QCD Background Estimation From Data for SUSY Searches at ATLAS

Introduction

One of the primary goals of the Large Hadron Collider (LHC) at CERN is the discovery of Supersymmetry (SUSY), a theoretical extension of the Standard Model of particle physics. SUSY searches are subject to a large amount of background signal, which could obscure a real signal, from Quantum Chromodynamic (QCD) multijet production. This is very difficult to quantify using simulation alone so it will be very important to use data-driven background estimation techniques when the LHC begins running in Autumn 2009. One such technique is the **jet smearing method** which will be described in this poster.

Background

Supersymmetry
The Standard Model (SM), depicted in Fig.1, is a hugely successful theory which accurately describes all known fundamental constituents of nature and their interactions.

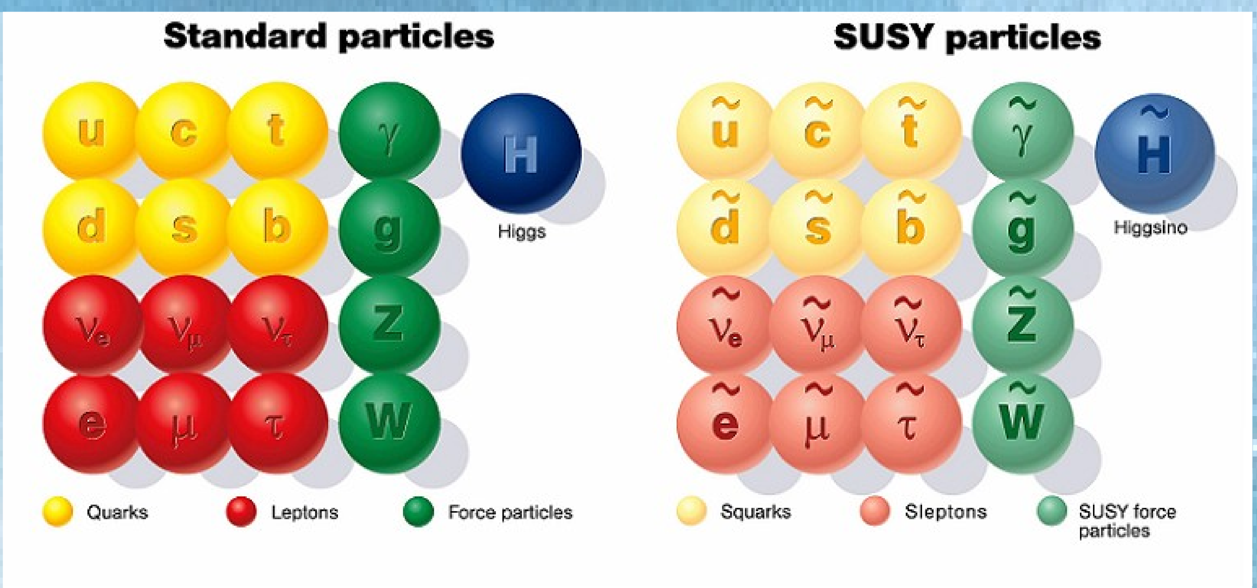

Figure 1. The Standard Model and Supersymmetry [1]

However, theoretical issues such as the hierarchy problem and the lack of gauge coupling unification at high energies [2] have led to the proposal of SUSY which predicts every known boson (force carrier) and fermion (matter particle) has a partner particle with a **much higher mass** and a half unit different spin as shown in Fig.1.
SUSY predicts that it's lightest particle, which in most models is the **neutralino**, is stable so it will never decay into SM particles. The neutralino is predicted to only interact through the weak interaction and gravity; it also has a high mass and is therefore an ideal candidate for **dark matter** in the universe.

The LHC and ATLAS
The LHC is a 27 km ring which accelerates protons to close to the speed of light and collides them at different points where detectors are stationed. It is designed to produce a centre of mass energy of 14 TeV (over **seven times** more energy than the Tevatron) and a luminosity of 10^{34} $cm^{-2}s^{-1}$ (over **thirty times** more than the Tevatron).
The 7000 tonne **ATLAS** experiment is one of the detectors aiming to discover SUSY at the LHC and is shown in Fig.2.

