Supersymmetry results at the Tevatron

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For the CDF and D0 collaborations

XL^{h} Recontres de Moriond QCD

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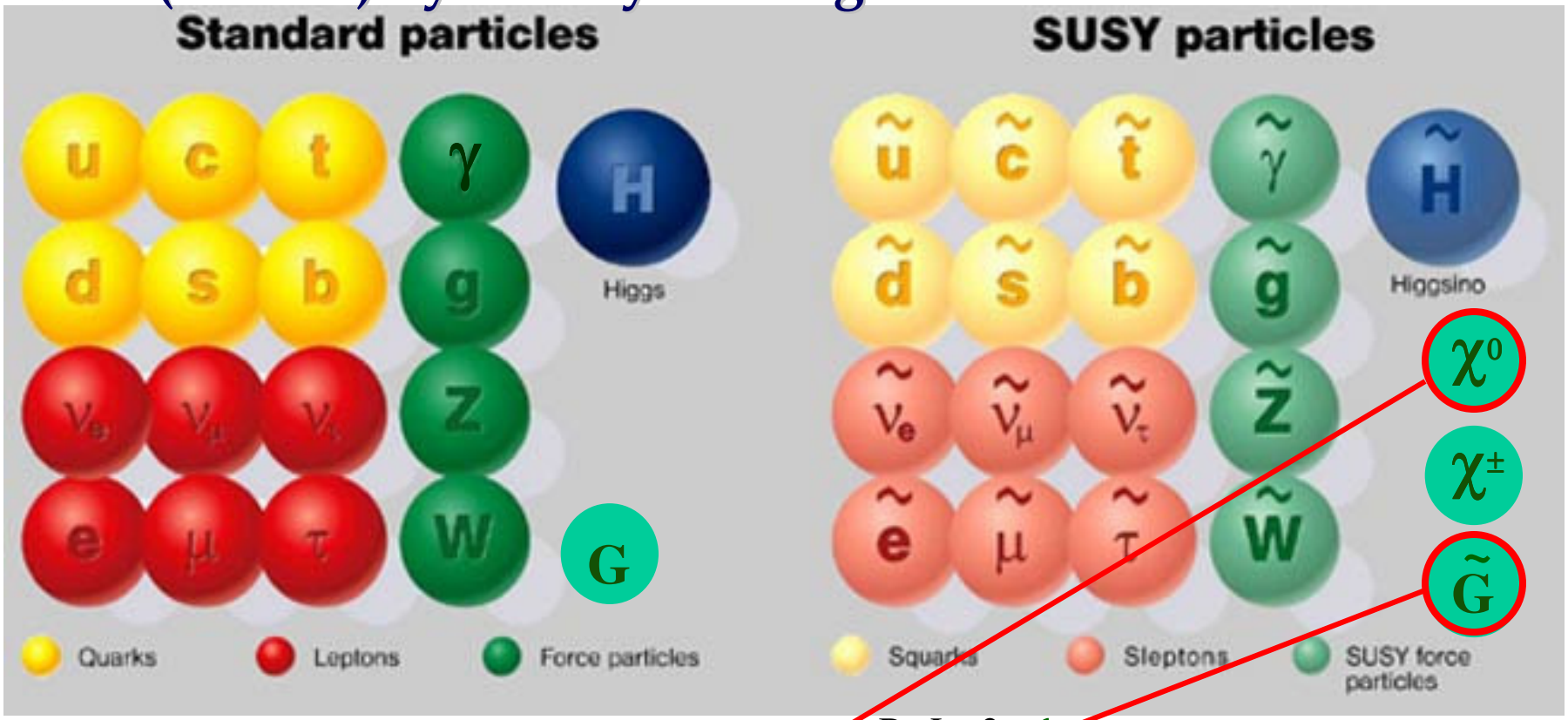
Outline

- Introduction and Motivation
- Detectors overview
- Supersymmetry
  - ➡Chargino and Neutralino (mSUGRA,GMSB)
  - ➡Squarks and Gluinos (mSUGRA)
  - ➡Other models (RPV)
- Conclusions

Supersymmetry: what ?

New (broken) Symmetry relating Fermions & Bosons

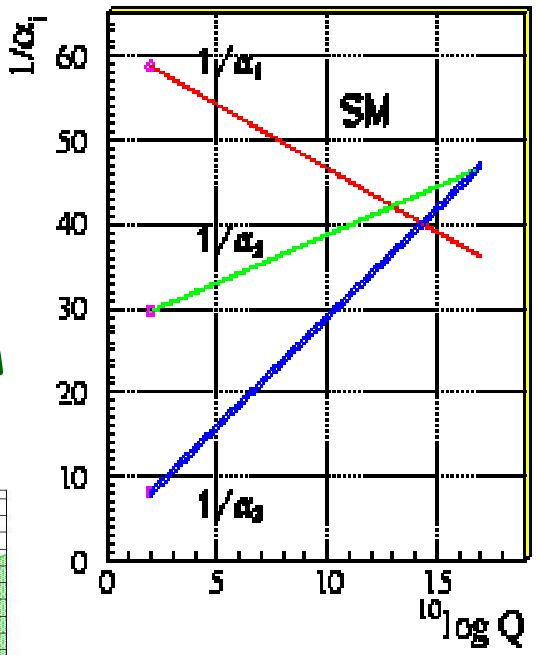


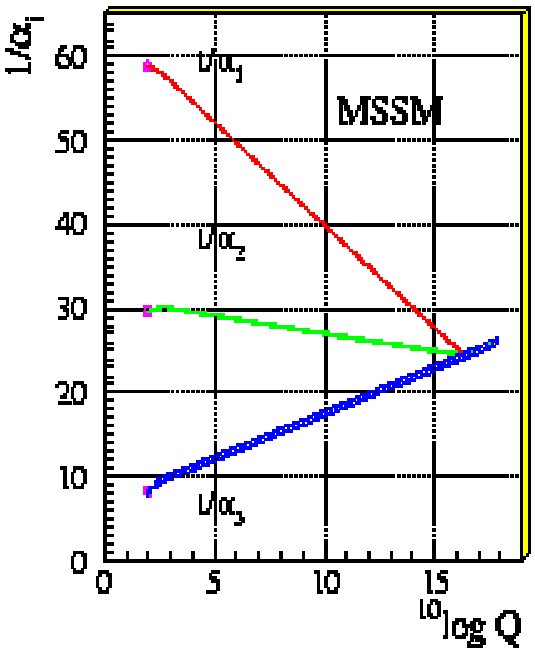
R-Parity Quantum Number-> $R_p = (-1)^{B+L+2s}$ { **+1 (SM particles)**, **-1 (Susy particles)**

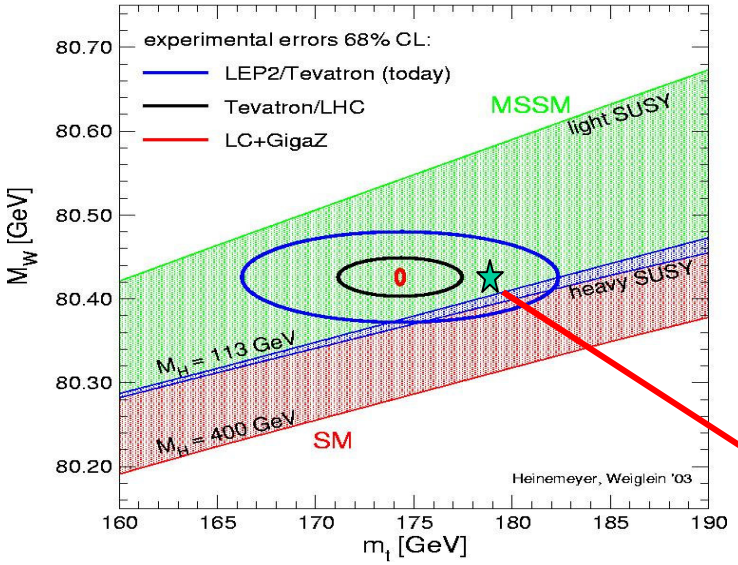
1. mSugra: χ^0_1 LSP, stable (parameters: $M_0, M_{1/2}, \tan\beta, A_0, \mu$)
2. GMSB: $\tilde{G}$ LSP, stable
3. ~~R_p~~ (RPV): LSP decays into SM particles

Supersymmetry: why ?

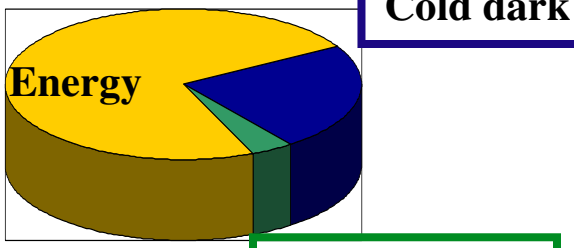
- Solves "Hierarchy Problem"
- Provides Grand Unification Theory at the 10^{16} GeV scale
- Consistent with results from Precision Data fits







New Top Mass

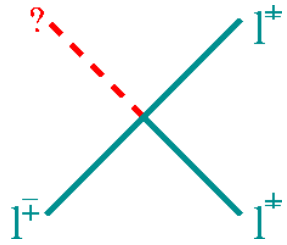


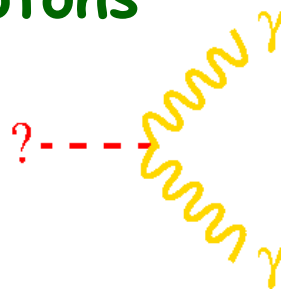
- R_p Conserving models provide good Dark Matter Candidate (LSP)

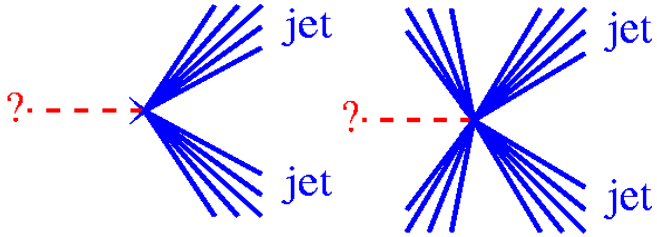
Supersymmetry: how ?

