Towards a new parametrization of tensor- and axial-vector-meson transition form factors

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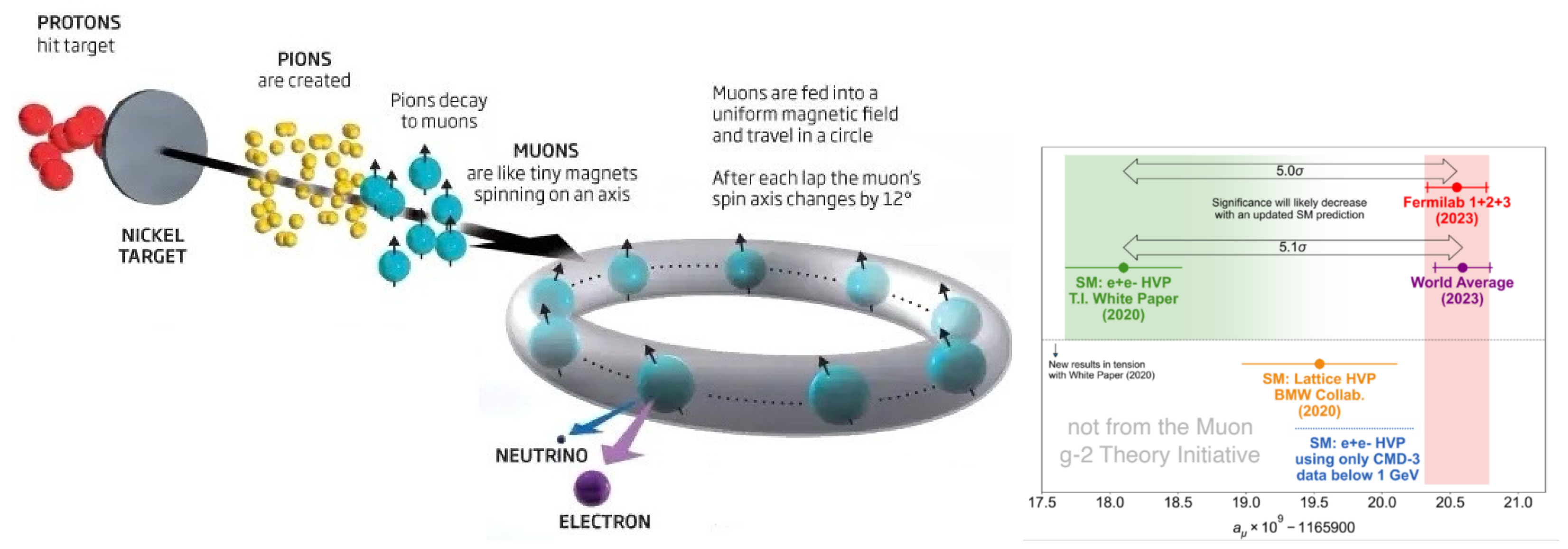
Motivation: g-2

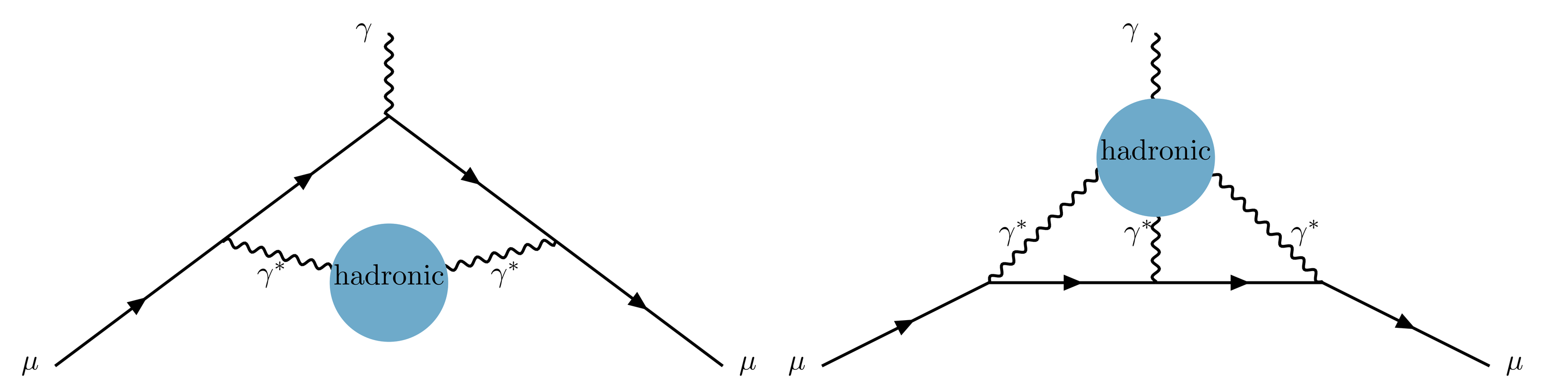
Anomalous magnetic moment of the muon: extremely high-precision quantity

