Physics United

Fermilab Users Meeting

June 2, 2004

Neil Calder, Director of Communications SLAC

The shape of things to come

PHYSICS | New sense of excitement

Continued from Page 1E

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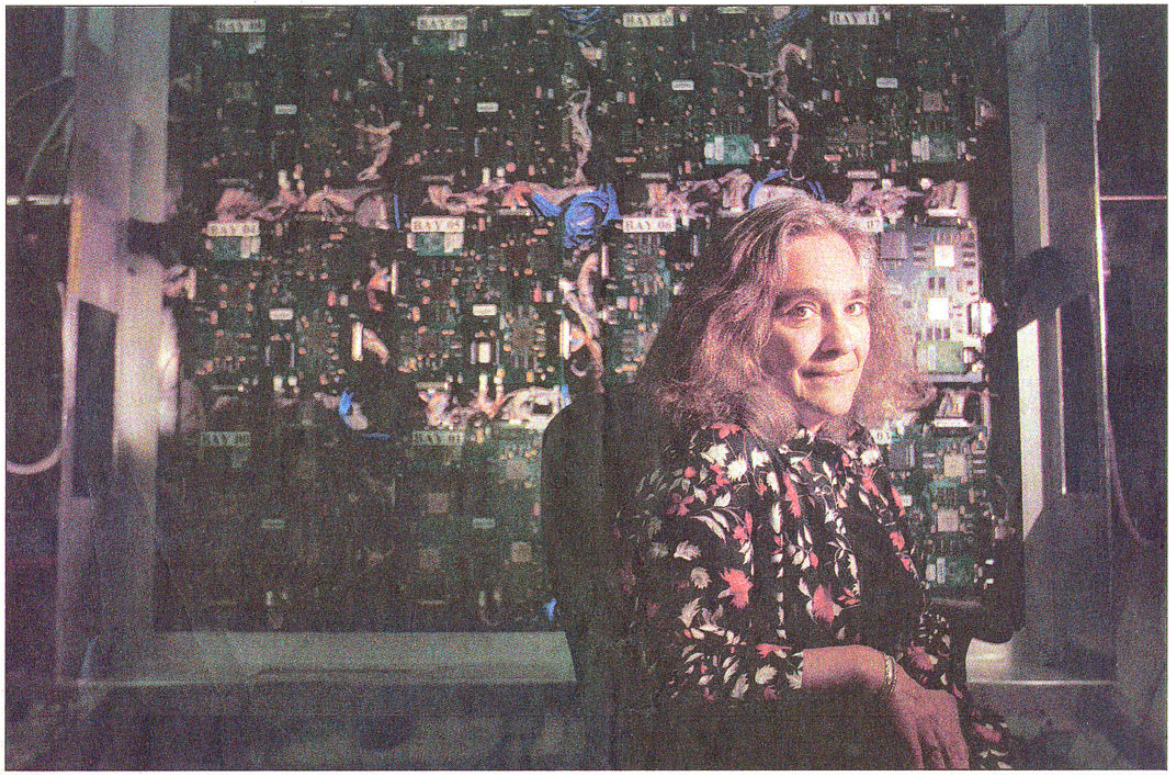

DAI SUGANO — MERCURY NEWS

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At the moment, there is no

June 1, 2004

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Director of Communications

SLAC

No 1 on Google

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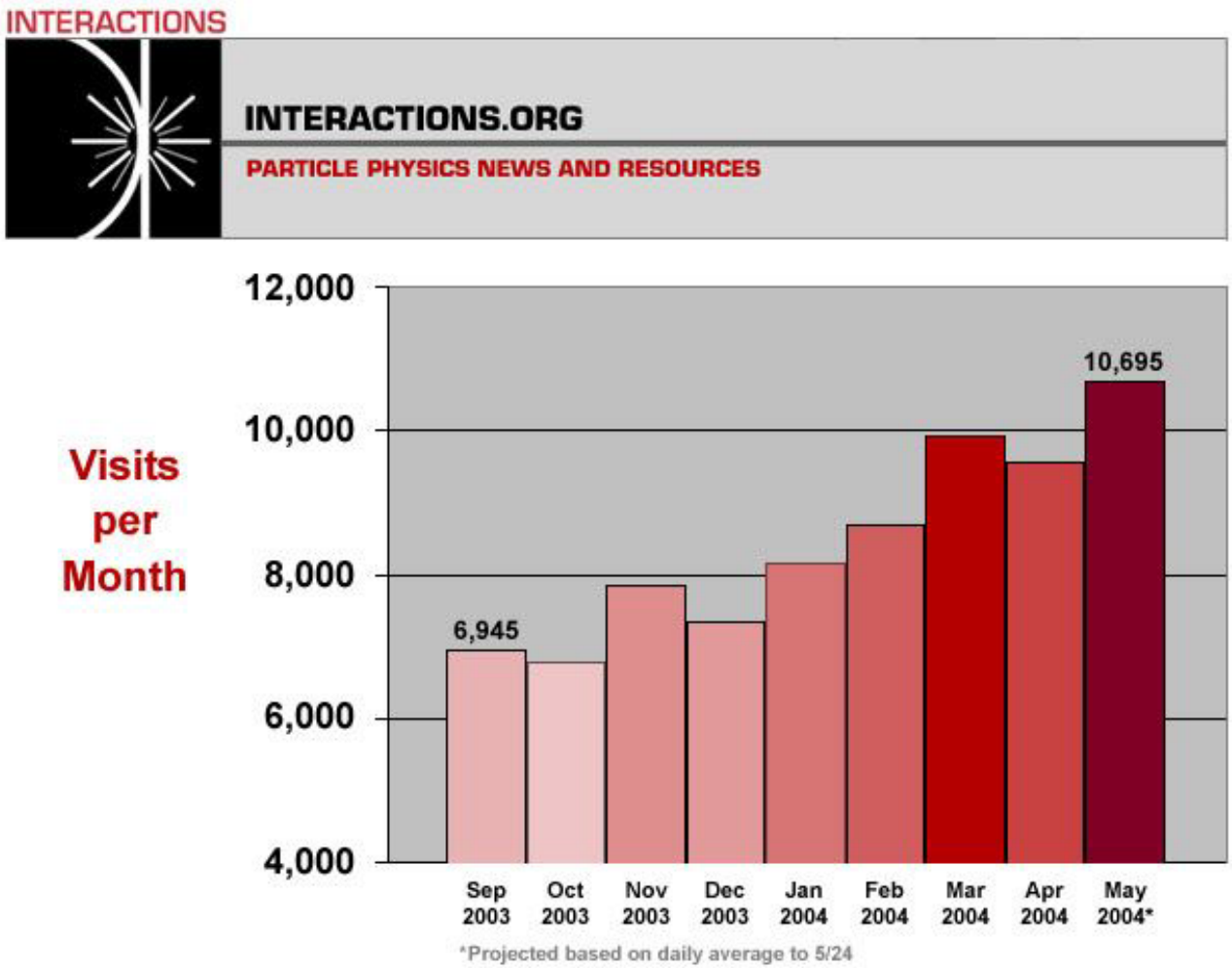
Up &Up



