

Ongoing Neutrino Programme

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UCL

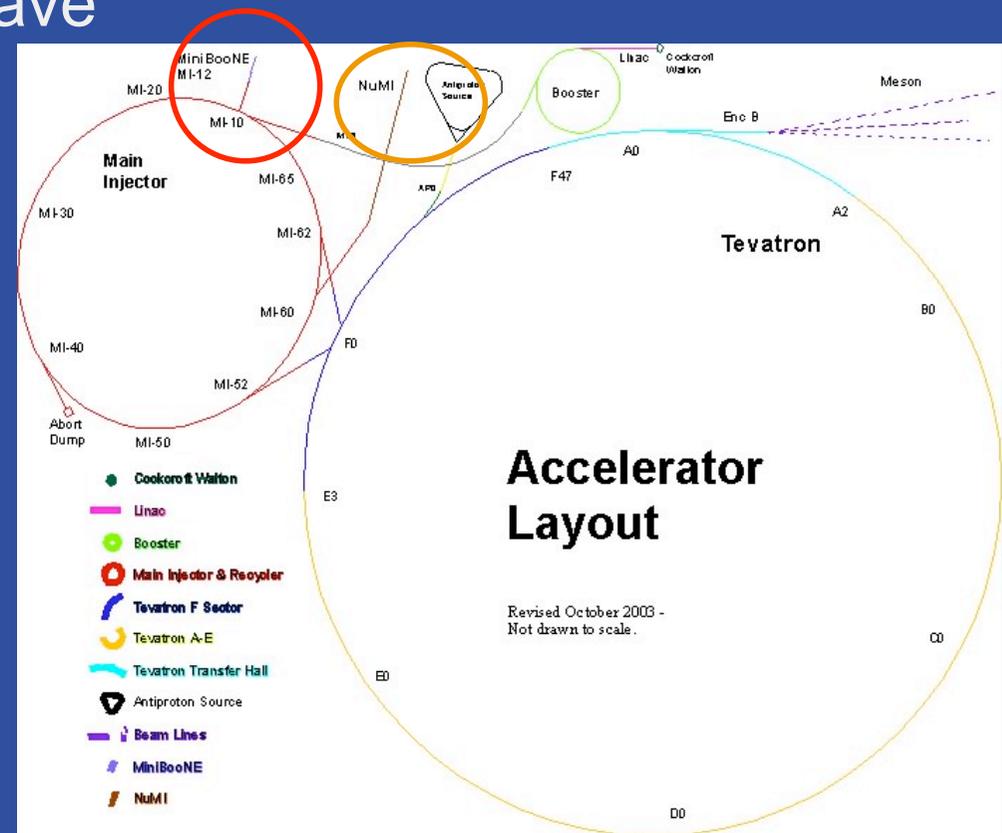
DOE Annual Science & Review

July 12-14, 2010



Experiments

- On the **Booster** beam there are
 - SciBooNE : analysis phase
 - Mini-BooNE : ongoing data taking
- On the **NuMI** beam we have
 - MINERvA : data taking
 - MINOS : data taking
- This is highlights only

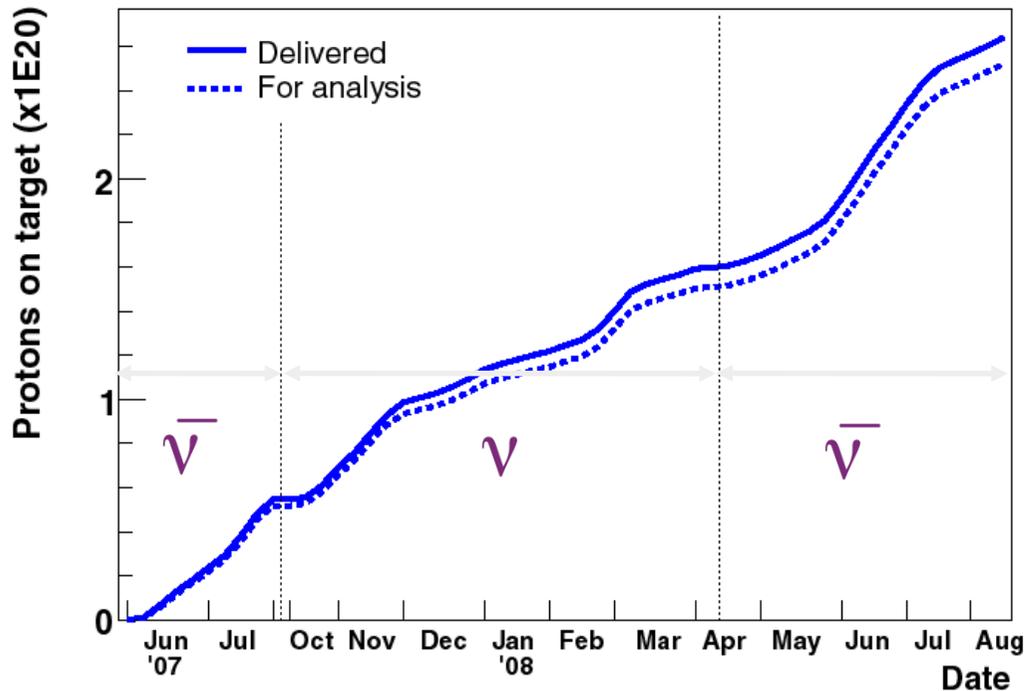


SciBooNE



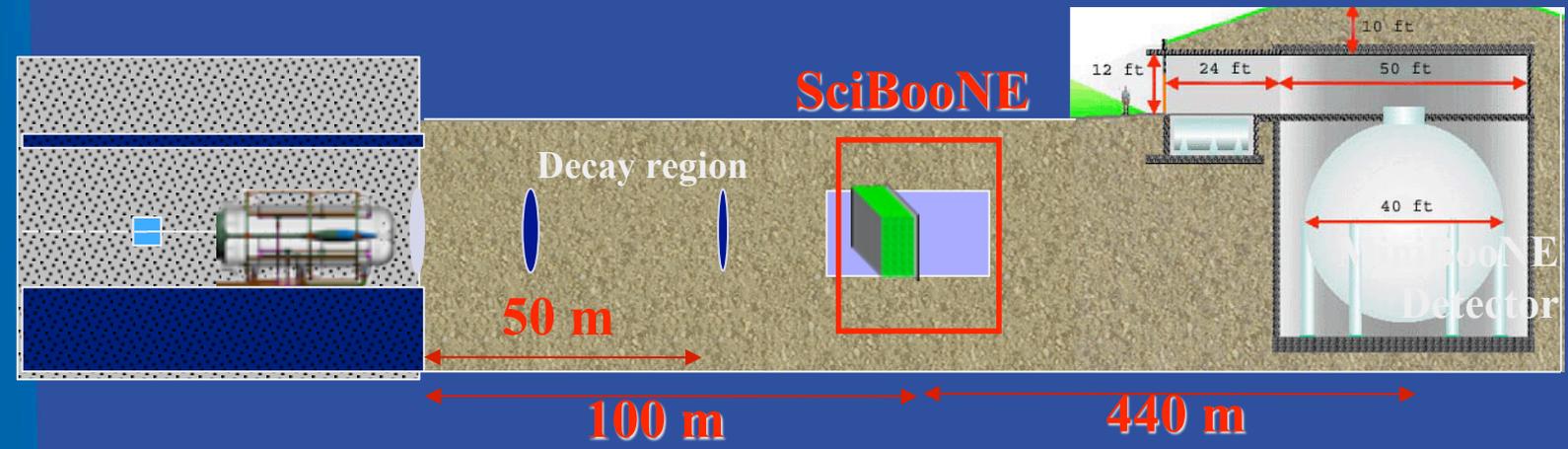
SciBooNE data-taking

Number of Protons on target (POT)

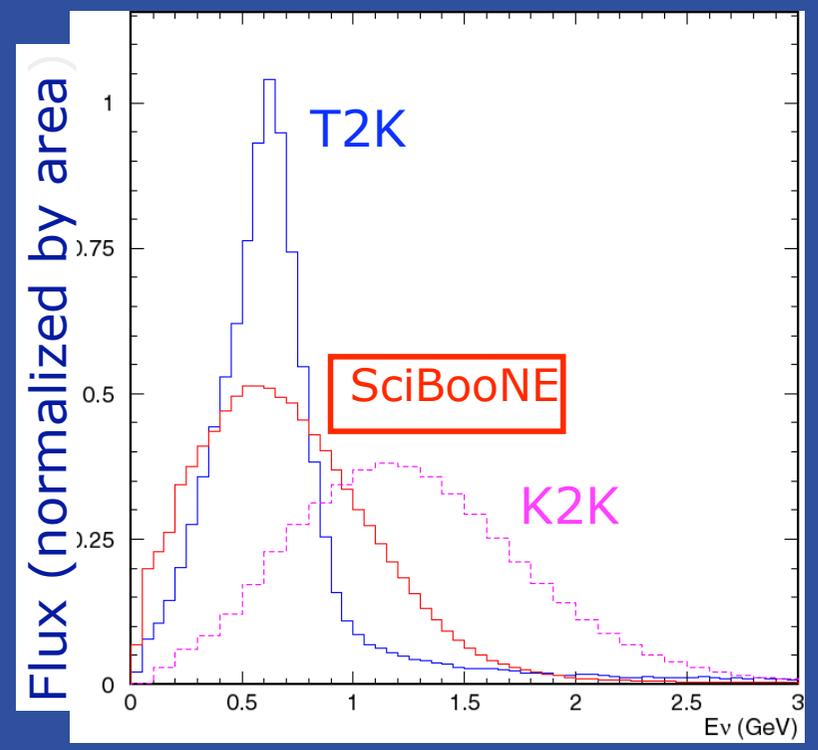


- Jun. 2007 – Aug. 2008
- 95% data efficiency
- 2.52×10^{20} POT in total
- neutrino : 0.99×10^{20} POT
- antineutrino: 1.53×10^{20} POT
- **Request to PAC: 2.0×10^{20} POT**

