Study of Kπ radiative transitions from Lattice QCD

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Summary

We present the study of the P-wave Kπ to Kγ transitions which features the resonance K*(892) from Lattice Quantum Chromodynamics (Lattice QCD).

Motivation

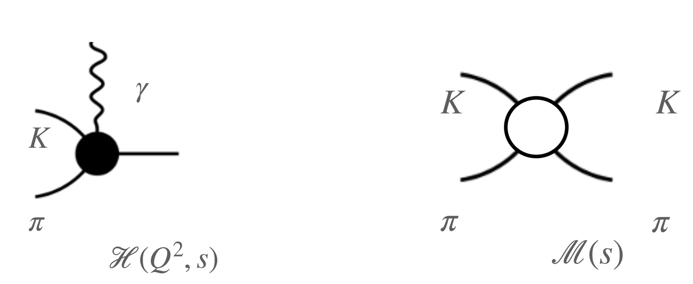
The electromagnetic transition matrix elements appear in Primakoff production. Measurements of such processes will be made in experiments like COMPASS[1]. Currently Lattice QCD is the only rigorous way to calculate such matrix elements directly from QCD.

The previous calculation of electromagnetic transition matrix elements from Lattice QCD has been done for the ππ to πγ system involving the ρ resonance[2][3]. This will be the first calculation of the K* transition matrix elements from LQCD.

Transition amplitudes

Transition amplitudes are related to the two particle scattering amplitude because the Kγ can create a Kπ which can then re-scatter. We are interested in calculating the amplitude $\mathscr{A}(Q^2, s)$ where s is the center of mass energy of the two particle system and Q² is square of the four momentum transfer.

$$\mathscr{H}(Q^2, s) = \mathscr{A}(Q^2, s)\frac{1}{k_{cm}}\mathscr{M}(s)$$

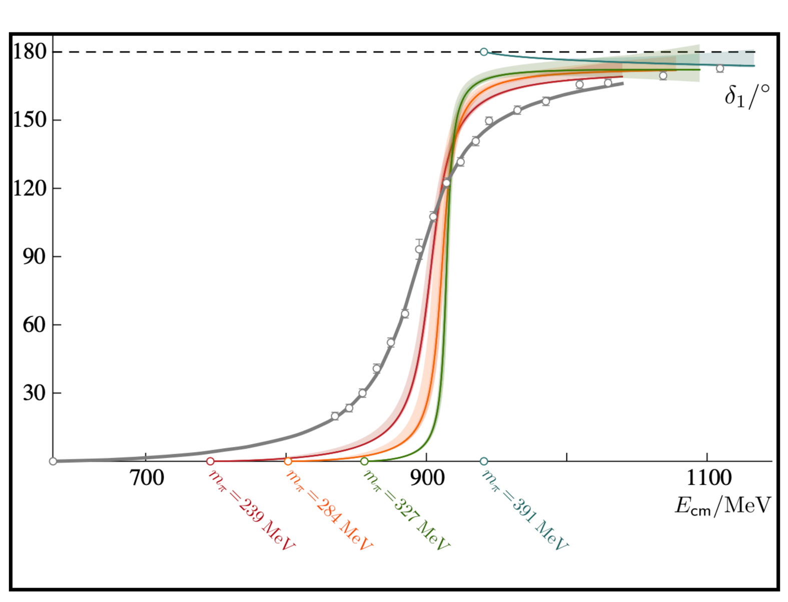


Same principle follows in finite volume where the transition amplitudes are finite volume corrected using the Lellouch-Lüscher factor[4][5] calculated from Kπ scattering amplitude.

