SUSY Trilepton Searches at the Tevatron

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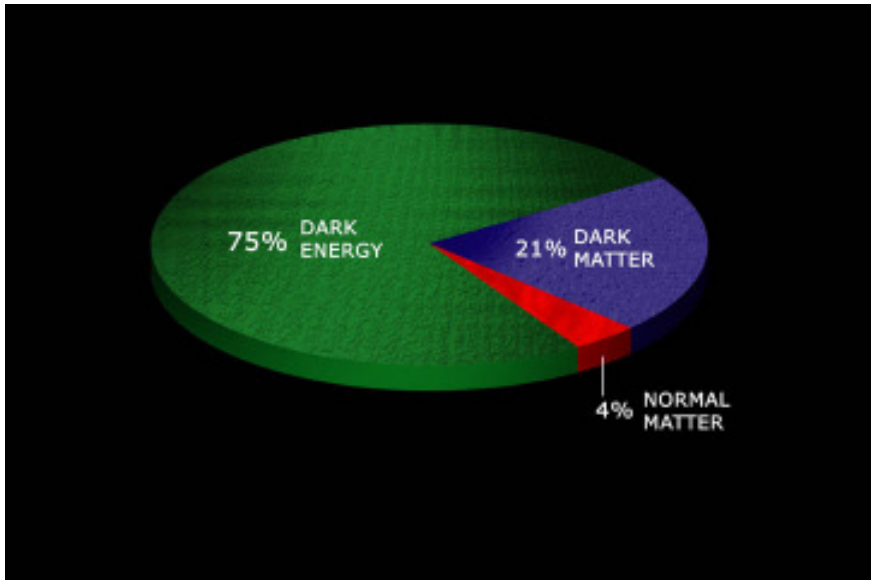
On behalf of the DØ and CDF experiments.

Supersymmetry

Supersymmetry provides possible solutions for remaining problems of the Standard Model:

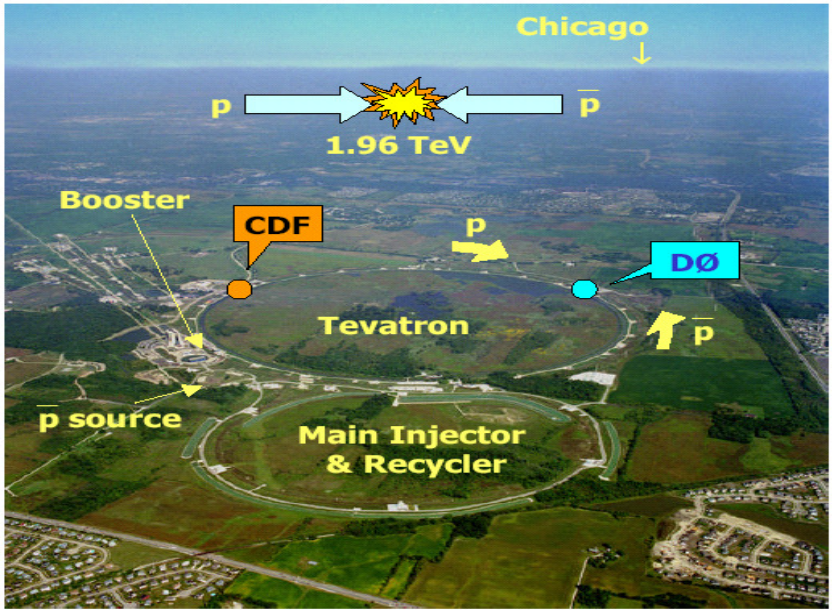
- Dark Matter Candidate
- Unification of gauge couplings at high energies
- Fine tuning of corrections to the Higgs mass

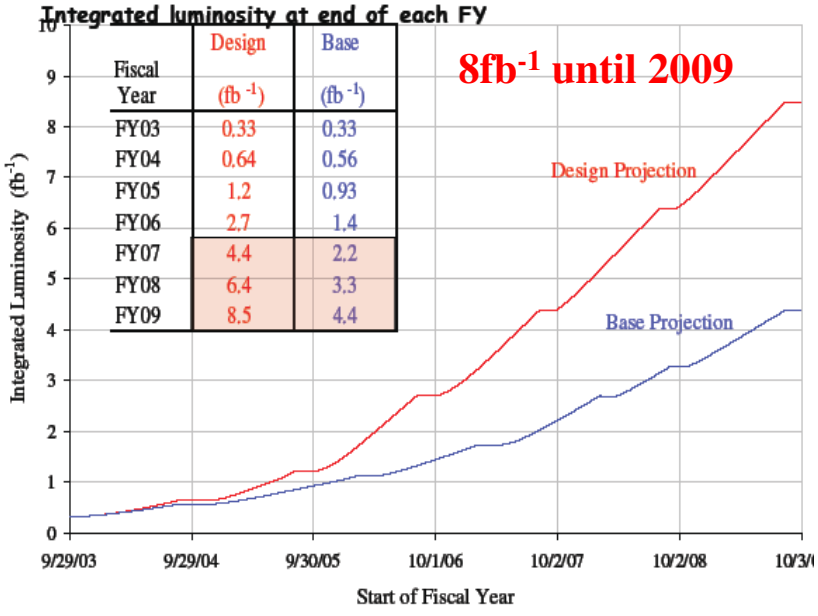


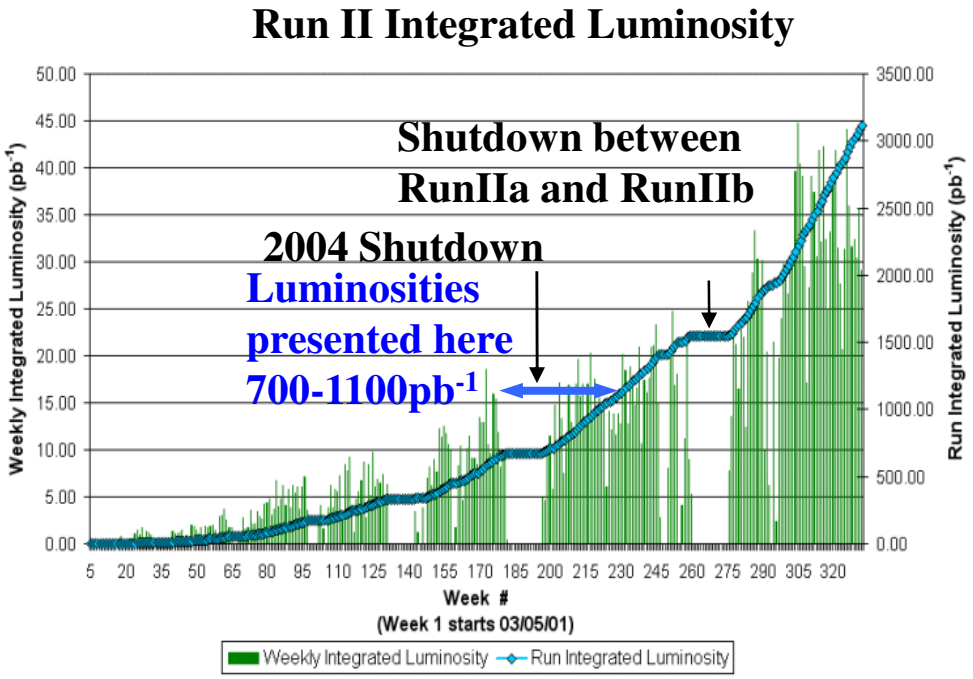
R–parity = +1			R–parity = –1			R–parity = –1		
Particle	Symbol	Spin	Particle	Symbol	Spin	Particle	Symbol	Spin
Lepton	ℓ	$\frac{1}{2}$	Slepton	$\tilde{\ell}_L, \tilde{\ell}_R$	0			
Neutrino	ν	$\frac{1}{2}$	Sneutrino	$\tilde{\nu}$	0			
Quark	q	$\frac{1}{2}$	Squark	$\tilde{q}_L, \tilde{q}_R$	0			
Gluon	g	1	Gluino	$\tilde{g}$	$\frac{1}{2}$			
Photon	γ	1	Photino	$\tilde{\gamma}$	$\frac{1}{2}$			
Z Boson	Z	1	Zino	$\tilde{Z}$	$\frac{1}{2}$			
W Boson	$W^{\pm}$	1	Wino	$\tilde{W}^{\pm}$	$\frac{1}{2}$	Neutralino	$\tilde{\chi}_i^0$	$\frac{1}{2}$
Higgs	$H^0, H^{\pm}$	0	Higgsino	$\tilde{H}_1^0, \tilde{H}_2^+$	$\frac{1}{2}$	Chargino	$\tilde{\chi}_j^{\pm}$	$\frac{1}{2}$
	h^0, A^0	0		$\tilde{H}_1^-, \tilde{H}_2^0$	$\frac{1}{2}$			

