The FNAL Research Program

DOE Annual Program Review
Hugh Montgomery

March 23, 2004

The FNAL Research Program

- 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

- 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

- **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 pb^{-1} to 4- 500 pb^{-1} during FY04

CDF/D0 Status

- Running very smoothly
  - Returned from a successful shutdown quickly
  - Achieved 90% efficiency!
  - Have 300 pb^{-1} 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

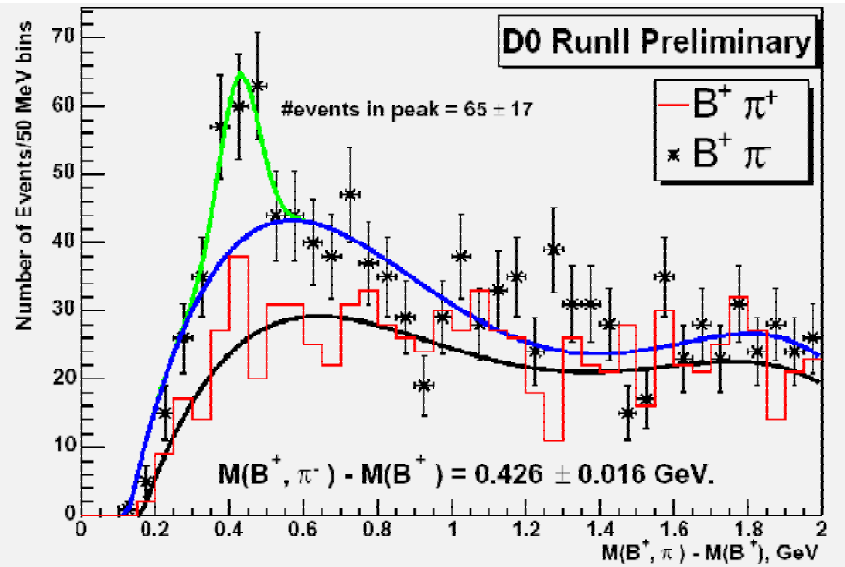
  - The 200 pb^{-1} pre-shutdown data processed and available for analyses.
  - Many billion events processed for Moriond

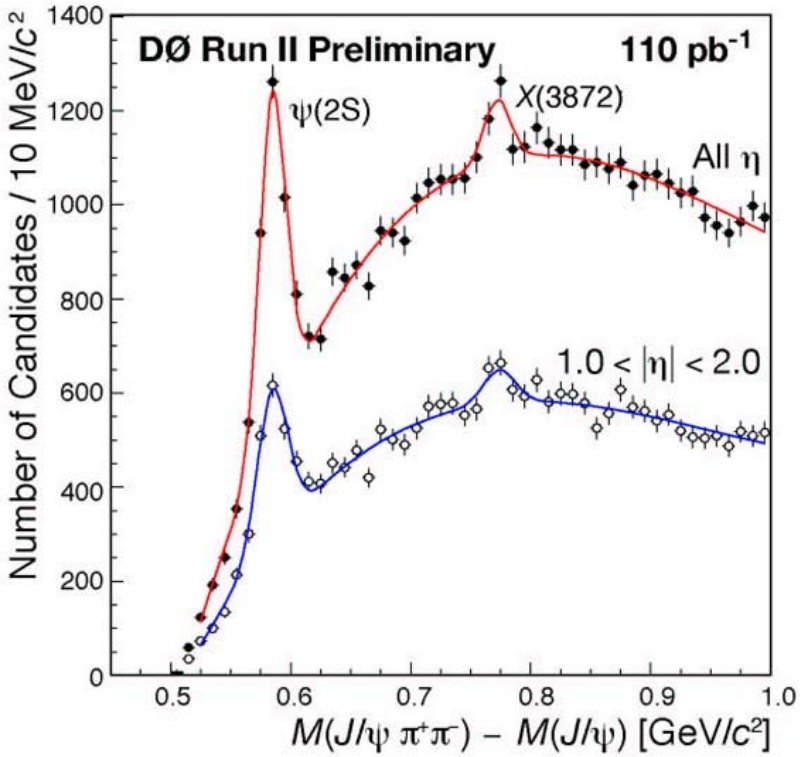
- The physics program is building steam
  - Each experiment incorporating its new features
  - Lots of analyses discussed and presented at "conference level"
  - Many publications expected this year

