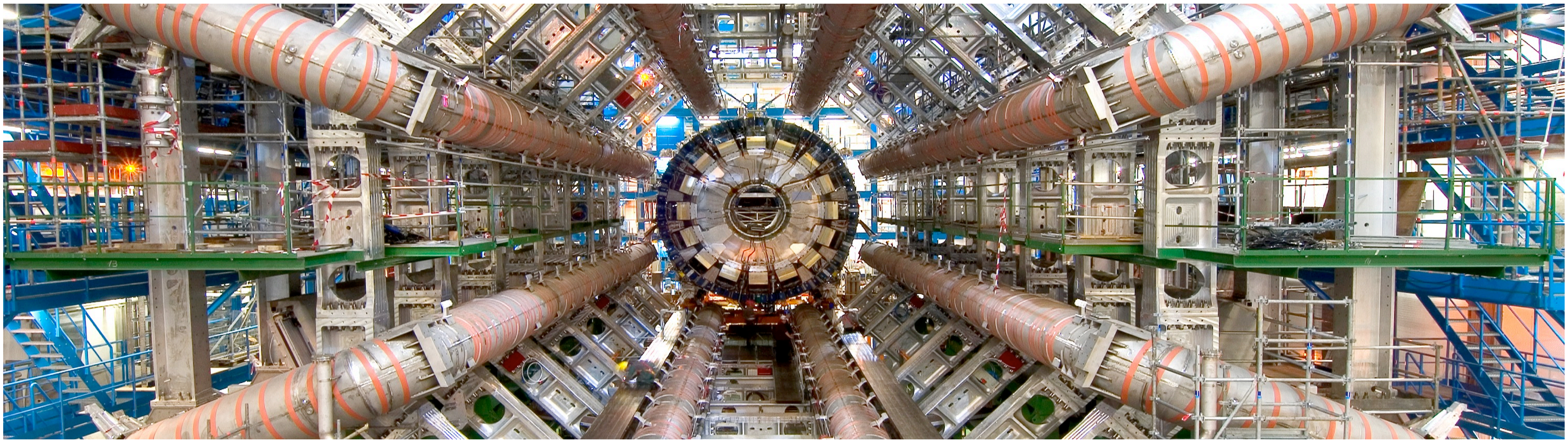

Prospects for Supersymmetry Discovery with the ATLAS Detector at 10 TeV centre-of-mass energy

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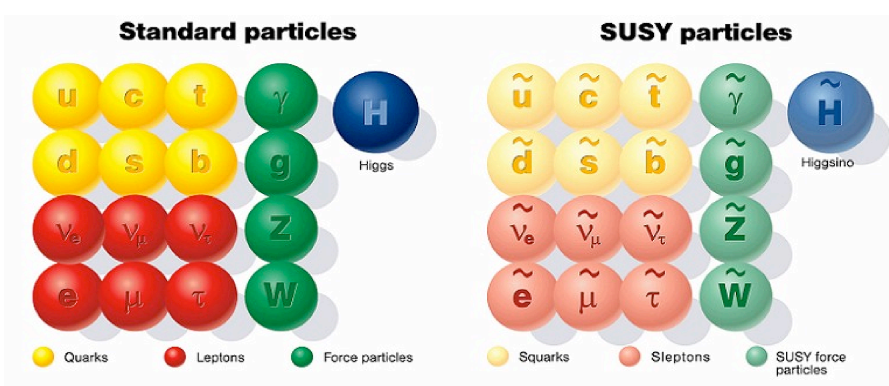
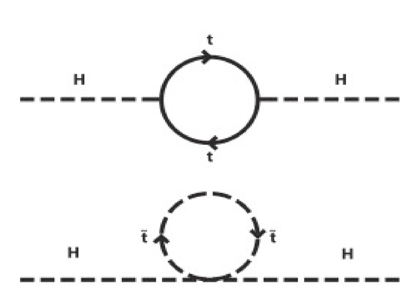
Institutes of Particle Physics

Supersymmetry:

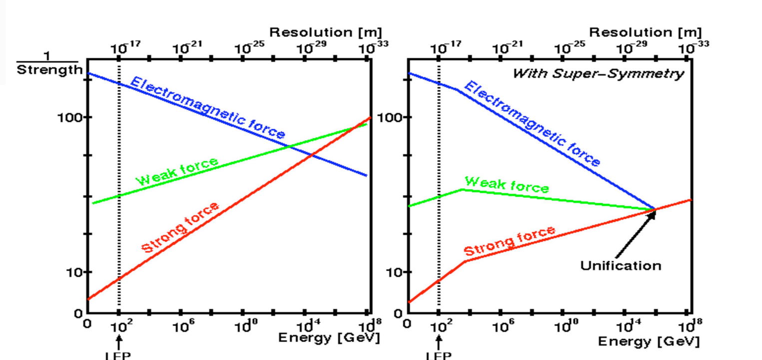
Supersymmetry (SUSY) is a proposed symmetry of nature that relates each elementary particle of a given spin to another of a spin differing by a half unit. That is, in a supersymmetric theory, for every boson there is a corresponding fermion and vice-versa. In order to incorporate supersymmetry into the Standard Model, we require the existence of a supersymmetric particle, coined a 'sparticle', for every Standard Model particle, this is shown on the right.



There are many theoretical thorns in the Standard Model that supersymmetry may solve. The first attempt to incorporate supersymmetry into the Standard Model was done in order to solve the Heirarchy Problem. This is the problem of why the Higgs boson is so much lighter than the Planck mass. One would expect the Higgs mass to be on the order of the scale at which new physics appears - expected to be the Planck scale - due to quadratically diverging radiative corrections. In the Standard Model, keeping the Higgs mass light requires incredible fine-tuning in order to get cancellation of the diverging radiative corrections. This is avoided by having automatic cancellations between fermionic and bosonic Higgs interactions rendered possible by supersymmetry. This is shown below, where the quadratic mass renormalisation due to the fermionic top quark loop is cancelled by the corresponding scalar stop squark loop diagram in the supersymmetric Standard Model.



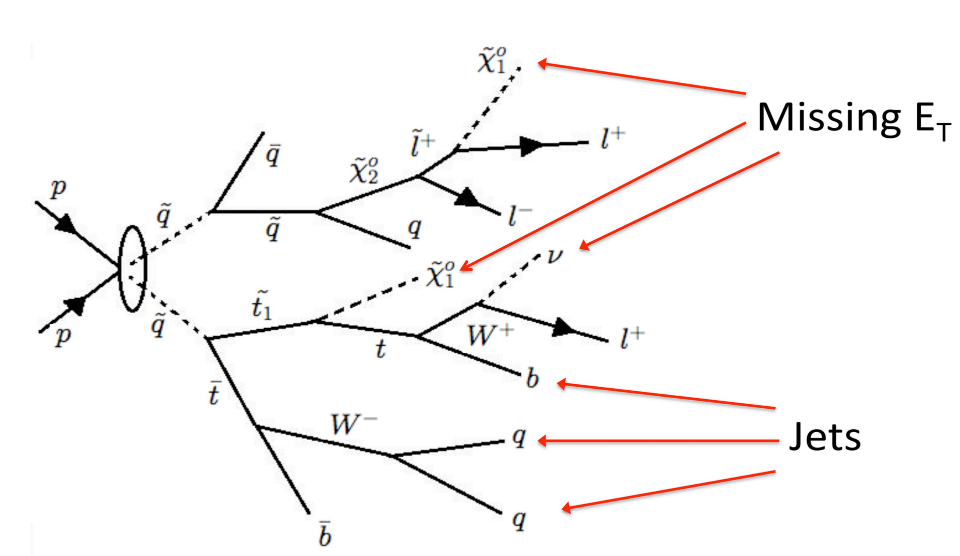
Supersymmetry also makes other nice predictions, of which, the unification of the forces of Nature is possible. Since supersymmetry changes the extrapolation of the coupling constants of the forces, with supersymmetry we are able to get unification of these couplings at high energy, as shown in below.



Finally, supersymmetry proposes a natural dark matter candidate particle. In order to have conservation of baryonic and leptonic quantum numbers, a new multiplicative quantum number must be introduced called R-parity. R-parity is 1 for particles and -1 for the supersymmetric partners. Models in which R-parity is violated can be formulated, but we will focus on R-parity conserving supersymmetric models. The consequences of R-parity conservation are that sparticles must be created in pairs, and that each will decay to the lightest supersymmetric particle (LSP) which must be stable. If the LSP were weakly interacting we would have a natural dark matter candidate.

