DIS 2011
Newport News, VA

Status of New Physics Searches at the Tevatron

Craig Group
(University of Virginia and Fermilab)

on behalf of the CDF and D0 experiments…

Outline

Searches at the Tevatron

- The Tevatron, CDF, and D0
- Dilepton/diphoton resonances
- Diboson resonances
- Complex final states

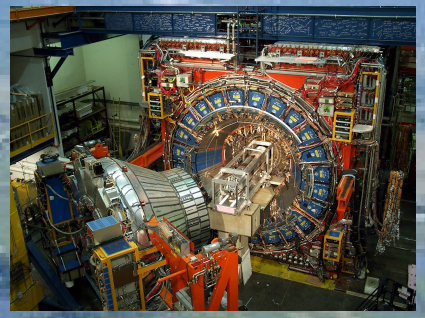
  (MET, jets, H.F.)
- Higgs (SM)
- Higgs (non-SM)

The Tevatron at Fermilab

The Tevatron currently provides the high energy proton-antiproton collisions:

E_{cm} = 1.96 TeV

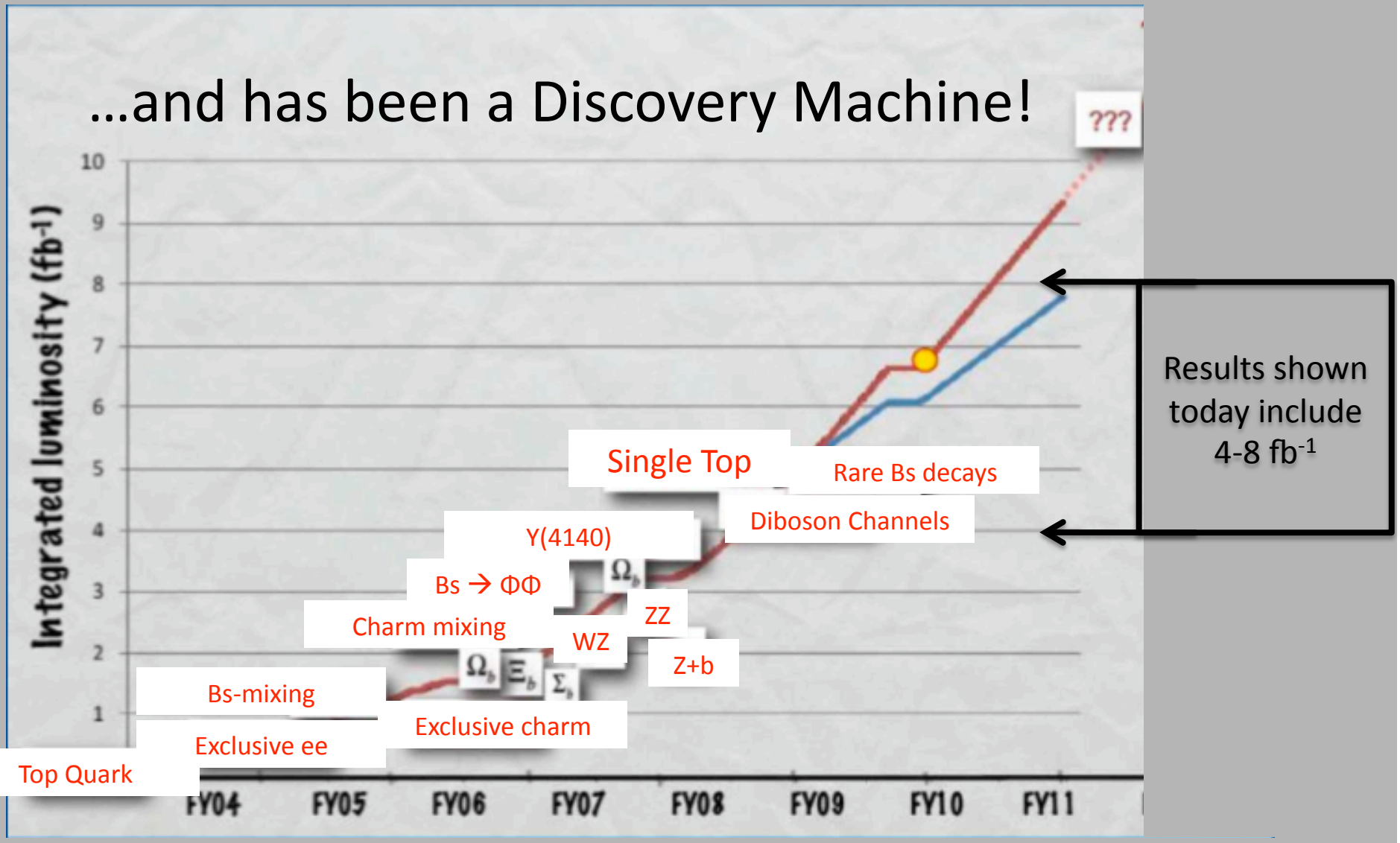
CDF



DO

Tevatron

The Tevatron is…



Dilepton Final States

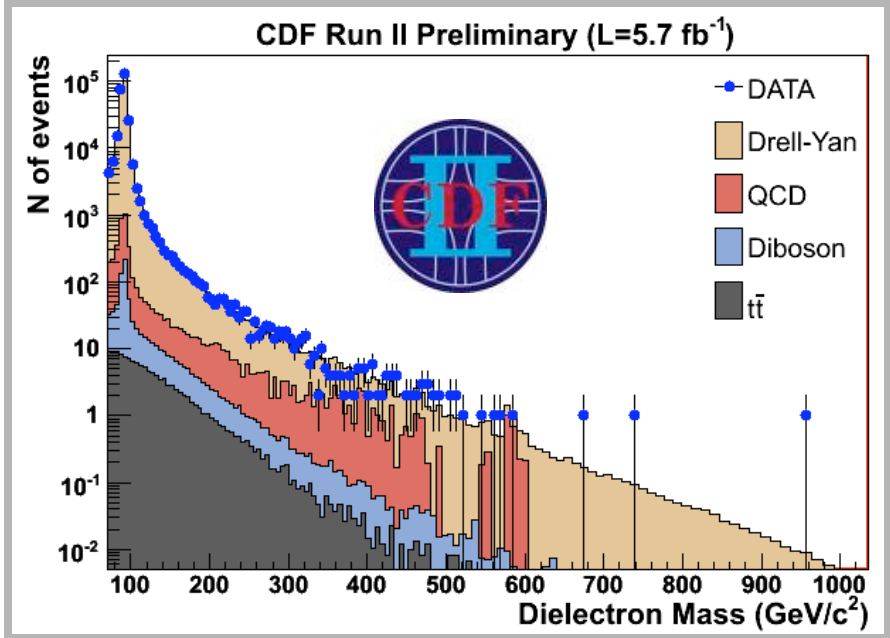
Old-fashioned bump hunt in M_{ee} distribution:

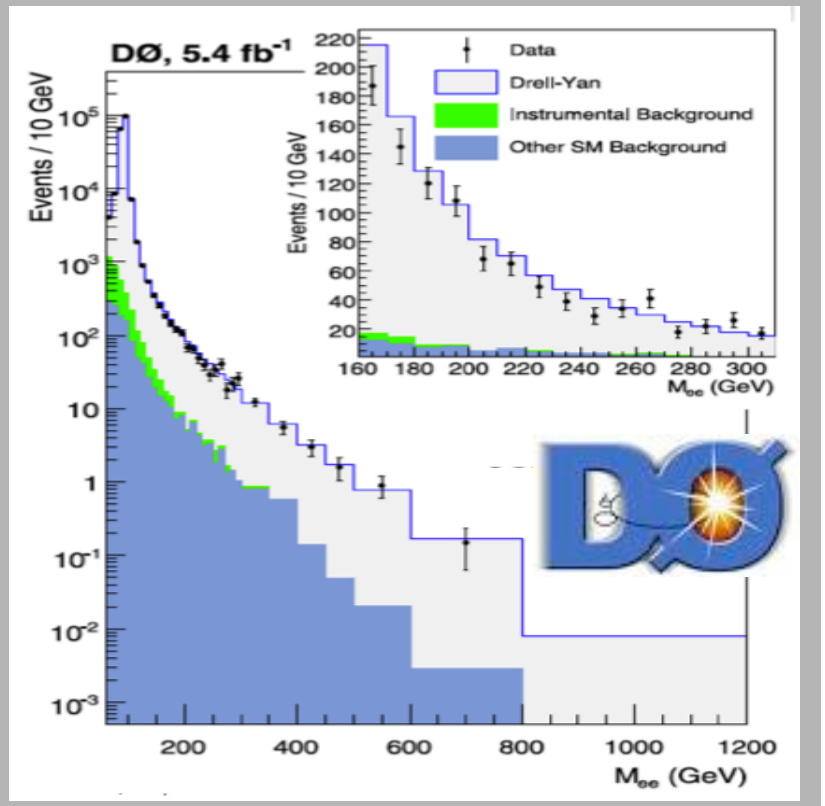
CDF: 5.7fb^{-1}
D0: 5.4fb^{-1}

-Z production and decay into ee/μμ precisely measured
-Lepton ID/Reco and Trigger efficiencies high and very well understood
-Background low and easily determined (QCD fakes)
-Clean events

