SUGRA subsection 4.F: Specific Channel Studies
(*Version 0.1*)

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August 11, 1998

NOTE: This is a brief report of status of the SUGRA analyses as of July 10, 1998. All figures/numbers are subject to update in the next version.

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1 Trilepton ($eee, ee\mu, e\mu\mu, \mu\mu\mu$) analysis:

1.1 Proposed trigger:

Prod.	Signature	Trigger Type	Trigger cuts in p_T or E_T
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$	$(\ell^{\pm}\nu\ \tilde{\chi}_1^0)\ (\ell^+\ell^-\ \tilde{\chi}_1^0)$ [$\tan\beta \lesssim 6$]	$\ell_1\ell_2$	9/6

- Asymmetric p_T cuts for dilepton (Fig. 1)

  √ $\left.\begin{array}{l} p_T(\ell_1) \gtrsim 10\ \mathrm{GeV}/c \\ p_T(\ell_2) \gtrsim\ \ 5\ \mathrm{GeV}/c \end{array}\right\}$ are low enough for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ events with $M \gtrsim 90\ \mathrm{GeV}/c^2$;

  √ Such low-p_T dilepton trigger allows us to study SM processes (Υ, γ^*/Z^0, $t\bar{t}$, $WW/WZ/ZZ$).

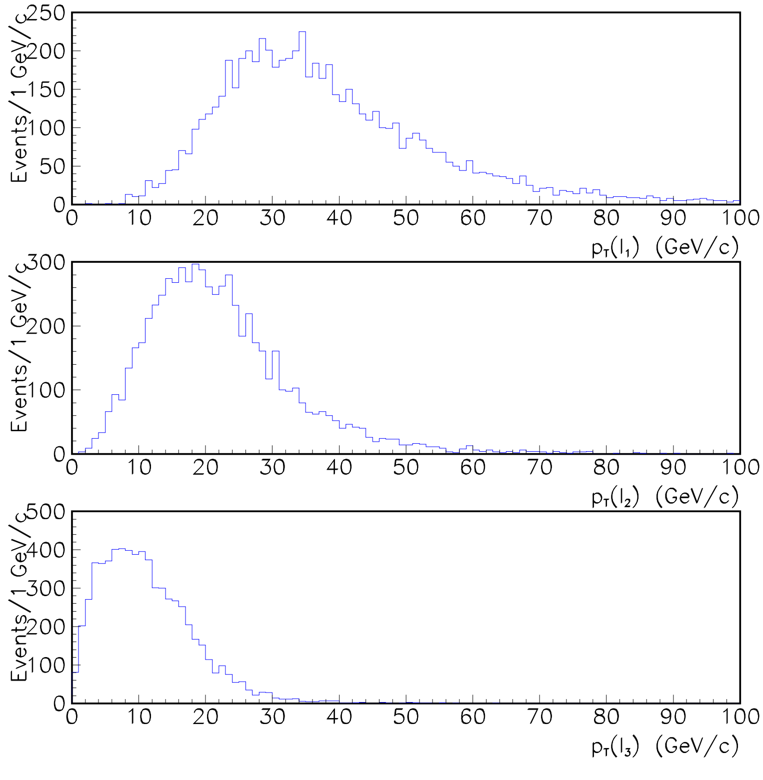


Figure 1: p_T distributions for leptons from $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to 3\ell + X$ events ($M(\tilde{\chi}_1^{\pm}) \simeq M(\tilde{\chi}_2^0) \simeq 100\ \mathrm{GeV}/c^2$) at a generator level.

1.2 Status:

- List of SM backgrounds: In the current analysis, $W + b\bar{b}$ events are not included.

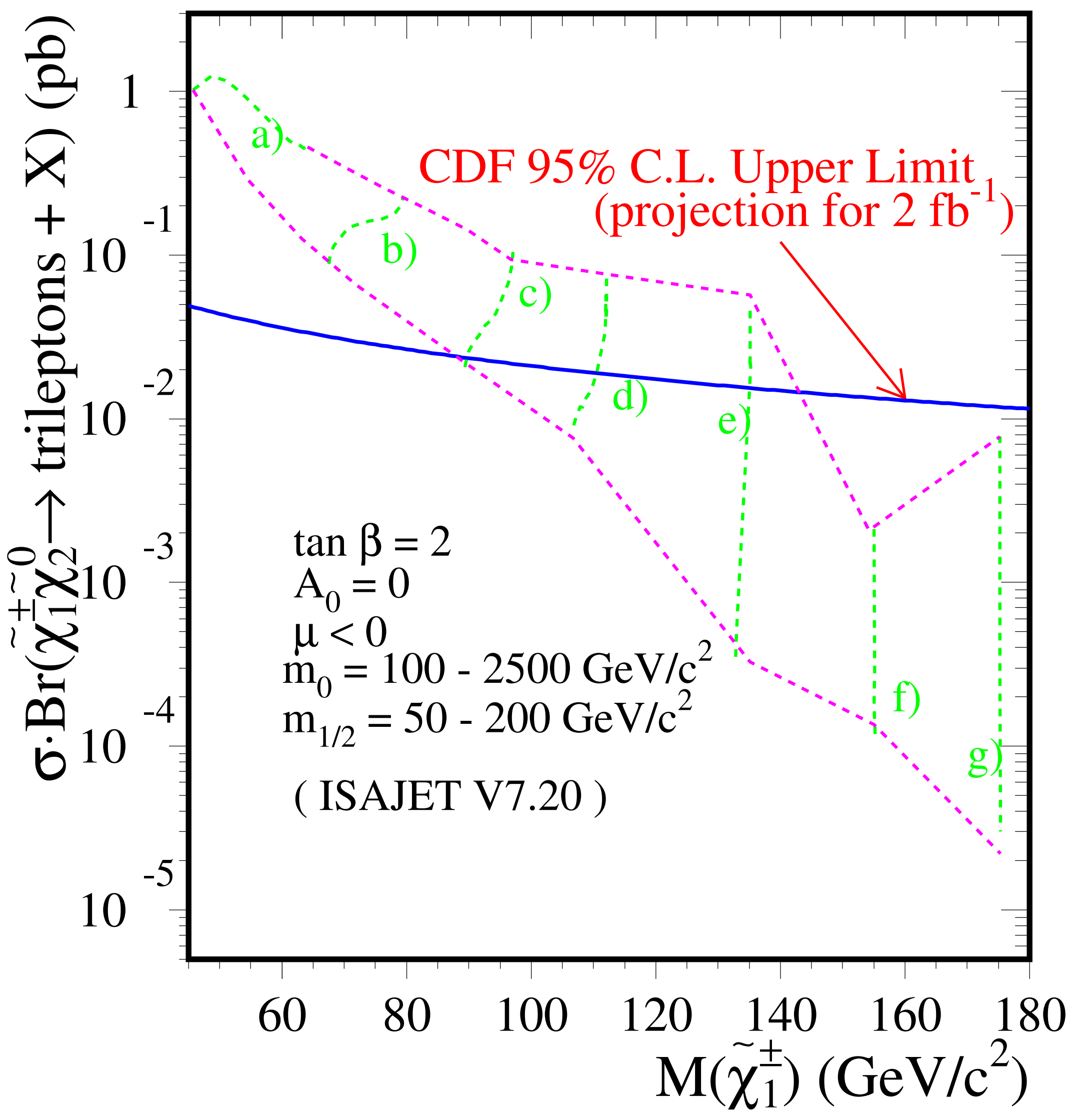
Type	Primary Process	Associated Obj.
Trilepton	$W^\pm Z^0$	—
	$Z^0 Z^0$	—
	$t\bar{t}$	—
	$b\bar{b}$	—
Dilepton + 'ℓ'	Drell-Yan; $Z^0(\to \tau\tau \to \ell\ell)$; $W^+W^-(\to \ell\ell\nu\nu)$	$\oplus \left\{ \begin{array}{l} +b\bar{b}(\to \ell + X) \\ +j(\text{fake lepton}) \end{array} \right.$
Single lepton + 'ℓ' 'ℓ'	$W(\to \ell\nu)$	$+ b\bar{b}$

- Comparion of four analyses: The CDF and DØ analyses (based on the current detector configuration) are preliminary.

