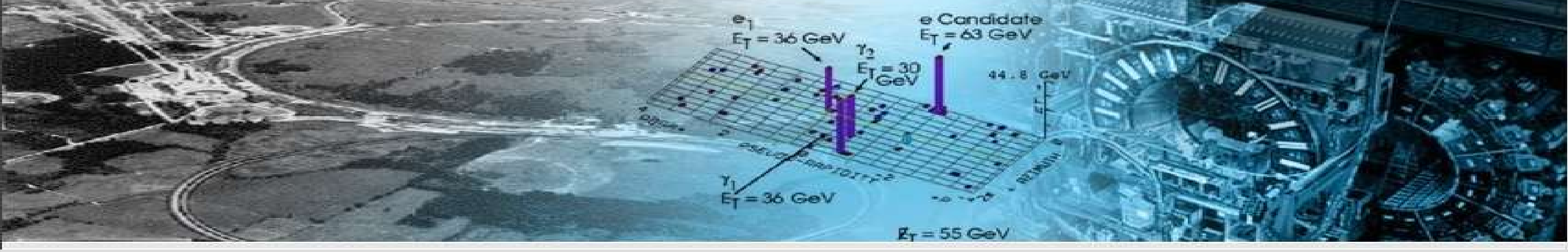

Prospects of a Search for Neutral, Long-Lived Particles Using Photon Timing at CDF

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Outline

- Motivation: Gauge Mediated SUSY Breaking
- The Tool: EMTiming
- Analysis (Prospects): Sensitivity to GMSB models
- Conclusion

The GMSB Model

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

"Gauge Mediated SUSY Breaking" has six free parameters:

- SUSY breaking scale (Λ)
- Messenger mass scale (M_M)
- Number of messenger fields (N_M)
- Ratio of the Higgs vacuum expectation values ($\tan(\beta)$)
- Sign of the Higgs mixing parameter ($\mathrm{sign}(\mu)$)
- Gravitino scale (c_{Grav})

Phenomenology

- Intrinsically suppresses FCNCs (Flavor Changing Neutral Currents)
- Breaks SUSY at low energy ⇒ large parts of parameter space predict new particles to be accessible at today's energies (TeV)
- Gravitino, $\tilde{G}$, is the lightest SUSY particle (LSP)
- Both Neutralino and Gravitino candidates for Dark Matter
- Cosmological constraints have a big effect

GMSB Neutralino

- For low tan(β) and a simple $N_M = 1$ GMSB predicts the lightest Neutralino to be the NLSP with the Gravitino as LSP
- The electroweak eigenstate of the Neutralino is mostly photino $\Rightarrow$ it decays preferably via:

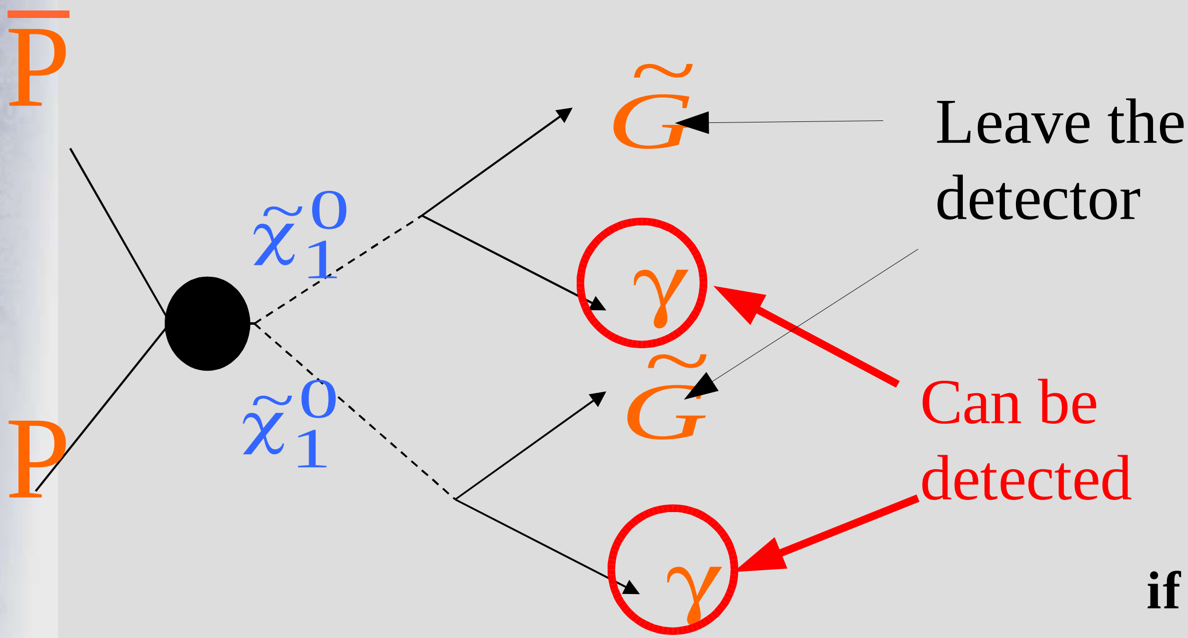
$$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$$