PLB 695, 88 (2011)

CDF Public Note 10405





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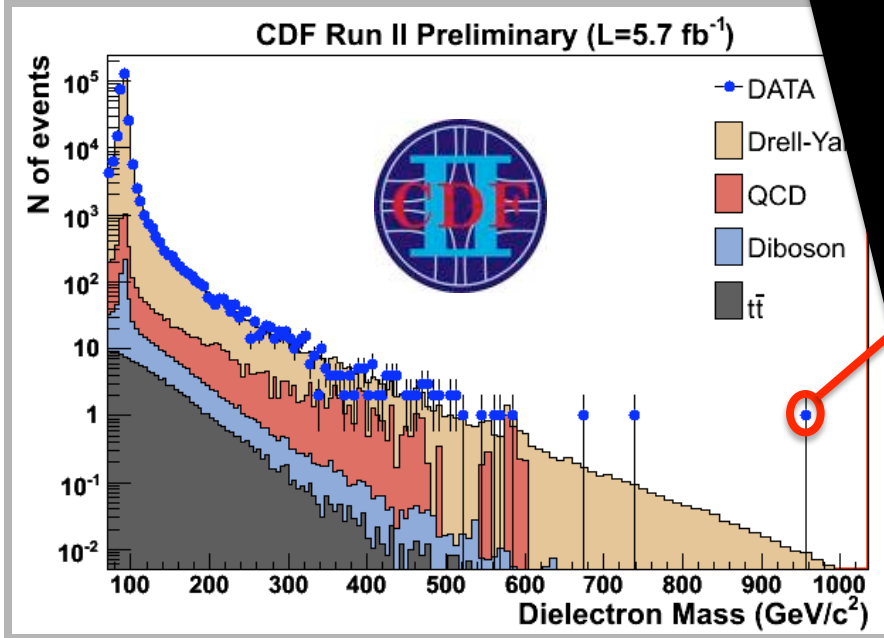
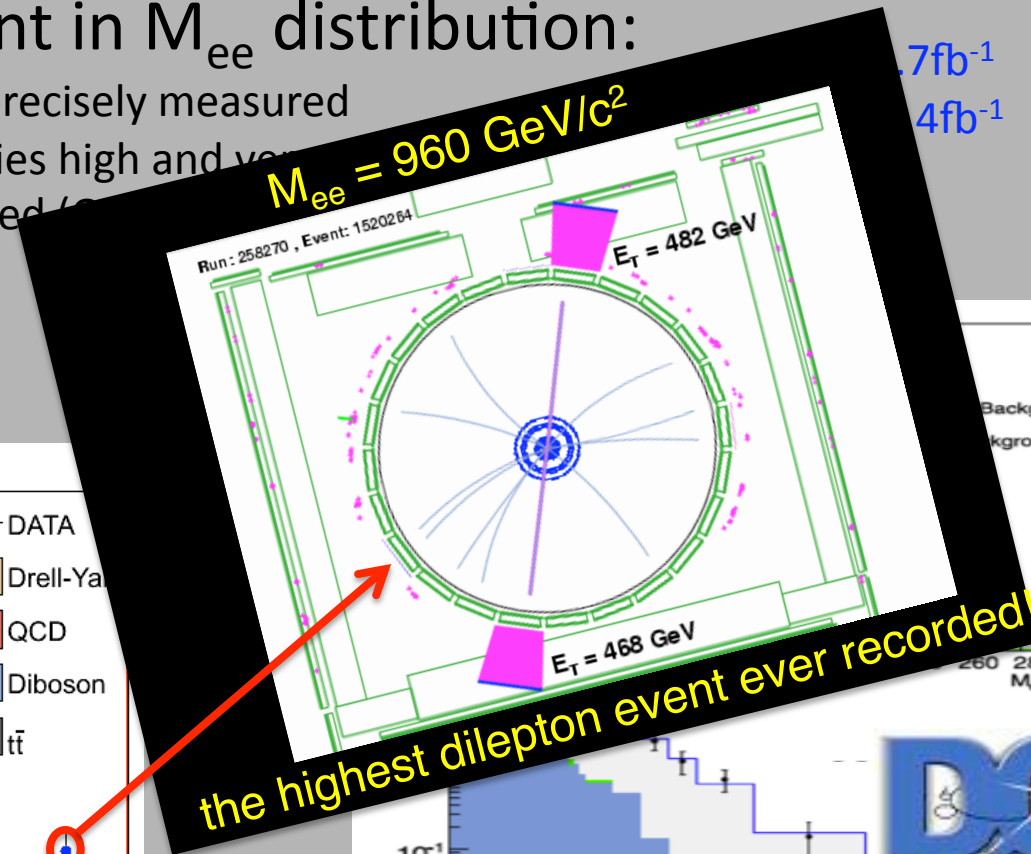
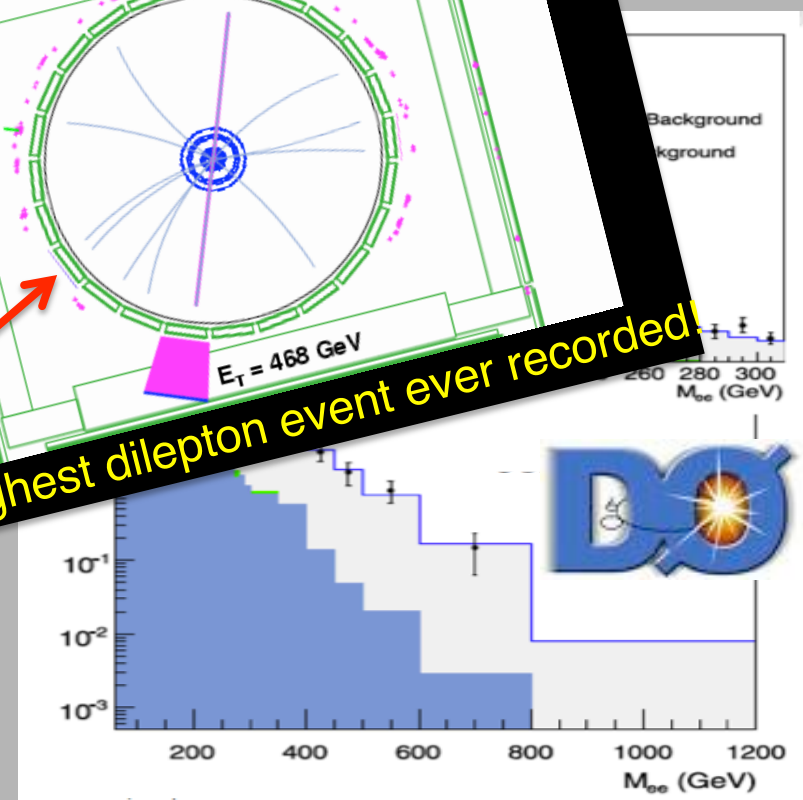
.7fb^{-1}
4fb^{-1}

