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Electric Polarizability of Charged Kaons from Lattice QCD Four-Point Functions

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** Speaker*

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Motivation

- Electromagnetic polarizabilities are important properties that shed light on the internal structure of hadrons.
- What is Electromagnetic polarizability? Polarizability usually refers to the tendency of matter, when subjected to an electric/magnetic field, to acquire an electric/magnetic dipole moment in proportion to that applied field.
- The quarks respond to probing electromagnetic fields, revealing the charge and current distributions inside the hadron.

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Why use four-point functions?

- Understanding electromagnetic polarizabilities has been a long-term goal of lattice QCD.
- The standard tool to compute polarizabilities is the background field method which uses two-point functions, but there are a number of unique challenges.
- The standard plateau technique of extracting energy from the large time behavior of the two-point correlator fails for charged hadrons because a charged hadron accelerates in an electric field. Such motions are unrelated to polarizability and must be isolated from the deformation due to quark and gluon dynamics inside the hadron.
- In this work, we examine the use of four-point functions to extract polarizabilities. As we shall see, the method is ideally suited to charged hadrons.

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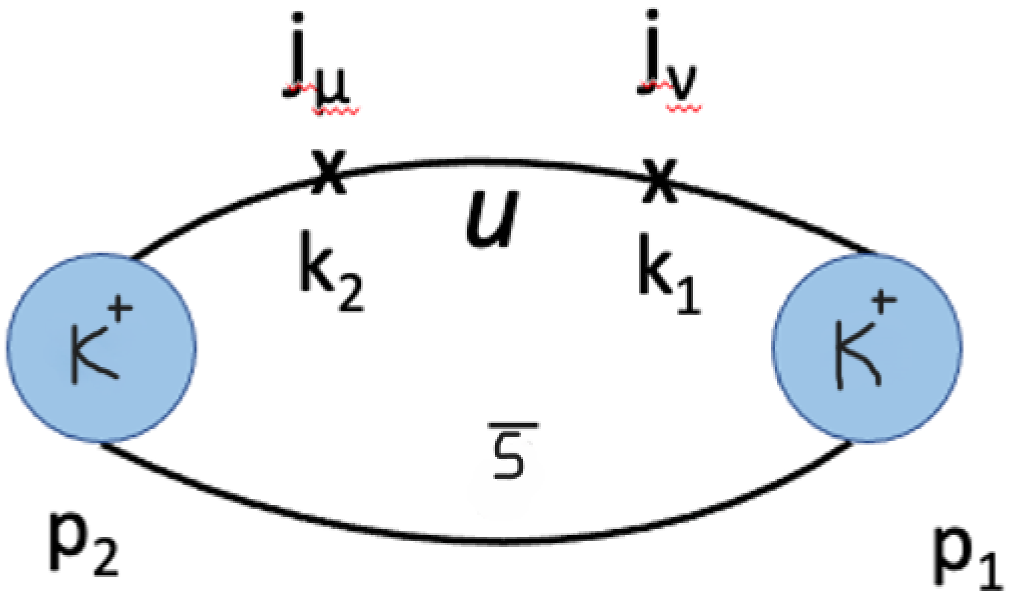
Charged Kaon

- The kaon is one of the simplest hadronic system to demonstrate the methodology.
- We use exactly conserved lattice currents



