



OPERA experiment reports anomaly in flight time of neutrinos from CERN to Gran Sasso

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UPDATE 8 June 2012

Neutrinos sent from CERN to Gran Sasso respect the cosmic speed limit

At the 25th International Conference on Neutrino Physics and Astrophysics in Kyoto today, CERN Research Director Sergio Bertolucci presented results on the time of flight of neutrinos from CERN to the INFN Gran Sasso Laboratory on behalf of four experiments situated at Gran Sasso. The four, Borexino, ICARUS, LVD and OPERA all measure a neutrino time of flight consistent with the speed of light. This is at odds with a measurement that the OPERA collaboration put up for scrutiny last September, indicating that the original OPERA measurement can be attributed to a faulty element of the experiment's fibre optic timing system.

"Although this result isn't as exciting as some would have liked," said Bertolucci, "it is what we all expected deep down. The story captured the public imagination, and has given people the opportunity to see the scientific method in action – an unexpected result was put up for scrutiny, thoroughly investigated and resolved in part thanks to collaboration between normally competing experiments. That's how science moves forward."

In another development reported in Kyoto, the OPERA experiment showed evidence for the appearance of a second tau-neutrino in the CERN muon-neutrino beam, this is an important step towards understanding the science of neutrino oscillations.

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UPDATE 16 March 2012

ICARUS experiment at Gran Sasso laboratory reports new measurement of neutrino time of flight consistent with the speed of light

The ICARUS experiment at the Italian Gran Sasso laboratory has today reported a new measurement of the time of flight of neutrinos from CERN to Gran Sasso. The ICARUS measurement, using last year's short pulsed beam from CERN, indicates that the neutrinos do not exceed the speed of light on their journey between the two laboratories. This is at odds with the initial measurement reported by OPERA last September.

"The evidence is beginning to point towards the OPERA result being an artefact of the measurement," said CERN Research Director Sergio Bertolucci, "but it's important to be rigorous, and the Gran Sasso experiments, BOREXINO, ICARUS, LVD and OPERA will be making new measurements with pulsed beams from CERN in May to give us the final verdict. In addition, cross-checks are underway at Gran Sasso to compare the timings of cosmic ray particles between the two experiments, OPERA and LVD. Whatever the

result, the OPERA experiment has behaved with perfect scientific integrity in opening their measurement to broad scrutiny, and inviting independent measurements. This is how science works."

The ICARUS experiment has independent timing from OPERA and measured seven neutrinos in the beam from CERN last year. These all arrived in a time consistent with the speed of light.

"The ICARUS experiment has provided an important cross check of the anomalous result reports from OPERA last year," said Carlo Rubbia, Nobel Prize winner and spokesperson of the ICARUS experiment. "ICARUS measures the neutrino's velocity to be no faster than the speed of light. These are difficult and sensitive measurements to make and they underline the importance of the scientific process. The ICARUS Liquid Argon Time Projection Chamber is a novel detector which allows an accurate reconstruction of the neutrino interactions comparable with the old bubble chambers with fully electronics acquisition systems. The fast associated scintillation pulse provides the precise timing of each event, and has been exploited for the neutrino time-of-flight measurement. This technique is now recognized world wide as the most appropriate for future large volume neutrino detectors".

<http://arxiv.org/abs/1203.3433>

UPDATE 23 February 2012

The OPERA collaboration has informed its funding agencies and host laboratories that it has identified two possible effects that could have an influence on its neutrino timing measurement. These both require further tests with a short pulsed beam. If confirmed, one would increase the size of the measured effect, the other would diminish it. The first possible effect concerns an oscillator used to provide the time stamps for GPS synchronizations. It could have led to an overestimate of the neutrino's time of flight. The second concerns the optical fibre connector that brings the external GPS signal to the OPERA master clock, which may not have been functioning correctly when the measurements were taken. If this is the case, it could have led to an underestimate of the time of flight of the neutrinos. The potential extent of these two effects is being studied by the OPERA collaboration. New measurements with short pulsed beams are scheduled for May.

UPDATE 18 November 2011

Following the OPERA collaboration's presentation at CERN on 23 September, inviting scrutiny of their neutrino time-of-flight measurement from the broader particle physics community, the collaboration has rechecked many aspects of its analysis and taken into account valuable suggestions from a wide range of sources. One key test was to repeat the measurement with very short beam pulses from CERN. This allowed the extraction time of the protons, that ultimately lead to the neutrino beam, to be measured more precisely.

The beam sent from CERN consisted of pulses three nanoseconds long separated by up to 524 nanoseconds. Some 20 clean neutrino events were measured at the Gran Sasso Laboratory, and precisely associated with the pulse leaving CERN. This test confirms the accuracy of OPERA's timing measurement, ruling out one potential source of systematic error. The new measurements do not change the initial conclusion. Nevertheless, the observed anomaly in the neutrinos' time of flight from CERN to Gran Sasso still needs further scrutiny and independent measurement before it can be refuted or confirmed.

On 17 November, the collaboration submitted a paper on this measurement to the peer reviewed Journal of High Energy Physics (JHEP). This paper is also available on the [Inspire website](#).

