

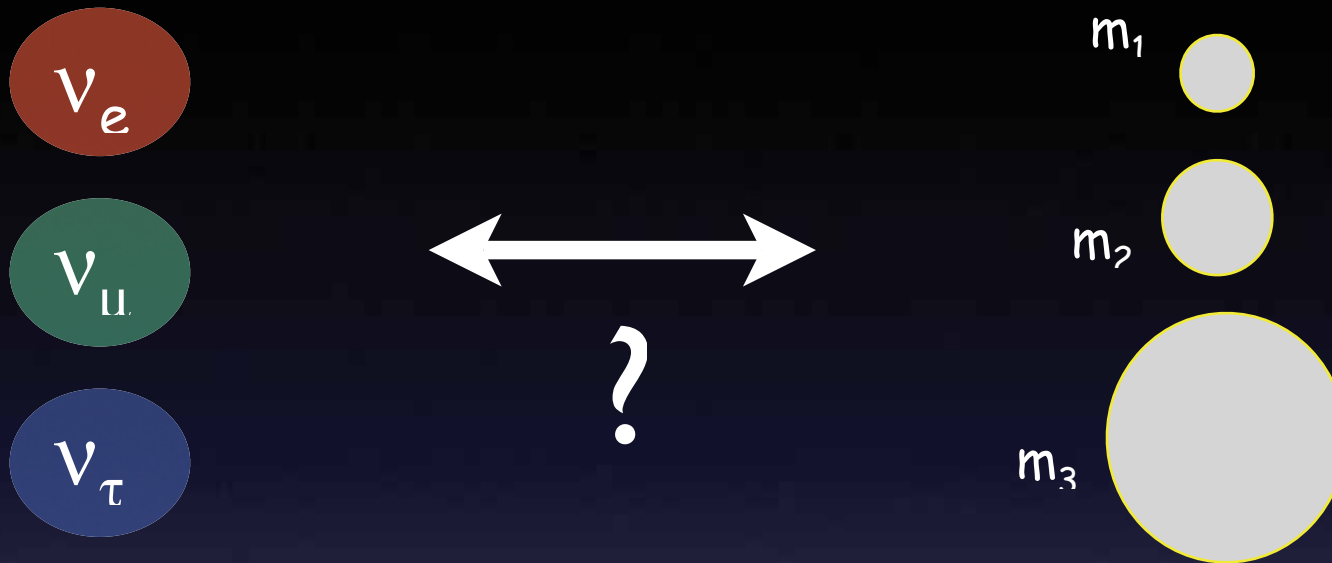
Final results from K2K and Status of T2K

Masashi Yokoyama
(Kyoto University)

XLII^e Rencontres de Moriond
Electroweak Interactions and Unified Theories
10-17 March 2007, La Thuile



Introduction



Atmospheric

Reactor

Solar/Reactor

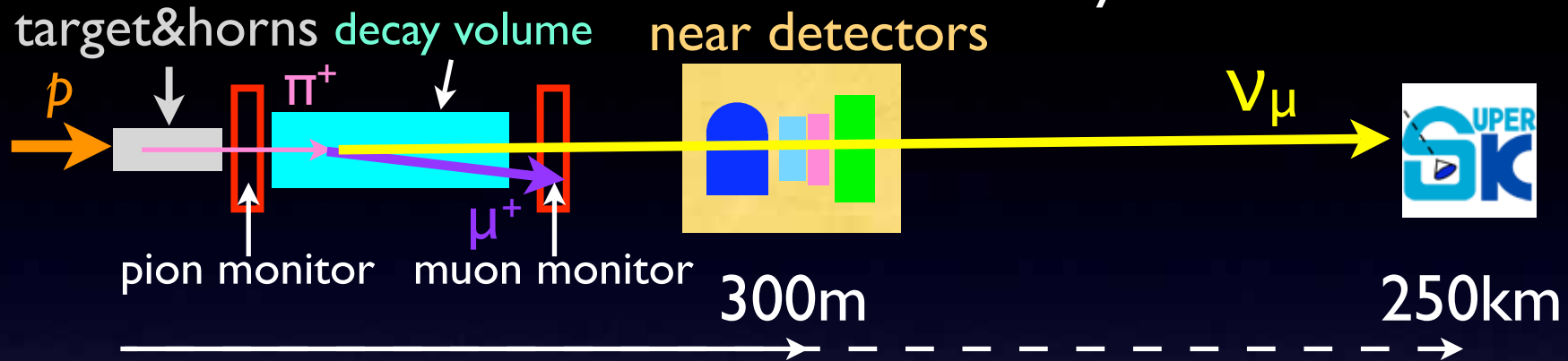
$$U_{PMNS} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Long baseline

$$s_{ij} = \sin\theta_{ij}, c_{ij} = \cos\theta_{ij}$$

K2K (KEK-PS-E362)

Physics run: 1999-2004



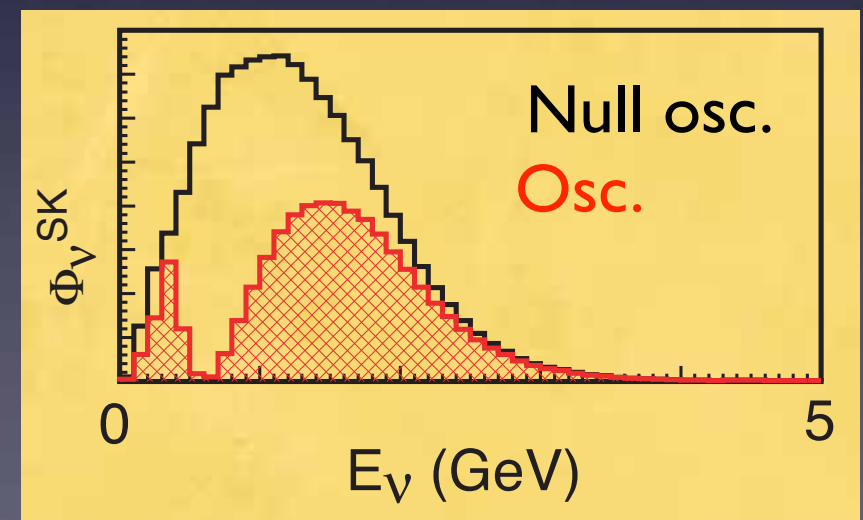
- **Controlled beam properties**

- $\langle E_\nu \rangle \sim 1.3 \text{ GeV}$
- $\nu_e/\nu_\mu \sim 1\%$
- Known beam timing
($1.1 \mu\text{s}/2.2 \text{ sec}$) sync. with GPS
- Known flight distance

- **'Two detector' configuration**

- Reduce systematics

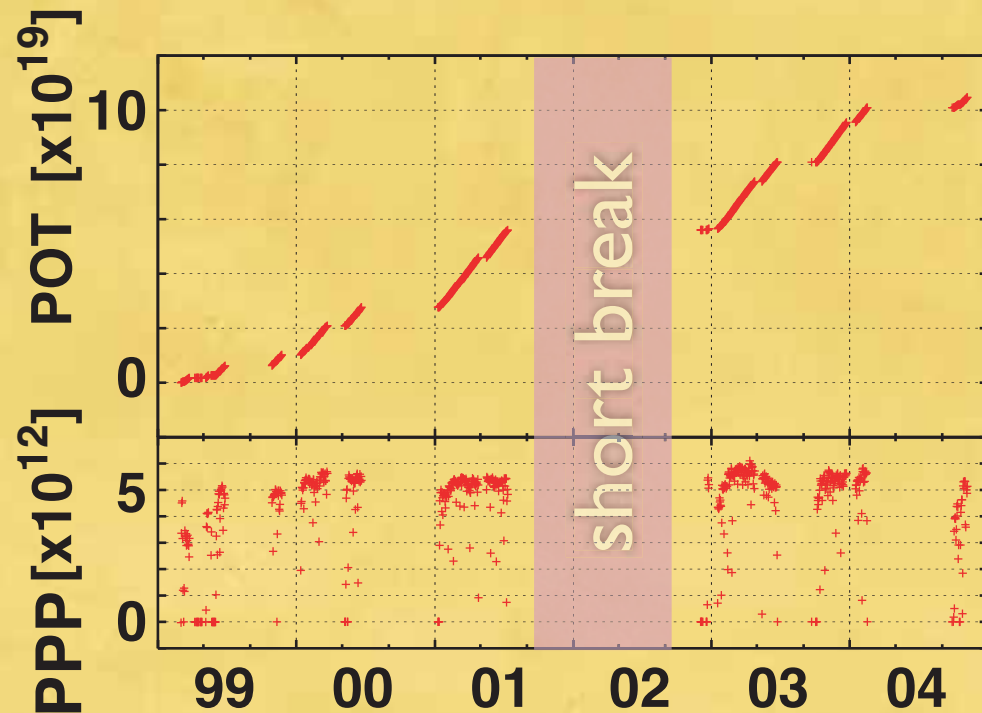
$$P(\nu_\mu \rightarrow \nu_\mu) = 1 - \sin^2 2\theta \cdot \sin^2(1.27 \Delta m^2 \cdot L/E)$$



Beam summary

* **FIRST** accelerator experiment
with **> 100km** baseline!

Delivered protons on target



ν event vertex profile center
in near detector (MRD)

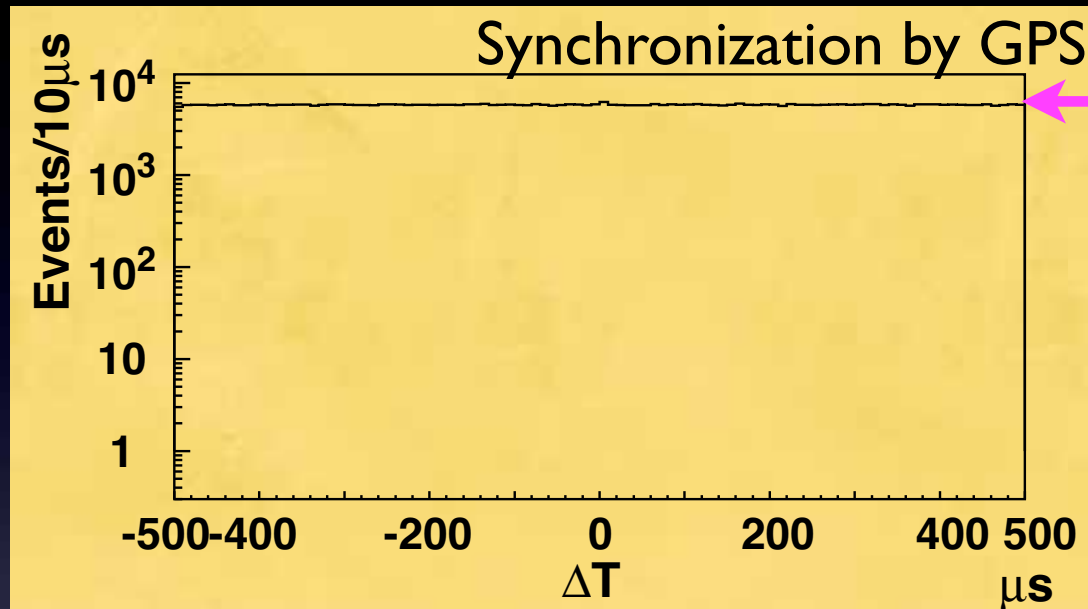


1.05×10^{20} POT delivered
 0.92×10^{20} POT used for analysis

Latest results from K2K and Status of T2K, M. Yokoyama (Kyoto)

