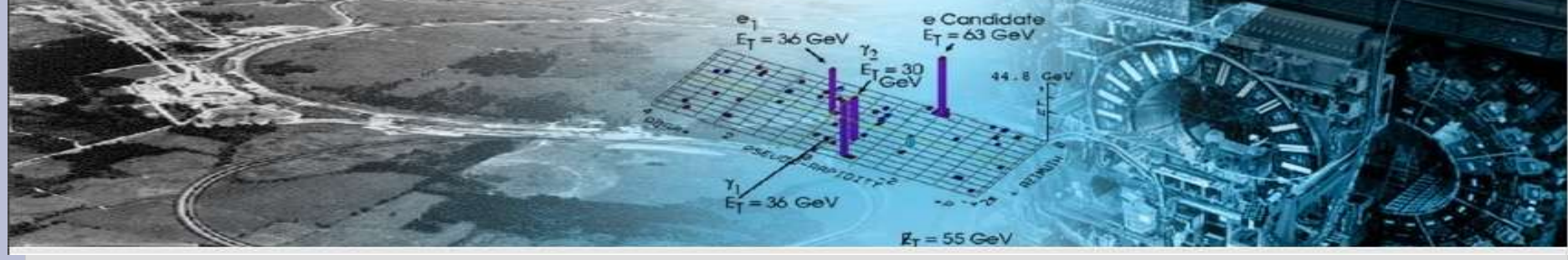


Prospects of a Search for neutral, long-lived Particles using the EMTiming system at CDF

Peter Wagner & Dave Toback

Texas A&M University

(June 04th 2004)

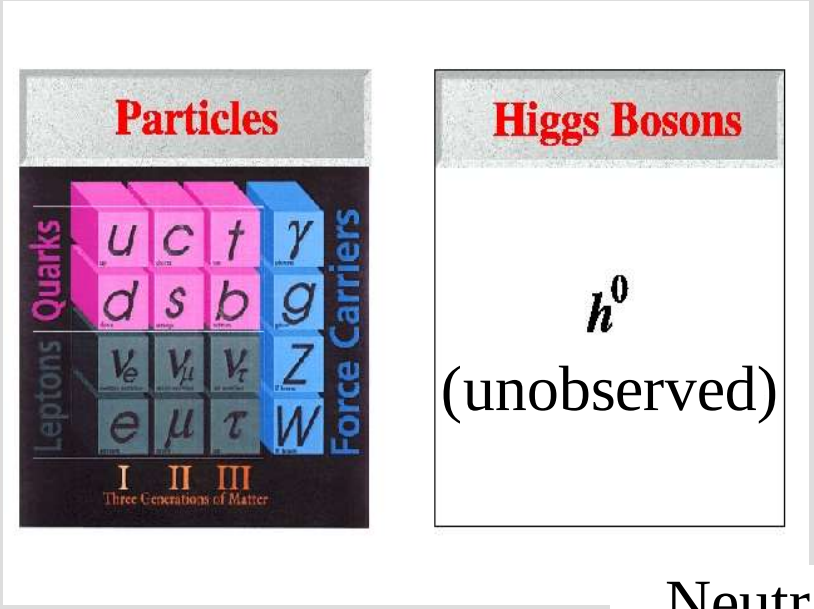
Outline

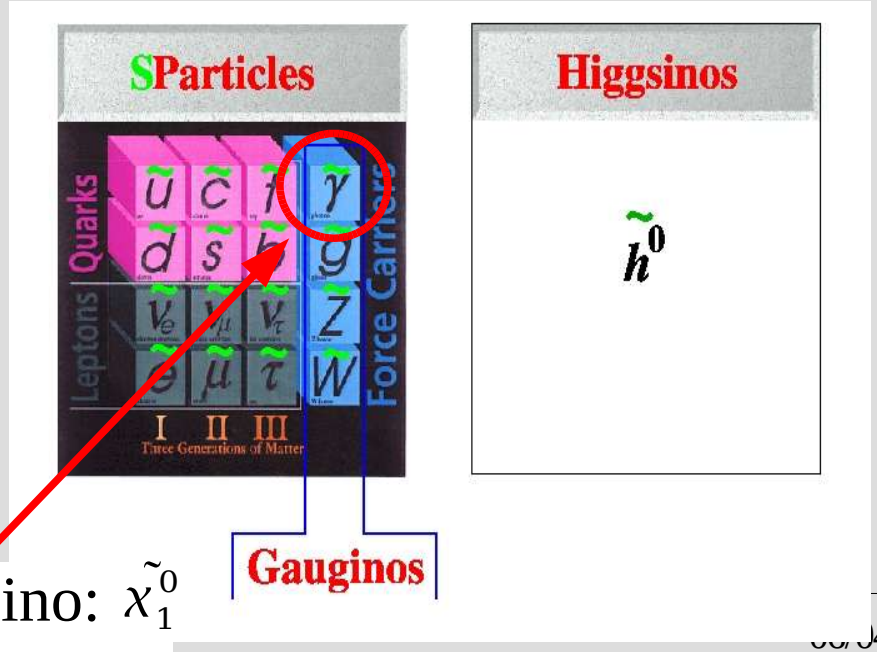
- Motivation for searching for long-lived particles
- Discriminating Variable
- Tools
- Sensitivity to GMSB models
- Conclusion

