



The FNAL Research Program

**URA Visiting Committee
Hugh Montgomery**

March 14, 2003

The FNAL Research Program



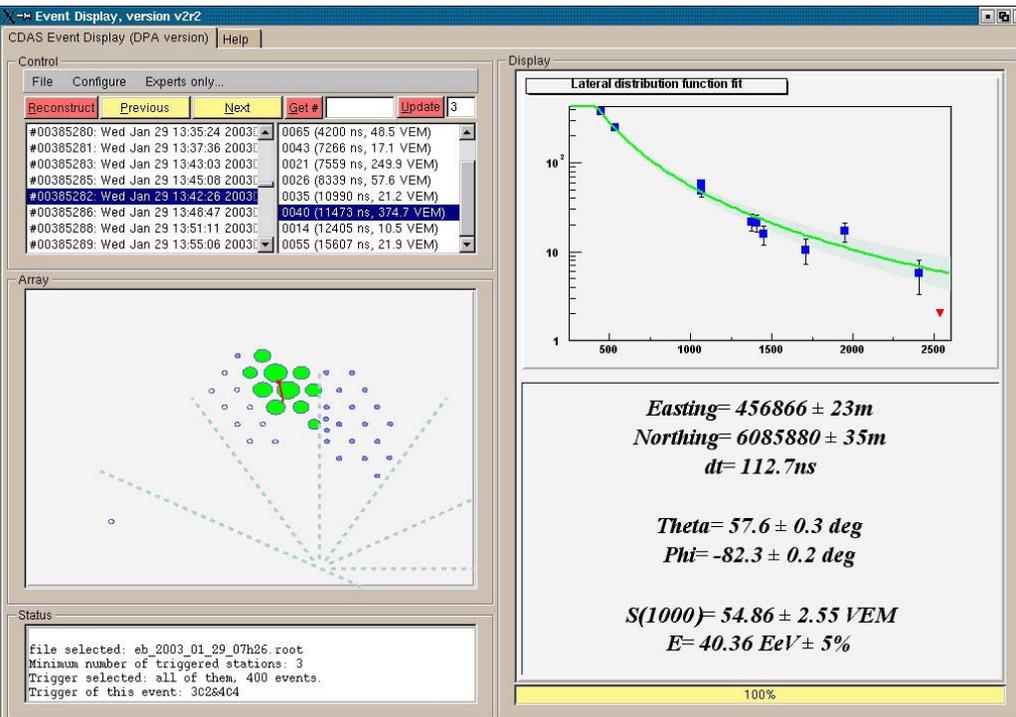
- Theory
- Particle Astrophysics Experiments
 - Pierre Auger
 - Cold Dark Matter Search(CDMS)
 - Sloan Digital Sky Survey
 - SNAP?
- Collider Physics
 - Tevatron Collider- CDF, D0
 - Tevatron Collider- CDF, D0 Upgrades
 - CMS Project
 - CMS Research Program
- Fixed target Program (hadron beams)
 - Past Analyses
 - MIPP
 - Test Beam
- Neutrino Physics
 - MiniBooNE
 - MINOS
- R&D for the Future
 - CKM
 - BTeV
 - Off Axis Neutrino
 - Linear Collider
- Summary

Theory



- **Particle Physics Theory**
 - **Approximately two years ago we held an external review.**
 - **A recommendation was made that we were understaffed in:**
 - flavor physics
 - **Beyond-the-standard-model physics (phenomenology)**
 - **Having made a hire in the flavor physics area earlier, we hired two associate scientists into the second category.**
 - **Another recommendation was to increase somewhat the number of Research Associates (offset to lack of students) however, given financial restraint, we remain at significantly less than one RA per senior person.**
 - **Fermilab aims for and achieves excellence in all areas of particle physics except formal String Theory**
- **Particle Astrophysics Theory**
 - **World class theory**
 - **Strong participation in the Sloan Digital Sky Survey work.**

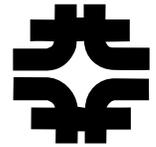
Pierre Auger



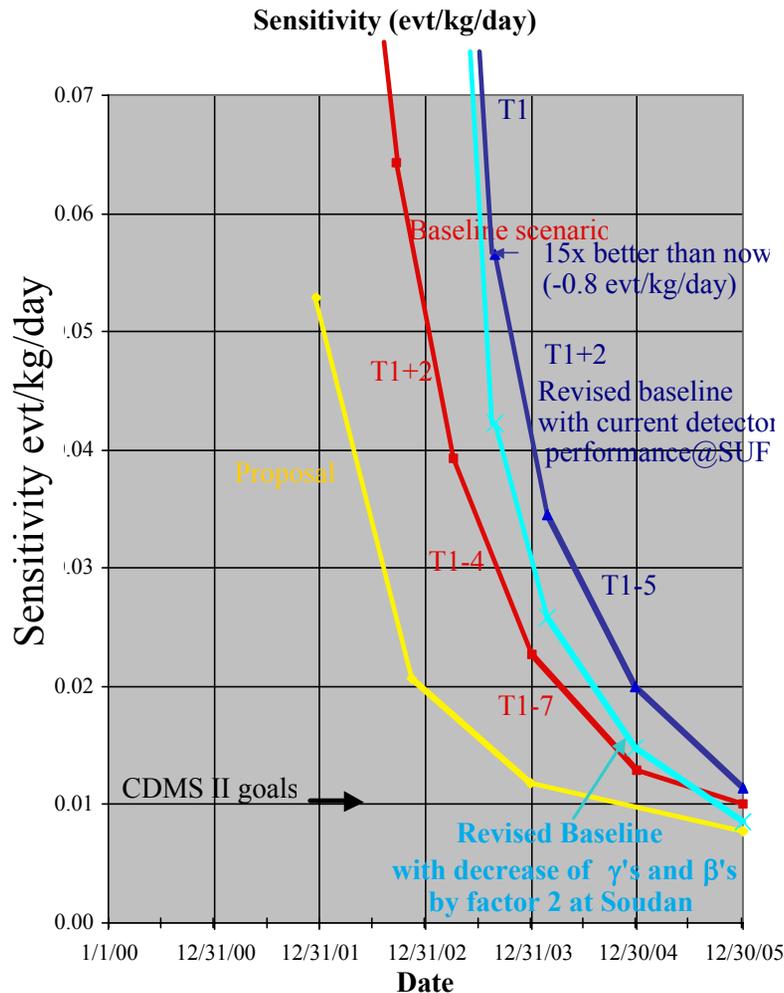
- Engineering Array is working well
- Maybe sensitive to neutrino showers at large zenith.

- 100 pre-production tanks being deployed. (Brazil, and now Mexico/Argentina)
- Still have full aperture as goal.





Cryogenic Dark Matter Search II



1 year delay: cryogenic problems

Dilution refrigerator and icebox are now working (Dec 20, 2002)

Experiment nearly ready at Soudan

System testing underway.

First detector deployment in Feb 2003

Tower 1: 4 Ge, 2 Si; Tower 2: 2 Ge, 4 Si

Ge more sensitive to WIMPs; Si needed to determine if signal due to neutrons.

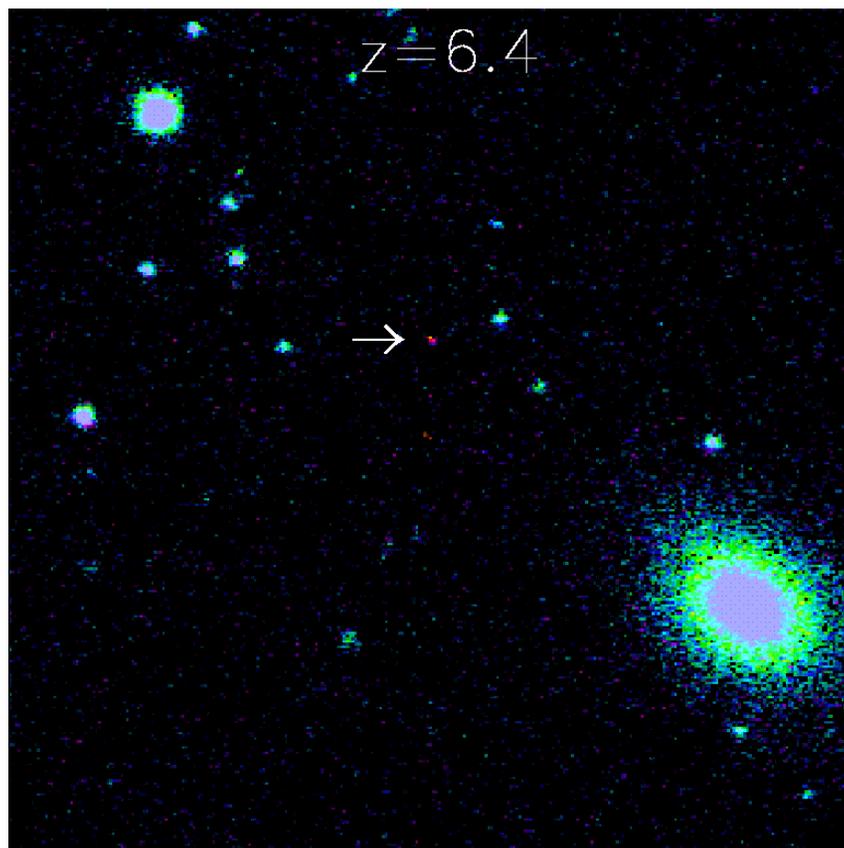
Deep site => Much lower neutron background
=> Rapid improvement in sensitivity

Expect factor of 10 improvement over CDMS I results by end of 2003.

