Search for Supersymmetry at the Tevatron

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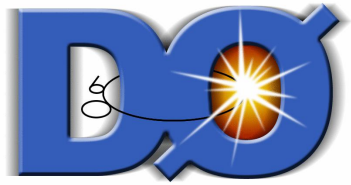
for the CDF and DØ Collaborations

CIEMAT

Les Rencontres de Physique de la Vallée d'Aoste
1-7 March, 2009



Outline

Tevatron

Proton-antiproton collisions at 1.96 TeV center of mass energy.
Tevatron is providing the highest collision energy at least until Fall 2009

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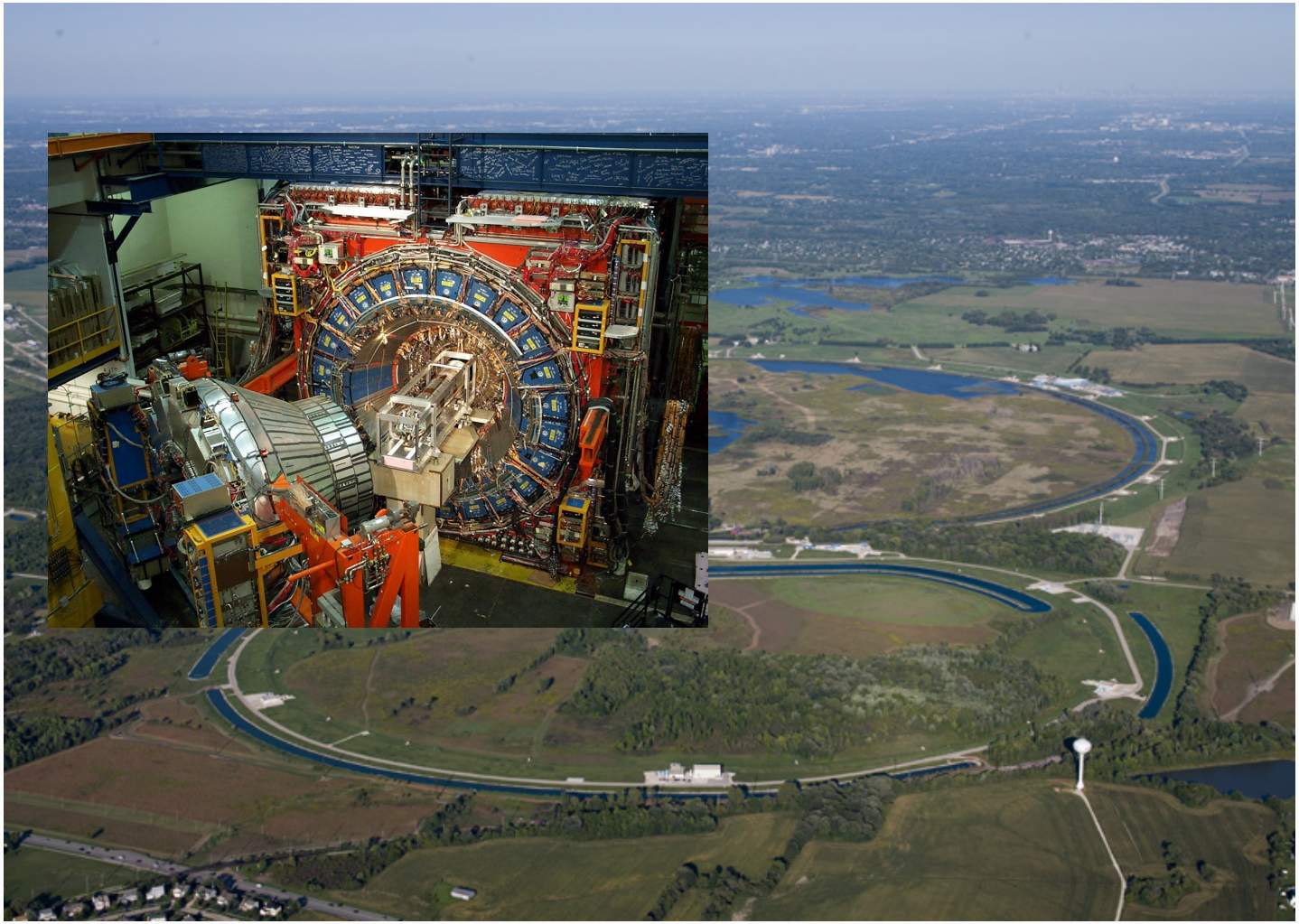

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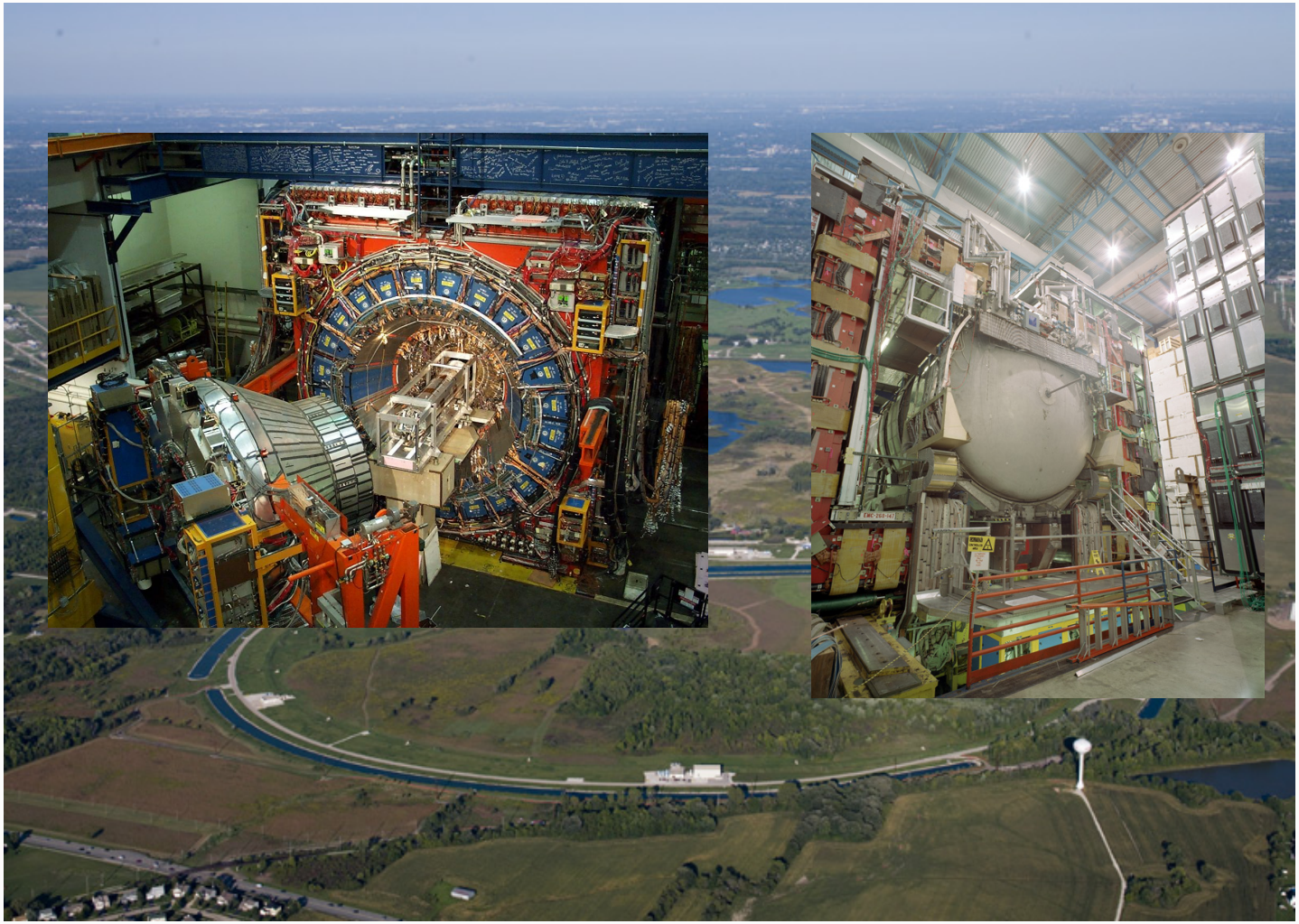
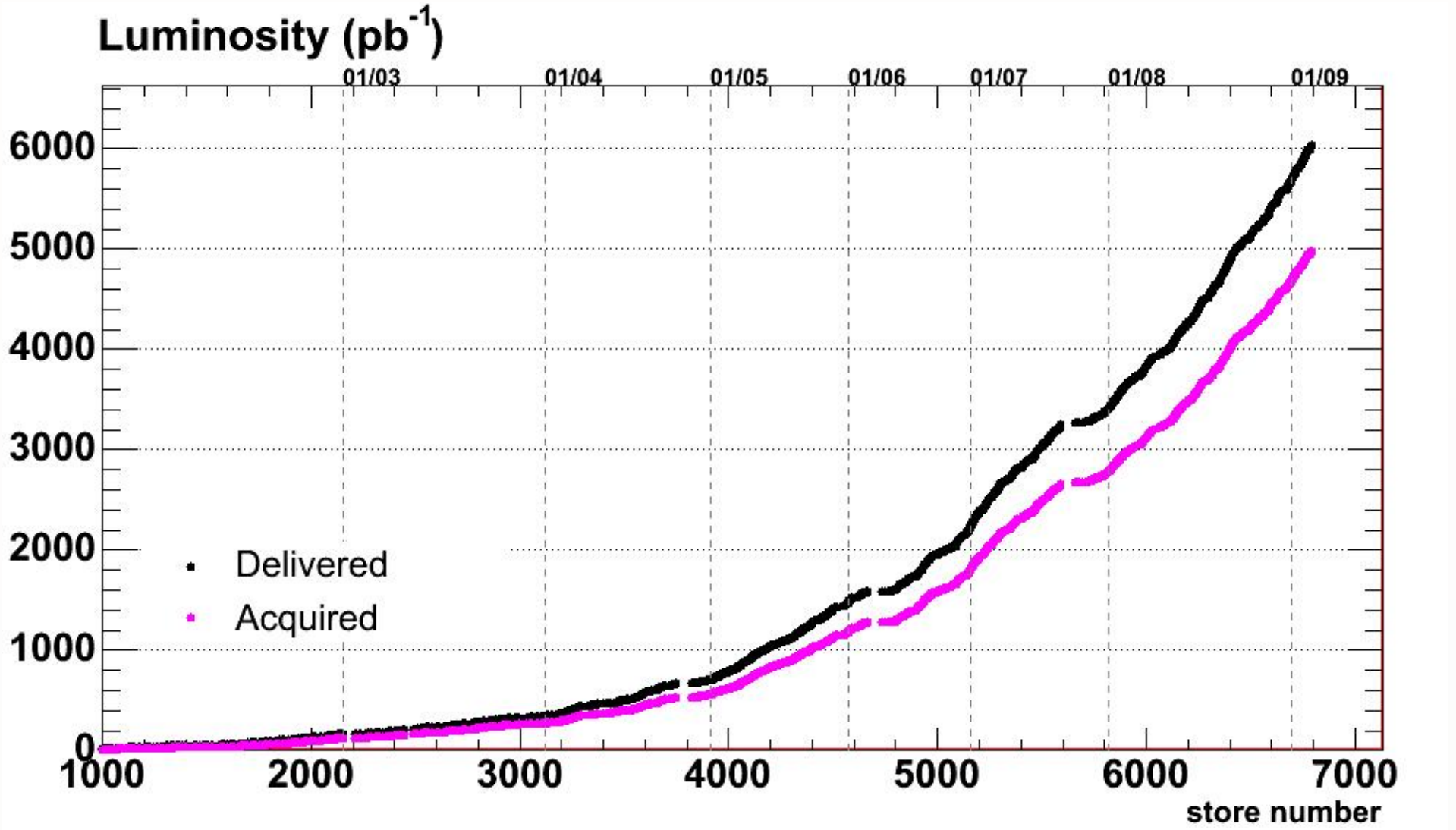


