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ON THE MASSES OF ELEMENTARY PARTICLES

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One of the apparent surprises in field theory is the insensitiveness of the axial-vector coupling constant renormalization in β- decay so far as radiative corrections from strong interactions are concerned. The argument is as follows. Empirically the vector coupling constants g_V^μ in μ-decay and g_V^β in β-decay are equal[1]. Even with the assumption of a universal Fermi interaction this is surprising for g_V^β should have renormalization corrections from strong interactions. The most plausible explanation is the suggestion of Gerhtejn and Zel'dovich[2] and Feynman and Gell-Mann[1] that the vector parts of μ and β-decay interactions satisfy a conservation relation. No such suggestion is possible for the axial-vector interaction and g_A^μ and g_A^β are indeed empirically different. Since experimentally $g_A^\mu \neq g_V^\mu$ for μ-decay, it is an attractive hypothesis to assume the same is true in β-decay case for bare coupling constants and to ascribe the deviation of observed constants $\left|\frac{g_A^\beta}{g_V^\beta}\right|$ from unity to renormalization effects. There still remains the quantitative mystery that this deviation

$$\left(\frac{g_A^\beta}{g_V^\beta} = 1.25 \pm .04\right)$$

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is not as large as one may reasonably expect from the very strong interactions which produce the radiative corrections.

One wonders if this insensitivity to higher order corrections is not a general feature of all self-charge renormalization effects, especially as a similar situation seems to prevail for the case of self-masses also. One of the strongly suggestive arguments in favour of this is the remark due to Gell-Mann and Schwinger[3] who deduces the relation

$$2(m_N + m_{\Xi}) = (m_\Lambda + 3m_\Sigma)$$

using second order perturbation theory, for K-meson interactions. Here m_N, m_{Ξ}, ..., are masses of nucleons Ξ-particles, etc., and it is assumed that π-mesons interact similarly with all hyperons (global symmetry). The relation itself is accurate up to 5 per cent.

It may be conjectured from these examples that for the computation of self-charge and self-mass effects use of second order perturbation theory may not be too misleading. On this basis we wish to point out that one may also hope to understand the remarkable empirical relation[4]

$$\frac{m_p}{m_e} \approx \frac{g_\pi^2}{e^2} \qquad (1)$$

With the present value of $g_\pi^2 \approx 15$, this is accurate to nearly 10%. Using the second order perturbation theory, the second order contribution to a fermion self-mass when it interacts with a boson equals

$$\delta m = \left(\frac{m_o}{4\pi} \log \frac{X}{m_o} \right) \quad (A \quad g_o^2) \qquad (2)$$

Here m_o is bare-mass, X is some cut-off mass, g_o is the bare coupling constant ($e^2 = \frac{1}{137}$ in the units used) and the constant A depends on the spin and parity of the boson.

$$A = +6 \qquad \text{for vector bosons}$$
$$= +1 \qquad \text{for pseudoscalar bosons}$$
$$= +3 \qquad \text{for scalar bosons.}$$

The physical mass m is given by

$$m = m_o + \delta m \tag{3}$$

Using relations (2), (3) and:

1) assuming that a nucleon and an electron have the same bare mass m_o (arising perhaps from some gravitational effects);
2) assuming that m_o is so small that it can be neglected in comparison with m;
3) assuming that to this order $g_o \gg g$ where g is the renormalized constant;
4) assuming that the same cut-off mass X should be always used, we have the result

$$\frac{m_p}{m_e} = \frac{3g_{\pi N}^2 + g_{k\Lambda}^2 + 3g_{k\Sigma}^2}{6e^2} \tag{4}$$

This is to be compared with (1). Provided $g_{k\Lambda}^2$ and $g_{k\Sigma}^2$ are strong couplings, second order perturbation theory used with (1) - (4) is able to reproduce nucleon-electron mass ratio. For this argument it is imperative that π-meson is pseudo-scalar for with a scalar meson one would get a negative self-mass and the bare mass could never be considered small. (This may also be an argument in favour of K-mesons also being pseudoscalar relative to ΛN and ΣN systems).

The same types of reasoning could be carried through for other hyperons. The Nambu-Frohlich[5] observation that the masses of all elementary particles are integer or half-integer multiples of 137 appears here in the form of a (somewhat mystical) statement that not merely $1/e^2$, but also g_{π}^2, $g_{k\Lambda}^2$ etc., are nearly integers. From

$$\frac{m_\mu}{m_e} \approx 137 \times \frac{3}{2}$$

one may infer, that μ-meson must possess a strong interaction with a coupling constant of the order of unity.

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