The Fermilab Program: Run 2 and Beyond

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HEPAP Meeting

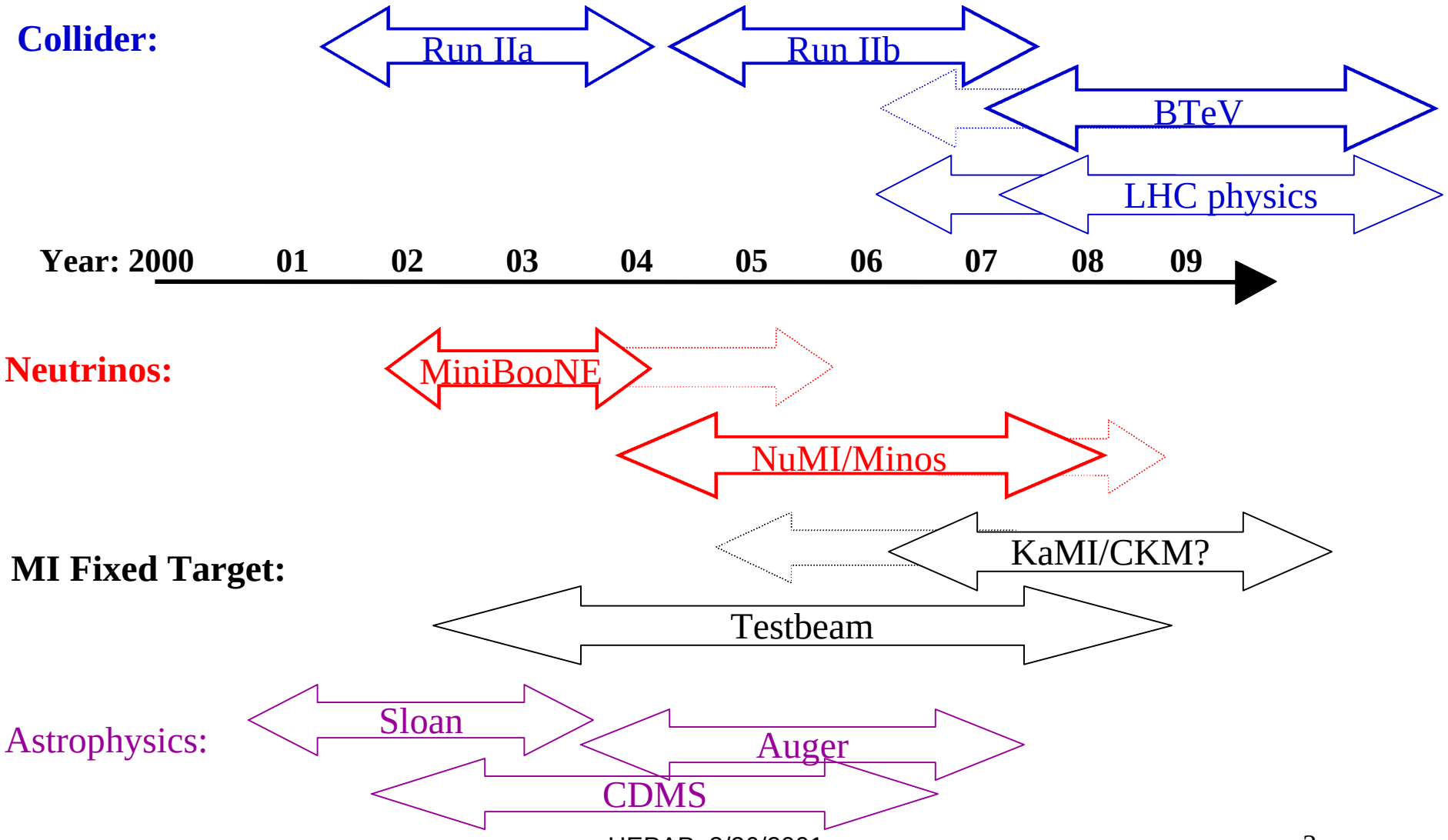
March 26, 2001

Ongoing Construction Projects

- Run 2 Upgrades (2001)
  - D0 DONE
  - CDF DONE
- Run 2b Upgrades (2004)
  - Accelerator luminosity
  - Detectors
- Neutrino Projects
  - NuMI/MINOS (2004)
  - MiniBooNE (2002)
- LHC (2005)
  - US LHC Accelerator project
  - US CMS
- Astrophysics
  - Auger Cosmic Ray Experiment (2002-4)
  - Cryogenic Dark Matter Search (2002-4)
- Wilson Hall(2001)

In addition, accelerator R&D efforts are among the most important activities at the laboratory.

Schedule for Physics Runs



The Tevatron Collider Program

The Accelerator complex and the **CDF** and **D0** experiments have been rebuilt for a long run.

Physics of the Weak Energy Scale

- Supersymmetry – Look for signs of supersymmetric particles.
- Precise *t*, *W* mass measurements – Narrow the SM Higgs region.
- EWSB – Look for one or more Higgs bosons of low mass.
- Search for effects of large hidden dimensions or other new physics.

