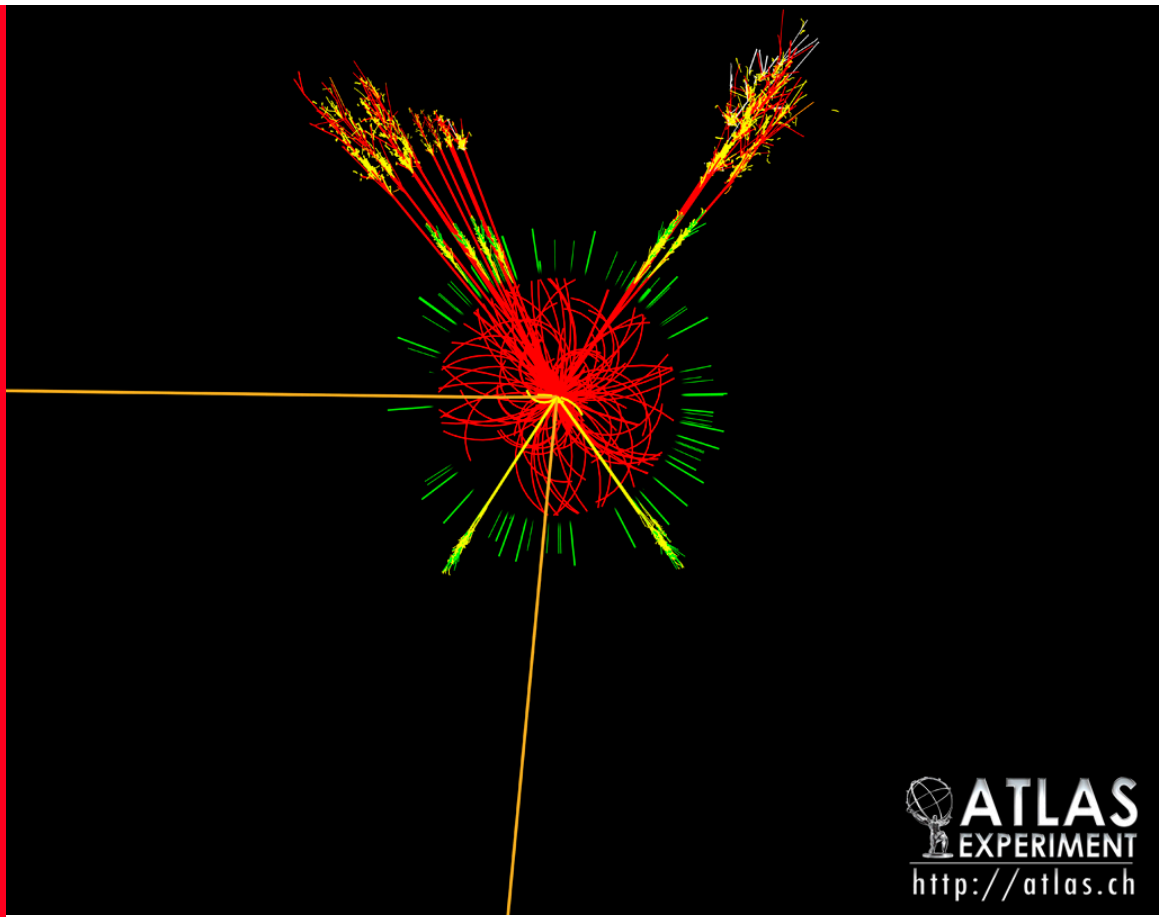
QUARKS SPACETIME and the BIGBANG

spring term 2012



A simulated Higgs Boson event as it might appear inside of the ATLAS detector at the Large Hadron Collider.

ISP220: Elementary Particle Physics and Cosmology

Professor Raymond Brock

What are the smallest and the largest things you can think of? You might have heard of quarks–or, of course, electrons–and they are indeed the smallest things we have discovered. They're so small, that we treat them as if they have no size at all.

The largest thing we can think of is...well, the entire Universe! Can't get any bigger than "everything," right?

What's surprising is that these two ideas, the smallest and the largest, are intimately and precisely related, a realization only a few decades old. When we crash elementary particles together at very high speeds, they recreate the conditions of the very early universe. It's like being at the dawn of time–millions of times a second.

We in the Department of Physics and Astronomy do both kinds of research and we thought that an ISP course that explored this relationship might be interesting.

It's especially timely as we're embarking on a new project in Geneva, Switzerland called the Large Hadron Collider (LHC). This gigantic instrument is

10^{-14} seconds
after the beginning of the universe

called a proton-proton collider and is so large that it sits underground beneath the borders of both Switzerland and France. The LHC is another in a long history of "particle accelerators" and the direct descendent of the Fermilab Tevatron, which is a proton-antiproton collider outside of Chicago. Our groups have worked in Illinois at the Tevatron for thirty years, but now we've followed the science to the next step: the LHC.

Quarks, Spacetime, and the Big Bang is a new ISP course for non-science students which will explore the science of Particle Physics and its link to Cosmology. It's complementary to the popular ISP205.

The topics we'll cover include:

- Enough quantum theory to be able to use a few concepts.
- Einstein's Special and General Theories of Relativity.
- The Elementary Particle Zoo: quarks, gluons, leptons, hadrons, photons, neutrinos, W & Z bosons...
- Antimatter! Tom Hanks aside, it's not really dangerous.
- The Quark Model–how "normal" matter is cobbled together.
- Our accelerators and our experiments. We'll learn about the devices that MSU has built and that we'll be using to unravel the secrets of many puzzles including:
  - *The Higgs Boson–the particle we've been looking for since the 1980s to account for why things have mass.*
  - *New ideas like Supersymmetry, leptoquarks, Superstrings: things that might go bump in the night, or might not. It depends on our experiments...and Nature!*
  - *Then, there are the big problems of Dark matter and Dark Energy!*

"Scientists don't really ever grow up. I read, as a 10-or-so-year-old, a book for kids by Einstein. I think it was The *Meaning of Relativity*. It was exciting! Science was compared to a detective story, replete with clues, and the solution was the search for a coherent account of all the known events."

Nobel Laureate Leon Lederman
former Director of Fermilab

The mathematics we'll need will be minimal: a little algebra, exponential notation, the ability to read graphs, and some geometry. The course will be concept-oriented with exercises designed to elucidate complex ideas by using analogy and graphical techniques.

left:
The 27 km around LHC is just north of the Swiss Alps, straddling the Swiss-French border.

right:
The enormous air-core, superconducting magnets of the **ATLAS detector** will pick out important remnants of the p-p collisions at the **Large Hadron Collider**