An Experiment can Proof that many Muons are Produced on the Ground

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Abstract

I find that an undergraduate physics experiment can proof that the most of muons on the earth's surface are not come from cosmic ray particles in the high altitude atmosphere. Most of those muons are produced on the ground for the reasons of interactions among neutrinos and electrons. The main points of views are that the decay time detected in the apparatus should be much smaller than muon's lifetime if all of the muons are come from high altitude atmosphere. On the other hand, the energy of muons that can arrive at ground must exceed 1GeV according to special relativity theory. Those muons that its energy is much lower cannot arrive at ground in their lifetime. The experiment results show that the natural muons' decay time on the ground is nearly equal to their lifetime. The experiments also detect that there are numerous muons that its energy close to 100MeV on the ground.

Key words

Muons; Neutrinos; Cosmic Ray

The passed experiments shown that there are numerous muons existed in the earth's surface. The old theories claim that all of those muons are come from the high altitude atmosphere. The height is about 15km. The muons are the secondary cosmic ray particles, which produced by the primary cosmic ray that interacting with the oxygen or nitrogen atoms and molecules. That is, after interacted with atoms or molecules in the atmosphere, the primary cosmic ray will produce mesons, neutrons and etc. The mesons will decay to muons.

Since muons' life time is very shorter, it will need to consider the special relativity effects to reach at the ground. It also becomes the important evidence to support the special relativity theory. [1]

However, I found that the interactions among neutrinos and electrons can also have the abilities to produce numerous muons besides the cosmic ray in the high altitude atmosphere in my previous works. [2, 3] On the other hand, the neutrinos can interact with electrons on the ground besides in the atmosphere. It is different from the older theories. So it can be proofed by the experiments. I will analysis it by an undergraduate experiment in this paper.

1 Wu's experiments on muons' lifetime

Since there are large amount of muons on the earth's surface and there are also mature detecting technologies, many instruments had been designed [4~6] to detect the muon's lifetime over the past few decades. Some instruments are designed specifically for undergraduate students. Because the popularity is very wide, a large number of students involved in the experiment, so the results are also very reliable.

Here I use the results of Wu et al. [6] to analysis this question. Wu and his co-workers designed an apparatus to measure the life time of muons naturally produced in the air in 2010. This apparatus can be used for teaching undergraduate students knowledge of muons.

The device of Wu et al. is mainly a plastic scintillator of about 0.3 meters long, and when a muon passes through the scintillator, it will produce electrons and fluorescent photons in the scintillator. At this point the muon produces a fluorescent trace that is a straight line. It can be detected immediately.

High-energy muons can pass directly through the scintillator without decay. But muons with lower energy at about 100MeV cannot wear out the scintillator and decay in them ultimately due to the occurrence of a large proportion of the energy loss. After decay, it will produce electrons as well as electron and muon neutrinos.

The electrons that produced by the muon decay process will interact with the scintillator to produce fluorescence. Since the electrons after decay are not necessarily in the same direction as the motion of the muons, and the decay process will also take times, it can be easily distinguished from the trajectories of the incident muons.

The external electronic device can measure when the muons incident scintillator and when the muons decay. After then, the time difference can be calculated to determine how long the muons decay.

2 Experiment results

Wu at el. collected 18296 events. Their results shown that the muons' decay time is about 2124.6 ±9.6ns. It is close to the actually lifetime 2197.03ns of muons.

3 Analysis

Here I carry out a simple analysis on Wu's results.

First of all, the experimental results of Wu et al. are smaller than the accepted results. Wu consider that this error is attributed to the interactions among part of the muons and material atoms. So part of muons cannot be detected. However, I think this can be more attributed to the fact that those muons incident on the scintillator has been running for tens of nanoseconds before entering the scintillator, because it is impossible for all of the muons that just come into the scintillator decayed instantaneously.

If we accept the fact that muons must run for tens of nanoseconds outside the scintillator, we can calculate the distance that the muons run over. According to Wu's data, the average velocity of muons is about 0.3c, so the distance is

$$70 \times 10^{-9} \times 3 \times 10^{8} = 21(m)$$

It means that the muons are produced at an average distance of 21 meters from the scintillator. It will not exceed 23 meters even taking into account of the effect of relativity.

So it can be sure that these muons cannot come from the atmosphere which height is more than ten kilometers. It can only be produced on the ground where the experimental device is located for some reason.

