MiniBooNE: Current Status.

R.G. Van de Water

Los Alamos NATIONAL LABORATORY

APS, Tampa, Fl.

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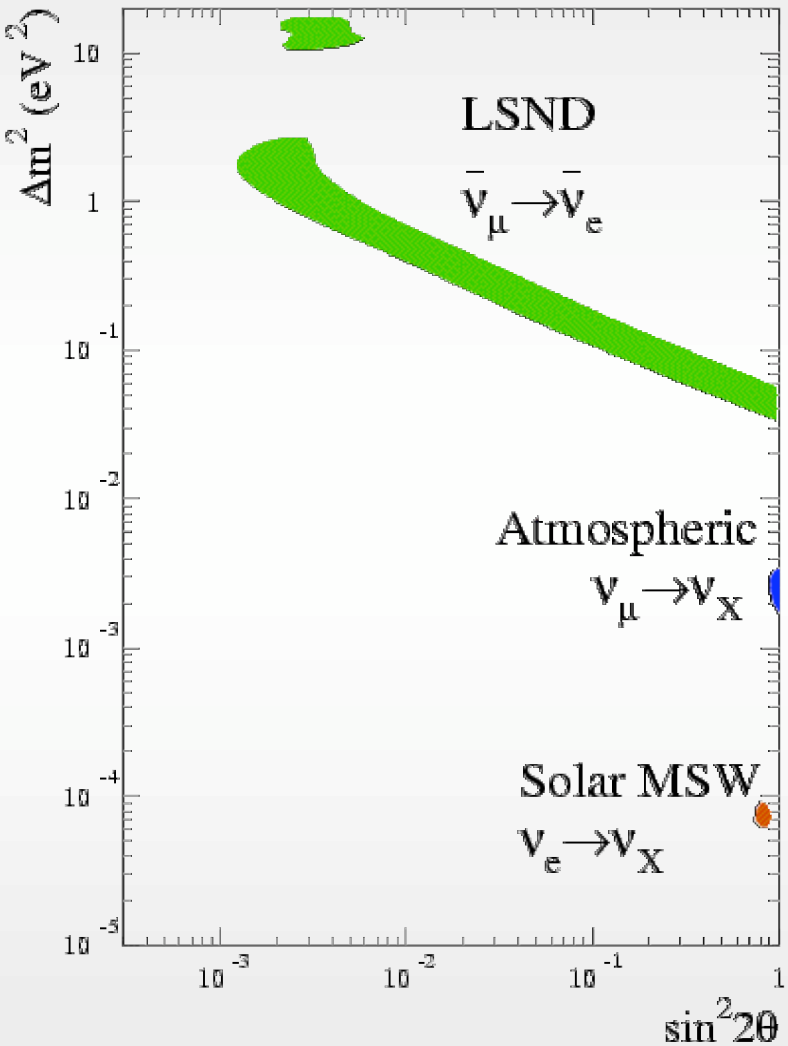
Why MiniBooNE?



- Results from the LSND experiment and solar and atmospheric neutrino experiments can be explained by neutrino oscillations with distinct values of _m^2.
- The Standard Model, with only 3 neutrino flavors, cannot accommodate all the _m^2 values.
- Either one or more of the results is not due to oscillations, or there is physics beyond the Standard Model.

Can we fix the Theory?

1. Add Sterile neutrinos (there are three available) giving you more independent Δm^2 scales?
2. Violate CPT (sacred theoretical tenant), giving you different mass scales for ν and anti-ν ?
3. Both??

The BooNE Collaboration

- 13 universities and 2 national laboratories

Y. Liu, I. Stancu
University of Alabama

S. Koutsoliotas
Bucknell University

R. A. Johnson, J. L. Raaf
University of Cincinnati

T. Hart, R. H. Nelson, M. Wilking, E. D. Zimmerman
University of Colorado

A. A. Aguilar-Arevalo, L. Bugel, L. Coney, J. M. Conrad, J. Link, K. McConnel, J. Monroe, D. Schmitz, M. H. Shaevitz, M. Sorel, G. P. Zeller
Columbia University, Nevis Labs

D. Smith
Embry Riddle Aeronautical University

L. Bartoszek, C. Bhat, S. J. Brice, B. C. Brown, D. A. Finley, R. Ford, F. G. Garcia, P. Kasper, T. Kobilarcik, I. Kourbanis, A. Malensek, W. Marsh, P. Martin, F. Mills, C. Moore, E. Prebys, A. D. Russell, P. Spentzouris, R. Stefanski, T. Williams
Fermi National Accelerator Laboratory

D. Cox, A. Green, T. Katori, H. Meyer, C. C. Polly, R. Tayloe
Indiana University

G. T. Garvey, A. Green, C. Green, W. C. Louis, G. A. McGregor, S. McKenney, G. B. Mills, H. Ray, V. Sandberg, B. Sapp, R. Schirato, R. Van de Water, N. Walbridge, D. H. White
Los Alamos National Laboratory

R. Imlay, W. Metcalf, S. Ouedraogo, M. Sung, M. O. Wascko
Louisiana State University

J. Cao, Y. Liu, B. P. Roe, H. Yang
University of Michigan

A. O. Bazarko, P. D. Meyers, R. B. Patterson,F. C. Shoemaker, H. A. Tanaka
Princeton University

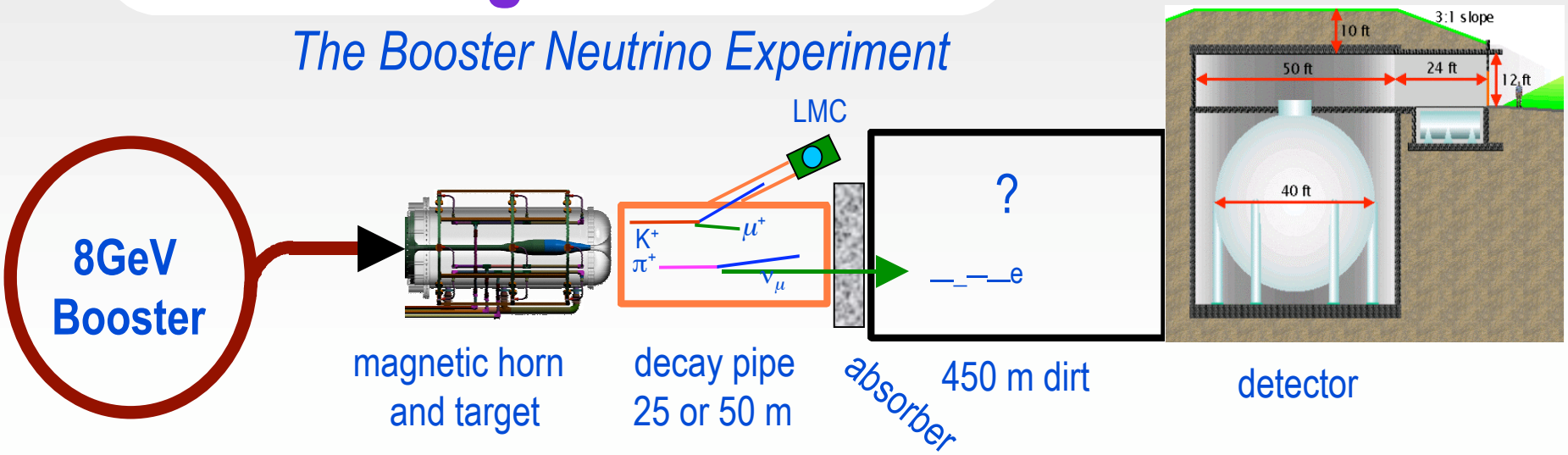
P. Nienaber
St. Mary's University of Minnesota

E. Hawker
Western Illinois University

A. Curioni, B. T. Fleming
Yale University

Introducing MiniBooNE:

