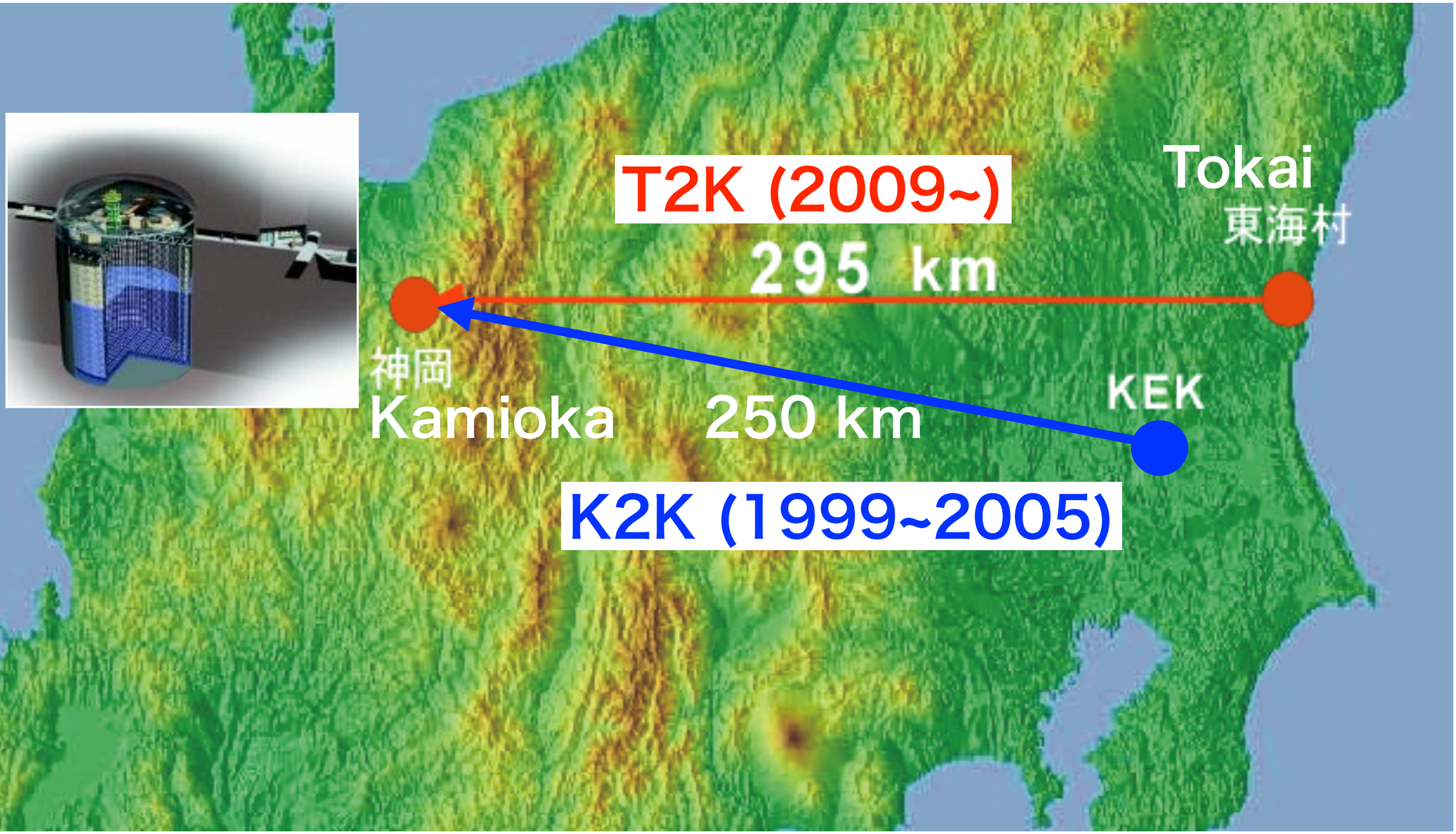
March 13, 2017@Neutrino Telescopes in Venice

K2K & T2K Experiment

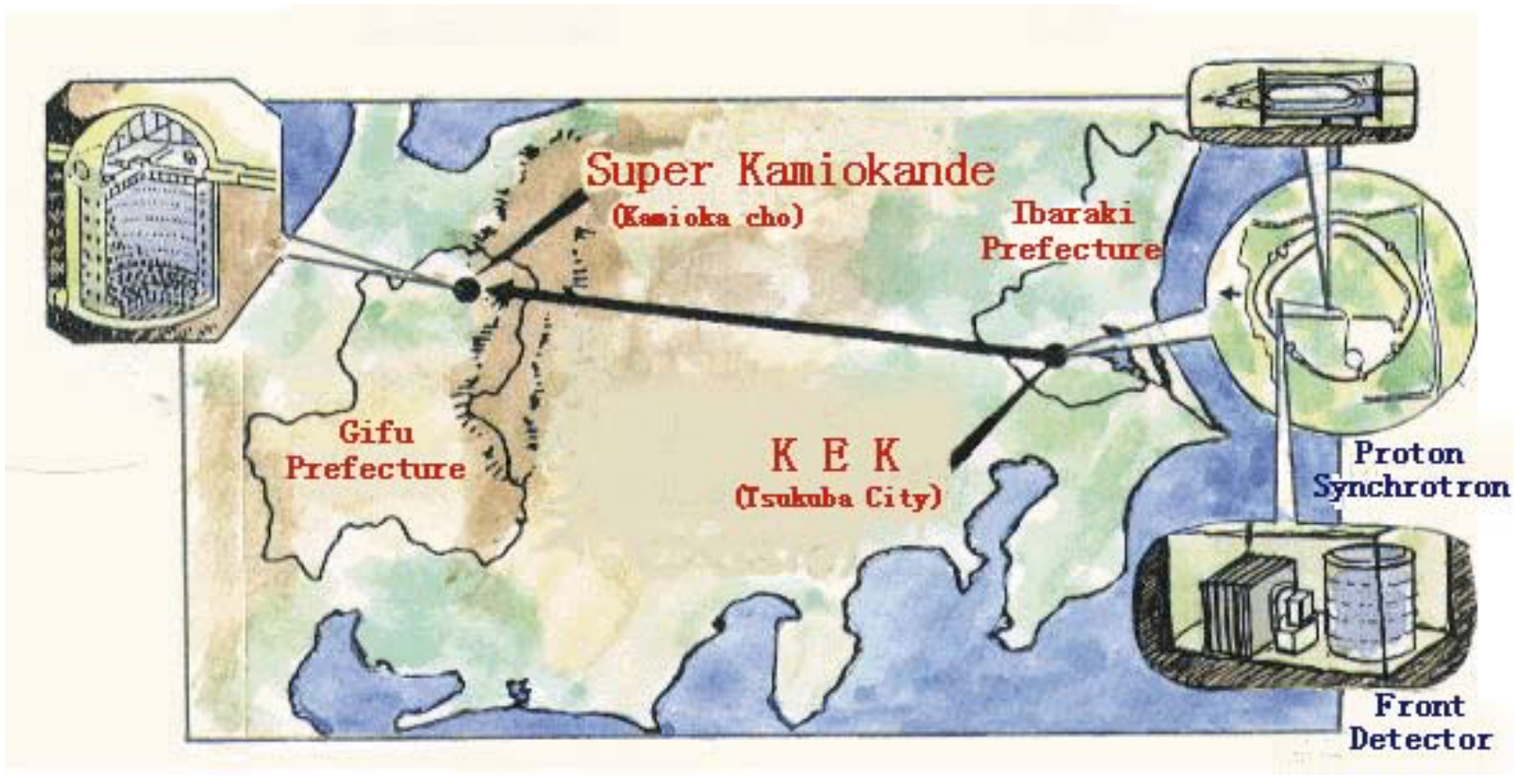
T. Nakaya (Kyoto) for

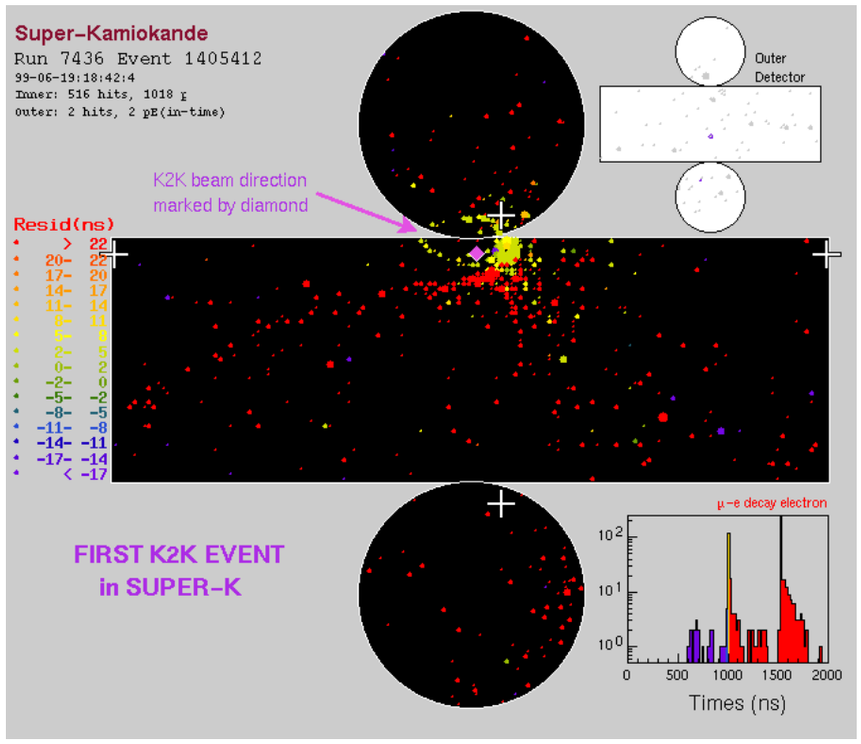
Koichiro Nishikawa and the K2K and T2K Collaboration