Secondly, the data provided by Wu shows that their devices can only detect the lifetime of muons that their energy is located in about 100 MeV. The frequency of events reaches 10 Hz. The scintillator's base area is about 0.045 m^2. So it means that the fluxes of these low energy muons is about

$$\frac{10}{0.045} = 222(m^{-2}s^{-1}) = 13320(m^{-2}min^{-1})$$

This value is similar to the current estimate of the muons flux on the Earth's surface.

That is, the muons of this energy region are the important component of the muons flux on the Earth's surface.

Then there is a problem here. If these muons are produced in more than ten kilometers height of the atmosphere, even we taking into account the relativistic effect, the muons that located in this energy region, or slightly higher, is not May reach the ground in its life. It will not run more than 1 km actually.

4 Conclusions

From the analysis of the experiment results of Wu et al., We can see that there are a lot of low-energy, normal-life muons on the earth's surface. If we rely solely on the calculation of these muons that produced by the cosmic rays in the atmosphere more than ten kilometers height away, we are unable to obtain such results. Therefore, it is believed that there is a mechanism on the ground that can produce a large number of low-energy muons in the air or other matters to supplement, in order to explain the experiment results of Wu and other authors.

My previous works [3] pointed out that the theory of the interaction between neutrinos and electrons can explain this phenomenon well. When the solar neutrinos or atmospheric neutrinos are incident on the ground, these neutrinos will interact with electrons in the air or other matters, and further produce muons and other leptons, which continuously provide a variety of energy range of fresh neutrinos for the ground.

In addition to explaining the origins of the ground muons, my previous works can well explain other phenomena such as neutrino oscillations and provide a new method for detecting neutrinos [3].

So Wu's experimental results provide a very good support to my previous works. [2, 3]

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Appendix: Chinese Version

一个证明地球表面 μ 子产生于地面的实验

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摘要：本文发现通过一个大学本科物理实验装置可以证明，地球表面数量众多的 μ 子并非来自高空大气层宇宙射线粒子，而是中微子与地表物质的相互作用产生的。其原理在于，如果地球表面的 μ 子来自高空中宇宙射线粒子，则通过仪器所测量的 μ 子衰变时间会比 μ 子的寿命小很多。另外通过相对论效应到达地面的 μ 子能量至少应该达到 1GeV，小于这一能量的 μ 子是很难通过相对论效应在其寿命期间到达地面的。实验测量结果表明地表所测量的 μ 子衰变所需时间与 μ 子的寿命非常接近，并且实验也探测到地表有大量能量为 100MeV 左右的 μ 子存在。*

关键词： *μ 子；中微子；宇宙射线*

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I find that an undergraduate physics experiment can proof that the most of muons on the earth's surface are not come from cosmic ray particles in the high altitude atmosphere. Most of those muons are produced on the ground for the reasons of interactions among neutrinos and electrons. The main points of views are that the decay time detected in the apparatus should be much smaller than muon's lifetime if all of the muons are come from high altitude atmosphere. On the other hand, the energy of muons that can arrive at ground must exceed 1GeV according to special relativity theory. Those muons that its energy is much lower cannot arrive at ground in their lifetime. The experiment results show that the natural muons' decay time on the ground is nearly equal to their lifetime. The experiments also detect that there are numerous muons that its energy close to 100MeV on the ground.

Key words

Muons; Neutrinos; Cosmic Ray

现有的实验已经证明，在地球表面存在大量的μ子。一般认为这些μ子主要来自大气层上空大约 15km 处，宇宙射线粒子与大气层中的氧和氮原子相互作用以后的产物。属于宇宙射线的二次粒子。即宇宙射线中的质子等粒子与大气层原子相互作用以后，形成π介子等粒子，这些π介子进一步衰变，就可以形成μ子等二次粒子。

由于 μ 子的寿命非常短，只有 2μs，要穿行十几千米达到地面，需要考虑狭义相对论效应。这也成为了支持狭义相对论的一个重要证据[1]。

不过我在前期分析粒子结构的工作[2,3]中发现，除了宇宙射线粒子（除了中微子）能够产生大量μ子以外，中微子直接同物质中的电子相互作用也同样能够产生大量的μ子。而且中微子可以直接在地面上直接与电子相互作用产生μ子，这极大地丰富了地球表面μ子的来源。本文将通过分析一个实验案例来证明新的理论。