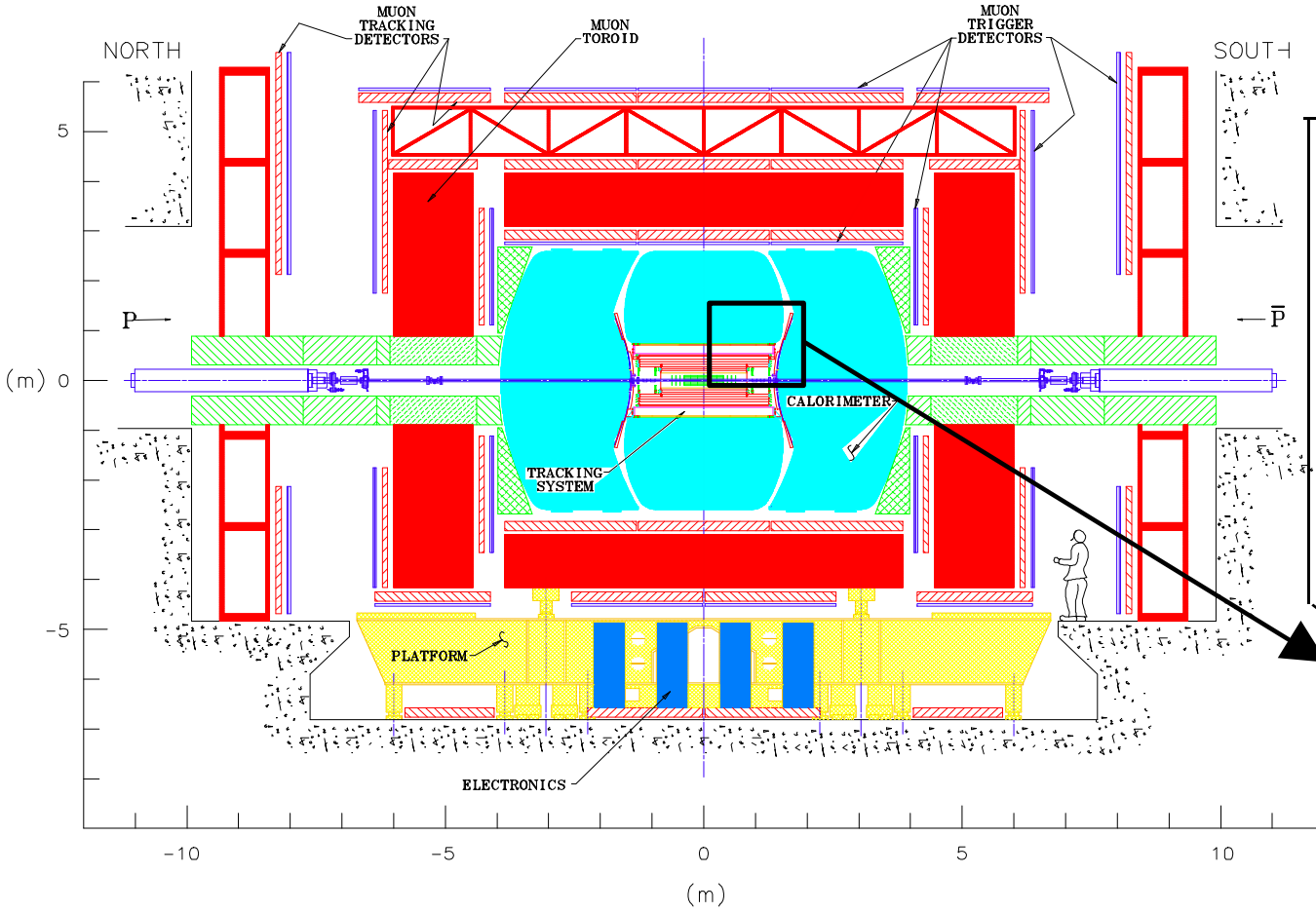
CP Violation and Quark Flavors

- Measure B_s mixing to determine V_{ts}.
- Measure CP-violating asymmetries

The Tevatron Collider Program

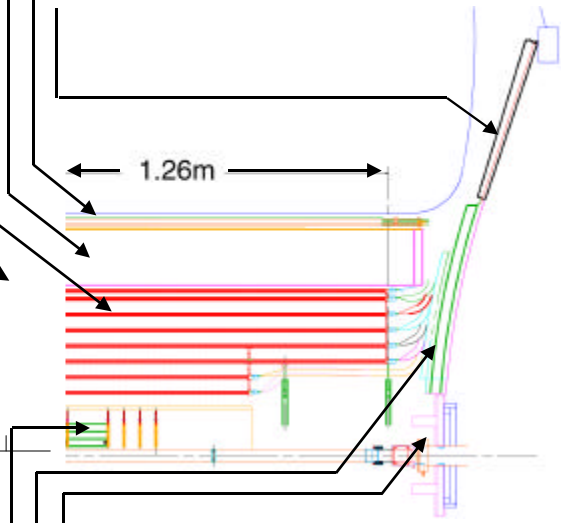
- The Highest Priority for the laboratory is getting as much integrated luminosity as possible by the time of LHC physics.
- For the last 18 months, we have been focusing attention on getting Run 2 started on time.
  - In October, 1999, we published an 18-month schedule continuing through the start of Run 2 in March 1, 2001.
  - We held to that schedule, despite the usual number of unforeseen problems.
- We will now emphasize maximizing the integrated luminosity.
  - The first goal is to take advantage of the installed upgrades quickly.
  - We are making more detailed accelerator and detector upgrade plans.
  - We will be operating the collider as continuously as possible while upgrade work proceeds.

D0 UPGRADE



New Systems

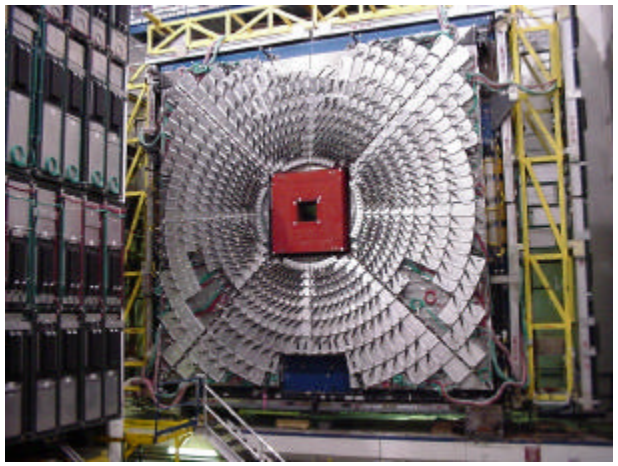
- Fiber Tracker
- 2T Super conducting Solenoid
- Central Preshower
- Intercryostat Detector



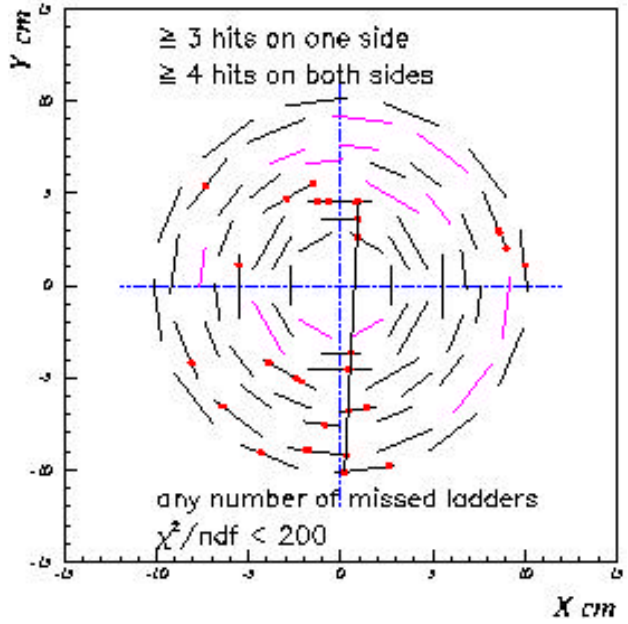
- **Shielding**
- **Central Muon Scintillators**
- **Forward Muon Tracking**
- **Forward Muon Trigger Pixels**
- **Calorimeter Electronics**
- **3 Level Trigger & DAQ**
- **Online System**
- **Offline Computing**
- **Luminosity Monitor**
- **Forward Preshower**
- **Silicon Tracker**

