US

LHC

Large Hadron Collider Update

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US CMS Program Manager

July 25, 2003

Outline

- Construction Status
  - ATLAS
  - CMS
  - Accelerator
- US LHC Research Program (RP)
  - SoftWare and Computing (SWC)
  - Maintenance and Operations (M&O)
  - LHC Accelerator
- US LHC Physics the First "Year"
- LHC Long Term Program – LHC Upgrades and Physics Reach.

US LHC hopes to make the status of the LHC program a regular feature of HEPAP meetings in future.

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ATLAS - the Barrel Toroids

Coil casing, 7 out of 8 at CERN

The complete delivery of these components is expected by end of Aug 2003

Cryostat vacuum vessel, 6 out of 8 delivered

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LAr Forward Calorimeters

The three modules for the first end-cap side were shipped last year to CERN and cold-tested, they are ready for a beam calibration in June 2003

The final integration work for the second end-cap has started as well

FCAL module during insertion of W rods

Cold test of the three FCAL modules for the first side

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Tile Calorimeter – April, 2003

Insertion of module 64

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ATLAS UX Cavern - BO

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CMS - Experimental Caverns

Service : USC55 ready Jan 04

Experiment: UXC55 ready J 04

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The Magnet Yoke

- Waiting for the cavern to be ready, CMS (compact design!) can be fully assembled, tested, and commissioned in the large surface hall SX5.
- Wheels and disks of the Yoke will be instrumented with Muon detectors in SX5.
- Metallic structures for racks are ready. Piping work for gas and cooling has started on the yoke.

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HCAL : HB and HE

HB complete,

install onboard electronics by Q2-04

HE-1 re-installed on YE-1 in Jan/Feb 2003.
Mount HE+1 by end of 2003,

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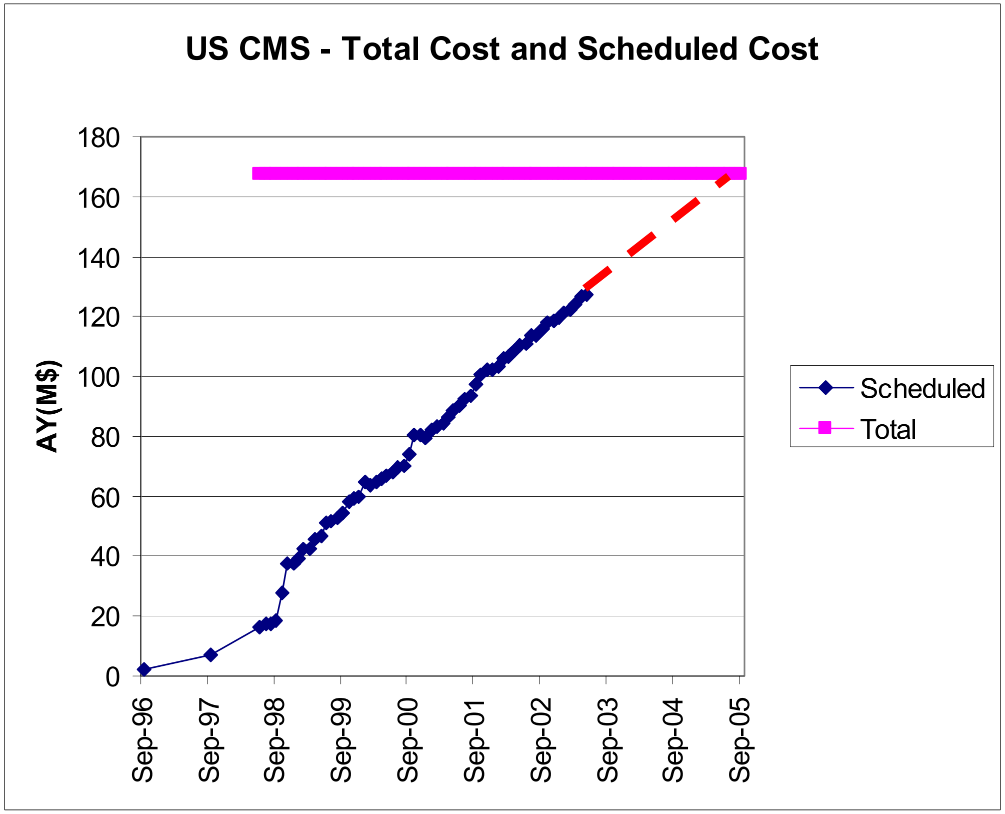
The Endcap CSC

Installation of CSC chambers has begun. Commissioning and “slice tests” with HCAL start at the end of CY03 after the 25 nsec Test Beam data taking. Portable Trigger and DAQ will also participate. Commission before final installation to get to the Physics asap.

US LHC Construction Projects



The 531 M$ investment has been wisely used. The Projects are on schedule (for 2005 ~ completion) and on budget. The US LHC Projects are progressing steadily toward completion.

Lehman – Detector Review – May 2003

The Review Committee feels that the U.S. CMS management has done an excellent job in carrying the construction project close to completion. Keeping such a complex enterprise on schedule and well within budget is a very significant achievement.

The Committee feels that separating the completion of the construction project into two parts was very wise in that it separates the construction completion of the project mostly under U.S. control (CD-4a) from the installation (CD-4b) that is much more correlated to the overall CERN schedules.

The U.S. CMS management should be given high accolades for their contingency experience of this project. The committee endorses the plan to keep a 50% contingency to close to the end of FY 2005 and 100% beyond.

The U.S. CMS management should also be complimented for the initiation of the slice tests, which is a very sensible use of the time window opened up by the slippage of the overall LHC schedule.