CDF Public Note 10405





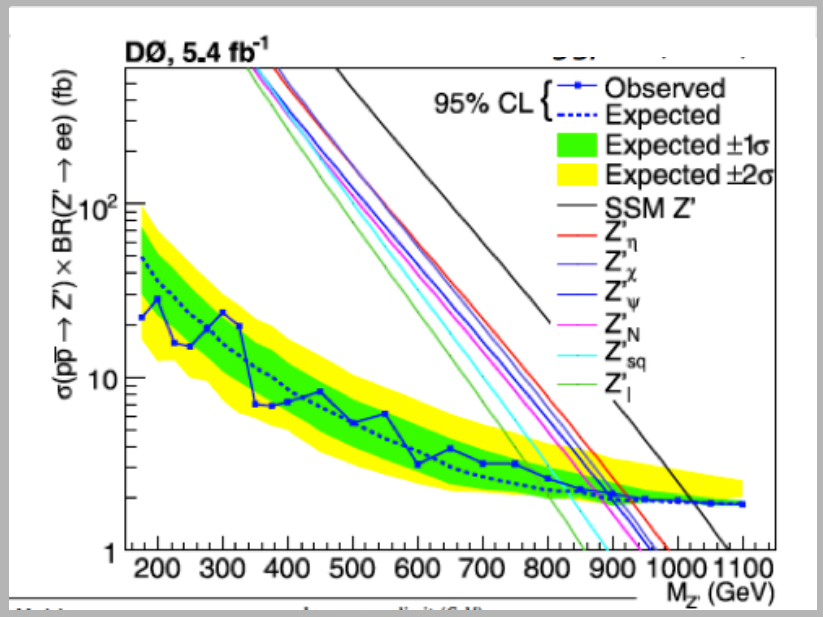


Dilepton Final States

No obvious resonant structure

→ limits on exotic models: ex. Z', RS Graviton

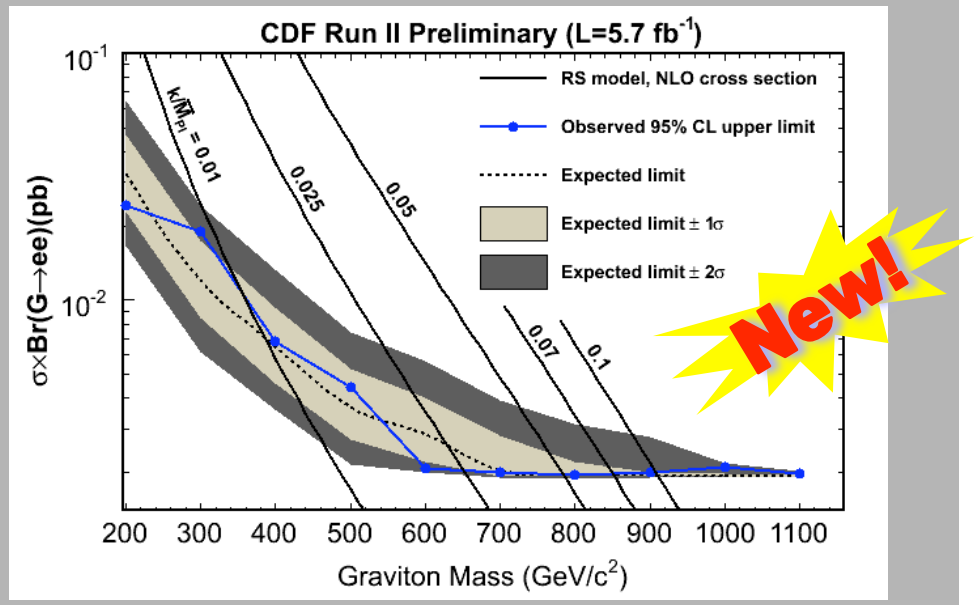
PLB 695, 88(2011)



$M(Z_{SSM}) > 1023$ @ 95% CL

Best limit in this channel!

CDF Public Note 10405

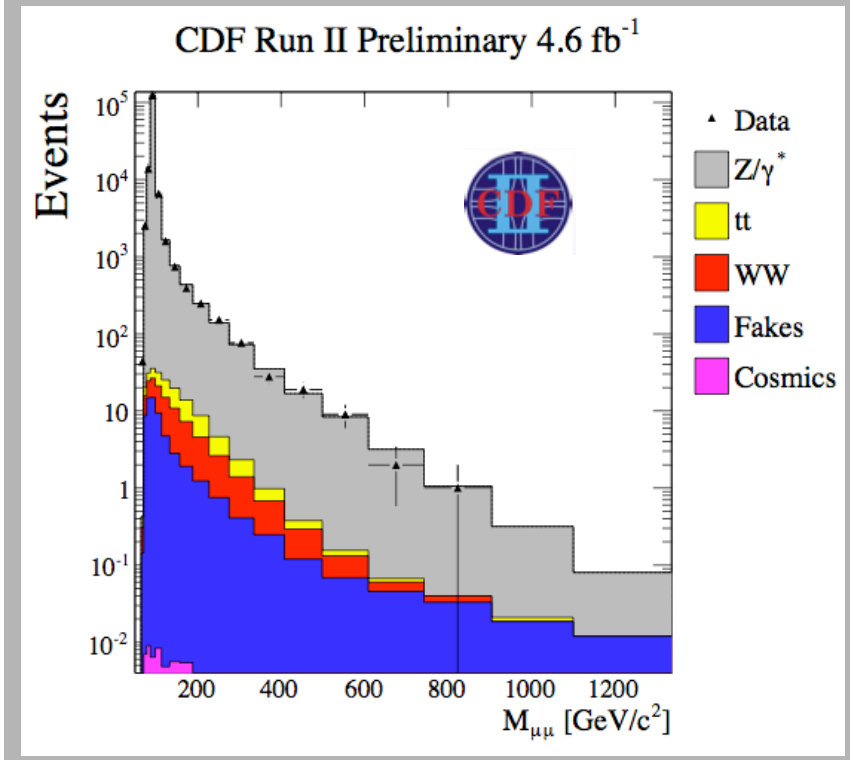


$M(RSG) > 907$ (k/M_{Pl}=0.1) @ 95%CL

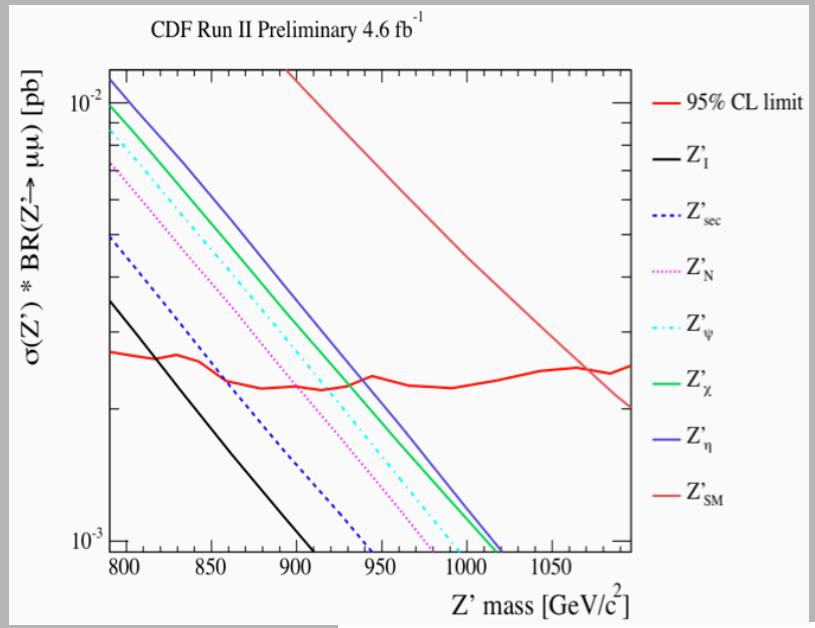
927 with fixed k-factor

Dilepton Final States

CDF has searched the $M_{\mu\mu}$ distribution as well: CDF:4.6fb^{-1}



PRL 106, 121801 (2011)



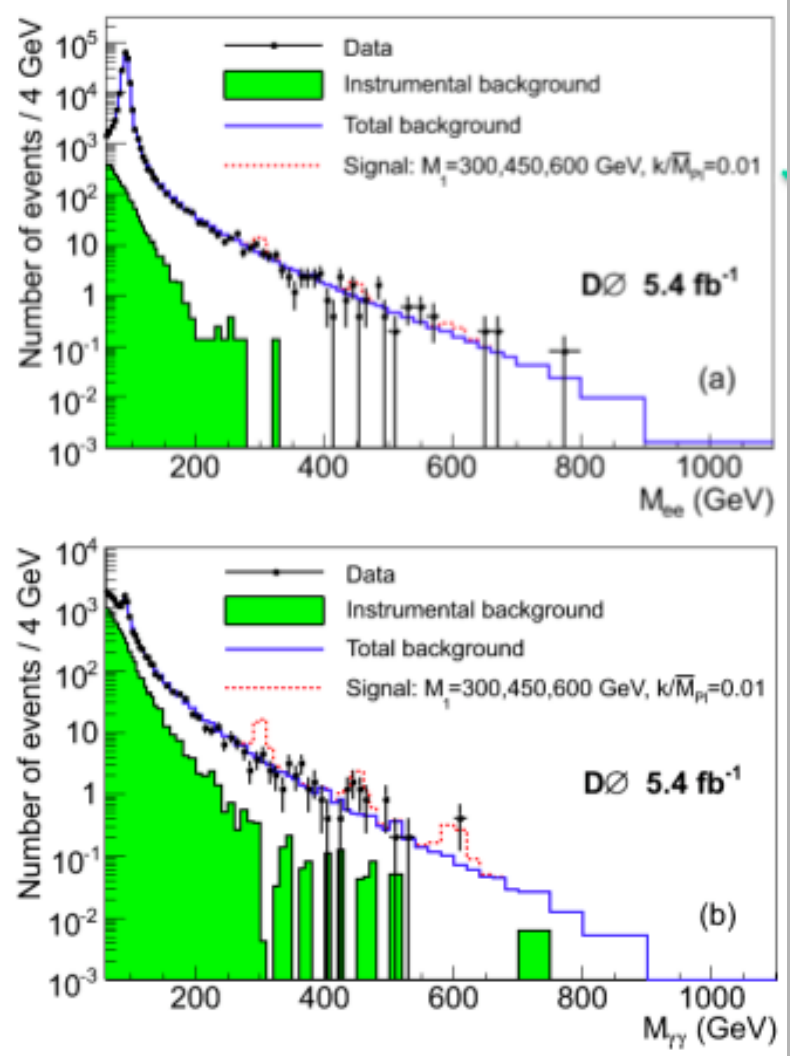
Model	Mass Limit (GeV/c^2)
Z'_l	817
Z'_{sec}	858
Z'_N	900
Z'_ψ	917
Z'_χ	930
Z'_η	938
Z'_{SM}	1071

Best limit in this channel!

