



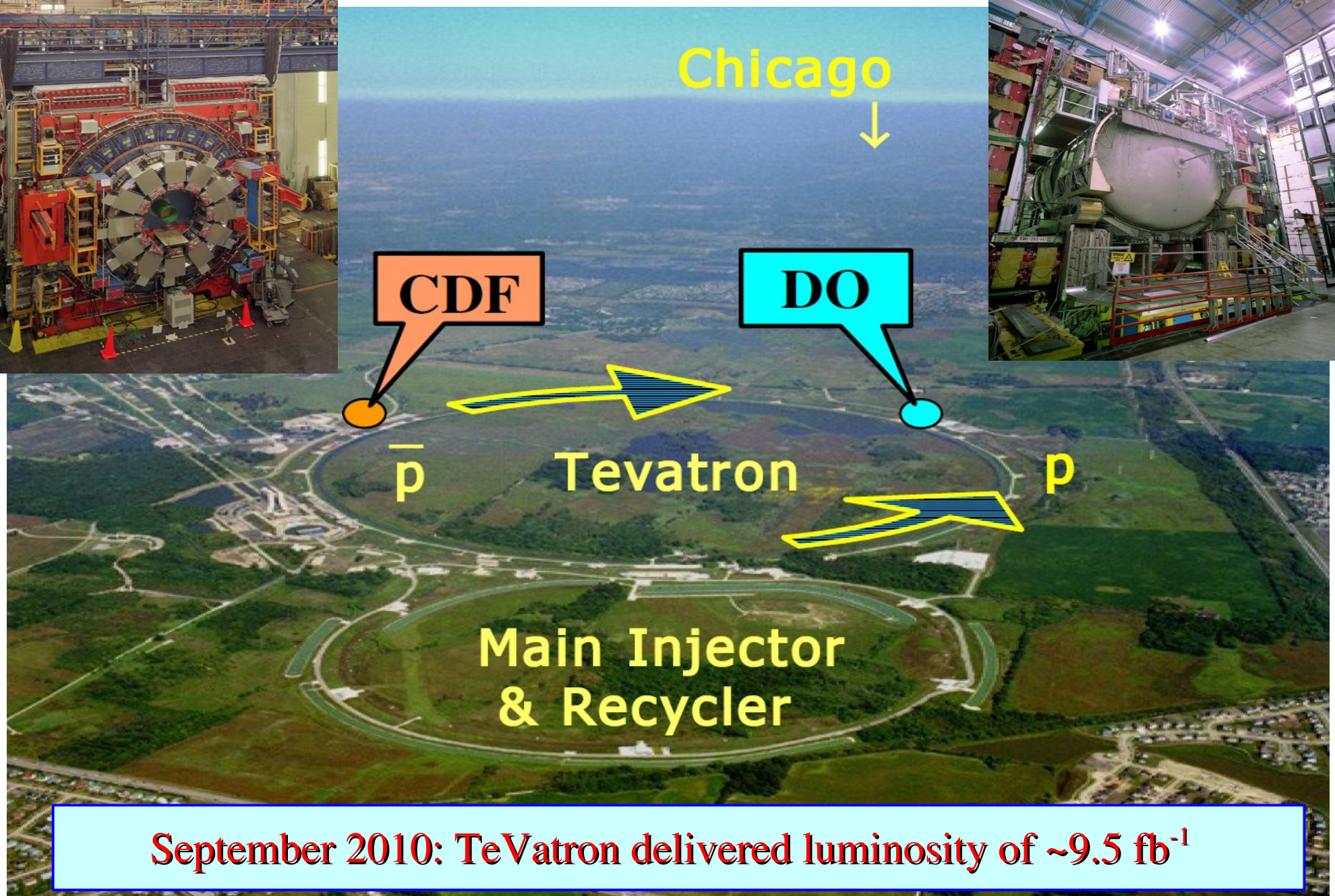
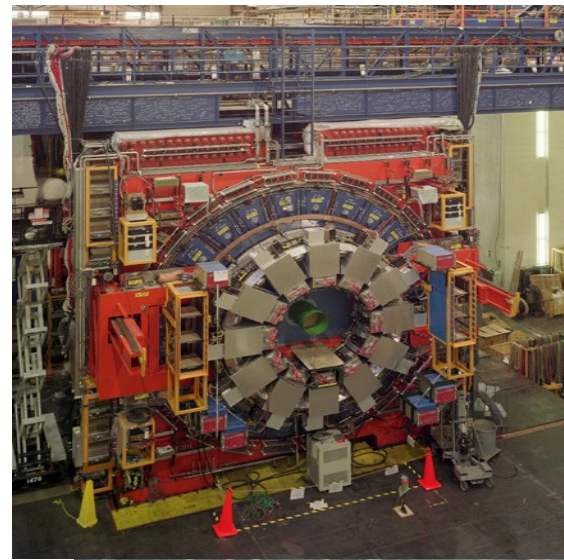
SUSY and BSM searches at the TeVatron

Sergey Uzunyan

On behalf of the CDF and D0 collaborations

LHC days in Split, Croatia, Oct 4-9 2010

The CDF and D0 experiments Run II $p\bar{p}$ @ 1.96 TeV



Outline.

■ SUSY and Leptoquarks:

- Sbottom/LQ3 2b-jets + MET, D0, **5.2 fb⁻¹**, PLB 693 (2010), 95-101
CDF, **2.6 fb⁻¹**, PRL 105 (2010), 081802
- Stop 2c-jets + MET, CDF, **2.6 fb⁻¹**, Public Note
- Stop 2jets+eμ + MET, D0, **5.4 fb⁻¹**, Submitted to PLB
- GMSB diphoton + MET, D0, **6.3 fb⁻¹**, Accepted by PRL
- RPV Sneutrinos + eμ, D0, **5.3 fb⁻¹**, Submitted to PRL

■ Resonances:

- RS graviton ($\gamma\gamma/ee$), D0, **5.4 fb⁻¹**, PRL 104 (2010), 241802
($\gamma\gamma$), CDF, **5.4 fb⁻¹**, Public Note 10158
- Z' $\rightarrow (\mu\mu)$, CDF, **4.6 fb⁻¹**, Public Note 10165
- Z' $\rightarrow (ee)$, D0, **5.4 fb⁻¹**, Submitted to PLB
- W', Z' $\rightarrow WW, WZ \rightarrow e+2jets+MET$, CDF, **2.9 fb⁻¹**, PRL 104 (2010), 241801
- W' $\rightarrow WZ$ in trileptons, D0, **4.1 fb⁻¹**, PRL 104 (2010), 061801
- RPV gg $\rightarrow 6+jets$, CDF, **3.2 fb⁻¹**, Public Note, 2010

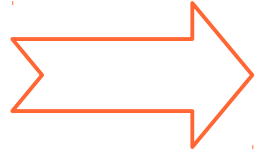
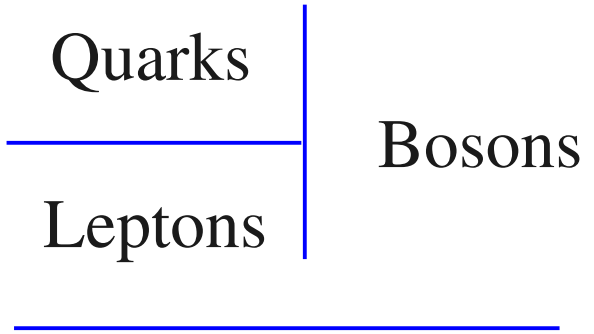
■ 4th generation quarks

- t', lepton+jets + MET CDF, **4.6 fb⁻¹**, Public Note
- b', dilepton+jets+MET CDF, **4.8 fb⁻¹**, Public Note

SUSY and Leptoquarks

Leptoquarks

$SU(3)_C \times SU(2)_L \times U(1)_Y$



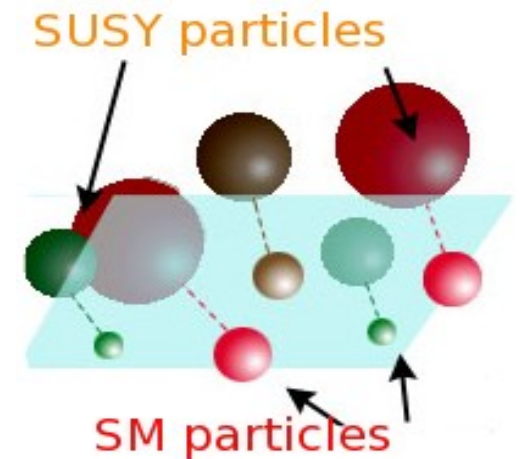
| sBosons | sFermions |
|----------------------------|--|
| \tilde{q}_L, \tilde{q}_R | \tilde{g} |
| $\tilde{\nu}$ | $\tilde{\gamma}, \tilde{Z}, \tilde{W}^\pm$ |
| \tilde{l}_L, \tilde{l}_R | $\tilde{H}_1^0, \tilde{H}_2^+, \tilde{H}_1^-, \tilde{H}_2^0$ |
| \tilde{q}_1, \tilde{q}_2 | $\tilde{\chi}_i^\pm \quad \tilde{\chi}_i^0$ |



SUSY (fermion \leftrightarrow boson)

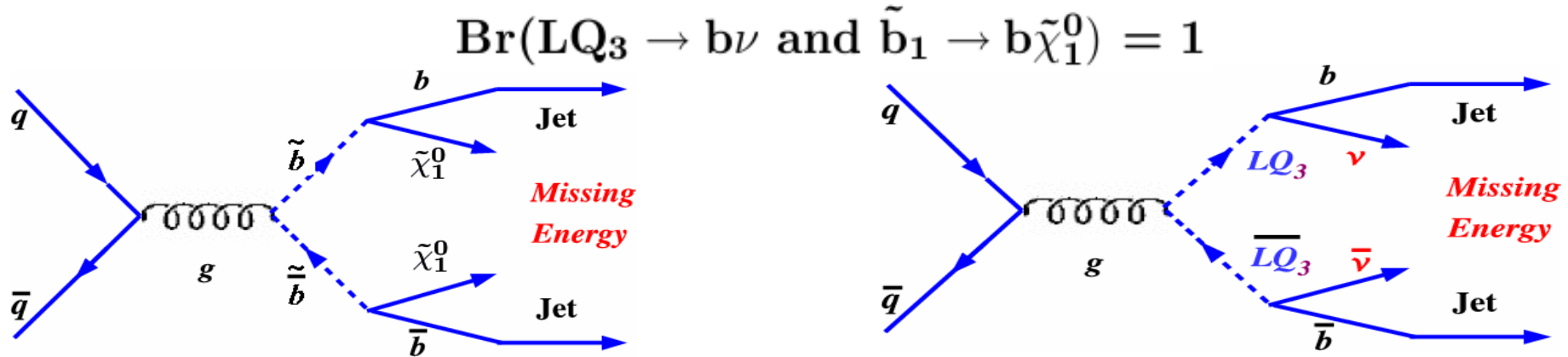
Different models

- **MSSM, conserved R-parity = $(-1)^{3(B-L)+2s-1}$**
 - pair production of SUSY particles (~ same mass as SM)
 - decay to SM particles and the stable LSP (the lightest SUSY particle)
- **GMSB, gravitino is LSP**
- **R-parity violated models (decaying LSP)**



Experimental signatures

**(Detector) EM objects, tracks, jets,
missing energy**



Backgrounds: **W/Z+jets**, ttbar, Multijet (negligible at MET>70 GeV)

Signal selections :

Isolated lepton veto

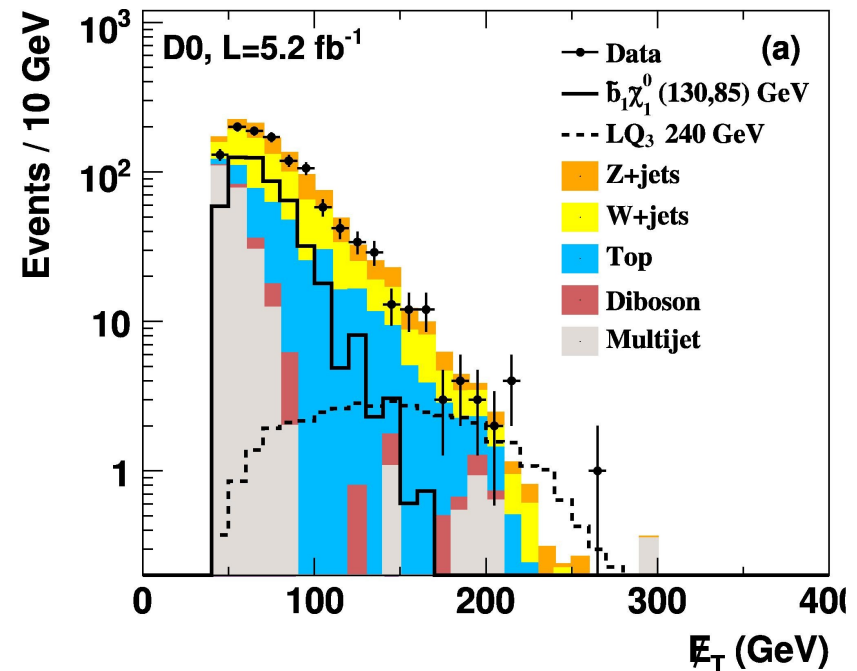
MET > 40 GeV

2 or 3 jets: E_T > 20 GeV

MET significance > 5

$\Delta\phi_{\min}(\vec{E}_T, \text{jets}) > 0.6 \text{ rad,}$

$(E_T^{\text{jet1}} + E_T^{\text{jet2}}) / (\sum_{\text{jets}} E_T) > 0.75/0.9$



Double b-tag (Neural Net algorithm using track and vertex information)