Collider Experiments: Issues

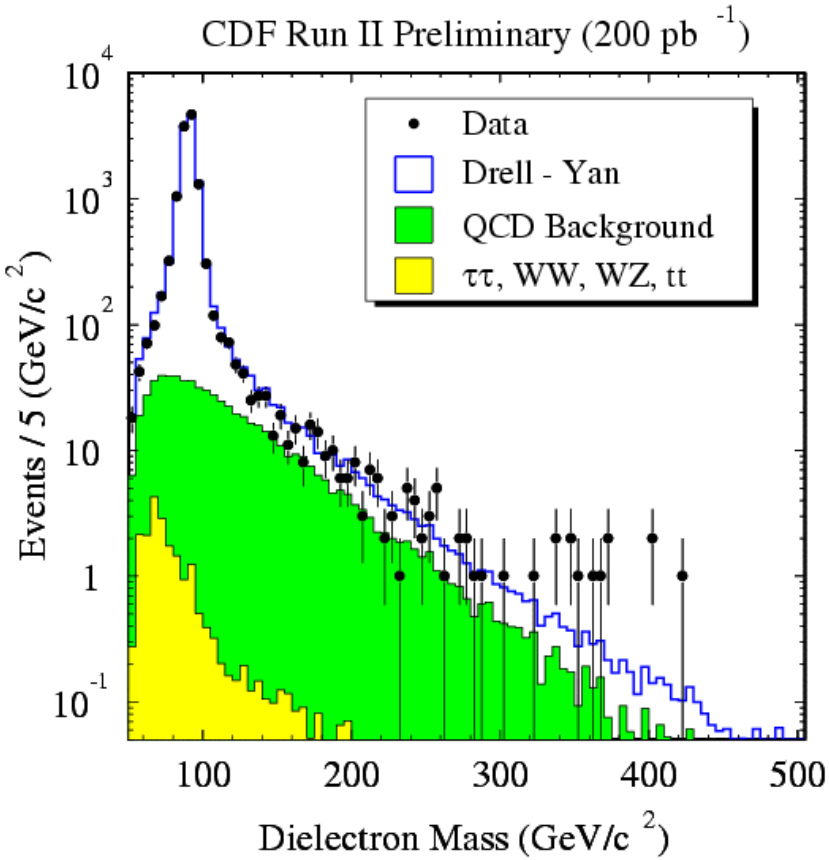
- CDF
  - COT response pattern
    - Aging, polution, contamination?
    - Extensive investigations underway
- D0
  - Noise in Muon Triggers, Calorimeter
    - From muon toroids?
    - Problem disappeared, not understood
  - Nervousness about silicon channel count
- CDF/D0
  - Accelerator losses
    - 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

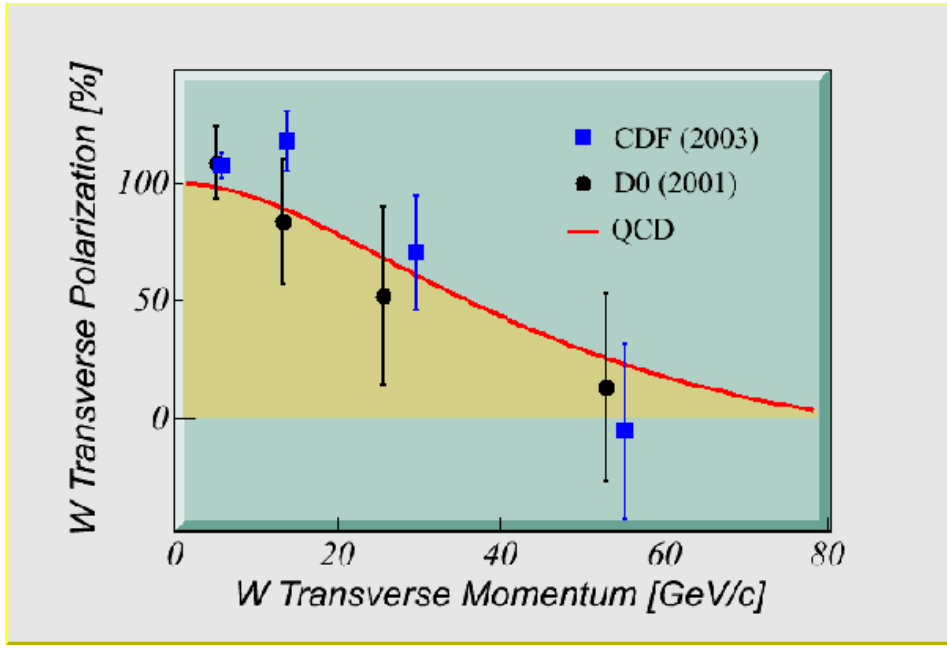
D-Zero Results





CDF Results


CDF Run II Preliminary (200 pb -1)
Data
Drell - Yan
QCD Background
ττ, WW, WZ, tt
Events / 5 (GeV/c 2)
Dielectron Mass (GeV/c 2)


