STATUS OF CHIRAL DOUBLERS OF HEAVY-LIGHT HADRONS IN LIGHT OF RECENT BABAR, CLEO, BELLE AND SELEX $D_s$ STATES

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We explain the main idea of the chiral doublers scenario, originating from simultaneous constraints of chiral symmetry and of heavy quark spin symmetry on effective theories of heavy-light hadrons. In particular we discuss chiral doublers for mesons, chiral doublers for excited mesons, chiral doublers for baryons and chiral doublers for excited baryons.

We point out the arguments why new states $D_s(2317)$ and $D_s(2457)$ might be viewed as chiral doublers of $D_s$ and $D_s^*$. Then we comment on non-strange mesons $D_0(2308)$ and $D_1^*(2427)$ observed by Belle and Focus, and on $\Theta_c(3099)$ signal observed by H1. Finally, we point out that very recent discovery by SELEX of $D_s(2632)$, if confirmed by other experiments and if spin-parity of this state is $1^-$, may be interpreted as a signal for chiral doubler of $D_{s1}(2536)$. Such an identification implies another narrow, spin-parity $2^-$ $D_s$ state ca 37 MeV above the new $1^-$, corresponding to chiral partner of $D_{s2}$.

Keywords: chiral symmetry, heavy quark symmetry, chiral doublers

1. New experimental results on open charm

During last year, several experiments have reported spectacular discoveries in the domain of charm spectroscopy. In particular:

– BaBar has announced new, narrow meson $D_{sJ}^+(2317)^+$, decaying into $D_s^+$ and $\pi^0$. This observation was then confirmed by CLEO, which also noticed another narrow state, $D_{sJ}^+(2463)^+$, decaying into $D_s^*$ and $\pi^0$. Both states were confirmed by Belle and finally, the CLEO observation was also confirmed by BaBar. The 2317 state was also confirmed by Focus.

– Belle provided first evidence for two new, broad states $D_0^+(2308 \pm 17 \pm 15 \pm 28)$ and $D_1^{'+}(2427 \pm 26 \pm 20 \pm 17)$. Both of them are approximately 400 MeV above the usual $D_0$, $D^*$ states and have opposite to them parity.

– Few days ago, Selex has announced a new, surprisingly narrow state $D_{sJ}^+(2632)$ with unusual decay properties.

– New results on charmed baryon spectroscopy appeared lately: Selex confirmed

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doubly charmed baryons\(^8\). H1 experiment at DESY has announced\(^9\) a signature for narrow charmed pentaquark \(\bar{c}udud\) at mass 3099 MeV.

The above states and in particular the decay patterns of all these particles challenged standard estimations based on quark potential models and triggered a renewal of interest on charmed hadrons spectroscopy among several theorists\(^10\),\(^11\).

An appealing possibility is that the presence of several above states is the consequence of so-called chiral doublers scenario, theoretically anticipated\(^12\),\(^13\) already a decade ago.

### 2. Chiral doublers scenario

Quarks with different flavors have very different masses: current masses of \(l(ight) = u, d,\) and \(s\) quark \((1.5 - 4.4 - 8, 80 - 130\) MeV) are smaller than the fundamental constant of QCD (in \(\overline{MS}\) scheme), \(\Lambda_{QCD} = 220 \pm 20\) MeV, whereas current masses of \(h(eavy) = c, b,\) and \(t\) quark \((1150 - 1350, 4100 - 4400, 174000 \pm 5000\) MeV) are considerably heavier than \(\Lambda_{QCD}\). In order to understand the dynamics of strong interaction, it is tempting to consider following limits:

- \(m_l/\Lambda_{QCD} \to 0\)
- \(\Lambda_{QCD}/m_h \to 0\).

First limit (massless light quark limit) is known as a chiral limit. In this case exact chiral symmetry of the QCD interactions is spontaneously broken. Vacuum state is respecting only vector part of the symmetry, whereas axial symmetry is broken, resulting in massless Goldstone excitation for each “direction” of the axial symmetry group. On top of this effect explicit breaking of the chiral symmetry (due to the finite masses of light quarks) takes place, shifting the massless pions to 140 MeV, massless kaons to 495 MeV etc. The breakdown of chiral symmetry leads to a well known wealth of predictions on low-energies processes, based on organizing the amplitudes in powers of the light meson momenta (low energy theorems, chiral Ward identities, chiral perturbation theory etc.)

