Electromagnetic form factors from a covariant Bethe-Salpeter approach

Ángel Miramontes (IFM, Universidad Michoacana de San Nicolás de Hidalgo)
Collaborators:
Helios Sanchis Alepuz (Silicon Austria Labs, Austria)
Reinhard Alkofer (University of Graz, Austria)
Adnan Bashir (Universidad Michoacana de San Nicolás de Hidalgo)

Based on: A.S Miramontes, Helios Sanchis-Alepuz and Reinhard Alkofer, 2102.12541[hep-ph]

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Why do we want to investigate Form factors?

- Fundamental tools to explore the inner structure of hadrons.
- They encode information about charge, magnetic moment and charge radius, but also are interrelated with hadron spectroscopy.
- Most of research facilities have programs to investigate them (JLAB, MAMI, ELSA, BES III, PANDA).
- A thorough understanding of time-like form factors is a very timely subject.

Formalism

Dyson-Schwinger equations

- They are the equations of motion of a quantum field theory.
- Infinite set of coupled integral equations.

Bethe-Salpeter equations

The solutions of the Bethe-Salpeter equations encode all information about the hadron.

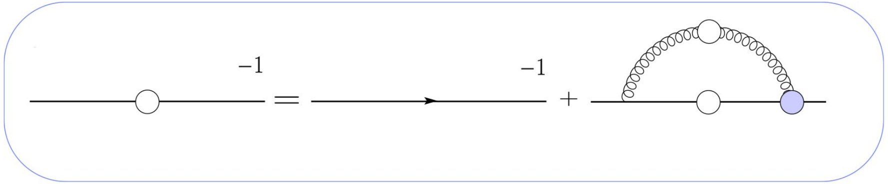
- Mass
- Decay constants
- Decay width

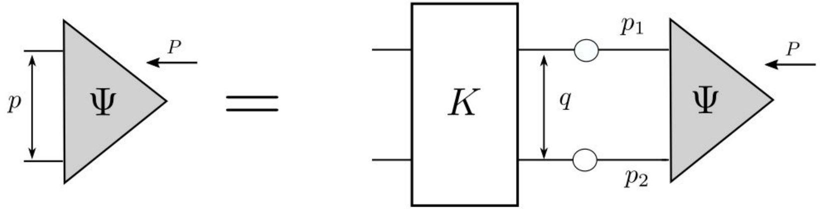
We have access to form factor when we couple to an external field

G. Eichmann, H. Sanchis-Alepuz, R. Williams, R. Alkofer and C. S. Fischer, Prog. Part. Nucl. Phys.91(2016) doi:10.1016/j.ppnp.2016.07.001 [arXiv:1606.09602 [hep-ph]]

DSE/BSE

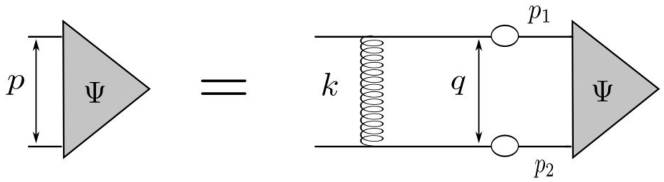
- They conform a non perturbative method to study QCD.
- Provide access to a continuum range of energies, from infrared to ultraviolet.
- Infinite set of integral equations, truncation will be necessary.





