Light Cone 2009-ITA

Is the Y(4140) a $D_s^* \bar{D}_s^*$ state?

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The QCD Theory permits that particles can be constituted by four or more quarks

Exotic Mesons

There is a growing evidence that some new charmonium states , discovery in the B factories, are non-conventional $c\bar{c}$ states.

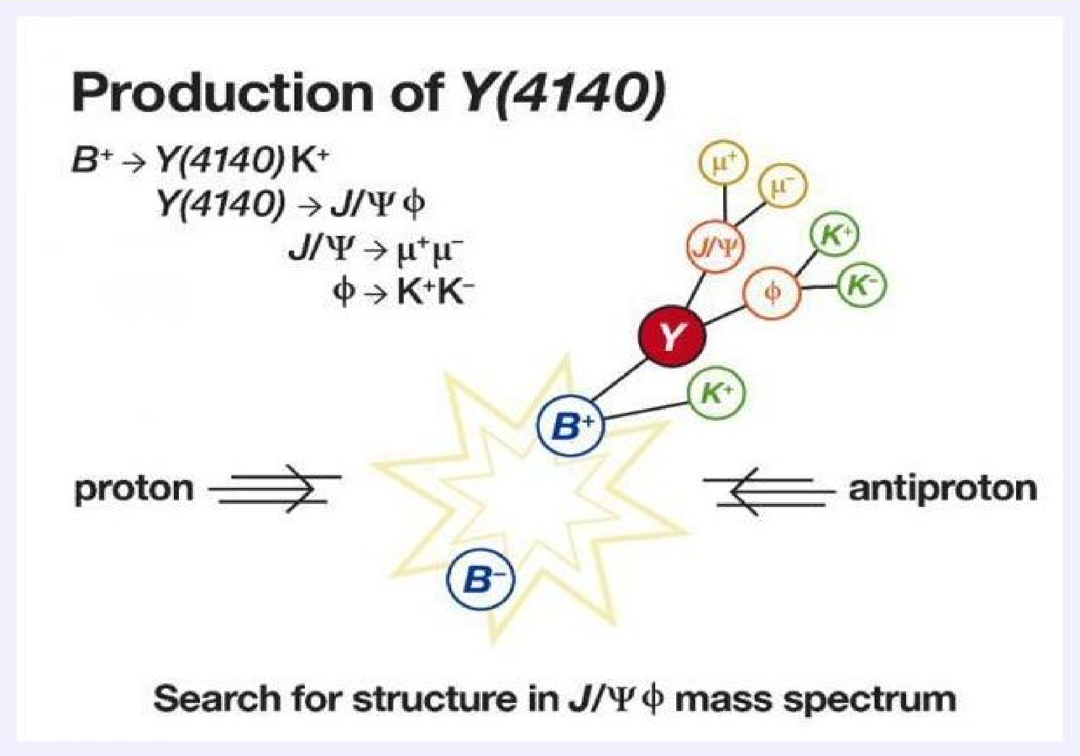
Some of these new mesons are:

$X(3872)$

$Z^+(4430) \longrightarrow c\bar{c}u\bar{d}$

Diquark antidiquark structure explain the properties of these mesons...

These year, the CDF Collaboration reported a narrow structure the Y(4140)



The CDF Collaboration find evidence from the B decay and studying near the $J/\psi\phi$

$$m_Y = 4143 \pm 2.9 \pm 1.2 MeV$$

$$\Gamma = 11.7^{+8.3}_{-5.0} \pm 3.7 MeV/c^2$$

CDF note that this structure decays to J/ψφ just above the Jψφ threshold, similar to the Y (3930) , which decays to J/ψω near the J/ψω threshold.

$$B \to Y(3930)K \to J/\Psi\omega K$$

Y(4140) , it is well above the threshold for open charm decays, so a $c\bar{c}$ charmonium meson with this mass would be expected to decay into an open charm pair dominantly

Thus, this structure does not fit conventional expectations for a charmonium state.

