Exotic open and hidden charm states

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Key references:

F.-K. Guo, C.H., U.-G. Meißner, arXiv:0904.3338.

F.-K. Guo, C.H., S. Krewald, U.-G. Meißner, Phys. Lett. **B**666 (2008)251.

F.-K. Guo, C.H., U.-G. Meißner, Phys. Lett. **B**665 (2008)26; arXiv:0901.1597; 0904.3338.

The Goal

We need methods that allow us

→ to identify exotics

→ with a clear connetction to QCD

→ with a controlled uncertainty

The tools we have at our disposal:

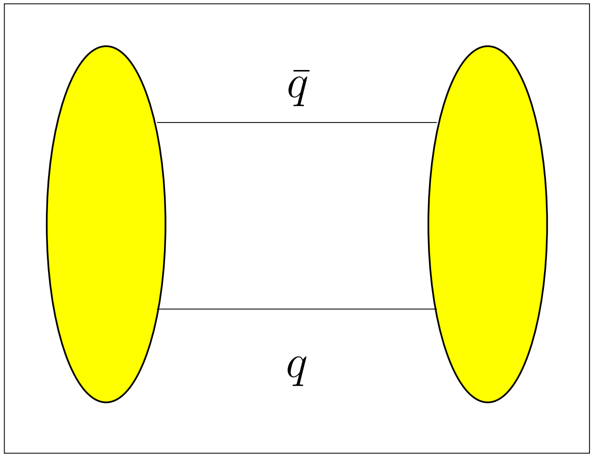
→ Lattice gauge theory

→ Effective field theory

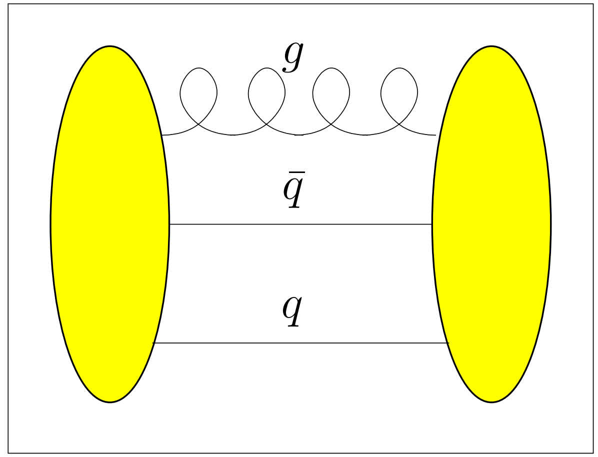
→ General theorems

Exotics

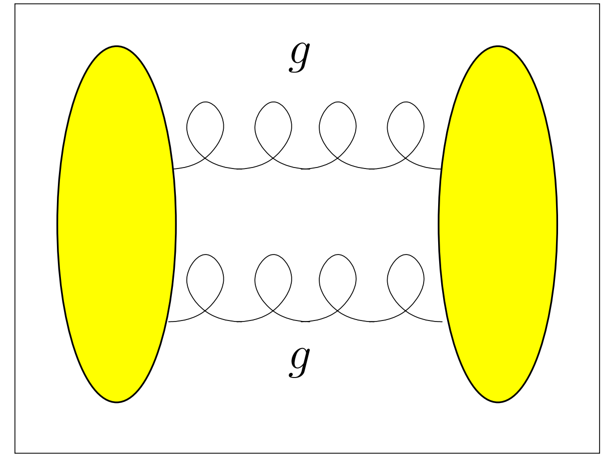
$\bar{q}q$



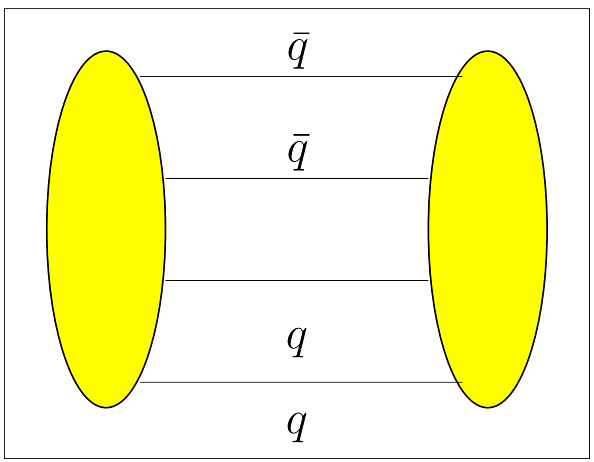
hybrid



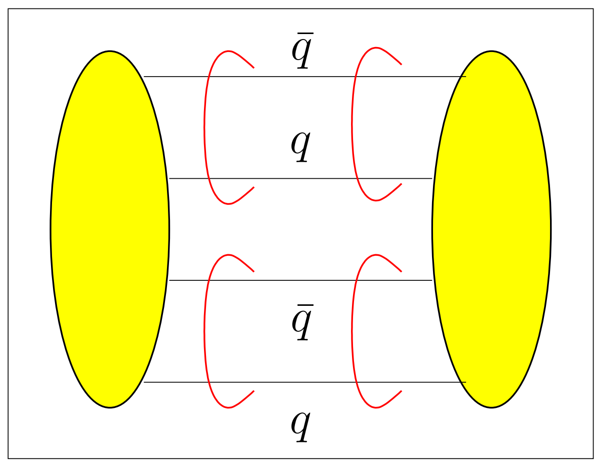
glueball



tetraquark



molecule



Only hadrons can go on-shell $\longrightarrow$ Unique analytic properties of molecular amplitude