- For much of the parameter space the Neutralino decay time (length) can be macroscopic (ns (meters))

$\Rightarrow$ Measure the arrival time of the photon at a collider detector

Event Signature

Proton-antiproton collisions at the Tevatron produce Neutralino pairs and they decay preferably via:



Signature:

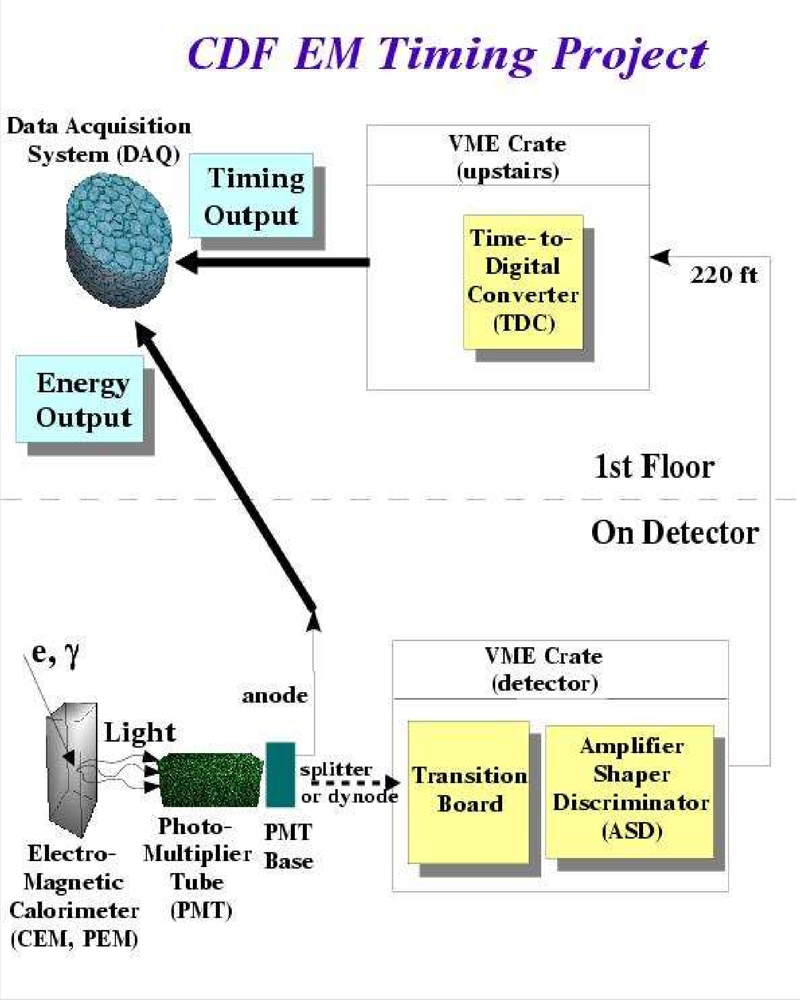
$\Rightarrow \not{E}_T$

$\Rightarrow \gamma\gamma$ or γ

if both or only 1 $\tilde{\chi}_1^0$ **decay in the detector due to large decay lengths**

New at CDF: Timing in the EM calorimeter - EMTiming

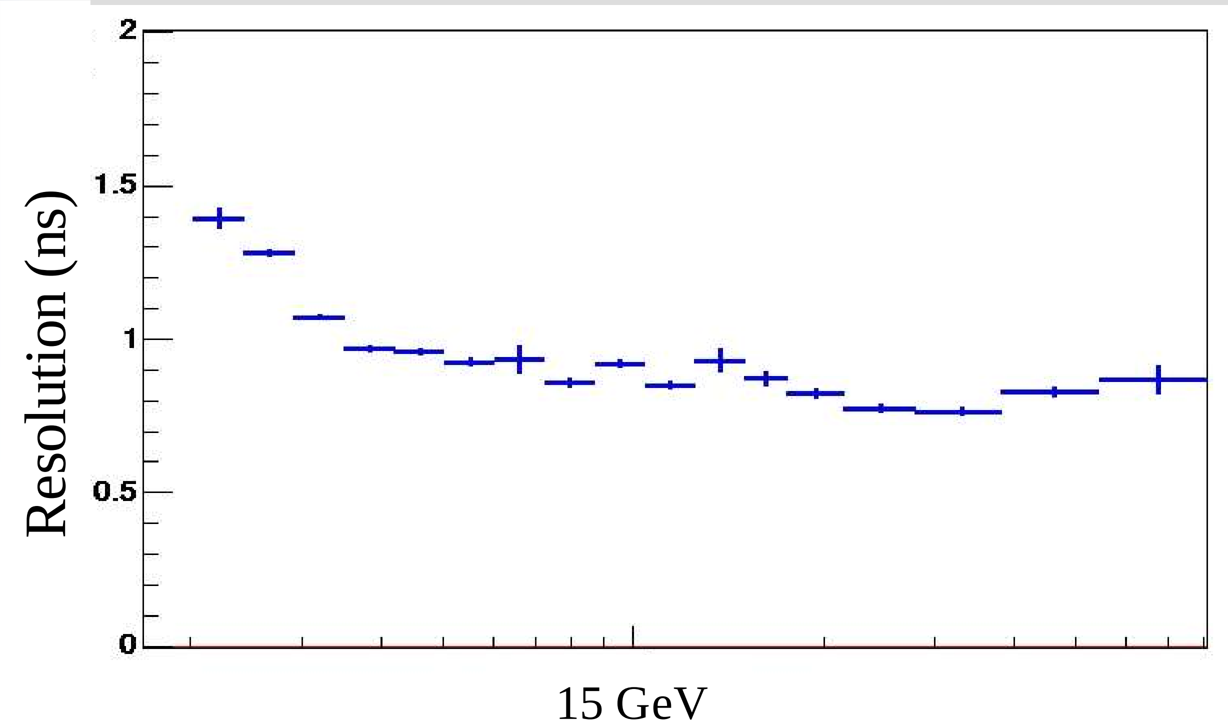
- Hardware similar to Timing system in the Hadronic Calorimeter (HAD)
- The installation of the forward part was finished in Fall 2003, the central part being installed now
- Especially efficient for photons which leave only little energy in the HAD



