Mass relationship between three valence quarks in proton

Jianming Wang

(Department of Physics, Lanzhou University, Lanzhou 730000, China)

E-mail: wsr529@sina.com

Abstract Protons are composed of quarks and gluons, and quarks are divided into valence quarks and sea quarks. In particle physics, there is no breakthrough in studying the mass relationship between three valence quarks in protons. Because **(1)** quarks are confined in protons, and the mass of quarks cannot be obtained directly from experiments, there is a lack of experimental basis for research. **(2)** The mass obtained by quarks through **Higgs mechanism** and vacuum condensation of **QCD** is not accurate, so there is a lack of theoretical data. The mass of different quarks needs different extraction methods because of their different properties. There are many methods to extract quark mass, such as **QCD summation rule**, calculation of mass matrix elements, **Lattice QCD**, and high-energy collision experiment, which generally need to be finally determined through experimental data and theoretical calculation.

How to extract the mass of up quark and down quark in proton? In this paper, a new extraction method is found. Although the exact mass of the up quark and the down quark in the proton cannot be obtained, the accurate ratio of the mass of the up quark and the down quark can be extracted, and the mass relationship among the three valence quarks can be found. Based on the experimental results of **Seaquest** carried out by **Fermilab** in 2021, through analysis, the accurate ratio of up quark to down quark mass ($m_u/m_d=0.707$) is obtained, and the mass triangle is established. It is deduced that the sum of squares of up quark mass in protons is equal to the square of down quark mass. The mathematical expression is $m_u^2+ m_u^2= m_d^2$. According to the observation of the decay law of other baryons, the quark law in baryons is obtained. The basic content of **quark law:** except protons, the heavy quarks in other baryons will decay into up quark or down quark, and the sum of squares of up quark mass should be equal to the square of down quark mass.

Key words valence quark quark law exact ratio new method

I Introduction

The **Standard Model Theory** and **QCD** have been born for decades, which have successfully explained many problems in particle physics. However, the value of quark mass given by the standard model is uncertain. Because the up quark and the down quark are confined in protons, the mass of the up quark and the down quark cannot be obtained directly from experiments. Based on the experimental results of **Seaquest** in **Fermi Laboratory** in 2021, this paper successfully found the accurate mass ratio of up quark and down quark ($m_u/m_d=0.707$), and skillfully established the mass triangle of up quark and down quark. The relation of three valence quarks in proton is deduced: $m_u^2+ m_u^2= m_d^2$.

II Experimental purpose and conclusion

In 2021, Fermilab carried out seaquest experiment to find the number ratio of anti-up quark to anti-down quark in proton.

The experimental conclusion is that **1** anti-up quark corresponds to **1.4** anti-down quarks **[1]**.

III Derivation of mass relation between up quark and down quark in proton.

Protons contain three valence quarks and a large number of sea quarks. The mass relationship of the three valence quarks was found through the **seaquest** experiment of Fermilab in 2021.

According to the experimental results of seaquest in Fermilab, **1** anti-up quark corresponds to **1.4** anti-down quarks. Therefore, in protons, the charge,mass and number of anti-up quark and anti-down quark are not equal.

Suppose that the product of charge,mass and number of the anti-up quark is equal to the product of charge,mass and number of the anti-down quark.

Because quarks and antiquarks have the same mass. Therefore, the mass of anti-up quark and anti-down quark in **seaquest's experimental** results can be expressed according to the mass of up quark and down quark.

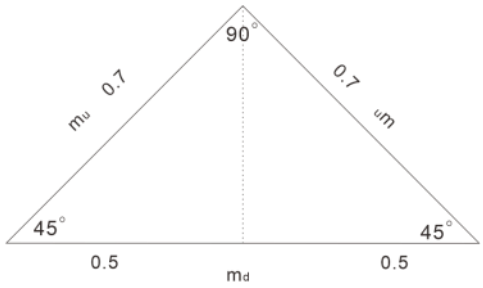
Because the products of the three are equal (the charges are all positive), the following relationship is obtained.

$$\frac{2}{3}\times 1.0\times m_u=\frac{1}{3}\times 1.4\times m_d$$

$$m_u/m_d=0.7$$

(m_u: **up quark mass** , m_d: down quark mass)

There are two up quarks and one down quark in the proton. Assuming that the down quark mass is **1** and the up quark mass is **0.7**, A mass triangle is established.



Figure(1) Triangular diagram of up quark and down quark

Cos a = $\frac{0.5}{0.7}$ = 0.7142 **cos45° = 0.7071**

Considering the error of experimental data, it can be considered that **a=45 °.**

Therefore, the pattern is an isosceles right triangle. Two up quarks are right-angled sides and one down quark is hypotenuse.

