Meson loops in the charm sector

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Key references:

F. K. Guo, J. Haidenbauer, C. H. and U.-G. Meißner, arXiv:1005.2055 [hep-ph].

F. K. Guo, C. Hanhart, G. Li, U. G. Meißner and Q. Zhao, arXiv:1002.2712 [hep-ph].

F. K. Guo, C. H. and U.-G. Meißner, Phys. Rev. Lett. **103** (2009) 082003.

F.-K. Guo, C.H., and U.-G. Meißner, Phys. Rev. Lett. **102** (2009) 242004.

F. K. Guo, C. H. and U.-G. Meißner, Phys. Lett. B **665** (2008) 26.

The Goal

We need methods that allow us

→ to identify exotics and to treat conventional states

→ with a clear connection to QCD

→ with a controlled uncertainty

The tools we have at our disposal:

→ Lattice gauge theory

→ Effective field theories (ChPT & HQEFT & NREFT)

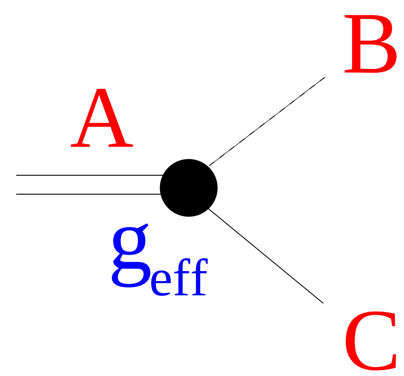
→ General theorems

General theorem

For an s–wave coupling g_{eff} for

$$A \to BC$$

(for A very near BC threshold)



one can derive

Landau (1960), Weinberg (1963), Baru et al. (2004)

$$\frac{g_{\text{eff}}^2}{4\pi} = 4(m_1+m_2)^2\lambda^2\sqrt{2\epsilon/\mu} \leq 4(m_1+m_2)^2\sqrt{2\epsilon/\mu}$$

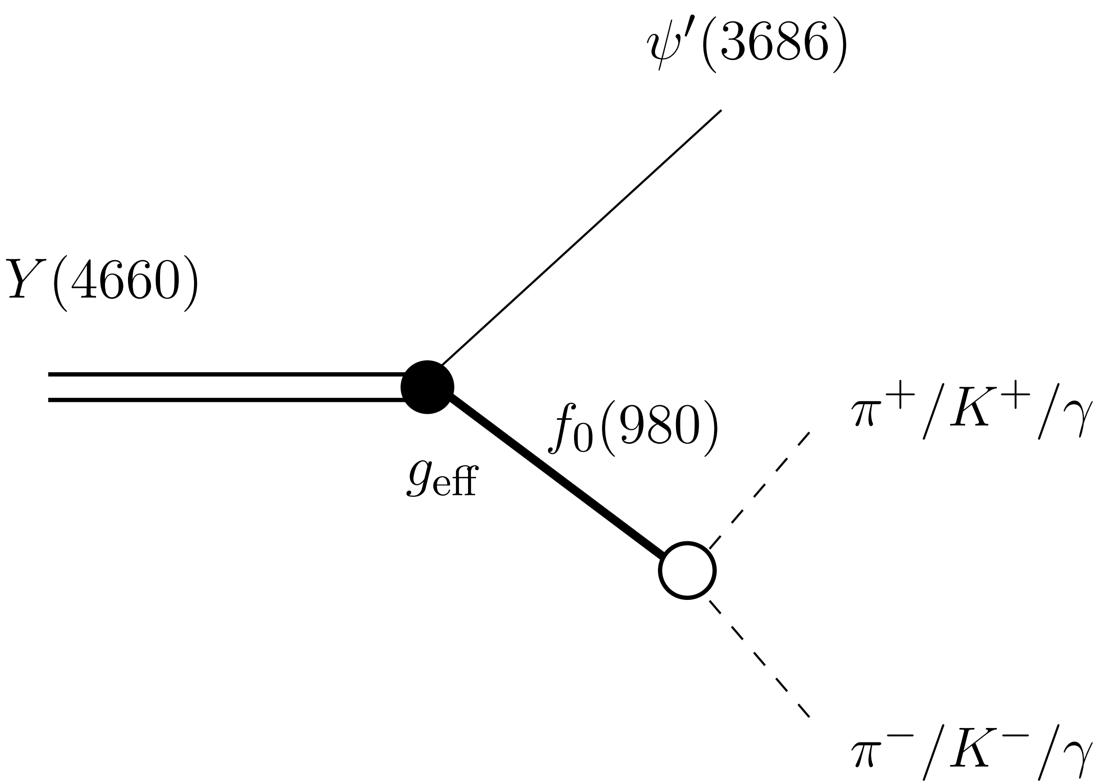
λ^2 = Probability to find hadron pair in physical state

