Fermilab Accelerator R&D Overview

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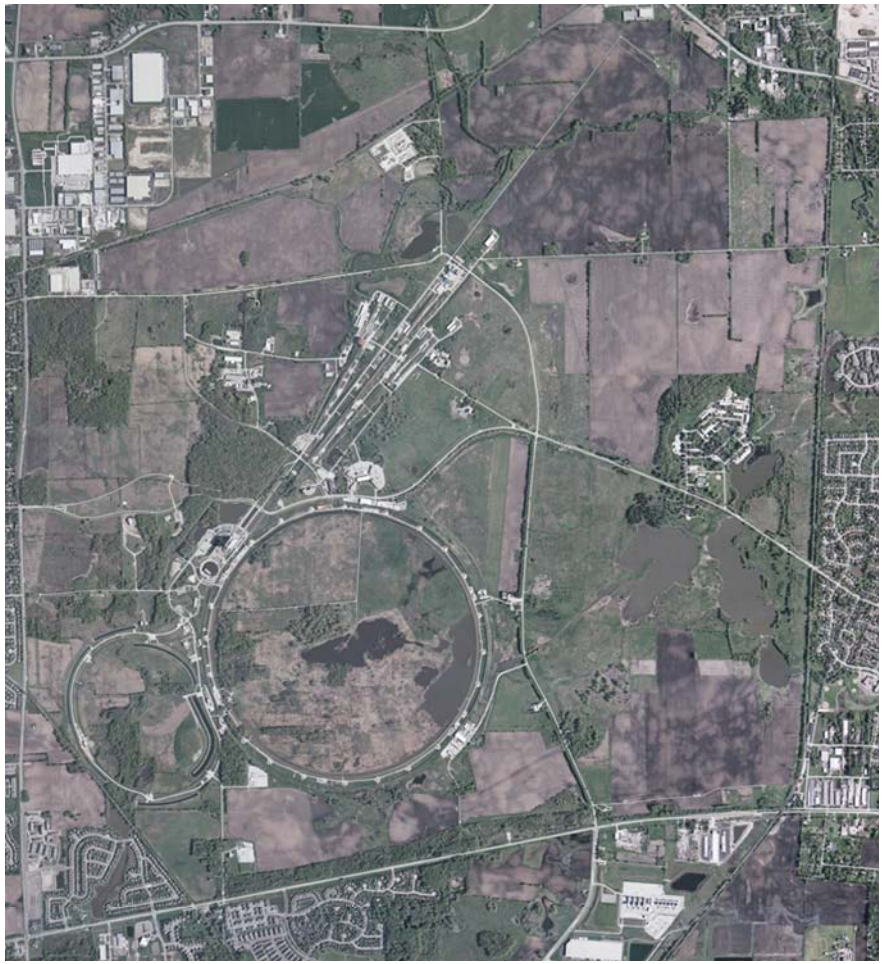
Outline

- Strategic Framework
- Program Elements and Goals
  - Includes integration within the national and international programs
- Educational Programs
- Resources

Strategic Framework:
Context

- Fermilab has operated the highest energy particle accelerator in the world since 1983. . .
  - This will change in 2007-09
  - Current plan: Tevatron operations will cease on October 1, 2009
- Fermilab currently operates the most advanced long-baseline neutrino program in the world. . .
  - J-PARC will become competitive in 2010-2011