First Measurements

M. Goncharov, priv. comm.

... and it has been shown to have a resolution of < 1.0 ns:



Energy of Photon

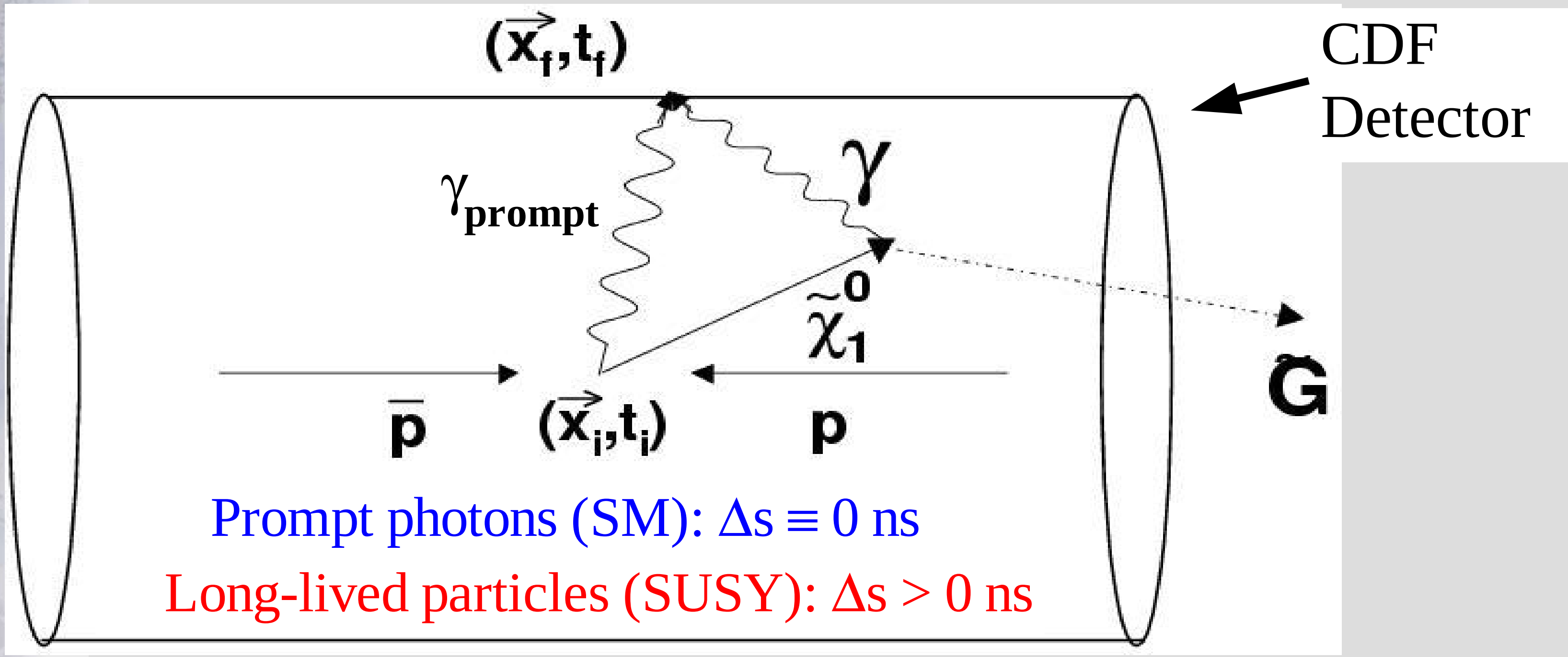
~0.9 ns

Discriminating Variable

<u>The idea:</u> Look at the difference between the time of arrival of the photon and the time a prompt photon would need to reach the same position:

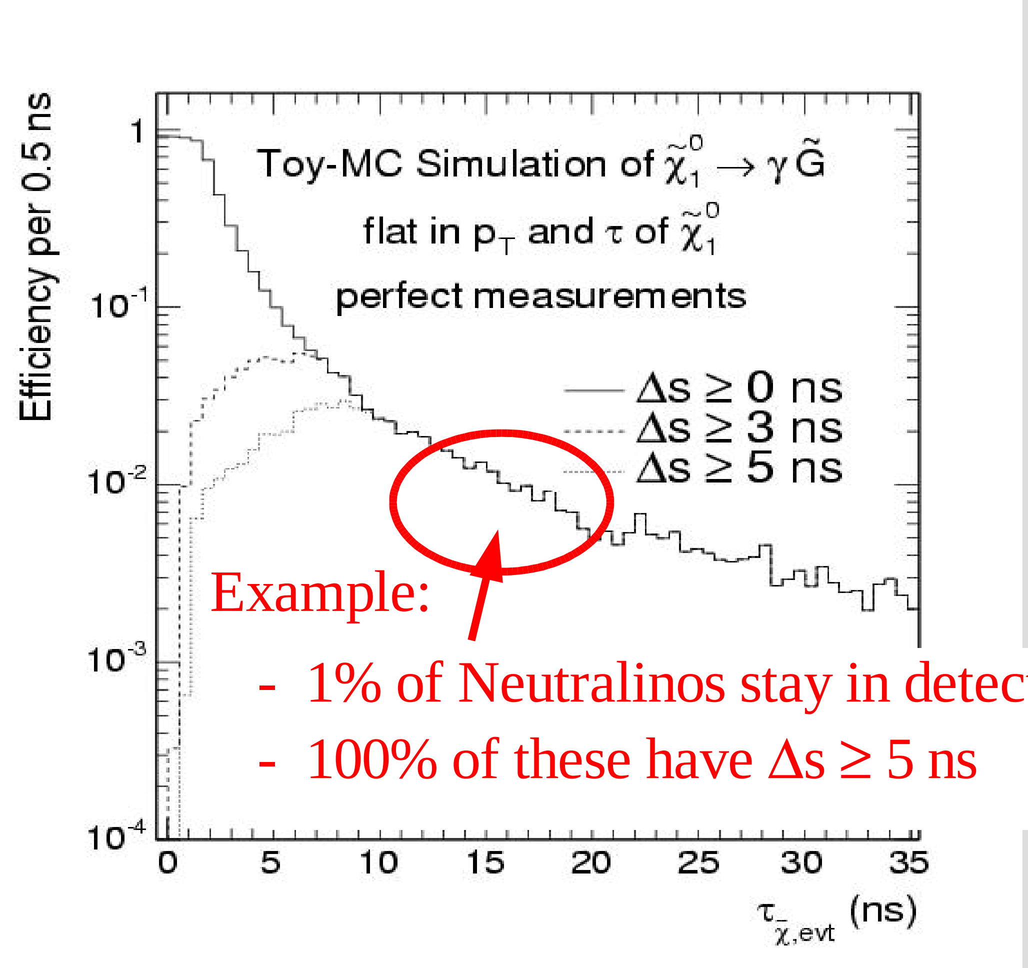
$$\Delta s \equiv \Delta t - \frac{|\vec{x}_f - \vec{x}_i|}{c}$$

... with the time of arrival measured with the EMTiming system.



Selection of long-lived particles

Long lifetime ⇔ High Δs



Example:

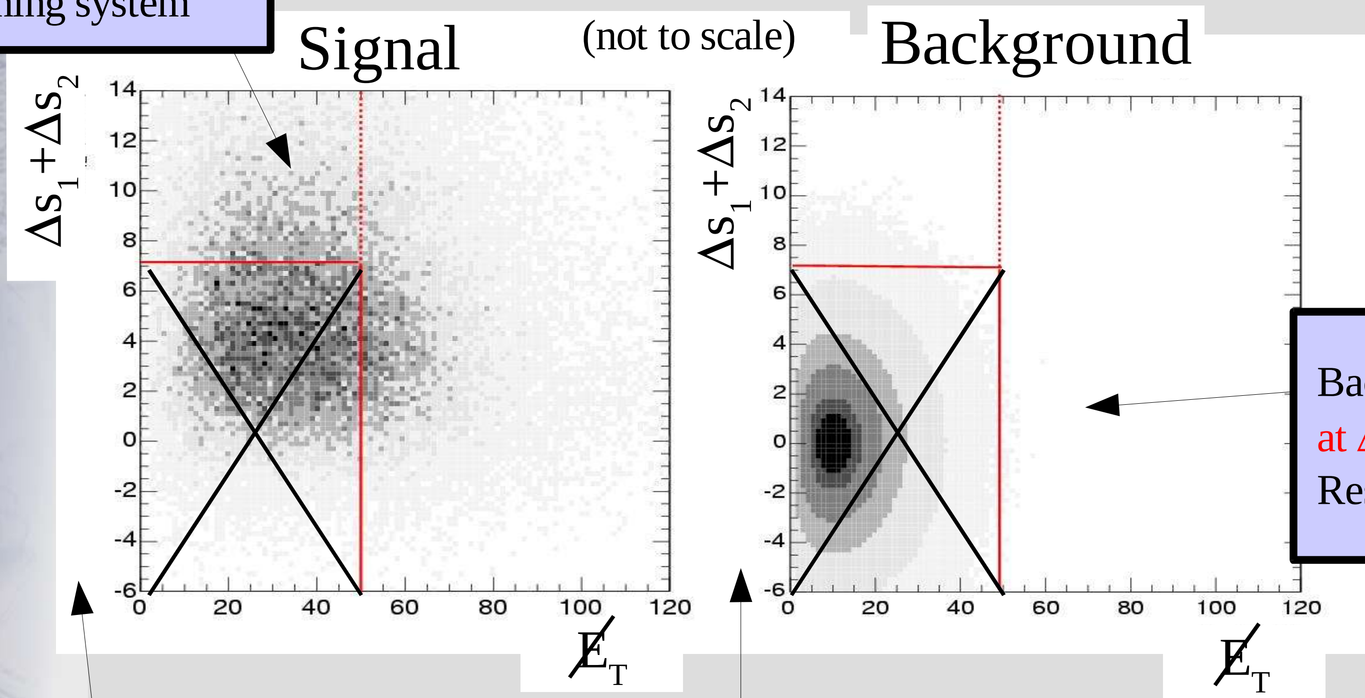
- 1% of Neutralinos stay in detector
- 100% of these have $\Delta s \geq 5$ ns