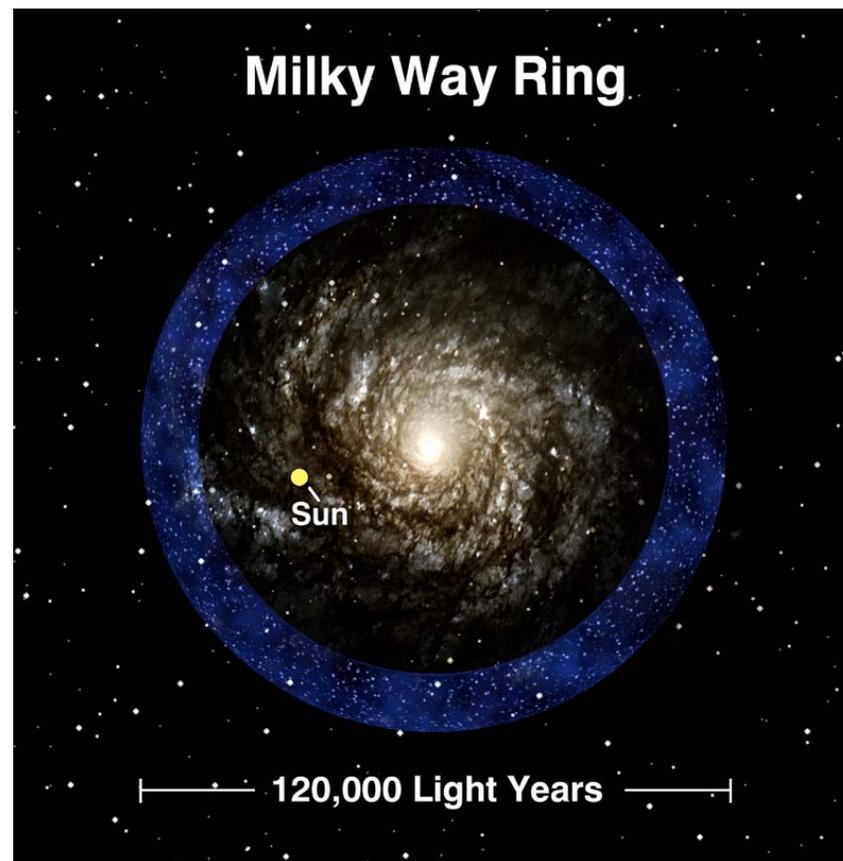
Deploy remainder of detectors in 2004 and run until end of 2005 (or longer)

Detector performance improvements mean we should still reach original CDMS II goals (cyan curve)

Sloan Digital Sky Survey

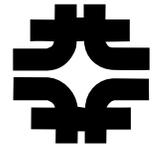


High Redshift, $Z= 6.4$ Object



Unexpected band of stars around Milky Way.
Indicator of dark matter distribution?

Astrophysics Future?



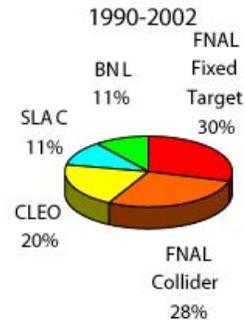
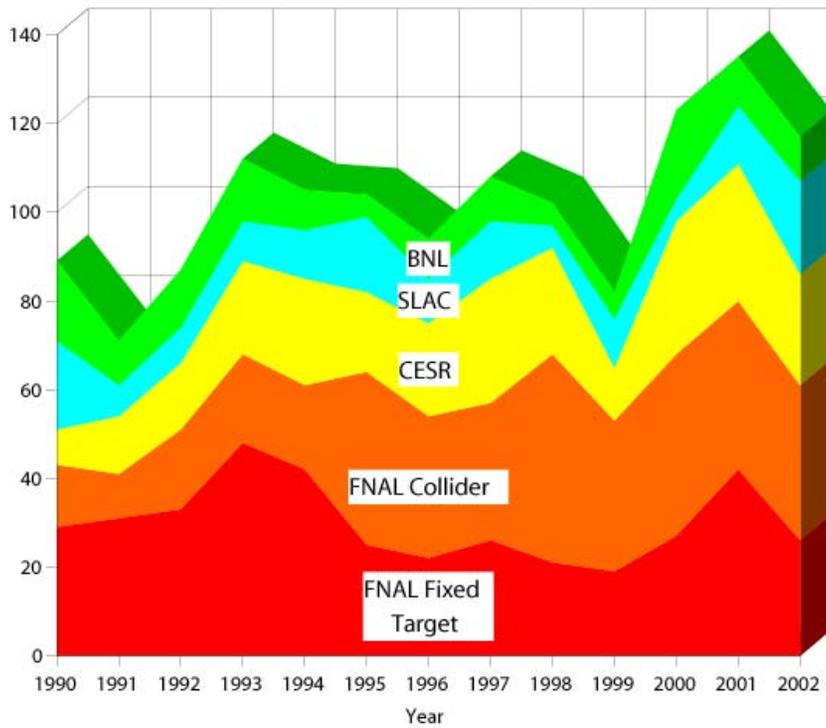
- We have been successful in the three experimental astroparticle physics initiatives thus far (SDSS, CDMS, Auger)
- We concentrated on things for which FNAL has a proven record and which matched to the individuals involved.
- The end of the SDSS in 2005 is in sight, there is a possible extension to 2007 which is uncertain.
- An initiative was made to join Prime; Prime was not approved.
- There has been a recent build up of interest in SNAP, which goes beyond the current personnel involved in astroparticle physics.
 - Exploration of participation in SNAP is underway
 - Modest resources assigned to enable this.
 - Presentation to PAC in late March
 - Discussions will lead to a defined process

SNAP



-
- **SuperNova/Acceleration Probe**
 - **Areas being explored by FNAL Physicists**
 - **Science and simulations**
 - **Photometric calibration**
 - **Scientific software**
 - **Electronics**
 - **Solid-state recorder**
 - **Data compression**
 - **..others**
 - **Radiation shields**
 - **Cosmic ray shield**
 - **Use Geant and Mars to help design**
 - **Light baffle**
 - **Thermal shield**

Experimental HEP Publications 1990-2002



Fixed Target Analysis Review



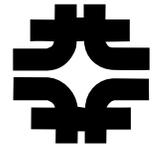
- Review Agenda
- **8:45 Executive Session for Review Committee**
- **9:00 Introduction - Mike Witherell**
- **9:10 E815 - NuTeV (Donna Naples)**
- **9:35 E872 - DONUT (Bruce Baller)**
- **10:00 E871 - HyperCP (Kam-Biu Luk)**
- **10:25 Coffee Break**
- **10:40 E835 - Charmonium (Stephen Pordes)**
- **11:05 E791 - TPL Charm (Milind Purohit)**
- **11:30 E781 - SELEX (Jim Russ)**
- **11:55 E831 - FOCUS (John Cumalat)**
- **12:20 Lunch**
- **1:20 E832 - KTeV (Ed Blucher)**
- **1:45 E799 - KTeV (Tony Barker)**
- **2:10 Executive Session**
- **3:00 Review Close Out**

