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

[1] Theory

Chapter 3

[1] # The CMS detector

Chapter 4

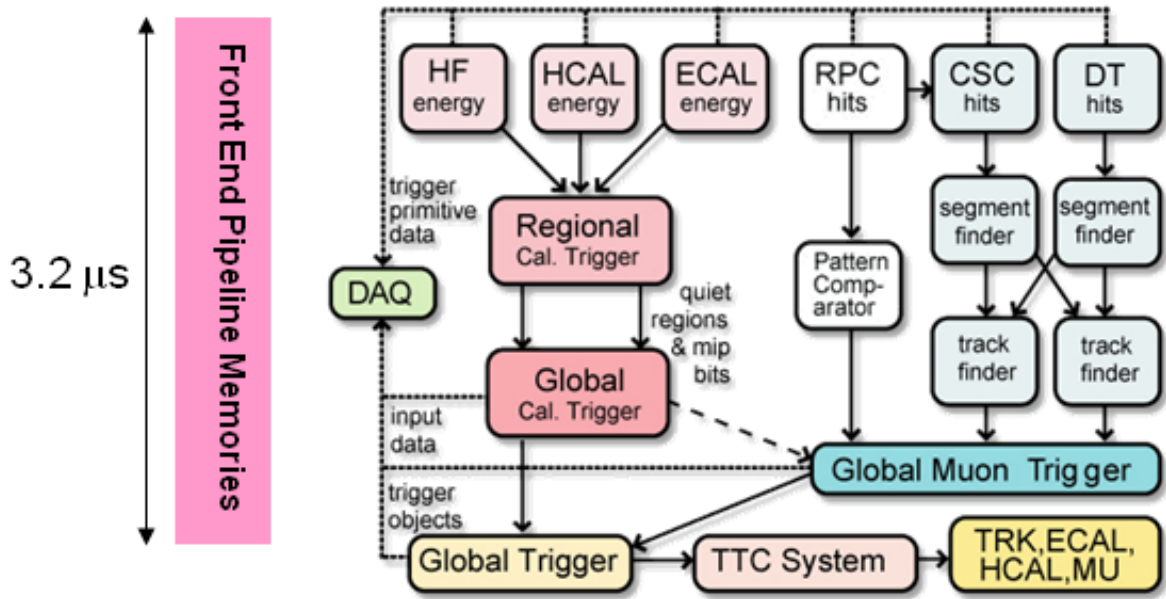# Level One Calorimeter Trigger

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.

4.1 Leve-1 Trigger Jet Algorithm

FIXME: This is taken pretty much straight from [6] might want to steal less??

The CMS detector can be un-rolled in the ϕ direction to form a rectangular grid of the 396 calorimeter regions, connected along the ϕ edge. The rectangle 18 ϕ divisions (from $-180° < \phi \leq 180°$) by 22 η divisions (from $-5 < \eta < 5$). Each ϕ division corresponds to 20°. The η divisions correspond to $\Delta\eta = 0.5$ in the forward calorimeters and to $\Delta\eta \approx 0.348$ in the barrel. A pictorial representation of this can be seen in figure 4.3.