- g-factor of muon expected to be 2 from spin: $\vec{\mu}_s = g\frac{e\vec{S}}{2m}$
- radiative/loop corrections effect deviations: $\frac{g_\mu - 2}{2} =: a_\mu \neq 0$
- can be measured by observing muon spin precession in a magnetic storage ring
- theory calculation in Standard Model using data-driven dispersive approaches and lattice methods; 2020 value (without lattice): $a_\mu^{\text{SM}} = 116591810(43) \times 10^{-11}$ [1]
- deviation of $\sim 5\sigma$ between Ref. [1] and experimental average measurement, $a_\mu^{\text{exp}} = 116592059(22) \times 10^{-11}$ [2]



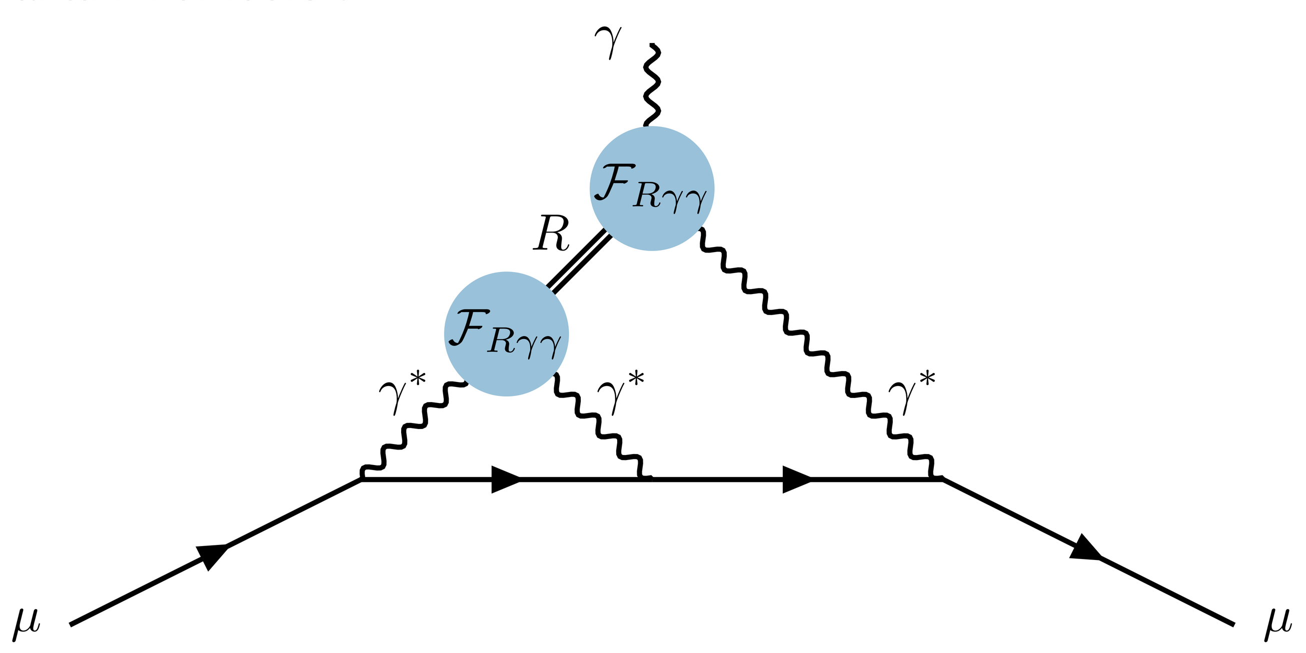
[NewScientist, "Muon whose army? (19 May 2010)]
[Bingzhi Li(Unlisted, CN) for the Muon g-2 collaboration. (Apr 29, 2024), PoS HQL2023 (2024) 009]

- a_μ includes QED and electroweak contributions (well-known)
- currently under debate: hadronic contributions, hadronic vacuum polarization (HVP) and **hadronic light-by-light** scattering (HLbL)



Poles and transition form factors

Different intermediate states contribute to the HLbL part of a_μ^{SM}, including resonances R with quantum numbers J^{PC}



- the resonance couples to (virtual) photons via transition form factor $\mathcal{F}_{R\gamma\gamma}$
- describe $\mathcal{F}_{R\gamma\gamma}$ with different models, involving vector-meson dominance and dispersive treatment

Axial-vector & tensor mesons

Can consider an axial-vector (A) or a tensor meson (T) as the intermediate resonance

Axial-vector mesons ($J^{PC} = 1^{++}$) notoriously difficult to measure due to Landau-Yang theorem which forbids decay to real photons

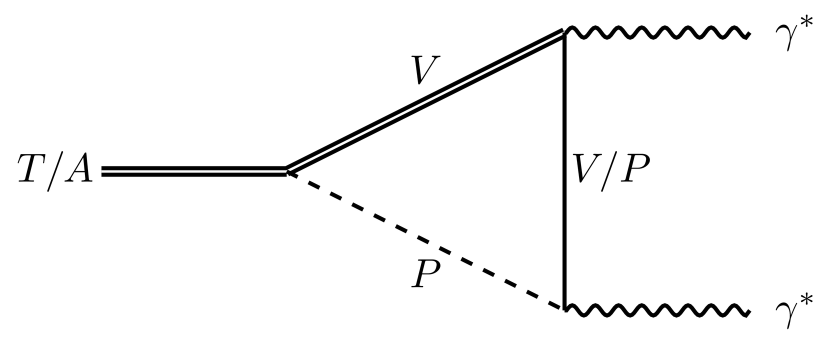
- for $A = f_1(1285)$, can make connection to decay $f_1 \to e^+e^-$, scattering $e^+e^- \to f_1\pi^+\pi^-$, and other processes [3, 4] as $\mathcal{F}_{A\gamma\gamma}$ is universal
- for $A = a_1(1260)$, less experimental data, but main decay to 3π or $\rho\pi$