The second limit (infinite heavy quark mass limit or Isgur-Wise\(^14\) limit) is equally illuminating. In this limit, dynamics of the heavy quark becomes independent of its spin and mass. As one of the consequences of such limit, the masses of the pseudoscalar \(0^-\) and vector \(1^-\) mesonic states including heavy quark become degenerate. Again, the systematic expansion in \(1/m_h\) is possible, establishing the principles of heavy quark effective theory.

The case of heavy-light mesons, as the simplest heavy-light hadrons, is particularly interesting. It is natural, from the aforementioned arguments, to consider their dynamics as simultaneously constrained by two above limits. After understanding these constraints, one can address the issue of finite light quark masses and/or finite \(1/m_h\) corrections.

The chief observation made in\(^12\),\(^13\) was that a consistent implementation of the spontaneous breakdown of the chiral symmetry for light quarks and Isgur-Wise symmetry for heavy quarks requires in addition to known \((0^-, 1^-)\) heavy mesons,
new heavy-light chiral partners, separated in the Isgur-Wise limit by the finite, small split originating solely from the spontaneous breakdown of the chiral symmetry. The similar doubling was expected for heavy-light baryonic states as well for hadronic excitations \[14\]. This prediction was in contrast to traditional heavy-light spectroscopy, which was much based on Coulomb bound states alike heavy-heavy systems, and was not taking into account the possibility that the constraints of chiral symmetry may be so manifest at the level of \(c\) and \(b\) quark physics.

From the point of view of the chiral symmetry, the chiral doubling for heavy-light systems is a fundamental phenomenon, representing a pattern of strong interaction. Let us present a simple argument, why the presence of doublers is not a puzzle. To one-loop approximation, the order \(m_0\) contribution to the mass of the heavy-light meson comes from the diagram shown in Fig. 1. The propagator of the heavy quark \((\hat{p} - m_h)^{-1}\) becomes \(\hat{p}/(vk)\), after decomposing the heavy quark momentum into \(p = m_h v + k\) with four-velocity \(v\). The light (massless) quark, when propagating through the non-trivial vacuum, dresses itself, and acquires a constituent mass \(\Sigma\).

Let us introduce, after \[16\] a following notation for the degenerate in the IW limit vector-pseudoscalar, \((0^-, 1^-)\) state:

\[
H = 1 + \frac{\hat{p}}{2} (\gamma^\mu D^*_\mu + i\gamma_5 D) \quad (1)
\]

with a transverse vector field, i.e. \(v \cdot D^* = 0\). Then the main contribution from the diagram shown on Fig. 1 reads

\[
m_H \text{tr} \bar{H} H \sim \text{Tr} \left( P_l \frac{\Sigma}{Q^2 - \Sigma^2} H P_h \frac{\hat{p}}{v \cdot Q} \bar{H} \right) \quad (2)
\]

where the trace (tr) is over flavor and spin, trace (Tr) includes additionally integrating over momenta circulating within the loop and \(P_l\) and \(P_h\) are projectors for light and heavy quark propagators (note that \(H\) and its conjugate \(\bar{H}\) mixes heavy-light quarks).

Let us consider now the similar diagram, but for states with opposite parity. We introduce a natural notation,

\[
G = \frac{1 + \hat{p}}{2} (\gamma^\mu \gamma_5 \tilde{D}^*_\mu + i\tilde{D}) \quad (3)
\]

for degenerated in the IW limit scalar-pseudovector multiplet \(G\). We denoted the doublers \((0^+, 1^+)\) by tilde. Then, the mass contribution reads

\[
m_G \text{tr} \bar{G} G \sim \text{Tr} \left( P_l \frac{\Sigma}{Q^2 - \Sigma^2} G P_h \frac{\hat{p}}{v \cdot Q} \bar{G} \right) \quad (4)
\]