K2K & T2K Experiment



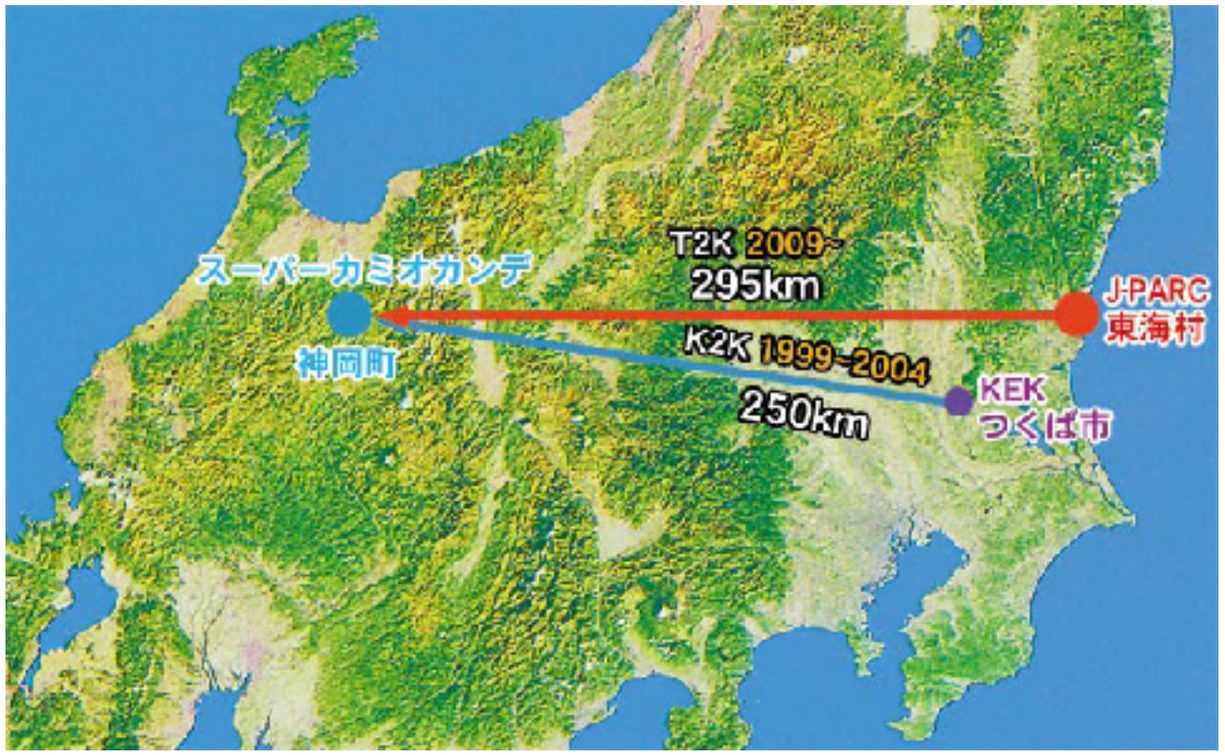
K2K Experiment

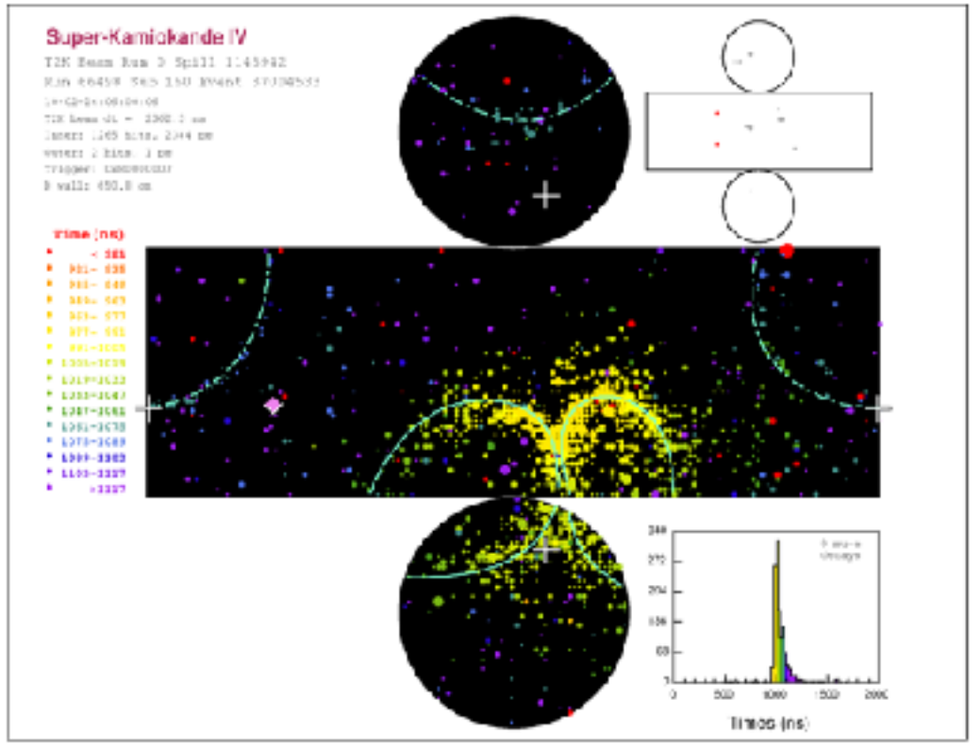




- 1995: K2K Proposal
- 1999: Data taking started
- 2002: Indication of Neutrino Oscillations
- 2004: Measurement of Neutrino Oscillations
- 2005: Data taking finished.

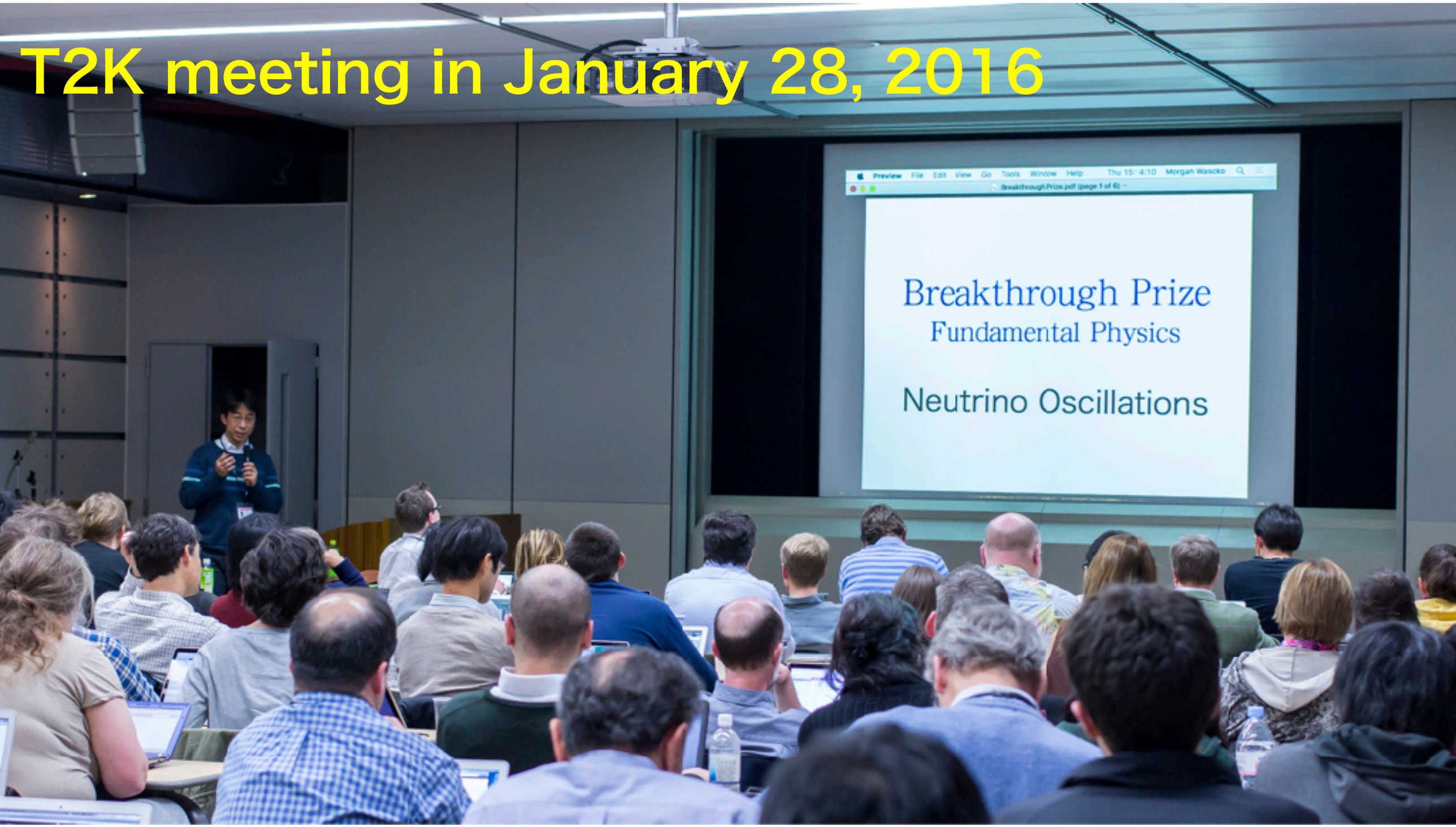
T2K Experiment





- 2000-2001: JHFnu LOI (base of the T2K proposal)
- 2004: Construction Started
- 2009: First Neutrino Beam
- 2011: Indication of electron neutrino appearance
- 2013: Observation of electron neutrino appearance
- 2016: A hint of neutrino CPV

T2K meeting in January 28, 2016



T2K meeting in January 28, 2016

T2K meeting in January 28, 2016

The Eve of K2K/T2K
1980's-2000

Koichiro Nishikawa

2016.1.28

@Breakthrough prize celebration

- 1950’s MNS-P

- 1988 Kamiokande atmospheric anomaly
- 1991 SK start construction
- 1995 K2K proposal
- 1995 A possible experiment at the new accelerator
- 1996 SK construction completed
- 1998 Takayama conference
- 1999 K2K beam line construction completed
- 2005 K2K completed
- 2000 T2K LOI
- 2001 J-PARC approved
- 2005 T2K Proposal
- 2009 T2K beam line construction completed
- 2012 ν_e appearance

