Dispersive analysis of the $\gamma^*\gamma^* \to \pi\pi$ process

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Abstract

In this paper, we present a dispersive analysis of the double-virtual photon-photon scattering to two pions up to 1.5 GeV. Through unitarity, this process is very sensitive to hadronic final state interaction. For the s-wave, we use a coupled-channel $\pi\pi$, $K\bar{K}$ analysis which allows a simultaneous description of both $f_0(500)$ and $f_0(980)$ resonances. For higher energies, $f_2(1270)$ shows up as a dominant structure which we approximate by a single channel $\pi\pi$ rescattering in the d-wave. In the dispersive approach, the latter requires taking into account t- and u-channel vector-meson exchange left-hand cuts which exhibit an anomalous-like behavior for large space-like virtualities. In our paper, we show how to readily incorporate such behavior using a contour deformation. Besides, we devote special attention to kinematic constraints of helicity amplitudes and show their correlations explicitly.

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Hadronic corrections to muon g-2

- Hadronic vacuum polarization: constrained by measurements of $e^+e^- \to hadrons$, measurements to be done BESIII and BELLE-II.
- Hadronic light-by-light processes:
  1. $\gamma^*\gamma^* \to \pi^0$. Constraints from VMD models, and experiment
  2. $\gamma^*\gamma^* \to \pi\pi$. Few experimental constraints
- Virtuality is important in HLBL.

Danilkin et al. calculation of $\gamma^*\gamma^* \to \pi\pi$

- s-wave: coupled channels analysis of $\pi\pi$ and $K\bar{K}$ final states provides simultaneous description of $f_0(500)$ and $f_0(1980)$
- d-wave: single channel $\pi\pi$ rescattering to describe $f_2(1270)$
- No treatment of the polarizabilities: Born amplitudes are evaluated, leading order polarizability terms could be calculated

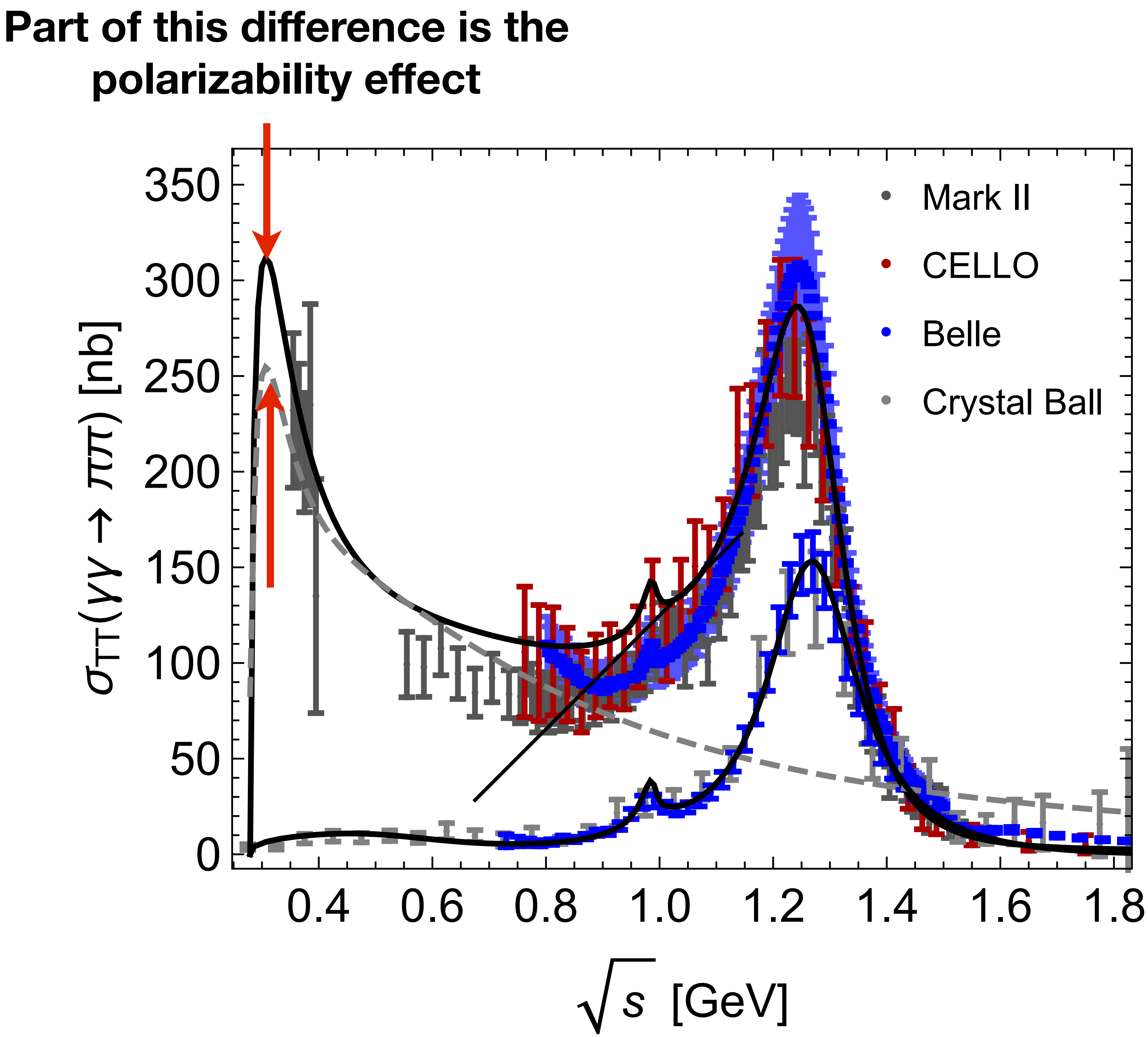

Figure 2: Total cross sections for $\gamma\gamma \to \pi^+\pi^-$ ($|\cos\theta| < 0.6$) (upper curve) and $\gamma\gamma \to \pi^0\pi^0$ ($|\cos\theta| < 0.8$) (lower curve). The Born result is shown by dashed gray curves. The data are taken from [35].

