

# Neutrino Group Overview

Zelimir Djurcic  
(for ANL neutrino group)



# Outline

- Neutrino Group Context

- Group Projects

  - MINOS

  - Double Chooz

  - NO $\nu$ A

  - LBNE

  - Other  $\nu$

- Plans



# Overview of the Neutrino Group

# ANL Neutrino Group within HEP

-ANL neutrino program aligned with HEP mission, i.e Intensity Frontier:

“The Intensity Frontier, where intense particle beams and highly sensitive detectors are used to pursue alternate pathways to investigate fundamental forces and particle interactions by studying events that occur rarely in nature.”

-Answer fundamental unanswered questions in neutrino physics, in particular:

- 1) What is the value of the third neutrino mixing angle,  $\theta_{13}$ ?
- 2) Do neutrinos violate CP symmetry and if so by how much?
- 3) What is the hierarchy of neutrino masses?



# ANL Neutrino Group Context

We are making significant contributions to **FOUR** neutrino projects

- MINOS
- Double Chooz
- NO $\nu$ A
- LBNE
- and
- Detector R&D

Plus...

- ✿ Monthly Neutrino Newsletters sent to > 1600.
- ✿ Particle Data Group
- ✿ Neutrino Security/Non-proliferation
- ✿ Neutrino Oscillation Industry Web Site  
<http://www.neutrinooscillation.org/>
- ✿ Soudan 2, HUSEP, UNO
- ✿ OMNIS/ADONIS & COGENT
- ✿ MIPP
- ✿ MiniBooNE
- ✿ Participation in reviews, referees...
- ✿ Neutrino Outreach
- ✿ Sponsor and co-organize many neutrino meetings
- ✿ Offers for more than our share of speakers at International Meetings



# Members of the Group

## » ANL Full time staff

- Maury Goodman (Group Leader)
- Richard Talaga
- Steve Magill
- Zelimir Djurcic
- Jonathan Paley

## » Postdocs

- Xiaobo Huang
- Sarah Budd
- Michelangelo D'Agostino
- Matt Wetstein (partial)

## » Others

- Mayly Sanchez Joint Appointment, Iowa State
- Phil Schreiner Faculty appointment from Benedictine
- Tom Fields Emeritus
- Paul Bloom Faculty appointment from North Central College
- David Ayres Emeritus
- Students IMSA & Vijay Jampani

## » Plus

- Mechanical Group: V. Guarino, K.Wood, et al.
- Electronics Group: G. Drake, et al.



# Experiments/Projects

## Neutrino Breakout Session Plan (Wednesday, 5/25/11)

- LBNE
- Double Chooz
- MINOS
- NOvA
- Other  $\nu$

- 2:20 Neutrino Overview (Maury Goodman, 10+5)
- 2:30 Double Chooz Calibration (Michelangelo D'Agostino, 10+5)
- 2:45 Double Chooz Analysis (Zelimir Djurcic, 10+5)
- 3:00 MINOS (Xiaobo Huang, 10+5)
- 3:15 Break
- 3:35 NOvA DAQ (Steve Magill, 10+5)
- 3:50 NOvA Operations (Jon Paley, 10+5)
- 4:05 NOvA PVC & Assembly (Richard Talaga, 10+5)
- 4:20 NOvA Analysis (Sarah Budd, 10+5)

## Detector R&D Breakout Session Plan (Wednesday, 5/25/11)

- 13:20 Wireless readout of neutrino detectors (15') Zelimir Djurcic
- 13:35 Neutrino detectors with LAPD (15') Mayly Sanchez



# MINOS

## (Main Injector Neutrino Oscillation Search)

# MINOS Timeline

- 1987 – First Calculations of neutrinos from Fermilab to Soudan at ANL
- 1990 – Letter of Intent
- 1991 – ANL ran “Long-Baseline Neutrino Oscillation” workshop at Fermilab
- 1992 – 822 proposal, ANL spokesperson
- 1994 – MINOS collaboration forms
- 1995 – MINOS approved, HEPAP subpanel on long-baseline oscillations
- 2003 – MINOS Far detector completed
- 2005 – First Far detector event in neutrino beam
- 2011 – (Probable) end of data taking
- 2012+ -- MINOS+, (ANL not participating), will continue to maintain ND electronics
  
- **Recent papers (15 since 2009):**  $\Delta m^2_{32}$ , search for  $\nu_e$  appearance, search for sterile neutrino component, atmospheric  $\mu^+/\mu^-$ , lorentz invariance, measurements with antineutrinos, seasonal variations, atmospheric  $K/\pi$ ,
- **Analyses in progress:** atmospheric  $\nu$ , lorentz invariance,  $\nu_e$  appearance, etc.

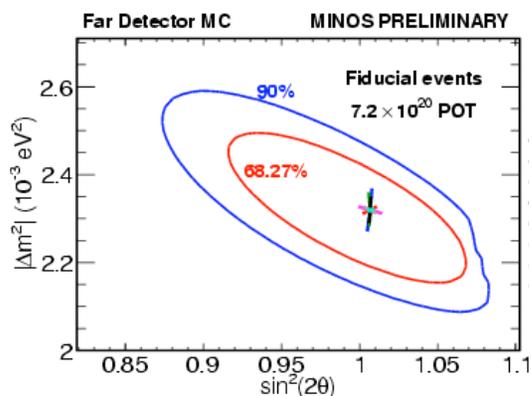


# MINOS Current Involvement

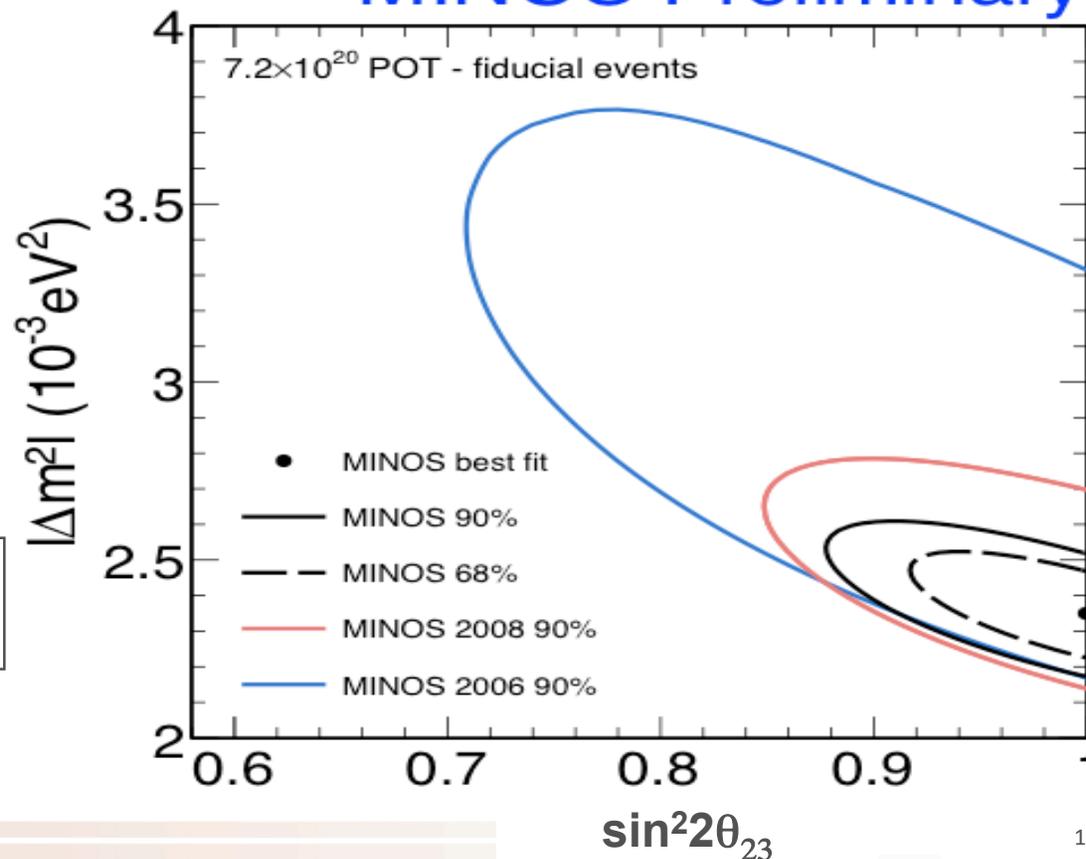
- Phil Schreiner, convenor of “Universal Physics Analysis Group”
  - Atmospheric neutrinos, cosmic rays,  $K^+/K^-$ ,  $p/K$
- Sarah Budd, convenor of the “Calibration Group”
- Maury Goodman, chairman of the Institutional Board, executive committee
  - Atmospheric neutrinos, cosmic rays
- Xiaobo Huang, calibration,  $\nu_e$
- Mayly Sanchez,  $\nu_e$ , chair of the atmospheric  $\nu$  paper committee
- Tom Fields, analysis of muon production
- Dave Ayres, maintains author lists & other collaboration lists
- Richard Talaga, shifts only
- Jon Paley, database



# World's best measurement of $\Delta m^2_{32}$



## MINOS Preliminary



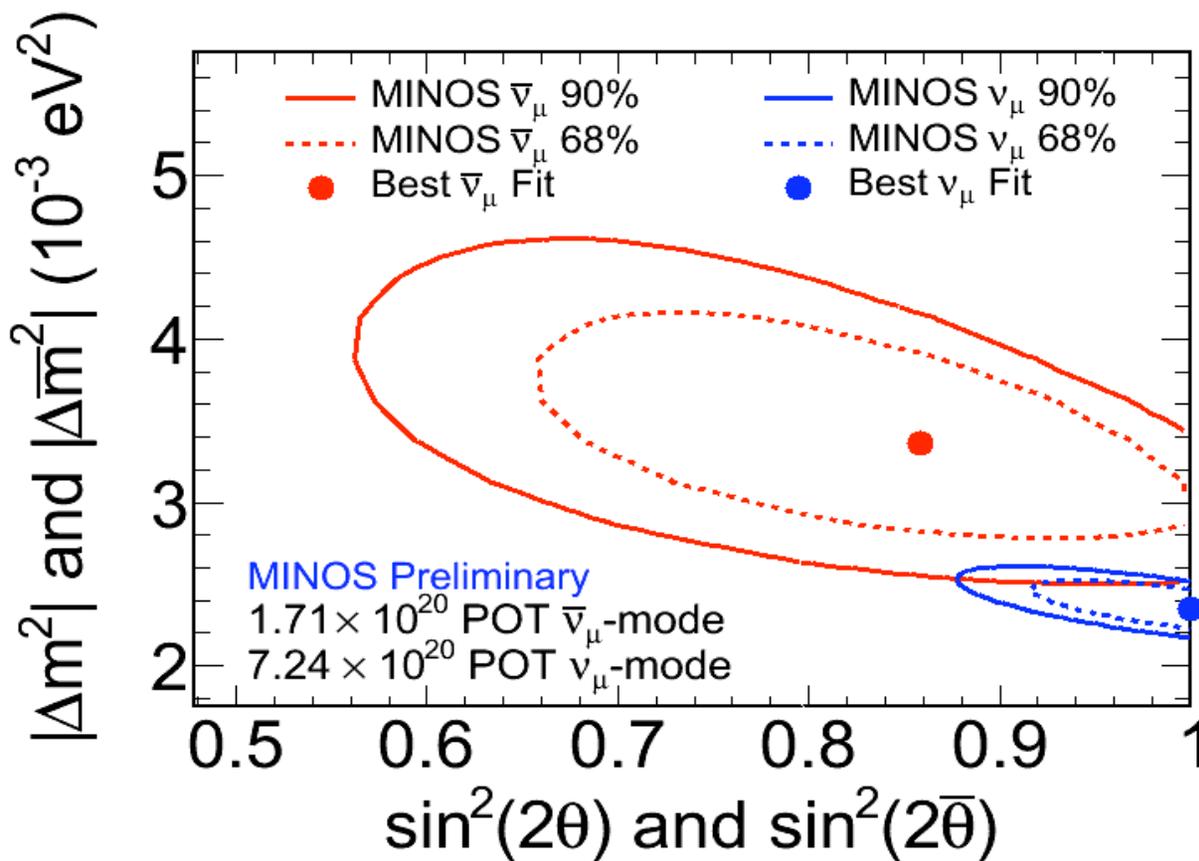
$$|\Delta m^2| = 2.35^{+0.11}_{-0.08} \times 10^{-3} \text{ eV}^2$$

0.19 uncertainty; was 0.26

# MINOS Antineutrinos



Is there a difference between  $\nu$  and anti- $\nu$ ?





# Double Chooz

## (Reactor Anti-neutrino Experiment)

# Double Chooz Current Involvement

- Michelangelo D'Agostino
  - leadership in calibration Z-axis system development/deployment
  - simulation and analysis of  ${}^9\text{Li}$  and Michel electrons from stopping muons
  - stopping muon fitter development
- Zelimir Djurcic
  - co-convenor of “Calibration Group”
  - simulation and analysis of spallation neutrons
  - reactor flux calculations and systematics
- Maury Goodman
  - executive committee
  - oversee articulated arm system and funding
  - $\theta_{13}$  sensitivity studies
- Everyone is participating in:
  - data analysis at collaboration level
  - data analysis within US cluster
  - work with summer intern students ( V.Jampani(current), A.Rizvi, J.Adams(last year) )
  - preparation for the radioactive source deployment
  - preparation for the data analysis of deployed radioactive sources
  - detector shifts



# Double Chooz Schedule

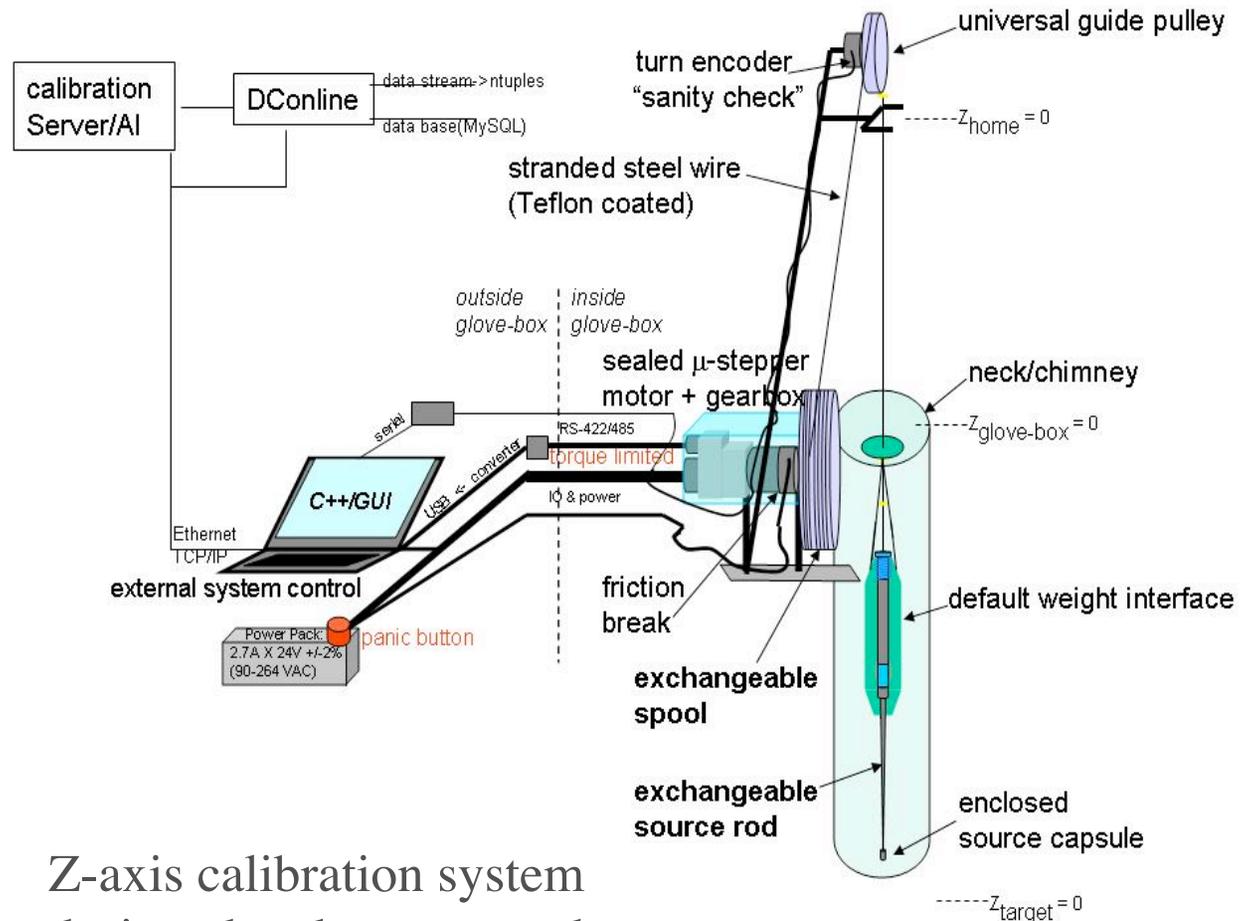
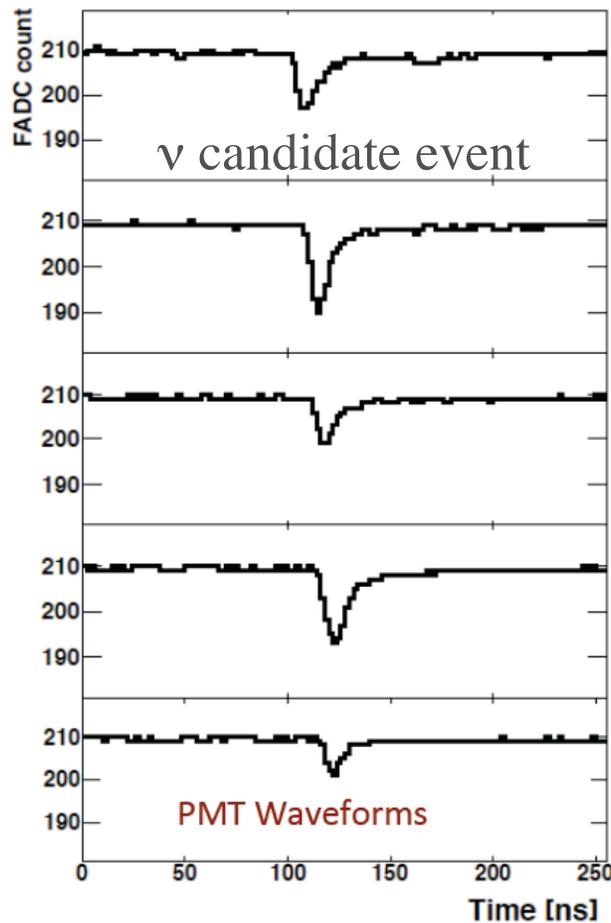
## Far Detector:

- **Far Detector commissioned and taking physics data from April 13, 2011.**
- **Remaining tasks:**
  - The lower Outer Veto (OV) installation is under way → date June 10.
  - The deck installation after the lower OV system is in place → end June 24.
  - The glove box installation → end date July 1.
  - The clean tent installation → end date July 8.
  - The Z-axis deployment system installation and commissioning, radioactive source deployments in the target by mid-July.**
  - The upper OV is installed after the first calibration deployments (FD complete).
- **First Results on  $\theta_{13}$ :**
  - Expect Far Detector only result this summer when sensitivity to  $\theta_{13}$  better than original CHOOZ sensitivity (~3 months of data at full reactor power).

## Near Detector:

- Near Detector Lab Construction started 29th April 2011.
- The lab will be delivered in March-April 2012 ready for physics.

# Double Chooz Current Status :

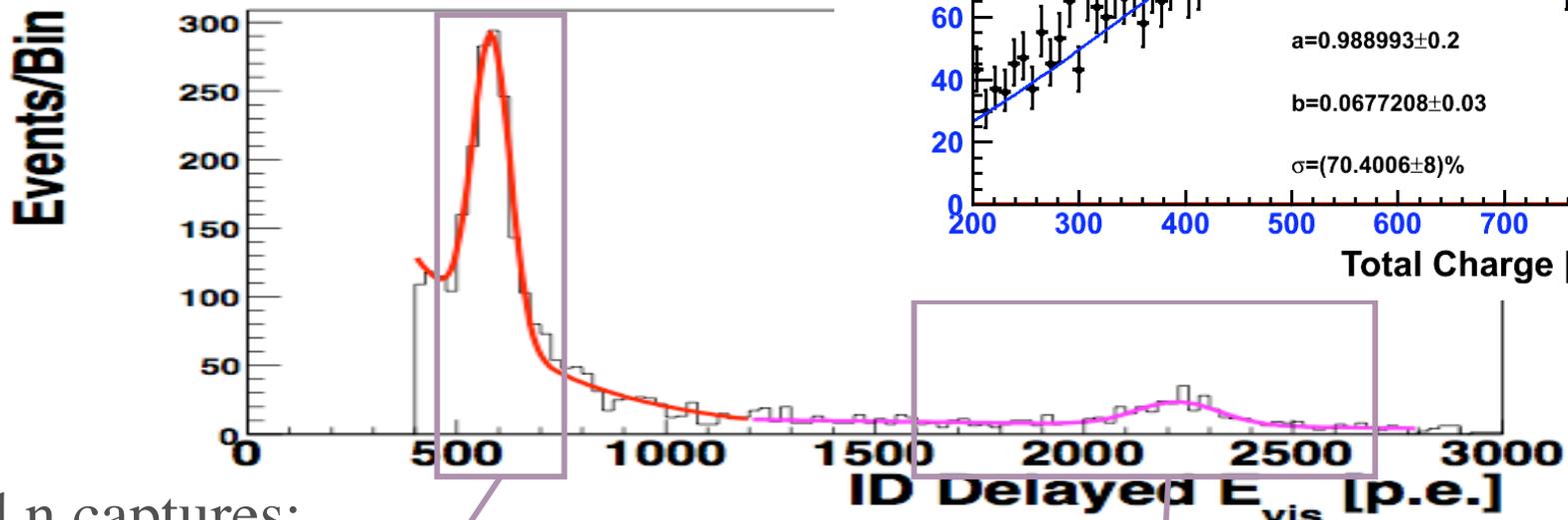
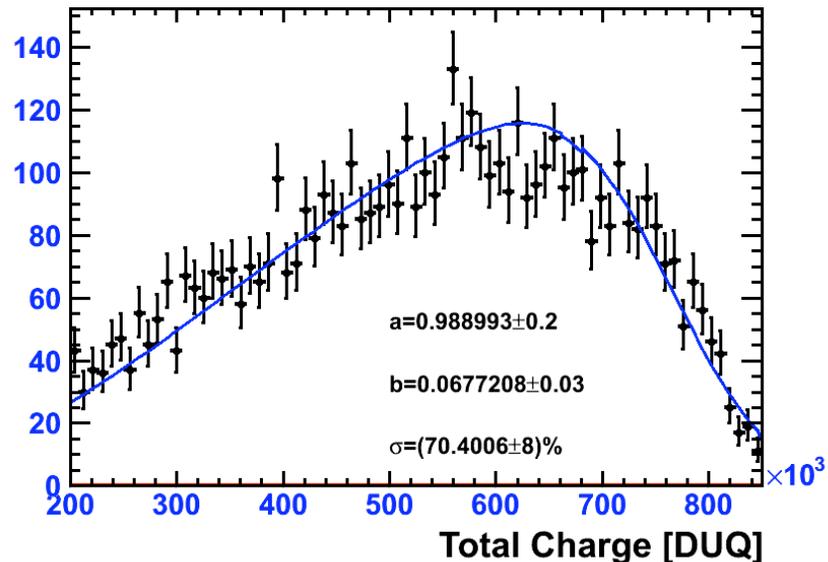


Z-axis calibration system designed and constructed at ANL is under readiness review, ready for deployment.

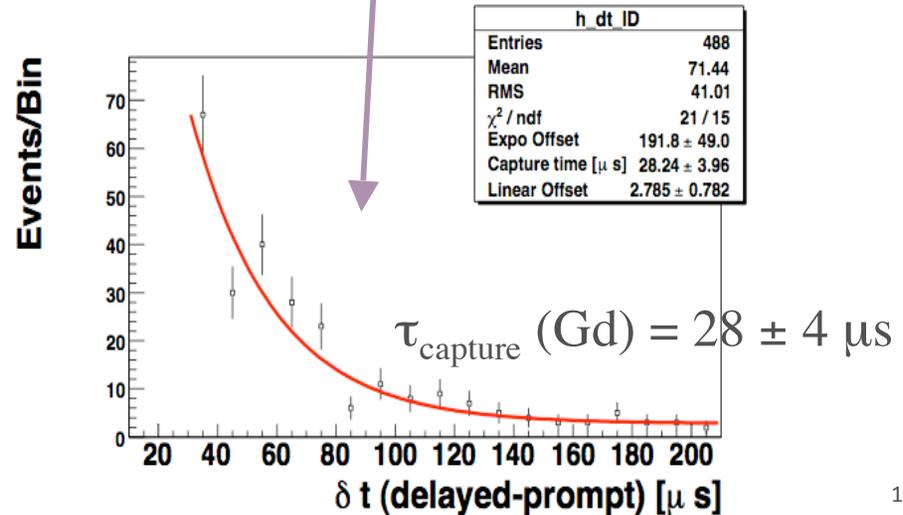
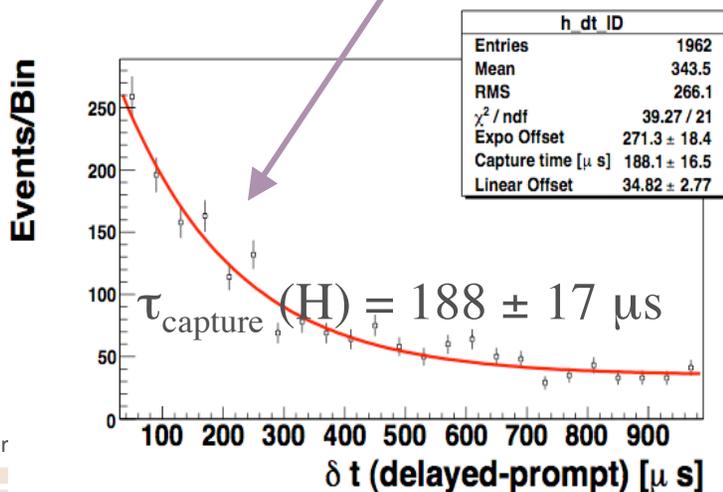
# ANL Analysis Examples

- spallation neutrons
- Michel electrons

Michel Electron Spectrum From 1 Day of Data



H/Gd n captures:





# NO $\nu$ A

(NuMI Off-Axis  $\nu_e$  Appearance Experiment)

# NOvA Current Involvement

## ■ Sarah Budd

- module construction
- Quality Control of detector components
- mechanical hardware database
- multiple analysis tasks

## ■ Zelimir Djurcic

- Developing leak checking system for Near and Far Detectors
- Booster Beam Simulation
- Beam Systematics Studies

## ■ Maury Goodman

- Speakers Committee chair

## ■ Vic Guarino

- Engineering Team

## ■ Xiaobo Huang

- Developing calibration techniques with stopping muons
- Preparing for analysis of cosmic ray induced backgrounds

Zelimir Djurcic: ANL Neutrino Group Overview



## ■ Steve Magill

- Developed data-logger for DAQ.
- Developing "cheater" for algorithm optimization.
- Optimization of the Near Detector e/pi0 selection algorithm

## ■ Jon Paley

- NOvA Run coordinator
- database coordinator
- developer of DAQ Run Control and Resource Manager
- IB member

## ■ Mayly Sanchez

- Offline Coordinator
- EC member
- developing timig calibration

## ■ Rich Talaga

- Level 2 manager for PVC
- CAM \$26M
- Financial Manager MOU, SOW
- EC member
- Tech Board
- ANL Assembly Leader

# NOvA Schedule

- Prototype Near Detector (NDOS) - operational, taking data.
  - Regular shifts started.
- Start Far Detector construction at Ash River – Fall 2011
- Accelerator shutdown starts for NOvA - March 2012
- Beam returns at 700 kW, with  $\sim 2/3$  of Far Detector ready – Feb. 2013
- Expect Far Detector complete by Fall 2013



# NOvA NDOS Construction and Gluing Machine

## Module Stacks & Leak Test Station



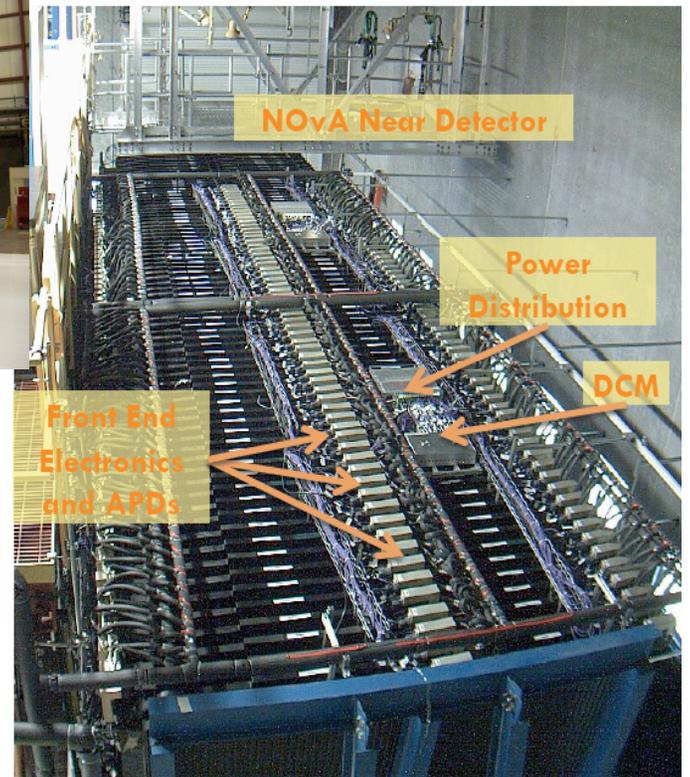
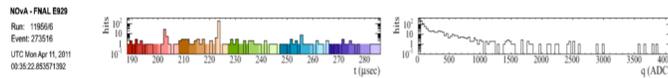
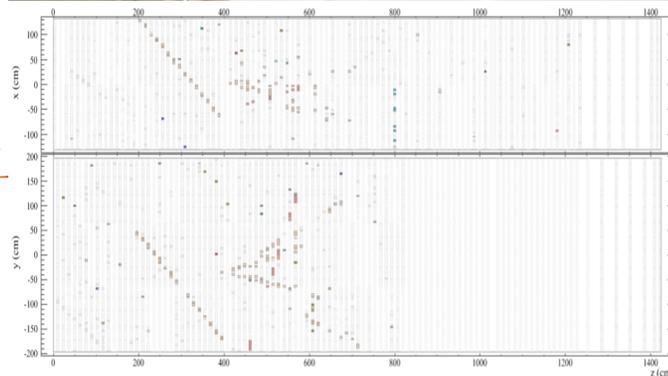
Placing Module in NDOS Block



NDOS Block Shipped to FNAL



Unique Gluing technique and technology developed at ANL

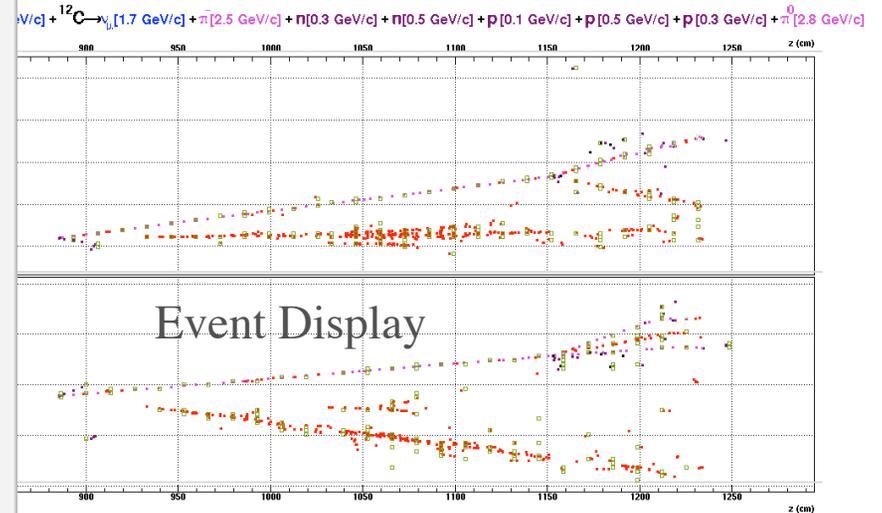
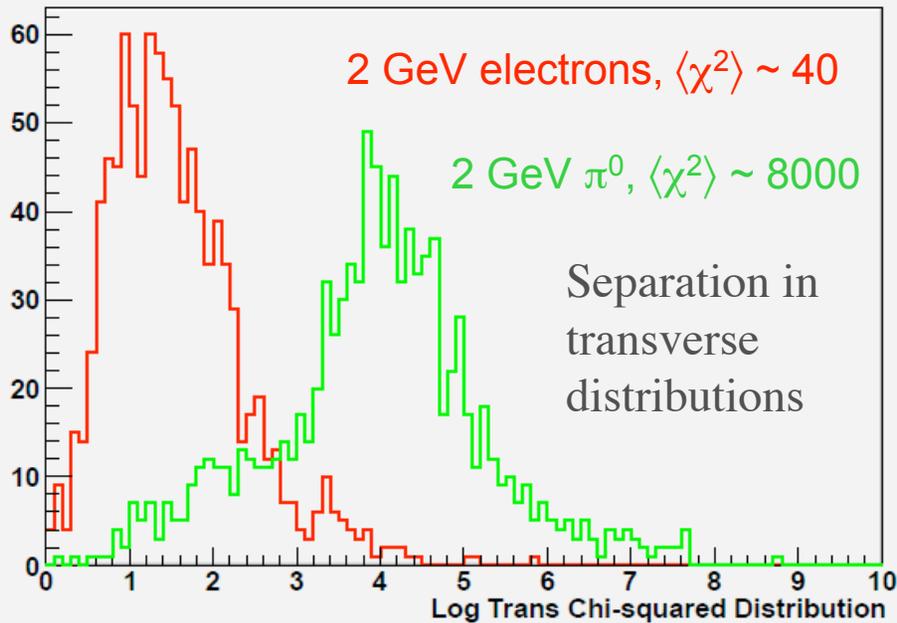


Overview

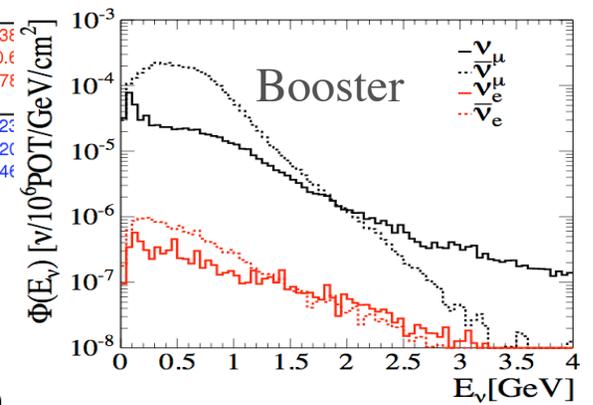
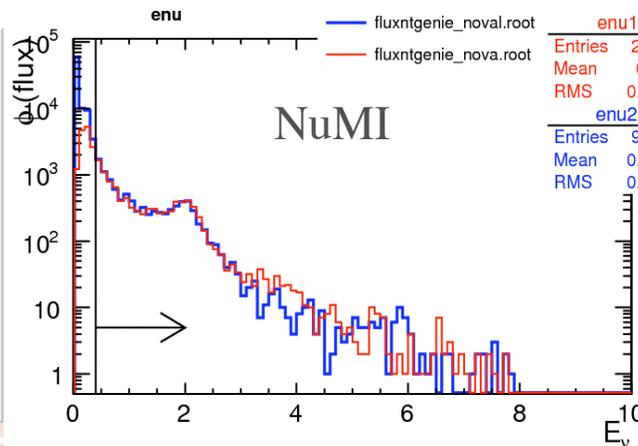
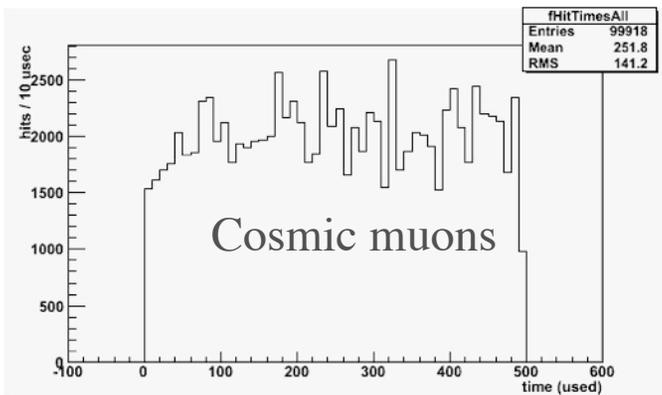


# ANL Analysis Examples

$e, \pi^0$  rejection with transverse H-Matrix



## Cosmic and beam Simulations





# LBNE

## (Long-baseline Neutrino Experiment)

# Long-Baseline Neutrino Experiment Collaboration

**Alabama:** J. Goon, I Stancu

**Argonne:** M. D'Agostino, G. Drake, Z. Djurcic, M. Goodman, X. Huang, V. Guarino, J. Paley, R. Talaga, M. Wetstein

**Boston:** E. Hazen, E. Kearns, S. Linden, J. Stone

**Brookhaven:** M. Bishai, R. Brown, H. Chen, M. Diwan, J. Dolph, G. Geronimo, R. Gill, R. Hackenberg, R. Hahn, S. Hans, D. Jaffe, S. Junnarkar, J.S. Kettell, F. Lanni, L. Littenberg, J. Ling, D. Makowiecki, W. Marciano, W. Morse, Z. Parsa, C. Pearson, V. Radeka, S. Rescia, T. Russo, N. Samios, R. Sharma, N. Simos, J. Sondericker, J. Stewart, H. Tanaka, C. Thorn, B. Viren, Z. Wang, S. White, L. Whitehead, M. Yeh, B. Yu

**Caltech:** R. McKeown, X. Qian, C. Zhang

**Cambridge:** A. Blake, M. Thomson

**Catania/INFN:** V. Bellini, G. Garilli, R. Potenza, M. Trovato

**Chicago:** E. Blucher

**Colorado:** S. Coleman, R. Johnson, A. Marino, M. Tzanov, E. Zimmerman

**Colorado State:** M. Bass, B. Berger, J. Brack, N. Buchanan, J. Harton, V. Kravtsov, W. Toki, D. Warner, R. Wilson

**Columbia:** R. Carr, L. Camillieri, C.Y. Chi, G. Karagiorgi, C. Mariani, M. Shaevitz, W. Sippach, W. Willis

**Crookston:** D. Demuth

**Dakota State:** B. Szczerbinska

**Davis:** M. Bergevin, R. Breedon, J. Felde, P. Gupta, M. Tripanthi, R. Svoboda

**Drexel:** C. Lane, J. Maricic, R. Milincic, K. Zbiri

**Duke:** T. Akiri, J. Fowler, K. Scholberg, C. Walter, R. Wendell

**Duluth:** R. Gran, A. Habig

**Fermilab:** D. Allspach, M. Andrews, B. Baller, E. Berman, D. Boehnlein, M. Campbell, A. Chen, S. Childress, B. DeMaat, A. Drozhdin, T. Dykhuis, C. Escobar, A. Hahn, S. Hays, A. Heavey, J. Howell, P. Huhr, J. Huyen, C. James, M. Johnson, J. Johnstone, T. Junk, B. Kayser, G. Koizumi, T. Lackowski, P. Lucas, B. Lundberg, T. Lundin, P. Mantsch, E. McCluskey, N. Mokhov, C. Moore, J. Morfin, B. Norris, V. Papadimitriou, R. Plunkett, C. Polly, S. Pordes, O. Prokofiev, J. Raaf, G. Rameika, B. Rebel, D. Reitzner, K. Riesselmann, R. Rucinski, R. Schmidt, D. Schmitz, P. Shanahan, M. Stancari, J. Strait, S. Striganov, K. Vaziri, G. Velez, G. Zeller, R. Zwaska

**Hawaii:** S. Dye, J. Kumar, J. Learned, S. Matsuno, S. Pakvasa, M. Rosen, G. Varner

**Indian Universities:** V. Singh (BHU); B. Choudhary, S. Mandal (DU); B. Bhuyan [IIT(G)]; V. Bhatnagar, A. Kumar, S. Sahijpal (PU)

**Indiana:** W. Fox, C. Johnson, M. Messier, S. Mufson, J. Musser, R. Tayloe, J. Urheim

**Iowa State:** M. Sanchez

**IPMU/Tokyo:** M. Vagins

**Irvine:** G. Carminati, W. Kropp, M. Smy, H. Sobel

**Kansas State:** T. Bolton, G. Horton-Smith

**LBL:** R. Kadel, B. Fujikawa, D. Taylor

**Livermore:** A. Bernstein, R. Bionta, S. Dazeley, S. Ouedraogo

**London-UCL:** J. Thomas

**Los Alamos:** S. Elliott, A. Friedland, V. Gehman, G. Garvey, T. Haines, D. Lee, W. Louis, C. Mauger, G. Mills, A. Norrick, Z. Pavlovic, G. Sinnis, W. Sondheim, R. Van de Water, H. White

**Louisiana State:** W. Coleman, T. Kutter, W. Metcalf, M. Tzanov

**Maryland:** E. Blaufuss, R. Hellauer, T. Straszheim, G. Sullivan

**Michigan State:** E. Arrieta-Diaz, C. Bromberg, D. Edmunds, J. Huston, B. Page

**Minnesota:** M. Marshak, W. Miller

**MIT:** W. Barletta, J. Conrad, T. Katori, R. Lanza, L. Winslow

**NGA:** S. Malys, S. Usman

**New Mexico:** B. Becker, J. Mathews

**Notre Dame:** J. Losecco

**Oxford:** G. Barr, J. DeJong, A. Weber

**Pennsylvania:** J. Klein, K. Lande, A. Mann, M. Newcomer, S. Seibert, R. vanBerg

**Pittsburgh:** D. Naples, V. Paolone

**Princeton:** Q. He, K. McDonald

**Rensselaer:** D. Kaminski, J. Napolitano, S. Salon, P. Stoler

**Rochester:** R. Bradford, K. McFarland

**SDMST:** X. Bai, R. Corey

**SMU:** T. Liu, J. Ye

**South Carolina:** H. Duyang, S. Mishra, R. Petti, C. Rosenfeld

**South Dakota State:** B. Bleakley, K. McTaggart

**Syracuse:** M. Artuso, S. Blusk, T. Skwarnicki, M. Soderberg, S. Stone

**Texas:** S. Köpp, K. Lang, R. Mehdiev

**Tufts:** H. Gallagher, T. Kafka, W. Mann, J. Schnepps

**UCLA:** K. Arisaka, D. Cline, K. Lee, Y. Meng, F. Serigiampietri, H. Wang

**Virginia Tech:** E. Guarnaccia, J. Link, D. Mohapatra, R. Raghavan

**Washington:** H. Berns, S. Enomoto, J. Kaspar, N. Tolich, H.K. Tseung

**Wisconsin:** B. Balantekin, F. Feyzi, K. Heeger, A. Karle, R. Maruyama, D. Webber, C. Wendt

**Yale:** E. Church, B. Fleming, R. Guenette, K. Partyka, J. Spitz, A. Szelc

# LBNE: Argonne Role

## Inside the box

- Veto detector for Liquid Argon option
  - Jon Paley, L3 manager
- Collaboration management
  - Maury Goodman, Deputy Spokesperson
- Calibration
  - Mayly Sanchez, L3 manager for Water C. Calibration
- Water Cerenkov testing
  - Thinking about a large water test facility at ANL for mounting, pressure, vibrations, water transparency, etc.