General theorem

One can derive

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

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

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

The structure information is hidden in the

effective coupling, extracted from experiment,

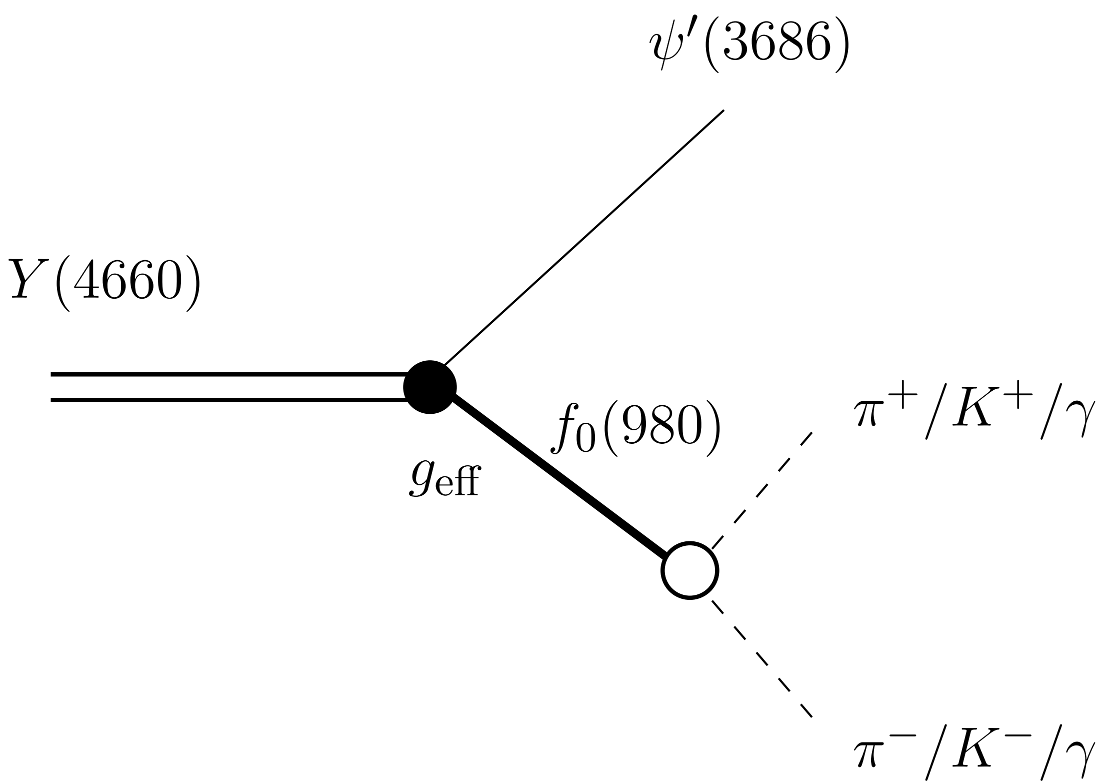
independent of the phenomenology

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

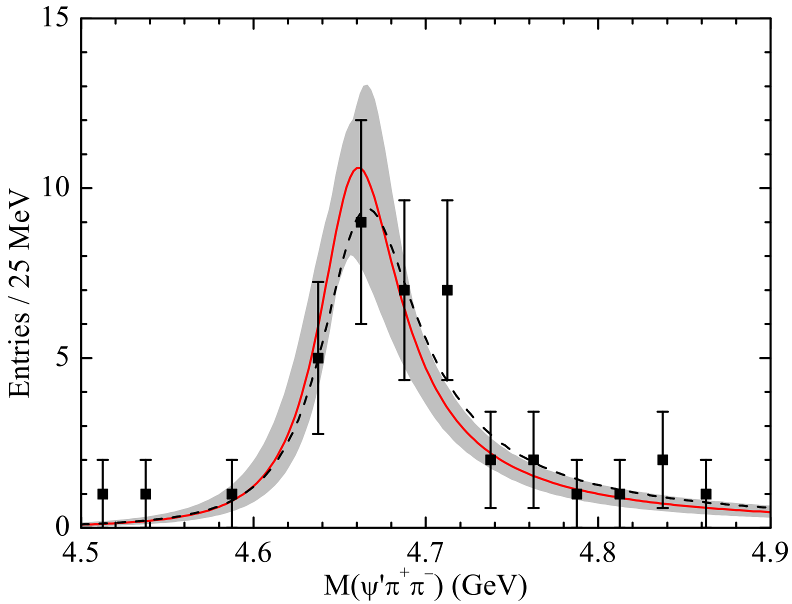
$$\frac{g_{\rm eff}^2}{4\pi} = 4(m_1+m_2)^2\sqrt{\frac{2\epsilon}{\mu}}$$