1980's Long / Short Baseline
A motivation of short baseline

Critical mass density of Universe ~ 5000 eV/cm^3
(flat curvature)

	number density (/cm^3)	mass (eV)	mass density (eV/cm^3)
Nucleon	10^{-7}	10^9	100
neutrino	100 / flavor	1~10	3~3000

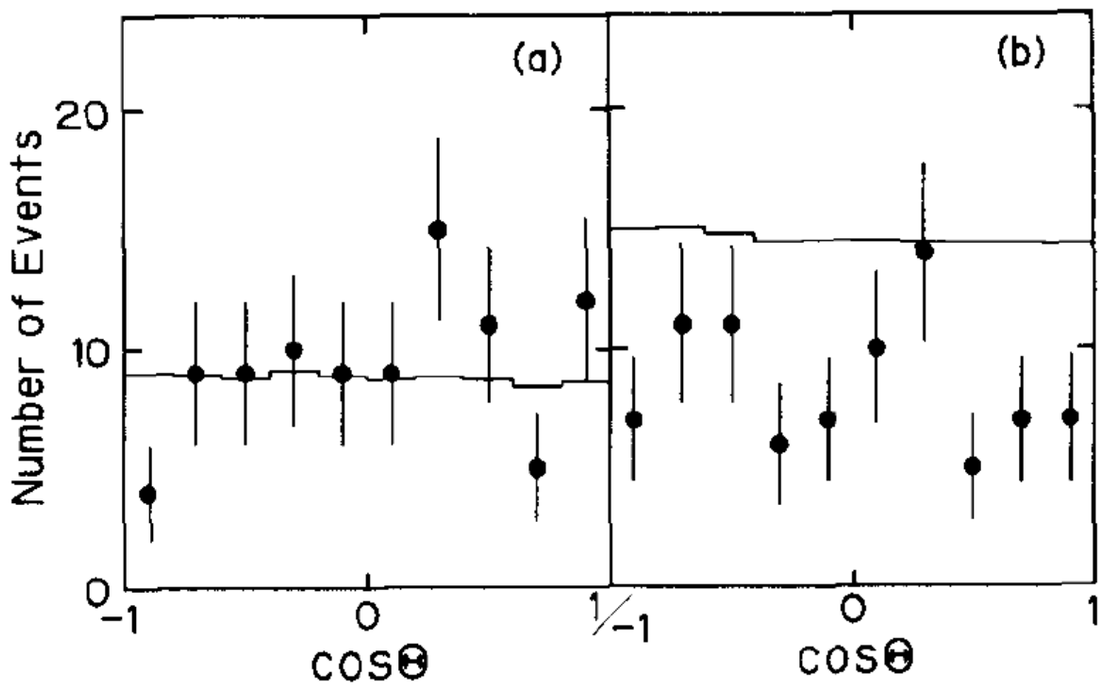
L(km)/E(GeV) ~ 1

4

New Δm^2 region

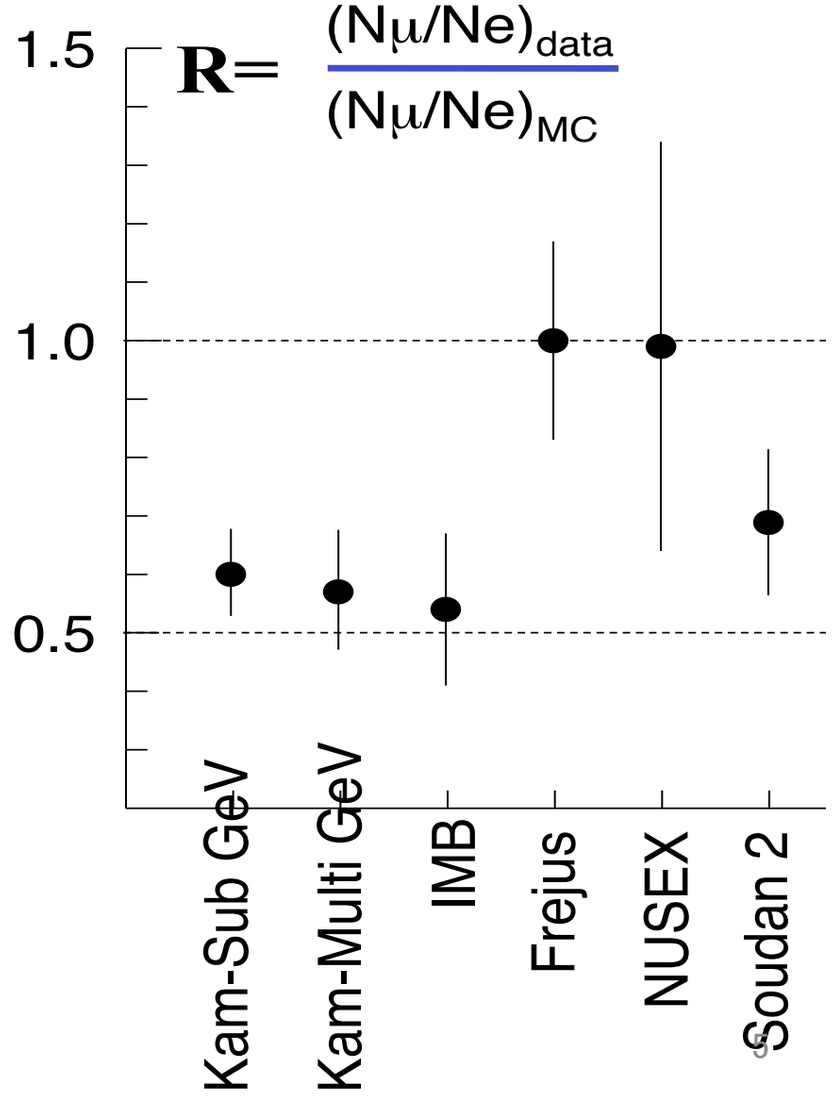
1988
KAMIOKANDE

Sub-GeV e-like Sub-GeV μ-like

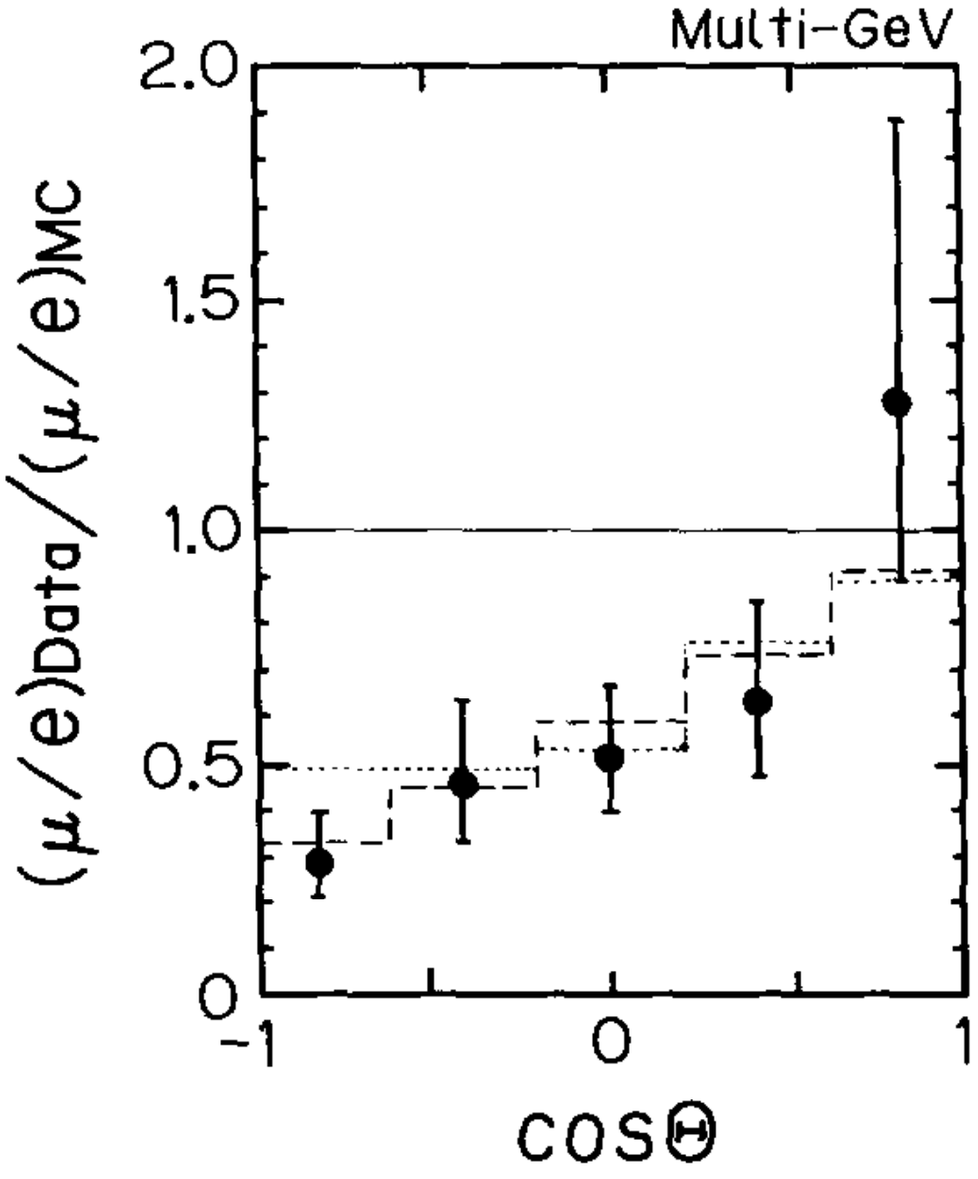


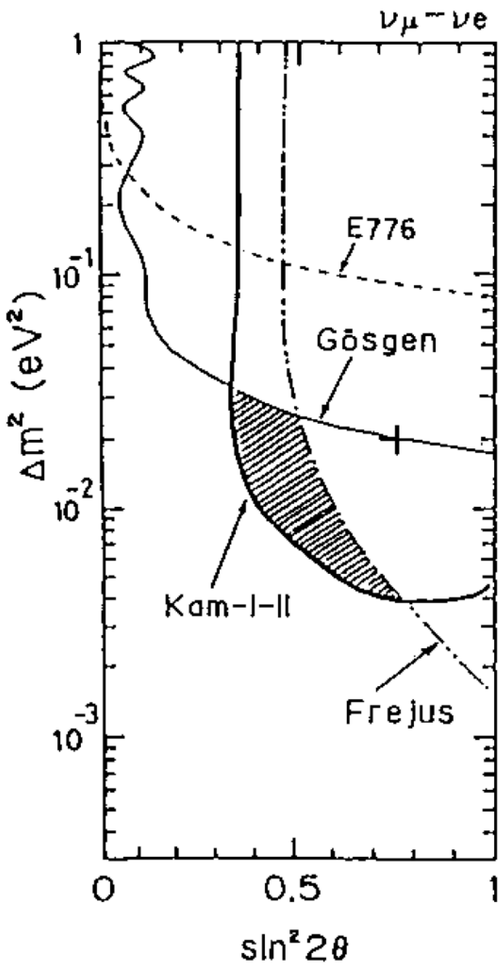
Kamiokande collab:.
Phys. Lett. **B 205**, 416 (1988)

