
Neutrino interactions and T2K

Andrew Furmanski

April 2014

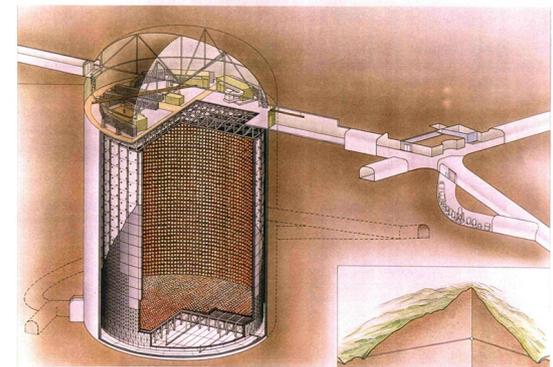
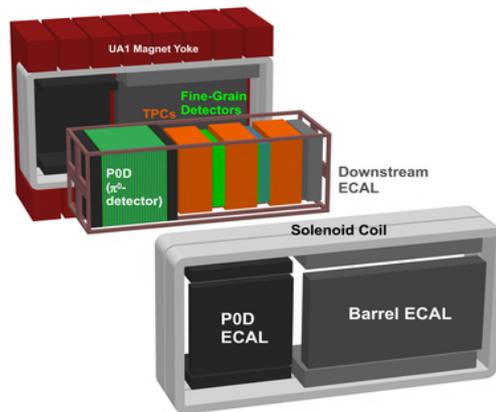
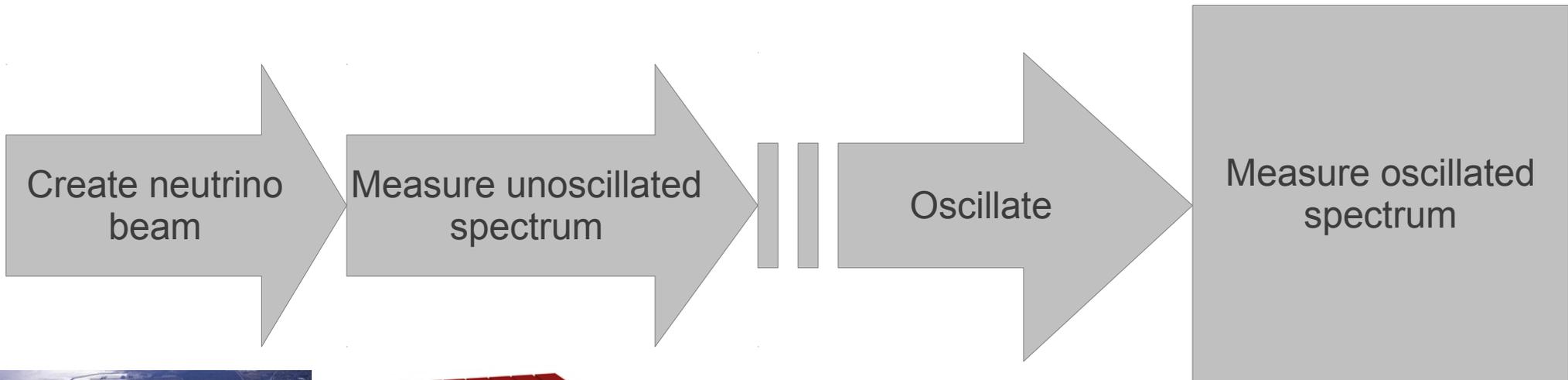


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T2K

- Long baseline neutrino experiment in Japan
- Looking for (and found!) $\mu_\nu \rightarrow \mu_e$