The Booster Neutrino Experiment



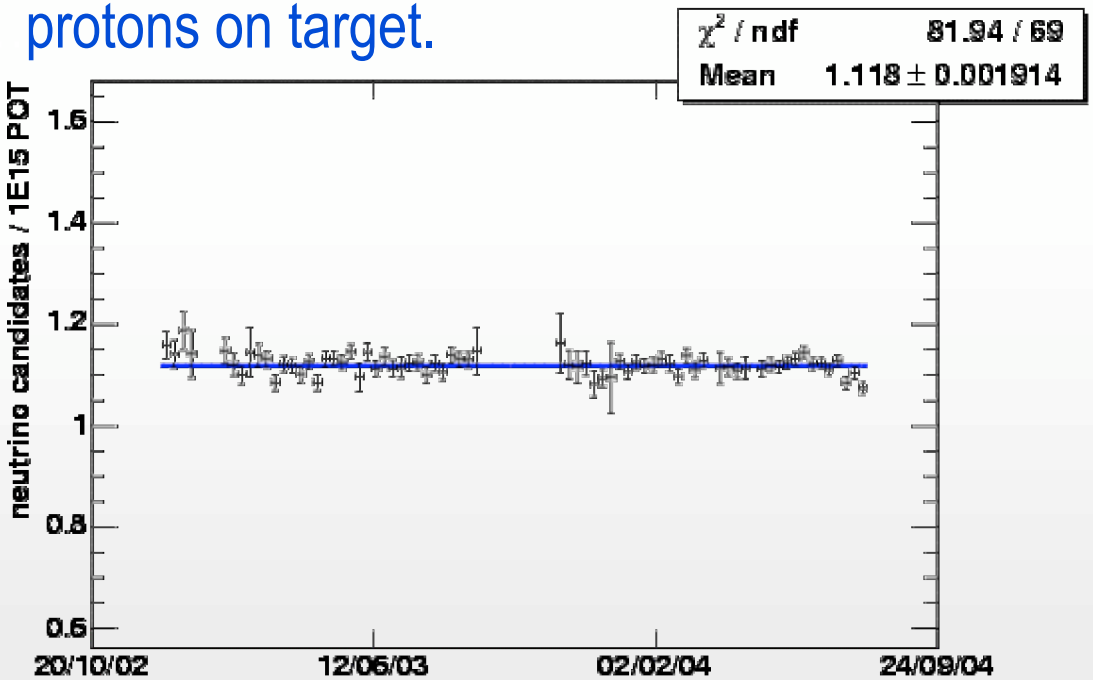
- Different systematics: beam energy _10 LSND (same L/E), event signatures and backgrounds different.
- Anticipate >4_ significance over entire LSND 90% CL region.
- **The goal: to check the LSND result.**

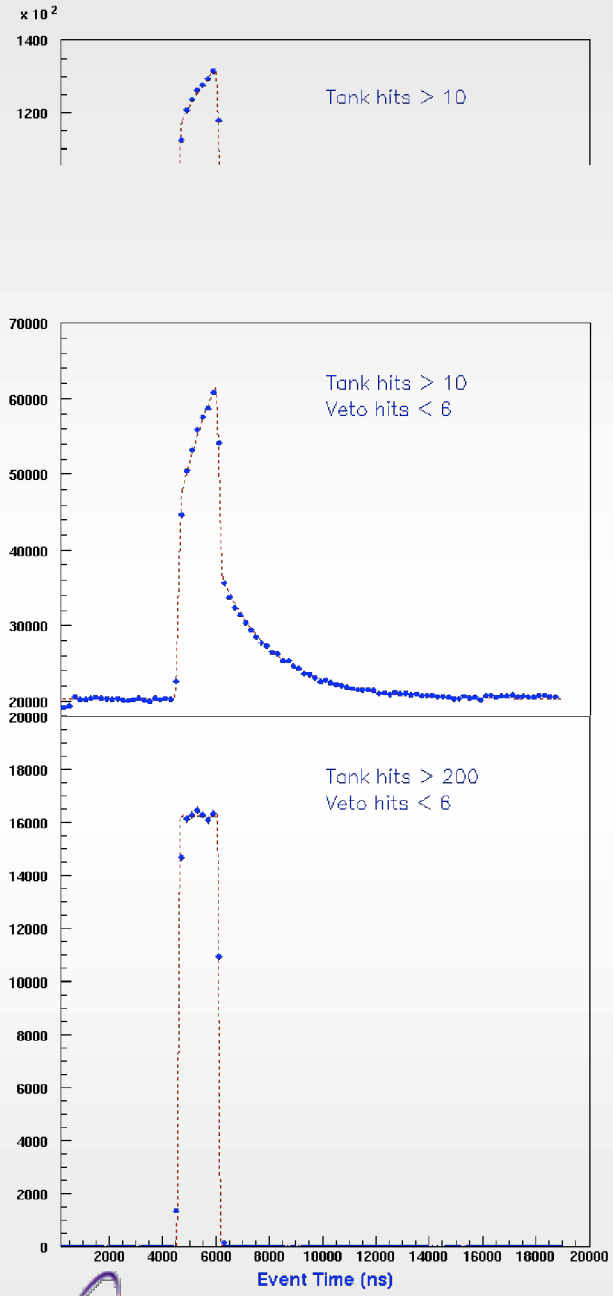
Neutrino Events

- the world's best short baseline _ beam

No high level analysis needed to see neutrino events.

- 479k neutrino candidates in 4.6_10^{20} protons on target.



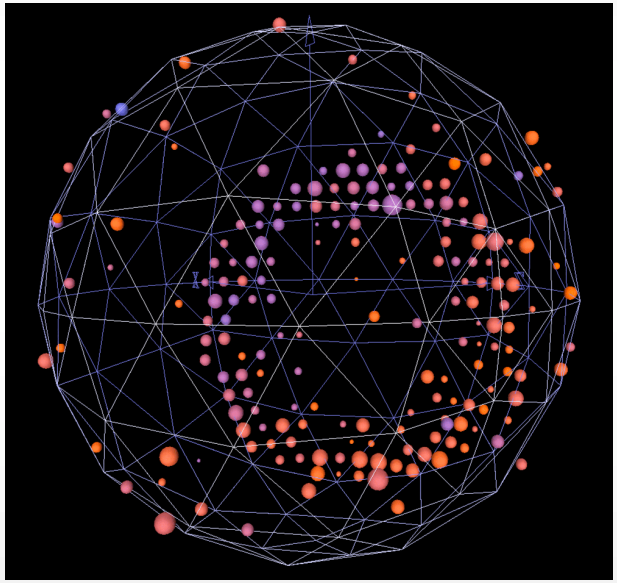


The MiniBooNE detector

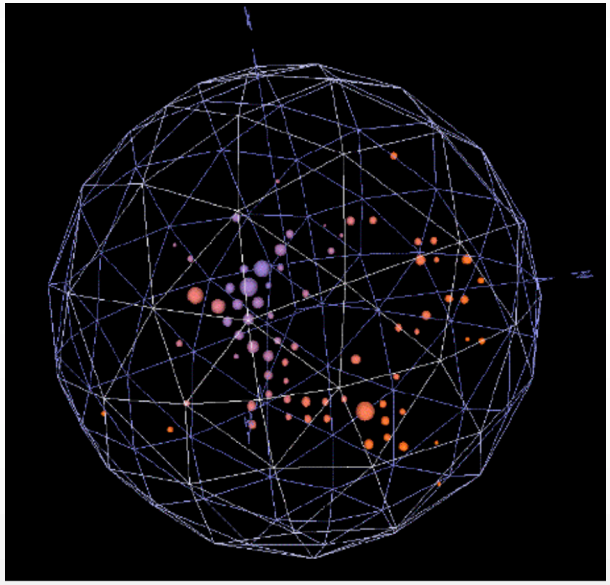
Event Reconstruction:

Pattern of hit tubes (with charge and time information) allows reconstruction of track location and direction and separation of different event types.

