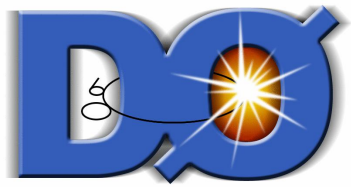
Searches for third generation squarks at the Tevatron

Miguel Vidal
for the CDF and DØ Collaborations

CIEMAT-Madrid

The 2009 Europhysics Conference on High Energy Physics
16-22 July, 2009 Krakow, Poland



Outline

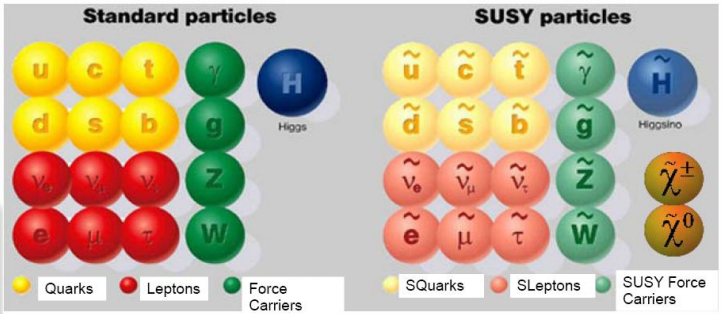
1. Introduction
2. Sbottom Searches
   - Sbottom $\longrightarrow$ bottom + neutralino
   - Sbottom from gluino decay
3. Stop Searches
   - Stop $\longrightarrow$ charm + neutralino
   - Stop in dilepton signature
   - Stop in top-like events
4. Summary

SUSY

Supersymmetry (SUSY) is the most promising extension of the SM.

New spin-based symmetry relating fermions and bosons:
$Q|Fermion>=|Boson>$
$Q|Boson>=|Fermion>$

Mirror spectrum of particles



R-parity

$R_P = (-1)^{2S+3B+L}$
1 for SM particles, -1 for super-partners

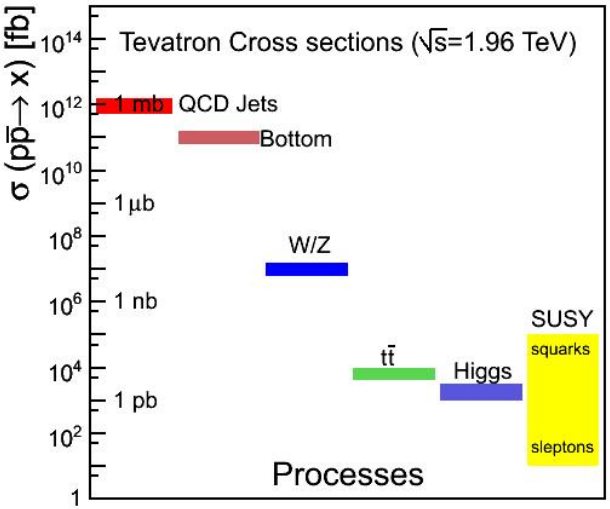
Under R-parity conservation $\Rightarrow$

- Dark Matter candidate (LSP)
- The SUSY particles are produced in pairs

SUSY must be broken

SUSY II

- The breaking mechanism determines the phenomenology and the search strategy
- $\tilde{t}$ and $\tilde{b}$ are good candidates for being the lightest s-quark state



Assuming large $tan\beta$

- the mass of third generation squarks could be really low $\sim$ 200 GeV/c^2
- Under these assumptions Tevatron is an excellent place to find SUSY!!

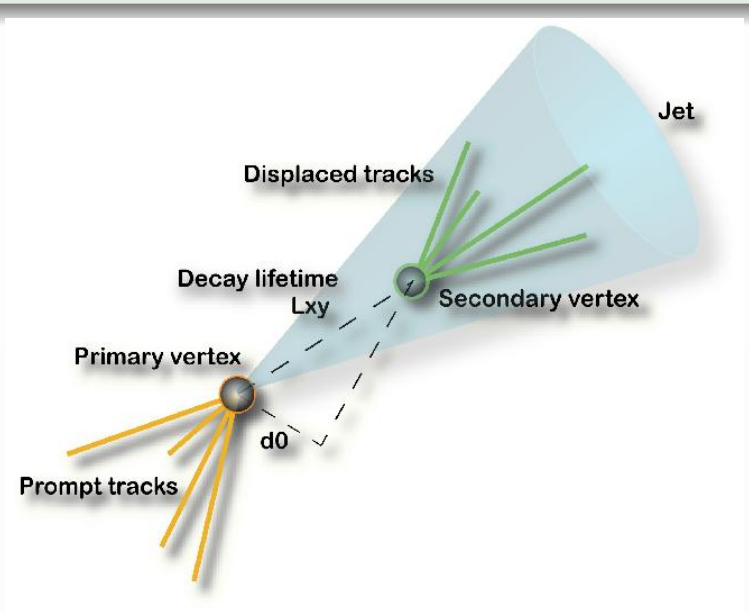
Most of the searches in this talk are signature-based and the goal is to optimize the selection to reduce backgrounds

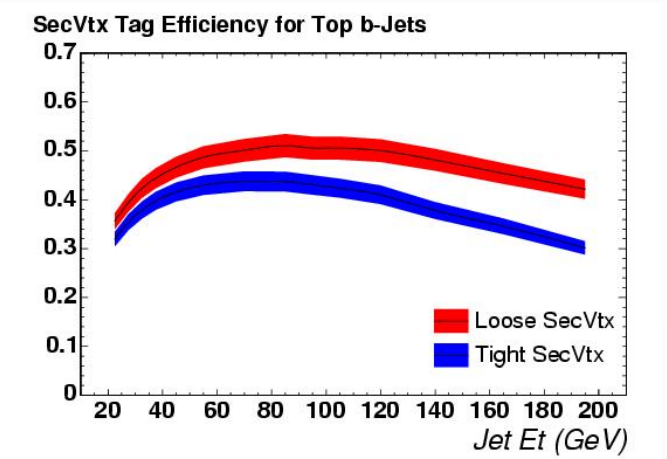
Tools like heavy flavour tagging are crucial

Heavy Flavour Tagging

The goal is to enhance the presence of signal in the sample by identifying HF jets in the final state

- The tagging algorithms identify vertices from long lifetime B hadrons
- The decay distance is $L_{xy} \sim 500\ \mu$m
- The algorithms are based on properties of the secondary vertex and the tracks associated to it
- Different requirements depending on the flavour of the tagged jet:
  - b jets
  - c jets

