Charged Current Pion Production Results From T2K

(For the T2K Collaboration)

NuInt 2012

24/10/12

Overview

- Models and ND280
- Motivation
- Current π-production selection
- Selection performance and MC results
- Future plans and next steps

π-Production Models

- Use NEUT and GENIE neutrino interaction generators
  - Rein-Seghal model
  - Relativistic Fermi Gas
- Cross-section parameters
  - Axial Mass, Vector Mass
- Final state interactions
  - NEUT cascade model
  - GENIE INTRNUKE/hA

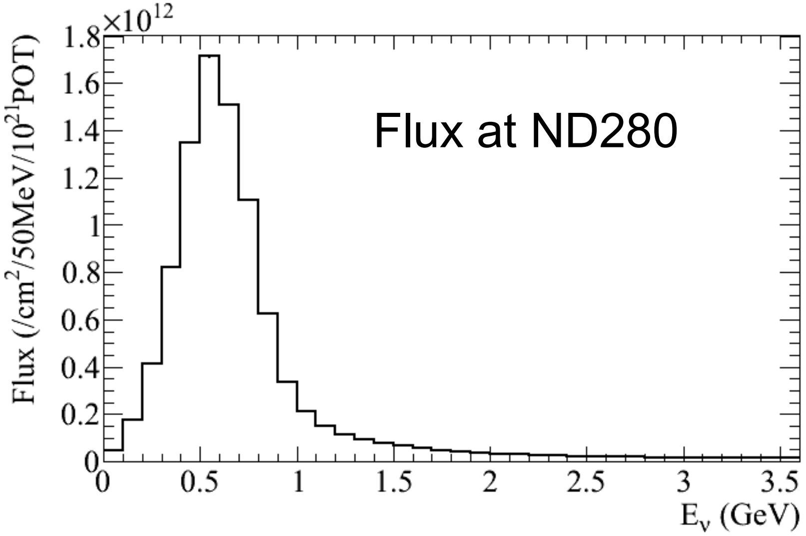
Generator parameters from fit to MiniBooNE data

Parameter	E_ν Range	Nominal	Error
M_A^{QE}	all	1.21 GeV/c^2	0.45
M_A^{RES}	all	1.16 GeV/c^2	0.11
CC1π Norm	0<Ev<2.5	1.63	0.43