A jet candidate is created if the sum of the ECAL and HCAL energies of the central calorimeter region has an energy deposit larger than all of its neighbours, as shown in figure 4.2 The jet is centered at this region where $p_T^{central} > p_T^{surrounding}$ and the transverse energies of the surrounding regions are summed in to the central region. The jet is then
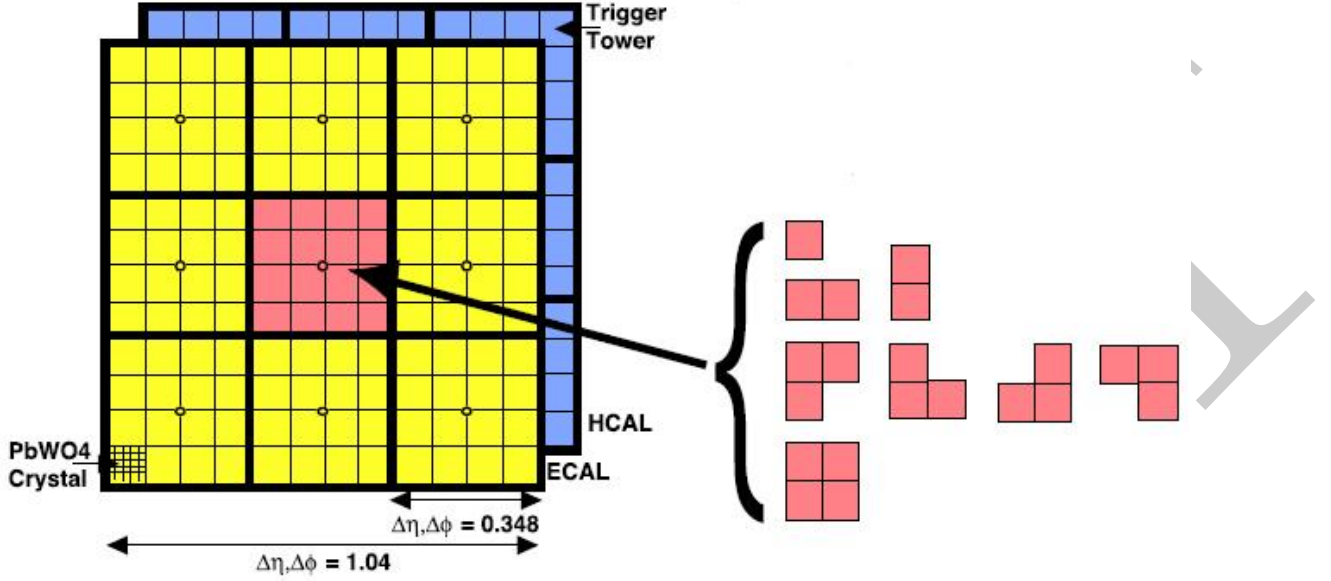
Figure 4.2: The 3×3 jet-finder window at Level-1. Each cell represents a trigger tower, which is the sum of the HCAL and ECAL transverse energies. The τ-jet veto patterns are shown to the right.

1 classified as a τ jet if $|\eta| < 3.0$ and none of the τ veto bits are set. If any τ vetoes are set
2 the jet is classified as a central jet. The jet is classified as forward if $3.0 < |\eta| < 5.0$

3 The τ-vetoes are set by the RCT depending on whether or not the energy depositions
4 in up to four contiguous trigger towers are below a programmable fraction of the regional
5 E_T as shown in Figure 4.2.

6 It is possible to apply separate jet energy corrections to each of the sub categories of
7 GCT jets. These corrections are discussed in detail in Section 4.2

8 **FIXME: Do we want to add some stuff on the pre-clustering here, i think**
9 **that the answer is yes, but how much?!?!**

