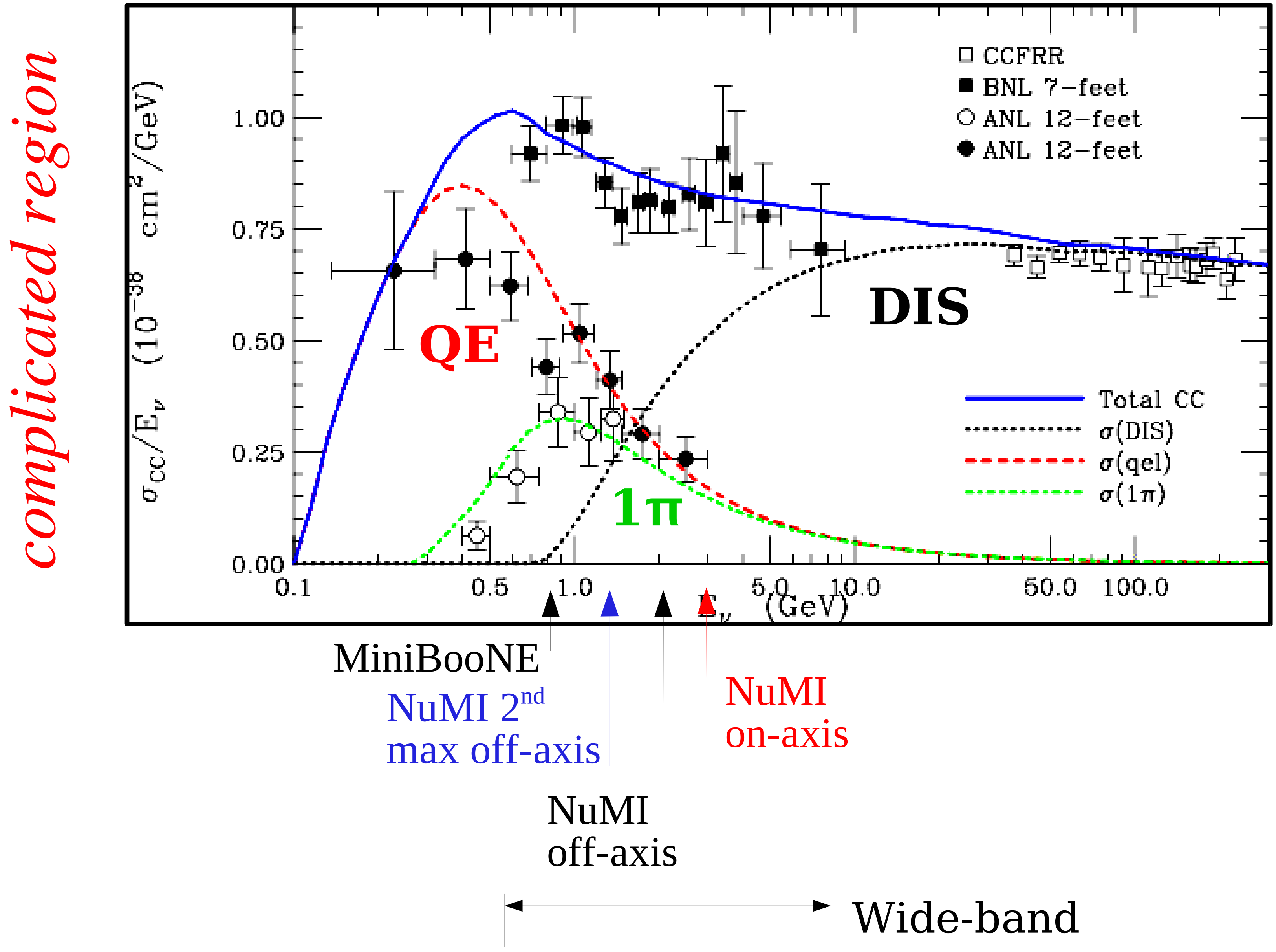
Bonnie T. Fleming
May 13th group mtg
LArTPC

Efficiencies and purities
- for what physics?
- existing work
- where to go from here

Resolutions
- where we are and where we're going

Need to study efficiencies and purities for
- off-axis physics using the NuMI beam
- wide band physics for VLBNO expts.



