Status of the first MiniBooNE Neutrino Oscillation Analysis

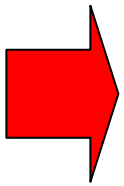
Janet Conrad & Bill Louis
for the MiniBooNE Collaboration

Outline:

Intro	Janet
Event Rates	
Particle Id	Bill
Backgrounds and signal	

Intro: The first question....

Have You or Haven't You !?



MiniBooNE has not opened the box.
We have not yet set a date for presentation.
We *are* in the endgame...
That's what we will show today

Intro: What we are asking for....

What are we,
the spokespersons of the neutrino run,
asking from this PAC?

Just a little more support and patience.

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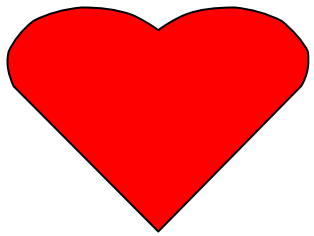
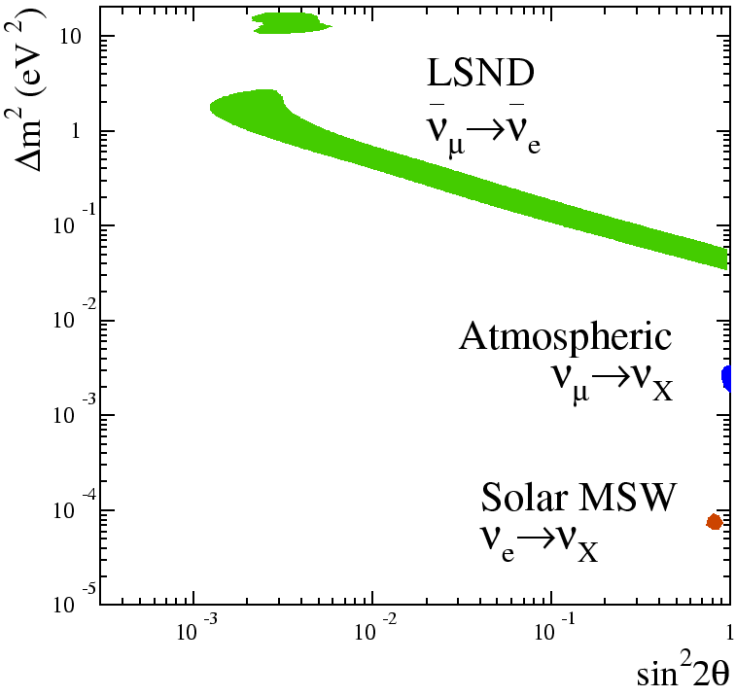


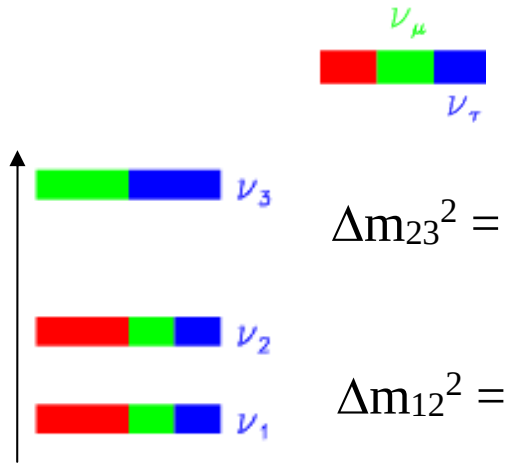
Just a little more support and patience.
And a shower of kudos on our collaborators for the great work shown here!

Intro: The LSND Question

ν_e excess:
87.9 ± 22.4 ±6.0 (4.σ)
interpreted as oscillation:



In SM there are only 3 neutrinos



$\Delta m_{23}^2 = m_2^2 - m_3^2$

$\Delta m_{12}^2 = m_1^2 - m_2^2$

And ... $\Delta m_{13}^2 = \Delta m_{12}^2 + \Delta m_{23}^2$

But ... $1 \neq 0.003 + 0.00005$

LSND | atmospheric | solar

Confirmation would imply a significant extension BSM

Intro: Analysis Strategy to Test LSND

- Our goal is to test whether
  LSND is due to $\nu_\mu \rightarrow \nu_e$ oscillations

- Our first result assumes no ν_μ disappearance,
  which is a good approximation given $P_{LSND} = 0.3\%$

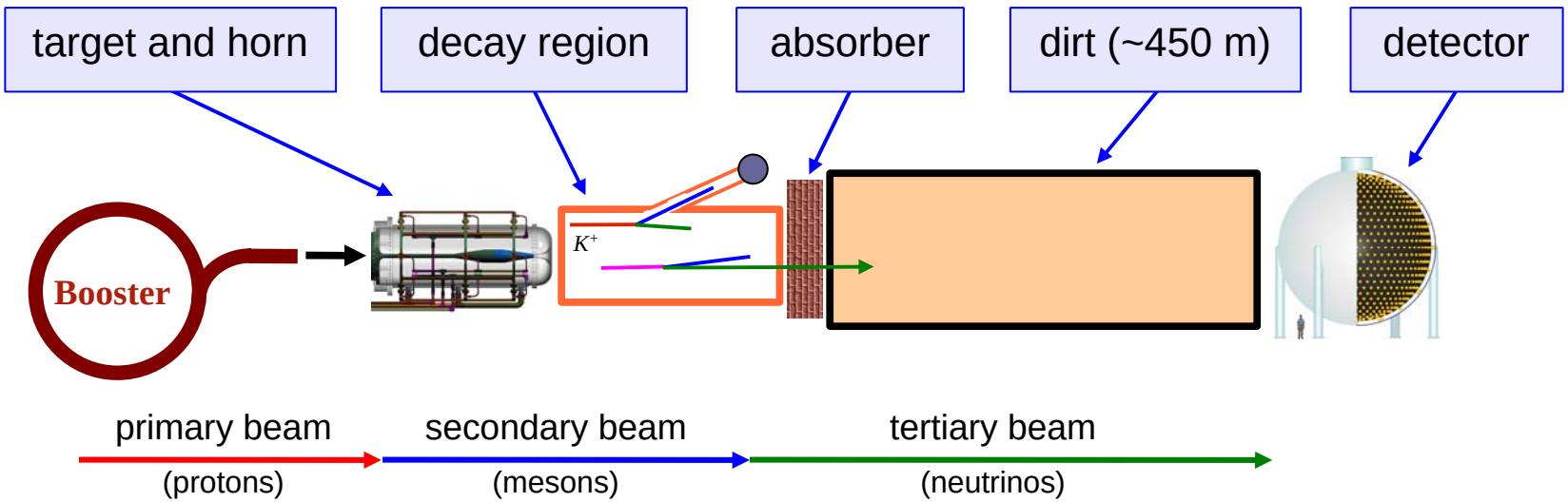
- We will use the ν_μ events to constrain the predicted ν_e events
  (many systematics will cancel)

