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Editor Focus

LHCb gets closer to discovering the second doubly charmed baryon

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Recently the LHCb Collaboration [1] published the results of a search for the doubly charmed baryon Ξ_{cc}^{+}. No significant signal is seen in the mass range from 3.4 to 3.8 GeV. To put this result in context, the Ξ_{cc}^{++} baryon was seen by LHCb in decay modes $\Lambda_c K^- \pi^+ \pi^+$ [2] (2017) and $\Xi_c^+ \pi^+$ [3] (2018). The weighted average of the Ξ_{cc}^{++} mass is 3621.24 ± 0.65 (stat.) $\pm$ 0.31 (syst.) MeV [3].

The Ξ_{cc}^{++} and Ξ_{cc}^{+} have the quark content *ccu* and *ccd*, respectively. Under the isospin symmetry of the strong interactions they form an isodoublet, like the proton and the neutron. Isospin breaking in hadron masses is a very small effect [4]. Consequently we have firm reasons to expect that the $\Xi_{cc}^{++} - \Xi_{cc}^{+}$ mass difference is quite small, $O(1.5)$ MeV [5]. The production rates of Ξ_{cc}^{++} and Ξ_{cc}^{+} should be similar, as the bottleneck—the production of the *cc* diquark—is the same in both cases. Consequently we *know* Ξ_{cc}^{+} exists in the vicinity of 3620 MeV. A claimed Ξ_{cc}^{+} at (3518.7±1.7) MeV [6, 7] is unlikely to be the isospin partner of the established Ξ_{cc}^{++}, and has not been confirmed by any other experiment.

The search was a "blind analysis", i.e., it was performed with the whole procedure defined before inspecting the data in the 3400 to 3800 MeV mass range. A search for a Ξ_{cc}^{+} signal was performed and the significance of the signal as a function of the Ξ_{cc}^{+} mass was evaluated. If the global significance, after considering the look-elsewhere effect, was found to be above 3σ, the Ξ_{cc}^{+} mass was measured; otherwise, upper limits were set on the production rates for different CM energies.

As can be seen from Figure 2 in ref. [1], the data exhibit several peaks, but the most significant one occurs just where it is expected. The largest local significance, corresponding to 3.1σ (2.7σ after considering systematic uncertainties), occurs around 3620 MeV. However, the look-elsewhere effect [8], intrinsic to the LHCb search procedure, reduces this to 1.7σ. We believe that in this case the look-elsewhere effect may be overstated, because the peak shows up nearly (but not precisely) where expected. The result of a fit, as given in the Supplementary Material of ref. [1], is $M(\Xi_{cc}^{+}) = (3623.4 \pm 1.7)$ MeV, a bit *larger* than $M(\Xi_{cc}^{++})$, in contrast to the prediction of ref. [5] and nearly all the others quoted there which find $M(\Xi_{cc}^{+})$ less than but within a few MeV of $M(\Xi_{cc}^{++})$.

The upper limit on Ξ_{cc}^{+} production (or the significance of a signal) increases with shorter assumed lifetime, as seen in Table 6 and Figure 6 of ref. [1]. As a result of the internal $cd \to su$ process in the decay of Ξ_{cc}^{+}, its lifetime is several times shorter than that of Ξ_{cc}^{++}: for example, ref. [9] finds $\tau(\Xi_{cc}^{+}) = 53$ fs, and $\tau(\Xi_{cc}^{++}) = 185$ fs. (The latter was measured by LHCb to be $256^{+24}_{-22} \pm 14$ fs [10].)

The validity of the prediction of $M(\Xi_{cc}^{++})$ [9] and the signal of its isospin partner not far from *its* predicted mass [5] lend credence to an estimate of the mass of the $cc\bar{u}\bar{d}$ tetraquark using similar methods, which finds this state to have a mass of (3882 ± 12) MeV [11] and hence unstable with respect to strong decay. The cross section for $cc\bar{u}\bar{d}$ tetraquark

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production is expected [11] to be somewhat, but not much, smaller than the cross section for production of Ξ_{cc}^{++} and Ξ_{cc}^{+} baryons. Thus the new LHCb results provide additional motivation for continuing the search for the $cc\bar{u}\bar{d}$ tetraquark.

In summary, the data contain a 2.7σ hint of the Ξ_{cc}^{+} signal at a mass consistent with predictions based on the measured Ξ_{cc}^{++} mass and isospin symmetry. More data are needed to exclude the possibility that this is a statistical fluctuation.

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