# A New Experiment to Verify/Refute the OPERA Result

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## 1 Introduction

The OPERA Collaboration observed that $\nu_\mu$ arrived earlier than expected [1]. Interpreted as an anomalous velocity, the neutrinos travel faster than $c$ by $2.48 \times 10^{-5}$. This result has caused much discussion and needs to be tested by an independent experiment with different methods. We propose such an experiment.

Our design avoids some of the possible pitfalls of the OPERA analysis. First we use a direct-sight laser to synchronize the primary proton beam and neutrino detector. Second, we build in comparisons to relativistic non-$\nu$ particles, mainly muons produced in $\pi/K$ decays. Third, we allow a minute fraction of the muons to reach the neutrino detector, in order to establish the expected TOF for a relativistic particle with no velocity anomaly. Finally, we take advantage of the time structure of the NuMI beam. Some aspects of our design were used in an earlier experiment by Kalbfleisch *et al.* [2].

The 120 GeV Main Injector beam would be used to collide 120 GeV protons on a target, just as with the NuMI beam. We assume we would take about 500 "batches" each $\sim 8$ ns long, spaced 18.8 ns apart. We consider $10^{19}$ or $10^{20}$ protons on target. The laser is synched to the batches using a non-interfering electrostatic pickup. The decay tube is 10 km long, and 1 m in radius. It is placed on the surface, not underground, to keep costs manageable. It can be filled with Helium gas at low pressure. The detector would collect three kinds of signals: 1) the laser pulses, 2) neutrinos from pion decays, and 3) muons from (other) pion decays. We assume a trasverse position resolution of 1 cm, and a longitudinal resolution of 3 cm. We assume a per-event time resolution of 10 ps, which might be achieved using quartz fibers to collect Cherenkov light from the electromagnetic core of hadronic showers [3].

We used a simple PYTHIA simulation to test our ideas. We modeled the pion production using a 120 GeV p incident on a fixed p, and represented the detector resolution by simple Gaussian smearing. We focussed on the TOF measurement and took the OPERA result as pertaining to the $\nu$ velocity: for a 10 km flight distance, the anomaly would correspond to 0.8 ns out of 3.3 $\mu$s. Our simulation indicates a yield of about $4 \times 10^{-5}$ $\nu$s per proton passing through a detector 1m$\times$1m in cross section. The mean momentum is about 8 GeV, so the cross section is roughly $4 \times 10^{-38}$ cm$^2$. If the detector mass is 24 tons, we would collect about $2 \times 10^4$ events for only $10^{19}$ pot, which is already twice the OPERA sample of contained events.

Figure 1 compares the TOF for muons and neutrinos passing through the target. A clear shift is seen, and even with a few hundred events, zero shift could be ruled out with many sigma.

This concept is under development and this contribution represents initial ideas only.

## References

[1] OPERA Collab., "Measurement of the neutrino velocity with the OPERA detector in the CNGS beam," [arXiv:1109.4897 [hep-ex]].

[2] G. R. Kalbfleisch, N. Baggett, E. C. Fowler, J. Alspector, "Experimental Comparison Of Neutrino, Anti-neutrino, And Muon Velocities," Phys. Rev. Lett. **43**, 1361 (1979).

[3] C. Adler, A. Denisov, E. Garcia, M. J. Murray, H. Strobele, S. N. White, "The RHIC zero degree calorimeter," Nucl. Instrum. Meth. **A470**, 488-499 (2001). [nucl-ex/0008005].

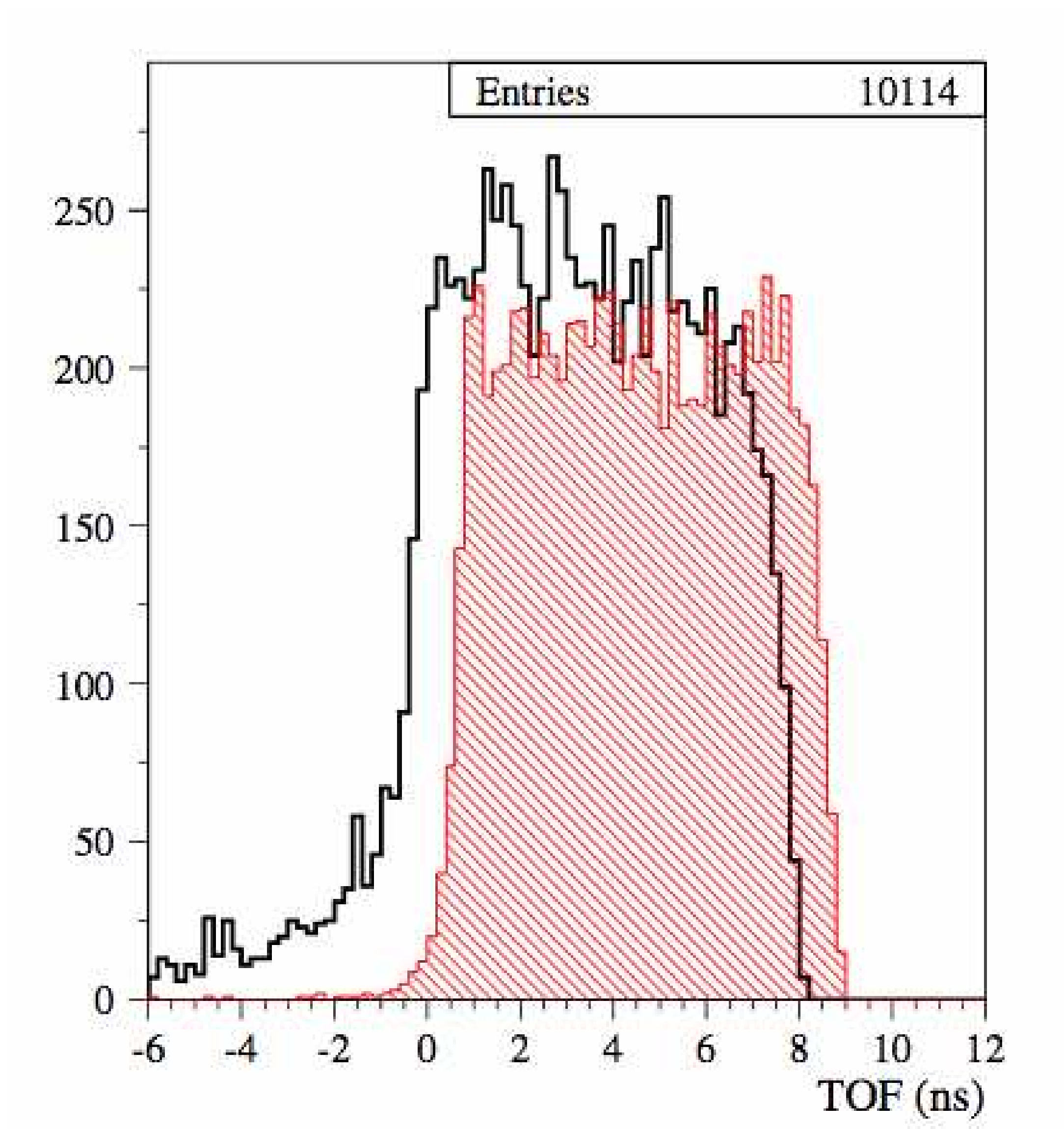


Figure 1: Comparison of the TOF distribution for muons (heavy dark line) and neutrino events (shaded red histogram) assuming that the OPERA $\nu$ velocity anomaly is correct.