The Fermilab Accelerator Science Program: Overview

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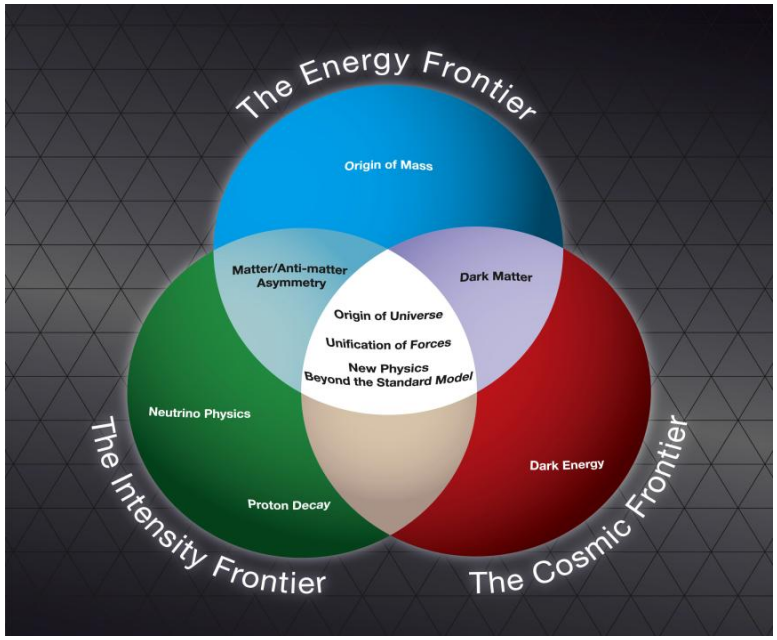
Outline

- Strategic Context and High Level Goals
- Program Elements/Alignment with OHEP Programmatic Thrusts
- Principal Recent Accomplishments
- Proposal Goals
- Leveraging Fermilab Resources
- Budget Request FY2009-2011

Introduction

- The Accelerator Science program at Fermilab supports the long term accelerator based physics mission of Fermilab and of the Department of Energy's Office of High Energy Physics.
  - Development of technologies and tools aimed at long term forefront accelerator facilities
    - Energy frontier colliders
    - Intensity frontier facilities
  - Critical support for ongoing accelerator based programs at the heart of the near term Fermilab research program (Collider Run II and the neutrino program).



Strategic Context

- This proposal specifically covers the period FY2009-2011, while anticipating the possible developments of the following decade:
  - Relocation of the high energy frontier in particle physics from the United States (Fermilab) to Europe (CERN) in ~2010 dominates the landscape
  - Strategy for the coming era developed by the Particle Physics Project Prioritization Panel (P5), and adopted by the High Energy Physics Advisory Panel (HEPAP)
    - Based on forefront programs addressing three frontiers: the energy frontier, the intensity frontier, and the cosmic frontier

⇒ **The overriding goal of the Fermilab Accelerator Science program is to support long term development of the high energy and intensity frontiers**

Strategic Context
The World in 2012

- A confluence of events points to the 2012 time frame as the period of decision on future directions on both frontiers:
  - Initial physics results based on significant integrated luminosity from LHC will be available and interpreted
    - Expected to provide guidance on the desired energy reach of a future lepton collider
  - International Linear Collider Technical Design Phase complete
    - Definitive information on the performance reach and costs of an electron-positron linear collider in the range 500-1000 TeV
  - Complete conceptual design and preliminary cost estimate for a multi-TeV electron-positron linear collider (CLIC)

Strategic Context
The World in 2012

- 2012 confluence (cont.)
  - J-PARC operational at up to 750 kW beam power at 30-40 GeV in support of the T2K long baseline neutrino experiment
  - NOvA long baseline neutrino experiment nearing the end of construction with 700 kW capability at 120 GeV from the Main Injector
  - Complete conceptual design of a Fermilab multi-MW proton source, and associated very long baseline neutrino beamline
  - Next round of neutrino experiments will indicate whether the mixing parameter $\sin^2 2\theta_{13}$ is greater than or less than ~0.02.

Strategic Context
High Level Goals

- Based on these factors we expect the international High Energy Physics community to be in a position to make decisions in the following areas:
  - What is the required energy reach of the lepton collider that will complement the LHC? What is the preferred technology base for such a collider?
  - What is the required reach of the next generation neutrino facility? Is a Neutrino Factory likely to be required to explore CP violation in the neutrino sector?
  - What are possible concepts that will support the next generation of HEP facilities beyond the lepton collider and/or Neutrino Factory?

The highest level goal of the Fermilab Accelerator Science proposal is to assure that the U.S. is in a position to answer the above posed questions in the 2012-2013 timeframe.

Fermilab Program Elements
Alignment with OHEP Thrusts

- Accelerator and Beam Physics
  - Beam studies at the Tevatron, Main Injector and Booster accelerators in support of optimizing performance in Collider Run II;
  - Development of beam optics and dynamics simulation and modeling tools (including energy deposition simulations);
  - Theory of beam instabilities in current & future accelerator facilities;
  - Development of new techniques for compensation of beam-beam effects;
  - Experimental studies of electron cloud effects in high intensity proton facilities;
  - Experimental studies of ground motion effects in accelerators;
  - Theory and experimentation on new collimation and cooling methods;
  - Training of the next generation of accelerator scientists and engineers.

