Search for SUSY Signatures with jets and photons

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For the CDF Collaboration

SUSY09

Boston MA, USA

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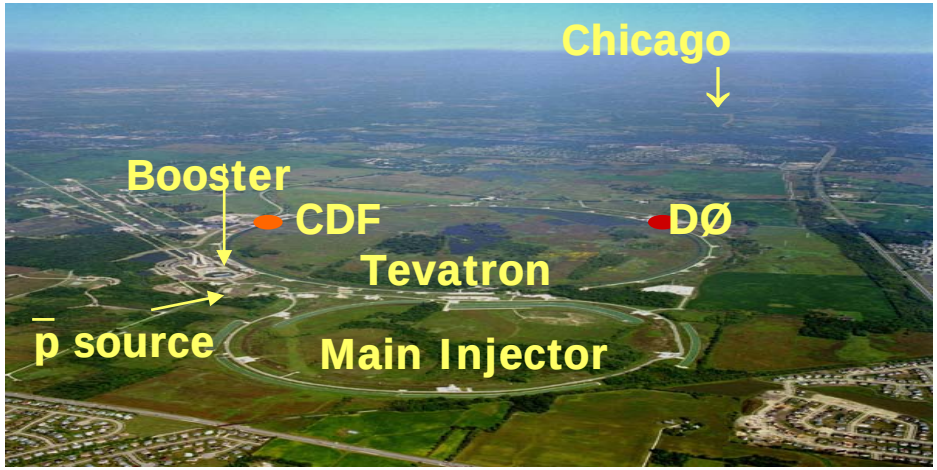
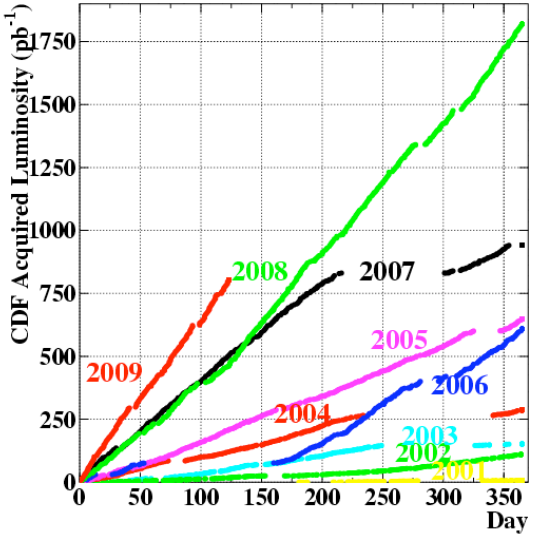
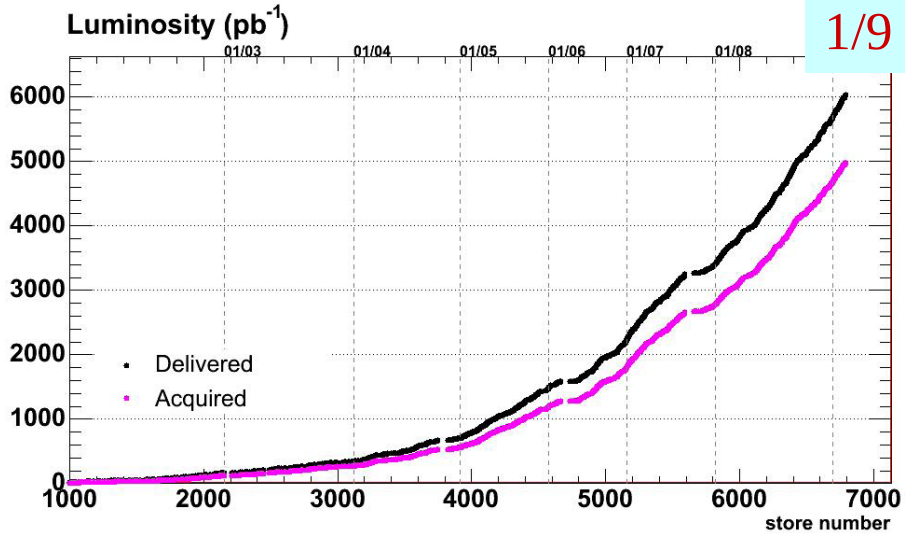
Outline

- Introduction
- Searches using jets
  - Squark and Gluino Search
  - Sbottom Searches
  - Stop Searches
- Searches with photons
  - Single Delayed Photons
  - Diphoton+MET
- Conclusions

Tevatron



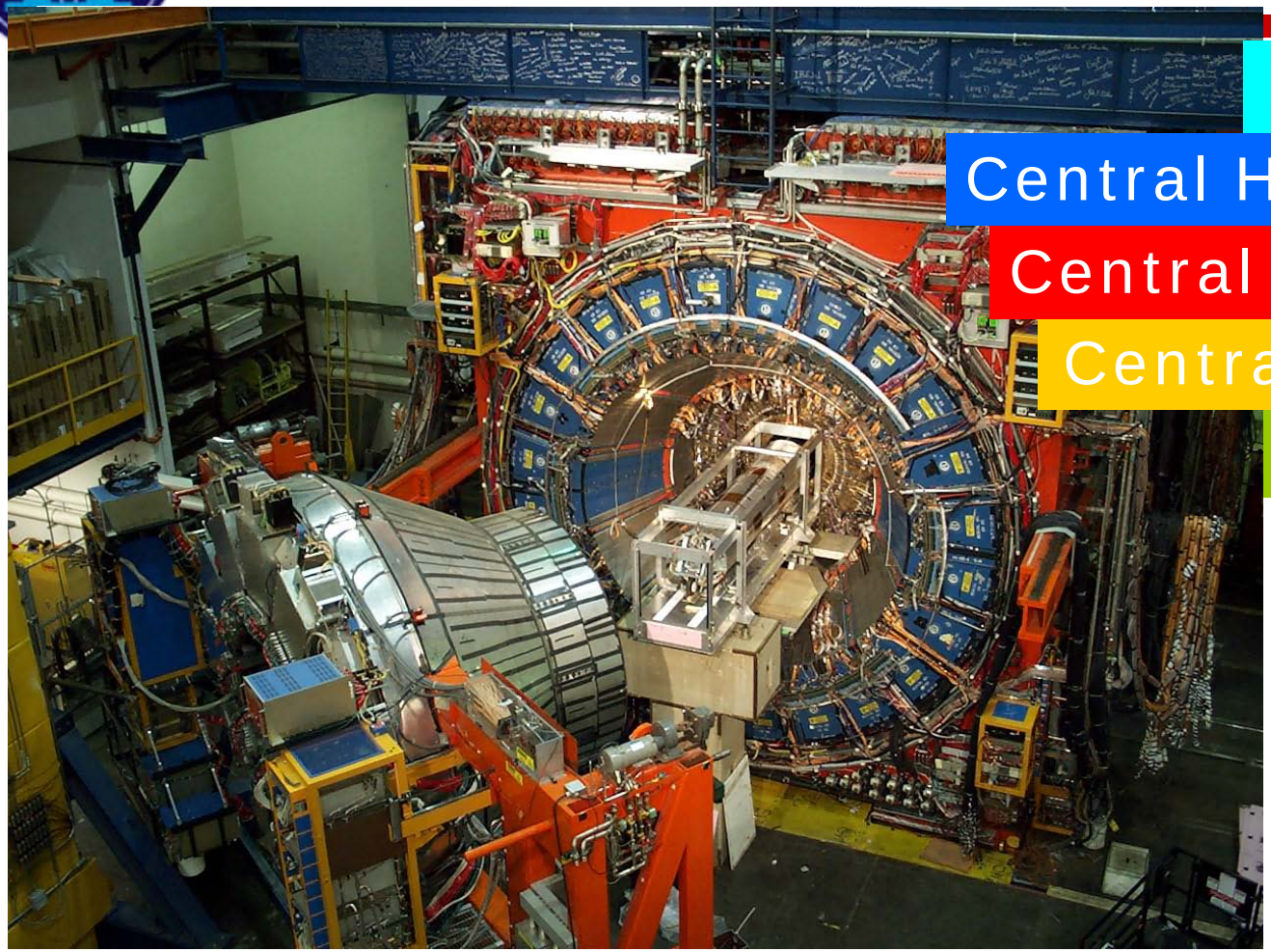




1/9

- Proton-antiproton Collider
  $\sqrt{s}$ = 1.96 TeV
- Integrated luminosiy
  > 6.8 (5.6) fb^{-1} delivered (on tape)
- Typical initial luminosity
  330 10^{30} cm^{-2} s^{-1}
- Integrated Luminosity/week (month)
  74 pb^{-1} (260 pb^{-1})