CDF (2003)
D0 (2001)
QCD
W Transverse Polarization [%]
W Transverse Momentum [GeV/c]

Run IIb Detector Upgrades

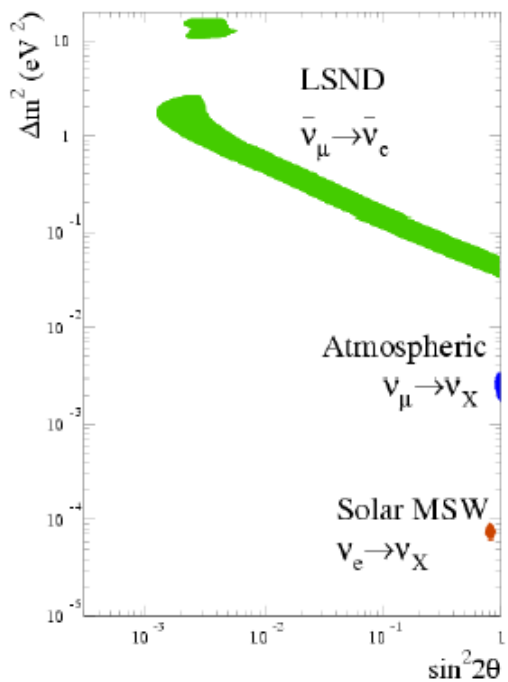
- Run IIB Silicon Detector construction cancelled.
  - Followed the development of the Accelerator Run II Upgrade Plan, delay in intregration of luminosity
  - Balance of resources
  - Retain upgrade of data acquisition and triggers to deal with higher instantaneous luminosity.
- P5 Recommendations, 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

- Inclusion in 1st Category of Orbach Office of Science 20 yr Facilities Report
- Recommendation of approval from P5
  - Strong endorsement of the physics
  - Recommended aggressive approach
- Directors' 1st 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
- 1st Lehman Review (CD1+ ??), April 2004
- Construction start in 2005?

Neutrino Oscillations

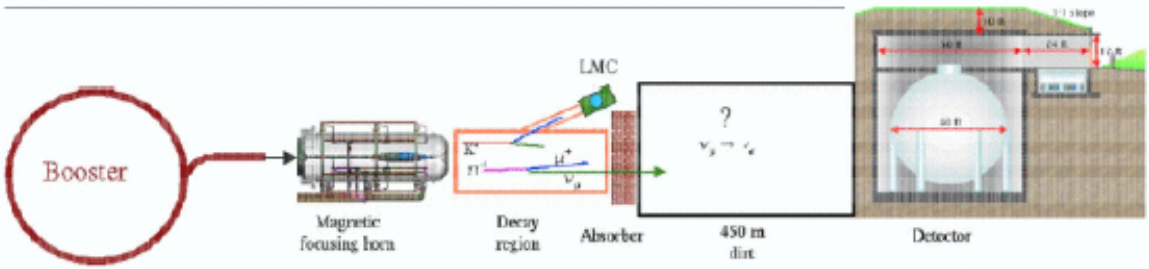
Current State of Neutrino Oscillation Evidence



Expt.	Type	Δm^2 (eV^2)	$\sin^2 2\theta$
LSND	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	~1	~3x10^{-3}
Atm.	$\nu_\mu \rightarrow \nu_\tau$	~2x10^{-3}	~1
Solar	$\nu_e \rightarrow \nu_{\mu,\tau}$	~7x10^{-5}	~0.8