Tensor mesons ($J^{PC} = 2^{++}$) are not restricted by the Landau-Yang theorem

- for $T = a_2(1320)$, the main decay channel is to 3π or $\rho\pi$; connection to scattering process $e^+e^- \to a_2\, e^+e^-$ [5]

Framework

Model the dynamical behavior of $\mathcal{F}_{A\gamma\gamma}$ and $\mathcal{F}_{T\gamma\gamma}$ via a left-hand cut

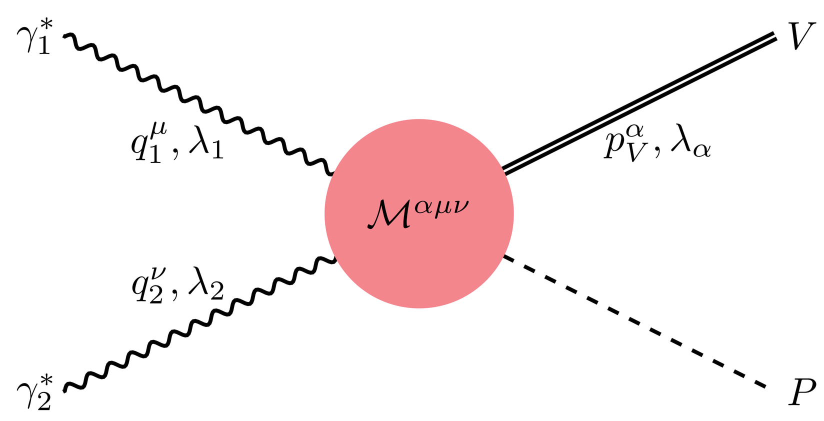


- dispersion relation for left-hand cut, describing the imaginary part in terms of the cross section with a vector-meson/pseudoscalar-meson pole
- framework based on ChPT including field representations for the pseudoscalar (P), vector (V_μ), axial-vector (A_μ) and tensor ($T_{\mu\nu}$) multiplets [6] (containing only the relevant degrees of freedom for considering $a_1^0/a_2^0 \to \rho^\pm\pi^\mp$)

$$P = \sqrt{2}\begin{pmatrix} 0 & \pi^+ & 0 \\ \pi^- & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad V_\mu = \sqrt{2}\begin{pmatrix} 0 & \rho_\mu^+ & 0 \\ \rho_\mu^- & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$A_\mu = \begin{pmatrix} a_{1\mu}^0 & 0 & 0 \\ 0 & -a_{1\mu}^0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad T_{\mu\nu} = \begin{pmatrix} a_{2\mu\nu}^0 & 0 & 0 \\ 0 & -a_{2\mu\nu}^0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

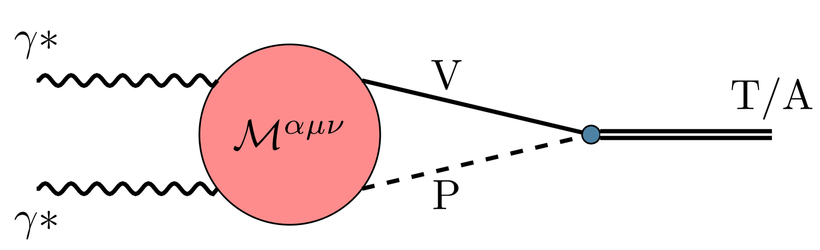
Connect to $VP \to \gamma^*\gamma^*$ amplitude $\mathcal{M}^{\alpha\mu\nu}$ (free indices will be contracted with polarization vectors of V, γ^*)



- decomposition as $\mathcal{M}^{\alpha\mu\nu} = \sum_i \mathcal{F}_i T_i^{\alpha\mu\nu}$
- need gauge-invariant description of the $VP \to \gamma^*\gamma^*$ vertex
- Lorentz structures $T_i^{\alpha\mu\nu}$ should be free of kinematic singularities and zeros $\to$ form factors $\mathcal{F}_i$ free of kinematic zeros and singularities (for dispersion relation)
- BTT procedure [7–9]: project $T_i^{\alpha\mu\nu}$ using Ward identities, form linear combinations in order to remove poles
- use Schouten identities to find basis for $\{T_i^{\alpha\mu\nu}\}$

Next steps

- contract $VP \to \gamma^*\gamma^*$ amplitude with the corresponding vertex for axial-vector or tensor meson,



- identify the form of the remaining form factors, based on dispersion relations, and perform the loop integral
- cross-check the model against experimental data

References

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