US LHC Accelerator Research Program

Jim Strait
For the BNL-FNAL-LBNL LHC Accelerator Collaboration

LHC Symposium
3 May 2003

Outline

Program Goals

R&D to Maximize the HEP Output of LHC

Fundamental Accelerator R&D

R&D for LHC Upgrades

Organization and Funding

Conclusions

Goals of the US LARP

Advance High Energy Physics

- Help bring the LHC on and up to design performance quickly.
- Improve LHC performance by advances in understanding and instrumentation.
- Use LHC as a tool to gain deeper knowledge of accelerator science and technology.
- Extend LHC as a frontier HEP instrument with a timely luminosity upgrade.

Advance U.S. Accelerator Science and Technology

- Keep skills sharp by helping commission the LHC.
- Conduct forefront AP research and development.
- Advance U.S. capabilities to improve the performance of our own machines.
- Prepare U.S. scientists to design the next generation hadron collider.
- Develop technologies necessary for the next generation of hadron colliders.

Advance International Cooperation in the High Energy Accelerators

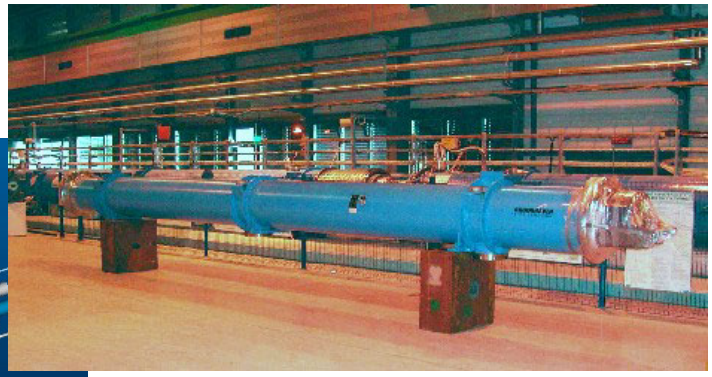
Summary of Planned Program

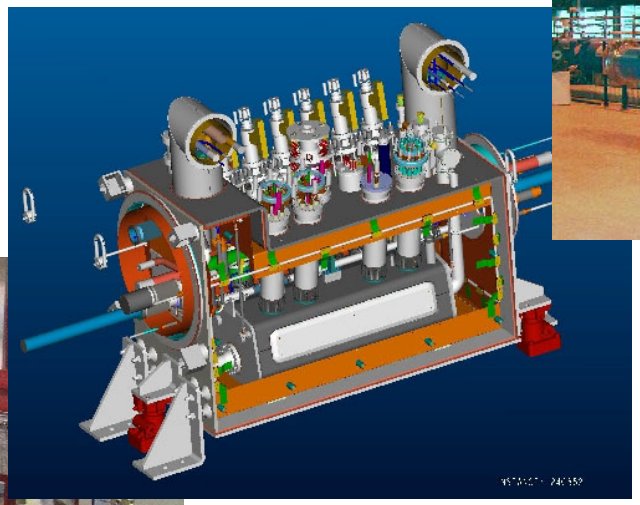
- Help commission the hardware delivered by the US LHC Accelerator Project and later by the LARP
- Help commission the LHC with initial beam.
- Develop and build new instruments that will improve the operation of the LHC and help us perform accelerator physics experiments.
- Use the LHC to perform experiments and test calculations and theories of fundamental accelerator science.
- Perform accelerator physics studies and advanced magnet R&D that will result in the IR designs and prototype IR magnets for a timely LHC luminosity upgrade.

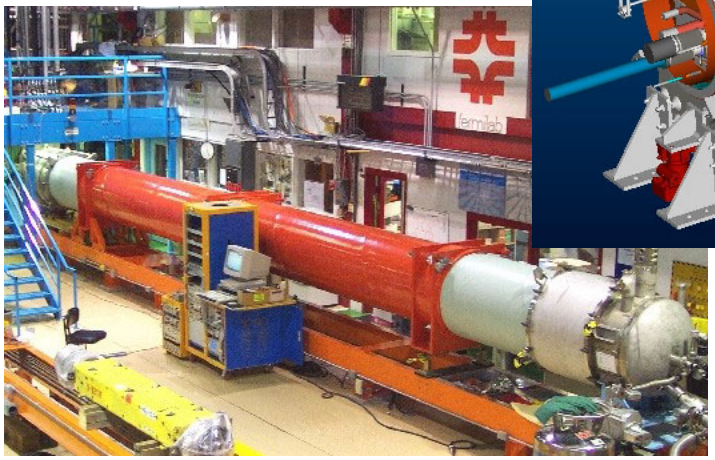
Commissioning the LHC

Hardware Commissioning

- A modest effort of on-site assistance will ensure that the US provided equipment is integrated efficiently with the other systems, speeding up the commissioning of LHC.







Commissioning the LHC

Beam Commissioning

- The LHC is complex and will be quite challenging to put into operation and bring to its design parameters..
- The participation of experienced US accelerator physicists – *one on each shift* – will help bring the LHC to design luminosity more quickly.
- Participation in commissioning is a once-in-a-decade opportunity to "learn from the school of hard knocks."
- This will help maintain a core of experience in the US labs, which will be important for our capabilities to design and commission new machines at home.
- We imagine a combination of long (~year) and short (~month) visits and a combination of experienced and the best semi-junior physicists to participate, to provide both breadth and depth of experience.

