Search for Supersymmetry in Trilepton Final States with the D0 detector

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- SUSY, Tri-lepton & Like Sign final states
- ee+track analysis
- Like Sign Muon analysis
- Limits
- Conclusions and Outlooks
The Standard Model (SM) is believed not to be a fundamental theory and Super Symmetry is one possible extension to the SM. Super symmetric particles and their SM partners differ in spin by 1/2.

**mSUGRA**: SUSY model with few parameters at GUT scale:

- $m_0$: Masses of scalars $\rightarrow$ sfermion masses
- $m_{1/2}$: mass of fermions
- $\tan \beta$: ratio of Higgs vacuum expectation values
- $\mu$: Higgsino mass parameter
- $A$: trilinear coupling $(\text{Higgs-Sfermion}_L - \text{Sfermion}_R)$
THREE LEPTON FINAL STATE

SUSY characteristica: Two electrons or muons + a third lepton and significant missing transverse energy.

Look for high quality track or Like Sign muons to increase efficiency

- charginos and neutralinos decay via gauge bosons or sfermions to LSP and SM particles.
- R-parity conserving models $\Rightarrow$ stable LSP
- LSP escapes detection in the detector
This is a continuation and extension of the earlier result published by D0 (PRL 95, 151805 (2005)) with $\int \mathcal{L} = 320 \text{ pb}^{-1}$
### SM Backgrounds: ee+track

| # leptons | true ET-miss | xsec(pb) | Remarks                              |
|----------|--------------|----------|--------------------------------------|
| Signal   | 3            | Yes      | 0.18                                 |
| WZ → III ν | 3            | Yes      | 0.1126 signal like                    |
| ZZ → II XX | 2 – 4        | Both     | 0.0710 Misidentified lepton / mismeasured Etmiss |
| WW→ II ν ν | 2            | Yes      | 1.2411 fakes                          |
| W→l ν + γ /jet | 1     | Yes      | 2500 fakes                           |
| (Z / γ ->II + γ /jet) | 2  | No       | 250-400 fakes, mismeasurement          |
| ttbar → II +2jets | 2 | Yes      | 0.7300 fakes, mismeasurement          |
| qqbar → jets | 0 | No       | fakes, mismeasurement                 |

- **Start by requiring two leptons in the event.**
- **Other important cuts:** Missing Transverse Energy, require a third, isolated track in the event.
18 GeV < M(e,e) < 60 GeV

MET > 22 GeV
large MET caused by poorly measured electron energy will be in the same direction as the lepton => small values of MT.

\[ MT = \sqrt{2 \text{MET} \cdot p_T \cdot (1 - \cos(\Delta \phi(\text{MET}, p_T)))} \]
To increase efficiency, a track is required instead of lepton.

Isolation in tracker and calorimeter is required to reject background from jets.

- $\sum p_T$ of other reconstructed tracks in a hollow cone around track $< 1 \text{ GeV}$
- efficient for $e, \mu, \tau$ (1 prong, 3 prong)
## CUT FLOW ee+track

| Cut                           | Data  | SM Expected    | MSUGRA example |
|-------------------------------|-------|----------------|-----------------|
| Preselection                  | 118518| 113592±119     | 18              |
| Anti-Z                        | 17459 | 18306±89       | 13              |
| Third track                   | 776   | 650±18         | 7.6             |
| MET                           | 2     | 1.97±0.73      | 4.64            |
| MET x PT(3.track)             | 0     | 0.76±0.67      | 3.45            |

- **Signal efficiency** 2.6% relative to lepton events with all flavour combinations
- **Error dominated by statistical uncertainty**
Important Standard Model background:

- multijet from QCD processes (b-bbar)
- Z/\gamma +\gamma/\text{jet} \rightarrow \ell\ell+\gamma/\text{jet}, \ W+\gamma/\text{jet} \rightarrow \ell\nu+\gamma/\text{jet}, \ tt\rightarrow\ell\ell+\text{jets}
- WZ\rightarrow\ell\nu\ell, \ ZZ\rightarrow\ell\ell\text{XX}, \ WW\rightarrow\ell\ell\gamma\gamma