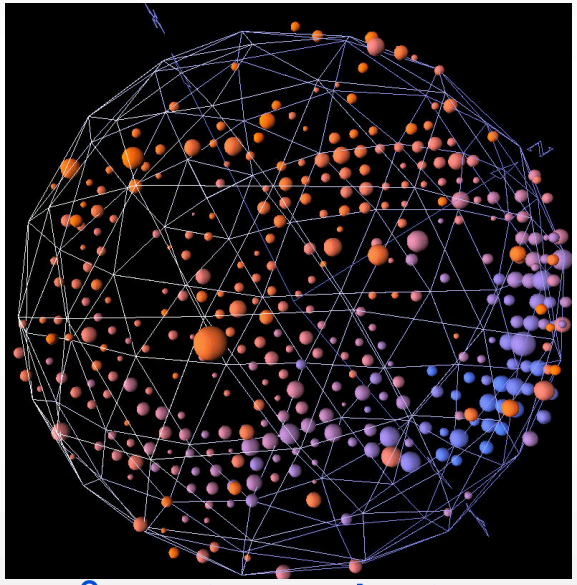
e.g. candidate events: size = charge; red = early, blue = late



muon
from ν_μ interaction



Michel electron
from stopped μ decay
after ν_μ interaction



$\pi^0 \rightarrow$ two photons
from ν_μ interaction

The road to $\nu_\mu \rightarrow \nu_e$ appearance analysis

- Blind ν_e appearance analysis:

  you can see all of the info on some events,
  or
  some of the info on all events,
  but
  you cannot see all of the info on all of the events.

- Early physics:

  Other analyses necessary for $\nu_\mu \rightarrow \nu_e$ search:

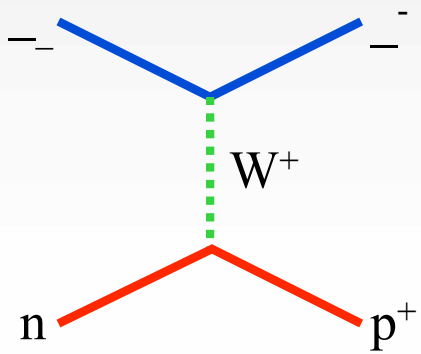
  Checks data-MC agreement (energy scale, optical, etc.), and reliability of reconstruction algorithms.

  Allows progress in understanding backgrounds.

  Interesting physics results on their own.

The Data

CC Quasi-elastic



- Simple topology.
- Kinematics give E and Q^2 from E and .
- **disappearance analysis.**

NC π^0 Production

resonant:

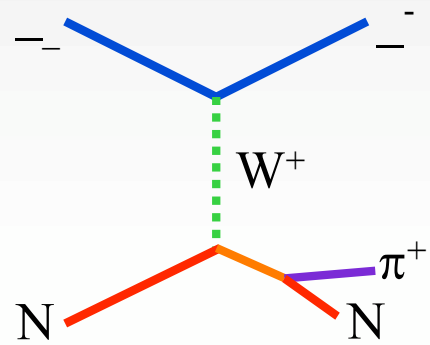
$$\nu + (p/n) \rightarrow \nu + \Delta$$
$$\Delta \rightarrow (p/n) + \pi$$

coherent:

$$\nu + C \rightarrow \nu + C + \pi^0$$

- π^0 .
- Reconstruct invariant mass of the two photons.
- **Background to the e appearance analysis.**

CC Resonant π^+



- Fledgling analysis.
- Should help disentangle nuclear interaction model.
- CCPiP oscillation search?

preliminary

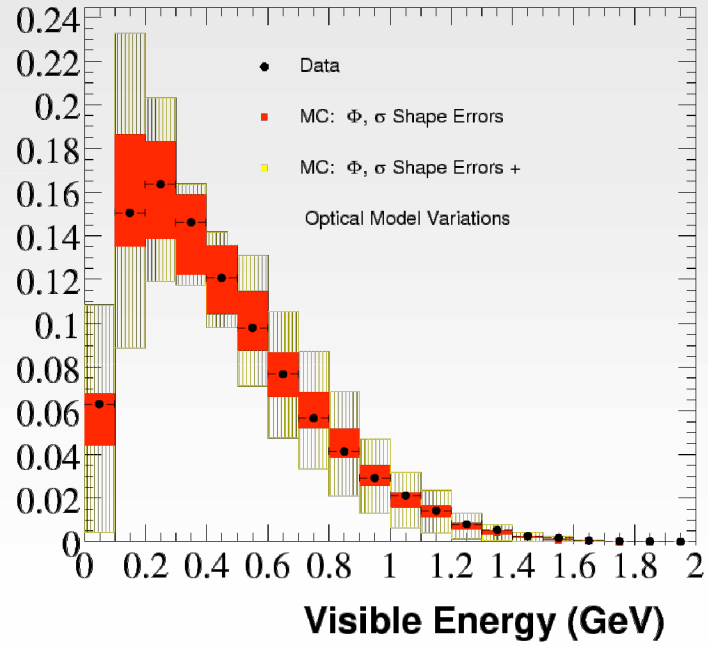
CC _ Quasi-elastic

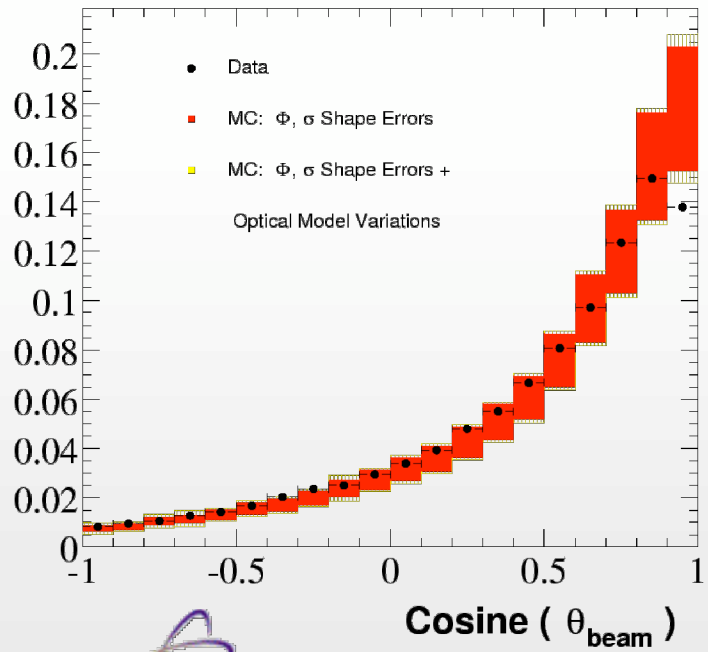
Selection based on PMT hit topology and timing. ~80% purity in remaining dataset.

Data and MC relatively normalized.

Red band: Monte Carlo with current uncertainties from
- flux prediction.
- –CCQE

Yellow band adds optical model variations.

