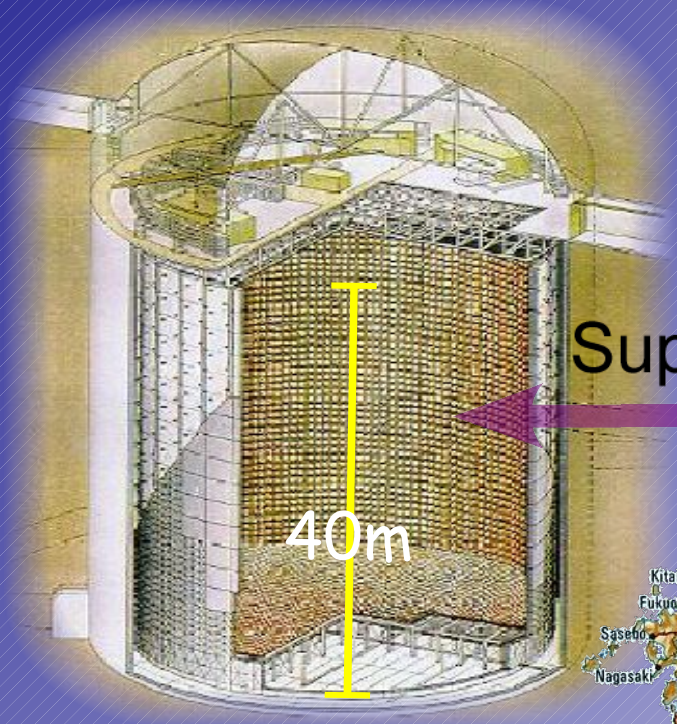
The J-PARC Neutrino Experiment T2K

Clark McGrew
Stony Brook

Tokai To Kamioka

295 km from target to SK

Beam 1° to 3° off axis



Super-Kamiokande

Tokyo

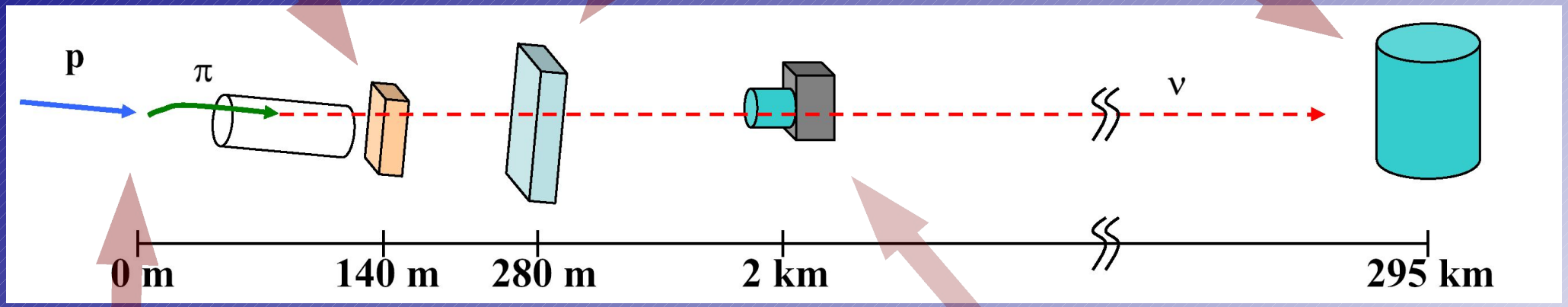
J-PARC

Experimental Layout

Muon Monitor

ND280m Detector

Super-Kamiokande



Beamline-Target-Horn

- See Yamada's Talk

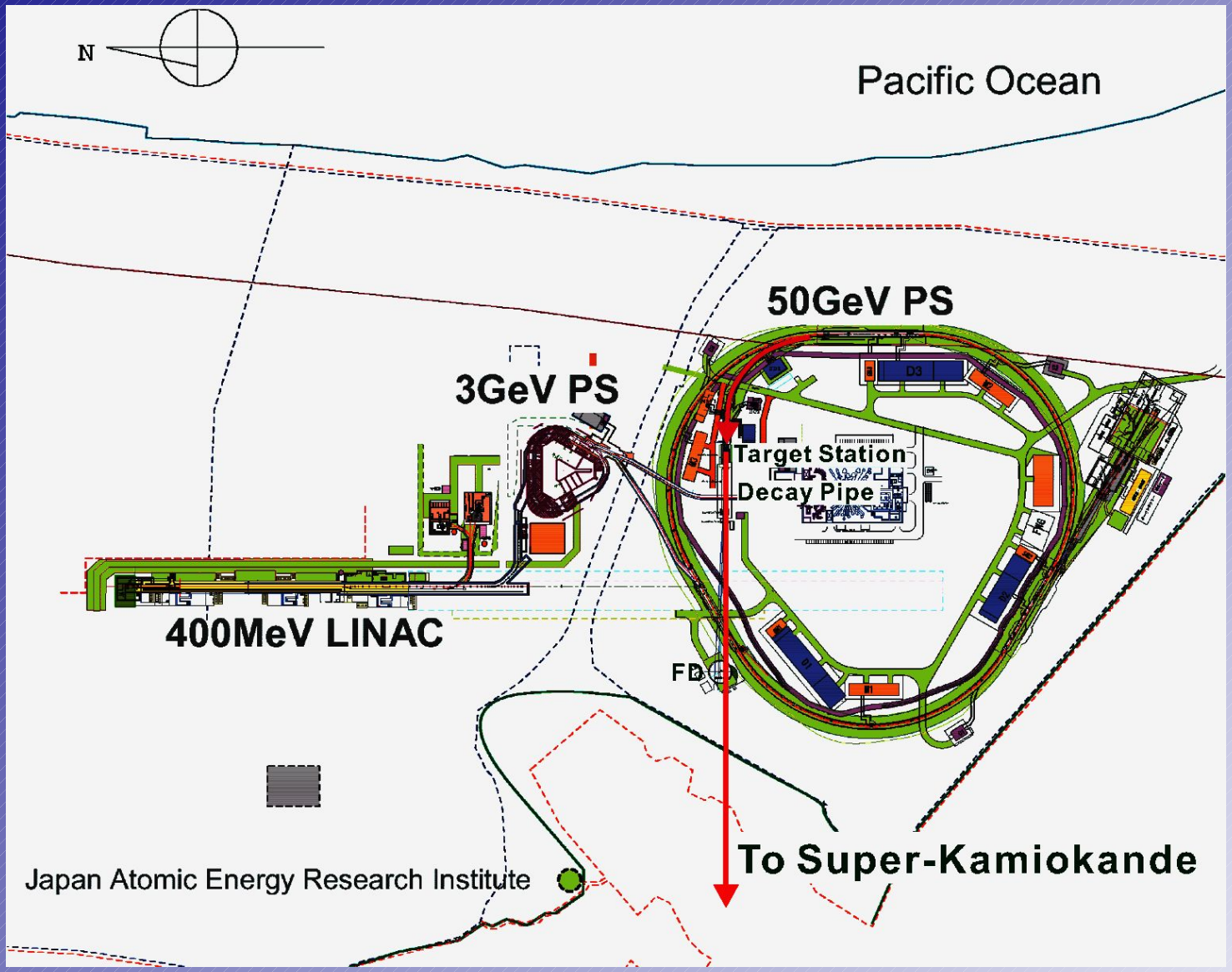
Possible 2km Detector

Idea: Measure Flux and Cross-sections at 280m and extrapolate to Super-Kamiokande