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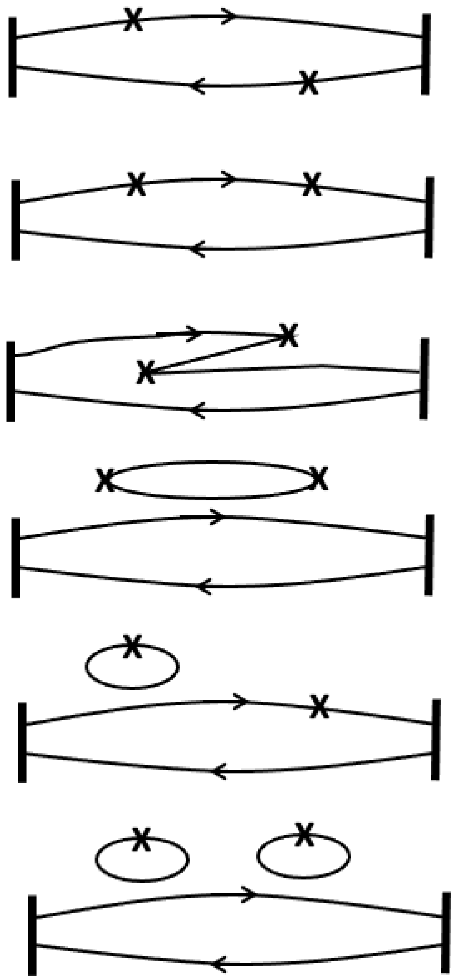
Compton scattering in lattice QCD



(a) connected insertion: different flavor

(b) connected insertion: same flavor

(c) connected insertion: same flavor Z-graph

(d) disconnected insertion: single loop, double current

(e) disconnected insertion: single loop

(f) disconnected insertion: double loop

Charged Kaon polarizabilities

- Kaon Electric Polarizability

$$\alpha_E^{\pi} = \alpha \left\{ \frac{\langle r^2 \rangle}{3m_\pi} + \frac{2a}{\vec{q}_1^{\,2}} \int_0^\infty dt \left[Q_{00}(\vec{q}_1, t) - Q_{00}^{elas}(\vec{q}_1, t) \right] \right\}$$