Event Selection for GMSB Analyses I

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
Background: QCD
Phys. Rev. D59 092002 (1999)

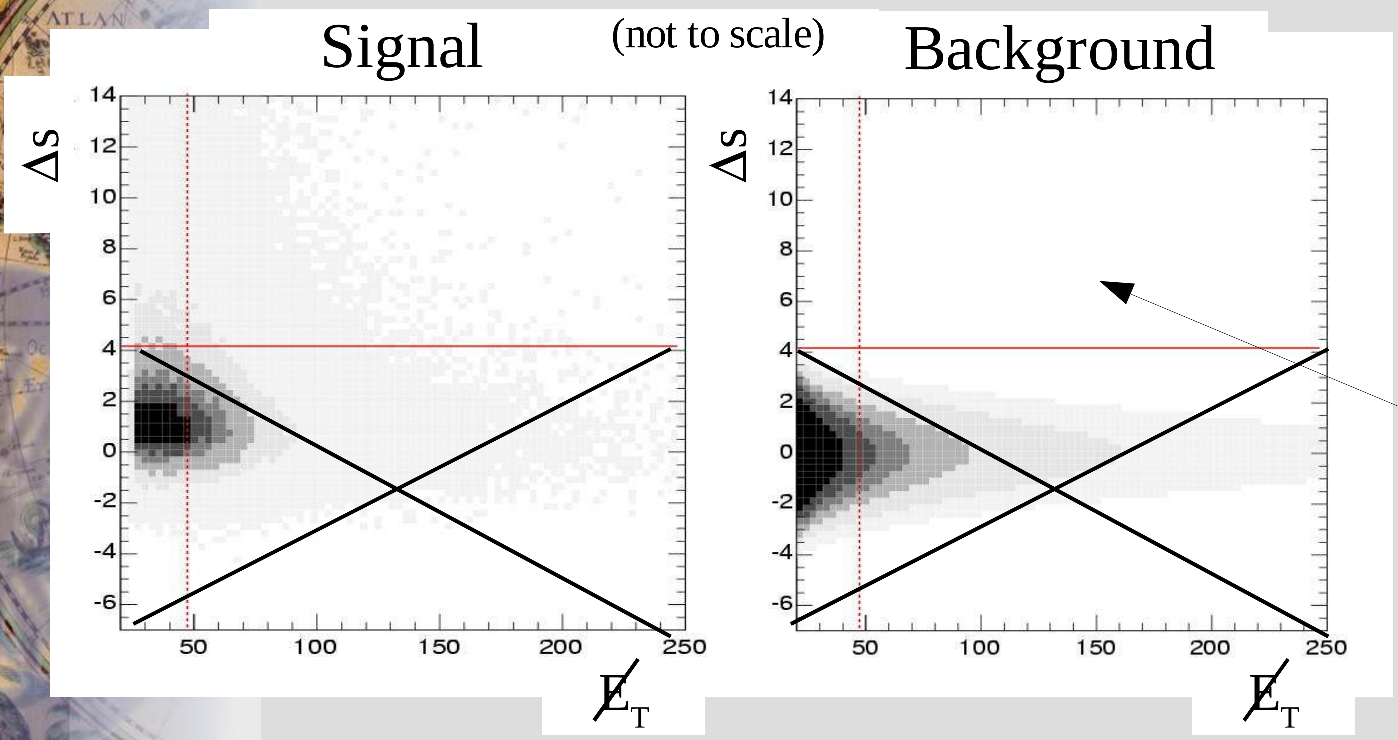


Background centered at Δs = 0 ns
Resolution: 1.41 ns

Add up the Δs values of the 2 photons

Event Selection for GMSB Analyses II

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



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

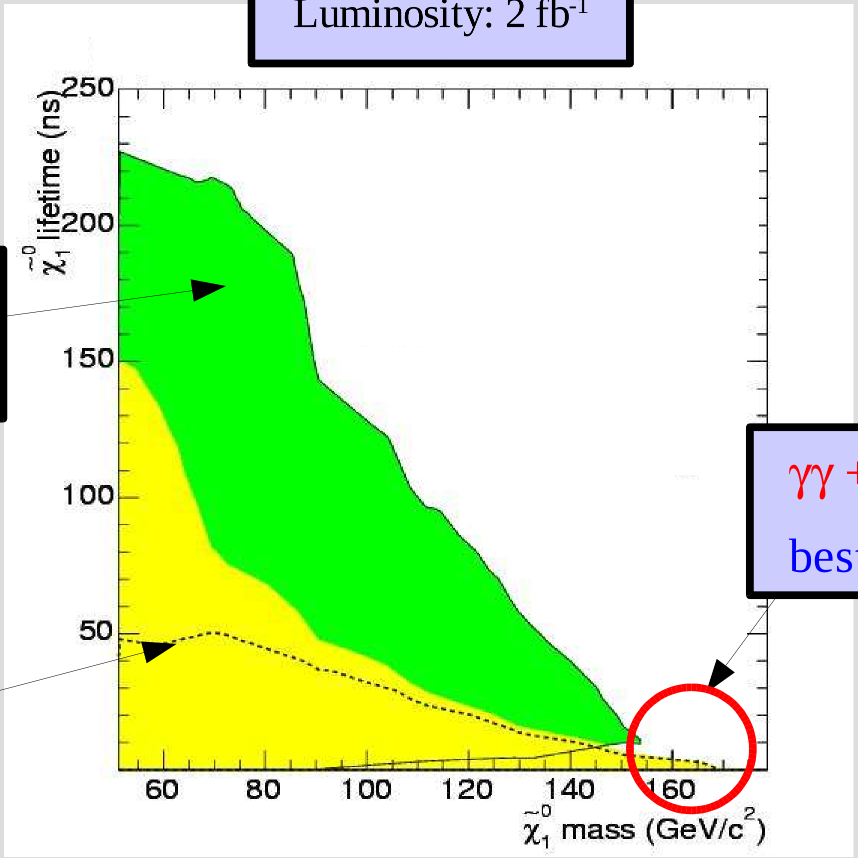
Good background rejection with the timing system

Exp. Exclusion Region for GMSB models

Luminosity: 2 fb^{-1}

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