- NEUT version v5.1.4.1
  - Plots shown use NEUT
- GENIE version v2.6.2

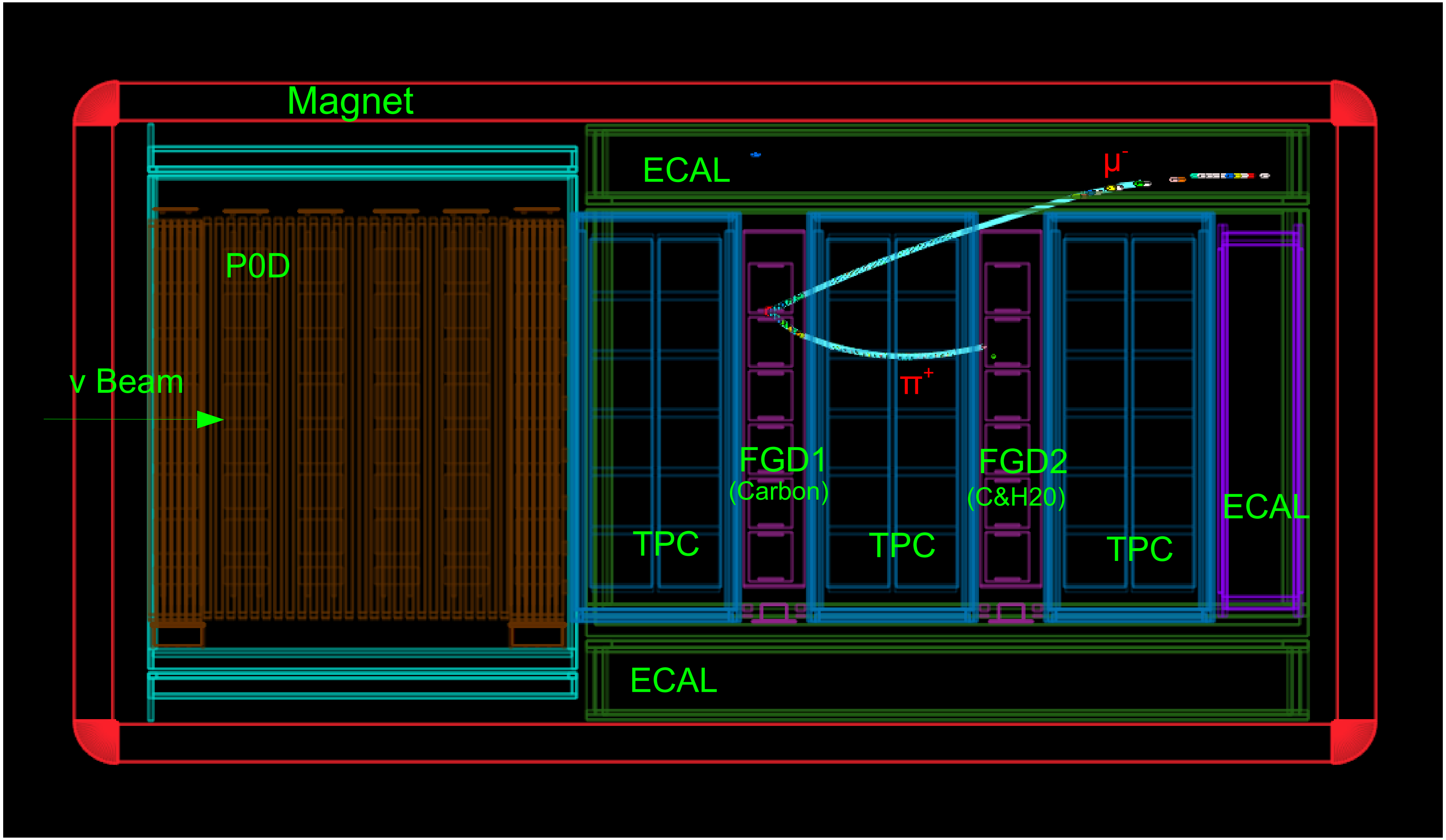
T2K

- Long baseline neutrino oscillation experiment
- Near detector ND280
  - Good potential for cross-section measurement
  - High final state resolution
- Narrow peaked flux
  - Maximum ~600 MeV
  - Large high energy tail
- Well known flux
  - NA61/SHINE data



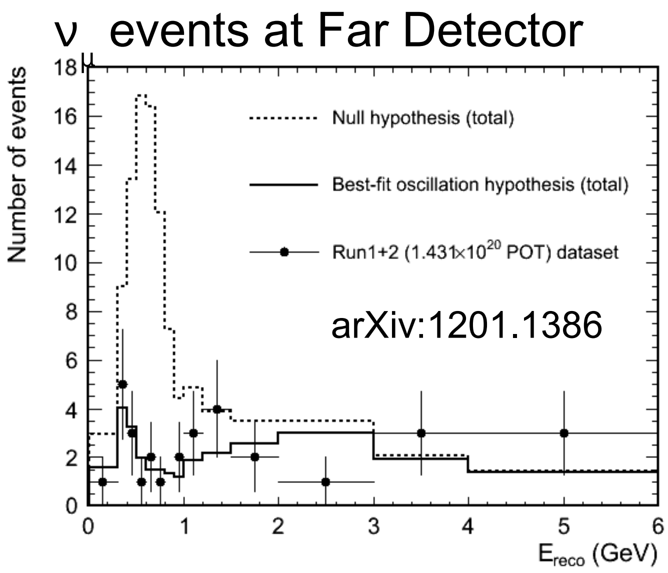
ND280

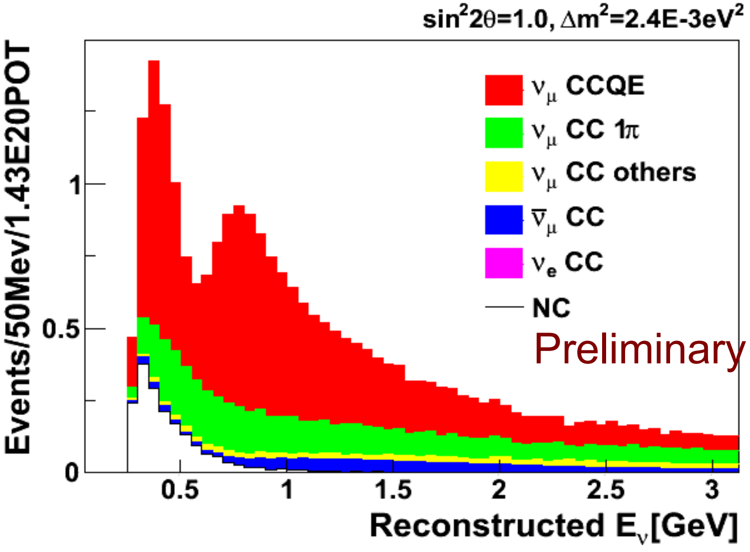
Monte Carlo



Why Measure π-Production at ND280

- Background to CCQE measurements
  - π absorption
- Selection needed for oscillation analysis
  - Dominant background around oscillation maxima
  - Energy misreconstruction
- Also background to other cross-section measurements

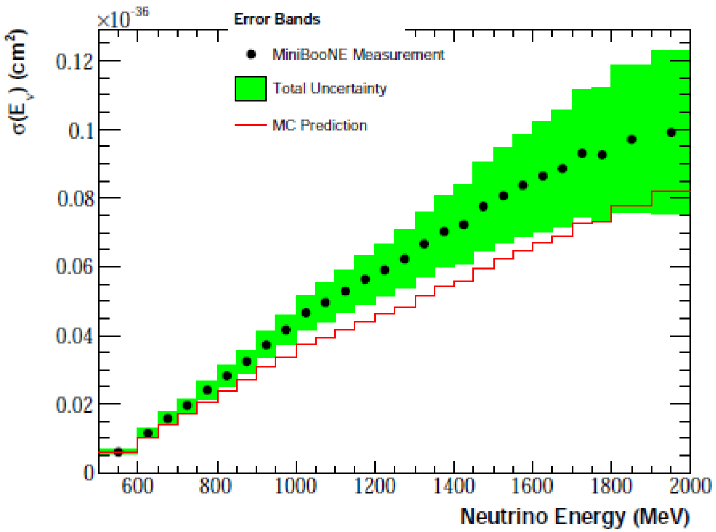


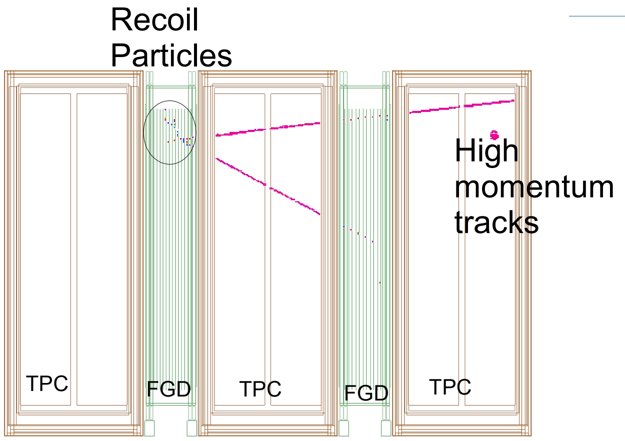


Why Measure π-Production at ND280

- Measure pion production cross-sections
  - Carbon (FGD1 target)
  - Oxygen 'subtraction' measurement ('FGD2 – FDG1' target)
- Similar peak energy as MiniBooNE
  - Compare results
- Unprecedented final state resolution
  - Sensitive to all final state particles