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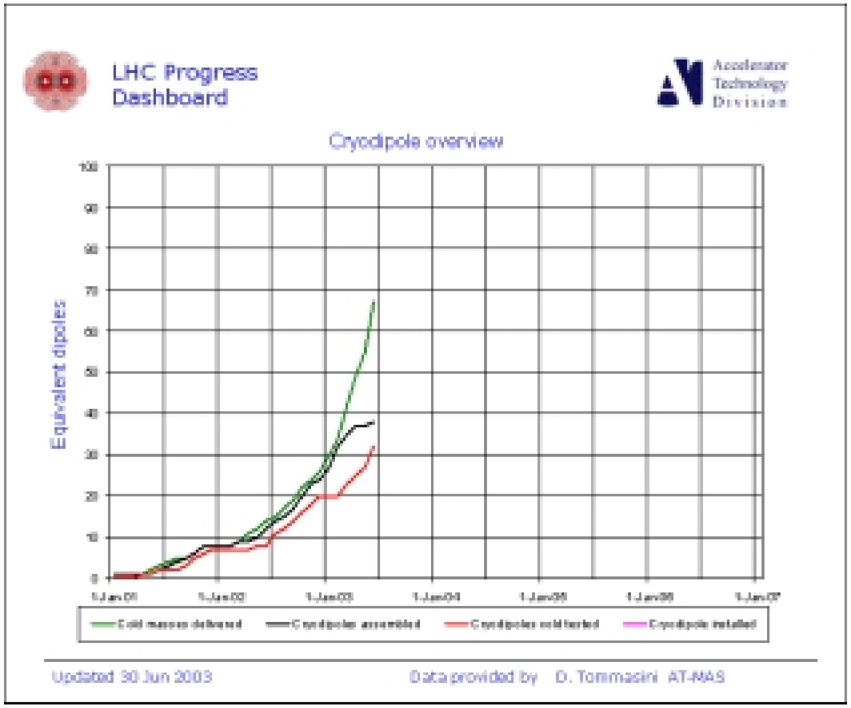
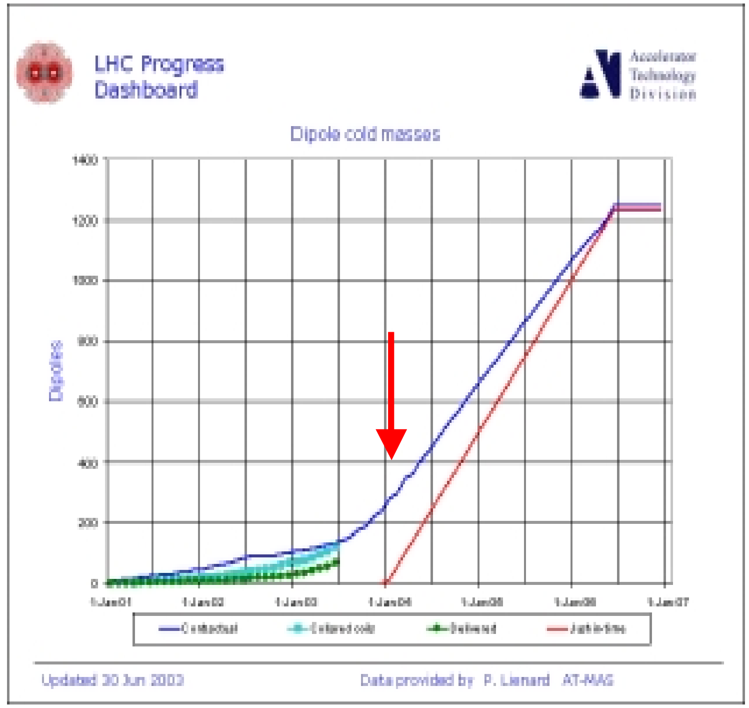
When Will the LHC Run?





Civil construction is ~ done. Cable is now a solved problem. The LHC schedule is ~ the dipole schedule. It is too early to say. By the end of CY03, we should have a good idea of the (steady) rate of delivery. At that time the date for first beam can be estimated with much more confidence. For now, Fall 2007 is the date for first Physics data.

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US LHC Accelerator

BNL – Beam Separation Dipoles

Three of 20 beam separation dipoles have been delivered to CERN, the 4th is in transit.

Dipole production is expected to be complete by the end of this year, and all magnets tested and shipped by next spring.

First BNL dipole at CERN – and the first SC magnet accepted by CERN for installation in LHC.

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US LHC Accelerator
FNAL – IR Quadrupoles

Ten of 18 quadrupole magnets are complete – 2 have been tested with excellent results. Corrector issues with CERN are nearing resolution.

Quadrupole production is expected to be complete by the end of next year, and all magnets tested and shipped by spring 2005.

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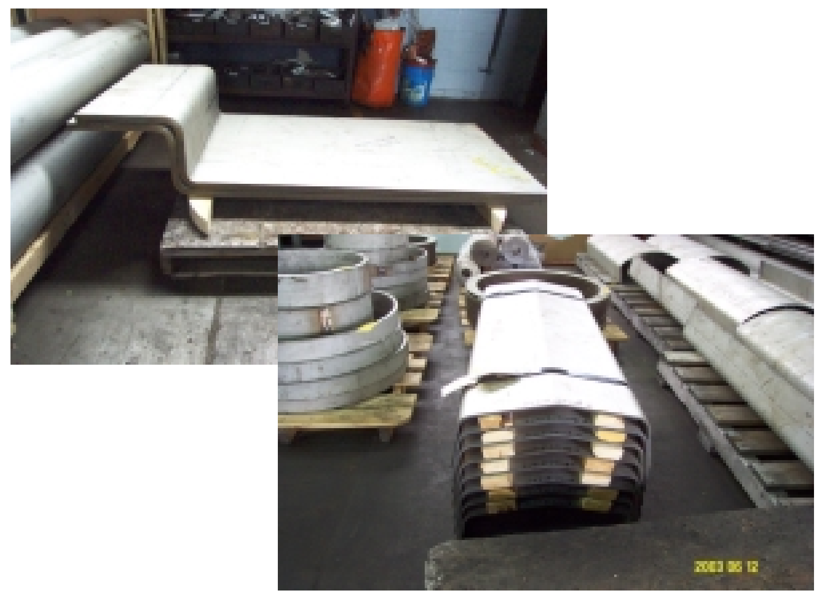
US LHC Accelerator
LBNL – Absorbers and Feedboxes

Four single aperture absorbers complete.
Four twin aperture absorbers to be completed in August.

