Excited Baryons in $1/N_c$ Expansion

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1. Short Introduction to Large N_c QCD

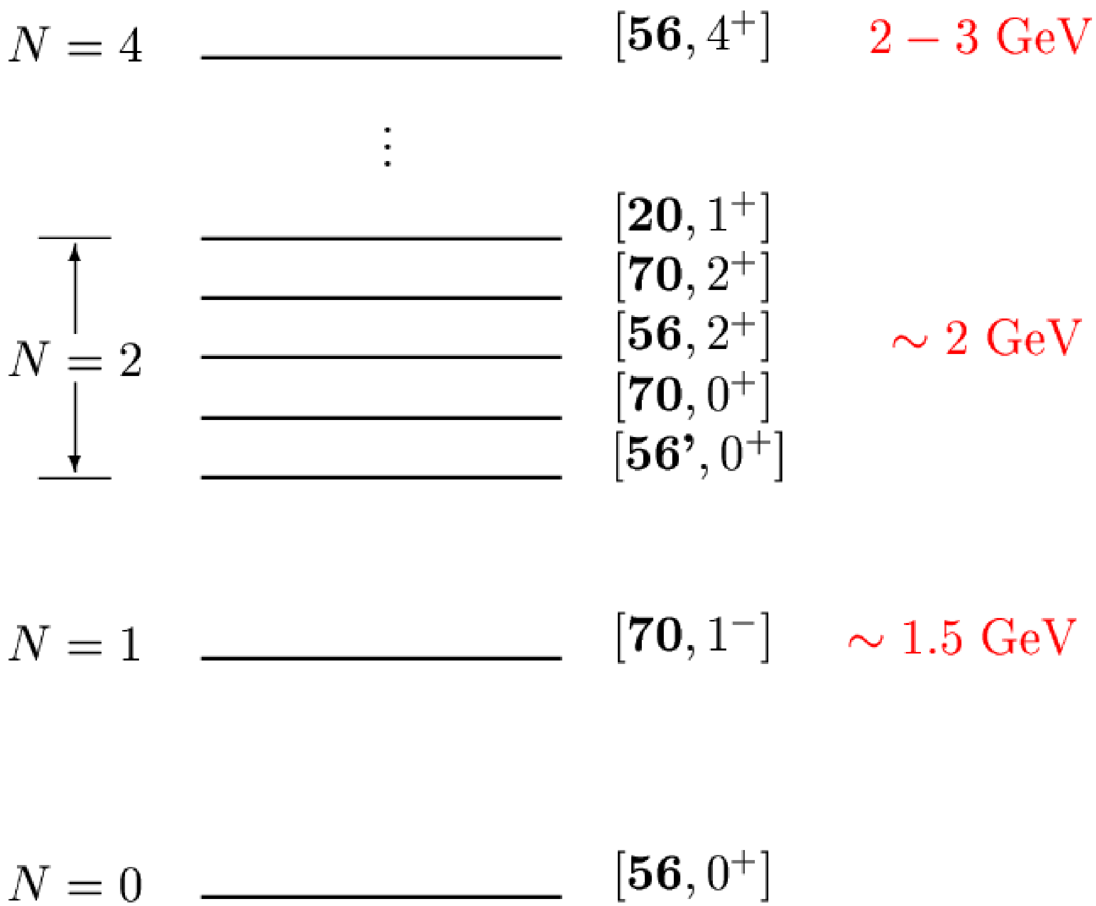
- Impossible to solve QCD exactly

- No perturbative development of QCD at low energies with respect to g

- 't Hooft (1974) suggested to generalize QCD to N_c color
  $\Rightarrow$ $1/N_c$ should be the expansion parameter of QCD
  In QCD with N_c colors, we have $N_c^2 - 1$ gluons and N_c quarks
  $\Rightarrow$ $1/N_c$ expansion leads suppression of some Feynman diagrams

