Ambulance Chasing CDF $\mu\gamma\not{E}_T$ Events

by

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Talk outline

- The events, [1]
- Low energy supersymmetry
- R-parity violation and a light gravitino
- Kinematical fits[2]

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[1] CDF, hep-ex/0202044, hep-ex/011015
[2] BCA, M. Lola and K. Sridhar, hep-ph/0111014, 0112321

Experiment

- Run I of Tevatron, CDF experiment
- 900 GeV p colliding with 900 GeV $\overline{p}$
- Search for: leptons, photons and missing transverse energy ($\not\!\!E_T$)
- All should have bigger than 25 GeV transverse energy to suppress background
- 86.34 pb^{-1} analysed

Data

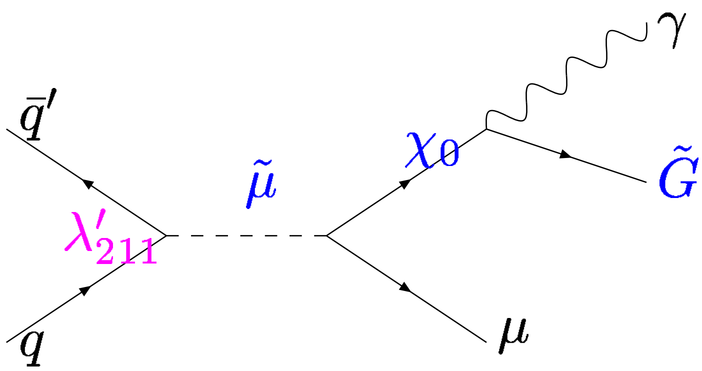
Backgrounds: $W/Z\gamma$, mis-id of jets or electrons as photons, hadron decays to photons

Channel	Background	N_{obs}	$P(N > N_{obs})$
$e\gamma$	12.6±1.4	20	0.043
$\mu\gamma$	12.3±1.8	13	0.46
$e\gamma\not{E}_T$	3.4±0.3	5	0.26
$\mu\gamma\not{E}_T$	4.5±0.5	11	0.0054
$ee\gamma$	3.5±0.4	4	0.45
$\mu\mu\gamma$	2.3±0.3	1	0.90
$e\mu\gamma$	0.05±0.1	0	0.95

$\mathcal{Q}$: What can make muons, photons and $\not{E}_T$?

$\mathcal{A}$: Supersymmetry

Resonant smuon production



Explains: the muon, photon and the missing energy, but also why it wasn't seen in other channels!
From $R_\pi = \Gamma(\pi \to e\nu)/(\pi \to \mu\nu)$:

$$\lambda'_{211} < 0.059 \times \frac{m_{\tilde{d}_R}}{100 \text{ GeV}}$$

Light Gravitinos

SUSY broken spontaneously $\rightarrow$ gravitino absorbs would-be-goldstino[3]

$$m_{\tilde{G}} = 5.9 \times 10^{-5} \frac{F_0}{(500\ \mathrm{GeV})^2}\ \mathrm{eV}$$

is small.

$$\begin{aligned} \mathcal{L} &= \frac{1}{8M_P}\bar{\lambda}^A \gamma^\rho \sigma^{\mu\nu} \tilde{G}_\rho F^A_{\mu\nu} + \frac{1}{\sqrt{2}M_P} \bar{\psi}_L \gamma^\mu \gamma^\nu \tilde{G}_\mu D_\nu \phi, \\ \tilde{G}_\mu &= \sqrt{2/3} i \partial_\mu \tilde{G}/m_{\tilde{G}} \end{aligned}$$

approximates well the spin-1/2 goldstino component which appears in external states.