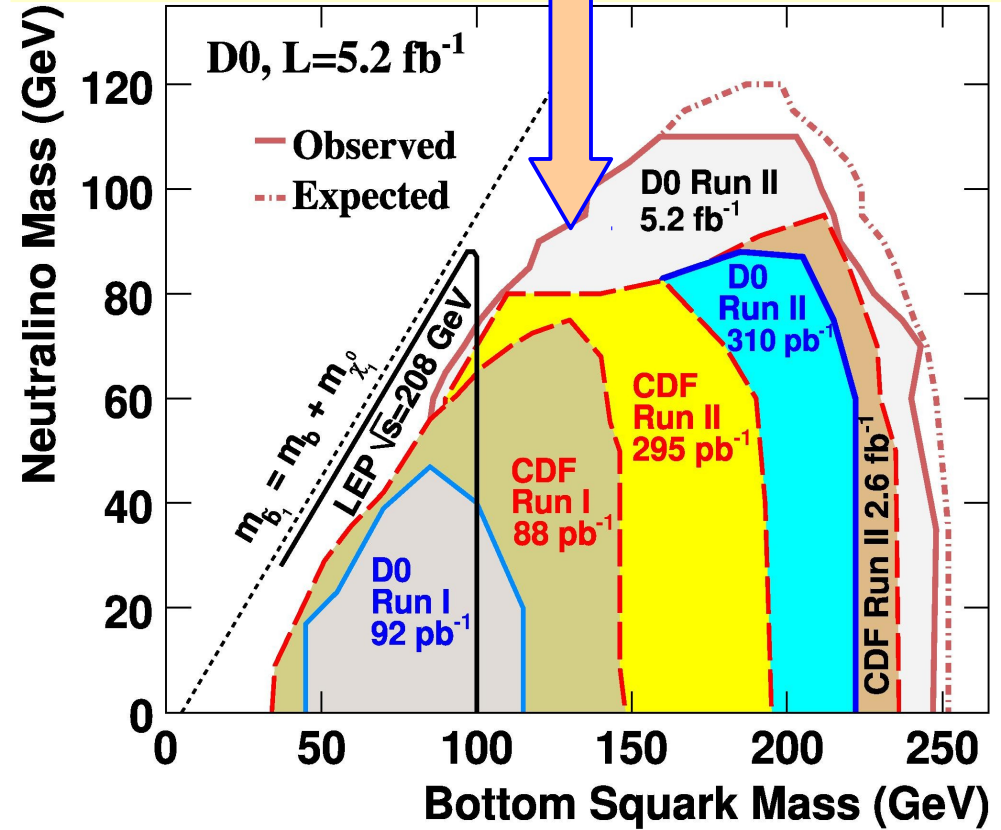
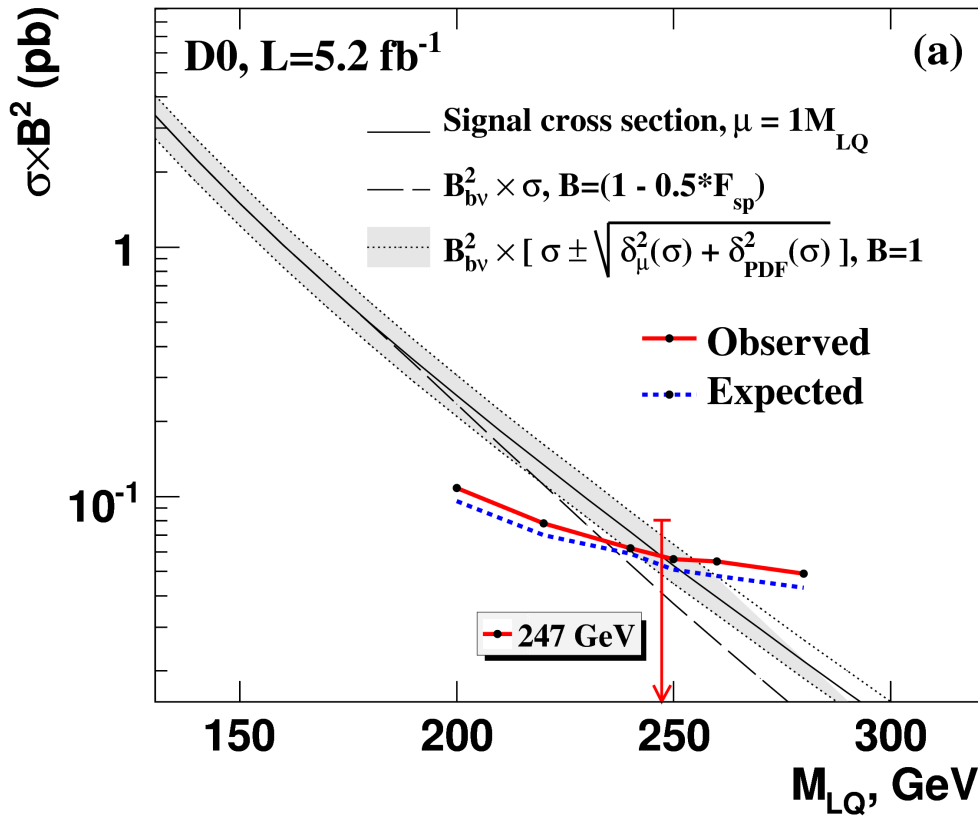
MET, HT cut optimized vs expected upper 95% C.L. limit on the x-section

Strong cuts on MET,HT

Soft cuts on MET,HT

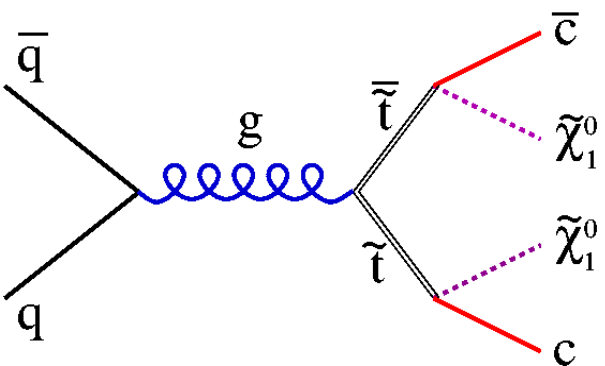
Data 7 Exp. Bkd 6.9+/- 1.7 $(m_{\tilde{b}_1}, m_{\tilde{\chi}_1^0}) = (240, 0)$ GeV
 acpt. 2.8%

Data 901 Exp. Bkd 971+/- 152 $(m_{\tilde{b}_1}, m_{\tilde{\chi}_1^0}) = (130, 85)$ GeV
 acpt. 2.7%

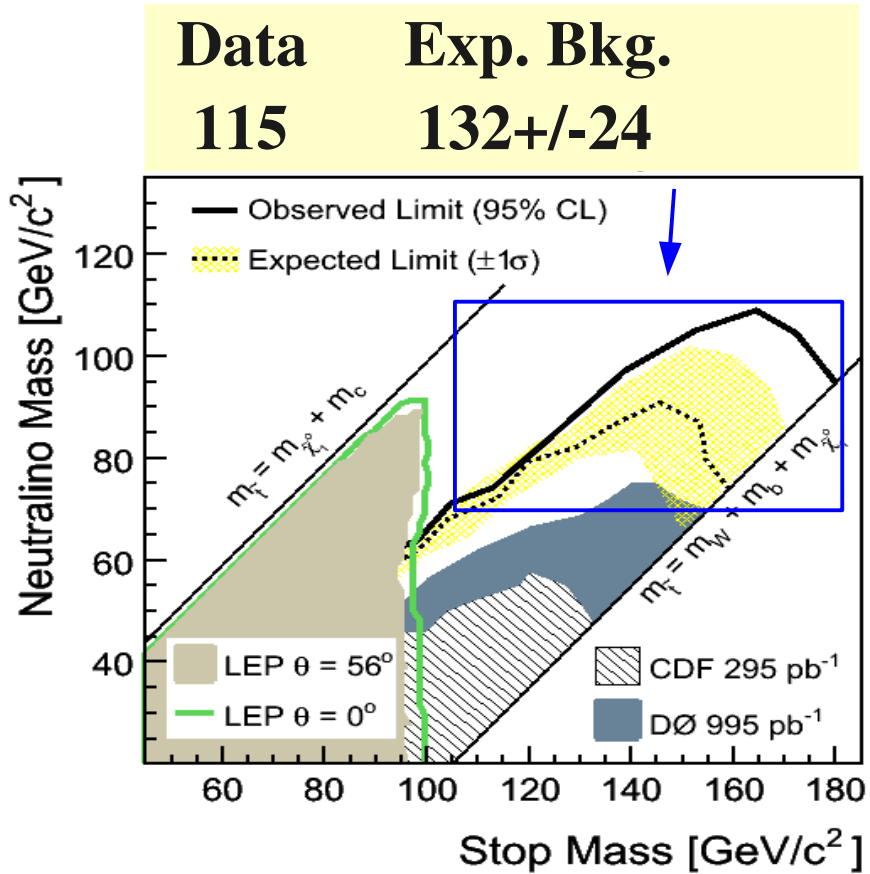
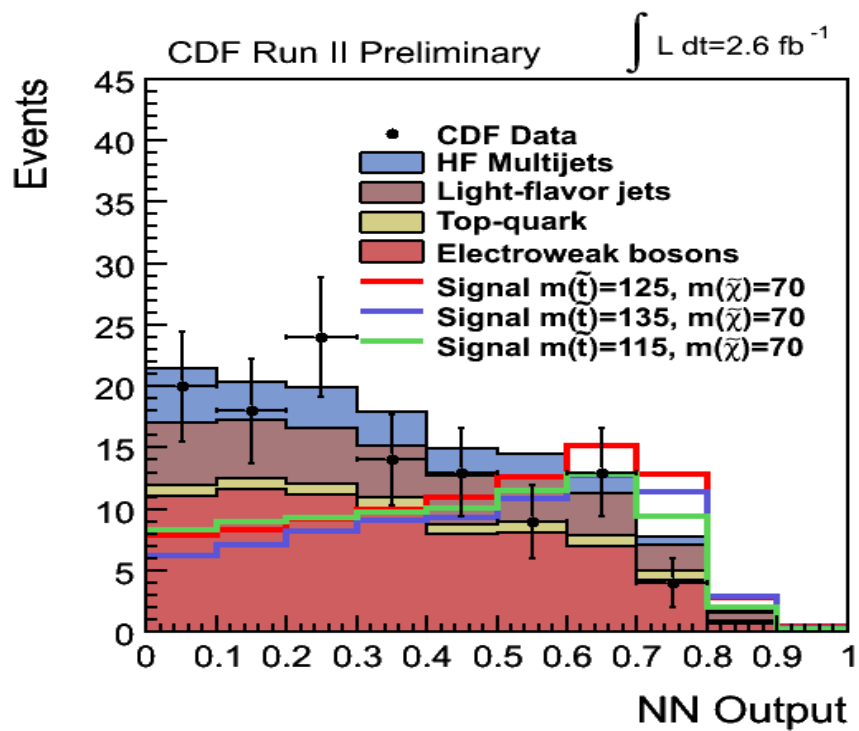


LQ3: excluded mass @ 95% C.L. : 247 GeV

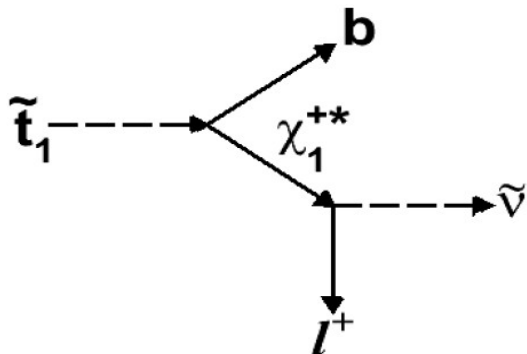
SBottom: improved constraints in the $(m_{\tilde{b}_1}, m_{\tilde{\chi}_1^0})$ mass plane



