

SEARCH FOR HEAVY, LONG-LIVED NEUTRAL PARTICLES THAT DECAY TO PHOTONS AT CDF II



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OUTLINE

What are we looking for?

- **Particles and Supersymmetry**
- **Photons from Heavy Neutral Particles**

How are we looking for it?

- **Fermilab/CDF and the Timing System**

The search and published results

- **Background and Possible Signal Timing Distributions**

How sensitive are we to new physics in this analysis?

- **Acceptance and Sensitivity**
- **Significance and Limits**

Conclusions

Particles and Supersymmetry

- Particles are the basic constituents of matter.
- Standard Model (S.M.) - Left Side

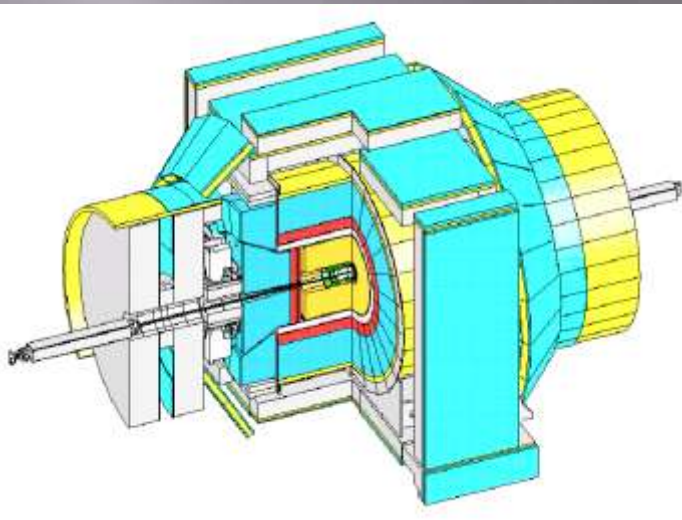


- Together you have a version of the Minimal Supersymmetric Standard Model (M.S.S.M.), though in this graphic not all the Higgs bosons are shown, nor is the gravitino.
- Many versions of the Supersymmetry models exist, and we are focusing on a Gauge Mediated model with the gravitino as the lightest SUSY particle.
- The neutralino, which will be one of our focuses, is one of these Supersymmetric partners to the neutral Standard Model bosons.