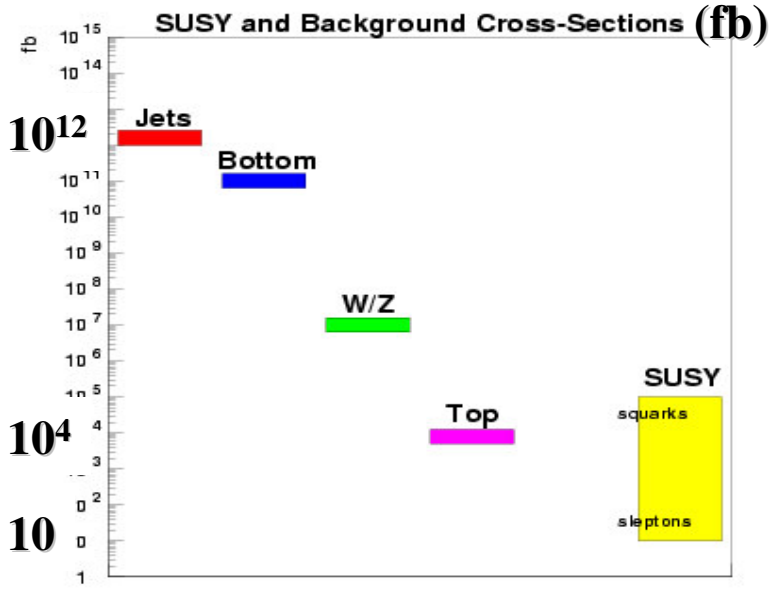
Wide range of signatures: look for SuSy specific signatures or excess in SM ones; here

- R_p: Large Missing Energy $\not{E}_T$ from LSPs
- Isolated leptons
- Diphotons
- Multijets





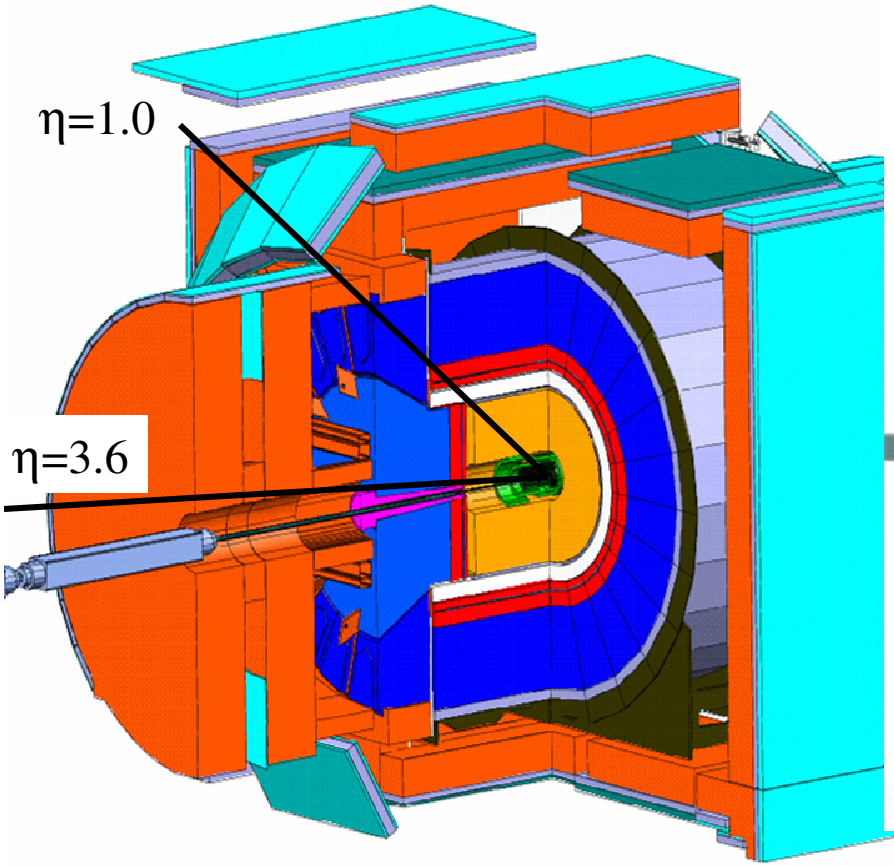


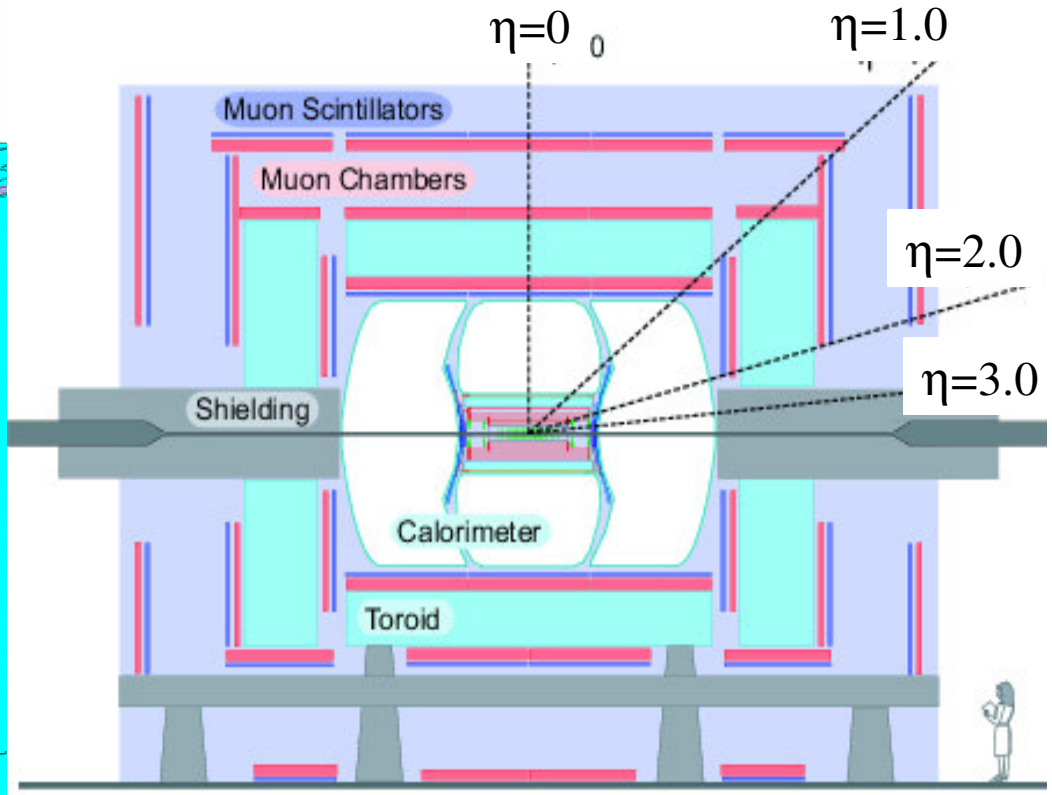


Remember :
VERY SMALL cross sections !!

CDF and D0

- Both detectors well understood and highly efficient
- Extensive calorimeter, tracking and muon coverage
- Luminosity up to 350 pb^{-1} (2002-2004)





Charginos and Neutralinos

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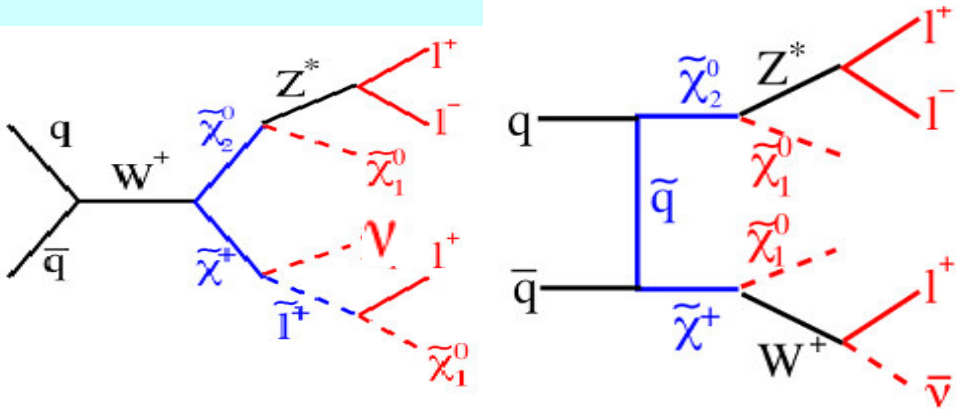
Chargino and Neutralino in $3\ell+\not{E}_T$

In mSUGRA: 3 leptons+$\not{E}_T$

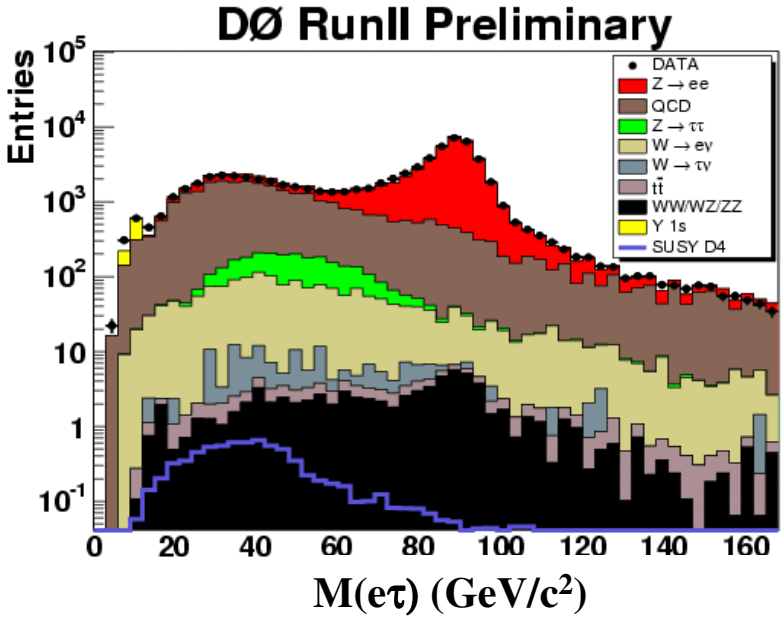
- $\sigma \times BR \sim 0.2$ pb
- Very clean signature
- SM background very small !



