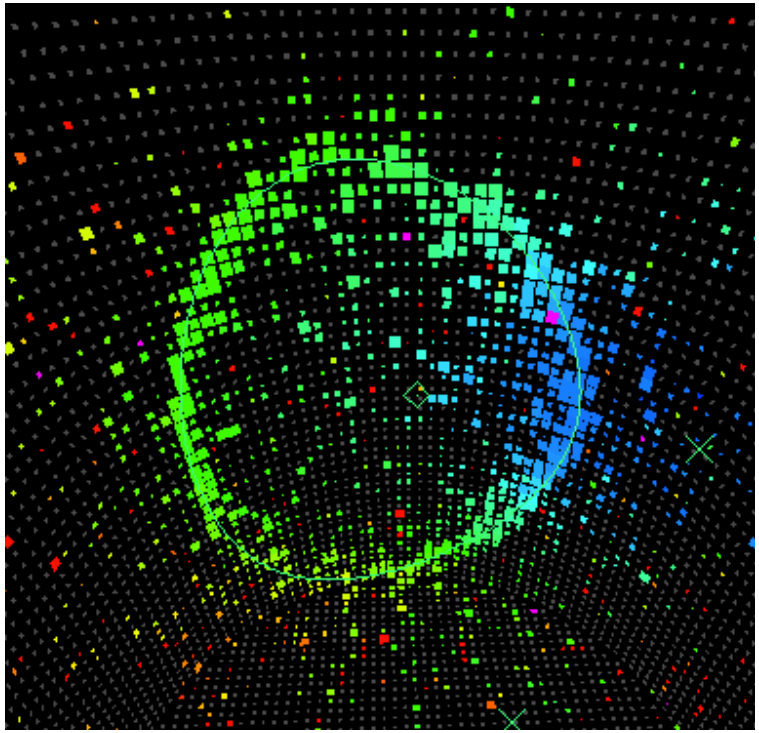
T2K実験



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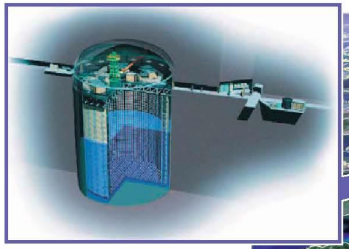
他 T2Kコラボレーション

2012年12月7日
平成24年度宇宙線研究所
共同利用研究成果発表会

T2K (Tokai-to-Kamioka) experiment



Super-Kamiokande

~500 members
from 12 nations

Intense ν_μ beam : J-PARC → SK

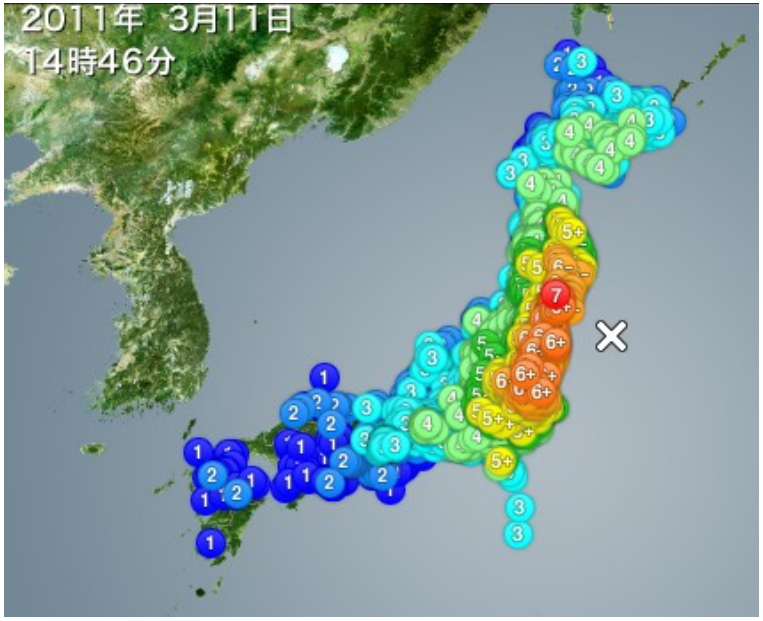
Main goals :