The Accelerator Complex

Aerial view looking south

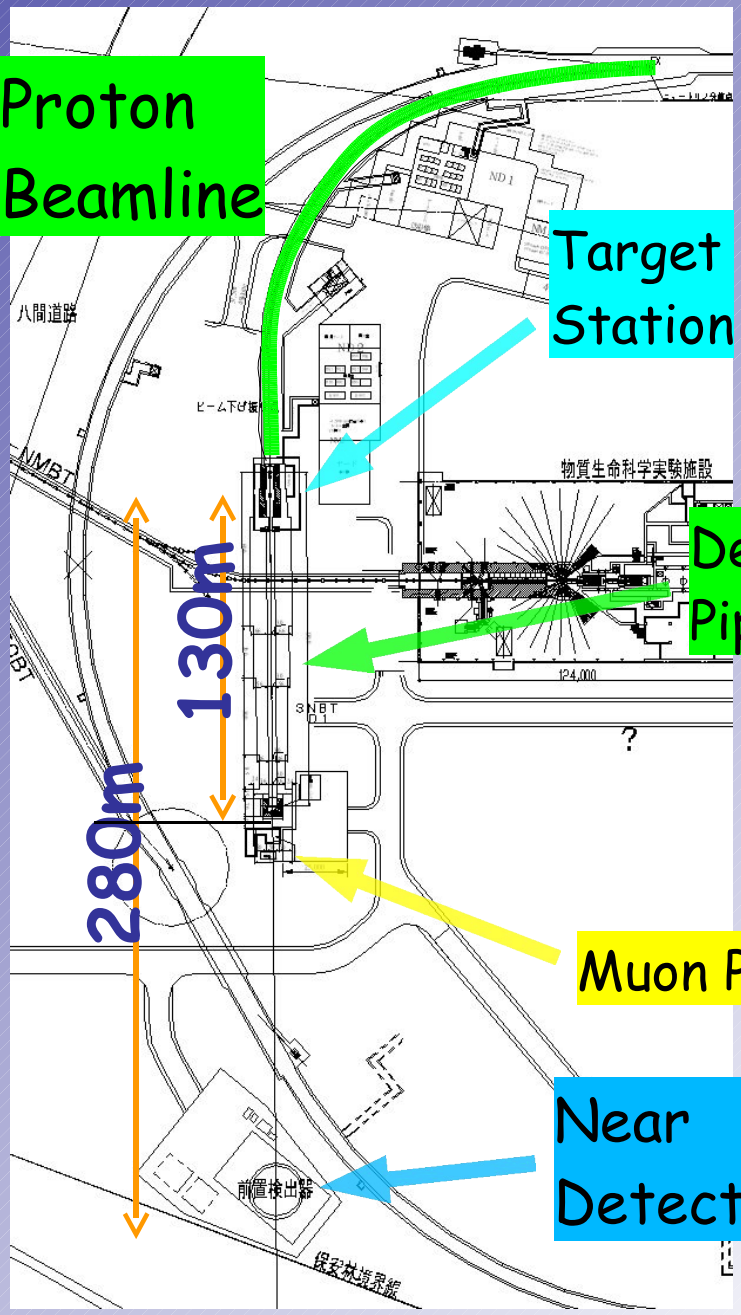
The J-PARC Facility



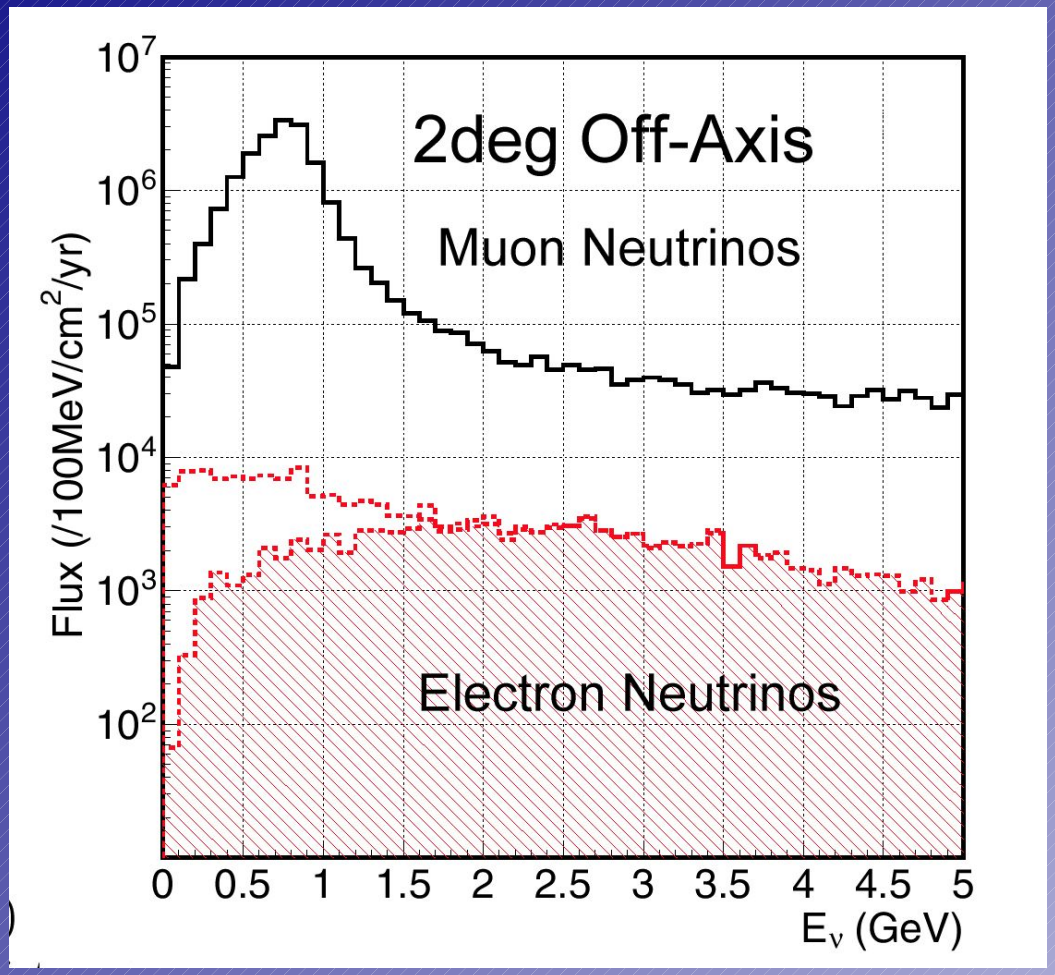
Commissioning FY2008, First Neutrino Data FY2009

Neutrino Beam Facility Overview

- Primary proton beam line
  - Normal Magnets
  - Combined Function Superconducting Magnets
- 10^{14} ppp
- 750 KW
- 3.6 sec/cycle
- Primary Energy 30-50 GeV
- Construction Ongoing
- Deliver 10^{21} pot in 5 years

