Sensitivity to New Scalar Production awith the $\gamma_{delayed}$ + MET Final State (Update)

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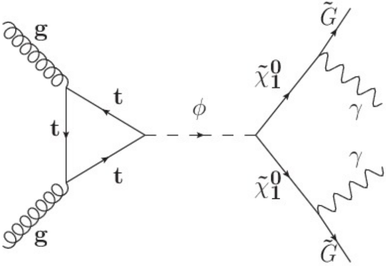
CDF Physics Meeting

Overview

1. Introduction - Theory and Analysis Overview
2. Signal Modelling
3. Setting Limits
   - The slope of the timing distribution as a function of the model parameters
   - N^{95} limits as a function of Slope
   - Acceptances
   - Cross Section Limits
4. Going Farther (This part is new)
5. Conclusions

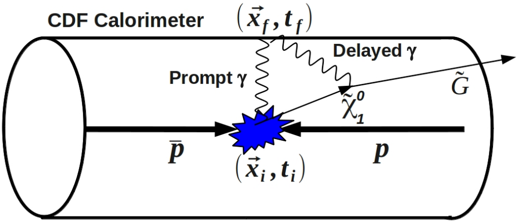
GMSB and Delayed Photons

- In Gauge Mediated SUSY Breaking (GMSB) models the Lightest SUSY Particle (LSP) is the Gravitino ($\tilde{G}$)
- Often the next-to lightest SUSY particle is often the $\tilde{\chi}_1^0$ and can decay to γ and $\tilde{G}$ (MET)
- The $\tilde{\chi}_1^0$ may have a lifetime on the order of a few nanoseconds. In this case, the photon's arrival time at the calorimeter would be delayed relative to expectations $\rightarrow$ Delayed photon ($\gamma_{Delayed}$) PRD 70 114032 (2004)



- In Light Neutralino and Gravitino (LNG) models, all but the LSP and NLSP are inaccessible at colliders. However, new scalar production can produce $\tilde{\chi}_1^0$ pairs with a large production cross section.
  PLB 702, 377(2011)

Delayed Photons and the Timing Signature



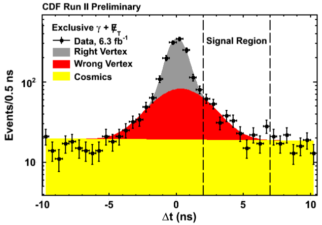
Using a simple time of flight equation, the time associated with the initial interaction(t_i), and the time of arrival at the detector(t_f) we can construct the variable Δt to separate delayed photons from other sources.

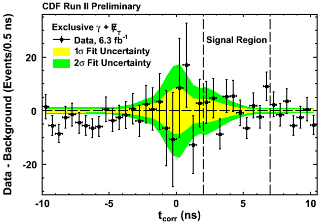
$$\Delta t = (t_{\mathrm{f}} - t_{\mathrm{i}}) - \frac{(|\vec{x}_{\mathrm{f}} - \vec{x}_{\mathrm{i}}|)}{c}$$

N.B.- A promply produced photon with a perfect detector has Δt=0, photons from heavy, long-lived particles have $\Delta t > 0$.

The Exclusive $\gamma + MET$ Final State and the Signal Region

3 distinct backgrounds estimated by data-driven methods (described in detail in CDF Notes 9924, 9171, and 8636)



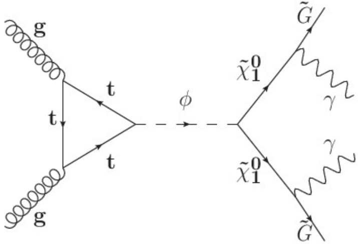


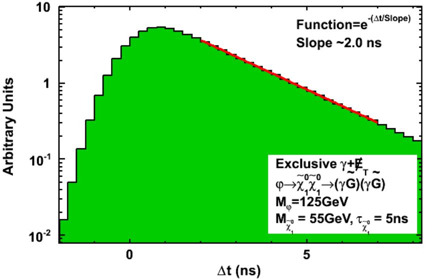
- Right Vertex: Resolution of the detector(0.65ns) and scaled to match the data in the region below the signal region
- Wrong Vertex: Shape has an RMS of 2.0 ns, but with a non-zero mean
- Cosmic rays: Estimated from large time regions
- Model-indepdent result published in PRD 88, 031103(R)(2013) and updated since publication, see talk by Vaikunth Thukral.
- No evidence for new physics.