10 In order to reduce the total data duplicated and shared between the jet finders
11 the GCT employs a pre-clustering algorithm, which involves 18 jet finders operating
12 simultaneously over the whole detector. These jet finders then only share information with
13 neighboring regions when the clustered jets are found. Figure 4.3 shows the boundaries
14 between which the jet finders operate, these map naturally on to one RCT crate per jet
15 finder. A maximum of 3 jets can be found on each of the ϕ strips acted on by the jet
16 finders, this gives a maximum of 108 jets per event. In order to preserve continuity across
17 the $\eta = 0$ boundary, the two adjacent trigger regions are shared between the jet finders.
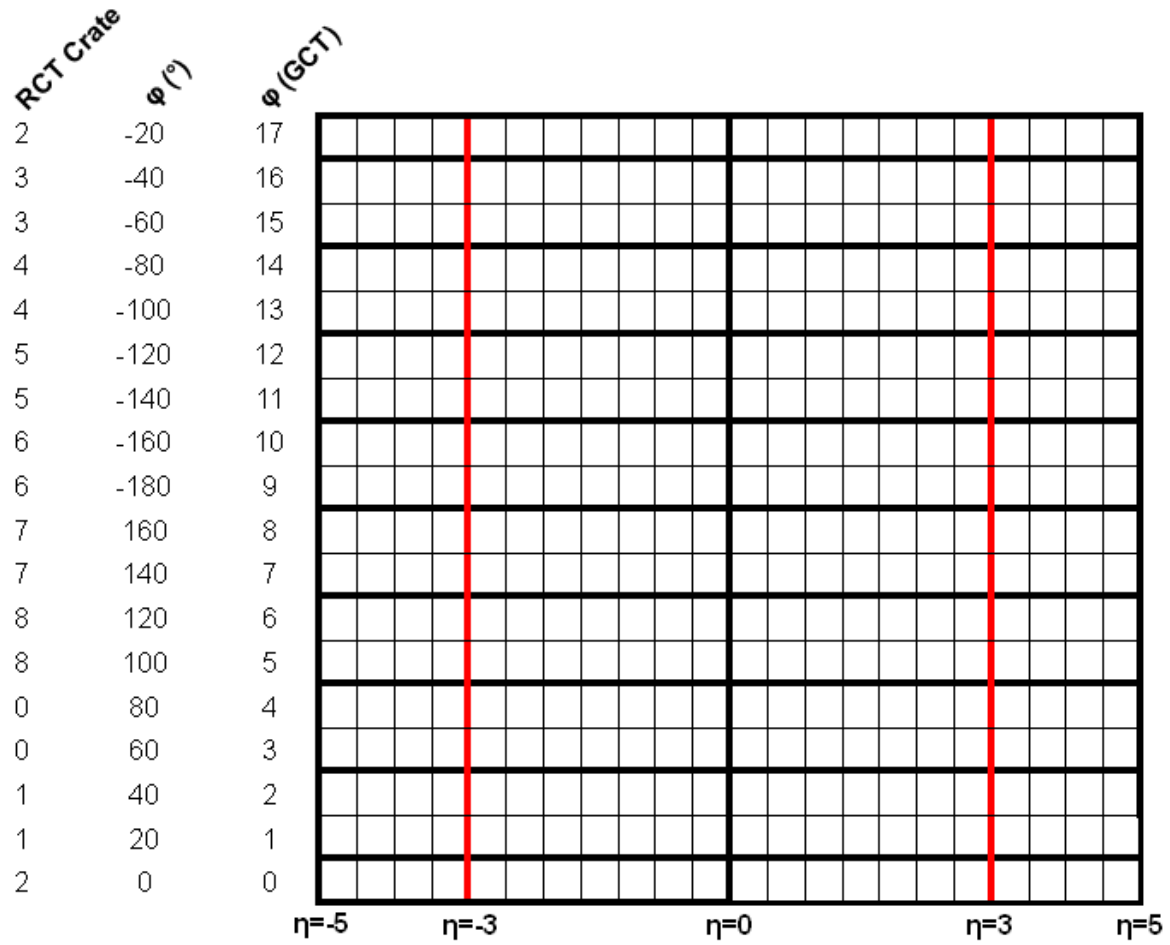
Figure 4.3: caption

