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# **The FNAL Research Program**

**URA Visiting Committee  
Hugh Montgomery**

**March 12, 2004**

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# The FNAL Research Program

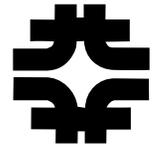
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- **FNAL Accel. Programs**
  - **Collider-Run II (CDF/D0)**
  - **Neutrinos**
    - **NuMI/Minos**
    - **MiniBooNE**
  - **MI-based Fixed Target**
    - **Test Beam**
    - **QCD, (Kaon) Expts**
- **LHC**
- **Theory**
  - **Particle**
  - **Astroparticle**
- **Astroparticle Expts**
- **Linear Collider R&D**
- **Computing**

# The Collider Experiments

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- **CDF, D0**
  - **Search for new phenomena**
    - Extra dimensions, SUSY, strong dynamics
    - Higgs
  - **Top Physics**
    - Top cross section, mass
    - Single top production
  - **W, Z Physics**
    - Multiboson production
    - W, Z asymmetries
    - W mass
  - **Flavor Physics**
    - Bottom, charm production, lifetimes
    - Heavy-heavy states
    - Mixing, CP violation
  - **QCD**
    - Production dynamics, the new spectroscopy
    - Diffractive physics
- **BTeV**
  - **Flavor Physics**
    - High precision, mixing, CP violation
    - New physics in decays

# Collider Experiments

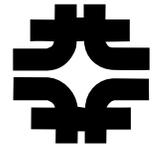
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- **Detector Operations**
  - Accelerator Operating conditions are, for a very large fraction of the time, fine for the experiments.
  - Detector Operational Efficiency is as high as was achieved in Run I
- **Offline Processing**
  - Basic Processing is going well
  - External Review of Run II Computing (Bird Committee) in Fall 2003
  - Incorporation of increasing amounts of off-site computing, nascent GRID!
- **Integrated Luminosity**
  - Double from  $>200 \text{ pb}^{-1}$  to 4- 500  $\text{pb}^{-1}$  during FY04

# CDF/D0 Status

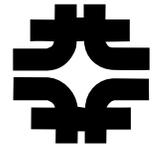
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- **Running very smoothly**
  - Returned from a successful shutdown quickly
  - Achieved 90% efficiency!
  - Have 300 pb<sup>-1</sup> to tape.
- **In CDF all systems operational**
- **In D0 Integration of systems continues successfully**
  - Luminosity uncertainty reduced to 6.5%
  - FPD in routine operations
  - STT fully integrated into readout
- **Both experiments are using both on site and off site computing:**
  - D0 reprocessing data analysis offsite
  - CDF Monte Carlo dominated by off site
  
  - The 200 pb<sup>-1</sup> pre-shutdown data processed and available for analyses.
  - Many billion events processed for Moriond
- **The physics program is building steam**
  - Each experiment incorporating its new features
  - Lots of analyses discussed and presented at “conference level”
  - Many publications expected this year

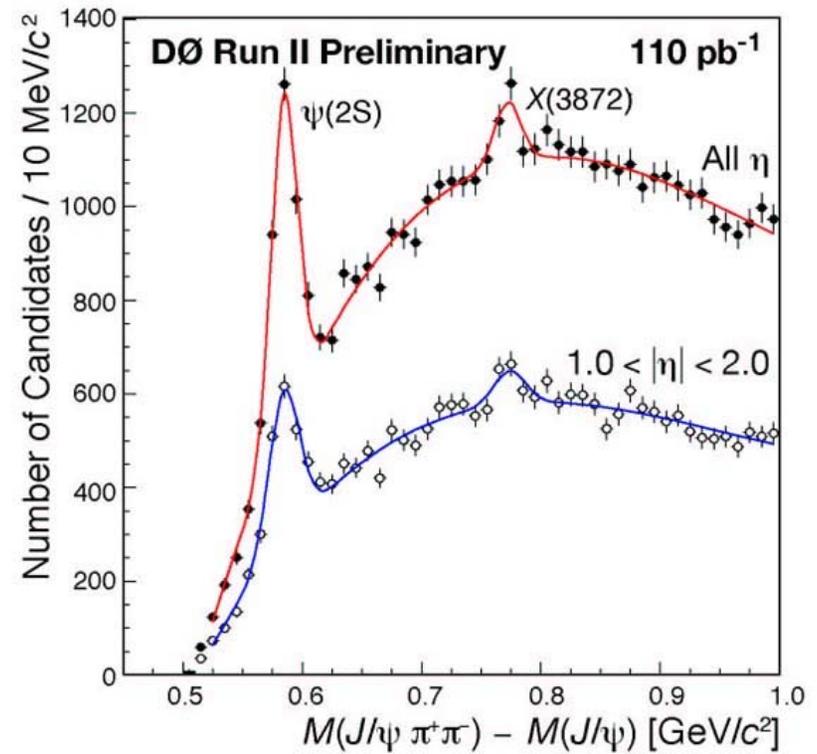
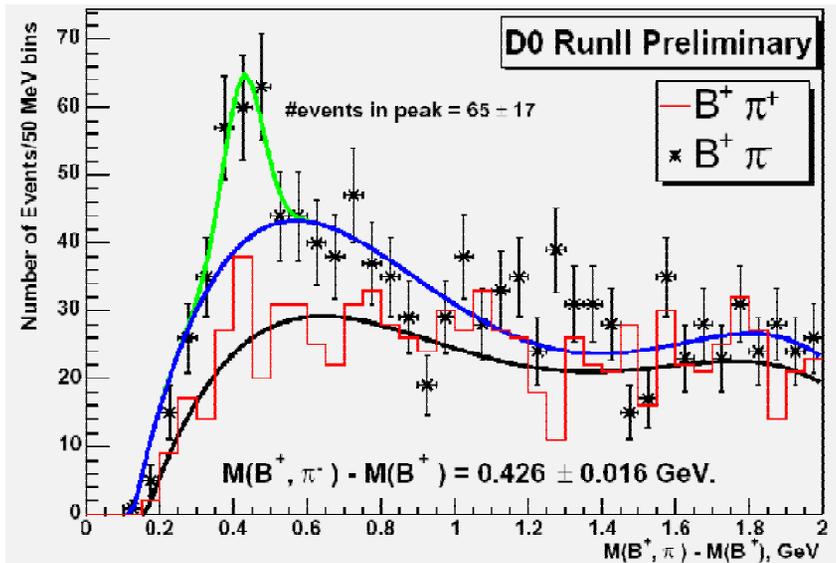
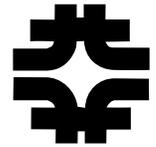
# Collider Experiments: Issues

