A new aspect on Excited baryons

Research at Inha Hadron Theory Group

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Research Topics at Inha HTG

Structure of hadrons I

- Development of the most general mean-field approaches for the description of excited baryons
- Heavy baryons in mean-field approaches
- Nonperturbative effects on Quarkonia (Instanton & Nonperturbative gluon effects)
- Derivation of the effective action for the heavy-light hadrons
- Exotic hadrons
- Generalized form factors of excited hadrons

Research Topics at Inha HTG

Structure of hadrons II

- PV processes of hadrons (Ch.H. Hyun & H.J. Lee)
- Strong decays of hadrons
- Decays of quarkonia with pions involved
- Nonleptonic decays of hadrons beyond SM (hadrons coupled with dark photons)
- Hadron tomographies & GPDs
- Medium modification of hadrons (U.T. Yakhshiev)
- Theoretical understanding of quark confinement

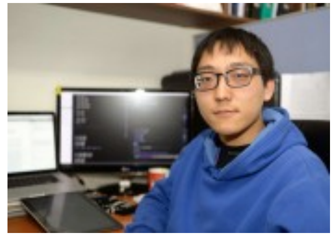
Research Topics at Inha HTG

Production of hadrons

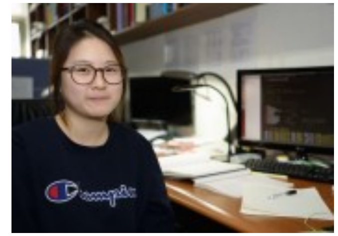
- Photoproduction of excited hadrons(S.i. Nam & S.H. Kim)
- Production of charm quarks
- General formalism of nonlinear unitarization:
  Nonlinear Integral equations (No form factors necessary) +
  Effective Field Theory
- Coupled formalism of the heavy-light systems (XYZ mesons and exotic hadrons generated dynamically)

Group Members at Inha HTG

Prof. Ulugbek Yakhshiev

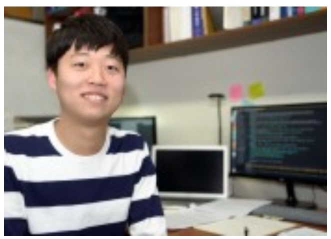


전유손 (석박사통합)



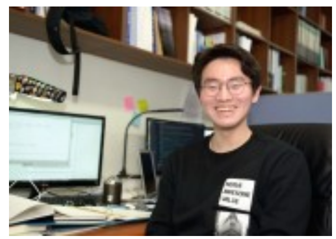
서정민 (박사과정)

김준영 (석박사통합)

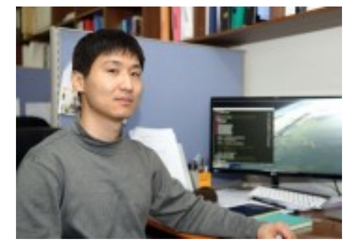


김희진 (석박사통합)

김규진 (석박사통합)



홍기훈 (학부 4학년)



심상인 (오사카대 박사과정)

김현철(H.-Ch. Kim)

- 김가영 (박사과정)
- 김남용 (학부)
- 원호연(학부)

이제희
(동경공대 박사과정)

손현동 (독일 Ruhr-U. Bochum 박사과정)

Physics for excited baryons

- Confinement & Chiral symmetry with its spontaneous breaking
- Relativistic Quantum field theory should be used for excited baryons ($q\bar{q}$ excitations).
- Vector, Axial-vector, and tensor mean fields for higher-lying excited states
- Question: How can one incorporate them to describe excited baryons?

Puzzles in excited baryon spectra

- Missing Resonances: Too many resonances were predicted. Additional symmetries?
- Mass orderings: N*(1440) & N*(1535), N*(1520)(3/2-) & N*(1535)(1/2-)
- Broad widths: Large coupling constants.
- Question: How can one resolve these puzzles?

Chiral quark-soliton model

Merits of the chiral quark-soliton model

- Fully relativistic field theoretic model.
- Related to QCD via the Instanton vacuum.
- Renormalisation scale is naturally given.
  $1/\rho \approx 600\,\mathrm{MeV}$
- All relevant parameters were fixed already.

$$\mathcal{Z}_{\chi\mathrm{QSM}} = \int \mathcal{D}U \exp(-S_{\mathrm{eff}})$$

$$\boxed{H(U) = -i\gamma_4\gamma_i\partial_i + \gamma_4 M U^{\gamma_5}}$$

$$S_{\mathrm{eff}} = -N_c \mathrm{Tr} \ln D(U)$$

$$\boxed{D(U) = \partial_4 + H(U) + \hat{m}}$$

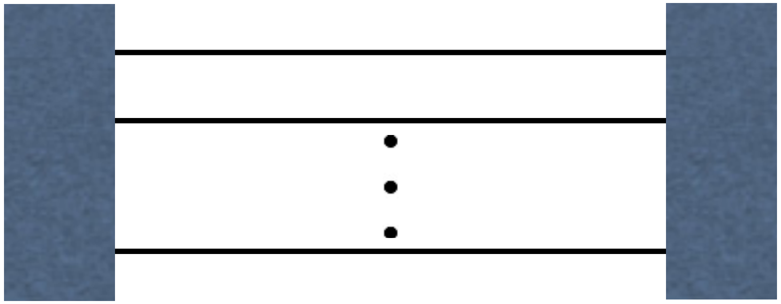
$$\boxed{\hat{m} = \mathrm{diag}(m_u, m_d, m_s)\gamma_4}$$

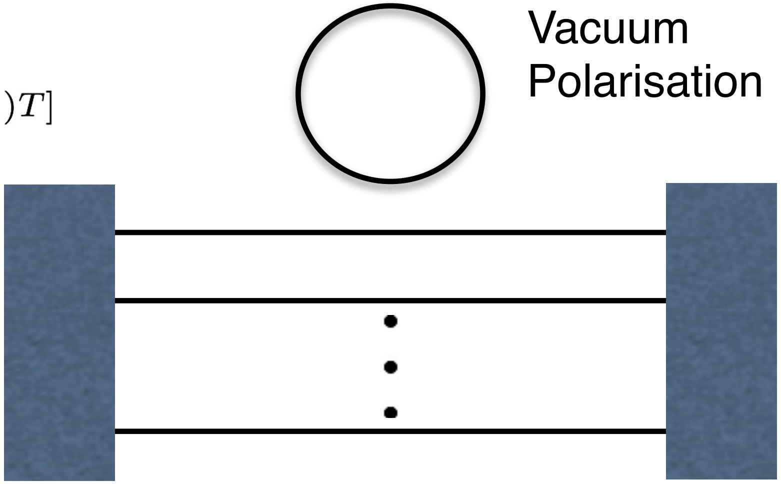
HChK et al. Prog. Part. Nucl. Phys. Vol.37, 91 (1996)

Chiral quark-soliton model

Classical solitons

$$\langle J_N(\vec{x},T)J_N^\dagger(\vec{y},-T)\rangle_0 \sim \Pi_N(T) \sim e^{-[(N_c E_{\rm val}+E_{\rm sea})T]}$$

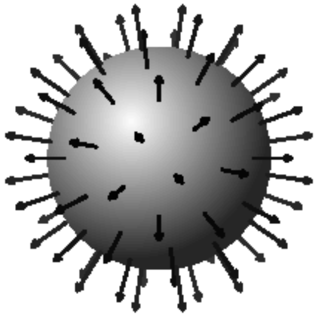




$$\frac{\delta}{\delta U}(N_c E_{\rm val} + E_{\rm sea}) = 0 \;\rightarrow\; M_{\rm cl} = N_c E_{\rm val}(U_c) + E_{\rm sea}(U_c)$$

Hedgehog Ansatz:

$$U_{\rm SU(2)} = \exp\left[i\gamma_5 \mathbf{n}\cdot\boldsymbol{\tau} P(r)\right]$$



HChK et al. Prog. Part. Nucl. Phys. Vol.95, (1995)

Chiral quark-soliton model

Collective (Zero-mode) quantisation

$$U_0 = \begin{bmatrix} e^{i\vec{n}\cdot\vec{\tau}P(r)} & 0 \\ 0 & 1 \end{bmatrix}$$

Zero-mode quantisation

$$\boxed{\begin{aligned} U(\boldsymbol{x},t) &= R(t)U_c(\boldsymbol{x}-\boldsymbol{Z}(t))R^\dagger(t) \\ \int DU[\cdots] &\rightarrow \int DADZ[\cdots] \end{aligned}}$$

$$\Rightarrow \quad \mathcal{L} = -M_{sol} + \frac{I_1}{2}\sum_{i=1}^{3}{\Omega_i}^2 + \frac{I_2}{2}\sum_{i=4}^{7}{\Omega_i}^2 + \frac{N_c}{2\sqrt{3}}\Omega_8$$

HChK et al. Prog. Part. Nucl. Phys. Vol.95, (1995)

Extended XQSM

Extended effective chiral action

- **How to incorporate quark confinement**

$$S_{\text{eff}} = -N_c \text{Tr}\log\left[i\partial\!\!\!/ + i\hat{m} + \boxed{iM(r)U^{\gamma_5}}\right]$$

$$M(r)U^{\gamma_5}(r) = S(r)\left[\cos P(r) + i\gamma_5 \tau\cdot\mathbf{n}\sin P(r)\right]$$

$S(r)$ Confining background (mean) field

$P(r)$ Pion background (mean) field

The confining and pion fields are non-linearly coupled within **hedgehog Ansatz**.

