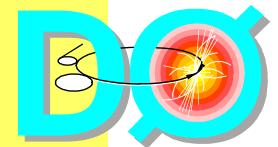




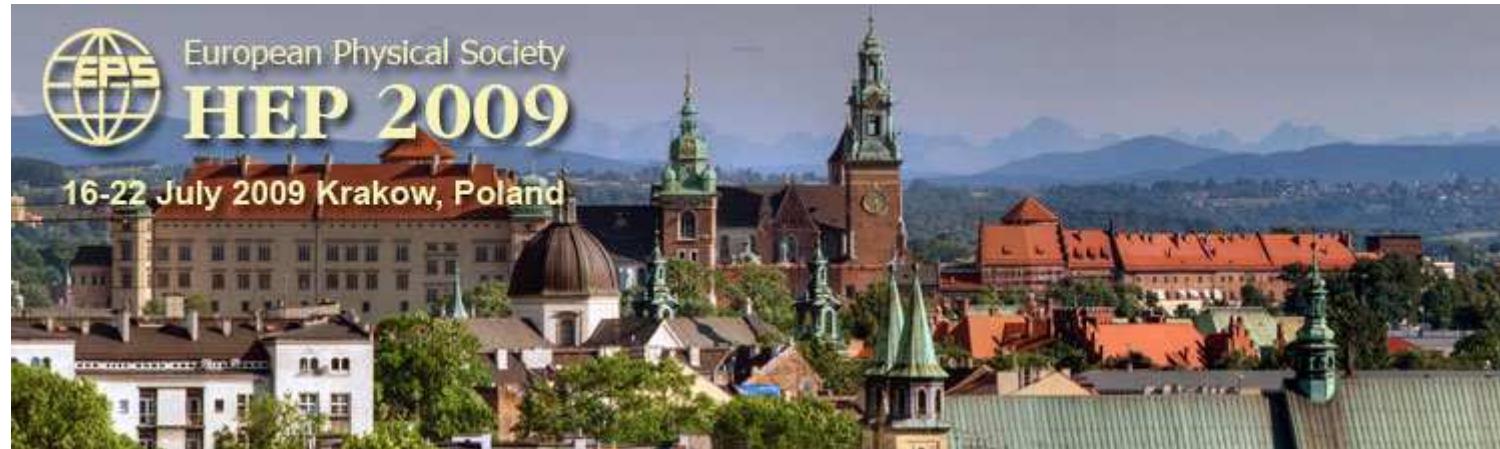
Search for high mass resonances in dilepton, dijet and diboson final states at the Tevatron



Michel Jaffré



on behalf of the CDF and D0 collaborations



Motivations

- Looking for new physics beyond the SM
 - $SU(3)_C \times SU(2)_L \times U(1)_Y$ embedded in a larger gauge group ($SO(10), E6, \dots$) to achieve grand unification, after symmetry breaking, $U(1)$ groups survive $\rightarrow Z'$
 - L-R symmetry, “little Higgs” models also predicts Z'
 - Randall Sundrum model, one extra dimension \rightarrow excited KK modes G^*
 - SUSY with RPV resonant production may occur with lepton pair of same or different flavour decay products
- Common point : narrow resonances with $\Gamma \ll$ detector resolution
 - Z' : coupling to $ee, \mu\mu$, or any fermion pair
 - RS ($0.01 < k/M_{Pl} < 0.10$) $\rightarrow ee, \gamma\gamma$
 - $\tilde{\nu}$ $\rightarrow \mu\mu, e\mu, e\tau, \mu\tau$
 - New gauge bosons as well as G^* couple to the SM gauge bosons
$$X(Z', G^*) \rightarrow ZZ; W^+W^- \quad W' \rightarrow WZ$$

Outline

Strategy in Tevatron analysis now

try to focus more on signature based searches,
rather than looking for a specific model

- ✓ ee, $\mu\mu$ (Z', RS graviton)
- ✓ e μ , e τ , $\mu\tau$ (RPV)
- ✓ e $\not{E}_T \geq 2$ jets (resonant diboson production)
- ✓ Di-jet (q*, Z', W',)

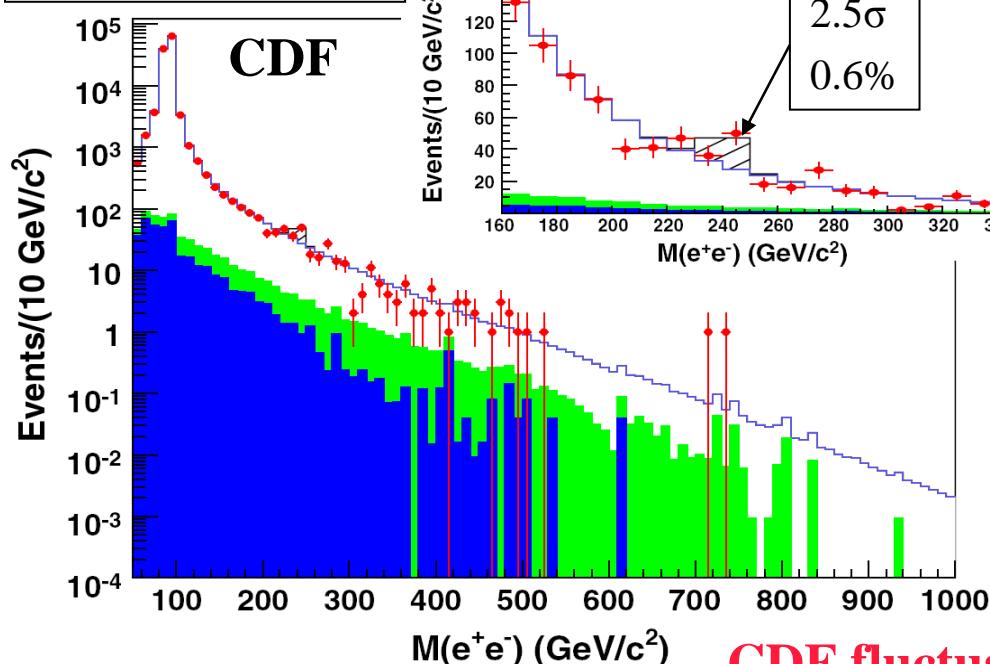
Di-electron mass distribution



(2.5 fb⁻¹) PRL 102, 031801 (2009)

1 electron in Central ($|\eta| < 1.1$), 2nd either Central or Forward ($|\eta| < 2$)
if both are Central, opposite charge

QCD misid
 $Z \rightarrow \tau\tau, WW, WZ, tt$



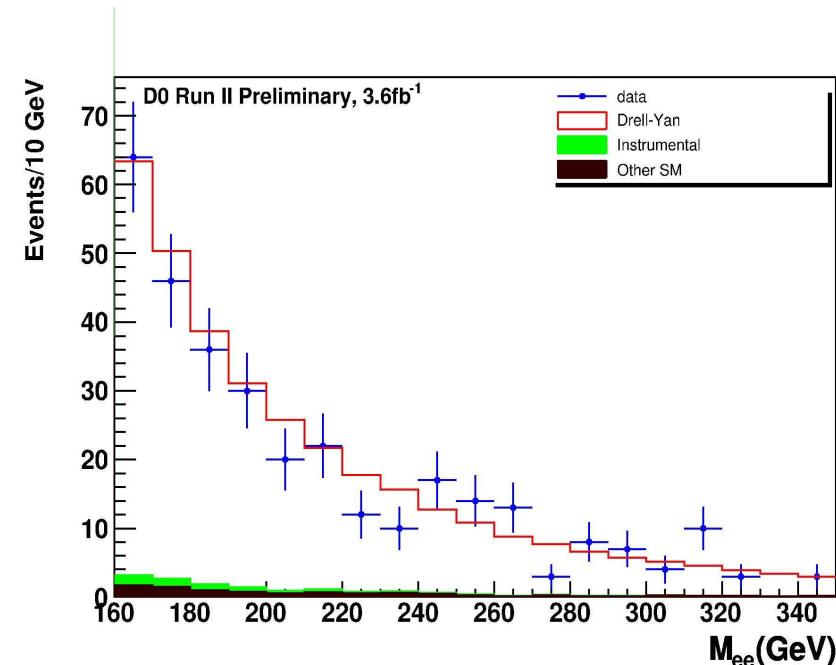
CDF fluctuation around 240 GeV not confirmed by D0



