Searches for Squarks and Gluinos at CDF

Xavier Portell*
(on behalf of the CDF collaboration)

(Barcelona)

Euro-GDR SUSY

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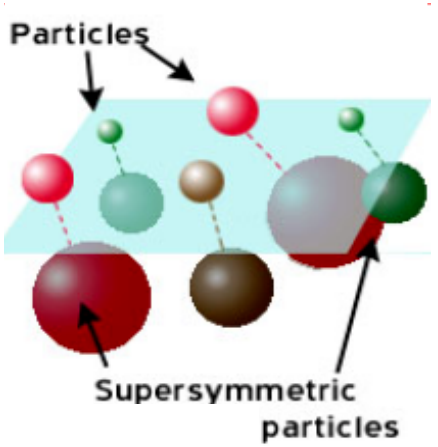
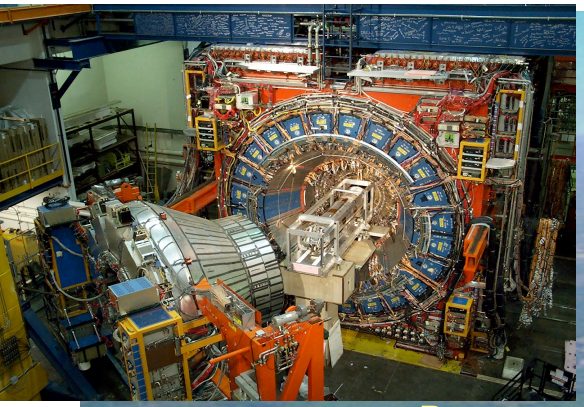
* Now at Freiburg University

Outline

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



Tevatron and CDF



396 ns bunch spacing

36x36 bunches

Chicago

p $\bar{p}$

√s = 1.96 TeV

Booster

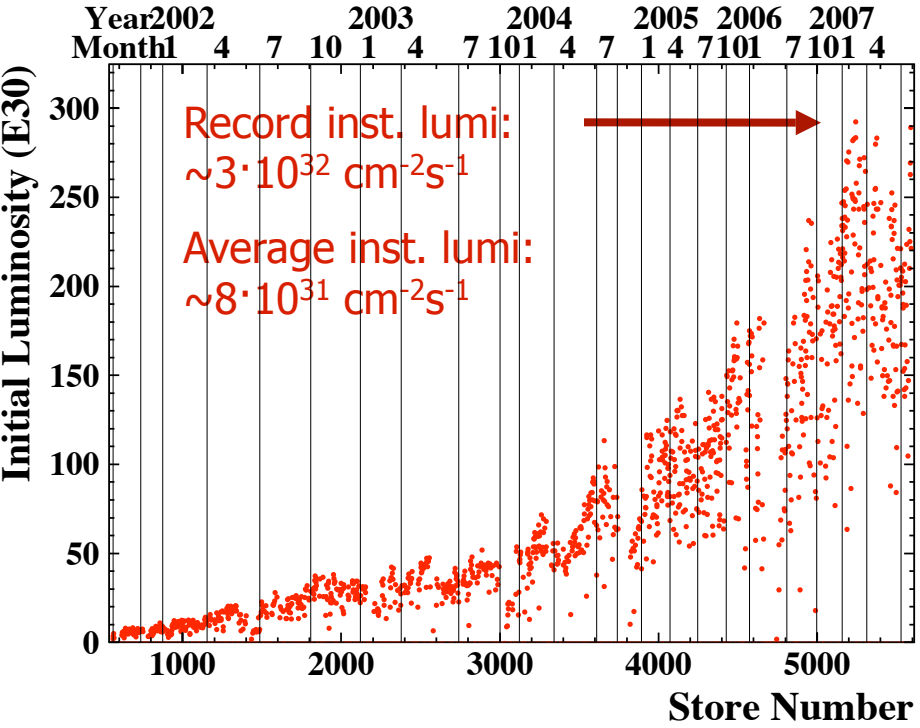
p source

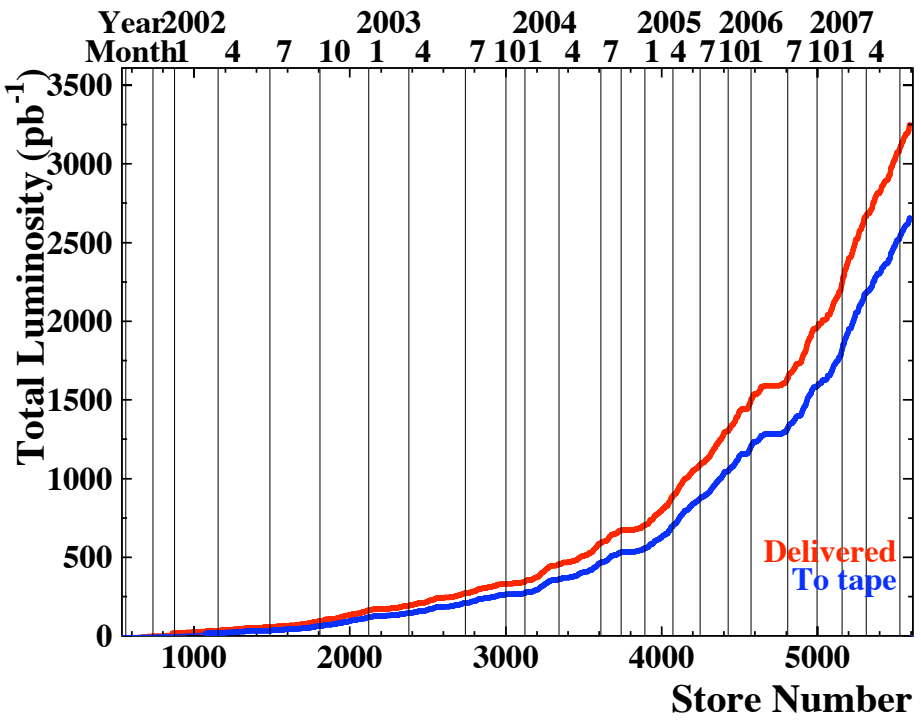
$\bar{p}$ source

Tevatron

Main Injector

Tevatron and CDF Performance





Tevatron has a very good performance

CDF working at high efficiency (~85%)

More than 2.6 fb^{-1} are already on tape

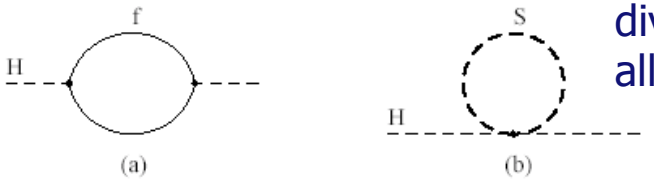
The analysis presented here is performed with ~1.4 fb^{-1}

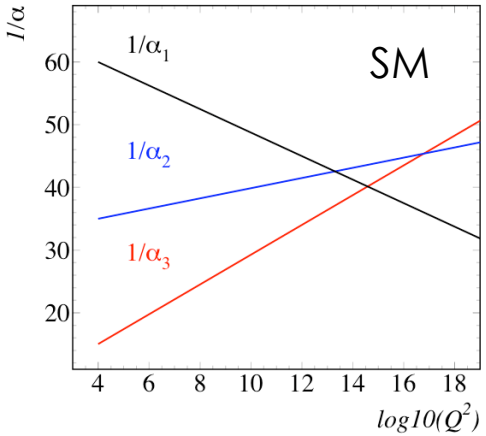
Supersymmetry in Few Words

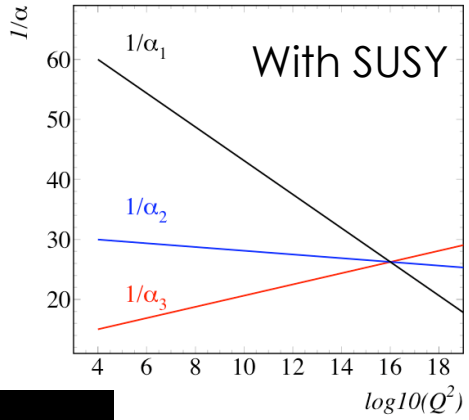
Supersymmetry predicts the existence of a symmetry between bosons and fermions:

Q | Boson> = Fermion
Q | Fermion> = Boson

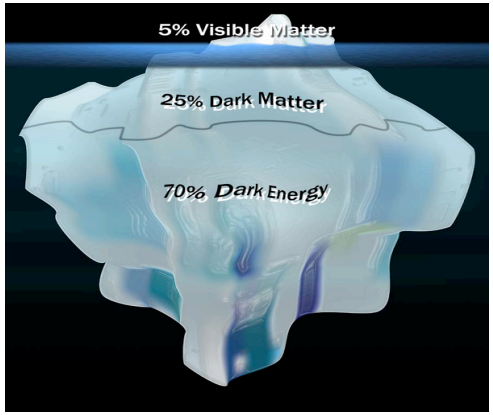
Natural cancellation of divergences at all orders



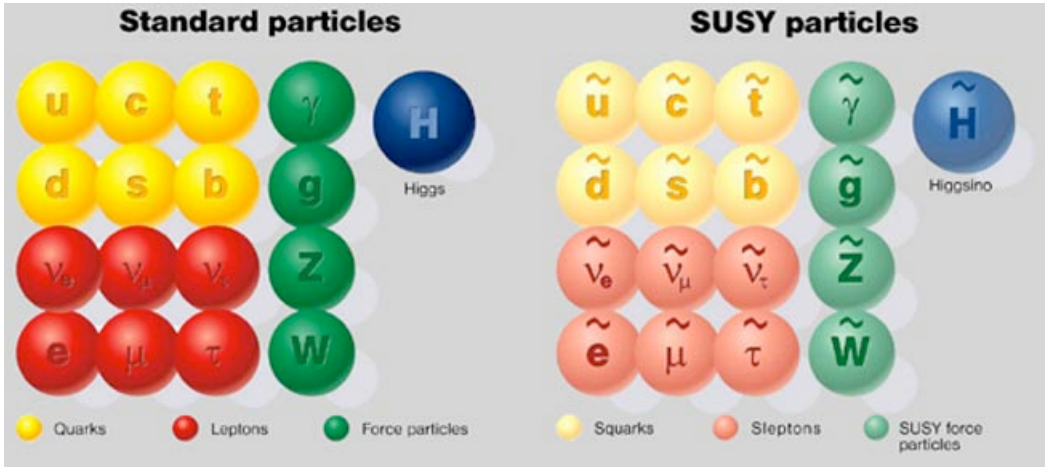




- ✓ Solves the hierarchy problem
- ✓ Contributes to the unification of forces
- ✓ Key ingredient for GUT and string theories.
- ✓ In some models, it presents a dark matter candidate.



