



The EPP2010 Report
Revealing the Hidden Nature
of Space and Time

Report of the Committee on Elementary Particle
Physics in (the First Decades of) the 21st Century

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What is EPP2010?

- A report of the National Research Council (NRC)
- What is the NRC?
 - Part of the National Academies

“The National Academies perform an unparalleled public service by bringing together committees of experts in all areas of scientific and technological endeavor. These experts serve pro bono to address critical national issues and give advice to the federal government and the public.”
(from the web site of the National Academies)

- NRC reports are not US policy; rather, they are recommendations about policy by independent experts
- NRC carries out “decadal surveys” of many scientific fields, including Elementary Particle Physics (EPP)

EPP2010 origin

- Requested by the NSF and DOE
- US is at a crossroads
 - PEP-II, Tevatron, CESR runs will end soon; BNL EPP program complete; the future of US facilities is uncertain
 - Past reports have identified priorities: LHC, ILC R&D, neutrinos, astrophysics, etc, but we have lacked a financially realistic, widely-supported plan.
 - There are underlying questions about the value of the field, and the merit of supporting it as facilities grow increasingly expensive.

How is EPP2010 different?

- Very diverse membership
 - Particle physicists
 - Physicists from outside EPP: astrophysics, nuclear physics, atomic physics, condensed matter physics.
 - And leaders from outside physics: energy policy, genetics, optics, aerospace engineering & economics.
- This breadth and expertise equipped the committee to
 - Assess the value of particle physics
Is it an important area of research? Why?
 - Judge opportunities within that context
Which are most worthwhile?

EPP2010 Membership

Harold T. Shapiro, <i>Chair</i> Princeton University	Sally Dawson, <i>Vice Chair</i> Brookhaven Natl. Lab
Norman Augustine Lockheed Martin (retired)	Neal Lane Rice University
Jonathan Bagger Johns Hopkins University	Nigel Lockyer University of Penn
Philip Burrows Oxford University	Sidney Nagel University of Chicago
Sandra Faber Univ. of California Observatories	Homer Neal University of Michigan
Stuart Freedman Univ. of California, Berkeley	Ritchie Patterson Cornell University
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 University
Norbert Holtkamp Oak Ridge Natl. Lab	Harold Varmus Sloan-Kettering
Takaaki Kajita University of Tokyo	Edward Witten Inst. for Advanced Study

About half are outside our field. Some are not physicists, or even scientists.

EPP2010 Charge

1. Identify the compelling questions that define the current particle physics agenda
2. Recommend a 15-year implementation plan with realistic, ordered priorities to address them

Procedure

- **6 meetings** - Talks by Quigg, Lykken, Drell, Turner, Staffin, Looney, McKee, Seiden, Barish, Hinchliffe, Murayama, Hewett, Cahn, Kayser, Kahn, Dorfan, Witherell, Wagner, Totsuka, Halliday, Holmes, Feldman, Kolb, Oddone, Arkani-Hamed, Aymar, Tigner, Kojita ...and many others
- **Visits to KEK, J-PARC, DESY, CERN, SLAC, Fermilab, Cornell**
- **Several town meetings with US HEP community**
- **Numerous written comments from around the world**

Overarching Conclusions

- Particle physics is a critical component of the physical sciences.
 - It inspires young people and contributes to cultural vitality
 - It attracts scientific talent from around the world
 - It drives technological frontiers
- Particle physics is at an exciting juncture
 - It faces important questions such as origin of mass, unification, dark matter, baryon asymmetry..
 - Powerful new tools - LHC, proposed ILC, space-based experiments, underground labs and others could address them

“The United States should remain globally competitive in elementary particle physics by playing a leading role in the worldwide effort to aggressively study Terascale physics.”

Status of US Program

- **Historic distinction**
- **Leadership moving abroad**
Committee was impressed by the vibrancy of the programs in Asia and Europe
- **Stagnant funding for the last decade**
“The committee believes that, in the long term, the current level of resources being committed to [U.S.] particle physics is inadequate to obtain the technological, economic, social and scientific benefits...”
- **Major programs (PEP-II, Tevatron) coming to an end**
Risk that funding will be lost to the field
- **Uncertain priorities for the future**
Past panels have identified the energy frontier as high priority, but there is no clear plan that fits ILC R&D into the rest of the program.
- **On the positive side: The conclusion of PEP-II and Tevatron creates an opportunity for fresh initiatives.**

Strategic Principles I

- The National Importance of Elementary Particle Physics
The committee affirms the intrinsic value of elementary particle physics as part of the broader scientific and technological enterprise and identifies it as a key priority within the physical sciences.
- U.S. Leadership
The U.S. program in elementary particle physics should be characterized by a commitment to leadership within the global particle physics enterprise.
Leadership is NOT dominance. Rather, leadership means:
 - Taking initiatives at the scientific frontier
 - Accepting risks
 - Catalyzing partnerships with colleagues at home and abroad.

Strategic Principles II

- A Global Particle Physics Program

Pooling resources is essential as facilities become more expensive.

- Sometimes the U.S. should invite international partnership on projects that will be located at home, and should be a lead investor in them.
- Sometimes it should join partnerships abroad, and invest there.
- True partnership means planning jointly from the earliest stages.

