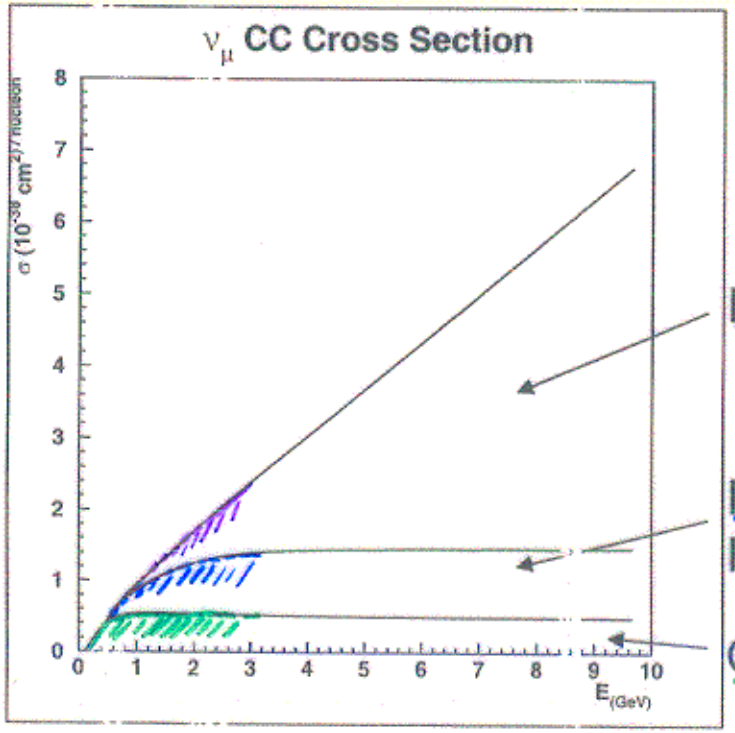
Neutrino Cross Sections

NuMI Off-Axis Meeting
April 2003
Argonne
W.A. Mann / H. Gallagher

ν_μ interactions (both NC and CC) can produce backgrounds to a ν_e appearance search. This talk is an attempt to address the following questions:

1) How well are the cross sections known in this energy range (1-5 GeV)
2) What processes are primarily important as ν_e appearance backgrounds
3) What information might we gain in the future to improve our knowledge.

… A big topic …



We are in an energy range where a lot of things matter…

All scattering mechanisms are important
Nuclear effects modify kinematics
Nuclear FSI modify observables

At 2 GeV , the quasi-elastic, resonance production, and DIS cross sections are comparable.