- Baryons in Large N_c : bound state of N_c quarks antisymmetric in color
  $\Rightarrow$ Baryon mass grows with N_c

2. The Baryon Spectrum with Linear Confinement and $N_c = 3$



Results for mass splittings for $[\mathbf{56}, 0^+]$, $[\mathbf{70}, 1^-]$, $[\mathbf{56}, 2^+]$ and $[\mathbf{56}, 4^+]$ multiplets in large N_c

3. Excited $[\mathbf{70}, \ell^+]$ Baryon Multiplet ($\ell = 0, 2$)

N. Matagne and Fl. Stancu, hep-ph/0505118, PLB, to appear

Mass operator :

$$M_{[\mathbf{70},\ell^+]} = \sum_{i=1}^{4} c_i O_i$$

Consider a symmetric core of $N_c - 1$ quarks and an excited quark.

$$\Rightarrow \begin{cases} \ell_c^i,\ S_c^i,\ T_c^a,\ G_c^{ia} \text{ acting on the core} \\ \ell_q^i,\ s^i,\ t^a,\ g^{ia} \text{ acting on the excited quark} \end{cases}$$

Case of the spin-orbit interaction, one-body operator :

$$\langle \Psi | \ell_q^i s^i | \Psi \rangle = \begin{cases} \mathcal{O}(N_c^0) & \text{if } \chi \text{ is mixed} - \text{symmetric} \\ \mathcal{O}(N_c^{-1}) & \text{if } \chi \text{ is symmetric} \end{cases}$$

where χ is the spin-flavor part of the wave function

Non-strange baryons so far

Mass operator :

$$M_{[\mathbf{70},\ell^+]} = \sum_{i=1}^{4} c_i O_i$$

Operator	Order	Fitted coef. (MeV)
$O_1 = N_c \mathbb{1}$	N_c	$c_1 =$ 555 $\pm$ 11
$O_2 = \ell_q^i s^i$	N_c^0	$c_2 =$ 47 $\pm$ 100
$O_3 = \frac{3}{N_c}(\ell_q^{(2)ij} g^{ia} G_c^{ja})$	N_c^0	$c_3 =$ -191 $\pm$ 132
$O_4 = \frac{1}{N_c}(S_c^i S_c^i + s^i S_c^i)$	N_c^{-1}	$c_4 =$ 261 $\pm$ 47

