Introducing Particle Physics to the Typical College Freshman

Richard E. Hughes
The Ohio State University
Popularizing Particle Physics
DPF2004

Ohio State's Freshman Seminar Program

In 2003, President Karen Holbrook fostered the OSU Freshman Seminar Program to provide unique learning experiences for first-year students.

- Courses should introduce students to topical and cutting-edge research areas from a wide variety of disciplines
- Class size maximum of 20
- Open to first year students only (actually relaxed this requirement)

Initial Freshman Seminar Offerings

- **American Indian Voices** Chadwick Allen
- **Glimpsing the Social Psychology of Everyday Life** Robert M. Arkin
- **From Babies to Adults: The Effect of Experience on Language** Elizabeth Hume
- **Chemical Pollutants in the Environment: Cause for Concern or Media Hype?** Roman Lanno
- **Theatrical Collaboration as a Problem Solving Process** Mark Shanda
- **Exploring Life on Earth through Time** Loren E. Babcock
- **Analyzing the Sounds of Language** Mary Beckman & Marios Fourakis
- **Demystifying the Scientific Research Process: How to Tackle Complex Problems in an Inter- disciplinary World (or, Is a Research Career for You?)** Paul Robbins & Peter Curtis
- **Research in the Visual Arts** Charles Massey, Jr.
- **Fixing the Body: Race and Gender in Visual Culture** Ruby C. Tapia
- **Climate, The Oceans, and Your World** Lawrence Krissek
- **The World's Freshwater Crisis** Frank W. Schwartz
- **Bugs in the System** David Horn
- **Four Quartets: An Interdisciplinary Approach** Sebastian D. G. Knowles
- **Polar Science: An Introduction to the Earth's Cold Regions** W. Berry Lyons
- **Fast, Faster,...Ultrafast! The Speed of Science in the 21 st Century** Bern Kohler
- **Ohio and the Hispanic World** Terrell A. Morgan
- **Audience Experience- What You Make of It** Esther Beth Sullivan
- **From Quarks to the Cosmos** Richard E. Hughes

A Seminar on Particle Physics?

- Should it only focus on my specific research areas (CDF & GLAST)?
- Or broaden topic to include all of particle and astroparticle physics?
  - Can pick and choose most interesting material from many different experiments
  - Allows students to see the incredible variety of research going on around the world

Easy to guess which path non-experts would like best….

A Seminar on Particle Physics

- From the syllabus…
  - "This course will review the major Particle and Astroparticle Physics experiments going on around the world, and how they will address the most important questions in these fields. These experiments generally involve hundreds of scientists, cost hundreds of millions of dollars (or more), and last for many years. Particular emphasis will be paid to experiments that Ohio State faculty are involved in."

Course Format

- The course met once per week for 48 minutes.
  - The students were expected to investigate the week's topic prior to each class using the web resources(~30-40 minutes per week).
  - The classes were organized as 48 minute "News Conferences"
    - one of the science experiments was discussed
    - The students were to act as reporters, whose **task was to write up a summary of the news conference**.
    - As reporters, they were expected to be experts, but the readings would them form intelligent questions to ask during the news conference.
    - The summary would be expected to be of a quality that might appear in the local newspaper.

Challenges

- Needed a "snappy" title!
  - "Quarks and the Cosmos" (ok, it is stolen..)
- How to explain physics to non-experts?
- Which experiments to choose?
  - Tried to include all of those in which OSU is involved: CDF, ATLAS/CMS, BaBaR, Auger, GLAST
  - Included others which seemed interesting and complementary: MINOS, SNAP

An approach like this allows the possibility of team-teaching in the future (assuming you can convince your colleagues to join in).

How to structure course

- Heavy reliance on the WEB
  - Every experiment has some outreach component which is usually easily accessible via the web
- Instructor can provide a path:
  - **Weeks 1: Introduction: Discovering the instruction manual for the Universe**
    - Questions particle physicists ask.
    - Imagine the Universe (Astronomy)
    - What is the world made of?
    - The Particle Adventure (click on Start Here, then explore...)
  - **Week 2: Studying quarks and leptons using protons and anti-protons! (OSU Involvement)**
    - The Tevatron Collider
    - The CDF Experiment
    - The D0 Experiment
  - **Week 3: Dark Matter: Most of the matter in the universe can't be found! (OSU Involvement)**
    - Explore the GLAST web pages:
  - Etc....