The CDF Detector



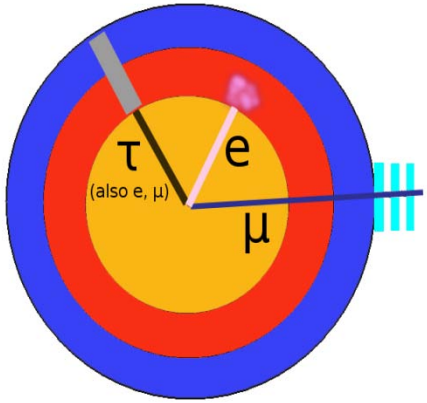
Muon chambers

Central HAD Calorimeter

Central EM Calorimeter

Central Outer Tracker

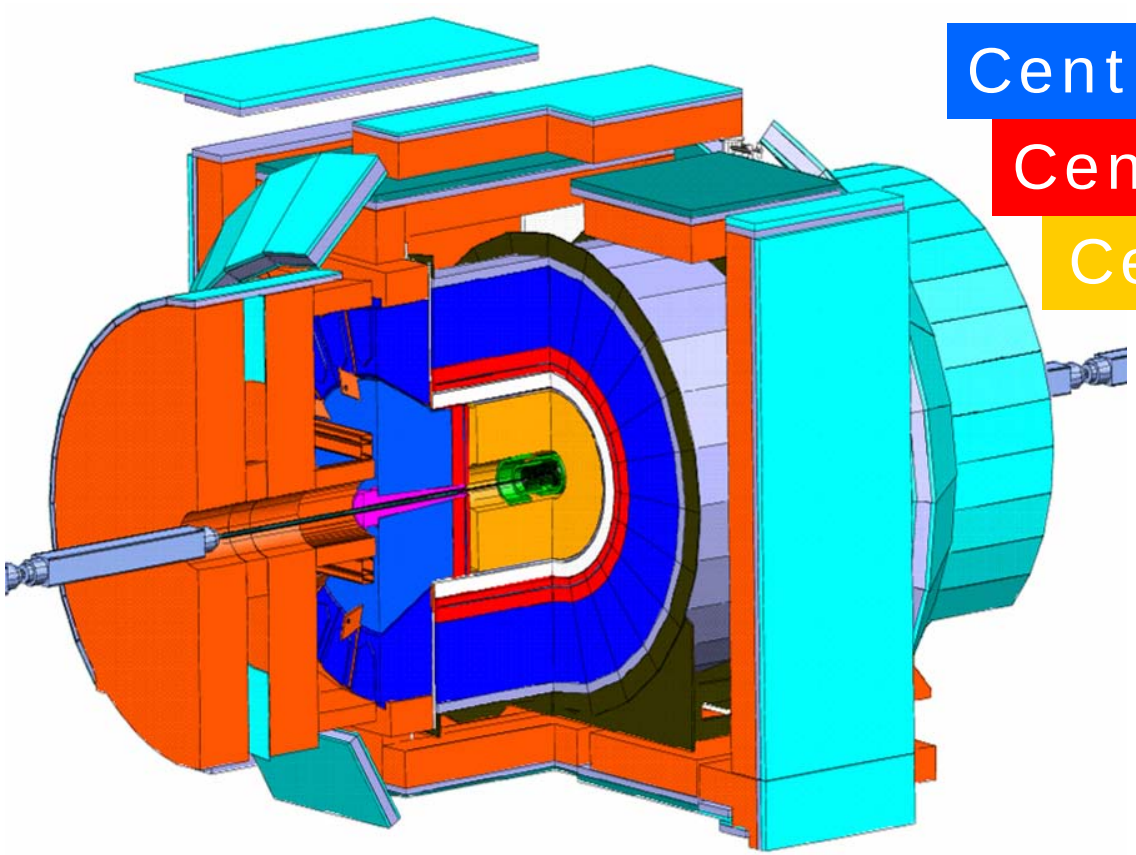
Silicon Tracker



Powerful multi-purpose detector

High quality identification for electrons, muons, taus, jets, missing energy, photons, b's etc.

The CDF Detector



Muon chambers

Central HAD Calorimeter

Central EM Calorimeter

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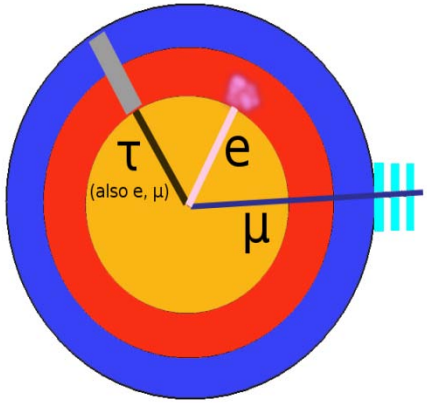


Powerful multi-purpose detector

High quality identification for electrons, muons, taus, jets, missing energy, photons, b's etc.

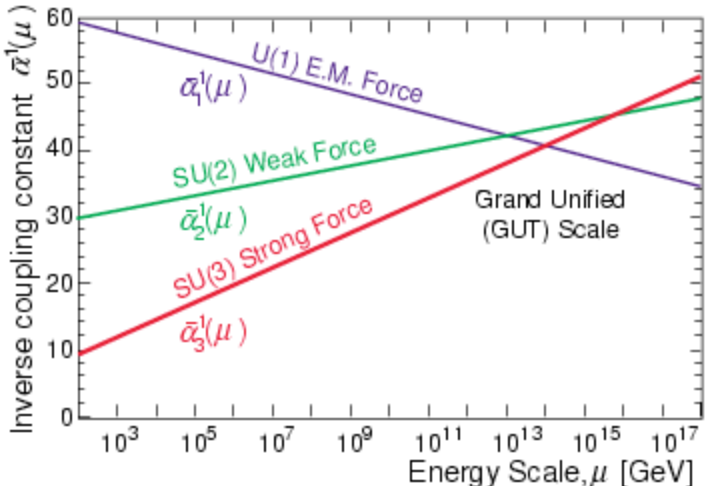
SuperSymmetry

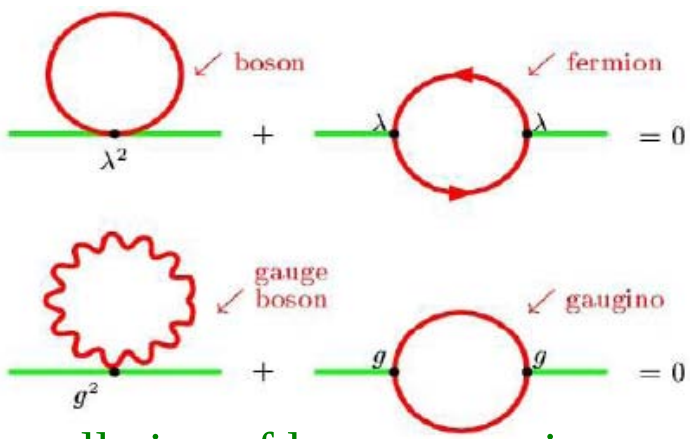
- Space-time symmetry

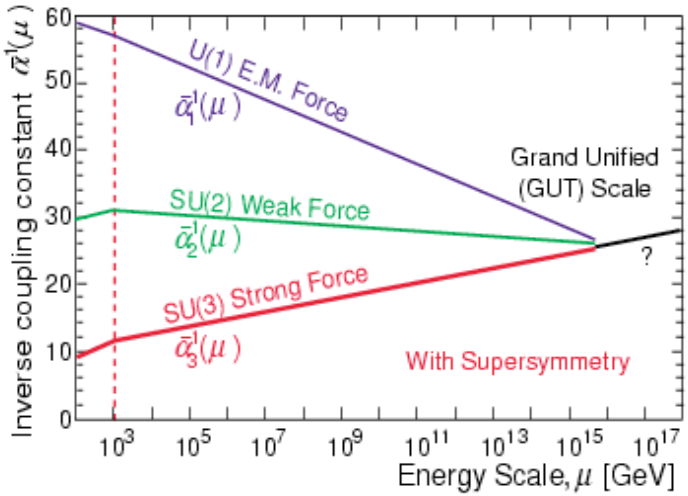
  Q|Fermion> = |Boson>

  Q|Boson> = |Fermion>

- Hierarchy Problem
- Unification of force strength
- Dark Matter Candidates

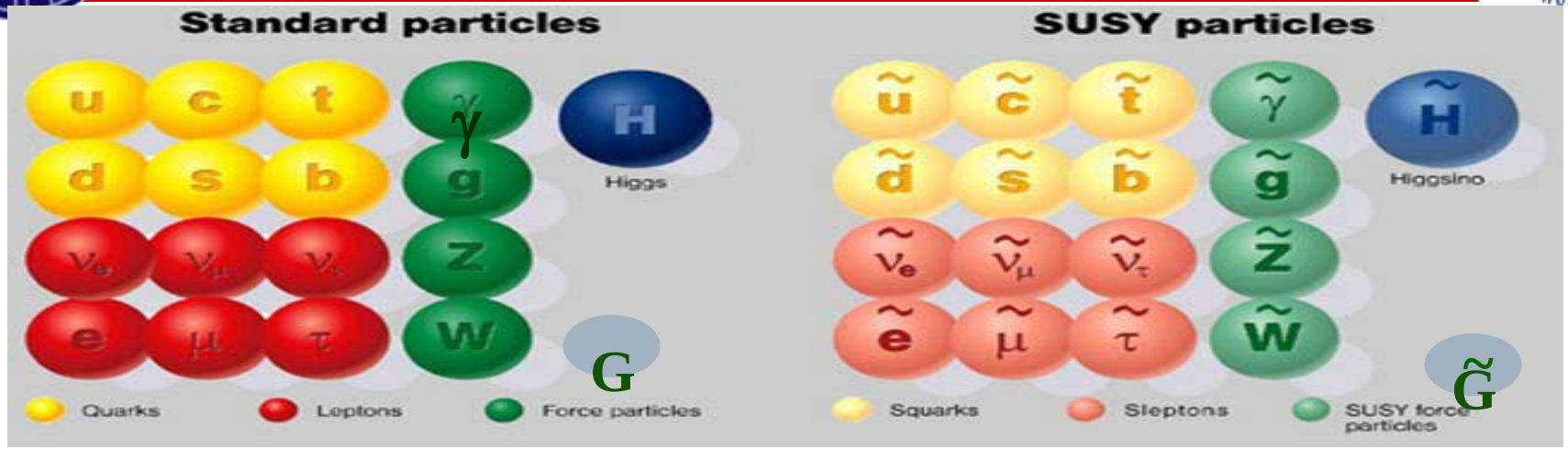






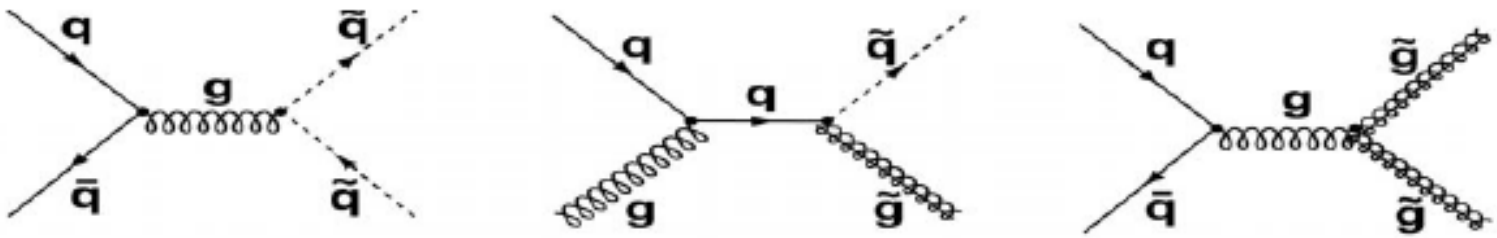
Cancellation of loop corrections as susy particles contribute with opposite sign.