All absorbers will be shipped to CERN by September.

Feedbox fabrication has begun at Meyer Tool (Oak Lawn, IL).

First of 8 feedboxes to be completed in about a year.
Last feedbox to be shipped summer 2005.



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US Role in the LHC Program

- The US is investing 531 M$, plus the efforts of many talented HEP physicists, in the LHC. The NP community may join soon.
- US physicists have achieved leadership roles in detector construction (e.g. R. Loveless – CMS ME), software and computing (e.g. D. Stickland – CMS SWC), and high- field superconducting quadrupole construction.
- It is essential to capitalize on that investment by ensuring that US physicists also play a leadership role in the analysis and publication of LHC data.

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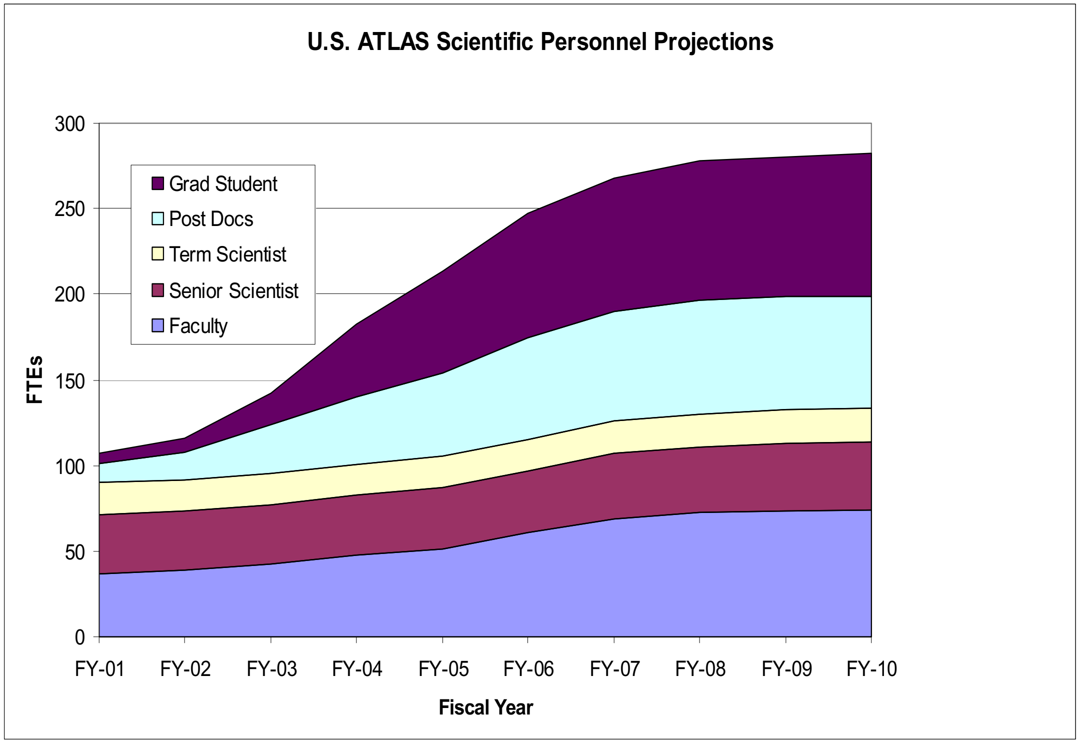
Scientific Effort on ATLAS



There is a large US ATLAS collaboration at present. The US ATLAS effort will ramp up by a factor ~ 2 by FY07 in anticipation of first LHC beam. US LHC Collaborations are committed to doing the Physics.

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Planning for the Physics

- The LHC schedule has slipped ~ 2 years. The US has maintained its schedule to complete in ~ 2005. This gives us a head start on early physics.
- SWC has already begun because U.S. physicists contribute to insure participation in the physics. The involvement is driven by the desire to do physics on day 1. In addition, considerable time is required to create and deploy the new, absolutely necessary Grid architecture.
- M&O has begun as needed in order to commission detector and accelerator systems built and delivered by the US. Again, we want to commission the detector to be ready for physics (for example a SUSY search) immediately after beam arrives.

LHC – Computing Grids

The IT tools developed for LHC physics analysis are and will be vital to the advancement of global science. Grid computing will make a major impact in many areas of business and commerce. The leading role of LHC was recognized in the HEPAP Subpanel Report.

The inherent advantages of coherently operating geographically distributed and disparate resources is becoming an important issue for many scientific disciplines as well as industry, where the Grid is seen as a strategic framework for business operations and commerce. As a result, research groups and industry in the United States, Europe and Asia are undertaking a broad array of Grid research and technology development efforts. Particle physicists in these regions have taken a leading role in defining a unifying architectural framework and in deploying a common multi-continent Grid laboratory, including a multi-Gigabit/second link between the United States and Europe, in partnership with other disciplines. The scale of this laboratory, which has a large focus on LHC computing, is expected to greatly advance progress in Data Grid technologies.

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Computing & Core Software

2003 Milestones

- July: Start GEANT4 production
- Sept: Software baseline for DC04

2004 Milestones

- April: DC04 [50M Events] Done
  Grid for 25% of LHC 1st Year Rate
  April: First Draft Computing TDR
- Oct: Computing TDR Submission

2005 Milestones

- Dec: Physics TDR Submission

Deployment of LCG-1 in FY2004 and Data Challenges for ATLAS and CMS.