Group	CDF	DØ	Barger *et al.*	Baer *et al.*
$\sqrt{s}$	1.8 TeV	1.8 TeV	2.0 TeV	2.0 TeV
Detector type	CDF-I	DØ-I	CDF-II like	DØ-II like
Primary Cut	(Fig. 2)	(Fig. 3)	(Fig. 4)	(Fig. 5)
$p_T(\ell_1)$	> 11	> 10	> 11	> 20
$p_T(\ell_2)$	> 7	> 10	> 7	> 15
$p_T(\ell_3)$	> 7	> 5	> 5	> 10
$\|\eta(e_{1,2/3})\|$	$< 1.1, 2.4$	< 3.0	$< 1.0, 2.0$	< 2.5
$\|\eta(\mu_{1,2/3})\|$	$< 0.6, 1.0$	< 1.7	$< 1.0, 2.0$	< 2.5
$ISO_{\Delta R=0.4}$	< 2 GeV	< 2 GeV	< 2 GeV	$< p_T(\ell)/4$
$\Delta\phi(\ell_1, \ell_2)$ cut	yes	yes	—	—
$\not{E}_T$	> 25	> 25	> 25	> 25
Z veto	76-106	76-106	81-101	83-99
$M(\ell, \ell')$ veto	J/ψ, Υ	—	—	—
$N(j)_{E_T>15}$	—	—	—	0
Total BG [fb]	0.44	0.45*	0.39	~ 0.2
Reach on m_0 at $\tan\beta = 2$, $\mu > 0$ and $A_0 = 0$				
	2 fb^{-1}	2 fb^{-1}	2 fb^{-1}	2 fb^{-1}
$m_{1/2} = 100$	—	—	$\simeq 400$	—
$m_{1/2} = 150$	$\simeq 340$	$\simeq 280$	$\simeq 360$	$\simeq 200$
$m_{1/2} = 200$	—	$\simeq 200$	$\simeq 240$	$\simeq 150$

$\star$ DØ's background estimate is just the Run-I estimate scaled by luminosity and additional rejection (compared to Run I) for the lepton ID using the new detectors.

Projected Limits for Run II



e) increase in trilepton signal from $\tilde{\chi}_2^0 \to \tilde{e}e, \tilde{\mu}\mu$

f) decrease in trilepton signal from $\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0$

g) increase in trilepton signal from $\tilde{\chi}_2^0 \to \tilde{e}e, \tilde{\mu}\mu$;

also have $\tilde{\chi}_1^\pm \to W^\pm \tilde{\chi}_1^0$

Figure 2: CDF preliminary projection of 95% C.L. upper limit on $\sigma \cdot Br$ for Run II. The branching ratio (Br) is the sum of four trilepton modes. Curves (a) - (g) represent $m_{1/2}$ = 50 - 200 GeV/c^2, incremented by 25 GeV/c^2, while upper and lower dashed curves represent m_0 = 100 and 2500 GeV/c^2.

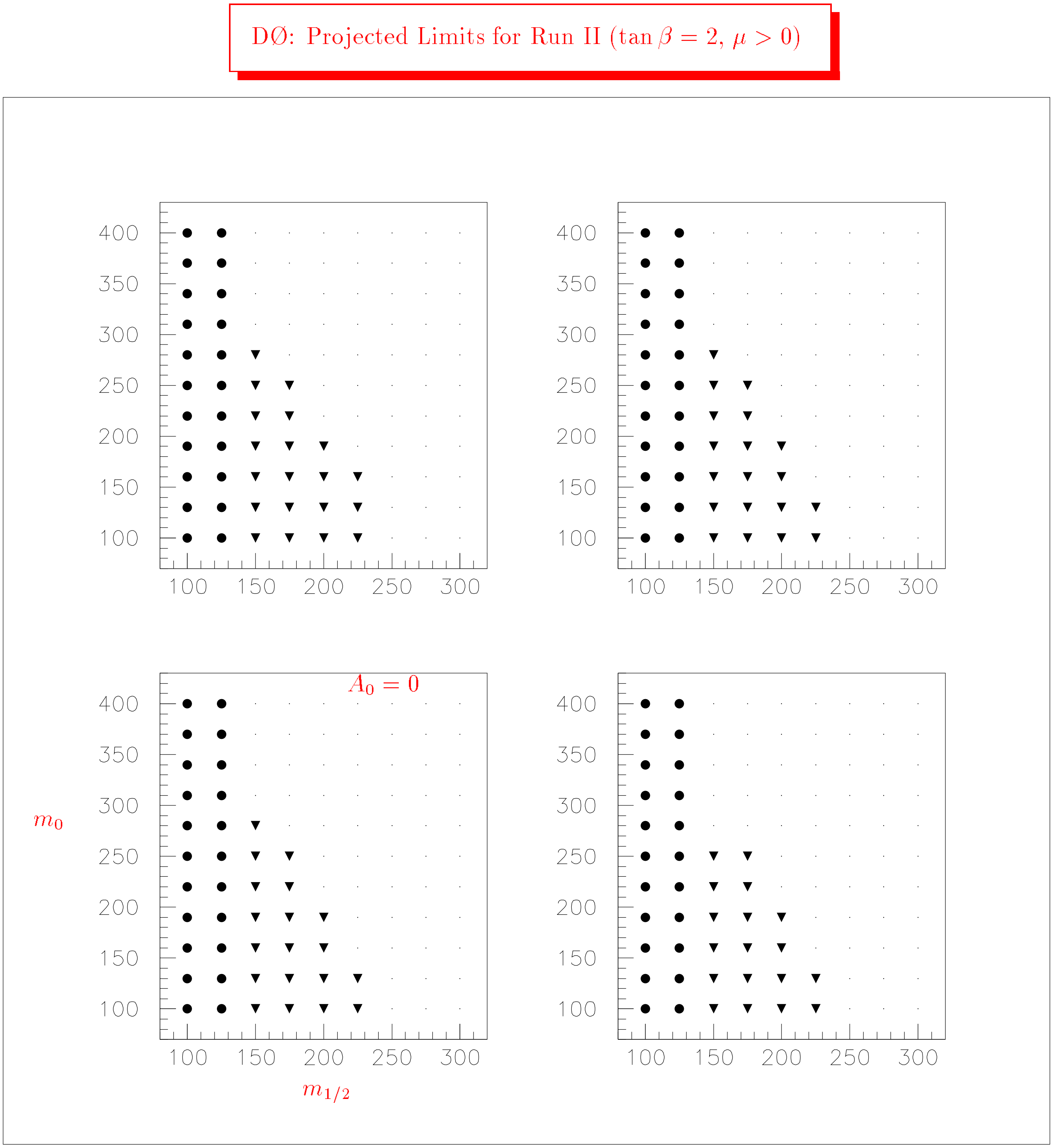


Figure 3: DØ preliminary projection of trilepton search at 2 fb^{-1} for $\tan\beta = 2$ and $\mu > 0$. Four m_0-$m_{1/2}$ contour plots are for $A_0 = -200, -100, 0, +100$ GeV$/c^2$ in clockwise from top right. The squares indicate the LEP2 limit. The inverted triangles are the region excluded at 95% C.L. by adding single tau channels (τee or $\tau\mu\mu$), where the τ is detected by tagging a soft lepton (e or μ) from $\tau \to \ell + X$. We assume no background events.

