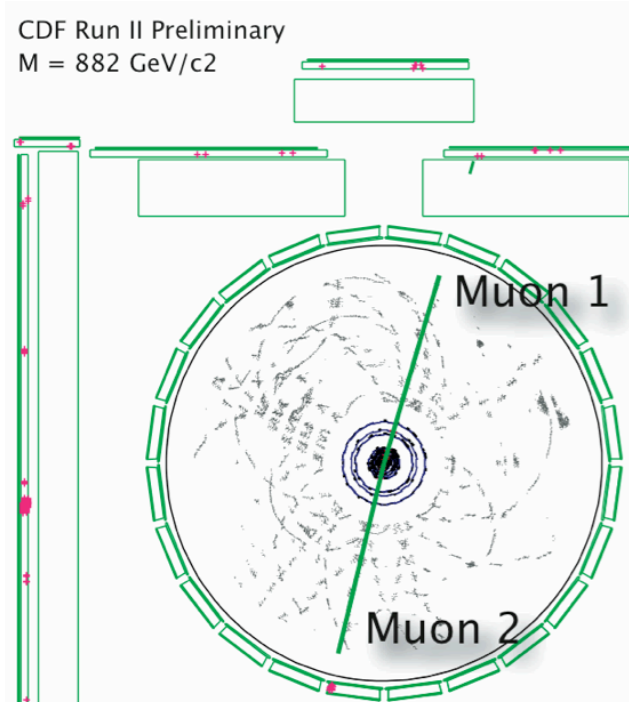


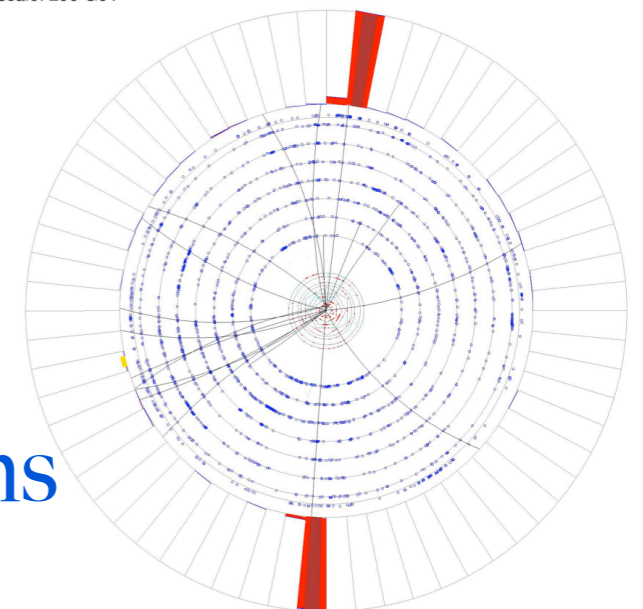
# Searches in dilepton and diphoton final states at the Tevatron



Run 233604 Evt 7403139 Tue Jun 12 00:44:32 2007  
ET scale: 296 GeV

Chris Hays,  
Oxford University

for the CDF and DØ Collaborations



35th International Conference on High Energy Physics  
Paris, France, 24 July, 2010

# Experimental motivation

\* Diphoton and dilepton searches provide a clean, model-independent probe for new particles

\* Excellent detector resolution

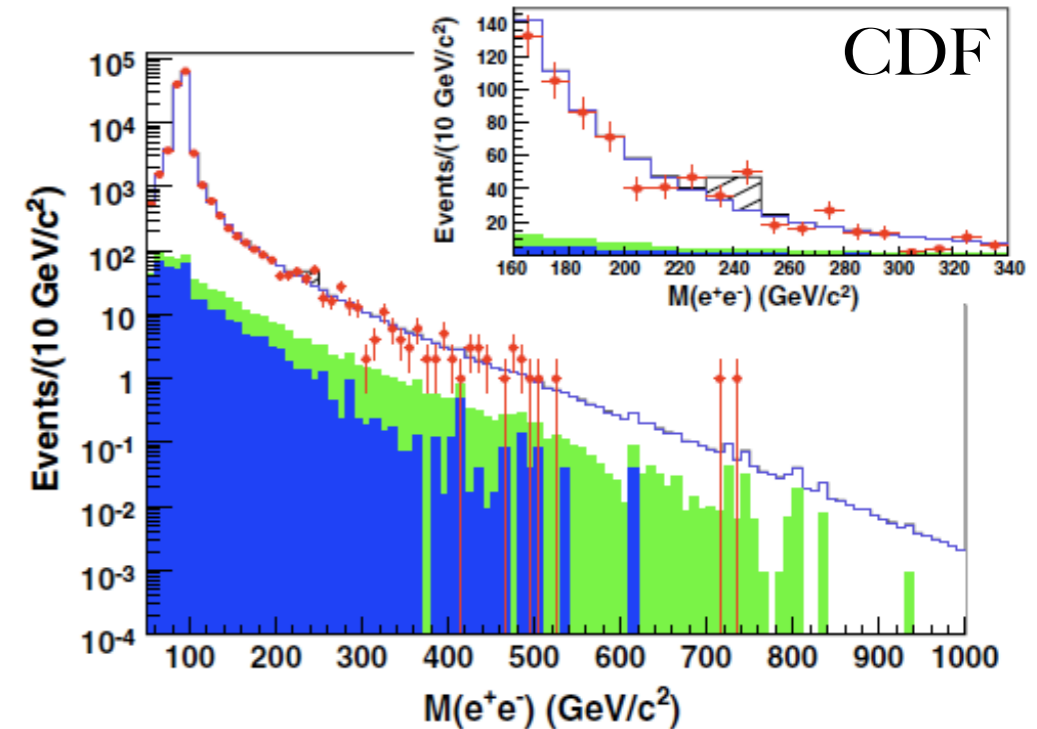
\* CDF dimuon mass resolution:  $\approx 15\%$  at 1 TeV

\* CDF dielectron mass resolution  $\approx 2\%$  at 1 TeV

\* Unambiguous mass peaks separable from background

\* Primary issue: statistics

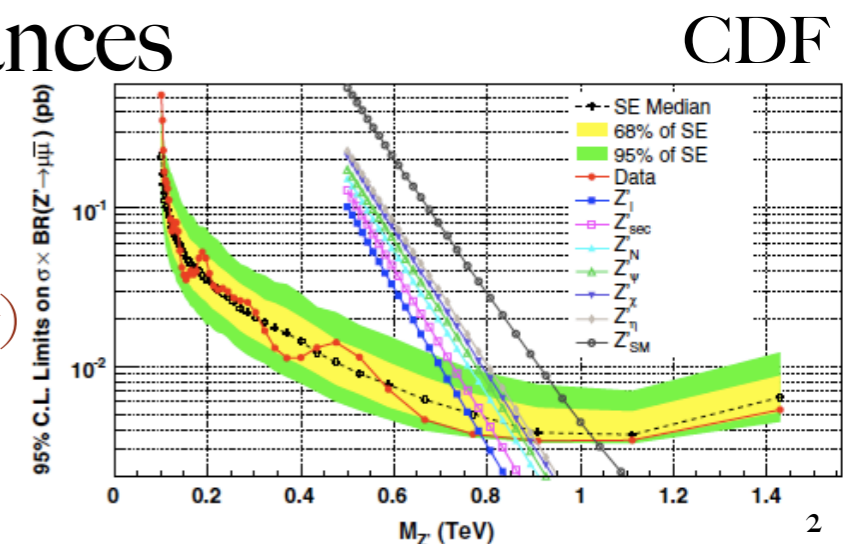
\* CDF ee search finds excess at 240 GeV with  $2.5\sigma$  significance



\* Tevatron has best sensitivity to new resonances

\* High-mass resonance searches approaching kinematic limit

\* Improving sensitivity to weakly coupled resonances ( $\alpha \lesssim \alpha_{EW}$ )

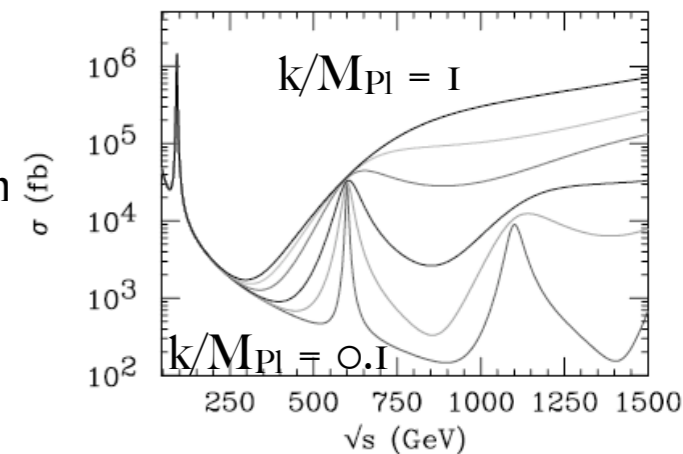


# Theoretical motivation

## \* New neutral resonances ubiquitous in models beyond the SM

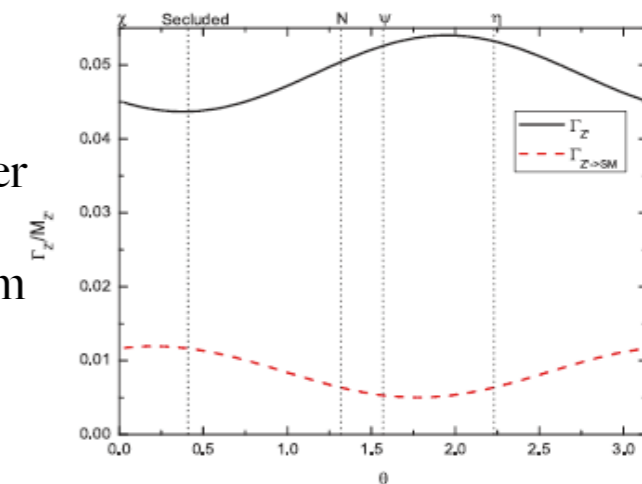
### \* Spin 2 gravitons in models with warped extra dimensions

