Mass Formulas for the X17 and E38 Particles, and the Proton Size Puzzle.

Sándor Varró
Extrem Light Infrastructure, ERIC, ALPS Facility, Szeged, Hungary.

Abstract. The angular correlations of electron-positron pairs, stemming from the products of several nuclear reactions, i.e. 7Li(p,e+e-)8Be, 3H(p,e+e-)4He, 11B(p,e+e-)12C, systematically show an anomaly at large relative angles, called the ATOMKI anomaly [1-3]. In each cases the observed effect can be explained by assuming the existence of a neutral boson, the X17 particle, having an invariant mass of 17 MeV/c^2 [1-3]. Other experiments on reactions like 63Cu(d,gg)65Zn show anomalous gamma diphoton (gg) correlations around the invariant mass 38 MeV/c^2 [4]. This may indicate the existence of the so-called E38 particle, mediating energy and momentum from the decaying products.

In the present talk we show that it is possible to derive the above-mentioned masses, on the basis of quantum electrodynamics. For this purpose we use the exact solutions of the Dirac equation of the system of a charged particle and quantized electromagnetic plane waves [5]. We have long realized that these non-perturbative solutions contain such kind of frequency blue-shift of the radiation quanta, which appears as an effective mass in the dispersion relation. In a recent application of these property of the solutions, we have taken the proton as the interacting charge, and derived a formula, which yields the value 17.0087 MeV/c^2 for the invariant mass of the X17 particle [6]. By applying this same method to the udd quark-photon plasma associated to the neutron, we receive a similar analytic formula, leading to the value 37.9937 MeV/c^2 for the invariant mass of the E38 particle [6]. We note that, besides the Sommerfeld fine structure constant and the nucleon masses, the derived formulas contain merely some elementaty statistical factors.

In our considerations a natural connection appears between the mass of the X17 particle and the proton size, the latter being a subject of intensive research, with puzzling outcomes [7,8]. We shall briefly review this subject, and higlight the just-mentioned connection in our scheeme, which delivers the value 0.846299 fm for the proton radius [6], and 0.845135 fm for the neutron radius. Each of these radii are smaller, by a factor of 0.640452, than the respective Compton wavelengths.

References.

[1] Krasznahorkay A J, Csatlós M, Csige L, et al., Observation of anomalous internal pair creation in 8Be : a possible indication of a light, neutral boson. Phys. Rev. Lett. 116, 042501 (2016).
[2] Krasznahorkay A J, Krasznahorkay A, Csatlós M, Csige L, et al., Observation of the X17 anomaly in the decay of the Giant Dipole Resonance of 8Be. arXiv:2308.06473 (2023).
[3] Ahn T T, Trong T D, Krasznahorkay A J, et al., Checking the anomaly with a two-arm electon positron pair spectrometer. Universe 2024, 10, 168. See
[4] Abraamyan K, Austin C, Baznat M, Check of the structure in photon pairs spectra at the invariant mass of about 38 MeV/c2. EJP Web of Conferences 204, 08004 (2019). See also arXiv: 2311.18632.
[5] Varró S, Theoretical study of the interaction of free electrons with intense light. (Ph.D. dissertation, 1981). Hungarian Physical Journal XXXI, 399-454 (1983).
[6] Varró S, Proposal for an electromagnetic mass formula for the X17 particle. Universe 2024, 10, 86. [https://doi.org/10.3390/universe10020086]. [Based on the talk presented at ISMD 2023 - 52nd International Symposium on Multiparticle Dynamics, August 21-25 2023 - Gyöngyös, Hungary.
This article belongs to the Special Issue "Multiparticle Dynamics", Edited by Csörgő T, Csanád M and Novák T; https://www.mdpi.com/journal/universe/special_issues/3R2XYDMCV9].
[7] Pohl R, Antognini A, Nez F, et al., The size of the proton. Nature 466, 213-216 (2010).
[8] Udem Th, Quantum electrodynamics and the proton size. Nature Physics 14, 632 (2018).