Research & Reviews: Journal of Pure and Applied Physics

e-ISSN:2320-2459
p-ISSN:2347-2316

The Interest of Muon–Antimuon (μ^- μ^+) pair production: $\gamma \rightarrow \mu^- \mu^+$

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Short Communication

Received date: 12/07/2017

Accepted date: 25/07/2017

Published date: 31/07/2017

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Keywords: Muon; Lepton: Cross-section: Decay mode

ABSTRACT

Many investigations about leptons interactions and calculations of Muons transport in the matter have been subjected to many kinds of research. Attention has been paid to the mathematical development of Muons and no more interest for doing it was demonstrated. That is why some question retained our attention. This questioning paper asked important questions concerning the Muon–Anti-muon pair production. It brought out that Electron and Muon are physically similar but, the used fields of an electron are too important and no attention had been paid on the exploration of the Muon (as well as a Tau).

INTRODUCTION

When hearing "Muon–Anti-muon production", people think about the electron–positron (e-e+) pair production. Some questions as "does the Muon and Tau have similar properties as the electron? What is the real comprehension about Muon properties?" Muon as electron and tau are leptons and have the same physical properties as mentioned in the following sentences. By leptons, we hear any of a family of element, any particle that interacts through the weak force and does not participate in the strong force. In the case that the Muon obeys to the same conservative rules as electron, and have the same properties ($B = o$; $q = -1$; $J^{\pi} = 1/2$; $L = 1$; ɒ I, I_3, S, Y *and Quarts composition*); we dream to explore leptons in many applications as electric power, detection... etc. Many scientists, especially physicists worked on the interaction of Muons in the atmosphere. Many attentions have been paid nowadays to simulate the gamma conversion into Muon pair process using Monte Carlo method. Burkhards [1] and Kelner [2] introduced some little information about this process [3]. We now decide to pay attention to the mathematical formulation of the cross-section of the Muon–Anti-muon pair production. This questioning paper aims to highlight mathematical formulation and development concerning the Muons production. In addition, many questions were asked concerning their physical properties and use.

Cross-section Formulation and Questioning

When a given photon energy converts in a material characterized by A and Z, the probability for conversion to take place is calculated according to a parameterized cross section. During the conversion process, the sharing between μ+ and μ- of the photon energy respects physical conservation rules as energy, momentum. The production the Muon can be possible only in the field of the nucleus on atomic electrons. Here is shown the equation of the interaction:

$$\gamma + e \rightarrow e + \mu^- + \mu^+ \tag{1}$$

This interaction has a threshold of [1]:

$$\frac{1}{m_e}\left[(m_\mu + m_\mu)m_\mu\right] + (m_\mu + m_\mu) = \frac{2m_\mu^2}{m_e} + 2m_\mu = \frac{2m_\mu(m_\mu + m_e)}{m_e} \cong 44\,GeV \tag{2}$$

e-ISSN:2320-2459
p-ISSN:2347-2316

At high energies, the cross section on atomic electrons depends on $\propto \frac{1}{Z}$ to the total cross section. For this reason, this process is a high energy physical process. The conservation rules of momentum and energy can be explained by:

$$E_\gamma + E_e = E_e + E_{\mu^-} + E_{\mu^+} \qquad \begin{aligned} E_{\mu^-} &= E_\mu^- \\ E_{\mu^+} &= E_\mu^+ \end{aligned} \tag{3}$$

Energy before interaction = energy after interaction. By using energy fraction,

$$q_+ = \frac{E_\mu^+}{E_\gamma} \qquad q_- = \frac{E_\mu^-}{E_\gamma} \qquad and \qquad q_+ + q_- = \frac{E_\mu^+ + E_\mu^-}{E_\gamma} = 1 \tag{4}$$

The differential cross section for electromagnetic Muons pair creation is:

$$\frac{d\sigma}{dq_+} = 4\alpha Z^2 r_c^2 \left(1 - \frac{4}{3} q_+ q_-\right) Log\left[\left(\frac{B Z^{-1/3}}{D_n}\frac{m_\mu}{m_e}\right)\left(\frac{1 + (D_n\sqrt{e} - 2)\, \delta/m_\mu}{1 + B Z^{-1/3}\sqrt{e}\, \delta/m_e}\right)\right] \tag{5}$$

In term of the energy fraction of Muons. In this formula, we have the following specifications:

Z is the charge of the nucleus, r_c is the classical radius of the particles which are produced (the Muon in this case); $\delta = \frac{m_\mu^2}{2 E_\gamma q_+ q_-}$; $\sqrt{e} = 1.6487...$; $B = 183$ (except the case of hydrogen atom where B=202.4) δ, the minimal momentum transfer and $D_n = 1.54\, A^{0.27}$ (except the case of hydrogen atom where $D_n = 1.49$). For writing consideration, we can assume that

$$W_\infty = \frac{B Z^{1/3}}{D_n}\frac{m_\mu}{m_e} \quad and \quad W = \frac{1 + (D_n\sqrt{e} - 2)\,\delta / m_\mu}{1 + B Z^{-1/3}\sqrt{e}\,\delta / m_e}.W_\infty \tag{6}$$

