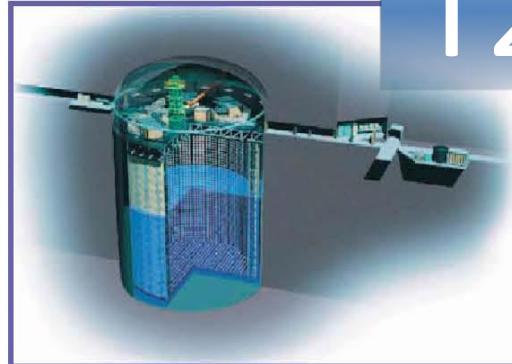


T2K Status in 2017



Super-Kamiokande
(ICRR, Univ. Tokyo)



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



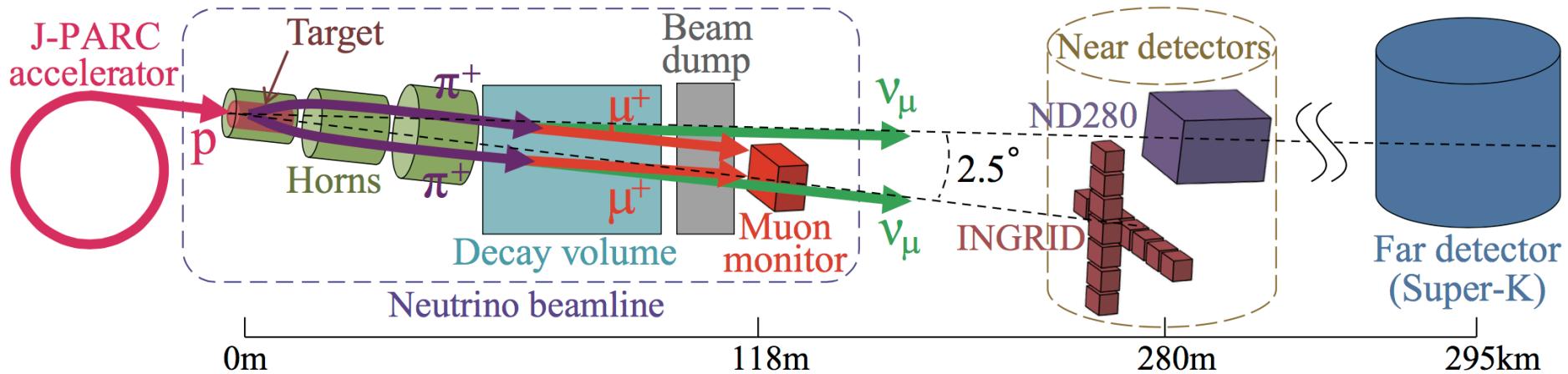
- ❖ The T2K experiment
- ❖ Neutrino beam status
- ❖ Detector status
- ❖ Highlight of latest results
- ❖ Future plans

