On a New Method to Detect Neutrinos

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Abstract

I proposed a new method to detect the neutrinos. The characteristic of this new method is to make use of the interactions between electron and neutrino. These interactions will produce the W bosons and etc. The produced W bosons will decay to pairs of lepton and neutrino. Then we only need to detect the leptons produced by W bosons to make sure how many neutrinos had arrived.

Key Words

Neutrino; Boson; Meson; Lepton

0 Introductions

It is a very difficult work to detect neutrino. The neutrino detection instruments all over the world are very large and expensive. Although we had spent lots of money, we can only detect very rare neutrinos.

I try to propose a new neutrino detection method based on my previous works, [1~4] Since this work is still in the beginning, I think there must be many problems in it. However, if we can think about the works of neutrino detection on another angle, it will be very helpful for us to understand more about neutrinos.

1 Oscillation vs. decay

It is a very important subject to research the neutrino oscillation. Currently we had made sure that there are three neutrino oscillation models. [5~8] The related theories point out that the reason why neutrinos will oscillate is due to the tiny mass of neutrinos. [9] However it is contradiction with the relativity theory.

The new theory of this work points out that the reason why neutrinos' flavor can change is due to the interactions between neutrino and electron. If a neutrino meets an electron, it will have the probabilities to interact with each other. The result of this interaction will form the W bosons and etc. Then in a very short time, the W boson will decay to the pairs of lepton and correspondent neutrino since the W boson's lifetime is very short. The ratio of neutrinos in different flavors will be stable after long travel of neutrinos.

2 The interactions between neutrino and electron

Here we use the example of interactions between neutrino and electron to describe how neutrinos' flavor changes.

2.1 There is no flavor changes after interaction

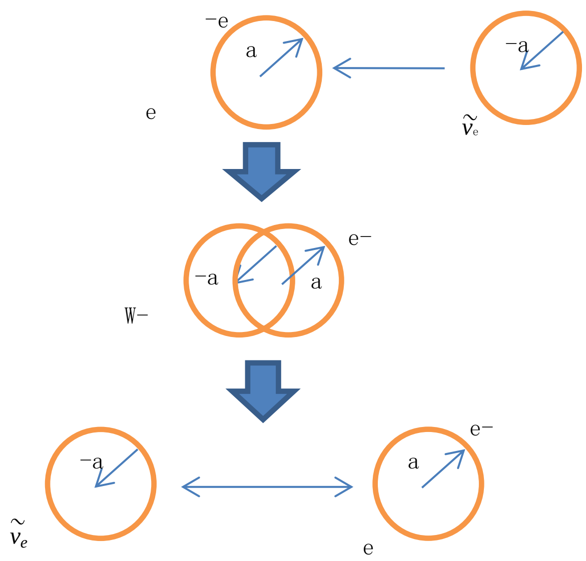

Figure 1. Decay back to electron and electron neutrino

After the antineutrino meets the electron as shown in figure 1, it will produce a W^- boson. However, W boson is very unstable, and it will decay back to a neutrino and an electron in a short time. It means that the neutrino's flavor is no change in the process shown in figure 1.

2.2 Electron antineutrino change to muon antineutrino after interaction

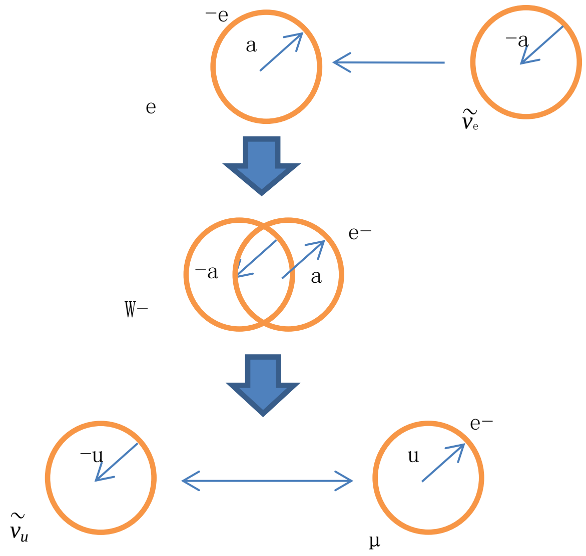

Figure 2. Decay to muon and muon antineutrino

The W boson can also decay to muon and muon neutrino according to standard model. Figure 2 shows that the neutrino flavor has changed. It may be the reason of why neutrinos can oscillate. However, it is different from neutrino oscillation process. The produced muon in this process can be detected in figure 2. If we detect enough muon in special matter, we can make sure that it was produced by the neutrinos.

