«LEPTONIC CONSTANTS OF TENSOR MESONS IN QCD»

P. CHESNOKOV

Physics Faculty of

LOMONOSOV MOSCOW STATE UNIVERSITY

General Nuclear Physics Department

june 27, 2015

Contents

Contents

Quantum Chromodynamics is field theory of strong interactions based on quark and gluon fields.

- **The purpose** *is hadrons discription using lagrangian of QCD:*

$$\boxed{\mathcal{L}_{QCD} = \sum_f \overline{\psi}_f (i\not{D} - m_f)\psi_f - \frac{1}{4} G_{\mu\nu} G^{\mu\nu}} \quad (1)$$

- **The problem** is CONFINEMENT:

$$\boxed{\alpha_s \simeq 1}$$

- **The solution** is non-perturbative methods:
  - Lattice QCD
  - QCD Sum rules

  ...

Comparison of two basic non-perturbative methods in QCD:

Characteristics	Lattice QCD	QCD Sum rules
Precision	$+$	$-$
Flexibility	$-$	$+$
Visibility	$-$	$+$
"Effectiveness"	$-(+)$	$+(-)$

Report purpose is:

- Using QCD Sum Rules for tensor mesons on the example of $D_{s2}^*(2573)$ meson
- Extraction of the mass and the current coupling constant for leptonic (weak) decay channel
- Method correction that improves the accuracy
- Error analysis of the result

$D_{s2}^*(2573)$ meson characteristics

Mass	Quark content	El. charge	J^P	I	τ
2573 MeV	$c\bar{s}$	$+1$	2^+	0	$3,8 \cdot 10^{-23}$ sec

Contents

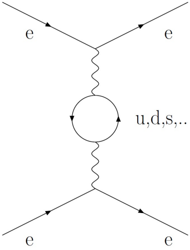
The basic idea of sum rules method is calculation of correlation function

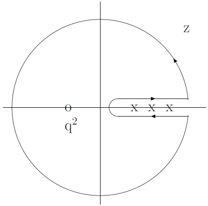
$$\Pi_{\mu\nu}(q) = i\int d^4x\, e^{iqx}\langle 0|T\{j_\mu(x), j_\nu^\dagger(0)\}|0\rangle \qquad (2)$$

in two ways:

- using hadronic states
- using quark-gluon fields when $q^2 \ll 0$

and equating of these two expressions when $q^2 < 0$.





Hadronic part:

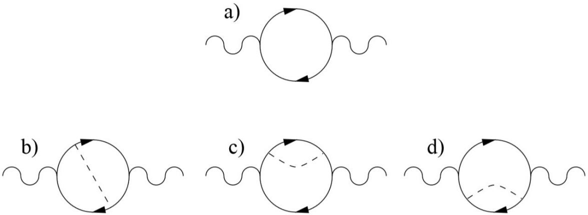
We insert into $\Pi\mu\nu(q)$ full system of hadronic states functions $\sum_n \mid n\rangle\langle n \mid = 1$ then we extract the ground state contribution and finally assosiate it with current coupling constant:

$$\Pi(q^2) = C(q^2) \cdot f^2_{D^*_{s2}(2573)} + \text{excited states} \tag{3}$$

QCD part:

We use OPE (Wilson Operator Product Expantion) that includes perturbative part and contribution of vacuum condensates (non-perturbative part):

$$\Pi(q^2) = \int\limits_{(m_c+m_s)^2}^{s_0} ds \frac{\rho^{pert}(s)}{(s-q^2)} + \Pi^{non-pert}(q^2) \tag{4}$$



$$\widehat{B}\frac{1}{m^2 - q^2} = e^{-m^2 T} \qquad (5)$$

Finally we apply Borel transformation (inverse Laplace transformation) to the both parts of Sum rules, which **improves convergence of expansions** and also **suppresses contribution of excited states**.

Contents

Input data:

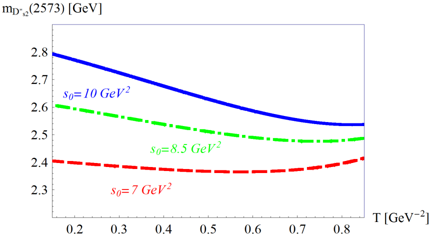
$$m_c = (1.275 \pm 0.025)\ \text{GeV}$$
$$m_s = (0.100 \pm 0.023)\ \text{GeV}$$
$$\langle \bar{s}s(\mu = m_c)\rangle = -0.8(0.24 \pm 0.01)^3\ \text{GeV}^3$$

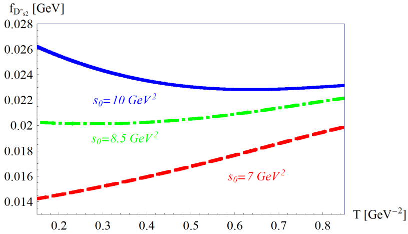
We have also two model parameters:

T - borel parameter

s_0 - effective continuum threshold

$$T_{max}:\ \Pi^{non-pert}(T)/\Pi^{pert}(T) \leq 30\%,$$
$$T_{min}:\ ground\ state/excited\ states \geqslant 10\%,$$
$$s_0 \approx E^2_{1\ ex.st}$$





$$f_{D^*_{s2}(2573)} = (21,2 \pm 1,1)\ \text{MeV}$$

$$m_{D^*_{s2}(2573)} = (2545 \pm 105)\ \text{MeV}$$

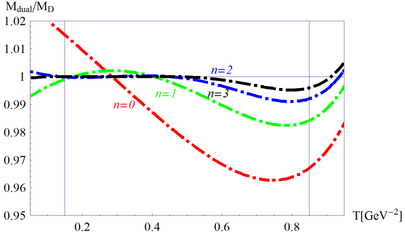
Current coupling constant results from different methods

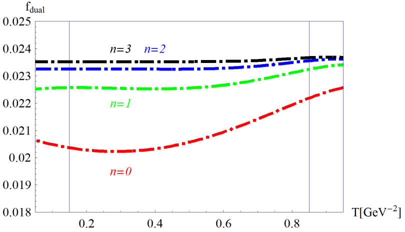
	D-meson	D_s-meson
QCD SR $(n = 0)$ [1]	$(181,3 \pm 8,4)$ MeV	$(218,8 \pm 16,1)$ MeV
QCD SR $(n \neq 0)$ [1]	$(206,2 \pm 7,3)$ MeV	$(245 \pm 15,7)$ MeV
Lattice QCD [2,3]	$(208.3 \pm 5,2)$ MeV	$(252,2 \pm 8,2)$ MeV
Experiment [4]	(205.2 ± 8.1) MeV	$(256,8 \pm 10,1)$ MeV

[1] W. Lucha, D. Melikhov, S. Simula, 2011 J. Phys. G: Nucl. Part. Phys. 38 105002
[2] Blossier Bet al(ETM Collaboration) 2009J. High Energy Phys.JHEP07(2009)043
[3] Follana E, Davies C T H, Lepage G P and Shigemitsu J (HPQCD Collaboration and UKQCD Collaboration) 2008Phys. Rev. Lett.100062002
[4] Nakamura Ket al(Particle Data Group) 2010J. Phys. G: Nucl. Part. Phys.37075021

Consideration of T-depend effective threshold s_0:

$$s_0^{(n)}(T) = \sum_{j=0}^{n} s_j^{(n)} T^j,\ n = 0, 1, 2, 3. \quad (6)$$





Coefficients $s_j^{(n)}$ can be found by minimizing the following functional:

$$\chi^2 \equiv \frac{1}{N} \sum_{i=1}^{N} [m^2_{D^*_{s2}(2573)}(T_i) - m^2_{exp}]^2 \quad (7)$$

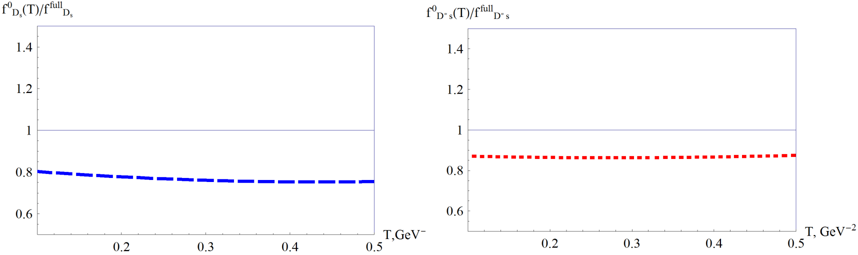
Method errors have different origin:

a) **Borel parameter dependence T $(\pm 5\%)$.**
b) **Uncertainty in value of qurk condensate $(\pm 10\%)$.**

Essentially this is the only errors that we can consider. However we should remember about unaccounted errors (its contribution for tensor mesons is unknown now):

c) **Contribution of high order condensates**
d) **$O(\alpha_s)$- and $O(\alpha_s^2)$- corrections in perturbative part**

Contribution of $O(\alpha_s)$, $O(\alpha_s^2)$ corrections and quark condensate to D_s and D_s^* meson parameters:



a) b)

Graphs shows contribution of petrurbative corrections and quark condensate: ***a) Ratio*** $f^0_{D_s}(T)/f_{D_s}$ ***b) Ratio*** $f^0_{D_s^*}(T)/f_{D_s^*}$

Contents

Conclusions

- We've got current coupling constant and mass for $D^*_{s2}(2573)$ meson using QCD Sum rules.
- We've considered T-depend effective threshold s_0 and demonstrated higher relative accuracy (5%) and also higher value of current coupling constant (10%).

	$f_{D^*_{s2}(2573)}$	$m_{D^*_{s2}(2573)}$
QCD SR ($n = 0$)	$(21,2 \pm 3,2)$ MeV	(2545 ± 105) MeV
QCD SR ($n \neq 0$)	$(23,1 \pm 2,2)$ MeV	(2556 ± 87) MeV
Experiment [5]	?	$(2571,9 \pm 0,8)$ MeV

- We've tried to estimate contribution of $O(\alpha_s)$, $O(\alpha_s^2)$ corrections and high order condensates to $D^*_{s2}(2573)$ current coupling constant by analyzing such corrections for pseudoscholar D^*_s and vector D_s mesons. We expect addition to $f_{D^*_{s2}(2573)}$ value about $15 - 25\%$.

[5] J. Beringer et al. (Particle Data Group), Phys. Rev. D 86, 010001 (2012).

...

Thanks for your attention!