MiniBooNE arXiv:1011.3572, Phys. Rev. D83, 052007 (2011)



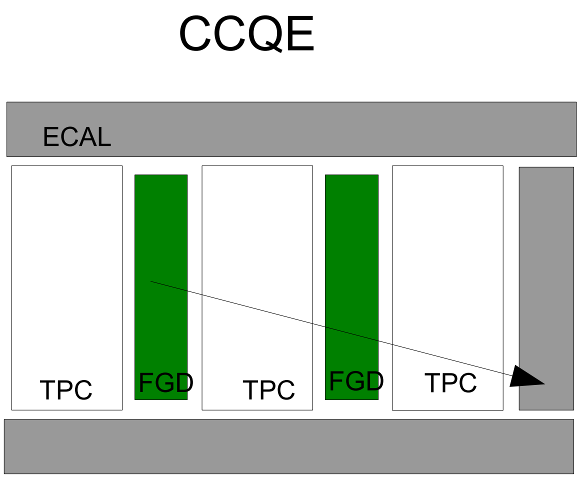


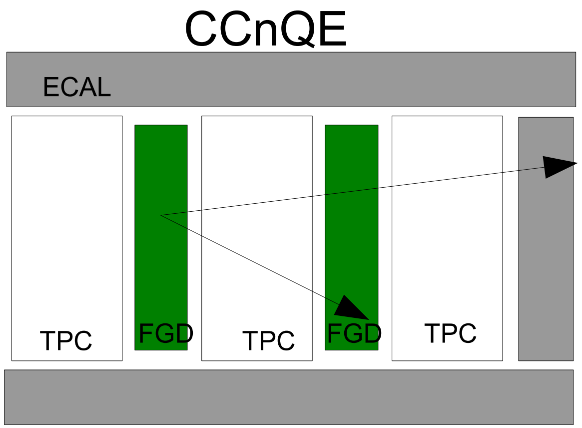
CC-Inclusive Selection

- Already have Charged Current (CC)-Inclusive Cross-Section Measurement
- Highest momentum negative track
  - Assume it is μ if TPC dE/dx consistent with μ
  - Must start in FGD & be forward going
  - Vertex taken as track start point
  - Any other tracks must not start more than 150mm upstream of vertex (TPC1 veto)
- More details:
  - See A. Weber's talk on 22nd - CC-Inclusive
  - See D. Ruterbories' talk on 25th – CCQE and NCQE

CCQE and CCnQE

- Split CC-Inclusive into 2 subsets
- CCQE (quasi elastic) subset
  - Only 1 FGD-TPC track
  - No Michel electron signature in FGD1
- CCnQE (non quasi elastic) sub set
  - All else





	Efficiency	Purity
CCQE	40%	72%
CCnQE	50%	88%

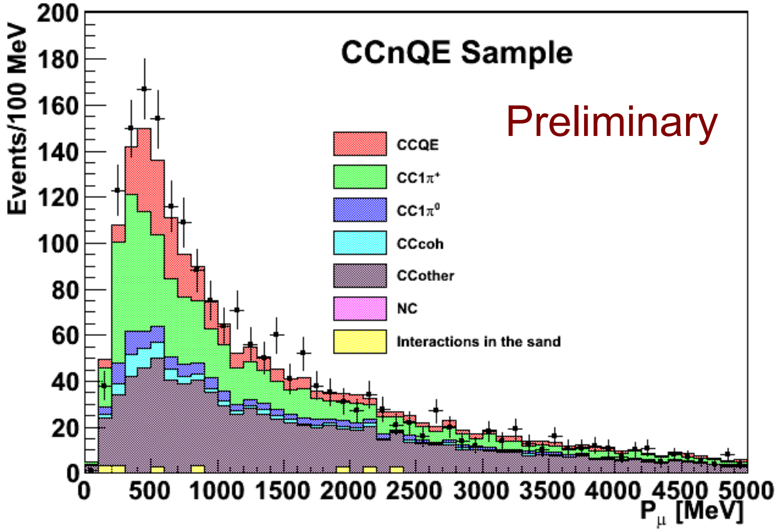
Effect of CC-Inclusive Measurement

- Fit to QE and nQE samples to tune parameters
  - Vary parameters, fit response in p_μ and θ_μ
  - Reduction in oscillation errors
- Introduce CC1π sample
  - Potential to increase performance
  - M_A^{RES}, CC1π norm, etc

Parameters used for oscillation fit

Preliminary	Prior Value and Uncertainty	Fitted Value and Uncertainty
M_A^{QE} (GeV)	1.21 ± 0.45	1.19 ± 0.19
M_A^{RES} (GeV)	1.162 ± 0.110	1.137 ± 0.095
CCQE Norm. 0-1.5 GeV	1.000 ± 0.110	0.941 ± 0.087
CC1π Norm. 0-2.5 GeV	1.63 ± 0.43	1.67 ± 0.28
NC1π^0 Norm.	1.19 ± 0.43	1.22 ± 0.40