Tevatron

- Proton-Antiproton Collider
- Centre-of-mass Energy 1.96 TeV
- Integrated luminosity ~3 fb^{-1} so far
- RunIIb upgrade of accelerator and detectors succesfully completed







CDF & DØ

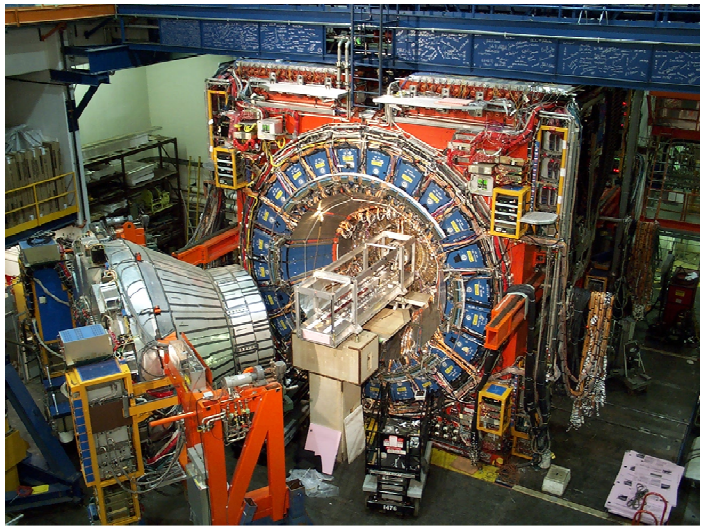
Two General Purpose Detectors: CDF DØ

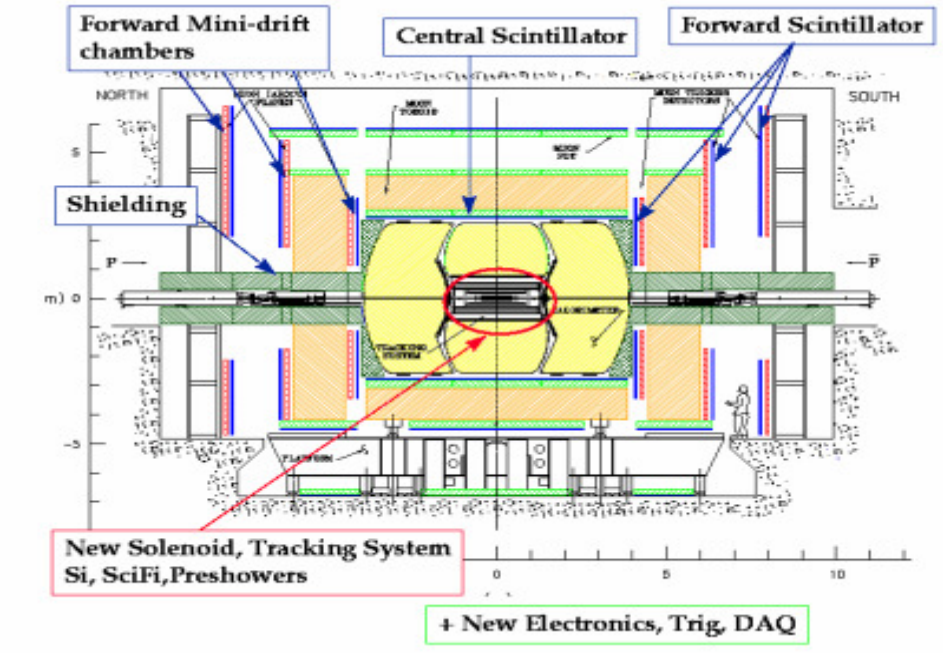
Electron acceptance	$\|\eta\|<2.0$	$\|\eta\|<3.0$
Muon acceptance	$\|\eta\|<1.5$	$\|\eta\|<2.0$
Silicon Precision tracking	$\|\eta\|<2.0$	$\|\eta\|<3.0$
Calorimeter	$\|\eta\|<3.6$	$\|\eta\|<4.2$

Powerful trigger systems (2.5MHz → 50Hz)

- Dilepton triggers starting at p_T>4GeV
- Jets + MET with E_T>25GeV

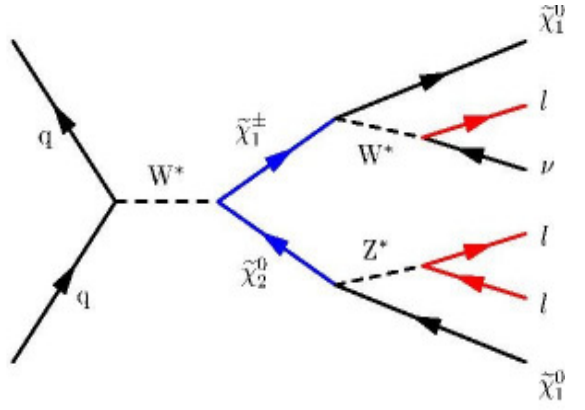
Average Efficiency up to ~90%

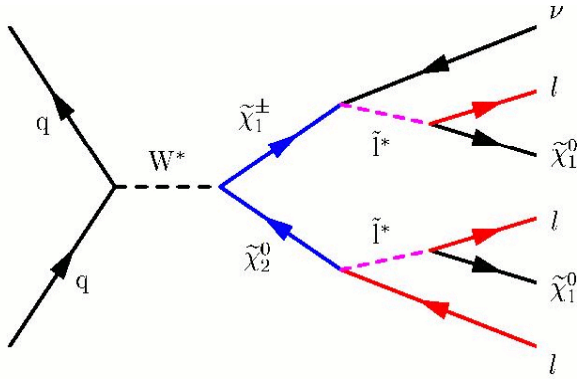


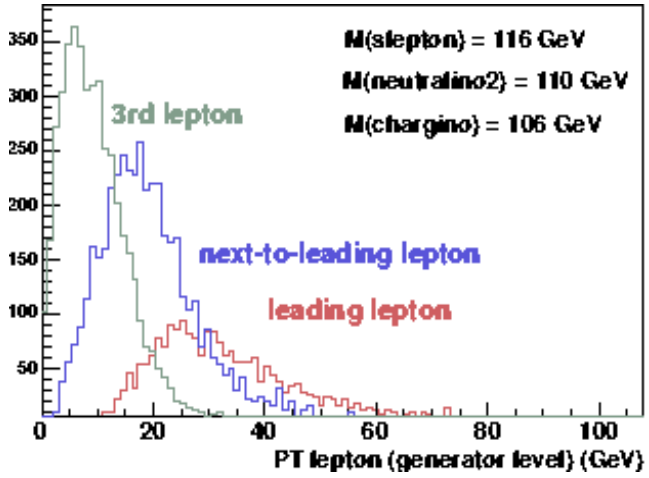


Production and Decay Mode

- Associated production of charginos and neutralinos
  - s-channel: via W boson
  - t-channel: squark exchange
  - Destructive interference
- Final state consists of
  - Three charged leptons
  - Two neutralinos (LSP)
  - One neutrino
- Golden decay mode for chargino/neutralino search at the Tevatron
- Challenges:
  - Leptons can have low transverse momenta
  - σ x BR is small (<0.5pb)

