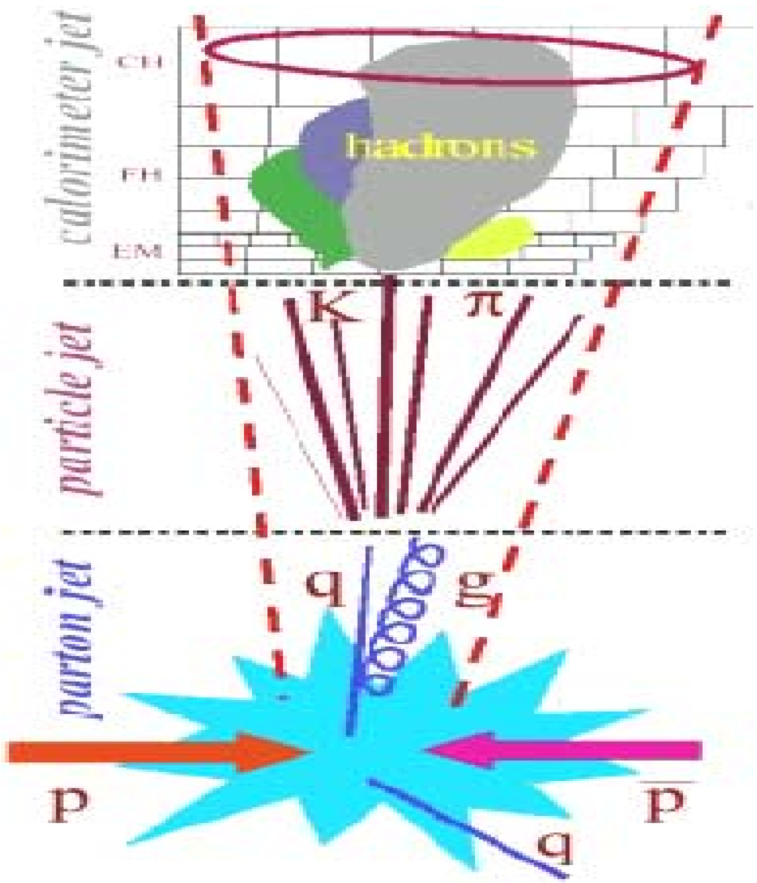
Dissecting D∅



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The D∅ experiment is situated at Fermilab in Batavia, Illinois. It is privy to one of the world's largest high-energy accelerators: the Tevatron Collider. One day, with the help of the proton-antiproton collisions generated by the Tevatron Collider, physicists hope to confirm the existence of the Higgs boson. Working at Nevis Laboratories this summer, I had the opportunity to play a role in the search for the Higgs. I joined the D∅ calorimeter team at Nevis and conducted research with respect to the Run 2b trigger and its upgrade.

BACKGROUND

What is D∅? The D∅ experiment is the analysis of the proton and antiproton beams of the Tevatron. When a proton collides into an antiproton, a lot of physics is produced. But how does one separate the good physics from the superfluous physics? That is not a concern but a programmed function of D∅. In the D∅ experiment, the good physics derives from hard scattering. In other words, partons collide with each other and generate one or two strong streams of particles or "jets," usually very high-energy. For example, jets can obtain a transverse energy as high as 450 GeV (only a tenth of the proton's initial energy). Meanwhile, the superfluous physics arrives in soft scattering. Soft scattering is the result of the energy traveling in the path of the broken proton or antiproton. Not enough energy is produced to create dominating jets that contain most of the incoming particle substructures. As a result, the scattered energy deposits make it difficult for the D∅ detector to properly record the amount of energy produced by the jets; therefore, QCD fails to enable one to fully understand parton scattering.

DISCOVERIES

The D∅ detector has led to many interesting discoveries. In Run I, many physicists found themselves finally being recognized in the physics world. Over 100 papers were published. The topics of these papers included such fascinating insights like the discovery of the top quark, QCD tests with jets and photons, and searches for Supersymmetry. All of which could not have been possible if it were not for the "jewel" of the D∅ detector: the liquid argon calorimeter.