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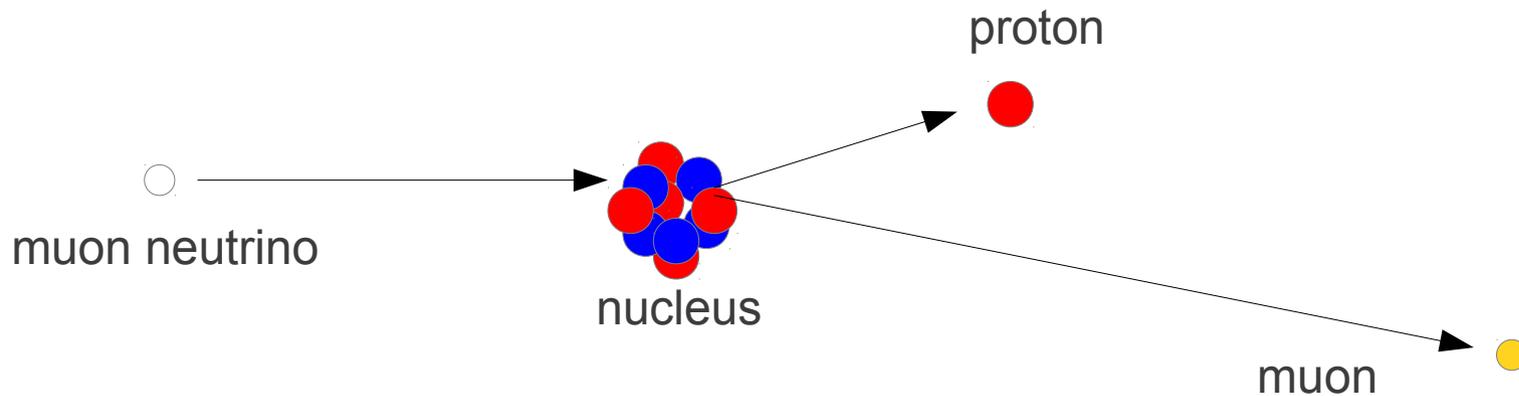
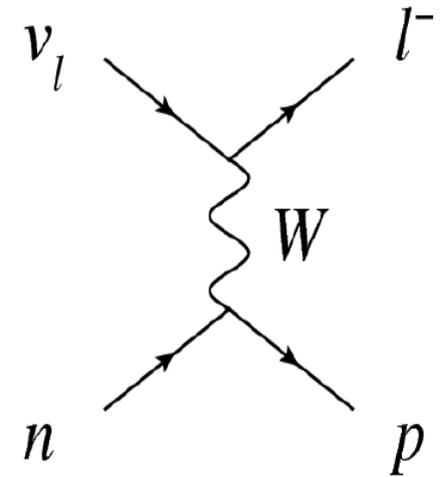


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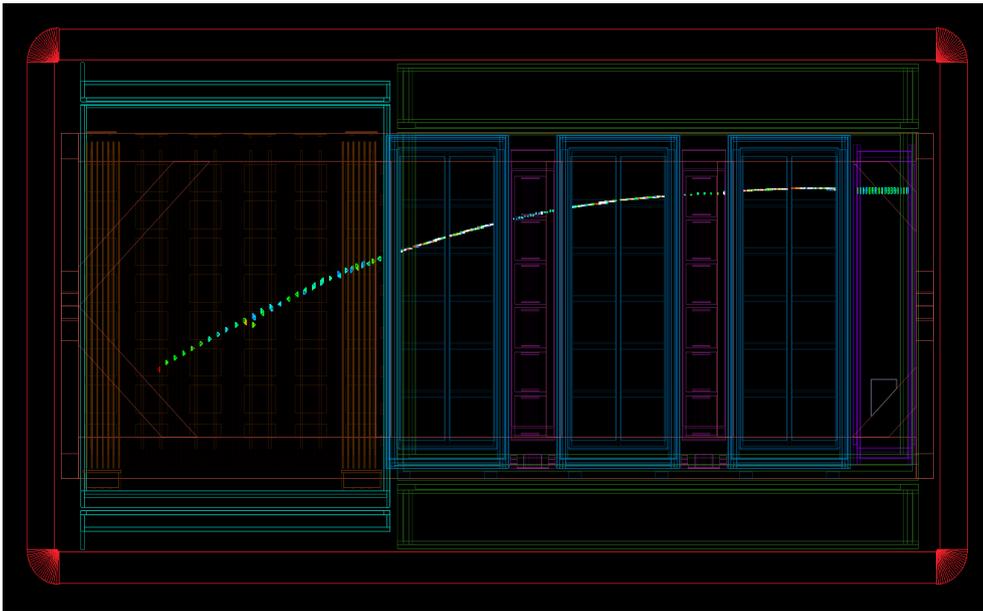
Signal