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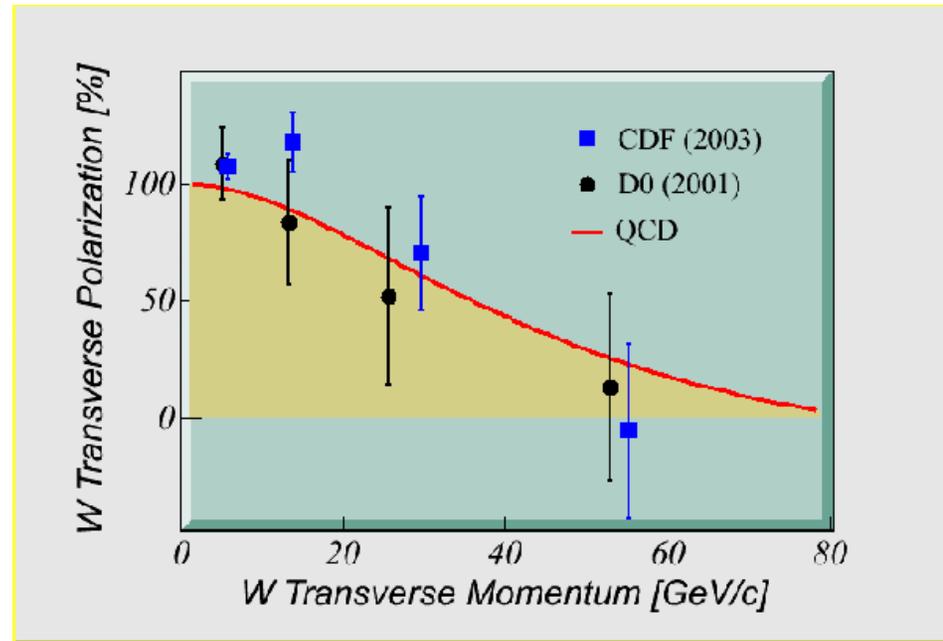
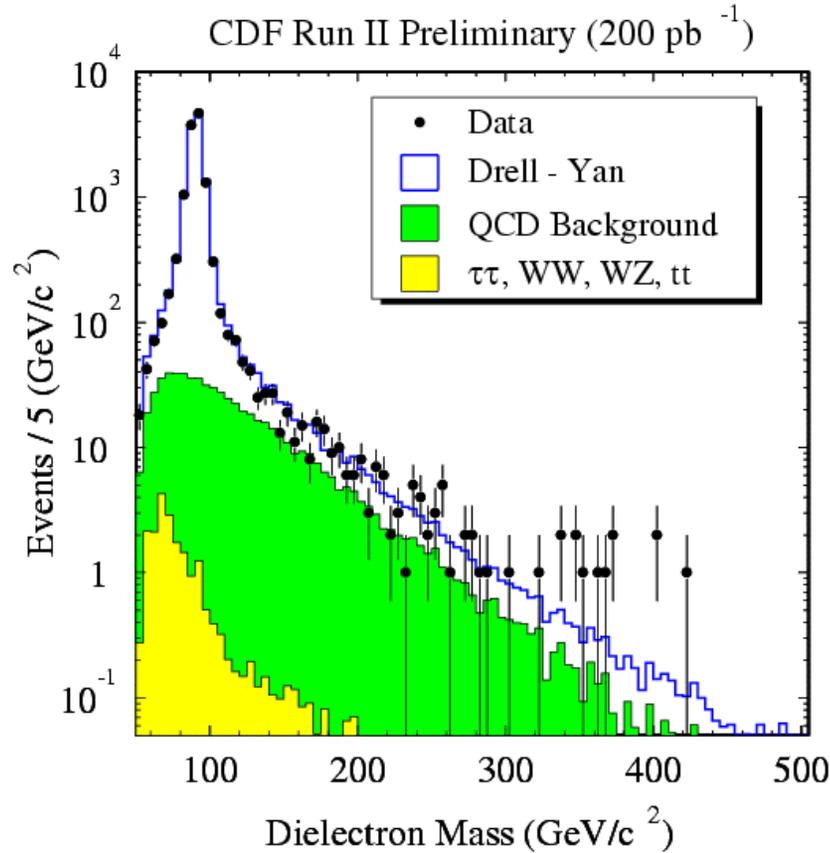


- **CDF**
  - **COT response pattern**
    - Aging, pollution, contamination?
    - Extensive investigations underway
- **D0**
  - **Noise in Muon Triggers, Calorimeter**
    - From muon toroids?
    - Problem disappeared, not understood
  - **Nervousness about silicon channel count**
- **CDF/D0**
  - **Accelerator losses**
    - During operation
    - Response to abnormal
    - Continual program of accelerator improvements
- **Offline Computing**
  - **D0 Reconstruction time, reduced dramatically but number of events increased**
  - **CDF analysis load – lots of physics lots of analyses**

# D-Zero Results

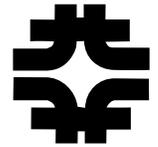


# CDF Results



# Run IIb Detector Upgrades

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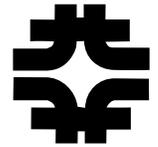
- **Run IIB Silicon Detector construction cancelled.**
  - Followed the development of the Accelerator Run II Upgrade Plan, delay in integration of luminosity
  - Balance of resources
  - Retain upgrade of data acquisition and triggers to deal with higher instantaneous luminosity.
- **P5 Recommendations, DOE HEP concurrence**
- **Internal Fermilab Reviews, Fall 2003**
  - CDF, D0 Trigger-DAQ plans endorsed
  - D0 Layer 0 added
- **ESAAB (approval from Acquisition Executive (Robin Staffin)) December, 2003.**
- **CD3 for Construction**
- **Projects progressing well**
  - Targetting Summer 2005 Shutdown for all subsystems

# BTeV

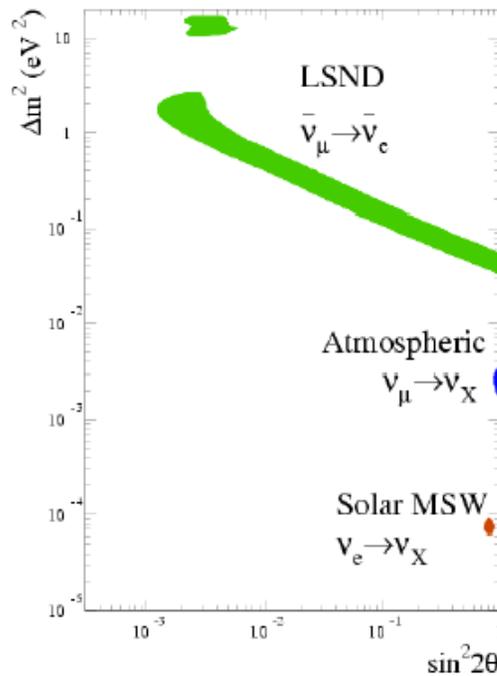


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- Inclusion in 1<sup>st</sup> Category of Orbach Office of Science 20 yr Facilities Report
  - Recommendation of approval from P5
    - Strong endorsement of the physics
    - Recommended aggressive approach
  - Directors' 1<sup>st</sup> CD1 Review in Fall 2003
  - Discussions with HEP Program Office
  - CD0 Approval of Mission need, February 2004
  - Staffing of Project Office, Winter 2004
  - Directors' reviews of IR, Outfitting, Overall Project, Spring 2004
  - 1<sup>st</sup> Lehman Review (CD1+ ??), April 2004
  - Construction start in 2005?
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# Neutrino Oscillations

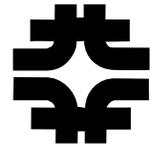


## Current State of Neutrino Oscillation Evidence

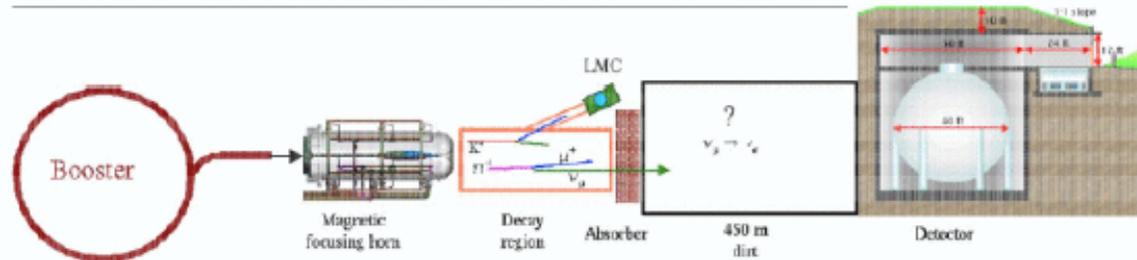


Expt.	Type	$\Delta m^2$ (eV <sup>2</sup> )	$\sin^2 2\theta$
LSND	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	$\sim 1$	$\sim 3 \times 10^{-3}$
Atm.	$\nu_\mu \rightarrow \nu_\tau$	$\sim 2 \times 10^{-3}$	$\sim 1$
Solar	$\nu_e \rightarrow \nu_{\mu,\tau}$	$\sim 7 \times 10^{-5}$	$\sim 0.8$

# MiniBooNE

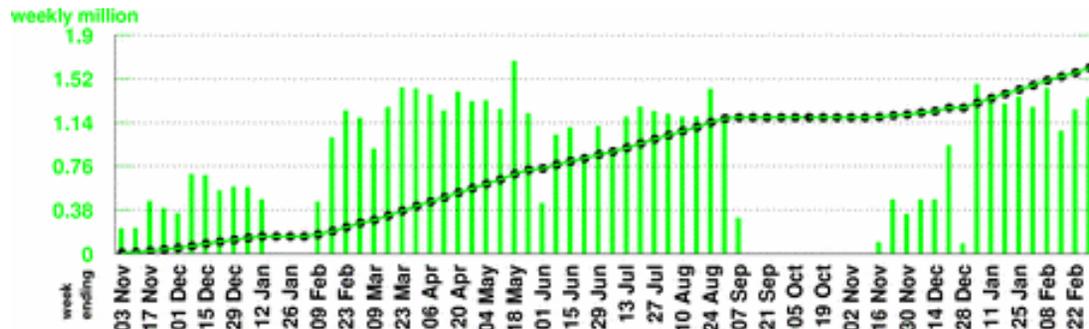
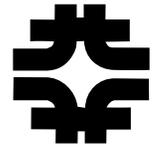


## MiniBooNE - A Definitive Test of the LSND Evidence for $\nu$ Oscillations

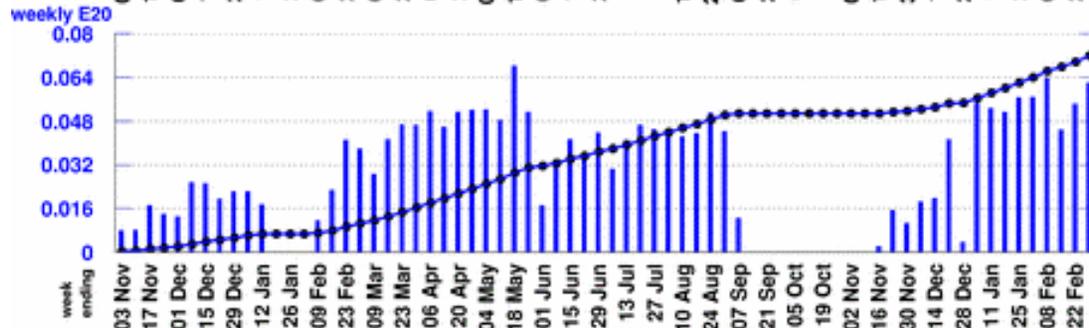


- **Booster** - 8 GeV proton beam ( $5 \times 10^{20}$  POT/y)
- **Target** - 71 cm Be
- **Horn** - 5 Hz, 170 kA, 143  $\mu$ s, 2.5 kV,  $10^8$  pulses/y
- **Decay Pipe** - 50 m (adjustable to 25 m)
- **Neutrino Distance** -  $\sim 0.5$  km
- $\langle E_{\nu} \rangle \sim 1$  GeV
- $(\nu_e / \nu_{\mu}) \sim 3 \times 10^{-3}$
- **Detector** - 40' diameter spherical tank
- **Mass** - 800 (450) tons of mineral oil
- **PMTs** - 1280 detector + 240 veto, 8" diameter

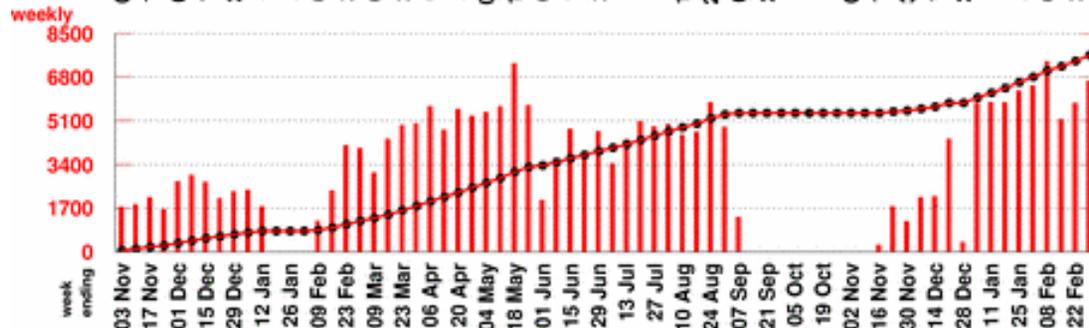
# MiniBooNE



**Number of Horn Pulses**  
To date: 55.28 million  
Largest week: 1.67 million  
Latest week: 1.35 million

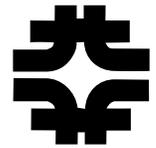


**Number of Protons on Target**  
To date: 2.0673 E20  
Largest week: 0.0682 E20  
Latest week: 0.0621 E20

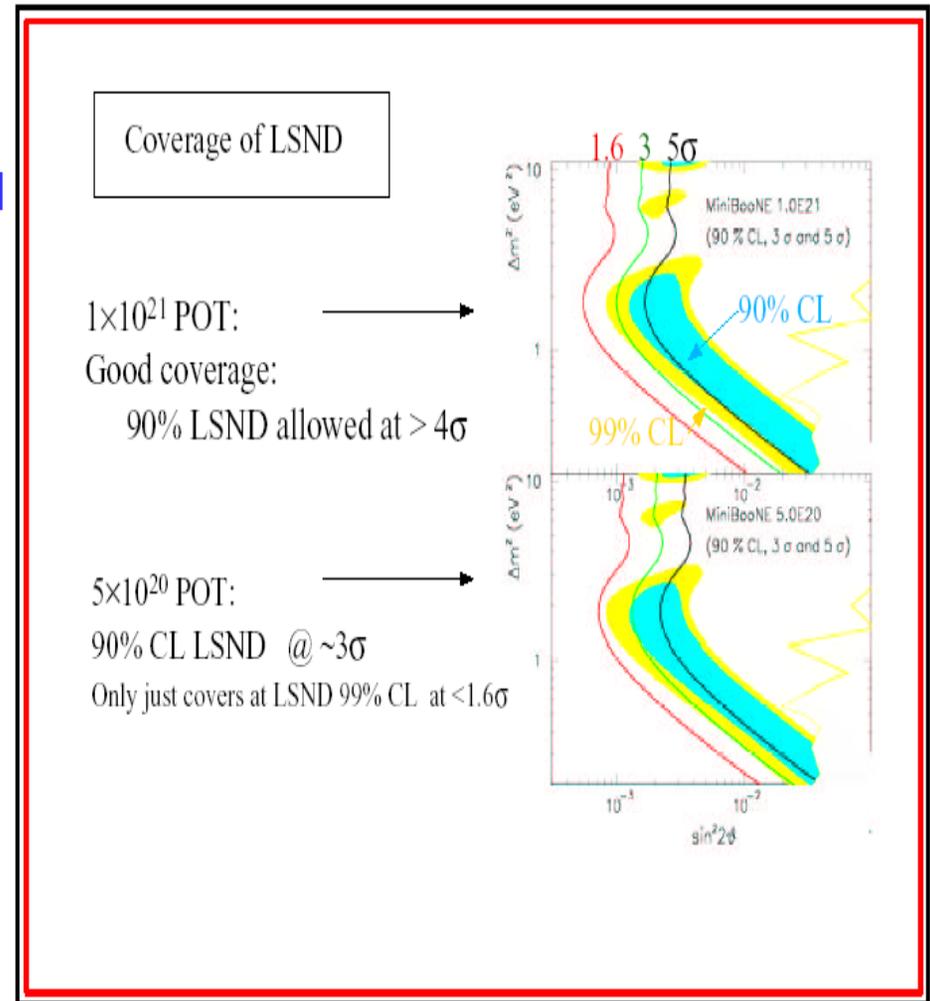


**Number of Neutrino Events**  
To date: 229334  
Largest week: 7402  
Latest week: 6656

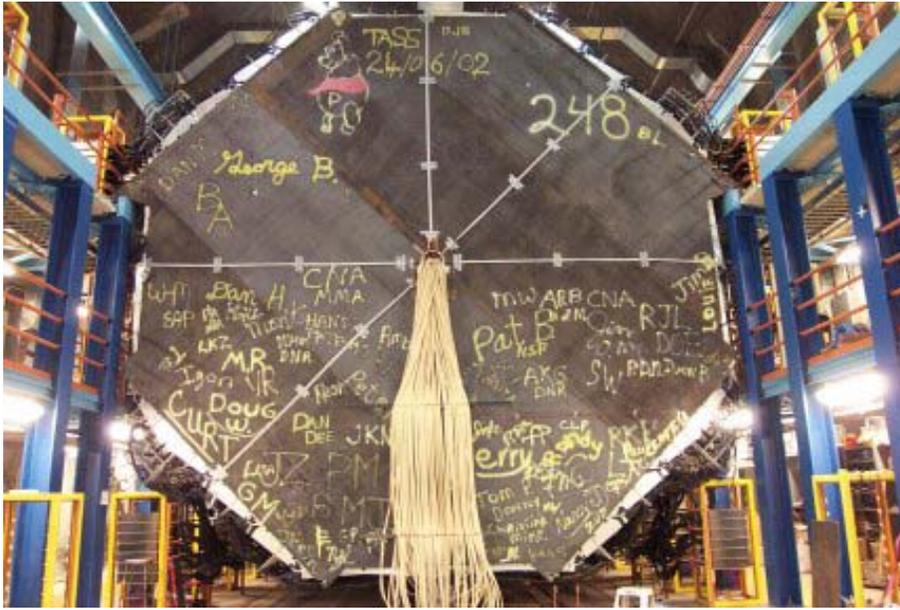
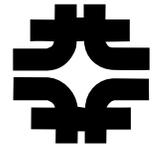
# MiniBooNE



- First event September 2002
- Neutrino Beam operates well
- Neutrinos per proton as expected
- Events match Monte Carlo
- Currently  $> 2 \cdot 10^{20}$  pot
- Limitation is from Booster losses and the Booster is key for all of the FNAL program.
- Potential for improvement is in place.
- Commitment to  $5 \cdot 10^{20}$  pot
- Goal is more through to NuMI start-up



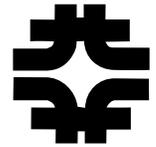
# NuMI/MINOS Project



## NuMI-MINOS

**Sensitive in the “Atmospheric Region”**  
**Long Baseline experiment with Near and Far Detectors**  
**Uses 120 GeV Protons from Main Injector**

# NuMI/MINOS Project



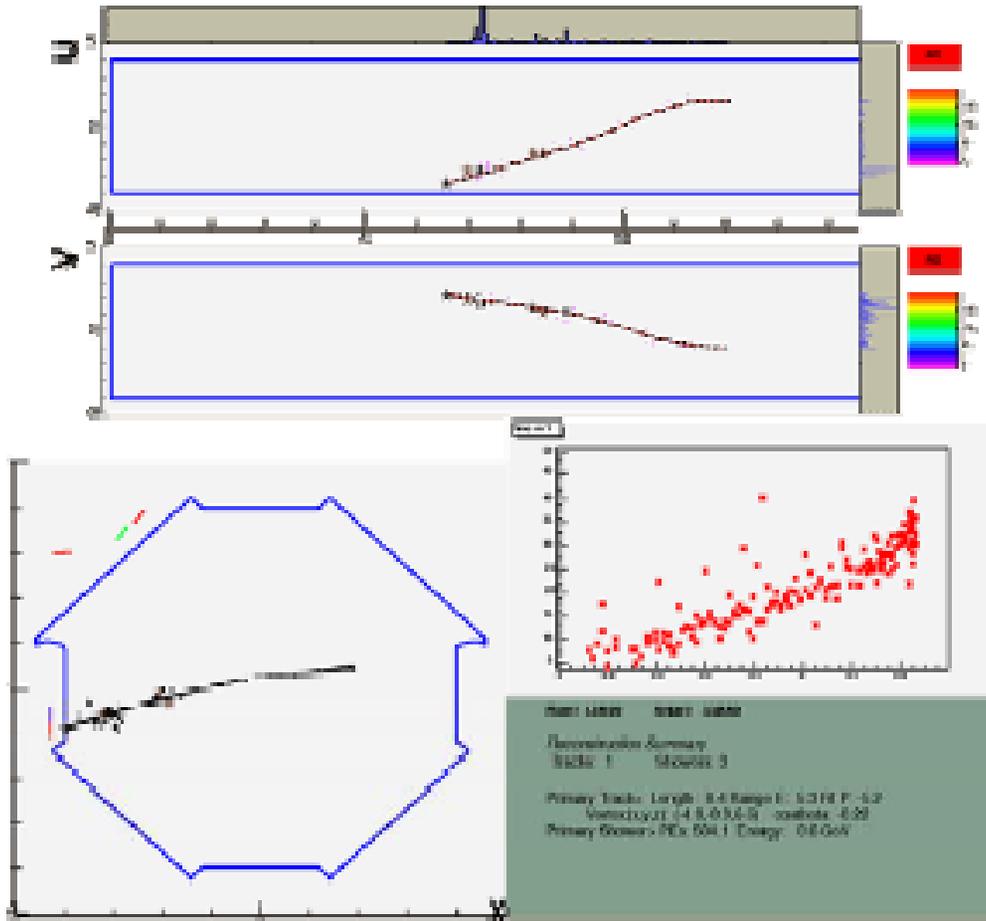
- 
- **Tunnels and Halls construction finished**
  - **Surface Buildings and Outfitting construction-finished March 10, 2004**
  - **NuMI Beam**
    - Last fall the NuMI primary proton beam bending and focussing magnets placed in position in the accelerator
    - commissioning plan for achieving the capability of FMI operation at  $2.5E13$  protons/2 sec cycle in place and progressing well
    - Since October a major installation effort in the upstream portion of the NuMI Facility has been underway
    - The final proton beam transport and focussing magnets in the new pretarget area are in place.
    - 6300 of the 7300 tons of target station steel shielding has been installed.
    - begin setting the special pieces which will hold the completed horn modules in their final positions.
  - **Directors' Review of Installation in February**
    - Acknowledged excellent progress
    - Acknowledged well developed plans