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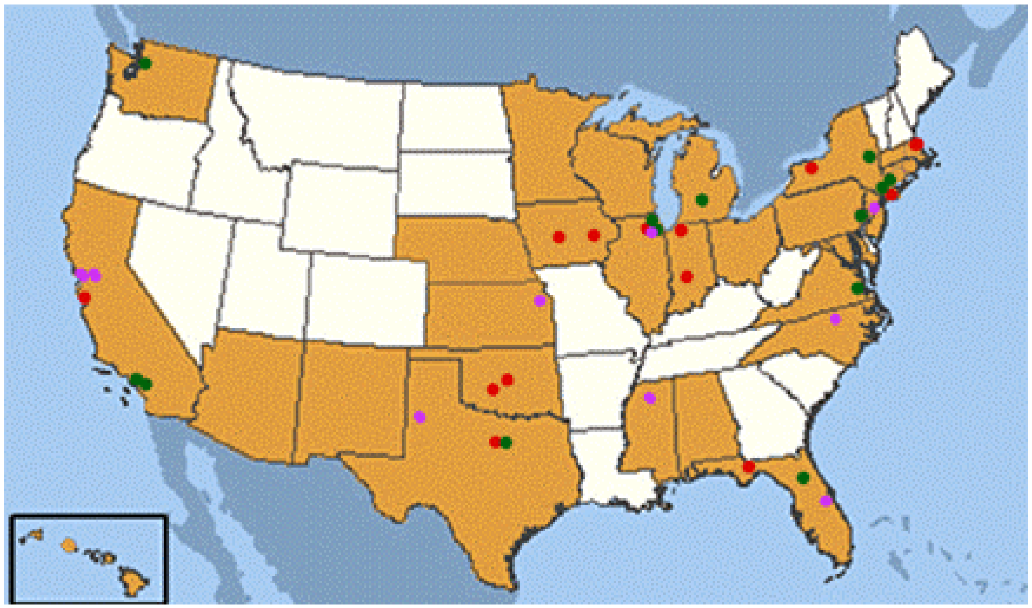
US LHC – Education and Outreach



US LHC is very active in Education and Outreach work. Examples are Research Experience for Undergraduates (REU), Research Experience for Teachers (RET) , and Quarknet (third year, 36 centers in the US)

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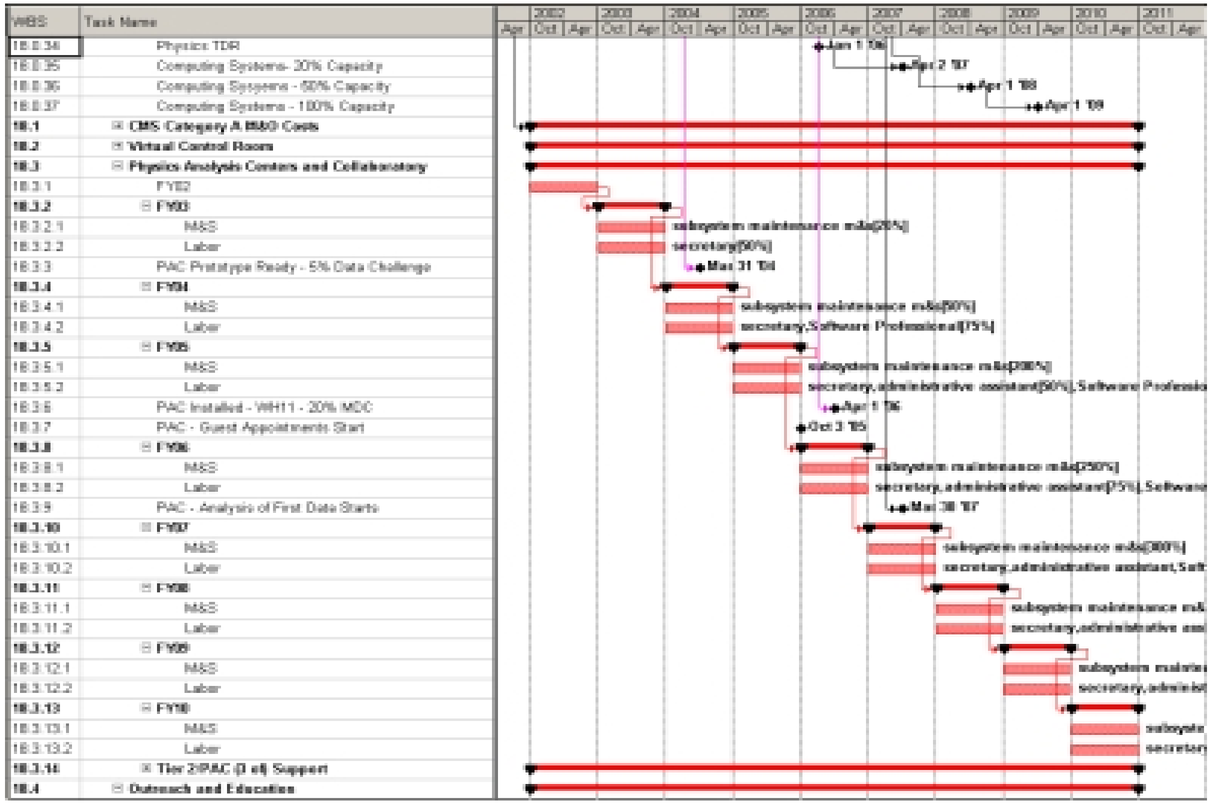
LHC Physics in the US



In US CMS, planning is in place for a "collaboratory" or virtual laboratory. Elements are Virtual Control Room (commissioning, shifts) and Physics Analysis Center (teleconf, analysis groups). This support goes directly and solely to US HEP physicists.

