Physics at the LHC: Using Muons to find Technicolor at CMS*

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Abstract

The construction of the Large Hadron Collider (LHC) is coming to an end. Eexperiments carried out there, once the collider is turned on, will prove to be a significant opportunity to study physics at the TeV scale. In preparation, many groups with vested interest in the Compact Muonic Solenoid (CMS) – one of the bigger ditactors of the collider – are carrying out simulations of events that might be seen at the LHC. Though, supersymmetry is the favorite theory to be confirmed by CMS, the possibility of technicolor being the correct explanatory option has not been ruled out. We have thus simulated over 50,000 LHC-like events to investigate the prospects of techniclor by searching for a particle it predicts exists: the techni-omega.

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The Large Hadron Collider (LHC) is a particle accelerator and collider located at CERN. Presently under construction and scheduled to start operation in 2007, it will become the world's largest particle accelerator. It uses the 27 km circumference tunnel created for the Large Eletron Positron (LEP) collider. Unlike the LEP, however, it will collide protons (one type of hadronparticle) instead of electrons and positrons. The protons used will have an energy of 7 TeV each giving a total collision energy of 14 TeV. Of the five experiments that will be built at the LHC two, ATLAS and CMS, are large, "general purpose" particle detectors. The other three (LHCb, ALICE, and TOTEM) are smaller and more specialized.

Physicists hope to use the collider to answer the following questions:

- What is mass? (We know how to measure it - but what is it?)
- What is the origin of mass of particles? (In particular, does the Higgs Boson exist?)
- What is the origin of mass of ? (By creating the quark-gluon plasma one will test the non-perturbative origin of a labaryonsrge fraction of the mass of the universe)
- Why do elementary particles have different masses? (I.e., do particles interact with a Higgs field?)
- We know that 95% of the universe's mass is not made of matter as we know it. What is it? (I.e. what is dark matter, dark energy?)
- Do supersymmetric (SUSY) particles exist?
- Are there extra dimensions, as predicted by various models inspired by string theory, and can we "see" them?
- Are there additional violations of the symmetry between matter and antimatter?

An alternative theory dealing with symmetry breaking at the electroweak scale and beyond is technicolor. The existence of a new force and new particles are two of it's main predictions. Events were simulated to study what a signal for a certain techni-particle would look like.

Results and Analysis

(i) Generator Level

A monte carlo based simulation of some 20,000 events was initially carried out to study cross-sections of techni-color events that would generate "techni-hadrons." There mass ratios were varied to see how they affected cross-section as seen in the plots below.

Figure 1: In this process, the techni-pi mass is in a 1:2 ratio with the techni-omega. We were seeking (pi_tc0 is the techni-pi).

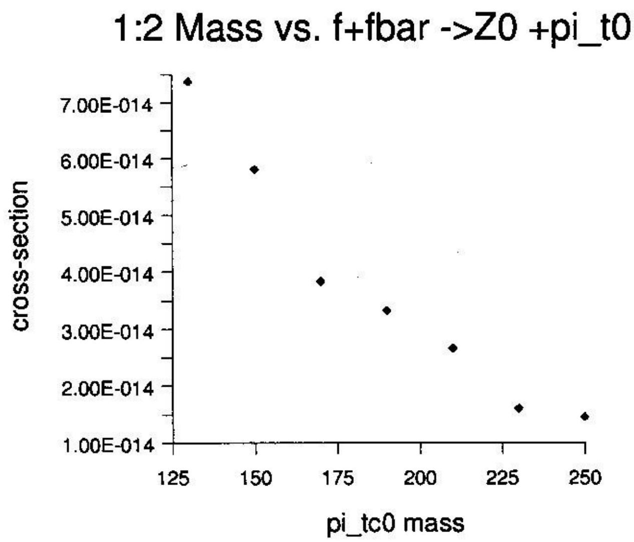
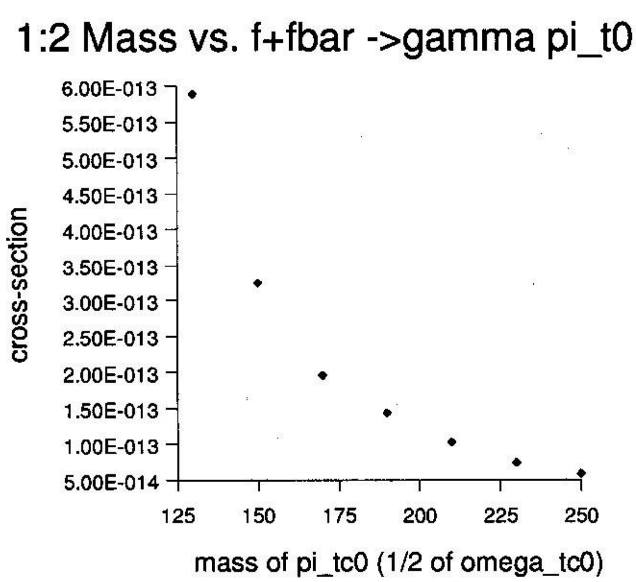