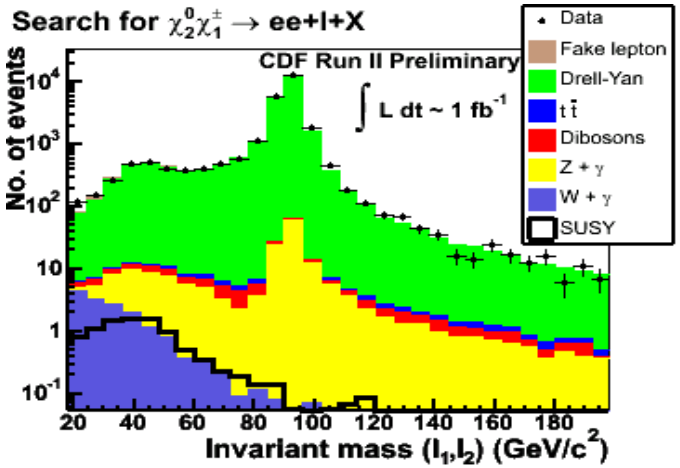


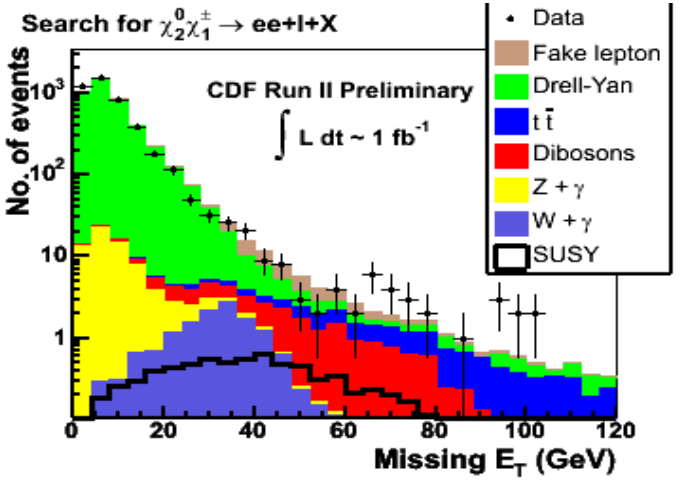




Backgrounds

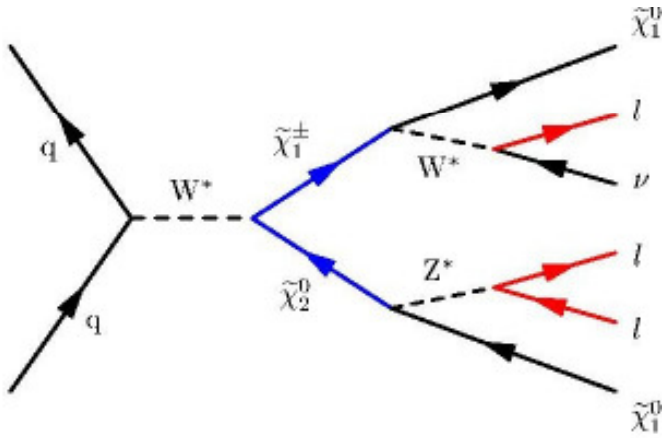
- Background Components
  - Vector boson production
    - Z/γ*->ee/μμ (2 leptons)
    - Z/γ*->ττ (2 leptons + MET)
    - W+jets/γ (1 lepton + MET)
  - Vector boson pair production
    - WW (2 leptons + MET)
    - WZ (3 leptons + MET)
    - ZZ (2 leptons + MET or 4 leptons)
  - Other components
    - Multijet production (no isolated leptons)
    - $t\bar{t}$ (2 leptons + MET)
    - Υ (2 leptons)
- QCD contribution determined from data by inverting lepton ID criteria





Selection Strategy

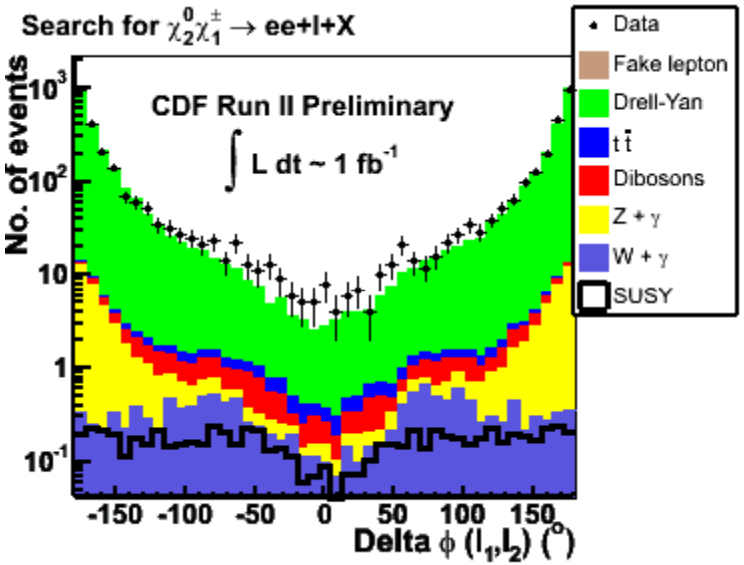
- Trilepton analysis
  - Require **two reconstructed leptons** (either e or μ)
  - Require **significant MET** to account for escaping neutralinos/neutrinos
  - Require **one additional lepton** candidate
    - Isolated high quality track (e, μ and τ; DØ)
    - A reconstructed lepton (e or μ)



- Likesign dilepton analysis
  - Require **two reconstructed leptons** of the same charge
  - Require **significant MET** to account for escaping neutralinos/neutrinos
  - No requirement for a third object

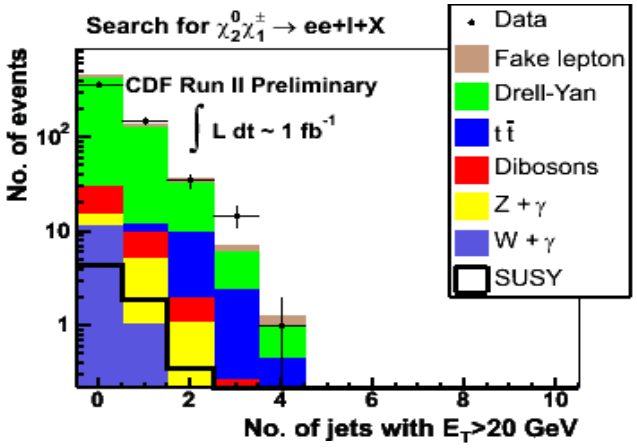
Event Selection (1)

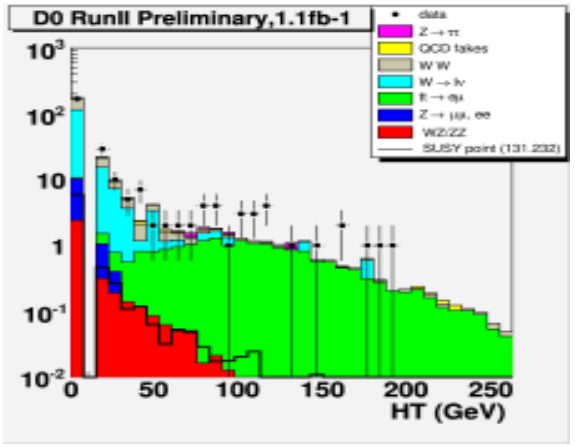
- Preselection
  - Two well reconstructed leptons (ee, μμ, eμ)
  - p_T > 5-20 GeV for the leading lepton
  - p_T > 5-10 GeV for the next-to-leading lepton
- Anti Z/γ* requirements
  - Invariant mass between resonances
  - Not back-to-back
- Anti $t\bar{t}$ requirement
  - Reject events with high jet activity
    - Number of jets (CDF)
    - Sum of jet momenta
- Third lepton candidate



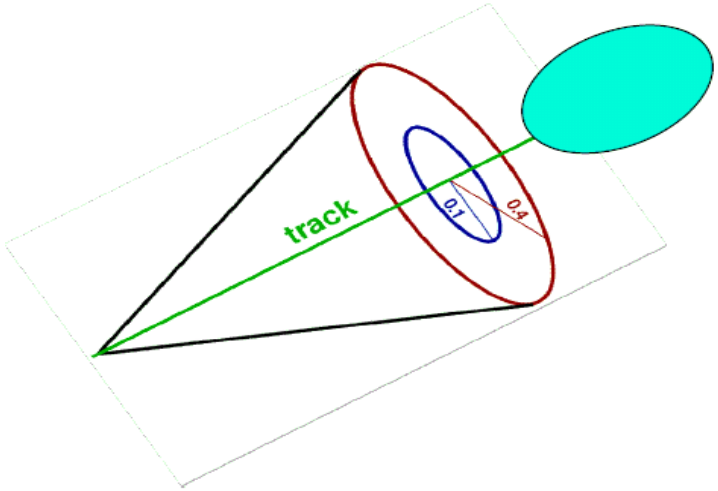
Event Selection (2)

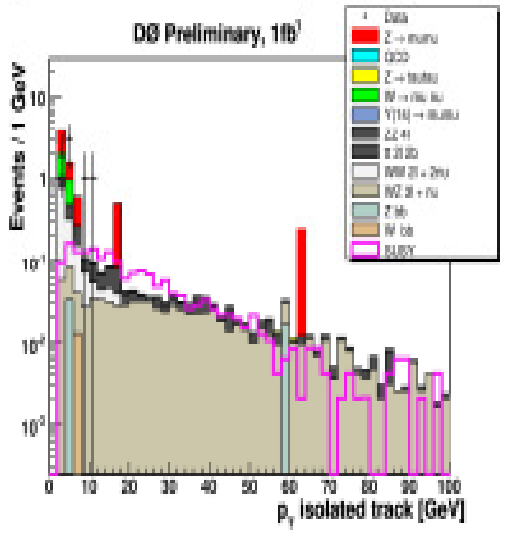
- Anti Multi-Jet requirements
  - Requirement on number of jet or on the sum of the jet p_T





- Third Lepton
  - Reconstructed lepton or track isolated in tracker and calorimeter

