



"Division discussion seminar on T2K result on theta13 and implications for HEP"

10 minutes **T2K result** Zelimir

10 minutes **Context** Maury

10 minutes **NOvA** sensitivity Sarah

10 minutes **MINOS** sensitivity Xiaobo

10 minutes **Double Chooz** sensitivity Michelangelo

10 minutes **Discussion** All

New T2K Results (June 15, 2011):

“Indication of Electron Neutrino Appearance from an Accelerator-produced Off-axis Muon Neutrino Beam”

- Submitted to PRL.
- Announced today at KEK Seminar by Ken Sakashita for T2K collaboration.
- More Information @ <http://jnusrv01.kek.jp/public/t2k/index.php>
- Also a week ago T2K submitted a detector paper: “T2K Experiment”, arXiv:1106.1238

Quick Summary:

Results from $1.43E20$ POT (full data set before earth quake in Japan)

6 electron signal observed over 1.5 ± 0.3 backgrounds expected:
0.7% probability to $\theta_{13}=0$ (significance: 2.5σ)

90% allowed region:

Normal hierarchy: $0.03 < \sin^2 2\theta_{13} < 0.28$ (best-fit $\sin^2 2\theta_{13} = 0.11$)

Inverted hierarchy: $0.04 < \sin^2 2\theta_{13} < 0.34$ (best-fit $\sin^2 2\theta_{13} = 0.14$)

-We have a great chance to measure θ_{13} in experiments Argonne is involved with.

Physics Motivation

★ discovery of $\nu_\mu \rightarrow \nu_e$

Direct detection of neutrino flavor mixing in “appearance” mode

Determine θ_{13}

The last mixing angle θ_{13} can be determined by $\nu_\mu \rightarrow \nu_e$

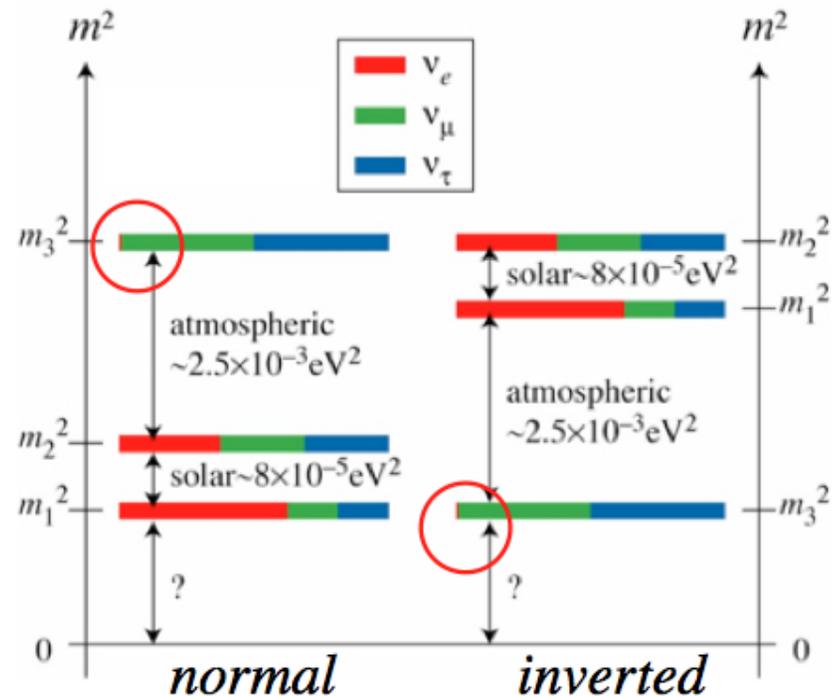
$$P(\nu_\mu \rightarrow \nu_e) = \sin^2 2\theta_{13} \sin^2 \theta_{23} \sin^2(\Delta m_{31}^2 L/4E) + \dots$$

($\Delta m_{23}^2 \sim \Delta m_{31}^2$)

Open a possibility to measure CP violation in lepton sector

CPV term in $P(\nu_\mu \rightarrow \nu_e) \propto \sin \theta_{12} \sin \theta_{13} \sin \theta_{23} \sin \delta$

Neutrino mass & three flavor mixing



Mixing angle: $\theta_{12}, \theta_{23}, \theta_{13}$

$$\theta_{12} = 34^\circ \pm 3^\circ \quad \theta_{23} = 45^\circ \pm 5^\circ$$

Last unknown mixing angle θ_{13}

$$\sin^2 2\theta_{13} < 0.15 \quad \text{at 90\% C.L.}$$

CHOOZ (reactor exp.) and MINOS (accelerator exp.)