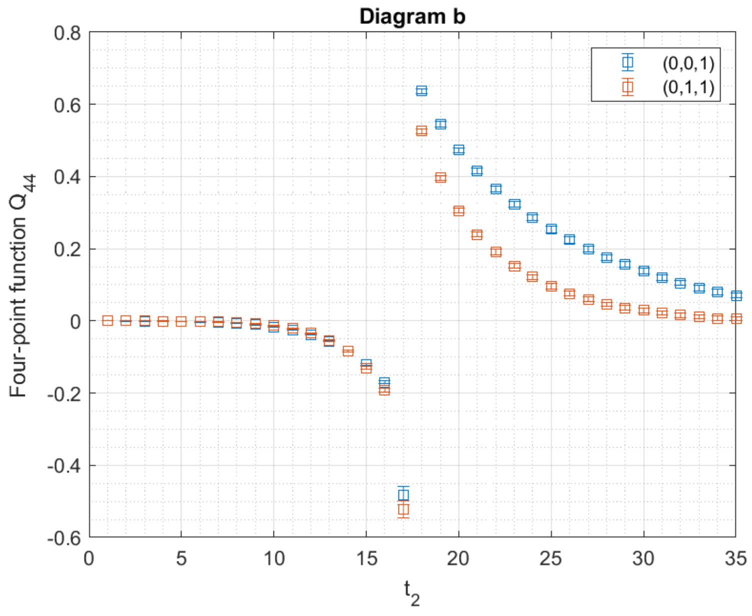
- Kaon Magnetic Polarizability

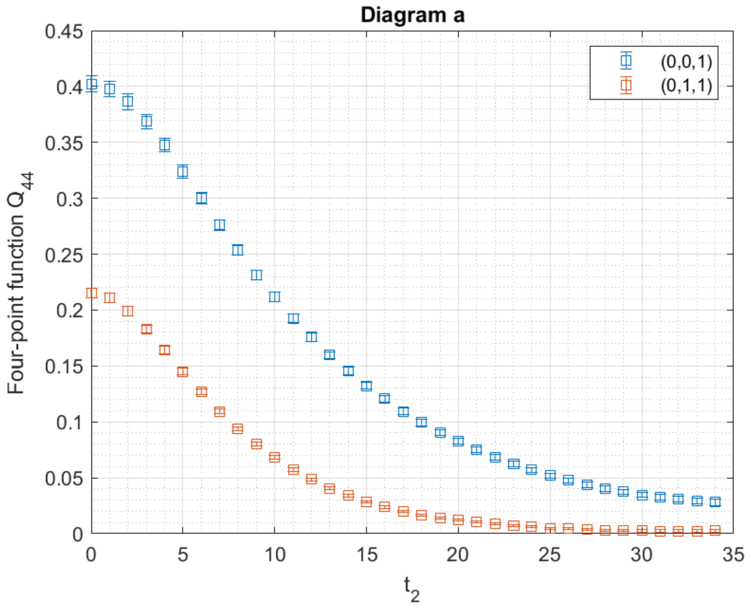
$$\beta_M^{\pi} = \alpha \left\{ -\frac{\langle r_E^2 \rangle}{3m_\pi} + \frac{2a}{\vec{q}_1^{\,2}} \int_0^\infty dt [Q_{11}(\vec{q}_1, t) - Q_{11}(\vec{0}, t)] \right\},$$

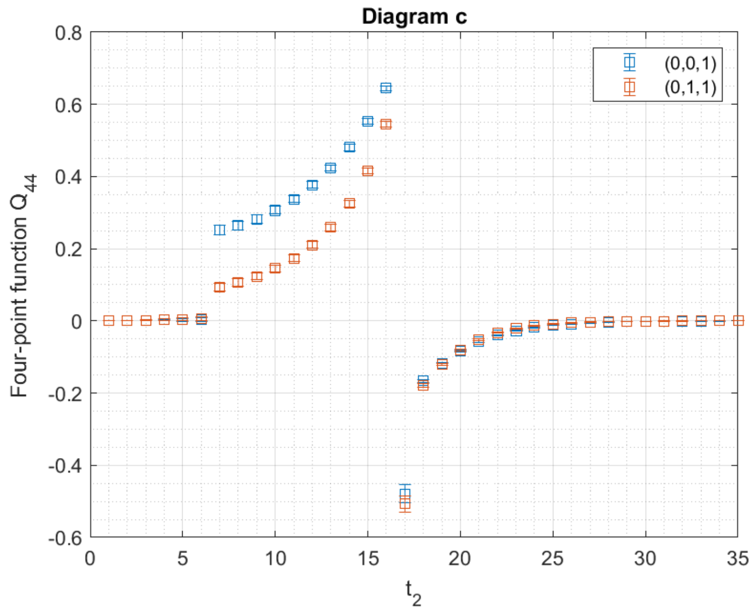
Limitations and possible improvements

- 99 configurations
- Only lowest two momentums used for analysis (linear fits)
- No disconnected diagrams
- Quenched Wilson fermions
- Proof of concept simulation