GMSB Signal Timing Distribution

New scalar production is well modelled using three parameters: M_φ, $M_{\tilde{\chi}_1^0}$, and $\tau_{\tilde{\chi}_1^0}$

- Studies show that the Δt distribution for the signal typically looks like an exponential in the 2-7ns region. (JHEP09 (2013)041, PRD 70(2004) 114032, and PRD 78 032015/PRL 99 121801,)





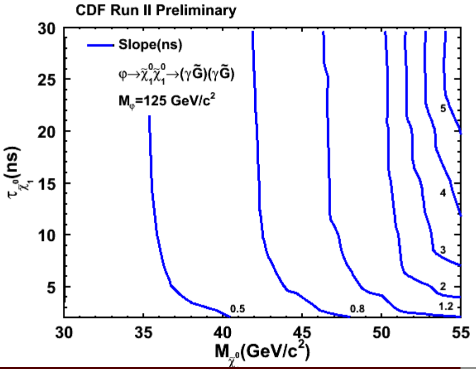
Pick a benchmark point of $M_\varphi = 125\text{GeV}, M_{\tilde{\chi}_1^0} = 55\text{GeV},$ and $\tau_{\tilde{\chi}_1^0} = 5\text{ns}$.
This will be ok for now but we will compare with new results at $M_\varphi = 200\text{GeV}$ (explained later).

N.B.- Results today have signal simulated using Pythia and PGS with the EMTiming modelled with a custom Monte Carlo (CDF 8636, CDF 9171)

Timing distribution as a function of the model parameters: Slope

These next few results are from before and we will show why our new benchmarch will be a significant imporvement.

Studies show it is straight forward to estimate the slope as a function of $M_\varphi, M_{\tilde{\chi}_1^0},$ and $\tau_{\tilde{\chi}_1^0}$ produces a finite slope:

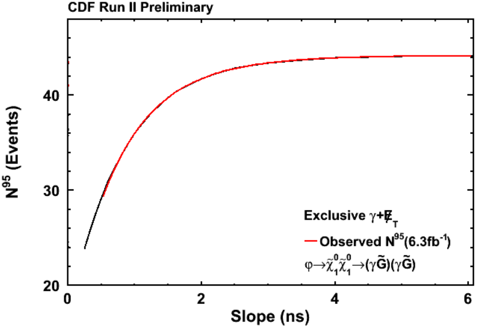


- Contour of constant slope for $M_\varphi = 125$ GeV
- Similar results for other φ masses
- Slope goes up as $M_{\tilde{\chi}_1^0}$ approaches $\dfrac{M_\varphi}{2}$

Results: N^{95} Limit verses Slope

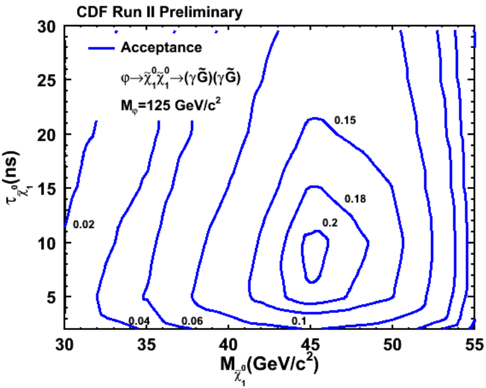
- Since each M_φ, $M_{\tilde{\chi}_1^0}$, and $\tau_{\tilde{\chi}_1^0}$ gives a known slope value, can set N^{95} vs. Slope
- Again the Cross Section Limit σ will be:

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



For simplicity agian we have used 6% uncertainty on L and 20% on the acceptance (see PRD(CDF 9171)/PRL(CDF 8636)). But even with these assumptions we see that the limits have been improved drastically. More on the acceptance next.

Acceptances

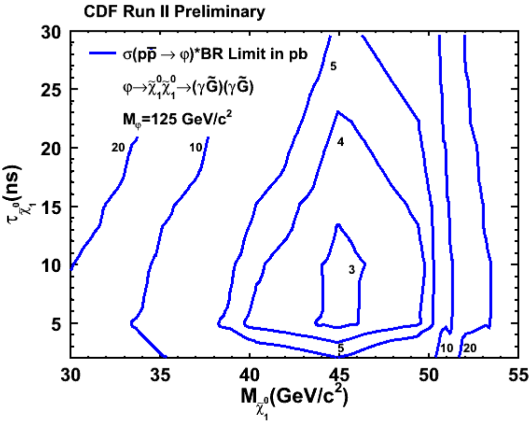


- To estimate the acceptance, we follow JHEP09 (2013)041 and use a customized PGS for each mass/lifetime configuration (will be fairly close... move to CDFsim in progress)
- Highest Acceptance for roughly: $M_{\tilde{\chi}_1^0} \approx \frac{M_\varphi - 24\text{GeV}}{2}$ and $\tau_{\tilde{\chi}_1^0} \approx$ 5-10 ns
- Correlates to the best balance between having the $\tilde{\chi}_1^0$ decay within the detector
- Produces photons that are measured in the signal region (consistent with PRD 2008 (CDF 9171))

95% Confidence Limits on Cross Section

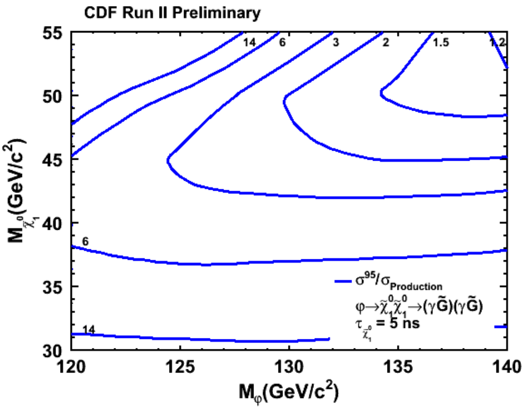
Convert to cross section limits: Use L=$6.3fb^{-1} \pm 6\%$, $\sigma_{Acc} = 20\%$ (Acc. from previous slide), and each M_φ, $M_{\tilde{\chi}^0_1}$, and $\tau_{\tilde{\chi}^0_1}$ combination gives a N^{95} which we can plug in to get σ_{95}.