Exisiting work:

Efficiency and Rejection study

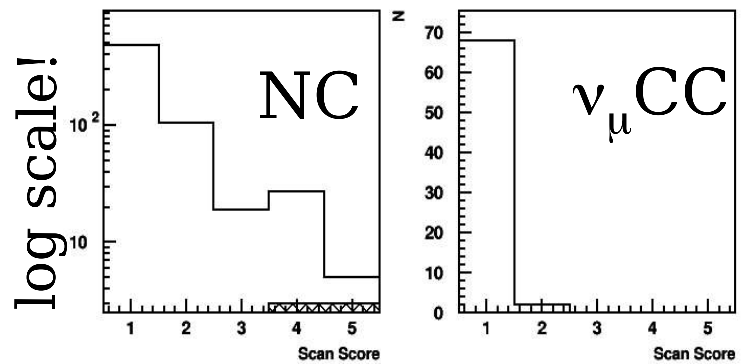
Analysis was based on a blind scan of 450 events, carried out by 4 undergraduates with additional scanning of “signal” events by experts.

- Neutrino event generator: NEUGEN3. Used by MINOS/NOvA collaboration. Hugh Gallagher (Tufts) is the principal author.
- GEANT 3 detector simulation: trace resulting particles through a homogeneous volume of liquid argon. Store energy deposits in thin slices.

Training samples:

50 events each of ν_eCC, ν_μCC and NC

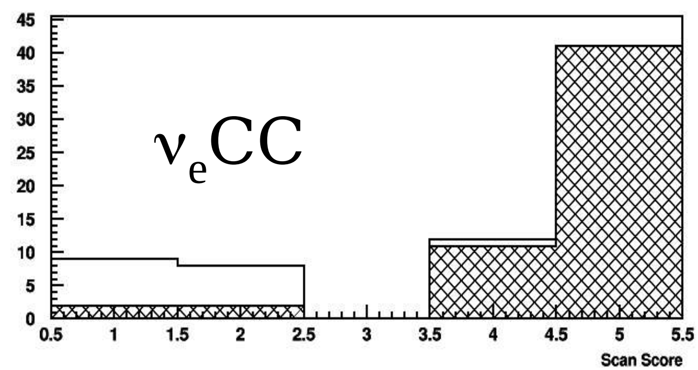
- individual samples to train
- mixed samples to test training