Luminosity



CDF luminosity

SUSY

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

New spin-based symmetry relating fermions and bosons:

$Q|Fermion>=|Boson>$

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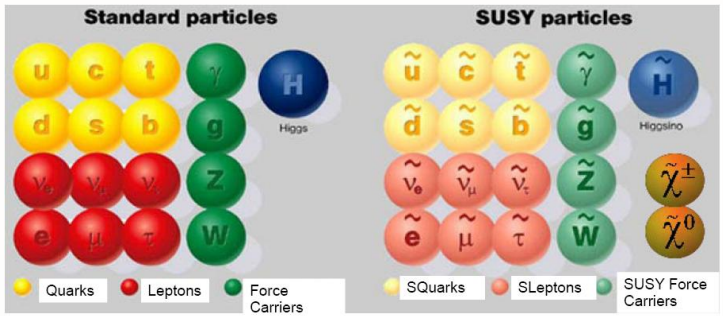
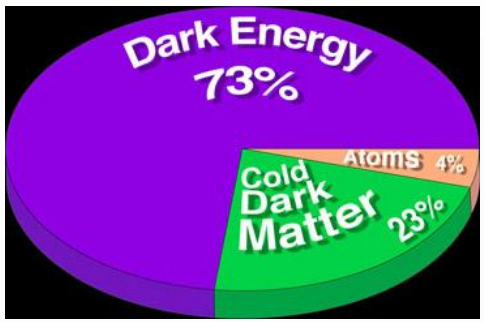


- Minimal SuperSymmetric Model (MSSM)
  - Mirror spectrum of particles



R-parity

$R_P = (-1)^{2S+3B+L}$

1 for SM particles, -1 for super-partners

Under R-parity conservation $\Rightarrow$

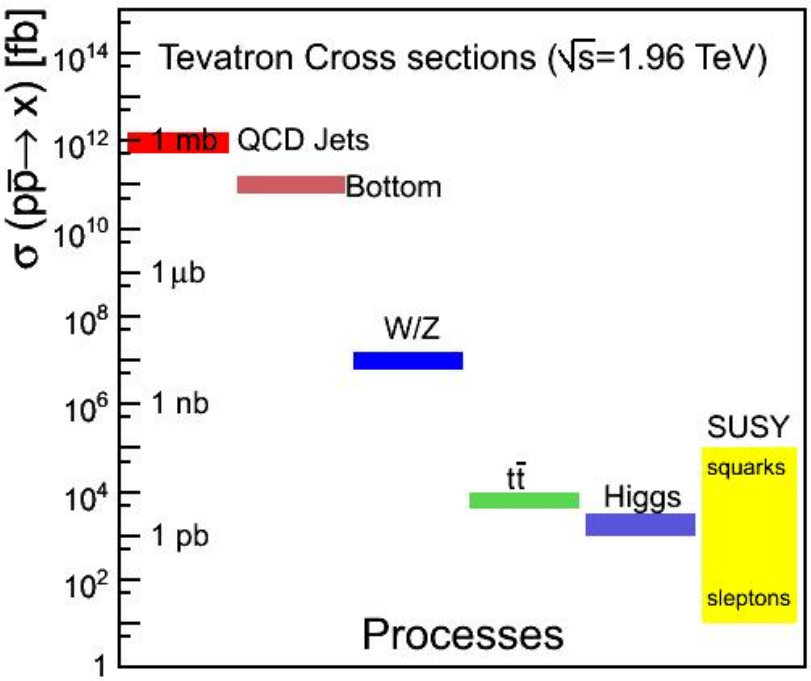
- Dark Matter candidate (LSP)
- The SUSY particles are produced in pairs

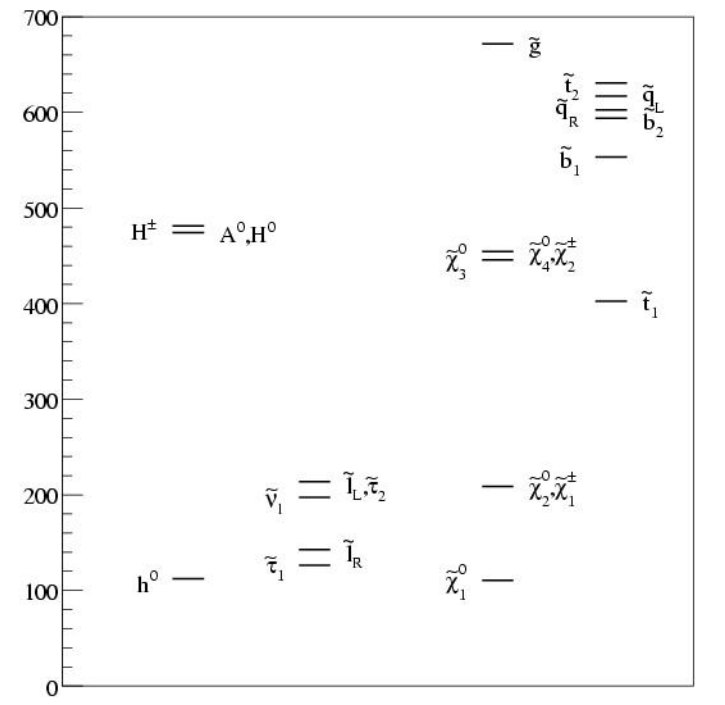
SUSY II

SUSY can be produced at the Tevatron in very different ways and is one of the most active and richest parts of the program

SUSY must be broken

Usually mSUGRA or Constrained MSSM used as benchmark

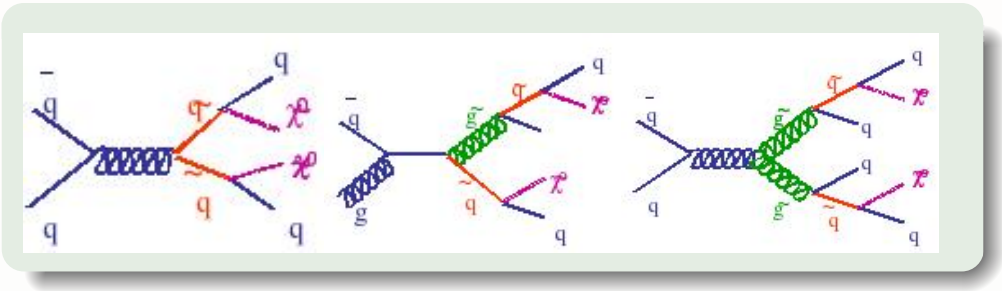




arXiv:0707.3447 O. Buchmueller et al.

