SUSY searches @ Tevatron

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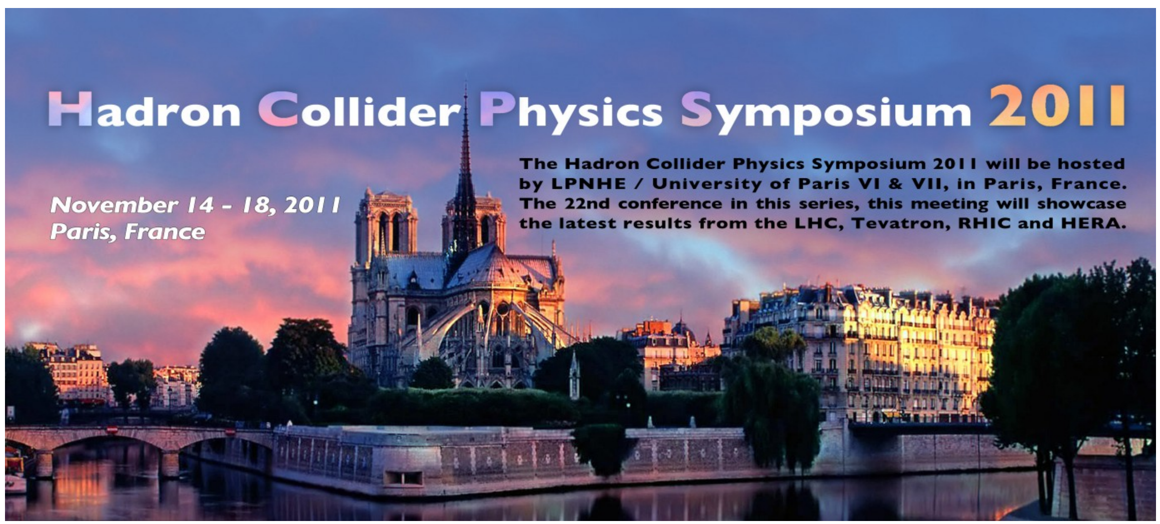
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

on behalf of the CDF and D0 collaborations

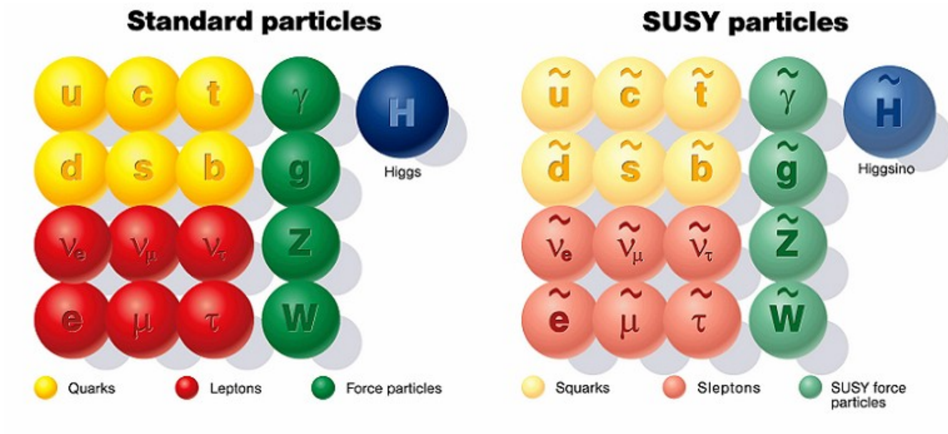


IN2P3
Institut National de Physique Nucléaire et de Physique des Particules

CNRS
Centre National de la Recherche Scientifique

Supersymmetry

Solves the hierarchy problem
Stabilizes the Higgs mass
Unifies forces at the GUT scale
Provides a candidate for dark matter



Doubles the nb of particles
Broken symmetry with unknown mechanism
Introduces a lot of new parameters

R-parity conservation : new symmetry to avoid some leptonic and baryonic number violating terms
$\Rightarrow$ sparticles are produced in pairs (LSP is stable, dark matter candidate)

R-parity violation : sparticles can be singly produced as resonances, and decay to SM particles

Tevatron vs LHC

LHC : $\boldsymbol{p\,p}$ collider running at 7 TeV since 2010

Suited to search for pair production of coloured SUSY particles ($\tilde{q}\,,\tilde{g}$)

Analyzed dataset ~1fb^{-1}

Tevatron $\boldsymbol{p\,\bar{p}}$ collider running at 2 TeV since 2002

Analyzed dataset → 6 fb^{-1}

Suited for pair production of non-coloured SUSY particles ($\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^{0}$)

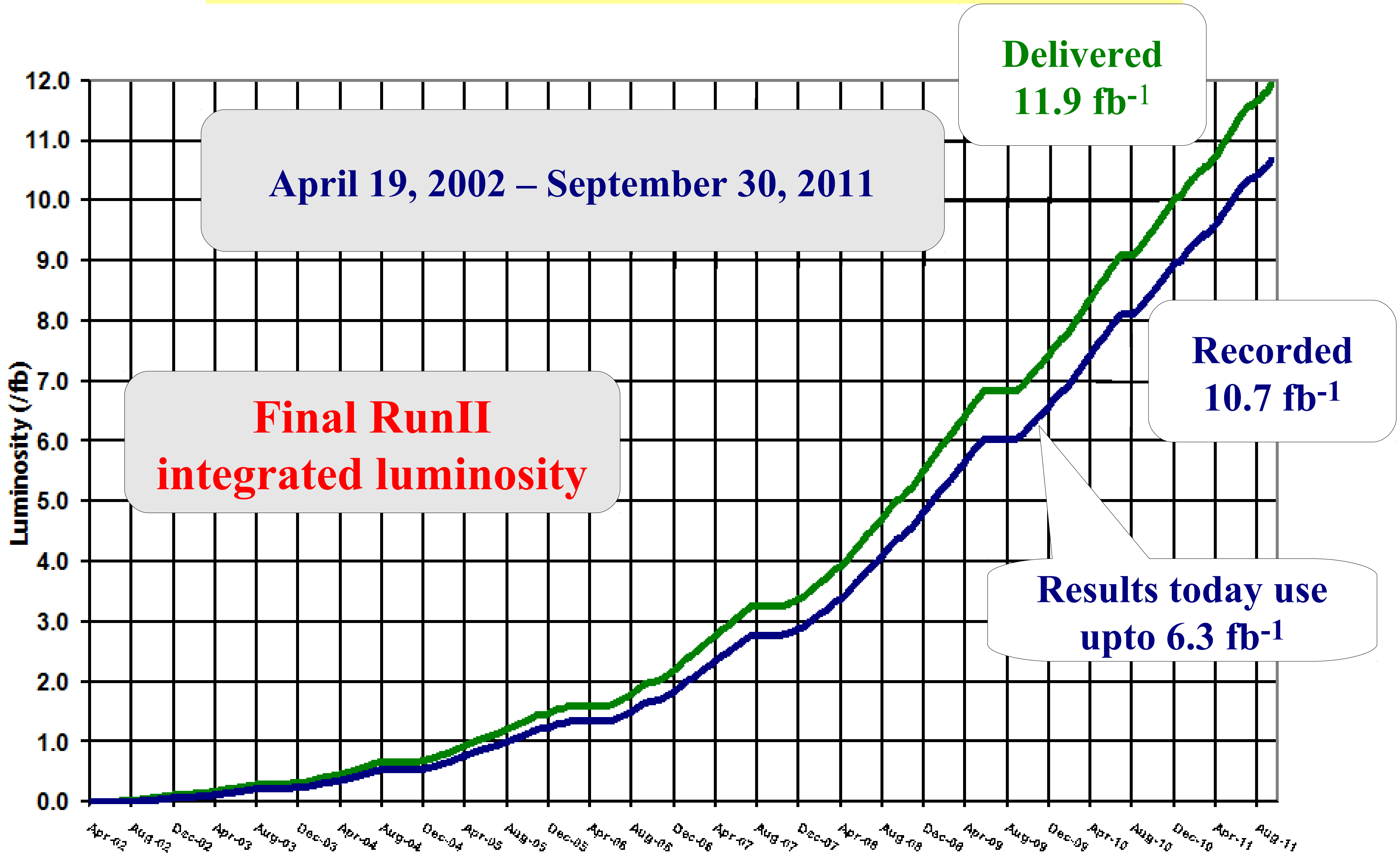
and production of 3rd generation sparticles

