Compact pentaquark Structures

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INTRODUCTION

In 2015, the Large Hadron Collider beauty experiment (LHCb) collaboration observed two hidden-charm pentaquarks, $P_c^+(4380)$ and $P_c^+(4450)$ in $\Lambda_B \to J/\psi K^- p$ decay [1].

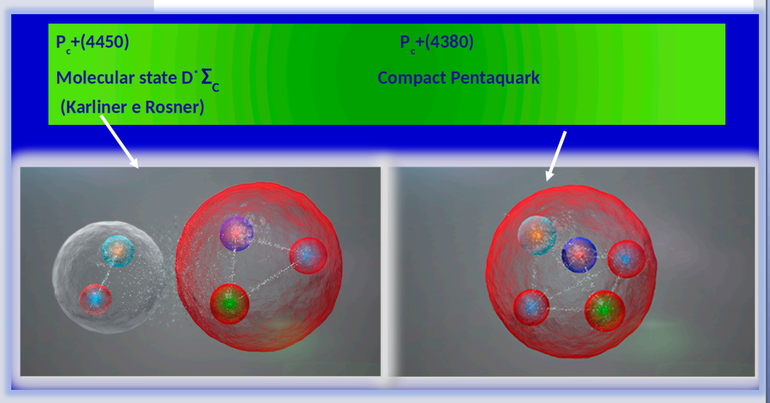
These two pentaquark states are found to have masses of $4380 \pm 8 \pm 28$ MeV and $4449.8 \pm 1.7 \pm 2.5$ MeV, with corresponding widths of $205 \pm 18 \pm 86$ MeV and $39 \pm 5 \pm 19$ MeV.

The parities of these states are preferred to be opposite, and one state has J = 3/2 and the other J =5/2.

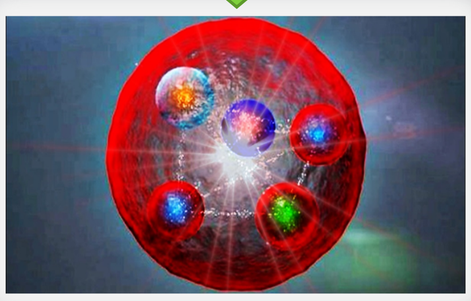
$\left(J^P_{P_c^+(4380)}, J^P_{P_c^+(4380)}\right) = \left(\frac{3}{2}^-, \frac{5}{2}^+\right)$ gives the best fit solution, but $\left(\frac{3}{2}^+, \frac{5}{2}^-\right)$ and $\left(\frac{5}{2}^-, \frac{3}{2}^-\right)$ are also acceptable

AIM OF THE STUDY

Within Karliner e Rosner's framework [2], the pentaquark state $P_c^+(4450)$ can be interpreted as molecular state, however the $P_c^+(4380)$ is missing in their description.



For this reson, we focused on the lightest pentaquark structure, Pc(4380), and adopted a **multiquark approach [3]**.



STRATEGY

In order to determine the SU(3) flavour multiplet to whom belongs the $P_c^+(4380)$ resonance, it has been necessary an extension of the GÜRSEY-RADICATI mass formula [4].

As yet, there is experimental evidence of only two charmonium pentaquark states; these are not enough to determine all parameters in the GR mass formula. For this reason, we used the values of the parameters determined from the three quark spectrum assuming that the coefficients in the GR formula are the same for different quark systems.

RESULTS

We have shown that the pentaquark ground multiplet is a SU_f (3) octet with spin S =3/2.

The theoretical mass of the lightest pentaquark state observed by LHCb, as predicted by the GR mass formula extension, is M = 4377 ± 49 MeV, in agreement with the experimental mass.

In calculating the decay widths of the predicted pentaquark states, we adopted an effective Lagrangian for the $p\,N\,J/\psi$ couplings from Ref. [5], with the upper branching ratio limit extracted by Wang et al. in [6].

Predicted pentaquark states	Masses [MeV]
$P^{00}(4377), P^{0+}(4377)$	4377 ± 49
$P^{1'0}(4520)$	4520 ± 47
$P^{1-}(4584), P^{10}(4584), P^{1+}(4584)$	4584 ± 50
$P^{2-}(4694), P^{20}(4694)$	4694 ± 47

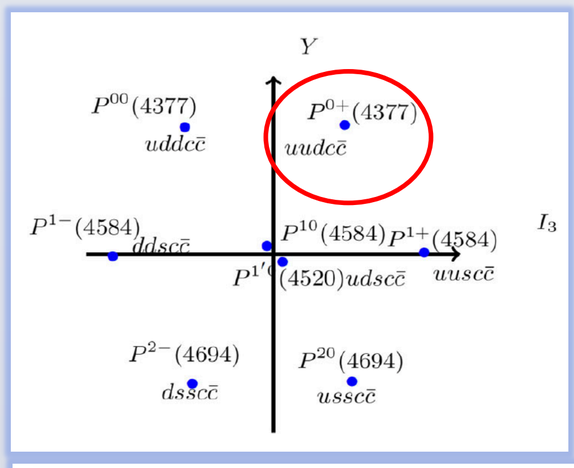


Table 1 and Figure 1: Octet of the charmonium pentaquark states each state is labeled as $P^{ij}(M)$., where $i = 0,1,2$ is the number of strange quarks of a given pentaquark state $j = 0, -, +.$ is the pentaquark's electric charge, and M is the predicted mass.

Initial state	Channel	Partial width [MeV]
$P^{1'0}$	$\Lambda J/\Psi$	7.94
P^{1-}, P^{10}, P^{1+}	$\Sigma J/\Psi$	7.21
P^{2-}, P^{20}	$\Xi J/\Psi$	6.35

We have calculated the partial decay widths for $\Lambda\, J/\Psi$, $\Sigma\, J/\Psi$, $\Xi\, J/\Psi$ channels.

CONCLUSIONS

We have studied all the charmonium pentaquark states which belong to the flavour octet, predicted their masses, and suggested possible bottom baryon decay channels which involve the predicted resonances as intermediate states. Finally, we computed the partial decay widths for all the suggested octet-pentaquark decay channels.

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