Overview of the Fermilab Research Program

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URA Visiting Committee

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Fermilab Today

- The primary goal of the Fermilab research program is to optimize the scientific output of the particle physics community in the U.S.

The Fermilab research program

Fermilab

- operates the Tevatron program;
  - CDF and Dzero
- operates a unique neutrino program;
  - MINOS with NuMI νs
  - MiniBooNE with Booster νs
- is building up the CMS research program to optimize the advantage to US researchers and to CMS.
- conducts a growing R&D program on the accelerators and detectors that are needed for the future;
- develops excellent particle astrophysics experiments;
- nourishes theoretical groups who work on the issues that drive experimental particle physics.

The Fermilab program 2005

The Weak Scale and the Energy Frontier

- Run II of the Tevatron: CDF and D0
- US-LHC and US-CMS
- Linear collider R&D

Quark Flavor Physics and CP violation

- CDF and D0

Neutrino and Lepton Flavor Physics

- The US accelerator-based neutrino program: MiniBooNE and MINOS
- NOνA and Minerva getting ready for construction
- Advancing design of Fermilab Proton Driver
- Detector R&D: FLARE

Particle Astrophysics and Cosmology

- Sloan Digital Sky Survey
- Auger
- CDMS
- Development of Dark Energy Survey

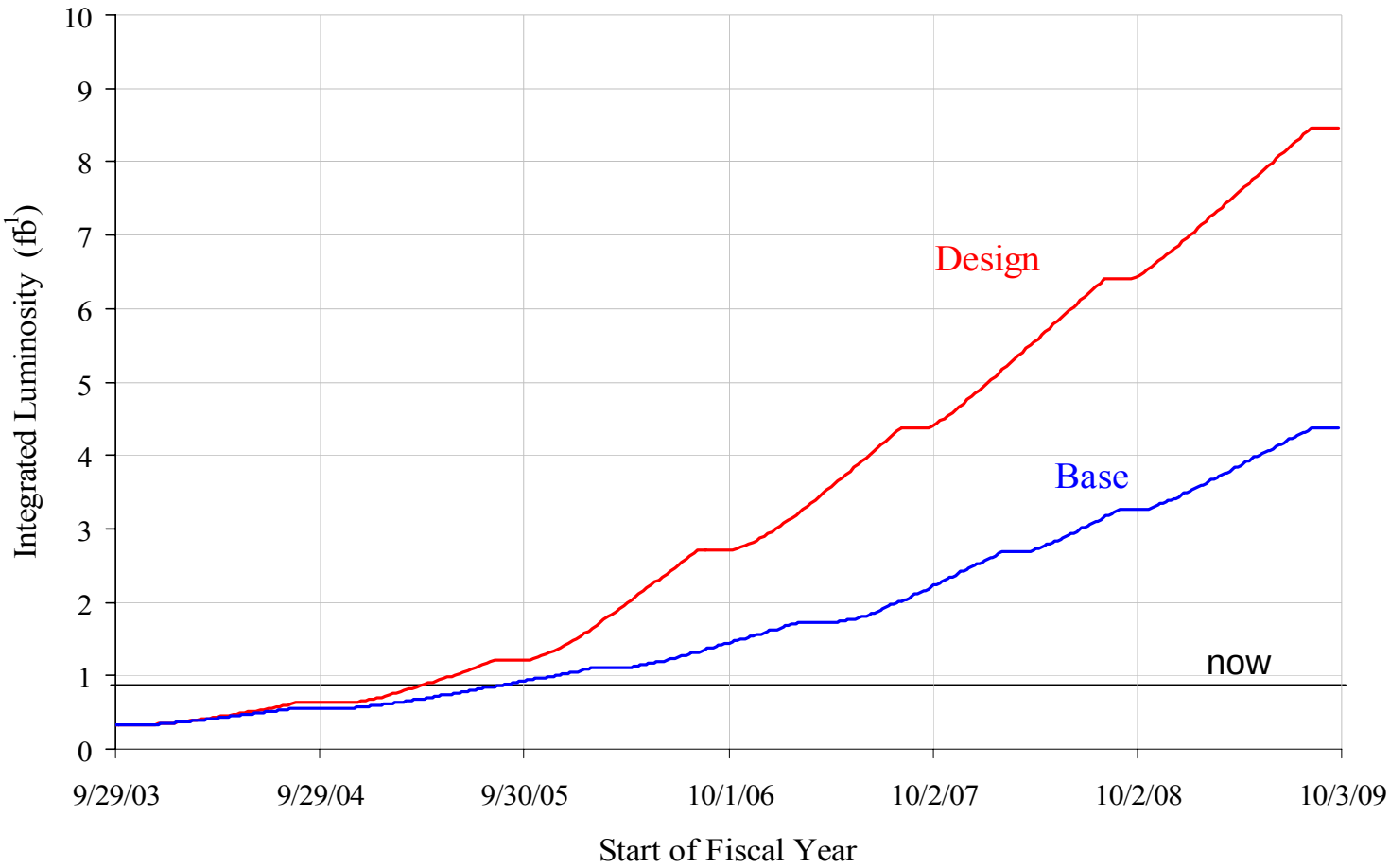
Run II

- The largest part of the Fermilab research program is Run II at the Tevatron.
- Several of the most important areas in particle physics are being addressed only by CDF and DZero right now:
  - Electroweak physics: top and W mass, diboson production
  - Supersymmetry searches
  - B physics: Δm_s & $\Delta\Gamma_s$, B_c, B_s decays
  - Extra dimensions
  - Quark compositeness, high p_T jets
- Published, accepted, and submitted articles on Run II physics:
  - 34 in PRL, 13 in PRD