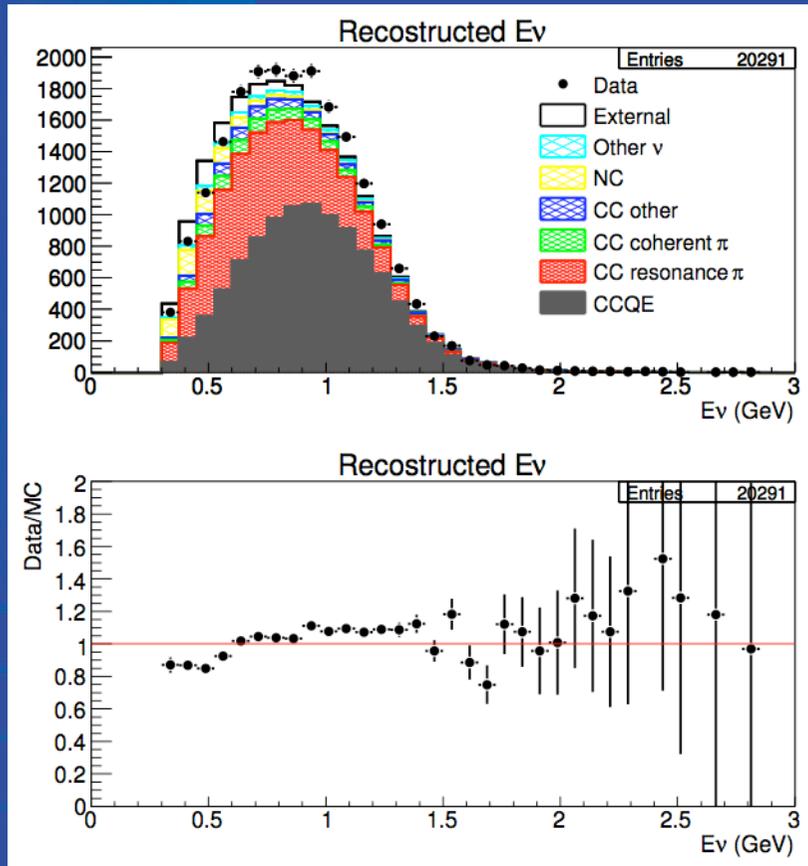
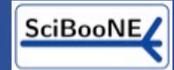
SciBooNE Intro



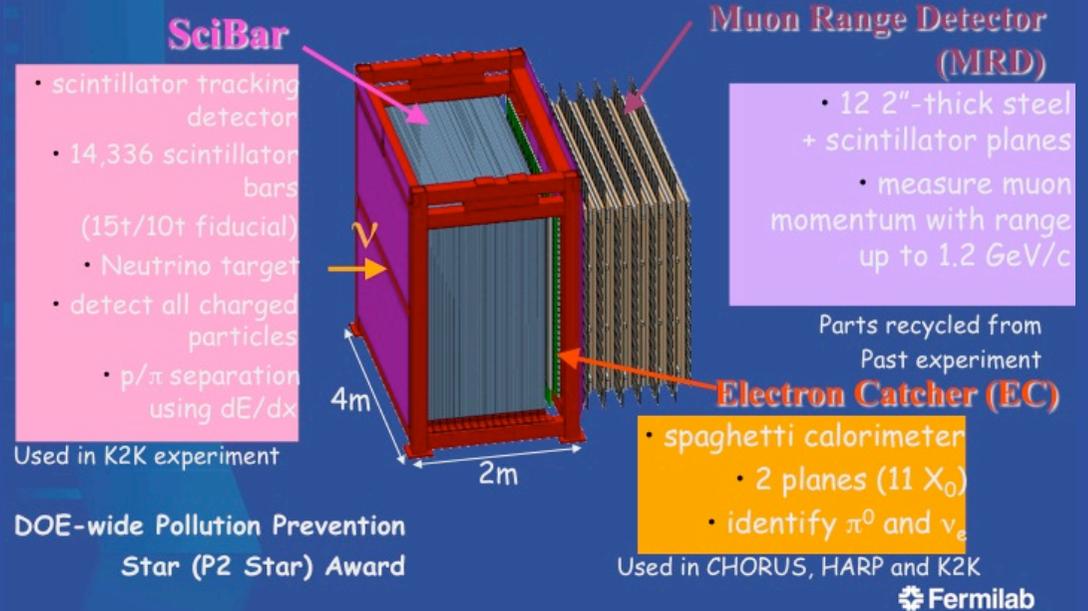
- Precise measurements of ν and $\bar{\nu}$ x-sec needed by T2K and other experiments for background estimation : small signal to noise
 - Non QE $\nu\mu$ interactions
 - Events which look like ν_e
- MiniBooNE near detector
 - Direct measurement of beam ν_e s
 - ν_μ disappearance



SciBoone Detector



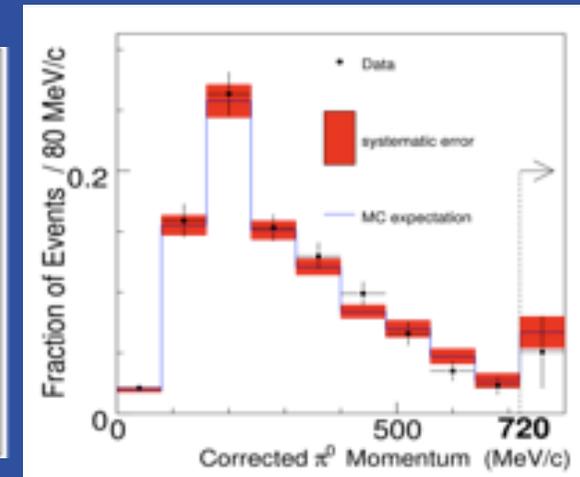
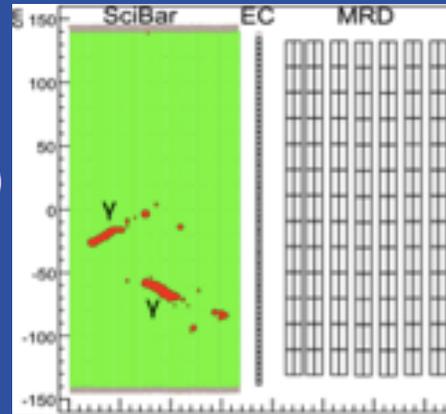
SciBooNE detector



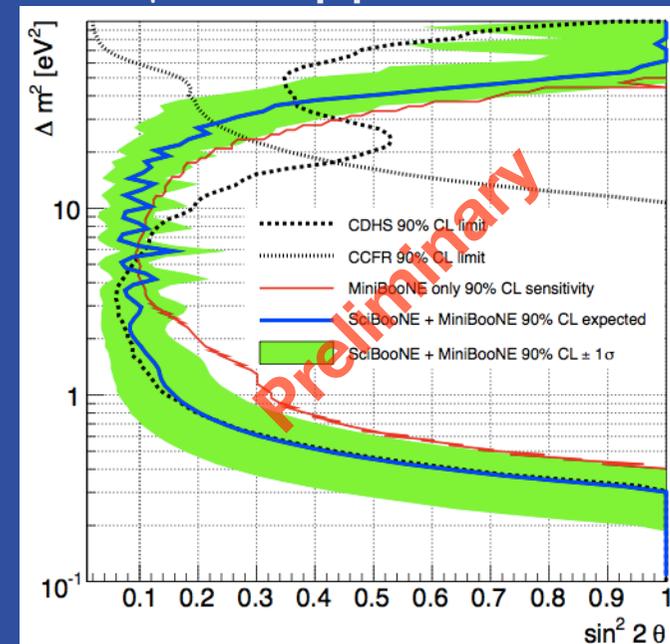
Physics Results

- Peer reviewed journals
 - Phys.Rev.D **78** 112004 (2008) limit on ν_μ CC coherent π production
 - Phys.Rev.D **81** 03304 (2010) measurements of ν_μ NC π^0 production
 - arXiv:1005.0059 (accepted by Phys.Rev.D RC) ν_μ NC coherent π production
- Conference Proceedings
 - NuInt05, NuInt07(8), NuInt09 (5)
 - NuFact07, NuFact08 (2), NuFact09 (2)
 - ICHEP08
 - NOW 2008, NOW 2009
 - PANIC 08