[3] P. Fayet, PLB70 (1999) 461, PLB175 (1986) 471

Our simulation

We use ISASUGRA7.58 and HERWIG6.301 to simulate signal events. We choose:

$$\lambda'_{211} = 0.01, \qquad \tan\beta = 10, \qquad m_{\tilde{G}} = 10^{-3} \text{ eV}$$

and all other sparticles *heavy* (generic), except for

$$m_{\tilde{e}} = m_{\tilde{\mu}}, \qquad m_{\chi_1^0}.$$

- Cuts to mimic experiment
- Parton showering, but no hadronisation
- Angular correlations taken into account
- $\ln L(x_i) = \ln L_{max} - s^2/2$ allows parameter x_i estimation. We normalise wrt SM prediction

Signal event numbers

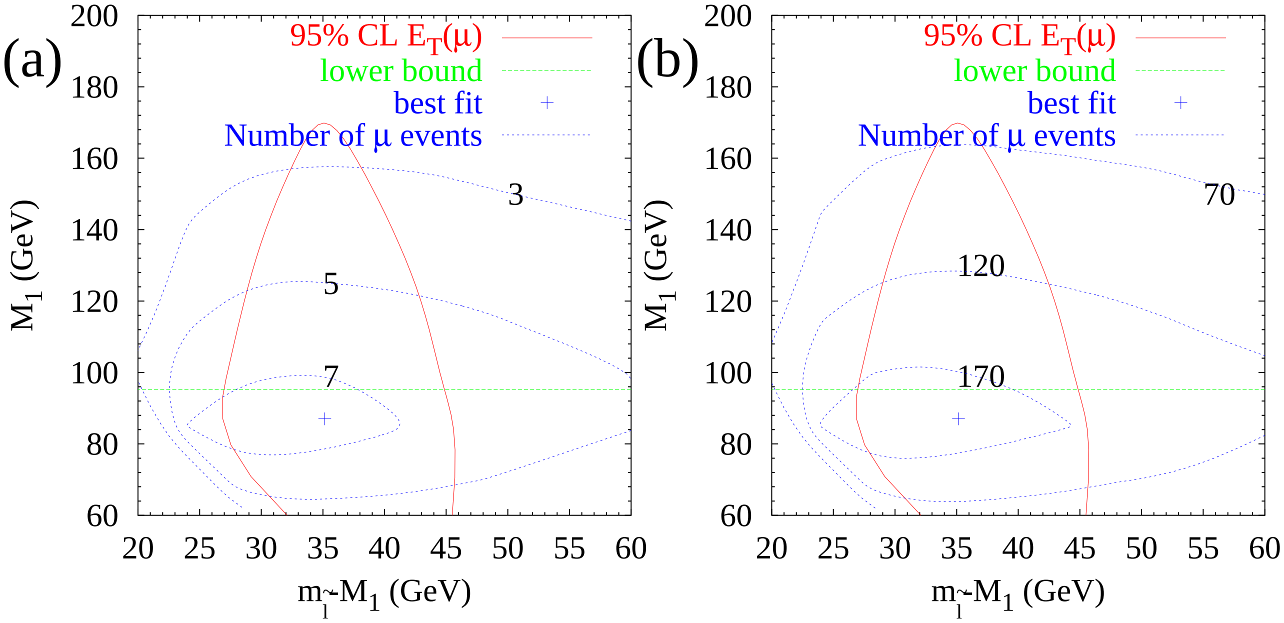


Figure 1: (a) $\mu\gamma\not{E}_T$ signal events at Run I, (b) at Run II. The lower bound comes from $\chi_1^0\chi_1^0 \rightarrow \gamma\gamma\not{E}_T$ at LEP2 (LEPSUSYWG/01-04.1).

We can fit the excess of 6.5 events.

Kinematic variables

$$
\begin{aligned}
p_T^2 &= p_x^2 + p_y^2 \\
{E_T}^2 &= p_T^2 + m^2 \\
{m_{l\gamma}}^2 &= \left(E(\gamma) + E(l)\right)^2 - \left(\underline{p}(\gamma) + \underline{p}(l)\right)^2 \\
M_T(p_1, p_2)^2 &= \left(E_T(\gamma) + E_T(l)\right)^2 - \left(\underline{p}_T(\gamma) + \underline{p}_T(l)\right)^2 \\
\Delta\phi(1,2) &= \phi_1 - \phi_2 \\
\eta &= -\ln\tan\frac{\theta}{2} \\
\Delta R(\mu\gamma) &= \sqrt{(\Delta\phi_{\mu\gamma})^2 + (\Delta\eta_{\mu\gamma})^2} \\
H_T &= E_T(\mu) + E_T(\gamma) + \not{E}_T
\end{aligned}
$$