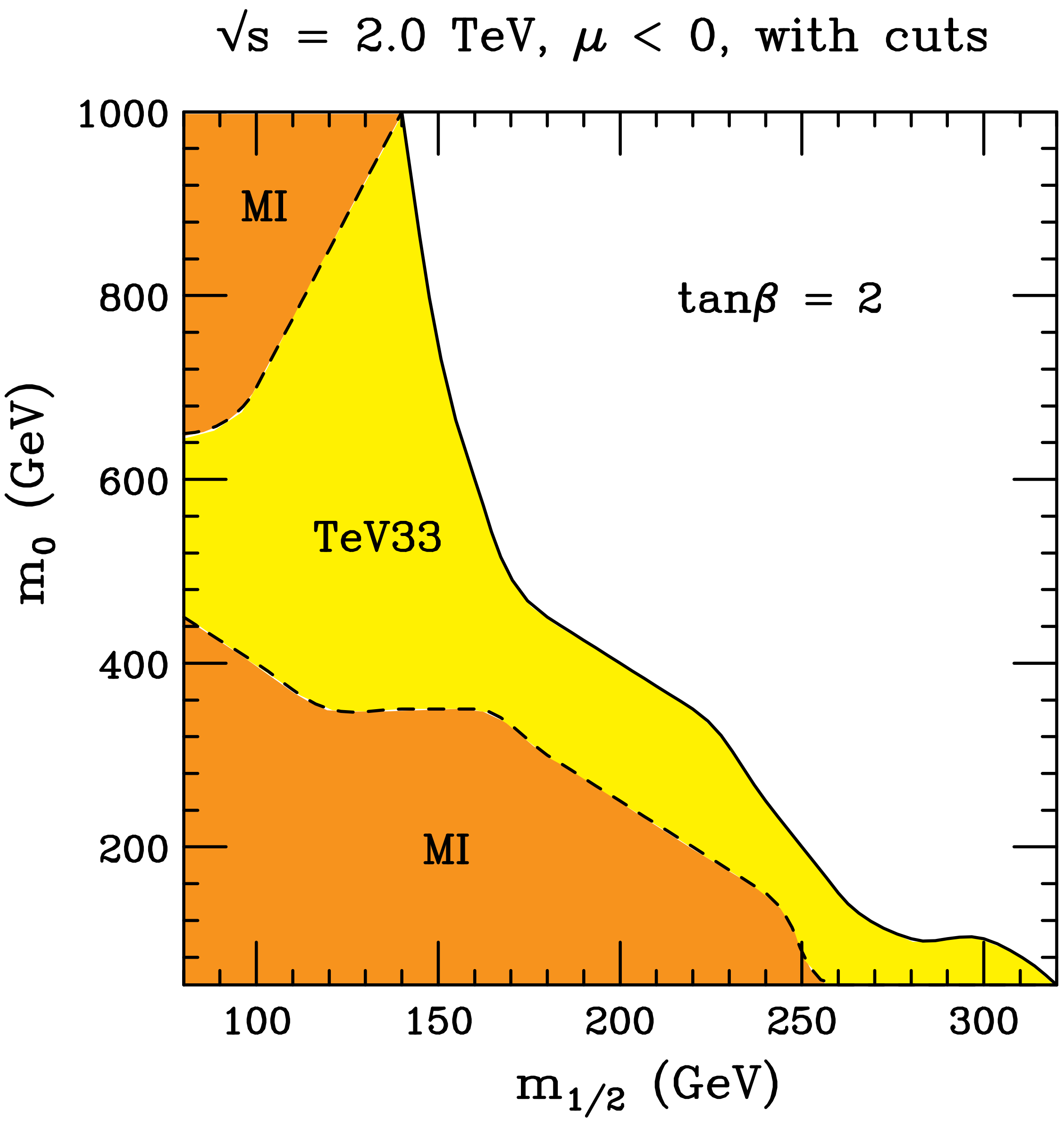


Figure 4: Ref. [1]: Discovery contours of $p\overline{p} \to \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to 3\ell + X$ at $\sqrt{s} = 2$ TeV with cut B, in the parameter plane of $(m_{1/2}, m_0)$, for $\mu < 0$, $\tan\beta = 2$ and $A_0 = 0$. Here, "3ℓ" includes $\ell^{\pm}\ell'^{+}\ell'^{-}, \ell^{\pm}\tau^{+}\tau^{-}$ and $\tau^{\pm}\ell^{+}\ell^{-}$, where the τ is detected by tagging a soft lepton (e or μ) from $\tau \to \ell + X$. We consider major SM backgrounds from WZ and $t\overline{t}$ and require 4 signal events for $\mathcal{L} = 2$ fb^{-1} (MI), and 5σ signal for $\mathcal{L} = 20$ fb^{-1} (TeV33). Note that the sign convention for μ is opposite to all other analyses in this summary talk.

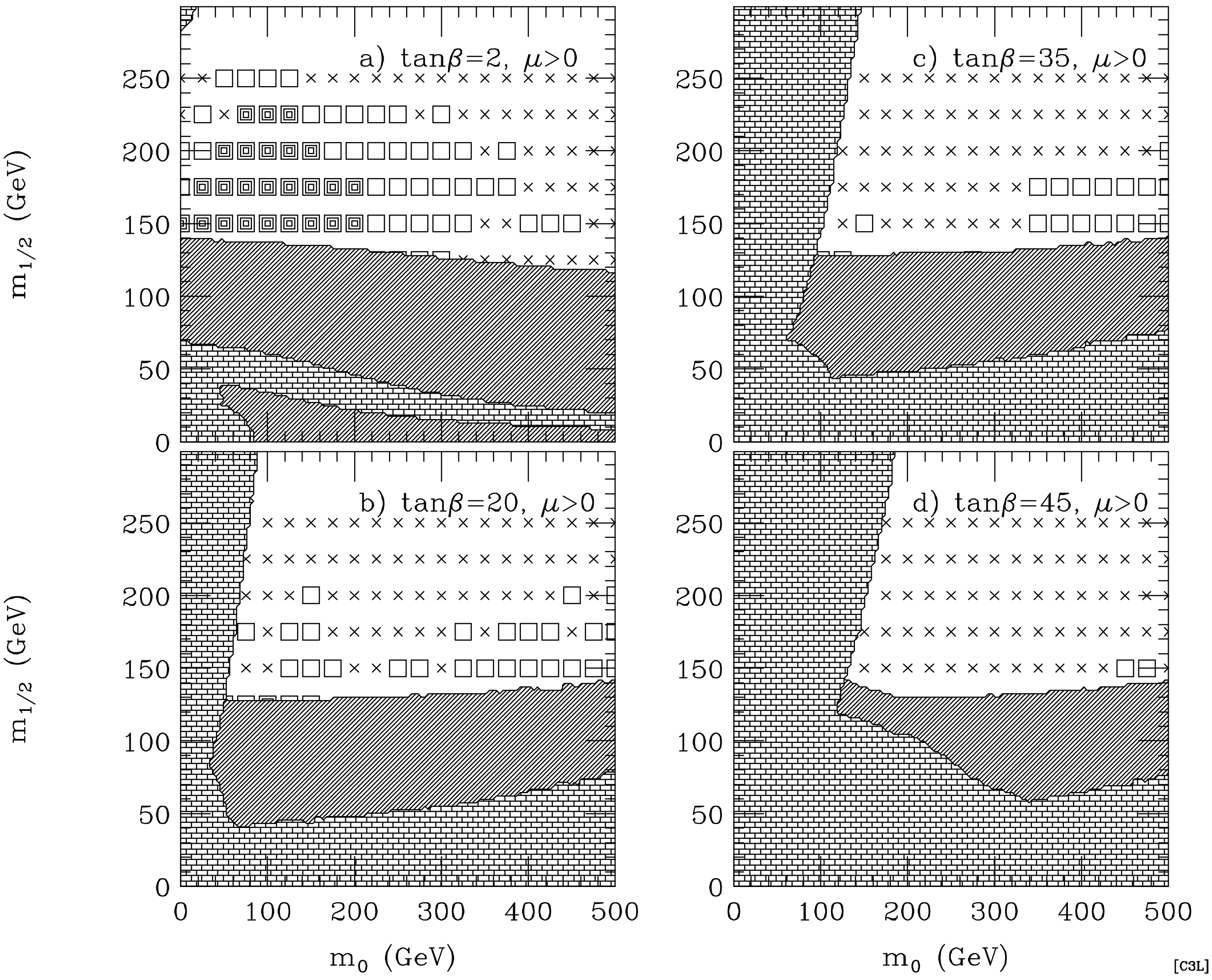


Figure 5: Ref. [2]: A plot of points accessible to Tevatron MI (2 fb^{-1}) and TeV33 (25 fb^{-1}) searches for mSUGRA ($A_0 = 0$ and $m_t = 170$ GeV/c^2) via clean trilepton (eee, $ee\mu$, $e\mu\mu$, $\mu\mu\mu$) events. The bricked regions are excluded by theoretical constraints, while the gray regions are excluded by LEP2 bounds on $M(\tilde{\chi}_1^{\pm})$.

