SEARCH FOR SCALAR TOP AND BOTTOM QUARKS AT THE TEVATRON

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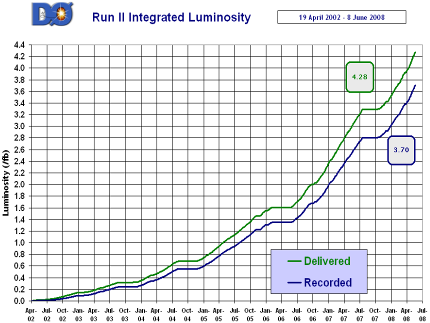
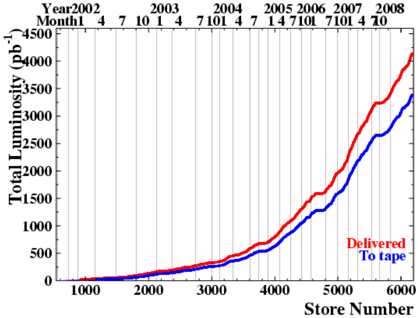
Outline

- Luminosity at DØ and CDF
- Scalar top ($\tilde{t}$), bottom ($\tilde{b}$): production and decay at the Tevatron
- Search for scalar bottom:
  - Search for $\tilde{g}$-mediated $\tilde{b}$ production in the b-jets+$\not{E}_T$ final state
- Searches for scalar top:
  - Search for $\tilde{t}$ pair-production in the acoplanar c-jets+$\not{E}_T$ final state
  - Search for $\tilde{t}$ pair-production in the $b\bar{b}e^{\pm}\mu^{\pm}\tilde{\nu}\bar{\tilde{\nu}}$ channel
  - Search for $\tilde{t}$ pair-production in the $t\bar{t}$ lepton+jets signature
  - Search for $\tilde{t}$ pair-production in the $t\bar{t}$ di-lepton signature

Luminosity at DØ and CDF

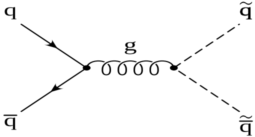


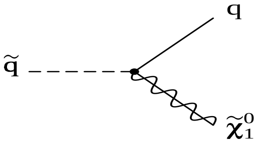


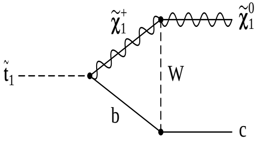
- The instantaneous luminosity has been increasing significantly
- The integrated luminosity recorded at CDF and DØ has reached nearly 3.5 fb^{-1} ($\sim$4 fb^{-1} delivered)
- Analyses shown today include integrated luminosities from 1 to 1.9 fb^{-1}

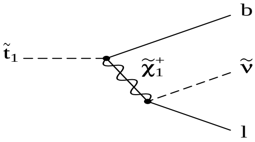
$\tilde{\mathrm{b}}$ and $\tilde{\mathrm{t}}$ production and decay at the Tevatron

- In the following, MSSM with conserved R_p
- $\tilde{b}$,$\tilde{t}$ production via strong coupling
  $\Rightarrow$ large $\sigma_{production}$
- Large $\tan\beta \Rightarrow$ large mass splitting in $\tilde{b}$ sector, maybe $m_{\tilde{b}}$ within reach of Tevatron
- Large $m_t \Rightarrow$ large mixing of $\tilde{t}_L/\tilde{t}_R$ and maybe $m_{\tilde{t}} \ll m_{\tilde{q}}$ within reach of Tevatron
- $\tilde{b}$ decay: $\tilde{b} \to b\tilde{\chi}_1^0$
- $\tilde{t}$ decay:
  - $\tilde{t}_1 \to t\tilde{\chi}_1^0$ kinematically forbidden (in interesting parameter region)
  - $\tilde{t}_1 \to b\tilde{\chi}_1^+$
  - $\tilde{t}_1 \to c\tilde{\chi}_1^0$
  - $\tilde{t}_1 \to b\ell\tilde{\nu}$
- HF-tagging provides efficient background suppression