Supersymmetry

- Modern particle theories predict a symmetry of fermions and bosons (“ Supersymmetry“) at energies of a few TeV
- These theories predict new, heavy particles to appear at energies, which may be now accessible at Fermilab (Tevatron) or in the future at CERN (LHC)

Standard Model: Supersymmetric counterparts:



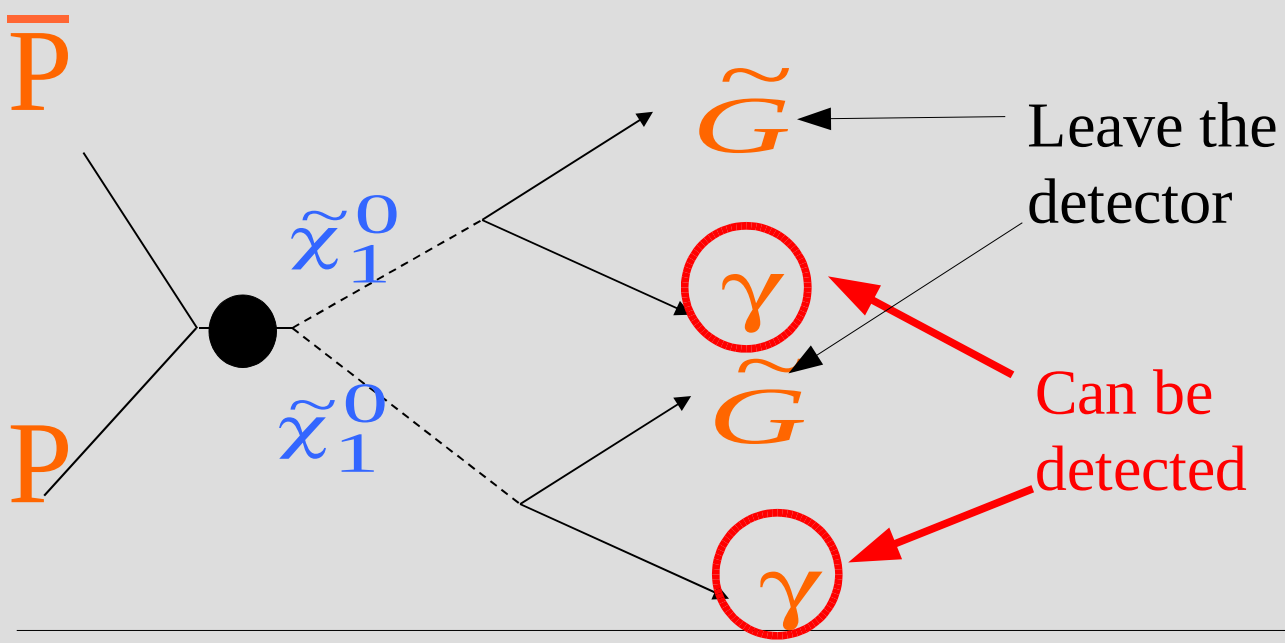


Neutralino: $\tilde{\chi}_1^0$

GMSB Neutralino

S. Dimopoulos, *et.al.*, Nucl.Phys. B488, 39-91

- A major supersymmetric model (Gauge Mediated Supersymmetry Breaking) predicts the lightest Neutralino, $\tilde{\chi}_1^0$, to be the NLSP and the Gravitino, $\tilde{G}$, the LSP
- For much of the parameter space the Neutralino decay time (length) can be macroscopic (ns (meters))
- In $P\bar{P}$ collisions at the Tevatron we can produce Neutralino pairs and they decay preferably via:



Signature:

$\Rightarrow \not{E}_T$

$\Rightarrow \gamma\gamma$ or γ

if both or only 1 $\tilde{\chi}_1^0$ decay in the detector

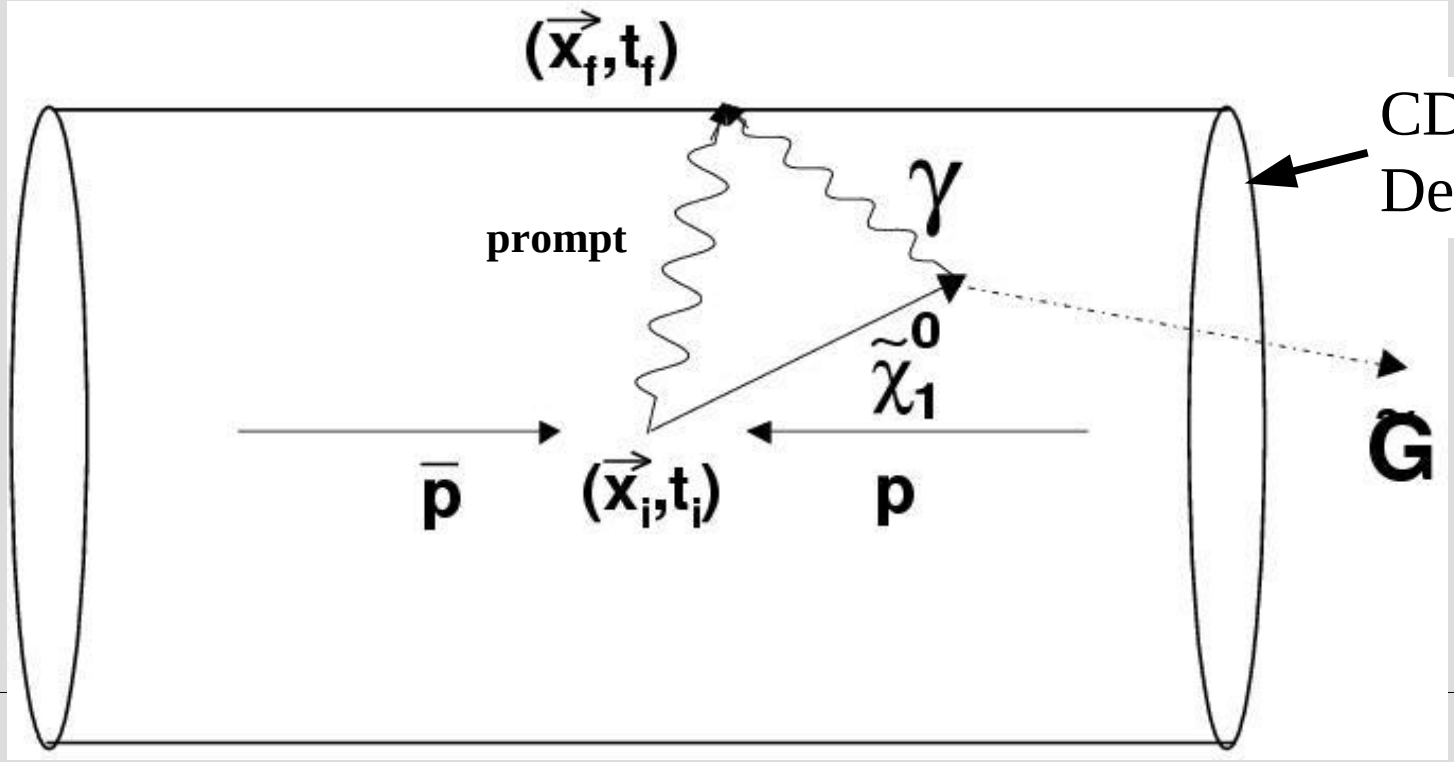
Discriminating Variable

(1) Measure the time of arrival of the photon ⇒ Time of Flight Δt

(2) Calculate the time at which a prompt (Standard Model) photon would arrive at same position