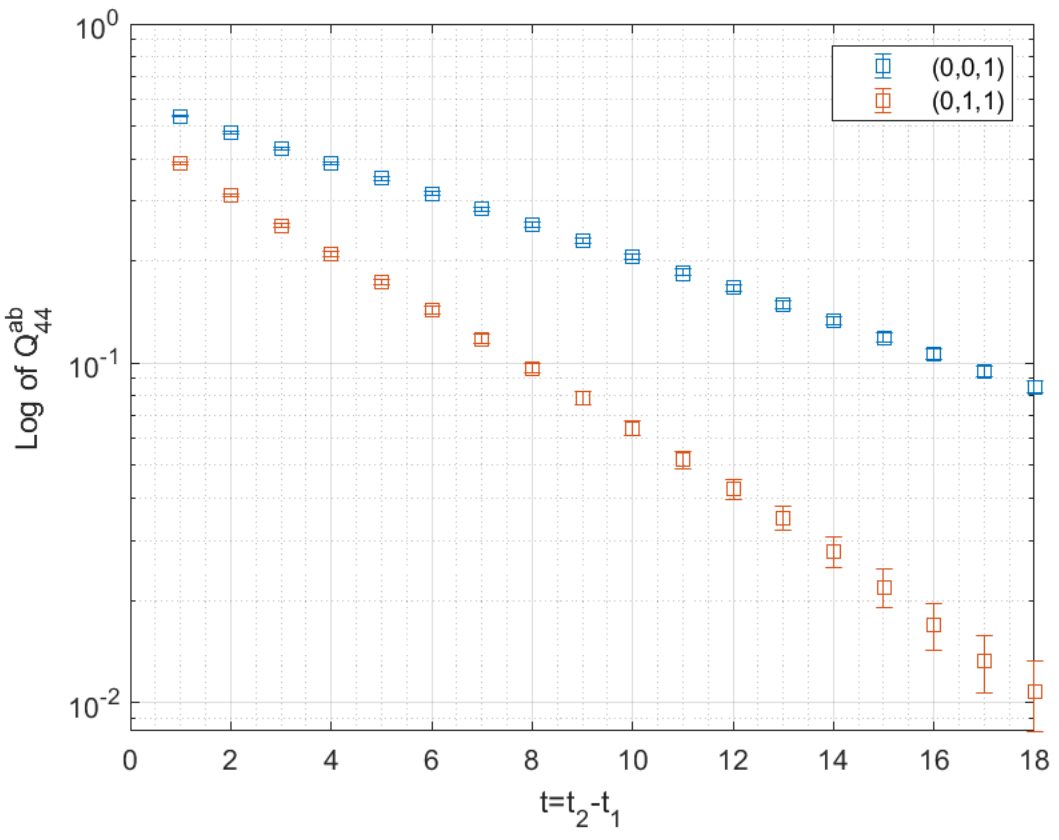
Normalized four-point functions for separate diagrams

