An Exercise for a Tevatron Inverse Problem

Tao Han

University of Wisconsin – Madison

LHC Inverse workshop
Ann Arbor, Univ. of Michigan
(April 14, 2006)

Outline:

CDF's recent like-sign dilepton searches

Outline:

CDF's recent like-sign dilepton searches

Setup the "problem"

Outline:

CDF's recent like-sign dilepton searches

Setup the "problem"

Inverse ?

Like-sign dilepton searches at CDF

The clean dilepton signal: *

*CDF: http://www-cdf.fnal.gov

Like-sign dilepton searches at CDF

The clean dilepton signal: *

- Trigger on $(\ell = e,\ \mu)$:

$$p_T(\ell) > 18 \text{ GeV}, \quad \not\!\!E_T > 15 \text{ GeV}.$$

- the angular coverage:

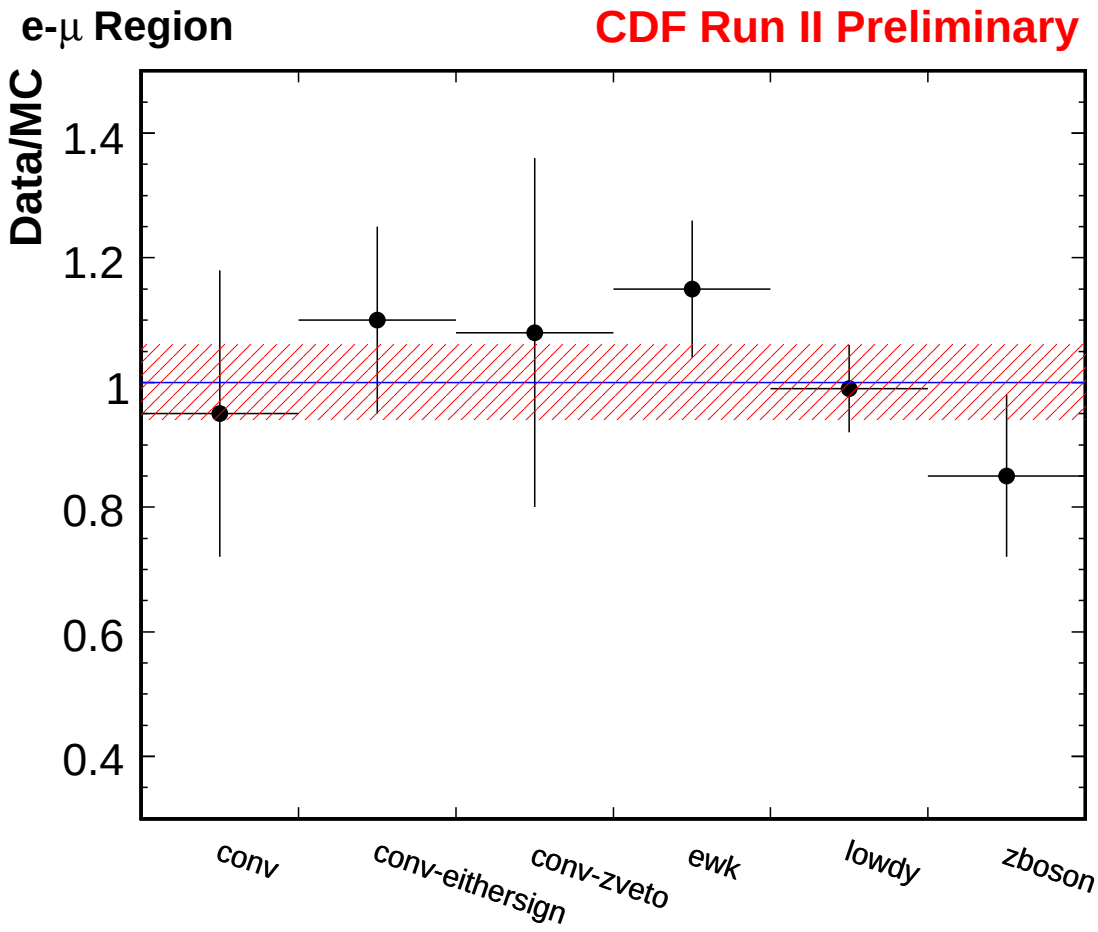
$$\eta(\mu) < 1-2, \quad \eta(e,j) < 1-3.$$

SM expectations:

$$\begin{aligned} p\bar{p} &\rightarrow W^{\pm} + \gamma^*/Z \rightarrow \ell^{\pm}\nu\ \ell^{+}\ell^{-}, \\ &\rightarrow W^{\pm} + j \rightarrow \ell^{\pm}\nu\ \ell^{\pm}, \\ &\rightarrow Z + \gamma^*/Z \rightarrow \ell^{+}\ell^{-}\ \ell^{+}\ell^{-}, \\ &\rightarrow t\ \bar{t} \rightarrow \ell^{+}\nu b\ jj\bar{b} \rightarrow \ell^{+}\nu b\ jj\bar{c}\nu\ell^{+}. \end{aligned}$$