D0 Status

- Detector
  - All detectors completed & installed
  - Muon & cal. electronics complete
  - Still completing electronics for tracking and trigger
  - Will commission all systems while completing and installing the remaining electronics

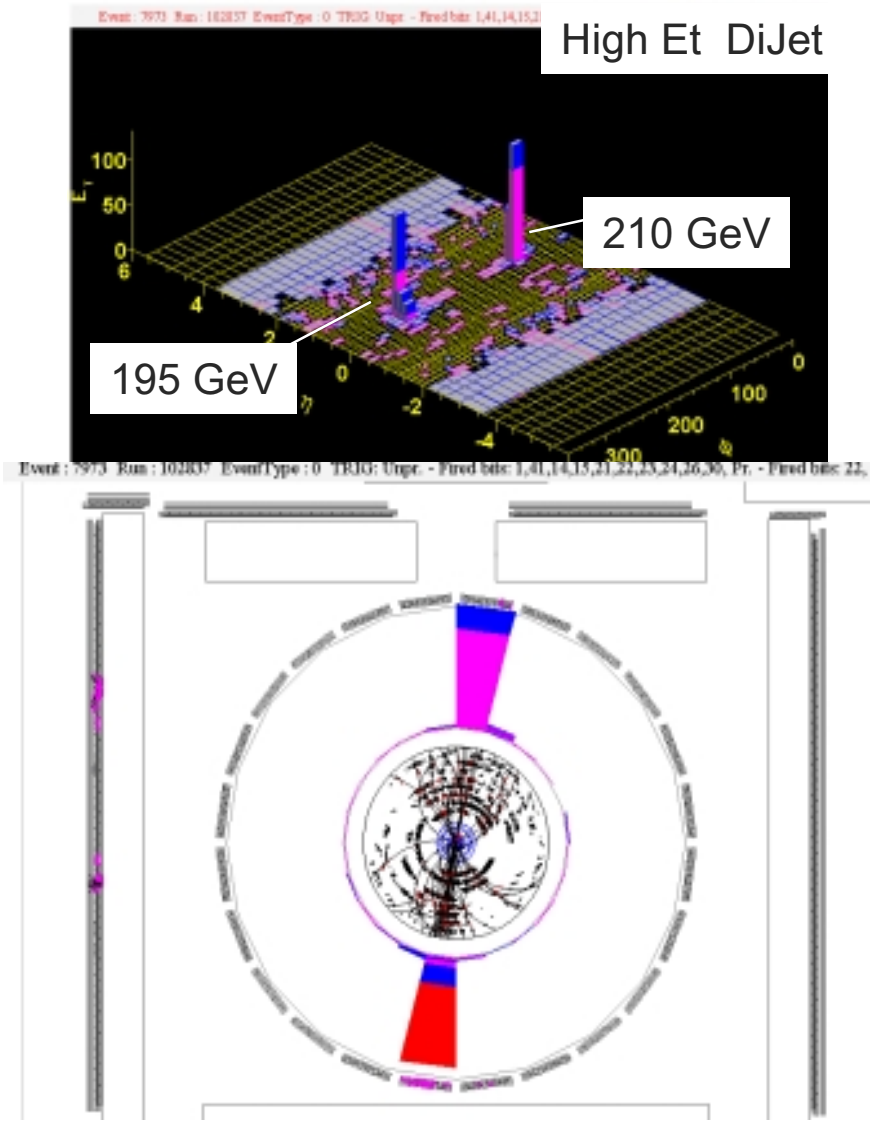


- Software and Computing
  - Online system complete and functioning
  - Storing data in final robot and retrieving it
  - Production farms in use
  - New tracking software well along

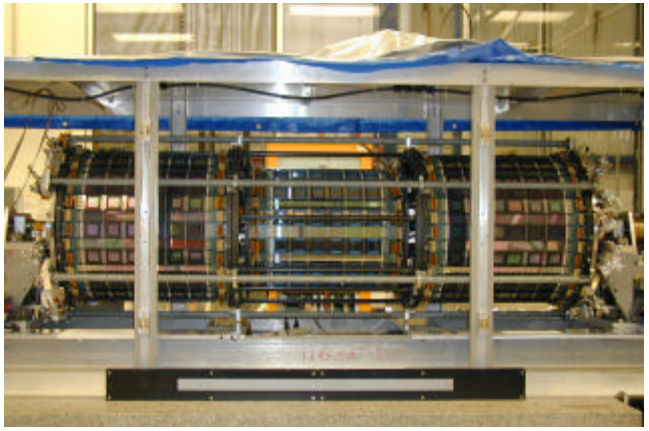


CDF Commissioning Run (Nov, 2000)

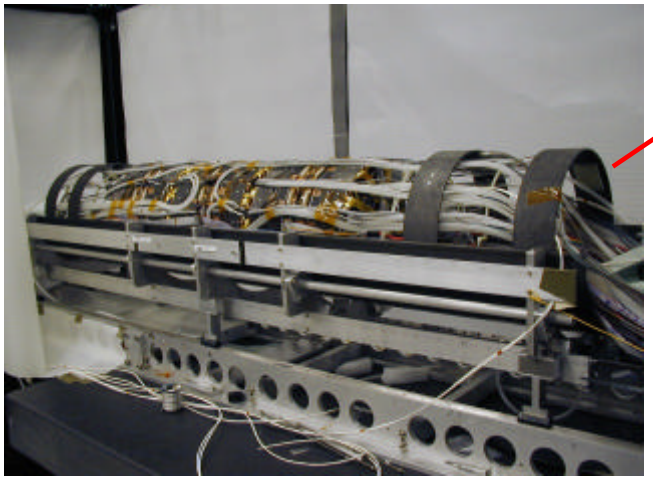
- 52 hours of 36x36 collisions @ ~$4x10^{29}cm^{-2}s^{-1}$
  - Established operating points
  - Established triggers
  - Exercise online DAQ monitoring
- Dramatic progress by the accelerator team to achieve 36x36 operation
- Over 5 million min-bias events recorded with most systems operational