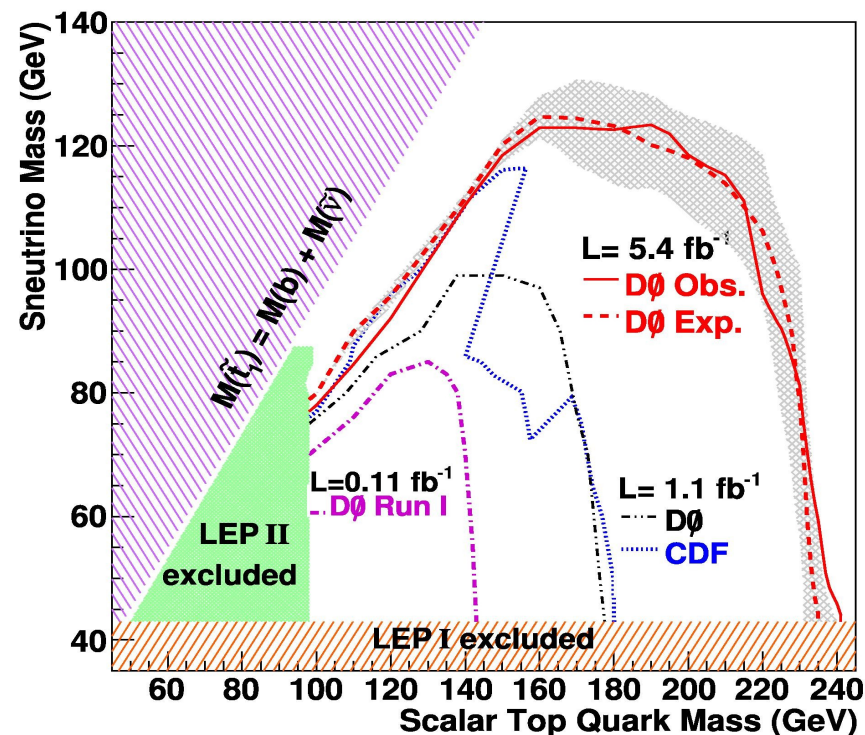
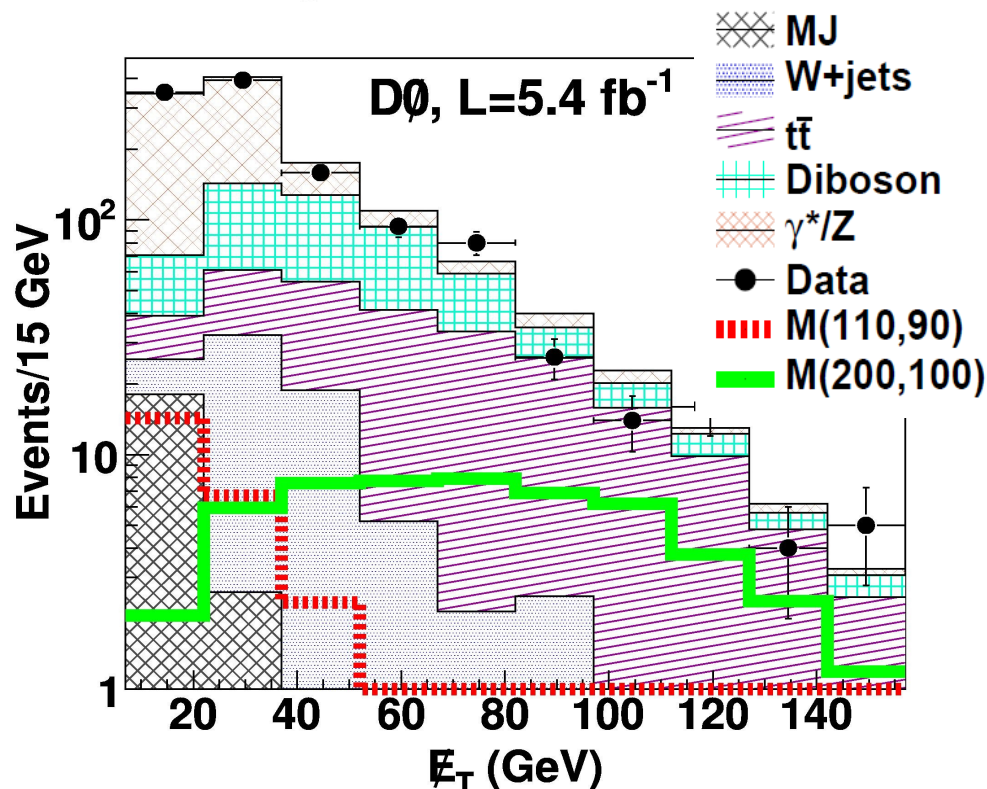
Signal selections : at least 2 Jets $ET > 25 \text{ GeV}$
MET > 50 GeV, 1 heavy flavor tag (vertex algorithm)
NN selection (MET, jets kinematic)
Backgrounds : W/Z+jets, HF multijet, top



Excluded @ 95% C.L., $m(\text{LSP})=80 \text{ GeV}$: $m(\text{Stop}) < 180 \text{ GeV}$



Signal selections : $\Delta M = M_{\tilde{t}_1} - M_{\tilde{\nu}}$ determines the kinematic, $p_T(e) > 15 \text{ GeV}$, $p_T(\mu) > 10 \text{ GeV}$, veto on ($\text{MET} < 20 \text{ GeV}$ for $\Delta\phi(e, \mu) < 2.8$) and (MET, e, μ) composite kinematic discriminants against $Z(\tau\tau) \rightarrow e, \mu + \nu\nu$, WW , $t\bar{t}$, W +jets

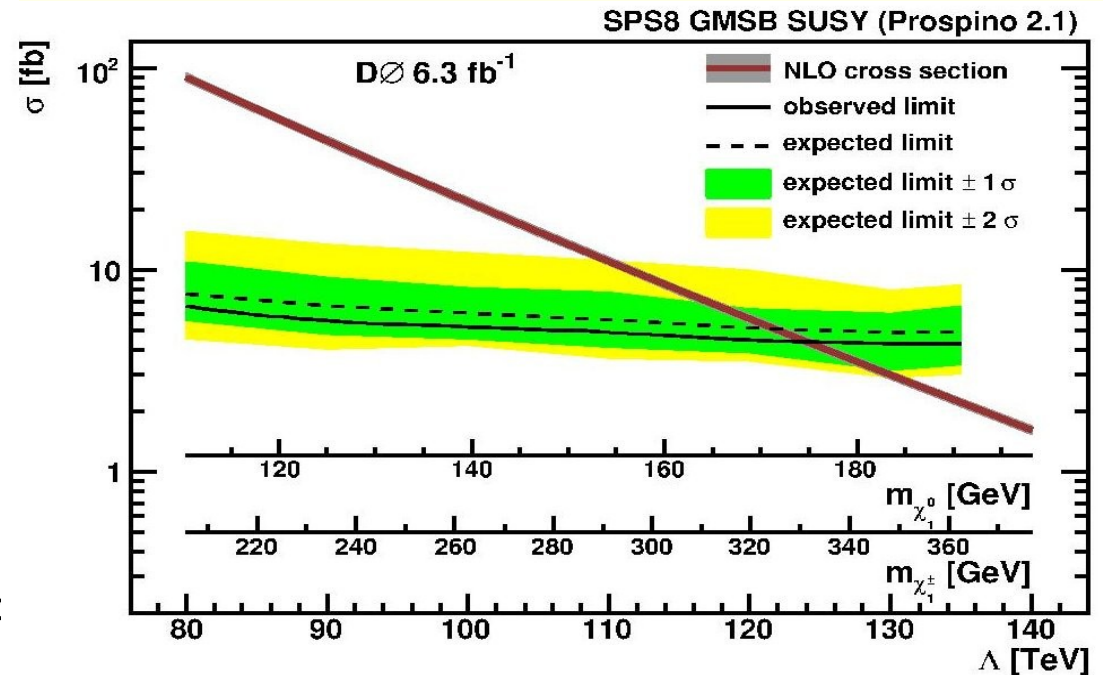
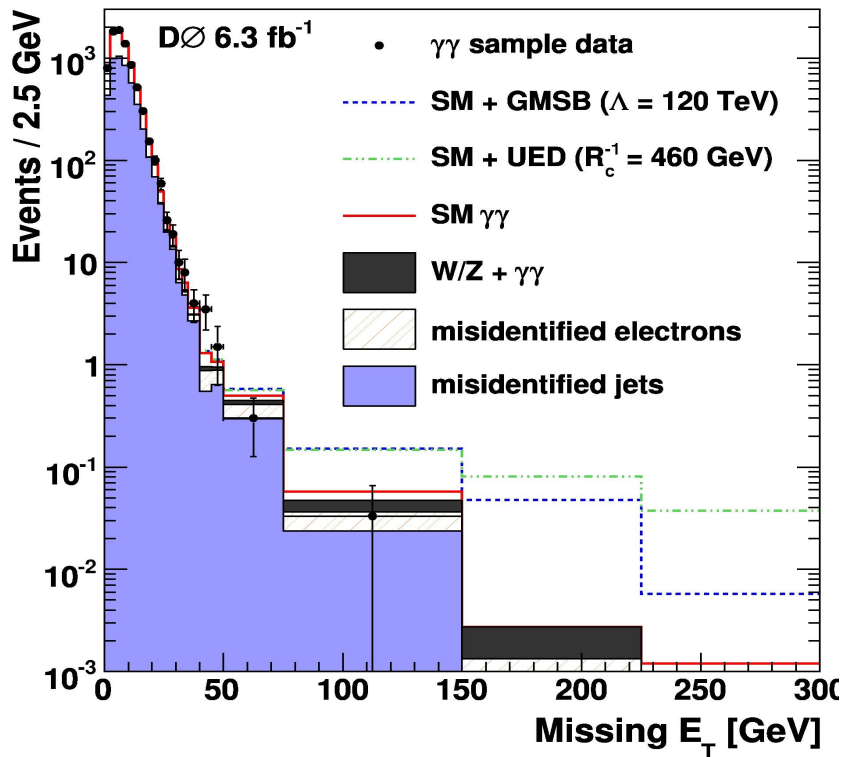


Significantly improved constraints at 95% C.L.
in the $(M_{\tilde{t}_1}, M_{\tilde{\nu}}$ mass plane

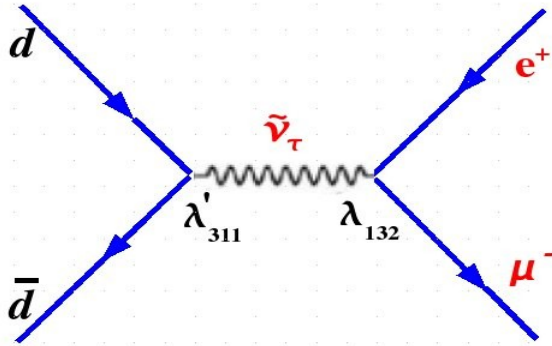
pp-> $\gamma\gamma$ +MET+X
 Lightest neutralino
 decays to γ and
 gravitino (LSP)

Signal selections : $E_T(\gamma) > 25$ GeV, MET > 50 GeV
Backgrounds : real MET - $W\gamma$, W +jet, $W/Z+\gamma\gamma$ +
 Instrumental - SM $\gamma\gamma$, γ +jet, multijet (dominant)

| Data | Exp. Bkg | $m(L)=120$ TeV |
|------|------------|----------------|
| 4 | 6.9+/-1.01 | 5.2+/-0.4 |



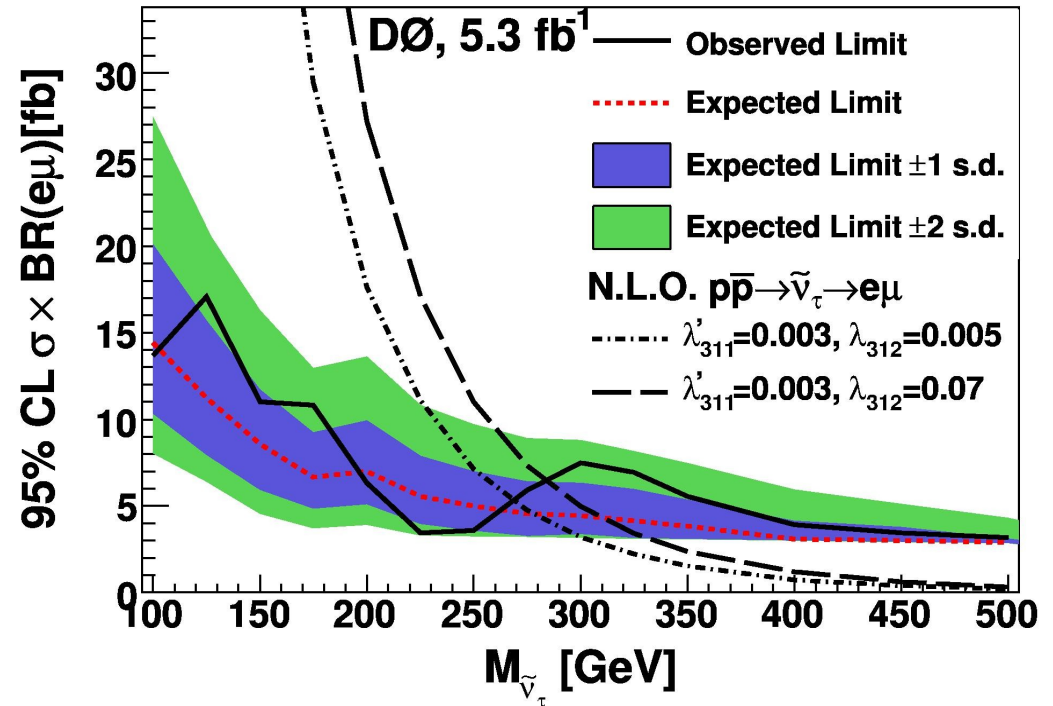
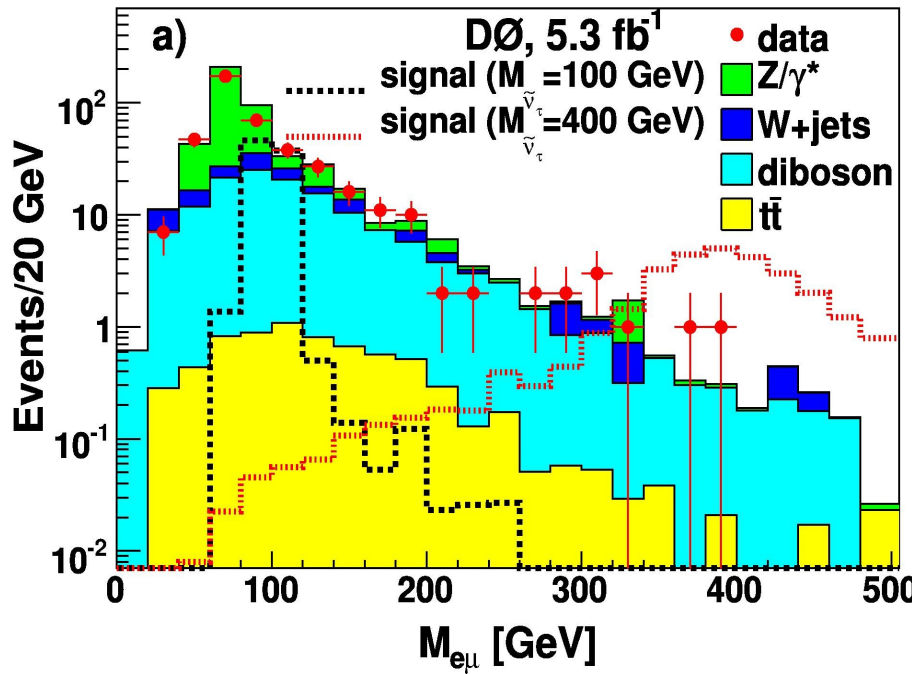
Excluded @ 95% C.L. : $m(\Lambda) < 124$ TeV, $m(\tilde{\chi}_1^0) < 175$ GeV