Inclusive search for squark/gluino

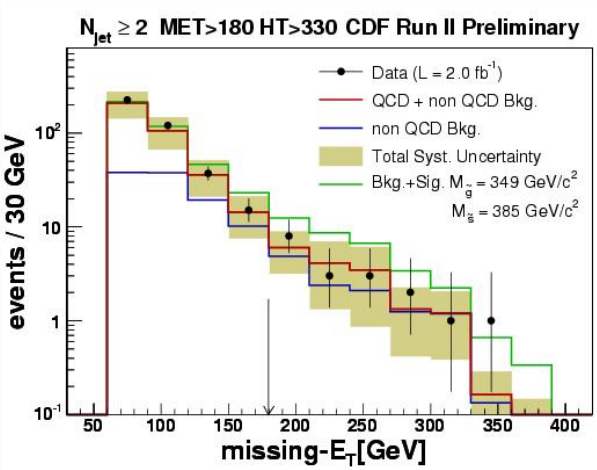
Final state: Jets + Missing E_T $\Rightarrow$ 3 different analysis depending on the jet multiplicity. One of the Golden Channels at Tevatron

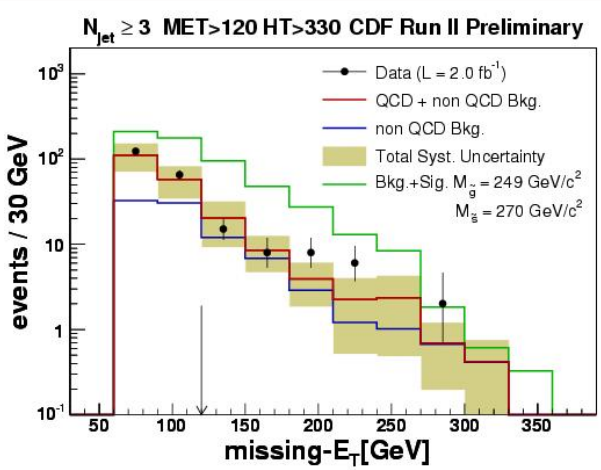


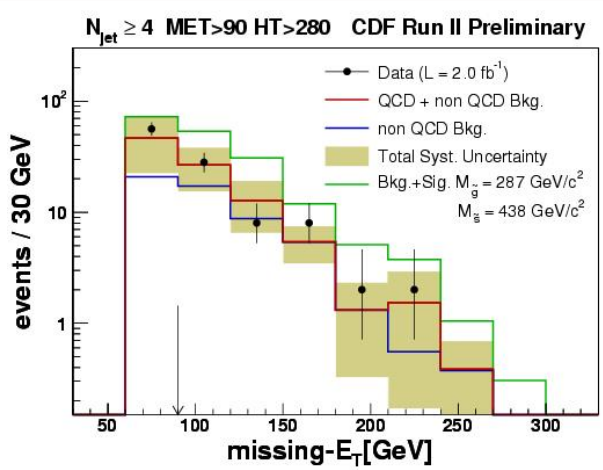
Key variables to define the final selection are:

- Missing E_T
- $H_T = \sum E_{T,jets}$

The $\tilde{\chi}^0$ is assumed to be stable (R_p conserved) and escapes detection