Advanced Beam Instrumentation

Three instrumentation systems have been chosen for initial development:

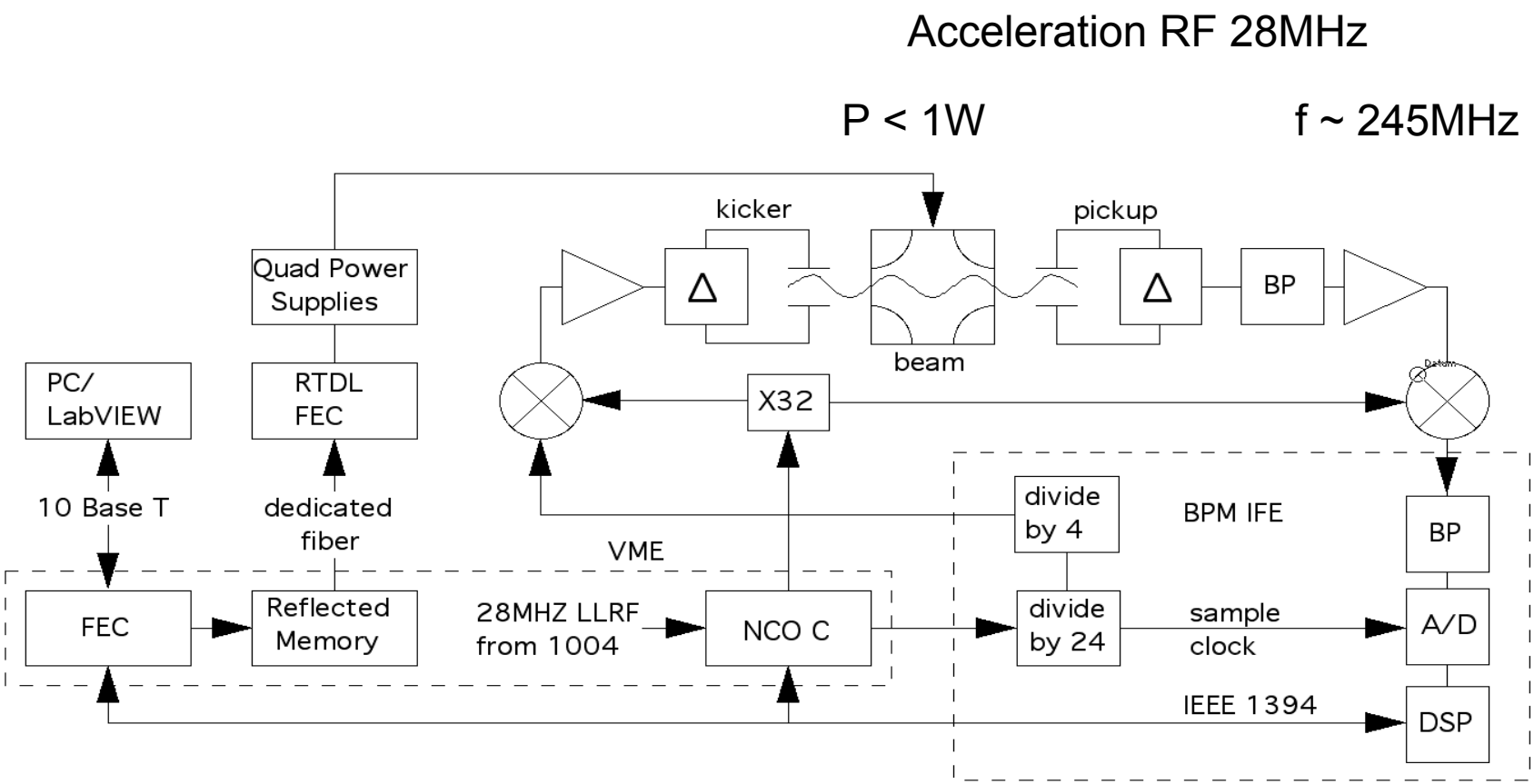
1) Real-time tune, chromaticity and coupling measurement and feedback.
2) Real-time fast luminosity measurement.
3) Longitudinal density monitor.

- All three are strong tools for efficient commissioning of LHC.
- All three push the state of the art.
- Their development also has the potential to contribute to the efficient operation of RHIC and the Tevatron.

Future instrumentation development will depend on LHC needs and technology development. Possible instruments include:

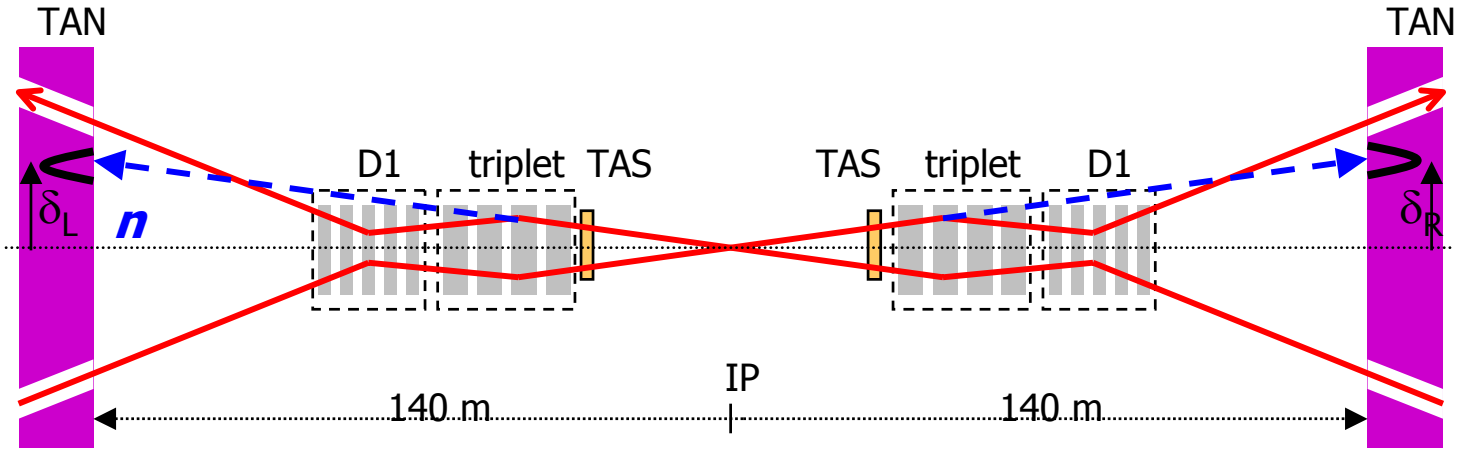
- Beam-beam compensation systems
- High-frequency Schottky monitors
- AC dipoles…..