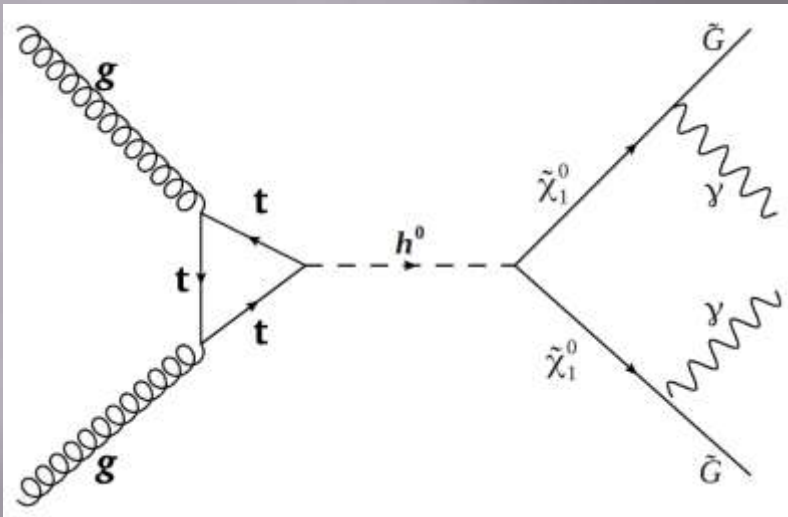
Fermilab, the Tevatron and CDF



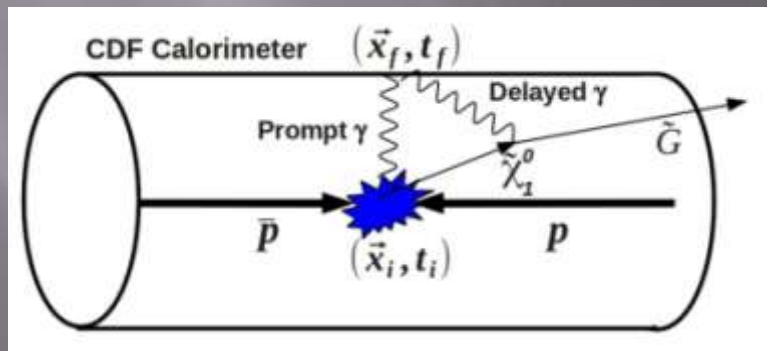
- ▣ The Tevatron is the high energy proton anti-proton collider at Fermi National Accelerator Laboratory, shown is the ring as can be seen from above ground.
- ▣ The CDF detector lies on the ring and can be seen in a mock up cross section below.
- ▣ High energy collisions can produce new particles that can decay to photons.
- ▣ The detector measures the arrival times of high energy photons.



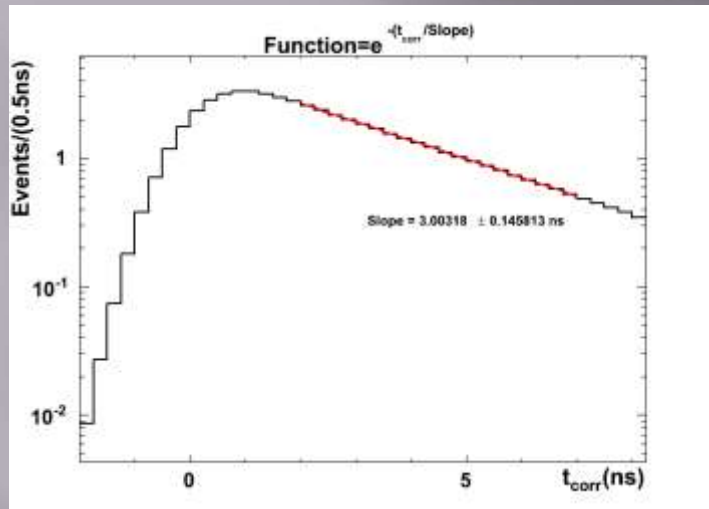
GMSB/Higgs Decay Processes



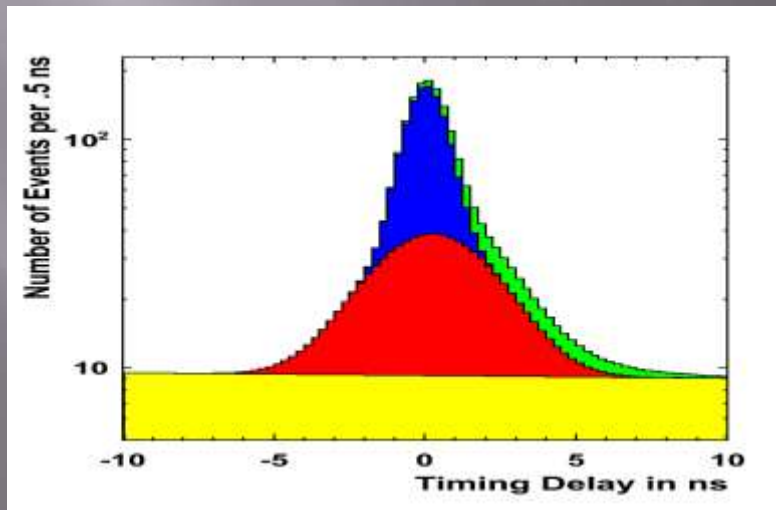
- This production and decay process from a GMSB model is for a neutral scalar, such as the Higgs, that decays through a pair of neutralinos of photons.
- The final state is a pair of photons, which we can detect, along with gravitinos which are pass show only as missing energy in the collision.
- If the lifetime of the SUSY particles, in this case the neutralinos, is sufficiently large, then the photons will arrive with a “delayed” time and the detector can measure this with a nanosecond timing resolution.