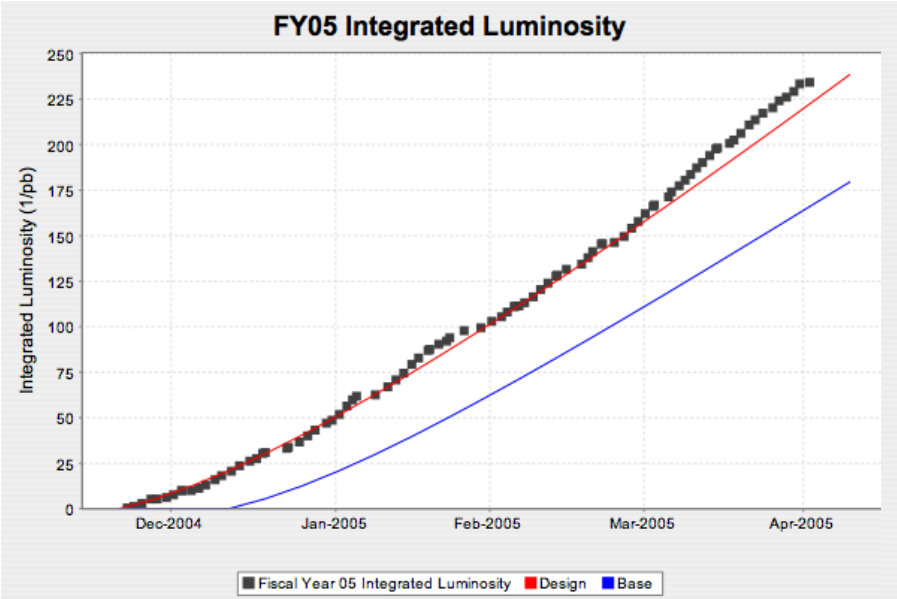
The Run II Campaign

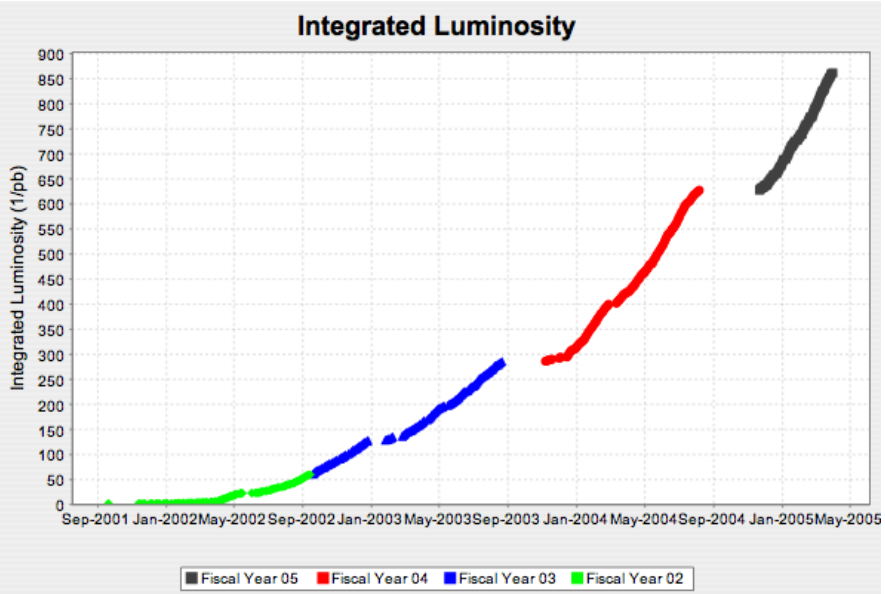
- We are in the middle of a campaign to optimize the science done throughout this period.
  - Organize entire laboratory to support the accelerator effort.
  - Build and install luminosity upgrade projects 2004-2006.
  - Deliver luminosity continuously 2004-2009.
  - Maintain efficient detector operation with modest upgrades.
  - Grow the computer capacity to keep up with the growing data sample.
  - Work with the collaborations to do the best the physics possible with Run II data.
- We are optimizing the science by delivering as much integrated luminosity as possible each year and by operating the detectors and the analysis system as well as possible.

Projected Integrated Luminosity



Run II: FY 2004 Plan and Status





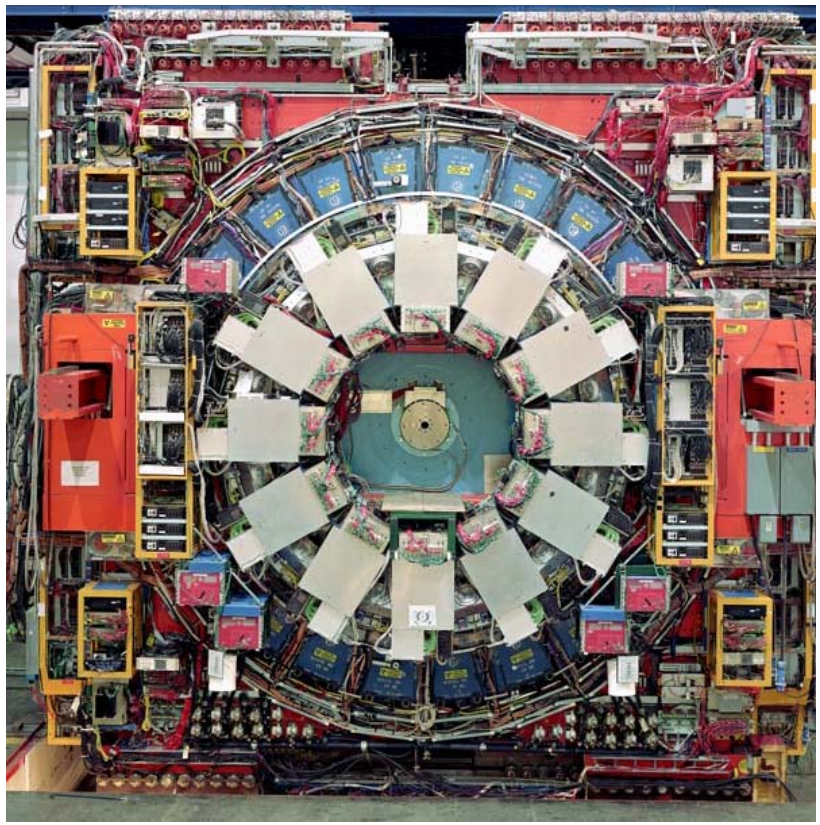
Run II Integrated luminosity ~0.65 fb^{-1} on 10/04; plan ~1.1 fb^{-1} by 10/05; now at 0.9 fb^{-1}

As of 4/19/05, 5 days ahead of the FY05 design curve with 0.24 fb^{-1}.