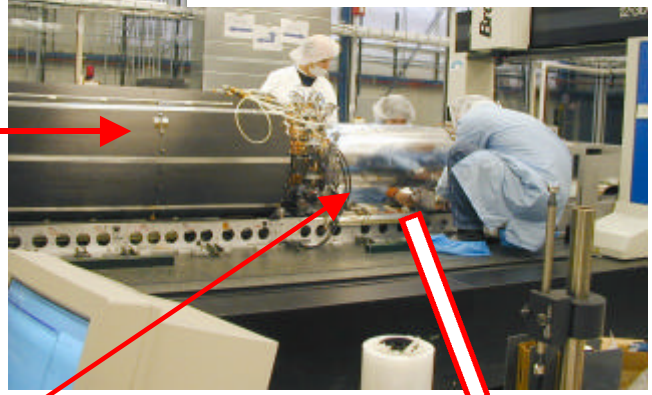
CDF Silicon Tracker



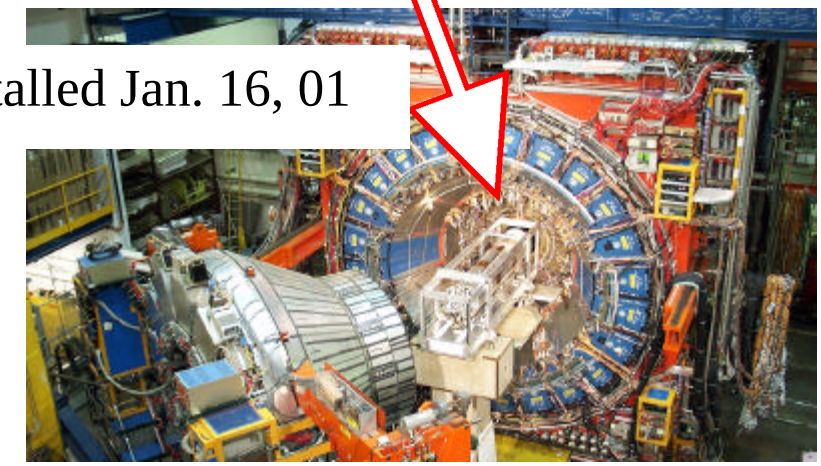
ISL (above) and SVXII (below)



Merged end of Dec.

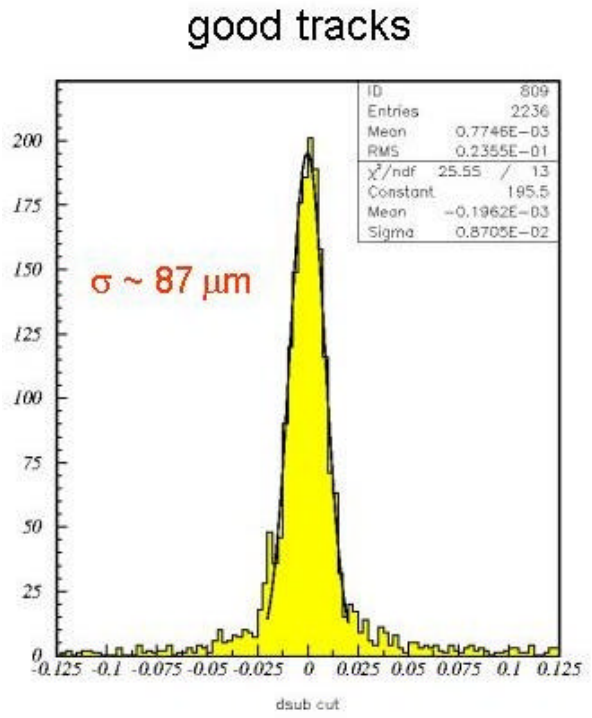


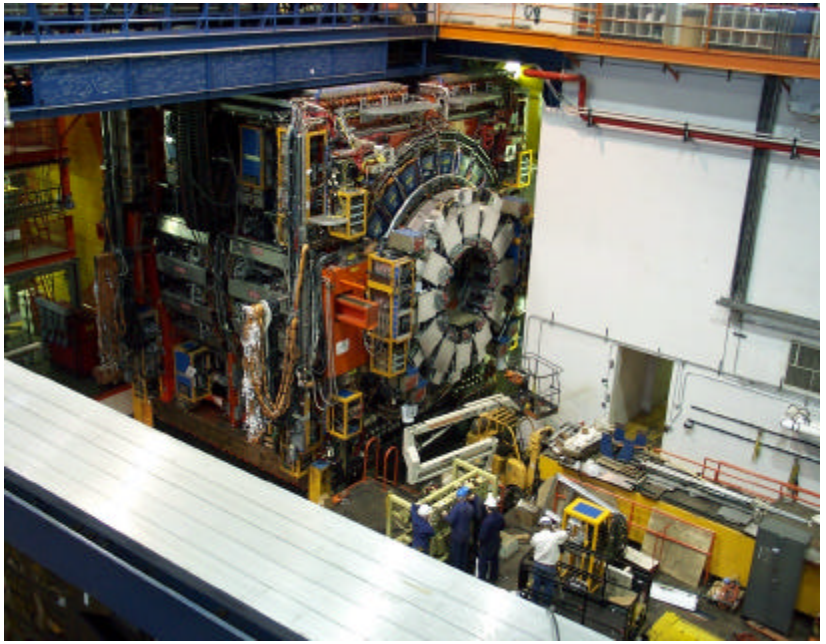
Installed Jan. 16, 01



CDF Status

- All detector and electronics systems installed
- Commissioning well along
- 3 TB of data to tape during commissioning run
- Offline software functioning: reconstructed mass peaks, excellent vertex resolution
- The goal is to obtain physics data by July 2001.



