K2K and T2K experiments

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Neutrino Oscillation Workshop 2006
at Conca Specchiulla, Otranto, Italy

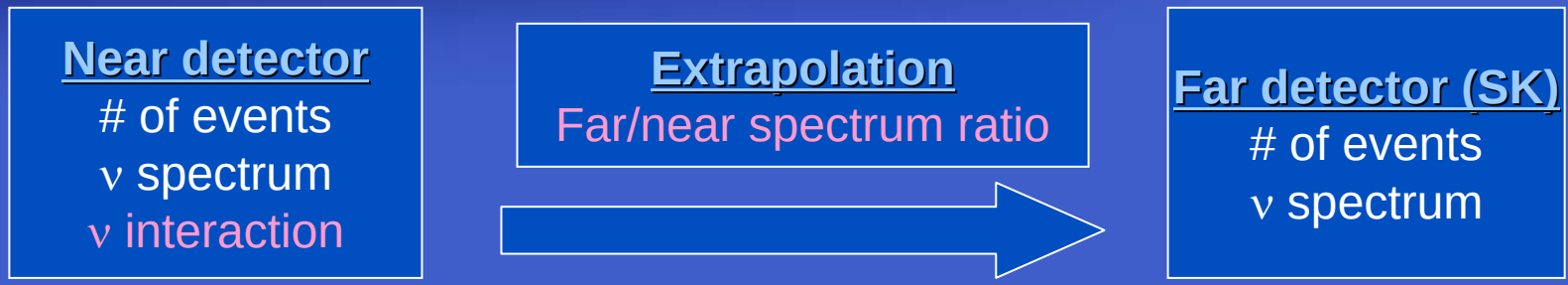
Outline

- K2K experiment, shortly
  - What's updated from the previous results, and the final results
- T2K experiment
  - Experimental setup
  - What needs to be measured
  - ND280 off-axis detectors
- Summary

K2K experiment

- KEK to Kamioka long baseline experiment
  - Pure ν_μ beam with $<E_\nu>$ = 1.3 GeV and L=250 km
  - To confirm neutrino oscillation seen in atmospheric neutrino observations
  - Search for ν_e appearance
- Brief history
  - 1996-1998: civil construction and detector installation
  - 1998-2004: physics run
    - 1998-2001 with SK-I and 2002-2004 with SK-II
  - 1998 June: the first event in SK
  - 2002: indications for oscillation (0.47×10^{20} pot)
  - 2004: evidence for oscillation (0.89×10^{20} pot)
  - 2006: the final results (0.92×10^{20} pot)

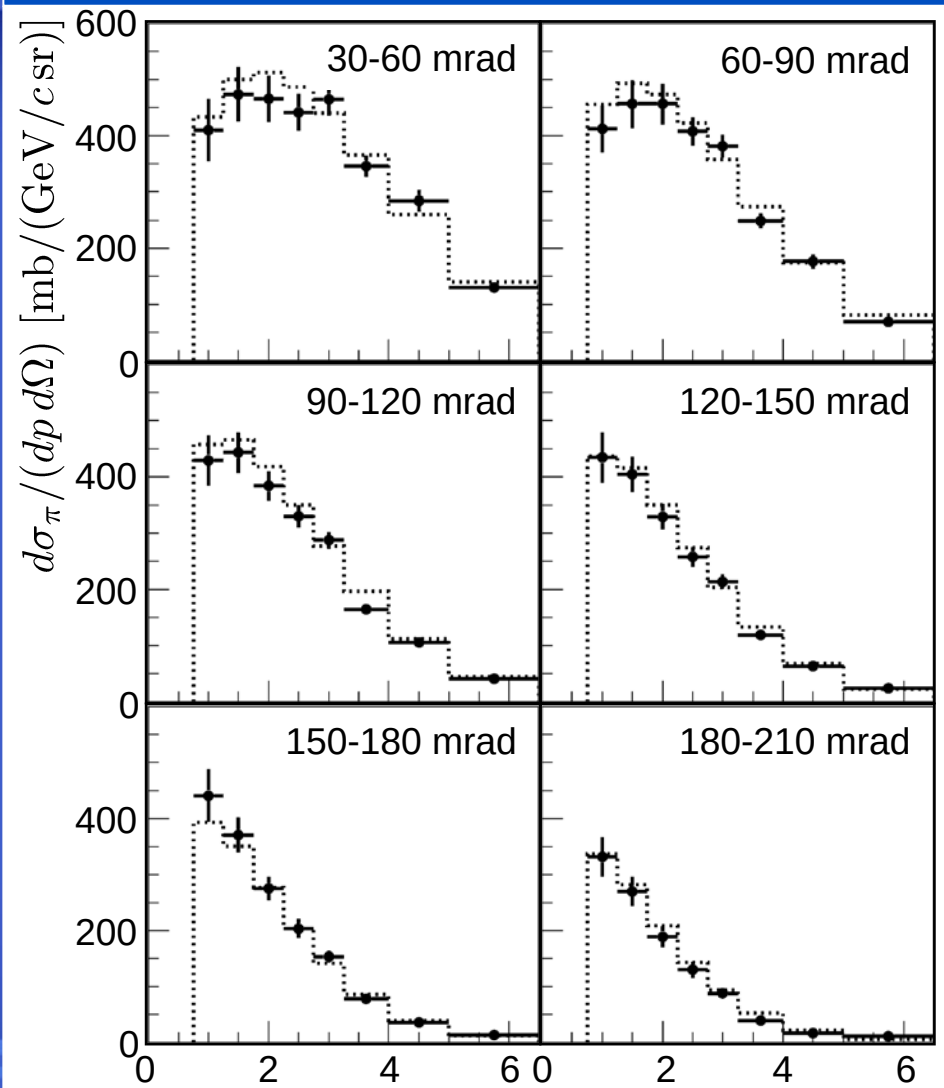
What's updated?



- Full date set is used
- Far-to-near spectrum ratio
  - Pion monitor measurements → HARP results
    - Published in Nucl. Phys. B732, 1-45 (2006)
- Neutrino interaction study
  - No CC coherent π production
    - Published in Phys. Rev. Lett. 95, 252301 (2005)
- For ν_e appearance search, more sophisticated selection applied to reject NC-π^0 events
  - Energy v.s. invariant mass of an event

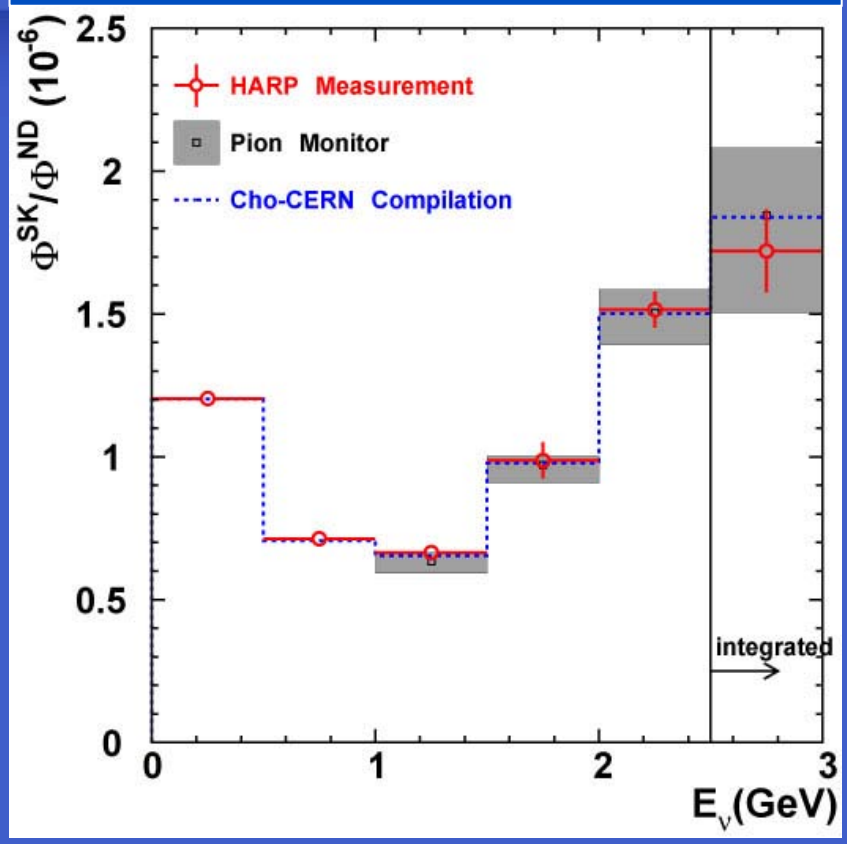
Far/near ratio from HARP

HARP Pion production (Al target, 12.9 GeV/c)