best for high lifetime searches



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

best $\tilde{\chi}_1^0$ mass reach

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

$\Rightarrow$ EMTiming is expected to extend the exclusion region especially at large lifetimes

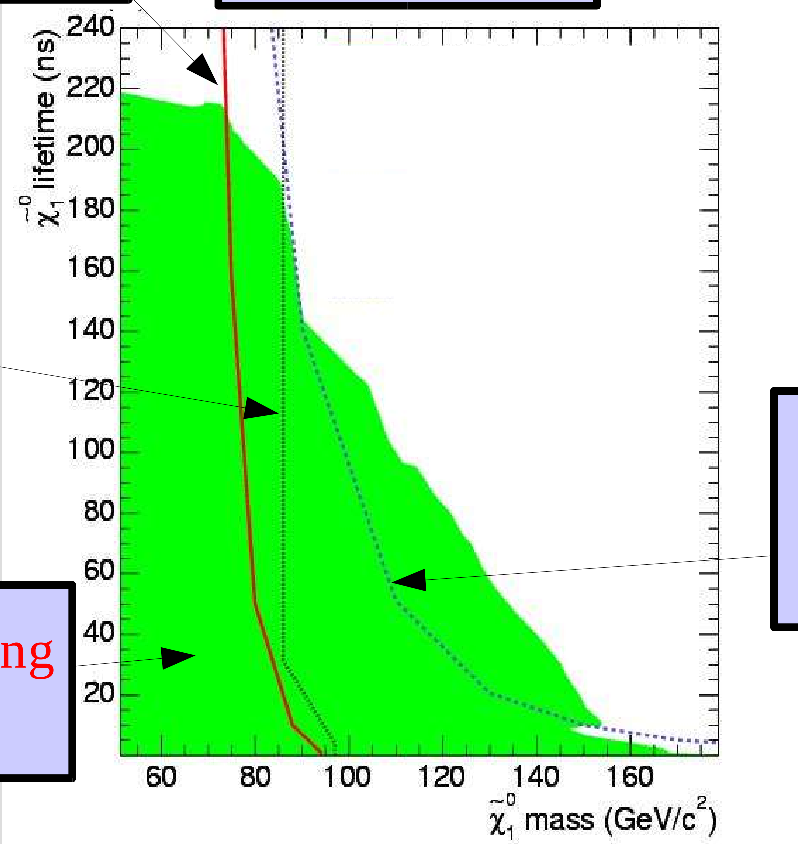
Comparison to other Constraints

ALEPH-Limit

Luminosity: 2 fb^{-1}

Limit from Higgs searches at LEP

Superimposed EMTiming exclusion regions



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

$\Rightarrow$ **EMTiming covers the entire region between LEP and the cosmological bound for neutralino masses below 150 GeV for 2 fb^{-1}**