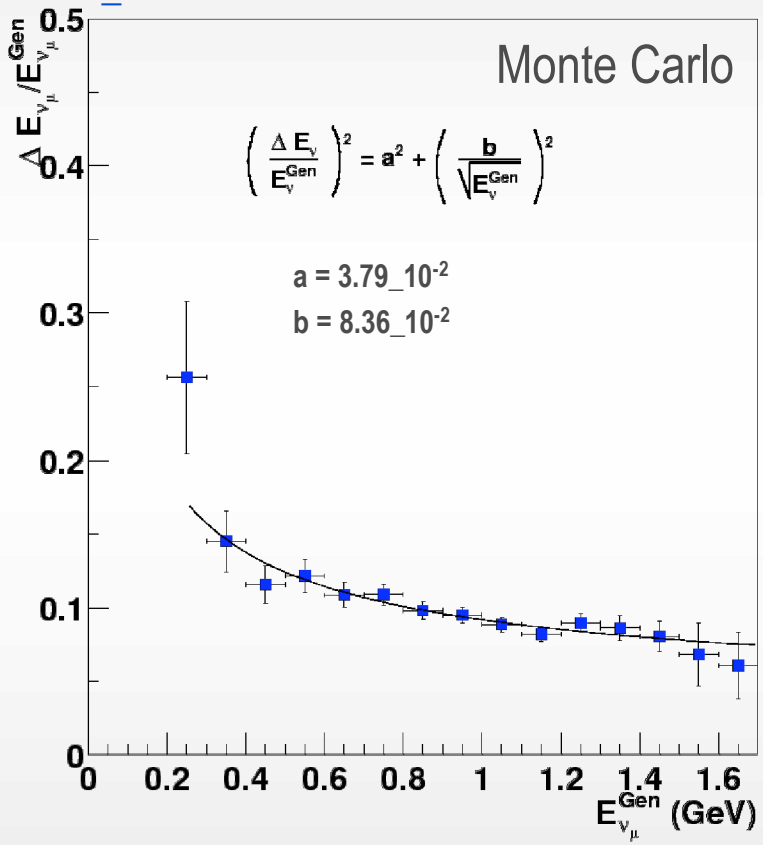


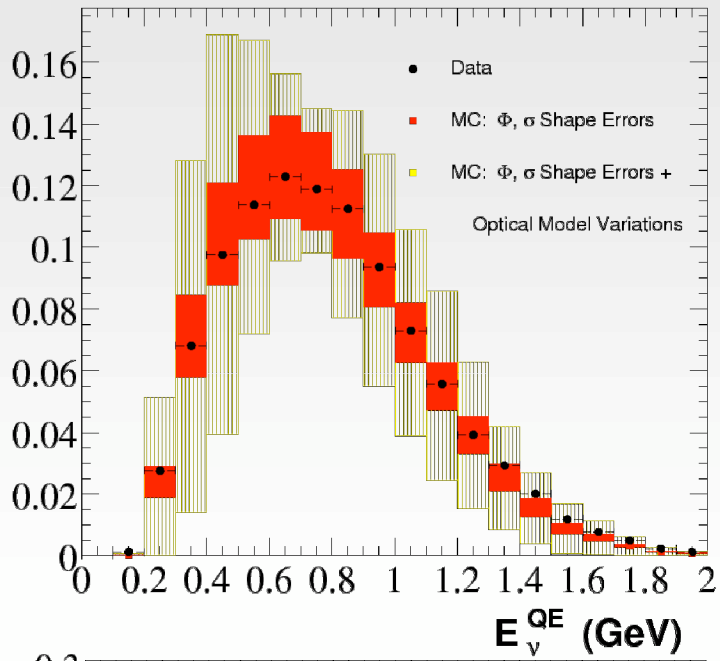


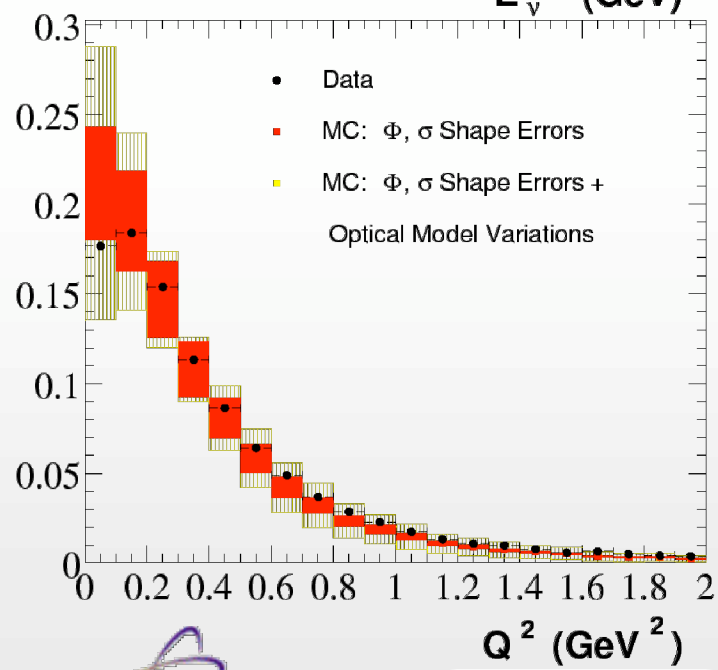
preliminary

CC _ Quasi-elastic

CC _ energy resolution.