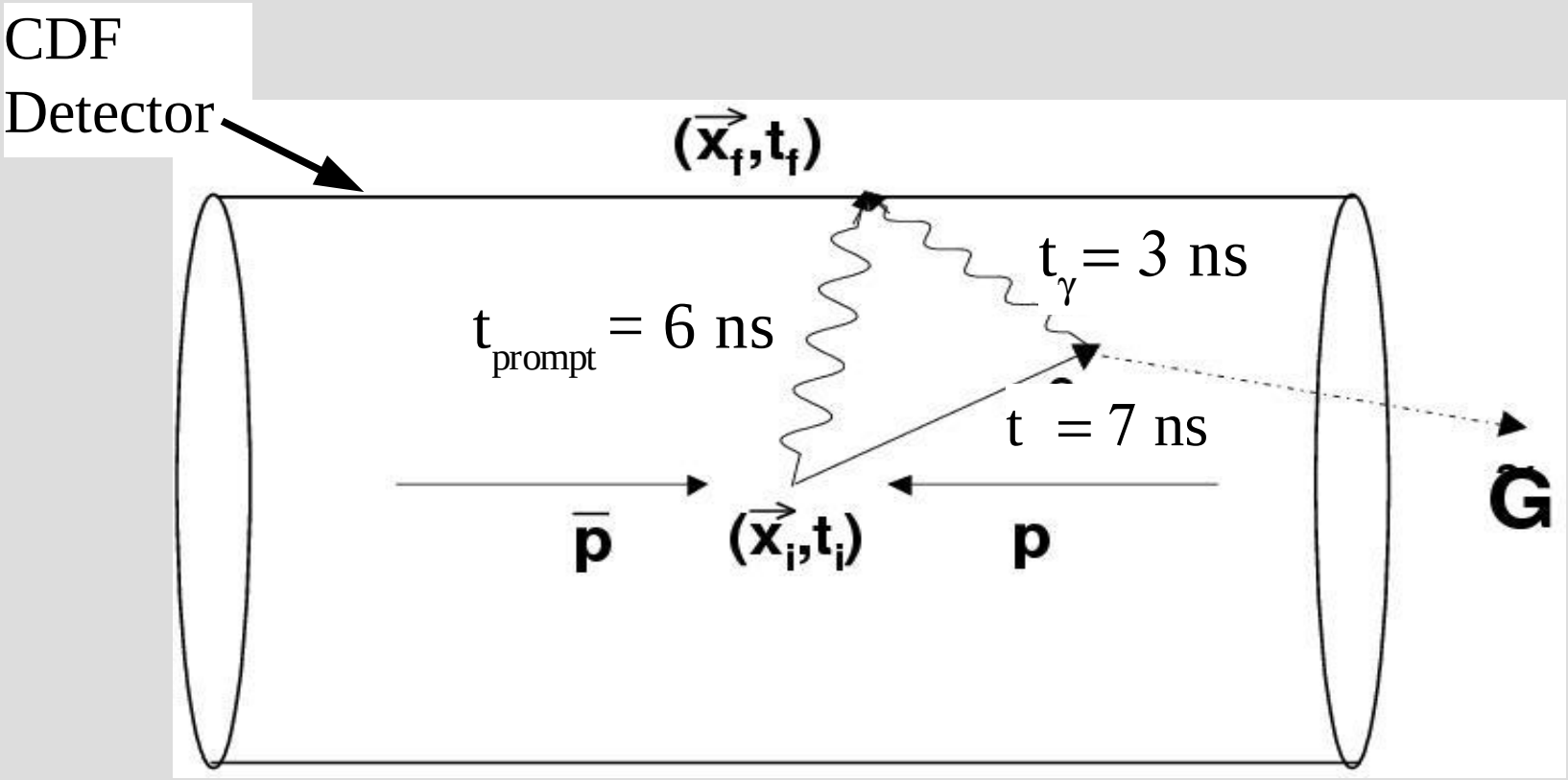
(3) Subtract:

$$\Delta s \equiv \Delta t - \frac{|\vec{x}_f - \vec{x}_i|}{c}$$



CDF Detector

Example:



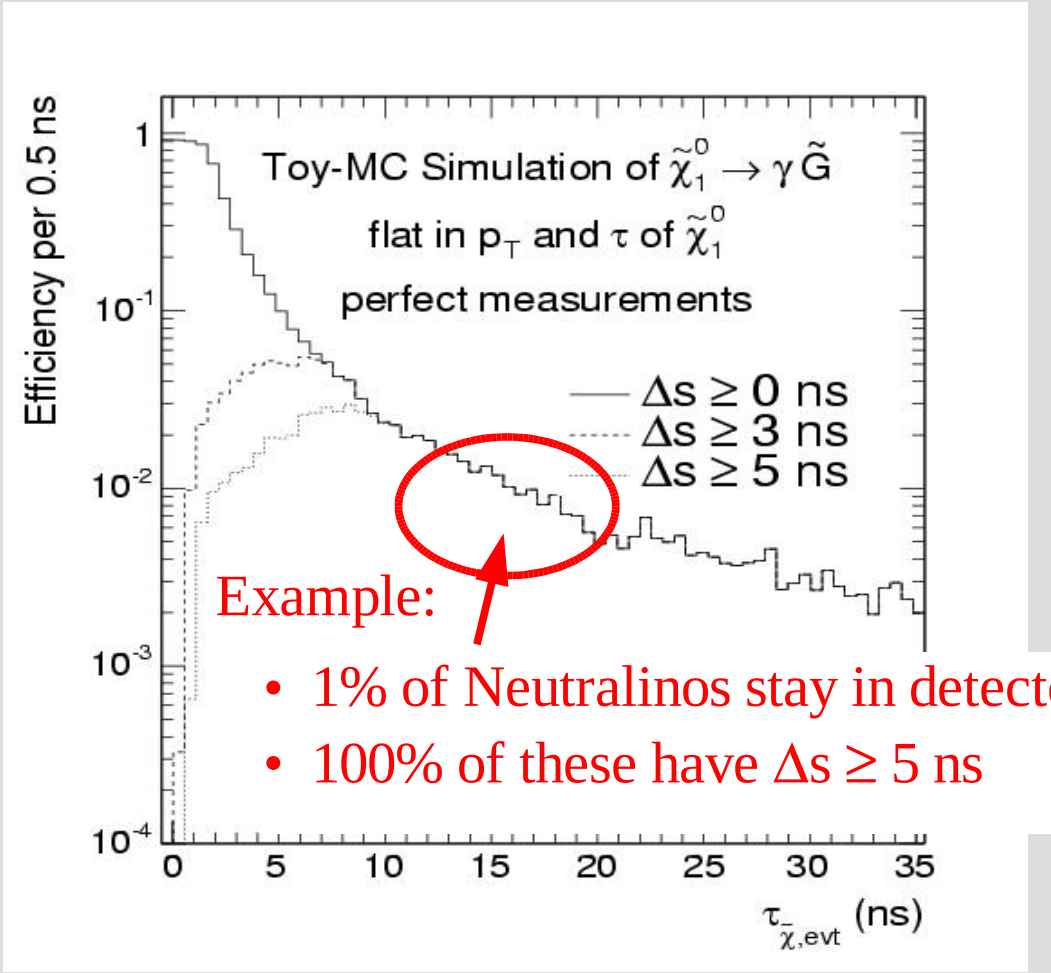
$$\Rightarrow \quad s = (3 + 7) - 6 = 4 \text{ ns}$$

