Summary of T2HK Near Detector Discussion

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Agenda

- Physics Requirements
- Ultimate capability and aging of the T2K ND280 detector
- New near detector ideas
- Organization of work

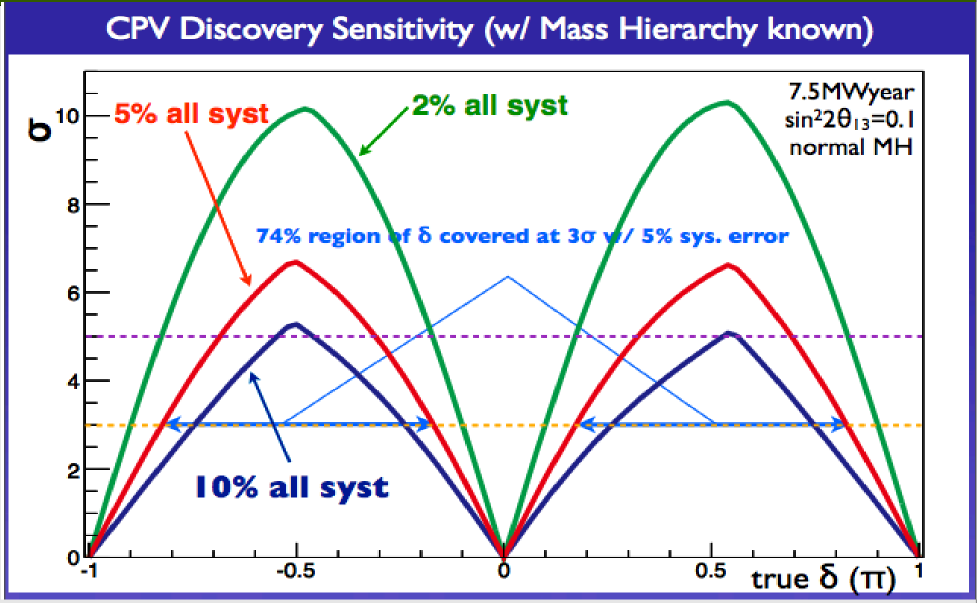
Physics Requirements

7.5MWy	ν		anti-ν	
	Signal	BG	Signal	BG
N(δ=0)	3458	1145	1900	1118
Fraction	75.1%	24.9%	63.0%	37.0%
Syst. (*)	0.038	0.012	0.031	0.019

* Contribution to total error assuming 5% syst for each component.

NB: BG may be further reduced w/ new recon.

M. Yokoyama



- To achieve the full potential in CP violation measurement → systematic errors at 2% level
- Sensitivity plots have been produced with a simple model for systematic errors
- Need sensitivity studies with more realistic systematic error treatment to guide near detector requirements

Better Understanding of Physics Requirements

To understand near detector requirements, need better understanding of requirements for CP violation measurement

- How important are correlations between neutrino/antineutrino predictions and wrong-sign/right-sign components?
- How important is the uncertainty on lepton kinematics/neutrino energy relationship or other uncertainties that affect the spectrum shape?
- How large is the NC background with reconstruction improvements and can it be solely constrained by HK?
- What are the requirements for the flux extrapolation, i.e. is 280m $\rightarrow$ 295km sufficient or do we need 2km detector?

T2K Systematic Errors

Error source	$\sin^2 2\theta_{13}$= 0	0.1
Beam flux & ν int. (ND280 meas.)	8.5	5.0
ν int. (from other exp.)		
$x_{CCother}$	0.2	0.1
x_{SF}	3.3	5.7
p_F	0.3	0.0
x^{CCcoh}	0.2	0.2
x^{NCcoh}	2.0	0.6
$x^{NCother}$	2.6	0.8
x_{ν_e/ν_μ}	1.8	2.6
W_{eff}	1.9	0.8
$x_{\pi-less}$	0.5	3.2
$x_{1\pi E_\nu}$	2.4	2.0
Final state interactions	2.9	2.3
Far detector	6.8	3.0
Total	13.0	9.9

- Beam flux & ν int. (ND280 meas.) → Flux error and part of cross section model constrained by near detector
- x_{SF}, p_F → Modeling of initial state of nucleus
- x_{ν_e/ν_μ} → Uncertainty on ν_e cross section
- W_{eff}, $x_{\pi-less}$ → Behavior of Δ resonance in nuclear medium

