Inclusive Searches for Squarks and Gluinos at the Tevatron

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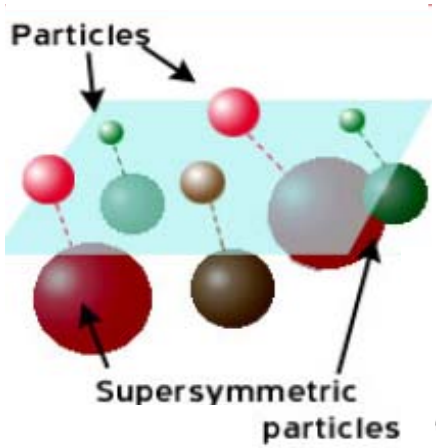
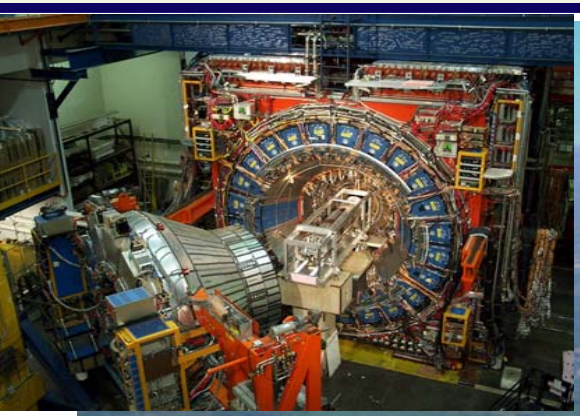
Outline

- Tevatron overview
- Supersymmetry in few words
- Squarks and Gluinos
- Background Processes
- Systematics
- Results
- Summary and Conclusions

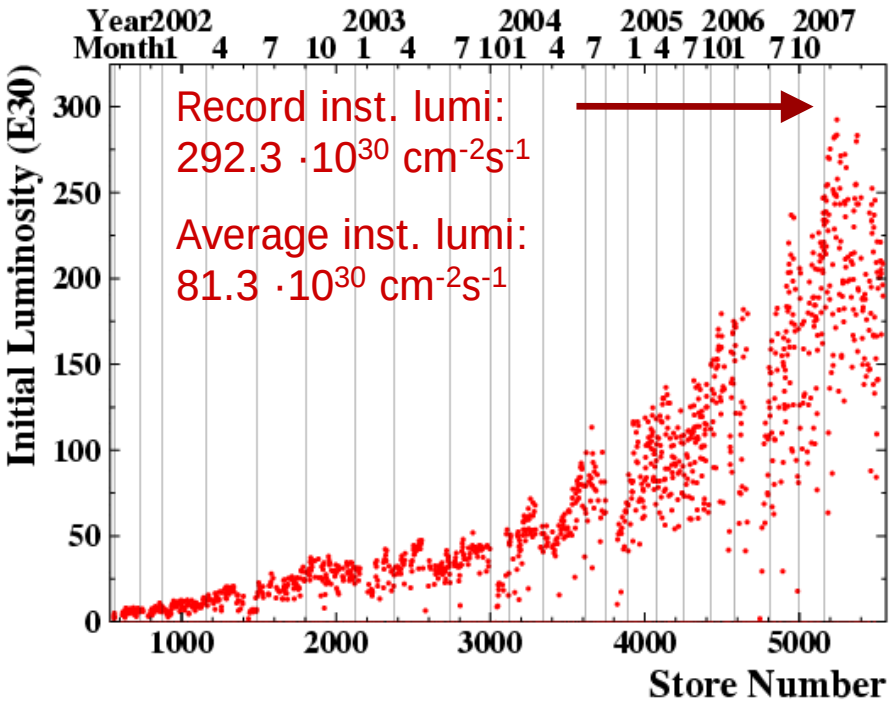


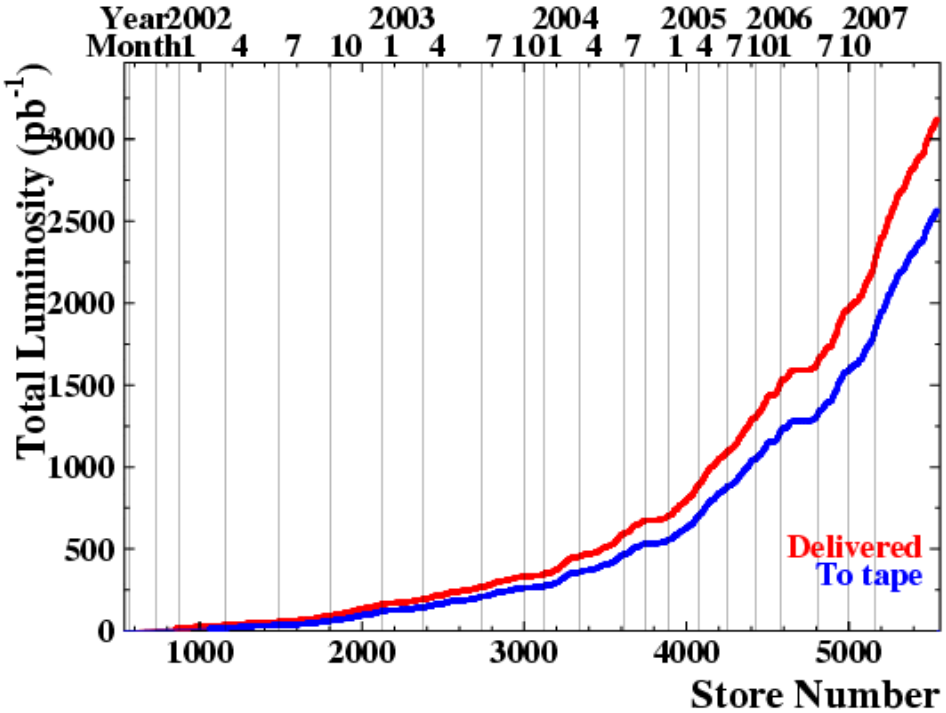
Tevatron



396 ns bunch spacing
Chicago
36x36 bunches
p
p̄
√s = 1.96 TeV
Booster
CDF
DØ
p source
p̄ source
Tevatron
Main Injector

CDF & D0





Tevatron has a very good performance

CDF and D0 working at high efficiency (~85%)

More than 2.5 fb^{-1} are already on tape

The analyses presented here are performed with ~1fb^{-1}

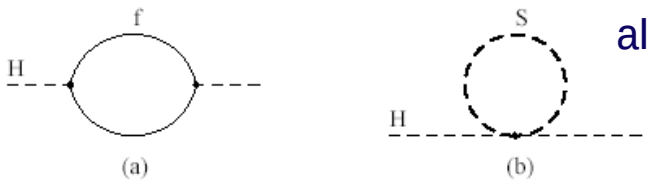
Supersymmetry in Few Words

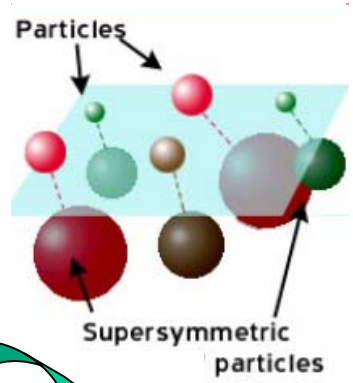
Supersymmetry predicts the existence of a symmetry between bosons and fermions:

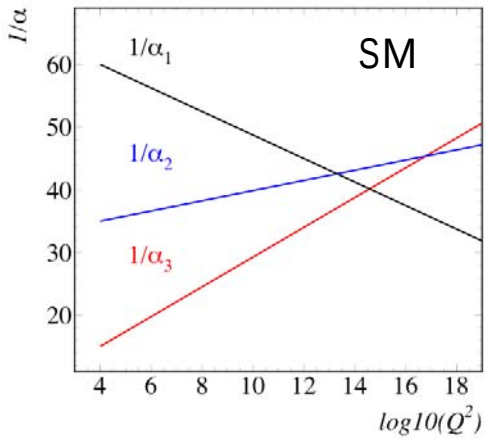
Q |Boson> = Fermion

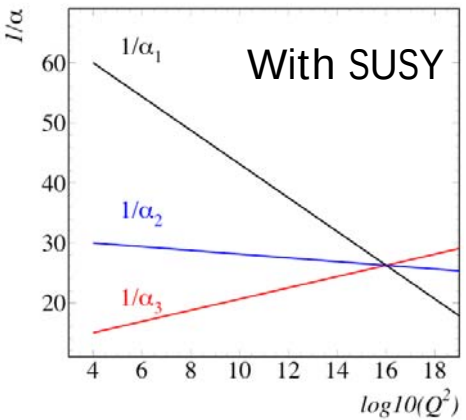
Q |Fermion> = Boson

Natural cancellation of divergences at all orders

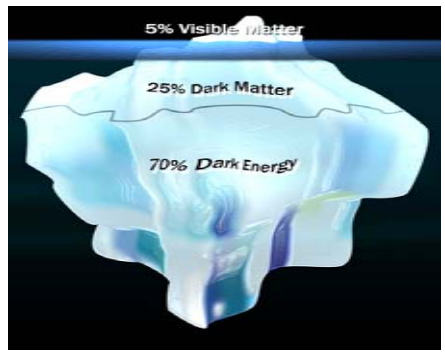




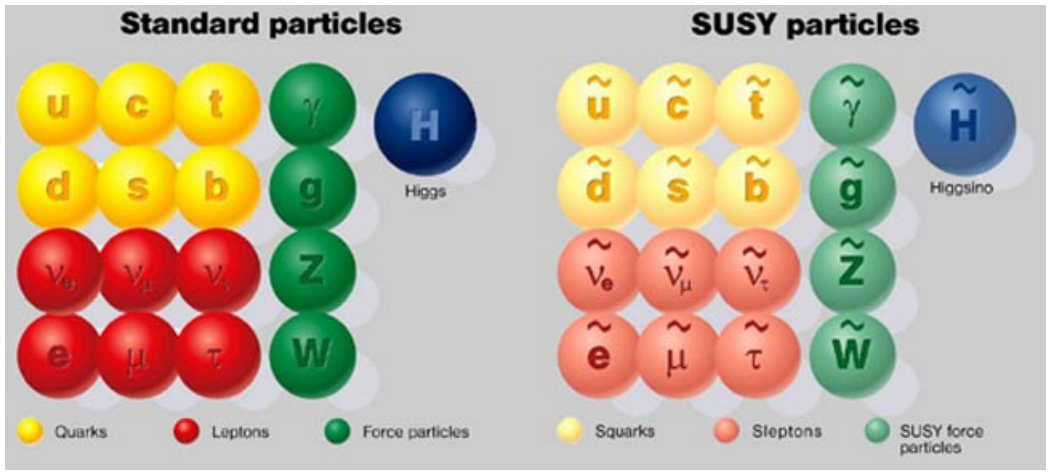




- ✓ Solves the hierarchy problem
- ✓ Contributes to the unification of forces
- ✓ Key ingredient for GUT and string theories.
- ✓ In some models, it presents a dark matter candidate.



Supersymmetry Zoo



Particles not discovered → SUSY is a **broken symmetry**

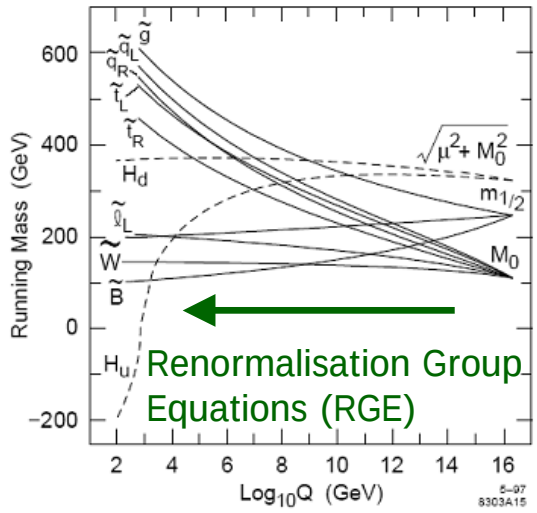
Without further constraints → 105 new parameters → Need to be reduced…

R-parity: symmetry introduced to avoid baryonic and leptonic number violations.

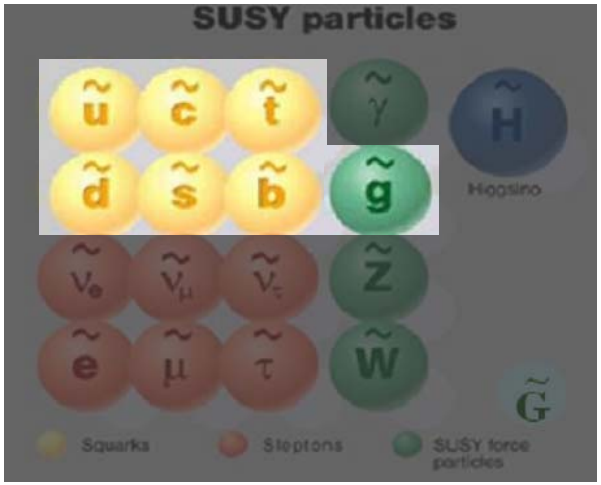
If conserved, SUSY particles need to be **pair-produced** and exist a **LSP** (dark matter candidate)

mSUGRA scenario is one theoretically motivated model to reduce the parameters to 5:

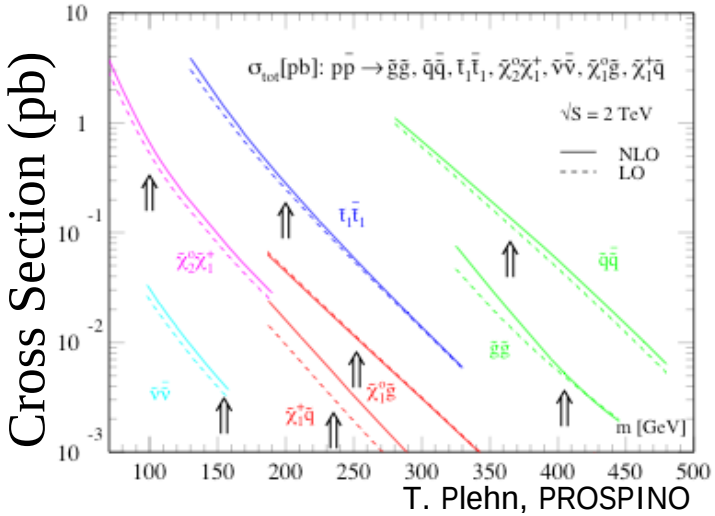
m_0, $m_{1/2}$, A_0, tanβ, signμ

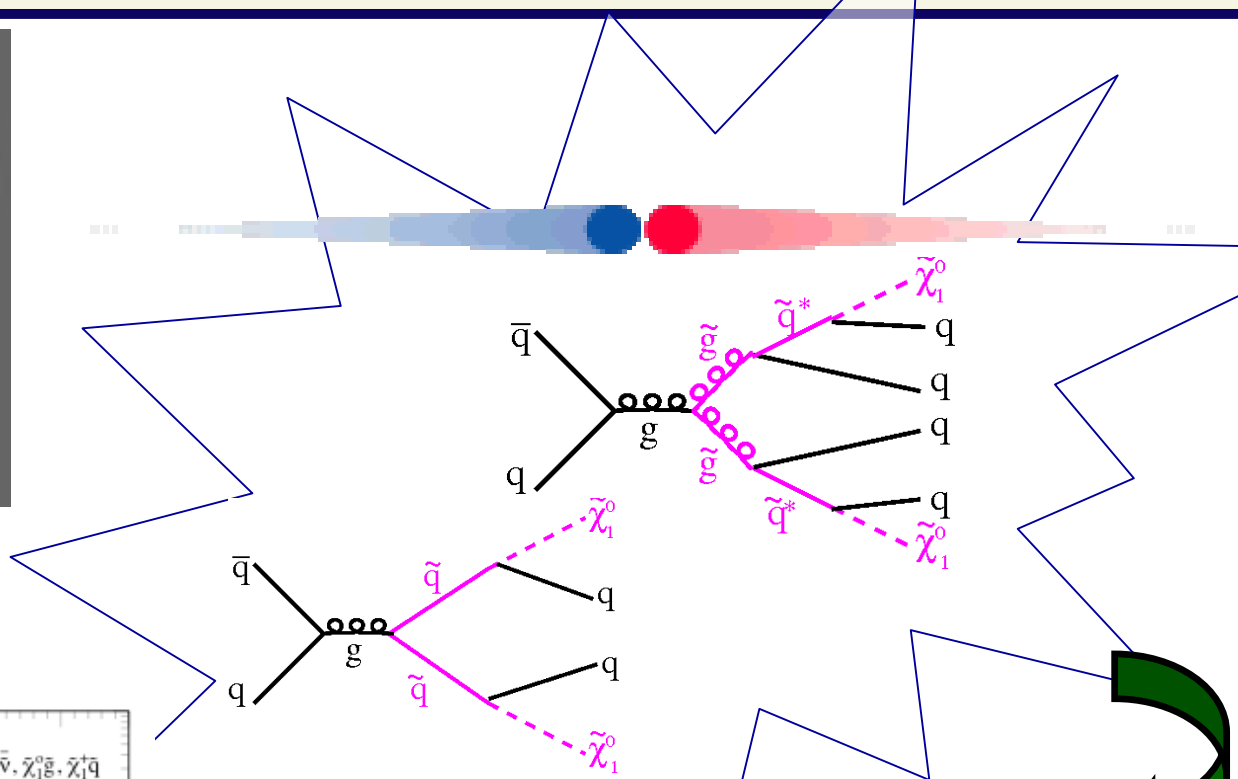


Squarks and Gluinos



Squarks and Gluinos may be copiously produced (strong interaction)





Very massive particles

Presence of neutralino (LSP)

Multiple Jets

Missing Transverse Energy (MET)

Squarks and Gluinos: Generation

CDF and DØ use similar approaches:

- ✓ R parity conservation assumed;
- ✓ Four 2→2 sub-processes:
  - **gluino - gluino** (and cc)
  - **gluino - squark**
  - **squark - squark** (and cc)
  - **squark - antisquark**
- ✓ different sub-processes normalised to NLO according to **PROSPINO**
  - PDF **CTEQ6.1M**
  - renormalisation-factorisation scale:
    - gluino-gluino → μ = Mgl
    - gluino-squark → μ = 1/2 * [Mgl + Msq]
    - squark-squark → μ = Msq
    - squark-antisquark → μ = Msq
- ✓ Remove stop from 2-to-2 processes (avoid too much dependence with the mixing parameters).

And also some small differences:

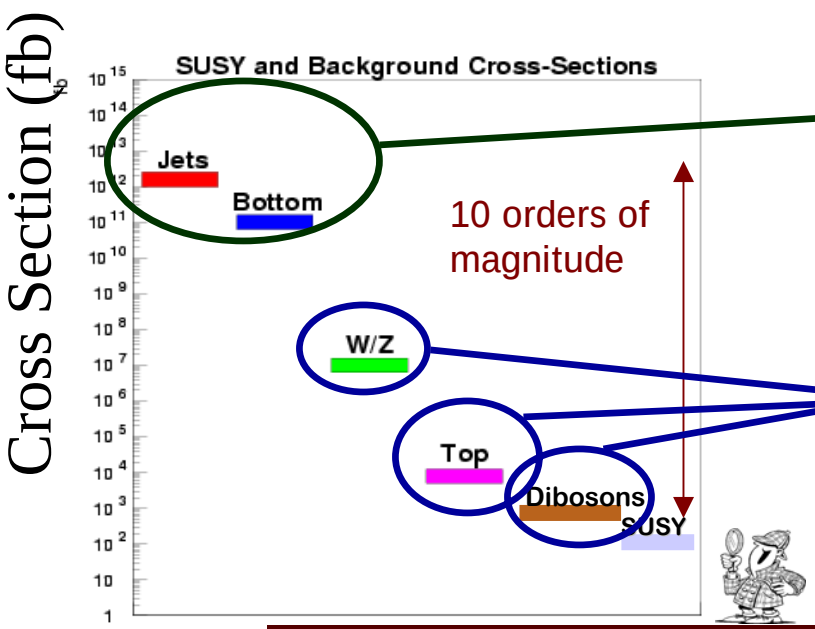
- ✓ Use slightly **different RGEs** (ISASUGRA vs SUSPECT and SDECAY packages)
- ✓ DØ **includes sbottom** in the 2-to-2 processes (**average 5 types** of squark masses) and CDF **excludes it** (**averages 4 types** of squark masses).
- ✓ mSUGRA scenarios:

DØ: A_0=0, **tanβ=3**, μ<0

CDF: A_0=0, **tanβ=5**, μ<0

They could translate on very small differences in the masses (<5 GeV/c^2)

Backgrounds



QCD multijet production dominates.