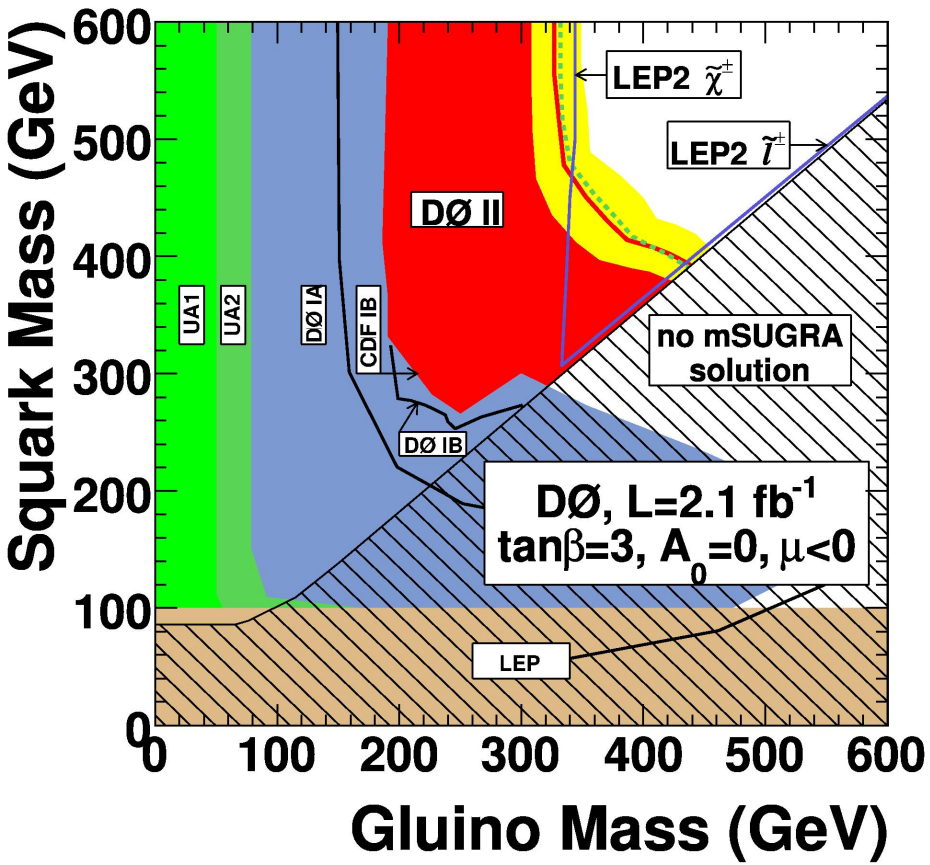


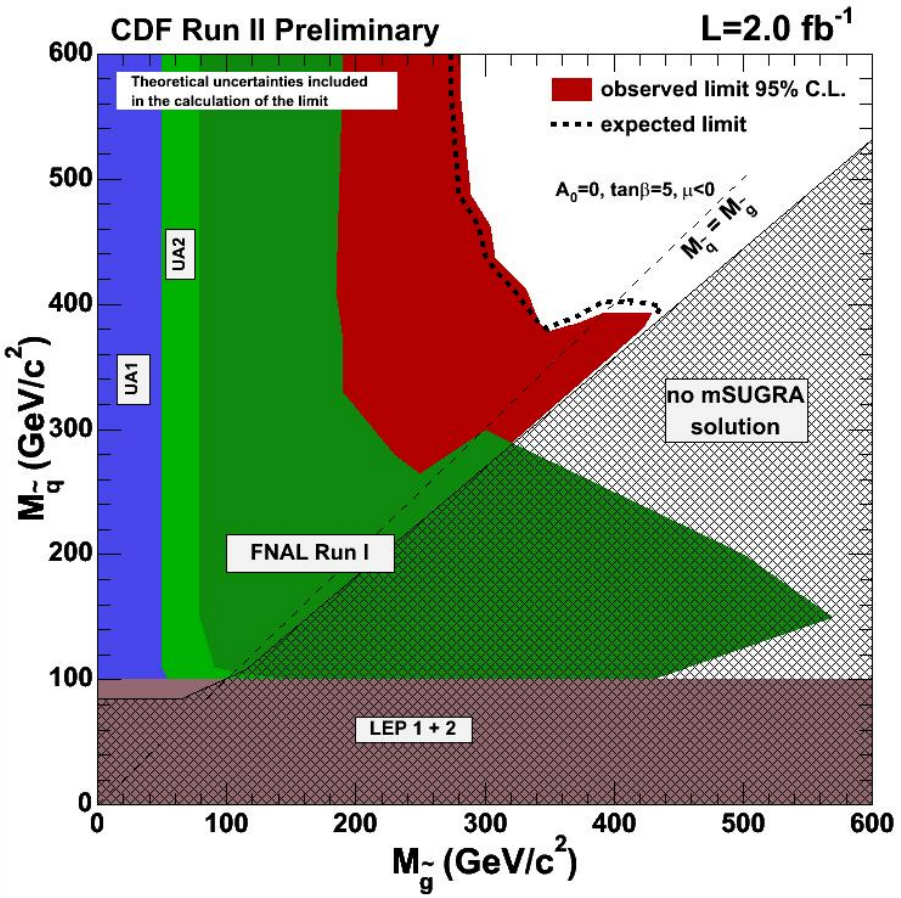




Inclusive search for squark/gluino II

95% C.L. Exclusion limit on M($\tilde{q}$)-M($\tilde{g}$) plane



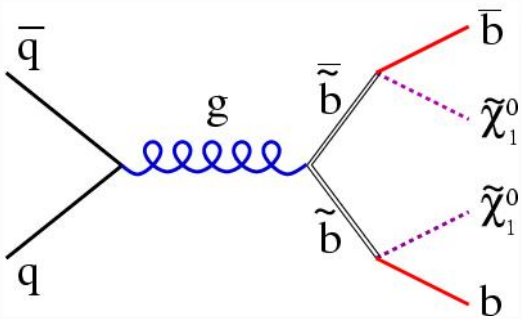


CDF & D0 combination underway with 2 fb^{-1}

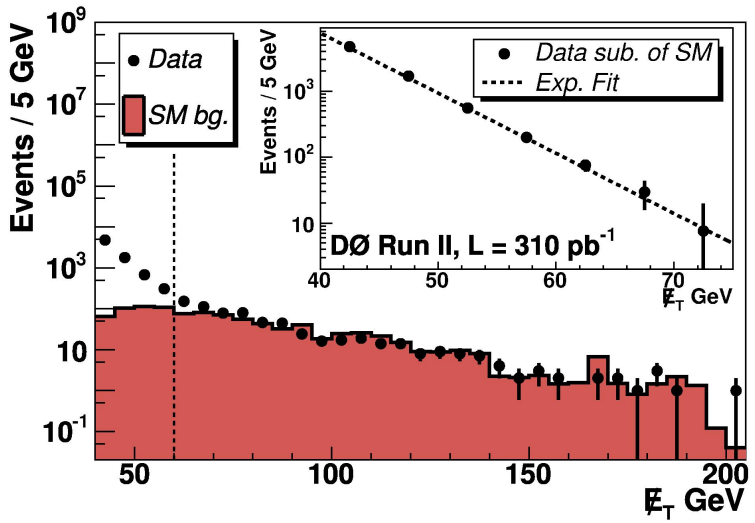
Sbottom direct production

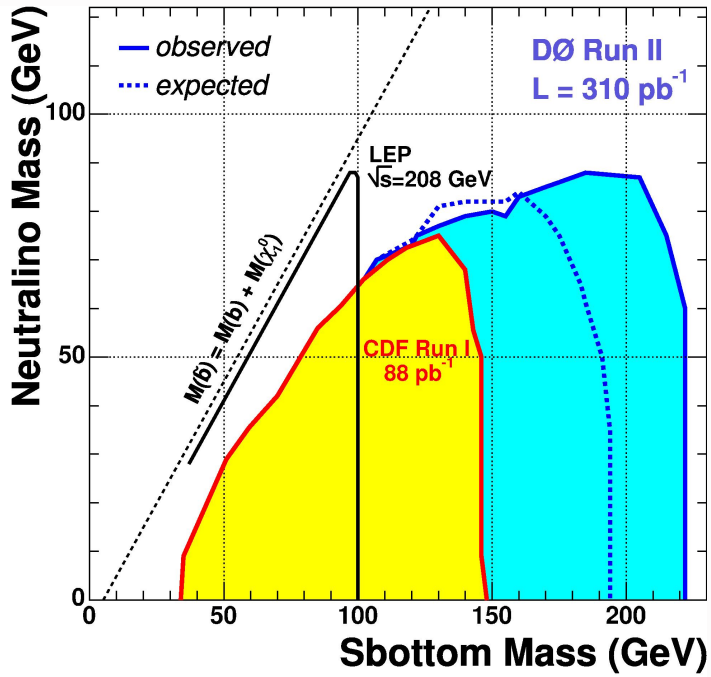
Constraining of the inclusive search for squarks $\Rightarrow$ looking for b-jets only

- 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)



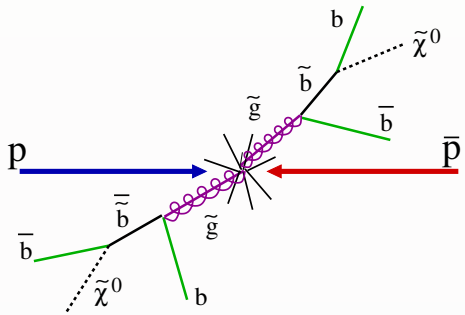


Sbottom from gluino decay

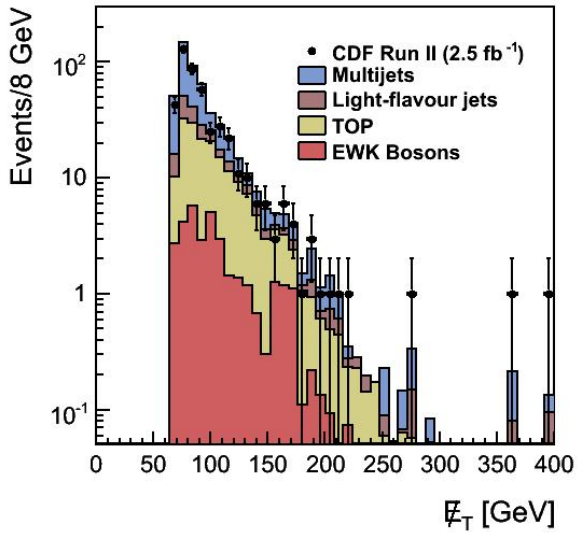
If sbottoms are light enough, they will be produced via gluino decay

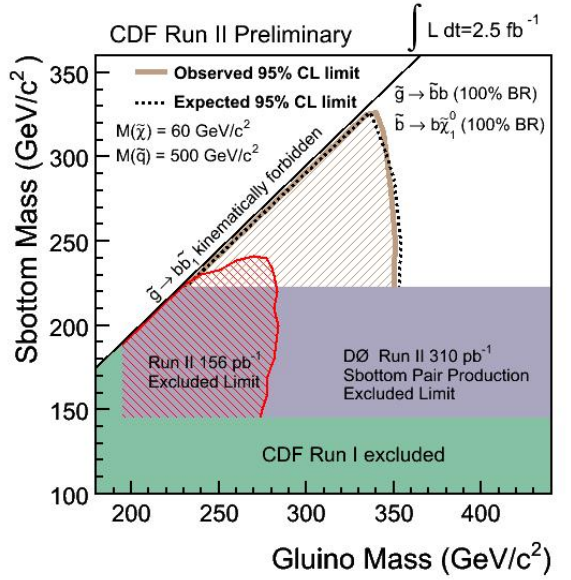
For similar masses, gluino cross section is much larger than the sbotton cross section

- Very clean signature (4-bjets + Missing E_T)



- Complementary to the previous search
- QCD-Multijet background from data
- Good agreement with SM prediction in a very high Missing E_T environment

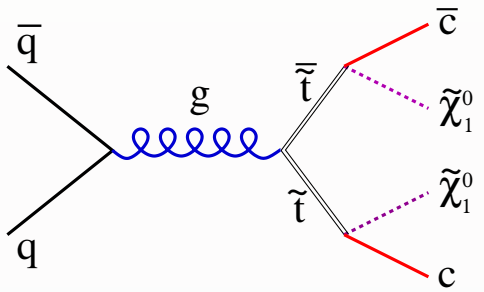




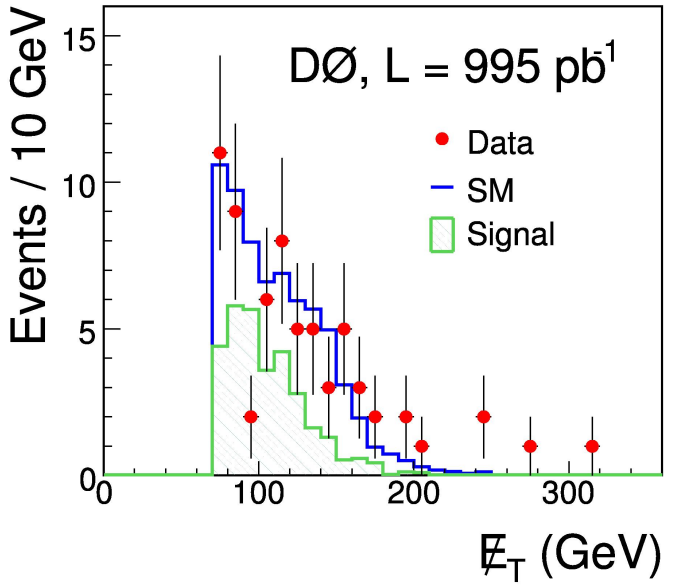
Stop decaying into charm and neutralino

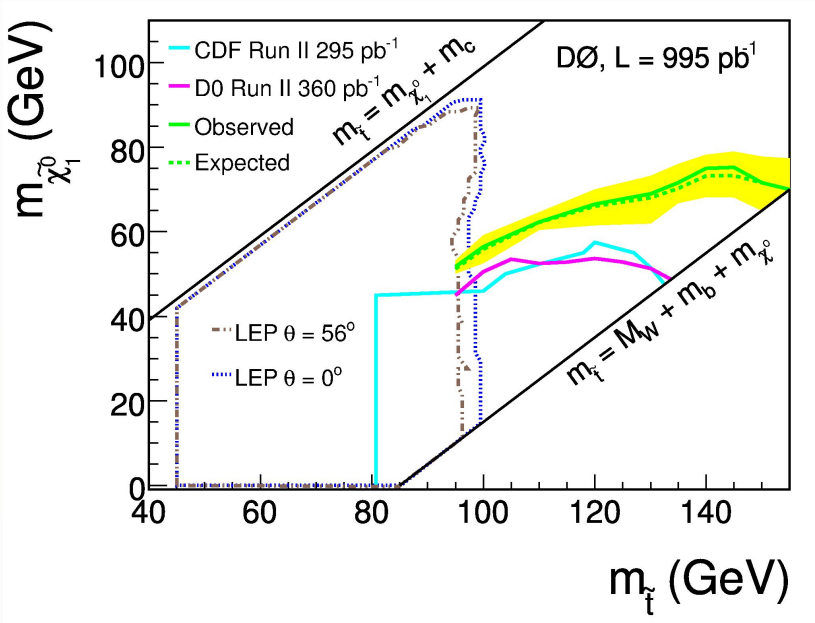
When the stop is the next-to-lightest SUSY particle, the main decay channel is to charm and neutralino