Supersymmetry Zoo



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

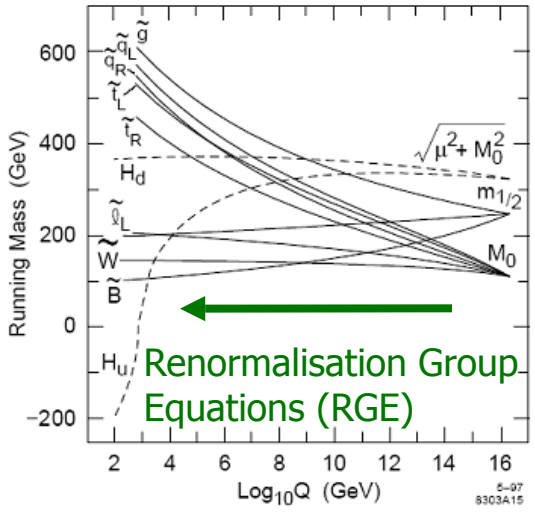
Without further constraints → 105 new parameters → Make some assumptions

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

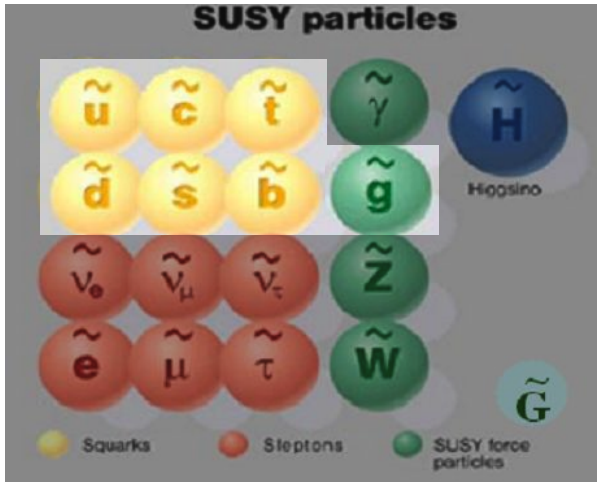
If conserved, SUSY particles need to be **pair-produced** and exist a **LSP** (dark matter candidate)

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

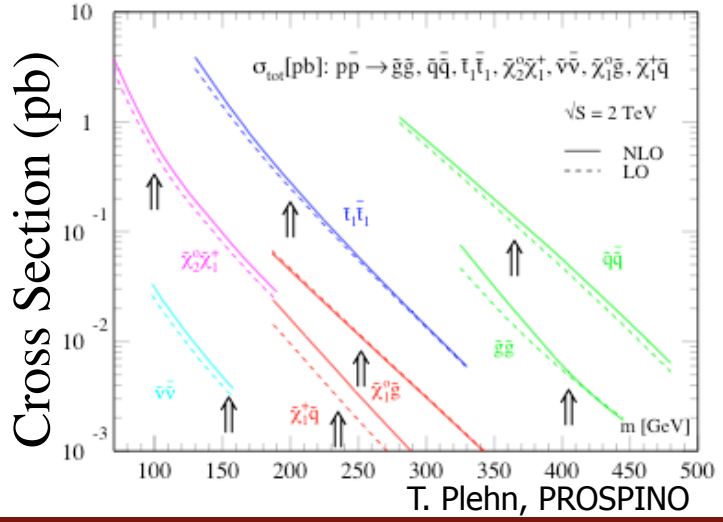
m_0, $m_{1/2}$, A_0, tanβ, signμ

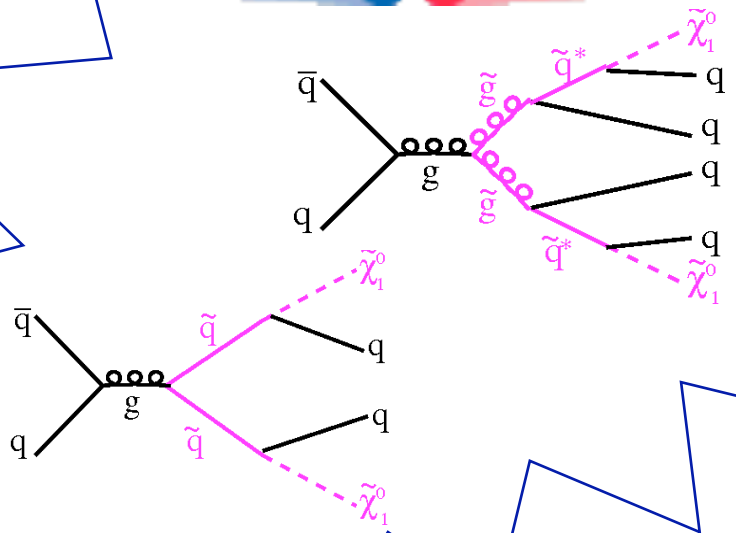


Squarks and Gluinos



Squarks and Gluinos may be copiously produced (strong interaction)





Very massive particles

Presence of neutralino (LSP)

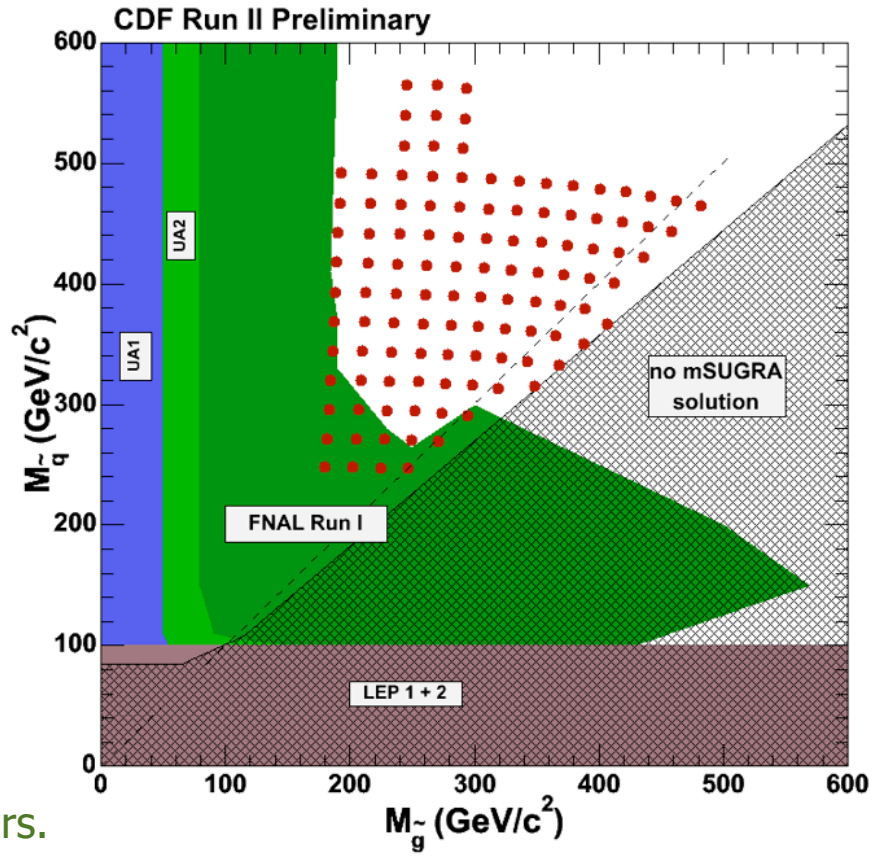
Multiple Jets

Missing Transverse Energy (MET)

Signal Generation

- ✓ Used PYTHIA Tune A and considered the four 2→2 sub-processes normalised to NLO using **PROSPINO** with appropriate renormalisation and factorisation scales:
  - gluino-gluino → μ = Mgl
  - gluino-squark → μ = 1/2 * [Mgl + Msq]
  - squark-squark → μ = Msq
  - squark-antisquark → μ = Msq
- ✓ Input masses, mixing and couplings generated using ISASUSY 7.74
- ✓ PDF **CTEQ6.1M**
- ✓ Remove stop and sbottom from 2-to-2 processes (avoid too much dependence with the mixing parameters).

R-parity conservation assumed
mSUGRA scenario: A_0=0, **tanβ=5**, μ<0



Squark masses: average of four squark flavours.

Backgrounds

QCD multijets production dominates:

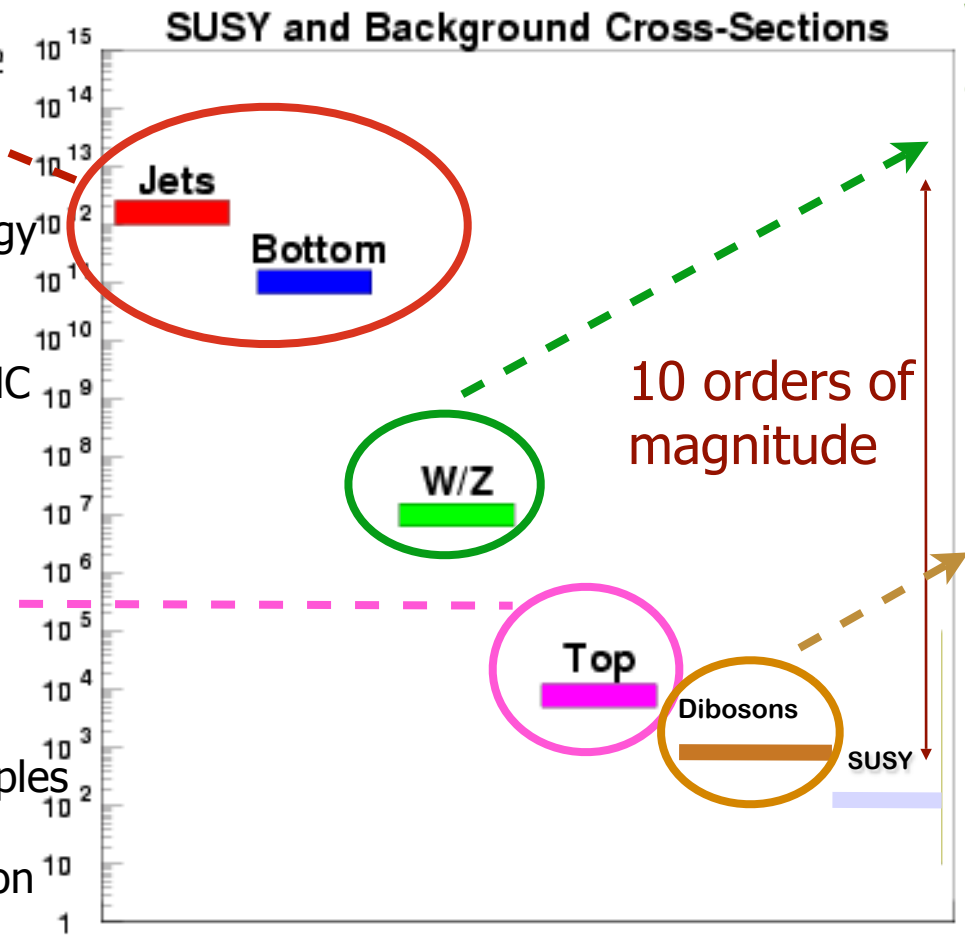
★ MET due to jet energy mismeasurements

★ Use Pythia Tune A MC normalised to data in low-missing E_T region

Top

★ m_t = 172 GeV/c^2

★ use Pythia MC samples normalised to the theoretical cross section σ_{ttbar}= 7.3 pb



