STRONG 2020 Virtual Workshop

25th November 2021

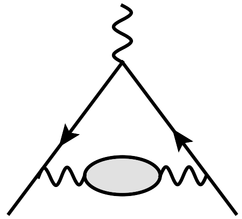
Remarks on mixed leptonic and hadronic contributions to g-2

UNIVERSITY OF LIVERPOOL

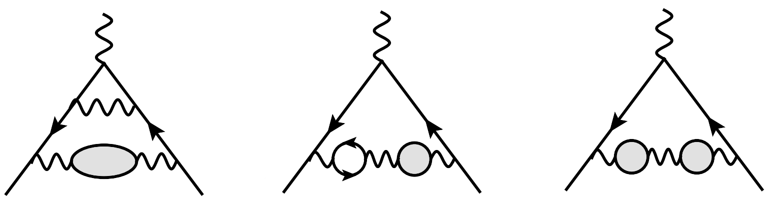
Thomas Teubner

- Power counting & series organisation
- Missing O(α^4) contributions from hadronic corrections in lepton loops
- Lepton pair emission in hadronic cross sections

a_μ^{HVP} : Higher orders & QED power counting (WP20 values in 10^{-11})



- ➤ Hadronic blobs must contain **photons**, i.e. QED real + virtual corrections
  means, at higher order, lepton pairs



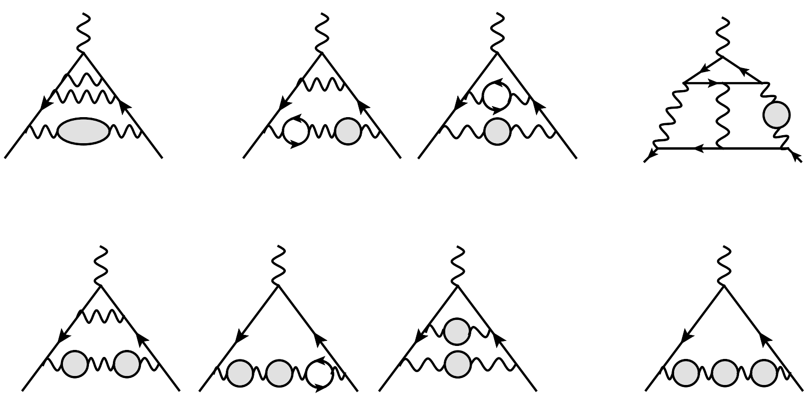
- LO: 6931(40)

- NLO: - 98.3(7)

  from three classes of graphs:

  - 207.7(7) + 105.9(4) + 3.4(1) [KNT19]

  (photonic, extra e-loop, 2 h-loops)



- NNLO: 12.4(1) [Kurz et al, PLB 734(2014)144, see also F Jegerlehner]

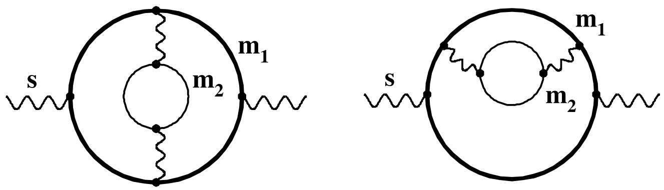
  from five classes of graphs:

  8.0 - 4.1 + 9.1 - 0.6 + 0.005

➥ good convergence,
iterations of hadronic blobs very small

$a_\mu^{lep\text{-}had}$: Missing contributions from `hadronic in leptonic' loops

But what about `double bubbles', where a lepton loop contains a hadronic loop?



with the outer loop labelled by m_1 any charged lepton, the inner m_2-loop any quark/hadron

- These appear at $O(\alpha^4)$ in QED, but:

- While **QED corrections** are known up to including $O(\alpha^5)$, they **do not include mixed leptonic-hadronic corrections**

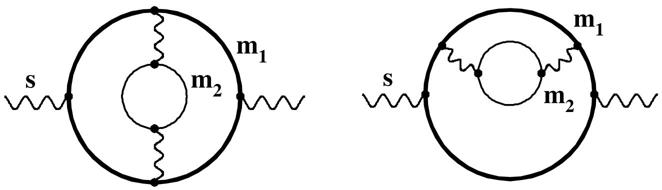
- However, of the $a_\mu^{QED}(\alpha^4) \sim 131\,(\alpha/\pi)^4 \sim 38 \times 10^{-10}$ only a small (~1%) fraction comes from double bubbles, and of those only a tiny fraction from higher-mass mixed (outer e or μ with inner τ) loops [decoupling of heavy loops]

➡ any double bubble with `outer lepton inner hadron' is **negligible**

- Same conclusion from studies of hadron radiation in leptonic Z decays, where hadron emission estimated using R-data [Hoang+(Jezabek+)Kuehn+Teubner, ('94/)'95]

a_μ^{HVP} : Missing contributions from `leptonic in hadronic' loops?

What about the other way round, where a hadron loop contains a lepton loop?



Now: outer loop labelled by m_1 any quark (leading to hadrons), inner m_2–loop any lepton

- They should, in principle, be included in the determination of a_μ^{HVP}
- For the lattice approach, this would require higher order QED contributions.
- For the dispersive data-driven approach:

  -- all virtual+soft/collinear (leptonic) corrections **are** always part of the measured cross section (unless subtracted by using some theory/MC)

  -- real & virtual emission enhanced by $\ln^2(m_{lep}^2/s)$, $\ln^2$ cancels in sum of real+virtual, which in the `high energy limit' (large s) is enhanced by $\ln(m_{lep}^2/s)$, but

  -- only small s contribute in the a_μ^{HVP} dispersion integral

a_μ^{HVP} : Missing contributions from `leptonic in hadronic' loops?

- For the dispersive data-driven approach: more Qs than As

  -- How much hard (lepton) radiation could be missed, leading to missing contributions?

  -- Could lepton pair radiation affect event selection?

  -- Need also to consider the role of `pairs' in normalisation cross sections (Bhabha or muon pair production)

  -- Given that extra FSR photon emissions seem to be under control at the currently required accuracy (see Michel's talk), and given that this is one order higher in $(\boldsymbol{\alpha/\pi})$, we are probably safe, but this may require more studies in the future

Discussion

- Event selection and cuts in experiments?
- `Pairs' in generators?