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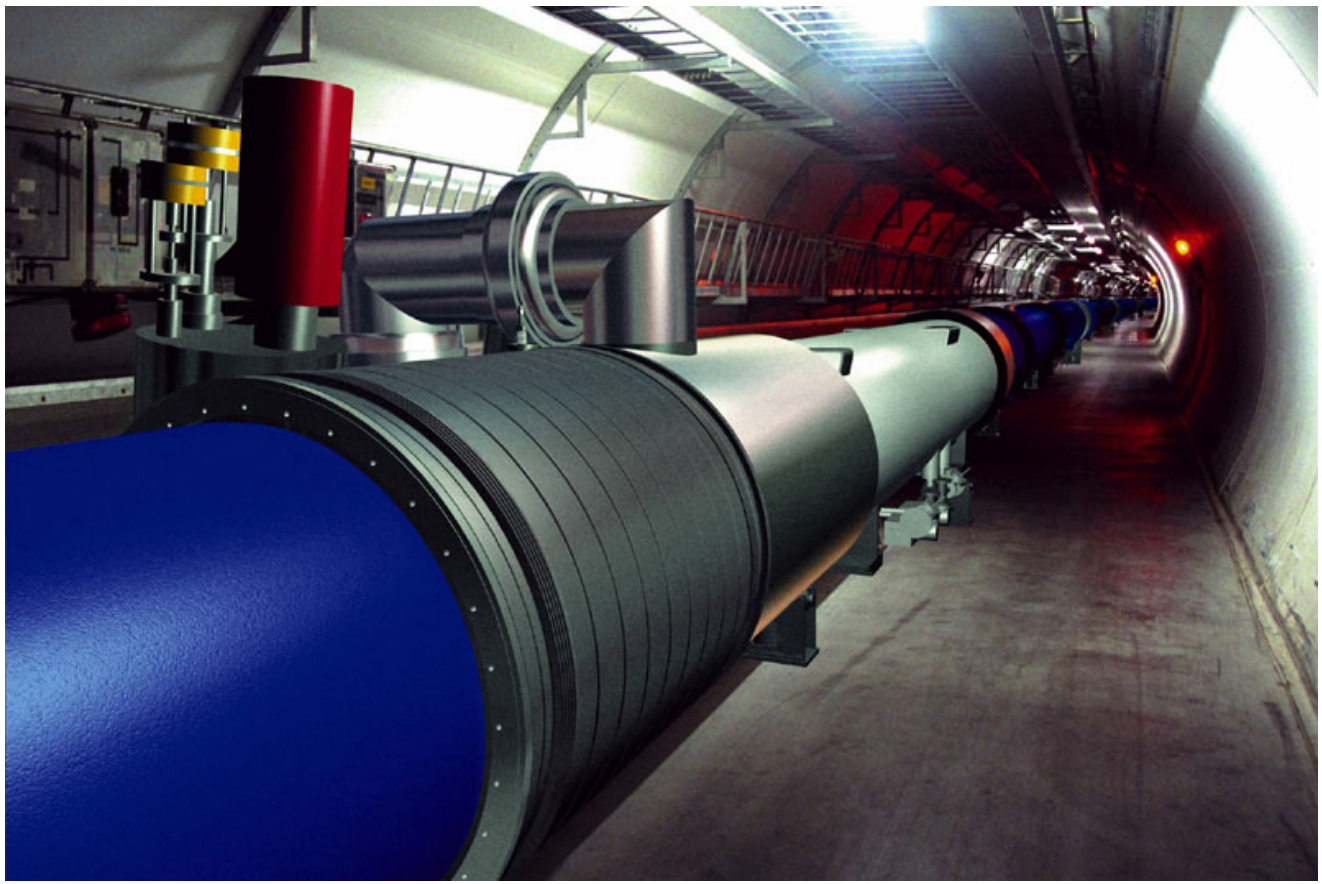
Coming Soon



LHC

PR06.04
11.05.

- **First Fermilab LHC magnet leaves Illinois, bound for CERN**

PRESS RELEASE

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- **FIRST FERMILAB LHC MAGNET LEAVES ILLINOIS, BOUND FOR GENEVA**

June 1, 2004

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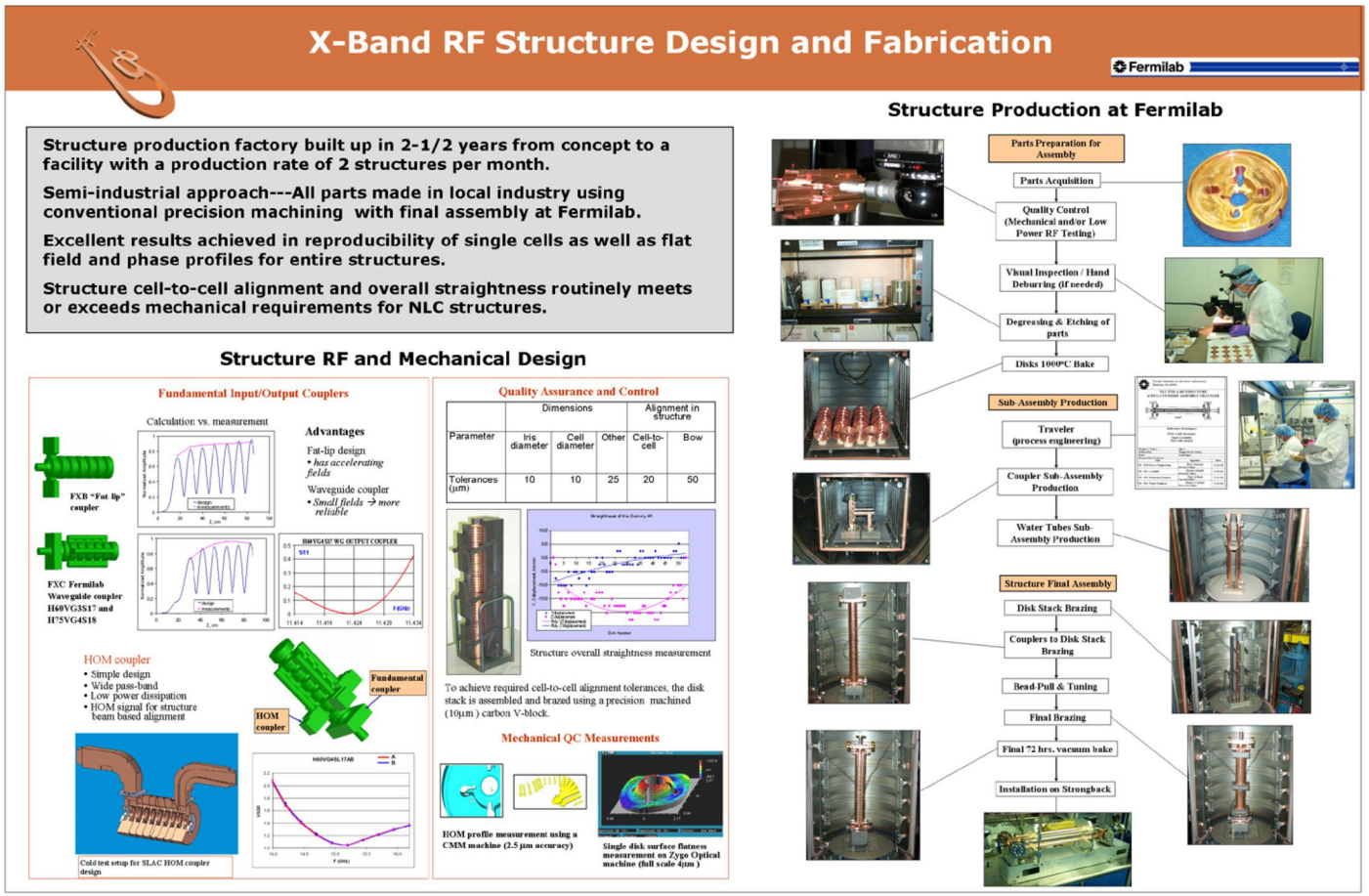
The Road to a Linear Collider