**Preselection:** Muon ID, two isolated LS \( \mu \), \( P_T > 5 \text{ GeV} \), \( \Delta \phi(\mu,\mu) < 2.9 \)

**Anti-QCD:** \( P_T(\mu_1) > 13 \text{ GeV} \), \( 35 \text{ GeV} > P_T(\mu_2) > 8 \text{ GeV} \)

**Anti-WZ:** \( 25 \text{ GeV} < M(\mu,\mu)_\text{OS} < 65 \text{ GeV} \) if OS

**Anti-Z:** \( 12 \text{ GeV} < M(\mu,\mu)_\text{LS} < 110 \text{ GeV} \)

**Large MET:** \( \text{MET} > 10 \text{ GeV} \), \( 65 \text{ GeV} > \text{Transv. mass (}\mu_2,\text{MET}) > 15 \text{ GeV} \), \( \text{MET} > 12 \times \sigma(\text{jet||MET}) \)

**MET x \( P_T(\mu_2) \):** \( > 160 \text{ GeV}^2 \)

Last 5 cuts used in optimization for best \( \sigma \times \text{Br} \)
D0 Run II preliminary, 0.9 fb⁻¹

| Cut         | Data  | SM Expected   | MSUGRA example |
|-------------|-------|---------------|----------------|
| Preselection| 15234 | 14922±981     | 8.4±0.6        |
| Minv OS     | 3569  | 3479±232      | 7.6±0.6        |
| Minv LS     | 2     | 2.9±0.8       | 5.7±0.5        |
| MET         | 1     | 1.7±0.6       | 4.6±0.4        |
| MET x PT(µ2)| 1     | 1.1±0.4       | 4.0±0.4        |

17 % QCD
20 % W
17 % WZ
9 % WW
15 % ZZ
15 % Zb b
Combination of $ee+l$ and LS muon with older D0 mu mu and e mu:
- upper limit $\sigma \times \text{BR}(3l)$ (modified freq., overlap subtracted from weakest analysis)

Chargino mass limit of 140 GeV in scenario with enhanced BR into leptons:
- $(3l$-max, $m$(slepton) > $m$(neu2))

- large $m_0$: W/Z exchange dominates (small $\text{Br}(3l)$)
- heavy-squarks: maximal cross section, t-channel contribution from squarks relaxing scalar mass unification
Light sleptons $\Rightarrow$ two body decays into letpons and LSP $\Rightarrow$ soft lepton

Significant improvement

Limit stable as a function of mass
CONCLUSION and OUTLOOK

Starting to probe difficult region of phase space with more luminosity.

- NO SUSY OBSERVED => LIMIT SET
- Combine ee+track and Like Sign muon with mumu+track and e+mu+track
- ROOM FOR IMPROVEMENTS
BACK UP
- Fermilab, Batavia, IL
- 1 km radius
- 2 experiments: CDF and DØ
- Run I (1992-1995)
  \[ \sqrt{s} = 1.8 \text{ TeV} \]
  \[ \int L \cdot dt = 125 \text{ pb}^{-1} \]
- Run II (since 2002)
  \[ \sqrt{s} = 1.96 \text{ TeV} \]
  \[ \int L \cdot dt = 1.5 \text{ fb}^{-1} \text{ recorded so far} \]
- Run II b just started -> upgrade of D0 and accelerator
Preselection: Electron-identification, 2 electrons with $P_T > 12$ GeV + 8 GeV

Anti-Z/DrellYan-$\rightarrow$ll: $M(Y) << M(e,e) << M(Z)$, $\Delta \phi (e,e) < 2.9$

Anti Top: Sum Jet-$P_T < 80$ GeV

Well identified third track, $P_T > 4$ GeV, isolation in tracker and calorimeter

Large MET: $MET > 22$ GeV, Transv. mass $(e,MET) > 20$ GeV, $MET > 8 \times \sigma(jet||MET)$

2-D cut: $MET \times P_T(3. \ track) > 220$ GeV$^2$
3\textsuperscript{rd} LEPTON -> isolation

- efficient for $e$, $\mu$, $\tau$ (1 prong, 3 prong):
Large slepton masses -> decay via W/Z dominates

$m(\text{slepton}) < m(\text{neu2})$: two body decays of neu2 -> slepton + lepton
  
  => very soft third lepton

Instead of requiring two leptons + track
  
  => require two leptons of same sign

Two QCD samples:
  
  one tight and one loose muon (sample S)
  
  one tight and one that fails loose cuts (sample Q)

Re-weight sample Q as a function of transverse momentum in a QCD enriched region of phase space ($\Delta \phi > 2.9$).
OPTIMIZATION OF CUTS

- Optimization of cuts performed to obtain a best expected limit on $\sigma \times \text{BR}(3l)$
- SUSY point with very soft third lepton used in the optimization