Complementarity between Tevatron and LHC searches

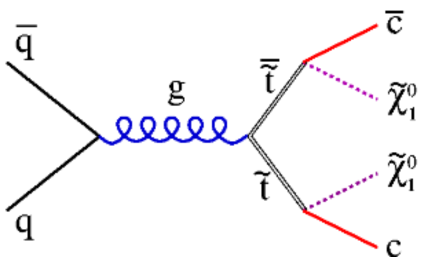
Outline

Stop, sbottom searches
GMSB diphoton+mET search
SS dileptons in squark/gluino pair production
Trileptons in gaugino pair production
Leptonic jets
CMLLP
RPV: sneutrino resonance production

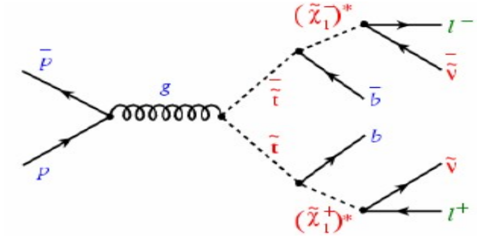
Tevatron


Delivered
11.9 fb-1
April 19, 2002 – September 30, 2011
Final RunII
integrated luminosity
Recorded
10.7 fb-1
Results today use
upto 6.3 fb-1
Luminosity (/fb)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Apr-02 Aug-02 Dec-02 Apr-03 Aug-03 Dec-03 Apr-04 Aug-04 Dec-04 Apr-05 Aug-05 Dec-05 Apr-06 Aug-06 Dec-06 Apr-07 Aug-07 Dec-07 Apr-08 Aug-08 Dec-08 Apr-09 Aug-09 Dec-09 Apr-10 Aug-10 Dec-10 Apr-11 Aug-11

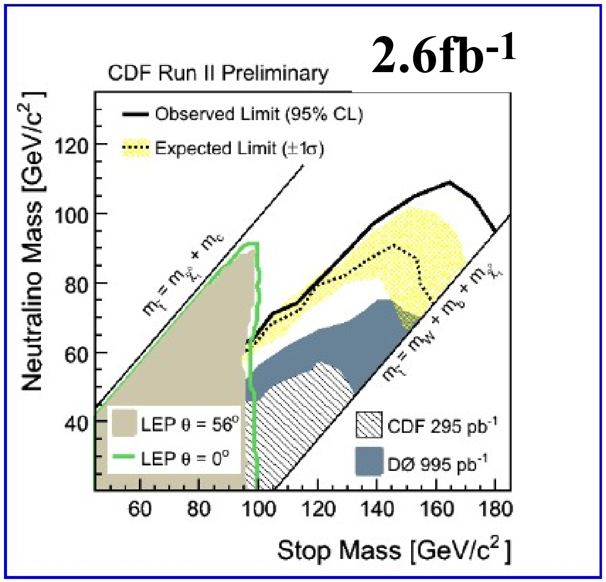
Stop searches



Stop may be the lightest squark
R-parity conserved
3 searches



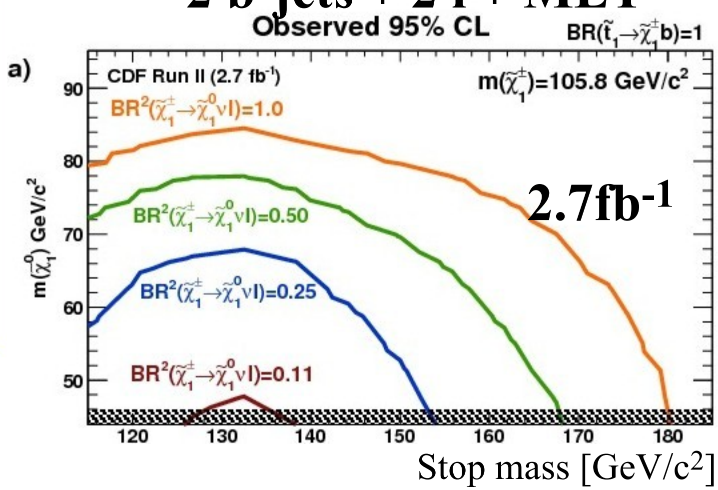
2 c-jets + MET



CDF note 9834 (2009)

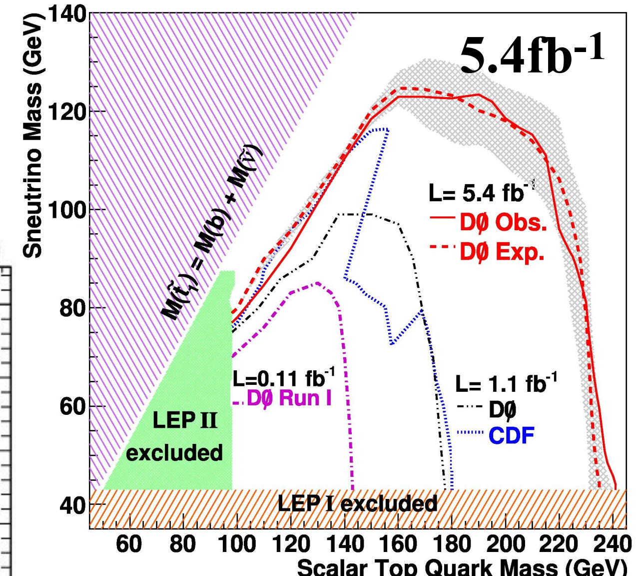
$$\tilde{t} \rightarrow b\,\tilde{\chi}^{\pm} \rightarrow b\,\tilde{\chi}^{0}\,l\,\nu$$

2 b-jets + 2 l + MET



PRL 104, 251801 (2010)

