Searching for a Dark Matter Candidate at the Fermilab Tevatron

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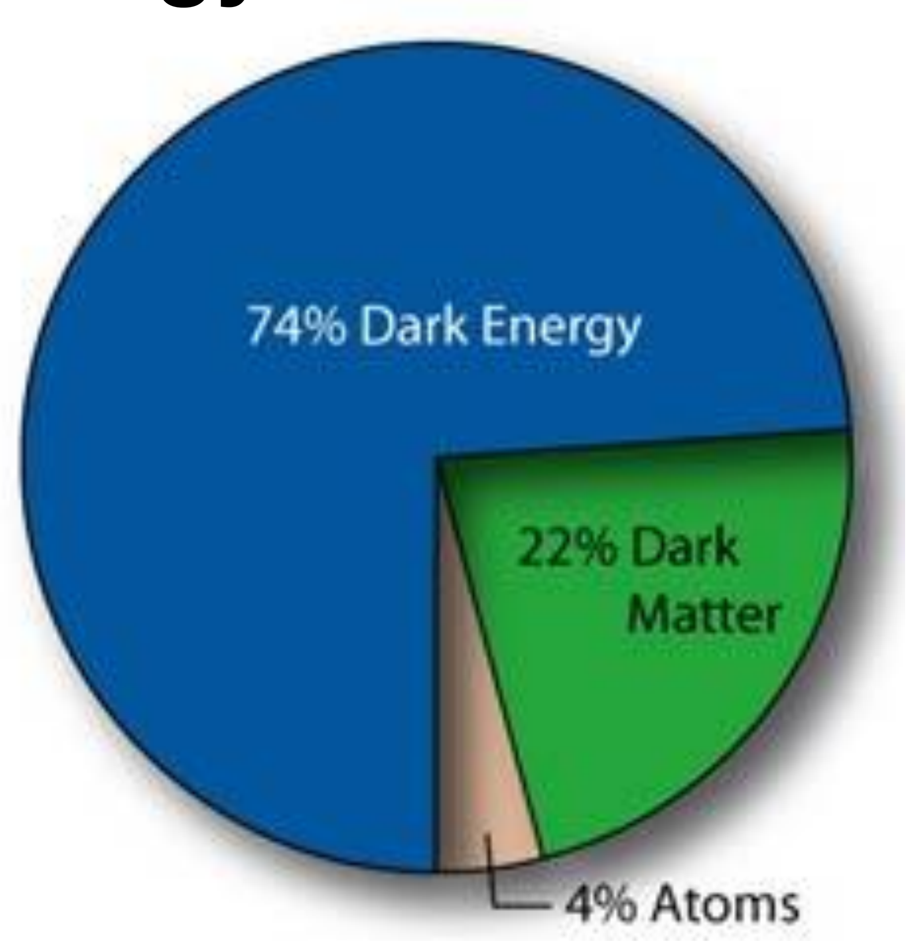
Objective: Astronomical observations have shown that the amount of visible matter in the universe comprises only a fraction of the total mass of the current universe. This extra mass is described as "dark matter". Different physical theories have been proposed that account for this dark matter with new predicted particles. I present a search for the neutralino ($\tilde{\chi}_1^0$), a predicted particle that decays into a dark matter candidate, the gravitino ($\tilde{G}$).

Method: We analyze data from particle collisions at the Fermilab Tevatron collider in Chicago to search for the undiscovered neutralino. If produced in a collision, the neutralino might decay into a gravitino and a photon (γ) inside the detector. Our search focuses on the distinctive signature such a decay would produce in the detector.