Conclusion

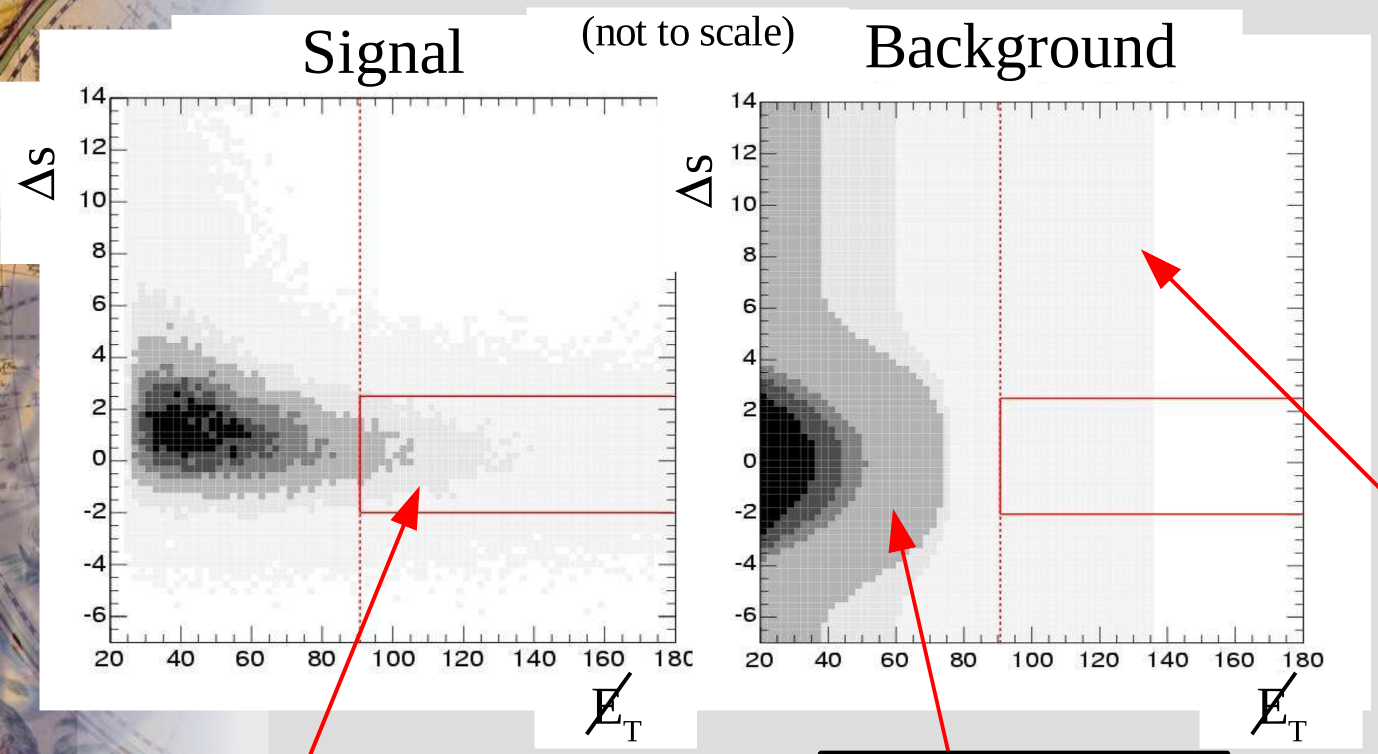
submitted to PRD: hep-ph/0407022

- The installation of the EMTiming system at CDF will be finished in Fall 2004
- The EMTiming system at CDF will be sensitive to yet unexplored regions in the search for long-lived particles in Run II ...and can test the GMSB model for some parameter choices up to its cosmological bound

Event Selection for Quasi-Model-Independent Analyses II

A $\gamma + \not{E}_T$ + 0jet analysis (for high lifetimes):

$\gamma + \not{E}_T$ + 0 jet analysis from CDF
Background: Zγ, Wγ, W→ eν, QCD and cosmics
Phys.Rev.Lett. 89, 281801 (2002)