NC π^0 production



ν_μ disappearance



Prospects

- Next publications
 - Neutrino disappearance (joint with MiniBooNE) - ICHEP 10
 - $\nu/\bar{\nu}$ CC coherent pion production - autumn 2010
 - Neutral current elastic scattering - end of 2010
 - CC QE cross section - end of 2010

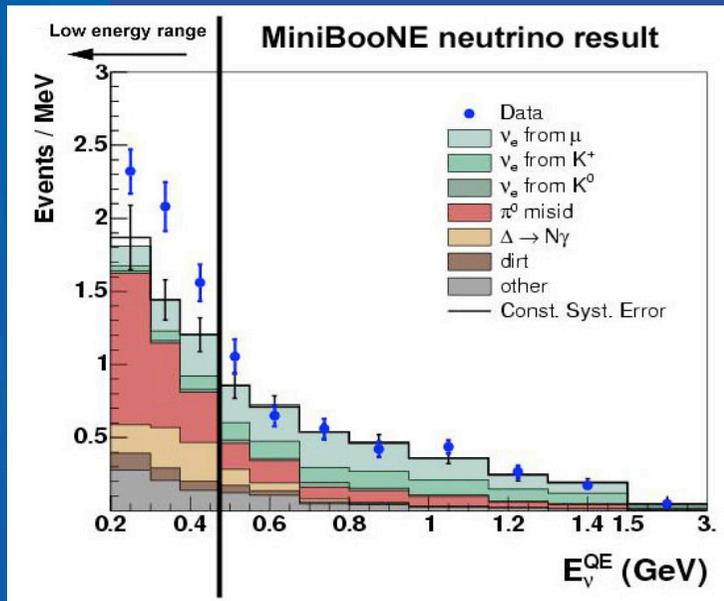
FNAL statistics

- 5 FTEs in total on MiniBoone / ~64 total collaborators
- 8 FNAL personnel (about 1 FTEs)

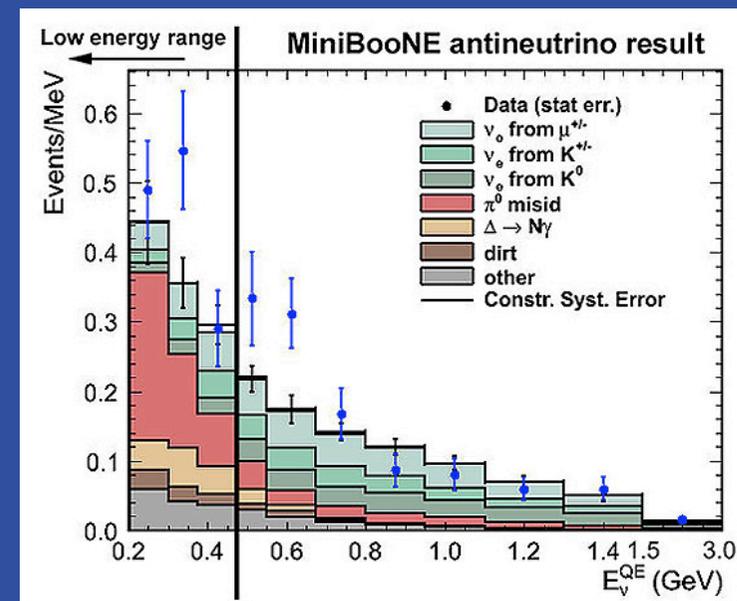
Status of MiniBooNE Oscillation Search

- MiniBooNE searches for LSND-like oscillations $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ (LSND used anti-neutrinos)
 - Appearance signals on this scale could indicate new physics
 - New antineutrino results announced (June 14) with $5.7e20$ POT
 - Neutrino mode: excess of events below 475 MeV
 - Antineutrino mode: excess of events above 475 MeV.

6.5e20 POT ν beam



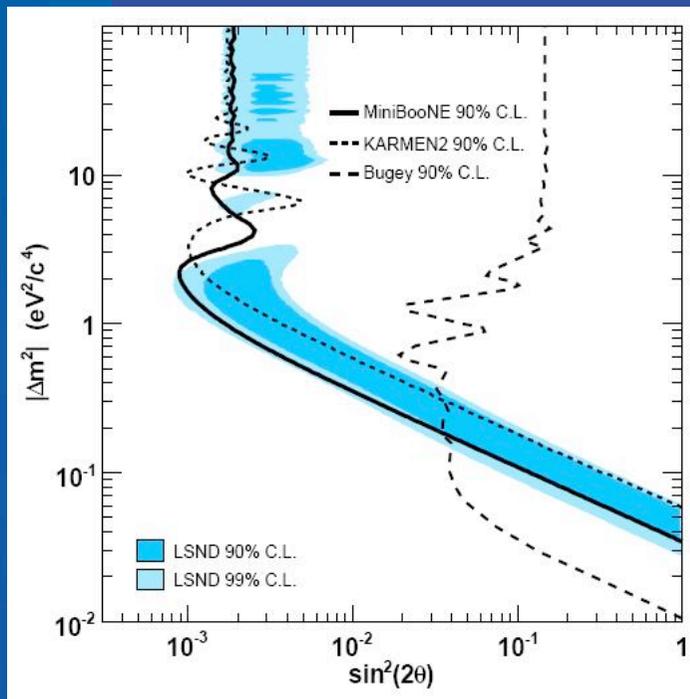
5.7e20 POT $\bar{\nu}$ beam



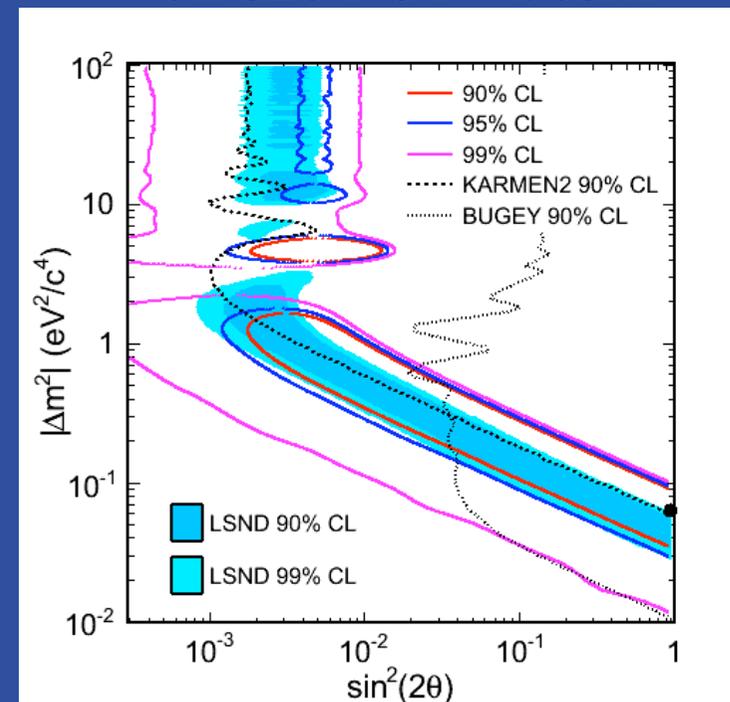
Status of MiniBooNE Oscillation Search

- Regions allowed/excluded by fit to 2ν mixing hypothesis shown below for neutrino and antineutrino beams
 - 475 – 1250 MeV is official oscillation fit region.
 - Lack of excess above 475 MeV in neutrino beam inconsistent with LSND oscillations
 - New antineutrino data favors LSND-like signal at a 99.4% CL

6.5e20 POT ν beam



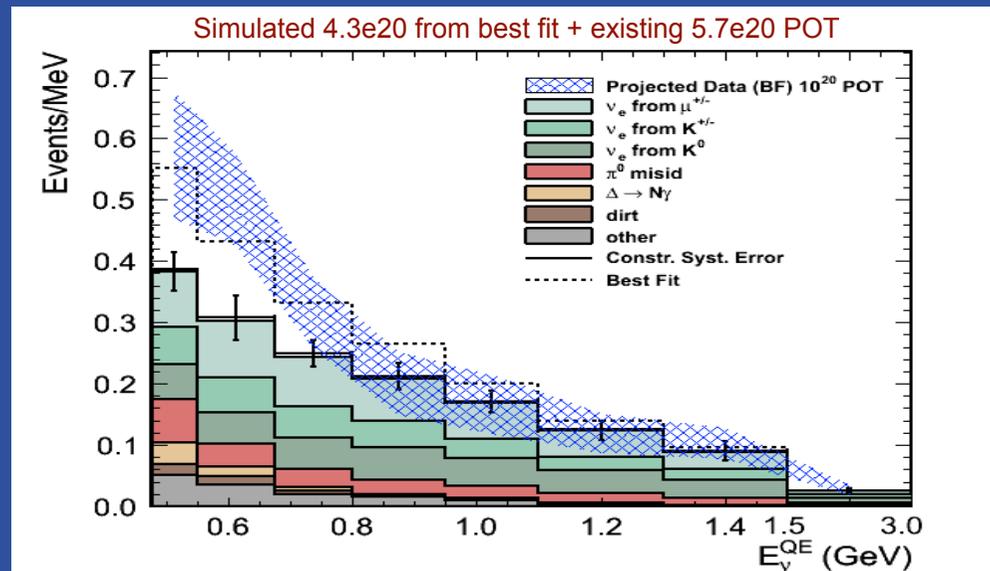
5.7e20 POT $\bar{\nu}$ beam



Appears to be a difference between neutrinos and antineutrinos

Projected MiniBooNE Results in 2012

- Continue to run with antineutrino beam with goal of reaching $10e20$ POT
 - Blue bands show range of outcomes (1σ) with $4.3e20$ POT simulated data added
 - Simulated data drawn from current best fit signal

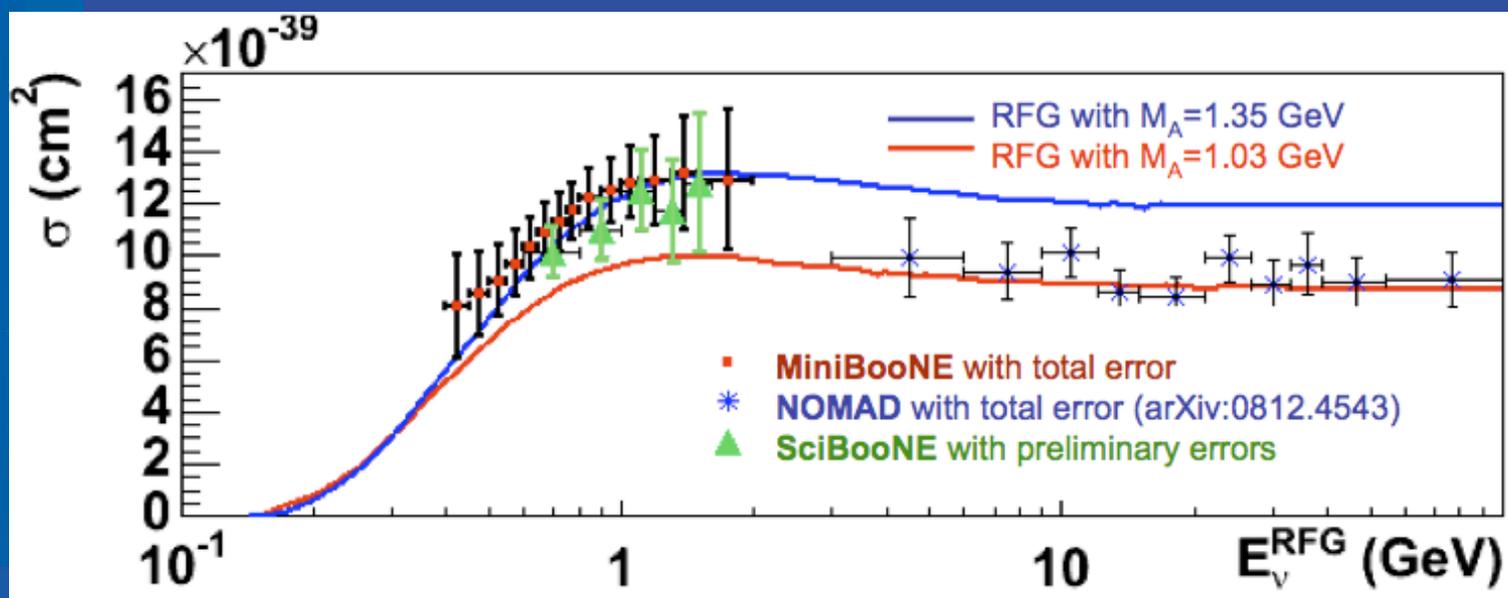


- Assuming additional $4.3e20$ comes from current best fit to data
 - The current 2.7σ (stat+sys) excess (200 – 1250 MeV) grows to $\sim 3.2\sigma$.
 - The current 3σ statistical excess (200 – 1250 MeV) grows to $\sim 4\sigma$.
 - AT LEAST WE WILL KNOW IT IS NOT A STATISTICAL FLUCTUATION
 - Preference of 2ν fit for LSND-like signal grows from 99.4% (2.7σ) to 99.86% (3.2σ)

MiniBooNE in 2012 and beyond

- Analyses up to 2012

- Analysis of final electron antineutrino appearance data (10E20 POT).
- Some continued cross-section analysis (not mentioned in this talk but high statistics of MiniBooNE data has resulted in 5 cross-section publications to date and 3 more close to journal submission)
- Incorporating any future SciBooNE constraints, and perform muon (anti)neutrino disappearance measurements (some exotic oscillation models expect large antineutrino disappearance to explain LSND/MiniBooNE signal).



MiniBooNE Future

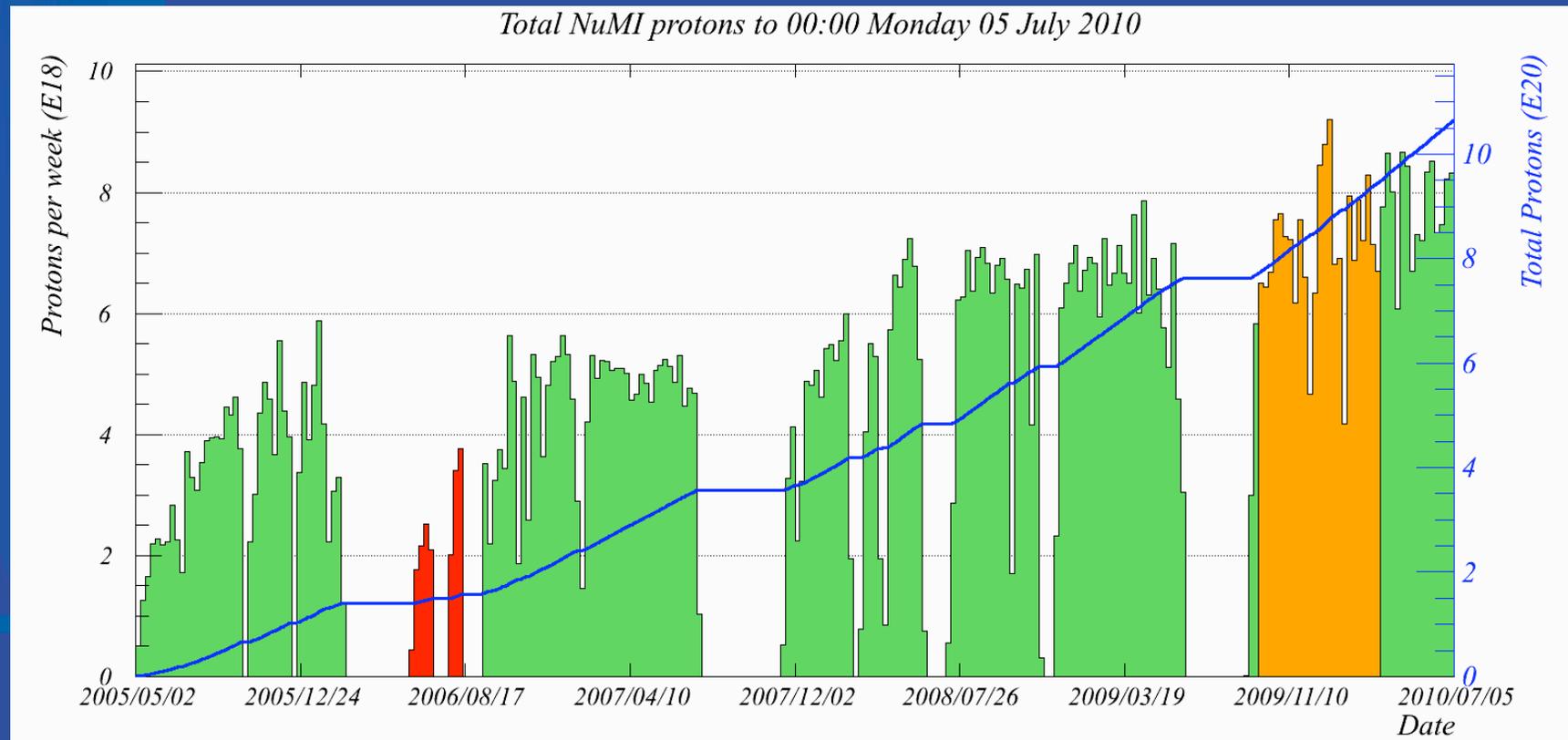
- Possible scenarios for MiniBooNE post 2012 to produce Ironclad ($>5\sigma$) resolution of LSND effect
 - MiniBooNE detector moved to 200m near location to form near/far ratio to confirm oscillation hypothesis (1.5 years to move detector plus 1 year of running).
 - MiniBooNE detector left in place to keep acquiring desperately needed stats in antineutrino mode, 2nd detector constructed at 200m near location to form near/far ratio (3.5 years to construct detector plus 1 year of running).

FNAL statistics

- 15 FTEs in total on MiniBoone / ~80 total collaborators
- 11 FNAL personnel (about 3 FTEs)
 - Steve Brice – past spokesperson
 - Sam Zeller, Chris Polly – Analysis coordinators
 - Ray Stefanski: timing analysis
 - Tom Kobilarcik: runs operations meetings

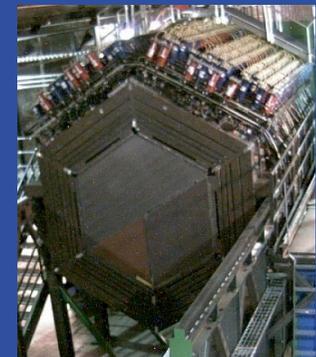
NuMI

- Numi has delivered exceptional running the last year (orange = anti- ν)=special runs)
- Hopefully it will last for the next year!



MINER ν A: Physics Goals

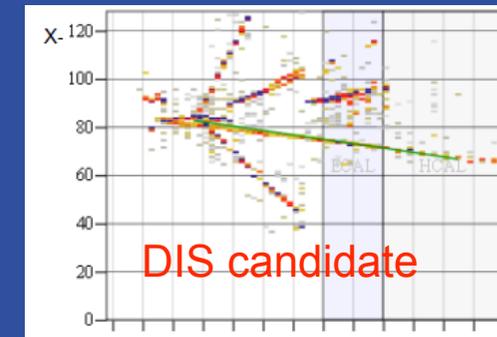
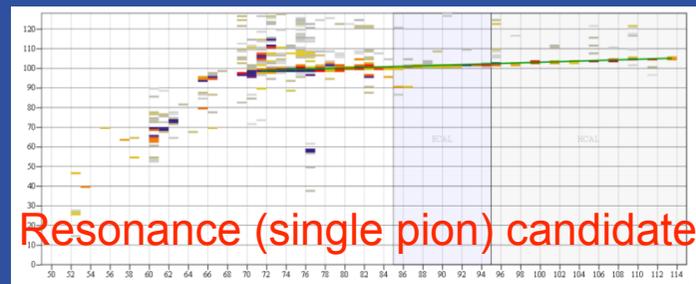
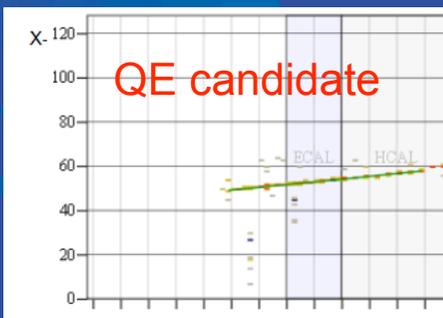
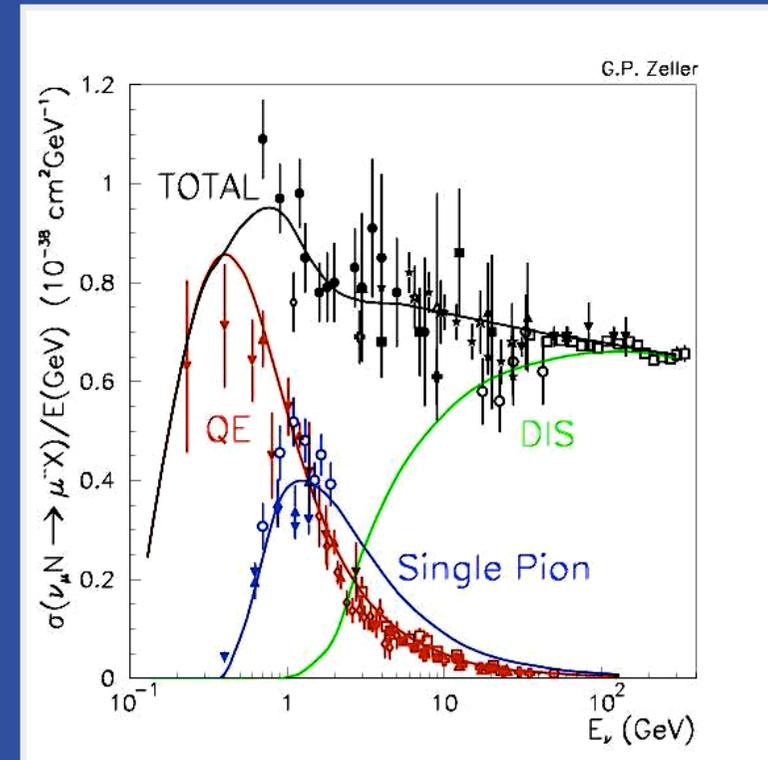
- MINER ν A sits upstream of MINOS Near Det.
- Goals : Study ν interactions in hi-fi detail
 - Measurements for current and future oscillation studies :
 - Measure background processes to ν_e
 - For MINOS and NO ν A (ν (sig&bkg) int modelling)
 - Measure (relative) nuclear energy loss on diff. targets
 - First direct comparison of weak interactions on a variety of strongly bound systems
- Why MINER ν A at NuMI?
 - High intensity for precision studies
 - Wide range of available energies
- MINER ν A detector
 - Supports reconstruction of broad range of final states



Interaction Channels at MINERvA

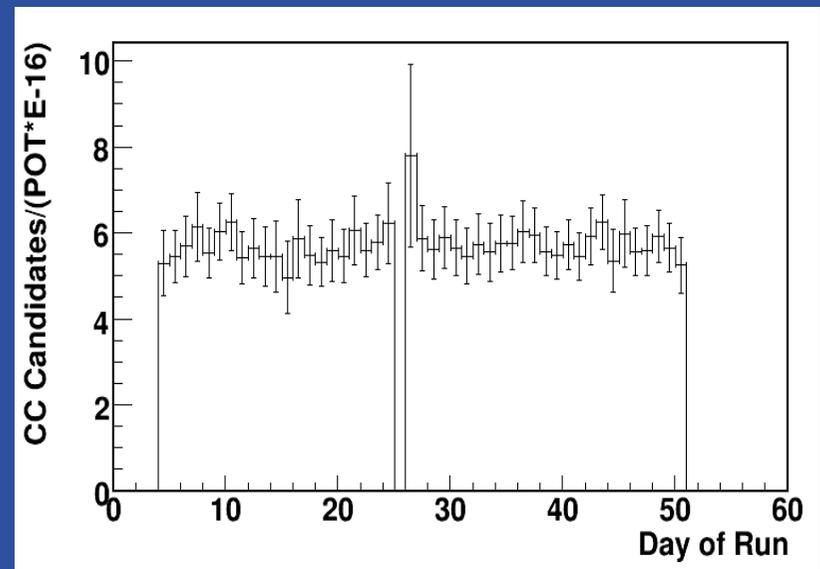
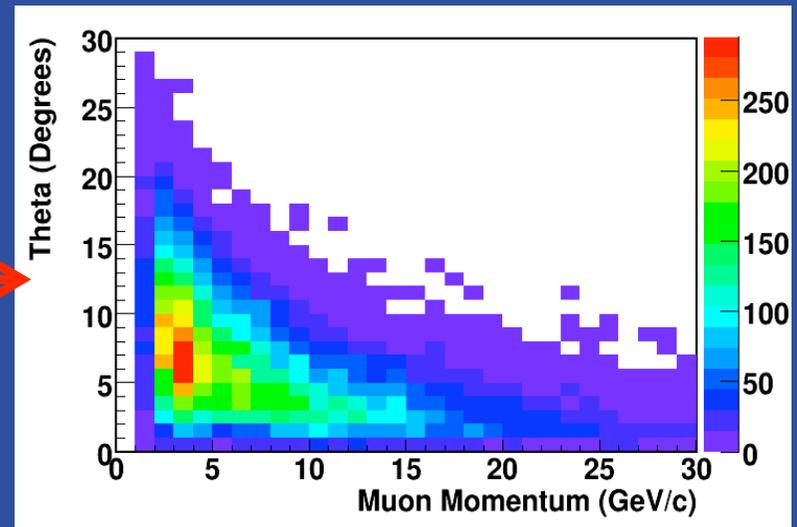
**for 4×10^{20} Protons
On Target in Low
Energy,
 12×10^{20} POT in
Medium Energy
NEUGEN prediction
Acceptance
corrections not
included
3 ton fiducial mass
assumed

Channel	Exptd Stats on fully active Target**
Quasi-Elastic	0.8M (CC)
Resonance	1.7M (CC)
Transition	2.1M (CC)
DIS	4.3M (CC)
Coherent Pion Production	89k CC 44k NC



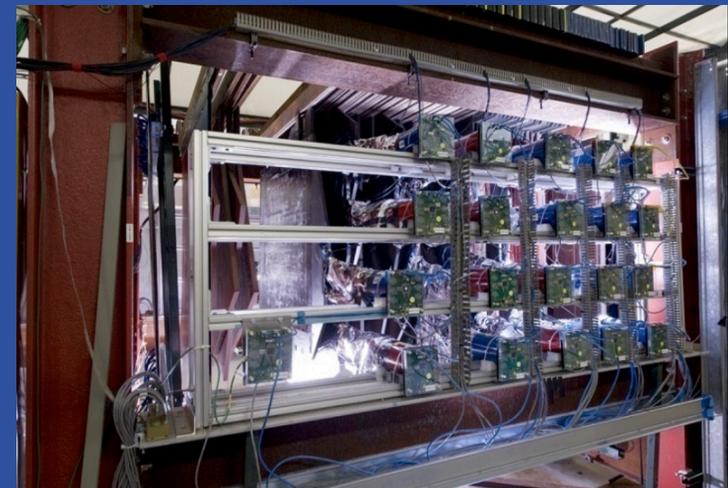
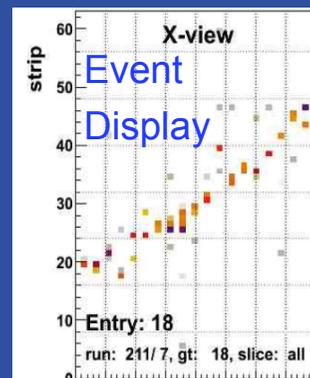
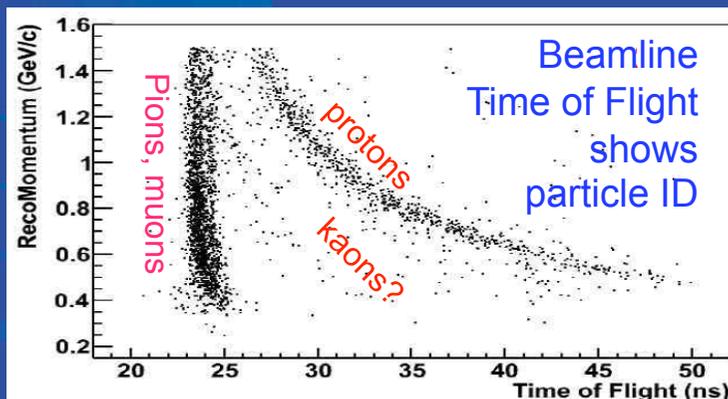
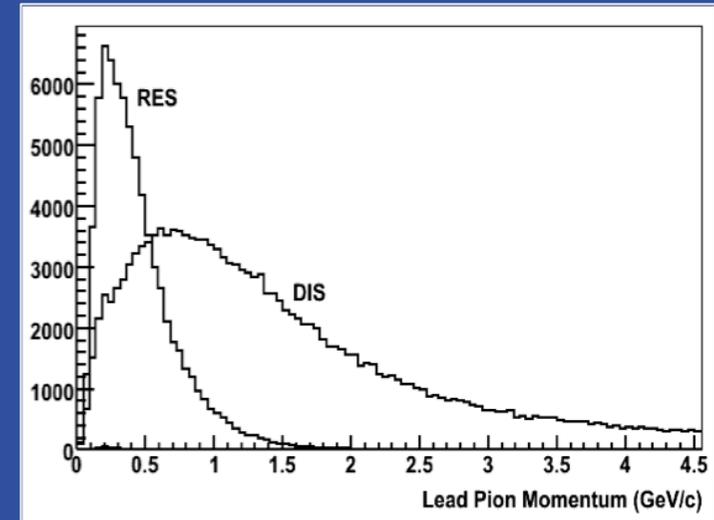
Status of Data-taking and Processing

- Reconstruction and calibration passes on first half of anti-neutrino data complete
- Muons matched to tracks in MINOS, plot shows muon angle at vertex vs total momentum
- Neutrino data analysis underway
- Detector live time >95%
- Neutrino CC candidates per day (in anti-neutrino mode) per POT
- 3 Ton fiducial mass
- 11/09-3/10 : 0.8×10^{20} POT anti- ν
- 3/10-present : 1.0×10^{20} POT ν



MINER ν A Recent Test Beam Activities

- Built 40-plane prototype of MINER ν A detector to calibrate calorimeter and tracker response at energies produced by NuMI neutrinos (see plot at right)
- Designed and commissioned (w/FNAL) new tertiary beam to provide low momentum p, π, K, μ , measurements of both charges of particles (0.4-1.2GeV)
- Taking data from 6/1 -7/19



MINERvA Highlights over the past year

- Start detector installation: 7/2009
- Installation complete: 3/2010
- Begin Neutrino run 3/23/2010
- CD-4 granted on 6/28/2010
 - On time (3 months early)
 - Under Budget (Estimate 9% under)
- Vibrant Guest scientist program
 - Students from Peru, Brazil, and Mexico for long stays
 - Test Beam Coordinator : Rik Gran
 - Co-Spokesperson : Kevin McFarland



FNAL statistics

- 47 FTEs in total on MINERvA / ~80 total collaborators
- Currently 6 physicists at FNAL (about 4.8 FTEs)
 - Jyotsna Osta — post-doc, Test beam detector construction, source mapping, commissioning, test beam data taking
 - Ray Stefanski — Test beam design work, survey and alignment checks, magnetic fields, shift coordinator after 2/2010
 - Dave Schmitz — Lederman Fellow, Reconstruction coordinator, code releaser, co-Run Coordinator until 7/2010
 - Dave Boehnlein — Shift coordinator until 2/2010, project documentation coordinator, leaving for DOE 9/2010
 - Debbie Harris — co-spokesperson as of 2/2010, MINERvA project manager
 - Jorge Morfin — co-spokesperson until 2/2010, test beam design, nuclear target group leader, Latin American Visitor Coordination

The MINOS Experiment



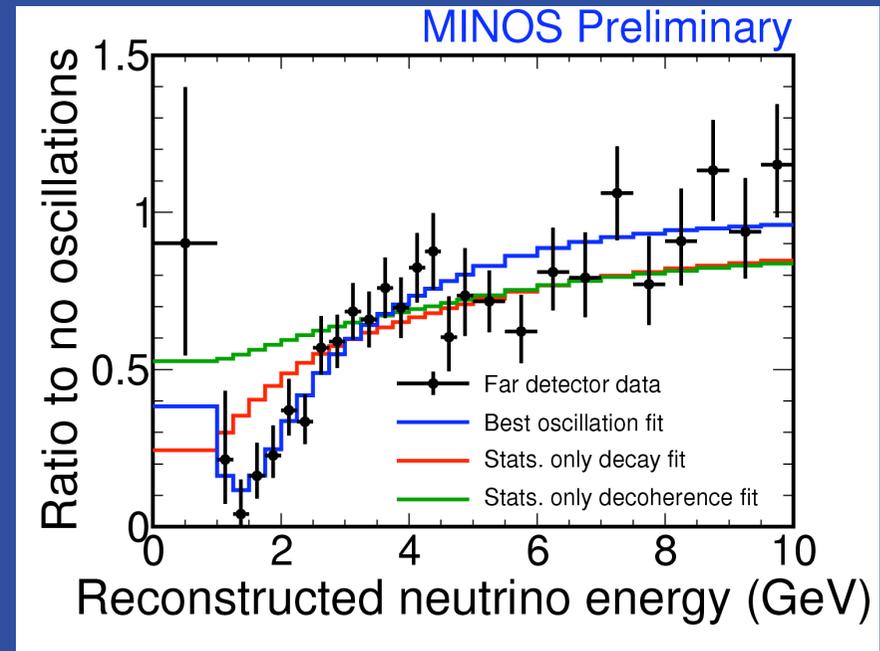
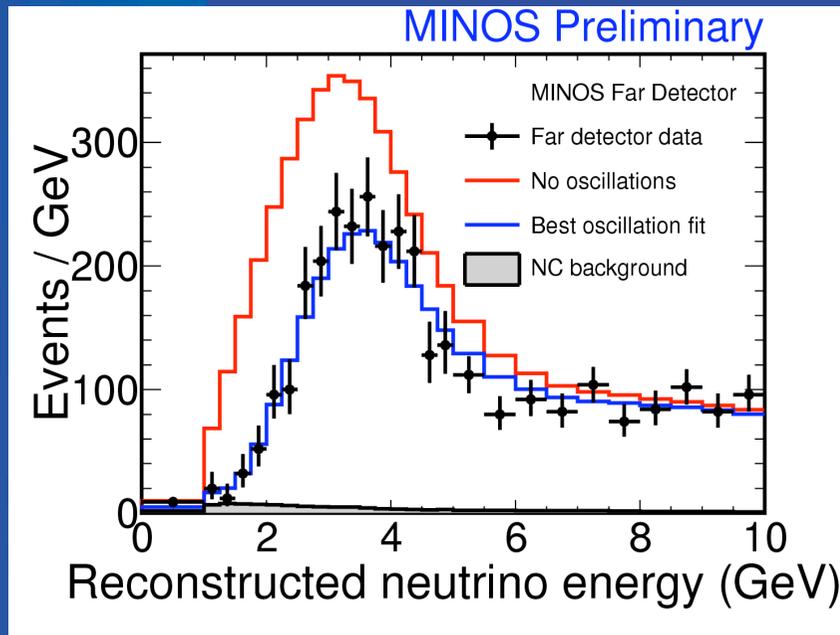
- Two detectors mitigate systematic effects
 - beam flux mis-modeling
 - neutrino interaction uncertainties