- We tie down our systematics with our own data
  External (runs in specialized set-ups)
  Internal (calibration and neutrino data)

Intro: The Design of MiniBooNE

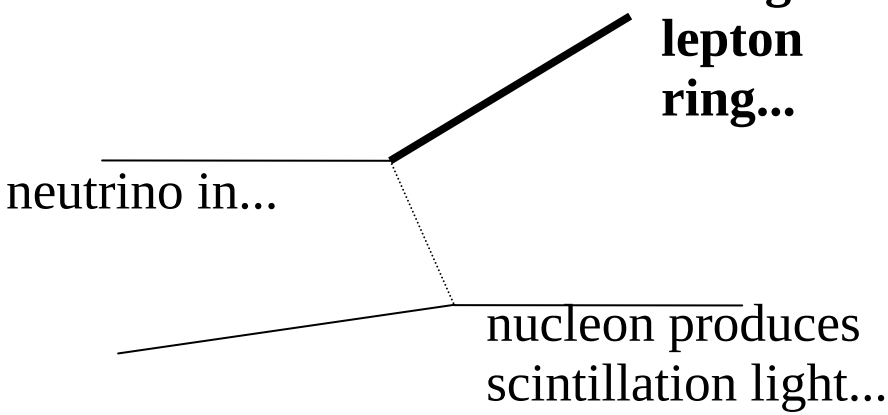
$$P(\nu_\mu \rightarrow \nu_e) = \sin^2 2\theta \, \sin^2(1.27 \Delta m^2 L/E)$$

Keep L/E same while changing systematics.
Design assumes we are looking for oscillations.

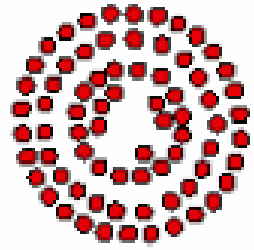


Intro: Signal and Background Basics

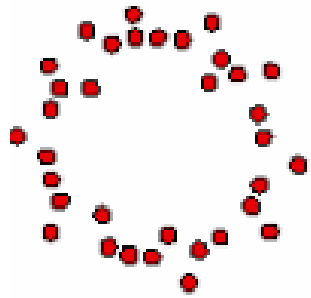
We use CCQE events



Muons

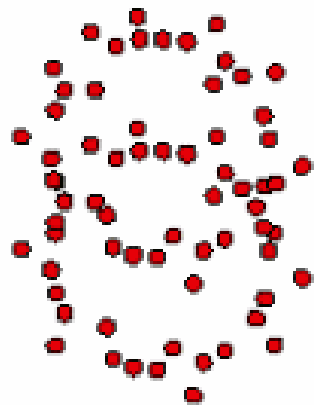


Electrons
"intrinsics"
& possibly
from osc.



Events which look "electromagnetic" can be a background:

- NC π^0 where one photon is lost
- NC radiative Δ decay
- etc



Event Rates: Introduction

ν Rate = flux $\times$ cross section $\times$ detector-related properties

Flux: From pion and kaon decays.
Use our own parameterization of outside data.

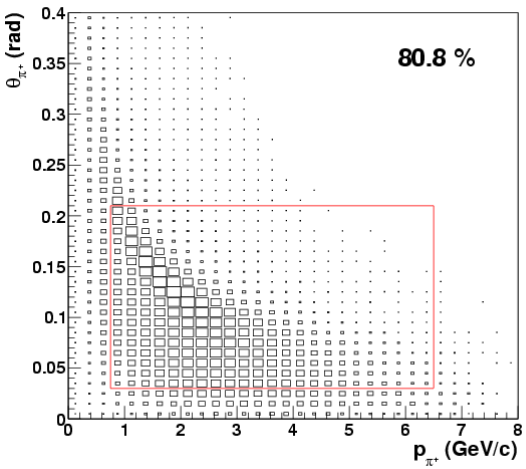
Cross section: Use the NUANCE package
With tuning to our data sets.

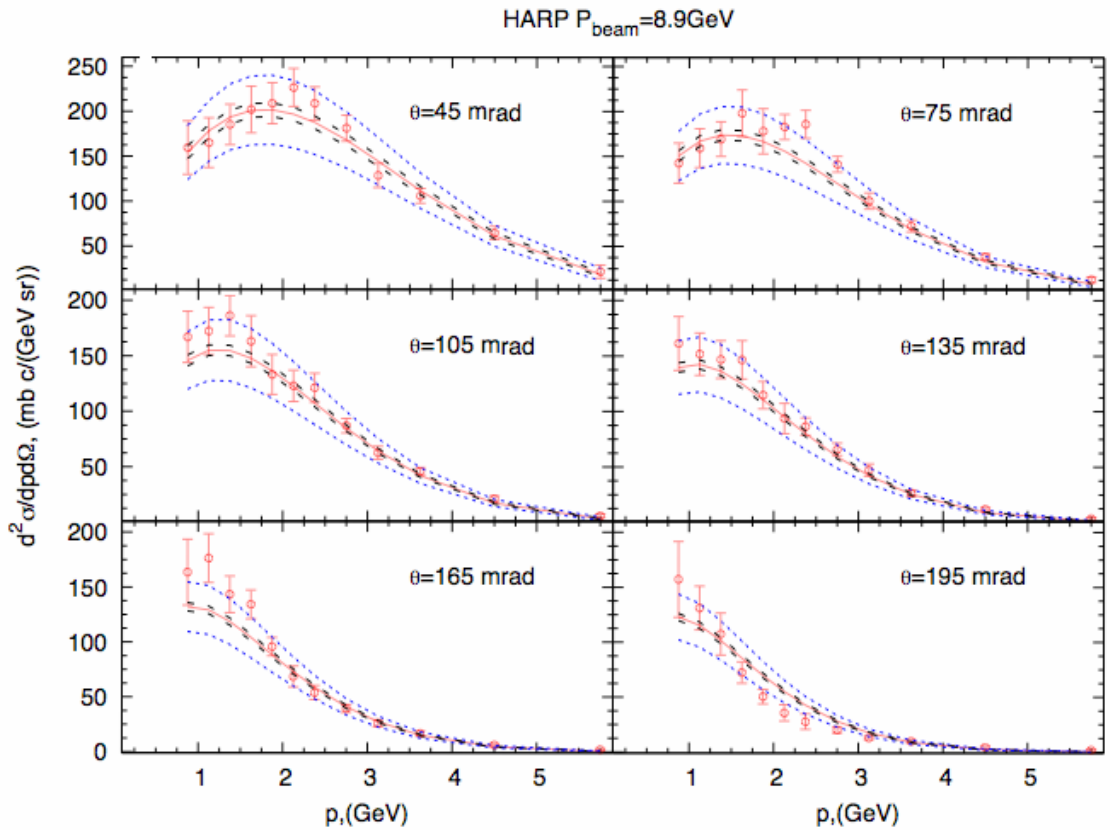
Detector: GEANT-based model.
Efficiency of reconstruction depends on
"Optical Model" of light in the detector

