Cosmic-Ray Showers and Muon Problem

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Abstract: The Pierre Auger Observatory has detected more muons from cosmic-ray showers (about 30% to 60% for centre-of-mass energies 110 TeV to 170 TeV) than predicted within the LHC models for the centre-of-mass energies about 10 times lower (i.e. below 13 TeV). It suggests that at the energies beyond LHC, there can dominate a phenomenon that is neglected at the LHC energies. Here, within the Scale-Symmetric Theory (SST), we show that the observed excess of muons concerns energies above the threshold energy about 18 TeV for the nucleons. At such energies, in proton-proton collisions, production of the spin-1 proton-antiproton pairs or narrow resonances dominates. This leads to the 50% positive excess of muons in comparison with the LHC-models prediction that should be observed in the cosmic-ray showers. It is consistent with the Auger data.

Introduction and motivation

The Pierre Auger Observatory has detected more muons from cosmic-ray showers (about 30% to 60% for centre-of-mass energies 110 TeV to 170 TeV) than predicted within the LHC models for the centre-of-mass energies about 10 times lower (i.e. below 13 TeV) [1]. It suggests that at the energies beyond LHC, there can dominate a phenomenon that is neglected at the LHC energies. Here, within the Scale-Symmetric Theory (SST) [2], we show that the observed excess of muons concerns energies above the threshold energy about 18 TeV for the nucleons. At such energies, in proton-proton collisions, production of spin-1 proton-antiproton pairs or narrow resonances dominates. This leads to the 50% positive excess of muons in comparison with the LHC-models prediction that should be observed in the cosmic-ray showers. It is consistent with the Auger data.

The Scale-Symmetric Theory (SST) shows that the successive topological phase transitions of the superluminal non-gravitating Higgs field during its inflation (the initial big bang) lead to the different scales of sizes/energies [2A]. Due to a few new symmetries, there consequently appear the superluminal binary systems of closed strings (the spin-1 entanglons) responsible for the quantum entanglement (it is the quantum-entanglement scale), neutrinos and the spin-1 neutrino-antineutrino pairs moving with the speed of light in "vacuum", c, which are the components of the gravitating Einstein spacetime (it is the Planck scale), cores of baryons (it is the electric-charge scale), and the cosmic-structures/protoworlds (it is the cosmological scale) that evolution leads to the dark-matter (DM) structures (they are the loops and filaments composed of entangled non-rotating-spin neutrino-antineutrino pairs), dark energy (it consists of the additional non-rotating-spin neutrino-antineutrino pairs interacting gravitationally only) and the expanding Universe (the "soft" big bang due to the inflows of the dark energy into Protoworld) [2A], [2B]. The electric-charge scale leads to the atom-like structure of baryons [2A].

The internal structure of the core of baryons should be maximally disturbed when the surface of the central condensate attains the torus/charge i.e. when the radius of the condensate increases $A/(3r_{p(proton)}) = 26.688$ times [1A]. It is when the mass of the proton increases $\{A/(3r_{p(prpton)})\}^3 = 1.9009 \cdot 10^4$ times. Mass of the central condensate in the rest is $Y = 424.12$ MeV i.e. for energies about 18 TeV and higher, the core is maximally disturbed. Above this threshold energy, the proton loses violently the surplus energy [2A].

Notice that according to SST, the mass distance between the condensate Y and the torus/charge is very close to the mass of muon and that mass of four muons is very close to Y so this scalar can decay, first of all, to two spin-1 muon-antimuon pairs with antiparallel spins.

At high energies, production of the QVRs groups (a group contains 1 quantum that is a precursor of the group, 1 vector boson, and 1 or 2 narrow resonances) in the nucleon-nucleon collisions dominates [3], [4], [5]. At highest LHC energies, there appear 1 vector boson and 1 narrow resonance with low standard deviation [5]. It should be characteristic for the centre-of-mass energies above 18 TeV also. The vector boson should be the spin-1 proton-antiproton pair.

According to SST, the initial single cosmic ray is in reality, due to a collision of ultra-high-energy neutrino with nucleon, the second-generation cosmic ray, which is the single relativistic nucleon. SST shows that nucleons with energies above 18 TeV should violently emit energy to reduce it below 18 TeV – this is a very fast reduction of nucleon momentum that leads to the air shower.

It is true that extensive air showers are initiated by nucleons at ultra-high energies. But notice that due to the collision of such nucleon with another one there is produced the spin-1 proton-antiproton pair (the vector boson) or a narrow resonance with low standard deviation and $J = 0$. It is obvious that the muon characteristics of proton and antiproton in the created proton-antiproton pair should be the same. Probabilities of creation of proton-antiproton pair and narrow resonance should be the same because their relativistic energies should be the same for the same energy of initial nucleon. It leads to conclusion that the air showers produced by the nucleon-nucleon collisions in which appears narrow resonance should behave according to the LHC models whereas number of produced muons in the nucleon-nucleon collisions in which appears the proton-antiproton pair should be two times greater. It means that the mean positive excess of muons in relation to the LHC-models prediction should be about 50%. It is consistent with the Auger data.

References

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