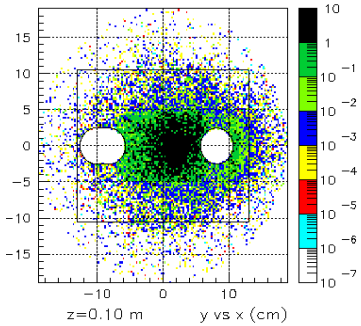
Real-Time Tune, Chromaticity and Coupling Measurement and Feedback



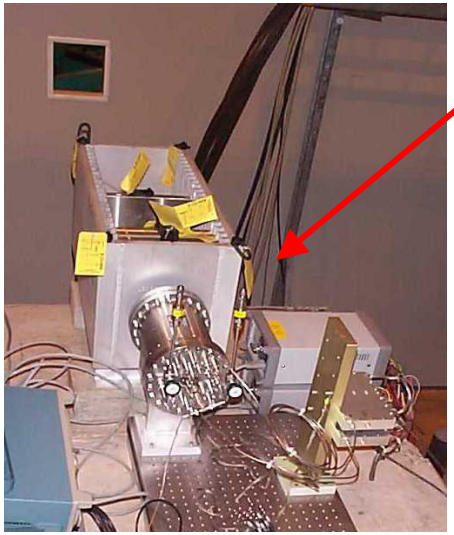
Feedback system under development for RHIC

Fast Bunch-by-Bunch Luminosity Measurements

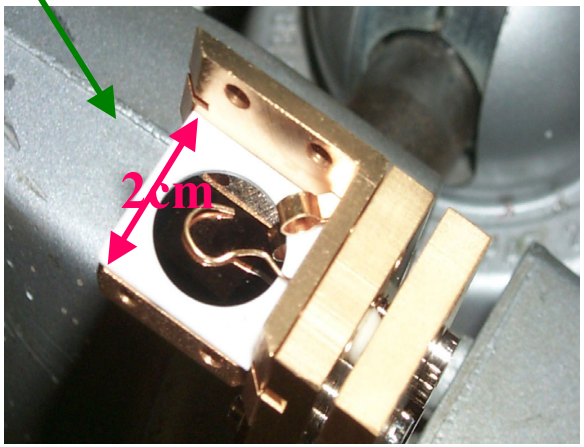




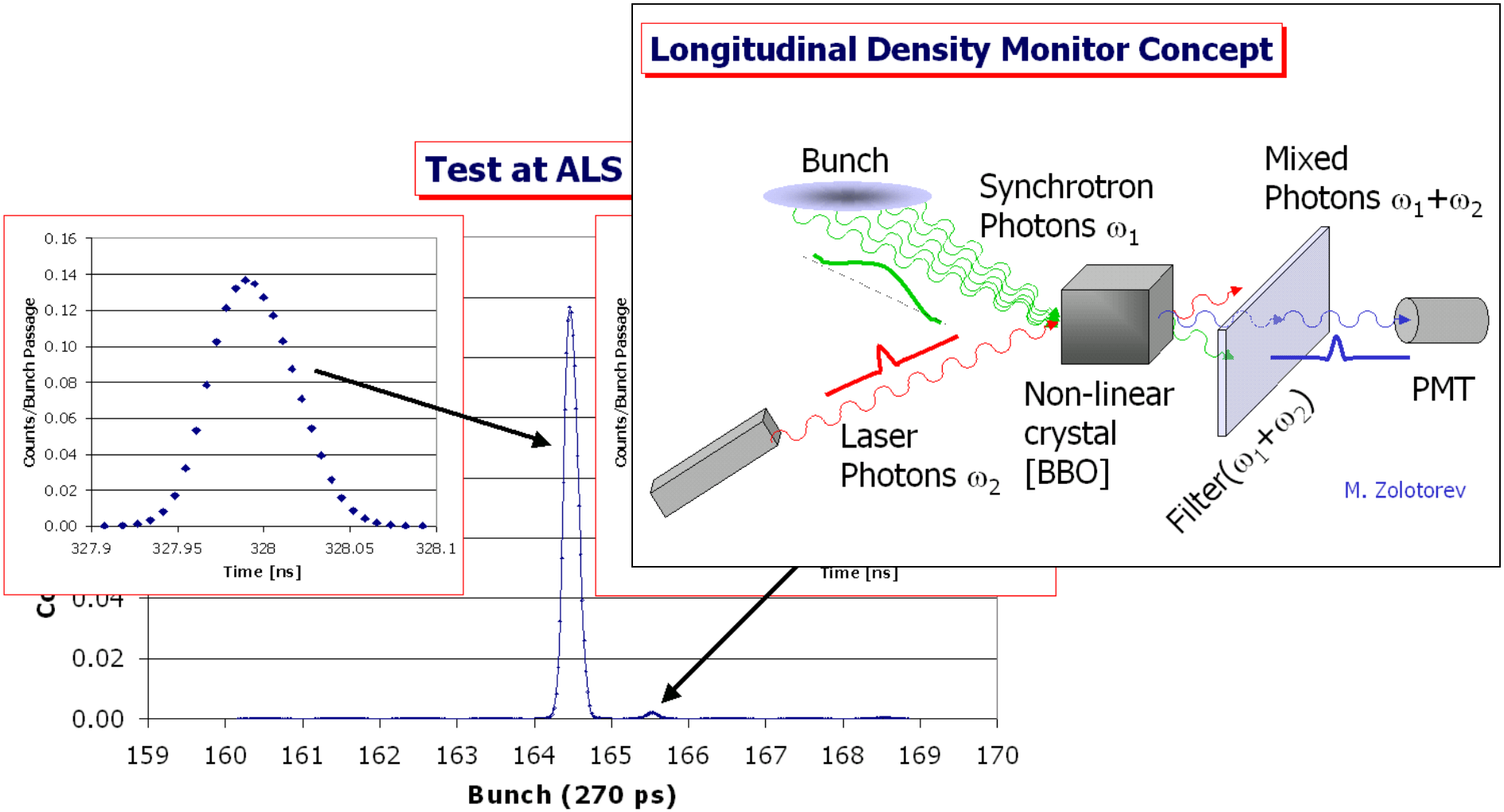
High pressure ionization chamber – Beam test in SPS 300 GeV proton beam.