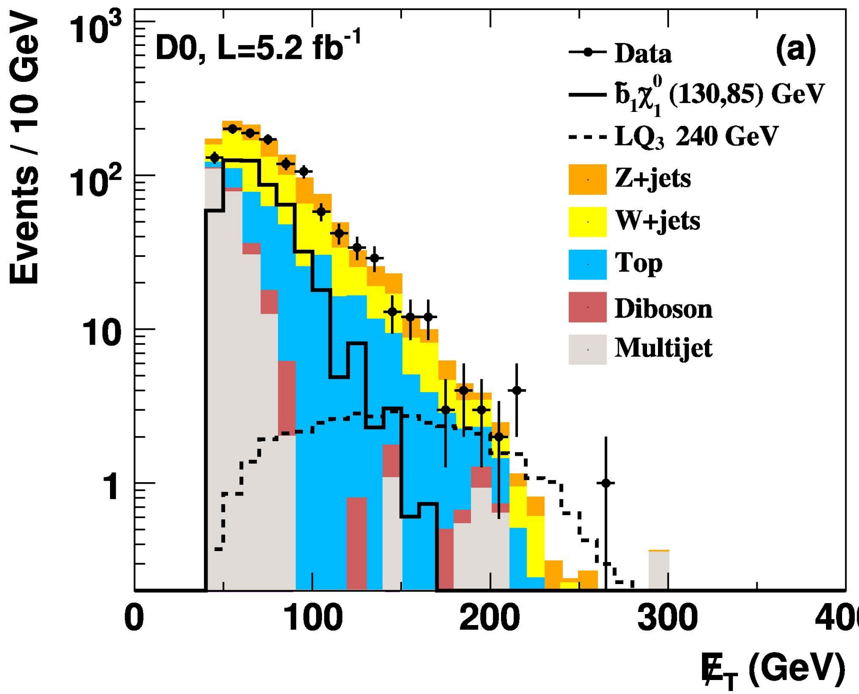
2b-jets + e + μ +MET

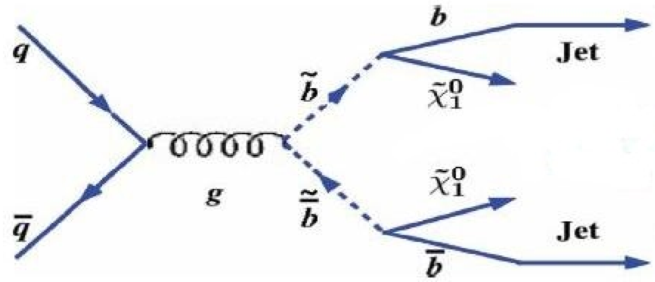


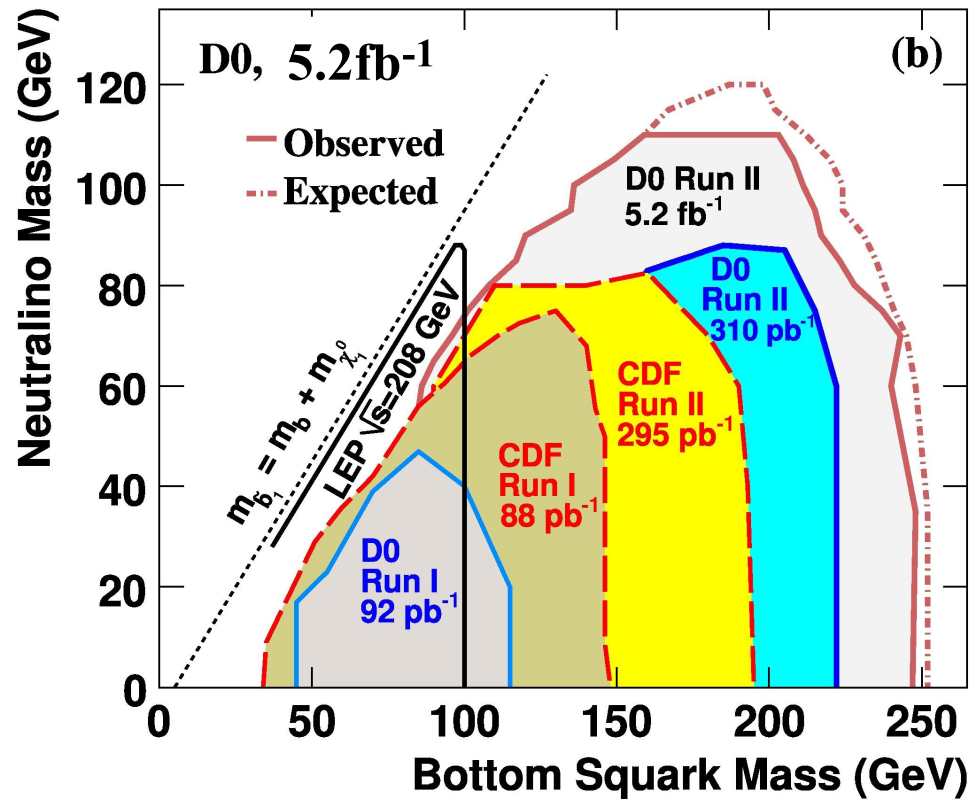
PLB 696, 321 (2011)

Sbottom searches

- Assume $\tilde{b} \rightarrow b\,\tilde{\chi}_1^0$ 100%
- 2 b-tagged jets + mET > 40 GeV







(2.65 fb^{-1}) PRL 105, 081802 (2010)

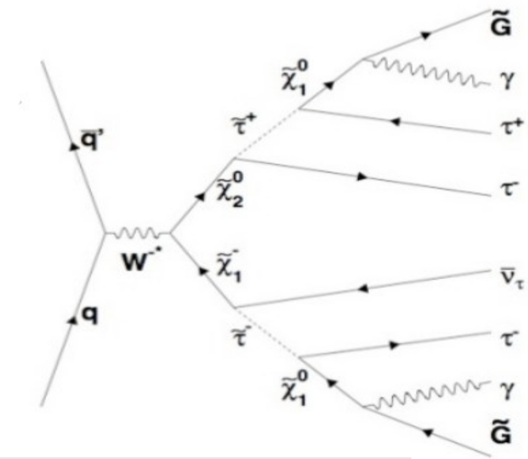
PLB 693, 95 (2010)

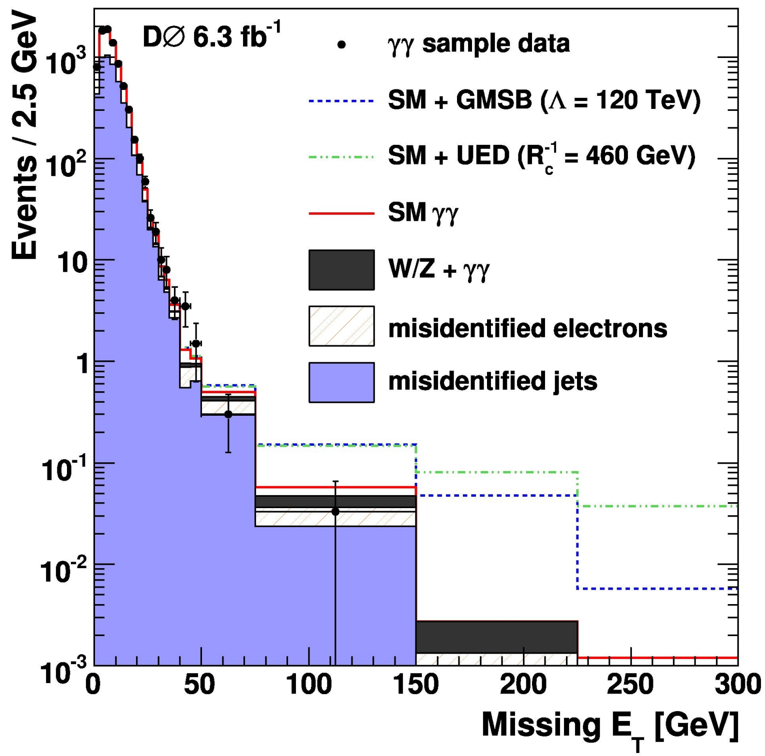
GMSB : γγ + mET

GMSB : Gravitino is LSP, NLSP is $\tilde{\chi}_1^0 \rightarrow \gamma\,\tilde{G}$