2 Trilepton ($\ell\tau\tau, \tau\ell\ell, \tau\tau\tau$) analysis:

2.1 Proposed triggers

Prod.	Signature	Trigger Type	Trigger cuts in p_T or E_T
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$	$(\ell^{\pm}\nu\ \tilde{\chi}_1^0)\ (\tau^+\tau^-\ \tilde{\chi}_1^0)$ [$\tan\beta \lesssim 6$]	$\ell_1\ell_2$	9/6
	$(\tau^{\pm}\nu\ \tilde{\chi}_1^0)\ (\ell^+\ell^-\ \tilde{\chi}_1^0)$ [$\tan\beta \lesssim 6$]	$\ell_1\tau_2$	9/?
	$(\tau^{\pm}\nu\ \tilde{\chi}_1^0)\ (\tau^+\tau^-\ \tilde{\chi}_1^0)$ [$\tan\beta \gtrsim 2$]	$\tau_1\tau_2(\tau_3)$	?/?

2.2 Comments on low p_T τ trigger

- H. Baer *et al.* [2]: Clean trilepton (C3LT) analysis with
  - $p_T(\ell_{1,2}) > 10$, 5 GeV/c, $E_T^{vis}(\tau) > 15$ GeV and $\not\!\!E_T > 15$ GeV

  OR
  - $p_T(\ell_{1,2}) > 5$, 5 GeV/c, $E_T^{vis}(\tau) > 15$ GeV and $\not\!\!E_T > 35$ GeV

  will accept $\ell\tau\tau$, $\tau\ell\ell$ and $\tau\tau\tau$ events. They found no reach beyond LEP-II at Run II for high $\tan\beta$ solutions (Fig.6).

- This set of cuts is insensitive to detect $\tau\tau\tau$ events. Thus, CDF/DØ need to develop a low p_T 1/3-prong τ trigger.

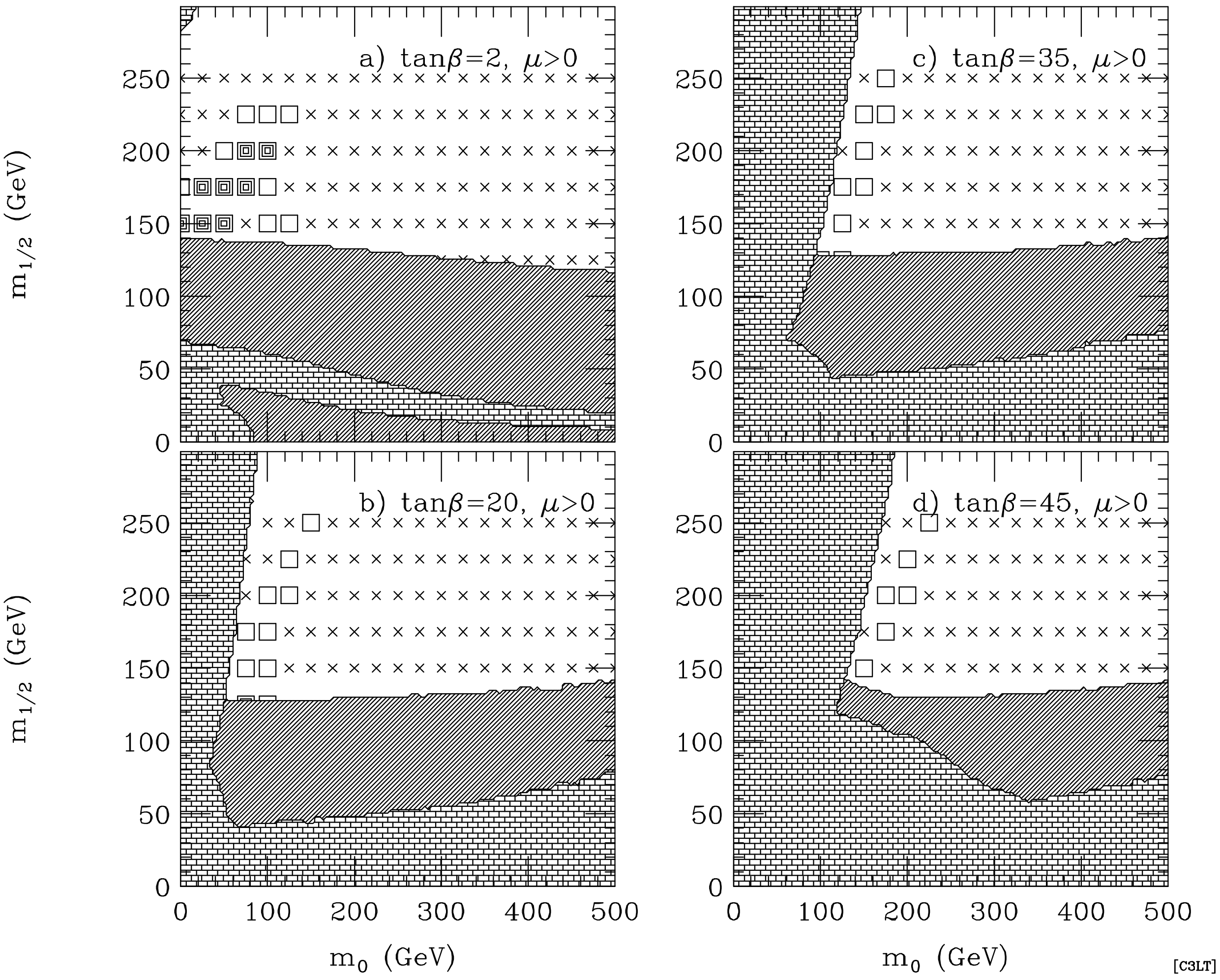


Figure 6: Ref. [2]: A plot of points accessible to Tevatron MI (2 fb^{-1}) and TeV33 (25 fb^{-1}) searches for mSUGRA ($A_0 = 0$ and $m_t = 170$ GeV$/c^2$) via clean trilepton ($\ell\tau\tau$, $\tau\ell\ell$, $\tau\tau\tau$) events. The bricked regions are excluded by theoretical constraints, while the gray regions are excluded by LEP2 bounds on $M(\tilde{\chi}_1^{\pm})$.

3 $\not\!\!E_T$ + jets analysis:

- Production: $p\overline{p} \to \tilde{g}\tilde{g}, \tilde{g}\tilde{q}, \tilde{q}\bar{\tilde{q}}$
- Decay: $\tilde{g} \to q\bar{q}'\tilde{\chi}_1^{\pm},\ q\bar{q}\tilde{\chi}_2^0$ & $\tilde{q} \to q'\tilde{\chi}_1^{+},\ q\tilde{\chi}_2^0$
- Chracterized by a large missing E_T ($\not\!\!E_T$): Fig. 7
- TeV2000 study: Max. reach on $M(\tilde{g})$ is $\simeq$390 GeV/c^2 (5σ).

Primary cut	Mrenna *et al.* (Fig. 8)	Baer *et al.*
$\not\!\!E_T$	> 75	> 75
$p_T(\ell)$ for lepton veto	> 15	> 15
$N(j)_{E_T>15}$	—	≥ 4
$E_T(j_1) + E_T(j_2) + \not\!\!E_T$	> 300	—
S_T (transverse sphericity)	> 0.2	—
Background [fb]		
$t\bar{t}$	24	145
W	11	710
Z	5	320
WW	—	0.4
ZZ	—	0.04
Total	40	1175

- The QCD background will be huge and difficult to estimate.
  - Run II: Low $\not\!\!E_T$ trigger ($\not\!\!E_T \gtrsim$ 25 GeV) is designed to estimate the QCD background from data !
  - Such a low $\not\!\!E_T$ trigger can also be used for other non-SM physics analyses (*e.g.*, $\not\!\!E_T + \ell/\gamma$, $\not\!\!E_T + b$).

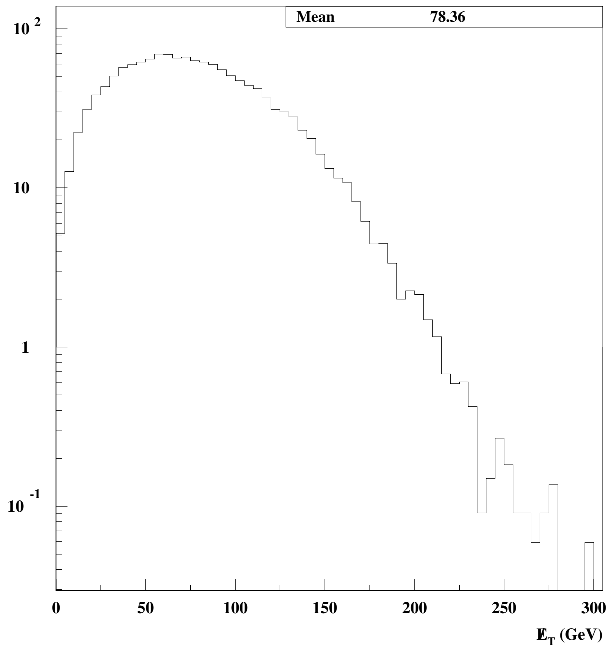


Figure 7: $\not{E}_T$ distribution at a SUGRA point at $\tan\beta = 2$, $\mu < 0$, and $A_0 = 0$: $(m_0,\ m_{1/2}) =$ (100,70), corresponding to $(M(\tilde{q}),\ M(\tilde{g})) =$ (207, 215).