The structure information is hidden in the effective coupling, extracted from experiment, independent of the phenomenology used to introduce the pole(s)

The $Y(4660)$

Properties:

- $\rightarrow$ Close to $f_0\psi'$ threshold ($m_{f_0} + M_{\psi'} = 4666$ MeV)
- $\rightarrow$ Seen only in $e^+e^- \rightarrow \gamma_{ISR}\pi^+\pi^-\psi' \rightarrow J^{CP} = 1^{--}$
- $\rightarrow$ Not seen in $e^+e^- \rightarrow \bar{D}^{(*)}\bar{D}^{(*)}$ and $e^+e^- \rightarrow \bar{J}/\psi D^{(*)}\bar{D}^{(*)}$



we use

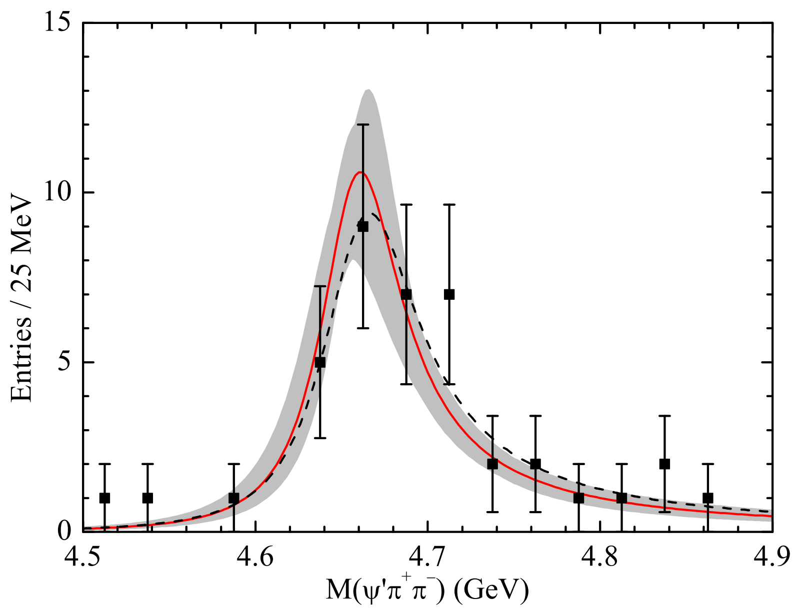
$$\frac{g_{\rm eff}^2}{4\pi} = 4(m_1 + m_2)^2\sqrt{\frac{2\epsilon}{\mu}}$$