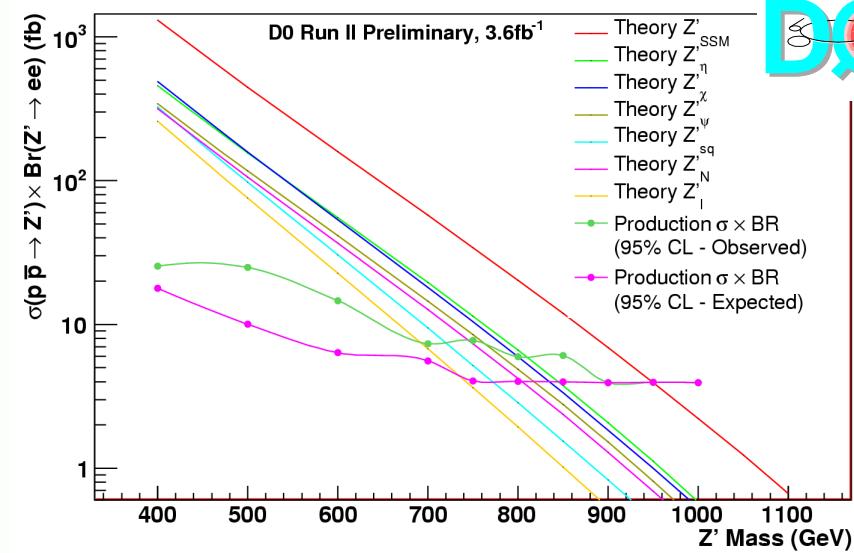
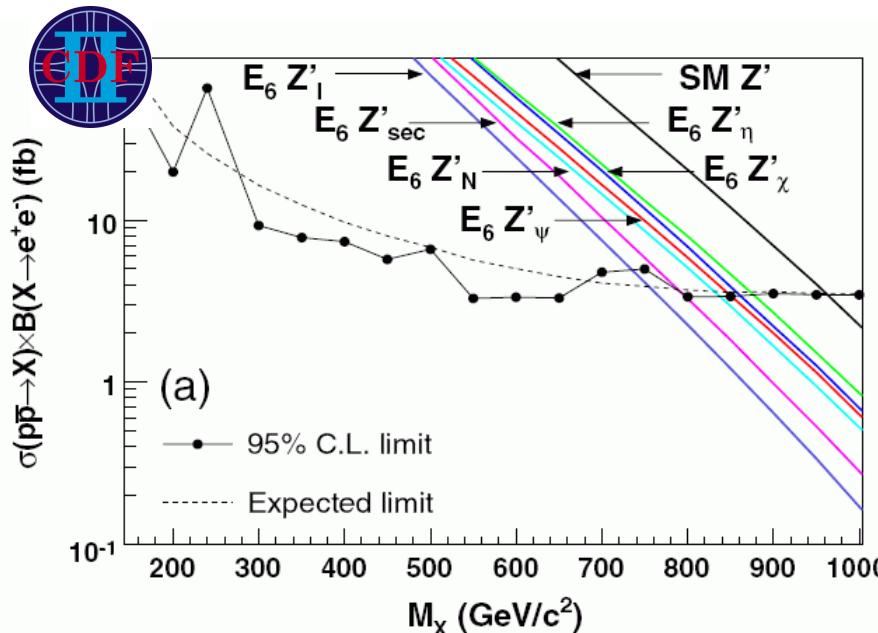
preliminary result on 3.6 fb⁻¹

(by-product of the FB asymmetry meas^t
with a tight electron selection)

Central($|\eta| < 1.1$) EM clusters with track match
only

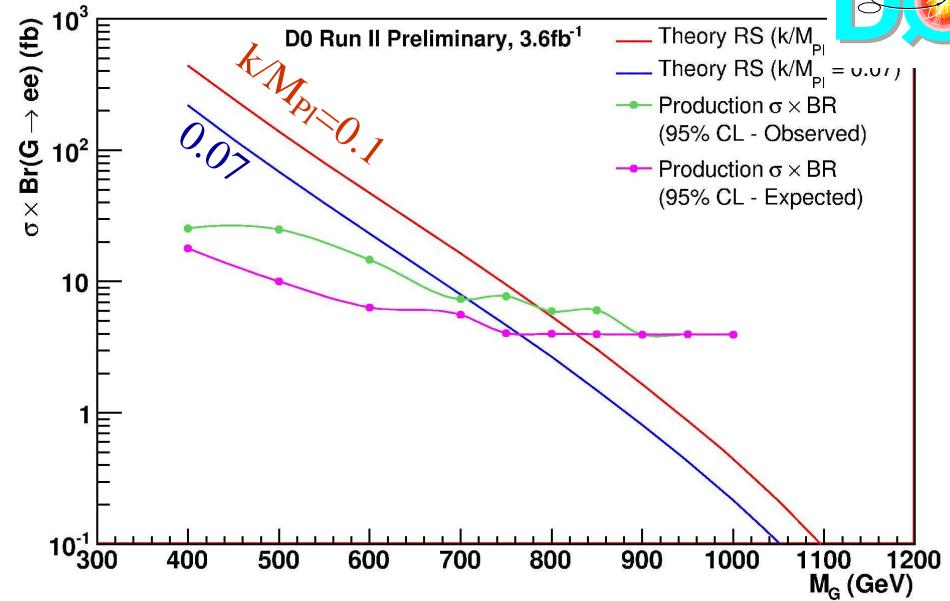
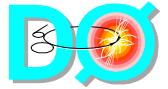
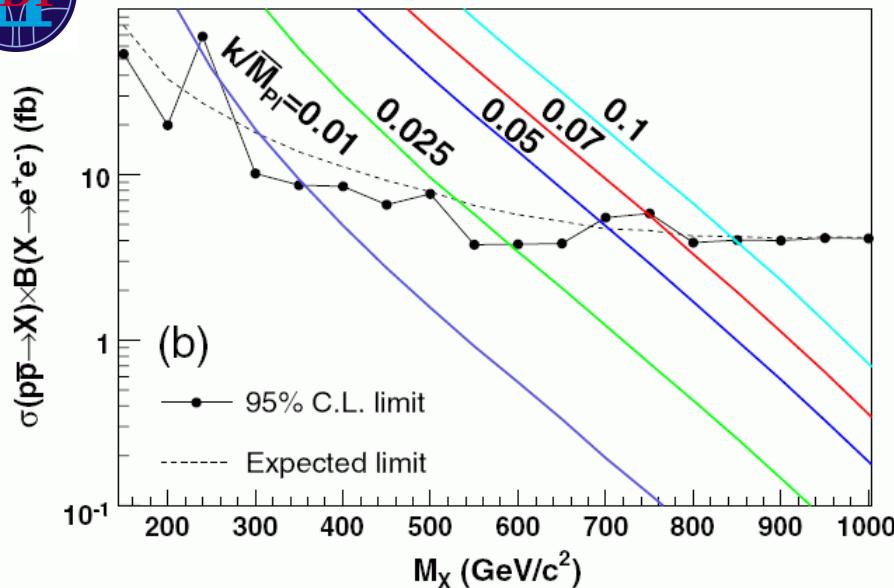