1 吴雨生的μ子寿命测量实验

由于地球表面μ子数量非常丰富，检测μ子的技术也非常成熟，国内外很早就已经设计了相应的装置[4~6]，提供大学本科生测量μ子寿命以及探讨相对论效应之用。由于普及面非常广，参与实验的大学生数量众多，因此其结果也非常可靠。

这里以 2010 年，中国科技大学的吴雨生等人设计了一个专门测量地面自然产生的μ子寿命的实验装置[6]为例来进行分析。

吴雨生等人的装置主要是一个大约 0.3 米长的塑料闪烁体，当μ子穿过该闪烁体的时候将在闪烁体中产生电子和荧光光子。此时μ子所产生的荧光轨迹是一条直线。这是可以被立即检测出来的。

高能μ子可以直接穿过闪烁体而不会发生衰变。但是能量在 100MeV 的μ子由于与闪烁体发生作用发生大比例的能量损失，最终无法穿出闪烁体而在其中产生衰变。衰变以后将产生电子以及电子和μ子中微子。

其中μ子衰变产生的电子又将与闪烁体相互作用产生荧光。由于衰变以后的电子其运动轨迹与μ子运动方向不一定相同，且衰变需要一定得时间，因此可以很容易将其与入射μ子的轨迹区分开来。

通过外部的电子装置测量μ子入射闪烁体的时间以及μ子发生衰变的时间，二者之差就是低能μ子的衰变时间。

2 实验结果

吴雨生等人收集了 18296 个结果，经过数据处理和分析以后，得出所测量的μ子衰变时间为

2124.6±9.6ns，该结果非常接近μ子实际的平均寿命 2197.03ns

3 分析

本文对吴雨生等人的结果进行一个简单的分析。

首先吴雨生等人的实验结果比公认的结果要小，吴文中将这一误差归咎于部分μ子与物质原子发生了相互作用，而无法检测到。不过我认为这其实可以归咎于入射到闪烁体的μ子已经运行了几十纳秒的时间才进入闪烁体。因为不可能所有的μ子刚好是在进入闪烁体瞬间产生的。

如果从所检测到的μ子需要在闪烁体外部运行几十纳秒才能进入闪烁体这一点来看，按照吴雨生等人所提供的数据，这些μ子的速度大约是 0.3c，70ns 可以运行的距离就是：

$$70 \times 10^{-9} \times 3 \times 10^{8} = 21(m)$$

也就是说这些μ子产生出来的地点离闪烁体的距离平均为 21 米，即便考虑到相对论的效应也不会超过 23 米。

因此可以肯定这些μ子不可能来自十几千米的大气层上空，只能够是在实验装置所在的地面上因为某种原因而产生的。

其次，从吴雨生等人提供的数据显示，他们的装置只能够检测能量大约为 100MeV 的μ子寿命，且频率达到 10Hz, 该闪烁体底面积大约 $0.045m^2$，也就是说这些低能μ子的通量大约是

$$\frac{10}{0.045} = 222(m^{-2}s^{-1}) = 13320(m^{-2}min^{-1})$$

这个数值与目前对地球表面μ子通量的估计结果差不多。

也就是说这一能量区域的μ子属于地球表面μ子通量的重要组成部分。

那么这里就有一个问题：如果这些μ子是在十几千米的大气层中产生的，则即便是考虑到相对论效应，这一能量区域，或者能量略高一些的μ子在其寿命期间是不可能达到地面的。其运行的距离不会超过 1 千米。

4 结论

从本文第三部分对吴雨生等人的实际结果进行分析可以看出，地球表面确实存在大量的低能、正常寿命的μ子。如果仅仅依靠大气层上空的宇宙射线与物质相互作用产生的μ子来计算，是无法获得这样的结果的。因此唯有相信在地面上存在一种机制能够不断在空气或者物质中

产生大量的低能 μ 子进行补充，才能够解释吴雨生以及国内外其他作者的实验结果。

我前期的工作[3]指出中微子与物质中的电子相互作用的理论能够很好地解释这一现象。当太阳中微子或者大气中微子入射到地面的时候，这些中微子就会与空气或者其他物质中的电子产生相互作用，并进一步产生 μ 子等轻子，这就为地面源源不断地提供了各种能量范围的新鲜中微子。从而满足各种在地面测量 μ 子寿命的本科实验所需。

除了解释地面 μ 子的来源以外，我的工作还能够很好地解释中微子振荡等现象，并提供检测中微子的新的方法[3]。

因此吴雨生等人的实验结果是对我前期工作的很好支持。

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