Fixed Target Analysis Review

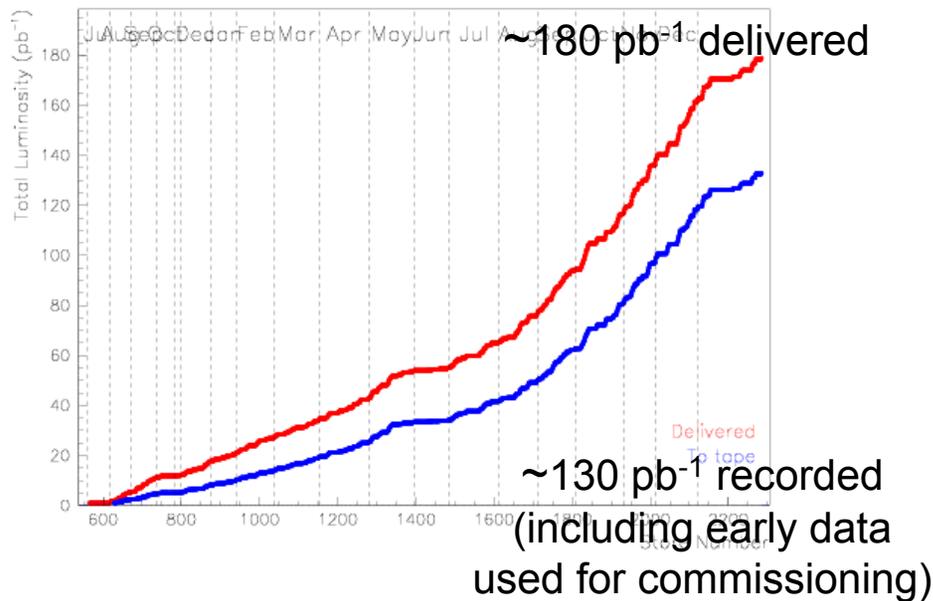


- **Committee**
 - **Avi Yagil-CDF, Chair**
 - **Steve Brice-MiniBooNE, Bogdan Dobrescu-Theory, Doug Glenzinski-CDF, Wyatt Merritt-D0**
- **Many experiments had achieved a “natural” end**
- **A few experiments were still in full publication flow.**
- **Strong encouragement to try and FIND the appropriate resources:**
 - **“The resources being requested are strikingly modest. Every effort should be made to allocate the necessary resources to ensure these investments are realized and the datasets fully exploited.”**
- **Overall the report was stellar!**

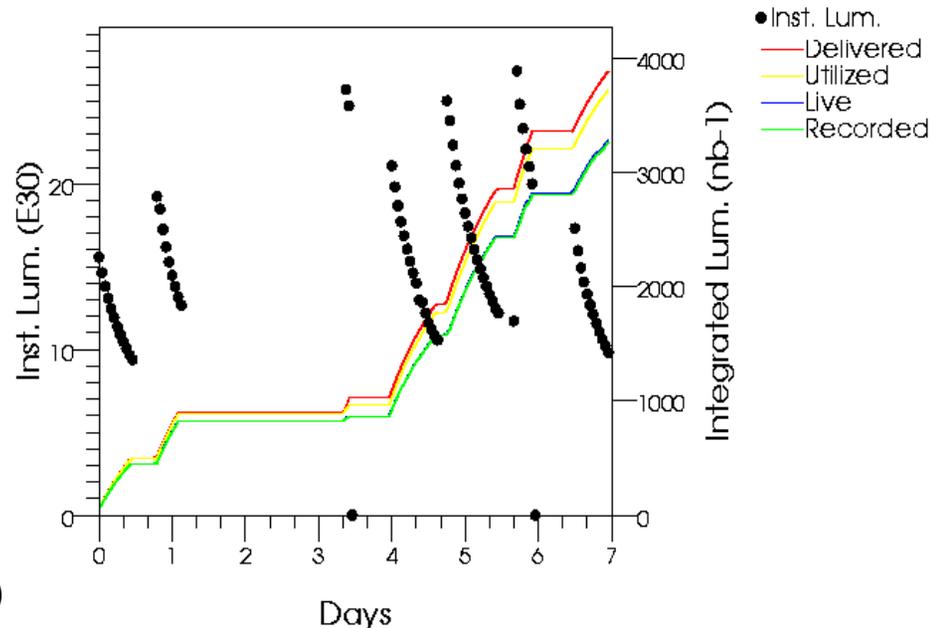
The Collider Experiments



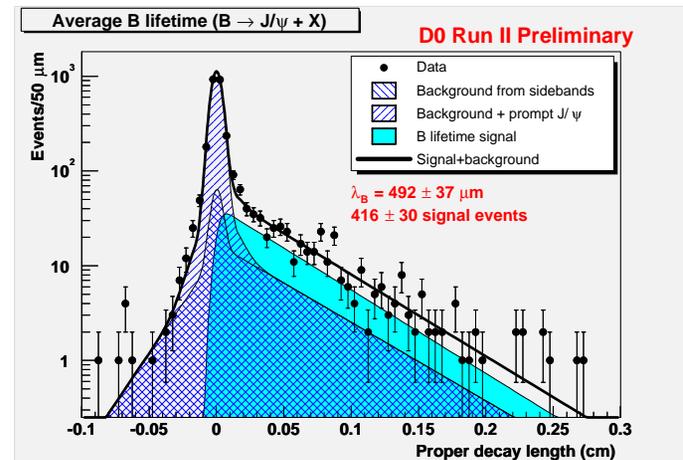
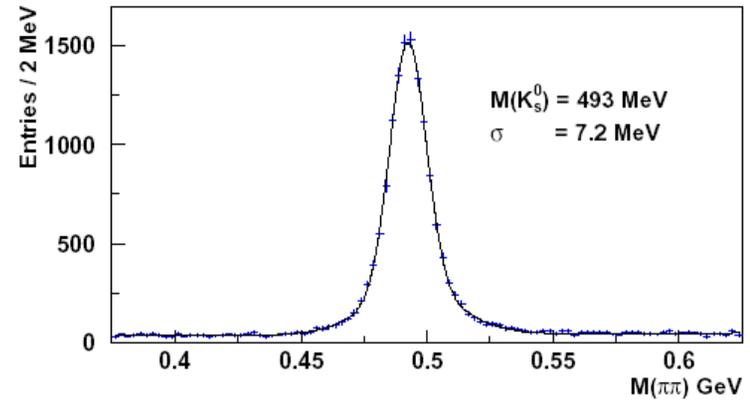
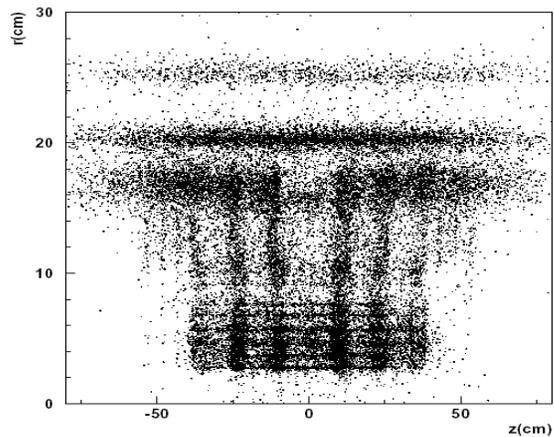
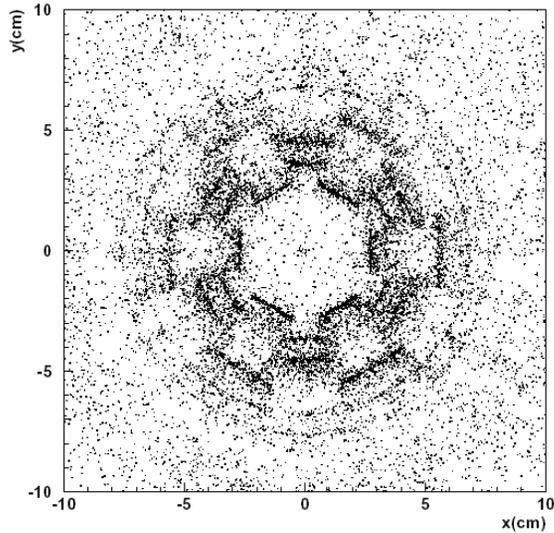
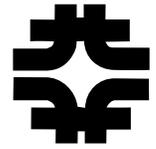
- Over the course of the past year the operation of the experiments has been tuned:
- Efficiencies of both now in >80% and >90% (short term) ranges.