High radiation beam test of ionization chamber and CdTe detector to be performed jointly by US labs and CERN at the FNAL Booster later this year.



Longitudinal Density Monitor



Fundamental Accelerator R&D

Accelerator physicists must exploit the LHC for the same reason as High Energy Physicists – it is the collider at the frontier.

The range of research topics is large. Examples include:

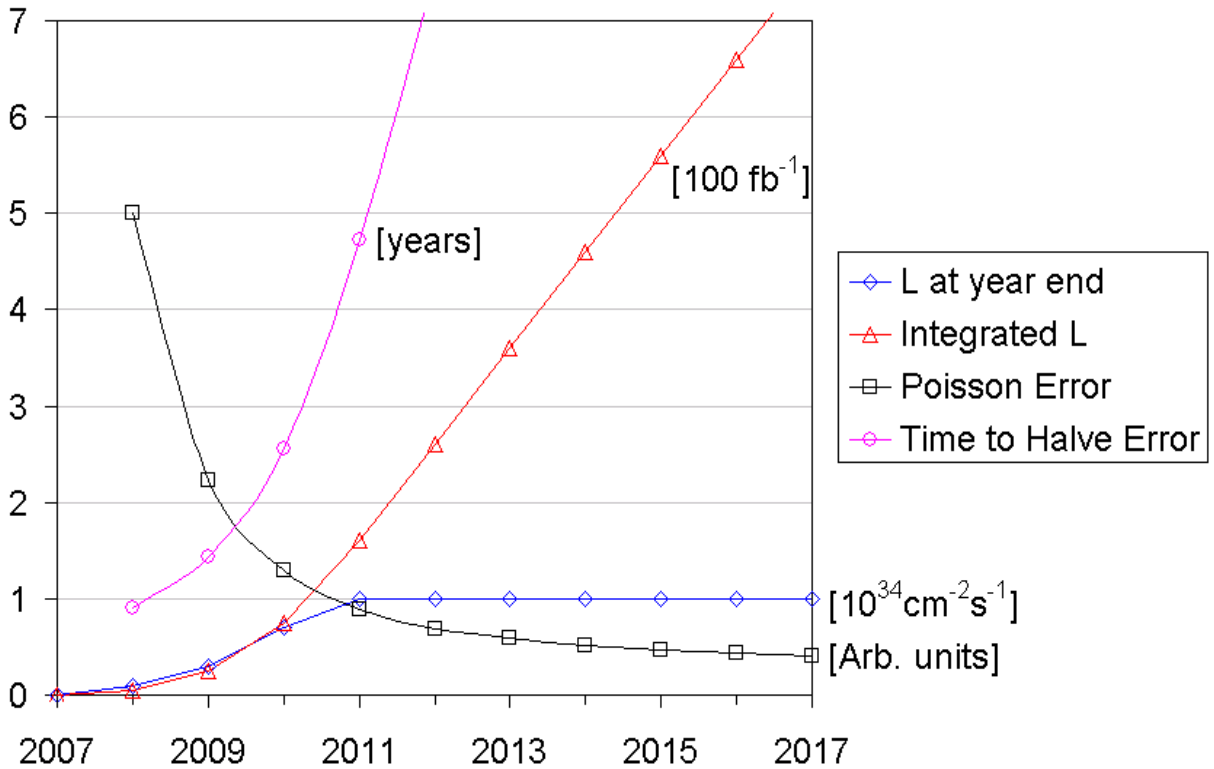
- Beam-beam interactions – a potential limit to the performance of all colliders, including Tevatron and RHIC.
- Electron cloud effects – effects beam stability and is a major heat source in a cryogenic accelerator.
- Other vacuum effects – synchrotron radiation in a cold bore environment is important in LHC and will be a central topic in higher energy machines.
- Remote operations and maintenance - an important tool for LHC accelerator physics and crucial for the next generation of truly global machine collaborations.

The results of this work will enable us to design and build the next generation hadron collider with confidence.