Note the limits are optimal around 5ns as in previous studies (PRD(CDF 9171)/PRL(CDF 8636)).



Ratio of Observed to Expected Cross Section

Compare σ^{95} to simple model of scalar production with BR=100%.



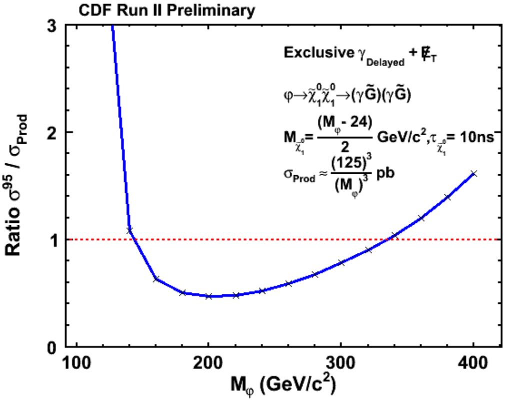
Strategy:
Move to higher $\tilde{\chi}_1^0$ and φ masses to find our optimal sensitivity

Currently uses the approximation that $\sigma_{Production} = \dfrac{(125\ \mathrm{GeV})^3}{(M_\varphi)^3}$ pb.

Moving to using PLB 702 (2011) 377382 (thanks to Tom Junk).

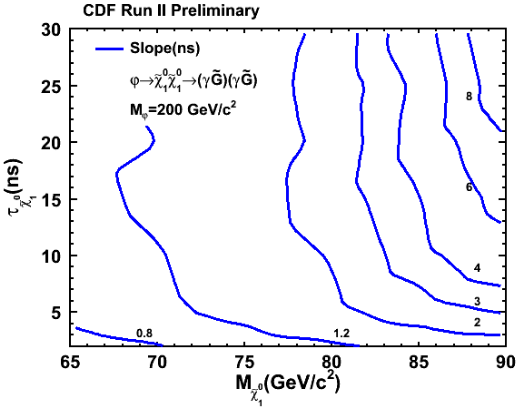
Possible Exclusion Region

Recall: Optimal cross section limits for $M_{\tilde{\chi}_1^0} \approx \frac{M_\varphi - 24\text{GeV}}{2}$.



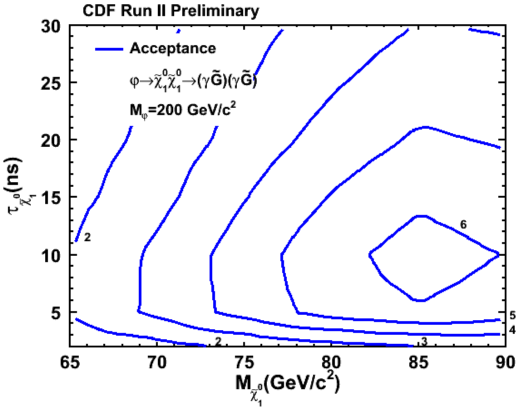
Slope at 200GeV

New Benchmark to replace plot on Slide 7



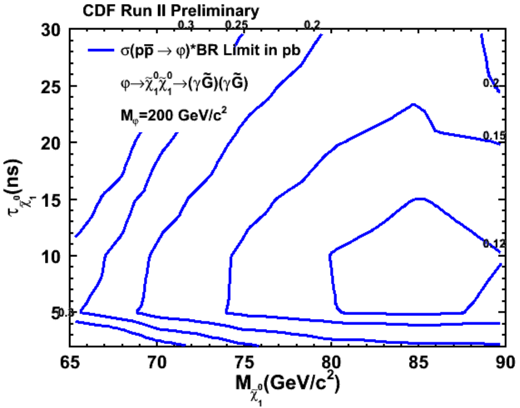
Acceptance at 200GeV

New Benchmark to replace plot on Slide 9



Cross Section at 200GeV

New Benchmark to replace plot on Slide 10



Conclusions

1. We have preliminary expected sensitivity limits on new scalar production and decay via $\varphi \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \gamma_{delayed} + MET$
2. Results as a function of M_{φ}, $M_{\tilde{\chi}_1^0}$,and $\tau_{\tilde{\chi}_1^0}$
3. Cross Section Limits appear optimal for $\tau_{\tilde{\chi}_1^0} \approx$10ns and $M_{\tilde{\chi}_1^0} \approx \frac{M_{\varphi} - 24}{2}$
4. The rest of the data with final acceptances and uncertainties to come using CDFsim (Nearing completion)
5. Plan: Finalize results, hope to publish a PRL on these results as well as a full PRD on the analysis methods.