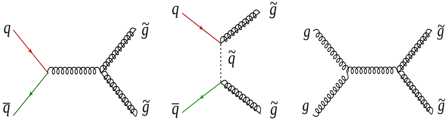


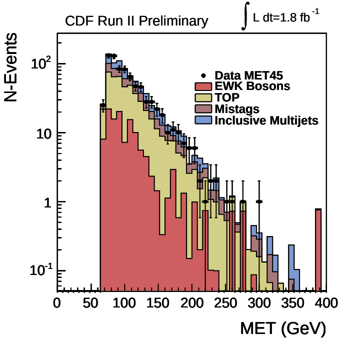


Search for $\tilde{g}$-mediated $\tilde{b}$ pair-production in the 4 b-jets + $\not{E}_T$ channel

- Preliminary result, May 2008
- $\mathcal{L} = 1.8\ \text{fb}^{-1}$
- Assumptions:
  - LSP $= \tilde{\chi}_1^0$ $m_{\tilde{\chi}_1^0} = 60$ GeV
  - $\tilde{b}$ light enough, $m_{\tilde{q}} = 500$ GeV $\Rightarrow Br(\tilde{g} \to b\tilde{b}) = 100\,\%$
  - $m_t, m_{\tilde{\chi}^+} > m_{\tilde{b}} > m_{\tilde{\chi}^0}$ $\Rightarrow Br(\tilde{b} \to b\tilde{\chi}^0) = 100\,\%$
- Require at least one b-tagged jet
- Main backgrounds: $t\bar{t}$ (PYTHIA) + QCD multi-jet (HF+mistag)
- QCD multi-jets contribution estimated from QCD enriched data sample (jet$_2$ and $\not{E}_T$ aligned in ϕ)

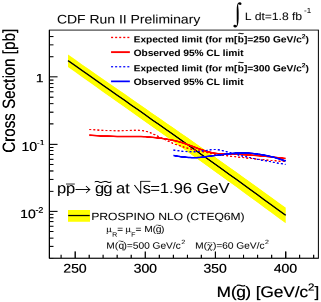
- $\sigma^{\tilde{g}\bar{\tilde{g}}}_{production} > \sigma^{\tilde{b}\bar{\tilde{b}}}_{production}$

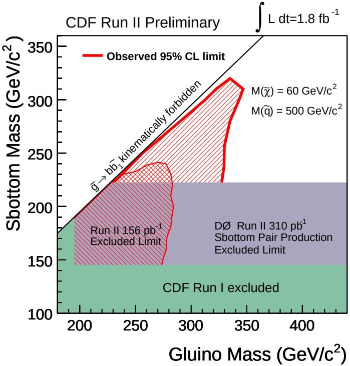




Search for $\tilde{g}$-mediated $\tilde{b}$ pair-production in the 4 b-jets + $\not\!\!E_T$ channel

- Two signal optimization regions: $\left(\frac{m_{\tilde{g}}}{\mathrm{GeV}}, \frac{m_{\tilde{b}}}{\mathrm{GeV}}\right) = (320{,}250)$ and $(300{,}280)$
- Iterative selection cuts over most discriminant variables using $\frac{S}{\sqrt{B}}$ as discriminant
- Main systematics:
  - b-tagging: 4.8% (mistag rate)
  - $t\bar{t}$ production cross section: 11%
  - QCD multi-jet: 50%
- $\sigma_{limit} < 0.1\,\mathrm{pb}$ at 95%C.L.

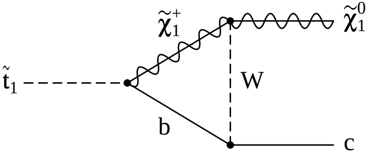




DØ Search for $\tilde{t}$ pair-production in the acoplanar 2 c-jets + $\not{E}_T$ channel

- Published, *Phys.Lett.B665:1-8,2008*
- $\mathcal{L} = 1\ \text{fb}^{-1}$
- Assumptions:
  - LSP $= \tilde{\chi}_1^0$
  - $\begin{cases} m_{\tilde{t}} < m_{\tilde{\chi}_1^+} + m_b \\ m_{\tilde{t}} < m_W + m_b + m_{\tilde{\chi}^0} \end{cases}$
  - $Br(\tilde{t} \to c\tilde{\chi}_1^0) = 100\,\%$
- Use jets+$\not{E}_T$ triggers
- Main backgrounds: W/Z+jets (ALPGEN)
- QCD multi-jet contribution estimated from data

- Flavor changing decay process:



- To remove instrumental background:

$$\begin{cases} \frac{\not{E}_T - \not{H}_T}{\not{E}_T + \not{H}_T} > -0.05 \\ \Delta\phi_{max} - \Delta\phi_{min} < 120\,^{\circ} \end{cases}$$