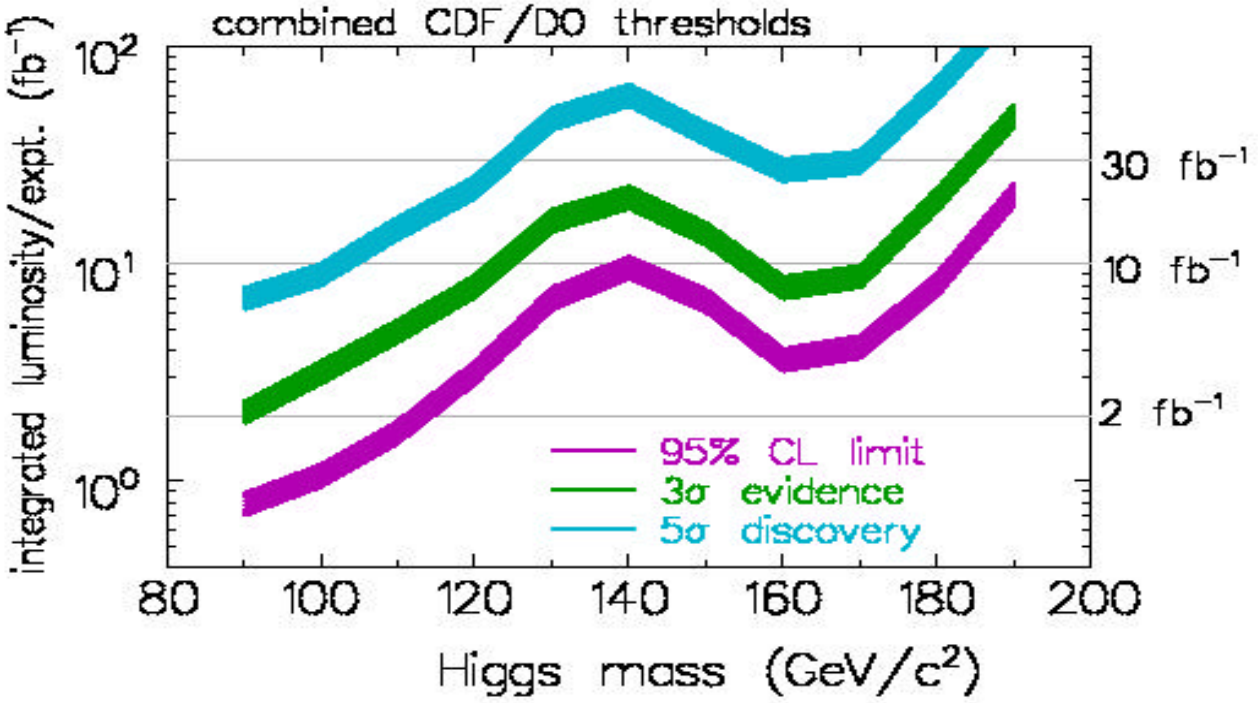


Collider Startup

- A great deal of work was done on the accelerators during the shutdown from 11/6/00 to 03/01/01.
  - Installation and repair in antiproton source and Main Injector
  - Installation of piping and magnets for NuMI and MiniBooNE
  - Installation of magnetic shielding, cooling, new optics in Recycler
  - Installation of CDF and D0, some magnet swapping and alignment
- The goal is to get to collisions quickly, then optimize.
  - 980 GeV protons achieved on 3/11
  - 1 x 8 collisions scheduled for ~4/4
  - 36 x 36 collisions scheduled for ~4/26

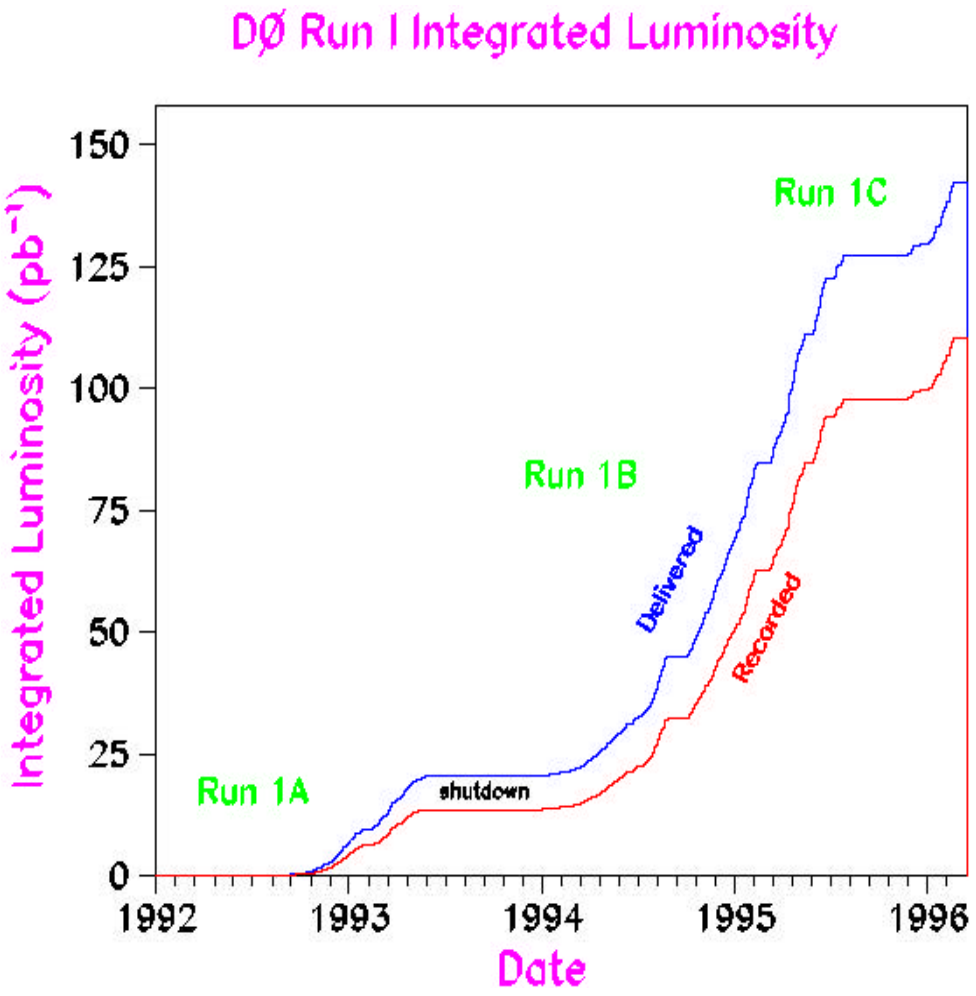
Run 2b

- Run 2a represents a big improvement in supersymmetry searches, top and W mass measurements, B physics, and QCD studies.
- For Higgs discovery, we need the full benefit of luminosity upgrades. These need incremental funding and manpower immediately.