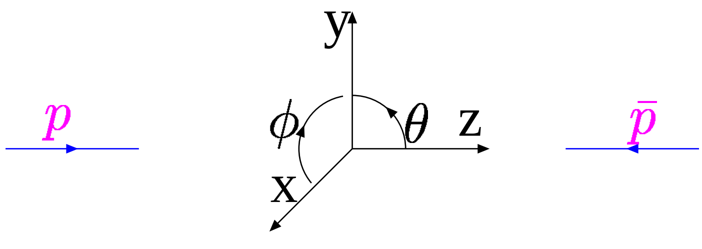


Figure 2: Coordinate system used

Scan

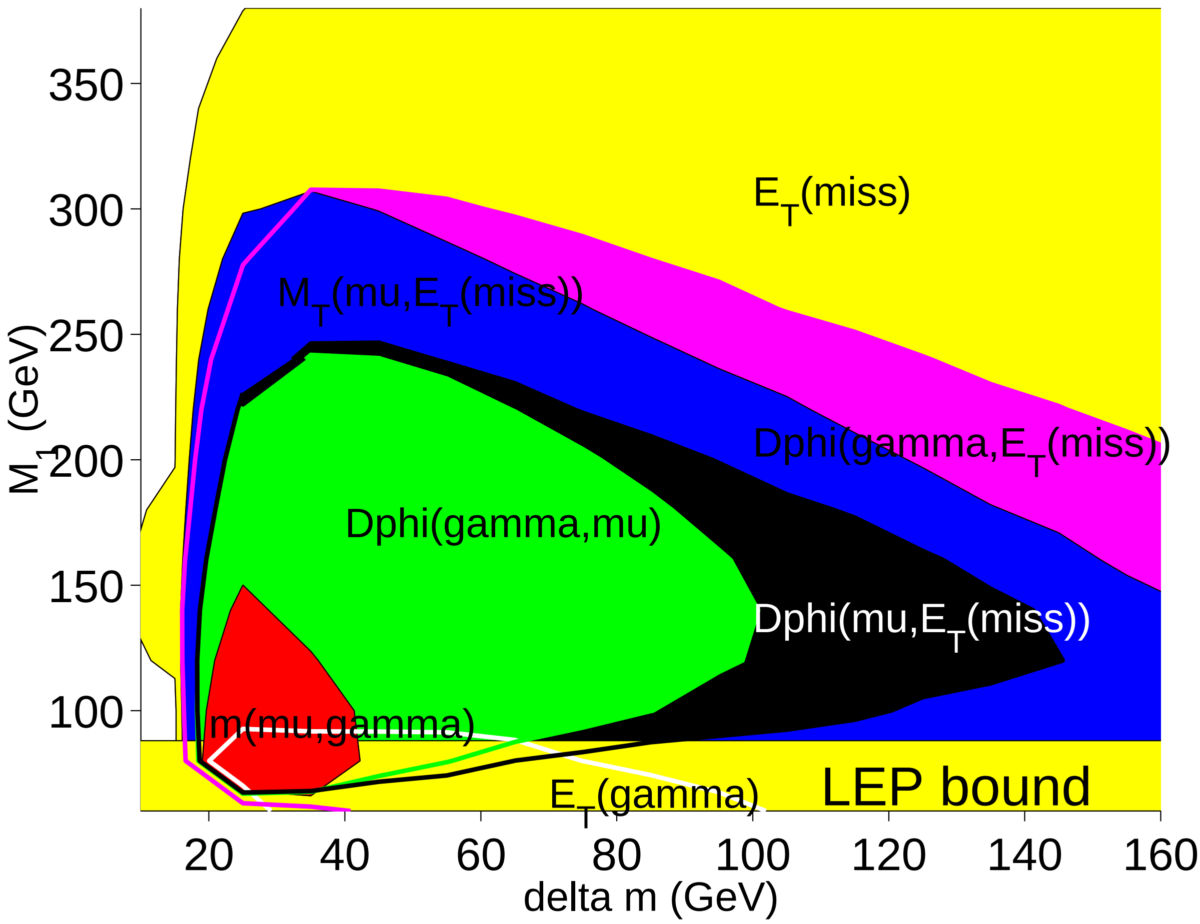


Figure 3: Fit to each variable showing 95% C.L. regions

Scan

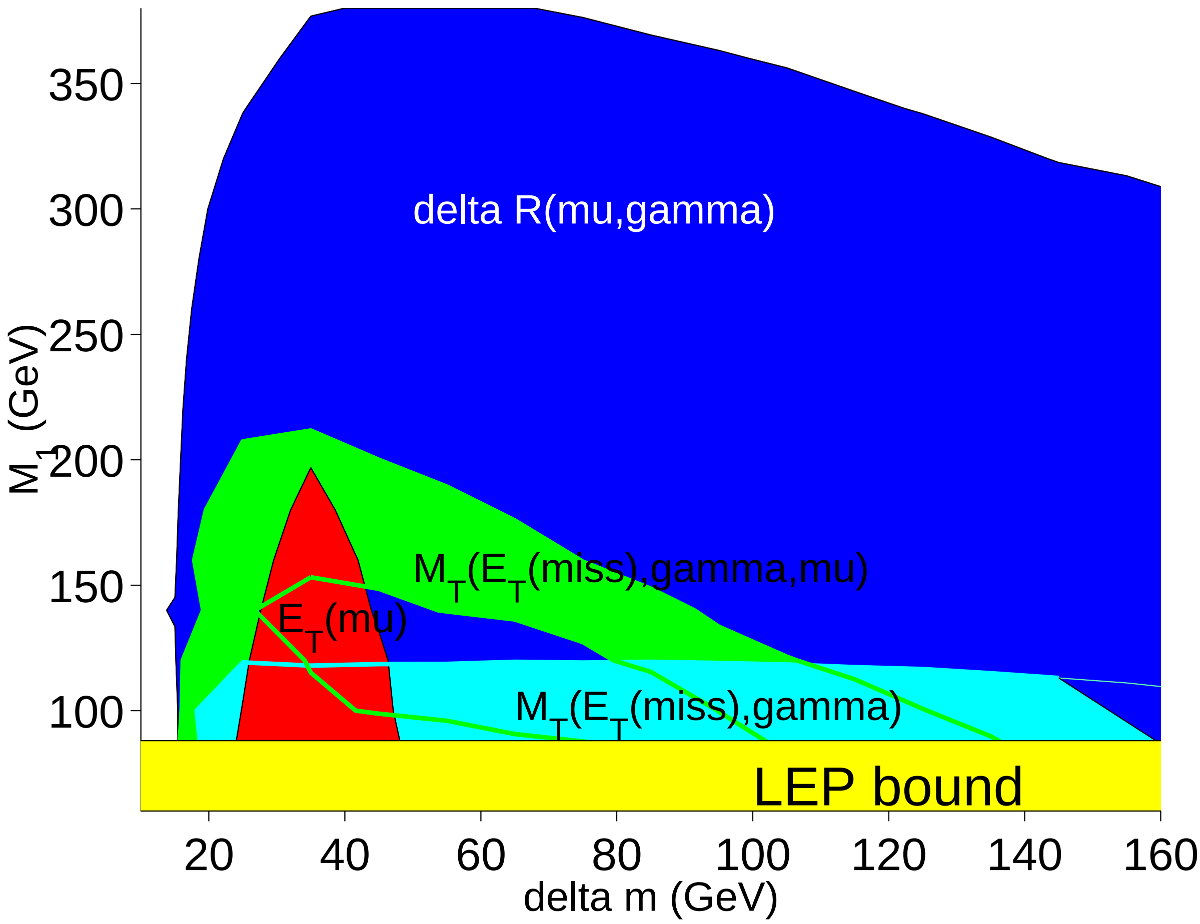


Figure 4: Fit to each variable showing 95% C.L. regions

Best-fit Points

Variable	M_1 (GeV)	$M_1 - m_{\tilde{\ell}}$ (GeV)	$\sigma_{SM} - \sigma_{model}$ (σ)
$E_T(\mu)$	87	35	3.31
$E_T(\gamma)$	67	30	3.06
$\not{E}_T$	104	47	2.47
$m_{\mu\gamma}$	82	23	3.15
$M_T(\mu \not{E}_T)$	96	44	2.56
$M_T(\gamma \not{E}_T)$	99	24	2.97
$M_T(\mu\gamma \not{E}_T)$	84	28	2.51
$\Delta\phi_{\gamma \not{E}_T}$	111	33	2.30
$\Delta\phi_{\mu\gamma}$	97	26	2.98
$\Delta\phi_{\mu \not{E}_T}$	99	25	3.00