$Z' \rightarrow ee$ limits



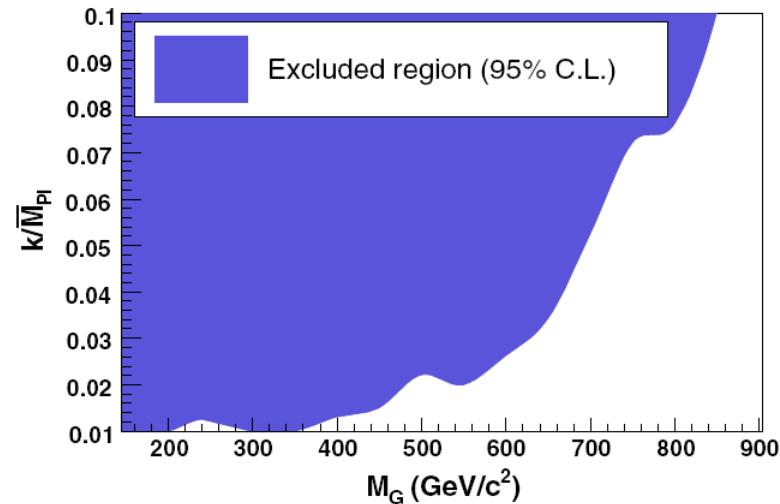
Z' model	Z'_{SM}	Z'_ψ	Z'_χ	Z'_η	Z'_I	Z'_{sec}	Z'_N
Exp. Lim (GeV)	961	846	857	873	755	788	831
Obs. Lim (GeV)	963	851	862	877	735	792	837
Exp. Lim (GeV)	949	817	834	844	732	774	803
Obs. Lim (GeV)	950	763	800	810	692	719	744

Randall-Sundrum graviton (ee) limits

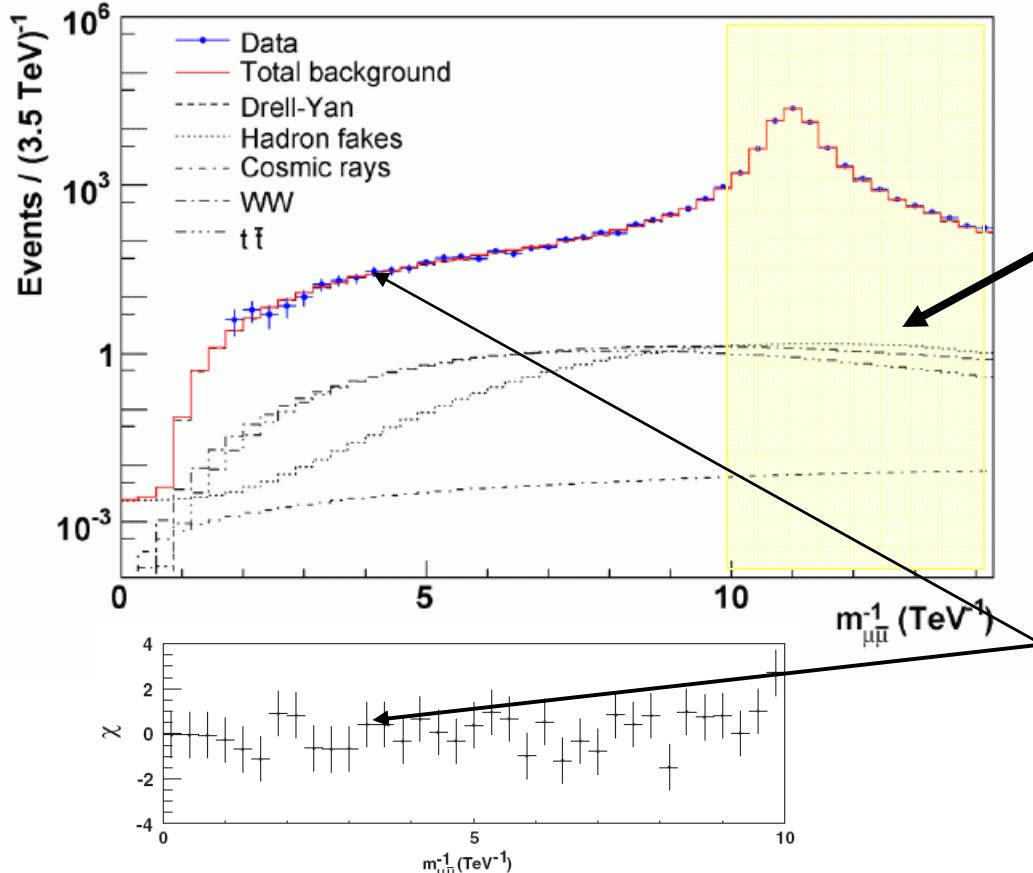


Narrow resonance for $k/\bar{M}_{\text{Pl}} < 0.1$
 k^2 : space time curvature in extra dim
 \bar{M}_{Pl} : reduced Planck mass
RS 95% CL limits ($k/\bar{M}_{\text{Pl}}=0.1$)

- CDF Obs. $> 848 \text{ GeV}$
- D0 prelim. Obs. (expected) $> 786 \text{ (826)} \text{ GeV}$



$\mu\mu$ mass distribution



$$\chi = (\text{Obs} - \text{Bkg})/\text{Stat. error}$$

2.3 fb^{-1} of data PRL 102, 091805 (2009)
 Select opposite charged μ in $|\eta| < 1$

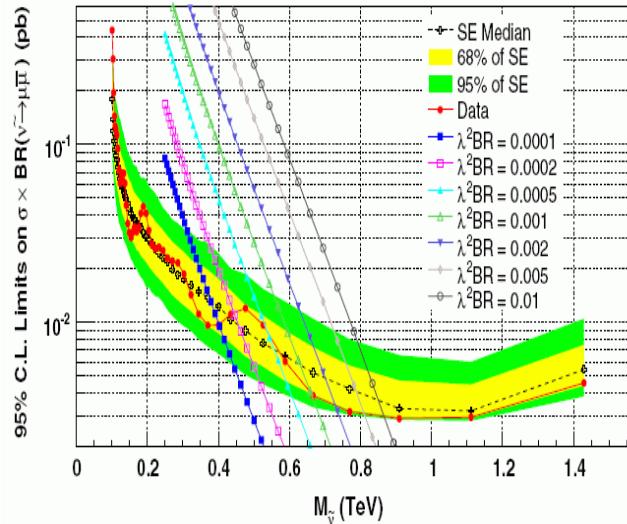
Data – Bckg normalisation

Almost constant resolution $> 100 \text{ GeV}$
 $\Delta m^{-1}_{\mu\mu} = 0.17 \text{ TeV}^{-1}$
 \Rightarrow A narrow resonance will appear as an excess of events in 3 adjacent bins
No excess around 240 GeV

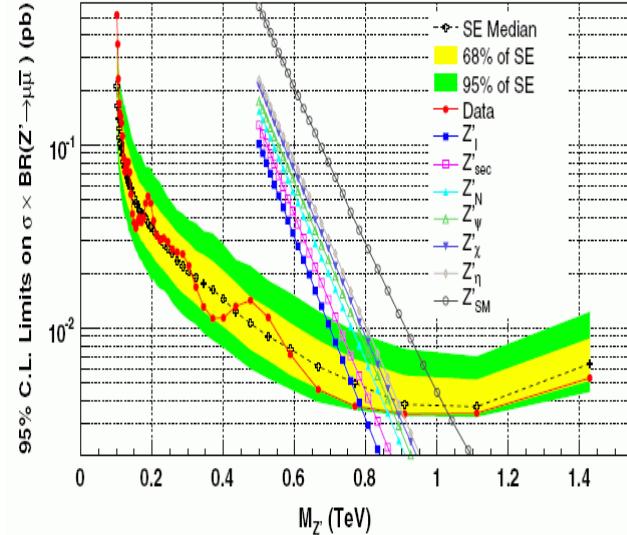
Observation consistent with SM expectation