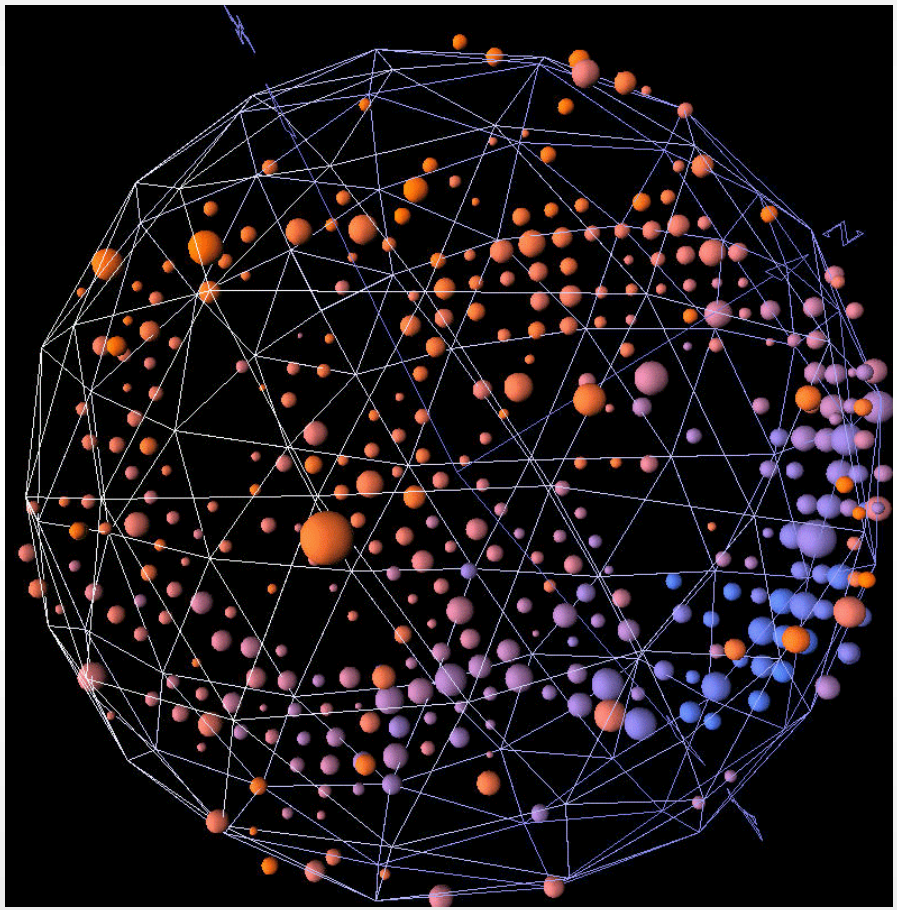


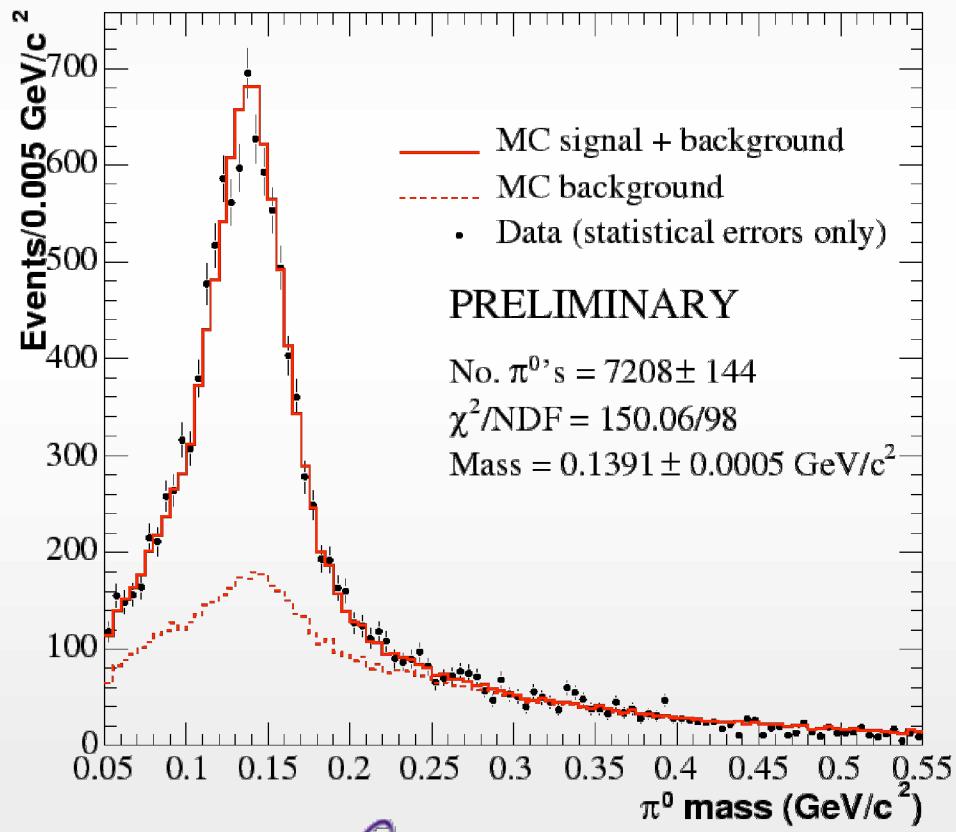
<10% for E _ >800 MeV

preliminary

NC π^0 Production

- N_{TANK}>200, N_{VETO}<6, no decay electron.
- Perform two ring fit on all events.
- Require ring energies E_1, E_2 > 40 MeV.
- Fit mass peak to extract signal yield and background (shape from Monte Carlo).





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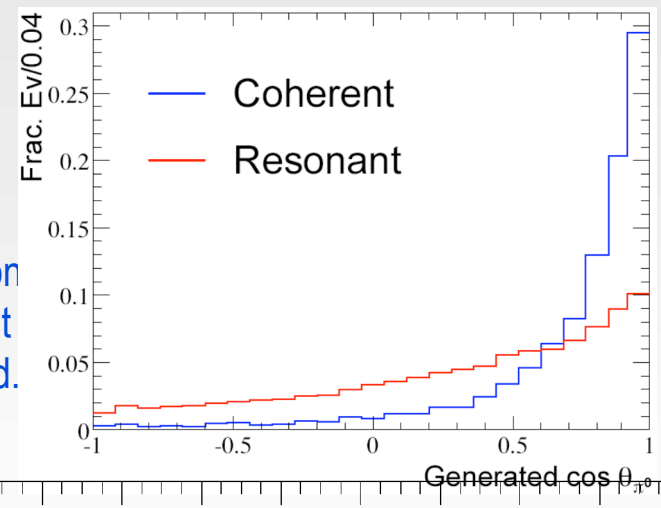
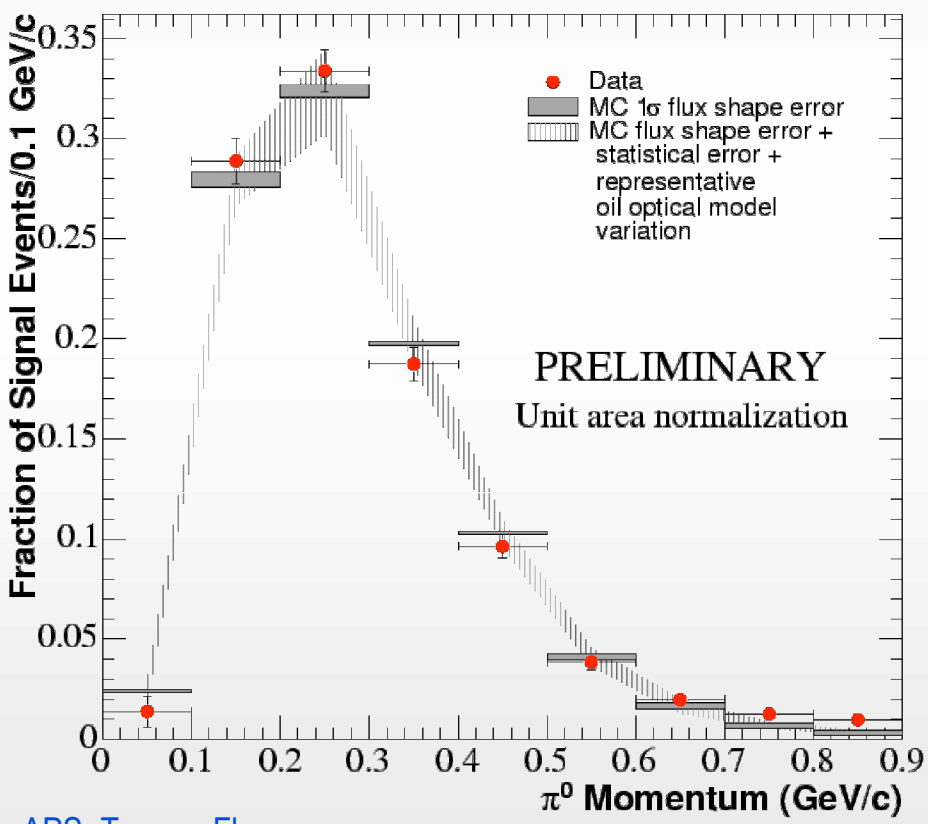
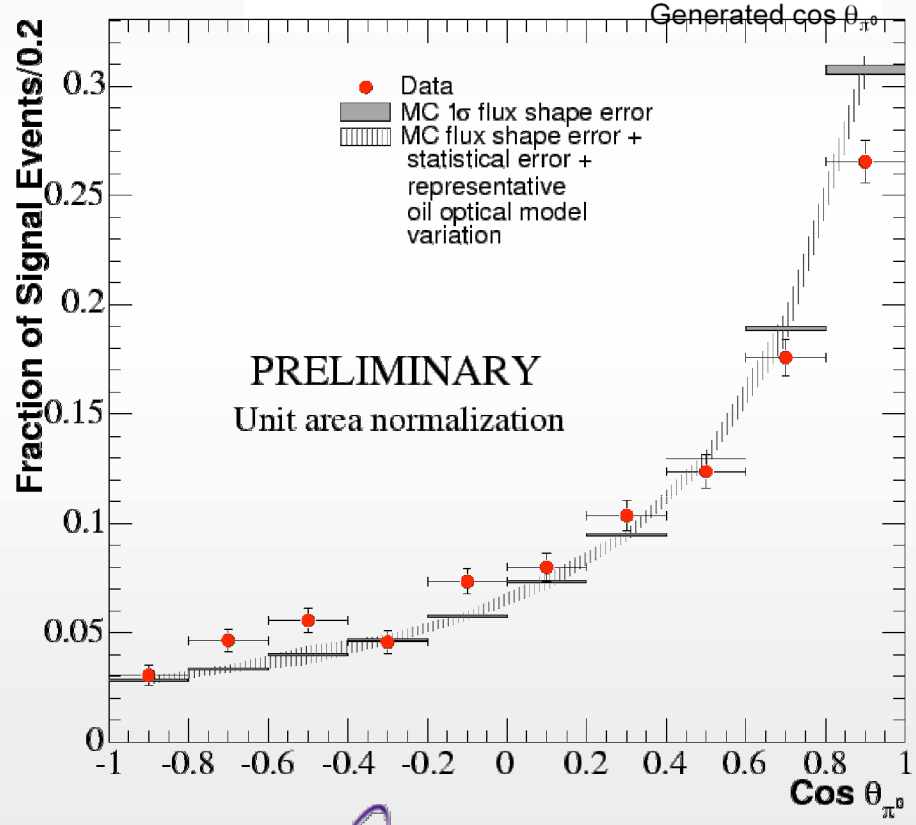
NC π^0 Production

Errors are shape errors
Dark grey : flux errors
Light grey : optical model

Sensitive to production mechanism. Coherent highly forward peaked.