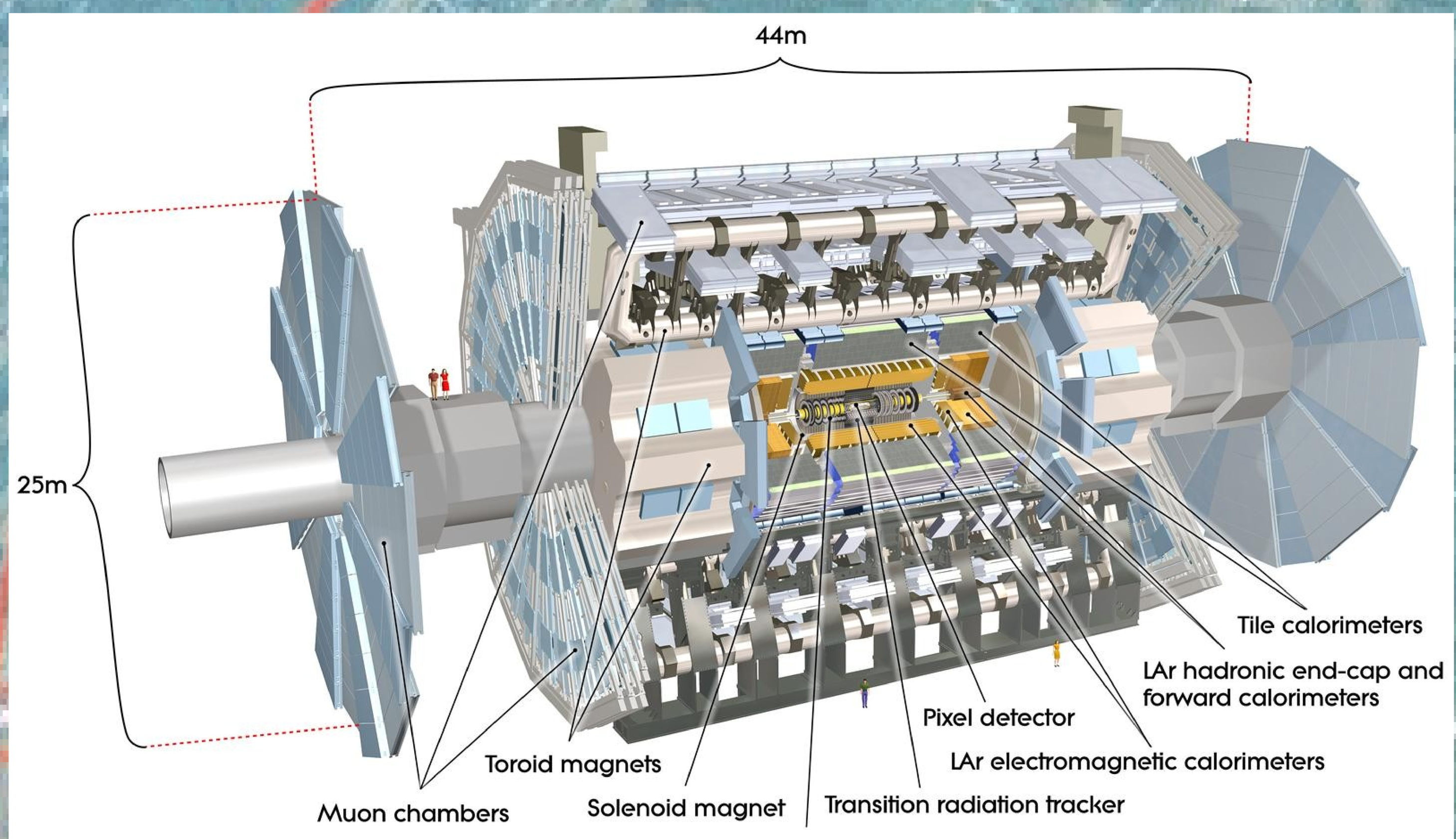

Figure 2. Schematic of the ATLAS Detector [3]

Jets
Jets are extremely important objects in any hadron collider experiment and are produced in large numbers through **QCD multijet production**. They consist mainly of a group of hadrons (particles made from quarks such as pions) all travelling in roughly the same direction and are produced because quarks and gluons can never be free particles and instead 'hadronise' into a jet.