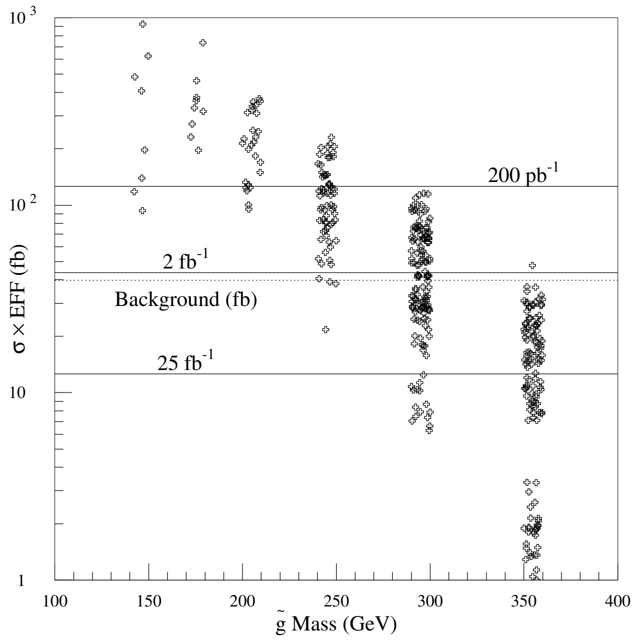


Figure 8: Ref. [3]: Gluino search in mSUGRA: The σ·EFF is plotted for $\not{E}_T$ + jets signal versus the gluino mass. The dotted line represents the background cross section of 40 fb. Three solid lines indicate the 10σ significance of the signal events above the background for 200 pb^{-1}, 2 fb^{-1}, and 25 fb^{-1}.

4 Stop analyses:

4.1 Proposed trigger:

Prod.	Signature	Trigger Type	Trigger cuts in p_T or E_T
$\tilde{t}_1\bar{\tilde{t}}_1$	$(b\tilde{\chi}_1^+)$ $(\bar{b}\tilde{\chi}_1^-) \to (b\ell^+\nu\tilde{\chi}_1^0)$ $(\bar{b}q\bar{q}'\tilde{\chi}_1^0)$	$\not{E}_T$+b_1b_2	20/15/15
	$(b\tilde{\chi}_1^+)$ $(\bar{b}\tilde{\chi}_1^-) \to (b\ell^+\nu\tilde{\chi}_1^0)$ $(\bar{b}\ell^-\nu\tilde{\chi}_1^0)$	$\ell_1\ell_2$	9/6
	$(c\tilde{\chi}_1^0)$ $(\bar{c}\tilde{\chi}_1^0)$	$\not{E}_T$+c_1c_2	20/15/15
	$(b\ell\tilde{\nu})$ $(b\ell\tilde{\nu}) \to (b\ell\nu\tilde{\chi}_1^0)$ $(b\ell\nu\tilde{\chi}_1^0)$	$\ell_1\ell_2$	9/6
	$(b\tau\tilde{\nu})$ $(b\tau\tilde{\nu}) \to (b\ell\nu' s\tilde{\chi}_1^0)$ $(b\ell\nu' s\tilde{\chi}_1^0)$	$\ell_1\ell_2$	9/6

4.2 Status:

- MSSM: Reach (3σ sensitivity) for $\tilde{t}_1 \to b\tilde{\chi}_1^+$, $b\ell\tilde{\nu}$, $c\tilde{\chi}_1^0$ with $\not{E}_T > 25, 20, 40$ GeV at CDF (Fig. 9)

- Reach on $M(\tilde{t}_1)$ for $\tilde{t}_1 \to c\tilde{\chi}_1^0$ with $\not{E}_T > 40$ GeV at DØ and CDF (Figs. 9, 10)

Exp.	Integrated Luminosity	Maximum Reach on $M(\tilde{t}_1)$ for $M(\tilde{t}_1) > M(W) + M(b) + M(\tilde{\chi}_1^0)$
DØ	7.4 pb^{-1}	$\simeq$ 93 GeV/c^2 (publisded)
DØ	2 fb^{-1}	$\simeq$120 GeV/c^2 (TeV2000 report [4])
CDF	88 pb^{-1}	$\simeq$120 GeV/c^2 (ICHEP 98)
CDF	2 fb^{-1}	$\simeq$150 GeV/c^2 (Fig. 9)

√ Need a lower $\not{E}_T$ trigger, especially for $\tilde{t}_1 \to c\tilde{\chi}_1^0$ to narrow the gap (*e.g.*, $\Delta M \equiv M(\tilde{t}_1) - M(\tilde{\chi}_1^0) = 30$ GeV/c^2 for $\not{E}_T > 40$ GeV)

√ Low-$\not{E}_T$ ($\gtrsim$20 GeV) + HFO trigger is designed to narrow the gap (*e.g.*, $\Delta M = 20$ GeV/c^2 for $\not{E}_T > 30$ GeV).