Signal selections : Isolated e, μ with $PT > 25 \text{ GeV}$,
Backgrounds : Drell-Yan $Z/\gamma^* - \tau\tau$ (dominant),
 W+jets, Diboson, $t\bar{t}$

Checking for $M(e\mu)$ peak

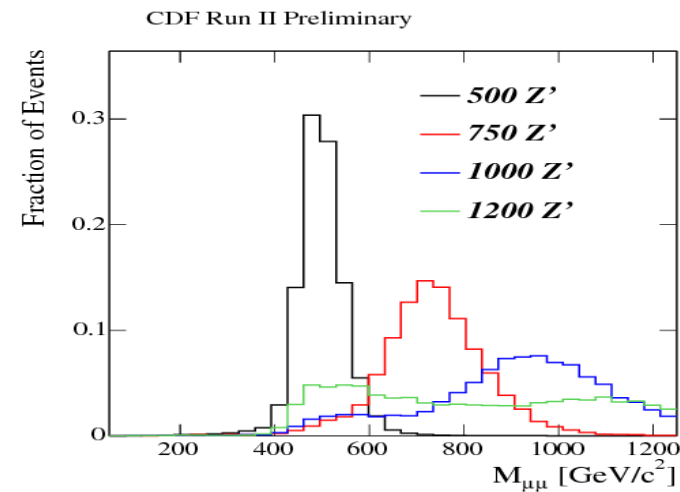
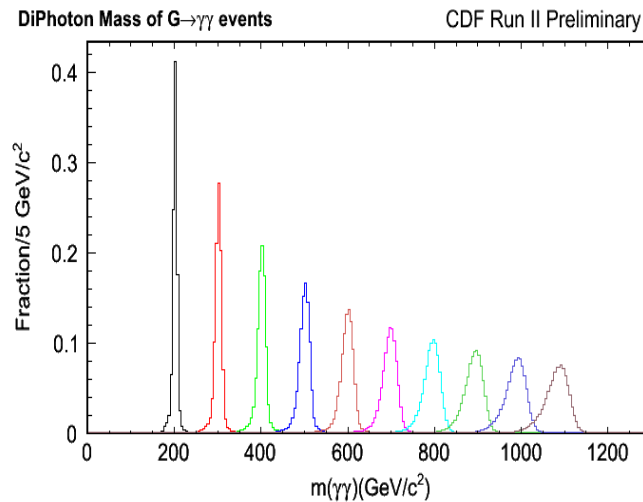
| Data | Exp. Bkg |
|------|------------|
| 414 | 410 +/- 38 |



Excluded @ 95% C.L. : $m(\text{sneutrino}) < 280 \text{ GeV}$, depending on coupling

Resonances.

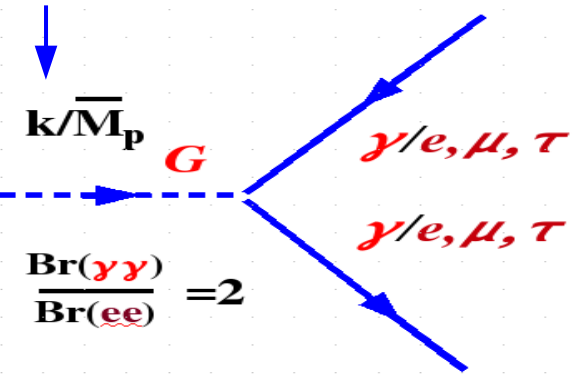
- **Extra Dimensions** (gravity and SM located in separate space branes)
 - explain why gravity is much weaker than other forces
 - predict spectrum of heavy $\gamma\gamma$ or lepton-lepton resonances
- **New Gauge Bosons (Z' , W')**
 - appear in GUTs and superstring SM extensions
 - searches for high mass lepton pairs or WW, WZ resonances



An important part of the TeVatron program, many results were recently updated

Randall-Sundrum Gravitons (CDF 5.4 fb⁻¹, DØ 5.4 fb⁻¹)

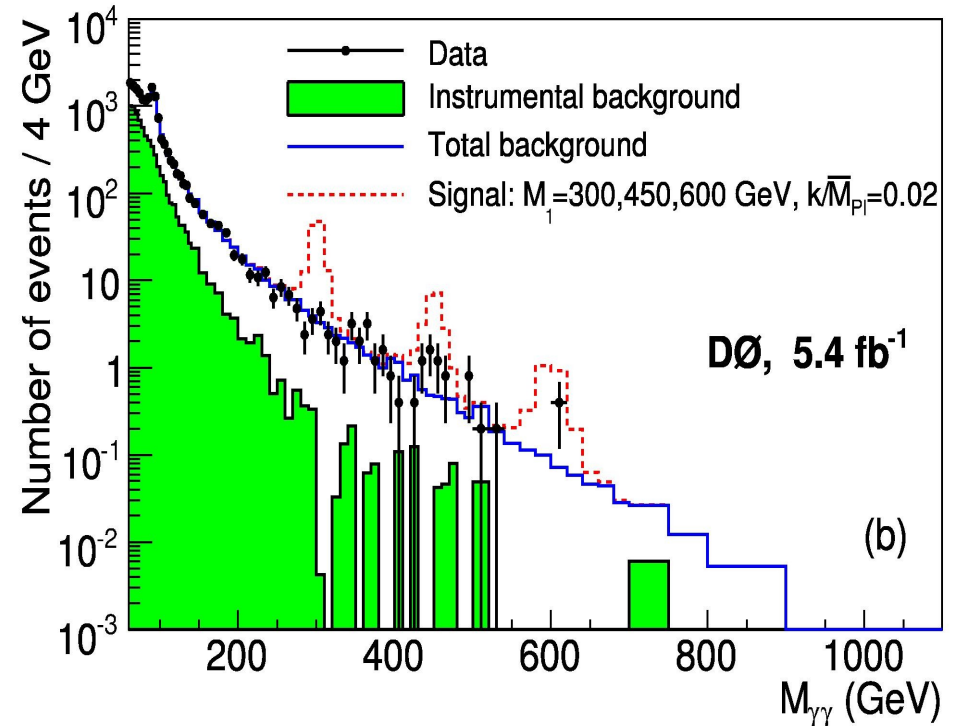
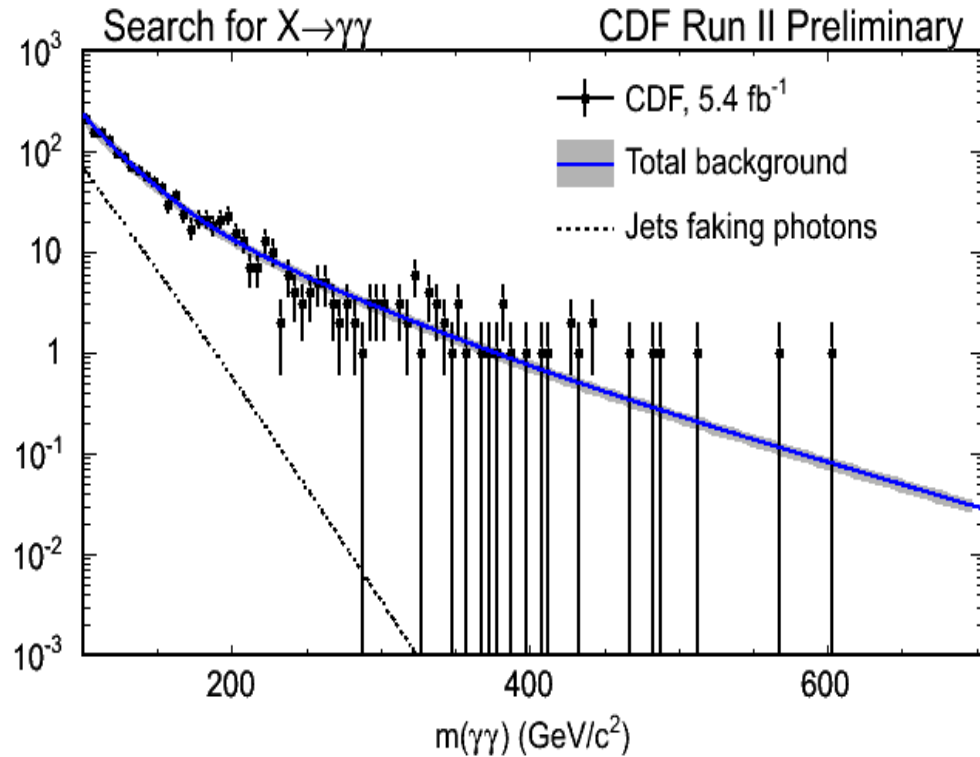
Parameter defined by the extra-dimension geometry