$\not{H}_T = \not{E}_T$ computed only from jets
$\Delta\phi$ = separation between jet and $\not{E}_T$

DØ Search for $\tilde{t}$ pair-production in the acoplanar 2 c-jets + $\not{E}_T$ channel

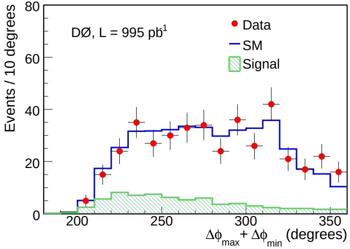
- Require at least one HF-tagged jet

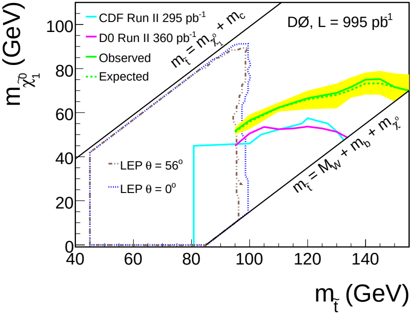
  Neural network tagger: $\begin{cases} \mathcal{E}_c \simeq 30\% \\ \mathcal{E}_{fake} \simeq 6\% \end{cases}$

- Final selection achieved with:

  $\begin{cases} \not{E}_T \\ \Delta\phi_{max} + \Delta\phi_{min} \\ H_T = \sum_{jets} p_T \end{cases}$

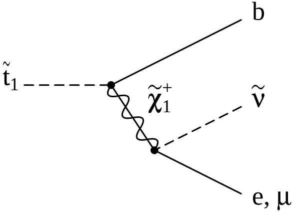
- Signal enhancement by maximizing expected lower limit on $m_{\tilde{\chi}_1^0}$ for given $m_{\tilde{t}}$
- Main systematics:
  - Trigger: 6%
  - HF tagging: 4.1% (bgd), 3.5% (signal)
  - Background normalization: 10%
  - PDF: 4% (bgd), +8.7/-5.5% (signal)
- Largest limit: $m_{\tilde{t}} > 150$ GeV

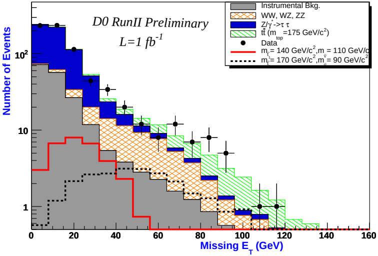




Search for $\tilde{t}$ pair-production in the $b\bar{b}e^{\pm}\mu^{\pm}\tilde{\nu}\bar{\tilde{\nu}}$ channel

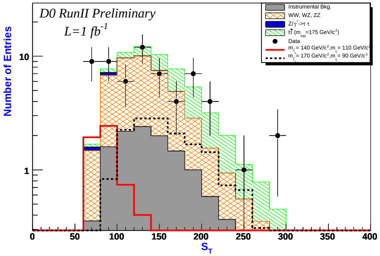
- Preliminary result, April 2008
- $\mathcal{L} = 1.1\ \text{fb}^{-1}$
- Assumptions:
  - LSP $= \tilde{\nu}$
  - $Br(\tilde{t}_1 \rightarrow b\ell\tilde{\nu}) = 100\,\%$ (decay through a virtual $\tilde{\chi}^+$)
- Use of low-p_T $e\mu$ triggers
- Main backgrounds: WW, $t\bar{t}$ (PYTHIA) and instrumental backgrounds, estimated from data (mis-identified leptons and jets, QCD multi-jet events mis-measured $\not{E}_T$)
- No b-tagging

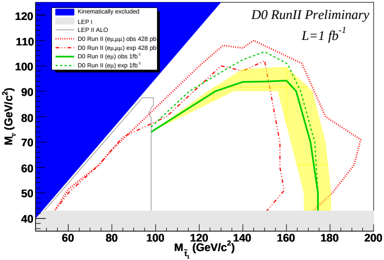




Search for $\tilde{t}$ pair-production in the $b\bar{b}e^{\pm}\mu^{\pm}\tilde{\nu}\bar{\tilde{\nu}}$ channel