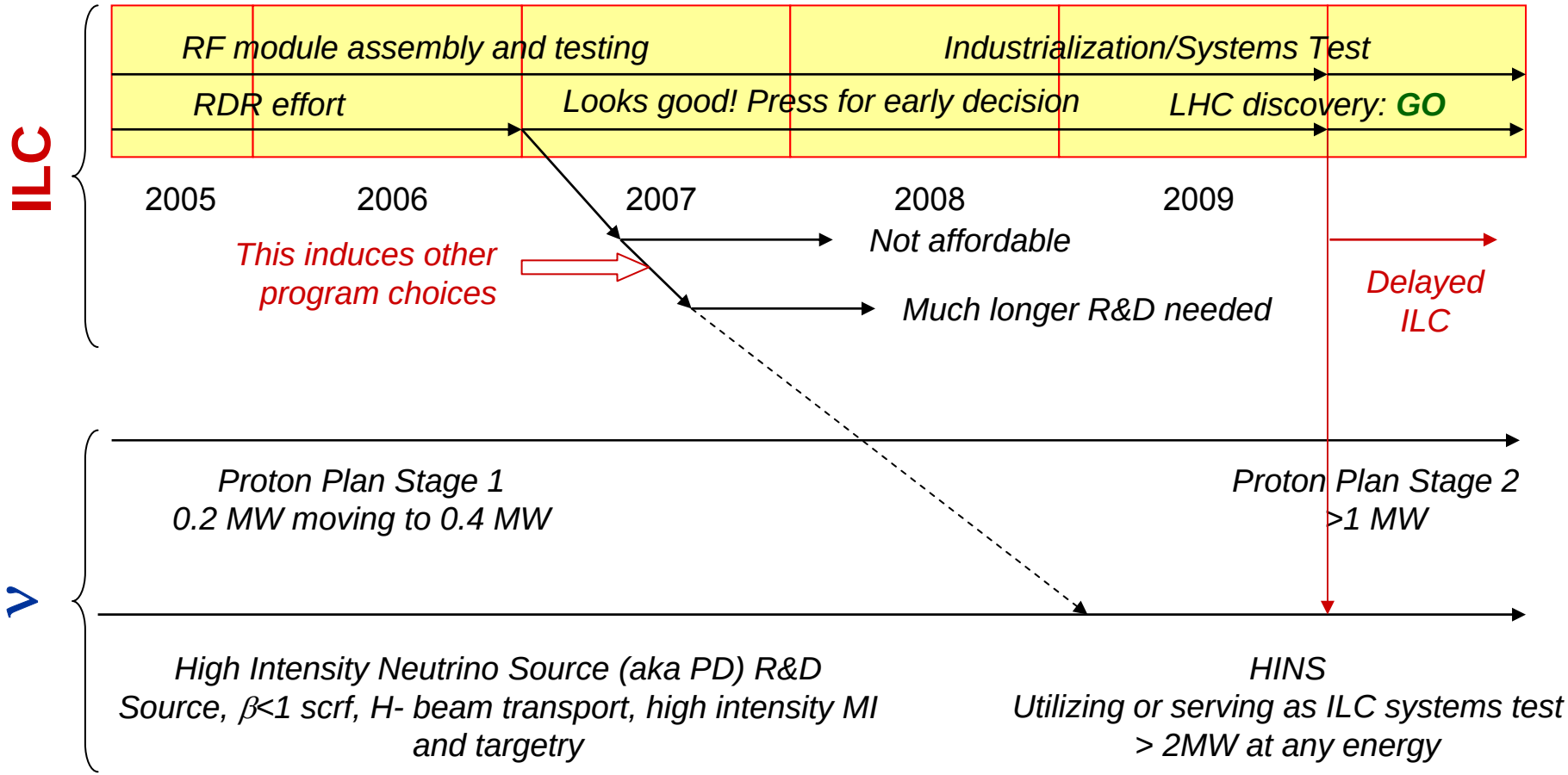


Strategic Framework:
The Vision

- The vision is that Fermilab will remain the U.S. center for accelerator-based High Energy Physics, and one of the (two) pre-eminent centers in the world, for the foreseeable future.
- The Fermilab Long Range Plan establishes the ILC as the primary goal, with a world-leading neutrino program if the ILC were delayed or constructed elsewhere.
- The ILC cold technology decision has allowed close alignment of Fermilab's R&D programs in support of these goals.

⇒ **To support this vision it is imperative that Fermilab become a world leader in superconducting rf technologies.**

Strategic Framework:
The Roadmap



Program Elements and Goals
Timeframes

- At Fermilab we think of near, intermediate, and far terms as:
  - Near term: The Run II era
    - Collider operations, Run II Upgrade Program, NuMI, Proton Plan
  - Intermediate term: The post-Run II era
    - ILC, LHC (upgrades), Proton Plan II, High Intensity Neutrino Source (aka Proton Driver)
  - Far term: Beyond the next generation
    - Neutrino Factory, Muon Collider, VLHC, new acceleration techniques

Program Elements and Goals
Near Term

- Goals: Successful completion of Run II; ~400 KW to NuMI target
  - Major intellectual/technical achievements include development of electron cooling, novel rf stacking schemes, and high intensity issues
  - Direct application into intermediate and long terms