W→lν+jets, Z→ll+jets and Z→νν+jets:

★ Use ALPGEN + PYTHIA

★ Normalisation to the inclusive D-Y cross section

DiBoson

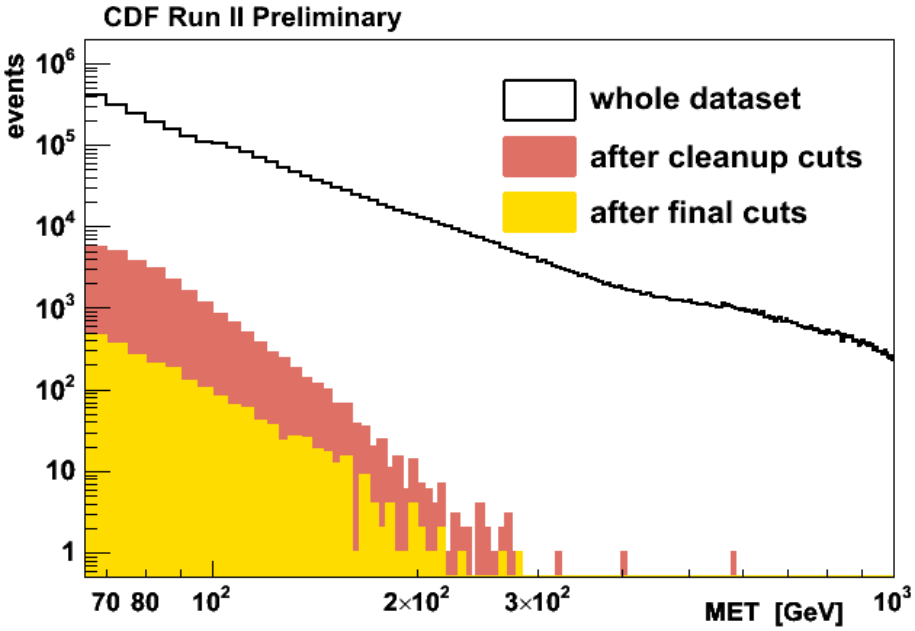
★Use PYTHIA MC normalised to MCFM NLO cross section.

Background Rejection

Beam-related and cosmics

There are **beam-related backgrounds** and **cosmics**.

Removed using vertex information, calorimeter activity with correspondent tracking activity...



QCD multijet rejection

$\Delta\varphi$ (MET, jets) > 0.7 to remove events with MET aligned with one of the jets.

W/Z, dibosons and top rejection

Muon and electron vetoes using **isolated track** information or the electromagnetic energy fraction (**EMF**) of the jets.

Signal Optimisation - I

To further discriminate signal from background:

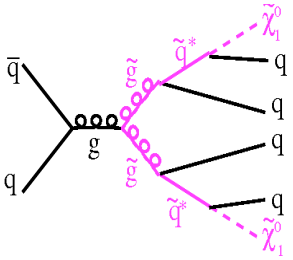
MET, H_T (scalar sum of the main jets) and **E_T** of the jets

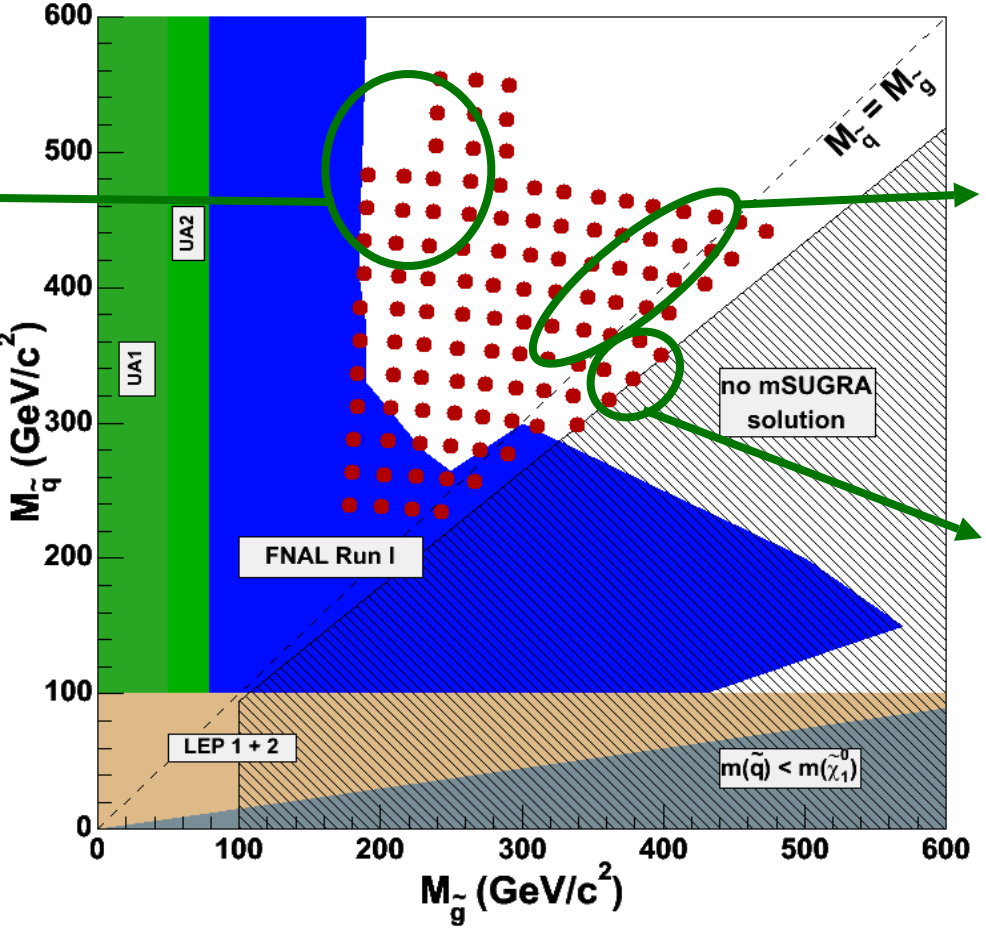
Use different topologies to maximise signal sensitivity and background rejection

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

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

≥ **4 jets expected**





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

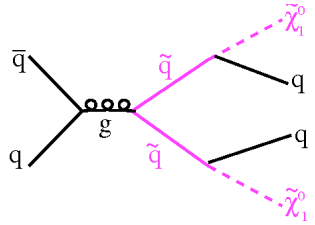
$\tilde{q}\tilde{g}$ prod. dominates

≥ **3 jets expected**

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

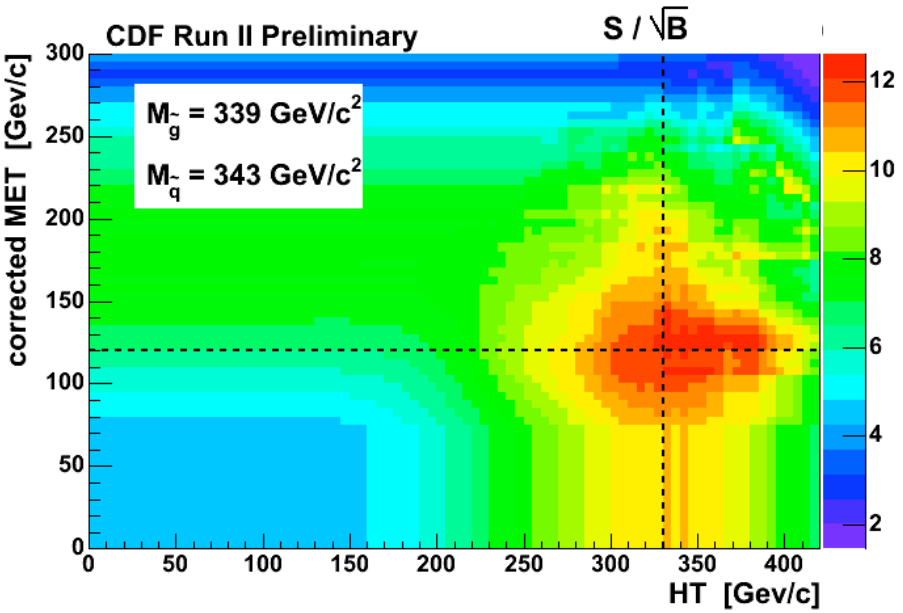
$\tilde{q}\tilde{q}$ prod. dominates

≥ **2 jets expected**



Signal Optimisation - II

5 different set of selections employed to maximise S/√B accross the gluino-squark mass plane.



Thresholds for each region:

[GeV]	**4 jets**	**3 jets (A)**	**3 jets (B)**	**3 jets (C)**	**2 jets**
H_T	280	230	280	330	330
missing E_T	90	75	90	120	180
E_T(jet1)	95	95	120	140	165
E_T(jet2)	55	55	70	100	100
E_T(jet3)	55	25	25	25	--
E_T(jet4)	25	--	--	--	--

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. Uncertainty dominated by signal production at high-x gluon

ISR/FSR:

Estimated using modified parton shower via Λ_{QCD} scale.

BACKGROUNDS

Top → 10% PDF uncert. from theory

Ren. Scale uncert. negligible

ISR/FSR estimated like in the signal.

Dibosons → 10% PDF+renorm. uncert. from theoretical calculations.

Z/W+jets → 10% global uncert. coming from the inclusive cross-section.

