About the inclusion of Fock States in AdS/QCD models

Alfredo Vega

In collaboration with
I. Schmidt, T. Gutsche and V. Lyubovitskij

QNP 2015, Valparaíso, Chile

March 3, 2015

Outline

Introduction

Hadronic Properties in AdS / QCD model with one Fock State

Hadronic Properties in AdS / QCD Models with Higher Fock States

Conclusions

Introduction

- Within the phenomenological models used recently in hadronic physics, some are based on the gauge/gravity duality.
- They suppose the existence of a gravity theory dual to QCD, and are divided into two classes: the Top-Down approach and the Bottom-Up models.
- The Bottom-Up models have proven to be quite useful because of their simplicity and variety of successful applications.

QCD

AdS / QCD

- Within the phenomenological models used recently in hadronic physics, some are based on the gauge/gravity duality.
- They suppose the existence of a gravity theory dual to QCD, and are divided into two classes: the Top-Down approach and the Bottom-Up models.
- The Bottom-Up models have proven to be quite useful because of their simplicity and variety of successful applications.

QCD

AdS / QCD

- Within the phenomenological models used recently in hadronic physics, some are based on the gauge/gravity duality.
- They suppose the existence of a gravity theory dual to QCD, and are divided into two classes: the Top-Down approach and the Bottom-Up models.
- The Bottom-Up models have proven to be quite useful because of their simplicity and variety of successful applications.

QCD

AdS / QCD

⋆ **Dictionary.**

QCD (4d)	Gravity (5d)
Operator ($\mathcal{O}$)	Normalizable Modes (Φ)
Hadron Mass (M)	Eigenvalues of Φ
Twist Dimension ([$\mathcal{O}$] - S)	Conformal Dimension (Δ)

In our model, 5d Dirac fields of different dimensions are duals to different Fock states components with specific number of partons in nucleons.

⋆ **Dictionary.**

QCD (4d)	Gravity (5d)
Operator ($\mathcal{O}$)	Normalizable Modes (Φ)
Hadron Mass (M)	Eigenvalues of Φ
Twist Dimension ([$\mathcal{O}$] - S)	Conformal Dimension (Δ)

In our model, 5d Dirac fields of different dimensions are duals to different Fock states components with specific number of partons in nucleons.

⋆ **Dictionary.**

QCD (4d)	Gravity (5d)
Operator ($\mathcal{O}$)	Normalizable Modes (Φ)
Hadron Mass (M)	Eigenvalues of Φ
Twist Dimension ($[\mathcal{O}]$ - S)	Conformal Dimension (Δ)

In our model, 5d Dirac fields of different dimensions are duals to different Fock states components with specific number of partons in nucleons.

Hadronic Properties in AdS / QCD models with one Fock State

The basic ingredients of the considered model are

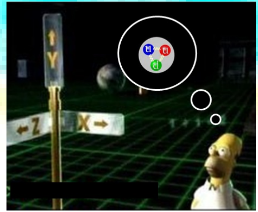
$$S = \int d^{d+1}x\sqrt{g}e^{-\Phi(z)}\left(\mathcal{L}_\psi + \mathcal{L}_V + \mathcal{L}_{int}\right),$$

where

$$ds^2 = \frac{1}{z^2}(\eta_{\mu\nu}dx^\mu dx^\nu - dz^2),$$

⋆ Hard Wall case: $\Phi(z) = Cte$ y z between 0 and z_0.

⋆ Soft Wall case: $\Phi(z) = \kappa^2 z^2$ and z between 0 and ∞.