Figure 2: Notice the higher relative cross-section in this plot compared to Figure 1, which motivated focus on this channel for the full Reconstruction Chain.



(ii) Full Reconstruction Chain

After generator level simulations were carried out, full simulation followed. At this level of simulation, the Monte Carlo information from the initial generator would be used to carry out a full-geometry simulation. This done with software that creates a virtual CMS.

Digitization – a process mimicking the results of techni-prcesses being electronically recorded – then follows. Once this is accomplished, the events can be reconstructed to get a better sense of the decay chain leading to the detected muons and photons. (The decay mentioned here is none other than the collision of two protons yielding techni-hadron intermediates that in turn decay into two muons and a photon.)

After this lengthy process, analysis is done to find out if any significant signal has been detected to warrant a "discovery." This is complicated by the fact that another process that will henceforth be called the background also ends with the di-muon + photon signature given by the techni-omega.

To overcome this problem, several background events are simulated to give adequate statistics with which to study the signal (if there is one). Di-muon masses of signal and background are then separately added to give Two Body Invariant Mass graphs. These graphs are then superposed for comparison.

Another kind of graph showing Three Body Invariant Mass is then constructed for signal and background separately. This is done by adding photons to the Two Body Invariant Mass graphs. Recalling that the techni-omega yields two muons and a photon every decay, we are able to find it's mass against the background. This, of course, is not the definitive mass of the techni-omega since choosing a different mass ratios of techni-hadrons at the generator level may yield a different techni-omega mass. Since the cross-section of any process is not infinite, however, what a complete study of the techni-omega mass gives should be a reasonable spectrum for its mass. Such an investigation requires more time than was available this summer.

As demonstrated by the graphs below, Three Body graphs show a significant lack of background. It is thus difficult to judge the exact nature of the signal obtained. With more time and simulated events, it would be interesting to see how signal ultimately compares with background. With a well-behaved signal one can go on to calculate the time needed to call the signal a discover, and in so doing legitimize the dynamics of techni-color. It is hoped that such a discovery would begin to shed some light on questions that have not been answered by the Standard Model.

Figure 3: The background seen here is made of two muons per decay.

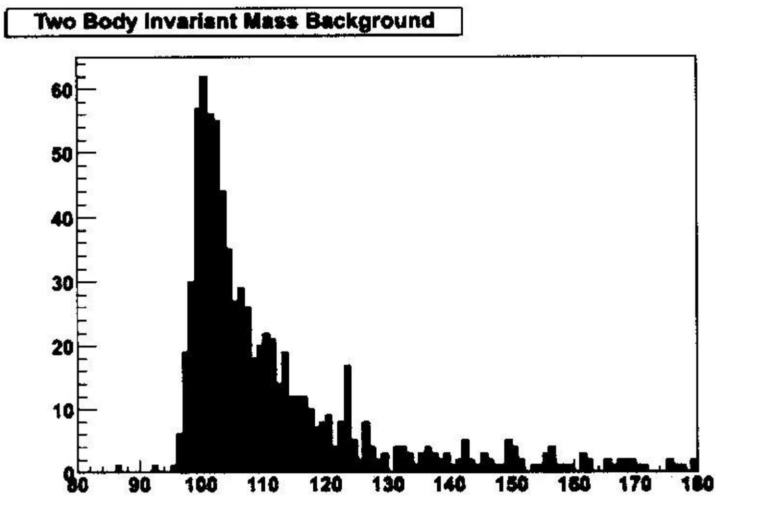


Figure 4: The signal found from adding two muons per decay.

