HEP in Madagascar

D. Rabetiarivony,

on behalf of the

Institute of High Energy Physics of Madagascar, Univ. Antananarivo (MG)







HEP-PHENOMENOLOGY QCD LAPLACE SUM RULES

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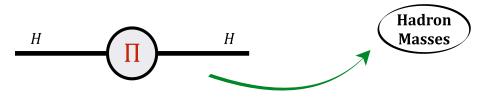
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2-point Spectral Function



QCD SUM RULES

We evaluate the two-point spectral function to obtain the mass of the hadronic state H:

$$-\frac{H}{\Pi} - \frac{H}{\Pi(q^2)} = i \int d^4x \ e^{-iq \cdot x} \ \langle 0|T \left[\mathcal{O}_H^J(x)\mathcal{O}_H^{J\dagger}(0)\right]|0\rangle$$

QCD side

- quark and gluon fields
- ✤ Inverse Laplace Transform
- condensates up to dim 5-7
- NLO calculation
- ✤ spectral functions

HADRONIC side

- \diamond phenomenology
- ♦ hadronic fields
- ✤ complete set of intermediate states
- decay constants
- ✤ spectral functions

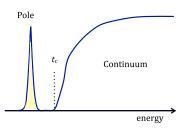
Quark-Hadron Duality

OUR METHOD

Finite Energy in QCD Laplace Sum Rules

$$\mathcal{L}_n(\tau,\mu) = \int_{(m_c+m_s)^2}^{t_c} dt \ t^n \ e^{-t\tau} \cdot \frac{1}{\pi} \mathrm{Im} \ \Pi(t,\mu)$$

Usual Ansatz:

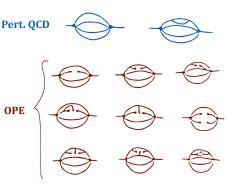


"one resonance" + $\theta(t - t_c) \times QCD$ continuum Im $\Pi \simeq f_H^2 M_H^8 \,\delta(t - M_H^2) + \Theta(t - t_c)$ "Continuum" where the coupling constants are defined as

> $\langle 0|\mathcal{O}_H|H\rangle = f_H M_H^4$ $\langle 0|\mathcal{O}_{H^*}^{\mu}|H^*\rangle = \epsilon^{\mu} f_{H^*} M_{H^*}^5$

- $\boldsymbol{\diamondsuit}$ continuum comes from the discontinuity of the Feynmann diagrams
- different tests of this ansatz from complete hadronic data have shown that it can reproduce with high-precision these complete data
- ✤ it has been also successfully tested in the large-Nc limit of QCD

OUR METHOD



- ✤ We get **OPE convergence** for *d* = 6 condensates.
- Higher dimension condensates are not indicated to improve convergence due to the violation of factorization.
- As τ, t_c, μ are free external parameters, we use stability criteria to extract the lowest ground state mass and coupling.
- NLO PT corrections are included as the convolution of the two spectral function built from two quark bilinear currents.
- NLO corrections are important to justify the use of MS running mass for the heavy quark mass.

A. Pich and E. de Rafael, *Phys. Lett.* **B158** (1985) 477.

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OUR METHOD

J.

Finite Energy in QCD Laplace Sum Rules

$$\mathcal{L}_n(au,\mu) = \int\limits_{(m_c+m_s)^2}^{t_c} dt \; t^n \, e^{-t au} \cdot rac{1}{\pi} \mathrm{Im} \; \Pi(t,\mu)$$

We extract the **lowest ground state mass** for the tetraquark and molecular states by using the ratio of the moments

$$M_H^2 \,\simeq\, {{\cal L}_1\over {\cal L}_0}$$

MAIN PAPERS

- Int. J. Mod. Phys. A 31, 1650093 (2016)
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- Phys. Lett. B 787, 111-123 (2018)
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- Nature of the X(5568) : A critical Laplace sum rule analysis at N2LO.
- XYZ-like spectra from Laplace sum rule at N2LO in chiral limit.
- XYZ-SU(3) breaking from Laplace sum rules at higher orders.
 - Scalar meson contributions to a_{μ} from light-by-light scattering.
 - Doubly-hidden scalar heavy molecules and tetraquarks states from QCD at NLO.
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