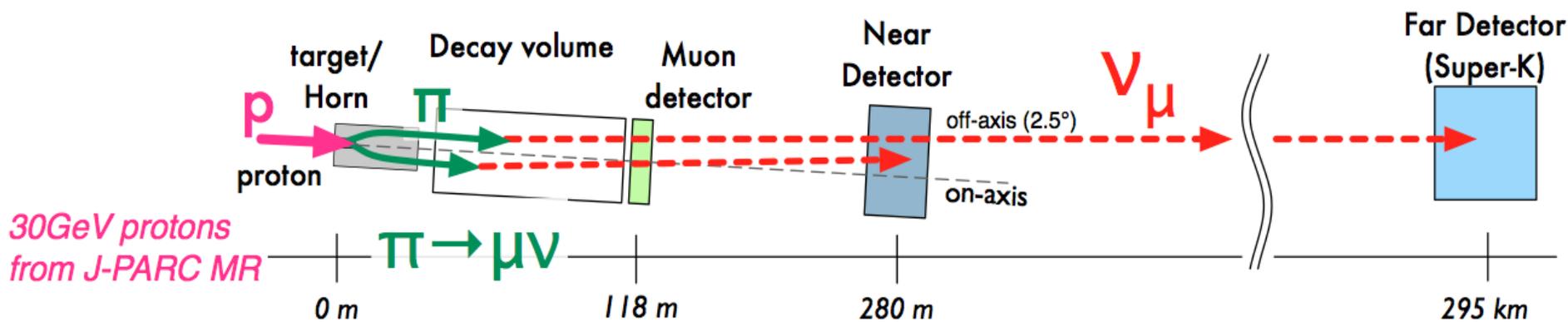
T2K Experiment



Super-Kamiokande
(ICRR, Univ. Tokyo)