CALORIMETER

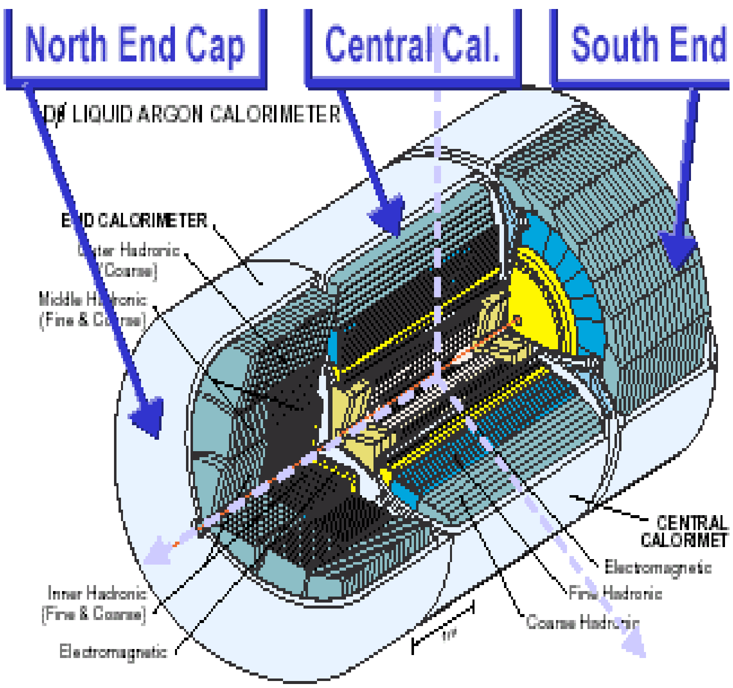

Figure 1: The Calorimeter for Run 2b

The liquid argon calorimeter is a prime example of great physics. It allows for the precise measurements of electrons, photons, jets, and missing energy. The electrons and photons' trajectory are often analyzed in the electromagnetic part of the calorimeter. Conversely, the hadronic part of the calorimeter finds information on the photons, jets, and missing energy. In this case, the missing energy refers to that which is involved with the Higgs production. Together, the Higgs and Z boson decay into an antineutrino-neutrino pair that is usually accompanied by missing energy (ppbar->WH and ppbar->ZH).

The technical make-up of the calorimeter is just as interesting.   The calorimeter is made up of a north end cap and a south end cap that connects to the central part of the calorimeter. Within the central calorimeter, there are 1280 trigger tower cells since η=40 and ϕ= 32. In addition each cell is 0.2 X 0.2 and includes an electromagnetic and a hadronic part.