Free parameters

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

Fit to data

Comparison with data



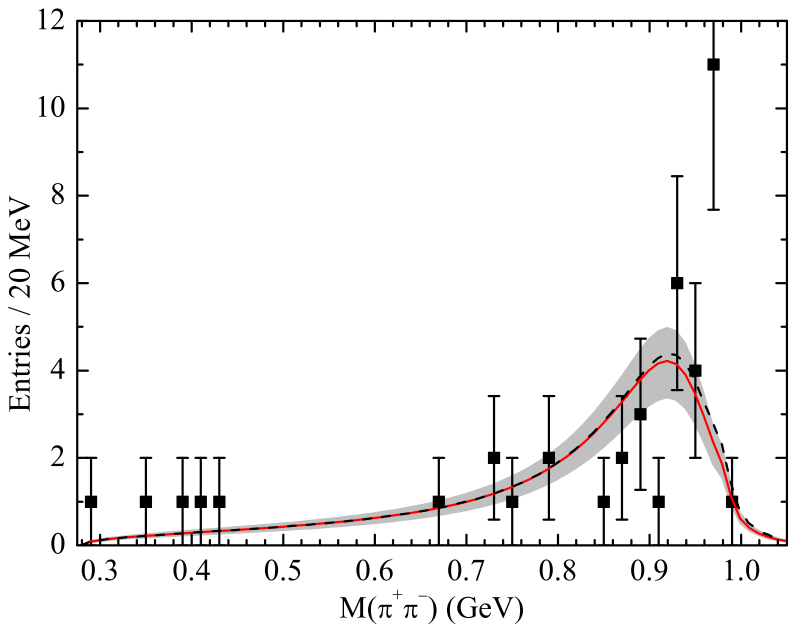
← this fitted, which yields

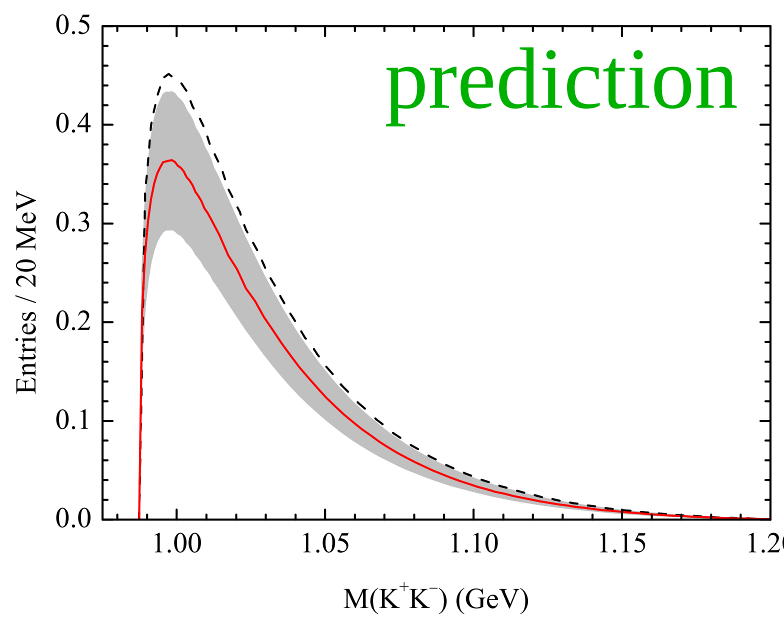
$$M_Y = (4665^{+3}_{-5})\ \text{MeV}$$

