New charm spectroscopy: Insights from theory

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Issue: recently discovered states in the $c\bar{q}$ system

Based on works in collaboration with P. Colangelo, R. Ferrandes, S. Nicotri, A. Ozpineci, M. Rizzi

Charmed mesons observed after 2003

- $D_0(2308)$, $D_1(2420)$
- $D_{s0}^*(2317)$, $D_{s1}(2460)$
- ~~$D_{sJ}(2632)$~~ → Seen only by SELEX, never confirmed
- $D_{sJ}(2860)$, $D_{sJ}(2700)$

Hadrons containing a single heavy quark Q

Spin of the heavy quark and of the light degrees of freedom decoupled in the $m_Q \to \infty$ limit

$\vec{J}_M = \vec{s}_\ell + \vec{s}_Q$ spin

$\vec{s}_\ell = \vec{L} + \vec{s}_q$ angular momentum of the light degrees of freedom (conserved)

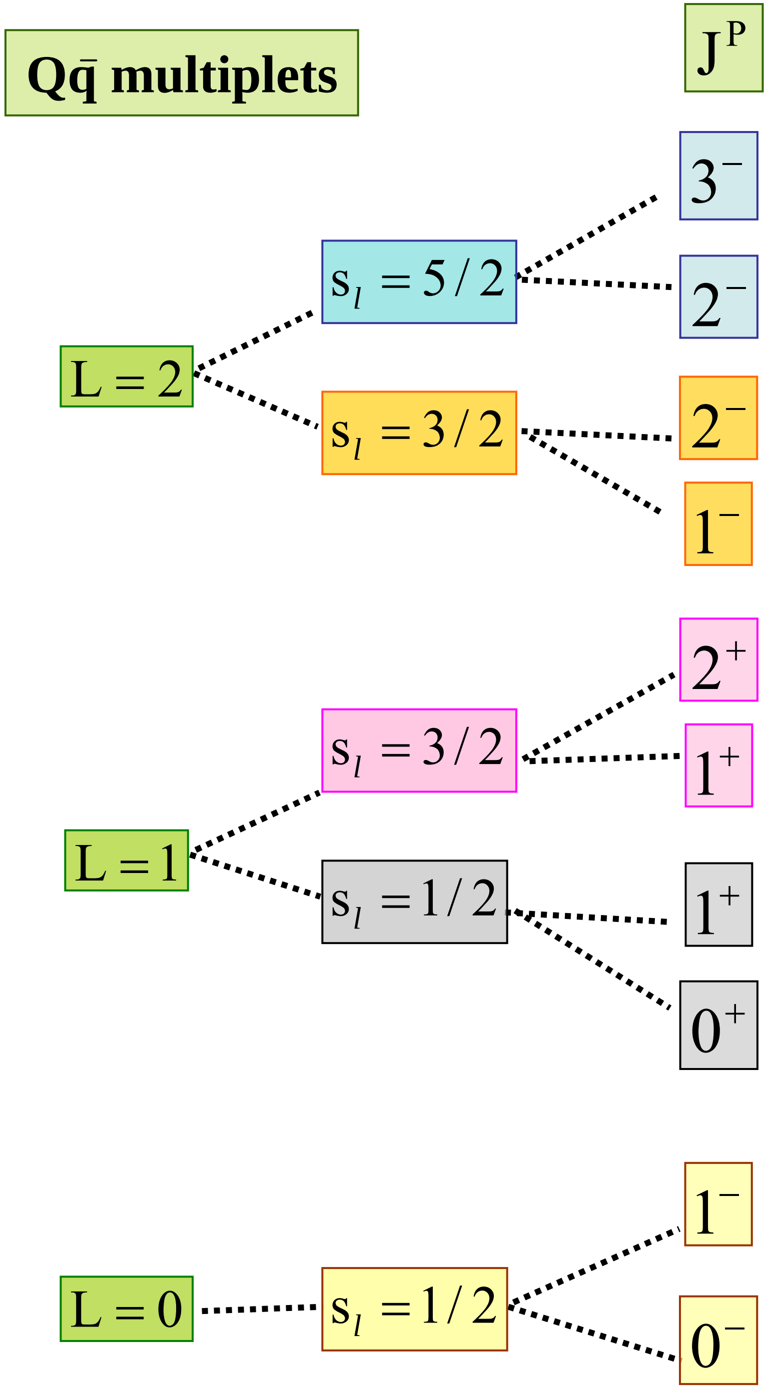
Mesons classified as doublets

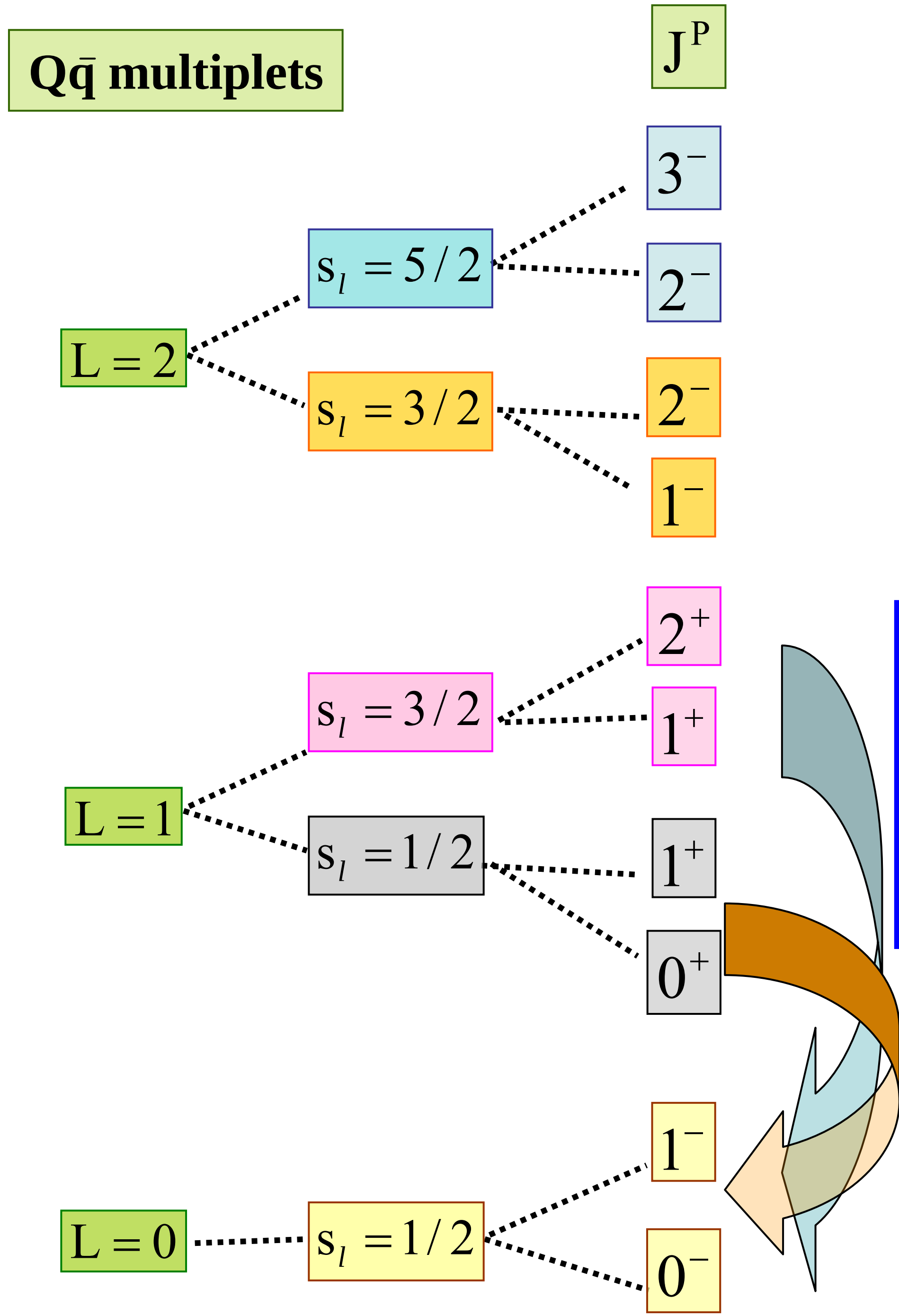
- In the HQ limit:

  - states with the same s_ℓ^P degenerate

- finite m_Q corrections

  - remove degeneracy between the states of the same doublet
  - induce mixing between states with the same J^P


Qq̄ multiplets
J^P
$L=2$
$s_l = 5/2$
$s_l = 3/2$
3^-
2^-
2^-
1^-
$L=1$
$s_l = 3/2$
$s_l = 1/2$
2^+
1^+
1^+
0^+
$L=0$
$s_l = 1/2$
1^-
0^-