Limits are derived for other scenarios (2.3fb^{-1})
Sneutrino: up to 866 GeV/c^2 (λ^2BR = 0.01),
RS graviton: up to 921 GeV/c^2 (K/M_{PL} = 0.1)

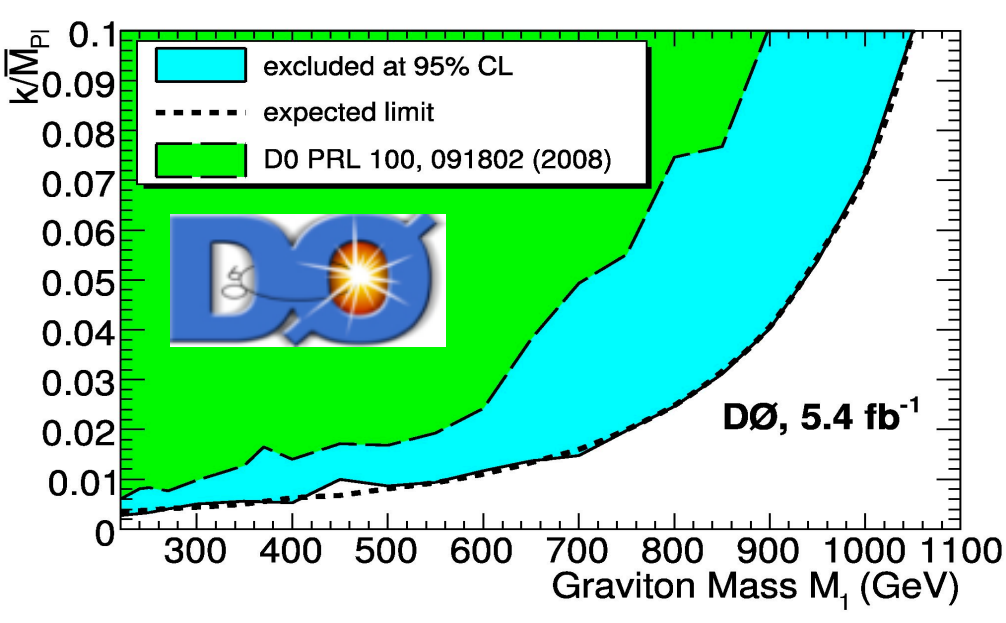
Dilepton + Diphoton Final States

Sensitivity to the Graviton is improved by combining searches in M_{ee} and $M_{\gamma\gamma}$.



Graviton KK excitation mass limits:

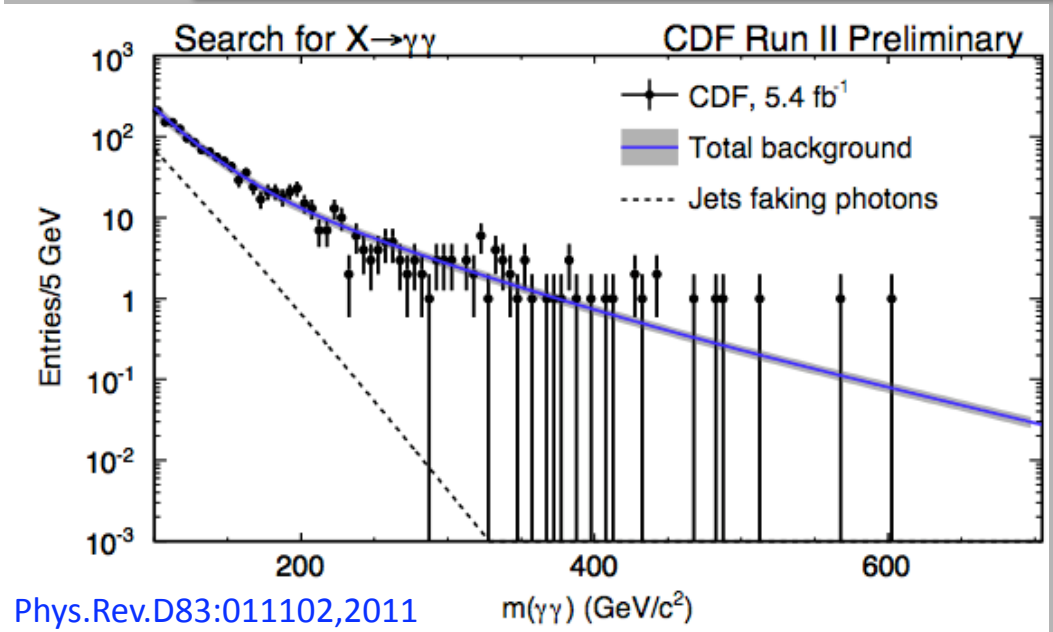
560-1050 GeV/c^2 for $0.01 \leq k/M_{PL} \leq 0.1$



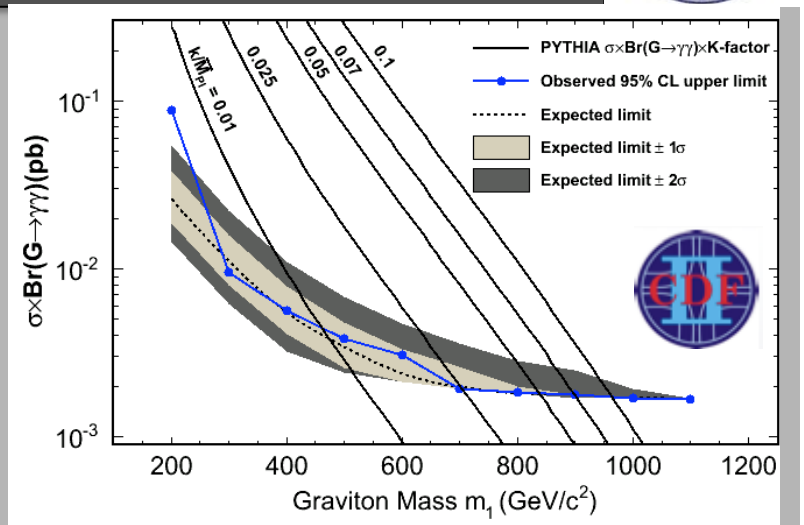
PRL 104, 241802 (2010)

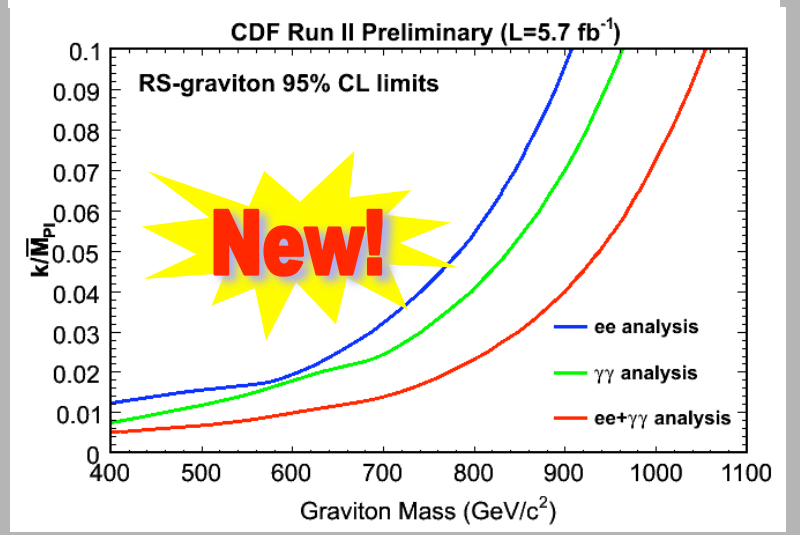
Excess at 450 GeV/c^2 (diphoton) - 2.3σ significance

Dilepton + Diphoton Final States



Phys.Rev.D83:011102,2011





Combined with dielectron channel gives the <u>most stringent limits to date</u> (M(RSG) > 963 GeV/c^2 $k/M_{PL} = 0.1$)

604-1055 GeV/c^2 for $0.01 \leq k/M_{PL} \leq 0.1$ (variable k-factor)
1089 for k/M_{PL} for fixed k-factor
CDF Public Note 10405

See details and most recent Graviton results from John Strologas
(Wed. session of EWK/BSM Working group talks)