- Final state: 2 c-jets + Missing E_T



- Complicated from the experimental point of view due to charm tagging
- One of the leading channels to find SUSY at Tevatron

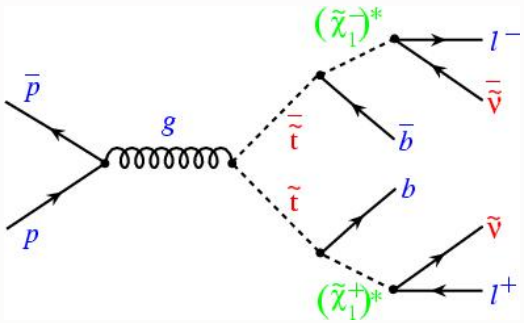




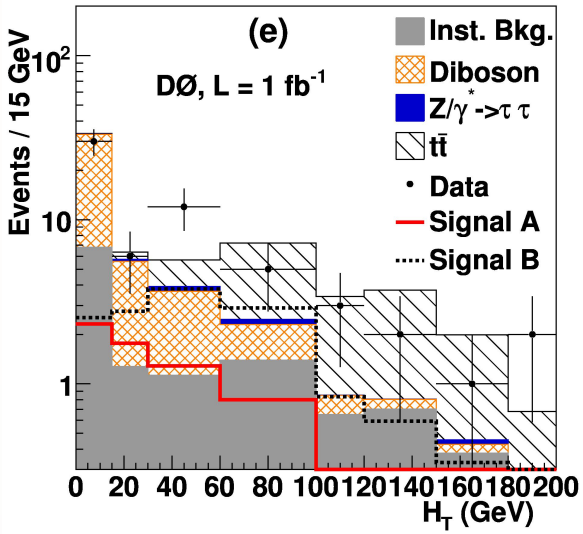
Stop in dilepton signature

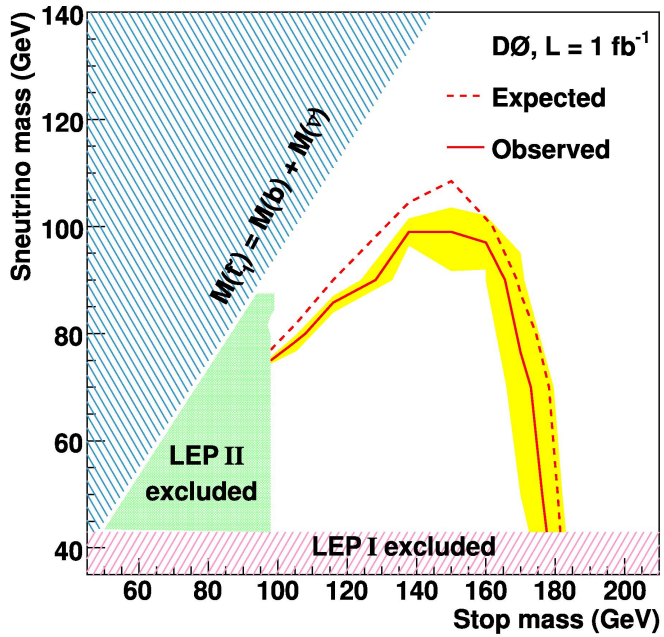
If the $\tilde{t}$ is light and the $\tilde{\nu}$ is also light, the dominant decay channel contains charged leptons

- 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 $\tilde{\nu}$



- Need to combine all the lepton channels
- The $e\mu$ channel is the most sensitive one





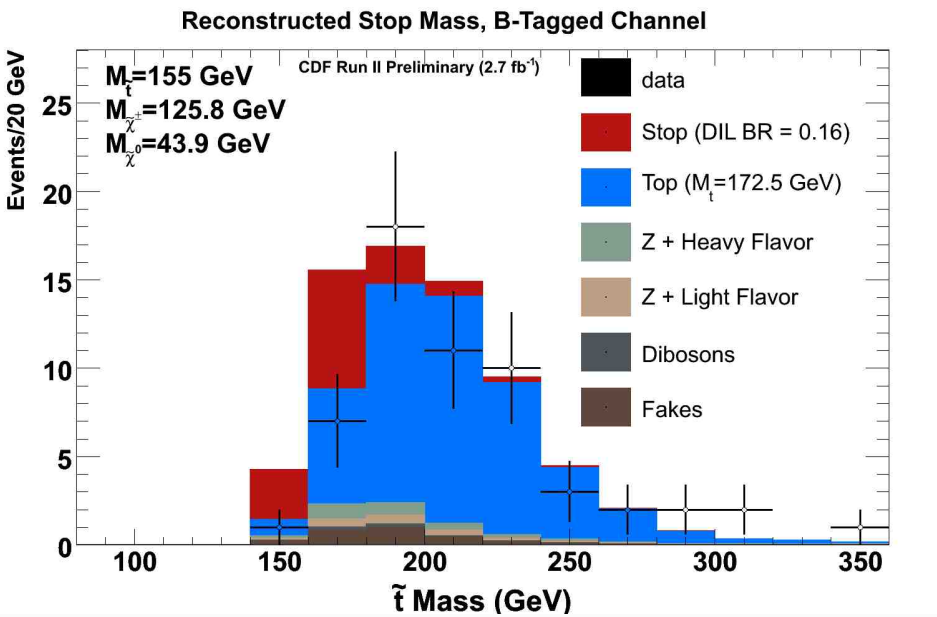
Stop in top-like events

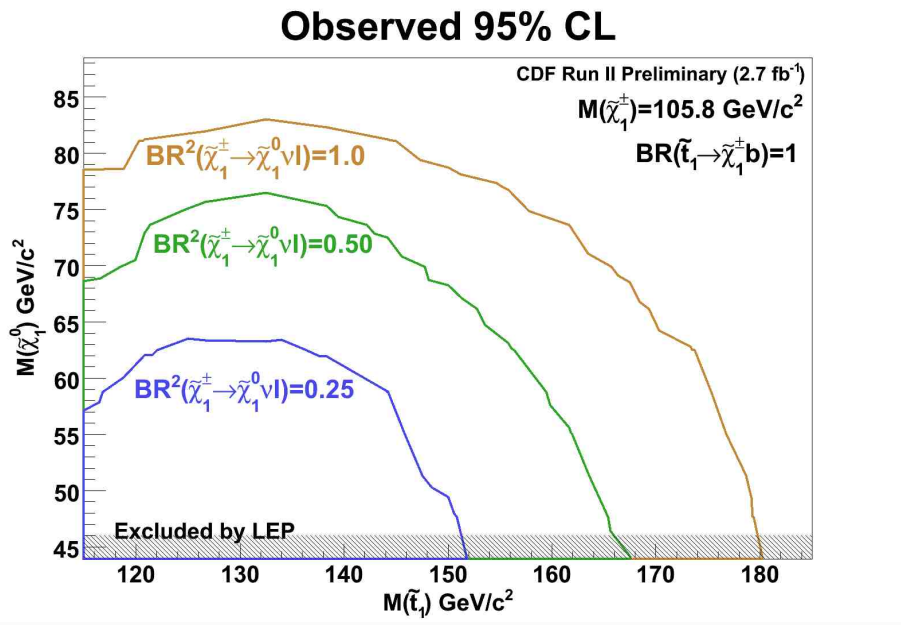
If the $\tilde{t}$ is the lightest squark and is more massive than the lightest $\tilde{\chi}^+$:

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

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 $t\bar{t}$)