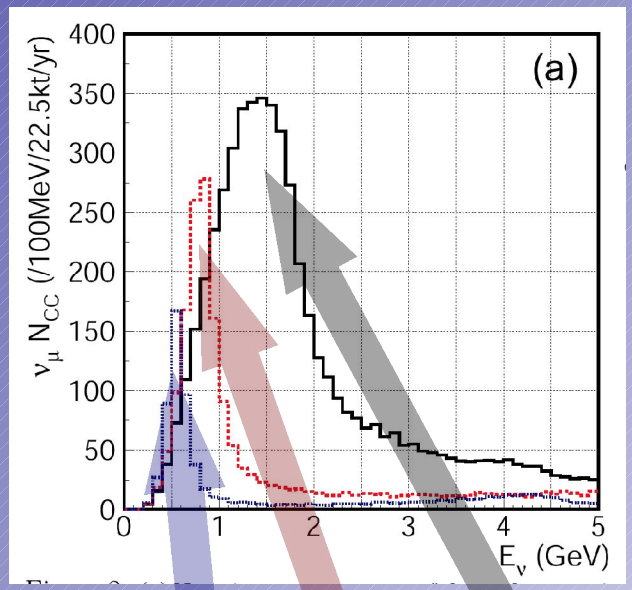


Events at Super-Kamiokande



Neutrino Flux

Events in Super-K



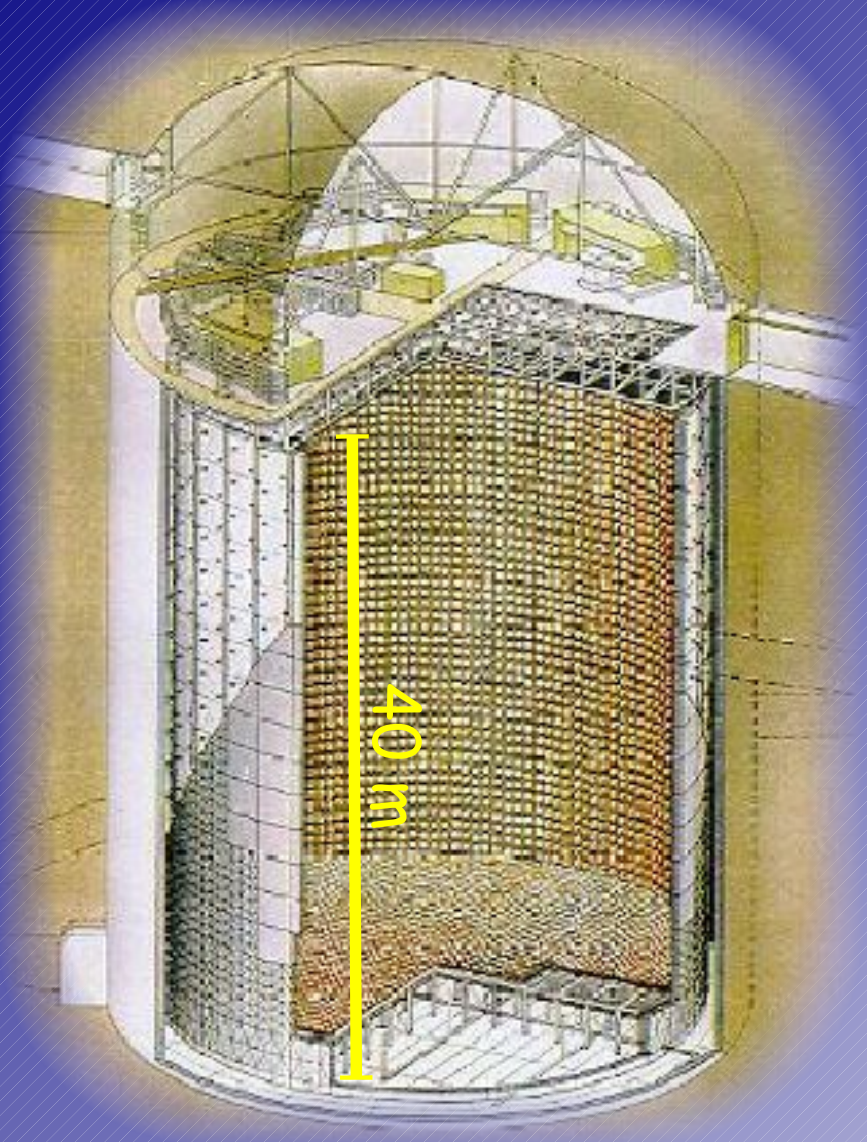
1 Degree

2 Degree

3 Degree

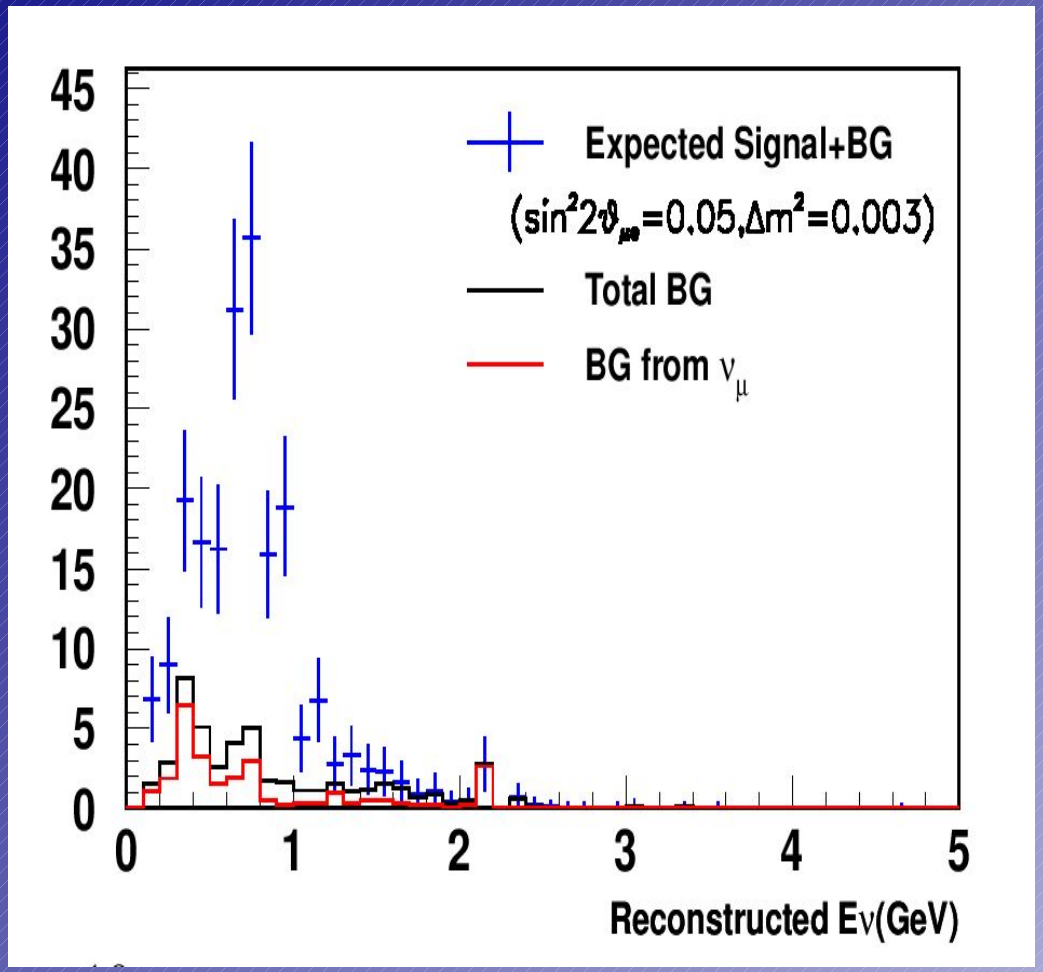
Tunable Beam Direction

The Far Detector: Super-Kamiokande



- Restore to Original Configuration
  - Begin in 2005
  - Restore to 40% PMT coverage
  - Add ~5000 20" PMTS
- Possibly Upgrade Electronics
- Improved PID and Ring Counting
- Solar Neutrino Trigger to 4.5 MeV

Electron Neutrino Appearance

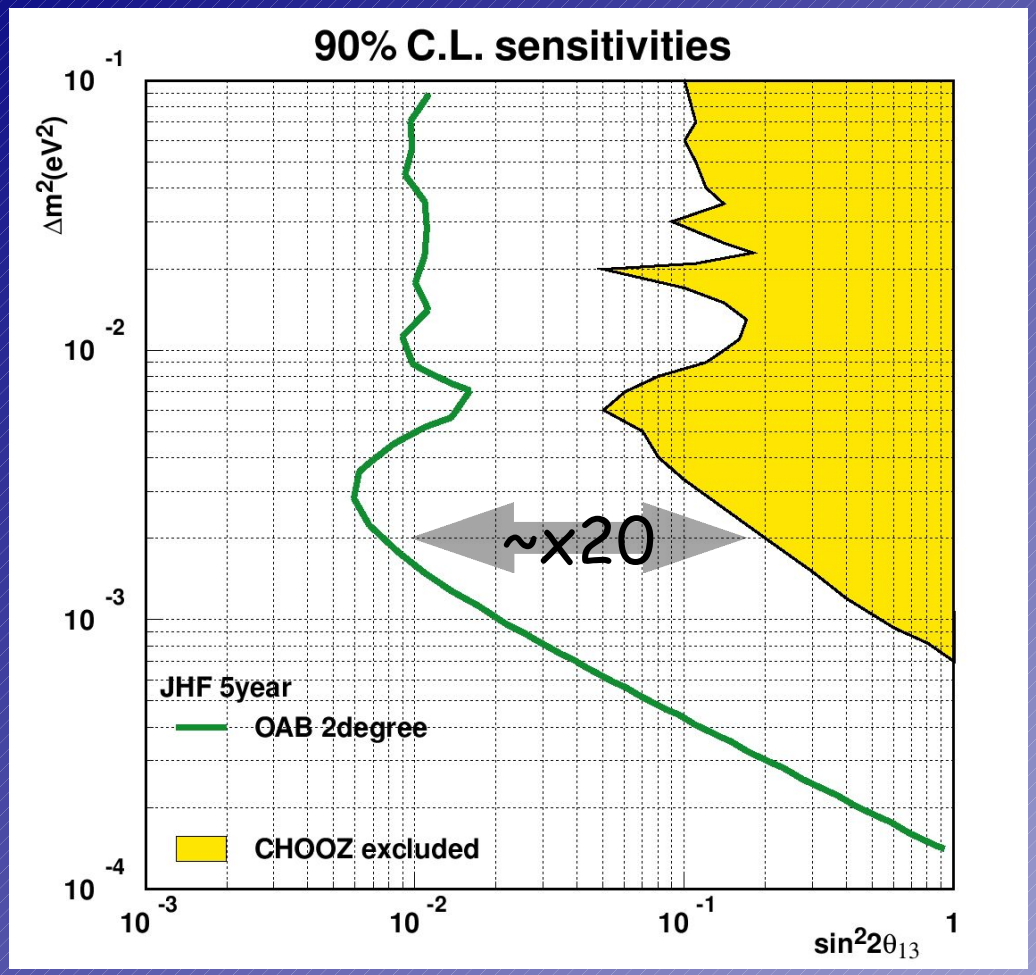


10^{21} Protons On Target

2° Off-Axis Beam

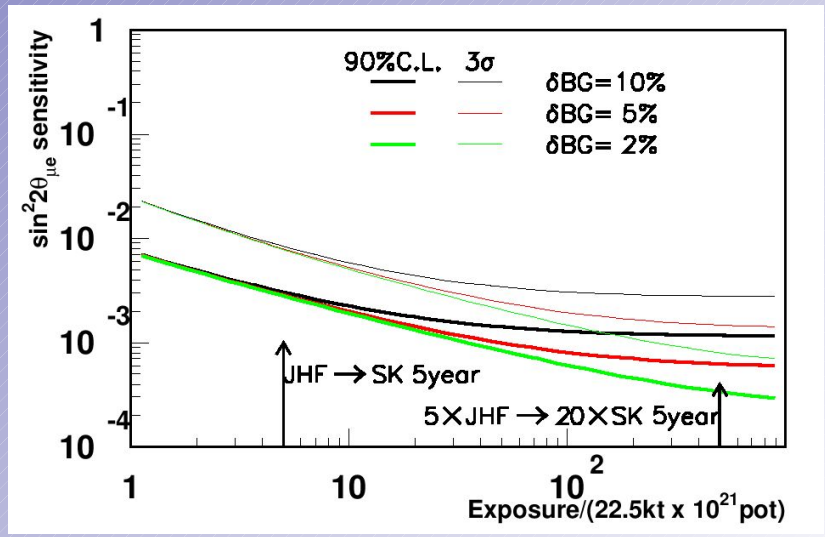
θ_{13} on edge of CHOOZ allowed region

Sensitivity to θ_{13}



- 10^{21} protons on target
- Background Rejection
- Control Systematics to 10%

Ambitious



- $\sin^2 2\theta_{13} \sim 0.006$
- $\sin^2 2\theta_{\mu e} \sim 0.003$

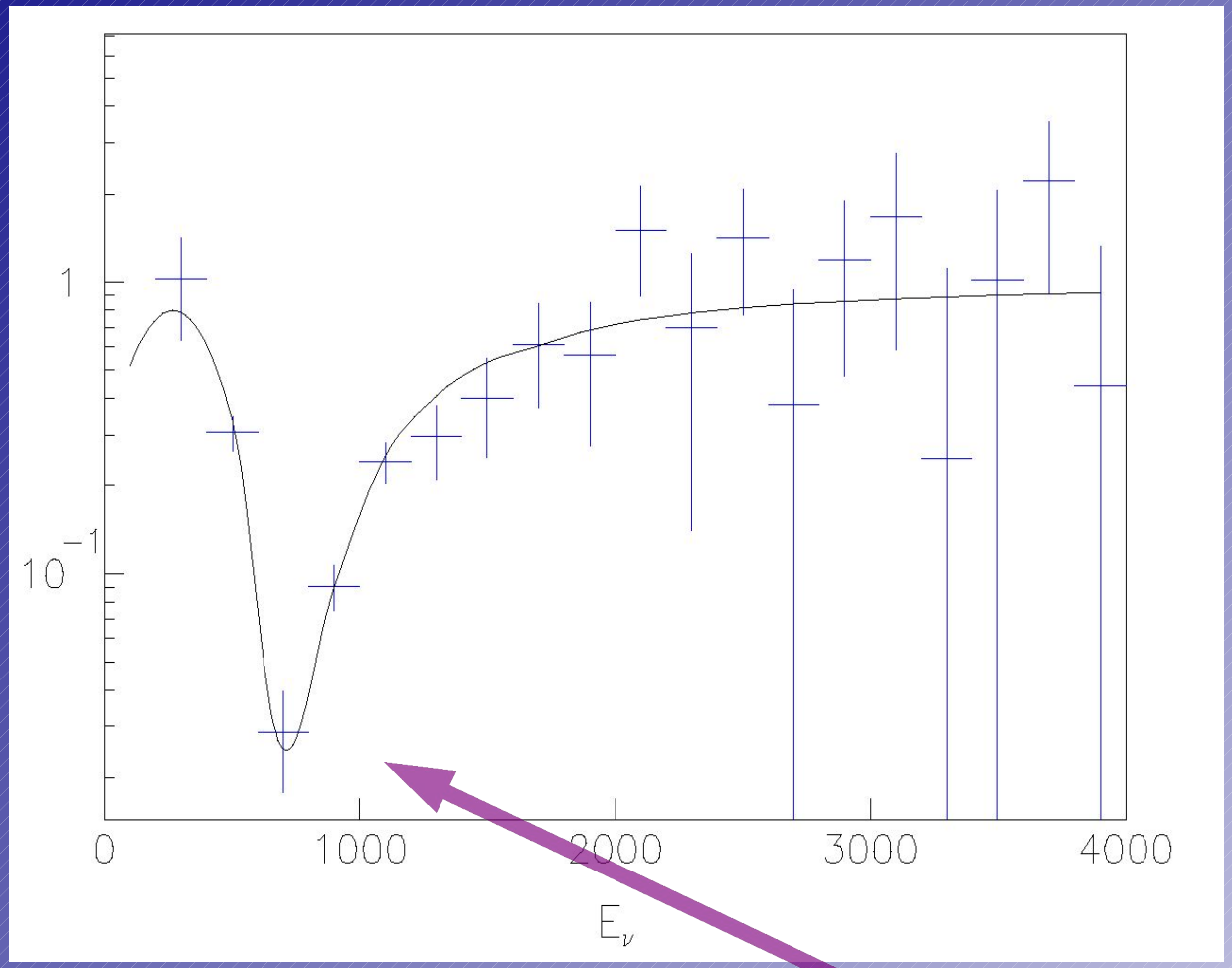
Systematic Error Budget For K2K ν_e Appearance