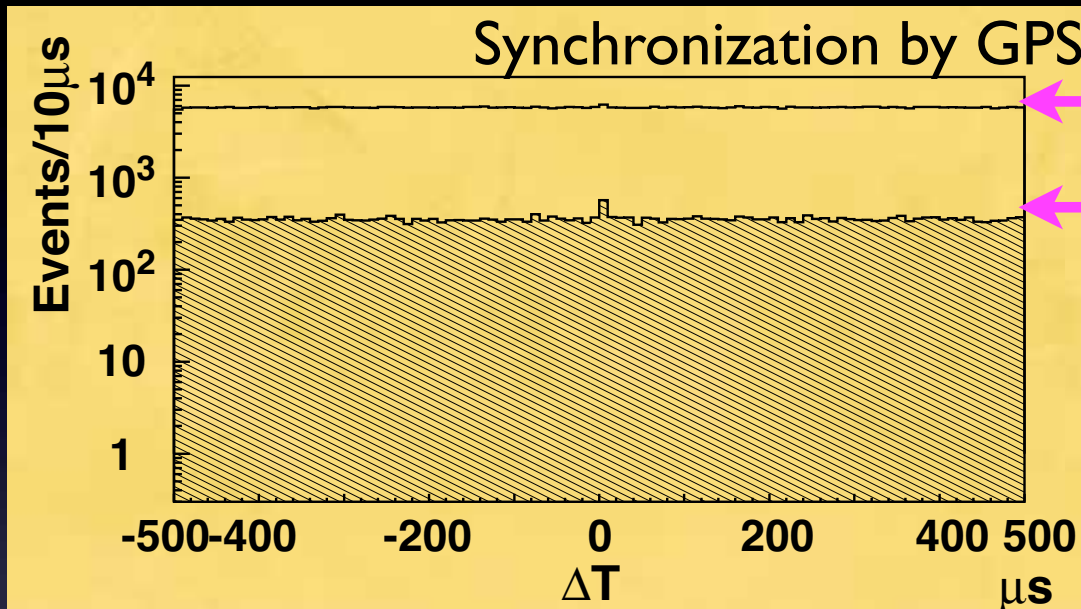
Stable for 5 years

Events at Super-K



No preactivity

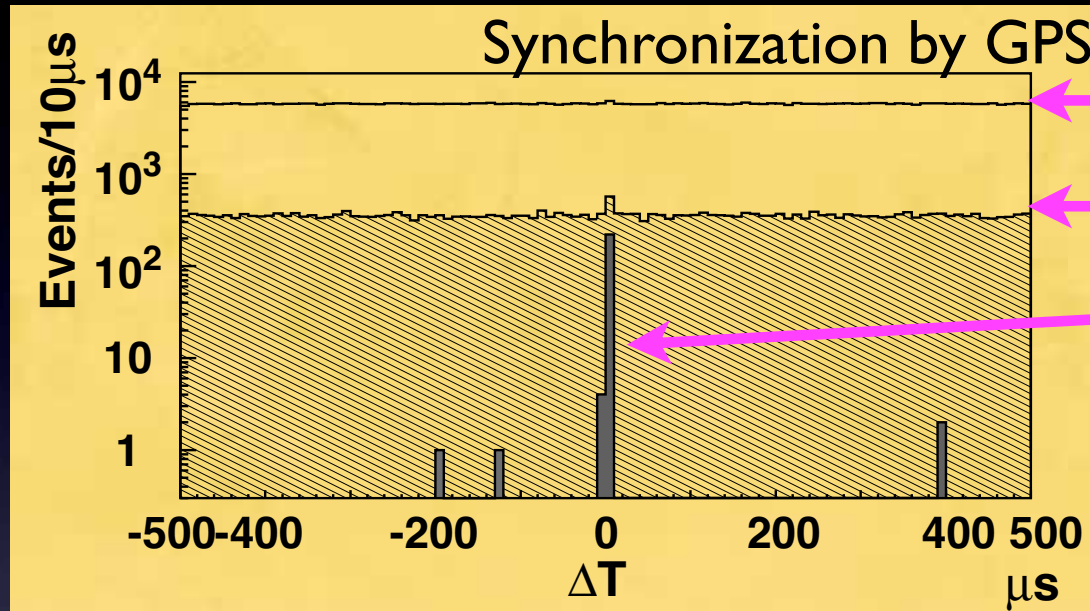
Events at Super-K



No preactivity

>20MeV energy deposit

Events at Super-K

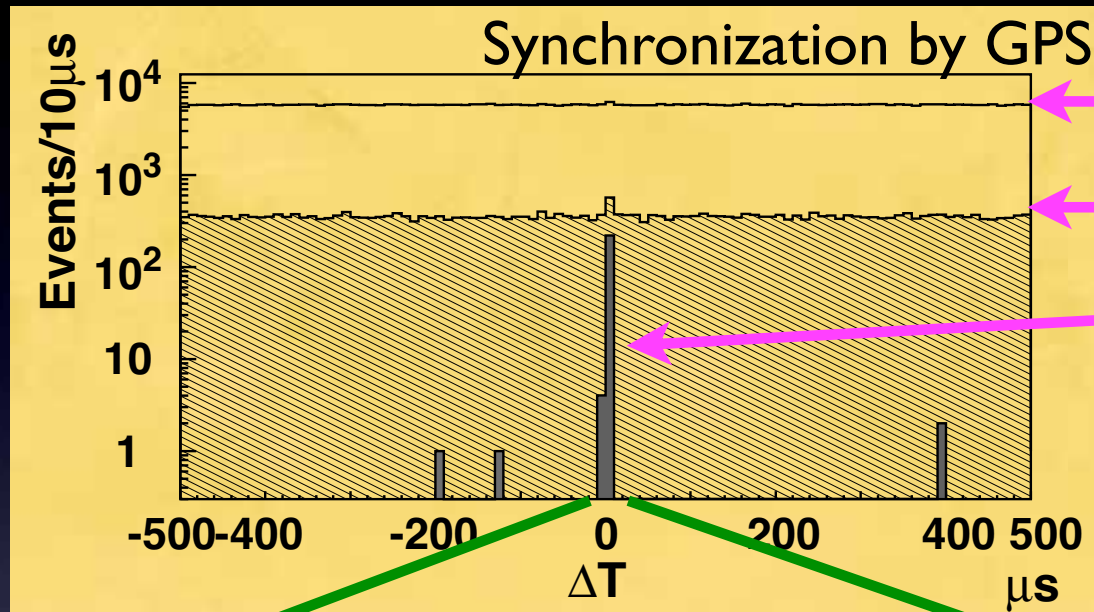


No preactivity

>20MeV energy deposit

Fully contained, $E_{vis} > 30\text{MeV}$
fiducial volume (22.5kT)

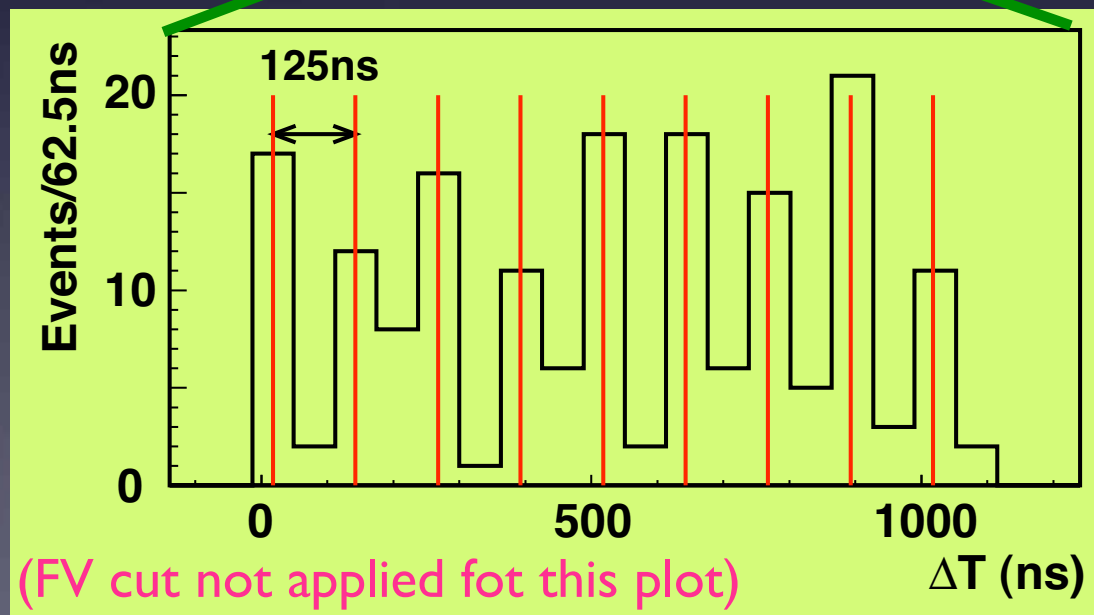
Events at Super-K



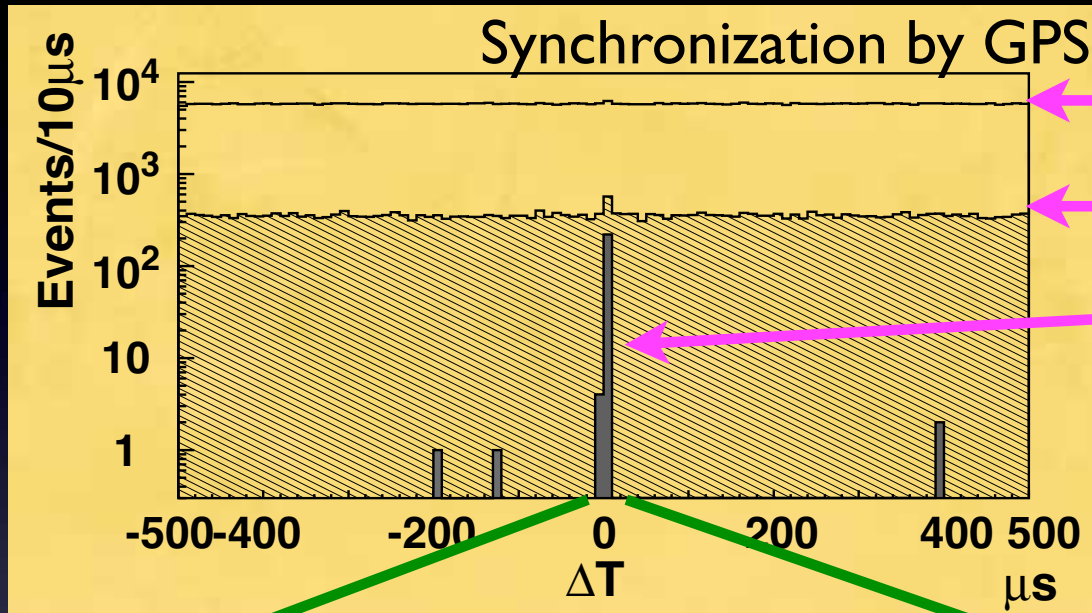
No preactivity

>20MeV energy deposit

Fully contained, $E_{vis} > 30$ MeV
fiducial volume (22.5kT)



Events at Super-K

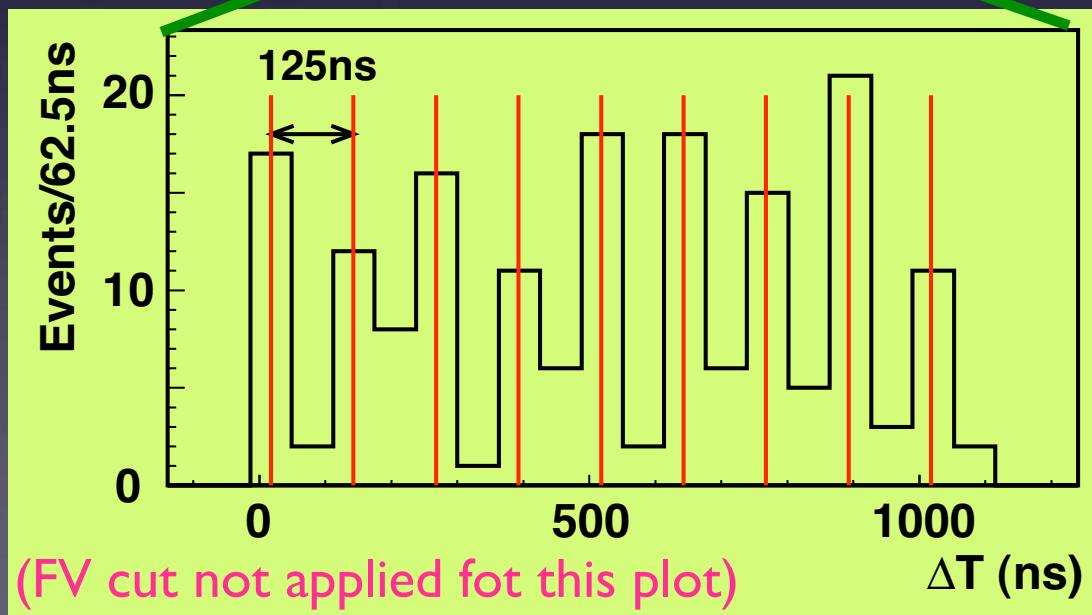


No preactivity

>20MeV energy deposit

Fully contained, $E_{vis} > 30$ MeV
fiducial volume (22.5kT)

$-0.2 < \Delta T < 1.3 \mu$ sec



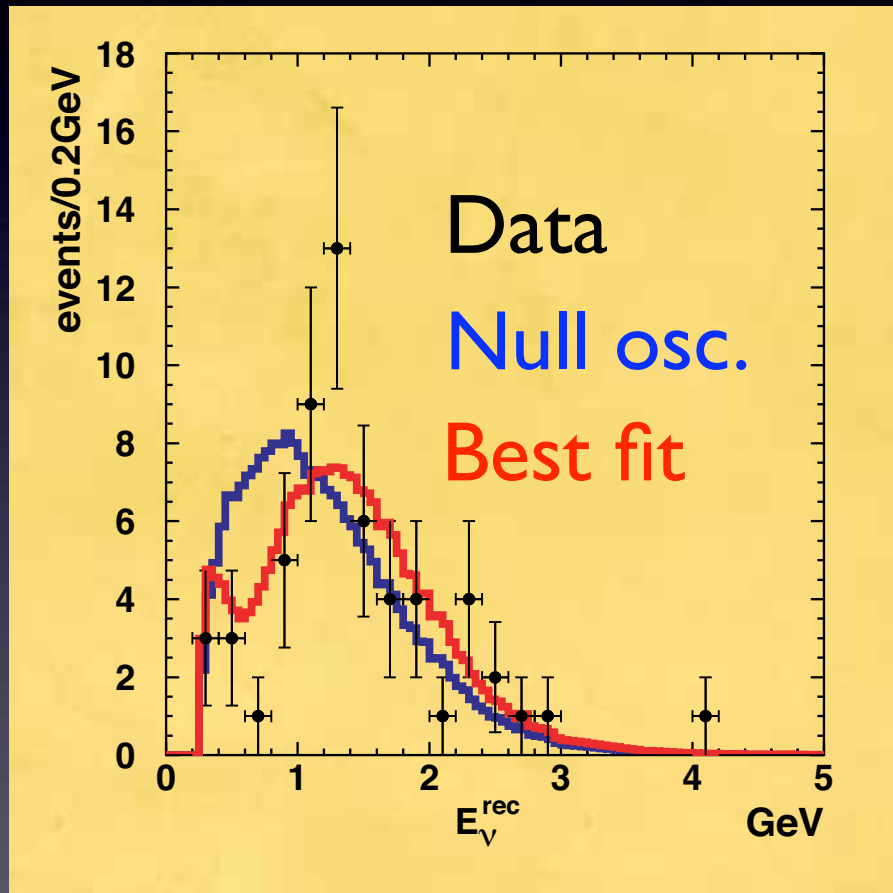
112 events

$158.1^{+9.2}_{-8.6}$ events
expected without osc.