Signal selections : $M(\gamma\gamma/ee) > 60 \text{ GeV}$

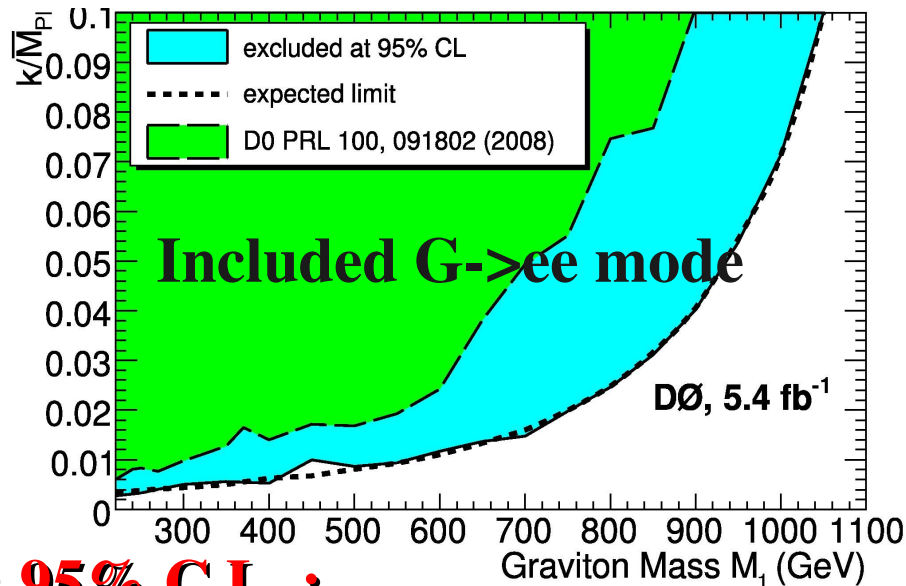
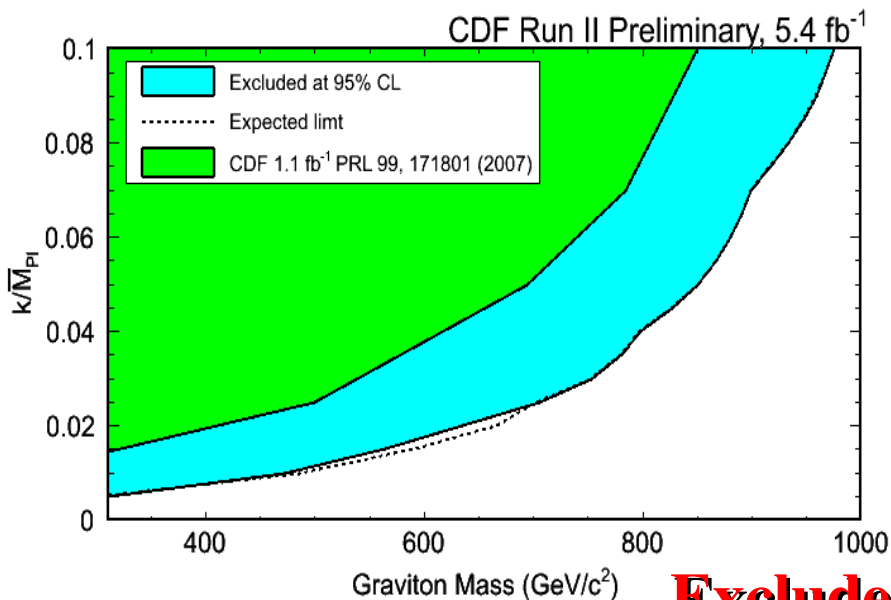
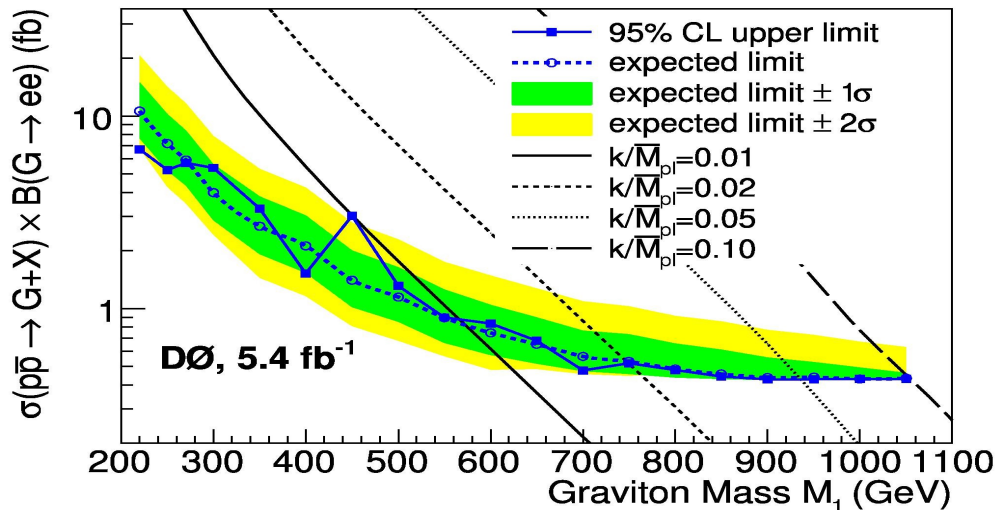
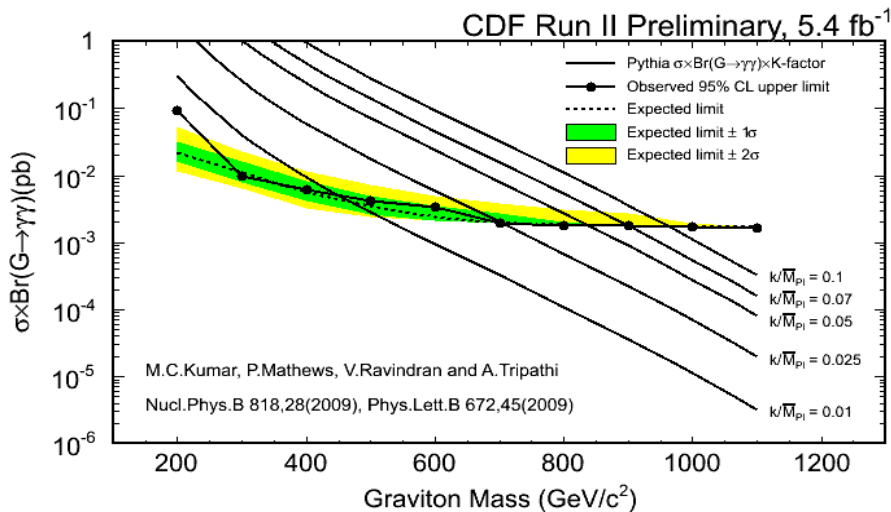
Backgrounds : SM $\gamma\gamma$ or $Z/\gamma^* \rightarrow ee$ (dominant)

Instrumental – jets misid as photon or electron



Absence of any significant signals – set limits on the graviton mass

Randall-Sundrum Gravitons (CDF5.4 fb⁻¹, DØ 5.4 fb⁻¹)



Excluded @ 95% C.L. :

476 < m(G), GeV < 976

560 < m(G), GeV < 1050



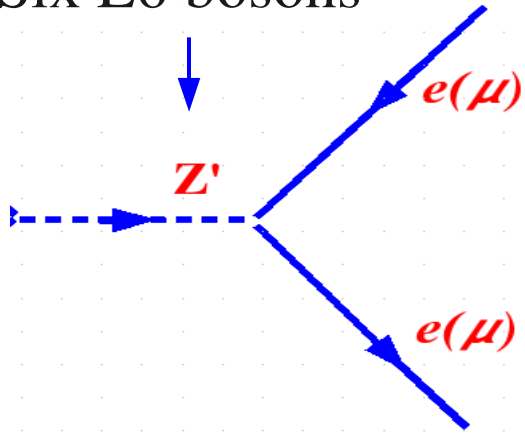
Public Note 10158, 2010



PRL 104 (2010) 241802

Dielectron and dimuon $5.4 \text{ fb}^{-1} \text{ D0 (ee)}$, $4.6 \text{ fb}^{-1} \text{ CDF } (\mu\mu)$

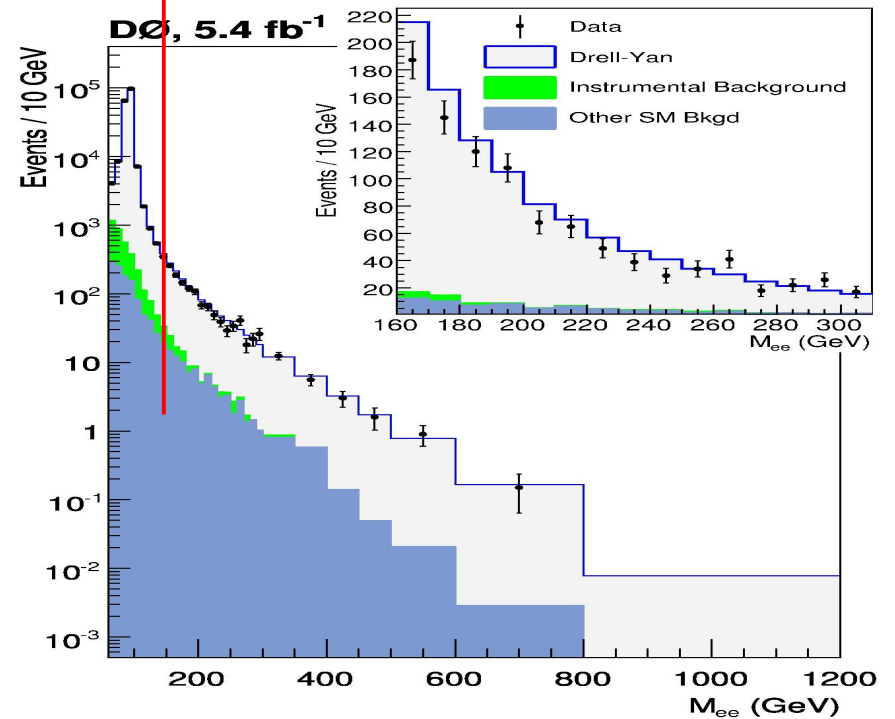
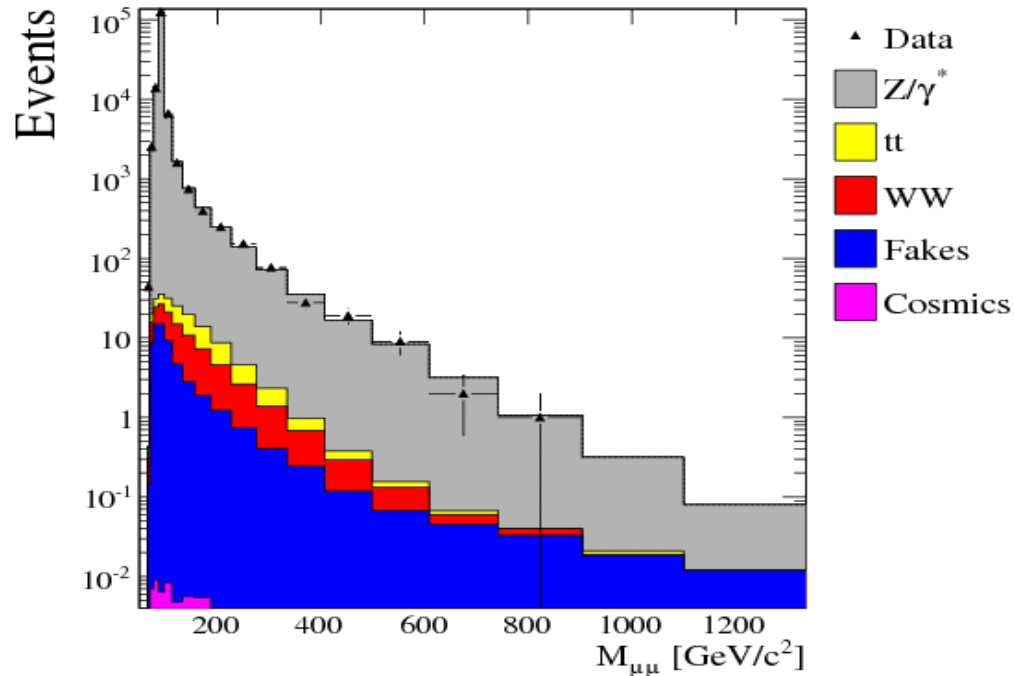
Six E6 bosons



Signal selections : $M(ee) > 60 \text{ GeV}$, $M(\mu\mu) > 130 \text{ GeV}$,
Backgrounds : $Z/\gamma^* \rightarrow ee (\mu\mu)$ (dominant)
Instrumental – electron/muon misidentification

$M(Z') < 150$ excluded earlier, control region

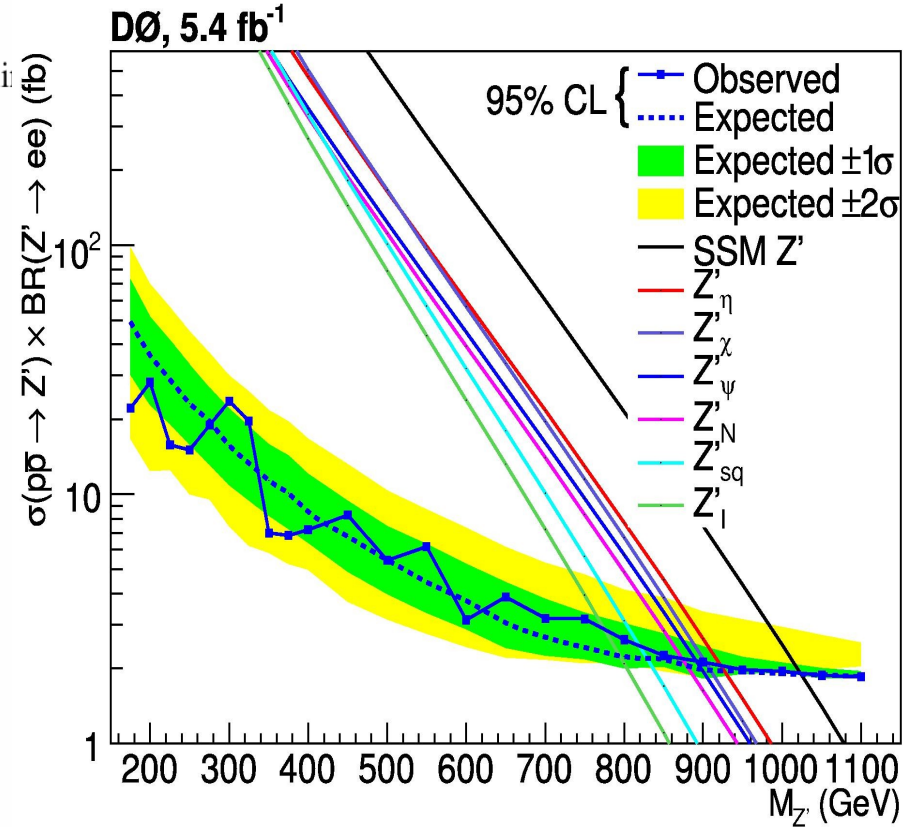
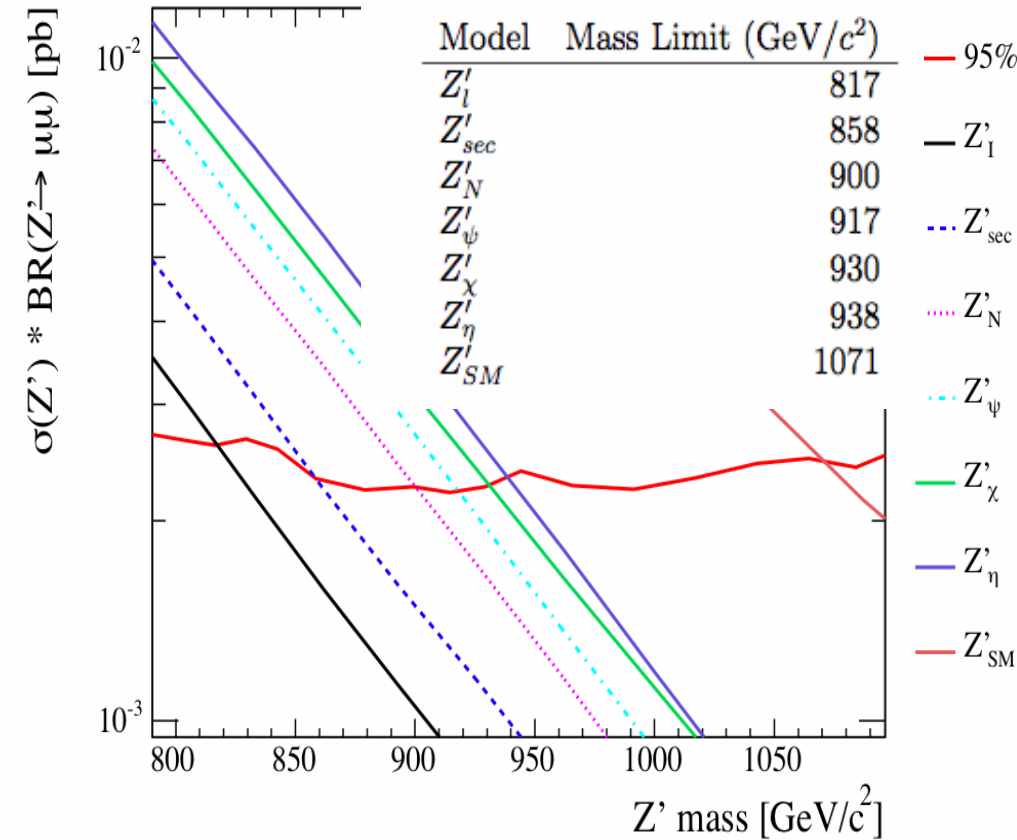
CDF Run II Preliminary 4.6 fb^{-1}