$$\chi^2_{\text{dof}} = 0.83$$

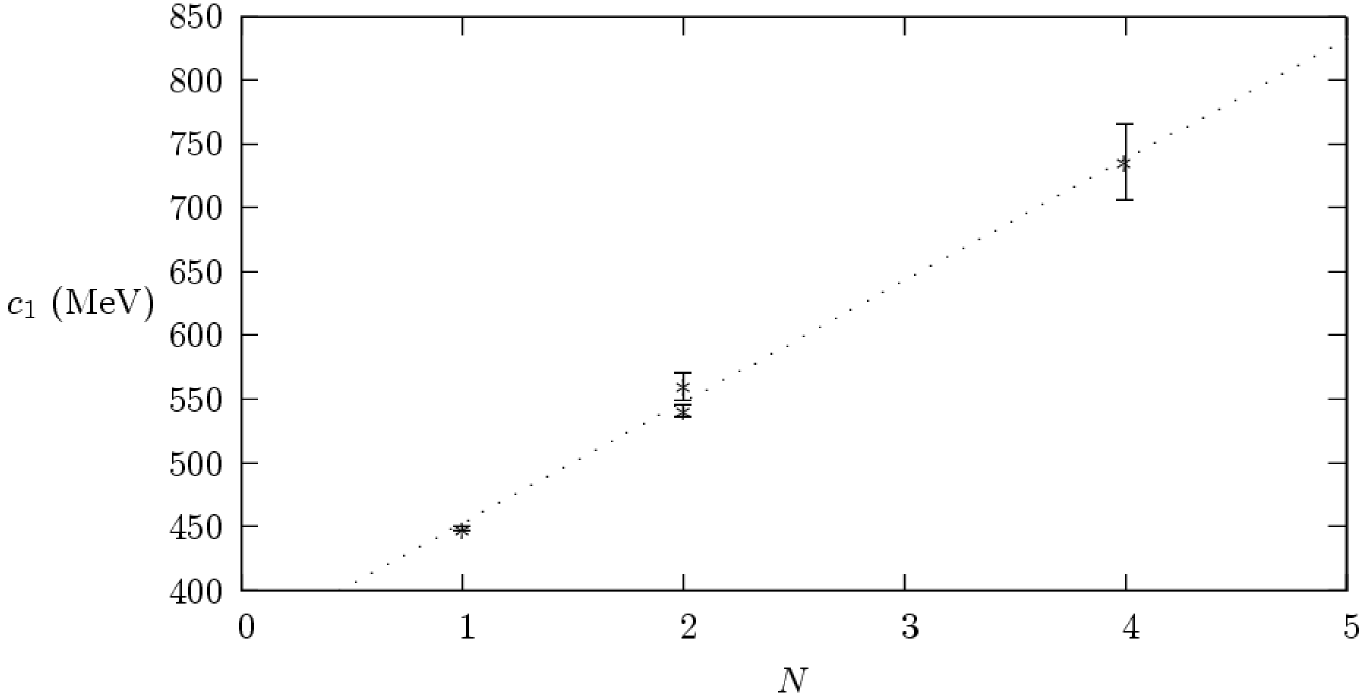
with

$$\ell_q^{(2)ij} = \frac{1}{2}\left\{\ell_q^i, \ell_q^j\right\} - \frac{1}{3}\delta_{i,-j}\vec{\ell}_q \cdot \vec{\ell}_q$$

	1/N_c expansion results						
	Partial contribution (MeV)				Total (MeV)	Empirical (MeV)	Name, status
	c_1O_1	c_2O_2	c_3O_3	c_4O_4			
$^4N[\mathbf{70},2^+]\frac{7}{2}^+$	1665	31	42	217	1956 ± 95	2016 ± 104	$F_{17}(1990)$**
$^2N[\mathbf{70},2^+]\frac{5}{2}^+$	1665	10	0	43	1719 ± 34		
$^4N[\mathbf{70},2^+]\frac{5}{2}^+$	1665	-5	-106	217	1771 ± 88	1981 ± 200	$F_{15}(2000)$**
$^4N[\mathbf{70},0^+]\frac{3}{2}^+$	1665	0	0	217	1883 ± 17	1879 ± 17	$P_{13}(1900)$**
$^2N[\mathbf{70},2^+]\frac{3}{2}^+$	1665	-16	0	43	1693 ± 42		
$^4N[\mathbf{70},2^+]\frac{3}{2}^+$	1665	-31	0	217	1851 ± 69		
$^2N[\mathbf{70},0^+]\frac{1}{2}^+$	1665	0	0	43	1709 ± 25	1710 ± 30	$P_{11}(1710)$***
$^4N[\mathbf{70},2^+]\frac{1}{2}^+$	1665	-47	149	217	1985 ± 26	1986 ± 26	$P_{11}(2100)$*
$^2\Delta[\mathbf{70},2^+]\frac{5}{2}^+$	1665	-10	0	87	1742 ± 29	1976 ± 237	$P_{35}(2000)$**
$^2\Delta[\mathbf{70},2^+]\frac{3}{2}^+$	1665	16	0	87	1768 ± 38		
$^2\Delta[\mathbf{70},0^+]\frac{1}{2}^+$	1665	0	0	87	1752 ± 19	1744 ± 36	$P_{31}(1750)$*

4. Comments on the dependence of the mass operator with the excitation energy

The coefficient of the SU(6) symmetric term as a function of excitation energy (N)