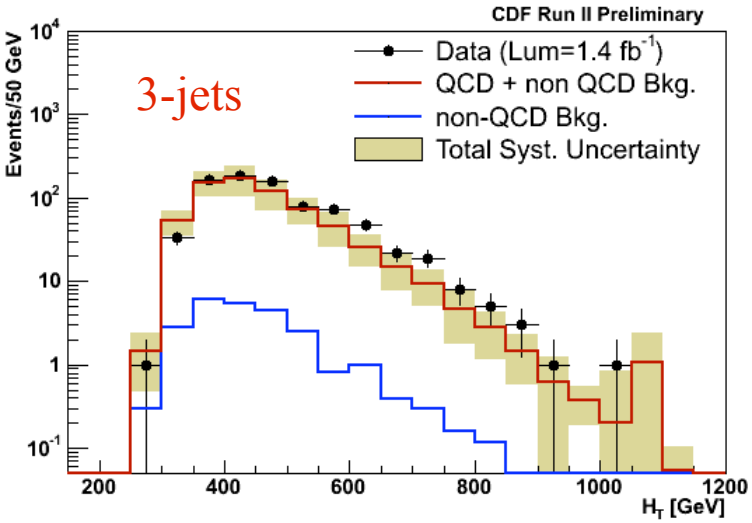
QCD → Uncertainty from normalisation

Background Control

Check that MC describes data *in background dominated regions*. Found **good agreement.**

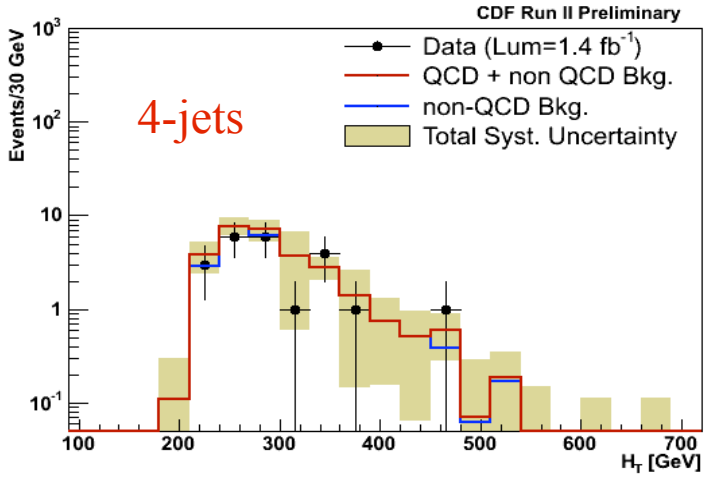
QCD dominated sample:

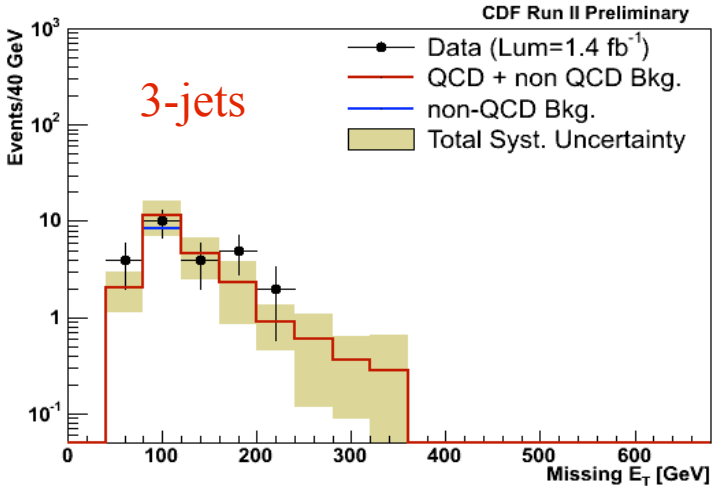
$|\Delta\phi$ (missingET-jets)$|$ cut is reversed to enhance the QCD contribution.



muons dominated sample:
require the presence of **isolated tracks.**

Electrons dominated sample:
Jets almost completely electromagnetic.

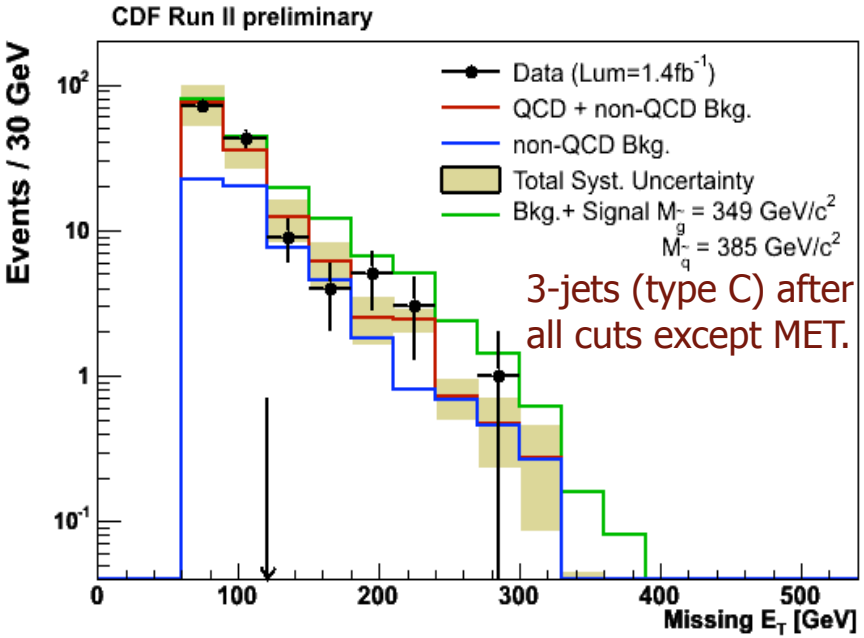


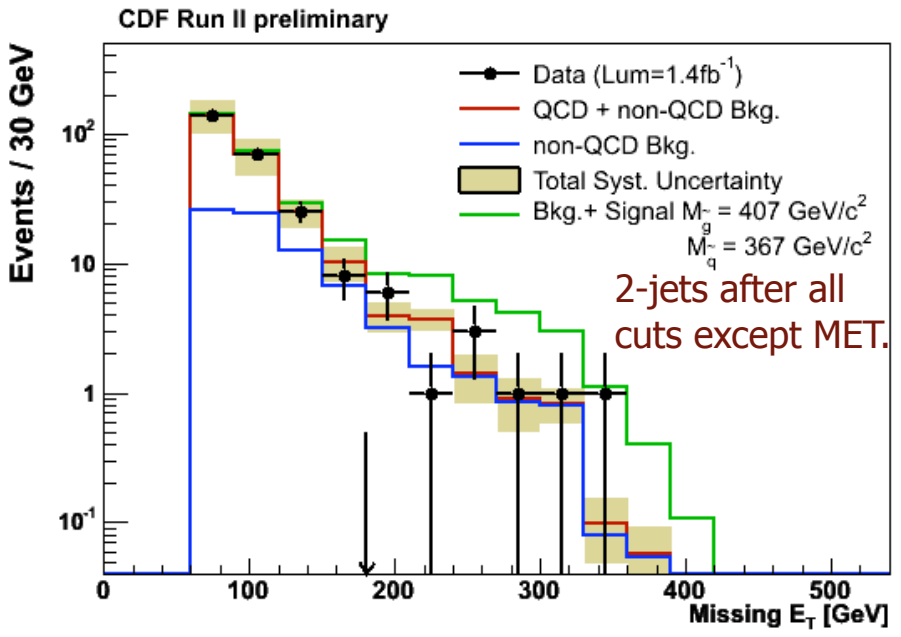


Results

Good agreement with SM expectations in all regions.

Events in 1.4 fb^{-1}	DATA	SM Expected
≥ 4 jets	29	$27 \pm 2 \pm 9$
≥ 3 jets (type A)	616	$607 \pm 16 \pm 146$
≥ 3 jets (type B)	166	$154 \pm 7 \pm 44$
≥ 3 jets (type C)	22	$25 \pm 2 \pm 8$
≥ 2 jets	13	$11 \pm 2 \pm 3$