Control With Near Detector

Neutral Current Cross-section	25%	→	~5%
Ring Counting	15%	→	~5%
Particle ID	11%	→	~5%
Near/Far Ratio	6%		
Energy Spectrum	1%		

ν_μ to ν_τ Oscillations

Ratio of "Data" to Monte Carlo
$\sin^2 2\theta = 1$, $\Delta m^2 = 0.003\ eV^2$



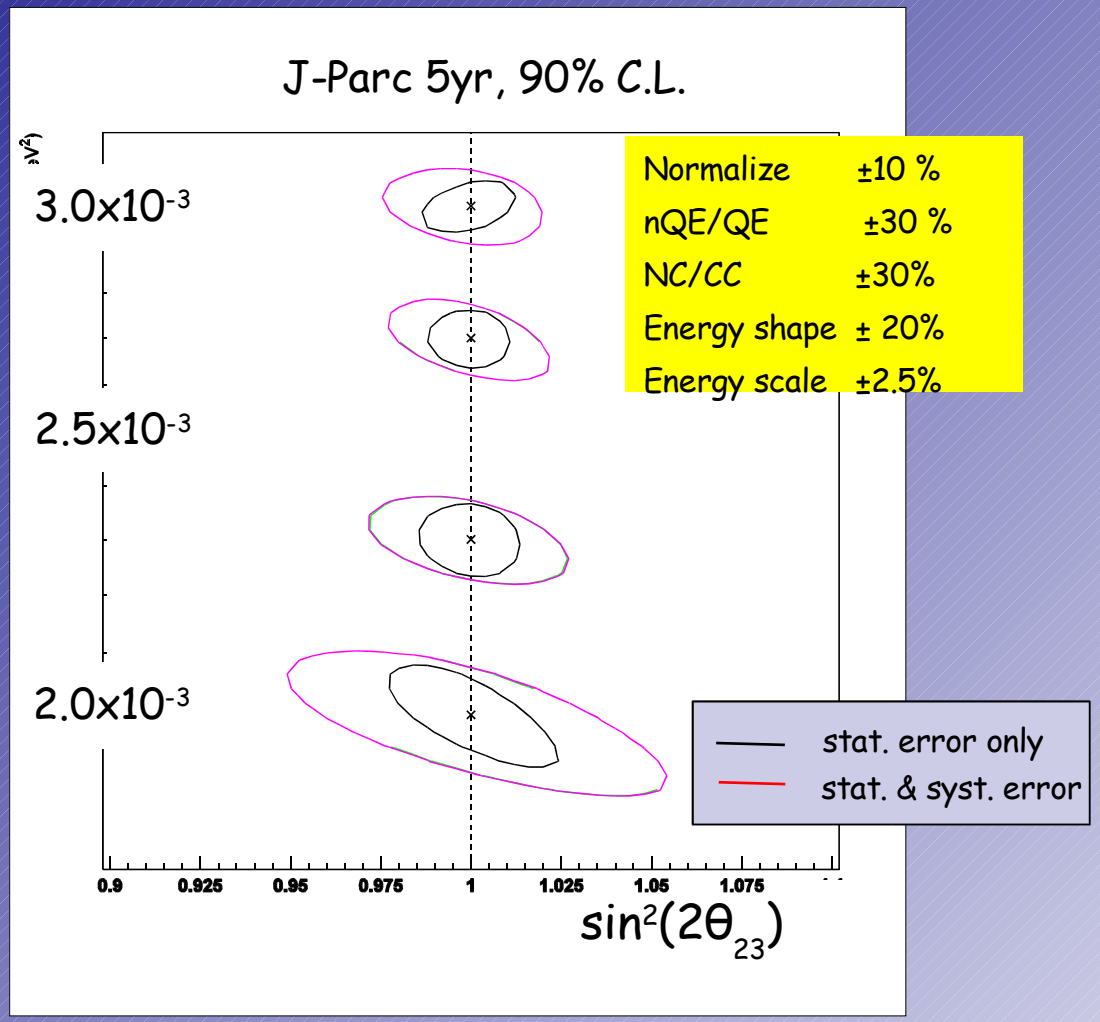
Comparable to K2K
- (6% in Normalization)

- 10% Flux Normalization
- 20% Bkgnd. Uncertainty
- 2.5% Energy Calibration

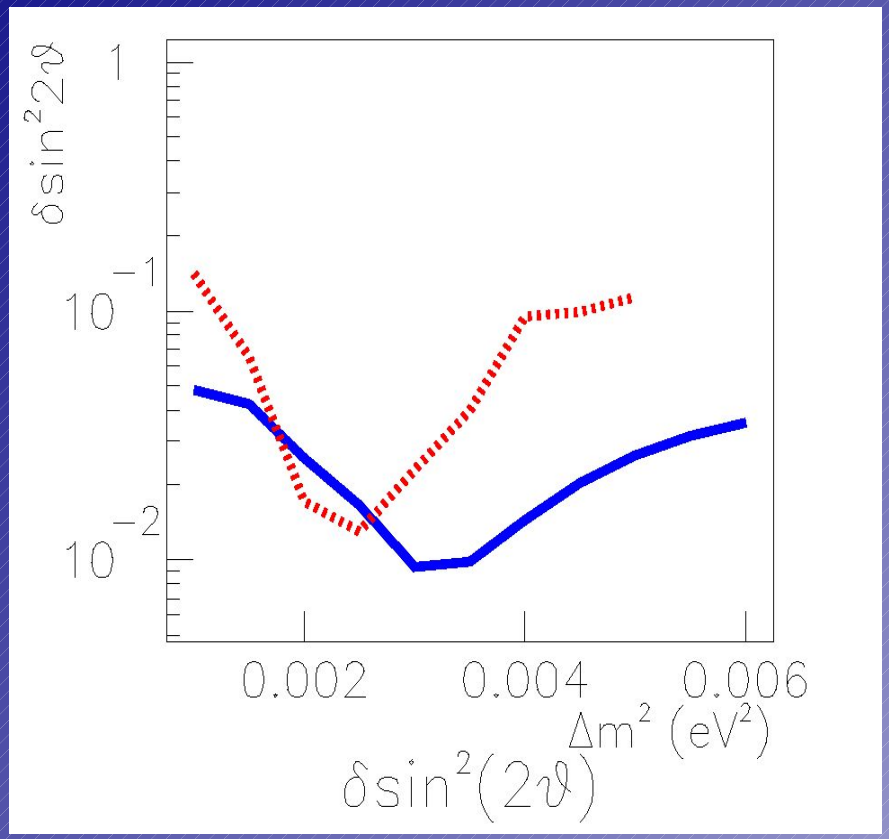
Comparable Super-Kamiokande
- (2.5% for muons)

97% Reduction at Osc. Max.

Effect of Systematic Uncertainty

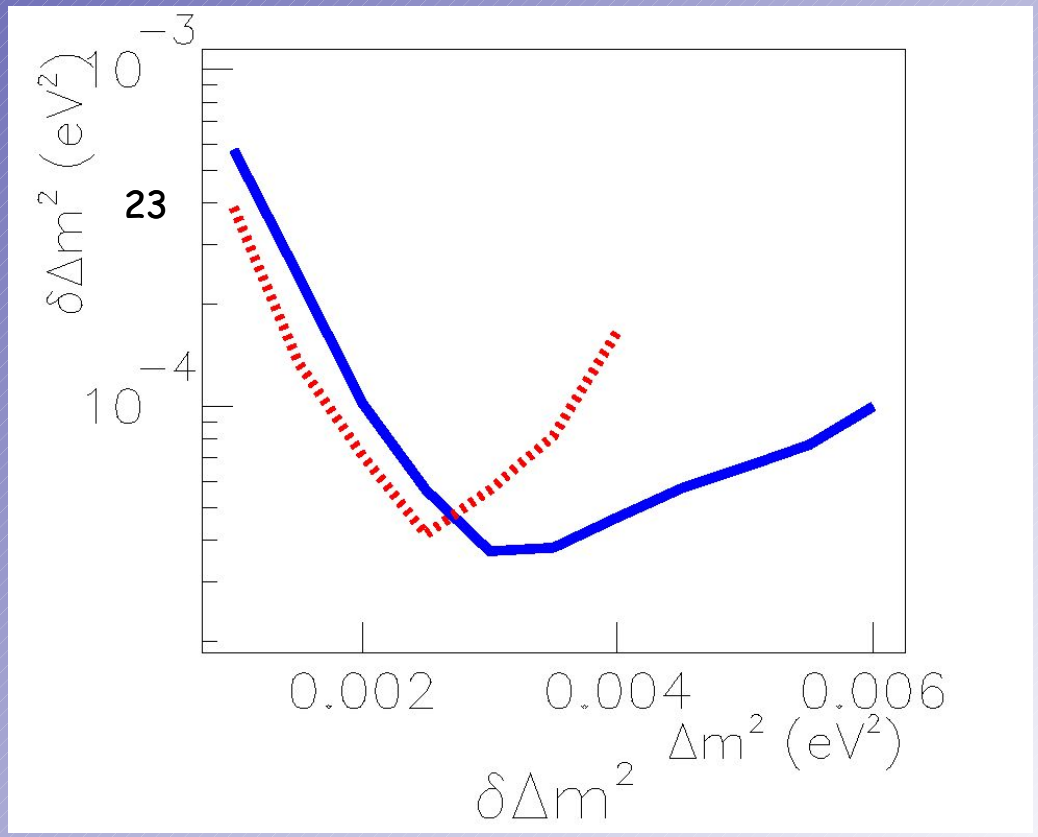


μ to τ Parameter Sensitivity



δ sin²2θ$_{23}$

δ Δm²$_{23}$

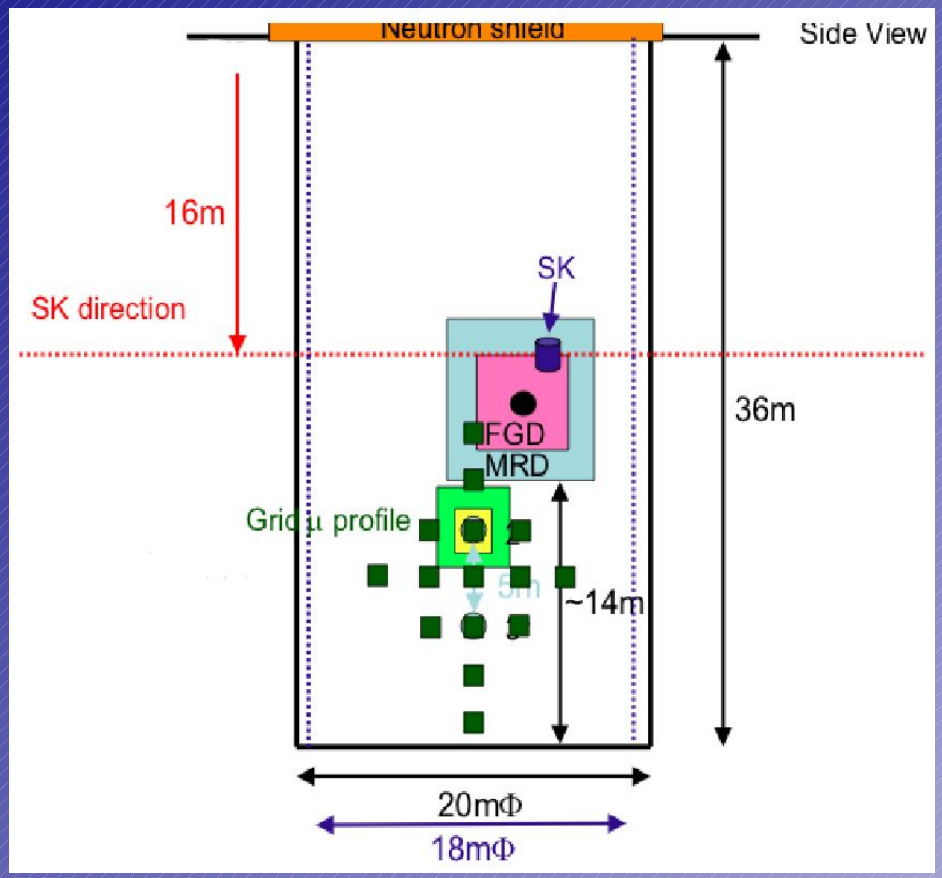


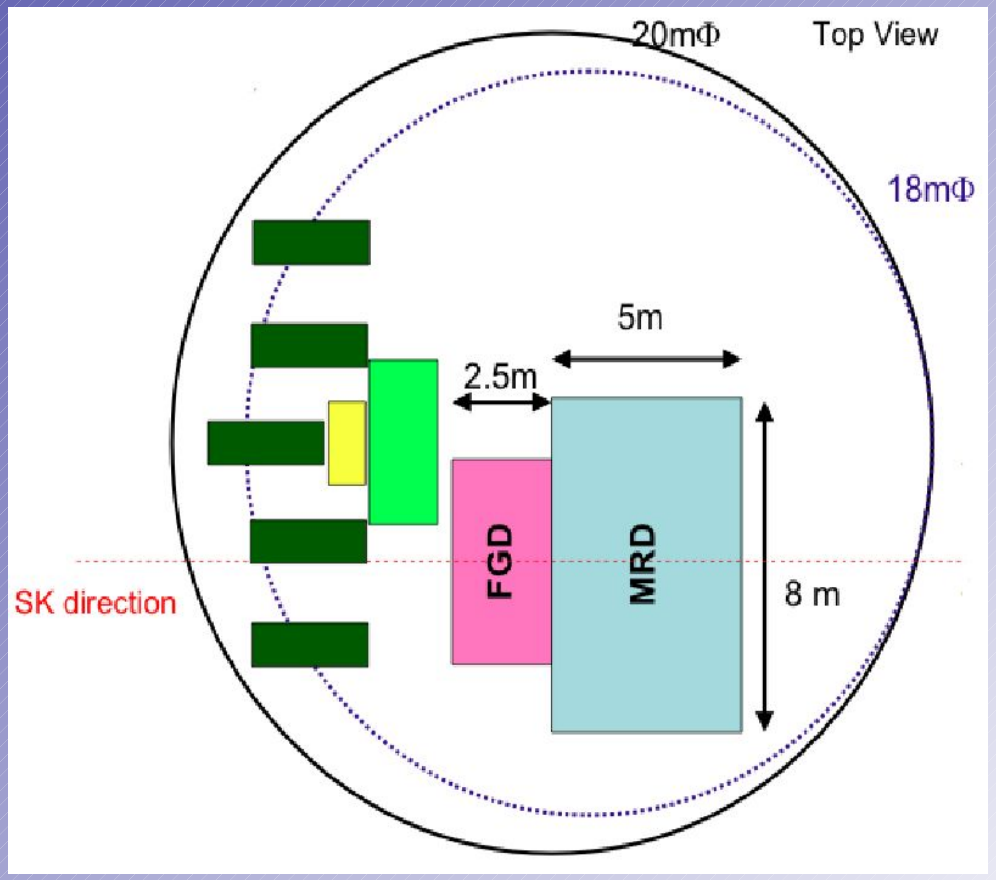
Goals Of the Near Detectors

- Monitor neutrino beam direction
- Predict the neutrino fluxes at SK
  - Contributions from π, μ, K^+, K^0
- Determine background to ν_e search
  - π^0 production on oxygen.
- Determine non quasi-elastic background
  - cross-sections on oxygen
- How much Δ goes to N+γ (1 γ production)?

The ND280 Conceptual Design

Ground Level Here



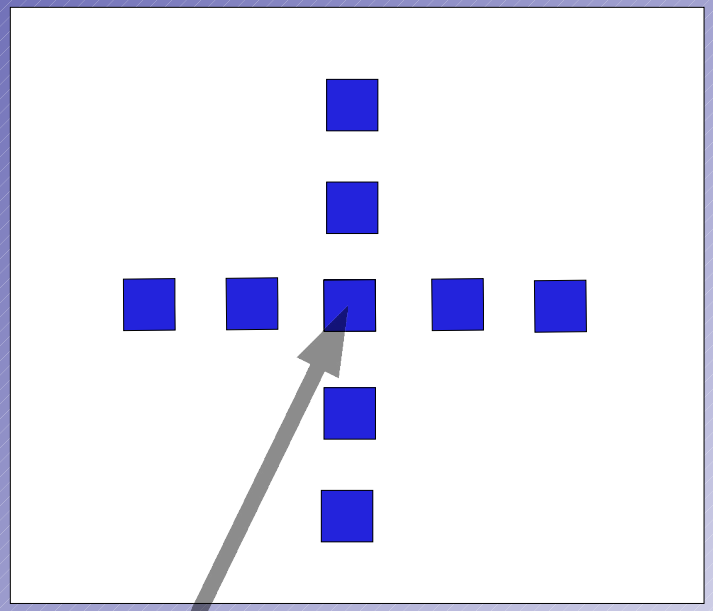


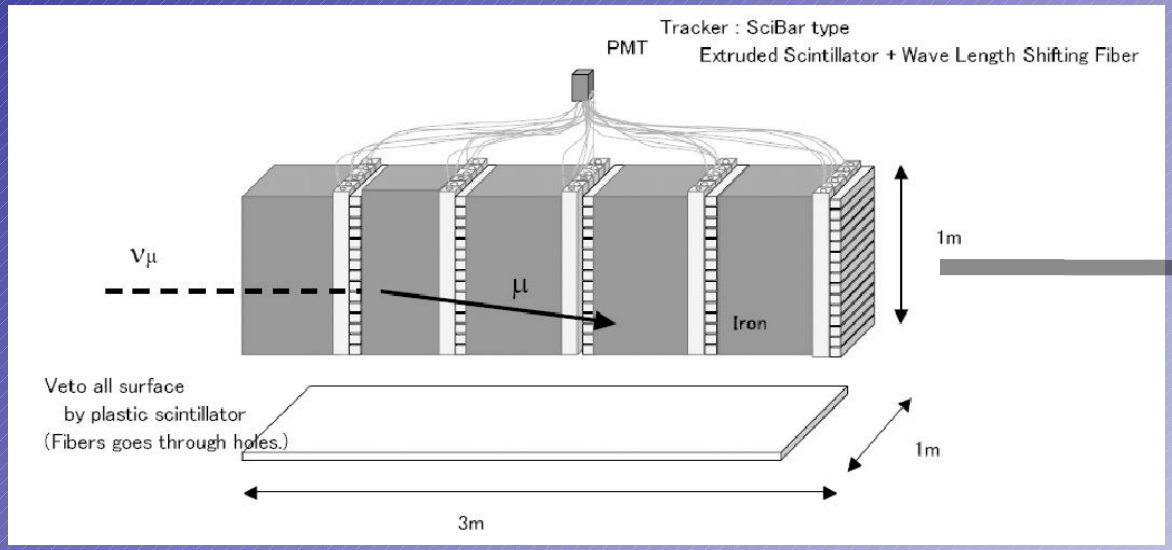
Side View

Top View

ND280 On-Axis Neutrino Detector Concept

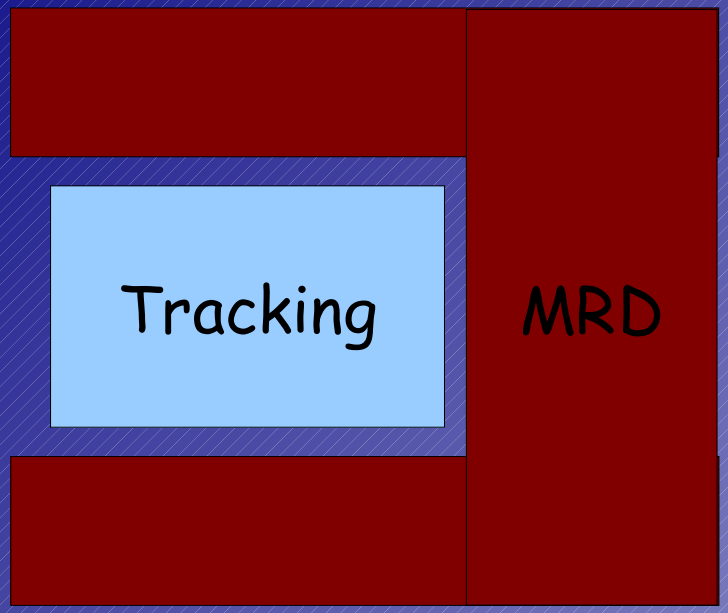
- Simple Detector
- Measure Beam Position and Profile
- With Calorimetry gives access to beam meson spectrum