6 analyses:

- 2l(l=e,μ,τ)+isolated track or $\mu^{\pm}\mu^{\pm}$
- $\not{E}_T$ and topological cuts ($M_{\ell\ell}$, $\Delta\phi$, M_T)

Selection	SM expected	OBSERVED
ee+l	0.21±0.12	0
eμ+l	0.31±0.13	0
μμ+l	1.75±0.57	2
$\mu^{\pm}\mu^{\pm}$	0.64±0.38	1
eτ+l	0.58±0.14	0
μτ+l	0.36±0.13	1
SUM	3.85±0.75	4



Chargino Neutralino Limits

mSUGRA: $M(\chi^{\pm}) \approx M(\chi^0_2) \approx 2M(\chi^0_1)$

"3l-max"

- $M(\tilde{\ell}) \gtrsim M(\chi^0_2)$
- No slepton mixing

Limits :

➡ σxBR < 0.2 pb

➡ $M(\chi^{\pm}_1) > 116$ GeV/c^2

"Heavy Squarks"

- $M(\chi^{\pm}) \approx M(\chi^0_2) \not\approx 3M(\tilde{q})$

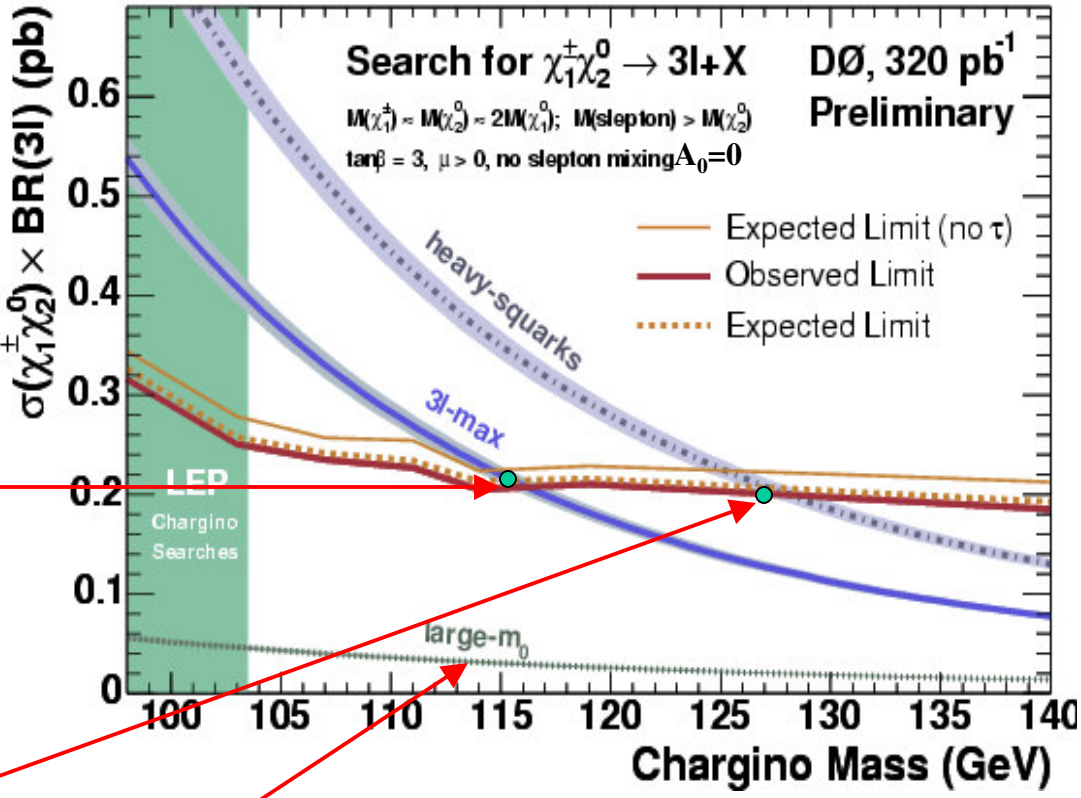
➡ σxBR < 0.2 pb

➡ $M(\chi^{\pm}_1) > 128$ GeV/c^2

"Large m0"

- $M(\tilde{\ell}) >> M(\chi^0_2, \chi^{\pm})$

➡ No sensitivity



Start testing above LEP limit for mSUGRA—but LEP Model Independent !!

Chargino and Neutralino in 3ℓ+$\not\!\!E_T$

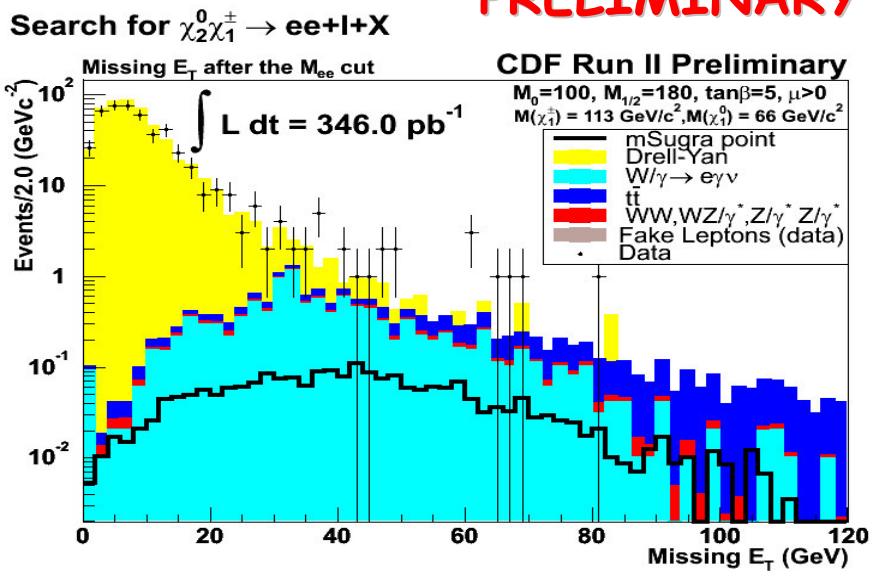
PRELIMINARY !!

In mSUGRA: 3 leptons+$\not\!\!E_T$

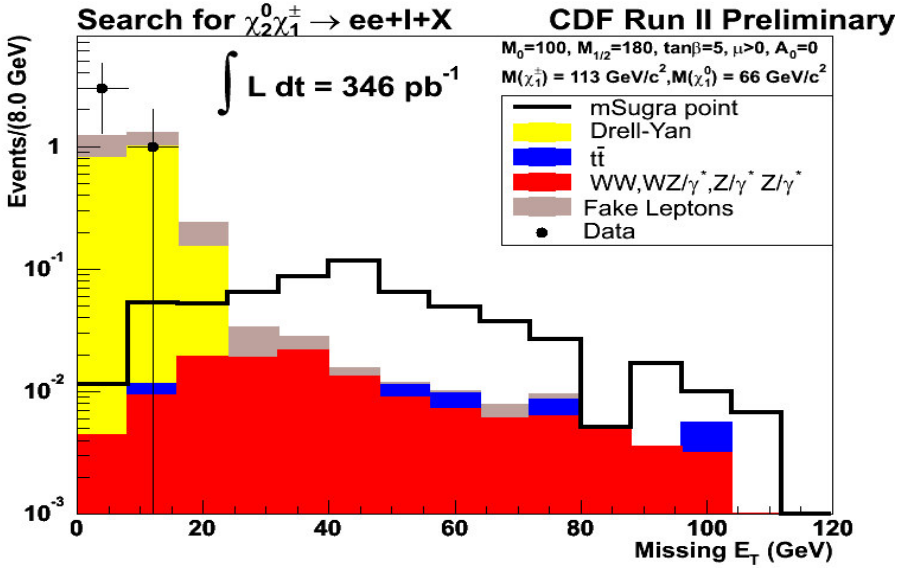
➡ σxBR~0.1 pb

SELECTION:

- -2 electrons+ ℓ (ℓ =e,μ) $|\eta|<1$
- large $\not\!\!E_T$
- $15<M_{ll}<76$, >106 GeV/c^2
- $|\Delta\phi|<160^o$
- Njets(20 GeV) <2



Asking for the third lepton:



ee+l (SUSY signal)	0.5
TOT SM Expected	0.16±0.07
OBSERVED	0

VERY FIRST LOOK AT THE DATA!!

Still to do:

- improve acceptance adding the plug
- add the other channels (almost ready)

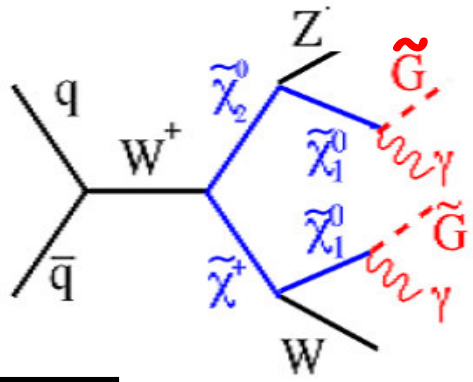
Chargino Neutralino in $\gamma\gamma+\not{E}_T$

In GMSB: 2 photons+$\not{E}_T$

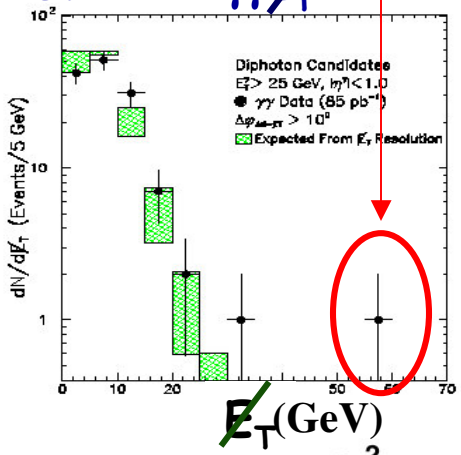
D0(CDF) Event selection:

-2 photons E_T -> 20(13) GeV

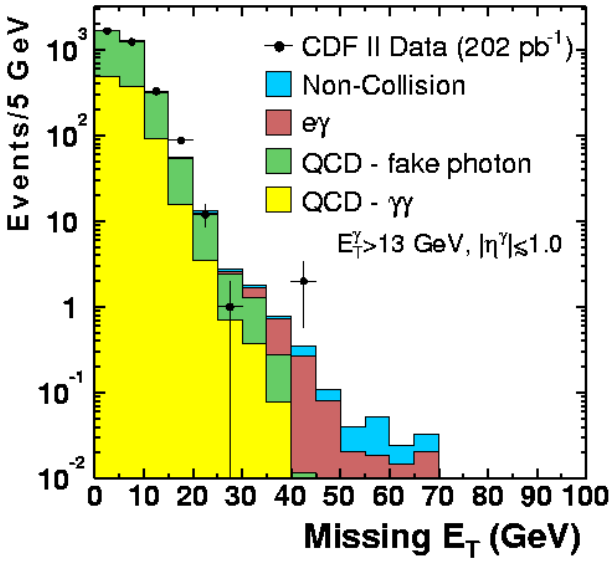
-$\not{E}_T$>40(45) GeV



Motivated from CDF-I ee$\gamma\gamma\not{E}_T$ event



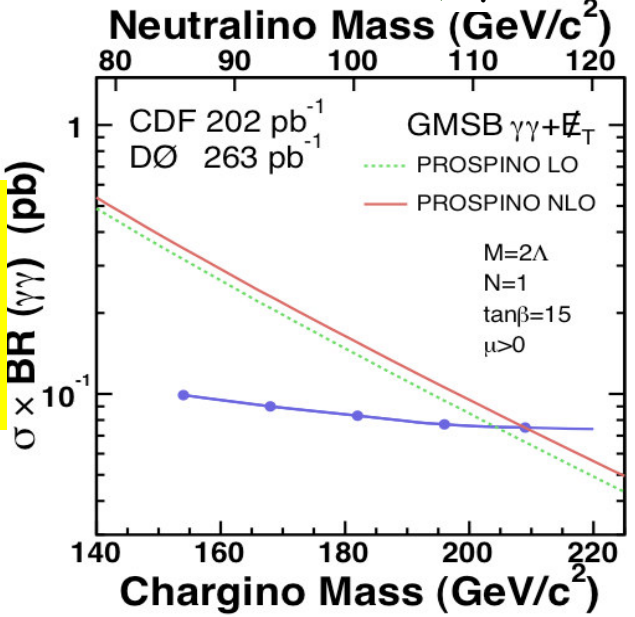
	SM Expected	OBSERVED
D0	3.7±0.6	2
CDF	0.3±0.1	0



CDF‡ and D0# combined result: m($\chi^\pm$)>209 GeV/c^2

‡Phys.Rev.D.71,3 031104(2004)

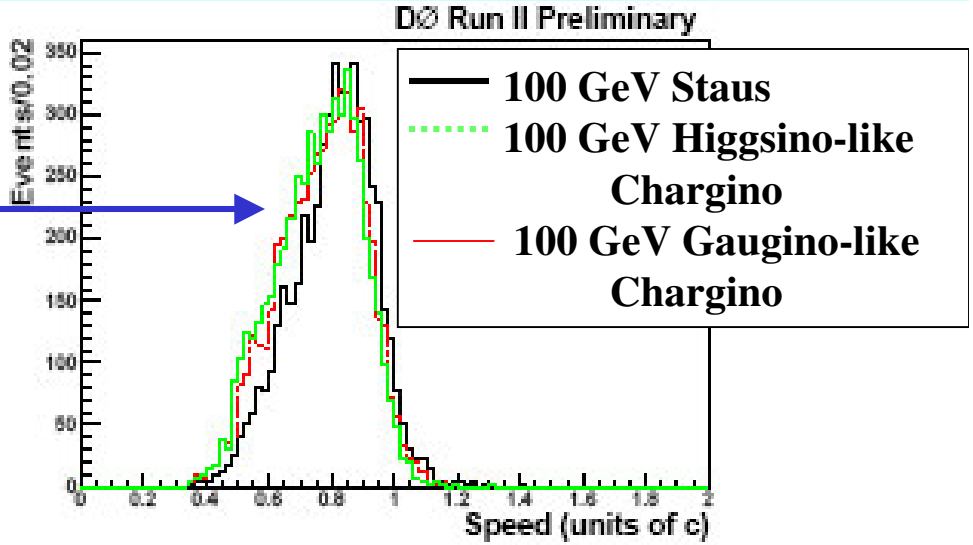
#Phys. Rev. Letters 94, 041801(2005)



Champs

CHArged Massive stable Particles:

- -electrically charged
- -massive->speed<<c
- -lifetime long enough to decay outside detector



Event Selection:

-2 muons Pt> 15 GeV, isolated

-Speed significantly slower than c

No SM Background!!->from DATA

Expected	OBSERVED
0.66±0.06	0

Limits:

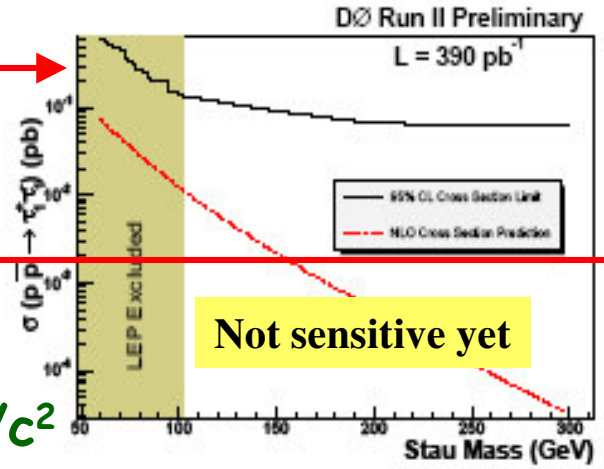
In GMSB:

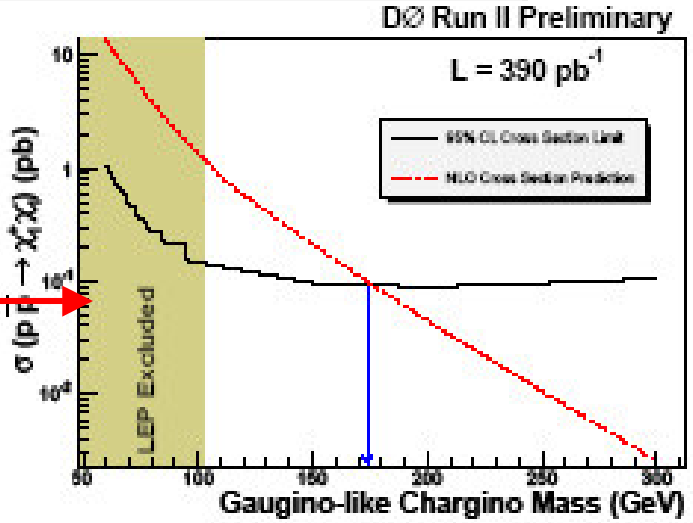
champ = $\tilde{\tau}$ (NLSP)

In AMSB:

champ = $\tilde{\chi}^{\pm}_1$

➡ $M(\chi^{\pm}_1)>174\ GeV/c^2$





Squarks and Gluinos

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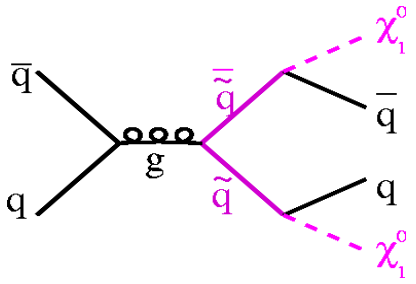
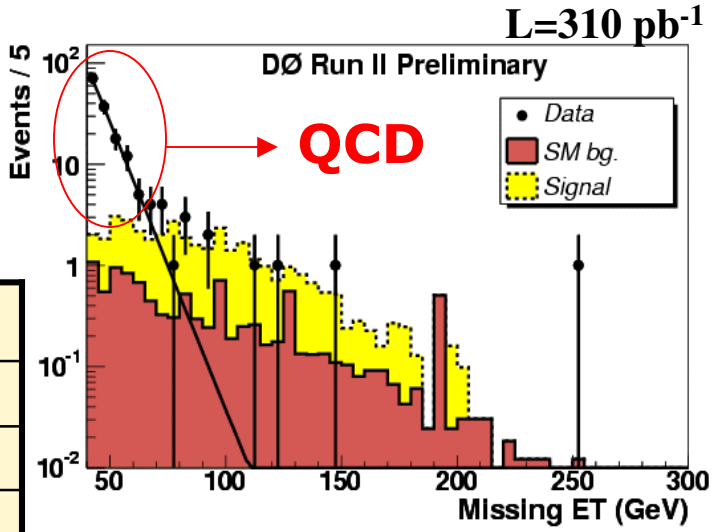
Squarks and Gluinos in jets+$\not\!\!E_T$

In mSUGRA: Njets+$\not\!\!E_T$



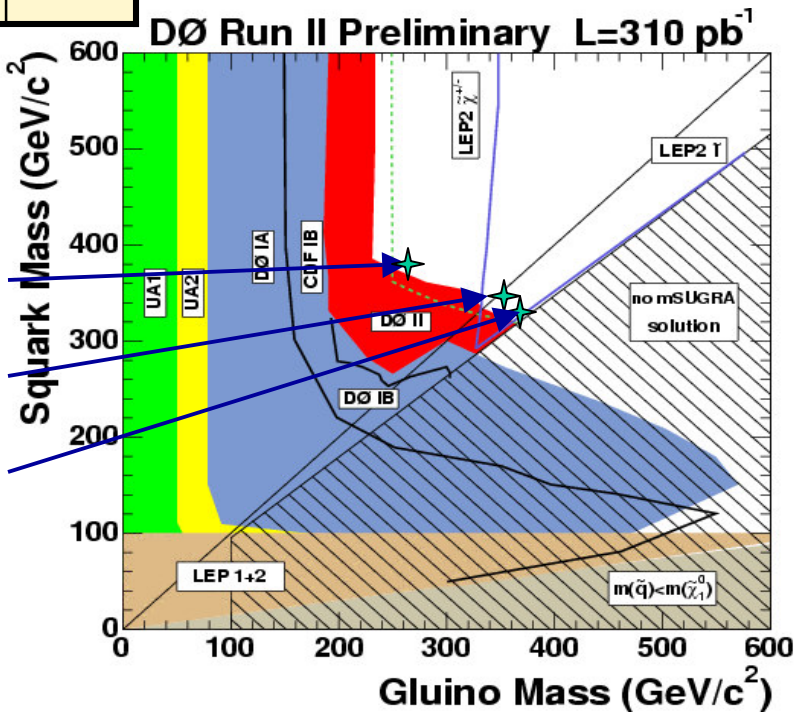
Selection = 3 analyses

#jets(P_T (GeV))	$\sum P_t^{jet}$	$\not\!\!E_T$	SM Expected	OBS
2jets(60,50)	250 GeV	175 GeV	12.8±5.4	12
3jets(60,40,25)	325 GeV	100 GeV	6.1±3.1	5
4jets(60,40,30,25)	175 GeV	75 GeV	7.1±0.9	10