Discovering SUSY in the ATLAS Detector
The energies produced at the LHC should be sufficient to produce the very massive SUSY particles. If SUSY particles are produced they will instantly decay, often through intermediate states, into stable neutralinos which will not interact in the detector. They can only been 'seen' by observing a large **missing transverse energy** (**MET**) signature. MET is measured by performing a vector sum of all of the energies transverse to the proton beam direction; energy conservation means the sum should equal zero and if it is not then MET has been found due to one of the following:

1. A particle did not interact in the detector, like a neutrino or neutralino.
2. The detector failed to reconstruct a particle (the particle might have travelled into a crack in the detector's coverage) or the particle's energy was not fully reconstructed.

A typical SUSY signature includes large MET and a number of high energy jets. In an ideal experiment, QCD multijet production should not obscure a SUSY signal because jets do not include enough 'invisible particles' (like neutrinos) to add up to the MET expected in a SUSY signal. However, point 2 above shows that the energy in a jet can be mismeasured and a **fake MET** signature can be reconstructed.

Simon Owen, The University of Sheffield. 03/2009

The Jet Smearing Method

The jet smearing method is a way of using data, rather than simulation, to estimate the amount of MET which ATLAS should expect from multijet production.

It works in the following way:

- Construct the **jet response function** by using special control samples to measure the amount of fluctuation in the measurement of a jet's energy. This is done in two stages:
  1. Measure the **Gaussian** component by using events where there is a jet back to back with a **photon**. As the photon's energy can be accurately measured in ATLAS therefore by conserving transverse energy one can see how much the jet's energy fluctuates.
  2. Measure the **non-Gaussian** component by looking at three jet 'Mercedes' events where there is a large amount of MET co-directional with one of the jets. See Fig.3 for a pictorial representation of these events.
- Use the response function to '**smear**' the four-momenta of jets in events with low MET. The smeared jets can now have sufficient MET to enter the SUSY signal region and hence provide an estimation of the multijet background in this region.

Fig.4 shows this technique has been proved to successfully reproduce the QCD background expected from simulation.

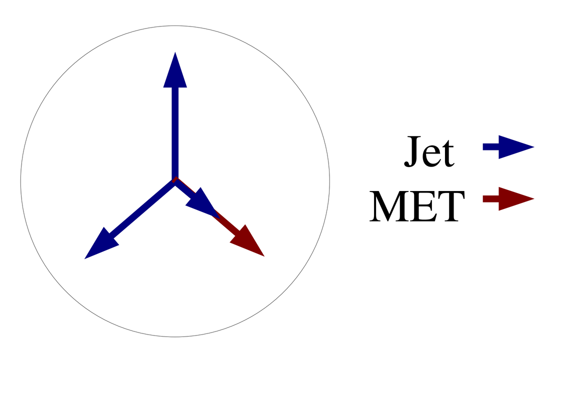

Figure 3. 'Mercedes jet events'

