposition in the on-shell basis.

- Give the transformation properties under space-time discrete symmetries of each term (no details).

- Give the from-factor decomposition in the standard kinetical configuration and in "ours".

- Remark that the decomposition is gauge dependent (Ward identities).

2.1.2 Extracting the contribution from a_τ

- Write matrix element with the general vertex decomposition.

- Perform an expansion of the form factors in α.

- Remark again the presence of gauge dependence in this decomposition.
- Remark the absence of effects due to real radiation in the form factor approach.
- Perform Taylor expansion of the form factors around $\frac{x}{s} \sim \frac{m^2}{s}$ $(x = t, u)$ to extract a_τ and d_τ contributions.

2.1.3 Coulomb term and Sommerfeld enhancement

- Explain the need of including the Coulomb term.
- Give the contribution from Coulomb term.

2.1.4 Analytical expressions for the helicity amplitudes (?)

- Give analytical expression in the spinor-helicity formalism for $\mathcal{M}^{(0)}$, $\mathcal{M}^{a_\tau}$, $\mathcal{M}^{d_\tau}$.

2.2 Technical aspects of the calculation and employed tools

- Use of equivalent-photon approximation.
- Use of iNWA to include spin correlations.
- Use of mixed input-parameter scheme.

Checks on the calculation

- Analytical expressions checked against FeynArts.
- Correct behaviour under $\mathcal{P}$, $\mathcal{C}$ and $\mathcal{CP}$ of $\mathcal{M}^{(0)}$, $\mathcal{M}^{a_\tau}$, $\mathcal{M}^{d_\tau}$ (?).

2.3 Set-up of the calculation

Numerical input

- Numerical inputs

Event selection

- ATLAS set-up

3 Results

3.1 Comparison between the form-factor and the fixed-order calculation

- Reference to the previous paper for details on the NLO prediction.
- Show the relevance of the non included effects in the form-factor approach, *i.e.*

$$\Delta_{\mathrm{FF}} = \frac{\sigma^{\mathrm{FF}} - \sigma^{\mathrm{QED_P}}}{\sigma^{\mathrm{QED_P}}} \tag{1}$$

3.1.1 Inclusive τ-pair production

- Comparison just for the production, *i.e.* no τ-decays.
  - Show it just for unpolarized τ-leptons.
  - Mention that a_τ is part of QED corrections, which are gauge invariant independently and, thus, they can be compared.

Fixed photon–photon centre-of-mass energy

- Show comparison for fixed c.m.e. $(3.8, 5(?), 10, 18\,\mathrm{GeV}?$ or all?)
  - Remark importance of the Coulomb term for small c.m.e..
  - Remark the importance of using observables that are not sensitive to collinear radiation off the produced τ-leptons.

Ultraperipheral heavy-ion collision

- Show comparison with photon flux.
  - Mention the problem in Ref. [1]:
    * Wrong input-parameter scheme $\rightarrow$ Fixable by considering the cross section, not just the correction.
    * They do not include the Coulomb term $\rightarrow$ Wrong value for a_τ obtained.

3.1.2 τ-pair production with leptonic τ-decays

- Comparison including leptonic τ-decays.
  - Show the comparison between $\sigma_{\mathrm{P}}^{\mathrm{QED}}$ vs σ^{FF}.
  - Show the comparison between σ^{NLO} vs $\sigma^{\mathrm{FF}} + \Delta\sigma_{\mathrm{D}}^{\mathrm{NLO}} + \Delta\sigma_{\overline{\mathrm{D}}}^{\mathrm{NLO}}$.
  - Remark the importance of including the corrections to the decays in the form-factor calculation (or of extracting these corrections to the fixed-order calculation). Specially if $p_{\mathrm{T},\mu}$ is employed in the analysis.

Fixed photon–photon centre-of-mass energy (?)

- Show inclusive predictions for fixed c.m.e.
  - Remark again the dominance of the Coulomb term in the NLO correction for small c.m.e.
  - Show that the sensitivity of $p_{\mathrm{T},\mu}$ to collinear radiation off the produced τ-leptons is not determinant and, thus, it is a good observable.

ATLAS set-up

- Show the comparison for the ATLAS set-up.
  - Comment that the Coulomb contribution is suppressed (neglectable) here due to the presence of $p_{\mathrm{T},\ell}$ cuts.

Dependence on the choice of $p_{\mathrm{T},\ell}$ cuts

- Show the comparison for $p_{\mathrm{T},\ell} > 2, 4, 6\,\mathrm{GeV}$.
    - Comment the problem of having a large $p_{\mathrm{T},\ell}$ cut if enough precision is reached.

Spin-correlation effects (?)

3.2 Impact of BSM contributions to a_τ in the cross section

- Show plot with different values of a_τ. (Maybe use $a_\tau^{\mathrm{SM}} + a_\tau^{\mathrm{BSM}}$).

3.3 Impact of BSM contributions to d_τ in the cross section

- $d_\tau^{\mathrm{SM}} = 0$.
    - $\mathcal{O}\big(d_\tau^{\mathrm{BSM}}\big) \to 0$.
    - $\mathcal{O}\big((d_\tau^{\mathrm{BSM}})^2\big)$ terms needed.

4 Conclusion

Appendix

References

[1] J. Jiang, P.-C. Lu, Z.-G. Si, H. Zhang, and X.-Y. Zhang, *NLO EW corrections to tau pair production via photon fusion in Pb-Pb ultraperipheral collision*. arXiv:2410.21963 [hep-ph].