$\tilde{\chi}^{\pm} + \tilde{\chi}^{0}$ search in the trilepton final state

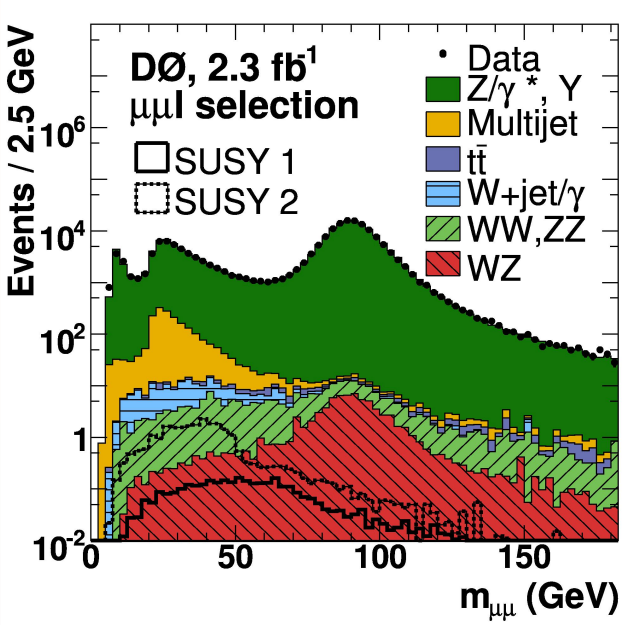
One of the Golden Channels at Tevatron

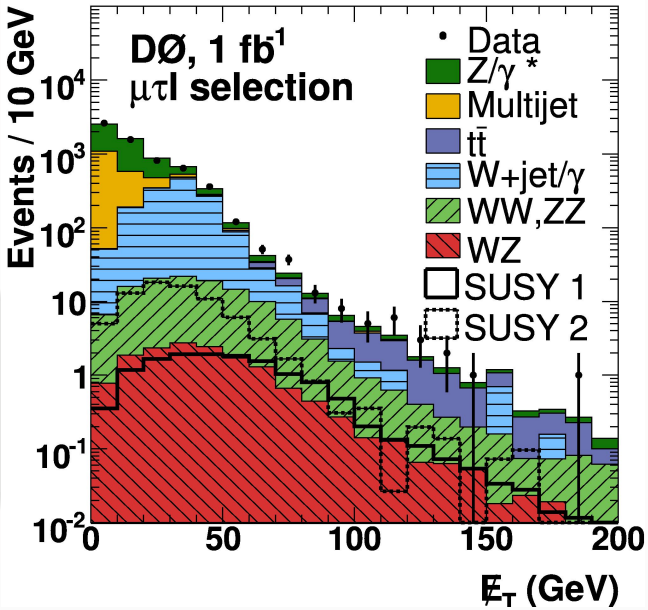
Final state: 3 lepton + Missing E_T, very clean signature at hadron colliders.

Backgrounds from Jets faking leptons and also Drell-Yan and EWK bosons production

Sensitivity depends on branching ratio for the $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^{\pm}$ into leptons

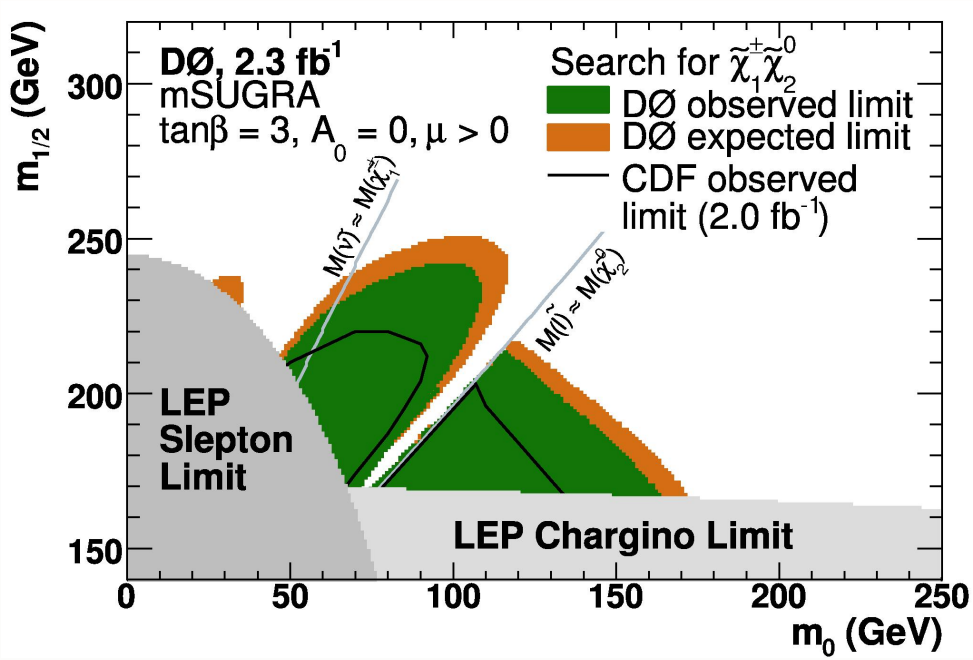
5 separate final states combined:
ee lepton, $\mu\mu$ lepton, $e\mu$ lepton,
$\mu\tau$ lepton and $\mu\tau\tau$

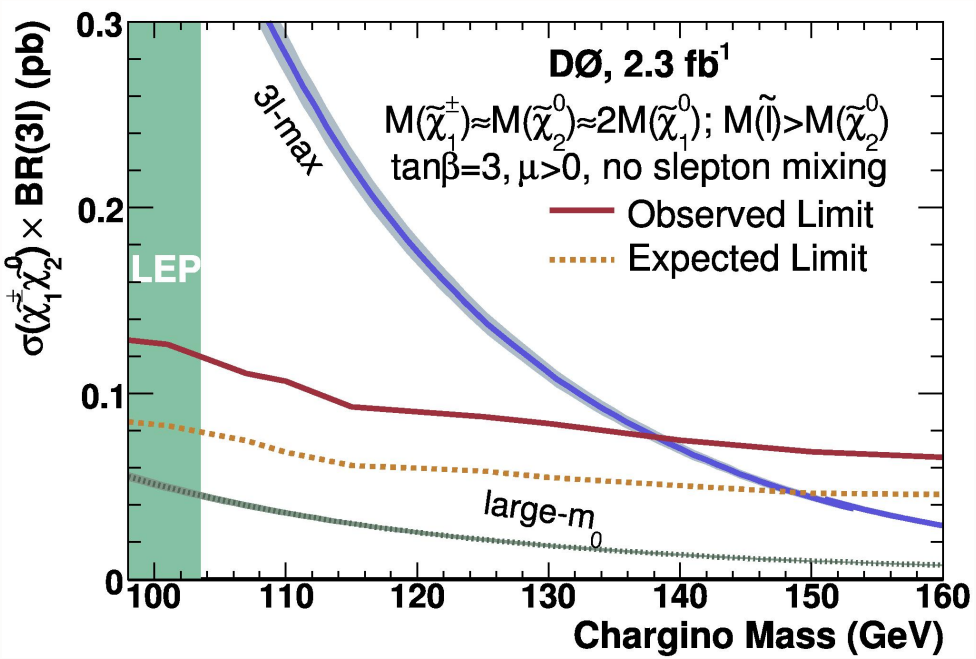




$\tilde{\chi}^{\pm} + \tilde{\chi}^{0}$ search in the trilepton final state

95% C.L. Exclusion limit on $m_{1/2}$-m_0 plane and cross section





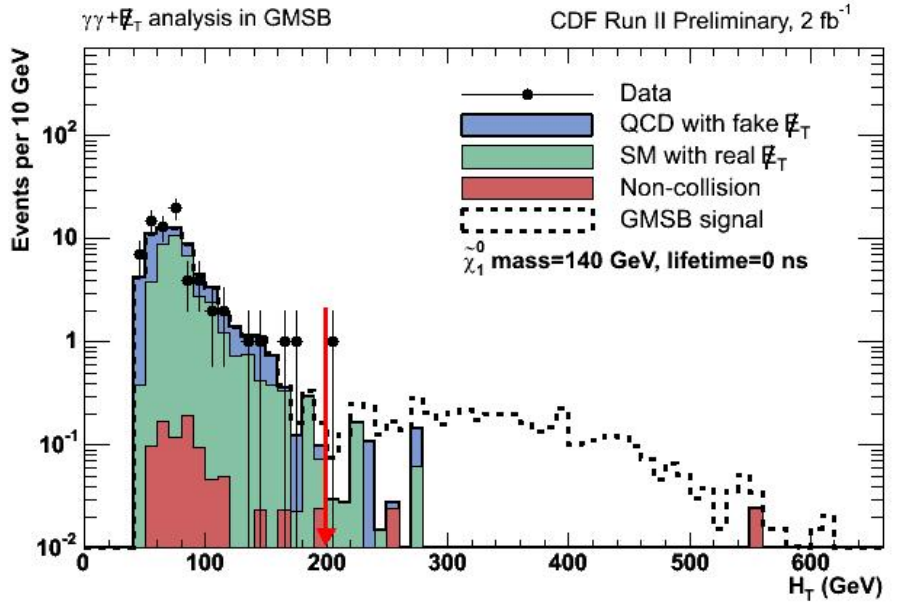
GMSB (Gauge Mediated Supersymmetry Breaking)