We used the QCD Sun Rules to study the mass of Y(4140)

Supposing that the current that describes Y(4140) has the quantum numbers of a molecular state : $D_s^* \bar{D}_s^*$

Y(4140) decays into two vector mesons $I^G(J^{PC}) = 0^-(1^{--})$

it has positive C and G parities, then a possibility for the quantum numbers is: $J^{PC} = 0^{++}$

The QCD Sum Rule

The starting point to evaluate the mass is

$$\Pi(q) = i \int d^4x \;\; e^{-iq\cdot y} \, \langle 0 | T\{ j_\mu^H(x) j^{H^\dagger}(y) \} | 0 \rangle$$

Interpolating current

$$j_H = (\bar{s}_a \gamma_\mu c_a)(\bar{c}_b \gamma^\mu s_b)$$

D_s^* $\quad$ $\bar{D}_s^*$

$$J^{PC} = 0^{++}$$

$$\Pi(q) = i \int d^4x \;\; e^{-iq\cdot y} \; \langle 0 | T\{ j_\mu^H(x) j^{H^\dagger}(y) \} | 0 \rangle$$

Dual description for this Green Function

QCD Side

In the OPE : the correlator is calculate at the quark level in terms of quark and gluon fields.

$$\Pi^{OPE}(q^2) = \int_{4m_c^2}^{\infty} ds \frac{\rho^{OPE}(s)}{s - q^2} \; ,$$

Phenomenological Side

Parametrized in function of hadronics properties, mass.

In the correlation function is inserting intermediate state of the current:

$$\Pi^{phen}(q^2) = \frac{\lambda^2}{M_H^2 - q^2} + \int_0^{\infty} ds \; \frac{\rho^{cont}(s)}{s - q^2},$$

Borel Transformed

$Q^2 \longrightarrow M^2$

$$\lambda^2 e^{-m^2_{D_s^* D_s^*}/M^2} = \int_{4m_c^2}^{s_0} ds\; e^{-s/M^2}\;\rho^{OPE}(s)\;,$$

To extract the mass we take the derivative of this equation and divide by the result

$$\rho^{OPE}(s) = \rho^{pert}(s) + \rho^{\langle\bar{s}s\rangle}(s) + \rho^{\langle G^2\rangle}(s) + \rho^{mix}(s) + \rho^{\langle\bar{s}s\rangle^2}(s) + \rho^{mix\langle\bar{s}s\rangle}(s)\;,$$

$$\rho^{pert}(s) = \frac{3}{2^9\pi^6}\int_{\alpha_{min}}^{\alpha_{max}}\frac{d\alpha}{\alpha^3}\int_{\beta_{min}}^{1-\alpha}\frac{d\beta}{\beta^2}(1-\alpha-\beta)\left[(\alpha+\beta)m_c^2-\alpha\beta s\right]^3\left(\left[\frac{(\alpha+\beta)m_c^2-\alpha\beta s}{\beta}\right]-4m_cm_s\right),$$

$$\rho^{\langle\bar{s}s\rangle}(s) = \frac{3\langle\bar{s}s\rangle}{2^5\pi^4}\int_{\alpha_{min}}^{\alpha_{max}}\frac{d\alpha}{\alpha}\left\{m_s\frac{(m_c^2-\alpha(1-\alpha)s)^2}{1-\alpha}-m_c\int_{\beta_{min}}^{1-\alpha}d\beta\left[(\alpha+\beta)m_c^2-\alpha\beta s\right]\times\right.$$
$$\left.\times\left[\frac{(\alpha+\beta)m_c^2-\alpha\beta s}{\alpha\beta}-\frac{4m_sm_c}{\beta}\right]\right\},$$

$$\rho^{\langle G^2\rangle}(s) = \frac{m_c^2\langle g^2G^2\rangle}{2^8\pi^6}\int_{\alpha_{min}}^{\alpha_{max}}\frac{d\alpha}{\alpha^3}\int_{\beta_{min}}^{1-\alpha}d\beta(1-\alpha-\beta)\left[(\alpha+\beta)m_c^2-\alpha\beta s\right],$$

$$\rho^{mix}(s) = -\frac{m_0^2\langle\bar{s}s\rangle}{2^6\pi^4}\left\{3m_c\int_{\alpha_{min}}^{\alpha_{max}}\frac{d\alpha}{\alpha}\left[m_c^2-\alpha(1-\alpha)s\right]-m_s(8m_c^2-s)\sqrt{1-4m_c^2/s}\right\},$$