S. Cao (IPNS, KEK)

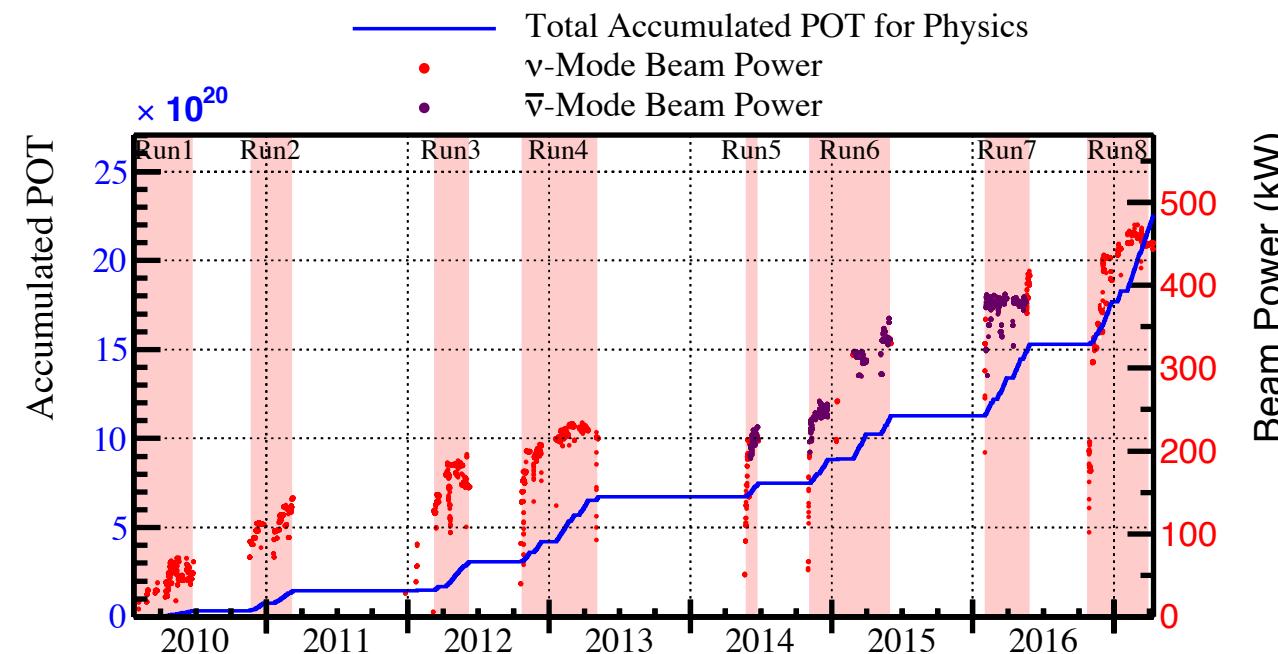
on behalf of T2K Collaboration

The T2K experiment

~500 researchers from 64 institutions in 12 countries



- ✧ Long-baseline neutrino experiment
 - ✧ Neutrino produced at J-PARC & detected at T2K far detector, Super-Kamiokande
 - ✧ Off-axis technique to optimize neutrino oscillation measurement.
 - ✧ Near detectors to constrain flux & neutrino interaction model
- ✧ Discovered appearance of $\nu_\mu \rightarrow \nu_e$ (2013)
- ✧ Leading effort of CP violation search
- ✧ Vibrant programs of non-standard physics & neutrino interactions

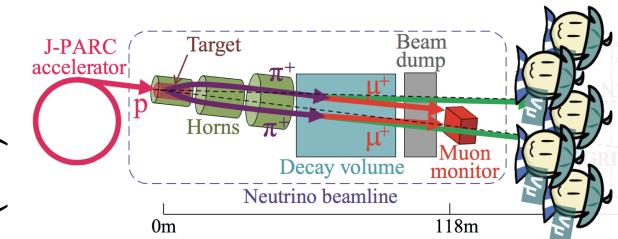


23 January 2010 – 12 April 2017

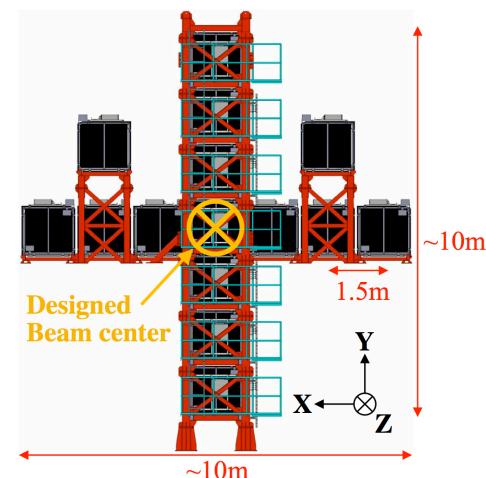
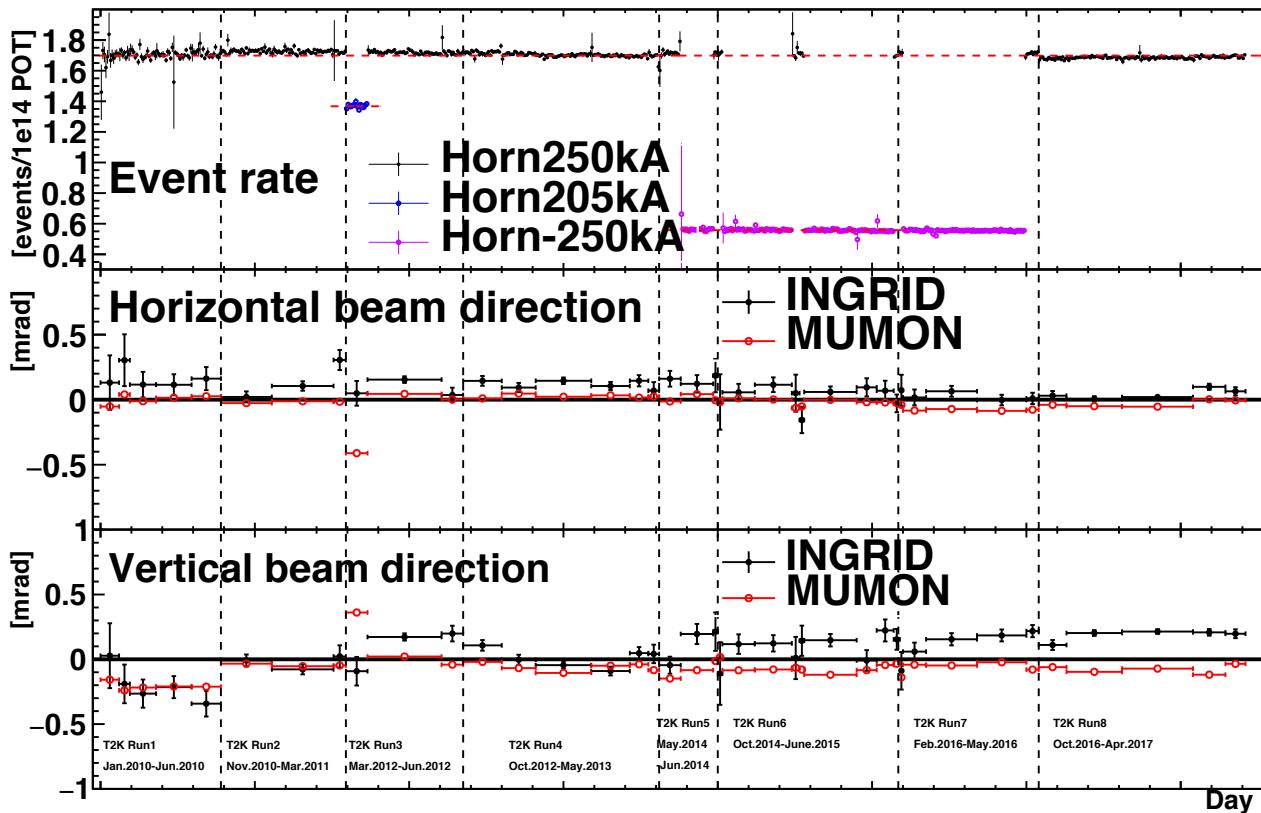
Total POT: 22.54×10^{20}

