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# Supersymmetry

## $4^{th}$ Year Project Outline

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# 1 Introduction

In present day elementary particle resarch the Standard Model (SM) is extremely successful in explaining a wide range of phenomena. However it has many shortcommings and supersymmetry is a possible solution for the difficulties encountered in the SM. In this project a search will be made for possible supersymmetric particles in the ZEUS data taken at the HERA (Hadron Electron Ring Accerator) $e^{\pm}$ p collider at DESY in Hamburg Germany.

# 2 The Standard Model

The matter states in the standard model are three generations of lepton and quark states, all being fermion particles. These are shown below,

$$\begin{pmatrix} \nu_e \\ \mathrm{e} \end{pmatrix} \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix} \textit{and}$$
$$\begin{pmatrix} \mathrm{u} \\ \mathrm{d} \end{pmatrix} \begin{pmatrix} \mathrm{c} \\ \mathrm{s} \end{pmatrix} \begin{pmatrix} \mathrm{t} \\ \mathrm{b} \end{pmatrix}.$$

Interactions are mediated by boson particles, the photon and the massive intermediate bosons of the electroweak interaction and the massless gluons of the strong interactions.

The outstanding questions posed by the SM are:-

- Why are there three generations of matter states?
- Can the electroweak and strong force be regarded as different manifestations of an underlying force? It appears that the coupling constants of these interactions evolve so that they might have a common value at $10^{16}$ Gev.
- Can the lepton and quark matter states be represented by a common multiplet of particle staes?
- What is the origin of mass? If it is the Higgs mechanism, how can the mass of the Higgs be prevented from evolving to the Planck mass which would be expexted by radiative effects in the SM. This is known as the hierarchy problem.

# 3 Supersymmetry

Supersymmetry postulates that every fermion has a boson superpartner and vice versa; clearly then this symmetry if true, must be badly broken. Boson partners of the electron have not been observed and such a partner must be therefore very massive. However supersymmetry would explain why the coupling constants evolve to a common value at $10^{16}$ Gev, which appears to be the case rather than $10^{15}$ Gev. For similar reasons the hierarchy problem involving the Higgs particle is also solved.

# 4 Search for Supersymmetric Particles at HERA

If a quantity called R-parity is conserved then supersymmetric particles would be produced in pairs. However there is no complelling reason that this should be so, and supersymmetric particles could be produced at an $e^{\pm}$ p collider. Supersymmetric quarks can be produced resonantly in $e^{+}$ p collisions provided the centre of mass energy of the $e^{+}$ quark system is larger than the mass of the squark (the superpartner of the quark). The squark can decay into the same $e^{+}$ quark state yielding a distinctive final state where the outgoing electron or positron can go into kinematic regions quite different from normal $e^{+}$ p interaction events. Furthermore if the electron is one of the final state particles, it would be very distinctive from the normal $e^{+}$ p deep inelastic events. Other squark decay modes are three body modes including either electrons, positrons or neutrinos in the final state. There are also distinctive in their different ways and it is possible to make experimental cuts to reduce the background from ordinary deep inelastic events.

# 5 Tasks Necessary To Carry Out The Search

It will be necessary to survey the current limits of supersymmetric particle searches at HERA, $e^{+}e^{-}$ and $p\overline{p}$ colliders. In the simplest models of supersymmetry there are parameters required by the model. Searches place restrictions on the possible values of these parameters and we wish to select a range of parameters which are not yet excluded, as well as searching in the region perhaps already excluded.

Having choosen a set of parameters and particular supersymmetric particle production and subsequent decay, the process has to be generated in a Monte Carlo (MC) program. It is planned to use SUSYGEN for this. It is then necessary to input these events into a program that simulates the response of the detector. It is planned to use GEANT for this and to put this through the FUNNEL chain at DESY.

Next an analysis program has to be written to select the sought after events with as high an efficiency as possible. Such a program must exploit the particlar kinematic properties of the events. So as to select the signal and reject the background.

The ordinary data events must be generated and their response in the detector determined. These events must be analysed using the same program as for the signal to determine the expected background for the signal sought.

Finally the experimental data must be analysed in the same way to see if it agrees with background expectation, or to determine if a signal is found.