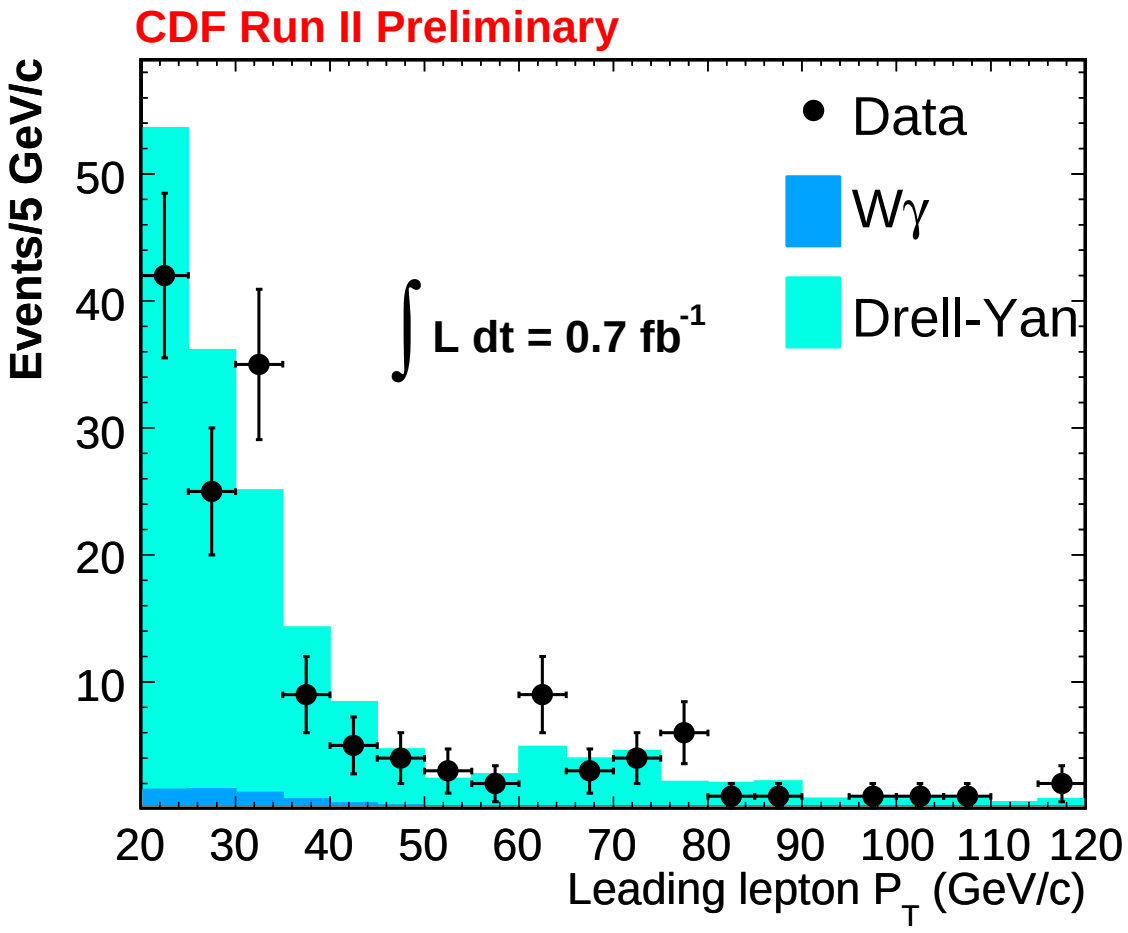
*CDF: http://www-cdf.fnal.gov

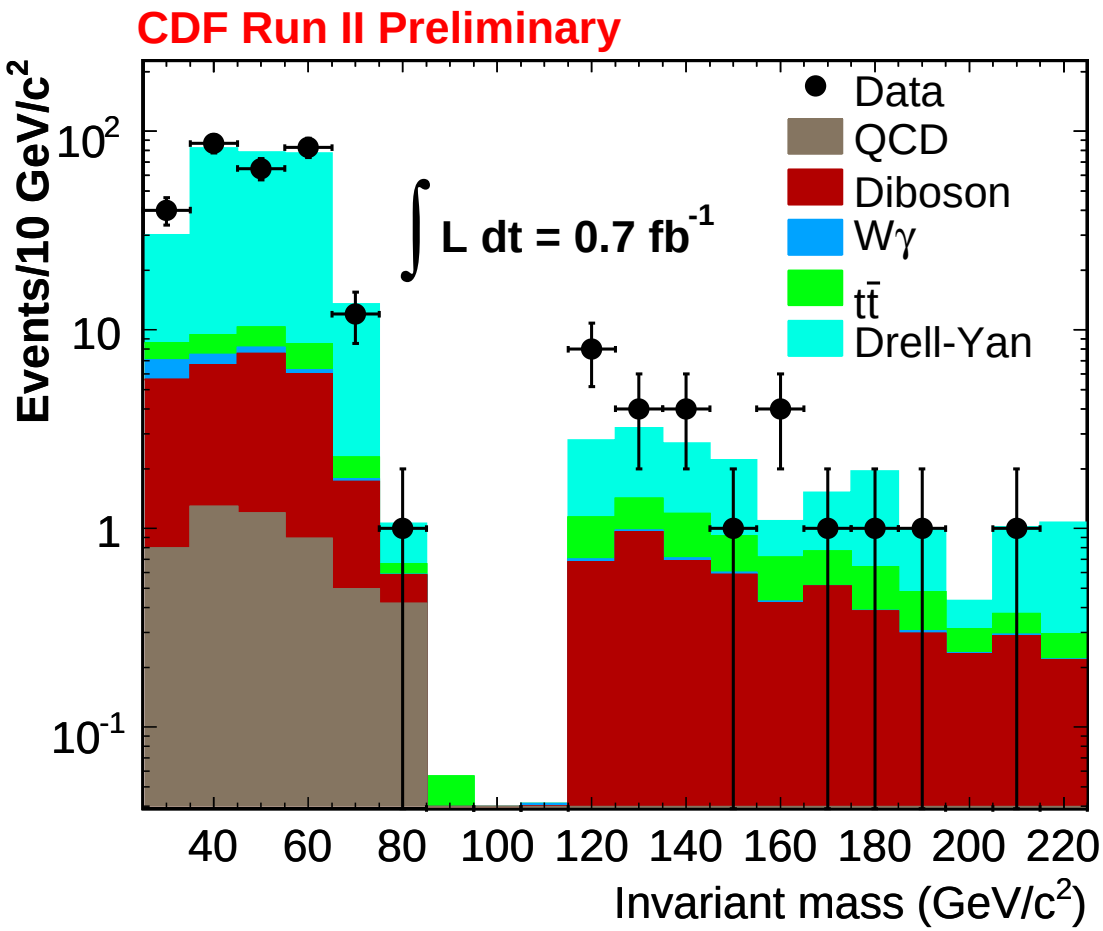
Testing: $\ell^+\ell^-$ in the control region:

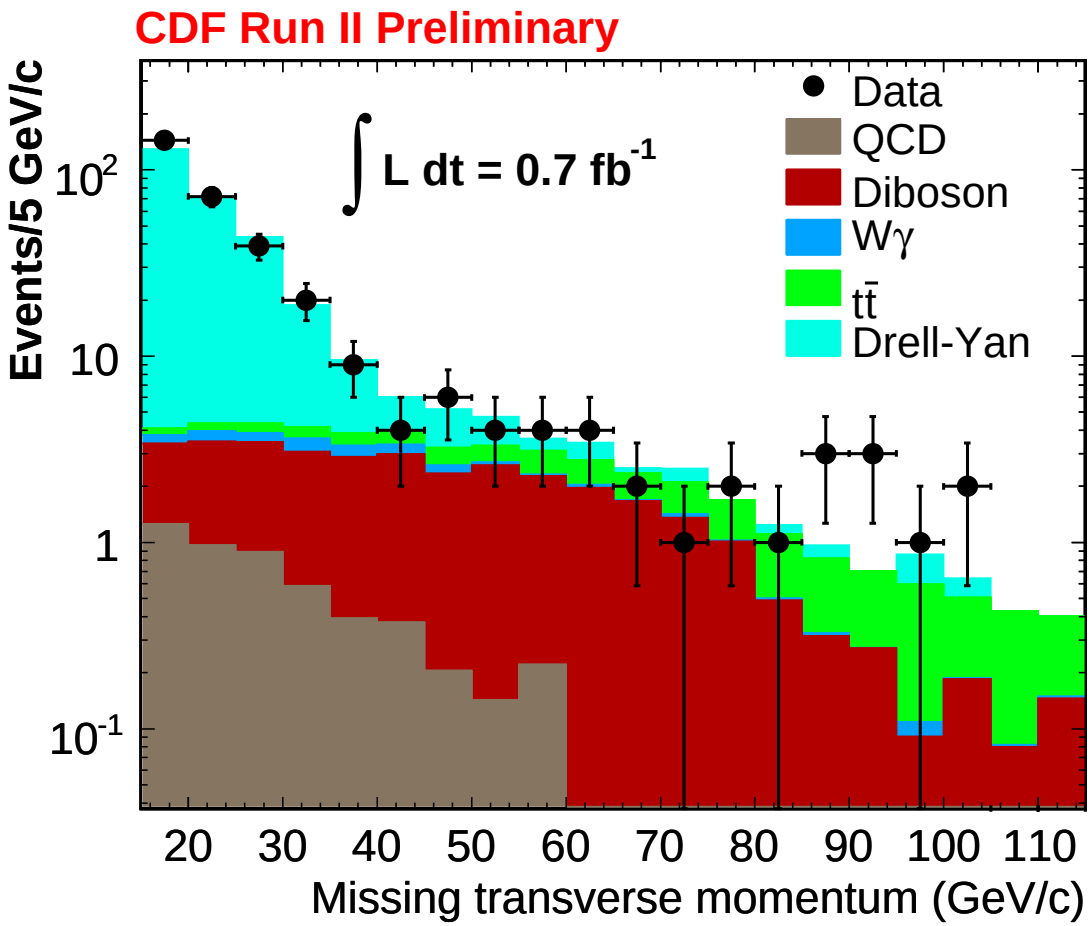


events well modeled (by Monte Carlo).

continue on in the control region:




CDF Run II Preliminary
Data
QCD
Diboson
Wγ
tt̄
Drell-Yan
∫ L dt = 0.7 fb-1
Events/10 GeV/c2
10²
10
1
10-1
40
60
80
100
120
140
160
180
200
220
Invariant mass (GeV/c2)



good agreement between data and MC.