Note that the difference for chiral masses origins from the additional \(\gamma_5\) in the definition of the fields \(H\) and \(G\), (note \(\gamma_5^2 = 1\), in other words from the parity assignmen. The range of integration over 4-momentum \(Q\) under trace (Tr) is \(0 < Q < \Lambda_{UV}\) where \(\Lambda_{UV}\) is an ultraviolet cut-off. Since \(H\hat{p} = -H\) and \(G\hat{p} = +G\), the result is a split between the heavy-light mesons of opposite chirality. This unusual contribution of the chiral quark mass stems from the fact that it tags to the velocity \(H\hat{p}H\).
of the heavy field and is therefore sensitive to parity. The reparametrization invariance (invariance under velocity shifts of the heavy quark to order one) introduces mass shifts that are parity insensitive to leading order in $1/m_h$. The $H^G$-mass difference is dictated by the spontaneous breaking of chiral symmetry:

i) the light quark contributes a mass shift of order an induced cut-off dependent constituent mass $\Sigma$;

ii) interaction is repulsive in the scalars (no $i\gamma_5$) and is attractive in the pseudoscalars (with $i\gamma_5$), so the mass of $G$ goes up and the mass of $H$ goes down.

In this limit, the spontaneous breakdown of chiral symmetry enforces the mass relation

$$m(\tilde{D}^*) - m(D^*) = m(\tilde{D}) - m(D) = m_G - m_H \sim O(\Sigma) \quad (5)$$

If we would restore (e.g. in Gedankenexperiment) the chiral symmetry, i.e. put $\Sigma = 0$ both chiral copies will be degenerated. In real world, chiral symmetry is broken, as well as IW symmetry is not exact. As a consequence, spin 0 and spin 1 states are split by the $1/m_h$ effects, and resulting both pairs $(0^-, 1^-)$ and $(0^+, 1^+)$ are also split by the spontaneous and explicit breakdown of the chiral symmetry. This split may be viewed (at least in the chiral limit) as an order parameter for spontaneous breakdown of the chiral symmetry.

Since chiral doublers scenario is based solely on patterns of QCD symmetries in the chiral and IW limit, one could expect a generic, model independent manifestation of this phenomenon, alike the case of low-energy theorems for the light-light systems. Indeed, this is the case. Goldberger-Treiman relations for heavy-light mesons, first written by $^{13}$ and extended for finite heavy and finite light masses in $^{17}$ constitute model-independent, low energy QCD theorems for heavy-light mesons. They explicitly demonstrate the appearance of small scale of pion decay constant $f_\pi \sim 100 MeV$ together with large mass scales of the $D$ or $B$ mesons. This small
Fig. 2. Cube representing schematic (e.g. the units in the upper and lower plaquettes are different) classification of chiral doublers. Labels correspond to the case of $c\bar{s}$ mesons. Selex signal $D_s(2632)$ is interpreted as an excited doubler, see text.

scale, magnified by the ratio of axial coupling constants, yields typical split of order of constituent mass of the light quark, i.e. 350 MeV.

2.1. “D-cubes”

One can visualize the consequences of the chiral doubling for mesons in the form of the cartoon, see Fig. 2. The three-dimensional “cube” is aligned along three “directions”:
- chiral symmetry breaking (horizontal, green)
- Isgur-Wise symmetry breaking (skew, red)
- total light angular momentum (vertical, blue).

The corners of the cube represent generic $h\bar{l}$ mesons, i.e. we expect similar “cubic” patterns for $c\bar{s}$, $c\bar{u}$, $c\bar{d}$, $b\bar{s}$, $b\bar{u}$, $b\bar{d}$ mesons.

We focus on $c\bar{s}$ states, i.e. $D_s$-cube. Lower left rung represents known pseudoscalar $0^- \ D_s(1969)$ and vector $1^- \ D_s^*(2112)$, belonging to $j_l = 1/2$ light angular momentum representation. The splitting between them (143 MeV) is an $1/m_c$ effect and is expected to vanish in infinitely heavy charm quark limit, i.e. both particles would have form the $H$ multiplet. The upper left rung corresponds to $j_l = 3/2$ representation, i.e. $1^+$ and $2^+$ excited multiplet. Here $D_{s1}(2536)$ and $D_{sJ}^*(2573)$ are the candidates, separated by (smaller for excited states, here only 37 MeV) $1/m_c$ origin mass splitting. This “left plaquette” of the $D_s$-cube represents the standard, “pre-BaBarian” charmed meson spectroscopy.