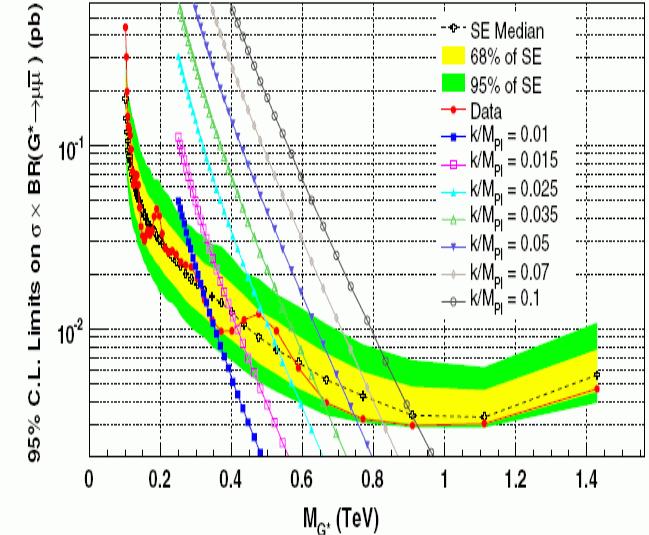
$\mu\mu$: Sneutrino, Z' , RS G^* cross section limits



$\tilde{\nu}$ spin 0



Z' spin 1

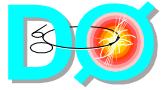


G^* spin 2

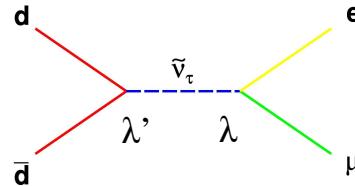
$\lambda^2 \cdot \text{BR}$	Mass Limit, 95% CL (GeV/c^2)
0.01	866
0.005	810
0.002	731
0.001	662
0.0005	541
0.0002	441
0.0001	397

Model	Mass Limits, 95% CL (GeV/c^2)
$Z'_{\text{(SM)}}$	1030
$Z'_{\text{(}\eta\text{)}}$	904
$Z'_{\text{(}\chi\text{)}}$	892
$Z'_{\text{(}\psi\text{)}}$	878
$Z'_{\text{(N)}}$	861
$Z'_{\text{(sec)}}$	821
$Z'_{\text{(i)}}$	789

Graviton k/M_{Pl}	Mass Limit, 95% CL (GeV/c^2)
0.1	921
0.07	824
0.05	746
0.035	651
0.025	493
0.015	409
0.01	293



R-parity violating: sneutrino \rightarrow e μ



$$\sigma_{e\mu} \propto (\lambda'_{311})^2 (\lambda_{312})^2 \frac{1}{|\hat{s} - M^2 + i\Gamma M|^2}$$

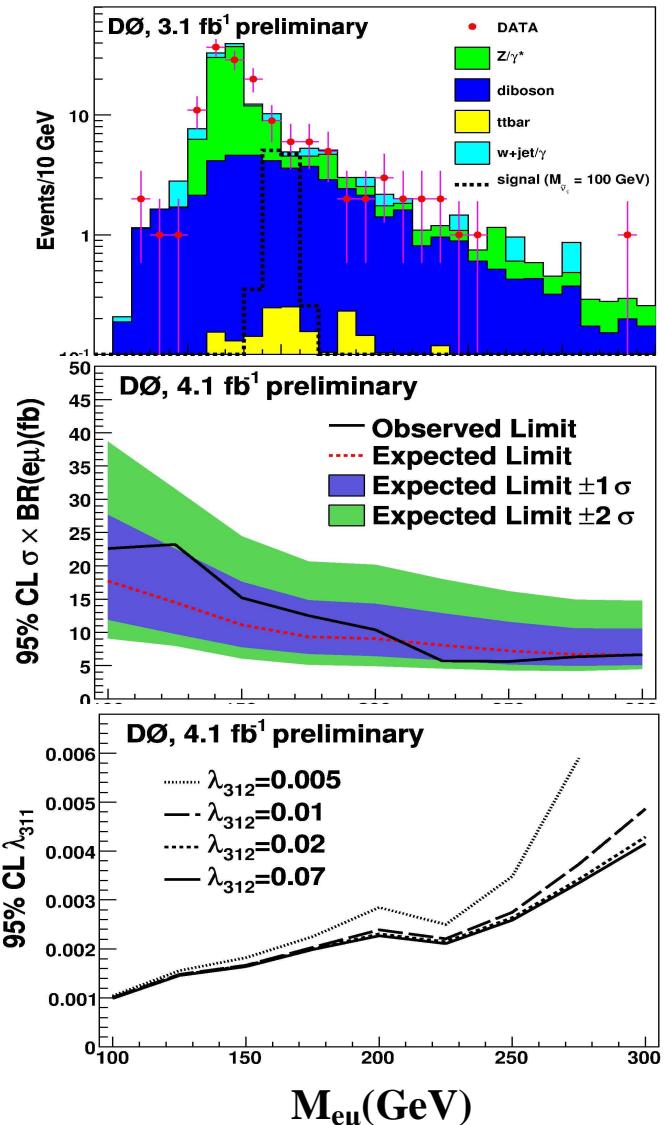
Clean topology: 2 isolated leptons with different flavor and charge, no jets, no E_T

Main bkgd : physics : $Z/\gamma^* \rightarrow \tau\tau$, WW, WZ, ZZ
MisId W+jet/ γ