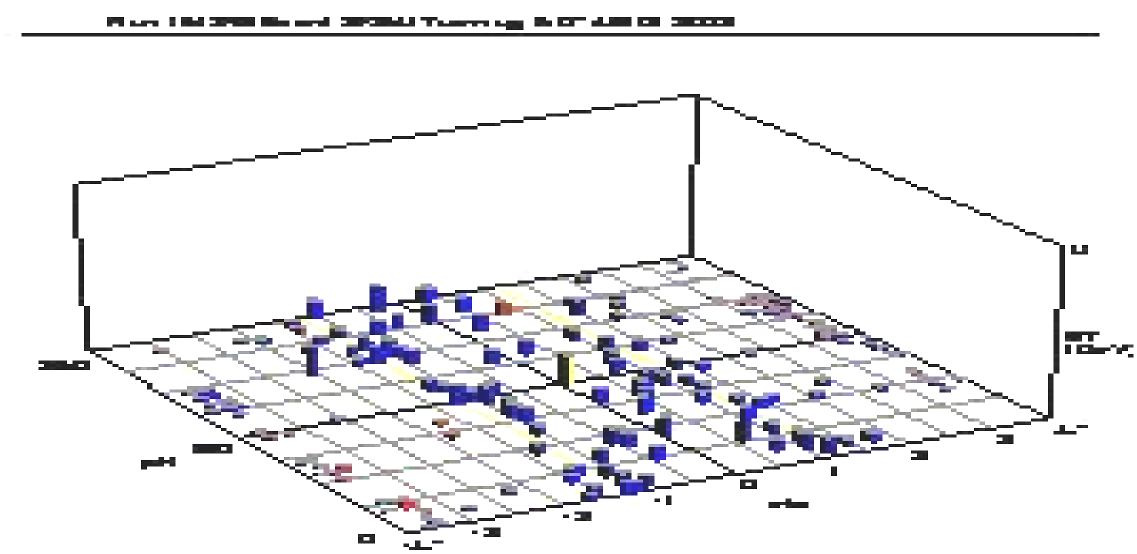

Figure 2: A phi-eta plot of the energy deposited in the calorimeter. a) The lower right axis is the eta plot, while the lower left axis is the phi plot. b) The blue color represents the hadronic part, while the em part is in red.

INTERCRYOSTAT REGION

One primary area of interest in the D∅ calorimeter team is whether the intercryostat region (ICR) should be included. The area between the two barrels of the calorimeter is home to the ICR. In past trigger runs, the intercryostat region has been ignored, since the trigger towers could not collect data properly. For a time, this puzzled the D∅ team. Nevertheless, the reason for the TT's (trigger towers) inaccurate behavior was soon discovered: an old version of d0sim that used the 7.5 minimum bias files was incorrectly mapping the TT's as the L1CalTT was built. Needless to say, the necessary corrections were applied and now the TT's are finally behaving correctly.

RUN 2B TRIGGER UPGRADE

These days the "hot topic" for the D∅ calorimeter team has been the Run 2b trigger upgrade. Run 2a is still running. However, if the D∅ team is to gain any insight on new physics, then improvements must be made. Actually, the ICR's inclusion is one of the advantages of the Run 2b trigger upgrade. Other perks of the trigger include it operating under a peak luminosity of about 5.10 $cm^{-2}s^{-1}$ (2.5 times higher than the luminosity of Run 2a) and a bunch crossing reduction to 132 ns (the current bunch crossing is 396 ns).

Much of my data compilation was due in part to ROOT, a data analysis system that is great for physics analysis and applications. From the Monte Carlo simulation files available to the D∅ team, I studied TT jets for the (2,0,1) and (3, -1,1) algorithms via computer programming in C++ and ROOT. These two algorithms allowed me to see how well the precision and trigger readouts fared.

