On a possibility of baryonic exotica

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in collaboration with
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G.-S. Yang (Soongsil University, Seoul)

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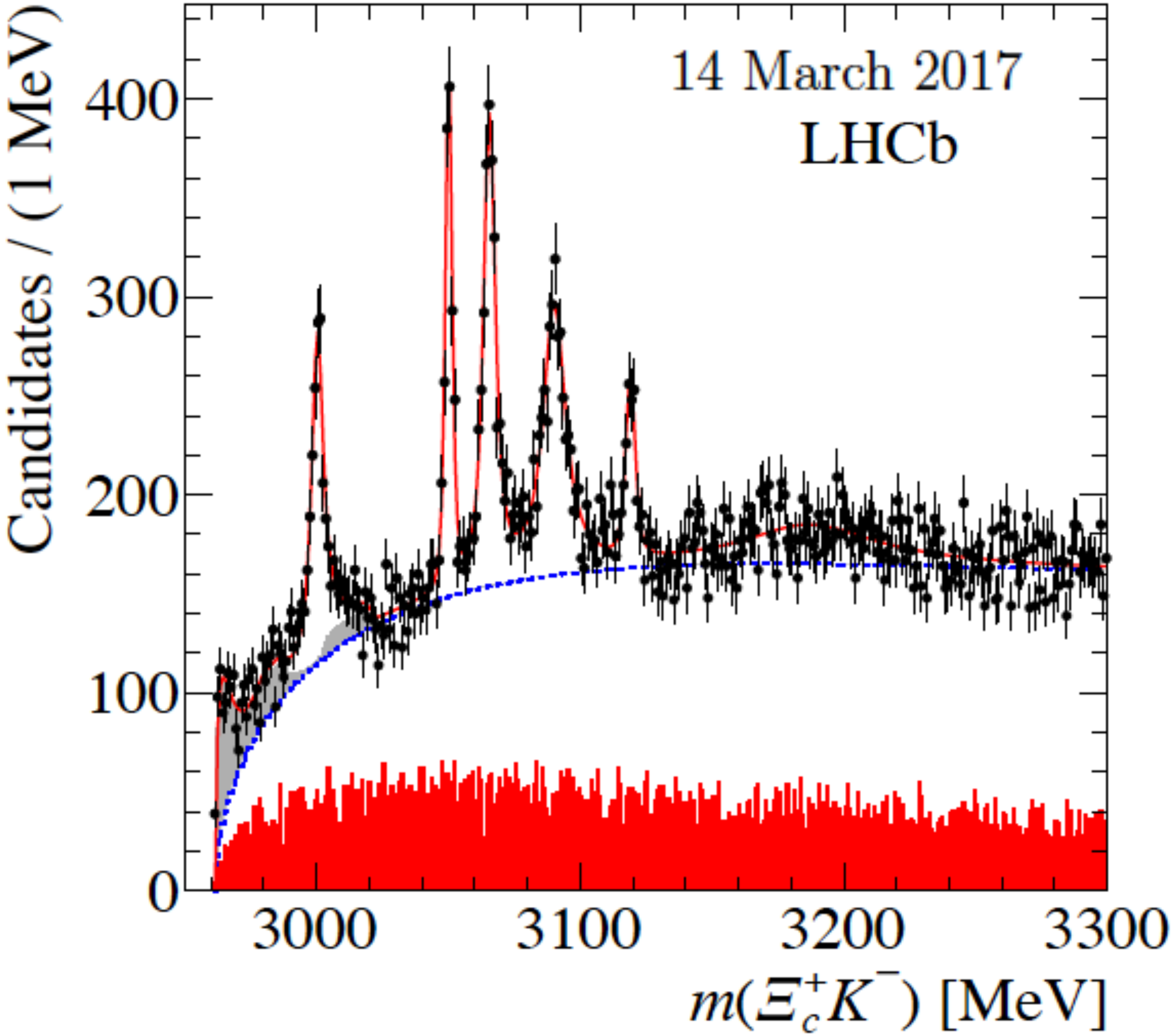
Phys.Rev. D96 (2017) 014009
and in preparation

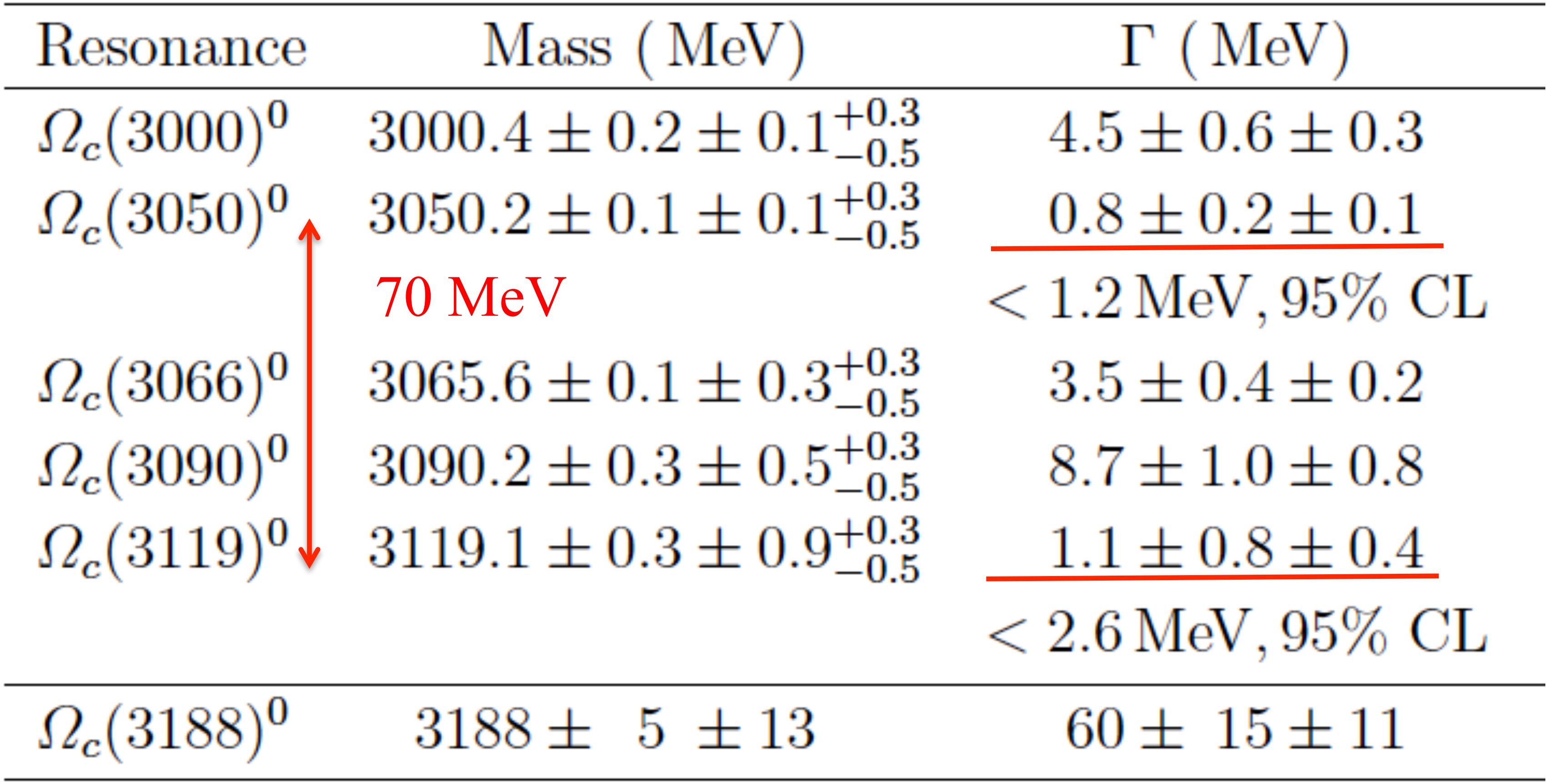
Workshop on Standard Model and Beyond, Corfu, Greece, September 4, 2017

Motivation

Motivation: 5 narrow Ω_c's

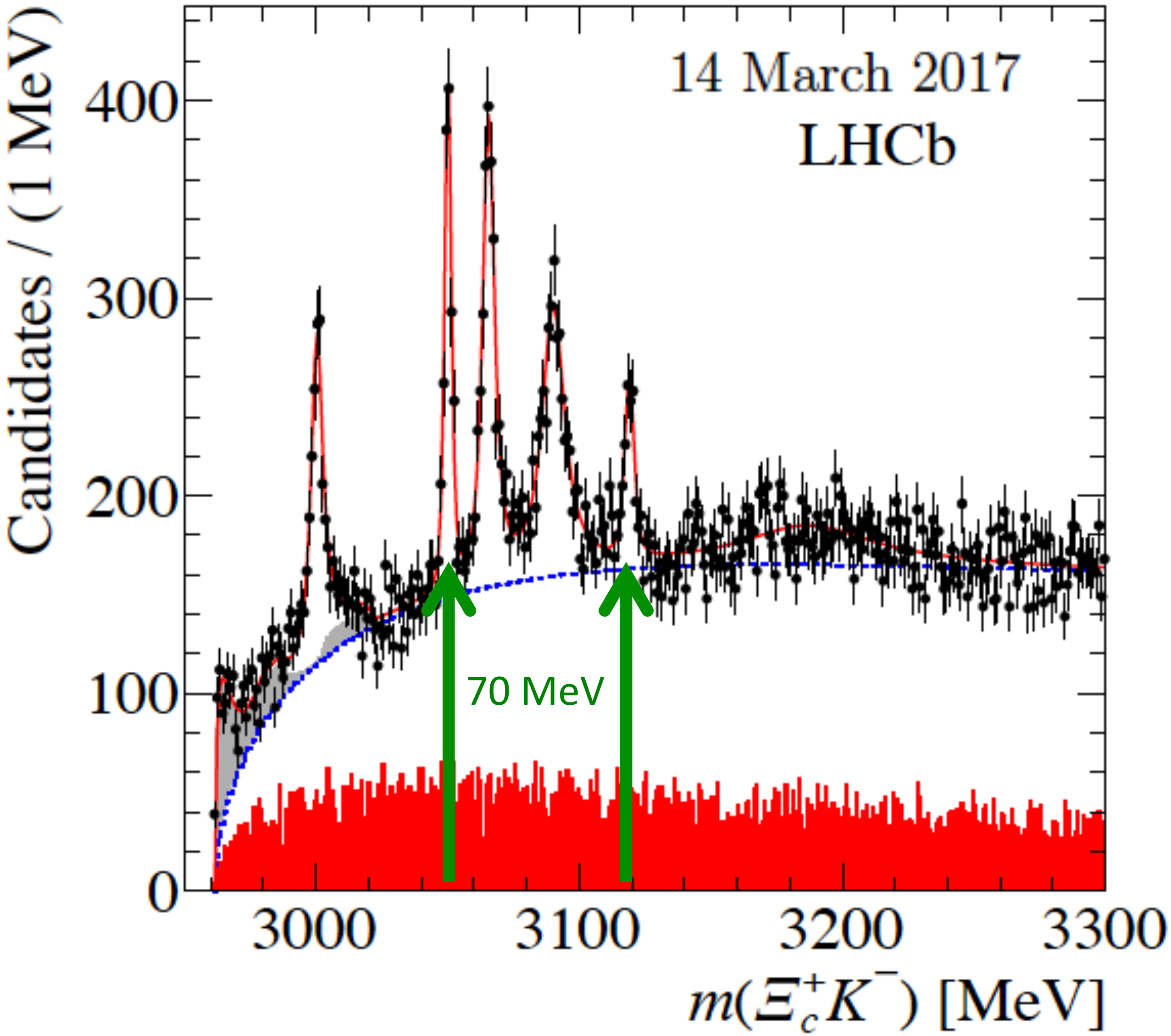


Motivation: 5 narrow Ω_c's



Resonance	Mass (MeV)	Γ (MeV)
$\Omega_c(3000)^0$	$3000.4 \pm 0.2 \pm 0.1^{+0.3}_{-0.5}$	$4.5 \pm 0.6 \pm 0.3$
$\Omega_c(3050)^0$	$3050.2 \pm 0.1 \pm 0.1^{+0.3}_{-0.5}$	$0.8 \pm 0.2 \pm 0.1$
	70 MeV	$< 1.2\,\mathrm{MeV}, 95\%\ \mathrm{CL}$
$\Omega_c(3066)^0$	$3065.6 \pm 0.1 \pm 0.3^{+0.3}_{-0.5}$	$3.5 \pm 0.4 \pm 0.2$
$\Omega_c(3090)^0$	$3090.2 \pm 0.3 \pm 0.5^{+0.3}_{-0.5}$	$8.7 \pm 1.0 \pm 0.8$
$\Omega_c(3119)^0$	$3119.1 \pm 0.3 \pm 0.9^{+0.3}_{-0.5}$	$1.1 \pm 0.8 \pm 0.4$
		$< 2.6\,\mathrm{MeV}, 95\%\ \mathrm{CL}$
$\Omega_c(3188)^0$	$3188 \pm 5 \pm 13$	$60 \pm 15 \pm 11$

Motivation: 5 narrow Ω_c's



Reminder

Heavy baryon ground states

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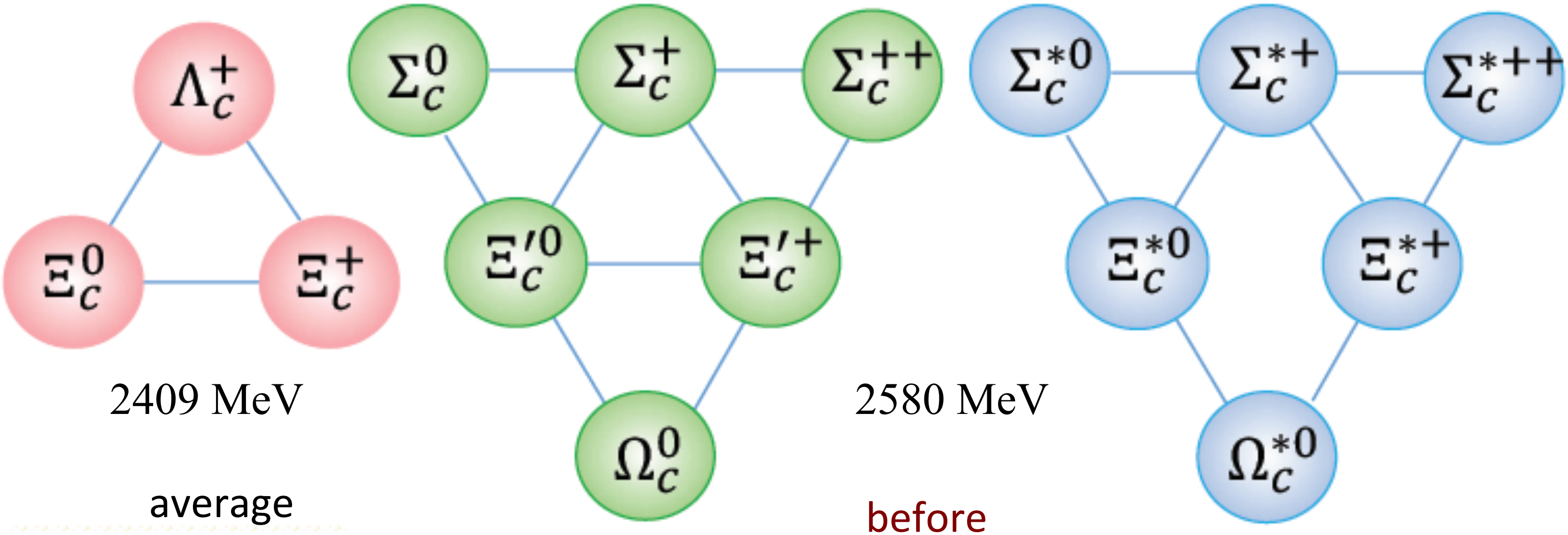
$(\bar{3}\ 1/2^+)$ $(6\ \ 1/2^+)$ $(6\ 3/2^+)$



2409 MeV

2580 MeV

average
multiplet
masses

before
hf splitting
70 MeV

2535 MeV

2602 MeV

$s = 0$ diquark $+\ s = 1/2$ HQ $\qquad$ $s = 1$ diquark $+\ s = 1/2$ HQ

Heavy baryon ground states

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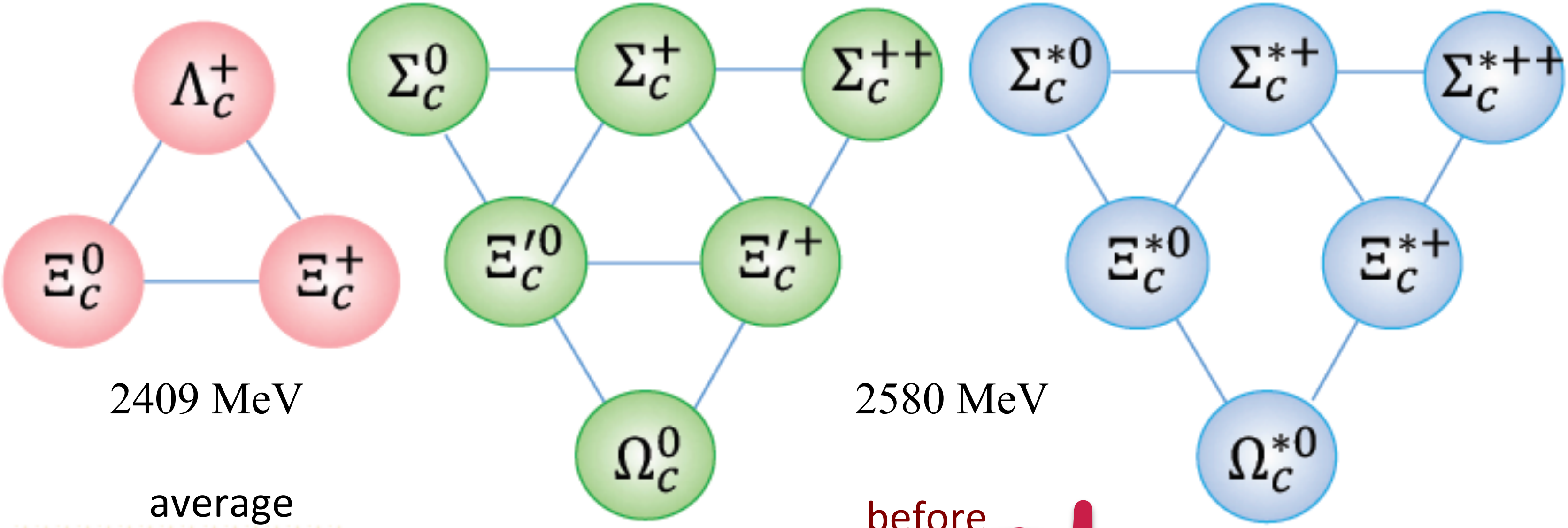
$(\overline{3}\ 1/2^+)$ $(6\ \ 1/2^+)$ $(6\ 3/2^+)$



2409 MeV

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masses

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hf splitting
70 MeV

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$s = 0$ diquark + $s = 1/2$ HQ $s = 1$ diquark + $s = 1/2$ HQ

Heavy baryon ground states

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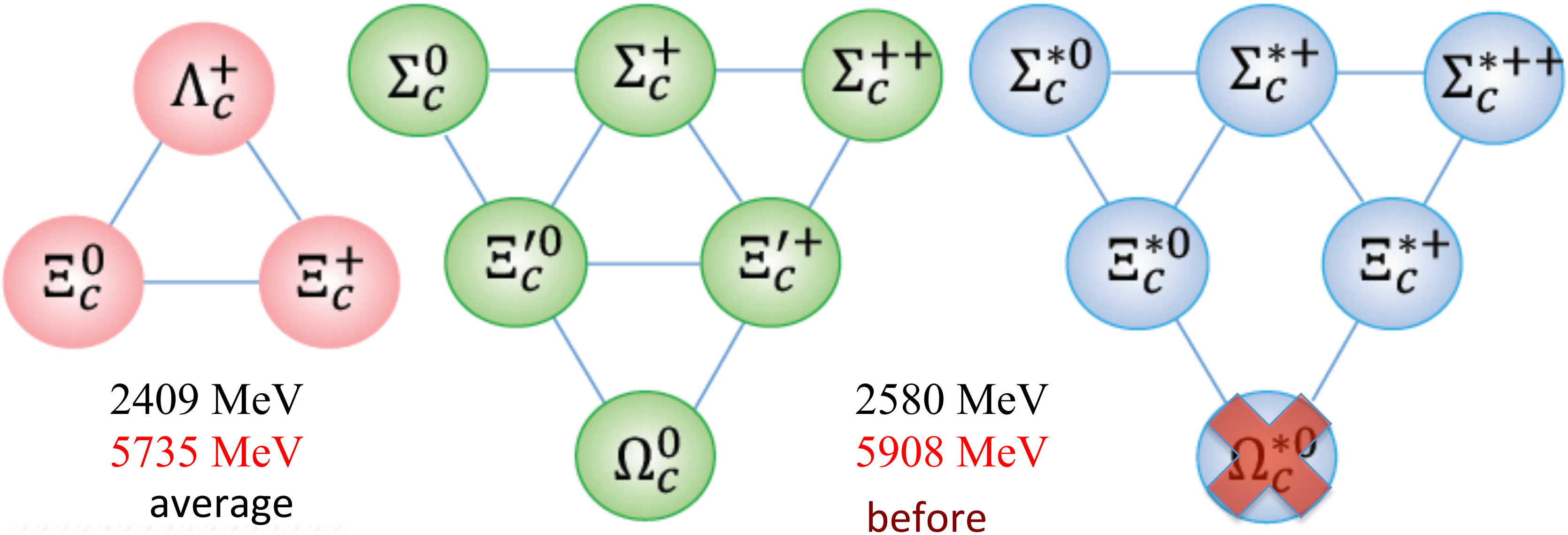
$(\bar{3}\ 1/2^+)$ $(6\ 1/2^+)$ $(6\ 3/2^+)$



2409 MeV
5735 MeV
average
multiplet
masses

2535 MeV
5893 MeV

2580 MeV
5908 MeV

before
hf splitting
70 MeV
20 MeV

2602 MeV
5913 MeV

same for the bottom

Heavy baryon ground states

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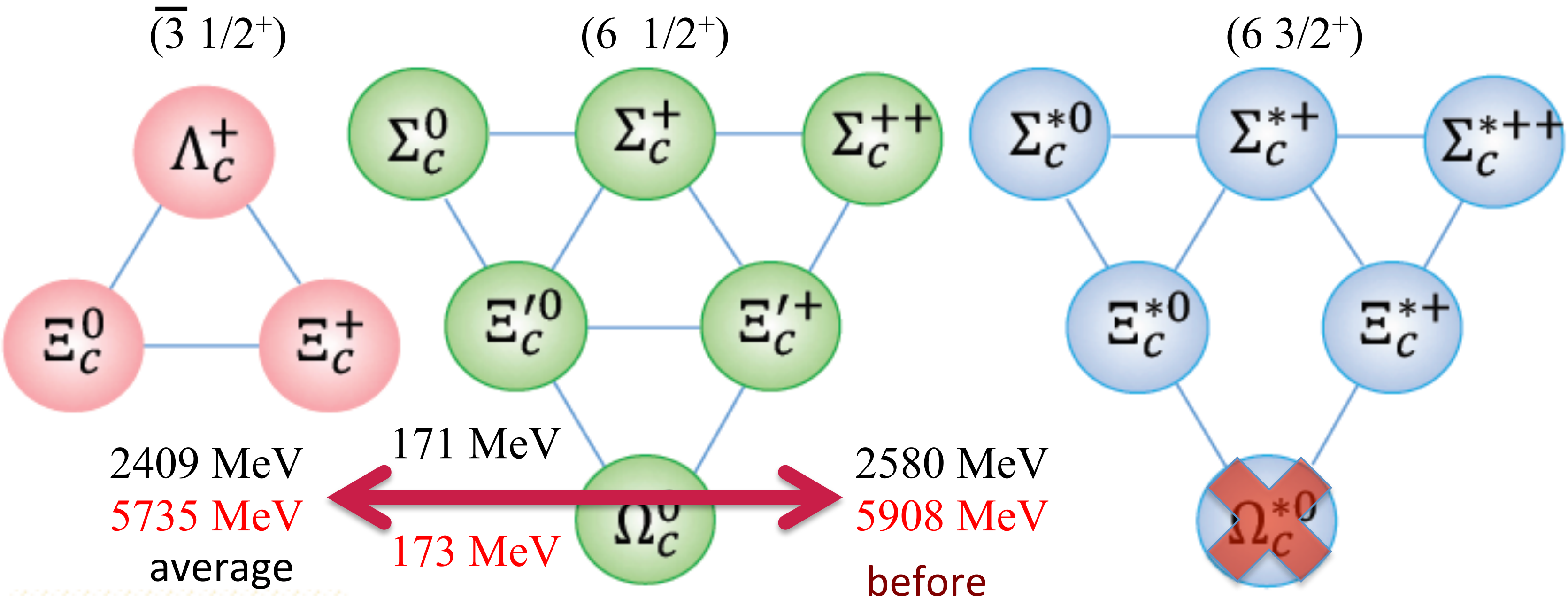