[D. Diakonov, V. Petrov, and A. Vladimirov, Phys. Rev. D 88, 074030 (2013)]

Hedgehog symmetry and mean field

Collective (Zero-mode) quantisation

$$U_0 = \begin{bmatrix} e^{i\vec{n}\cdot\vec{\tau}P(r)} & 0 \\ 0 & 1 \end{bmatrix} \quad \mathrm{SU(3)_f} \otimes \mathrm{O(3)_{space}} \rightarrow \mathrm{SU(2)_{iso+space}}$$

- Breaking of this higher symmetry will reduce the number of baryon states!
- We keep the zero-mode quantization for the moment.
- For excited states, meson loops should come into play. (**beyond the zero modes. Future works**)
- Vector and axial-vector, and tensor mean fields should be considered! **(Future works)**

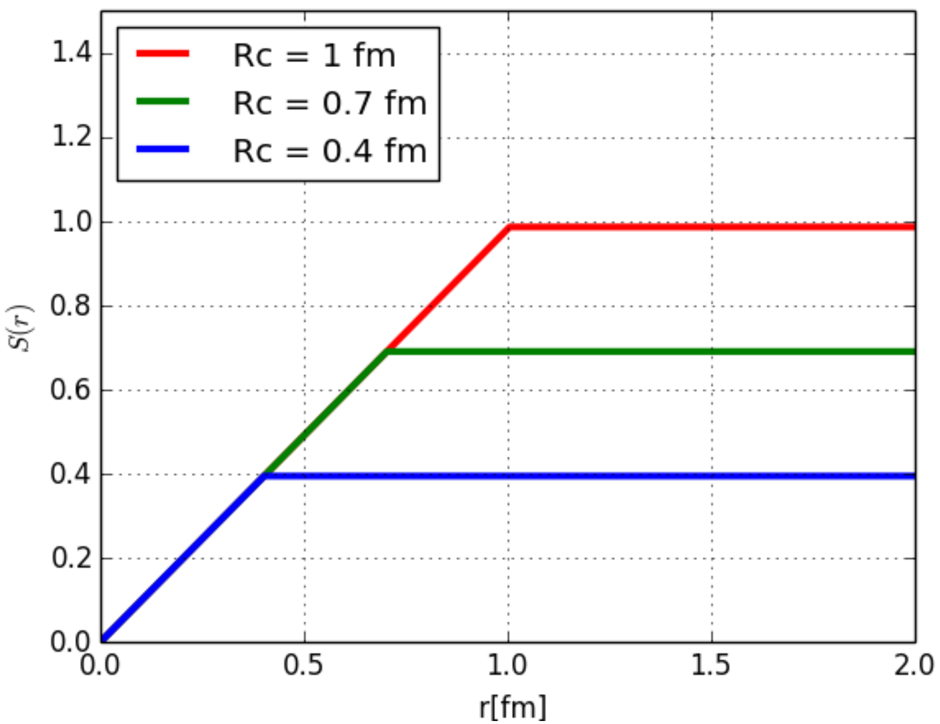
Confining background field

Critical distance

$$\sigma R_c \approx M, \quad \lim_{r\to\infty} S(r) = M \qquad \sigma = (0.44\ \text{GeV})^2$$

We need to saturate S(r) to avoid a divergence

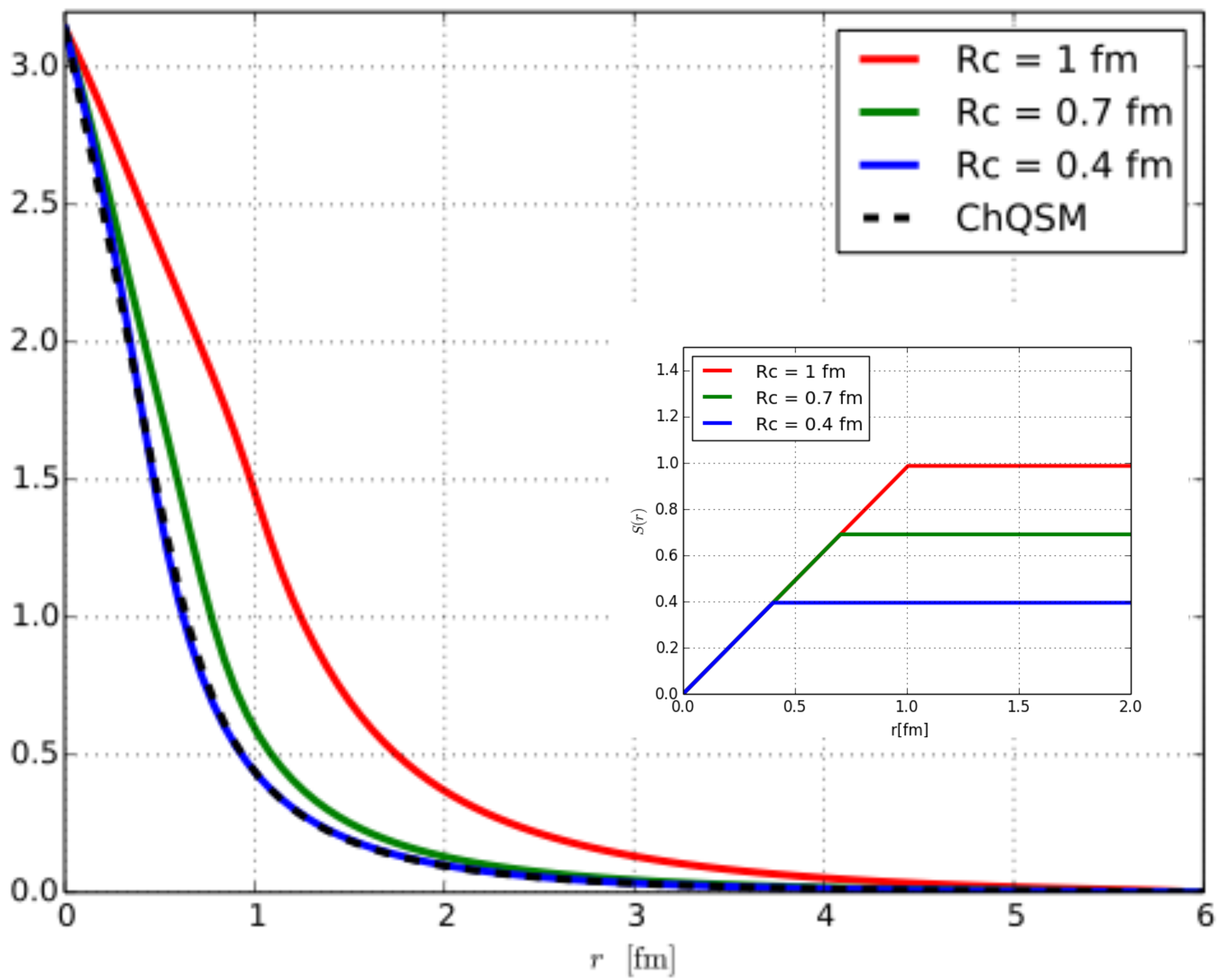
$$S(r) = \sigma r\, \theta(R_c - r) + \sigma R_c\, \theta(r - R_c)$$



This is plausible, since the string should be broken into creating mesons.

