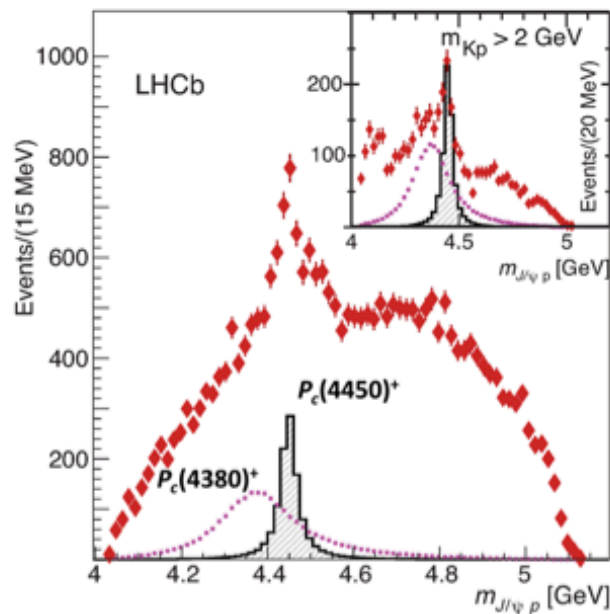


# CERN's LHCb experiment reports observation of exotic pentaquark particles

July 14 2015



The mass of  $J/\psi$ -proton ( $J/\psi p$ ) combinations from  $L_b \rightarrow J/\psi p K$  decays. The data are shown as red diamonds. The predicted contributions from the  $P_c(4380)^+$  and  $P_c(4450)^+$  states are indicated in the purple and black distributions, respectively. Inset: the mass of  $J/\psi p$  combinations for a restricted range of the  $K p$  mass, where the contribution of the wider  $P_c(4380)^+$  state is more pronounced. (The other contributions from conventional hadrons, which are responsible for the remaining features in the data distributions, are not displayed.)

Credit: CERN / LHCb Collaboration

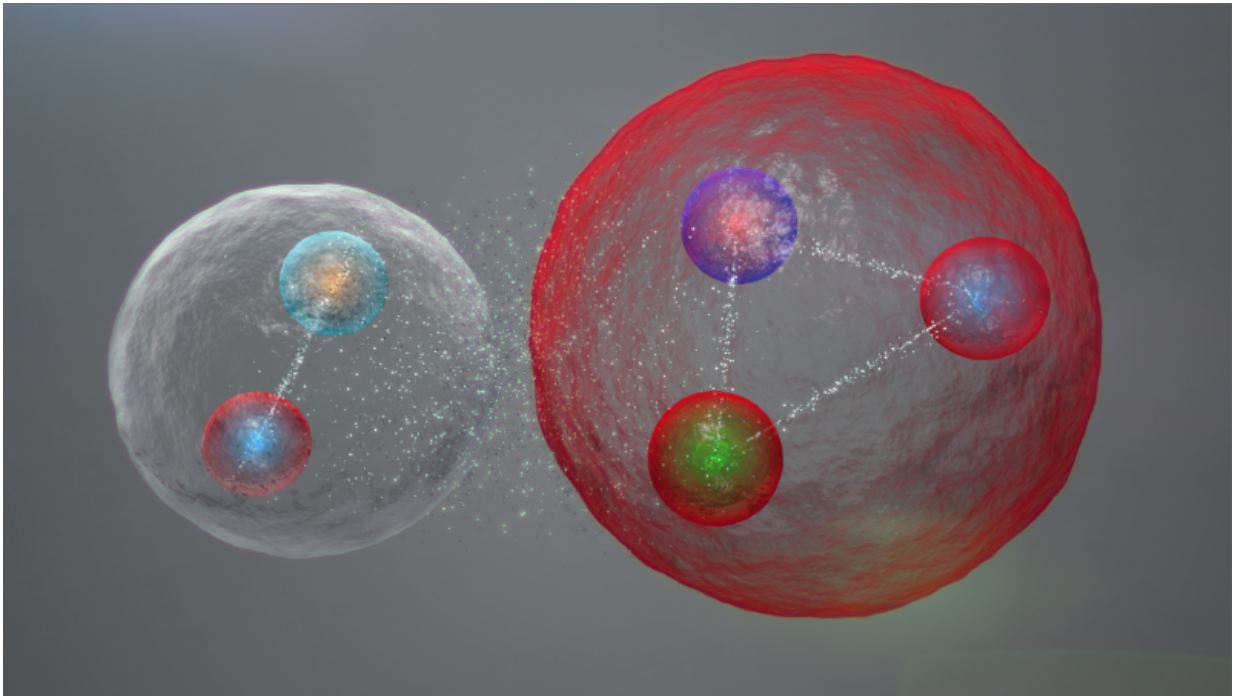
Today, the LHCb experiment at CERN's Large Hadron Collider has

reported the discovery of a class of particles known as pentaquarks. The collaboration has submitted a paper reporting these findings to the journal *Physical Review Letters*.

"The pentaquark is not just any new particle," said LHCb spokesperson Guy Wilkinson. "It represents a way to aggregate [quarks](#), namely the fundamental constituents of ordinary protons and neutrons, in a pattern that has never been observed before in over fifty years of experimental searches. Studying its properties may allow us to understand better how ordinary matter, the protons and neutrons from which we're all made, is constituted."