ν mode POT: 14.93×10^{20} (66.2%)

$\bar{\nu}$ mode POT: 7.62×10^{20} (33.8%)

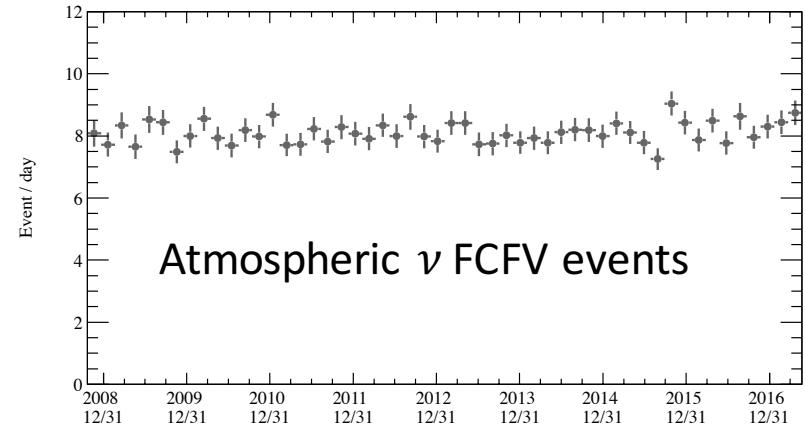
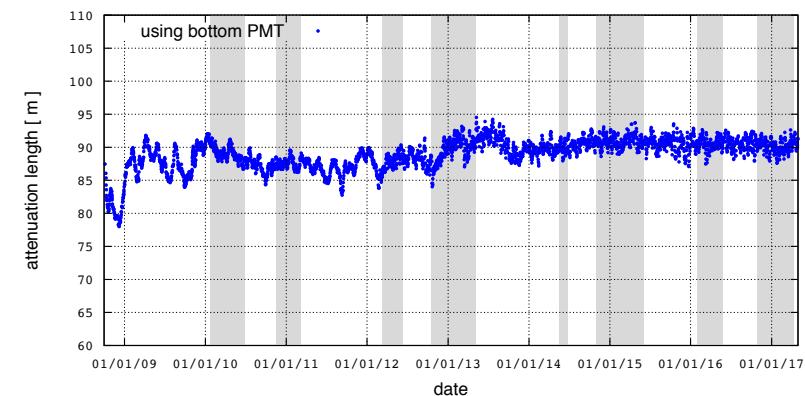
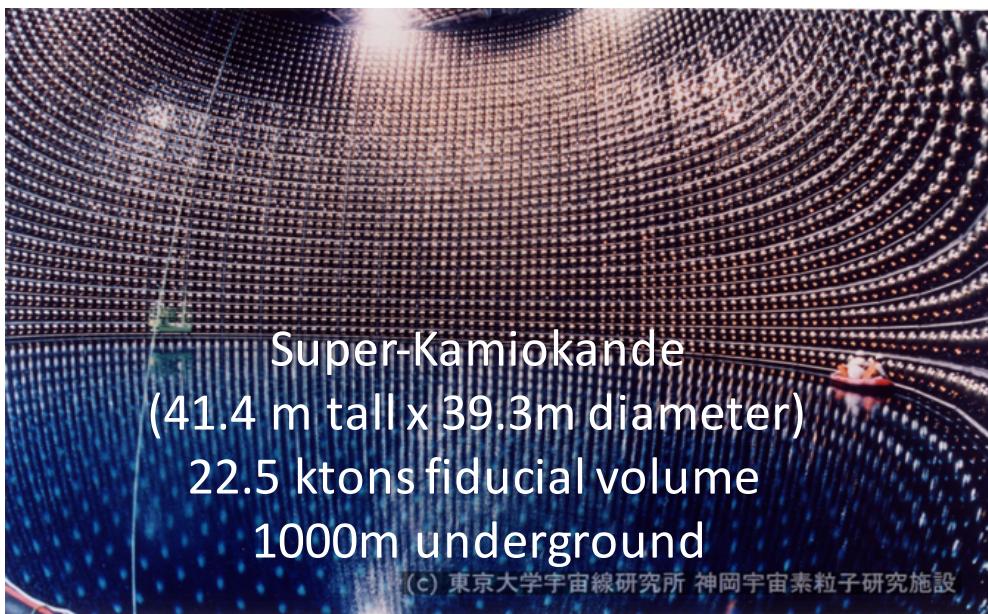
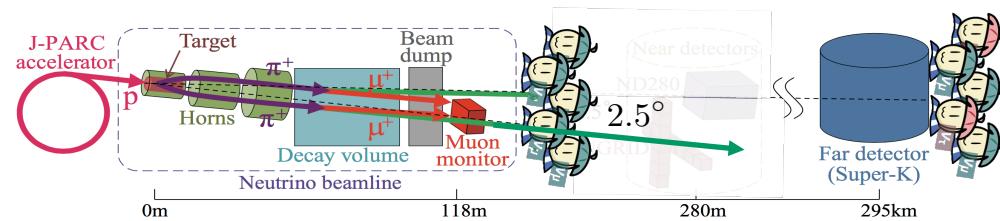