Record week 3/20-26: 21 pb^{-1}. Record luminosity 3/21: $1.17 \times 10^{32} cm^{-2} s^{-1}$

CDF and D0 at the Tevatron

Two detector facilities, each producing data for a 600-scientist collaboration.

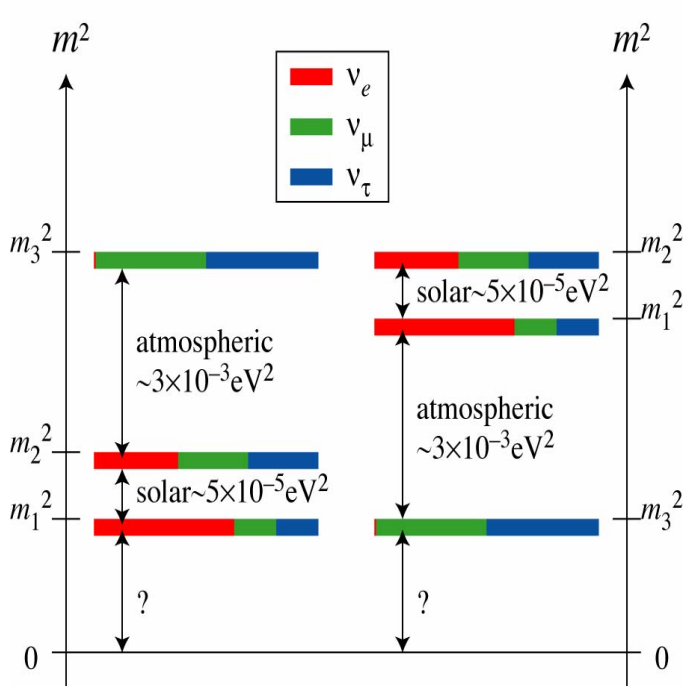


The Neutrino Program

The greatest experimental surprise of the last decade: neutrino oscillations.

- Neutrino oscillations may signal new physics at a much higher mass scale.
- We may be on a path to viewing a new source of CP violation.

- Fermilab is home of the accelerator-based neutrino program:
  - MiniBooNE with Booster Neutrino Beam
  - NuMI/MINOS with NuMI neutrino beam



MINOS

For the atmospheric oscillation

- measure precisely the fundamental parameters of the oscillation
  - Δm^2 to ~10%
  - $\mathrm{Sin}^2\, 2\theta_{23}$ to ~5%
- improved sensitivity to transition of ν_μ to flavors other than ν_τ
  - improved sensitivity to θ_{13}

NuMI-MINOS status

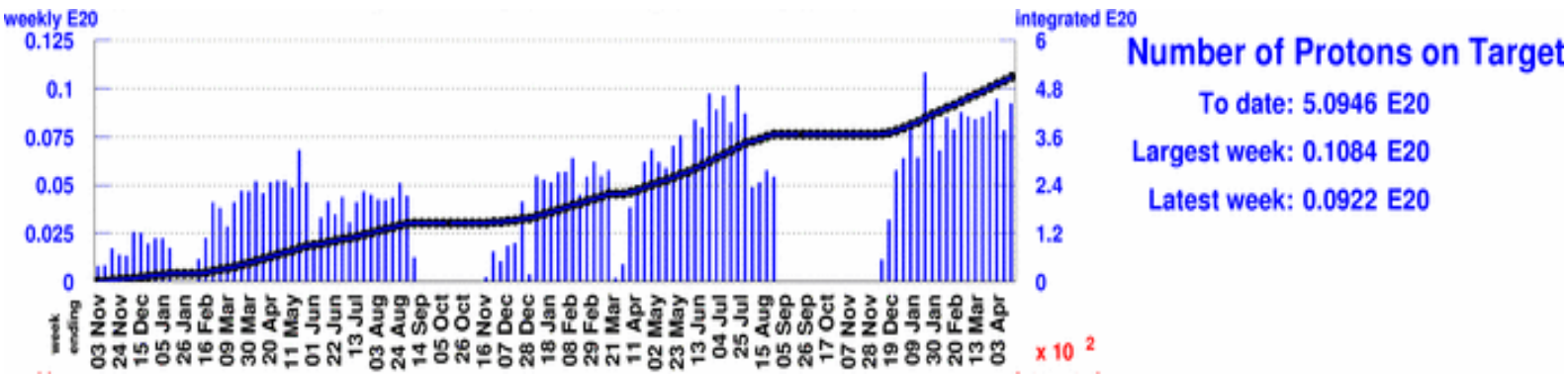
The NuMI construction project is complete.

- MINOS is starting to operate for physics.
  - The initial goal is 2.5×10^{13} protons/pulse @ 0.5 Hz.
  - The near and far detectors are up and running.
- We are integrating the NuMI beam into routine operation of the accelerator complex.
  - fix target water leak
  - run full intensity

1/21:The first event in the near detector
3/20: The first event in the far detector

MiniBooNE

- MiniBooNE is designed to follow up on the LSND evidence of a $\nu_\mu - \nu_e$ oscillation at high Δm^2.
  - If MiniBooNE confirms LSND, it will change the worldwide neutrino program overnight.
- The beam and experiment are running well.
  - Installed new horn during shutdown.
  - passed 5×10^{20} protons on target in April. This was a very demanding milestone.
- The result on ν_e appearance will be known by the end of 2005.