Free parameters

- $\rightarrow$ M_Y
- $\rightarrow$ normalization

Fit to data

Comparison with data



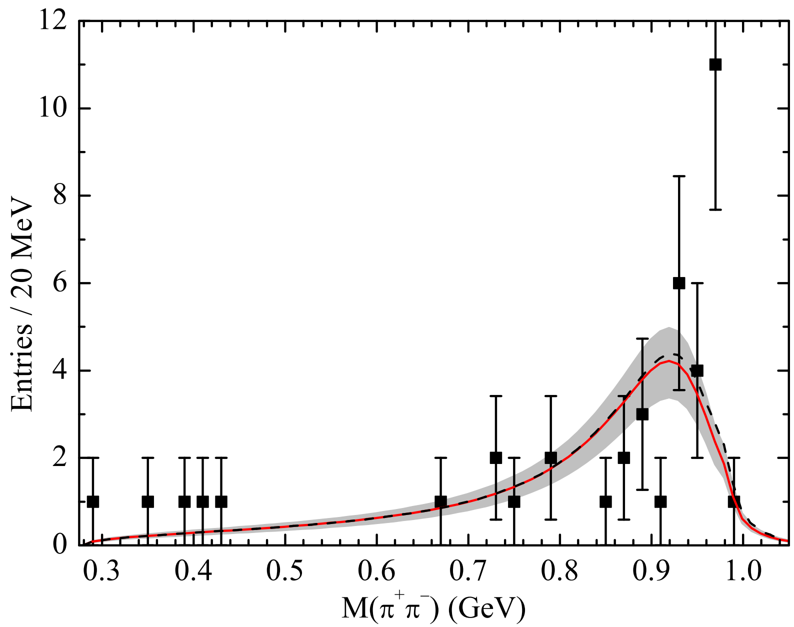
← this fitted, which yields

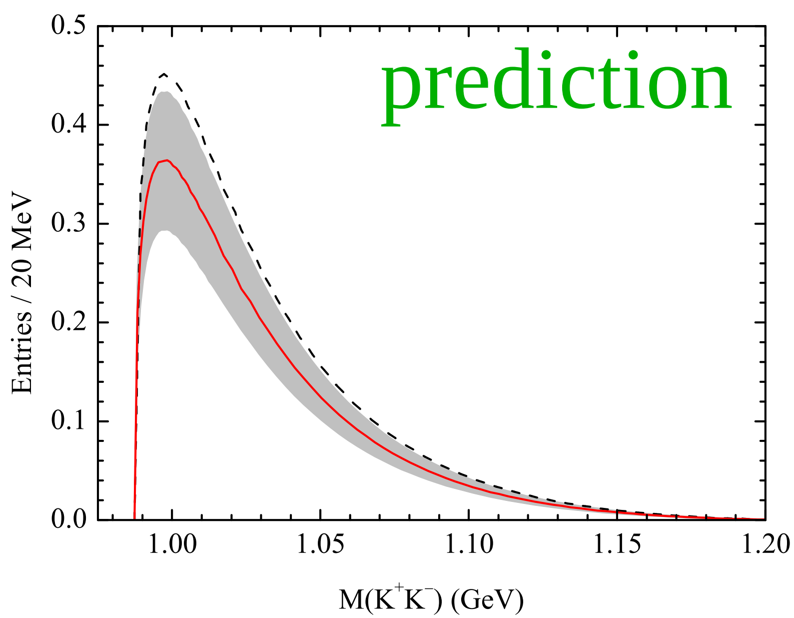
$$M_Y = (4665^{+3}_{-5})\ \text{MeV}$$

and thus $g_{\text{eff}} = 11..14$ GeV.

dashed line: g also fitted

→ $g = (13 \pm 2)$ GeV,
$M_Y = (4672 \pm 9)$ MeV





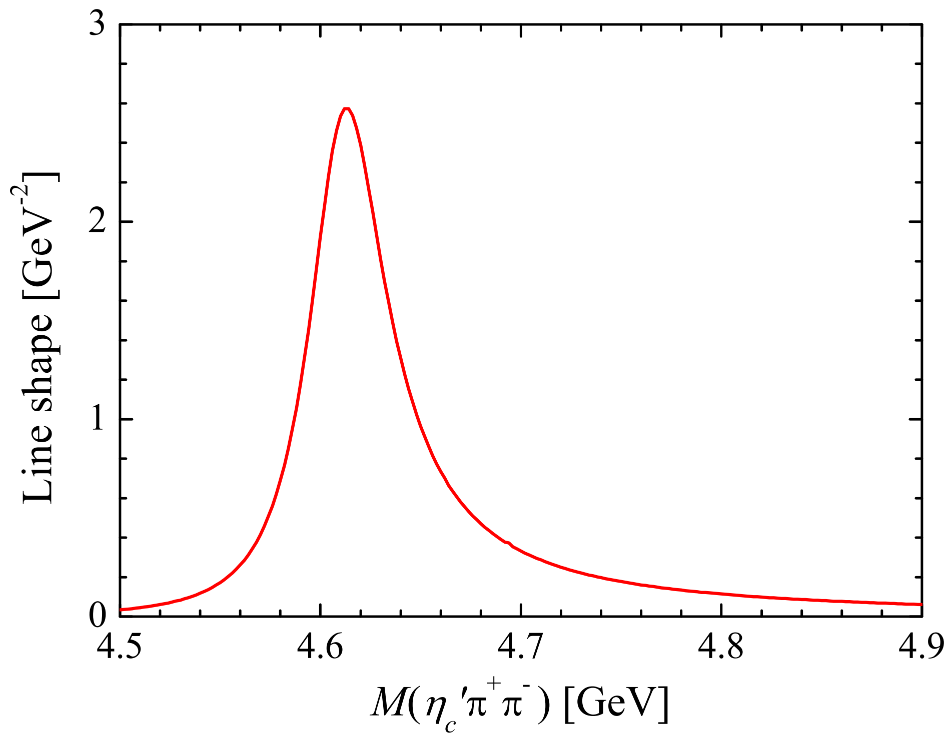
Data: Belle (2007); F.-K. Guo, C.H., U.-G. Meißner (2008)