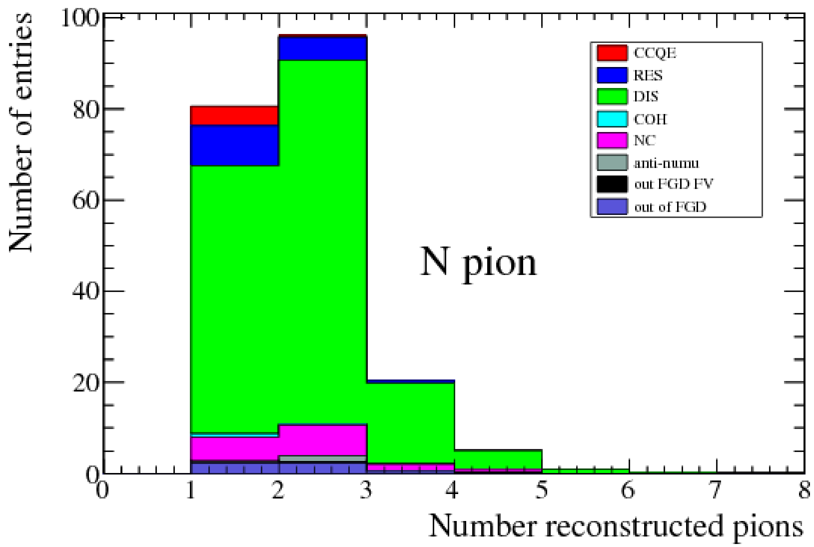
Prior value and uncertainty from fit to MiniBooNE single pion samples



Dividing the Non-QE Selection

- Pion production events currently in the CCnQE selection
- Implement additional cuts to select pions in nQE
  - $1\pi^{\pm}$ selection (both charges)
  - $N\pi^{\pm}$ selection
- ~4000 nQE data events
  - From 2.65×10^{20} protons on target

1π and Nπ Selection MC

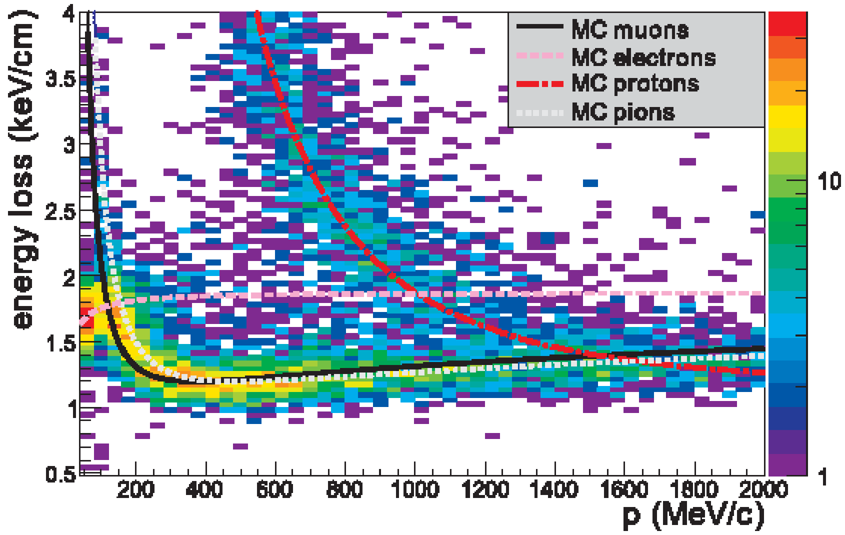


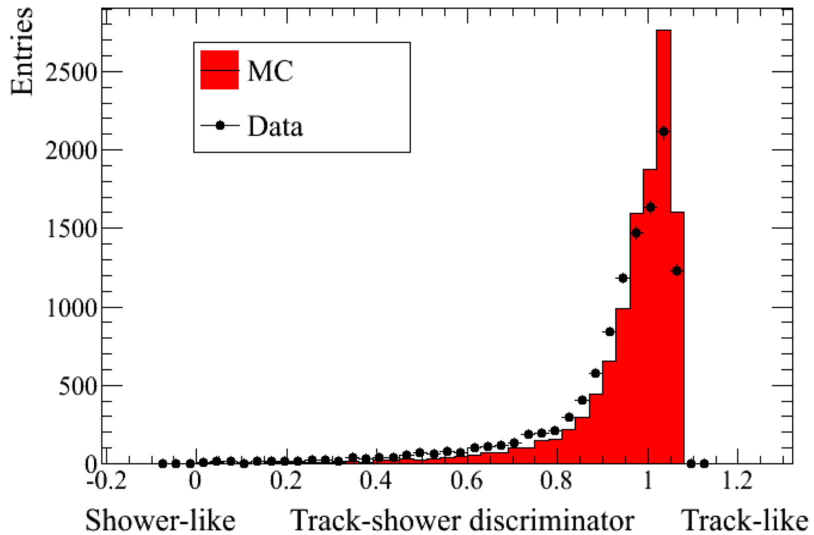
Future Selection Study, Preliminary

π Selection

- Start with CCnQE selection
  - Negative muon track & other tracks. FGD1
- Identify $\pi^{\pm}$'s
  - TPC dE/dx consistent with π hypothesis
- On going study
  - Use ECal to identify side going π
  - Track-like, & dE/dx