2409 MeV
5735 MeV

average
multiplet
masses

171 MeV
173 MeV

2580 MeV
5908 MeV

before
hf splitting

70 MeV
20 MeV

2535 MeV
5893 MeV

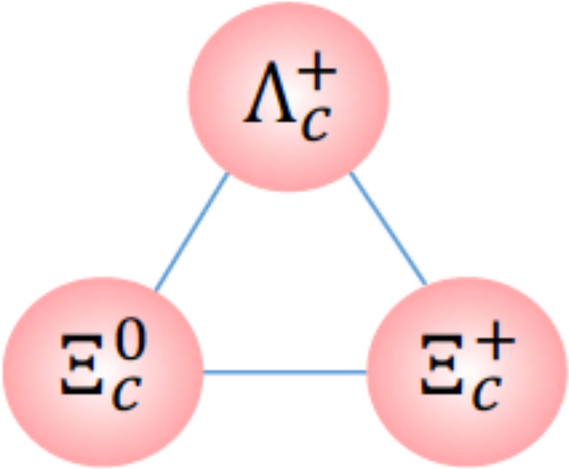
2602 MeV
5913 MeV

hf splitting ratio ~ 0.3 ~ m_c/m_b

same for the bottom

Heavy baryon excited states

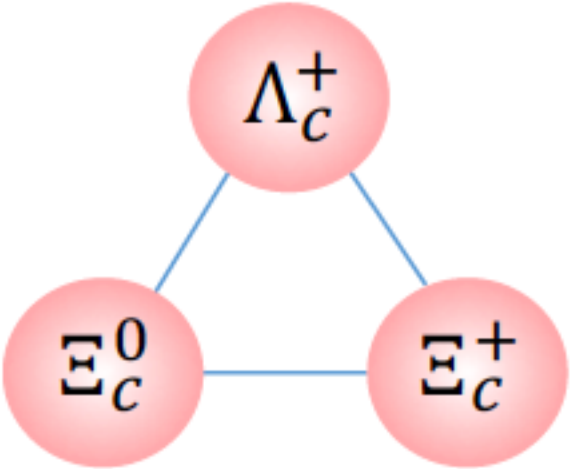
$(\bar{3}\ 1/2^-)$



2724 MeV

30 MeV

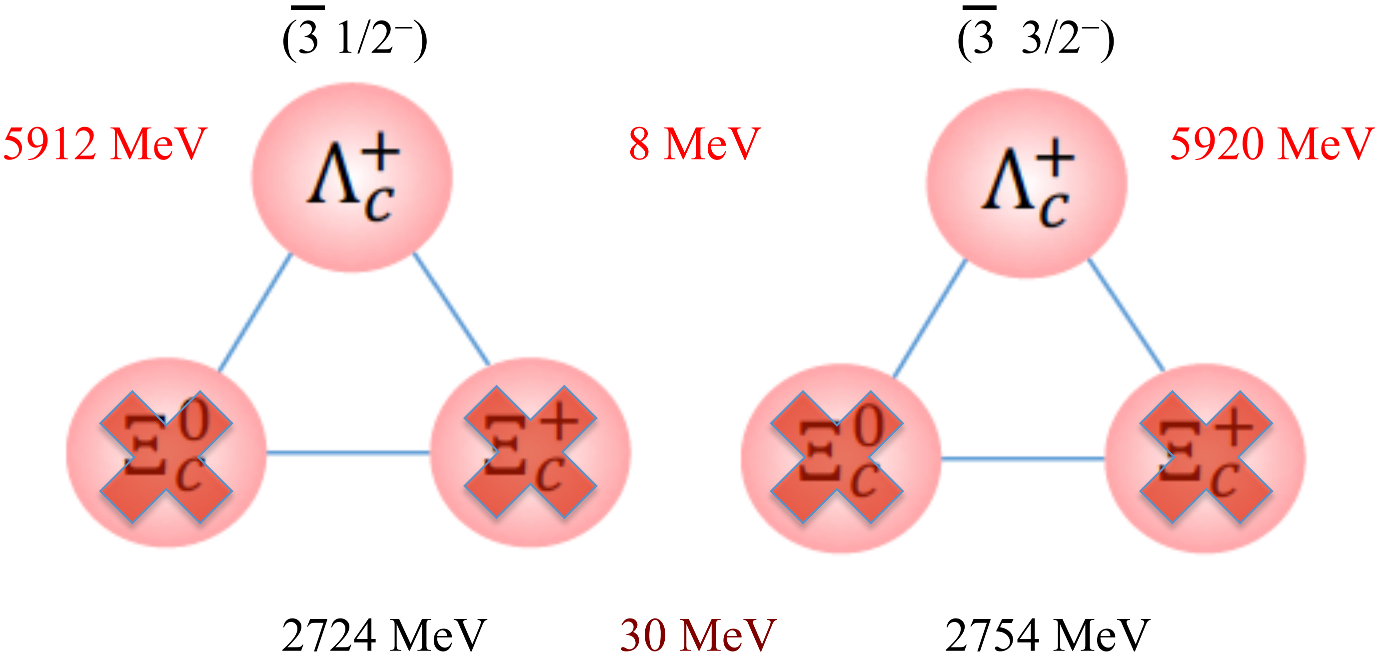
$(\bar{3}\ \ 3/2^-)$



2754 MeV

$s = 0$ diquark + $s = 1/2$ HQ + $L = 1$

Heavy baryon excited states



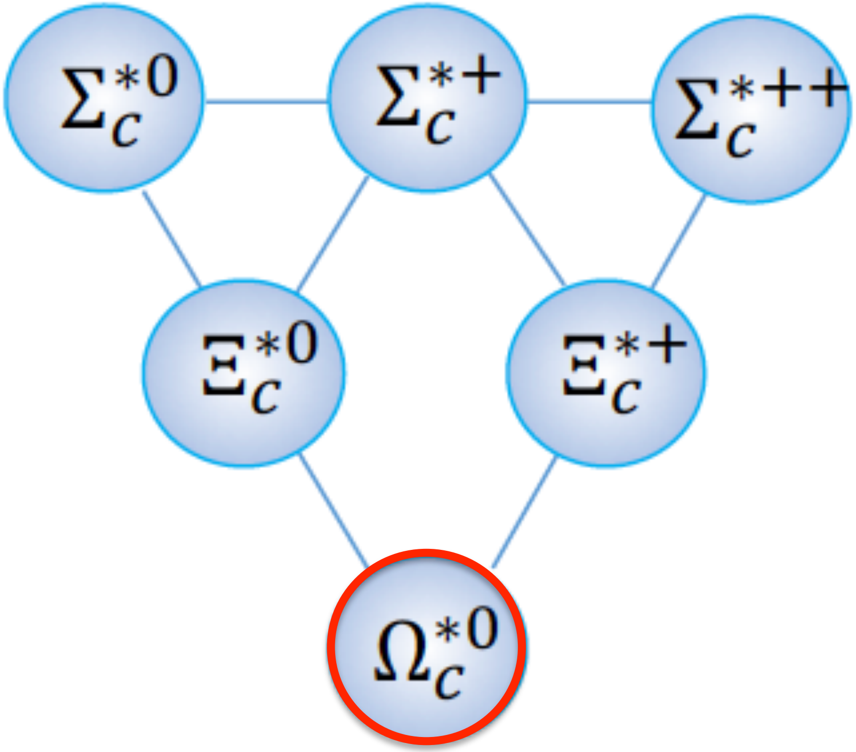
$(\bar{3}\ 1/2^-)$ $(\bar{3}\ 3/2^-)$

5912 MeV 8 MeV 5920 MeV

2724 MeV 30 MeV 2754 MeV

not much known in the bottom sector

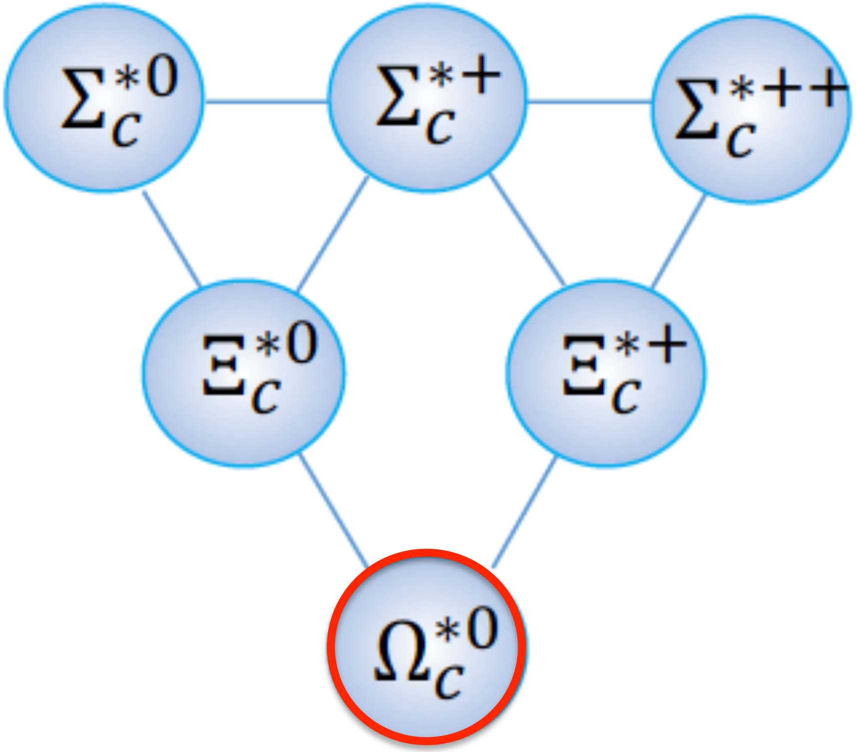
Sextet excitations $1/2^-$ and $3/2^-$?



$s = 1$ diquark + $s = 1/2$ HQ + $L = 1$

→ 1/2, 1/2, 3/2, 3/2, 5/2 → 5 states!

Sextet excitations 1/2⁻ and 3/2⁻?



however:
one has to fit both
masses
and
widths

$s = 1$ diquark + $s = 1/2$ HQ + $L = 1$

→ 1/2, 1/2, 3/2, 3/2, 5/2 → 5 states!

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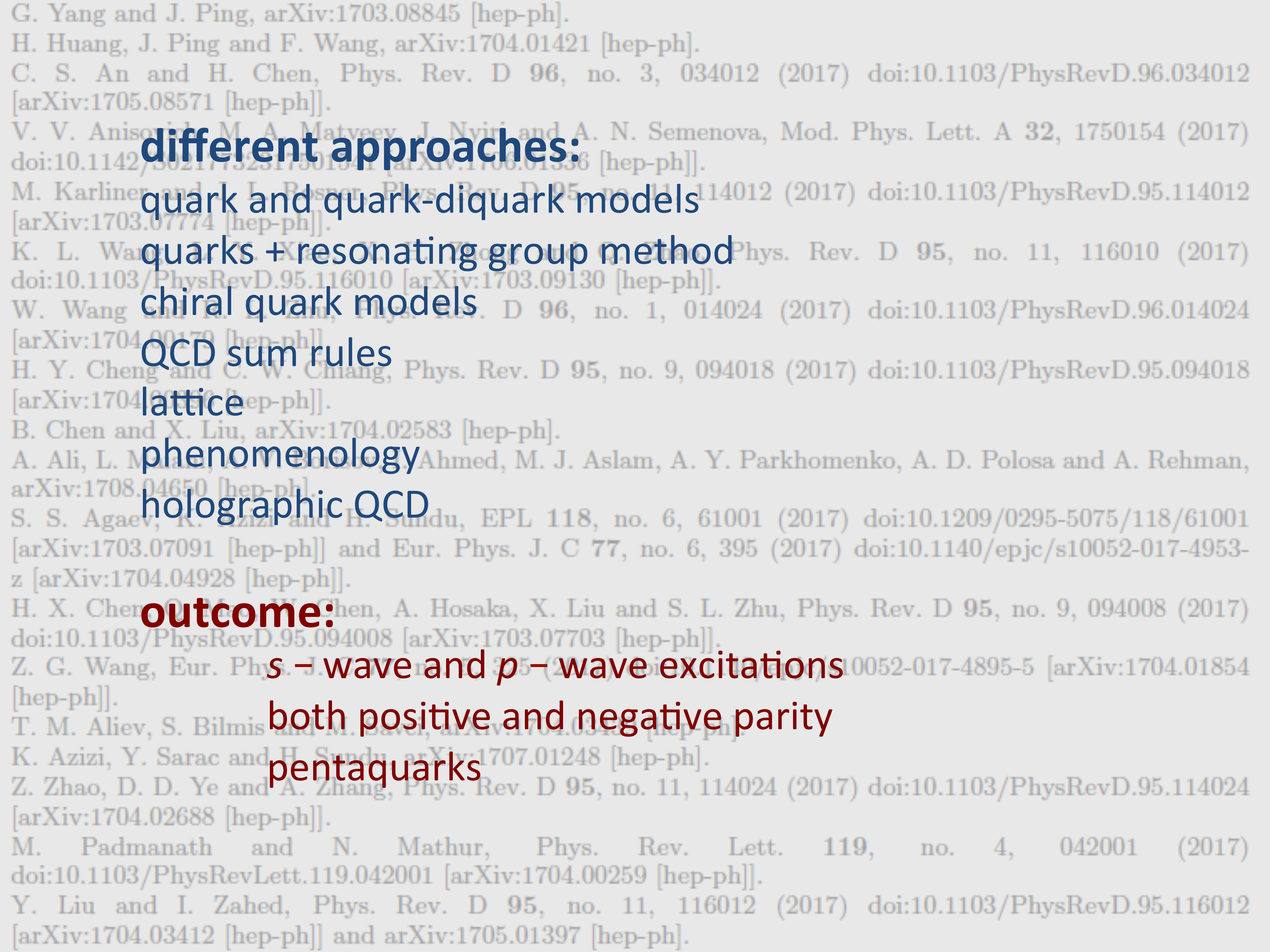
different approaches:

quark and quark-diquark models
quarks + resonating group method
chiral quark models
QCD sum rules
lattice
phenomenology
holographic QCD

outcome:

s – wave and p – wave excitations
both positive and negative parity
pentaquarks



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Y. Liu and I. Zahed, Phys. Rev. D **95**, no. 11, 116012 (2017) doi:10.1103/PhysRevD.95.116012 [arXiv:1704.03412 [hep-ph]] and arXiv:1705.01397 [hep-ph].

Chiral Quark-Soliton Model

Why Chiral Quark-Soliton Model?

- Why not?

Why Chiral Quark-Soliton Model?

- ~~Why not?~~
- because it predicts small widths
  for some specific decays

QCD: quarks and gluons

integrate out gluons

many quark nonlocal interactions

Lagrangian chirally symmetric

approximation:

manyq, nonl. ⟶ 4q, local

Nambu Jona Lasinio model

spontaneous chiral symmetry breaking

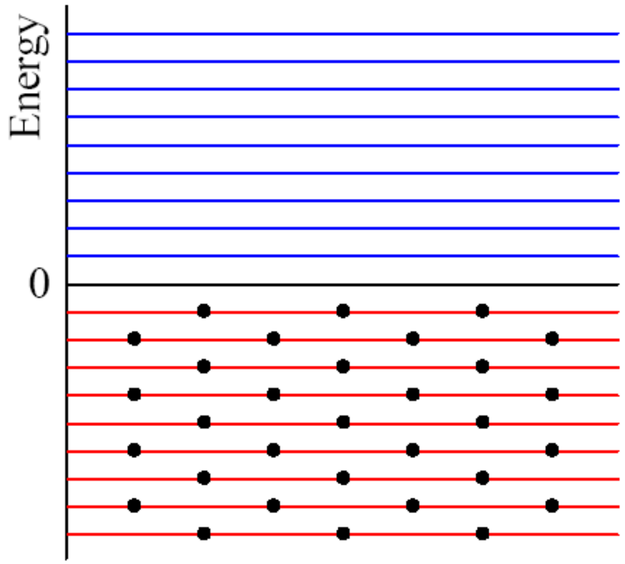
semibosonization:

$q\bar{q}q\bar{q} \longrightarrow q\bar{q}\pi$

Chiral Quark Model

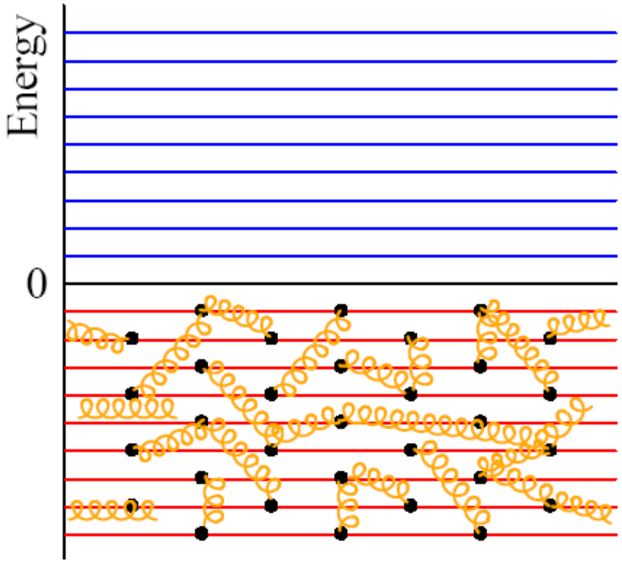
Chiral Quark Soliton Model

QCD vacuum:



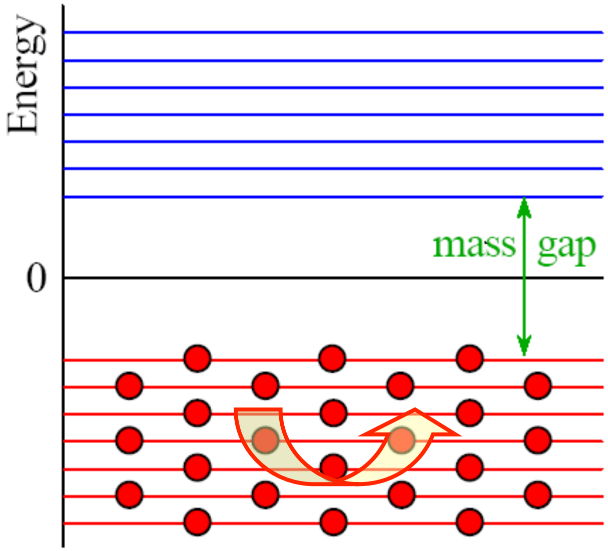
Chiral Quark Soliton Model

QCD vacuum:



Chiral Quark Soliton Model

chiral symmetry breaking:

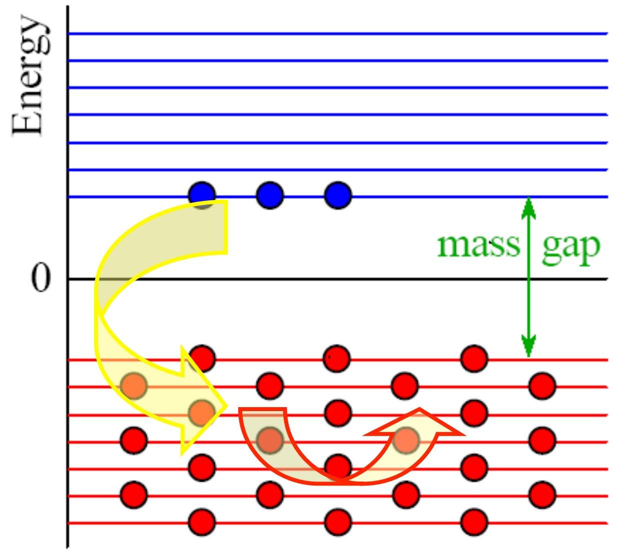


chirally inv. manyquark int.

Chiral Quark Soliton Model

baryon:

adding vlence quarks:

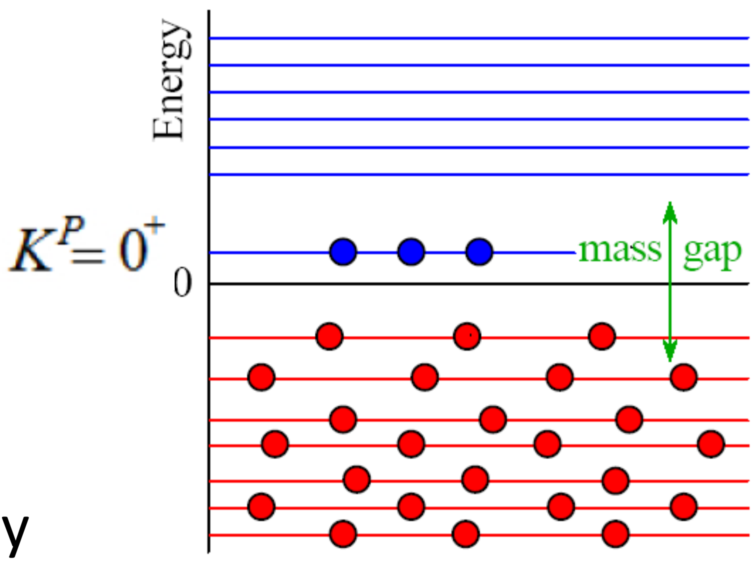


chirally inv. manyquark int.

Chiral Quark Soliton Model

baryon:

“classical” baryon:



due to hedgehog symmetry
of the mean field only

grand spin

$$K = T + S$$

is a *good* quantum number

chirally inv. manyquark int.

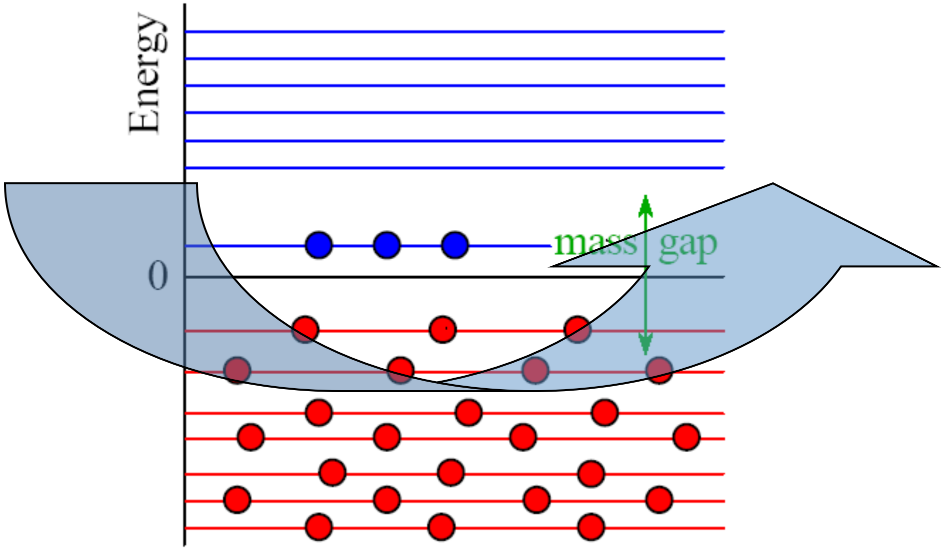
soliton configuration

no quantum numbers except B

Chiral Quark Soliton Model

baryon:

“quantum” baryon:



chirally inv. manyquark int.

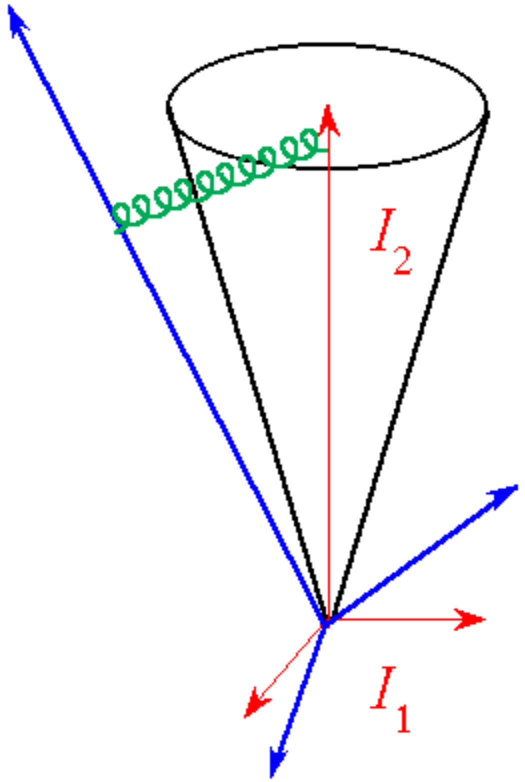
soliton configuration
no quantum numbers except B

rotation generates flavor and spin

Mass formula

$\pi_8 = N_c/2\sqrt{3}$

$$H_0 = M_{\rm cl} + \frac{1}{2I_1} S(S+1) + \frac{1}{2I_2}\left(C_2(\mathcal{R}) - S(S+1) - \frac{N_c^2}{12}\right)$$



P.O. Mazur, M.A. Nowak, MP, Phys. Lett. 147B (1984) 137
E. Guadagnini, Nucl. Phys. B236 (1984) 35
S. Jain, S.R. Wadia, Nucl. Phys. B258 (1985) 713

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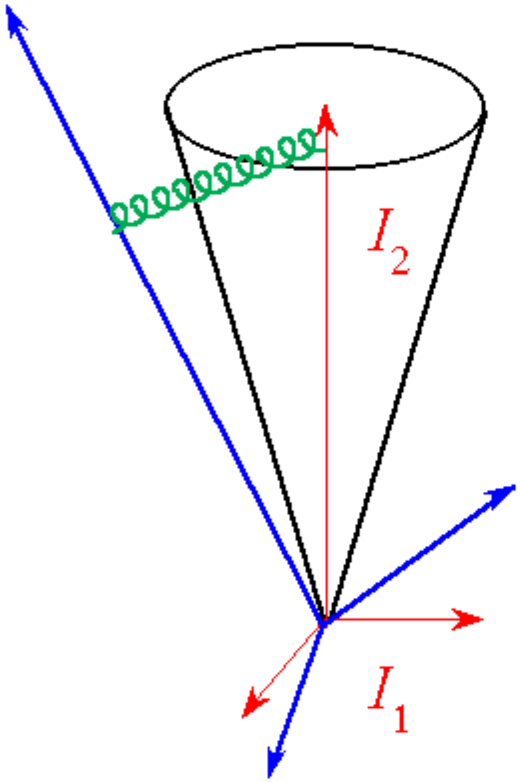

first order perturbation in the strange quark mass and in N_c:

$$H_{\mathrm{br}} = \alpha\, D_{88}^{(8)} + \beta\,\hat{Y} + \frac{\gamma}{\sqrt{3}} \sum_{i=1}^{3} D_{8i}^{(8)}\,\hat{J}_i$$

$$\alpha \sim m_s N_{\mathrm{c}}, \quad \beta, \gamma \sim m_s \mathcal{O}(1)$$

P.O. Mazur, M.A. Nowak, MP, Phys. Lett. 147B (1984) 137
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Mass formula