2.3 Electron antineutrino change to tau antineutrino after interaction

There is another decay process shown in figure 3. The W boson decays to tau and tau neutrino in this process.

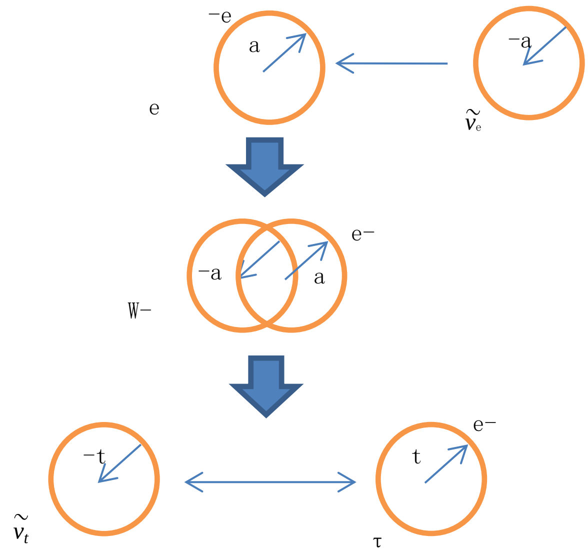

Figure 3. Decay to tau and tau antineutrino

3 The new method to detect neutrino

When a neutrino passes by an electron, they will have the possibilities to interact with each other. We can detect the lepton's flavor changing to make sure there is neutrino. It is shown in the part 2 in this paper. It can provide a new method to detect neutrino.

If the lepton's flavor changed, it will produce the new atoms that surrounded by muon or tau instead of electron. Those new atoms will absorb or emit special wavelength photons. If we can detect these special wavelength photons, we can make sure that there are lots of neutrinos passed by. The numbers of these photons are proportional to the numbers of neutrinos.

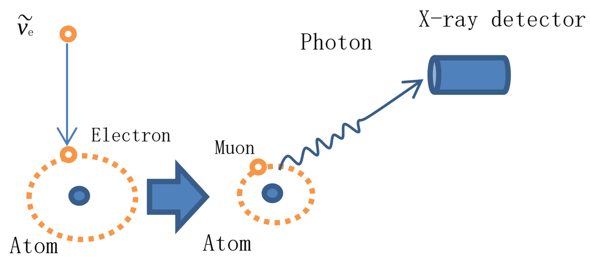

Figure 4. The neutrino detection process

Here we can roughly estimate the numbers of muons that produced by the neutrinos.

Assume the number of incoming neutrinos is N. we can also assume the interaction ratio between neutrinos and electrons is *p* for convenient. Then we can calculate the number of W bosons produced by this process.

$$n_w = pN$$

If the probability of W boson decay to three lepton pairs is equal, we can calculate the number of muons as

$$n_u = \frac{1}{3} pN$$

It is equal to the number of muon neutrinos.

It is the same of tau neutrino calculation.

If the new atoms surrounded by muons have been formed, it will absorb or emit correspondent photons. We can estimate those photons energy by considering the simplest hydrogen atom.

$$E \approx \alpha^2 m_u c^2 \approx 3keV$$

Where, m_u is the mass of muon.

This energy is located in X ray area. We can use lots of X-ray detection technologies to detect these photons. Since there are portable X-ray detection machine already, the neutrino detection machine can also be portable.

However, the interaction ratio *p* is difficult to determine. It involves the neutrino fly distance and electron density in special matter, and etc.

If we consider the electron density is uniform distributed, then after passed through L distance, the remaining electron neutrinos will be

$$N_1 = N\left(1 - \frac{2}{3} p\right)^{L}$$

For example, we can assume the height that producing muon in atmosphere neutrino oscillation is 100km. We use 1m as unit distance. By considering *p* is very smaller, we can obtain

$$N_1 = N\left(1 - \frac{2}{3} p\right)^{100000} \approx N\left(1 - 7 \times 10^6 p\right)$$

If $N_1 = 0.6N$

We can calculate $p \approx 6 \times 10^{-8}$

If this result is also suitable for solar neutrinos, then we can estimate that there will be nearly 10^6 neutrinos interact with electrons per square meter and per second in the earth since the density of solar neutrino is $10^{13}/m^2$ per second in the earth surface. Even if only a fraction of the reaction is eventually converted into muons, the number of muons is still very impressive. It will be easy to detect neutrinos.