Events around expected Z' poles used to set limits

Dielectron and dimuon 5.4 fb^{-1} D0 (ee), 4.6 fb^{-1} CDF ($\mu\mu$)

CDF Run II Preliminary 4.6 fb^{-1}



Excluded @ 95% C.L. :

$m(Z'sm) < 1071 \text{ GeV}$

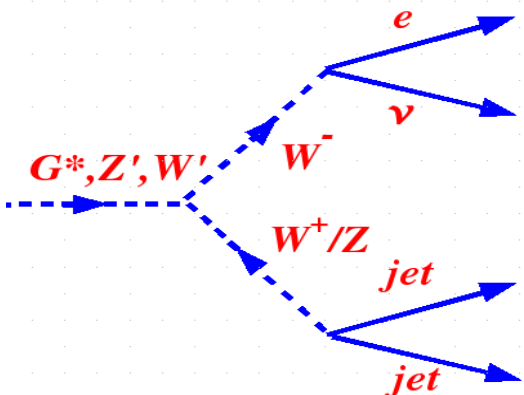
$m(Z'sm) < 1023 \text{ GeV}$



Public Note 10165, 2010



arXiv:1008.2023,
Submitted to PLB



Signal selections : $ET(e) > 30 \text{ GeV}, MET > 30 \text{ GeV},$
 $HT > 150 \text{ GeV}, 65 < Mw(jj) < 95 \text{ GeV}; 75 < Mz(jj) < 105 \text{ GeV}$
Backgrounds : SM (W+jets, ttbar, Dibosons)

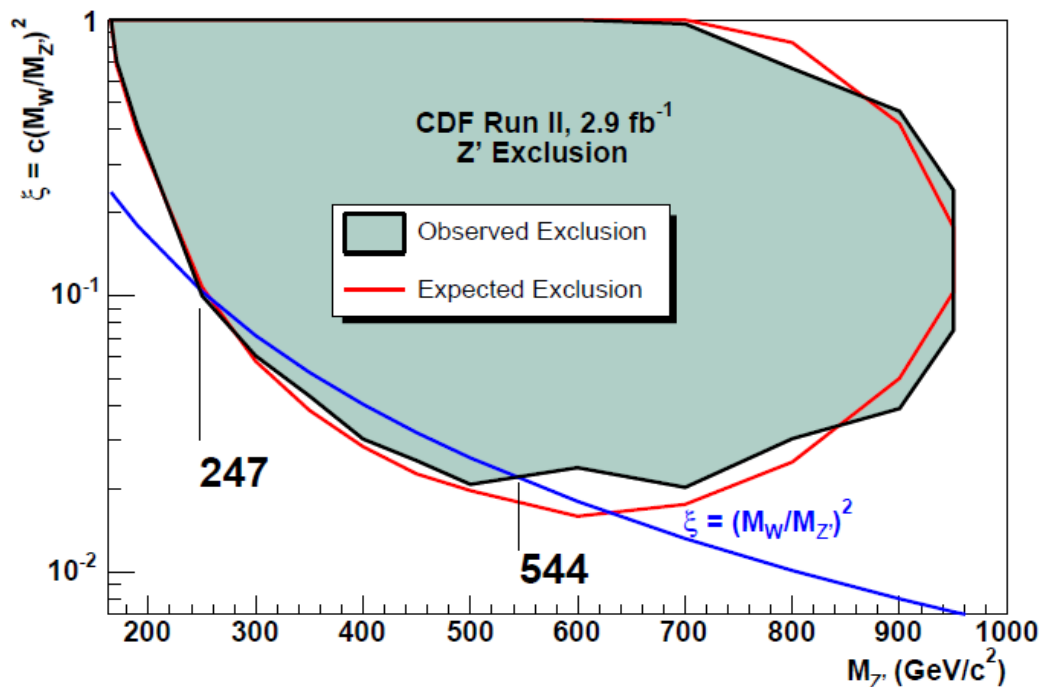
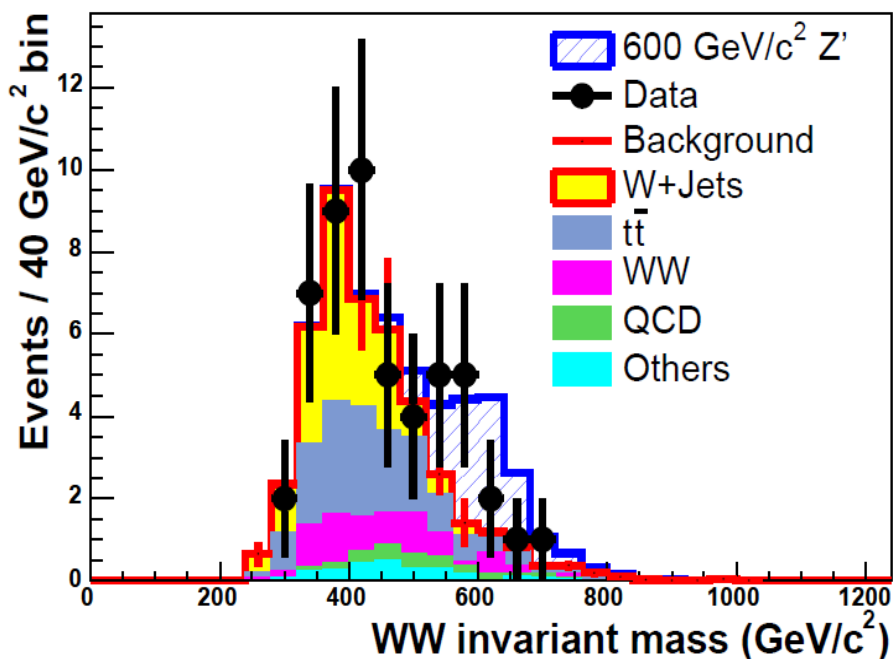
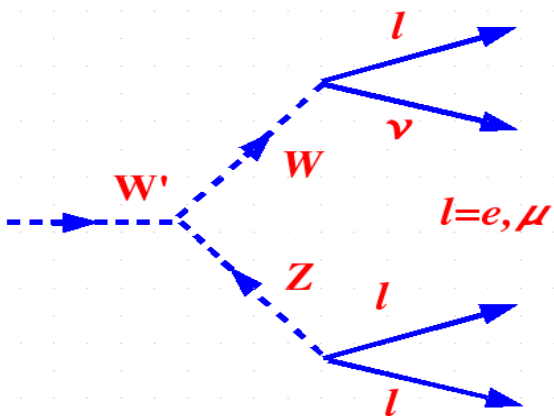


TABLE II: Mass exclusion region at 95% C.L. with $k/\overline{M}_{Pl} = 0.1$ for G^* , and $\xi = (M_W/M_V)^2$ ($C = 1$) for Z' and W' .

| | G^* | Z' | W' |
|---|---------|---------|---------|
| Expected Exclusion (GeV/c^2) | < 632 | 257-630 | 381-421 |
| Observed Exclusion (GeV/c^2) | < 607 | 247-544 | 285-516 |

Excluded @ 95% C.L. :

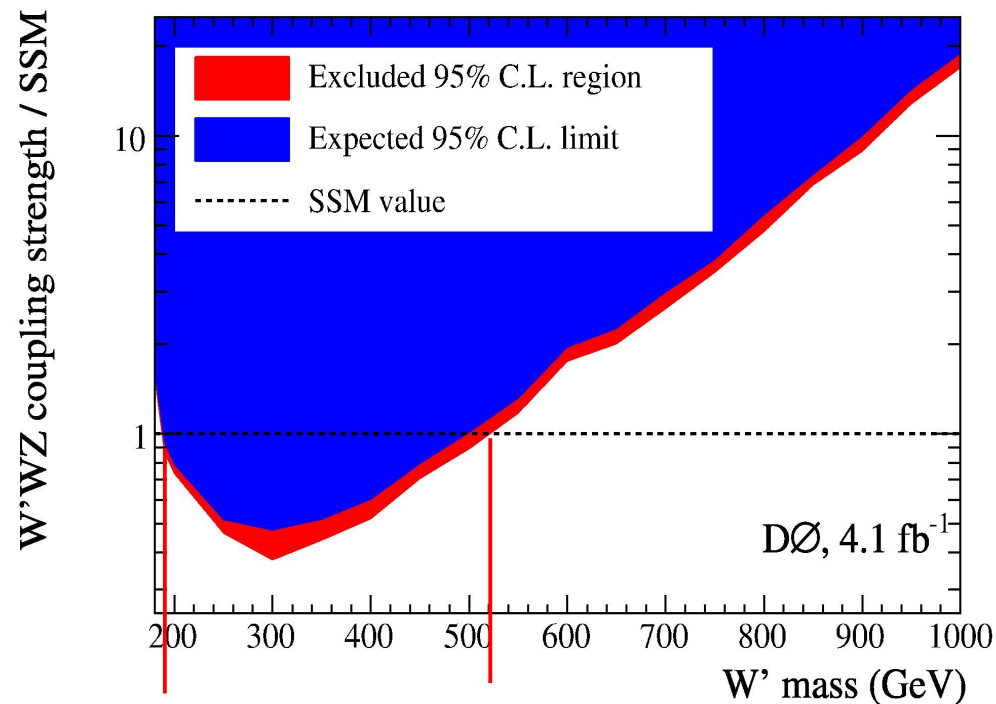
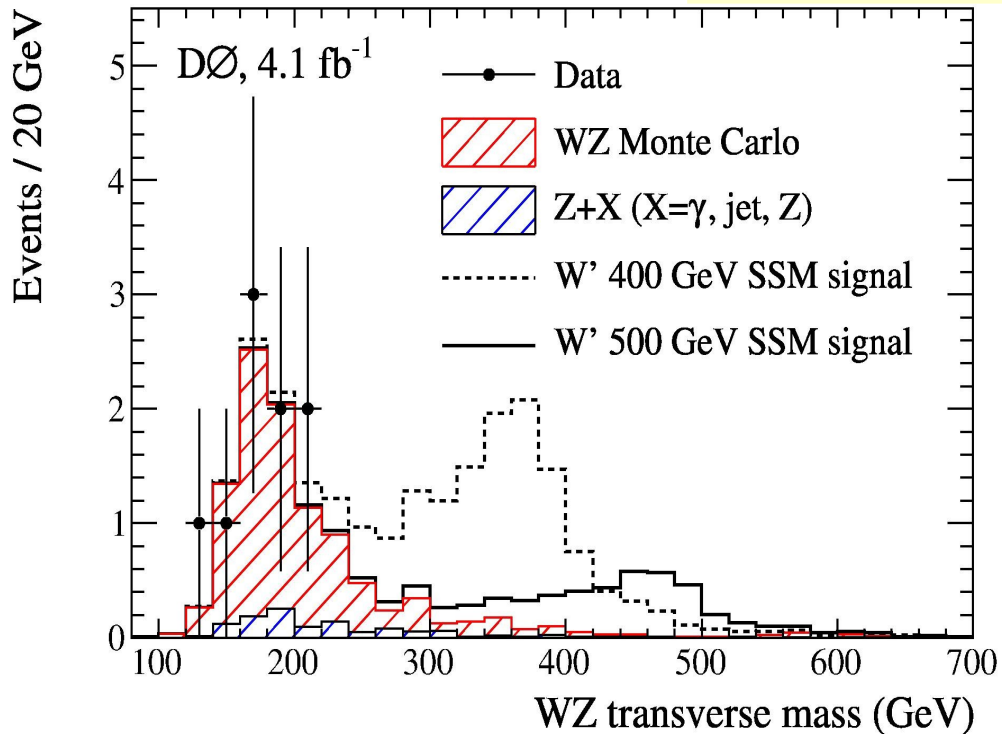