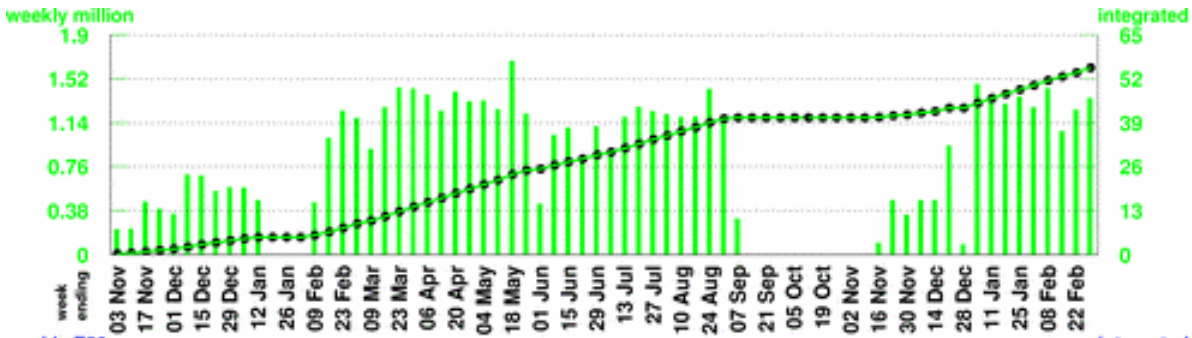
MiniBooNE

MiniBooNE - A Definitive Test of the LSND Evidence for ν Oscillations



- Booster - 8 GeV proton beam (5×10^{20} POT/y)
- Target - 71 cm Be
- Horn - 5 Hz, 170 kA, 143 μs, 2.5 kV, 10^8 pulses/y
- Decay Pipe - 50 m (adjustable to 25 m)
- Neutrino Distance - ~ 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