We use $E_T(\mu)$ best-fit point, since it's got the highest likelihood, and it's the most restrictive distribution.

$$BR(\tilde{\mu} \rightarrow \mu\chi_1^0) = 0.984 \qquad BR(\chi_1^0 \rightarrow \gamma\tilde{G}) = 0.975$$

$$m_{\chi_1^0} = 86.8 \text{ GeV}, \qquad m_{\tilde{e}_L, \tilde{\mu}_L} = 130.8 \text{ GeV},$$

Energy Distributions

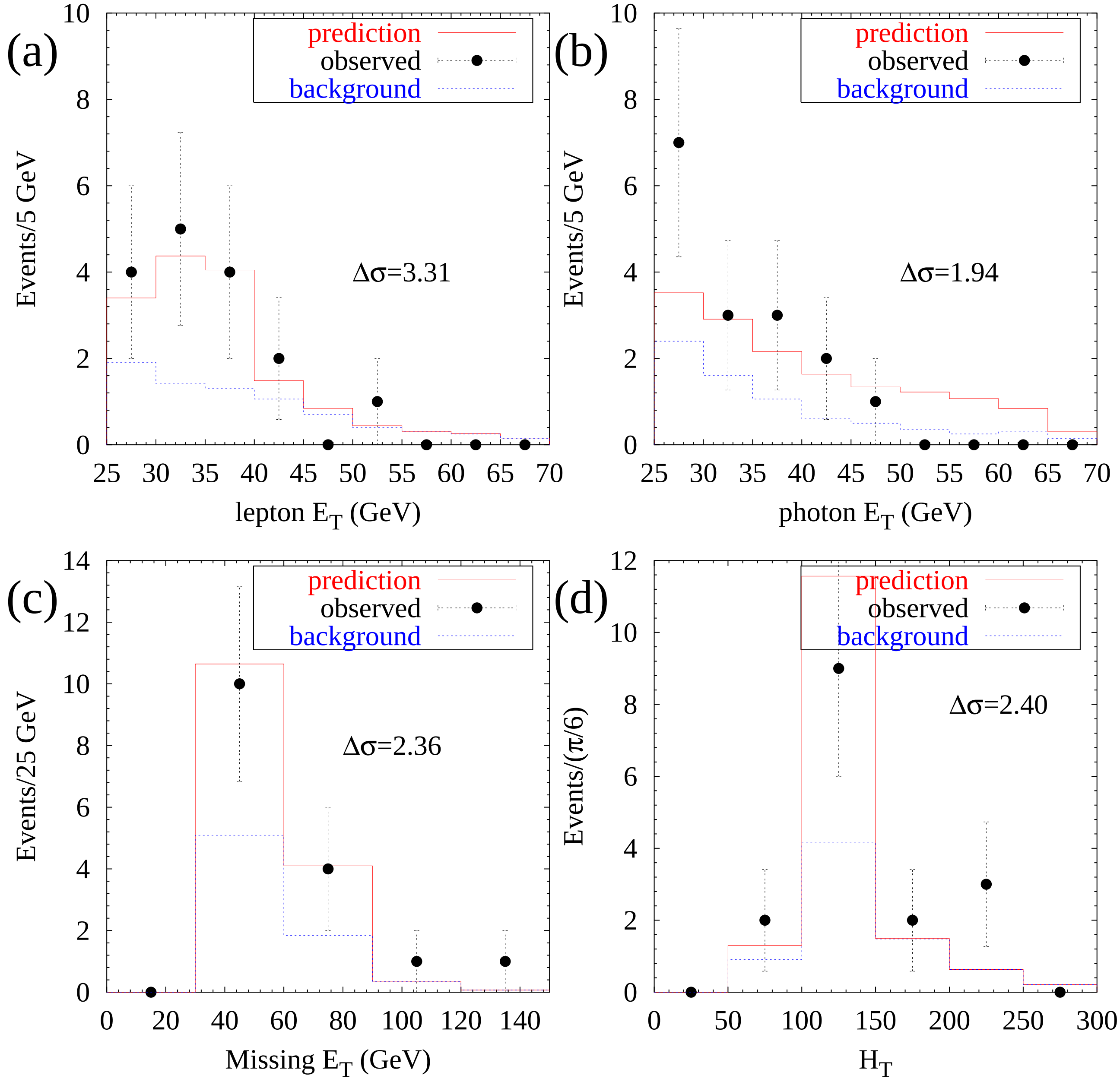


Figure 5: Red=model, blue=background, black=data

Mass Distributions

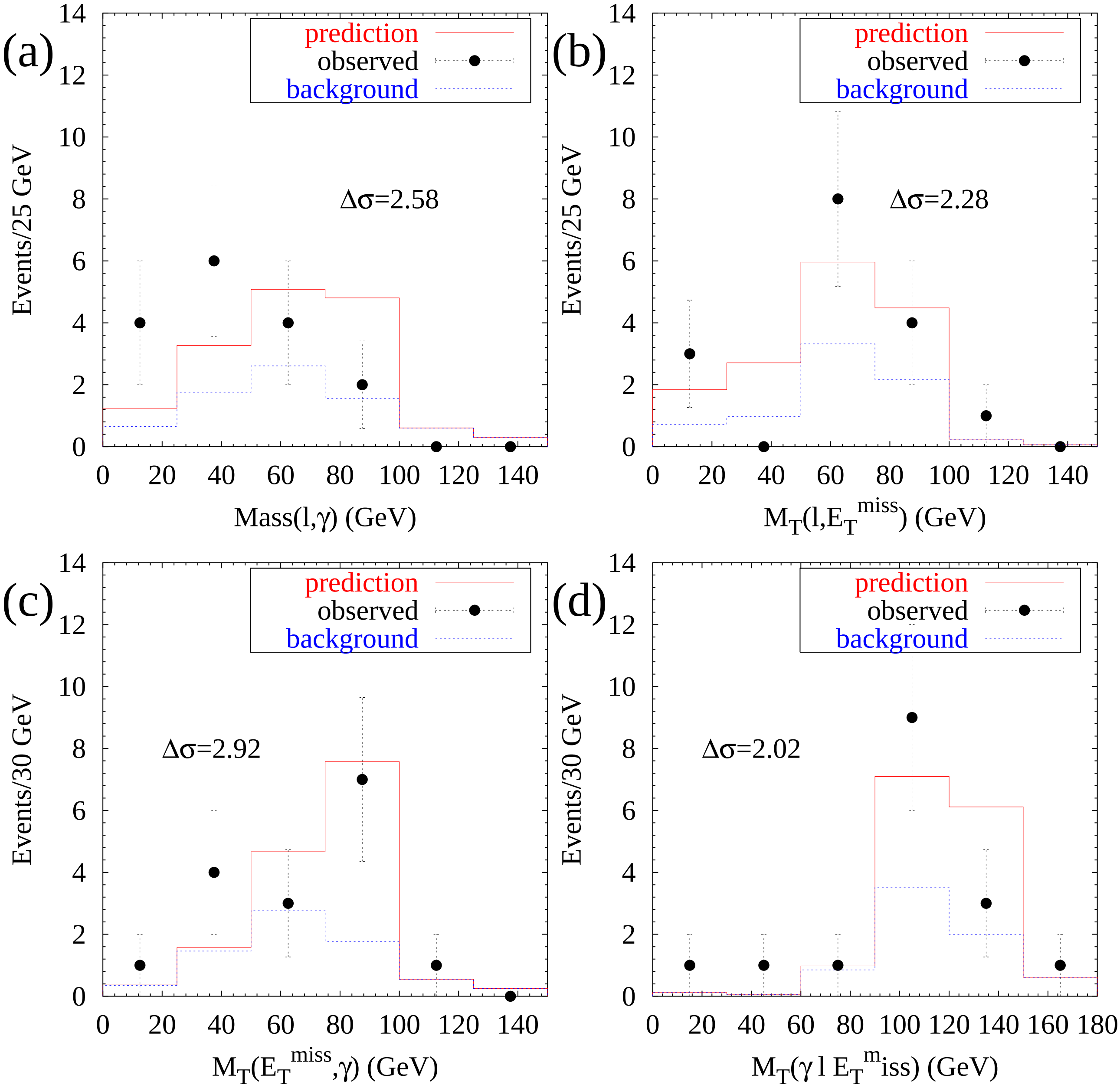


Figure 6: Red=model, blue=background, black=data

Angular Distributions