Student Profiles

- 14 students total: seminar program requires ≤ 20
- Variety of majors
  - 4 physics
  - 3 biology
  - 3 engineering
  - 1 astronomy
  - 1 pre-med
  - 1 molecular genetics
  - 1 political science

How to Present HEP to These Students

- Some background on the experiment in question
  - Why is this physics important?
- Some History
  - Who had some of the early bright ideas?
  - Who laid some of the experimental ground work?
- How is the problem being pursued
  - Students are attracted by the complexity!
  - Time for some pretty pictures of detectors, electronics, etc
- What should they expect in the future?
  - Are results expected soon?
  - Are there plans for something after this?

Describing an Experiment

- The next 7 slides are a subset of those used to describe the physics of the CDF experiment at the Fermilab Tevatron
- Some things I tried to emphasize
  - Pretty pictures
  - Simplified discussions of everything
  - Humor is always appreciated…especially on Friday mornings!

Particle Accelerators

- **Accelerators** are machines used to speed up particles to very high energies. This way, we achieve two things:
  - ✓ We decrease the particle's wavelength, so we can use it to **probe** inside atoms, nuclei, even quarks.
  - ✓ We increase its energy, and since E = mc², can use that energy to **create** new, massive particles that can study

Tevatron Accelerator at Fermilab

FNAL: Fermi National Accelerator Laboratory

- Fermilab is located in Batavia, Illinois (about an hour west of Chicago).
- Fermilab is home to the Tevatron, the world's highest-energy hadronic accelerator.
- Fermilab is also a park, with 1,000 acres of prairie-restoration land!

Danger of working too hard at physics!

How Flat is the Illinois Prairie?
Not as flat as Kansas!

Kansas Is Flatter Than a Pancake

by Mark Fonstad [1], William Pugatch [1], and Brandon Vogt [2]

1. Department of Geography, Texas State University, San Marcos, Texas
2. Department of Geography, Arizona State University, Tempe, Arizona

In this report, we apply basic scie[illegible] te[illegible] q[illegible] t[illegible] ns[illegible] question "Is Kansas as flat as a pancake?"

While driving across th[illegible]mer[illegible]est, it[illegible]om[illegible]t[illegible]r travelers remark, "[illegible]is a[illegible]a pa[illegible]e." [illegible]he authors, this ada[illegible]eem[illegible]qua[illegible]ap[illegible]me characteristic of[illegible]graphic [illegible]det[illegible]vey [2]. This obvious question "how f[illegible]a p[illegible]ak[illegible]purned our analytical interest, and we set out t[illegible]flatness' of both a pancake and one particular state: Kansas.

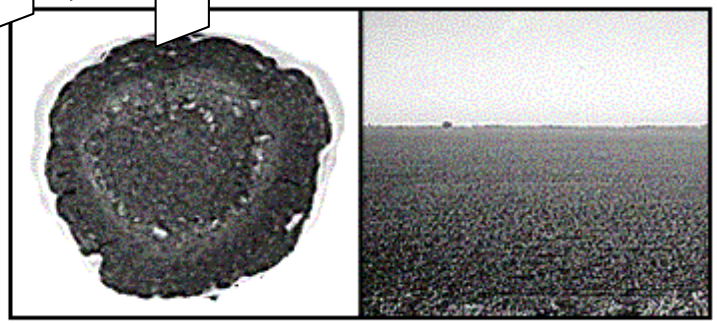


Figure 1. *(a) A well-cooked pancake; and (b) Kansas.* [1]

A Technical Approach to Pancakes and Kansas

Barring the acquisition of either a Kansas-sized pancake or a pancake-sized Kansas, mathematical techniques are needed to do a