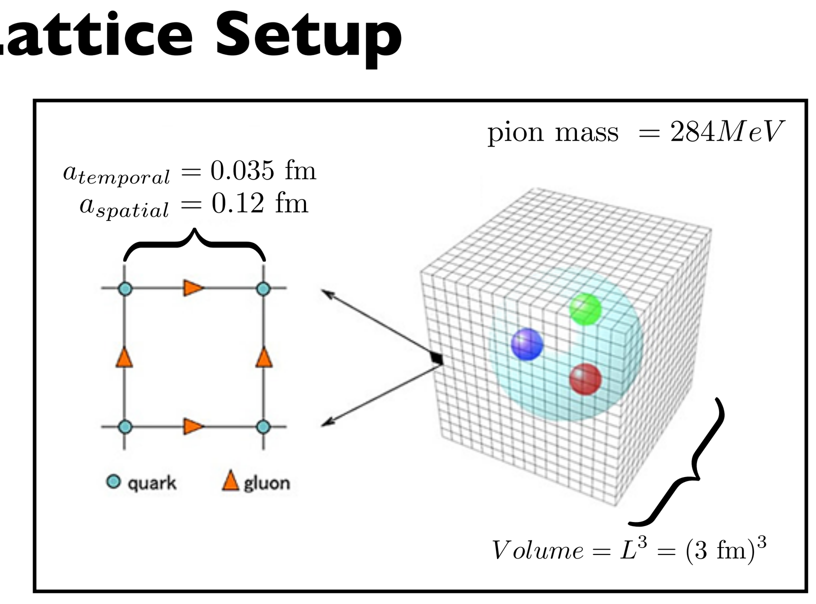
Kπ Scattering

This work builds upon the previous calculation of Kπ scattering where the amplitude ($\mathscr{M}(s)$)[5] was determined.

Using $\mathscr{M}(s)$ from different choices of parameterizations, the finite volume corrections to the matrix elements are determined using the Lellouch-Lüscher formalism.

