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A SUGGESTED NEW MEDIUM ALTITUDE COSMIC RAY EXPERIMENT

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ABSTRACT

Some years ago it was suggested independently by Schwinger and the author that the fundamental constituents of hadrons are heavy highly charged particles. Recent observations with accelerators on $e^+e^- \rightarrow$ hadrons and gammaisation appear to support, at least qualitatively, this suggestion. A search is to be made for evidence of heavy highly charged particles at the CERN intersecting storage rings. It is suggested here that a search for penetrating highly ionizing particles could also be made at medium altitudes in the cosmic rays, where higher production energies are available.

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1. INTRODUCTION

Two models have been published which assume the existence of highly charged hadron constituents. These are the "dyon-monopole" model of Schwinger[1, 2] and the independently proposed "subnucleon" model of the author.[3-6] In this paper the two models are briefly reviewed and their possible implications in some high energy cosmic ray experiments are discussed. The related model of Itoh et al.[7] of "strongly charged" hadron constituents is not discussed here because the strong charge envisaged by Itoh et al. is neither electric nor magnetic and it would not appear to have a direct physical experimental manifestation.

2. MOTIVATIONS FOR PROPOSING THE "DYON-MONOPOLE" AND "SUBNUCLEON" MODELS

2a. Dyon-Monopole Model

The motivation underlying this model is the Dirac equation for charge quantization.[8] This is

$$\frac{eg}{4\pi} = \frac{n}{2} \tag{1}$$

Here e is the electron charge and g is the magnetic charge of any monopole which is assumed to exist. We have set $\hbar = c = 1$. Equation (1) implies that all charges are quantized. It also implies, if monopoles exist, that they are very highly charged, i.e.,

$$\frac{g^2}{4\pi} = n^2\left(\frac{137}{4}\right) \tag{2}$$

As was noted by Dirac, Eq. (2) implies very strong attraction between N and S poles. This provides the motivation for Schwinger's constituent model. He assumed that hadron constituents are magnetic monopoles (carrying electric charge also) and that they are bound together in baryons and mesons by the very strong N-S attraction.

2b. Subnucleon Model

This model was constructed with the intention of providing a modified form of conventional quantum electrodynamics in which infinite "renormalizations" are absent. To illustrate a typical infinite renormalization of conventional QED we consider here the contribution of vacuum polarization to the Lamb shift in hydrogen. In lowest order this occurs when a virtual γ which is exchanged between the proton and electron converts temporarily to a virtual e^+e^- pair. The e^+e^- pair allows the vacuum to become polarized and the Coulomb interaction is consequently modified. In the conventional treatment (see for example, Bjorken and Drell, and Bogoliubov and Shirkov[9]) one obtains

$$V(\vec{r}) = -\frac{e_0^2}{4\pi\epsilon r} - \frac{e_0^4}{60\pi^2\epsilon^2 m^2}\,\delta^3(\vec{r}) \tag{3}$$

Here e_0 is the "bare" charge of the electron and ϵ represents the effect of vacuum polarization. The dielectric constant ϵ is sometimes denoted by Z_3^{-1}. The conventional treatment[9] also yields a possible value for ϵ, namely $\epsilon = 0$. This undesired result is conventionally incorporated into the theory by the assumption of "infinite (charge) renormalization". One assumes, conventionally,

$$\epsilon = e_0 = 0 \quad \text{and} \quad Z_3 = \infty \tag{4}$$

where

$$\frac{e_0^2}{4\pi\epsilon} = \frac{1}{137} \tag{5}$$

With this assumption one has

$$V(\vec{r}) = -\frac{e^2}{4\pi r} - \frac{e^4}{60\pi^2 m^2}\,\delta^3(\vec{r}) \tag{6}$$

where $e^2/4\pi = 1/137$, and the second term in (6) then correctly yields the observed contribution of -27 MHz to the Lamb shift. Despite this success, Eq. (4) and consequently the above derivation is unphysical and therefore incorrect (even if it is mathematically consistent) in the opinion of this author. The need to construct a modified version of QED which does not require infinite renormalizations was the motivation underlying the proposal of the "subnucleon" model.

It was argued (but not proven—see Ref. 3) that a finite theory might be able to be constructed if, besides the usual leptons, there exists a class of hitherto unobserved spin 1/2 elementary particles with electric charges g satisfying

$$\frac{g^2}{4\pi} = \text{order unity} \tag{7}$$

Equation (7) may be compared with Eq. (2) for monopoles. Equation (7) implies g is of the order of $\pm 10\,e$ so that there would be strong attractions between the particles and antiparticles of the new predicted class. A model of hadron constituents (termed "subnucleons") was then constructed in which this strong attraction is the binding mechanism. The so constructed "subnucleon model" is similar in several respects to the independently proposed "dyon-monopole model" of Schwinger, and some aspects of the two models are briefly reviewed in the next section. Further details are of course contained in Refs. 1-6.