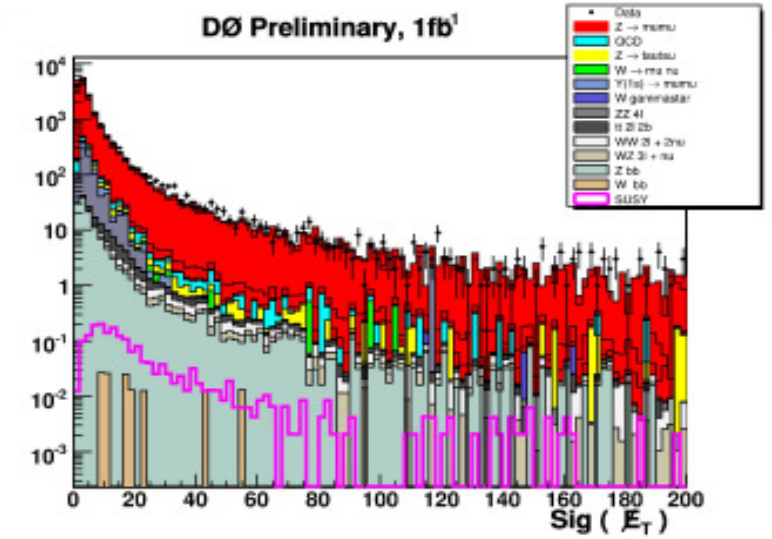


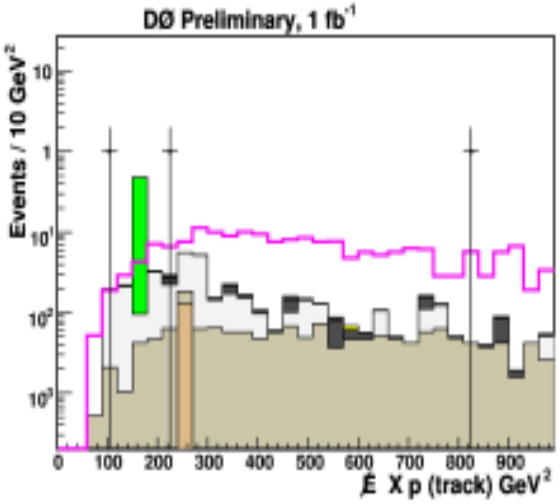


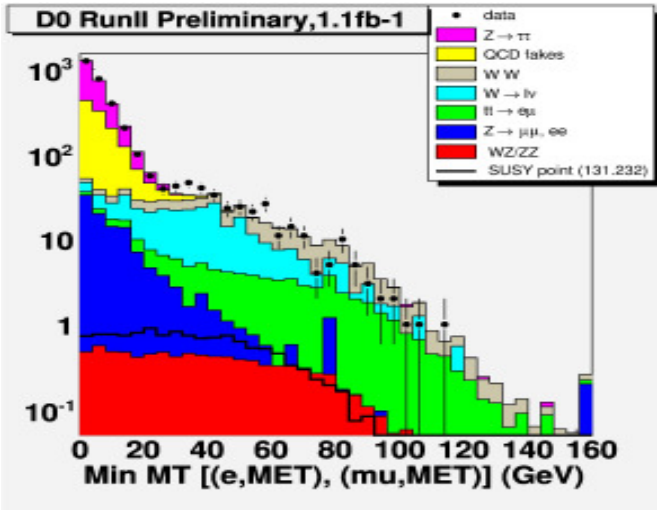
Event Selection (3)

- Anti Multi-Jet requirements
  - MET > 10 – 20 GeV
  - DØ only
    - Transverse mass

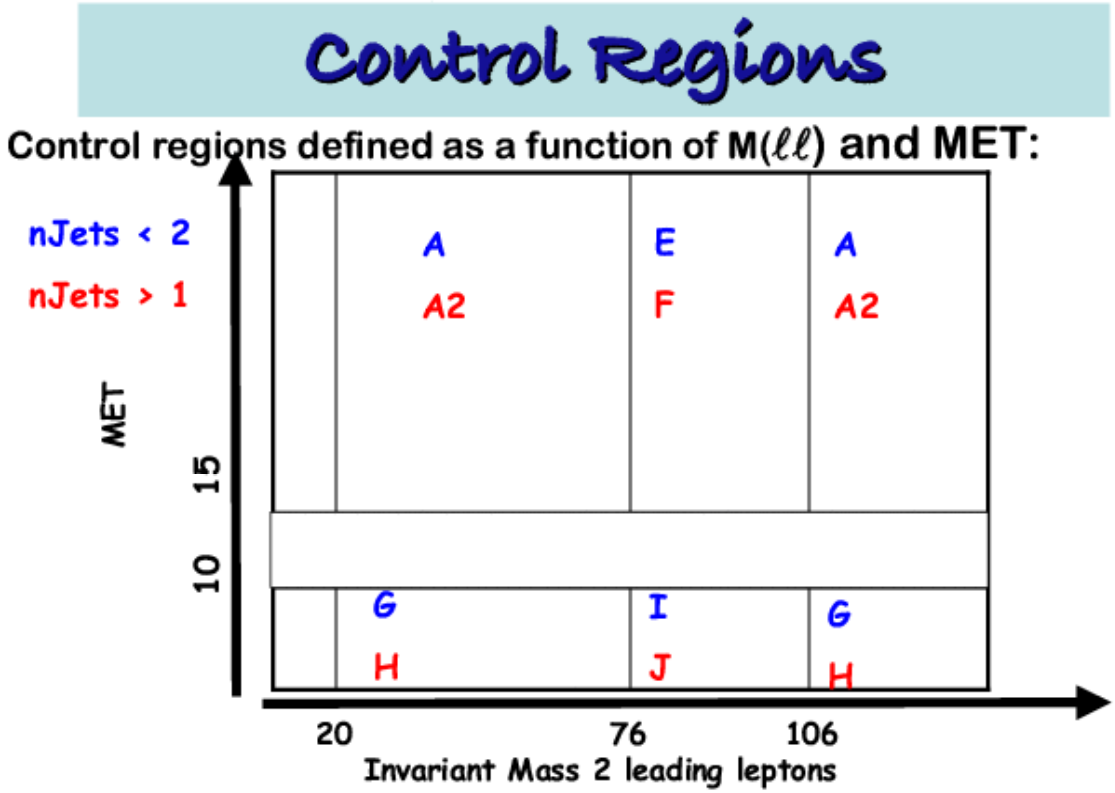
      $m_T = \sqrt{p_T \cdot \not\!\!E_T \cdot (1 - \Delta\Phi(e, \not\!\!E_T))} > 20$ GeV
    - MET significance > 8 GeV
    - Product of MET and track p_T
    - Sum of p_T







Systematic Studies (CDF)



CR Z is everything with 2 leps in the Z mass, regardless of Njets or Met; Z tight is both leptons > 20 GeV;

- Each control region is investigated
  - With different jet multiplicity
  - With 2 leptons required
    - Increased statistics
  - With 3 leptons required
    - Signal like topology

Result: Event Numbers

Trilepton	ee+l CEM	ee+l PLUG	eμ+l	μμ+l high p_T	μe+l CEM	μe+l PLUG	ee+trk	μμ+l low p_T
lum [pb^{-1}]	1034	954	1034	745	745	680	1013	976
exp bg	0.44 ± 0.08	0.34 ± 0.10	0.28 ± 0.09	0.64 ± 0.18	0.42 ± 0.08	0.36 ± 0.07	0.97 ± 0.28	0.42 ± 0.12
obs	0	0	0	1	0	0	3	1

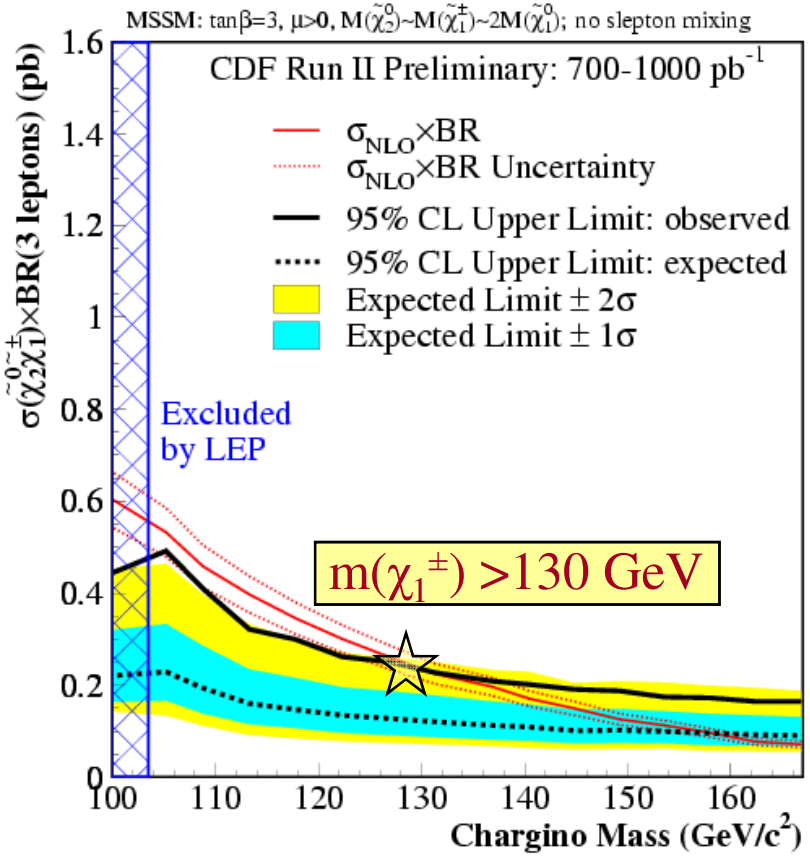
LS Dilep	ee	$e_{si}e$	$e_{si}e_{si}$	$e_{si}\mu$	eμ	μμ
lum [pb^{-1}]	993	993	993	971	971	1087
exp bg	0.1 ± 0.1	1.5 ± 0.3	1.3 ± 0.3	1.7 ± 0.2	2.3 ± 0.5	0.9 ± 0.1
observed	1	2	1	4	4	1