$\diamond$ Electromagnetic Form Factors for Nucleons[1].

$$S = \int d^{d+1}x\sqrt{g}e^{-\Phi(z)}\left(\bar{\Psi}e^N_A\Gamma^A V_M\Psi + i\frac{1}{2}\eta_{S,V}\bar{\Psi}e^M_A e^M_B[\Gamma^A,\Gamma^B]F^{S,V}_{MN}\Psi\right),$$

$$F^p_1(Q^2) = C_1(Q^2) + \eta_p C_2(Q^2) \quad , \quad F^n_1(Q^2) = \eta_n C_3(Q^2),$$

$$F^p_2(Q^2) = \eta_p C_2(Q^2) \quad and \quad F^n_2(Q^2) = \eta_n C_3(Q^2)$$

where

$$C_1(Q^2) = \int dz e^{-\Phi}\frac{V(Q,z)}{2z^3}(f^2_L(z) + f^2_R(z))$$

$$C_2(Q^2) = \int dz e^{-\Phi}\frac{\partial_z V(Q,z)}{2z^2}(f^2_L(z) - f^2_R(z))$$

$$C_3(Q^2) = \int dz e^{-\Phi}\frac{2m_N V(Q,z)}{2z^3}(f^2_L(z) f^2_R(z))$$

[1] Z. Abidin and C. E. Carlson, Phys. Rev. D**79**, 115003 (2009)

Hadronic Properties in AdS / QCD model with one Fock State

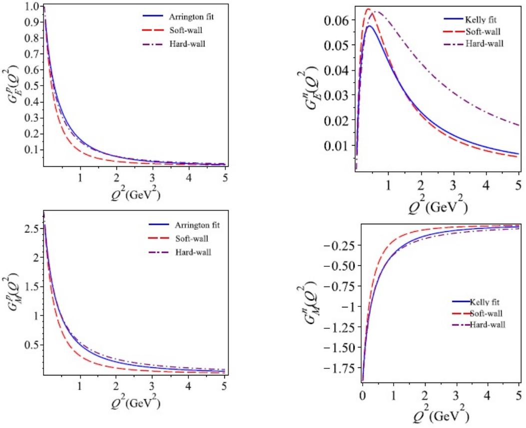


Figure: Electric and Magnetic Form Factors in a Hard wall and in a Soft wall model [Abidin and Carlson (2009)].

Hadronic Properties in AdS / QCD Models with Higher Fock States [2]

[2] Thomas Gutsche, Valery E. Lyubovitskij, Ivan Schmidt y A. V, Phys. Rev. D86 (2012) 036007; Phys. Rev. D **87**, 016017 (2013).

To include several Fock states we consider

$$S = \sum_\tau c_\tau S_\tau,$$

where c_τ are a set of parameters.

If we integrate over z and we consider normalizations conditions for $f^{L/R}$

$$S = \int dx^4 \bar{\psi}_n(x)[\sum_\tau c_\tau i \not{\partial} - \sum_\tau c_\tau M_{n\tau}]\psi_n(x),$$

then

$$\sum_\tau c_\tau = 1 \quad , \quad \sum_\tau c_\tau M_{n\tau} = M_n,$$

In this work we consider

$$\tau = 3\ (3q),\ 4\ (3q+g)\ and\ 5\ (3q+q\bar{q}\ or\ 3q+2g)$$

NOTE: Form Factors are generated by interaction terms in action.

$$S^V_{int} = \int d^4xdz\sqrt{g}e^{-\phi(z)}\mathcal{L}^V_{int}(x,z).$$

◇ **Mass Spectrum.**

$$M_n = \sum_\tau c_\tau M_{n\tau} \quad \rightarrow \quad M_n = 2\kappa \sum_\tau c_\tau \sqrt{n+\tau-1}$$

◇ **Electromagnetic Form Factors.**

Expressions for Dirac and Pauli Form Factors are given by

$$F_1^p(Q^2) = C_1(Q^2) + g_V C_2(Q^2) + \eta_V^p C_3(Q^2). \quad F_2^p(Q^2) = \eta_V^p C_4(Q^2).$$

$$F_1^n(Q^2) = -g_V C_2(Q^2) + \eta_V^n C_3(Q^2). \quad F_2^n(Q^2) = \eta_V^n C_4(Q^2).$$

where

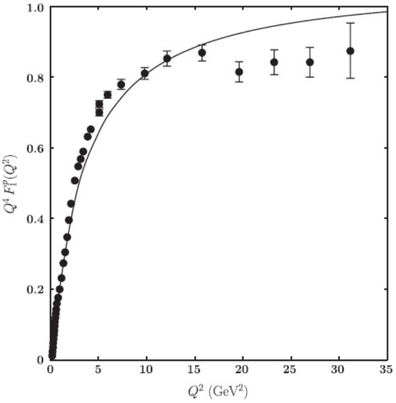
$$C_1(Q^2) = \frac{1}{2}\int_0^\infty dz\ V(Q,z) \sum_\tau c_\tau ([f_\tau^L(z)]^2 + [f_\tau^R(z)]^2).$$