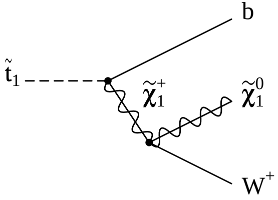
- Selection cuts based on $\Delta\Phi$ between lepton and $\not{E}_T$, and $M_T(\ell, \not{E}_T)$
- Limit setting via CL_s method
  Use of 12 bins:
  $$\begin{cases} \text{3 bins from } S_T = p_T^{\mu} + p_T^{e} + \not{E}_T \\ \text{4 bins from } H_T = \sum_{jets} p_T \end{cases}$$
- Main systematics:
  - Jet energy scale: 12-16%
  - PDF: 6%
  - electron ID, instr. bgd: $\simeq$ 5%
- Expected sensitivity increased by ∼15 GeV w.r.t previous ($e\mu$,$\mu\mu$) analysis



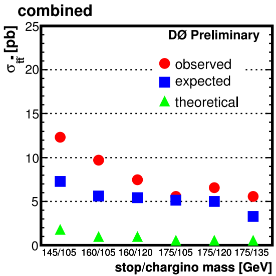


Search for $\tilde{t}$ pair-production in the $t\bar{t}$ lepton+jets channel

- Preliminary result, July 2007
- $\mathcal{L} \simeq 1\ \text{fb}^{-1}$
- Assumptions: LSP $= \tilde{\chi}_1^0$ and $m_{\tilde{t}} \leq m_t$
- $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm} \to b\tilde{\chi}_1^0 W^{\pm}$
- One W decays to hadrons, the other one to leptons
- Combine e+jets and μ+jets channels
- Main backgrounds: $t\bar{t}$ (PYTHIA) and W+jets (ALPGEN)
- W+jets normalized to data
- At least one b-tagged jet
- Limit setting via Bayesian approach using a likelihood based on kinematic and constructed quantities as signal/background discriminant



- $\sigma^{\tilde{t}\bar{\tilde{t}}}_{production}$ upper limits:

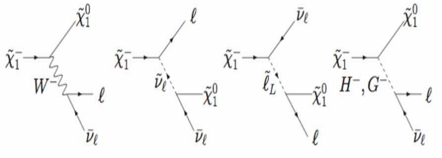


σ_{limit} ~7-12 times higher than prediction

Search for $\tilde{t}$ pair-production in the $t\bar{t}$ di-lepton channel

- Preliminary result, April 2008
- $\mathcal{L} = 1.9\ \text{fb}^{-1}$
- Assumptions:
  - $\text{LSP} = \tilde{\chi}_1^0$
  - $m_{\tilde{t}} \leq m_t$
  - $m_{\tilde{\chi}^{\pm}} \leq m_{\tilde{t}} - m_b$

  $\Rightarrow \tilde{t}_1 \to b\tilde{\chi}_1^+$
- if $m_{\tilde{\chi}_1^{\pm}} - m_{\tilde{\chi}_1^0} < m_{W^{\pm}}$:



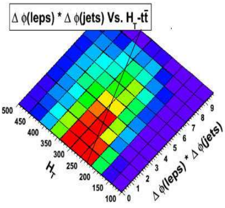
otherwise: $Br^2(\tilde{t}_1 \to b\tilde{\chi}_1^0 \ell\nu) = 0.11$
(same as for top events)

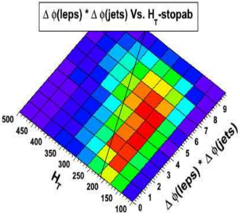
- Combine ee, $\mu\mu$ and $e\mu$ channels

- Main backgrounds: $t\bar{t}$ (PYTHIA) and Z/γ^* (ALPGEN)
- Z/γ^* normalized to data under the Z resonance
- Event Selection:
  - Z-veto by requiring: $\frac{\not\!\!E_T}{\sqrt{\sum E_T}} > 4$ GeV
  - $t\bar{t}$ suppression by imposing:

$$H_T < 215 + \frac{\Delta\Phi(jet_0, jet_1)\Delta\Phi(\ell_0, \ell_1)}{\pi^2} \times 325$$

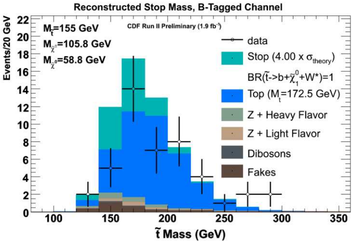
$$(H_T = \textstyle\sum_{all\ objects} p_T)$$