- ITRP process drawing to a close
- Recommendation in August
- Coordinated response
- Be prepared!

ITRP Thanks Fermilab



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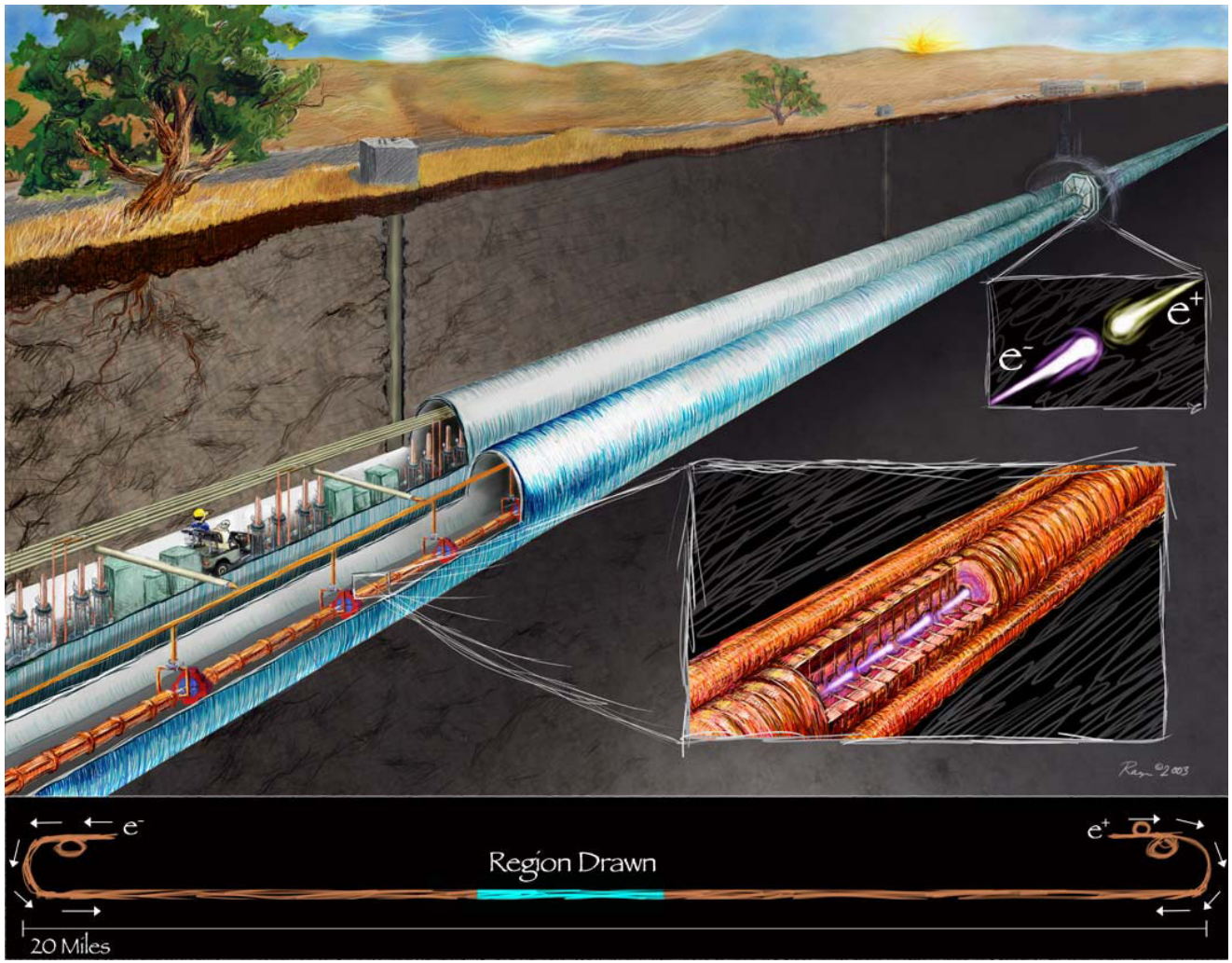