- Use charged-current, quasi-elastic events (CCQE)
- 2 body kinematics for neutrino energy reconstruction
- Identify neutrino flavour from lepton

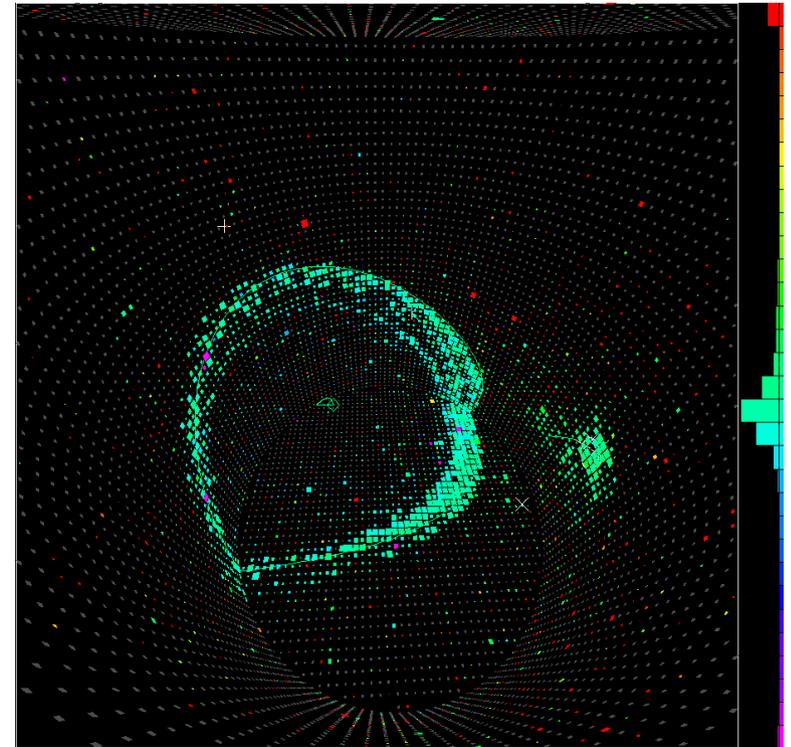


Detectors

- Signal acceptance different at near/far detectors
- Need cross-section prediction to fill in the gaps