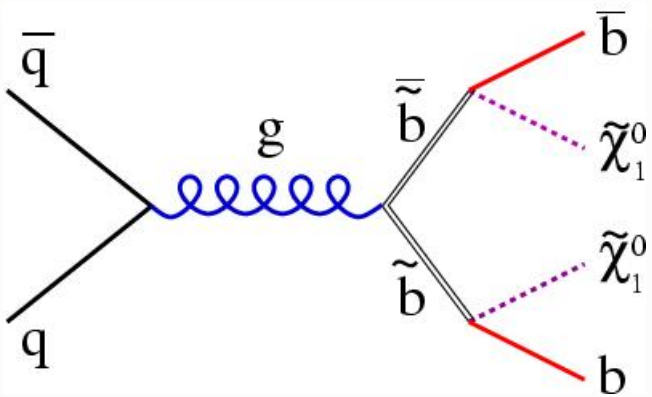


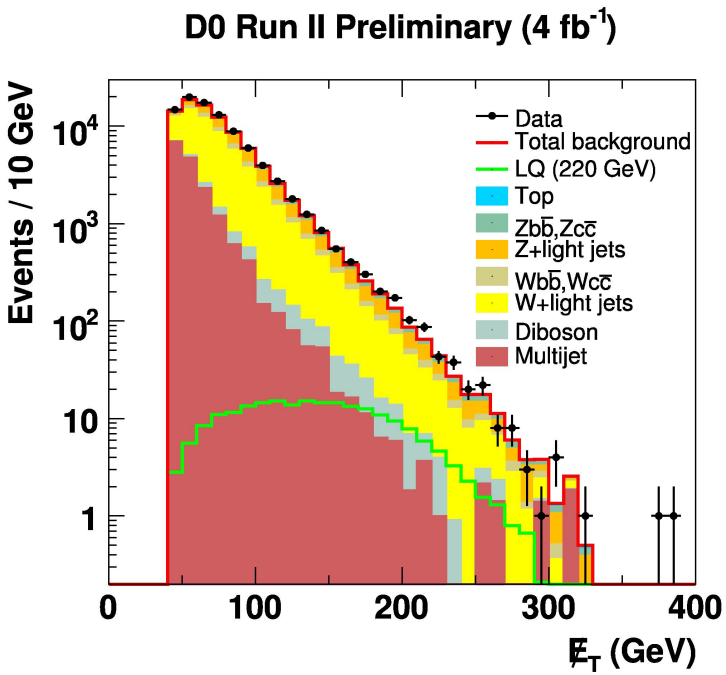


Sbottom direct production (I)

Constraining of the inclusive search for squarks (previous talk)
$\Rightarrow$ looking for b-jets only

- Direct sbottom production means:
  2 b-jets + Missing E_T from the LSP





The b-tagging is the main tool to enhance the sensitivity
(events containing sbottom quarks)

Sbottom direct production (II)

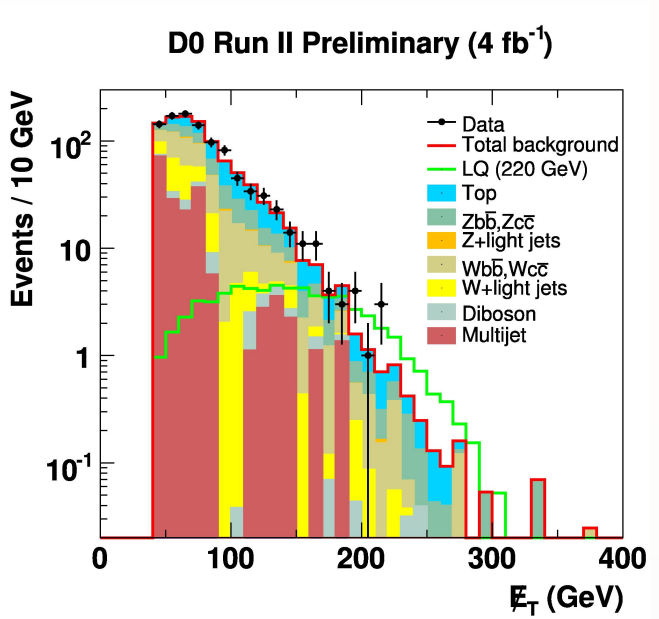
Main background before optimization: QCD-Multijet from data

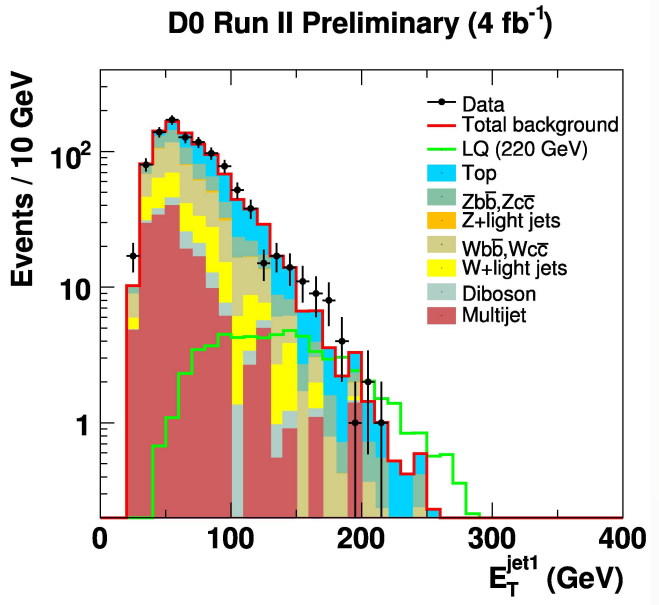
Optimization based on cuts in kinematic variables:

- Missing E_T
- Lead jet E_T
- H_T

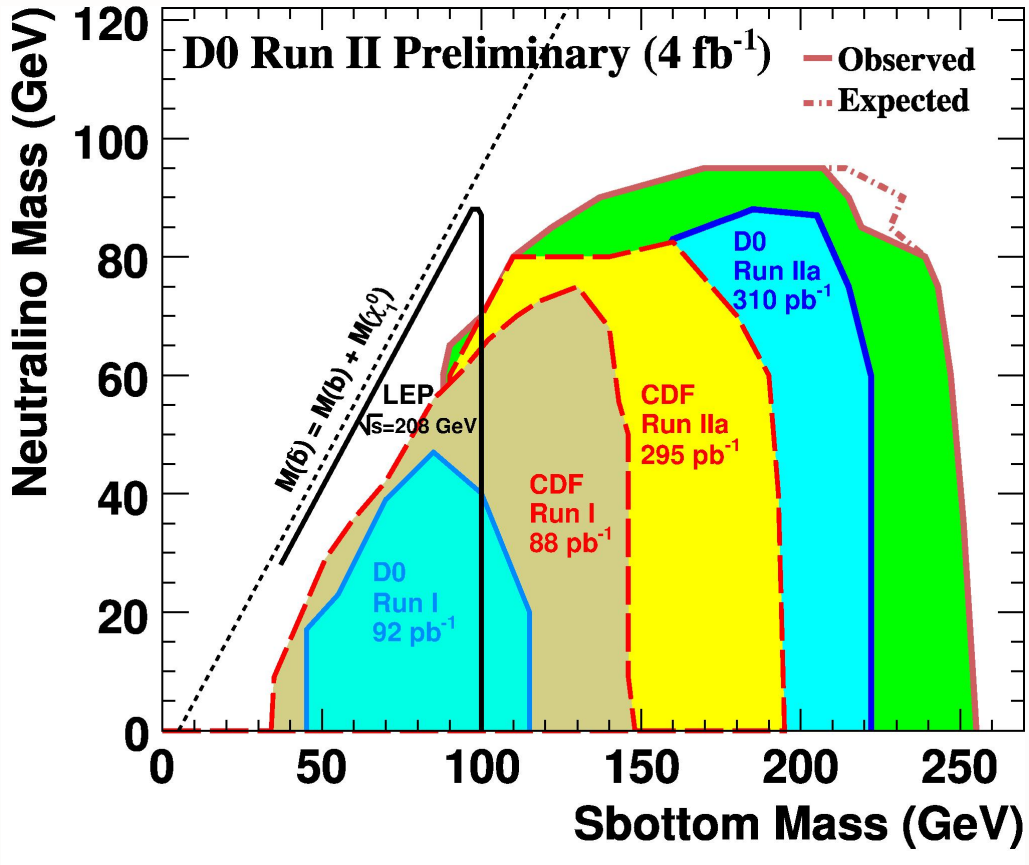
Two different optimization depending on the mass difference m($\tilde{b}$)-m($\tilde{\chi}^0$)