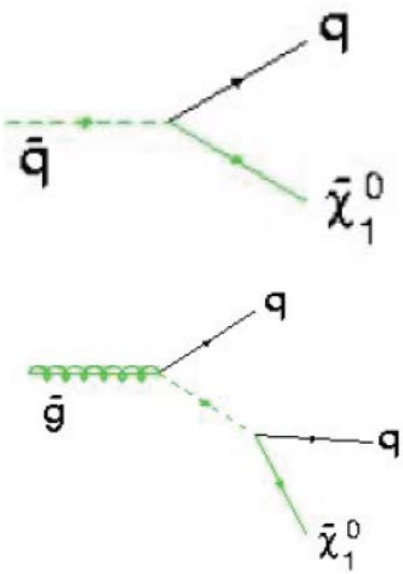
Particles and Super-particles



- SM particles have super-symmetric partners which differ by 1/2 unit in spin
  - **Sfermions** (squarks, selectron, smuon, ...): spin 0
  - **Gauginos** (chargino, neutralino, gluino,…): spin ½
- Two complex Higgs doublets
  - $H_u=(H_u^0,H_u^-),H_d=(H_d^0,H_d^+)\rightarrow H^0,h^0,A^0,H^\pm$
- Charginos $\tilde{W}^\pm,\tilde{H}^\pm \Rightarrow \chi^\pm_{1,2}$
- Neutralinos $\tilde{W}^0,\tilde{B}^0,\tilde{H}^0_u,\tilde{H}^0_d \Rightarrow \chi^0_{1-4}$

Gluinos and Squark Production



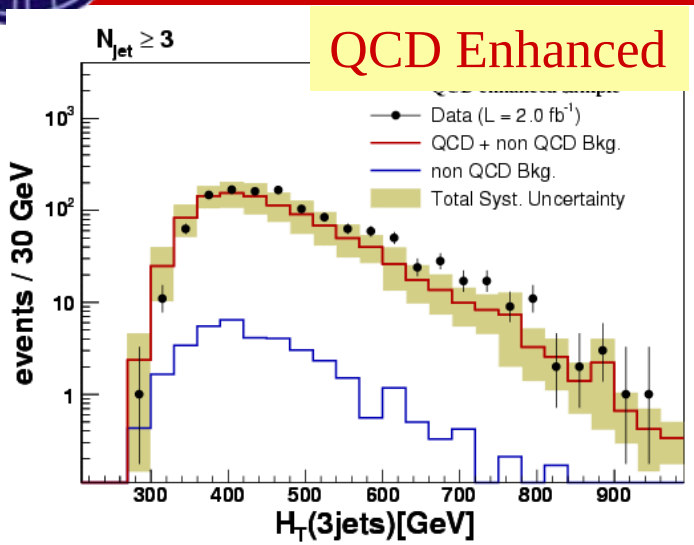


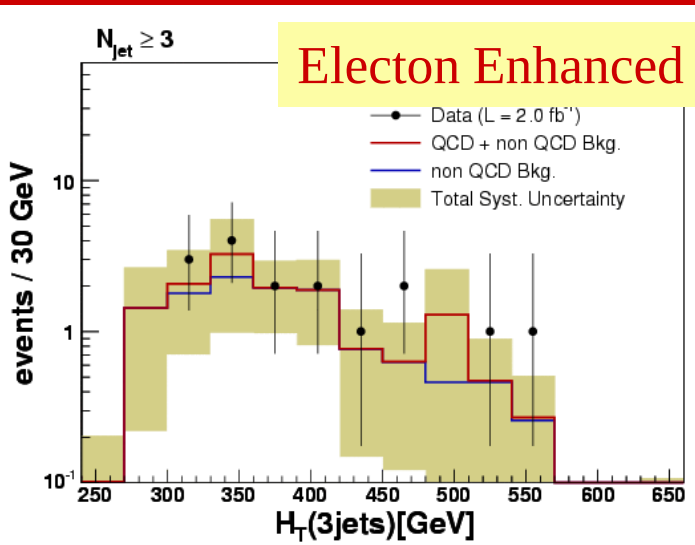
Three optimized analyses
$\geq$ 2 jets + MET
$\geq$ 3 jets + MET
$\geq$ 4 jets + MET

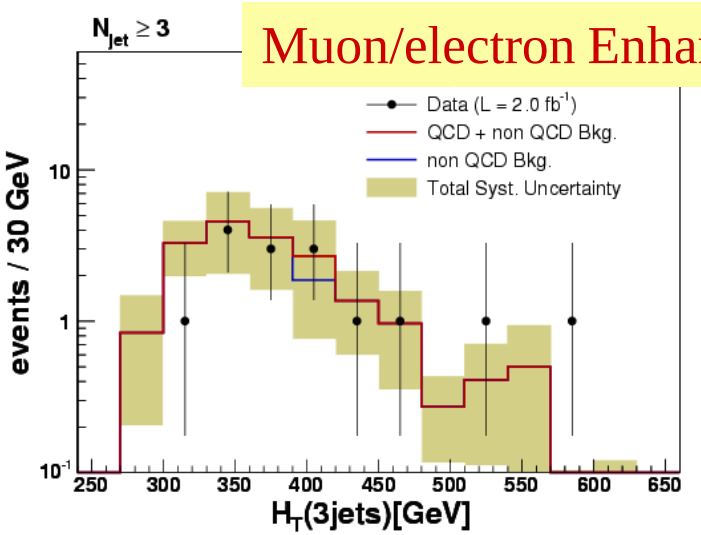
Gluino and Squark Search

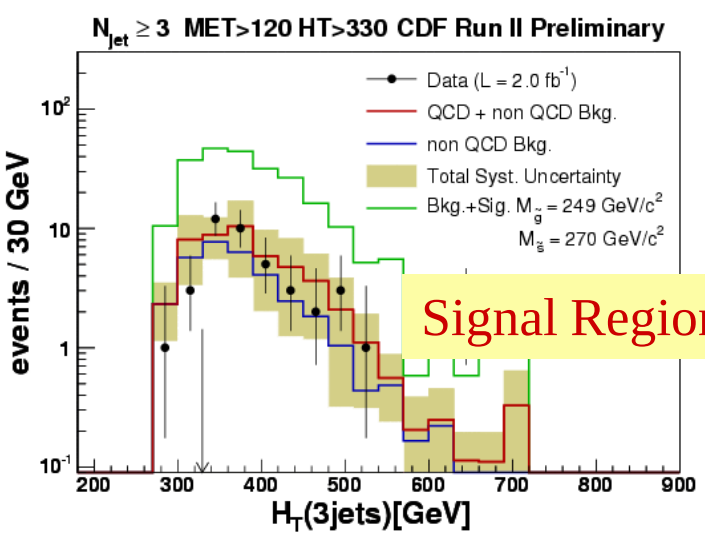
- Event Selection Cuts
  - MET > 70 GeV + cleanup cuts
  - At least two/three/four jets with ET > 25 GeV and $|\eta|<2.0$
  - At least one jet in central region $|\eta| < 1.1$
  - Jet EM Fraction < 0.9
  - $\Delta\varphi$ (MET-jet)> 0.7, first two/three leading jets
    - In case of 2-jets region, $\Delta\varphi$ (MET-3rd jet)> 0.2, if a third jet Et>25 GeV, $|\eta|<2.0$ is present
    - In case of 4-jets region, $\Delta\varphi$ (MET-4th jet)> 0.3
  - No reconstructed Z bosons / No isolated tracks with $\Delta\varphi$ (MET-track)< 0.7
- Verify accuracy of simulations in the control regions
  - QCD Enhanced Regions MET aligned with the one of the jet
  - Electron Enhance Region JetEMF > 0.9
  - Muon Enhanced Regions Z boson or tracks Pt-track>10 GeV, $\Delta\varphi$(MET,track)<0.7
- Using Simulated Events to predict SM backgrounds in signal region