Nucl. Phys. B732, 1-45 (2006)

Far/near spectrum ratio



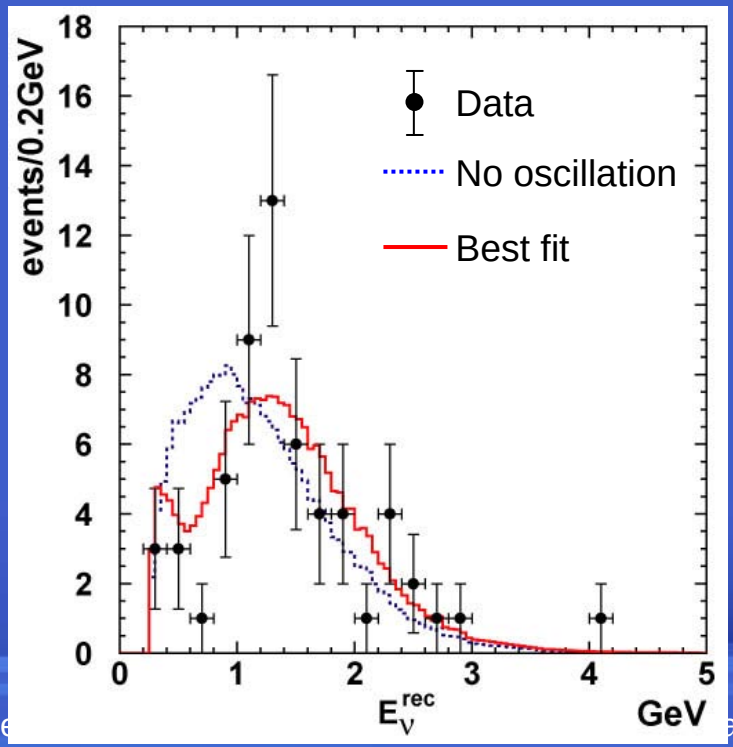
- Far/near ratio is estimated using HARP results

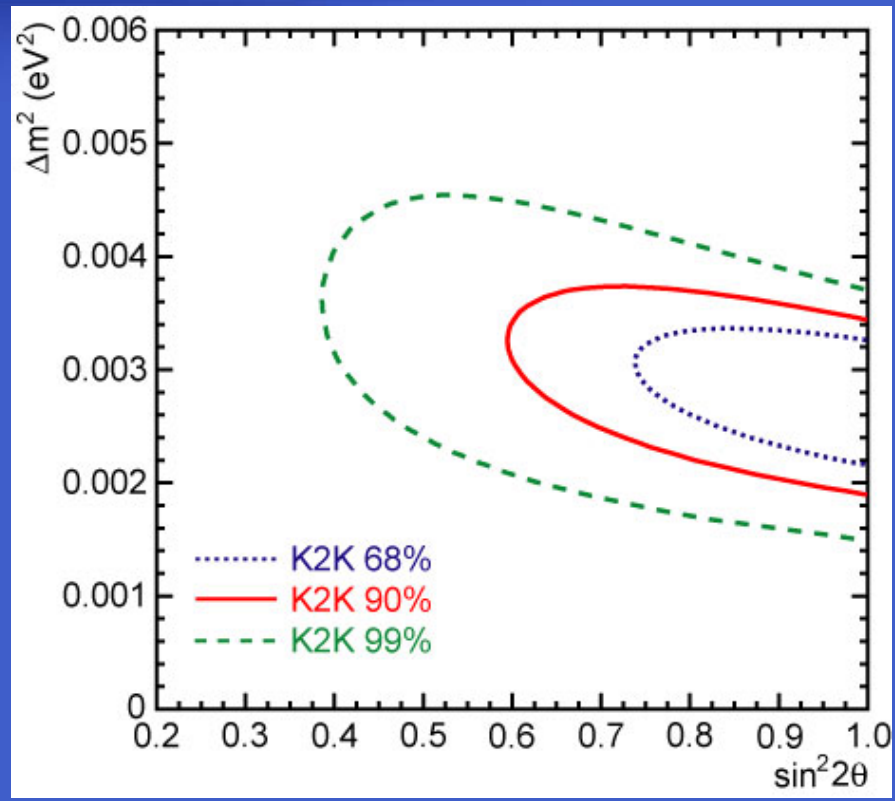
Results for disappearance

hep-ex/0606032, will be soon published in Phys. Rev. D

Best Fit (phys. Region) at
$(\sin^2 2\theta, \Delta m^2) = (1.0, 2.8\times10^{-3}\ \mathrm{eV}^2)$

# of events observed = 112
Expected (null osc.) = $158.1^{+9.2}_{-8.6}$
Expected (best fit) = 107.2



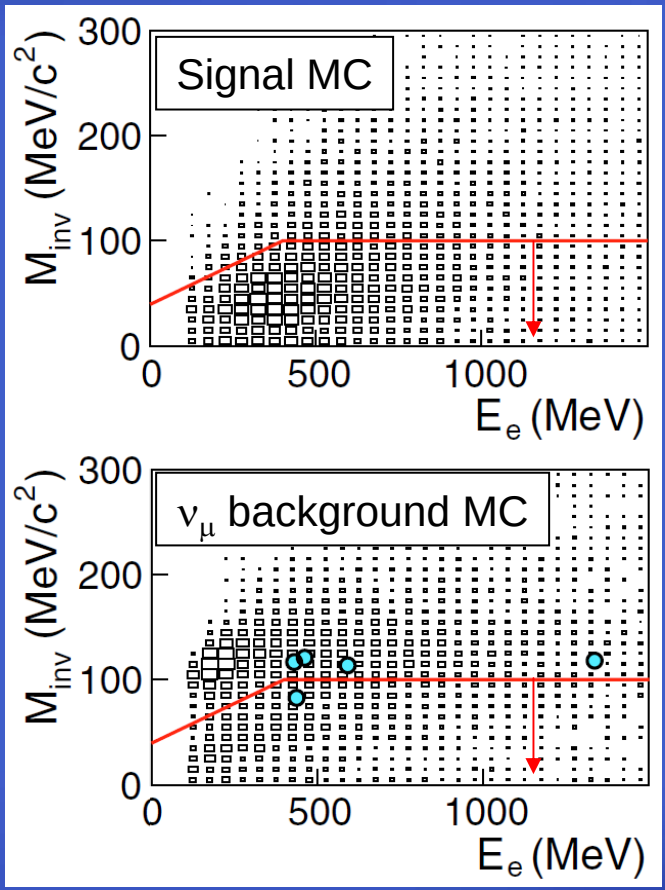


- Null Oscillation : 0.0015% (4.3σ)
- Allowed region of Δm^2 at $\sin^2 2\theta = 1.0$
  $1.9\times10^{-3} < \Delta m^2 < 3.5\times10^{-3}\ \mathrm{eV}^2$ (90% C.L.)

