Searching for SUSY in all hadronic final states with the α_T variable

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Abstract

This is a thesis.

Declaration

There are many like it.

Author

Acknowledgements

Thanks.

Contents

Chapter 1

Introduction

The accelerator and detectors The Large Hadron Collider (LHC) [3] is a proton-proton collider which is situated in the Large Electron Positron (LEP) tunnel approximately 100 m under the franco-swiss border. Design center of mass energy is 14 TeV with an instantaneous luminosity of $1 \times 10e^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. However during 2011 the center of mass energy was 7 TeV and the maximum luminosity was $5 \times 10e^{33}$ $\mathrm{cm}^{-2}\mathrm{s}^{-1}$. To achieve this high energy and high beam current the LHC uses superconducting niobium-titanium magnets, cooled to a temperature of 1.8 Kelvin, that produce a maximum field strength of 8.36 Tesla.

TODO: we might well need some more stuff about the LHC its self in here!

Situated around the LHC ring are four detectors, two general detectors ATLAS [1] and CMS (see Chapter 3 for a detailed discussion of the CMS detector) [5][8] which are designed to measure the standard model to high precision and search for new physics. The LHC beauty experiment [7] is designed to study at previously unattainable precision the decays of heavy quark flavors, both to measure the standard model couplings and to search for beyond the standard model (BSM) physical processes. Finally the ALICE [2] experiment is designed to run when the LHC is running in it's secondary mode where rather than proton bunches, lead ions are collided, in an effort to study the quark-gluon plasma.

New physics Whilst the theory of the standard model and of new physics models will be discussed in chapter 2 it is prudent to discuss the observable features of these models with regard to design requirements for the general purpose detectors.

Chapter 2

Theory

Chapter 3

The CMS detector

Chapter 4

Level One Calorimeter Trigger

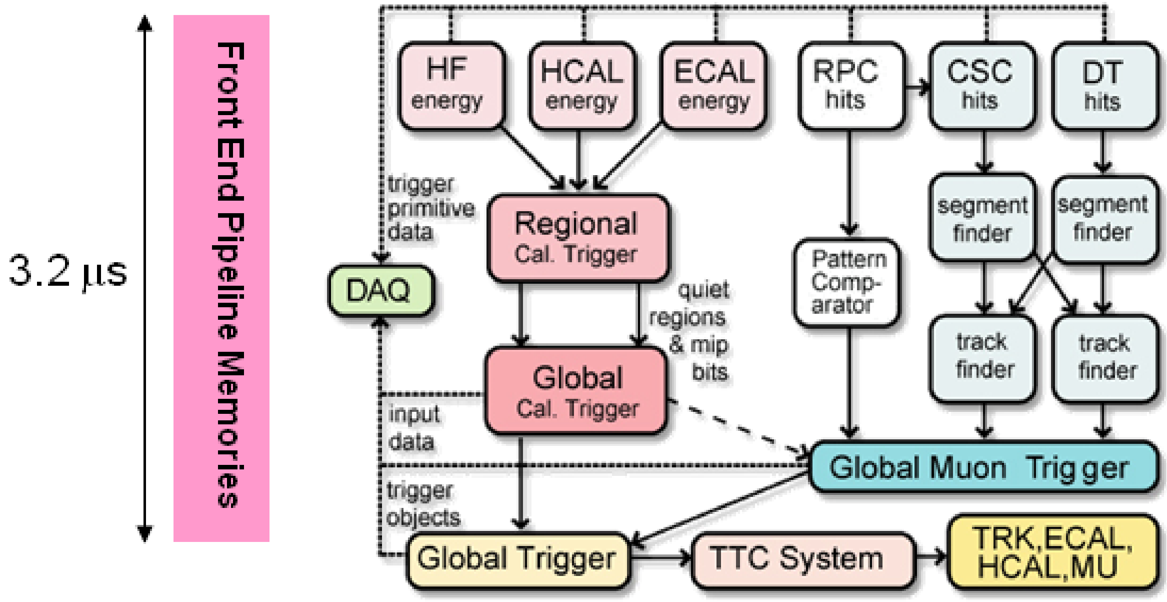


Figure 4.1: The CMS Level-1 Trigger system

The CMS Level-1 trigger system[4] is a pipelined dead-timeless system based on custom-built electronics. The Level-1 trigger is a combination of several sub systems, which are interconnected as depicted in Figure 4.1.