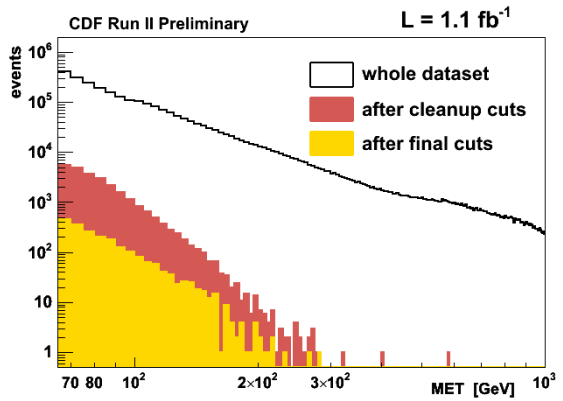
MET coming from energy mismeasurements in the calorimeter.

W/Z+jets with W→lν or Z→νν, diboson and ttbar production

Signatures very similar to SUSY

Careful understanding of jet energy reconstruction and calibration
Data-driven estimations for backgrounds whenever possible.

There are also **beam-related backgrounds** and **cosmics**. Removed using vertex information, calorimeter activity with correspondent tracking activity…



Background Strategies

QCD

Estimated from data. Use a **fit in the low MET region to extrapolate** at high region.

Generated with PYTHIA Tune A. Use **region of low MET to normalise** the samples.

Reduce the QCD using the azimuthal distance between each of the jets and the MET.

W/Z+ jets

Exclusive n-parton samples ALPGEN+PYTHIA (MLM matching)

Normalisation to the W/Z inclusive cross section.

Reduce contributions applying electron and muon vetoes: isolated tracks, fraction of jet electromagnetic energy…

ttbar and dibosons

Used ALPGEN+PYTHIA for both and normalise to their theoretical NNLO cross sections (m_{top}=175 GeV/c^2).

Used PYTHIA for both. Top normalised to NLO cross-section (m_{top}=172 GeV/c^2) and dibosons used MCFM NLO calculations.

Reduce contributions applying electron and muon vetoes like in the previous case.

Cuts: Optimisation

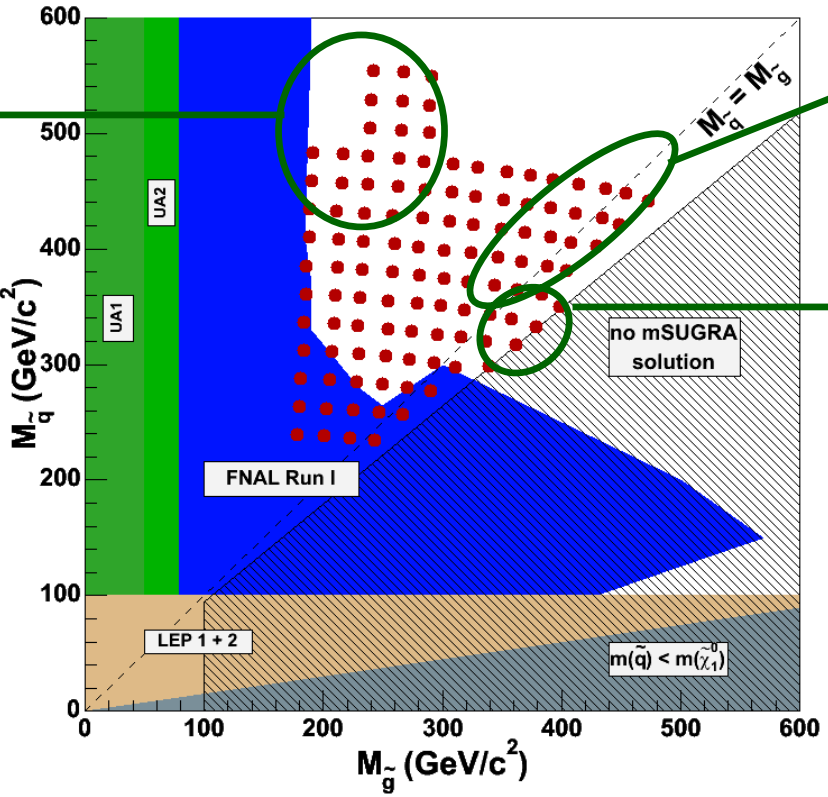
Further reduction of the SM backgrounds is needed.
Used variables such as **MET** and $\mathbf{H_T}$ (scalar sum of the main jets).

Different topologies expected throughout the squark-gluino plane.

$M_{\tilde{q}} > M_{\tilde{g}}$

$\tilde{g}\tilde{g}$ prod. dominates

$\geq$ 4 jets expected



$M_{\tilde{q}} \sim M_{\tilde{g}}$

$\tilde{q}\tilde{g}$ prod. dominates

$\geq$ 3 jets expected

$M_{\tilde{q}} < M_{\tilde{g}}$

$\tilde{q}\tilde{q}$ prod. dominates

$\geq$ 2 jets expected

Both CDF and DØ use the different jet multiplicity topologies to maximise the acceptance/rejection.

Systematics

Sig. & Bkgs: ~3% Jet Energy Scale (JES): Main uncert. → ~10% (20%) sig (bkg)

~6% uncertainty on the Luminosity

SIGNAL

Renormalisation scale:

Nominal PROSPINO μ varied: values 2μ and $\mu/2$ considered

PDF uncertainties:

Used Hessian method. Uncert. dominated by signal production at high-x gluon

ISR/FSR:

Motivated for unknown topologies from the undiscovered processes.

Estimated varying the Λ_{QCD} scale

BACKGROUNDS

QCD → Uncertainty from normalisation (CDF) and from extrapolation (D0). Both are small.

Top → PDF uncert. from theory

Ren. Scale uncert. negligible

ISR/FSR estimated like in the signal.

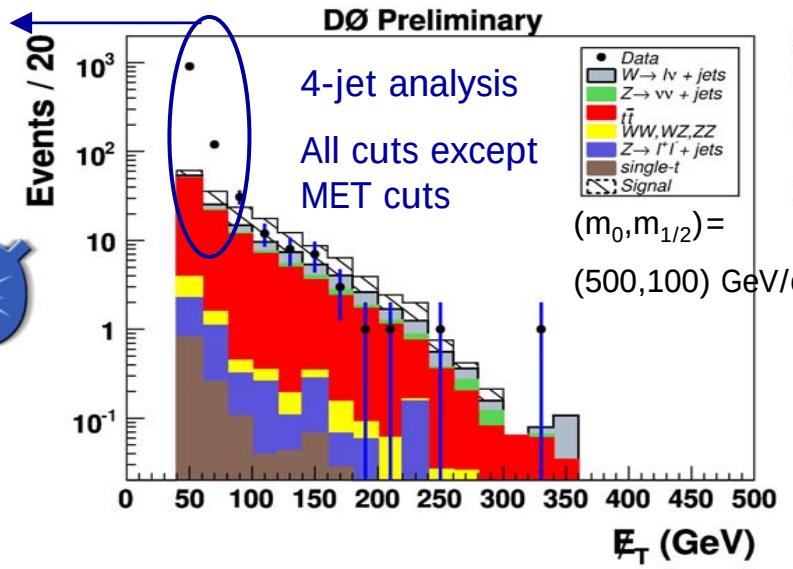
Z/W+jets → Global uncert. coming from the inclusive cross-section.