- \* Randall-Sundrum model: metric contains exponential factor as function of extra dimension
- \* Predicts tower of graviton resonances with masses and couplings determined by  $k/M_{\text{Pl}}$



### \* Spin 1 gauge bosons in models with new $U(1)$ gauge group

- \* Superstring-inspired grand unified theory ( $E_8 \times E_8$ ): couplings determined by one parameter
- \* Stueckelberg model where Abelian gauge boson acquires mass without a Higgs mechanism
- \*  $U(1)$  with flavor-dependent charge



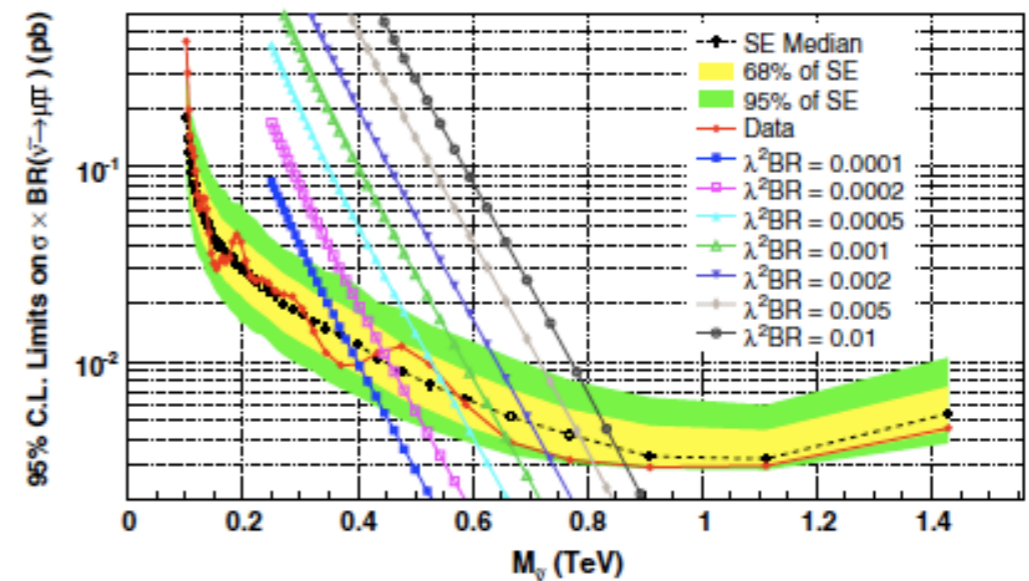
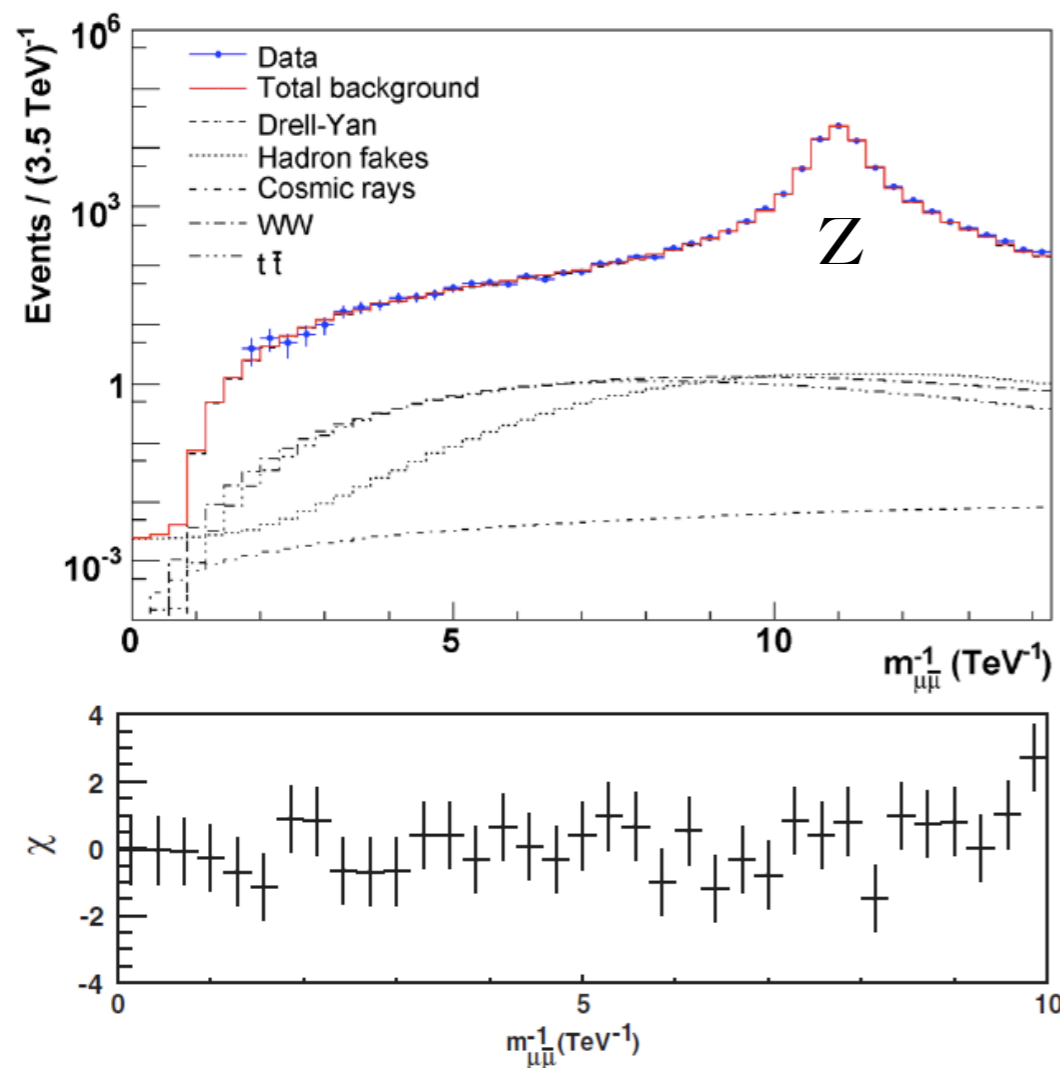
### \* Spin 0 Higgs bosons and sneutrinos in supersymmetric models

- \* R-parity-violation models allow direct  $q$ - $q$ -sneutrino and  $l$ - $l$ -sneutrino couplings
- \* Conserves baryon number, allowing greater suppression of proton decay than R-parity

# CDF searches in $ee$ and $\mu\mu$

\* CDF search in  $2.3 \text{ fb}^{-1}$  of  $\mu\mu$  data gives best published sensitivity to sneutrino and  $Z'$  production

\* Uses novel method of fitting  $1/m$  distribution, which is  $\approx$  constant in resolution



$Z'$ Model	$Z'$ Mass limit	RS graviton $k/M_{\text{Planck}}$	Graviton Mass limit	$\tilde{\nu}$ $\lambda^2 \text{BR}$	$\tilde{\nu}$ Mass limit
$Z'_1$	789	0.01	293	0.0001	397
$Z'_{\text{sec}}$	821	0.015	409	0.0002	441
$Z'_N$	861	0.025	493	0.0005	541
$Z'_\psi$	878	0.035	651	0.001	662
$Z'_\chi$	892	0.05	746	0.002	731
$Z'_\eta$	904	0.07	824	0.005	810
$Z'_{\text{SM}}$	1030	0.1	921	0.01	866

Phys. Rev. Lett. 102, 091805 (2009)

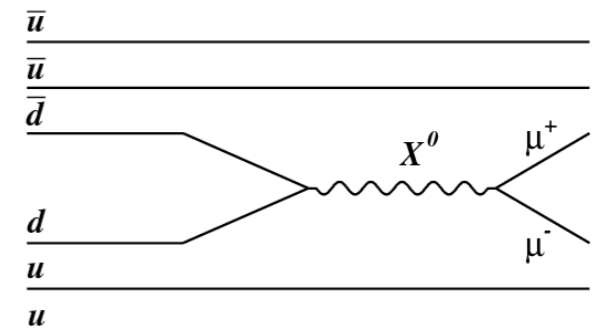
\* CDF  $ee$  search finds excess at 240 GeV with  $2.5\sigma$  significance

Phys. Rev. Lett. 102, 031801 (2009)