- ✧ Stable operation with 470kW beam power
- ✧ Double neutrino data in 1 year!
- ✧ Totally 22.50×10^{20} POT collected, ~30% of currently approved exposure



- ❖ Stability of ν production rate monitored by T2K on-axis INGRID detector
- ❖ Stability of ν beam direction monitored by INGRID and MUMON
(1mrad shift corresponds to 2% shift in ν peak energy)

T2K far detector status



- ✧ Super-K performs stably
- ✧ Data taking efficiency of 98.8% for T2K run8

✧ Super-K event selection & new data sample

- ✧ Use iTQuen algorithm (complete charge & time information) → enable to extend detector fiducial volume, lead to 20% effectively statistic increases in selecting e-like events
- ✧ Add CC1 π e-like sample → increase 10% for neutrino mode e-like

✧ Usage of ND280 data

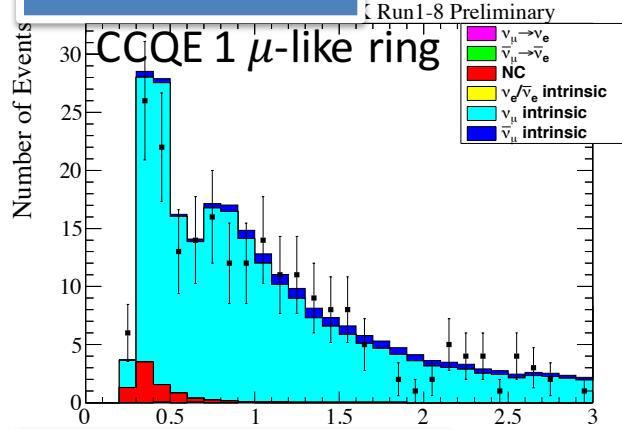
- ✧ Include FGD2 (water targets) to include interactions on water

✧ Interaction model improvements in NEUT (neutrino event generator)

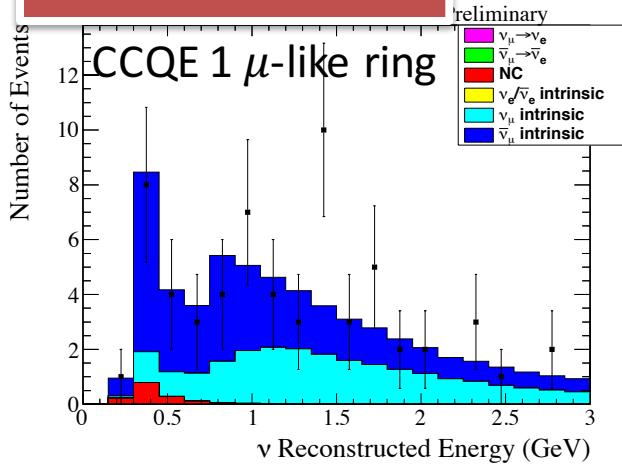
- ✧ Improve pion production model
- ✧ Include a model for multi-nucleon scattering
- ✧ Improve CCQE model by including effect of long-range correlations in nucleus

