# Probing 23\% of the Universe at the Large Hadron Collider <br>  <br> <br> Will Flanagan ${ }^{1}$ <br> <br> Will Flanagan ${ }^{1}$ Advisor: Dr Teruki Kamon² Advisor: Dr Teruki Kamon² <br> <br> Cyclotron Institute <br> <br> Cyclotron Institute Texas A\&M University 

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## Introduction

With recent astronomical measurements, we know that $23 \%$ of the Universe is composed of dark matter, whose origin is unknown. Supersymmetry (SUSY), a leading theory in particle physics, provides us with a cold dark matter candidate, the lightest supersymmetric particle (LSP). SUSY particles, including the LSP, can be created at the Large Hadron Collider (LHC) at CERN. We perform a systematic study to characterize the SUSY signals in the "focus point" region, one of a few cosmologically-allowed parameter regions in our SUSY
 model. We also present a methodology for extracting the dark matter signals at the LHC, and show the accuracy to which we can measure the dark matter relic density and the SUSY parameters.

The 'focus point' is one of the few regions in the mSUGRA parameter space that is consistent with both cosmological constraints and particle physics observations. This region got its name from another parameter, $\mu$, being 'focused to a small value'. The LSP (dark matter candidate) of focus point is the neutralino-1, $\widetilde{\chi}_{1}^{0}$ a combination of the photino, bino and higgsino fermions. One particularly interesting trait of having a small $\mu$ in focus point is that the $\bar{\chi}_{1}^{0}$ has a very large higgsino component. This causes $\vec{\chi}_{1}^{0}$ to couple more strongly to heavier particles, favoring the top quark in hadronic decays to the $\widetilde{\chi}_{\mathbf{2}}^{0}$


## What is cosmologically significant about 'focus

 point'?The $\tilde{\chi}_{1}^{0}$ is allowed to annihilate with itself since it is its own antimatter particle. The $\bar{\chi}_{1^{-}}^{0} \bar{\chi}_{1}^{0}$ annihilation cross section is typically too small (predicting a relic
 allows for a larger annihilation $\underbrace{\Omega_{\hat{z}_{i}^{\prime}}}_{0.23} h^{2} \sim \int_{0}^{x_{f}} \frac{1}{\left\langle\sigma_{\text {ann }} \nu\right\rangle} d x$ cross section for our dark matter candidate by opening up the ' $Z$ channel' (pictured $\underbrace{\left\langle\sigma_{\mathrm{am}} v\right\rangle}_{0.9 \mathrm{pb}}=\frac{\pi \alpha^{2}}{8 M^{2}}$ above).

## Methodology

We first perform a monte-carlo event simulation using a program called ISAJET. This program calculates the outcomes of p-p collisions at LHC energies. We then put this data through a detector level simulation, PGS4, to account for observational errors such as track smearing. This data is then analyzed in ROOT in order to hunt for observational signatures that can allow us to predict our input parameters. Finally we determine a method of solving for our input parameters and use this information to predict the dark matter relic density of our SUSY


## Analysis

We first decide which events we want to look for Since $\bar{\chi}_{\mathbf{1}}^{\mathbf{0}}$ is undetectable (otherwise it wouldn't be 'dark $\begin{array}{ll}\text { Red - Jet distribution } & \text { matter'!), we look for events with a } \\ \text { large amount of missing transverse } \\ \text { energy. Also, due to the nature of }\end{array}$ require two energetic jets.
 the invariant dilepton mass of $\widetilde{\chi}_{2,3}^{0}>\bar{\chi}_{1}^{0}$ decays to probe the mass differences of the $\bar{\chi}_{1}^{0}$ to the $\bar{\chi}_{2}^{0}$ and the $\bar{\chi}_{3}^{0}$.


## Current/Future Work

We are working on how-we can disect the gluiño mass from cbservables. We will then use these values: to calculate our mSUGRA paranteters and the dark matter relic density In the mean time we are testing the efficiencies: of:oür generation còdes and analyzing ourr cuts for data-ahà sis at the CMS. To be continued! Many thanks to the Cyclotron REU and TAMU HEP