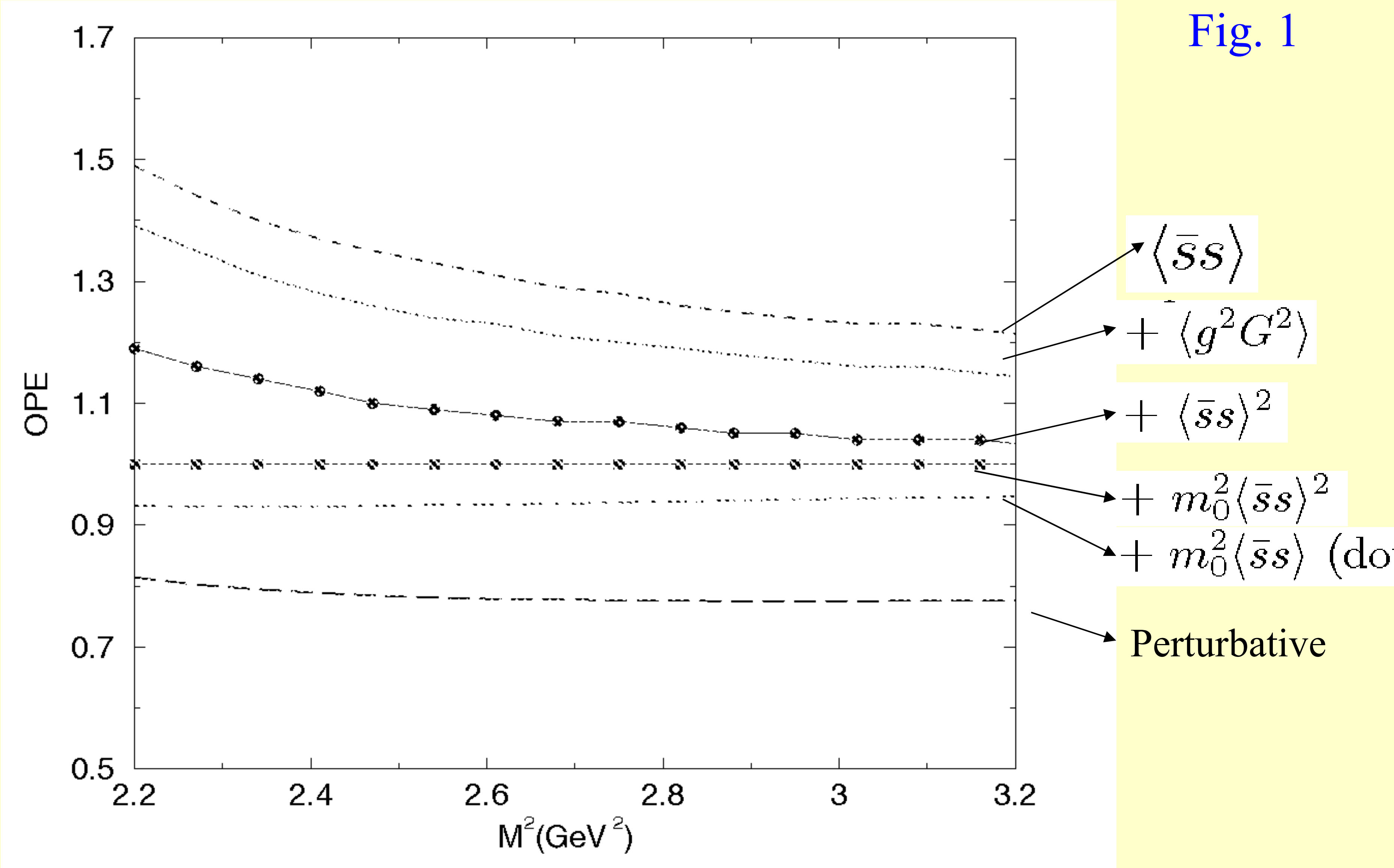
$$\rho^{\langle\bar{s}s\rangle^2}(s) = \frac{m_c\langle\bar{s}s\rangle^2}{8\pi^2}\left\{\sqrt{1-4m_c^2/s}\,(2m_c-m_s)-m_sm_c^2\int_0^1\frac{d\alpha}{\alpha}\,\delta\left(s-\frac{m_c^2}{\alpha(1-\alpha)}\right)\right\}, \qquad (9$$

To extract the mass, we take the derivative of the equation repecte 1/M2 and divide by the result.

