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AS-ITP-93-56
August 1993

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Remarks On The Limit of ν_τ Mass Determined From the Experimental Value of τ - Mass*

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ABSTRACT

It is shown, that the new value of τ- mass of 1776.9 $^{+0.4}_{-0.5}\pm0.2$ MeV/c^2 should lead to a smaller value of the upper limit of mass of ν_τ as $m_{\nu_\tau} < 22$MeV/c^2 (90% c.l.). And if this limit is combined with the constraints obtained from the nuclear synthesis of light elements in cosmology as well as from the neutrino burst observed during the explosion of SN 1987A, it can be further reduced down to $m_{\nu_\tau} < 0.5$ MeV/c^2 and m_{ν_τ} <1 to 15 KeV/c^2 for Dirac neutrinos.

Recently the BES collaboration of the Beijing Electron Positron Collider (BEPC) remeasured the τ - mass and published [1] the following value of

$$m_\tau = 1776^{+0.4}_{-0.5} \pm 0.2 MeV/c^2.$$

*Supported by the National Natual Science Foundation of China

The central value has been lowered by 7.2 MeV in comparison with the previous world - average value quoted by the Particle Data Group (PDG) [4], which was

$$m_\tau = 1784.1^{+2.7}_{-3.6} MeV/c^2.$$

The error given by BES is substantially decreased by a factor of 5 due to the large statistics available. Not only does this result alleviate previous concern about lepton universality but it also affect the ν_τ mass limit.

As early as 1988, the ARGUS group gave a limit of [2]

$$m_{\nu_\tau} < 35 MeV.$$

Recently ARGUS re-determined the τ - mass and obtained the following value

$$m_\tau = 1776.3 \pm 2.4 \pm 1.4 MeV/c^2,$$

which is in full agreement with the BES results within the precision they achieved[3]. Then this value was used to re-set a new ν_τ - mass limit† from 19 events of the 5π decay mode

$$\tau^- \to \pi^-\pi^-\pi^-\pi^+\Pi^+\nu_\tau$$

(previously they used only 11 events)as

$$m_{\nu_\tau} < 31 MeV/c^2,$$

which is 4 Mev/c^2 below the old value [3]. However, as the authors have stressed, the number of identified events of this mode actually was 20 (or 12 in the previous paper [2]), but one event with the highest 5 π's mass was removed, "because of the possible uncertainty in the background determination" [2].

†After completing this article, we learnt about the new limit published by the CLEO collaboration[7] of 32.6 MeV/c^2

The question then is why this particular event should be removed and how big the effect of the left out event is on the ν_τ - mass limit.

From the experimental point of view, any measured event should not be dropped only based on an argument given a priori, unless it is shown that this particular event is out of the confidence level range that the detector or the experimental set can achieve. In this respect, the "possible uncertainty in the background determination" is not a good excuse for doing that but rather a factor that may lower the confidence level on the whole final result.

In fact the only reason for the authors to do this is that this particular event is out of the phase space, or in other words, the 5 π mass is bigger than m_τ ! This is clearly seen in Fig. 1, which is taken directly from Ref.[3]. Since $E^\pi{}_i$, $p^\pi{}_i$ are determined indepedently by the likelihood fits, the statistical fluctuations may lead situation where $M_{5\pi} > m_\tau$. This phenomenon has been observed experimentally in the determination of ν_e - mass from the β - spectra near the end point of the tritium β - decay. This situation happened to almost every experimental group, resulting in a negative central value of $m^2_{\nu_e}$ [4], which did not prevent the groups from keeping all negative $m^2_{\nu_e}$ values in the statistics.

Therfore, we argue that this highest 5π mass event should not be dropped. The question now is how big is the effect?

