

# Searching for SUSY in all hadronic final states with the $\alpha_T$ variable

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## Abstract

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This is a thesis.

## Declaration

There are many like it.

Author

## Acknowledgements

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Thanks.

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# 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  $1 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$ . However during 2011 the center of mass energy was 7 TeV and the maximum luminosity was  $5 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$ . 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

### <sub>1</sub> Theory

## Chapter 3

### <sub>1</sub> The CMS detector



# Chapter 4

## Level One Trigger

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.

- Regional Calorimeter (RCT).
- Global Muon Trigger (GMT).
- Global Calorimeter Trigger (GCT).
- Global Trigger (GT).

Some stuff about each of the sub systems

### 4.1 GCT Hadronic triggers

The global calorimeter trigger is responsible for forming hadronic jets in the central and forward sections of the hadronic calorimeters, there is a separate algorithm for forming hadronic  $\tau$  jets. First 108 internal jets are formed and ordered, these jets are then used to calculate  $H_T$  and  $H_T^{\text{miss}}$ . The four highest energy jets then have their energy corrected, by passing through a look up table which is dependent on  $E_T$  and  $|\eta|$ , these jets are then passed to the Global Trigger so that the final trigger decision can be made.

**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!!!**

htht

Figure 4.1: caption

### 4.1.1 Level-1 Trigger Jet Algorithm

The jet finding algorithm [6] at Level-1 finds local maxima from  $3 \times 3$  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.

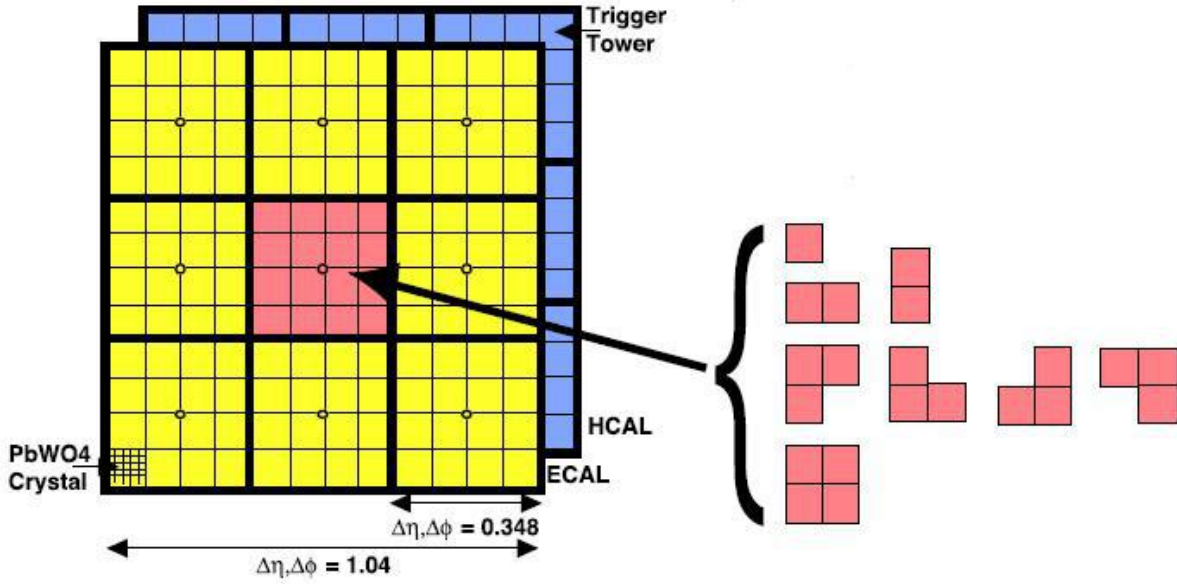


Figure 4.2: graphic of Level-1 jet algorithm

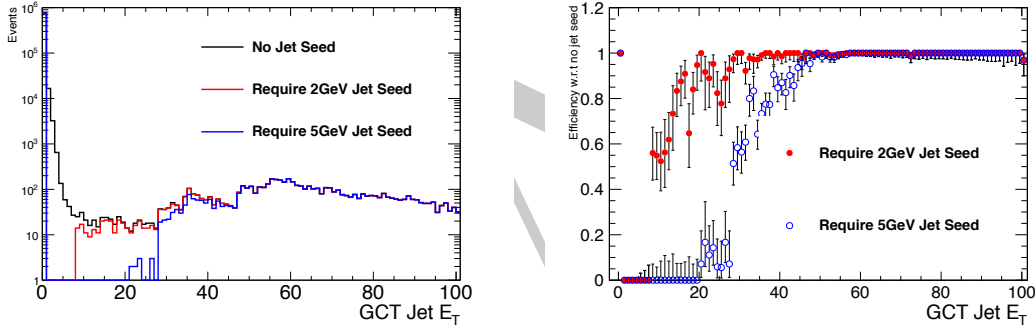
Due to the lack of a requirement of a jet seed threshold, soft non-collimated jets, such as those expected in a high pile up environment are found. Trigger decisions are then made using these pile up jets.

This is less of a problem for the single jet triggers which have a high  $P_T$  threshold. However the  $H_T$  triggers, where  $H_T = \sum_{jets} E_T^{jet}$  and the requirement of  $E_T^{jet} \geq 10$  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 4.2 depicts  $3 \times 3$  trigger regions, each of which are built from  $4 \times 4$  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  $3 \times 3$  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  $\eta$ , 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 4.3:** Effect of requiring a jet seed threshold on GCT internal jets.

Figure 4.3 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 4.3(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  $\approx 35$  are not effected, for a seed threshold of 5 GeV jets above a rank of 55 are not effected.

## Chapter 5

### <sub>1</sub> Offline Object Definitions

## Chapter 6

### <sub>1</sub> The $\alpha_T$ analysis

## Chapter 7

### <sub>1</sub> Conclusion

DRAFT

# 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 Physics*, 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 Imler, 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,



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[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*.