≥3 Jet Analysis

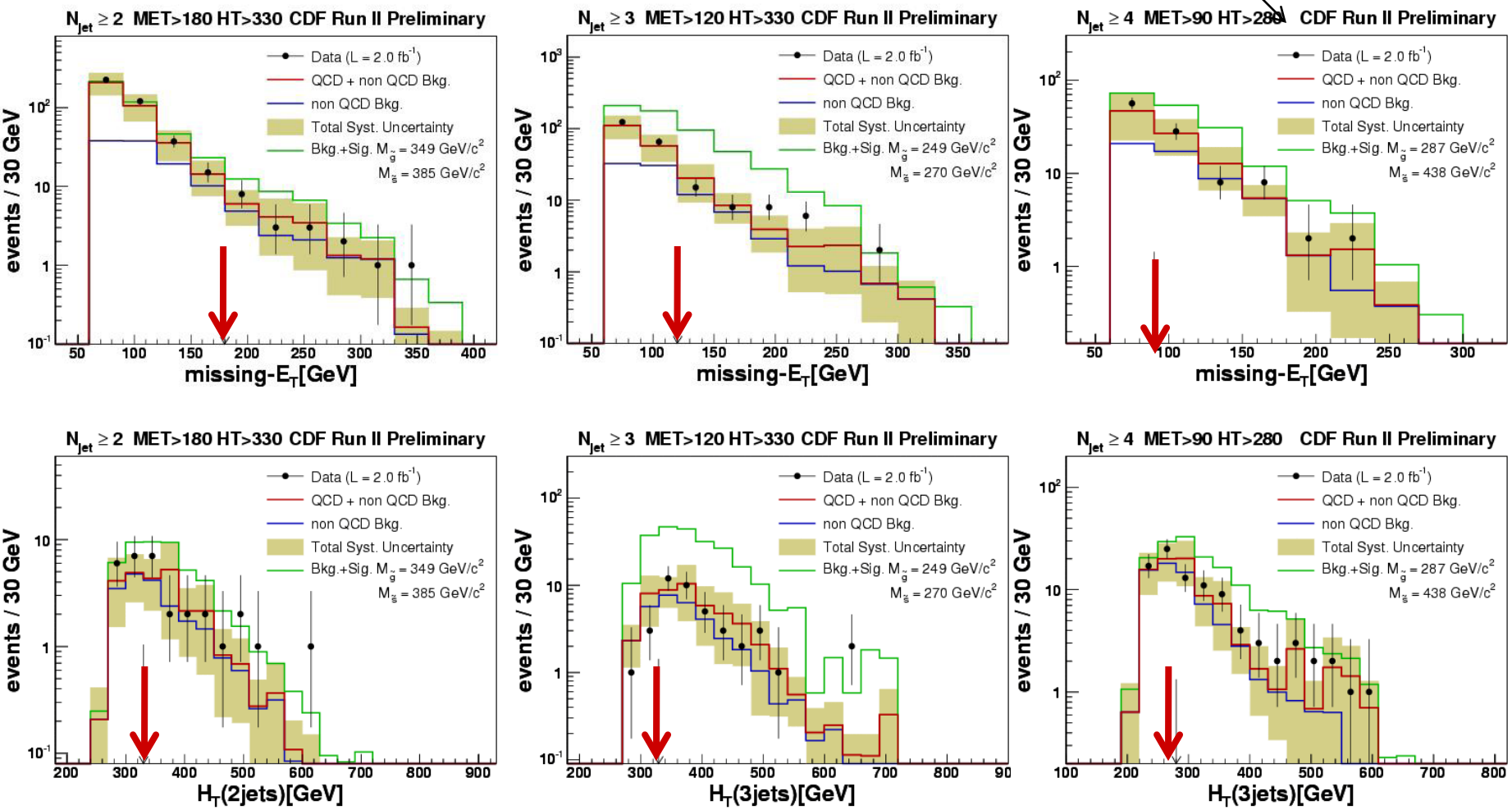




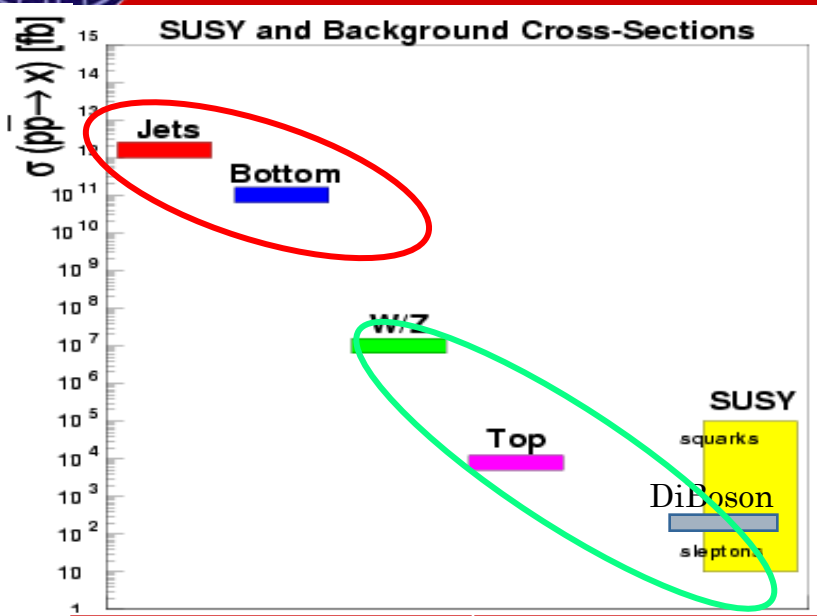




HT and Missing Et distributions



Results



QCD BG Fraction

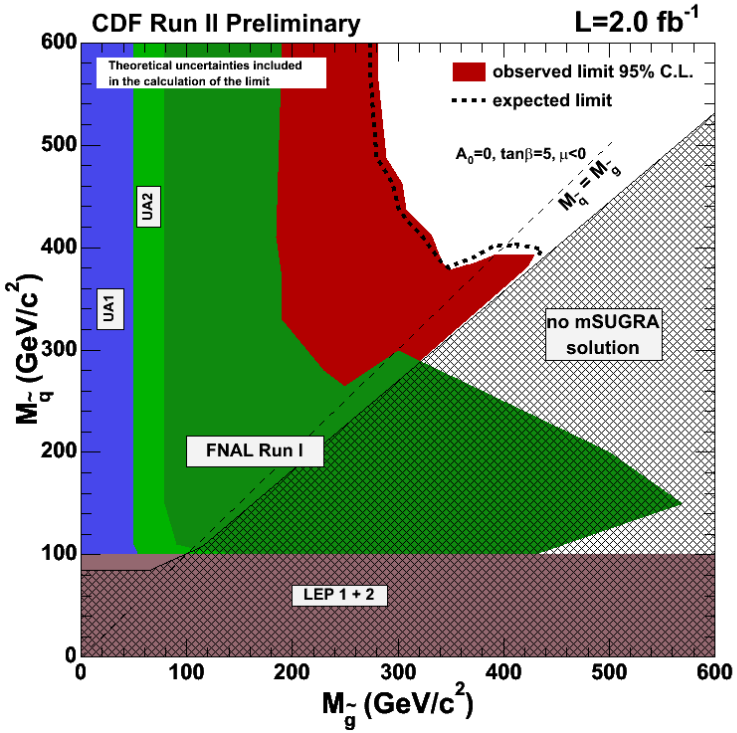
2-jets	25%
3-jets	36%
4-jets	32%

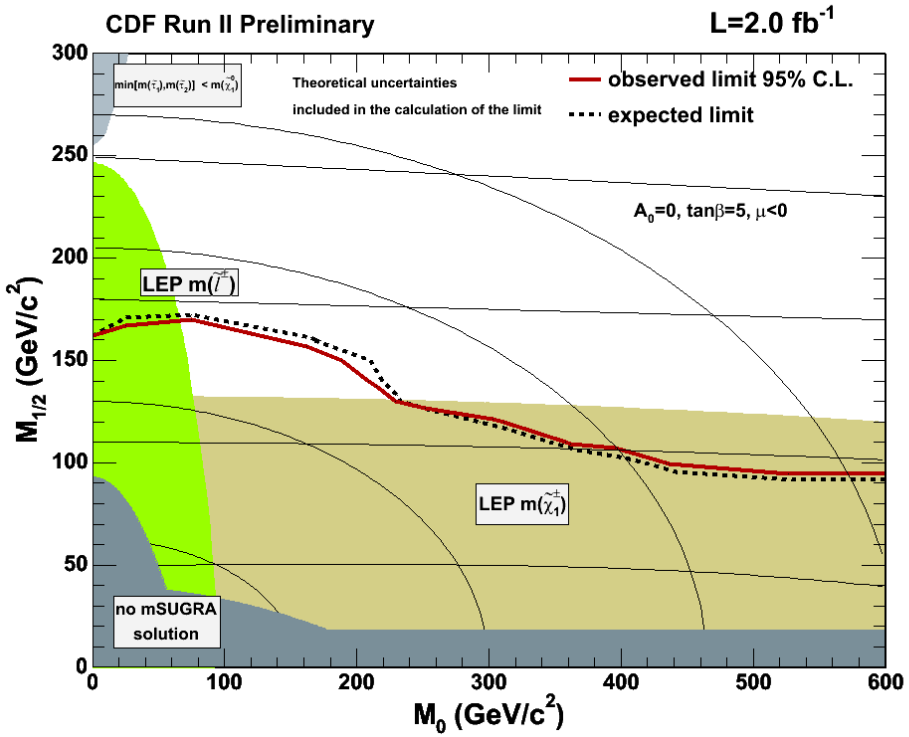
Systematic uncertainty is dominated by jet energy scale.

	2 jets	3 jets	4 jets
Selections	H_T > 330 GeV EtMiss>180 GeV	H_T>330 GeV EtMiss >120 GeV	H_T>280 GeV EtMiss>90 GeV
QCD	4.4	13.3	15.25
EW/top	11.6	24.15	33.19
Expected SM	16±5	37±12	48±17
Observed in data	18	38	45

Exclusion Regions

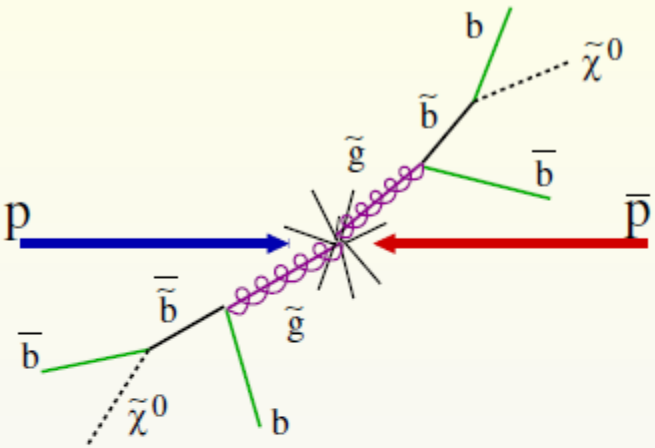
PRL 102, 121801 (2009)





For gluino masses below 280 GeV/c2, arbitrarily large squark masses are excluded at the 95% C.L., while for mass degenerate gluinos and squarks, masses below 392 GeV/c2 are excluded at the 95% C.L.