Good agreement with the SM expectation





Sbottom direct production (III)



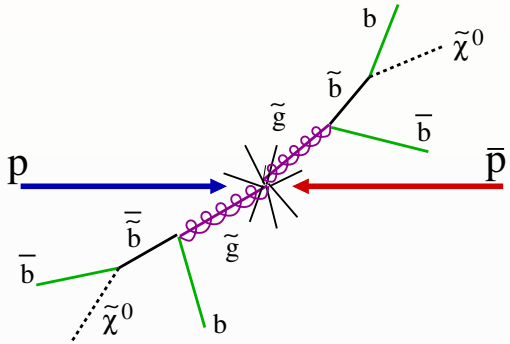
95% C.L. limit on m($\tilde{b}$)-m($\tilde{g}$) plane

New analysis coming soon at CDF!!

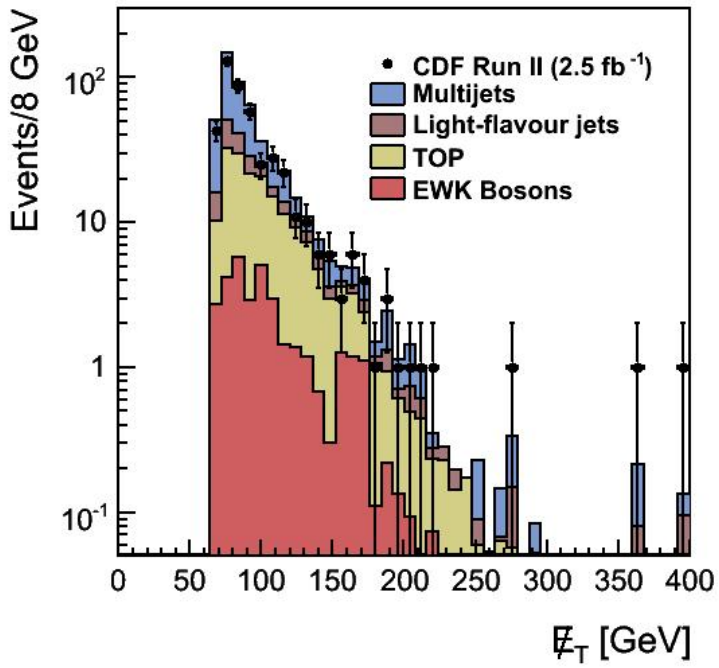
Sbottom from gluino decay (I)

If sbottoms are light enough, they will be produced via gluino decay

For similar masses, gluino cross section is much larger than the sbottom cross section



- Very clean signature (4-bjets + Missing E_T)
- Complementary to the previous search
- QCD-Multijet background estimated from data as tag-rate



Sbottom from gluino decay (II)

Missing E_T > 70 GeV and double b-tagging required in all events

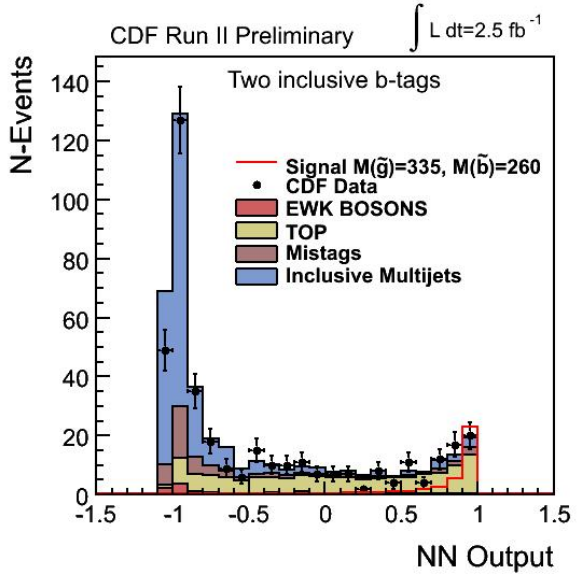
Optimization Process:

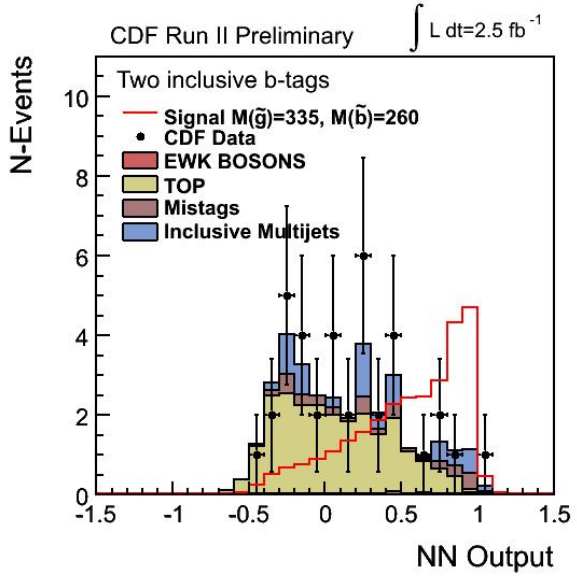
1st NN to remove the QCD-Multijet background
2nd NN to remove the top-pair background

Optimization Regions:

Large Δ**m** $\Rightarrow$ m($\tilde{g}$) = 335, m($\tilde{b}$) = 260
Small Δ**m** $\Rightarrow$ m($\tilde{g}$) = 335, m($\tilde{b}$) = 315

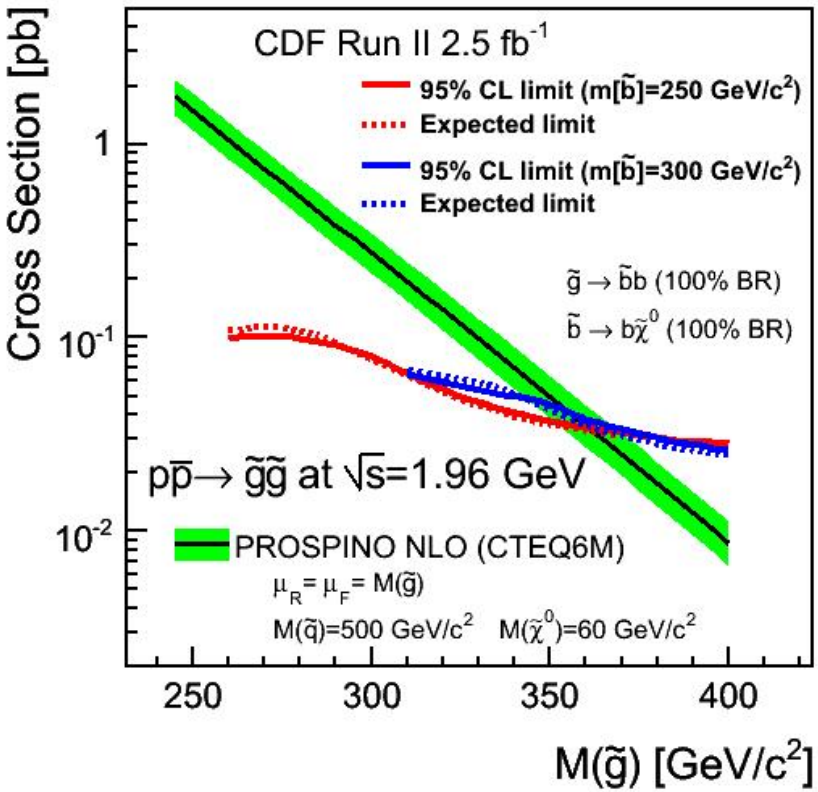
Good agreement with SM prediction in a high Missing E_T environment