Single Pion Cross Sections

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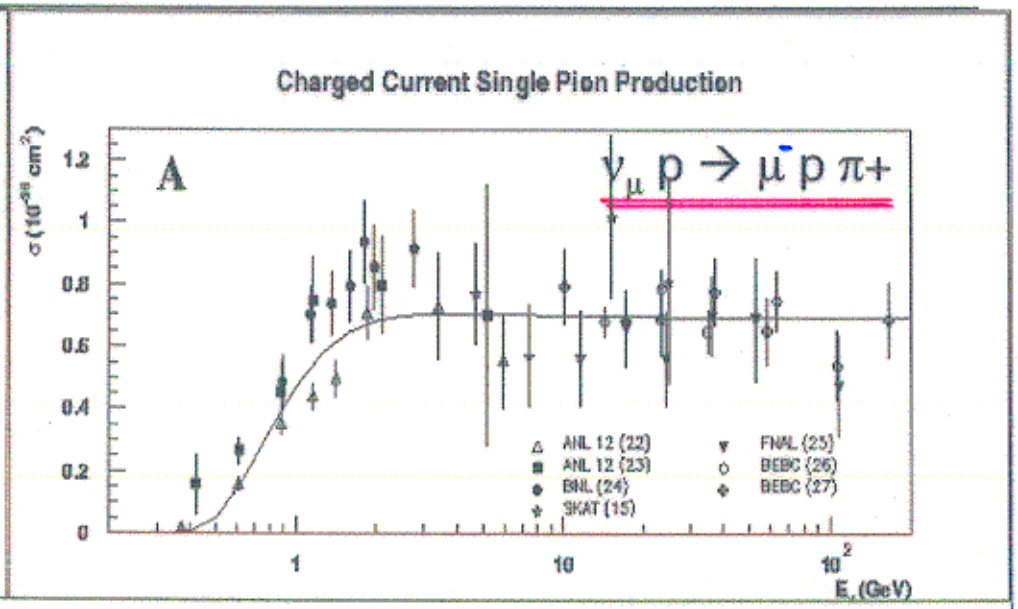
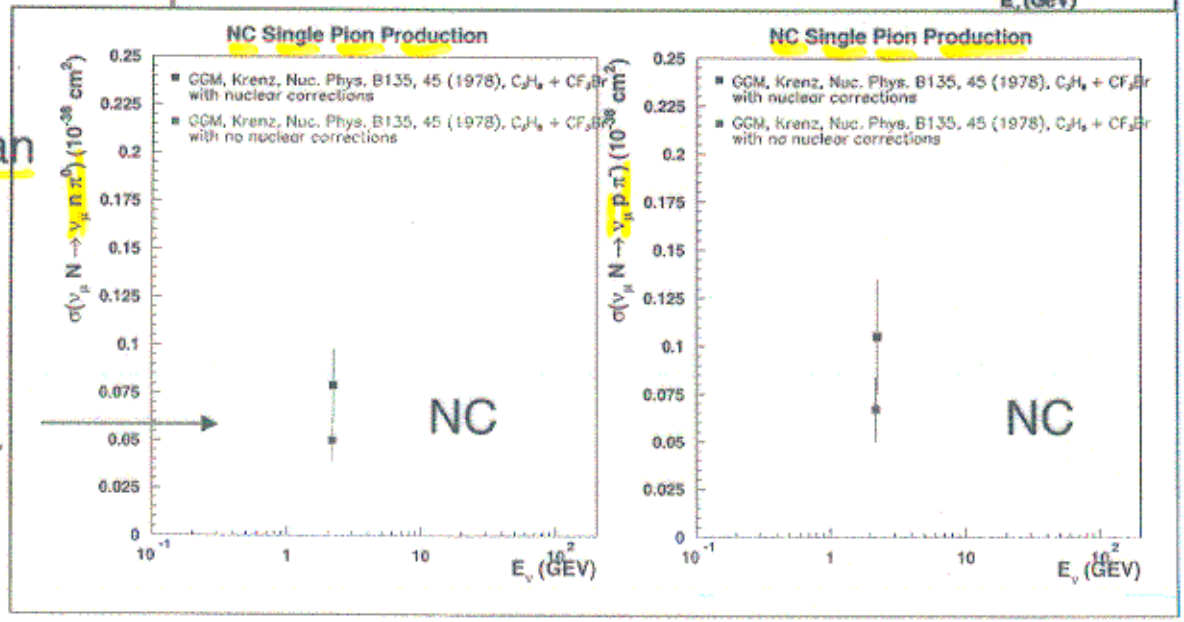
Single pi states measured much better in CC channels.

GGM NC:

$\nu p \pi^0$	240 events
$\nu n \pi^+$	104 events
$\nu n \pi^0$	31 events
$\nu p \pi^-$	94 events



Typically quoted are ratios of NC exclusive channels rates to a related CC channel, rather than absolute cross sections.



Data from a re-analysis of GGM data by E. Hawker and J. Morfin.

Plots provided by Sam Zeller.