Energy in the Universe



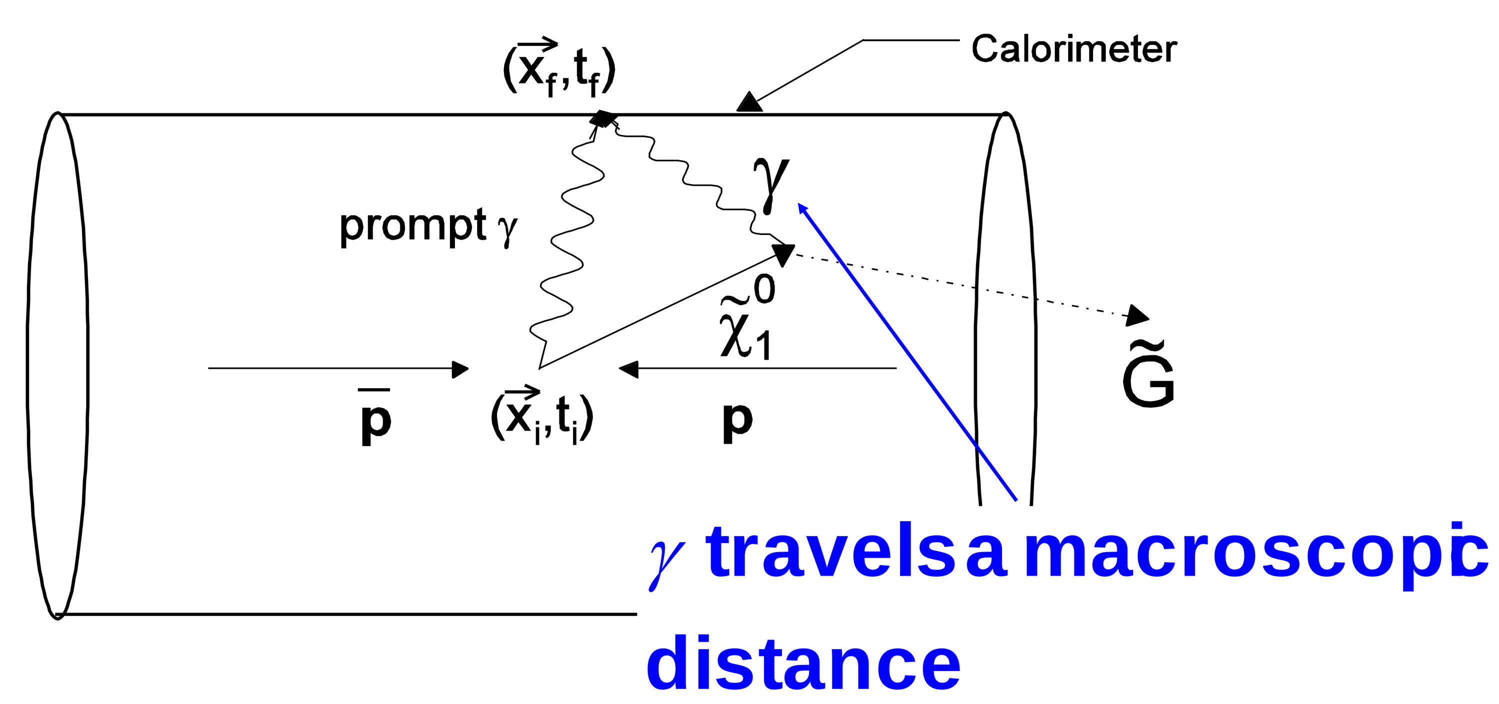
Dark Matter:

We are interested in dark matter, which we know to reasonable accuracy is 22% of the energy of the universe, much more than the known particles. The existence of this huge amount of unseen mass was first hinted at when the rotational velocities of galaxies differed wildly from predictions. Dark matter gets its name from the fact that it does not interact electromagnetically and hence emits no light.

Supersymmetry:

Supersymmetry is a theory of particle physics that predicts many new particles. Among these new predicted particles may be the dark matter. Due to conservation principles, the lightest supersymmetric particle might be stable and therefore a viable dark matter candidate. For this analysis, we use a gauge-mediated supersymmetry breaking (GMSB) model. This model predicts a gravitino as its lightest supersymmetric particle, which is our dark matter candidate.