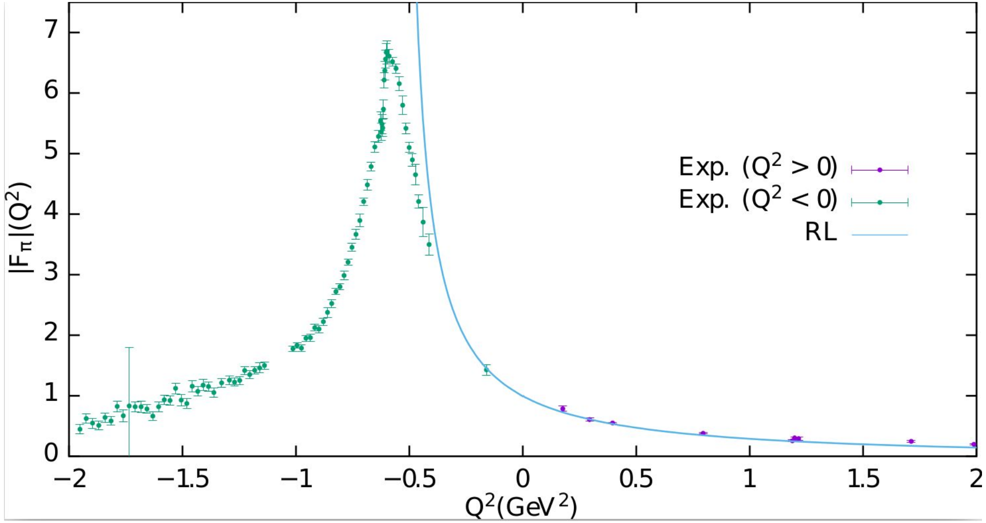
Rainbow-ladder

- Simplest truncation to preserve chiral symmetry.
- It has a lot of success to describe hadron spectroscopy.
- Model needed to describe the effective coupling.
- We use Maris-Tandy model for this exploratory study.



$$\alpha(k^2) = \pi\eta^7 \left(\frac{k^2}{\Lambda^2}\right)^2 \exp^{-\eta^2 \frac{k^2}{\Lambda^2}} + \alpha_{UV}$$

Problems with R-L truncation

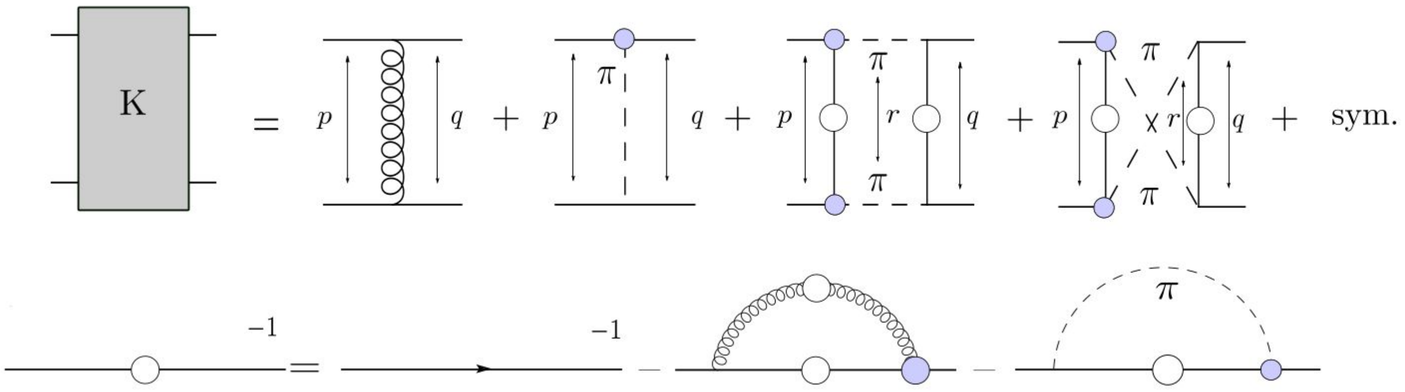


- The solutions are stable bound states, do not describe the decay width.
- Describes quite well the data for a space-like photon.
- Fails to reproduce the experimental data for a time-like photon.
- Objective: use a more sophisticated truncation into the DSE/ BSE system to describe the correct behaviour of the form factor.