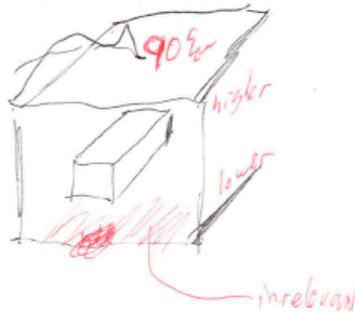
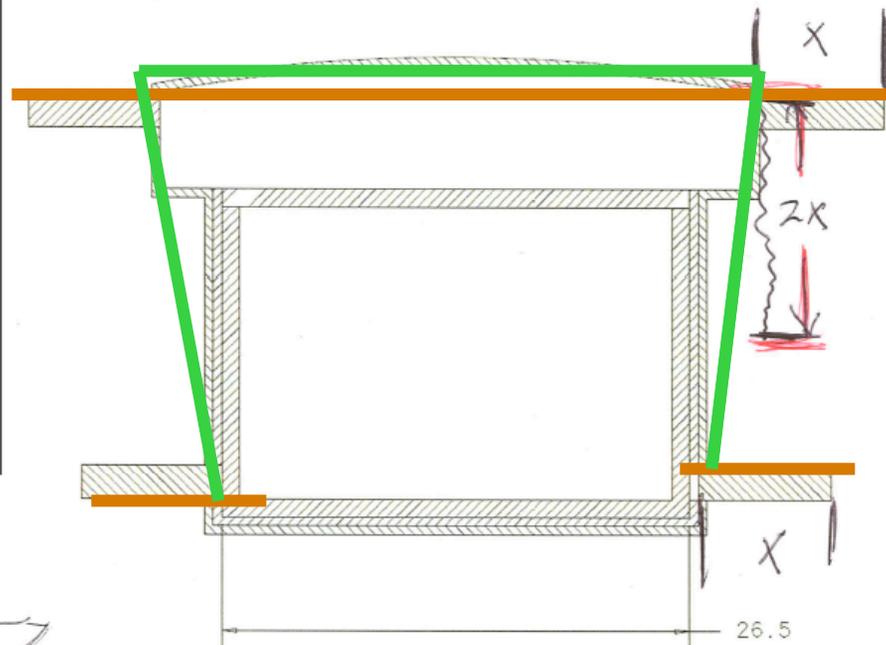
## Outside the box

- LAPPD
  - Simulations by Mayly Sanchez & Matt Wetstein
- Wireless electronics & HV
  - LDRD by Zelimir Djurcic
  - Related work of David Underwood
- Water based scintillators
  - Following work at BNL
- Other New Ideas
  - DAE $\delta$ ALUS idea



# Liquid Argon Veto

- Veto at top & bottom or walls?
- Purpose is to identify muons which might lead to a  $K_L$ , which could cause background for proton decay ( $p \rightarrow \nu K^+$ )
  - Alternative schemes to study:

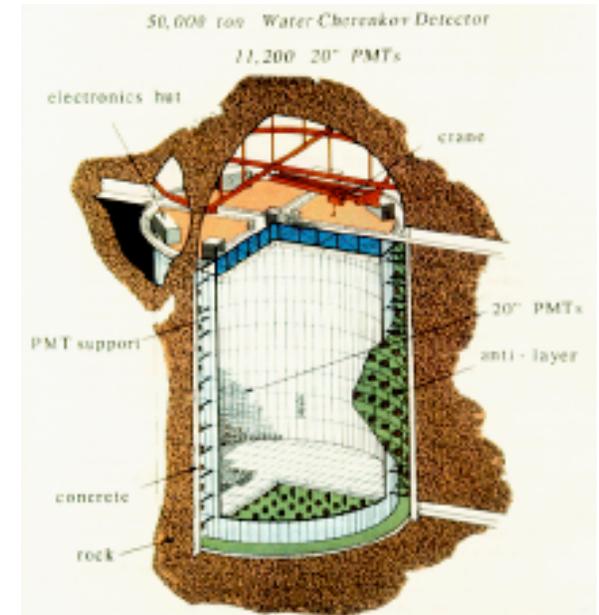


SECTION B



## Possible Water Tank at ANL

- New idea for large water tank (~1000 tons of water) for:
  - Testing mounting prototypes
  - Testing pressure
  - Testing vibrations
  - Testing wireless electronics
  - Testing wired electronics
  - Testing battery sources of power in water
  - Testing water transparency
  - Testing water based liquid scintillator
  - Testing LAPPD compatibility with water



- To be developed and presented at Water Cherenkov workshop in July 2011



# Plans

## Short Term

- MINOS, Double Chooz and NOvA can keep us quite busy in next 5 years:
  - MINOS: analysis, expect reducing activity in next year.
  - Double Chooz: taking data, expect peak in 2-3 years.
  - NOvA: very active, will be peaking right after Double Chooz
- Will learn on the size of  $\theta_{13}$  from current involvement:
  - MINOS provides most-sensitive measurement of atmospheric  $\Delta m^2$  relevant to  $\theta_{13}$
  - If Double Chooz measure  $\theta_{13}$  (if large enough), NOvA will be in position to measure mass hierarchy and perform to CP-violation search
  - If  $\theta_{13}$  is large enough, an ambitious long-baseline program is in our future.
  - If  $\theta_{13}$  is smaller, a slower program to continue pushing the sensitivity will be a top priority.
- LBNE: expect to steadily grow our involvement over a long period (>5 year).



# Longer Term Opportunities

We expect to shape the field and drive new developments to the far future:

- LBNE

- possible new techniques (constantly trying to make cheaper and more sensitive detectors):

  - LAPPD detectors

  - wireless readout

  - Combined ionization/scintillation readout of LAr detector

- possible evolution of neutrino goals:

  - short baseline neutrino workshop at FNAL (May 12-14, 2001)  
discussed follow up on anomalies (LSND, MiniBooNE, MINOS, reactor anomaly)

  - sterile neutrinos?