- SUGRA plots: Figs. 11, 12, 13

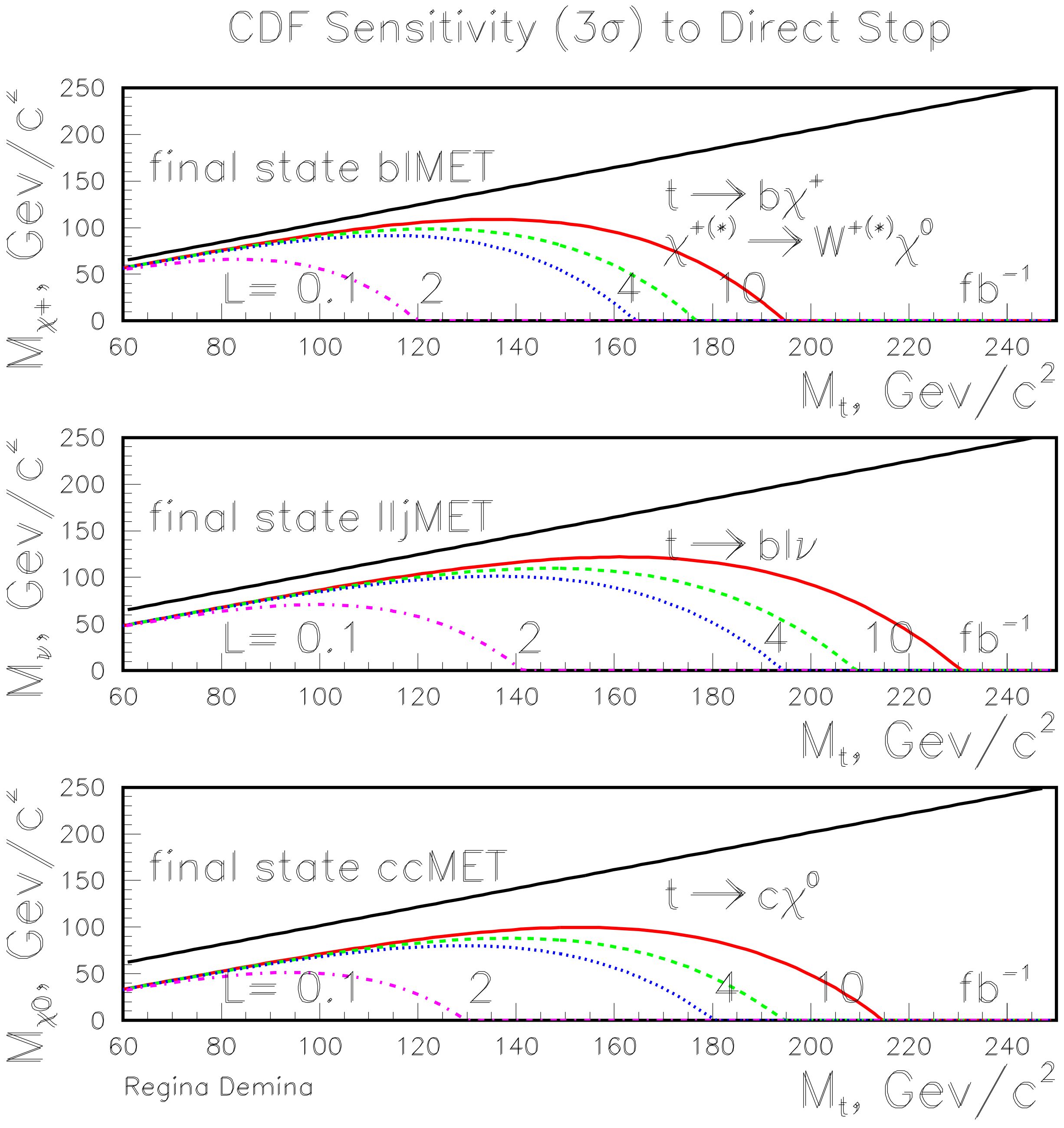
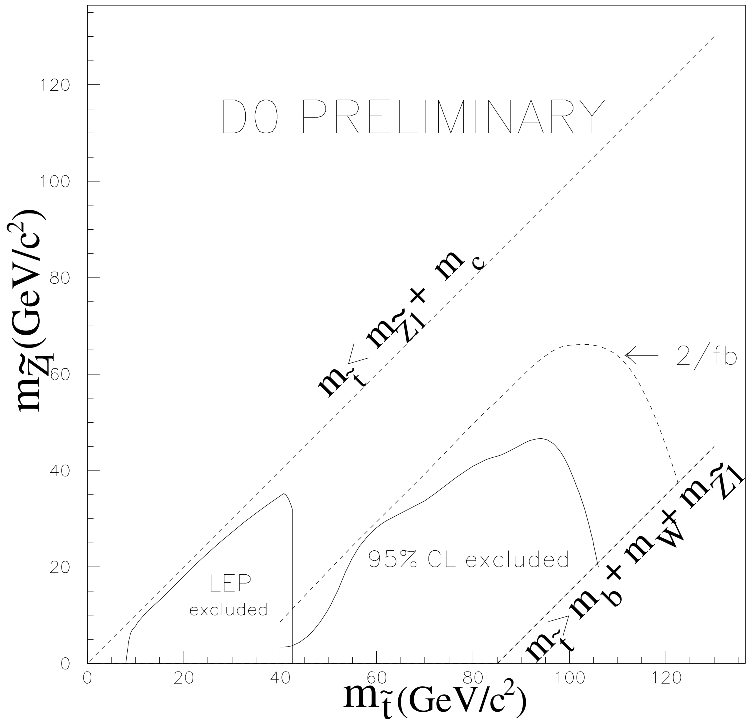


Figure 9: CDF sensitivity to searches for $\tilde{t}_1$ in $\tilde{t}_1 \to b\tilde{\chi}_1^+$ ($\not\!\!E_T > 25$ GeV), $\tilde{t}_1 \to b\ell\tilde{\nu}$ ($\not\!\!E_T > 20$ GeV), and $\tilde{t}_1 \to c\tilde{\chi}_1^0$ ($\not\!\!E_T > 40$ GeV). The branching ratios for $\tilde{t}_1 \to b\tilde{\chi}_1^+$, $\tilde{t}_1 \to b\ell\tilde{\nu}$, and $\tilde{t}_1 \to c\tilde{\chi}_1^0$ are assumed to be 100%, 33%, and 100%, respectively. We also assume $Br(\tilde{\chi}_1^\pm \to \ell^\pm\nu\tilde{\chi}_1^0) = 11\%$.



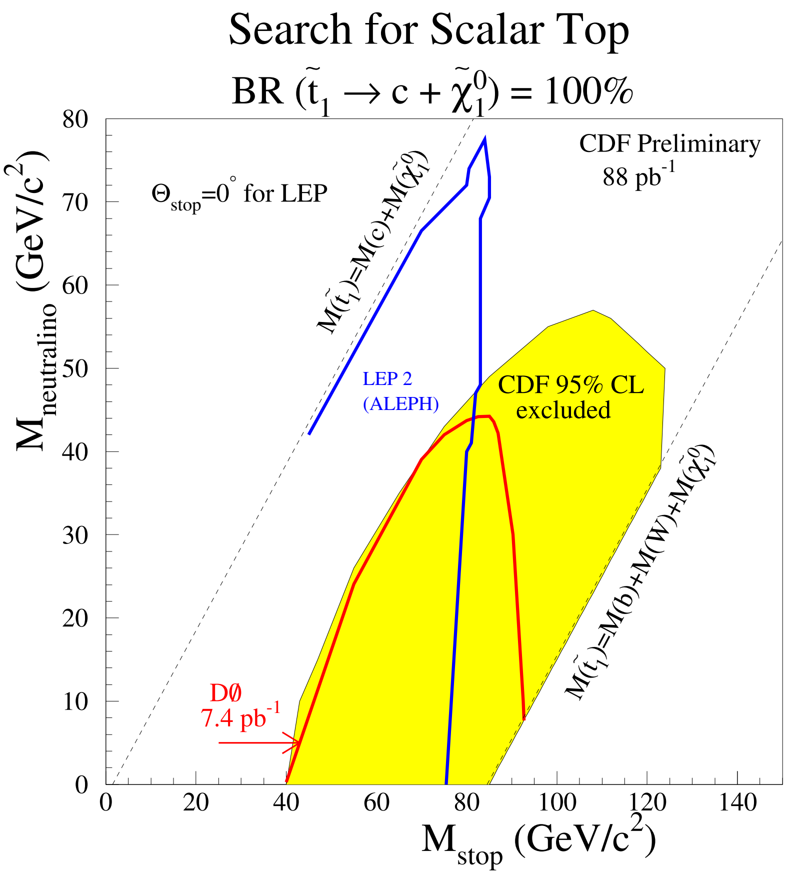


Figure 10: **Top:** DØ sensitivity to search for $\tilde{t}_1$ with $\not{E}_T > 40$ GeV [4]. **Bottom:** CDF and DØ exclusion regions in $M(\tilde{\chi}_1^0)$-$M(\tilde{t}_1)$ plane with $\not{E}_T > 40$ GeV. The branching ratio for $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$ is assumed to be 100%.