HD Son & HChK, in preparation

Self-consistent pion background field



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Classical Nucleon mass

[MeV]	Valence	Sea	Total
ChQSM M = 420 MeV	589	707	1296
Rc = 0.4 fm	701	557	1258
Rc = 0.7 fm	269	916	1185
Rc = 1.0 fm	x	916	916

HD Son & HChK, in preparation

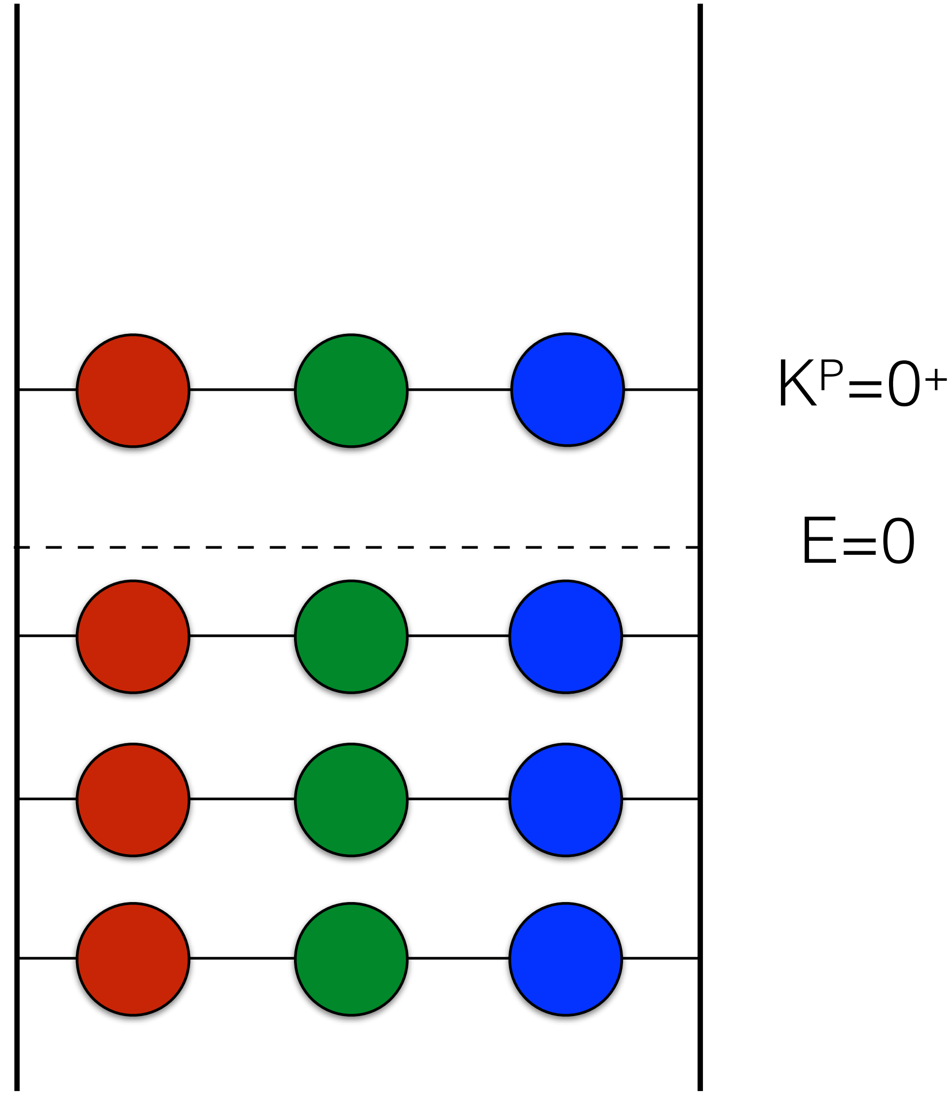
Ground baryons

$$\boldsymbol{K} = \boldsymbol{J} + \boldsymbol{T} = \boldsymbol{0}, \quad T_8 = \frac{N_c}{2\sqrt{3}}$$

Right hypercharge

$$Y' = \frac{N_c}{3}$$

- Nc quark gives the baryon number in the XQSM.



Ground state

Collective Hamiltonian for ground baryons

$$H = H_{\mathrm{cl}} + H_{\mathrm{rot}} + H_{\mathrm{sb}}$$

$$H_{\mathrm{rot}} = \frac{1}{2I_1}\sum_{i=1}^{3} J_i^2 + \frac{1}{2I_2}\sum_{a=4}^{7} J_a^2$$

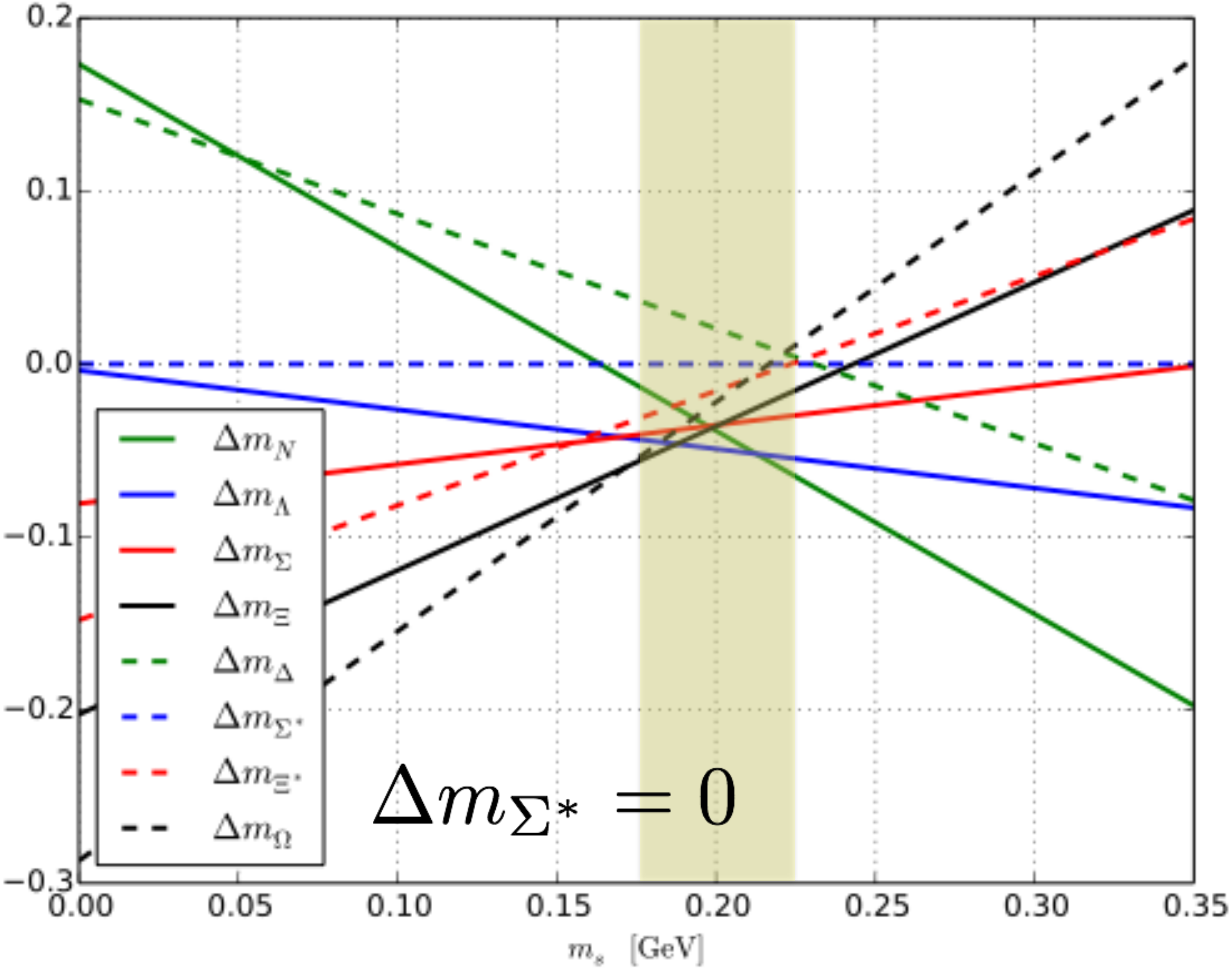
$$H_{\mathrm{sb}} = \alpha D_{88}^{(8)}(R) + \beta Y + \frac{1}{\sqrt{3}}\gamma \sum_{i=1}^{3} D_{8i}^{(8)} J_i$$

$$\alpha = -\left(\frac{2}{3}\frac{\Sigma_{\pi N}}{m_{\mathrm{u}} + m_{\mathrm{d}}} - \frac{K_2}{I_2}\right), \quad \beta = -\frac{K_2}{I_2}, \quad \gamma = 2\left(\frac{K_1}{I_1} - \frac{K_2}{I_2}\right)$$