The CDFII Collaboration

Canada
McGill Univ.
Univ. of Toronto

USA
Argonne National Laboratory,IL
Brandeis Univ.,MS
Univ. of Chicago,IL
Davis UC,CA
Duke Univ.,NC
FNAL,IL
Univ. of Florida,FL
Harvard Univ.,MA
Univ. of Illinois,IL
The Johns Hopkins Univ.,MD
LBNL,CA
MIT,MA
Michigan State Univ.,MI
Univ. of Michigan,MI
Univ. of New Mexico,NM
The Ohio State Univ.,OH
Univ. of Pennsylvania,PA
Univ. of Pittsburgh,PA
Purdue Univ.,IN
Univ. of Rochester,NY
Rockefeller Univ.,NY
Rutgers Univ.,NJ
Texas A&M Univ.,TX
Texas Tech Univ.,TX
Tufts Univ.,MA
UCLA,CA
Univ. of Wisconsin,WI
Yale Univ.,CT

China
Academia Sinica, Taiwan

Korea
KHCL

Russia
JINR, Dubna
ITEP, Moscow

Germany
Univ. Karlsruhe

Switzerland
Univ. of Geneva

UK
Glasgow Univ.
Univ. of Liverpool
Univ. of Oxford
Univ. College London

Italy
Univ. of B a,IN
Frascati,
Univ. di
Pisa, IN
Univ. di I,INF
INFN-Tr
Univ. di

Spain
Univ. of Cantabria

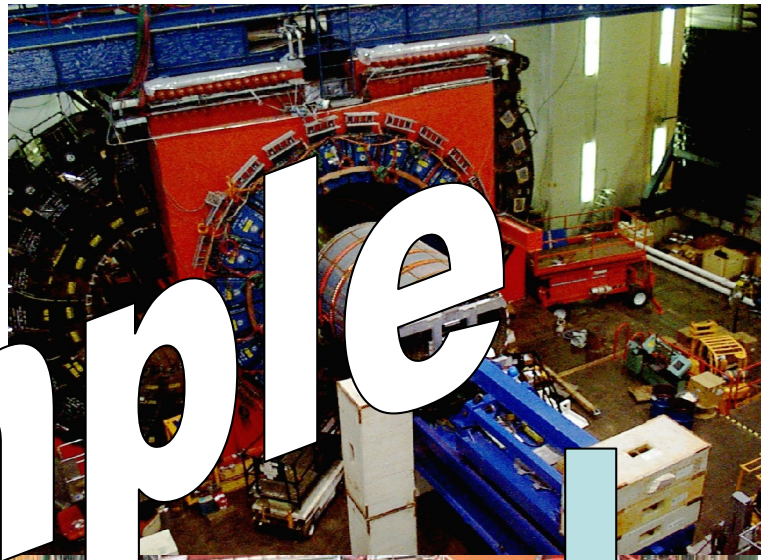
Japan
Hiroshima Univ.
KEK
Osaka City Univ.
Univ. of Tsukuba
Waseda Univ., Tokyo

