UBPub-EPPG-PHYS-37

BUCHAREST UNIVERSITY

EXPERIMENTAL PARTICLE PHYSICS GROUP

FEB 16 1998

UBPub. EPPG/PHYS. 37

January 1998

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MASS PREDICTIONS FOR BARYONS

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Abstract.

In the present paper, the existing parametrisation for light baryons [1, 2] are extended to other families. The masses for baryons with charm and bottom are predicted and compared with other estimations, and with experimental data, when available.

The consequences of model hypothesis are also analysed, and their validity checked.

paper presented at the Third General Conference of the Balkan Physical Union, Cluj-Napoca, 2-5 Sept. 1997, Romania
to be published in Balkan Physics Letters

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Abstract. In the present paper, the existing parametrisation for light baryons [1, 2] are extended to other families. The masses for baryons with charm and bottom are predicted and compared with other estimations, and with experimental data, when available.

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1. Introduction

The general parametrisation method (GPM) provides the most general form of the spin-flavour structure, derivable from the QCD Lagrangean, for, e.g. masses, magnetic moments, semileptonic matrix elements.

In the $SU(3)\otimes SU(2)_{spin}$ group of representation, in the GPM, the masses of the lowest **8** and **10** multiplets of baryons can be calculated, after [1] as:

$$\begin{aligned} \text{"parametrised mass"} &= M_o + B\sum_i P_i^s + C\sum_{i>k}(\sigma_i\sigma_k) \\ &+ D\sum_{i>k}(\sigma_i\sigma_k)(P_i^s + P_k^s) + E\sum_{\substack{i\neq k\neq j\\(i>k)}}(\sigma_i\sigma_k)P_j^s + a\sum P_i^s P_k^s \\ &+ b\sum_{i>k}(\sigma_i\sigma_k)P_i^s P_k^s + c\sum_{\substack{i\neq k\neq j\\(i>k)}}(\sigma_i\sigma_k)(P_i^s + P_k^s)P_j^s + dP_1^s P_2^s P_3^s \end{aligned} \qquad (1)$$

where the σ_i's are the Pauli matrices, and P^s is the projector on the strange quark field:

$$\begin{vmatrix} 0 & & \\ & 0 & \\ & & 1 \end{vmatrix} \equiv (1-\lambda_s)/3 \;;\; P^s s = s; P^s u = 0; P^s d = 0 \qquad (2)$$

The "parametrised mass" contains nine parameters. In the cited work [1], Dillon and Morpurgo shown that the flavour-breaking scale for baryons and mesons is the same, and established the relations between the magnitudes of different parameters [2,3].

In the present work we extend the mass prediction model in the sectors of the baryons with charm and bottom and discuss the consequences for the baryons containing the top quark.

2. Model

The present paper is an extension of the model presented in [1], for the heavier sectors of the baryons with charm and bottom. We work in the frame of the $SU(3)\otimes SU(2)_{spin}$ group, that is a subgroup of the $SU(4)\otimes SU(2)_{spin}$ and respectively $SU(5)\otimes SU(2)_{spin}$ groups. The model predicts the masses of the baryons with the structures (qqx), (qxx) and (xxx), where q is the light quark (u, d), and x is the quark with strangeness (s), charm (c) or bottom (b).

Because for the heavy baryons there are only few experimental data, we cannot determine all nine parameters from equation (1). So, we made some additional assumptions:

- In the parametrised masses, the magnitudes of the parameters decrease from M_0 to d. The parameters M_0, B, C and D are essential, all others can be seen as corrections, and are neglected.

- The parameter B and the ratio D/C are the same for the baryons and for mesons.