Now like-sign dileptons:

$$e^{\pm}e^{\pm}\not{E}_T X, \quad e^{\pm}\mu^{\pm}\not{E}_T X, \quad \mu^{\pm}\mu^{\pm}\not{E}_T X$$

Tighter acceptance on the isolated dileptons:

$$p_T(\ell)_{high} > 20 \text{ GeV}, \quad p_T(\ell)_{low} > 10 \text{ GeV}, \quad m(\ell\ell) > 25 \text{ GeV}.$$

Now like-sign dileptons:

$$e^{\pm}e^{\pm}\not{E}_T X, \quad e^{\pm}\mu^{\pm}\not{E}_T X, \quad \mu^{\pm}\mu^{\pm}\not{E}_T X$$

Tighter acceptance on the isolated dileptons:

$$p_T(\ell)_{high} > 20 \text{ GeV}, \quad p_T(\ell)_{low} > 10 \text{ GeV}, \quad m(\ell\ell) > 25 \text{ GeV}.$$

SM expectation by MC:

channel	ee	$e\mu$	$\mu\mu$	combine
$W\gamma^*$	1.38	1.72	0.27	3.37
jet faked	0.53	0.53	0.22	1.28
Drell-Yan	0.42	0.81	0.0	1.23
di-bosons	0.21	0.46	0.24	0.91
tot. predicted	2.54	3.52	0.73	6.79
stats. uncern.	0.32	0.25	0.08	0.49
systm. uncern.	17%	18%	10%	15%

Now like-sign dileptons:

$$e^{\pm}e^{\pm}\not{E}_T X, \quad e^{\pm}\mu^{\pm}\not{E}_T X, \quad \mu^{\pm}\mu^{\pm}\not{E}_T X$$

Tighter acceptance on the isolated dileptons:

$$p_T(\ell)_{high} > 20 \text{ GeV}, \quad p_T(\ell)_{low} > 10 \text{ GeV}, \quad m(\ell\ell) > 25 \text{ GeV}.$$

SM expectation by MC:

channel	ee	$e\mu$	$\mu\mu$	combine
$W\gamma^*$	1.38	1.72	0.27	3.37
jet faked	0.53	0.53	0.22	1.28
Drell-Yan	0.42	0.81	0.0	1.23
di-bosons	0.21	0.46	0.24	0.91
tot. predicted	2.54	3.52	0.73	6.79
stats. uncern.	0.32	0.25	0.08	0.49
systm. uncern.	17%	18%	10%	15%

Observation:

channel	ee	$e\mu$	$\mu\mu$	combine
total	4	5	0	9

The "Problem":

The "Problem":

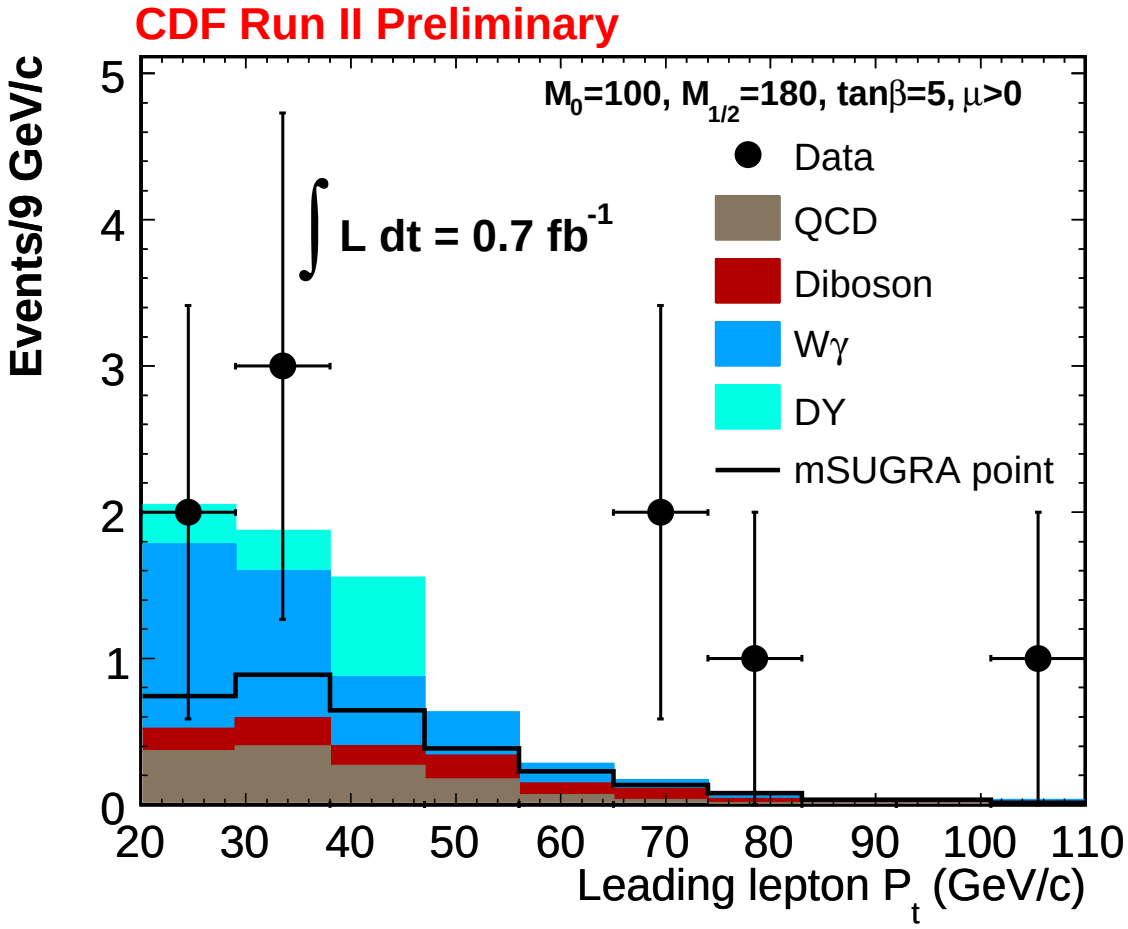
- There is NO problem!

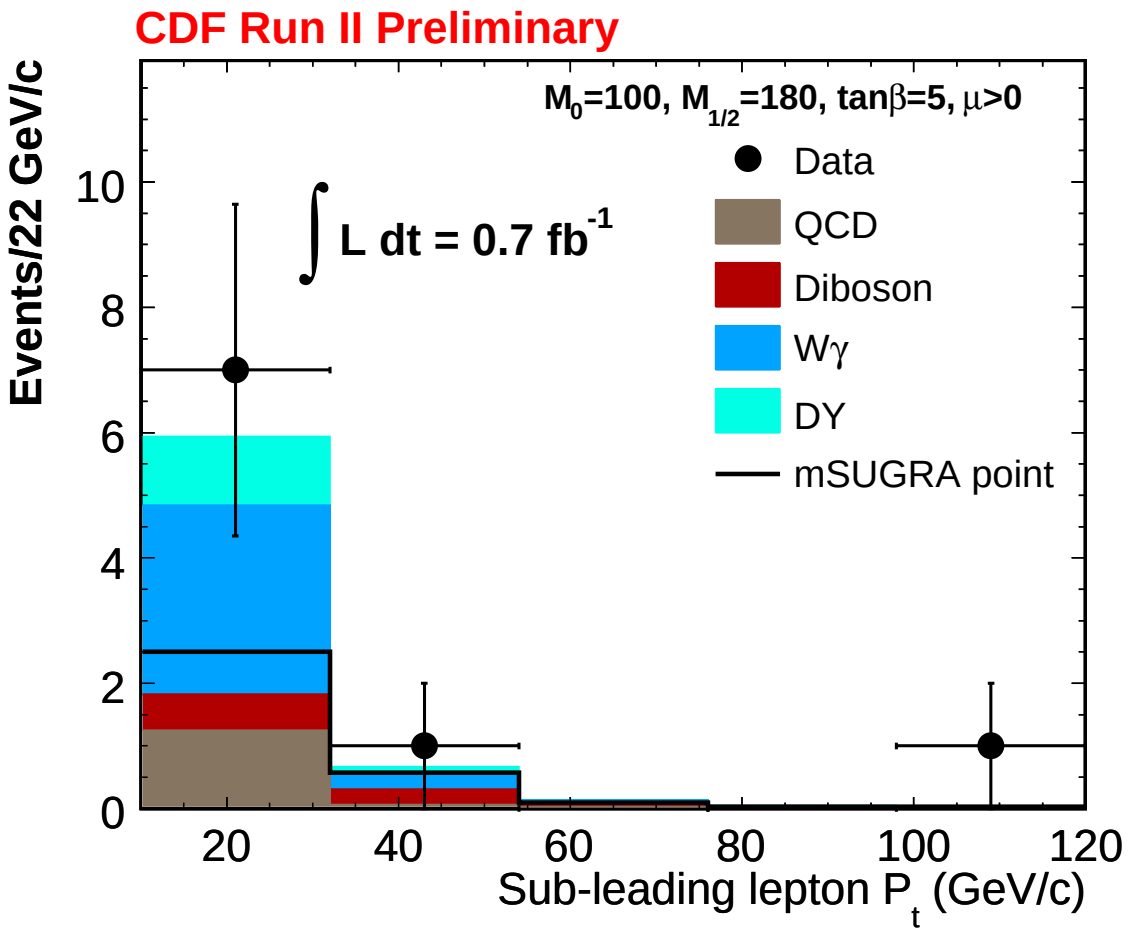
The "Problem":