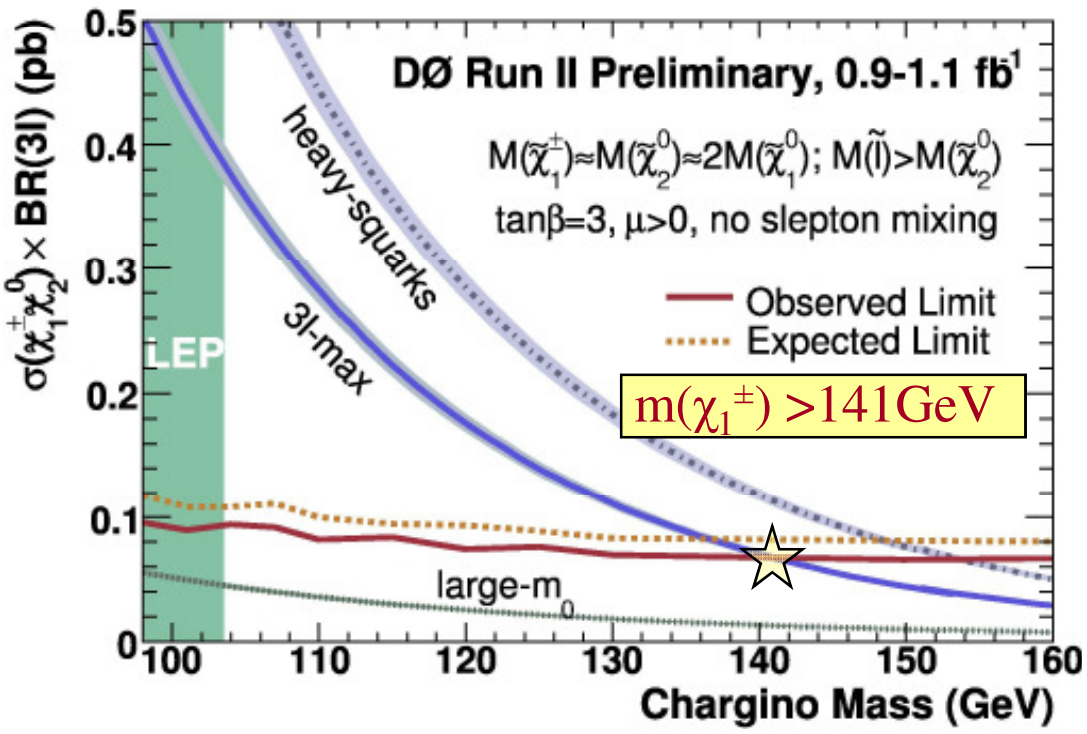
	ee+l	μμ+l	eμ+l	μμ LS
lum [pb^{-1}]	1000	1100	1100	1000
exp bg	0.76 ± 0.67	0.32 ± 1.34	0.94 ± 0.4	1.1 ± 0.4
observed	0	2	1	1

No Excess Observed
→ Set Limit

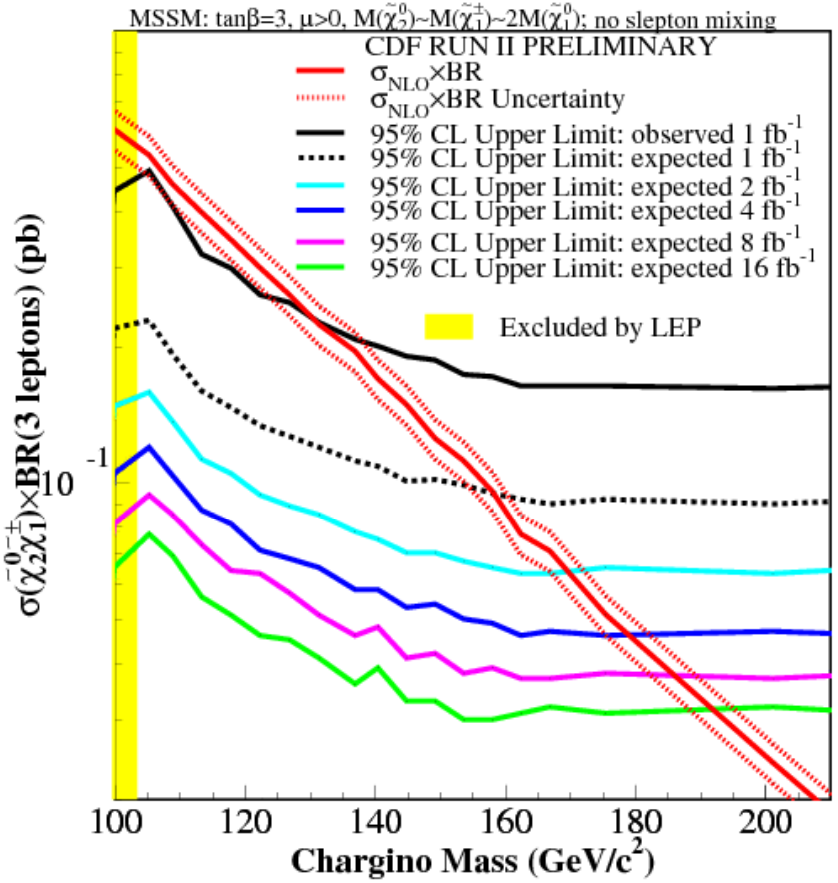
Constraining SUSY Models

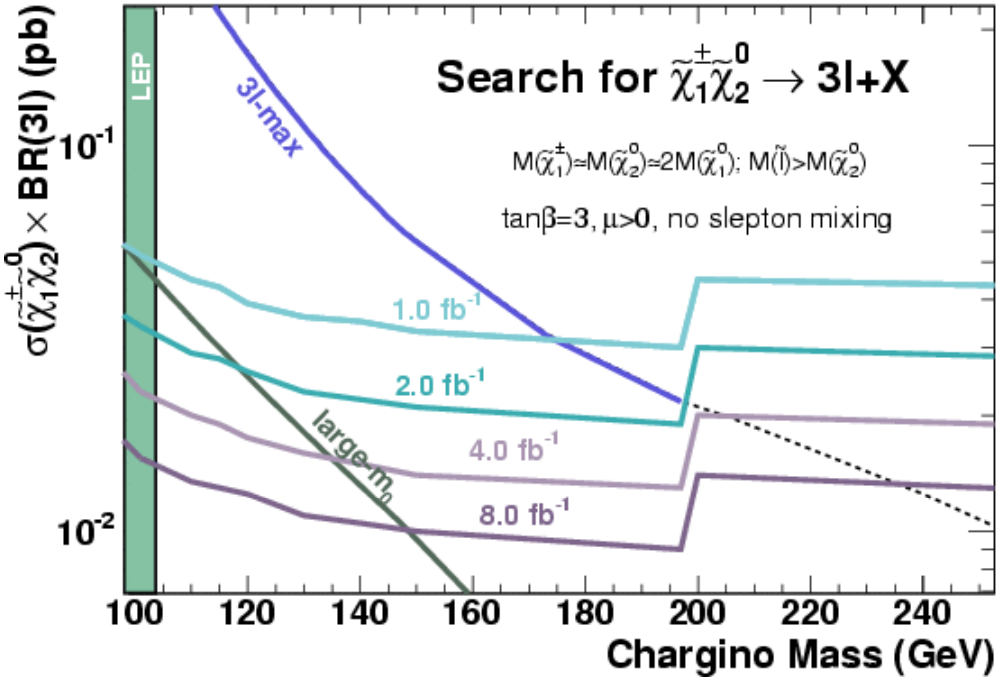
- Combine all trilepton and dilepton channels to set a limit on the chargino mass in a specific model
- CDF and DØ use similar but not identical mSUGRA inspired models
  - CDF: tanβ=3, A_0=0, μ>0, m_0=70, $m_{1/2}$=162-240
  - DØ: tanβ=3, A_0=0, μ>0, $m(\tilde{l}) \gtrsim m(\tilde{\chi}_2^0)$





Trileptons in the future





- CDF projected sensitivity based on 1fb^{-1} analyses expected sensitivity

- DØ assumes an improvement in the analysis in the future.
- At ~200GeV new decay modes become available.