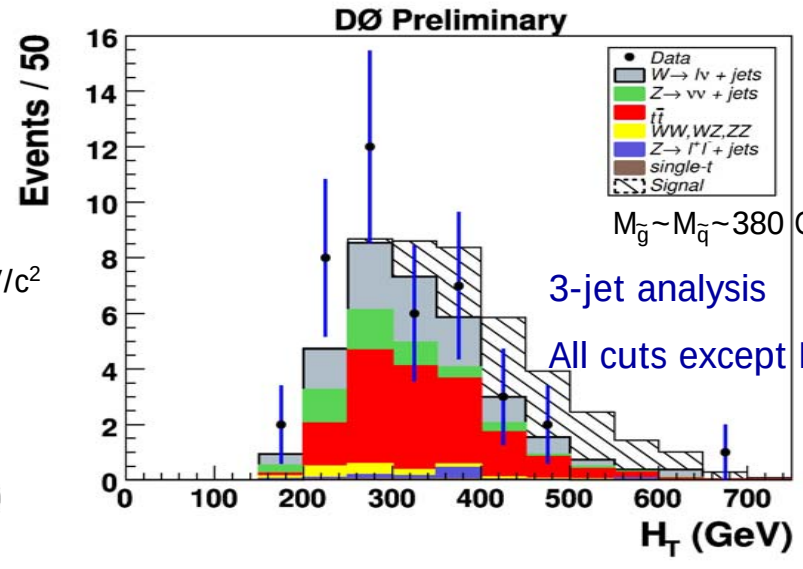
Dibosons → PDF+renorm. uncert. from theoretical calculations.

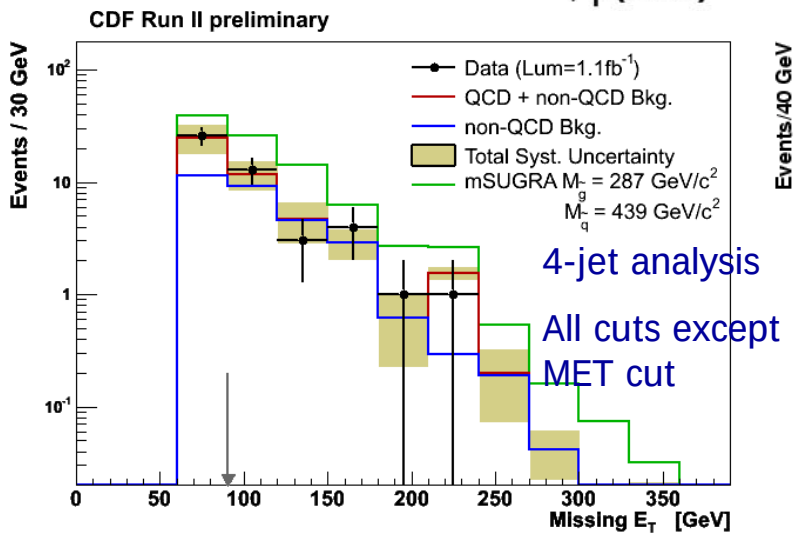
PDF and Renorm. scale systematics for signal cross-sections ~15%-50%

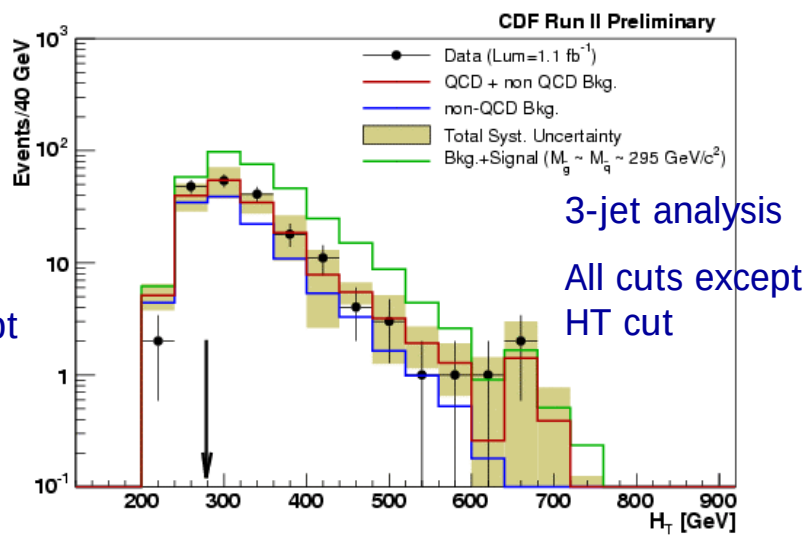
Results

QCD (not generated)