[ND meas. + HARP hadron prod.]

ν_μ disappearance final results

Reconstructed E_ν spectrum
[58 single-ring, μ -like events]



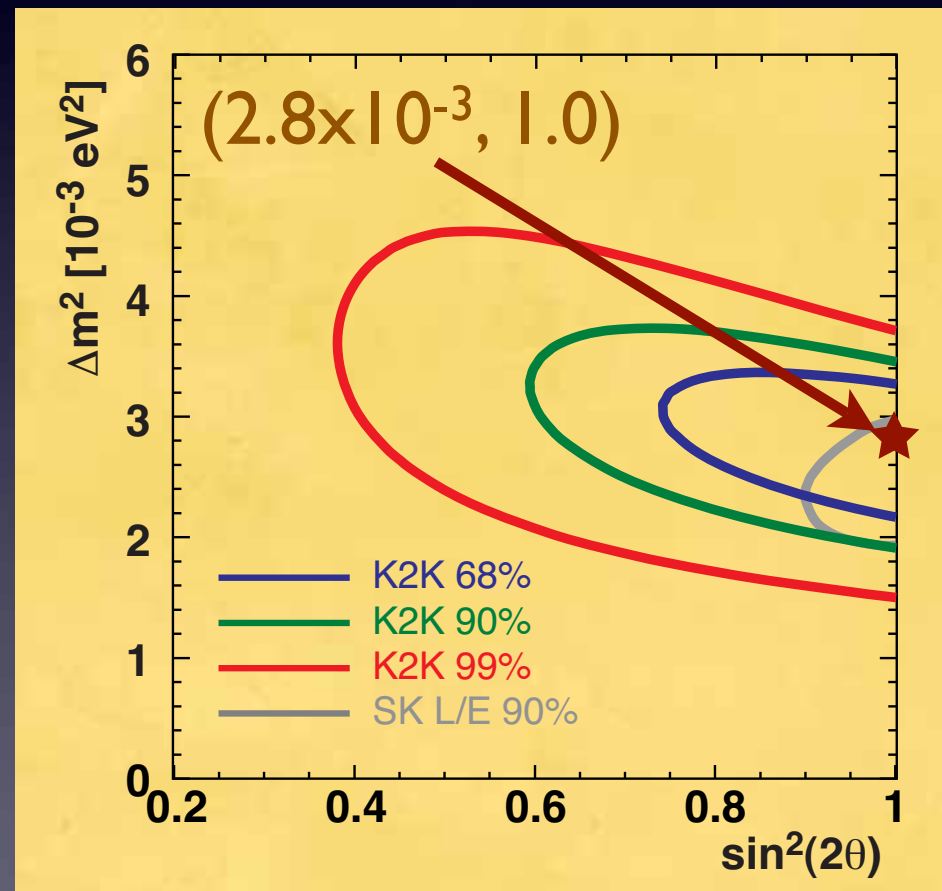
PRD 74, 072003 (2006)

Null oscillation probability

Normalization 0.06%

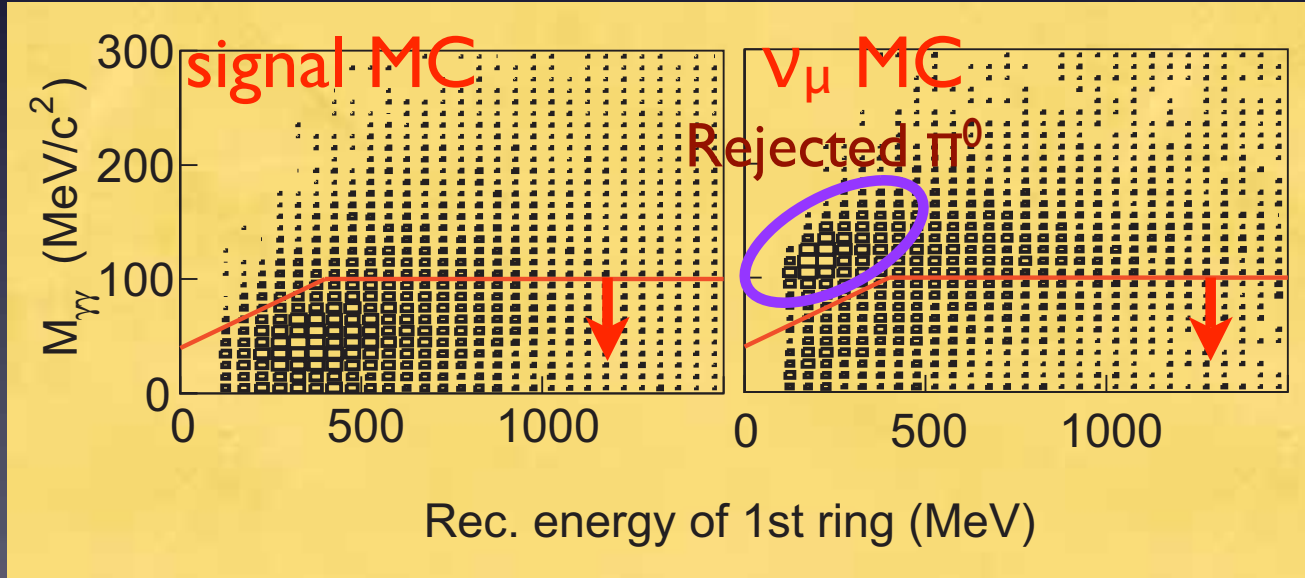
E_ν spectrum shape 0.42%

Total **0.0015% (4.3σ)**

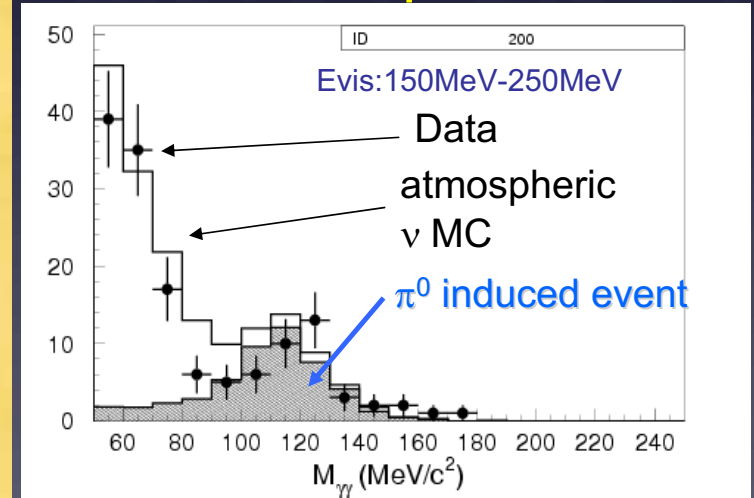


Search for $\nu_\mu \rightarrow \nu_e$

- Sensitive to unknown mixing angle θ_{13}
- Search single-ring, e-like event (good PID in WČ)
- Main background: ν_μ NC $\pi^0 \rightarrow \cancel{\gamma}\gamma$
→ Developed special 2nd ring search algorithm



Verified w/ Super-K atm. ν

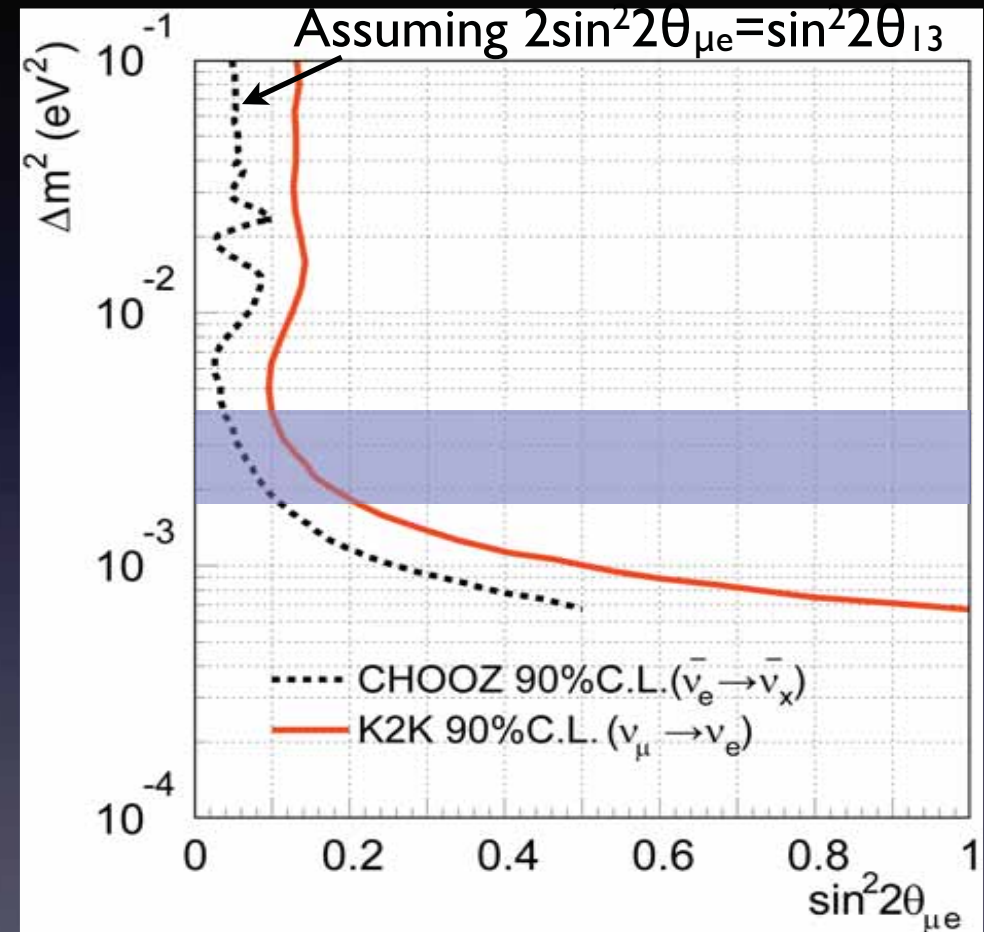
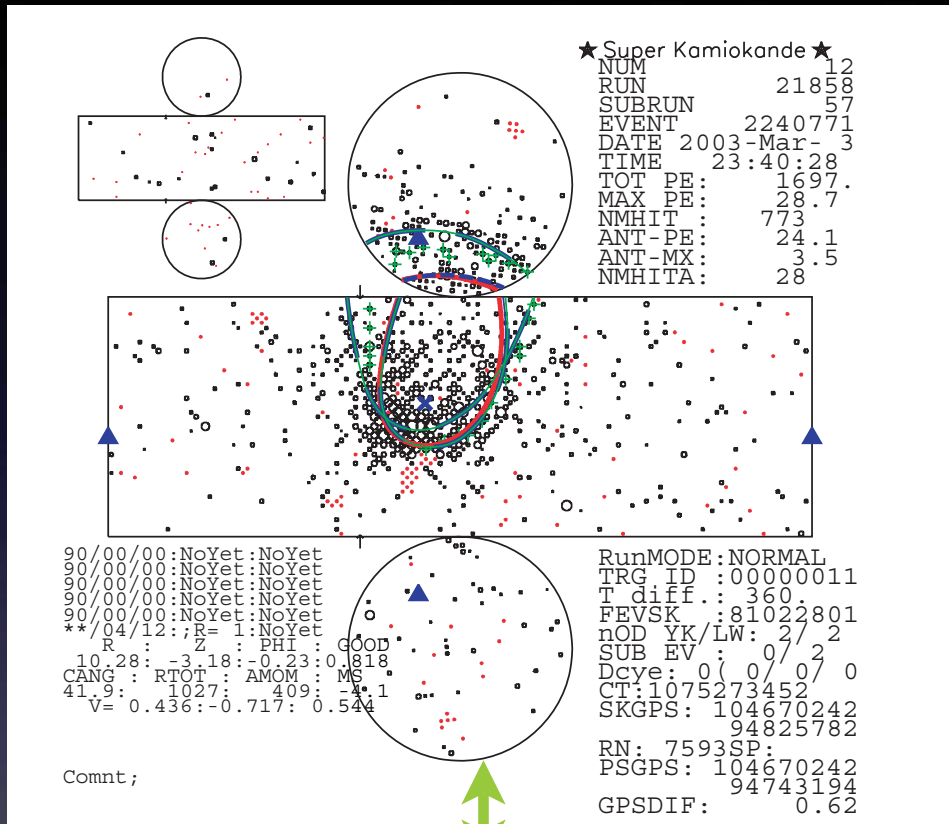