Sbottom from gluino decays



Final State:

- 4 b-jets
- MET (from $\tilde{\chi}^0$)

- Process strongly dependent on the $\tilde{g}$ cross section production
- Test in the SUSY region $m_t, m_{\tilde{\chi}^+} > m_{\tilde{b}} > m_{\tilde{\chi}^0}$
- $\tilde{g} \rightarrow b\tilde{b}$, $\tilde{b} \rightarrow b\tilde{\chi}^0$ with 100% B.R.

- Pros:
  - Distinctive signature
- Assumptions:
  - M($\tilde{g}$) $\Rightarrow$ low enough to be produced at Tevatron
  - M($\tilde{g}$) $\Rightarrow$ larger than M($\tilde{b}$)

Sbottom from Gluino Decay

- Selection cuts:
- MET trigger (L1,L2,L3 25,35,45 GeV)
- MET >70 GeV+clean-up cuts
- At least 2 Jets

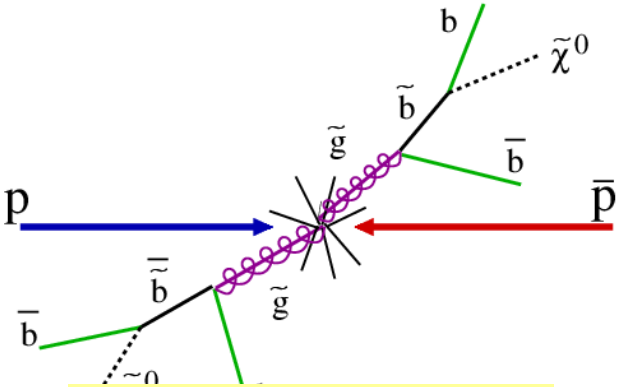
  $E_T > 25$ GeV and $|\eta| < 2.4$

  Leading Jet $E_T > 35$ GeV

  1 Central Jet $|\eta| < 0.9$

  Jet EM Fraction < 0.9
- ≥ 2 b-tagged jets
- Use exclusive one b-tagged jet events as a control region.
- Two Neural-Networks to remove BG
  1. QCD (trained on 1-tag sample)
  2. Top (trained on MC events)

  Both NN use the same variables.



Large $\Delta m = m(\tilde{g}) - m(\tilde{b})$

$m(\tilde{g}) = 335\ GeV$

$m(\tilde{b}) = 260\ GeV$

$m(\chi_1^0) = 60\ GeV$

Small $\Delta m = m(\tilde{g}) - m(\tilde{b})$

$m(\tilde{g}) = 335\ GeV$

$m(\tilde{b}) = 315\ GeV$

$m(\chi_1^0) = 60\ GeV$

Control Regions

Three Control Regions:

Inclusive multi-jet region: MET aligned with 2nd jet

Lepton Region : At least one lepton

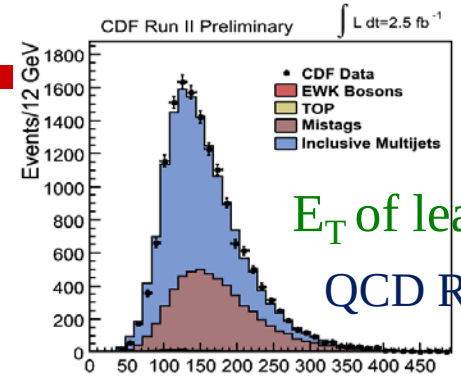
Pre-Optimization Region: Bench mark point to optimize sensitivity

Exclusive One Tags

CDF Run II Preliminary 2.5 fb^{-1}

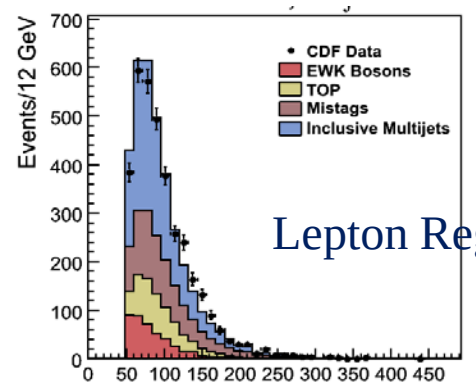
One Exclusive Tag	QCD Region	Lepton Region	Preoptimization Region
W/Z + jets production	84 ± 36	132 ± 57	376 ± 162
Diboson production	4 ± 1	20 ± 5	41 ± 10
Top pair production	60 ± 15	371 ± 93	478 ± 119
Single top production	5 ± 1	34 ± 8	45 ± 11
HF QCD Multijets	9741 ± 4870	195 ± 97	1660 ± 830
Light-flavour contamination	5430 ± 2226	190 ± 78	919 ± 377
Total expected	15325 ± 5355	943 ± 166	3520 ± 934
Observed	15390	890	3525