Coherent Production

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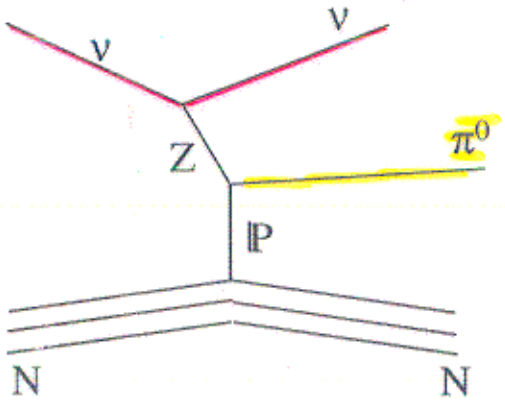
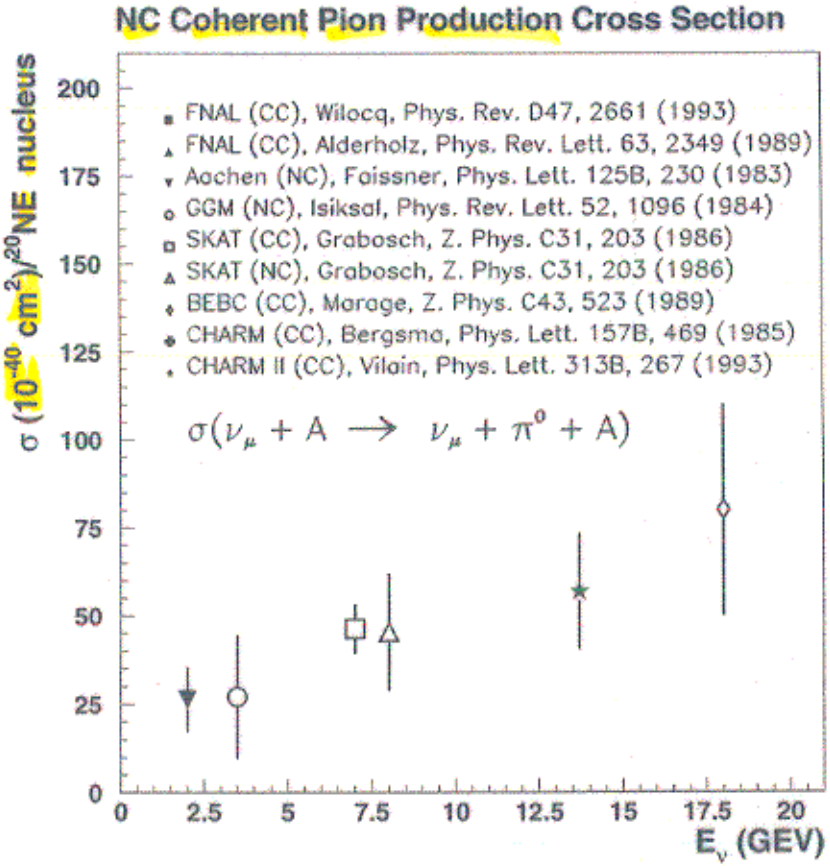


PCAC prediction starting from Adler's relation ($q^2=0$). Assumptions about the q^2 dependence, and the treatment of the pion-nucleus scattering. Other calculations based on VMD treatment. Characterized by a small energy transfer to the nucleus, forward going π.

Rein-Seghal model:

1. Purely axial
2. $\sigma(CC) = 2\,\sigma(NC)$
3. $\sigma(A) \sim A^{1/3}$
4. Relatively less important for increasing A



Plots from Sam Zeller.