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

dashed line: g also fi tted

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





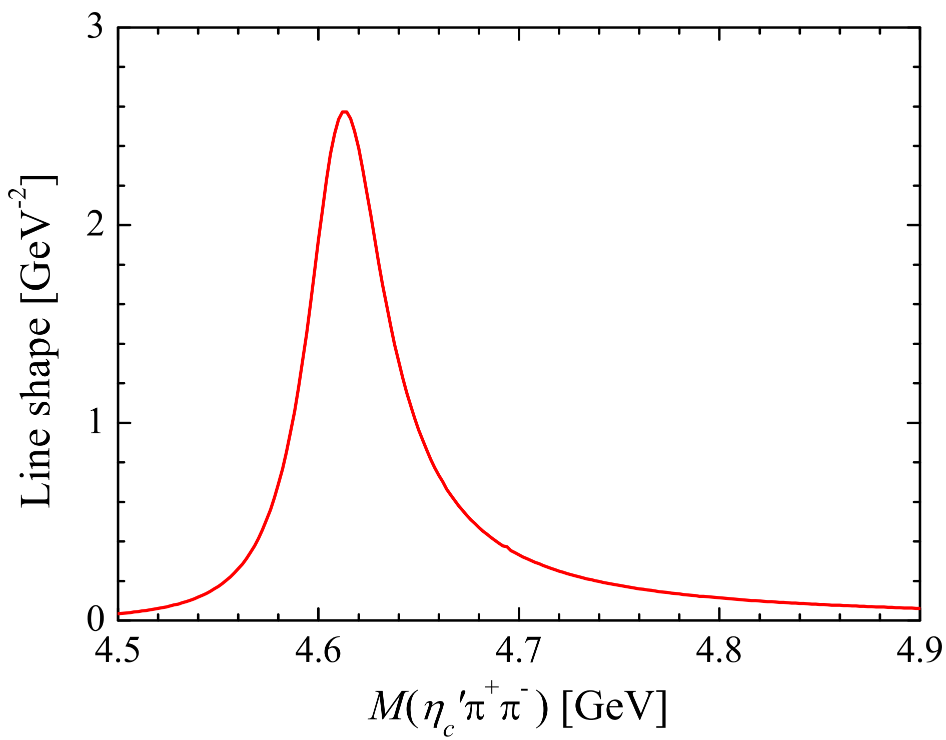
Data: Belle (2007); F.-K. Guo, C.H., U.-G. Meißner (2008)