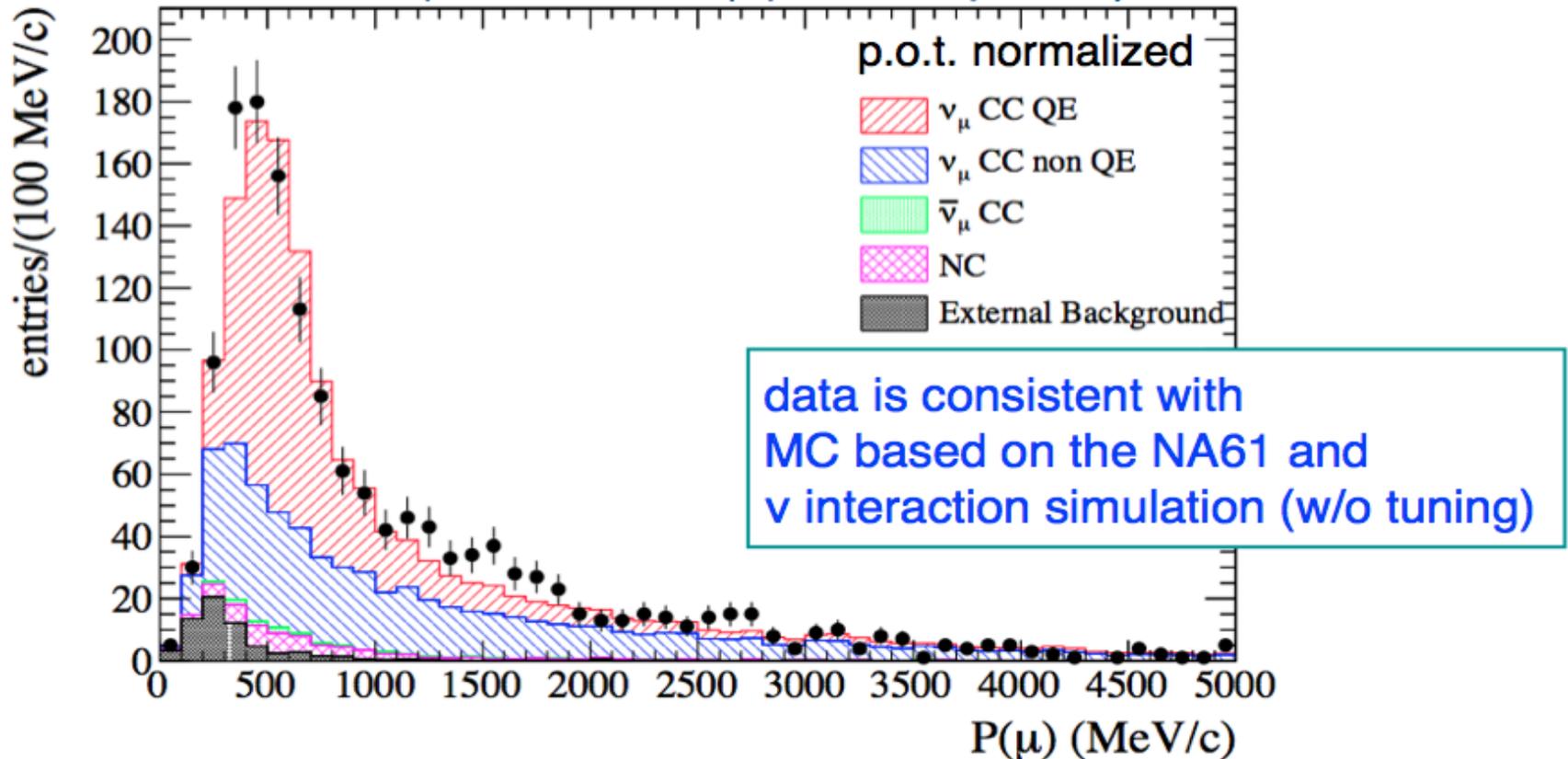


J-PARC Main Ring
(KEK-JAEA, Tokai)



Near off-axis fine-grained detector measurement

ND Measurement of muon momentum in inclusive ν_μ CC events ($\nu_\mu + N \rightarrow \mu^+ + X$)