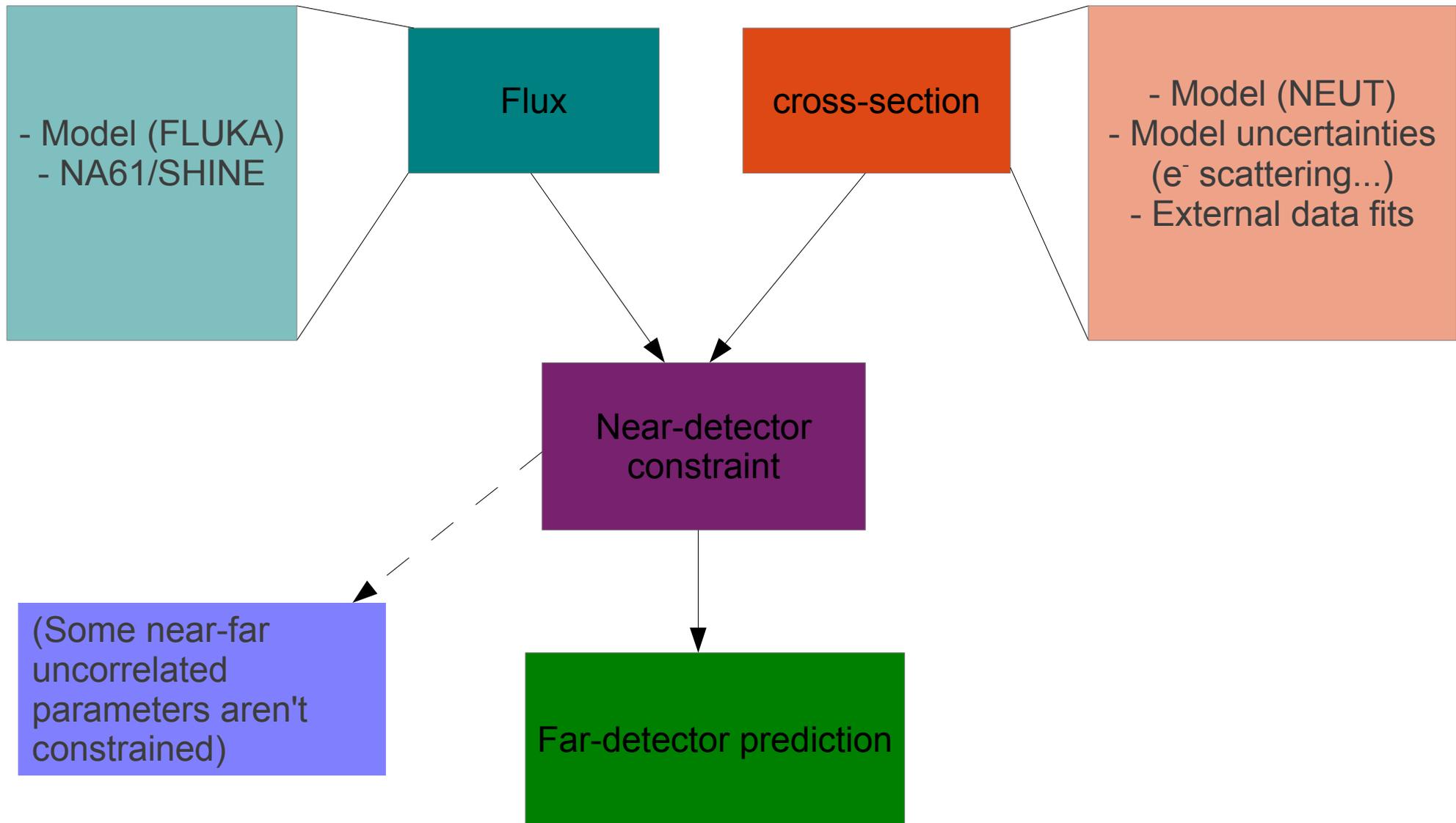


Near detector
mainly accepts forward-going events



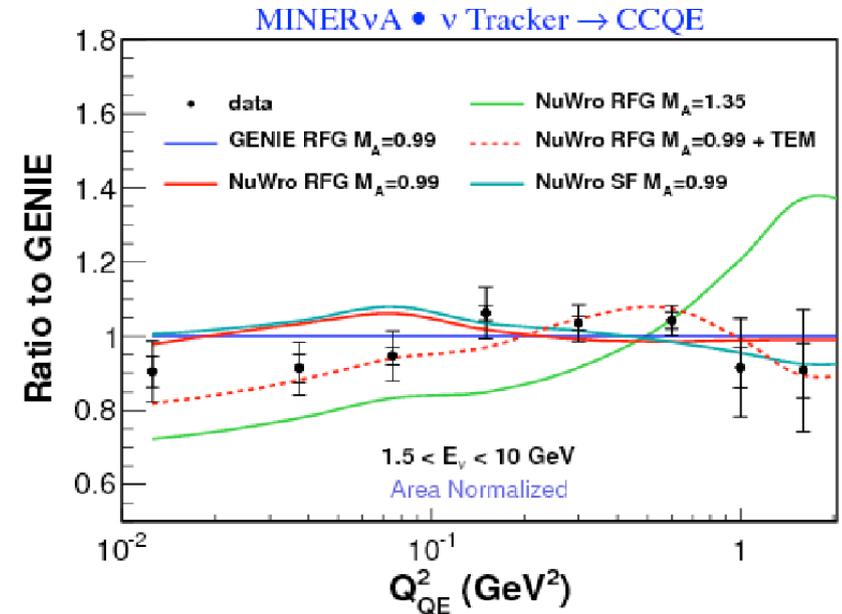
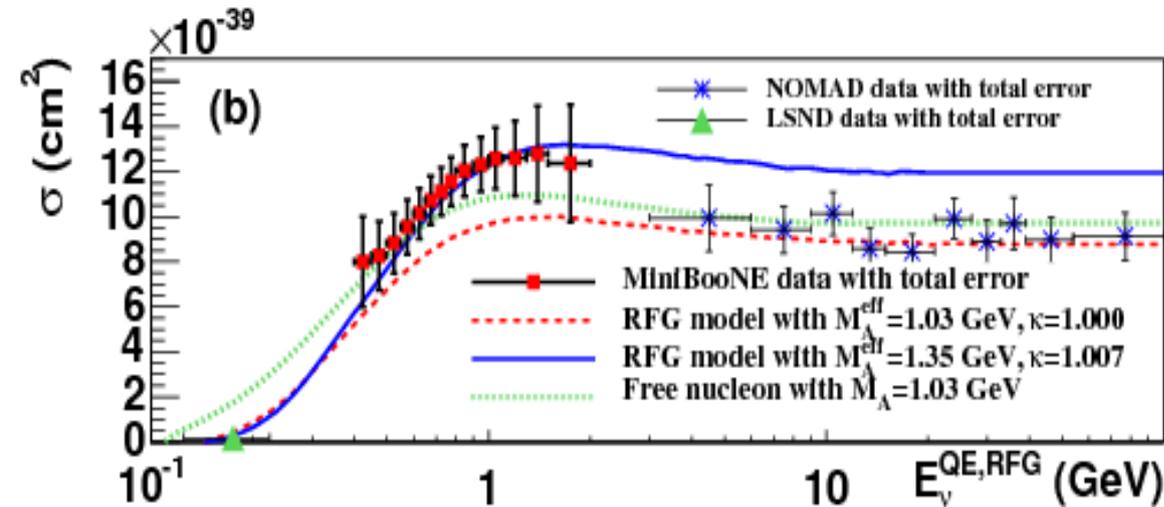
Super-K
4 π coverage

