Sensitivity to New Particle Production with Photon Timing at CDF

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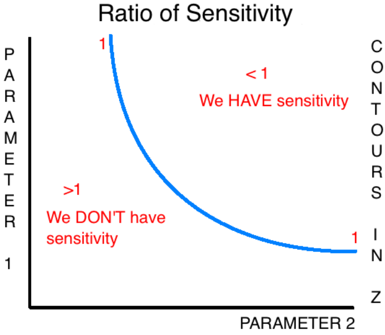
Overview

1. What it means to be sensitive to new particles
2. The signature we are looking for
3. How we model what we are looking for
4. Setting upper limits with this analysis
5. Our acceptances and sensitivity to new particles
6. Results and Conclusions

Are we sensitive to the creation of new particles?

- Question: If new particles were produced in a collision, is our experiment sensitive enough to detect them?
- Define a quantity such that if it's value is less than 1 we are sensitive to the new particle. Greater than 1, we aren't.

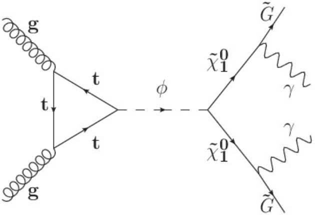
Consider our sensitivity as a function of some parameters, for example, mass and lifetime of the particle. In the example to the right, the plot says we have sensitivity at large mass of the particle and large lifetime of the particle. We don't have sensitivity for low masses or low lifetimes.



(For those of you who know the field, we are comparing the expected cross section limits to the production cross section)

New particle production with the delayed photon signature

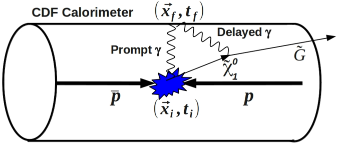
Using the collider at Fermilab we collide protons and anti-protons at very high energies and record the interaction with the Collider Detector at Fermilab (CDF) to see if new particles are produced.



- This is an example of new particle production that we can look for and may have sensitivity to.
- In this diagram a new particle is created which then decays into two other new particles which then decay to photons (the particles of light) as well as particles that leave the detector.

We focus on the neutralinos($\tilde{\chi}_1^0$) and photons(γ).

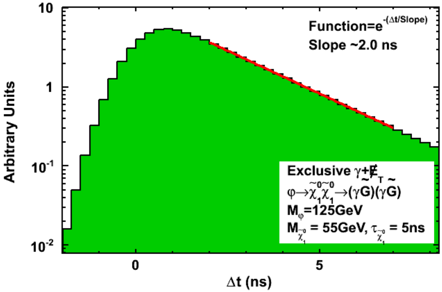
- What is special about the photons from these collisions is that since they are the decay products of a neutralino, they will will arrive 'late' to the detector due to the non-negligable lifetime of the $\tilde{\chi}_1^0$.



Signal Distribution Shape (Slope)

Lets describe the timing of these 'delayed' photons.

These photons from the decay of the neutralinos are what is called the signal.



- The background is when there is no neutralino. In this a photon is produced directly and travels at the speed of light to the detector. We know exactly when it arrives.
- If it was produced from a new particle, then it will arrive later. This amount of 'later' is what we call Δt.

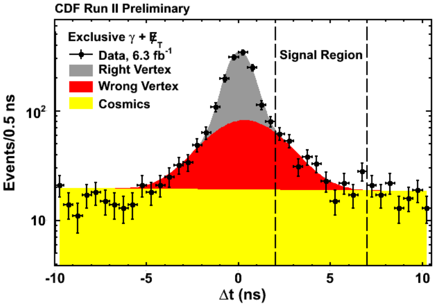
We have a timing system installed in the detector that measures the delay time of the photons with a nanosecond resolution. Therefore the shape of the signal timing distribution is will be very important in analyzing its contribution to the data.

(JHEP09 (2013)041, PRD 70(2004) 114032, and PRD 78 032015/PRL 99 121801)

Timing Distributions and Motivations

Record lots of data with the CDF detector for events with photons and look at the Δt distribution

Question: Does the data appear to be consistent with the backgrounds only or have a component of 'signal' also?



The 3 distinct backgrounds are scaled to match the data in the times below the signal region.

No evidence for new physics.

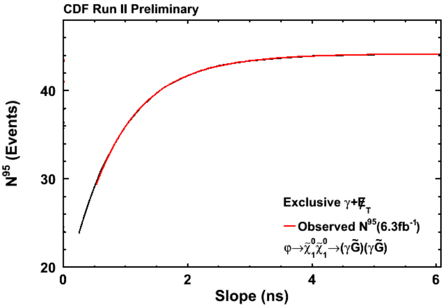
Results published in CDF PRD-RC 88, 031103(R)(2014). No limits set or sensitivity described for new particles.

Goal: Find the sensitivity to new particles that have never been searched for before.

95% Confidence Upper Limits

Questions: How many events of the signal could still be in the data and we wouldn't be able to tell?

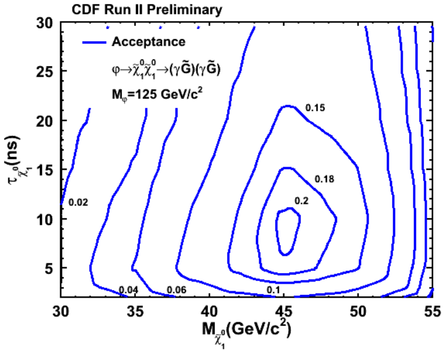
- Use analysis techniques to determine N^{95} (the 95% Confidence Level on the amount of signal that could be hidden... we exclude amounts BIGGER than this with 95% confidence).
- Every combination of the mass and lifetime has a finite slope, and by this, an N^{95}.



"Hard to hide lots of events when the slope is small, easy to hide lots of events when the slope is big"

Acceptances and Cross Sections

- Acceptance is the fraction of the events that our detector would say 'look like new particles,' i.e., we would be able to identify them.
- The acceptances depend on the masses of the particles and their lifetimes. The bigger the acceptance the better.



This was the last piece we needed to arrive at the cross section limit:

$$\sigma = \frac{N^{95}}{L * A}$$

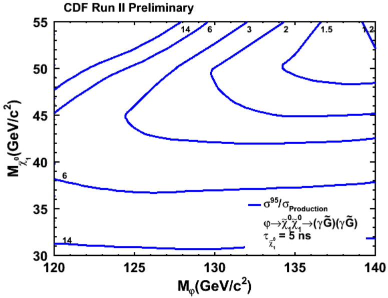
L is the luminosity (amount of data)

Do we have sensitivity to new particle production?

If theory predicts some number of new particles produced (production cross section), would we be sensitive enough to see them?

Back to our definition of sensitivity:

Expected Cross Section Limit divided by Production Cross Section



If this ratio has a value of 1.2, we need to be 20% more sensitive to detect them.

Answer: We see that for some masses and lifetimes we are very close to being sensitivive.

Future: Look at larger masses and lifetimes and perhaps we can find sensitivity below 1!

We are close to results that could exclude the regions for the first time (Areas where we would have detected the new particle production if was occuring).

Conclusions

1. We have used the Collider Detector at Fermilab (CDF) and its photon timing to search the data for evidence of new particles.
2. No evidence for new particles, but we are in the process of setting the first limits of their kind. $(\varphi \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \gamma_{delayed} + MET)$
3. Preliminary results are hopeful and we might have sensitivity at larger masses.
4. Final results and hopefully exclusion regions will be included as the major components of a PRD, a PRL and my own Undgraduate Honors Thesis.