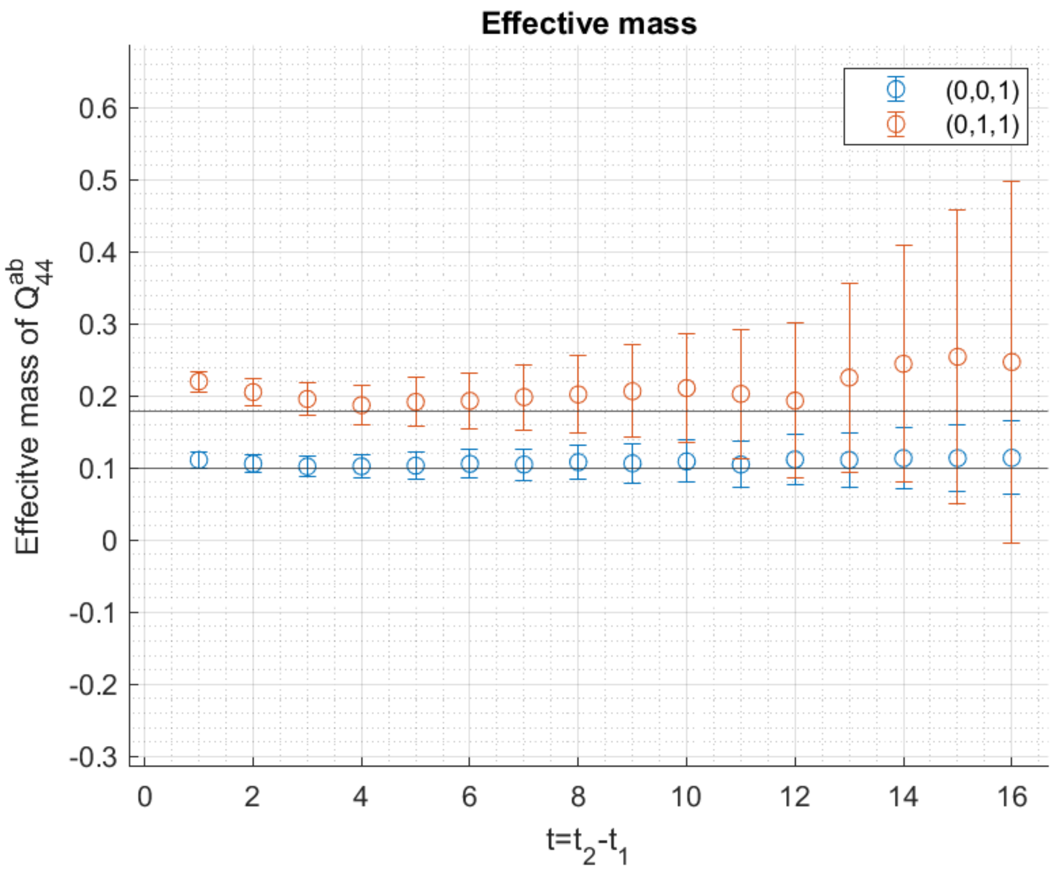






Normalized four-point functions for diagram a+b





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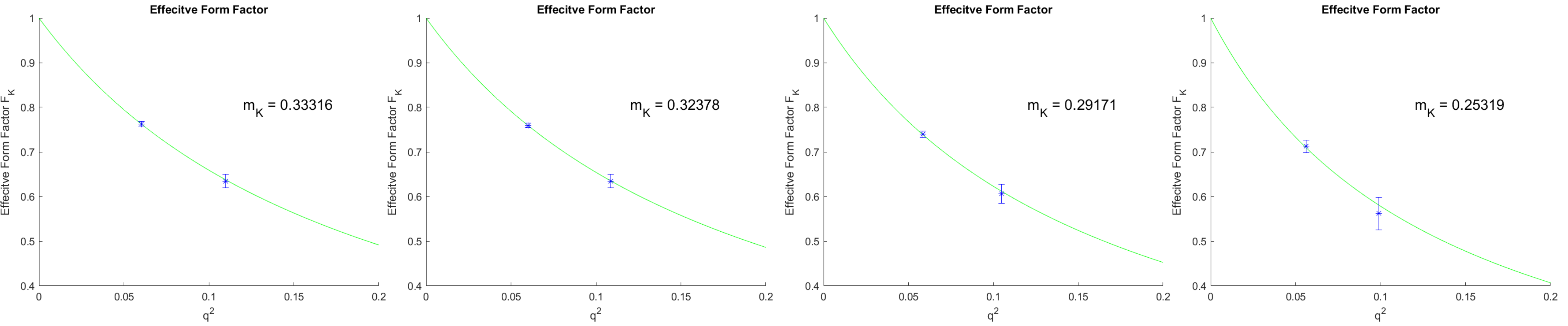
Elastic form factors