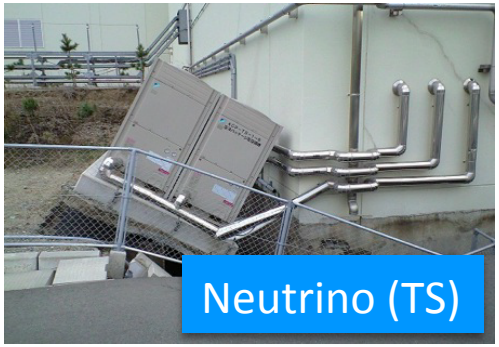
- Discovery of ν_e appearance
  - Measure non-zero θ_{13}
- Precision measurement of ν_μ disappearance
  - $\delta(\Delta m^2_{23}) \sim 1 \times 10^{-4}$ eV^2 , $\delta(\sin^2 2\theta_{23}) \sim 0.01$

In 2011 June, T2K reported the first indication of $\theta_{13} \neq 0$ (2.5σ)

- In 2012, solid confirmation by reactor experiments. (anti-ν_e disappearance)

Recovery after the 3.11 earthquake

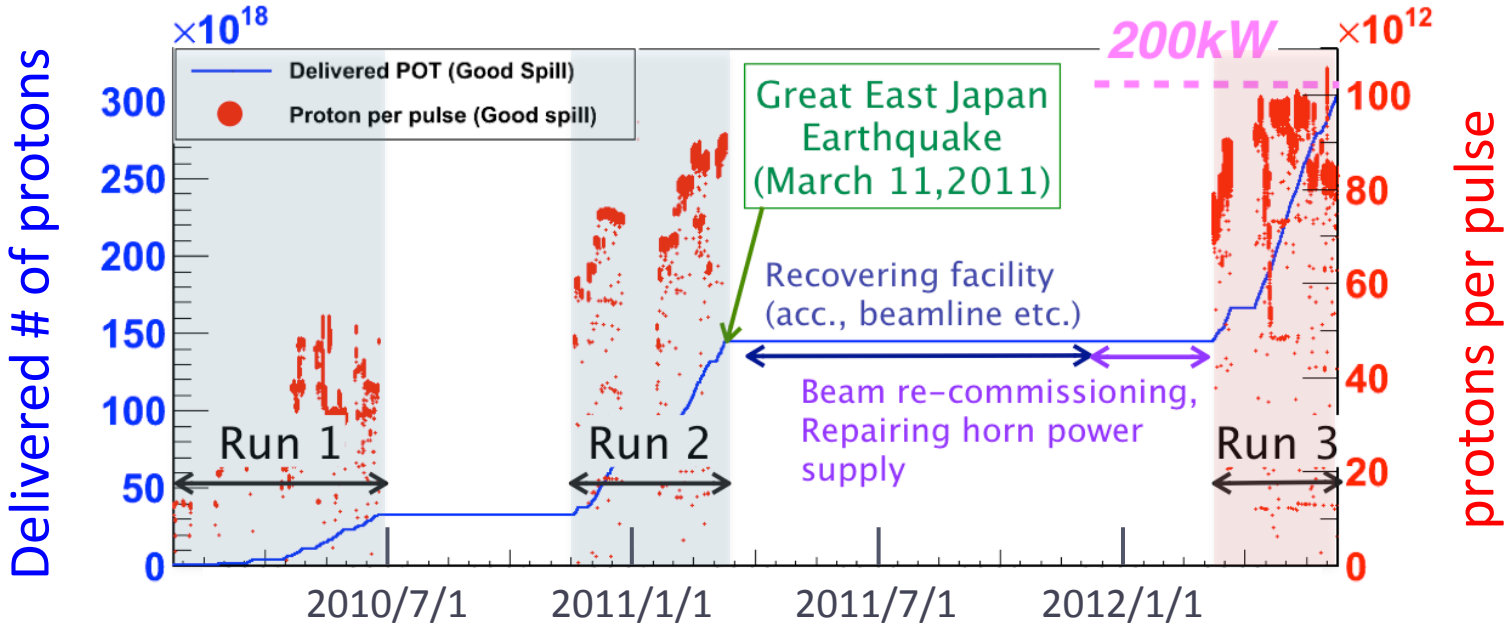




