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Formal Report (Summary)

[PARTICLE-96-SYM#2]

Future High Energy Colliders

Symposium

(October 21 - 25, 1996)

Summary Report

BY

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**Future High Energy Colliders
Symposium
(October 21 - 25, 1996)
Summary Report**

BY

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MASTER

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“Future High Energy Colliders”

A “Future High Energy Colliders” Symposium was held October 21-25, 1996 at the Institute for Theoretical Physics (ITP) in Santa Barbara. This was one of the 3 symposia¹ hosted by the ITP and supported by its sponsor, the National Science Foundation, as part of a 5 month program on “New Ideas for Particle Accelerators.” The long term program and symposia were organized and coordinated by Dr. Zohreh Parsa of Brookhaven National Laboratory /ITP.

The purpose of the symposium was to discuss the future direction of high energy physics by bringing together leaders from the theoretical, experimental and accelerator physics communities. Their talks provided personal perspectives on the physics objectives and the technology demands of future high energy colliders. Collectively, they formed a vision for where the field should be heading and how it might best reach its objectives.

As the name of this conference suggests, the primary tools for performing high energy physics research are particle beam colliders. Following the famous Einstein equation $E = mc^2$, collisions of high energy particles produce events in which much of the energy of the beams is converted into the masses of new heavy particles not normally found in nature. By studying the production and decay of these new particles, the underlying structure of the universe and the laws that govern it are unveiled.

The design and construction of particle accelerators used in high energy physics are motivated and constrained by 1) the forefront physics questions being asked, 2) the availability of technology needed to build and operate these machines as well as capabilities to detect and analyze the collisions, and 3) the cost of the machine and the availability of construction funds from home and foreign governments. High Energy Physics in the United States is now at a crossroads where its future will depend on: participation in foreign projects, upgrading and utilizing existing facilities, and new construction initiatives.

Some of the underlying physics motivations and technical issues had been addressed at earlier workshops such as Snowmass 1996. The Santa Barbara “Future High Energy Colliders” Symposium’s novel aim was to begin the process of reaching a consensus on how to attain the vision.

¹In addition to this symposium, a week long symposium was held on “New Modes of Particle Acceleration – Techniques and Sources” August 19-23, 1996. Some of the highlights of that meeting included Novel Modes of laser, plasma, wakefield accelerations, techniques and power sources. A third symposium on “Beam Stability and Nonlinear Dynamics” will be held on December 3 - 5, 1996 and will deal with some of the fundamental theoretical problems associated with accelerator physics.

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The goal of Elementary Particle Physics is to understand the nature of matter and the forces acting on it. Experiments over the last two decades have convincingly shown that the strong, electromagnetic, and weak forces are all closely related and are simply described by the "Standard Model." In particular the anticipated sixth quark, top, has been recently found at Fermilab, and the predicted properties of the Z boson, one of the carriers of the weak force, have been tested to better than 1%. There is now little doubt that the Standard Model is a very good description of the basic forces responsible for all atomic and nuclear physics. While the Standard Model is a great success, there remain many open questions in Elementary Particle Physics. Perhaps the most urgent is to understand how masses of the particles originate. To that end, new physics beyond what is currently known is required. The simplest possibility, the "Higgs Mechanism" predicts the existence of a fundamental Higgs Boson. Finding that elusive particle or whatever new physics is actually responsible for mass generation motivated the Superconducting Supercollider (SSC) and remains the primary goal of the next generation of colliders. A number of other interesting and more elaborate models have been proposed, but there is as yet no direct experimental evidence supporting any of them. Nevertheless, consistency of the Standard Model requires that the new physics responsible for mass generation occur at an energy scale of less than about 1 TeV, i.e. within the range of the next generation of accelerators. In addition to the origin of mass, there are other compelling questions. For example, the observed matter-antimatter asymmetry in the universe is not understood. Also, astrophysical observations suggest that between 90% and 99% of the matter that makes up the universe is invisible. There are a number of possible candidates for this "dark matter," but none have been proven experimentally to exist.

Currently, the operation of the Tevatron proton-antiproton collider at the Fermi National Accelerator Laboratory and the SLC electron-positron collider at the Stanford Linear Accelerator Center are at the energy frontier of the field. The use of both proton-antiproton and electron-positron collisions is important in order to provide complementary information. At the energy frontier new particles never before observed are discovered and studied, providing unique insight into the laws of nature. Recently, the LEP electron-positron collider at the CERN laboratory in Geneva began upgrading its energy, expanding the energy frontier in electron-positron collisions by about a factor of 2. Sometime near the year 2005 the LHC proton-proton collider in Geneva will operate with world record beam energy about 7 times that of the Fermilab Tevatron.

The Large Hadron Collider (LHC) at CERN is intended to address the question of

the origin of mass. Because we know the energy scale associated with mass generation, we can be reasonably confident that the LHC will discover this new physics, whether it is a Higgs boson or something quite different.