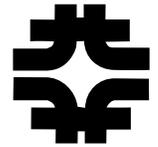
CDF integrated luminosity



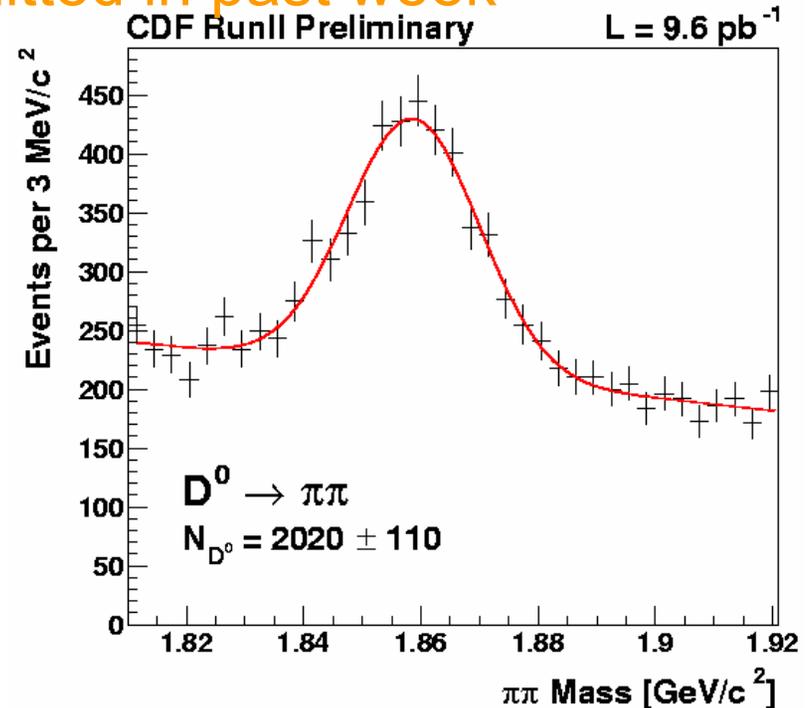
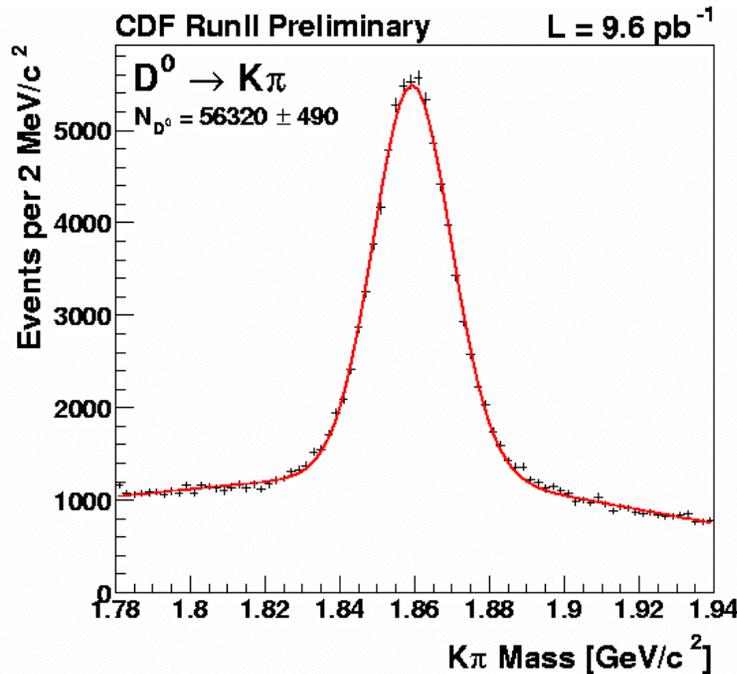
D-Zero: Strange and Beauty



CDF: Charm

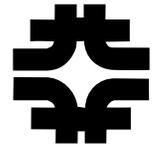


Silicon Vertex Trigger selects huge charm signals!
Publication submitted in past week

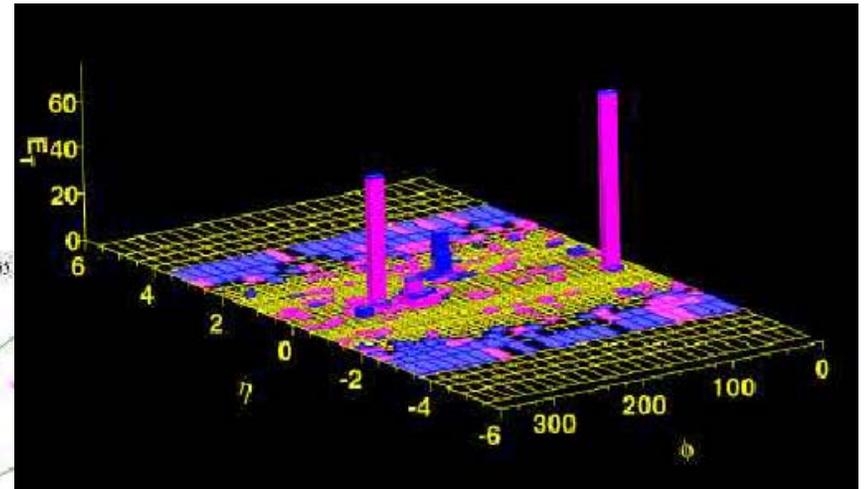
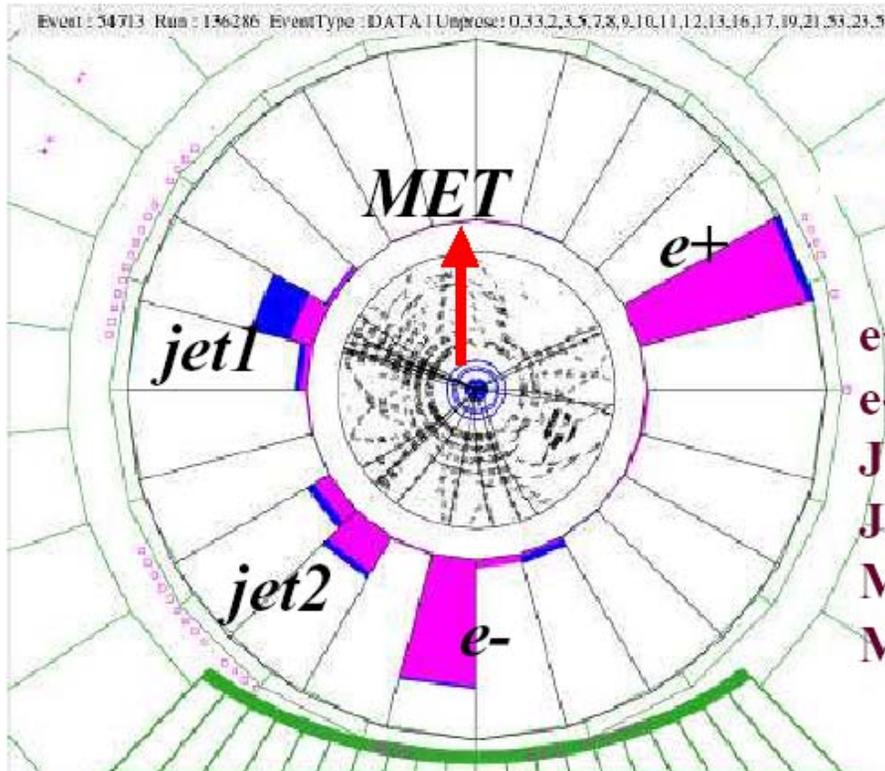


- $\Gamma(D \rightarrow KK)/\Gamma(D \rightarrow K\pi) = (11.17 \pm 0.48 \pm 0.98)\%$ (PDG: 10.83 ± 0.27)
- $\Gamma(D \rightarrow \pi\pi)/\Gamma(D \rightarrow K\pi) = (3.37 \pm 0.20 \pm 0.16)\%$ (PDG: 3.76 ± 0.17)

Top:CDF



Top Rediscovery?



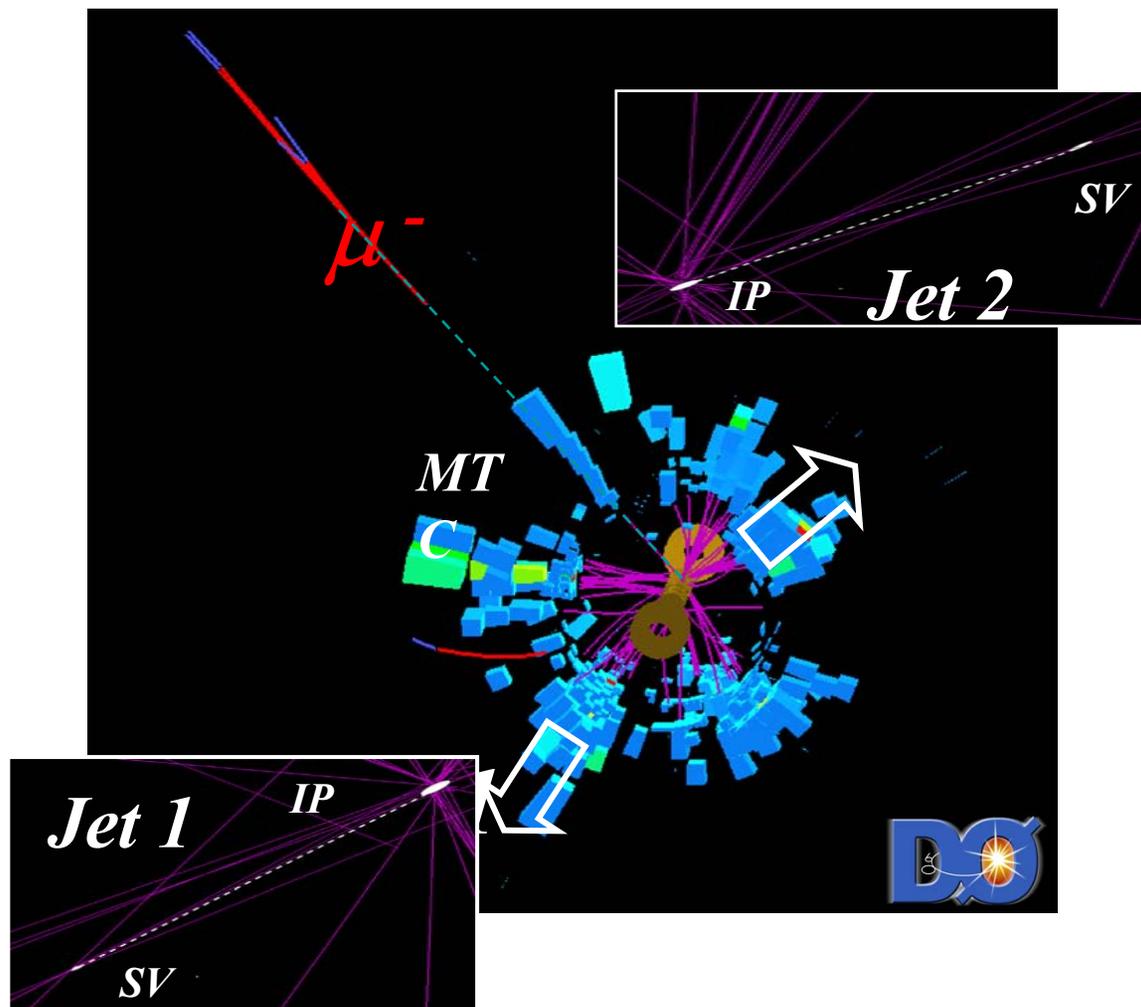
e⁺: Et=73 GeV
e⁻: Et=56 GeV
Jet1: Et= 35 GeV
Jet2: Et = 34 GeV
Missing Et = 43 GeV
Mass (e-e+)=118 GeV