We can also estimate the up limit power of the X-ray.

$$E_{x-ray} = 10^9 eV / s \approx 10^{-10} W$$

It is much smaller than the power of ordinary X-ray machine. So it is important to improve the sensitivity of the X-ray instruments when detecting these X-ray.

On the other hand, we can find that the number of electron neutrinos will continue to decrease from the calculation. However, the produced muon and tau neutrinos will also change to electron neutrino. It will supplement the electron neutrinos to the neutrino beam. It will make the ratio of three types of neutrinos reach a stable state.

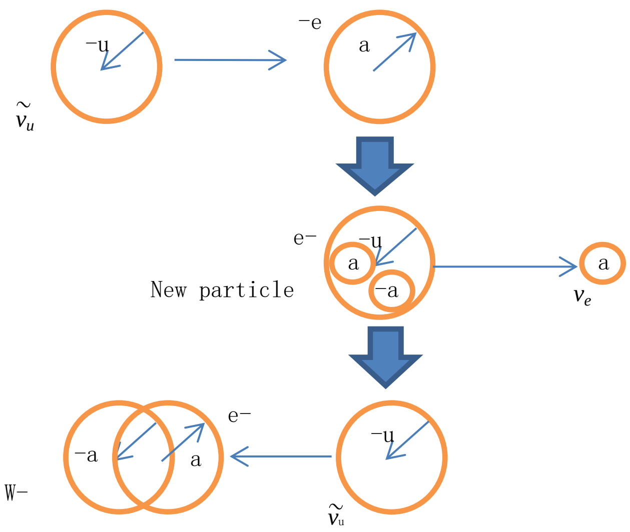

Figure 5. The possible interaction between muon neutrino and electron

Figure 5 shows the possible interaction between muon neutrino and electron. It will produce electron neutrinos. However, this process will need a new short lifetime particle. The mass of new particle will be about 400MeV according to previous calculations. [1, 4]

Perhaps we can also make such a hypothesis that the muon or tau neutrinos are unstable just like muon or tau. So muon or tau neutrinos will decay to electron neutrinos in a short time.

4 Conclusion

In this paper, I try to propose a new method to detect the neutrinos. The purpose of this paper is tried to solve the problems of higher price, huge instruments and complex technologies of current methods.

The new method relies on new theories. Therefore, the successful of this new method can also be a proof of the new neutrino theories. Currently, there are several questions on this new method.

1. The new neutrino theory is not yet mature, there are many unknown factors constrain the theoretical analysis and prediction. It is expected that the new neutrino theory will be perfected on the basis of obtaining more experimental data.
2. The new theory predicts that neutrino oscillations are actually due to the interaction of different flavors of neutrinos and electrons. This also means that the interaction process may take time, which will result in the measurement of the neutrino overall velocity after decay. So the velocity of some neutrinos may be less than the speed of light. Although it is possible to consider the interaction in virtual space-time, there may be superluminal phenomena. However, this still brings a lot of uncertainty to the theory and needs further support of experimental data.
3. There are still many things for further improvement on the new method.

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Appendix: Chinese Version

探测中微子的一种新方案

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摘要：本文基于虚时空的中微子模型，提出一种探测中微子的新方案。该方案的特点在于利用中微子与相应的轻子形成中间玻色子或介子的可能性，探测这些中间玻色子或介子衰变后的产物，进而计算出中微子的数量。由于中微子与相应轻子反应的截面比较大，故该方法应该能够更准确地确定中微子的数量。

关键词：中微子；玻色子；介子；轻子

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Abstract

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Key Words

Neutrino; Boson; Meson; Lepton

0 导言

中微子的探测是一个非常困难的工作。目前分布在世界各地的探测中微子的装置都非常庞大。即便是这样，所能够探测到的中微子的数量相对整体数量来说还是非常稀少。这自然会影响到中微子探测的精度。

基于我前面的工作基础[1~4]，这里我尝试提出一种新的探测中微子的方案。当然由于这一工作还处于起步阶段，所提出方案可能存在一些问题，但是相信如果我们能够从另一个方面来进行思考，还是有相当大的启发性的。

