New support for 'intrinsic' charm quarks

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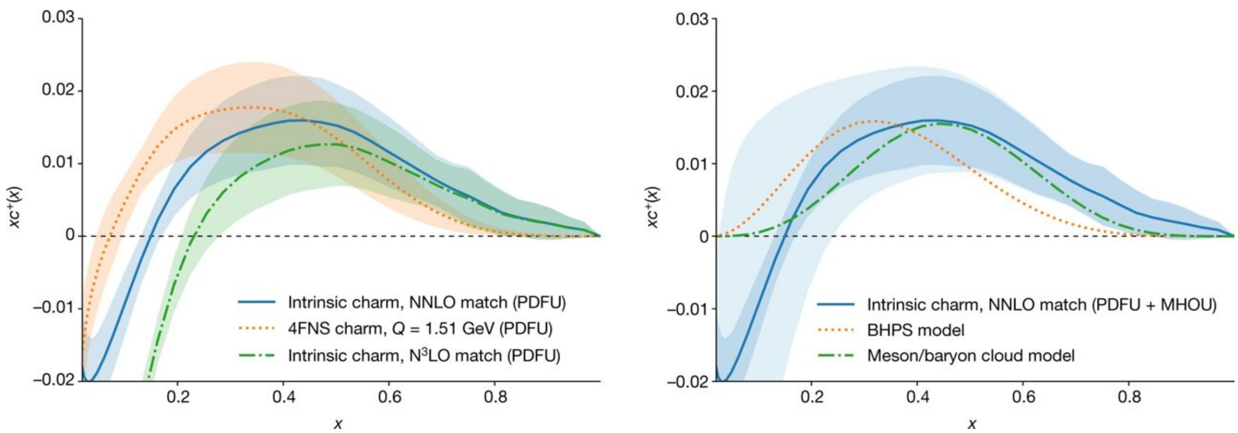

The intrinsic charm PDF and comparison with models. Left, the purely intrinsic (3FNS) result (blue) with PDFU alone, compared to the 4FNS PDF, which includes both an intrinsic and a radiative component, at $Q = m_c = 1.51$ GeV (orange). The purely intrinsic (3FNS) result obtained using N^3LO matching is also shown (green). Right, the purely intrinsic (3FNS) final result with total uncertainty (PDFU + MHOU), with the PDFU indicated as a dark shaded band; the predictions from the original BHPS model and from the more recent meson/baryon cloud model are also shown for comparison (dotted and dot-dashed curves, respectively). Credit: *Nature* (2022). DOI: 10.1038/s41586-022-04998-2

A team of researchers with The NNPDF Collaboration has found new evidence to support the theory of "intrinsic" charm quarks. In their paper published in the journal *Nature*, the group describes how they used a machine learning model to develop a proton structure and then used it to compare against results from real-world collisions in particle accelerators and what they learned by doing so. Ramona Vogt, with Lawrence Livermore National Laboratory has published a News & Views piece in the same journal issue outlining the work by the team on this new effort. *Nature* has also published a podcast where Nick Petrić Howe and Benjamin Thompson discuss the work done by the team.

Prior research involving the use of particle accelerators has suggested that protons contain quarks that are held together by gluons. A reasonable amount of evidence has also shown that there are at least two up quarks and one down quark. There have also been theories suggesting that there is another, the so-called charm quark, but little real evidence of them exists. That might be changing, however, as the researchers on this new effort have used a new approach to "prove" that they exist.

They have found evidence of one small part (0.5%) of a proton's momentum coming from a charm quark. The researchers found this new evidence by using a machine learning model to build a hypothetical proton structure, including different flavors of quarks, and of course the elusive charm quark. They then ran their model and compared characteristics of the model with real-world data that has been observed from over 500,000 collisions in accelerators over the last decade.

The researchers also found that if a proton does not have a charm-anticharm pair of quarks, then there is just a 0.3% chance of them seeing the results found in their comparisons. And that calculation has led them to give their results a 3-sigma level of confidence—a level that is generally reserved for confidence levels denoting that something interesting has been found. A 5-sigma level is needed for the physics community to agree that a discovery has been made.

More information: The NNPDF Collaboration, Evidence for intrinsic charm quarks in the proton, *Nature* (2022). DOI:

10.1038/s41586-022-04998-2

Ramona Vogt, Evidence at last that the proton has intrinsic charm, *Nature* (2022). DOI: 10.1038/d41586-022-02186-w

Benjamin Thompson et al, Do protons have intrinsic charm? New evidence suggests yes, *Nature* (2022). DOI: 10.1038/d41586-022-02237-2