TPC dE/dx - positive particles



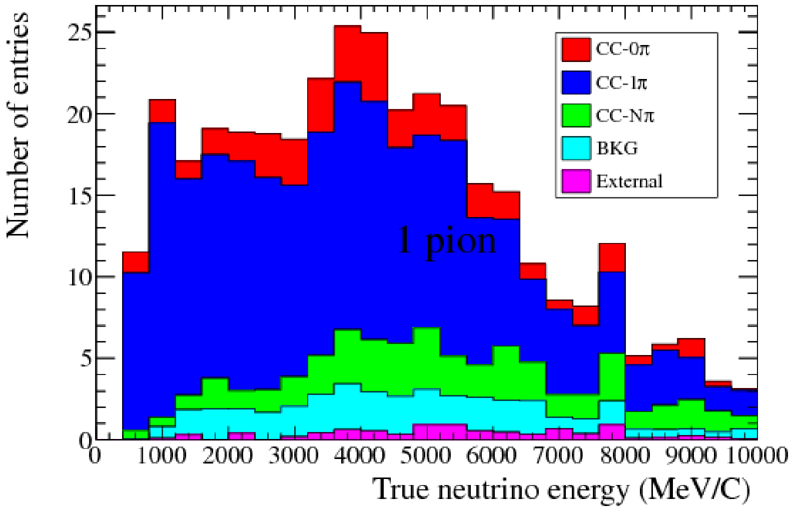


Track identifcation variable for μ

MC Study Results

1π Selection

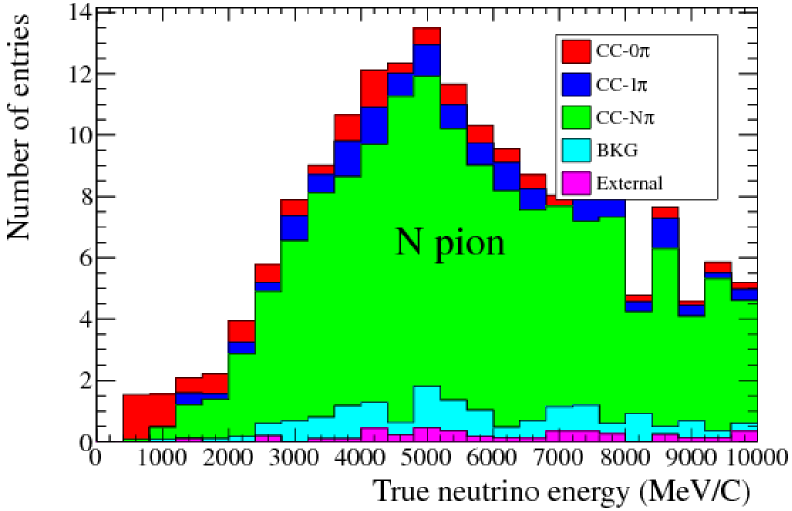
(1 reconstructed π^{+})



Future Selection Study, Preliminary

Nπ Selection

(1≤ reconstructed $\pi^{\pm}$)



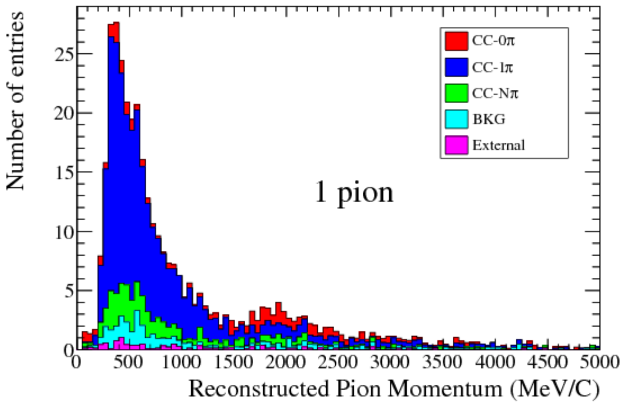
Future Selection Study, Preliminary

Efficiency and purity being finalised

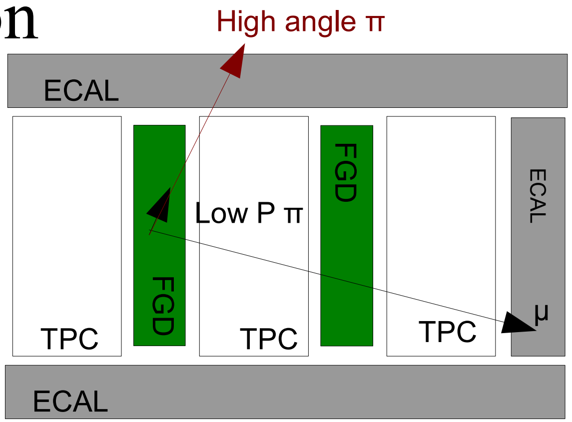
The Future: Short Term

- First analysis - limited kinematic space accepted
- Working to extend accepted phase space
  - Main focus- low momentum & high angle
- Developing and validating improved reconstruction tools
  - Improved FGD tools - low momentum region
    - Michel Tagging, dE/dx
    - Short range π
  - Further investigation into ECal tools – high angle region

1π selection composition MC



Future Selection Study, Preliminary



Conclusions & Plans

- Progress towards CC1π cross-section measurement at T2K
  - Complement to MiniBooNE data at ~1GeV
  - Measure exclusive final states
- First analysis near completion
  - First results coming soon
- Extract cross-section on carbon
  - Confront models with data
  - Compare to predictions
- Cross-section on oxygen (water target)
  - In development