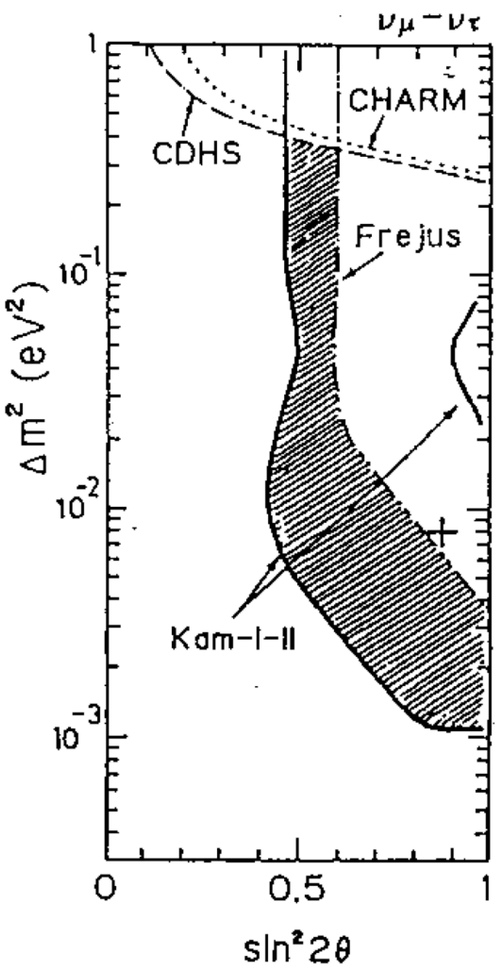
1992



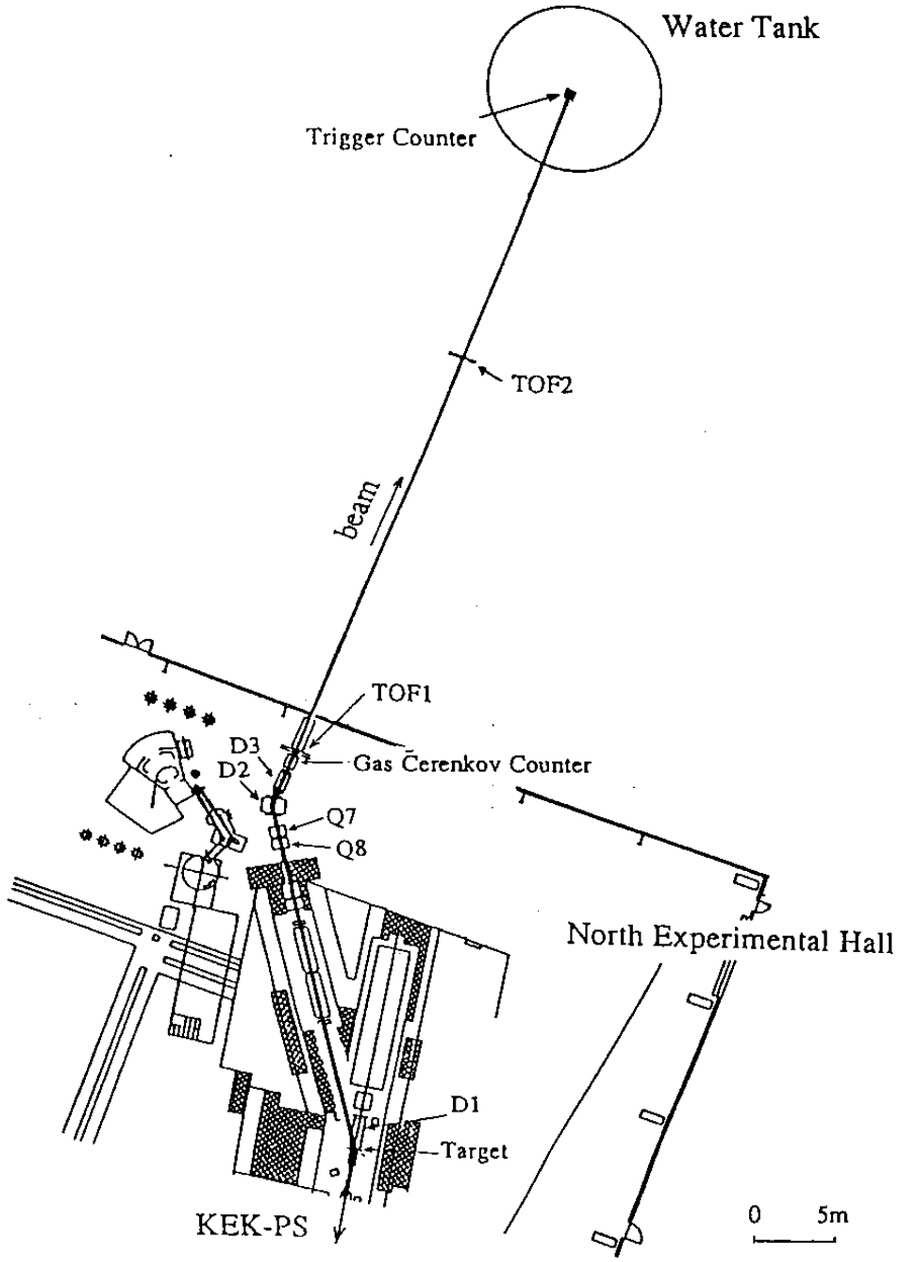
Long Baseline !