# NuMI/MINOS Project



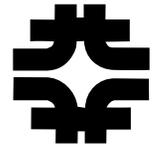
- 
- MINOS far detector installed and operating
    - Only large underground detector with magnetic field
  - Cosmic ray data taking
    - few dozen upward going atmospheric neutrino candidates
  - CalDet
    - three year program successfully collected beam data at CERN
    - absolute and relative calibrations of the Far and Near detectors
  - MINOS Near Detector
    - preassembled and are awaiting installation starting soon
    - 9 scintillator planes (of 282 planes ) fully instrumented/powerd,
    - cosmic ray muon events traversing the 9-planes read out
    - use the actual MINOS DAQ system.

# NuMI/Minos Project



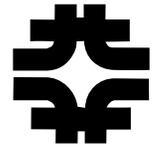
# Future Neutrinos

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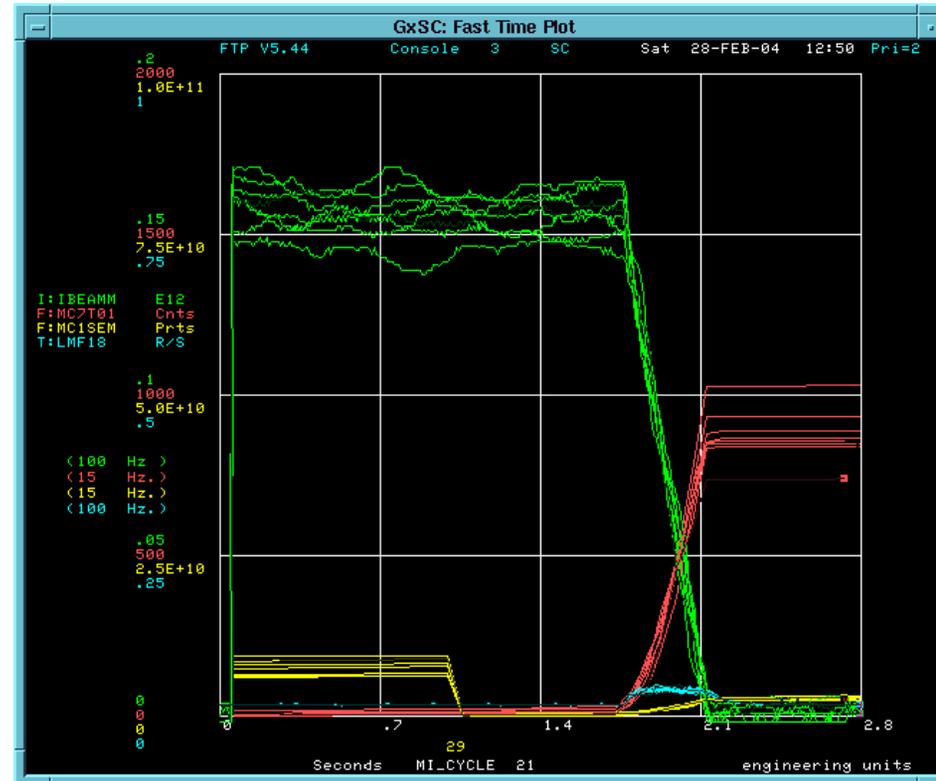


- **MINERvA**
  - NuMI Beam
  - detector in MINOS near hall
  - Low energy neutrino interactions
  - Relevant for long baseline measurements
  - Proposal under consideration
- **OPERA Test**
  - NuMI Beam
  - Test of emulsion bricks in MINOS near hall
  - Discussions under way
- **NOvA**
  - Numi Off-axis electron  $\bar{\nu}$  Appearance
  - Long Baseline
  - Large detector
  - Proposal received this week

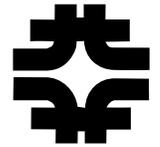
# Main Injector: Fixed Target (SY120)



- MI to MIPP
  - 120 GeV protons
  - slow spill – 400 msec
  - M-Center beam line
  - secondary beam line
    - 40GeV/c



# MIPP

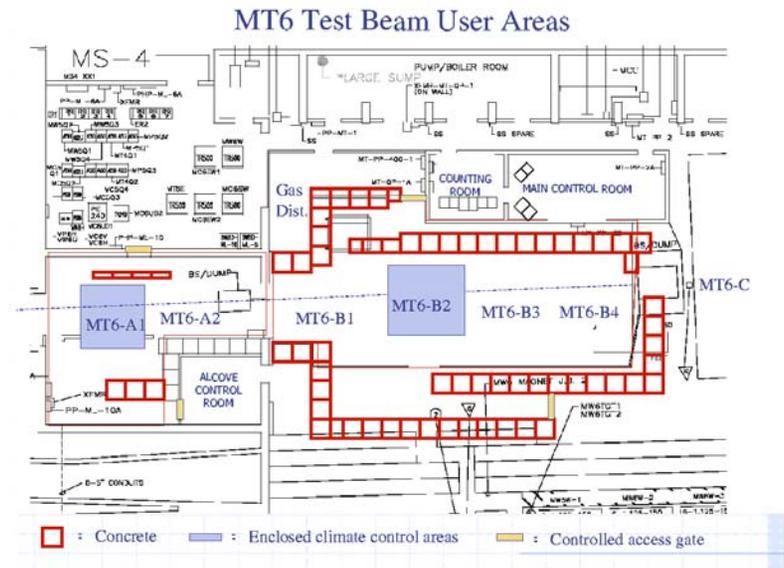


- 
- **MIPP is logging data**
    - **beam chambers, and**
    - **1<sup>st</sup> 4 drift chambers**
    - **RICH and Calorimeters**
    - **TPC soon**
  - **Commissioning the experiment**
  - **Beam tuning**
    - **beam intensities ~30,000 per slow spill.**
      - **on the T01 counter (2" square) next to TPC**