Prompt photons (SM): $\Delta s \equiv 0$ ns

Long-lived particles (SUSY): $\Delta s > 0$ ns

Selection of long-lived particles

Long lifetime ⇔ High Δs



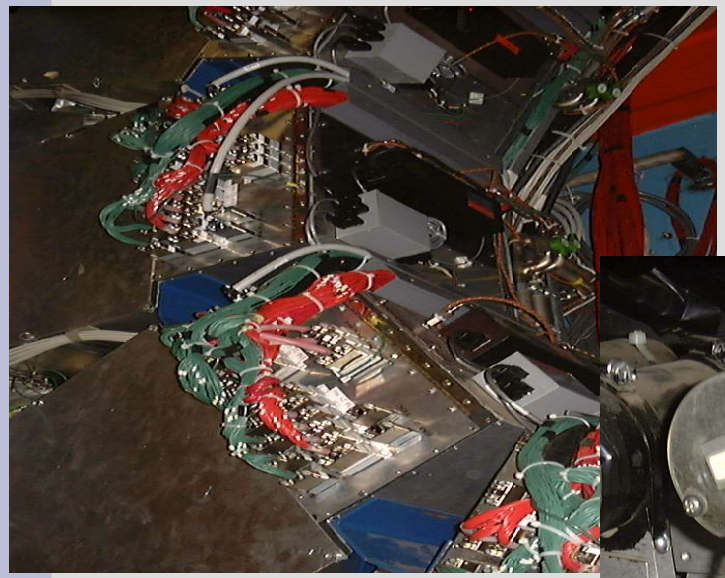
Example:

- 1% of Neutralinos stay in detector
- 100% of these have Δs ≥ 5 ns

⇒ Δs is the right variable to select long-lived particles.

Tools

- Particle positions measured by the EMCalorimeter
- The newly installed EMTiming System at CDF allows us to perform the time measurements
- EMTiming resolution is ~1.0 ns