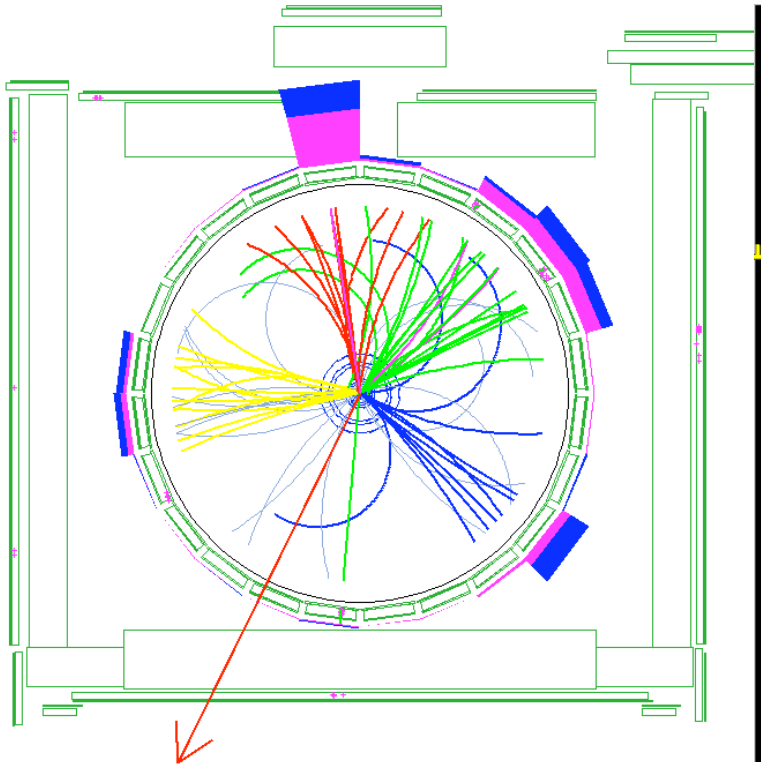




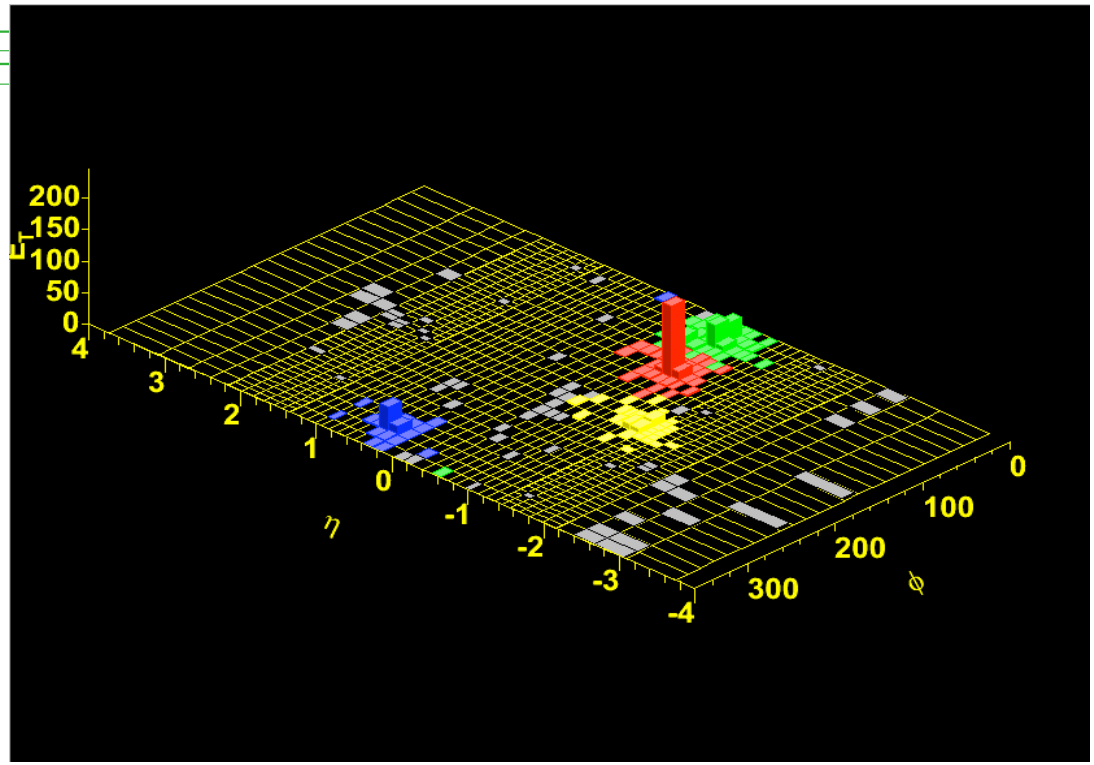
One of the Events

MET=196 GeV H_T=470 GeV **3-jets (type C)**

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



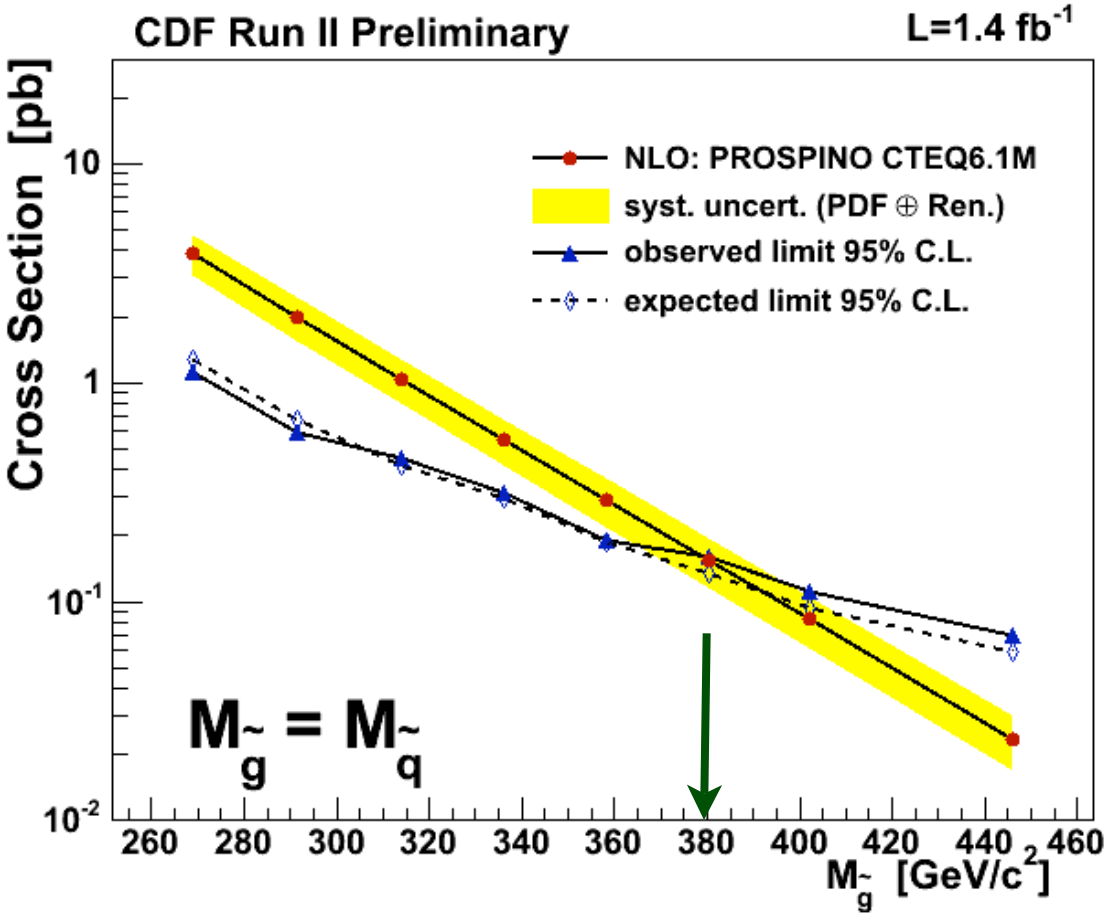
R-ϕ view of the detector



η-ϕ view of the detector

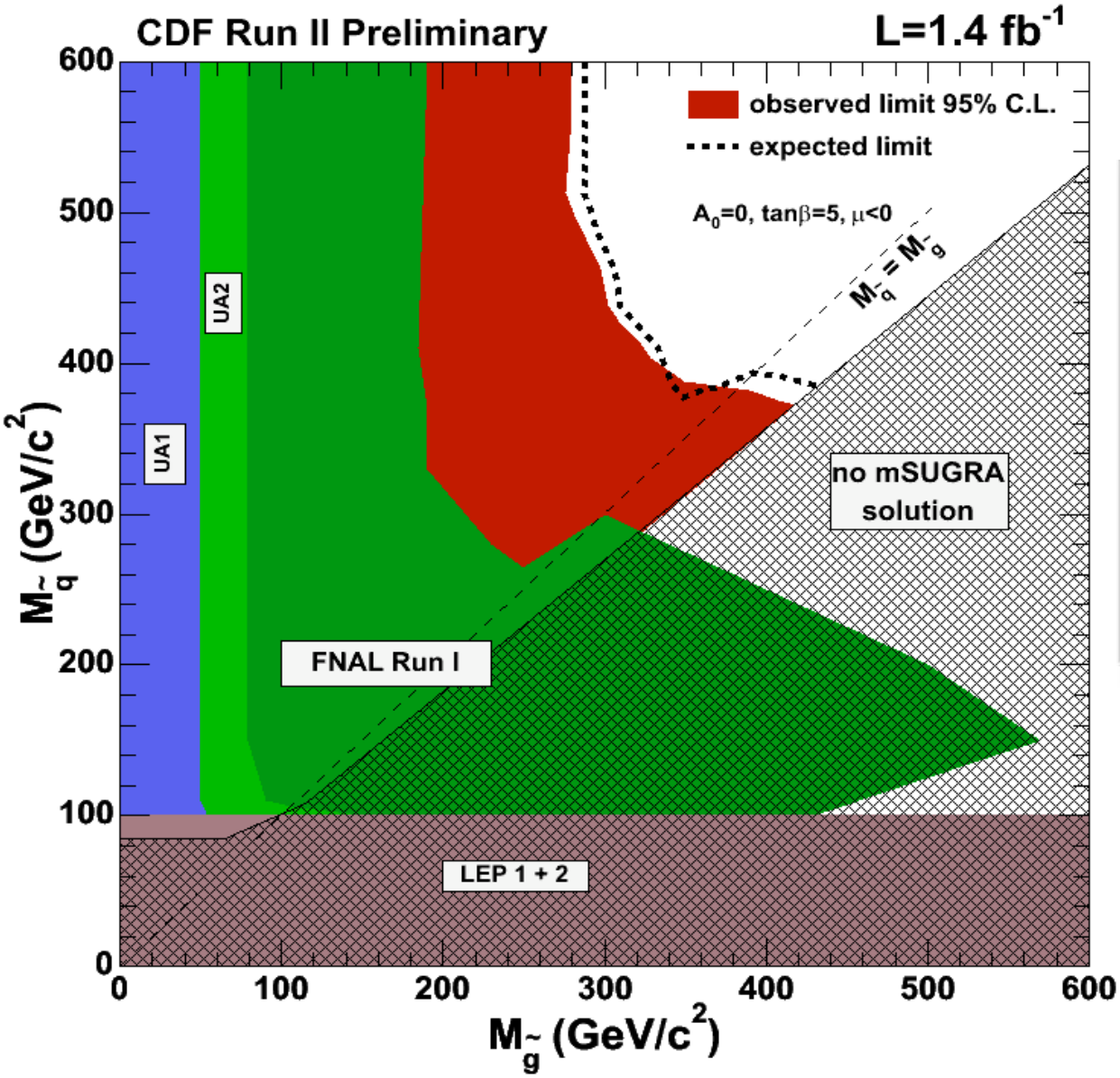
Limit Calculation

- ✓ Bayesian approach: curves at 95% C.L.
- ✓ Include correlations between signal and background systematic uncertainties
- ✓ Systematic uncertainties on signal cross section **included** in the limit calculation (15-50% from PDF+Renormalization scale)
- ✓ Mass limit quoted as the cross point with the nominal NLO prediction.