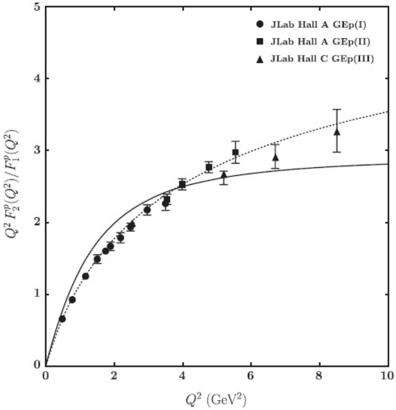
$$C_2(Q^2) = \frac{1}{2}\int_0^\infty dz\ V(Q,z) \sum_\tau c_\tau ([f_\tau^R(z)]^2 + [f_\tau^L(z)]^2).$$

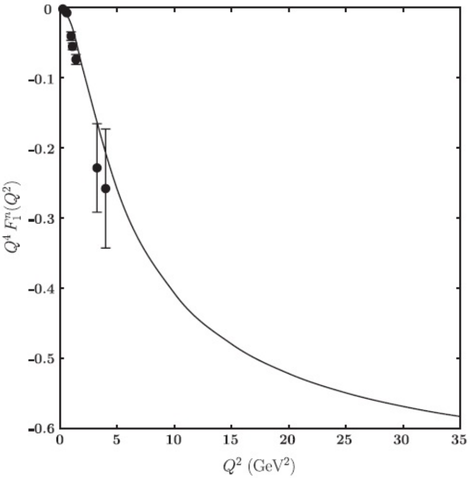
$$C_3(Q^2) = \frac{1}{2}\int_0^\infty dz\ z(\partial_z V(Q,z)) \sum_\tau c_\tau ([f_\tau^L(z)]^2 - [f_\tau^R(z)]^2).$$

$$C_4(Q^2) = 2m_N \int_0^\infty dz\ zV(Q,z) \sum_\tau c_\tau f_\tau^L(z) f_\tau^R(z).$$

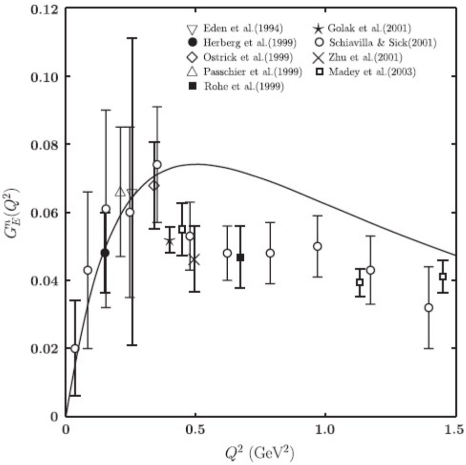
Hadronic Properties in AdS / QCD Models with Higher Fock States






0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0
5
10
15
20
25
30
35
$Q^4 F_1^n(Q^2)$
Q^2 (GeV^2)

Hadronic Properties in AdS / QCD Models with Higher Fock States



Conclusions

- We present a review of an AdS / QCD model for nucleons that consider several Fock states, and it is different from the one suggested by Brodsky, de Teramond and Cao.
- We restrict ourselves to contribution of $\tau = 3$, 4 and 5 parton components in the nucleons, but in principle it is possible consider higher τ.
- Condition $\sum_\tau c_\tau = 1$ suggest a probabilistic interpretation.
- We think that model can be used for extraction parameters in Fock expansion for Proton Wave Function. Actually, we are working on this.
- In a future we are planning to explore more phenomenology of this kind of models in barionic sector and also extend it to mesons.

