Search for SUSY in photonic states and for long-lived particles at the Tevatron

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SUper SYmmetry

Symmetry of Nature for Boson<->Fermion interchange
Basic ingredient for unification with gravity (SuperString/M-theory)
The only nontrivial extension of the Lorentz-Poincaré group
Provides elegant solution to evade the fine tuning problem

Minimal extension of the SM: MSSM
every SM particle has $\Delta S = \pm 1/2$ partner
$R = (-1)^{3B+L+2S} = +1$ (SM); = -1 (SUSY)
2nd Higgs doublet is needed

$$q,l \leftrightarrow \tilde{q},\tilde{l}$$

$$R = +1$$
$$g \leftrightarrow g$$
$\gamma, Z, h, H, A \leftrightarrow \chi^0_{1,...,4}$
$W^\pm, H^\pm \leftrightarrow \chi^\pm_{1,2}$

If SUSY were exact: only 1 additional parameter ($\mu$) needed

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E.Nagy: Search for SUSY in photonic states at the Tevatron
SUSY is a broken symmetry since nobody has seen the partners many more parameters describe breaking.

With additional hypotheses they are reduced, e.g.
in gravitation mediated (mSUGRA) model to 5 \((m_0, m_{1/2}, \tan\beta, \text{sgn}\mu, A_0)\)
in gauge mediated (GMSB) model to 6 \((\Lambda, M_m, N_5, \tan\beta, \text{sgn}\mu, C_{\text{grav}})\) parameters.
In anomaly mediated (AMSB) model – no mass unification is assumed.

In most cases R-parity is assumed to be conserved:
since there are severe limits on B- and L-violating processes.
Then: SUSY partners are pair produced
LSP is stable (neutral and weakly interacting) – dark matter candidate

In this talk we assume R-parity conservation and use models with GMSB and AMSB
Run IIa ended in March 2006 – full dataset $1.3 \text{ fb}^{-1}$ (10x Run I) reported here
Run IIb started in June 2006 – hoping to reach $8 \text{ fb}^{-1}$ by ~2010
→ an order of magnitude of potential improvement in luminosity for the analyses
The central preshower (CPS) is particularly useful: to provide photon (high p\_T electron) pointing to disentangle electromagnetic and hadronic jets.

Timing information from muon scintillation trigger counters.
Timing information:
TOF counters at the end of the tracking volume
Track residuals from COT drift time measurements
EM Timing system: measures arrival time of electrons and photons in the calo
Fermiophobic Higgs

In some extensions of the SM \( \text{BR}(h \rightarrow \gamma \gamma) \) can be \( \sim 1 \) since only \( h \rightarrow V V (V=W,Z) \) exists.

An example is the 2H doublet model (e.g. SUSY) with mixing between the CP even \( h^0 \) and \( H^0 \) \( \alpha = \pi/2 \).

\( \text{DØ} \): searches for peaks in \( M_{\gamma\gamma} \)

Background: jets faking photons separated by their shapes in the CPS.
GMSB

Signal: 2 photons and MET
Background: mainly instrumental
mismeasured MET from $\gamma\gamma$
jets faking photons

Photon pointing algorithm developed
using em cluster centroids and CPS
helps choosing primary vertex

$N_5=1$, $\tan\beta=15$, $\mu>0$, $M_m=2\Lambda$
$C_{grav}$ chosen for prompt decays

$m_{\chi^\pm} < 229$ GeV
$m_{\chi^0} < 125$ GeV
excluded
GMSB $N_5=1$, $\tan\beta=15$, $\mu>0$, $M_m=2\Lambda$

$C_{\text{grav}}$ chosen for long decaytime

Signal: $E_T^\gamma>30$ GeV, MET$>40$ GeV, $E_T^j>35$ GeV

Bg: SM (misID $\gamma$, $W\rightarrow e\nu$), cosmics, beam halo

Selected by: $2\text{ns} < t_c^\gamma = t_f^\gamma - t_i^\gamma - \frac{|\bar{x}_f - \bar{x}_i|}{c} < 10\text{ns}$