- Not included in T2K analysis so far: uncertainty on the relationship between neutrino energy and lepton kinematics due to multinucleon correlations
- No estimate of uncertainties when running in anti-nu mode

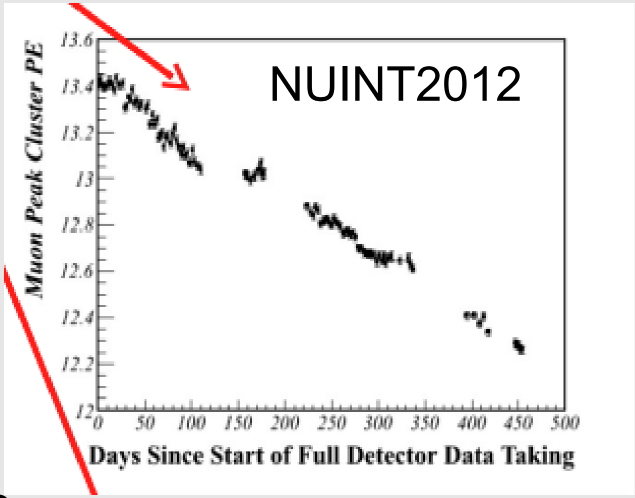
Ultimate ND280 Capability

We need to consider the ultimate capabilities and limitations of ND280 in the following areas:

- Measurements on oxygen: not done yet
- Irreducible uncertainty in 280m → 295km flux extrapolation: we can make these studies
- Measurement of the ν_e contamination and cross section
- Measurement of NC backgrounds
- Coverage of large Q^2 phase space: need improvements in inter-detector timing
- Performance of right-sign/wrong-sign separation in anti-nu mode
- Study ultimate event rates in ND280 with planned exposure for HK

ND280 Aging

- ND280 would be ~20 years old by end of T2HK physics program
- Aging of the plastic scintillator
  - MINERvA sees 7-10% light reduction per year at 80F (27C)
  - T2K: co-extrusion of the scintillator with reflecting layer may protect against crazing at surface.
  - T2K is investigating the aging of the scintillators
- Aging of electronics



Flux Prediction for T2HK

- Ultimate T2K flux uncertainty will be reduced with replica target data
- Target geometry may be changed for T2HK
- If so, will new replica target data be necessary to meet flux uncertainty goals