NOνA

- We have granted stage 1 approval to NOνA, a large off-axis neutrino experiment using the NuMI beam. It is designed to provide
  - the most sensitive search for $P(\nu_\mu \rightarrow \nu_e)$ at the wavelength of atmospheric oscillations;
  - a good measurement of θ_{13} if it is not too small; and
  - a unique capability to resolve the mass hierarchy.
- It will be the most powerful experiment in the world for advancing our understanding of neutrino properties.

- The APS neutrino study "The Neutrino Matrix" recommends a comprehensive U.S. program to complete our understanding of neutrino mixing, including "a timely accelerator experiments with comparable $\sin^2 2\theta_{13}$ sensitivity (0.01) and sensitivity to the mass hierarchy through matter effects."

That experiment is NOνA

Minerνa

- We have also given stage 1 approval to Minerνa, a smaller neutrino experiment designed to operate in the NuMI beamline at short baseline. It is designed to provide measurements of exclusive neutrino cross sections at energies crucial for oscillation experiments.

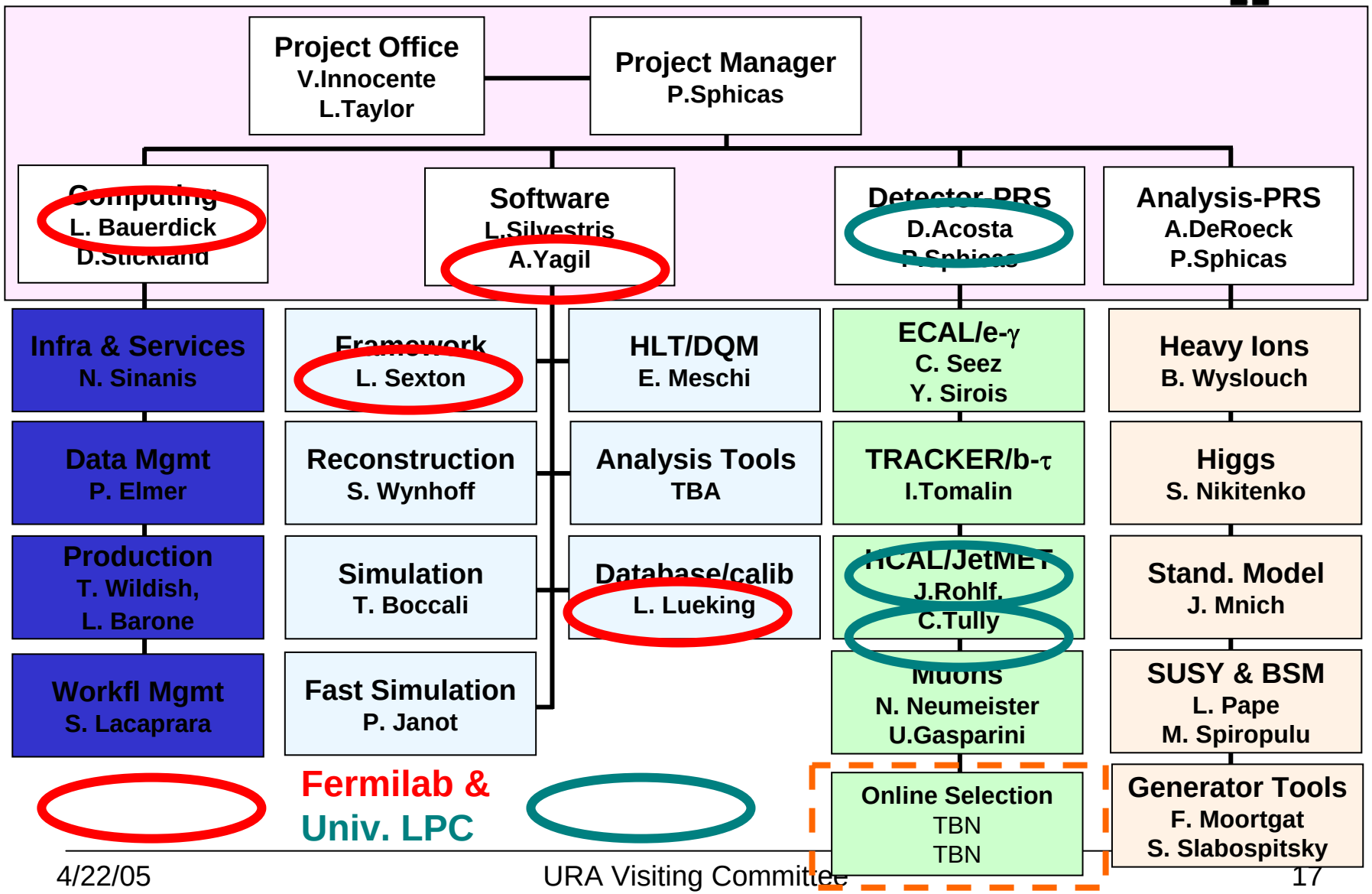
- The existing measurements come from bubble chamber experiments in the 1970s.

CMS at Fermilab

- Fermilab will play a critical role in enabling U.S. scientists to take full advantage of it.
- The critical features for a world-leading research center on LHC physics are
  - the computing infrastructure,
  - the expertise of the people involved,
  - most of all, the concentration of intellectual talent leading the research.

The new LHC Physics Center on the 11th floor. This will be the research home for physicists from many institutions working on CMS physics.

