Calculate the Top Quark Mass

$E=mc^2$ Used in the Creation of the Most Massive Quark Yet Discovered!

http://ed.fnal.gov/samplers/hsphys/activities/student/

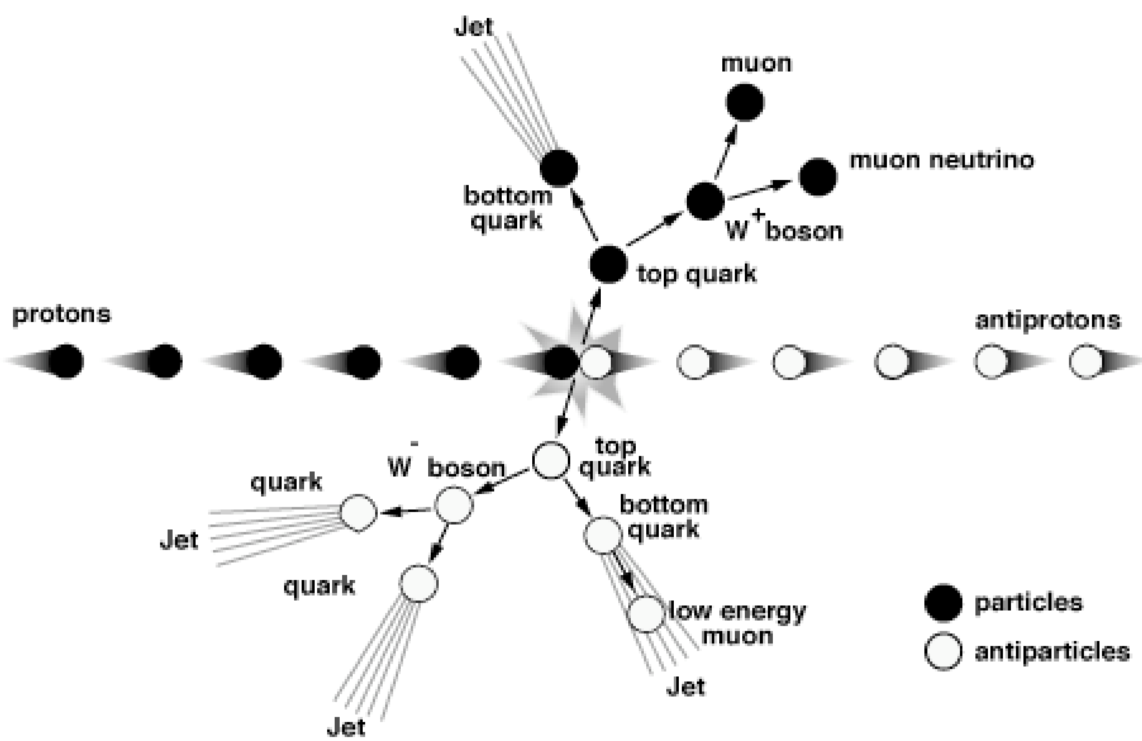
Analysis of D-Zero Data From Fermi National Accelerator Laboratory:

Introduction: Today you will make use of Einstein's famous equation and actual experimental data collected in 1995 from a special event that is two-dimensional rather than three-dimensional to determine the mass of the top quark; this is the most massive quark ever discovered.

Before you begin this activity, review the tutorial at the website above.

Procedure - Part One: You will be given a computer generated plot of a collision between a proton and an antiproton (see attached). You will need to determine the momentum of each bit of debris that comes from the collision. Be sure to remember that momentum has direction!

The diagram below shows the collision for the event labeled *Run 92704 Event 14022*. The other data plots can be represented by diagrams similar to this but may not have exactly the same debris, going in the directions shown here.



ATop Antitop Quark Event from the D-Zero Detector at Fermilab

While this event looks complex at first, it may be summarized by noting that a proton and antiproton collide to create a top antitop pair that exist for a very short time. Almost immediately the very massive top and antitop decay into the constituents that are known to be their signature. These include four "jets" (large blasts of particles) that are the result of decays of W bosons and some less massive quarks. It is important to note that one of the jets will often contain a low energy or "soft" muon. The soft muon helps identify the jet as a bottom quark jet. In addition, a muon and neutrino come out as debris from the collision. You can see it in the upper right part of the diagram. Check out the Quicktime event animation.

You will notice that there is no information given about the neutrino except the magenta tower indicating its direction on the color plot. While scientists can predict with confidence that it comes out of the collision, it cannot be detected very easily. Still, a careful consideration of the momenta before the collision and after the collision may give you a clue as to how much momentum this particle has!

On a separate sheet of paper, make a momentum vector diagram (to scale) or a table showing the magnitude and direction of the momenta of jets 1,2,3,4, the muon, and the soft muon) to determine the magnitude of the momentum of the neutrino. Be sure to remember that the total momentum of the system must be zero so any "missing" momentum must belong to the muon neutrino. You may add the momentum vectors either graphically or by components. Show all work.

Question 1. What is the momentum of the missing neutrino?

Procedure - Part Two: It turns out that if you are careful about your choice of units, it is possible to equate momentum and energy in a way that is similar to the way mass and energy are related. Specifically, it maybe shown that the momentum you measured above is the same numerical value as the energy or mass of the particle. In other words,

E (in GeV) = p (in GeV) = m (in GeV)

This shows, then, that the total energy that came from the two top quarks that were formed is equal to the numerical sum of all the momenta discovered in the collision. Fill in all the momentum values from your color plot in the table below. Finally add the measured value for the neutrino that you just determined at the end of this table.

	Jet 1	Jet 2	Jet 3	Jet 4	Muon	Soft Muon	Neutrino
Momentum, Energy or Mass							

Question 2. What do you determine the mass of the top quark to be?