Backup

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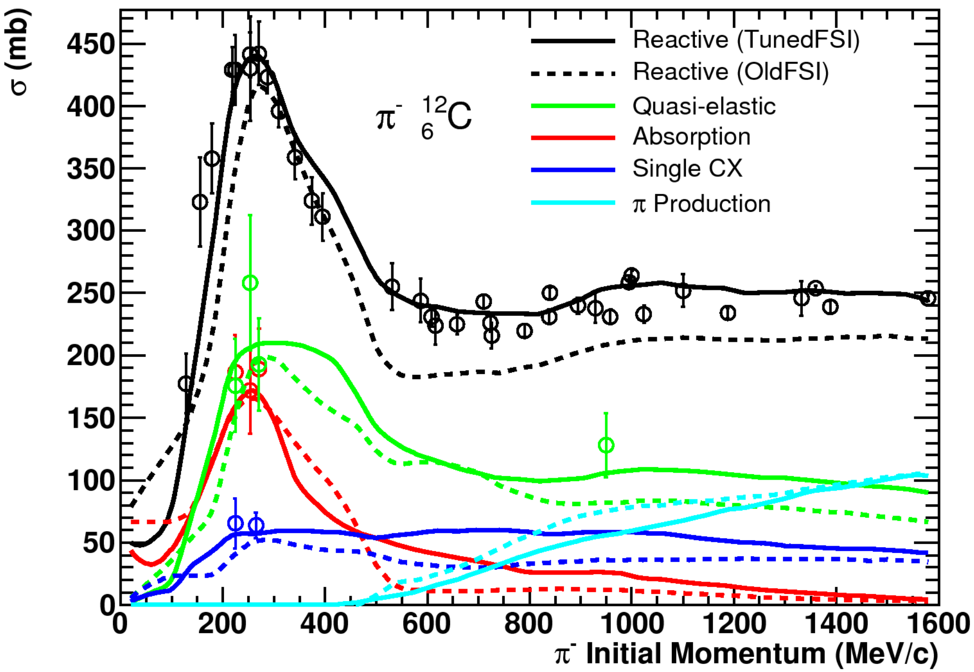
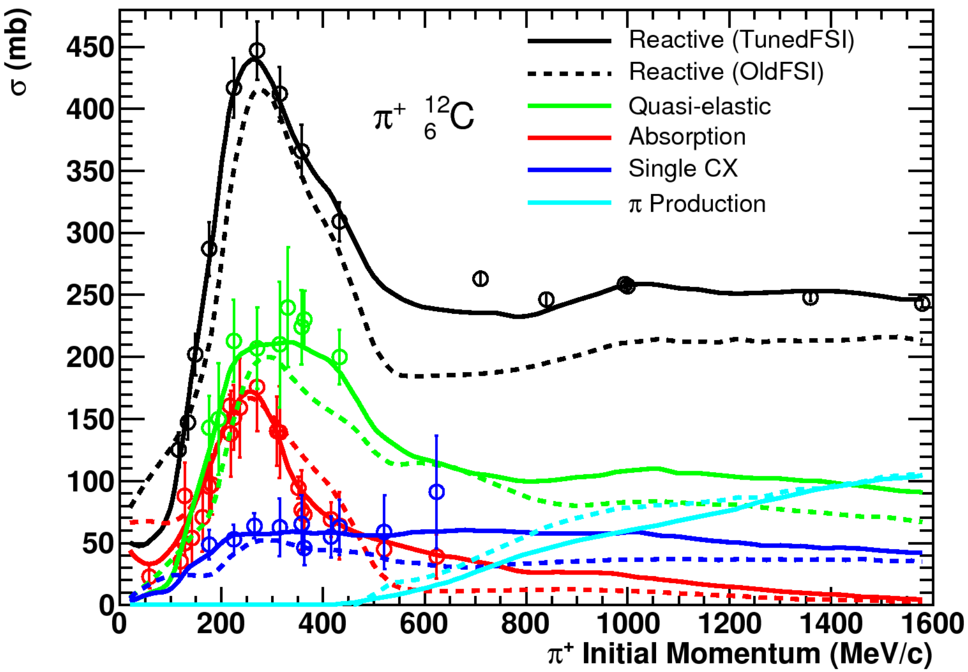
NEUT Nuclear Cascade Model

- Propagate π classically through nucleus in steps
  - Probabilities for each interaction are calculated at each step
  - Interaction type at step calculated using random number
  - Nuclear density taken as Woods-Saxon potential

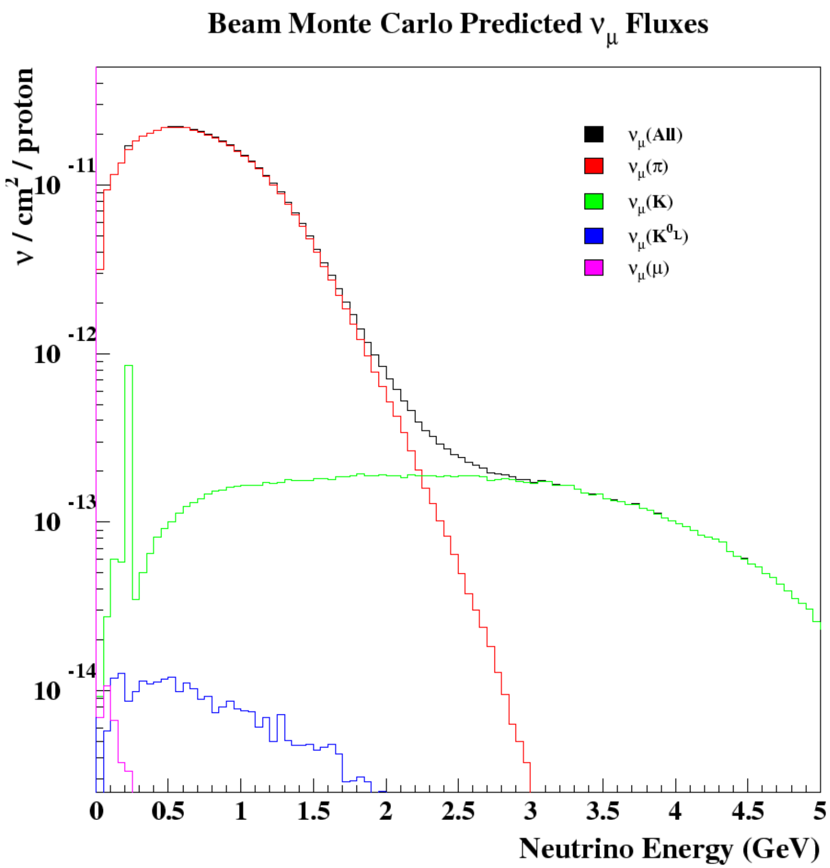
- Cascade ends when pion exits nucleus
  - Taken to be 2.5 nuclear radii (N_R)
  - Step size used = $N_R/100$