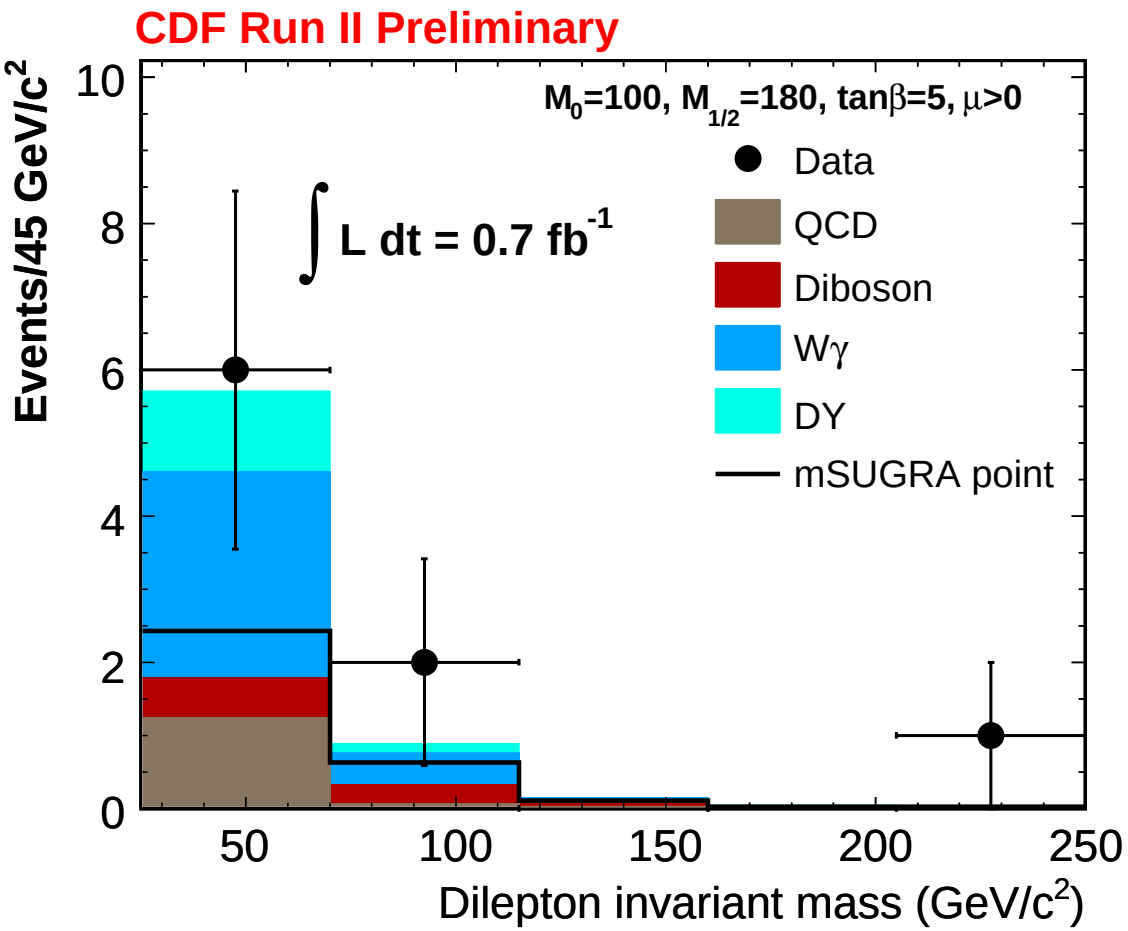
- There is NO problem!
- Two extra events?

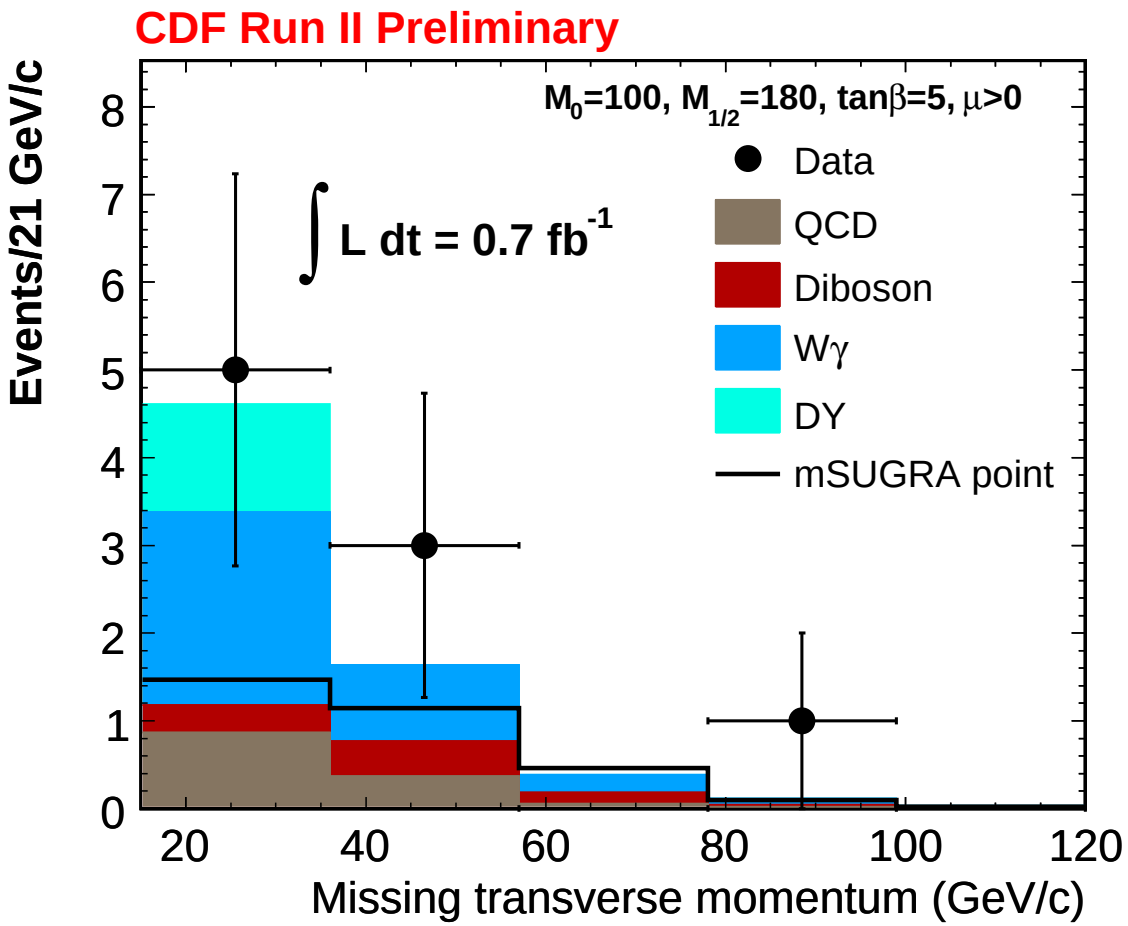
The "Problem":