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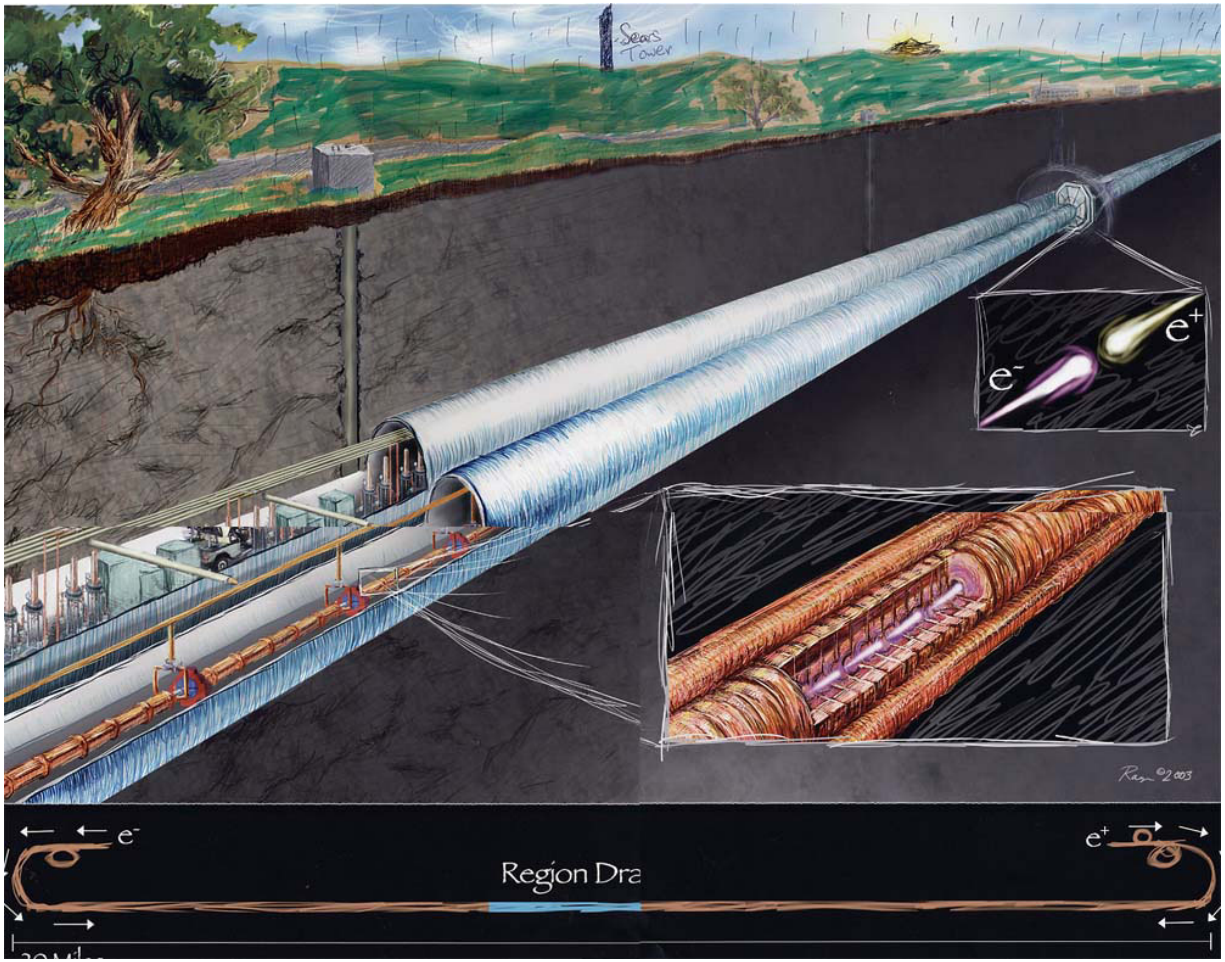
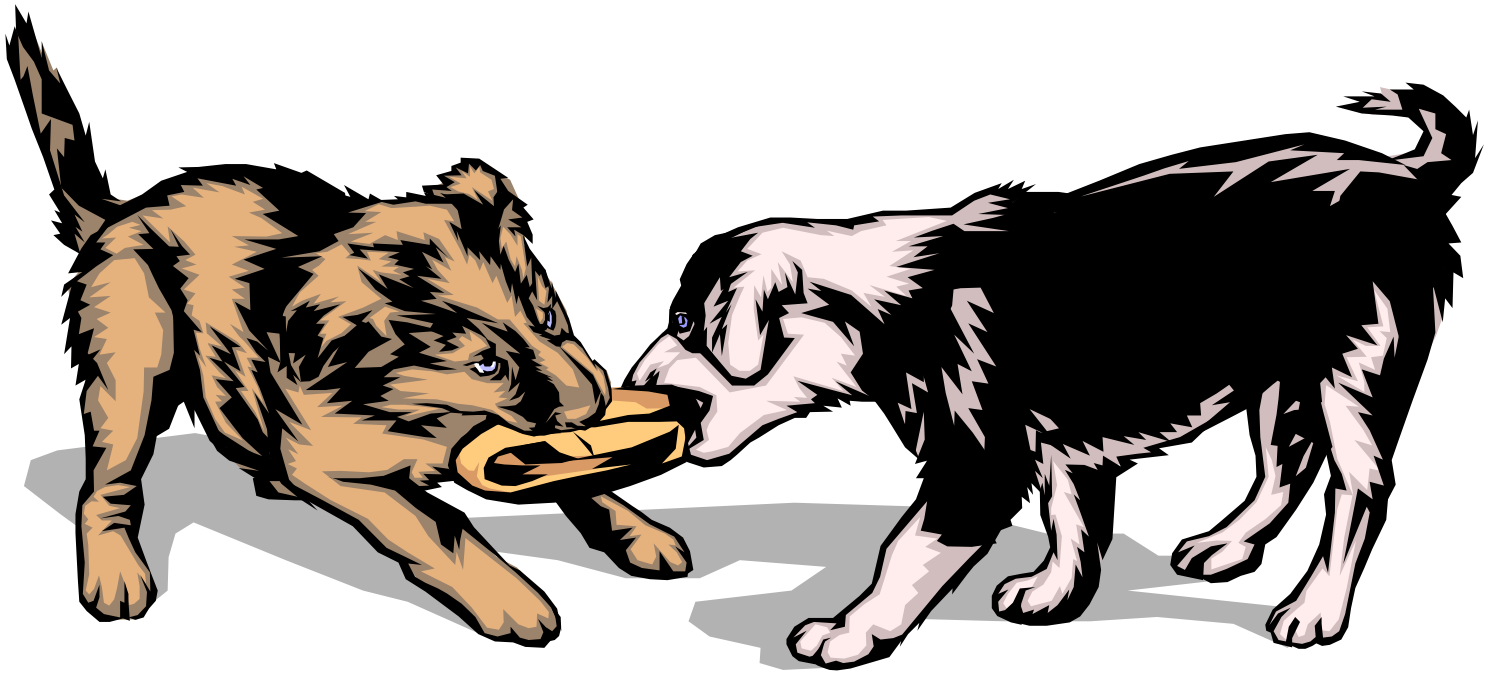