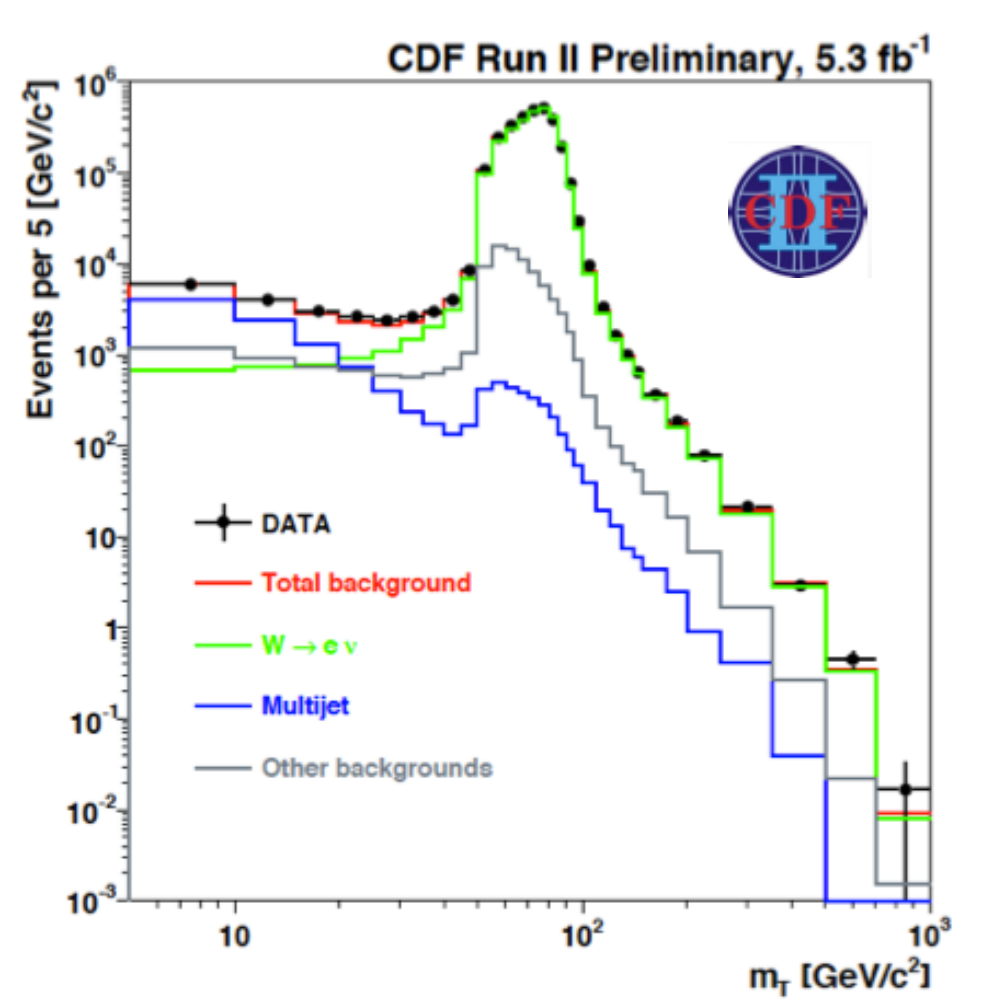
New W' Result

Search for heavier versions of the EW gauge boson: simple final state with lepton and neutrino

Pushing the envelope by going up to energies far from benchmarks!
Understanding of the SM tails very important.

No excess observed-
95% CL limit $m_{W'} > 1.1$TeV

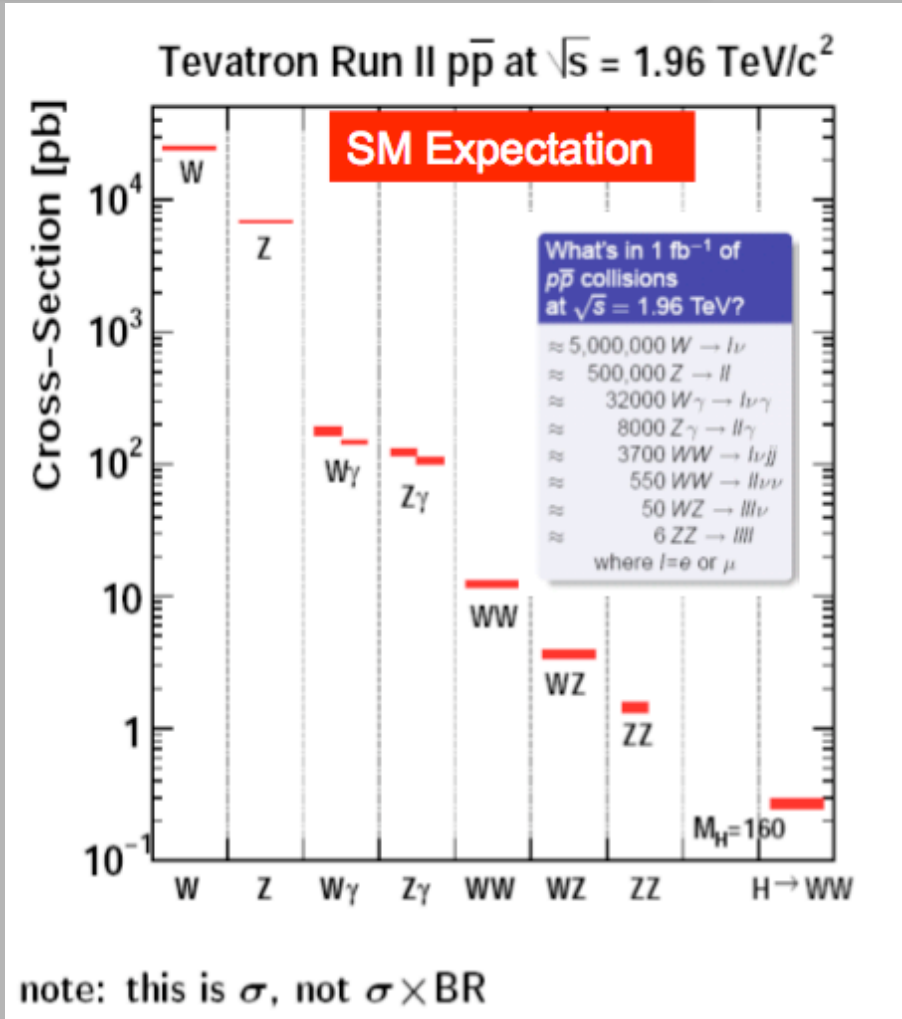
(CMS limit already at 1.6 TeV!)



Phys.Rev.D83:031102,2011

Diboson Production

- Diboson production is one of the least tested areas of the SM
- The triple gauge vertices are sensitive to physics beyond the SM
- SM diboson production share many characteristics and represent background to Higgs and SUSY searches

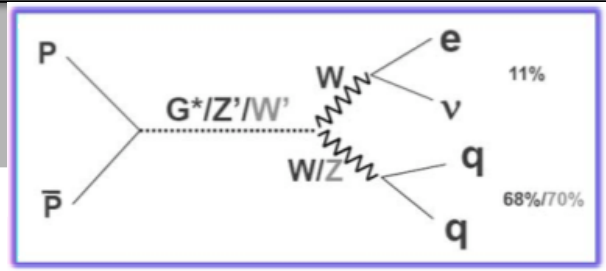


note: this is σ, not $\sigma \times$ BR

See details and most D0 Diboson results from Joe Haley
(Thurs. session of EWK/BSM Working group talks)

Diboson Searches

Limits from combining: lνjj, lljj, and tri-leptons.



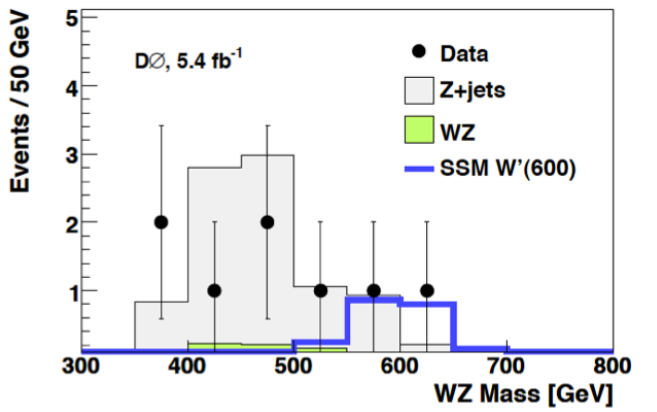
arXiv.org:1011.6278 (acc by PRL)

Tri-leptons: PRL 104, 061801 (2010)

