

# The Root-Mean-Square Charge Radius of Proton

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**Abstract:** Within the Scale-Symmetric Theory (SST) we calculated the electron and muon radii of proton. We obtained that the electron radius of proton is 0.87673 fm - it is consistent with the central value obtained in experiments. The calculated muon radius of proton is 0.84077 fm and this result is consistent with experimental data also. The two different radii follow from the atom-like structure of protons described within SST.

## 1. Introduction

The General Relativity leads to the superluminal Higgs field composed of non-gravitating tachyons [1A]. The succeeding phase transitions of such Higgs field lead to the size scales described within the Scale-Symmetric Theory (SST) [1A]. Theory of one of the size scales leads to the atom-like structure of baryons [1A].

The proton consists of three parts: the core composed of the torus/charge (it is responsible for the nuclear strong and electromagnetic interactions and has the half-integral spin) and the central ball/condensate (it is responsible for the nuclear weak interactions) and of the relativistic pion in the  $S$  state/circle outside the core (the azimuthal quantum number is  $l = 0$ ; radius of such circle is  $C = A + B$ , where  $A = 0.6974425$  fm and  $B = 0.5018395$  fm; it is the  $d = I$  state) [1A]. The total mass of the core is  $M_{core-of-baryons} = 727.44$  MeV [1A].

The core of baryons is created from loop that radius is  $A$ , and such loop has mass equal to  $M_{core-of-baryons}$ . Due to the weak interactions, inside the baryons appear the spokes composed of the entangled Einstein-spacetime components (i.e. of the neutrino-antineutrino pairs) that can transform into loops. If length of a spoke is  $L$  then radius of the loop is  $R_{loop} = L / (2\pi)$ . Mass of a loop is directly proportional to its radius and for  $L = A$  is equal to  $M_{core-of-baryons}$ .

## 2. Calculations

We can assume that in approximation the volume of a free proton is the volume of the cylinder that radius of the circle/base is  $C = A + B$ . Since the smallest radius of the torus is  $A/3$  [1A] so the height of the cylinder is  $D = 2A/3 = 0.464962$  fm. The volume of the cylinder is  $\pi C^2 D$ . Comparing the volume of a free proton with volume of a sphere  $4\pi R^3/3$ , we obtain

$$R^3 = 3 C^2 D / 4. \quad (1)$$

When protons interact then the created pairs of virtual loops appear mostly in the  $d = I$  state as the charge-anticharge pairs. We can see that in the  $d = I$  state is created charged cloud composed of the pairs – such cloud does not violate the state of the core. This cloud increases the radius  $C$  of the interacting proton. The modified radius is  $C' = C + R_{loop}$ . This means that the modified radius  $R'$  can be calculated from following formula

$$(R')^3 = 3 (C')^2 D / 4. \quad (2)$$

For loop created from the radius of the core  $A$  is

$$M_{loop-A} = M_{core-of-baryons} / (2 \pi) = 115.78 \text{ MeV}. \quad (3)$$

This mass is close to the mass of the muon and for such mass we obtain

$$R_{loop-muon-maximum} = A / (2 \pi) = 0.1110014 \text{ fm}. \quad (4)$$

Now we can calculate the maximum root-mean-square charge radius of protons for such initial conditions:

$$C'_{proton-muon-maximum} = 1.31028 \text{ fm so } R'_{proton-muon-maximum} = 0.84282 \text{ fm}.$$

There can appear the loops corresponding to the exact mass of the interacting (not free) muon with the core of baryons:  $M_{muon} = 105.82889 \text{ MeV}$  [1A]. Such loop has following radius

$$R_{loop-muon-minimum} = A M_{muon} / M_{core-of-baryons} = 0.1014648 \text{ fm}. \quad (5)$$

For such loop we obtain

$$C'_{proton-muon-minimum} = 1.300747 \text{ fm so } R'_{proton-muon-minimum} = 0.83873 \text{ fm}.$$

It is the lower limit. The arithmetic mean is

$$(R'_{proton-muon-maximum} + R'_{proton-muon-minimum}) / 2 = \underline{0.84077 \text{ fm}}.$$

It is the muon radius of proton. This value is consistent with experimental data [2].

The electrons interact with the most distant electric charge i.e. with the relativistic charged pion in the  $d = I$  state. Radius of orbit for such pion is  $C = A + B$ . This means that there are produced loops that radius is

$$R_{loop-electron} = (A + B) / (2 \pi) = 0.1908717 \text{ fm}. \quad (6)$$

For protons interacting with electrons we obtain

$$C'_{proton-electron} = 1.390154 \text{ fm so } R'_{proton-electron} = \underline{0.87673 \text{ fm}}.$$

It is the electron radius of proton – this radius is the central value (!) obtained in following experiment [3].

### 3. Summary

Within the Scale-Symmetric Theory we calculated the electron and muon radii of proton. We obtained that the electron radius of proton is 0.87673 fm – it is consistent with the central value obtained in experiments. The calculated muon radius of proton is 0.84077 fm and this result is consistent with experimental data also.

The two different radii follow from the atom-like structure of protons described within SST.

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