When gluino and squark masses are similar, limit is set at 380 GeV/c^2

Exclusion Limits

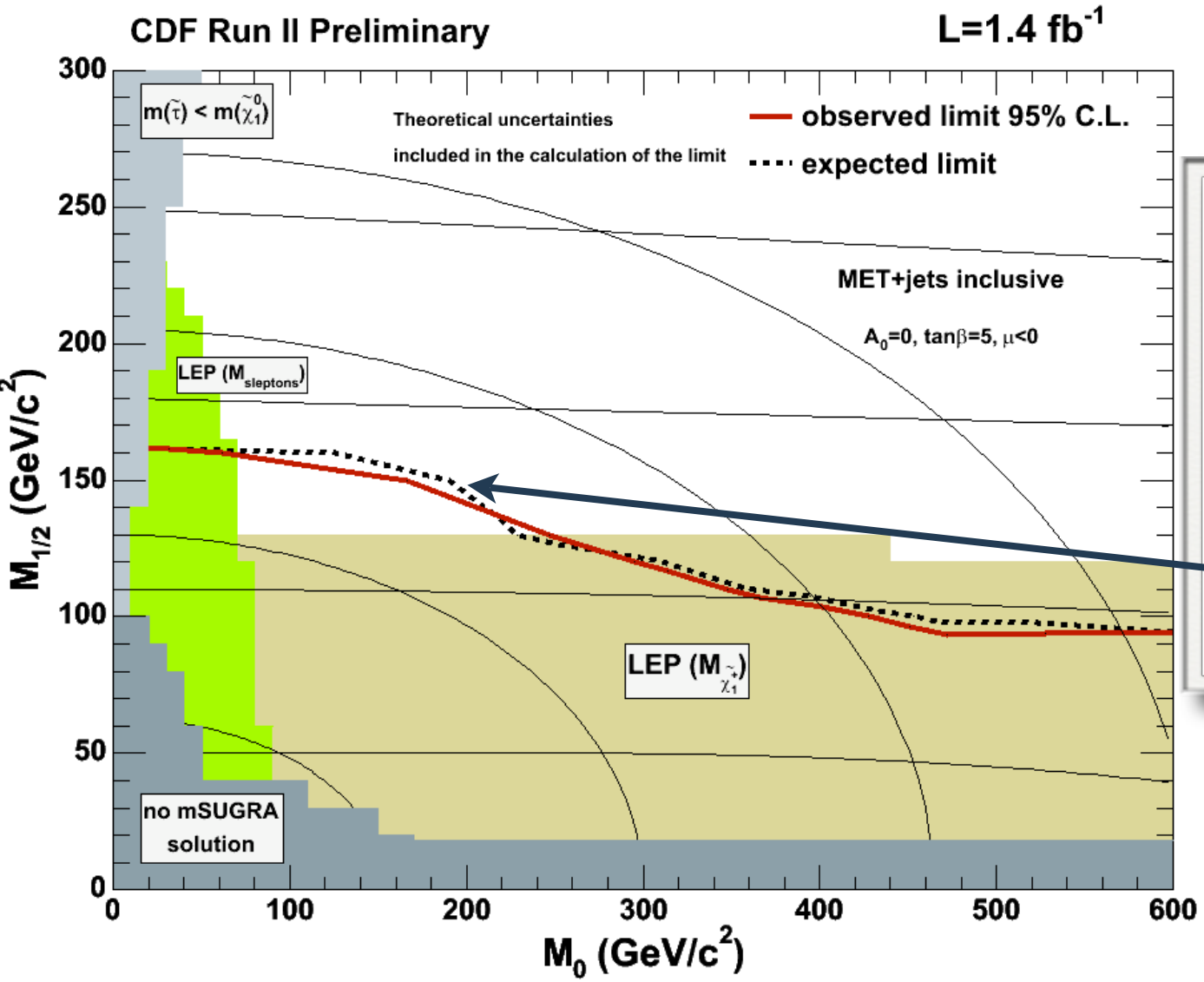


Gluino masses excluded below ~280 GeV/c^2

Squark masses excluded below ~375 GeV/c^2

When $M_{\tilde{q}} \sim M_{\tilde{g}}$: masses excluded below ~380 GeV/c^2

Limits on M_0 - $M_{1/2}$ Plane



Exclusion limit expressed in terms of M_0 and $M_{1/2}$ mSUGRA parameters.

Better limits respect to LEP chargino and sleptons searches in the region $75<M_0<250$ and $130<M_{1/2}<165$ GeV/c^2

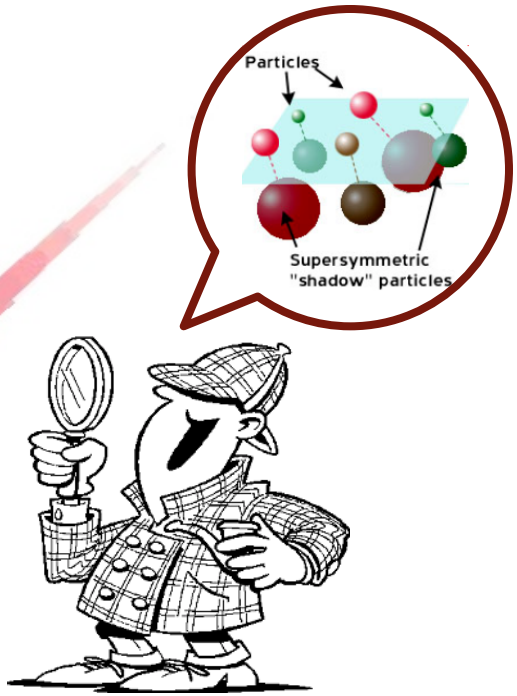
Summary & Conclusions

✓ No evidence of Squarks and Gluinos in samples of ~1.4 fb^{-1} has been found in CDF dedicated inclusive analyses.

✓ Complex analysis considering different final states performed.

✓ Limits are set for a particular mSUGRA scenario: $A_0=0$, $\tan\beta=5$ and $\mu<0$.

Gluino masses excluded below ~280 GeV/c^2
Squark masses excluded below ~375 GeV/c^2
When $M_q \sim M_g$: masses excluded below ~380 GeV/c^2

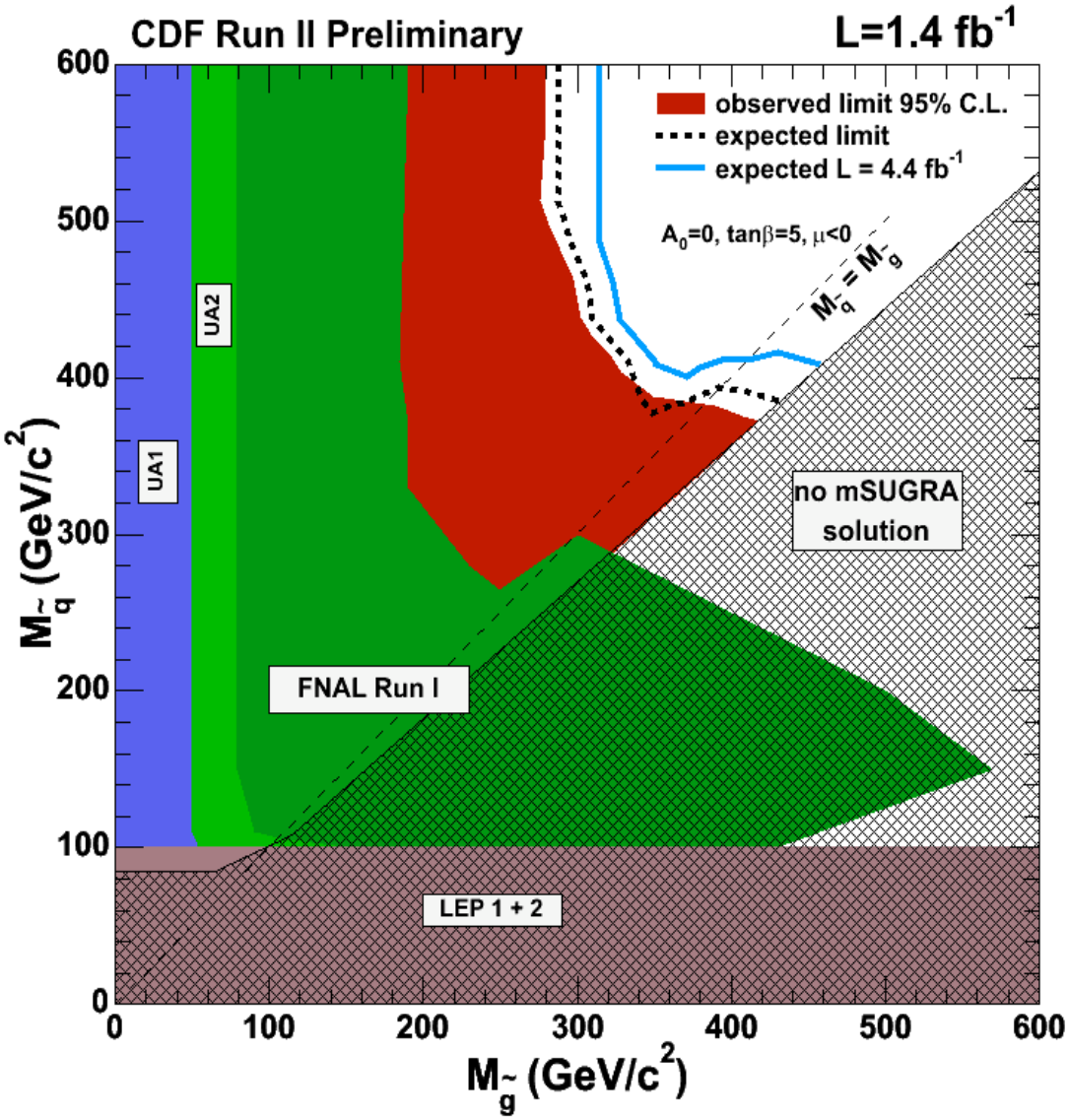


More data will be added soon...