Corse grain information from the electro-magnetic, hadronic and forward calorimeters is processed by the Regional Calorimeter Trigger (RCT), this is then passed to the Global Calorimeter Trigger (GCT) where the corse grain information is clustered in to physics objects, these objects are then passed to the Global Trigger where the Level-1 accept decision is made. Due to the limited size of the pipe line this Level-1 accept must be issued within 4.0 μs.

The objects passed from the GCT to the GT include electro-magnetic objects, both electrons and photons as due to the lack of tracking information at the Level-1 trigger these objects are indistinguishable, jets and energy sums.

The RCT generates up to 72 isolated and non-isolated electro-magnetic objects, these are sorted by rank, which is equivalent to transverse energy E_{T}. The four highest ranked electro-magnetic objects are then passed via the GCT to the GT at an equivalent data rate of 29 Gbs^{-1} per type.

Hadronic objects under go two clustering steps. First the transverse energy sums of the ECAL and corresponding HCAL towers are calculated, the towers are then summed in to 4×4 trigger regions, these are passed to the GCT at a data rate of 172.8 Gbs^{-1}. These trigger regions are clustered in to jet candidates by the GCT and ranked. The jets are then sub-divided in the categories depending on their pseudo-rapidity and the result of τ identification.

Energy sums come in two forms, the total transverse energy E_{T} which is the scalar sum of all transverse energies and the total jet transverse energy H_{T} which is calculated as the scalar sum of all jets above some programable threshold.

The missing energy equivalents of these $E_{\mathrm{T}}^{\mathrm{miss}}$ and $H_{\mathrm{T}}^{\mathrm{miss}}$ are formed from the negative vector sum of the objects considered for the transverse sums.

THIS IS BY NO MEANS FINISHED, NEED TO DISCUSS IN DEPTH THE L1 JET FINDING AND THE PERFORMANCE AT LOW PU OF BOTH SETS OF CORRECTIONS. PERFORMANCE IN 2011 THEN MOVE ON TO WHY ITS IMPORTANT TO DO SOME SORT OF PILE UP CORRECTION. REMEMBER TO USE THE FOLLOWING IMAGE!!! Figure 4.3

4.0.1 Level-1 Trigger Jet Algorithm

The jet finding algorithm [6] at Level-1 finds local maxima from 3×3 blocks of trigger regions. The central trigger region is required to have $E_T^{cen} \geq E_T^{surrounding}$, however there is no direct requirement on the energy deposited in the central region.

The jet finding algorithm [6] at Level-1 finds local maxima from 3×3 blocks of trigger regions. The central trigger region is required to have $E_T^{cen} \geq E_T^{surrounding}$, however there is no direct requirement on the energy deposited in the central region.

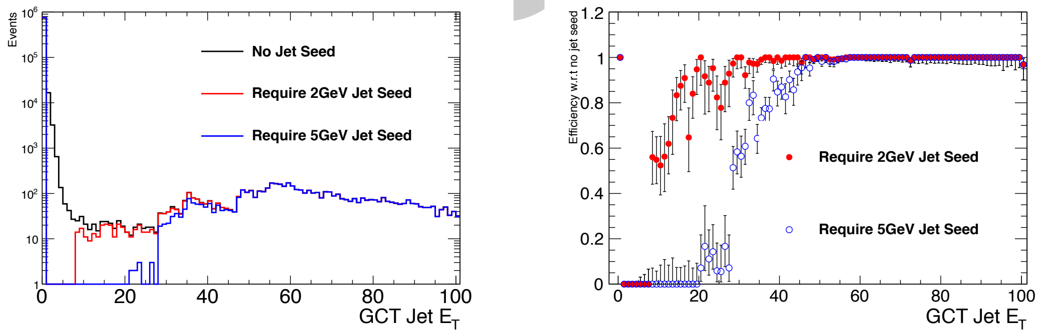
Due to the lack of a requirement of a jet seed threshold, soft non-collimated jets, such as those expected in a high pile up environment are found. Trigger decisions are then made using these pile up jets.