- There is NO problem!
- Two extra events?
- And:

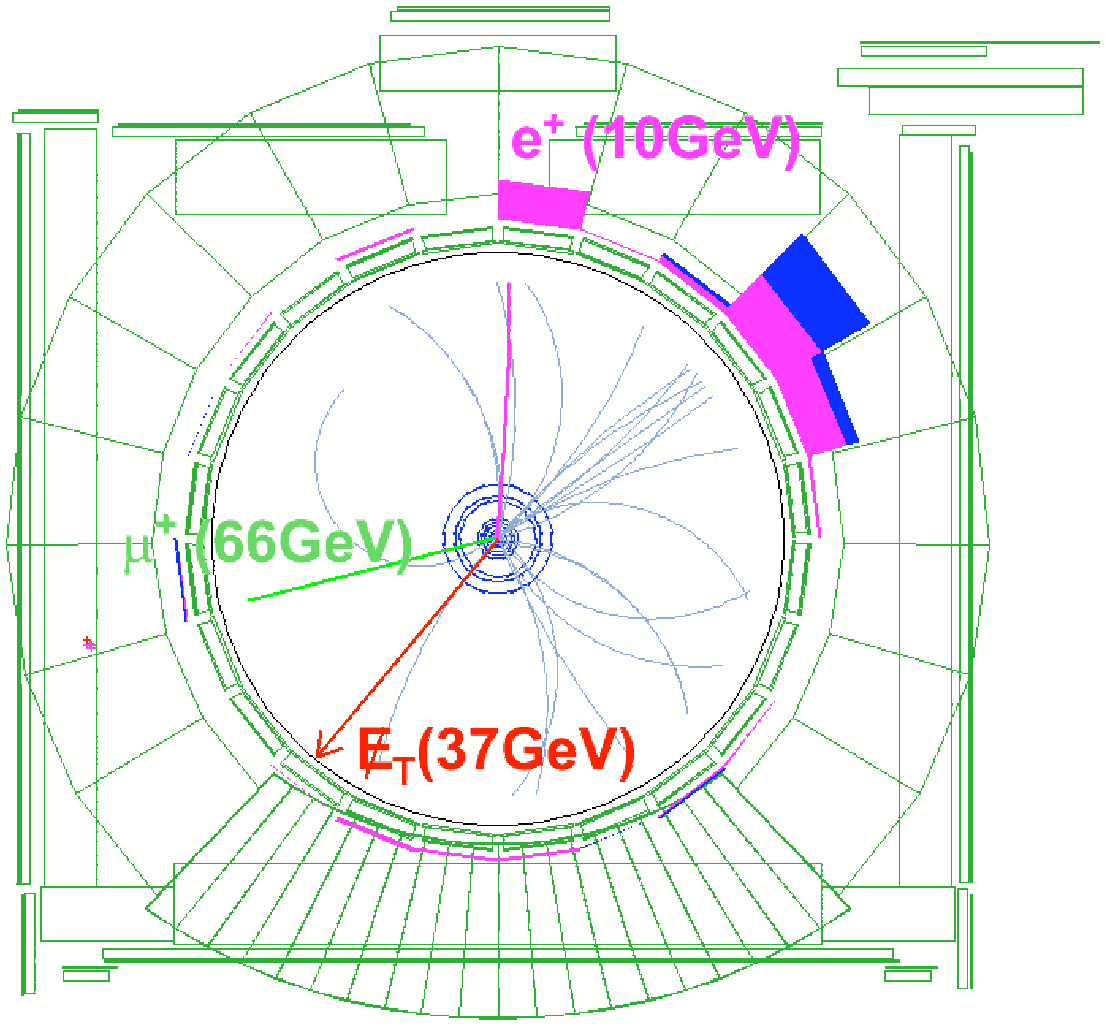



CDF Run II Preliminary
M0=100, M1/2=180, tanβ=5, μ>0
∫ L dt = 0.7 fb-1
Data
QCD
Diboson
Wγ
DY
mSUGRA point
Events/22 GeV/c
0
2
4
6
8
10
20
40
60
80
100
120
Sub-leading lepton Pt (GeV/c)


CDF Run II Preliminary
M_0=100, $M_{1/2}$=180, tanβ=5, μ>0
∫ L dt = 0.7 fb^{-1}
Data
QCD
Diboson
Wγ
DY
mSUGRA point
Events/45 GeV/c^2
Dilepton invariant mass (GeV/c^2)
0
2
4
6
8
10
50
100
150
200
250