LPC & International CMS

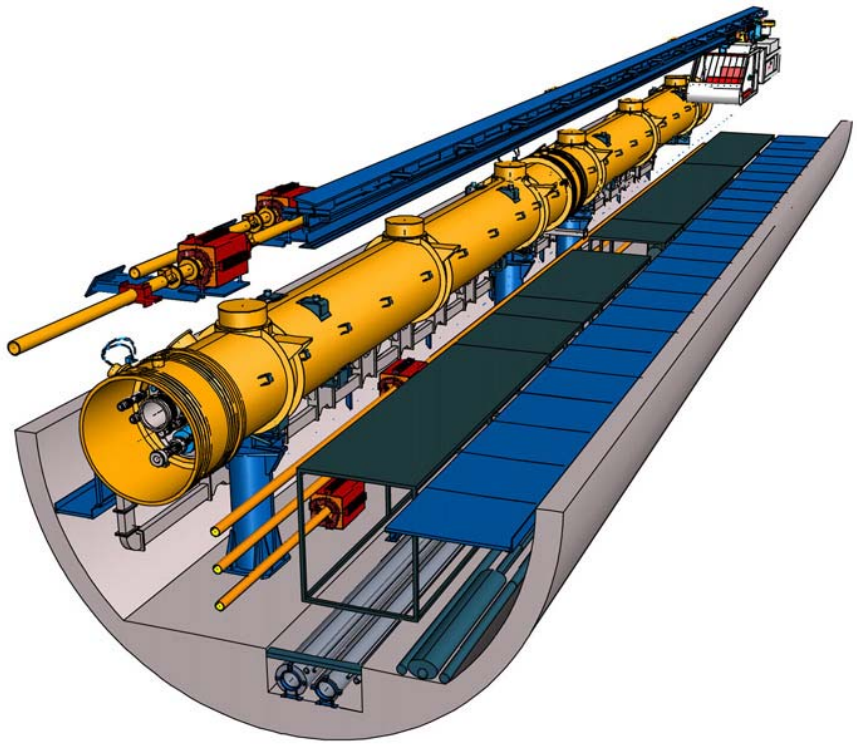


LHC Accelerator Program

- The US-LHC accelerator project continues to finish good magnets and send them to CERN.
- Fermilab is also the host laboratory for the LHC Accelerator Research Program (LARP).
  - Steve Peggs has a Fermilab appointment as program manager for this effort.
  - US accelerator physicists will on commissioning the LHC
  - US cryogenic magnet experts will work to develop higher-strength quadrupoles using new SC materials to increase luminosity
- We are studying the design of a remote operations center serving both LARP and US-CMS.

The International Linear Collider

- The revolutionary discoveries at the LHC will focus additional attention on the science program of the International Linear Collider



Fermilab and the ILC

- We stated to the International Technology Recommendation Panel:

  "In the event of a cold decision Fermilab would be ready and able to assume the leadership role in establishing a U.S. collaboration to push the SCRF development under the aegis of an international LC organization."

- We have a responsibility and a strong interest to follow through on this commitment.
- We have made a lot of progress in about 6 months.
- The centerpiece of the superconducting rf development will be the Superconducting Module & Test Facility.

Fermilab and the ILC

- We were limited to $3 M of support for linear collider per year, 2000-2004.
  - –This was fixed in our budget document, not a Fermilab decision.
- We also were host to a small but effective program in superconducting rf development.
  - –TTF involvement
  - –Fermilab NICADD Photoinjector
  - –CKM beam line development
- With DOE's concurrence, we were able to redirect both of these programs into ILC R&D within the tight budget constraints of FY 2005. We immediately assembled a team that can be immediately redirected to support the SCRF work.
- We will need to increase this further to keep ILC moving at the desired rate in '06 and '07.

Fermilab as a site for the ILC

- We believe Fermilab has several advantages as a site.
  - a site nearby an operating HEP lab
  - large supply of trained and talented people
  - very good geology
  - modest power and construction costs
  - convenient to international airport
- Ray Orbach has announced that Fermilab will be the U.S. site advanced to the Global Design Effort.

R&D on Future Accelerators

- We are doing accelerator R&D aligned with the future facilities called out in the Fermilab Long-range plan and the SC facilities plan.
  - LHC luminosity upgrade on LARP
  - International Linear Collider
  - Fermilab Proton Driver
- We do a very small amount of R&D toward the longer-term future.
- We are also working with university programs to provide opportunities for training students.
- The imperatives of maintaining the world-class operating program under flat budgets reduced accelerator R&D to too low a level. We are now reversing that trend.

Experimental Astrophysics

- The experimental particle astrophysics efforts are making excellent progress.
  - The Sloan Digital Sky Survey is producing important discoveries continuously. The extension is now funded.
  - The Cryogenic Dark Matter Search (CDMS) has first results from a short run with one tower in Soudan. They are leading the world already.
  - The Auger cosmic ray observatory is the largest operating cosmic ray array. Construction of the full observatory continues in Argentina.
  - The Dark Energy Survey collaboration is growing and is well along in developing a funding plan.
  - There is a small R&D program on JDEM.
- On November 1, we established the Particle Astrophysics Center with Rocky Kolb as head.
  - unifying experimental and theoretical astrophysics