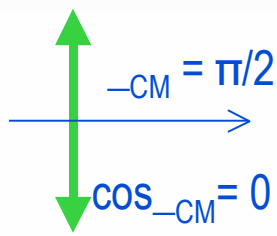




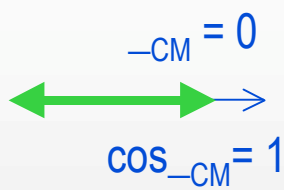
preliminary

NC π^0 Production

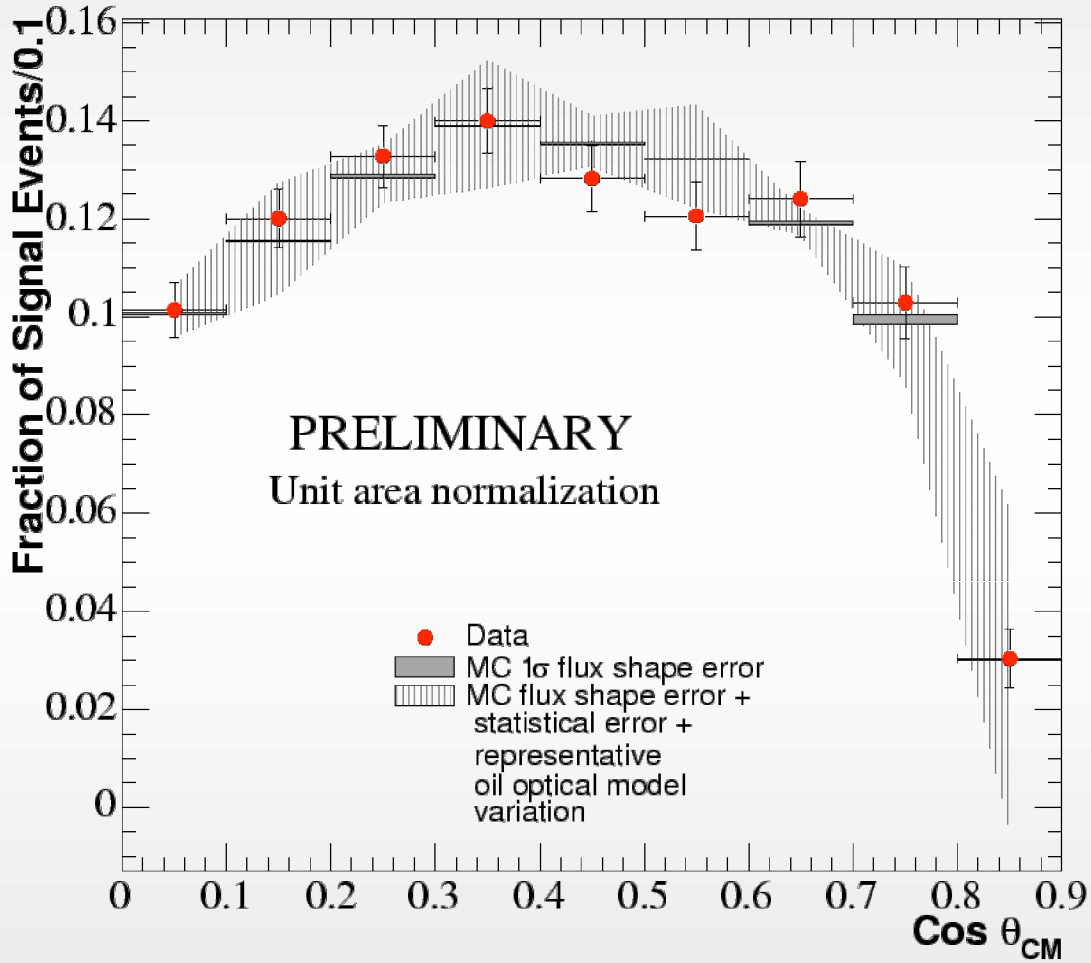
CM frame | lab frame



α small _ _ opening angle



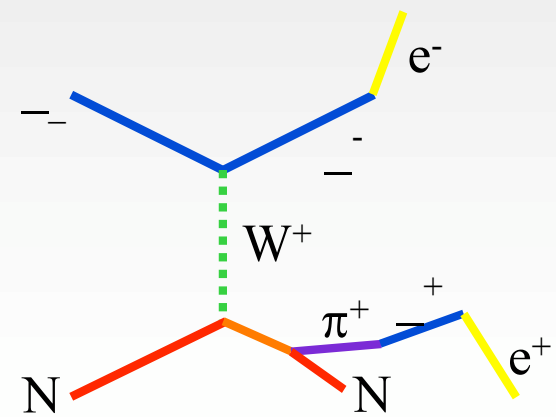
α photon energies asymmetric



preliminary

CCPiP Event Selection

- Neutrino events with 2 Michels:
  - First (Neutrino) subevent
    - Must be in beam spill
    - Tank Hits>175, Veto Hits<6
  - Need at least 2 Michels:
    - 20<Tank Hits<200, Veto hits<6
  - Monte Carlo event breakdown:
    - 78% resonant single pion – all resonant channels
    - 9% coherent pion production
    - 13% background (multi pion 7%, QE 4%, DIS 2%)
  - This data set is 2.62_10^{20} protons on target.
  - 36028 events : 4-5 times more than all bubble chamber data combined.

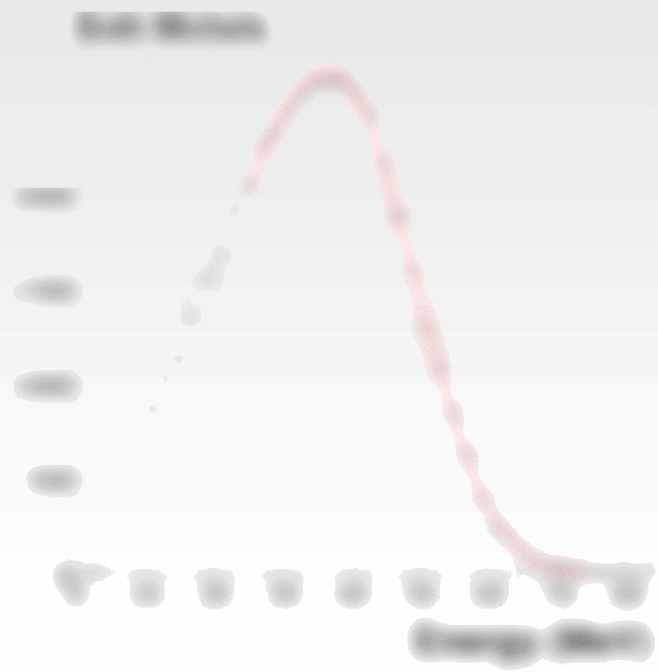


preliminary

CCPiP Michels

Energy distribution fits Michel spectrum.

Separate into close and far samples – with respect to the muon track.