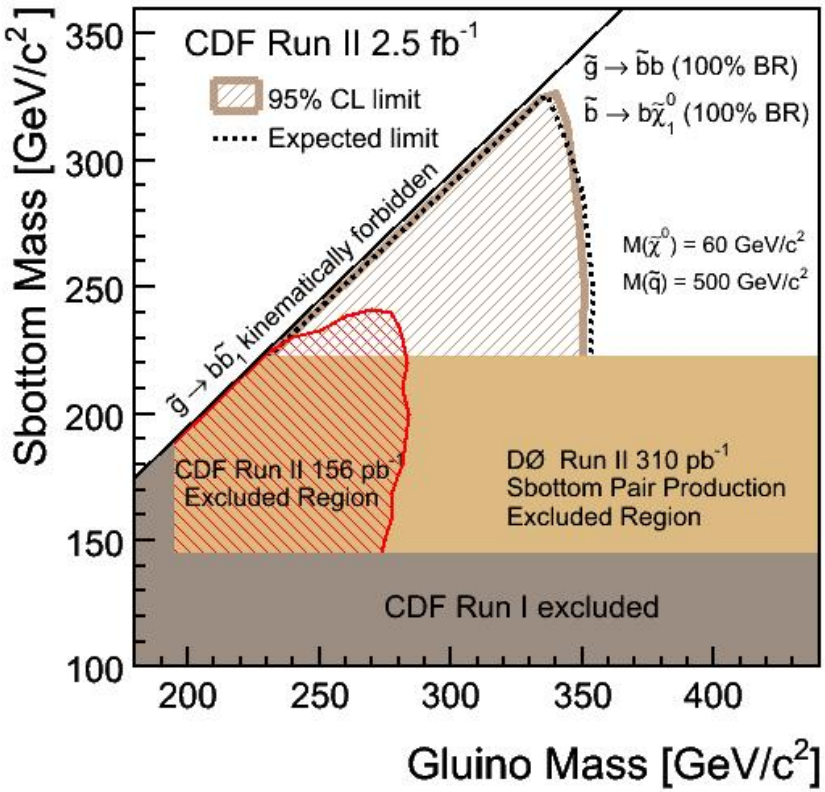




Sbottom from gluino decay (III)

95% C.L. limits on Cross Section and m($\tilde{b}$)-m($\tilde{g}$) plane



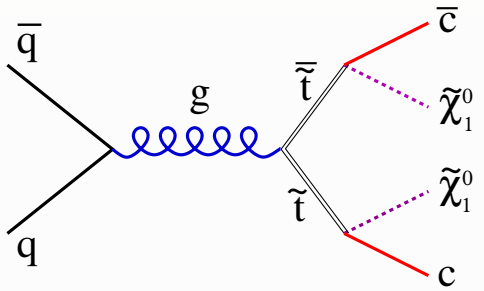


Phys. Rev. Lett 102, 221801 (2009)

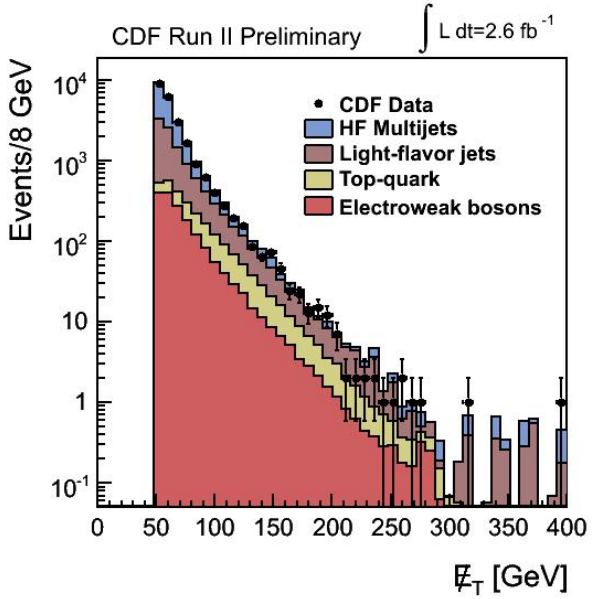
Stop decaying into charm and neutralino (I)

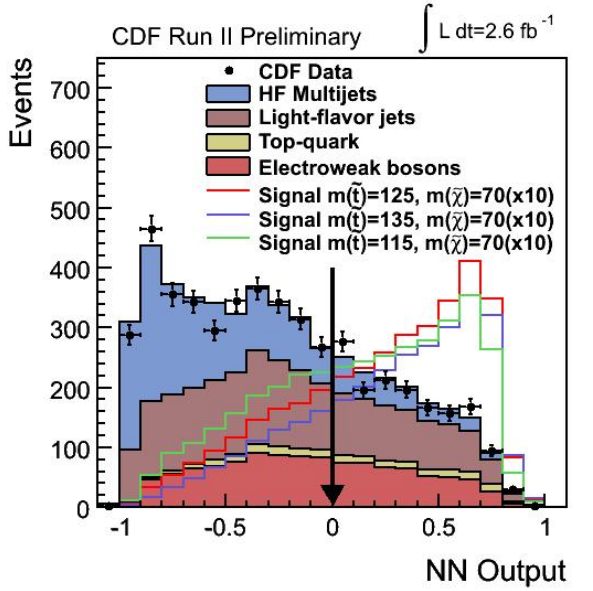
When the stop is the next-to-lightest SUSY particle, the main decay channel is to charm and neutralino

- Final state: 2 c-jets + Missing E_T



- QCD-Multijet background estimated from data as a tag-rate
- NN against QCD-Multijet, the main background





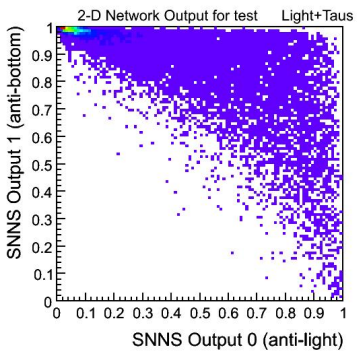
Stop decaying into charm and neutralino (II)

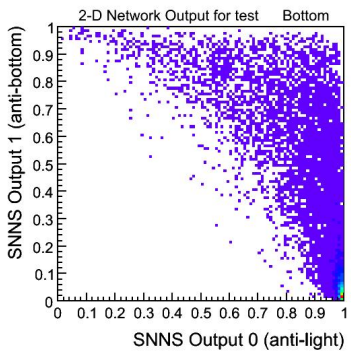
Challenging from the experimental point of view due to charm tagging

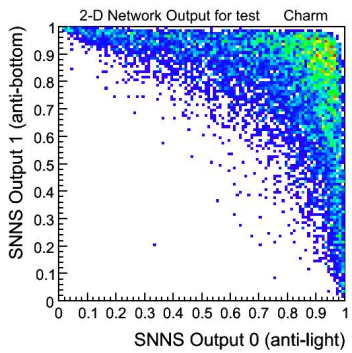
A dedicated flavour separator for this analysis:

Charm **H**adron **A**nalysis-**O**riented **S**eparator (**CHAOS**)

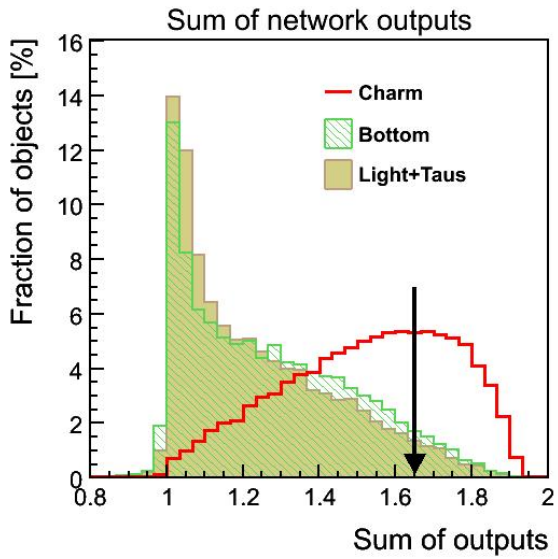
CHAOS is a NN with a two dimensional output optimized to enhance the sample with c jets

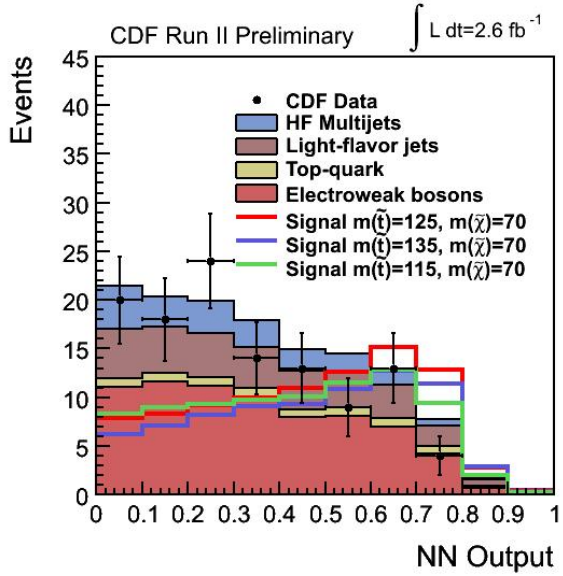






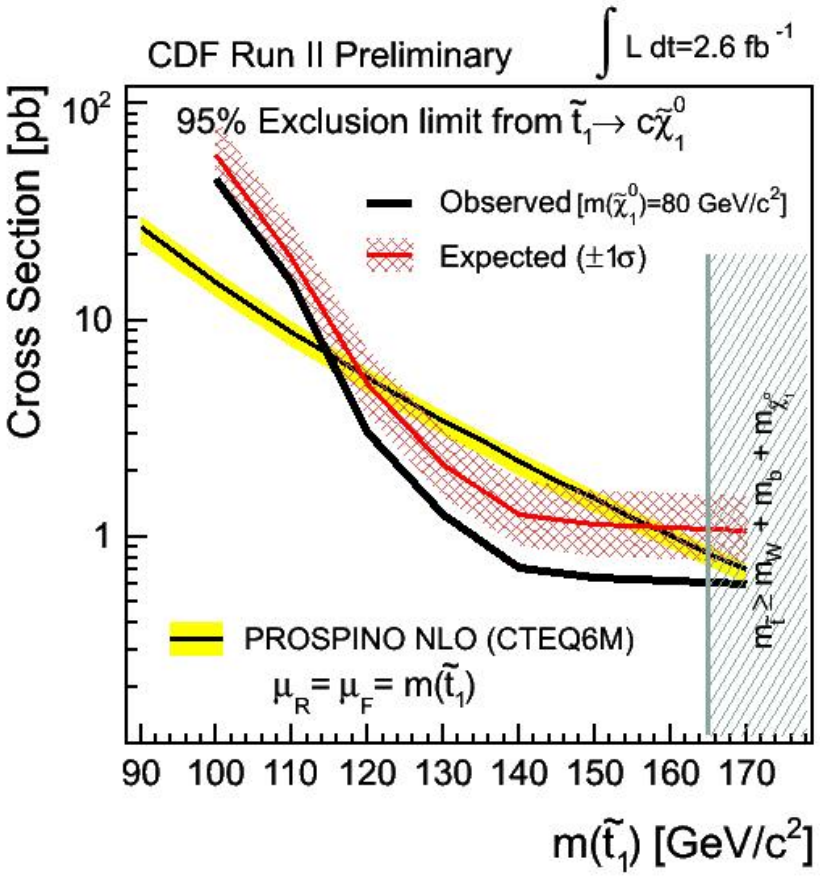
Good agreement with the SM in the final discriminant

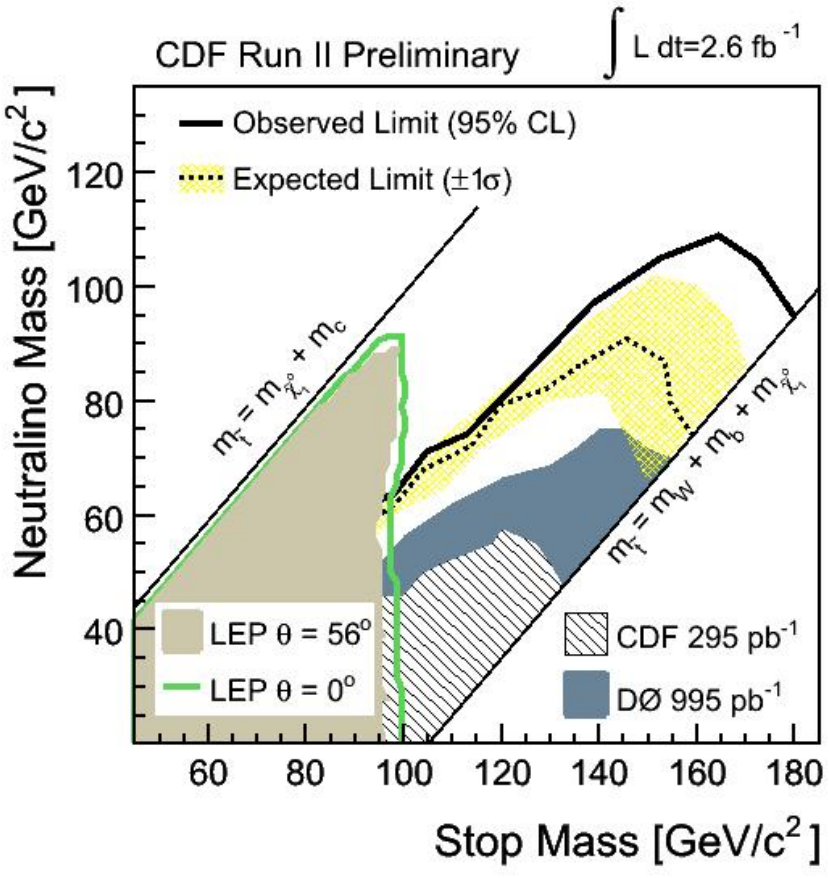




Stop decaying into charm and neutralino (III)