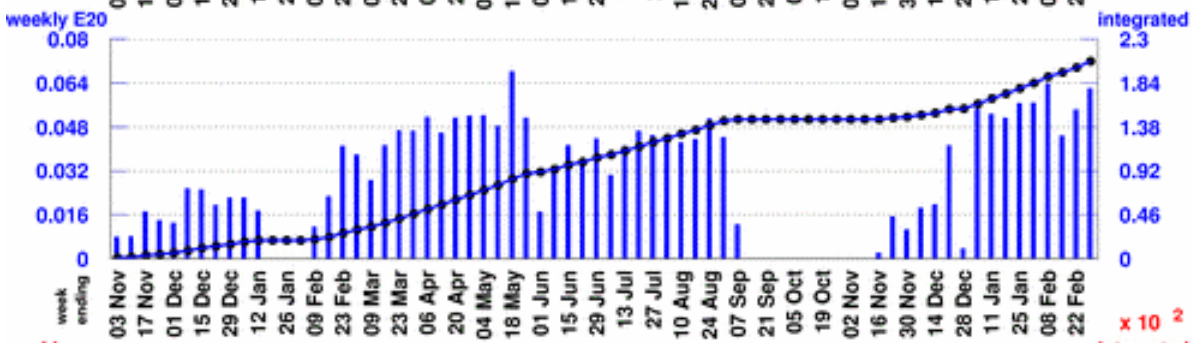


Number of Horn Pulses

To date: 55.28 million

Largest week: 1.67 million

Latest week: 1.35 million

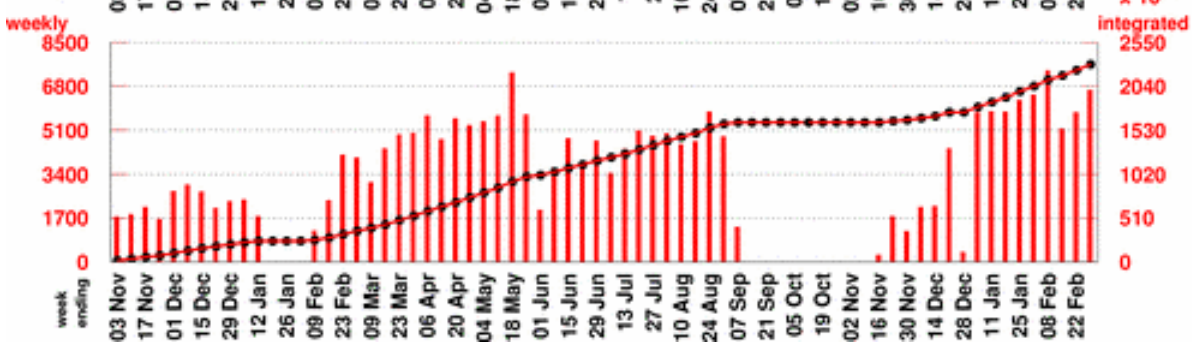


Number of Protons on Target

To date: 2.0673 E20

Largest week: 0.0682 E20

Latest week: 0.0621 E20



Number of Neutrino Events

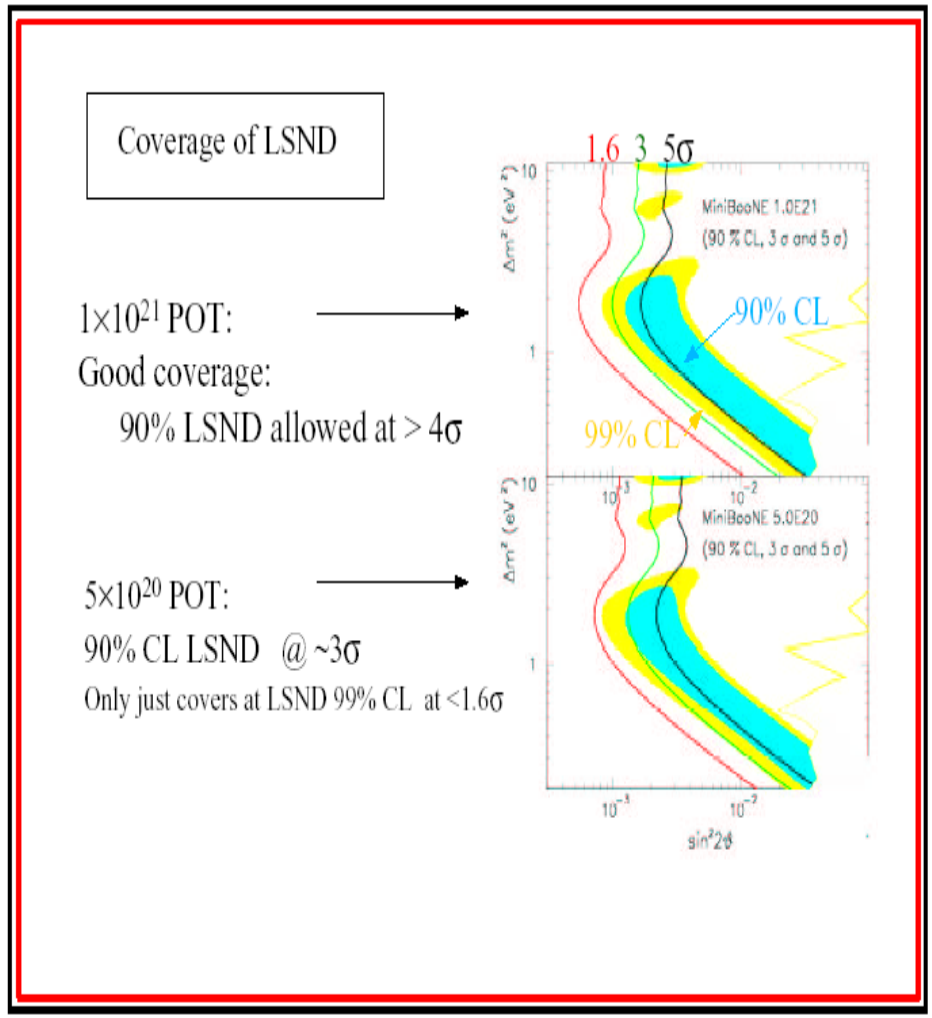
To date: 229334

Largest week: 7402

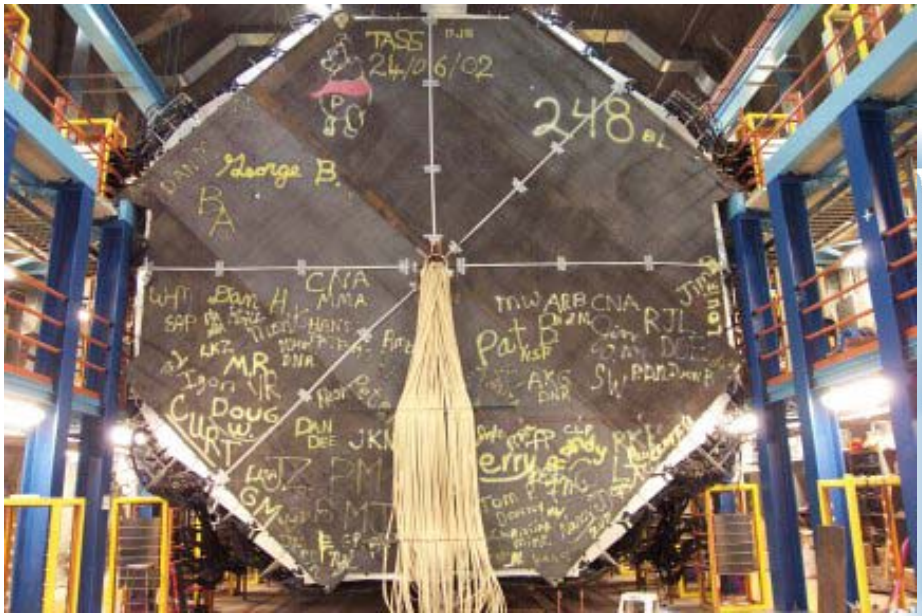
Latest week: 6656

MiniBooNE

- First event September 2002
- Neutrino Beam operates well
- Neutrinos per proton as expected
- Events match Monte Carlo
- Currently > 2. 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 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