- December 9, 2011 : J-PARC LINAC operation restarted.
- December 24, 2011 : Neutrino events observed at T2K ND280.
- March 8, 2012 : T2K physics run restarted within 1 year after the earthquake.

T2K run history

Beam power reached ~200kW !



Run 1+2 (2010 Jan – 2011 Mar) : 1.43 x 10^{20} p.o.t.

- data set for the 2011 results

Run 3 (2012 Mar – Jun) : 1.58 x 10^{20} p.o.t.

- including 0.21 x 10^{20} p.o.t. with 200kA horn operation (13% flux reduction @peak)

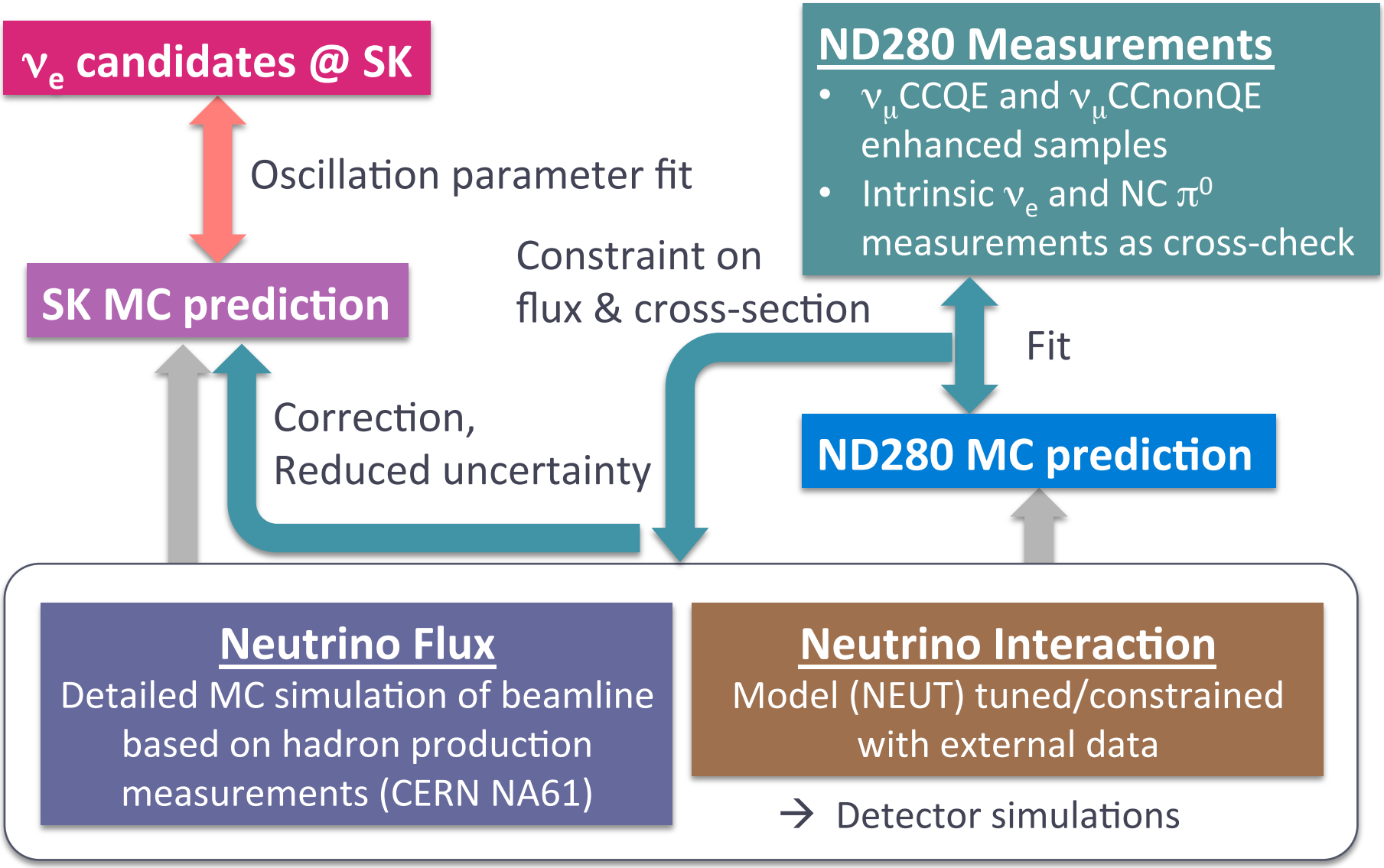
Run 4 (2012 Oct –) :