Blind scan of 450 events scored from 1-5 with

- signal=5
- background=1

plain region: students
Hatched region: experts



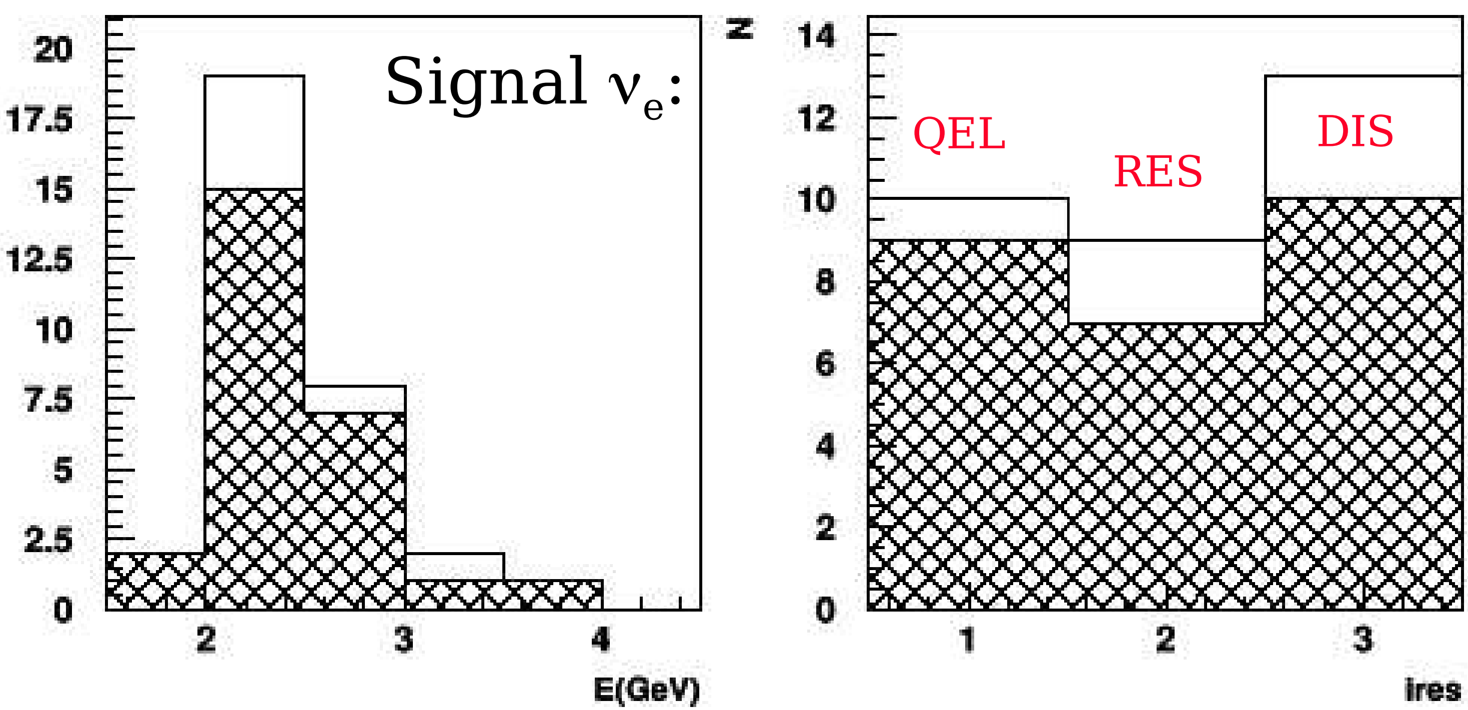
Tufts University Group

Overall efficiencies, rejection factors

	N	pass	ε	η
NC	290	4	-	72.5
signal ν_e	32	26	0.81	-
Beam ν_e: CC	24	14	0.58	-
NC	8	0	-	

Efficiencies

90% 77% 70%



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can we improve on these?