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Experimental Demonstration of Relativistic Electron Cooling

Sergei Nagaitsev, Daniel Broemmelsiek, Alexey Burov, Kermit Carlson, Consolato Gattuso, Martin Hu, Thomas Kroc, Lionel Prost, Stanley Pruss, Mary Sutherland, Charles W. Schmidt, Alexander Shemyakin, Vitali Tupikov, and Arden Warner
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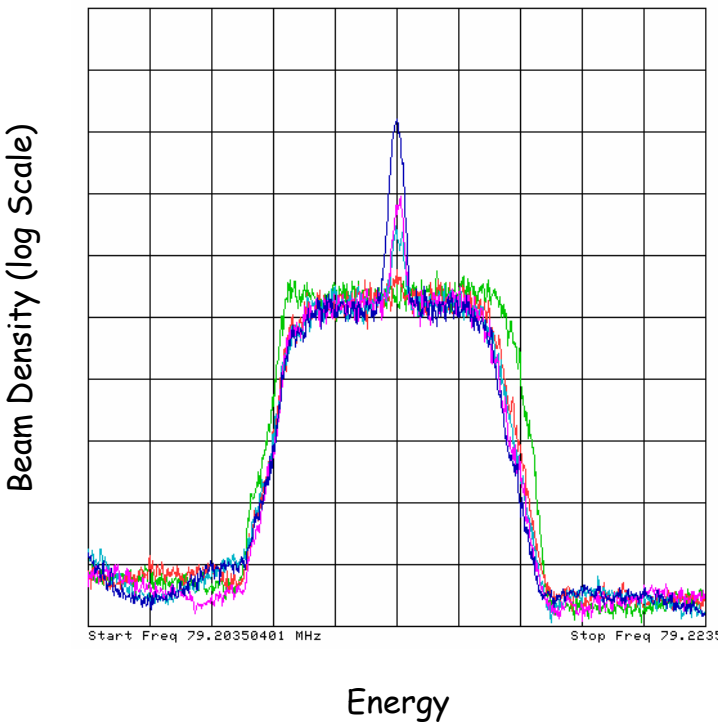
(Received 22 November 2005; published 30 January 2006)

We report on an experimental demonstration of electron cooling of high-energy antiprotons circulating in a storage ring. In our experiments, electron cooling, a well-established method at low energies (<500 MeV/nucleon), was carried out in a new region of beam parameters, requiring a multi-MeV dc electron beam and an unusual beam transport line. In this Letter, we present the results of the longitudinal cooling force measurements and compare them with theoretical predictions.

DOI: 10.1103/PhysRevLett.96.044801 PACS numbers: 29.27.Eg, 29.27.Fh, 29.20.Dh, 41.75.−i

Recycler Electron Cooling

- Electron cooling commisioning
  - Electron cooling was demonstrated in July 2005 two months ahead of schedule.
  - By the end of August 2005, electron cooling was being used on every Tevatron shot
- Electron cooling rates
  - Drag rate: 20 MeV/hr for particles at 4 MeV
  - Cooling rate: 25 hr^{-1} for small amplitude particle
  - Can presently support final design goal of rapid transfers (30eV-sec every hour)
  - Have achieved 500 mA of electron beam which is the final design goal.