FSI Cross Sections

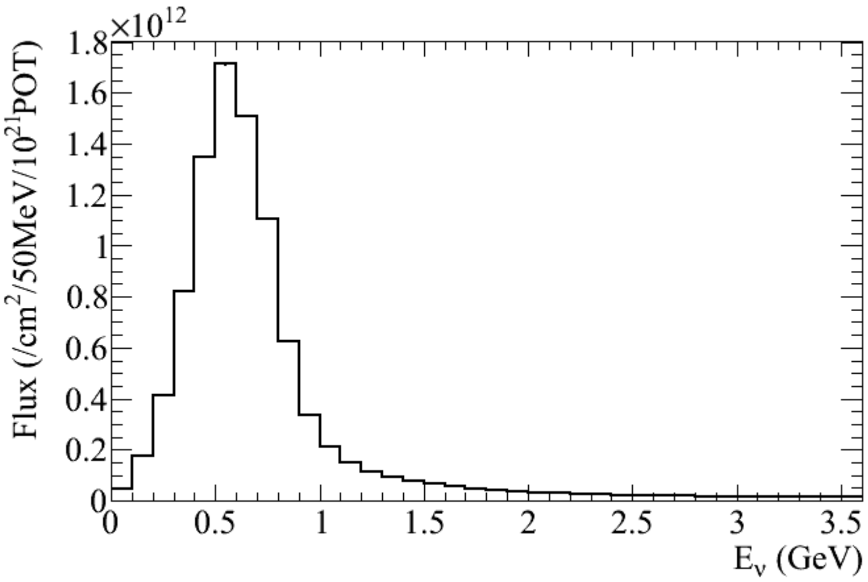




Comparison of Fluxes

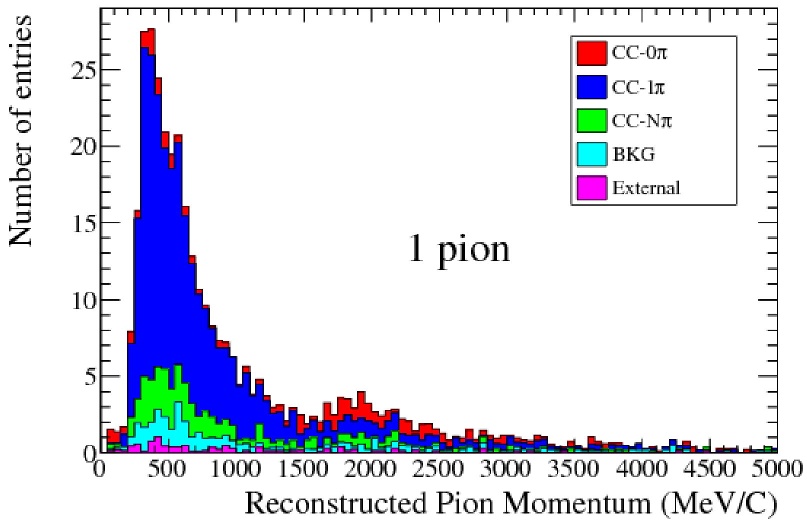


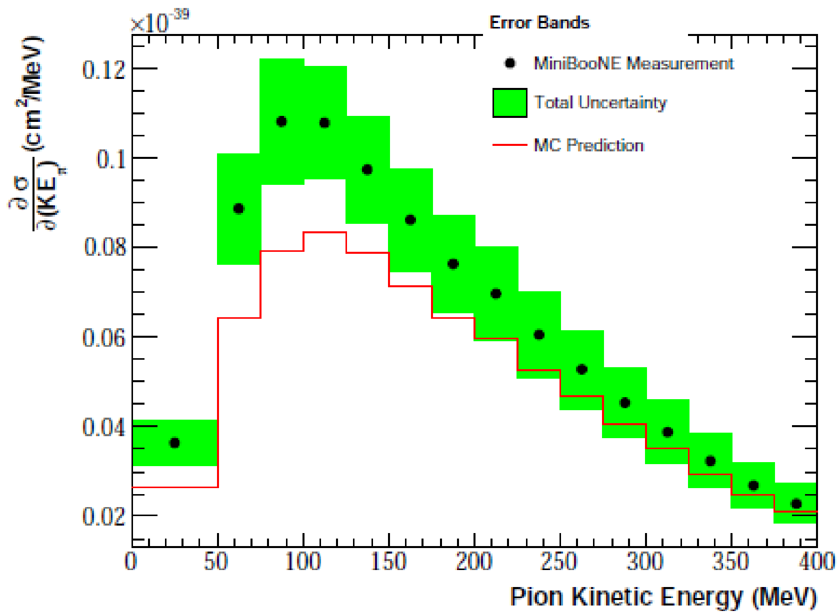
MiniBooNE flux



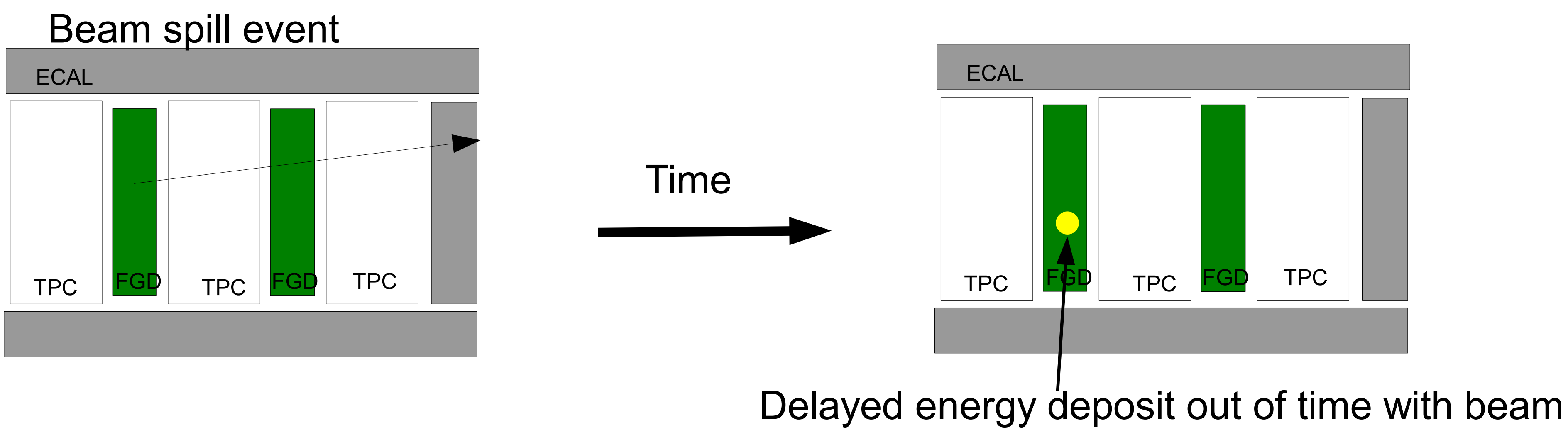
T2K flux at ND280