- Two-detector, long baseline neutrino oscillation experiment
- Neutrinos from NuMI beam line
- $L/E \sim 500 \text{ km/GeV}$
- atmospheric Δm^2



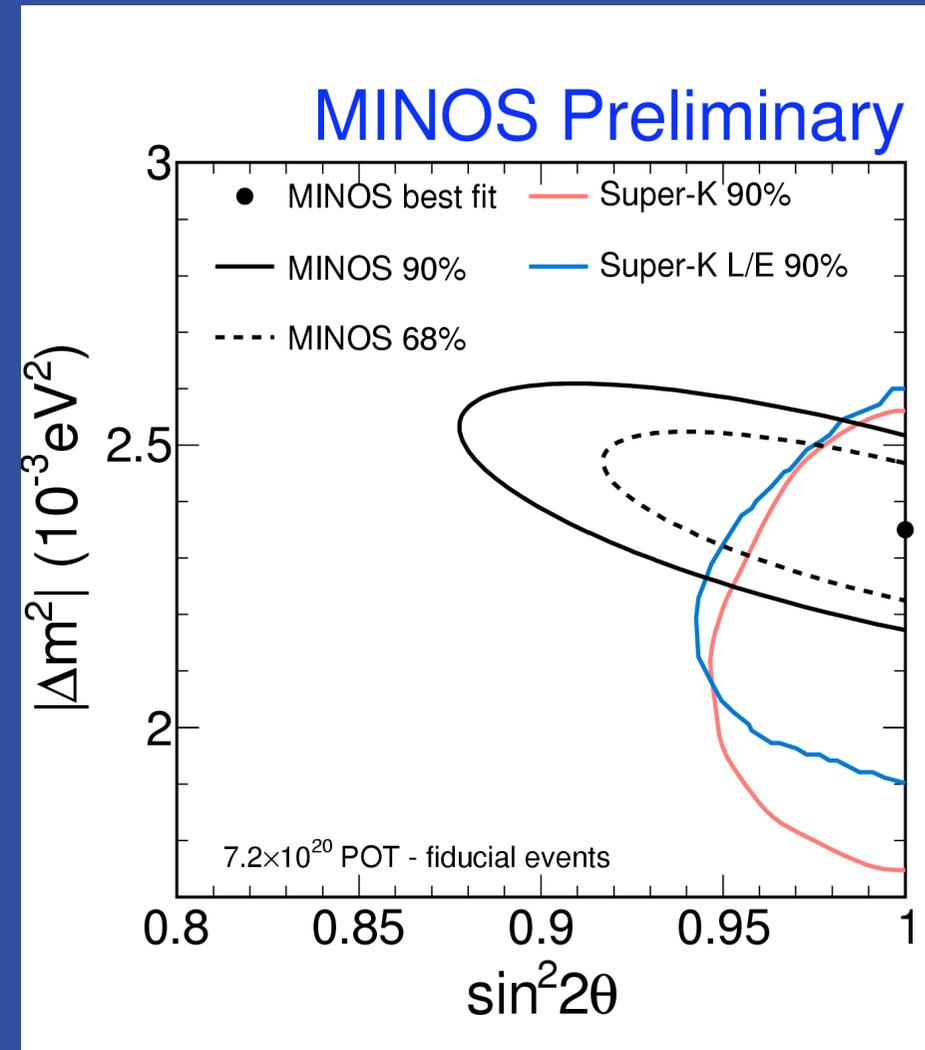
Far Detector neutrino Energy Spectrum



- Oscillations fit the data well, 66% of experiments have worse χ^2
- Pure decoherence[†] disfavored: $> 8\sigma$
- Pure Decay[‡] disfavored: $> 6\sigma$ (7.8σ if NC events included)

Contours

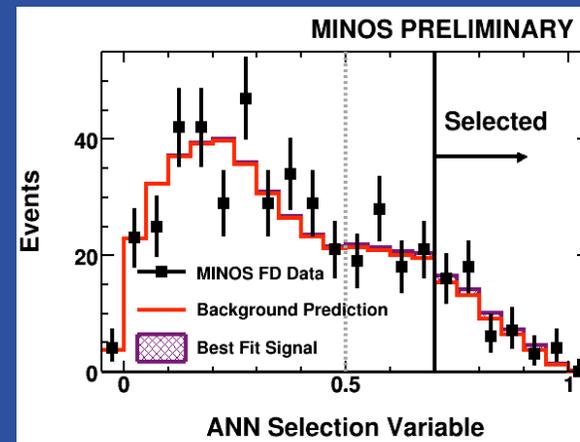
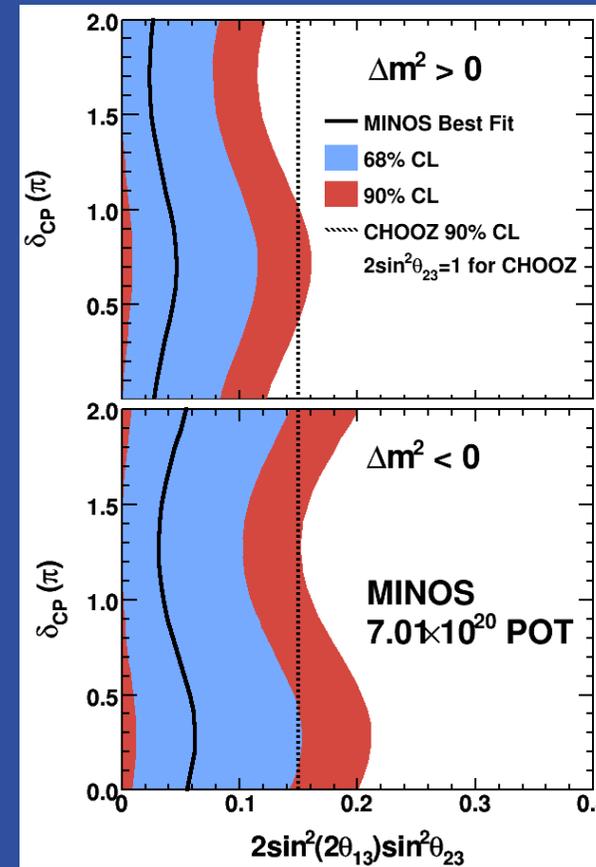
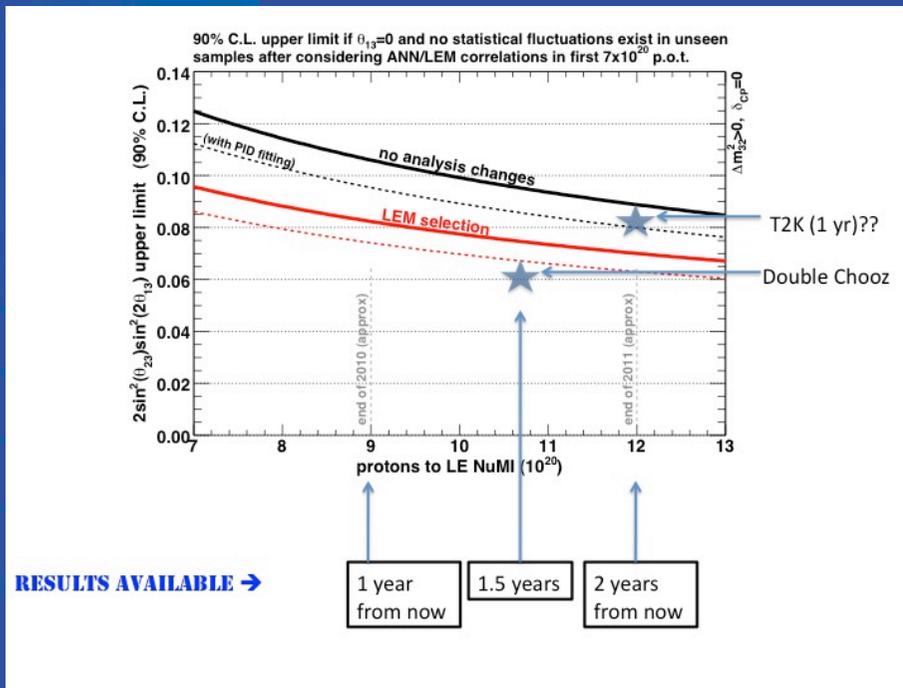
- A number of analysis improvements have been implemented to improve sensitivity by about 10% over previous publications
- Contour includes effects of dominant systematic uncertainties
 - normalization
 - NC background
 - shower energy
 - track energy