Good agreement with SM expectation
143 events observed 145 ± 4 expected

Final result : RunIIa 1fb^{-1} PRL 100, 241803(2008)
RunIIb 3.1fb^{-1}

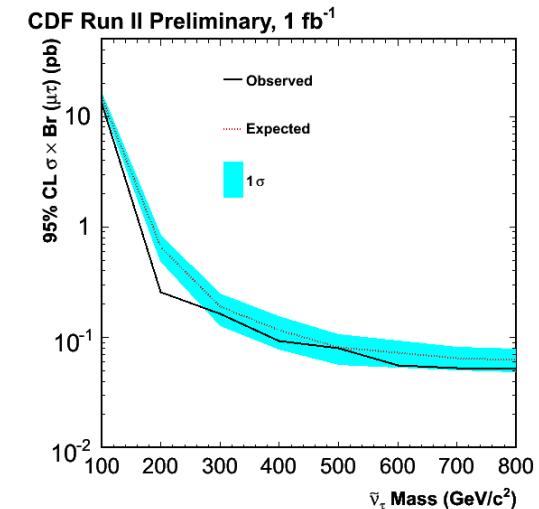
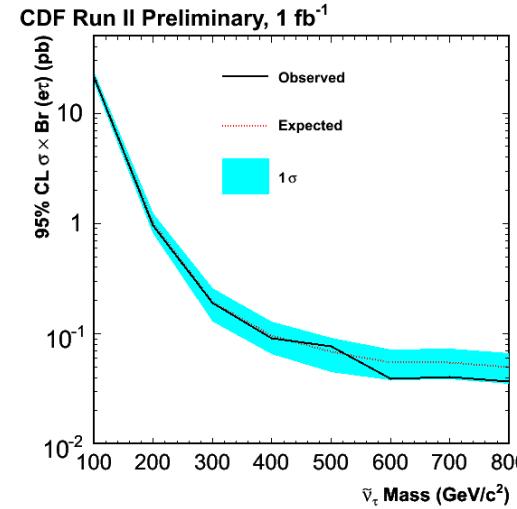
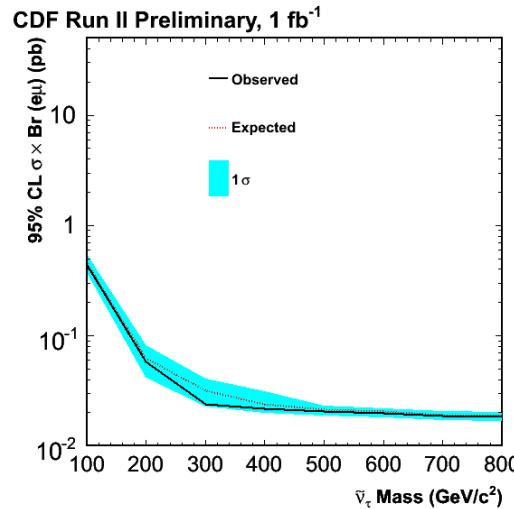
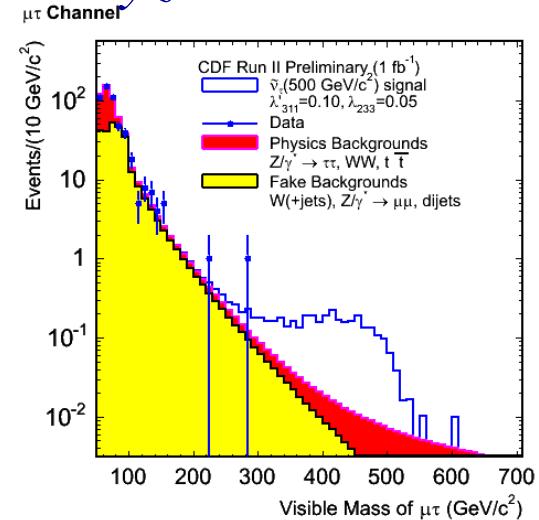
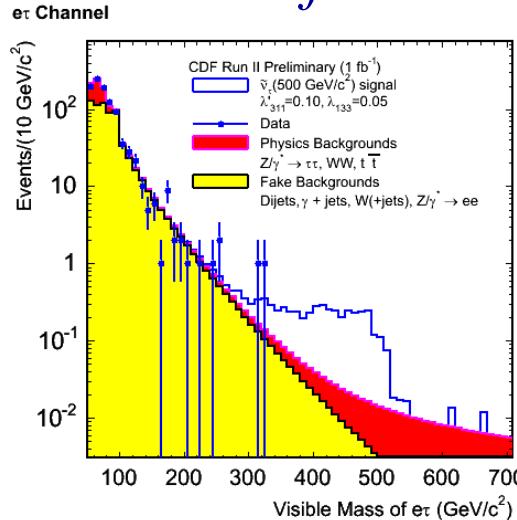
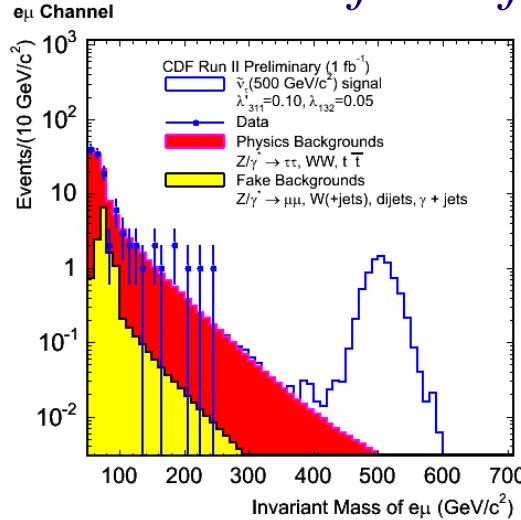
Limits significantly improved / LEP results
 $\lambda'_{311} < 0.12$, $\lambda_{312} = \lambda_{321} < 0.07$ for $M=100\text{GeV}$





R-parity violating sneutrino $\rightarrow e\mu$, or $e\tau$, or $\mu\tau$

1 fb-1 of data but more final states analyzed



Observation of vector boson pairs in a hadronic final state

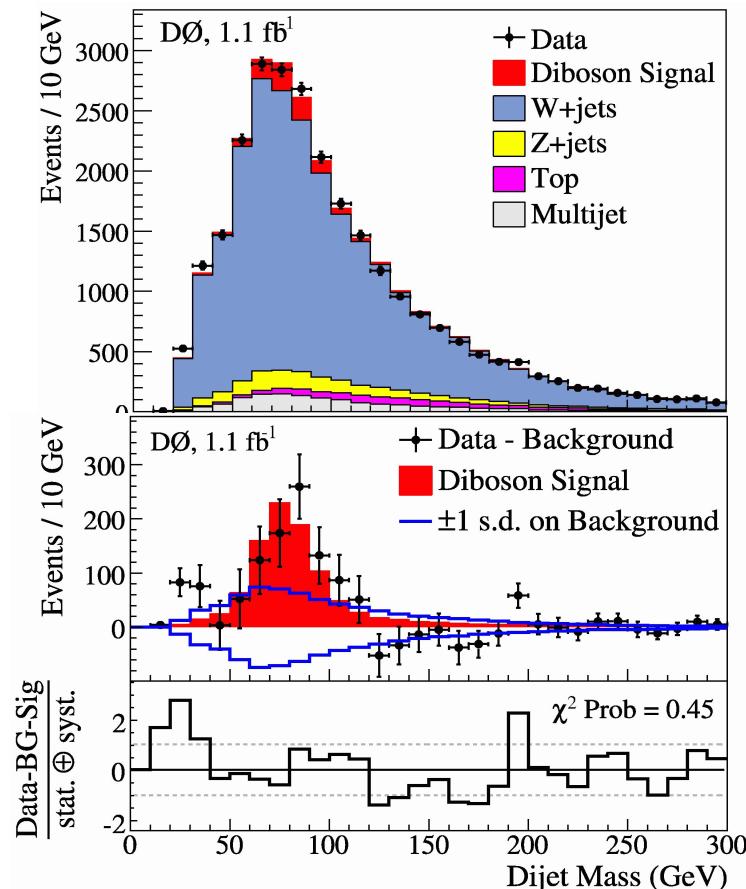
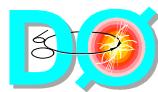
PRL 102, 161801 (2009)

$\mathcal{L} = 1.1 \text{ fb}^{-1}$

e or μ , \cancel{E}_T , ≥ 2 jets

WW + WZ

see J. Haley talk



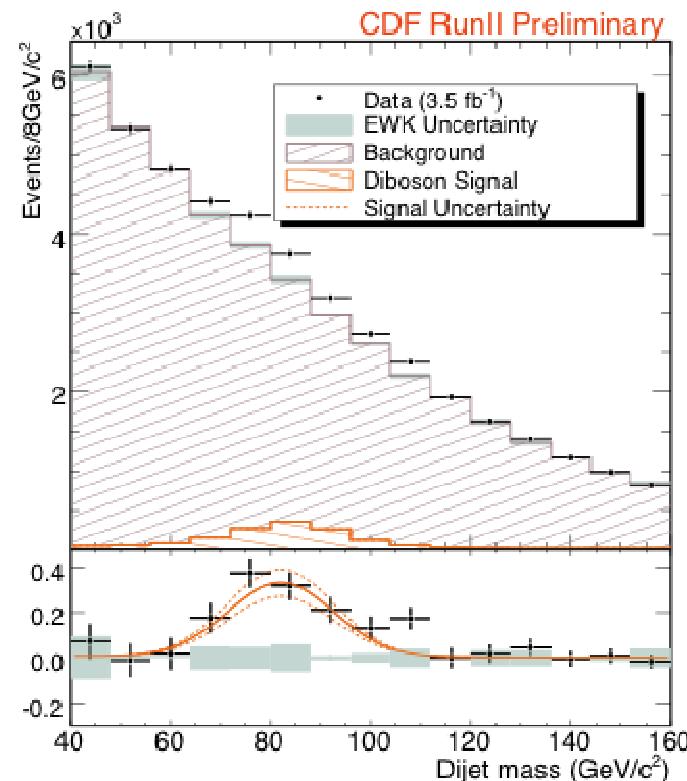
arXiv:0905.4714

$\mathcal{L} = 3.5 \text{ fb}^{-1}$

$\cancel{E}_T > 60 \text{ GeV} + 2$ jets

WW+WZ+ZZ

see V. Cavaliere talk



Cross section consistent with SM expectation



X \rightarrow WW/WZ \rightarrow (e ν)+(2 jets) resonance search (I)