$\pi_8 = N_c/2\sqrt{3}$

O(1) corrections to M_{cl} do not allow for absolute mass predictions

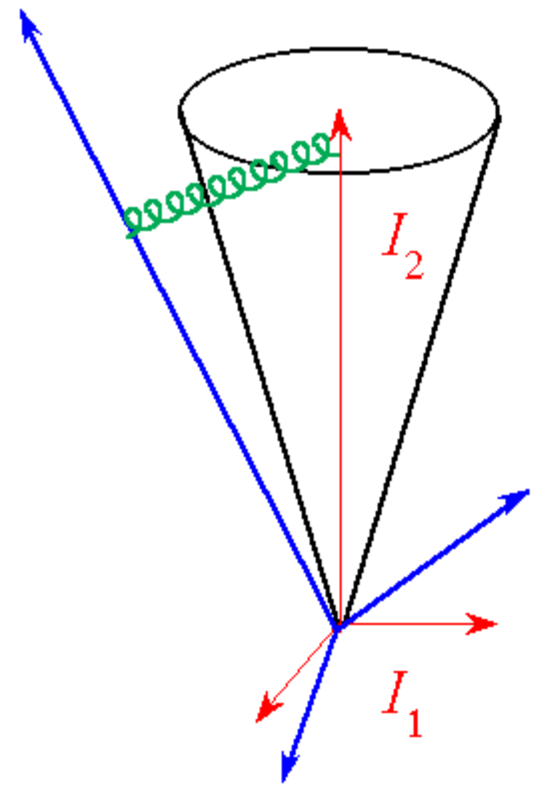
$$H_0 = M_{\rm cl} + \frac{1}{2I_1} S(S+1) + \frac{1}{2I_2}\left(C_2(\mathcal{R}) - S(S+1) - \frac{N_c^2}{12}\right)$$

octet-decuplet splitting

known

?

exotic-nonexotic splittings



first order perturbation in the strange quark mass and in N_c:

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$$\alpha \sim m_s N_c, \qquad \beta, \gamma \sim m_s \mathcal{O}(1)$$

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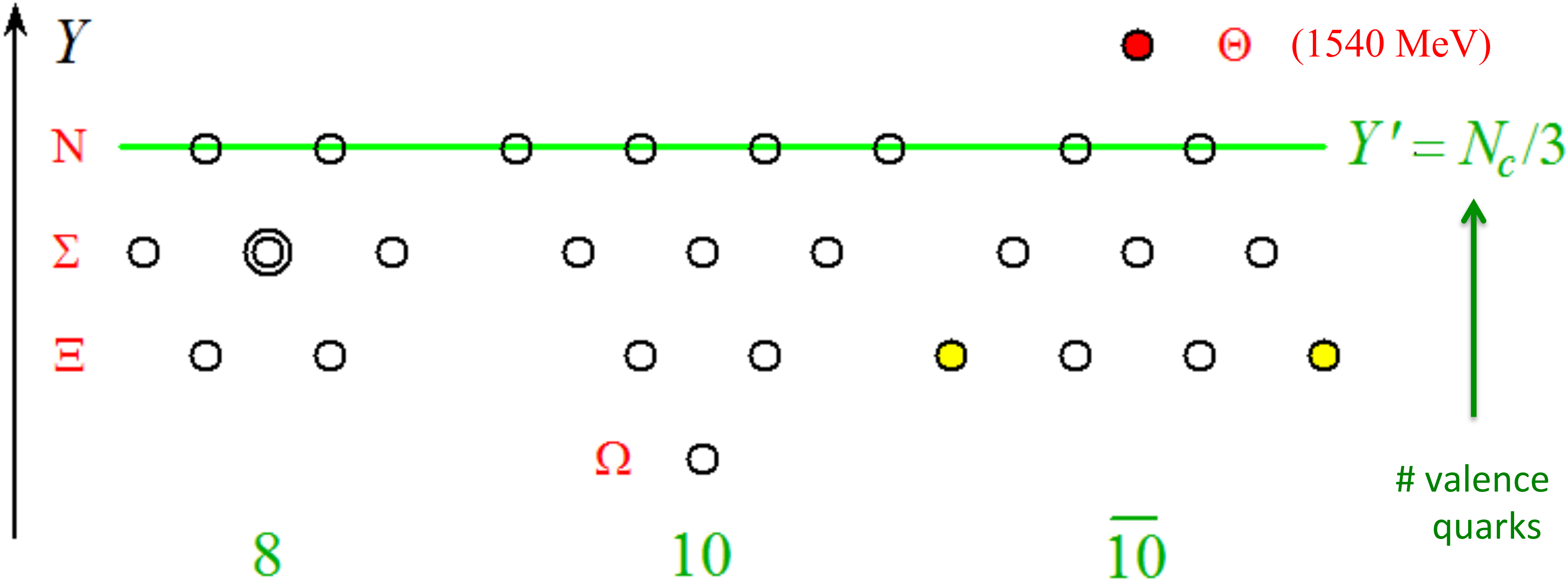
S. Jain, S.R. Wadia, Nucl. Phys. B258 (1985) 713

Allowed states

- allowed SU(3) representations must contain states with hypercharge $Y' = N_c/3$,
- the isospin $\boldsymbol{T}'$ of the states with $Y' = N_c/3$ couples with the soliton spin $\boldsymbol{J}$ to a singlet: $\boldsymbol{T}' + \boldsymbol{J} = 0$.



Ch.V. Christov et al. Prog. Part. Nucl. Phys. 37 (1996) 91

Successful Phenomenology

In a ”model independent” approach
one can get both good fits to the existing data
(including very narrow light pentaquark Θ^+)
one can fix all necessary model parameters:
M, I_1, I_2, α, β, γ

Ch.V. Christov et al. Prog. Part. Nucl. Phys. 37 (1996) 91

Successful Phenomenology

In a ”model independent” approach
one can get both good fits to the existing data
(including very narrow light pentaquark Θ^+)
one can fix all necessary model parameters:
M, I_1, I_2, α, β, γ

but also one can recover the NRQM result
in a special limit

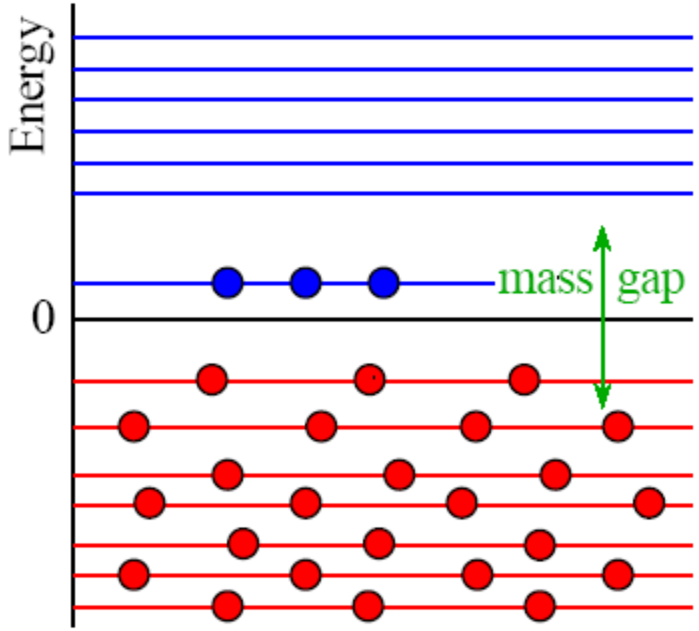
NRQM limit =
= squeezing the soliton to zero size

MP, A. Blotz, K. Goeke Phys. Lett. B354 (1995) 415

NRQM Limit

Diakonov, Petrov, Polyakov, Z.Phys **A359** (97) 305
MP, A.Blotz K.Goeke, Phys.Lett.**B354**:415-422,1995

energy is calculated
with respect to the vacuum:



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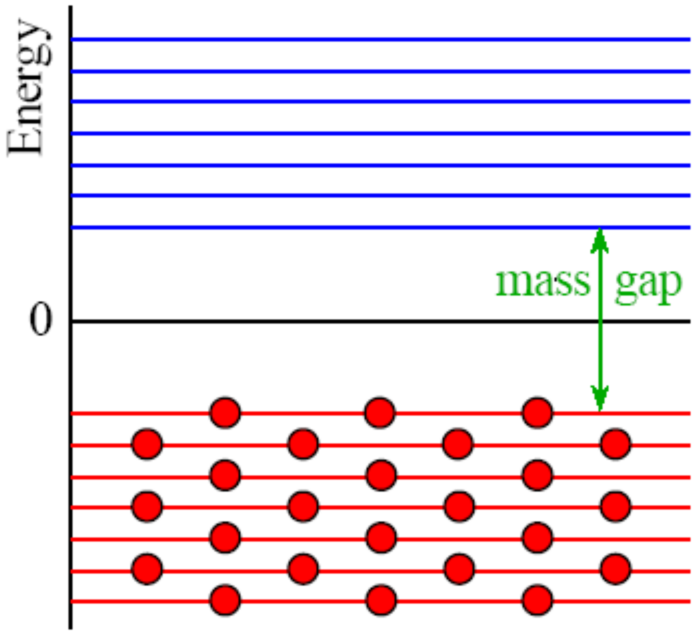

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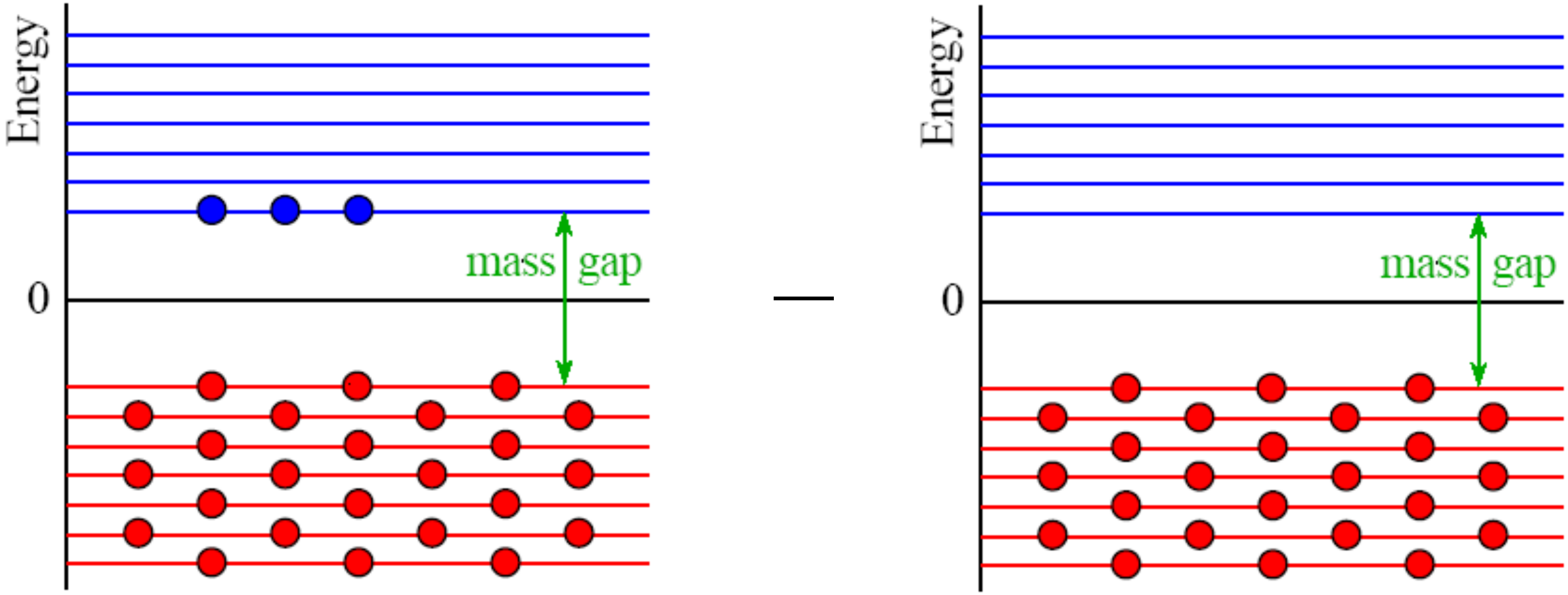

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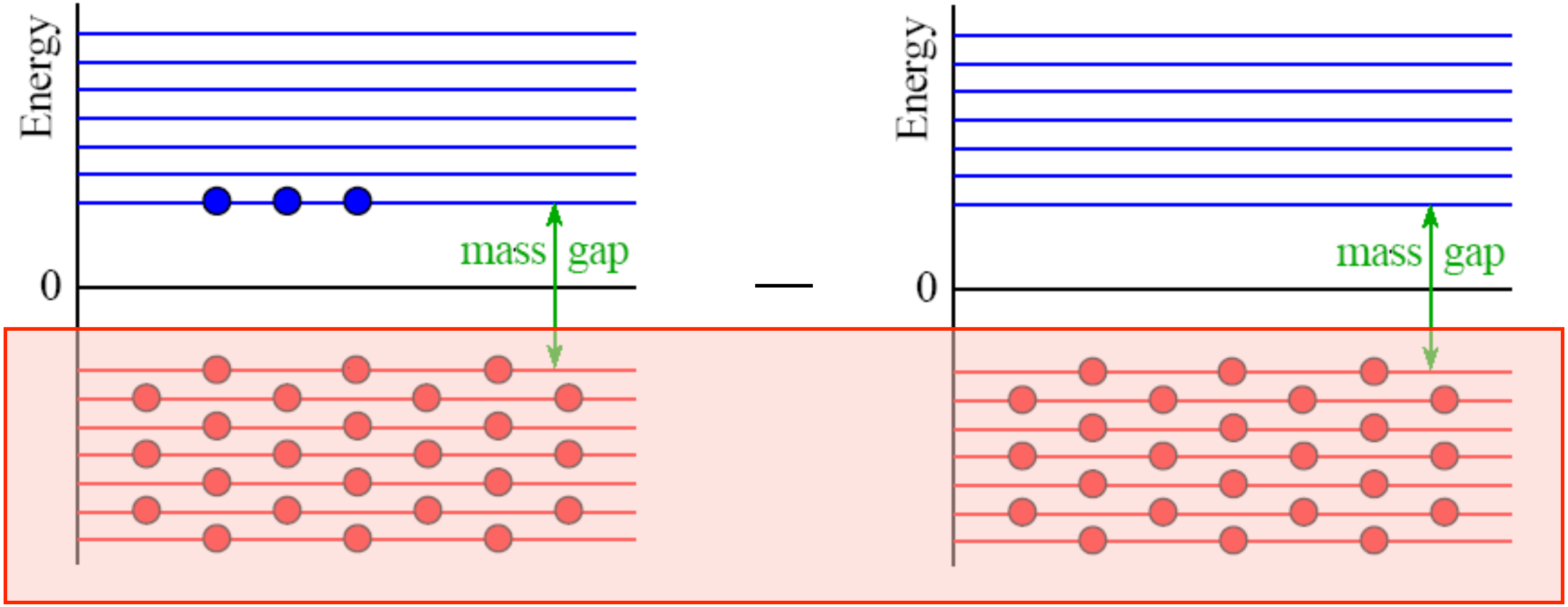


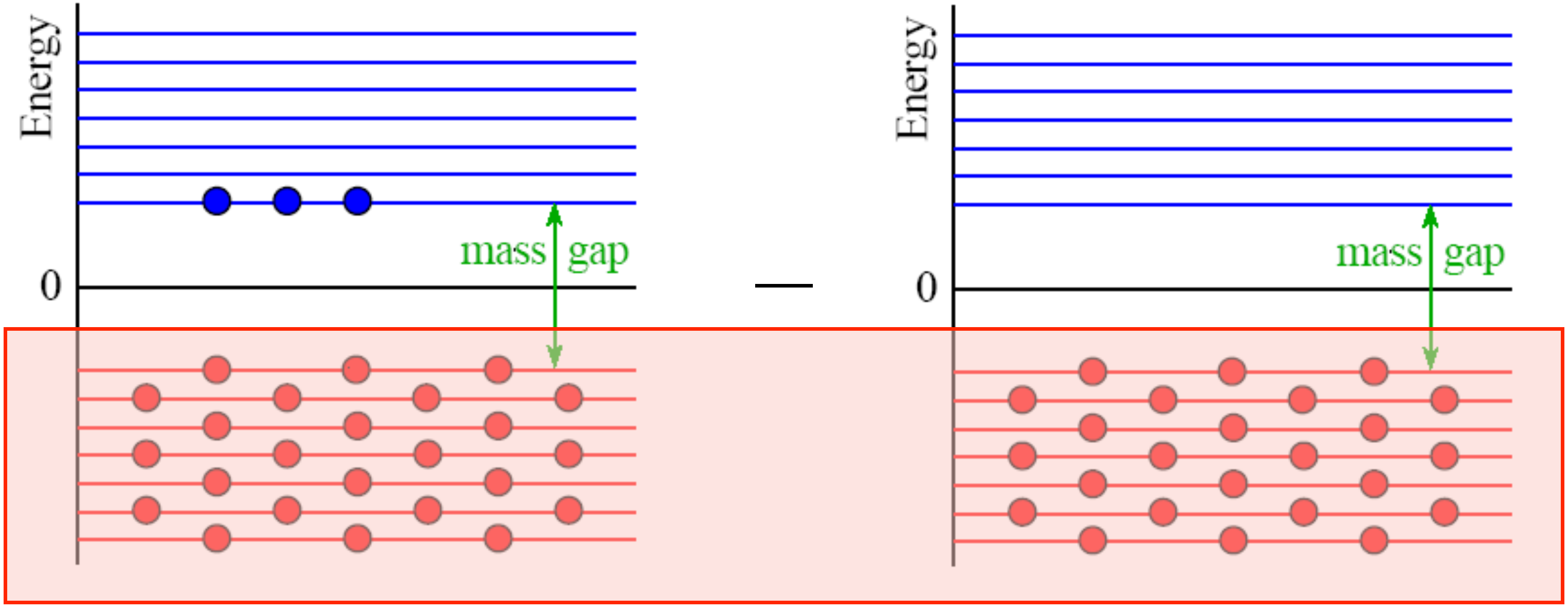
in the NRQM limit only valence level contributes

NRQM Limit

$$g_A^{(3)} = \frac{5}{3}, \qquad \Delta\Sigma = 1, \qquad \frac{\mu_p}{\mu_n} = -\frac{3}{2}$$

Diakonov, Petrov, Polyakov, Z.Phys **A359** (97) 305
MP, A.Blotz K.Goeke, Phys.Lett.**B354**:415-422,1995

energy is calculated
with respect to the vacuum:



in the NRQM limit only valence level contributes

NRQM Limit

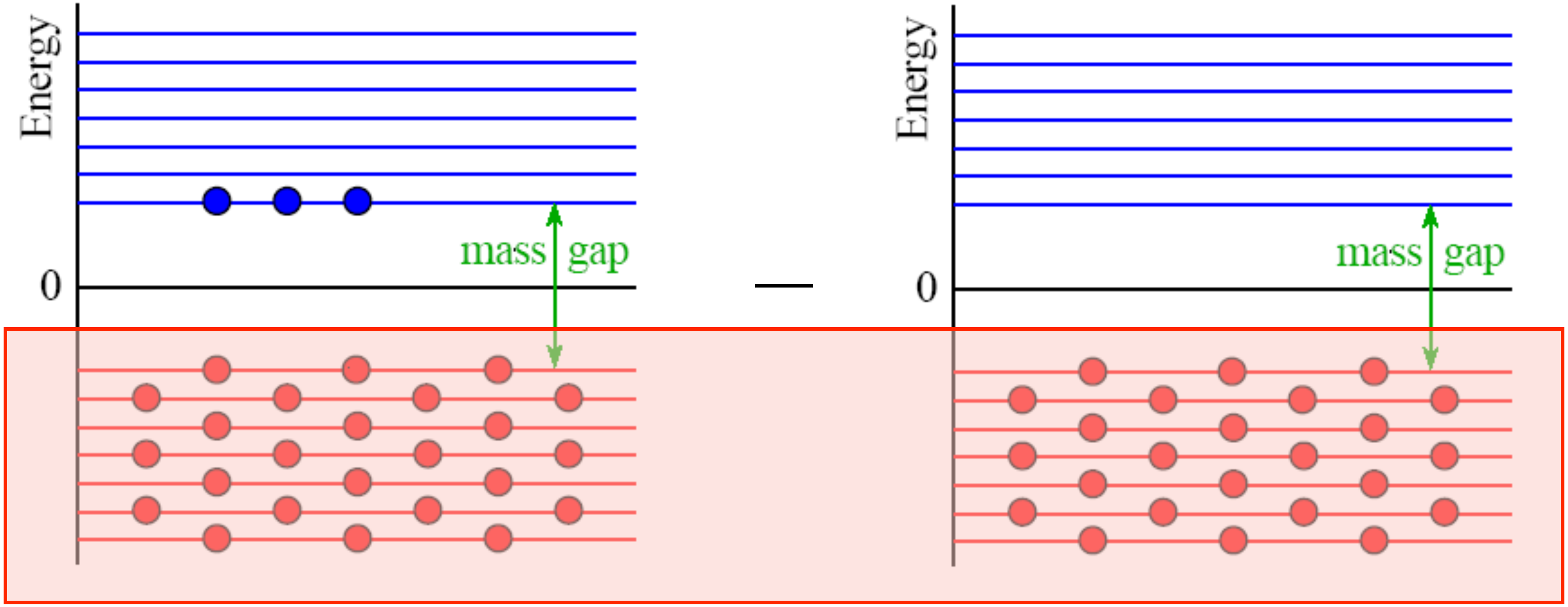
$$g_A^{(3)} = \frac{5}{3}, \quad \Delta\Sigma = 1, \quad \frac{\mu_p}{\mu_n} = -\frac{3}{2}$$

Diakonov, Petrov, Polyakov, Z.Phys **A359** (97) 305
MP, A.Blotz K.Goeke, Phys.Lett.**B354**:415-422,1995

$$\boxed{G_{\overline{10}} = 0}$$

energy is calculated
with respect to the vacuum:

pentaquark width = 0 !

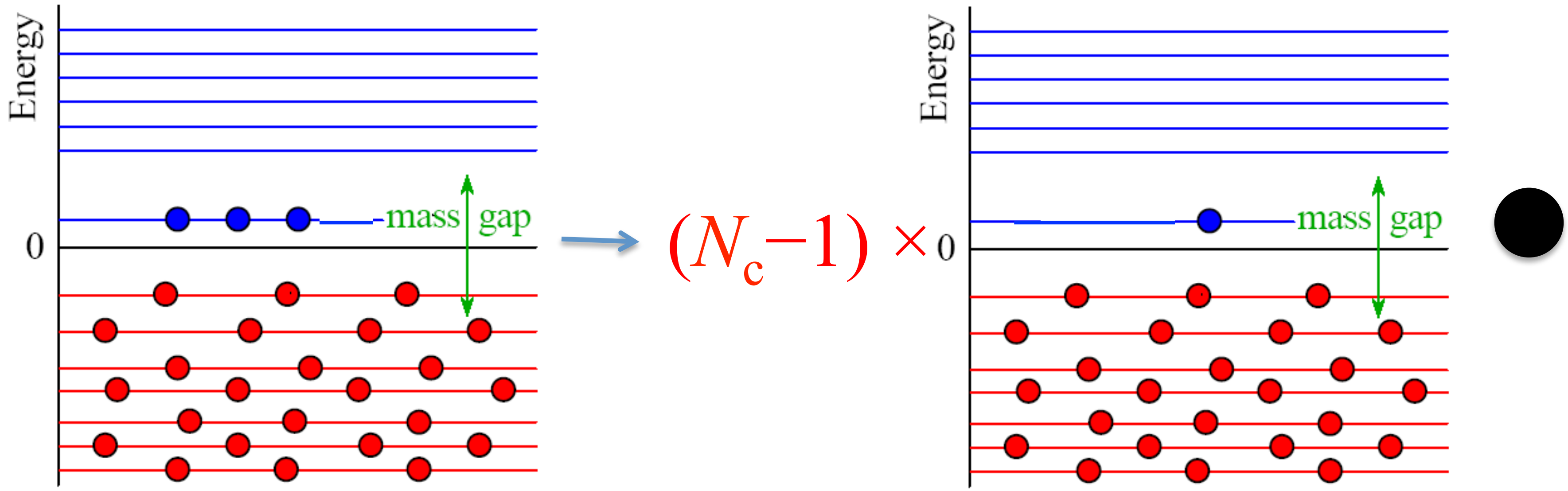


in the NRQM limit only valence level contributes

Heavy baryons in the Chiral Quark-Soliton Model

Soliton with $N_c - 1$ quarks

if N_c is large, $N_c - 1$ is also large and one can use the same mean field arguments

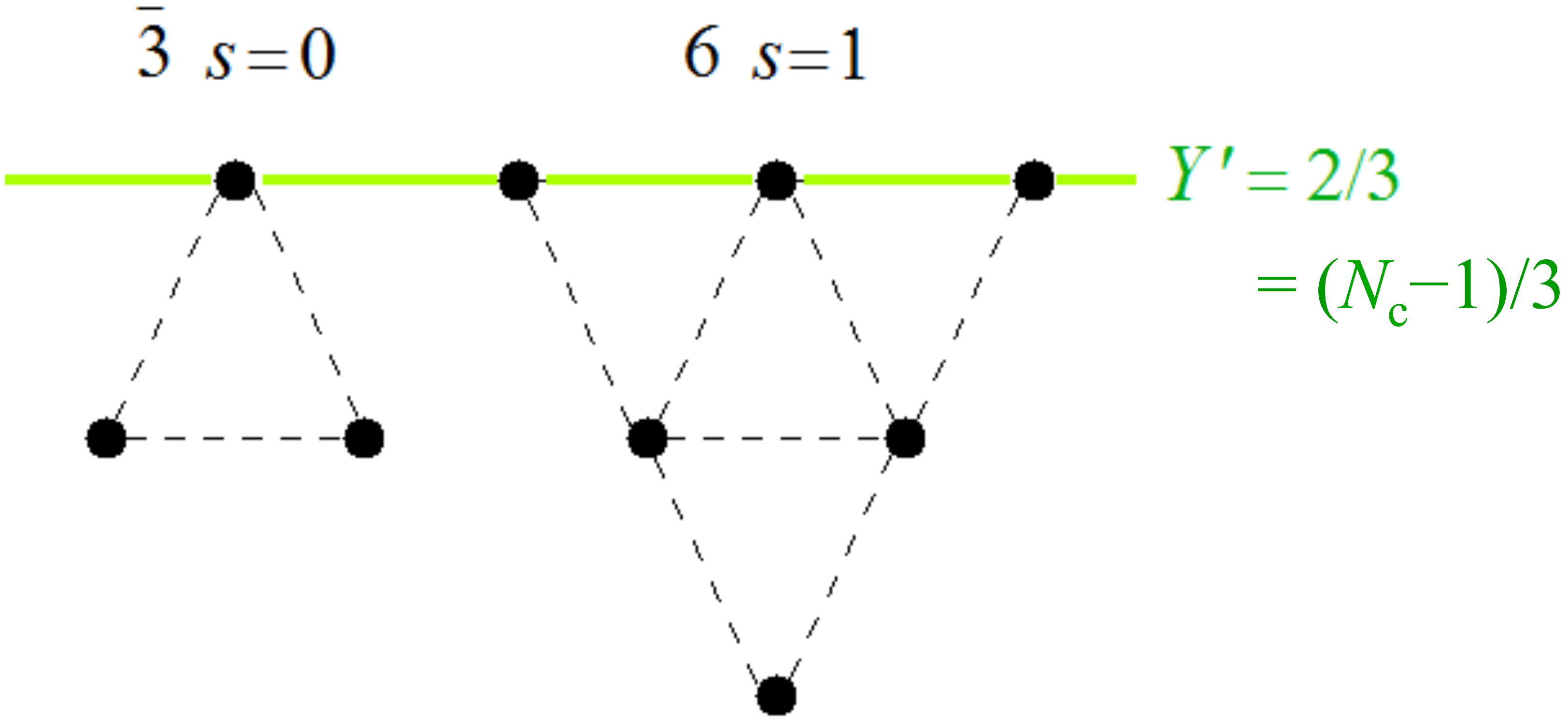


color factorizes!