The differential cross section can now be written as:

$$\frac{d\sigma}{dq_+} = 4\alpha Z^2 r_c^2 \left(1 - \frac{4}{3} q_+ q_-\right) Log(W) \tag{7}$$

Many authors as Bethe and Heitler explain the cross-section of the Bremsstrahlung. The photo production of Muons by ordinary photons has been analyzed in numerous papers [4,5] and the corresponding cross-section is connected with the Bremsstrahlung cross-section by crossing [6]:

$$d\sigma\left(\gamma + Z \rightarrow Z + \mu^+ + \mu^-\right) = \alpha_\mu \left(\frac{2 Z \alpha}{m_\mu}\right)^2 \left(1 - \frac{4 q_+ q_-}{3}\right) \times \left[\ln\left(\frac{2 m_\mu}{3 m_e}\frac{A_0}{Z^{2/3}}\right) - \ln\left(1 + \frac{A_0}{Z^{1/3}}\frac{\delta\sqrt{e}}{m_e}\right)\right] dq_+ \tag{8}$$

Where α=1/137, $\alpha_\mu = 10^{-5}\alpha$, A≅ 190 a constant which determines the value of the radiation logarithm. $E_\gamma \approx 40\, GeV$ and $0.1 < q_\pm < 0.9$, the atomic screening may be neglected, so that the logarithm factor simplifies:

$$\ln\left(\frac{2}{3}\frac{m_\mu}{\delta Z^{1/3}\sqrt{e}}\right) = \ln\left(\frac{4}{3}\frac{E_\gamma q_+ q_-}{m_\mu Z^{1/3}}\right) - \frac{1}{2} \tag{9}$$

Taking this into account, the cross-section can be written as:

$$d\sigma = \alpha_\mu \left(\frac{2 Z \alpha}{m_\mu}\right)^2 \left(1 - \frac{4 q_+ q_-}{3}\right) \times \left[\ln\left(\frac{\frac{B}{Z^{1/3}}\frac{m_\mu}{m_e}}{1 + \frac{B}{Z^{1/3}}\frac{\delta}{m_e}\sqrt{e}}\right) - \ln\left(\frac{D_n}{1 + \frac{\delta}{m_\mu}\left(D_n\sqrt{e} - 2\right)}\right)\right] dq_+ \tag{10}$$

It is important to denote that for not too important value of δ parameter, $\frac{\delta}{m_e} >>> \frac{Z^{1/3}}{B\sqrt{e}}$ and the square bracket in the previous expression remind the expression of W. if we neglect both atomic and nuclear form-factor and integrate over dq_+, we reproduce and expression similar to the well-known result.

$$\sigma = \alpha_\mu \frac{7}{9}\left(\frac{2 Z \alpha}{m_\mu}\right)^2 \left(\ln\left(\frac{2 E_{\gamma_\mu}}{m_\mu}\right) - \frac{109}{42}\right) \tag{11}$$

While Muon obeys to the previous cross-section equations, they also obey to the same conservation rules as electron: for this reason, “matter (atom) can be also constituted with Muons”.

Many questions can now be open for the attention of scientists especially physicists:

Does Muons (Tau on the other hand) constitute matter (Atom) as Electron? If yes, how are they organised in the atomic shell, nuclear field? If no, why?

If the matter is made with Muon as Electron, is it possible to easily create a pair of Muon–Anti-muon (μ^- / μ^+)? Is it possible to find it in a special matter? What is the favourite environment for their production except for the atmosphere?

In the case that the production of Muon is physically possible, does the collection of Muon be used in electrical power exploitation? Does it be used in detection systems?

The real difficulty of this lepton is his instability due to his short half-life. Why do the scientists pay too attention to the simulation of Muons pair production? Are there any utility in medicine, in technology or in another field of interest?

All these questions are just an introduction to a new topic and the "controversy of the Constitution of the matter, especially atom (electron trajectory and "Muon trajectory" around the nucleus)". The verification of the Muon (as well as Tau) will be addressed in the future to denote the difference between these two leptons and electrons. Moreover, the application of electron in physics and related technologic applications are evidenced in nowadays' life.

CONCLUSION

The conclusion of this questioning paper is highlighted by the following questions: "Electron, Muon: are they twin? – The problem is their lifetime. Are their brother? – Their production and the decay mode of Muon can seem as mistakes. Are they friend or parent and son? Their mass, lifetime and decay mode bring much difference to evidence that they are similar but different. The real question is: "what is lepton in the sense of conservation rules, interaction and decay mode?"

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