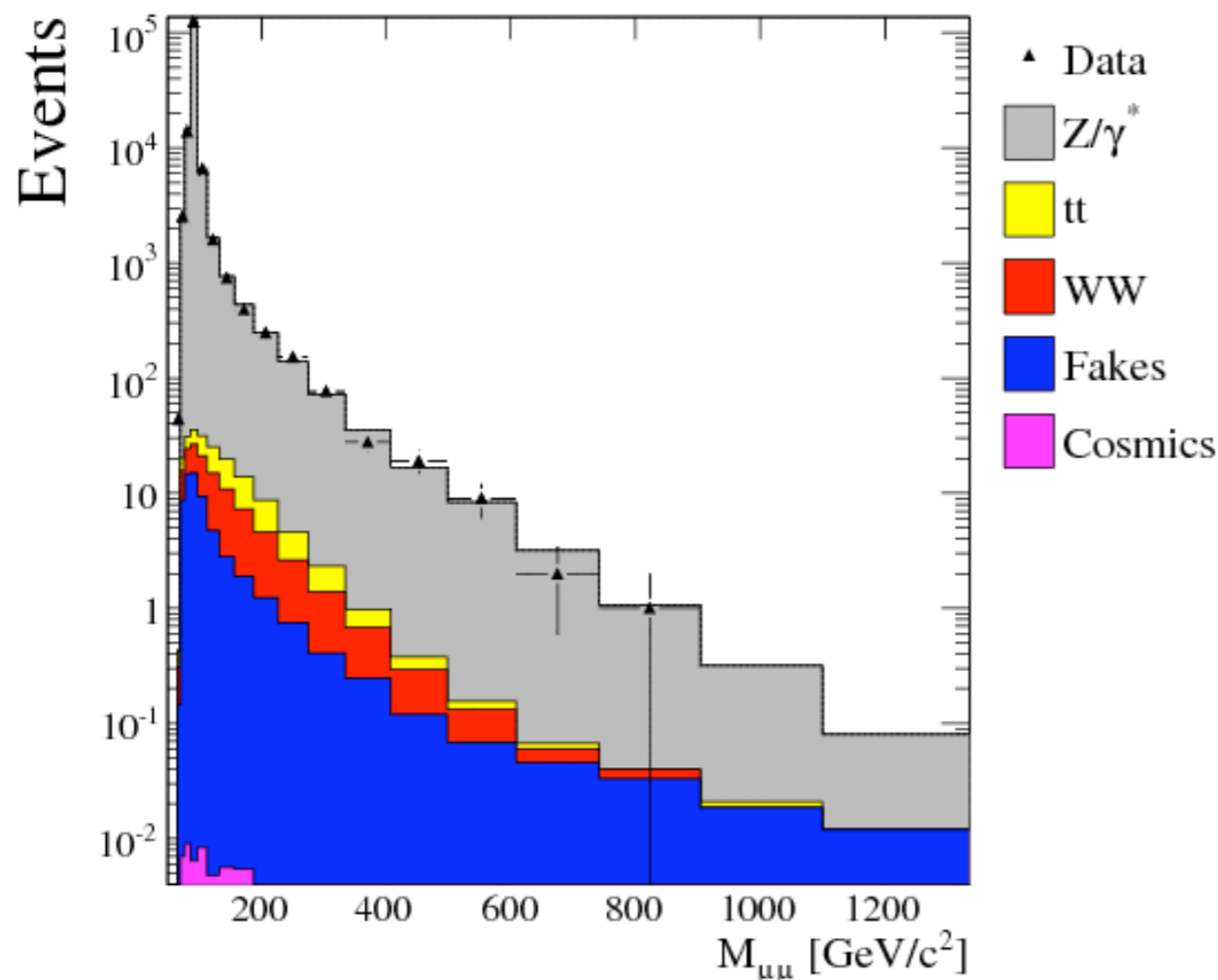
# CDF 4.6 fb<sup>-1</sup> search in $\mu\mu$

\* New CDF search uses matrix-element-based likelihood to separate  $Z'$  signal from Drell-Yan and maximize sensitivity

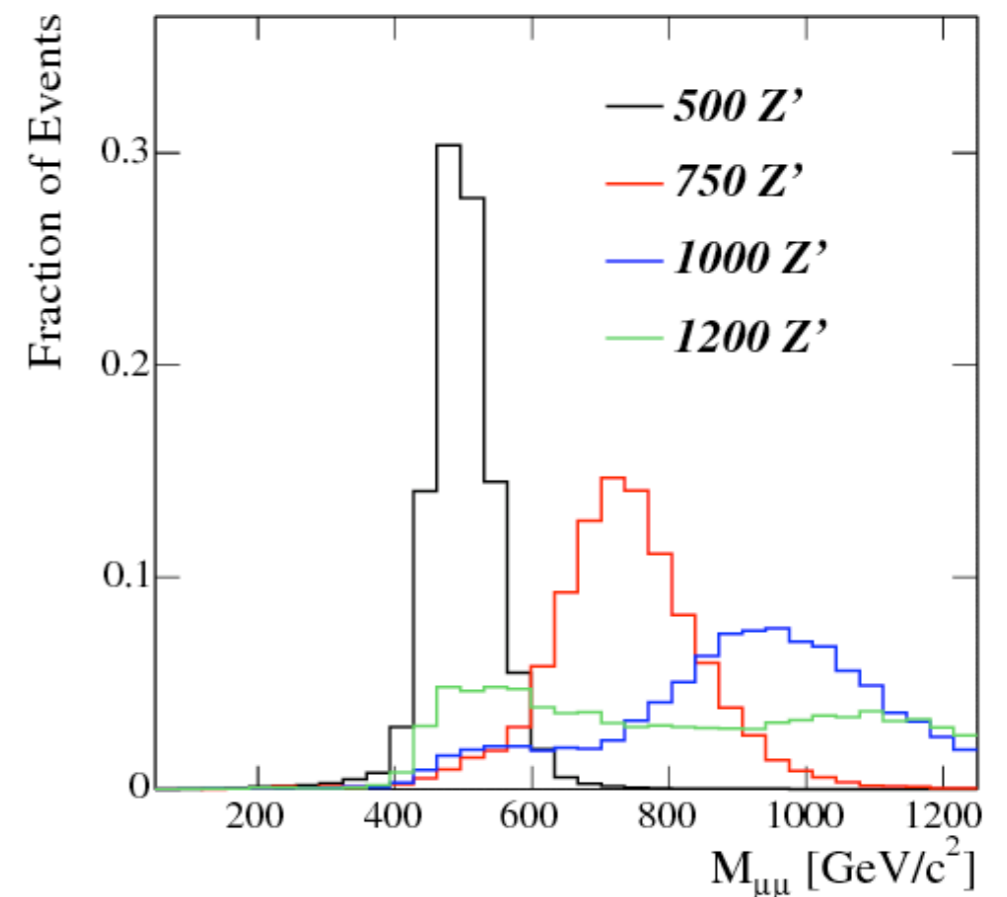
\* Gains 20% in cross section sensitivity relative to previous search