Summary and Outlook

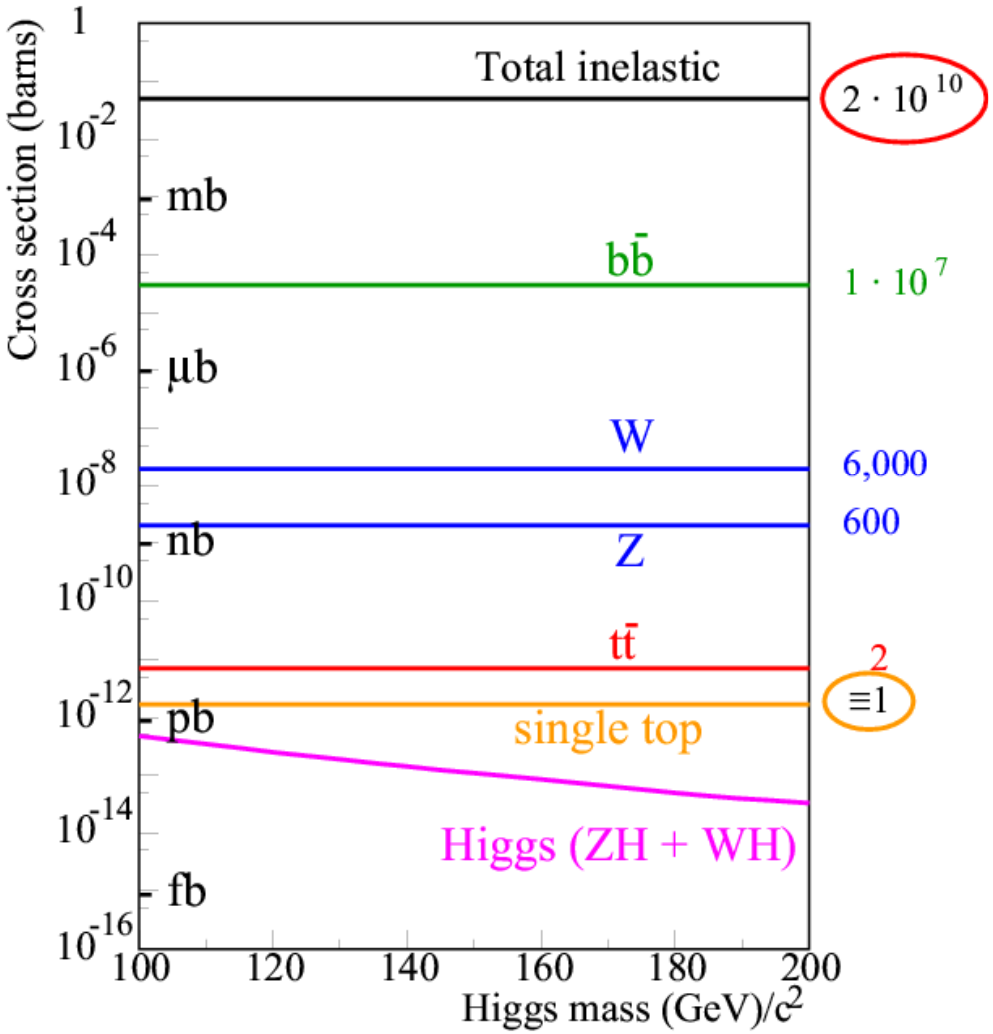
- There is **Physics beyond the Standard Model**
  - Dark Matter is a convincing indicator
  - **SUSY** is one of the options
- Trilepton final states are the gold plated decay modes at the Tevatron, augmented by like-sign dilepton searches.
- CDF and D0 have seen no significant excess above standard model expections.
- Therefore **limits on on the lightest chargino mass** could be set

$m(\chi_1^{\pm}) > 130$ GeV (CDF)
$m(\chi_1^{\pm}) > 141$ GeV (DØ)

- More data is being analyzed.
- The upgrade for RunIIb has been very successful. Data taking continues. Both experiments take loads of data!

Backup Slides

Tevatron Cross Sections



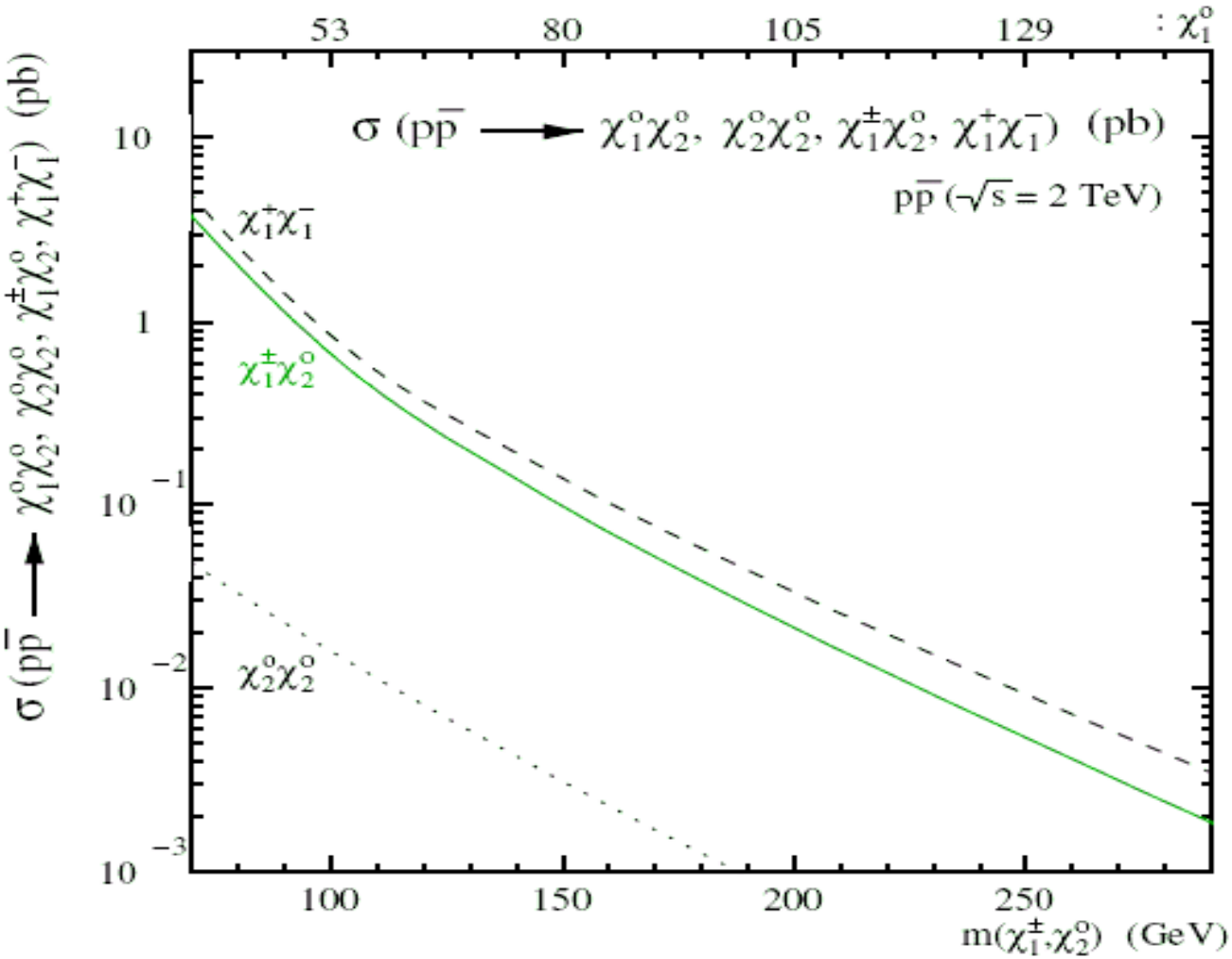
Total inelastic cross section.