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M&O Review – April, 2003

U.S. CMS has prepared a comprehensive M&O proposal. The proposal addresses the current understanding of the U.S. M&O responsibilities including activities that are funded through a common fund managed by CMS and those that are in-kind contributions from the U.S. groups. U.S. CMS has also sought efficiencies in resources and efforts, e.g. plans to use technician pools and plans for a vertical slice test to maximize commissioning benefits and results.

The Physics Analysis Center (PAC) and Virtual Control Room (VCR) are important concepts worth pursuing with the collaboration.

U.S. CMS vertical integration of the HCAL and EMU efforts has made the M&O planning particularly coherent. As mentioned, the planned vertical slice test will be a tremendous asset and an important ingredient for CMS commissioning.

In conclusion, the committee was impressed with the quality of the U.S. CMS M&O proposal. The proposal is adequately detailed to support an evaluation that the M&O needs defined over the next few years are justified.

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US LHC Accelerator Research Program

- The U.S. labs can play an important role in speeding startup, bringing LHC up to design performance, and performing R&D for a luminosity upgrade, thereby maximizing the physics return on our large national investment.
- The LHC will be the frontier high energy accelerator, offering forefront opportunities for advanced accelerator physics and technology research and development.
- The US-CERN collaboration on LHC has been and will continue to be essential to advancing international cooperation in high energy accelerators, which will be crucial to the future of our field.

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LHC Accelerator RP Lehman Review

EXECUTIVE SUMMARY

This report summarizes the conclusions of the review of the proposed LHC Accelerator Research Program conducted on June 10-11, 2003. The program is intended to exploit the technology and experience developed in the current LHC Accelerator Construction Program by teams at three Department of Energy High Energy Physics laboratories. The Committee found the proposed work plan was sound, made good use of the personnel at the three labs, and moved the accelerator technology base of the United States in a positive direction. The committee endorsed the program and recommended funding at the guidance levels consistent with the specific recommendations within this report.

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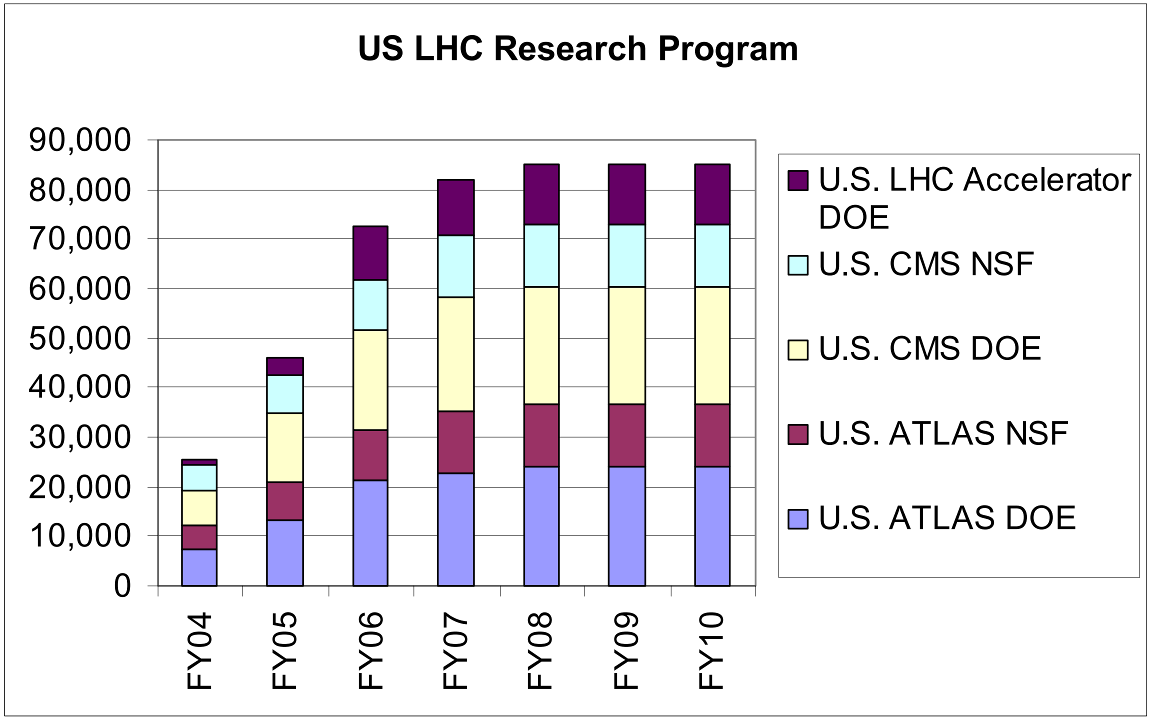
RP – Budget Authority



There was an M&O review by an "Evaluation Group" in April, 2003. The recommendation was to begin to report to the BA "baseline" for the US LHC Research Program. The Research Program contains SWC, M&O and R&D for Upgrades.