No significant deviation from SM expectations

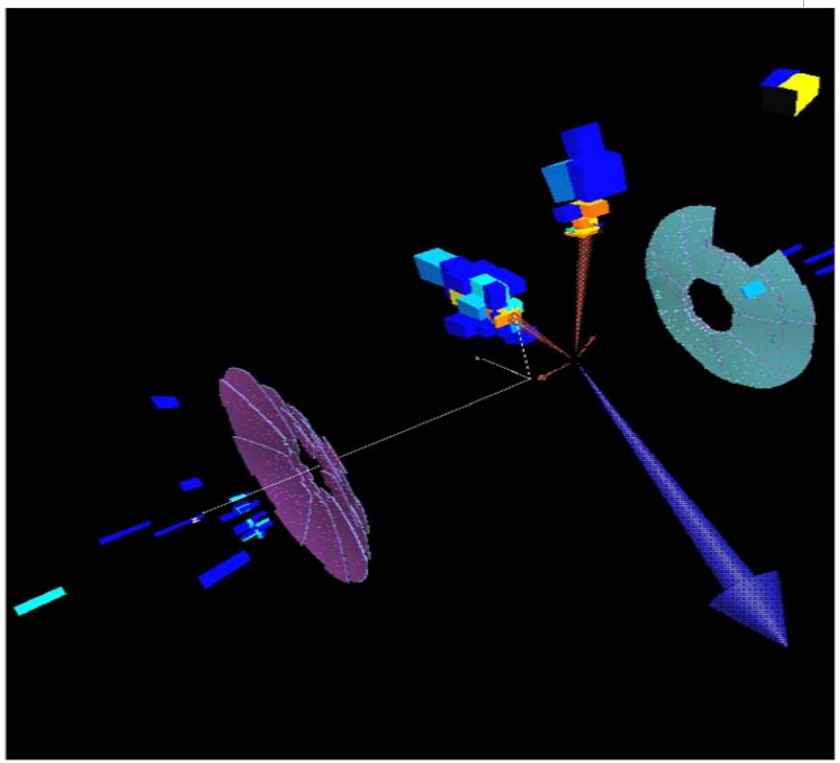
Events of High MET and Jet ET

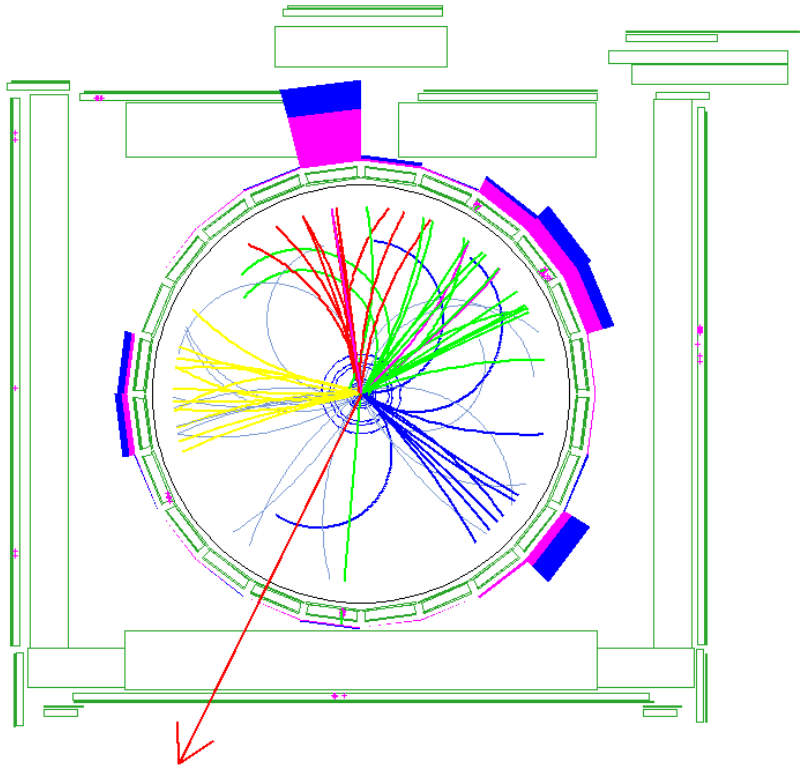
MET=368 GeV H_T=489 GeV

E_T^{1st}=282 GeV E_T^{2nd}=174 GeV E_T^{3rd}=33 GeV

MET=196 GeV H_T=470 GeV

E_T^{1st}=236 GeV E_T^{2nd}=150 GeV E_T^{3rd}=84 GeV





R-ϕ view of the detector

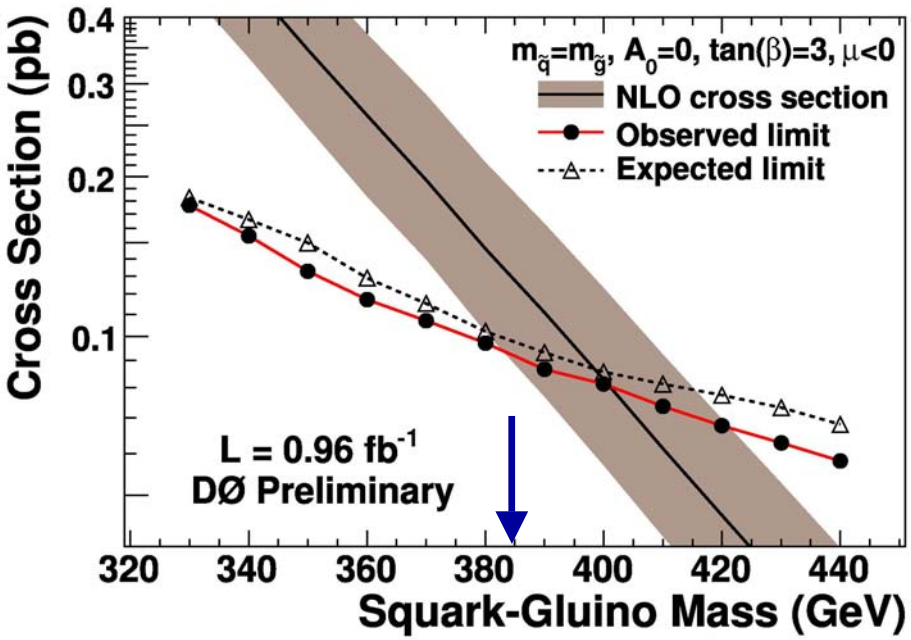
Limit Calculations

✓ Bayesian approach: curves at 95% C.L.

✓ Considered the correlations between signal and background systematics.

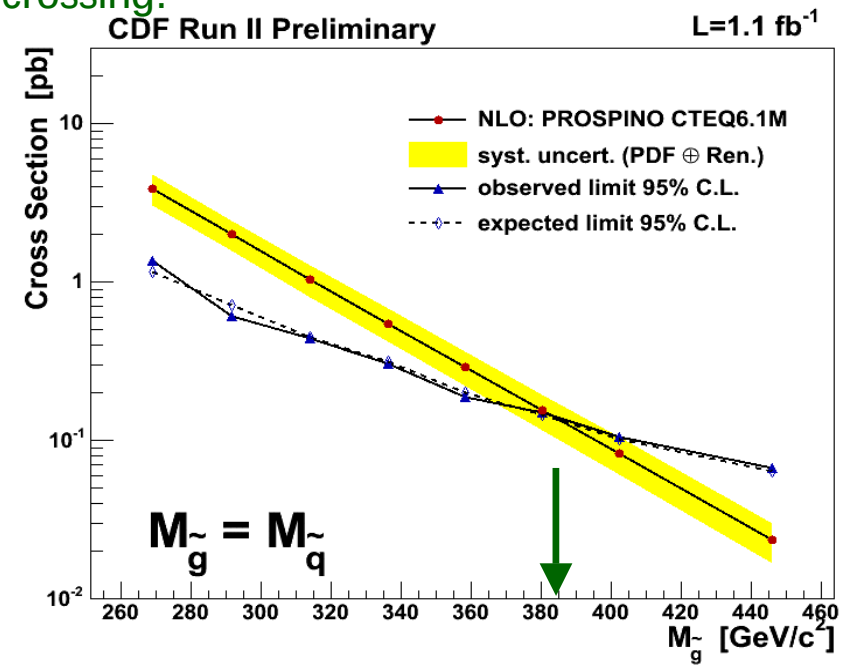
➢ Systematics affecting the signal cross-section not included in the cross-section limit.

➢ 3 cases considered: low, nominal and high σ values. Quoted the most conservative limit.