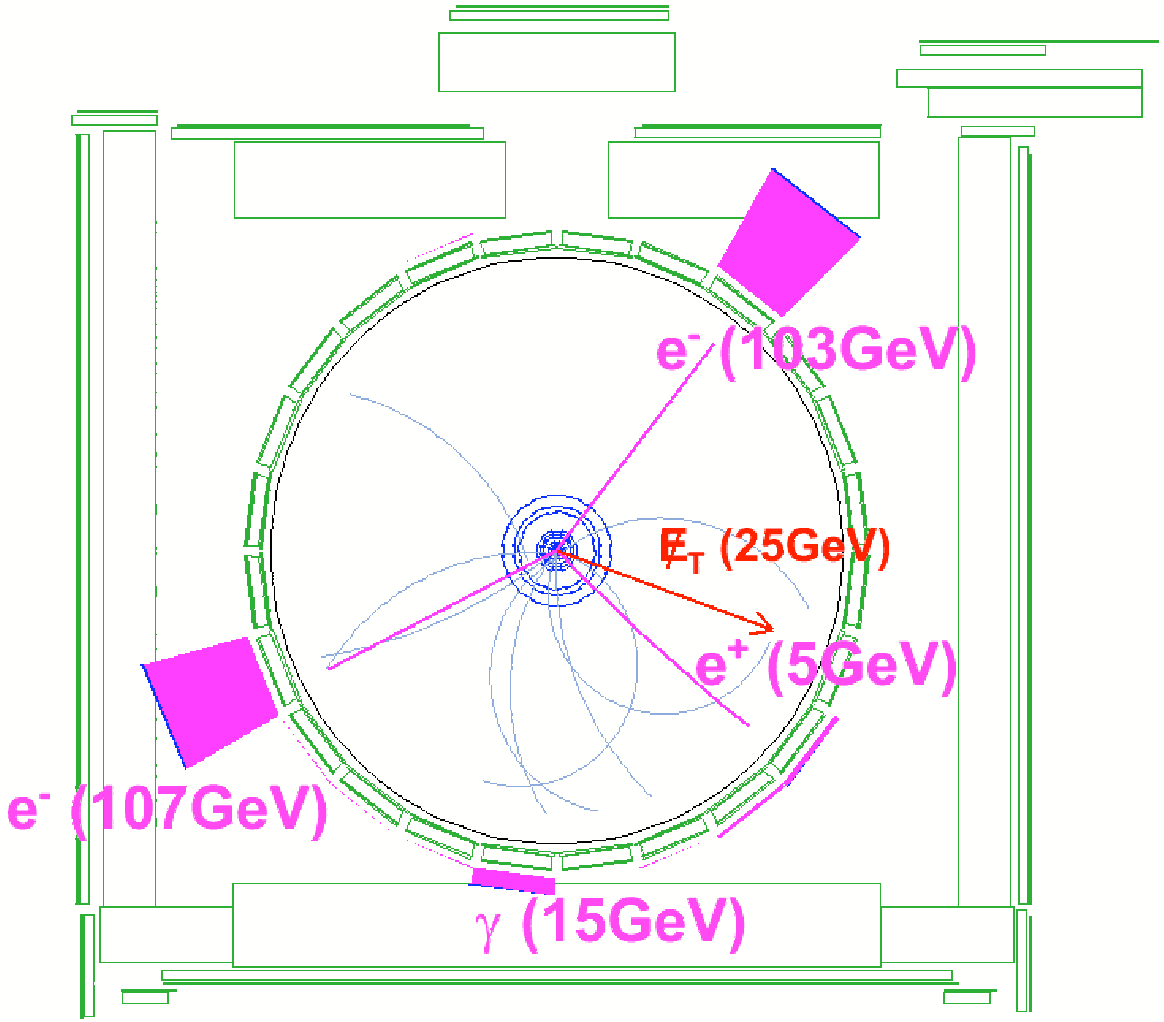

CDF Run II Preliminary
M_0=100, $M_{1/2}$=180, tanβ=5, μ>0
∫ L dt = 0.7 fb^{-1}
Data
QCD
Diboson
Wγ
DY
mSUGRA point
Events/21 GeV/c
Missing transverse momentum (GeV/c)
0
1
2
3
4
5
6
7
8
20
40
60
80
100
120

One of the events for display: $e^+\mu^+\not{E}_T$



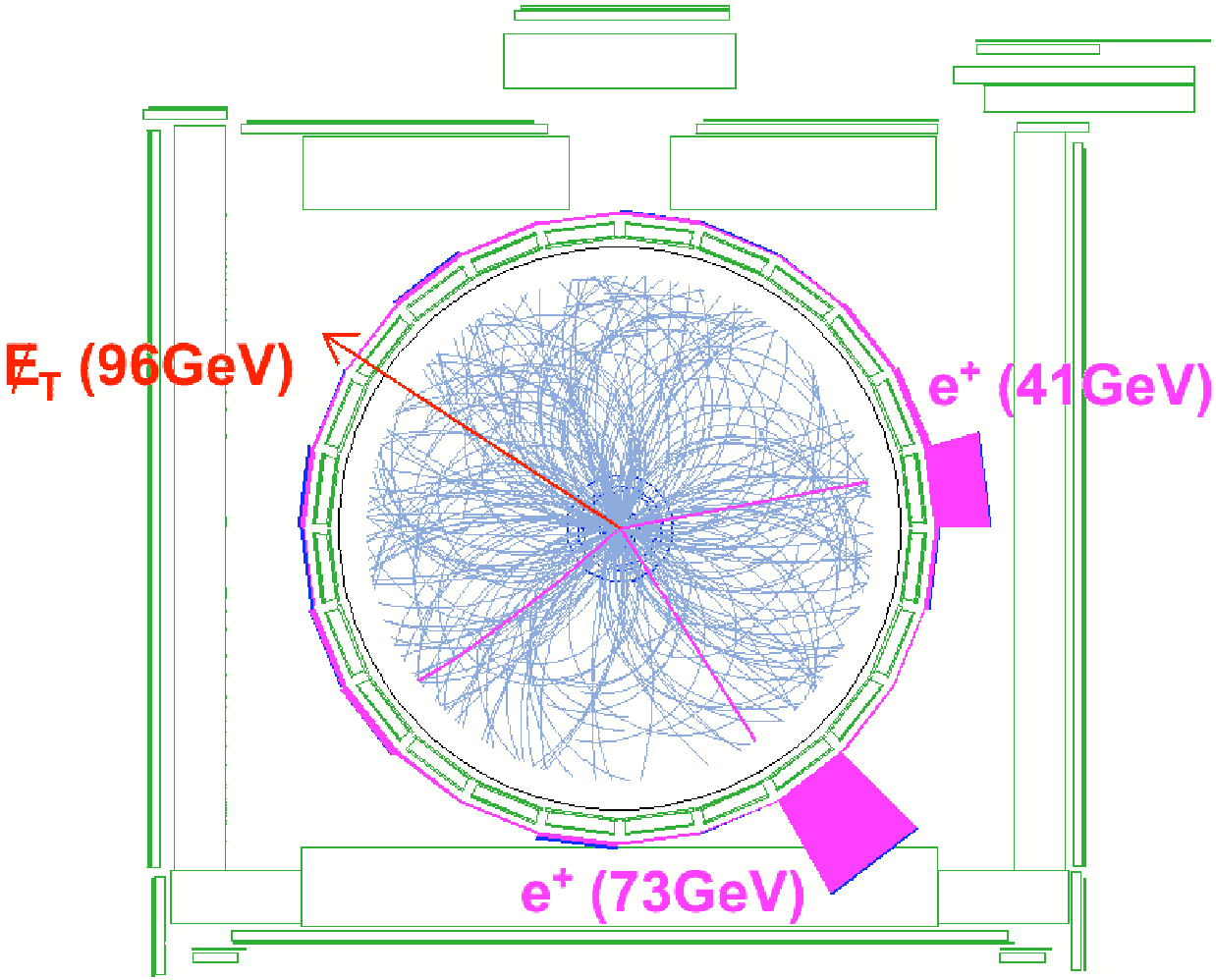
Very clean, and rather quiet.

Another interesting one: $e^-e^-\gamma\ e^+\not{E}_T$



Again, clean and quiet.

Finally, e^+e^+ $\not\!\!E_T$



less quiet, still no very hard jets.

The "Inverse":

The "Inverse":

Assume that:

- the excess is a signal of new Physics.

The "Inverse":

Assume that:

- the excess is a signal of new Physics.
- seek interpretation from SUSY.

The "Inverse":

Assume that:

- the excess is a signal of new Physics.
- seek interpretation from SUSY.