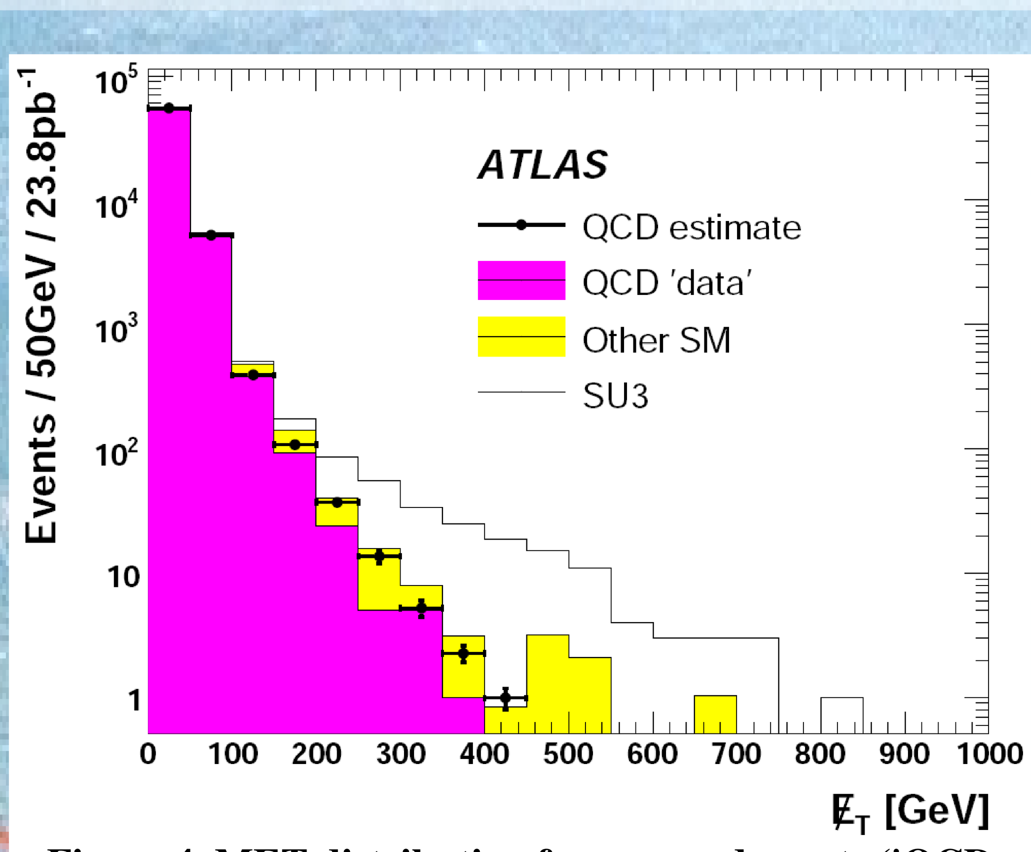

Figure 4. MET distribution for smeared events ('QCD estimate') and simulated data ('QCD 'data'') for events in SUSY signal region. 'Other SM' is signal from other backgrounds and 'SU3' is estimated SUSY signal. [4]

Trigger for Measuring non-Gaussian Component

The limiting factor to the smearing function method is to record enough events for measuring the non-Gaussian component of the response function.
At ATLAS data is collected using triggers which 'flag' an event to be recorded if it has certain properties. The response function measurement is triggered by finding a jet with energy above a certain threshold; a proportion of these events are not recorded to keep data recorded by the detector to a manageable level (**prescaling**).

dπ Trigger
A technique is being developed at Sheffield which allows a reduction in trigger prescaling for measuring jet response. This is done by triggering on a function of the angle between the leading two jets: **dπ**. This favours the shape of Mercedes jet events and cuts events with other event shapes reducing the trigger data rate. This allows a relaxation of the prescaling increasing the available statistics.

Fig.5 shows the measurement of the non-Gaussian component of the jet response function comparing the standard jet trigger with the dPi trigger.