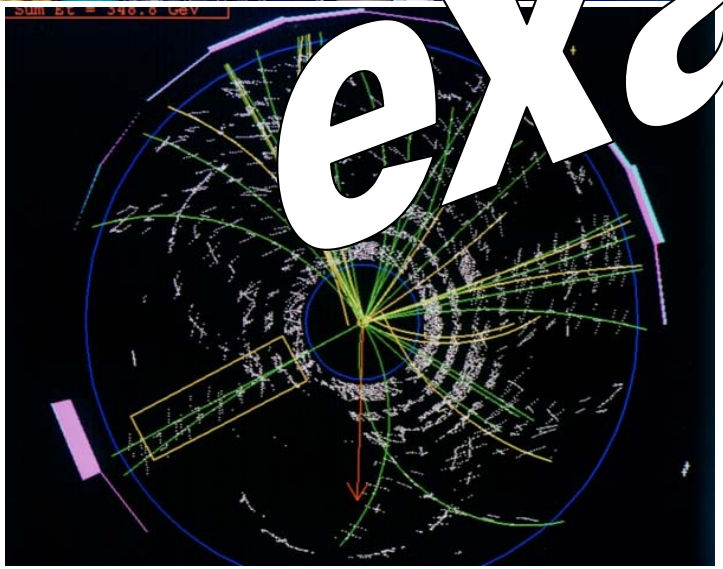
example

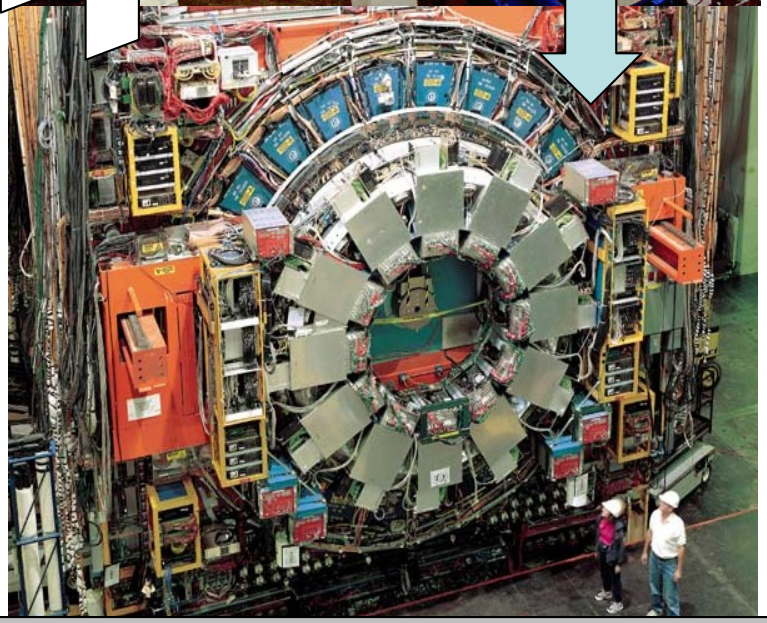
700+ scientists
55 Institutions
11 countries

Students
Post doc's
Professors
Research Scientists

What does an event look like?