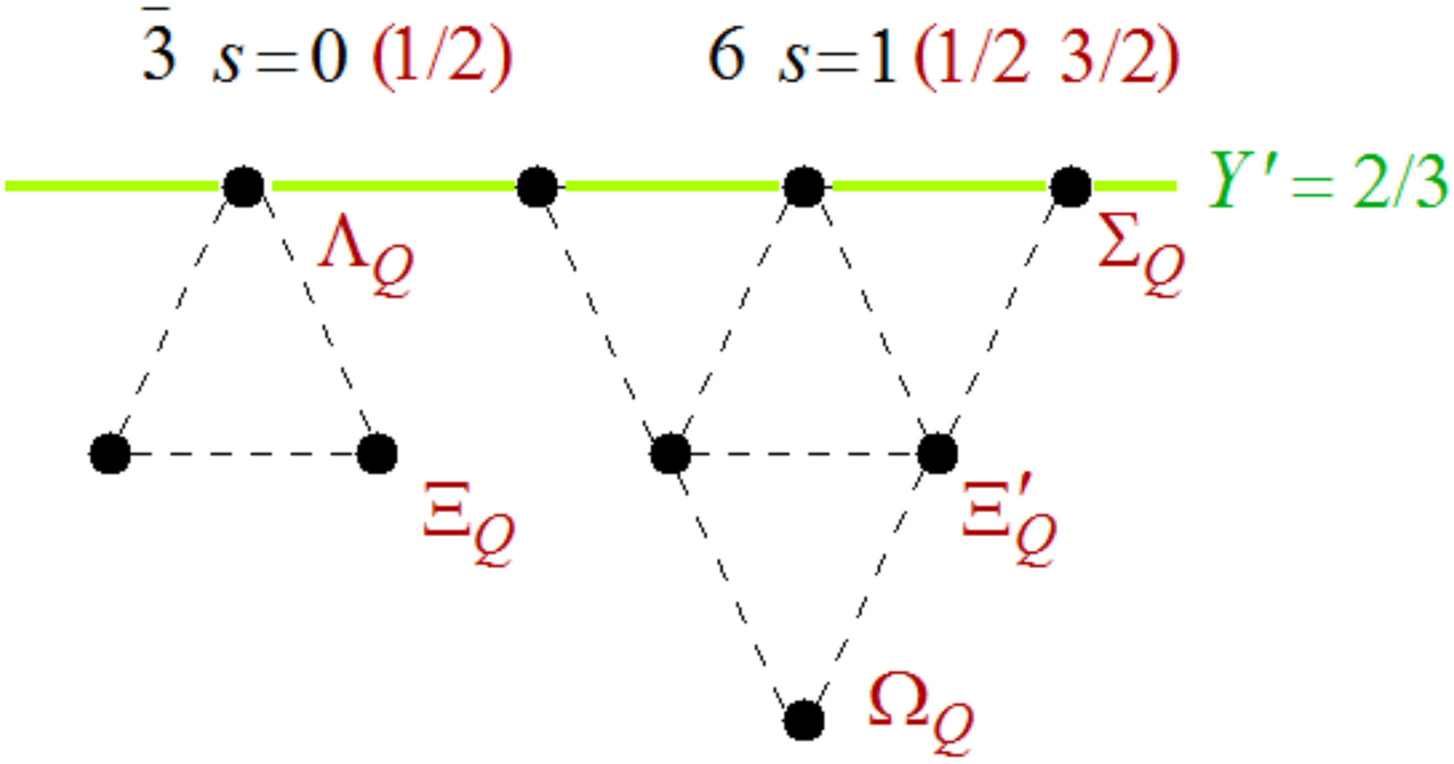
plus one heavy quark

G.S. Yang, H.C. Kim, M.V. Polyakov, MP Phys. Rev. D94 (2016) 071502

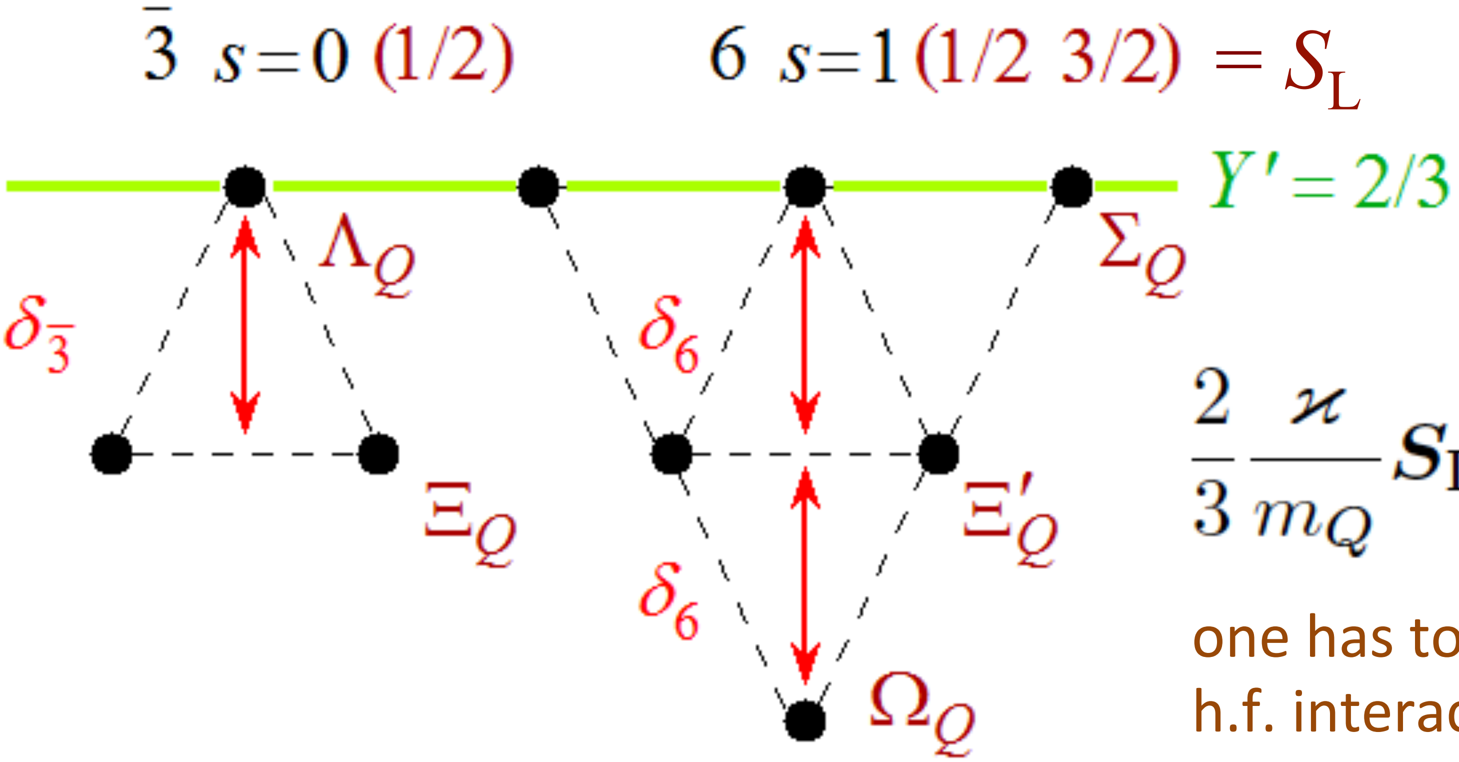
Allowed SU(3) irreps.



Heavy Baryons: soliton + heavy Q



Splittings inside multiplets

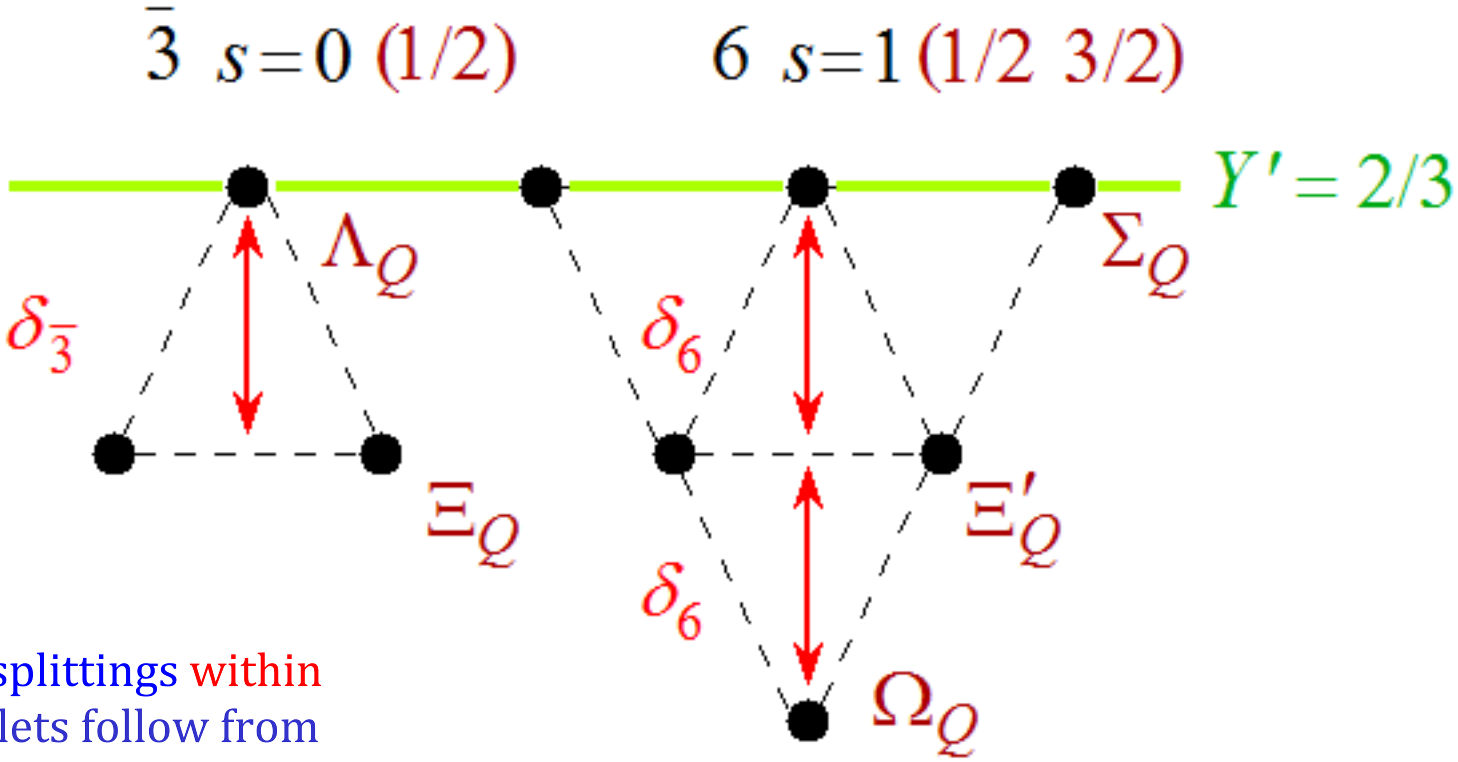


$$\frac{2}{3}\frac{\varkappa}{m_Q}\boldsymbol{S}_{\mathrm{L}} \cdot \boldsymbol{S}_Q$$

one has to add
h.f. interaction

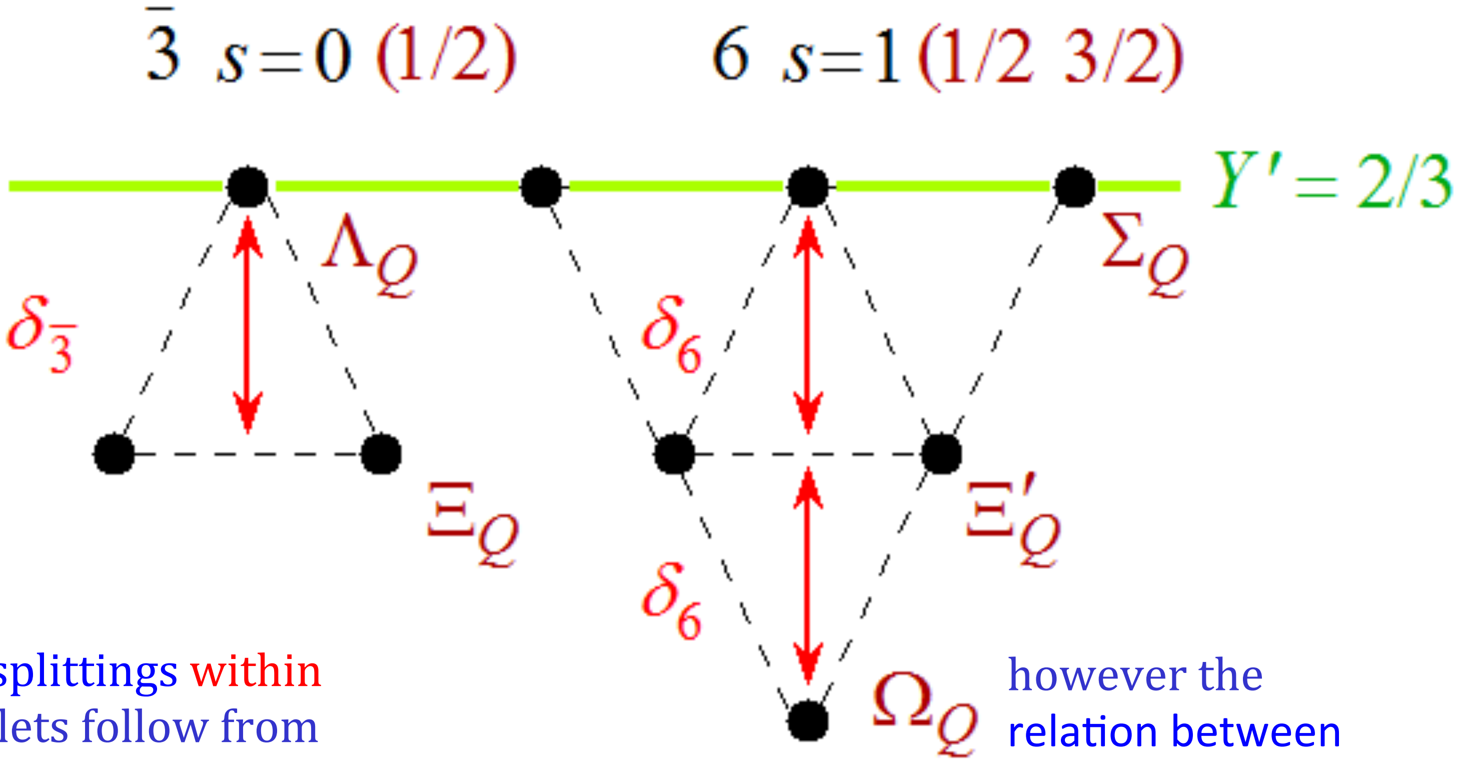
$$\kappa/m_c = 70 \text{ MeV}$$

Splittings inside multiplets



Equal splittings within multiplets follow from Eckhart-Wigner theorem (GMO relations)

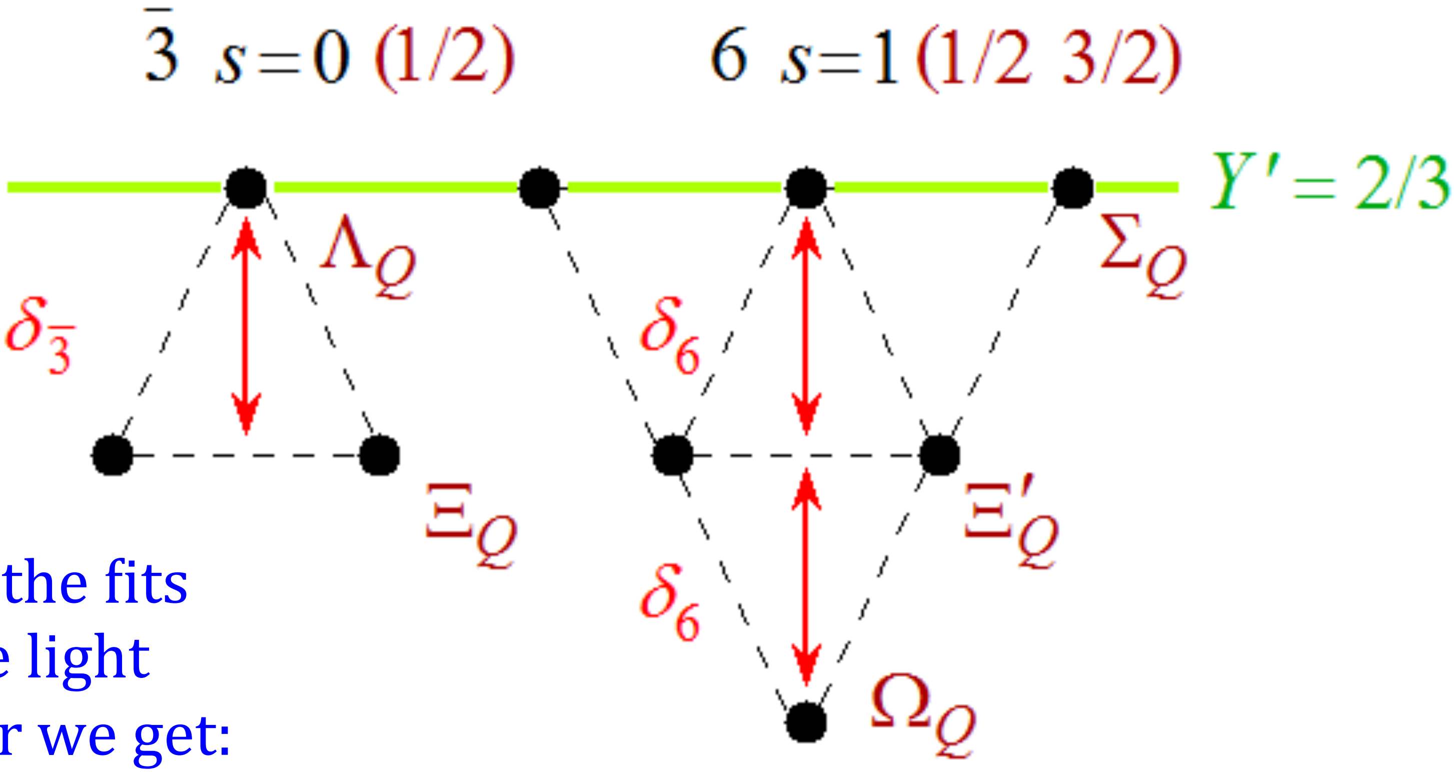
Splittings inside multiplets



Equal splittings within multiplets follow from Eckhart-Wigner theorem (GMO relations)

however the relation between the deltas does not follow from Eckhart-Wigner theorem

Splittings inside multiplets



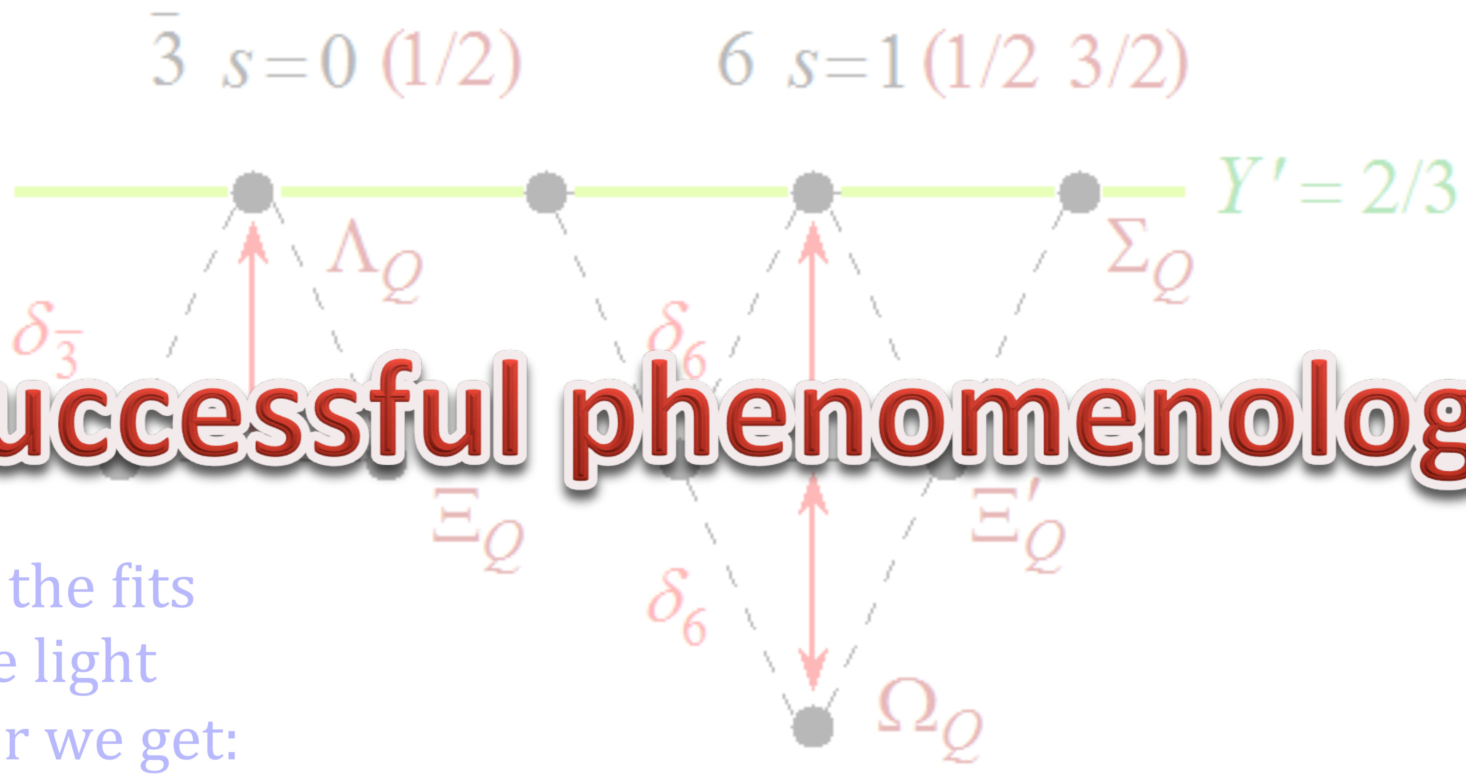
from the fits
to the light
sector we get:

$$\delta_{\bar{\mathbf{3}}} = 203.8 \pm 3.5\ \mathrm{MeV},$$ (exp.: 178 MeV)

$$\delta_{\mathbf{6}} = 135.2 \pm 3.3\ \mathrm{MeV},$$ (exp.: 121 MeV)

13%

Splittings inside multiplets



Successful phenomenology

from the fits
to the light
sector we get:

G.S. Yang, H.C. Kim, M.V. Polyakov, MP Phys. Rev. D94 (2016) 071502

$$\delta_{\overline{\mathbf{3}}} = 203.8 \pm 3.5\ \mathrm{MeV}, \quad \text{(exp.: 178 MeV)}$$

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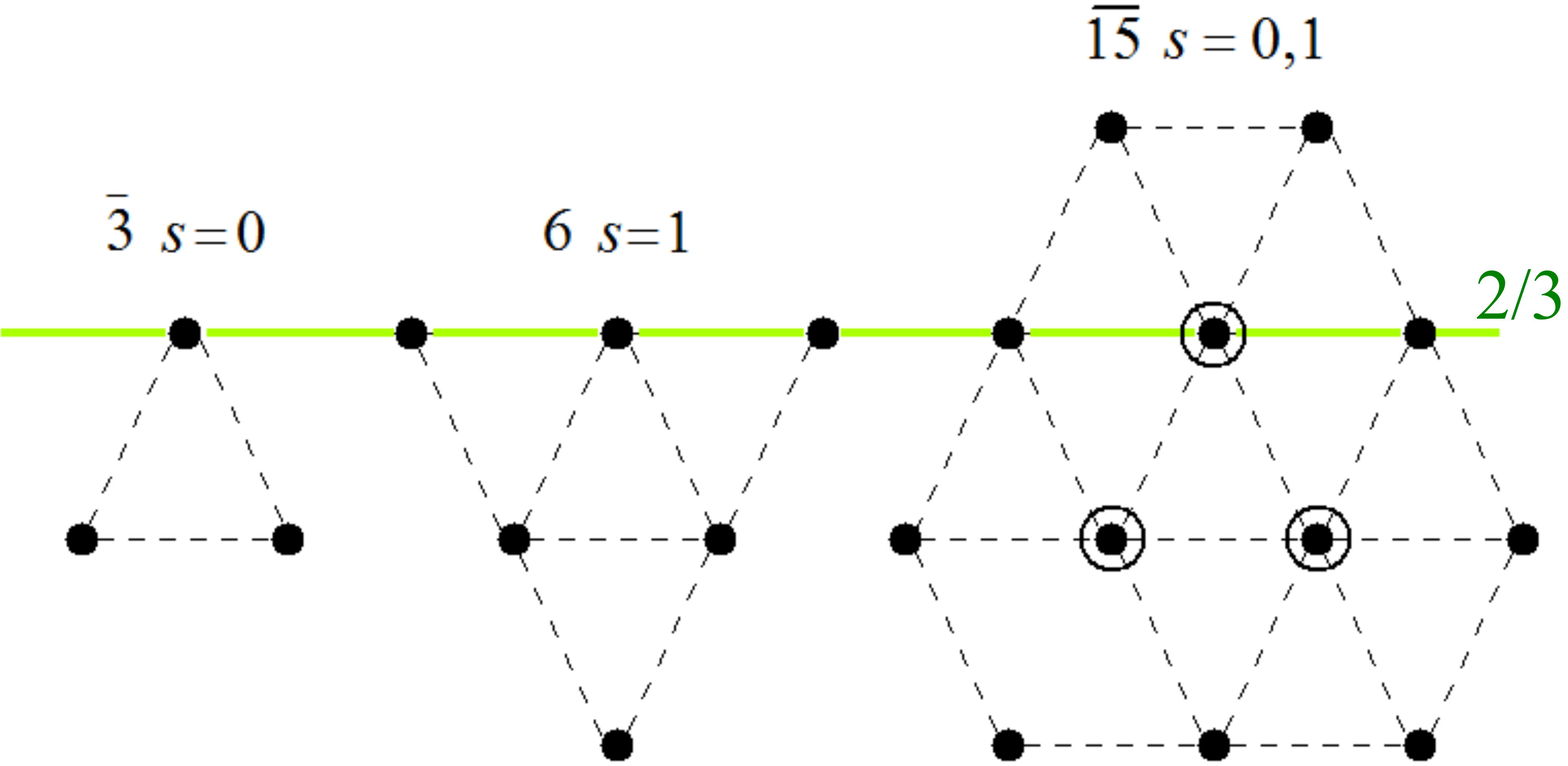
13%