Good agreement

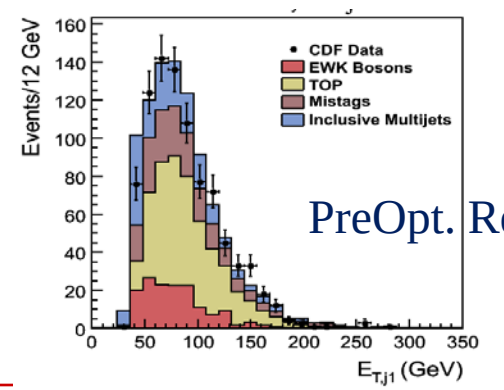


E_T of lead jet

QCD Regions



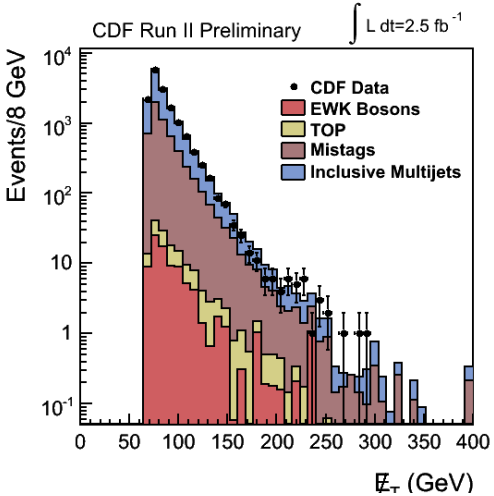
Lepton Regions

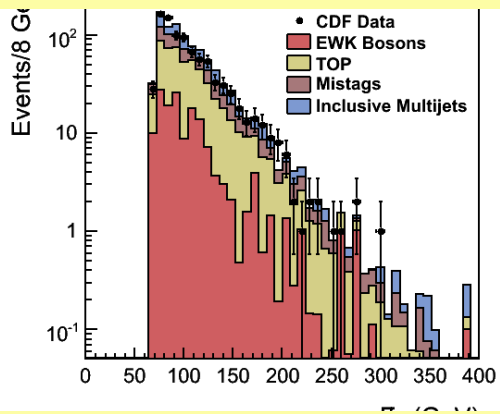


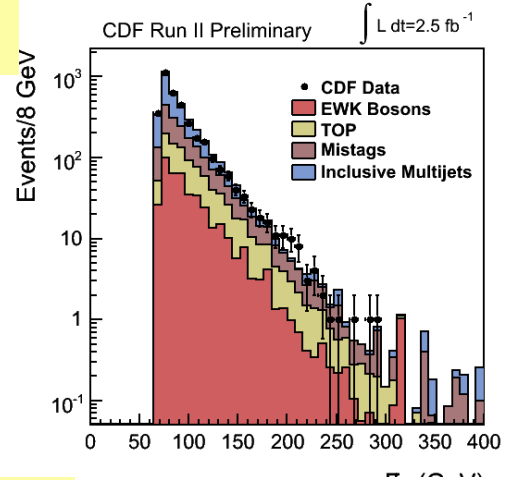
PreOpt. Regions

Missing Transverse Energy Distributions

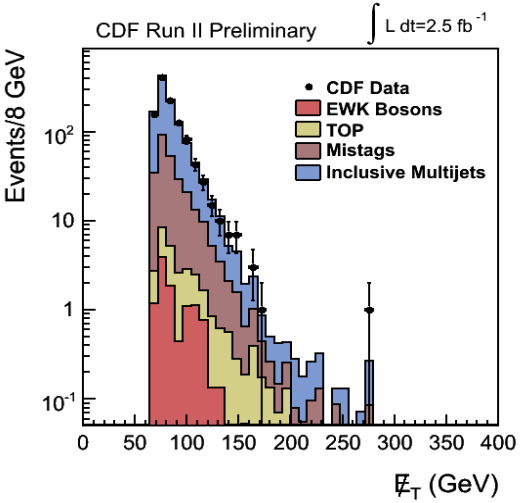
One exclusive b tag

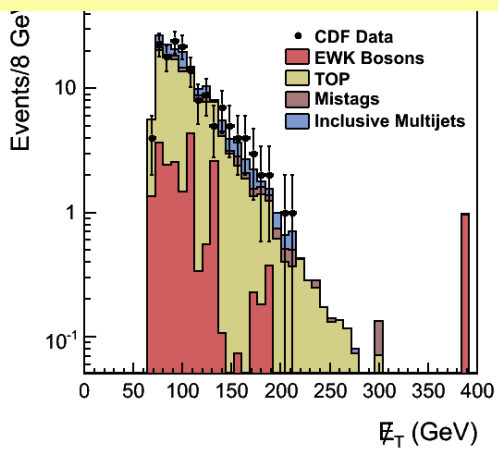


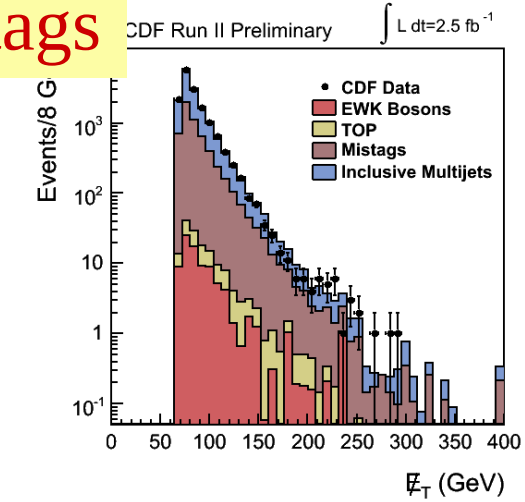




Two inclusive b tags

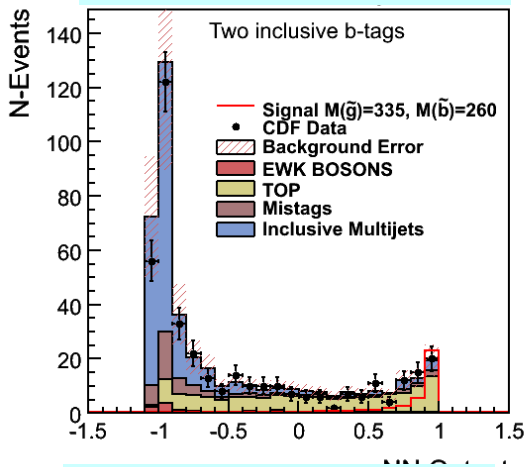




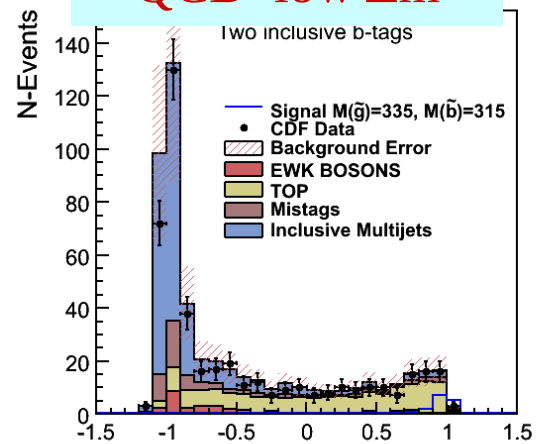


Neural Network outputs

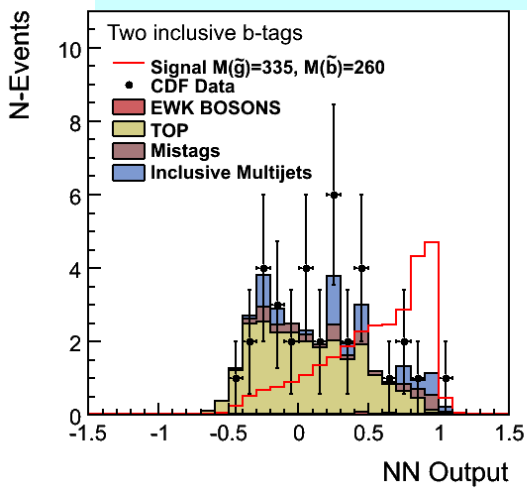
QCD high Δm



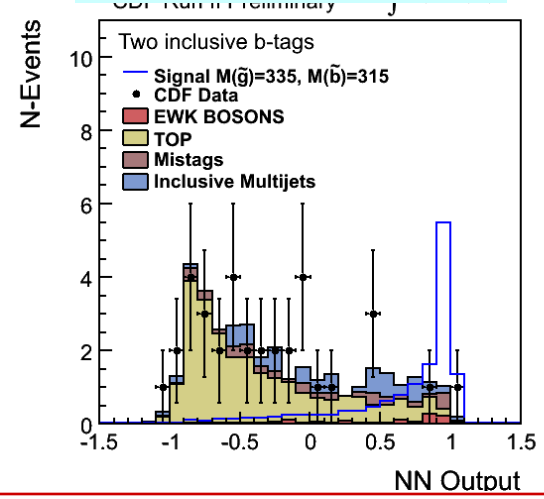
QCD low Δm



Top high Δm

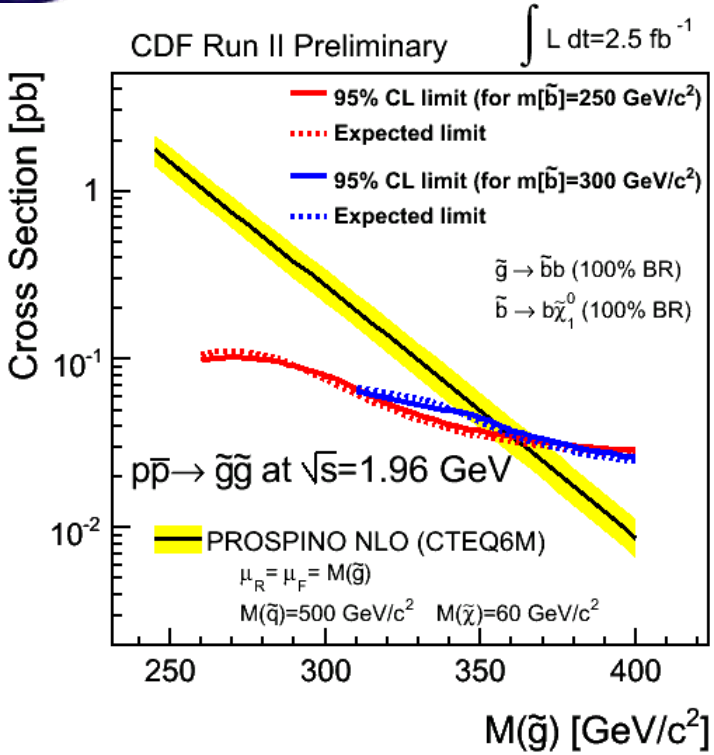


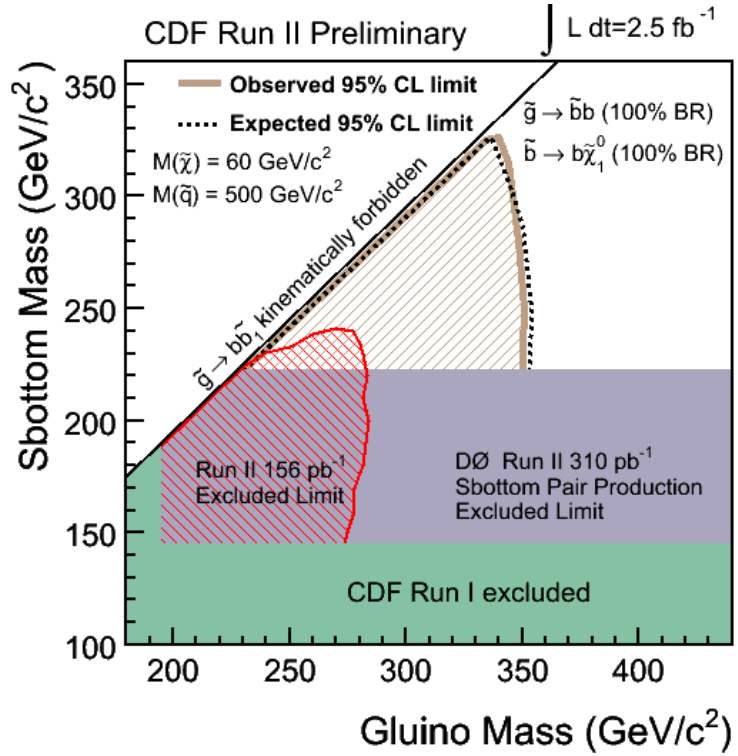
Top low Δm



Limit on Sbottom

arXiv:0903.2618





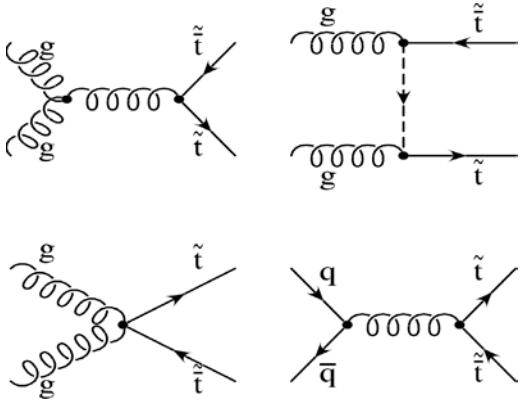
- Good agreement with SM.
- No hint of SUSY in gluino decaying into sbottom dedicated search.
- Cross section limit ~40 *fb* for m($\tilde{g}$) = 350 GeV.

Direct Sbottom/Stop Production

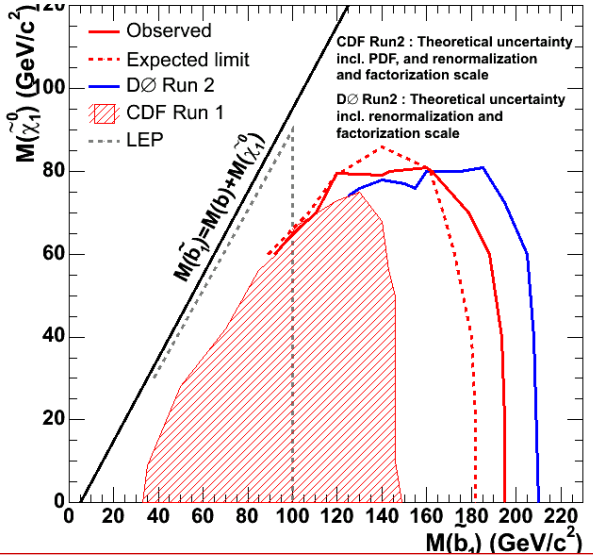
- For 3rd gen squarks, large mixing in the L- and R-handed weak eigen states could lead to one of the stop and sbottom quark to be light → Large cross section.
- Final state has large MET and HF jets
- SM backgrounds : W/Z+jets, Di-boson, top, QCD multi-jets
- Use Jet Probability algorithm to tag c/b-jets
- Assume that stop and sbottom are light, and only decays in these channels :

$$p\bar{p} \rightarrow \tilde{t}_1\bar{\tilde{t}}_1 \rightarrow c\tilde{\chi}_1^0\bar{c}\tilde{\chi}_1^0$$