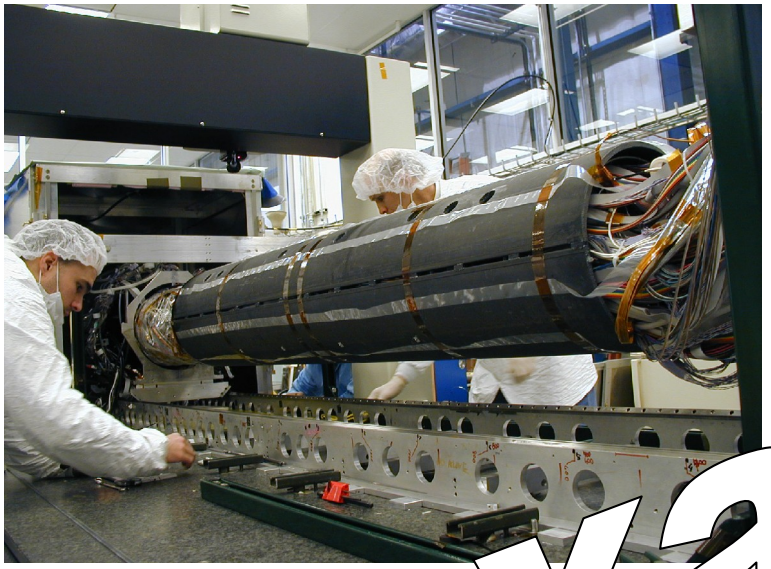


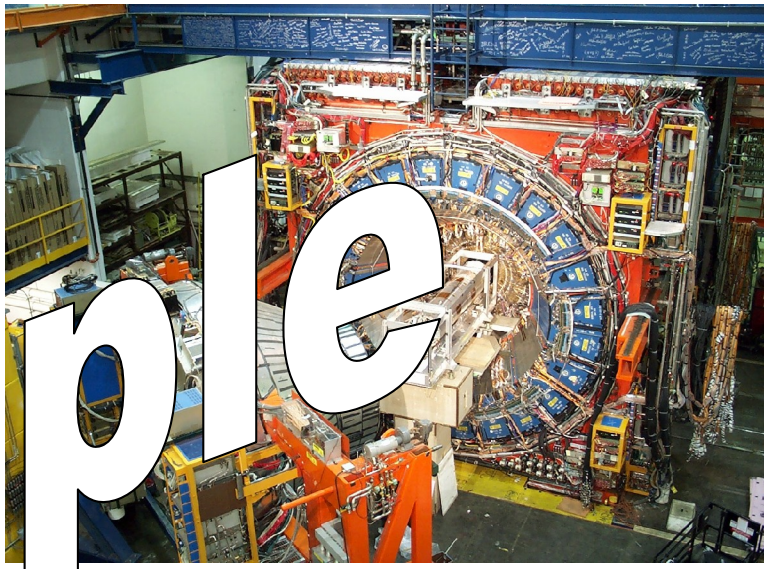




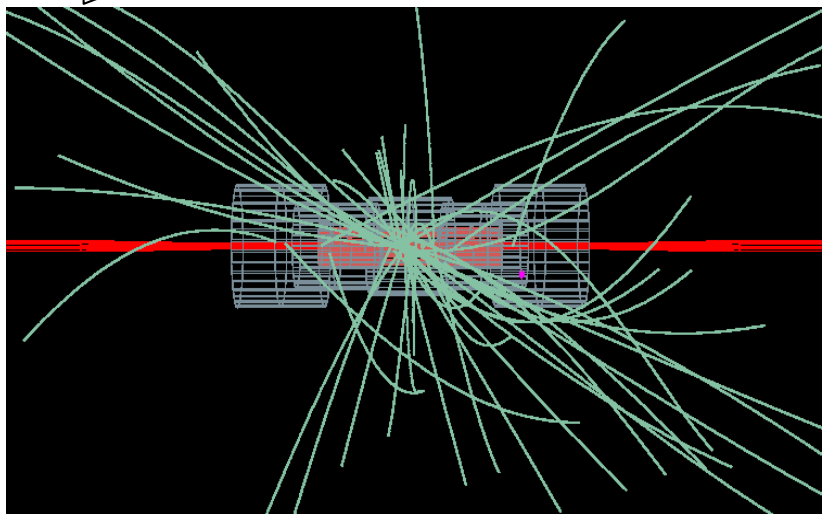
example

The SVX



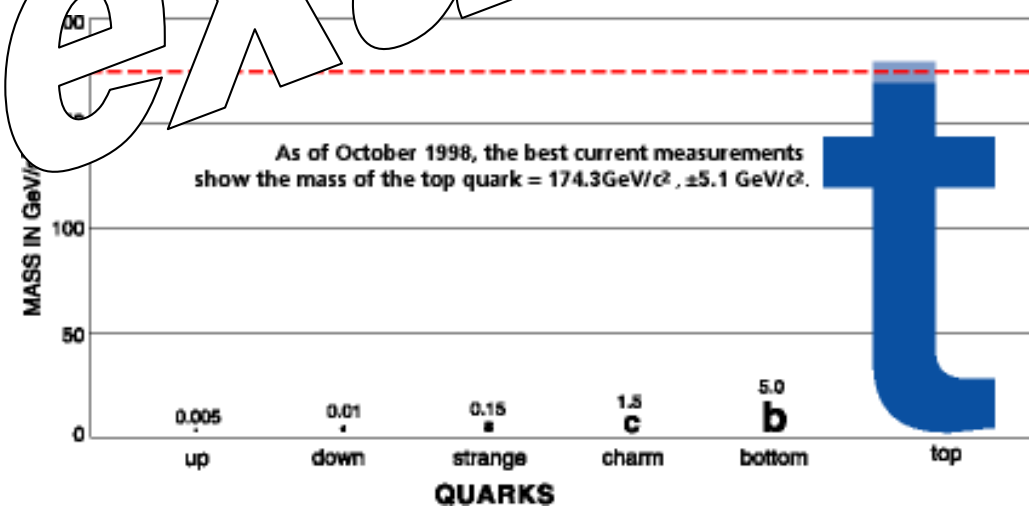


- About 1 milli[illegible] an[illegible]
- Extremely p[illegible]ise measurements
  - Precision ~40 microns (width of human hair)
- Excellent b-quark "tagger"



What Now?

- Now we have the world's largest (only) collection of top quarks. And we are continually adding to the collection. What can we learn about this quark?
- Since the top quark is so massive, maybe it can tell us something about mass itself.
  - Theorist Chris Hill of Fermilab claims that our understanding of the origin of mass would rank as "another Copernican revolution with the greatest scientific strides in physics since Newton's establishing the universal law of gravity and Einstein's connection of energy to mass and the speed of light."