- stable operation with ~200kW

Data in this talk
= 3.01 x 10^{20} p.o.t.

(4% of the approved T2K exposure)

$\nu_\mu \rightarrow \nu_e$ oscillation analysis strategy



Preliminary

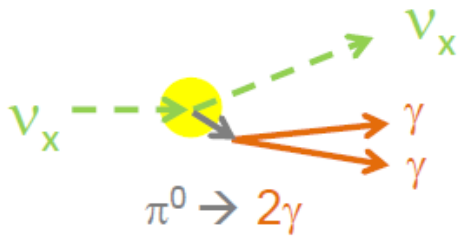
T2K ν_e event selection

Number of remaining events after each cut

Signals : Single-electron events by osc. ν_e CCQE

Backgrounds :

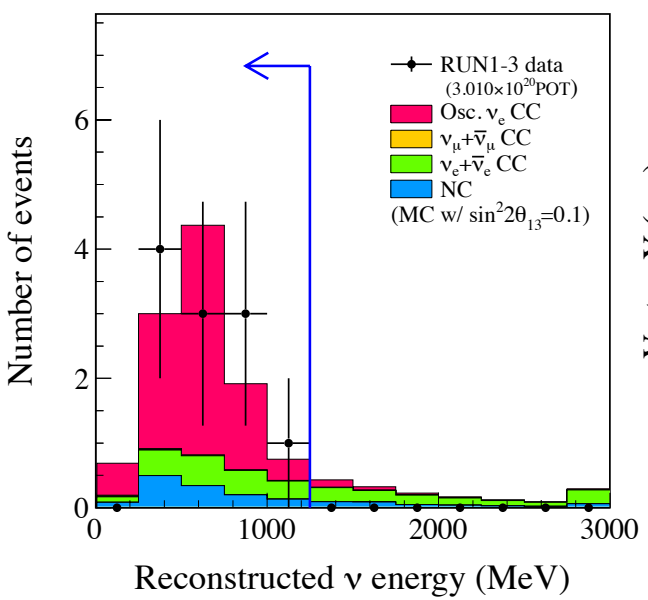
- ✓ Intrinsic beam ν_e
- ✓ NC π^0 events
  - overlap of 2 γ rings
  - asymmetric decay