1 振荡还是衰变

中微子振荡是中微子研究的重要课题[5~8]。目前已经通过实验证实中微子存在三种振荡模式。相关理论则指出，中微子振荡的原因在于中微子存在微小的质量[9]。然而这跟相对论存在矛盾。

本文在过往工作的基础上提出中微子振荡的另一种原因，就是中微子不同味道的转变是由于中微子与电子相互作用而引起的。即中微子在飞行途中如果遇到了电子，则可以与其结合形成 W 等粒子。然后在极短时间中，这些粒子又重新衰变成不同的轻子以及相对应的中微子。这样原先只有一种味道的中微子，就会在飞行了一段时间以后转变成三种不同味道的中微子，并在飞行足够长的距离之后不同味道中微子的数量比例会稳定下来。

2 中微子与电子的相互作用

这里以比较典型的中微子与电子的相互作用为例来说明中微子味道是如何转变的。

2.1 相互作用以后味道不产生变化

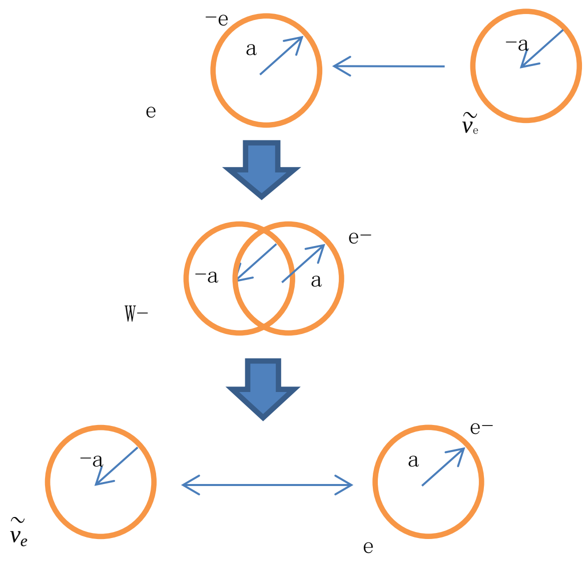

图 1 衰变回电子和电子中微子

按照图 1 的情况，反中微子在运行的途中，遇到了电子，则可以与其形成 W 玻色子，然而

W 玻色子非常不稳定，在很短的时间就会产生衰变。其中图 1 显示了一部分的 W 玻色子将衰变回电子和反电子中微子。这样整个过程，中微子的味道并没有产生变化。

2.2 相互作用以后电子中微子转变成 μ 中微子

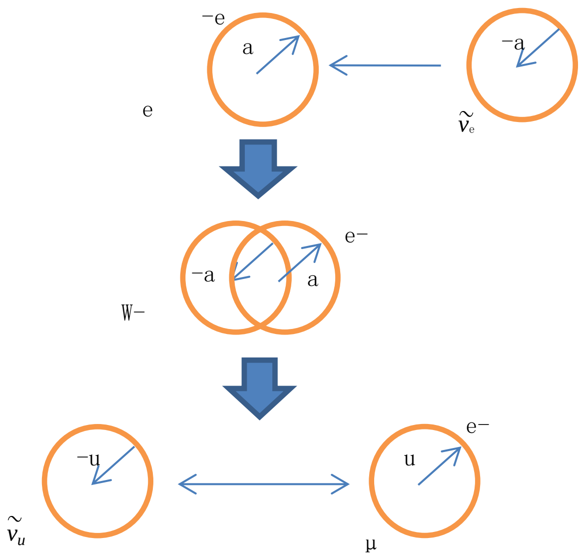

图 2 衰变成 μ 子和 μ 中微子

按照标准模型，从图 2 可以看出在形成了 W 玻色子以后，其中存在一部分衰变成 μ 子和反 μ 中微子。在图 2 的过程中出现了中微子味道的变化，这或许是中微子产生振荡的一个原因。不过这一过程中产生的 μ 子是可以探测到的。由于 μ 子的产生与反电子中微子的到来有关，因此可以通过探测在某些特定物质中产生的 μ 子数量来确定反 μ 中微子的数量。