- We present a review of an AdS / QCD model for nucleons that consider several Fock states, and it is different from the one suggested by Brodsky, de Teramond and Cao.
- We restrict ourselves to contribution of $\tau = 3$, 4 and 5 parton components in the nucleons, but in principle it is possible consider higher τ.
- Condition $\sum_\tau c_\tau = 1$ suggest a probabilistic interpretation.
- We think that model can be used for extraction parameters in Fock expansion for Proton Wave Function. Actually, we are working on this.
- In a future we are planning to explore more phenomenology of this kind of models in barionic sector and also extend it to mesons.

Conclusions

- We present a review of an AdS / QCD model for nucleons that consider several Fock states, and it is different from the one suggested by Brodsky, de Teramond and Cao.
- We restrict ourselves to contribution of $\tau = 3$, 4 and 5 parton components in the nucleons, but in principle it is possible consider higher τ.
- Condition $\sum_{\tau} c_{\tau} = 1$ suggest a probabilistic interpretation.
- We think that model can be used for extraction parameters in Fock expansion for Proton Wave Function. Actually, we are working on this.
- In a future we are planning to explore more phenomenology of this kind of models in barionic sector and also extend it to mesons.

Conclusions

- We present a review of an AdS / QCD model for nucleons that consider several Fock states, and it is different from the one suggested by Brodsky, de Teramond and Cao.
- We restrict ourselves to contribution of $\tau = 3$, 4 and 5 parton components in the nucleons, but in principle it is possible consider higher τ.
- Condition $\sum_\tau c_\tau = 1$ suggest a probabilistic interpretation.
- We think that model can be used for extraction parameters in Fock expansion for Proton Wave Function. Actually, we are working on this.
- In a future we are planning to explore more phenomenology of this kind of models in barionic sector and also extend it to mesons.

Conclusions

- We present a review of an AdS / QCD model for nucleons that consider several Fock states, and it is different from the one suggested by Brodsky, de Teramond and Cao.
- We restrict ourselves to contribution of $\tau = 3$, 4 and 5 parton components in the nucleons, but in principle it is possible consider higher τ.
- Condition $\sum_\tau c_\tau = 1$ suggest a probabilistic interpretation.
- We think that model can be used for extraction parameters in Fock expansion for Proton Wave Function. Actually, we are working on this.
- In a future we are planning to explore more phenomenology of this kind of models in barionic sector and also extend it to mesons.

◇ **Brief (an incomplete) list of additional uses.**

- **Deep Inelastic Scattering** [Polchinski and Strassler; Ballon - Ballona, Boschi and Braga; Braga and A. V].
- **Quark potentials** [Maldacena; Jugeau].
- **Generalizaed Parton Distributions** [A.V, Schmidt, Gutsche and Lyubovitskij; Dehghani; Sharma].
- **Hadronic wave functions (in Light Front Holography)** [Brodsky and de Teramond; Gutsche, Lyubovitskij, Schmidt and A.V].
- **Hadronic spectrum** [Brodsky and de Teramond; A.V and Schmidt; Gutsche, Lyubovitskij, Schmidt and A.V; Braga and Boschi; Forkel, Beyer and Frederico].
- **Transition form factors** [Brodsky, Cao and de Teramond; Gutsche, Lyubovitskij, Schmidt and A.V].
- Etc.

Other examples of Gauge / Gravity in hadronic physics that will be presented at this Conference.

- Today:
  AdS / CFT, Confinement Deformation, and DIS at small-x.
  (Timothy Raben).
  Decay constants of the pion and its excitations in holographic QCD.
  (Gastao Krein).
- Thursday:
  Light - Front Holography and New Advances in Non - Perturbative QCD.
  (Stanley Brodsky).
- Friday:
  Applications of Light - Front Superconformal Quantum Mechanics to Hadronic Physics.
  (Guy de Teramond).

Conclusions


That's all Folks!