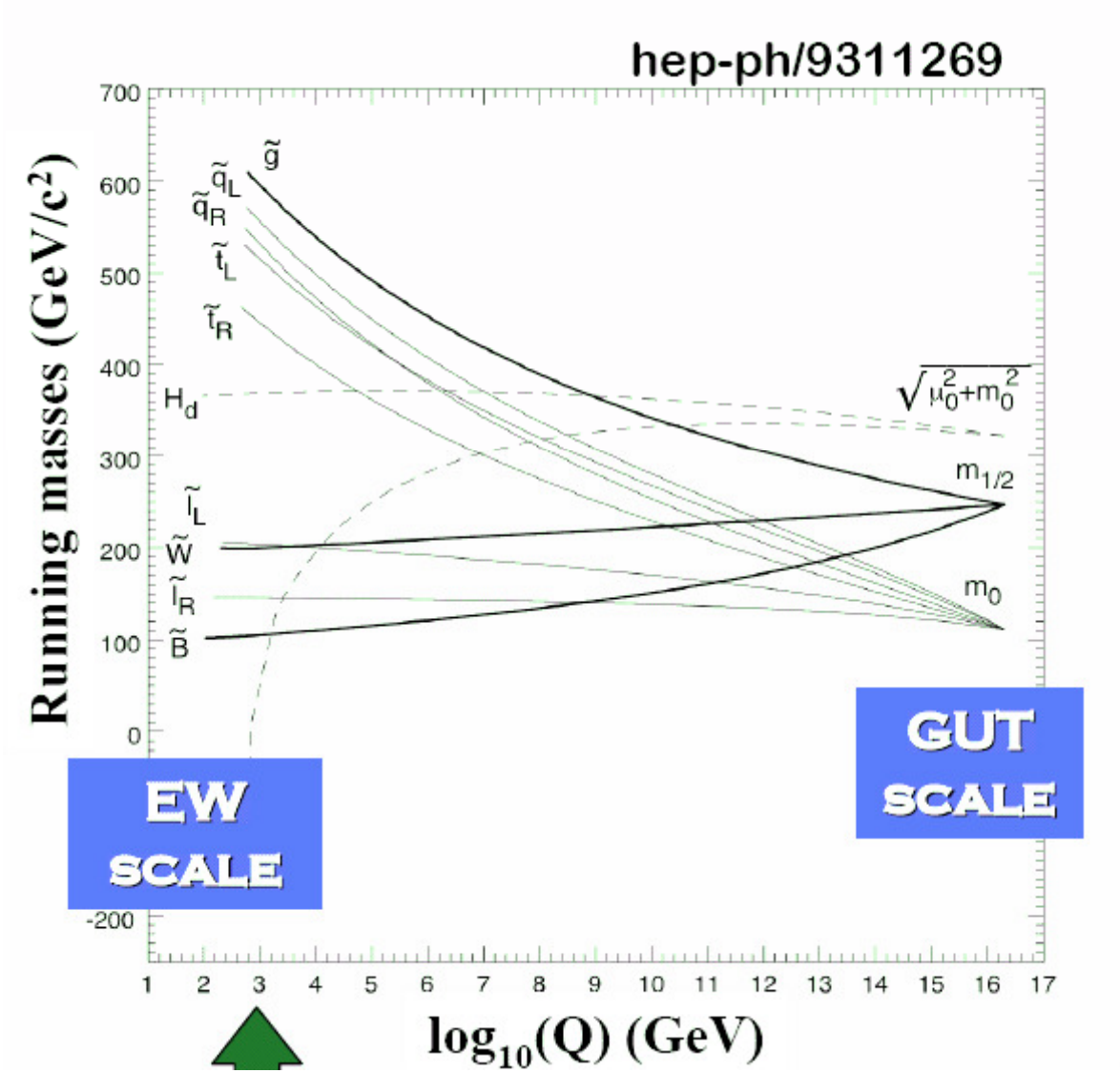
Light quarks are ubiquitous.

Plenty of W and Z bosons → calibration.

Evidence of single top production is an important milestone towards the Higgs boson.

The Higgs cross section is 10-11 orders of magnitudes lower than the total inelastic cross section.


53
80
105
129
: χ_1^0
$\sigma\ (p\bar{p} \rightarrow \chi_1^0\chi_2^0,\ \chi_2^0\chi_2^0,\ \chi_1^\pm\chi_2^0,\ \chi_1^+\chi_1^-)$ (pb)
$p\bar{p}\ (\sqrt{s} = 2$ TeV)
$\chi_1^+\chi_1^-$
$\chi_1^\pm\chi_2^0$
$\chi_2^0\chi_2^0$
$\sigma\ (p\bar{p} \rightarrow \chi_1^0\chi_2^0,\ \chi_2^0\chi_2^0,\ \chi_1^\pm\chi_2^0,\ \chi_1^+\chi_1^-)$ (pb)
10
1
10^{-1}
10^{-2}
10^{-3}
100
150
200
250
$m(\chi_1^\pm, \chi_2^0)$ (GeV)

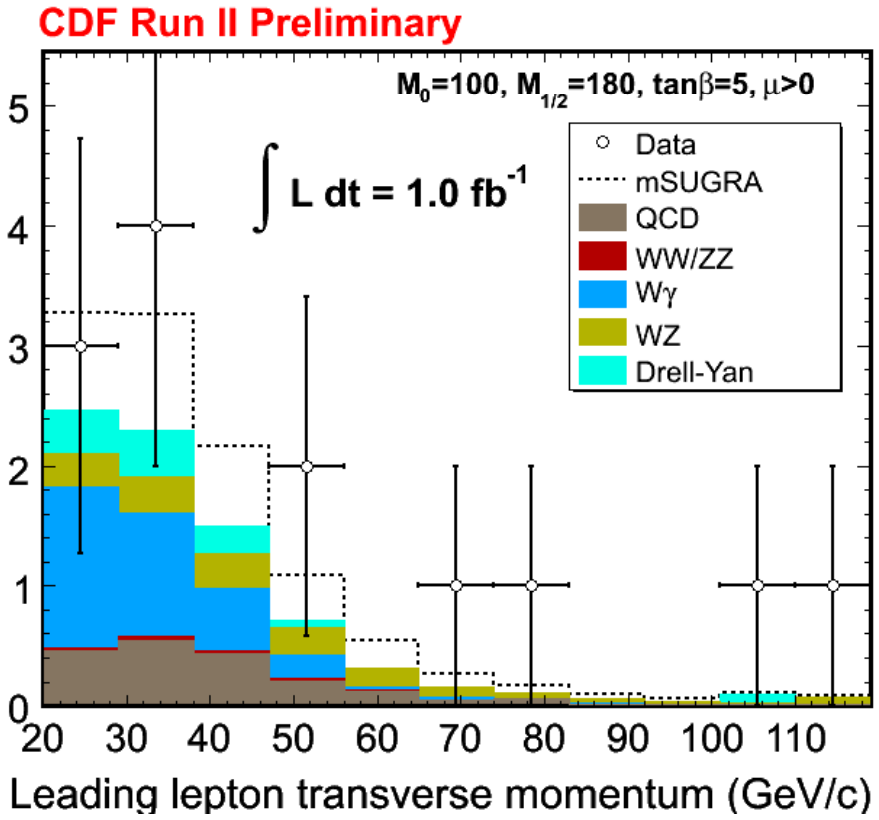

hep-ph/9311269
Running masses (GeV/c²)
log10(Q) (GeV)
EW SCALE
GUT SCALE
g̃
q̃L
q̃R
t̃L
t̃R
Hd
√(μ0²+m0²)
m1/2
l̃L
W̃
l̃R
B̃
m0
700
600
500
400
300
200
100
0
-200
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

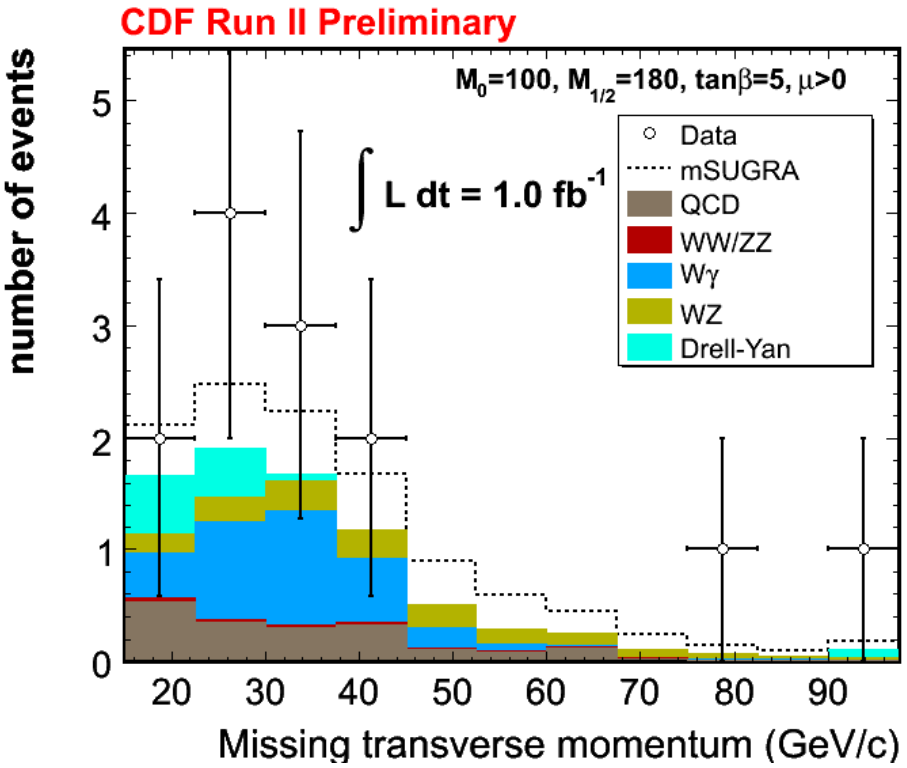
Reference points (Les Houches)