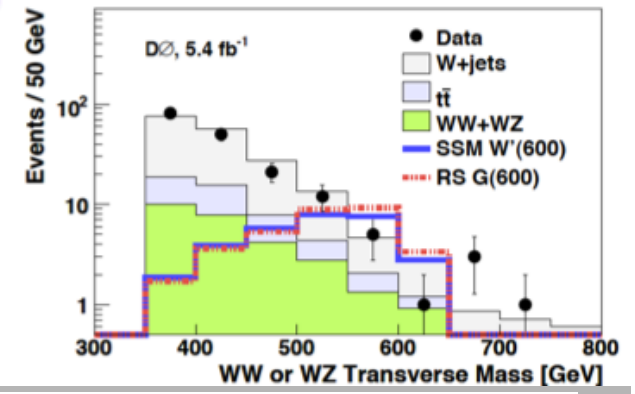
4.1-5.4 fb^{-1}

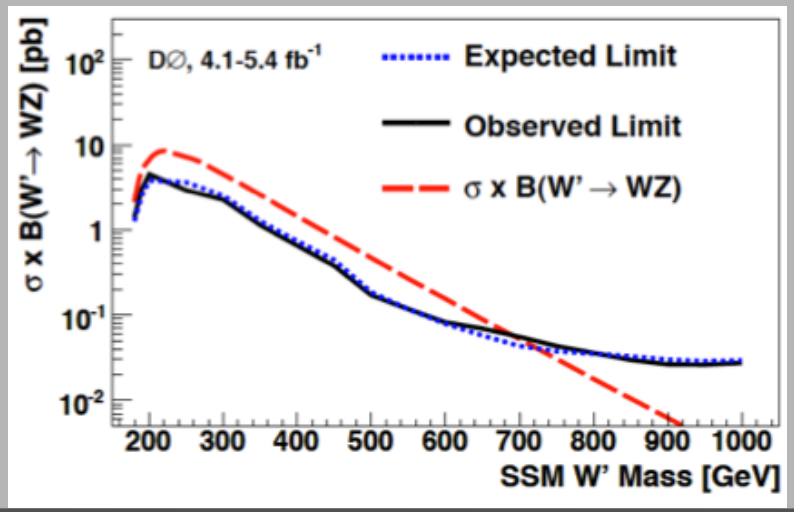
Search sensitivity increased by splitting into high mass/low mass regions

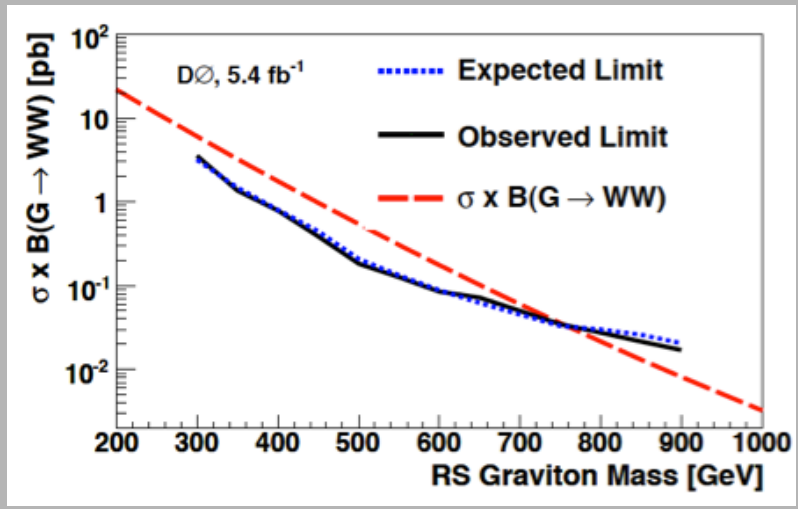
llj(j)



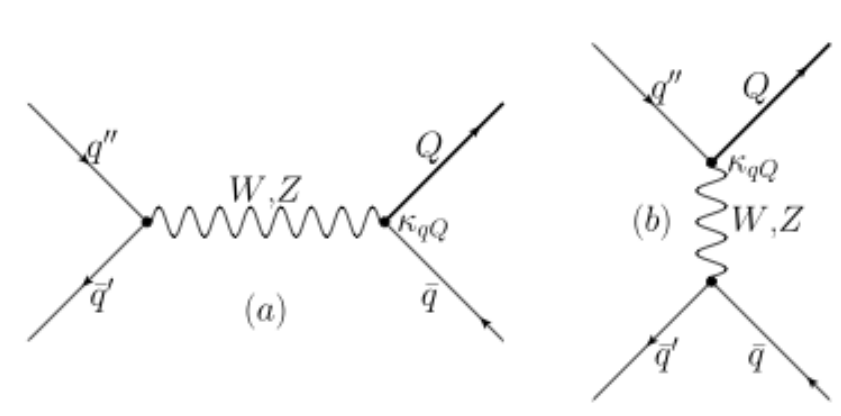
lνj(j)





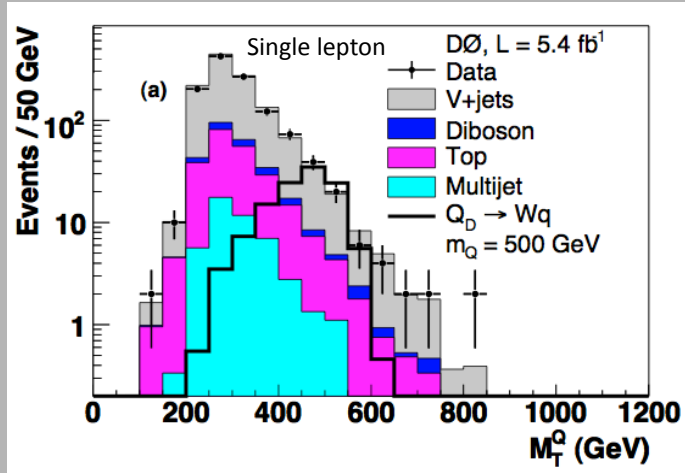


Vector-like Quarks

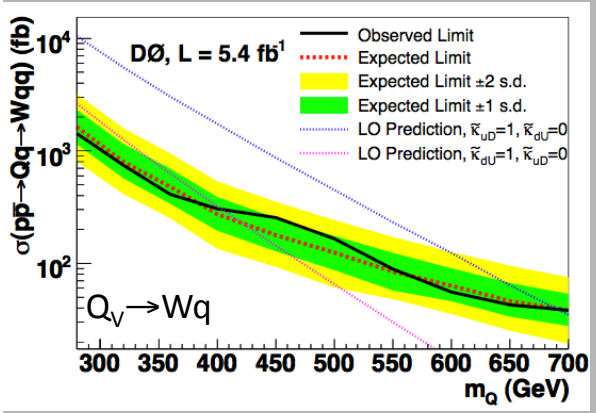


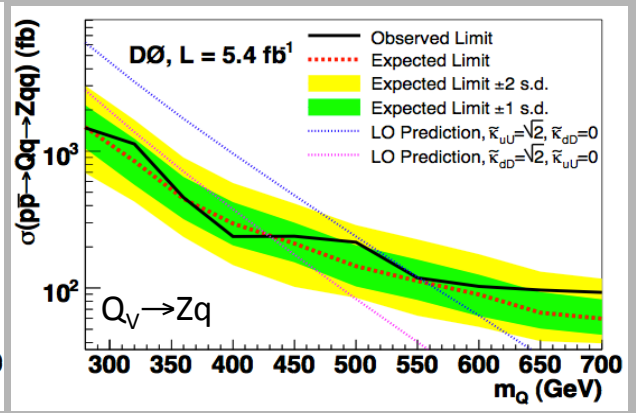
→Q decays into W/Z +q
→Final state of lepton(s), MET and at least 2 jets

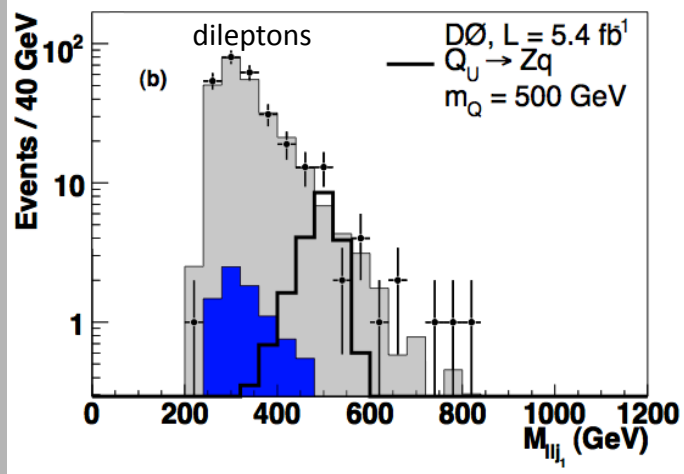
5.4 fb^{-1}



Use M_T^Q (lepton plus MET) and M_{llj} masses and search for evidence of the Q_v decay.