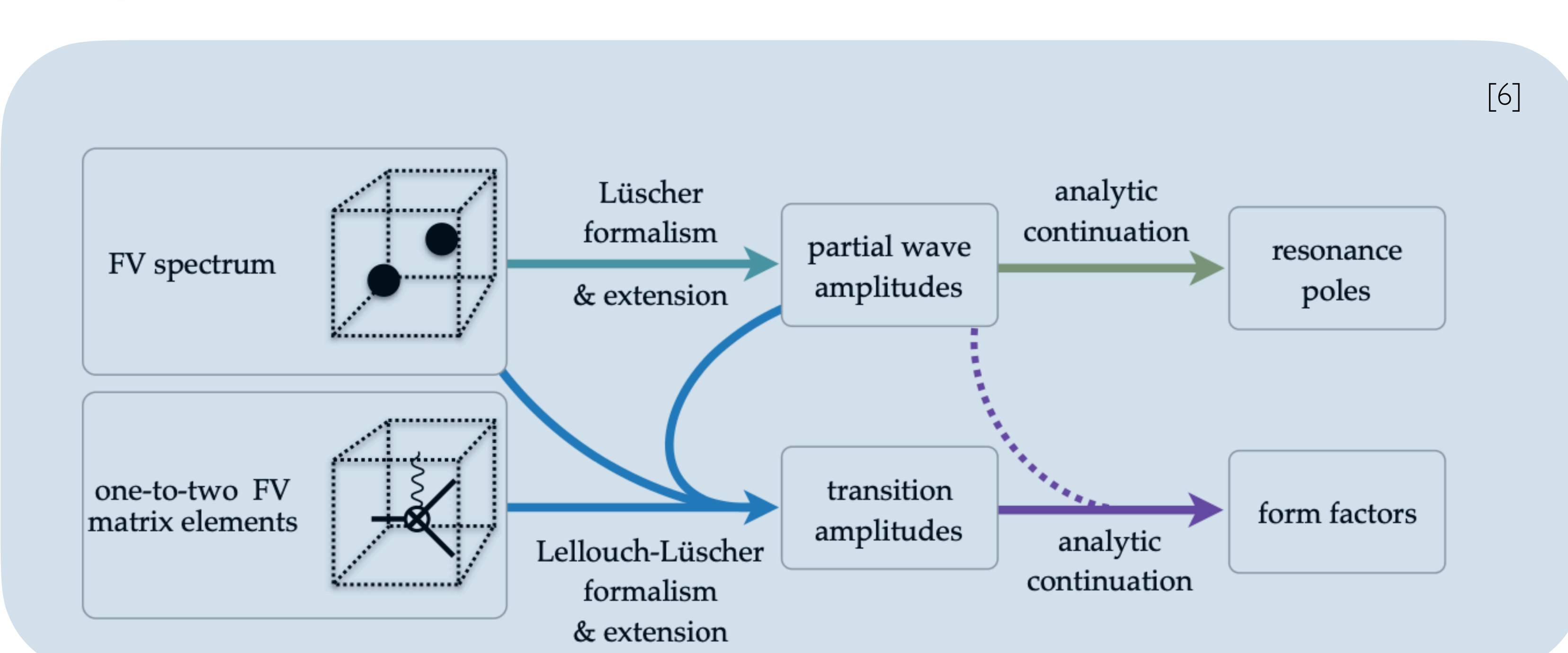


Lattice Setup

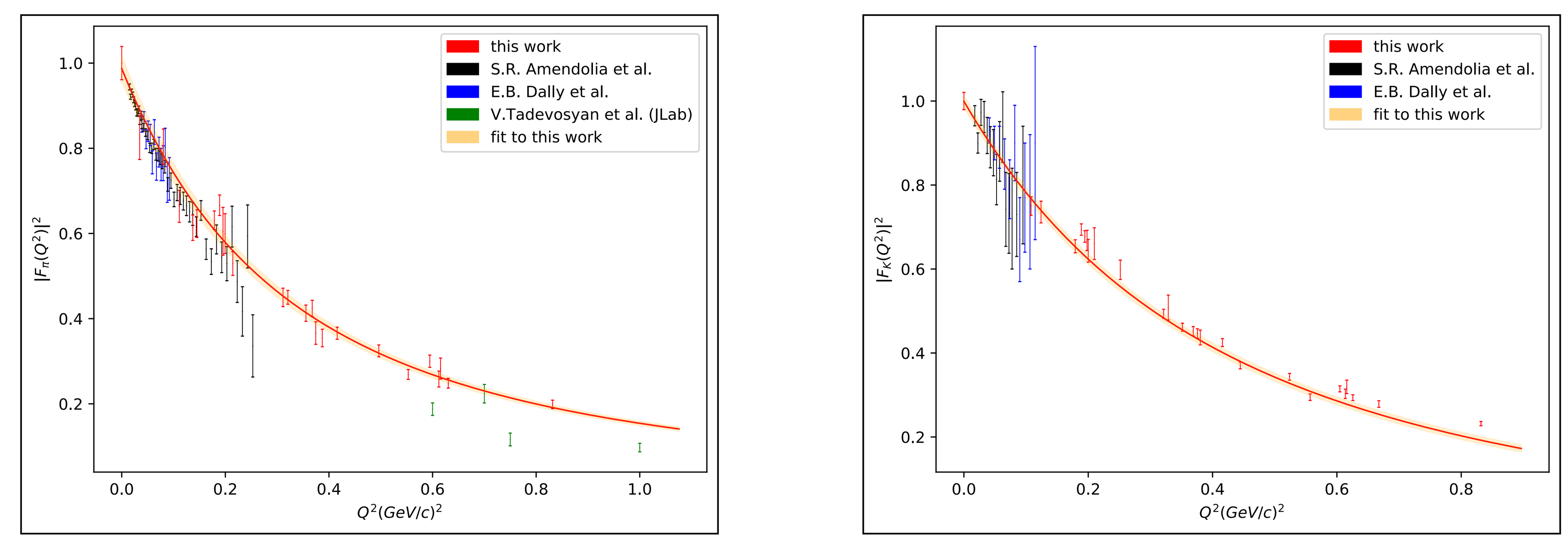


- The finite lattice spacing implies that the matrix elements have to be renormalized.
- The finite volume means that there has to be a mapping to the infinite volume to calculate scattering amplitudes.
- Work with unphysically heavy quark