	Heavy	Medium	Light
m_0 (GeV)	121	98	88
$m_{1/2}$ (GeV)	221	192	182
$\tan\beta$	3	3	3
μ	> 0	> 0	> 0
A_0	0	0	0
$m_{\tilde{\chi}_1^\pm}$ (Gev)	150	125	115
$m_{\tilde{\chi}_2^0}$ (GeV)	152	127	118
$m_{\tilde{\chi}_1^0}$ (GeV)	82	69	63
$m_{\tilde{\ell}_R}$ (GeV)	153	129	119
$\sigma \times$ BR (pb)	0.058	0.14	0.22

Like-Sign dileptons

- Signature-based search -- low Standard Model background
- Currently: chargino-neutralino production





Basic selection: expect 34+/-4, see 44

Tight selection: expect 8 +/- 1, see 13

Small excess at high pt – waiting to see in new data

Event Numbers: CDF Trilepton

TRILEPTON ANALYSES

	$ee(CEM)+\ell$	$ee(PLUG)+\ell$	$e\mu+\ell$	$\mu\mu+\ell$ (high-p_T)	$\mu e(CEM)+\ell$	$\mu e(PLUG)+\ell$	$ee+track$	$\mu\mu+\ell$ (low-p_T)
Luminosity	1034 pb^{-1}	954 pb^{-1}	1034 pb^{-1}	745 pb^{-1}	745 pb^{-1}	680 pb^{-1}	1013 pb^{-1}	976 pb^{-1}
Expected number of signal events	1.15± 0.19	0.32± 0.07	0.84± 0.14	1.60± 0.22	0.83± 0.12	0.20± 0.03	1.98± 0.13	0.57± 0.11
Expected number of SM background events	0.44± 0.08	0.34± 0.10	0.28± 0.09	0.64± 0.18	0.42± 0.08	0.36± 0.07	0.97± 0.28	0.42± 0.12
Number of observed events	0	0	0	1	0	0	3	1

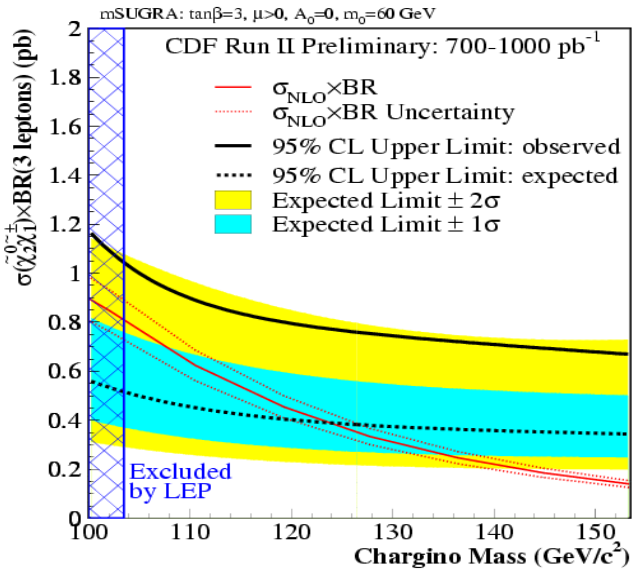
high-p_T trilepton analyses

Event Numbers: CDF LS-Dilepton

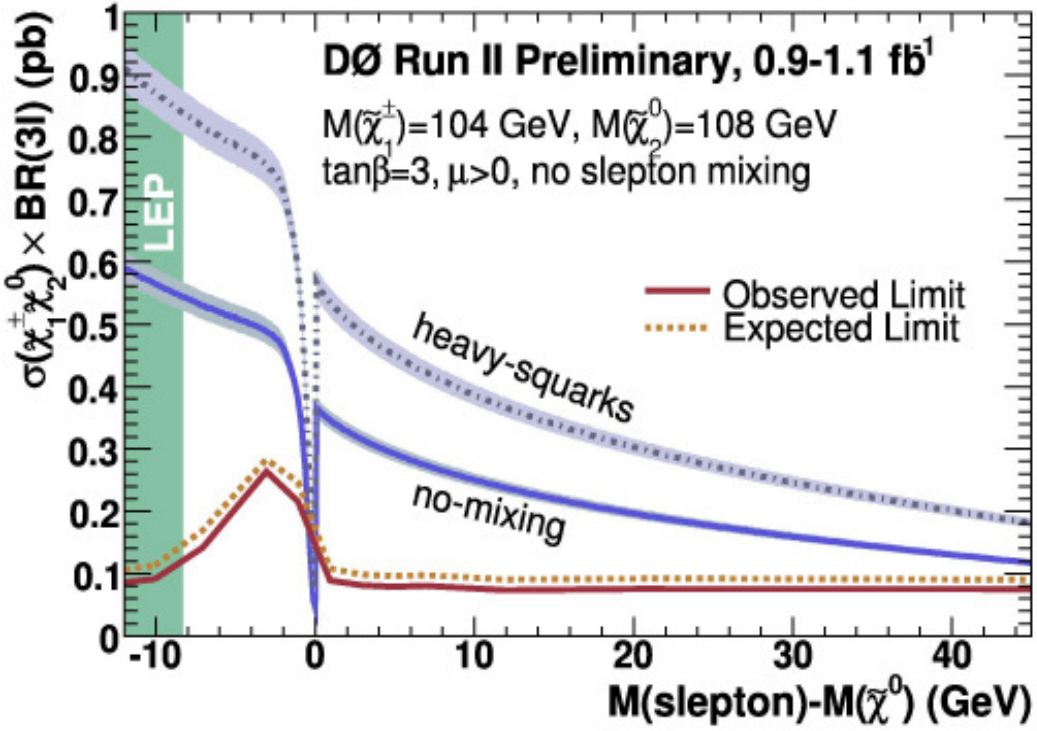
LS-DILEPTON ANALYSES

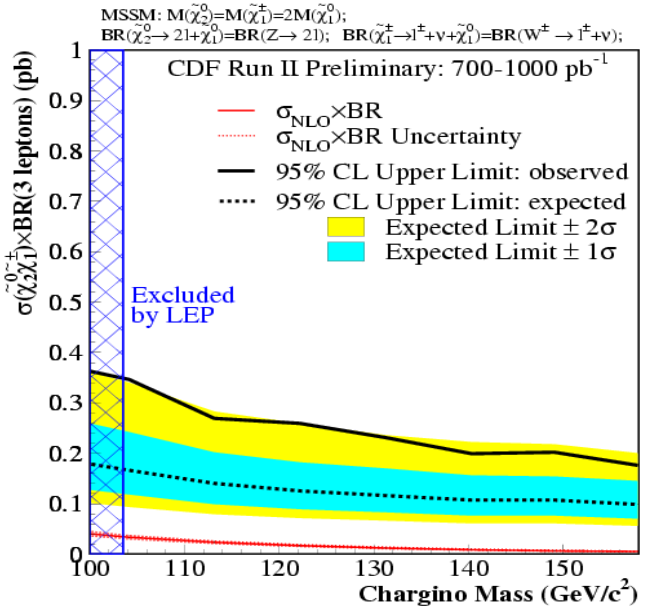
	ee LS	$e_{si}e$ LS	$e_{si}e_{si}$ LS	$e_{si}\mu$ LS	$e\mu$ LS	$\mu\mu$ LS
Luminosity	993 pb^{-1}	993 pb^{-1}	993 pb^{-1}	971 pb^{-1}	971 pb^{-1}	1087 pb^{-1}
Expected number of signal events	0.040± 0.004	0.070± 0.007	0.510± 0.051	1.540± 0.154	0.200± 0.020	0.950± 0.095
Expected number of SM background events	0.10± 0.10	1.50± 0.30	1.30± 0.30	1.70± 0.20	2.30± 0.50	0.90± 0.10
Number of observed events	1	2	1	4	4	1

Constraining SUSY models



MSUGRA model: no limit yet





MSSM with BR of chargino/neutralino into leptons same as W/Z