Heavy Quark Symmetry

If the $Y(4660)$ is a $f_0\psi'$ molecule, heavy quark symmetry allows us to predict

the $J^{PC} = 0^{-+}$ state $Y_\eta(4616)$ as a $\eta_c' f_0$ molecule

Guo, C.H., Meißner (2009)



$$M_{Y_\eta} = M_Y - (M_{\psi'} - M_{\eta_c'}) + \mathcal{O}\left(\left(\Lambda_{QCD}/m_c\right)^2\right)$$

$$\frac{g_{\rm eff}^2}{4\pi} = 4(m_1+m_2)^2\sqrt{\frac{2\epsilon}{\mu}}$$

$$\Gamma(\eta_c'\pi\pi) = (60 \pm 30) \text{ MeV}$$

Proposed discovery channel: $B^\pm \to \eta_c' K^\pm \pi^+\pi^-$

VALUE OF M_{Y_η} SPECIFIC FOR MOLECULAR PICTURE!!!

Origin of $X(4630)$?

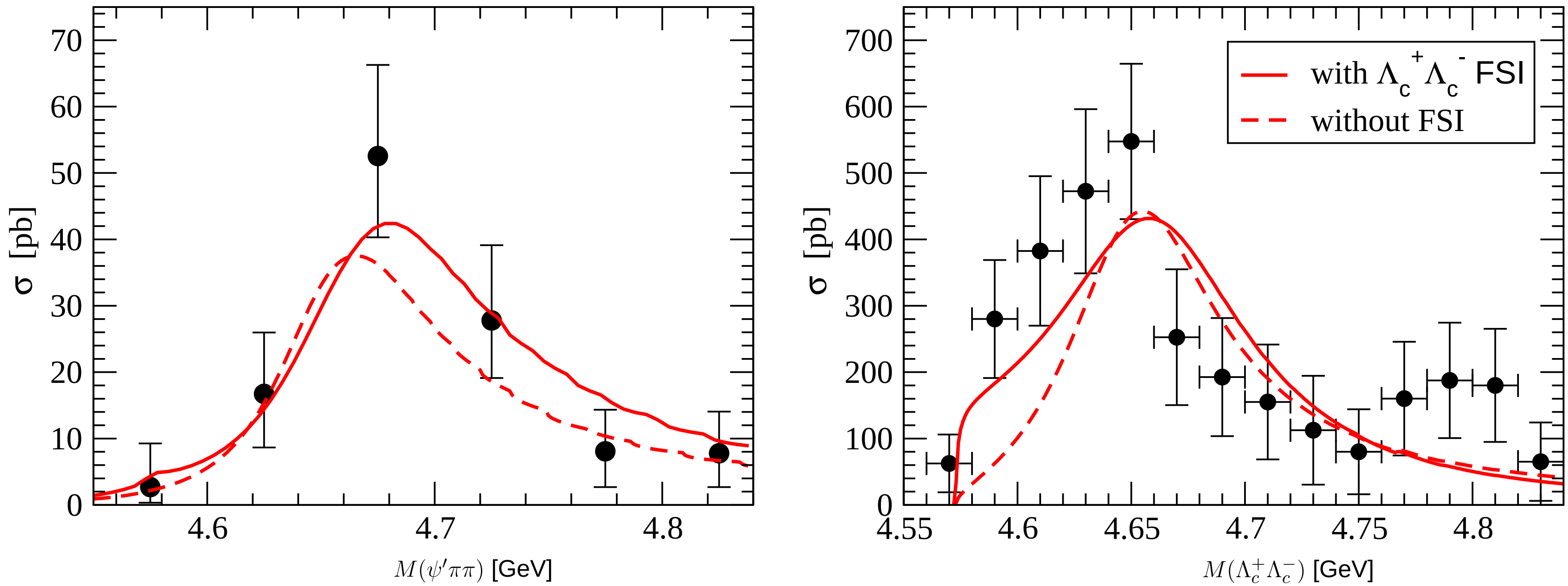
The same state as $Y(4660)$?