Search for ν_e appearance

Published in Phys. Rev. Lett. 96, 181801 (2006)

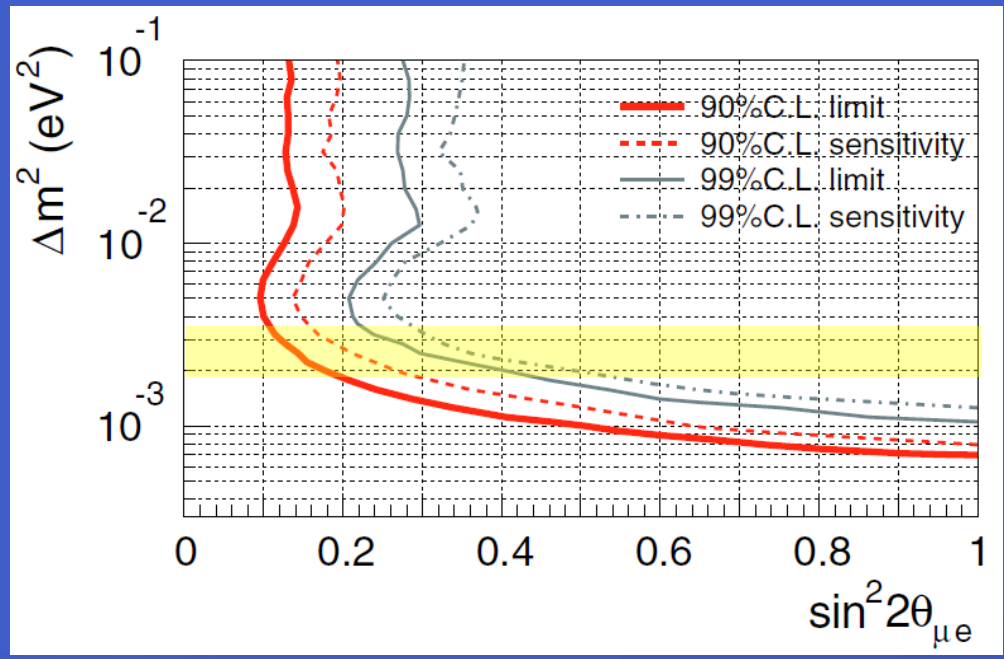
Invariant mass v.s. Energy



# of events in the signal region = 1

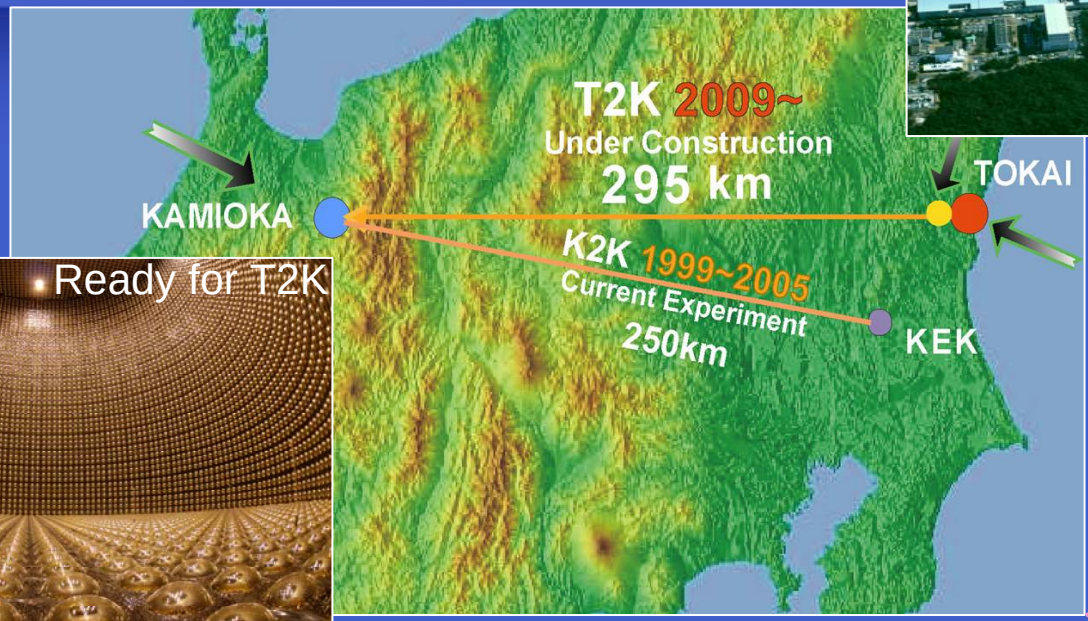
Expected B.G. = $1.7^{+0.6}_{-0.4}$ (no oscillation case)

(ν_μ int. = 1.3, beam-ν_e = 0.4)



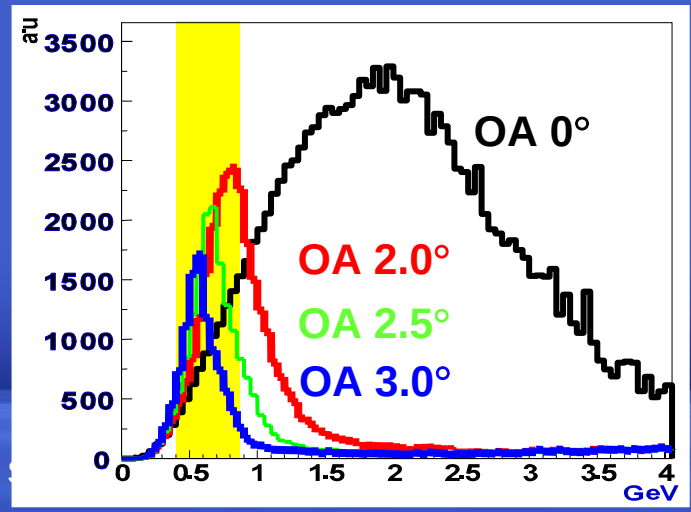
- $\sin^2\theta_{\mu e} < 0.13$ at $\Delta m^2_{\mu e} = 2.8\times10^{-3}$ eV^2

T2K experiment

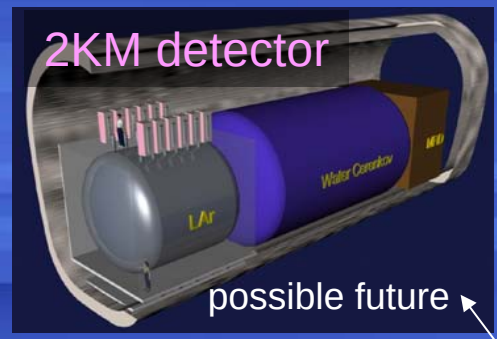


Tokai (J-PARC) to Kamioka neutrino experiment

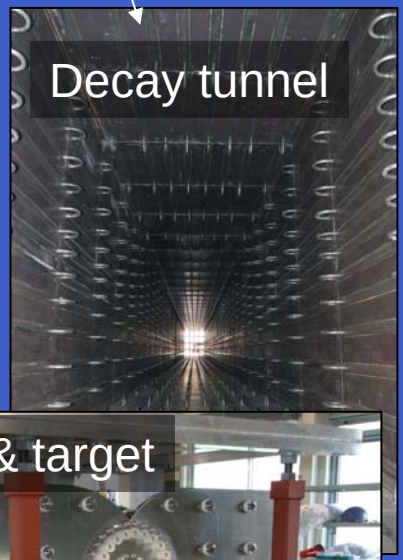
- to determine θ_{23} and Δm_{23} presicely,
- to discover the θ_{13} and beyond
- with intense neutrino beam tuned at the oscillation maximum by off-axis technique