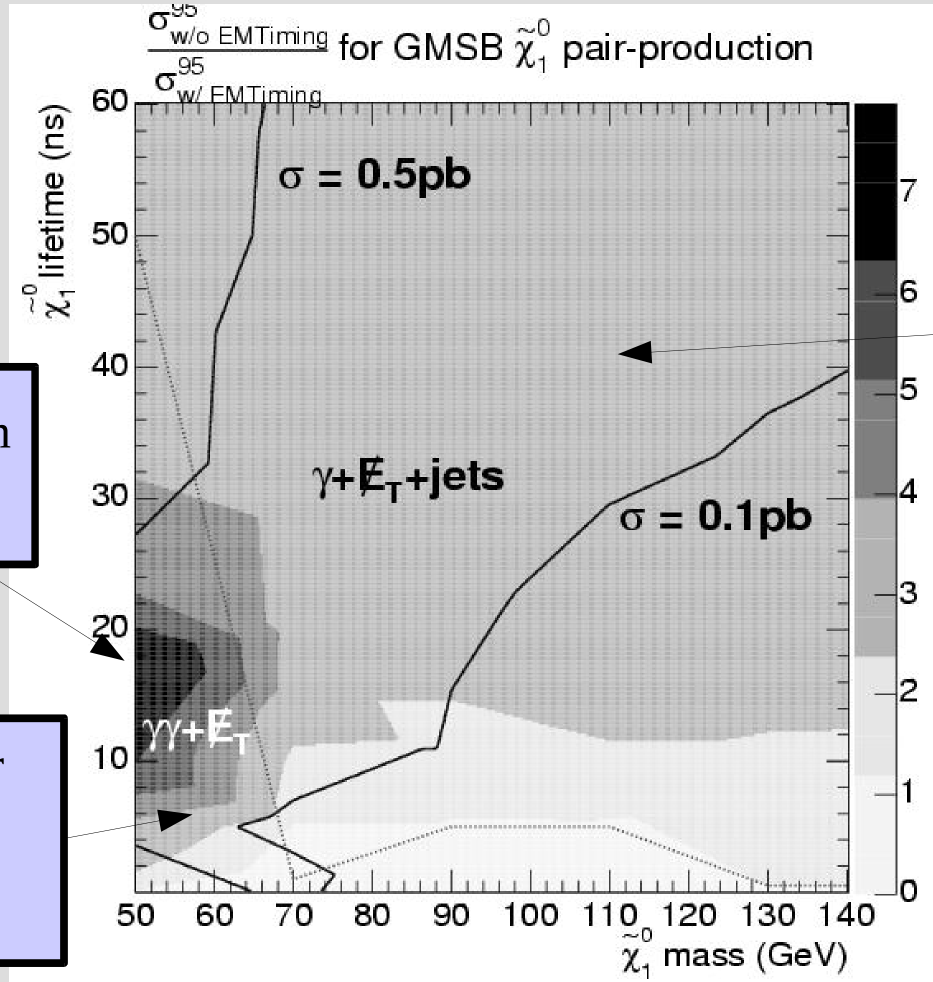
Cosmics background: randomly in Δs

QCD background: centered at Δs = 0 ns

Accepted events

Sensitivity in a Quasi-Model-Independent Search

Compare the cross section limits of with EMTiming and kinematics-only at each ($\tau_{\tilde{\chi}}$,$m_{\tilde{\chi}}$) point:



The EMTiming system is most effective here

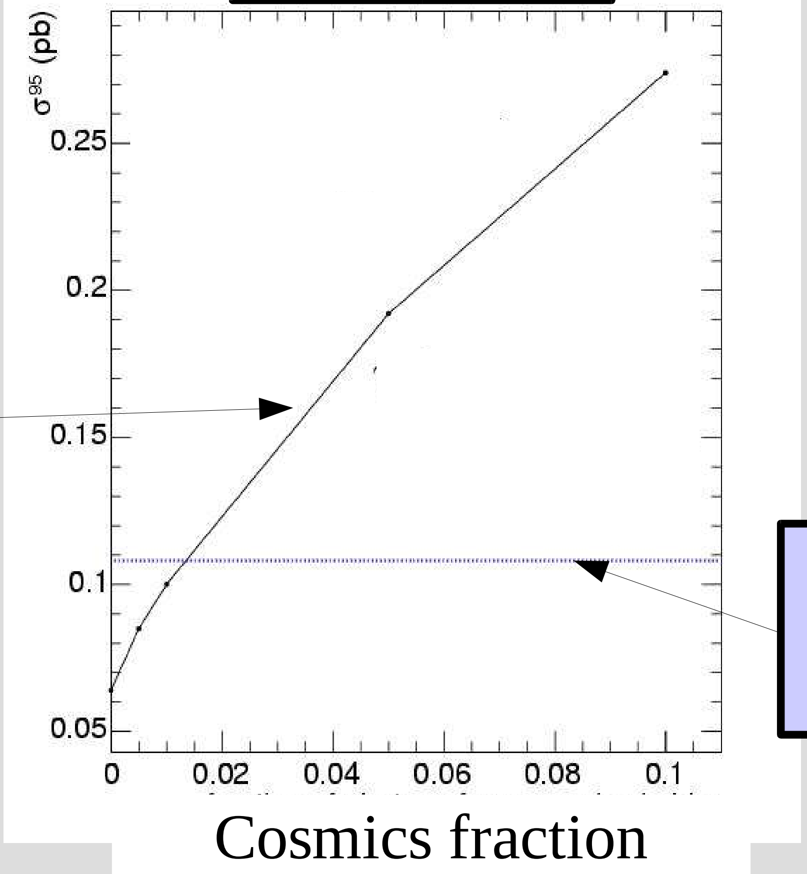
– $\gamma + \not{E}_T$ analysis dominates

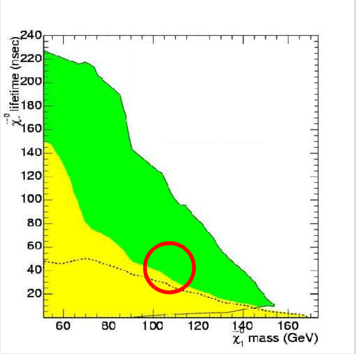
– remains effective up to high lifetimes

$\gamma\gamma + \not{E}_T$ analysis better at low lifetimes and low masses

Factors That Might Change the Exclusion Region

Luminosity: 2 fb^{-1}





95% C.L. cross section limit

Prod. cross section at $m_{\tilde{\chi}}$ = 110 GeV $\tau_{\tilde{\chi}}$ = 40 ns

$\Rightarrow$ Good cosmics rejection is valuable