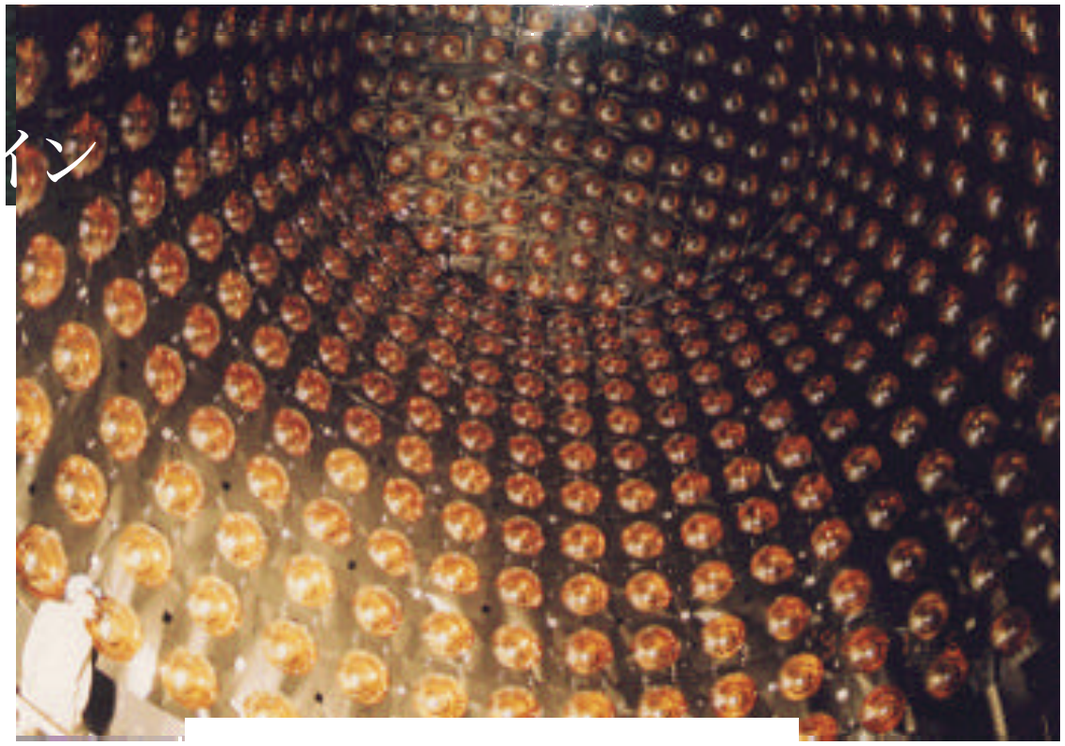






1995
Kasuga MS thesis





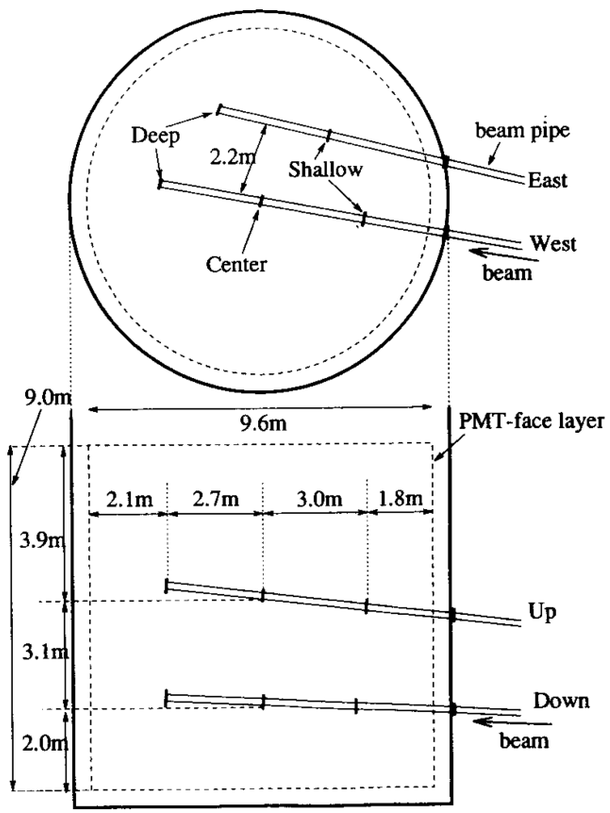


Table-4

Accelerator	Fiducial Tonnage	No. of Charged-Current Events/10^7sec	Oscillation Probability $\Delta m^2=10^{-2}$ eV^2 $\sin^2 2\theta=1.0$
KEK-PS	22,000 ton	500*	65%
BNL-AGS	6,300 ton	10,000**	5%
CERN-SPS	15,000 ton	<2,000***	50%
FNAL-MI	1,000 ton-> ?	2,000****	43%

* Assumed x5 intensity upgrade
** Distance of 24km is assumed
*** This estimate is based on occupation of 100% of the beam time. Actually 1/2 may be realistic.
**** Construction of a new detector (15-20kton) is proposed.

Possible new accelerator in near future
Is it worthwhile to do in Japan?

K2K proposal

Feb.14,1995
Revised Feb.24,1995
Revised Apr. 4,1995

Proposal for
a Long Baseline Neutrino Oscillation Experiment,
using KEK-PS and Super-Kamiokande

Abstract

We propose an experiment to draw a definite conclusion on the possibilities of neutrino oscillations with squared mass differences Δm^2 around 10^{-2} eV^2 which has been indicated by the Kamiokande group and by other undeground experiments (IMB, SOUDAN-II) analyzing atmospheric neutrinos. The experiment uses a well-defined muon neutrino (ν_μ) beam produced at the KEK-PS and three detectors, including the existing Super-Kamiokande detector. The experiment will be sensitive to the $\nu_\mu \rightarrow \nu_e$ and $\nu_\mu \rightarrow \nu_\tau$ oscillations, $\Delta m^2 > 3\times10^{-3}$ eV^2 and $\sin^2 2\theta > 0.1$, at more than the 3σ confidence level. The experimental methods, accelerator modification, schedule and cost estimates are described.

US-Japan collaboration
Proposed as a joint project of ICRR, KEK and INS

Neutrino Oscillation Experiment with 50 GeV-PS

Koichiro Nishikawa

1995.9.26

T2K origin

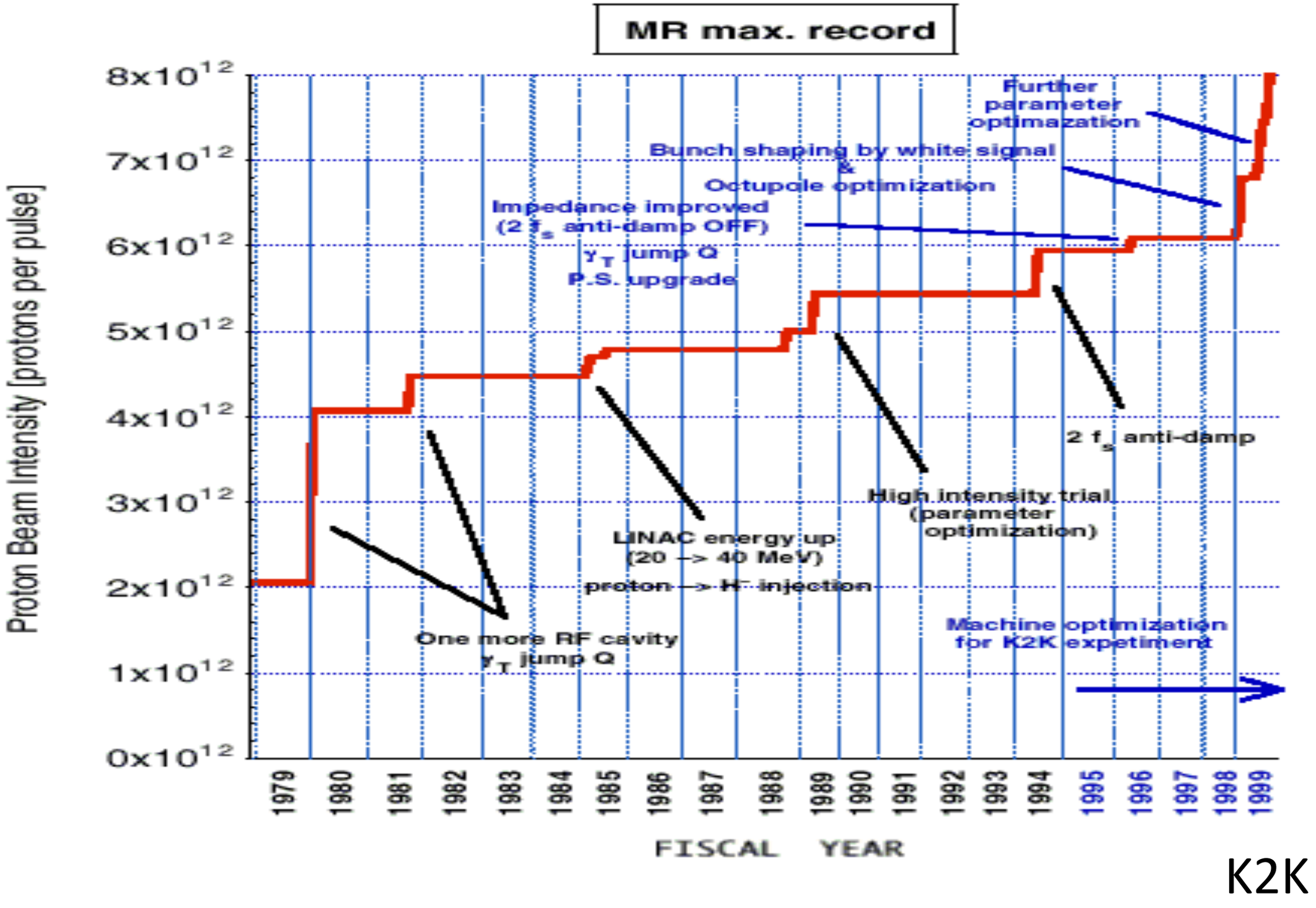
1 Implications of Neutrino mass

2 Neutrino Oscillation and
Physics of Leptons

3 Present - Near Future - Future

4 Neutrino Beam with 50 GeV Protons

- 4-1 Over-view
- 4-2 Neutrino Beam
- 4-3 Understanding Beam
- 4-4 Discovery Potential
- 4-5 Schedule



Intensity History of KEK 12-GeV PS

T2K LOI

Letter of Intent:
A Long Baseline Neutrino Oscillation Experiment using the JHF 50 GeV Proton-Synchrotron and the Super-Kamiokande Detector

February 3, 2000

—V1.0—

JHF Neutrino Working Group

Y. Itow[1], Y. Obayashi, Y. Totsuka
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Inst. of Particle and Nuclear Studies, High Energy Accelerator Research Org. (KEK), Tsukuba, Ibaraki 305-0801, Japan

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T. Nakaya[3], K. Nishikawa[4]
Department of Physics, Kyoto University, Kyoto 606-8502, Japan

T. Hasegawa, K. Ishihara, A. Suzuki
Department of Physics, Tohoku University, Sendai, Miyagi, 980-8578, Japan

[1]Super Kamiokande Contact Person: itow@suketto.icrr.u-tokyo.ac.jp
[2]Neutrino Beam Contact Person: kobayasi@neutrino.kek.jp
[3]Near Detector Contact Person: nakaya@scphys.kyoto-u.ac.jp
[4]Organizer: nishikaw@neutrino.kek.jp