For comparison with other results obtained for the other molecular states that we made with the QCDSR, we use:

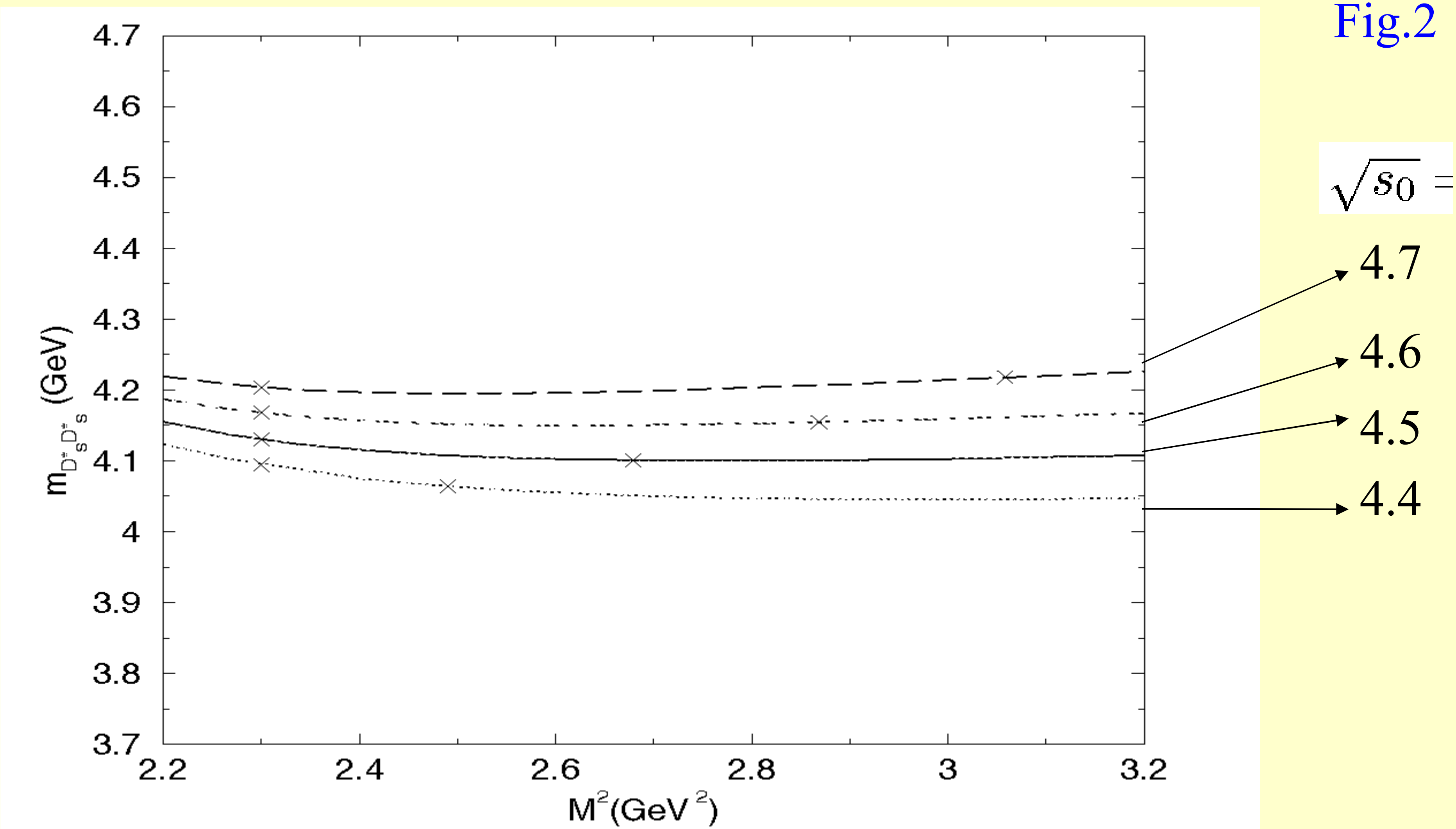
Quark masses [GeV]	Condensates
$m_c = 1.23 \pm 0.05$	$\langle \bar{q}q \rangle = -(0.23 \pm 0.03)^3 \text{ GeV}^3$
$m_s = 1.13 \pm 0.03$	$\langle \bar{s}s \rangle = 0.8 \langle \bar{q}q \rangle$
	$\langle \bar{s}g\sigma.Gs \rangle = m_0^2 \langle \bar{s}s \rangle$ with $m_0^2 = 0.8 \text{ GeV}^2$
	$\langle g^2 G^2 \rangle = 0.88 \text{ GeV}^4$