1   An example of the jet finding is shown in Figure 4.4. The first step is to create a 2×3
2 mini cluster around any local maxima found in the 12×2 strip. Equality statements
3 are imposed so that the central cell is greater than its neighbors in some directions and
4 greater than or equal to the neighbors other directions to enforce a gap of at least one
5 trigger region in both η and ϕ between the centers of the clustered jets.
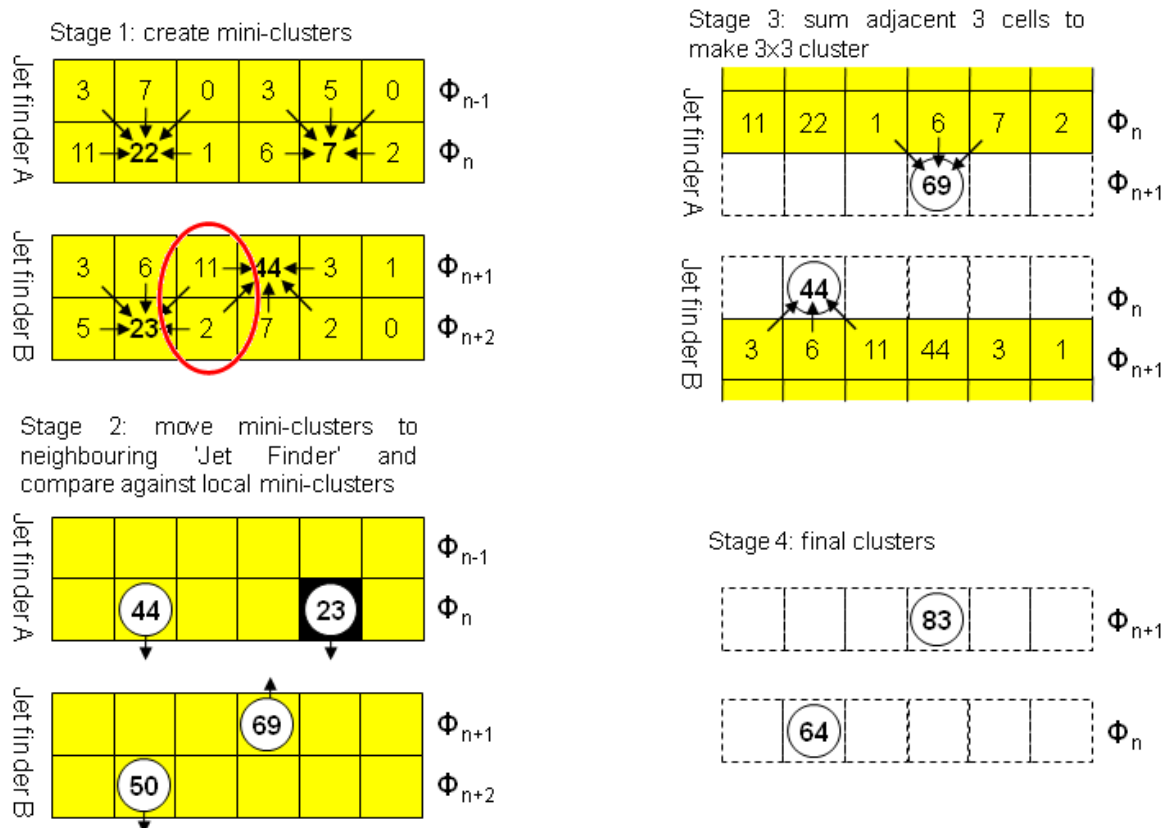
Figure 4.4: caption

4.2 Level-1 Trigger Performance

4.3 Level-1 Trigger Pile-up Mitigation

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.

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

4   The study of using jet seed thresholds of 2 and 5 GeV is presented. The maximum
5 energy of effected jets is 18 GeV when requiring a seed of 2 GeV and 45 GeV when
6 requiring a seed of 5 GeV for jets made from 3×3 trigger regions, however some jets can
7 include more than 9 trigger regions. The jet clustering is performed before the Level-1
8 jets are corrected according to their E_T and η, hence the effects are manifested in trigger
9 decisions for Level-1 jets above 18 or 45 GeV.
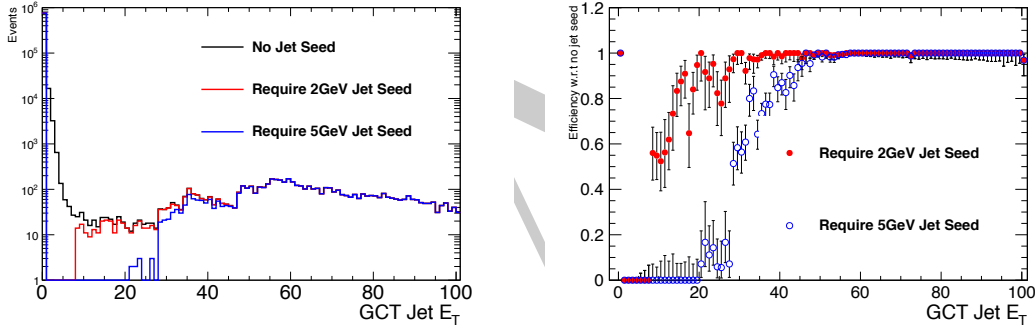
(a) GCT jet E_T distributions for the same events with a 0, 2 or 5 GeV seed requirement.
(b) Efficiency of applying a requirement of 2 or 5 GeV with respect to no requirement.

