

Search for Charged Massive Stable Particles at DØ

Thomas Nunnemann
(LMU Munich)

for the DØ Collaboration

EPS HEP2005 – Lisboa – 21.07.2005

Charged Massive Stable Particles (CMSP)

Several SUSY models can include a long-lived, quasi-stable particle as NLSP:

- Gauge-Mediated Susy Breaking (GMSB):
 - gauge interactions with messenger fields at a scale $M_{mess} \ll M_{Planck}$ are responsible for SUSY breaking
 - LSP is the Gravitino \tilde{G} : $M(\tilde{G}) \leq 1 \text{ keV}$ (small coupling)
 - NLSP is either lightest $\tilde{\chi}^0$ or a charged \tilde{l} (mostly $\tilde{\tau}$)
 $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$
 $\tilde{\tau} \rightarrow \tau \tilde{G}$
- Anomaly-Mediated Susy Breaking (AMSB):
 - SUSY breaking is mediated by anomalies in the supergravity Lagrangian
 - LSP is $\tilde{\chi}_1^0$
 - NLSP is $\tilde{\chi}_1^\pm$, nearly mass degenerate with $\tilde{\chi}_1^0$

Search for CMSPs

T. Nunnemann
(LMU Munich)
for the DØ
Collaboration

CMSPs in GMSB
and AMSB

ToF with DØ
Muon Detector

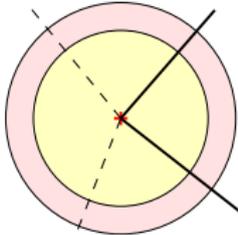
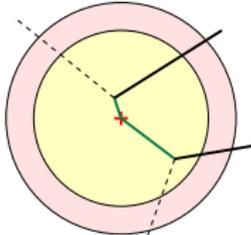
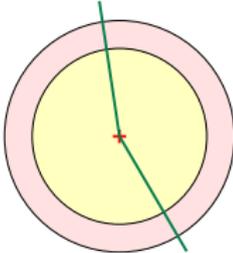
Search for Stable
 $\tilde{\tau}$ in GMSB

Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
Lifetime

Signatures of charged NLSP

- NLSP lifetime can range from 0 to ∞
 \Rightarrow many different topologies

NLSP	NLSP lifetime:		
	short	medium	long
stau, sleptons (charged particles)	2 leptons + missing energy: 	secondary vertices, kinked tracks: 	2 heavy, charged particles: 

here: concentrate on long NLSP lifetimes, identify CMSP using time-of-flight measurements