Comparison to MiniBooNE

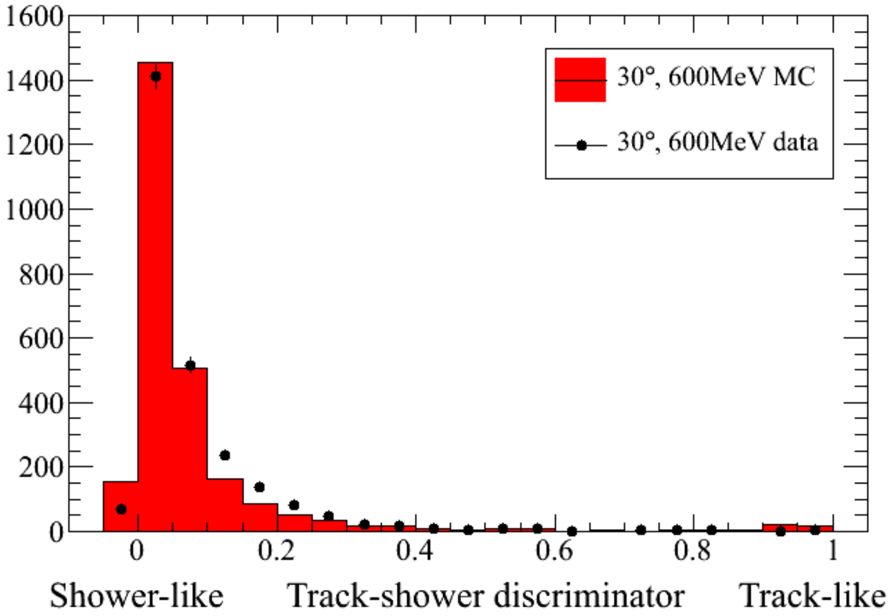




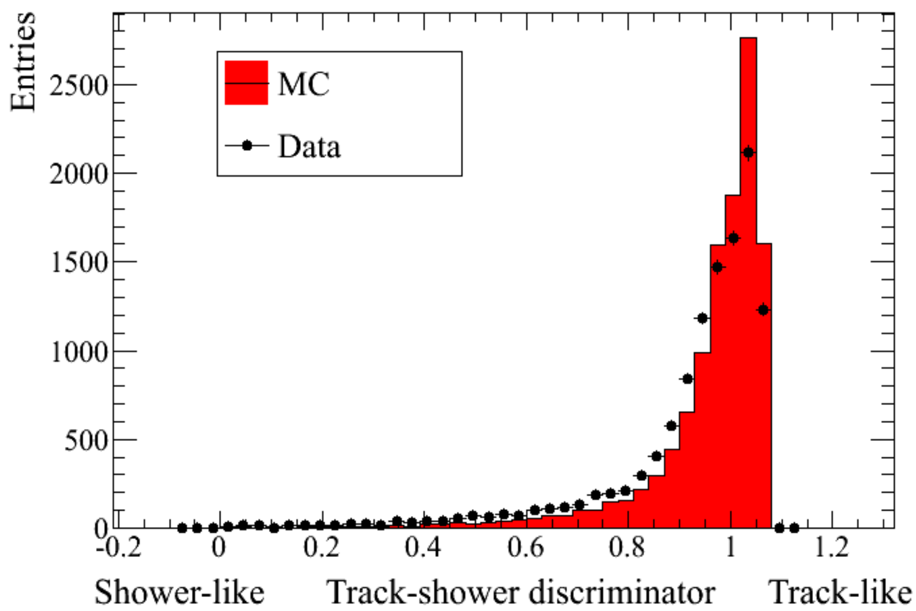
Michel Electron Signature



ECal Track-Shower Discriminator



Track identifcation variable for e



Track identifcation variable for μ