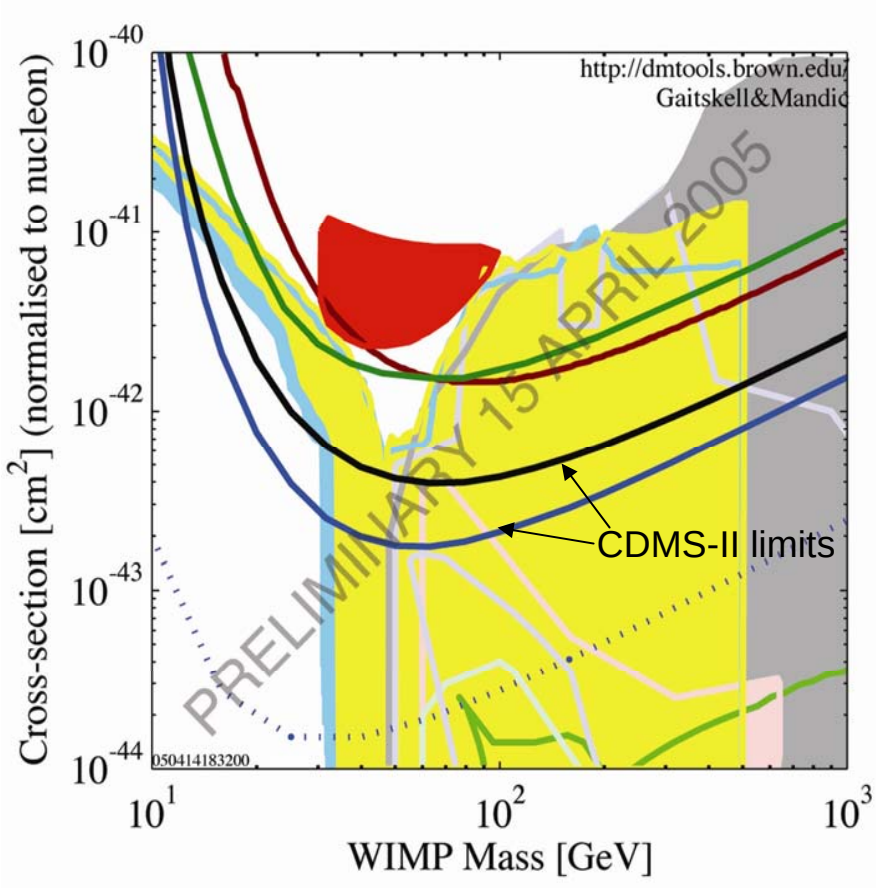
Observing the dark matter halo with CDMS-II

Cryogenic Dark Matter Search detectors operate at T=20 mK.

- They measure ionization energy and recoil energy separately to reduce dominant radioactive backgrounds.

CDMS II has completed their first two physics runs at Soudan.

- reduced neutron background from ~1/kg/day to ~4/kg/year
- world's best limit by x10



Theoretical Particle Physics

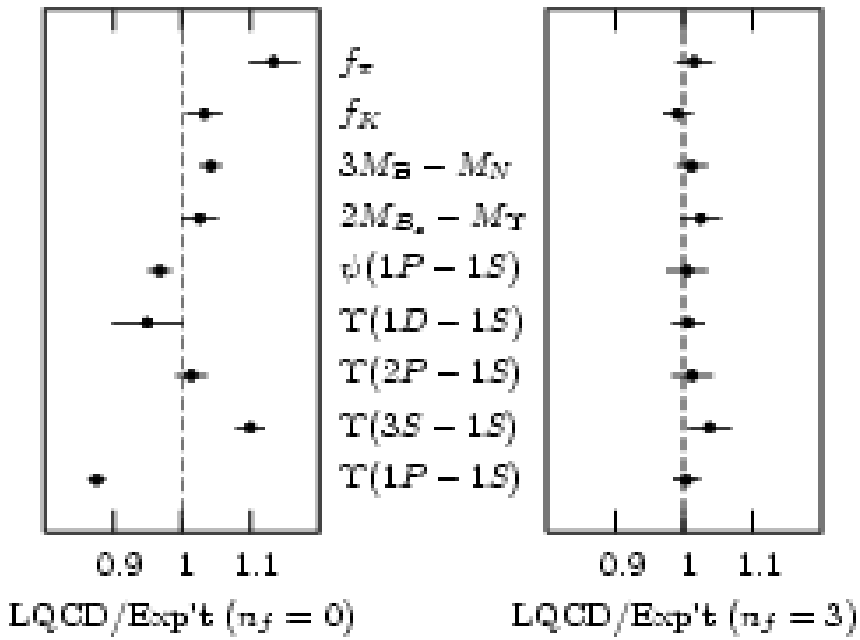
- The Fermilab particle theory group is doing excellent theoretical research related to all of the principal areas of experimental particle physics.
  - They do very well at training theoretical particle physicists working on problems relevant to the experimental program.
- The strong lattice QCD group has teamed with university groups in proposing to DOE a coordinated lattice QCD strategy for the U.S.
- The group has an important role in planning the U.S. program in particle physics.
  - Fermilab PAC and Long-range Planning Committee
  - SLAC EPAC
  - APS Neutrino Study co-chair, DPF chair-elect
  - HEPAP ILC subpanel co-chair
  - Kavli Institute of Theoretical Physics advisory board

Theoretical Astrophysics

- The Fermilab theoretical astrophysics group has been a leader in research at the overlap of particle physics, cosmology, and astrophysics.
  - NASA renewed the grant that partially funds this group.
  - Members of the group directly participate in the SDSS science, as they will on JDEM.
- The group has an important role in planning the U.S. program in astroparticle physics.
  - Fermilab Long-range Planning Committee
  - NASA Space Science Advisory Committee; Chair, Structure & Evolution of the Universe Subcommittee
  - SLAC Scientific Policy Comm.
  - Executive Committee, APS-Div. Astrophysics

Computing at Fermilab

- Fermilab is a leader in the development of the large-scale computing facilities needed for particle physics.
  - Run II computing project was a success.
  - We are planning the computing evolution for the rest of Run II.
- Fermilab is also leading the US-CMS computing and software effort.
- Other special projects
  - SciDAC
  - Grid projects
  - Lattice QCD project



Physics results from LQCD collaboration

The last year at Fermilab

- Run II
  - Increased Run II integrated luminosity from ~0.45 to 0.9 fb^{-1}.
  - Increased record luminosity from 0.7 to 1.17 x 10^{32} cm^{-2} s^{-1}.
  - Integrated Recycler into routine operations.
  - Set new records for stacking rate using slip-stacking.
  - Installed the e-cooling apparatus into the Recycler.
  - Produced a lot of physics results
- Neutrinos
  - Completed NuMI project and celebrated.
  - Commissioned NuMI beamline.
  - Observed first neutrinos in MINOS near detector.
  - Increased MiniBooNE total POT from 2.2E20 to 5.1E20.
  - Installed Replacement MiniBooNE horn.