CC Backgrounds

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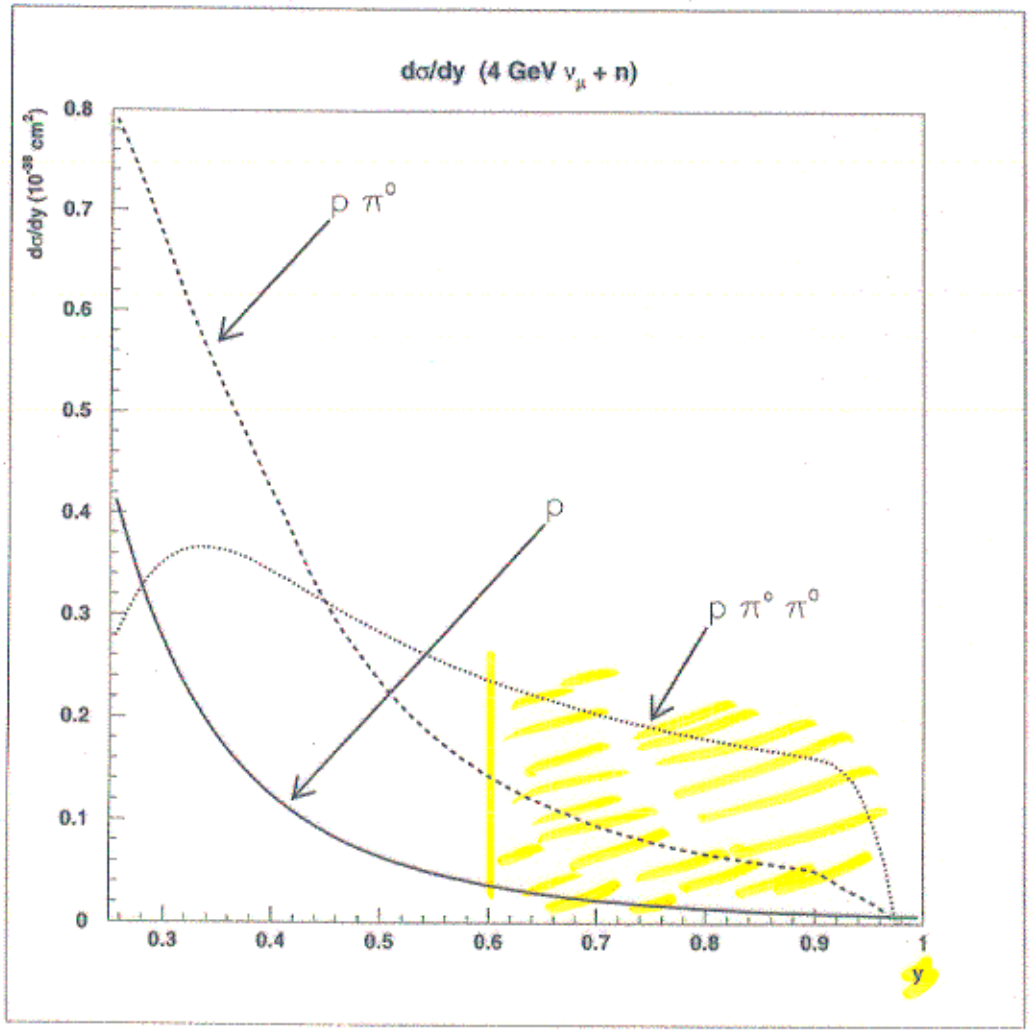
Depending on the detector, high-y CC events can also pass cuts.

I am not aware of any good data on the CC y-distribution at low energy.



(y ≈ fraction of E_ν transferred to the hadronic system)