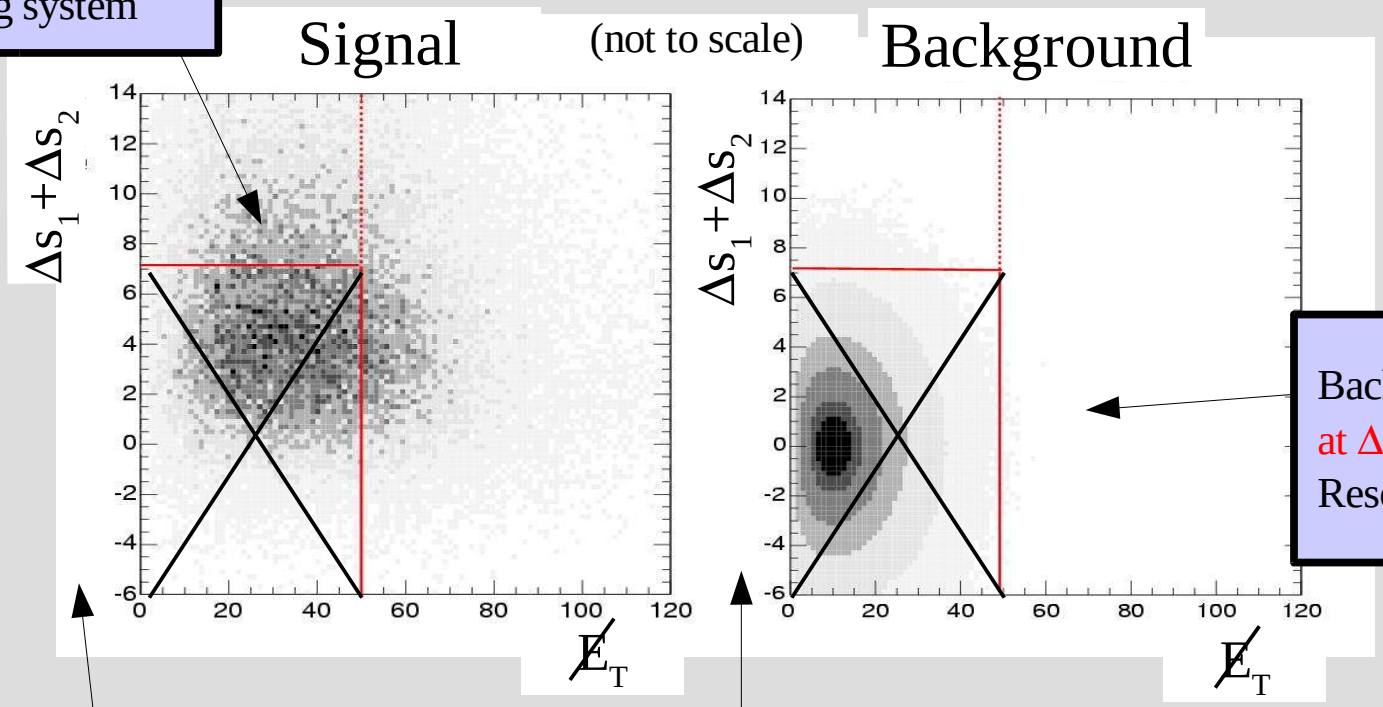


Event Selection for GMSB Analyses

To optimize the sensitivity for the largest possible neutralino lifetime range, we use 2 analyses: a $\gamma\gamma + \not{E}_T$ analysis (for low lifetimes)...

Additional gain with the timing system

$\gamma\gamma + \not{E}_T$ analysis from CDF Phys. Rev. D59 092002 (1999)



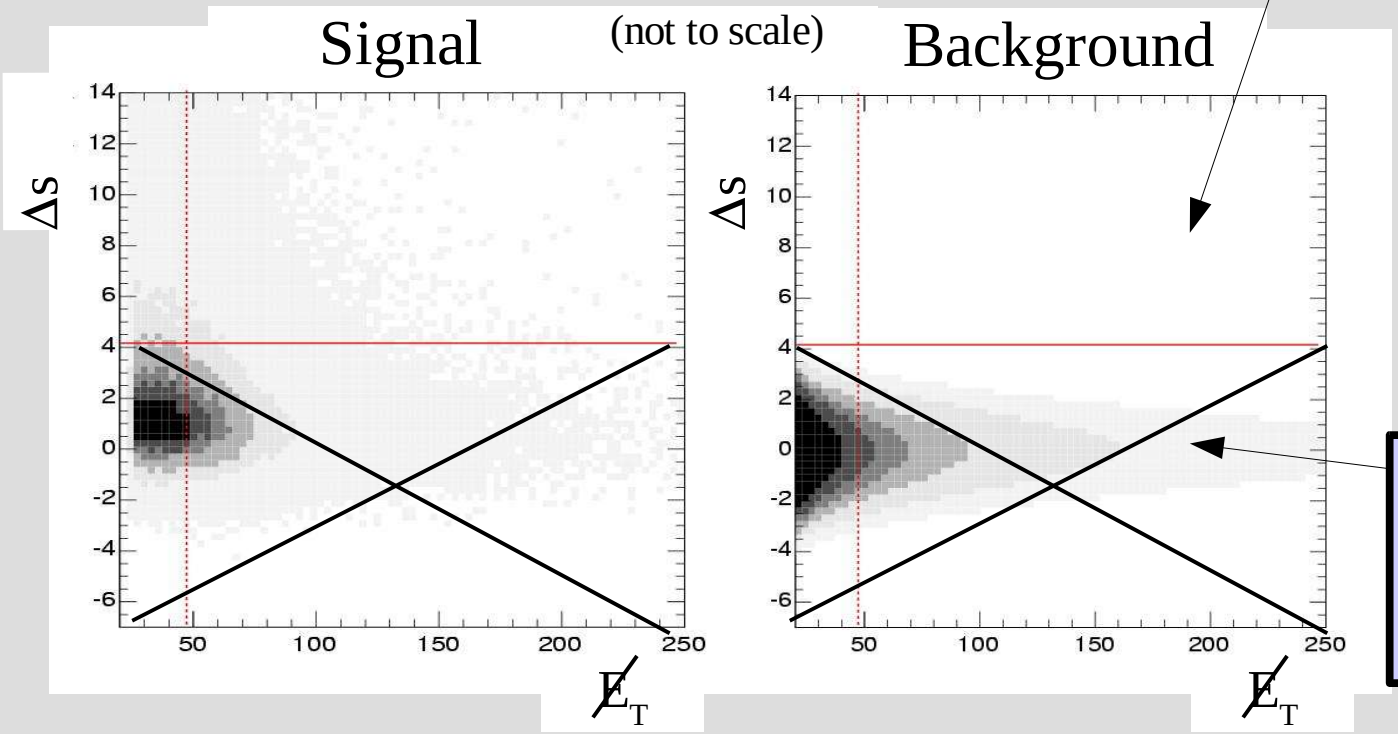
Background centered at $\Delta s = 0$ ns
Resolution: 2.12 ns