Close (_$^-$) capture on C (8%):

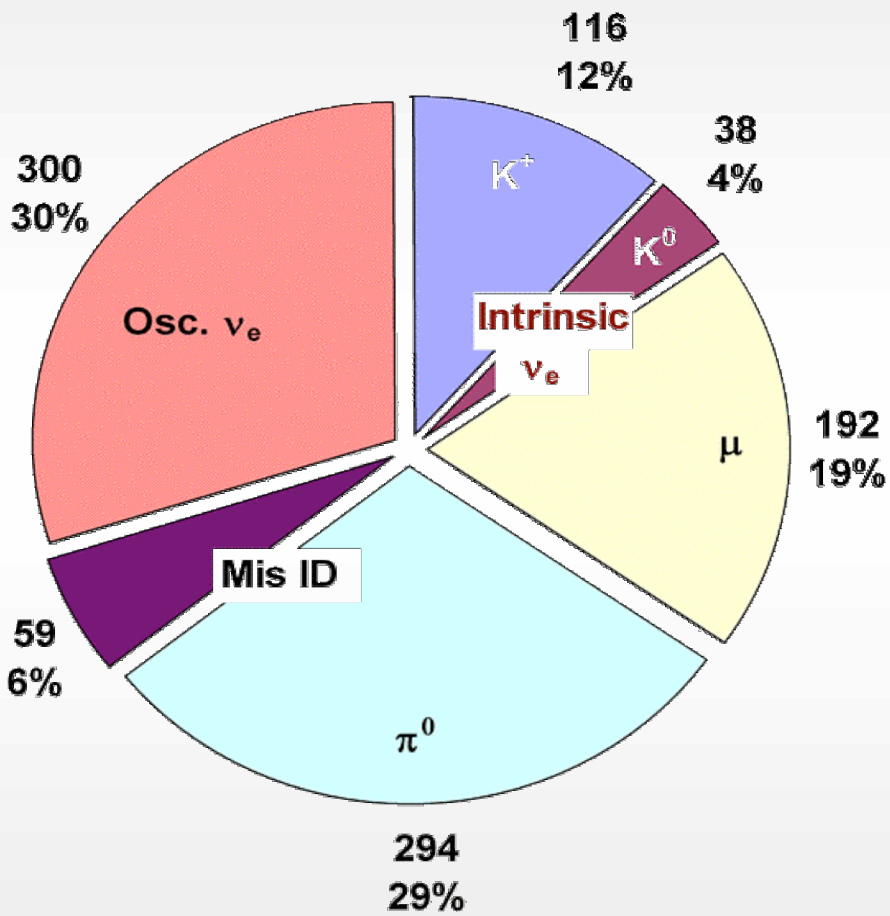
- _=2026±1.5 ns
- Close Michels _=2057±14 ns

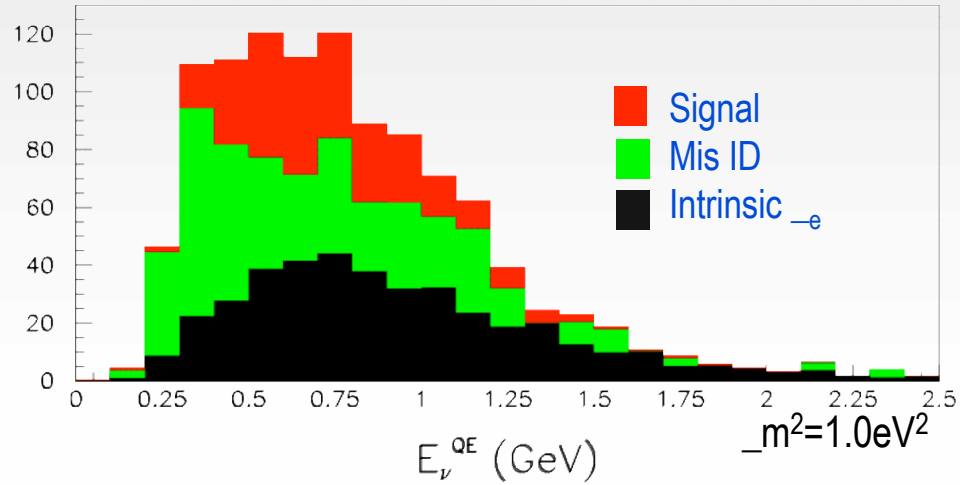
Far (_$^+$) do not capture:

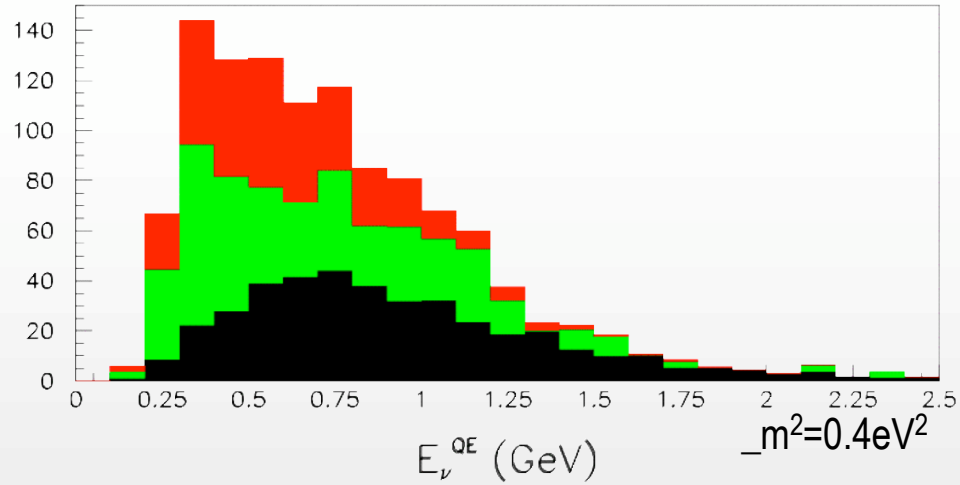
- _=2197.03±0.04 ns
- Far Michels _=2215±15 ns