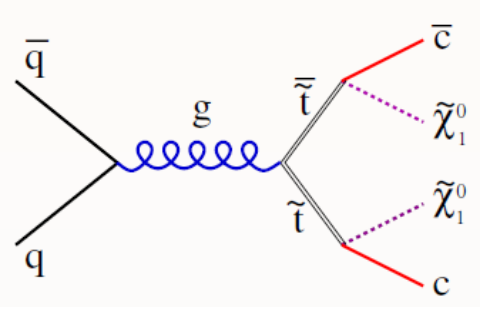
$$p\bar{p} \rightarrow \tilde{b}_1\bar{\tilde{b}}_1 \rightarrow b\tilde{\chi}_1^0\bar{b}\tilde{\chi}_1^0$$

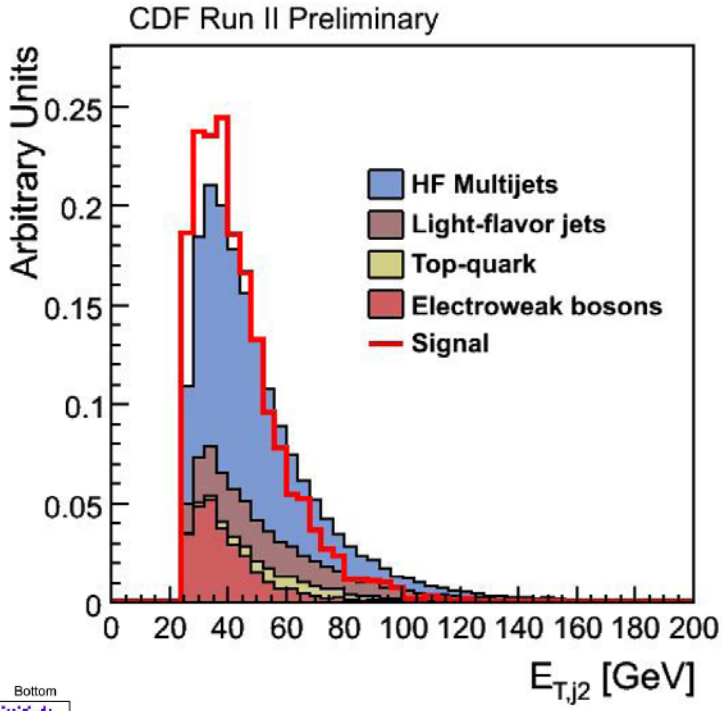


CDF PRD 76, 072010 (2007)



Direct stop Production using charm-tagging



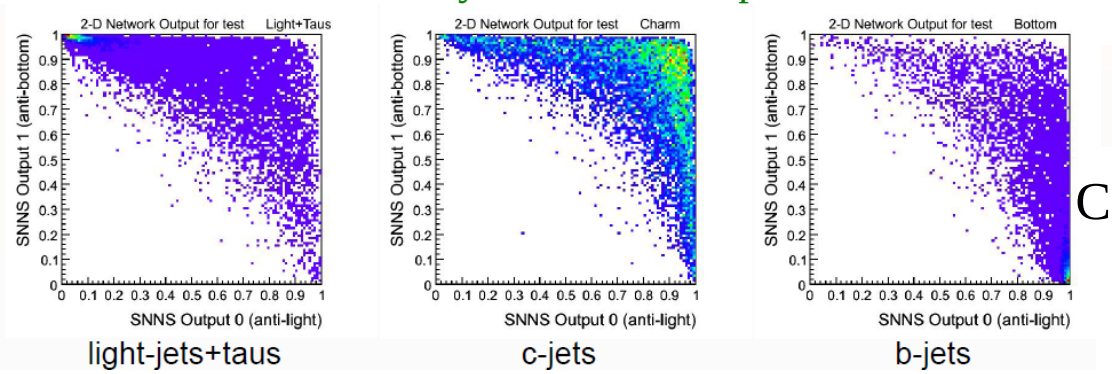


$\tilde{t} \rightarrow c\chi_1^0$ dominate decay mode.

2 -jets + MET

CHAOS: Neural Network with 2D output:

Charm Hadron Analysis Oriented Separator:



- Stop signal:
  - $M(\tilde{t})$=150 GeV/c^2, $M(\tilde{\chi}^0)$=80 GeV/c^2

CHOAS improved S/B by factor of 5.

Results soon

More on stop search in

Searches in Dilepton Final States at CDF
Andrew Ivanov UC Davis

P1.BSaturday June 6, 10:30 AM – 105 Shillman

Gauge Mediated Symmetry Breaking

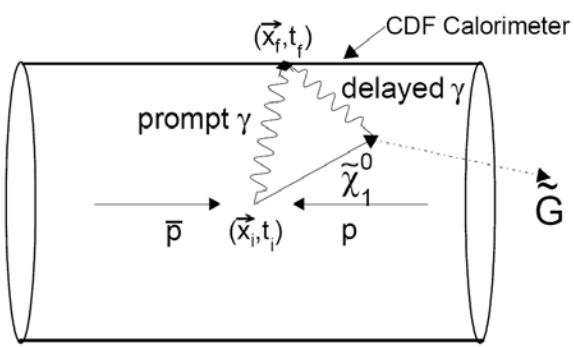
- Gauge interactions mediate SUSY breaking.
- LSP is Gravitino with mass «1GeV
- NLSP is either neutralino or slepton depending on
- Lifetime model-dependent **($c\tau$ from μm to km)**

$$\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$$

a) Long life time → delayed photons

b) Short life time → Prompt Photons

Λ	Effective SUSY breaking scale	free
Mm	Messanger mass scale	Mm/Λ=2
N	Number of messanger fields	1
C_G	Gravitino mass factor	free
tanβ	Ratio of MSSM vacuum exp. Value	(15)
Sign(μ)	sign of Higgs mixing param.	(>0)

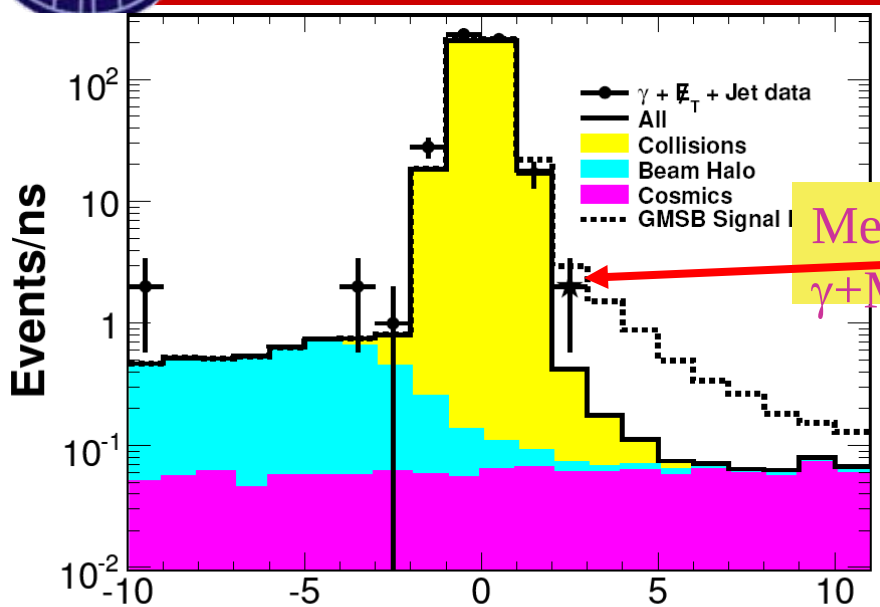


Warm dark matter models of GMSB with $\chi_1^0 \rightarrow \gamma \tilde{G}$ favor kev $\tilde{G}$ masses and ns χ_1^0 lifetimes.

Neutralino Lifetime Searches

CDF, PRD 78, 0321015 (2008)

CDF, PRL 99, 121801 (2007)