Amplitudes from Lattice QCD



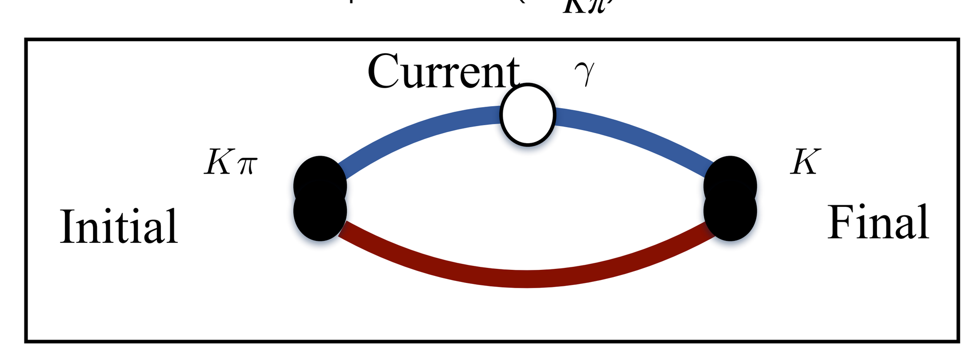
Renormalization



- The vector current renormalization for the light and strange quarks are calculated non-perturbatively by calculating the pion (left) and kaon(right) form-factors and setting the form factor at zero momentum transfer ($Q^2 = 0$) to the charge.
- As expected the charge radius calculated from the slope of the form-factor at $Q^2 = 0$) is seen to be slightly smaller than the PDG average because of heavier quark mass.

Kπ transition matrix elements

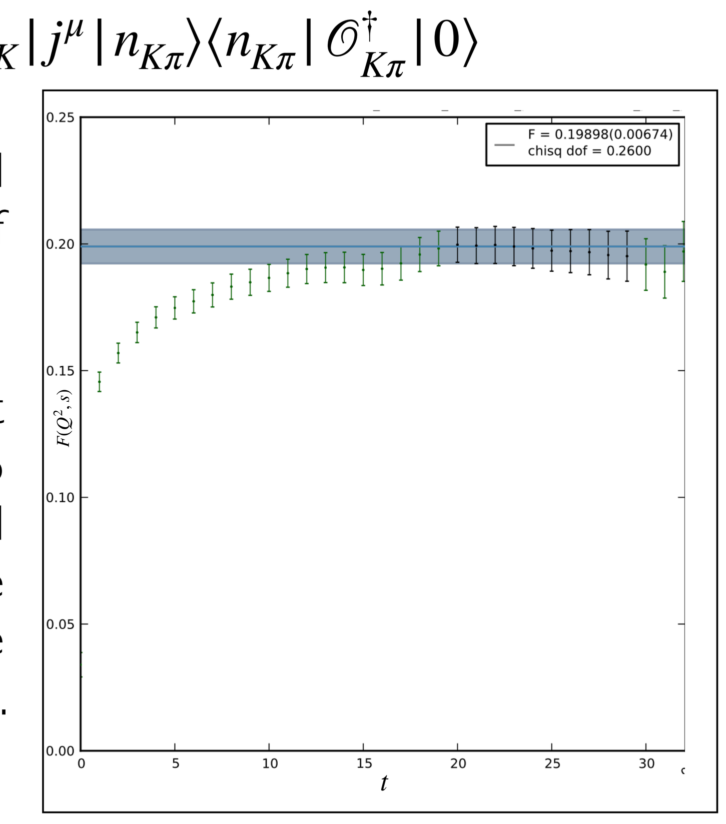
The Kπ to Kγ transition matrix elements are calculated by computing the three point-functions $\langle 0|\mathcal{O}_K(\Delta t)j^\mu(t)\mathcal{O}^\dagger_{K\pi}(0)|0\rangle$ with Kaon operator ($\mathcal{O}_K$) at time Δt, a vector current (j^μ) at time t and a Kπ operator ($\mathcal{O}^\dagger_{K\pi}$) at time 0.