Event predictions



Sounds fine, but...

- Current cross-section models do not describe the data well

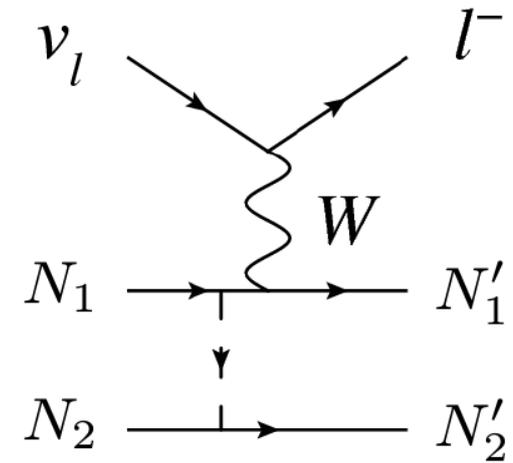
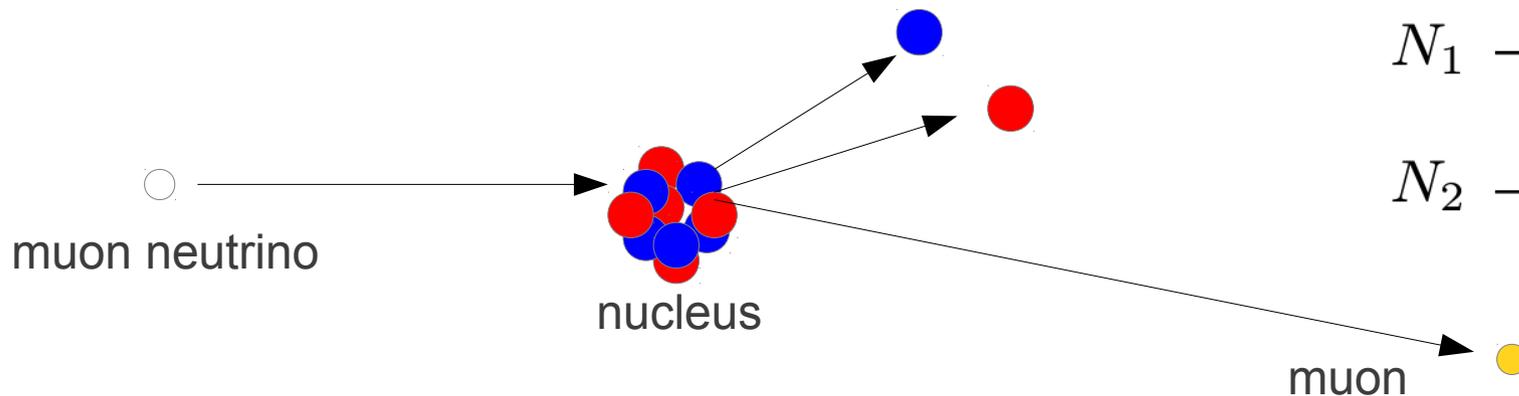