Multi-Pion Production

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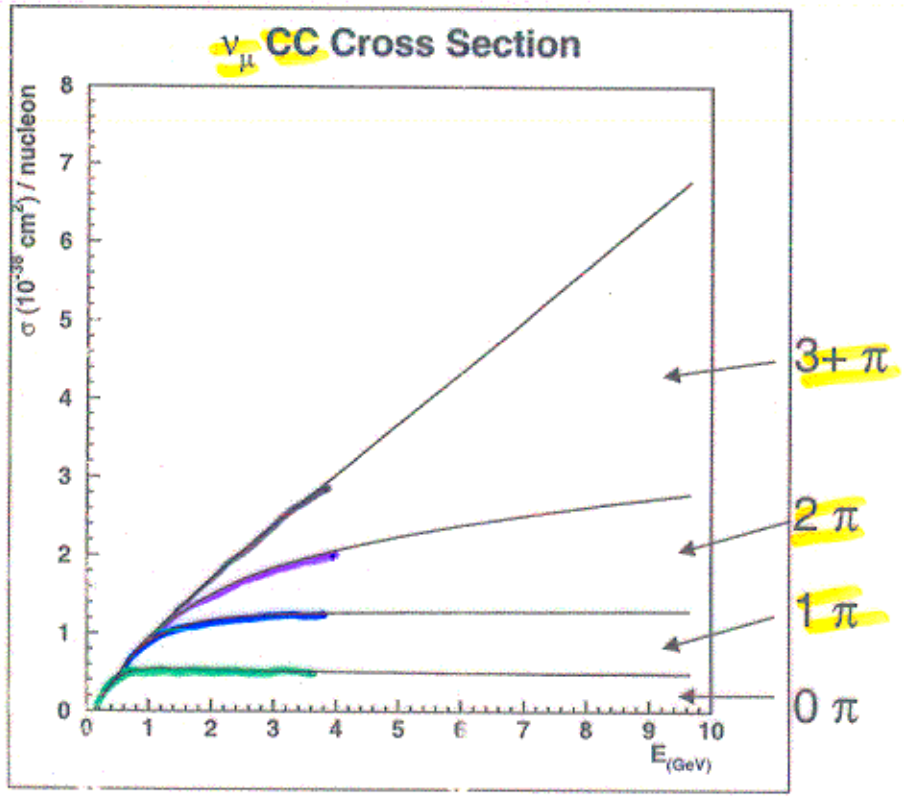
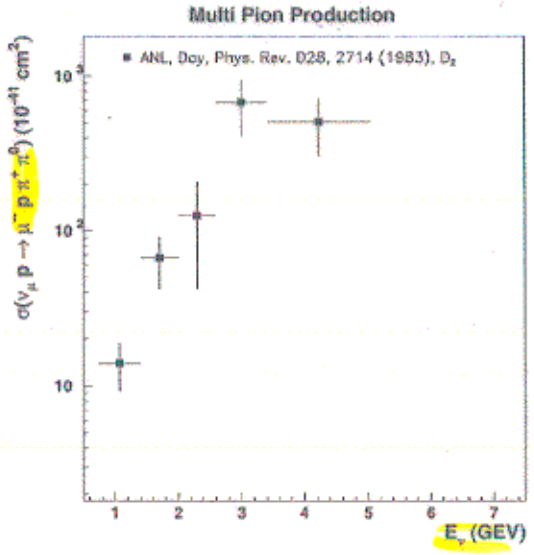
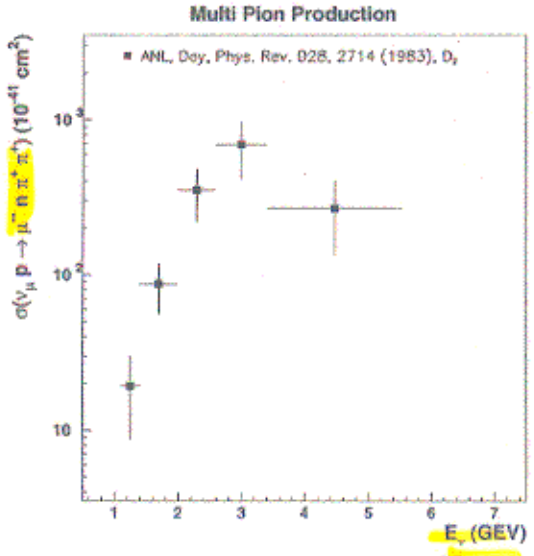
Feed-down (from detection inefficiencies and nuclear absorption) from 2π channels can also be significant.

Both 1 and 2π have contributions from both DIS and resonance production.