The phenomenon of chiral doublers implies the appearance of the right plaquette. First, we expect two chiral partners for $D_s$ and $D_s^*$, representing right lower rung. Here newly discovered $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$ are the candidates for the $(0^+, 1^+)$ scalar-axial $G$ multiplet. The averaged splitting for $(0^+, 0^-)$ and the averaged splitting for $(1^+, 1^-)$ are $349.2 \pm 0.8$ and $346.8 \pm 1.1$, respectively, i.e. almost identical, as predicted a decade ago. It is intriguing that the combined effects of the finite light mass and finite charm mass are so small, that both chiral shifts are so
The narrowness of the new states is basically the consequence of the kinematic constraint, as pointed by\cite{18}, since the chiral split is smaller than the mass of the kaon, these states live longer. On top of this effect, the isospin conservation most probably forces the pionic decay via virtual $\eta$ decay, suppressing the rate even further\cite{18}. Electromagnetic transitions, estimated on the basis of chirally doubled Lagrangians in\cite{18,19,20} are also in agreement with the experimental data. Chiral Ward identities additionally constraint the amplitudes of the pionic decays for the $H$ multiplets, $G$ and for $G = H$ pionic transitions\cite{17}.

On the basis of the chiral doublers scenario, we would also expect the chiral partners for the excited $j_l = 3/2$ multiplet, i.e. new chiral pair $(1^-, 2^-)$\cite{15}. Alternatively, this pair could be also viewed as the $j_l = 3/2$ excitation of the BaBar-Cleo $(0^+, 1^+)$ multiplet. The states within this new multiplet would be separated by similar $1/m_c$ split, like the split between $D_{s2}$ and $D_{s1}$, i.e. by 37 MeV. A crucial question is how large is the chiral split for the excited states, is it also equal to 350 MeV alike the chiral split for the $j_l = 1/2$ plaquette or is different? One can try to get some insight using the construction for effective chiral action for excited mesons\cite{15}. In particular, we obtained the formulae for chiral mass shifts for excited mesonic states, for $D$ type mesons. After tuning the ultraviolet cutoff to recover the experimental value of 350 MeV for the chiral split of ground states, we obtained\cite{17} substantially smaller chiral shift for the excited states, approximately half of the value of the shift for $j_l = 1/2$ multiplet (170 MeV), i.e we placed the new pair above 2700 MeV, at 2720 and 2760 MeV, for $1^-$ and $2^-$, respectively. The fact that excited states are less sensitive to the effects of the QCD vacuum is not totally unexpected, see e.g.\cite{21}. Of course, the precise value of the chiral shift for the excited doubler can be provided only by an experiment. It is tempting to speculate that the very recent signal reported by SELEX\cite{14} is a $1^-$ doubler of $D_{s1}\cite{22}$, if the state is confirmed and its spin-parity is indeed $1^-$. Then the chiral shift for excited strange charmed mesons would be of order of 100 MeV only. If indeed this is the case, a natural expectation in the chiral doubler scenario is the presence of the chiral doubler for $D_{s2}$ state as well, i.e. one would expect new, $2^-$ state within few MeV around 2669 MeV, possibly in $D_{s2}^{*}\eta$ channel, to follow the pattern of the decay of other doublers. The presence of such state, completing the identification of corners of the “$D_s$-cube”, could be viewed as a strong argument in favor of the chiral doublers scenario.

2.2. D-cube, $B_s$-cube and $B$ – cube

D-cube construction is generic. Left and right plaquettes are chiral copies, front and back plaquettes become degenerate in infinite mass of the heavy quark and the lower and upper plaquettes are separated by the excitation of total light angular momentum $j_l$. We briefly note the possibility of even higher angular excitations,
i.e. additional $j_l = 5/2$ plateau, pointing only that first such states ($2^-, 3^-$) may naturally appear above 3 GeV for $D(D_s)$ mesons.

Let us consider non-strange charmed mesons. Left plaquette is formed by known non-strange charmed mesons i.e. $D(1865)$, $D^*(2010)$, $D_1(2420)$ and $D_2(2460)$. Here two states from Belle, $D_0^+(2308)$ and $D'_1(2427)$ are natural candidates for lower right rung of the D-cube, i.e. for the chiral doublers of $D(1825)$ and $D^*(2010)$. There are however broad, since neither kinematic nor isospin restrictions apply here, contrary to their strange cousins. The precise value of the chiral shift is still an open problem, due to the experimental errors and systematic difference between the Focus 6 and Belle signals. We would like to mention, that the fact that chiral mass shift seems to be equal of even larger for the non-strange mesons than for the strange ones, is not in contradiction with certain models of spontaneous breakdown of the chiral symmetry, although other models make opposite prediction. We should also mention, that the masses (modulo above experimental uncertainties) of these two states can be also understood in the quark model.