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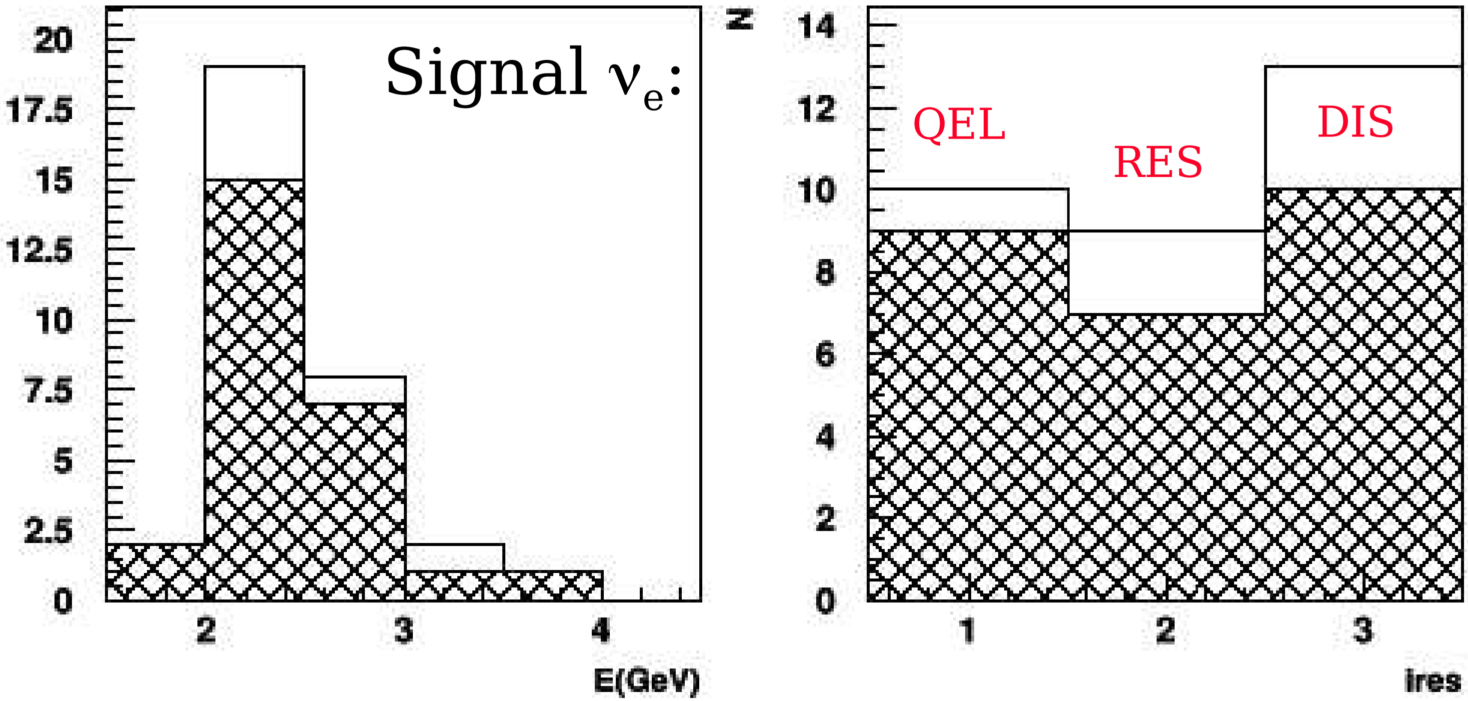
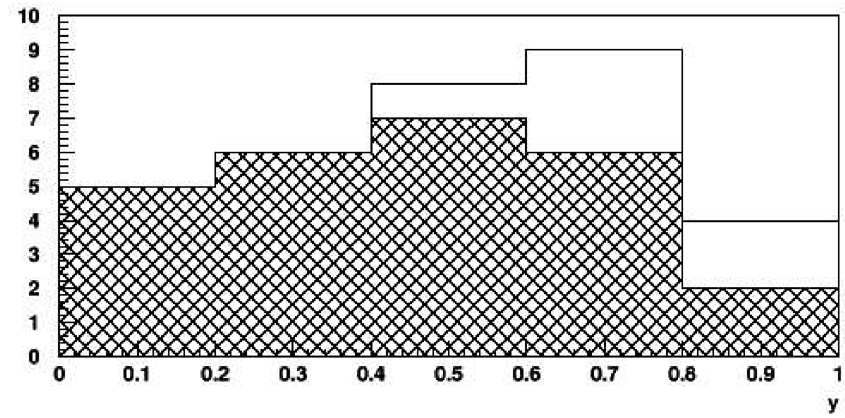


Efficiency is ~100% for y<0.5, and ~50% above this



$y=E_{had}/E_{\nu}$

Can we improve on this?

T2K 2km studies from A. Rubbia's group:

e/pi0 separation

- dE/dx in first 2.4 cm studied for 1000 e and pi0 events (simulation with noise): 0.25, 0.5, and 2 GeV