Many systematics will overlap for ν_μ and ν_e in the above.

Event Rates: Flux Prediction from Pion Decay

Based on pBe data:
BNL E910 @ 6,12 G
HARP @ 8.9 GeV
(with target replica)





Uses a "Sanford-Wang" Parameterization

data -- red points
total error (fit ⊕ parameterization) -- blue dash

Event Rates: Flux Prediction from Kaon Decay

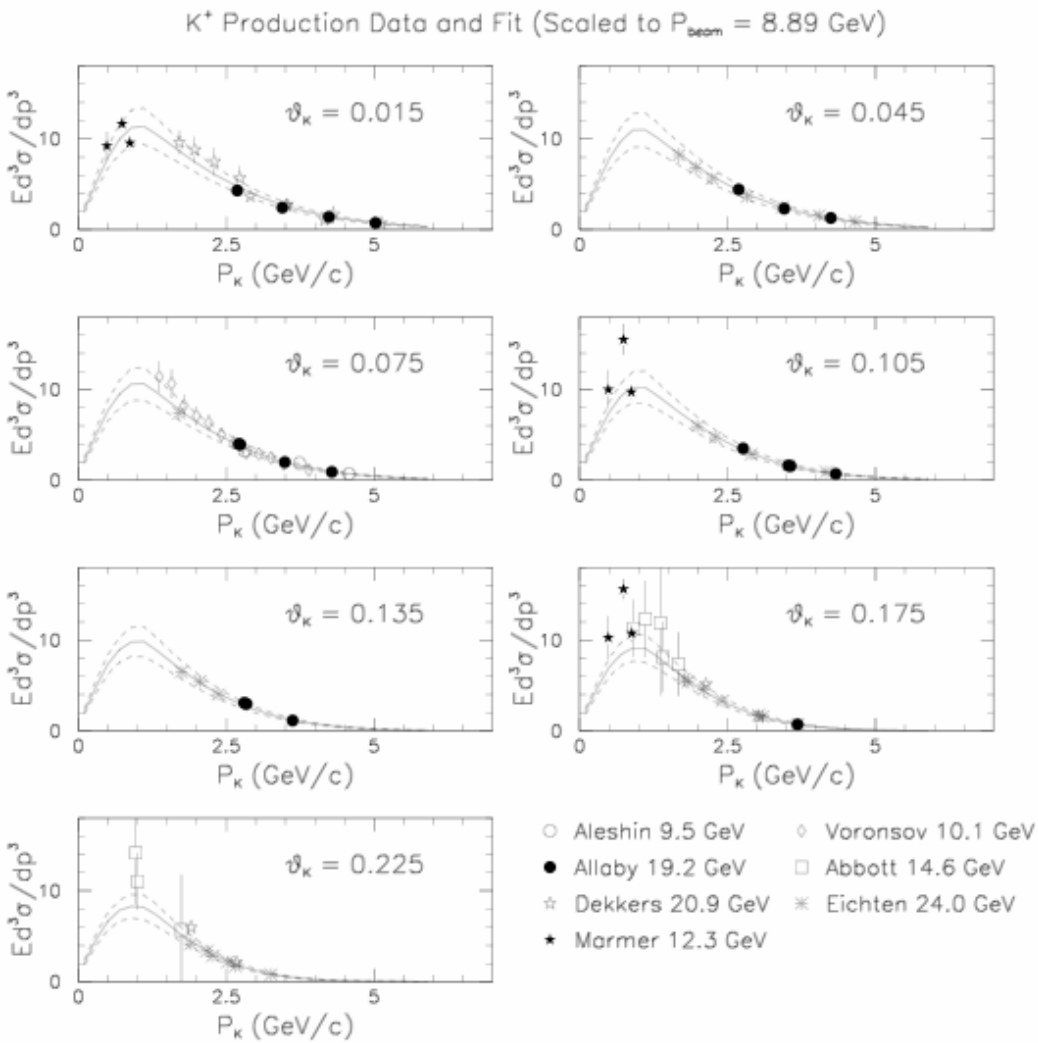
K^+ Data from 10 - 24 GeV.

Uses a Feynman Scaling Parameterization developed by MB collaborators.