Efficiency: 70% for signal ν_e , 30% for BG π^0

$\nu_\mu \rightarrow \nu_e$ final result

Observed: 1

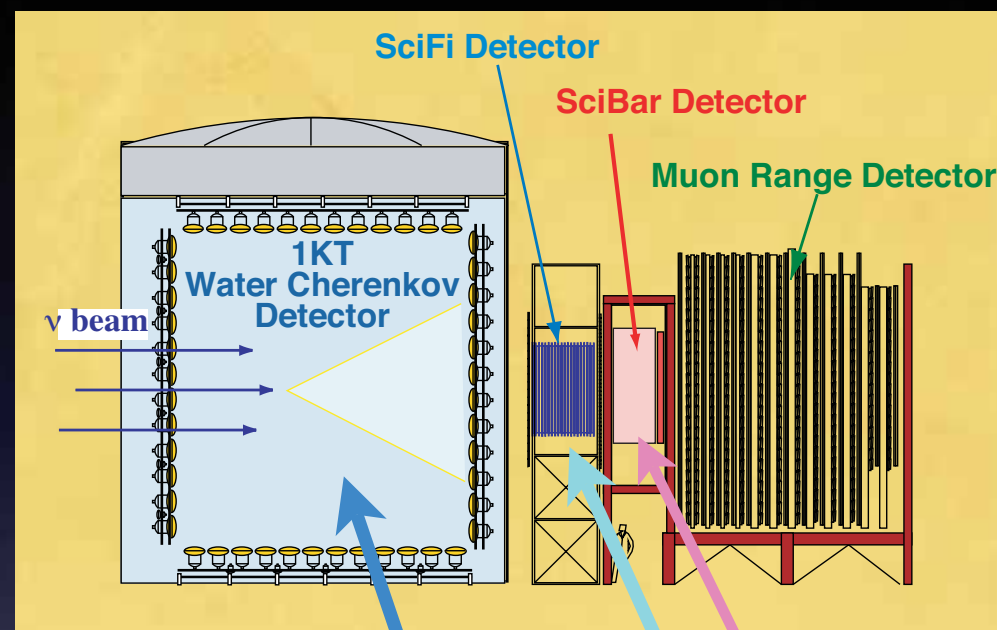
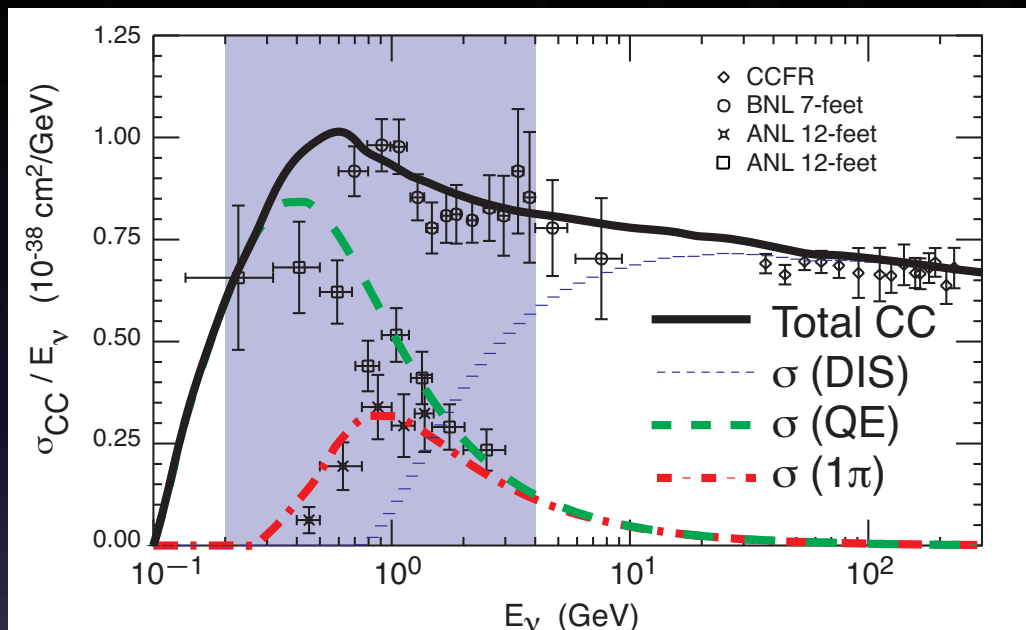
PRL 96, 181801 (2006)



Expected BG: 1.7
 (1.3 ν_μ , 0.4 ν_e)

$\sin^2 2\theta_{\mu e} = 0.13 @ \Delta m^2 = 2.8 \times 10^{-3} \text{eV}^2$ (90% CL)
 First sensitive search in this Δm^2 region

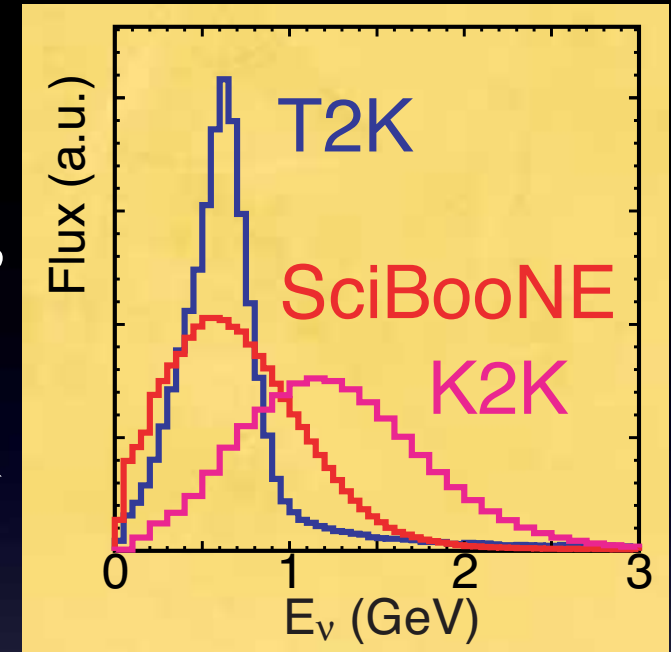
Neutrino interaction study with near detectors



- NC π^0 production PLB 619, 255 (2005) [IKTWČ]
 $\sigma(\text{NC}\pi^0)/\sigma(\text{CC})=0.064\pm 0.001\pm 0.007$
- CC quasi-elastic form factor PRD 74, 052002 (2006) [SciFi]
 $M_A=1.20\pm 0.12 \text{ GeV}$
- CC coherent pion production PRL 95, 252301 (2005) [SciBar]
 $\sigma(\text{CC coherent } \pi)/\sigma(\text{CC})<0.060 \text{ (90\% CL)}$

~Interlude~

- One of K2K-ND (SciBar) is reused for new ν -N scattering experiment, FNAL-E954 [SciBooNE]
- Precise $\nu/\bar{\nu}$ interaction study before T2K
- ‘Near detector’ for MiniBooNE



SciBar @ CDF hall



Assembled detectors



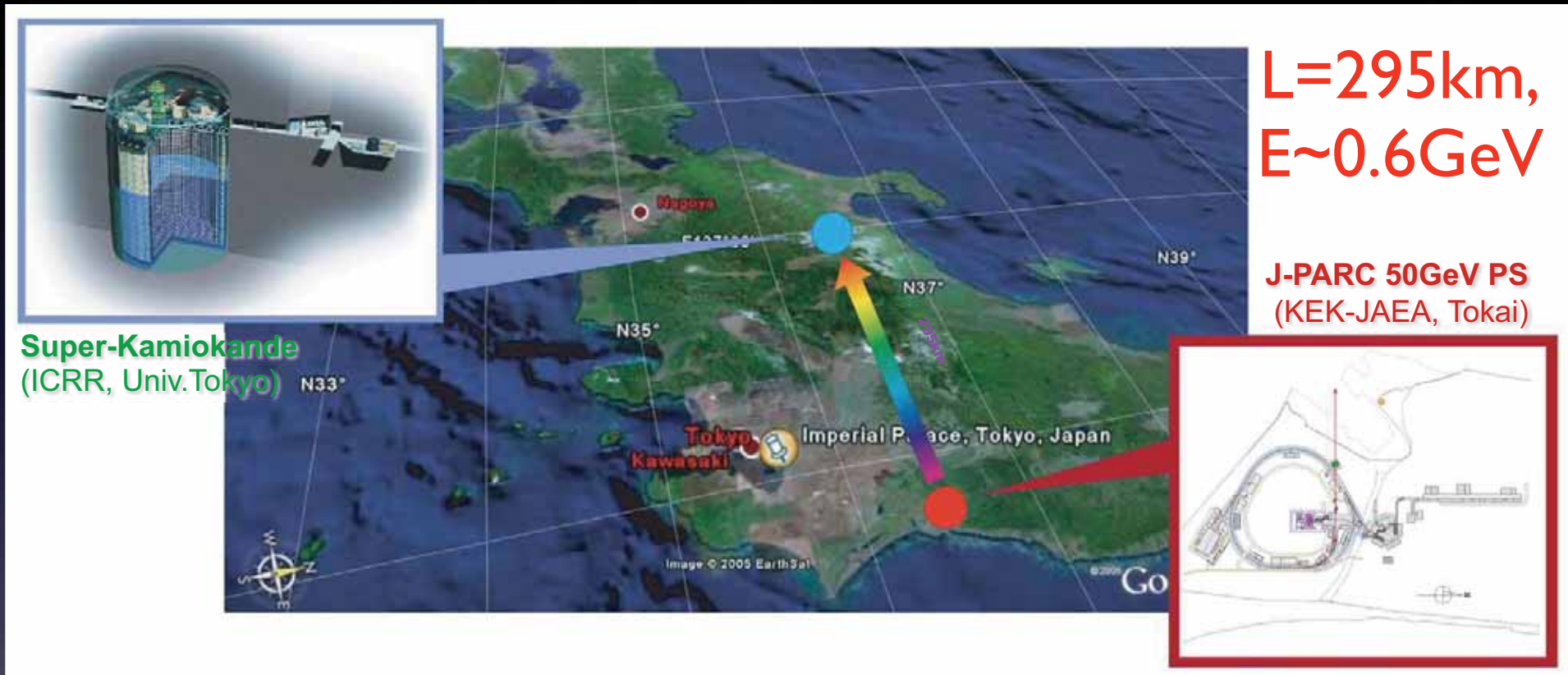
Approved in Dec. 2005,

New detector hall @ Booster ν Beamline



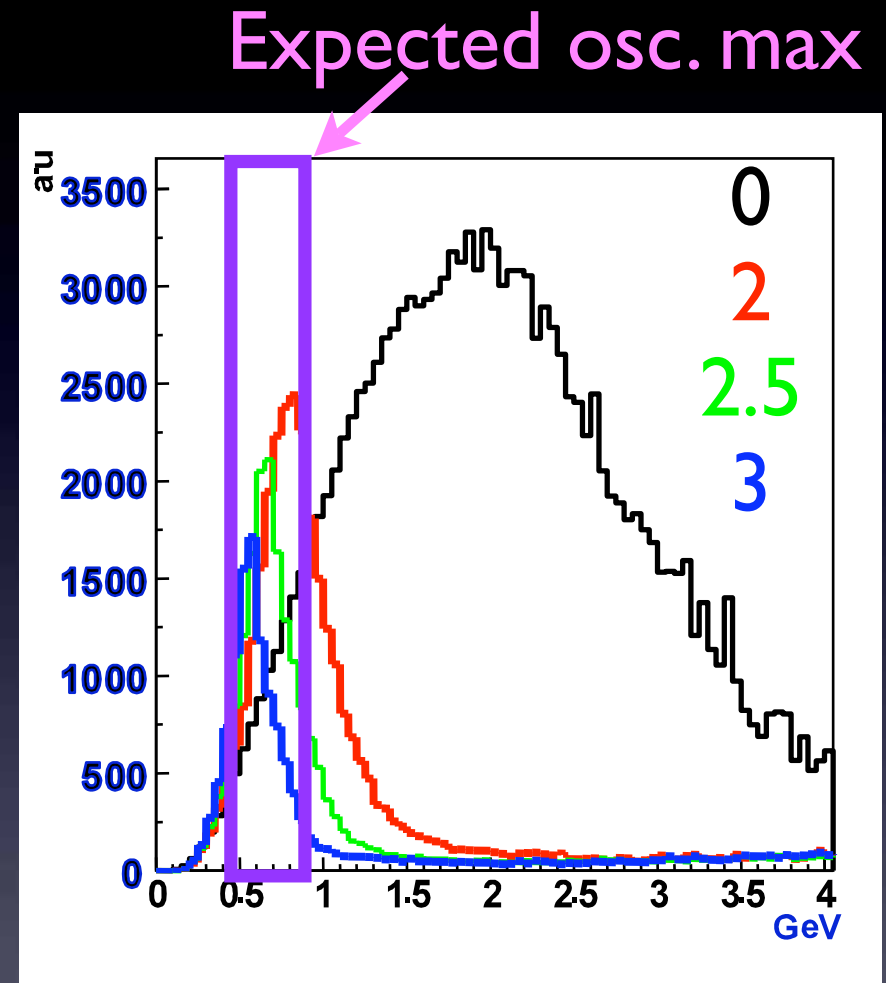
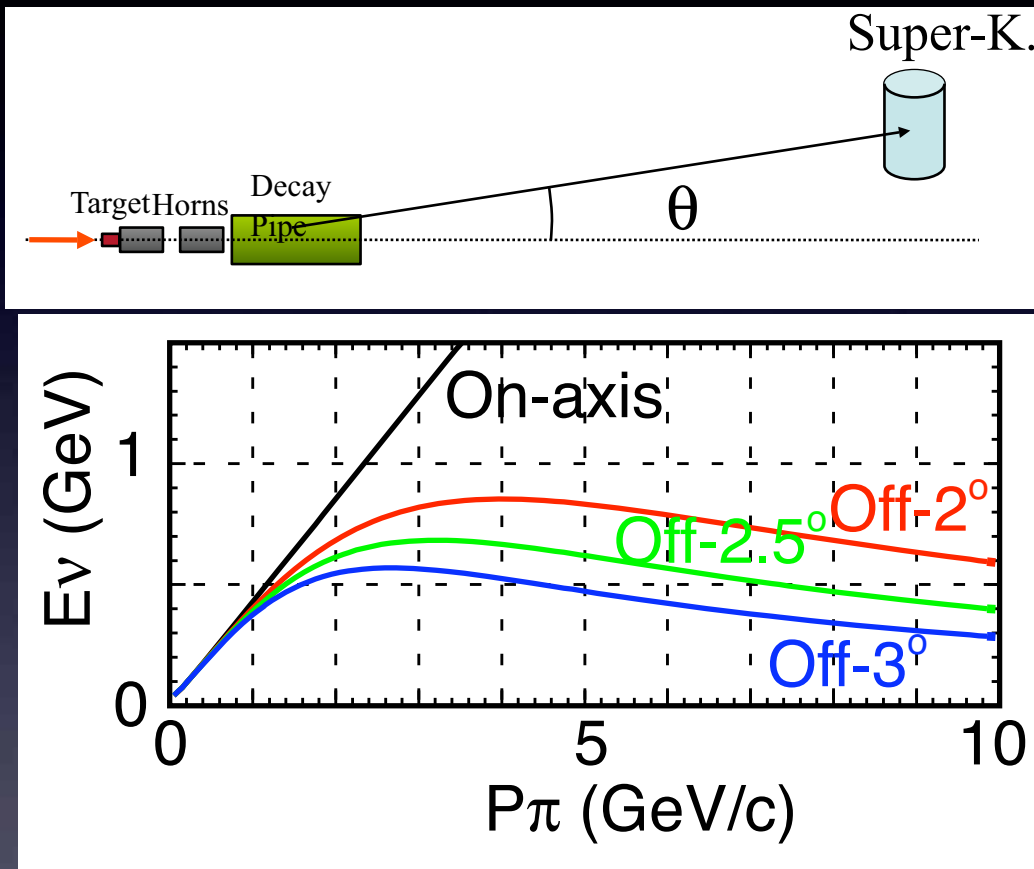
Physics run expected before summer 2007!