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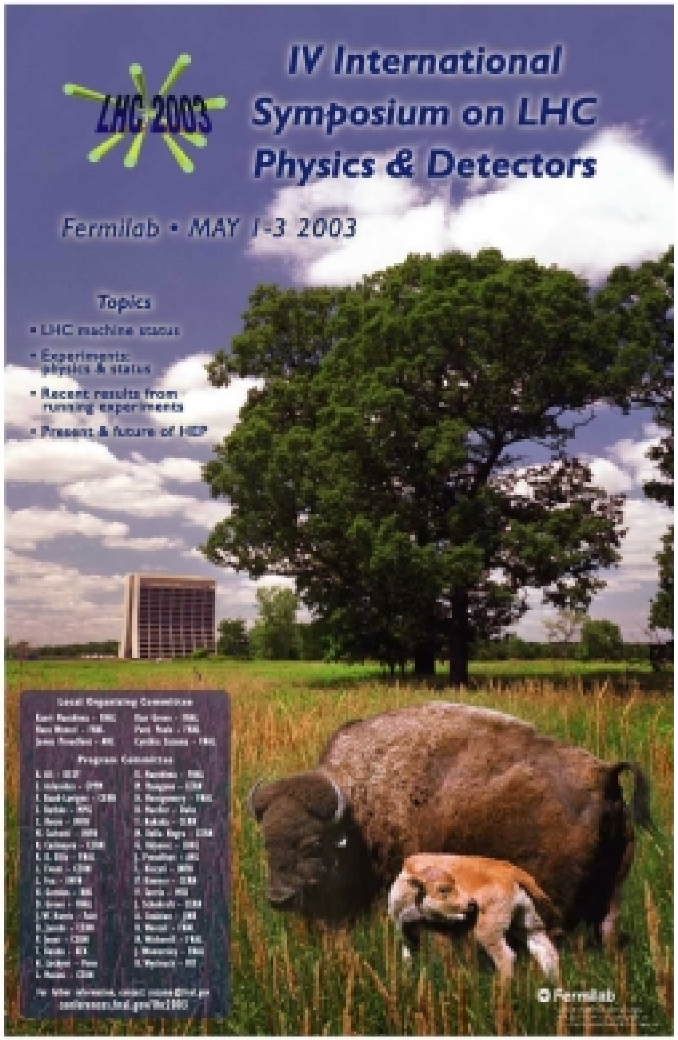
LHC Symposium, May 2003



Held in the U.S. at Fermilab. Emphasis was on the initial commissioning and data taking. The question was – "What Physics is accessible at 10 fb^{-1} in the first "year" of data taking?"

Commissioning

Several steps:

- **Test beams – calibration and transfer to all elements**
- **Mapping of detector material and magnetic field**
- **Alignment – optical and with tracks (field on/off)**
- **Electronic calibration – test pulses, lasers, LEDs**
- **Cosmic running – "slice tests", muons through all towers, chambers.**
- **One proton beam**
- **Proton proton collisions - MIP muons, jet balance, mass peaks.**

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Basics for W, Z, top with 10 fb^{-1} – HLT Trigger Table

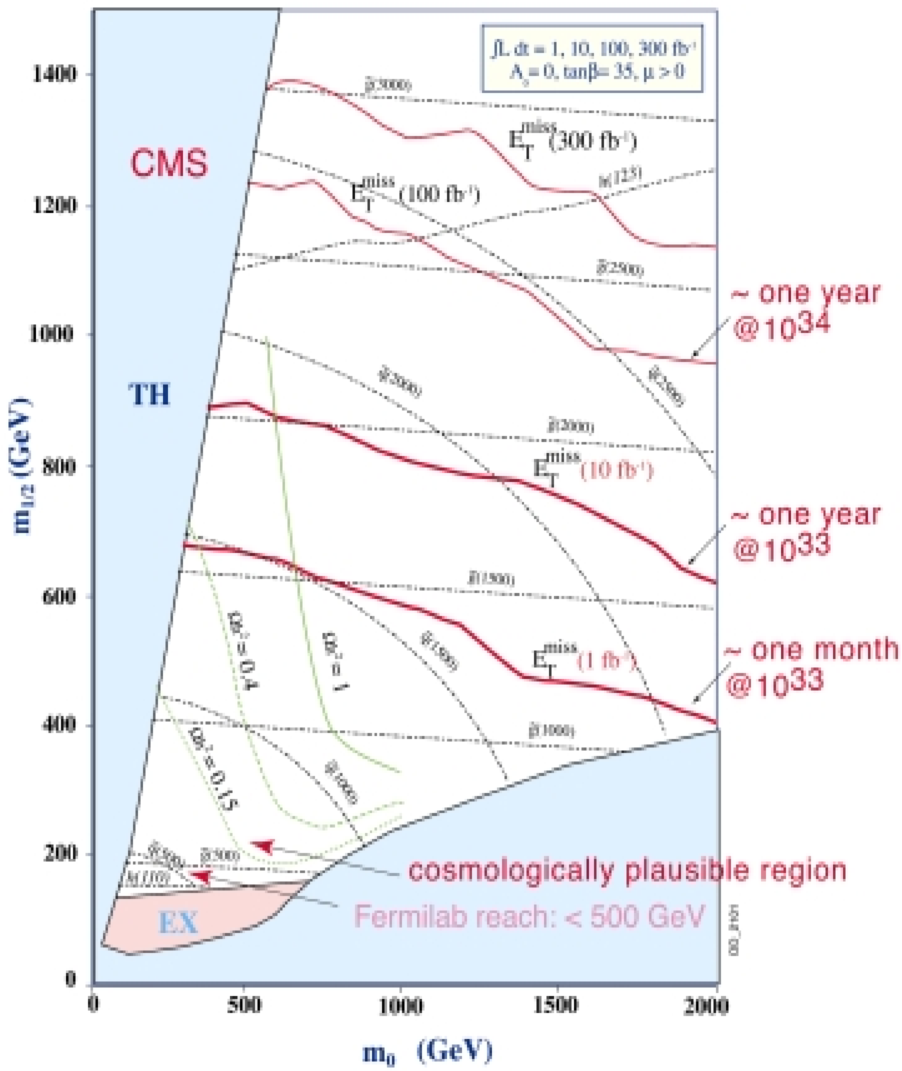
Assumption: 10 fb^{-1} in 1 year @ **L** = 2 x 10^{33} cm^{-2} s^{-1}

Trigger cuts at L=2 x 10^{33} cm^{-2} s^{-1}	L1 p_T cut [GeV]	HLT p_T cut [GeV]	Exclusive rate [Hz] after HLT μ isolation
Single muon	14	19	25
Double muon	3	7	4

Channels	Pythia Cross section [nb]	Acceptance (1 μ in $\lvert\eta\rvert$<2.1)	Eff. after HLT with μ isolation	Yield for 10 fb^{-1}
W μ ν	19.6	50 %	69 %	7 x 10^7
Z μ μ	1.84	71 %	92 %	1.1 x 10^7
tt W b W b μ ν + X	0.126	86 %	72 %	0.08 x 10^7

Squark and Gluino Mass Reach

SUSY will be found quickly – if it exists. The LHC energy is important in that it opens a large part of SUSY parameter space, and one populated by dark matter candidates, very quickly.