Bugg (2008); Cotugno et al. (2010); Guo et al. (2010)

Note:

$$\frac{\mathrm{Br}(Y \to \Lambda_c \bar{\Lambda}_c)}{\mathrm{Br}(Y \to \psi' \pi\pi)} \sim 10 - 20 \ .$$

In conflict with molecular picture? combined fit possible!



But then: $\psi'\pi\pi$ spectrum no longer saturated by $\psi' f_0(980)$ ...

Again: Important to find spin partner

Charmonium decays

Extraction of m_u/m_d from $\psi' \to J/\psi \pi^0(\eta)$

$$\frac{\mathcal{B}(\psi' \to J/\psi\pi^0)}{\mathcal{B}(\psi' \to J/\psi\eta)} = 3\left(\frac{m_d - m_u}{m_d + m_u}\right)^2 \frac{F_\pi^2}{F_\eta^2}\frac{M_\pi^4}{M_\eta^4}\left|\frac{\vec{q}_\pi}{\vec{q}_\eta}\right|^3,$$

Joffe, Shifman (1980); Donoghue, Holstein, Wyler (1992)

from this one gets - using data from CLEO (2008)

$$\frac{m_u}{m_d} = 0.40 \pm 0.01.$$

On the other hand

$$\frac{m_u}{m_d} = \frac{M_{K^+}^2 - M_{K^0}^2 + 2M_{\pi^0}^2 - M_{\pi^+}^2}{M_{K^0}^2 - M_{K^+}^2 + M_{\pi^+}^2} = 0.56$$

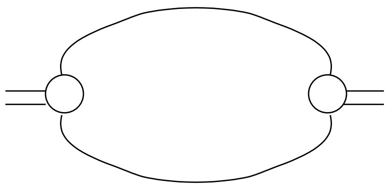
Weinberg (1977); Gasser, Leutwyler (1982); Leutwyler (1996)

Serious discrepancy!

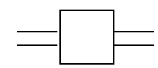
NREFT

Influence of meson loops on properties of $\psi(ns)$

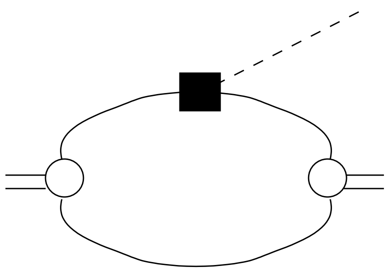
natural expansion parameter: velocity v for $\psi' \to J/\psi\pi^0 : \; v \sim 1/2$



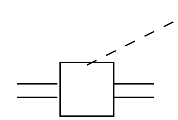
$$\simeq \frac{v^3 v^2}{v^2} = v^3$$



$$\simeq 1$$



$$\simeq \frac{q v^5}{v^4}\left(\frac{\delta}{v^2}\right) = \frac{q\delta}{v}$$



$$\simeq q\delta$$

Thus, in certain decays loops are to be significant!

