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A String Model for Preons and the Standard Model Particles

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Abstract

A preon model for standard model particles is proposed based on spin $\frac{1}{2}$ fermion and spin 0 boson constituents. The preons are light quantum states of a string. Implications to the number of generations, heavy boson states, dark matter, and gravity are briefly considered.

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1 Introduction

A model for the first generation quark and lepton subconstituents was suggested in [1]. Each quark and lepton was supposed to consist of three mini black hole preons bound together by a confining subcolor interaction. Considering internal symmetry and spin, it turns out that this type of construction leads to too broad a spectrum of states. Recent LHC data indicate support of the SM without any new particles so far. Additionally, QCD-like preon interactions may not be realistic to explain the spectrum of quarks and leptons, and the standard Planck mass scale is too high.

A more economic scheme is to assume quarks and leptons consisting of two preons. The preons are ordinary quantum strings of some mass scale m in 4D. The preons couple to a massive scalar field. We propose that the standard model quarks and leptons are built of a preon pair bound by the scalar field.

2 A String Model of Preons, Quarks and Leptons

The basic building block of the model is a string of length l such that $l_P < l < l_w$ where $1/l_w$ is of the order of the electro-weak symmetry breaking scale of about 100 GeV. For a string of length nl_P, using plane wave quantisation with Planck length l_P as the cutoff, the number of states is $\frac{1}{2}(n^2 - n)$.

We setup this model with a lefthanded spin $\frac{1}{2}$ isospin doublet fermions p of charge $+\frac{1}{2}$ and m with charge -$\frac{1}{2}$ [2]. To provide color and lepton number the fermion is "dressed" with a scalar preon h = (l, r, g, b) with charges -$\frac{1}{2}$, $+\frac{1}{6}$, $+\frac{1}{6}$, $+\frac{1}{6}$, resp. The first generation quarks and leptons are the following bound states

$$u_r = (p, r) \quad (1)$$
$$d_r = (m, r) \quad (2)$$

$$e^- = (m, l) \quad (3)$$
$$\nu_e = (p, l) \quad (4)$$

The bound states are formed by the scalar field interaction. The second and third generation quarks and leptons are string excitations (m_i) of the lowest states: (m_0, m_1) and (m_1, m_1). Dynamical details, from first principles, would be needed to determine the exact number of generations. Three generations imply a shallow short range potential.

The the scalar field interaction between the preons in our scheme is supported as follows. On the basis of lattice spinor gravity model [3] there are calcuations that this could be the short distance limit of gravity. It is concluded in [4] that in the long distance limit the metric is universal and is described by a massless graviton. In the short distance limit, around the Planck length geometry looses its universal meaning and other degrees of freedom come to play, namely massive scalars and symmetric second rank tensors.

The W, Z, Higgs, and the top quark masses are of the order of m while the light particles need an argument.

3 The Preon Model Bosons

The scalar, whether the Higgs or a mixture, is basically elementary in our model. The weak bosons may be considered as either elementary as in the Standard Model, or bound states (in fact, they are mixtures, too) as follows:

$$W^+ = \overline{m}p \tag{5}$$
$$W^- = \overline{p}m \tag{6}$$
$$W^3 = \frac{1}{\sqrt{2}}(\overline{p}p - \overline{m}m) \tag{7}$$

$$X^0 = \frac{1}{\sqrt{2}}(\overline{p}p + \overline{m}m) \tag{8}$$

X^0 is not in the Standard Model. Its mass must be large, around 1 TeV. Other models also predict new states in this mass region. It would a subject of its own to study all these - after the mass region around 125 GeV has been cleared experimentally.

In addition, preon-antipreon bound states $\overline{p}p$, $\overline{h}h$ with spins 0 and 1 (and $\frac{3}{2}$ etc.) must exist, in three families. The preon-antipreon states are candidates for dark matter. There may be mixing due to electromagnetic interaction between dark and ordinary matter.

For the early moments of the Big Bang this model predicts three times more dark matter production than ordinary matter. Relic density is by construction right order of magnitude. Generally, a particle's thermal relic density is [5]

$$\Omega_x \propto \frac{1}{\langle\sigma v\rangle} \sim \frac{m_x^2}{g_x^4} \ , \tag{9}$$

where $\langle\sigma v\rangle$ is its thermally-averaged annihilation cross section, m_x and g_x are the characteristic mass scale and coupling in this cross section, and the last step follows from dimensional analysis. The observed value $\Omega_X \approx 0.24$ is obtained within an order of magnitude for $m_x \sim 100GeV$ and $g_x \sim 0.6$.

4 Summary

The preon model discussed here is built on the following assumptions:

- basic quantum constituents are strings with gravitational interaction,
- gravity at short distances is approximated by a scalar interaction,
- the string mass scale is close to the weak scale,
- preons consist of a string,
- two preon bound states make the standard model particles.

A scalar particle has a long history in gravity. The scalar looks like the Higgs particle or is mixing with it. The model implies new preon-antipreon bound states. They are candidates for dark matter and they may have been formed in Big Bang. They also contribute at the LHC with background-like behavior.

Issues for further study include open versus closed strings, effects of relativity, spin, ie. the Lagrangian, and consequences to astrophysics and cosmology.

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