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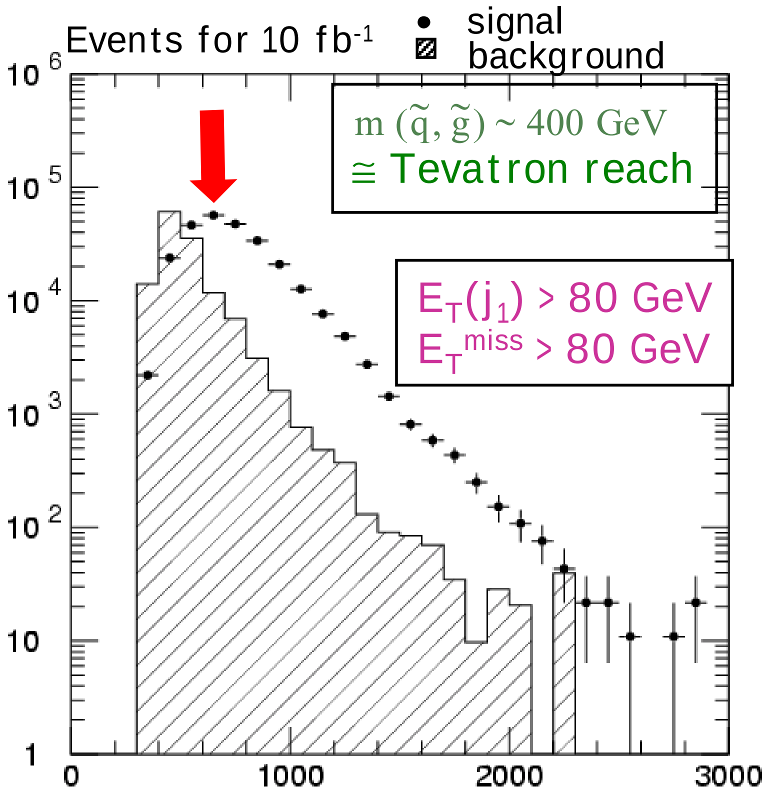
Lower SUSY Masses



$$M_{eff} = E_T^{miss} + \sum_{i=1}^{4} p_T\,(jet_i) \quad (GeV)$$

Position of peak correlated to SUSY mass scale

$$M_{SUSY} \equiv \min(m(\tilde{q}), m(\tilde{g}))$$

Measurement of SUSY mass scale ≈ 20% (mSUGRA) with 10 fb^{-1}

Low trigger thresholds necessary to measure mass scale in overlap region with Tevatron (400 GeV)

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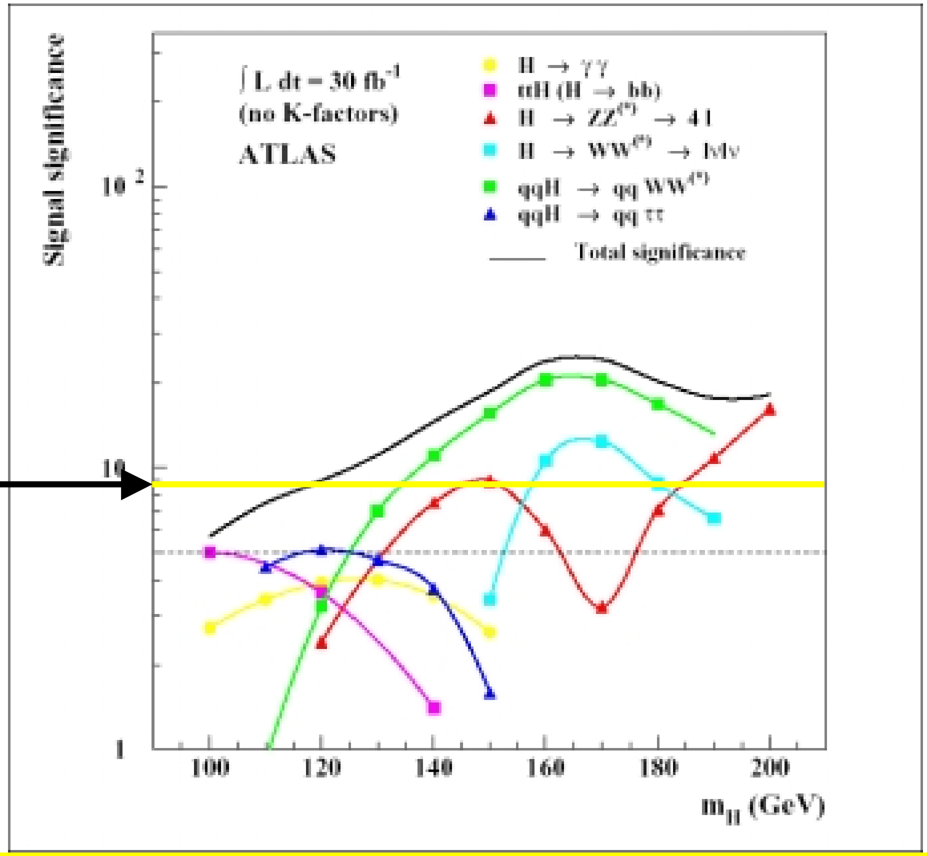
LHC - SM Higgs

5σ, 10 fb^{-1}

1 expt. for

1 "year" at

1/10 design L



The LHC detectors are designed to find the SM Higgs. Low mass is covered by $\gamma\gamma$, ttH(bb), qqH(WW*,$\tau\tau$). A low mass Higgs has many accessible decay modes couplings measured.