T2K



- Search for $\nu_{\mu} \rightarrow \nu_e$
- Precise measurement of ν_{μ} oscillation
- CP violation in lepton sector (2nd stage)

T2K beam

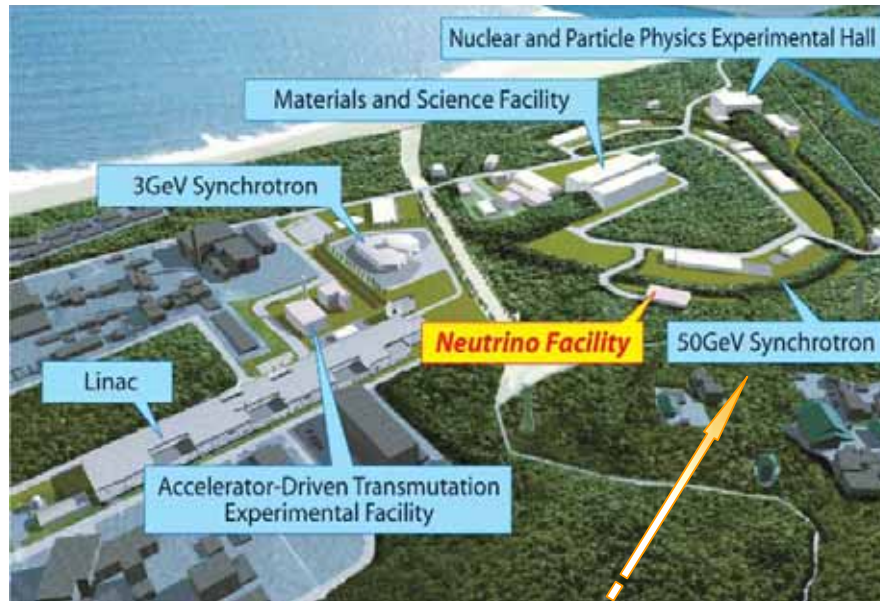


Quasi-monochromatic, intense beam by 'off-axis' scheme

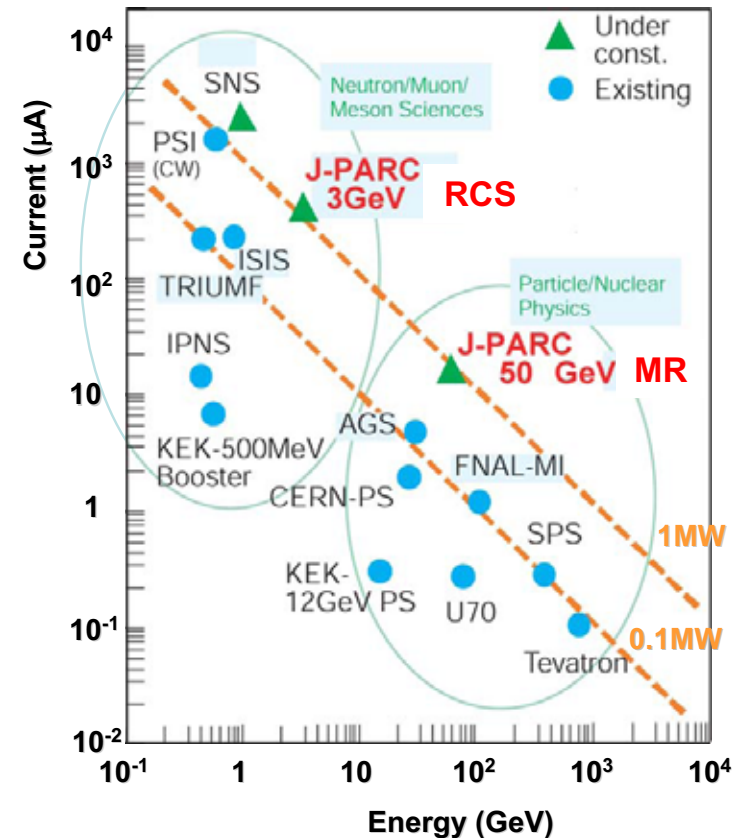
- Tuned to oscillation maximum
- Less background from high-energy tail

J-PARC

www.j-parc.jp



Proton beam kinetic energy	50GeV (40GeV@T=0)
# of protons / pulse	3.3×10^{14} ppp
Beam power	750kW (2.64MJ per pulse)
Bunch structure	8 bunches
Bunch length / spacing	58 ns / 598ns
Spill width	4.2 μ s
Beam Emittance	6π mm.mr (7.5 π @40GeV)
Cycle	3.64 sec



- $\sim 1 \times 10^{21}$ protons per year
[130 days operation per year, 50GeV]

MR beam power **750kW**, construction 2001-2008



Feb. 2006

← Main ring

→ to Super-K

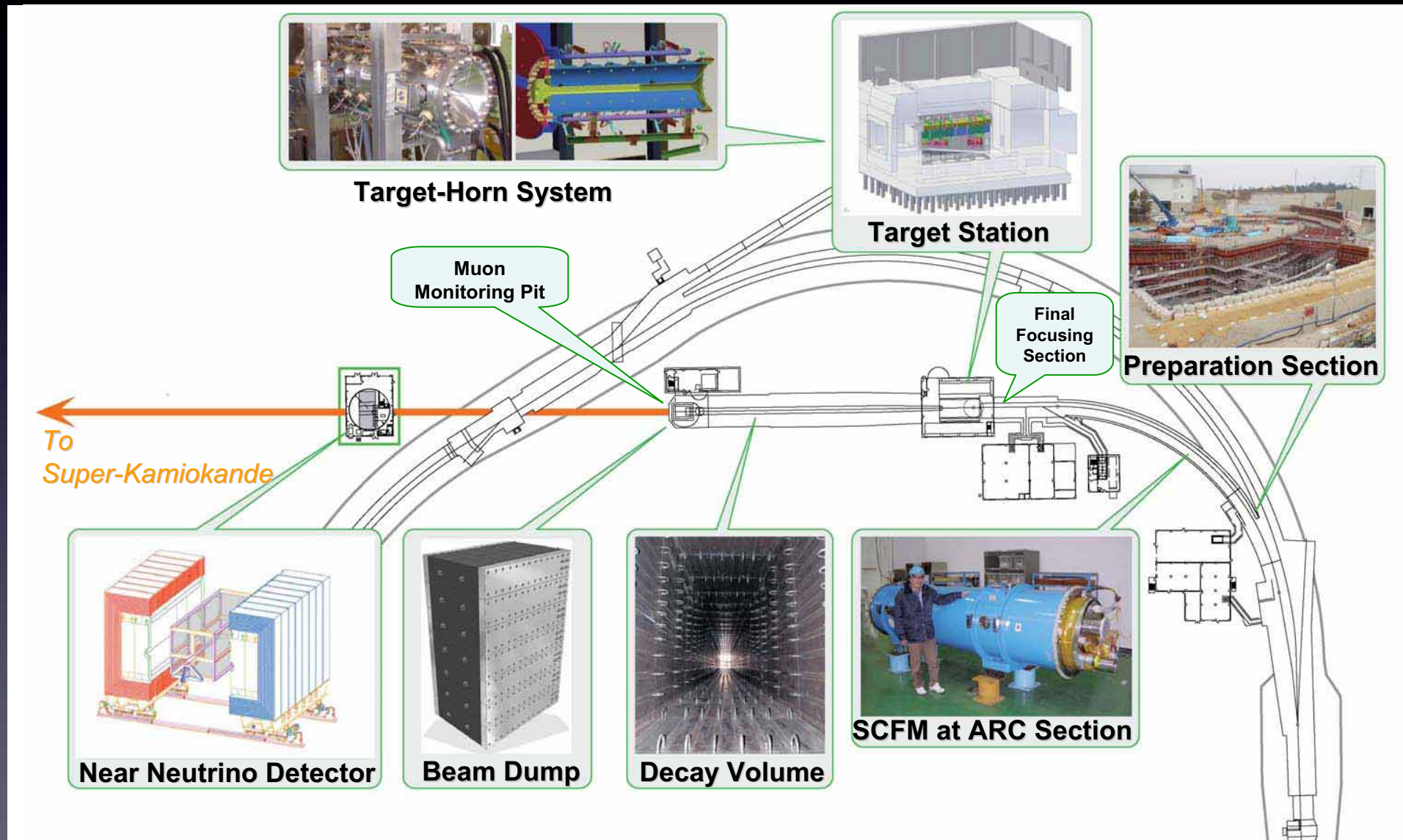
3GeV RCS

Linac

J-PARC LINAC accelerated protons to 181 MeV (as designed)!



Neutrino beamline



Primary beamline tunnel connected to MR on Nov. 21, 2006!



March, 2006

July, 2006



Target station



Mar. 2007

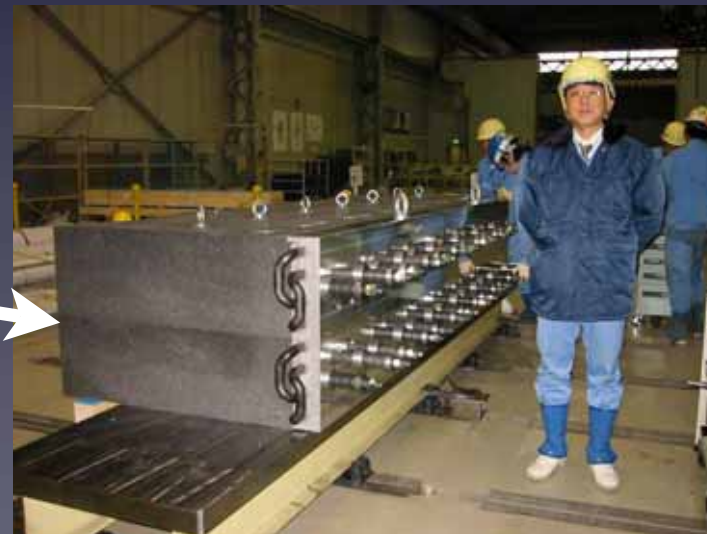
Decay volume



partly (50m)
constructed

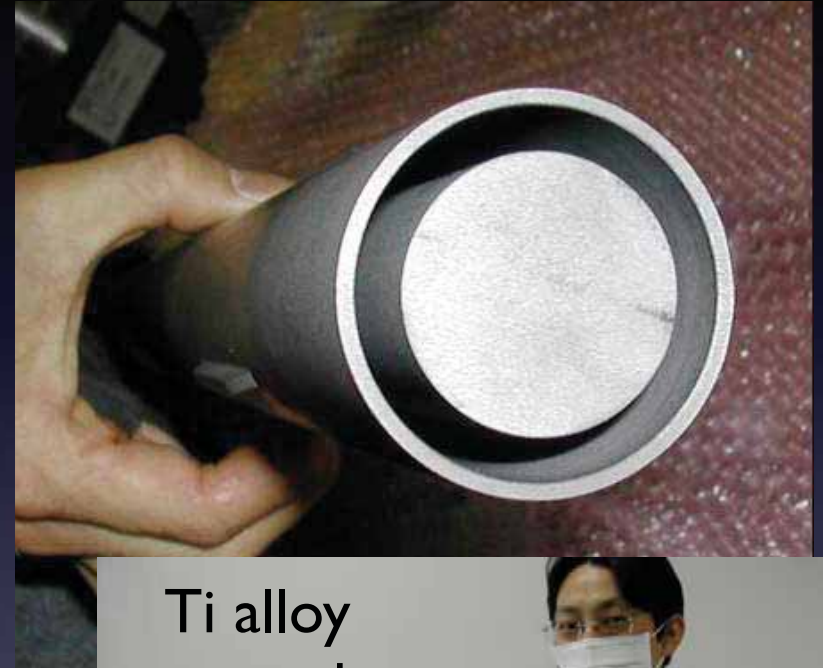


Hadron absorber
(beam dump)
core module
(Mar. 13, 2007)



Horn/target

Graphite target prototype



Ti alloy
outer tube



Prototype of 1st horn tested with
850k pulses @ 320kA (design current)!