- Large uncertainties must be assigned to the cross-section parameters
- Uncertainties propagate to oscillation parameters

Error source [%]	$\sin^2 2\theta_{13} = 0.1$	$\sin^2 2\theta_{13} = 0$
Beam flux and near detector	2.9	4.8
(w/o ND280 constraint)	(25.9)	(21.7)
ν interaction (external data)	7.5	6.8
Far detector and FSI+SI+PN	3.5	7.3
Total	8.8	11.1

More nucleons?

- Current CCQE models assume quasi-free nucleons
- CCQE-like cross-section may be enhanced by multi-nucleon interactions
- Interact with a pair of nucleons

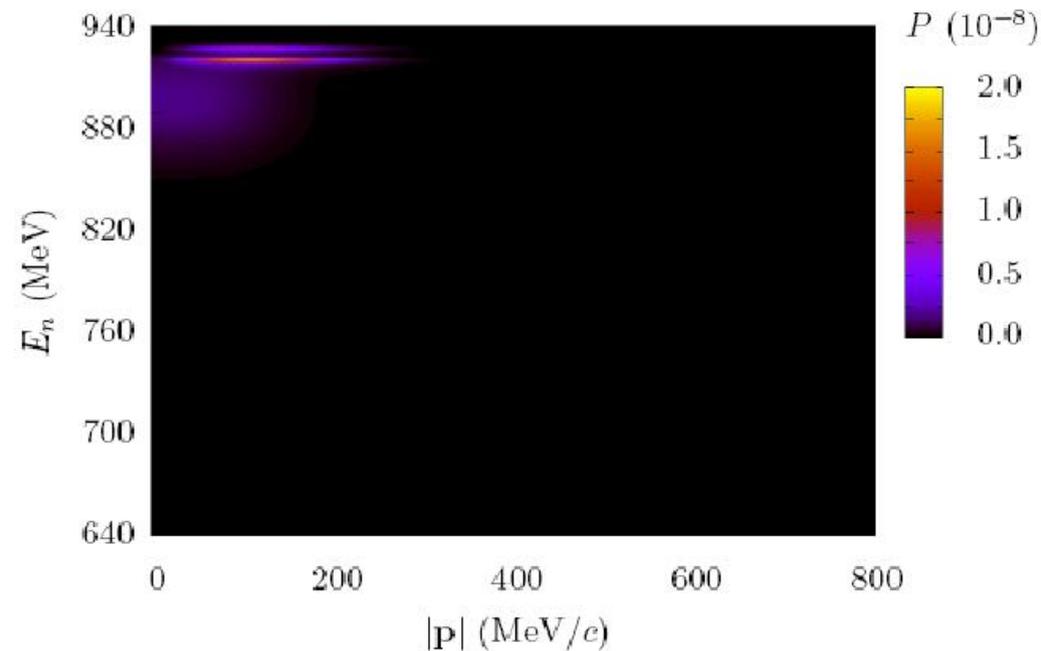
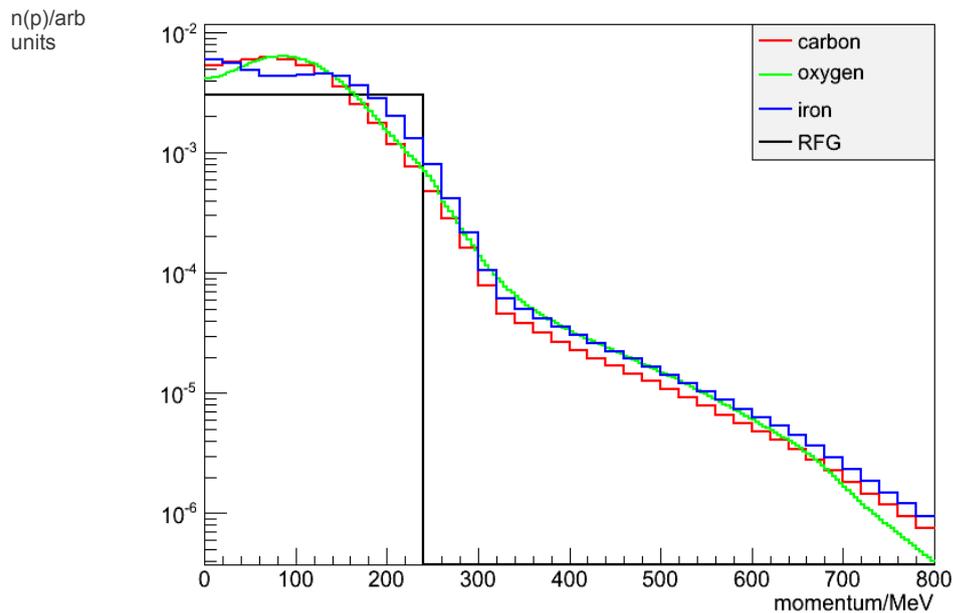