Figure 4.5: Effect of requiring a jet seed threshold on GCT internal jets.

10   Figure 4.5 shows how the different threshold requirements effect the rank of the
11 internal GCT jets. The effect is to remove all jets below 2(5) GeV and to cut out jets
12 from the low end of the distribution. From Figure 4.5(b) it is possible to see the point
13 beyond which the requirement of a jet seed has no effect. For a cut of 2 GeV jets above
14 a rank of ≈ 35 are not effected, for a seed threshold of 5 GeV jets above a rank of 55 are
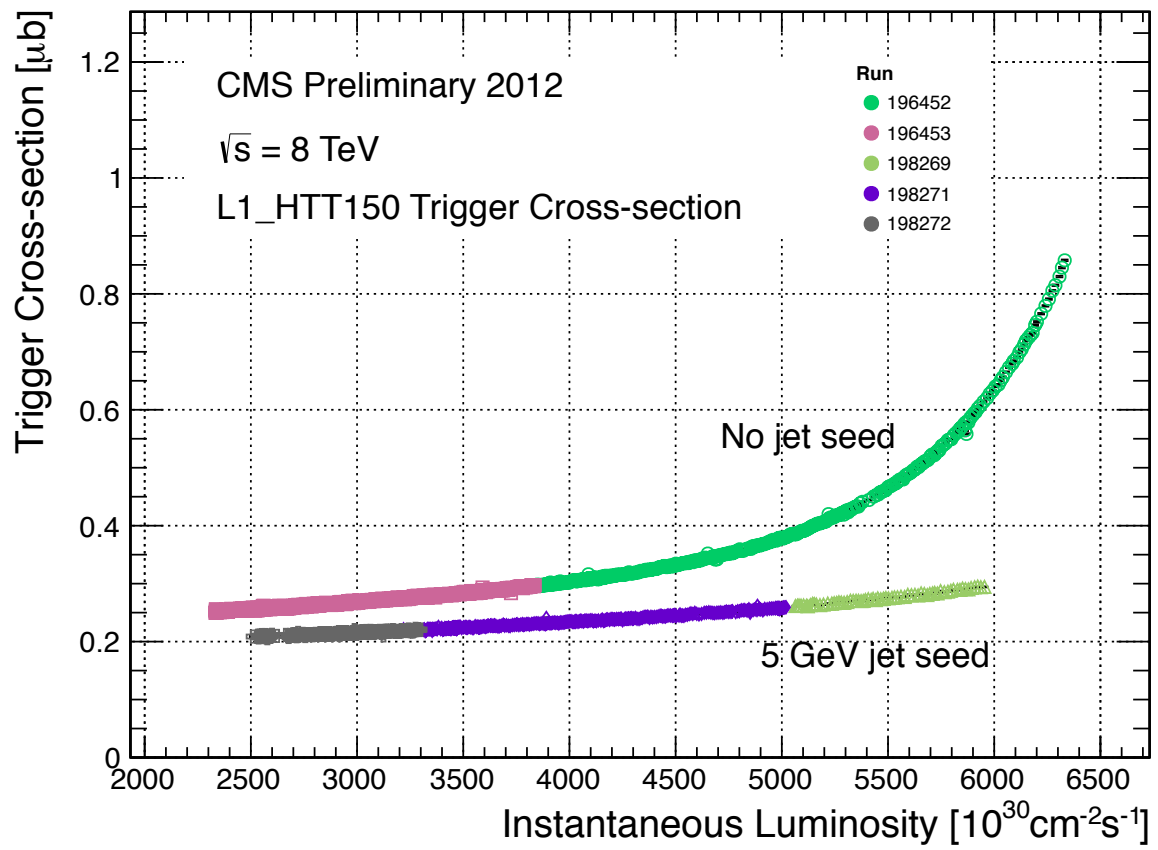15 not effected.

Figure 4.6: caption

Chapter 5

Offline Object Definitions

Chapter 6

[1] The α_T analysis

Chapter 7

[1] Conclusion

1

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