CDF Run II Preliminary 4.6 fb<sup>-1</sup>



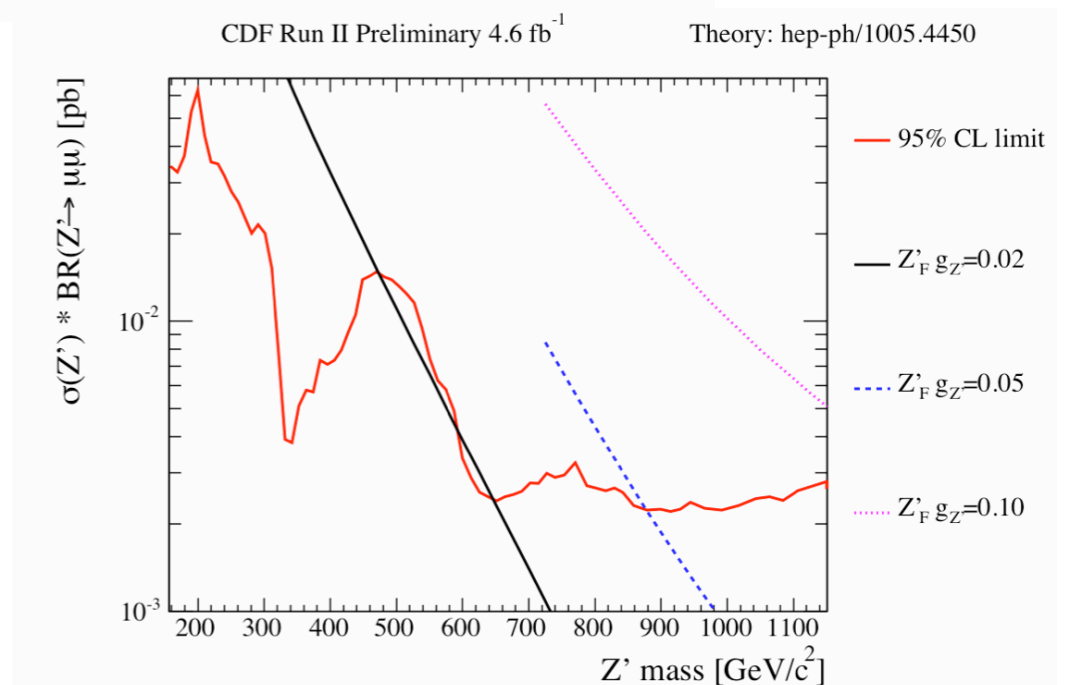
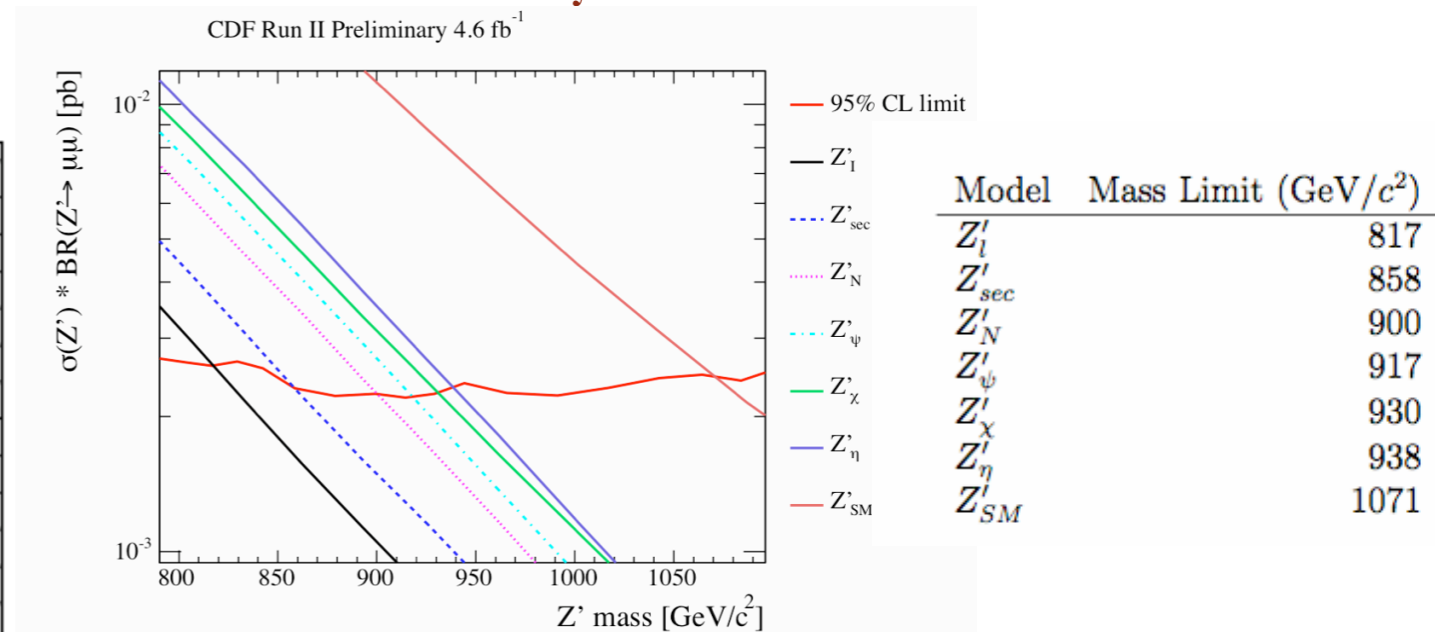
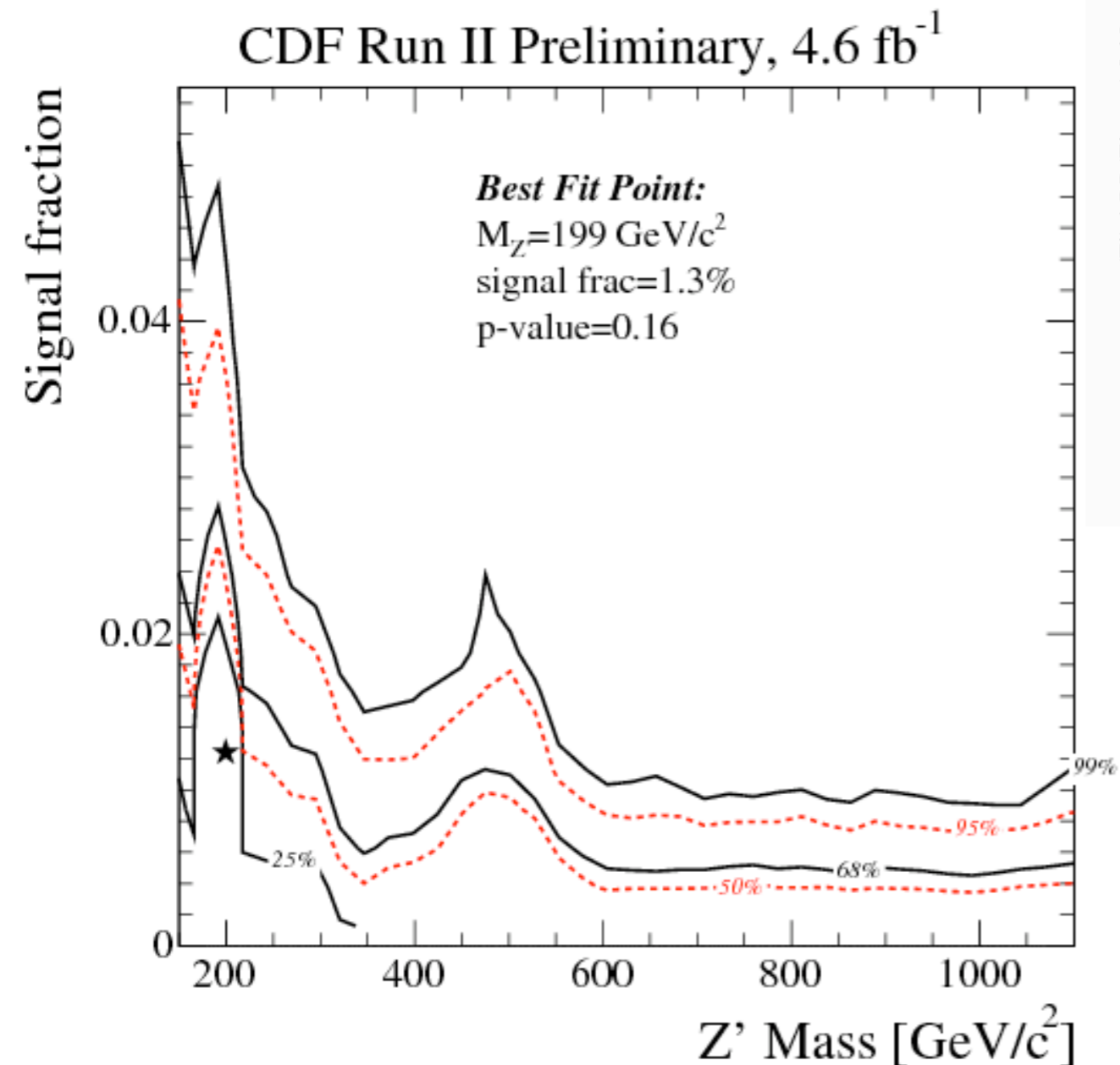
CDF Run II Preliminary



