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NLO and NNLO hadronic vacuum polarization contributions to the muon g-2 in the space-like region

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The leading-order (LO) hadronic vacuum polarization (HVP) contribution to the muon g-2, $a_\mu^{\rm HVP}({\rm LO})$, is traditionally computed via dispersive "time-like" integrals using measurements of the hadronic production cross-section in e^-e^+ annihilations. An alternative method is provided by lattice QCD. At LO, simple "space-like" formulas are well-known and form the basis for the lattice QCD calculation as well as for the determination of $a_\mu^{\rm HVP}({\rm LO})$ expected from the proposed MUonE experiment at CERN.

In this talk, we describe the results of a joint work of Elisa Balzani, Stefano Laporta, and Massimo Passera (see arXiv:2112.05704). We present simple exact analytic formulas for the space-like determination of $a_\mu^{\rm HVP}$ at next-to-leading order (NLO) and a mix of exact and approximated formulas at next-to-next-to-leading order (NNLO).

First, we review the well-known simple space-like integral formula for the LO contribution $a_\mu^{\rm HVP}({\rm LO})$. Then, we consider the NLO contributions. Using the results of Barbieri and Remiddi (1975), we obtain the exact time-like integral formulas for the HVP contributions of all three classes of NLO diagrams. In particular we get the exact two-loop space-like kernel $\kappa^{(4)}(x)$. We analyze also some approximations to $\kappa^{(4)}(x)$ considered in the past in the literature, and show that these approximations give rise to an error of $\sim 6\%$ of the total NLO contribution. This error can be eliminated using our exact expression for $\kappa^{(4)}(x)$.

At last, we consider the NNLO contributions. For the diagrams composed of one- or two-loop vertices and one or more HVP insertions on the same photon line, we are able to get exact space-like integral formulas. For the diagrams containing actual three-loop vertices, like e.g. light-light diagrams, by using the large-s expansions of the time-like kernels provided in the literature, we are able to find very good approximations of the space-like kernels.

In the case of the problematic class of diagrams containing a two-loop vertex and HVP insertions on both photon lines, bidimensional space-like kernels are required. For this class of diagrams, we are able to get a good approximated bidimensional space-like kernel from the bidimensional expansions of the time-like one.

The results presented in this talk can be employed in lattice QCD calculations of $a_\mu^{\rm HVP}$, as well as in space-like determinations based on scattering data, like that expected from the proposed MUonE experiment at CERN. They will allow precise and consistent comparisons, through NNLO, with results already obtained via time-like data.

In-person participation

Yes

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