Plots from Sam Zeller

Intranuclear Rescattering

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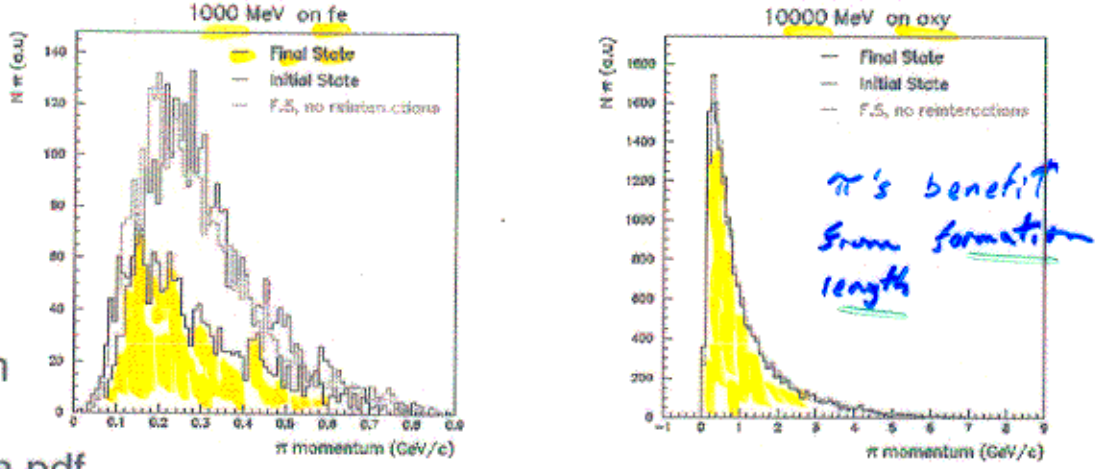
At these energies, final state rescattering of the pions in the nucleus leads to significant changes in the observed multiplicities and pion energies.

From a comparison of D_2 and Neon Bubble chamber exposures at atmospheric neutrino energies, (Merenyi et al., PRD45 (1992) 743.)

$$P_\pi(\text{abs}) = 0.22 \pm 0.05$$
$$P_\pi(\text{cex}) = 0.10 \pm 0.08$$

Charged pion spectra after ν_μ interaction.
Initial State == particles still inside the nucleus
Final State == particles outside the nucleus
No reinteractions == only the effect of potentials



From a FLUKA / Peanut simulation shown by P. Sala at NuInt 02
http://www.ps.uci.edu/nuint/slides/Sala.pdf

Only 55% escape at 1 GeV on Fe, 75% on Oxygen

Future Improvements

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Our knowledge of cross sections in this low energy range will improve over the next few years with the analysis of high-statistics experiments:

1. K2K: ~ 8k events in their SciFi detector
2. miniBoone (~ 1 GeV on undoped mineral oil). 50k events already, 5% of goal.
3. NuMI Scattering Experiment (at the EOI stage)
   new ~10 ton detector in the MINOS near hall
   joint particle / nuclear physics effort
   fully-active fine grained detector (entirely scintillator strips?)
   proposal to be submitted later this year
4. Electron scattering (in particular Hall B and Hall C data from the Jefferson Lab).

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* Detailed match-ups of the World's ν generators:
  (NEUGEN, NUANCE, NEUT, GENEVE, NUX)
* NuInt#1, NuInt#2 Workshops - are venue for community dialogue on the above physics issues.