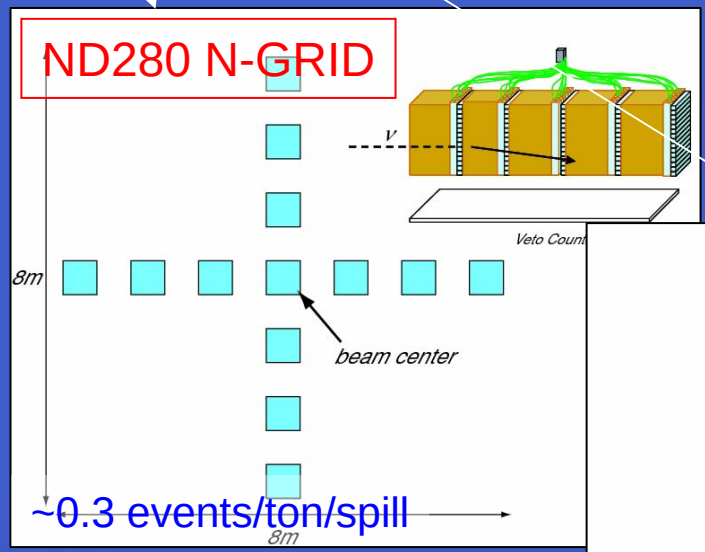
T2K setup


2KM detector
possible future

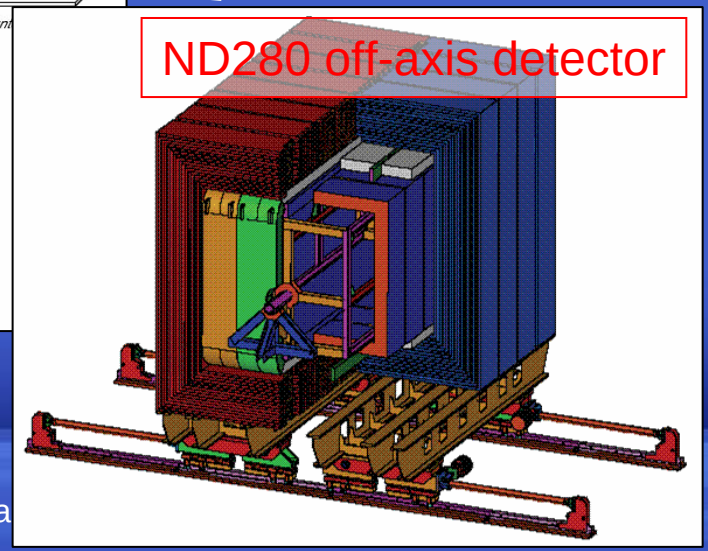

0 m
~130 m
280 m
2 km
295 km
proton beam
π
μ-monitor
2.5° off-axis
0° on-axis


Decay tunnel

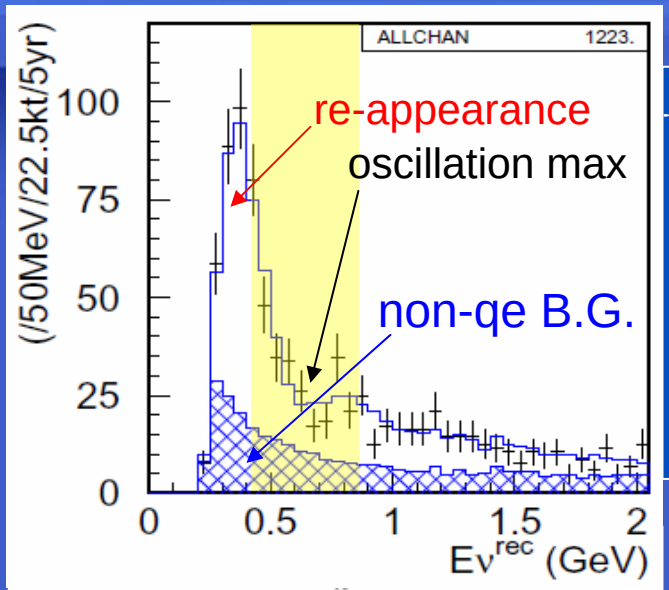

Super-K
Fully reconstructed!!


ND280 N-GRID
ν
Veto Count
8m
beam center
~0.3 events/ton/spill
8m


1st horn & target

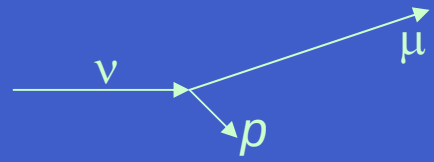

ND280 off-axis detector

What needs to be measured?



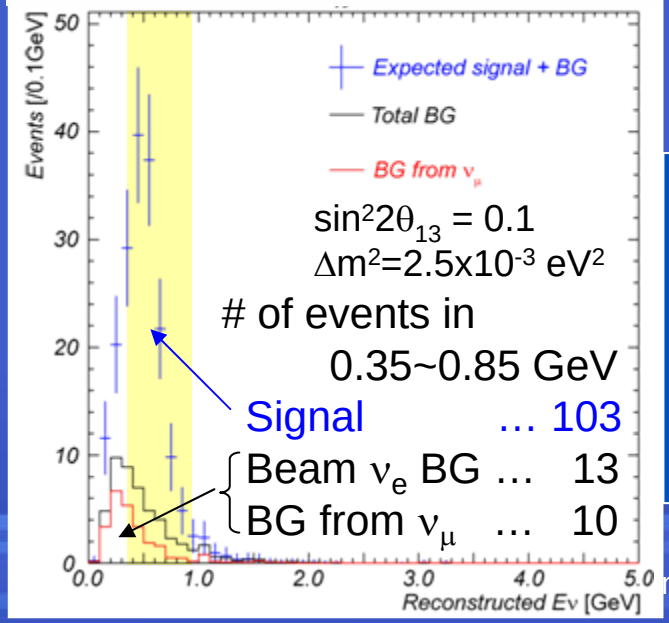
ν_μ disappearance

- Towards precise measurements of ν_μ disappearance
  - With energy spectrum (CCQE events)



$$E_\nu = \frac{m_N E_l - m_l^2/2}{m_N - E_l + p_l \cos\theta_l}$$

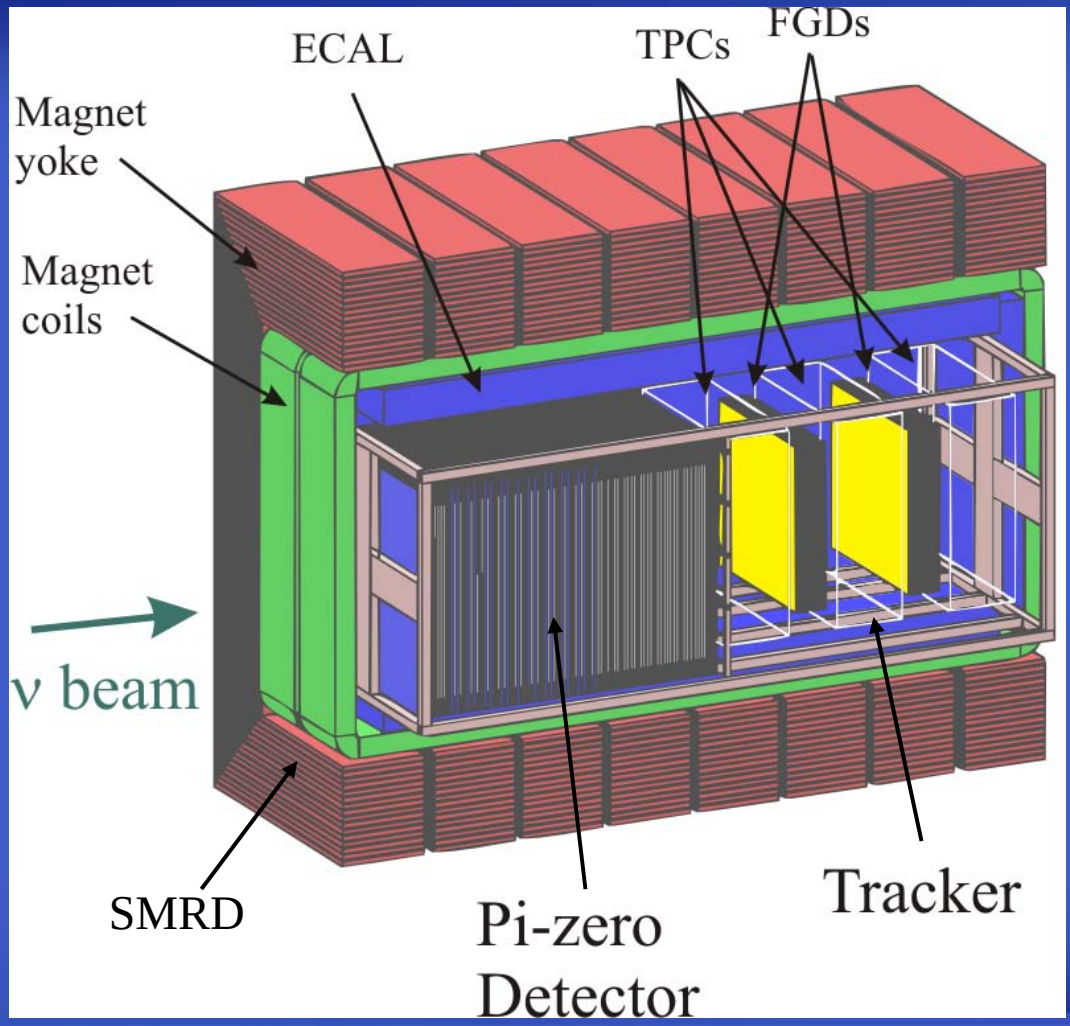
  - To see its re-appearance
  - Understanding of the ν_μ spectrum and backgrounds (mainly CC1π and NC1π) is the key issue