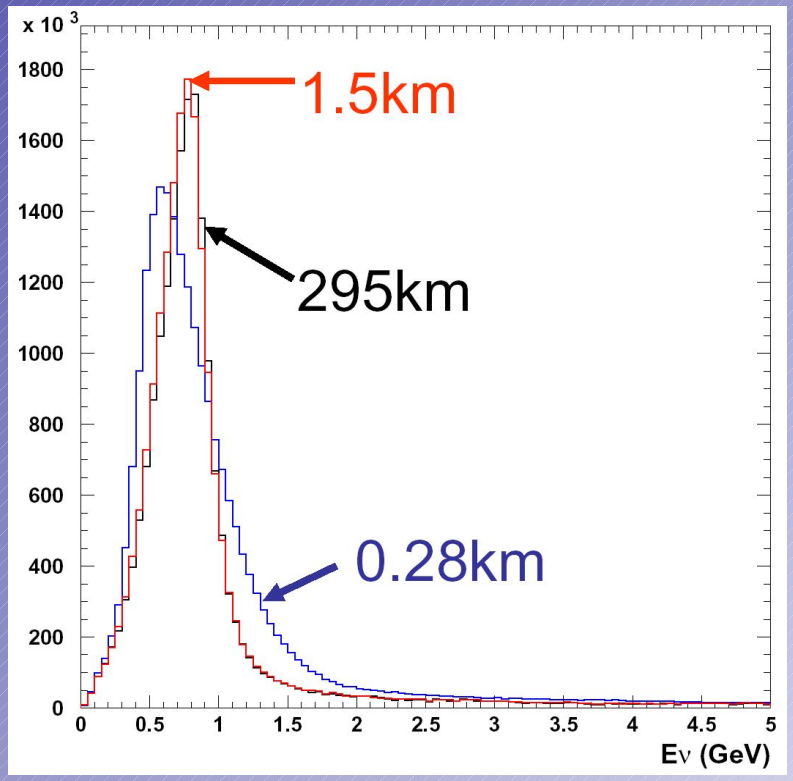




Beam Direction

ND 280m Off-Axis Detector





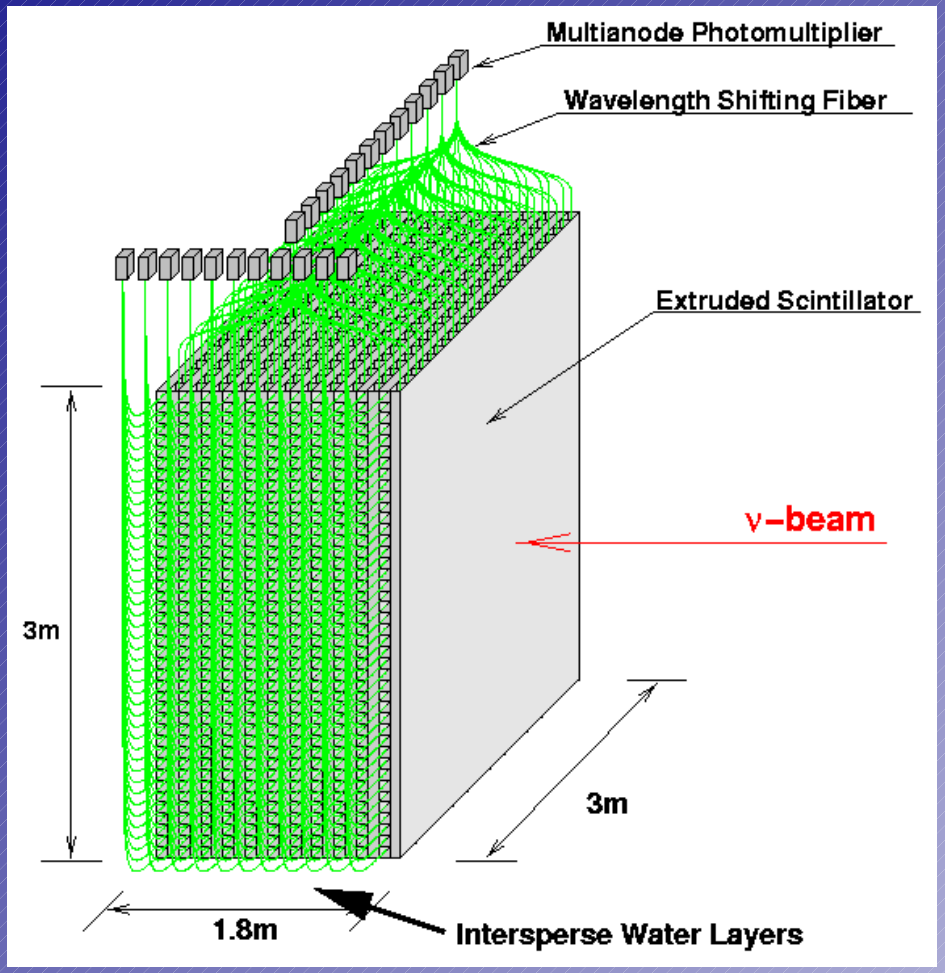
Technologies Will Be Determined During Tech. Design Phase

- Spectrum Similar to SK
- Determine beam meson kinematics to predict SK beam (using QE events)
- Measure NC/CC ratio
- Detailed cross-section measurements with fine-grained tracking and calorimeter

Possible Off-Axis Fine Grain Tracker Designs

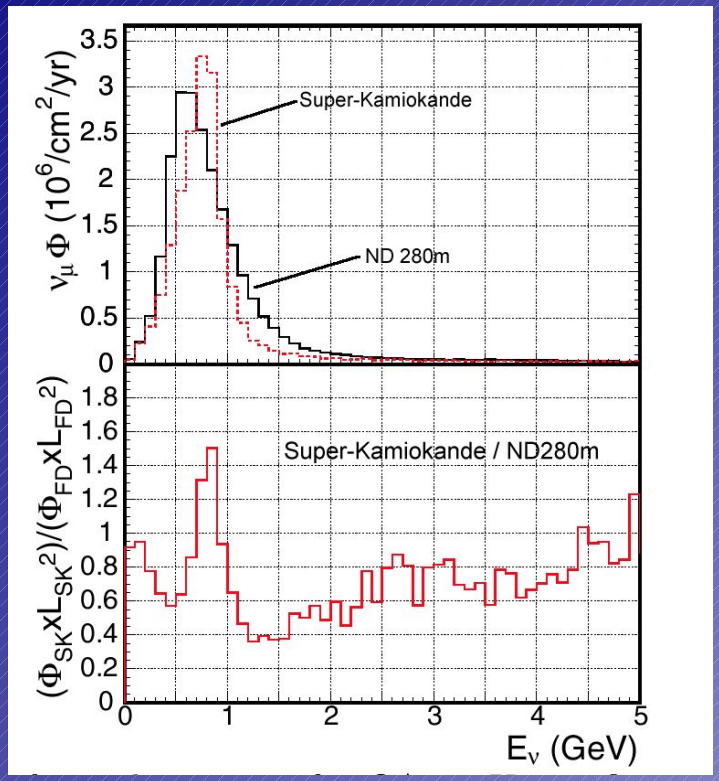
- Three Designs have been suggested
  - SciBAR: K2K
    - Pro: Exists
    - Con: Course Granularity, Water target is difficult
  - Large Triangular Bars: Minerva
    - Pro: Being "Prototyped" by Minerva
    - Con: Enough Granularity? Select Oxygen events statistically
  - Small Triangular Bars: D0 Pre-Shower
    - Pro: Great Granularity, demonstrate vertex is in water target
    - Con: No current ν application

Working Design I: The SciBAR



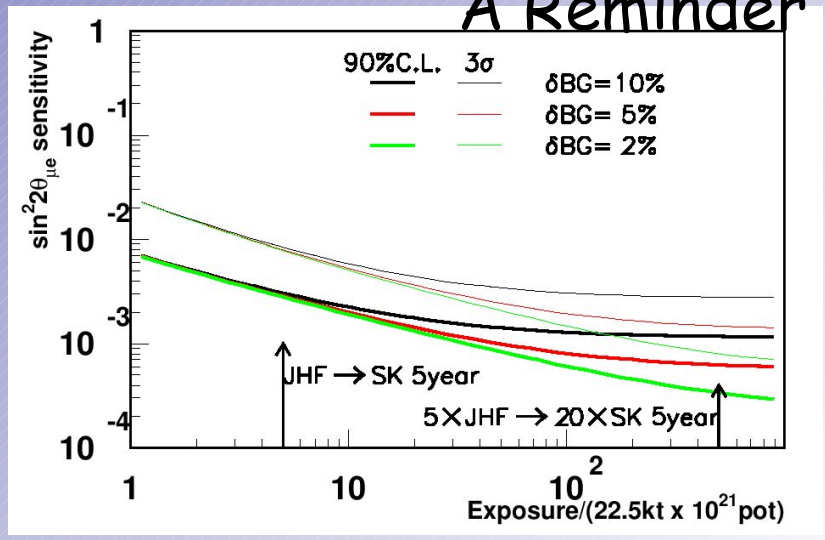
- Fundamental Structure Shared by all designs
  - Planes of Scintillator
  - Interspersed Water?
- Variations
  - Granularity
  - Bar Shape
  - Photodetection Tech.