- Has a large effect on reconstructed neutrino energy

Spectral Function

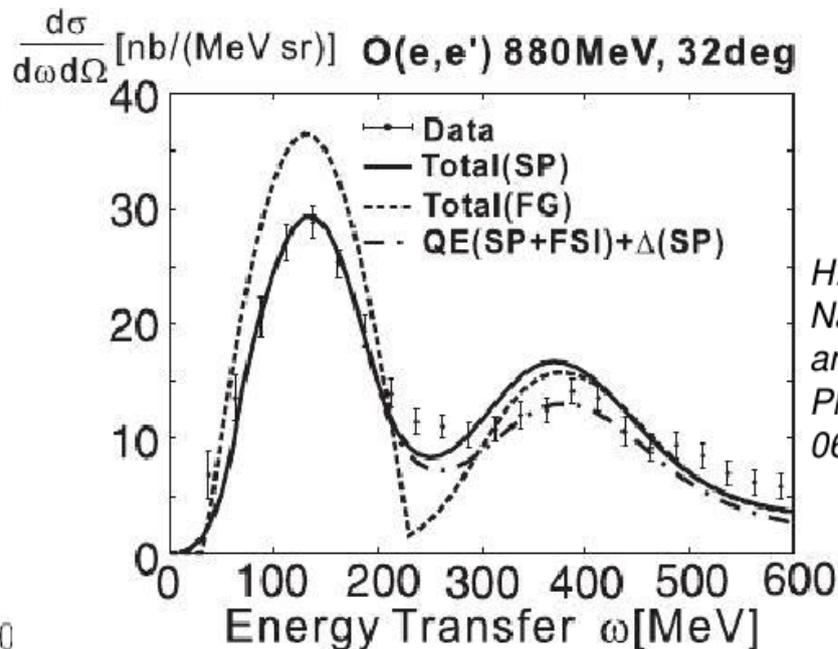
- Previously used relativistic fermi gas (RFG) model
 - describes nuclear initial state (momentum and binding energy of nucleons)
- More realistic – spectral function (SF)
 - Combination of nuclear theory and electron scattering fits
 - Long high-momentum tail
 - Variable binding energy (shell model orbitals visible)