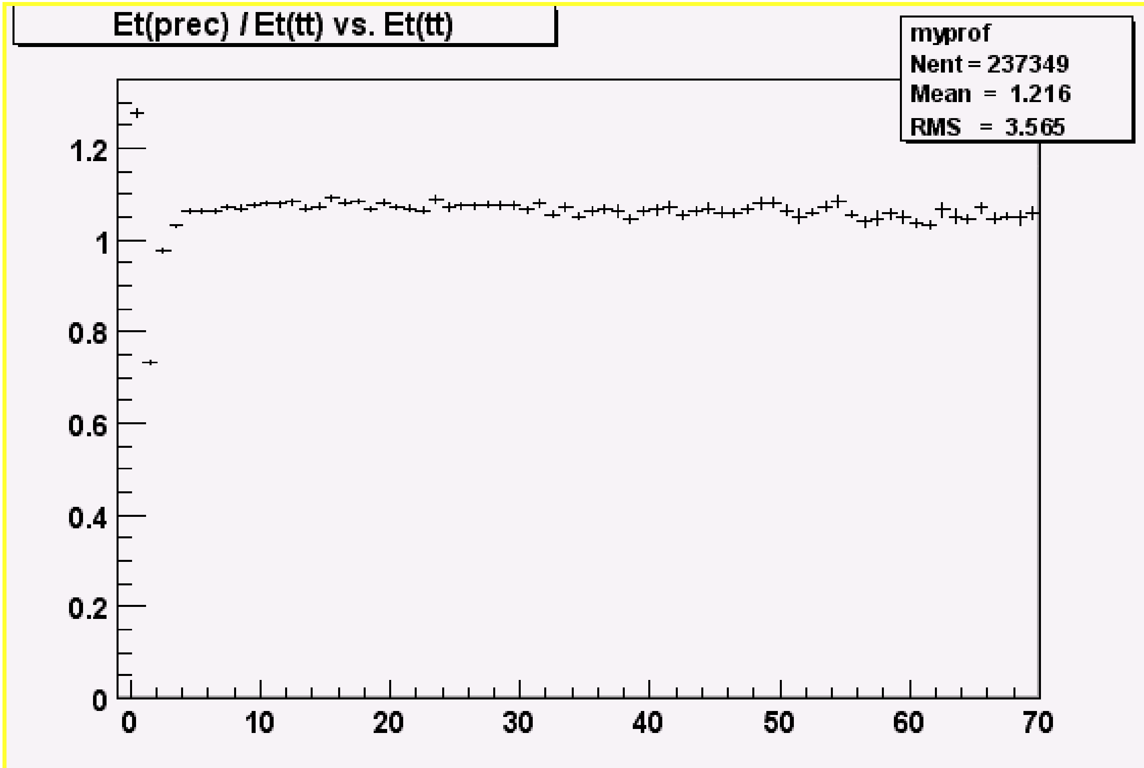

Figure 3: The energy ratio between the precision and trigger readouts against the energy precision readouts.

Figure 3 is a profile plot that illustrates how well the precision and trigger readouts performed regarding the intercryostat region and used the (2,0,1) algorithm. Furthermore, I used the formula $R^2 = \Delta\phi^2 + \Delta\eta^2$ and discovered that it is necessary to find the best delta R squared value when matching between jets. Delta R alludes to the region of interest (ROI) in the trigger tower clusters that had the most jet-energy deposition (see Figure 4).

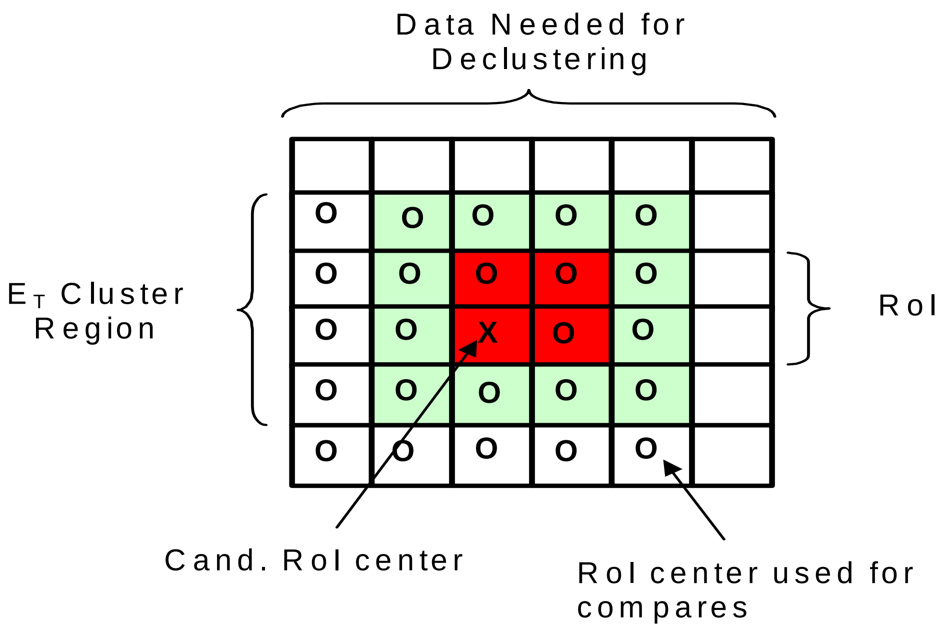

Figure 4: a.) The (2,1,1) algorithm. b.)The trigger tower is shown as the green shaded region. c.)The local maximum is found by declustering the algorithm. It is the shaded red region.