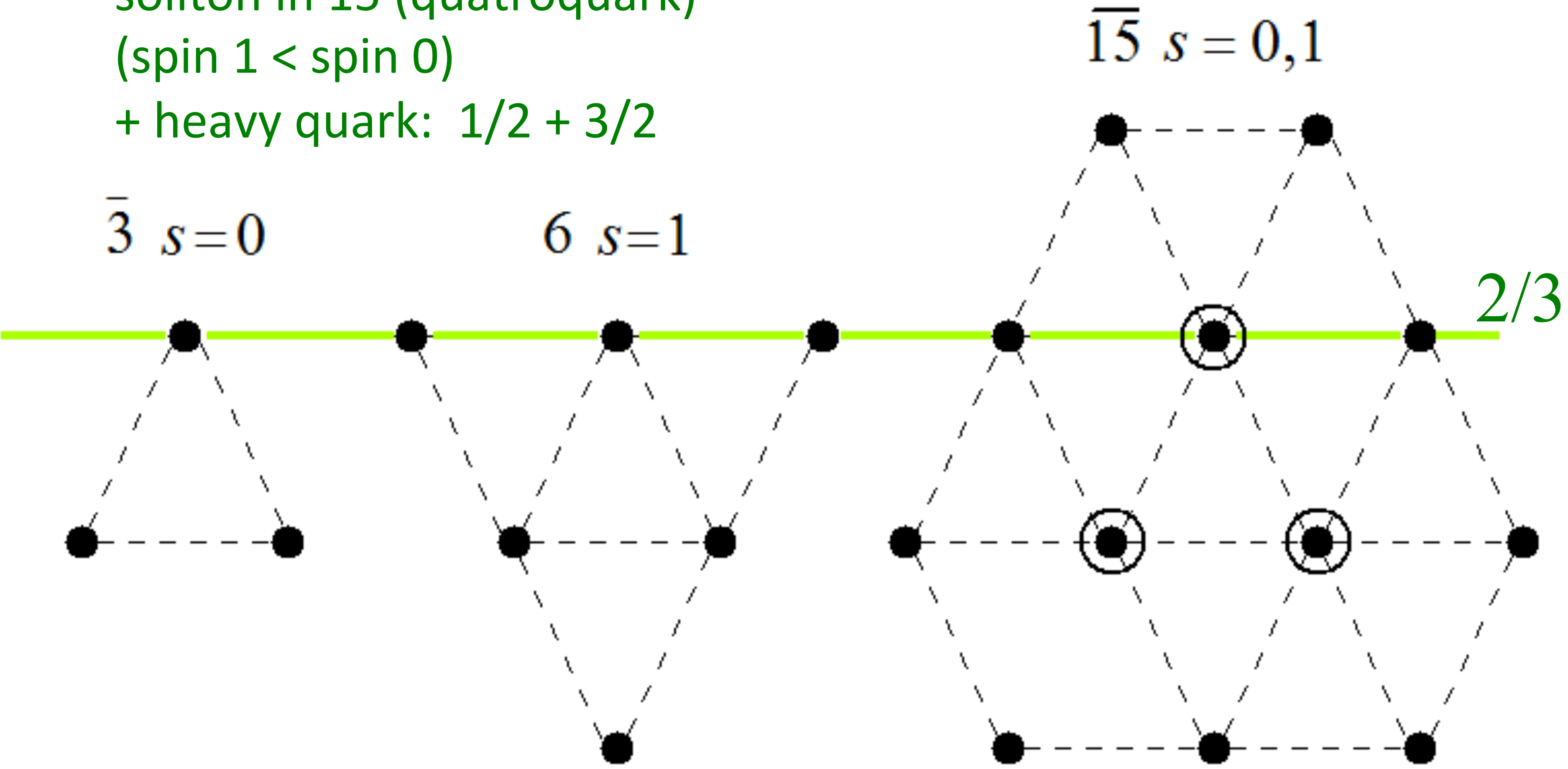
Rotational excitations: heavy pentaquarks



H.C. Kim, M.V. Plyakov, MP arXiv:1704.04082 [hep-ph]

Rotational excitations: heavy pentaquarks

soliton in 15 (quatroquark)
(spin 1 < spin 0)
+ heavy quark: 1/2 + 3/2



H.C. Kim, M.V. Plyakov, MP arXiv:1704.04082 [hep-ph]

Rotational excitations: heavy pentaquarks

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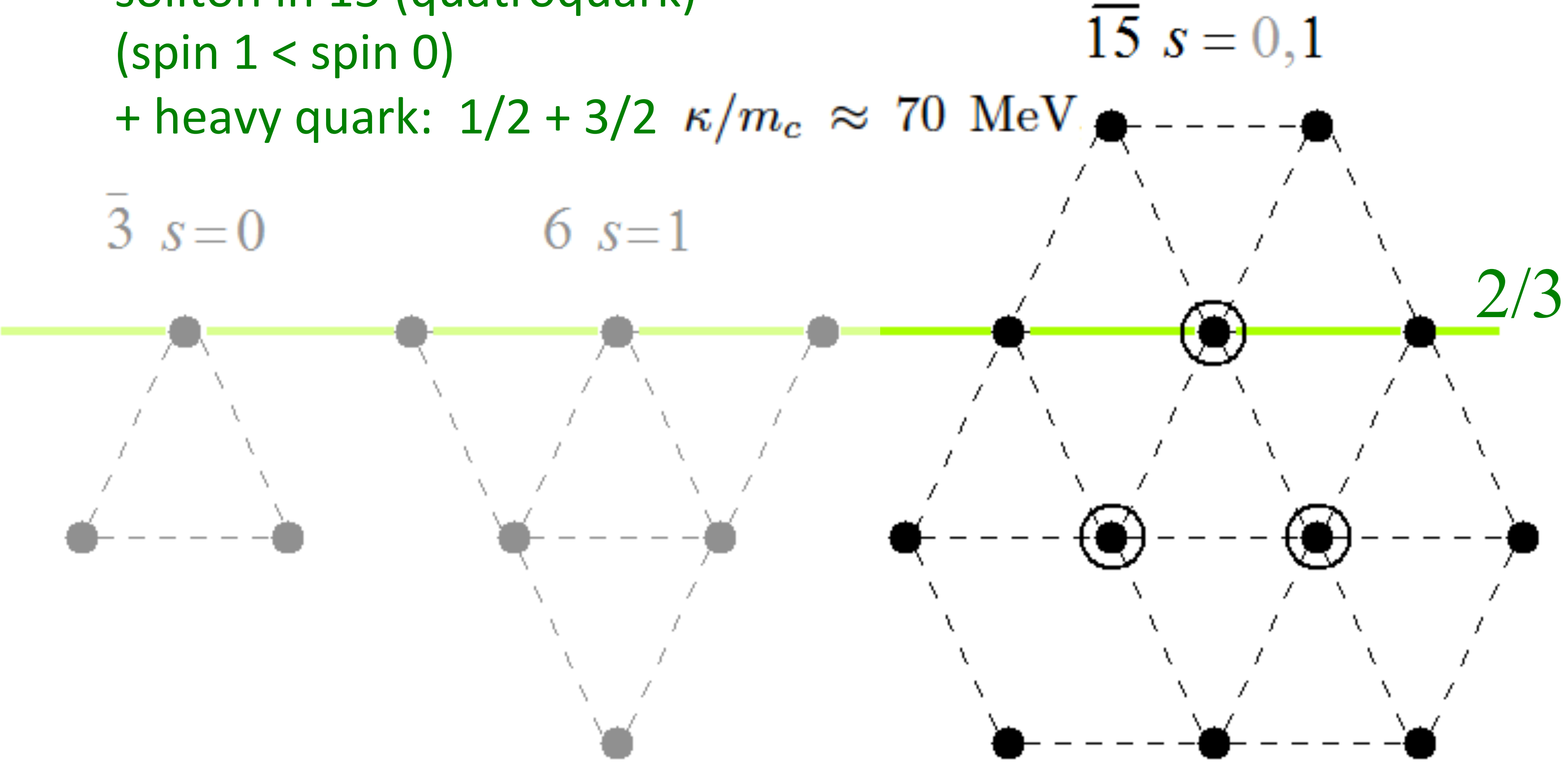


H.C. Kim, M.V. Plyakov, MP arXiv:1704.04082 [hep-ph]

Decays

axial-vector constants with $X = 3, 8, 0$

$$g^{(B_1\to B_2)} = a_1\langle B_2|D^{(8)}_{X3}|B_1\rangle \ + \ a_2 d_{pq3}\langle B_2|D^{(8)}_{Xp}\,\hat{S}_q|B_1\rangle \ + \ \frac{a_3}{\sqrt{3}}\langle B_2|D^{(8)}_{X8}\,\hat{S}_3|B_1\rangle$$

$a_1 \sim N_c\; a_2 \sim O(1)\;\; a_3 \sim O(1)$ fixed from the data on weak hyperon decays

Goldberger-Treiman relation:

for strong decays $B_1 \to B_2 + \varphi$ use the same operator, but

$$\{a_1, a_2, a_3\} \to \frac{M_1 + M_2}{2F_\varphi}\{a_1, a_2, a_3\}$$

example

$$\Gamma_{\Sigma(\mathbf{6}_1)\to\Lambda(\overline{\mathbf{3}}_0)+\pi} = \frac{1}{72\pi}\frac{p^3}{F_\pi^2}\frac{M_{\Lambda(\overline{\mathbf{3}}_0)}}{M_{\Sigma(\mathbf{6}_1)}}H_{\overline{\mathbf{3}}}^2\frac{3}{8} \qquad H_{\overline{\mathbf{3}}} = -a_1 + \frac{1}{2}a_2$$

Decay constants

$a_1 \sim N_c \longrightarrow a_1 \sim N_c - 1$

$$\overline{\mathbf{15}}_1 \to \overline{\mathbf{3}}_0$$

$$\overline{\mathbf{15}}_1 \to \mathbf{6}_1$$

H.C. Kim, M.V. Plyakov, MP arXiv:1704.04082 [hep-ph]

Decay constants

$a_1 \sim N_c \longrightarrow a_1 \sim N_c - 1$

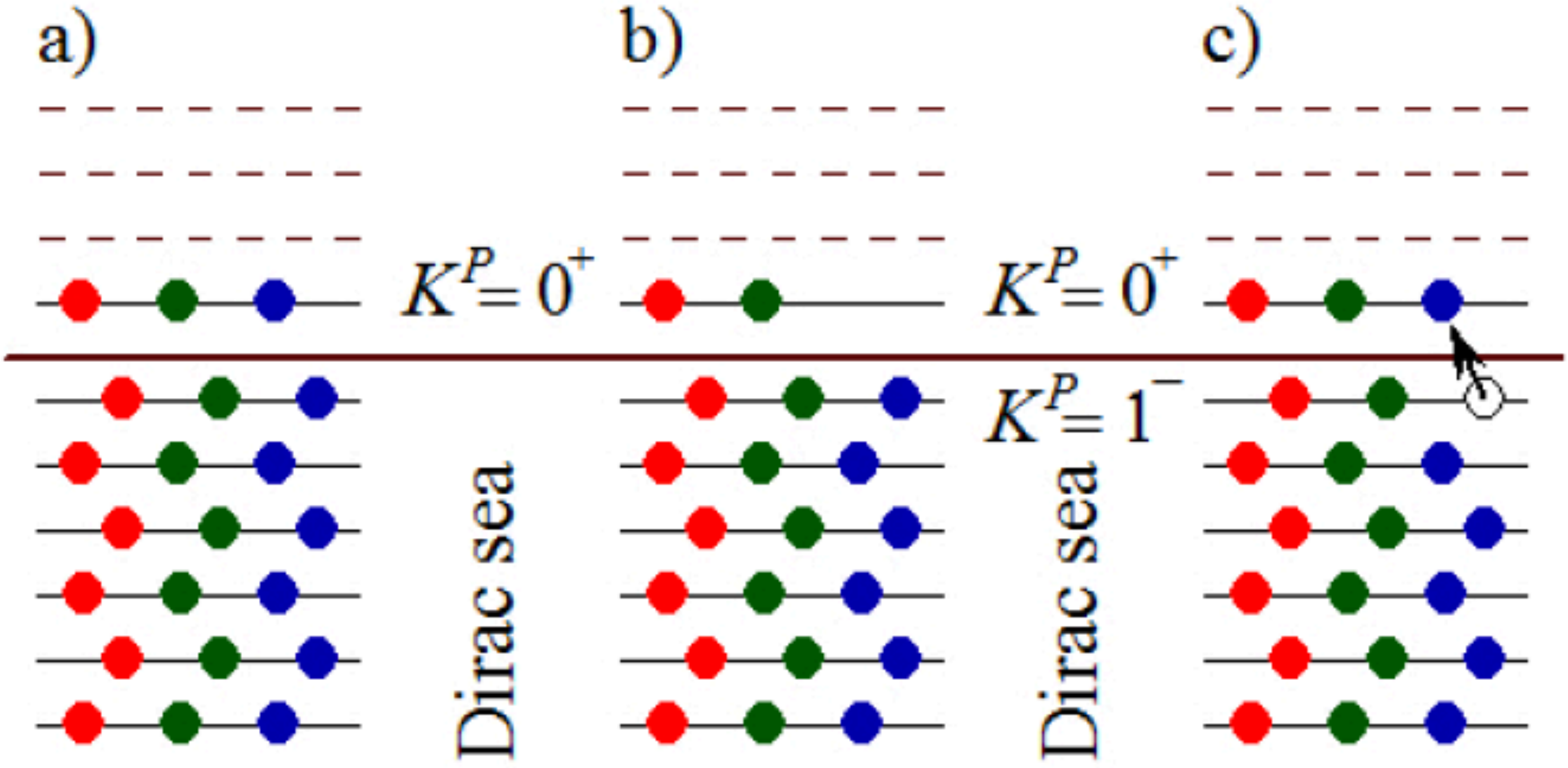
$$\overline{\mathbf{15}}_1 \to \overline{\mathbf{3}}_0$$

$\overline{\mathbf{15}}_1 \to \mathbf{6}_1$ In NRQM limit: $G_{\mathbf{6}} = 0$

Expectations:
some decays will be suppressed

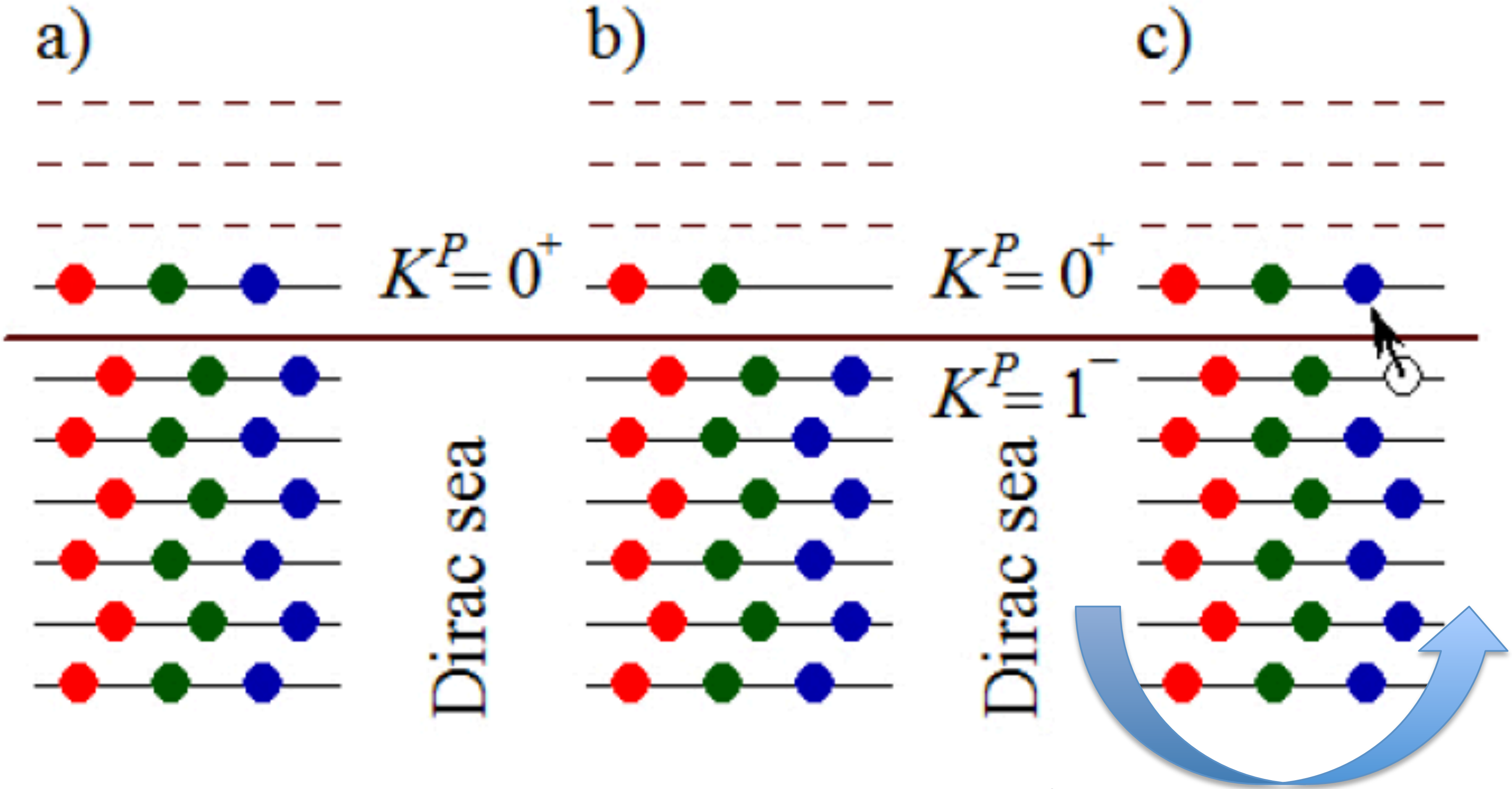
H.C. Kim, M.V. Plyakov, MP arXiv:1704.04082 [hep-ph]

Quark excitations: non-exotic heavy baryons



V. Petrov, Acta Phys. Pol. B47 (2016) 59

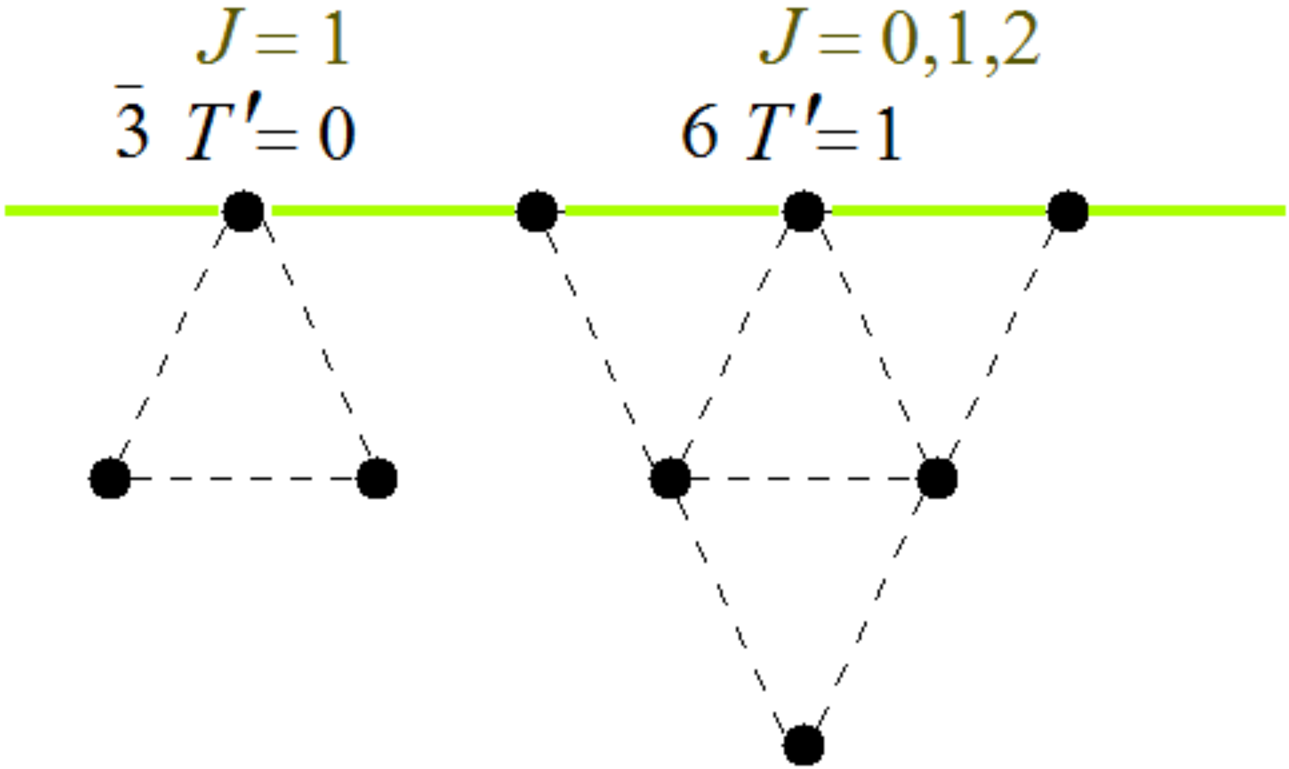
Quark excitations: non-exotic heavy baryons



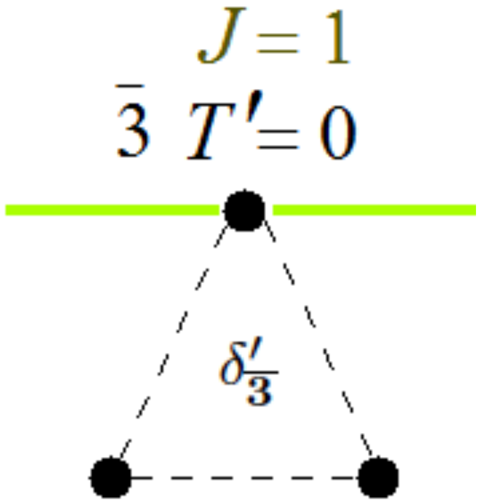
Rotations generate quantum numbers

One *K*=1 quark excited solitons

- the isospin $\boldsymbol{T}'$ of the states with $Y' = (N_c - 1)/3$ couples with the soliton spin $\boldsymbol{J}$ as follows: $\boldsymbol{T}' + \boldsymbol{J} = \boldsymbol{K}$, where $\boldsymbol{K}$ is the grand spin of the excited level.



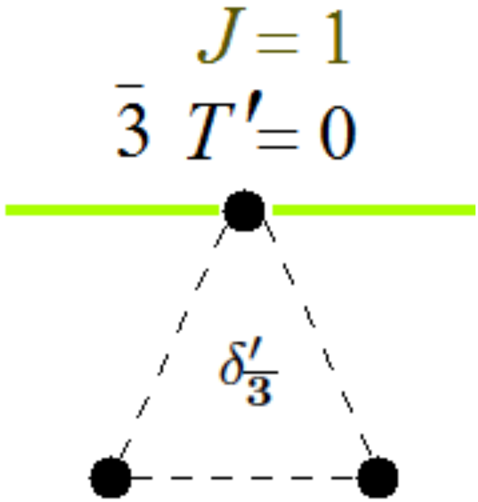
3bar excited heavy baryons



add heavy quark
total spin 1/2 and 3/2

$$\delta'_{\bar{\mathbf{3}}} = \delta_{\bar{\mathbf{3}}} = -180\ \mathrm{MeV}$$

3bar excited heavy baryons



experimentally:

$\Lambda_c(2592)$	$\Lambda_c(2628)$
198 MeV	190 MeV
$\Xi_c(2790)$	$\Xi_c(2818)$
$(1/2)^-$	$(3/2)^-$

add heavy quark
total spin 1/2 and 3/2

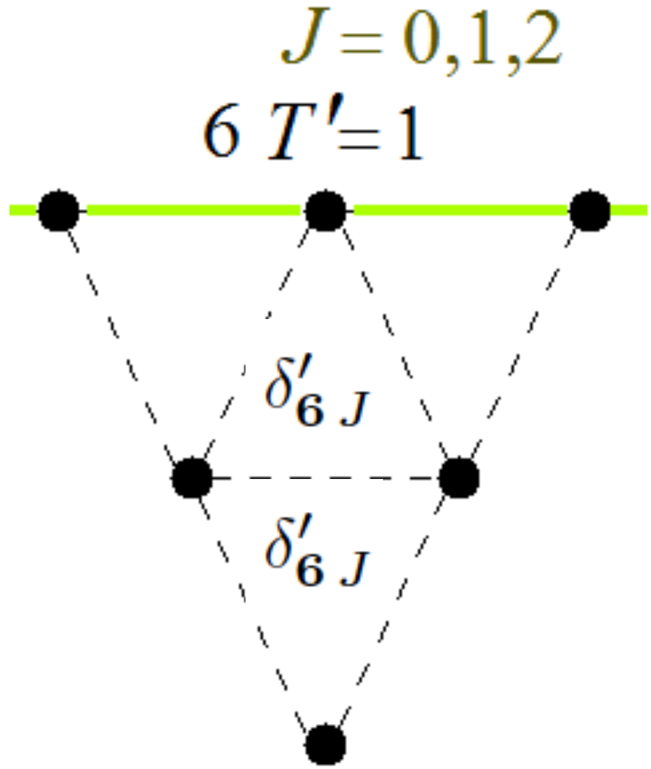
$$\delta'_{\bar{3}} = \delta_{\bar{3}} = -180\ \mathrm{MeV}$$

$$\frac{\kappa'}{m_c} = 30\ \mathrm{MeV}$$

$$H_{\mathrm{hf}} = \frac{2}{3}\frac{\kappa}{m_Q}\boldsymbol{J}\cdot\boldsymbol{J}_Q$$

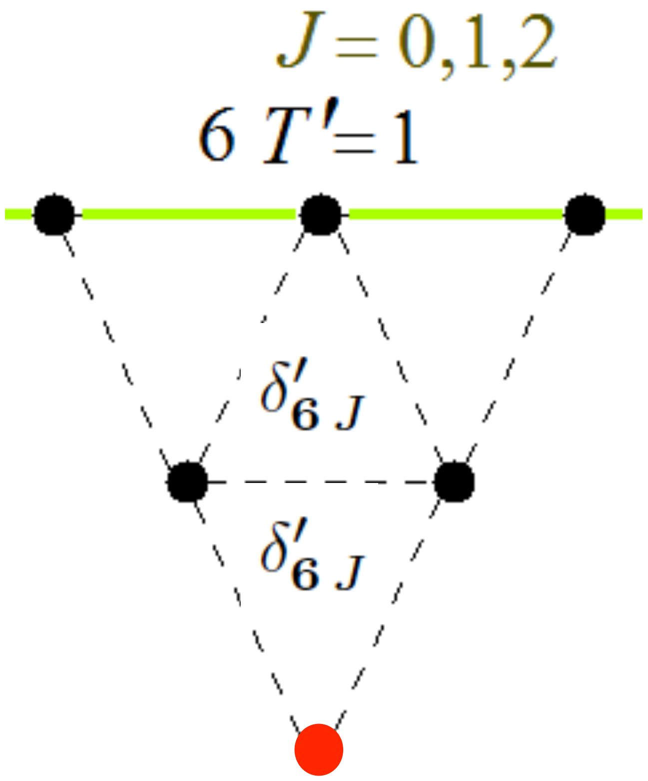
hyprfine
splitting
different
from the
ground
state

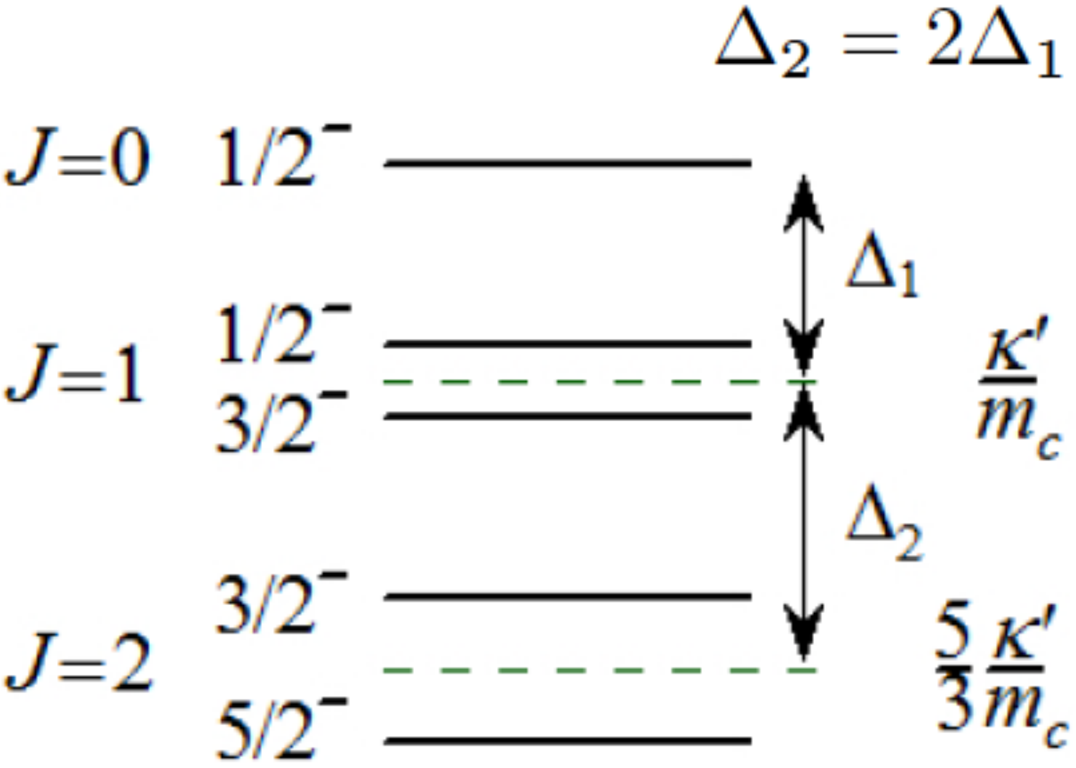
sextet excited baryons



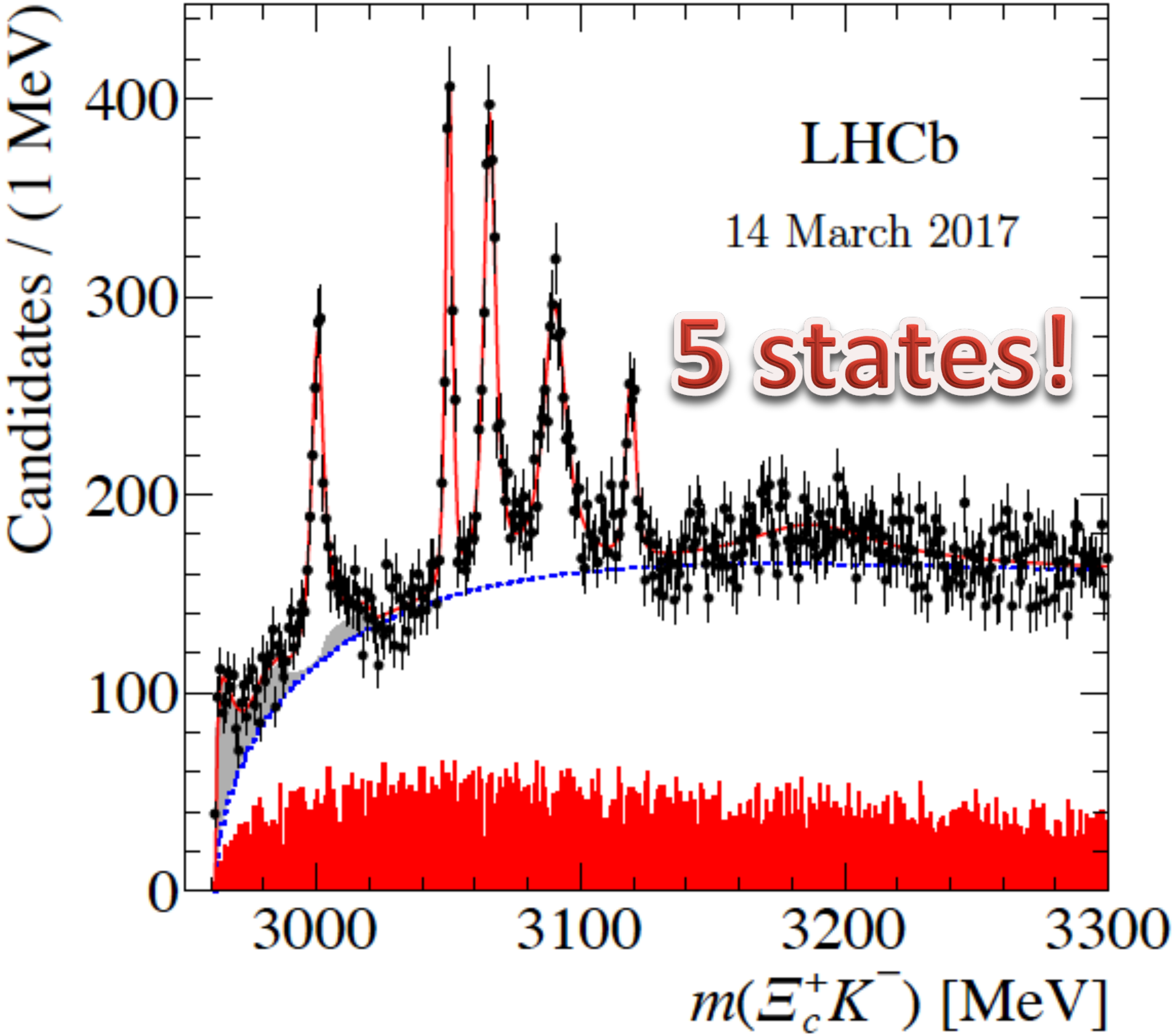
$$\delta'_{\mathbf{6}\ J} = \delta_{\mathbf{6}} - \frac{3}{20}\delta \times \begin{cases} 2 & \text{for} \quad J=0 \\ 1 & \text{for} \quad J=1 \\ -1 & \text{for} \quad J=2 \end{cases}$$

sextet excited baryons



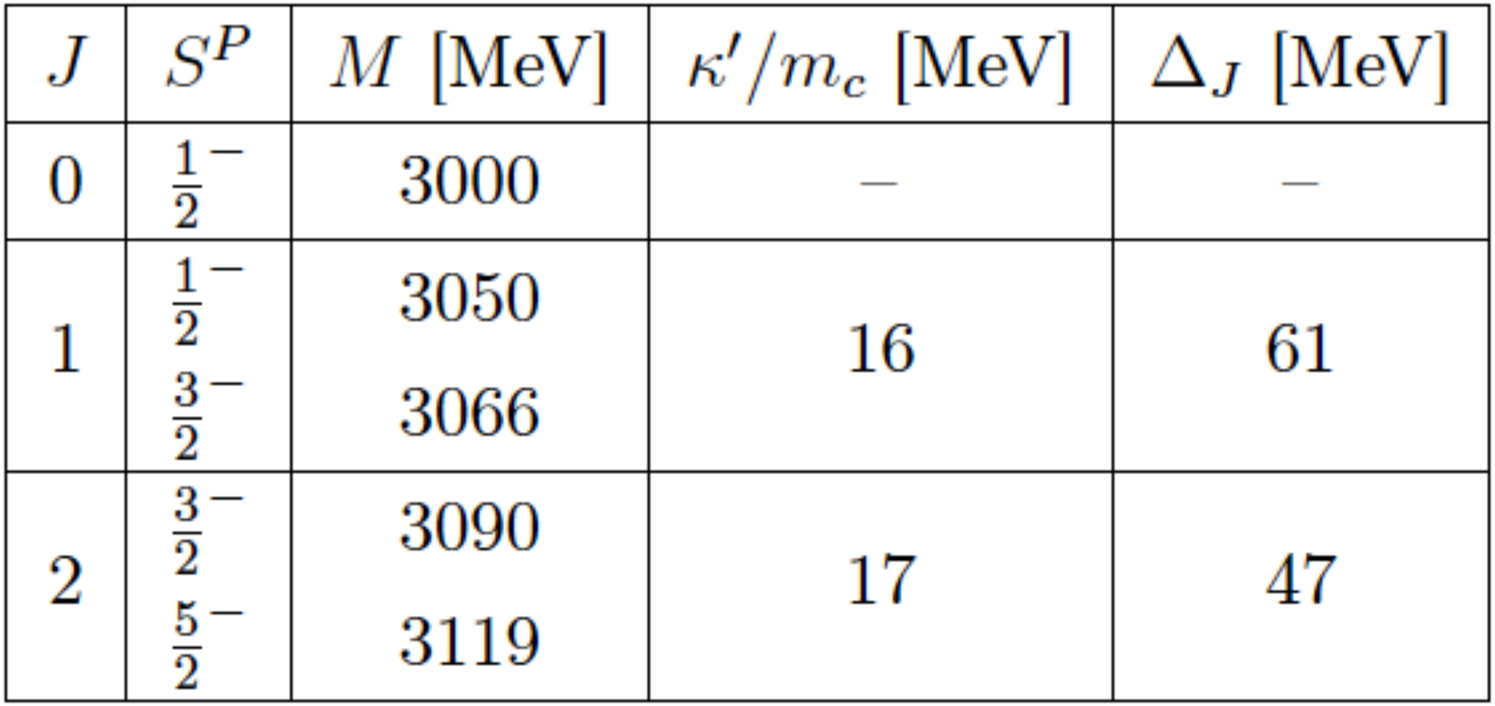


excited Omega_Q spectrum,
5 states


Candidates / (1 MeV)
0
100
200
300
400
3000
3100
3200
3300
$m(\Xi_c^+ K^-)$ [MeV]
LHCb
14 March 2017

5 states!

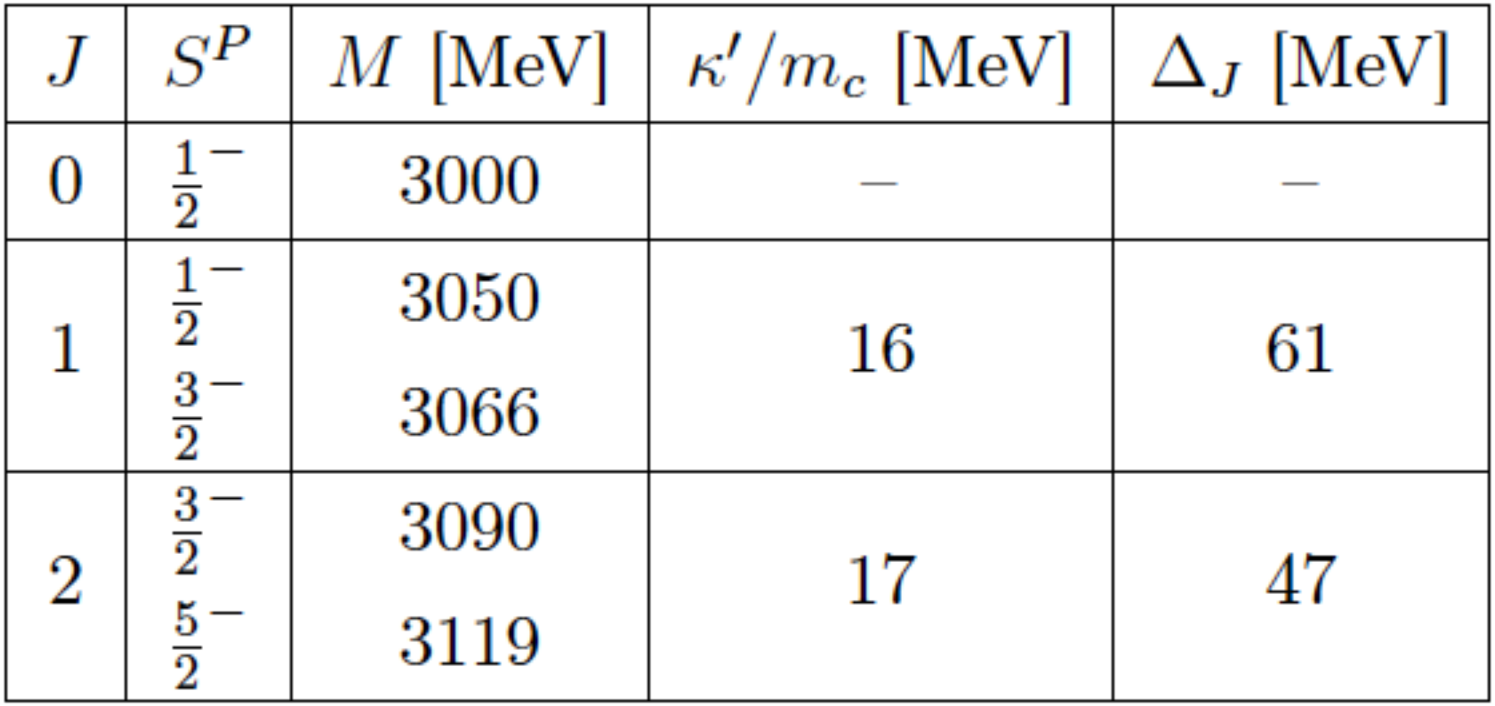
Scenario 1:
all LHCb Omega’s are sextet states



J	S^P	M [MeV]	κ'/m_c [MeV]	Δ_J [MeV]
0	$\frac{1}{2}^-$	3000	–	–
1	$\frac{1}{2}^-$	3050	16	61
	$\frac{3}{2}^-$	3066		
2	$\frac{3}{2}^-$	3090	17	47
	$\frac{5}{2}^-$	3119		

violates constraints: $\frac{\kappa'}{m_c} = 30 \text{ MeV} \qquad \Delta_2 = 2\Delta_1$

Scenario 1:
all LHCb Omega’s are sextet states



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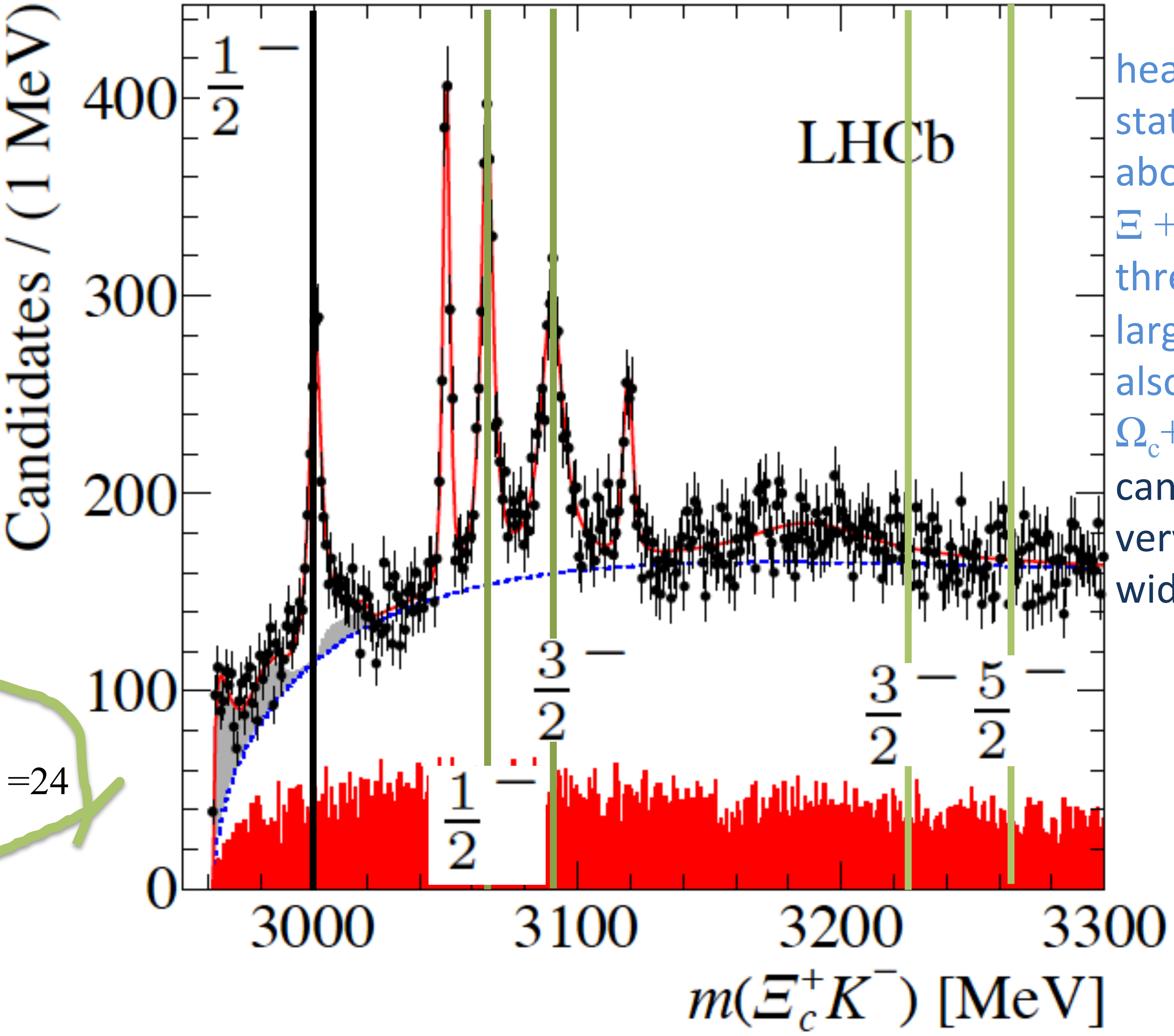
violates constraints: $\frac{\kappa'}{m_c} = 30$ MeV $\quad \Delta_2 = 2\Delta_1$

similar problem in the quark models

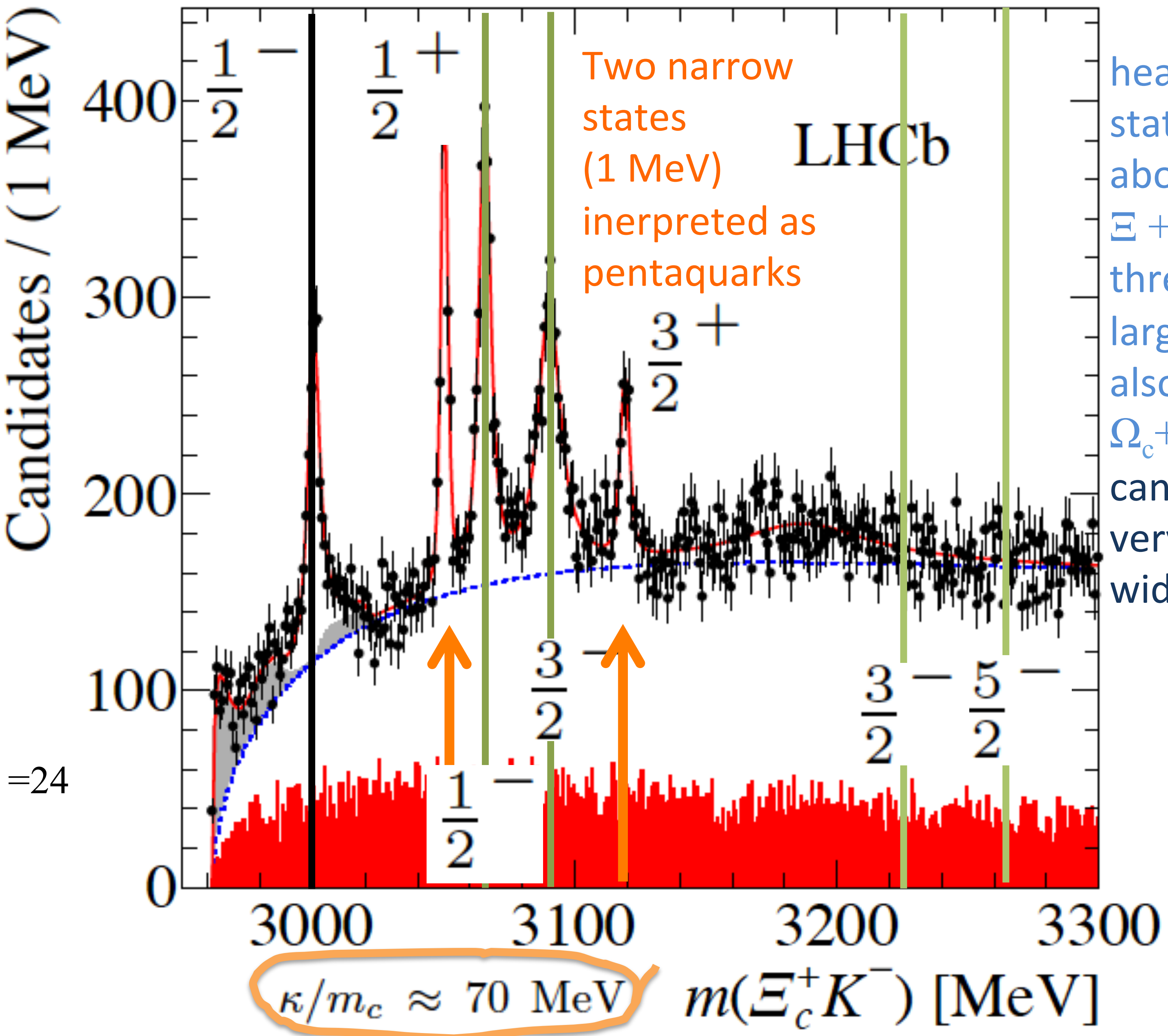
Scenario 2

force sextet constraints



$\frac{\kappa'}{m_c}$ =24

heavy states above $\Xi + D$ threshold, large p.s. also to $\Omega_c + \pi$, can be very wide



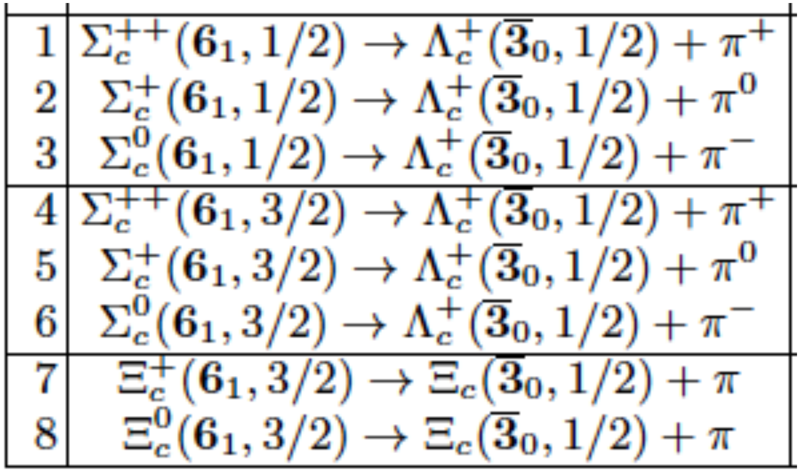
Two narrow states (1 MeV) inerpreted as pentaquarks

$\kappa/m_c \approx 70$ MeV

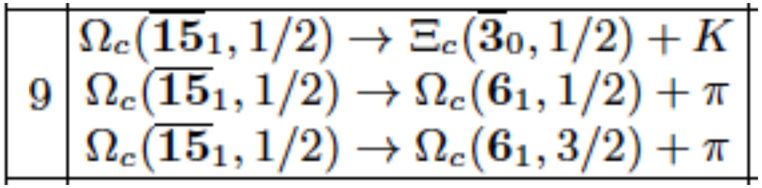
$\frac{\kappa'}{m_c}$ =24

heavy states above $\Xi + D$ threshold, large p.s. also to $\Omega_c + \pi$, can be very wide

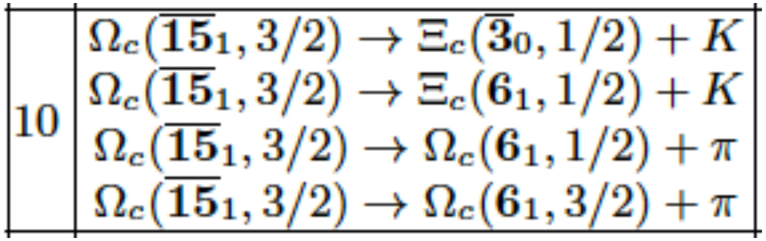
Charm decay widths



1	$\Sigma_c^{++}(\mathbf{6}_1,1/2) \to \Lambda_c^+(\overline{\mathbf{3}}_0,1/2)+\pi^+$
2	$\Sigma_c^{+}(\mathbf{6}_1,1/2) \to \Lambda_c^+(\overline{\mathbf{3}}_0,1/2)+\pi^0$
3	$\Sigma_c^{0}(\mathbf{6}_1,1/2) \to \Lambda_c^+(\overline{\mathbf{3}}_0,1/2)+\pi^-$
4	$\Sigma_c^{++}(\mathbf{6}_1,3/2) \to \Lambda_c^+(\overline{\mathbf{3}}_0,1/2)+\pi^+$
5	$\Sigma_c^{+}(\mathbf{6}_1,3/2) \to \Lambda_c^+(\overline{\mathbf{3}}_0,1/2)+\pi^0$
6	$\Sigma_c^{0}(\mathbf{6}_1,3/2) \to \Lambda_c^+(\overline{\mathbf{3}}_0,1/2)+\pi^-$
7	$\Xi_c^{+}(\mathbf{6}_1,3/2) \to \Xi_c(\overline{\mathbf{3}}_0,1/2)+\pi$
8	$\Xi_c^{0}(\mathbf{6}_1,3/2) \to \Xi_c(\overline{\mathbf{3}}_0,1/2)+\pi$

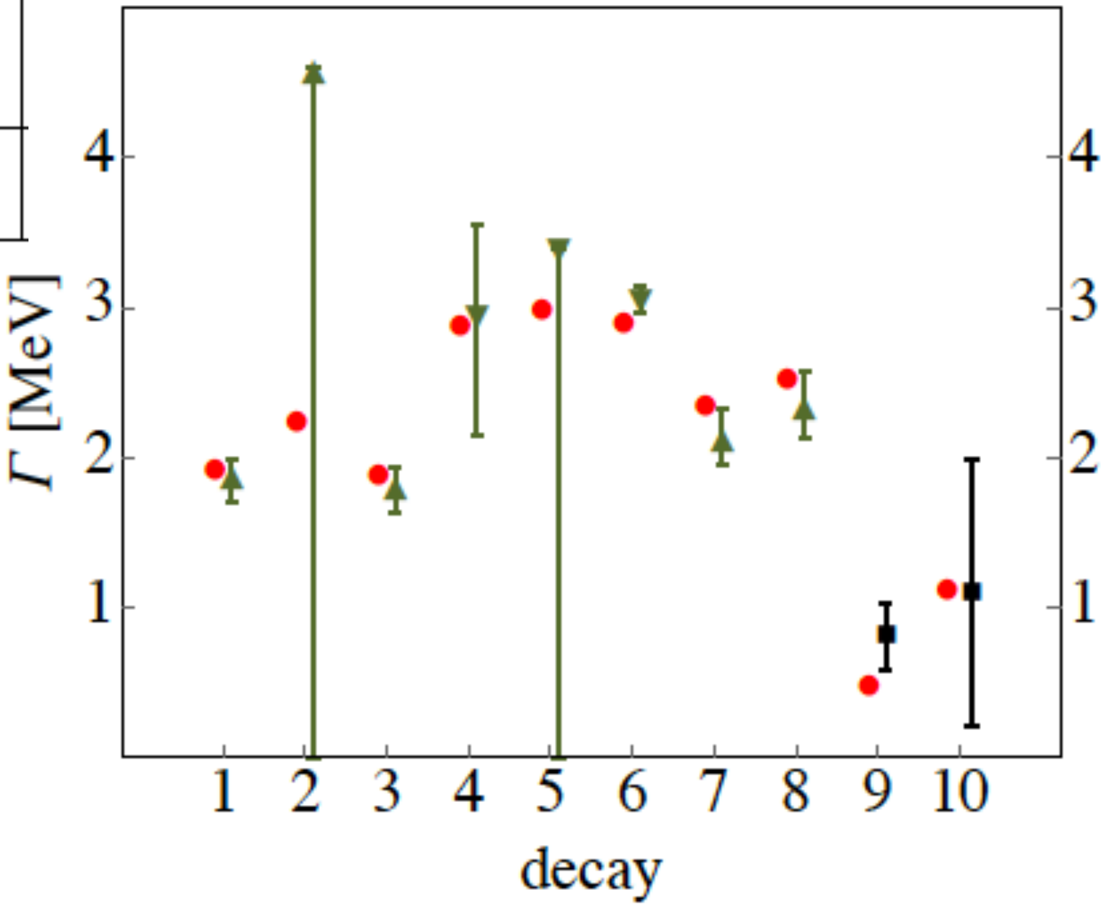


9	$\Omega_c(\overline{\mathbf{15}}_1,1/2) \to \Xi_c(\overline{\mathbf{3}}_0,1/2)+K$ $\Omega_c(\overline{\mathbf{15}}_1,1/2) \to \Omega_c(\mathbf{6}_1,1/2)+\pi$ $\Omega_c(\overline{\mathbf{15}}_1,1/2) \to \Omega_c(\mathbf{6}_1,3/2)+\pi$



10	$\Omega_c(\overline{\mathbf{15}}_1,3/2) \to \Xi_c(\overline{\mathbf{3}}_0,1/2)+K$ $\Omega_c(\overline{\mathbf{15}}_1,3/2) \to \Xi_c(\mathbf{6}_1,1/2)+K$ $\Omega_c(\overline{\mathbf{15}}_1,3/2) \to \Omega_c(\mathbf{6}_1,1/2)+\pi$ $\Omega_c(\overline{\mathbf{15}}_1,3/2) \to \Omega_c(\mathbf{6}_1,3/2)+\pi$

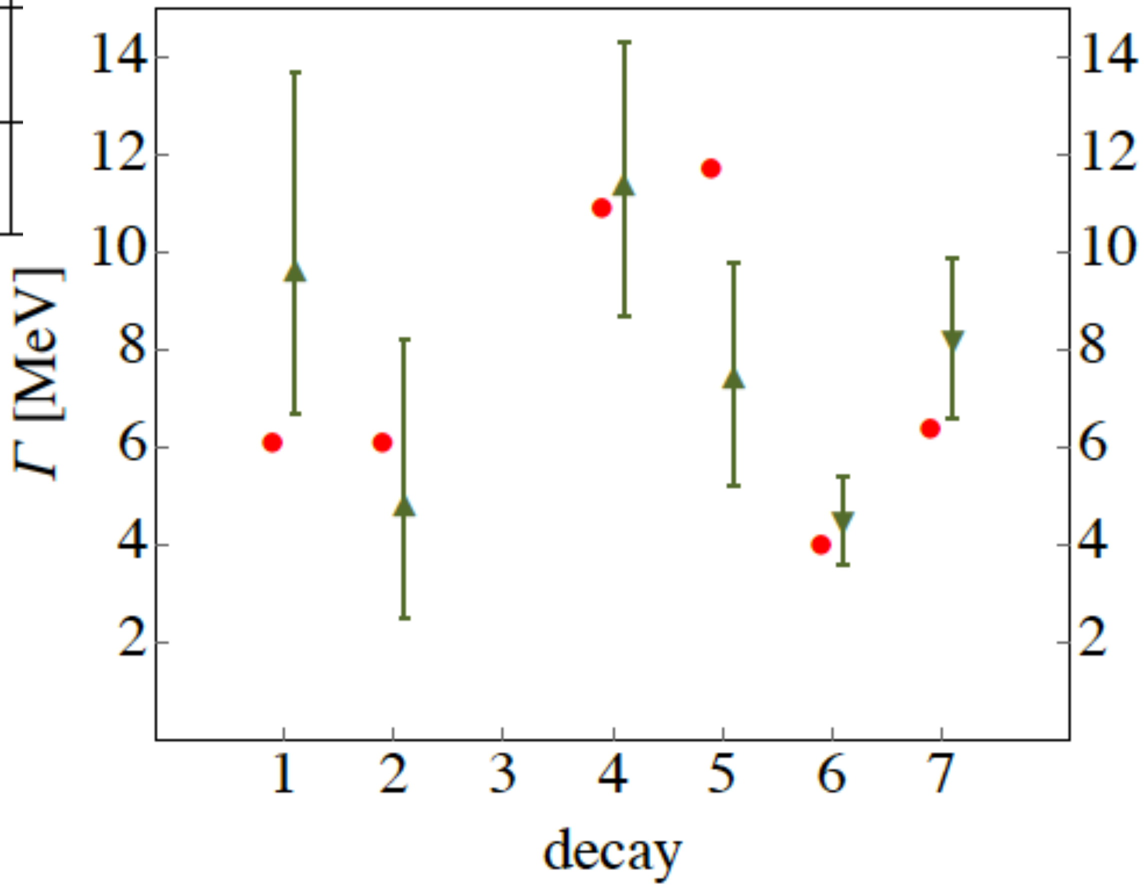
with one adjustable parameter that takes into account the fact that soliton is built up from $N_c - 1$ quarks. 15% correction to a_1



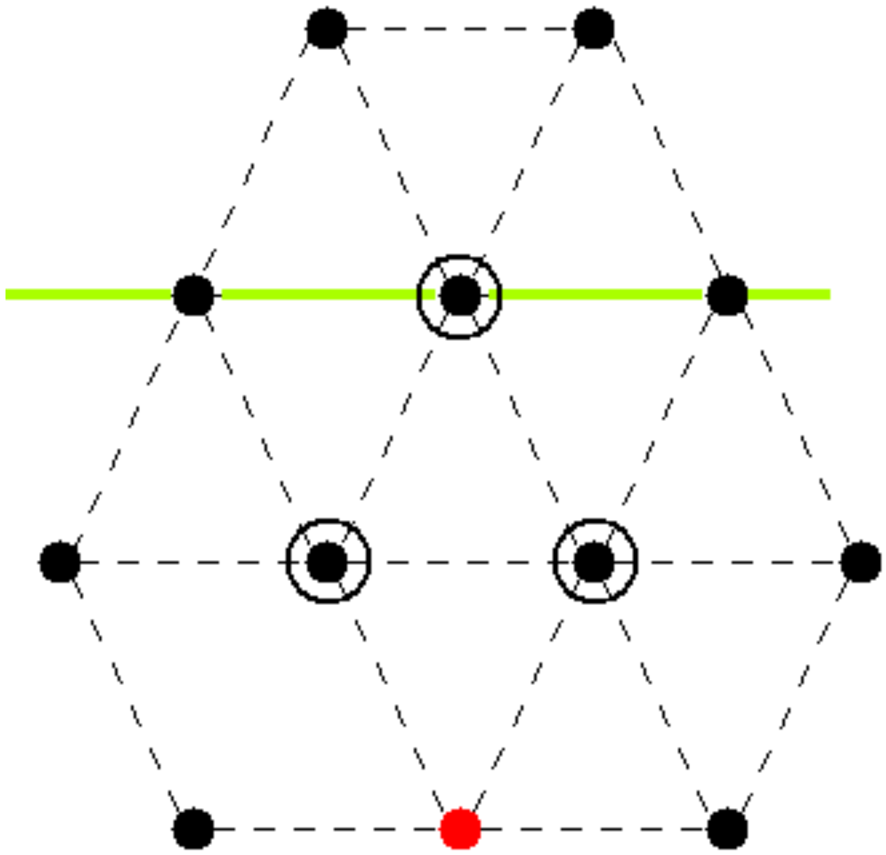
Bottom decay widths

1	$\Sigma_b^+(\mathbf{6}_1,1/2) \to \Lambda_b^0(\overline{\mathbf{3}}_0,1/2)+\pi^+$
2	$\Sigma_b^-(\mathbf{6}_1,1/2) \to \Lambda_b^0(\overline{\mathbf{3}}_0,1/2)+\pi^-$
3	$\Xi_b'(\mathbf{6}_1,1/2) \to \Xi_c(\overline{\mathbf{3}}_0,1/2)+\pi$
4	$\Sigma_b^+(\mathbf{6}_1,3/2) \to \Lambda_b^0(\overline{\mathbf{3}}_0,1/2)+\pi^+$
5	$\Sigma_b^-(\mathbf{6}_1,3/2) \to \Lambda_c^0(\overline{\mathbf{3}}_0,1/2)+\pi^-$
6	$\Xi_b^0(\mathbf{6}_1,3/2) \to \Xi_b(\overline{\mathbf{3}}_0,1/2)+\pi$
7	$\Xi_b^-(\mathbf{6}_1,3/2) \to \Xi_b(\overline{\mathbf{3}}_0,1/2)+\pi$

experimental data
a little puzzling
beacuse of rather strong
isospin
violation



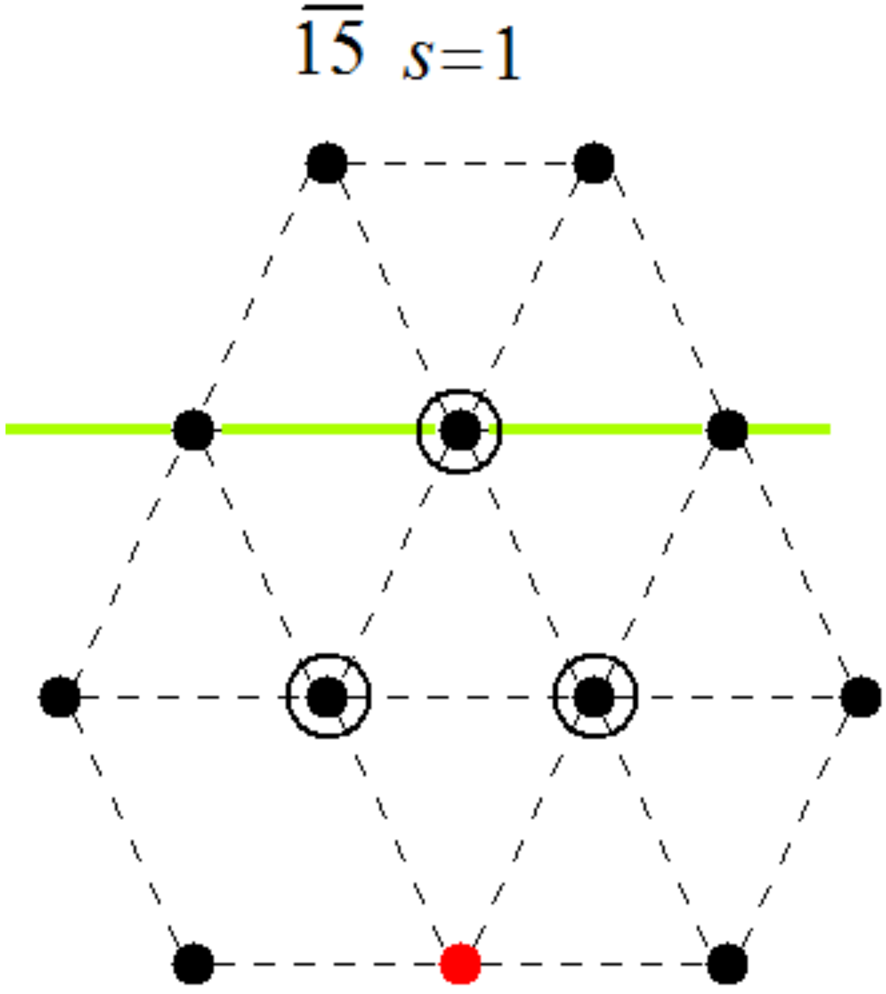
Consequences



$\overline{15}$ $s=1$

Omega’s form isospin triplet, easy to check experimentally

Consequences



rich structure -
- many new states,
also in the case of b baryons

Omega's form isospin triplet,
easy to check experimentally

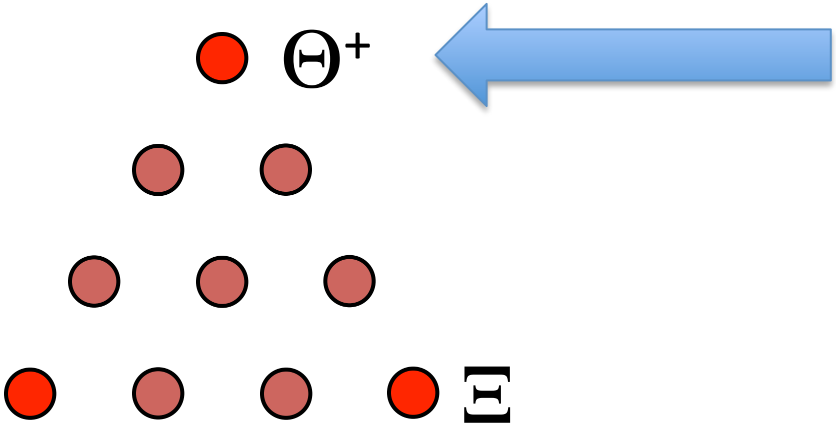
Conclusions

- soliton models **ARE** quark models
- **successful phenomenology** in the light baryon sector
- in soliton models pentaquarks are **naturally light**
- in NR limit **no decay** of antidecuplet to octet (!)
- heavy baryons can be desribed in terms of **N_c-1 quark soliton**
- two types of excitations:
  - **rotations**: 15-bar (exotic)
  - **quark** excitations (regular)

- decay widths **agree** well with the data with one free parameter
- **two** of the LHCb Omega_c states may be interpreted as **5q**

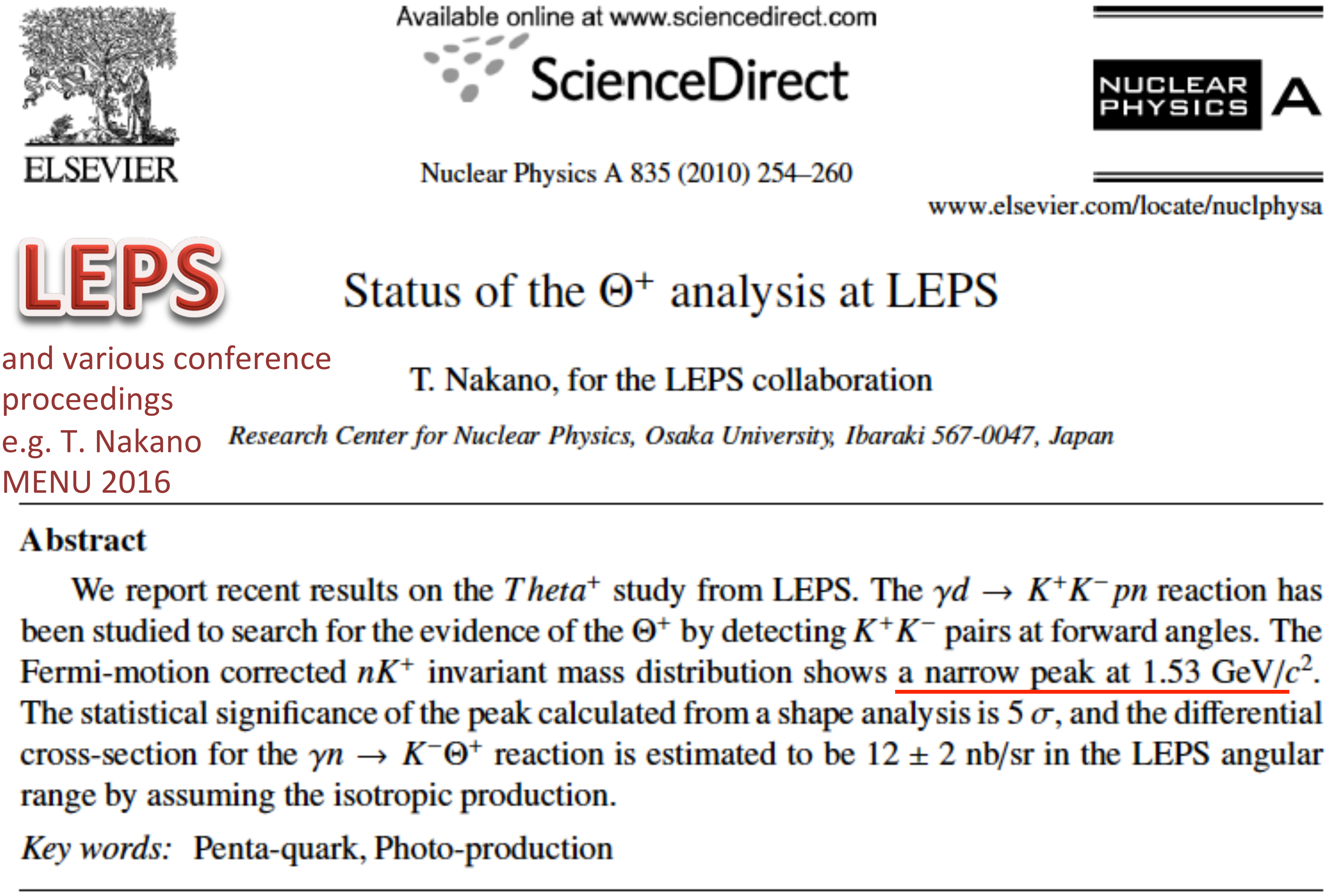
Backup slides

What is the experimental status of light pentaquarks today?



LEPS

and various conference proceedings
e.g. T. Nakano MENU 2016



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NUCLEAR PHYSICS A
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Status of the Θ^+ analysis at LEPS

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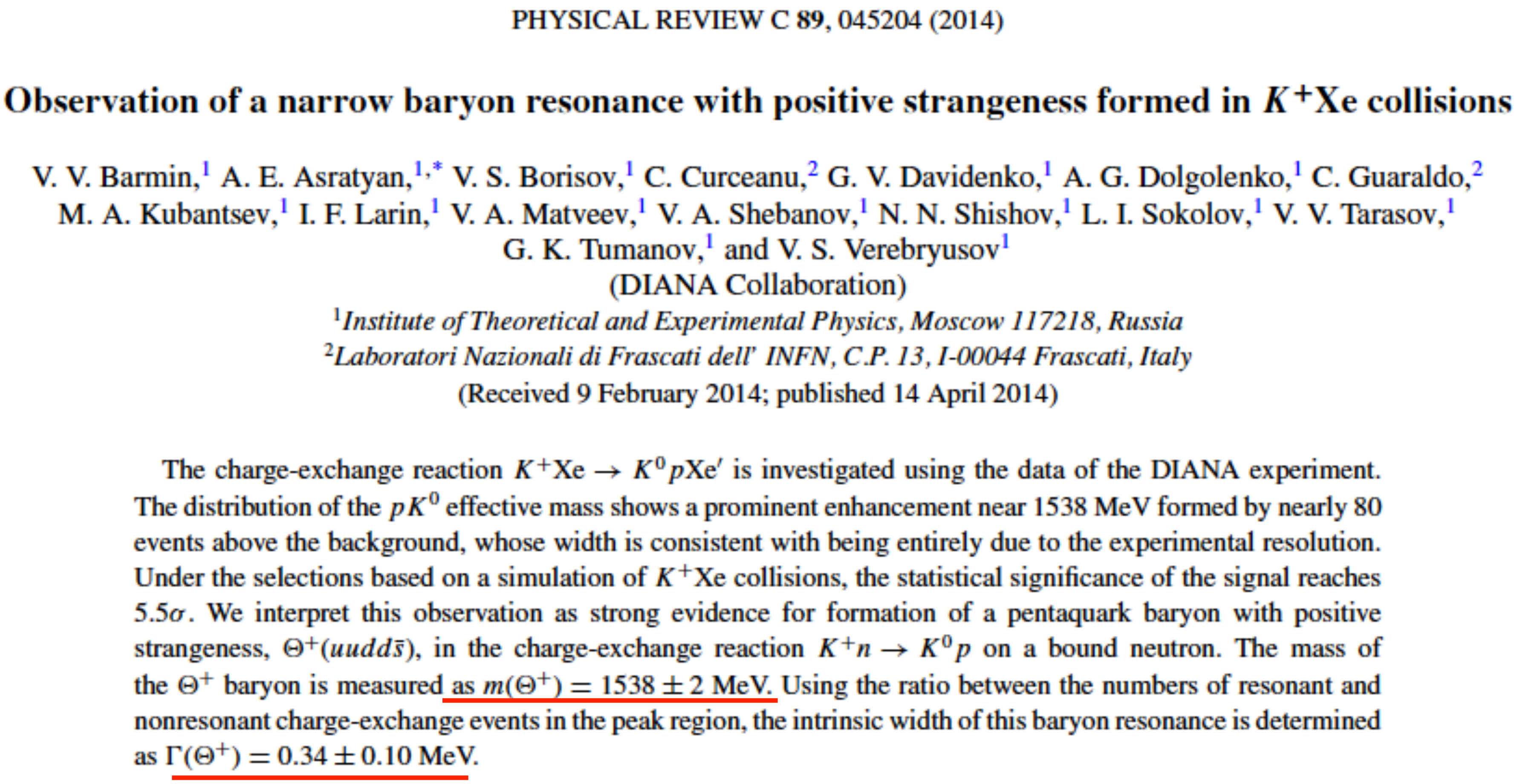
Abstract

We report recent results on the *Theta*$^+$ study from LEPS. The $\gamma d \to K^+K^-pn$ reaction has been studied to search for the evidence of the Θ^+ by detecting K^+K^- pairs at forward angles. The Fermi-motion corrected nK^+ invariant mass distribution shows a narrow peak at 1.53 GeV/c^2. The statistical significance of the peak calculated from a shape analysis is 5 σ, and the differential cross-section for the $\gamma n \to K^-\Theta^+$ reaction is estimated to be 12 ± 2 nb/sr in the LEPS angular range by assuming the isotropic production.