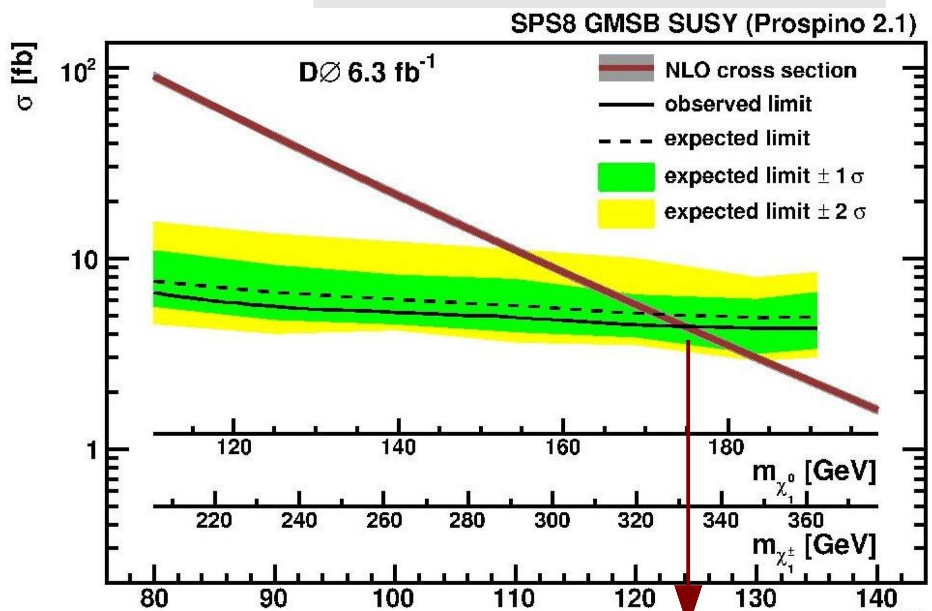
SPS8 benchmark model (Λ, $M_{mes}=2\Lambda$, $\tan\beta=15$, $\mu>0$)

Selection : 2 central γ ($|\eta|<1.1$), $E_T > 25$ GeV





PRL 105, 221802 (2010)

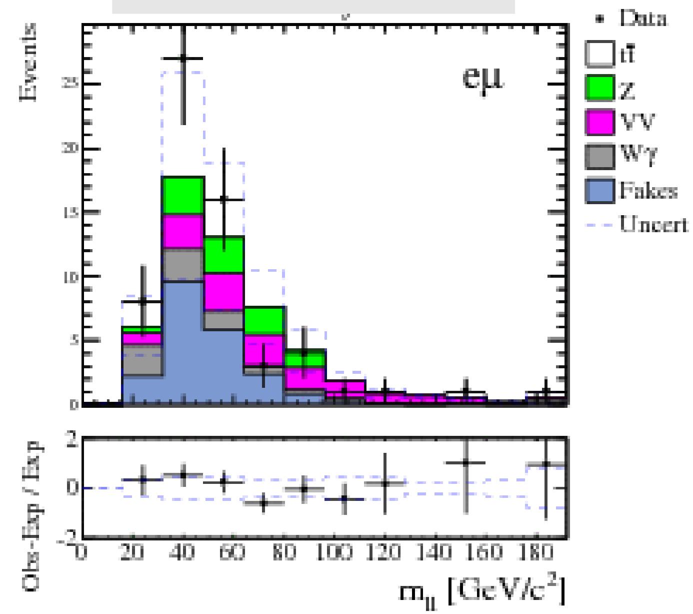


$\Lambda > 124$ TeV, $M(\tilde{\chi}_1^0) > 175$ GeV, $M(\tilde{\chi}_1^\pm) > 331$ GeV

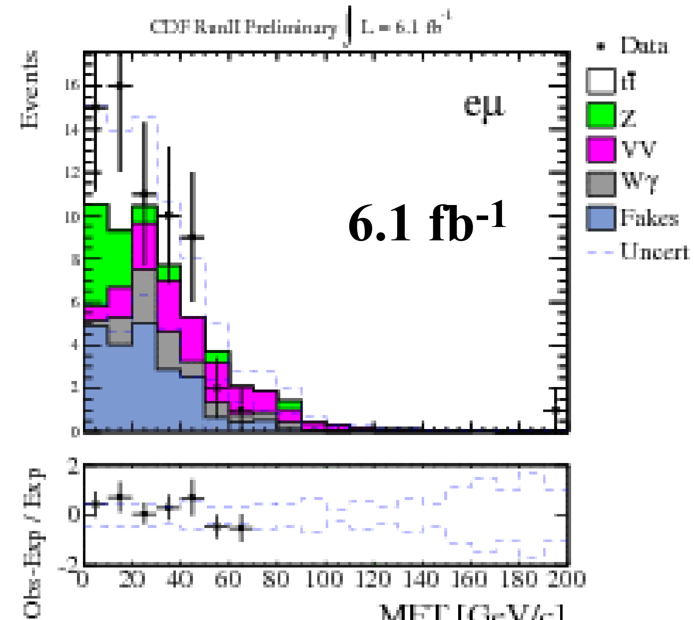
SS dileptons

CDF note 10464

- Same sign dilepton events rare in SM (WZ, ZZ diboson)
- **Model independent search in ee, μμ and eμ**
- Lepton pT > 20 GeV, |η| < 1.1
- Veto [86,96] GeV Z mass for $\mu^+\mu^-$ and ee
- Main background is "fake" isolated leptons from heavy flavor decays (estimated from data)

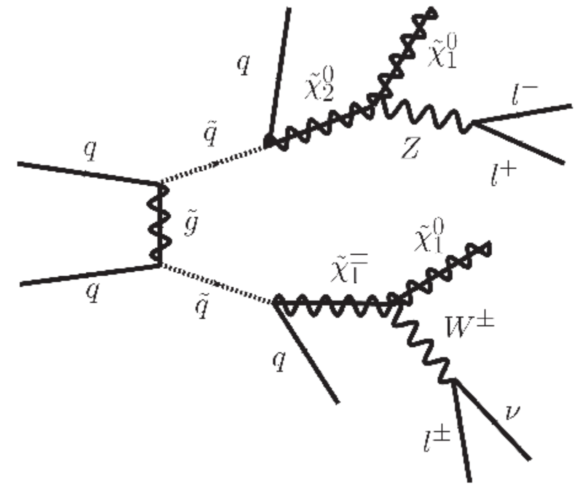


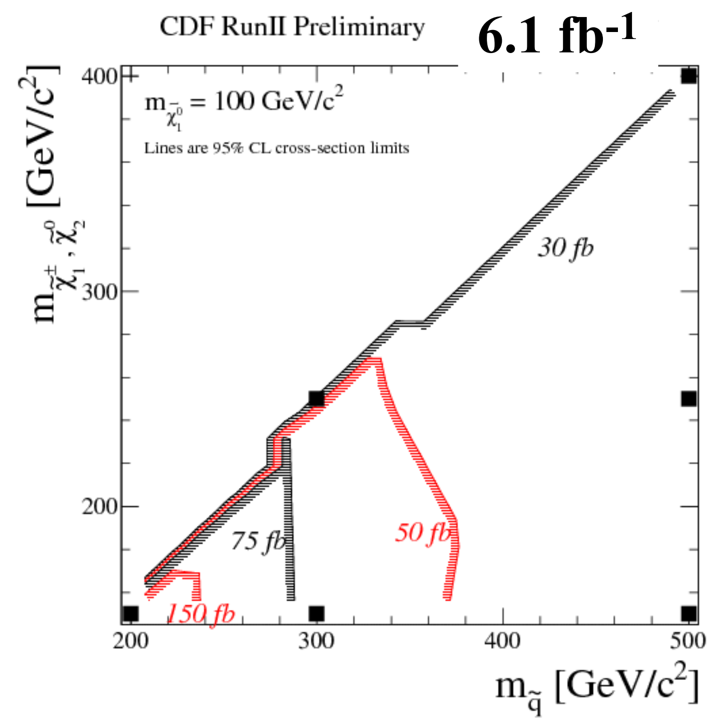
CDF RunII Preliminary $\int \mathcal{L}dt = 6.1\ \mathrm{fb}^{-1}$				
Process	Total $\ell\ell$	$\mu\mu$	ee	$e\mu$
$t\bar{t}$	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.0
$Z \to ee$	15.7 ± 2.7	0.0 ± 0.0	15.7 ± 2.7	0.0 ± 0.0
$Z \to \mu\mu$	8.7 ± 2.0	0.0 ± 0.0	0.0 ± 0.0	8.7 ± 2.0
$Z \to \tau\tau$	2.2 ± 0.9	0.0 ± 0.0	1.3 ± 0.6	1.0 ± 0.6
WZ	24.7 ± 1.3	7.0 ± 0.4	5.1 ± 0.3	12.7 ± 0.7
WW	0.2 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.0
ZZ	3.5 ± 0.2	0.9 ± 0.1	0.8 ± 0.1	1.7 ± 0.1
$W(\to e\nu)\gamma$	7.8 ± 1.7	0.0 ± 0.0	7.8 ± 1.7	0.0 ± 0.0
$W(\to \mu\nu)\gamma$	7.8 ± 1.7	0.0 ± 0.0	0.0 ± 0.0	7.8 ± 1.7
$W(\to \tau\nu)\gamma$	0.6 ± 0.4	0.0 ± 0.0	0.3 ± 0.3	0.3 ± 0.3
Fakes	51.6 ± 24.2	8.2 ± 5.3	22.1 ± 8.9	21.3 ± 10.6
Total	123.0 ± 24.6	16.1 ± 5.4	53.3 ± 9.5	53.6 ± 10.9
Data	145	14	66	65