$\mathcal{L}=2.9 \text{ fb}^{-1}$

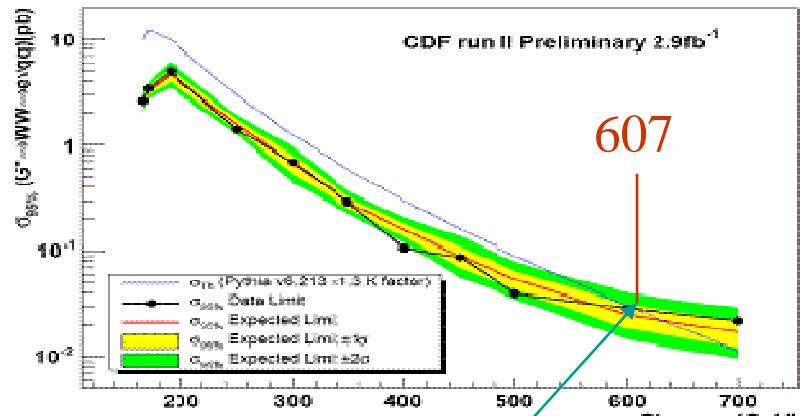
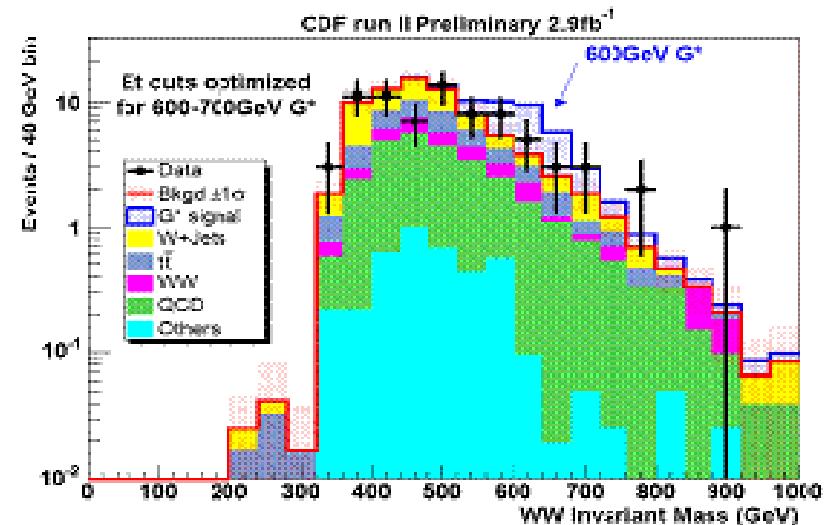
e + ν \rightarrow W (2 solutions)

Dijet mass: W [65,95] Z[70,105]

if 3 jets (pair closest to W/Z mass is chosen)

- ✓ QCD background estimated from data and normalised to data at small \cancel{E}_T
- ✓ Other bkgd from MC

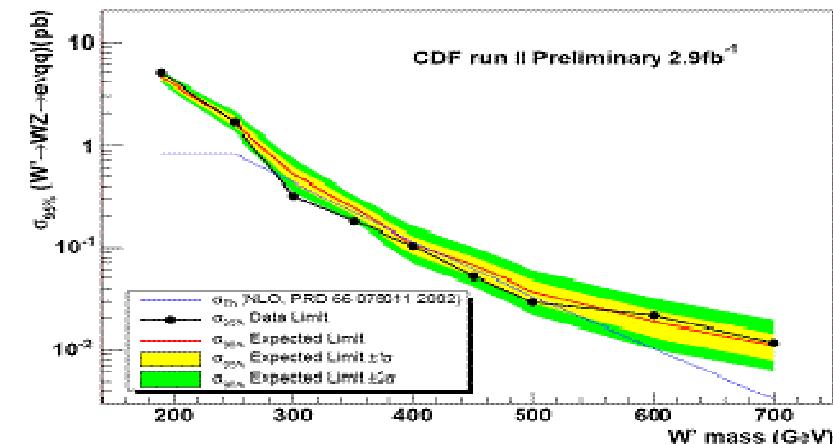
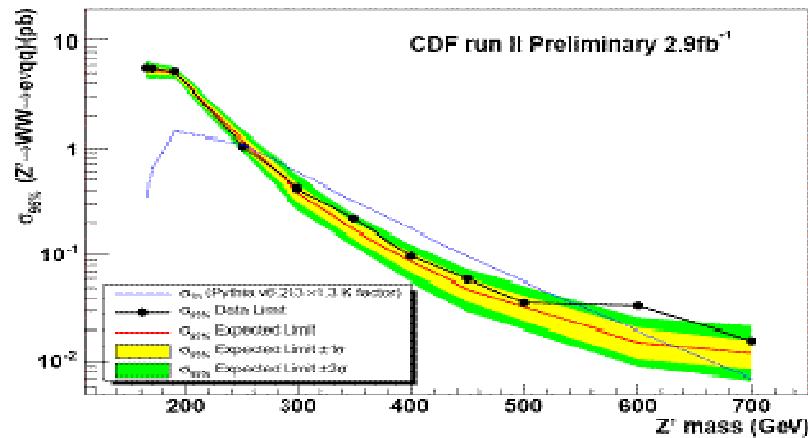
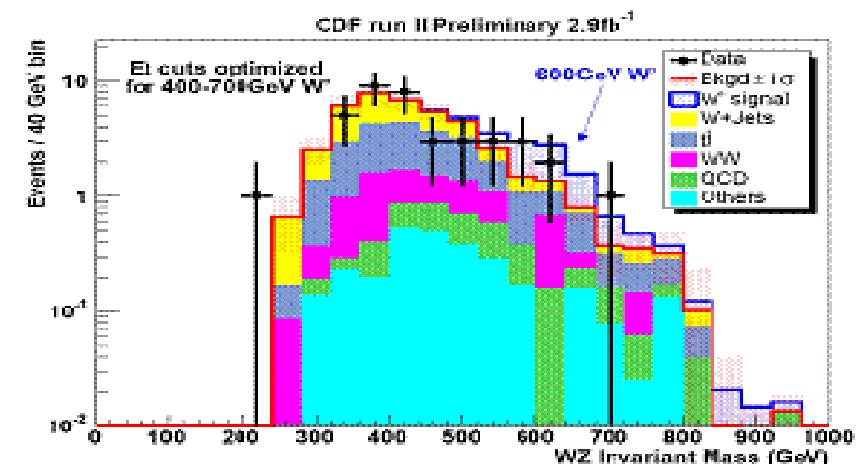
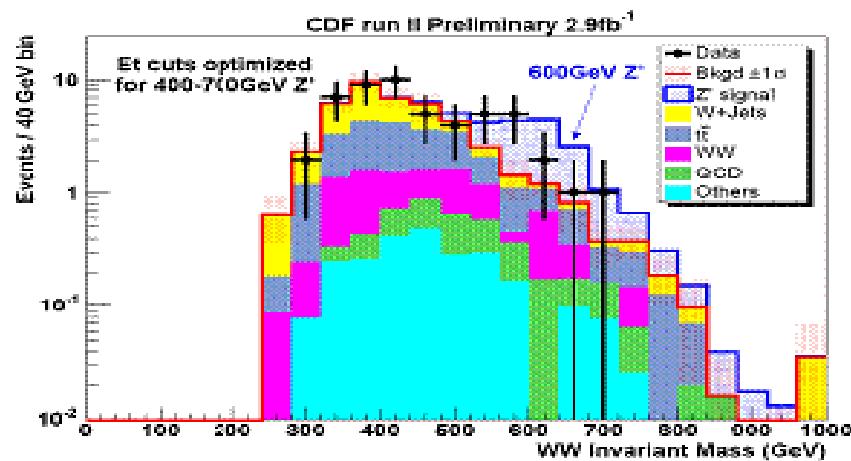
E_T cut optimization to get the best expected limit for a given X mass