1_10^21 pot

Estimates of _ → _e Appearance



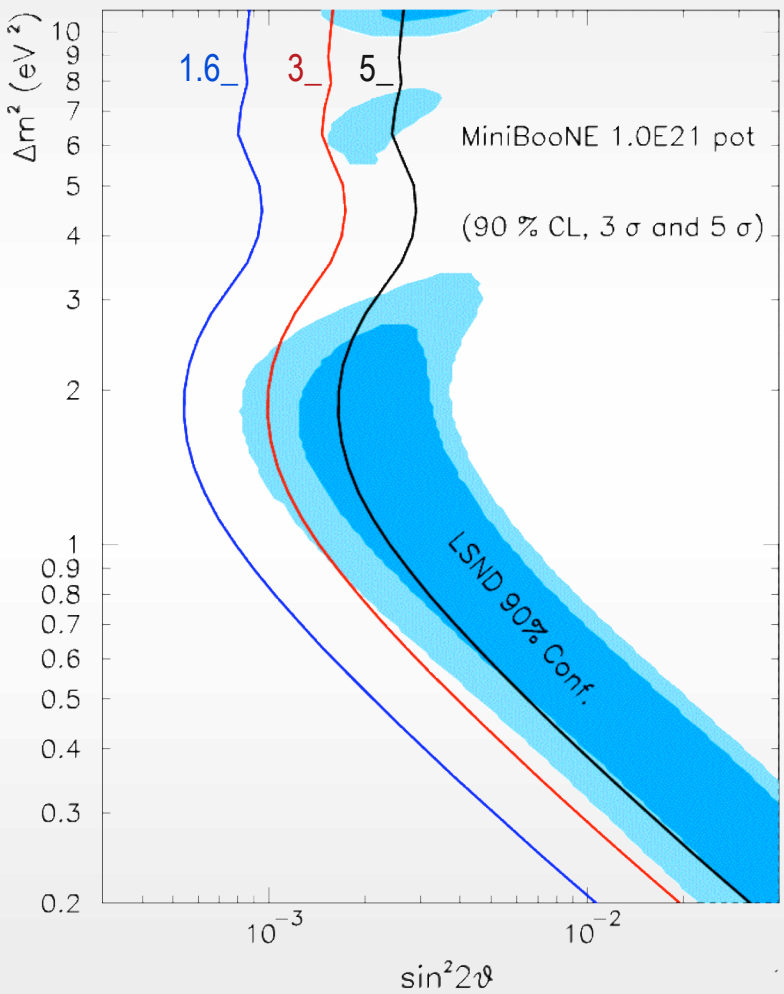


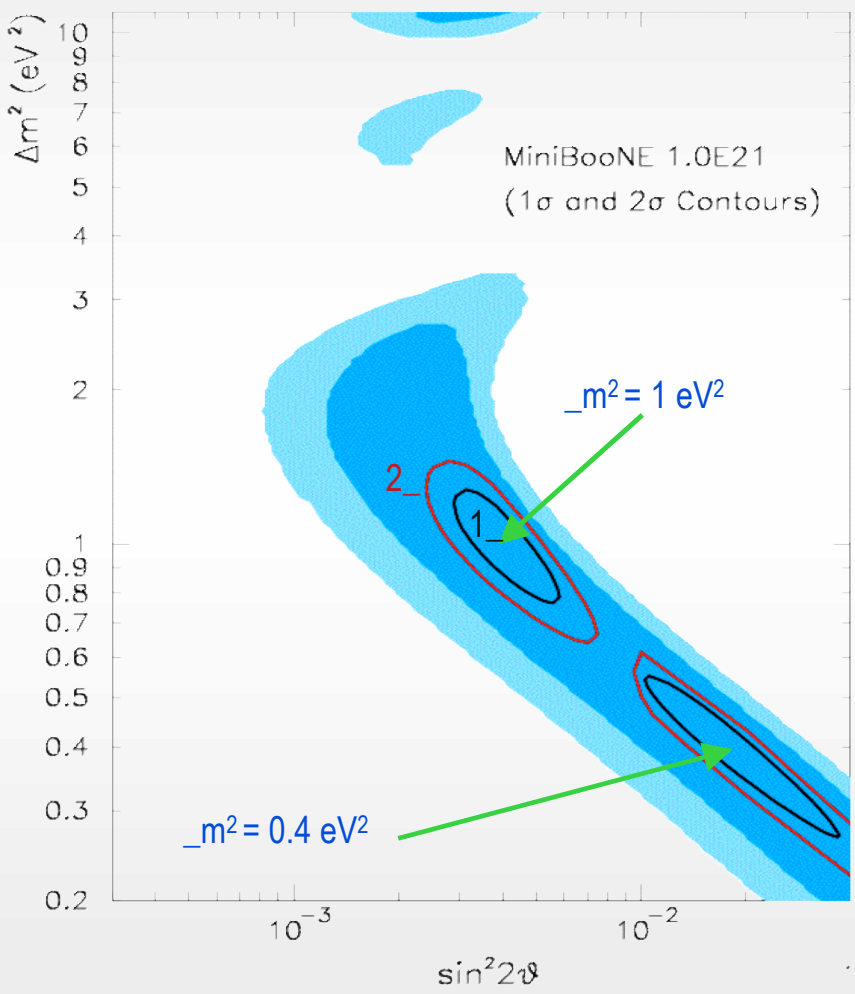


1_10^21 pot

MiniBooNE Oscillation Sensitivity

- systematic errors on backgrounds average ~5%



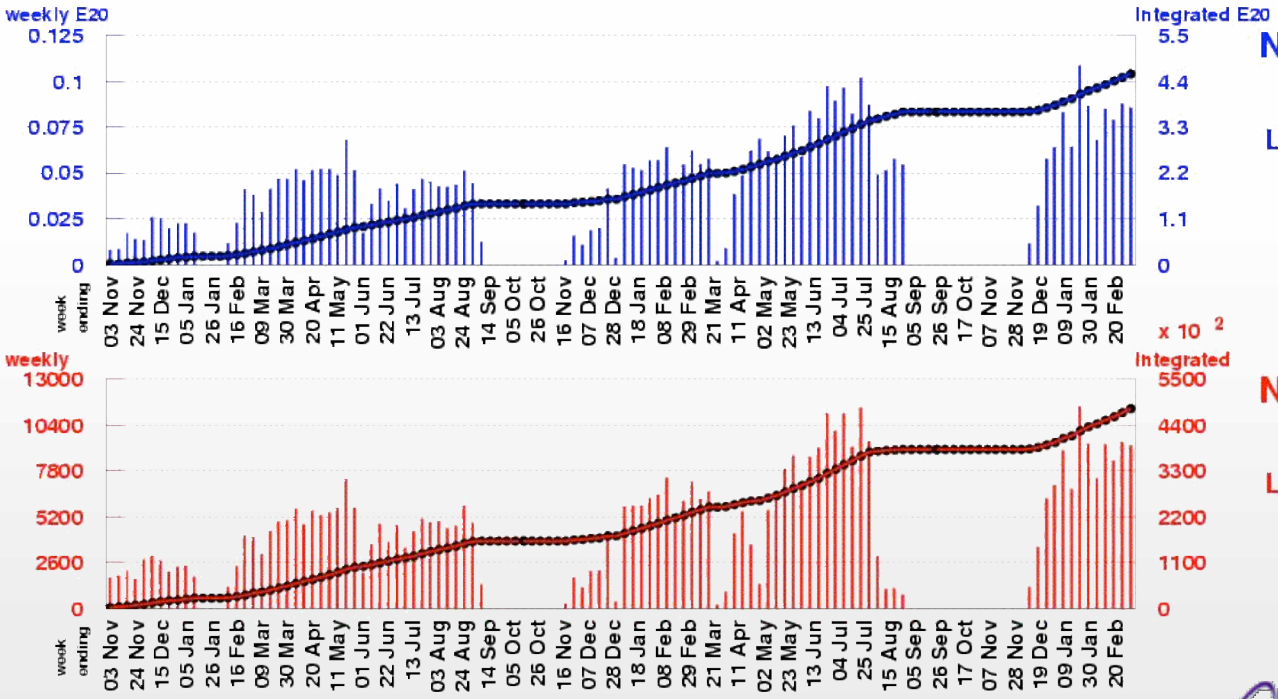


Looking ahead: FY 2006 and beyond

- MiniBooNE approved for FY06 running.
- Some or all of FY06 running may be in antineutrino mode: studies of O(1 GeV) _ interactions.
- If MiniBooNE sees a signal, there is potential for a direct search for sterile oscillations at SNS or FNAL using a stopped pion source: hep-ph/0501013.

Conclusions

- MiniBooNE is running well.
- Currently past 5_10^{20} protons on target!
- _ → _e appearance results by hopefully late 2005.



Number of Protons on Target

To date: 4.5719 E20

Largest week: 0.1084 E20

Latest week: 0.0854 E20

Number of Neutrino Events

To date: 478908

Largest week: 11447

Latest week: 9235

Why Should Cosmologists Care about Neutrino Physics?

-New knowledge of the structure of matter has always had an impact.

Fundamental Questions in Neutrino Physics Still Remain!

_Did LSND observe neutrino oscillations?

_What is the neutrino absolute mass, and hierarchy?

_What are the neutrino mixing angles?

_Are the sterile neutrinos light or heavy?

_Are CP and CPT conserved?

_Are neutrinos Dirac particles, Majorana particles, or both?

_How is mass generated?

_.....

What does CPT violation or Sterile Neutrinos do for you?

- *CPT violations with a LSND type mass scale can naturally explain matter-antimatter asymmetry in the early Universe (hep-ph/0108199).*
- *Heavy sterile neutrinos are a candidate for dark matter, and evade BBN limits.*
- *Variable mass sterile neutrinos are a mechanism to explain dark energy (astro-ph/0309800).*
- *Heavy element nucleosynthesis in Type II Super-nova (R-process) can be made to work with a heavy sterile neutrino (hep-ph/0205029).*
- *Sterile neutrinos can generate Pulsar kicks.*
- *Sterile neutinos can explain current Solar neutrino anomoly.*