CDF

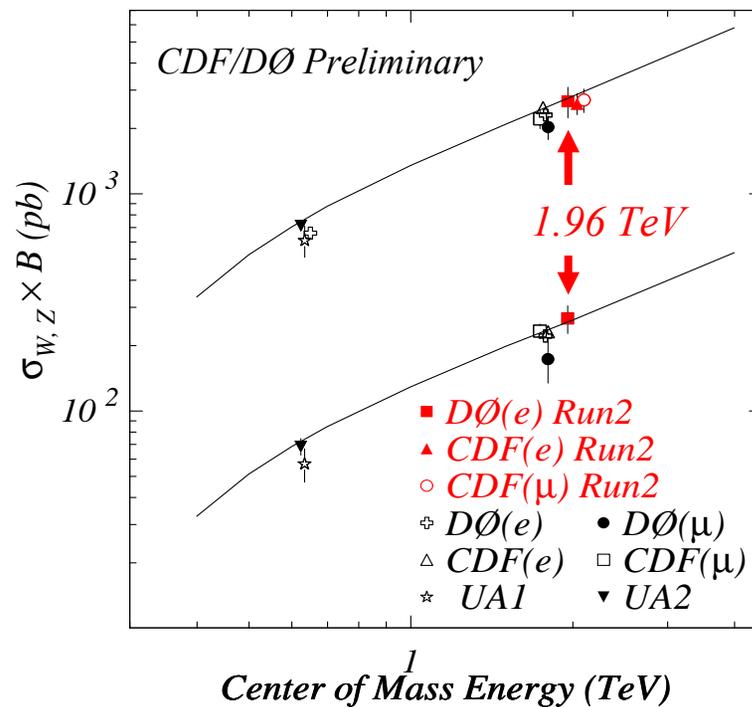
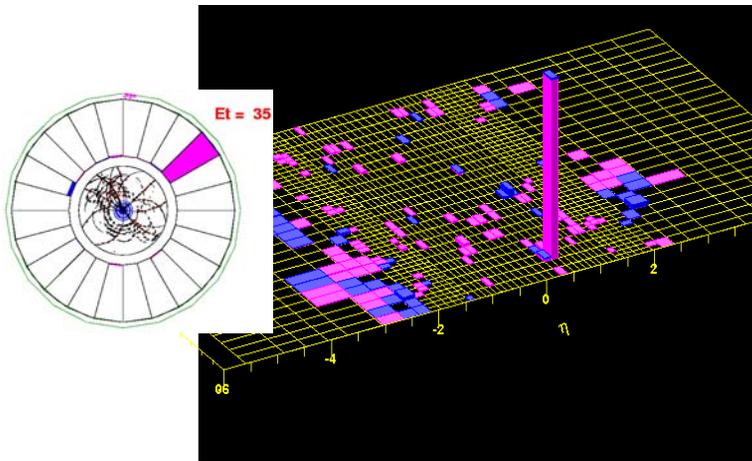
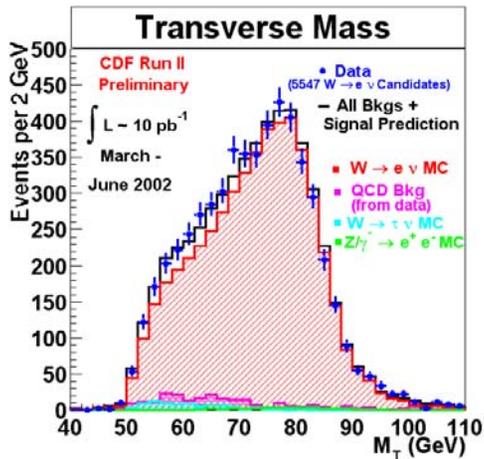
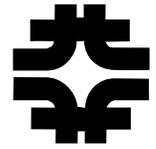
Top: DZero



Top Rediscovery?



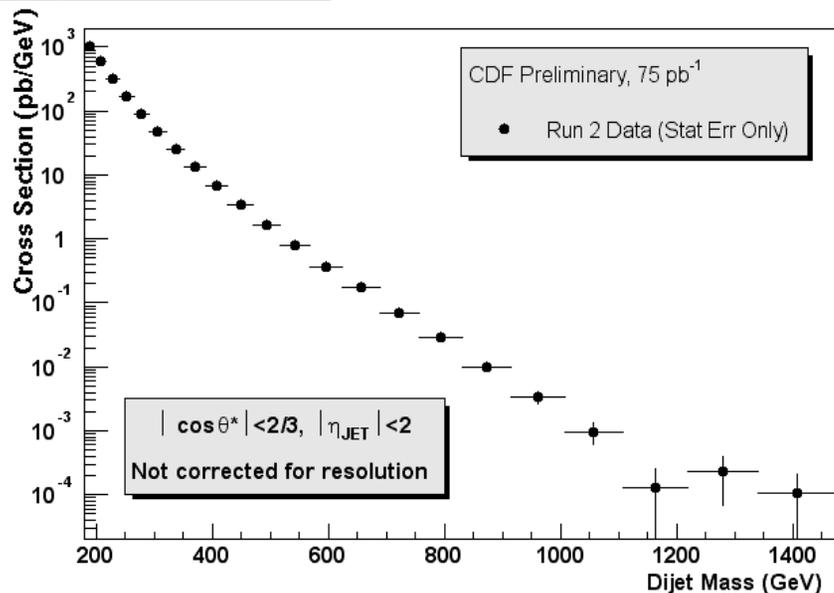
CDF/D0: Electroweak Bosons



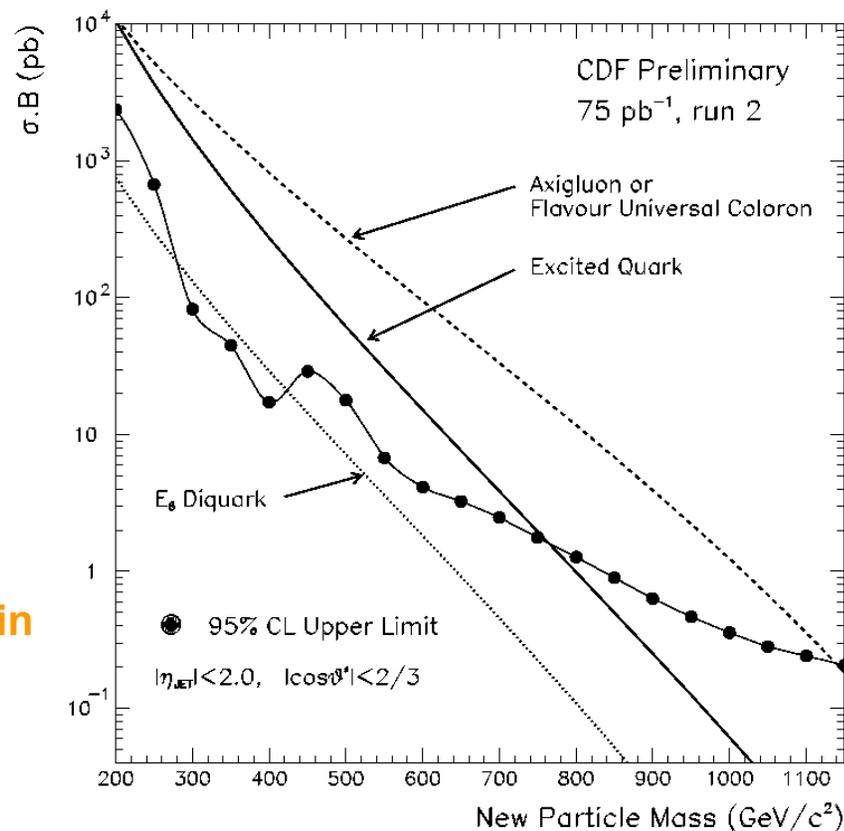


CDF: High Mass Dijets

Dijet Mass from Run 2



Search for New Particles Decaying to Dijets



Preliminary excluded masses of new particles in Run 2 (95% CL):