Baryon wave functions

$$|B\rangle = \sqrt{\dim(\mathcal{R})}(-1)^{J_3 + Y'/2} D^{(\mathcal{R})*}_{(Y,T,T_3)(-Y',J,-J_3)}$$

Hyperon mass splitting to the first order of m_s



Original XQSM

— octet

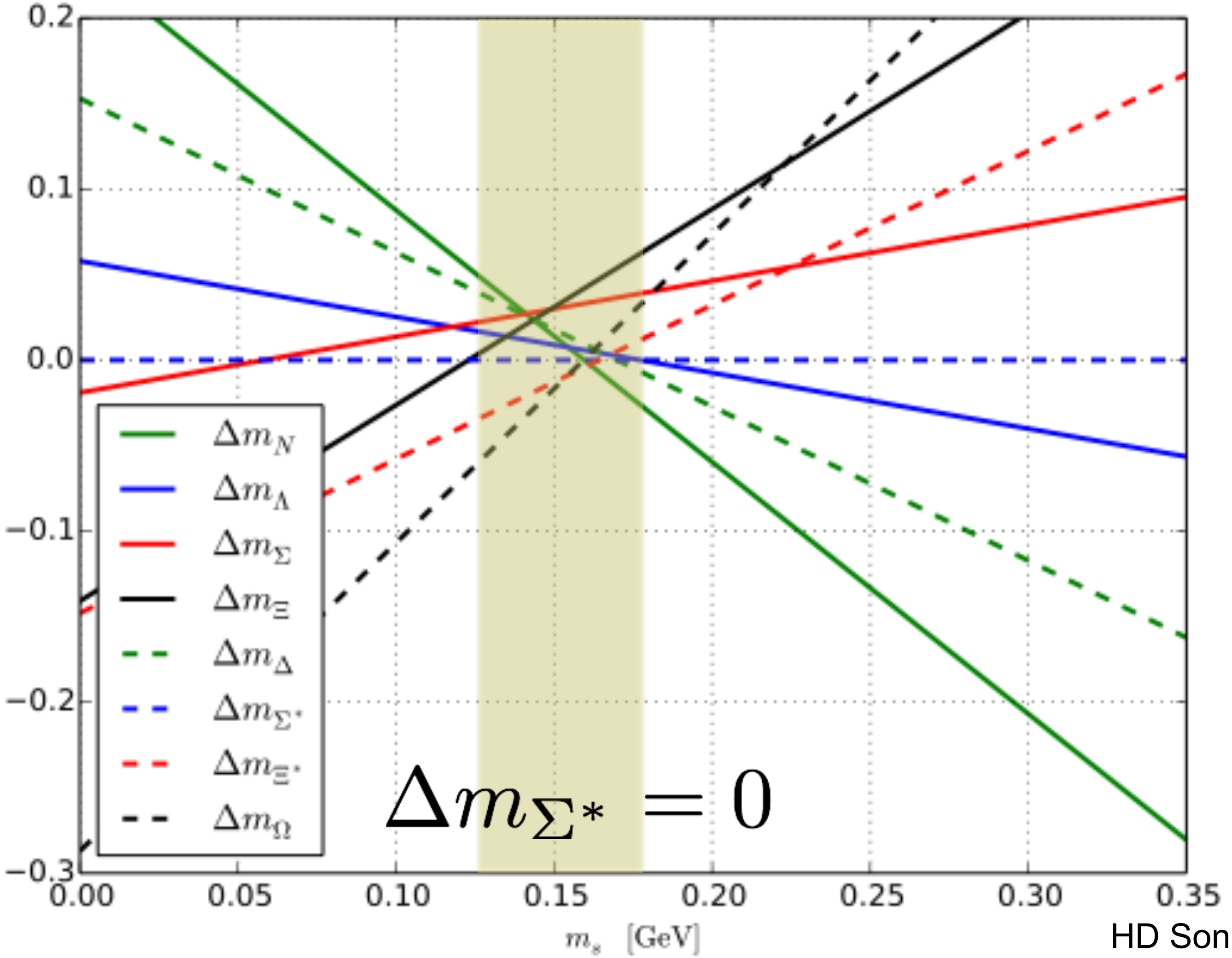
- - decuplet

HD Son & HChK, in preparation

Hyperon mass splitting to the first order of m_s

Rc = 0.42 fm: — octet - - decuplet

Large σ-term → smaller strange quark mass



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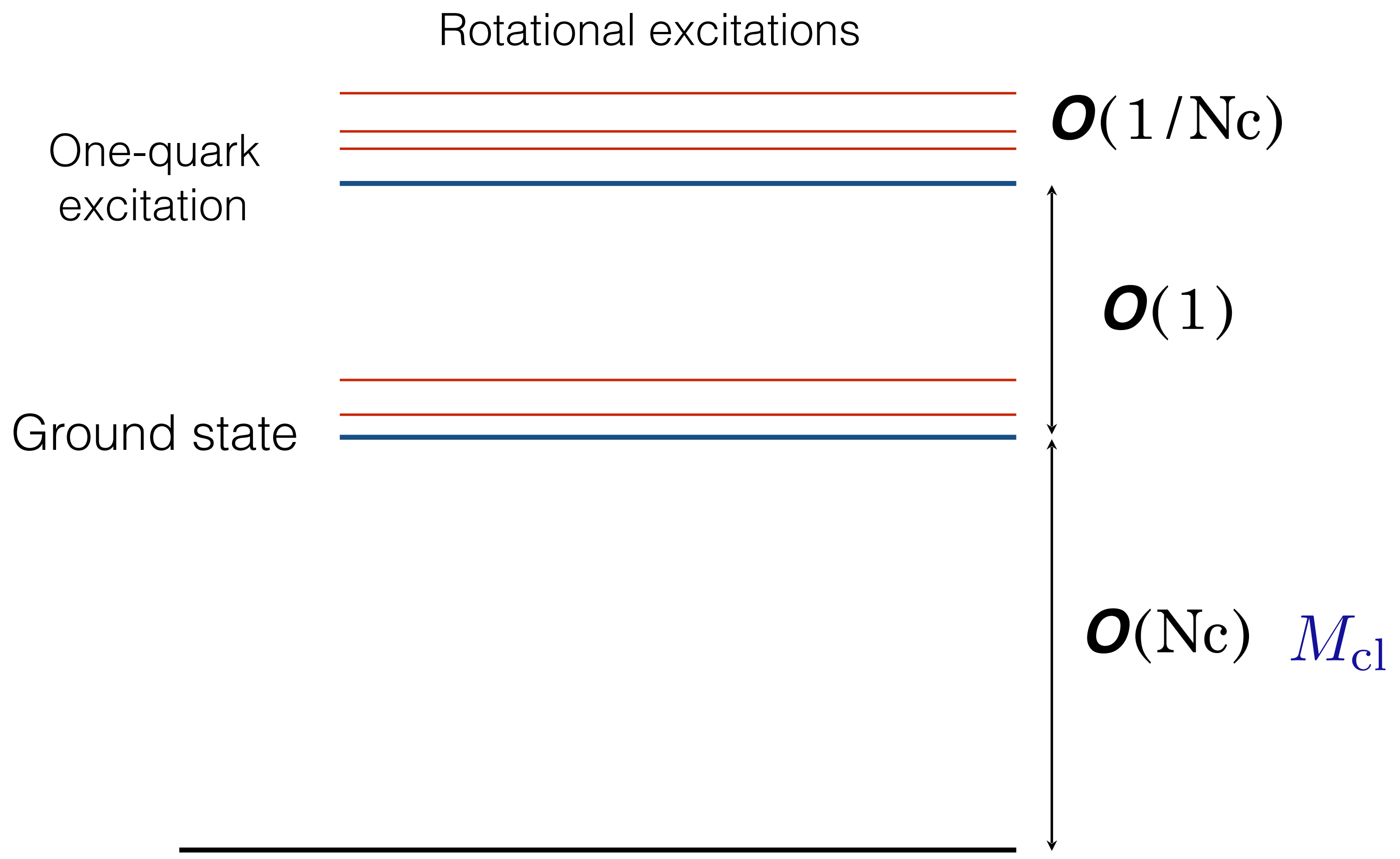
Excited valence quark