Measure the time of arrival of photons in γ+Met+Jet events

$$t_{\rm corr} \equiv (t_f - t_i) - \frac{|\vec{x}_f - \vec{x}_i|}{c}$$

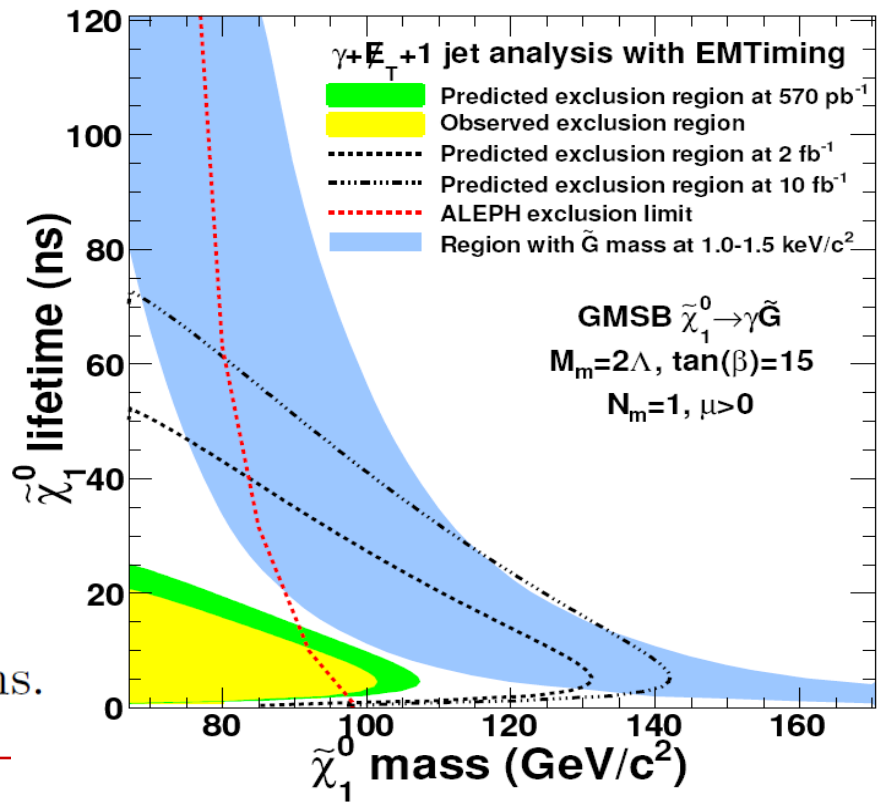
Et-photon>30, EtMiss>40, PtJet>30 GeV

Observed : 2 events

Background: 1.3±0.7

95% CL Lower limit

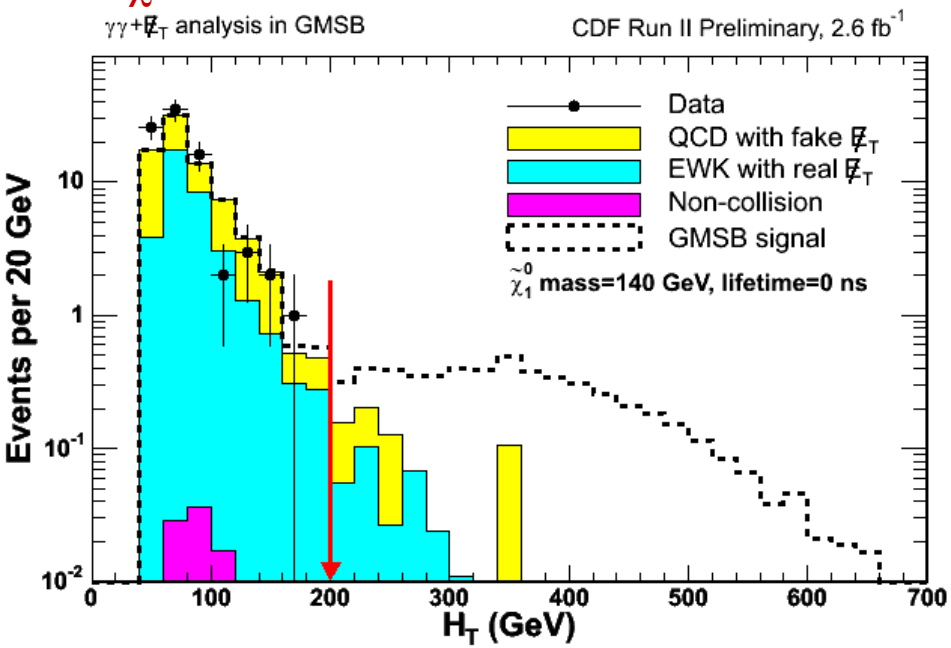
$\tilde{\chi}_1^0$ mass of 101 GeV/c^2 at $\tau_{\tilde{\chi}_1^0} = 5$ ns.

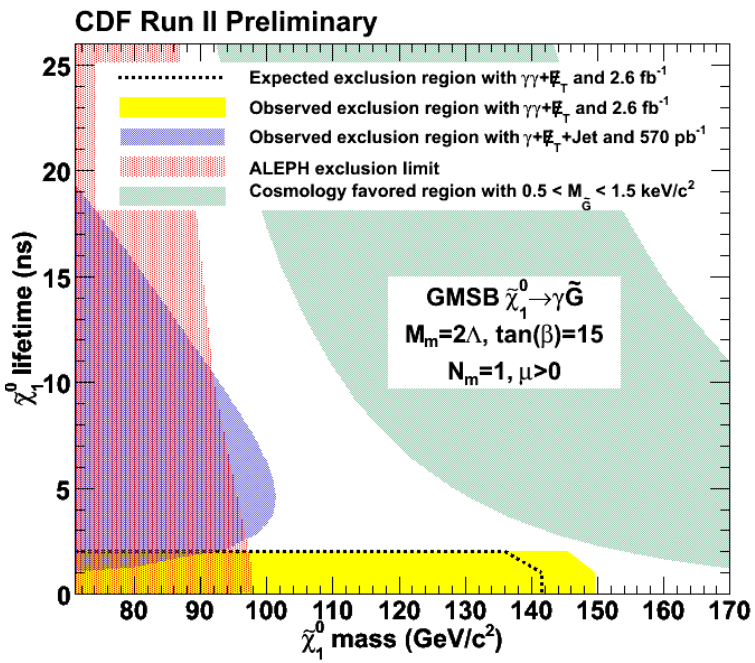


Diphoton+MET

- Optimize the γγ+Met analysis for 0 ns lifetime:
- Significant Met and Large H_T
- Complementary to the Delayed Photon Analysis
- 0 event observed over BG =1.23± 0.38

m_χ >149 GeV/c^2 at $\tau(\chi)$=0 ns.

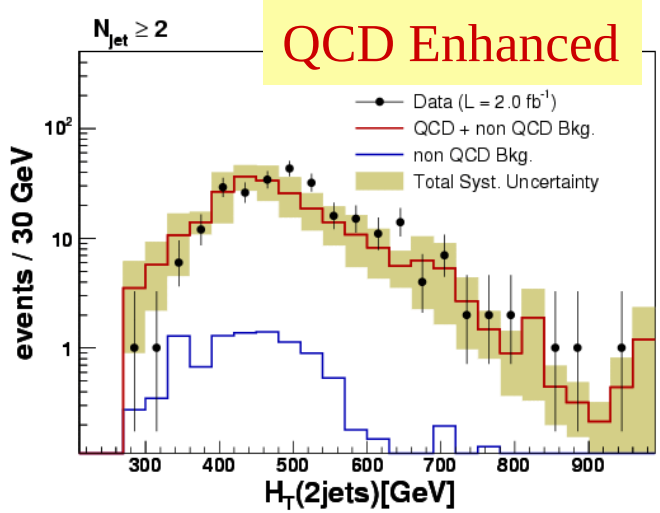
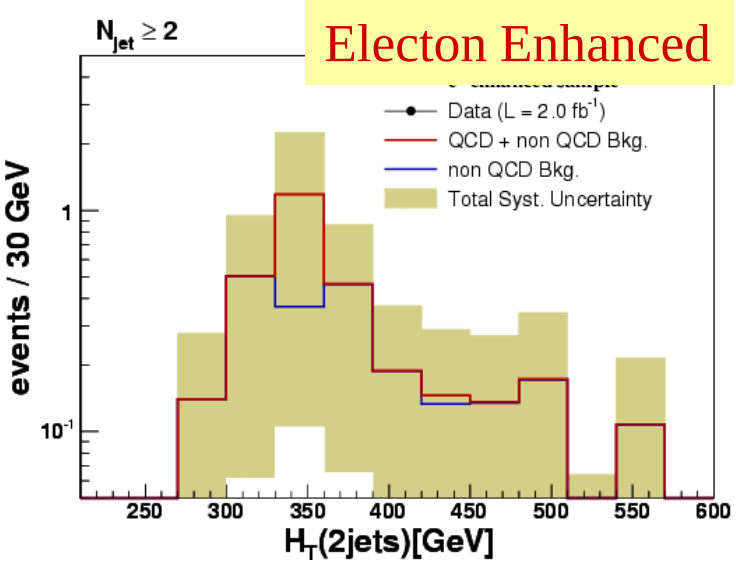
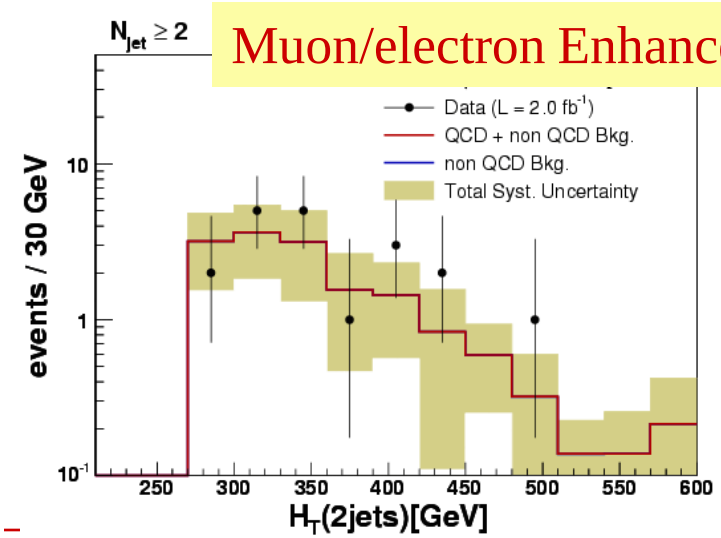
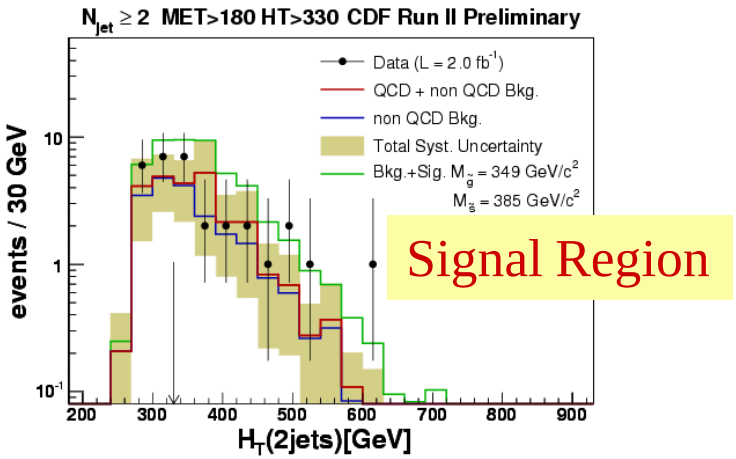




Conclusions

No evidence of Super-symmetry observed yet but we are still looking …

New results expected soon on

- stop decaying into charm
- dijet+MET model independent search (not shown)
- direct sbottom production (not shown)
- combined limits on squark-gluino masses with D0

≥2 Jet Analysis