OPERA -First Beam Results-

M. NAKAMURA
on behalf of the OPERA Collaboration

F-lab, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, 464-8602, JAPAN.

Abstract. OPERA is a long base-line neutrino oscillation experiment to detect tau-neutrino appearance and to prove that the origin of the atmospheric muon neutrino deficit observed by Kamiokande is the neutrino oscillation. A Hybrid emulsion detector, of which weight is about1.3kton, has been installed in Gran Sasso laboratory. New muon neutrino beam line, CNGS, has been constructed at CERN to send neutrinos to Gran Sasso, 730km apart from CERN. In 2006, first neutrinos were sent from CERN to LNGS and were detected by the OPERA detector successfully as planned.

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INTRODUCTION

OPERA is an emulsion-counter hybrid experiment intends to give a final conclusion to the question of the existence of neutrino oscillation [1].

The first generation experiments, SK, K2K and MINOS confirmed the observation of Kamiokande, i.e. the muon neutrino deficit in atmospheric neutrino interactions. The most probable hypothesis to explain these observations is the neutrino oscillation between muon and tau neutrinos. The detection of tau neutrino appearance in pure muon neutrino beam will give the clear and the final conclusion to this hypothesis.

Only the detector using nuclear emulsion can detect the appearance of tau neutrino as was proven in DONUT experiment [2].

Because of the expected small mass difference, the detector should be set at far cite in order to give a time to oscillate. The base line length of OPERA is set to be 730km between CERN and Gran Sasso. By this long distance, the required detector mass is at least one thousand ton in order to accumulate minimum statistics for the conclusion. A new beam line, CNGS, was constructed at CERN for OPERA. The average energy (17 GeV) of CNGS is well above the tau production threshold.

STATUS OF THE DETECTOR CONSTRUCTION

In order to realize a target mass of thousand ton, so-called ECC structure is utilized. ECC has a sandwich structure of material plates and films and has been used in many emulsion experiments in cosmic-ray and particle research. In OPERA, 1mm thick Lead plates and newly developed nuclear emulsion films (OPERA film [3]) are used.

The required area of the emulsion film is the order to 0.1 million m^2, which is about 160 times larger than CHORUS [4], the largest experiment before OPERA. In CHORUS, films were produced manually in a dark room, but for OPERA such kind method is impossible, therefore new films, which can be produced in the mass production line of the normal color photographic films, were developed by a cooperative work between Nagoya University and Fujifilm.

The OPERA film has a function of "refreshing". By this function, we can erase unwanted tracks recorded in films before their use by keeping them in an environment of >25 degree and >95% relative humidity. More than 98% of recorded minimum ionizing trajectories were erased. Refreshing facilities were constructed in TONO mine near NAGOYA to apply this process to all of the films for OPERA.

Totally, films of about 0.12 million m^2 were produced and refreshed for OPERA from 2003 to 2007. All of the films were shipped to Gran Sasso and

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assembled into ECC bricks. The brick production is still going on and will be continued until May 2008.

Each Brick was attached by a set of special low background films called changeable sheet. The role of CS is to pick up tracks relating to the recorded events.

ECC bricks are installed in the walls sandwiched between tracking devices composed from 2.6cm wide bar scintillators read-out by WLS fibers. By using recorded hit patterns in the tracker, the bricks where neutrino interactions are recorded will be tagged and extracted from the wall. The films in the bricks will be developed and read-out by automated emulsion read-out systems. Using read-out track information, the neutrino interactions will be reconstructed and decays of taus will be searched for as in the case of DONUT experiment [5].

In parallel with the emulsion film, the other Key technology in OPERA is the automated emulsion read-out system, which has been proposed by K.Niwa in 70's and developed in Japan for these 30 years[6]. The most recent system has a read-out speed of about 100 cm^2/h. One SUTS can read-out one OPERA film within about 2 hours. In Japan, five SUTS systems will be used for the OPERA analysis. Also in Europe about 25 systems with the read-out speed of $20cm^2/h$ will be used.

THE FIRST NEUTRINO BEAM FROM CNGS

In the August 2006, we have the first beam from CNGS. In Fig.1 and 2, typical events recorded in the beam time are shown. Fig.1 is so-called rock muon event. A neutrino interaction occurred in the material in front of the detector and only survived muon track reached to the OPERA detector. Fig.2 shows a neutrino event occurred in the magnet of the OPERA muon spectrometer.

The relation of these events to the CNGS beam was checked by the timing and the direction of the tracks [7].

The event timing relations to the extraction timing of protons in SPS are shown in Fig.3. CNGS has two extractions per cycle. The recorded events were really coinciding with the extraction timing.

Also the track direction was analyzed as shown in Fig.4. We can see CERN in the figure as a point source. The center of the cluster shown in Fig.4 is around 3.5 degree which is well coincide with the CERN direction. (Neutrino is rising up from the ground.)

