Quarks: Quantum Mechanics

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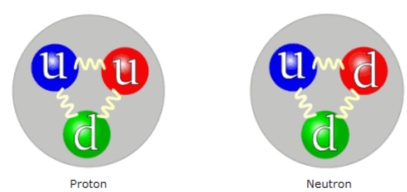
Abstract

This experiment investigates how scattering experiments are used to infer the internal structure of fundamental particles, with a conceptual focus on quarks. Like leptons, quarks are considered elementary and cannot be directly observed or isolated. Instead, their properties are inferred through high-energy scattering experiments in which incoming particles are deflected by internal charge distributions. In this lab, a Rutherford scattering simulation is used to analyze the deflection of alpha particles by atomic nuclei. By measuring scattering angles as a function of projectile energy and nuclear charge, the experiment demonstrates how large-angle deflections arise from concentrated internal structures. This method serves as a classical analogue to deep inelastic scattering, where similar deflection patterns provided experimental evidence for quarks within protons. The results illustrate how deflection measurements can be used to indirectly probe force strength, distance of interaction, and internal structure at scales that cannot be directly observed.

I. Introduction

Quarks are found to be housed in elementary particles and when looking at their spin, they can be classified as either bosons or fermions where boson possessed an integral spin of $0\hbar$, $1\hbar$, $2\hbar$, etc. while fermions possessed an integral spin of $\frac{1}{2}\hbar$, $\frac{3}{2}\hbar$, etc. Then, when looking at fermions, they can be broken down into leptons and quarks, where leptons do not have the interaction with a strong force while quarks do have that interaction. From here, quarks are found to be housed in spin-fermions ($s = \frac{1}{2}$) and they are classified into six categories: up (u), down (d), strange (s), charmed (c), bottom (b), and top (t), where they all share common characteristics of having a baryon number: $B = \frac{1}{3}$, all having a fractional charge of either $\frac{1}{3}e$ or $\frac{2}{3}e$, and all have having an antiquark that possess an opposite baryon number and charge, but maintains equal mass.



Furthermore, hadrons are formed when quarks bind in either groups of three or two, and quarks also have a property known as color where it acts as a strong charge. Therefore, each type of quark comes with three colors labeled as green, blue, and red, and the result of when quarks bind together must be a neutral color. Thus, when three quarks bind together where each quark must contain a distinct color, it results in baryons to be formed, with some being protons (p, formed from two up quarks and one down quark), negative xi(Ξ^-, formed from two strange quarks and one down quark), charmed lambda(Λ_C^+, formed a up, down, and charmed quark), and other baryon quarks. Finally, when two quarks, a quark with a color and an antiquark with it's corresponding anti-color, bind together it results in mensons to be formed, with some being positive rho (ρ^+, formed from an up quark and a down antiquark), negative koan (K^-, formed from an up antiquark and a strange quark), neutral D (D^0, formed from an up antiquark and a charm quark), and other menson quarks.

II. History

The journey of discovering quarks started when quantum physics and Albert Einstein's theory of relativity contradicted with the idea that an atom contained only protons, electrons, neutrons, and a nucleus. Quantum physics proved that particles behaved like a wave or as a particle and the theory of relativity proposed that energy and mass are equivalent, and that by using $E = mc^2$, mass could be converted to energy. This then led to experiments to be performed on atoms to discover potential particles, with pions first discovered inside the nucleus by using cosmic-ray tracing and found that they serve as a force between neutrons and protons. Afterwards, the particle accelerators were fully developed where subatomic particles traveled at very fast speeds to collide with atoms, leading to discovering subatomic particles when the collision resulted in the atoms breaking apart. From here, the particle accelerators led to developing specific classifications of particles and general classifications of particles known as families due to the huge volume in new particles being discovered. This then led to physicist Murray Gell-Mann to analyze the classifications of subatomic particles and forces, and proposed in 1964 that quarks were smaller particles that composed protons and neutrons, and then latter added that "gluons" were responsible for keeping the quarks together. As a result, this led to an experiment to be conducted in 1968 at Stanford's SLAC National Accelerator Laboratory where electrons traveled at very fast speeds and collided with protons, resulting in inelastic collisions. It was then discovered here that protons possessed smaller sub-particles as Bjorken recognized that after the collision the smaller sub-particles should have a unique signature if protons possessed hard substructures, which led to discovering that the smaller sub-particles were consistent and proving Murray Gell-Mann's proposal of quarks and gluons.

III. Experiment

This experiment...

IV. Measurements

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V. Results and Comparison

To have...

VI. Conclusion

This paper proved...

References

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