Although the LHC should elucidate the origin of mass, it probably cannot answer all the outstanding questions. For that reason, a collaboration involving institutions from Germany, Japan, the United States and many other countries has been developing a design for a high energy e^+e^- collider, the Next Linear Collider (NLC). This would have a somewhat lower energy reach than the LHC, at least initially, but it would be able to make many interesting unique measurements that would complement those at the LHC. Together the LHC and the NLC should clarify the origin of mass and address many other open questions. They might also find the explanation for the dark matter in the universe and open new frontiers such as the much anticipated spectrum of heavy particles predicted by supersymmetry, an elegant extension of the underlying structure of space - time. If supersymmetry is found, it will become the focus of high energy physics. Studying its spectrum of particles and their properties will be a major experimental enterprise.

Also under discussion at Brookhaven National Laboratory, Fermilab, Lawrence Berkeley National Laboratory, and many Universities is a muon collider. The feasibility of building an accelerator in which muons collide with antimuons is currently under serious investigation. Since muons (at rest) decay in about two millionth of a second, building such a collider would be a major technological achievement. A survey of the physics that could be studied at such a machine overlaps with e^+e^- collider capabilities but also includes novelties such as the possibility for fusion of the colliding beams to produce Higgs particles. This process would permit e.g. the precise direct measurement of the mass and lifetime of the Higgs particle as well as its decay properties. However, the main enthusiasm for the muon collider stems from its potential to reach very high energies and the possibility that it could be constructed at an existing national laboratory.

An explanation of the matter-antimatter asymmetry in our universe requires first an understanding of the origin of mass. In addition, important supporting information can be obtained by studying rare interactions of a variety of known particles, including B mesons, K mesons, and muons. Such experiments are ongoing at several laboratories, and with the advent of B factories and intensity upgrades of proton synchrotrons at Brookhaven and Fermilab more will be carried out in the future.

A unique feature of the symposium was the bringing together of many physicists who will have a major impact on the future direction of the field. Especially important

was the set of presentations made by the Department of Energy Director of Energy Research M. Krebs, by B. Kayser of the National Science Foundation, and by the directors of the three U.S. High Energy Physics laboratories, J. Peoples (Fermilab), B. Richter (Stanford Linear Accelerator Center) and N. Samios (Brookhaven National Laboratory). Their perspectives combined with presentations by internationally distinguished high energy and accelerator physicists provided a comprehensive picture of the issues involved in formulating appropriate goals for the future. The difficult aspects and the far reaching consequences of the decisions that must be made were further clarified during a unique panel discussion designed to initiate the process of reaching accord in the high energy community as to what the future physics and accelerator priorities should be. Although there is not unanimity of opinion in all matters, there is a consensus that an NLC should be built somewhere in the world and vigorous R & D should be pursued in promising new areas such as the muon collider concept and new modes of particle acceleration.

Given the long lead times necessary for the design of new particle accelerators, it is important for the high energy physics community to decide soon what types and energy ranges of colliders are necessary to address the additional questions which the LEP and LHC may not be able to answer.

The perspectives that were presented at the symposium on the state and future of high energy physics are vital ingredients in the continuing discussion of how the U.S. High Energy Physics community should best marshal its national scientific resources while continuing a high level of international collaboration. They should provide valuable input for ongoing discussions and in making decisions regarding the future direction of the field.

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ITP Conference on Future High Energy Colliders

October 21-25, 1996

Coordinator: *Z. Parsa*

Advisory Committee: *D. Cline, G. Jackson, W. Marciano, and P. Wilson*

SCHEDULE

Monday, October 21, 1996

<u>Time:</u>	<u>Speaker:</u>	<u>Title:</u>
8:00 am	Registration	ITP Lobby

Convener: **Z. Parsa, BNL**

8:40	J. Hartle, ITP Director	Welcome
	Z. Parsa, BNL	Welcome & Introduction

Defining Perspective Presentations:

9:00	D. Gross, Princeton Univ.	Perspectives on Future High Energy Physics
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9:55	Refreshment Break	ITP Front Patio
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Convener: **G. Jackson, FNAL**

10:25	J. Peoples, FNAL Director	Perspectives on Future High Energy Physics
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11:20	B. Richter, SLAC Director	Perspectives on Future High Energy Physics
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12:15 pm	Lunch	ITP Front Patio
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Convener: **R. Peccei, UCLA**

1:45	N. Samios, BNL Director	Perspectives on Future High Energy Physics
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View From Washington:

2:40	M. Krebs, DOE	Perspectives on Future High Energy Physics,
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3:35	Refreshment Break	ITP Front Patio
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4:05	B. Kayser, NSF	Perspectives on Future High Energy Physics,
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5:00	Session Ends	
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5:15	Wine & Cheese	ITP Front Patio
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5:45	Buffet Dinner	ITP Front Patio
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Tuesday, October 22, 1996:

<u>Time:</u>	<u>Speaker:</u>	<u>Title:</u>
<u>Convener:</u>	V. Barger, U. Wisconsin	
9:00 am	W. J. Marciano, BNL	Physics of the Standard Model and Beyond
9:45	S. Willenbrock, UII	Higgs Physics
10:30	Refreshment Break	ITP Front Patio
11:00	J. Gunion, UCD	Supersymmetry
11:45	T. Appelquist, Yale	Strongly Interacting New Physics
12:30 pm	Lunch	ITP Front Patio
<u>Convener:</u>	M. Harrison, BNL	
2:00	L. Rolandi, CERN	LEP Status Report
2:55	D. Amidei, U Michigan	Collider Physics at FNAL & TeV2000, Physics Issues
3:45	Refreshment Break	ITP Front Patio
4:15	G. Jackson, FNAL	TeV2000, Accelerator Issues
5:30	Session ends	

Wednesday, October 23, 1996:

<u>Time:</u>	<u>Speaker:</u>	<u>Title:</u>
<u>Convener:</u>	N. Lockyer, U. Pennsylvania	
9:00 am	E. Keil, CERN	Status of LEP II and LHC
9:45	I. Hinchliffe, LBL	Large Hadron Collider (LHC) Physics
10:30	Refreshment Break	ITP Front Patio
11:00	M. Harrison, BNL	Big Hadron Collider
11:45	H. Murayama, LBL	e^+e^- Physics
12:30 pm	Lunch	ITP Front Patio
<u>Convener:</u>	D. Silverman, UC Irvine	
1:45	F. Paige, BNL	Complementarity of Lepton and Hadron Colliders
2:25	D. Burke, SLAC	Overview & Outlook for Linear Colliders and Next Linear Collider SLAC ZDR Design
3:30	Refreshment Break	ITP Front Patio
<u>Convener:</u>	L. Rolandi, CERN	
4:05	N. Toge, KEK	Japan's Status on Next Linear Collider
4:45	R. Brinkman, DESY	Superconducting Collider (TESLA)
5:25	Session ends	

Thursday, October 24, 1996

<u>Time:</u>	<u>Speaker:</u>	<u>Title:</u>
<u>Convener:</u> A. Tollestrup, FNAL		
8:30 am	P. Wilson, SLAC	Scaling Linear Collider to 5 TeV and above
9:10	Refreshment Break	ITP Front Patio
9:45	R. Palmer, BNL	Overview of Muon Collider Design Simulations & Detector
10:40	D. Cline, UCLA	Concepts for $\mu^+ \mu^-$ Cooling and Polarized Sources
11:20	V. Barger, UWI	$\mu^+ \mu^-$ Collider Physics Capabilities
12:05	Lunch	ITP Front Patio
<u>Convener:</u> R. Sawyer, UCSB		
1:30	C. Heusch, UCSC	$e^- e^-$ Collider
1:50	V. Telnov, INP	Photon-Photon Collider
2:30	S. Ritz, Columbia Univ	Lepton - Hadron Collider
3:05	Refreshment Break	ITP Front Patio
<u>Convener:</u> C. Pellegrini, UCLA		
3:35	R. Siemann, SLAC	Snowmass 96 - Summary
4:15	Z. Parsa, R. Palmer, M. Harrison (BNL) G. Jackson, A Tollestrup, (FNAL) R. Ruth, J. Irwin,, P. Wilson (SLAC) C. Pellegrini , (UCLA) and other speakers	New Reports* & Round Table Discussion on Basic Issues in the Accelerator. Physics & Technology of: Linear, Accelerators, Muon, Big Hadron. Collider, etc.. (* = To be announced)
5:30	Light Buffet Dinner	ITP Front Patio

Friday, October 25, 1996

<u>Time:</u>	<u>Speaker:</u>	<u>Title:</u>
<u>Convener:</u>	M. Mugge, LBL	
9:00 am	J. Irwin, SLAC	Fundamental Limitations of Particle Accelerators
9:40	Refreshment Break	ITP Front Patio

Futuristic Technology

10:15	T. Katsouleas, USC	Highlights of "New Modes of Particle Acceleration Techniques and Sources" Symposium, ITP (96)
10:55	S. Chattopadhyay, LBL	A Report on the Advanced Accelerator Concepts Workshop (96)
11:35	Z. Parsa, BNL	Summary and Closing Talk
12:20 pm	Lunch	ITP Front Patio

BNL	Brookhaven National Laboratory
FNAL	Fermi National Accelerator Laboratory
ITP	Institute for Theoretical Physics
LBL	Lawrence Berkeley National Laboratory
LANL	Los Alamos National Laboratory
SLAC	Stanford Linear Accelerator Center
*	Space for late contributions

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