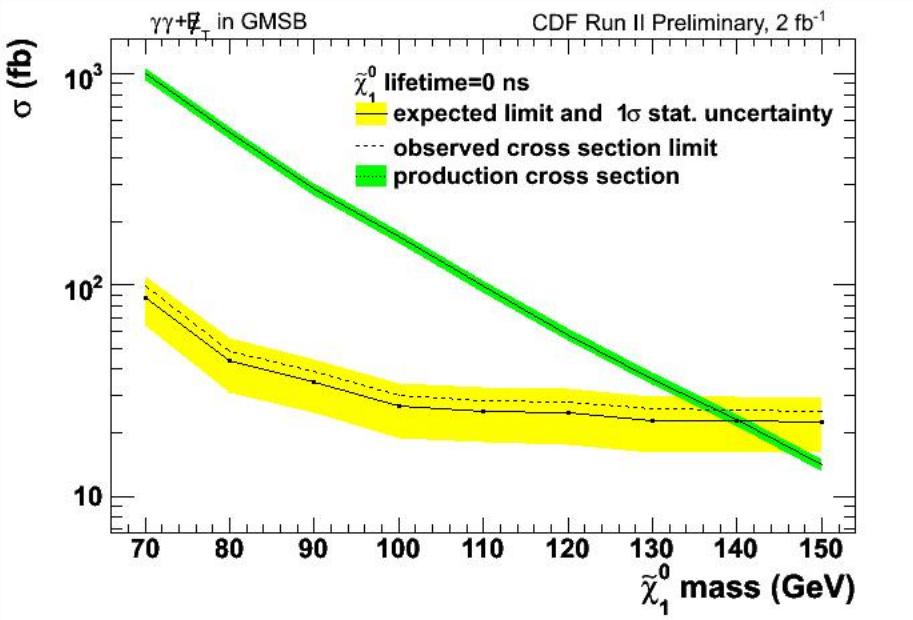
GMSB models $\Rightarrow$ SUSY is broken with a mechanism that is mediated by "messengers" which couple to the SUSY particles

- LSP is gravitino and next-to-LSP is neutralino or slepton:

$$\tilde{\chi}^0 \rightarrow \gamma\tilde{G}$$

- Assuming $\tilde{\chi}^0$ lifetime $\simeq$ 0 ns
- In R-parity conserved models the final state is $\gamma\gamma$ *Missing* E_T
- Very clean signature, negligible SM contribuition

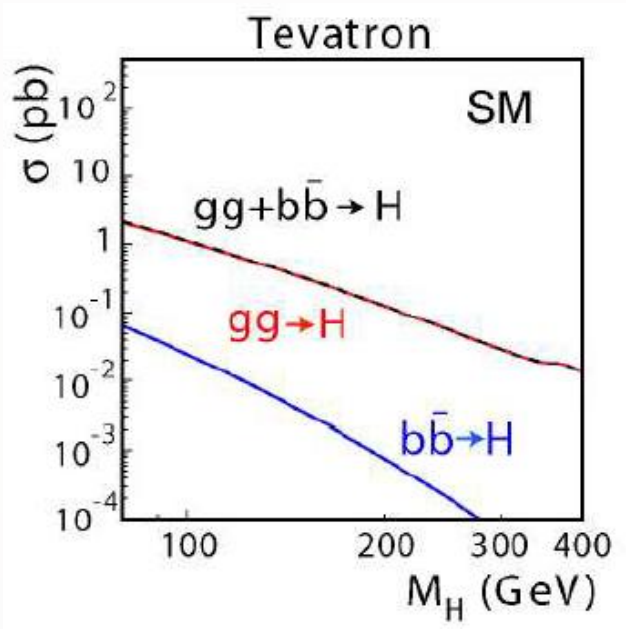


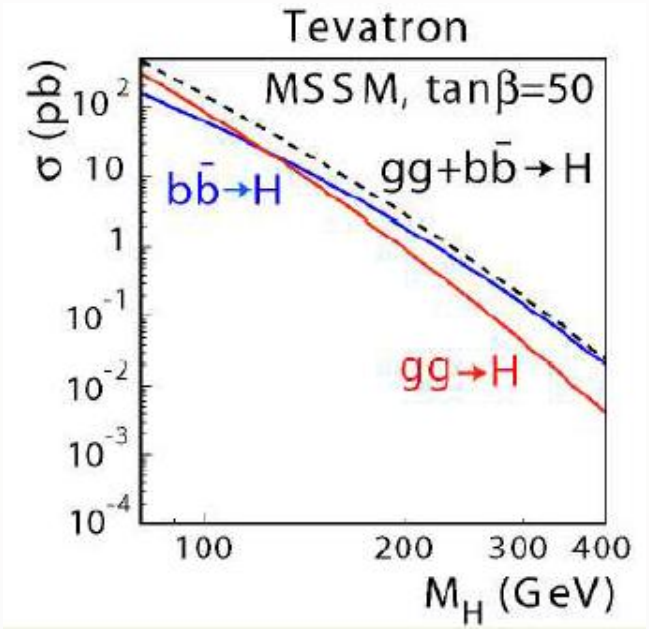


MSSM Higgs

In the MSSM we expect 5 Higgs bosons: h, H, A and $H^{\pm}$

- For large *tan*β: A is degenerate in mass with h or H and the cross section is enhanced (coupling to down-type quarks)
- bottom-quark loop enters in the production diagrams, and associated production (Hbb) has a very relevant contribution.
- The degenerated state ϕ decays into $\tau\tau$ (10%) and bb (90%)





MSSM Higgs with taus

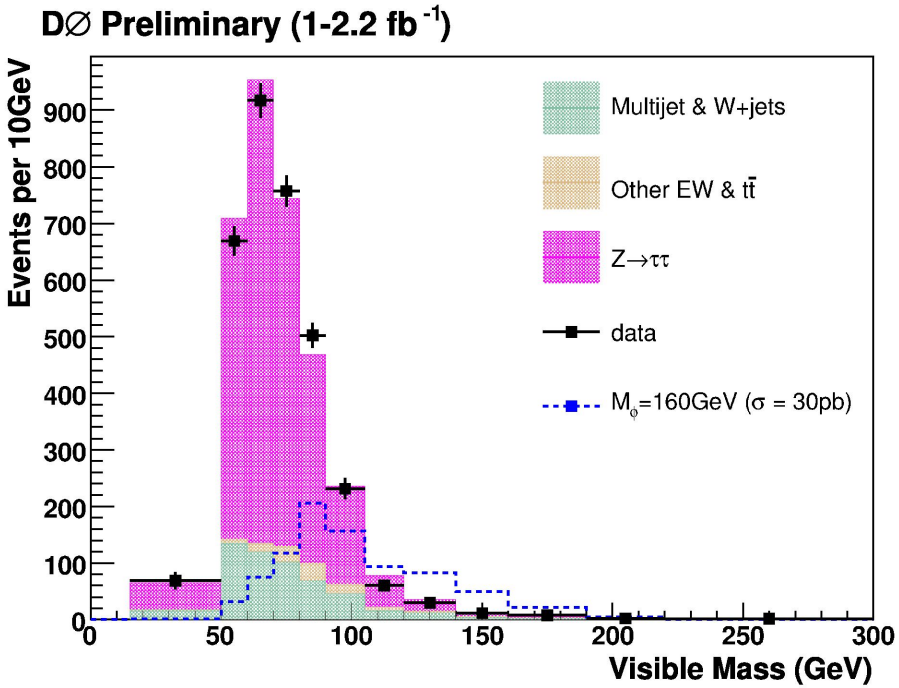
The analysis was performed using one leptonic τ and one leptonic or hadronic τ