Geneva, 23 September 2011. The OPERA¹ experiment, which observes a neutrino beam from CERN² 730 km away at Italy's INFN Gran Sasso Laboratory, will present new results in a seminar at CERN this afternoon at 16:00 CEST. The seminar will be webcast at <http://webcast.cern.ch>. Journalists wishing to ask questions may do so via twitter using the hash tag #nuquestions, or via the usual CERN press office channels.

The OPERA result is based on the observation of over 15000 neutrino events measured at Gran Sasso, and

appears to indicate that the neutrinos travel at a velocity 20 parts per million above the speed of light, nature's cosmic speed limit. Given the potential far-reaching consequences of such a result, independent measurements are needed before the effect can either be refuted or firmly established. This is why the OPERA collaboration has decided to open the result to broader scrutiny. The collaboration's result is available on the preprint server arxiv.org: <http://arxiv.org/abs/1109.4897>.

The OPERA measurement is at odds with well-established laws of nature, though science frequently progresses by overthrowing the established paradigms. For this reason, many searches have been made for deviations from Einstein's theory of relativity, so far not finding any such evidence. The strong constraints arising from these observations makes an interpretation of the OPERA measurement in terms of modification of Einstein's theory unlikely, and give further strong reason to seek new independent measurements.

"This result comes as a complete surprise," said OPERA spokesperson, Antonio Ereditato of the University of Bern. *"After many months of studies and cross checks we have not found any instrumental effect that could explain the result of the measurement. While OPERA researchers will continue their studies, we are also looking forward to independent measurements to fully assess the nature of this observation."*

"When an experiment finds an apparently unbelievable result and can find no artefact of the measurement to account for it, it's normal procedure to invite broader scrutiny, and this is exactly what the OPERA collaboration is doing, it's good scientific practice," said CERN Research Director Sergio Bertolucci. *"If this measurement is confirmed, it might change our view of physics, but we need to be sure that there are no other, more mundane, explanations. That will require independent measurements."*

In order to perform this study, the OPERA Collaboration teamed up with experts in metrology from CERN and other institutions to perform a series of high precision measurements of the distance between the source and the detector, and of the neutrinos' time of flight. The distance between the origin of the neutrino beam and OPERA was measured with an uncertainty of 20 cm over the 730 km travel path. The neutrinos' time of flight was determined with an accuracy of less than 10 nanoseconds by using sophisticated instruments including advanced GPS systems and atomic clocks. The time response of all elements of the CNGS beam line and of the OPERA detector has also been measured with great precision.

"We have established synchronization between CERN and Gran Sasso that gives us nanosecond accuracy, and we've measured the distance between the two sites to 20 centimetres," said Dario Autiero, the CNRS researcher who will give this afternoon's seminar. *"Although our measurements have low systematic uncertainty and high statistical accuracy, and we place great confidence in our results, we're looking forward to comparing them with those from other experiments."*

"The potential impact on science is too large to draw immediate conclusions or attempt physics interpretations. My first reaction is that the neutrino is still surprising us with its mysteries," said Ereditato. *"Today's seminar is intended to invite scrutiny from the broader particle physics community."*

The OPERA experiment was inaugurated in 2006, with the main goal of studying the rare transformation (oscillation) of muon neutrinos into tau neutrinos. One first such event was observed in 2010, proving the unique ability of the experiment in the detection of the elusive signal of tau neutrinos.

Further information:

- [OPERA website](#)
- Quantum diaries blog post: [Elementary, my dear neutrino...](#)
- Photos from the OPERA collaboration:
 - <http://www.infn.it/comunicazione/scambio/>
 - [CNRS](#)
 - [Photos of the seminar on OPERA Results](#)

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1. OPERA has been designed and is being conducted by a team of researchers from Belgium, Croatia, France, Germany, Israel, Italy, Japan, Korea, Russia, Switzerland and Turkey. The experiment constitutes a complex scientific enterprise that has been realised thanks to the skill of a large number of scientists, engineers, technicians and students, and with the strong commitment of the various actors of the project. In particular we mention the LNGS/INFN and CERN laboratories, and the major financial support of Italy and Japan with substantial contributions from Belgium, France, Germany and Switzerland. The OPERA Collaboration presently includes about 160 researchers from 30 institutions and 11 countries: IIHE-ULB Brussels, Belgium; IRB Zagreb, Croatia; LAPP Annecy, France; IPNL Lyon, France; IPHC Strasbourg, France; Hamburg, Germany; Technion Haifa, Israel; Bari, Italy; Bologna, Italy; LNF, Italy, L'Aquila, Italy; LNGS, Italy; Naples, Italy; Padova, Italy; Rome, Italy; Salerno, Italy; Aichi, Japan; Toho, Japan; Kobe, Japan; Nagoya, Japan; Utsunomiya, Japan; GNU Jinju, Korea; INR RAS Moscow, Russia; LPI RAS Moscow, Russia; ITEP Moscow, Russia; SINP MSU Moscow, Russia; JINR Dubna, Russia; Bern, Switzerland; ETH Zurich, Switzerland; METU Ankara, Turkey.

2. CERN, the European Organization for Nuclear Research, is the world's leading laboratory for particle physics. It has its headquarters in Geneva. At present, its Member States are Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. Romania is a candidate for accession. India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO have Observer status.

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