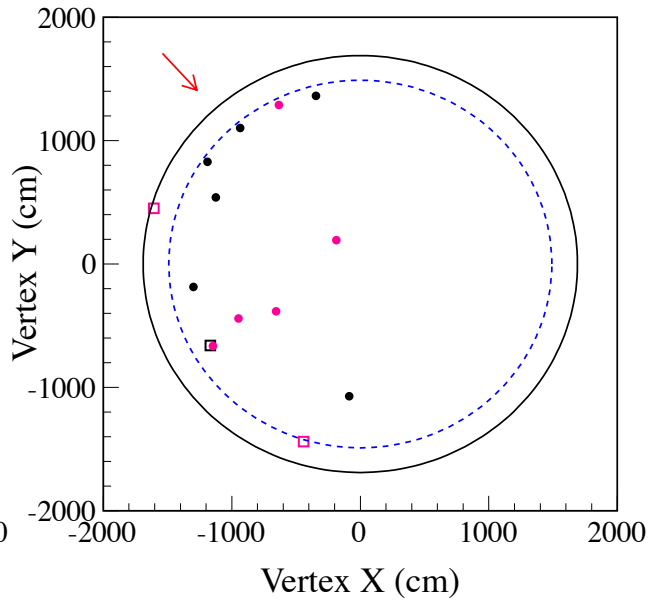


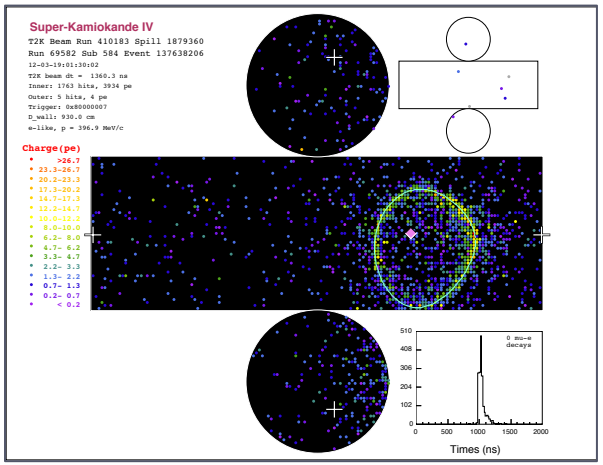
- Beam timing, FC, fiducial (174)
- Single-ring electron-like (22)
- Visible energy > 100MeV (21)
- No delayed electron signal (16)
- Invariant mass < 105MeV/c^2 (11)
- Rec. ν energy < 1250MeV (11)

→ 11 events observed

(6 events in Run1+2)







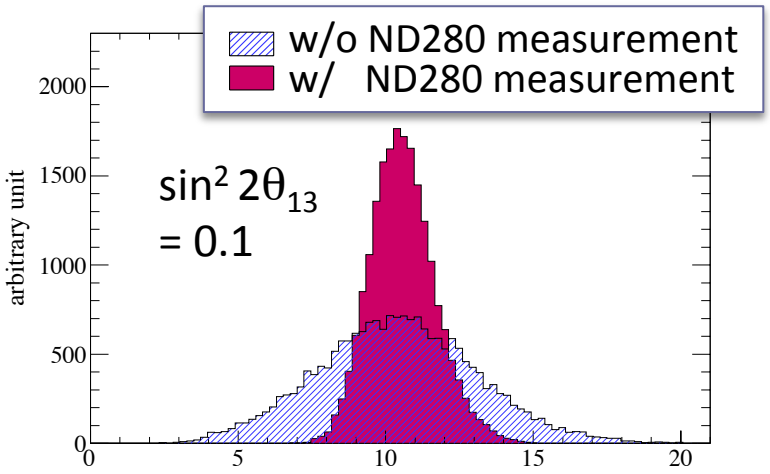
Preliminary

Predicted number of events & Significance

Predicted # of events w/ 3.01 x 10^{20} p.o.t.