Add up the Δs values of the 2 photons

...and a $\gamma + \not{E}_T$ + jets analysis (for high lifetimes):

Good background rejection with the timing system

$\gamma + \not{E}_T$ + jets analysis from D0
Background: QCD, W+jets
Phys.Rev.Lett. 82, 29 (1999)



Background centered at $\Delta s = 0$ ns
Resolution: 1.0 ns

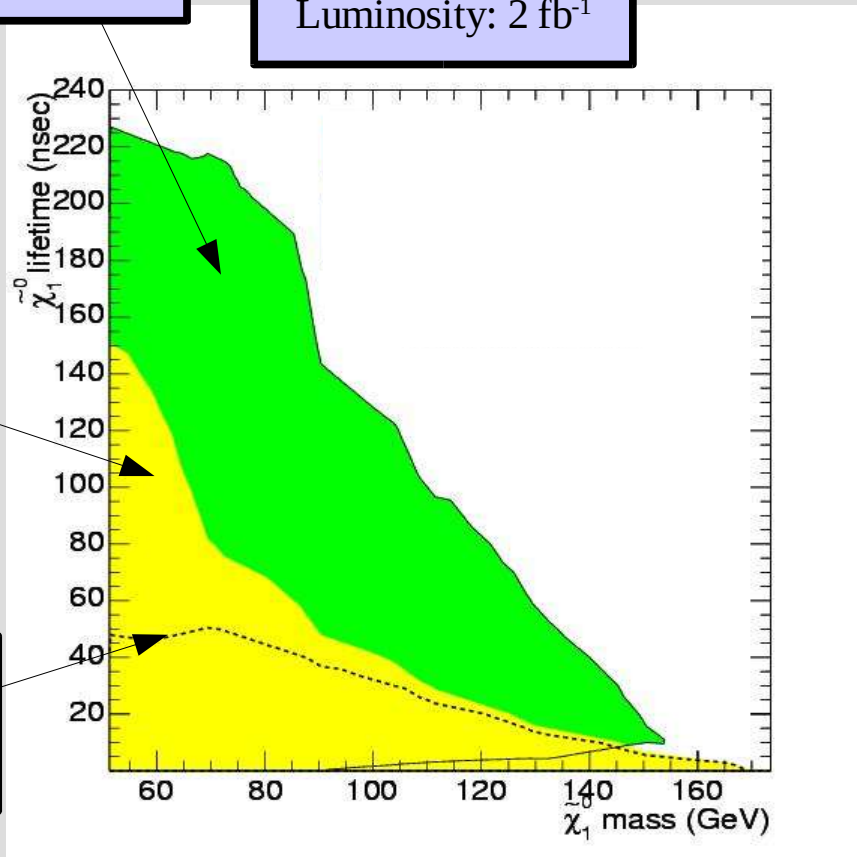
Exclusion Region for GMSB models

$\gamma + \not{E}_T$ + jets analysis

Luminosity: 2 fb^{-1}

$\gamma\gamma + \not{E}_T$ analysis

Limit with kinematical cuts only ($\not{E}_T$)

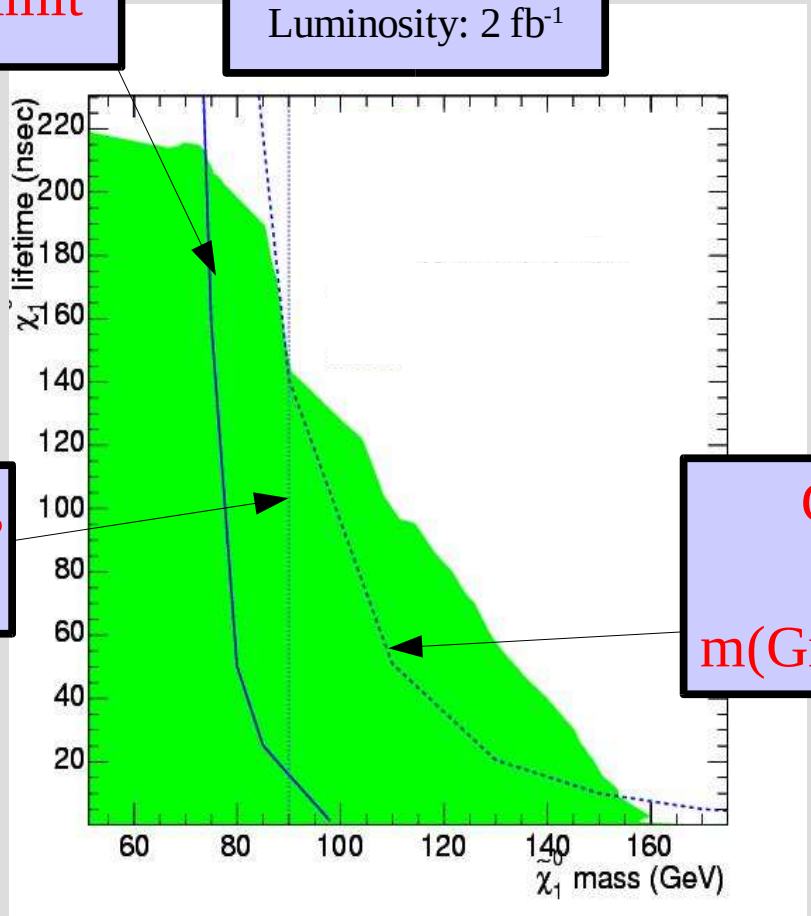


⇒ EMTiming extends the exclusion region compared to kinematics-only cuts especially at low masses