Let us move towards the $B_s$ and $B$ mesons. In this case, the chiral doubling should be even more pronounced for bottom mesons, since the $1/m_h$ corrections are three times smaller, i.e. the skew-symmetric (red) edges of the cubes are three times shorter, for $J_l = 1/2$ and $J_l = 3/2$ states, correspondingly. For $m_s = 150$ MeV, we expect the chiral partners of $B_s$ and $B_s^*$ to be 323 MeV heavier, while the chiral partners of $B$ and $B^*$ to be 345 MeV heavier, i.e. close to predictions in 17. We note that any observation of chiral doubling for $B$ mesons would be a strong validation for chiral doublers proposal. For several recently proposed alternative scenarios for new states (multiquark states, hadronic molecules, modifications of quark potential, unitarization) a repeating pattern from charm to bottom seems to be hard to achieve without additional assumptions.

### 2.3. Chiral doublers for baryons

In two next sections, we briefly discuss the extension of the chiral doublers scenario for all baryons, including the exotic states (pentaquarks). To avoid any new parameters, we simply view baryons as solitons of the effective mesonic Lagrangian including both chiral copies of heavy-light mesons, a point addressed already in 12 and recently reanalyzed in 24. We are working in large $N_c$ limit, which justifies the soliton picture, and large heavy quark mass limit, where we exploit the Isgur-Wise symmetry. This approach could be viewed as a starting point for including $1/m_h$ corrections from the finite mass of the heavy quark, explicit breaking of chiral symmetry, etc.

The description of baryons as solitons of the mesonic Lagrangians has a long history. Original Skyrme idea was elaborated by Witten and Adkins, Nappi and Witten for $SU(2)_{flavor}$ with enormous success and hundreds of followers. In 28 it was pointed out how to use effective chiral Lagrangian for light sector and simultaneously respect
the Isgur-Wise symmetry. The main idea was that the SU(2)-flavored soliton binds the degenerate in the IW limit pair of a pseudoscalar and a vector, i.e. $D$ and $D^*$. Charmed hyperons emerge therefore as bound states of $D$ and $D^*$ in the presence of the SU(2) Skyrmion (soliton) background. Isgur-Wise symmetry at the baryonic level results in the degeneration of spin 1/2 and 3/2 multiplets. Schematically,

$$\text{charmed hyperon} \rightarrow \text{chiral soliton} + H \text{ multiplet}$$

It is natural to generalize this idea for chiral doublers, i.e. to obtain charmed hyperons of negative parity as bound states of SU(2) soliton and chiral doublers of $D$ and $D^*$, i.e.

$$\text{chiral soliton} + G \text{ multiplet} \rightarrow \text{chiral doubler of charmed hyperon}$$

Explicitly, we get for both copies (for details and references see 24)

$$M = M_{\text{soliton}} + m_D - 3/2 g_H F'(0) + a/I_1$$

$$\tilde{M} = M_{\text{soliton}} + m_{\tilde{D}} - 3/2 g_G F'(0) + a/I_1$$

where $M_{\text{soliton}}$ is the $O(N_c)$ classical mass of the Skyrmion, $m_D = (3 M_{D^*} + M_D)/4$ is the averaged over heavy spin mass of heavy-light mesons, $m_{\tilde{D}}$ is similar mass for the chiral mesonic doubler with parity $(0^+, 1^+)$, $g_h$ is the axial coupling constant responsible for the $D^*$ decays into a $D$ and a pion, similarly $g_G$ is the corresponding axial coupling for the doublers, and the inverse of moment of inertia of the Skyrmion $1/I_1$ provides the splitting between the various isospin states (e.g. for isosinglet $a = 3/8$). We follow here the conventions of 29. It is of primary importance that, despite the additional $\gamma_5$ in the definition of the $G$ field both mass formulae have the same functional form of $M$ for $H$ and $\tilde{M}$ for $G$. It happens due to the fact, that the term mixing $G$ and $H$ multiplets vanishes for the Skyrmion configuration 24. Hence both parity partners emerge as $H$ and $G$ bound states in the SU(2) solitonic background.