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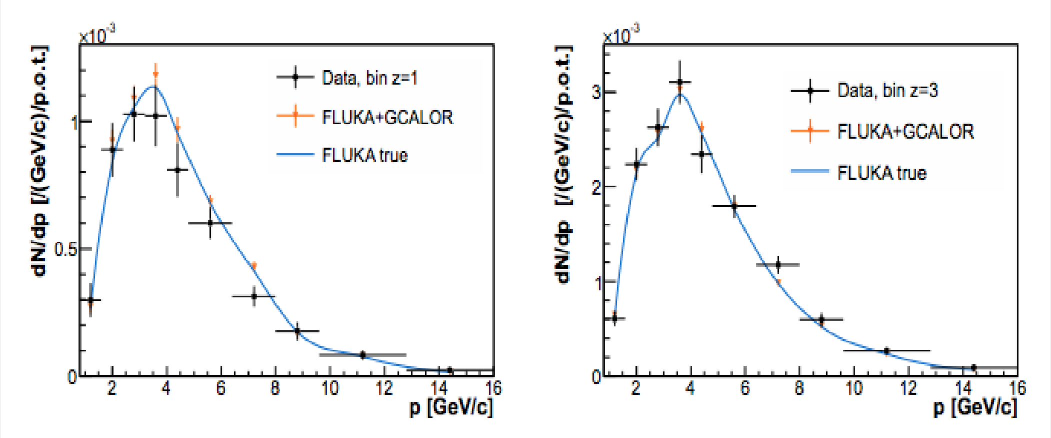
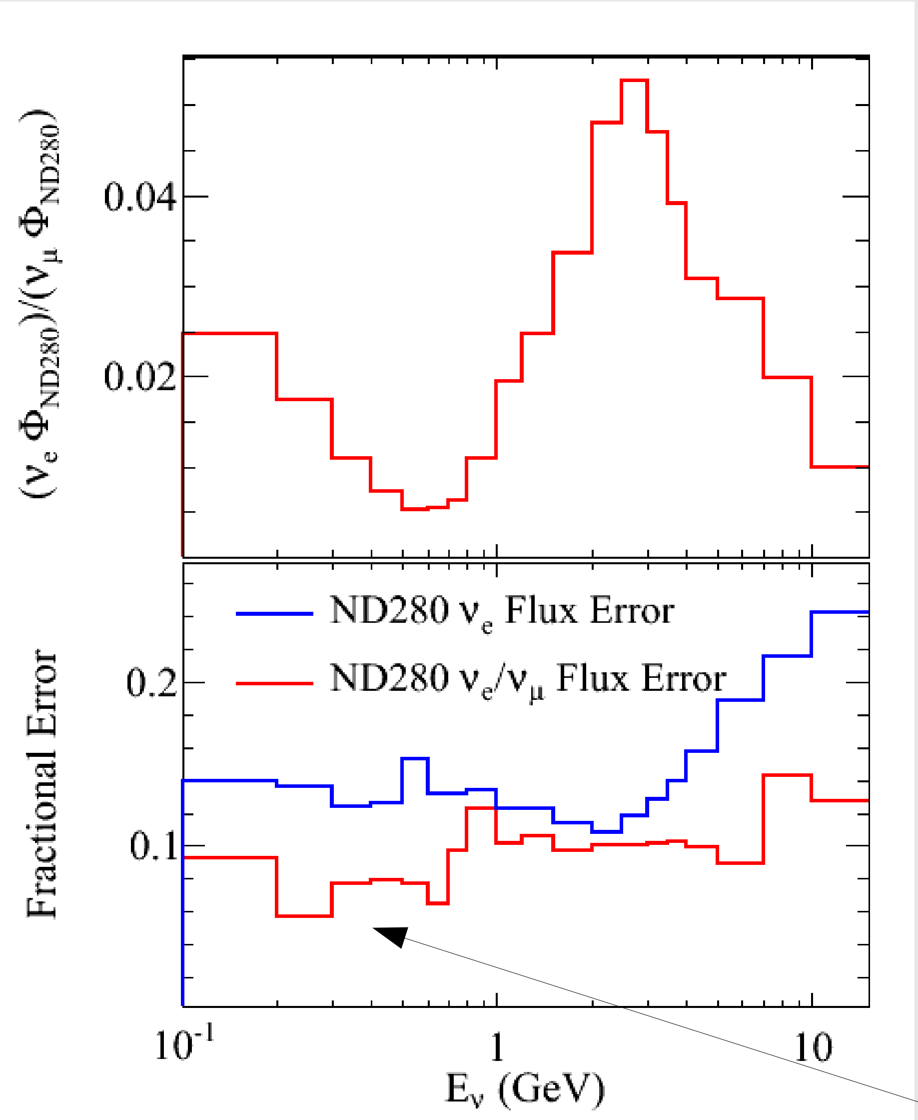


- Will performance of proton beam monitors at high power be changed?
- Any optimization of the beam line configuration for CP violation measurement?

Qualitative Improvements

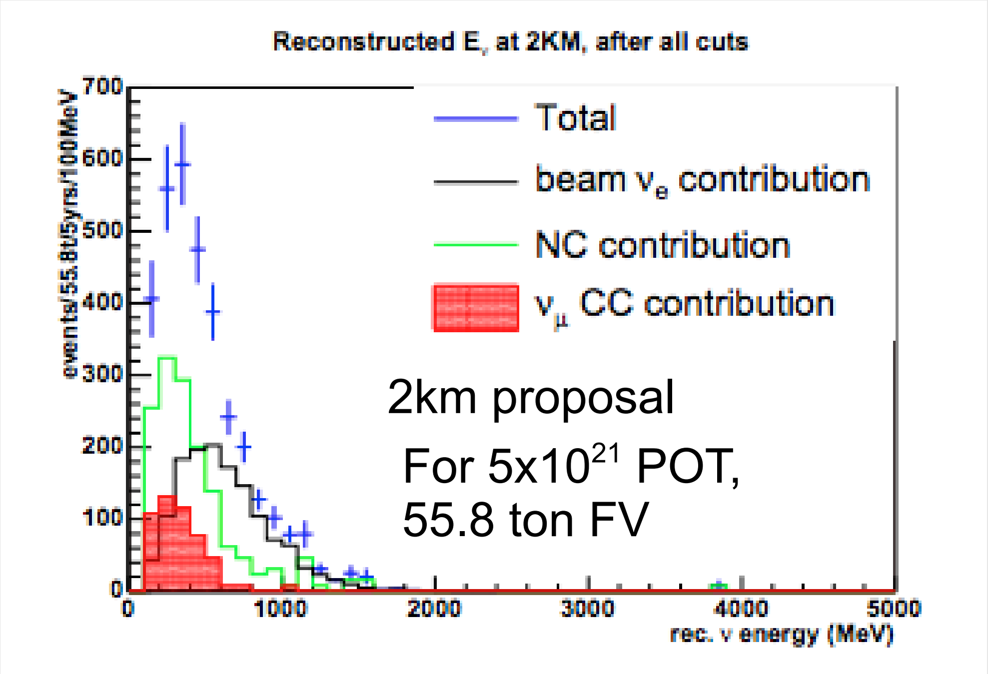
- Better measurements of rates on H_2O to reduce nuclear model uncertainties
- Measurements of hadronic final states with more fine grained detectors, liquid or high pressure TPCs
- Range of off-axis detectors to better constrain neutrino energy vs. muon kinematics
- Constrain the ν_e/ν_μ cross section? Requires a muon beam?
- Measurements at >280m to reduce extrapolation uncertainties on flux
- Measurements on deuterium to better constrain fundamental cross sections
- Is magnetized detector necessary to sufficiently constrain the wrong-sign component