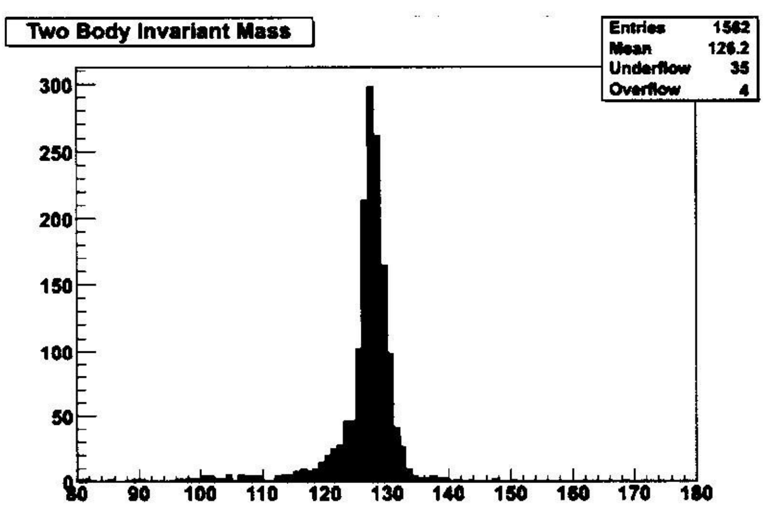


Figure 5: Two Body graphs weighted and superposed.

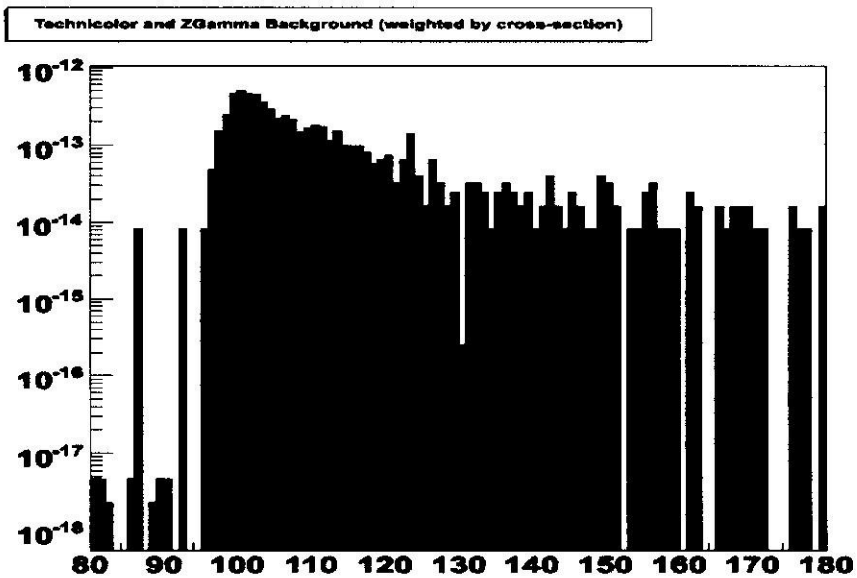


Figure 6: Three Body graph for the signal.

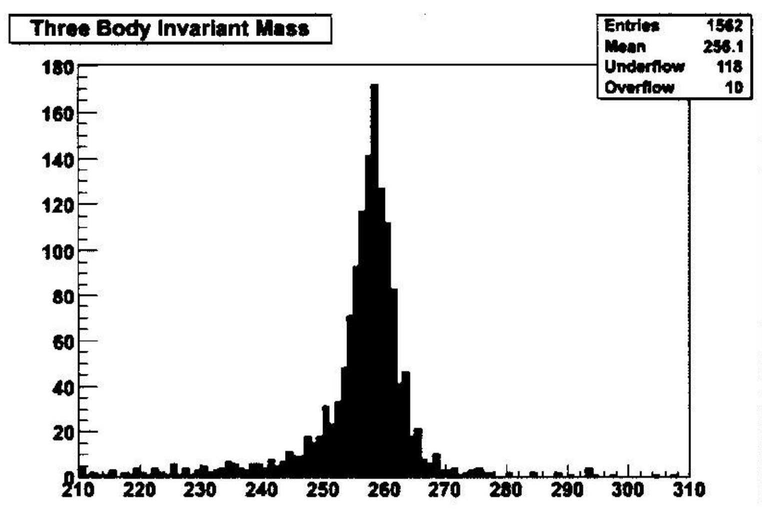


Figure 7: Three Body graphs superposed. Though the most important of the graphs, this Three Body plot clearly has a serious deficiency of background events that would allow one to gage the significance of the signal.