Electron E_T or $\cancel{E}_T > 120 \text{ GeV}$
+ E_{T jet1} > 120 GeV



X \rightarrow WW/WZ \rightarrow (e ν)+(2 jets) resonance search (II)



Exclusions	$G^*(k/M_{Pl}=0.1)$	Z'	W'
Observed	< 607	247-545	284-515
Expected	< 632	257-630	381-420



X \rightarrow ZZ \rightarrow (ll) (l'l') or (jet+jet) resonance search

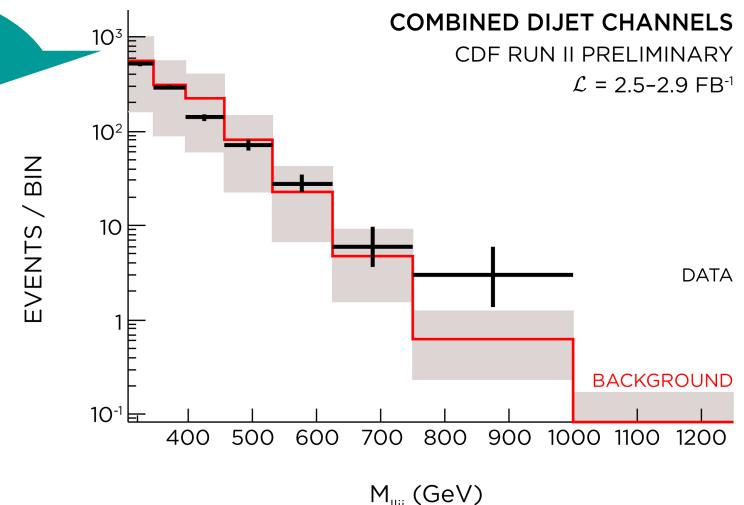
$\mathcal{L} = 2.5\text{--}2.9 \text{ fb}^{-1}$

eeee, ee $\mu\mu$, $\mu\mu\mu\mu$ eejj, $\mu\mu jj$

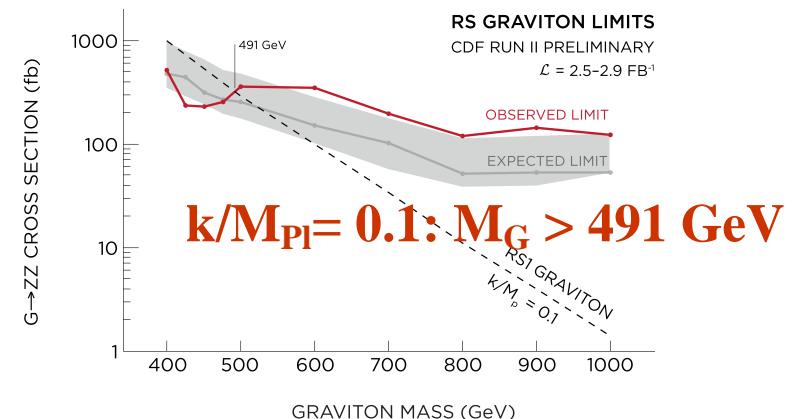
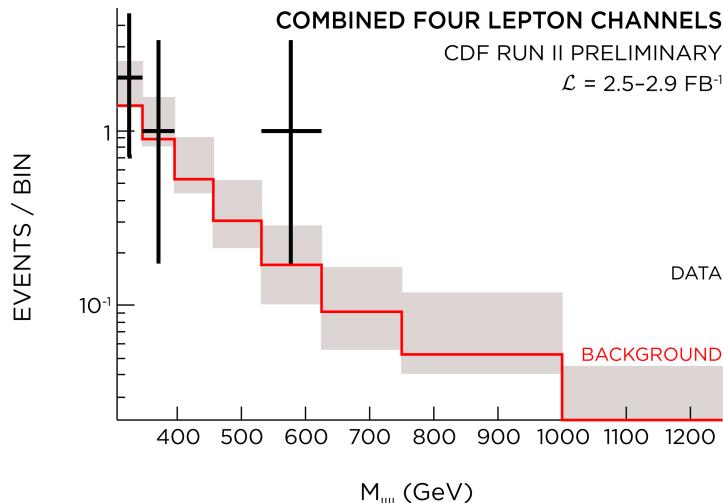
$$(M_{ll}-91.2)^2/(\sigma_M^2 + 2.5^2) < 25$$

$$65 < M_{jj} < 120 \text{ GeV}$$

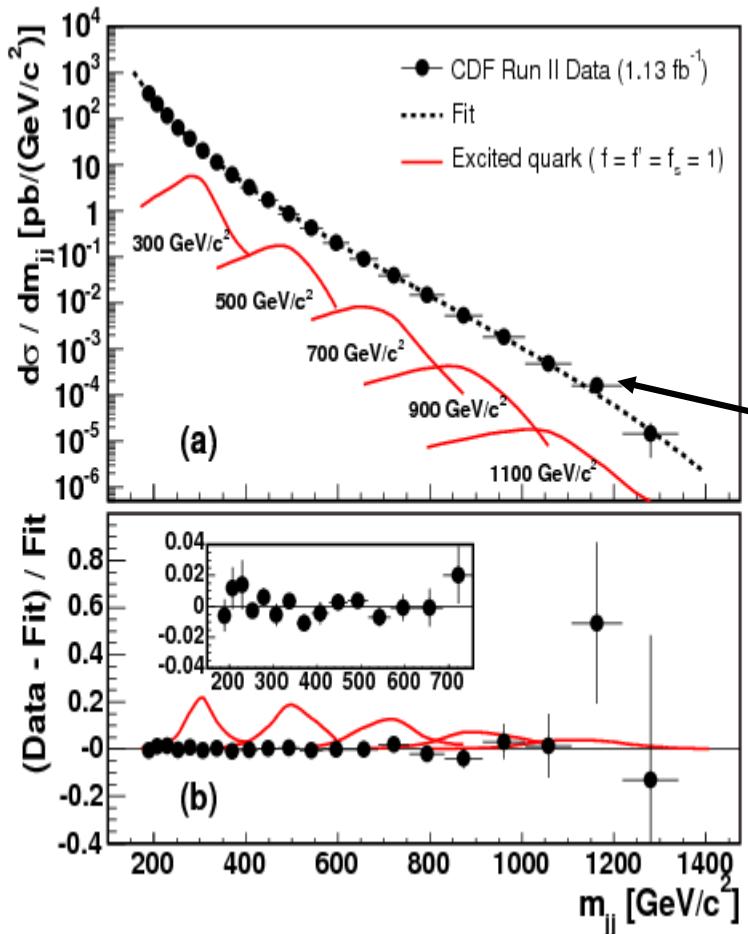
Increase acceptance by loose lepton selection and large η coverage



No evidence for ZZ resonant production
Acceptance from Herwig KK graviton



Search for dijet mass resonances (I)