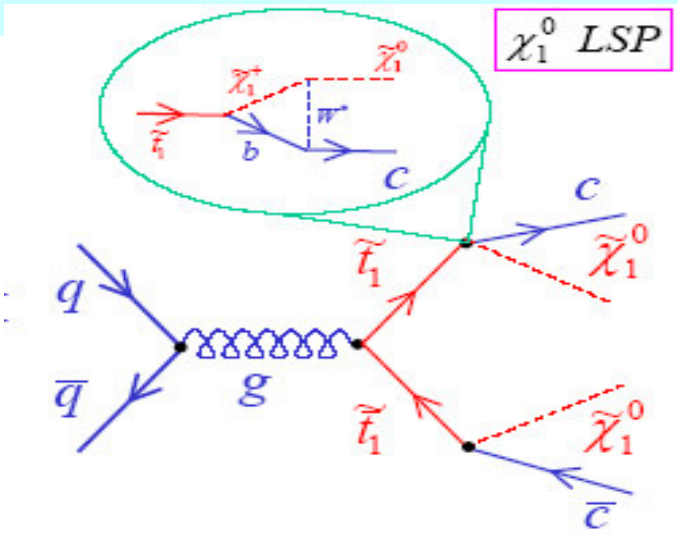
Limits (tanβ=3, A_0=0, μ<0, $\tilde{q}$=$\tilde{u}$,$\tilde{d}$,$\tilde{c}$,$\tilde{s}$,$\tilde{b}$):

- 4j($\tilde{g}\tilde{g}$) : M_0=500 GeV -> $M(\tilde{g})$> 233 GeV/c^2
- 3j($\tilde{g}\tilde{q}$) : $M(\tilde{g})=M(\tilde{q})$ -> $M(\tilde{q})$ > 333 GeV/c^2
- 2j($\tilde{q}\tilde{q}$) : M_0=25 GeV -> $M(\tilde{q})$ > 318 GeV/c^2



Extended LEP mSUGRA reach for $M(\tilde{q})<M(\tilde{g})$

Stop in mSUGRA

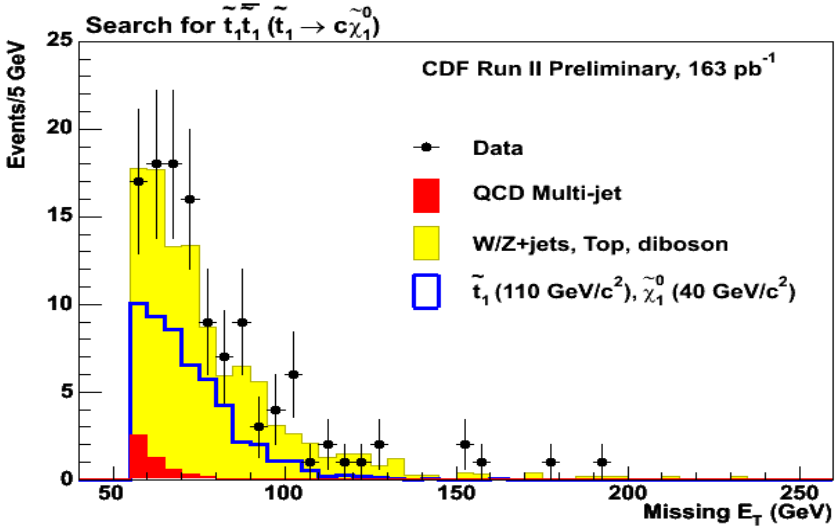


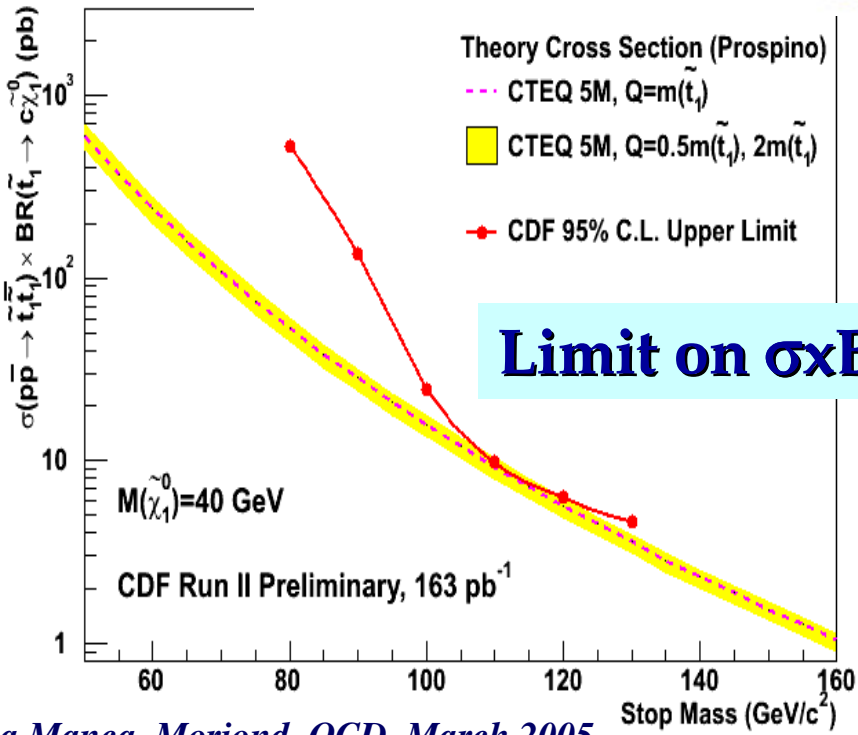
In mSUGRA with stop NLSP:

- ➡ BR($\tilde{t}_1$->$c\tilde{\chi}^0_1$) ~ 100%
- ➡ M($\tilde{\chi}^0_1$) = 40 GeV/c^2

selection: *2 jets + large $\not\!\!E_T$ + lepton veto*

	Expected	Observed
Pre-tag	105 ± 12	119
Tag (silicon)	8.3 ± 2.3	11





Limit on σxBR

R-Parity Violation

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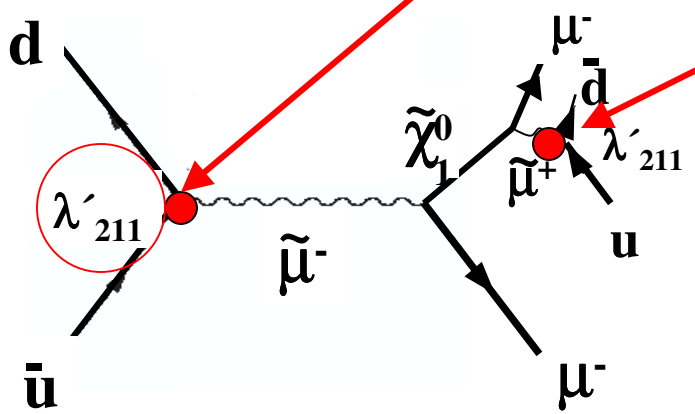
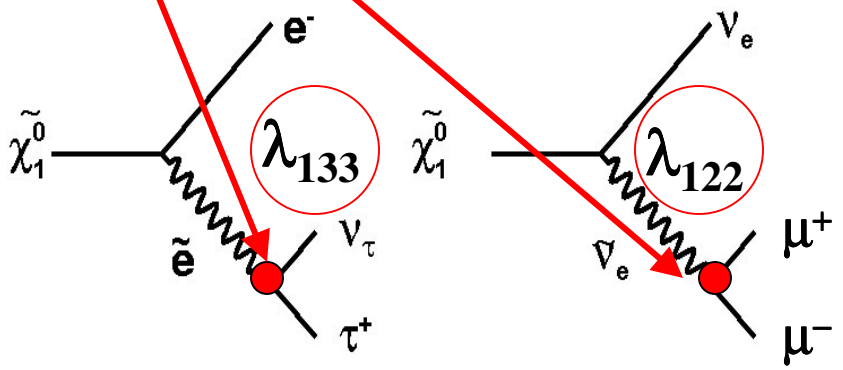
R Parity Violation

- RPV tested in Production and Decay of SUSY particles





➡ Resonant sparticle production

-> λ'_{ijk} coupling

➡ Selection:

2jets+2isolated μ's

- λ'_{211}

➡ RPV decay of LSP(χ^0_1)

-> λ_{ijk} coupling

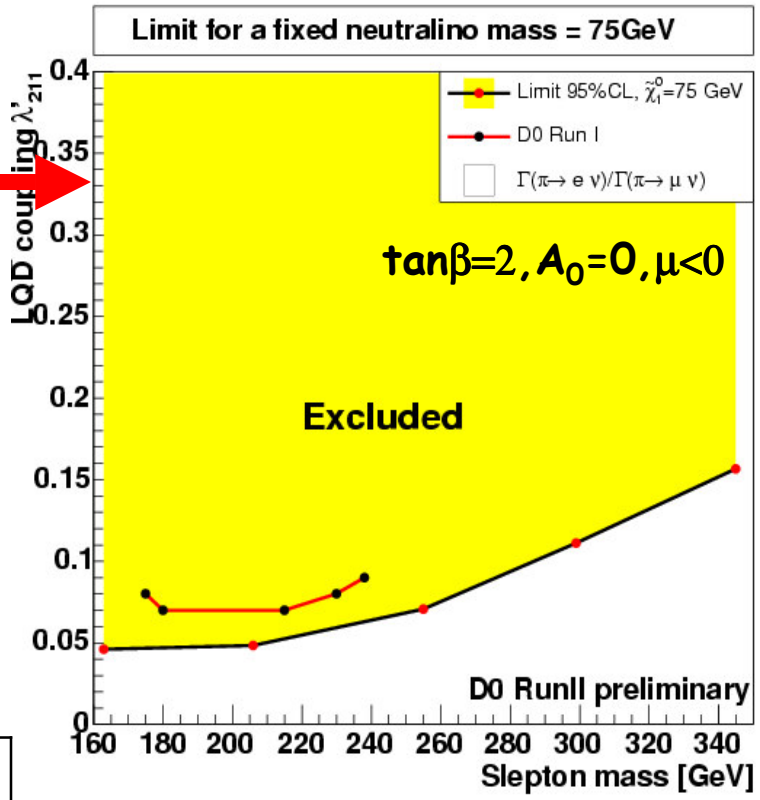
➡ Selection:

3ℓ(ℓ=e,μ)+$\not\!\!E_T$+channel dependent cuts

- λ_{121} ->(eeee,eeeμ,eeμμ) +νν
- λ_{122} ->(μμμμ,μμμe,μμee) +νν

R Parity Violation Limits

	EXP	OBS
➡(L=154 pb^{-1}) : λ'_{211}	1.1±0.4	2



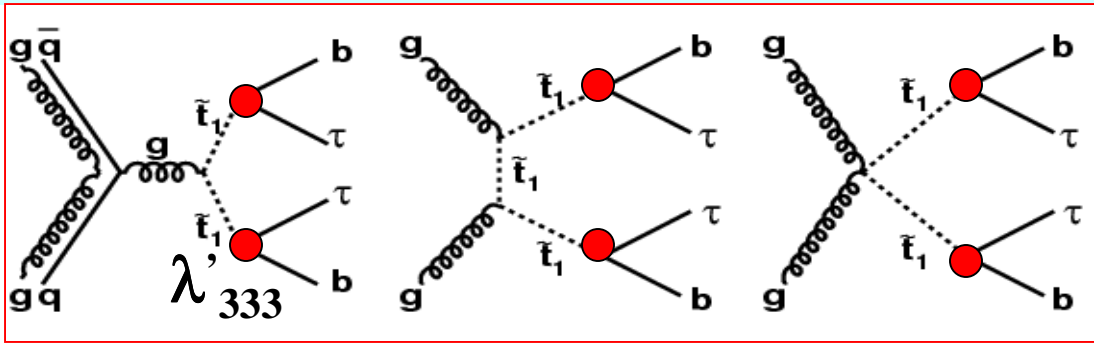
	EXP	OBS	
➡(L=160 pb^{-1}) : λ_{122}	0.6±1.9	2	⇨$M(\chi^{0(+)}_1)$>84(165) GeV/c^2
➡(L=238 pb^{-1}) : λ_{121}	0.5±0.4	0	⇨$M(\chi^{0(+)}_1)$>95(181) GeV/c^2
➡(L=200 pb^{-1}) : λ_{133}	1.0±1.4	0	⇨$M(\chi^{0(+)}_1)$>66(118) GeV/c^2

All improve on Run I

Stop in $\not{R}_p$ Susy

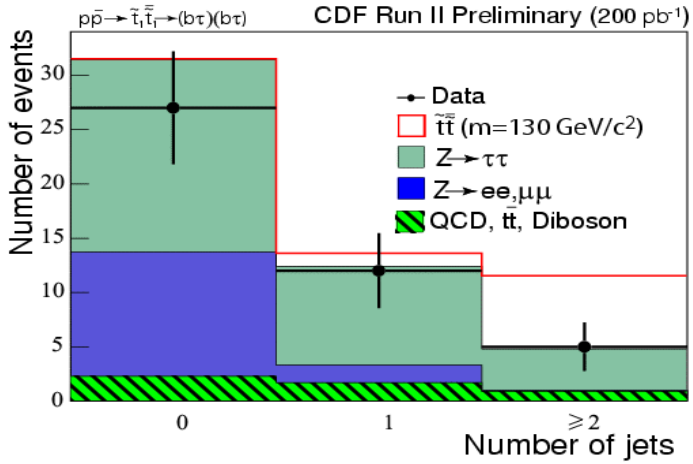
- Stop very light
- BR($\tilde{t}_1$->bτ) ~ 100%
- Search for :

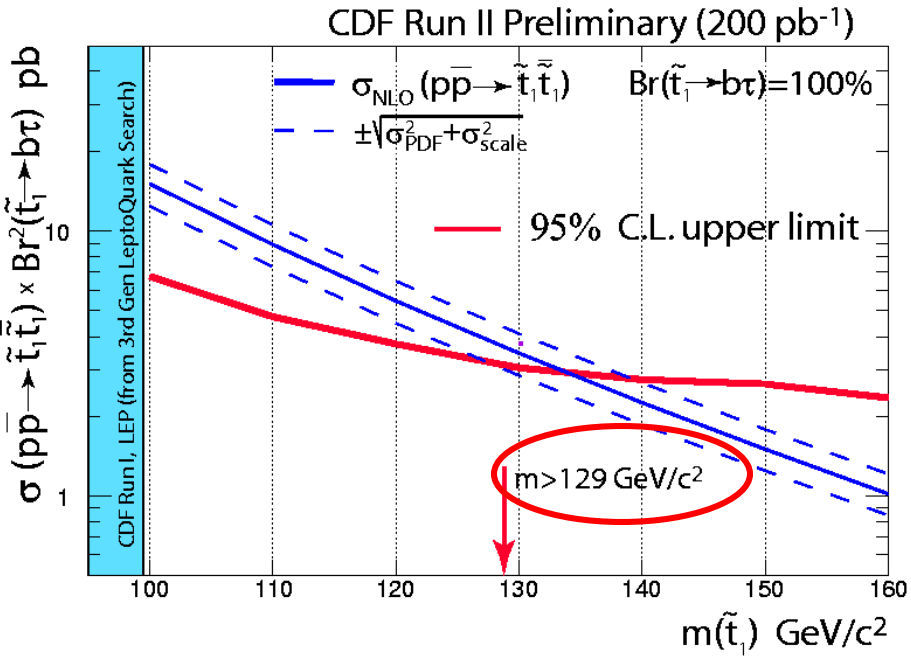
$qq(gg) \rightarrow \tilde{t}_1\tilde{t}_1 \rightarrow b\tau(had)b\tau(lep)$



selection: 1ℓ (ℓ=e,m)+ 1τ + ≥ 2 jets

	e+τ	μ+τ	SUM
Expected	2.6±0.6	2.2±0.5	4.8±0.7
Observed	2	3	5





Limit:

$M(\tilde{t}_1) > 129$ GeV/c²

Conclusions

- Tevatron, CDF and DO running efficiently
- Luminosity already 350 pb^{-1} and rising quickly !
- Start to test region above LEP limits and improve over Run I ones
- Presented many key results (and many more are not even shown here !)
- Still a lot of models to explore and improve on the current analyses

Backup slides

LEP: mSUGRA Limits

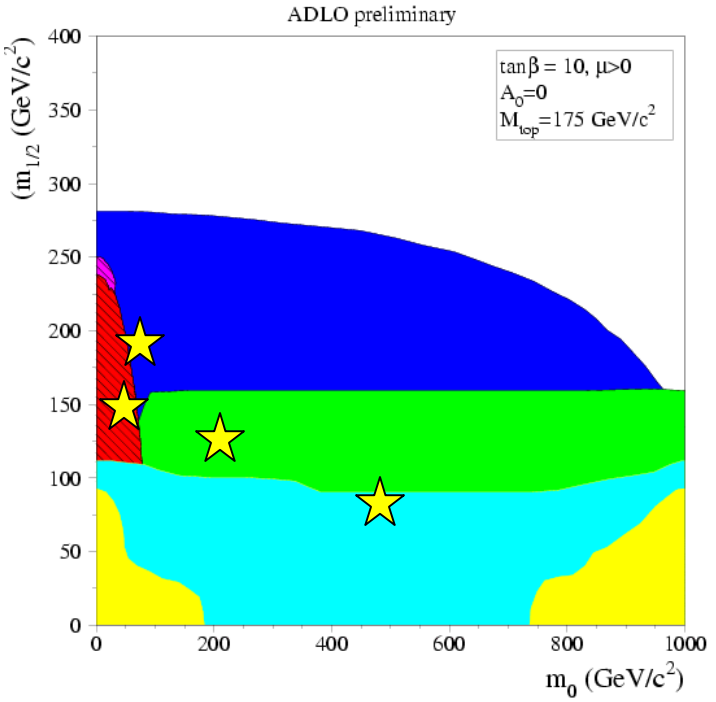
SM Higgs Limits

Slepton Limits

Chargino-Limits

LEP I Precision measurements

Theoretically forbidden



m_0: Common scalar mass at GUT scale

$m_{1/2}$: Common gaugino mass at GUT scale

A_0: Common trilinear scalar interaction at GUT scale

$\tan\beta$: Ratio of Higgs vevs

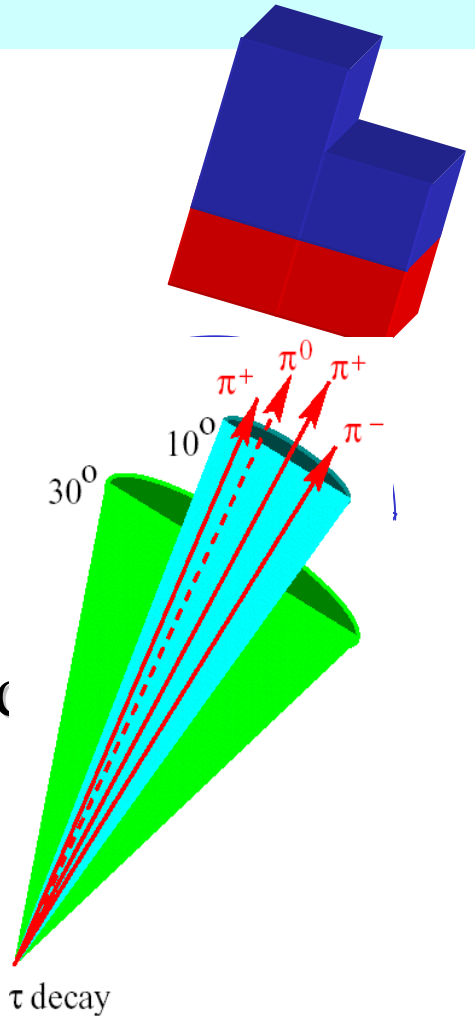
Sign of μ (Higgsino mass parameter)