ν_e appearance

- Towards search for ν_e appearance
  - Small signal in 0.5-1.0 GeV region
  - Understanding of the backgrounds (NC1π^0 and beam-ν_e) is the key issue

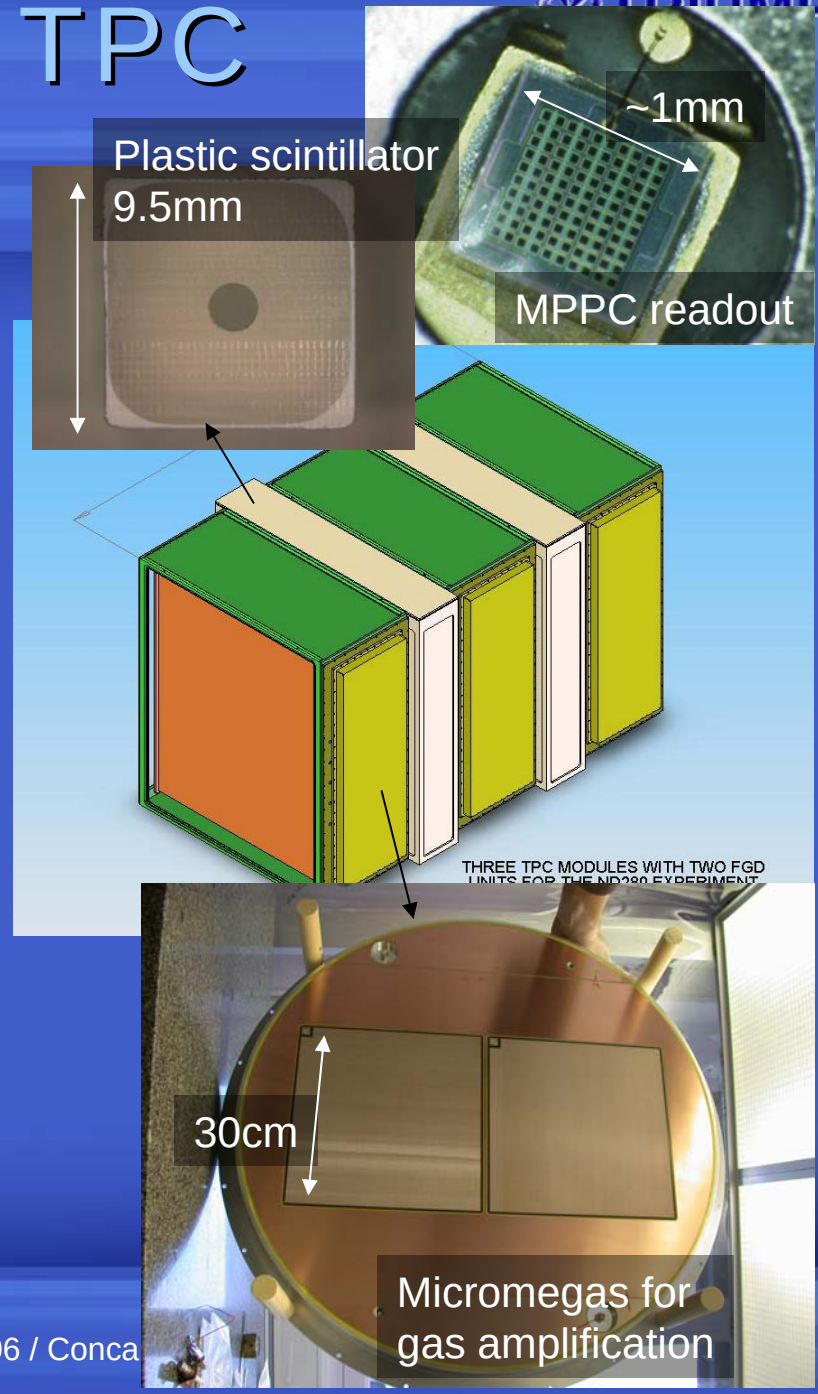
ND280m off-axis detectors



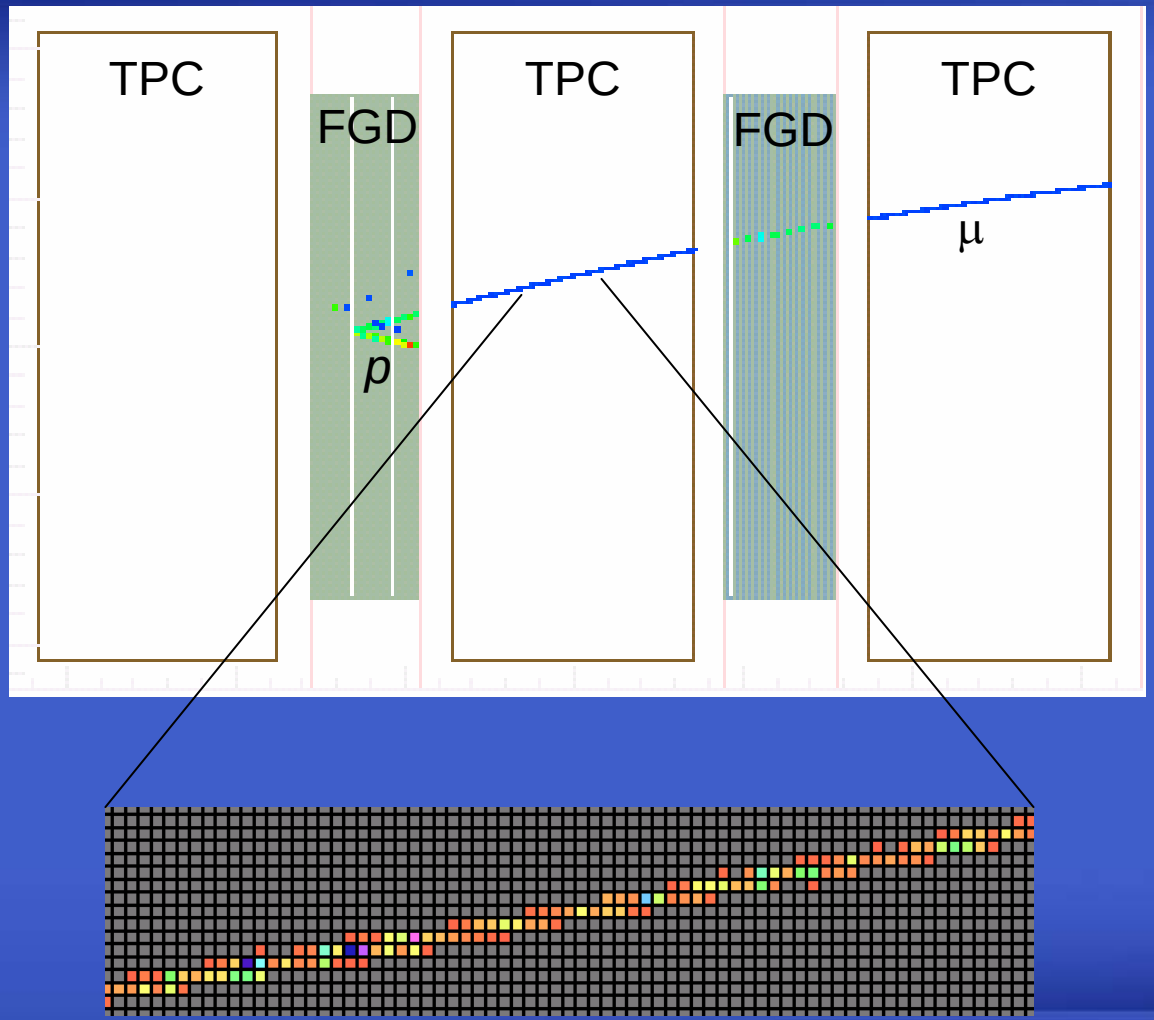
- To measure the neutrino spectrum
  - UA1 Magnet (0.2T)
  - Tracker (FGD+TPC)
  - Side-MRD (SMRD)
- To estimate the background events
  - Pi-zero detector (P0D)
  - EM calorimeter (ECAL) + Tracker