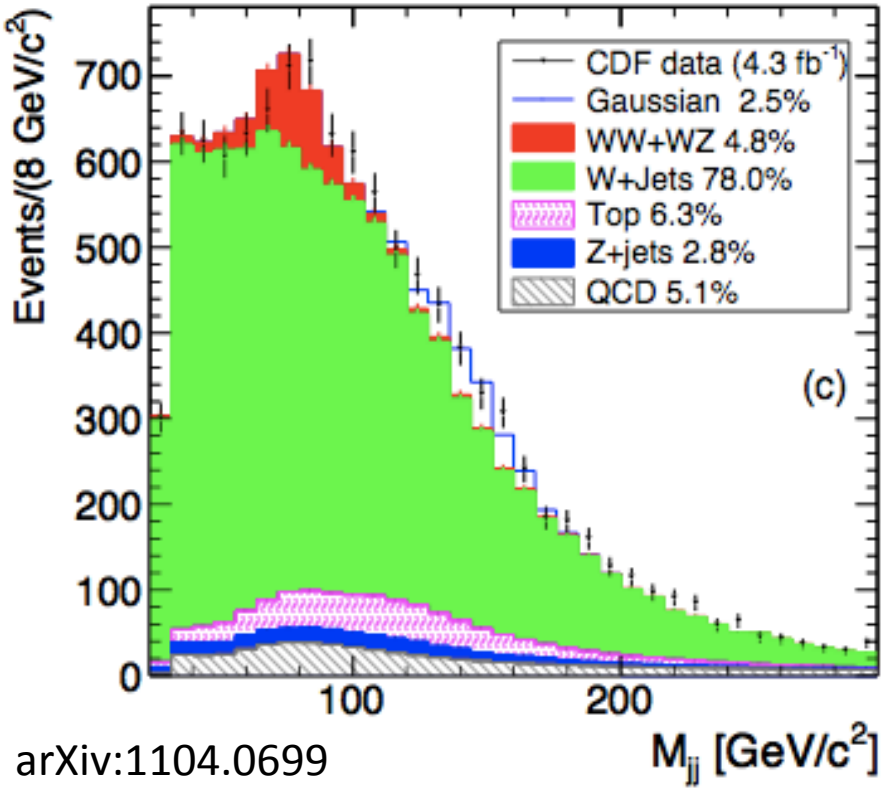


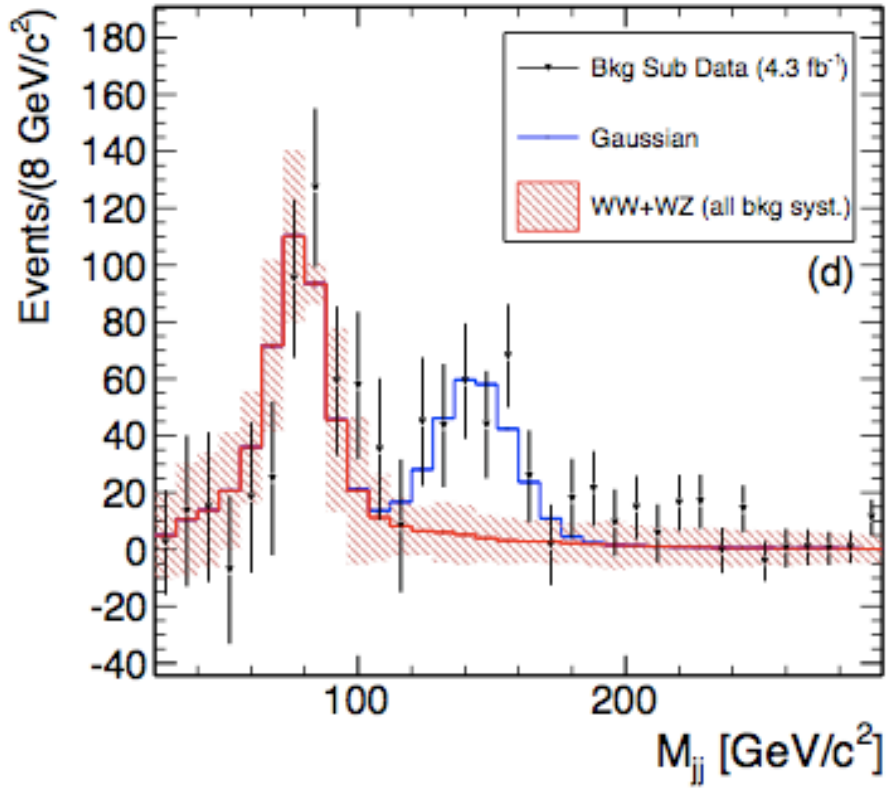




PRL 106, 081801 (2011)

New! W+jj New!





arXiv:1104.0699

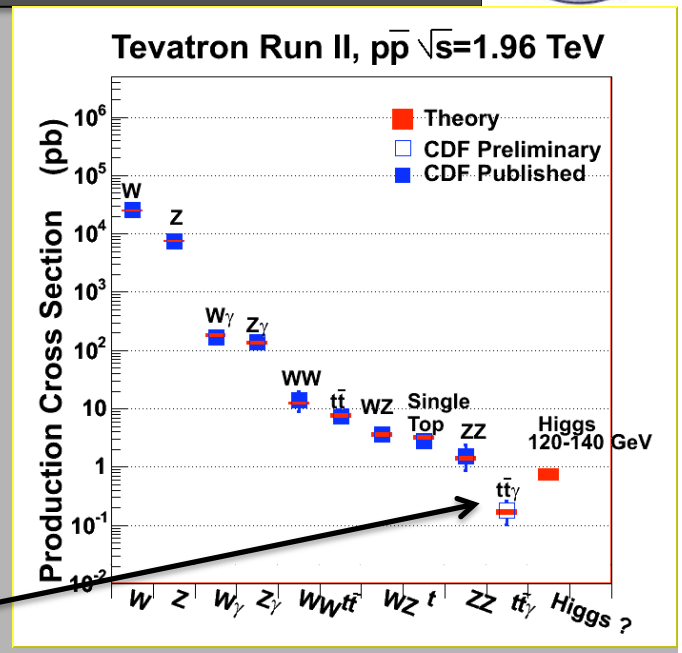
- Special Wine & Cheese seminar: 3.2 sigma excess!
- CDF has an excess in the dijet mass for W+2 jet events above the W mass peak.
- If fit to Gaussian of with of mass resolution the significance can be calculated as 3.2 sigma
- Not consistent with SM Higgs, not seen in Z+jets
- Provisionally accepted by PRL within 48 hours of submission

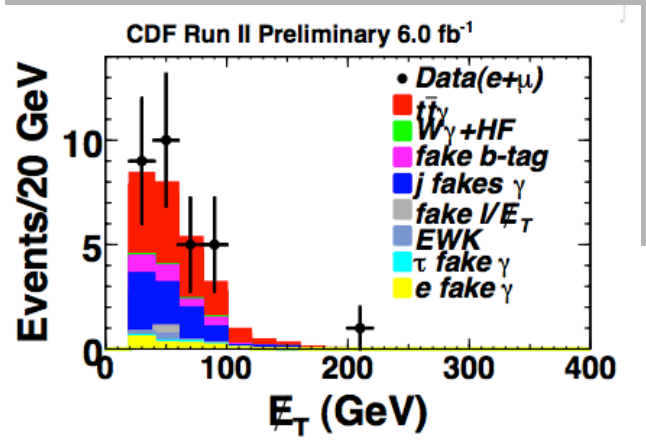
  → Analysis web page: http://www-cdf.fnal.gov/physics/ewk/2011/wjj/

More Exotic Final States

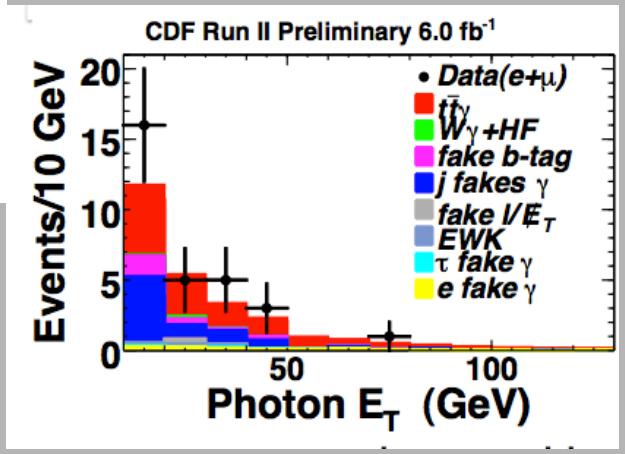
Photon + MET + b-jet + lepton : $t\bar{t}\gamma$

- Leading background is Standard Model t-tbar + γ.
- Search for deviation from the Standard Model, and measurement of the ratio of the cross section: γ-ttbar/ ttbar.





Possibly the smallest cross-section measured!



CDF Public Note 10270

No excess observed, σ(ditop+γ) =0.18 ±0.07 pb

R($t\bar{t}\gamma$/$t\bar{t}$) = 0.024 ± 0.009

6.0 fb^{-1}

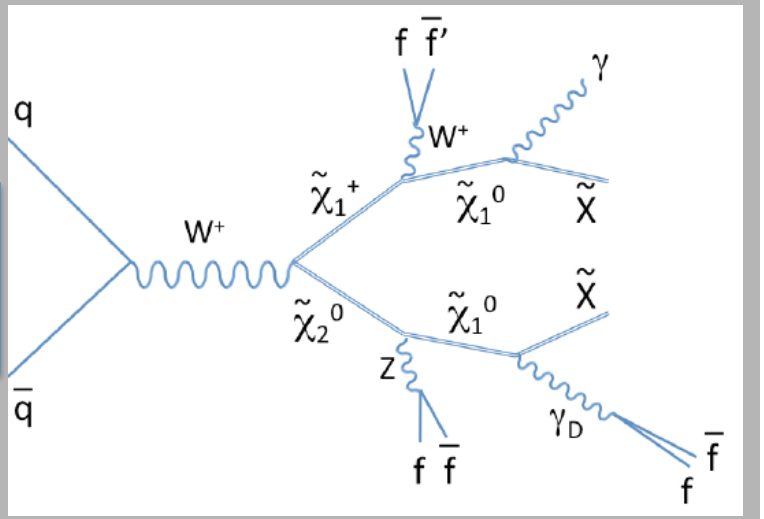
New!