# CDF 4.6 fb<sup>-1</sup> search in $\mu\mu$

\* Determines best fit to data in cross section vs mass plane

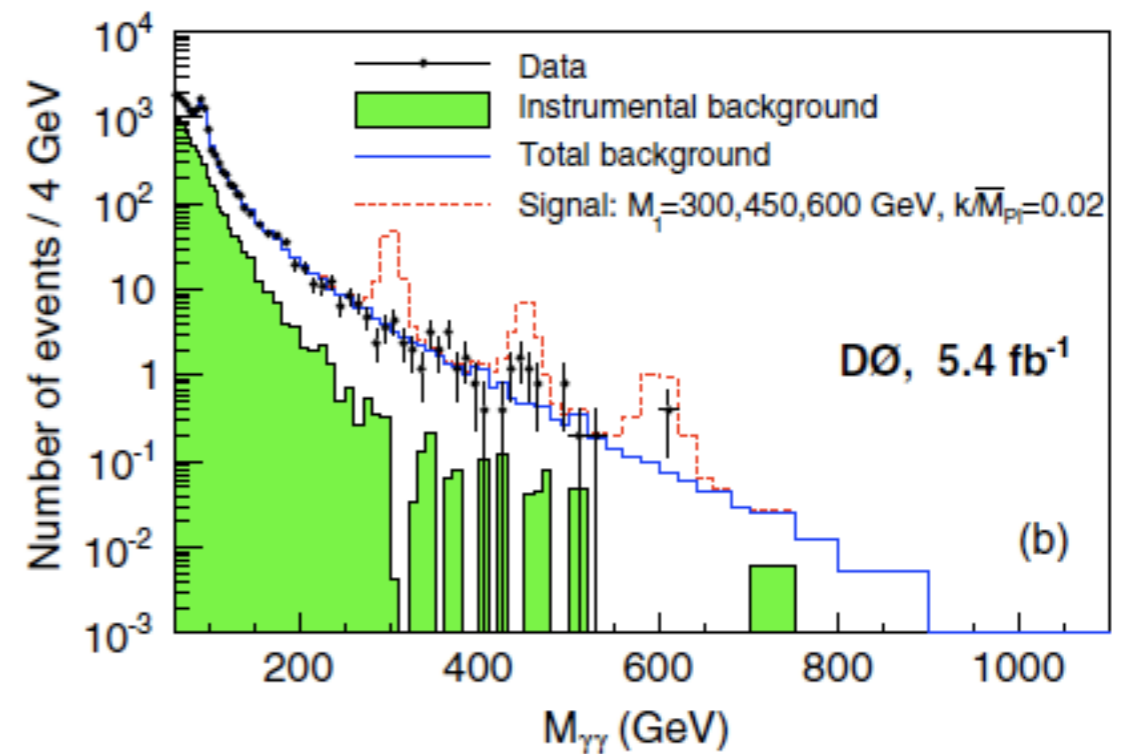
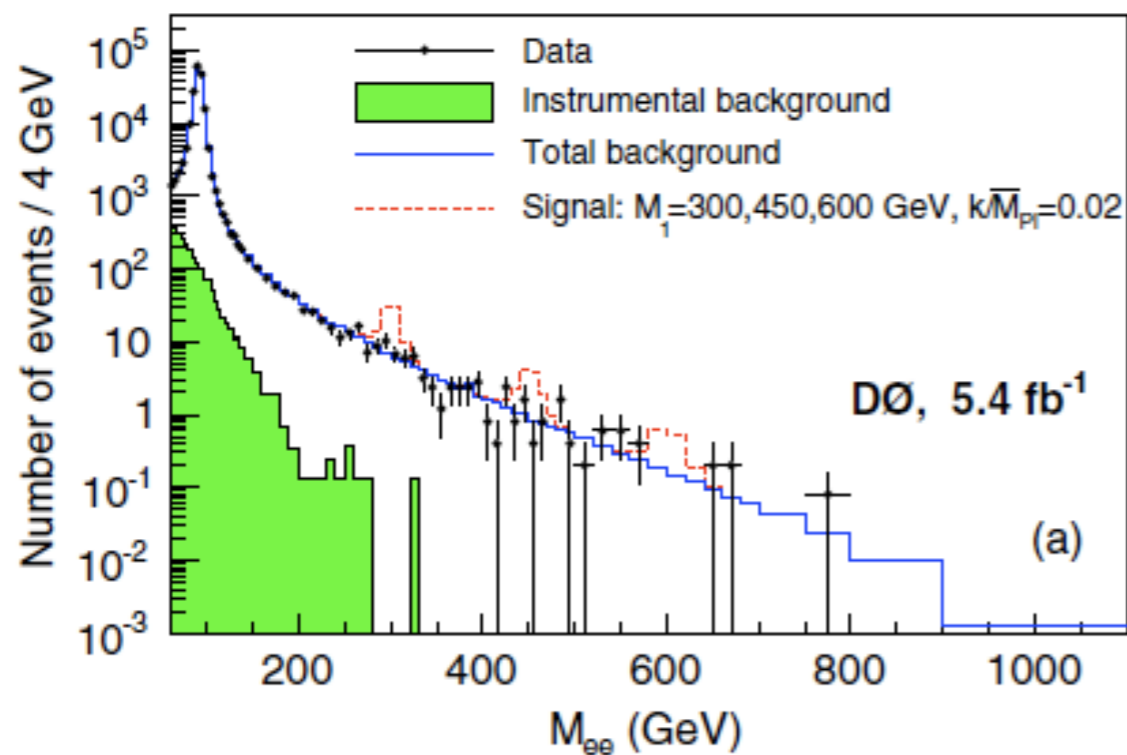
\* Feldman-Cousins contours account for 'look elsewhere' effect by construction



# DØ combined $ee/\gamma\gamma$ search

\* Graviton branching ratio to photons twice that of electrons

\* Gain sensitivity by separately searching dielectrons and diphotons



\* Most significant excess at mass of 450 GeV in  $\gamma\gamma$

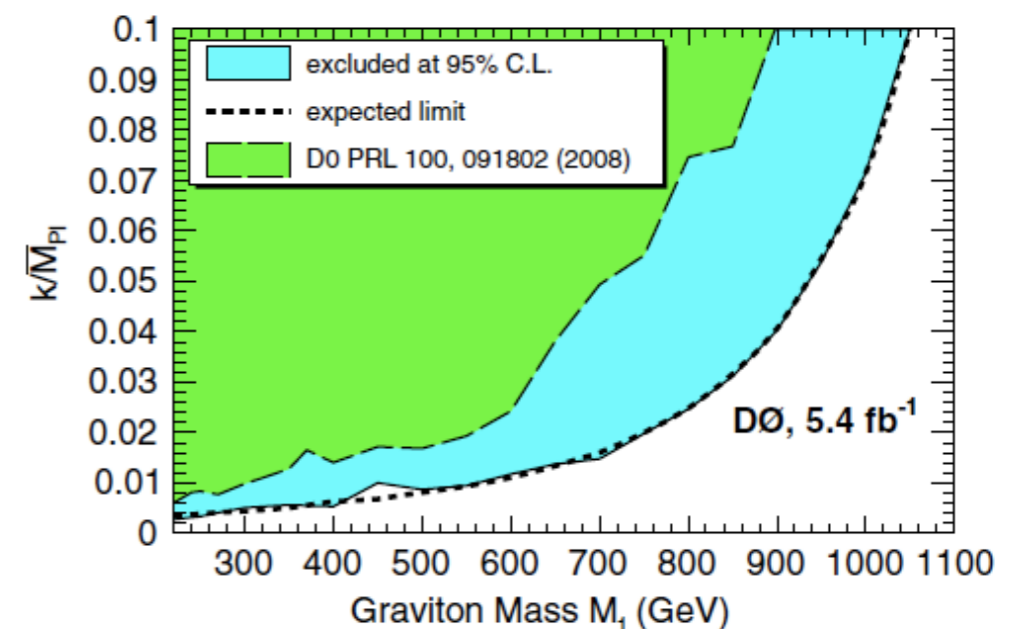
\*  $2.3\sigma$  after accounting for mass scan

\* Not confirmed in dielectrons

\* Set world's highest mass limits on R-S gravitons

Phys. Rev. Lett. 104,

241802 (2010)

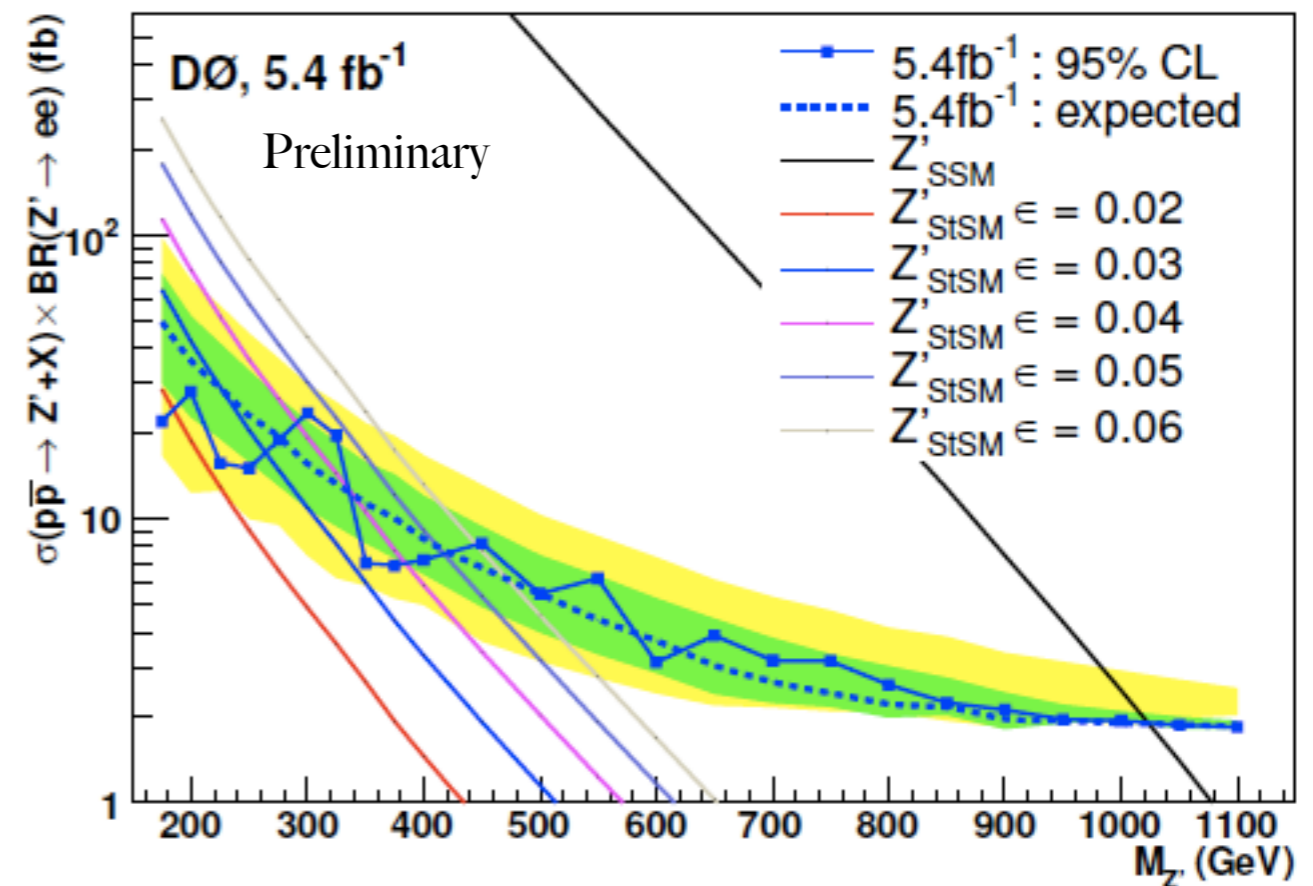
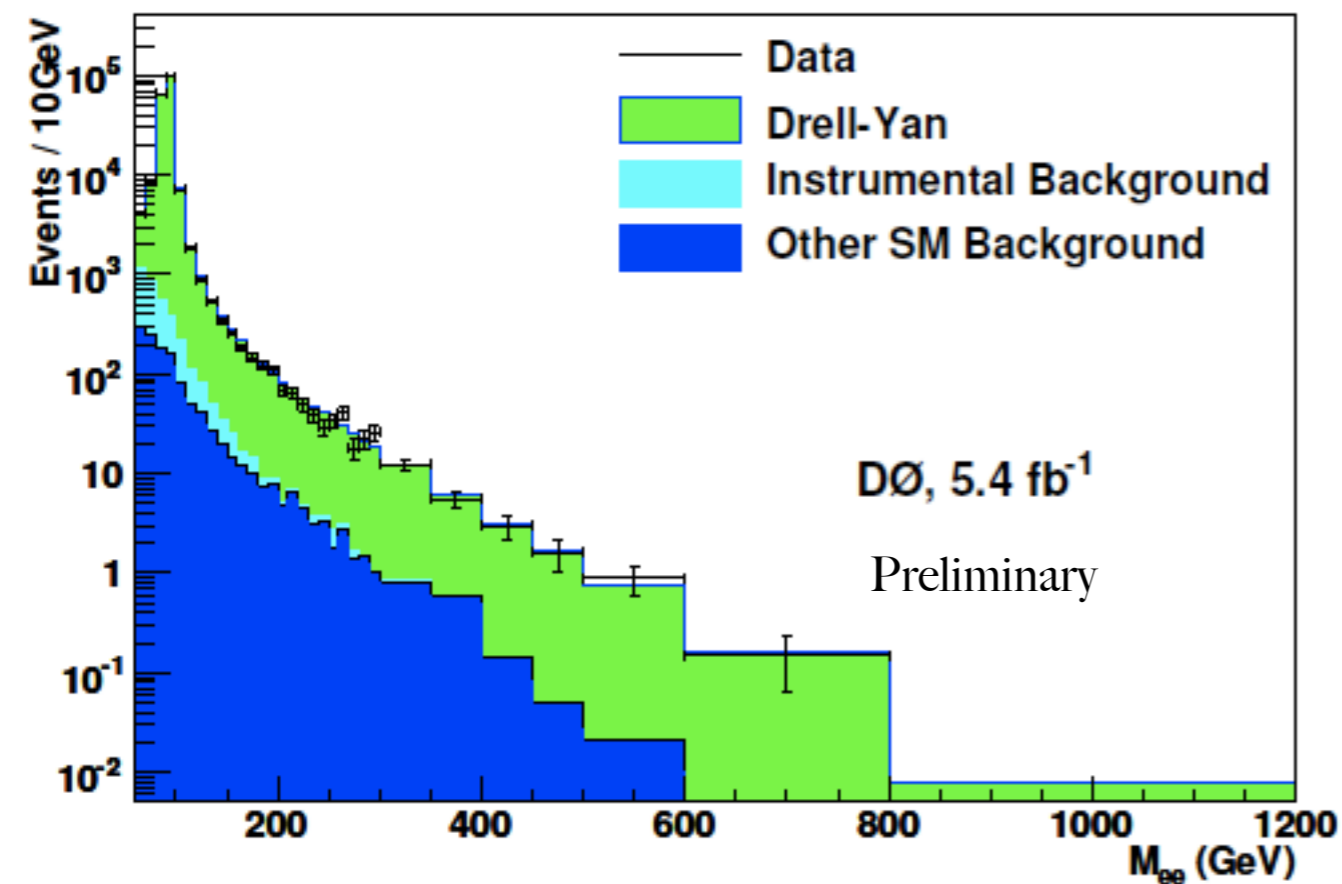