Fig. 1



We show the relative contributions of the all terms in the OPE side; we see that for $M^2 \geq 2.3 GeV^2$, the dimension 8 is less that 20 % of the total contributions, then we fix as a lower value of a Borel mass..

Fig.2



We show the mass for different values of the threshold of continuum contribution. We made a study of this variation that give the higher value of Borel mass.

$$s_0 \approx (m_H + 0.5GeV)^2$$

We obtain

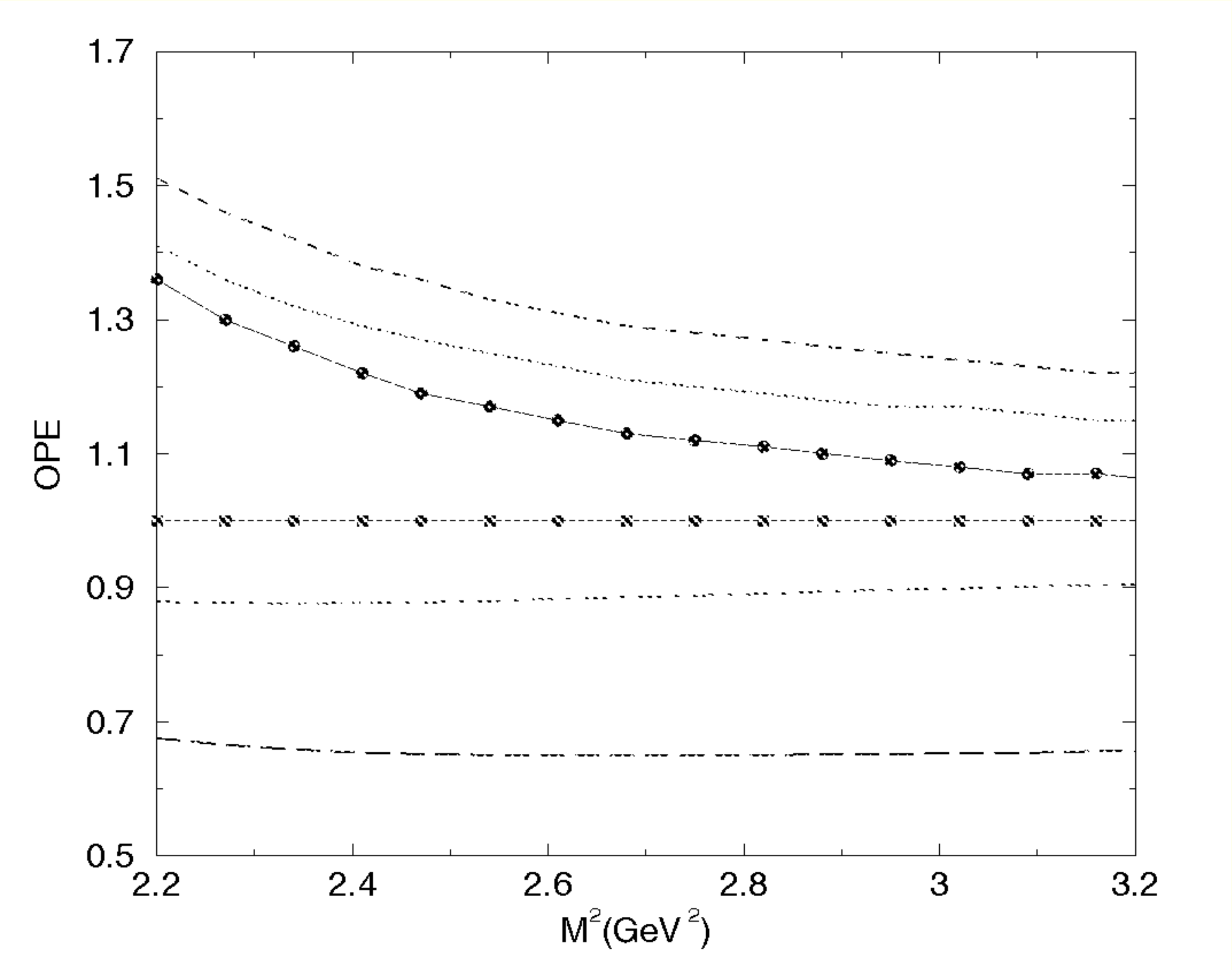
$$m_{D_s^* \bar{D}_s^*} = 4.14 \pm 0.08 GeV$$