95% C.L. limits on Cross Section and m($\tilde{\chi}^0$)-m($\tilde{t}$) plane

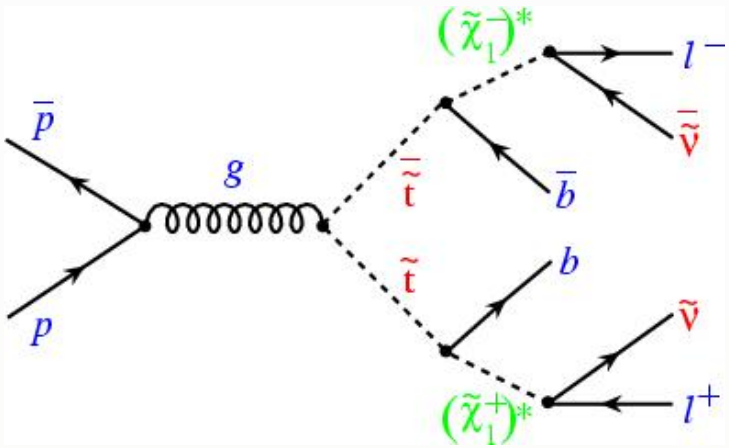


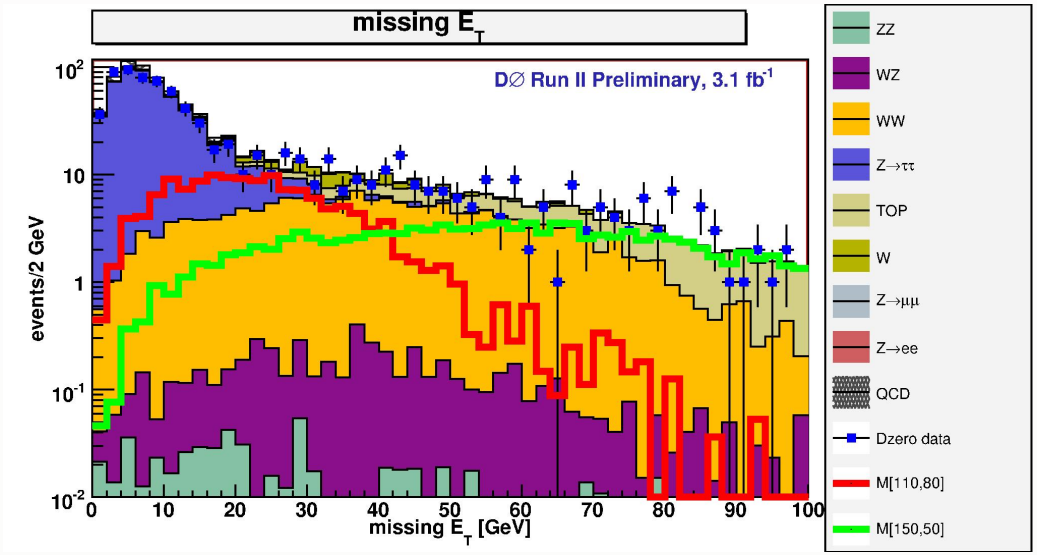


Stop in dilepton signature (I)

If the $\tilde{t}$ is light and the $\tilde{\nu}$ is also light, the dominant decay channel contains charged leptons

- Signature similar to the $t\bar{t}$ production in the dilepton channel
- Softer leptons in the final state
- Kinematics also different because of the large mass of the $\tilde{\nu}$





- The $e\mu$ channel is the most sensitive one

Stop in dilepton signature (II)

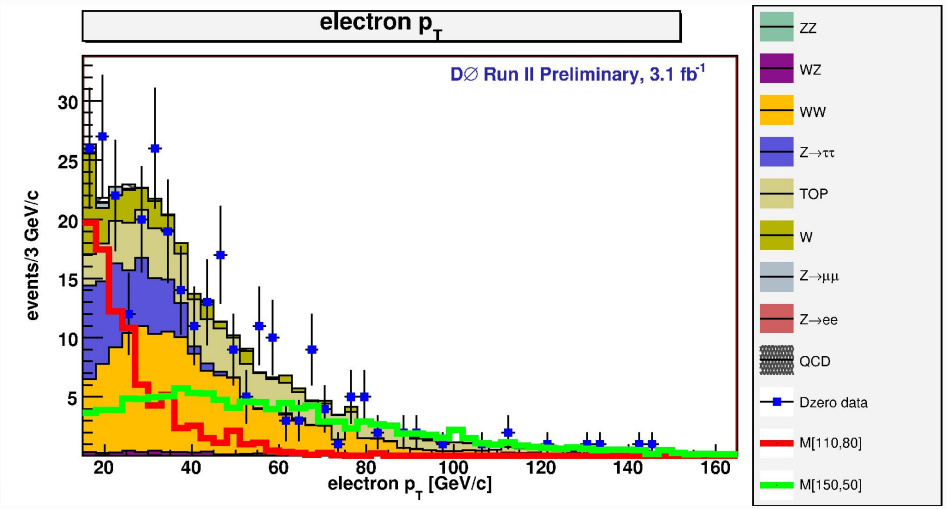
Main backgrounds:

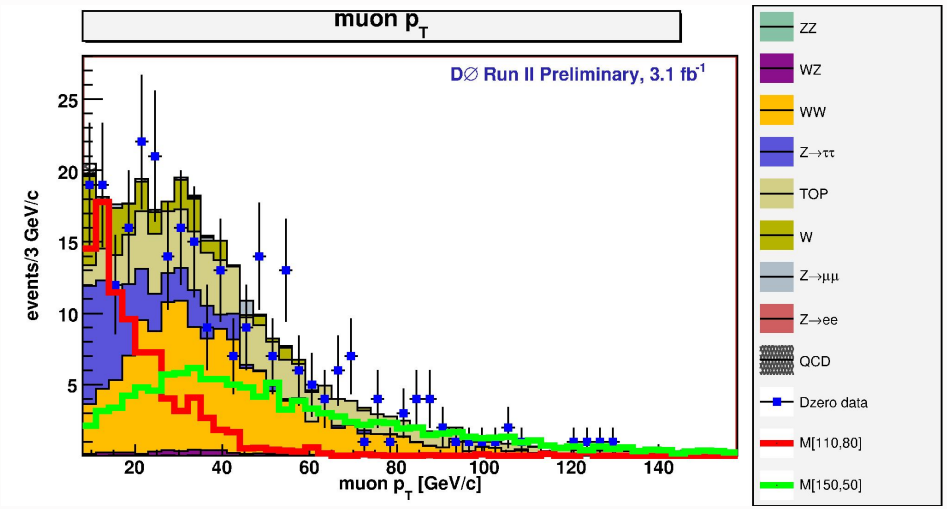
- QCD multijets
- $Z \rightarrow \tau\tau$

Optimization via:

- Missing E_T cut > 18 GeV
- Angular cuts: leptons (e and μ) not aligned with Missing E_T