ν_e Cross Section Measurement



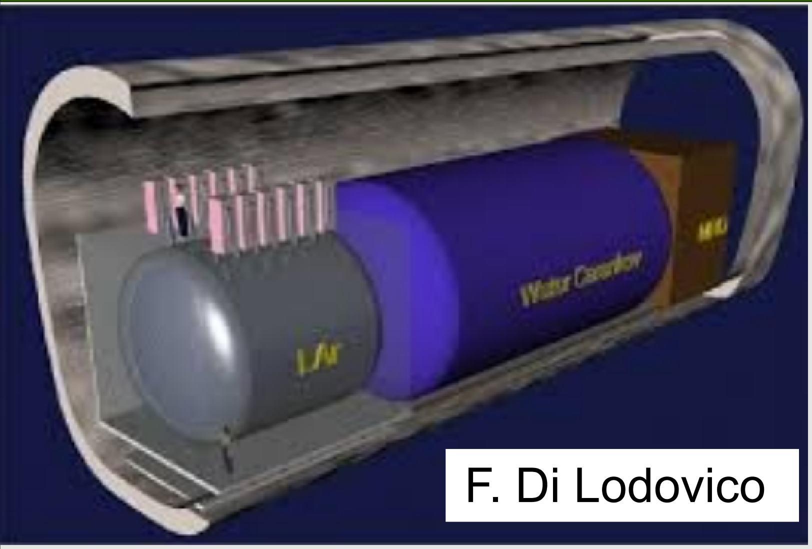
Can the ν_e cross section be measured using the beam contamination from muon and kaon decays?