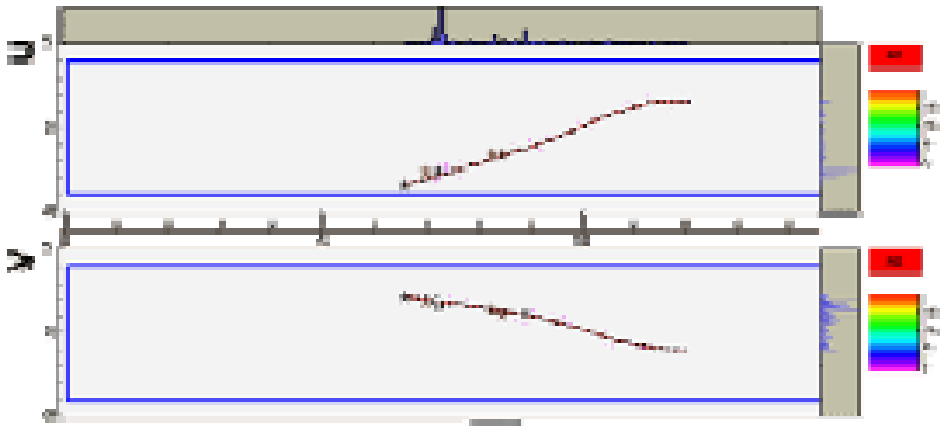
- Tunnels and Halls construction finished
- Surface Buildings and Outfitting construction-finished March 10, 2004
- NuMI Beam
  - Last fall the NuMI primary proton beam bending and focussing magnets placed in position in the accelerator
  - commissioning plan for achieving the capability of FMI operation 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

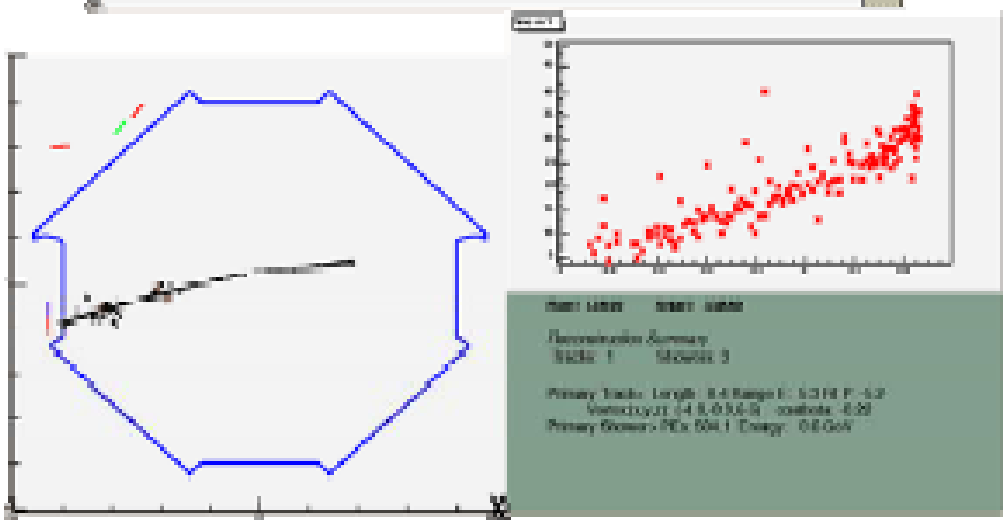
- MINOS far detector installed and operating
  - Only large underground detector with magnetic field
- Cosmic ray data taking
  - few dozen upward going atmospheric neutrino candidates
- CalDet
  - three year program successfully collected beam data at CERN
  - absolute and relative calibrations of the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

NuMI/Minos Project



MINOS is the first large underground detector which has a magnetic field

We can directly compare whether atmospheric ν_μ and ν_μ oscillate in the same way.



Example Upward Muon

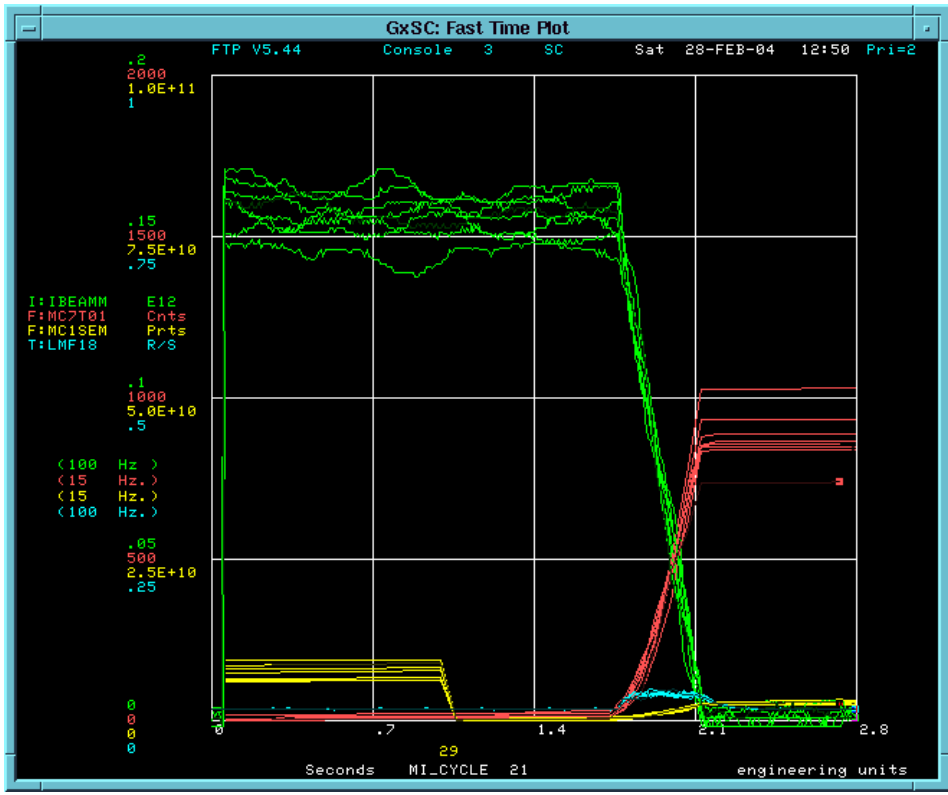
$p_{\mu+} = 5.3$ GeV/c

Future Neutrinos

- MINERνA
  - 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
- NOνA
  - Numi Off-axis electron ν 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

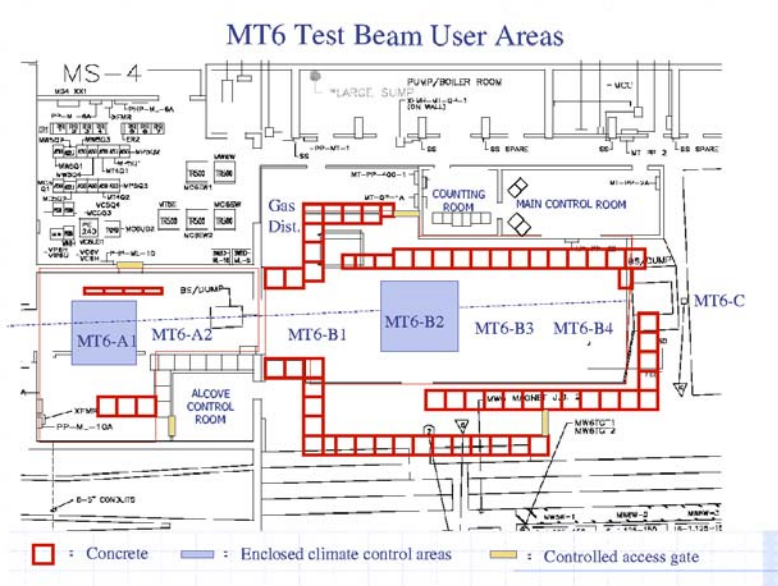


MIPP

- MIPP is logging data
  - beam chambers, and
  - 1st 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



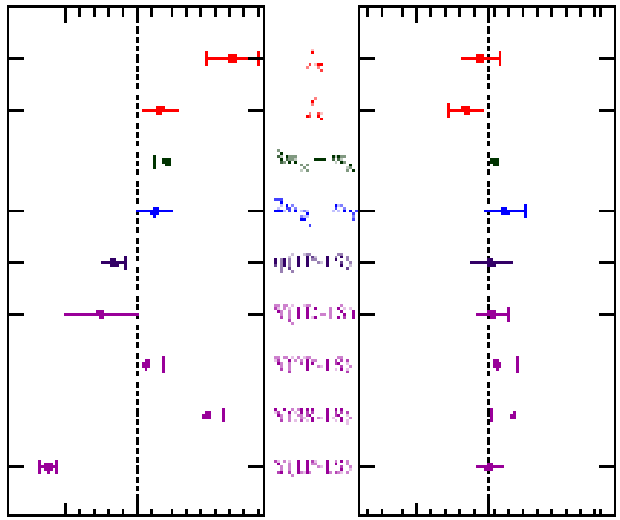
http://www-ppd.fnal.gov/mtbfw/Meetings/mtbf_meetings.htm

Large Hadron Collider Projects

- 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 loose 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