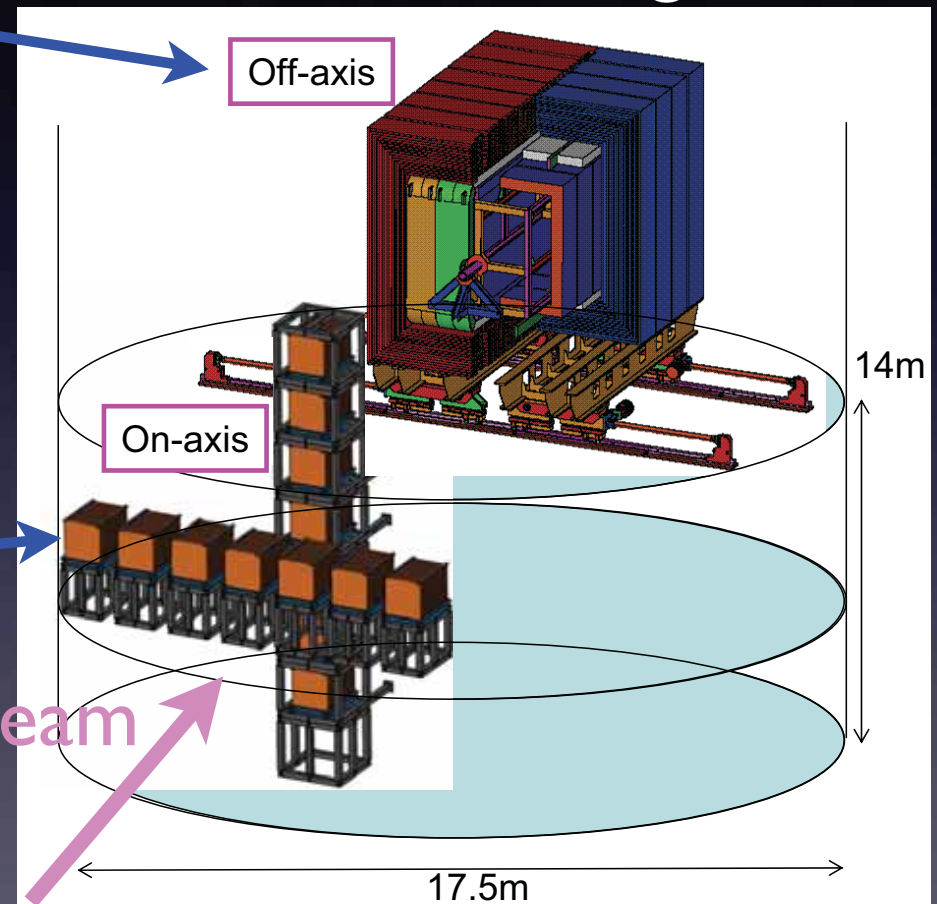
Latest results from K2K and Status of T2K, M.Yokoyama (Kyoto)

Near neutrino detectors

- Off-axis detector
 - Inside **UAI** magnet
 - Measure ν energy spectrum, cross-section, species..
- On-axis detector
 - Monitor beam direction
- New photon-sensor MPPC/MRS-APD

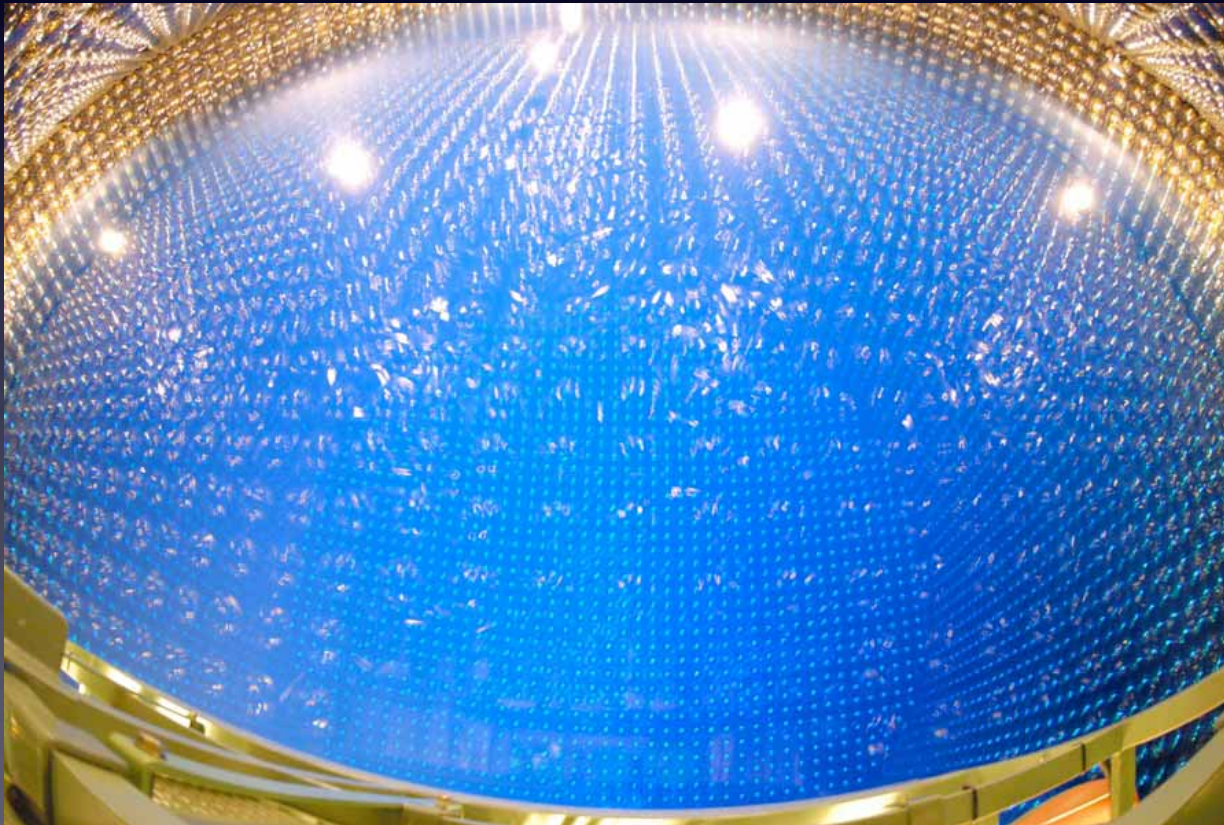


~280m from target



Super-K

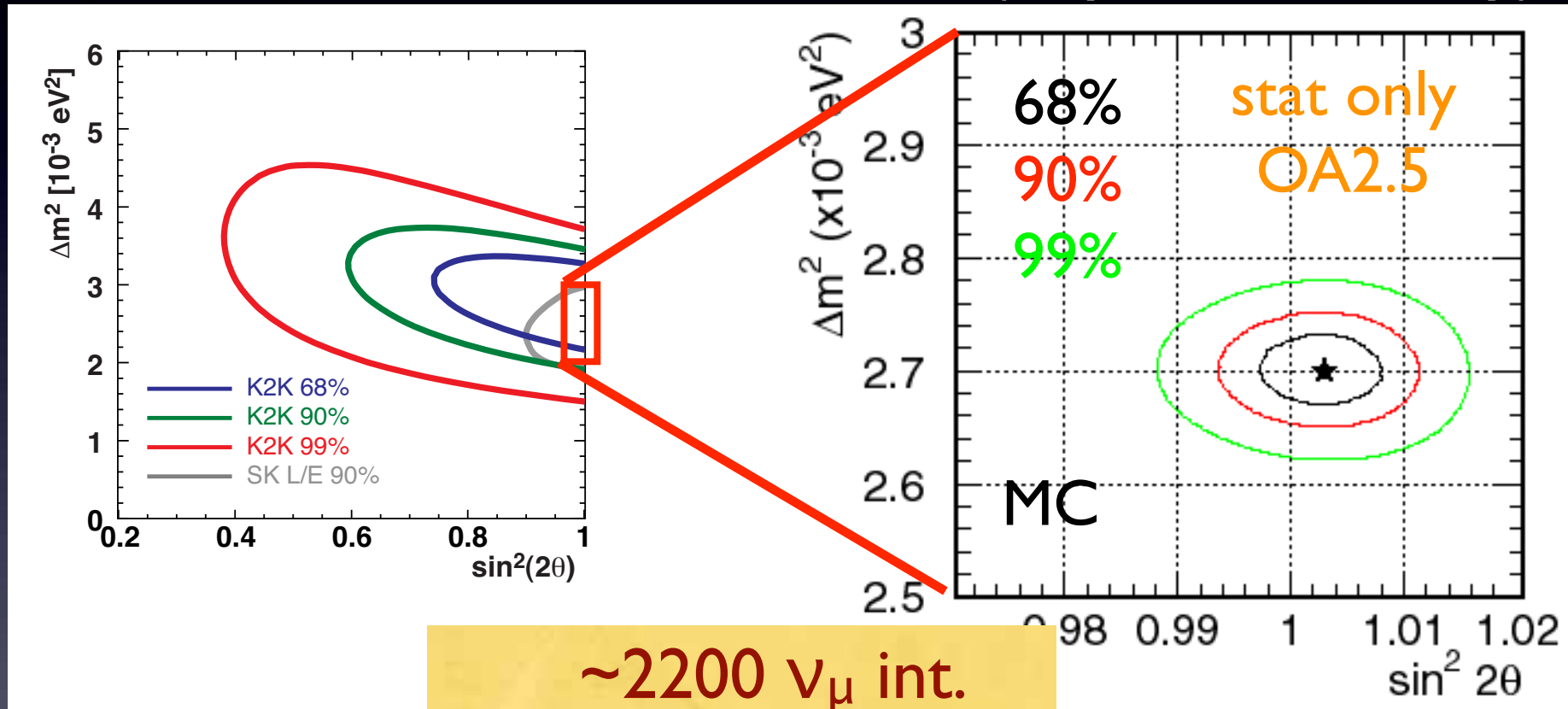
- Recovered its original photo coverage and running from last summer!



Precise measurement of $\Delta m^2_{23}/\theta_{23}$

K2K/Super-K

T2K 5×10^{21} POT
(~5yr full intensity)