Category	$\sin^2 2\theta_{13} = 0$	$\sin^2 2\theta_{13} = 0.1$
Total	3.22 ± 0.43	10.71 ± 1.10
ν_e signal	0.18	7.79
ν_e BG	1.67	1.56
ν_μ BG	1.21	1.21
$\bar{\nu}_\mu$+$\bar{\nu}_e$ BG	0.16	0.16

Predicted # of events w/ sys. error



Systematic uncertainties

Error source	$\sin^2 2\theta_{13} = 0$	$\sin^2 2\theta_{13} = 0.1$
Beam flux+ν int. in T2K fit	8.7 %	5.7 %
ν int. (from other exp.)	5.9 %	7.5 %
Final state interaction	3.1 %	2.4 %
Far detector	7.1 %	3.1 %
Total	13.4 %	10.3 %
T2K 2011 results	~23 %	~18 %

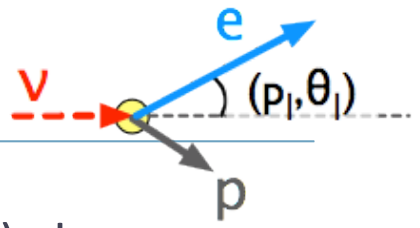
Under $\sin^2 2\theta_{13}$=0 hypothesis, the probability to observe ≥11 candidate events is 0.08%.

→ 3.2σ significance

Evidence of ν_e appearance !

opens the possibility to measure CP violation in the lepton sector

Oscillation parameter fits



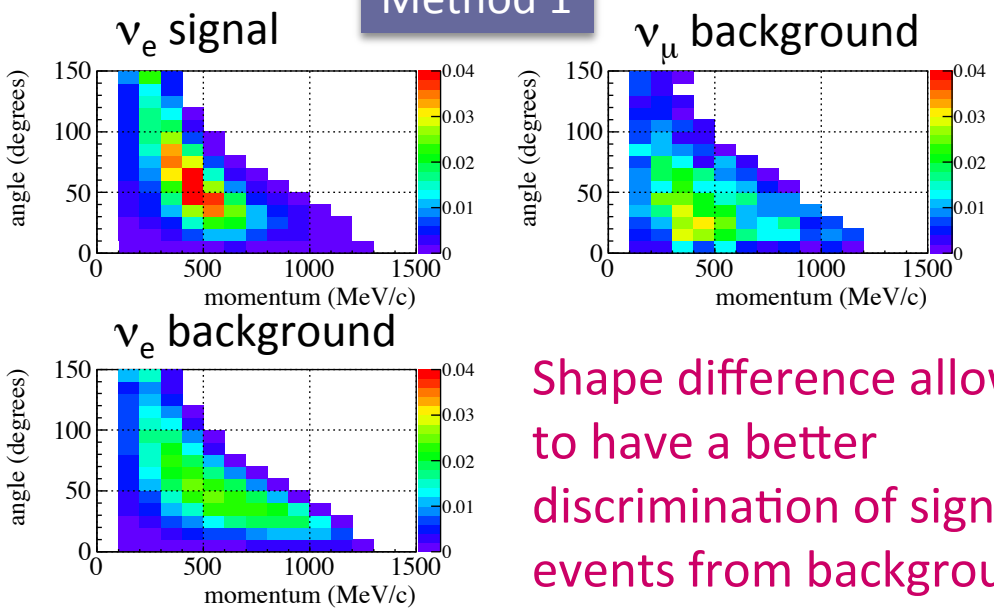
- Method 1 : Maximum likelihood fit w/ Rate + (p_e , θ_e) shape
- Method 2 : Maximum likelihood fit w/ Rate + reconstructed E_ν
- Method 3 : Feldman&Cousins for rate only

Likelihood in Method-1&2

$$\mathcal{L}(N_{obs.}, \underline{x}; \underline{o}, \underline{f}) = \mathcal{L}_{norm}(N_{obs.}; \underline{o}, \underline{f}) \times \mathcal{L}_{shape}(\underline{x}; \underline{o}, \underline{f}) \times \mathcal{L}_{syst.}(\underline{f})$$

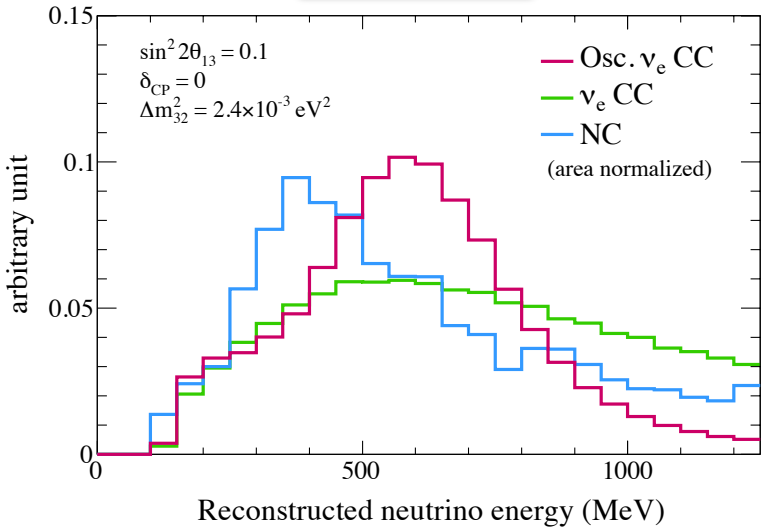
measurement variables — oscillation parameter — systematic parameters (prior: ND280 results)

Method 1



Shape difference allows to have a better discrimination of signal events from background

Method 2



Preliminary

Results

Confidence interval for each δ

Method 2

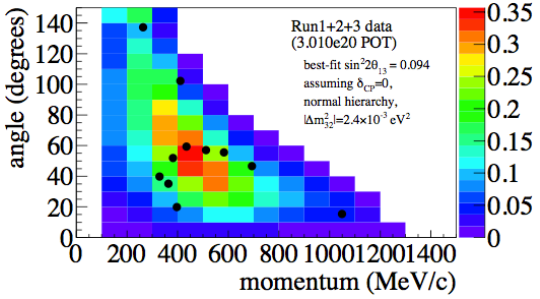
Best fit with 1σ errors

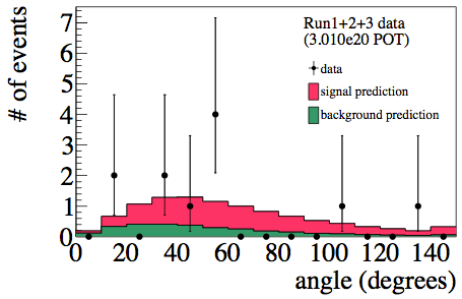
$\delta_{CP}=0$, $\sin^2\theta_{23}=0.5$

