Run II Searches for Supersymmetry

Dave Toback
Texas A&M University
Structure

- SUSY searches at the Tevatron focus on mSUGRA/MSSM, GMSB and RPV
- Present every Run II result from first 200 pb\(^{-1}\) using COLOR code

**Minor excesses or interesting events which I’ll be keeping my eye on as the dataset doubles, quadruples or goes up by an order of magnitude**

**New world’s best limit**

**Hot off the presses result**
Overview of Results

• CHAMP Searches
• Jets + Met Searches
• Multi-lepton Searches
• Diphoton+Met Searches
Search for long-lived charged particles using Time-of-Flight system

Particles behave like slow, but high $P_T$ muons

$2.9\pm0.3\text{(stat)}\pm3.1\text{(sys)}$ expected from instrumental mis-measurement

Observe 7
- Small excess...Lots more data already taken and being analyzed

Track $P_T>18$ GeV
$L = 53\text{ pb}$

Cut on TOF (nsec)

Final cut here
CHAMPS: Results and Limits

- Lots of theories predict CHAMPS
  - Stop
  - Staus
  - Charginos
  - Sleptons
- New limits on Stop at 107 GeV which is the new world limit
- Nice complement to the Run I decay based searches for Stop

L = 53/pb

Excluded by ALEPH
Search for New Physics in Jets+Met

- Direct searches for Squarks and Gluinos in jets+Met final state
- Two searches at the Tevatron with preliminary results
  - Light-quark jets+Met
  - Heavy flavor jets+Met
- Extend sensitivity beyond LEPs kinematic reach
Light-quark jets+Met

• Squarks and Gluinos produce acoplanar jets + Met
  • Require:
    - At least two large jets
    - Total $H_T$ > 275 GeV
    - Met > 175

• $2.67 \pm 0.95$ expected

• 4 events observed in the data

Background predictions dominated by Electroweak not QCD

Z → νν + 2jets
W → τν + jet

Final Cut here
The interesting event on the tail

Kinematics:
• 2 big jets: $E_T=289$ GeV and 117 GeV
• 2 little jets: $E_T=14$ GeV and 11 GeV
• Met=381 GeV

Expect 1 event above 300 GeV; $\sim\frac{1}{4}$ above 350 GeV

Background dominated by $Z\rightarrow\nu\nu+\text{jets}$

Doesn’t particularly look like signal or background
• Set limits in mSUGRA scenario
• New gluino mass limit at 333 GeV (for a squark mass of 292 GeV) extends previous world’s best

![Graph showing limits on gluino mass and cross-sections]

mSUGRA model with $M_0 = 25 \text{ GeV/c}^2$, $A_0=0$, $\tan B = 3$, $\mu < 0$, varying $M_{\frac{3}{2}}$

Excluded by CDF Run I

Gluino Mass (GeV/c$^2$) vs. Cross-section (pb)
Search for Sbottom Squarks

- Gluinos decay into Sbottom quarks and produce $b$-jets and Met
- Two separate analyses:
  1. Single-tag + Met:
     Back = $16.4 \pm 3.6$
     Observe 21
  2. Double-tag + Met:
     Back = $2.6 \pm 0.7$
     Observe 4
- Backgrounds dominated by Top quark pairs
  ~1/2 event expected above 125, 2 observed

Final Cut: Met > 80 GeV
New limits are not sensitive to when Sbottom mass is close to the LSP mass. LEP sensitivity is still best there.

Gluino production allows significant extension of the best limits at high mass Sbottom and low mass neutralinos.

\[ \text{Sbottom Mass (GeV)} \]

\[ \text{Gluino Mass (GeV)} \]

\[ \text{CDF Run I} \]

\[ \text{CDF Run II} \]

\[ \text{L = 156/pb} \]
Multi-lepton searches

Multi-lepton final states have been a staple of SUSY searches for many years

- Low mass indirect searches in $B_S \rightarrow \mu \mu$
- High mass resonance searches for RPV Sneutrinos
- Chargino/Neutralino Pair-production and decay
$B_s \rightarrow \mu \mu^*$

- Indirect search for SUSY via loop diagrams which affect the branching ratio by one to three orders of magnitude.
- Search in $4\sigma$ mass window around known world average and optimize using topology cuts
- $1.1\pm0.3$ events expected
- 1 Event observed