What about a 2km Detector?



- Electron Appearance Statistics Limited
  - Maybe required after a few years
- Not officially approved by Japanese government
- There is a strong US group seeking funding

A Reminder



At 2km Near/Far Ratio constant within ±10%

May make it easier to understand NC background.

Status & Schedule

- Approved by MEXT
  - 5 year construction (16B-yen)
  - Includes funds for beamline and ND280
  - Does not include funds for 2km detector
- Initial Design for ND280 by August
  - Technical Design Proposal in One Year
- Expect Collaboration Agreement in August
  - Sets Timeline for U.S. Proposals
  - Proposal expected later this year

U.S. Involvement in T2K

- Crucial Cost Reductions
  - BNL and KEK are Collaborating on Superconducting Magnet Technology
- Design and Study T2K Physics Reach
- Strong Leadership Role in Collaboration
  - U.S. Chairs the IBR (Interim Board of Review)
  - Co-Chairing of Working Groups
  - Good working relationship with Japanese Leadership through K2K

U.S. Contribution: Magnets

- U.S. (BNL) played in Guiding R&D to SC Combined Function Magnets
  - Close Collaboration between KEK and BNL
- First Large SC Combined Function Magnets
  - Requires correction coils (BNL has Expertise)
- Possible U.S. Contribution: 32 Correction Coils (<$1M)

U.S. Contribution: Neutrino Horn System

- U.S. Members have Experience with MiniBooNE horn (Colorado)
  - Required State of the Art Technology
- Possible U.S. Contribution: Input to Design and Instrumentation of Horn Systems

U.S. Contribution: ND280 Fine Grained Tracking Detector

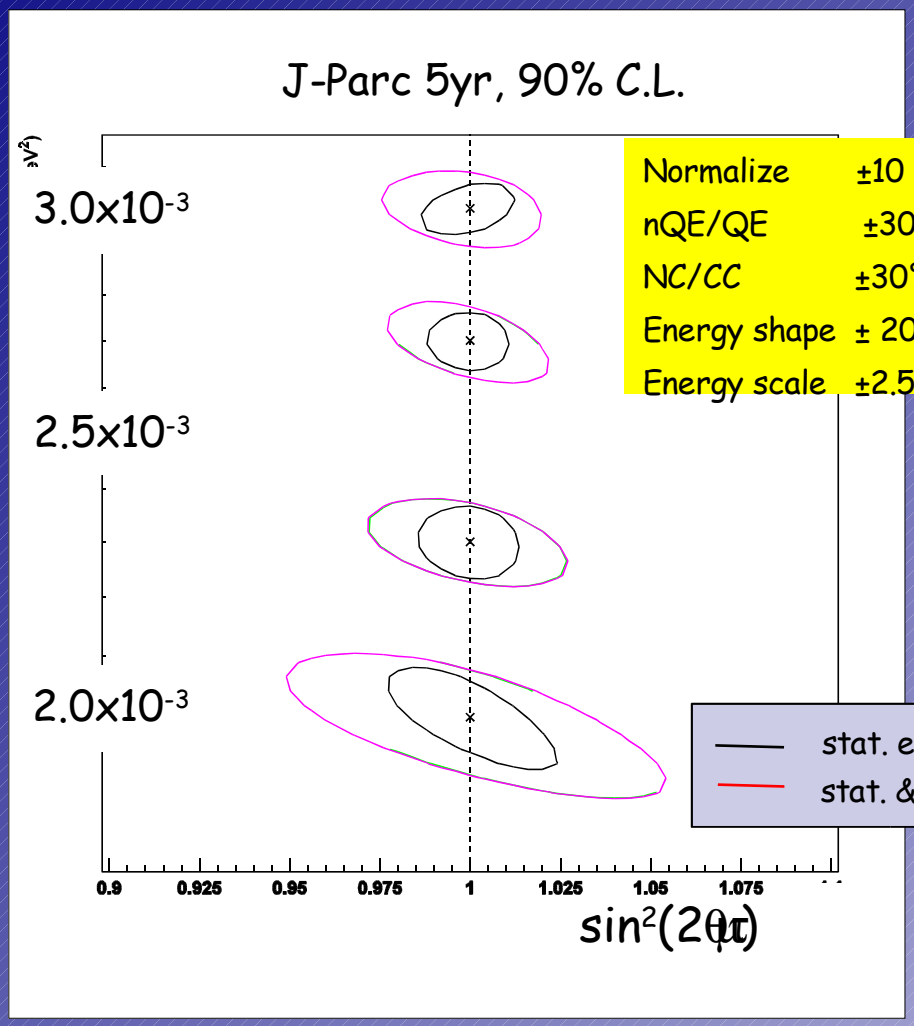
- U.S. Experience with Scintillation Trackers
  - D0 Pre-shower Detector (SUNY-SB)
  - MINERVA (Rochester)
- A Consortium will bid for construction.
  - Total Cost: $5M - $8M
  - U. Penn, Rochester, Stony Brook
- A crucial and Highly Visible contribution to the success of T2K

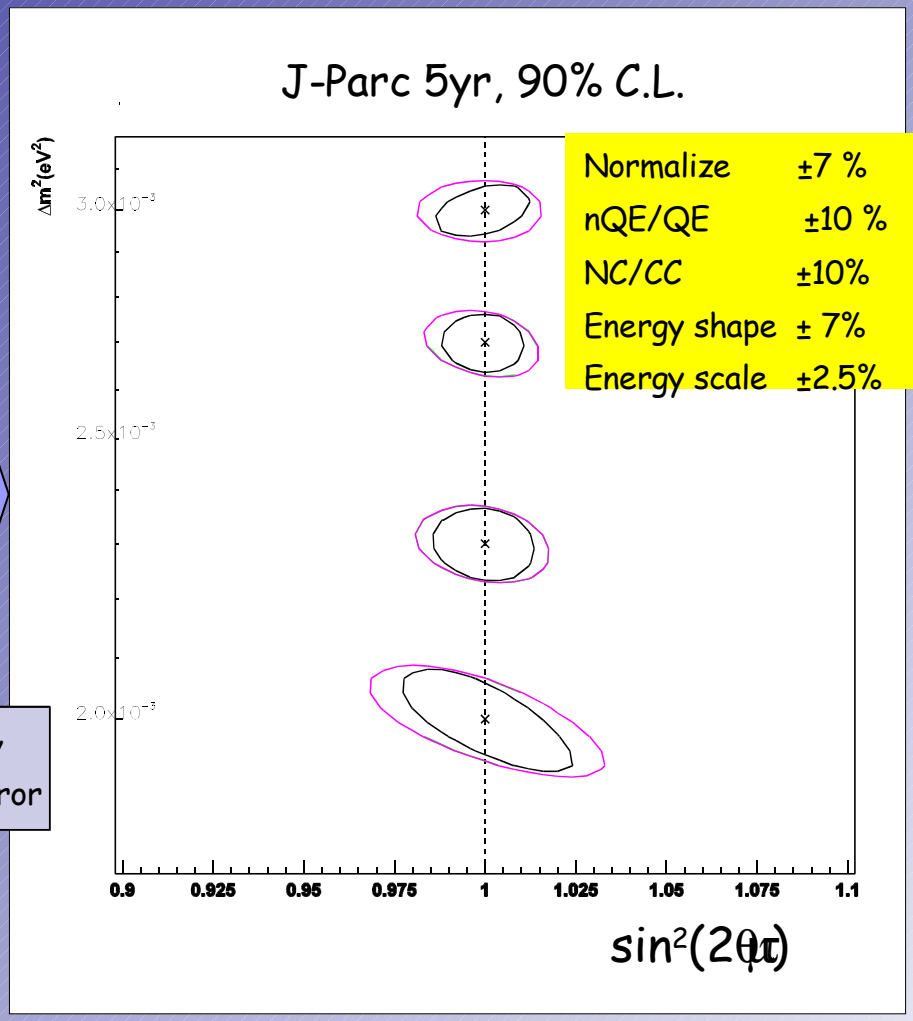
Summary

- T2K approved by MEXT for FY2004
- Sensitivities
  - $\sin^2 2\theta_{13} > 0.006$
  - $\delta \Delta m^2_{23} \sim 0.0001\ eV^2$
  - $\delta \sin^2 2\theta_{23} \sim 0.01$
- Commissioning in 2008
- Physics data in 2009
- Strong US interest to participate in Beamline/ND280m, and 2km detector