Our understanding of the structure of matter was revolutionized in 1964 when American physicist, Murray Gell-Mann, proposed that a category of particles known as baryons, which includes protons and neutrons, are comprised of three fractionally charged objects called quarks, and that another category, mesons, are formed of quark-antiquark pairs. Gell-Mann was awarded the Nobel Prize in physics for this work in 1969. This quark model also allows the existence of other quark composite states, such as pentaquarks composed of four quarks and an antiquark. Until now, however, no conclusive evidence for pentaquarks had been seen.

LHCb researchers looked for pentaquark states by examining the decay of a baryon known as  $\Lambda_b$  (Lambda b) into three other particles, a  $J/\psi$  ( $J/\psi$ ), a proton and a charged kaon. Studying the spectrum of masses of the  $J/\psi$  and the proton revealed that intermediate states were sometimes involved in their production. These have been named  $P_c(4450)^+$  and  $P_c(4380)^+$ , the former being clearly visible as a peak in the data, with the latter being required to describe the data fully.



The five quarks might also be assembled into a meson (one quark and one antiquark) and a baryon (three quarks), weakly bonded together. Credit: CERN / LHCb Collaboration

"Benefitting from the large data set provided by the LHC, and the excellent precision of our detector, we have examined all possibilities for these signals, and conclude that they can only be explained by pentaquark states", says LHCb physicist Tomasz Skwarnicki of Syracuse University.

"More precisely the [states](#) must be formed of two up quarks, one down quark, one charm quark and one anti-charm quark."

Earlier experiments that have searched for pentaquarks have proved inconclusive. Where the LHCb experiment differs is that it has been able to look for pentaquarks from many perspectives, with all pointing to the

same conclusion. It's as if the previous searches were looking for silhouettes in the dark, whereas LHCb conducted the search with the lights on, and from all angles. The next step in the analysis will be to study how the quarks are bound together within the pentaquarks.

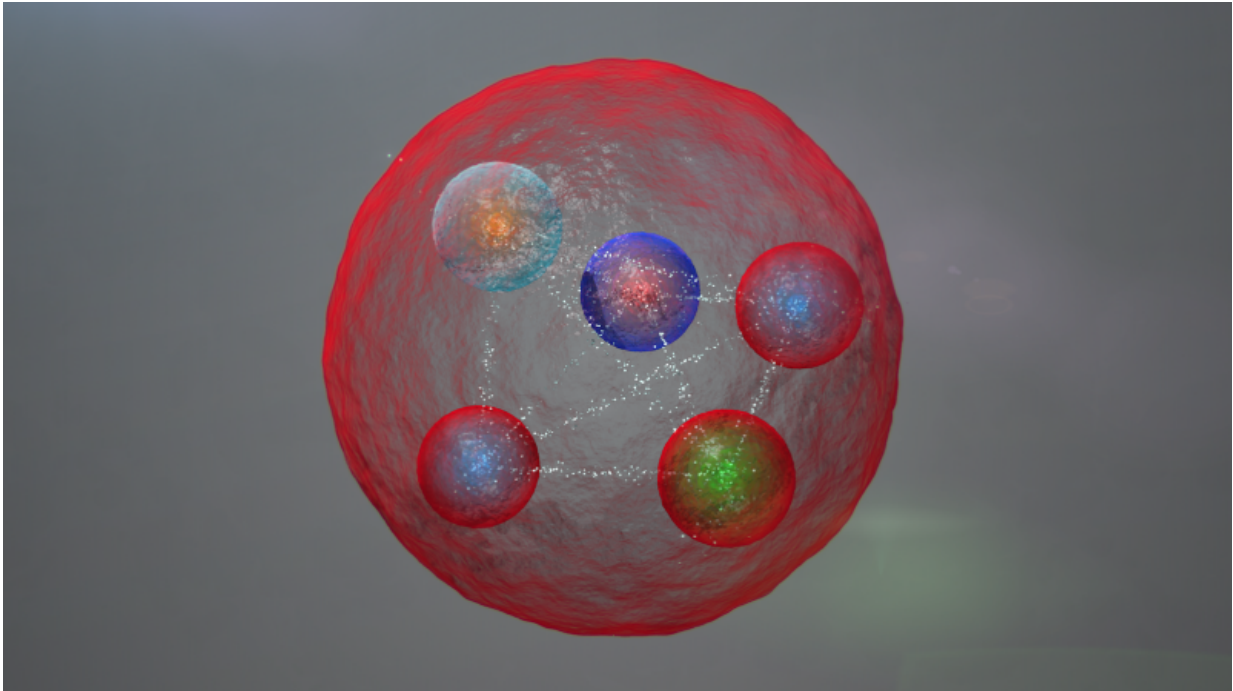


Illustration of the possible layout of the quarks in a pentaquark particle such as those discovered at LHCb. The five quarks might be tightly bonded (left).  
Credit: CERN / LHCb Collaboration

"The quarks could be tightly bound," said LHCb physicist Liming Zhang of Tsinghua University, "or they could be loosely bound in a sort of meson-baryon molecule, in which the meson and baryon feel a residual strong force similar to the one binding protons and neutrons to form nuclei."

More studies will be needed to distinguish between these possibilities, and to see what else pentaquarks can teach us. The new data that LHCb will collect in LHC run 2 will allow progress to be made on these questions.

**More information:** "Observation of  $J/\psi$  resonances consistent with pentaquark states in  $\Lambda_b^0 \rightarrow J/\psi K^- p$  decays." [arxiv.org/abs/1507.03414](https://arxiv.org/abs/1507.03414) , [journals.aps.org/prl/abstract/ ... ysRevLett.115.072001](https://journals.aps.org/prl/abstract/...ysRevLett.115.072001)

Provided by CERN

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