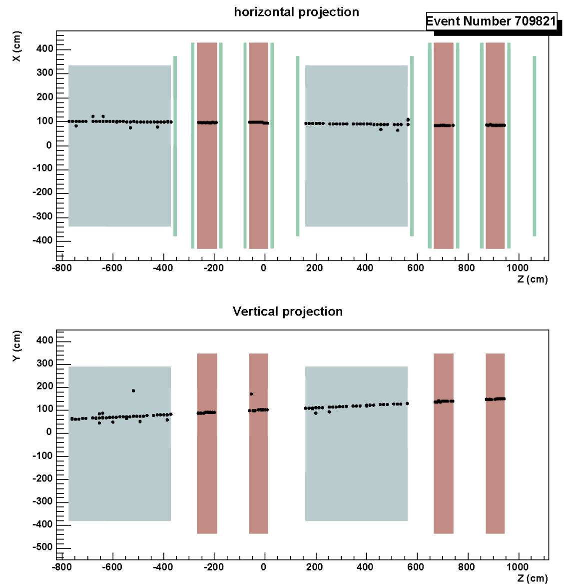

FIGURE 1. Recorded rock muon event.

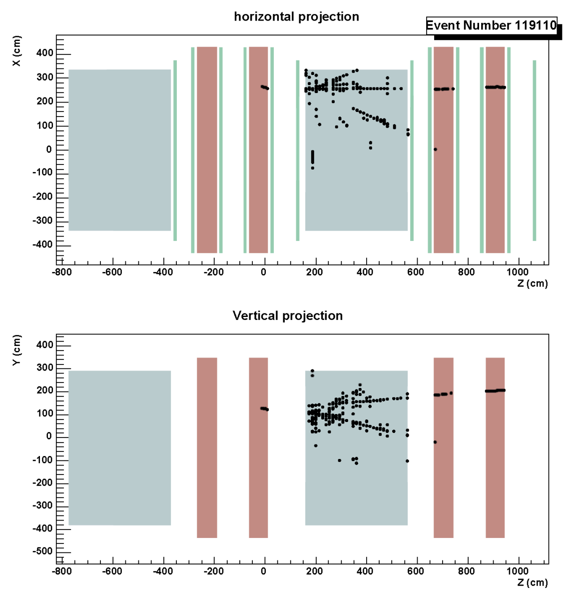

FIGURE 2. Magnet event.

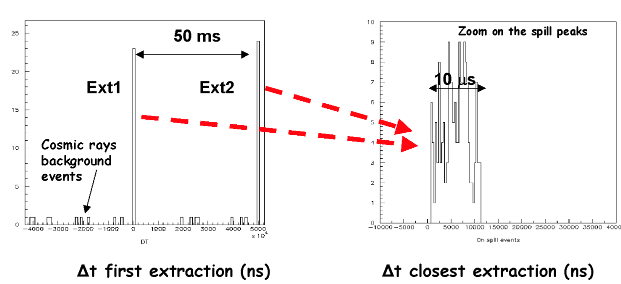

FIGURE 3. Event timing .

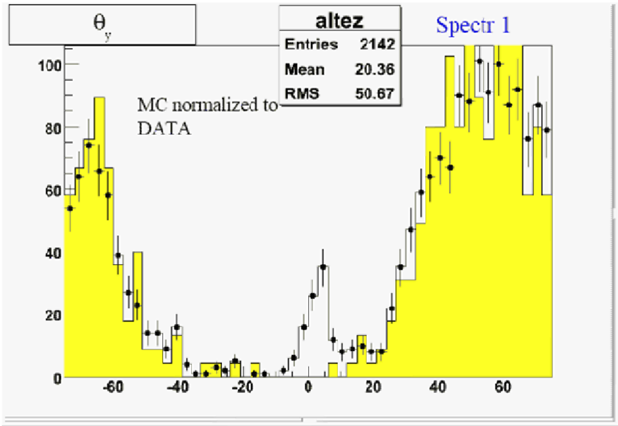

FIGURE 4. Dip angle distribution of the tracks recorded. The trackswith the dip angle of >20 degree and <-20 degree are cosmic-rays. A cluster, which can be seen around -10 to 10 degree, are the events caused by neutrinos from CERN.

Also the quality of the CS was checked by using rock muons and cosmic-rays. In Total 55 tracks were picked up and scanned in the CS, 47 tracks were found uniquely, but 8 tracks were not found. In those events, tracks penetrated near the edge of the CS. Although there was a dead space between CS, we are still investigating the quality of the CS edge.

In October 2006 RUN, a few bricks were installed in the wall. Although the running time is only a few day, one rock muon was penetrated one brick. The rock muon was uniquely identified in the CS and the brick and the momentum of the track was measured by multiple coulomb scattering. The momentum was measured to be 6.4+1.2-0.9 GeV/c in the ECC and 7.05 ± 0.4 GeV/c in the downstream muon spectrometer. It was proven that the planned method of momentum measurement is working.

COMING RUNS OF OPERA

In normal year, we will have 4.5×10^{19} P.O.T. (Proton On Target). About 3600ν（NC+CC）events and 16 ντ CC events will be recorded per 1000 tons ($\sin^2 2\theta = 1$, $\Delta m^2 = 2.5\times10^{-3}$ eV^2) . The ratio of the good tau events will be around 10% of the occurred ντ CCevents. At present, we will have target mass of 1280tons, therefore the expected clean ντ CC events are 1.8 per year.

We hope that we can report our physics results within coming few years.

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