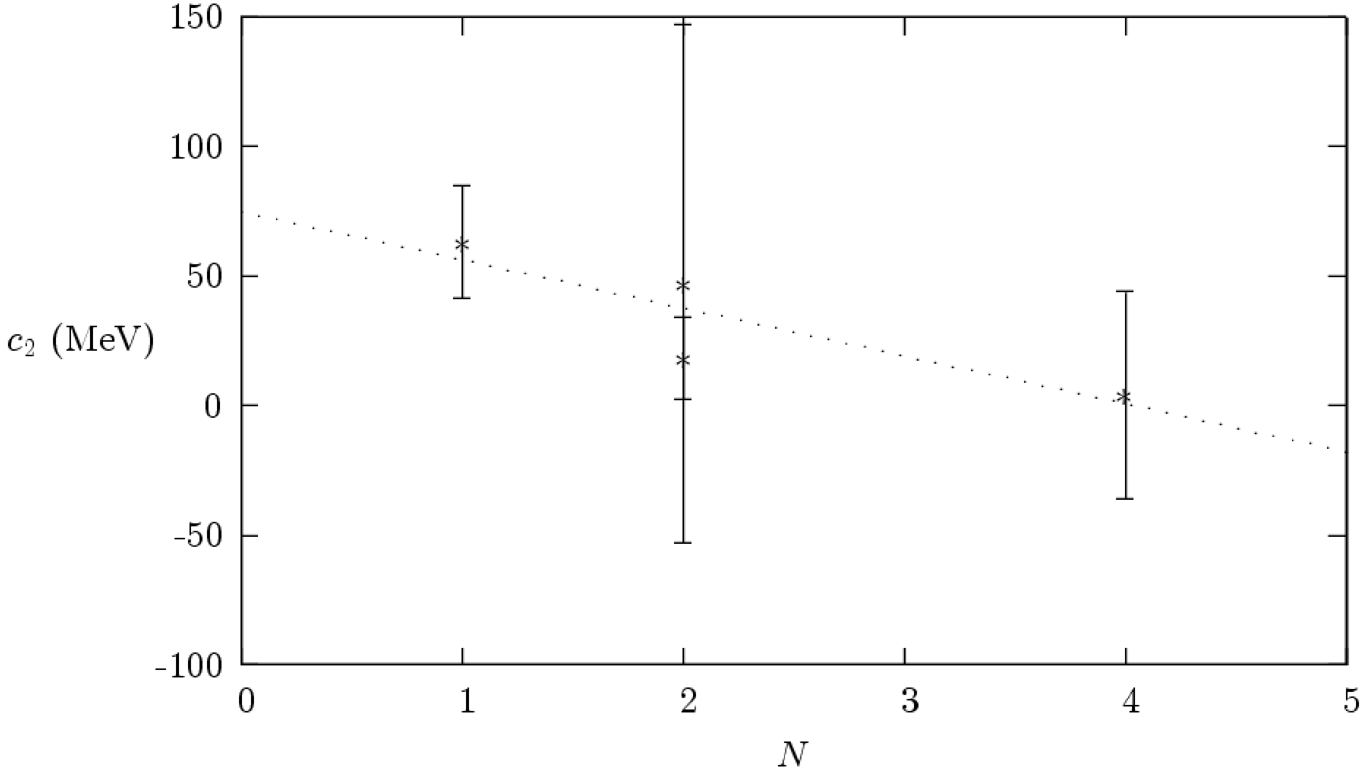
$N = 1$, $[\mathbf{70}, 1^-]$ C.E. Carlson, C.D. Carone, J.L. Goity and R.F. Lebed, Phys. Rev. **D59**, 114008 (1999).

$N = 2$, $[\mathbf{56}, 2^+]$ J.L. Goity, C.L. Schat, N.N. Scoccola, Phys. Lett. **B564**, 83 (2003).

$N = 2$, $[\mathbf{70}, \ell^+]$ Present results.

$N = 4$, $[\mathbf{56}, 4^+]$ N. Matagne, Fl. Stancu, Phys. Rev. **D71**, 014010 (2005).