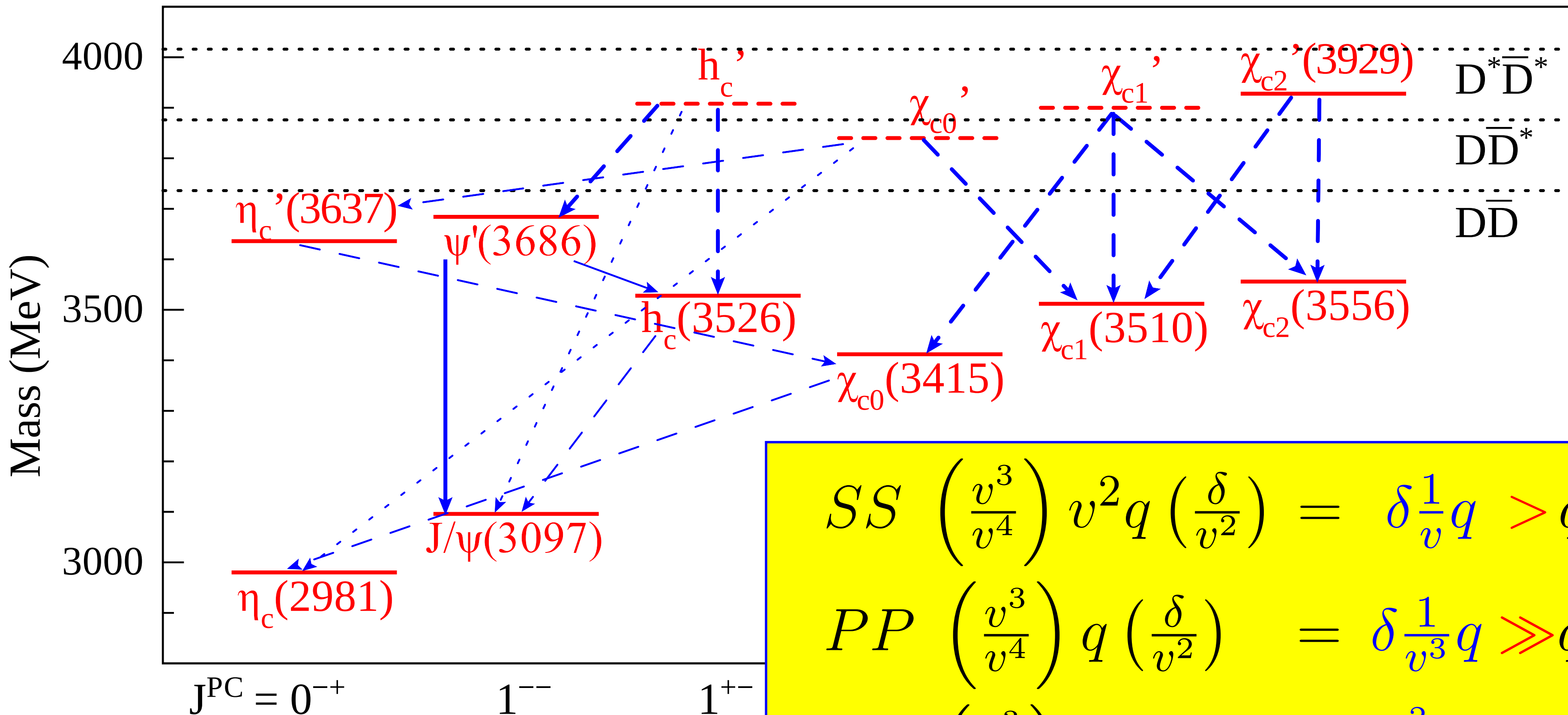
$$\left(\frac{\mathcal{B}(\psi' \to J/\psi\pi^0)}{\mathcal{B}(\psi' \to J/\psi\eta)}\right)_{\rm loops} = 11 \pm 6 \; \% \; (\text{Exp: } 4.0 \pm 0.3)\%$$

Guo, C.H., Meißner (2009); see also: Voloshin (2005)

parameter free at leading order (note: sizable uncertainty!)

Whats missing?

Measure analogeous transitions



$$SS \; \left(\frac{v^3}{v^4}\right) v^2 q \left(\frac{\delta}{v^2}\right) = \delta \frac{1}{v} q > q\delta$$

$$PP \; \left(\frac{v^3}{v^4}\right) q \left(\frac{\delta}{v^2}\right) = \delta \frac{1}{v^3} q \gg q\delta$$

$$SP \; \left(\frac{v^3}{v^4}\right) \frac{qq}{M_D^2} \left(\frac{\delta}{v^2}\right) = \frac{q^2}{v^3 M_D^2} \delta < \delta$$

Results double checked with relat. phenomenolog. approach.

Very non–trivial pattern allows for clean test!

Summary

There is strong evidence that (heavy) meson loops play an important role in heavy meson phenomenology in both ways:

$\rightarrow$ non-perturbatively

$\Longrightarrow$ Formation of Hadronic molecules

$\rightarrow$ perturbatively

$\Longrightarrow$ Changing certain charmonium decay rates

To check this we need

$\rightarrow$ From Th. :full exploration of symmetries (spin partners!)

$\rightarrow$ From Exp.:high accuracy data for various channels

Thanks for your attention