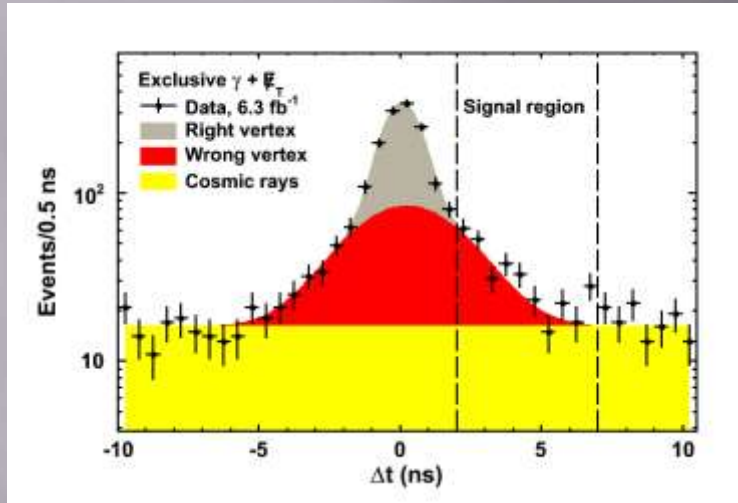
Timing Distributions



- Shown is one possible shape for the signal timing distribution. In this case a slope chosen to be 3 nanoseconds.
- The slope term is not determined experimentally but is a property of the mass and lifetime choices of the neutralino.
- Below is a mock up of what an example signal (green) would look like on top of the expected background distributions.



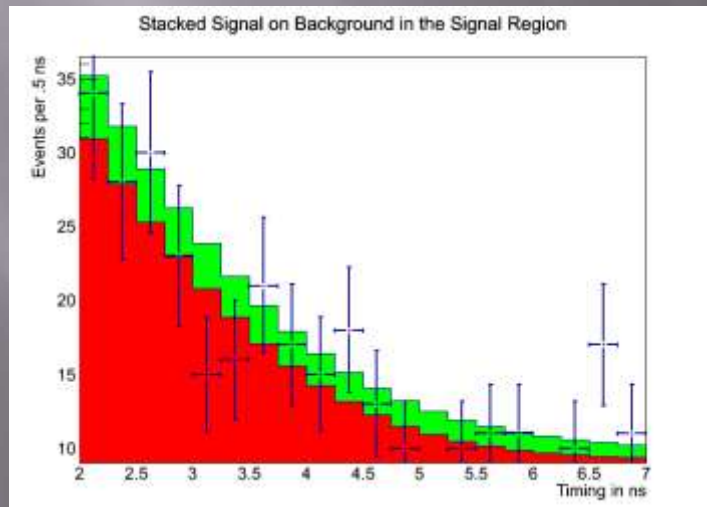
Resultant Distributions



[CDF Phys. Rev. D 88, 031103\(R\) 2013](#)

- Above is the published plot of the data form CDF. There looks to be an excess events here in the data, for which we then focused on finding the significance.

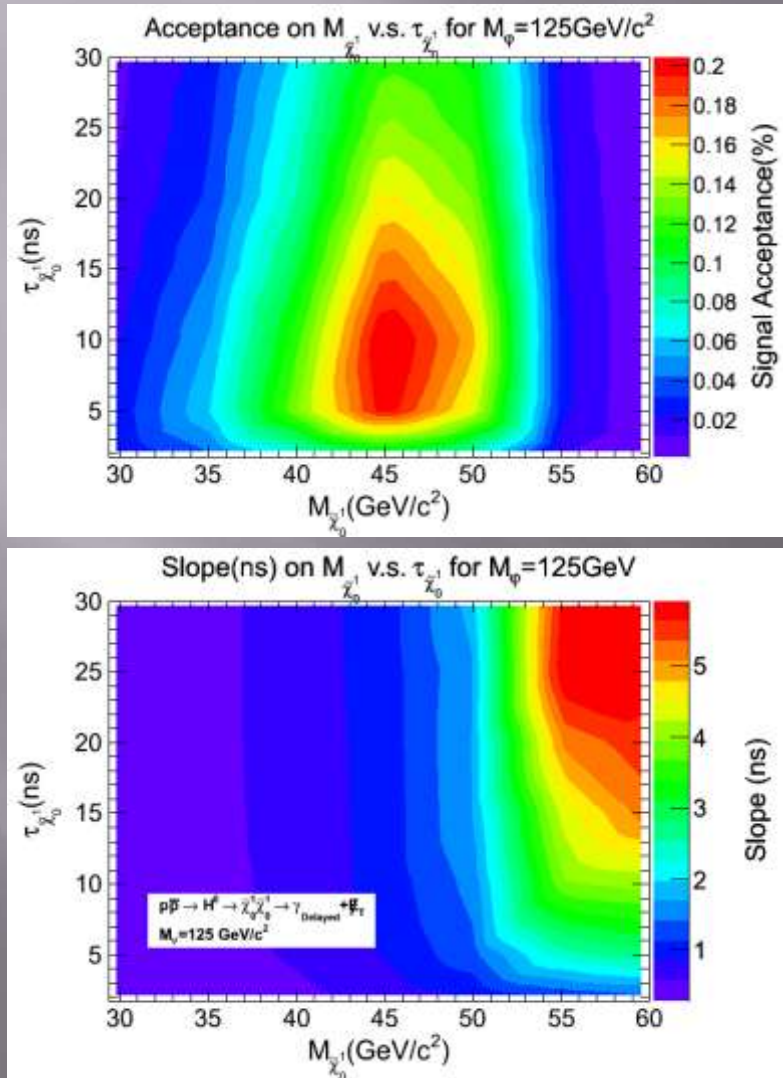
- Though the “excess” wasn’t statistically significant, there is still information here to interpret. The interpretation of this region and setting limits on what signal could be observed in this region became the focus of our analysis.