The coefficient of the spin-orbit term vs N



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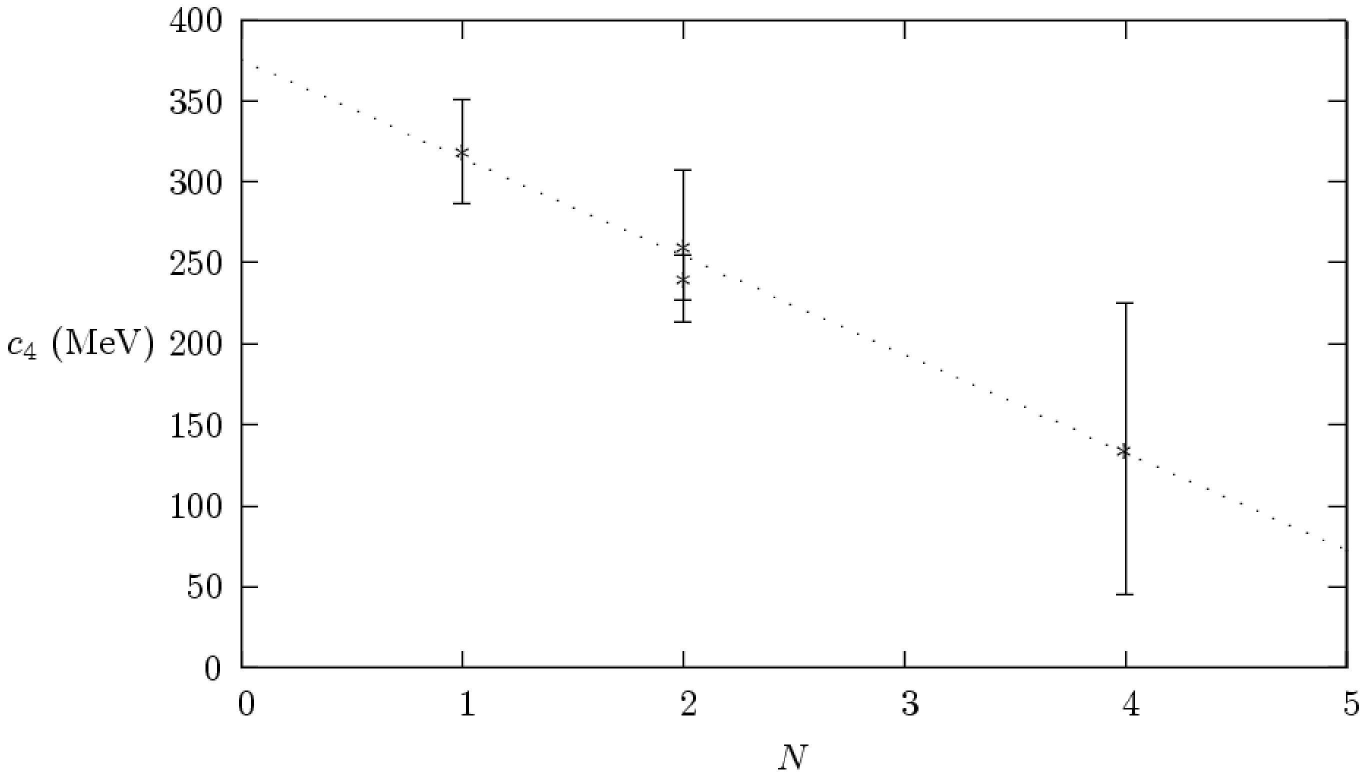
The coefficient of the spin-spin term vs N



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5. Conclusions

- The $1/N_c$ expansion is successful for excited states
- Dominant spin-spin interaction
- The spin-orbit interaction pratically vanishes above 2 GeV
- Better experimental data are needed
- Include strange baryons – data are badly needed
- Incorporate configuration mixing in the $N = 2$ sector