Fermilab Program Elements
Alignment with OHEP Thrusts

- Muon Collider/Neutrino Factory
  - Design concepts, and major subsystem simulations and technology demonstrations for muon-based facilities;
  - Joint leadership (with BNL and LBNL) of the national Neutrino Factory and Muon Collider Collaboration (NFMCC);
  - Leadership of the Muon Collider Task Force (MCTF);
  - Strong cooperation with companies funded via the DOE Small Business Innovation Research program
- Beam Sources and Instrumentation
  - Activities centered at the A0 Photoinjector, in collaboration with a variety of outside laboratories and universities;
  - High performance electron source and diagnostics development;
  - Beam emittance manipulations;
  - Significant source of accelerator science PhDs at Fermilab.

Fermilab Program Elements
Principal Recent Accomplishments

- Accelerator and Beam Physics:
  - Developed and implemented optimized beam optics and helical beam separation schemes in the Tevatron, resulting in significant increases in Collider Run II luminosity
  - Developed and implemented instrumentation for improved beam emittance measurements, orbit stabilization, and beam stabilization in the Tevatron, Main Injector and Booster.
  - Studies and parameterization of proton-antiproton beam-beam effects; developed of numerical simulation tools capable of predicting emittance growth and particle losses.
  - Developed, constructed, installed, and operated two Tevatron Electron Lenses
    - Experimental demonstration of active compensation of beam-beam effects utilizing low-energy electron beams

Fermilab Program Elements
Principal Recent Accomplishments

- Accelerator and Beam Physics (cont.):
  - Developed and installed two-stage collimation systems in the Tevatron, Booster and Main Injector
    - ➢ Demonstrated high halo cleaning efficiency of proton and antiproton beams, in conformance with MARS simulations
  - Demonstrated high efficiency channeling of 980 GeV proton halo particles by bent crystals in the Tevatron.
  - Established a systematic program of ground and magnet motion studies covering time scales from years to msec
    - ➢ Results provided valuable input for the Tevatron Run II operation (e.g. continuous monitoring of the orbit drift sources), and ILC design studies

⇒ Note: Nearly all of these efforts have direct application to future facilities, including LHC and future lepton colliders

Fermilab Program Elements
Principal Recent Accomplishments

- Muon Collider/Neutrino Factory
  - Lead first complete feasibility study for a muon storage ring based neutrino factory (in collaboration with the NFMCC)
  - Unique advancements in critical muon sub-systems: bunching systems, non-scaling FFAGs, and 6-D cooling schemes (with Muons Inc.)
  - Developed integrated design concept for a multi-TeV muon collider (MCTF, with NFMCC and Muons Inc.)
  - Host to the muon cooling technology development (MuCool) program within NFMCC.
    - Construction and initial operations of the MuCool Test Area (MTA).
  - Measured and characterized 200 MHz accelerating cavity performance in a variety of configurations and within a magnetic field.
  - Demonstrated (with Muons Inc) increased gradients with high pressure gas filled cavities.

Fermilab Program Elements
Principal Recent Accomplishments

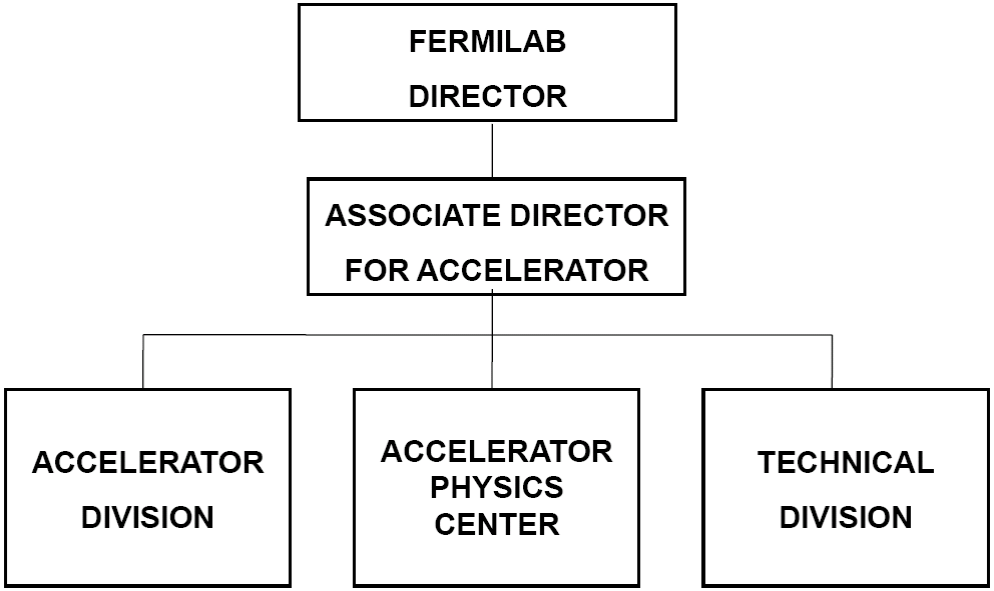
- Beam Sources and Instrumentation
  - First demonstration of the production of a flat electron beam with an emittance ratio of 100:1 via a “flat beam transformer”
  - Developed and characterized a higher harmonic deflecting mode cavity for transverse/longitudinal emittance exchange.
  - First demonstration of electro-optical techniques for high precision beam measurement.
- Education
  - Graduated 16 PhD students over the period 2000-2008. (Fermilab PhD program only)
  - Conducted two sessions annually of the U.S. Particle Accelerator School

