# Thermal expansion of the earth and the speed of neutrinos

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**Abstract**

It is pointed out that one of the systematic effects that can affect the measurement of the speed of neutrinos significantly is the variability of the unaveraged measurement of the distance between two points on the earth due to thermal expansion. Possible difference between estimates done with surface GPS apparatus and the true underground baseline can change substantially the statistical significance of the result of superluminal speed of neutrinos, reported recently.

While it is reasonable to believe that no particle can be accelerated through the speed-of-light barrier to beyond the speed of light, it is not obvious that there could not be particles that travel always with speed larger than the speed of light, with no possibility of 'decelerating' them to below the speed of light [1]. Whether there are fundamental particles that travel at speeds beyond that of light can only be answered from careful experiments. A recent long baseline neutrino experiment that has results consistent with a faster-than-light neutrino [2] is therefore very significant and need to be carefully examined.

The result reported in [2] is that the muon neutrinos seem to travel faster than light by a small increment amounting to $(v-c)/c \simeq 2.5 \times 10^{-5}$ with combined errors of about $4 \times 10^{-6}$. Referred to the base line of about 730 km, this amounts to 60 ns, or a spatial distance of 18 metres. Therefore, if the accurately measured baseline has an unaccounted systematic error of 1-2 parts in $10^{-5}$, the statistical significance of the result can be affected drastically. Curiously, this is the level of systematic error than can happen due to differential thermal expansion of relevant baselines. If the distance determination was done with a bias towards thermally expanded baseline on the surface of the earth for some reason and if the experiment in the underground tunnel corresponds to a true average baseline that is different from the baseline determined with GPS receivers on surface, the anomaly reduces significantly. For example, with a conservative thermal expansion coefficient of $7 \times 10^{-6}$ for the surface layers and a difference in temperature of $3^oC$, the result becomes consistent with neutrinos travelling below the speed-of-light barrier. In any case, even a modest temperature change of 50 millidegree C results in a change in the baseline that is *larger than the quoted error* of baseline determination in the experiment.

It is not easy to estimate the thermal expansion due to temperature variations over a long baseline consisting of different types of soil and rocks, especially if there are micro-cracks in the soil. However, this can be measured using the GPS and the variations over different time scales can be accounted for. Inside the tunnel where the experiments are performed, as well as along the whole baseline deep inside the earth the temperature variations are expected to be well below $0.1^oC$. So, the relevant quantity is the *difference* between baseline measured with GPS instruments that are relatively near the surface of the earth, where temperature variations can be large, and the estimate of the actual deep underground baseline. The experiment was done in averaging mode that average variations over days and also over seasons. Hence, repeated measurements on the baseline covering various possibilities of temperature variations are also required for eliminating doubts on possible systematic effects arising from thermal expansion effects.

To directly detect propagation delays due to thermally generated variations of the underground baseline, one may need statistical accuracies better than $10^{-7}$ ($<$0.3 ns over a 1000 km baseline).

# References


[1] O. M. P. Bilaniuk, V. K, Deshpande, and E. C. G. Sudarshan, *'Meta' Relativity*, Am. Jl. Phys. **30**, 718 (1962).

[2] T. Adam *et al*, *Measurement of the neutrino velocity with the OPERA detector in the CNGS beam*, arXiv:1109.4897-1