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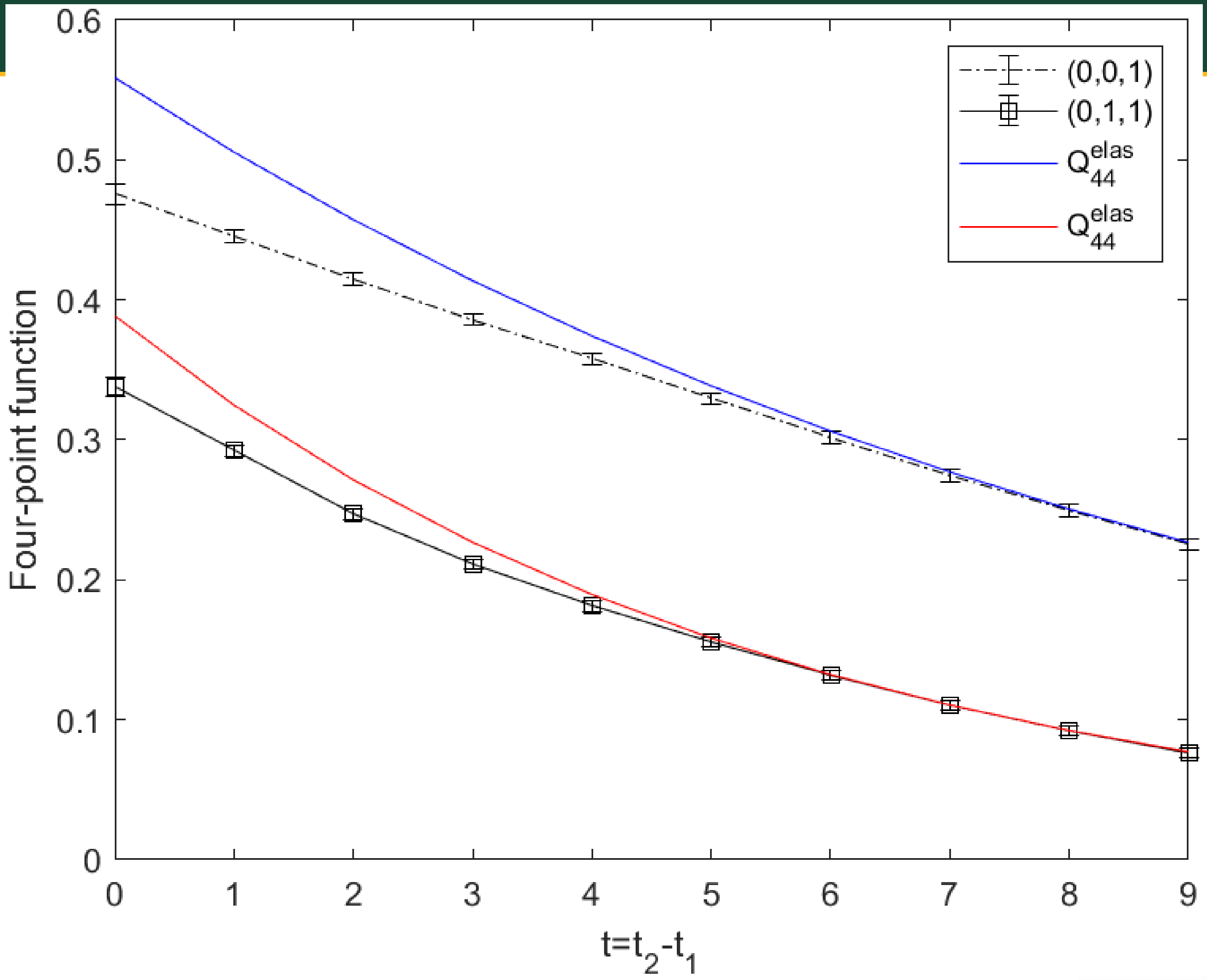
Total four-point function



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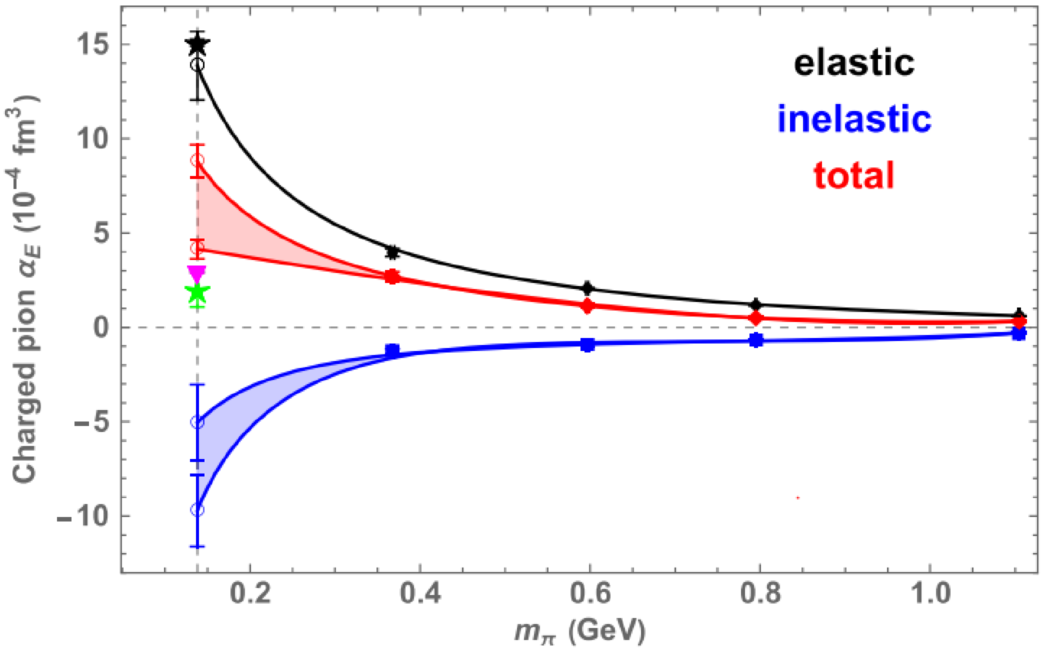