It is interesting to notice that even in 1988 in Ref. [3] with the twelfth event included, the resulting ν_τ mass limit was obtained as

$$m_{\nu_\tau} < 25 MeV/c^2 \ (95\%).$$

Later on, the additional events are all far from the end point. Therefore these additional events would not affect the result quoted above. Then, what happens if the m_τ value is lowered to 1776.9 MeV $/c^2$ according to BES or 1776.3 MeV$/c^2$ according to ARGUS? A mass limit can be obtained with a simple perturbation development:

$$m_{\nu_\tau} < (25 - 25 \times \frac{35-31}{35}) = 22 MeV/c^2 (90\% c.l.),$$

where the 90% confidence level is estimated by assuming that the probability of rejecting any one event among the total 20 events is 1/20, and hence the resulting probability is $(0.95)^2 \simeq 90\%$.

Given this new mass limit of m_{ν_τ}, it can be shown that the upper limit of m_{ν_τ} can roll down further using the following arguments:

i) E.Kolb et al.[5] have pointed that a neutrino mass within the following range

$$0.5 MeV/c^2 < m_\nu < 25 MeV/c^2$$

would affect the relative abundances of light nuclei. Therefore, with the likely assumption that the ν_τ live longer than about 1 second , then this particle has either to be lighter than 0.5 MeV$/c^2$ or heavier than 25 MeV$/c^2$. As the 25 MeV$/c^2$ has been excluded following our analysis, then one can conclude that

$$m_{\nu_\tau} < 0.5 \ MeV/c^2$$

is reasonable.

ii) There is another constraint coming from the SN 1987A observed neutrino burst. It has been argued[6] that the neutrino mass range lying between

$$(1 \sim 15) KeV/c^2 < m_{\nu_\tau} < 1 MeV/c^2$$

can be excluded, where the lower bound was obtained by studying the time structure of the neutrino events from SN 1987A, and the upper bound can be deduced from the temperature of the supernova bursts, provided the neutrinos are Dirac particles.

Since this upper bound can be excluded by the limit obtained with the nucleosynthesis argument, the lower bound means simply

$$m_{\nu_\tau} < 1 \sim 15 KeV/c^2.$$

Acknowledgements The authors are indebted to Dr. Charling Tao for she first called our attention to whether the newly determined τ - mass has influenced the ν_τ - mass limit. We also thank Prof. H.Klapdor of the Max-Planck Institute fur Kernphysik in Heidelberg, as well as Prof. M.Spiro and the staff of the SPP/DAPNIA in Saclay, for inviting us and providing assistance in the short visit, during which this work was performed.

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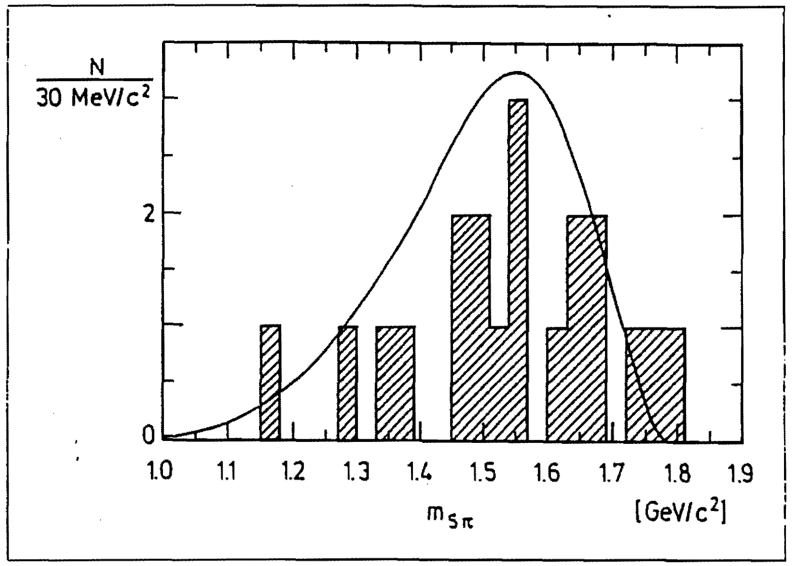

Fig I