Axigluon or Coloron

Run 2: $M < 1130$ GeV (Run 1: 980 GeV)

Excited Quarks

Run 2: $M < 760$ GeV (Run 1: 760 GeV)

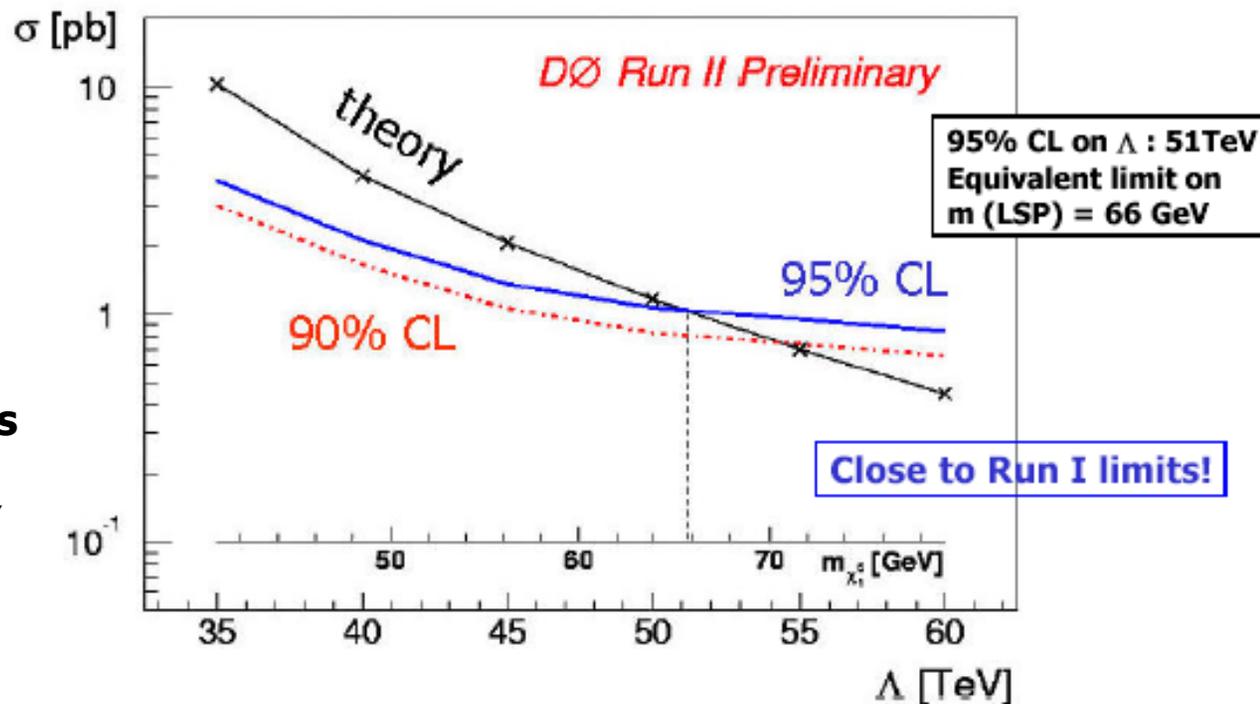
E₆ Diquark

Run 2: $280 < M < 420$ GeV (Run 1: $290 < M < 420$ GeV)

D-Zero: New Physics?



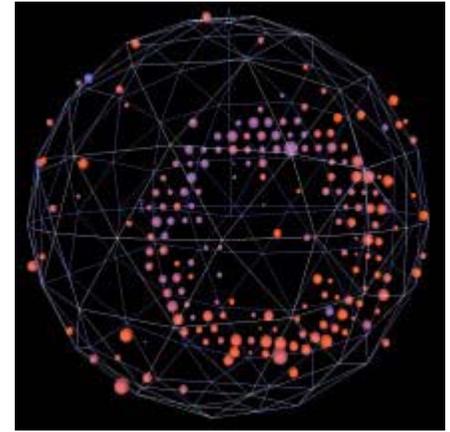
**2 photons +
missing E_T :
Limit on
neutralino mass
in gauge
mediated SUSY**



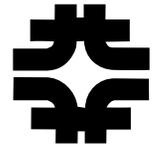
MiniBooNE



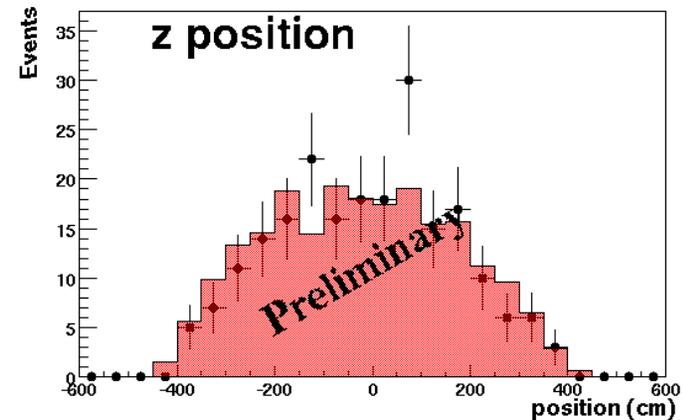
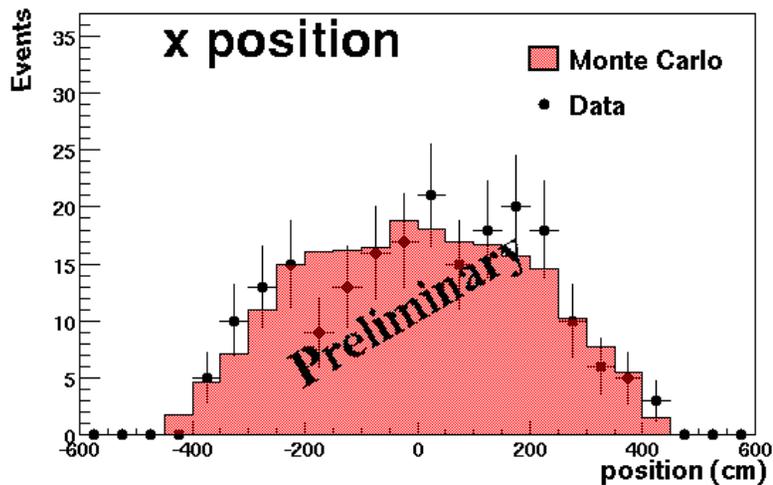
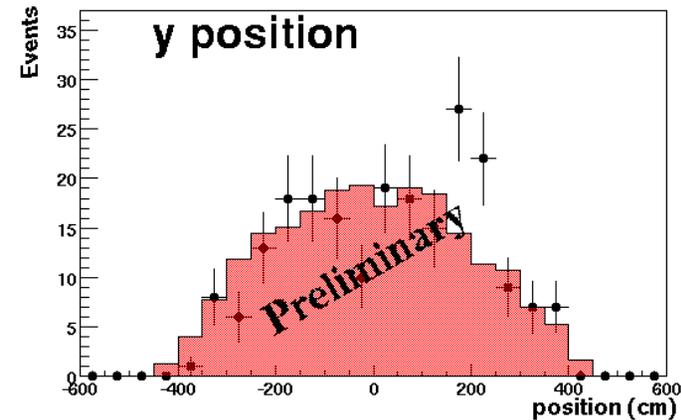
- The experiment has operated very efficiently since Summer 2002.
- The experiment takes 8 GeV protons from the Booster.
- Operation is limited by radiation losses
- Neutrino Beam operates 140 hrs per week, components are very reliable.
- Intensity has been increasing steadily.
 - Increased the Booster repetition rate capability
 - Reduced Booster losses
- Currently $\sim 3\text{-}4 \times 10^{16}$ protons on target per hour with antiproton stacking
- Record of 5.5×10^{16} protons on target per hour under special conditions



MiniBooNE



- Events within the beam timing window
- Spatial distributions fit expectations
- Presentations at Winter Conferences
- physics by summer.