Fermilab Proposal
Principal Goals

- The principal goals of the Fermilab proposal are aligned with the strategic goal of defining the path for the long term evolution of accelerator based high energy physics facilities:
  - Completion, with international partners, of a Reference Design Report for a muon-storage-ring-based Neutrino Factory by ~2013
  - Completion, with national partners, of a feasibility study for a Muon Collider with a center of mass energy in excess of 1 TeV by ~2013
  - Demonstration of a series of novel emittance manipulation techniques at the A0 Photoinjector with potential application to lepton colliders and/or advanced free electron lasers
  - Development of advanced computational and simulation tools, as well as novel accelerator technologies and methods, in support of the above

Organization and Personnel

- Activities are conducted within the Fermilab Accelerator Organization
  - Accelerator Physics Center formed in June 2007 to coordinate accelerator R&D activities aimed at the future
  - Note: Resources from the Computing and Particle Physics divisions are coordinated through APC:



Accelerator Science Personnel
Awards and Recognitions

- Wilson Prize
  - A. Tollestrup
  - H. Edwards
- National Medal of Technology
  - H. Edwards
- European Accelerator Prize
  - V. Shiltsev
- USPAS Prize
  - H. Edwards
  - S. Nagaitsev
- Faraday Cup Prize
  - A. Jansson
- National Academy of Sciences
  - A. Tollestrup
- APS Fellows
  - A. Bross
  - H. Edwards
  - S. Geer
  - S. Holmes
  - N. Mokhov
  - S. Nagaitsev
  - D. Neuffer
  - V. Shiltsev
  - M. Syphers
  - A. Tollestrup
  - V. Yarba

Leveraging Fermilab Resources

- The Fermilab Accelerator Science program is embedded in, and leverages resources and infrastructure from, the much larger operations and general technology development programs at Fermilab:
  - Accelerator facilities: The Fermilab complex is very flexible in its ability to deliver beam at a variety of energies to a variety of locations, simultaneous with ongoing operations
    - MuCool Test Area and Meson Area Test Beam are current examples
  - Accelerator personnel: Fermilab staff possess unique capabilities and skills in accelerator design, construction, and operations, and in advanced accelerator R&D. Personnel are available to support the Accelerator Science program on either temporary or longer term basis via full or part time assignment.

Leveraging Fermilab Resources (cont.)

- Accelerator computation/simulations tools: A variety of advanced computation and simulation tools are available in the APC and via the SciDAC sponsored national accelerator computational program, which is led by Fermilab and closely aligned with APC.
- Accelerator infrastructure: Very substantial cryogenics, electrical, and low conductivity water infrastructure are available within the accelerator complex at Fermilab.
- Local Universities and Laboratories: Several local universities, plus ANL, are active or potential participants in the Fermilab
- Support functions: Procurement, ESH, QA, accounting, etc. support are available at minimal incremental cost.

- In addition, because of our role in the U.S. program, Fermilab is uniquely positioned to provide the leadership in programs aimed at the development of future accelerator facilities in the U.S.

Budget Request

	All amounts in $K, fully burdened			
	Proposal Request Amounts			
	FY09	**FY10**	**FY11**	**FY12**
	Total	**Total**	**Total**	**Total**
Fermilab Accelerator Science Program	**9,876**	**12,702**	**14,620**	**TBD**
Beam Sources and Instrumentation	2,782	3,948	4,885	TBD
Muon Collider and Neutrino Factory	5,697	7,015	7,622	8,087
Accelerator and Beam Physics	1,397	1,739	2,113	2,095
February Presentation to OHEP (PBR)	**6,432**	**7,947**		
Difference	3,444	4,755		

- Notes:
  - Support for USPAS included in KA 15 01 02 starting in FY09 (subsequent to February budget presentation)
  - AARD program at NML (Beam Sources and Instrumentation) in FY12 will be developed of the next year.

Summary

- The Fermilab Accelerator Science Proposal supports the development of tools and technologies required for future accelerator facilities on the energy and intensity frontiers
  - Well aligned with the OHEP strategic plan and associated Accelerator Science thrusts
- The Accelerator Science Proposal has a strong educational component
  - USPAS office; Accelerator PhD program; Lee Teng internship (wth ANL)
- The Resource Request is matched to the proposal deliverables
- Details in the following presentations