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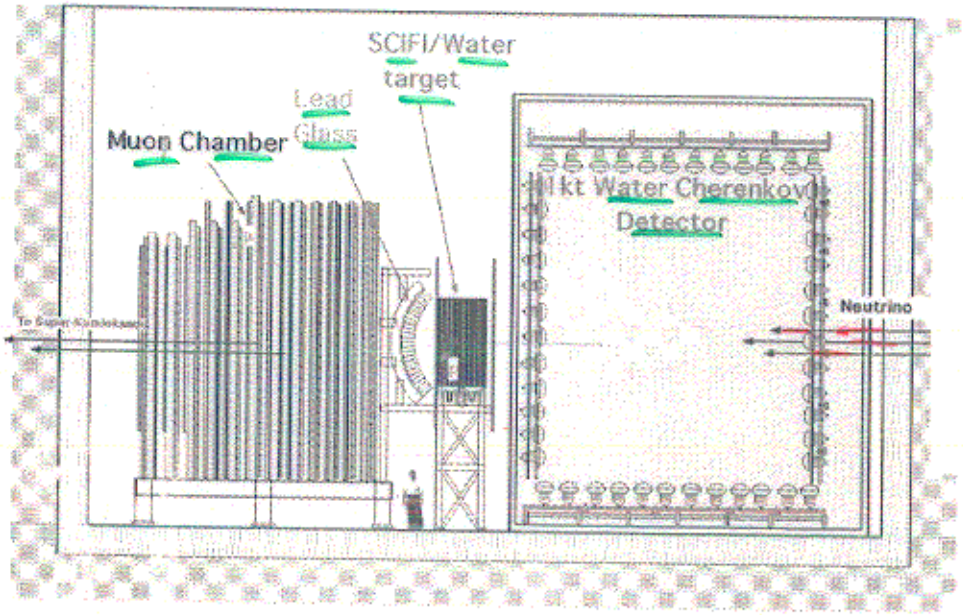
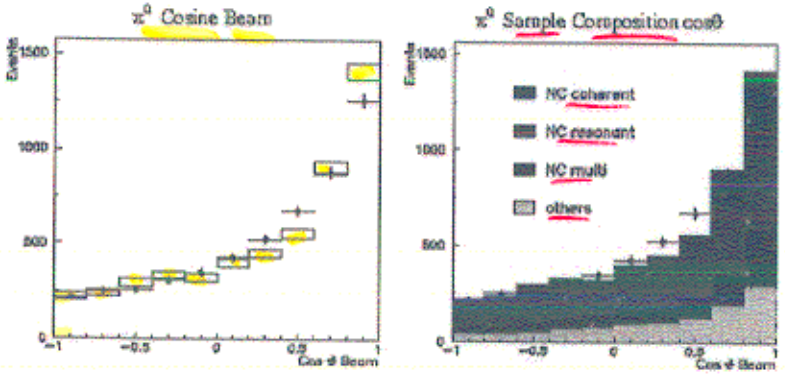
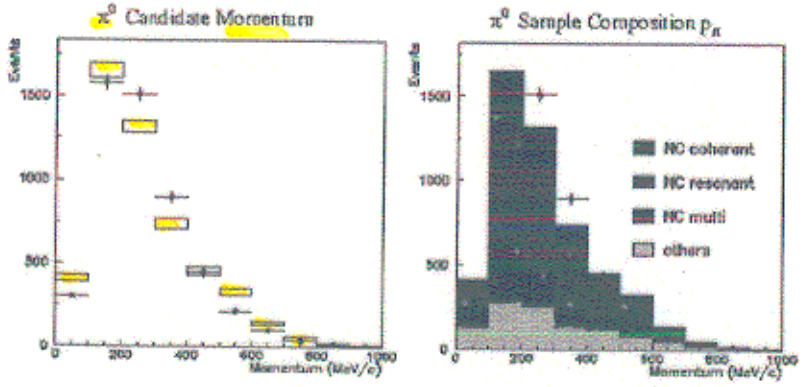




With the analysis of π^0 events in the K2K Near detector, the uncertainty in the predicted ratio π^0/μ has been reduced by about a factor of two.



$$\frac{(\pi^0)/\mu \text{ - data}}{(\pi^0)/\mu \text{ - MC}} = 1.03 \pm 0.02 \text{ (stat)} \pm 0.09 \text{ (syst)}$$

C. Mauger Nucl. Proc. Suppl **112** (2002).