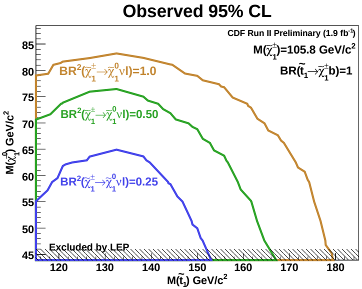


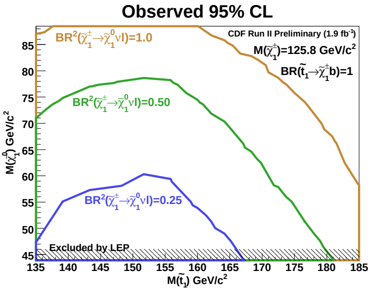
Search for $\tilde{t}$ pair-production in the $t\bar{t}$ di-lepton channel

- 2 signal regions:
  - at least one *b*-tagged jet,
  - anti-tagged jets, with slightly tighter selection cuts
- $m_{\tilde{t}}$ reconstruction using method similar to top mass in di-lepton channel with $\nu \leftrightarrow (\tilde{\chi}_1^0 + \nu)$



- CL_s limit setting technique using the reconstructed stop mass as discrimiant





Conclusion

- No evidence of scalar top or scalar bottom by either DØ or CDF, but significant improvement of limits and new channels investigated
- BSM signal with characteristic topologies involving *leptons*, *jets*, and $\not\!\!E_T$
- Results shown based on 1 to 1.9 fb^{-1}

⇒ Prospects for luminosity: up to 10 fb^{-1} by 2009-2010

- For further details, see:

  http://www-cdf.fnal.gov/physics/physics.html
  http://www-d0.fnal.gov/Run2Physics/WWW/results.htm

Search for $\tilde{t}$ pair-production in the top di-lepton channel (BACKUP)

Stop mass reconstruction with method similar to neutrino weighting

- $\tilde{t}_1$ decay: $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm} \to b\tilde{\chi}_1^0 W^{\pm(*)} \to b\tilde{\chi}_1^0 \ell\nu$
- $(\tilde{\chi}_1^0 + \nu)$ = pseudo-particle (PP)
- Assume $M_{PP} = M_{PP}^{generator}$, $M_{PP,\ell} = M_{\tilde{\chi}_1^{\pm}}$, and $m_{\tilde{t}_1} = m_{\bar{\tilde{t}}_1}$
- Event kinematics still underconstrained (by 1 constraint)

$\Rightarrow$ ignore $\not{E}_T$, and assume PP Φ and $m_{\tilde{t}_1}$

Minimize following χ^2:

$$\chi^2 = \frac{\left(\vec{\ell}_{meas} - \vec{\ell}_{fit}\right)^2}{\sigma_\ell^2} + \frac{\left(\vec{\bar{\ell}}_{meas} - \vec{\bar{\ell}}_{fit}\right)^2}{\sigma_\ell^2} + \frac{\left(\vec{u}_{meas} - \vec{u}_{fit}\right)^2}{\sigma_{uncl}^2}$$
$$+ \sum_{jets\,i} \frac{\left(\vec{j}_{i_{meas}} - \vec{j}_{i_{fit}}\right)}{\sigma_{jet_i}^2} + \frac{\left(M_{PP_1}^{fit} - M_{PP}^{assume}\right)^2}{\Gamma_{PP}^{gen}}$$
$$+ \frac{\left(M_{PP_2}^{fit} - M_{PP}^{assume}\right)^2}{\Gamma_{PP}^{gen}} + \frac{\left(M_{PP_1,\ell} - M_{\tilde{\chi}^\pm}\right)^2}{\Gamma^{\tilde{\chi}^\pm}}$$
$$+ \frac{\left(M_{PP_1,\bar{\ell}} - M_{\tilde{\chi}^\pm}\right)^2}{\Gamma^{\tilde{\chi}^\pm}} + \frac{\left(M_{PP_1,\bar{\ell},b_{jet}} - M_{PP_2,l,\bar{b}_{jet}}\right)}{\Gamma^{\tilde{t}}}$$

Finally:

$$M_{\tilde{t}_1}^{Reco} = \frac{1}{\sum_{\phi\, i,j} e^{-\chi_{i,j}^2}} \sum_{\phi\, i,j} M_{i,j}^{fit} e^{-\chi_{i,j}^2}$$