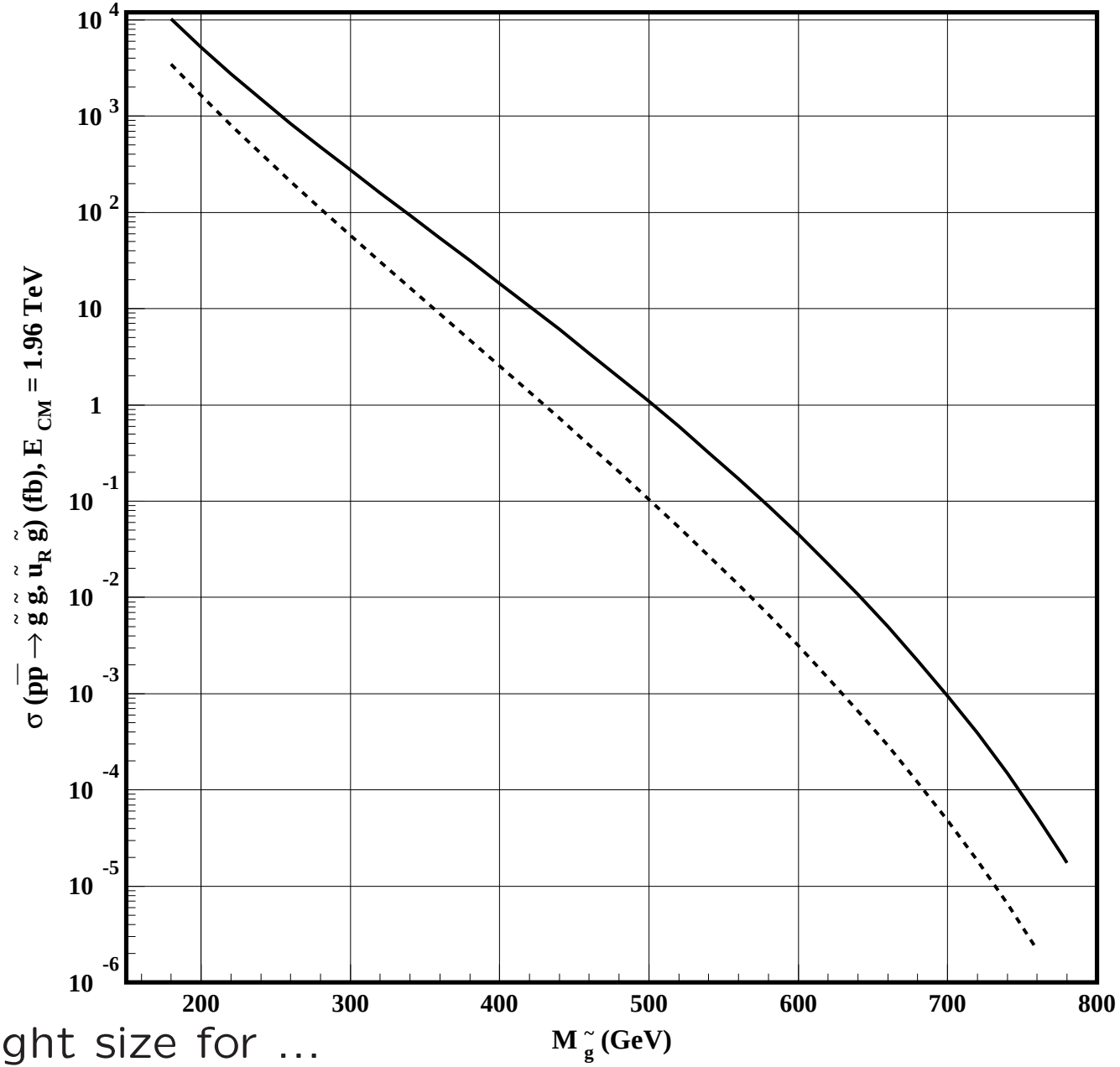
Reminder:

- Generic bounds from the Tevatron: *

$$M_{\tilde{g}} > 330 \text{ GeV}, \quad M_{\tilde{q}} > 300 \text{ GeV}, \quad M_{\chi^{\pm}} > 210 \text{ GeV}.$$

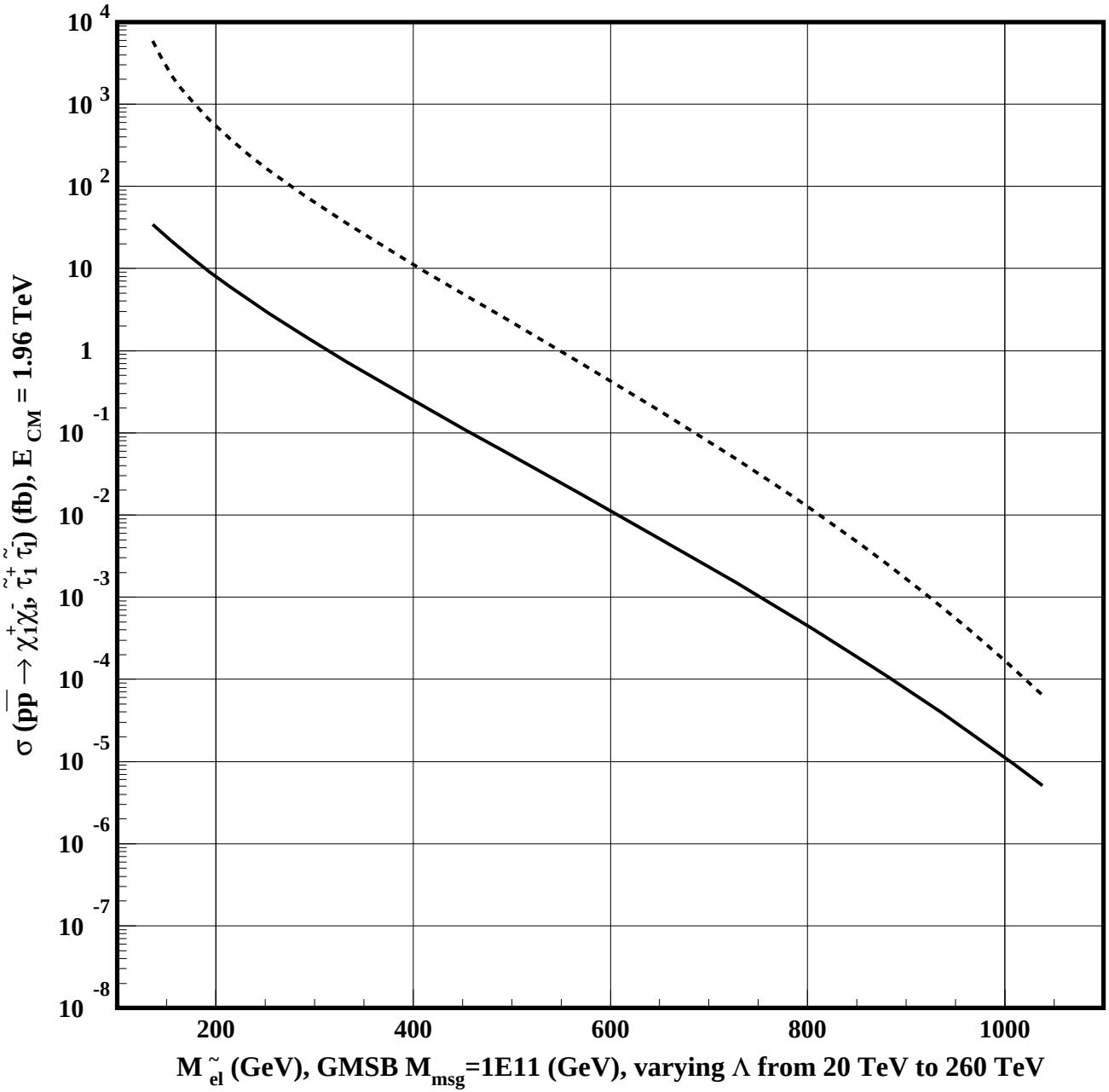
*CDF+D0: hep-ex/0505056.

Colored S-particle cross sections at the Tevatron:



It's about right size for ...

GMSB cross sections at the Tevatron:



It's about right size for ...

Trial I: colored particle production

$$\begin{aligned} p\bar{p} &\rightarrow \tilde{g}\tilde{g}\ (\tilde{g}\tilde{q}) \rightarrow j_1\tilde{q}\quad j_2\tilde{q} \\ &\rightarrow j_1 j_3 \chi^{\pm}\quad j_2 j_4 \chi^{\pm} \\ &\rightarrow jets\quad \ell^{\pm}\ell^{\pm}\not{E}_T. \end{aligned}$$

Trial I: colored particle production

$$\begin{aligned} p\bar{p} &\rightarrow \tilde{g}\tilde{g}\ (\tilde{g}\tilde{q}) \rightarrow j_1\tilde{q}\quad j_2\tilde{q} \\ &\rightarrow j_1 j_3 \chi^{\pm}\quad j_2 j_4 \chi^{\pm} \\ &\rightarrow jets\quad \ell^{\pm}\ell^{\pm}\not{E}_T. \end{aligned}$$

Need:

- reduce jet activities: $M_{\tilde{g}} \approx M_{\tilde{q}} \approx M_{\chi}$;

Trial I: colored particle production

$$\begin{aligned} p\bar{p} &\rightarrow \tilde{g}\tilde{g}\ (\tilde{g}\tilde{q}) \rightarrow j_1\tilde{q}\quad j_2\tilde{q} \\ &\rightarrow j_1 j_3\chi^{\pm}\quad j_2 j_4\chi^{\pm} \\ &\rightarrow jets\quad \ell^{\pm}\ell^{\pm}\not{E}_T. \end{aligned}$$

Need:

- reduce jet activities: $M_{\tilde{g}} \approx M_{\tilde{q}} \approx M_{\chi}$;

- hard leptons: $M_{\chi} > 200$ GeV $\gg M_{\chi^0}$.