# DØ ee search

\* Use dielectron data to probe for  $Z'$  bosons

\*  $Z'$  with non-universal flavor couplings has higher branching ratio to electrons than muons

\* Test CDF excess at mass of 240 GeV

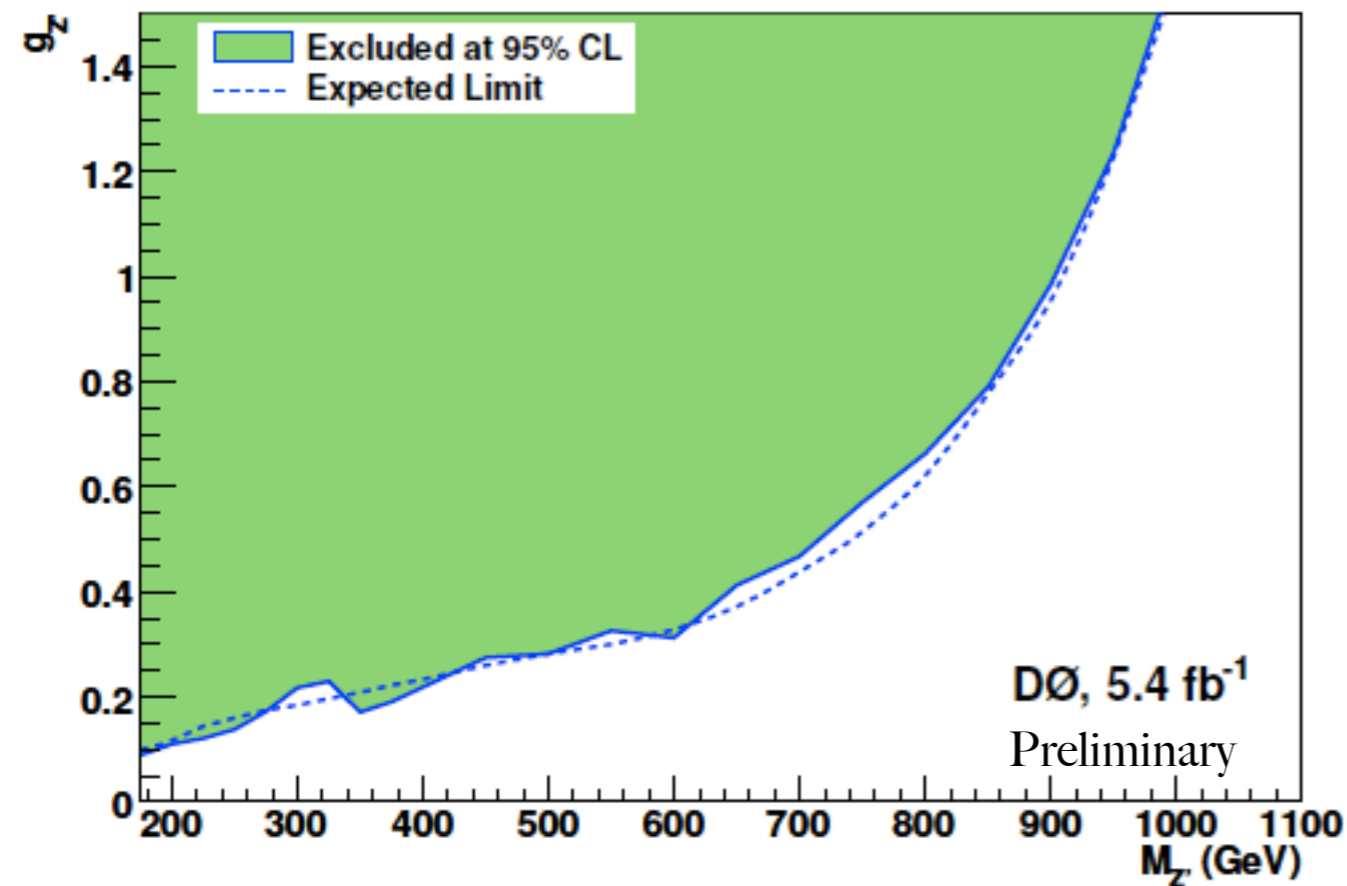




# DØ ee search

\* Set limits on gauge coupling in superstring inspired  $E_6$  model as a function of mass

