Strangeness Suppression in $q\overline{q}$ Creation Observed in Exclusive Reactions

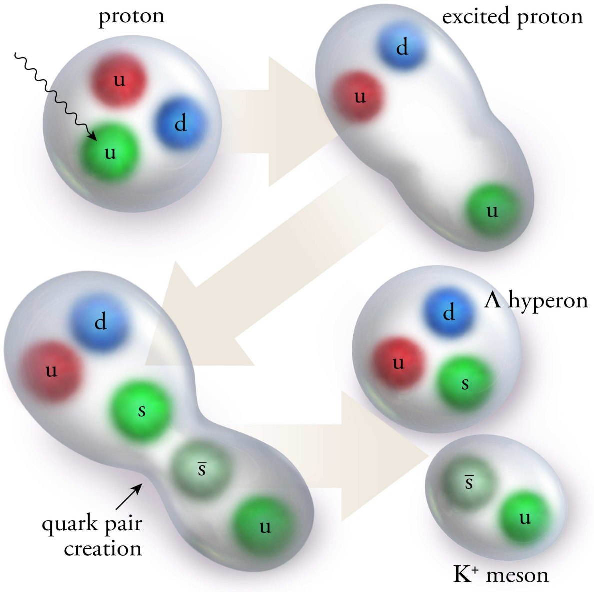
Since the 1950's it has been known that protons and neutrons, which form the nucleus of every atom, are not "point" particles, but have internal structure. Electron scattering experiments in the 1970's confirmed that the proton has structure and identified the constituents as "quarks". These quarks have interesting properties. There are three of them in each proton or neutron. They each possess the same amount of internal angular momentum, called "spin", as the proton or neutron itself. They are also charged, like the proton, but instead of having a charge value of 1 like the proton, or -1 like the electron they have values of +2/3 or -1/3, depending on whether they are so-called "up" or "down" type. In this way, the proton, which consists of two "up" and one "down" quark has total charge of +1; while the neutron, which consists of two "down" and one "up" has total charge of 0.

Another very interesting feature of quarks is that no experiment has ever detected a single quark by itself. They are always bound up as 3-quark states, like protons and neutrons, or in another type of matter, called "mesons", which are comprised of one quark and one "anti-quark". As an aside, all particles have anti-particles which have opposite charge. So, quarks are never seen alone, but only in groups of three or paired with an anti-quark. Over the years, this was understood as a consequence of what happens when you "break" a proton apart.

The picture shows a proton being struck by a high energy electromagnetic photon (the wavy black line) followed by the formation of a quark-anti-quark ($q\overline{q}$) pair which breaks the force field and creates new particles. The type of $q\overline{q}$ pair is shown by the small letter on the pair; in this case the "s" indicates that the $q\overline{q}$ pair consists of a "strange" quark and its anti-quark partner. This results in final state particles that are well-known to contain strange quarks: the "Lambda"(Λ) and the "K^+" meson.

We were interested in testing whether the $q\overline{q}$ production rate was the same for up, down and strange quarks in a very simple case: when only a single pair is created and there are only two final particles flying out into our detector.

We directed the Jlab electron beam, with an energy of 5.5 billion electron-volts, at a target of liquid Hydrogen which has a single proton as its nucleus. We studied reactions in which only one neutral particle and one positively-charged particle was produced: $n\pi^+$, $p\pi^0$ or ΛK^+. We detected only the positive particle. By summing up energies and momentum we were able to calculate the mass (and thus the identity) of the missing neutral particle. We counted the rates (number per second) in different angle and momentum bins and accounted for "blind spots" in our detector with a simulation program. Using very simple arithmetic, we converted our measured ratios of the three rates into ratios of production rates for the three types of $q\overline{q}$.



Our experimental results [1], [2] showed that creation of strange $q\overline{q}$ pairs is suppressed relative to production of "up anti-up" or "down anti-down" pairs. This was known to happen at very high energies like at the LHC collider, but we were the first to show that the amount of suppression was essentially the same at our energies where we selected that only a single $q\overline{q}$ pair be produced. Although $q\overline{q}$ creation is the "kernel" of the process which transforms quarks into observable hadrons, its dynamics is still not well-understood. We hope that our measurement can shed a bit of light on this mystery. In the words of the late Richard Feynman, "It does not do harm to the mystery to know a little more about it."

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[1] M.D. Mestayer, K. Park *et al.*(CLAS Collaboration), Phys. Rev. Lett. **113**, 152004 (2014).

[2] This paper was an "Editors' Suggestion" in PRL.