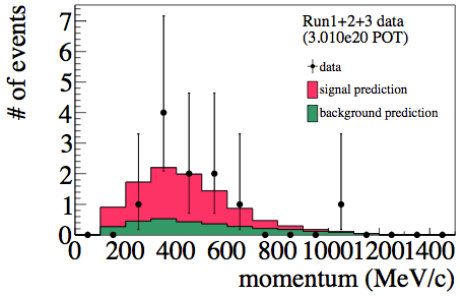
Method 1

$$\sin^2 2\theta_{13} = 0.094^{+0.053}_{-0.040} \quad \text{(NH)}$$

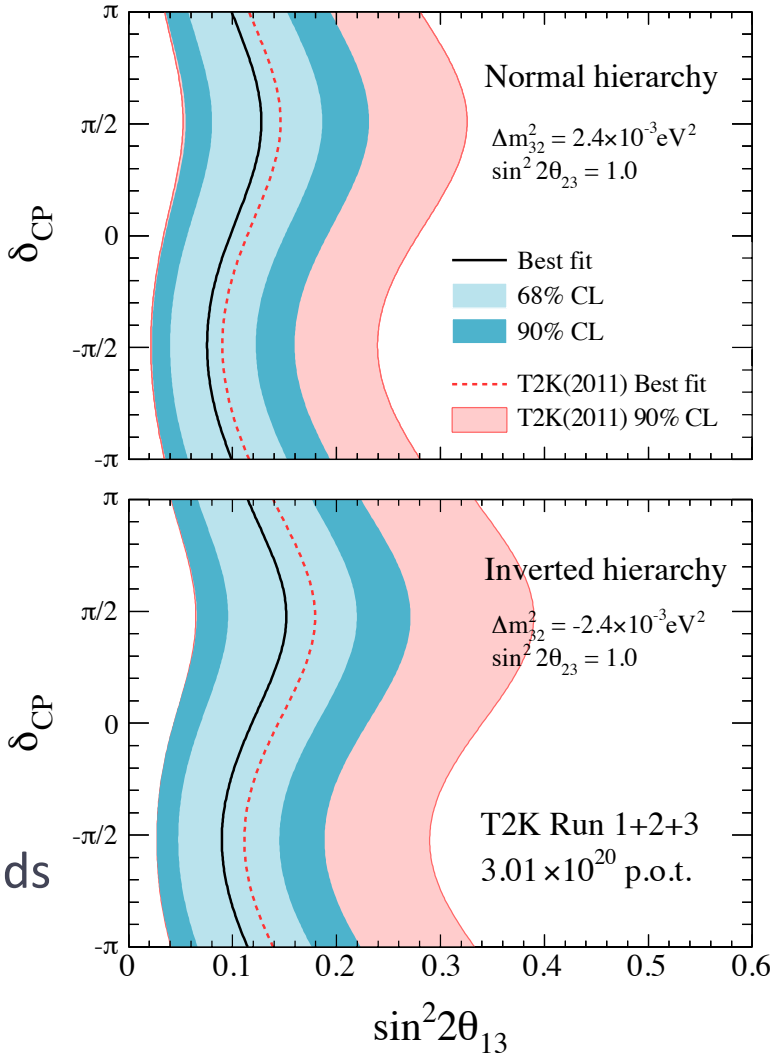
$$\sin^2 2\theta_{13} = 0.116^{+0.063}_{-0.049} \quad \text{(IH)}$$







Results from the 3 methods are very consistent

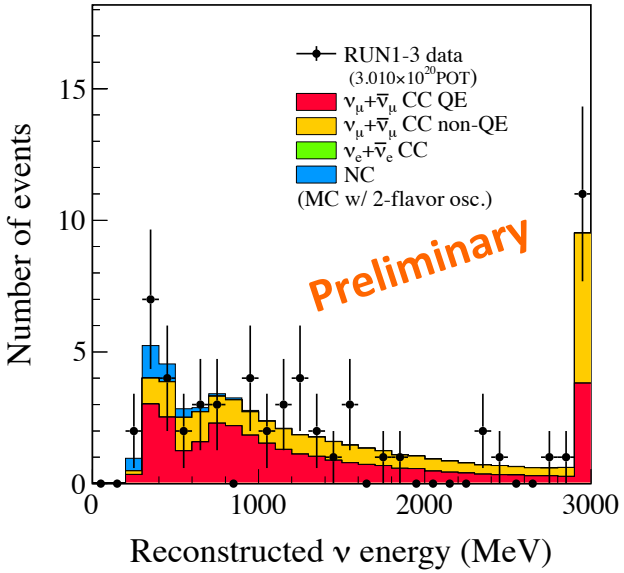


The result is consistent with the 2011 result and improved.

Outlook

- Will take more data with new high power runs.
  - 8×10^{20} p.o.t. (2013) → 12×10^{20} p.o.t. (2014) → 18×10^{20} p.o.t. (2015)
  - More precise measurement of ν_e appearance
    → hint on CPV and mass hierarchy in combination with precise θ_{13} measurements by reactor experiments

- An updated ν_μ disappearance measurement is coming soon.
  - Using Run1+2+3 data
  - Important for studies of sub-leading effects (CPV, mass hierarchy, …)



- And more …
  - Cross section measurements, Sterile ν search, etc.

For more detailed information,

please see my slide @ ICRR seminar in August.

http://www.icrr.u-tokyo.ac.jp/icrr_seminar/seminars12/20120824_Nakayama.pdf