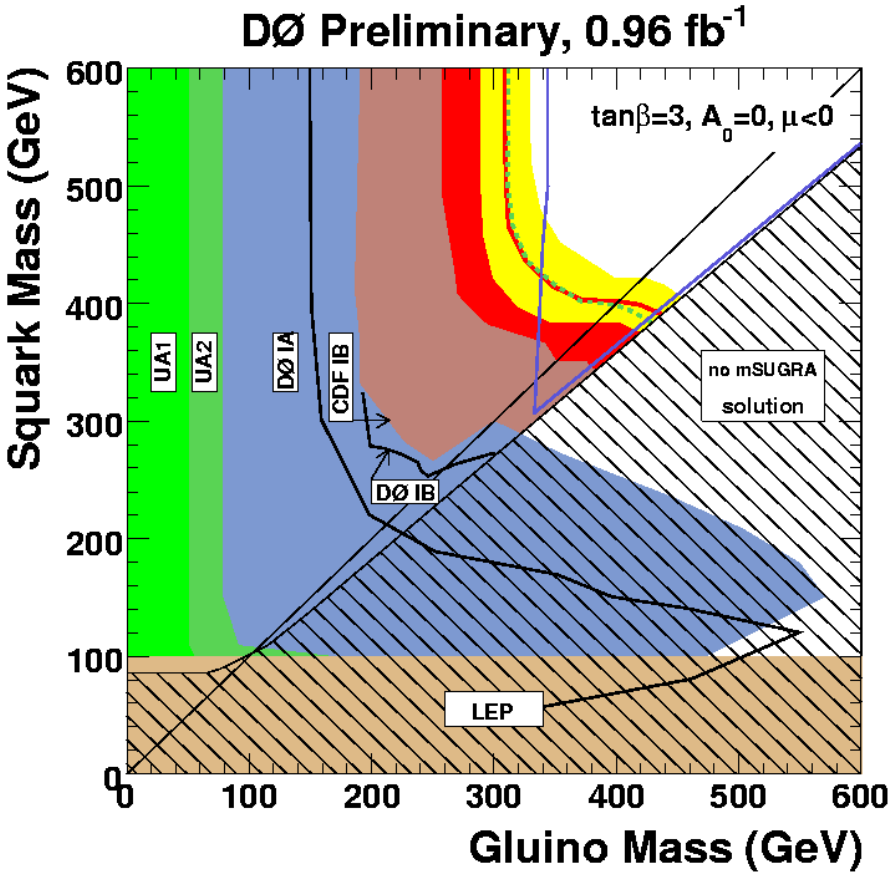
➢ Statistical and systematic uncertainties are included inside the limit calculation.

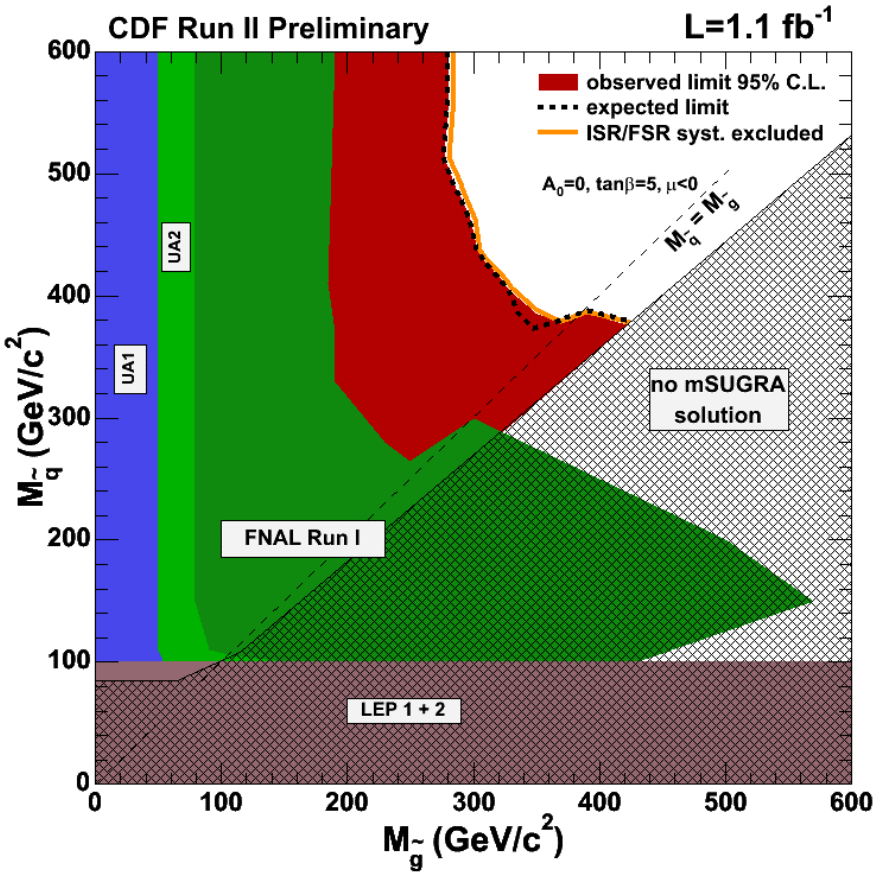
➢ Mass limit placed at the NLO nominal σ crossing.



For $M_g \sim M_q$: masses excl. up to 385 GeV/c^2.

Exclusion Limits





Both experiments have similar results:

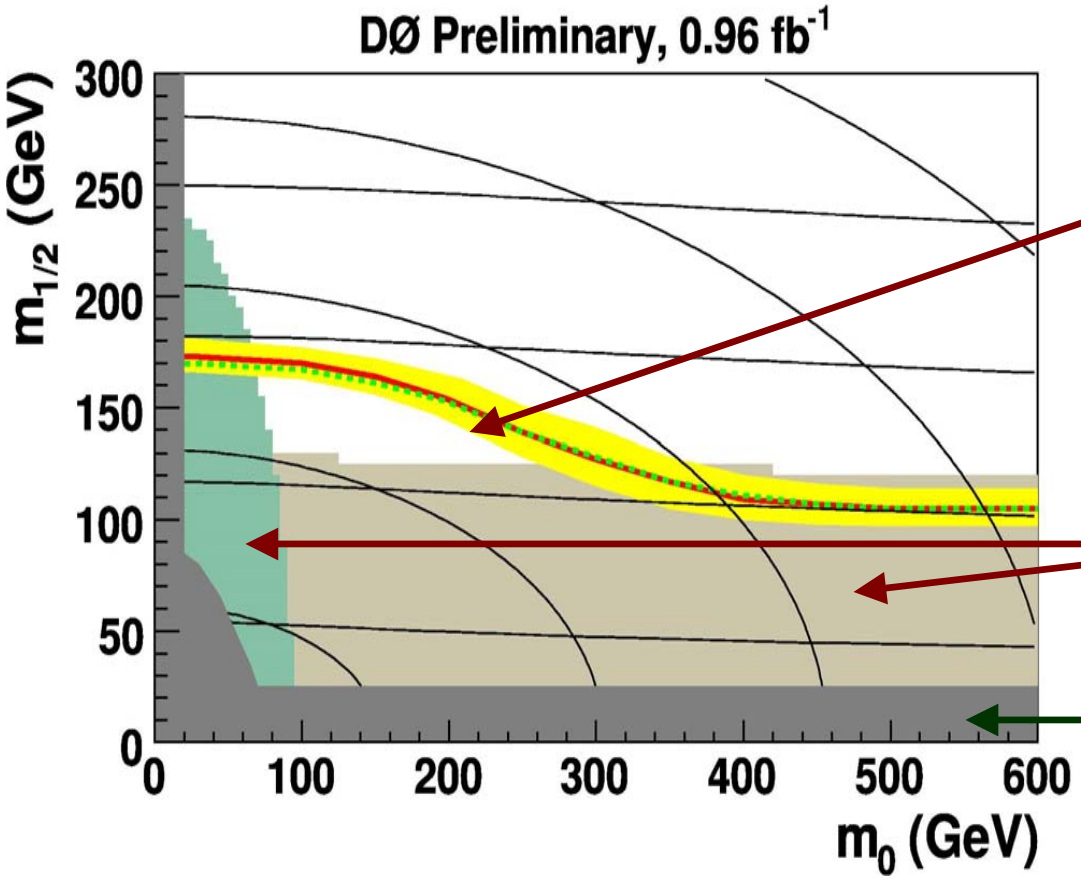
Gluino masses below ~280 GeV/c^2 excluded.