# Main Injector Test Beam



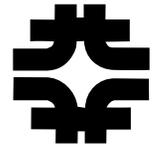
- **Status**
  - **Fast Spill RICE(926 (Radio Ice Cerenkov Experiment) has data**
  - **T930 (BTeV straw detector) has begun commissioning**
  - **Both fast extraction and slow spill extraction (400 msec) on a daily basis**
  - **Tuning begun for momenta other than 120 GeV (60 GeV)**
  - **Several tests with MOUs**



[http://www-ppd.fnal.gov/mtbfw/Meetings/mtbf\\_meetings.htm](http://www-ppd.fnal.gov/mtbfw/Meetings/mtbf_meetings.htm)

# Large Hadron Collider Projects

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- **CMS Construction Project**
  - HCAL and Muons Detector installation doing well
  - Silicon Project troubled by parts delivery
- **Research Program**
  - **CMS Computing & Software Project**
    - Embedded in the Computing Division, staffing increasing
    - Data Challenge, 2004 is the current challenge
  - **CMS M&O**
    - Slice Tests on Surface at CMS now accepted
    - Commissioning Plan being developed
- **Grid**
  - CD Head is US rep on the LHC Grid Deployment board
  - GRID2003 was a major success for CMS (and US more generally)
- **Physics activity on increase**
  - PAC Space, planning
  - Analysis Workshops with CDF/D0 participation
  - Core analysis interest
  - Physics Workshop TeV4LHC in Fall 2004

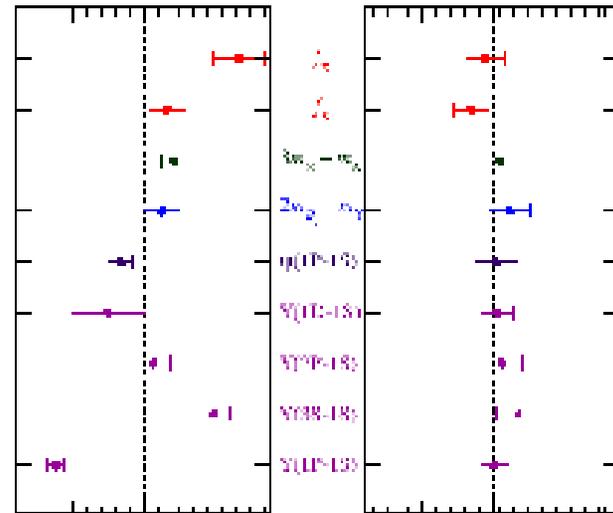
# Theory



- **Particle Physics Theory**

- **Staffing Plan**

- We continue to recruit Associate Scientists, the ones we choose are very good and have a high vapor pressure.
    - The quality of our research associates is such that we can be aggressive in recruiting without blowing the budget since there is a very finite probability that we will lose one or more per year to faculty positions.



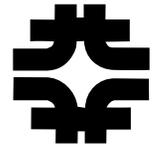
- **Particle Astrophysics Theory**

- World class theory
  - Strong participation in the Sloan Digital Sky Survey work.
  - Contributions to planning JDEM initiatives

- **One Result of the Week**

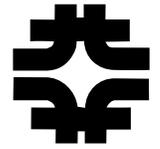
# Particle Astrophysics

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- **Strong astrophysics program**  
(FNAL was the pioneer among HEP labs)
  - **Dark Matter ( SDSS, CDMS, Collider SUSY searches)**
  - **Dark Energy ( JDEM nascent)**
  - **Ultra high energy cosmic rays (Auger)**
- »
- **New initiatives**
  - **SDSS Program considering an extension.**
  - **Fermilab Technical Expertise significant (Focal Plane Arrays)**
  - **To list above, add CTIO/DECAM and LSST**
  - **PAC augmented to handle the discussion.**

# Pierre Auger



- construction of the Auger Observatory is proceeding well.
- More than 340 stations of a total of 1600 stations are deployed
- 200 of stations taking data.
- 6/24 fluorescence telescopes in operation



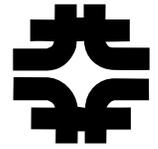
# Cryogenic Dark Matter Search (II)

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- searching for WIMPs at the Soudan Underground mine
- accumulated 60 live-days of data with the first tower of 6 detectors
  - detectors were also used for the last data run of CDMS I at Stanford, they are very well understood.
  - have been operating stably at 50 mK, with acceptable electrical noise, for the last 7 months.
  - High quality gamma and neutron source calibration data has been obtained, and is being analyzed to define selection criteria
  - data taking efficiency reached 88% for the last month of the run,
    - remarkably good for a cryogenic experiment deep underground!
- should yield an order of magnitude improvement in WIMP sensitivity
  - lack of cosmic-ray-induced neutrons at the depth of Soudan
- commissioned the second tower of 6 detectors
  - installed at the same time as the first tower
  - begun a "two tower" data run
  - Goal is another 120 live-days of data by July
  - Later this year, we will install the remaining 3 towers of detectors
- CDMS III Program under consideration
  - SAGENAP
  - PAC