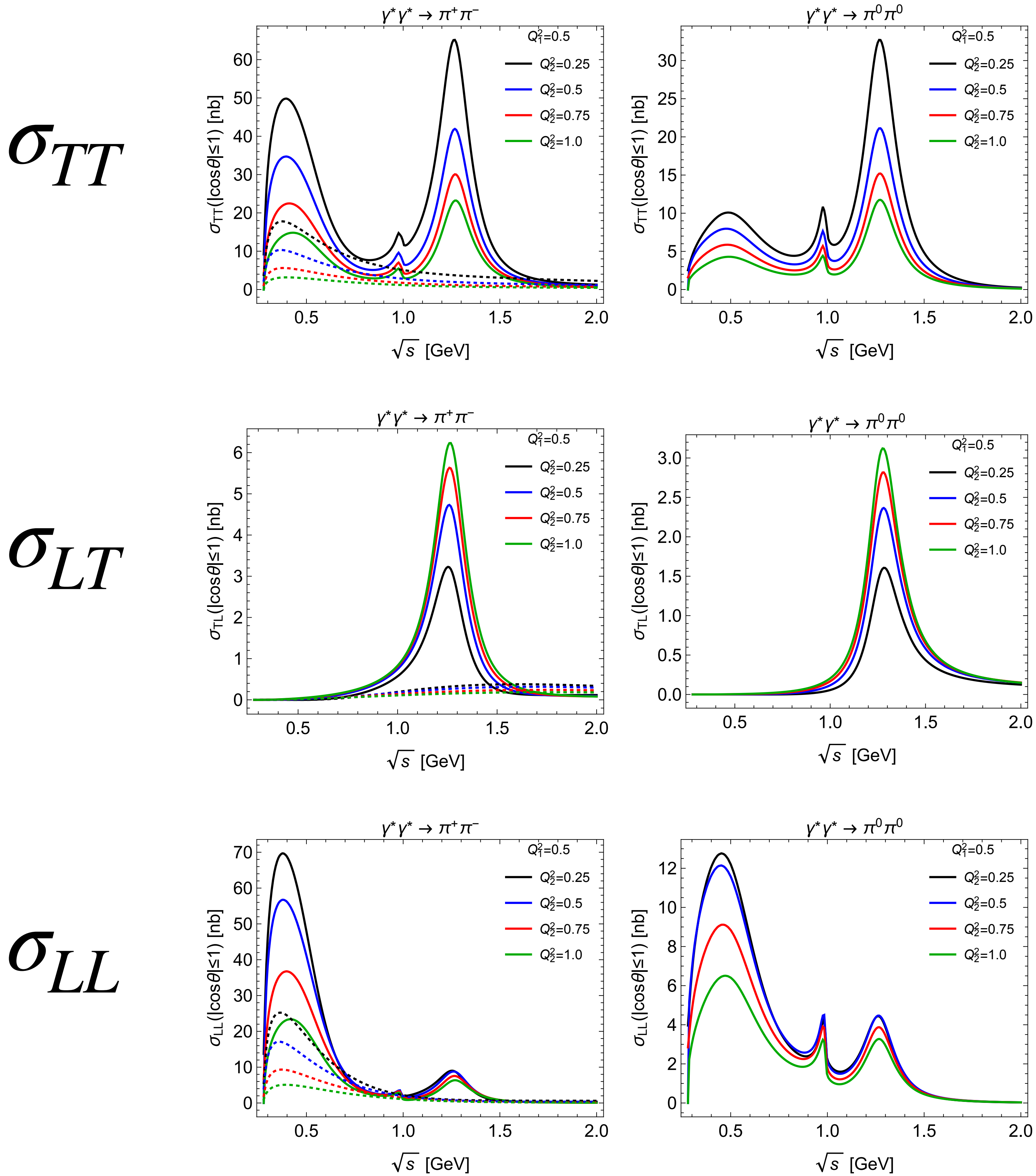

Figure 3: Predictions for σ_{TT}, σ_{TL}, σ_{LL} cross sections for $\gamma^*\gamma^* \to \pi^+\pi^-$ (left panels) and $\gamma^*\gamma^* \to \pi^0\pi^0$ (right panels) for $Q_1^2 = 0.5$ GeV^2 and $Q_2^2 = 0.25, 0.5, 0.75, 1.0$ GeV^2 and for full angular coverage $|\cos\theta| \leq 1$. The Born results are shown by dotted curves.

Papers on $\gamma\gamma \to \pi\pi$

Pasquini, Drechsel, Scherer, “Polarizability of the pion: no conflict between dispersion theory and chiral perturbation theory”. 2008

Dai and Pennington, “Pion polarizabilities from a $\gamma\gamma \to \pi\pi$ analysis”. 2016

Danilkin, Deineka, Vanderhaeghen, “Dispersive analysis of the $\gamma^*\gamma^* \to \pi\pi$ process”. 2019