The (2,1,1) algorithm was chosen for the Run 2b upgrade. This algorithm was found to perform better than the others.

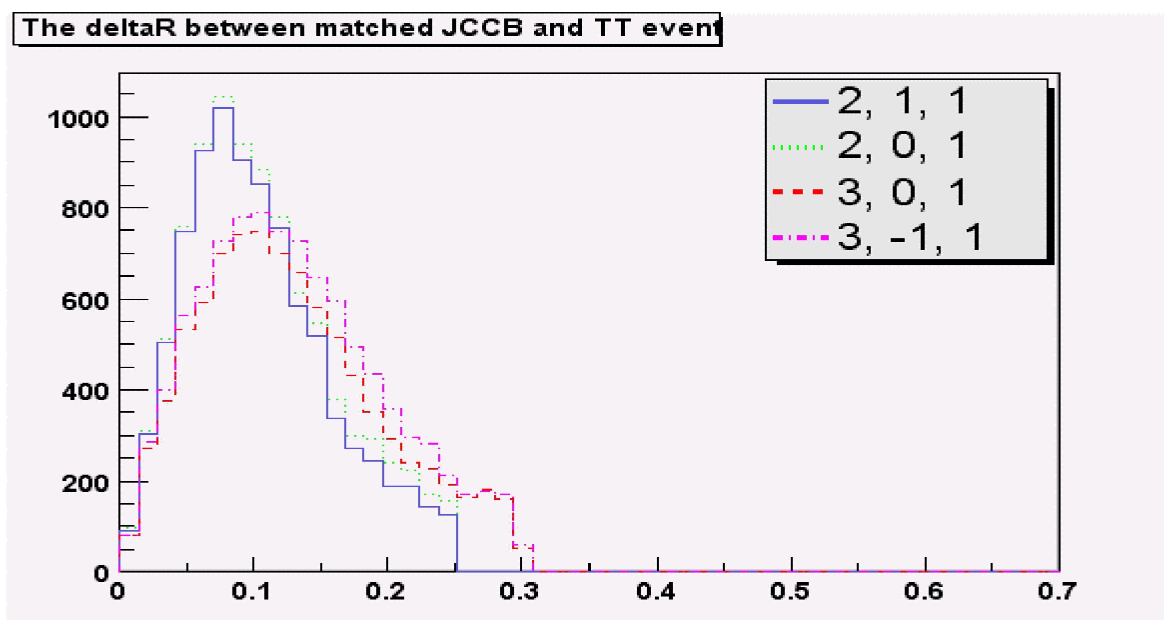

Figure 5: The delta R between JCCB and TT events

As a matter of fact, the (2,1,1) algorithm is a sliding windows algorithm, a new and exciting feature for the Run 2b trigger. The sliding windows algorithm is a window grid that travels across the calorimeter until it has maximized the transverse energy seen in that same window.

It is imperative that one study the transverse momentum or "P_T" of the jets. High transverse momentum is an important feature of the calorimeter since high P_T events are the most interesting. Also P_T cuts are implemented to reduce the amount of background received in the D∅ detector. So the vast amount of parton information that enters the D∅ detector is controlled.

CONCLUSIONS

The higher luminosity of the Run 2b trigger will accommodate for the new advances in physics that usually require higher energy production. Thus, the signals received in the calorimeter will be more abundant. Moreover, the sliding window algorithms will enable the Run 2b trigger to perform at a more sophisticated and satisfactory rate. Due to the sliding windows, physical objects will become easier to identify. And most importantly, great discoveries for the D∅ team are on their way.

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