(Paper Coming Soon)

data -- points
total error
(fit ⊕ parameterization) -- dash

(We also parameterize the K^0's w/ a SW fit)

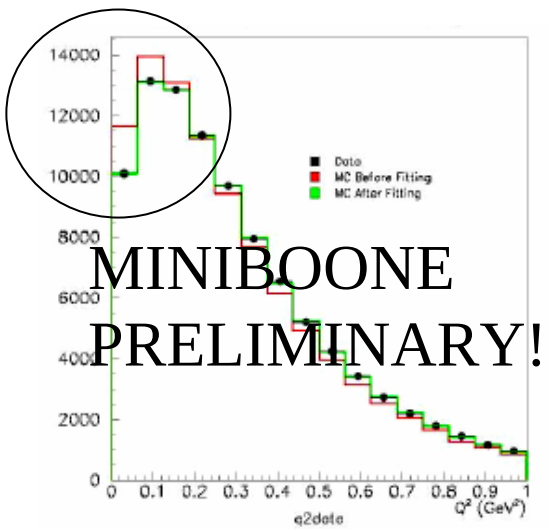


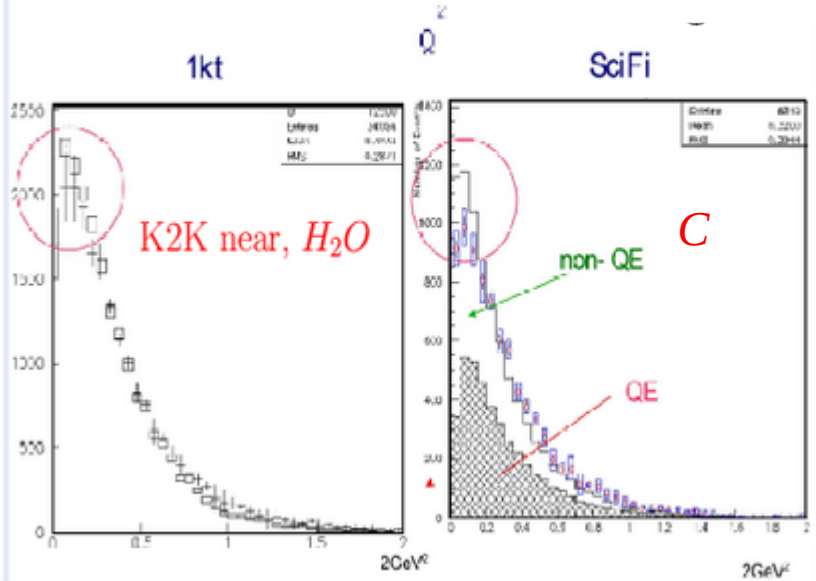
Event Rates: CCQE Cross Section Prediction

Assumes Binding Energy and Fermi Momentum from e-scattering.

Takes the RFG as a model and fits for an effective-M_A and Pauli Blocking parameter. (Paper planned)

With this, the longstanding "low Q2 discrepancy" (also seen at K2K and BNL) is addressed.



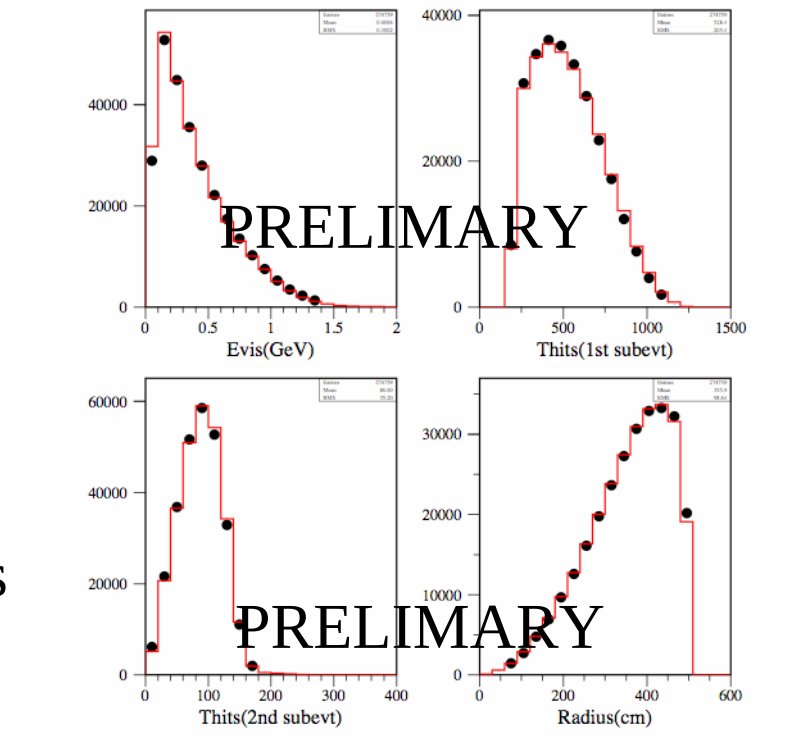


Event Rates: Modeling the Detector

Geant simulation with a 35-parameter optical model,
tuned using external data, Michel electrons, cosmics, NC events

Example:
Inclusive CC events
(tagged by Michel electron)

MC includes:
- Events in surroundings (“dirt”)
- Strobe overlay for noise, cosmics

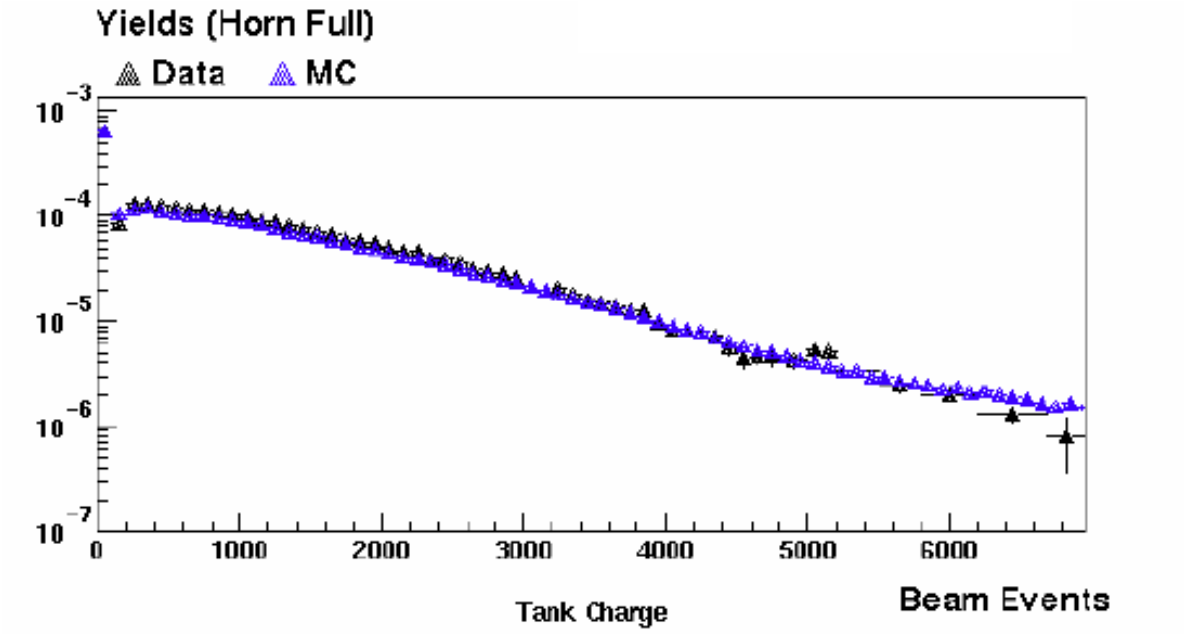


Enormous amounts of work went into tuning this MC!