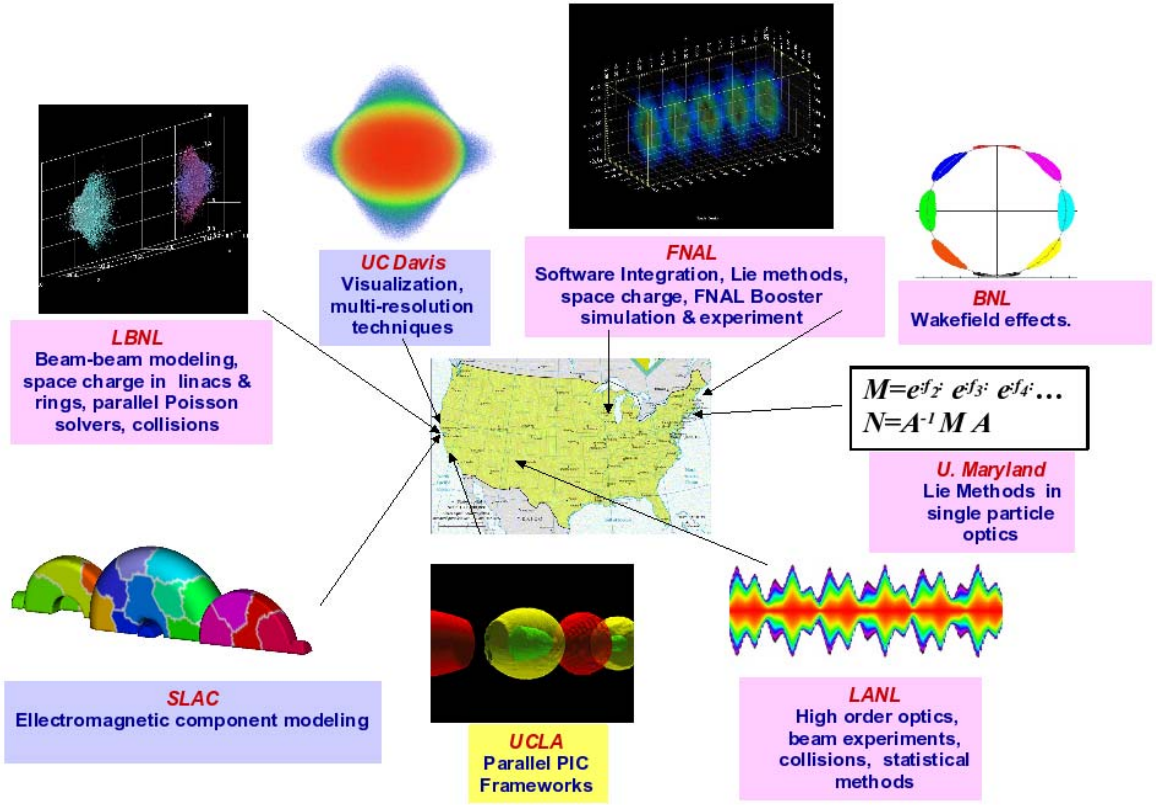
Program Elements and Goals
Intermediate Term

- Goals:
  - Establish Fermilab as preferred host lab for ILC.
    - In collaboration with national and international partners
    - World leader in scrf technologies
  - Work with GDE to define and implement an industrialization plan and the associated major systems test which we believe is required before the start of construction.
  - Develop technologies that could be married to ILC developed cryomodules, to support construction of a high intensity neutrino source if ILC construction is delayed.
  - Assist in the successful commissioning of the LHC and develop a full scale Nb_3Sn quadrupole for LHC upgrade.
    - Under the aegis of the LHC Accelerator Research Program (LARP)

Program Elements and Goals
Establishing Core Competencies

- The two main branches within our future rely on superconducting radio frequency acceleration as a technology base.
  - ⇒It is critical that Fermilab establish world-leading expertise.
  - – Has triggered a very significant investment in infrastructure and people
- Fermilab has historically been a/the world leader in superconducting magnet technologies, a capability that was dissipated and then reconstituted at great effort in the late 1990s. We will continue the investment.
- Accelerator simulations are an increasingly important component in the design of large, state-of-the-art accelerator facilities
  - – We have been a major participant in the SciDAC program and will continue/expand this effort

Program Elements and Goals
SciDAC (R. Ryne @ Palo Alto)



Program Elements and Goals
Long Term

- The role of future directed R&D in the Fermilab program?
  - Not a traditional strength or point of emphasis within the laboratory
  - Fermilab's primary mission is operations and will remain so (we hope) for decades; generally translates into emphasis on near and intermediate terms.
  - However, as the center of U.S. accelerator-based HEP at the end of the decade we recognize a responsibility to invest effort in the generation beyond.
    - "Discretionary" R&D is important for maintaining flexibility for the future.
    - These efforts often provide the best opportunities for the training of students and other staff.
    - Expect to preserve AARD program at the photoinjector following relocation to the ILC Test Area accompanied by meaningful participation in the worldwide muon effort.