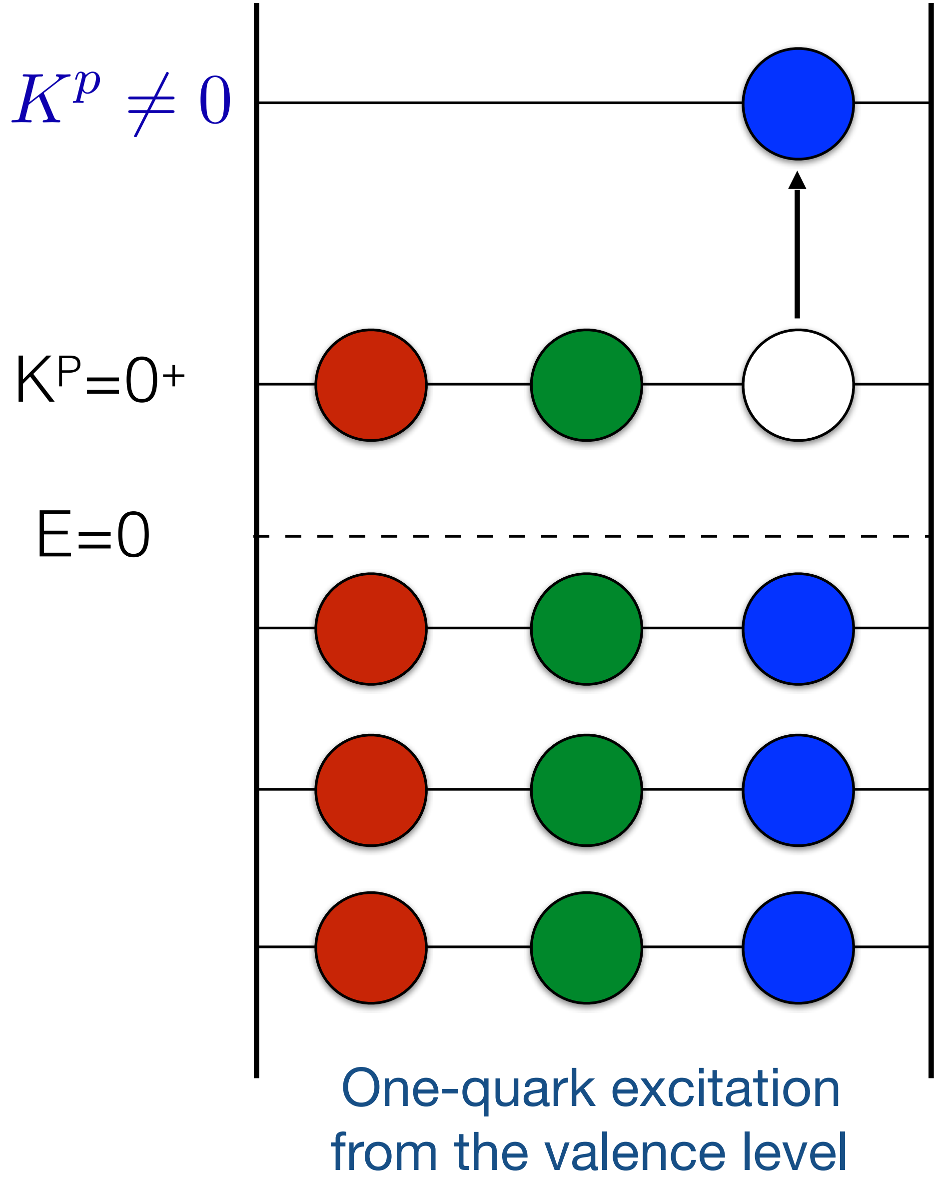
Schematic picture at large N_c



Excited valence quark for 8(J^P=1/2$^+$)

$$\boldsymbol{K} = \boldsymbol{J} + \boldsymbol{T},$$

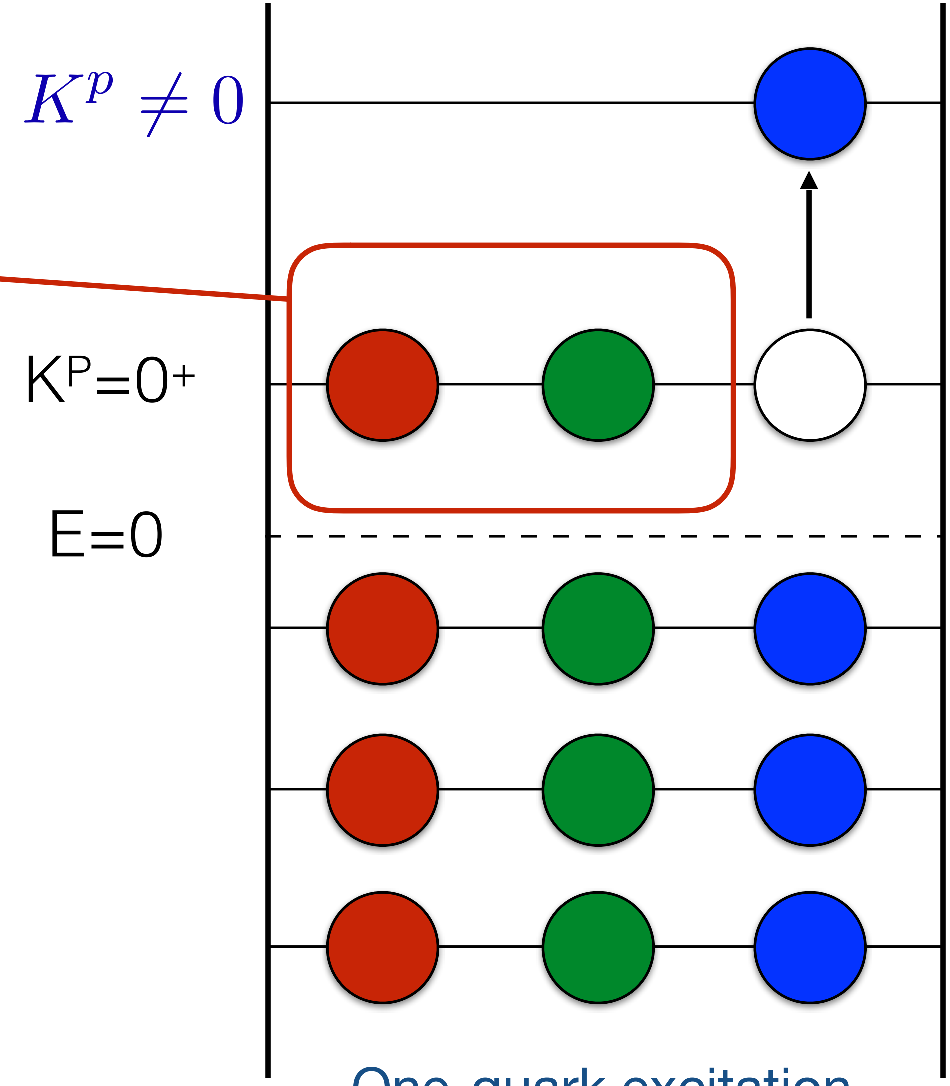
$$Y' = \frac{N_c}{3} = \frac{2}{\sqrt{3}} T_8$$



Collective Hamiltonian for excited baryons

$$H = H_{\rm cl} + H_K + H_{\rm m}$$

$$M_{\rm cl} = (N_c - 1)E_{\rm val} + E_{\rm sea}$$



One-quark excitation
from the valence level

Collective Hamiltonian for excited baryons

$$H = H_{\mathrm{cl}} + H_K + H_{\mathrm{m}}$$

$$\boldsymbol{T} = \boldsymbol{K} - \boldsymbol{J}$$

$$H_K = \frac{1}{2I_2}\sum_{a=4}^{7} T_a^2 + \frac{(\boldsymbol{T} - a_K \boxed{\boldsymbol{K})^2}}{2I_1}$$

$$H_m = \alpha D_{88}^{(8)}(R) + \beta Y + \frac{1}{\sqrt{3}}\gamma \sum_{i=1}^{3} D_{8i}^{(8)}(R)\boxed{T_i} + \boxed{\frac{1}{\sqrt{3}}\delta_K \sum_{i=1}^{3} D_{8i}^{(8)}(R) K_i}$$

$$\delta_K = \frac{2m_s}{3}\left(d_K - \frac{K_1}{I_1} a_K\right)$$

wave functions for excited baryons

$$\Psi_K(R,S,\chi) = \sqrt{\frac{\dim(R)(2J+1)}{2K+1}} \sum_{TT_3J_3} C^{KK_3}_{TT_3JJ_3} D_{Y'T'T'_3,YTT_3}(R^\dagger) D_{J'_3J_3}(S^\dagger)\chi_{K_3}$$