R&D for LHC Upgrades

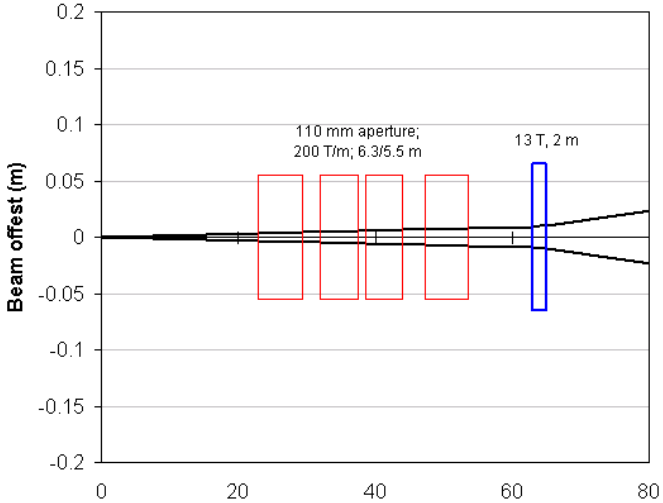
HEPAP* has set its highest priority on R&D for a luminosity upgrade:

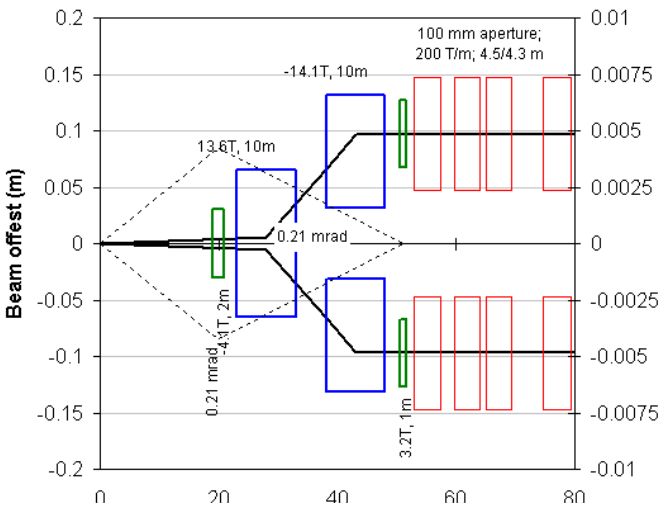
The science of extending exploration of the energy frontier with the LHC accelerator and detector luminosity upgrades is *absolutely central*. The *R&D phase* for these will need to start soon if the upgrades are to be finished by the present target date of 2014.

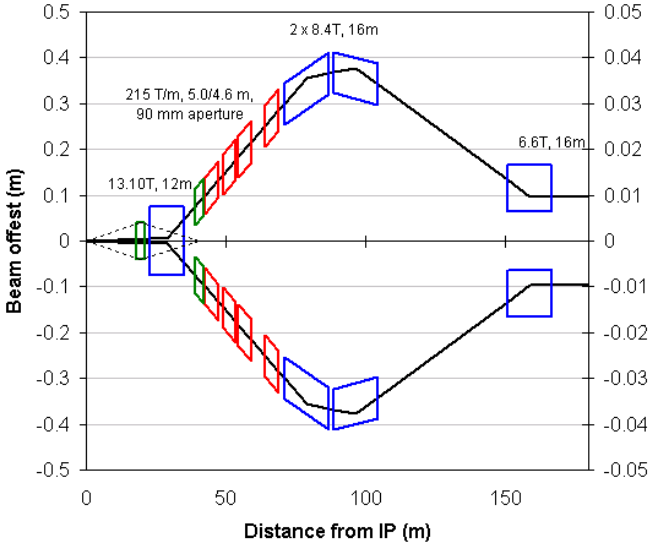


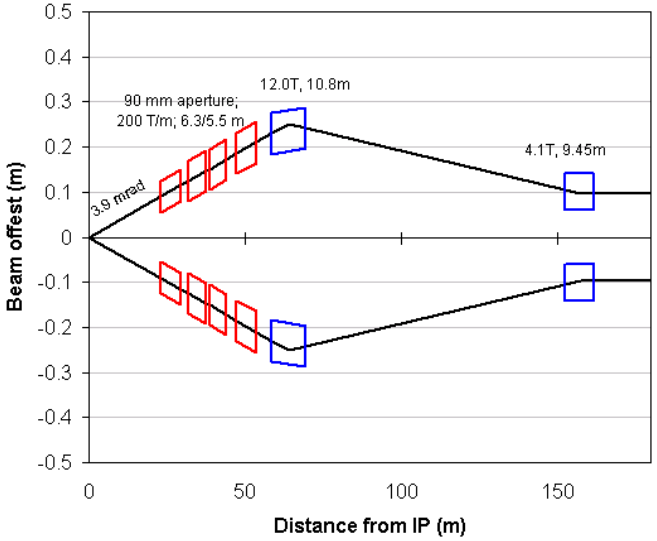
*High-Energy Physics Facilities of the DOE Office of Science Twenty-Year Road Map, HEPAP report to the Director of the Office of Science, 17 March 2003.

New IRs: The Major US Role in R&D for a Luminosity Upgrade









Accelerator Physics for Luminosity Upgrade

Accelerator Physics for luminosity upgrades is the earliest AP activity.

- It informs the type of upgrade that can take place.
- It is necessary to guide the magnet R&D program, which must be launched soon and must be launched on the right path.
- Close cooperation with CERN required.