Observed: 2 events
Predicted: $1.25\pm0.66$
GMSB

Long-lived $\chi_1^0 \rightarrow \tilde{G} + Z$

$\chi_1^0$ can travel several meters
The displaced vertex is reconstructed by the tracker (CDF)
or using the calorimeter and CPS (DØ)

For long-lived particles
excess of $R_{xy} > 0$ expected
Not observed in data

$\text{Bg estimated from } R_{xy} < 0$

Cross section x BR limits

$\sigma \times \text{Br} \text{ (pb)}$

- $M_{ee} > 20 \text{GeV, MET} > 30 \text{GeV}$: $DØ$ 1.1 fb$^{-1}$
- $20 < M_{ee} < 40 \text{GeV}$
- $40 < M_{ee} < 75 \text{GeV}$
- $M_{ee} > 75 \text{GeV}$ $b'$
Several meters of lifetime have been excluded for $b' \rightarrow Z + b$ ($m_{b'} < m_t$)
GMSB

These staus live long (CMSP) appear as muons in the detector, but they are slower: \( v \sim p/E \)
Speed significance (sps): \( (1-v)/\sigma_v \)
\( \sigma_t \sim 2-3 \text{ ns in D0 muon detector} \)

Select: 2 muons \( p_T > 15 \text{ GeV} \)

at least 1 muon isolated cosmic ray veto

sps > 0 for both muon
cut optimized in the \( M_{\mu\mu} \) vs sps_1 * sps_2 plane depending on the CMSP mass

Background are muons of missmeasured time: estimated from data \( Z \rightarrow \mu \mu \) (sps<0)

Data is compatible with expectation of the SM
No event observed for \( M_{\text{CMSP}} \geq 100 \text{ GeV} \)
typical background: \( 0.60 \pm 0.05 \)
(depending slightly on the mass)

95% upper limits on stau pair production
No mass limit yet
AMSBS

Long-lived chargino pair production

if $M_{\chi^\pm} - M_{\chi^0} \leq 150\text{ MeV}$

DØ reinterpreted the search for GMSB staus

Exclude $M_{\chi^\pm} < 140\text{ GeV}$ (higgsino-like)

Exclude $M_{\chi^\pm} < 174\text{ GeV}$ (gaugino-like)
CHAMP

Search for charged, massive stable particles (stop)

Select: 2 high $p_T$ ($p_T > 40$ GeV)
slow ($v < 0.9$)
penetrating (muon-like) tracks
Reject cosmics
Calculate mass: $M^2 = p^2(1/v^2-1)$

1 event remains beyond $M > 100$ GeV
Distribution agrees with bg prediction

Determine: $v = d_{TOF}/(t_{TOF}-t_0)$
t_0 from $p_T < 20$ GeV particles in TOF and in COT track residuals

Estimate background by convoluting $p^2$ and $1/v^2-1$ distributions of particles
with $20 < p_T < 40$ GeV (mainly $W \rightarrow l\nu$)

CDF Run II Preliminary

$M_{\tilde{t}} < 250$ GeV excluded

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CDF Run II Preliminary

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Search for anomalous production of $\gamma+b+j+\text{MET}$

From chargino-neutralino pair-prod: $\chi_1^+\chi_2^0 \rightarrow (b\bar{t})(\gamma\chi_1^0) \rightarrow (bc\chi_1^0)(\gamma\chi_2^0) \rightarrow \gamma bc\text{MET}$

Select: photon $E_T > 25$ GeV, 2 jets (1b-tag) $E_T > 15$ GeV, MET $> 25$ GeV

Photons and jets are separated by shape in the shower-maximum detector (low ET) and in the preshower (high ET)

HF are separated by the mass templates of the secondary vertex

No excess has been found beyond the SM background
Conclusions

Photonic final states and long-lived particles are powerful tools for searching new physics at the Tevatron.

The excellent performance of the collider and detectors together with innovative methods in the analyses allowed to study these topologies.

No evidence for new physics has been found so far.

New domains have been excluded thereby shrinking considerably the allowed parameter space.
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More information can be found on:
http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm
http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm
http://www-cdf.fnal.gov/physics/exotic/exotic.html