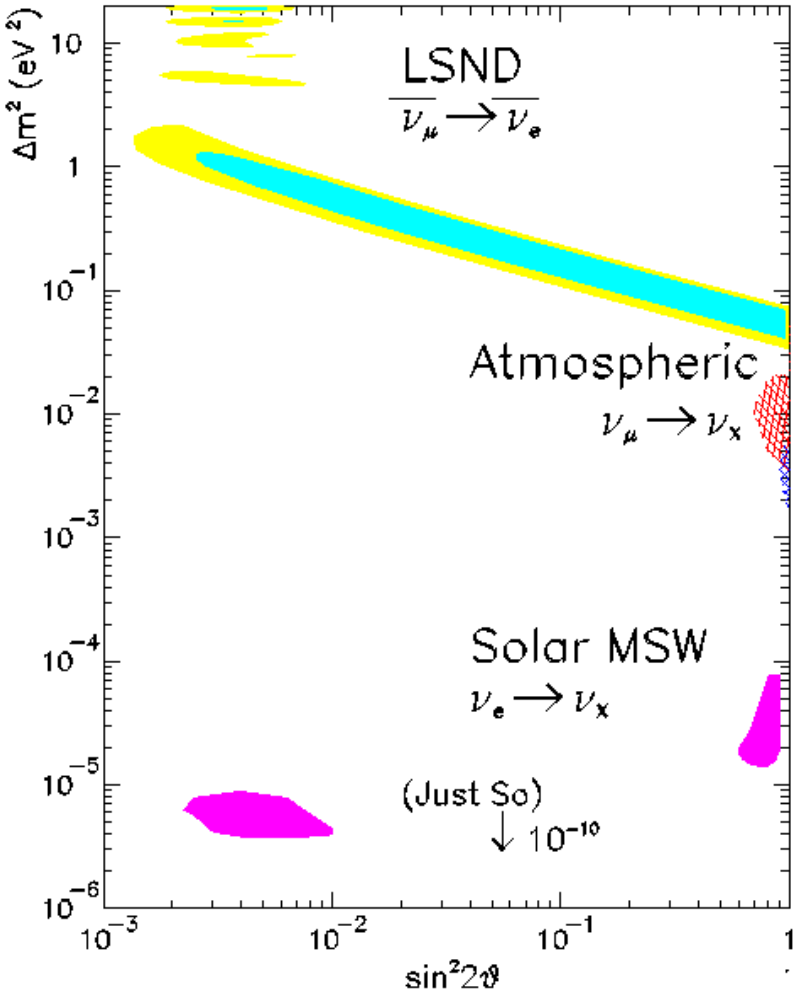
Running time: Past vs Future

- **We have a long run ahead.**
  - Remember that the entire Run I for D0 consisted of ~26 months of beam time.
  - We should run that long for Run 2a and again for Run 2b.
- It is clearly worth investing in Run 2b luminosity upgrades.
  - The physics opportunities are compelling.
  - There will be enough running time to get the full physics payoff.
  - If physics demands running beyond 2007, we will be prepared for it.



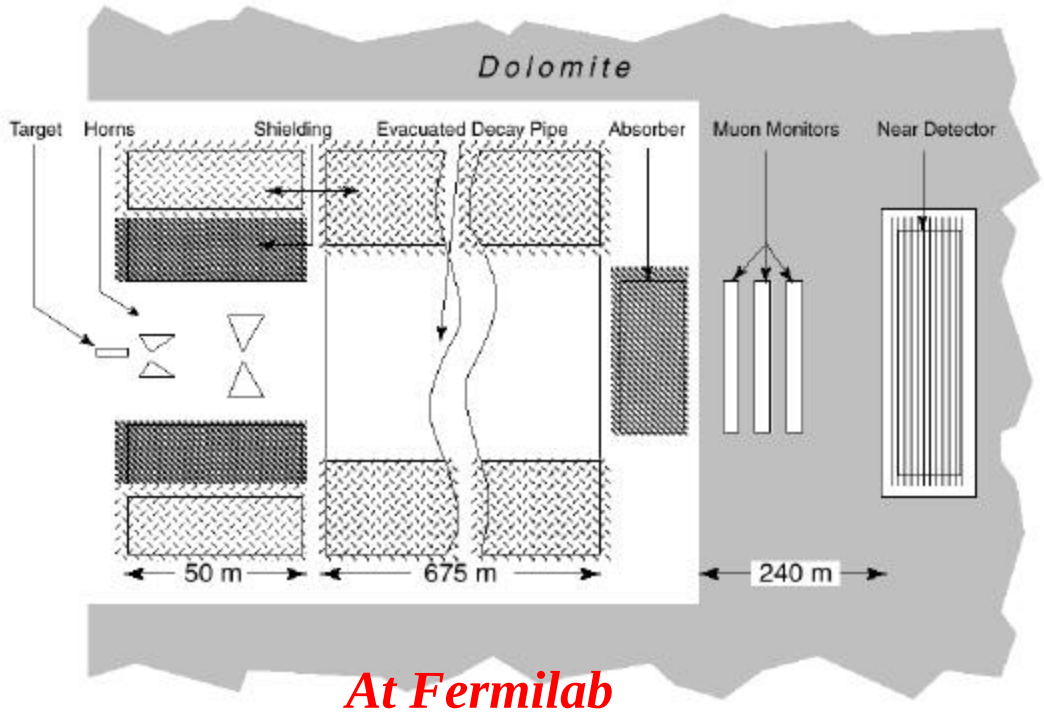
The Neutrino Program

- **MINOS**
  - The goal is to study the atmospheric neutrino oscillation with high statistics and a controlled source.
  - The experiment will start operating in 2004.
  - 3-20 GeV ν, 740 km distance
- **MiniBooNE**
  - It will be possible to make a definitive check of the LSND anomaly, with high statistics and measured backgrounds.
  - MiniBooNE will start operating in early 2002.
  - 1 GeV ν, 500 m distance

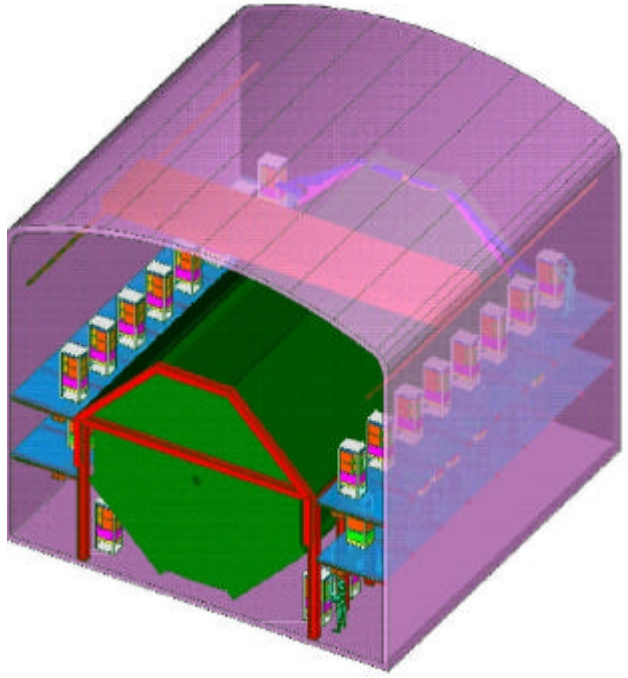


NuMI/Minos Project

- Start Far Detector Installation 8/01
- Start Near Detector Installation 1/03
- First Beam to Soudan 1/04
- First Operation of Experiment 4/04



At Fermilab



8m

At Soudan, Minnesota

NuMI Status and Schedule

We are preparing a new baseline for the project

- Very difficult underground construction projects at Fermilab and Soudan
- New baseline about to be submitted:
  - Restoration of reasonable contingency: add 11 months and ~15% to TPC
  - Needs **$4 M** increase in Other Project Costs (OPC) in FY 02 to keep this schedule.