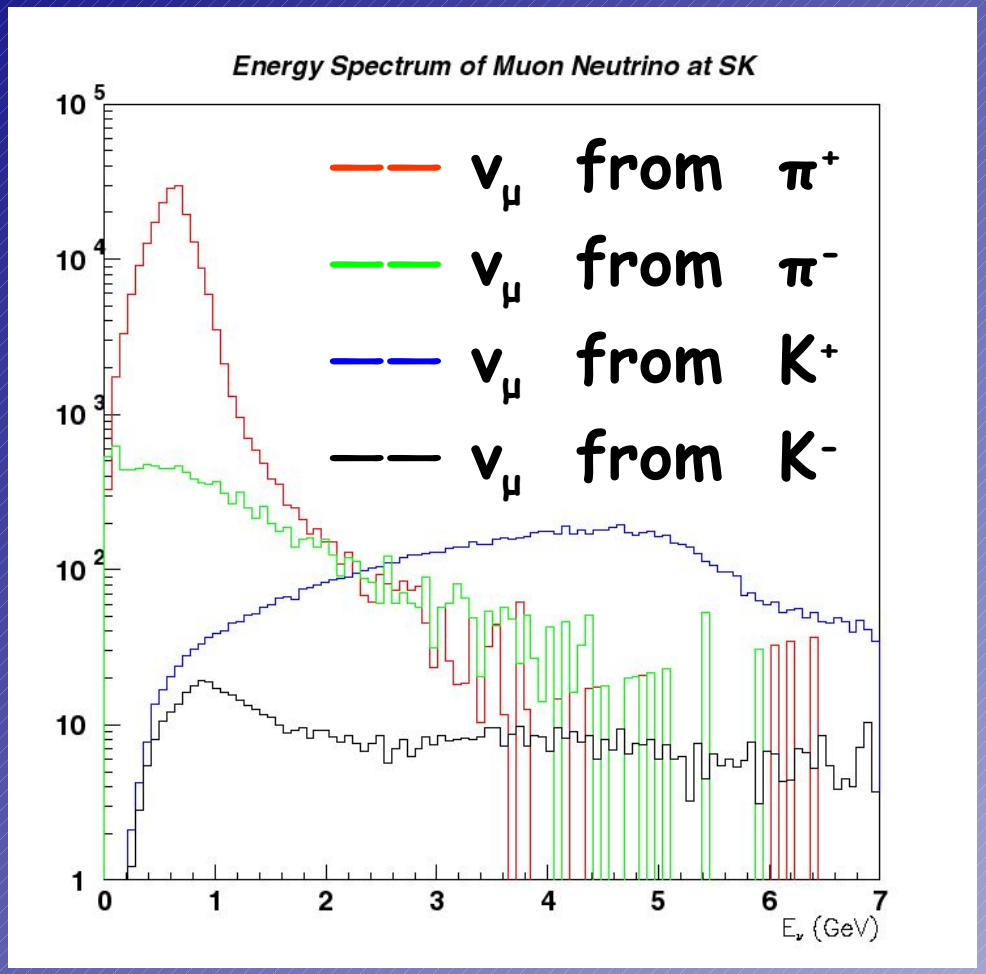
THE END

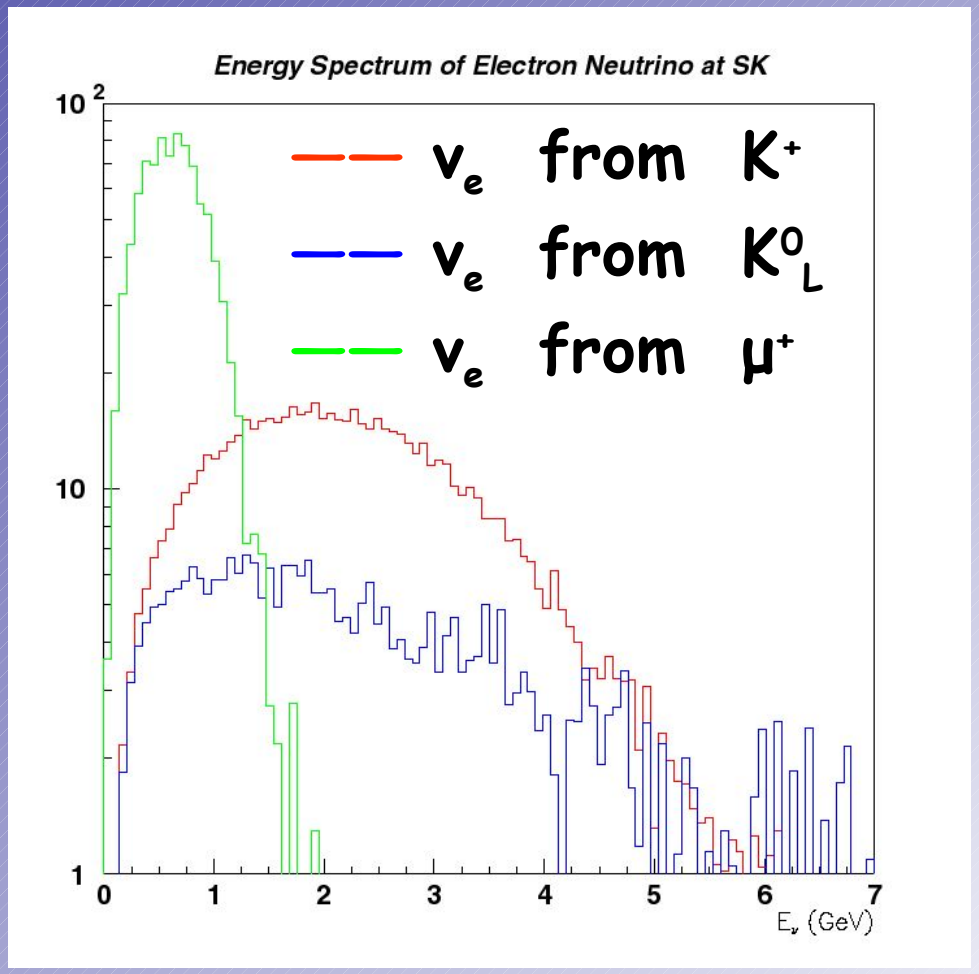
Effect of Reduces Uncertainty





Expected Flux at Super-Kamiokande
(2.5°° off-axis)



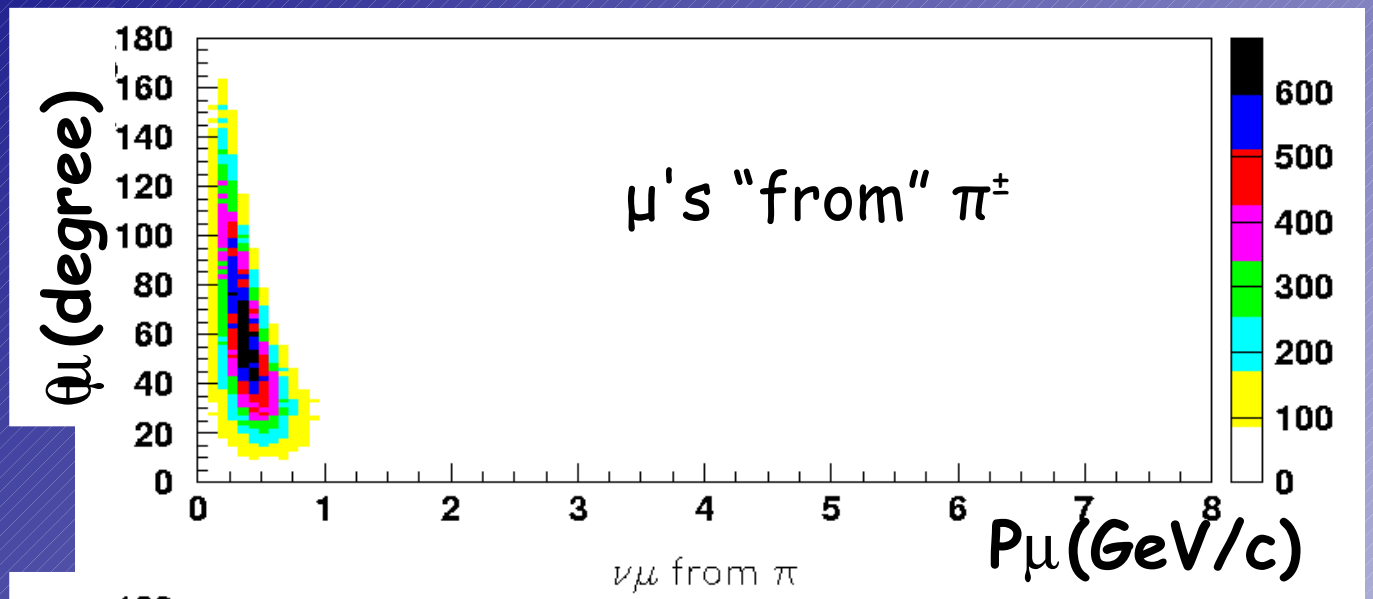


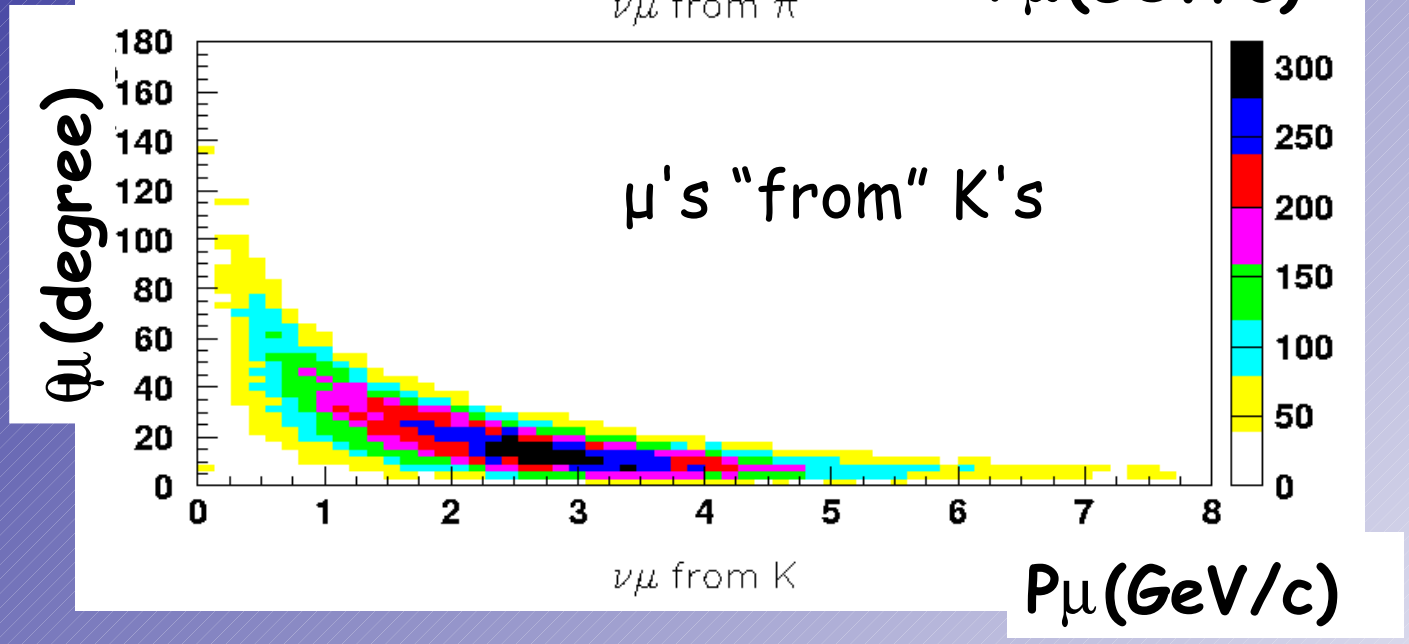
True $E_{\nu\mu}$(GeV)

True $E_{\nu e}$(GeV)

Use Near Detectors to Predict Flux

Contributions from K and π





ND280-off can clearly separate these two contributions.