The last year

- External 120 GeV beams
  - Operated MIPP experiment measuring central production of hadrons.
  - Operated Main Injector test beam.
- Experimental astrophysics
  - Operated CDMS-II in Soudan, produced results that are best in the world, installed more detectors.
  - Built toward full Auger while taking data with largest operating array.
  - Operated SDSS and made important discoveries.
  - Developed Dark Energy Survey.
  - Did some work on the Joint Dark Energy Mission.

The last year

- We published the long-range plan in May, 2004 and took several immediate steps to implement it.
  - advanced ILC R&D and advanced ILC organization.
  - started SCRF test facility, SMTF.
  - did Proton Driver design study and technical review.
  - did Proton Driver physics study.
  - developed NOνA and smaller neutrino experiments
  - established LHC physics center (LPC).
  - launched LHC accelerator research program (LARP).
  - established Center for Particle Astrophysics.
  - are reacting to cancellation of BTeV in FY 2006 budget request

Program Planning and The Physics Advisory Committee

- We make good use of the Physics Advisory Committee in determining the scientific program of the laboratory.
- The Fermilab PAC does the most thorough review of experimental proposals of any similar committee in US HEP.
  - review by a technical committee
  - presentations and questions through several PAC meetings leading up to a presentation meeting in April followed by a weeklong retreat at Aspen
  - carefully written reports produced at the end of each meeting
  - extraordinary dedication of an excellent committee

Fermilab's core capabilities

1. Construction and operation of accelerator facilities for particle physics
2. Construction and operation of experimental facilities for particle physics and particle astrophysics
3. Research, design, and development of accelerator technology
4. High-performance scientific computing and networking
5. International scientific collaboration

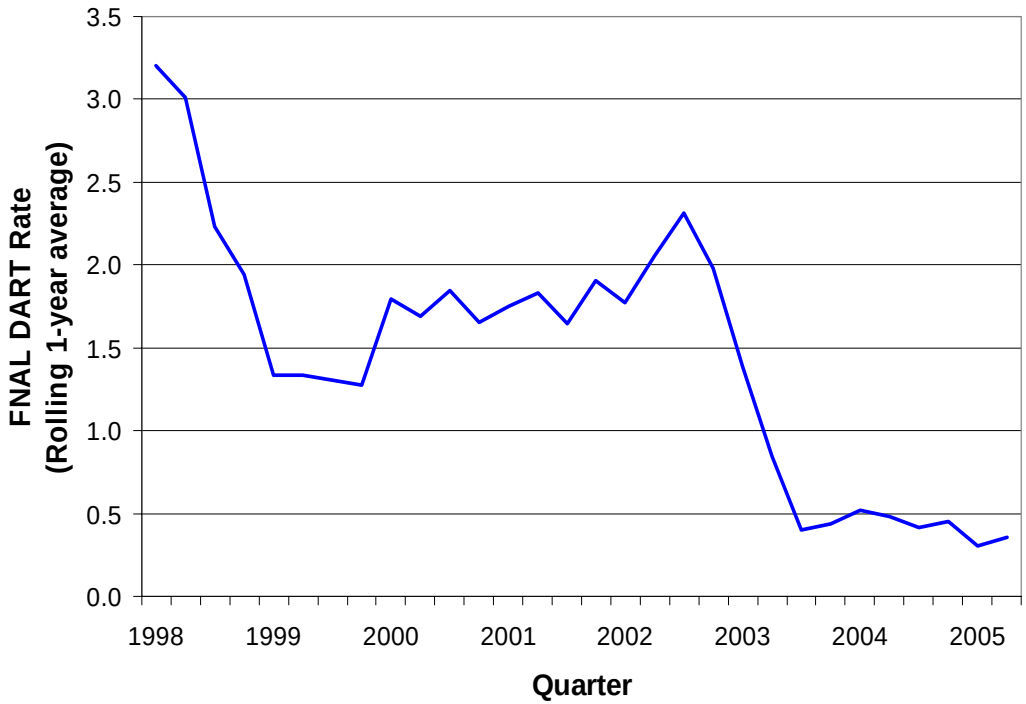
Project management

- We have been working on three construction projects in the $100-200 M range.
  - NuMI is complete.
  - US-LHC is getting close to completion.
  - US-CMS is well along, but some critical subprojects are still ahead.
- All of these have been technically very difficult projects.
- We have done well at managing those projects over the last three years, and the Lehman reviews have been very positive.
  - The Project Management Oversight office is important in this success.
  - We have added rigorous director's reviews, to make sure that we recognize problems early and move to correct them.
  - You should refer to the material and reports from recent DOE project reviews.