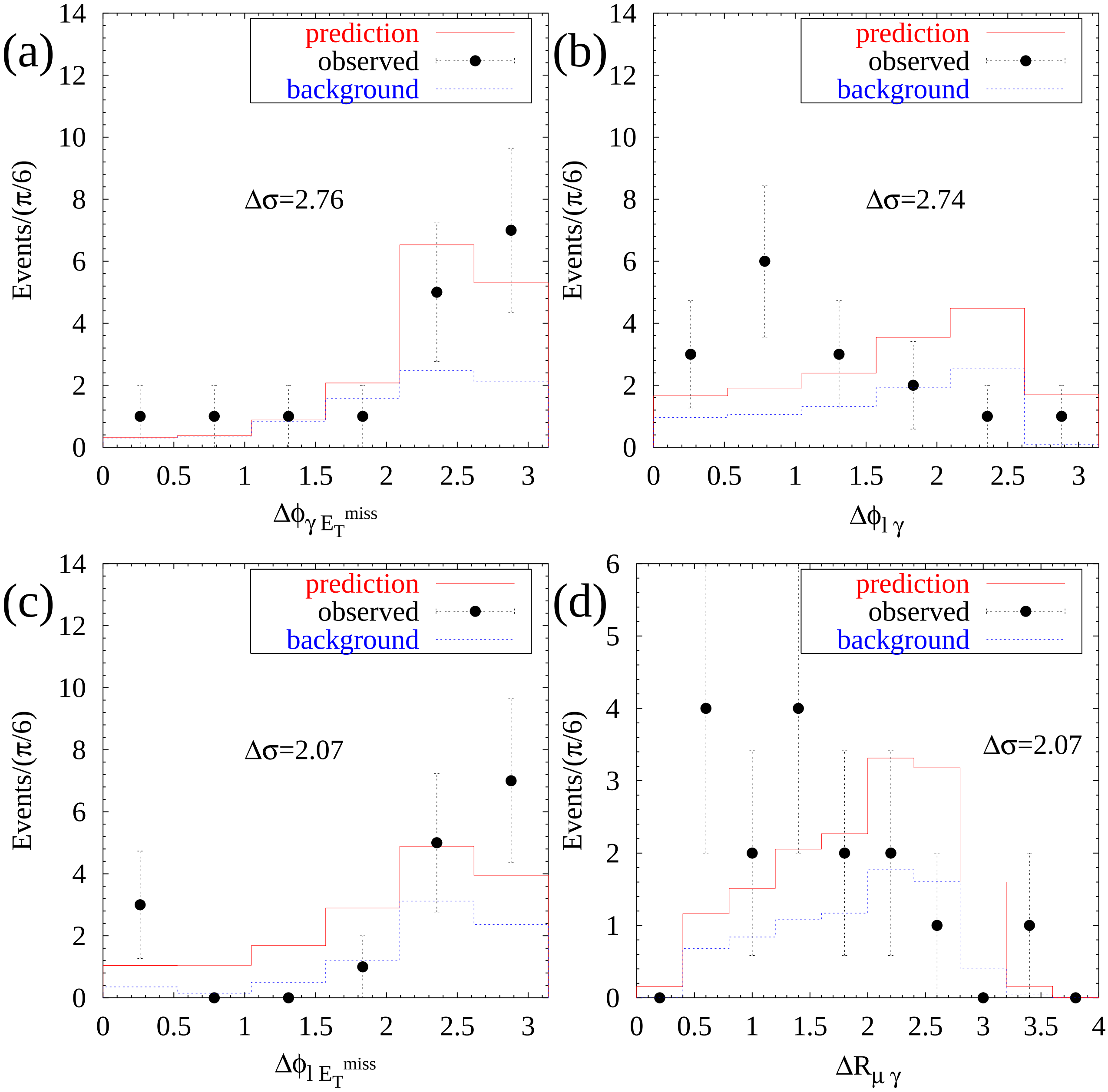


Figure 7: Red=model, blue=background, black=data

Other Processes

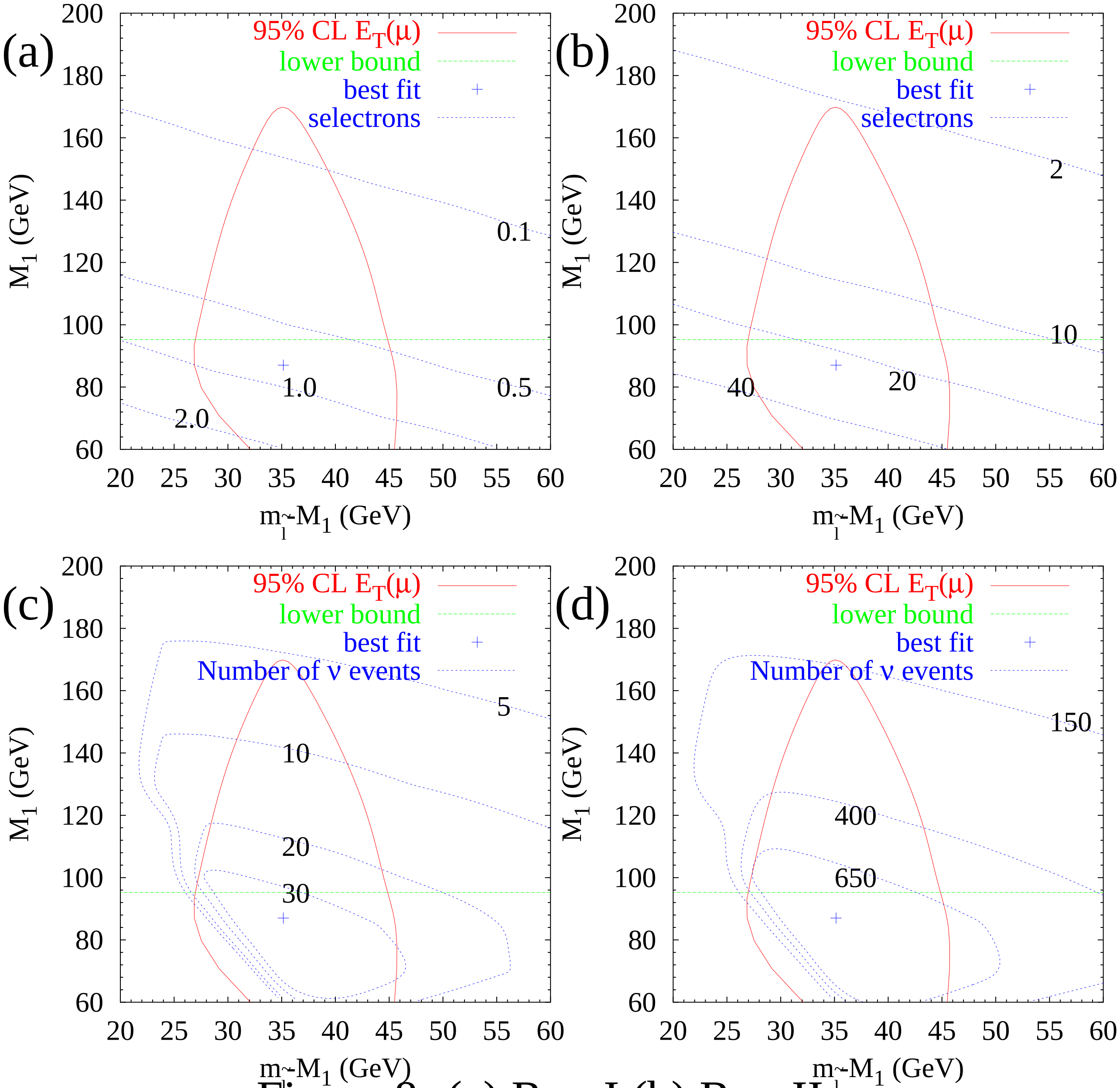


Figure 8: (a) Run I (b) Run II

Summary

- $\mu\gamma\not{E}_T$ events are in discrepancy with Standard Model background
- $ee\gamma\gamma\not{E}_T$ event also
- $\not{R}_p$ with light gravitino can explain them
- Kinematic distributions are well fit
- $\gamma\not{E}_T$ channel available: 10s of events at run I, 100s at Run II
- Run II of Tevatron will provide conclusive tests: expect 70-193 similar events at run II