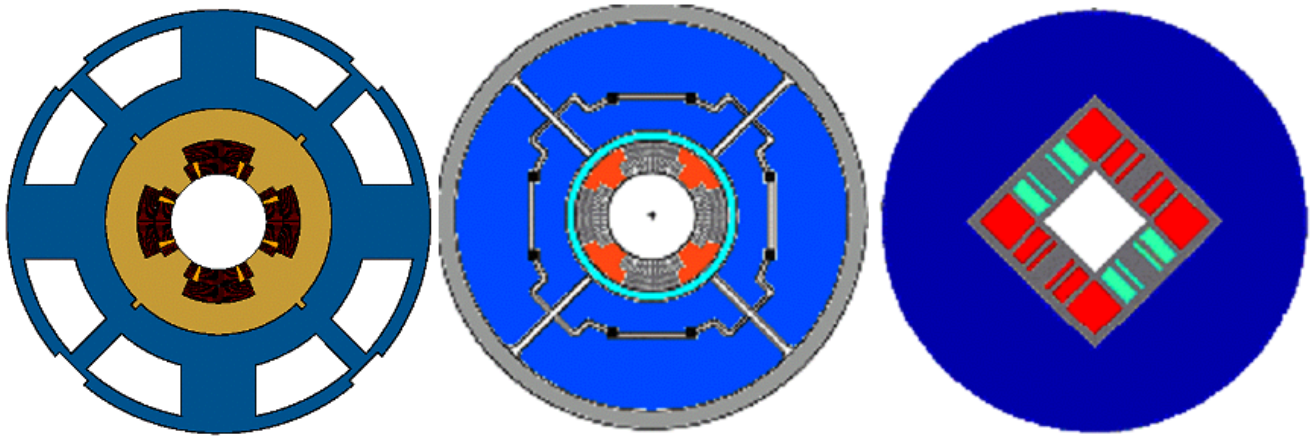
Currently planned work:

- Interaction region optics.
- Energy deposition.
- Beam-beam calculations.
- Interaction region field error compensation.
- Beam loss scenarios.
- Effects of and requirements for other machine upgrades.

Magnet R&D for a Luminosity Upgrade

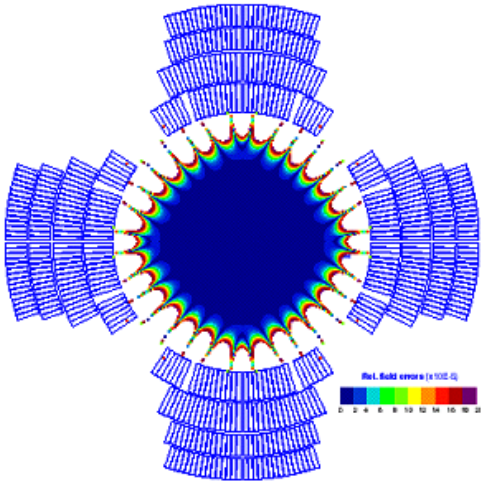
- Magnet R&D will eventually become the largest part of the US LHC Accelerator Research Program.
- Plan to pursue R&D on both quadrupoles and dipoles:
  - Quads with the largest possible aperture with G_{op} > 200 T/m, required for any new IR. (FNAL + LBNL)
  - Large-aperture dipoles for the extreme radiation environment of a dipole-first IR. (BNL + LBNL)
  - Vigorous program to develop Nb_3Sn magnet technology is required.
- Deliverables will be successful R&D, leading to accelerator-ready magnet design(s), ready for production on the time scale required for for a luminosity upgrade.
- This work is a stepping stone to the magnets required for the next, higher energy hadron collider.

IR Quadrupole Conceptual Designs

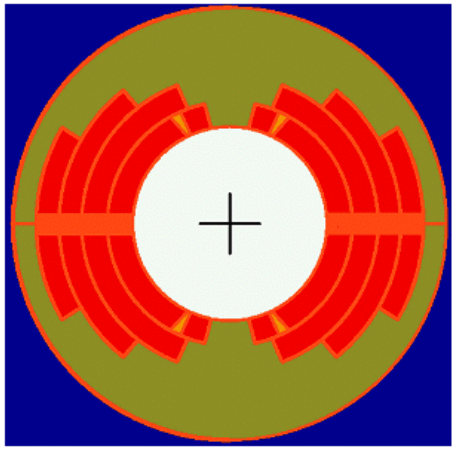


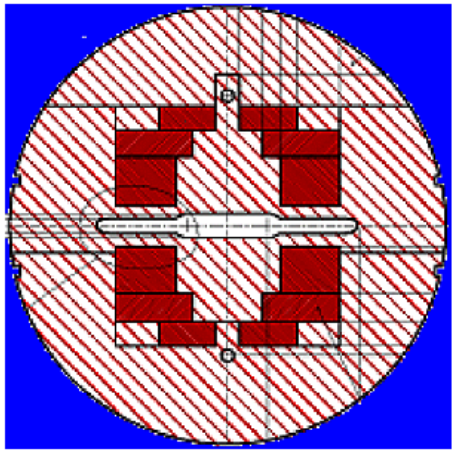
Large aperture (70->90 mm) quadrupoles => x2 reduction in β^*

Even larger aperture (70->110 mm) quadrupole => x3 reduction in β^* …or even x4 in twin-aperture, large crossing angle layout.