A Neutralino Decay inside the Detector



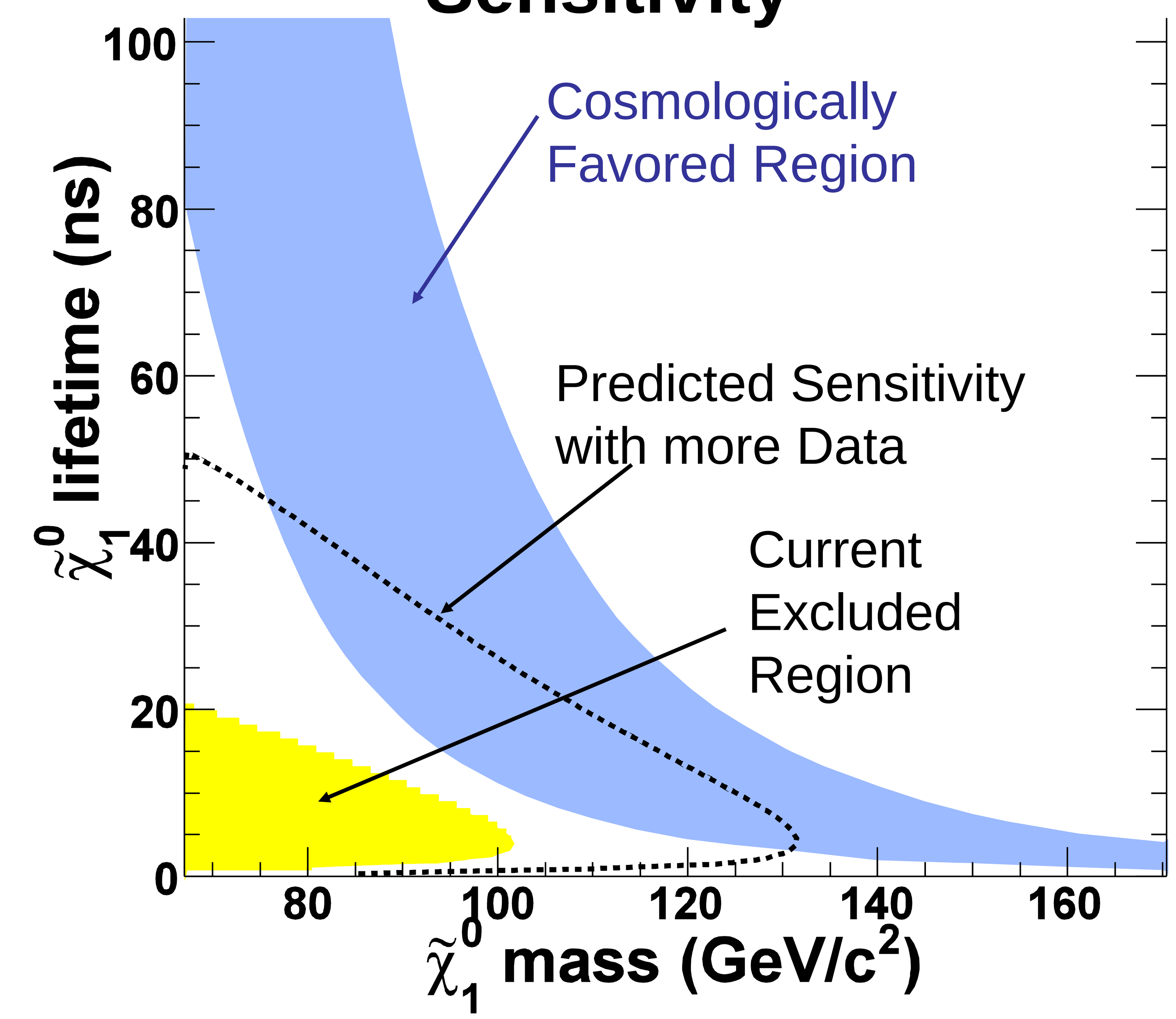
Searching for Neutralinos in particle collisions:

Neutralinos with a lifetime on the order of nanoseconds, as is very likely in our model, could travel a macroscopic distance within the detector but decay before leaving. A neutralino decays to a photon and a gravitino, our dark matter candidate. The photon is readily detected with great precision. However, the gravitino will not interact with the detector and hence escape undetected as shown in the above figure. This will result in an imbalance of energy measured by the detector, called "missing energy". As shown in the figure above, the path length from the collision point to the detector for the neutralino decay photon is greater than that of a photon produced directly by the collision. This increased path length causes the neutralino photon to arrive at the detector significantly later than expected, i.e. "delayed". Our search focuses on finding events with delayed photons and a large missing energy signature.

Improvements:

An analysis searching for these neutralinos has already been completed (Phys. Rev. Lett. **99** 121801 (2007)) with no discovery. I am working to improve and update this previous analysis. One goal is to simplify the way the location of the collision that produced the γ is determined. Additionally I am implementing an algorithm that will determine if the missing energy in an event is just from poor detector measurements or real physics. Most importantly, the amount of available data has increased by more than a factor of 4 since the original analysis!

Neutralino Mass/Lifetime Sensitivity



Results/Predictions:

In the figure above, the current neutralino excluded region is shown in yellow while the innermost dotted black line shows the predicted sensitivity with the additional data. This sensitivity should increase with other improvements to the search. The blue shaded area represents the region that is favored based on astronomical observations. As you can see, the improved analysis will have considerable sensitivity in this region.