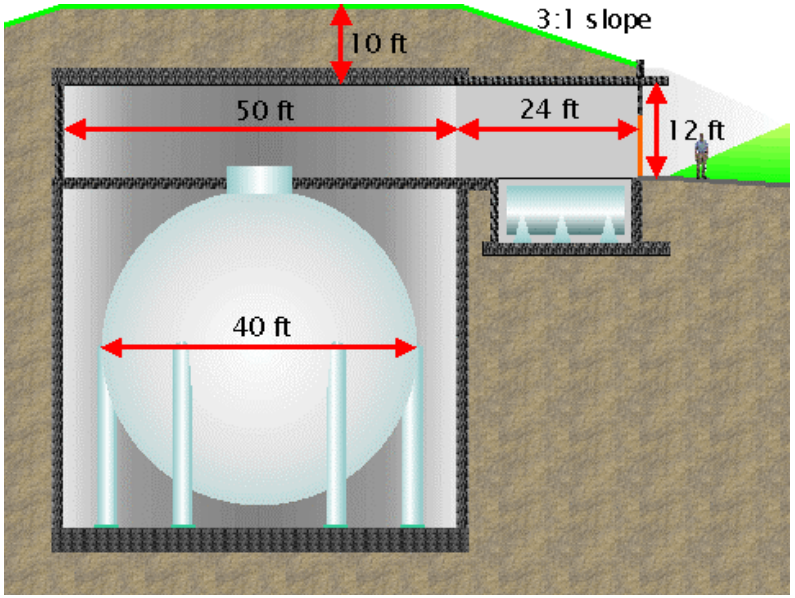
Target Hall

MINOS Cavern

MiniBooNE Status

- If the LSND result is correct, it will change completely our assumptions about oscillations:
  - Sterile ν's needed
  - One $\Delta m^2 \sim 1\ eV^2$.
  - CP studies more likely

- MiniBooNE will produce a decisive investigation of the LSND region.



MiniBooNE Status

- 8 GeV Beamline Project

9/01 Beneficial occupancy of beam enclosure

4/02 Beamline ready for beam

- MiniBooNE Project

12/01 Detector installation complete

1/02 Detector ready for beam

10/01 Beneficial occupancy of target hall

1/02 Horn tests complete

4/02 First neutrino events

The Particle Astrophysics Program

- Fermilab has an important role in astrophysics experiments, as a partner with NSF, U.S. university groups (DOE and NSF), and foreign institutions:
  - The **Cryogenic Dark Matter Search** (CDMS-II) is going to extend its search for direct detection of cold dark matter with a new facility in the Soudan mine.
  - The **Auger Cosmic Ray Observatory** will study cosmic rays with energy 10^{19} – 10^{21} ev at Los Leones, Argentina.
  - The **Sloan Digital Sky Survey** is now operating at Apache Point Observatory, NM and early results are attracting great attention.

Experiments in construction

- Pierre Auger Status
  - Detector Assembly Building complete
  - First fluorescence building complete
  - Eighteen (of 38) Engineering Array surface detector tanks deployed.
  - Construction of the full observatory 2002 -2004.
  - Transition to data taking during construction period

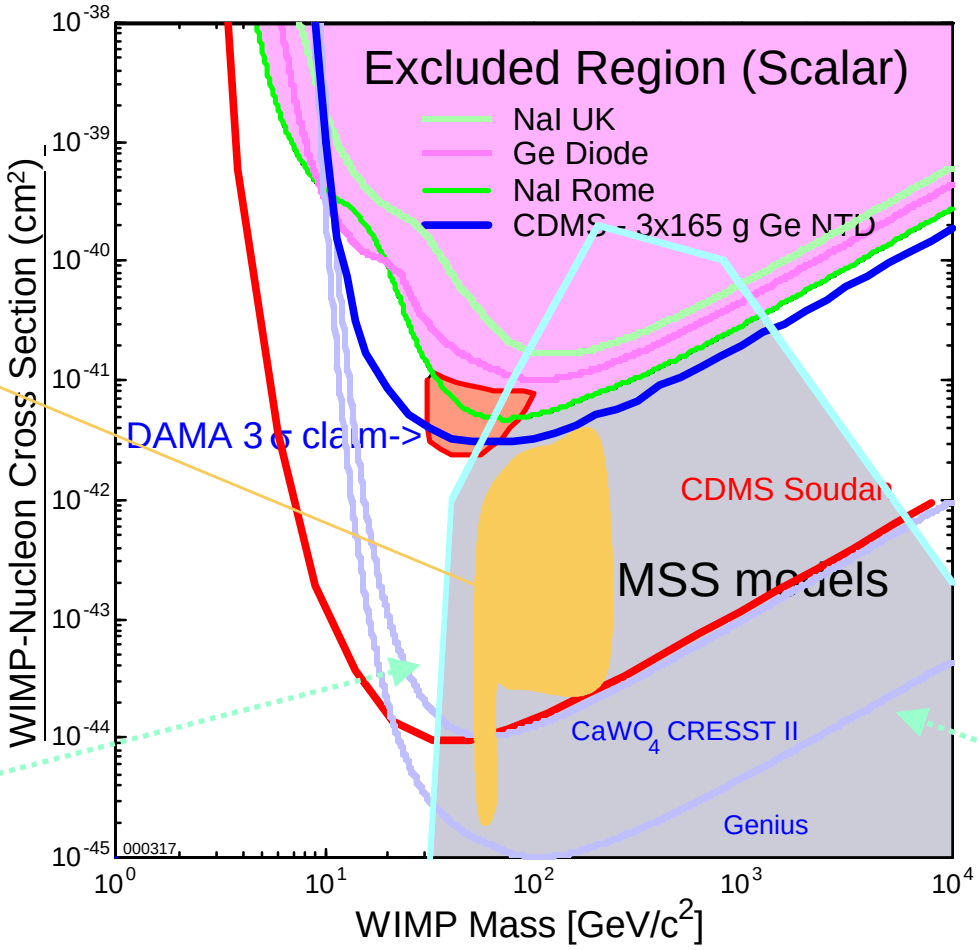
PIERRE AUGER OBSERVATORY

- CDMS II Status
  - CDMS-I results most sensitive
  - All infrastructure at Soudan, by Fall 2001
  - System Test at Soudan, December, 2001
  - CDMS II "First Dark" early 2002
    - Sensitivity of first tower 10 times better than CDMS-I
    - 9 towers by 2004, sensitivity 100 times present

The Fluorescence Detector Building and Communication tower at Los Leones

Icebox and Frig Assembly at Soudan

CDMS : status and prospects



Currently favored
<=g-2 of μ

CDMS II

0.01 evt./kg/day
$(MT)_{eff}$=230kg.day

CRESST II
Technology has to be extrapolated from 6g to 300g

GENIUS not approved, Genino could run in 2002, GENIUS in 2004+

The mid-term future

Projects that prepare for exciting physics late in the decade.