\* Also set mass limits for Stueckelberg  $Z'$  bosons with weak coupling to SM



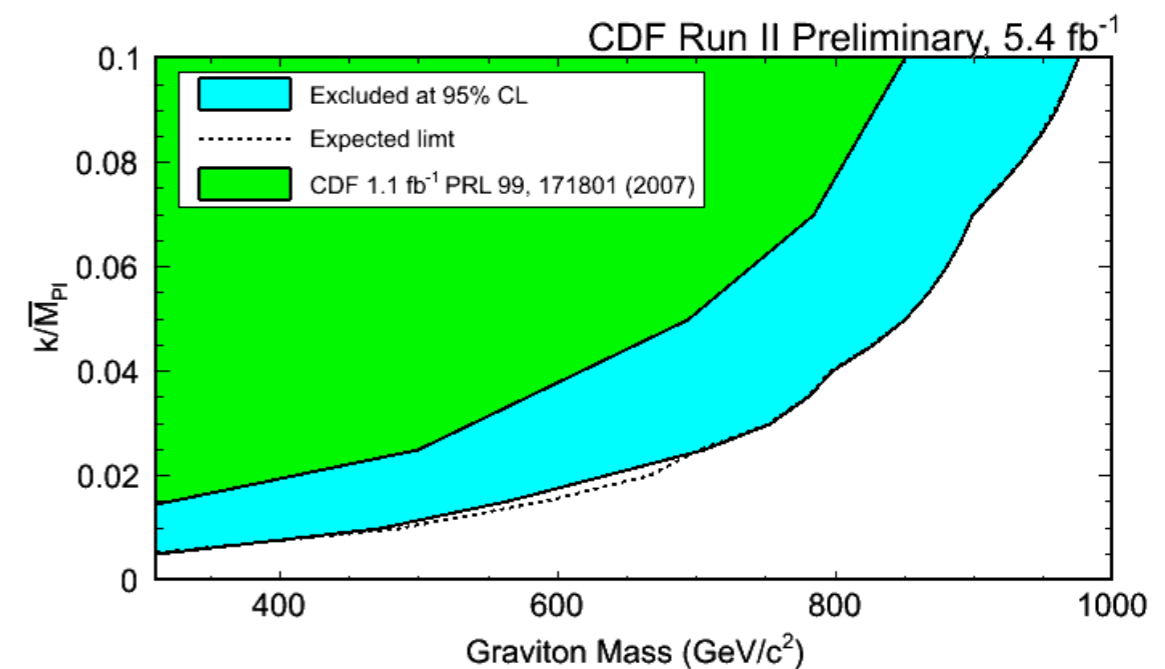
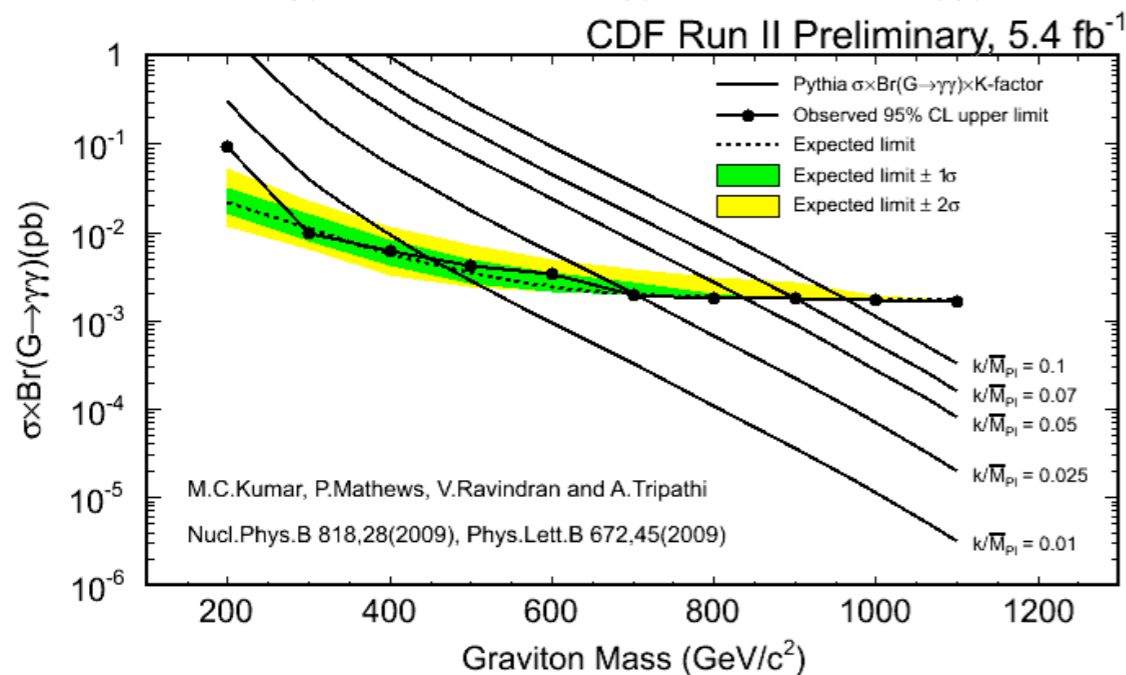
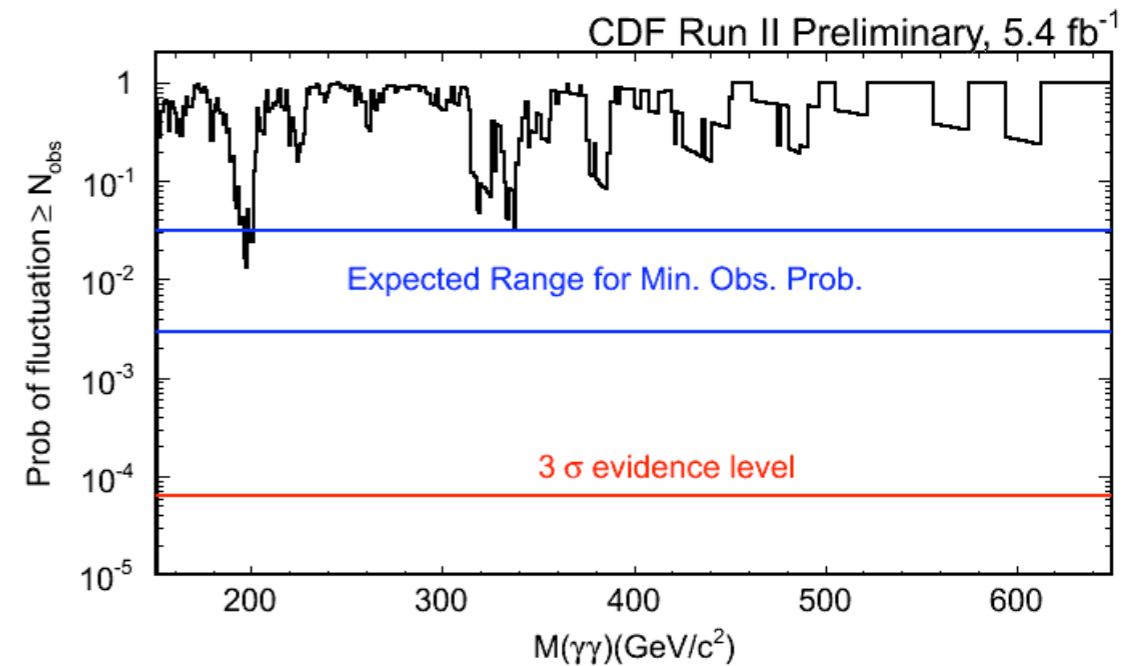
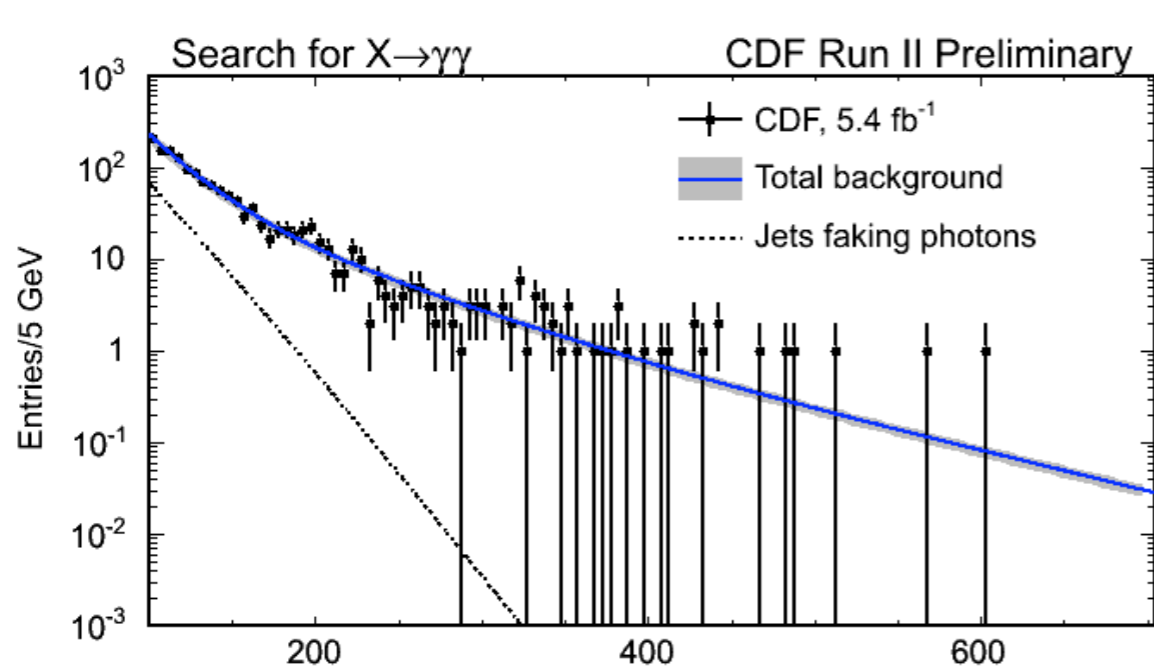
Model	Lower Mass Limit (GeV)	
	Expected	Observed
$Z'_{SSM}$	1024	1023
$Z'_{\eta}$	927	923
$Z'_{\chi}$	910	903
$Z'_{\psi}$	898	891
$Z'_N$	879	874
$Z'_{sq}$	829	822
$Z'_I$	795	772
$Z'_{StSM}(\epsilon = 0.06)$	471	443
$Z'_{StSM}(\epsilon = 0.05)$	414	417
$Z'_{StSM}(\epsilon = 0.04)$	340	289
$Z'_{StSM}(\epsilon = 0.03)$	227	264
$Z'_{StSM}(\epsilon = 0.02)$	—	180

Preliminary

# CDF diphoton search

\* CDF has updated an earlier diphoton search for R-S gravitons

\* Most significant excess at 200 GeV



# DØ search in diphoton + $\cancel{E}_T$

\* Probing diphoton sample with significant energy imbalance sensitive to new class of models