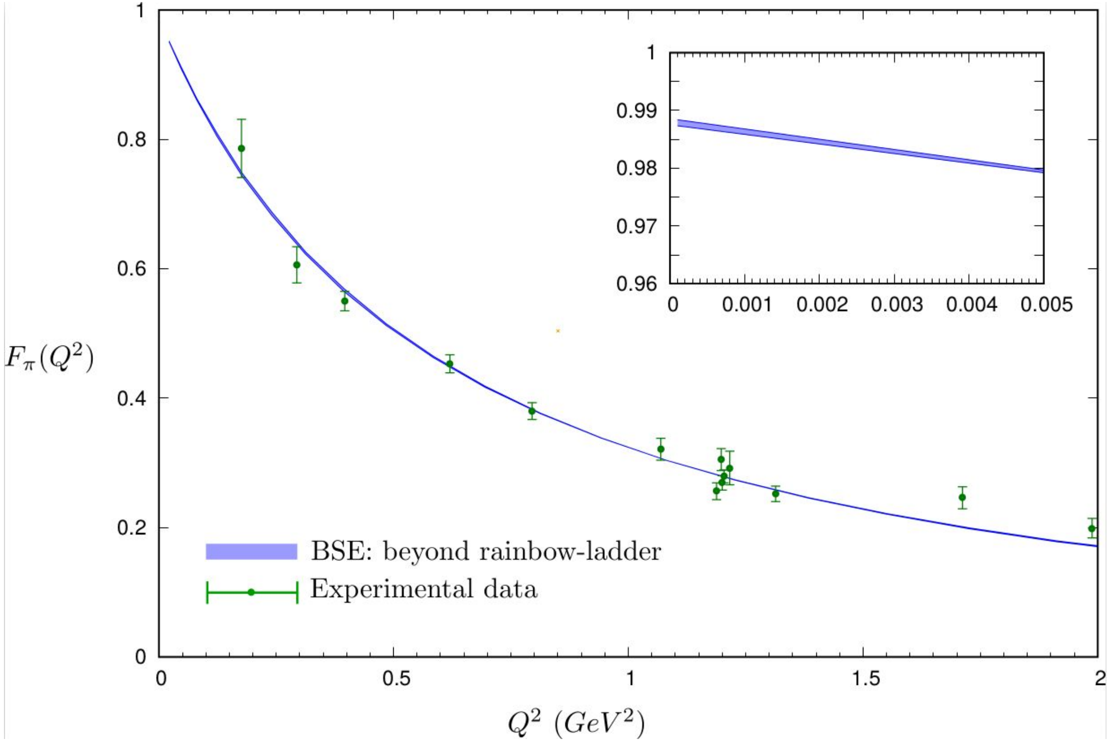
R. R. Akhmetshin et al. [CMD-2], Phys. Lett. B 648, 28-38 (2007) doi:10.1016/j.physletb.2007.01.073 [arXiv:hep-ex/0610021 [hep-ex]].
C. J. Bebek, C. N. Brown, M. Herzlinger, S. D. Holmes, C. A. Lichtenstein, F. M. Pipkin, S. Raither and L. K. Sisterson, Phys. Rev. D 13 (1976), 25 doi:10.1103/PhysRevD.13.25

Pion form factor

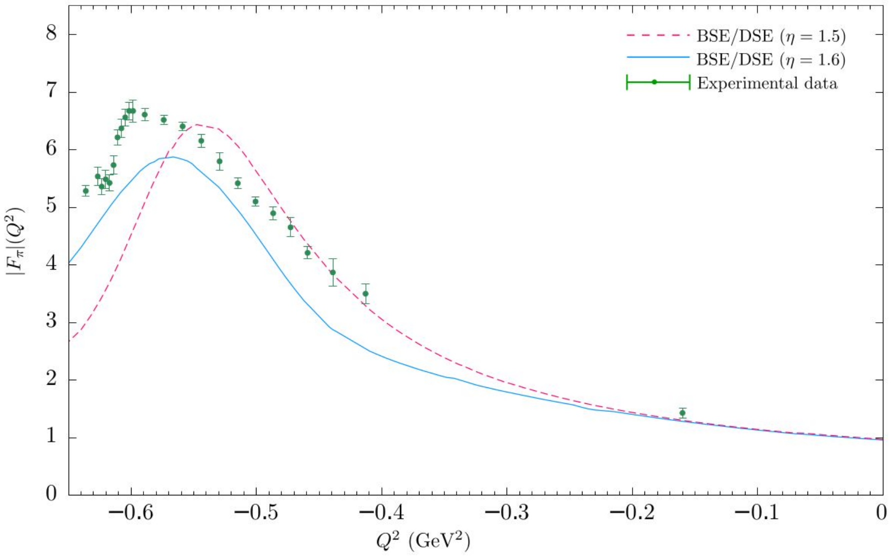
- Pion as quark-antiquark bound state and as pseudo Goldstone Boson.
- Mixing of the ρ-meson with a virtual photon (quark-antiquark bound state in the quark-photon vertex).
- ρ-meson decay, ρ -> π π.
- Exploratory study in the isospin limit.
- To allow a decay mechanism we include pion cloud effects.