NuMI Beamline



Target Hall looking with the beam

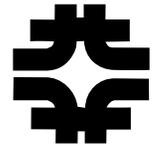
MINOS Beam looking upstream

Fixed Target with the Main Injector

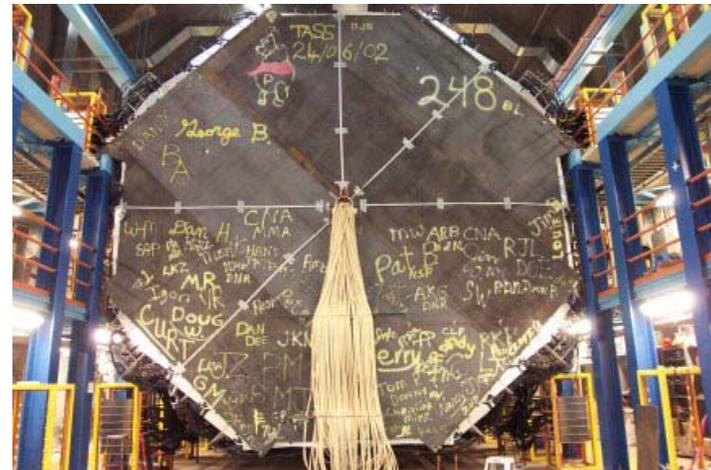
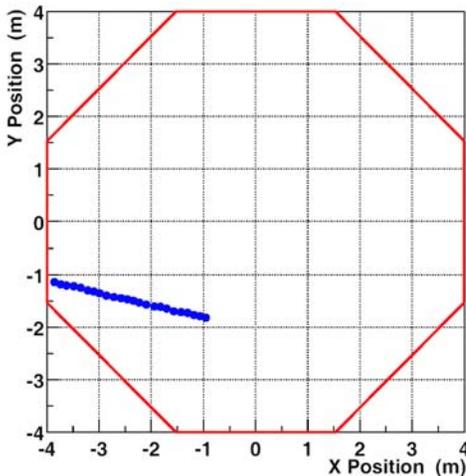


- With minimal resources we have attempted to establish the capability to extract a slow spill from the Main Injector and to transport it to the Meson Area.
- Goal is to establish a low (negative) impact physics program
- Near future that has two components
 - **Test Beam (missing for years)**
 - Generic R&D, eg Diamond Tests, RICE Test
 - Directed R&D, eg BTeV tests
 - **MIPP**
 - **Multiparticle production (funded primarily through Livermore)**
 - Hadronic production physics, models, A dependence
 - Underpinning for source term for neutrino oscillation experiments

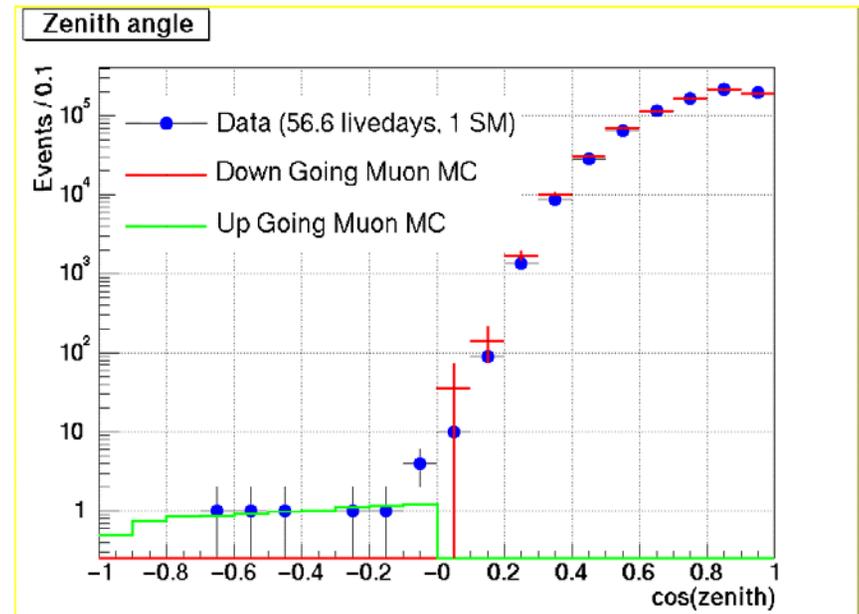
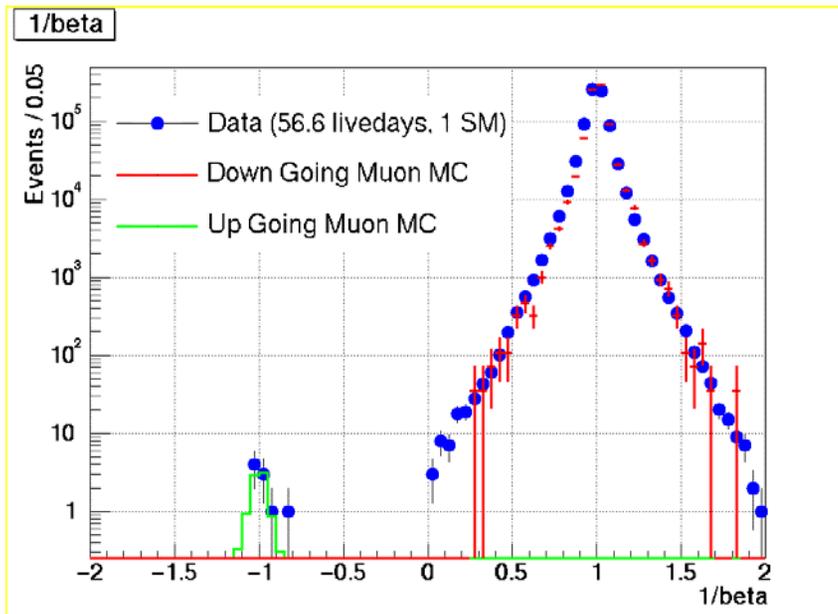
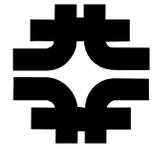
Status of the NuMI/MINOS Project



- Tunnels and Halls construction complete 11/22/02
- Surface Buildings and Outfitting construction started 11/1/02
- >426/484 planes of MINOS far detector installed and operating
- Cosmic ray studies underway
- Near Detector Preassembly
- **Serious risk of being ready for beam in less than 2 years**



MINOS: Upward-going Muons

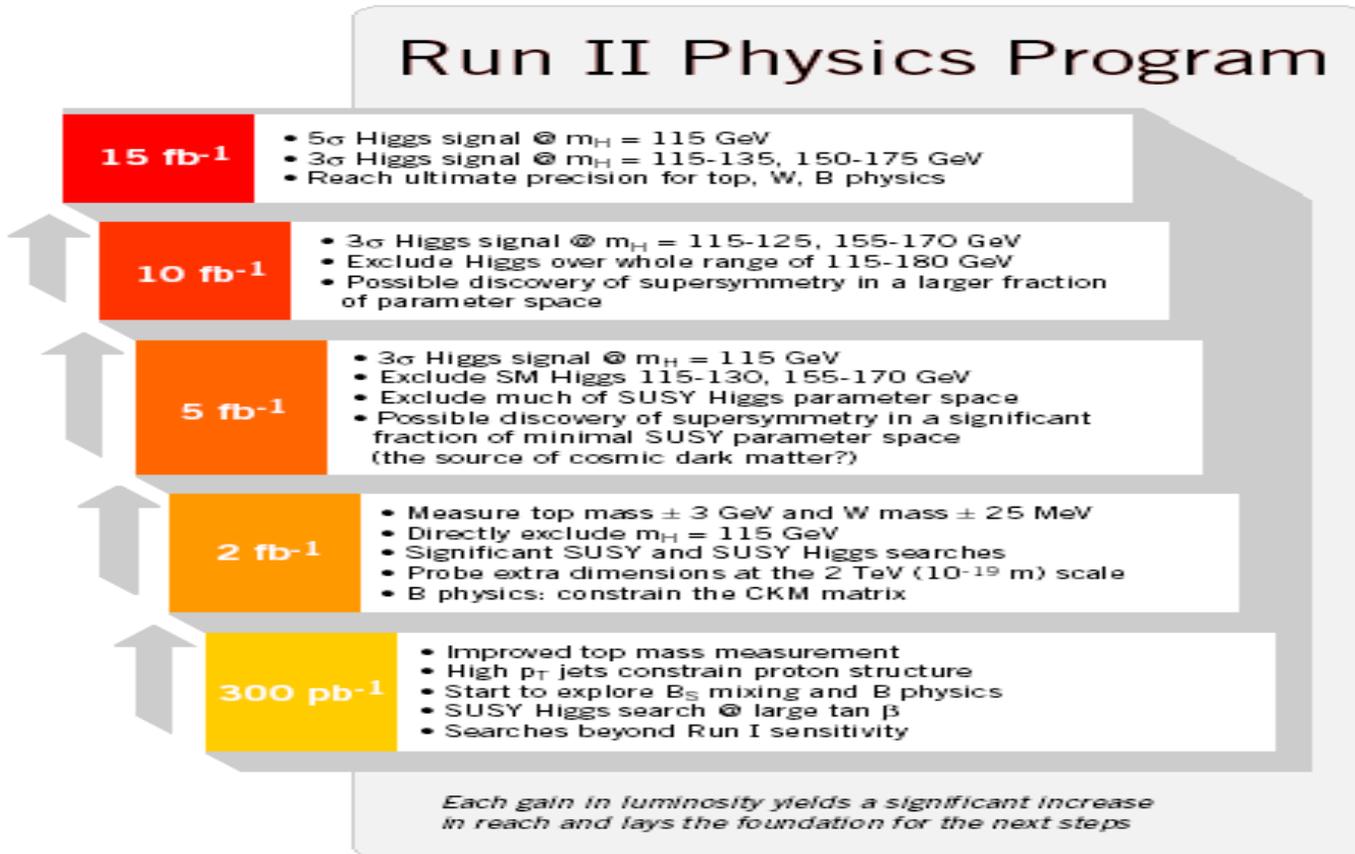
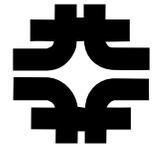