Event Rates: Comment on Overall Normalization

Data vs MC consistent with expected error

(more precise comment coming in a few weeks.)



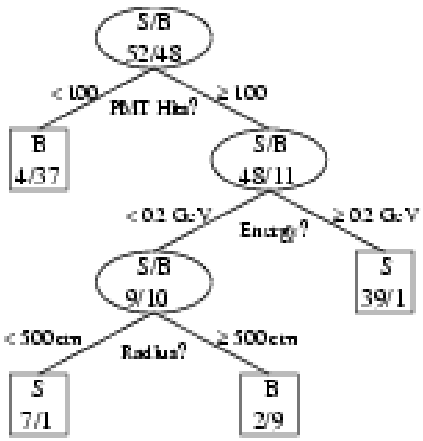
Wasn't it ~1.6 in your last PAC presentation?

Yes, improvements were all-around:

- Beam: HARP, corrected incoming beam model
- Cross Section: improved CCQE model
- Detector: improved optical model, leading to better fiducial volume agreement

Particle Identification

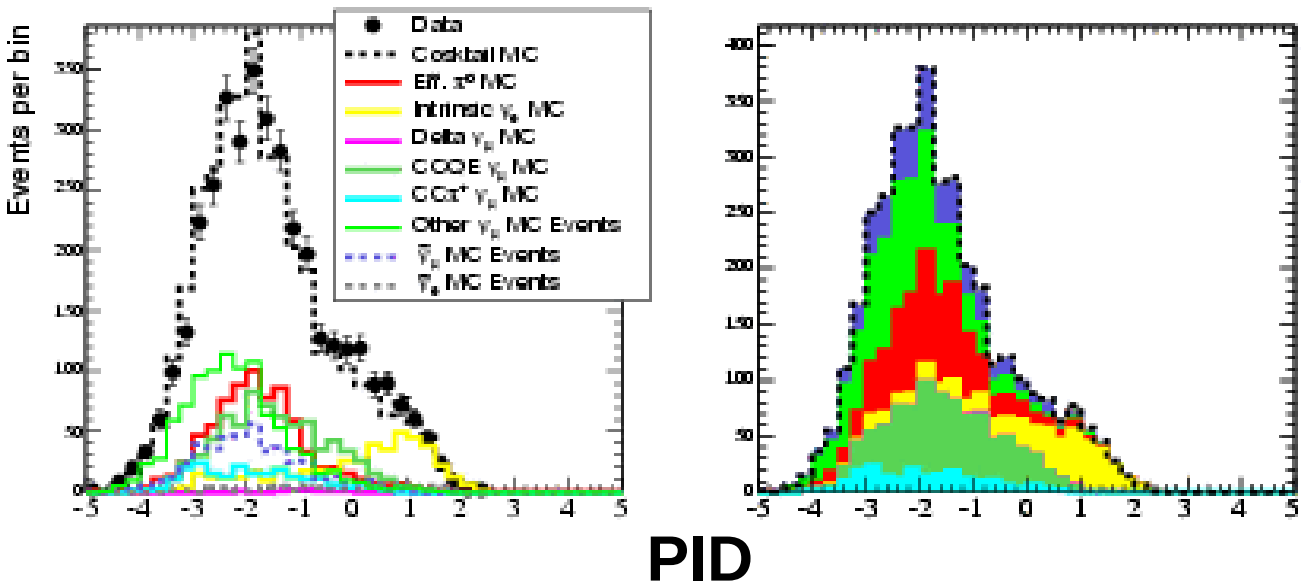
- We will use two different methods for Particle Identification: Boosted Decision Trees (**PID**) & Likelihood Cuts ($\mathbf{L_{e\mu}}$,$\mathbf{L_{e\pi}}$)
- See **NIM A543 (2005) 577 & NIM A555 (2005) 370** for discussions of Boosted Decision Trees, which give better performance than ANNs



PID Distribution for Contained NuMI 1 Sub-Events

Good agreement between data and MC!

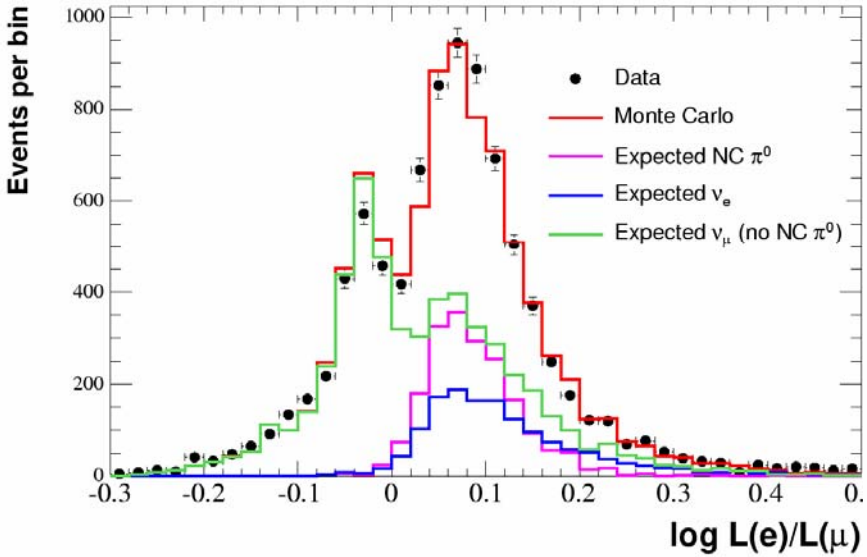
Preliminary!