Far detector data samples with fit

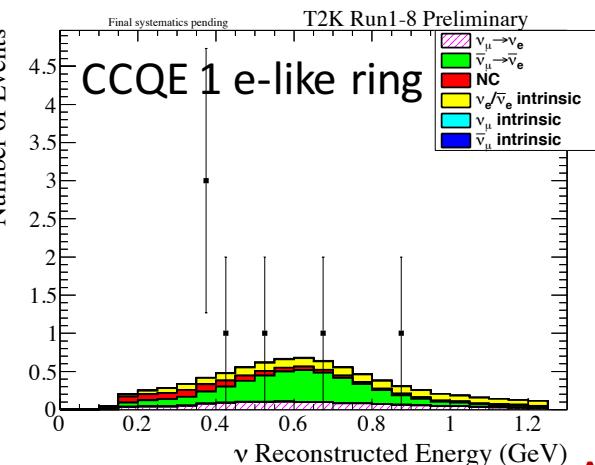
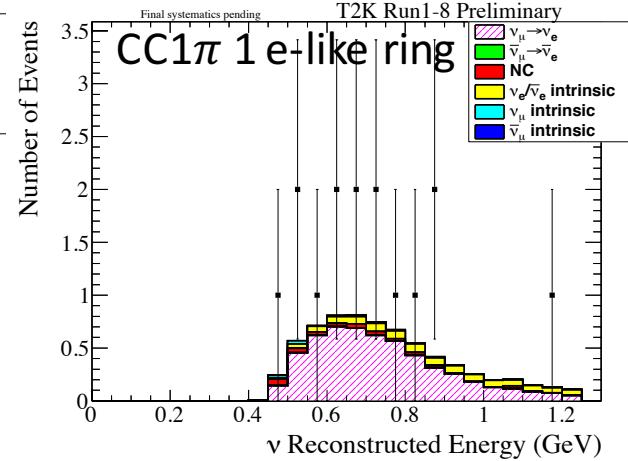
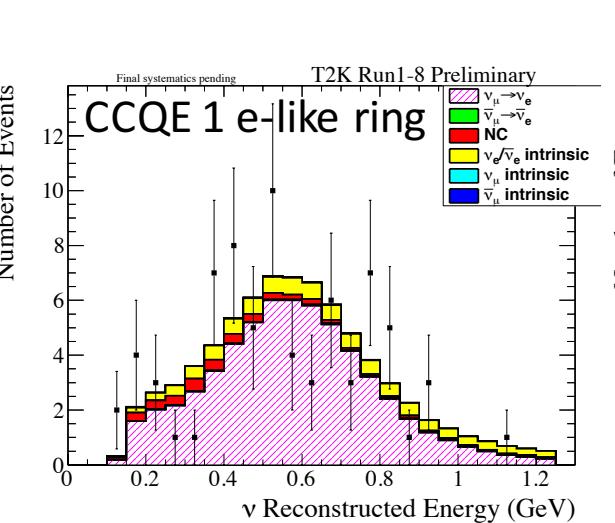
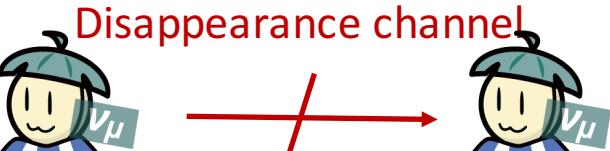
Neutrino mode