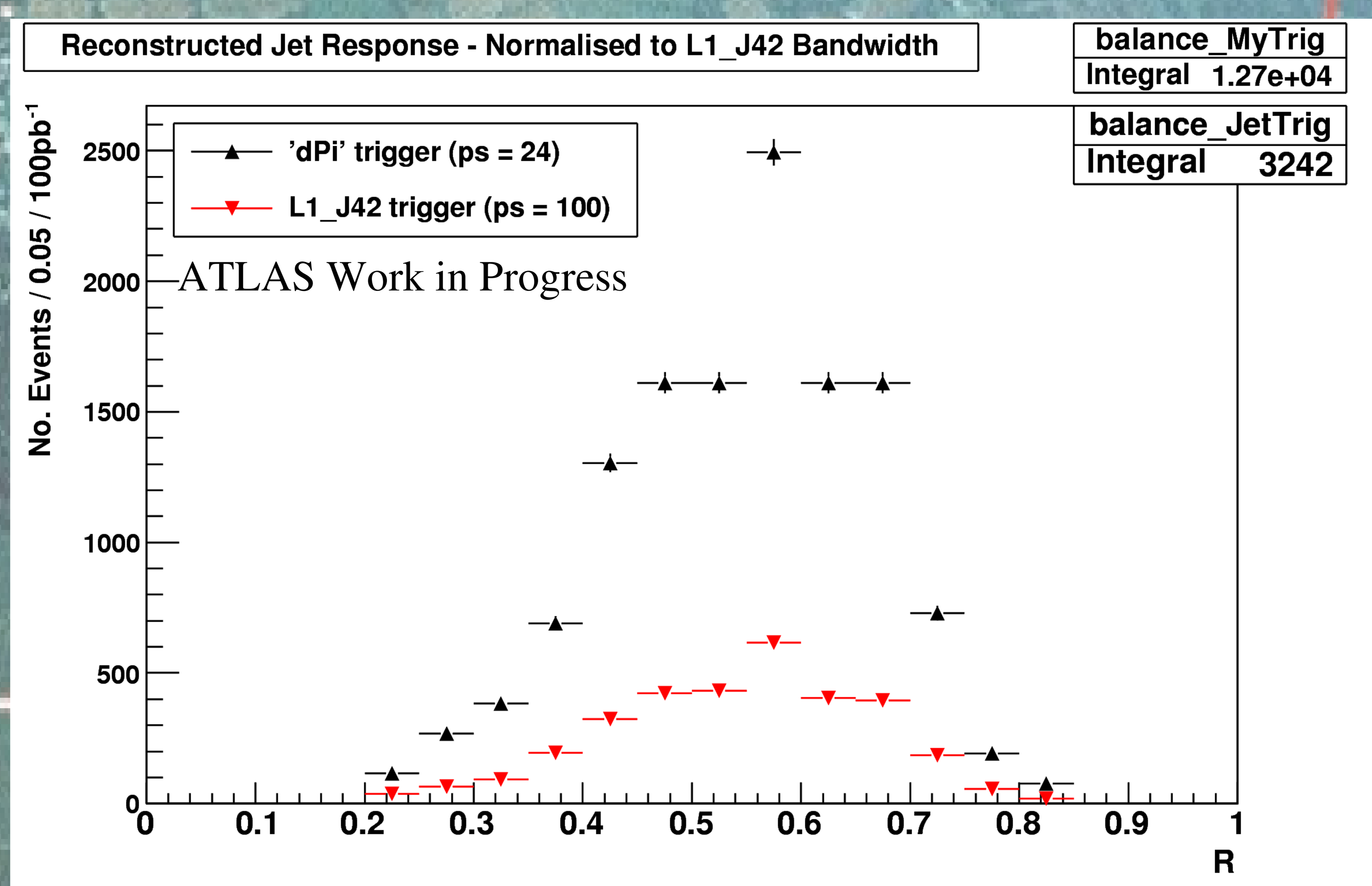

Figure 5. Measurement of non-Gaussian jet response function (R). Normalised to output of 'standard' jet trigger L1_J42 with integrated luminosity of 100pb^{-1}. In legend ps is prescaling value.

References and Acknowledgements

[1] From webpages of Particle Physics Theory Research Group, University of Glasgow.
[2] Ian J.R. Aitchinson, "Supersymmetry and the MSSM: An Elementary Intoduction", 2005, http://arxiv.org/pdf/hep-ph/0505105
[3] Adapted from: http://atlas.ch/photos/full-detector-cgi.html
[4] ATLAS Collaboration, "Expected Performance of the ATLAS Experiment: Detector, Trigger and Physics", 2008, arXiv:0901.0512

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