2.3 相互作用以后电子中微子转变成 τ 中微子

以此类推，还存在图 3 所示的衰变结果，即最终 W 玻色子衰变成 τ 子和 τ 中微子。

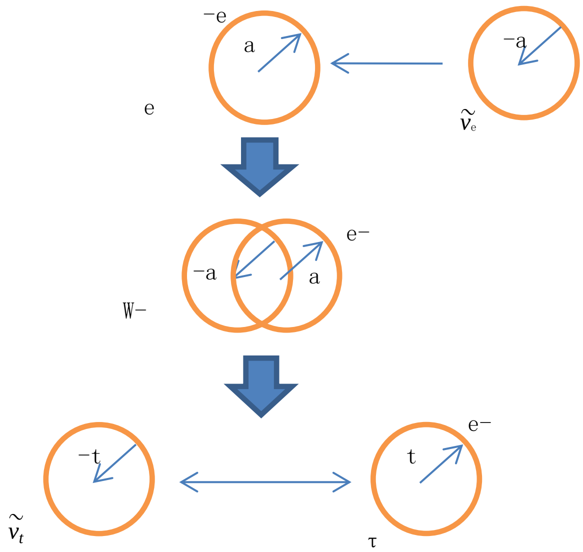

图 3 衰变成 τ 子以及 τ 中微子

因此新的方法原理在于如果我们能够检测图 2 或者图 3 中所产生的 μ 子或者 τ 子，就可以按照衰变几率等参数确定出所探测的电子中微子的数量。

上述三个过程也可以从标准模型获得解释。按照标准模型，不同味道的中微子总是与相对应味道的轻子成对出现的。如果中微子在飞行的途中出现了味道的变化，按照对称性的要求，则意味着也应该会有相应数量的轻子出现味道的变化（否则整体上会否出现轻子数不守恒的问题？）。然而按照标准模型不知道这些味道出现变化的轻子出现在哪里。

3 探测中微子的新方案

从本文第二节的分析可以看出，由于中微子在飞行途中存在与途经的电子产生相互作用的可能，而相互作用以后会有相当大的一部分中微子味道产生转变。这样就为中微子的探测提供了一种新的方法。

当然要直接探测不同味道的中微子是非常困难的。但考虑到图 2 和图 3 的过程，相互作用以后除了产生不同味道的中微子以外，还会产生 μ 子和 τ 子这两个中间产物，即电子会在与中微子相互作用以后味道也产生变化，短时间形成外围为 μ 子或 τ 子的原子。这些新的原子形式在跃迁的过程中，会辐射或吸收特定波长的光子。如果能够探测到这些光子，则意味着存在大量中微子经过的可能。而这些特定波长光子数量的多少跟途经的中微子数量成正比。

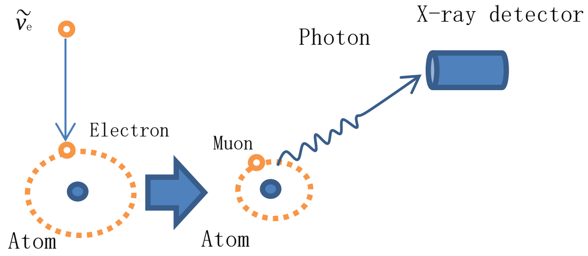

图 4 中微子探测过程

这里简单估算一下产生的 μ 子数量。

假设入射的中微子数量为 N，为简便起见，假设单位长度中微子与物质中电子的反应比率为 p，则总共可以产生 W-玻色子的数量为：

$$n_w = pN$$

如果 W-玻色子衰变成三种轻子对的概率相等，则将产生 μ 子的数量为：

$$n_u = \frac{1}{3} pN$$

由于轻子成对出现，因此这也是所产生的 μ 中微子的数量。

所产生的 τ 中微子的数量相同。

由于形成了外围为 μ 子的原子，则该原子在 μ 子寿命期间可以发射或吸收相应的光子。如果是氢原子这样比较简单的原子，可以估算出该光子的能量大约为：

$$E \approx \alpha^2 m_u c^2 \approx 3keV$$

该能量位于 X 射线区域。目前探测 X 射线的技术很多，包括荧光测量技术以及衍射测量技术等。这样只要能够在 X 射线光谱中发现有 μ 子构成原子所具备的特征，即可以判断为中微子经过的时候所产生的反应。因为还没能够在普通物质中产生大量 μ 子的其他反应。