New idea of off-axis beam

1994 TRIUMF KAON factory workshop

Paper presented at the 9th Lake Louise Winter Institute, Lake Louise, Feb. 20-26

TRI-PP-94-34
June 1994

A NEW LONG BASELINE NEUTRINO OSCILLATION EXPERIMENT AT BROOKHAVEN

R. L. HELMER

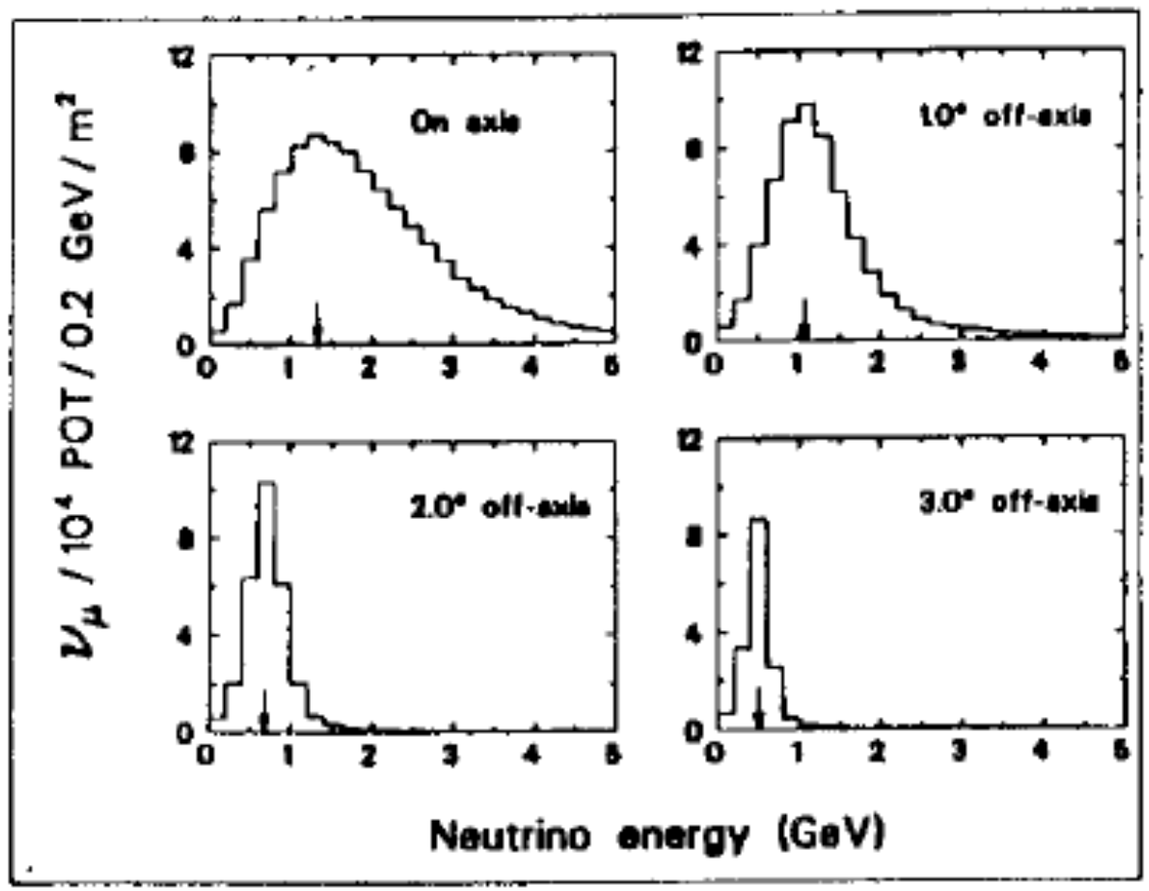
TRIUMF, 4004 Wesbrook Mall
Vancouver, B.C., Canada V6T 2A3

Abstract

J. Anderson	G. Azuelos	M. Barnes
J. Beveridge	G. Chadwick	B. Dall
P. Depommier	F. Farzanpay	D. Frekers
P. Fuchs	P. Gumplinger	S. Hayward
R. Helmer	R. Henderson	G. Jonkmans
H. Laman	B. Larson	R. Meier-Drees
J.-M. Poutissou	M. Sevior	A. Trudel
B. Vander Ende	M. Vetterli	G. Wait
W. Wall	C. Waltham	N. Weiss
D. Wright	S. Yen	

Table 1: Members of the TRIUMF Neutrino Working Group.

seen, there will be no ambiguities in its interpretation.



BNL long baseline proposal (not realized)

Strong leadership and broad physics view of the Directorates and trust from funding agency

Prof. Hirotaka Sugawara and
the late Prof. Yoji Totsuka

Your choice

Known unknown

result from phenomena which are recognized, but poorly understood.

Unknown unknown

are phenomena which cannot be expected because there has been no prior experience or theoretical basis for expecting the phenomena.

Breakthrough Prize Party

T2K (&K2K) Collaboration

January 28, 2016

Bruno Pontecorvo prize for 2016

- Nihikawa-san is awarded the international Bruno Pontekorvo Proze with Prof. WANG Yifang and Prof. KIM Soo-Bong.

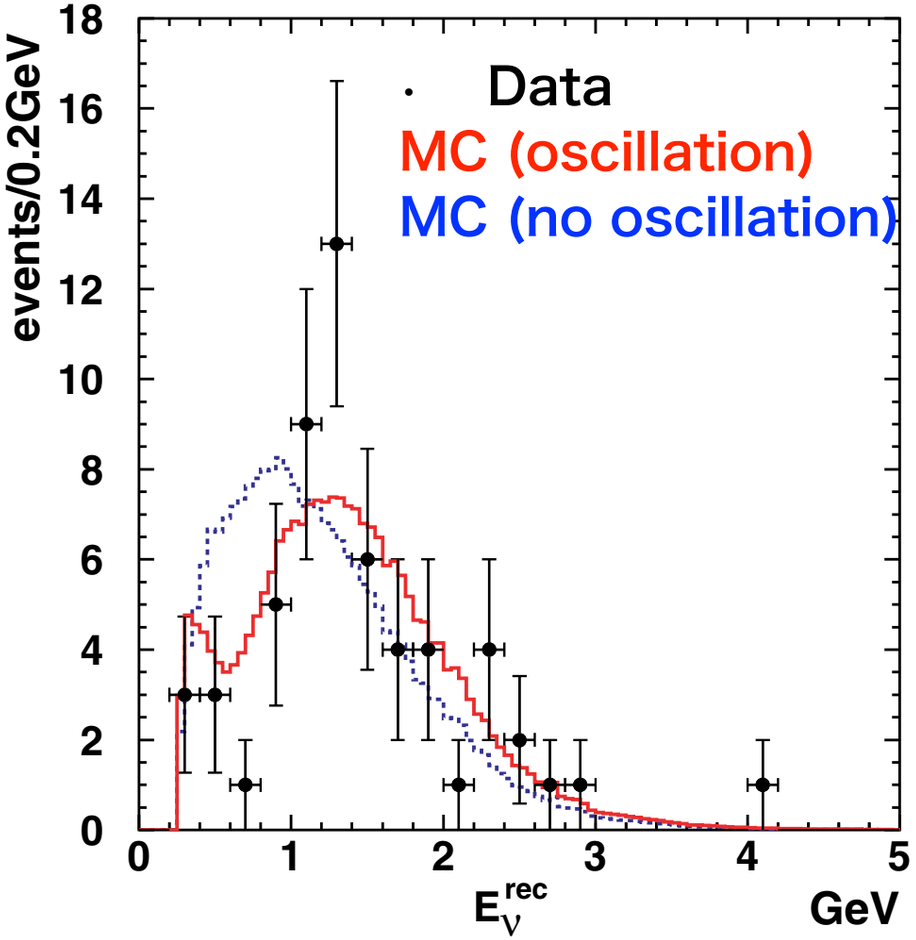
- *For their outstanding contributions to the study of the neutrino oscillation phenomenon and to the measurement of the Theta13 mixing angle in the Daya Bay, RENO and T2K experiments.*

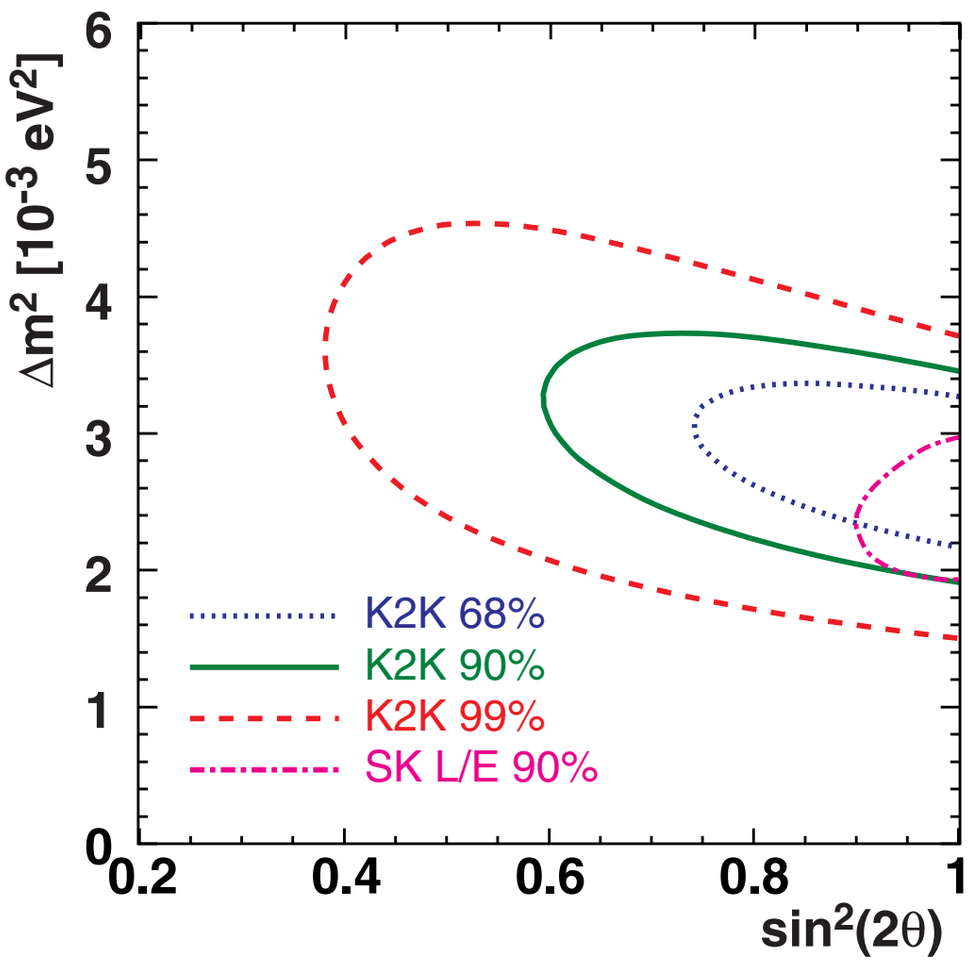
Neutrino Oscillation studies with accelerator neutrino beams

- Intensity of the Proton Accelerator
  - K2K: 8×10^{12} Protons/Pulse @12GeV
  - T2K: 2×10^{14} Protons/Pulse @30GeV
- Understanding of the neutrino beam
  - Precise beam monitoring with hadron production data from
    - K2K: CERN HARP Experiment
    - T2K: CERN NA61 Experiment
- Understanding of the neutrino interactions with near detectors:
  - K2K: 1kton WC, SciFi and SciBar detectors
  - T2K: INGRID and ND280 detectors (ND280 upgrade for the future)
- Understanding of the detector
  - Excellent PID and particle counting with novel reconstruction algorithms