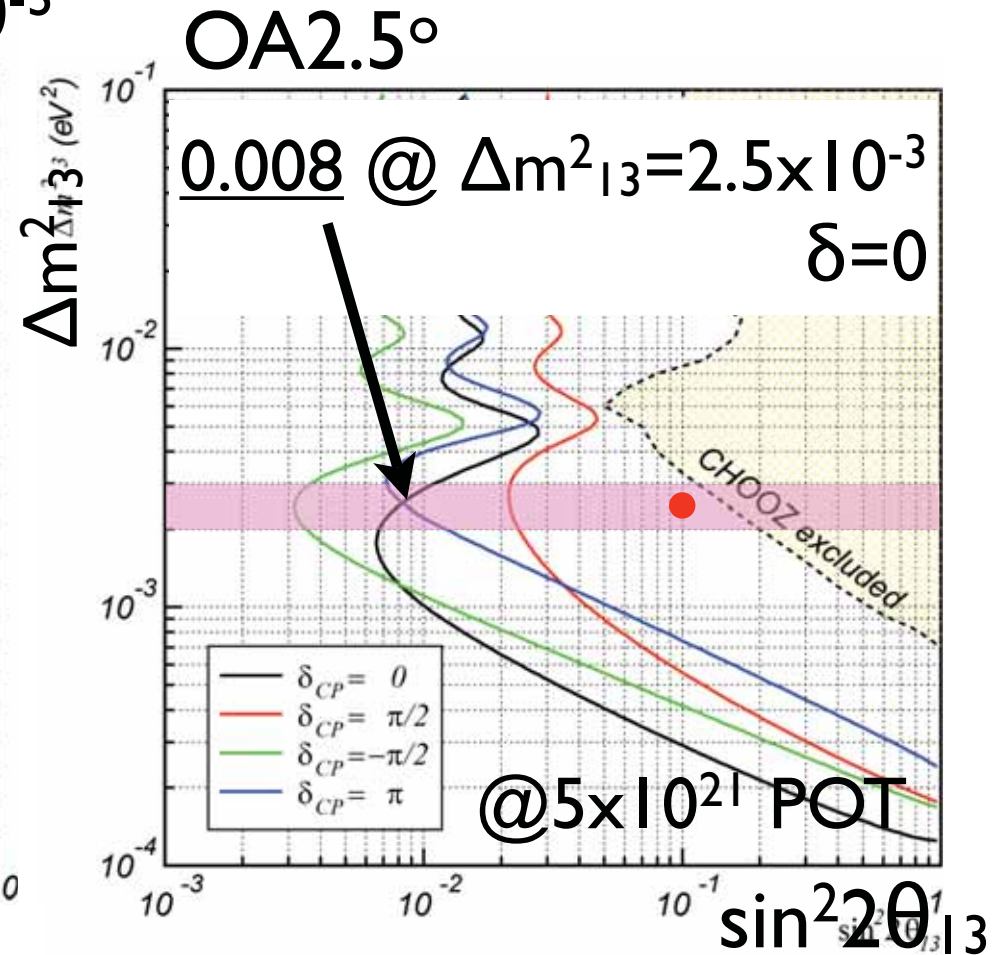
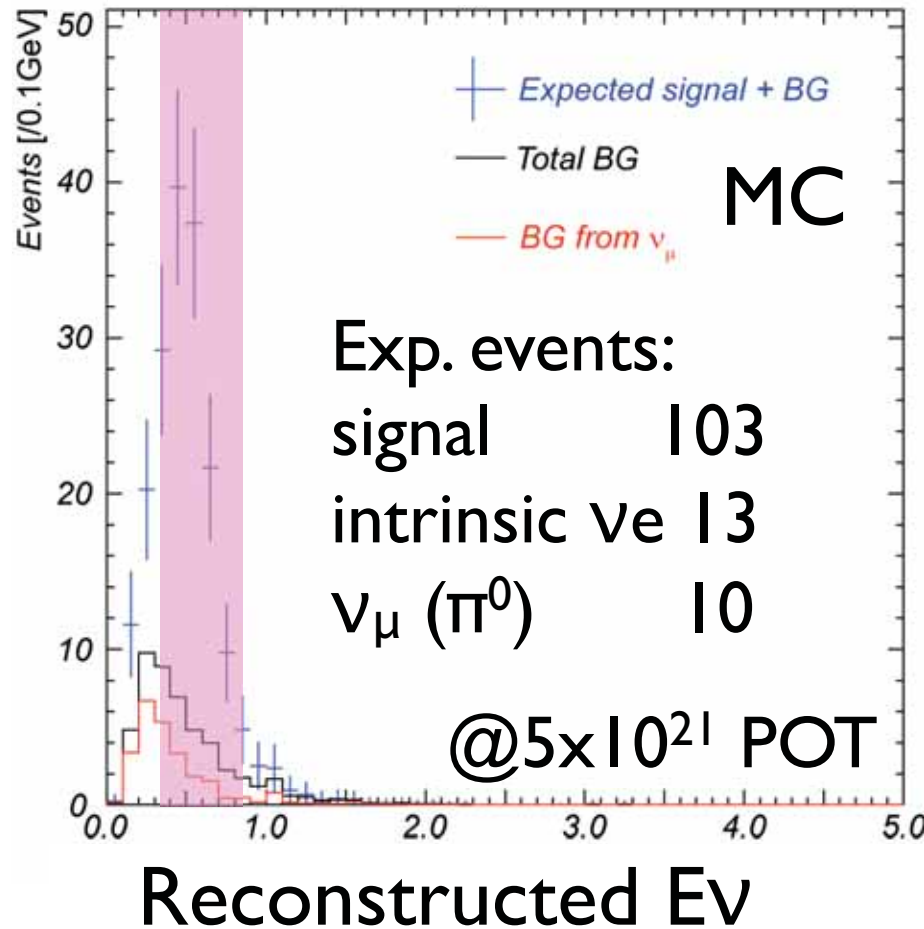


~2200 ν_μ int.
~1600 ν_μ CC
per year,
~0.4% ν_e @ peak

$\delta(\sin^2 2\theta_{13}) \sim 0.01$
 $\delta(\Delta m^2_{23}) < 10^{-4} \text{eV}^2$

$\nu_\mu \rightarrow \nu_e$ sensitivity

$\sin^2 2\theta_{13} = 0.1, \Delta m^2 = 2.5 \times 10^{-3}$



10% uncertainty
assumed for BG

Summary

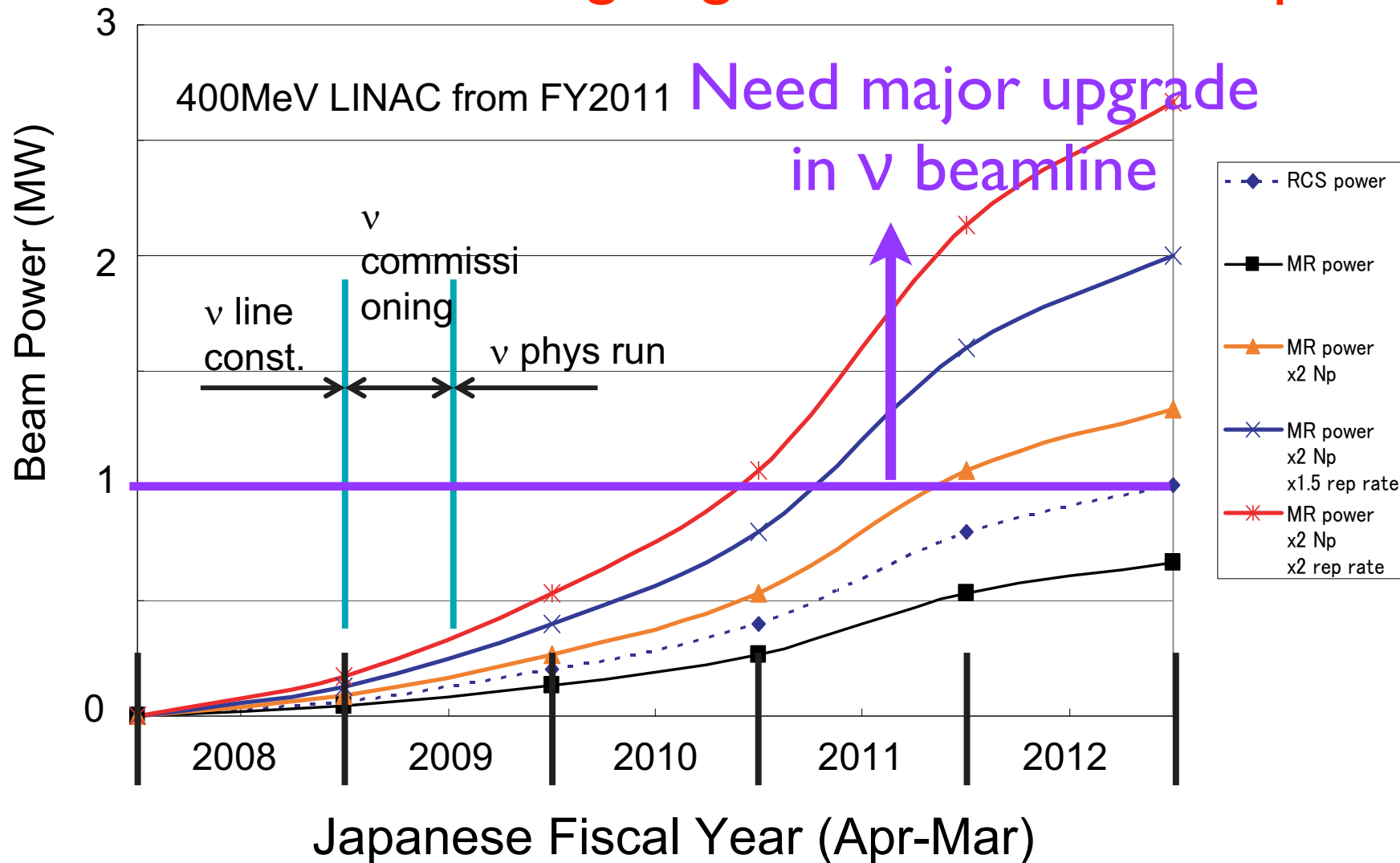
- K2K was successfully completed.
 - Confirmed ν_{μ} oscillation.
 - Proved “long baseline” experiment to (excellently) work.
- Preparation for T2K is in the final stage.
 - Accelerator/beamline under construction.
 - Super-K recovered original photo-coverage.
 - First beam in **April 2009.**

Backup

J-PARC beam power

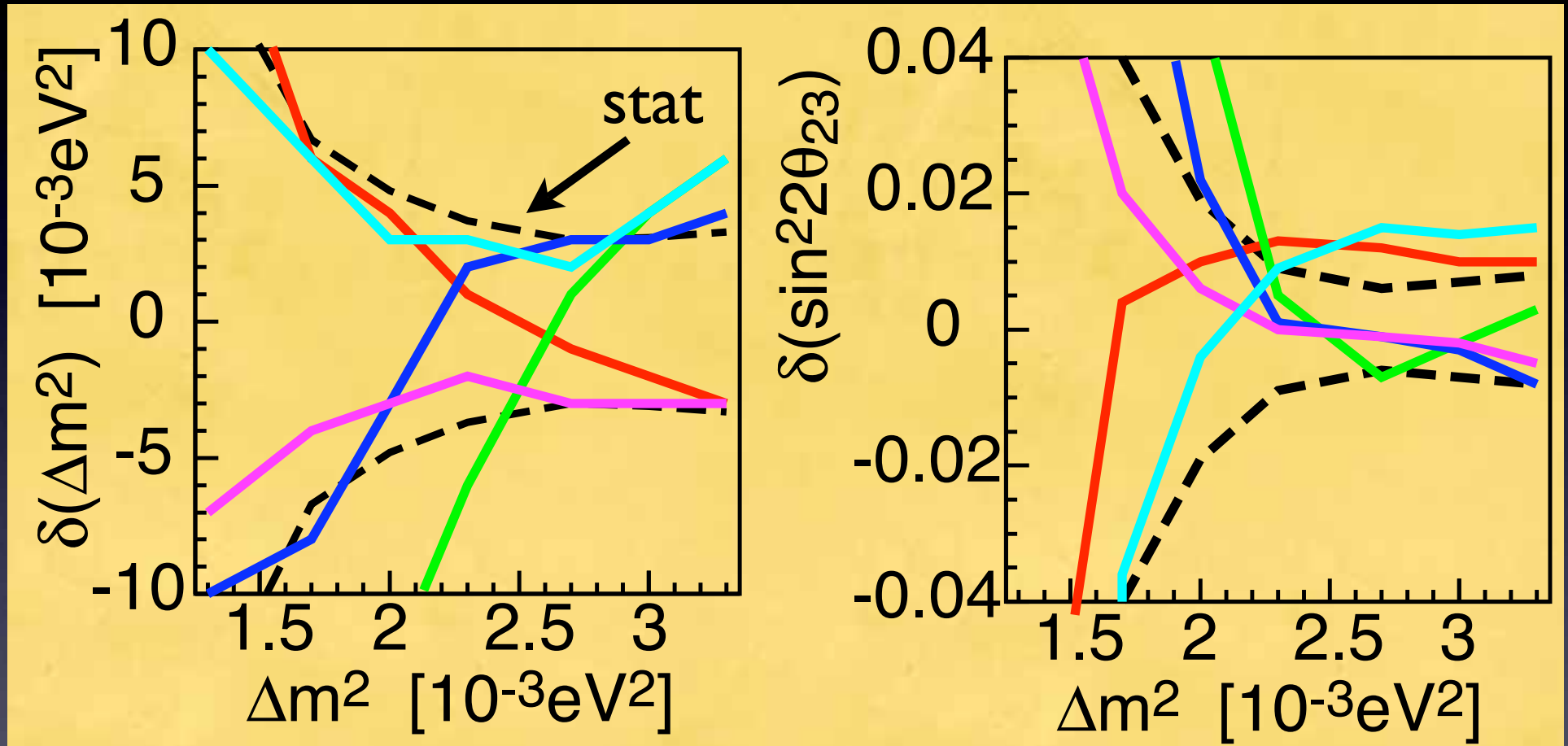
Example commissioning scenarios

Discussion ongoing to maximize beam power.