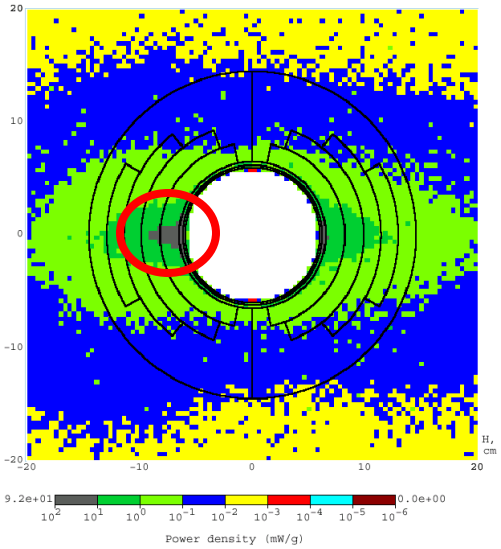
IR Dipole Conceptual Designs

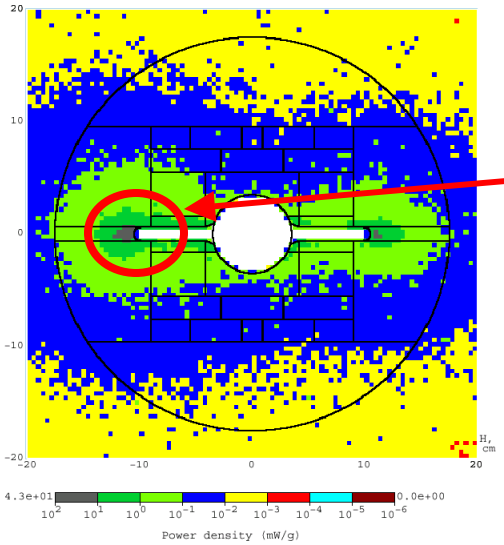




D1 for dipole-first IR

=> x2 reduction
long-range beam-beam interaction.

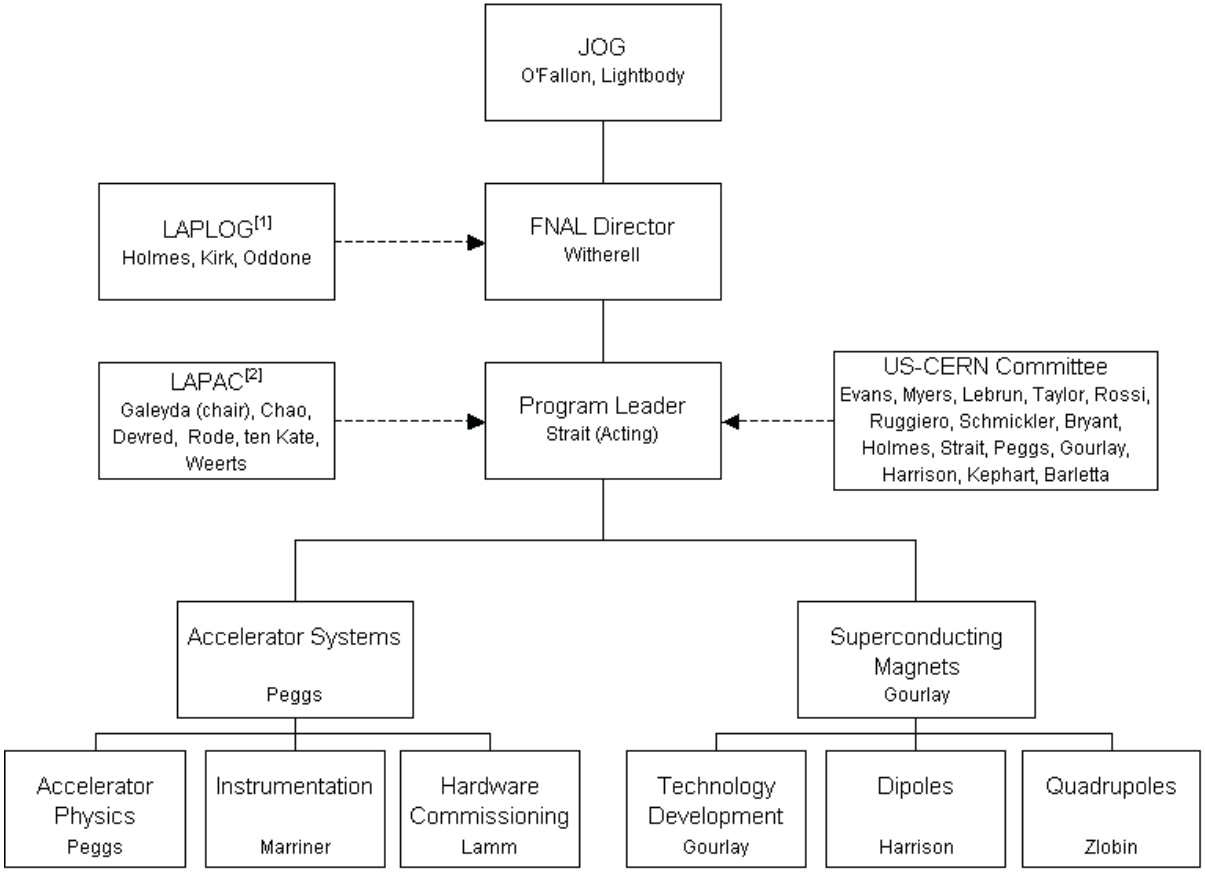




Major challenge is high radiation load.

- Peak power density 50-100 x that in baseline quads at $L=10^{34}$.
- Total power >3kW per magnet!

Initial Organizational Structure



Program Direction and Reporting

Advice

[1] US LHC Accelerator Program Laboratory Oversight Group

[2] US LHC Accelerator Program Advisory Committee

Coordination with CERN

Many formal and informal meetings with CERN over the past ≥ 1 year to develop the US LHC Accelerator Research Program proposal.

US-CERN Committee combines leaders of the LHC at CERN with leaders of the LHC accelerator effort at the US Labs, and provides for formal coordination of the US effort with the CERN LHC program.

The US-CERN Committee, at its first meeting on 10 April, approved our program plans, as documented in a letter from Lyn Evans.