Anti-neutrino mode



Disappearance channel

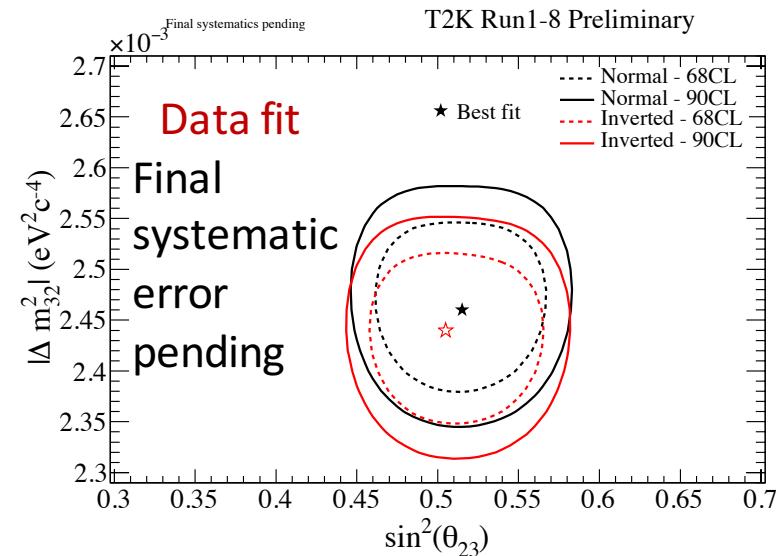


Appearance channel

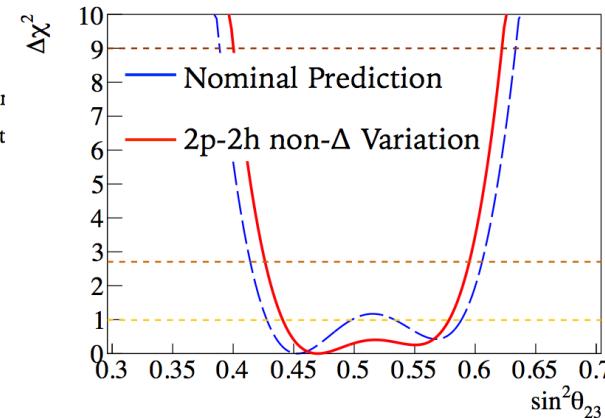
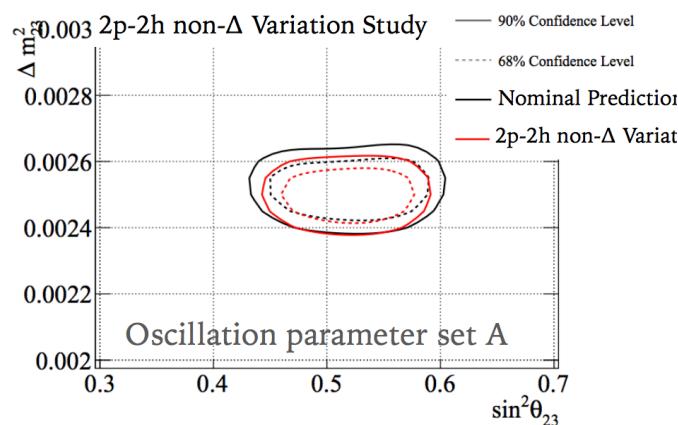


- ✧ Data is fitted separately for normal and inverted hierarchy

	$\sin^2\theta_{23} < 0.5$	$\sin^2\theta_{23} > 0.5$	Sum
NH ($\Delta m^2_{32} > 0$)	0.193	0.674	0.868
IH ($\Delta m^2_{32} < 0$)	0.026	0.106	0.132
Sum	0.219	0.781	



- ✧ Pending final systematic error, results maybe updated in future



(Study of ND data-driven variation show effect on atmospheric parameters)

Mixing angle θ_{13} & δ_{CP}

- ❖ T2K $\sin^2 \theta_{13}$ measurement is consistent with PDG 2016 average

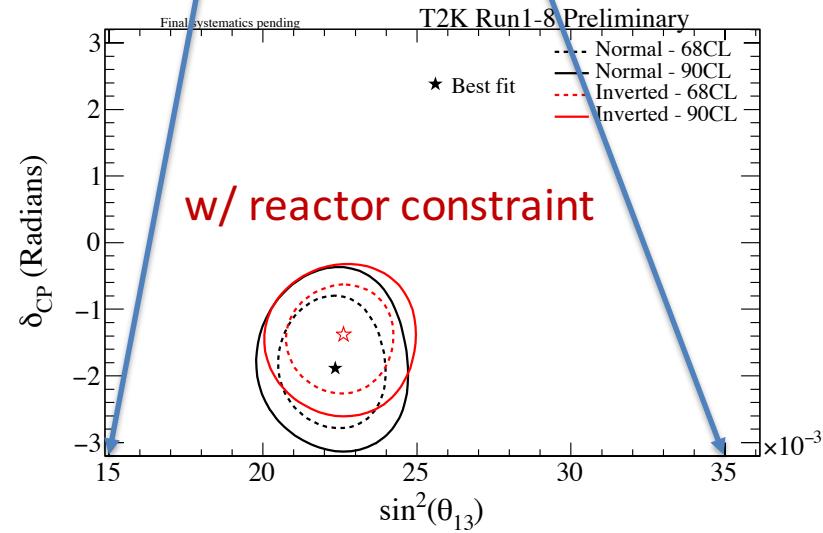
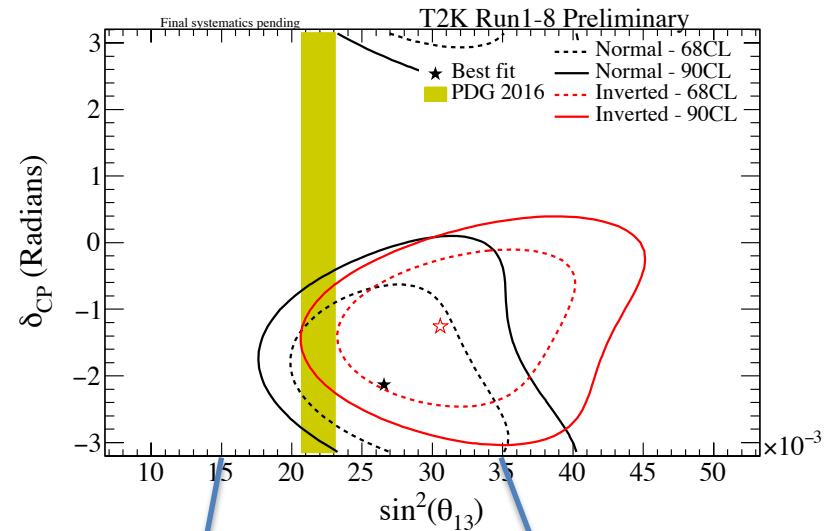
T2K value:

$$\sin^2 \theta_{13} = 0.0277^{+0.0054}_{-0.0047} \text{ (NH)}$$

PDG 2016:

$$\sin^2 \theta_{13} = 0.0210 \pm 0.0011$$

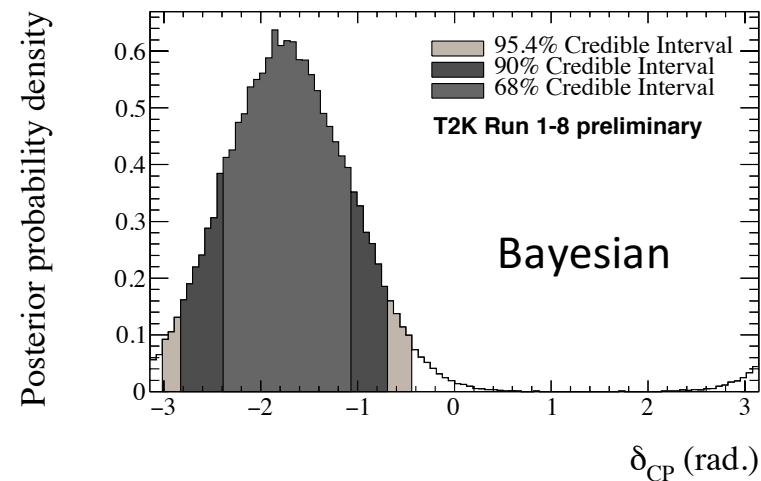
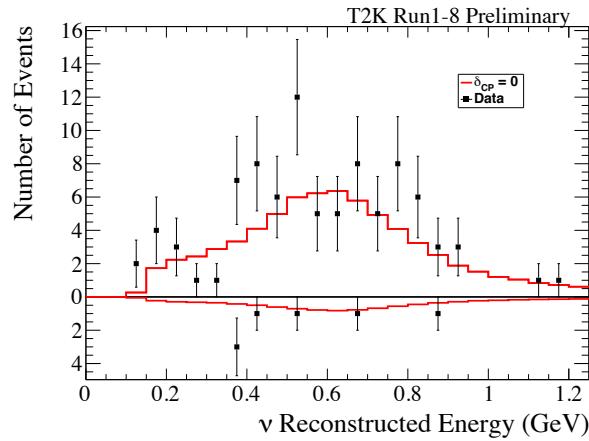
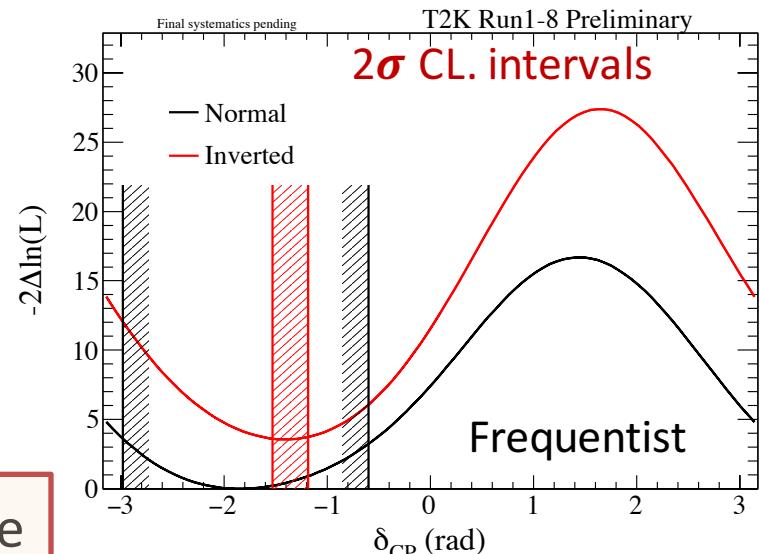
- ❖ Include the reactor constraint on θ_{13} improves constraint on δ_{CP}



δ_{CP} measurement

- ✧ 1σ CL. confidence interval
Normal Hierarchy $[-2.49, -1.23]$ rad.
- ✧ 2σ CL. confidence interval
Normal hierarchy $[-2.91, -0.60]$ rad.
Inverted hierarchy $[-1.54, -1.19]$ rad.