So we get the following conclusion:. $m_u^2+ m_u^2= m_d^2$

Described in physical terms as: the sum of squares of the up quark mass is equal to the square of the down quark mass.

According to the existing experimental data, the up quark has a mass of **(1.7~3.3)MeV** and the down quark has a mass of **(4.1~5.8)MeV**. The above conclusions are also within a reasonable range.

IV Results

(1) Although the exact mass of up quark and down quark in proton cannot be obtained, the exact mass ratio of up quark and down quark can be obtained through Seaquest experiment. $m_u/m_d=0.707$.

In Seaquest's experiment,**1** anti-up quark corresponds to **1.4** anti-down quarks. Considering the experimental error, the most accurate experimental result is that **1**anti-up quark corresponds to **1.414** anti-down quarks, so $m_u/m_d=0.707$.

(2) The sum of squares of the up quark mass in proton is equal to the square of the down quark mass. $m_u^2+ m_u^2= m_d^2$

V Discussion

(a) Quark law in baryons

Because the three valence quarks in the proton satisfy $m_u^2+ m_u^2= m_d^2$, there is no such relationship in other baryons. In particle physics, other baryons will eventually decay into protons.

According to the decay results of other baryons, the quark law in baryons is summarized.
Quark law in baryons: except protons, heavy quarks in other baryons will decay into up quark or down quark. The purpose is to keep the sum of squares of up quark mass equal to the square of down quark mass.

(b) In particle physics, quark mass mainly comes from two aspects: **Higgs mechanism** [2] and **vacuum condensation of QCD** [3,4,5], both of which have complicated discussions. The seaquest experiment in Fermilab provides a new idea for studying the quark mass.

The contribution of **Seaquest** experiment in Fermilab to the study of quark mass is: on the premise that the exact mass of up quark and down quark cannot be obtained, the exact mass ratio of up quark and down quark is obtained by finding the quantitative ratio of anti-up quark and anti-down quark. This experiment transforms the uncertainty of quark mass into the exact ratio of up quark mass to down quark mass, which is a paradigm shift in research thinking. Therefore, it is meaningful to study the mass ratio between valence quarks in the same system, because quarks in the same system exist in the same environment and are affected by the same external conditions. The accurate mass ratio of up quark to down quark in proton ($m_u/m_d=0.707$) was found by experiments, which provided an experimental basis for the discovery of $m_u^2+ m_u^2= m_d^2$.

(c) In this paper, the extraction of quark mass in protons no longer depends on the exact mass of each quark, but seeks the exact mass ratio of quarks in the same system through experiments. Because in proton, based on **Seaquest** experiment, it is easier to extract the accurate mass ratio of up quark and down quark than to measure the accurate mass of up quark and down quark.

(d) There is no contradiction between the extraction method of quark mass in proton and the traditional extraction method. In this paper, the mass ratio (**relative mass**) of up quark and down quark is emphasized, while the traditional method attaches importance to the absolute mass of up quark and down quark.
In proton, the accurate mass ratio of up quark and down quark is extracted, and it is easier to deduce the relationship of three valence quarks: $m_u^2 + m_u^2 = m_d^2$.

(e) This paper is based on the equal product of mass, quantity and charge of anti-upper quark and anti-lower quark in proton**(C×M×N)**. The mass relation of three valence quarks in proton is successfully found: $m_u^2 + m_u^2 = m_d^2$. This relationship reveals the natural laws followed in the process of proton formation and provides help for further study of protons, so this assumption is reasonable.

VI Summary

Protons are the main particles that make up stars. With regard to the extraction of quark mass in protons, based on experiments, the exact ratio of the mass of up quark to down quark in protons ($m_u/m_d=0.707$) was obtained, and three mass relations of valence quarks were obtained: $m_u^2 + m_u^2 = m_d^2$. This is a new method to extract quark mass in protons, which is a supplement to the original method. Whether $m_u^2 + m_u^2 = m_d^2$ is a natural law left by protons needs to be tested by experiments and theories.

VII References

[1] J.Dove,B.Kerns,and R.E.mcclean, Nature 590, 559-560 (2021)
The asymmetry of antimatter in the proton
Nature(2021).DOI:10.1038/S41586-021-03282-Z,
dx.doi.org/10.1038/s41586-021-03282-z.

[2] Quang Hoim, Xuan-Yem Pham. Elementary Particles and Their Interactions. Berlin Heidelberg:Springerverlag, 1998.

[3] Thomas A W, Weise W. The Structure of Nucleon.
John Wiley and Sons Press, 2002,163.

[4]He Xiaorong, Zhou Lijuan,Ma Weixing. Commun Theor Phys,2005,44(4):670.

[5]Pan Jihuan,Meng Chengju,Zhou Lijuan,et al. Nuclear Physics Review,2007,24(4):258(in Chinese).