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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Notre référence/Our reference: DG/DI/LE/jf/2003-058

Dr James STRAIT
Fermi National Accelerator Laboratory (FNAL)
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Geneva, 14th April 2003

Dear Dr Strait,

I am writing to communicate to you my conclusions after the first meeting of the US-CERN Committee for the U.S. LHC Accelerator Research Program, held at CERN on 10 April 2003, at which you and your colleagues presented the draft of the proposal that you will submit to US Department of Energy within the next few weeks. I note that this meeting was attended by T. Taylor, N. Siegel (representing Ph. Lebrun), L. Rossi, F. Ruggiero, H. Schmickler, P. Bryant, and myself from CERN; and S. Holmes, S. Peggs, S. Gourlay, R. Kephart, P. Limon and yourself, representing the U.S. laboratories. S. Myers, M. Harrison, and R. Barletta were excused.

On behalf of CERN, I should like to express my strong support for continuing, after 2005, the very valuable collaboration that we have currently with the U.S. laboratories. Your proposed programme that engages the US laboratories on 'a best effort' basis in hardware and beam commissioning will be particularly appreciated by CERN. Similarly, the proposed collaboration in accelerator physics studies and R&D for beam instrumentation with the appropriate CERN groups will certainly have an important and positive impact by both speeding the start-up of the machine and by helping to optimise its performance. It is also clear to me that the proposal by the U.S. laboratories to work on accelerator physics and high-field superconducting magnets for an eventual luminosity upgrade would be invaluable to CERN, no doubt making it possible to start such an upgrade at an earlier date than would otherwise be conceivable. To increase the luminosity beyond the nominal value will be an extremely challenging task and the American contribution to this effort, done in close collaboration with CERN and other partners, will help to ensure that this upgrade can be done in a timely way and on the time-scale required by the physics programme.

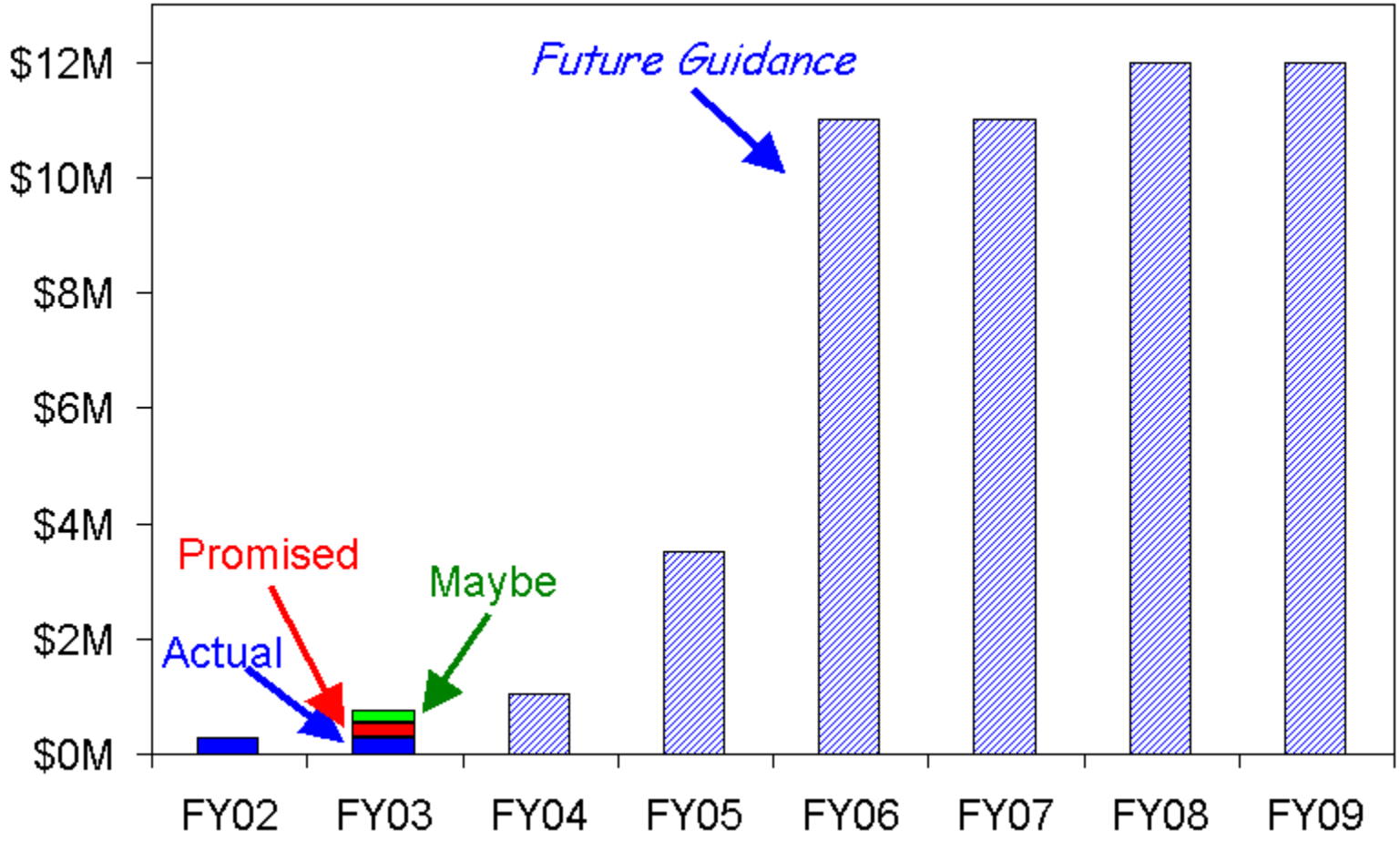
I am particularly pleased to see the evident close cooperation with CERN with which this proposal has been developed.

Yours sincerely,

L.R. Evans
Director, LHC Project Leader

C.c.: Director-General

Funding Guidance



Conclusions

- We are now establishing the framework to extend the highly productive US-CERN collaboration on the LHC accelerator.
- 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.