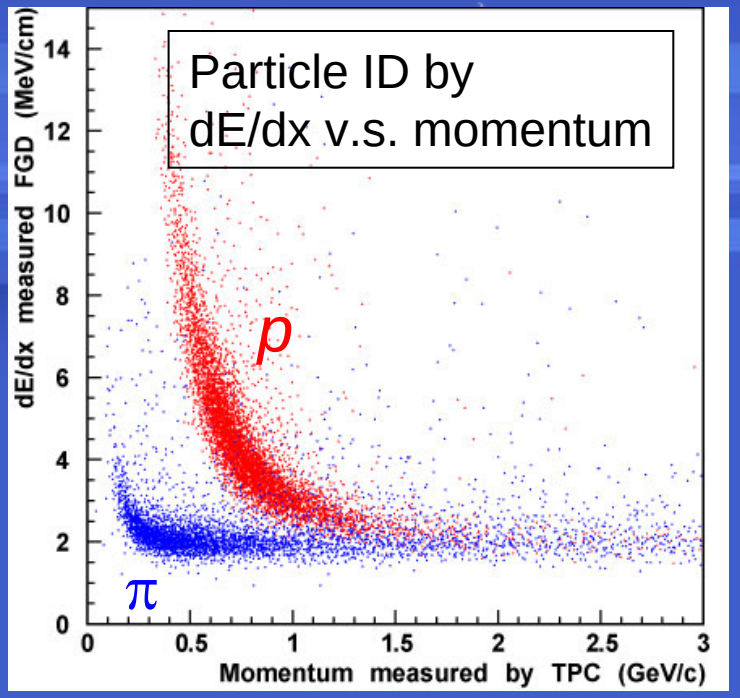
Tracker – FGD + TPC CC measurements

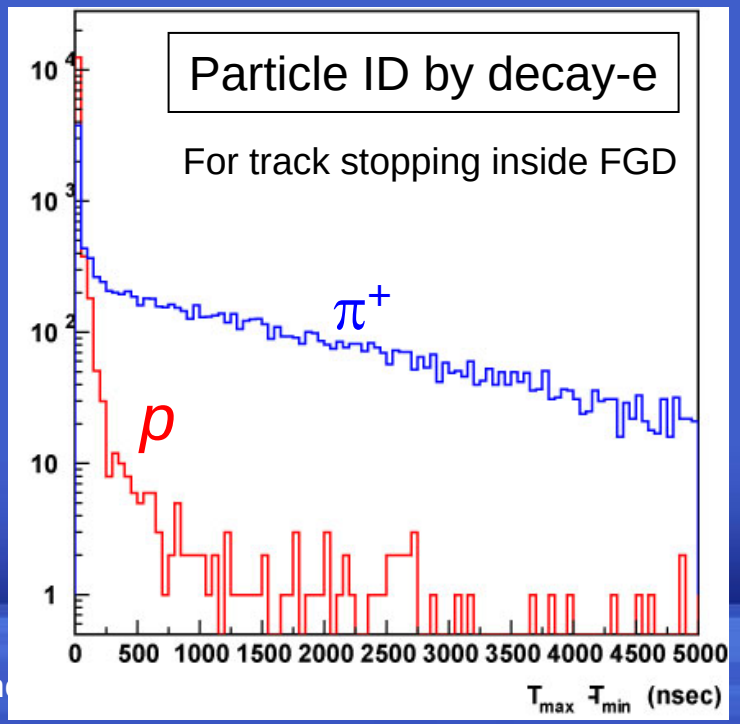
- FGD + TPC with magnet
  - For CC measurements
    - Spectrum and backgrounds
- To select pure CCQE
  - Select μ by negative track with small dE/dx
  - Momentum measured by TPC/SMRD
  - Proton by dE/dx v.s. momentum
- To select/reject CC π productions
  - Tagging pions by
    - Positive track in TPC (π^+)
    - dE/dx v.s. momenum
    - Decay-e in FGD (10μs active window)
    - Interaction in FGD
    - EM/hadron clusters in ECAL ($\pi^0/\pi^\pm$)



The tracker

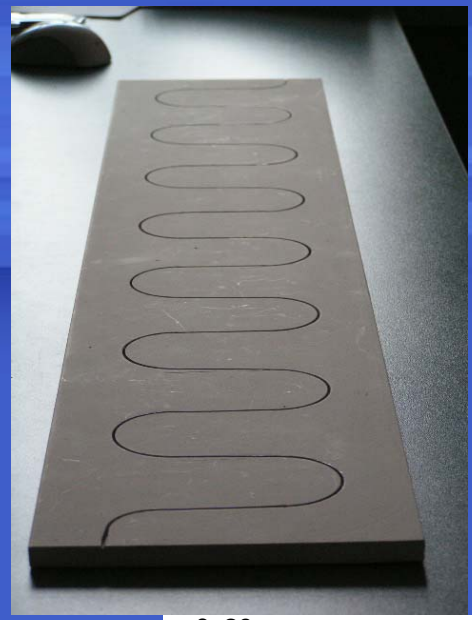

TPC
FGD
TPC
FGD
TPC
p
μ


Particle ID by
dE/dx v.s. momentum
dE/dx measured FGD (MeV/cm)
Momentum measured by TPC (GeV/c)
p
π


Particle ID by decay-e
For track stopping inside FGD
π+
p
T_max - T_min (nsec)

Side-MRD

- Relatively large fraction of muons going sideway.
- SMRD measures these muons' energy by range



Scintillator slabs inserted in between the iron plates of magnet yoke

Scillator Slab:

Length = ~ 87 cm

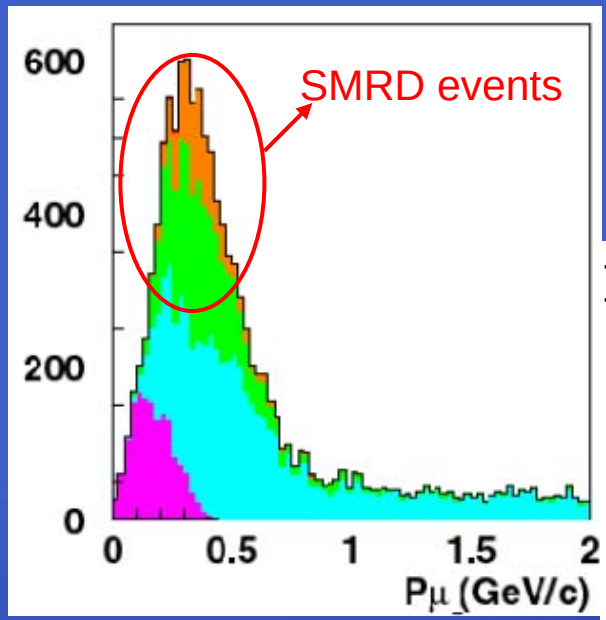
Width = ~ 18 cm

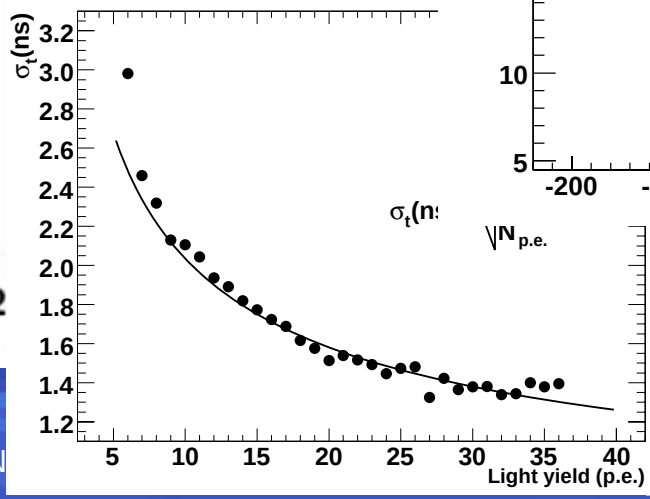
Thickmess = 10 mm

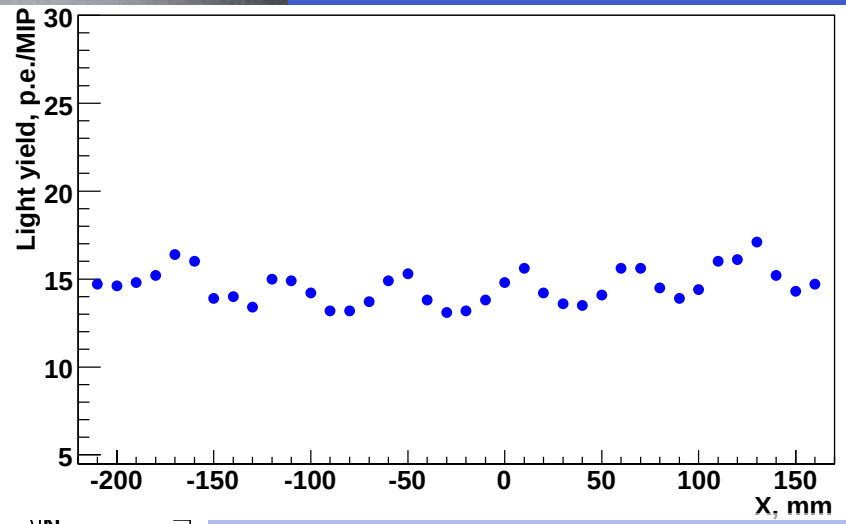
S-shape grooves for WLS fiber readout:

Depth = 4 mm

Length = ~ 2.5 m





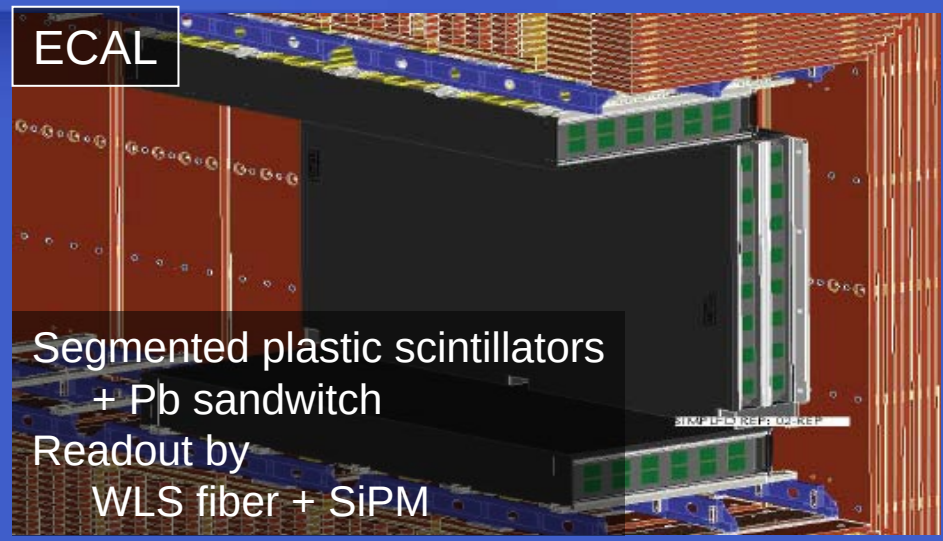


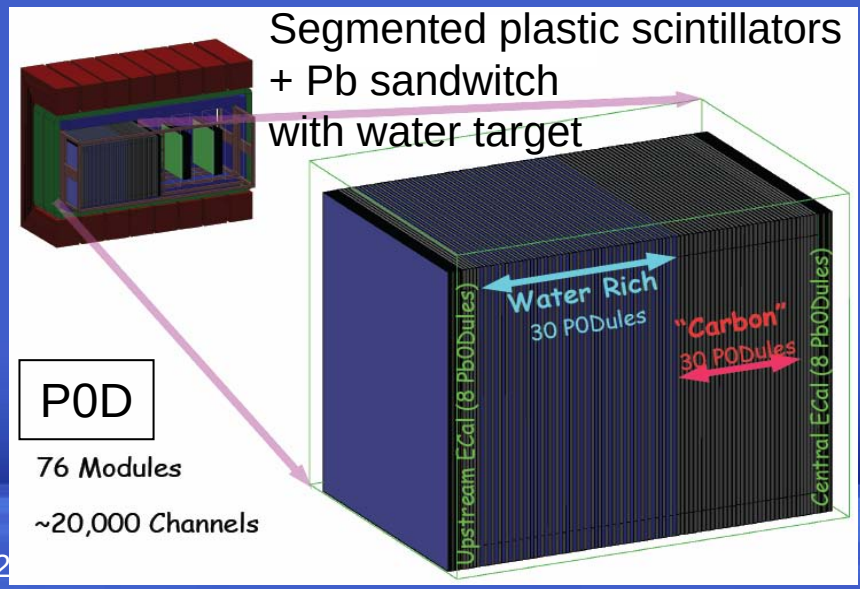
Beam test with 1.4 GeV/c pions

Light yield	15-20 p.e.
Timing (σ_t)	1.5 – 2.0 ns
space resolution	10-11 cm
efficiency(MIP)	> 99%

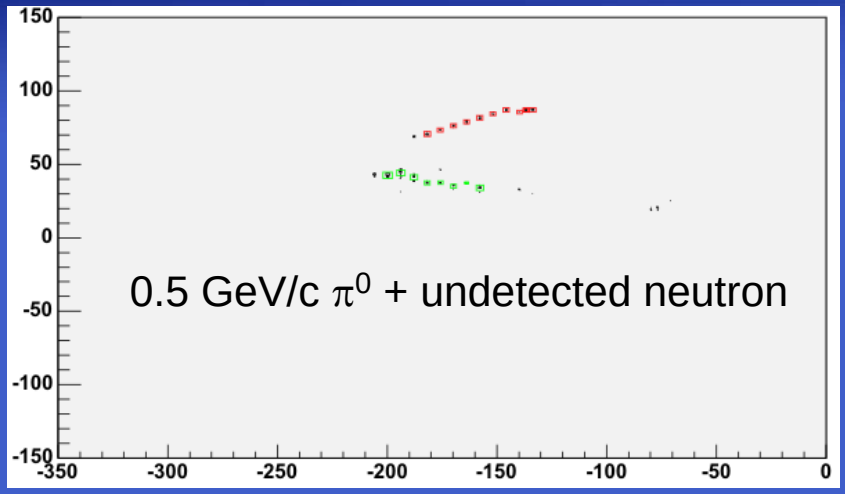
ECAL and P0D Backgrounds to ν_e appearance

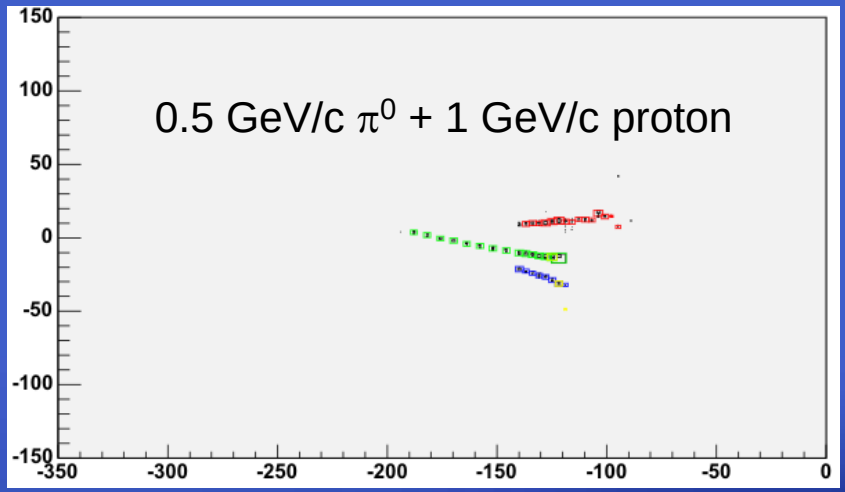
- Beam-ν_e measurement
  - ECAL surrounding the tracker
    - Electron ID using EM shower in ECAL and dE/dx in TPC
- NC π^0 production by ν_μ
  - Pi-zero detector (P0D)
    - Detector design optimized for NC-π^0 measurements
    - With large statistics
      - 1.7x10^4 NC1π^0 events/year
  - ECAL with tracker can also do the job
    - Exclusive NC1π^0 study
    - But low efficiency (low stat.)
      - ~800 NC1π^0 events/year