SS dileptons + jets (2)

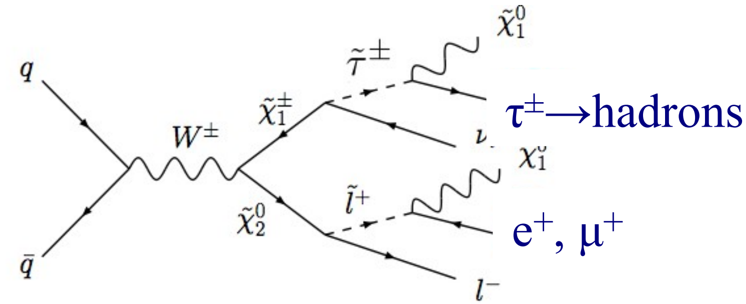
- Requesting ≥ 2 jets (p_T> 15 GeV, $|\eta| < 2.4$)
- **Use a "practical" SUSY model see PRD79, 075020 (2009)**
  - ✓ **specific production + decay modes**
  - ✓ **minimal particle content**
  - ✓ **Only squark and gluino pair production considered (large cross sections)**
  - ✓ $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ **exist in cascade, decay through W/Z**
  - ✓ **sleptons are very heavy**
  - ✓ $BR(\tilde{q} \rightarrow q\tilde{\chi}_1^{\pm}) = BR(\tilde{q} \rightarrow q\tilde{\chi}_2^0) = 0.5$
- **Obtain limits on cross section × BR vs sparticle mass**



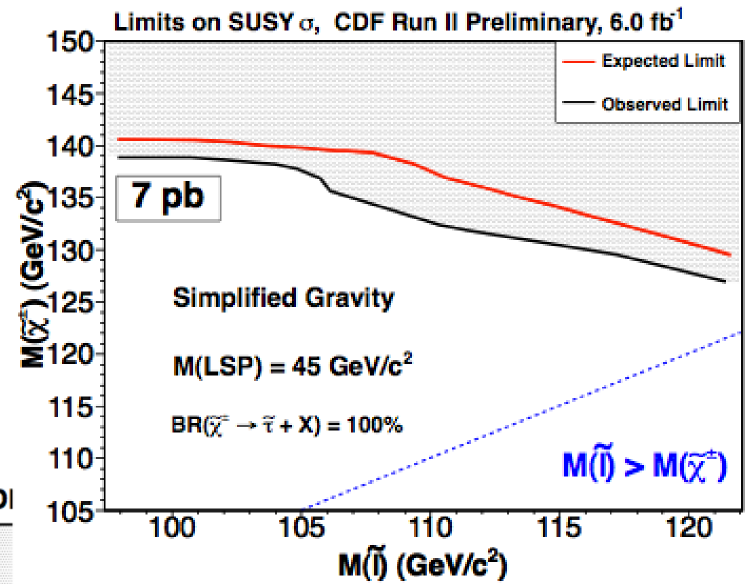


CDF note 10465

SS dileptons (e or μ + τ_h)



Adopt a generic approach with the minimal list of sparticles, and mimic models which favors decays to taus



"Simplified Gravity" models

$$Br(\tilde{\chi}_2^0 \rightarrow \tilde{\tau}^\pm \tau^\mp) = Br(\tilde{\chi}_1^\pm \rightarrow \tilde{\tau}^\pm \nu) = [1, 1/3]$$

$$Br(\tilde{l}^\pm \rightarrow l \tilde{\chi}_1^0) = 1$$

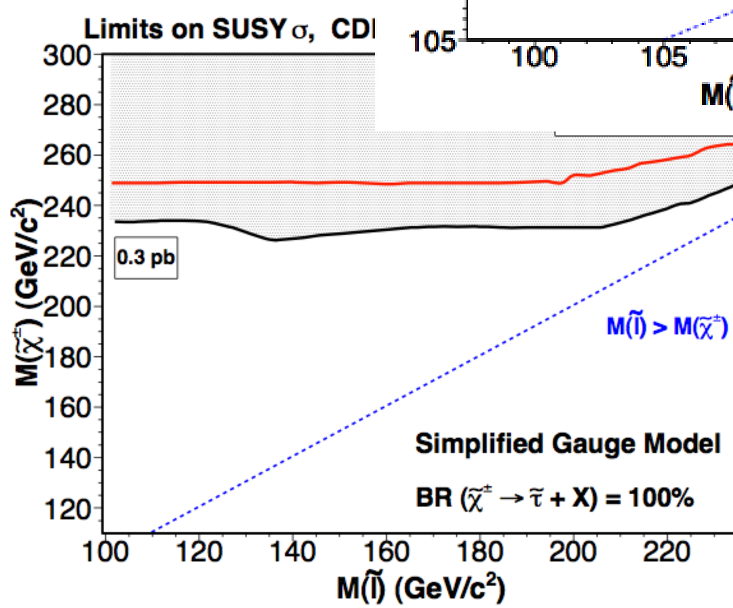
$$m(\tilde{\chi}_2^0) = m(\tilde{\chi}_1^\pm)$$