Key words: Penta-quark, Photo-production

DIANA



PHYSICAL REVIEW C **89**, 045204 (2014)

Observation of a narrow baryon resonance with positive strangeness formed in K^+Xe collisions

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The charge-exchange reaction $K^+\mathrm{Xe} \rightarrow K^0 p\mathrm{Xe}'$ is investigated using the data of the DIANA experiment. The distribution of the pK^0 effective mass shows a prominent enhancement near 1538 MeV formed by nearly 80 events above the background, whose width is consistent with being entirely due to the experimental resolution. Under the selections based on a simulation of K^+Xe collisions, the statistical significance of the signal reaches 5.5σ. We interpret this observation as strong evidence for formation of a pentaquark baryon with positive strangeness, $\Theta^+(uudd\bar{s})$, in the charge-exchange reaction $K^+n \rightarrow K^0p$ on a bound neutron. The mass of the Θ^+ baryon is measured as $m(\Theta^+) = 1538 \pm 2$ MeV. Using the ratio between the numbers of resonant and nonresonant charge-exchange events in the peak region, the intrinsic width of this baryon resonance is determined as $\Gamma(\Theta^+) = 0.34 \pm 0.10$ MeV.

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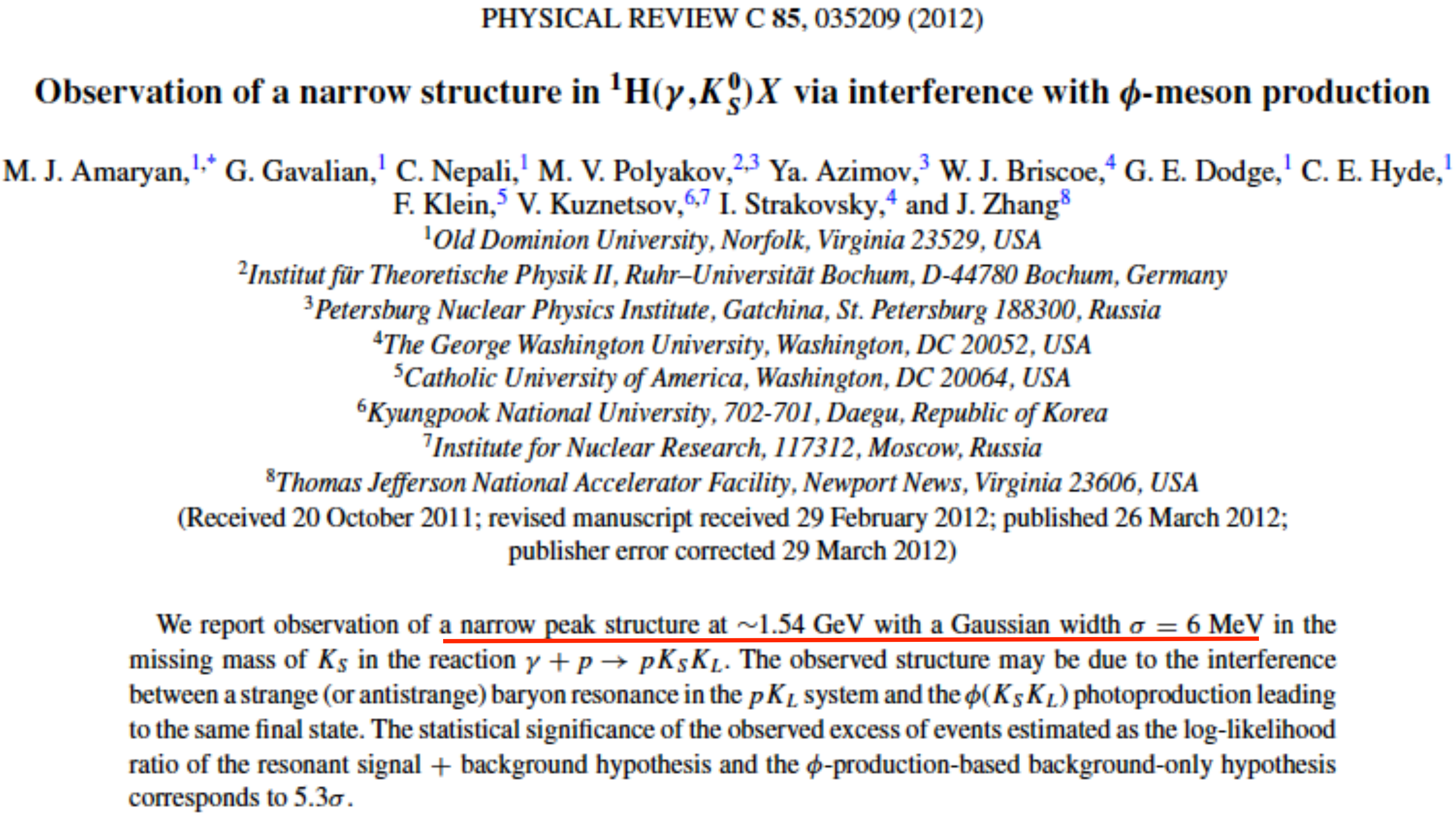

PHYSICAL REVIEW C **85**, 035209 (2012)

Observation of a narrow structure in $^1\mathrm{H}(\gamma,K_S^0)X$ via interference with ϕ-meson production

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publisher error corrected 29 March 2012)

We report observation of a narrow peak structure at ~1.54 GeV with a Gaussian width $\sigma = 6$ MeV in the missing mass of K_S in the reaction $\gamma + p \to pK_SK_L$. The observed structure may be due to the interference between a strange (or antistrange) baryon resonance in the pK_L system and the $\phi(K_SK_L)$ photoproduction leading to the same final state. The statistical significance of the observed excess of events estimated as the log-likelihood ratio of the resonant signal + background hypothesis and the ϕ-production-based background-only hypothesis corresponds to 5.3σ.

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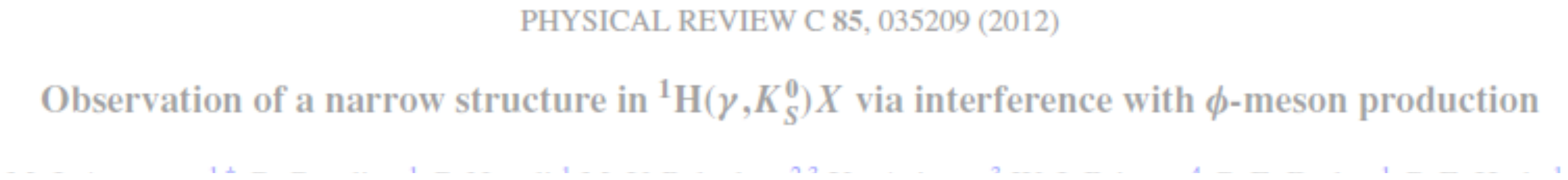
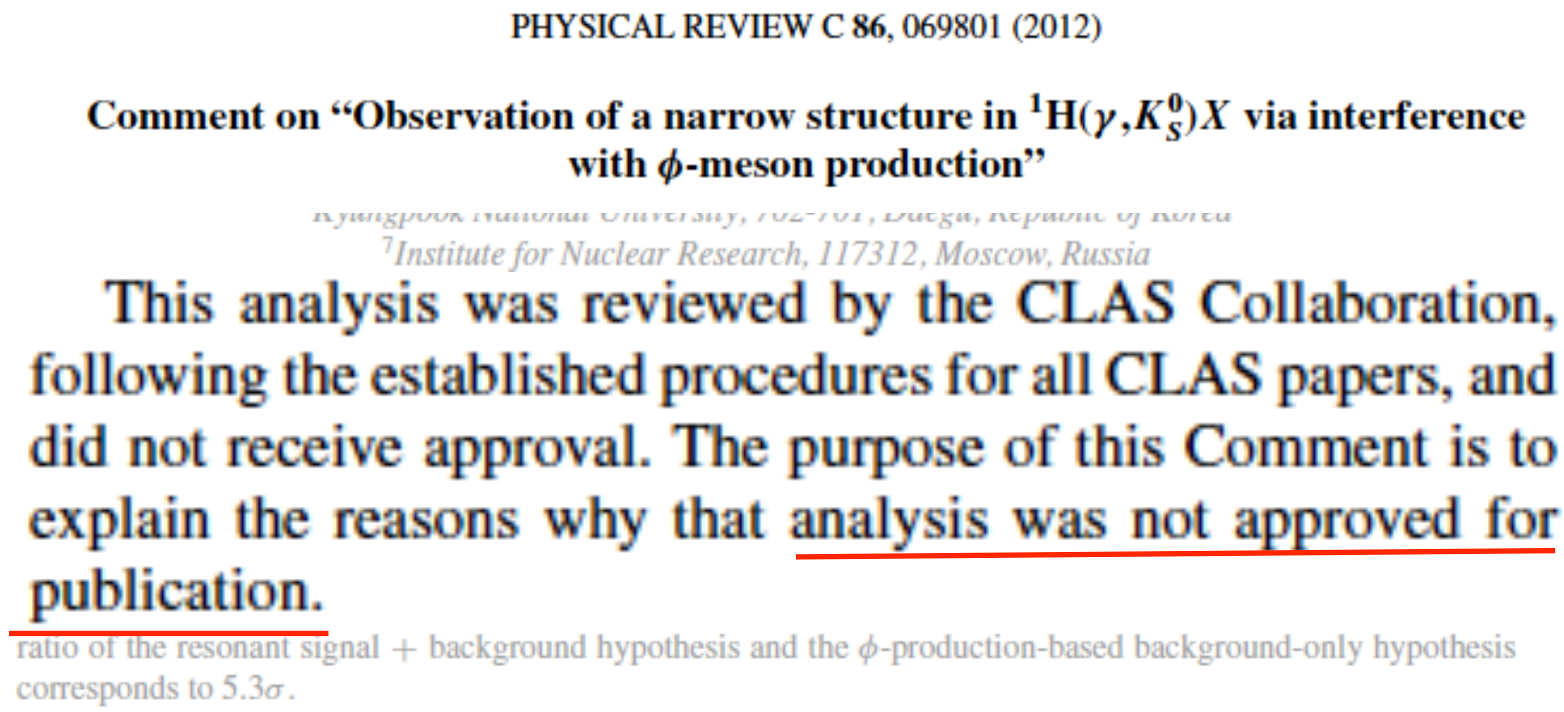


PHYSICAL REVIEW C 85, 035209 (2012)

Observation of a narrow structure in ${}^{1}\mathrm{H}(\gamma, K^0_S)X$ via interference with ϕ-meson production



PHYSICAL REVIEW C **86**, 069801 (2012)

Comment on "Observation of a narrow structure in ${}^{1}\mathrm{H}(\gamma, K^0_S)X$ via interference with ϕ-meson production"

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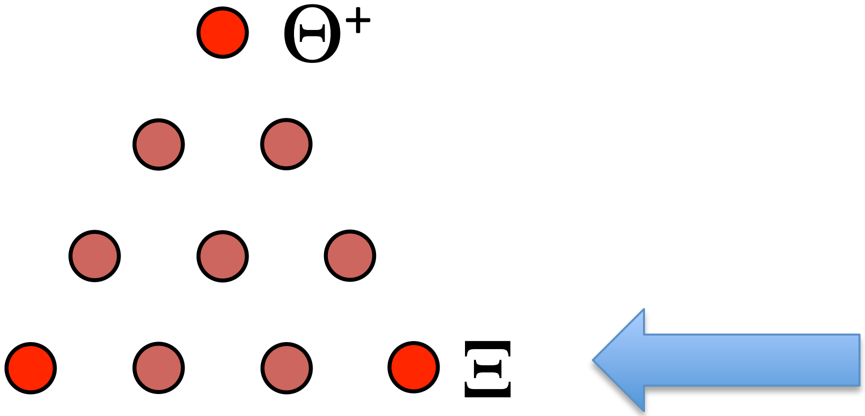
This analysis was reviewed by the CLAS Collaboration, following the established procedures for all CLAS papers, and did not receive approval. The purpose of this Comment is to explain the reasons why that analysis was not approved for publication.

ratio of the resonant signal + background hypothesis and the ϕ-production-based background-only hypothesis corresponds to 5.3σ.

What is the experimental status of light pentaquarks today?



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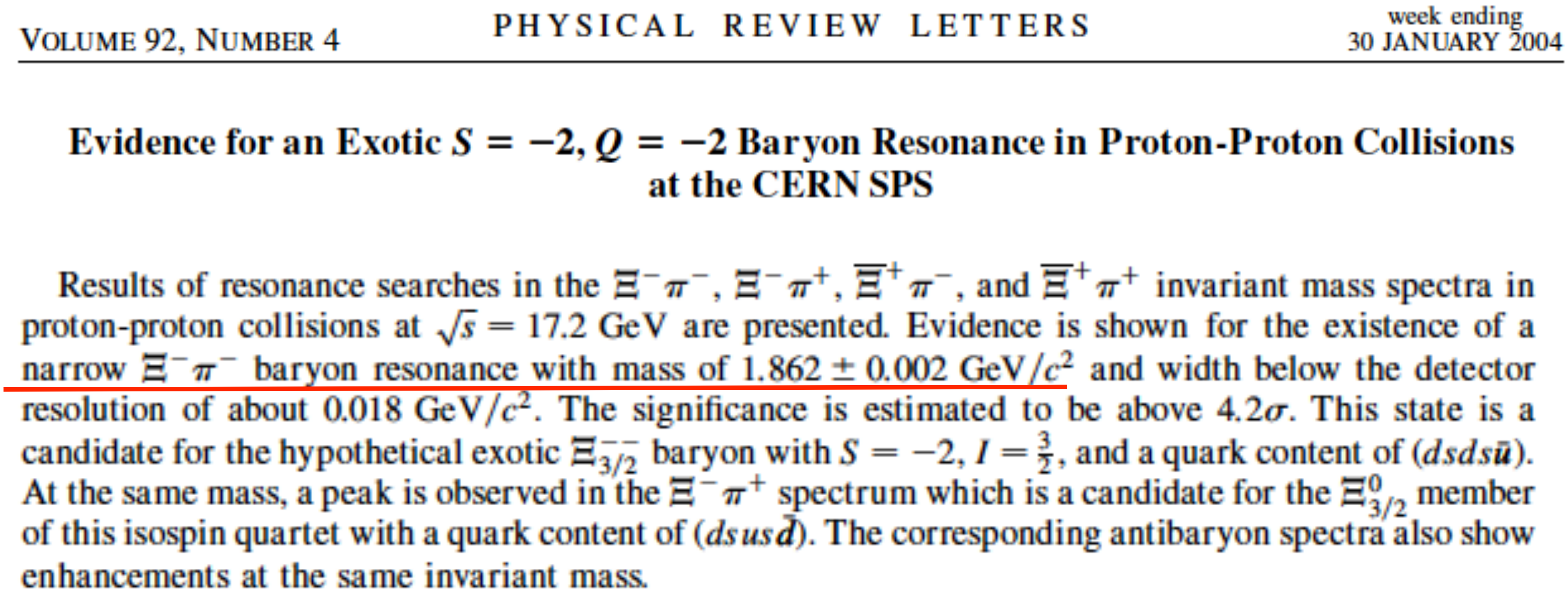
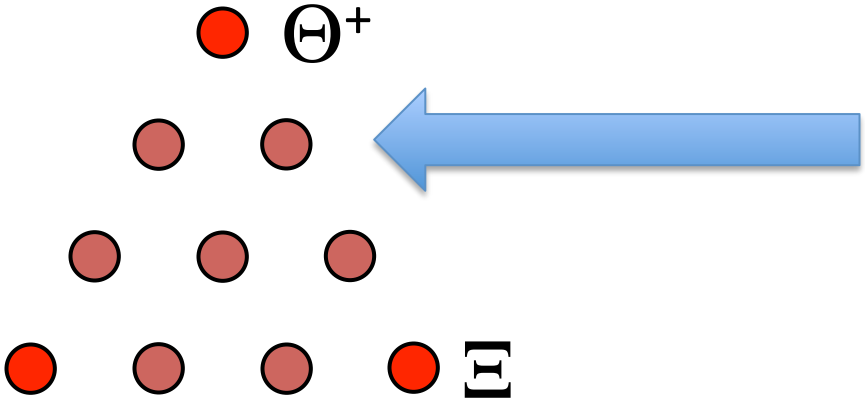


VOLUME 92, NUMBER 4 PHYSICAL REVIEW LETTERS week ending 30 JANUARY 2004

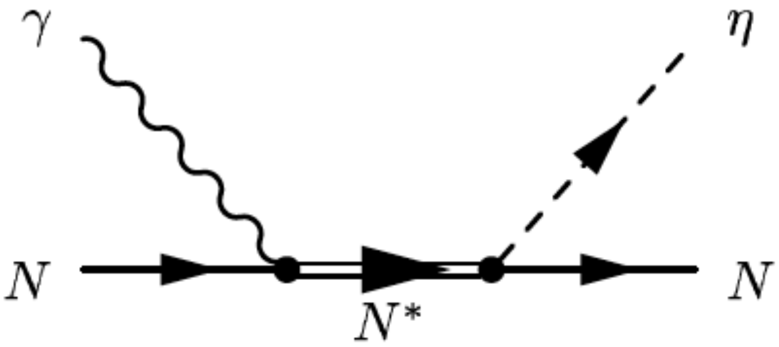
Evidence for an Exotic $S = -2$, $Q = -2$ Baryon Resonance in Proton-Proton Collisions at the CERN SPS

Results of resonance searches in the $\Xi^-\pi^-$, $\Xi^-\pi^+$, $\overline{\Xi}^+\pi^-$, and $\overline{\Xi}^+\pi^+$ invariant mass spectra in proton-proton collisions at $\sqrt{s} = 17.2$ GeV are presented. Evidence is shown for the existence of a narrow $\Xi^-\pi^-$ baryon resonance with mass of 1.862 ± 0.002 GeV$/c^2$ and width below the detector resolution of about 0.018 GeV$/c^2$. The significance is estimated to be above 4.2σ. This state is a candidate for the hypothetical exotic $\Xi^{--}_{3/2}$ baryon with $S = -2$, $I = \frac{3}{2}$, and a quark content of $(dsds\bar{u})$. At the same mass, a peak is observed in the $\Xi^-\pi^+$ spectrum which is a candidate for the $\Xi^0_{3/2}$ member of this isospin quartet with a quark content of $(dsus\bar{d})$. The corresponding antibaryon spectra also show enhancements at the same invariant mass.

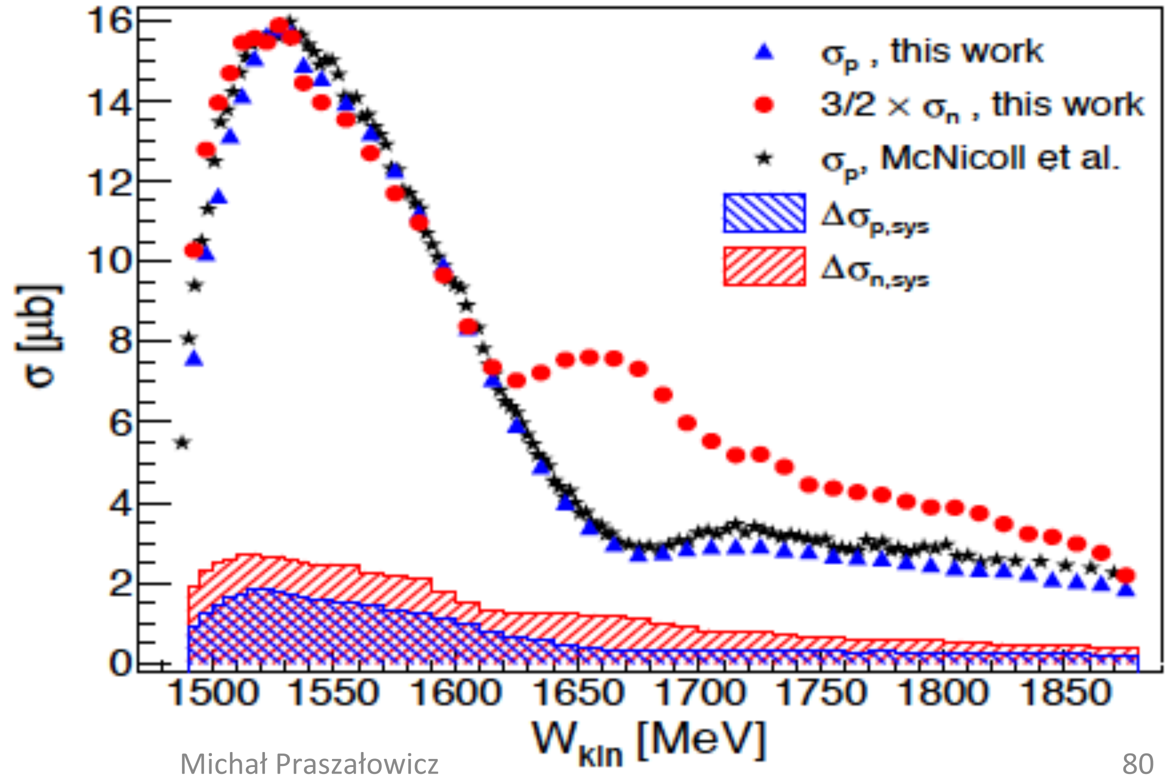
What is the experimental status of light pentaquarks today?



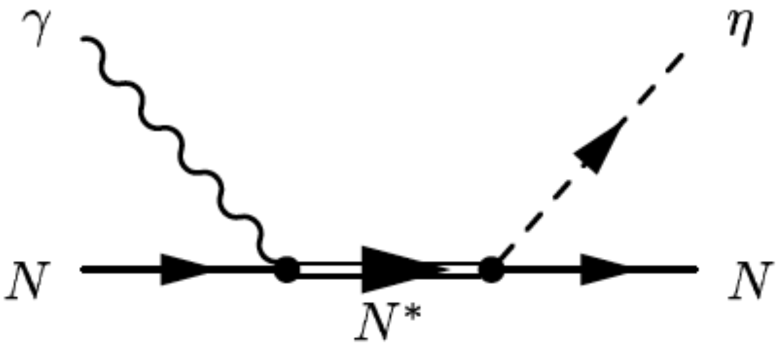
Pentanucleon?



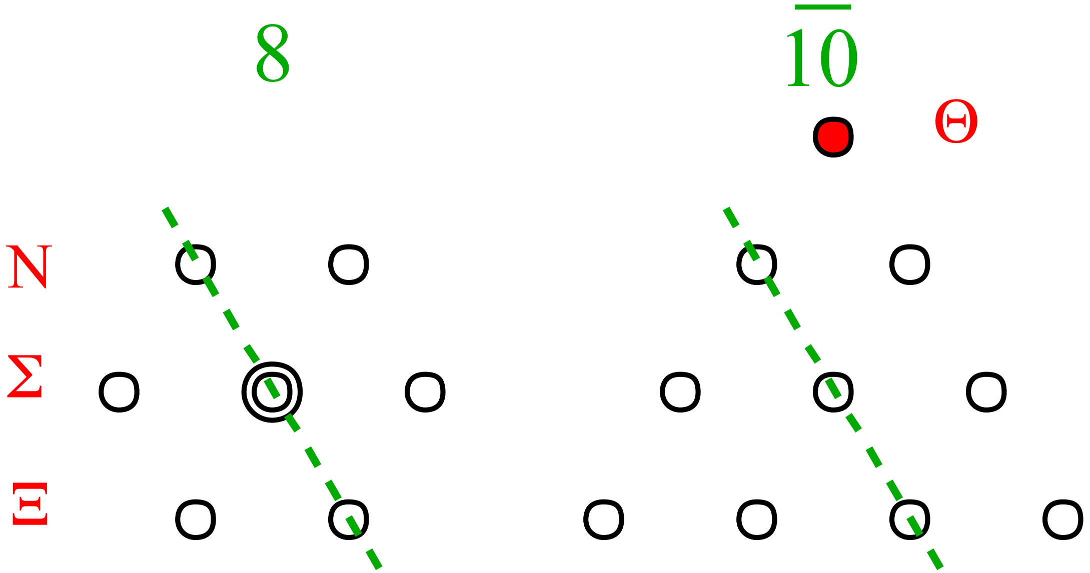
D. Werthmuller et al. [A2 Collaboration]
Phys. Rev. Lett. 111 (2013) 23, 232001
Eur. Phys. J. A 49 (2013) 154
Phys. Rev. Rev. C 90 (2014) 015205



Pentanucleon?



M.V. Polyakov and A. Rathke,
On photoexcitation of baryon anti-decuplet
Eur. Phys. J. A 18 (2003) 691



natural (but not the only one) explanation if N^* is a pentaquark

PRL **117,** 132502 (2016) PHYSICAL REVIEW LETTERS week ending 23 SEPTEMBER 2016

Insight into the Narrow Structure in η Photoproduction on the Neutron from Helicity-Dependent Cross Sections

(A2 Collaboration at MAMI)

The double polarization observable E and the helicity dependent cross sections $\sigma_{1/2}$ and $\sigma_{3/2}$ were measured for η photoproduction from quasifree protons and neutrons. The circularly polarized tagged photon beam of the A2 experiment at the Mainz MAMI accelerator was used in combination with a longitudinally polarized deuterated butanol target. The almost 4π detector setup of the Crystal Ball and TAPS is ideally suited to detect the recoil nucleons and the decay photons from $\eta \to 2\gamma$ and $\eta \to 3\pi^0$. The results show that the narrow structure previously observed in η photoproduction from the neutron is only apparent in $\sigma_{1/2}$ and hence, most likely related to a spin-$1/2$ amplitude. Nucleon resonances that contribute to this partial wave in η production are only $N1/2^-$ (S_{11}) and $N1/2^+$ (P_{11}). Furthermore, the extracted Legendre coefficients of the angular distributions for $\sigma_{1/2}$ are in good agreement with recent reaction model predictions assuming a narrow resonance in the P_{11} wave as the origin of this structure.