†SK preliminary

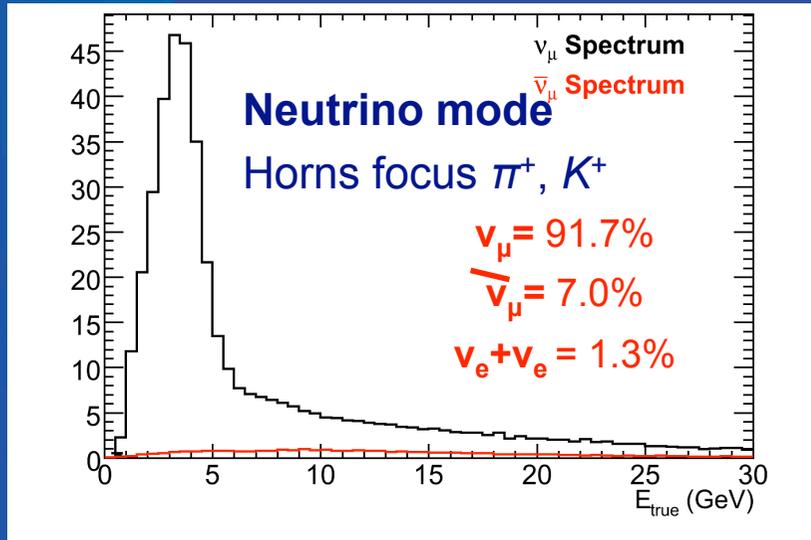
ν_e Appearance Results

- Expect: $49.1 \pm 7.0(\text{stat.}) \pm 2.7(\text{syst.})$
- Observe: **54** events (0.7σ excess)
- At $\delta_{cp}=0$: $\sin^2\theta_{13} < 0.12, 0.20$ (IH)
- Improvements expected from analysis
- Little to be gained from more ν running

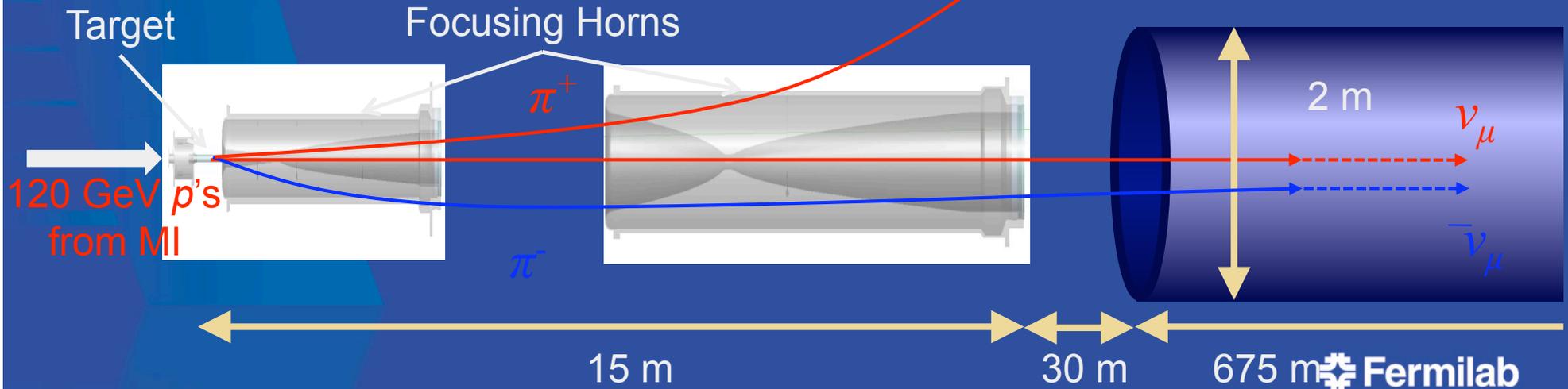
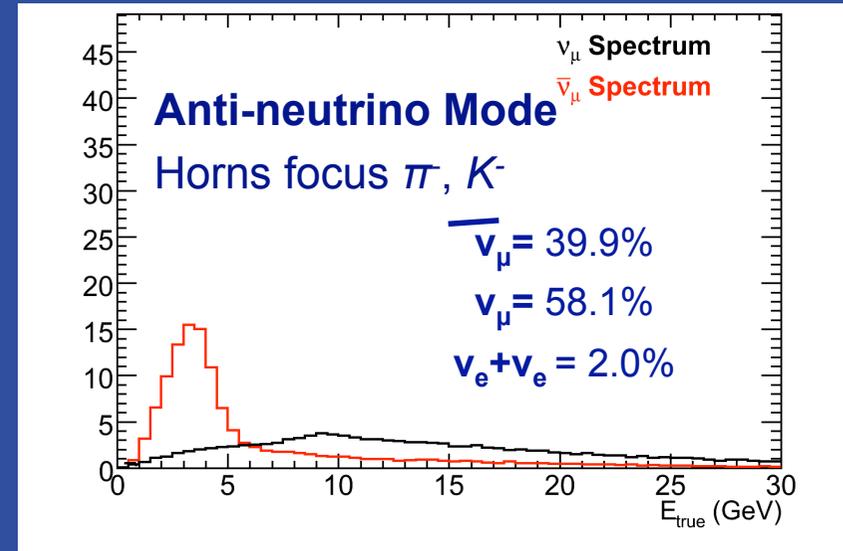


Making an anti-neutrino beam

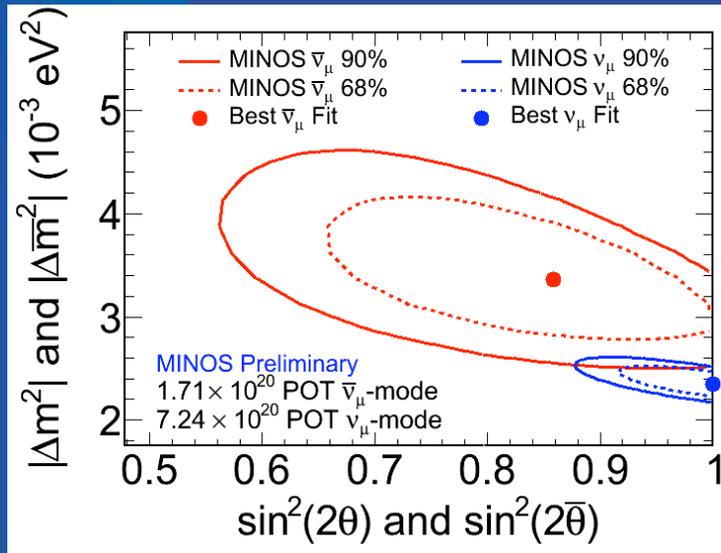
Events



Events



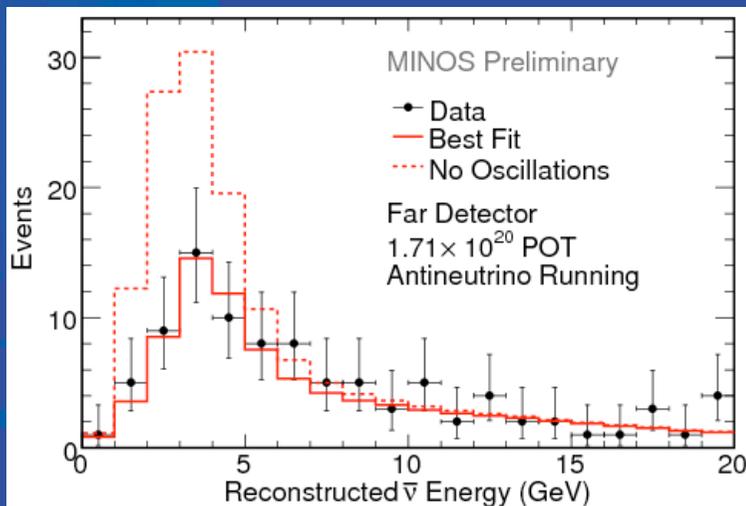
MINOS FD anti- $\bar{\nu}$ Data



- No oscillation Prediction: **155**
- Observe: **97**
- No oscillations disfavored at 6.3σ
- More anti- $\bar{\nu}$ running requested

FNAL statistics

- 5 publications in the last year
- 60 FTEs in total on MINOS but reducing / ~120 total collaborators
- 20 FNAL personnel
 - A.Kreymer and R. Hatcher (CS)
 - D.Toretta (DAQ)
 - R.Plunkett (Co-Spoke)
 - P.Adamson, S. Childress, R. Zwaska (beam)
 - B.Rebel (MAP chair)



Summary

- Ongoing neutrino programme at FNAL packed with results results results
- Neutrino and anti-neutrino differences must be ironed out with more data and possibly significant investment
- FNAL is presently leading in the area of neutrino oscillations and neutrino cross section measurements