Comparison to other theoret. and exp. Constraints

ALEPH-Limit

Luminosity: 2 fb^{-1}



Current Higgs mass limit

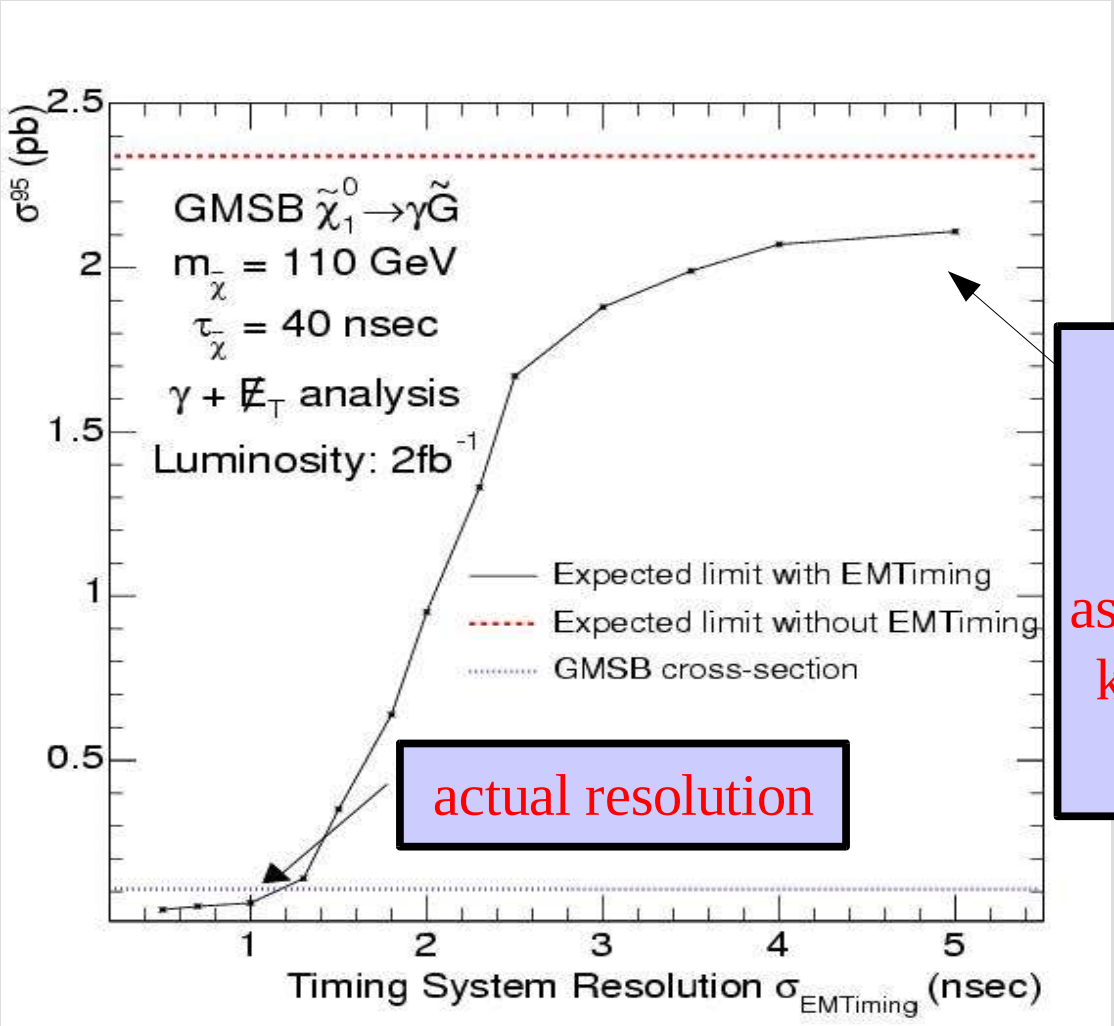
Cosmological Constraint: m(Gravitino) $\leq$ 1 keV

$\Rightarrow$ EMTiming covers the entire region between LEP and the cosmological bound

Conclusion

- The installation of the Timing System at CDF is lead by the Texas A&M Group - and will be finished in Fall 2004
- With the current resolution the EMTiming system is sensitive to yet unexplored regions

Effect of Timing resolution



actual resolution

EMTiming cross section limit reaches asymptotically the kinematics-only limit