- **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

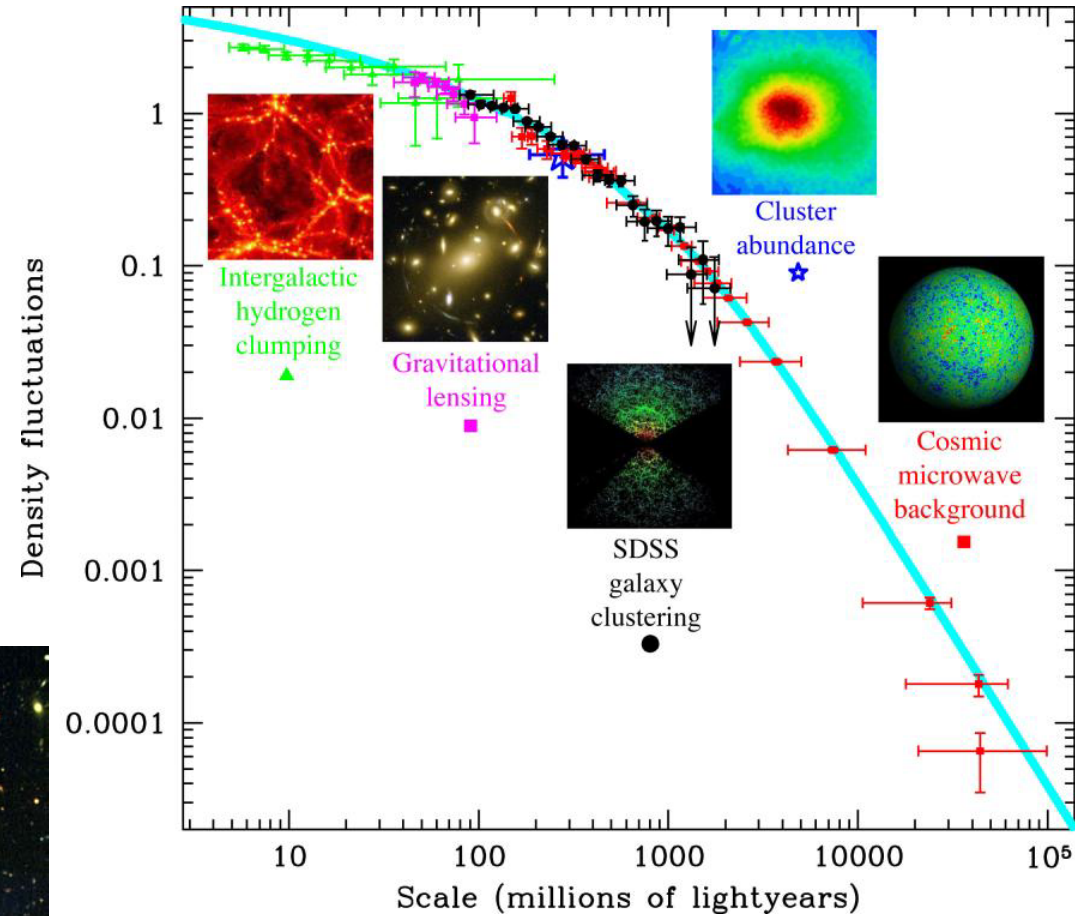
- construction of the Auger Observatory is proceeding well.
- More than 340 stations of a total of 1600 stations are deployed
- 200 of stations taking data.
- 6/24 fluorescence telescopes in operation

Cryogenic Dark Matter Search (II)

- 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

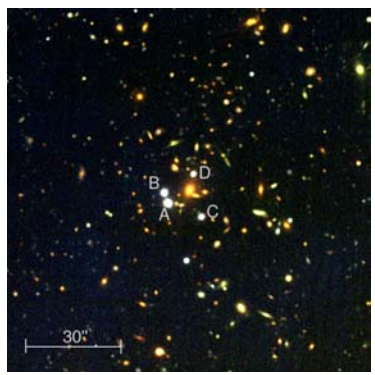
- **Data taking**
  - 5th year of 5
  - 68% of 5 yr target
- **Data Release**
  - 2nd release March 15
  - 35% of total data set
- **361 Publications**



Power Spectrum → Dark Energy (curve)

4-way split of Quasar

Enormous Dark Matter in foreground cluster



JDEM

SuperNova/Acceleration Probe is one candidate

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

Linear Collider Physics & Detector R&D

- 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
Neutrino Program	B	MiniBooNE	MiniBooNE / OPEN
	MI	MINOS	MINOS
Meson 120	MT	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 38-40 weeks of scheduled accelerator operation per year.

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

4 March, 2004

Summary

- 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