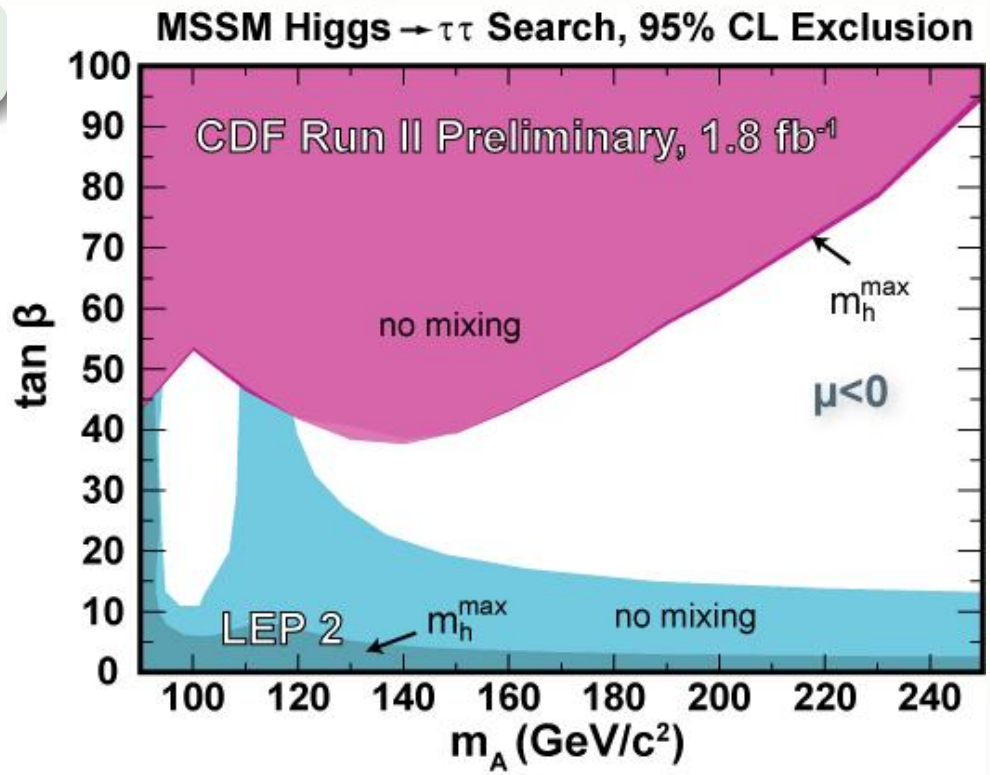
$$\phi \rightarrow \tau^+\tau^-$$

- Main background $\Rightarrow$ Drell-Yan production of tau pairs

Good agreement with the SM predictions

CDF & D0 combination underway





MSSM Higgs with b-jets

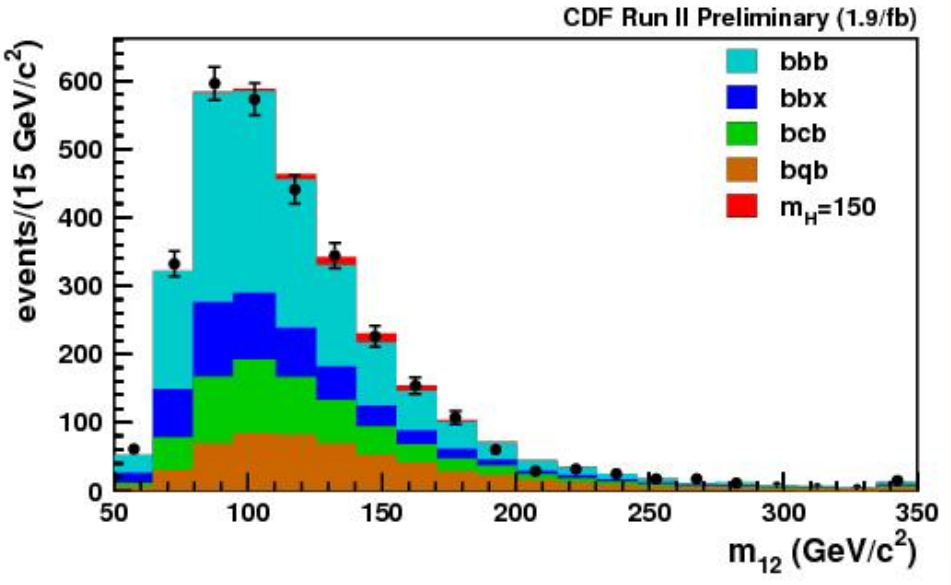
Higgs production in association with b-quarks is enhanced in the MSSM (with large tanβ)

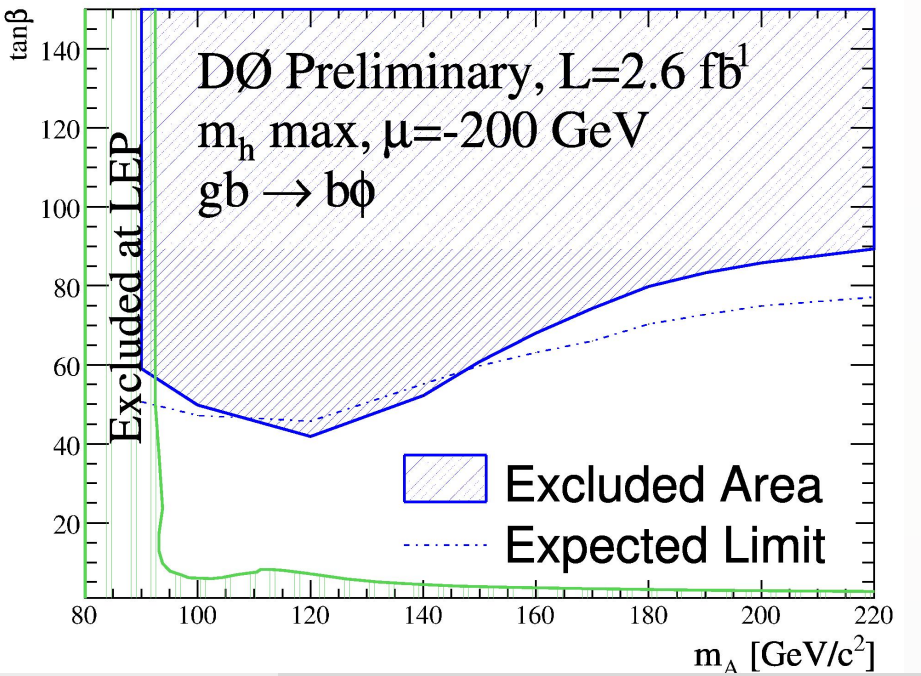
$$b\phi \rightarrow bbb$$

- Exclusive regions depending on jet multiplicity
- Hard to understand the quark content of 3 jets
- Heavy- flavour Multijets (QCD) from data

Good agreement with the SM predictions

Combination of channels underway





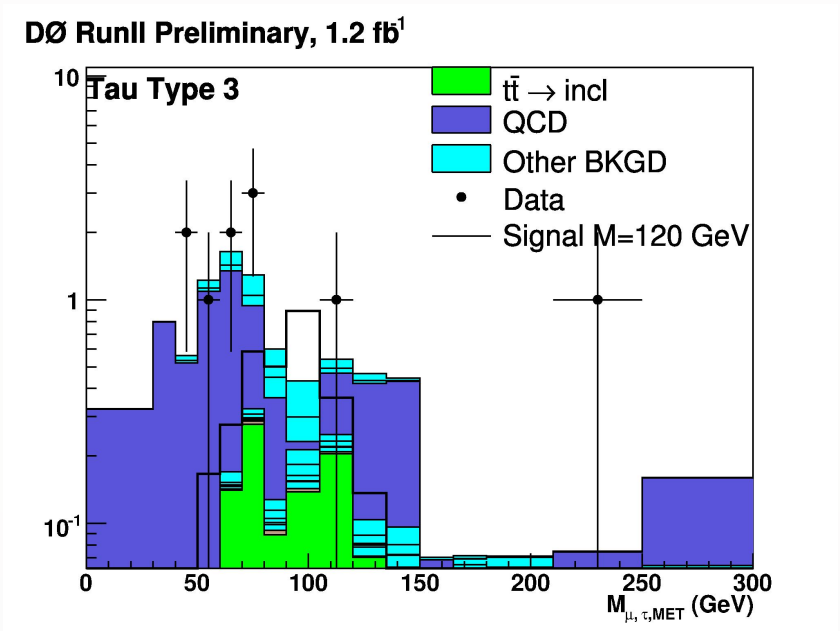
MSSM Higgs with taus + bjet

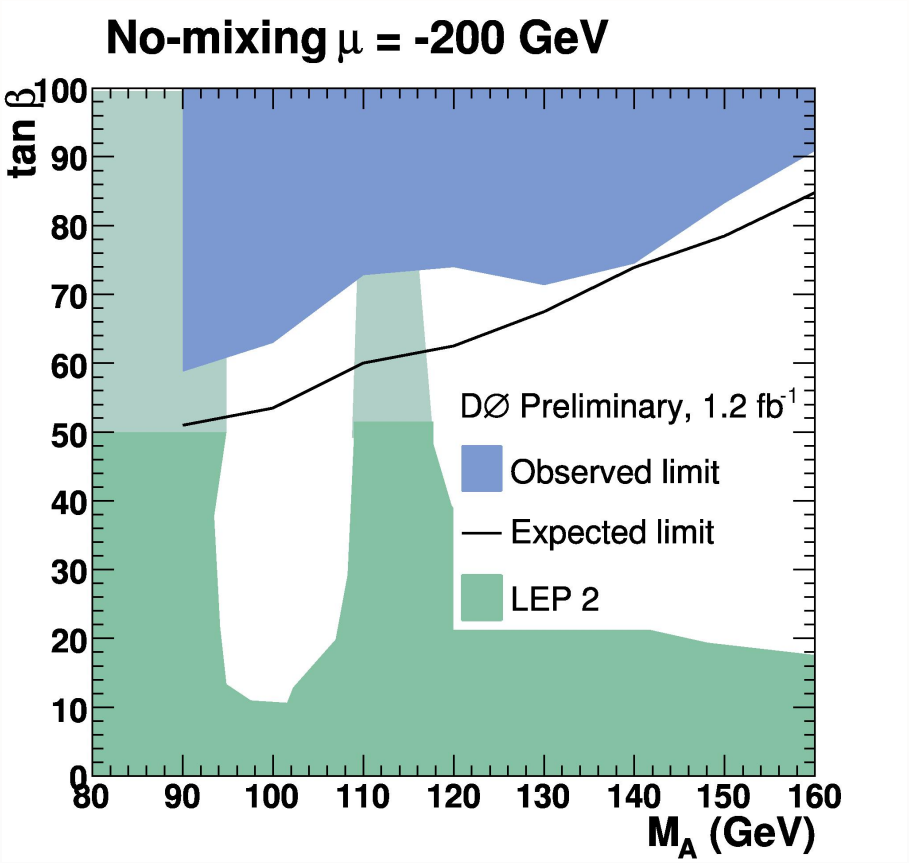
The analysis was performed using one leptonic τ, one hadronic τ and one b-jet

$$b\phi \rightarrow \tau^+\tau^- b$$

The b-tagging enhances the sensitivity

D0 combination with previous channels underway





Summary

- Tevatron and experiments are performing really well
  - 6 fb^{-1} delivered
  - 5 fb^{-1} recorded
- No evidence of SUSY in almost 3 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.htm

Backup Slides