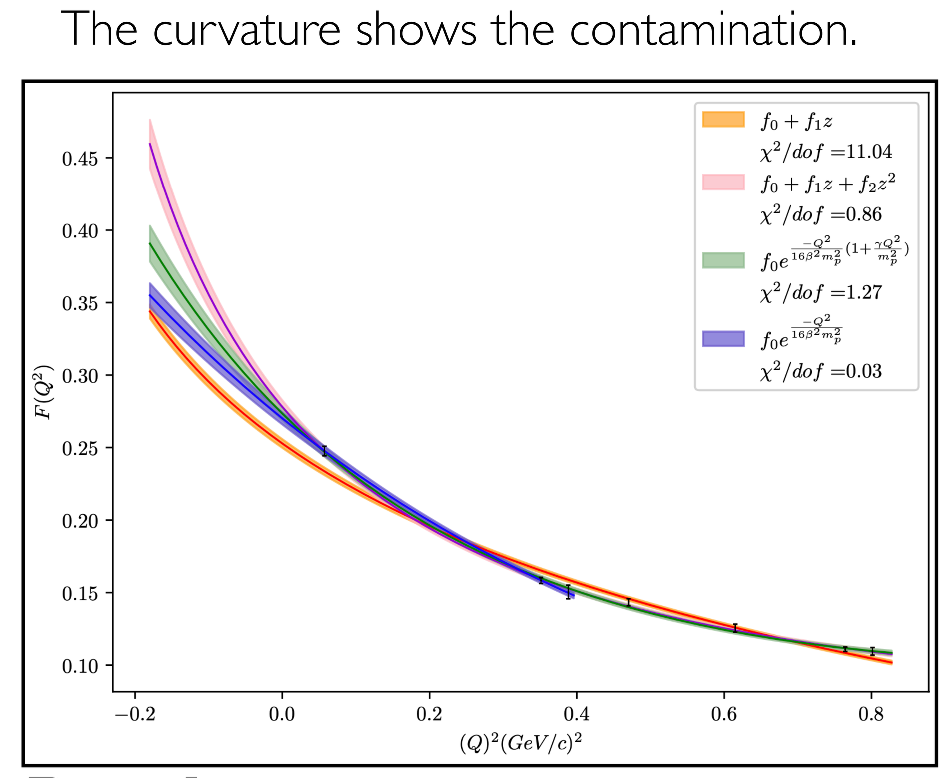


By adding a complete set of basis n_K and $n_{K\pi}$,

$$\sum_{n_K, n_{K\pi}} e^{-E_{n_{K\pi}}t}e^{-E_{n_K}(\Delta t - t)}\langle 0|\mathcal{O}_K|n_K\rangle\langle n_K|j^\mu|n_{K\pi}\rangle\langle n_{K\pi}|\mathcal{O}^\dagger_{K\pi}|0\rangle$$

- The leading order exponentials are divided out and the current is inserted at a range of values between 0 and Δt.
- The matrix element, $\langle n_K|j^\mu|n_{K\pi}\rangle$ from a fit to an appropriate function that takes into account other contaminations from excited states. Clear in figure (right) which shows the time t from 0 to 32 on the x-axis and the raw form-factor value $F(Q^2,s)$ on the y-axis. The curvature shows the contamination.





- The renormalized and finite volume corrected form-factors $\mathscr{A}(Q^2, s)$ are calculated for a range of 'Q²' and 's'. This data is used to parametrize the 'Q²' and 's' dependence of the transition form-factor.
- An example of the dependence at a particular 's' is given in the plot (right).

Results

The Q² and s dependence of the Kπ transition matrix elements are determined. The global analysis of the data is underway to calculate the radiative width.

References

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[2]R. A. Briceño, J. J. Dudek, R. G. Edwards, C. J. Shultz, C. E. Thomas, and D. J. Wilson, Phys. Rev. Lett. 115, 242001 (2015), 1507.06622

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