SUSY and the ATLAS detector:

Assuming that the stable LSPs are weakly interacting, we expect them to pass undetected through the ATLAS detector. Thus we expect a characteristic feature of SUSY events: an imbalance in the transverse energy measured in the detector, which we will denote $\not{E}_T$ and refer to as the missing transverse energy. We also generally expect many jets and leptons with high transverse momentum, denoted P_T. A typical SUSY decay, producing large $\not{E}_T$ and a high multiplicity of high P_T jets and leptons, is shown below. Since there are many supersymmetry models, with many parameters, we must make our searches as model independent as possible. Thus, in searching for generic R-parity conserving SUSY signatures, we simply look for an excess of events in various search channels. In this study we used channels with (2, 3, 4) jets, (0, 1, 2) leptons and having high $\not{E}_T$. We assume an LHC centre-of-mass energy of 10 TeV and an Integrated luminosity of 200 pb^{-1}. The analysis that we employed was model independent, but we used a SUSY Monte Carlo dataset from the SU4 point in the mSUGRA parameter space. mSUGRA (minimal super gravity) is a class of models in which SUSY breaking is mediated by the gravitational interaction. The important aspect, at this level, of the mSUGRA models is that they have high predictive power since they require only four input parameters and a sign.



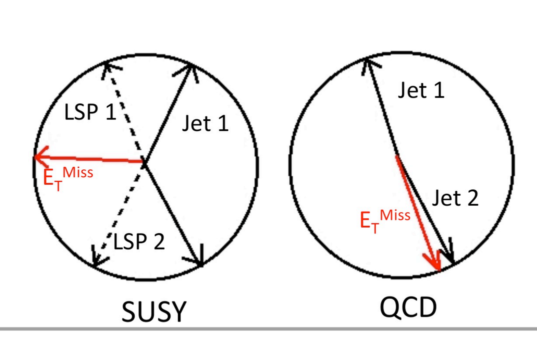
Analysis:

- Data
  - We analysed on the order of 10 TBs of Monte Carlo simulated data. Acquisition and first manipulation of this data was done on the Grid. Subsequent manipulation and analysis was done locally using the ROOT framework.
- Object Identification
  - Jets are reconstructed in a cone with an angular size of 0.4 in (η , ϕ), and are required to have a P_T > 20 GeV and | η | < 2.5 to ensure proper jet calibration.
  - Electrons must pass the "medium" purity cuts, which include E_T dependent isolation criteria. They must also have P_T > 10 GeV and | η | < 2.5.
  - Muons are reconstructed by matching the track reconstructed in the muon spectrometer with its corresponding inner detector track. To ensure the muons selected are isolated, it is required that the total energy in the calorimeter within a cone of ΔR < 0.2 is less than 10 GeV. We further require that the standard acceptance cuts of P_T > 10 GeV and | η | < 2.5 are passed.
  - Overlap removal and electron crack veto.
- Event Selection
  - Effective Mass: $M_{eff} = \sum_{i=1}^{N_{jets}} {}^{jet}P_T^i + \sum_{i=1}^{N_{leps}} {}^{lep}P_T^i + \not{E}_T$
  - Transverse Mass: $M_T = \sqrt{2\,{}^{lep}P_T\,\not{E}_T\,(1 - \cos\Delta\phi)}$
  - Transverse Sphericity: $S_T = \frac{2\,\lambda_2}{\lambda_1 + \lambda_2}$
    - Where λ_1 and λ_2 are the eigenvalues of the 2x2 sphericity tensor $S_{ij} = \sum_k p_{ki}p^{kj}$.
  - Cuts: Each channel must pass one of the below jet columns

Number of jets	≥ 2 jets	≥ 3 jets	≥ 4 jets
Leading jet P_T (GeV)	>180	>100	>100
Jet P_T (GeV)	>50 (jet 2)	>40 (jet 2-3)	>40 (jet 2-4)
$\not{E}_T > \max(80\text{ GeV},\ f \cdot M_{eff})$	$f = 0.3$	$f = 0.25$	$f = 0.2$
$\Delta(jet_i, \not{E}_T)$	> 0.2 for the defining jets in the channel		
S_T	> 0.2		

  - Zero-lepton channels: No leptons with P_T > 20 GeV
  - One-lepton channels: One lepton with P_T > 20 GeV and no others with P_T > 10 GeV, and M_T > 100 GeV
  - Two-lepton channels: Two leptons with P_T > 10 GeV with opposite charge.

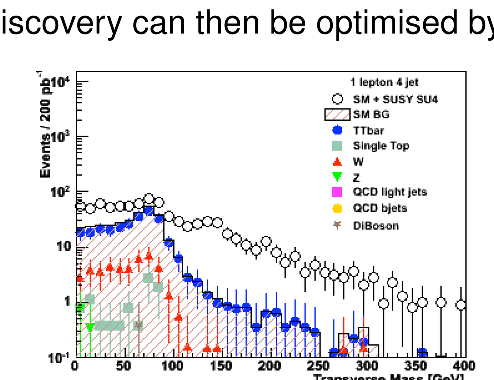
Why S_T and $\Delta\phi(jet_i, \not{E}_T)$ cuts?