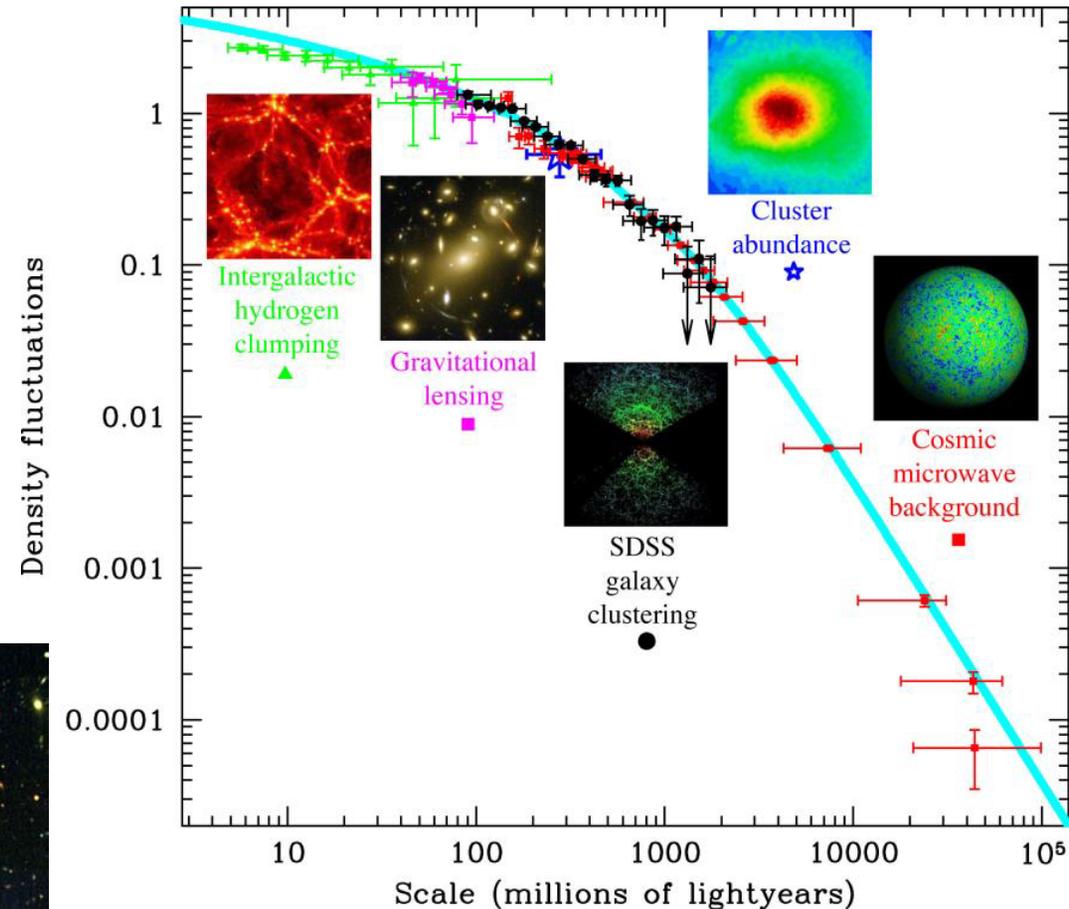
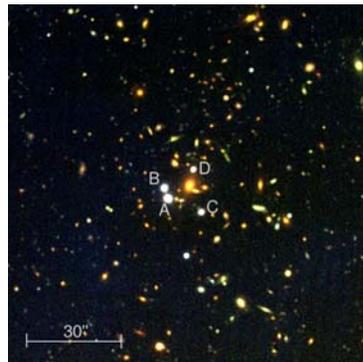
# Sloan Digital Sky Survey



- **Data taking**
  - 5<sup>th</sup> year of 5
  - 68% of 5 yr target
- **Data Release**
  - 2<sup>nd</sup> release March 15
  - 35% of total data set
- **361 Publications**

**4-way split of Quasar**

**Enormous Dark Matter in foreground cluster**



**Power Spectrum → Dark Energy ( curve)**

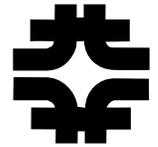
# JDEM



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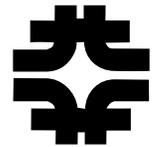
**SuperNova/Acceleration Probe is one candidate**

- **PAC Recommendation**
  - **Modest R&D program**
- **FNAL participation**
  - **Science and simulations**
  - **Photometric calibration**
  - **Scientific software**
  - **Electronics**
  - **Radiation shields**



- **Established Tkaczyk & Fisk as leaders**
- **Increased FNAL participation in R&D**
  - **Concentrated on collaboration with University partners**
  - **Muon System with Northern Illinois, Wayne State**
  - **Calorimetry in collaboration with NIU, ANL**
  - **Silicon Tracking**
  - **ASIC design**
  - **Mechanical Engineering**
- **Test Beam**
  - **Significant interest from CALICE ( digital Tile Calorimeter) collaboration**

# Schedule



## 2004-5 Fermilab Accelerator Experiments Schedule

This Schedule will be updated regularly, as plans change.

Calendar Year		2004				2005			
Tevatron Collider									BTeV
		CDF & Dzero	CDF & Dzero			CDF & Dzero			CDF & Dzero
Neutrino Program	B	MiniBooNE	MiniBooNE		MiniBooNE	OPEN			OPEN
	MI		MINOS			MINOS			MINOS
Meson 120	MT	Test Beam	Test Beam			Test Beam			Test Beam
	MC		E907/MIPP			E907/MIPP			OPEN

Shutdown for M&D and CDF COT work, beginning March 15, 2004.

Summer 04 Shutdown is scheduled to begin on August 23, and is planned to last a nominal 13 weeks.

The length of the shutdown is driven by installation of electron cooling in the Recycler Ring.

The major 2005 shutdown is scheduled for the last 8 weeks of FY05.

This draft schedule will be updated as more precise information is made available.

Additional shutdown periods will be added, typically allowing 36-40 weeks of scheduled accelerator operation per year.

	RUN or DATA
	STARTUP/COMMISSIONING
	INSTALLATION
	M&D (SHUTDOWN)

4 March, 2004

# Summary

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- **Collider Run II**
  - Detectors are operating well
  - Physics analysis is a big deal
- **Neutrino operations established**
  - MiniBooNE operating well
  - NuMI - MINOS Operations in 2005 on track
- **CMS (hampered by funding)**
  - Construction is proceeding
  - Maintenance & operations being established
  - Computing & Software going well
  - Physics and Analysis Center – increased activities
- **Excellent Astroparticle Physics Program**
- **Strong Theory**
- **Result of the Week**

<http://www.fnal.gov/pub/today/resultoftheweek/index.html>

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