K2K results: PRD 74, 072003 (2006)

- Measurement of ν_μ disappearance
  - 112 neutrino events observed with 158+9.2-8.6 expected events without oscillations.
  - 0.00015% (4.3σ)



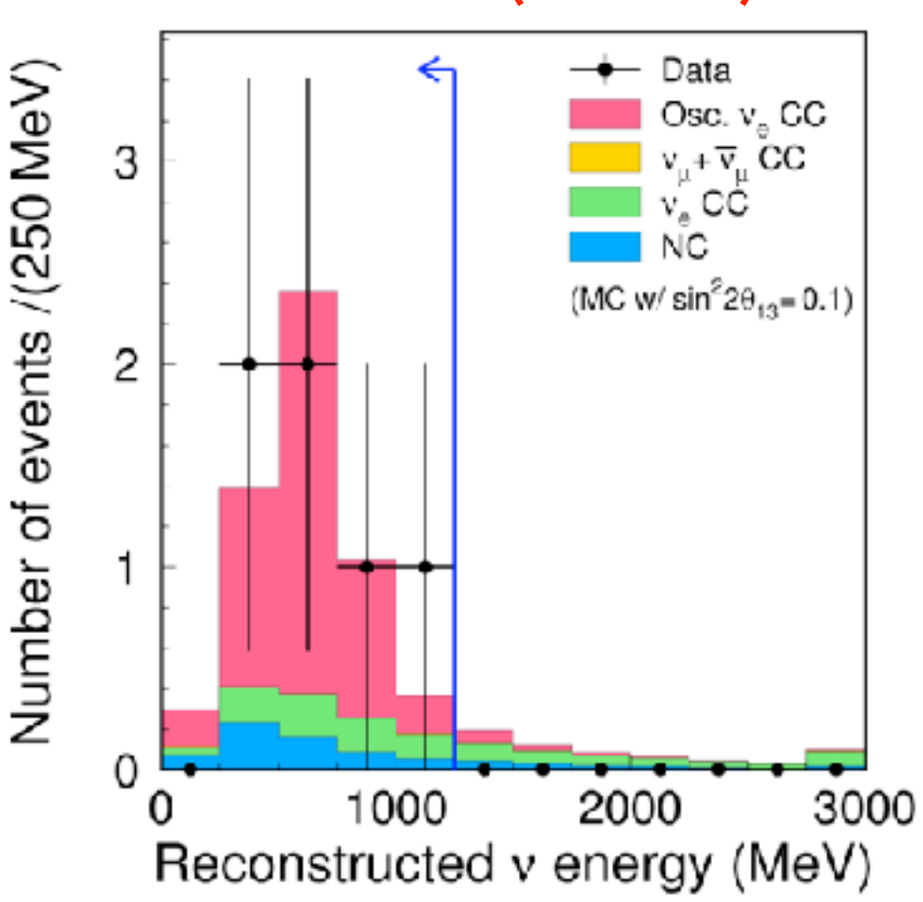


Initial T2K results:

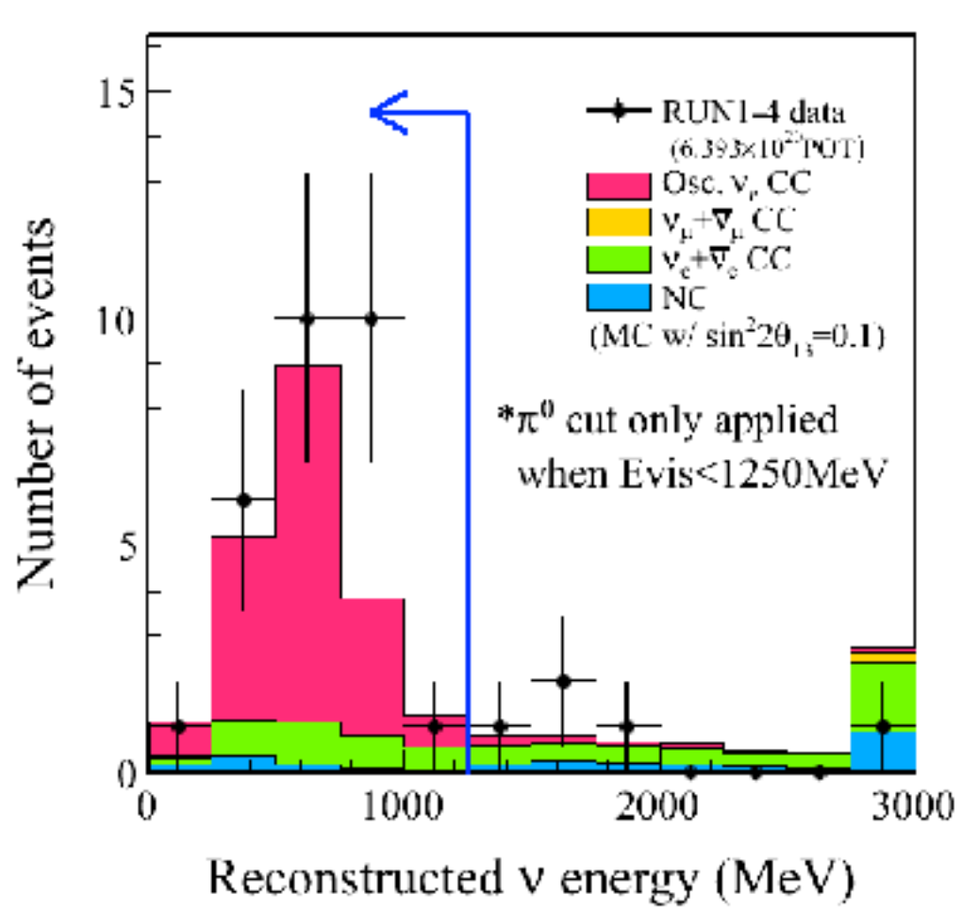
PRL 107, 041801 (2011), PRL 112, 061802 (2014)

- In 2011, Indication of electron neutrino appearance (non-zero θ_{13}) with 6 electron events over 1.5±0.3 background events corresponding to 2.5σ.
- In 2014, Observation of electron neutrino appearance with 28 events over 4.92 ±0.55 background events corresponding to 7.3σ.

6 events(2011)



28 events (2013)