Hence the mass difference comes: first, from meson mass difference $m_{\tilde{D}} - m_D$; second, from the difference of the coupling constants $g_G - g_H$. Using recent Belle data 2, i.e. $0^+$ candidate $D'_0$ ($2308 \pm 17 \pm 15 \pm 28$) and $1^+$ candidate $D'_1$ ($2427 \pm 26 \pm 20 \pm 17$), we get $M_{\tilde{D}} = 2397$ MeV, unfortunately with still large errors. Comparing the mass shift between the lowest $\Lambda_c$ states of opposite parities, $\Lambda_c(1/2^+, 2285)$ and $\Lambda_c(1/2^-, 2593)$ we arrive at chiral baryonic shift $\Delta_B = 310$ MeV. Similarly, $\Xi_c(1/2^+, 2470)$ and $\Xi_c(1/2^-, 2790)$ give $\Delta_B = 320$ MeV. These numbers suggest, that indeed the leading effect for chiral doubling of baryons comes from the chiral mesonic shift, on top of which one has to add the smaller effects of different axial couplings for two copies. Similar effect is expected for double-heavy baryons of opposite chiralities.

### 2.4. Chiral doublers for exotic states

The above formalism allows easily an incorporation of exotic states. In the fervor of ongoing discussion on pentaquarks, the issue of heavy pentaquarks is far from being
academic. Note, that we may consider the possibility of chiral soliton binding the anti-flavored heavy meson ($\bar{c}l$), resulting in bound state with minimal content of four light quarks and one heavy antiquark. Model-dependent calculations show that the binding in this case is three times weaker, predicting the value of the mass of isosinglet charmed pentaquark with spin-parity $1/2^+$ to be 2700 MeV. Repeating this reasoning for the case of chiral soliton binding the anti-flavored chiral doubler leads us to the mass formula for isosinglet heavy pentaquark of opposite parity

$$M_5 = M_{\text{soliton}} + m_{\bar{D}} - 1/2gGF^2(0) + 3/(8I_1)$$

Combining above formulae we get the value of chiral shift between the pentaquarks expressed in terms of chiral shift for mesons and ground state baryons of opposite chiralities 24, i.e.

$$\Delta_P = \Delta_B + 2\Delta_M \sim 350 \pm 60 \text{ MeV.}$$

where we inferred the shift of the opposite parity heavy charmed mesons from very recent Belle 5, $\Delta_M = 425$ MeV unfortunately with still large errors. This gives the mass of the chiral doubler of the pentaquark as high as $3052 \pm 60$ MeV. Recently, H1 9 noticed a narrow signal at 3099 MeV interpreted as charmed pentaquark (although this signal was not confirmed by other experiments). We dare to interpret the recent H1 state 9 as a parity partner $\tilde{\Theta_c}$ of the yet undiscovered isosinglet pentaquark $\Theta_c$ of opposite parity and $M_5 \approx 2700$ MeV, i.e. even below the strong decay threshold. Chiral doublers scenario offers also a hint how to understand the narrowness of the H1 state. The natural channel for the decay of this state into a nucleon and parity partners of the standard $D(D^*)$ mesons is kinematically blocked. De-excitation of $\Theta_c$ into $\Theta_c$ and a pion is isospin forbidden and to $\eta^0$ kinematically blocked. The only way the decay process may proceed, is a chiral fluctuation of a bound $\bar{D}$ into $D$ by virtual interaction with a pion from the nucleon cloud. That requires, however, spatial rearrangement, since the $D$ meson must be in a partial wave of opposite parity with respect to the partial wave of $\bar{D}$. Hence the overlap of the $\bar{D}$-soliton bound state wave function with the one of the $D$-soliton is expected to be small. Above argument shows, that the surprisingly heavy mass of the charmed pentaquark combined with its narrow width, if confirmed by other experiments, may be qualitatively explained in the chiral doubler scenario. Obviously, if heavy pentaquarks do not exist, one does not expect the existence of their chiral partners.

3. Summary

Chiral symmetry plays crucial role in understanding the properties of light hadrons, and it is exciting that the consequences of spontaneous breakdown of chiral symmetry may be so dramatic even at the level of charmed and bottomed hadrons. We hope, that the renaissance of the charm spectroscopy, causing present excitement in both the experimental and theoretical hadronic physics community, and several on-going and planned new experiments, will trigger a major effort to explore what the new states discussed in this talk teach us about non-perturbative QCD.
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