*Accepted for publication in PRL*
• $\text{Br}_{\text{SM}} = 3.5 \times 10^{-9}$
• Previous best limit at $2.0 \times 10^{-6}$ (CDF Run 1)
• New Limit: $\text{Br}(B_s \rightarrow \mu\mu) = 7.5 \times 10^{-7}$ → World’s best
• No official model interpretation

*Blow up of example from previous talk by A. Belyaev
High Mass Resonance Searches

- Tevatron searches for resonances in ee and $\mu \mu$ have been done for many years for $Z'$, E6, Higgs, Technicolor etc. (See talks by M. Gold/M. Karagoz)
- New interpretation in terms of RPV Sneutrino production and decay.
- First limits for large masses

$L = 200/\text{pb}$
Chargino/Neutralino Pair Production

- Chargino/Neutralino pair production can produce three leptons + Met
- Since the end of Run I, LEP has significantly improved the limits
- Three new results in this mode:
  - Like- sign muons
  - Two electrons + lepton
  - Electron + Muon + lepton

Gold plated signature of mSUGRA for low tanb
Like-Sign Muons

Increase acceptance by only requiring two out of three leptons
Reduce background by requiring them to be like-sign
- $P_T^1 > 11$ GeV
- $P_T^2 > 5$ GeV
- $M_{\mu\mu} < 80$ GeV

In 147/pb:
Predict $0.13 \pm 0.06$
1 Observed

- Backgrounds dominated by WZ (0.07) and bb (0.04)
- No third lepton candidate $\rightarrow$ bb?
Electron+Muon+lepton

Require:
- Electron > 12 GeV
- Muon > 8 GeV
- Met > 15

Look for a third isolated track: e, μ or τ

Predict 0.5±0.2

0 observed

L = 158/\text{pb}
Two-electrons+lepton

Two high $P_T$ isolated $e$'s, a 3rd lepton (high $P_T$ isolated track) and $\text{Met}$

Predict 0.3 $^{+0.4}_{-0.3}$
Observe 1 event

$\text{Met} \times P_T(3\text{rd Track}) > 250 \text{ GeV}^2$

Electron $E_T = 33 \text{ GeV}$ and $26 \text{ GeV}$
Track $P_T = 8.6 \text{ GeV}$
$\text{Met} = 52.1 \text{ GeV}$
Background dominated by $WW$, but is likely $W\gamma$ where the photon converted
Combine results to set limits

• All three searches are optimized for the region above the LEP limits

• Combined result produces the most stringent limits from the Tevatron to date

• Significant improvement over Run I results, but no extension of the exclusion region from LEP (yet)
GMSB Searches in Two Photons+Met

- In Run I CDF found an eeγγ+Met candidate event
- Extensive searches for similar events at LEP and the Tevatron produced no other interesting events
- New results from CDF and DØ which optimize for GMBS \( \chi^0 \rightarrow \gamma G \) scenario
CDF (202/pb)

E_T>13 GeV, Met>45 GeV
Predict 0.6±0.5
0 Observed

DØ (185/pb)

E_T>20 GeV, Met>40 GeV
Predict 2.5±0.5
1 Observed
Limits on GMSB with $\tilde{\chi}^0 \rightarrow \gamma \tilde{G}$

CDF (202/pb)

DØ (185/pb)

New world best limit!

$\Lambda > 78.8$ TeV
Chargino mass $> 192$ GeV
Neutralino Mass $> 105$ GeV
Interesting Event

- Event is in data later than previous result, but is interesting nonetheless
- $E_T$ of photons: 69 & 27 GeV
- $E_T$ of electron 24 GeV
  - All well measured & well separated
- Met=63 GeV

$W_{\gamma\gamma}$?
Cousin of CDF $ee_{\gamma\gamma}$Met?
If all “$ee_{\gamma\gamma}$Met” favored SUSY parameter space is nearly excluded, then what is it?
Conclusions

• It’s an exciting time to be at the Tevatron as it is the high energy frontier for the next $N$ years.

• Preliminary results on the first 200 pb$^{-1}$ are starting to come rapid-fire with first publications already submitted & accepted.

• Many of these results are the world’s most sensitive.

• Results on the next 200 pb$^{-1}$ are in the pipeline and the detectors and the Tevatron continue to improve and provide new sensitivity.

• Lots of interesting things to keep our eyes on in the coming year...