Signal selections : 3 leptons with $ET > 20 \text{ GeV}$, $MET > 30 \text{ GeV}$

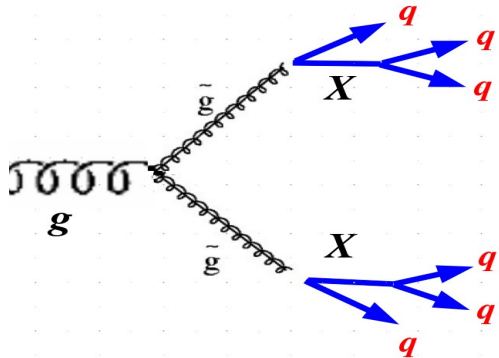
Reconstruct $M_T = \sqrt{(E_T^Z + E_T^W)^2 - (p_x^Z + p_x^W)^2 - (p_y^Z + p_y^W)^2}$

Backgrounds : SM WZ dominant, Z+X

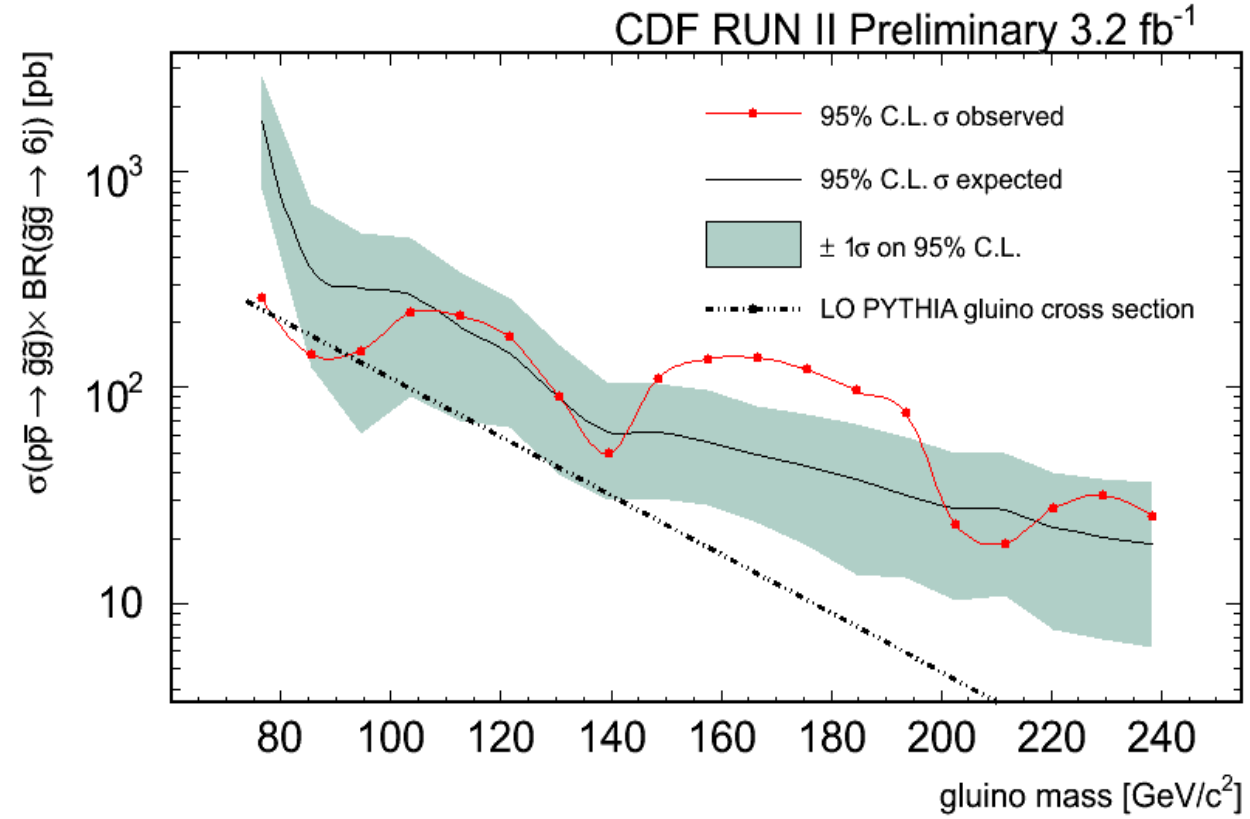
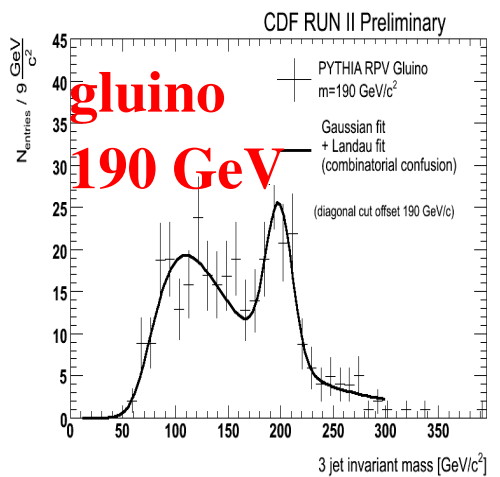
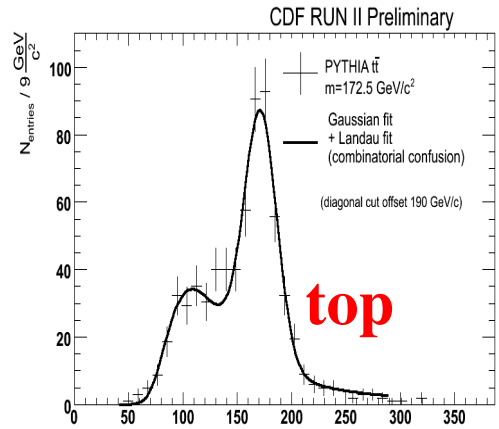
| Data | Exp. Bkg. |
|------|--------------|
| 9 | 10.2 +/- 1.6 |



Excluded @ 95% C.L. : $188 < m(W') < 520 \text{ GeV}$



Signal selections : 6+ jets, small MET <50 GeV, $\Sigma pT(6jets) > 250$ GeV. $[M_{3J}, \Sigma pT(3jets)]$ correlation
Backgrounds : QCD, ttbar



95% C.L. limits using invariant mass of 3jet ensembles

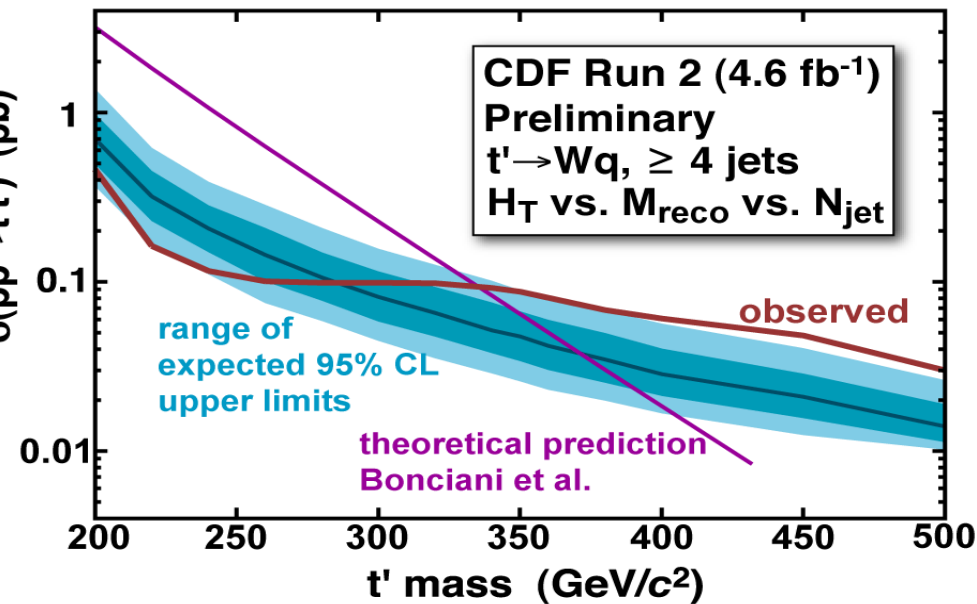
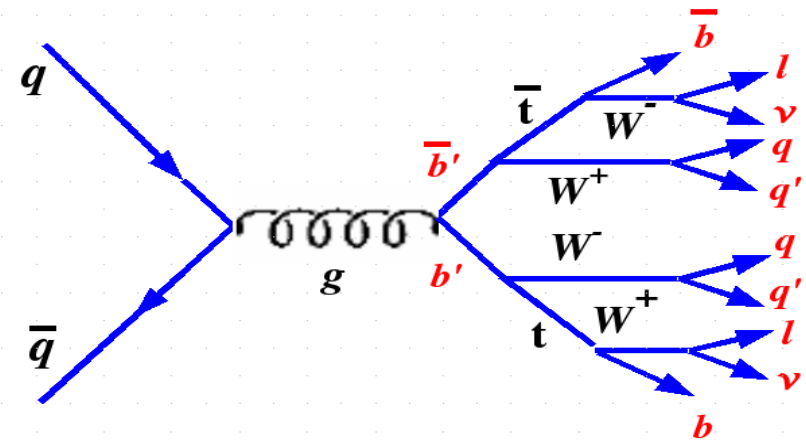
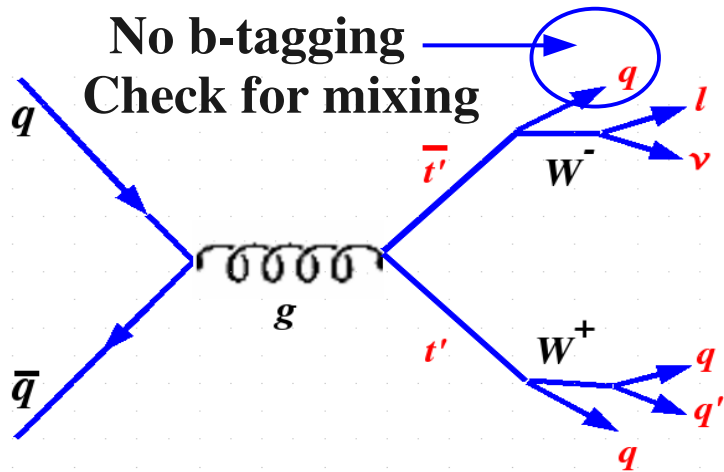
- not prohibited by SM
- if exist allow theory to adopt
 - high SM Higgs mass
 - recent large CP violation result
- Decay chains to SM 3rd generation quarks ($q' \rightarrow q + W$)
- Convenient signatures - multijet events with high transverse



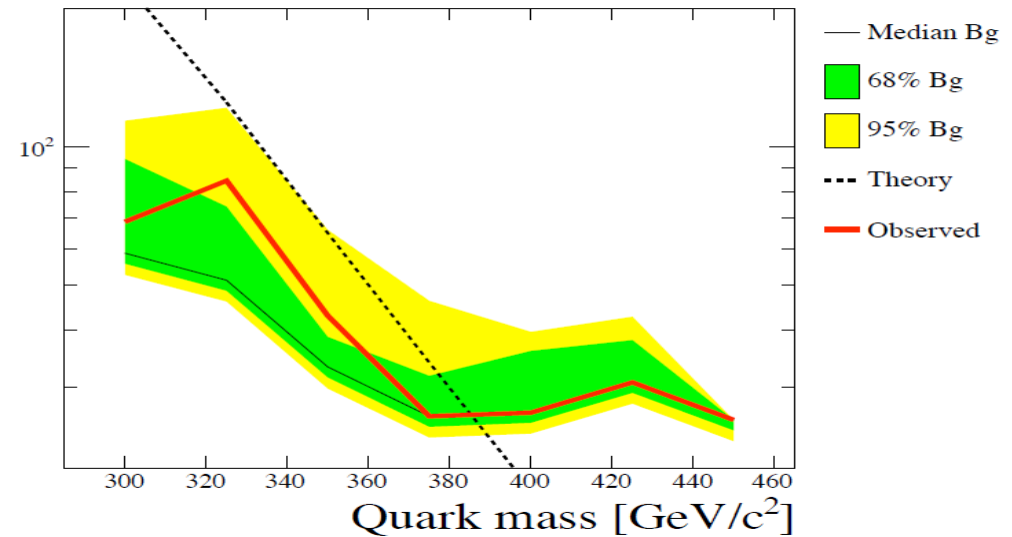
PRD 82, (2010), 032001

3.2 σ disagreement with SM in b-hadrons decay, D0 6.1 fb⁻¹

energy $H_T = \sum_{jets} E_{T,j} + E_{T,\ell} + \cancel{E}_T$



CDF Run II Preliminary L=4.8 fb⁻¹



Inspect ($M_{reco}(t'), H_T$) space
Excluded $m(t') < 335$ GeV

Divide observed multijet events
 in 5,6,7+ N_{jet} bins and 0,1,2 btag bins
Excluded $m(b') < 385$ GeV