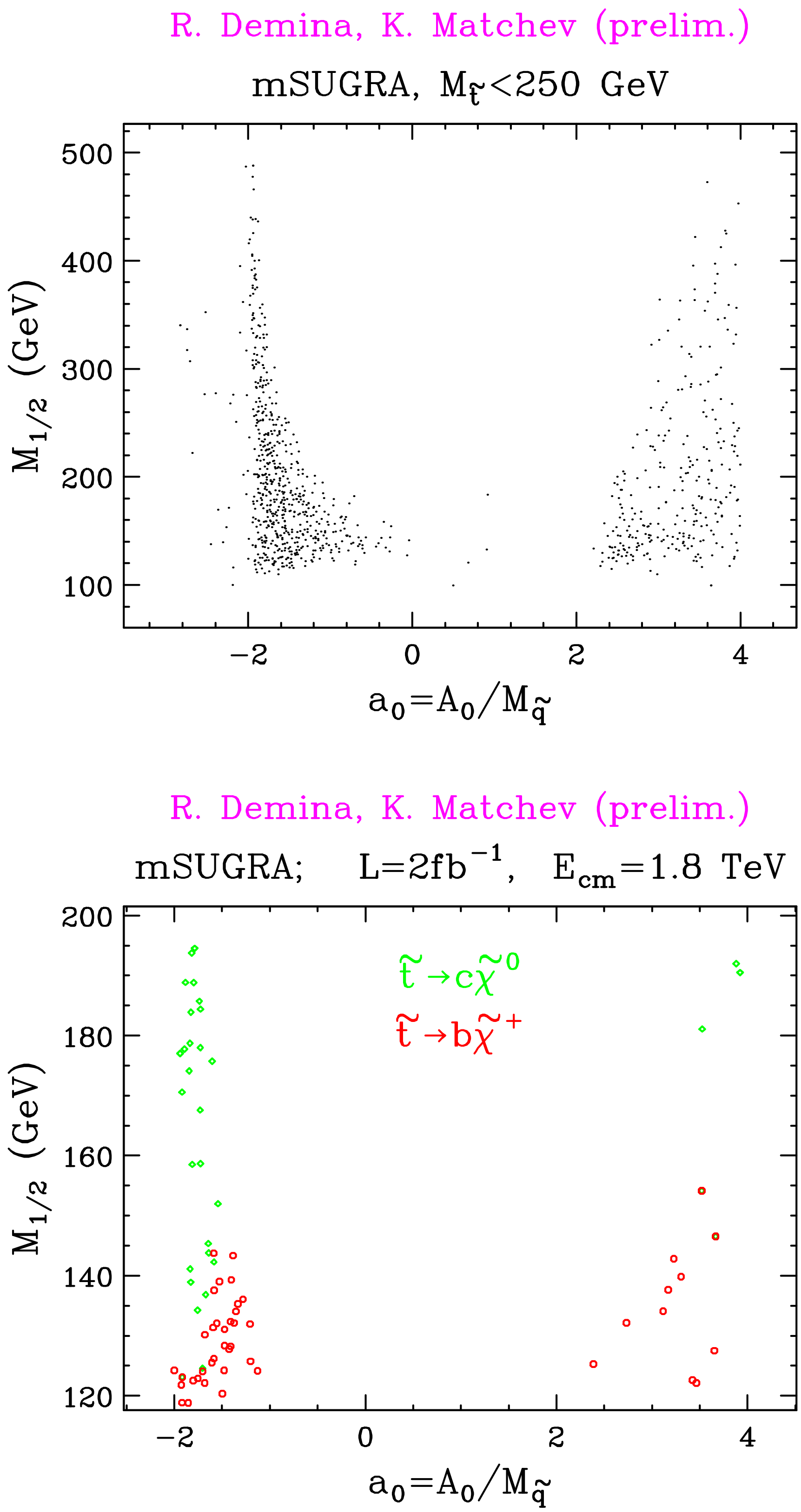
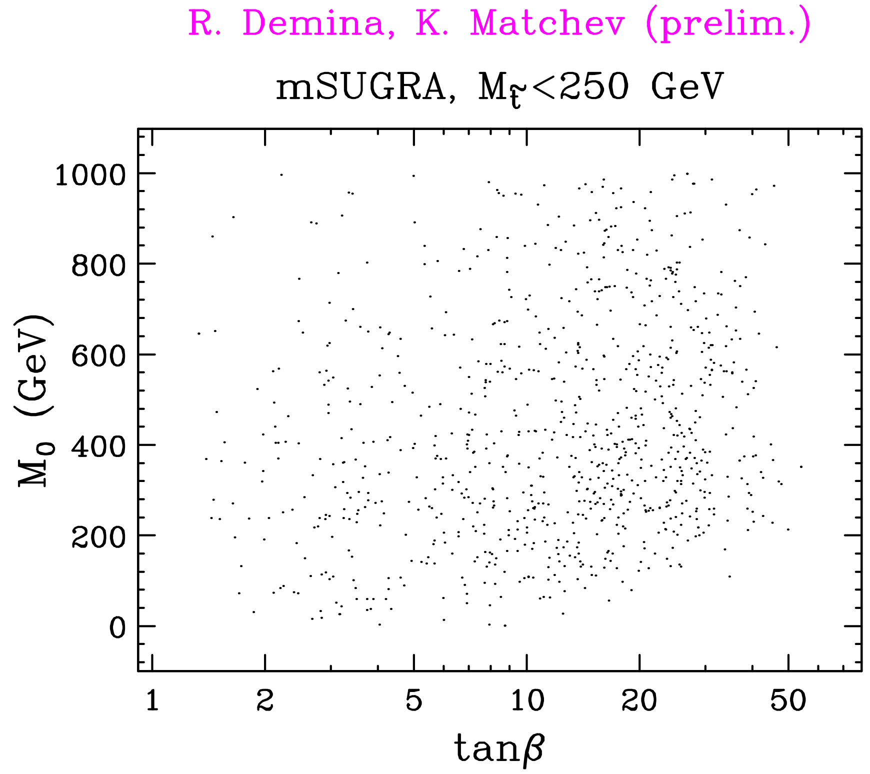


Figure 11: **Top:** possible SUGRA points for $M(\tilde{t}_1) < 250$ GeV$/c^2$ in $m_{1/2}$-a_0 plane, where $a_0 \equiv A_0/M(\tilde{q})$. **Bottom:** CDF sensitivity to searches for $\tilde{t}_1$ with 2 fb^{-1}.



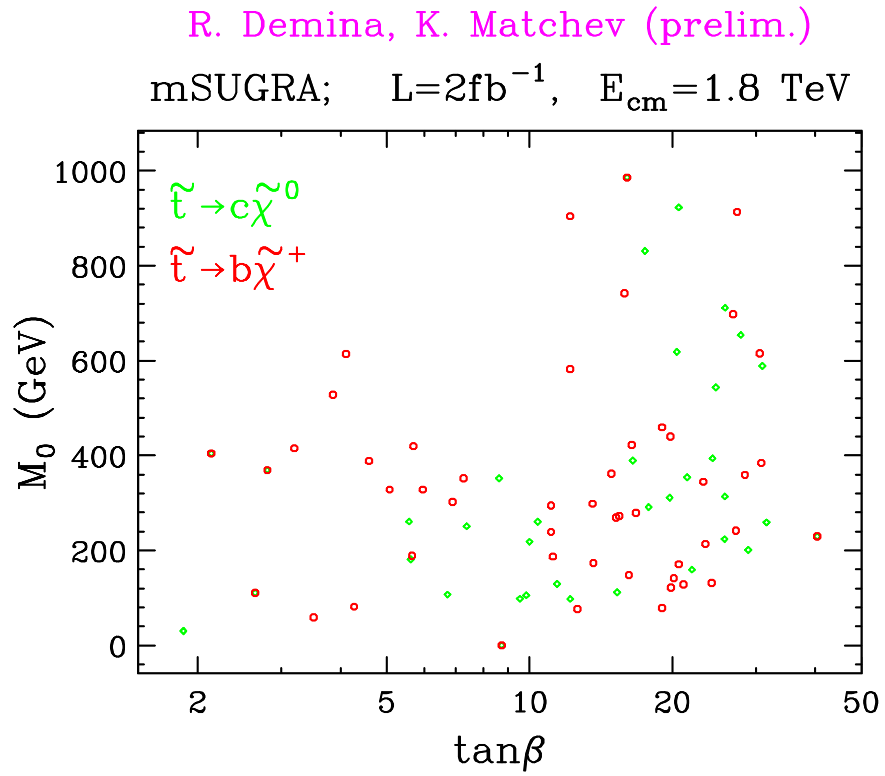


Figure 12: **Top:** possible SUGRA points for $M(\tilde{t}_1) < 250$ GeV$/c^2$ in m_0-$\tan\beta$ plane. **Bottom:** CDF sensitivity to searches for $\tilde{t}_1$ with 2 fb^{-1}.

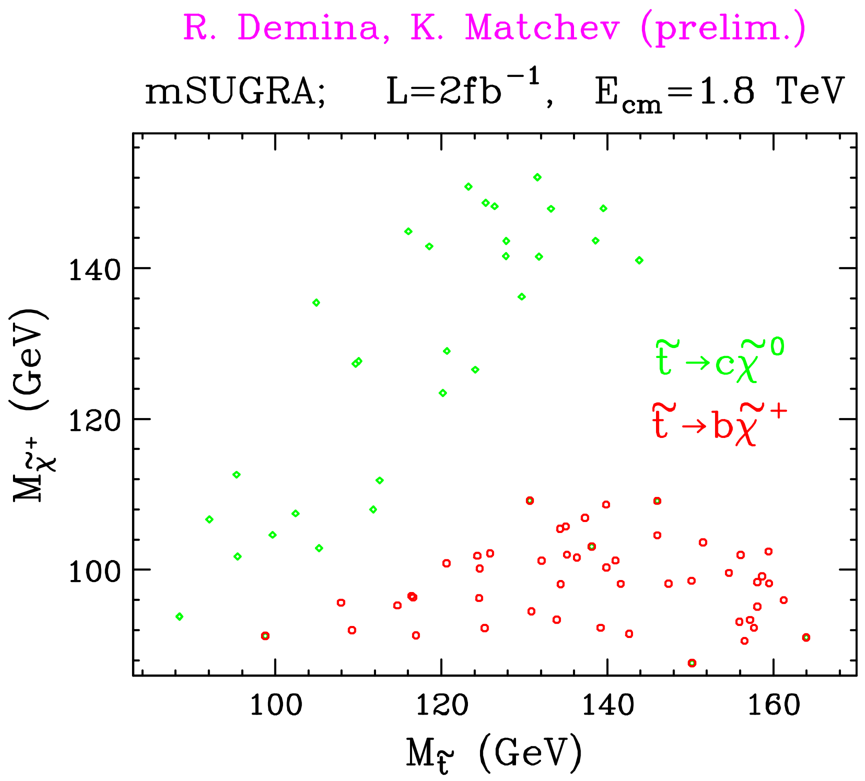


Figure 13: CDF sensitivity to searches for $\tilde{t}_1$ with 2 fb^{-1} in $M(\tilde{\chi}_1^{\pm})$ vs $M(\tilde{t}_1)$ plane.