surviving pion fraction

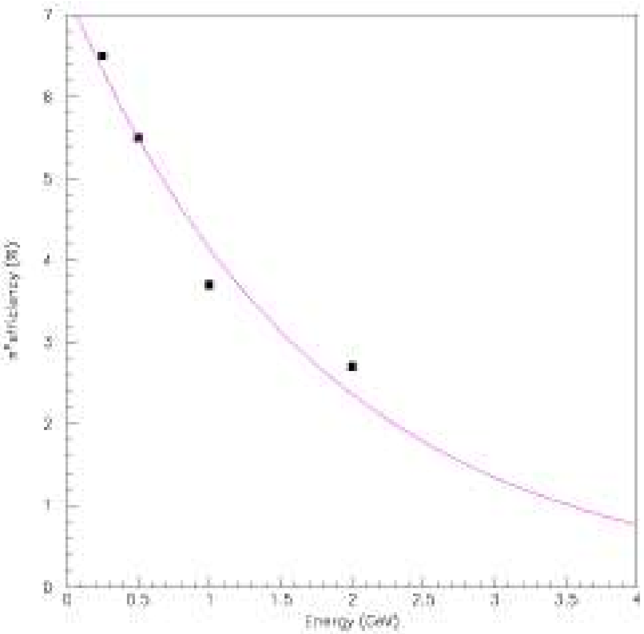


Figure 33: Survival π^0 efficiencies as a function of the incoming energy. The points are simulations and the cu is the result of an exponential fit.

inefficiency improves as E increases (as Compton Scattering process decreases)

fold in vertex separation from hand scan: overall 0.2% inefficiency

→ what fraction of pi0 events do you start with?

Hadron ID: automated recon plus neural net to separate muons, pions, protons, and kaons via dE/dxand decay products

what event samples? don't know

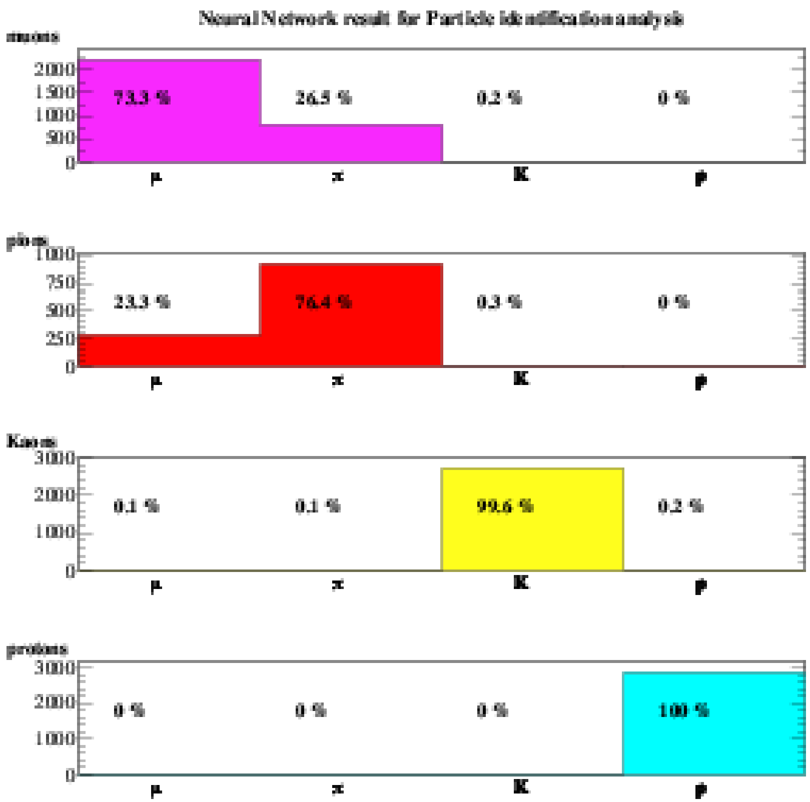


Figure 34: Multi-layer perceptron Neural Network analysis results on particle identification. The histograms (fr top to bottom) show how each type of particle gets classified in different categories (bins from left to right).

preliminary automated event classification for T2K events

1) Cut based selection for ν_μ CCQE events yields ~90% efficiency with contamination of ν_μNC events at low energy