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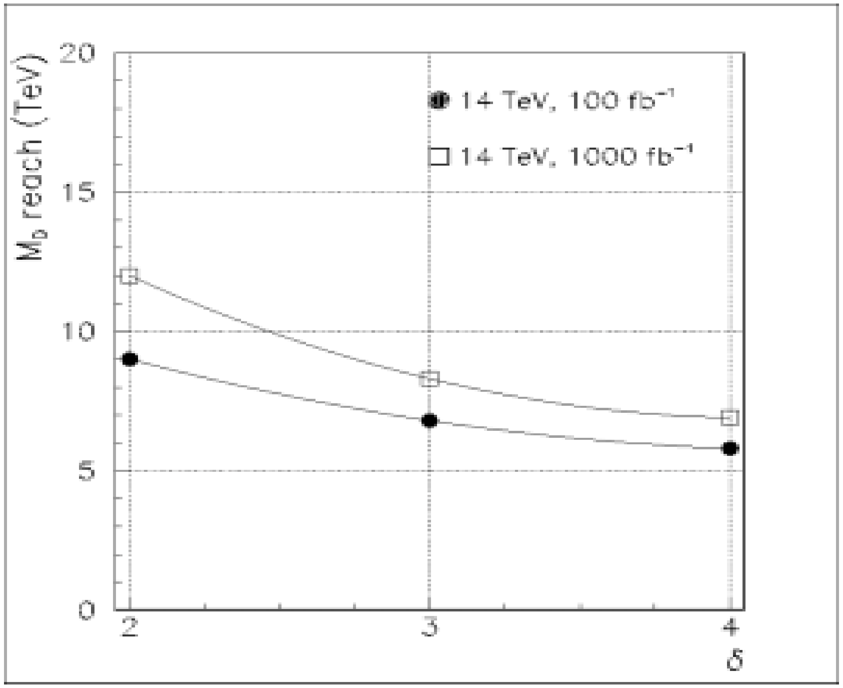
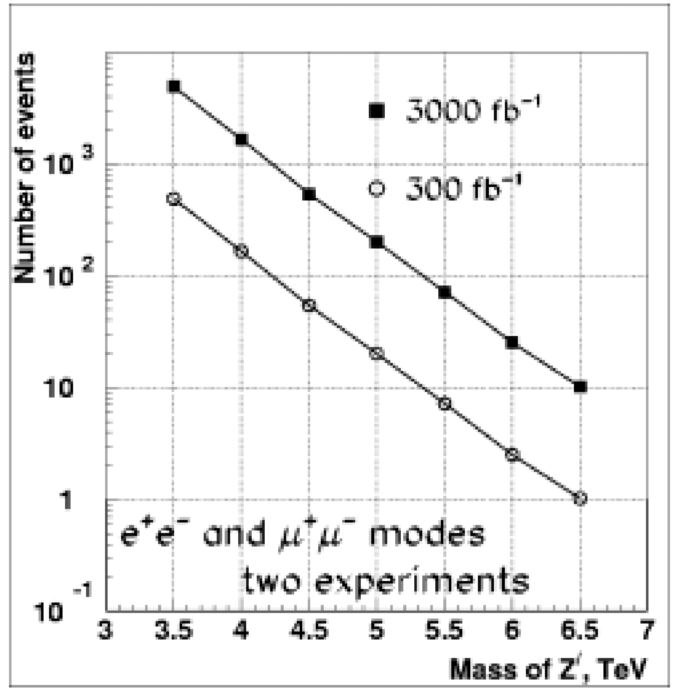
LHC Physics and Upgrade





In general mass reach is increased by ~ 1.5 TeV (25 %) for Z', heavy SUSY squarks or gluinos or extra dimension mass scales. A ~ 20% measurement of the HHH coupling is possible for Higgs masses from ~150 to 200 GeV. However, to realize these improvements we need to launch the necessary accelerator R&D and maintain the capabilities of the LHC detectors by upgrading them in a modest fashion.

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HEPAP – Facilities Subcommittee - March, 2003

LHC Luminosity Upgrade - The U.S. is participating in the construction of the LHC proton-proton collider that is to begin operation in 2007 and explore the energy frontier with seven times the energy we can reach with present accelerators. U.S. physicists, supported by the DOE and NSF, comprise approximately 20% of the international detector collaborations, ATLAS and CMS. Both the U.S. accelerator and detector projects are more than 70% complete and plans are underway for U.S. scientists to play an essential role in producing science with this facility. Upgrades of the LHC are being envisaged. The more cost-effective upgrade is an increase in the luminosity, with the goal of a factor of 10 above the design value. This involves modifications of the accelerator (particularly the focusing magnets around the interaction regions) and the detectors (particularly the tracking systems). The science of extending exploration of the energy frontier with the LHC accelerator and detector luminosity upgrades is *absolutely central*. The *R&D phase* for these will need to start soon if the upgrades are to be finished by the present target date of 2014.

Additional U.S. funds will also be needed after the R&D to upgrade the LHC and its detectors if the U.S. is to provide its appropriate share. A realistic profile cannot yet be made.

Summary

- The Physics program available at the LHC is absolutely first class – with both discovery potential and precision measurements.
- The US LHC program is on schedule and performing well.
- The technical edge given by advanced detectors, high field magnets and grid computing enables the LHC program and its US participants to stay on the frontier of our science.
- US physicists are in leadership positions in the LHC. This is made possible by the DOE/NSF investment.
- The gains realized from US LHC investment are, and will continue to be, a great bargain.
- In order to realize that benefit, there must be sustained attention to the Research Program. Strong participation in the Physics Analysis and Upgrades are crucial if the US is to maintain its leadership.