A Strange Coincidence in the Behaviour of Leptons and Mesons

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Abstract: According to the Scale-Symmetric Theory (SST), all hadrons are built of the Einstein-spacetime (ES) components (they are the neutrino-antineutrino pairs - their detection is much difficult than neutrinos) and neutrino(s). The ES components are the carriers of the photons and gluons (they are the rotational energies). It leads to conclusion that sometimes we should observe some coincidences in the behaviour of neutrinos and hadrons. Here we show one of such lepton-meson coincidence - there is the similarity of the curves for the neutrino cross-section per neutrino energy in quasi-elastic (QE) scattering and for the kaon-to-pion ratio - in both curves, there is a “horn” and the origin of the separated two curves is the same.

1. Introduction

According to the Scale-Symmetric Theory (SST), all hadrons are built of the Einstein-spacetime (ES) components (they are the neutrino-antineutrino pairs – their detection is much difficult than neutrinos) and neutrino(s) [1]. The ES components are the carriers of the photons and gluons (they are the rotational energies) [1]. It leads to conclusion that sometimes we should observe some coincidences in the behaviour of neutrinos and hadrons. Here we show one of such lepton-meson coincidence – there is the similarity of the curves for the neutrino cross-section per neutrino energy in quasi-elastic (QE) scattering (the curve in Fig. 1 is drawn on the basis of the data presented in [2]) and for the kaon-to-pion ratio (the curve in Fig. 2 is drawn on the basis of the data presented in [3] and on the basis of the theoretical results presented in [4]) – in both curves, there is a “horn” and the origin of the separated two curves is the same.

2. Theoretical curve for the kaon-to-pion ratio [4]

The atom-like structure of baryons leads to two curves for ratio $K/\pi = f(s_{NN}^{1/2})$ [4] and they are consistent with experimental data [3].

Number of produced particles is inversely proportional to their mass. For the K/π ratio is

$$K / \pi = m_i / m_{kaon(+-)} , \tag{1}$$

where m_i is the mass of loops composed of gluons or structures composed of gluon loops whereas $m_{kaon(+-)}$ is the mass of the charged kaon [1]. With increasing energy of collision there appears more and more of the more energetic gluons, loops and structures. Pions are the binary systems of gluon loops and mass of each loop for resting pion is 67.54 MeV and consists of two neutrinos [1]. Each such neutrino carries energy equal to 33.77 MeV [1].

Mass of charged pion is 139.57 MeV [1]. Mass of pion leads to the coupling constant for the strong interactions of the non-relativistic nucleons $\alpha_s^{NN} = 14.4$ [1]. For very short period of the K and π production in the nucleon-nucleon collisions, the nucleons pairs are in the rest. The strong masses of the charged pion and kaon we can calculate multiplying their masses by the coupling constant. For the charged pion, we obtain $sqrt(s_{NN}) = 2.0$ GeV and it is the starting point of the curve for the K/π ratio. For the charged kaon, we obtain $sqrt(s_{NN}) = 7.1$ GeV. A kaon is the binary system of binary systems of loops so it is a quadrupole of loops [1]. Masses of the gluon loops the resting kaons consist of are greater than in the resting pions [1]. Due to the pairing of gluon loops (in pions) and the four-object symmetry, there can appear particles built of following number, x, of gluon loops

$$x = 2^d, \tag{2}$$

where $d = 0, 1, 2, 4, 8\ldots$

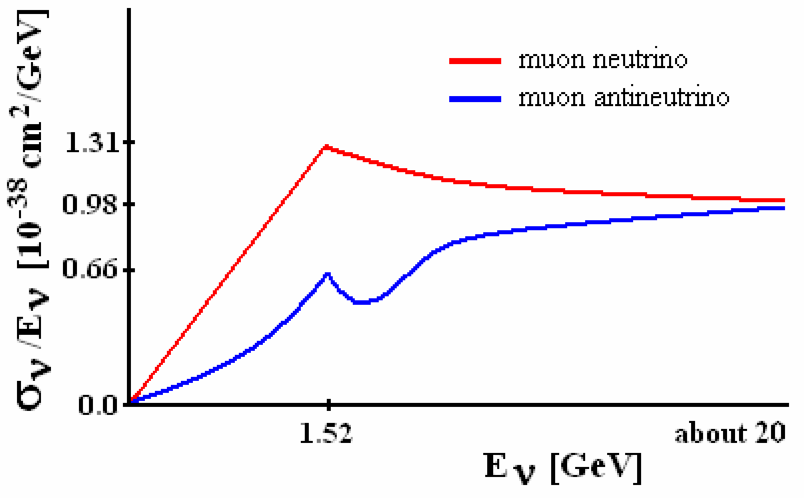

Fig.1 The 'horn' for the $\sigma_{neutrino} / E_{neutrino}$ ratio in the QE scattering.