Trial I: colored particle production

$$\begin{aligned} p\bar{p} &\to \tilde{g}\tilde{g}\ (\tilde{g}\tilde{q}) \to j_1\tilde{q}\quad j_2\tilde{q} \\ &\to j_1 j_3\chi^{\pm}\quad j_2 j_4\chi^{\pm} \\ &\to jets\quad \ell^{\pm}\ell^{\pm}\not{E}_T. \end{aligned}$$

Need:

- reduce jet activities: $M_{\tilde{g}} \approx M_{\tilde{q}} \approx M_{\chi}$;

- hard leptons: $M_{\chi} > 200$ GeV $\gg M_{\chi^0}$.

Trial II: gaugino production

$$\begin{aligned} p\bar{p} &\to \chi^{\pm}\chi_2^0 \to \ell^{\pm}\chi_1^0\quad \ell^{\pm}\tilde{\ell}^* \\ &\to \ell^{\pm}\ell^{\pm}\not{E}_T + \text{a bit more.} \end{aligned}$$

Trial I: colored particle production

$$\begin{aligned} p\bar{p} &\to \tilde{g}\tilde{g}\ (\tilde{g}\tilde{q}) \to j_1\tilde{q}\ \ j_2\tilde{q} \\ &\to j_1 j_3 \chi^{\pm}\ \ j_2 j_4 \chi^{\pm} \\ &\to jets\ \ \ell^{\pm}\ell^{\pm}\not{E}_T. \end{aligned}$$

Need:

- reduce jet activities: $M_{\tilde{g}} \approx M_{\tilde{q}} \approx M_{\chi}$;

- hard leptons: $M_{\chi} > 200$ GeV $\gg M_{\chi^0}$.

Trial II: gaugino production

$$\begin{aligned} p\bar{p} &\to \chi^{\pm}\chi_2^0 \to \ell^{\pm}\chi_1^0\ \ \ell^{\pm}\tilde{\ell}^* \\ &\to \ell^{\pm}\ell^{\pm}\not{E}_T + \text{a bit more.} \end{aligned}$$

Could be a solution:

- in mSUGRA (CDF): $M_0 = 100$ GeV, $M_{1/2} = 180$ GeV
$\Longrightarrow 0.6\ ee,\ 1.6\ e\mu,\ 0.9\ \mu\mu \approx 3$!

kinematics (details) ?

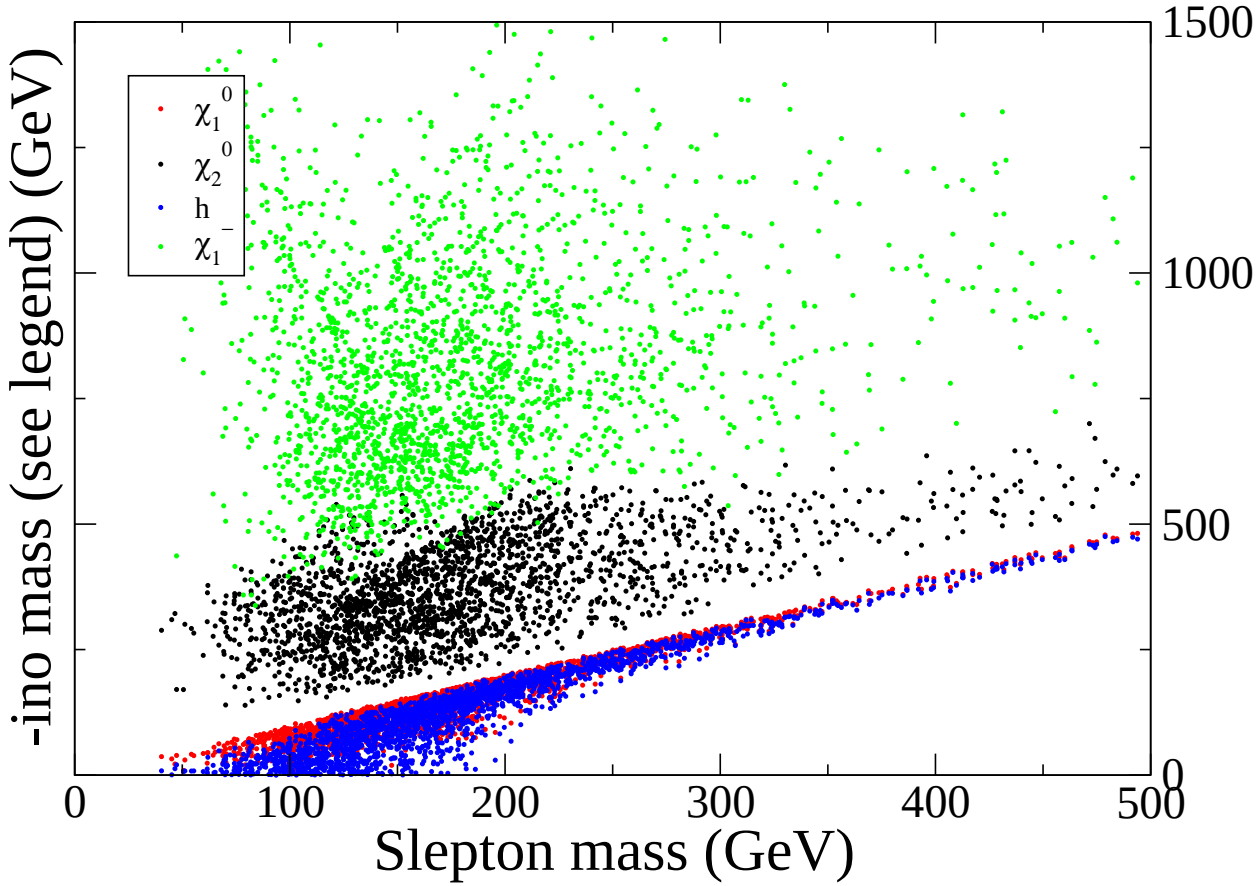
Trial III: in GMSB

$$
\begin{aligned}
p\bar{p} &\rightarrow \chi_1^- \chi_2^0 \rightarrow e^- \nu \chi_1^0 \quad e^- \tilde{e}^+ \\
&\rightarrow e^- e^- \; e^+ \; \gamma \; \tilde{G}'s \\
\text{with} \qquad & \tilde{e} \rightarrow e^+ \chi_1^0, \quad \chi_1^0 \rightarrow \gamma \tilde{G} \text{ (or not).}
\end{aligned}
$$

Trial III: in GMSB

$$
\begin{aligned}
p\bar{p} \;&\rightarrow\; \chi_1^- \chi_2^0 \rightarrow e^- \nu \chi_1^0 \;\; e^- \tilde{e}^+ \\
&\rightarrow\; e^- e^- \; e^+ \; \gamma \; \tilde{G}'s \\
\text{with} \qquad & \tilde{e} \rightarrow e^+ \chi_1^0, \quad \chi_1^0 \rightarrow \gamma \tilde{G} \text{ (or not).}
\end{aligned}
$$

Kinematical fit to the CDF event: *



*Bob McElrath

What else ?

What else ?

We need to ask for more:

What else ?

We need to ask for more:

- flavor contents, including τ's;

What else ?

We need to ask for more:

- flavor contents, including τ's;
- different acceptance cuts and event identifications;

What else ?

We need to ask for more:

- flavor contents, including τ's;
- different acceptance cuts and event identifications;
- (a lot) more data ...