Search for CMSPs

T. Nunnemann
(LMU Munich)
for the DØ
Collaboration

CMSPs in GMSB
and AMSB

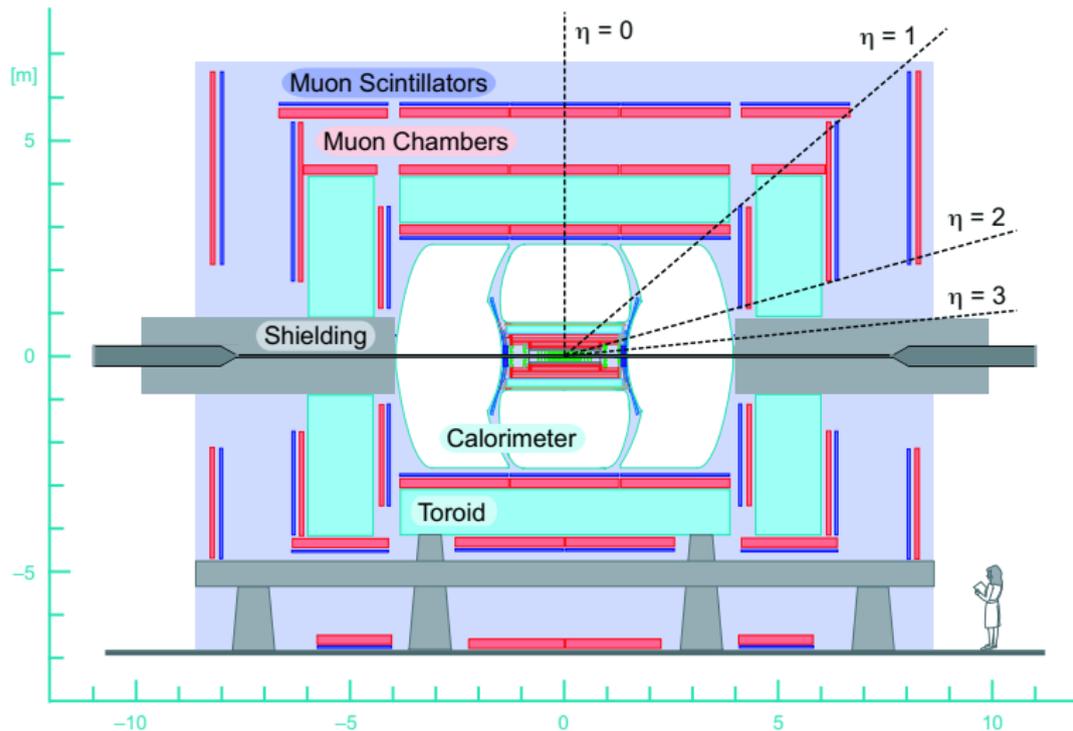
ToF with DØ
Muon Detector

Search for Stable
 $\tilde{\tau}$ in GMSB

Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
Lifetime

DØ Muon Detector System



Search for CMSPs

T. Nunnemann
(LMU Munich)
for the DØ
Collaboration

CMSPs in GMSB
and AMSB

ToF with DØ
Muon Detector

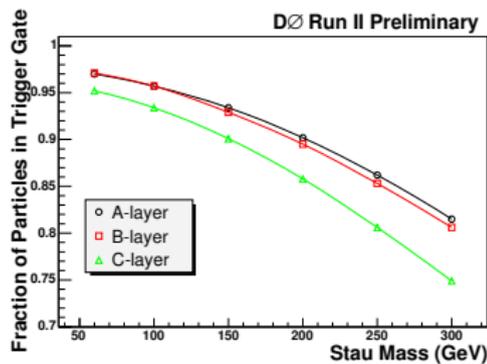
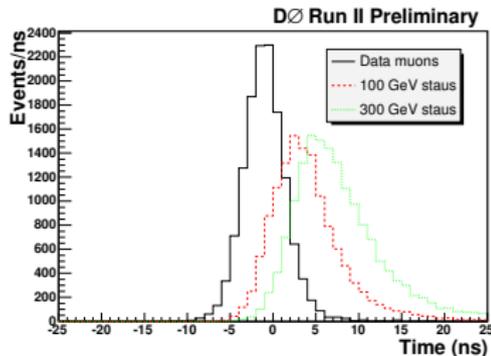
Search for Stable
 $\tilde{\tau}$ in GMSB

Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
Lifetime

ToF Measurement and Trigger

- 2-3 layers of scintillators with time resolution 2-3 ns
- CMSP can be discriminated from muons with ToF measurement
- trigger requires two tracks in muon system
 - asymmetric trigger gate allows for later particles
 - but decrease of trigger efficiency for increasing CMSP masses



Search for CMSPs

T. Nunnemann
(LMU Munich)
for the DØ
Collaboration

CMSPs in GMSB
and AMSB

ToF with DØ
Muon Detector

Search for Stable
 $\tilde{\tau}$ in GMSB

Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
Lifetime

Search for Stable $\tilde{\tau}$ in GMSB

Search for CMSPs

T. Nunnemann
(LMU Munich)
for the DØ
Collaboration

CMSPs in GMSB
and AMSB

ToF with DØ
Muon Detector

Search for Stable
 $\tilde{\tau}$ in GMSB

Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
Lifetime

- search performed within GMSB Model Line D (Snowmass 2001)

Λ_m	scale of SUSY breaking	19 - 100 TeV
M_m	messenger mass scale	$2\Lambda_m$
N_5	number of messenger fields	3
$\tan\beta$	ratio of Higgs v.e.v.'s	15
$\text{sign}\mu$	sign of \tilde{H} mass term	+1