We can see that for energies lower than 7.1 GeV, the pions and kaons arise from the single loops ($x = 1$ for $d = 0$). When the energy of collisions increases then there arise more and more the more energetic gluons from which the kaon loops arise. For energies higher than 7.1 GeV, pions are produced from single loops ($m_i = 67.54$ MeV) whereas kaons are produced at once as the quadrupoles of gluon loops ($x = 4$ for $d = 2$). This leads to $K/\pi = 67.54 / 493.7 \approx 0.14$ and it is the asymptote for positive and negative particles. To obtain the real curves, we must take into account also the internal helicity of electric charge inside pions [1]. The splitting into two curves follows from the different helicities of electric charges of pions (left internal helicity for positive pions and right for negative ones [1]) in relation to the helicity of the colliding nucleons (left internal helicity). The internal helicity of charge of the negative pions is opposite to the colliding nucleons so for the threshold energy for kaons, i.e. 7.1 GeV, they are produced from the neutrinos that carry energy equal to $m_i = 33.77$ MeV. This means that for energy $sqrt(s_{NN}) = 7.1$ GeV, for the negative particles should be $K/\pi = 33.77 / 493.7 \approx 0.07$. We can see that the curve $K/\pi = f(s_{NN}^{1/2})$ for negative particles is lowered in relation to the curve for positive particles and should have a small maximum for the threshold energy. The internal helicity of electric charge of the positive pions is the same as of the colliding nucleons so they arise at once as the positive pions. This means that for the threshold energy, for the positive particles should be K/π = 139.57 / 493.7 ≈ 0.28. We can see that the curve $K/\pi = f(s_{NN}^{1/2})$ for positive particles is elevated and there appears the big "horn".

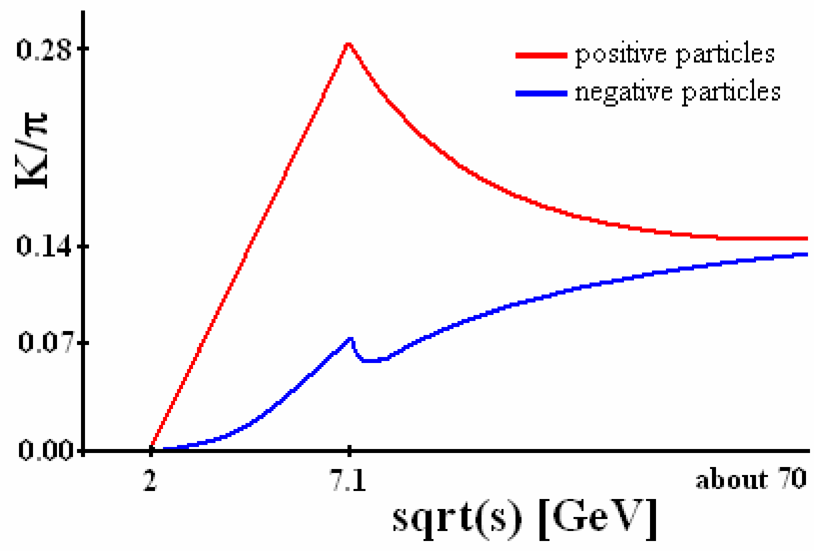

Fig.2 The 'horn' for the K/π ratio

3. Theoretical curve for the ratio of the neutrino cross-section to neutrino energy in the quasi-elastic (QE) scattering

In SST, the ν_μ and $\nu_{\mu,anti}$ charged current (CC) inclusive scattering is the neutrino scattering on nucleon (N) in massive target (for example, $\nu_\mu N \rightarrow \mu^- X$). At very high energies it is the deep inelastic scattering. We already described the cross sections divided by neutrino energy as a function of neutrino energy for such CC inclusive scattering [5].

The ν_μ and $\nu_{\mu,anti}$ quasi-elastic (QE) scattering is the neutrino scattering on free atomic nuclei (for example, $\nu_\mu H_2 \rightarrow \mu^- p$). It is described below – the theoretical results are collected in Fig.1.

The ν_μ and $\nu_{\mu,anti}$ neutral current (NC) scattering is the neutrino scattering in which there appears single pion (for example, $\nu_\mu p \rightarrow \nu_\mu p \pi^o$). It is described below – the theoretical results are collected in Fig.3.

Mass of the neutrino disc is directly proportional to squared radius of the disc so neutrino cross-section is directly proportional to involved mass in the scattering of neutrinos on nucleons. During the QE scattering there are produced muons in the cost of the mass of the disc [5]. It leads to conclusion that in the numerator of the ratio σ_ν/E_ν there is muon instead the kaon which appears in the K/π ratio. In the denominator there is neutrino energy which is equal to the mass of the disc. We can see that instead the K/π ratio there is the μ/ν ratio.

According to SST, muon neutrino (the same as the positively charged pion) has the same left-handed internal helicity as nucleons whereas the muon antineutrino (the same as the negatively charged pion) has the right-handed internal helicity i.e. has helicity opposite to nucleons ([1]: see Table 6). We can see that the curve for antineutrinos should be lowered – it is consistent with experimental data [2].

We can assume that the muons appear due to the decays of charged pions which are produced due to the nuclear strong interactions. Threshold energy for such pion production is 2.0 GeV so the threshold energy that corresponds to muon mass (emphasize that muons do not interact strongly) is 1.52 GeV – it as well is consistent with experimental data [2]. For the threshold energy 1.52 GeV, the ratio of QE (it is the neutrino scattering on atomic nucleus containing two nucleons, for example, on H_2 or D_2) to the CC (it is the neutrino scattering on single nucleon) should be QE/CC = 2. For muon neutrino, the CC inclusive scattering is $(\sigma_\nu/E_\nu)_{invariant} \approx 0.656 \cdot 10^{-38}$ cm^2/GeV [5] so, for the QE threshold energy 1.52 GeV, for the muon neutrino, the QE scattering leads to $1.31 \cdot 10^{-38}$ cm^2/GeV. For muon antineutrino, the CC inclusive scattering is about $0.33 \cdot 10^{-38}$ cm^2/GeV [5] so, for the QE threshold energy 1.52 GeV, for the muon antineutrino, the QE scattering leads to about $0.66 \cdot 10^{-38}$ cm^2/GeV. Obtained here theoretical results are consistent with experimental data [2].

In the NC scattering, the intermediate state consists of neutrino or antineutrino, neutron-antineutron pair and neutral pion-pion pair. Such a state leads to neutral current. Moreover, there is neutron and antineutron so neutrino cross section per neutrino energy should be the same for neutrinos and antineutrinos. The threshold energy for such NC scattering is (for the threshold energy, the ratio σ_ν/E_ν reaches its maximum)

$$E_{threshold,NC} = (M_{proton} + 2\ M_{neutron} + 2\ M_{pion(o)})\ \alpha_s^{NN} \approx 44 \text{ GeV}\ . \qquad (3)$$

The $(\sigma_\nu/E_\nu)_{invariant}$ we calculated for neutrino energy equal to the rest mass of proton – it is in denominator [5]. For the NC scattering, there should be $E_{threshold,NC}$ instead M_{proton}. It leads to conclusion that above the $E_{threshold,NC}$, value of σ_ν/E_ν should be

$$(\sigma_\nu/E_\nu)_{maximum,NC} = (\sigma_\nu / E_\nu)_{invariant}\ M_{proton} / (M_{proton} + 2\ M_{neutron} + 2\ M_{pion(o)}) =$$

$$= 0.20 \cdot 10^{-38} \text{ cm}^2/\text{GeV}. \qquad (4)$$

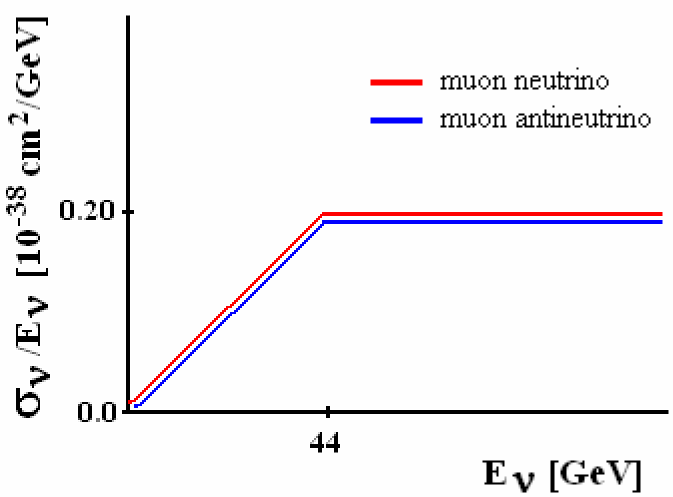

Fig.3 The $\sigma_{neutrino}/E_{neutrino}$ ratio in the NC scattering.

4. Summary

Here we showed that the origin of the similarity of the curves for the neutrino cross-section per neutrino energy as a function of neutrino energy in QE scattering and for the kaon-to-pion ratio as a function of s_{NN} [GeV] is the same.

The splitting of curves for neutrinos and antineutrinos on the one hand and positively charged mesons and negatively charged ones on the other hand results from different internal helicities of particles in relation to nucleons.

The appearing “horns” in the curves, are the result of the threshold energy for production of muons in the neutrino discs (about 1.52 GeV) and for production of kaons in the collisions of nucleons (about 7.1 GeV).

Obtained within SST theoretical results for CC inclusive scattering, QE scattering and NC scattering are consistent with experimental data.

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