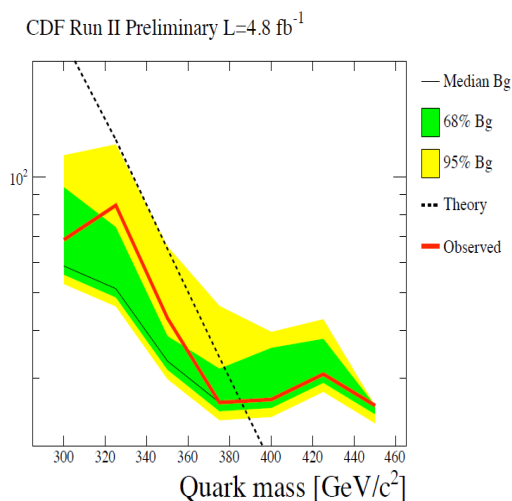
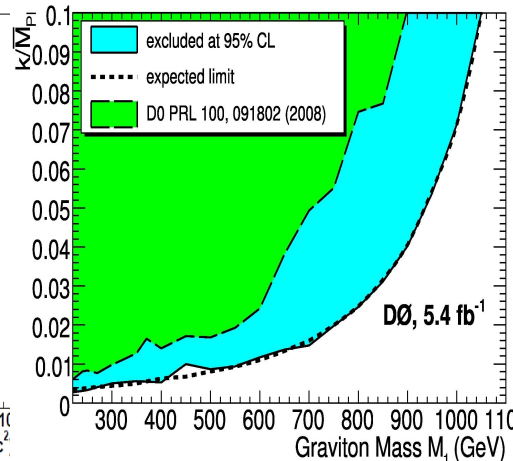
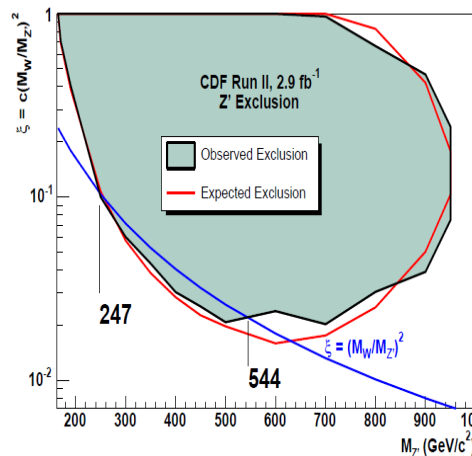
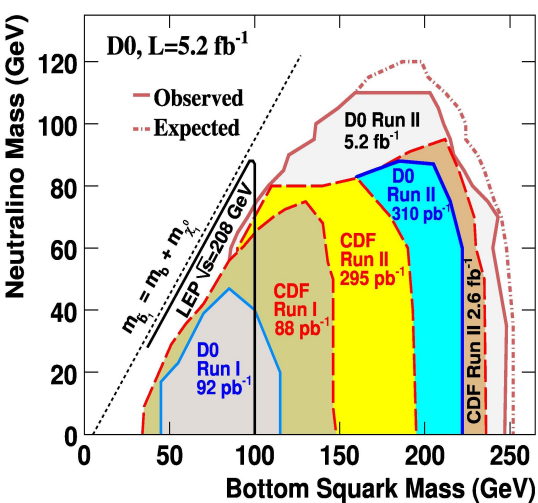
Presented recent results from D0 and CDF BSM searches in 2.6-6.3 fb⁻¹ data samples

Set of 95% C.L. exclusion limits have been obtained,
improving previous TeVatron results

Complete documentation :

<http://www-cdf.fnal.gov/physics/physics.html>

<http://www-d0.fnal.gov/Run2Physics/WWW/results/np.html>



Backup Slides

D0 operations

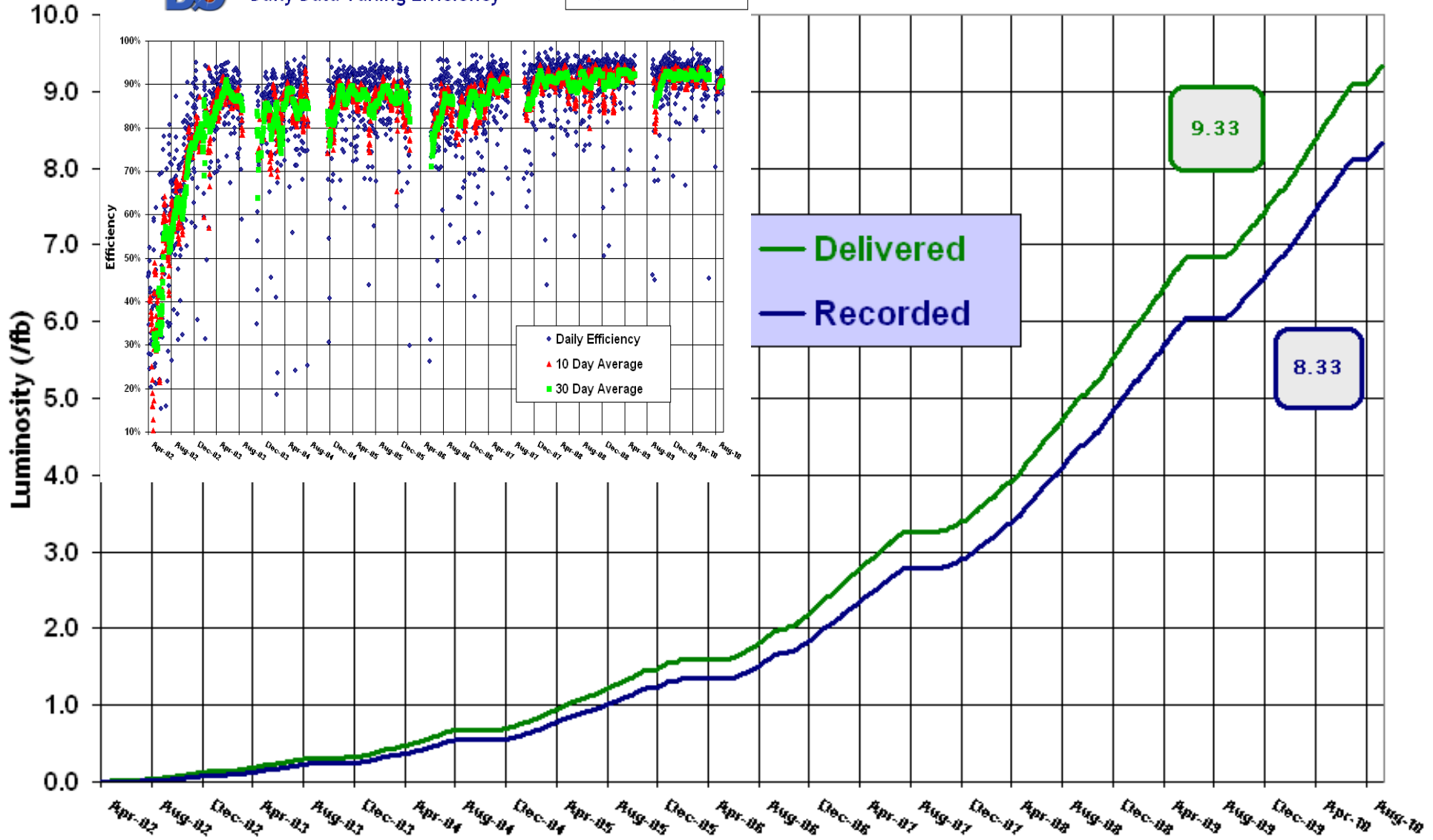


Run II Integrated Luminosity

19 April 2002 - 26 September 2010

Daily Data Taking Efficiency

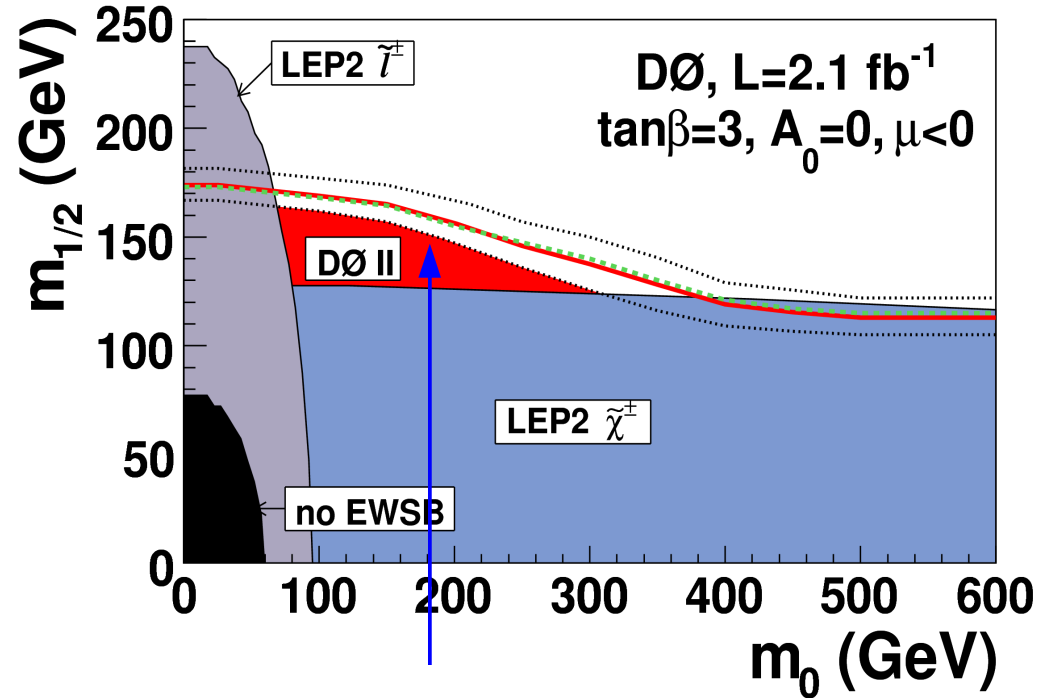
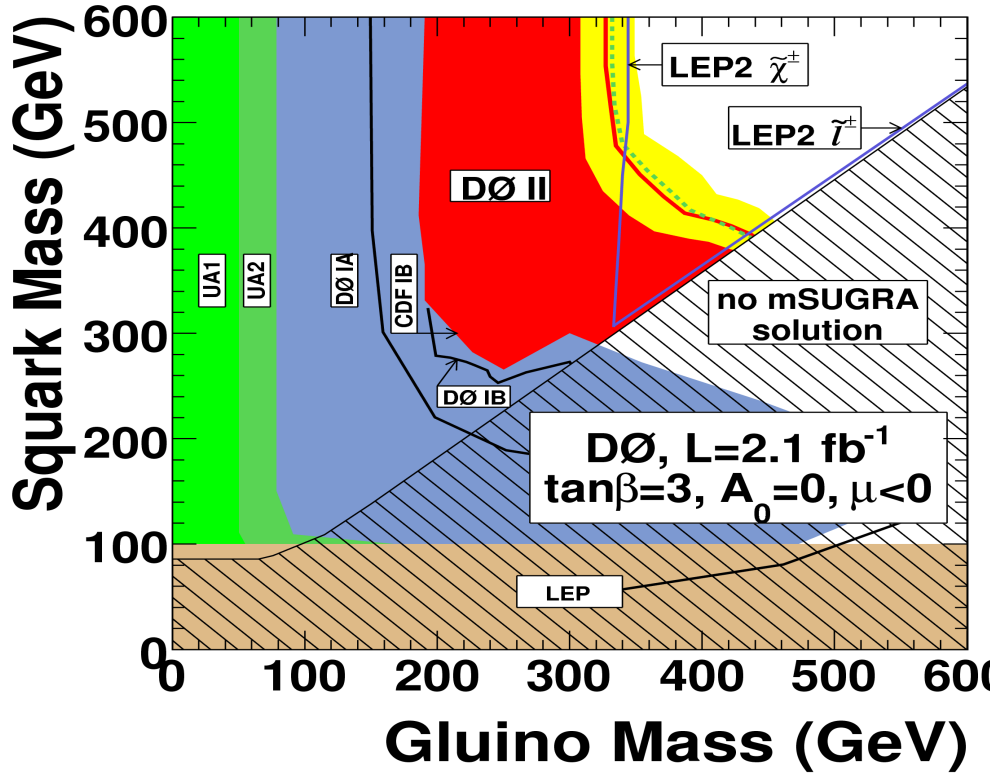
19 April 2002 - 26 September 2010



Squarks and Gluinos (2.1 fb⁻¹ jets+MET inclusive)

95% C.L. limits set on squark and gluino masses and mSUGRA parameters

D0 PLB, 660, 449 (2008), similar limits CDF PRL 102 (2009) 121801



Improvement vs LEP2 results

Excluded:

M(squark) < 379 GeV, M(gluino) < 308 GeV

(most conservative hypothesis accounting PDF and RF scale uncertainty on the signal NLO cross-section)

masses up to 390 GeV for M(squark) \approx M(gluino)