Strategic Principles III

- Characteristics of a Leadership Program
 - A long-term vision
 - A clear set of priorities
 - A willingness to take scientific risks where justified by the potential for major advances
 - A determination to seek mutually advantageous joint ventures with colleagues abroad
 - A considerable degree of flexibility and resiliency
 - A budget consistent with an aspiration for leadership
 - As robust and a diversified a portfolio of research efforts as investment levels permit.

Budgets

- Effective Long-Term Budget Planning
The Secretary of Energy and the Director of the NSF, working with the White House OSTP and the OMB and in consultation with the relevant authorization and appropriations committees of Congress, should as a matter of strategic policy establish a 10- to 15-year budget planning projection for the EPP program.

Long-term budgeting is essential both to U.S. planning and to international partnerships

U.S. Considerations

- The Role of Fermilab

A strong and vital Fermilab is an essential element of U.S. leadership in EPP. Fermilab must play a major role in advancing the priorities identified in this report.

Fermilab will soon be the only U.S. laboratory devoted *primarily* to particle physics. The committee expects it to support and help mobilize the national program.

- The Advisory Structure

A standing national program committee should be established to evaluate the merits of specific projects and to make recommendations to the DOE and NSF regarding the national particle physics program within the context of international efforts.

This could be P5, but transformed into a standing committee with a broader mandate.

Priorities in a nutshell

1. Exploit the opportunities offered by the LHC.
2. Participate vigorously in the global effort of R&D for the ILC.
3. Mount an internationally compelling bid to build the ILC on U.S. soil.
4. Expand, in coordination with NASA, efforts at the intersection of particle physics, astrophysics, and cosmology.
5. Pursue an internationally coordinated, staged program in the physics of neutrinos and proton decay.
6. Pursue precision probes of physics beyond the Standard Model at a level guided by resources while maintaining diversity.

Funding will dictate how many of these can be accomplished.

LHC

- ***Finding:*** The study of LHC physics will be at the center of the U.S. Particle physics program during the coming decade.
- ***Action Item:*** The highest priority in the U.S. national effort in elementary particle physics should be to continue to be an active partner in realizing the physics potential of the LHC program.

ILC Readiness

- *Finding:* An aggressive approach to the realization of the ILC is the central element in a new strategic plan for the U.S. program in particle physics.
- *Action item:* The U.S. should launch a major program of R&D, design, industrialization, and management and financing studies of the ILC accelerator and detectors.

This commitment to R&D for the ILC is independent of where it is eventually sited. Wherever the ILC is built, the U.S. wants to be a major participant.

Bidding to host the ILC

- *Finding:* Hosting the ILC will inspire students, attract talented scientists from throughout the world, create a suite of high-technology jobs, and strengthen national leadership in science and technology.
- *Action item:* The U.S. should announce its strong intent to become the host country for the ILC and should undertake the necessary work to provide a viable site and mount a compelling bid.

The committee expects that other regions will also seek to host the ILC (see, for example, Japan's "Federation of Diet Members for the Realisation of the ILC").

We should embrace this: strong interest in hosting the ILC is crucial if the ILC is to be built.

Astrophysics & Cosmology

- ***Finding:*** EPP has an extraordinary opportunity to make breakthrough discoveries by engaging in astrophysics and cosmology research...
 - Direct detection of dark matter
 - CMB polarization
 - Dark energy properties
- ***Action items:***
Scientific priorities at the interface of particle physics, astrophysics, and cosmology should be determined through a mechanism jointly involving NSF, DOE and NASA, with emphasis on DOE and NSF participation in projects where the intellectual and technological capabilities of particle physicists can make unique contributions.

The committee recommends that an increased share of the current U.S. elementary particle physics research budget should be allocated to address the questions identified above.

Neutrinos and Proton Decay

- *Finding:* A program of neutrino physics, including, eventually, a detector large enough for sensitivity to proton decay, offers a probe of unification physics.
- *Action item:* The committee recommends that the properties of neutrinos be determined through a well-coordinated, staged program of experiments developed with international planning and cooperation.
 - A phased program of neutrinoless double beta decay searches should be pursued with high priority.
 - DOE and NSF should invite international partners to initiate a multiparty study to explore joint efforts in accelerator-based neutrino experiments. Major investments in this area should be evaluated in light of the outcome of this process.
 - Longer term goals should include experiments to unravel possible CP violation in the physics of neutrinos and renewed searches for proton decay. If placed deep underground, the same instrument may serve both objectives.

Precision Experiments

- ***Finding:*** Studies of the patterns of weak interactions (particularly rare decays and CP violation in the quark sector), dipole moments, table-top tests of gravity, and lepton flavor- and lepton number-violation offer a window to search for and more precisely define the physics that could lie beyond the Standard Model.
- ***Action Item:*** U.S. participation in large-scale high-precision experiments that probe particle physics beyond the SM should continue, but the level of support that can be sustained will have to be very sensitive to the overall budget picture. Only very limited participation will be feasible in budget scenarios with little to no real growth. Participation in inexpensive, small-scale, high-precision measurements should be encouraged in any budget scenario.

Final Observations

- **This is an exciting time in particle physics. It was gratifying, even inspiring, to see this excitement infect the non-physicists on the EPP2010 committee.**
- **The report strongly endorses the value of particle physics to the U.S. and lays a path to revitalize the U.S. program. The ILC is central to this plan.**
- **In the future, expect the U.S. to seek international partnership on all major projects from the earliest stages of planning.**