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

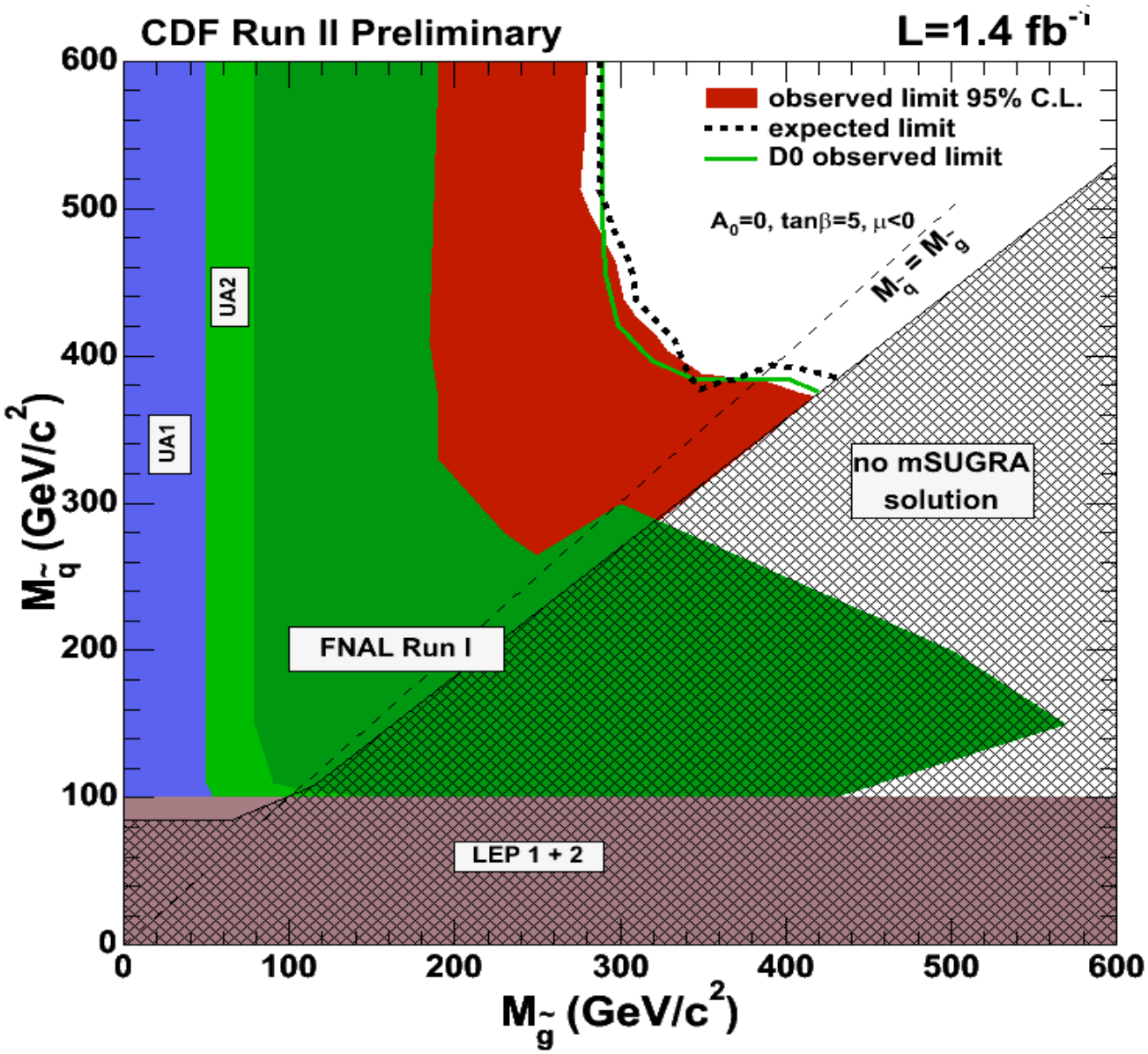
BACKUPS

Future Projections



- ✓ Same relative systematic uncertainties contributions assumed
- ✓ Number of signal and background events and statistical uncertainties scaled according to the luminosity
- ✓ When similar masses of gluino and squarks, mass limits are extended until ~ 400 GeV/c^2 for 4.4 fb^{-1}