No Squabbling



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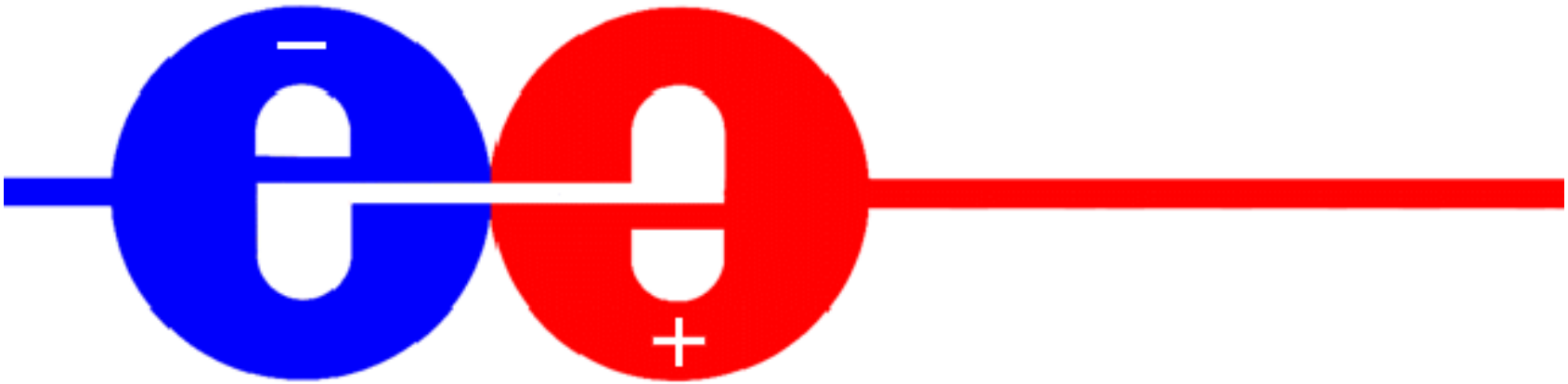
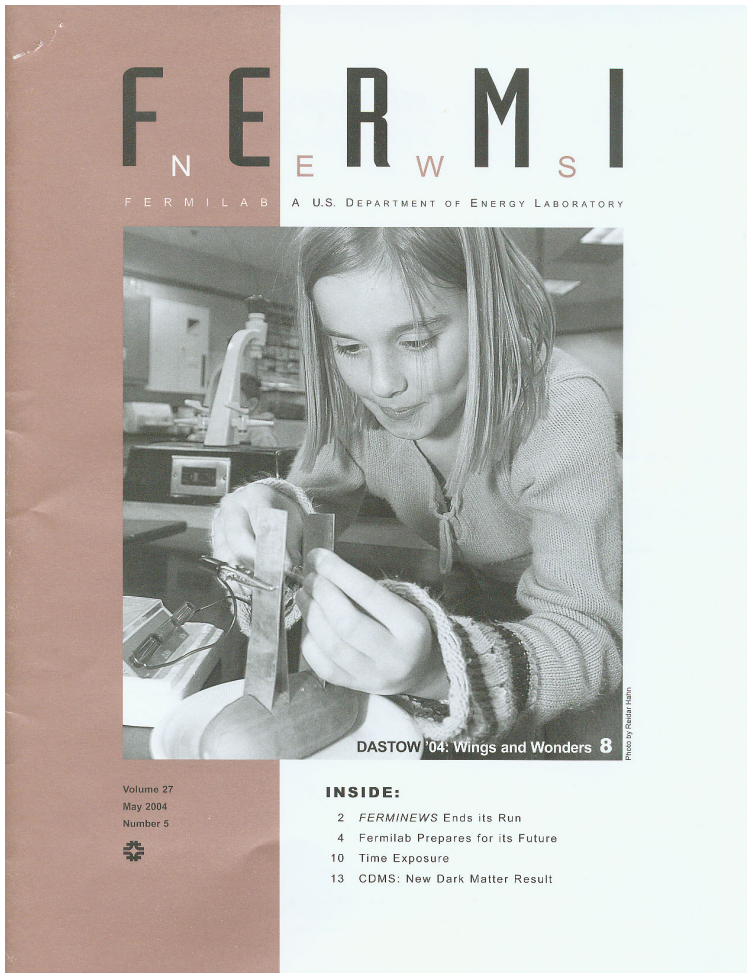
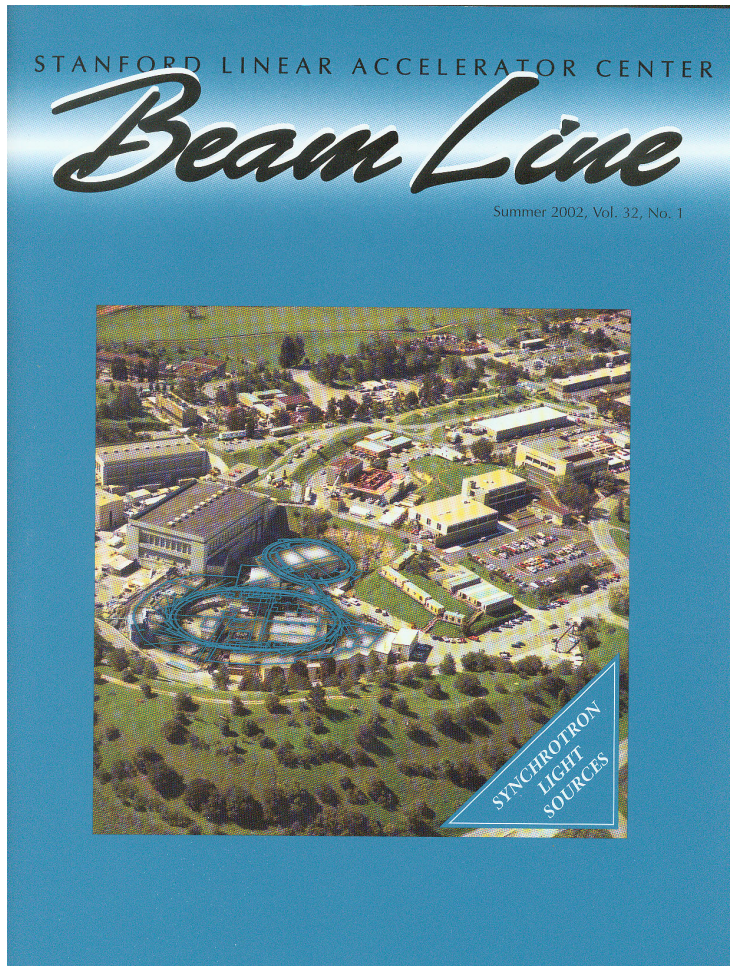


Actively preparing one centralized web site

So long





June 1, 2004

Neil Calder,
Director of Communications

Symmetry will Super

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Director of Communications

What

- Jointly published and edited by the Fermilab and SLAC Communications offices.
- Other national and international laboratories actively encouraged to contribute
- Content not exclusively HEP-based
- Editorial priority to publish writers of stature on the subjects of HEP and other branches of science and science policy

WHO

- Policy makers and opinion leaders who will determine the course of HEP in the coming years
- International HEP community and other branches of science
- Resource for educators and a source of insight and information for interested public

Super Symmetry

- Symmetry will be:

novel, credible, engaging,
stylish, dynamic

Thanks for the support

- Michael Witherell
- Jonathan Dorfan
- Robin Staffin

- No risk, No fun

Commercial Break

June 1, 2004

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PHYSICS | New sense of excitement

Continued from Page 1E

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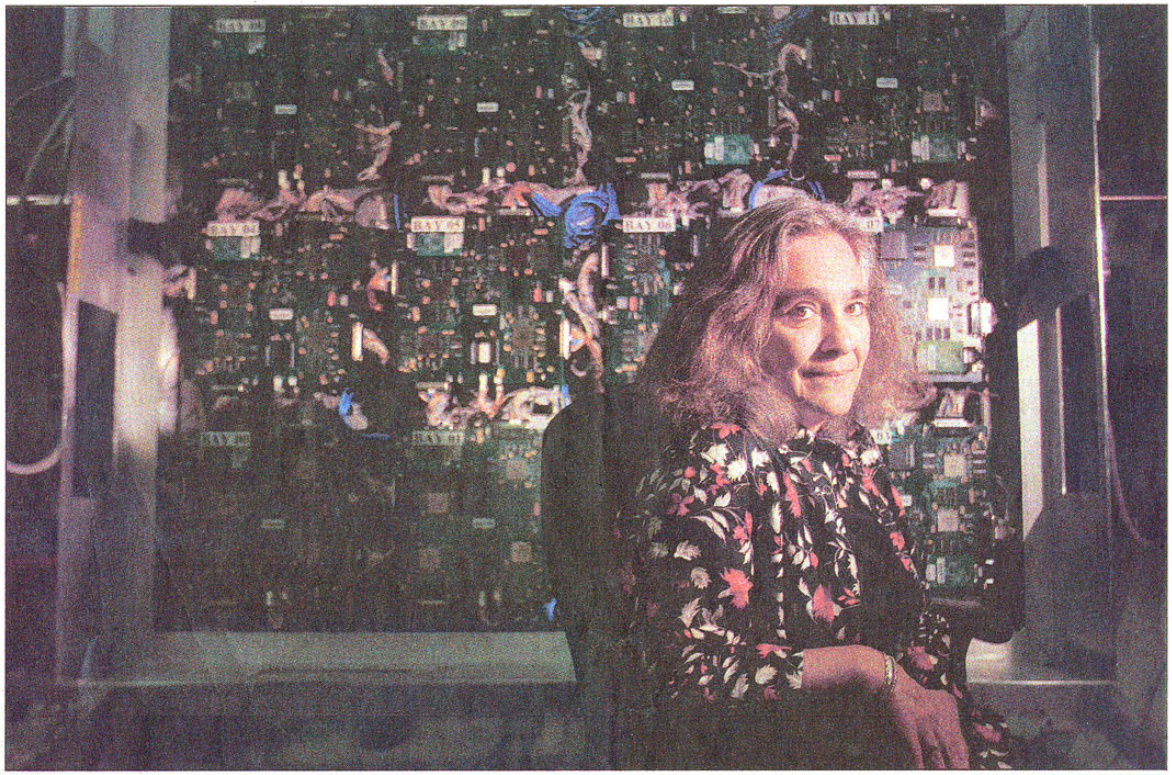

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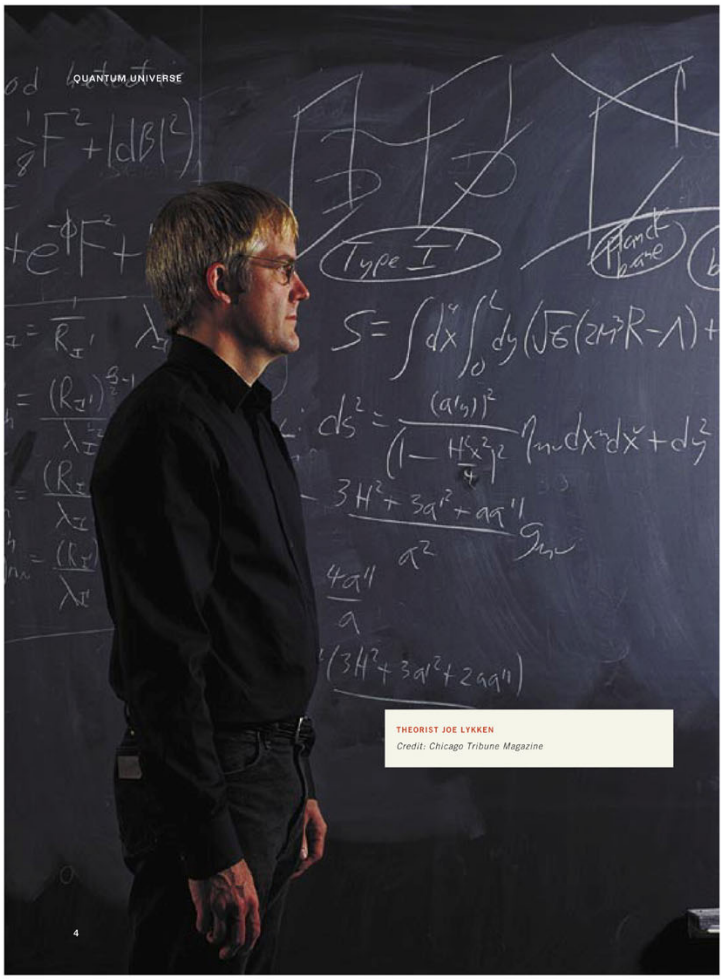
New Excitement



1
ARE THERE UNDISCOVERED PRINCIPLES OF NATURE : NEW SYMMETRIES, NEW PHYSICAL LAWS?

2
HOW CAN WE SOLVE THE MYSTERY OF DARK ENERGY?

3
ARE THERE EXTRA DIMENSIONS OF SPACE?

4
DO ALL THE FORCES BECOME ONE?

CHAPTER II
THE FUNDAMENTAL NATURE OF MATTER, ENERGY, SPACE AND TIME

EINSTEIN'S DREAM OF UNIFIED FORCES

Since Einstein, physicists have sought a unified theory to explain all the fundamental forces and particles in the universe. The result is a stunningly successful theory that reduces the complexity of microscopic physics to a set of concise laws. But these same quantum ideas fail when applied to cosmic physics. Some fundamental piece is missing; gravity, dark matter and dark energy must have quantum explanations. A new theoretical vision is required, one that embraces the Standard Model and general relativity, while resolving the mystery of dark energy. Particle accelerators provide the means to reach a unified theoretical perspective in experiments characterized by four well-defined intellectual thrusts.

5

9 Big Questions

EINSTEIN'S DREAM OF UNIFIED FORCES

1

ARE THERE UNDISCOVERED PRINCIPLES OF NATURE : NEW SYMMETRIES, NEW PHYSICAL LAWS?

The quantum ideas that so successfully describe familiar matter fail when applied to cosmic physics. Solving the problem requires the appearance of new forces and new particles signaling the discovery of new symmetries–undiscovered principles of nature's behavior.

2

HOW CAN WE SOLVE THE MYSTERY OF DARK ENERGY?

The dark energy that permeates empty space and accelerates the expansion of the universe must have a quantum explanation. Dark energy might be related to the Higgs field, a force that fills space and gives particles mass.

3

ARE THERE EXTRA DIMENSIONS OF SPACE?

String theory predicts seven undiscovered dimensions of space that give rise to much of the apparent complexity of particle physics. The discovery of extra dimensions would be an epochal event in human history; it would change our understanding of the birth and evolution of the universe. String theory could reshape our concept of gravity.

4

DO ALL THE FORCES BECOME ONE?

At the most fundamental level all forces and particles in the universe may be related, and all the forces might be manifestations of a single grand unified force, realizing Einstein's dream.

THE PARTICLE WORLD

5

WHY ARE THERE SO MANY KINDS OF PARTICLES?

Why do three families of particles exist, and why do their masses differ so dramatically? Patterns and variations in the families of elementary particles suggest undiscovered underlying principles that tie together the quarks and leptons of the Standard Model.

6

WHAT IS DARK MATTER?
HOW CAN WE MAKE IT IN THE LABORATORY?

Most of the matter in the universe is unknown dark matter, probably heavy particles produced in the big bang. While most of these particles annihilated into pure energy, some remained. These remaining particles should have a small enough mass to be produced and studied at accelerators.

7

WHAT ARE NEUTRINOS TELLING US?

Of all the known particles, neutrinos are the most mysterious. They played an essential role in the evolution of the universe, and their tiny nonzero mass may signal new physics at very high energies.

THE BIRTH OF THE UNIVERSE

8

HOW DID THE UNIVERSE COME TO BE?

According to cosmic theory, the universe began with a singular explosion followed by a burst of inflationary expansion. Following inflation, the universe cooled, passing through a series of phase transitions and allowing the formation of stars, galaxies and life on earth. Understanding inflation requires breakthroughs in quantum physics and quantum gravity.

9

WHAT HAPPENED TO THE ANTIMATTER?

The big bang almost certainly produced equal amounts of matter and antimatter, yet the universe seems to contain no antimatter. How did the asymmetry arise?

OPPORTUNITIES FOR DISCOVERY

We live in an age when the exploration of great questions is leading toward a revolutionary new understanding of the universe.

"Opportunities have emerged for discovery about the fundamental nature of the universe that we never expected," Presidential Science Advisor John Marburger said recently. "Technology places these discoveries within our reach, but we need to focus efforts across widely separated disciplines to realize the new opportunities."

Quantum Universe is a response to that challenge. It serves as a guide to where the search for understanding has taken us so far, and to where it is going. The chapters that follow articulate how existing and planned particle physics experiments at accelerators and underground laboratories, together with space probes and ground-based telescopes, bring within reach new opportunities for discovery about the fundamental nature of the universe.

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Think about the audience

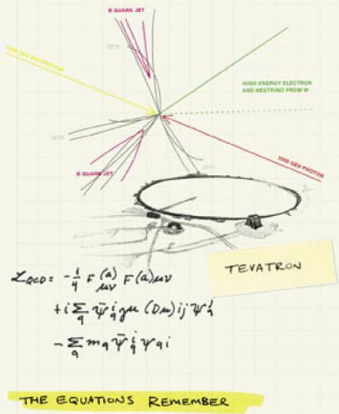
- Executive Summary
- Chapter 1

  No previous knowledge
- Chapter 2

  Some
- Chapter 3

  Loads

New



THE EQUATIONS REMEMBER

We live in a cold and empty universe, in a time when energies are so low that we can no longer see what space contained in the fiery instants when the universe was born. But every kind of particle that ever existed is still there, in the equations that describe the particles and forces of the universe. And we can use accelerators to make the equations come alive: not just as metaphor but as reality.

The universe today contains only the stable relics and leftovers of the big bang. The unstable particles have decayed away with time, and the perfect symmetries have been broken as the universe has cooled. But the structure of space "remembers" all the particles and forces we can no longer see around us. Particle accelerators pump energy into empty space to create the particles and uncover the symmetries that existed in the earliest universe. As accelerators go to higher energies, we probe ever closer to the beginning.

Ultimately we must combine what we learn from accelerators with what we learn by detecting the surviving relics of the big bang, using telescopes on the ground and in the sky. It is by synthesizing what we learn from each of these approaches that we will make the two ends meet and develop a comprehensive picture of the universe and how it evolved.

At present, we expect the Higgs to be accompanied by a whole new sector of fundamental physics. This Higgs sector may involve many new particles and interactions. Initial Higgs discoveries will occur at the LHC; a Linear Collider will be essential to explore the landscape of Higgs physics.

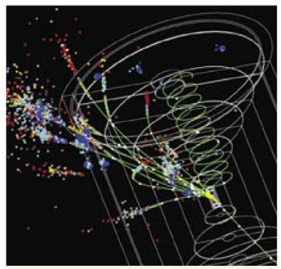
Dark energy may have relationships to both supersymmetry and the Higgs sector, implying a new emphasis on the quantum consistency of Higgs physics, including Higgs self-interactions. Such measurements will present additional challenges for the experimental program of the Linear Collider and may provide a foundation to explore the origin of dark energy.

3

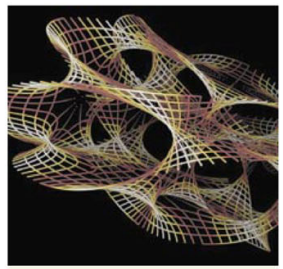
ARE THERE EXTRA DIMENSIONS OF SPACE?

The physical effects of extra dimensions depend on their sizes and shapes, and on what kinds of matter or forces can penetrate them. The sizes of the extra dimensions are unknown, but they should be related to fundamental energy scales of particle physics: the cosmological scale, the density of dark energy, the TeV electroweak scale, or the scale of ultimate unification. It may be possible to infer extra dimensions of macroscopic size from inconsistencies in cosmological observations, or from precision tests of short-range gravitational forces. More likely, the extra dimensions are microscopic, in which case high-energy particle accelerators and cosmic ray experiments are the only ways to detect their physical effects.

The LHC and a Linear Collider will address many questions about extra dimensions: How many extra dimensions are there? What are their shapes and sizes?



NEUTRALINO Simulation of the signature a neutralino, a predicted supersymmetric particle that is one candidate for dark matter. *Credit: Norman Graf*



SUPERSTRINGS A computer's graphical representation of multi-dimensional spacetime. *Credit: Jean-Francois Colonna*

How are they hidden? What are the new particles associated with extra dimensions? Through the production of new particles that move in the extra space, the LHC will have direct sensitivity to extra dimensions 10 billion times smaller than the size of an atom. A Linear Collider would determine the number, size and shape of extra dimensions through their small effects on particle masses and interactions. There is also a chance that, due to the existence of extra dimensions, microscopic black holes may be detected at the LHC or in the highest energy cosmic rays.

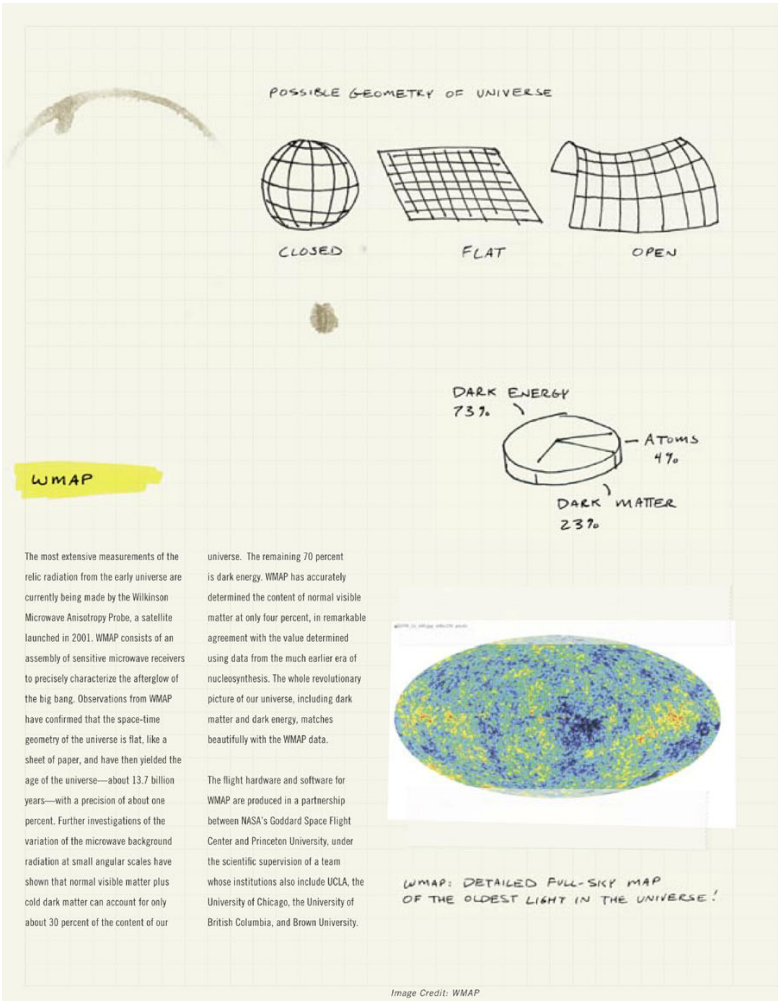
Ultimately particle physics seeks to know if dark energy, dark matter and cosmic inflation are affected by the physics of extra dimensions. Collider data will provide insight into the exploration of these deep connections.

4

DO ALL THE FORCES BECOME ONE?

High-energy particle physics experiments are exploring the unification of the weak and electromagnetic forces. Does the unification continue? At the most fundamental level, particles and forces may be related, either through hidden symmetries like grand unification, or through radical physics like superstrings. Essential clues can come from laboratory observations of extremely rare particle decays and other rare processes, as well as from precision measurements at the highest energies. Such breadth of approach is necessary because we do not know where the clues will appear.

Design


POSSIBLE GEOMETRY OF UNIVERSE
CLOSED
FLAT
OPEN
DARK ENERGY
73%
ATOMS
4%
DARK MATTER
23%
WMAP
The most extensive measurements of the relic radiation from the early universe are currently being made by the Wilkinson Microwave Anisotropy Probe, a satellite launched in 2001. WMAP consists of an assembly of sensitive microwave receivers to precisely characterize the afterglow of the big bang. Observations from WMAP have confirmed that the space-time geometry of the universe is flat, like a sheet of paper, and have then yielded the age of the universe—about 13.7 billion years—with a precision of about one percent. Further investigations of the variation of the microwave background radiation at small angular scales have shown that normal visible matter plus cold dark matter can account for only about 30 percent of the content of our universe. The remaining 70 percent is dark energy. WMAP has accurately determined the content of normal visible matter at only four percent, in remarkable agreement with the value determined using data from the much earlier era of nucleosynthesis. The whole revolutionary picture of our universe, including dark matter and dark energy, matches beautifully with the WMAP data.
The flight hardware and software for WMAP are produced in a partnership between NASA's Goddard Space Flight Center and Princeton University, under the scientific supervision of a team whose institutions also include UCLA, the University of Chicago, the University of British Columbia, and Brown University.
WMAP: DETAILED FULL-SKY MAP OF THE OLDEST LIGHT IN THE UNIVERSE!
Image Credit: WMAP
CHAPTER III
TOOLS FOR A SCIENTIFIC REVOLUTION
THE BIRTH OF THE UNIVERSE
The understanding of the history and future of the universe is deeply entwined with questions of the fundamental nature of matter, energy, space and time. Today the strong connections between the largest and smallest domains are clearly apparent.
8
HOW DID THE UNIVERSE COME TO BE?
According to current theories of cosmic evolution, the universe begins with an "initial singularity," a point where all known laws of physics break down. This singularity produced a delicately balanced universe, like a pencil so precisely balanced on its point that it stays upright for 14 billion years. How did the universe reach such a state? How did it get to be so old? Why has it not blasted even further apart, or collapsed back on itself?
For the last two decades, the theory of cosmic inflation has offered a compelling explanation of the start of the big bang. According to this theory, an early phase of accelerated expansion gave rise to the balanced universe we see today. Cosmic inflation is the hand that balanced the pencil on its point. As a by-product, it also produced the seeds that evolved into stars, galaxies, clusters of galaxies and other structures in the universe.
Cosmic inflation presents challenges related to the fundamental questions in this report. One possibility is that cosmic inflation originated with a form of dark energy, akin to the dark energy observed today. If so, what kind of matter produced it? Does this form of matter play a role in unification? How does it relate to extra dimensions? Even more radical is the possibility that space and time changed their nature at the start of the big bang. Does string theory smooth the initial singularity? Which model did nature really choose?
At present, measurements of fluctuations in the cosmic microwave background, especially from WMAP, provide the best evidence in favor of inflation. Constraints on cosmic parameters, such as the curvature of the universe, and the nature of the cosmic structure, are in broad agreement with the predictions of inflationary theory. Eventually, measurements of the polarization of the CMB may permit the detection of the signatures of gravitational
35

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