This is less of a problem for the single jet triggers which have a high P_T threshold. However the H_{T} triggers, where $H_{\mathrm{T}} = \sum_{jets} E_T^{jet}$ and the requirement of $E_{\mathrm{T}}{}^{jet} \geq$10 GeV is made, see a large increase in rate due to pile-up, this is due to the low energy threshold required for a jet to be added to the H_{T} sum.

To counteract the effect of pile up on trigger rate we study the effects of requiring a jet seed threshold on the rate and efficiency of the individual jet and H_{T} triggers.

Figure **??** depicts 3×3 trigger regions, each of which are built from 4×4 trigger towers. In this case the central region is the jet seed. The proposed change would require there to be a threshold energy in the seed region.

The study of using jet seed thresholds of 2 and 5 GeV is presented. The maximum energy of effected jets is 18 GeV when requiring a seed of 2 GeV and 45 GeV when requiring a seed of 5 GeV for jets made from 3×3 trigger regions, however some jets can include more than 9 trigger regions. The jet clustering is performed before the Level-1 jets are corrected according to their E_{T} and η, hence the effects are manifested in trigger decisions for Level-1 jets above 18 or 45 GeV.



(a) GCT jet E_T distributions for the same events with a 0, 2 or 5 GeV seed requirement.

(b) Efficiency of applying a requirement of 2 or 5 GeV with respect to no requirement.

Figure 4.2: Effect of requiring a jet seed threshold on GCT internal jets.

Figure 4.2 shows how the different threshold requirements effect the rank of the internal GCT jets. The effect is to remove all jets below 2(5) GeV and to cut out jets from the low end of the distribution. From Figure 4.2(b) it is possible to see the point beyond which the requirement of a jet seed has no effect. For a cut of 2 GeV jets above a rank of ≈ 35 are not effected, for a seed threshold of 5 GeV jets above a rank of 55 are not effected.