Squark masses below ~370 GeV/c^2 excluded.

When $M_{\tilde{q}} \sim M_{\tilde{g}}$: masses below ~385 GeV/$c^2$ excluded.

Limits on m_0-$m_{1/2}$ Plane

Exclusion limits can also be set in terms of m_0-$m_{1/2}$:



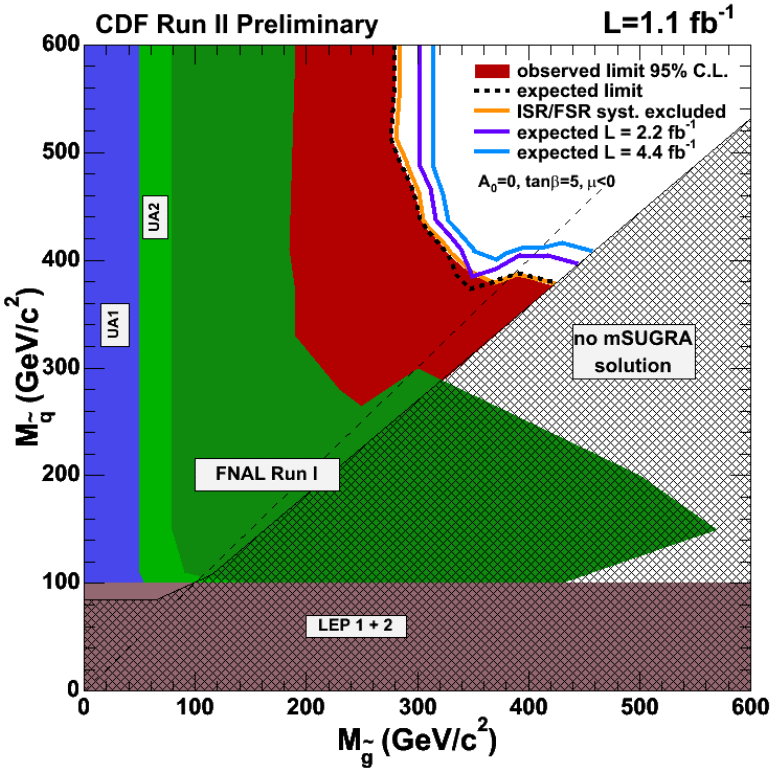
Limits are the lower part of the band.

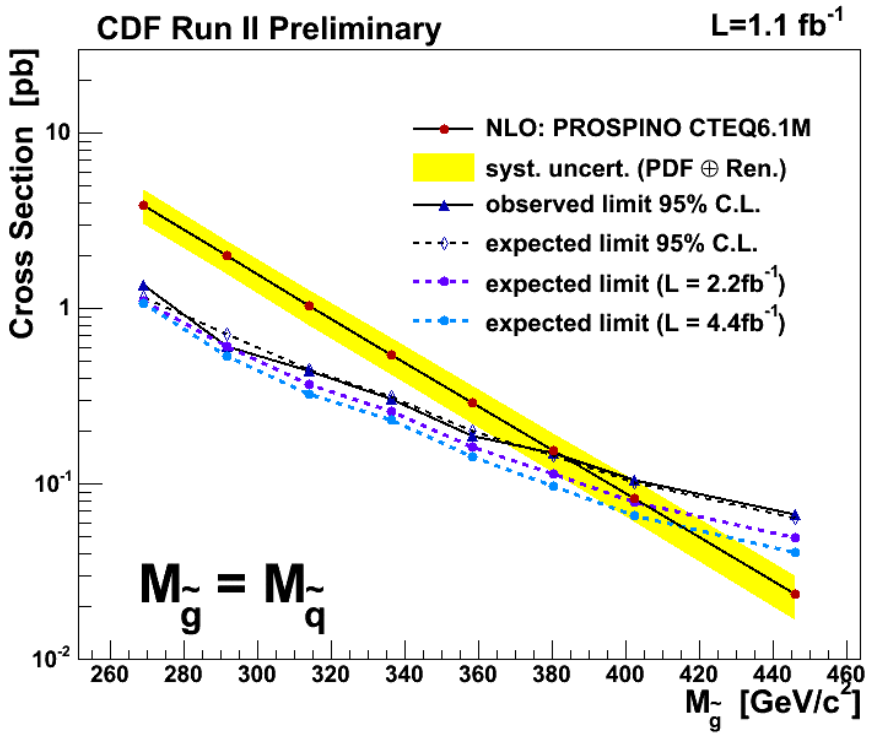
Indirect limits from LEP

No mSUGRA solution.

Also similar results from CDF…

Future Projections





- ✓ Same relative systematic uncertainties contributions assumed
- ✓ Number of signal and background events and statistical uncertainties scaled according to the luminosity
- ✓ When $M_{\tilde{g}} \sim M_{\tilde{q}}$, $M_{\tilde{g}} < 405$ and $M_{\tilde{g}} < 420$ GeV/c^2 excluded for $\mathcal{L}=2.2$ and $\mathcal{L}=4.4$ fb^{-1} respectively

Summary and Conclusions

✓ No evidence of Squarks and Gluinos in samples of ~1fb^{-1} has been found in CDF and DØ dedicated inclusive analyses.

✓ Both collaborations performed careful studies to understand and reduce the different background contributions and the systematic uncertainties.

✓ Limits are set for a particular mSUGRA scenario: A_0=0, tanβ=3 or 5 and μ<0. Both experiments provide comparable limits.

At this point, collaborations may consider to combine their results to achieve one common result.

In addition, studies are ready to add more data already on tape (currently more than 1.5 fb^{-1} unexplored).

It may be that the first SUSY hint is just around the corner...