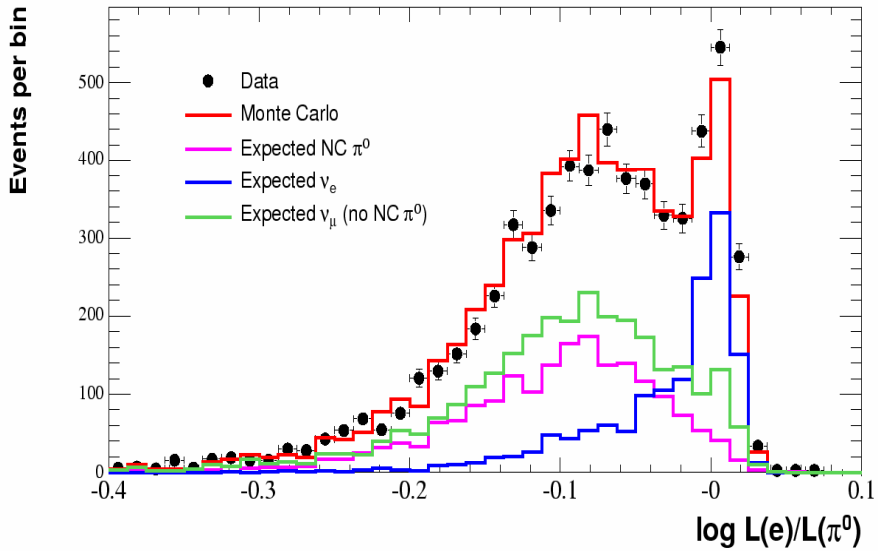


Likelihoods for Contained NuMI 1 Sub-Events

Good agreement between data and MC!

Preliminary!





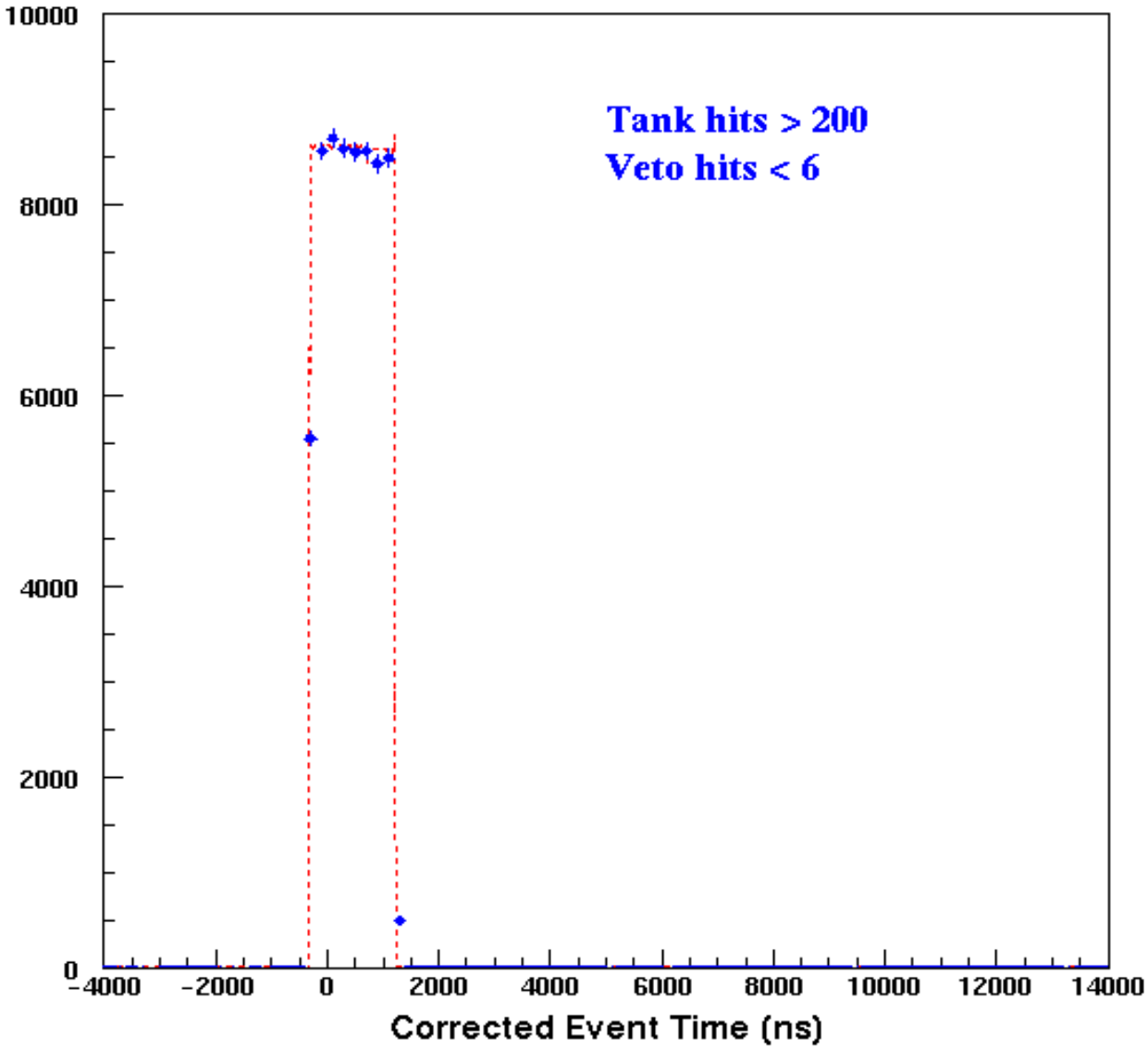
Backgrounds

- **Non- ν_e Backgrounds**
- Beam Off
- CC Inclusive
- NC π^0
- NC Δ–>Nγ
- NC Coherent γ
- NC Radiative γ

- **Intrinsic- ν_e Backgrounds**
- From μ -> ν_e decay
- From K-> ν_e decay
- From π -> ν_e decay

Beam-Off Background is Negligible!

Neutrino Signal to Cosmic-Ray Background ~ 5000 to 1!