Heavy Quark Symmetry

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

$Y_\eta(4616)$ as a $\eta_c' f_0$ molecule

Guo, C.H., Meißner (2009)



$$M_{Y_\eta} = M_Y - (M_{\psi'} - M_{\eta_c'})$$

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

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

Proposed discovery channel: $B^\pm \to \eta_c' K^\pm \pi^+\pi^-$ (or $\Lambda_c\bar{\Lambda}_c$)

Connection to QCD

Some observables may be directly calculated from QCD

e.g. for $\pi/K/\eta 4$–D-Meson scattering: scattering lengths from

- → lattice gauge theory
- → chiral perturbation theory

  Weinberg/ Gasser, Leutwyler

  → controlled quark mass dependence

- → chiral perturbation theory with unitarization

  → dynamical generation of poles

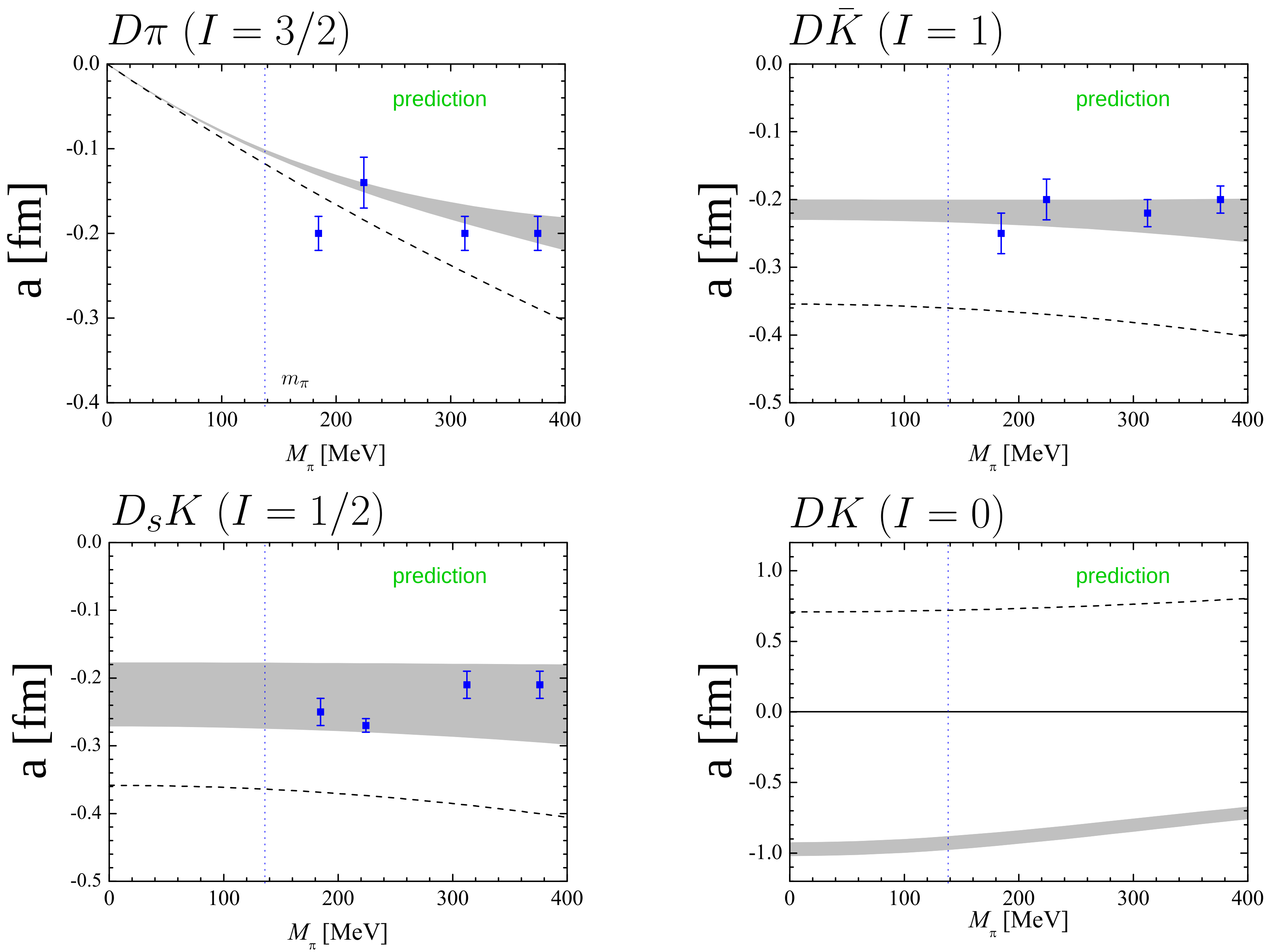
  Kaiser, Weise/ Oller, Oset, Pelaez/ Lutz, Kolomeitsev, Soyeur/ Guo, C.H., Krewald, Meißner (2008)/ Guo, C.H., Meißner (2009)