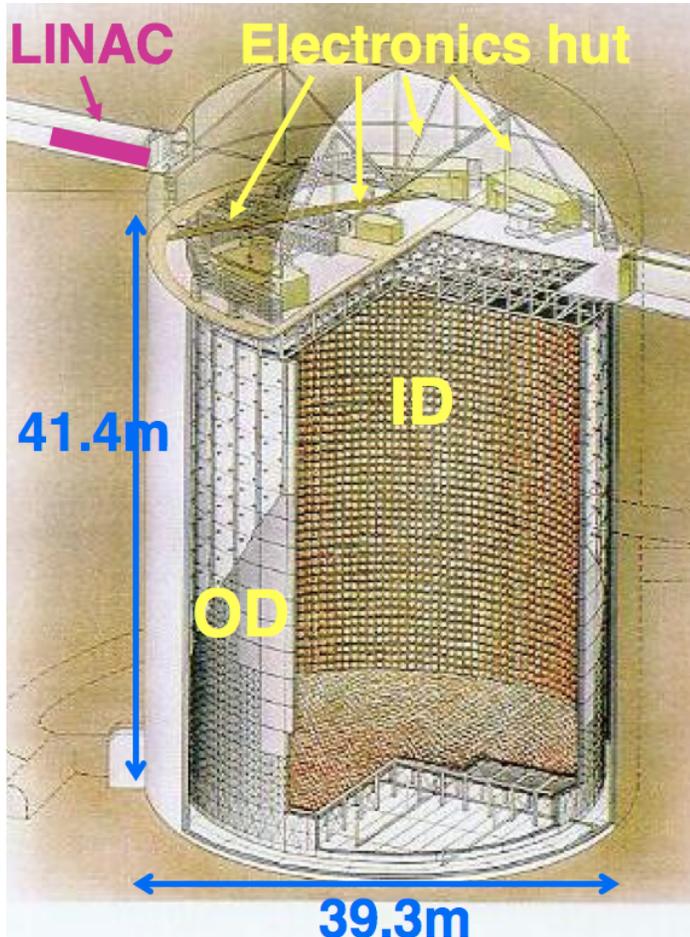


Results

$$R_{ND}^{\mu, Data} = 1529 \text{ events} / 2.9 \times 10^{19} \text{ p.o.t.}$$

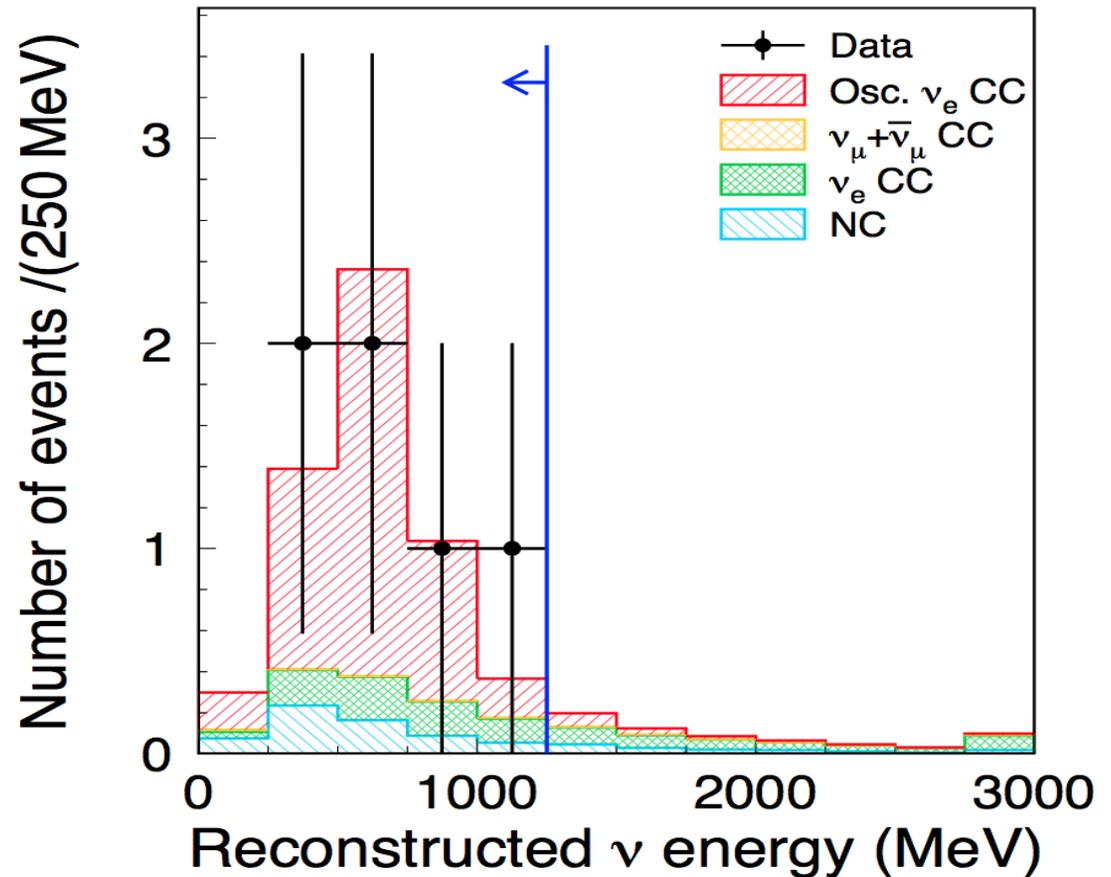
$$\frac{R_{ND}^{\mu, Data}}{R_{ND}^{\mu, MC}} = 1.036 \pm 0.028(\text{stat.})^{+0.044}_{-0.037}(\text{det. syst.}) \pm 0.038(\text{phys. syst.})$$

Predicting Events in the Far Detector



-Near detector rate measurement used as normalization

$$N_{SK}^{exp} = \left(R_{ND}^{\mu, Data} / R_{ND}^{\mu, MC} \right) \cdot N_{SK}^{MC}$$



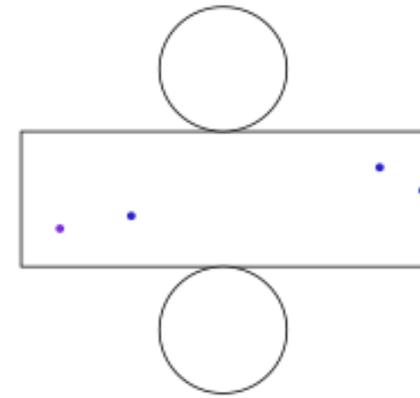
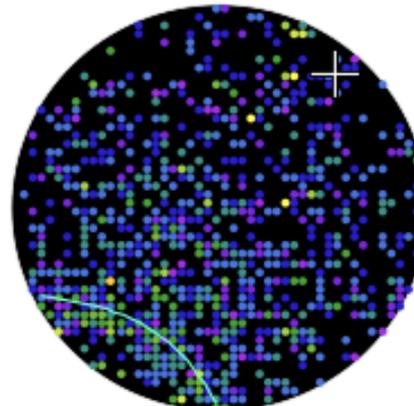
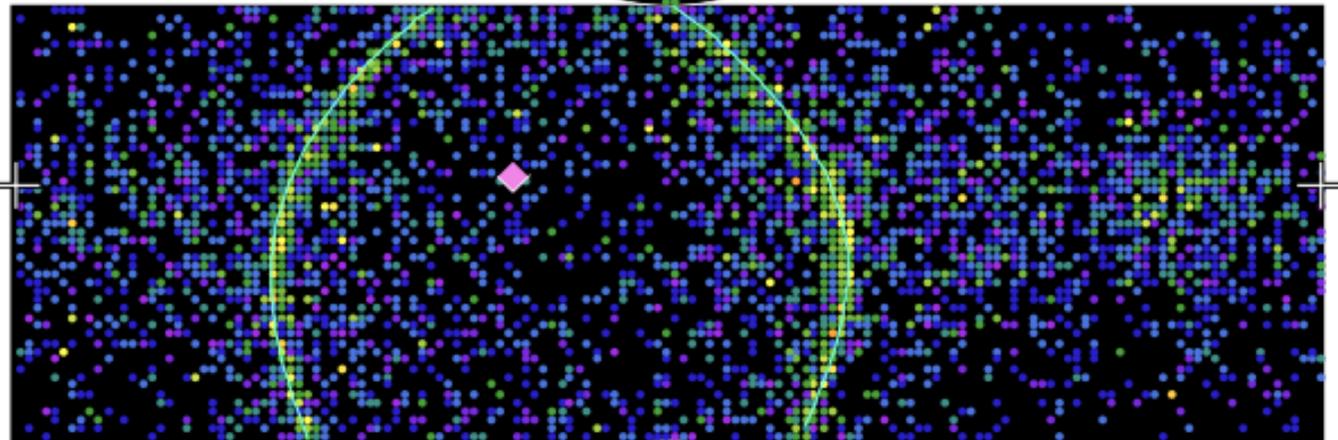
ν_e Candidate Event

Super-Kamiokande IV

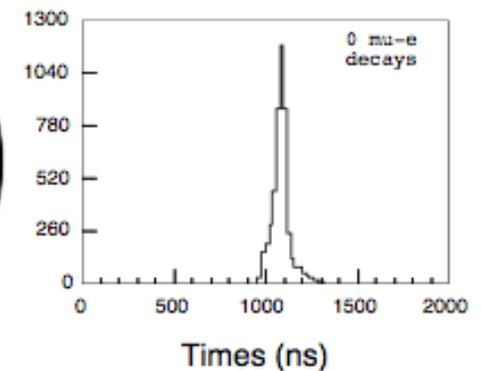
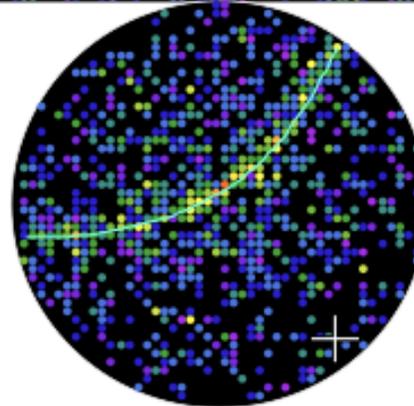
T2K Beam Run 0 Spill 1039222
Run 67969 Sub 921 Event 218931934
10-12-22:14:15:18
T2K beam dt = 1782.6 ns
Inner: 4804 hits, 9970 pe
Outer: 4 hits, 3 pe
Trigger: 0x80000007
D_wall: 244.2 cm
e-like, p = 1049.0 MeV/c