Trileptons

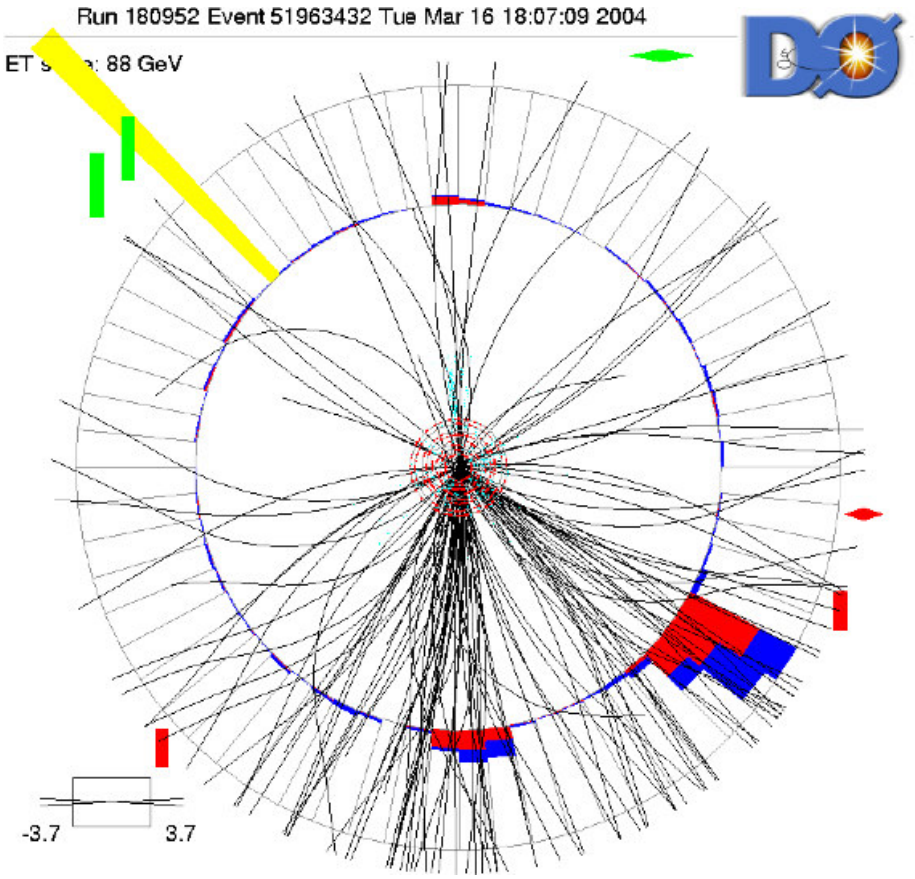
Selection	Main BG	Main Systematic
ee+l	Zgg,Wenu	JES,MC stat
eτ+l	QCD(38%) Wenu,WW,WZ	JES(3%),QCD,eff
μτ+l	WZ,Wmunu	QCD,JES,reco
SUM	QCD(m),WZ(e)	JES,modelling of qcd bg

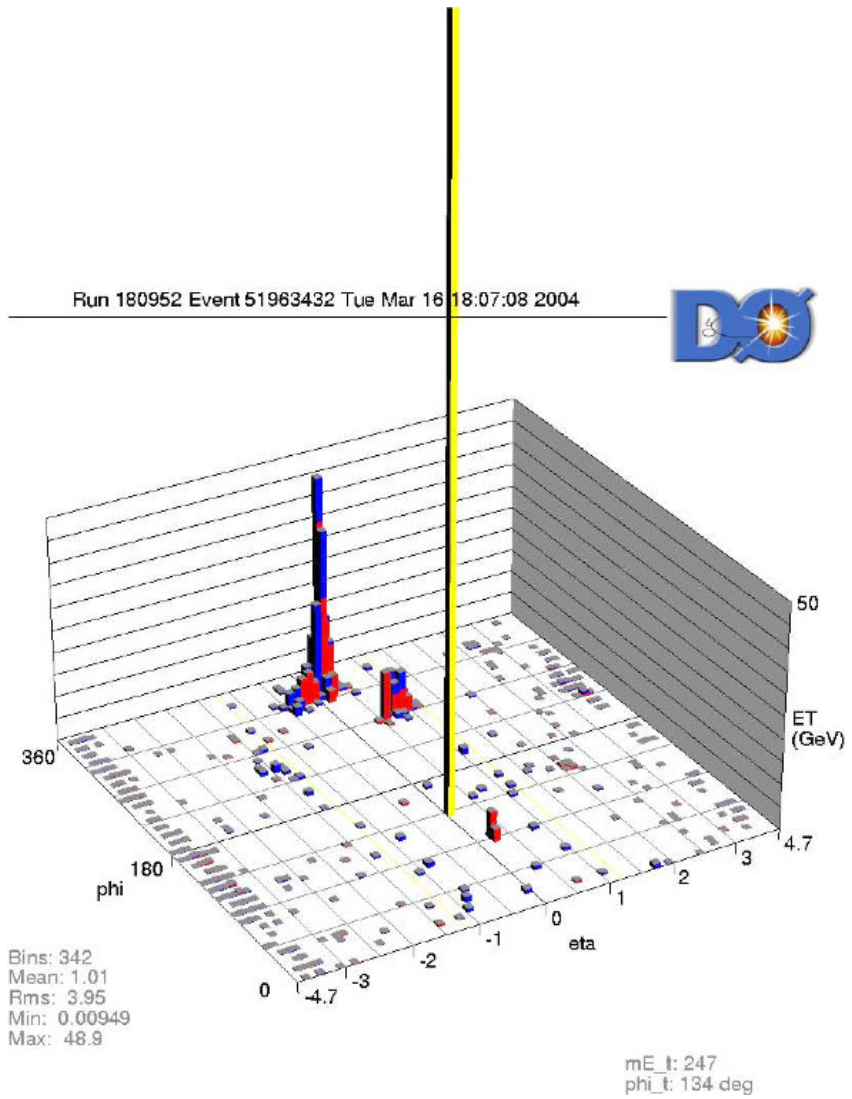
Tau identification

- narrow cluster in central calorimeter
-search for matching high-Pt track
-define 2 cones 10^o and 30^o around the track
-let more tracks to enter in the inner cone
–discard event if there are tracks between the 2 cones
-reconstruct the cluster in the ShowerMax and create a π^0
-select events with mass(π^0 ,tracks) < M(tau)
-check E(cal) = sum(P)(tracks+ π^0)



Squark-gluino: The event with highest $\not\!\!E_t$





$\not\!\!E_t$=354 GeV

Jets: E_t=264 GeV, E_t=106 GeV

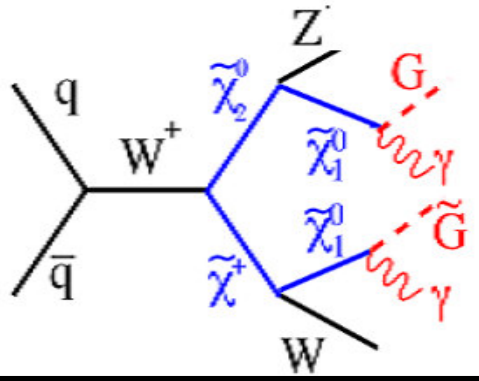
Chargino Neutralino in $\gamma\gamma+\not{E}_T$

In GMSB: 2 photons+$\not{E}_T$

D0(CDF) Event selection:

-2 photons E_T > 20(13) GeV

-$\not{E}_T$>40(45) GeV



	Limit	Main Syst	Main BG
D0	195 GeV	gID (8%)	QCD (70%)
CDF	167 GeV	gID (14%)	eg(50%)

CDF‡ and D0# combined result: $m(\chi^{\pm})>209$ GeV/c^2

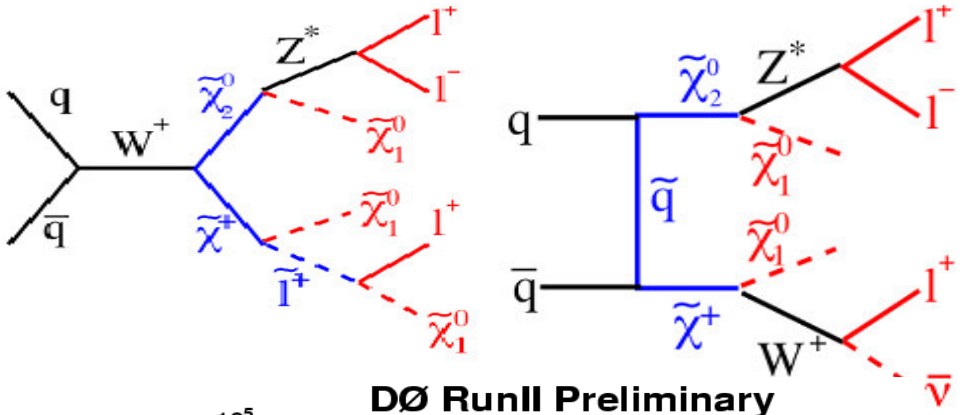
‡Phys.Rev.D.71,3 031104(2004)

#Phys. Rev. Letters 94, 041801(2005)

Chargino and Neutralino

In mSugra: 3 leptons+$\not\!\!E_T$

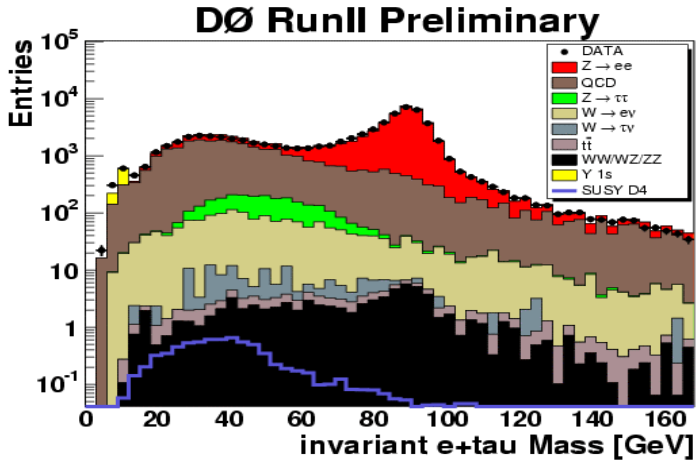
- ➡ σxBR~0.2 pb
- ➡ Very clean signature
- ➡ SM background very small !