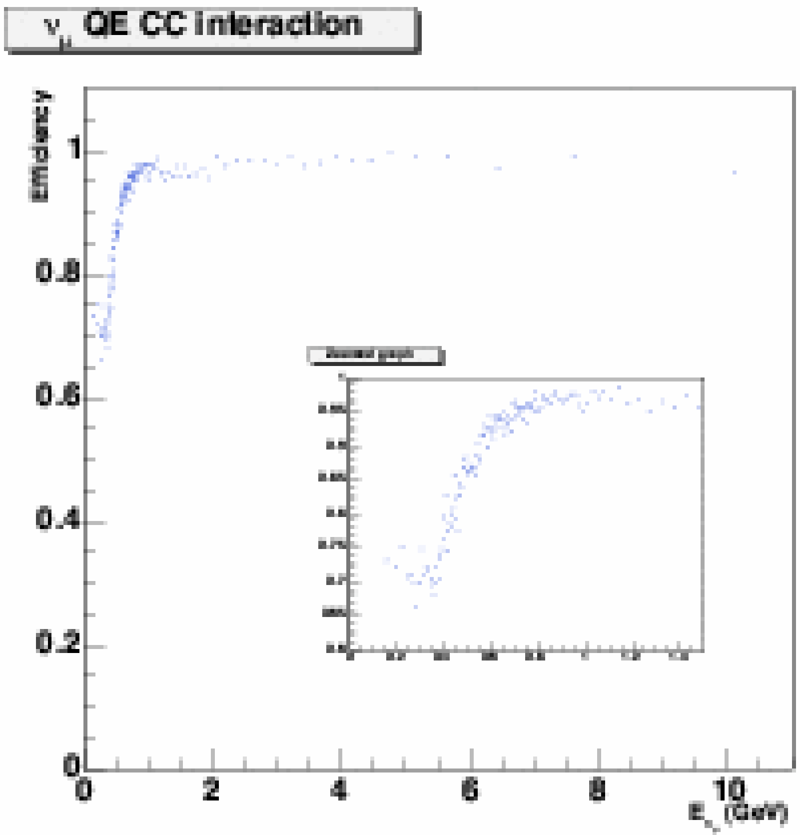


Figure 38: Efficiency for selecting QE ν_μ CC events as a function of the true neutrino energy.

Normalizing to the flux at 2km site: gives 1% contamination of NC events

suggests samples used are flat in energy.....
over what range?

preliminary automated event classification for T2K events cont.

2) “Random Forest” method based on eight input vars

further stage folds in kinematics and particle ID (eg: calculationof event total transverse momentum) of muons, pions, and protons -- classification algorithm rerun...

Table 4: Event classification results based on Random Forest analysis.

classification approach	original sample	events classified as: ν_μ CC	ν NC	ν_e CC
topology	ν_μ CC	86.0 %	10.9 %	3.1%
	ν NC	8.7 %	70.6 %	20.7%
	ν_e CC	3.7 %	11.5 %	84.8 %
topology + kinematics, PID	ν_μ CC	95.2 %	2.5 %	2.3 %
	ν NC	3.1 %	90.0 %	6.9%
	ν_e CC	1.8 %	3.6 %	94.5 %

8 var input

+ kinematics and PID

preliminary automated event classification for T2K events cont.

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8 var input

+ kinematics and PID

soft muons accompanied by pi0 showers -> biggest misID preliminary automated event classification for T2K events cont.

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+ kinematics and PID

soft electrons -> no showers: biggest misID

preliminary automated event classification for T2K events cont.

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photon induced shower taken as primary electron
-> should improve with dE/dx implementation
in algorithm