Reconstructed jet-jet mass

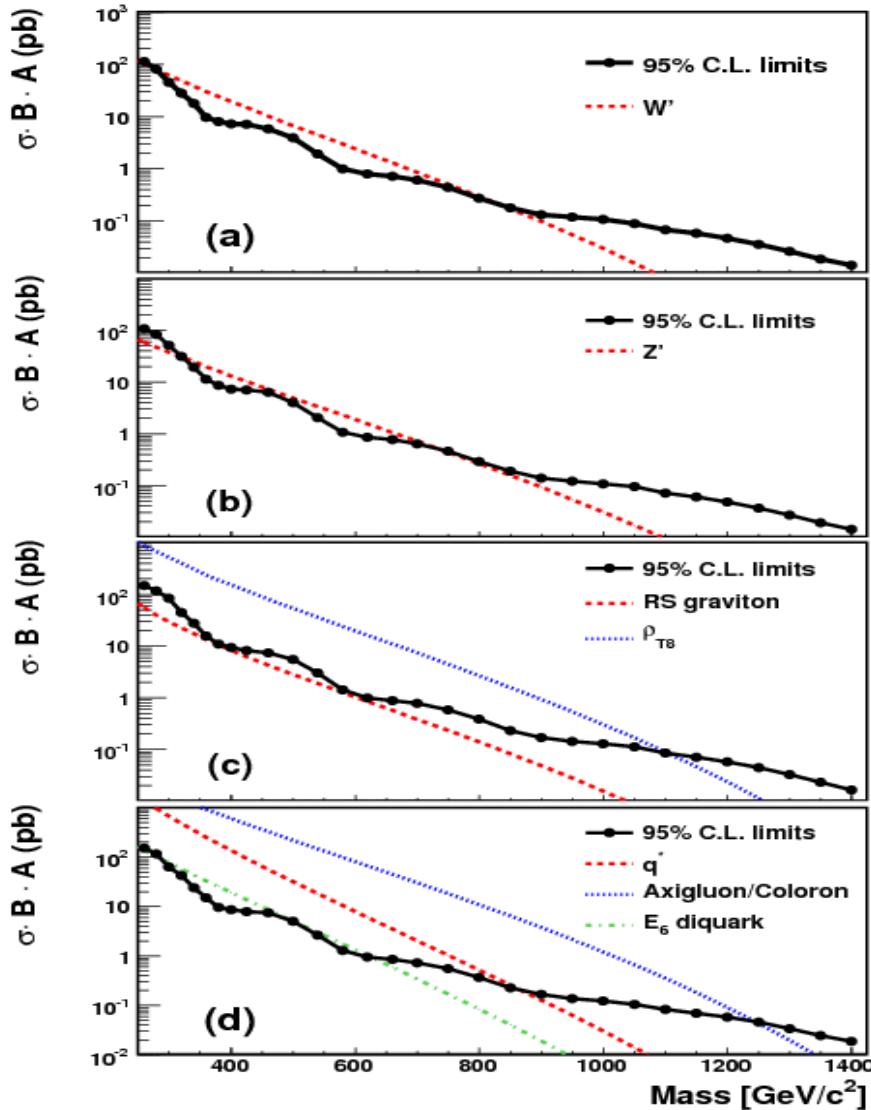
- ✓ PRD 79, 112002 (2009)
- ✓ Central ($|y| < 1$) jets with mid-point algo. $R=0.7$
- ✓ Dijet mass spectrum agrees with NLO pQCD predictions
- ✓ To search for narrow mass resonances in this spectrum a smooth functional form is fitted

$$\frac{d\sigma}{dm} = p_0 (1-x)^{p_1} / x^{p_2 + p_3 \log(x)}, \quad x = m / \sqrt{s}$$

- ✓ A large variety of models : excited quark, W' , Z' , RS graviton,.....
- See T. Nunnemann talk in Higgs + NP session for other searches on dijet topology

No significant indication of resonant structure is observed. $\Rightarrow 95\% \text{ CL limits}$

Search for dijet mass resonances (II)



Model description	Observed mass exclusion range (GeV/c^2)
$W'(\text{SM couplings})$	280- 840
$Z'(\text{SM couplings})$	320- 740
RS graviton	No exclusion
Color octet technirho (top-color-assisted-technicolor (TC2) couplings)	260-1100
Excited quark ($f=f'=f_s=1$)	260- 870
Axigluon and flavor universal coloron	260-1250
E6 diquark	290- 630

Summary and outlook

- ✓ No excess of events over SM expectations in (1- 4.1 fb^{-1})

- ✓ Search for sign of new physics will continue at the Tevatron
 - > 6 fb^{-1} of data already recorded
 - Expect to collect at least 10 fb^{-1} of data in the next years
- ✓ Signature based searches in CDF and D0 take over model specific searches

All CDF and D0 results are available on :

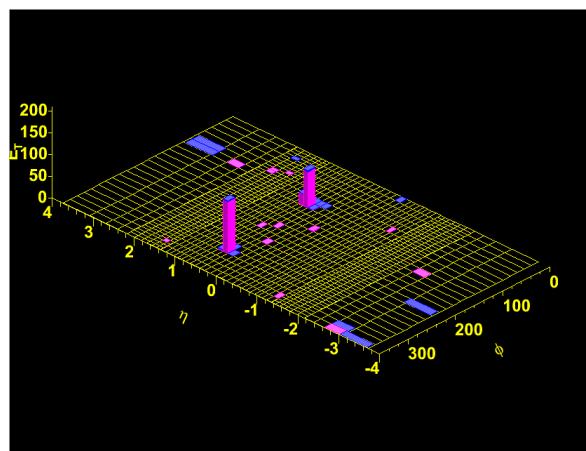
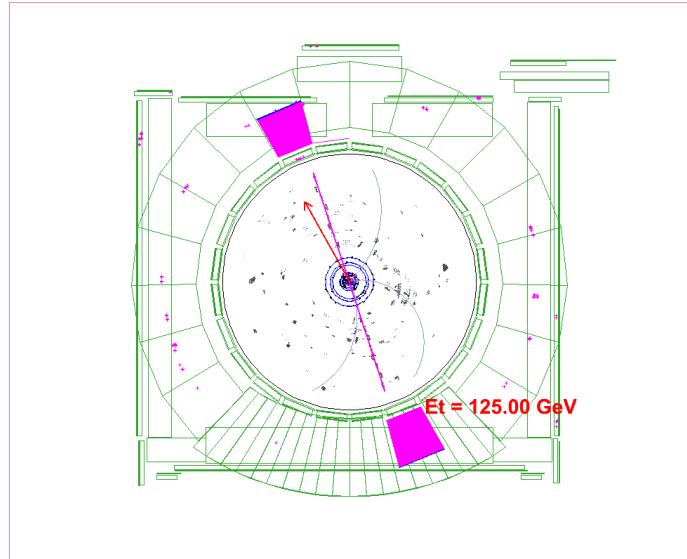
<http://www-cdf.fnal.gov/physics/exotic/exotic.html>

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

Backup

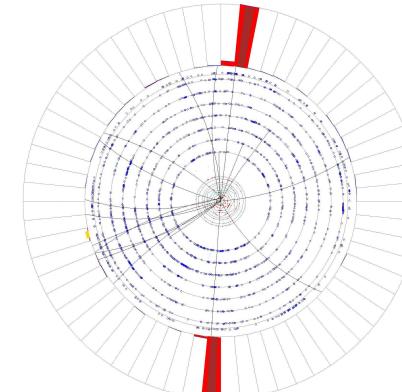


ee events



Run 233604 Evt 7403139 Tue Jun 12 00:44:32 2007

ET scale: 296 GeV



Run 233604 Evt 7403139 Tue Jun 12 00:44:32 2007