"Simplified gauge" model

$\tilde{\chi}_2^0 \rightarrow \tilde{l}^\pm l^\mp$ where $l = e, \mu$, or τ

$$Br(\tilde{\chi}_1^\pm \rightarrow \tilde{\tau}^\pm \nu) = 1$$

$Br(\tilde{l}^\pm \rightarrow l G) = 1$ co-NLSPs

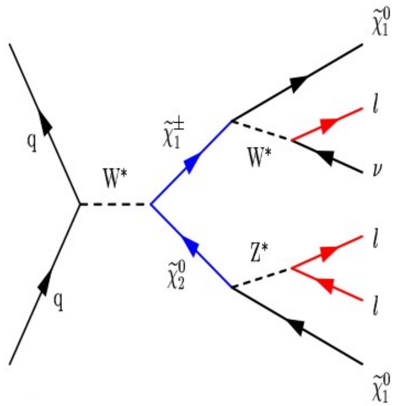


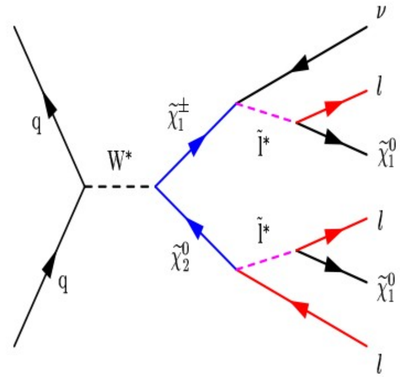
CDF note 10611

Trileptons

- SUSY golden mode: electroweak production of charginos and neutralinos

decay through W/Z
if $\tilde{l}^{\pm}$ are heavy
BR(lll) is low



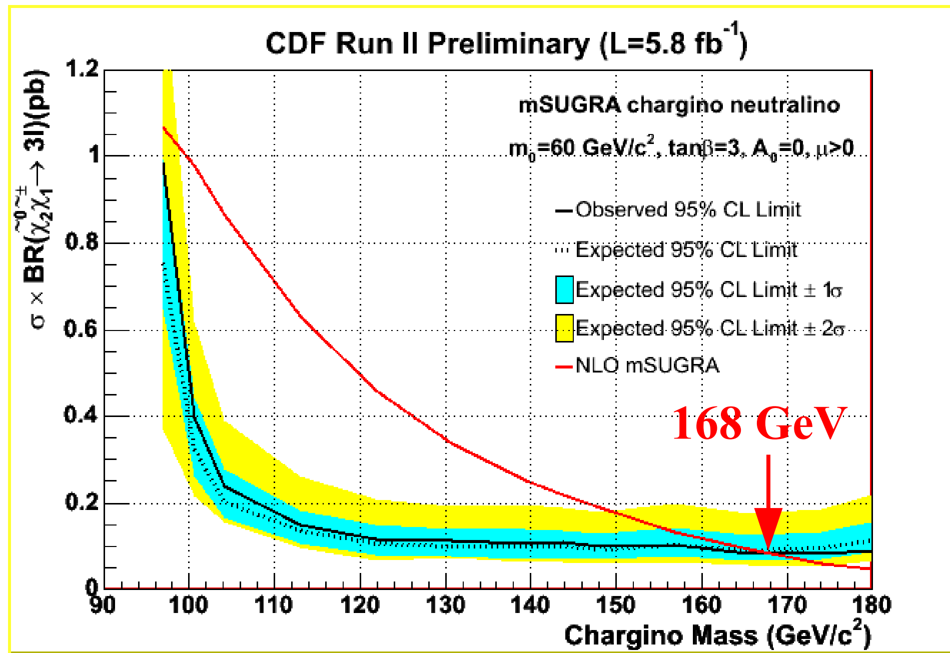


decay through light
$\tilde{l}^{\pm}$ (usually $\tilde{\tau}^{\pm}$)
3 leptons (τ's)

ee+lepton, ee+track, μμ+lepton,μμ+track
where lepton=e, μ, or τ_h
Extend acceptance to forward region and
to lower lepton momenta (→5GeV)
Validate background in 32 control regions

No excess of data over expectation

$$\sigma(\tilde{\chi}_1^{\pm}\tilde{\chi}_2^{0}) \times Br(3leptons) < 0.1\, pb$$



CDF note 10636

Leptonic jets + mET

PRL 105, 211802 (2010)

∃ hidden sector weakly coupled to SM particles

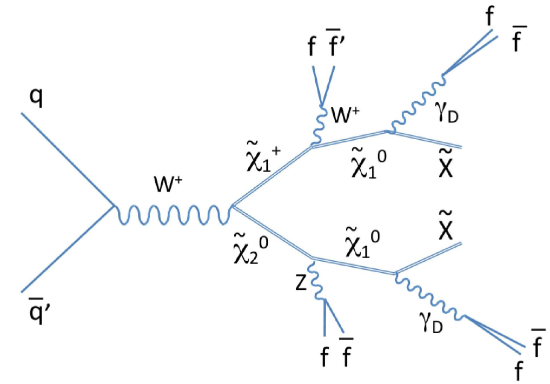
Dark photon γ_D is light → collimated lepton pair

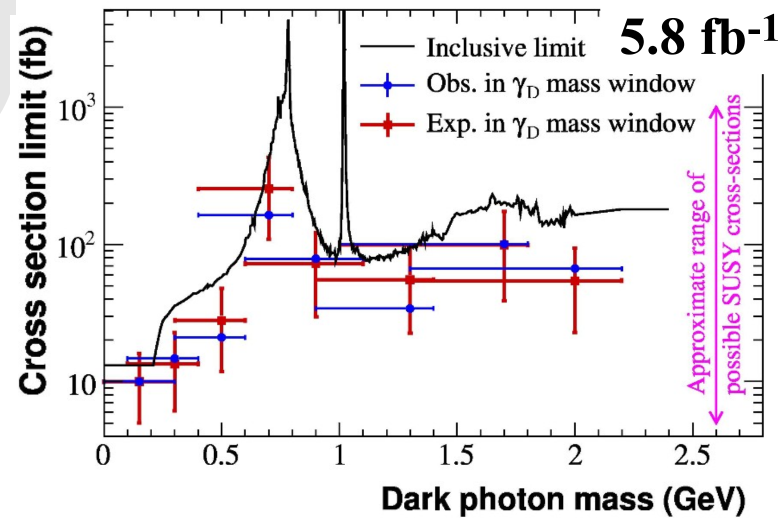
If SUSY, sparticles in hidden sector

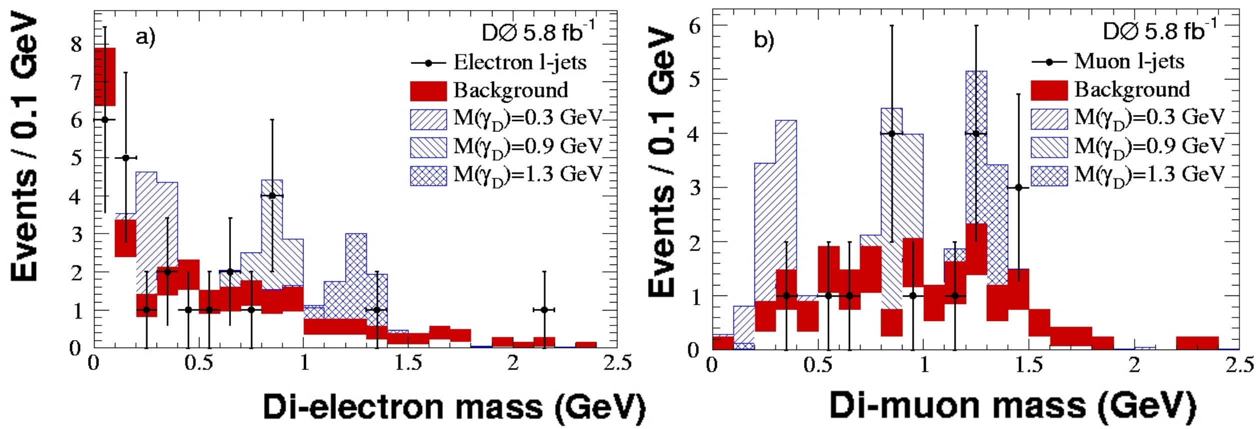
LSP of hidden sector $\tilde{X}_D$ escapes detection → mET

Ask for a track of opposite charge close to lepton candidate

Change the isolation criteria in lepton definition







Charged Massive Long Lived Particles

CMLLPs exist in many models ⇒ implications in cosmology

CMLLP ≈ slow moving and heavy μ

low speed ($\beta < 1$)