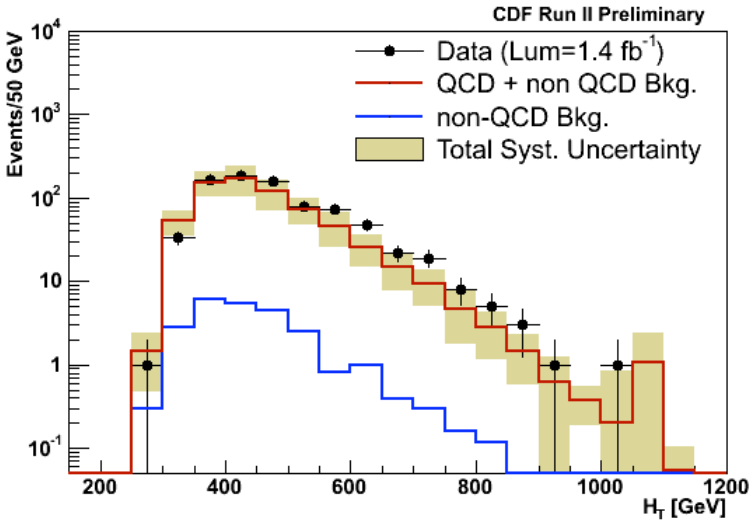
CDF and D0 Comparison

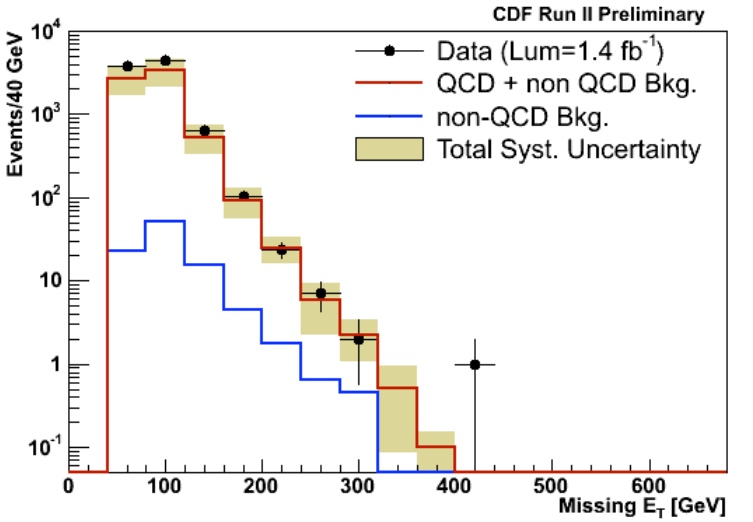


CDF and D0 have very similar results

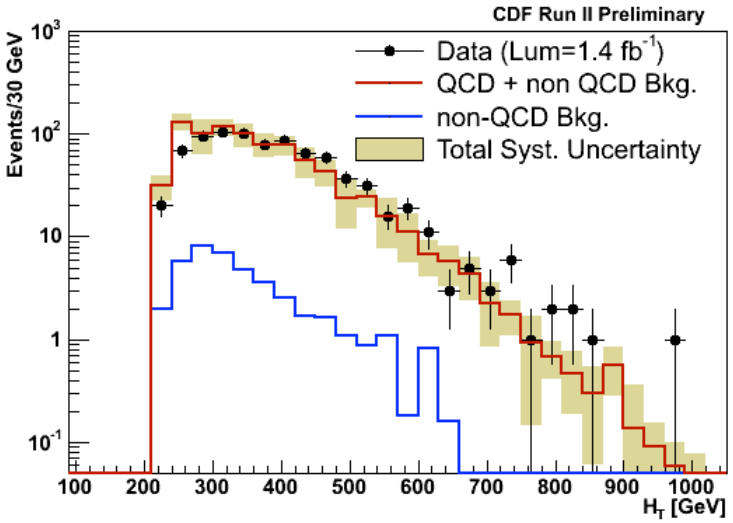
Reverse Δφ Cuts

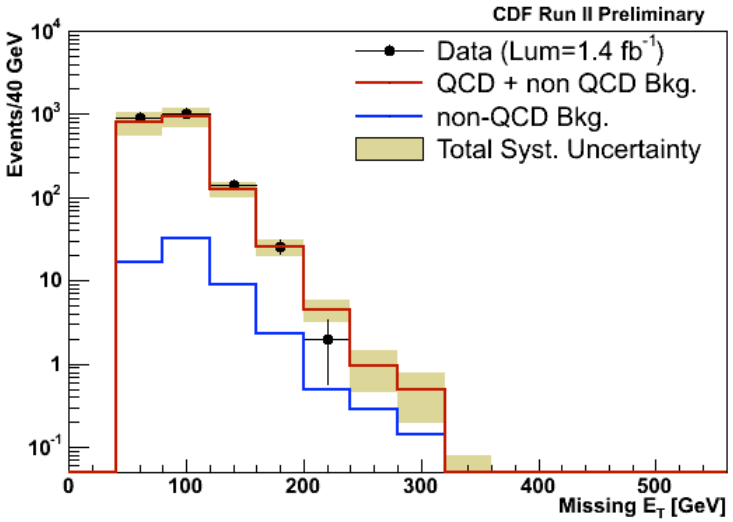
HT and MET for 3-jets zone C





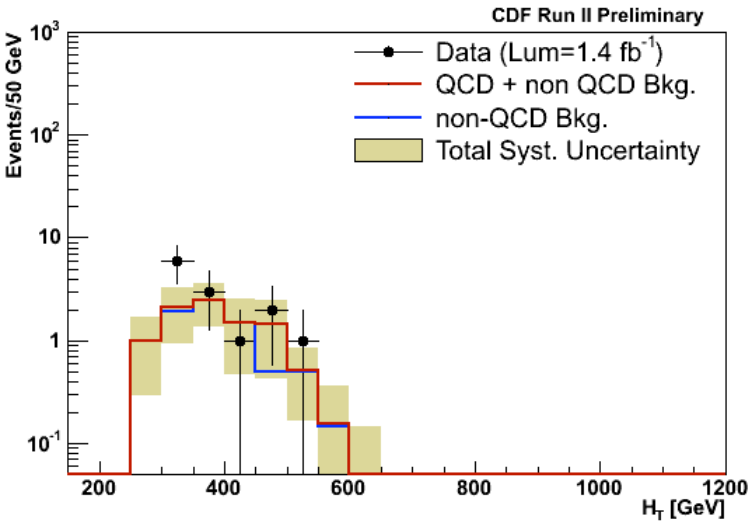
HT and MET for 4-jets

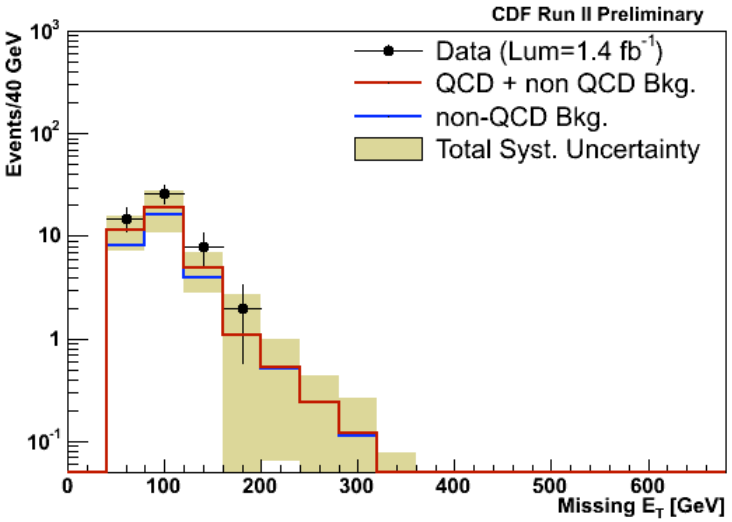




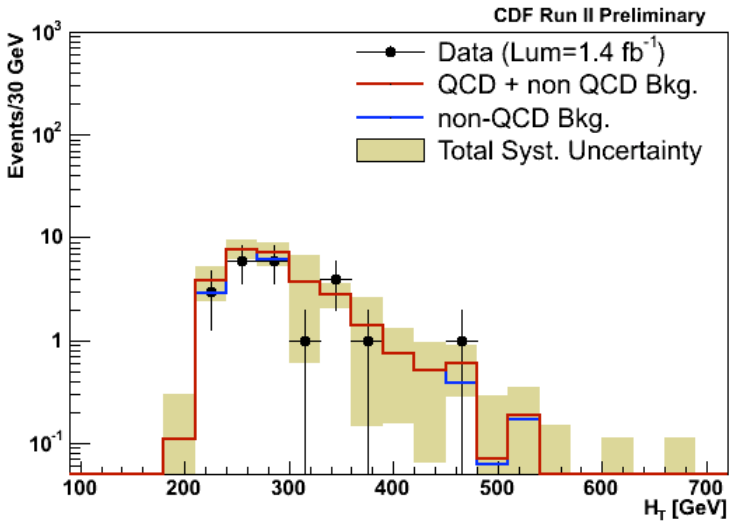
Reverse EMF Cuts

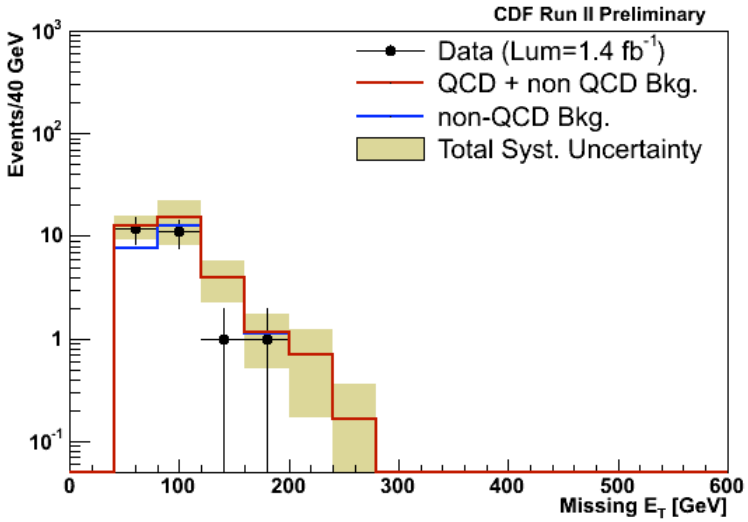
HT and MET for 3-jets zone C





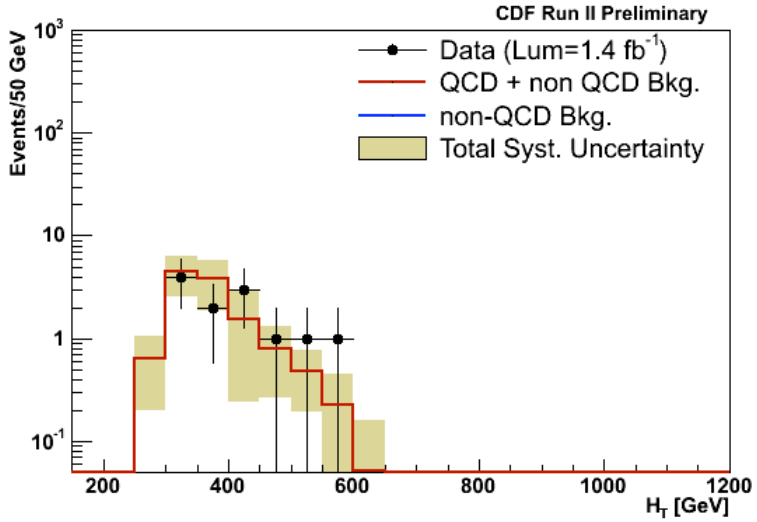
HT and MET for 4-jets

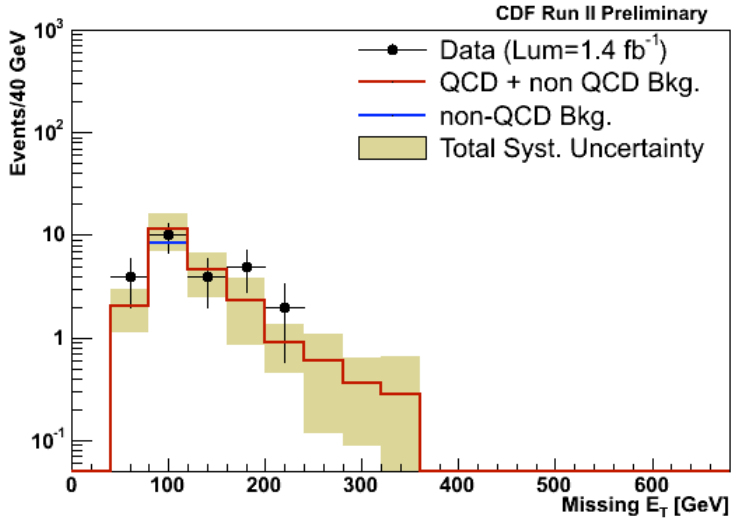




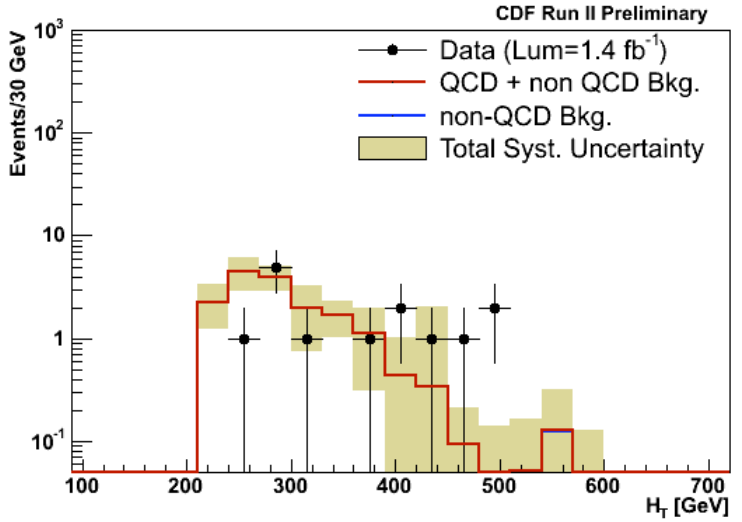
Reverse Muon Veto Cuts

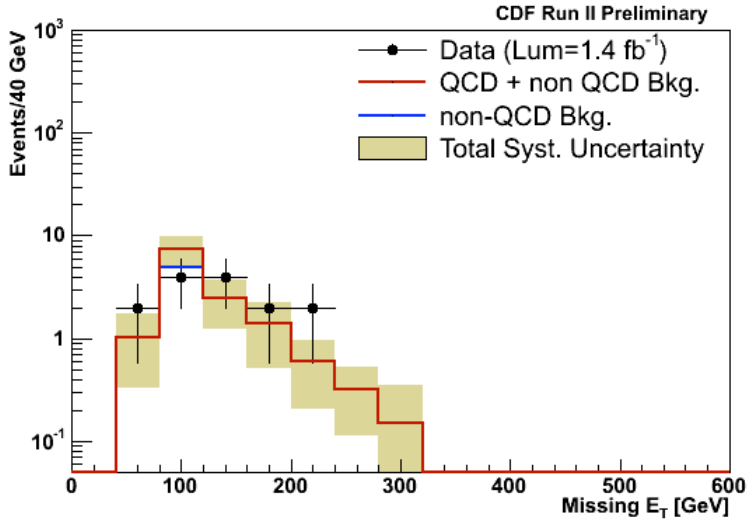
HT and MET for 3-jets zone C



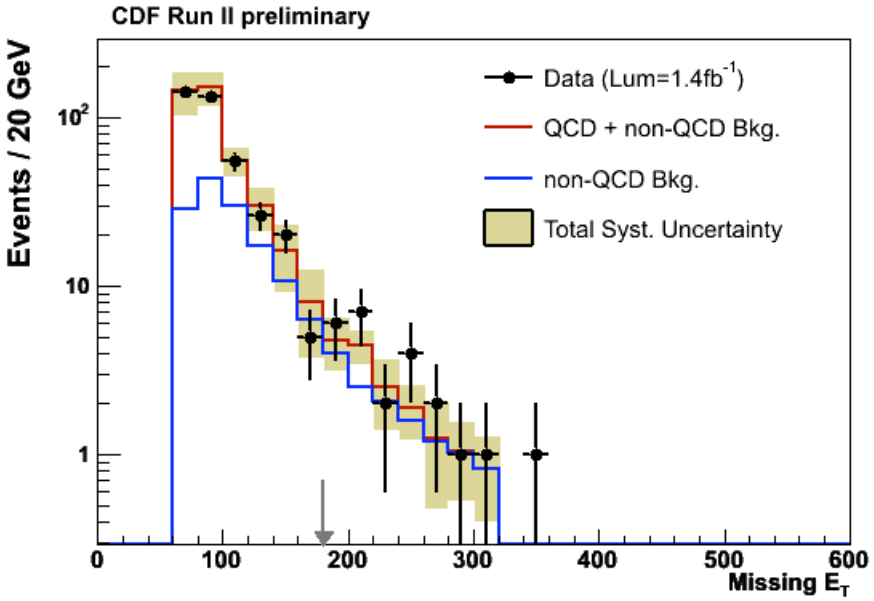


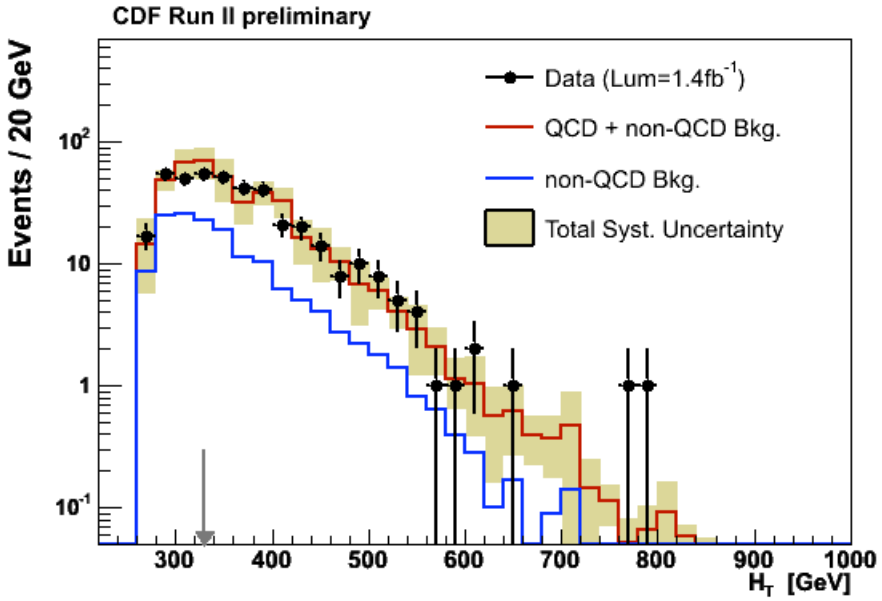
HT and MET for 4-jets





Example of 2-Jets Case





MET and HT distributions after 2-jets selection with neither MET nor HT final cuts applied.