A Comparison between Z Boson Decays

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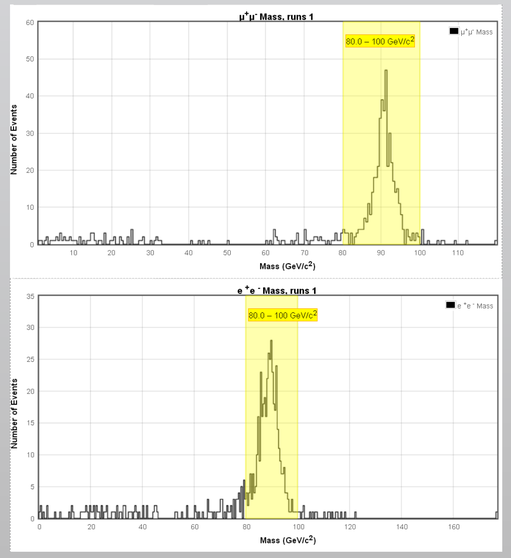
Abstract

While looking through the data from the 2010 LHC run, a discrepency between the average mass of the e-/e+ pairs and the muon/anti-muon pairs are found. This phenomenon was mentioned in the 2013 poster "Z Boson Decay into Electrons and Muons" by Nick Varberg. A wider mass distribution of the e-/e+ pair mass is also present. While these evidence could suggest the unlikely erronous calibration of the detectors at CERN, it could also be that the e-/e+ pairs simply has lower measured masses because the electrons lose more energy. Individual events are analyzed and compared from the 3D event display, in search for any difference between the two types of decays. It is found that the average number of jets involved in e-/e+ events are higher than that of the di-muon events.

Introduction

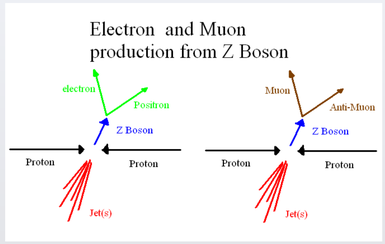
The mass distribution of the parent particle candidates widens when the parent particle is more massive. This pattern occurs because massive particles have more decay options, therefore they are more prone to decay. Z0 bosons naturally have varying rest masses, which contribute to the mass distribution on the histograms; however, the e-/e+ decays seem to have a wider mass distribution and a lower average mass than di-muon events. This indicates more energy is somehow lost during the e+/e- events.



Here is the comparison between the mass distribution of Z boson decay into μ-/μ+ and e-/e+. The average mass of the e-/e+ pair seem to be lower than that of the μ-/μ+ pair. Also, the e-/e+ events have more varied masses.

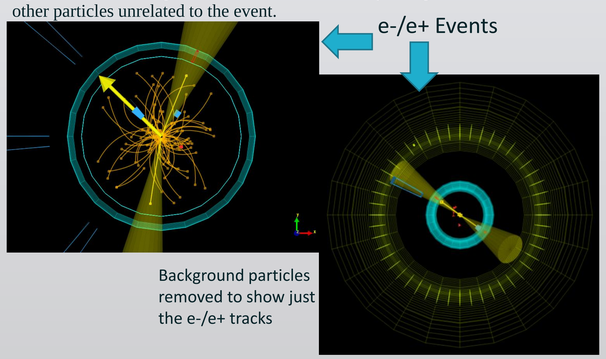
What Happens in the LHC

When two protons collide, there is a chance that a Z boson is produced. This particle exists for a very short time, it decays almost instantly into other particles.



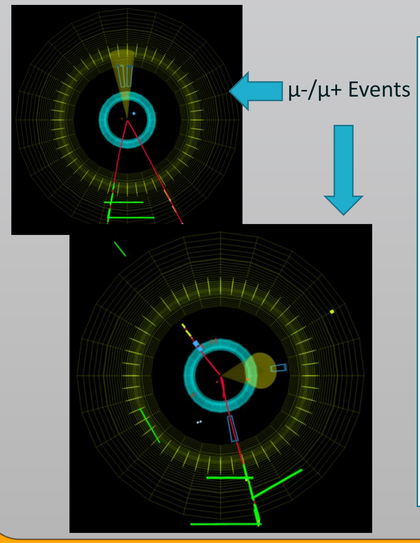
Because the Z boson is electrically neutral, the particles it decays into must add up to a total electrical charge of zero (Conservation of Charge).

These are pictures from the 3D event display. The thick yellow arrow represents the missing momentum vector. The many orange tracks are other particles unrelated to the event.



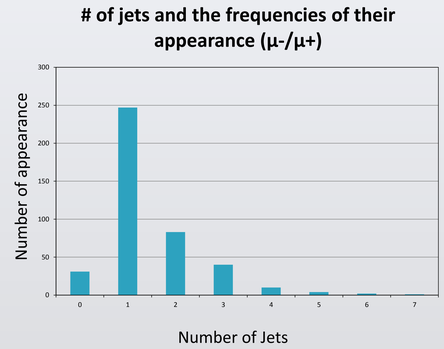
Background particles removed to show just the e-/e+ tracks

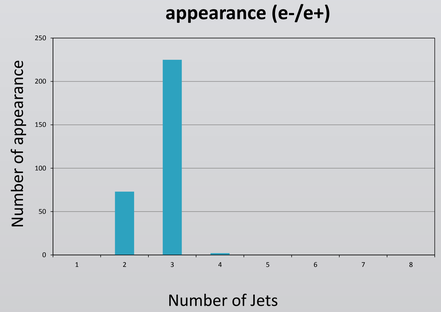
One phenomenon is observed from the 3D event display, the Jets (yellow cones) very often travel along side the electrons (yellow lines). This does not happen with the muons; the jets in muon events does not follow the muon tracks (red lines).



The Pattern

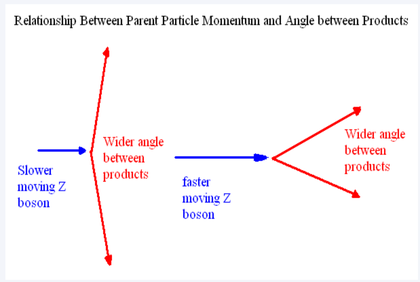
The number of 418 μ-/μ+ events and 300 e-/e+ events from the 3D display are counted. It appears that e-/e+ events more frequently see 2 jets along the electron tracks, and the μ-/μ+ events often involve 1 jet traveling away from the muon tracks.





As seen here, e-/e+ events often have2 jets, while μ-/μ+ events often see 1 jet. On the other hand, μ-/μ+ events have a more varied numbers of jets in the 75%-100% energy range, whereas the e-/e+ events only involve 1,2, or 3 jets.

About the Angle between the decay products



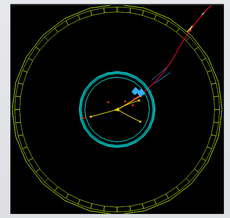
Different events from the 3D event display have different angles between the decay products. Narrower angle between decay products indicate that the parent particle had more momentum/energy. Note that this angle is only observed from the detector's frame of reference. From the center of momentum reference, the decay products actually moves away from each other at a 180 degrees angle!

Discussions and Questions

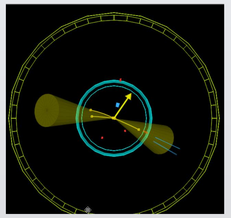
•With the data that are available, the most noticeable difference between the e-/e+ pairs and the μ-/μ+ pairs is the number of jets involved. But does this have any effect on the different average mass of the two types of decay?

•Why do jets from e-/e+ events tend to follow the tracks of the electron?

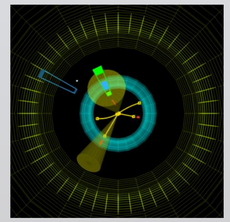
•Some uncommon events are observed from the 3D event display:



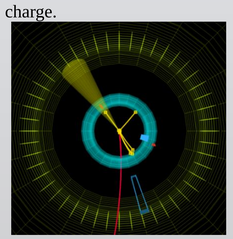
2 e-/e+ pairs are seen in this event; however, there is a muon present, which is a violation of the conservation of charge.



1 e-/e+ pair is seen in this event; however, there is only one other electron/positron present, this violates the conservation of charge.



Not sure if the Z boson decayed into 2 e-/e+ pairs here , or the second pair is simply background.



5 electrons/positrons and one muon, charge appears to be conserved, but it is rare to see a Z decay into 6 particles.

References

C. Amsler et al. (Particle Data Group), PL B667, 1 (2008) and 2009 partial update for the 2010 edition

J.D.Jackson(LBNL), "Kinematics,"http://pdg.lbl.gov/2005/reviews/kinemarpp.pdf

"Decay of Z Bosons." *International Physics Masterclasses*. CERN, n.d. Web. 26 July 2013.

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CMS 3D event display

The Particle Adventure website

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