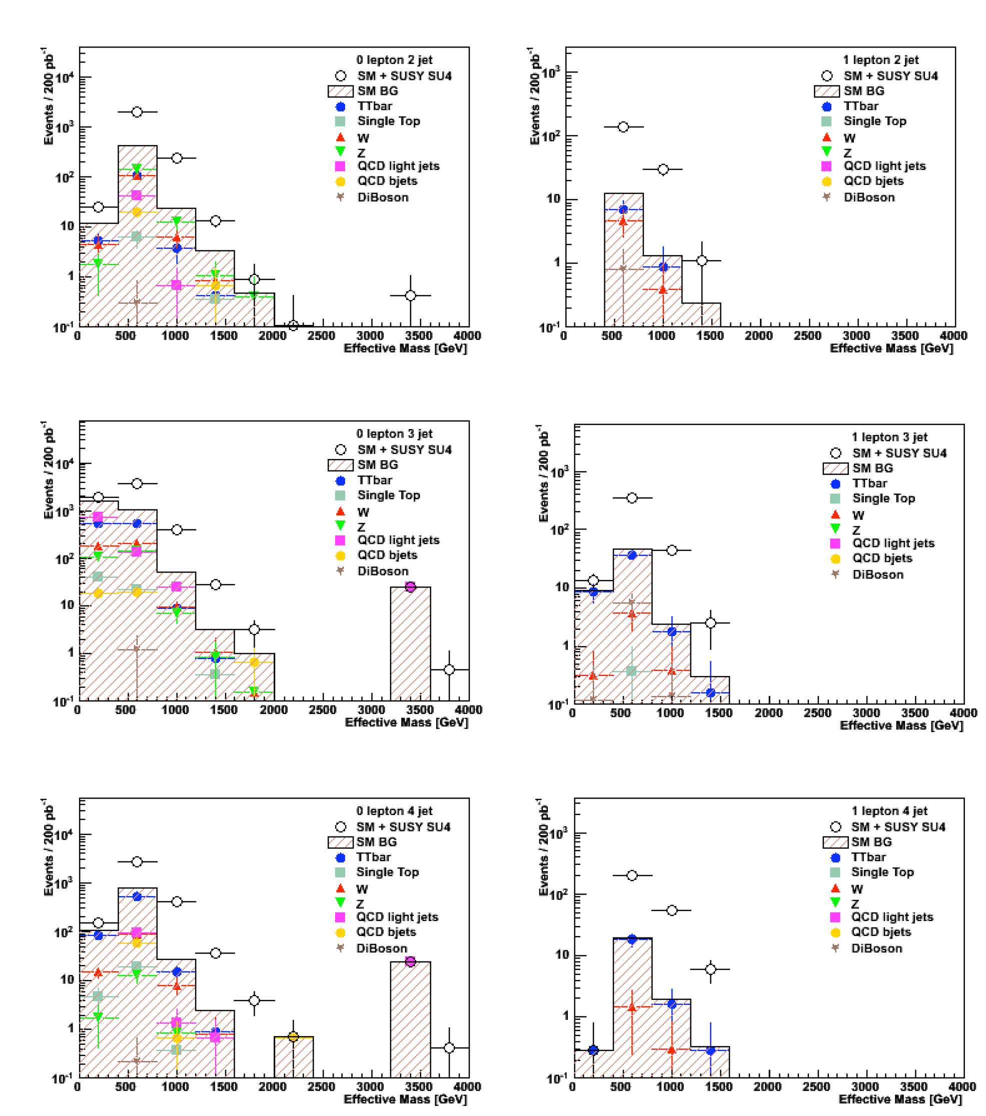


Results:

To perform the SUSY search in a model independent fashion, the effective mass distribution is used to find deviations between the Standard Model plus the Signal and the expected Standard Model background. The significance of a discovery can then be optimised by varying the M_{eff} > X GeV cut.

Plots of the effective mass are shown for the zero and one-lepton channels on the far right and a plot of the transverse mass for the one-lepton-four-jets channel is shown on the near right.





Conclusions:

The background composition and SUSY SU4 signal have been investigated for channels with 0, 1 and 2 opposite signed leptons and 2, 3 and 4 jets for an LHC running scenario of 10 TeV centre-of-mass energy and an integrated luminosity of 200 pb^{-1}. The results of this analysis show that in many channels the signal lies an order of magnitude above the background, but to quantify this in terms of discovery potential, we would need to compute the significance of the measurements presented in this study. This is the natural following step, and given that the framework has been laid it would be a smooth step to make.