Efficiency vs neutrino energy: flat

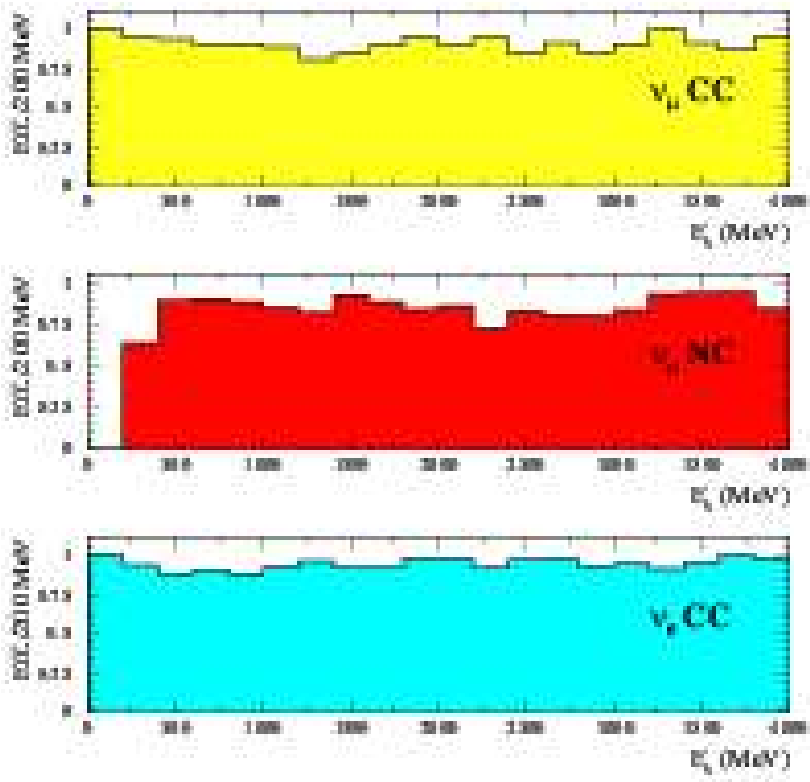
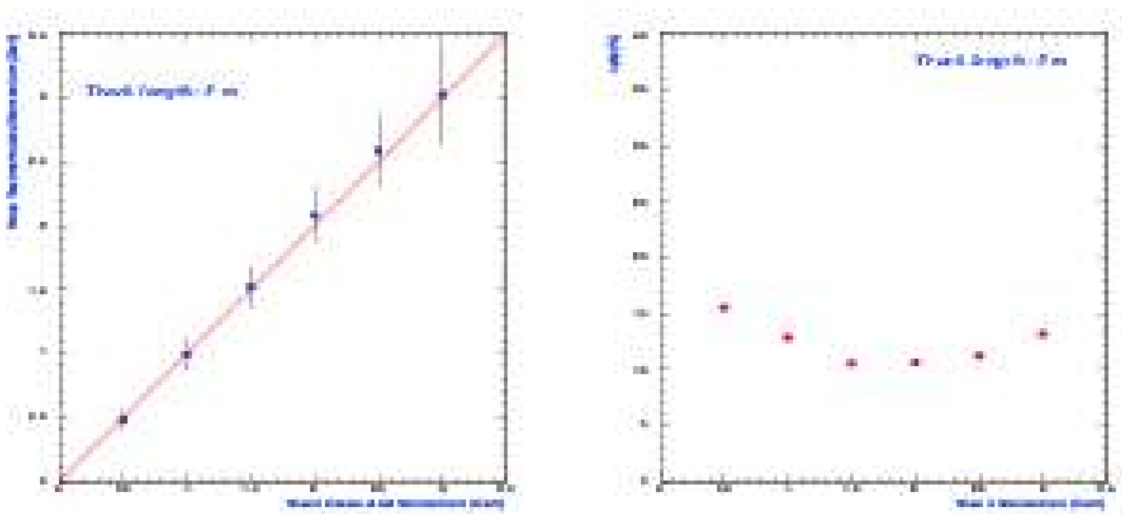


Figure 39: Classification efficiency as function of the incident neutrino energy.

Muon momentum measurement via dE/dx using Kalman fitting on track by track basis

Important for small detectors for uncontained muons (1 GeV muon _> 200 MeV/m for mip: 5m track)



~15% resolution for long tracks (short tracks are contained!

Figure 40: (left) measured momenta using the Kalman Filter versus the generated Monte Carlo momenta; (right) expected muon momentum resolution as a function of muon energy for a given track length.

1000 muons from 0.5-3 GeV reconstructed

Reconstructing neutrino energy using total energy deposited vs IDing all particles and converting Evis into momentum.