Is an excellent agreement with the mass of the narrow structure Y(4140), observed at CDF

We can check how the violation of the factorization hypothesis would modify our results and also we can vary the masses of the quarks and the finally results is:

$$m_{D_s^* \bar{D}_s^*} = 4.14 \pm 0.09 GeV$$

We can also study the D*D* molecular type current, in the same way that we made before



OPE side

$m_s = 0$

$< \bar{s}s > = < \bar{q}q >$

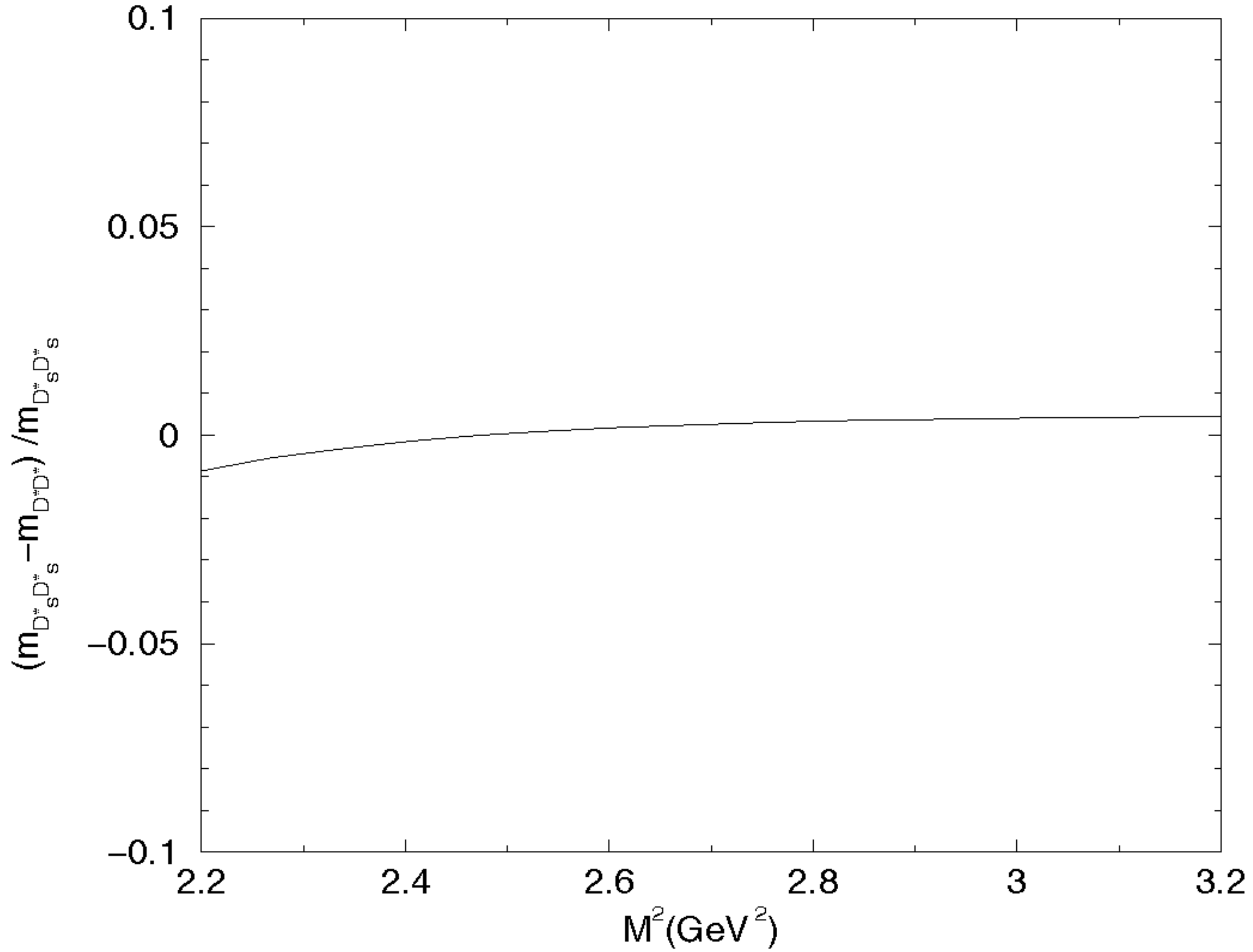
$m_{D^*\bar{D}^*} = 4.13 \pm 0.11 GeV$

$$m_{D_s^* \bar{D}_s^*} = 4.14 \pm 0.09 \;\; GeV^2$$

$$m_{D^* \bar{D}^*} = 4.13 \pm 0.11 \;\; GeV^2$$

Therefore from a QCD Sum Rules, the difference between the masses of D*s D*s and D* D* currents is consistent with zero

- The mass is 100 MeV above the D*D*(4020) threshold, This could be an indication that there is a repulsive interaction between the two meson D* (it is a virtual state).
- This result is unexpected since, in general strange quarks adds approximately 100 MeV to the mass of the particle.



We show the relative ratio , as a function of Borel mass.

The ratio is very stable as Borel mass, the difference is about 0,5 %.

If we choose another values of threshold s, we had not difference

The relative ratio between the masses of the scalar states $m_{D_s^* D_s^*}$ and $m_{D^* D^*}$ for $\sqrt{s_0} = 4.55$ GeV.

We can also calculated the parameter lambda that is:

$$\langle 0|j|H\rangle = \lambda.$$

$$\lambda_{D_s^* \bar{D}_s^*} = (4.22 \pm 0.83) \times 10^{-2}\ \mathrm{GeV}^5,$$

$$\lambda_{D^* D^*} = (4.20 \pm 0.96) \times 10^{-2}\ \mathrm{GeV}^5.$$

The currents couple with similar strength

↓ Both can represent a Y(4140)?

Conclusion

However the Y(4140) observed at CDF, in the decay off

$$B^+ \to Y(4140)K^+ \to J/\Psi\phi K^+$$

can be very well described by $D_s^*\bar{D}_s^*$

We have obtained similar masses, that could be represent the Y, when we use a current that represent a molecular state $D^*\bar{D}^*$ this assignment can not be excluded since they have the same quantum numbers.

But the mass obtained with D*D* is about 100 MeV above the threshold of D*D*(4020), that indicated a repulsive interaction, maybe a virtual state.

I would like to thanks the opportunity and the invitation at the organizing committe, specially to Prof. Tobias Frederico.

Thanks for all of you that listening this seminary with my poor english-mixture.

There are some others interpretations:

1.- June 2009, Stancu, Fl.
Calculate the spectrum of tetraquarks, within a simple quarks model chomomagnetic interaction. Conclude that Y could be a partner of X(3872) , with 1++.

2.- Xuang Liu, assuming Y as the second radial excitation of the P-wave charmonium xhi"_cJ, looking at the hidden charm decay mode. The conclusion was that this description was complicated.