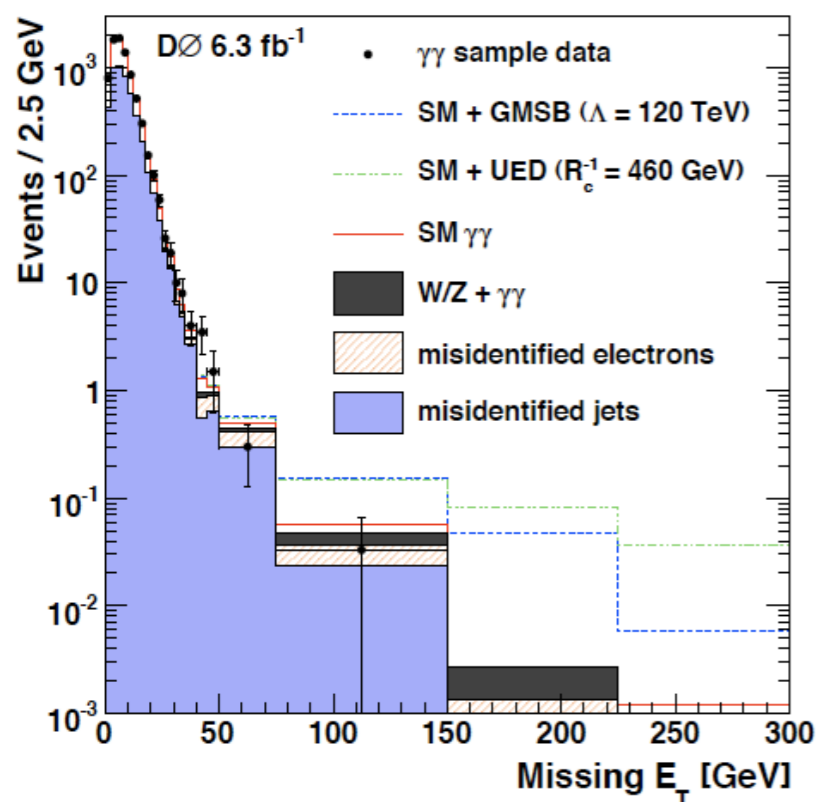
\* Pair production of particles decaying to a photon and unidentified particle

\* Neutralino production in gauge-mediated supersymmetry breaking models

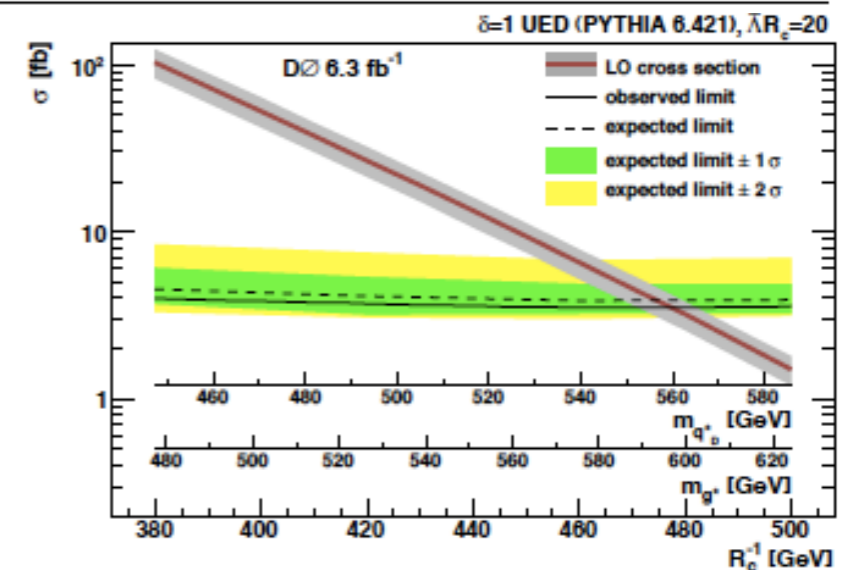
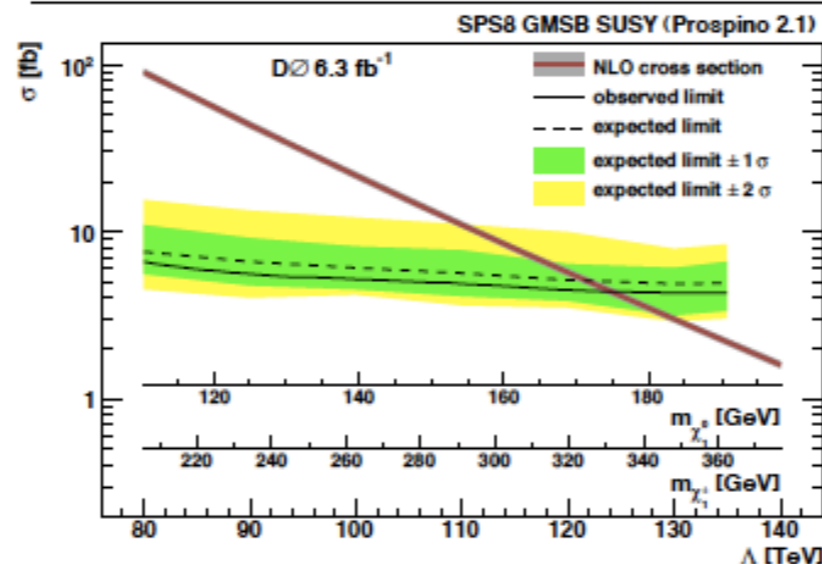
\* Neutralino decays to photon and lightest supersymmetric particle

\* Graviton production in models of universal extra dimensions with Kaluza-Klein-parity violating decays

\* Kaluza-Klein photon decays to photon and graviton



$\cancel{E}_T$ Interval, GeV	Observed Events	SM Background Events			Expected Signal Events			
		Instr. $\cancel{E}_T$	Genuine $\cancel{E}_T$	Total	GMSB $\Lambda = 100$ TeV	GMSB $\Lambda = 120$ TeV	UED $R_c^{-1} = 420$ GeV	UED $R_c^{-1} = 460$ GeV
35 – 50	18	$9.6 \pm 1.9$	$2.3 \pm 0.5$	$11.9 \pm 2.0$	$1.8 \pm 0.1$	$0.3 \pm 0.1$	$1.4 \pm 0.1$	$0.3 \pm 0.1$
50 – 75	3	$3.5 \pm 0.8$	$1.5 \pm 0.3$	$5.0 \pm 0.9$	$4.1 \pm 0.3$	$0.8 \pm 0.1$	$2.9 \pm 0.2$	$0.6 \pm 0.1$
> 75	1	$1.1 \pm 0.4$	$0.8 \pm 0.1$	$1.9 \pm 0.4$	$14.3 \pm 1.1$	$4.4 \pm 0.4$	$24.7 \pm 2.0$	$6.4 \pm 0.5$



# Summary

- \* Tevatron searches for dileptons and diphotons continually expanding sensitivity

- \* Resonances with couplings of order of the SM Z are reaching kinematic limit

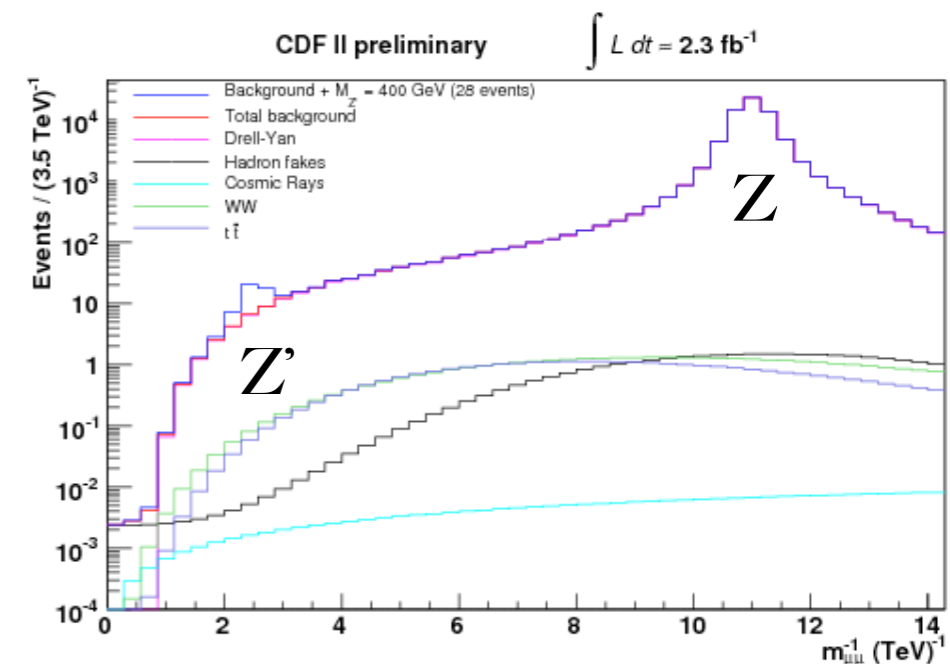
- \* Results with  $5 \text{ fb}^{-1}$  of data per experiment: probing ever weaker couplings

- \* Tevatron continues to pioneer new search techniques and probe new models

- \* Matrix-element provides background separation

- \* For weak couplings searches no longer background-free

- \* Covering many Z' models, general mass vs coupling limits



- \* More ground still to cover with full Tevatron data set