LHC

- The LHC will illuminate the full 1 TeV mass scale.
- It will be a centerpiece of the US program for a long time to come.
- Fermilab is host for the US effort on the accelerator project and **CMS**.
- We are giving a lot of attention to the ramping up of the CMS software and computing project and the transition to physics research.

BTeV

- BTeV will be the leading experiment for precise tests of the crucial aspects of CP violation in the Standard Model.
- We need to get started now, but it will become a project in FY 2004.

BTeV

- Both BTeV and the higher-luminosity e^+e^- B-factories are needed to ultimately clarify the picture of CP violation.
  - The goal is to look for new physics by comparing CP-violating asymmetries involving B_d and B_s mixing to expectations from measuring CKM amplitudes directly.
  - The BTeV detector design makes it ideally suited to making precise measurements of all these quantities.
- US HEP needs a major experiment of this quality doing physics in the period 2008-201x.
  - We need to keep developing state-of-the-art detector technology, such as pixels.

Accelerator R&D

- The U.S. should have strong R&D programs on the accelerator R&D efforts that are likely to lead to future accelerators: the linear collider, the neutrino factory, and the next generation hadron collider.
- Fermilab must take a central role in developing the future program for U.S. HEP.
- We should and do have R&D efforts on all 3 major accelerator types.
  - Each will probably be done somewhere in the world, assuming good support for HEP.
  - All large future projects will be international efforts with U.S. participation.
  - Fermilab is a favorable site for any accelerator built in the U.S.

The Linear Collider

- Fermilab has become an important part of the NLC effort.
  - Limited by budget restrictions
- Discussion of physics prospects
  - LCWS 2000 in October, 2000
  - Line Drive series January-June, 2001
- Developments elsewhere
  - TESLA proposal released; ICFA study to come.
  - Japanese HEP community is studying options.
  - At LCWS 2000 the Lab directors discussed the need of a technical evaluation panel for the three technologies. ICFA is pursuing this.

Neutrino Factory

- Fermilab is taking leadership in R&D on muon cooling, in collaboration with university physicists.
- Studies continue
  - Physics and detector study group is looking at experiments with a high-intensity conventional neutrino beam.
  - An accelerator study of a high-intensity Proton Driver was recently completed.
  - Fermilab physicists are contributing to Feasibility 2 study.

VLHC/Superconducting Magnet R&D

- We need to invest today in the magnet R&D needed for such an accelerator in the future.
  - Other uses include special magnets for Tevatron upgrades, magnets for muon storage rings, and possible 2nd generation LHC quadrupoles.
  - We have asked for a study of a two-stage future facility so that we can properly identify the R&D issues that need attention now.

What we need to do in FY 2002

- Run II
  - Operate the collider and the experiments efficiently.
  - Finish the computer acquisition.
  - Do a large fraction of the collider upgrade.
- Neutrino program
  - Keep NuMI/MINOS construction on the new schedule.
  - Complete MiniBooNE construction and start operation.
- Accelerator R&D
  - Increase effort, especially on NLC.
- BTeV
  - Do modest R&D and engineering needed to be ready to start construction.
- Infrastructure
  - Reduce backlog of long-overdue maintenance, repair, and pay back Utilities Improvement Projects.

Incremental Analysis: FY2001 - FY2002

	FY2001 Budget	FY2002 Need	Increase Needed
SWF for present personnel	166.7	174.5	7.8
Accelerator operations & maintenance*	23.3	26.8	3.5
CDF/DØ upgrades, offices & computing	9.6	8.0	(1.6)
Run 2b collider upgrade*	1.3	9.2	7.9
Run 2b detector upgrades	0.0	5.2	5.2
NuMI / MINOS	29.2	24.6	(4.6)
MiniBooNE	4.3	3.1	(1.2)
Accelerator R&D*	3.8	10.6	6.8
BTeV (& other experimental projects)	1.4	2.8	1.4
Project management software	0.0	0.8	0.8
Infrastructure (GPP + UIP payback)	5.8	9.3	3.5
Wilson Hall project	3.8	0.0	(3.8)
Other materials and services	24.7	25.6	0.9
Base Budget Required	273.9	300.5	26.6
(with safeguards and security)	276.4	303.0	

* These items include costs for *additional* personnel needed in FY 2002.
All other personnel costs are included in the first row.

FY 2002 Budget

- The whole of the High Energy Physics program needs more funding in FY 2002 to take advantage of the terrific scientific opportunities ahead of us.
  - Accelerator laboratories, user laboratories, and university groups
- At Fermilab, the highest priority items that depend critically on FY 2002 funding level are
  - Tevatron collider and detector upgrades
  - MINOS construction
  - Accelerator R&D

The Central Experimental Questions in 2000

- The Fundamental Scales of Mass and Energy
  - What breaks the electroweak symmetry and sets the electroweak scale of 246 GeV?
  - Is there a supersymmetry that is broken at this scale?
- Neutrinos
  - What is the pattern of neutrino masses and mixing?
- Quarks and CP violation
  - Are all CP violations consistent with a single source?
- Cosmological Dark Matter
  - Do new particles make up a significant component of dark matter?
- Radically New Physics
  - Are there observable effects of large hidden dimensions?

The Fermilab program has experiments that will address all of these questions this decade.

Summary

- We have great opportunities for discoveries ahead.
  - Exploring a new mass region in Run 2
  - An excellent program in the fast-moving area of neutrinos
  - Unique experiments in particle astrophysics
  - LHC physics
  - BTeV (and possibly K) experiments
- We are exploring how to build the next generation of accelerators in an affordable way.

But

- The FY 2002 budget will do much to determine the future of particle physics in the U.S. and at Fermilab.
  - Can we aggressively pursue the opportunity of the Tevatron?
  - Are we able to prepare for the future?