Comparison will allow one to constrain LECs

At this point: use LEC to fix pole position of $D_s(2317)$

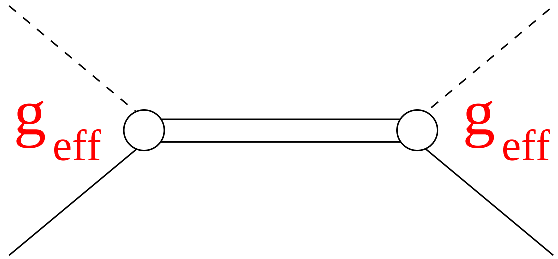
Prediction of other observables

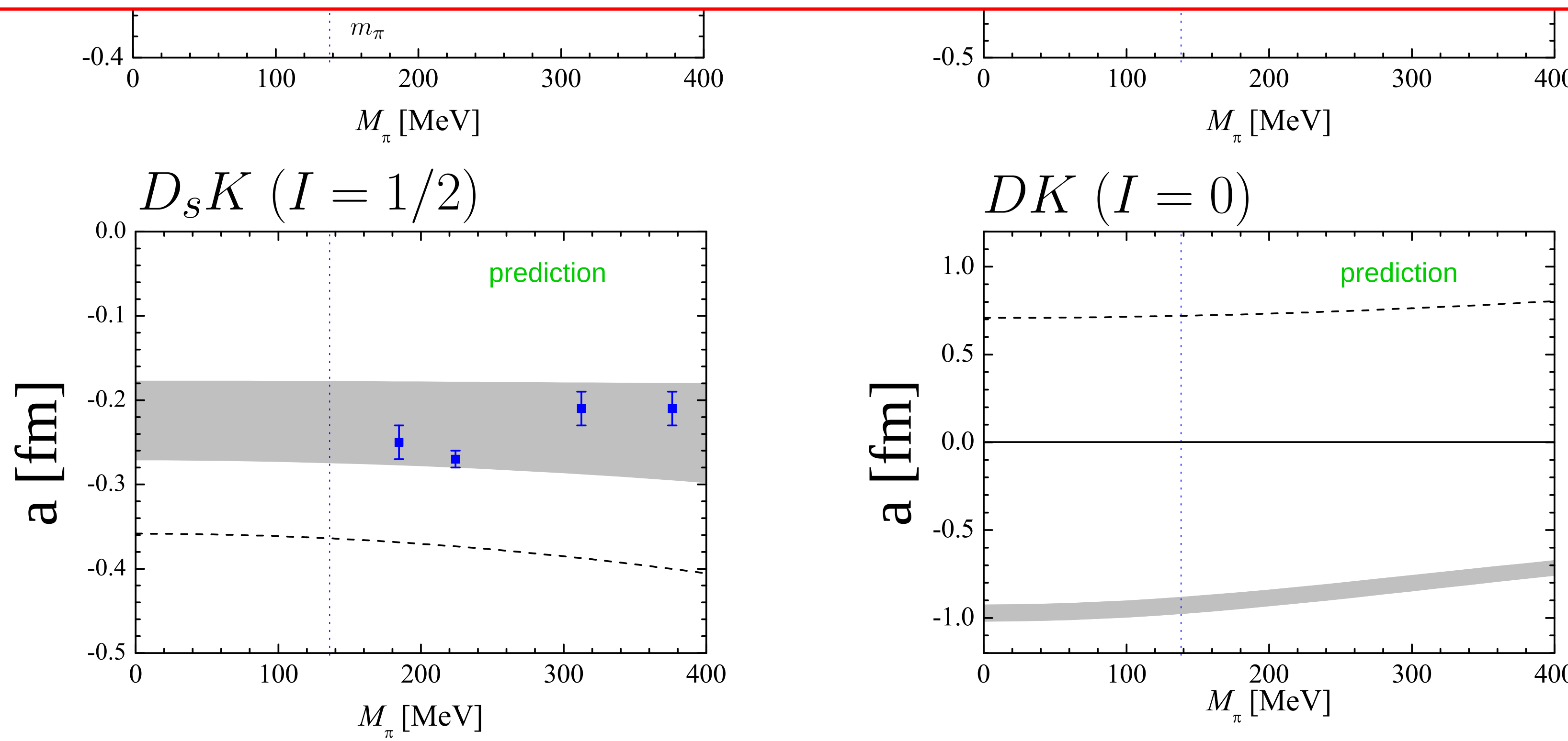
Chiral extrapolation



Lattice: Liu, Lin, Orginos (2008); UChPT: Guo et al. (2009)

Chiral extrapolation

$D_S(2317)$: $a =$ g_{eff}  g_{eff} $+\mathcal{O}(1/\beta) \simeq -1/\sqrt{2m_K\epsilon}$



Lattice: Liu, Lin, Orginos (2008); UChPT: Guo et al. (2009)

$D_s(2317) \to \pi^0 D_s$

Isospin breaking in QCD and EFT through quark mass and charge differences

The same effective operators lead to

$\to$ mass differences, e.g.

- $\triangleright$ $m_{D^+} - m_{D^0} = \Delta m^{\text{strong}} + \Delta m^{\text{e.m.}}$
  $= ((2.5 \pm 0.2) + (2.3 \pm 0.6))$ MeV
- $\triangleright$ $\pi^0 - \eta$ mixing $\longrightarrow$ parameters fixed

$\to$ Isospin breaking scattering amplitude

- $\triangleright$ e.g. $KD \to \pi^0 D_s$ predicted; with this

$$\Gamma(D_s(2317) \to D_s \pi^0) = (180 \pm 110)\text{keV}$$

Lutz, Soyeur (2007); complete to NLO+uncertainty estimate: Guo et al. (2008)

much smaller in quark model $\to$ direct measurement necessary

Outlook

JÜLICH FORSCHUNGSZENTRUM

- $\longrightarrow$ Direct measurement of $\Gamma(D_s(2317))$ possible with PANDA
- $\longrightarrow$ next step: inclusion of D^*; with this
  - ▷ investigation of axial mesons
  - ▷ calculation of radiative decays
- $\longrightarrow$ higher orders in ChPT and HQEFT

Progress through interplay of
controlled theorie,
experiments of high quality
numerical simulations with super computers