Conformal parametrization of the pion vector form factor

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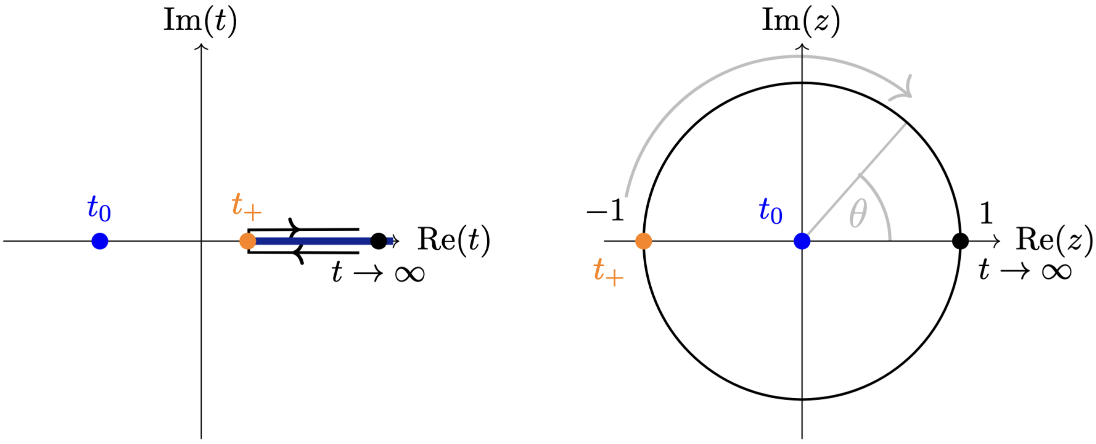
This presentation introduces an approach to the parametrization of the pion vector form factor through the application of conformal mapping.

So far, Quantum Chromodynamics (QCD) provides the most successful description of the strong interaction. In contrast to Quantum Electrodynamics (QED), the mediators of the strong interaction, the gluons, carry color charge and can therefore couple not only to quarks, but also to themselves. This results in a different running coupling constant for QCD, leading to asymptotic freedom at high energies and the phenomenon of confinement at low energies. The latter means that the coupling of the quarks among each other is large enough that they form color-neutral bound states, also called hadrons. Mesons are the simplest hadronic particles, composed of a quark and an anti-quark, that are subject to the strong interaction and serve as suitable candidates for a variety of fundamental tests that challenge the Standard Model. To handle these confined states in QCD, calculations based on perturbation theory are not possible and one needs to resort to an alternative ansatz.

Heuristically, the pion vector form factor describes the spatial charge distribution and hence the structure of the pion, which is the lightest meson. The form factor can most conveniently be accessed in the sophisticated framework of dispersion theory, which solely builds on the fundamental physical concepts of causality, which is closely liked to analyticity, and probability conservation, implying unitarity. This approach offers a solution to the pion vector form factor, which is given by the so-called Omnès function, describing the resummation of intermediate states involving pions across all orders.

This analysis is in need of experimental input, here given by the phase of the Omnès function. To avoid having any assumptions on the behavior of the phase shift, work on a more precise reconstruction of form factors, and thus minimize discrepancies between predictions and observations, it is useful to search for an alternative approach, such as a study of conformal representations of form factors. While still being model-independent, conformal mapping allows for a easier way to access information on the form factor, such as its asymptotic behavior. Conformal transformations are used to convert one complex plane into another, simpler geometric form, such as the unit circle by using the conformal parameter $z(t, t_0) = (\sqrt{t_+ - t} - \sqrt{t_+ - t_0})/(\sqrt{t_+ - t} + \sqrt{t_+ - t_0})$, which is illustrated in the figure below.



Combining the concept of conformal parametrizations and dispersion theory allows for the introduction of dispersive bounds. These are calculated in both, a partonic (using an operator product expansion) and a hadronic (by inserting hadronic states into a form derived by unitarity) manner.

Past attempts have faced challenges, yet recent findings suggest that, with minor adjustments, particularly in restating the form factor's asymptotic behavior near important points in the complex z plane an accurate parametrization will be achieved.

In this work, the final outcome is assessed by comparing the theoretical prediction to the Omnès function. A minimization procedure resulted in the best fit with $\chi^2_{\text{red}} = 1.29$ achieved by using a conformal series expansion with 39 coefficients.