spectral functions momentum distributions for different nuclei



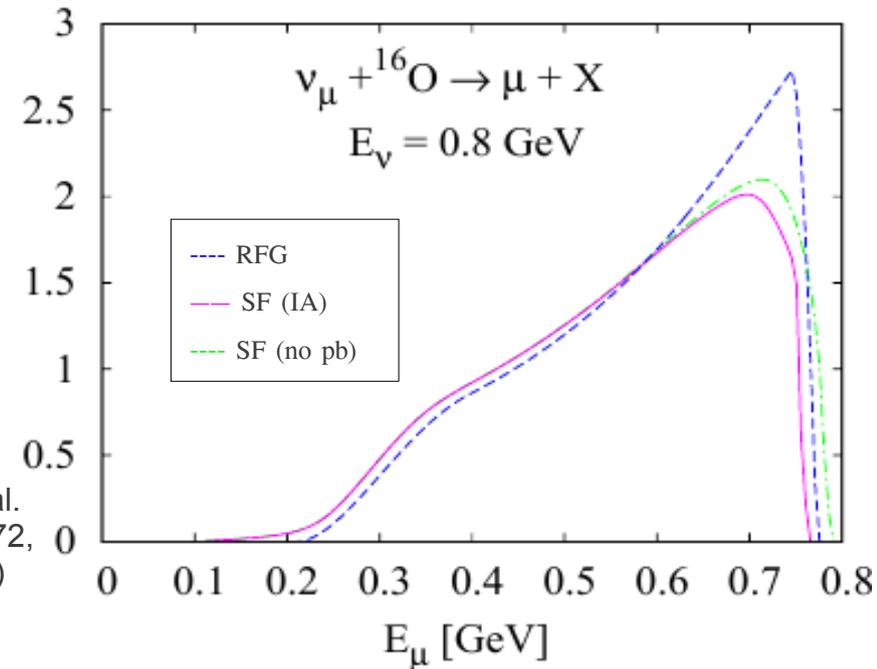
Spectral Function (cont)

- SF can have a large effect on the shape and normalisation of cross-sections
 - leads to large systematic in oscillation analysis (largest cross-section systematic)
 - Currently uses difference between two models
- Performs better than RFG in electron scattering



H. Nakamura, T. Nasu, M. Sakuda and Omar Benhar, *Phys. Rev. C* 76, 065208 (2007)

O. Benhar et al. *Phys. Rev. D* 72, 053005 (2005)



Generators

- Completed implementing these models in our interaction generator
- Why is this important?

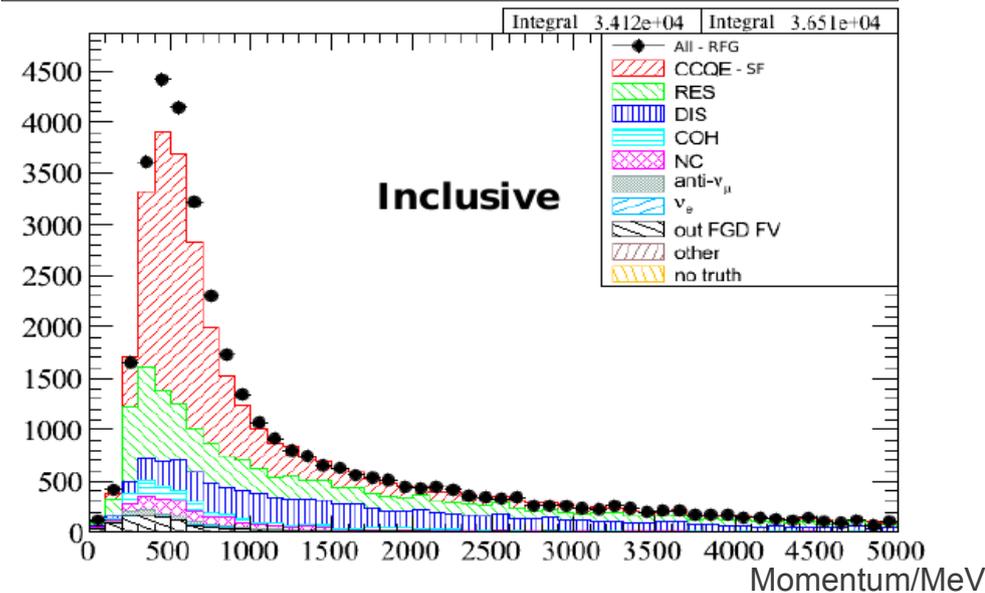
1. Simulate events in detector

- Direct comparison with data
- Look for signal
 - Extra nucleons...
- Energy misreconstruction

- Also implemented improved pion production model and uncertainties

2. External data fits

- Consistent fits over multiple datasets
- Reduce uncertainty on xsec parameters



Summary

- T2K is starting to make precision measurements of neutrino oscillation parameters
- A large source of uncertainty comes from interaction cross-sections
- New models should allow us to reduce these uncertainties
- These models are being put to use in our generators
- Next: direct comparisons with data! (ours and others)



Backup slides



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