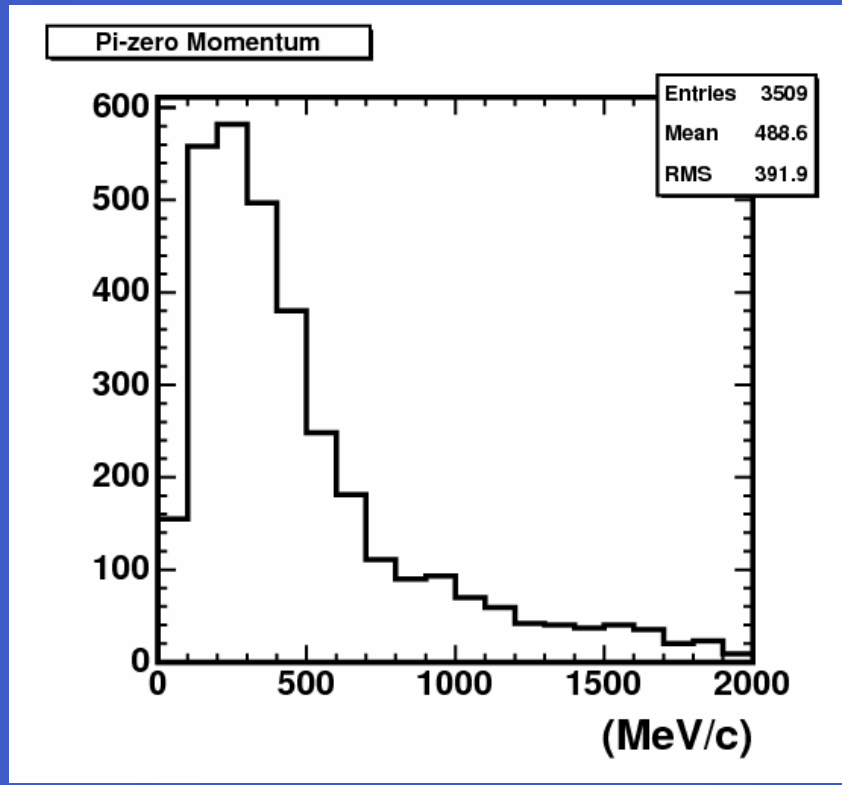




NC1π^0 in P0D







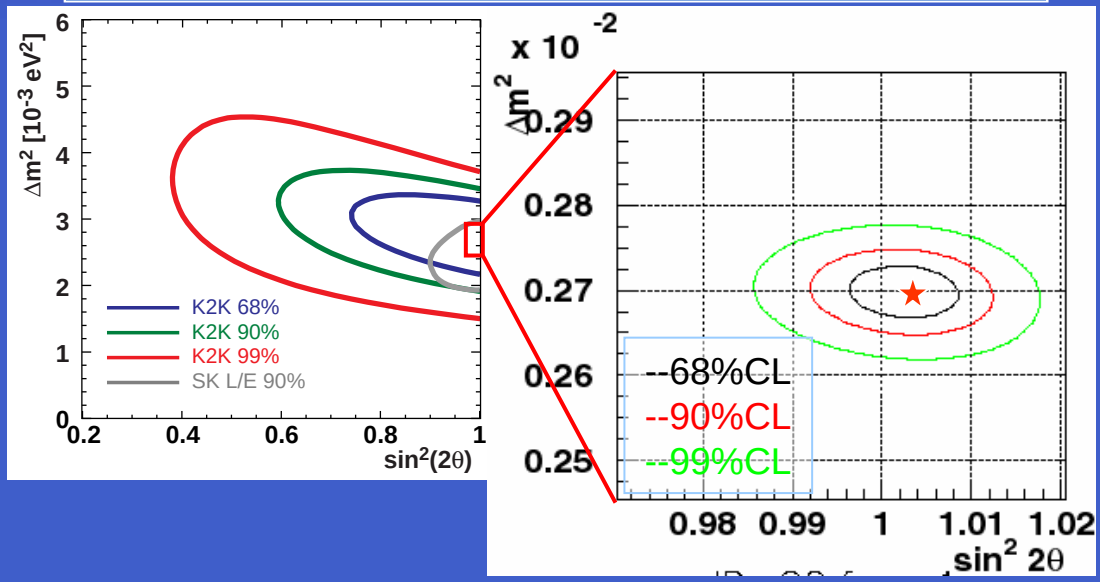
Requirements for systematics

- To estimate the neutrino beam properties with systematic uncertainty well below the SK statistical error
  - Neutrino flux: < 5%
  - Spectrum shape: width of shape, for example, < 10%
  - Non-QE/QE: < 5–10%
  - NC-1π^0, beam-ν_e: < 10%
  - SK energy scale: < 2%

T2K prospects

Precision of ν_μ disappearance measurement

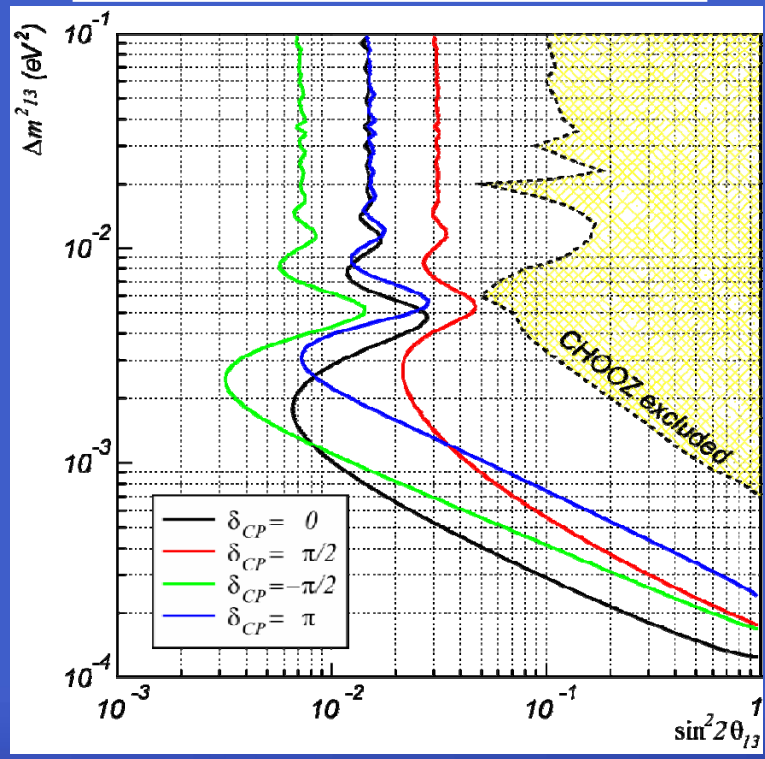
T2K 5 years (5×10^{21} pot), Stat. only



Goal : $\delta(\sin^2 2\theta_{23}) \sim 0.01$, $\delta(\Delta m^2_{23}) < 1\times10^{-4}$ eV^2

Sensitivity to ν_e appearance

T2K 5 years (5x1021 pot)
Stat.+10% B.G. syst.



Sensitivity down to $\sin^2 2\theta_{13}$~0.005

Summary and T2K schedule

- K2K confirmed the neutrino oscillation observed in atmospheric neutrino
  - Null oscillation: < 0.0015% (4.3σ)
  - Allowed region: $1.9\times10^{-3} < \Delta m^2 < 3.5\times10^{-3}$ eV^2 at $\sin^2 2\theta=1$ (90%C.L.)
- T2K: the next generation neutrino experiment
  - To measure Δm^2_{23} and $\sin^2 2\theta_{23}$ precisely
  - To discover ν_e appearance, measure the θ_{13}, and beyond

T2K schedule:

• Beam line construction started in April 2004	on schedule
• Start of ND280m detectors manufacturing	Fall 2006
• ND280 hall construction start	April 2007
• UA1 magnet installation	May 2008
• Complete ND280 building	December 2008
• 50 GeV MR commissioning	2008
• Begin installation of ND280 detectors	January 2009
• Neutrino beam line commissioning	April 2009
• T2K physics run	2009 ……