Excited valence quark for 8($J^P=1/2^+$)

K=0+ → K=0+ : No contribution from χ_K

	Y	Mass	Candidates	Status	I(J^P)	Δ_{calc}	Δ_{exp}
N	1	**1458**	1440	****	1/2($1/2^+$)	**190**	**220**
Λ	0	**1648**	1660	***	0($1/2^+$)	**102**	
Σ	0	**1750**	1660	****	1($1/2^+$)	**139**	
Ξ	-1	**1889**	1690	*	1/2($?^?$)		

HD Son & HChK, in preparation

Excited valence quark for 8(J^P=3/2$^+$)

K=0+ → K=0+ : No contribution from χ_K

	Y	Mass	Candidates	Status	I(J^P)	Δ_{calc}	Δ_{exp}
Δ	1	**1826**	1600	****	3/2(3/2$^+$)		
Σ	0	**1977**	1660	*	1(3/2$^+$)	**151**	
Ξ	-1	**2128**	1950	***	1/2(?$^?$)	**151**	
Ω	-2	**2280**	2250	***	0(?$^?$)	**151**	

HD Son & HChK, in preparation

Parameters for the baryons with negative parity

c_K, a_K, and d_K

	$\Delta E(0+\rightarrow 1-)$ [MeV]	c_K	a_K	d_K
ChQSM (M=420MeV)	240	0.377	0.217	0.213
R_C=0.42 fm	163	0.391	0.207	0.201
R_C=0.44 fm	249	0.398	0.202	0.198
R_C=0.46 fm	337	0.407	0.195	0.193
Diakonov *et al*	468		0.336	

HD Son & HChK, in preparation

Excited valence quark for 8(J^P=1/2$^-$)

K=0+ → K=1-

	Y	Mass[MeV]	Candidates	Status	I(J^P)	Δ_{calc}	Δ_{exp}
N	1	1408	1535	****	1/2(1/2$^-$)	145	135
Λ	0	1553	1670	****	0(1/2$^-$)	92	
Σ	0	1645				99	
Ξ	-1	1744	?	?	?		

HD Son & HChK, in preparation

Excited valence quark for 8(J^P=3/2$^-$)

K=0+ → K=1-

	Y	Mass[MeV]	Candidates	Status	I(J^P)	Δ_{calc}	Δ_{exp}
N	1	$\boxed{1432}$	$\boxed{1520}$	****	1/2(3/2$^-$)	170	170
Λ	0	1602	1690	****	0(3/2$^-$)	103	-20
Σ	0	1705	1670	****	1(3/2$^-$)	119	150
Ξ	-1	1824	1820	***	1/2(3/2$^-$)		

HD Son & HChK, in preparation

Excited valence quark for 10($J^P=1/2^-$)

K=0+ → K=1-

	Y	Mass[MeV]	Candidates	Status	I(J^P)	Δ_{calc}	Δ_{exp}
Δ	1	**1669**	1620	****	3/2($1/2^-$)	**139**	**130**
Σ*	0	**1808**	1750	***	1($1/2^-$)	**139**	
Ξ*	-1	**1947**	1900	?	?	**139**	
Ω	-2	**2085**	2050	?	?		

Predictions by V. Petrov

HD Son & HChK, in preparation

Excited valence quark for 10($J^P=3/2^-$)

$K=0+ \rightarrow K=1-$

	Y	Mass[MeV]	Candidates	Status	I(J^P)	Δ_{calc}	Δ_{exp}
Δ	1	**1726**	1700	****	3/2($3/2^-$)		
						136	
Σ*	0	**1862**	1850	?	?		
						136	
Ξ*	-1	**1999**	2000	?	?		
						136	
Ω	-2	**2135**	2150	?	?		

Predictions by V. Petrov

HD Son & HChK, in preparation

What is missing in this approach?

- Meson-loop corrections (1/Nc): So far, the approach is just like a mean-field approach. We need to do more: RPA-like meson-loop contributions.

- qqbar excitations more than pions: vector, Axial-vector, and tensor mean fields and meson loops for higher-lying excited states

Summary and Outlook

Summary & Outlook

- We constructed the extended chiral quark-soliton model, deriving the pion mean field self-consistently in the presence of the confining field.
- The mass ordering problems are not solved but the mass differences are better than the other quark models.
- Meson-loop corrections (RPA-like contributions) to the excited baryons
- Contribution of the vector, axial-vector, and tensor mean fields to the excited baryons
- Radiative and strong decays of the excited baryons
- Transition form factors of the excited baryons

Summary & Outlook

- Application to Heavy baryon systems (We already did recently.)
- Model-independent analysis

(We can describe the correct mass ordering.)

- Long way to go for a complete generalization of the chiral quark-soliton model.

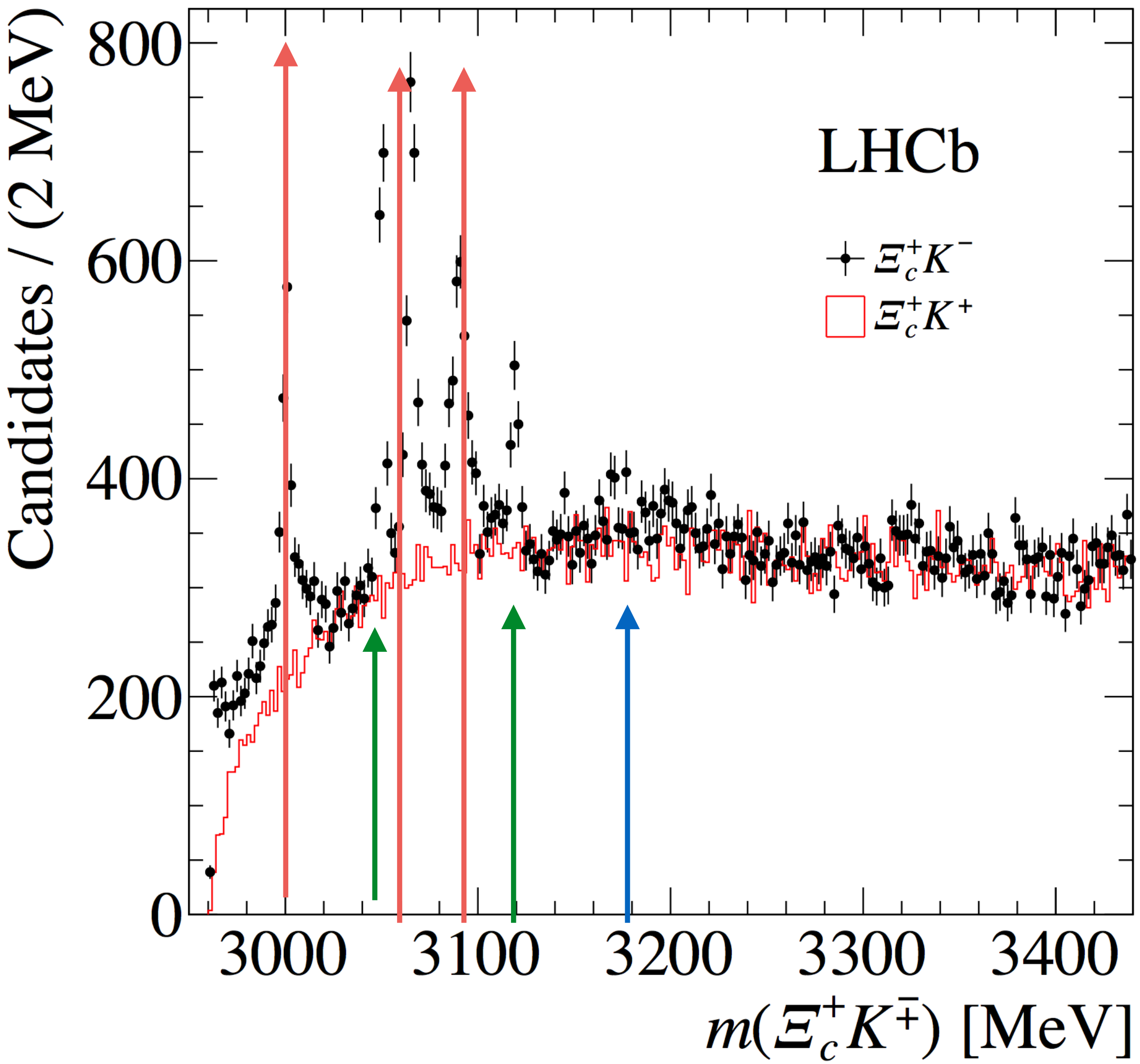
Though this be madness, yet there is method in it.