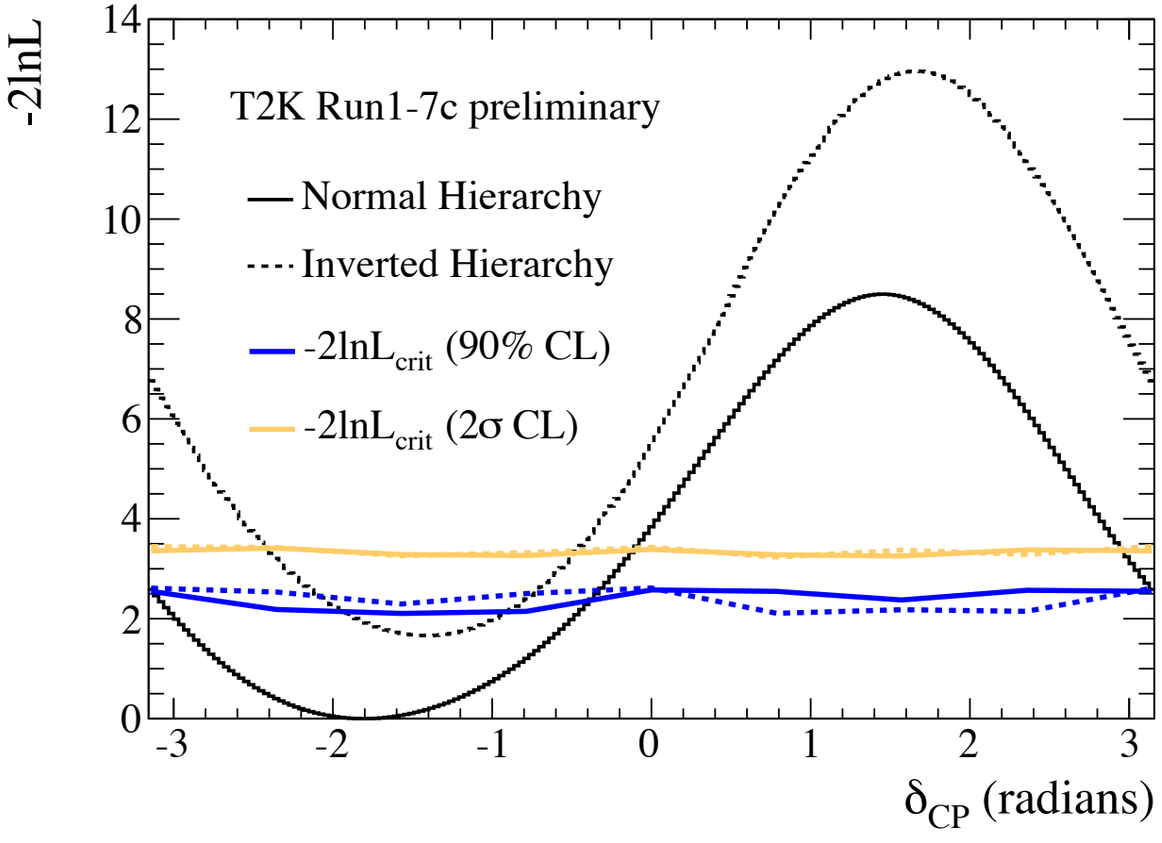


Current status and future of T2K

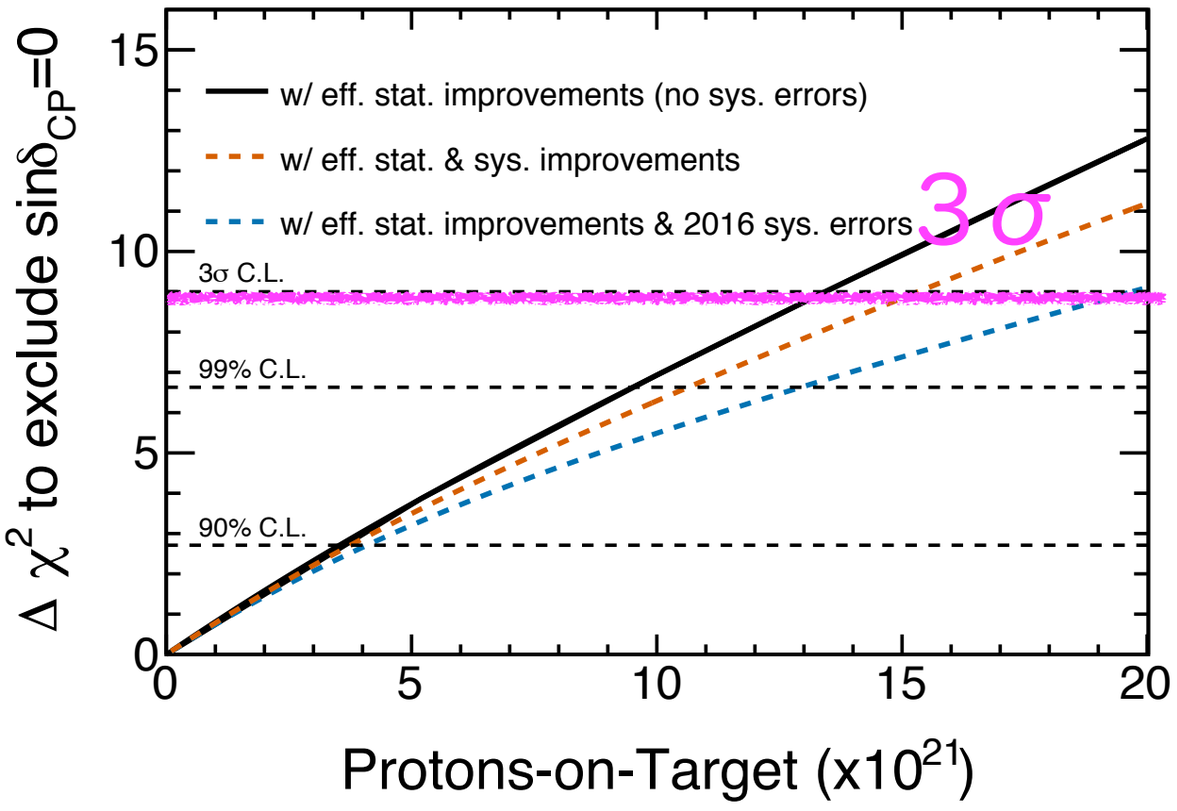
(a talk will be given by Dr. IZMAYLOV Alexander tomorrow)

- A hint of neutrino CP violation with 90% CL in 2016
  - arXiv: 1701.00432 [hep-ex] accepted by PRL
- T2K-II for search for CP violation with 3 σ (T2K-II)
  - Stage 1 status in J-PARC PAC

Today (arXiv: 1702.00432 [hep-ex]



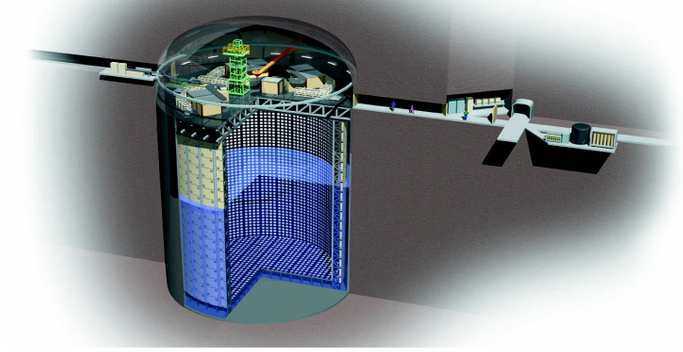
Future with T2K-II

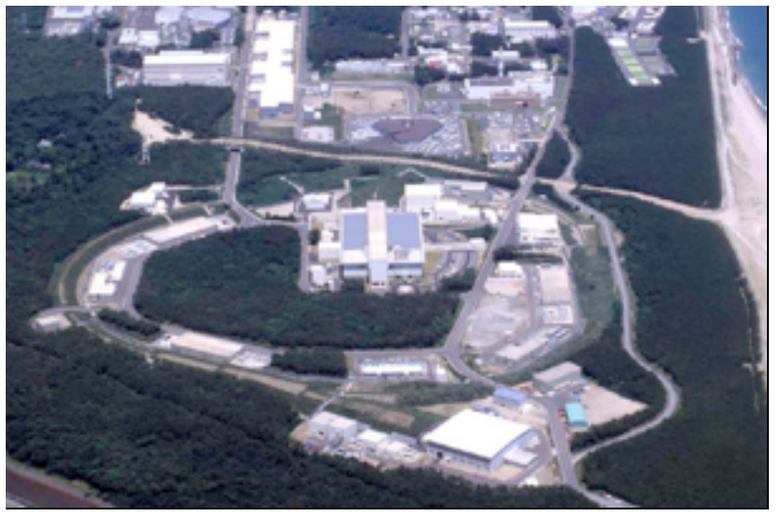


J-PARC Neutrino Beam and the detectors

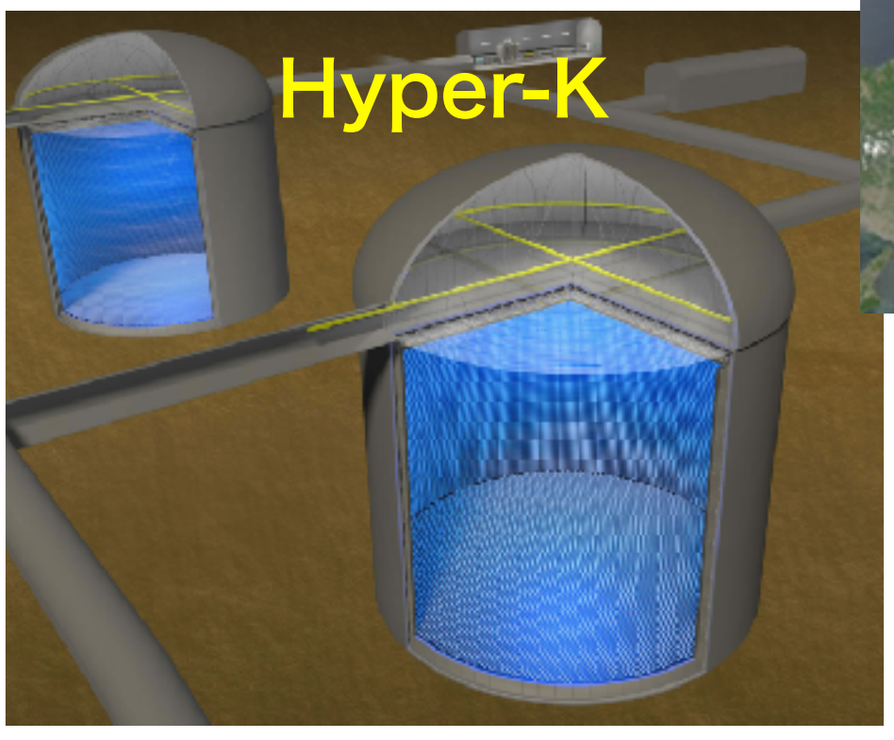
Very Intense Neutrino Beam for $\overset{(-)}{\nu}_{\mu} \rightarrow \overset{(-)}{\nu}_{e}$ study

Super-K

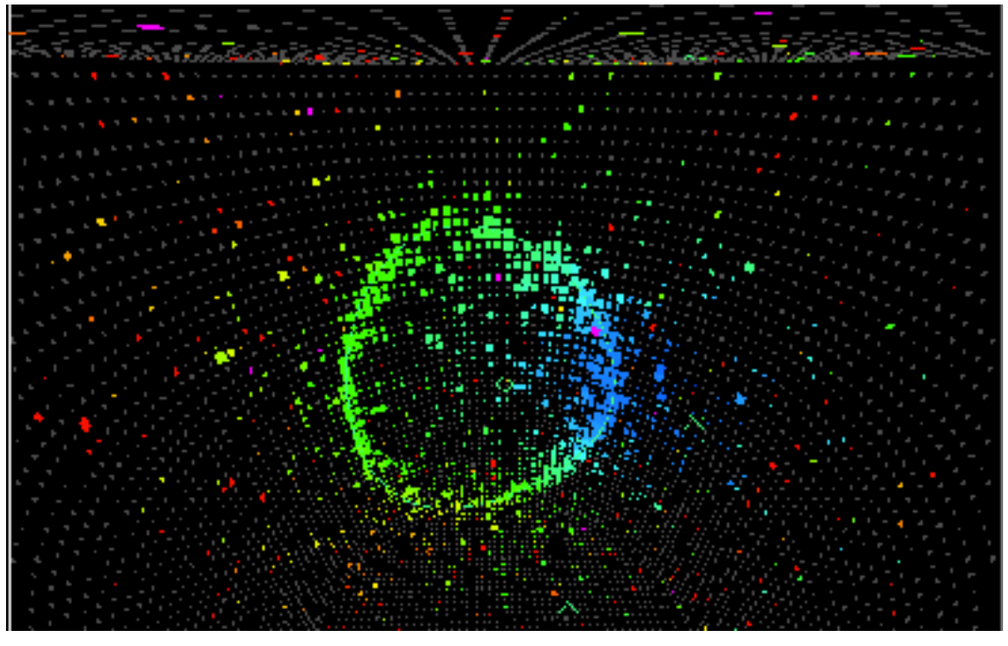




- 480 kW (today)
- ~1MW (2020)
- 1.3 MW (2025)



- 22.5 kton (Super-K, ~2026)
- 190(×2) kton (Hyper-K, 2026~)



My comments for a summary

- Thank Nishikawa-san with his leadership for the K2K and T2K experiments.

- These excellent results are achieved with great efforts by all K2K and T2K collaborators.

- We are in an exciting stage with neutrino oscillations to explore CP violation.

- Let’s keep going forward with more measurements and more observations by current and new experiments.