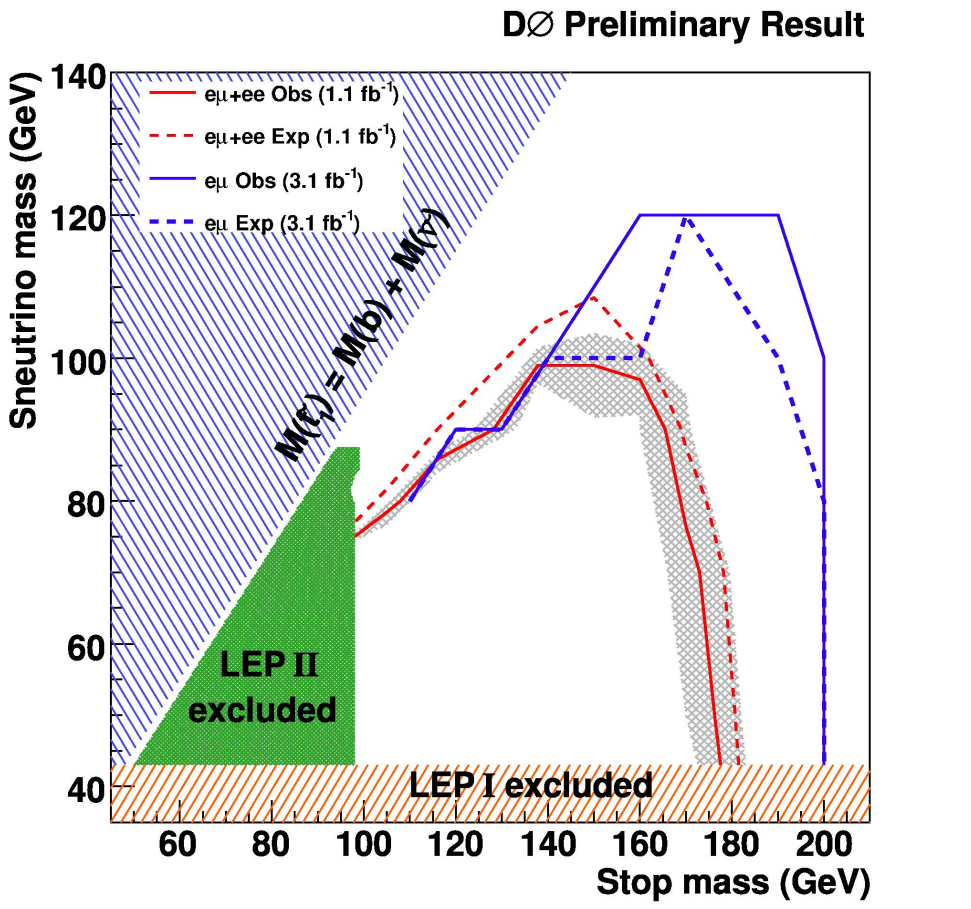
Remaining backgrounds: WW and $t\bar{t}$

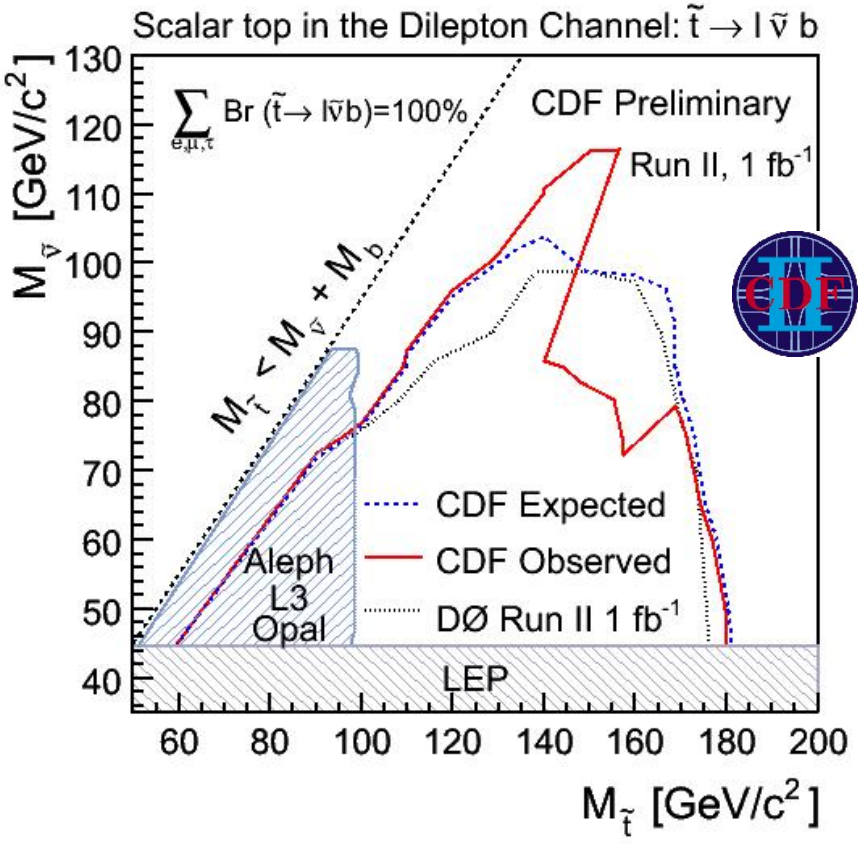




Stop in dilepton signature (III)

95% C.L. limit on m($\tilde{\nu}$)-m($\tilde{t}$) plane





Also new CDF result with 1 fb^{-1}

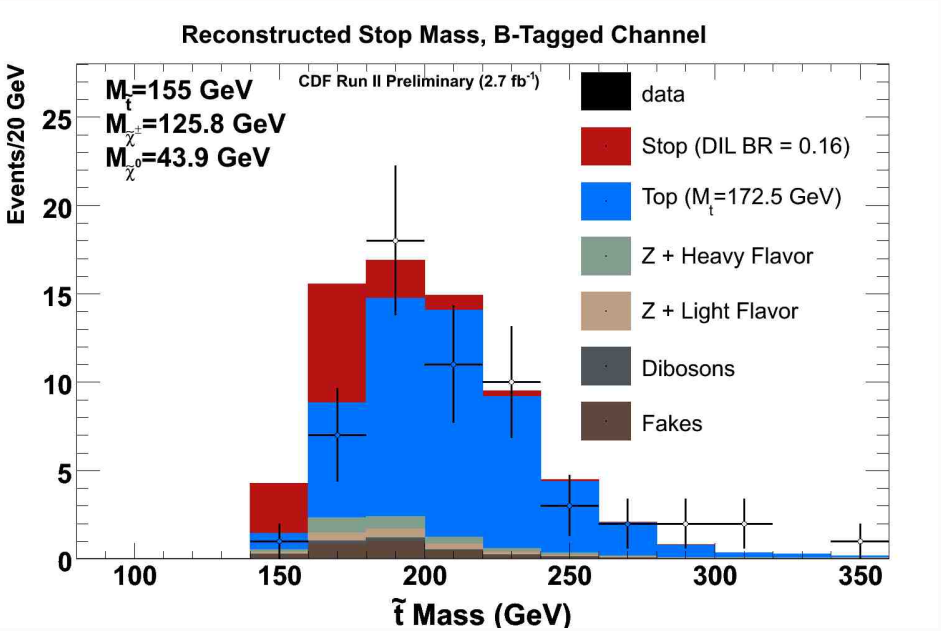
Stop in top-like events (I)