Hamlet Act 2, Scene 2

Thank you very much!

$$\Omega_c$$

LHCb Findings: New five Omega_cs

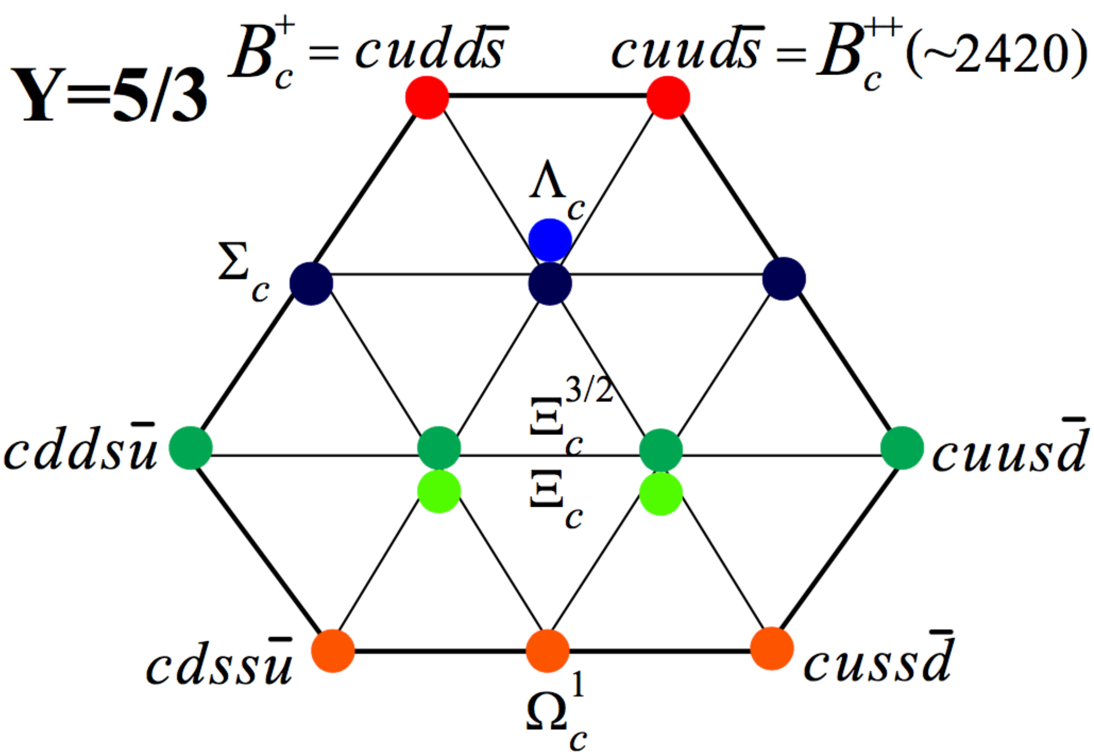


LHCb Findings: New five Omega_cs

Resonance	Mass (MeV)	Γ (MeV)	Yield	N_σ
$\Omega_c(3000)^0$	$3000.4 \pm 0.2 \pm 0.1^{+0.3}_{-0.5}$	$4.5 \pm 0.6 \pm 0.3$	$1300 \pm 100 \pm 80$	20.4
$\Omega_c(3050)^0$	$3050.2 \pm 0.1 \pm 0.1^{+0.3}_{-0.5}$	$0.8 \pm 0.2 \pm 0.1$	$970 \pm 60 \pm 20$	20.4
		$< 1.2\,\mathrm{MeV}$, 95% CL		
$\Omega_c(3066)^0$	$3065.6 \pm 0.1 \pm 0.3^{+0.3}_{-0.5}$	$3.5 \pm 0.4 \pm 0.2$	$1740 \pm 100 \pm 50$	23.9
$\Omega_c(3090)^0$	$3090.2 \pm 0.3 \pm 0.5^{+0.3}_{-0.5}$	$8.7 \pm 1.0 \pm 0.8$	$2000 \pm 140 \pm 130$	21.1
$\Omega_c(3119)^0$	$3119.1 \pm 0.3 \pm 0.9^{+0.3}_{-0.5}$	$1.1 \pm 0.8 \pm 0.4$	$480 \pm 70 \pm 30$	10.4
		$< 2.6\,\mathrm{MeV}$, 95% CL		
$\Omega_c(3188)^0$	$3188 \pm 5 \pm 13$	$60 \pm 15 \pm 11$	$1670 \pm 450 \pm 360$	
$\Omega_c(3066)^0_{\mathrm{fd}}$			$700 \pm 40 \pm 140$	
$\Omega_c(3090)^0_{\mathrm{fd}}$			$220 \pm 60 \pm 90$	
$\Omega_c(3119)^0_{\mathrm{fd}}$			$190 \pm 70 \pm 20$	

Anti-15plet

Exotic anti-15plet naturally arises from the XQSM.



Anti-15plet

- Mass splitting due to the mean fields

$$\mathcal{M}_{\overline{\mathbf{15}},J=0} = M_{\rm sol} + \frac{5}{2}\frac{1}{\rho I_2},$$

$$\mathcal{M}_{\overline{\mathbf{15}},J=1} = M_{\rm sol} + \frac{3}{2}\frac{1}{\rho I_2} + \frac{1}{\rho I_1}$$

- Mass splitting is positive!

$$\Delta_{\overline{\mathbf{15}}} = \mathcal{M}_{\overline{\mathbf{15}},J=0} - \mathcal{M}_{\overline{\mathbf{15}},J=1} = \frac{1}{\rho}\left(\frac{1}{I_2} - \frac{1}{I_1}\right) > 0\,!$$

HChK, M. V. Polyakov, M. Praszalowicz, PRD **96**, 014009 (2017)

Anti-15plet

- SU(3) symmetry-breaking splitting

$$\Delta_s M_{\overline{\mathbf{15}}} = Y\left(\beta + \frac{17}{144}(\alpha - 2\gamma)\right) + \left(-\frac{2}{27} + \frac{1}{24}\left(T(T+1) - \frac{1}{4}Y^2\right)\right)(\alpha - 2\gamma).$$

HChK, M. V. Polyakov, M. Praszalowicz, PRD **96**, 014009 (2017)

Excited anti-3plet and 6plet

$$K = 1$$

$$\mathcal{M}'_{\overline{\mathbf{3}}} = M'_{\rm sol} + \frac{1}{2I_2} + \frac{1}{I_1}(1 - a_1^2).$$

$$\mathcal{M}'_{\mathbf{6}\;J} = \mathcal{M}'_{\overline{\mathbf{3}}} + \frac{1 - a_1}{I_1} + \frac{a_1}{I_1} \times \left\{ \begin{array}{rcl} -1 & \text{for} & J = 0 \\ 0 & \text{for} & J = 1 \\ 2 & \text{for} & J = 2 \end{array} \right. .$$

$$\delta'_{\overline{\mathbf{3}}} = \frac{3}{8}\bar{\alpha} + \beta = \delta_{\overline{\mathbf{3}}}$$

$$\delta'_{\mathbf{6}\;J} = \delta_{\mathbf{6}} - \frac{3}{20}\delta \times \left\{ \begin{array}{rcl} 2 & \text{for} & J = 0 \\ 1 & \text{for} & J = 1 \\ -1 & \text{for} & J = 2 \end{array} \right.$$

HChK, M. V. Polyakov, M. Praszalowicz, PRD **96**, 014009 (2017)

Hyperfine splittings

$$\Delta^{\mathrm{hf}}_{\overline{\mathbf{3}}} = \Delta^{\mathrm{hf}}_{\mathbf{6}\,J=1} = \frac{\kappa'}{m_c}, \quad \Delta^{\mathrm{hf}}_{\mathbf{6}\,J=2} = \frac{5}{3}\frac{\kappa'}{m_c}$$