Requires excellent rejection of muons and π^0

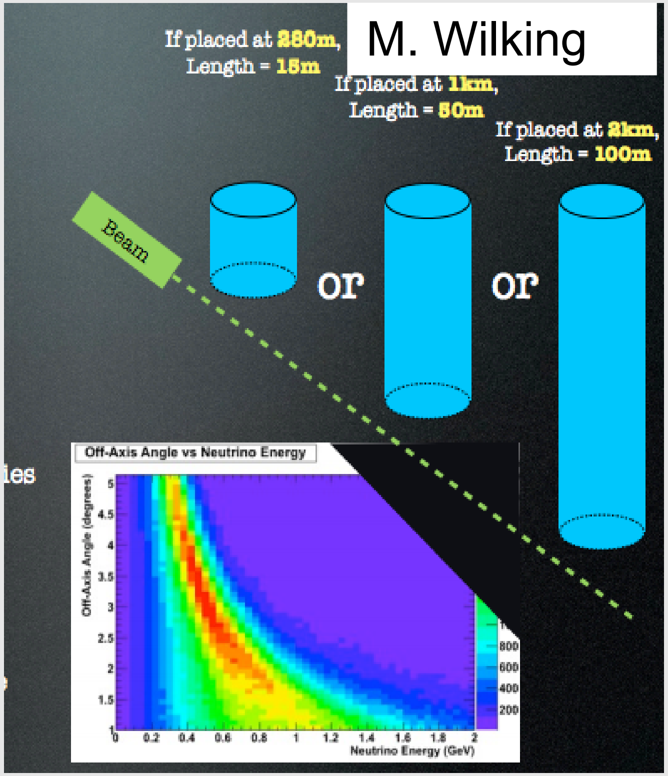


ν_e/ν_μ flux uncertainty should be small

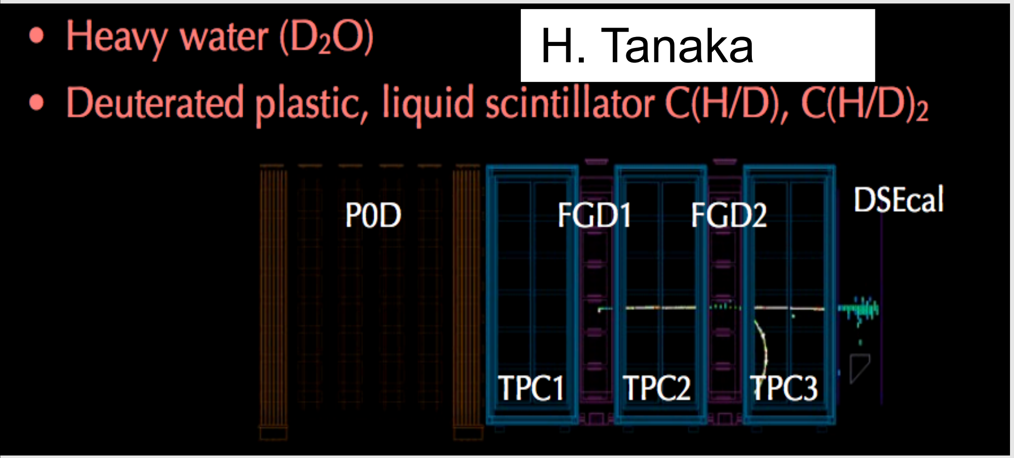
Detector Ideas



Resurrect the 2km proposal



WC detector covering range of off-axis angles



Deuterated plastic, D_2O, liquid scintillator to get at fundamental cross sections

Other ideas:
High pressure Ne TPC
High pressure CO_2 TPC
Scintillating fiber tracker
Water-based liquid scintillator

Logistics

- Better quantification of goals → what measurements are needed from HK CPV measurement to be statistics limited
- Use of T2K tools:
  - Flux files for neutrino and antineutrino mode exist
  - Need to produce antineutrino mode uncertainties
- Access to configurable HK sensitivity code to study near detector requirements
- Discussion with T2K about accommodation of R&D detectors at ND280 site

Work Items

- ND280 capabilities, aging (F. Di Lodovico)
- Quantitative requirements from sensitivity studies (M. Ikeda)
- Flux files, ultimate NA61 constraint and flux uncertainties (M. Hartz)
- Detector ideas (M. Wilking, H. Tanaka ...)
- 2km vs 280m constraints (F. Di Lodovico, M. Hartz)
- Determine status of the 2km site

Plan Moving Forward

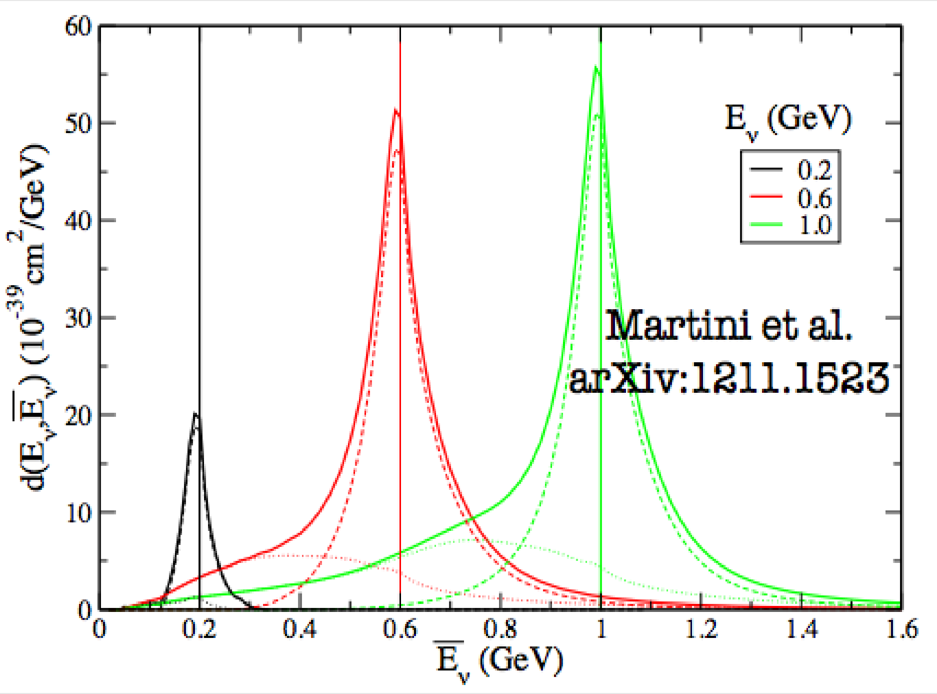
- Start bi-weekly or monthly meetings → will circulate a poll soon
- Set up mailing list: send email to mark.hartz@ipmu.jp to be added to list
- Prepare a preliminary report for next meeting, TDR:

1. Physics requirements for near detector
2. Feasibility of achieving requirements with the current T2K near detectors
3. Uncertainties at 280m vs. 2km (is 2km site necessary?)
4. Investigation of new near detectors to meet requirements
5. Identification of best options and first cost estimates

Extra Slides

Neutrino Energy vs. Lepton Kinematics

- Even if muon and electron p,cosθ well measured at near detector, extrapolation is not trivial
  - Need to apply the oscillation probability to the measured spectrum to predict far detector spectrum
  - Need relationship between lepton p,cosθ and E_ν

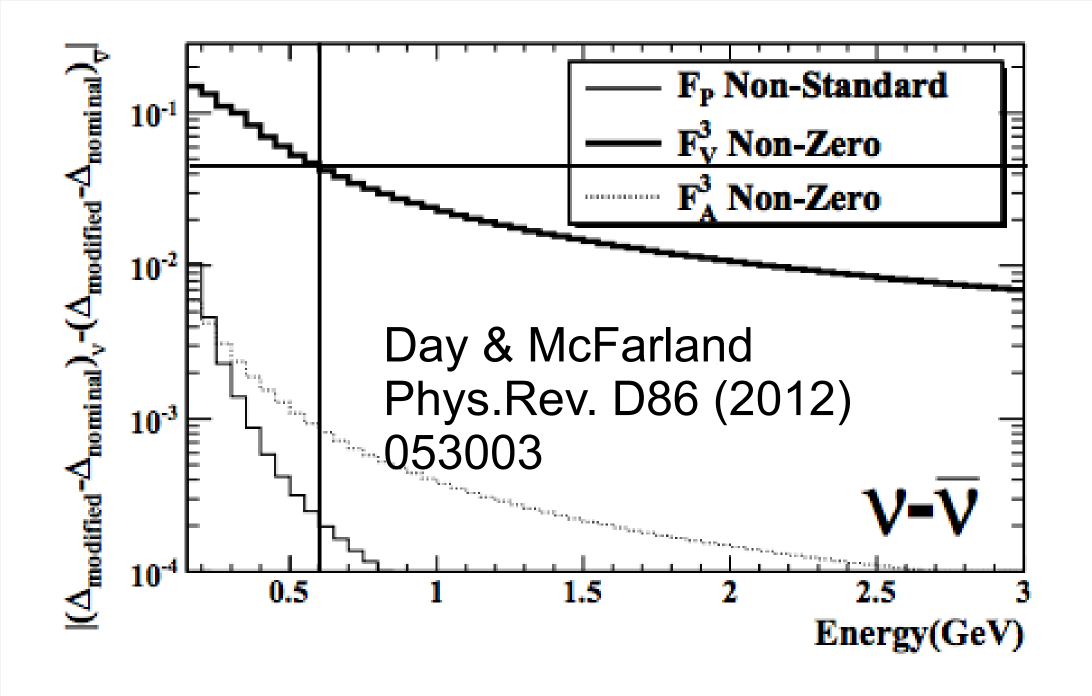


Measurements of the hadronic final states better constrain the neutrino energy

Correlated measurements at different off-axis angles

Measurements with ν_μ must be "extrapolated" to ν_e

Electron Neutrino Cross Section



Uncertainties on ν_e/ν_μ from radiative corrections or second class currents

Measurements on deuterium or helium to extract F_V^3?

Direct measurement of ν_e/ν_μ cross section using ν_e beam contamination → Need good electron/muon and electron/π0 separation