



Revealing the Hidden Nature of Space and Time

Final Report of the Committee on
Elementary Particle Physics in 21st Century

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on behalf of the full committee

Two Distinctive Features of this Report

- Over the past 10 years, many committees have examined the future of elementary physics
 - What makes this assessment by the National Academies ANY different?
- 1. Committee membership was extraordinary in its breadth and its depth
 - Over half of the committee members were drawn from outside particle physics, bringing expertise in astronomy, astrophysics, condensed-matter physics, AMO science, even genetics, aerospace engineering, and economics
 - Report reflects the efforts of a broad group of distinguished individuals to place particle physics in the larger context and to understand the significance of the current opportunities
- 2. Report is framed both by exciting scientific opportunities and the ongoing national discussion of competitiveness, innovation, and the future position of U.S. science and technology in an increasingly globalized world

The “EPP2010” Committee

- National Academies convened this committee in response to an informal request from NSF and DOE to
 1. Identify the compelling questions that define particle physics
 2. Recommend a 15-year implementation plan with realistic, ordered priorities to address them
- Half of the members were drawn from outside of particle physics
- Committee met six times in person and conducted numerous site visits & discussions around the world

Harold T. Shapiro, <i>Chair</i> Princeton Univ	Sally Dawson, <i>Vice Chair</i> Brookhaven Natl Lab
Norman Augustine Lockheed Martin (retired)	Neal Lane Rice Univ
Jonathan Bagger Johns Hopkins Univ	Nigel Lockyer Univ of Penn
Philip Burrows Oxford Univ	Sidney Nagel Univ of Chicago
Sandra Faber Univ of Calif Observatories	Homer Neal Univ of Michigan
Stuart Freedman Univ of Calif, Berkeley	Ritchie Patterson Cornell Univ
Jerome Friedman MIT	Helen Quinn Stanford Linear Accel. Center
David Gross Kavli Inst for Theor. Physics	Charles Shank Lawrence Berkeley Natl Lab
Joseph Hezir EOP Group, Inc.	Paul Steinhardt Princeton Univ
Norbert Holtkamp Oak Ridge Natl Lab	Harold Varmus Sloan-Kettering
Takaaki Kajita Univ of Tokyo	Edward Witten Inst for Advanced Study

Nature of the Scientific Agenda

- As a committee of skeptics, outsiders, and insiders, how exciting were the scientific opportunities in particle physics?
- The committee concluded that not only is the scientific agenda especially exciting, but also that we are at a pivotal moment
 - Answers to long-standing questions are within reach
 - Convergence of separate lines of inquiries has special significance
- We are perhaps entering the most exciting era of particle physics in at least a generation

Status of the U.S. Program

- Historical distinction
- Stagnating level of support for past 10 years
- Intellectual center of gravity moving abroad
- Major US-based experiments are coming to the end of their scientifically useful lives

- → There is no clear follow-on plan in place
- → Significant risk of losing substantial (intellectual and financial) resources

Does Particle Physics Matter?

- Committee concluded that particle physics continues to be a critical component of the physical sciences
 - Intellectual vitality and connectedness to many other fields
 - Inspiration to and attractor for young people
 - One of the drivers of technological frontiers
- Particle physics is a discovery science
- Leadership in this field does not mean domination
- Being among the leaders, however, is critical for fully realizing the intellectual, economic, social, and cultural dividends

Experimental Opportunities

- The past success of particle physics has been built upon the drive to higher and higher energies
 - Paced by technological capability as well as the ability to pool resources around the world
 - Large Hadron Collider at CERN (Geneva) will open new horizons
 - ILC will broaden that horizon, and explore it
- The next step is not just a small step: it could be the next revolution
 - The convergence of interests in this energy range from particle physics, astrophysics, and cosmology indicate the potential for major scientific breakthrough
 - Discoveries are anticipated that could change how we think about particle physics, the universe, and the nature of space and time around us

Is There a Strategy Going Forward?

- Given the extraordinary scientific opportunities and the current state of the U.S. effort, was there a path forward that could return the United States to distinction in this field?
- The committee articulated a framework and evaluated several alternative strategies under different budget scenarios
 - Clear, relative priorities were proposed in this framework
- Alternatives
 - continued major commitment to accelerators in US - ILC
 - no new domestically-based accelerator
- Only a strategy that included a major commitment to exploit the Terascale opportunities with domestically based accelerator studies would stand a good chance to sustain U.S. distinction in particle physics.

Strategic Framework (1)

- Particle physics is an important part of the national effort in the physical sciences
 - Key intellectual role in physics
 - Driver of scientific and technological frontiers
 - Inspiration and attraction for future generations
- The United States should aspire to a leadership role in the global program of particle physics
 - In the modern world, leadership does not mean singular dominance but rather taking initiative at the frontiers, accepting appropriate risks, and catalyzing partnerships both at home and abroad

Strategic Framework (2)

- A diverse portfolio of activities is crucial
- To fully achieve the potential of particle physics, multi-year planning is required
 - Large-scale science requires long-term commitment
- The U.S. program in particle physics is poised for change
 - Fermilab will become the nation's only laboratory devoted primarily to particle physics and must play an integral role
 - A new level of national and international planning is required to make the next breakthroughs possible
 - Advisory and guidance processes for the field should be adjusted

Action Items

1. Exploit the opportunities offered by the LHC
2. Plan and initiate a comprehensive program to participate in the global effort to complete the necessary R&D to design and plan an international linear collider
3. Do what is necessary to mount an internationally compelling bid to build the international linear collider on U.S. soil
4. Seize the opportunities at the intersection of particle physics, astrophysics, and cosmology by coordinating and expanding domestic efforts
5. Pursue an internationally coordinated, staged program in the physics of neutrinos
6. Use large-scale and small scale opportunities in precision physics to hunt for physics beyond the Standard Model. (Large scale efforts (eg super B factory) should be undertaken via international cooperation, and only if budget allows.)

International Linear Collider

- **Scientific role**
 - LHC will map out the territory but a precision tool will be necessary for comprehensive understanding
- **Cost and schedule**
 - Global scientific consensus has led to a world-wide planning activity (the Global Design Effort)
 - Key objective is determination of a credible design, cost, and schedule
- **Relative timing**
 - ILC would only become tenable after cost and initial LHC results complete the grounds for decision-making
- **Opportunity for the United States**
 - Preliminary investment is needed
 - A successful U.S. bid-to-host requires taking initiative now

Bid to Host –some comments

Site specific planning and R&D

-- infrastructure needs, management structure

Industrialization

--some US-Based industry partners are key to success (both practically and politically)

Participation

-- US scientists playing key roles in both machine and detector development

Take-Home Message

- **Particle physics is at a crossroads**
 - Scientific discoveries are just within reach whose impact is likely to transform and even transcend particle physics
 - U.S. facilities are being closed or converted to other uses and federal investments have stagnated
 - Intellectual center of gravity is moving overseas with the construction of new facilities in Europe and Japan
- **→ Without clear, decisive action in the next few years, the U.S. program will collapse**
- **→ The United States should continue to support a competitive program in this key scientific field**
- **→ The committee outlines a strategy that puts the United States at the forefront of the field with a program of distinction and importance**