- Candidates for excited anti-3plet

$$\Lambda_c(2592), \quad \Xi_c(2790) \text{ for } J^p = 1/2^-$$

$$\Lambda_c(2628), \quad \Xi_c(2818) \quad \text{for } J^P = 3/2^-$$

- Determine the parameters

$$\frac{\kappa'}{m_c} = \frac{1}{3}\left(M_{\Lambda_c(2628)} + 2M_{\Xi_c(2818)}\right) - \frac{1}{3}\left(M_{\Lambda_c(2252)} + 2M_{\Xi_c(2790)}\right) = 30 \text{ MeV},$$

$$\mathcal{M}'_{\overline{\mathbf{3}}} = \frac{2}{9}\left(M_{\Lambda_c(2628)} + 2M_{\Xi_c(2818)}\right) + \frac{1}{9}\left(M_{\Lambda_c(2252)} + 2M_{\Xi_c(2790)}\right) = 2744 \text{ MeV}$$

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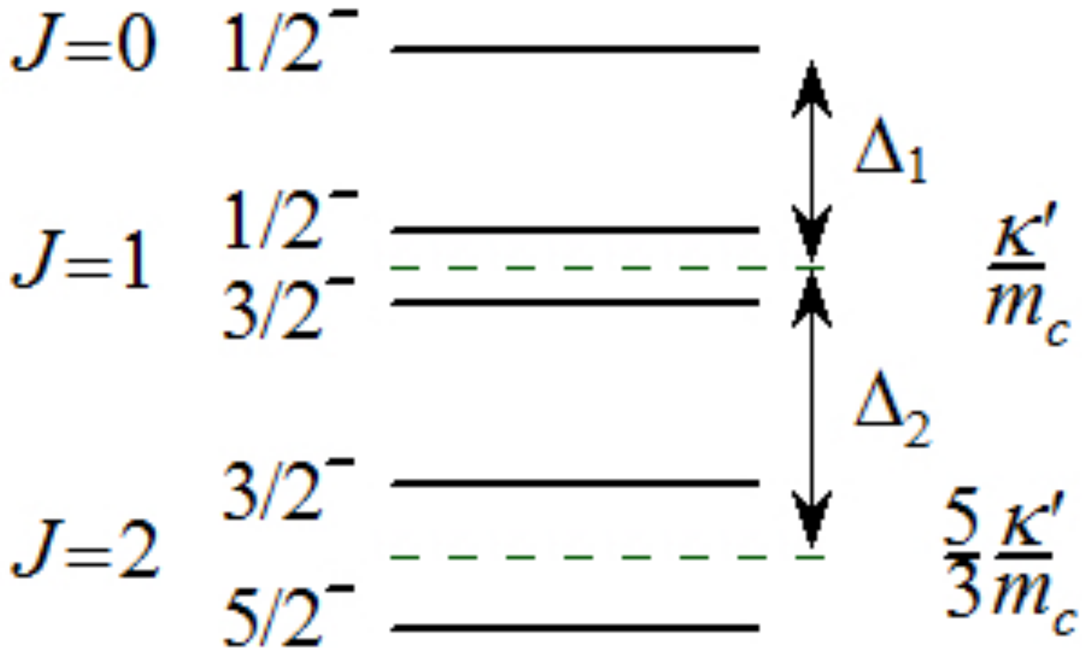
Hyperfine splittings



$$\Delta_1 = \frac{a_1}{I_1} + \frac{3}{20}\delta, \qquad \Delta_2 = 2\Delta_1$$

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Scenario I

Assertion: Five Omega_cs belong to excited sextets.

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		

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

The HF splittings are very much deviated from what we have determined from the anti-3plet.

Scenario II

Assertion: Thee Omega_cs belong to excited sextets, whereas two Omega_cs with smaller widths belongs to the anti-15plet.

J	S^P	M [MeV]	κ'/m_c [MeV]	Δ_J [MeV]
0	$\frac{1}{2}^-$	3000	–	–
1	$\frac{1}{2}^-$	3066	24	82
	$\frac{3}{2}^-$	3090		
2	$\frac{3}{2}^-$	*3222*	input	input
	$\frac{5}{2}^-$	*3262*	24	164

$$\frac{\kappa}{m_c} \approx 70\,\mathrm{MeV}$$

Excellent agreement with the ground-state value!

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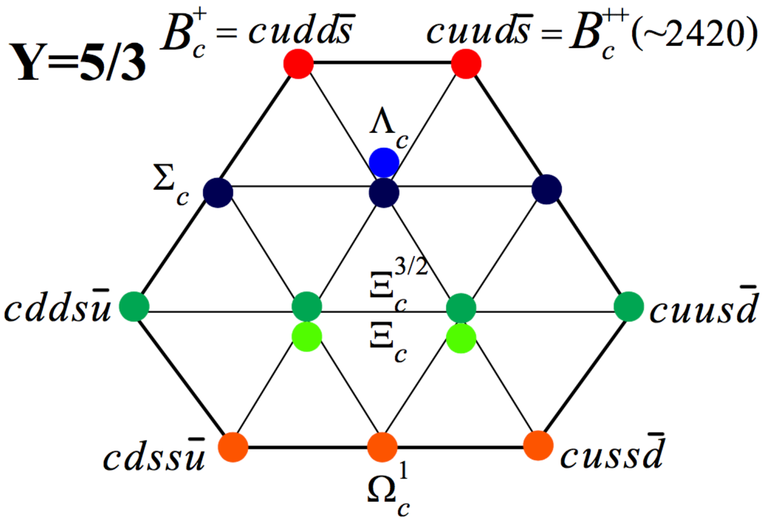
LHCb Findings: New five Omega_cs

$\Omega_c(3050)$ and $\Omega_c(3119)$ as a exotic anti-15plet

Resonance	Mass (MeV)	Γ (MeV)	Yield	N_σ
$\Omega_c(3000)^0$	$3000.4 \pm 0.2 \pm 0.1^{+0.3}_{-0.5}$	$4.5 \pm 0.6 \pm 0.3$	$1300 \pm 100 \pm 80$	20.4
$\Omega_c(3050)^0$	$3050.2 \pm 0.1 \pm 0.1^{+0.3}_{-0.5}$	$0.8 \pm 0.2 \pm 0.1$	$970 \pm 60 \pm 20$	20.4
		$< 1.2\,\mathrm{MeV}$, 95% CL		
$\Omega_c(3066)^0$	$3065.6 \pm 0.1 \pm 0.3^{+0.3}_{-0.5}$	$3.5 \pm 0.4 \pm 0.2$	$1740 \pm 100 \pm 50$	23.9
$\Omega_c(3090)^0$	$3090.2 \pm 0.3 \pm 0.5^{+0.3}_{-0.5}$	$8.7 \pm 1.0 \pm 0.8$	$2000 \pm 140 \pm 130$	21.1
$\Omega_c(3119)^0$	$3119.1 \pm 0.3 \pm 0.9^{+0.3}_{-0.5}$	$1.1 \pm 0.8 \pm 0.4$	$480 \pm 70 \pm 30$	10.4
		$< 2.6\,\mathrm{MeV}$, 95% CL		
$\Omega_c(3188)^0$	$3188 \pm 5 \pm 13$	$60 \pm 15 \pm 11$	$1670 \pm 450 \pm 360$	
$\Omega_c(3066)^0_{\mathrm{fd}}$			$700 \pm 40 \pm 140$	
$\Omega_c(3090)^0_{\mathrm{fd}}$			$220 \pm 60 \pm 90$	
$\Omega_c(3119)^0_{\mathrm{fd}}$			$190 \pm 70 \pm 20$	

LHCb Findings: New five Omega_cs

	Y	T	$S^P = \frac{1}{2}^+$	$S^P = \frac{3}{2}^+$
B_c	$\frac{5}{3}$	$\frac{1}{2}$	2685	2754
Σ_c	$\frac{2}{3}$	1	2808	2877
Λ_c	$\frac{2}{3}$	0	2806	2875
Ξ_c	$-\frac{1}{3}$	$\frac{1}{2}$	2928	2997
$\Xi_c^{3/2}$	$-\frac{1}{3}$	$\frac{3}{2}$	2931	3000
Ω_c	$-\frac{4}{3}$	1	3050	3119



Bc baryons will decay weakly. So, they should be stable!