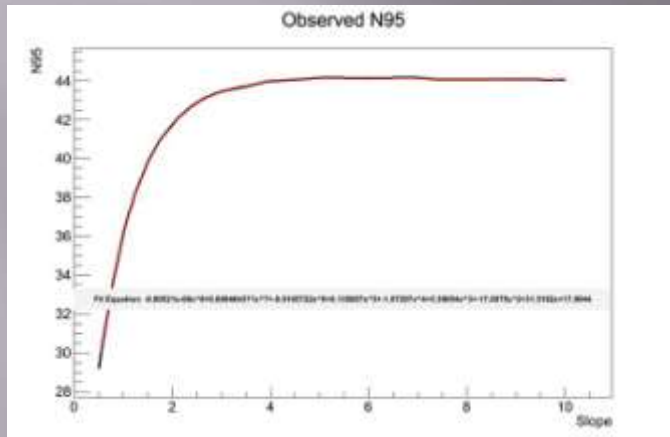
- Below is an overlaid plot of the signal (green) on top of the background (red) with the published Data in blue, taken as the points out of the above plot.
- The amount of signal shown matches a chosen shape and the level of signal excluded by the limit process, which will be shown from our analysis of these previous results.

Acceptance and Sensitivity

- Paired values of mass of the chi and lifetime (tau) will have predicted properties due to the theory behind the decay process. These were published in a phenomenology paper earlier this year.
- For each value there is a given acceptance, which is the percentage of events of this type that we would see.
- Also a slope is predicted for each value pair, which would correspond the shape of timing distribution it would produce.

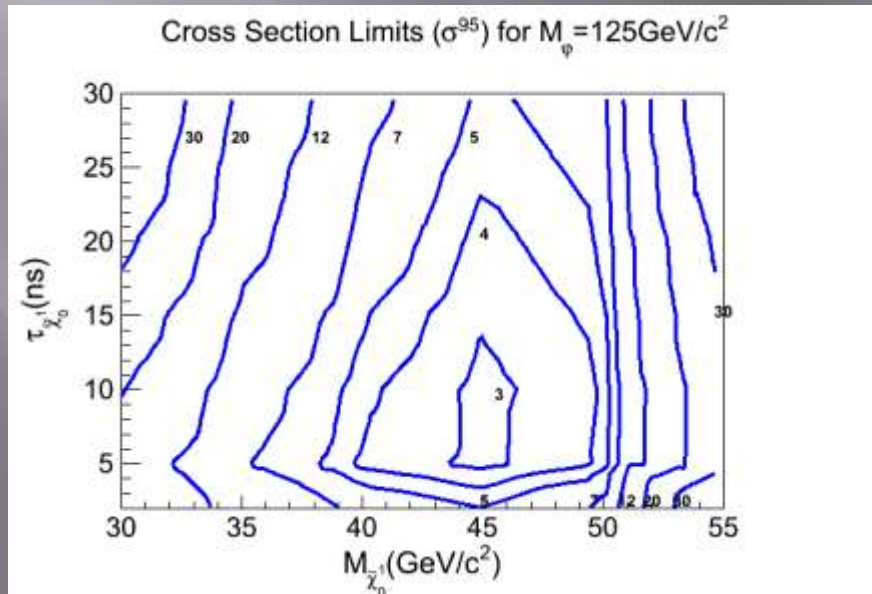


Significance and Limits



- Running the distributions through a limit calculating program, we could analyze the significance of the previous data in the signal region.