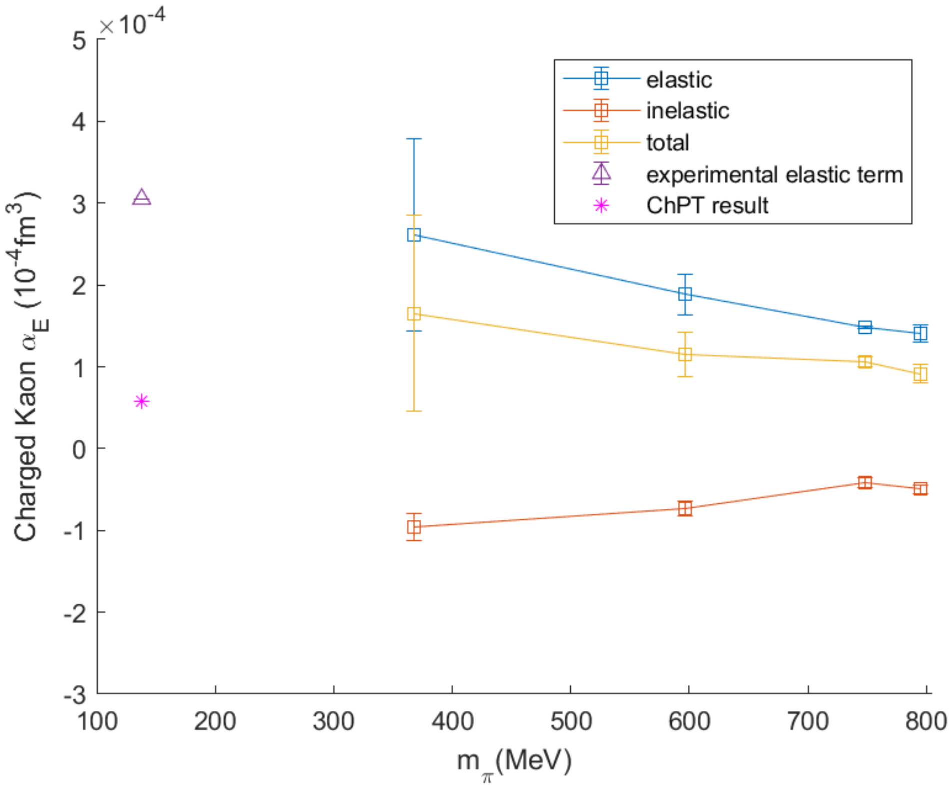

Electric Polarizability

Conclusion

- Proof of concept simulations for K^+ with quenched Wilson fermions on $24^3 \times 48$ lattices with reasonable error bars.
- Four-point functions offer good physics payout
  - Kaon masses
  - form factors (charge radius)
  - polarizabilities
  - analyze three particles at once (charged kaon, neutral kaon, phi)

THANK YOU!!