Now, we rewrite the equation (1) as:

$$\begin{aligned} \text{"parametrised mass"} &= M_o + B\sum_i P_i^s + C\sum_{i>k}(\sigma_i\sigma_k) \\ &+ D\sum_{i>k}(\sigma_i\sigma_k)(P_i^s + P_k^s) \end{aligned} \qquad (3)$$

3. Results and Discussion

First we tested the validity of the above mentioned hypothesis for light baryons. The parameter B and the ratio D/C were determined from the masses of π, ρ, K and K^* mesons [2,4]; while M_0 and C from the nucleon and Δ_{33} masses, using the GPM.

The model parameters M_0, B, C and D for the light family are shown in Table 1.

Table 1

	Model parameters			
	M_0 (MeV)	B (MeV)	C (MeV)	D (MeV)
Light baryons	1085.5	182	48.83	-17.92
Baryons with charm	1085.5	1362.75	48.83	-37.59
Baryon with bottom	1085.5	4700	48.83	-44.92

Using the before determined parameters, listed in Table 1, the model has been tested for light strange baryons (x=s), whose structure is given in Table 2.

Table 2

Baryon	Quark and spin structure	"Parametrised mass"
Σ_x	$(qqx)\otimes(\uparrow\uparrow\downarrow)$	M_0 +B - 3C -4D
Σ_x^*	$(qqx)\otimes(\uparrow\uparrow\uparrow)$	M_0 +B + 3C +2D
Ξ_x	$(qxx)\otimes(\uparrow\uparrow\downarrow)$	M_0 +2B - 3C -2D
Ξ_x^*	$(qxx)\otimes(\uparrow\uparrow\uparrow)$	M_0 +2B + 3C + 4D
Ω_x	$(xxx)\otimes(\uparrow\uparrow\uparrow)$	M_0 +3B + 3C + 6D
Λ_x	$(udx)\otimes(\uparrow\uparrow\downarrow)$	M_0 +B - 3C

The very good concordance between model calculations and experimental data for strange baryons (see Table 3) is an important argument for the validity of the listed hypothesis.

For heavy baryons, the same calculation method has been applied. The model parameters B and D have been determined using the experimental masses for D, D* and B, B* mesons respectively These values are also listed in Table 1. The obtained results and the comparison with experimental data or other model predictions, when available, are presented in Table 3. A very good agreement has been found in this case, too.

Table 3

	Strange baryons (x = s)		Heavy baryons (x = c)		Heavy baryons (x = b)	
Baryon	Predicted mass (MeV)	Exp. mass (MeV) [5]	Predicted mass (MeV)	Exp. mass (MeV) [5]	Predicted mass (MeV)	Exp. or calc. mass (MeV) [5], [6]
Σ_x	1193	1193	2452	2452.9 ± 0.9	5819	5818 ± 20
Σ_x^*	1378	1385	2511		5842	5843 ± 22
Ξ_x	1339	1318	3740		10429	
Ξ_x^*	1524	1530	3807		10452	
Ω_x	1670	1672	5095		15062	
Λ_x	1121	1116	2302	2284.9 ± 0.6	5639	5641 ± 50

From the analysis of the parameters from Table 1, it can be observed, with the passage from light to heavy baryons, an increase of the weight of the B parameter in the mass, the last one being dominant for baryons with bottom. This way, for heavy baryons, the spin - spin splitting (see also the values of C and D) becomes unimportant.

If the model will be valid in the energy range of the top quark (175 GeV/c^2), then the B parameter with an extrapolated value of B ≅ 166 GeV gives the dominant term in the parametrised mass. But the existence of these baryons is doubtful, because the width due to single quark decay ($t \rightarrow b + W$), that is around 1.55 GeV [7] exceeds the spacing between the spectrum states.

4. Summary

The model of the general parametrisation has been applied for the heavy baryon masses with quark structure: (qqs), (qss), (sss), (qqc), (qcc), (ccc), (udc), (qqb), (qbb) and (bbb), with the spin structure $1/2^+$ and $3/2^+$.

New mass predictions have been obtained for heavy baryon families.

The very good agreement between the mass calculations and the experimental data, when existent, is an important argument for the validity of the before mentioned model hypothesis.

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