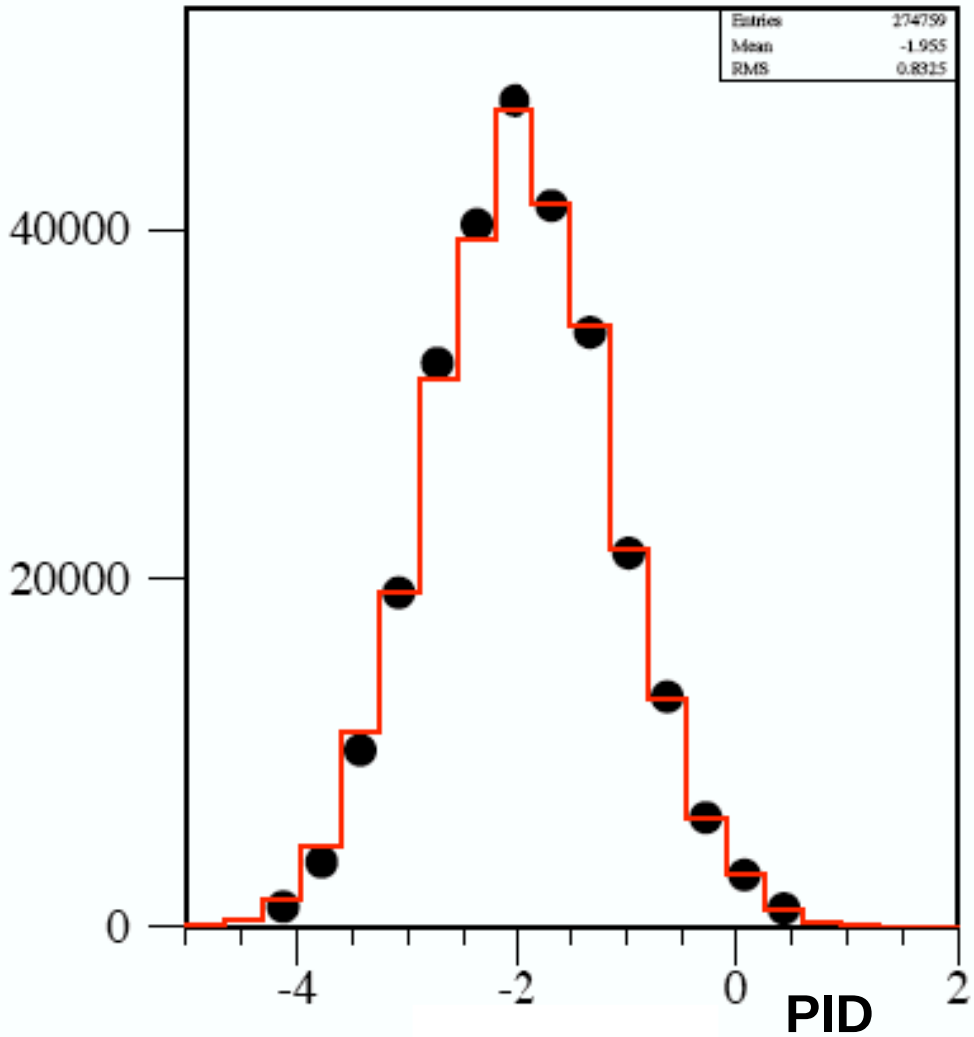
Good PID Agreement for CC Inclusive Events

Preliminary!

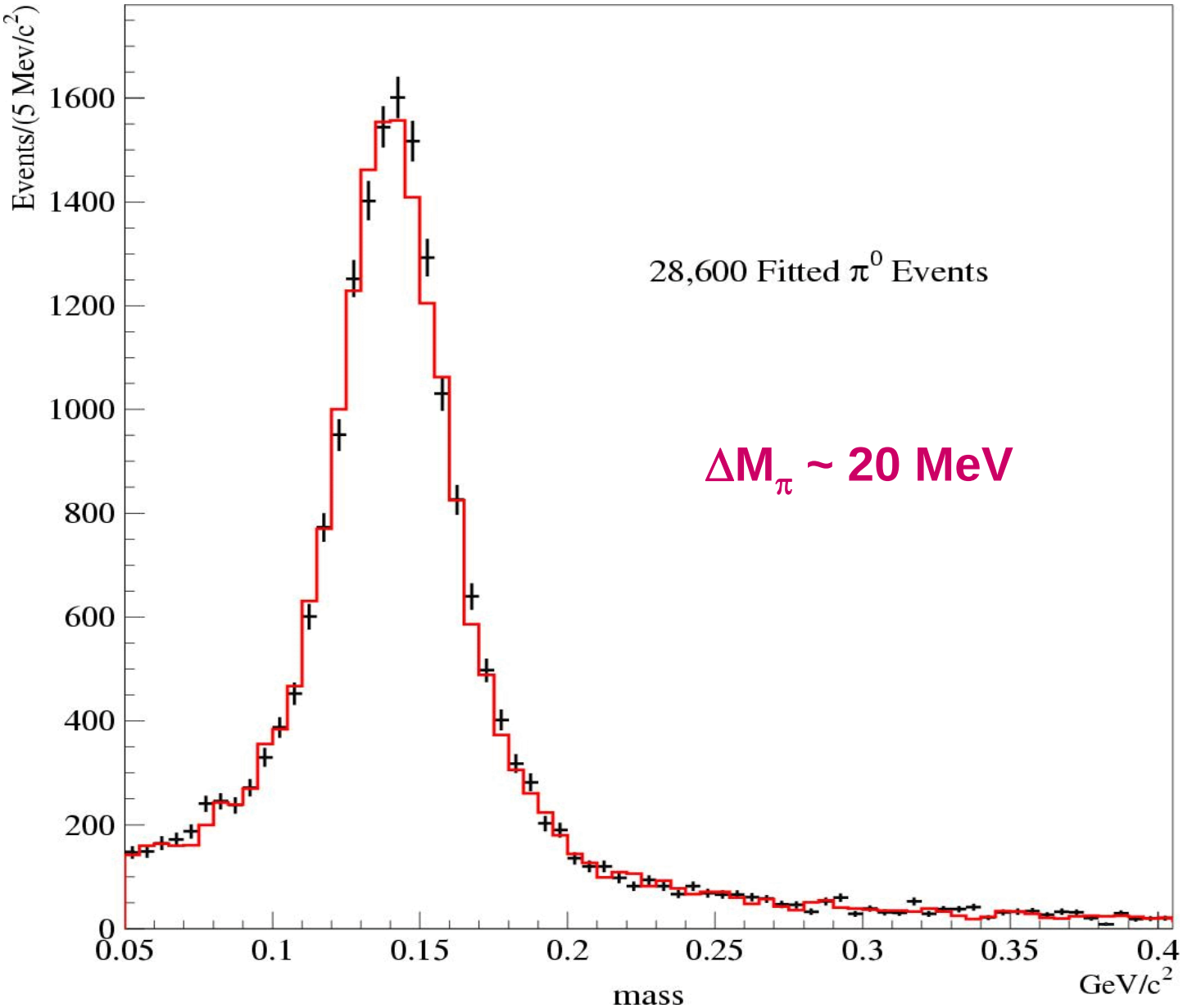
CC inclusive events tagged by Michel electrons