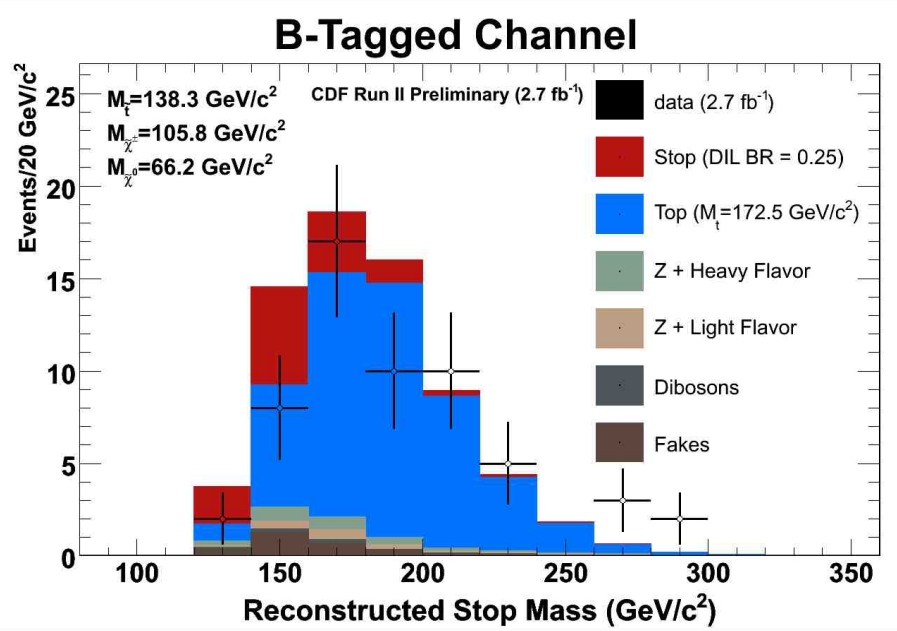
If the $\tilde{t}$ is the lightest squark and is more massive than the lightest $\tilde{\chi}^+$:

$$\tilde{t} \rightarrow b\tilde{\chi}^+ \rightarrow bl\nu\tilde{\chi}^0$$

Final state: 2 b-jets, Missing E_T and 2 opposite-sign leptons

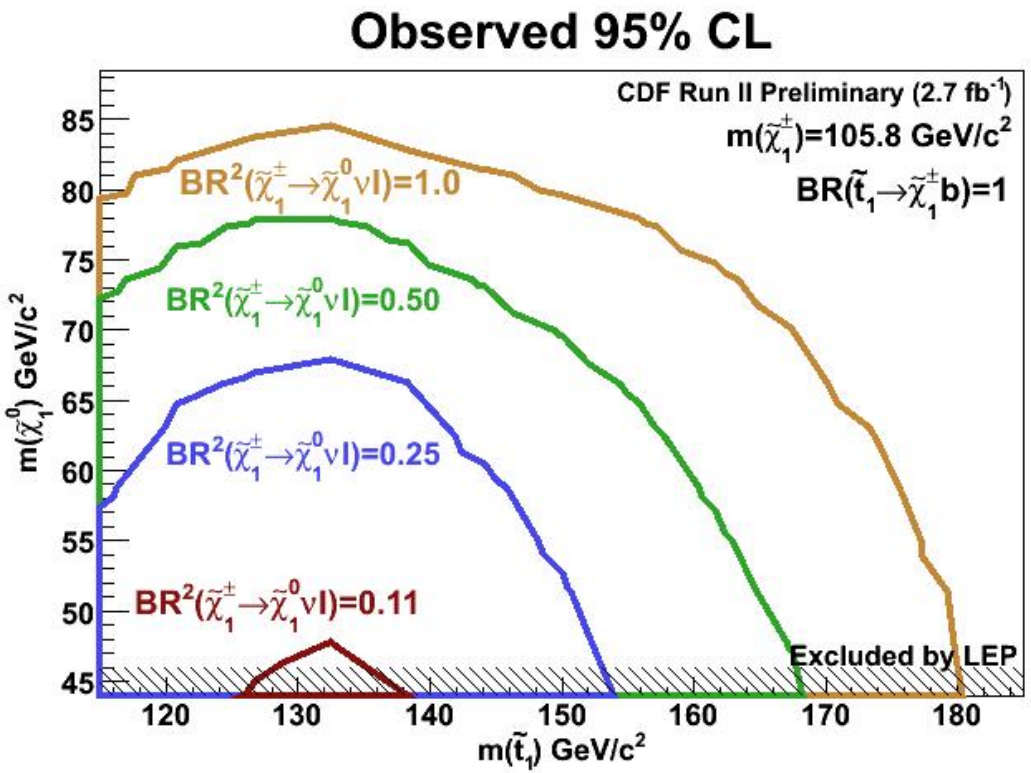
- Decay very similar to the top quark $\Rightarrow$ main background top production
- Good agreement with the SM predictions (mainly $t\bar{t}$)



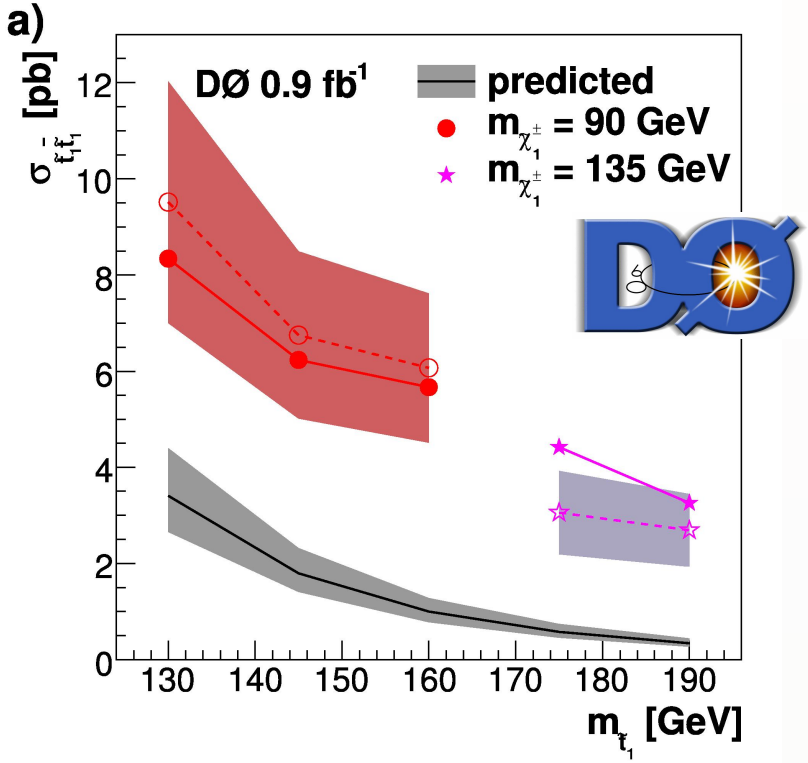


Stop in top-like events (II)

95% C.L. limits on Cross Section and m($\tilde{\chi}^0$)-m($\tilde{t}$) plane



Lepton + jets final state



D0 limit in cross section $\Rightarrow$ **Phys. Lett. B 674, 4 (2009)**

Summary

- Tevatron and experiments are performing really well
  - ~ 7 fb^{-1} delivered
  - ~ 6 fb^{-1} recorded
- No evidence of third generation squarks
  in more than 4 fb^{-1} of data
- The SUSY search program is continuously producing new results
  (and improving limits)
- New tools under development to increase sensitivity

Tevatron is already where nobody has been before
and we will stay there for a while !!!

More information:
http://www-cdf.fnal.gov/physics/exotic/exotic.html
http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm