For Elementary Particle Physics

- Together with Cosmology and Astrophysics, Elementary Particle Physics seeks understanding of the basic physical character of the world around us
  - What is it made of?
  - What are the rules by which it is put together?
  - How did it get to be as it is?
  - How will it evolve in the future?
Particle accelerators allow us to create interactions (reactions) among “elementary” particles under carefully controlled conditions. Such experiments can discover the constituents of the physical world and the underlying interactions by which they are put together. Today there are thought to be three fundamental interactions (or forces)

♥ The strong interaction (holds nuclei together)
♥ The electro-weak interaction
  ◊ ◊ electromagnetic interaction (chemistry + electric effects)
  ◊ ◊ weak interaction (radioactivity)
♥ The gravitational interaction (masses attract)
• Particular questions being asked today to which experiments with accelerators can offer help:
  ♥  What is the origin of mass?
  ♥  How did electromagnetism and the weak interaction become one force when the temperature of the universe was much higher than it is today?
  ♥  Are there really only three fundamental interactions?
  ♥  How many dimensions are needed to describe the most basic facts about our world (are four enough?)
  ♥  How does gravity fit with the other interactions?
  ♥  AND MANY MORE………………

• Two basic types of accelerators are in use for Elementary Particle Physics today: *they are complementary*
  ♥  Proton accelerators (colliders) - nucleus of Hydrogen
  ♥  Electron & positron accelerators (colliders)
The Large Hadron Collider or LHC

- 27 km in circumference, this accelerator is now under construction near Geneva Switzerland at the CERN laboratory.
- It is slated to begin taking data in 2007 and will operate at an energy (temperature) $7 \times$ that of today’s highest energy accelerator.
Large Hadron Collider (LHC) @ CERN

27 km Tunnel in Switzerland & France

Search for Origin of Mass & Supersymmetry (2007 – ?)
The Large Hadron Collider (LHC)

In the LHC tunnel

7 TeV + 7 TeV

Protons

Protons

Luminosity = $10^{34}$ cm$^{-2}$sec$^{-1}$

Targets:
- Higgs Boson(s)
- Super-symmetric Particles
- Quark-Gluon Plasma
- CP violation in B
Cross Section of Magnet

LHC DIPOLE: STANDARD CROSS-SECTION

- ALIGNMENT TARGET
- MAIN QUADRUPOLE BUS-BARS
- HEAT EXCHANGER PIPE
- SUPERINSULATION
- SUPERCONDUCTING COILS
- BEAM PIPE
- VACUUM VESSEL
- BEAM SCREEN
- AUXILIARY BUS-BARS
- SHRINKING CYLINDER / HE I-VESSEL
- THERMAL SHIELD (55 to 75K)
- NON-MAGNETIC COLLARS
- IRON YOKE (COLD MASS, 1.9K)
- DIPOLE BUS-BARS
- SUPPORT POST
One of the detectors identifies interaction products, frequency of occurrence, spatial and momentum distributions.
BT-1 installation in the cavern
but

• Protons are composite particles with the energy being distributed among the constituents. This results in a rather wide momentum distribution among the colliding constituents so that proton collisions result in reactions at many different “temperatures” and thus are good for spotting new phenomena or types of particles.

• If one collides electrons and positrons, since they are elementary as far as we know, we know precisely at what temperature the reactions take place and thus can be sure of the properties of the products and reactions. This makes possible the completing of the picture partly revealed by the proton colliders.
The International Linear Collider or ILC

• Now in the planning stage is an electron collider based on linear accelerators with superconducting microwave acceleration units. It is known as the International Linear Collider since it is being designed by international teams from Europe, Asia and North America.

• It is hoped that this facility can be in operation by 2015
This prototype particle physics machine will be used part of the time as a free electron laser in the ultra-violet for chemistry, condensed matter physics and biology.
Synergies

• Use of accelerators for research in fields spanning structural biology to nanotechnology is expanding. Most frequently encountered are x-ray and neutron sources. These machines have their own special requirements but in the course of devising solutions, new ideas which can be used in other accelerators are produced. For example, the technology for the ILC and the x-ray Free Electron Laser are being developed in parallel in the same test facility as we have seen.

• Here we have another example of the overarching unity of science.