3. BRIEF REVIEW OF THE TWO MODELS

Both models in question are unified theories of hadrons and leptons in the sense that they ascribe a common origin to strong and electromagnetic interactions.

Both interpret baryon number in a similar manner to electric charge. In the subnucleon model strangeness is also described in a similar manner.

Both predict that at asymptotic interaction energies (i.e., centre of mass energy >> all hadron constituent masses) free highly charged constituents will be produced. As the asymptotic regime is approached "nearly free" constituents would be produced, and these would emit electromagnetic radiation (bremsstrahlung, etc.) while descending to their ground states.[10] Such emission could conceivably be the origin of (1) the "gammaisation" effect reported by Nikolskii[11] in cosmic ray interactions above about $10^{13} - 10^{14}$ eV, of (2) the multigamma events observed more recently at the CERN intersecting storage rings by Yuan et al.,[12] and of (3) the so-called "energy crisis" very recently observed in $e^+e^- \rightarrow$ hadrons.[13] Moreover, if hadron constituents are highly charged, then the now much discussed ratio

$$R \equiv \frac{\sigma(e^+e^- \rightarrow \text{hadrons})}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)} \approx \frac{\Sigma\,(\text{constituent charges})^2}{e^2} >> \text{unity} \qquad (8)$$

in the asymptotic regime and in the one photon exchange approximation. At low energies $R \approx 2$ so that, as the asymptotic regime is approached, the ratio R was[5] predicted to increase greatly. This may be the origin of the increase of R with energy recently observed at CEA[14] and SPEAR.[13] The considerations of this paragraph suggest that, if highly charged hadron constituents exist, then the lightest one has a mass in the approximate range 10 - 100 GeV/c^2.

In its original and simplest form the dyon-monopole model predicts that the neutron electric dipole moment $\approx 10^{-14}$ e cm which is about 8 orders of magnitude greater than the observed upper limit for this quantity. Subsequent modifications of the dyon-monopole model have been constructed which avoid this somewhat difficult confrontation with fact.[15, 16] The subnucleon model predicts that the neutron electric dipole moment vanishes.

In the subnucleon model a hadron classification was proposed which is not fundamentally based on SU(3) multiplets. This is in contrast to the dyon-monopole model. We note here that experimental evidence for "exotic" states (i.e., those which are not classifiable in the simplest SU(3) scheme) remains.[17]

The subnucleon model <u>possibly</u> requires[5] the existence of a peculiar class of hadronic states, and this may account for the apparently short-lived particle observed by Niu et al.,[18] and also the apparently heavy particle observed by the Yunnan group.[19] This was discussed in Ref. 5. The incredible "Centauro" event of the Japanese-Brazillian collaboration[20] may possibly also be classified in terms of one of the members of this new class, e.g., the dissociation of a particle such as the X in Eq. (14) of Ref. 5. This latter <u>speculation</u> would require that one of the particles in Centauro is highly charged.

Finally in this section it is stressed that both the models in question are not generally soluble using perturbation theory, so that exact quantitative predictions are not generally available, as yet. Because of this both of these models may presently be most directly tested by searching for the predicted highly charged hadron constituents. Such searches are the subject of the remaining section.

4. SEARCHES FOR DYON-MONOPOLES AND SUBNUCLEONS: PAST AND FUTURE

4a. Dyon-Monopoles

Dyon-monopoles would be extremely highly ionizing. According to Eq. (2) dE/dx would be greater than that of a relativistic nucleus with $Z = 68$. Searches based on this fact have been made in the cosmic rays at sea-level, where the heavy nucleus flux is negligible, and at low energies and at high energies, respectively, Carithers et al.[21] and Fleischer et al.[22] found

$$\text{dyon-monopole flux} < 10^{-14}\ \text{cm}^{-2}\ \text{sec}^{-1}\ \text{sr}^{-1} \tag{9}$$

To improve on this result one would need to utilize extremely large-area detectors and/or operate at higher altitudes. This would be difficult but not impossible. We also note that an unsuccessful monopole search using plastic Lexan detectors was carried out at the CERN intersecting storage rings.[23]

4b. Subnucleons

These particles would be highly ionizing, with dE/dx roughly similar to that of a nucleus with $Z = 10$ (see Eq. (7)). A search[6] with a fairly small cosmic ray telescope (containing plastic scintillators, spark chambers and absorbers) located at sea-level under 600 g/cm^2 concrete shielding yielded the 90% confidence result

$$\text{subnucleon flux} < 7 \cdot 10^{-10}\ \text{cm}^{-2}\ \text{sec}^{-1}\ \text{sr}^{-1} \tag{10}$$

This result could, of course, be improved easily using larger detectors and/or operating at higher altitudes. In 1975 the telescope of Ref. 6 will be re-operated without the concrete shielding, and also a search will be made with the CERN intersecting storage rings. It is pointed out here that some presently existing medium-altitude large-area cosmic ray detectors could possibly be utilized to search for these particles.

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