上述估算过程中涉及到的中微子电子反应比率 p 的估算则比较困难，因为这涉及到中微子飞行的距离、物质中电子的密度等。

假设物质的密度是均匀的，N 个电子中微子经过了 L 长度之后，剩余的电子中微子数量为：

$$N_1 = N\left(1 - \frac{2}{3}p\right)^L$$

比如以大气中微子振荡数据为例，假如 μ 子的产生高度为 100km，以 1m 作为单位长度，考虑 p 很小，则可以获得：

$$N_1 = N\left(1 - \frac{2}{3}p\right)^{100000} \approx N\left(1 - 7\times 10^6 p\right)$$

如果 $N_1 = 0.6N$

则可以计算出 $p \approx 6\times 10^{-8}$

如果这一数据也适用于太阳中微子，则考虑到每秒太阳中微子到达地球表面的密度为；$10^{13}/m^2$，则每秒每平方米大约会有 10^6 个中微子与物质中的电子产生反应。如果该假设成立，即便只有很少一部分反应最终转换成 μ 子，数量都是非常可观的，则中微子都将变得很容易检测。

还可以估算出反应以后发射的 X 射线的功率上限大约是：

$$E_{x-ray} = 10^9 eV/s \approx 10^{-10} W$$

这跟普通 X 光机大约 100W 功率相比，还是非常小的，因此在检测的时候提高 X 射线检测设备的灵敏度很重要。

另外从计算上来看，虽然电子中微子的数量在持续减少。然而由于衰变出来的 μ 和 τ 中微子等通过适当的过程还将会转换成电子中微子，这样将不断补充电子中微子，从而使三种中微子最终达到稳定状态。

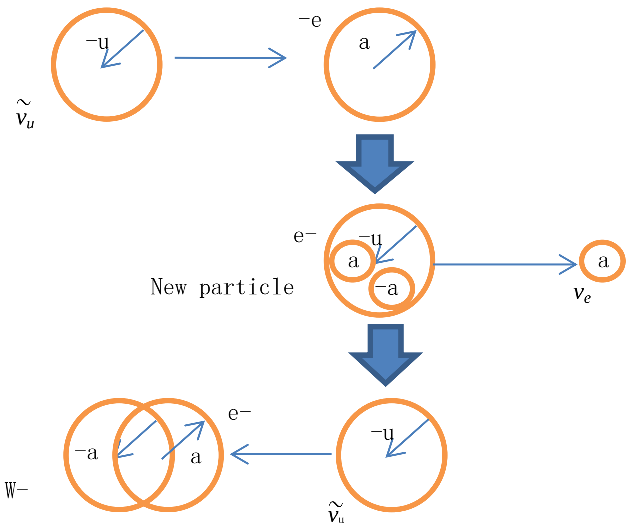

图 5 μ 中微子与电子的相互作用

图 5 显示了 μ 中微子与电子的相互作用，该过程可以产生电子中微子，实现 μ 中微子到电子中微子的转换。不过这一过程需要一个寿命非常短的新粒子，该粒子由 μ 中微子和电子组成一种新的结构，该粒子的质量可能介于 W 玻色子和 π 介子之间，按照前述方法[1, 4]，可以估算出该粒子的质量大约 400MeV。

当然也可以做这样的假设，比如有可能如同 μ 子一样，μ 中微子也有一个比较短的寿命，会自然衰变成电子中微子。

以此类推，τ 中微子的转换与此相似。

4 结论

本文尝试提出一种检测中微子的新方法，目的是为了解决目前各种中微子检测方法设备庞大、复杂、造价高昂等问题。期待有一种比较小，甚至便携式设备能够实现中微子的检测。该方法需要新理论的支持。因此该方法能否成功，也是检验新理论是否有效的一个途径。目前来看该方法存在的问题主要表现在这么几个方面：

1、 新中微子理论还不太成熟，还有很多未知的因素制约着理论的分析和预测。期待能够在获得更多的实验数据支持的基础上不断完善新的中微子理论。
2、 新的理论预测中微子的振荡实际上是由于不同味道的中微子与电子等轻子相互作用引起的。这意味着相互作用过程可能会消耗时间，这将导致衰变以后的中微子整体速度的测量可能小于光速。尽管可能考虑虚时空的相互作用确实可能存在超光速的现象，但这给理论还是带来了很多不确定性，需要获得实验数据的进一步支持。
3、 就新方法本身而言，还存在有待进一步改进的地方。

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