Run IIb Detector Upgrades



- In June PAC recommended laboratory approval to CDF and D0 upgrade projects that would
 - replace radiation-damaged silicon detectors with new detectors of simpler design with more radiation-hard technology.
 - upgrade data acquisition and triggers to deal with higher luminosity.
- We held successful Lehman baseline reviews in September.
 - No action items, recommended reduced contingency, which we accepted
- External Independent Review completed in Nov. 2002
- ESAAB (approval from Acquisition Executive (Peter Rosen)) on December 17, 2002.
- We now have CD0, 1, 2, 3A.. Construction through FY2003
- Project has started
 - Key component SVX4 submission in progress
 - Key sensor purchases being made
 - Readiness Reviews done, reqs in process

Collider Physics Goals!



Large Hadron Collider Projects



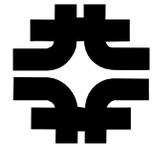
- **CMS Construction Project**
 - Longstanding projects in very good shape
 - Silicon Project will be major client at SiDet
 - Manifestly US CMS is a key piece of the overall CMS story.
 - **Research Program**
 - **CMS Computing & Software Project**
 - Embedded in the Computing Division
 - Tried to maintain and bolster the base program physicist participation
 - Increased utilization of FNAL effort within the project and also on the periphery of the project.
 - Strong push to assist in the development of proposals including the ITRs at NSF
 - **CMS M&O**
 - Transition to operating systems already on surface at CMS intersection
 - **Strong participation in the LHC Grid**
 - CD Head is US rep on the LHC Grid Deployment board.
 - **Would like to have a stronger physics presence, commensurate with our technical contributions**
 - Will try to use the Data Challenge, 2004 as a trigger.
-



R&D for Future experiments

- Over the past two years, we have provided very limited resources to future experiments. Despite the strictures they have made excellent progress with the technical aspects of the projects.
- **BTeV**
 - **B production at the Tevatron**
 - Pixel R&D
 - Rich Counter R&D
 - Electromagnetic (PbWO_4) Calorimeter
 - Fault tolerant computing and triggering (NSF funding)
 - Cost estimate well developed
- **CKM**
 - **$K^+ \rightarrow \pi^+ \nu \nu$**
 - Superconducting RF cavities
 - Vacuum Tracking
 - Photon Veto system
 - “Trigger” DAQ

Linear Collider Physics & Detector R&D



- During 2001 and after, the Director established a Group (LC Octet) of users and staff to “do whatever was needed” to advance the LC cause.
- Fermilab Physicists participated in the development of the UCLC and LCRD proposals for detector R&D.
 - Note FNAL will not receive funding from this
- We perceived that the best path is to maximize the extent to which we could be exploited by the User community.
- In FY2003, established a small group in PPD, (Tkaczyk, Fisk) to lead and to act as point of contact for collaboration, to facilitate.
- In FY2003, established a (very) modest budget for materials and services to permit effective participation by the FNAL physicists.
- Hope to publicize more when funds are released to University groups.
- Looking for the next step

Fermilab PAC November 2002



- 2:00 - 2:20 Letter of Intent to Build an Off-Axis Detector to Study $\nu_\mu \rightarrow \nu_e$ Oscillations with the NuMI Neutrino Beam (A. Para)
- 2:30 - 2:50 Detector R&D for Future Experiments with the NuMI Beamline (D. Harris)
- 3:00 - 3:20 Expression of Interest in Construction of an Off-Axis Near Detector to Measure Neutrino Cross Sections on Nuclear Targets in the Few GeV Region with the NuMI Beam (K. McFarland)
- 3:30 - 3:45 Break
- 3:45 - 4:05 Expression of Interest to Perform a High-Statistics Neutrino Scattering Experiment Using a Fine-Grained Detector in the NuMI Beam (J. Morfin)
- 4:15 - 4:35 Expression of Interest: Physics with a Near Detector on the Booster Neutrino Beamline (B. Fleming/R. Tayloe)

Fermilab PAC, June 2002: Neutrino Initiatives

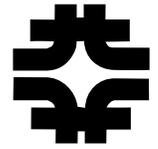


At the Aspen meeting, the PAC considered two submissions addressing initiatives which go beyond the neutrino program consisting of the NuMI/MINOS and MiniBooNE experiments. The PAC response to a potential extension of the neutrino program was positive. Therefore, we will encourage a series of workshops and discussions, designed to help convergence on strong proposals within the next few years. These should involve as broad a community as possible so that we can accurately gauge the interest and chart our course. Understanding the demands on the accelerator complex and the need for possible modest improvements is also a goal. Potentially, an extension of the neutrino program could be a strong addition to the Fermilab program in the medium term. We hope to get started on this early in 2003.

Michael Witherell

**We are doing this: Off-Axis Detector Workshop at SLAC
Special Lecture Series**

Nu Horizons



What is the neutrino mass pattern? Does it provide clues to the origin of mass? How much do neutrinos contribute to dark matter? Do neutrinos violate CP? Is this CP violation enough to explain the matter-antimatter asymmetry of the universe? Recent discoveries have opened the door for neutrino physics to answer key questions that are fundamental to particle physics and astrophysics.

NEUTRINOS NU HORIZONS OFF THE AXIS

In Spring 2003, Fermilab presents a series of lectures that capture the excitement of current neutrino physics—and ideas for future long-baseline neutrino experiments at Fermilab and around the world.

Thursday, March 13
Atmospheric Neutrinos in the Age of Long-Baseline Experiments
Ed Kearns, Boston University

Thursday, March 20
Solar Neutrinos: Current Implications and Future Possibilities
John Wilkinson, University of Washington

Thursday, April 3
The Neutrinos: What Have We Learned and What Would We Like to Find Out?
Boris Kayser, Fermilab

Thursday, April 17
Current Long-Baseline Experiments
Stan Wojcicki, Stanford University

Thursday, May 8
The Future of Reactors in the Quest for Neutrino Oscillations
Giorgio Gratta, Stanford University

Thursday, May 29
The JHF to Kamioka Neutrino Project
Takaaki Kajita, ICRP University of Tokyo

+

The BNL Long-Baseline Neutrino Project
Mitridi Diwan, Brookhaven National Laboratory

Friday, May 30
The NuMI Off-Axis Detector Project
Gary Feldman, Harvard University

All lectures are at 3:30 pm in the One West Conference Room. Refreshments will be served following the lectures.

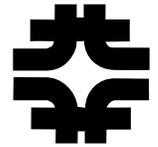
Questions? Call Michelle Gleason at (630) 940-6082, michelle@fnal.gov

www.fnal.gov/pub/events/nuhorizons.html

Fermilab

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4850 South State Street / P.O. Box 5008 / Batavia, IL 60007-5008 / www.fnal.gov / 630.940.1000

Schedule: Components



- Depends on continuing discussions with the experiments and with the Physics Advisory Committee. We are also vulnerable to discoveries.
- **2003-2004**
 - Collider Physics
 - MiniBooNE
 - MI Extracted Beam
 - Test Beam
 - MIPP (E907)
- **2005-2006**
 - Collider Physics
 - MINOS

Summary



- **There is a restrained Astroparticle Physics program at Fermilab both below and on the earth's surface. We are planning the future.**
- **Collider Run II**
 - **Detectors are operating well**
 - **Physics has started to appear.**
 - **1st publication submitted**
 - **Run IIB Upgrade Projects launched**
- **We have started a new era of neutrino operations at Fermilab.**
 - **MiniBooNE Physics results are expected by Summer**
 - **MINOS Operations in 2005**
- **We are trying to do R&D for future experiments**
- **CMS will grow in terms of its physicist involvement**
- **We are trying to establish a long range schedule as a basis for operation and evolution.**