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Geodetic distance determination between the MINOS detectors for the Neutrino Time of Flight measurements

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The NuMI beamline and the MINOS expriment study the long baseline oscillation of muon neutrinos and perform high-precision measurements of the oscillation parameters. The project directs a beam of muon neutrinos from the Fermilab Main Injector towards both near and far detectors capable of studying neutrino oscillations. The accurate aiming of the beam towards both the near and far underground detectors, as well as the precise alignment of the beamline elements, is of vital importance for the experiment.

The beam travels approximately 735 km through the Earth from Fermilab towards a remote iron mine in northern Minnesota where, 710 m below the surface, a massive 5400 metric ton detector has been built. For the neutrino energy spectrum physics to work properly, the primary proton beam must be directed within ± 12 m from its ideal position at Soudan, MN, corresponding to ± 1.63 x 10-5 radians, i.e. 3.4 arcseconds. Achieving this tolerance requires a rather exact knowledge of the geometry of the beam, expressed in terms of the azimuth and the slope of the vector joining the two sites.

Recent results on neutrino velocity measured with the Opera detector and CNGS beam raised questions about the neutrinos possibly traveling faster than light. As a result, this generated increased interest in determining the precise distance between the two MINOS detectors for verification of the neutrino time-of-flight (TOF).

A rigorous solution for computing the Euclidian distance between the two detectors along the beam path requires precise knowledge of the absolute positions of those detectors in space.

This paper reviews the concepts, methodology, implementation and the results of the geodetic surveying and precise positioning effort for the construction, installation, and alignment of the NuMI neutrino beamline and the two MINOS detectors as well as for calculating the distance between the two detectors for the TOF measurements.

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