Program Elements and Goals
Long Term

- Goals:
  - Muons
    - Participation in the MICE experiment: demonstration of ionization cooling
    - Participation in the development of a Neutrino Factory Conceptual Design as an option for the future beyond LHC/ILC
  - Continuation with some room for growth of a program of advanced accelerator R&D at the photoinjector, following its relocation to the ILC Test Area
  - Development of superconducting magnet technology beyond the requirements of the LARP

Program Elements and Goals
Integration within the National Program

All our efforts are now leveraged via (inter)national partnerships

- Why collaboration?
  - Achieving together more than can be achieved individually
    - External collaborators bring unique knowledge, facilities, and capabilities that we do not have;
    - We bring access to unique facilities, expertise, and infrastructure that are not accessible in outside institutions.
- SCRF
  - We are committed to becoming the U.S. center for scrf development for ILC.
    - Can't do this on our own: significant help from ANL, Cornell, DESY, INFN, JLab, KEK, LANL, MSU, NIU, Penn, SLAC
  - National collaboration formed to pursue R&D on the Neutrino Source: Fermilab, ANL, BNL, LBNL, MSU, NIU, (SLAC, JLAb)

Program Elements and Goals
Integration within the National Program

- ILC/GDE
  - Primary responsibility for linac design and technology, industrialization, civil and site development, communications
- LARP
  - National collaboration with Fermilab as lead lab: Fermilab, BNL, LBNL, SLAC; close cooperation with CERN
  - Close cooperation in our materials program with UW and NWU.
- Muon Collaboration
  - Collaboration sponsored by Fermilab, BNL, and LBNL
  - Lot's of university involvement including (locally) IIT, NIU, UIUC, UC, NWU
- University Connections
  - Joint operations of the photoinjector with NIU
    - Participating institutions include Rochester, Chicago, UCLA

Educational Programs

- Accelerator Phd Program
  - Initiated 1984; first graduate in 1987
  - 30 PhD and 1 Masters graduates
    - Distinguished alumni: Colby, Harkay, Merminga, Spentzouris, Syphers
  - 26 home universities represented
  - 8 current students
- USPAS host
- Joint appointments
  - With IIT and NIU (tenure track level)
- Joint programs
  - Joint operation with NIU of FNPL (aka A0 photoinjector)
  - Joint ME program in rf under development with NIU

Educational Programs

- Fellowships
  - Peoples Fellowship – Accelerator Science
  - Bardeen Fellowship – Accelerator Engineering
- Other Programs
  - Summer exchange with Russian universities
  - Summer Internships for Physics Majors
  - Summer Internships in Science and Technology for Minority Students
  - Cooperative Education Program

Resources

	Fermilab Accelerator R&D Program					
	Dollar amounts in millions, Direct cost only					
	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009
Run II Upgrades	$21.0	$14.4	$5.6	$0.0	$0.0	$0.0
Proton Plan	$0.0	$3.9	$6.9	$6.9	$1.6	$1.7
Near Total	$21.0	$18.3	$12.5	$6.9	$1.6	$1.7
Linear Collider	$3.3	$4.9	$9.2	$31.6	$33.9	$35.1
RF Infrastructure & Industrialization	$0.0	$6.4	$12.6	$5.0	$10.0	$30.0
ILC Bid to Host	$0.0	$0.0	$0.0	$3.0	$4.0	$5.0
High Intensity Neutrino Source	$0.9	$4.4	$8.3	$8.5	$8.8	$9.1
Superconducting Magnets (core)	$2.9	$3.1	$2.5	$2.3	$2.4	$2.4
LARP	$0.0	$0.8	$2.9	$3.0	$3.0	$3.1
Intermediate Total	$7.1	$19.6	$35.5	$53.3	$62.0	$84.7
Photoinjector	$1.1	$1.6	$1.0	$1.0	$1.0	$1.5
Muons	$1.5	$1.3	$1.2	$1.5	$1.6	$2.2
SciDAC	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Far Total	$2.7	$2.9	$2.3	$2.7	$2.8	$3.9

- The message:
  - Very significant buildup has already started: ILC, HINS, and associated rf infrastructure.

Summary

- The Fermilab strategic plan requires that we become a world leader in scrf technologies, while maintaining our core competency in superconducting magnets.
  - By the end of the decade we expect to be the world leader in scrf and in sc magnets.
- We are in the initial stages for a very significant buildup in scrf capabilities and infrastructure.
  - We are doing this within an extensive collaborative framework involving outside laboratories and universities.
- Advanced accelerator R&D aimed at the long term will be an important and increasing activity, but it will not be dominant .
- Details will all be covered in subsequent talks.