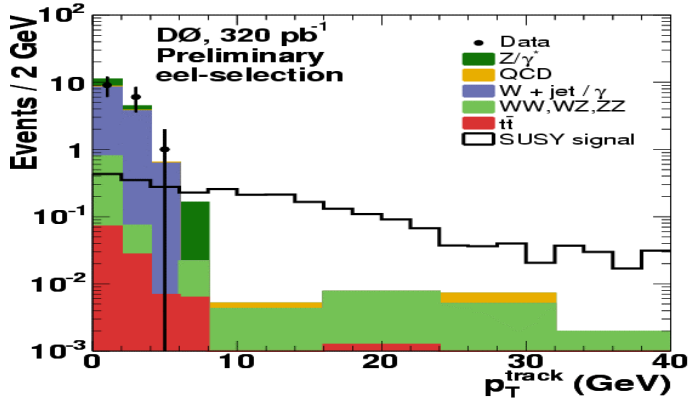


6 analyses:

- -2l(l=e,μ,τ)+isolated track or $\mu^\pm\mu^\pm$
- -$\not\!\!E_T$ and topological cuts (M_{ll},Δφ, M_T)

Selection	SM expected	OBSERVED
ee+l	0.21±0.12	0
eμ+l	0.31±0.13	0
μμ+l	1.75±0.57	2
$\mu^\pm\mu^\pm$	0.64±0.38	1
eτ+l	0.58±0.14	0
μτ+l	0.36±0.13	1
SUM	3.85±0.75	4





Champs

CHArged Massive stable Particles:

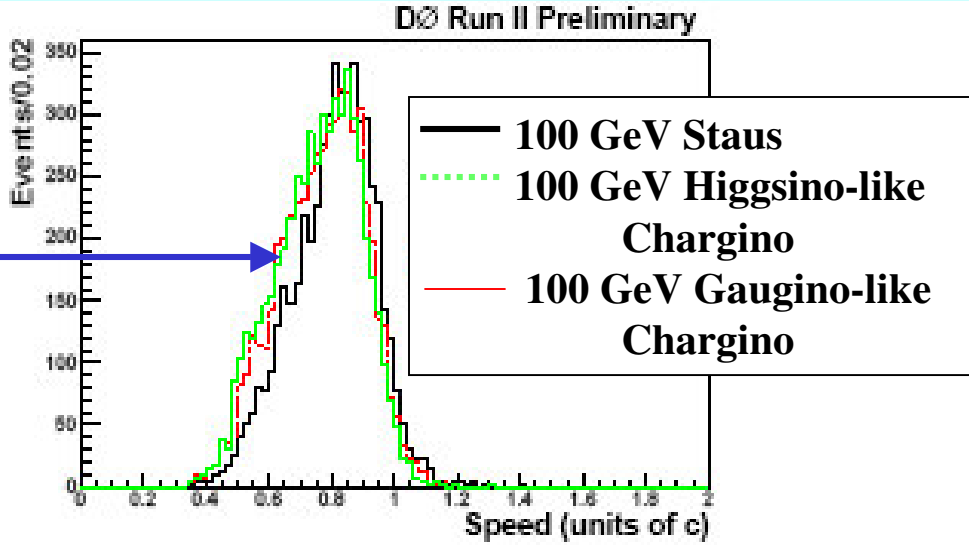
- -electrically charged
- -massive->speed<<c
- -lifetime long enough to decay outside detector

DO Event Selection:

-2 muons Pt> 15 GeV/c, isolated

-speed significantly slower than c

No SM Background!!->from DATA



SM EXP	OBS
0.66±0.06	0

In GMSB:

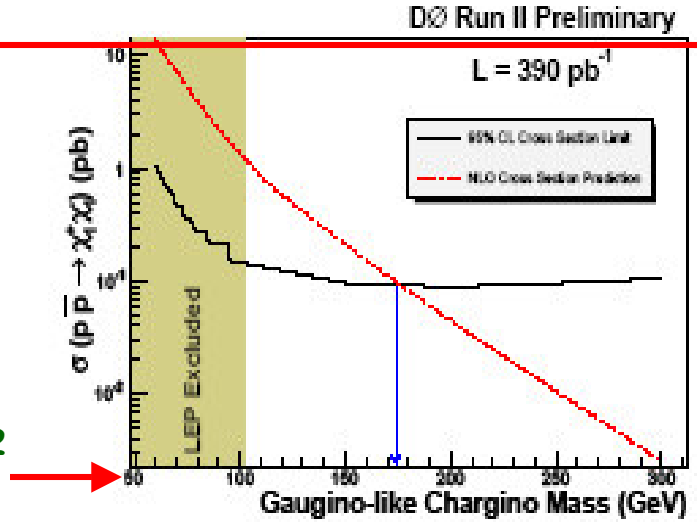
champ=$\tilde{\tau}$ or $\tilde{t}$

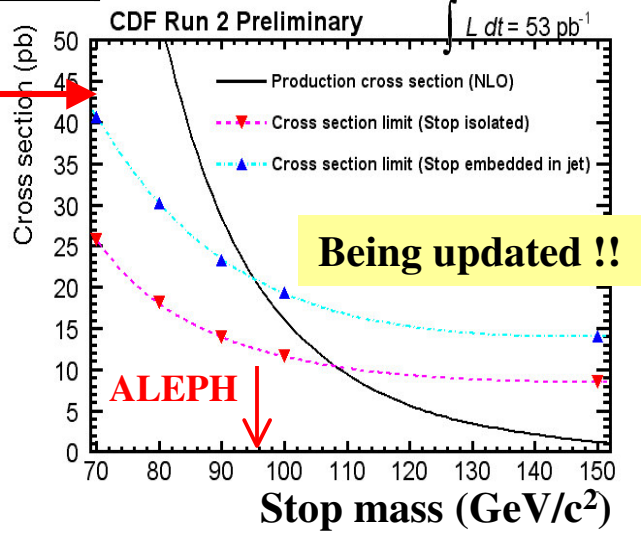
$M(\tilde{t})>109$ GeV/c^2

In AMSB:

champ = $\tilde{\chi}^{\pm}_1$

$M(\chi^{\pm}_1)>174$ GeV/c^2



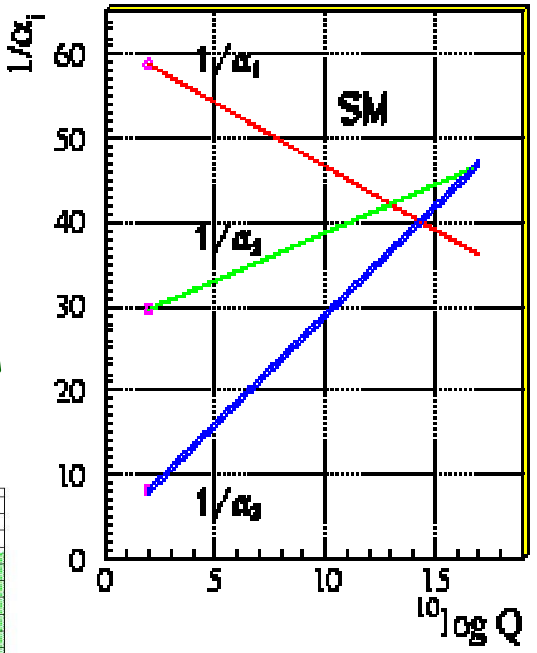


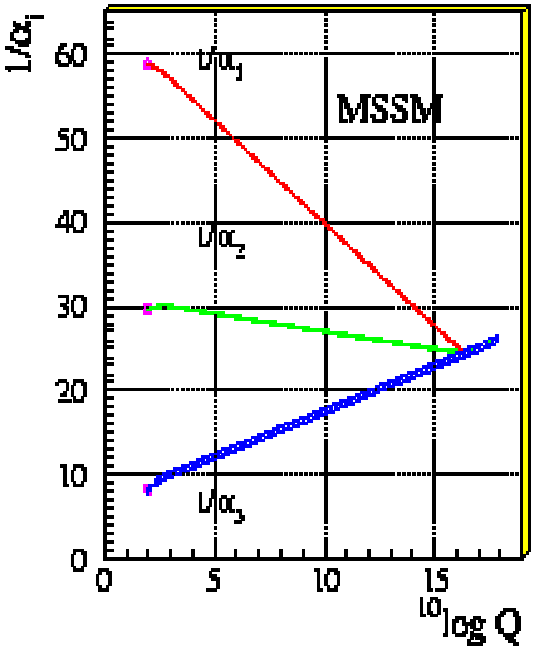
Being updated !!

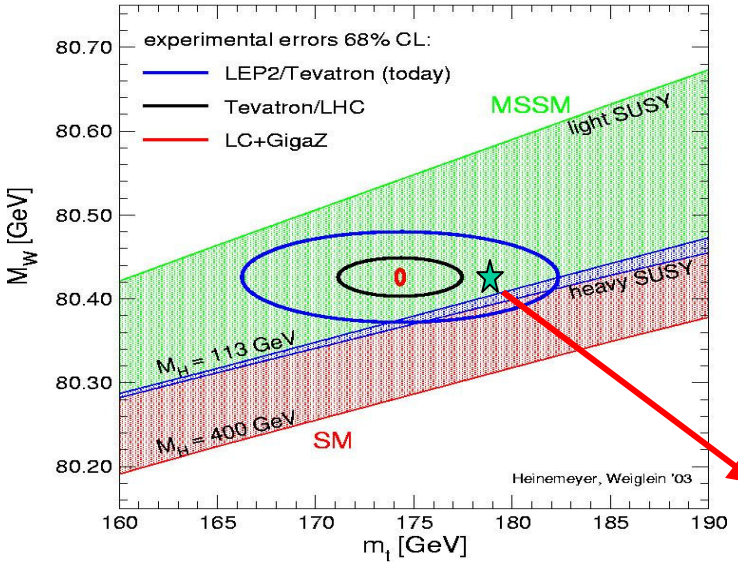
ca, Moriond QCD, 17th March 2005

Supersymmetry: why ?

- Solves "Hierarchy Problem"
- Provides Grand Unification Theory at the 10^{16} GeV scale
- Consistent with results from Precision Data fits







Run I CDF-D0 Combined Top Mass

Three models:

1. mSUGRA: $\tilde{\chi}^0_1$ LSP, stable
2. GMSB : $\tilde{G}$ LSP, stable
3. ~~R_p~~ (RPV) : LSP decays into SM particles