Safety

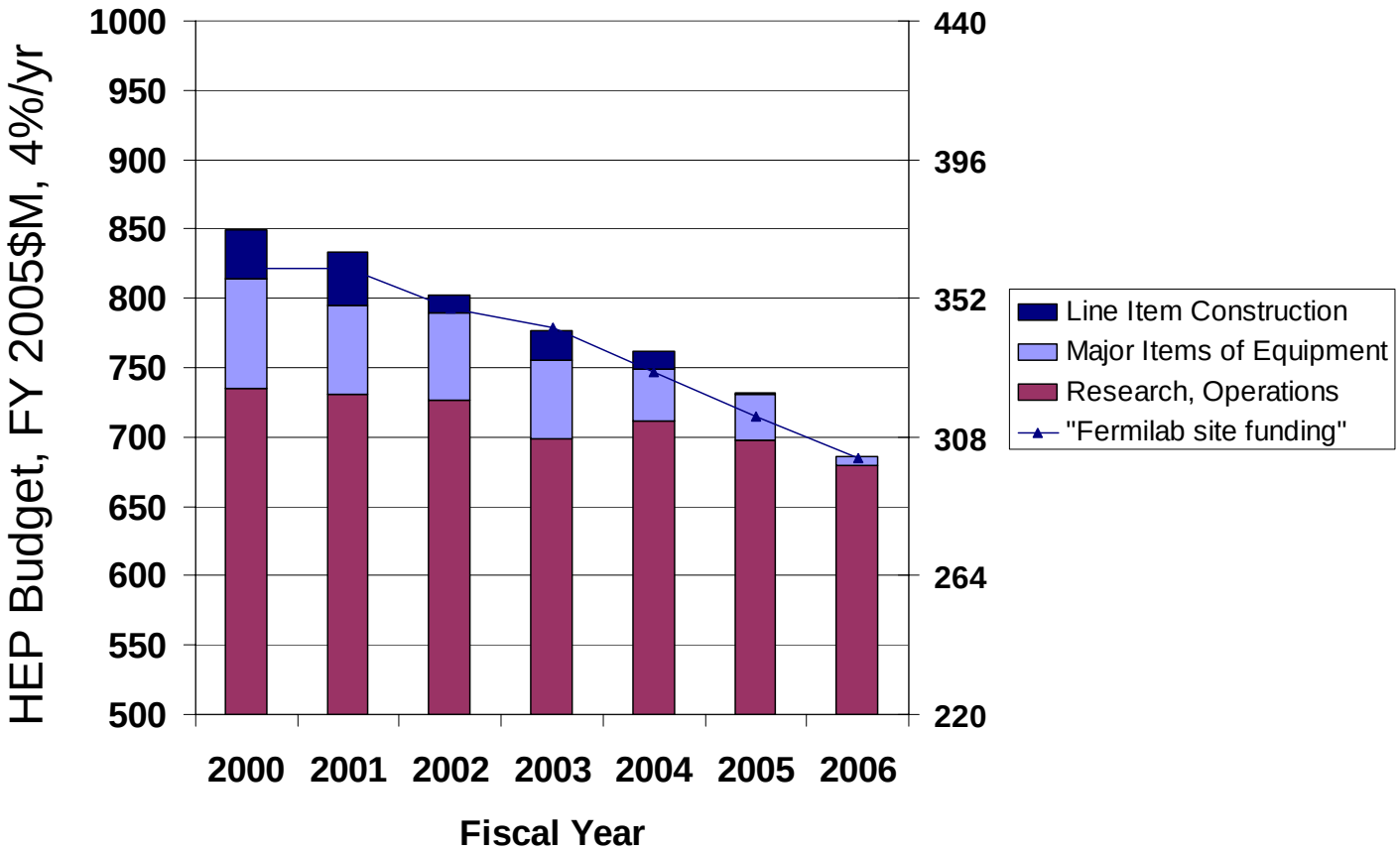
The laboratory management and staff have embraced Integrated Safety Management and have worked hard to bring the accident rates down.

- We have also made progress on integrating contractors into the safety culture we maintain.



- We have reduced the DART (Days Away, Restricted, and Transferred) rate for FY 2003 to a record low of 0.4 per 100 worker-years.

HEP and Fermilab Budget 2000-2006, corrected at 4%/yr



This describes the contraction in the field over this period.

FY 2005 Budget Strategy

- Redirect resources from
  - NuMI project
  - LHC and CMS projects
  - BTeV R&D and preconstruction effort
  - Muon and NLC R&D (small amounts)
- Redirect resources to
  - ILC R&D
  - LARP and CMS research program
  - MINOS operations
  - Proton plan
  - NOνA and Proton Driver
  - SMTF
- Manage this with ~$10 M less in real effort.
  - Reduce staff by ~90 people + attrition.

FY 2006-7 Goals

- Run II
  - Deliver 2.9(1.2) fb^{-1} design (base).
  - Complete Run II upgrade.
  - Operate experiments reliably; analyze data; produce results.
- Neutrinos
  - Deliver to MINOS >2E20 POT/yr ; produce results.
  - Execute Proton Plan.
  - Build SMTF.
  - Publish MiniBooNE result; decide future beyond FY 2006.
- LHC
  - Commission accelerator
  - Commission detector; develop research program.
- ILC
  - Complete/test first US ILC cryomodule.
  - Build SMTF.
  - Establish ILC test beam effort.
- Particle Astrophysics
  - Complete construction of Auger South and operate.
  - Operate CDMS II and prepare CDMS III.
  - Build much of DES.

FY 2006-7 Flat Budget Strategy

- Redirect resources from
  - Run II accelerator and detector upgrades
- Redirect resources to
  - ILC R&D
  - NOνA
  - Proton Driver R&D
  - SMTF
- Manage this with ~$20 M real effort.
- Make a strong case for a better budget than flat.

The U.S. HEP program: experiments operating in 2010

1. LHC
   - Atlas
   - CMS
2. Lepton flavor
   - MINOS
   - (MECO)
   - SNO, other solar expts
   - (NOvA, Reactor, $\beta\beta(0\nu)$, Minerva)
3. Quark Flavor
   - (KOPIO)
4. Particle Astrophysics
   - Auger South & (North)
   - GLAST
   - Ice Cube
   - Veritas
   - (Super)-CDMS
   - (DES)

Fermilab is host laboratory of those in red.

(Experiments without funding approval)

Major DOE reviews

- Major annual reviews of the laboratory by the DOE
  - OHEP Budget meeting
  - Operations Review
  - Business Plan Review by Office of Science
  - Annual Program Review
- The Operations reviews covered
  - Accelerators
    - Run II and fixed target operations
    - Run II upgrade program
    - Proton source improvements
  - Detectors
    - Operations of CDF, D0, and neutrino experiments
    - Computing for experiments
- We are presenting the rest of the laboratory program in the Annual Program Review.
- This review is closely matched to the Annual Program Review.

Summary

- Fermilab has a broad physics program matched to the most compelling issues in particle physics.
- Fermilab has a central role in the future of US HEP.
- We plan carefully to get the optimal balance of
  - the presently operating program
  - building the program for the intermediate future
  - getting ready to build the facilities for 2020 and beyond.
- We are starting to invest more in ILC and neutrinos.
- We must plan to do this in an environment in which budgets are flat and staff size is shrinking.
  - But to have a strong future, HEP needs to do better than flat funding.