- Here we set limits on the number of signal events excluded at each possible signal shape (shown as the Observe N95).



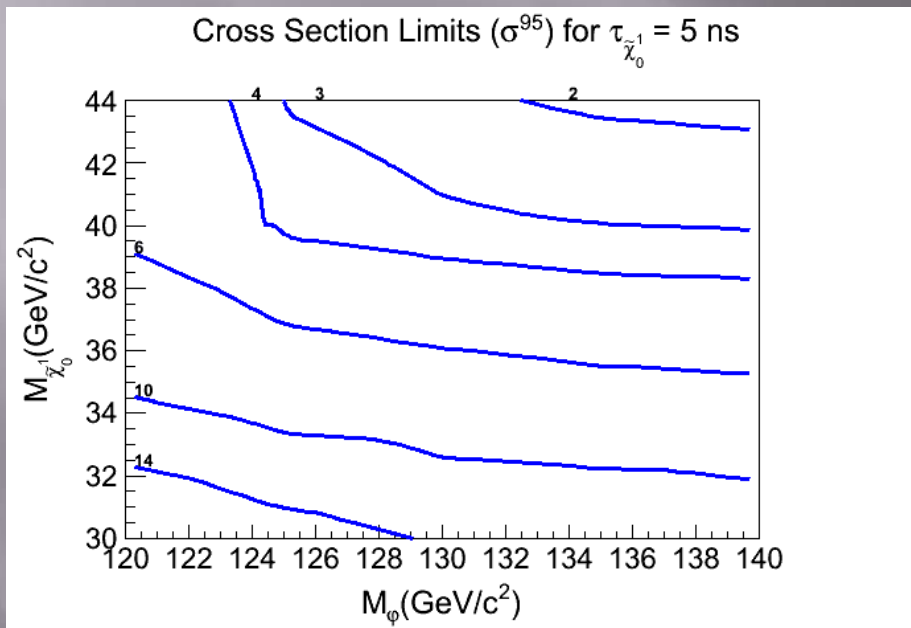
- One could take these limits and with the known values of acceptance and signal slope, create a limit for the probability of this decay for each pair of mass and lifetime of the neutralino.
- These limits are a measure of probability using a standard unit in particle physics for cross sections, picobarns or pb.

Conclusions

- ▣ The published CDF search for long-lived neutral particles decaying to photons had revealed our sensitivity to new SUSY particles, but it did not set limits.
- ▣ Our analysis has been to reveal the significance behind the results of this search and to set quantitative limits on the probability of these processes using timing distributions.
- ▣ This type of analysis could provide valuable insight on regions of possible values of the neutralinos mass and lifetimes. As well it could be used to see properties of this decay in other possible masses of a neutral scalar, such as heavier Higgs bosons.
- ▣ Overall these results are the first of its kind and will be included in future papers using the full CDF dataset. A portion of this analysis will also be the focus of my honors thesis within the next year.

Extra Slides

Limits and Other Neutral Scalars



- Here looking at the values that the limits take as the mass of the scalar is changed, one can see the limits improve at higher masses of both the neutralino and the scalar.
- This is important for if there exists a larger mass scalars, such as the other possible Higgs bosons, that could potentially have a larger branching fraction for the decay to the neutralino pair that we could be sensitive to.

SEARCH FOR HEAVY, LONG-LIVED NEUTRAL PARTICLES THAT DECAY TO PHOTONS AT CDF II USING A NANOSECOND PHOTON TIMING SYSTEM

New particles can be produced from the high energy proton anti-proton collisions at the Fermi National Accelerator Laboratory (Fermilab). The products of these collisions, recorded by the Collider Detector at Fermilab (CDF), can be measured for the arrival times of photons produced in the decay of particles created in the interaction. Thus we may be sensitive to the production of new, massive particles that decay in flight to photons. Such particles can be produced in versions of Supersymmetry, and even be produced as the decay of a Higgs boson. Since the photons that may have come from such events will arrive at the surface of the detector later than photons produced directly from the primary collision, they can be separated in time and analyzed for significance with a nanosecond timing resolution. New results will be presented.