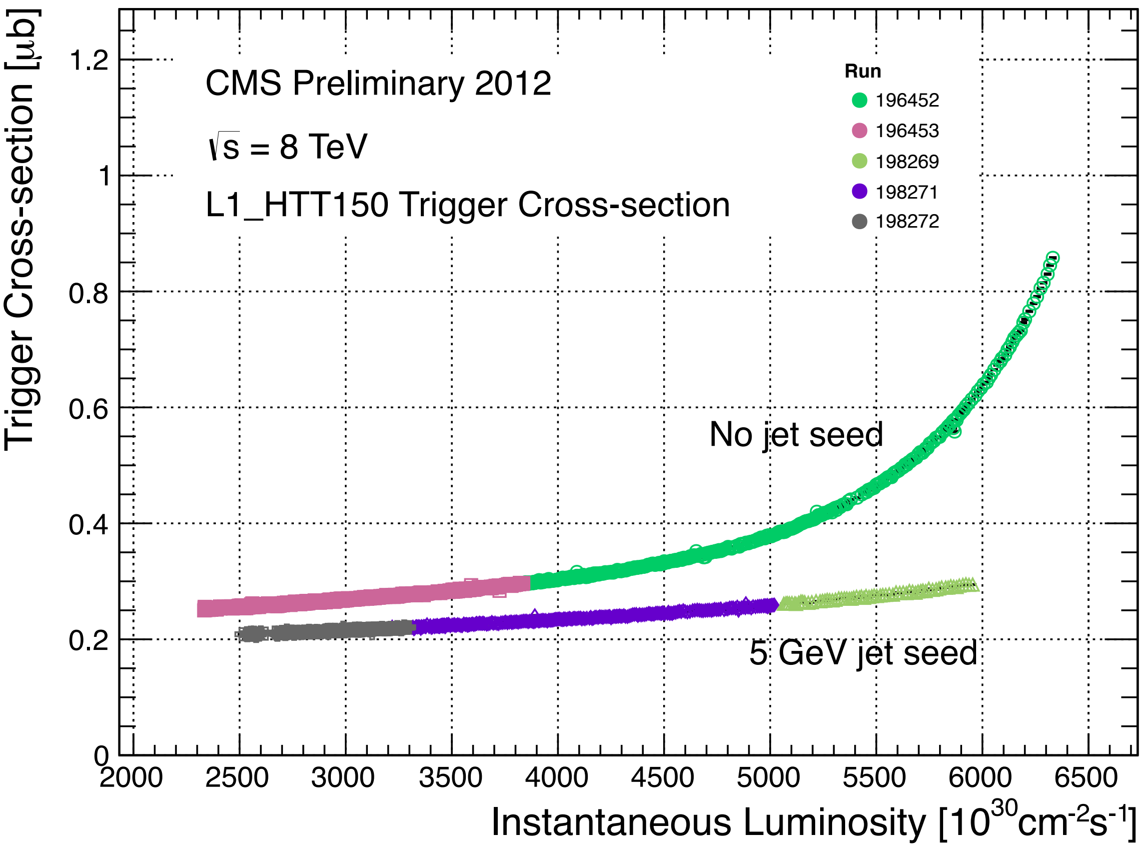


Figure 4.3: caption

Chapter 5

Offline Object Deffinitions

Chapter 6

The α_T analysis

Chapter 7

Conclusion

Bibliography

[1] T Åkesson. The ATLAS experiment at the CERN Large Hadron Collider - CERN Document Server. *Particles*, 1999.

[2] B Alessandro, F Antinori, J Belikov, and C Blume. ALICE: Physics performance report, volume II. *Journal of Physics G: Nuclear and Particle Phyiscs*, January 2006.

[3] Michael Benedikt, Paul Collier, V Mertens, John Poole, and Karlheinz Schindl. *LHC Design Report*. CERN, Geneva, 2004.

[4] CMS Collaboration. The Trigger and Data Acquisition Project Technical Design Report, Volume 1, The Level-1 Trigger. *CERN/LHCC 2000-038, CMS TDR 6.1*, 2000.

[5] M Friedl, N Frischauf, T Bauer, T Bergauer, W Waltenberger, A R Knapitsch, C Irmler, I Kratschmer, W Treberer-treberspurg, B Rahbaran, V Innocente, T Camporesi, S Gowdy, L Malgeri, A Marchioro, L Moneta, W Weingarten, M Giunta, M Rovere, A Bonato, A C Spataru, S Zhang, A Perieanu, N Heracleous, H K V Reithler, B Philipps, M K Merschmeyer, C A Heidemann, H Geenen, Y Kuessel, E Kuznetsova, J Olzem, A Bethani, L Calligaris, R Walsh bastos rangel, T M M Dorland, G Quast, A H Dierlamm, I Katkov, R M Ulrich, F M H Stober, C Barth, X Mol, A Kornmayer, F Matorras, A Calderon tazon, A Lopez garcia, J A Brochero cifuentes, M J Bercher, M Haguenauer, Y Sirois, C M Mironov, P Depasse, L Sgandurra, G P Heath, Z Meng, D A Hartley, N I Geddes, S Quinton, I R Tomalin, K Harder, V B Francis, Z Zhang, T Geralis, D Loukas, I Topsis giotis, G Bencze, S T Hernath, I Szeberenyi, S Banerjee, S Singh, A Colaleo, G P Maggi, M Maggi, F Loddo, R Campanini, I D'antone, C Grandi, L Guiducci, M Gulmini, S Fantinel, P Meridiani, K K Joo, S Song, J Rhee, E Won, M Jo, H Kim, D H Kim, G N Kim, J E Kim, T Son, W M Dominik, K Bunkowski, J C Rasteiro da silva, J Varela, A Alves, V Sulimov, A Vorobyev, V Murzin, S Lukyanenko, G Mesyats, V Postoev, A Pashenkov, A Solovey, S Troitsky, N Lychkovskaya, G Safronov, A Fedotov, K Olimov, M Fazilov, A Umaraliev,

I Dumanoglu, N M Bakirci, C Dozen, M Zeyrek, M Yalvac, S Ozkorucuklu, K Sevim, Y Chang, W T Lin, S Bahinipati, K A Biery, E E Gottschalk, K Maeshima, T Kramer, S W L Kwan, S J Murray, L Taylor, N Mokhov, J M Marraffino, S Mrenna, V Yarba, B Banerjee, V D Elvira, D C Hare, B Holzman, F X Yumiceva del pozo, W Dagenhart, C L Dumitrescu, S C Ryu, B J Kilminster, J K Adelman-mc carthy, V E Bazterra, I Bucinskaite, P E Karchin, J R Incandela, M D'Alfonso, R Rossin, C A West, J L Gran, G Zilizi, P P Raics, A Bhardwaj, M Naimuddin, A Kumar, N Smiljkovic, C P De oliveira martins, M Petek, A Vercosa custodio, E J Tonelli manganote, M T Narjanen, P Graehling, F Blekman, J M Keaveney, S Blyweert, N van Remortel, X J Janssen, D Druzhkin, M Bansal, A Aleksandrov, M F Shopova, T R Fernandez perez tomei, C Krug, A A Shinoda, T V Rohe, P Arce, M Daniel, J J Navarrete marin, I Redondo fernandez, A Guirao elias, J Santaolalla camino, J Lottin, P Gras, F Kircher, B Levesy, A Payn, A K Nayak, V Bhatnagar, C Randieri, M Bruzzi, O Starodubtsev, A Tropiano, D Piccolo, C Sciacca, S Meola, A Saccomanno, M Esposito, P Azzi, E Conti, S Lacaprara, M Margoni, M Sgaravatto, N Pozzobon, P Torre, B Checcucci, L Fanò, S Taroni, A Lucaroni, F Romeo, G Bagliesi, M A Ciocci, A Giassi, T Boccali, S Arezzini, A Rizzi, G Broccolo, D Dattola, C Mariotti, A Ballestrero, E Camacho-Pérez, R Magaña-Villalba, J Martínez-Ortega, M Górski, G Wrochna, M J Bluj, A Zarubin, M Nozdrin, V Ladygin, A Golunov, A Sotnikov, N Evdokimov, I Lokhtin, A Ershov, N Tyurin, S Akimenko, V Talov, N Belikov, A Ryazanov, G W Hou, Y Chao, J Alwall, X Shi, D R Wood, D C Baumgartel, J Zhang, P D Luckey, K C Sumorok, G Gomez ceballos retuerto, S H Jaditz, G S Stephans, T Ma, P J Lehtonen, M H Chan, I J Moult, R A Ofierzynski, A Pozdnyakov, B L Pollack, P B Padley, A H Adair, W J Clarida, E Tiras, G Cerizza, M Pieri, V A Sharma, M W Lebourgeois, M Norman, F Golf, M J Murray, J L S Bowen, K Buterbaugh, M Sharma, J Bunn, H Newman, M Gataullin, M Spiropulu, J Veverka, S D Thomas, K J Rose, S M Panwalkar, A Calamba, Z Xie, J S Werner, A M Zuranski, A Ferapontov, E M Laird, G Kukartsev, Z Mao, S J Wimpenny, S Gleyzer, M G Weinberg, V Veeraraghavan, and J... Bochenek. CMS - The Compact Muon Solenoid. January 1996.

[6] J Marrouche and others. Commissioning the CMS Global Calorimeter Trigger. *CMS IN*, 2010/029, 2010.

[7] J Rademacker. LHCb: Status and Physics Prospects. *Arxiv preprint hep-ex*, January 2005.

[8] C Wulz. The CMS experiment at CERN. *cdsweb.cern.ch.*