92% of μ^- decay
8% of μ^- capture

MC is correctly estimating CC inclusive background



MiniBooNE NC π^0 Events are Measured



Gamma Backgrounds

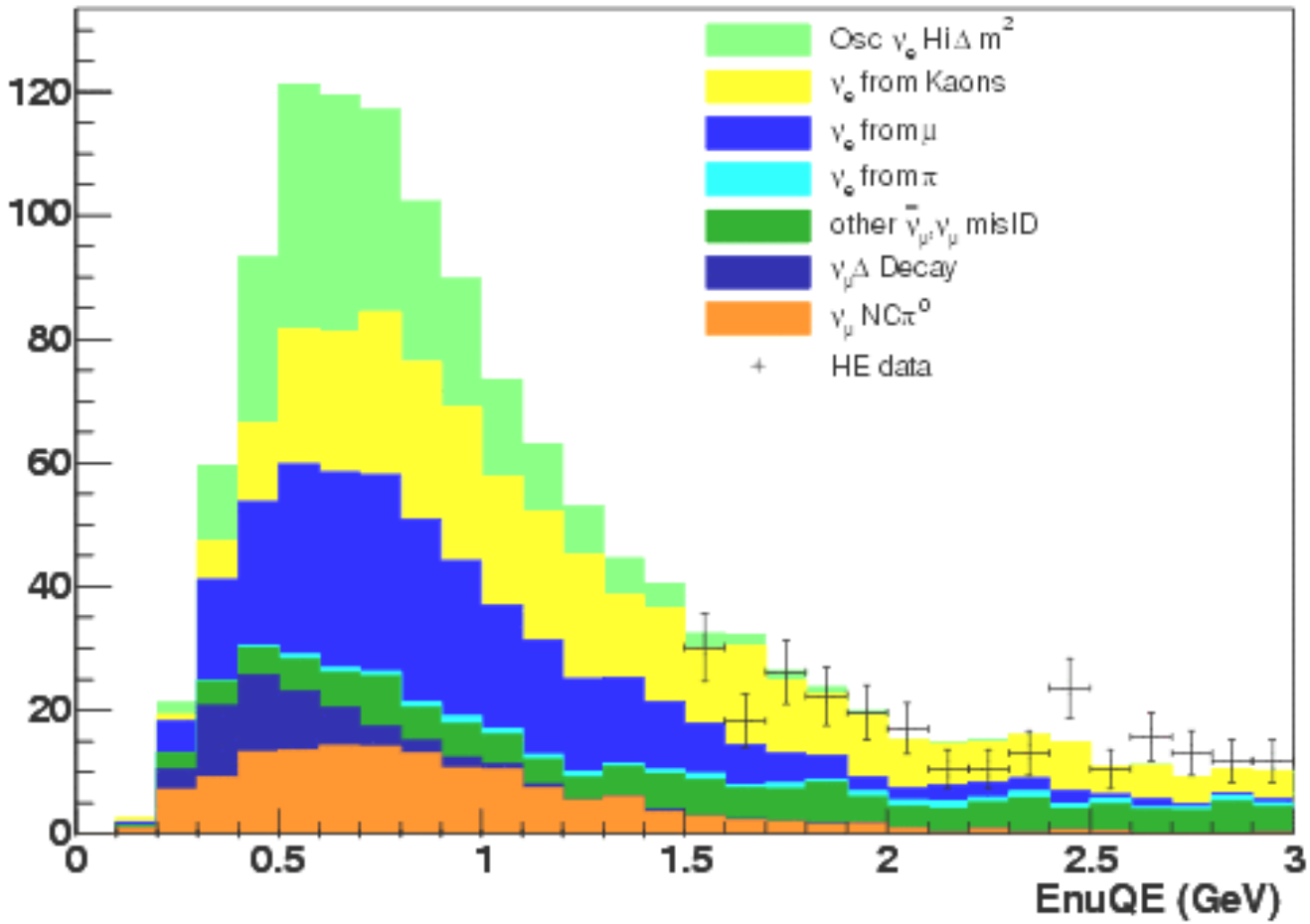
- **NC $\Delta \rightarrow N\gamma$** : BR ~ 0.56% at peak; small but non-negligible background; now properly handled by modified version of NUANCE
- **NC Coherent γ** : Calculated from Rein & Sehgal (Phys. Lett. 104B (1981) 394) & estimated to be negligible
- **NC Radiative γ** : Two sources have been considered, and both are negligible: (1) Bremsstrahlung Term, where γ emanates from recoil proton; (2) Contact Term, where γ emanates from the interaction vertex

Intrinsic ν_e Backgrounds

- **From μ -> ν_e decay** : Well determined from ν_μ CCQE events
- **From K-> ν_e decay** : Measure kaon-induced neutrino flux at high energies & extrapolate to low energies
- **From π -> ν_e decay** : Well determined from ν_μ CCQE events

Expectations for 5E20 Protons on Target

Preliminary!



Future: BooNE

If MiniBooNE confirms LSND, what new physics is there beyond the Standard Model?

With two identical detectors at different distances, many of the systematic errors cancel.

Search for sterile neutrinos by looking for oscillations of **NC π^0** & **NC elastic** scattering events.

Conclusions

- MiniBooNE will soon test the LSND signal
- If the LSND signal is confirmed, then **BooNE** (with two detectors) would provide a great opportunity for Fermilab & particle physics
- Make precision measurements of the oscillation parameters
- Explore physics beyond the Standard Model (e.g. **sterile neutrinos**)