→ CP conserving values $(0, \pi)$ fall outside of the 2σ CL. confidence/credible interval



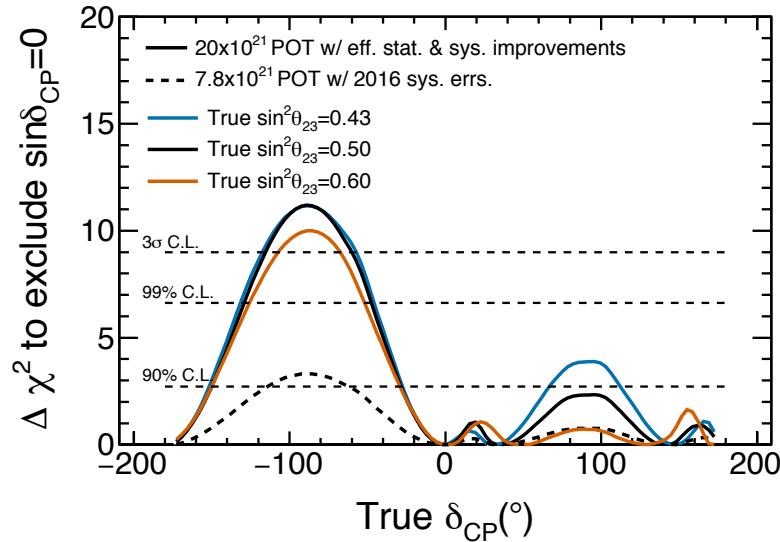
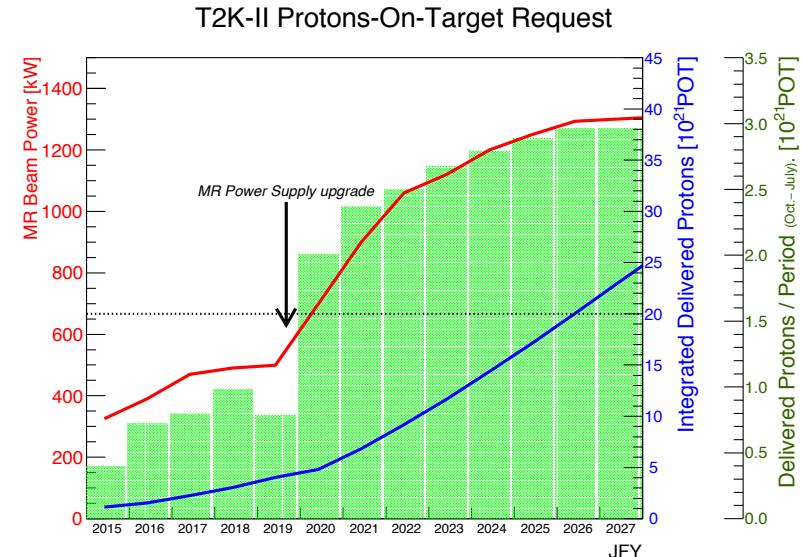
Future plans

Short-term

- ✧ Requested 9×10^{20} POT before summer 2018 (mainly in anti-neutrino mode)
- ✧ Super-K tank open from June 2018 to repair the leak, install a new water pipe and replace dead PMT

Long-term

- ✧ Upgrade MR power supplies to increase beam power
- ✧ T2K-II
 - ✧ Proposal to collect 20×10^{21} by JFY2026
 - ✧ Neutrino beamline upgrade & analysis improvement to effectively add 50% statistics
 - ✧ ND280 upgrade is proposed and formally approved by T2K



Summary

- ✧ T2K primary goal ($\nu_\mu \rightarrow \nu_e$) has achieved but our journey is not over. Now is an exciting and challenging time.
- ✧ T2K is leading the effort to measure CP violation & continues to produce high-impact results.
- ✧ T2K future plans are happening now! Physics prospects of T2K-II and ND280 upgrades are sensational!



The T2K Collaboration



Italy

~500 members, 64 Institutes, 12 countries

Canada

TRIUMF
U. B. Columbia
U. Regina
U. Toronto
U. Victoria
U. Winnipeg
York U.

France

CEA Saclay
LLR E. Poly.
LPNHE Paris

Germany

Aachen

Poland

IFJ PAN, Cracow
NCBJ, Warsaw
U. Silesia, Katowice
U. Warsaw
Warsaw U. T.
Wroclaw U.

Switzerland

ETH Zurich
U. Bern
U. Geneva

USA

Boston U.
Colorado S. U.
Duke U.
Louisiana State U.
Michigan S.U.
Stony Brook U.
U. C. Irvine
U. Colorado

United Kingdom

Imperial C. London
Lancaster U.
Oxford U.
Queen Mary U. L.
Royal Holloway U.L.
STFC/Daresbury
STFC/RAL

Vietnam

IFIRSE
IOP, VAST

Russia

INR

Spain

IFAE, Barcelona
IFIC, Valencia
U. Autonoma Madrid

U. Liverpool
U. Sheffield
U. Warwick