Strong transitions between multiplets

$\frac{3}{2}^+ \to \frac{1}{2}^- +$ pseudoscalar meson

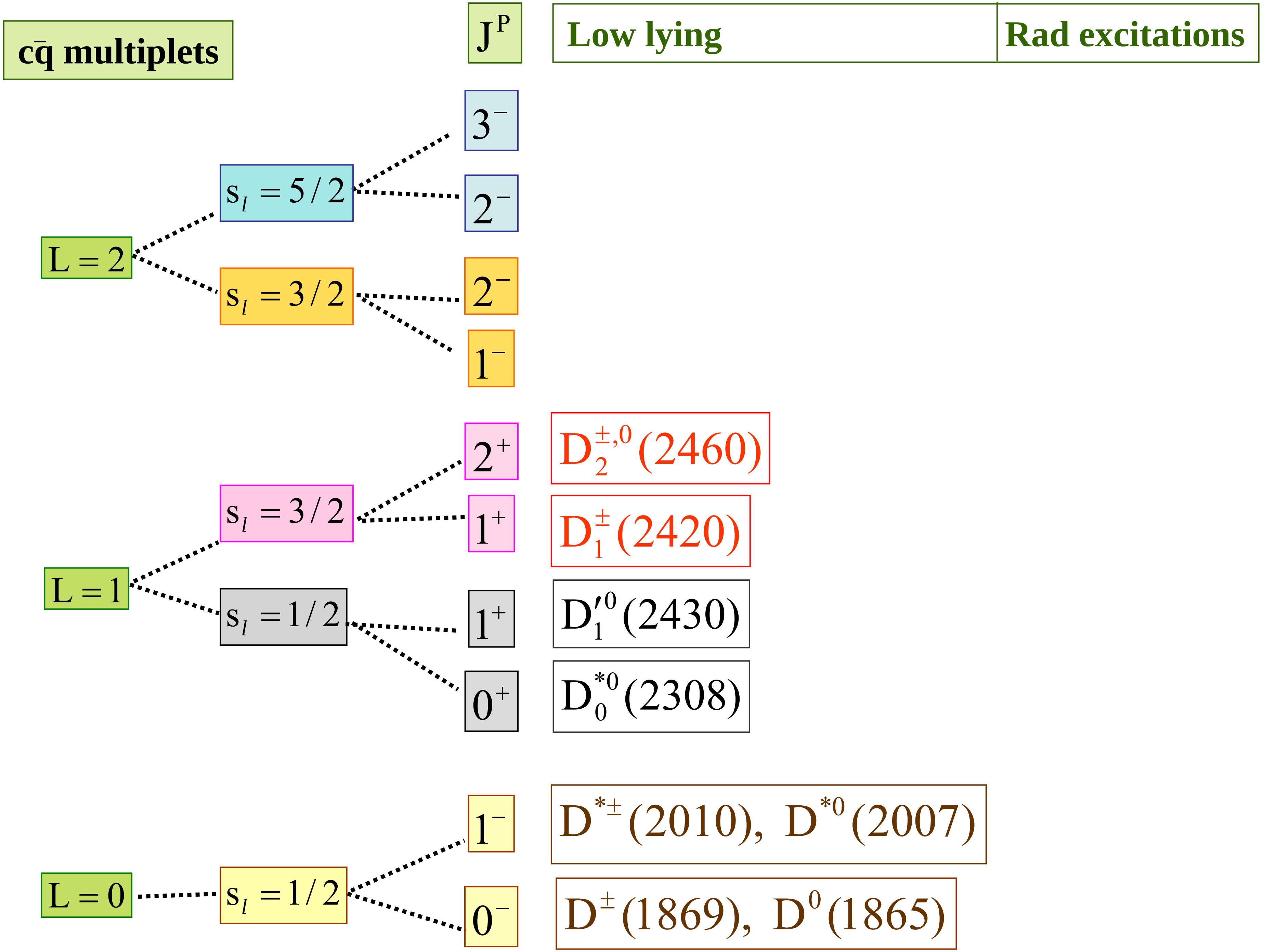
d-wave transition

$\frac{3}{2}^+$ mesons are expected to be narrow

$\frac{1}{2}^+ \to \frac{1}{2}^- +$ pseudoscalar meson

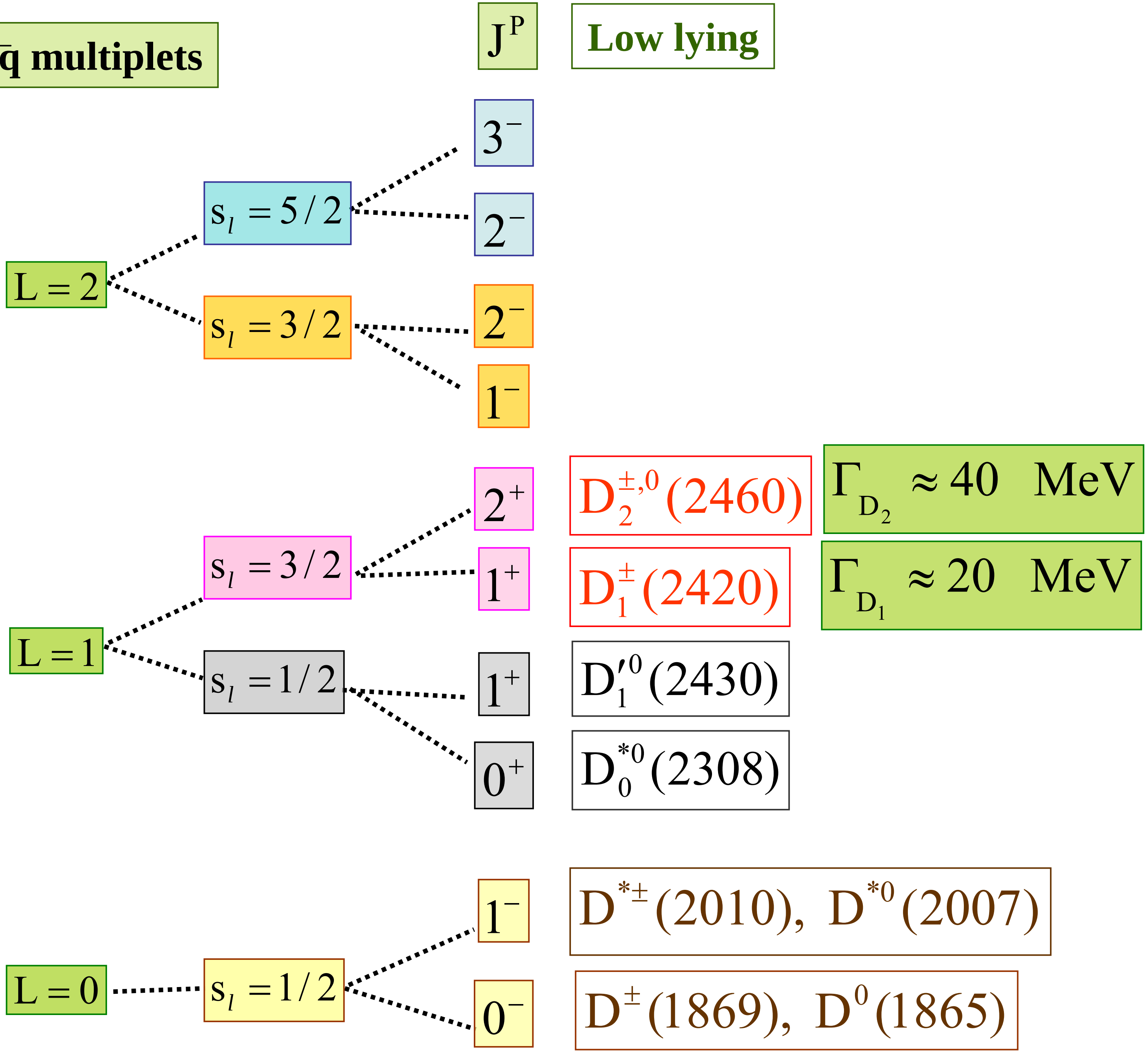
s-wave transition

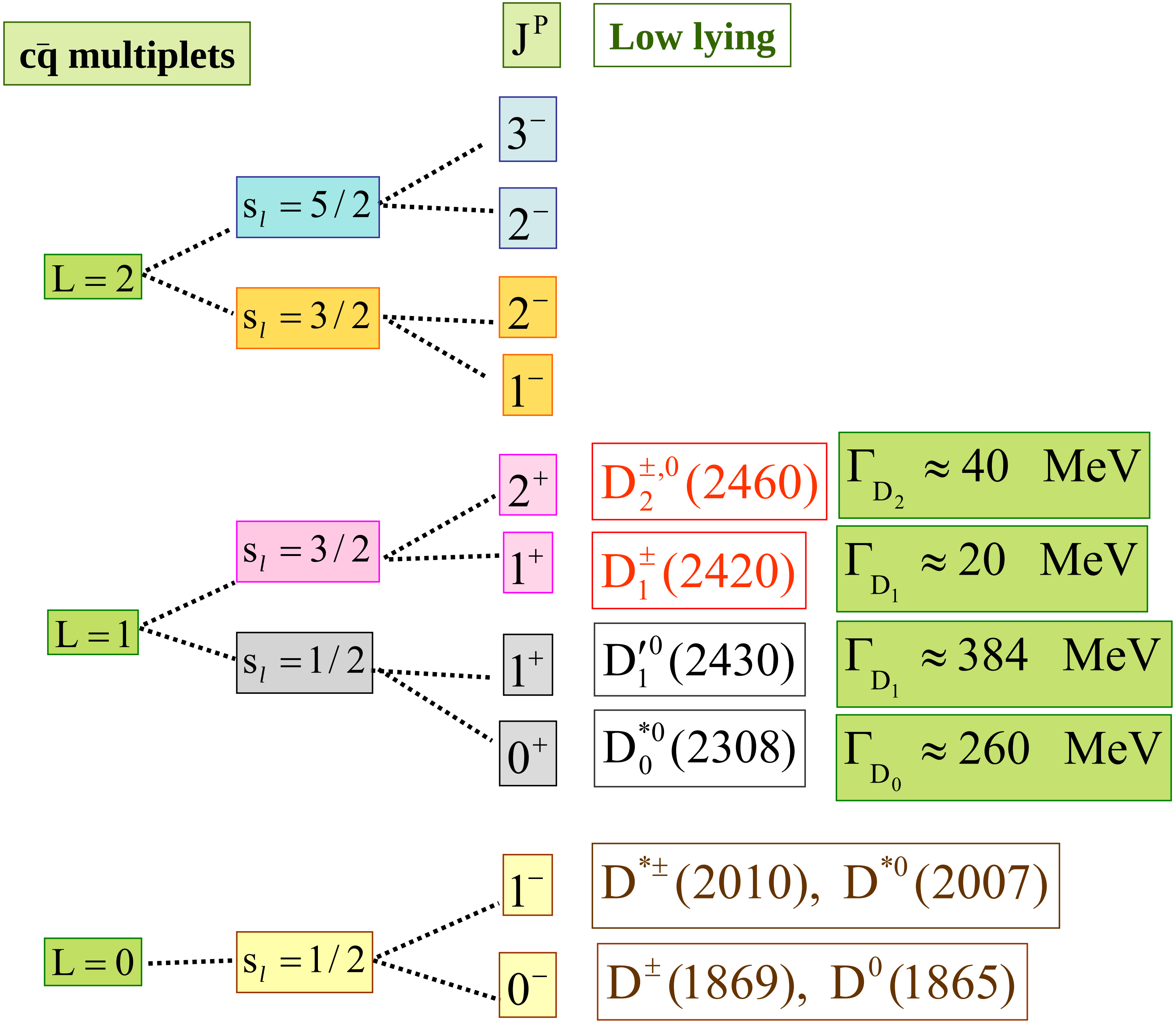
$\frac{1}{2}^+$ mesons are expected to be broad



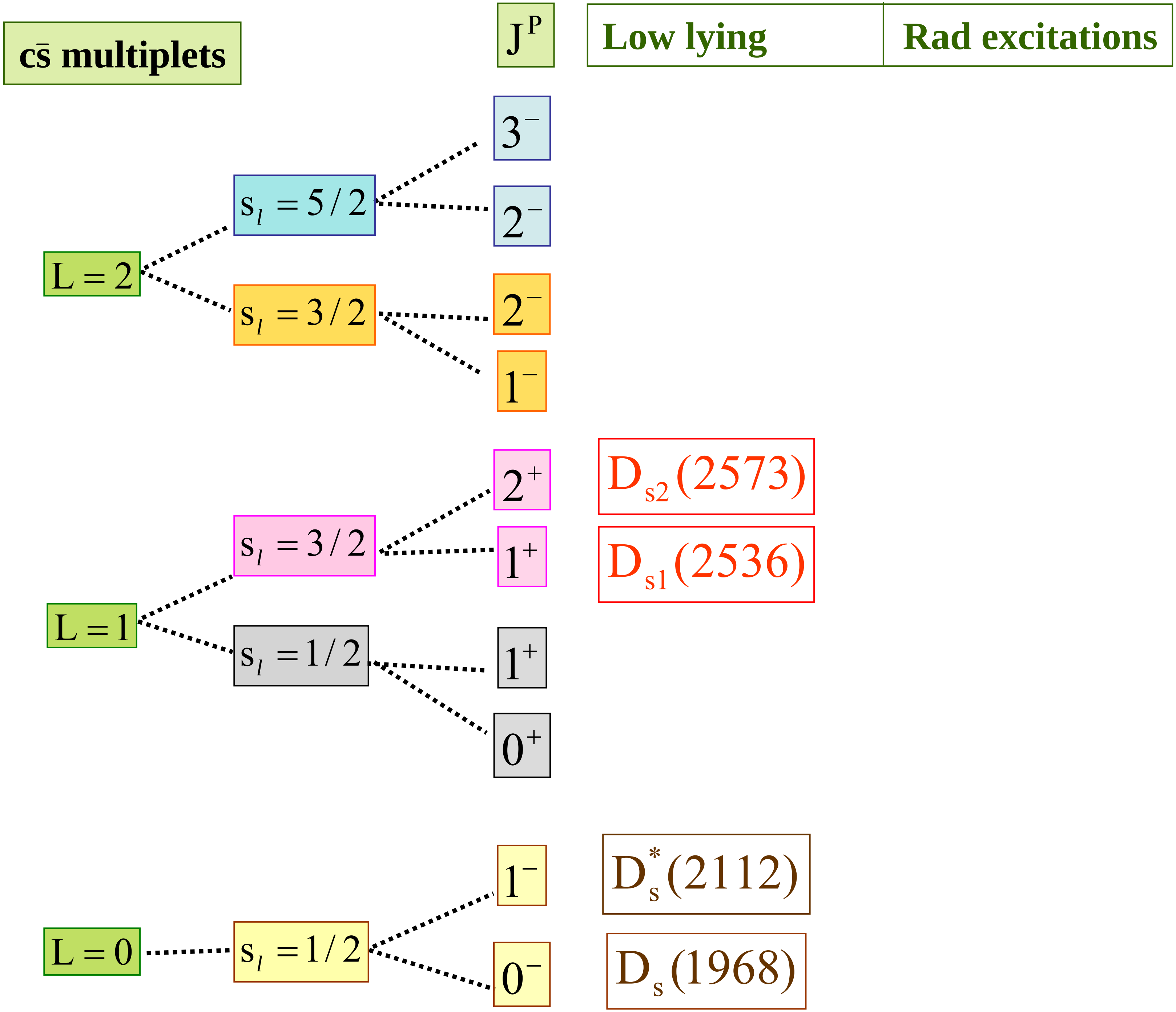
$c\bar{q}$ multiplets
J^P
Low lying
Rad excitations
$L = 2$
$s_l = 5/2$
$s_l = 3/2$
3^-
2^-
2^-
1^-
$L = 1$
$s_l = 3/2$
$s_l = 1/2$
2^+
1^+
1^+
0^+
$D_2^{\pm,0}(2460)$
$D_1^{\pm}(2420)$
$D_1'^{0}(2430)$
$D_0^{*0}(2308)$
$L = 0$
$s_l = 1/2$
1^-
0^-
$D^{*\pm}(2010),\ D^{*0}(2007)$
$D^{\pm}(1869),\ D^{0}(1865)$

$c\bar{q}$ multiplets

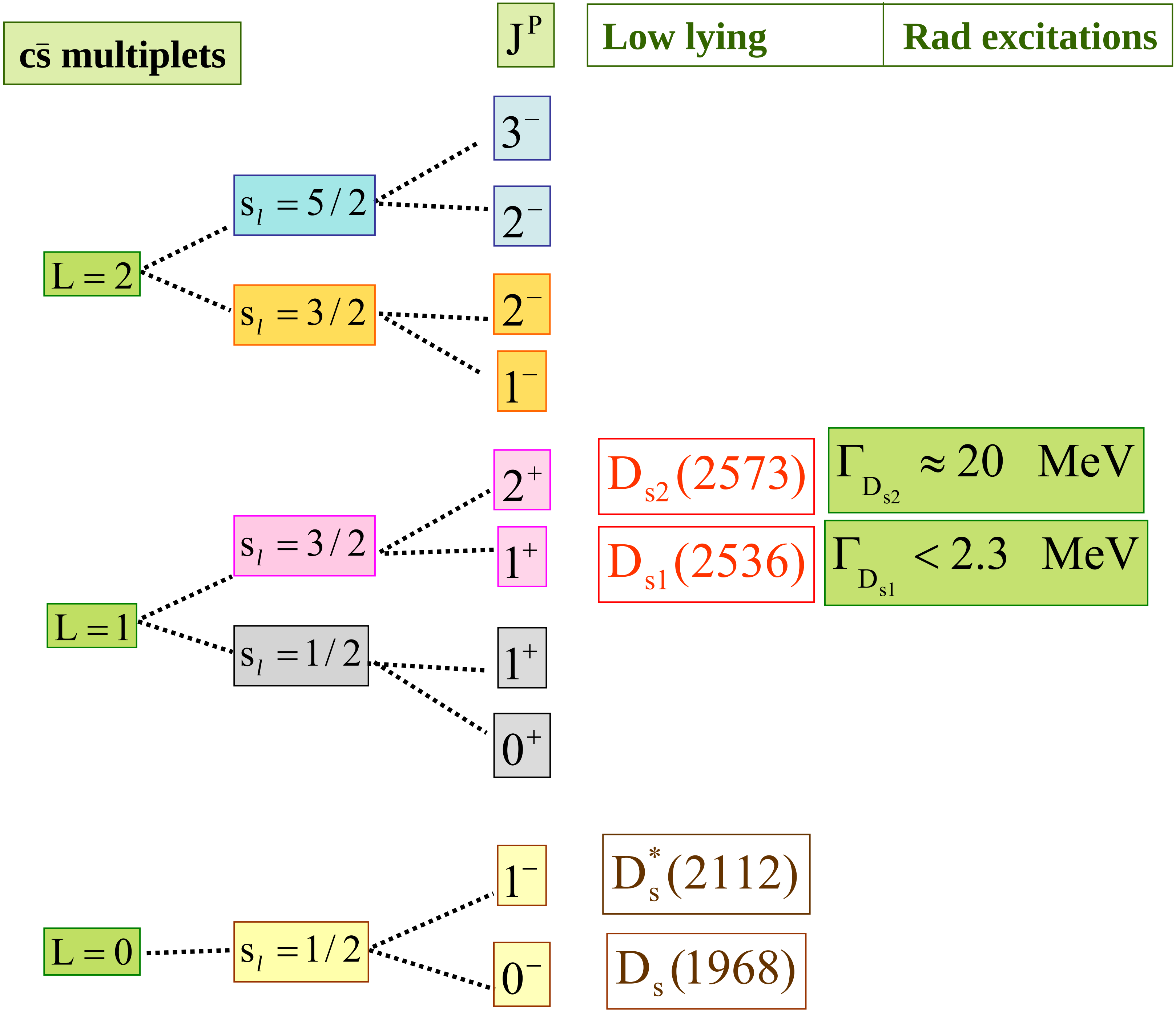




cq̄ multiplets
J^P
Low lying
$L=2$
$s_l = 5/2$
$s_l = 3/2$
3^-
2^-
2^-
1^-
$L=1$
$s_l = 3/2$
$s_l = 1/2$
2^+
1^+
1^+
0^+
$D_2^{\pm,0}(2460)$
$D_1^{\pm}(2420)$
$D_1'^{0}(2430)$
$D_0^{*0}(2308)$
$\Gamma_{D_2} \approx 40$ MeV
$\Gamma_{D_1} \approx 20$ MeV
$\Gamma_{D_1} \approx 384$ MeV
$\Gamma_{D_0} \approx 260$ MeV
$L=0$
$s_l = 1/2$
1^-
0^-
$D^{*\pm}(2010),\ D^{*0}(2007)$
$D^{\pm}(1869),\ D^{0}(1865)$



$c\bar{s}$ multiplets
J^P
Low lying
Rad excitations
$L=2$
$s_l = 5/2$
$s_l = 3/2$
3^-
2^-
2^-
1^-
$L=1$
$s_l = 3/2$
$s_l = 1/2$
2^+
1^+
1^+
0^+
$D_{s2}(2573)$
$D_{s1}(2536)$
$L=0$
$s_l = 1/2$
1^-
0^-
$D_s^*(2112)$
$D_s(1968)$


cs̄ multiplets
J^P
Low lying
Rad excitations
$L=2$
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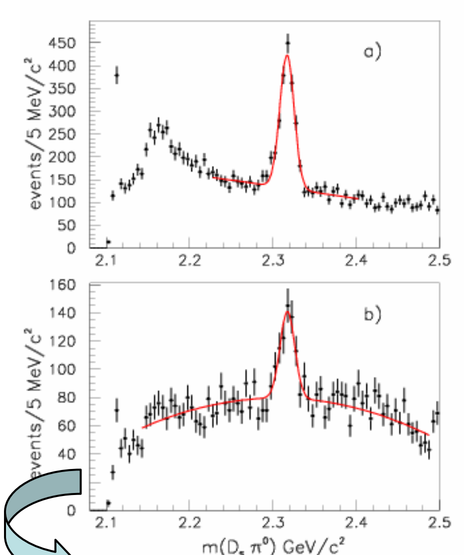
$s_l = 3/2$
3^-
2^-
2^-
1^-
$L=1$
$s_l = 3/2$
$s_l = 1/2$
2^+
1^+
1^+
0^+
$D_{s2}(2573)$
$\Gamma_{D_{s2}} \approx 20$ MeV
$D_{s1}(2536)$
$\Gamma_{D_{s1}} < 2.3$ MeV
$L=0$
$s_l = 1/2$
1^-
0^-
$D_s^*(2112)$
$D_s(1968)$

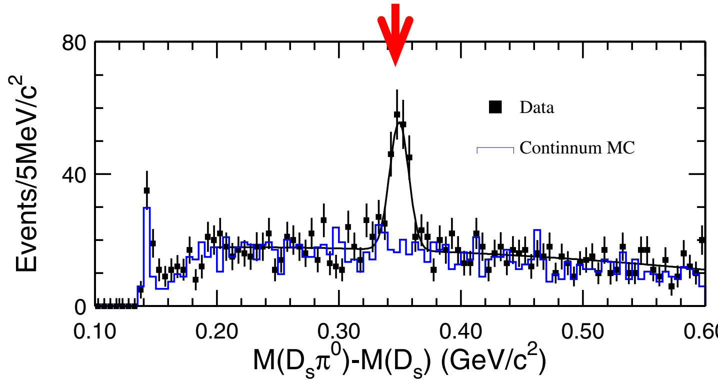
Narrow peak in the $D_s^+\pi^0$ mass distribution: $D_{sJ}^*(2317)$

BaBar

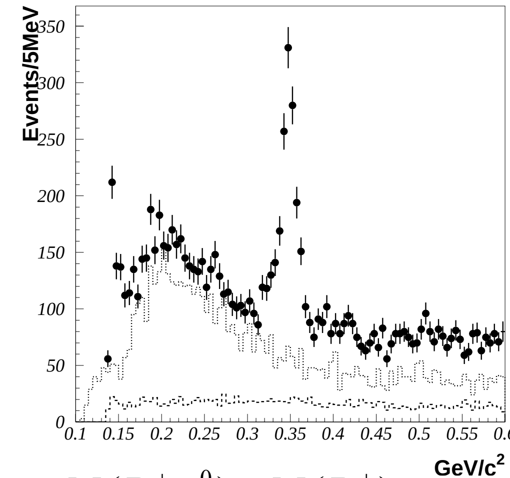


see A. Palano

CLEO **2.32 GeV**



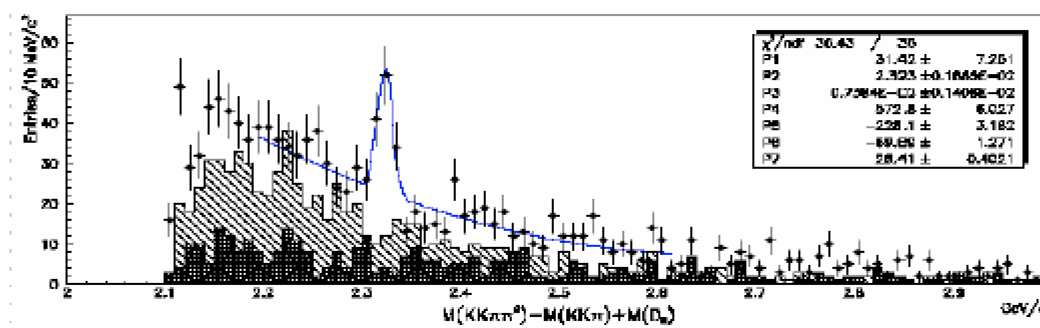
Belle



$M(D_s^+\pi^0) - M(D_s^+)$

production also observed at a fixed target exp ⟶

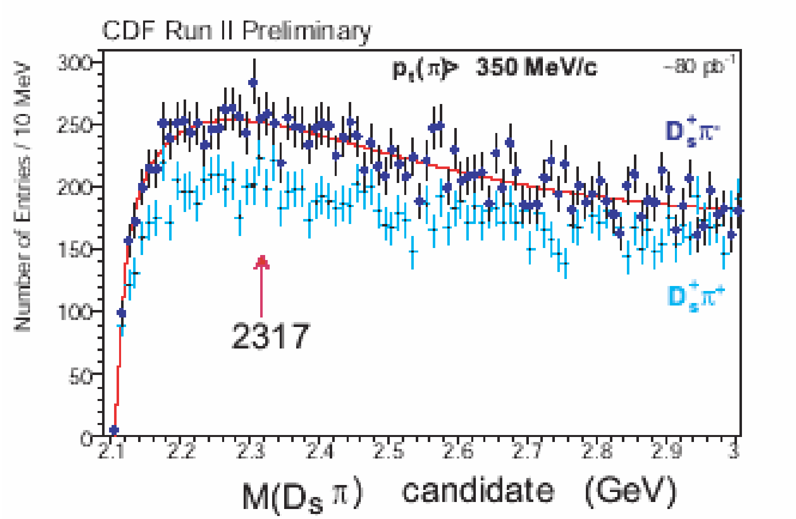
Focus



observed width consistent with exp. Resolution (<10 MeV)
intrinsic width smaller

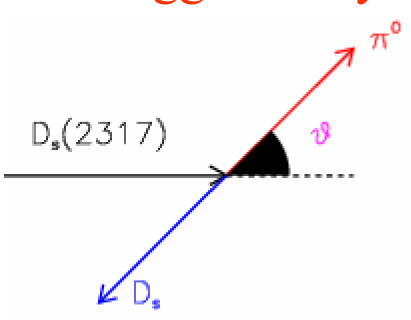
$D_{s0}^{*}(2317)$ quantum numbers

The narrow width suggests Isospin violating decay i.e. $I \neq 1$
confirmed by the absence of isospin partners
eventually decaying in $D_s^{\pm}\pi^{\mp}, D_s^{\pm}\pi^{\pm}$

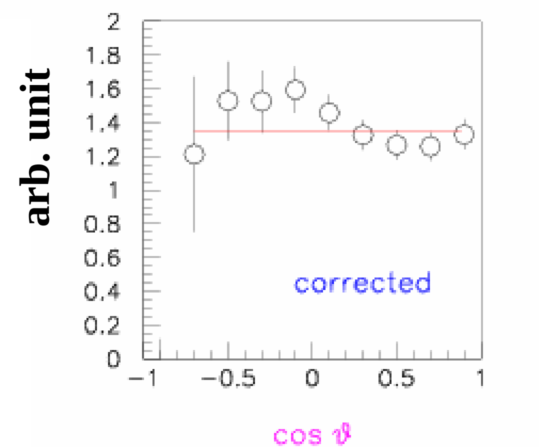


I=0 is the preferred assignment

The observation of the mode $D_s^{*}(2317) \rightarrow D_s\pi^0$
favours the assignment $J^P = 0^+$
Also suggested by the helicity angle distribution



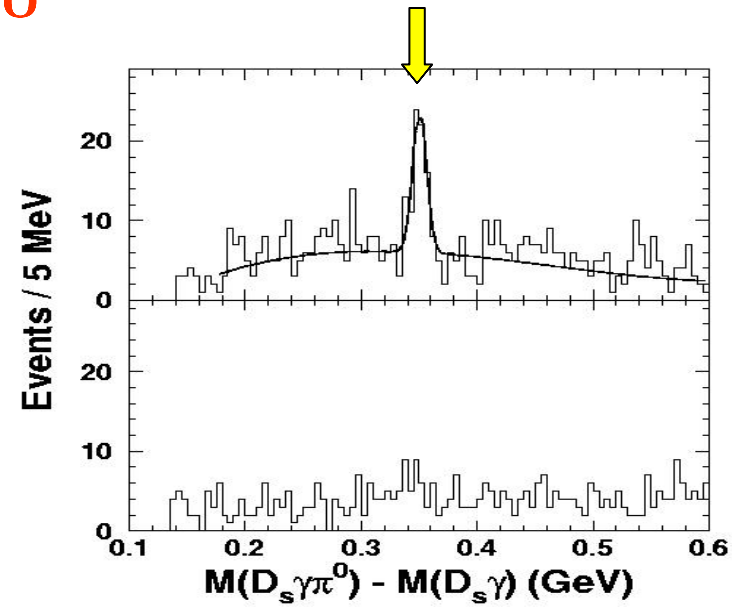
Consistent with being flat

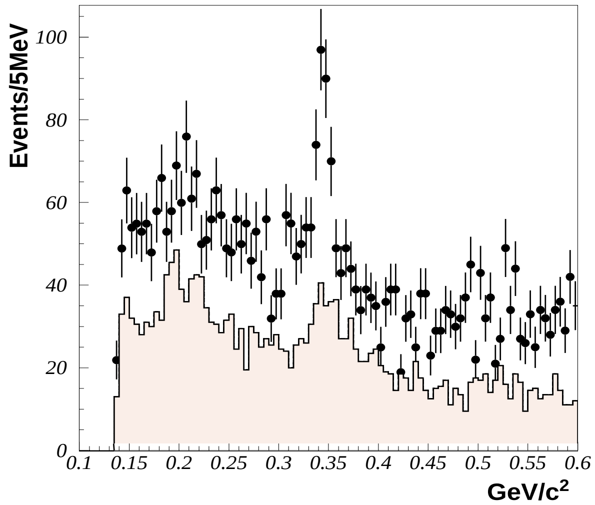


Another narrow peak in the $D_s^{*+}\pi^0$ mass distribution: $D_{sJ}(2460)$

CLEO

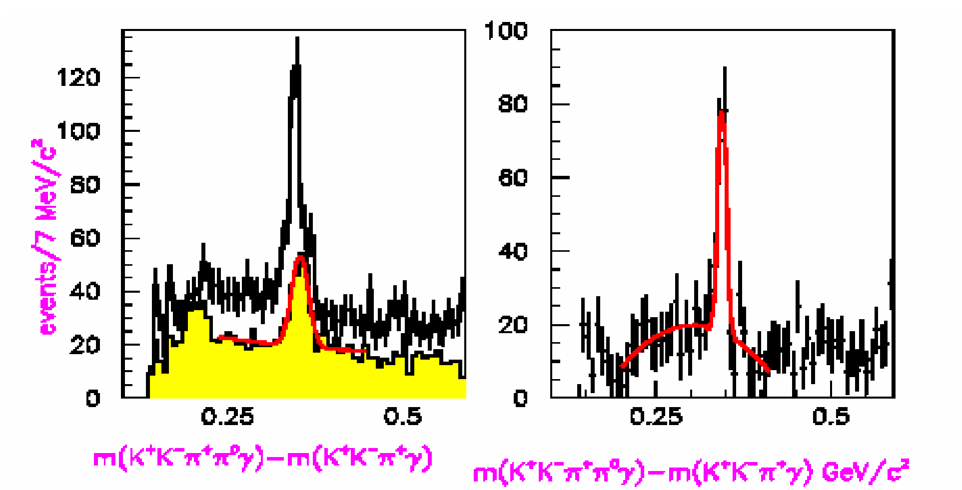
2.46 GeV





$M(D_s^{*+}\pi^0) - M(D_s^{*+})$

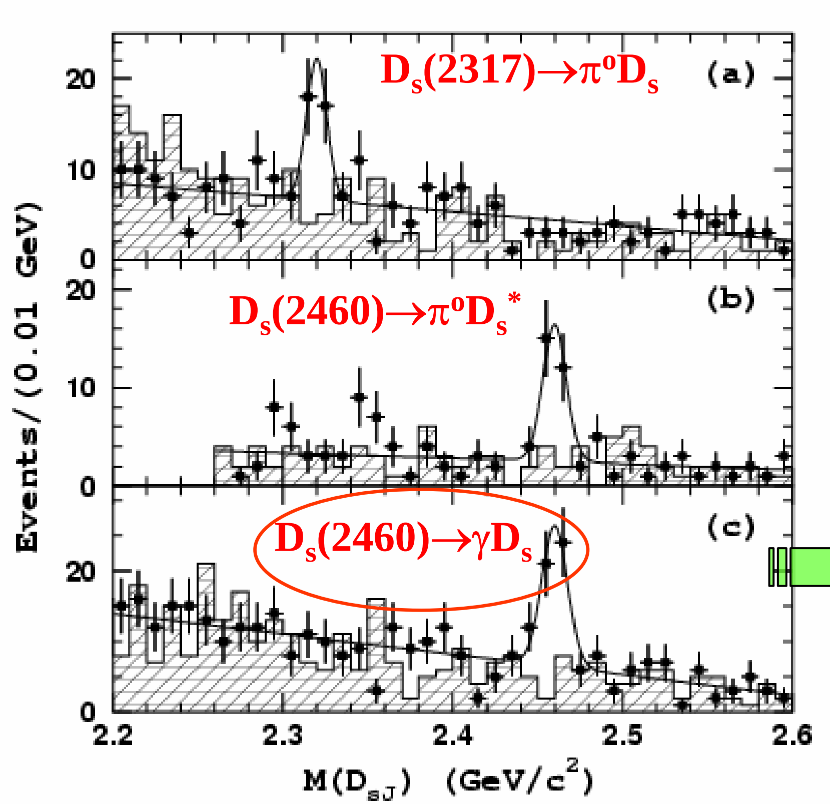
Belle



width consistent
with exp resolution

BaBar

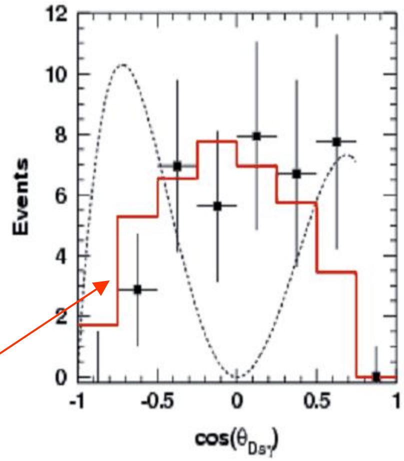
D_{sJ} produced in B decays $B \to DD_{sJ}$



Belle observes radiative decay of $D_{sJ}(2460)$

rules out J=0

Analysis of helicity angle distribution suggests **J=1**



spin 1

Exp. summary

two narrow states with $J^P=0^+$ and 1^+

$D^*_{sJ}(2317)$ M (MeV)	$D^*_{sJ}(2317)$ Γ (MeV)	$D_{sJ}(2460)$ M (MeV)	$D_{sJ}(2460)$ Γ (MeV)	Collaboration
$2317.3 \pm 0.4 \pm 0.8$	< 10	$2458.0 \pm 1.0 \pm 1.0$	< 10	BaBar[9,14]
$2317.2 \pm 0.5 \pm 0.9$	< 4.6	$2456.5 \pm 1.3 \pm 1.3$	< 5.5	Belle[15]
$2318.5 \pm 1.2 \pm 1.1$	< 7	$2463.6 \pm 1.7 \pm 1.2$	< 7	Cleo[11]
2317.4 ± 0.6		2458.8 ± 1.0		

M(D)+M(K)=2360 MeV **$M(D^*)+M(K)$=2510 MeV**

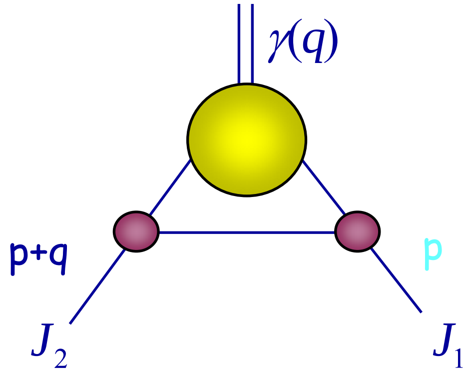
The two new narrow states identified as the $J^P=(0^+,1^+)$ lowest lying $c\bar{s}$ states with L=1

- are data consistent with this interpretation?
- are data consistent with other interpretations?

Radiative decays depend on the structure of the mesons
They are useful to distinguish among different structures

Light-cone QCD sum rule calculation of radiative decays of D_{sJ} mesons

Starting point: two-point correlation function with an external photon state



$$\Pi(p,q) = i \int dx \; \langle \gamma\,(q) |\, T[J_1(x), \bar{J}_2(0)]\, | 0 \rangle \; e^{ipx}$$

two ways of computing the correlation function:

1. inserting hadrons

$$\Pi^{HAD}(p,q) = \frac{\langle 0 | J_1 | M_1(p) \rangle}{p^2 - m_1^2} \langle \gamma(q) M_1(p) | M_2(p+q) \rangle \frac{\langle M_2(p+q) | \bar{J}_2 | 0 \rangle}{(p+q)^2 - m_2^2} + \cdots$$

2. in the Euclidean region $p^2 << 0$ and $(p+q)^2 << 0$: in QCD by an OPE light-cone expansion $x^2 \to 0$

equating both the expressions: sum rule

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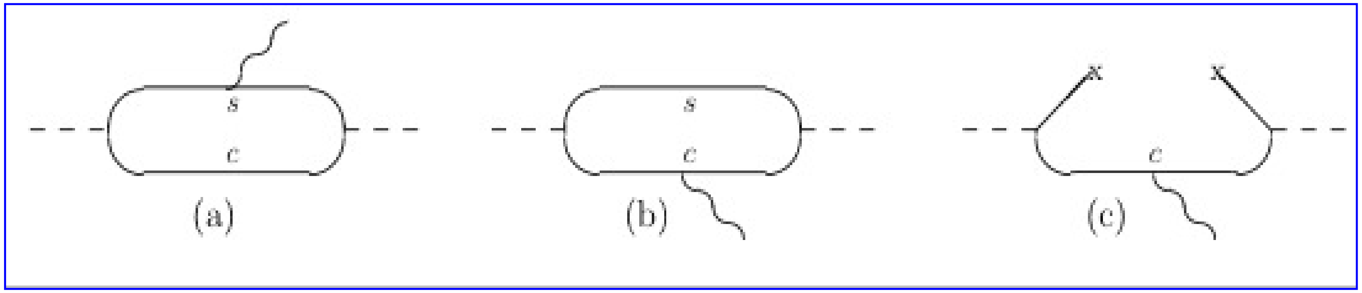
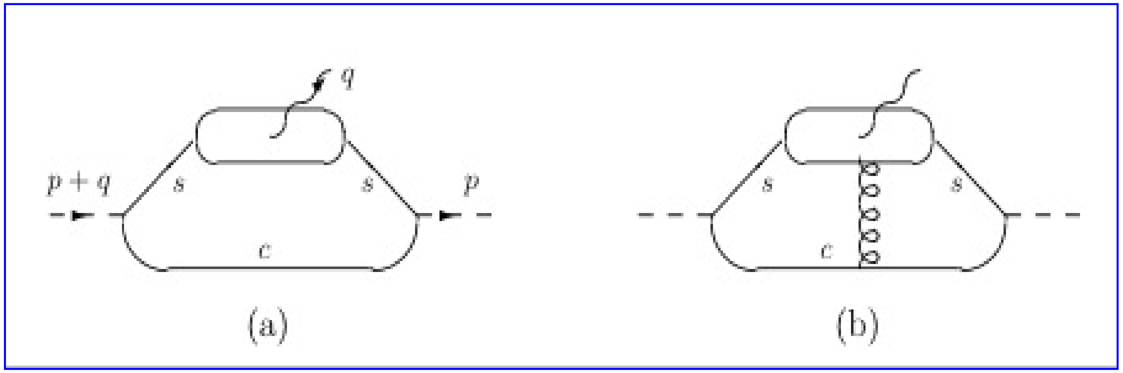
PRD 72 (05) 074004

OPE :

perturbative photon emission



photon emission from the soft light quark



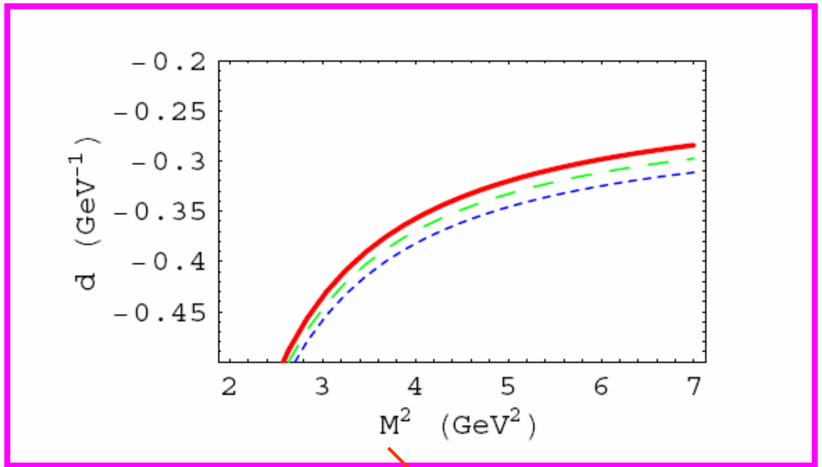
light-cone photon distribution amplitudes of different twist involved

$D_{sJ}^*(2317) \to D_s^* \gamma$

$$\langle \gamma(q,\varepsilon) D_s^*(p,\eta) | D_{s0}^*(p+q) \rangle = e\, d\, (\varepsilon^* \eta^*\, pq - \varepsilon^* p\, \eta^* q)$$

$J_1 = \bar{c}\gamma_\mu s$

$J_2 = \bar{c}\, s$



Borel parameter

$$-0.35\,\mathrm{GeV}^{-1} \le d \le -0.28\,\mathrm{GeV}^{-1}$$

Borel transformation
(enhance the contribution of the lowest-lying hadrons and suppress higher twist terms)
Borel parameter M : results should be independent of it

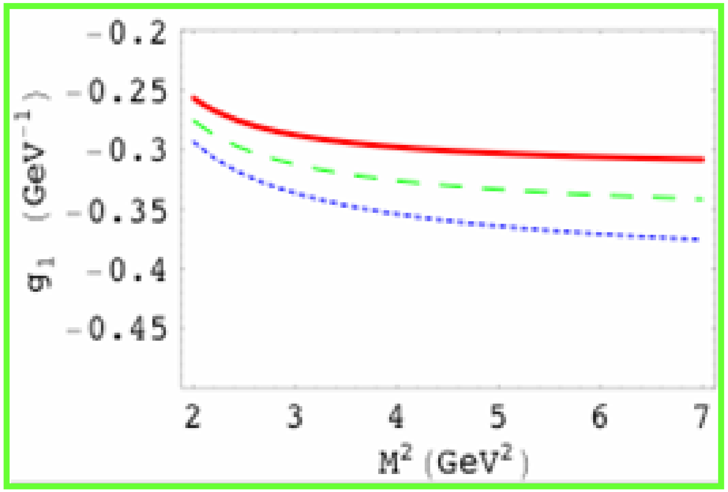
Result $\Gamma(D_{s0}^* \to D_s^* \gamma) = (4-6)\ \mathrm{keV}$

$D_{sJ}(2460)$ -> $D_s\,\gamma$

$$\langle \gamma(q,\varepsilon) D_s(p) | D'_{s1}(p+q,\eta) \rangle = ie\, g_1\, (\varepsilon^* \eta\, pq - \varepsilon^* p\ \eta q)$$

$$J_1 = \bar{c}\, i\gamma_5 s$$

$$J_2 = \bar{c}\ \gamma_\mu \gamma_5 s$$



$$-0.37\ \mathrm{GeV}^{-1} \le g_1 \le -0.29\ \mathrm{GeV}^{-1}$$

Result

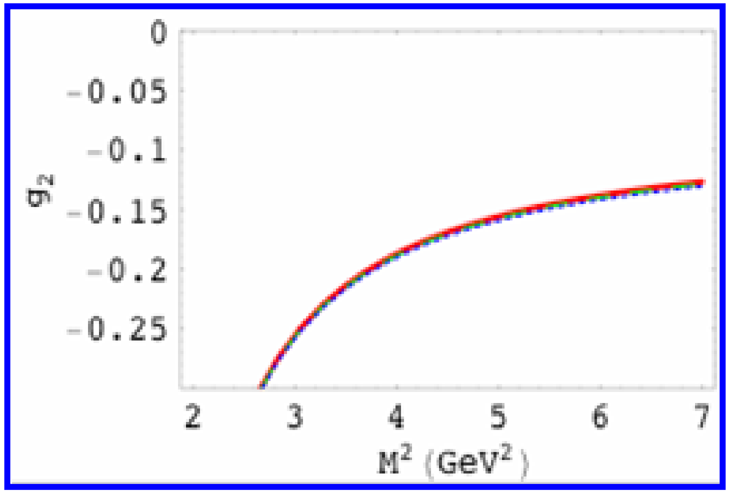
$$\Gamma(D'_{s1} \to D_s \gamma) = (19-29)\ \ \mathrm{keV}$$

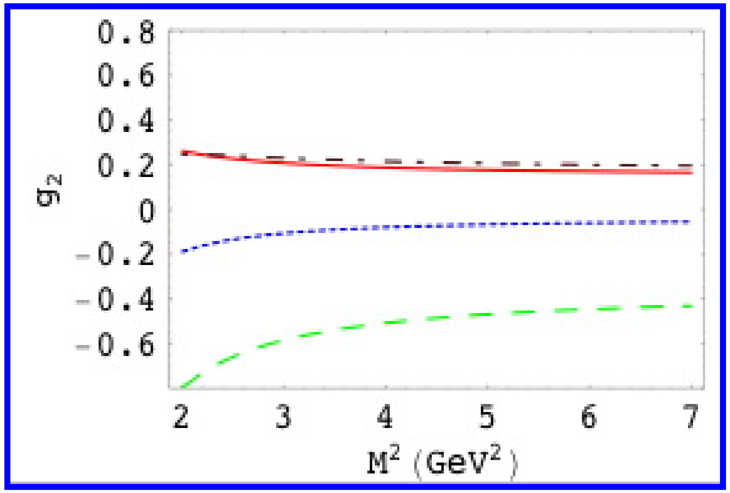
$D_{sJ}(2460) \to D_s^* \gamma$

$$J_1 = \bar{c}\gamma_\mu s$$

$$J_2 = \bar{c}\ \gamma_\mu\gamma_5 s$$

$$\left\langle \gamma(q,\varepsilon) D_s^*(p,\tilde{\eta}) \middle| D_{s1}^{'}(p+q,\eta) \right\rangle = ie\, g_2\, \varepsilon_{\alpha\beta\sigma\tau}\eta^\alpha \tilde{\eta}^{*\beta}\varepsilon^{*\sigma} q^\tau$$





$$-0.18 \leq g_2 \leq -0.13$$

Result

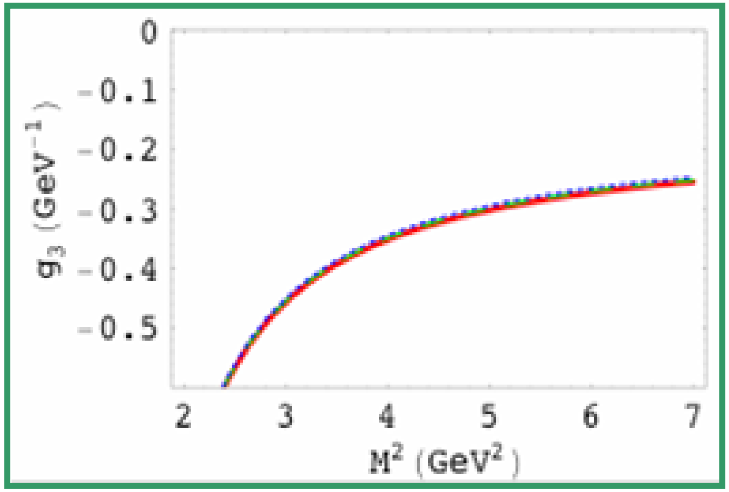
$$\Gamma(D_{s1}^{'} \to D_{s0}\gamma) = (0.6 - 1.1)\ \text{keV}$$

$D_{sJ}(2460) \rightarrow D_{sJ}^{*}(2317)\ \gamma$

$$\left\langle \gamma(q,\varepsilon) D_{s0}(p) \middle| D_{s1}^{'}(p+q,\eta) \right\rangle = ie\, g_3\, \varepsilon_{\alpha\beta\sigma\tau} \varepsilon^{*\alpha} \eta^{\beta} p^{\sigma} q^{\tau}$$

$J_1 = \bar{c}\ s$

$J_2 = \bar{c}\ \gamma_\mu \gamma_5 s$



$$-0.35\ \mathrm{GeV}^{-1} \le g_3 \le -0.27\ \mathrm{GeV}^{-1}$$

Result

$$\Gamma(D_{s1}^{'} \rightarrow D_{s0}\gamma) = (0.5-0.8)\ \ \mathrm{keV}$$

Initial state	Final state	LCQSR	VMD [2, 3]	QM [5]	QM [6]
$D^*_{sJ}(2317)$	$D^*_s\gamma$	4-6	0.85	1.9	1.74
$D_{sJ}(2460)$	$D_s\gamma$	19-29	3.3	6.2	5.08
	$D^*_s\gamma$	0.6-1.1	1.5	5.5	4.66
	$D^*_{sJ}(2317)\gamma$	0.5-0.8		0.012	2.74

$(m_c \to \infty)$

PDG

$D_{s1}(2460)^+$ DECAY MODES

$D_{s1}(2460)^-$ modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_i/Γ)
Γ_1	$D_s^{*+}\pi^0$	(48 ± 11) %
Γ_2	$D_s^+\gamma$	(18 ± 4) %
Γ_3	$D_s^+\pi^+\pi^-$	(4.3 ± 1.3) %
Γ_4	$D_s^{*+}\gamma$	< 8 %
Γ_5	$D^*_{s0}(2317)^+\gamma$	$(3.7^{+5.1}_{-2.4})$ %
Γ_6	$D_s^+\pi^0$	
Γ_7	$D_s^+\pi^0\pi^0$	
Γ_8	$D_s^+\gamma\gamma$	

LCSR results deviate from other methods

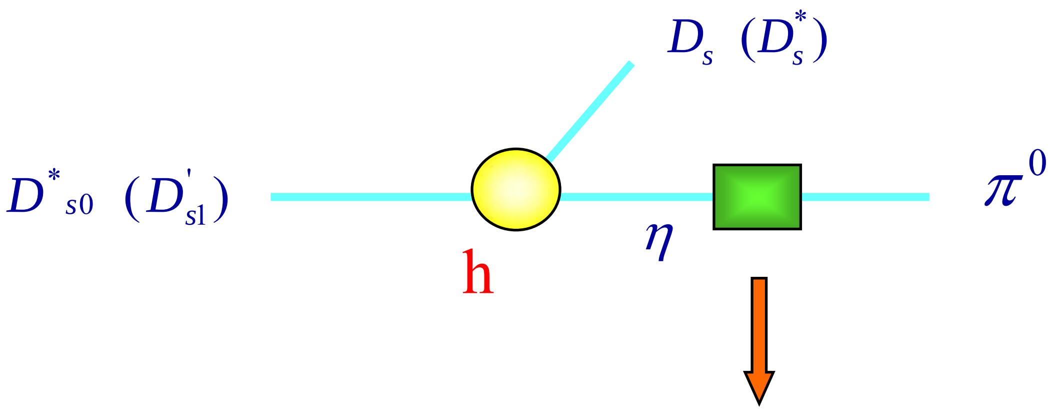
The largest computed rate corresponds to the largest measured radiative branching ratio

Computed radiative decay rates of **$D_{sJ}^*(2317)$ and $D_{sJ}(2460)$** follow the pattern which is experimentally observed

What do we know of the hadronic decays?

The decays $D_{s0}(D'_{s1}) \to D_s^{(*)}\pi^0$ can be described as the result of the strong transition $D_{s0}(D'_{s1}) \to D_s^{(*)}\eta$ followed by the π-η mixing

P. Colangelo, FDF
PLB570 (03) 180
P. Colangelo, R. Ferrandes, FDF
MPLA19 (04) 2083



Isospin violation enters in low energy lagrangian of pseudoscalar mesons through the mass term

$$L_{mass} = \frac{\tilde{\mu}\, f^2}{4} Tr\left[\xi\, m_q\, \xi + \xi^+\, m_q\, \xi^+\right] \qquad m_q = \begin{pmatrix} m_u & 0 & 0 \\ 0 & m_d & 0 \\ 0 & 0 & m_s \end{pmatrix}$$

Cho, Wise

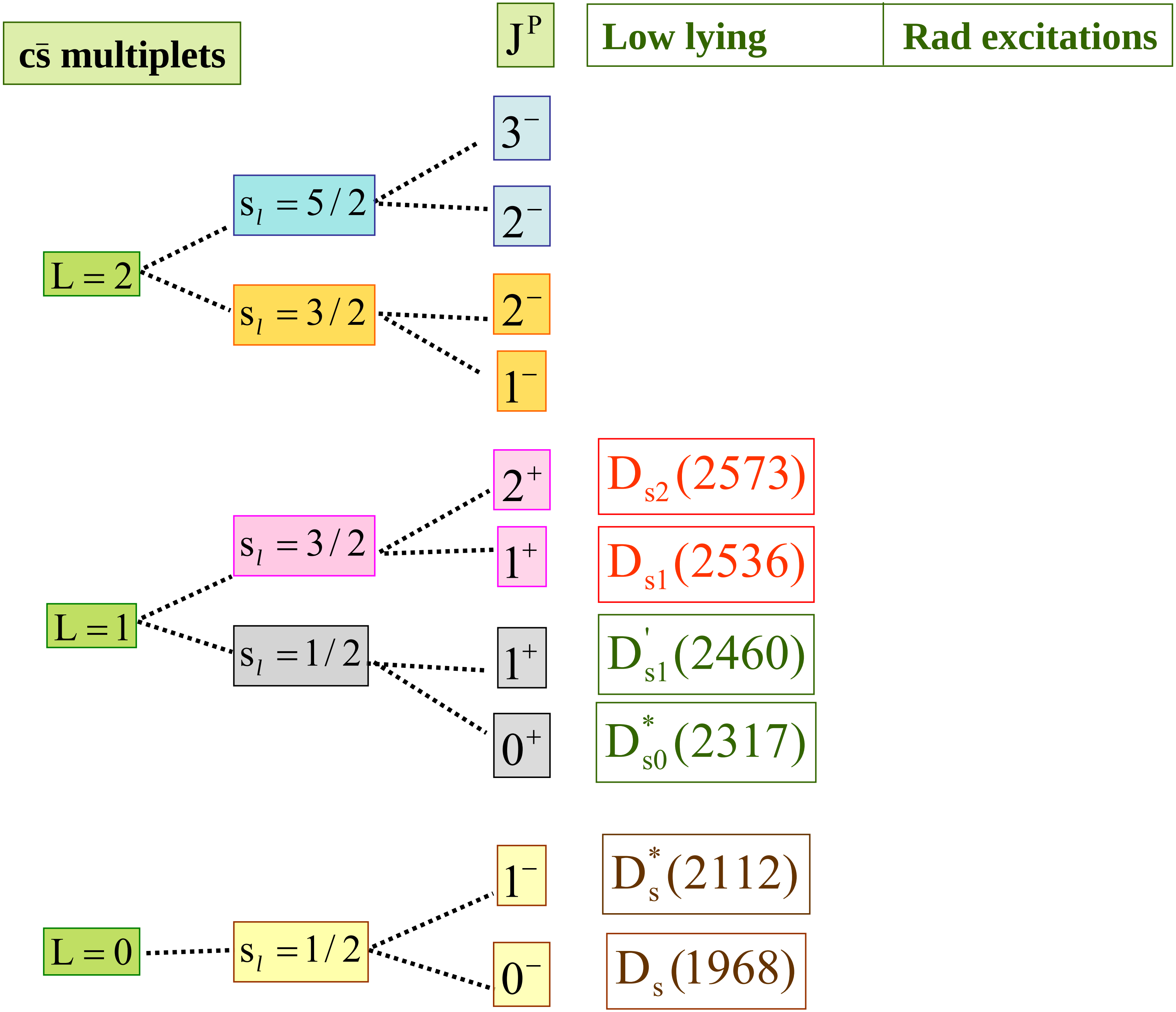
$$L_{mixing} = \frac{\tilde{\mu}}{2} \frac{m_d - m_u}{\sqrt{3}} \pi^0 \eta$$

$$\Gamma(D_{s0} \to D_s \pi^0) = \frac{1}{16\pi} \frac{h^2}{f^2} \frac{M_{D_s}}{M_{D_{s0}}} \left(\frac{m_d - m_u}{m_s - \frac{m_d + m_u}{2}} \right)^2 \left(1 + \frac{m^2_{\pi^0}}{p^2_{\pi^0}}\right) p^3_{\pi^0}$$

⇒

$$\Gamma(D_{sJ}(2317) \to D_s \pi^0) = 7 \pm 1 \quad \text{KeV}$$
$$\Gamma(D_{sJ}(2460) \to D_s^* \pi^0) = 7 \pm 1 \quad \text{KeV}$$

D^*_{s0}(2317) and D'_{s1}(2460) behave as ordinary $c\bar{s}$ mesons



$c\bar{s}$ multiplets
J^P
Low lying
Rad excitations
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$D^*_s(2112)$
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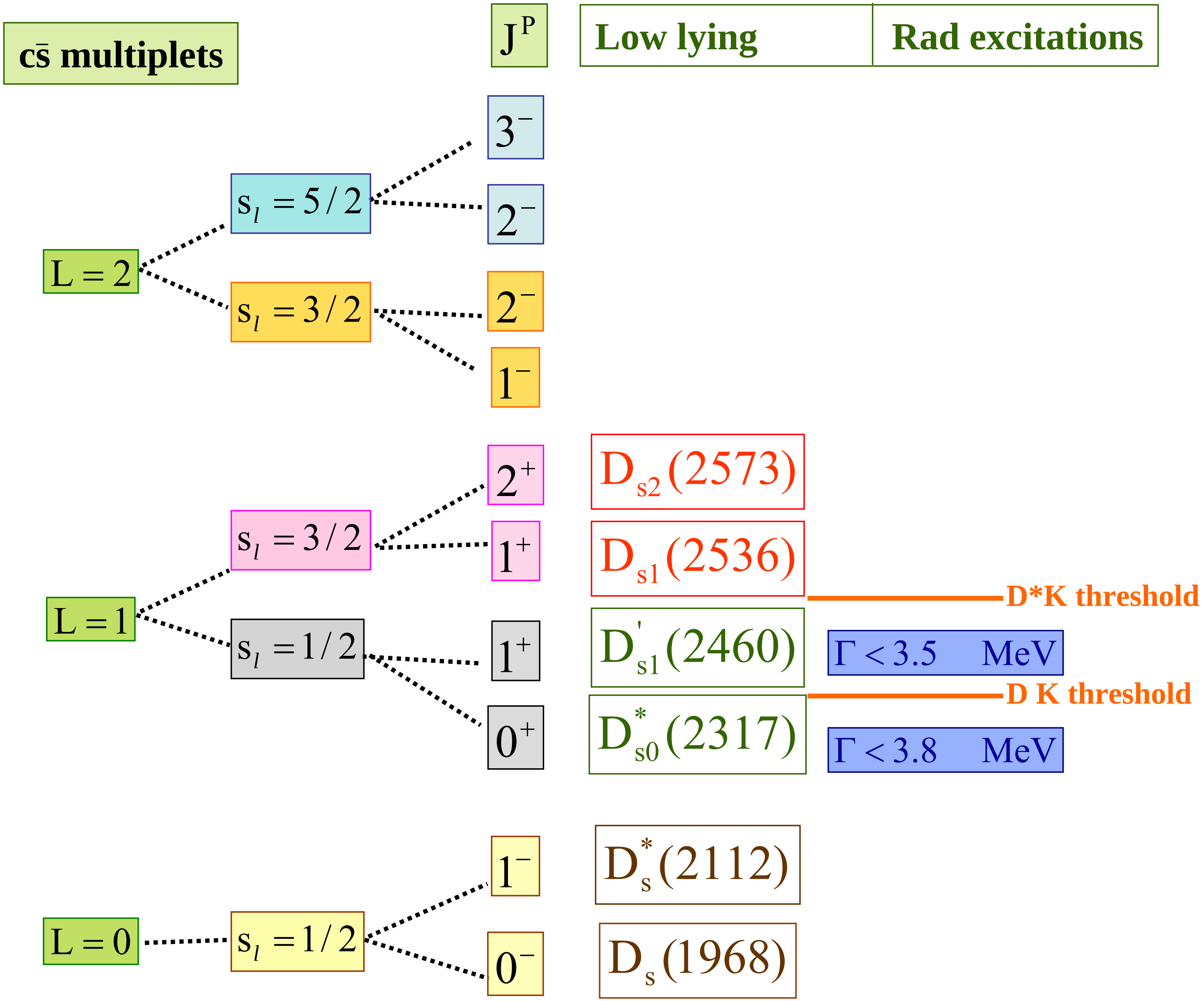

cs̄ multiplets
J^P
Low lying
Rad excitations
$L=2$
$s_l = 5/2$
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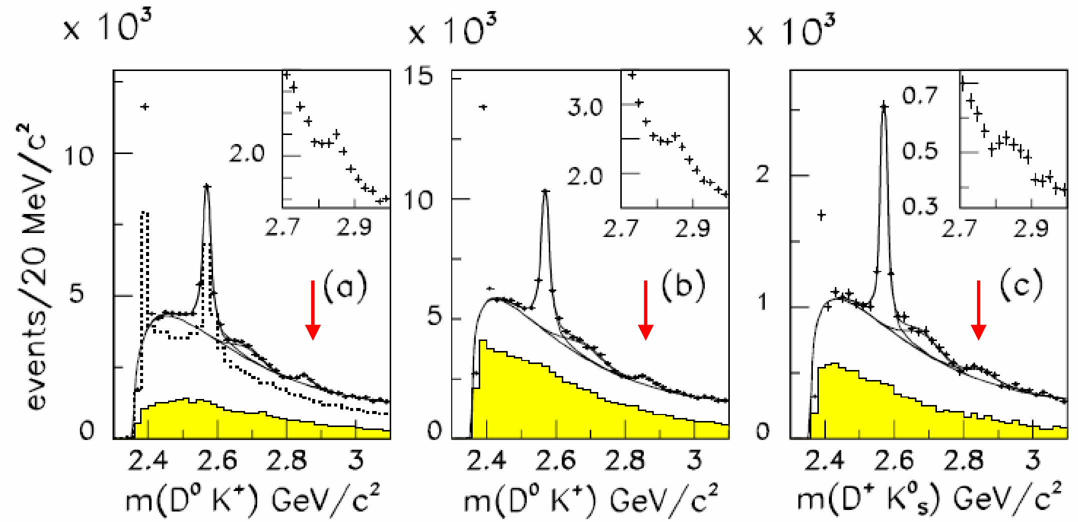
3^-
2^-
2^-
1^-
$L=1$
$s_l = 3/2$
$s_l = 1/2$
2^+
1^+
1^+
0^+
$D_{s2}(2573)$
$D_{s1}(2536)$
D*K threshold
$D'_{s1}(2460)$
$\Gamma < 3.5$ MeV
D K threshold
$D^*_{s0}(2317)$
$\Gamma < 3.8$ MeV
$L=0$
$s_l = 1/2$
1^-
0^-
$D^*_s(2112)$
$D_s(1968)$

$D_{sJ}(2860)$

- Discovered by BaBar Collab.
- Reconstructed in

$$D^0K^+ \rightarrow (K^-\pi^+)K^+$$
$$\rightarrow (K^-\pi^+\pi^0)K^+$$

and in $D^+K_S^0$



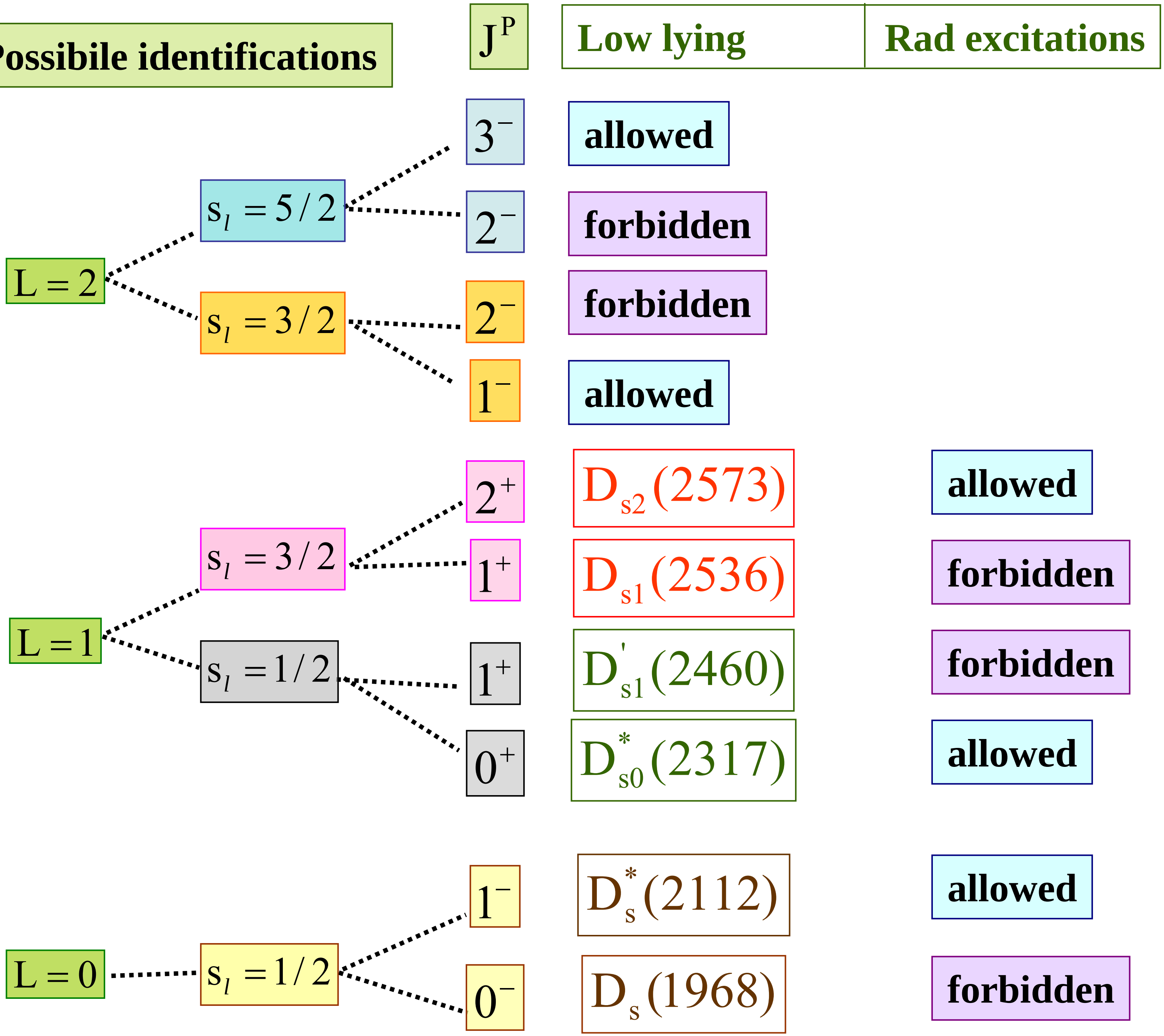
BaBar Collab., PRL 97 (06) 222001

$$M = 2856.6 \pm 1.5 \pm 5.0 \quad \text{MeV}$$
$$\Gamma = 48 \pm 7 \pm 10 \quad \text{MeV}$$

Quantum number assignment required in order to identify it
Possibilities: - low lying state not yet observed
- radial excitation of an already observed state

Only states that can decay to the observed mode DK are allowed

Possibile identifications



$D_{sJ}(2860)$ predictions on allowed decay rates can help to distinguish among the various possibilities

HQ limit: the members of the doublets are described by effective fields:

L=0

$s_\ell^P = \frac{1}{2}^-$

$$H_a = \frac{1+\not{v}}{2}\left[P^*_{a\mu}\gamma^\mu - P_a\gamma_5\right]$$

L=0

$s_\ell^P = \frac{1}{2}^+$

$$S_a = \frac{1+\not{v}}{2}\left[P'^{\mu}_{1a}\gamma_\mu\gamma_5 - P^*_{0a}\right]$$

$s_\ell^P = \frac{3}{2}^+$

$$T^\mu_a = \frac{1+\not{v}}{2}\left\{P^{\mu\nu}_{2a}\gamma_\nu - P_{1a\nu}\sqrt{\frac{3}{2}}\gamma_5\left[g^{\mu\nu} - \frac{1}{3}\gamma^\nu(\gamma^\mu - v^\mu)\right]\right\}$$

L=0

$s_\ell^P = \frac{3}{2}^-$

$$X^\mu_a = \frac{1+\not{v}}{2}\left\{P^{*\mu\nu}_{2a}\gamma_5\gamma_\nu - P^{*\prime}_{1a\nu}\sqrt{\frac{3}{2}}\left[g^{\mu\nu} - \frac{1}{3}\gamma^\nu(\gamma^\mu - v^\mu)\right]\right\}$$

$s_\ell^P = \frac{5}{2}^-$

$$X'^{\mu\nu}_a = \frac{1+\not{v}}{2}\left\{P^{\mu\nu\sigma}_{3a}\gamma_\sigma - P^{*\prime\alpha\beta}_{2a}\sqrt{\frac{5}{3}}\gamma_5\left[g^\mu_\alpha g^\nu_\beta - \frac{1}{5}\gamma_\alpha g^\nu_\beta(\gamma^\mu - v^\mu) - \frac{1}{5}\gamma_\beta g^\mu_\alpha(\gamma^\nu - v^\nu)\right]\right\}$$

$D_{sJ}(2860)$

Interactions with the emission of a light pseudoscalar meson described through effective Lagrangian terms

$$\mathcal{L}_H = g\,\mathrm{Tr}[\bar{H}_a H_b \gamma_\mu \gamma_5 \mathcal{A}^\mu_{ba}],$$

H → **H π**

$$\mathcal{L}_S = h\,\mathrm{Tr}[\bar{H}_a S_b \gamma_\mu \gamma_5 \mathcal{A}^\mu_{ba}] + \mathrm{h.c.},$$

S → **H π**

$$\mathcal{L}_T = \frac{h'}{\Lambda_\chi}\mathrm{Tr}[\bar{H}_a T^\mu_b (i D_\mu \not{\mathcal{A}} + i \not{D} \mathcal{A}_\mu)_{ba} \gamma_5] + \mathrm{h.c.},$$

T → **H π**

$$\mathcal{L}_X = \frac{k'}{\Lambda_\chi}\mathrm{Tr}[\bar{H}_a X^\mu_b (i D_\mu \not{\mathcal{A}} + i \not{D} \mathcal{A}_\mu)_{ba} \gamma_5] + \mathrm{h.c.},$$

X → **H π**

$$\mathcal{L}_{X'} = \frac{1}{\Lambda_\chi{}^2}\mathrm{Tr}[\bar{H}_a X'^{\mu\nu}_b [k_1 \{D_\mu, D_\nu\} \mathcal{A}_\lambda + k_2 (D_\mu D_\nu \mathcal{A}_\lambda + D_\nu D_\lambda \mathcal{A}_\mu)]_{ba} \gamma^\lambda \gamma_5] + \mathrm{h.c.},$$

X' → **H π**

$$\mathcal{A}_{\mu ba} = \frac{i}{2}(\xi^\dagger \partial_\mu \xi - \xi \partial_\mu \xi^\dagger)_{ba} \qquad \xi = e^{\frac{i\mathcal{M}}{f_\pi}} \qquad \mathcal{M} = \begin{pmatrix} \sqrt{\frac{1}{2}}\pi^0 + \sqrt{\frac{1}{6}}\eta & \pi^+ & K^+ \\ \pi^- & -\sqrt{\frac{1}{2}}\pi^0 + \sqrt{\frac{1}{6}}\eta & K^0 \\ K^- & \bar{K}^0 & -\sqrt{\frac{2}{3}}\eta \end{pmatrix}$$

Analogous terms describe the interactions involving radial excitation doublets:

$$g \to \tilde{g}, \quad h \to \tilde{h}, \ldots$$

D_{sJ}(2860): results for width ratios

P. Colangelo, S. Nicotri, FDF, PLB 642 (06) 48

	$D_{sJ}(2860)$	$D_{sJ}(2860) \to DK$	$\frac{\Gamma(D_{sJ}(2860)\to D^* K)}{\Gamma(D_{sJ}(2860)\to DK)}$	$\frac{\Gamma(D_{sJ}(2860)\to D_s \eta)}{\Gamma(D_{sJ}(2860)\to DK)}$
1	$s_\ell^P = \frac{1}{2}^-,\ J^P = 1^-,\ n=2$	p-wave	1.23	0.27
2	$s_\ell^P = \frac{1}{2}^+,\ J^P = 0^+,\ n=2$	s-wave	0	0.34
3	$s_\ell^P = \frac{3}{2}^+,\ J^P = 2^+,\ n=2$	d-wave	0.63	0.19
4	$s_\ell^P = \frac{3}{2}^-,\ J^P = 1^-,\ n=1$	p-wave	0.06	0.23
5	$s_\ell^P = \frac{5}{2}^-,\ J^P = 3^-,\ n=1$	f-wave	0.39	0.13

Would explain the observed narrowness

$D_{sJ}(2860)$

What about option 2 $s_\ell^P = \frac{1}{2}^+,\ J^P = 0^+,\ n = 2$?

Supported in:
Van Beveren et al
PRL 97 (06) 202001
Close et al, PLB 647 (07) 159

- **No signal expected in D^*K**
- Signal expected in $D_s\,\eta$
- a spin partner with $s_\ell^P = \frac{1}{2}^+,\ J^P = 1^+,\ n = 2$ is expected in the same range of mass decaying to D^*K in s-wave with small width $\longrightarrow$ rather easy to detect

Why the production of the 0^+ state is favoured with respect to the 1^+ state?
(For n=1 both states are produced $D_{sJ}(2317)$ and $D_{sJ}(2460)$)

We would exclude option 2

D_{sJ}(2860)

Our supported option: 5 $s_\ell^P = \frac{5}{2}^-, \; J^P = 3^-, \; n = 1$

- **Signal expected in D^*K**
- Small signal expected also in $D_s\,\eta$

In this case the small width can be attributed to the suppression due to the kaon momentum factor:

$$\Gamma(D_{sJ} \to DK) = \frac{6}{35} \frac{(k_1+k_2)^2}{\pi f_\pi^2 \Lambda_\chi^4} \frac{M_D}{M_{D_{sJ}}} q_K^7$$

f-wave transition

Assuming the experimentally measured width would predict $k_1 + k_2 \approx 0.5$ in the typical range of these couplings

The spin 2 partner could decay in p-wave due to the effect of $1/m_Q$ corrections

may escape detection

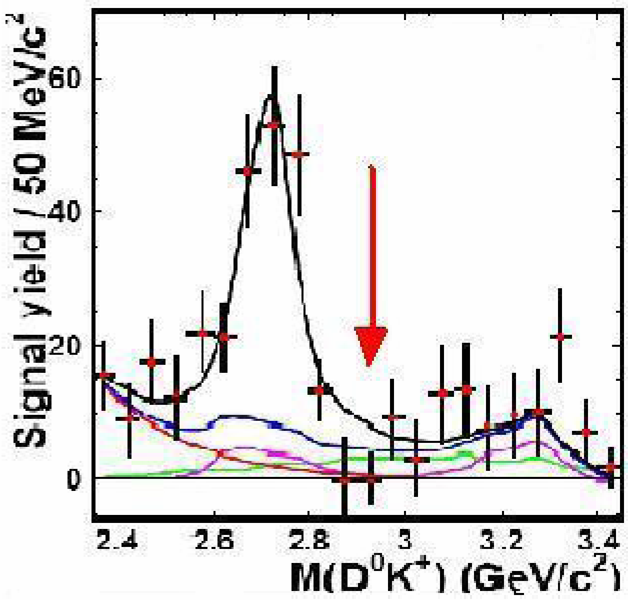
Our conclusion: D_{sJ}(2860) is likely to be a $J^P=3^-$ state

The D*K channel can discriminate between the two possibilities

$D_{sJ}(2860)$

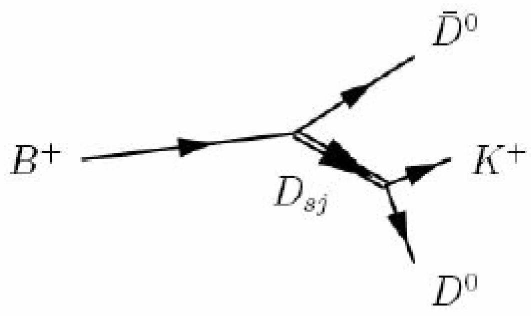
Some hint in favour of our interpretation came afterwards from Belle collab.

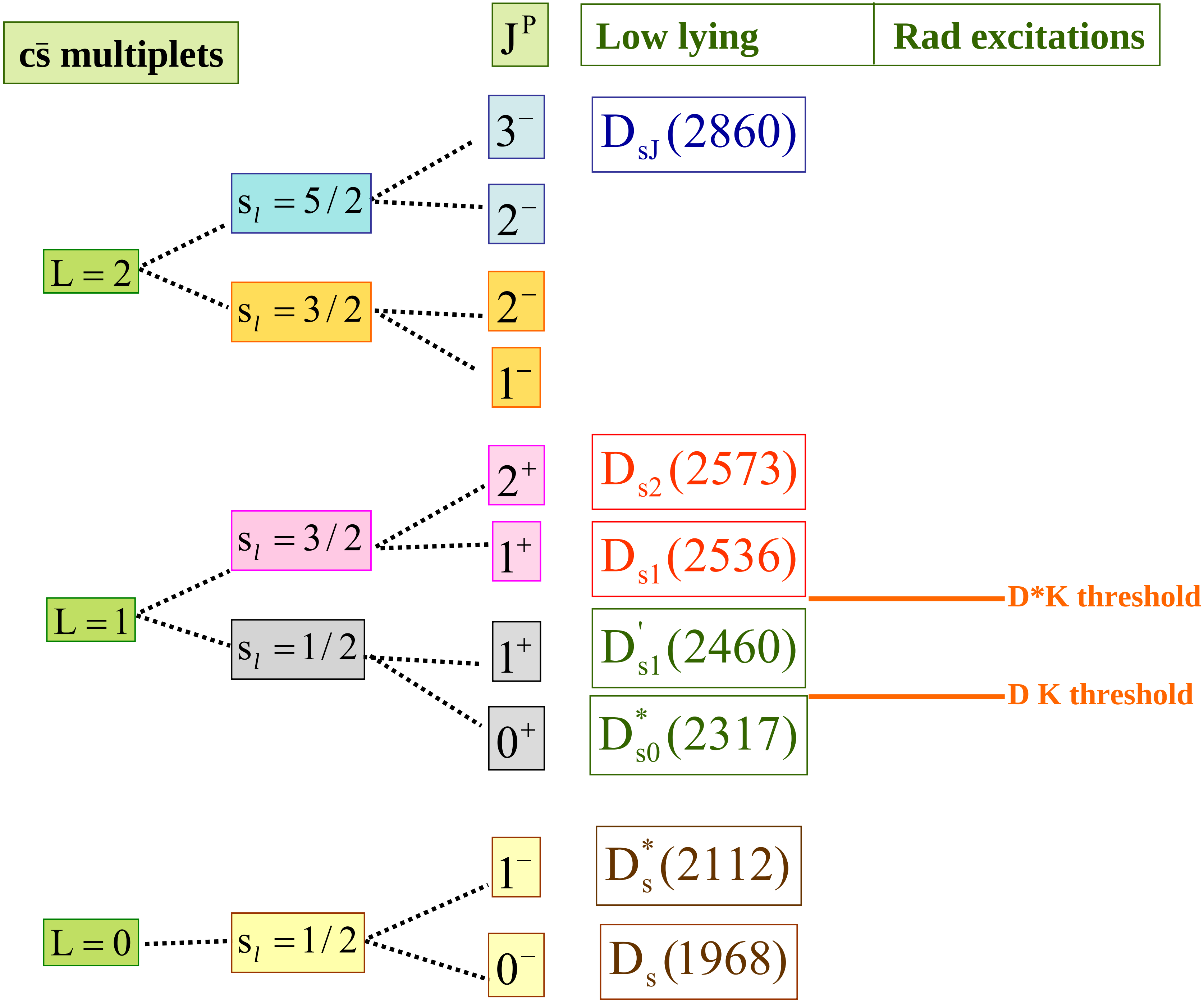
hep-ex/0608031



Invariant mass of the D^0K^+ system in the process $B^+ \to D^0 \bar{D}^0 K^+$

A $J^P=3^-$ state is not expected to be produced in non- leptonic B decays in the factorization approximation: the vacuum matrix element of the weak V-A current with a spin 3 particle vanishes

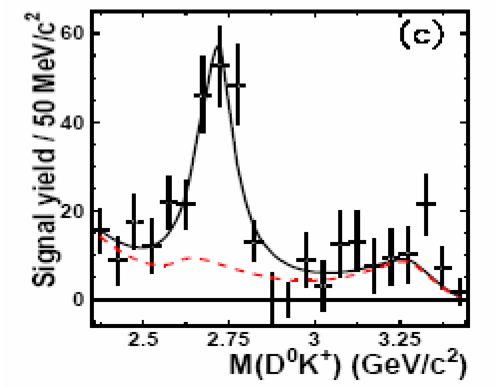




cs̄ multiplets
J^P
Low lying
Rad excitations
L = 2
s_l = 5/2
s_l = 3/2
3^−
2^−
2^−
1^−
D_sJ(2860)
L = 1
s_l = 3/2
s_l = 1/2
2^+
1^+
1^+
0^+
D_s2(2573)
D_s1(2536)
D*K threshold
D'_s1(2460)
D K threshold
D*_s0(2317)
L = 0
s_l = 1/2
1^−
0^−
D*_s(2112)
D_s(1968)

$D_{sJ}(2700)$

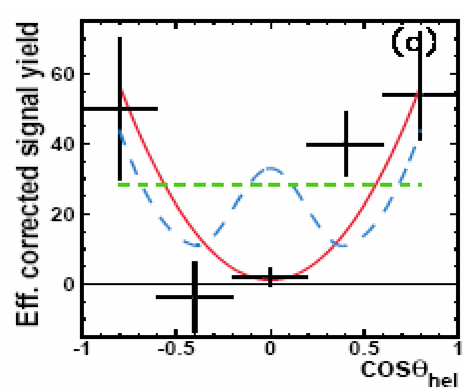
Belle Collab.: analysis of the mode $B^+ \to \overline{D}^0 D^0 K^+$



New resonance decaying to D^0K^+ with:

$M = 2708 \pm 9 \pm^{11}_{10}$ MeV $\quad\quad \Gamma = 108 \pm 23 \pm^{36}_{31}$ MeV

$1^- \to 0^- 0^-$ implies P=-1

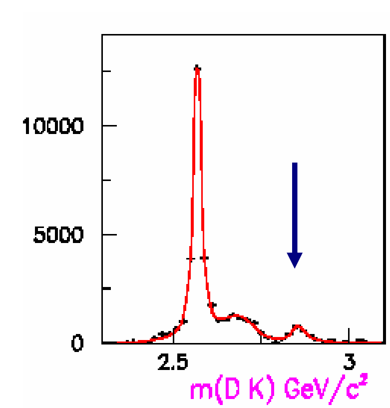


J=0

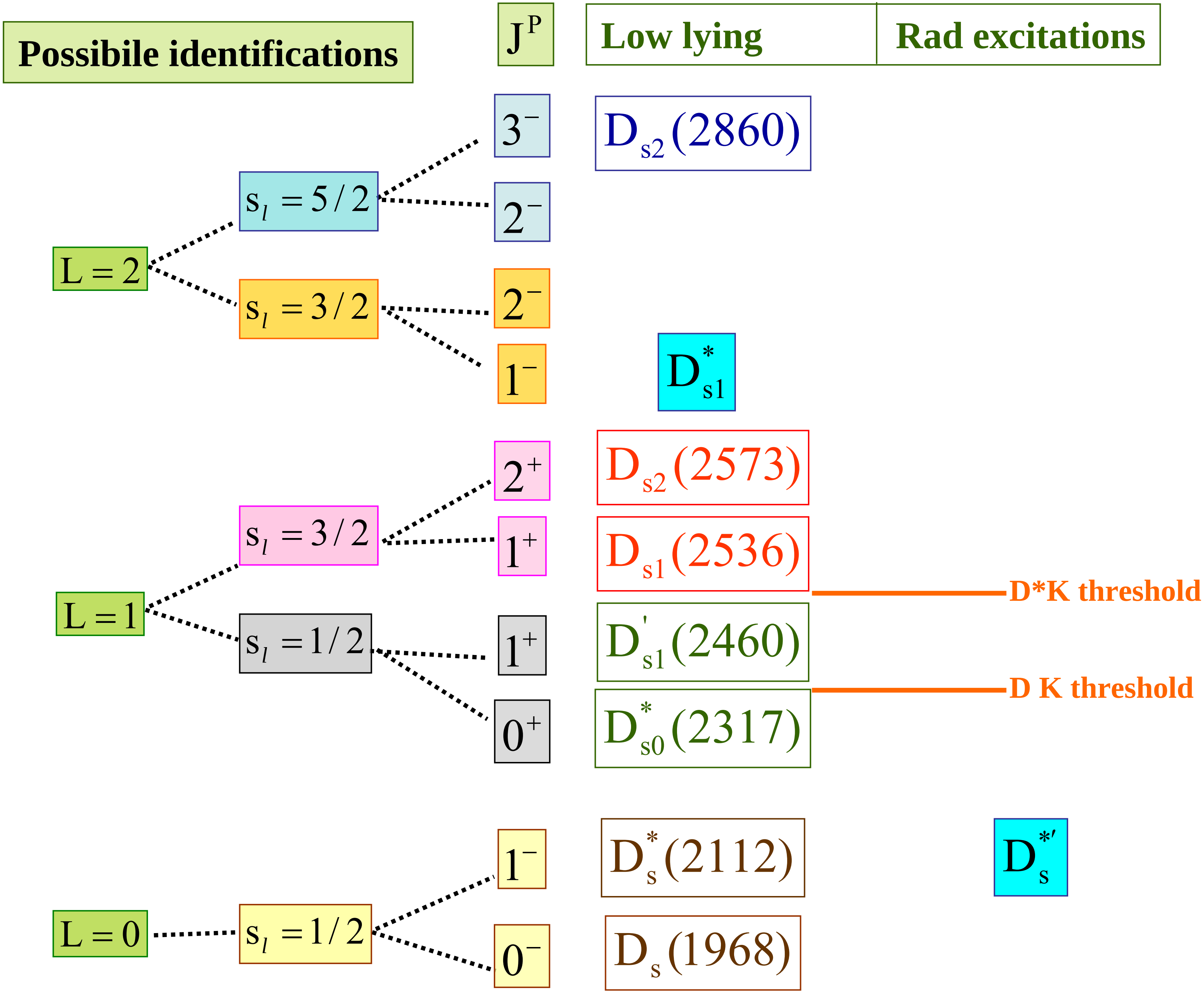
J=1

J=2

$J^P=1^-$ is favoured



A broad structure at M=2688 MeV with Γ=112 MeV had been found by BaBar in the DK mass distribution



Possibile identifications
J^P
Low lying
Rad excitations
$L = 2$
$s_l = 5/2$
$s_l = 3/2$
3^-
2^-
2^-
1^-
$D_{s2}(2860)$
D^*_{s1}
$L = 1$
$s_l = 3/2$
$s_l = 1/2$
2^+
1^+
1^+
0^+
$D_{s2}(2573)$
$D_{s1}(2536)$
D*K threshold
$D'_{s1}(2460)$
D K threshold
$D^*_{s0}(2317)$
$L = 0$
$s_l = 1/2$
1^-
0^-
$D^*_s(2112)$
$D_s(1968)$
$D^{*\prime}_s$

Identifying $D_{sJ}(2700)$ through its decay modes

P. Colangelo, S. Nicotri, M. Rizzi, FDF
Phys. Rev. D77 (08) 014012

$$R_1 = \frac{\Gamma(D_{sJ} \to D^* K)}{\Gamma(D_{sJ} \to DK)} \qquad R_2 = \frac{\Gamma(D_{sJ} \to D_s \eta)}{\Gamma(D_{sJ} \to DK)} \qquad R_3 = \frac{\Gamma(D_{sJ} \to D_s^* \eta)}{\Gamma(D_{sJ} \to DK)}$$

the dependence on the (unknown) couplings drops out

	$R_1 \times 10^2$	$R_2 \times 10^2$	$R_3 \times 10^2$
$D_s^{*\prime}$	91 ± 4	20 ± 1	5 ± 2
D_{s1}^*	4.3 ± 0.2	16.3 ± 0.9	0.18 ± 0.07

The D^*K decay is the signal that must be investigated in order to distinguish the two possible assignments

$D_{sJ}(2700)$

From the measurement of the total width:

- D^*_{s1} → $\tilde{g} = 0.26 \pm 0.05$
- $D^{*\prime}_{s}$ → $k' = 0.14 \pm 0.03$

Predicted individual branching fractions

	$\mathcal{B}(D_{sJ} \to D^0 K^+)$	$\mathcal{B}(D_{sJ} \to D^+ K_S)$	$\mathcal{B}(D_{sJ} \to D_s \eta)$	$\mathcal{B}(D_{sJ} \to D^{*0} K^+)$	$\mathcal{B}(D_{sJ} \to D^{*+} K_S)$	$\mathcal{B}(D_{sJ} \to D^*_s \eta)$
$D^{*\prime}_s$	$(24 \pm 14)\%$	$(12 \pm 7.0)\%$	$(7 \pm 4)\%$	$(22 \pm 13)\%$	$(10 \pm 6)\%$	$(1.7 \pm 1.2)\%$
D^*_{s1}	$(44 \pm 25)\%$	$(21 \pm 12)\%$	$(11 \pm 6)\%$	$(1.9 \pm 1.1)\%$	$(0.9 \pm 0.5)\%$	$(0.12 \pm 0.09)\%$

Total width of the spin partners

$D^*_{s1} \to D^*_{s2}$ $\quad \Gamma(D^*_{s2}) = (12 \pm 5)$ MeV

$D^{*\prime}_{s} \to D'_{s}$ $\quad \Gamma(D'_s) = (70 \pm 30)$ MeV

In both cases the dominant mode is predicted to be D^*K

Conclusions

Many new discoveries since 2003:

- **$D_{sJ}(2317)$** and **$D_{sJ}(2460)$** most likely ordinary $\bar{c}s$ mesons

- study of the decay modes of **$D_{sJ}(2860)$** leads to assign $J^P=3^-$ to this state (our conclusion)
  D*K channel fundamental to confirm/discard

- identification of **$D_{sJ}(2700)$** possible through the search of D^*K final state