How to Grade the course

- Students need to feel involved in the course
  - to get a grade
  - To keep interest level high
- Possibilities:
  - Short Presentation at course end
  - Short paper at end
  - Tests...
- Settled on: short writeups throughout course
  - One writeup per experiment discussed (7 total)

Student Writeups(1)

- Some were funny:
  - The puns were flying today as Richard Hughes, distinguished physicist and self proclaimed internet inventor gave a conference on particles known as antimatter. In what may go down as the most scripted news conference since the invention of the microphone, the press was rampant with questions.

Prodded the students with "sample" questions

Prior to one presentation (on antimatter and BaBaR), gave the students these questions to ask:

- 1) If there is antimatter hitting the upper atmosphere, how come there aren't explosions?
- 2) Does any antimatter survive to the surface? What happens if it hits a person?
- 3) Why is it everything is mostly matter and not anti-matter?
- 4) Why does it cost so much to make anti-matter, if it is made at Fermilab every day?
- 5) Does it hurt when you get a pet scan?
- 6) Are deuterons found in nature?
- 7) Does the antimatter cloud at the center of the milky way mean that there is a lot more antimatter than previously thought?
- 8) How big is the BaBar collaboration? How many universities? How many countries?
- 9) How much did it cost to make BaBar?
- 10) Since SLAC is in California, is it ever effected by earthquakes?
- 11) How are the positrons made that SLAC uses?
- 12) How is it possible to measure the lifetimes of particles that last for a billionth of a second?
- 13) If the amount of CP violation measured by BABAR is not enough to explain why there is not antimatter, is the experiment a failure?
- 14) Does any of this really matter?

Told the students: This is how George Bush does his press conferences!

Student Writeups(2)

Accounting for the matter/anti- matter divide

Scientists have long known that matter exits in two mirror forms: matter and anti-matter. Each basic building block of matter, the leptons and the quarks, has its own anti-particle. It seems intuitive then that both forms of matter would exist in equal amounts in the universe, but this does not appear to be the case. In fact, almost all sectors of space observed thus far exhibit little to no anti-matter- hardly enough to account for all the matter we see. It is believed that at universal creation there were near equal amounts of each type of matter. Therefore, there must be a mechanism in universal creation that also accounts for today's matter/anti-matter divide. This mechanism has been identified as CP violation, or the tendency for certain particles to deteriorate in a manner that slightly favors matter.

It is believed that small amounts of CP violation created all the excess matter making up our universe today. Most all other matter and anti-matter collided in the universe's beginnings to annihilate and form photons- we are the lucky leftovers. To measure CP violation and see if this mechanism accounts for the necessary deviation allowing for our existence, an experiment has been set up in Stanford California. Its main component is BaBar, a detector which observes the creation and decay of B meson particles (a combo of a quark and its antiparticle). To make these particles, three km long tracks are used to accelerate protons and antiprotons, which are then cycled through rings and collide in BaBar.

Since its first report was issued in 2000, Babar seems to indicate that the CP violation occurring may not account for all this extra matter. "Possible discrepancies have been seen between predicted properties of B mesons and those observed at the B-factories" notes BaBar docmaster Ray Cohen, "If this is confirmed by further investigation, it could be a sign that new physical phenomena exist beyond the "Standard Model".

Evaluations

- Students liked….
  - Small class size
  - Ease of asking questions, participating in discussions
  - Coverage of many different experiments

- Students did not like….
  - Not enough time to go over the topics!
  - Meeting on Friday morning!

Lessons Learned

- This course covered ALOT of physics quickly:
  - 2 Introductory lectures
  - 7 Different experiments
  - 1 wrap-up lecture
- Students can handle a fair amount of complication in a short time
  - But they like the history
  - Also the experimental methods and detectors
  - They can handle (and appreciate) complexity, as long as it is in small doses
- Do Differently:
  - Need better map to web resources
  - Need a "give-away" (e.g. Quantum Universe booklet)
  - Need ideas on how to spur questions/discussion