- $\tilde{\tau}$ mass range: 60 - 300 GeV
- $\tilde{\tau}$ assumed to be 'stable'

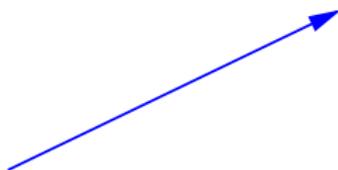
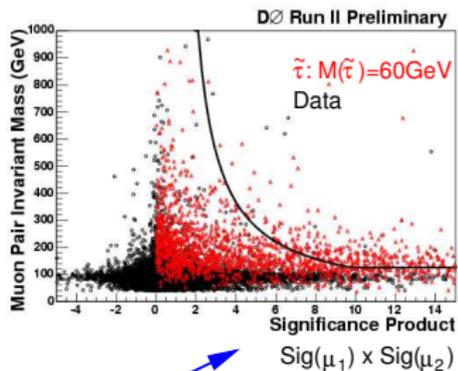
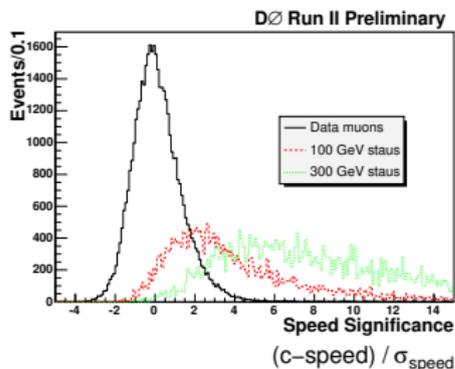
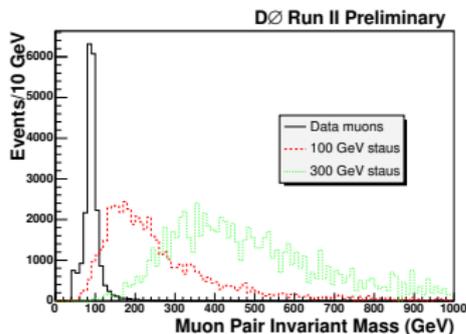
Selection Cuts

- 2 reconstructed μ with $p_T > 15 \text{ GeV}$ with isolation requirement
- reject background from cosmic μ and calorimeter leakage requiring consistent speed measurements, $\chi^2 < 4$:

$$\chi^2 = \sum_{\text{layer}} \frac{(\bar{v} - v_{\text{layer}})^2}{\sigma^2}$$

- dominating background: $Z/\text{Drell-Yan}$
- no separation with dE/dx in $D\emptyset$ Central Fiber Tracker due to small number of layers (16) and small photon statistics from scintillation
- 2-dim analysis cut on invariant di- μ -mass $M(\mu\mu)$ and speed significance $(c - \text{speed})/\sigma_{\text{speed}}$

2-dim Analysis Cut



2-dim cut optimized
for each $M(\tilde{\tau})$
hypothesis

Search for CMSPs

T. Nunnemann
(LMU Munich)
for the DØ
Collaboration

CMSPs in GMSB
and AMSB

ToF with DØ
Muon Detector

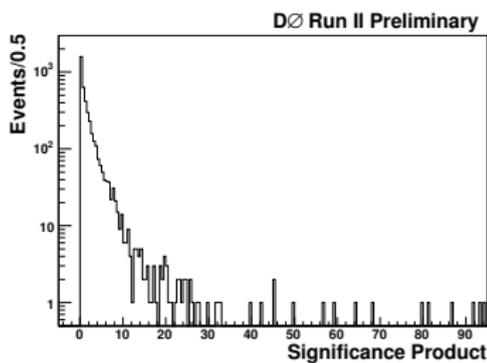
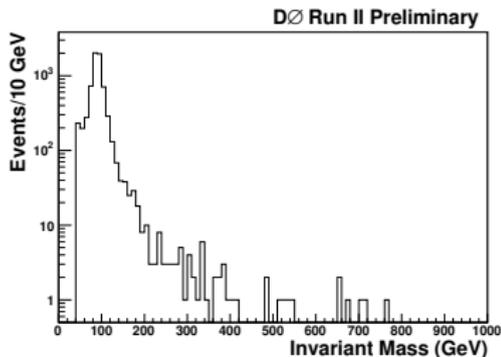
Search for Stable
 $\tilde{\tau}$ in GMSB

Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
Lifetime

Background Estimation

- after preselection
Z/Drell-Yan production
dominating background
- background estimation
entirely based on data, using
orthogonal sets to describe
2-dim PDF
- events with apparent v_{μ_1}
and $v_{\mu_2} > c$ to estimate
 $M(\mu\mu)$ distribution
- events with $M(\mu\mu) \approx M_Z$
to estimate significance
product



Search for CMSPs

T. Nunnemann
(LMU Munich)
for the DØ
Collaboration

CMSPs in GMSB
and AMSB

ToF with DØ
Muon Detector

Search for Stable
 $\tilde{\tau}$ in GMSB

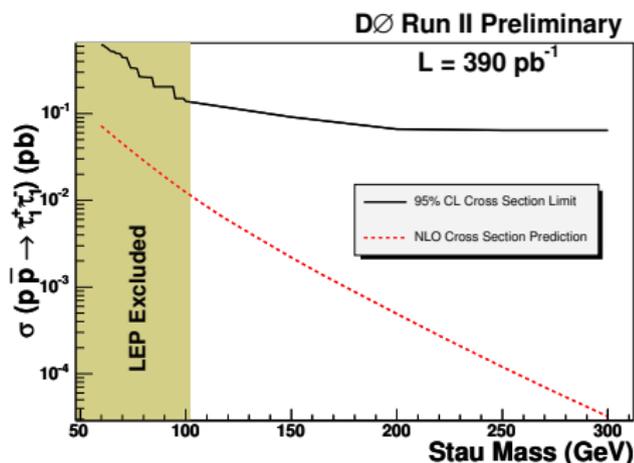
Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
Lifetime

Result of GMSB $\tilde{\tau}$ Search

$M(\tilde{\tau})$ (GeV)	Data	Background
60	13	$13.6 \pm 0.7 \pm 0.5$
100	0	$0.66 \pm 0.06 \pm 0.02$
150	0	$0.69 \pm 0.05 \pm 0.02$
250	0	$0.47 \pm 0.03 \pm 0.02$
300	0	$0.61 \pm 0.05 \pm 0.02$

- derive upper cross-section limit
- no exclusion of GMSB models, but best limits from Tevatron



Search for CMSPs

T. Nunnemann
 (LMU Munich)
 for the DØ
 Collaboration

CMSPs in GMSB
 and AMSB

ToF with DØ
 Muon Detector

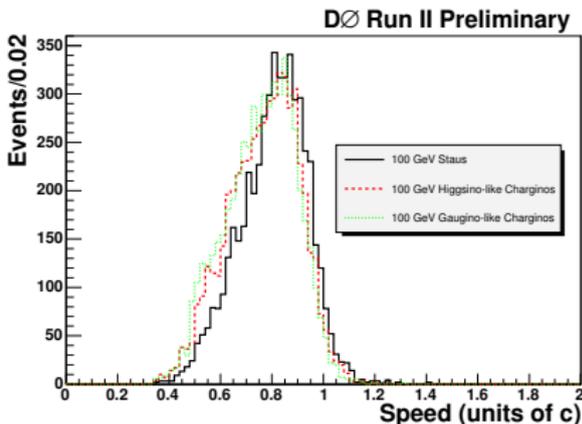
Search for Stable
 $\tilde{\tau}$ in GMSB

Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
 Lifetime

Interpretation in Terms of Stable $\tilde{\chi}_1^\pm$

- 'stable' $\tilde{\chi}_1^\pm$ if $\Delta M(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0)$ small
 - AMSMB
 - MSSM (*deep-higgsino*)
- kinematics of $\tilde{\chi}_1^\pm$ pair-production similar to $\tilde{\tau}$ of same mass
- can use same analysis cuts and reinterpret result in terms of cross-section limits for $\tilde{\chi}_1^\pm$ pair-production
- MSSM parameter sets:



Model	μ (GeV)	M_1 (GeV)	M_2 (GeV)	M_3 (GeV)	$\tan \beta$	$M(\tilde{q})$ (GeV)
gaugino-like $\tilde{\chi}_1^\pm$	10,000	$3M_2$	60 - 300	500	15	800
higgsino-like $\tilde{\chi}_1^\pm$	60 - 300	100,000	100,000	500	15	800

Search for CMSPs

T. Nunnemann
(LMU Munich)
for the DØ
Collaboration

CMSPs in GMSB
and AMSB

ToF with DØ
Muon Detector

Search for Stable
 $\tilde{\tau}$ in GMSB

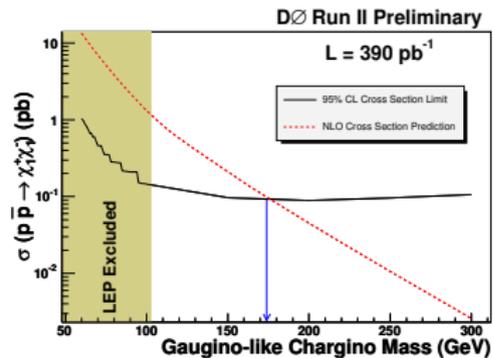
Search for Stable
 $\tilde{\chi}_1^\pm$

Effect of Finite
Lifetime

Result of Stable $\tilde{\chi}_1^\pm$ Search

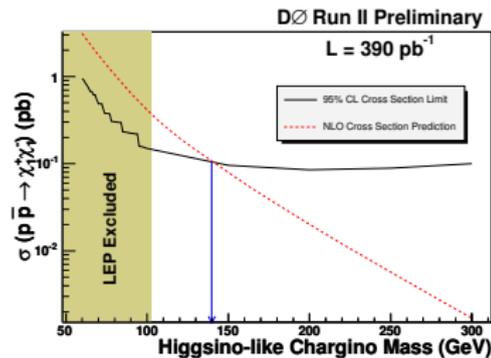
- limits on chargino masses (95% C.L.):

gaugino-like
(AMSB inspired)



$$M(\tilde{\chi}_1^\pm) > 174 \text{ GeV}$$

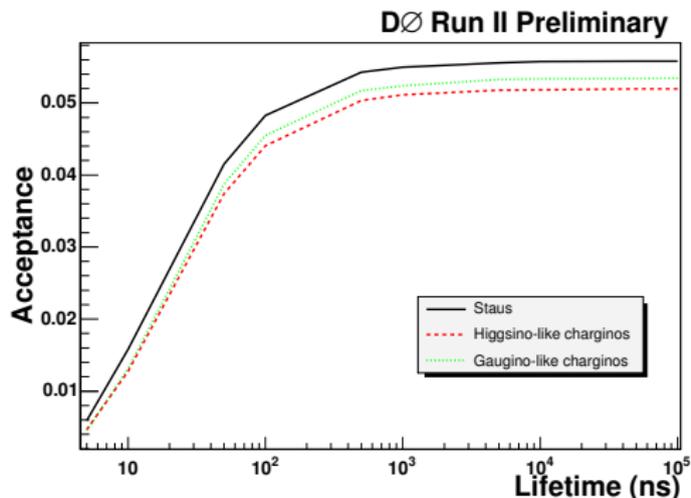
higgsino-like
(MSSM, *deep-higgsino*)



$$M(\tilde{\chi}_1^\pm) > 140 \text{ GeV}$$

Effect of Finite Lifetime

- reduced acceptance if particles decay within detector



$$M(\tilde{\tau}) = M(\tilde{\chi}_1^\pm) = 100 \text{ GeV assumed}$$

Conclusions

- DØ has searched for charged massive stable particles which can exist in GMSB ($\tilde{\tau}$) and AMSB/MSSM ($\tilde{\chi}_1^\pm$) models.
- most sensitive search at Tevatron
- mass limits for stable chargino well beyond LEP reach
 - gaugino-like: $M(\tilde{\chi}_1^\pm) > 174 \text{ GeV}$
 - higgsino-like: $M(\tilde{\chi}_1^\pm) > 140 \text{ GeV}$