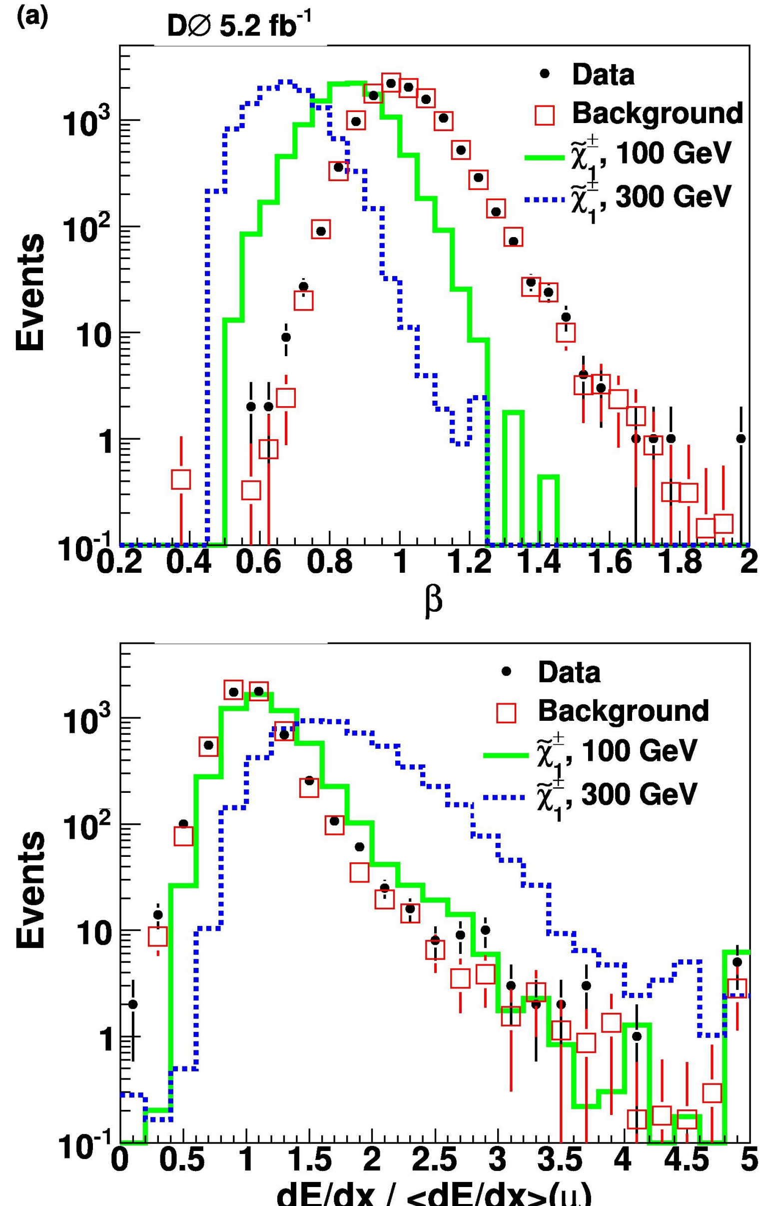
measured in μ scintillation counters

large ionization loss

measured by Silicon Microstrip Tracker

Background = mismeasured μ (mostly from $W \to \mu\nu$ decay)

Bckg model = data with $M_T < 200$ GeV

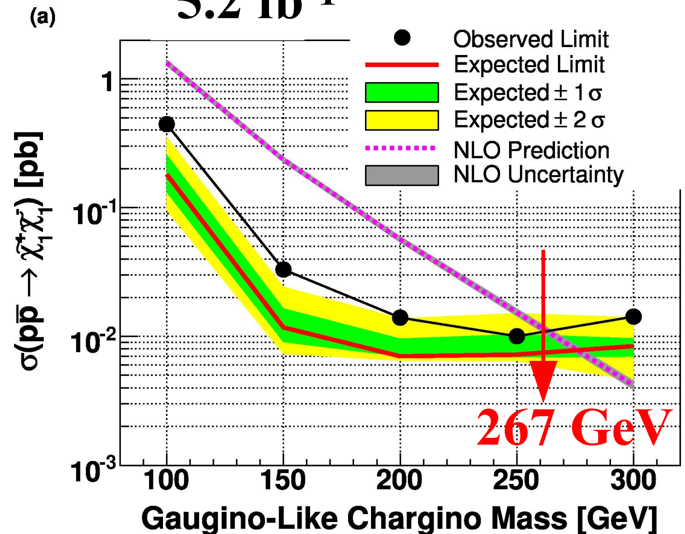


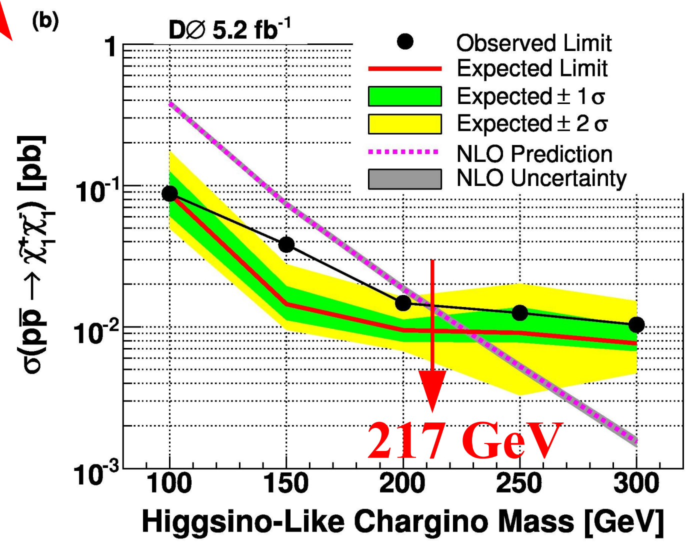
CMLLP (2)

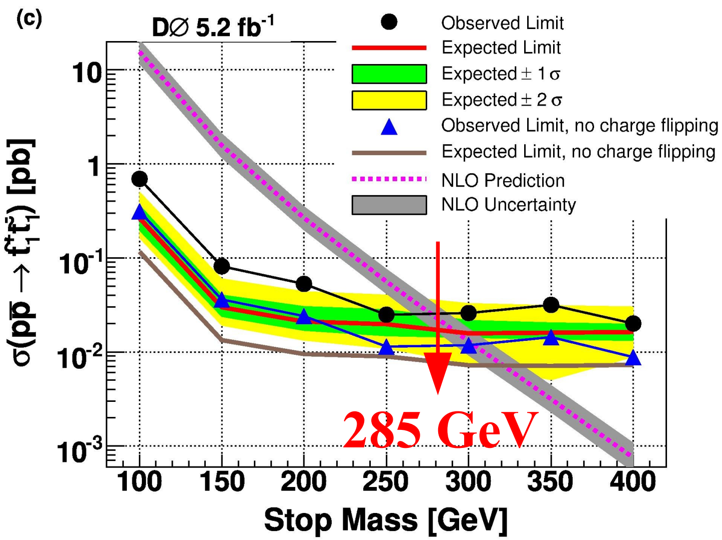
- in SUSY, where LSP is stable, NLSP may be long lived if weakly coupled to LSP or if mass difference is small
Charginos (gaugino-, or higgsino-like)

- Also top squark could be long lived if lightest coloured sparticle

5.2 fb^{-1}



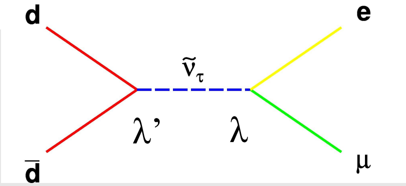




assuming a charge survival probability of 38%

arXiv:1110.3302

RPV: sneutrino→eμ



$$\sigma_{e\mu} \propto \left(\lambda'_{311}\right)^2 \left(\lambda_{312}\right)^2 \frac{1}{\left|\hat{s}-M^2+i\Gamma M\right|^2}$$

PRL 105, 191802 (2010)

Clean topology: 2 isolated leptons with different flavor and charge, no jets, no mET