Pion form factor: Space-like



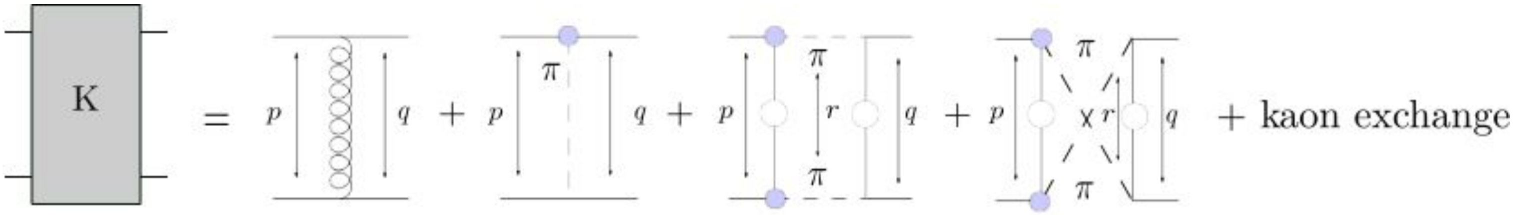
Pion form factor: Time-like

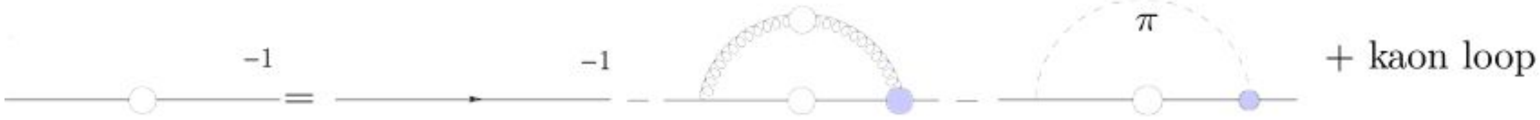


$\Lambda = 0.78$	m_π	f_π	m_ρ	m_ω	M_ρ	Γ_ρ
$\eta = 1.5$	0.139	0.138	0.768	0.778	0.750	0.100
$\eta = 1.6$	0.126	0.138	0.774	0.784	0.759	0.105

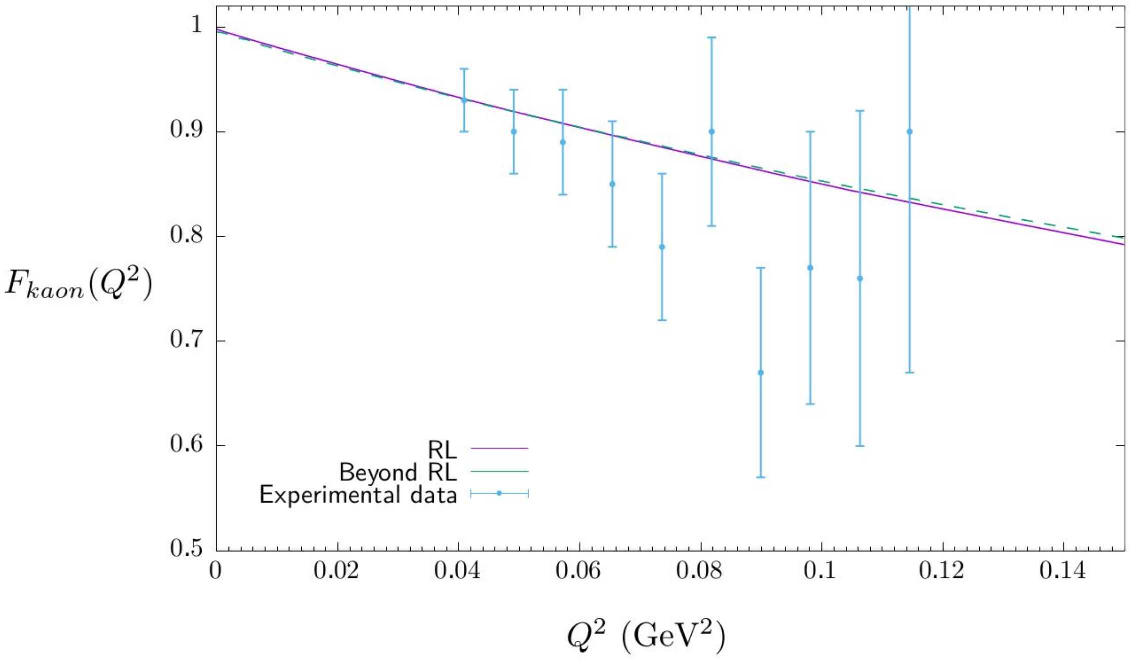
Next step: kaon form factor

- Kaon as bound state of quarks up/down and strange
- In this case, the photon couples also to the strange quark, giving origin to the phi-meson resonance pole for the time-like form factor.
- The phi-meson decays into two kaons.
- Pion cloud will not be enough to describe to correct physics in the time-like regime.





Kaon form factor (Space-like)



- First, we calculate the kaon form factor using R-L truncation and including only pion cloud effects.
- Kaon cloud effects not included yet.
- The calculation for a space-like photon describes well the experimental data.

Summary

- First calculation for a time-like form factor using the formalism of Bethe-Salpeter and Dyson Schwinger equations including pion cloud effects.
- On the space-like region our calculations agree with the experimental data at the quantitative level.
- On the time-like regime, the agreement is mostly quantitative.