T2K ν_μ disapp. systematics

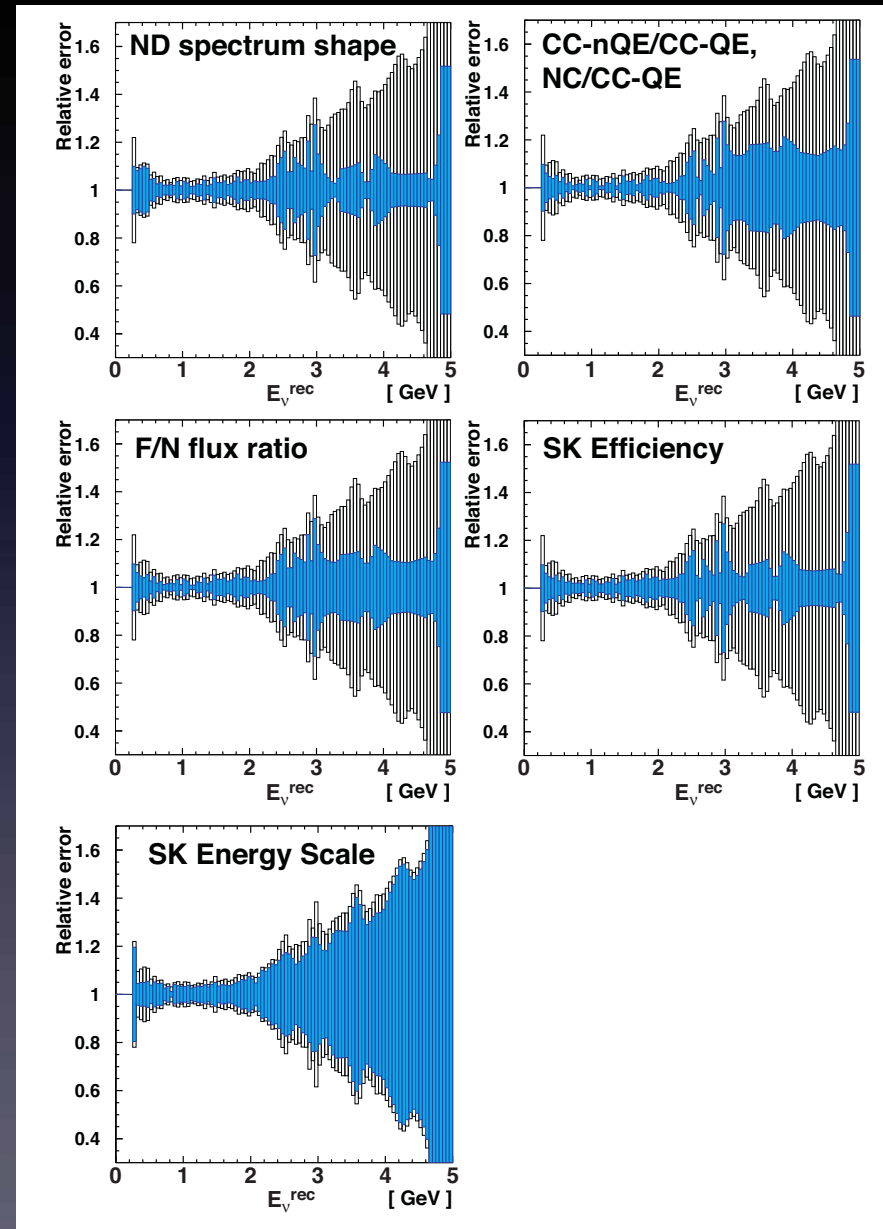
OA2.5°, 5×10^{21} POT



Normalization (10%), non-QE/QE (20%),* will improve with ND & NA49 measurements,
Energy scale (4%), Spectrum shape,
Spectrum width (10%)

K2K ν_μ disapp. systematics

Source	Error(%)
ND meas.	4.1
Super-K fid.	3.0
F/N ratio	2.9
E_ν spectrum	2.5
Live time	0.3
Cross-section	0.8



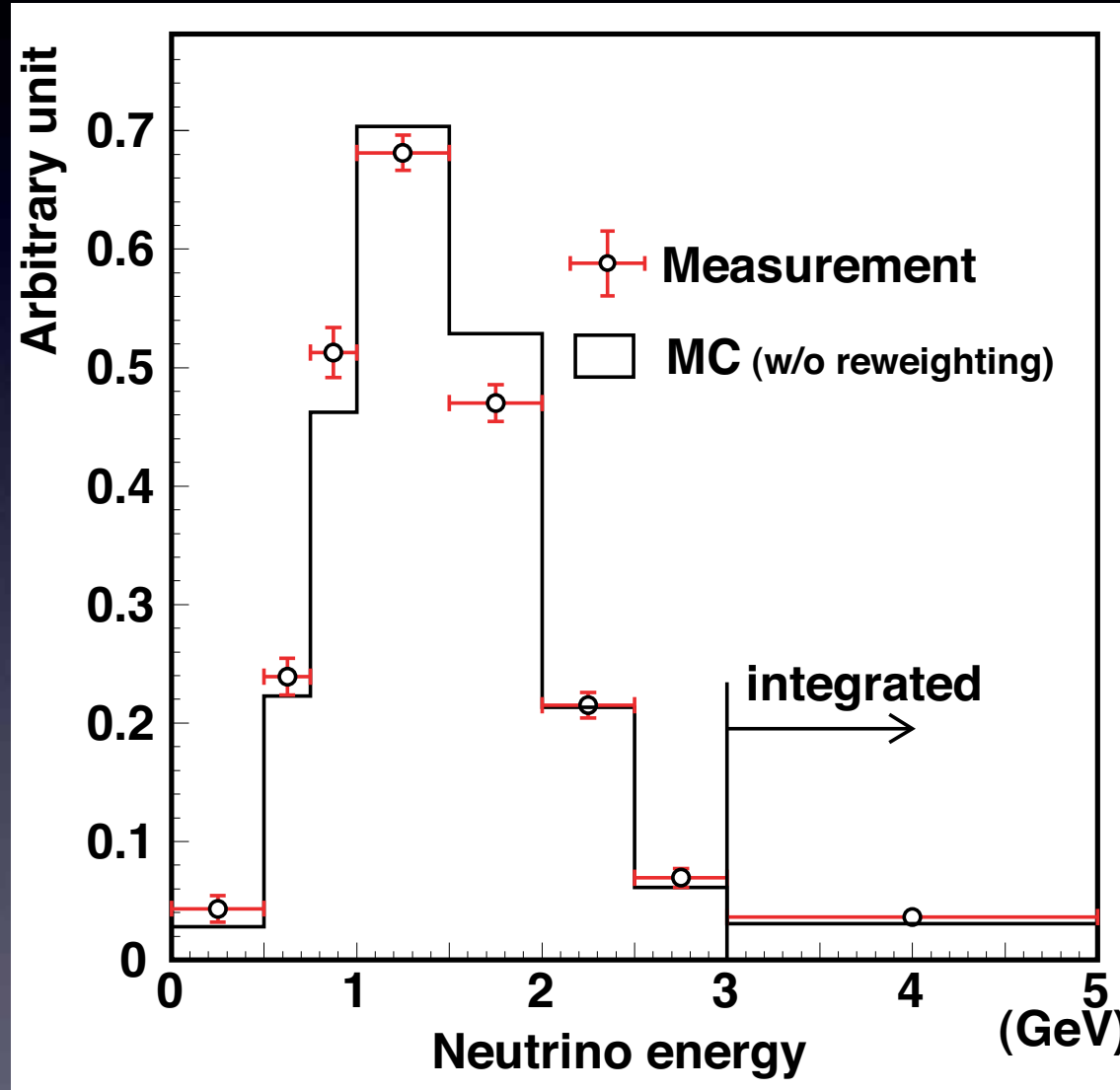
K2K

ν_e candidate selection

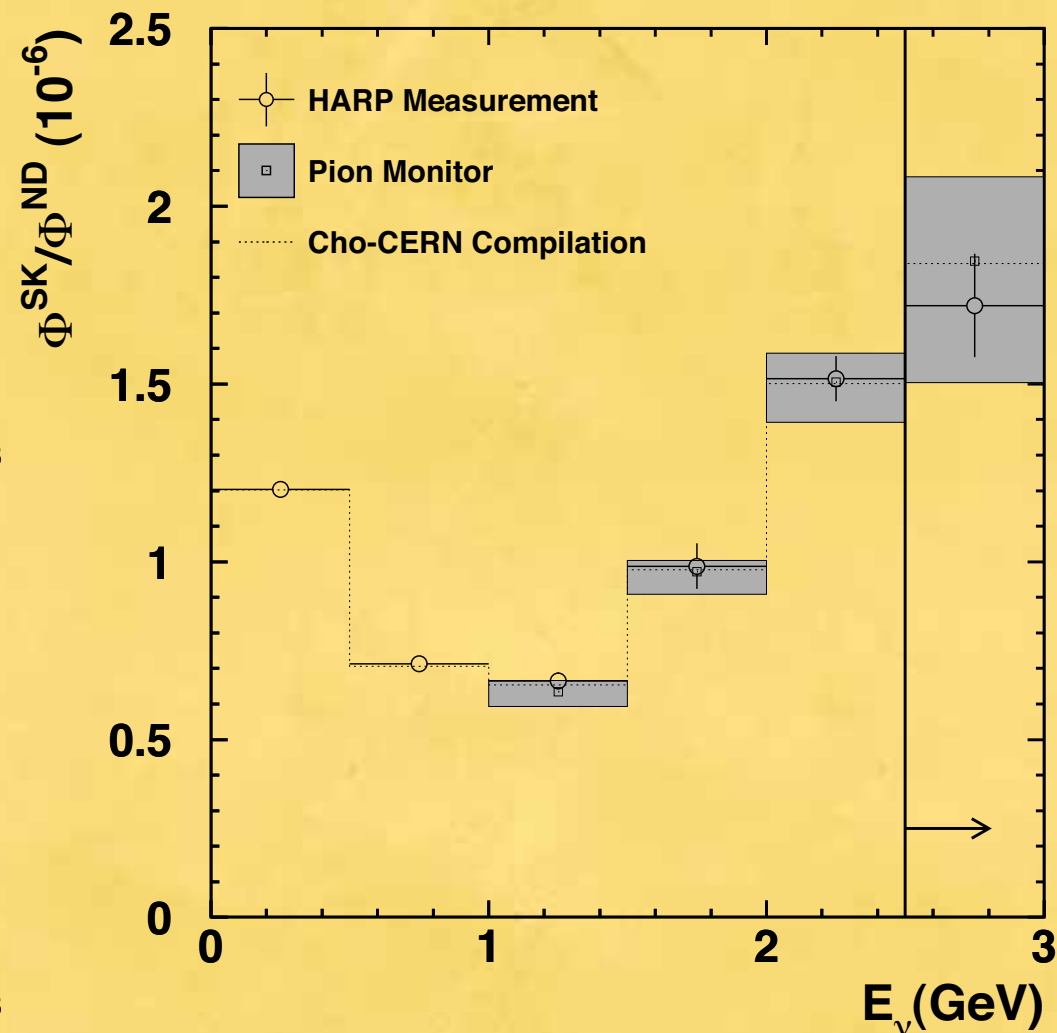
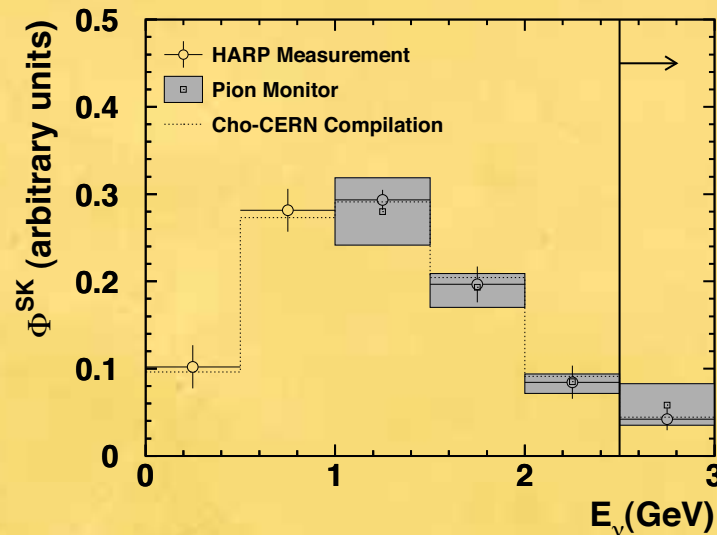
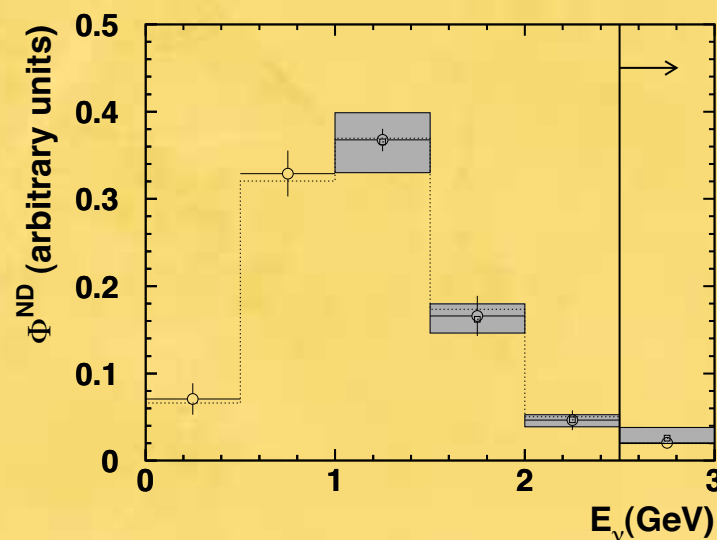
	ν_μ MC	beam ν_e MC	Data
FCFV	158.5	1.67	112
Single ring	100.3	0.99	67
Tight e-like	5.9	0.84	8
$E_{\text{vis}} > 100\text{MeV}$	5.4	0.84	7
No decay-e	4.1	0.74	5
π^0 rejection	1.3	0.38	1

K2K

Ev spectrum @ ND



Near to far extrapolation



HARP results + beamline MC

confirmed by in-situ measurement of π kinematics

Secondary beamline