Charge (pe)

- >26.7
- 23.3-26.7
- 20.2-23.3
- 17.3-20.2
- 14.7-17.3
- 12.2-14.7
- 10.0-12.2
- 8.0-10.0
- 6.2- 8.0
- 4.7- 6.2
- 3.3- 4.7
- 2.2- 3.3
- 1.3- 2.2
- 0.7- 1.3
- 0.2- 0.7
- < 0.2



visible energy : 1049 MeV
of decay-e : 0
2 γ Inv. mass : 0.04 MeV/c²
recon. energy : 1120.9 MeV



Results for ν_e Appearance Search with 1.43×10^{20} POT

The observed number of events is **6**

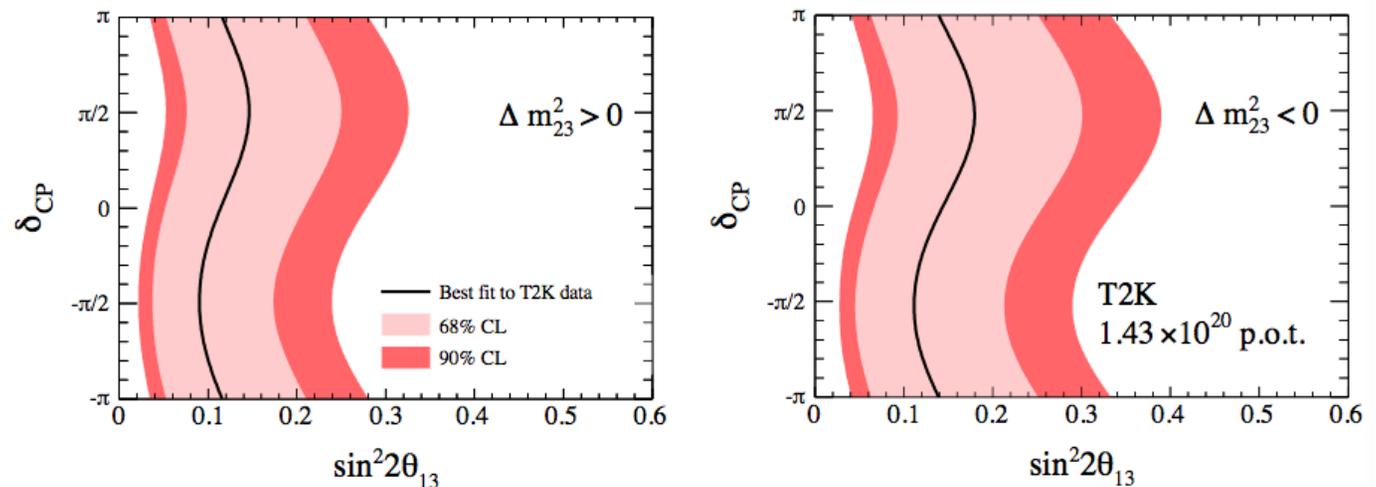
The expected number of events is 1.5 ± 0.3

for $\sin^2 2\theta_{13}=0$

Under the $\theta_{13}=0$ hypothesis, the probability to observe six or more candidate events is 0.007 (equivalent to 2.5σ significance)

Allowed region of $\sin^2 2\theta_{13}$ as a function of δ_{CP}

(assuming $\Delta m^2_{23}=2.4 \times 10^{-3} \text{ eV}^2$, $\sin^2 2\theta_{23}=1$)



90% C.L. interval & Best fit point (assuming $\Delta m^2_{23}=2.4 \times 10^{-3} \text{ eV}^2$, $\sin^2 2\theta_{23}=1$, $\delta_{CP}=0$)

$$0.03 < \sin^2 2\theta_{13} < 0.28$$

$$\sin^2 2\theta_{13} = 0.11$$

$$0.04 < \sin^2 2\theta_{13} < 0.34$$

$$\sin^2 2\theta_{13} = 0.14$$