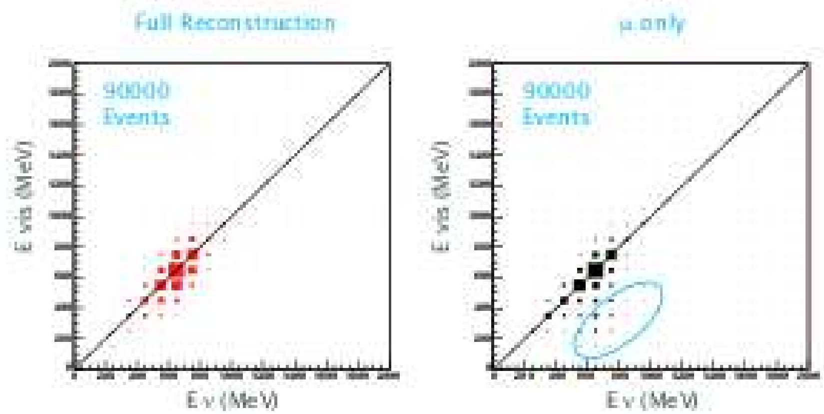


Figure 41: Visible energy vs true neutrino energy obtained by measuring both muon and hadronic energy (left) and only the muon energy (right). The region selected (right) contains mainly non-QE events not well reconstructed by only measuring the muon energy.

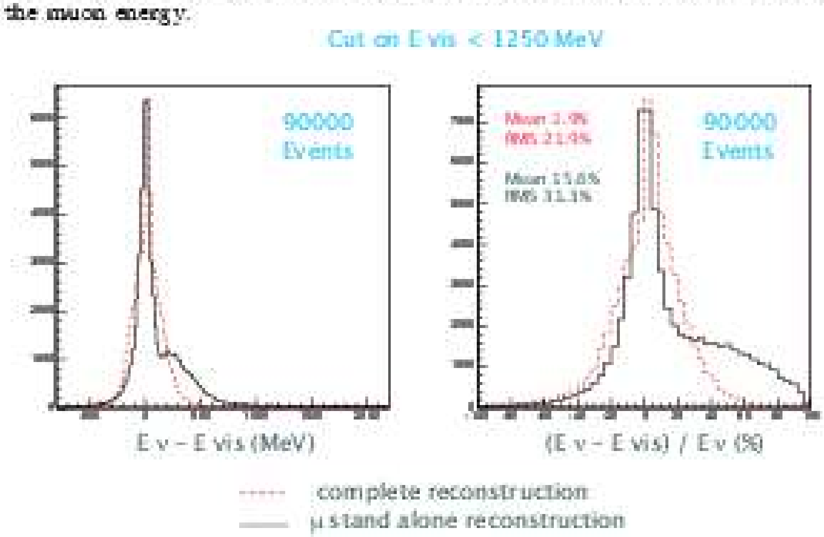


Figure 42: Difference between the true neutrino energy and the reconstructed one (left), and resolution of the reconstructed energy (right) after applying a cut of 1250 MeV on the visible energy. The solid gray line shows the results obtained measuring only the muon whereas the dashed red line shows the results obtained taking into account the hadronic energy.

Conclusion:
Use muon
and hadron info:
reconstruct Enu
to 22%

Also note:
Kimentatic
Recon studies:
Resolutions for
QE events
Q^2 ~16%
W ~10%

Summary of ICARUS performances

- Tracking device
  - Precise event topology
  - Momentum via multiple scattering
- Measurement of local energy deposition dE/dx
  - e / π° separation (2%X_0 sampling)
  - Particle ID by means of dE/dx vs range measurement
- Total energy reconstruction of the events from charge integration
  - Full sampling, homogeneous calorimeter with excellent accuracy for contained events
- Trigger provided by scintillation light from LAr (both scintillation and Cerenkov light are detectable)

RESOLUTIONS

Low energy electrons: $\sigma(E)/E = 11\% / \sqrt{E(MeV)}+2\%$

Electromagn. showers: $\sigma(E)/E = 3\% / \sqrt{E(GeV)}$

Hadron shower (pure LAr): $\sigma(E)/E \approx 30\% / \sqrt{E(GeV)}$

Hadron shower (+TMG): $\sigma(E)/E \approx 17\% / \sqrt{E(GeV)}$

C. Rubbia

Next Steps

- containment studies for “small” detectors using MC truth information. (Steve Linden starting detector MC work now)
- move towards automated reconstruction
  - modify Full Reco?
  - start with simple hough transform?
    - (Colin Anderson starting work on this now)

form a MC/Reconstruction group... -- see discussion