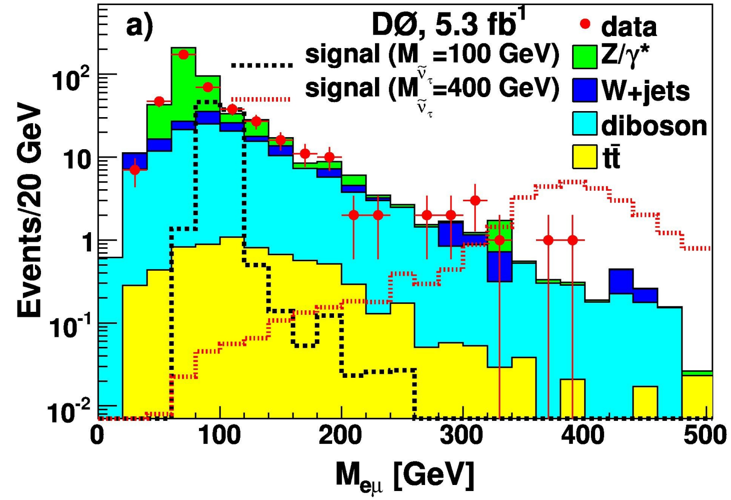
Main bkgd : Z/γ* → ττ, dibosons

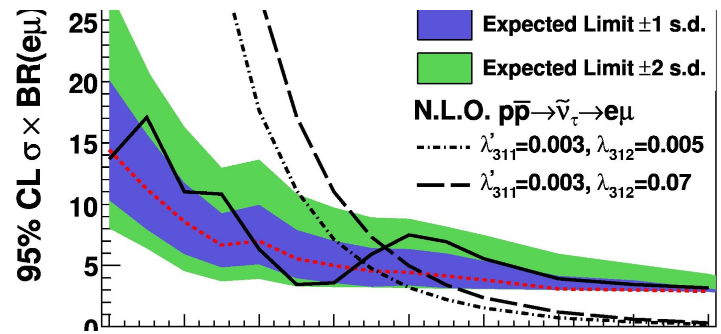
Good agreement with SM expectation

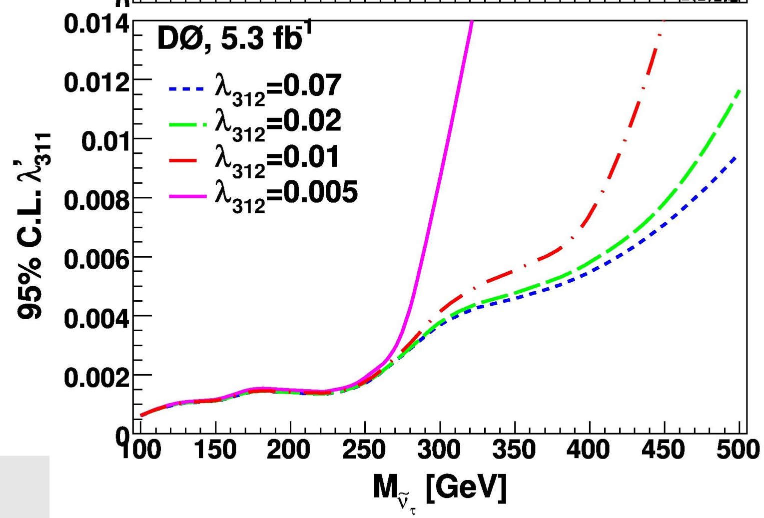
Limits for $\lambda_{312} = \lambda_{321} \leq 0.07$ and M=100GeV :

$\lambda'_{311} < 6.2\ 10^{-4}$

Better than ATLAS limit (*arXiv:1109.3089*) in the low mass region







$1 fb^{-1}$ (eμ, or eτ, or μτ) *PRL 105, 191801 (2010)*

Summary and Outlook

Performances of the Tevatron has brought limits on BSM physics beyond one could have expected.

More than 10 fb^{-1} of data recorded by CDF and D0

Extensive searches for SUSY signals have been performed at the Tevatron

No evidence of SUSY yet, but …

Search for BSM physics is now in the ballpark of LHC, it has already surpass some of Tevatron results (squarks and gluinos)

Given the large datasets, searches at the Tevatron will be pursued in areas where it is competitive (charginos, neutralinos prod.)

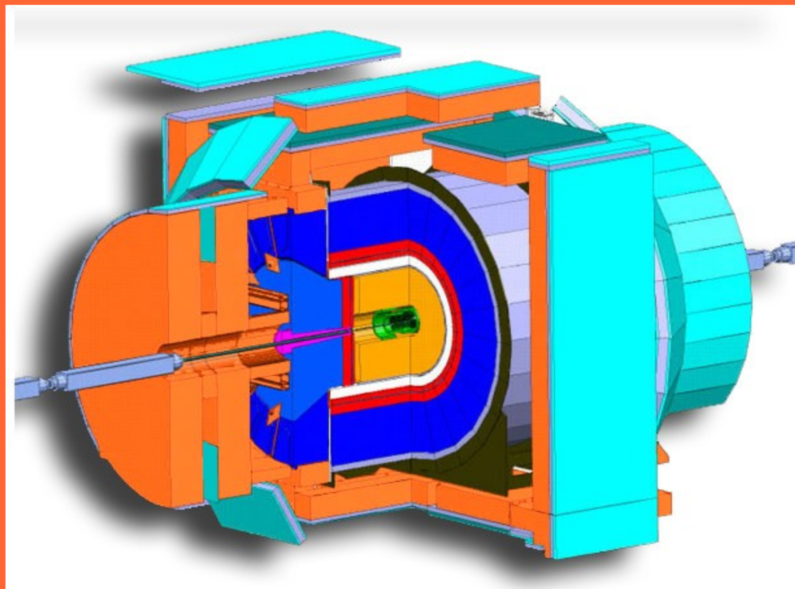
All BSM CDF and D0 results are available on :

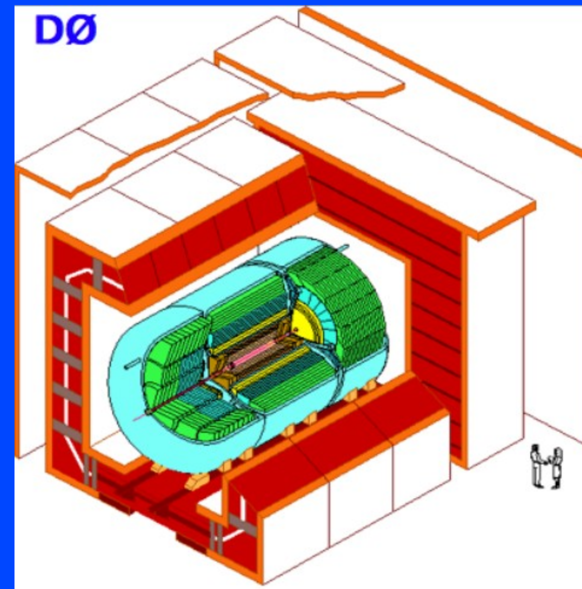
http://www-cdf.fnal.gov/physics/exotic/exotic.html

http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

Backup

CDF & D0 detectors





Silicon Tracking, |η|<2.5
Open Drift Cell Tracker
1.4 T B Field, |η|<1.1
Pb/Cu/Scint Calorimeter, |η|<3.6
Jet Energy Scale 2-3%
μ Drift/Scintillator Counters, |η|<1.5

Silicon Tracking, |η|<3
Scintillating Fiber Tracker
2.0 T B Field, |η|<2
LAr/U Calorimeter, |η|<4
Jet Energy Scale 1-2%
μ Drift/Scintillator Counters, |η|<2