5 Sbottom analyses:

5.1 Proposed trigger:

Prod.	Signature	Trigger Type	Trigger cuts in p_T or E_T
$\tilde{g}\tilde{g}$	$(\bar{b}\tilde{b})$ $(\bar{b}\tilde{b}) \to (\bar{b}b\tilde{\chi}_2^0)(\bar{b}b\tilde{\chi}_2^0)$ $\to (\ell^+\ell^- b\bar{b}\tilde{\chi}_1^0)(q\bar{q}b\bar{b}\tilde{\chi}_1^0)$	$\ell_1\ell_2$	9/6
	$(\bar{b}\tilde{b})$ $(\bar{b}\tilde{b}) \to (\bar{b}b\tilde{\chi}_1^0)(\bar{b}b\tilde{\chi}_1^0)$	$\not{E}_T + b_1 b_2$	20/15/15

5.2 Status:

(a) $\tilde{b} \to b\tilde{\chi}_1^0$: in progress.
(b) $\tilde{g} \to b\tilde{b}$, $\tilde{b} \to b\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \to \ell\ell\tilde{\chi}_1^0$ [5]:

- Isolated OS ee or $\mu\mu$ with $p_T > 8$ GeV/c for e ($|\eta| < 2.0$) and μ ($|\eta| < 1.4$)
- $N_b \geq 2$ with $E_T > 10$ GeV ($|\eta| < 2.0$) @$\epsilon_b = 66\%$
- $\not{E}_T > 20$ GeV

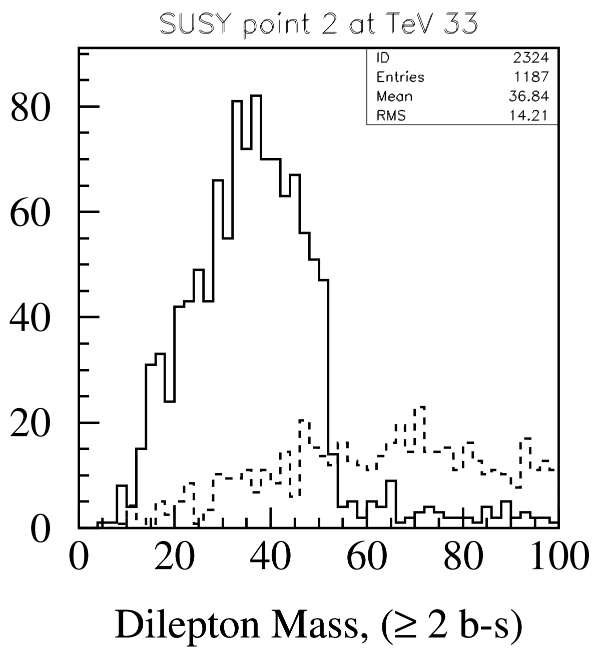


Figure 14: Dilepton invariant mass distribution from SUSY (solid line) and top production (dashed line) for 30 fb^{-1} of data at TeV33 [5]. Snowmass common point 2 ($m_0 = 200$, $m_{1/2} = 100$, $A_0 = 0$, $\tan\beta = 2$, $\mu < 0$) is used. Events are required to contain at least 2 b-tags.

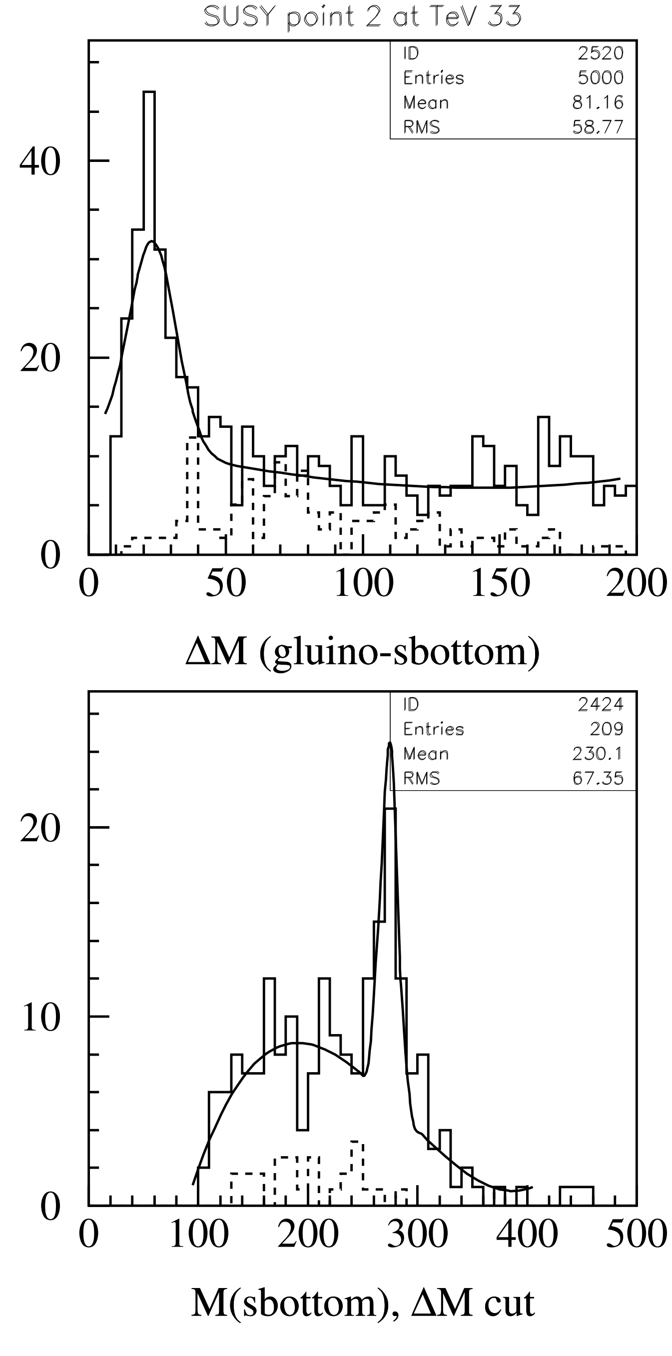


Figure 15: Top: Gluino-sbottom mass difference from SUSY (solid line) and top production (dashed line) for 30 fb^{-1} of data at TeV 33 (Snowmass common point 2); Bottom: the reconstructed sbottom mass after $\Delta M(gluino - sbottom) < 45$ GeV.

References

[1] V. Barger, C. Kao, and T. Li, "Trilepton Signal of Minimal Supergravity at the Tevatron Including τ-lepton Contributions," hep-ph/9804451, MADPH-98-1028.

[2] H. Baer, C.-H. Chen, M. Drees, F. Paige, and X. Tata, "Supersymmetry Reach of Tevatron Upgrades: The Large $\tan\beta$ Case," hep-ph/9802441, FSU-HEP-980204, BNL-HET-98/9, APCTP 98-02, UH-511-894-98.

[3] S. Mrenna, G.L. Kane, G.D. Kribs, and J.D. Wells, Phys. Rev. D53, 1168 (1996).

[4] TeV2000 Group, "Future ElectrWeak Physics at the Fermilab Tevatron: Report of the TeV2000 Study Group," Fermilab-Pub-96/082 (1996).

[5] S. Mrenna *et al.*, "Supersymmetry Prospects at an Upgraded Fermilab Tevatron Collider," Snowmass Workshop for New Directions for High-Energy Physics (1996).