More Exotic Final States

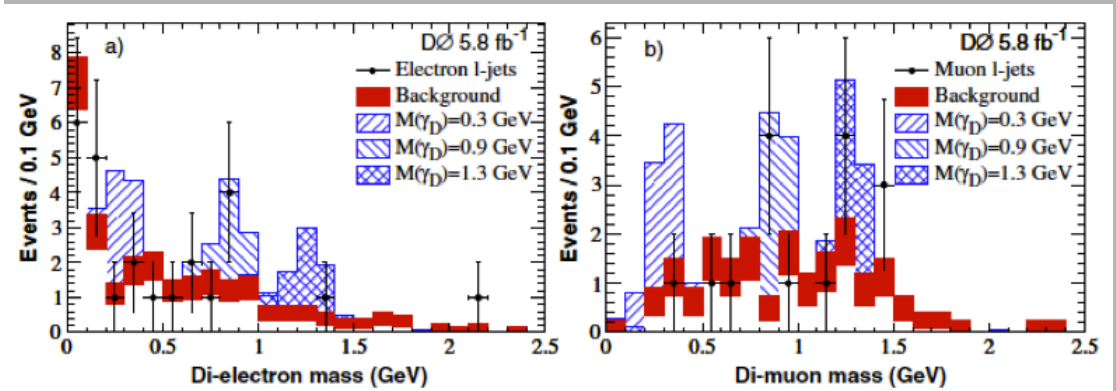
MET + leptonic jet (exotic SUSY)

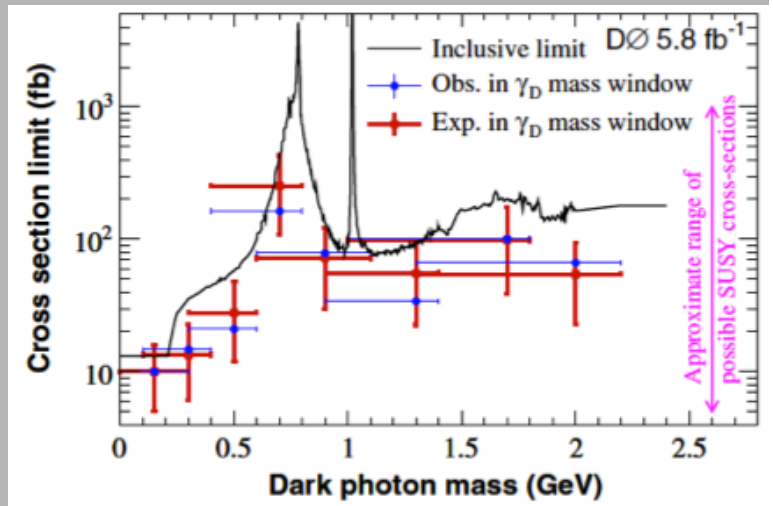
5.8 fb^{-1}

- hidden sector weakly coupled to SM particles
- Force carrier in the hidden sector: dark photon
- Dark photon decays to highly collimated SM particles



- Signature: two *leptonic* jets and MET
- Leptonic jet - regular lepton + additional track(s) of opposite charge near the lepton





NOTE: efficiency times acceptance varies over range of masses due to hadronic decays.

PRL, 105, 211802 (2010)

More Exotic Final States

4th Generation: t' (w/ Dark Matter)

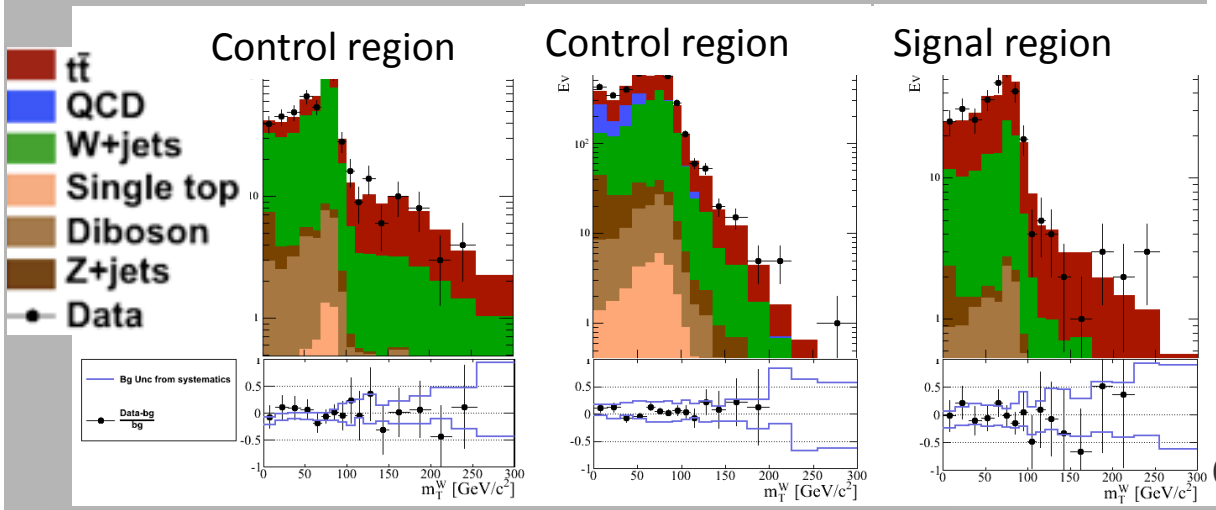
Exotic 4th generation quarks t'-> tX, where X is a dark matter candidate

- J.Feng et al, arXiv:1002.3366
- Other scenario: stop -> top + neutralino
- Signature: ttbar + large MET
- Dominant background, ttbar and W+jets

4.8 fb^{-1}

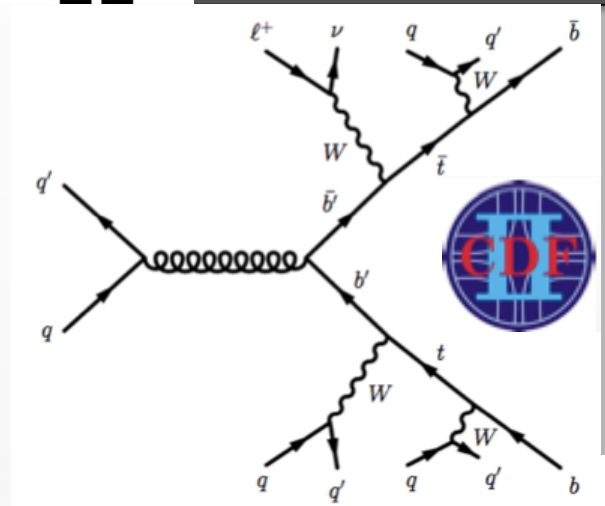
Strategy:
1) fit background + signal transverse mass distribution
2) Optimize the MET cut for different points
3) Test modeling of background is in control regions

CDF Public Note 10374



CDF Public Note 10374

More Exotic Final States



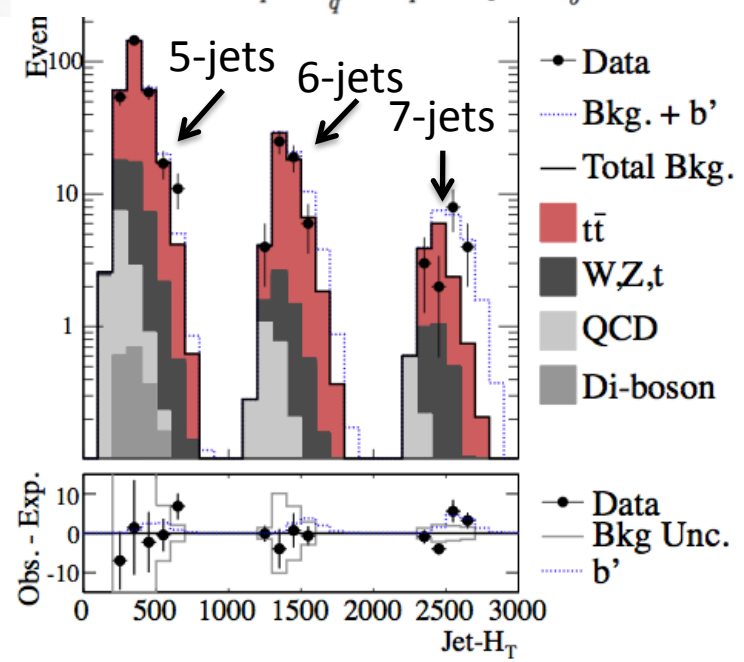
4th Generation: b'

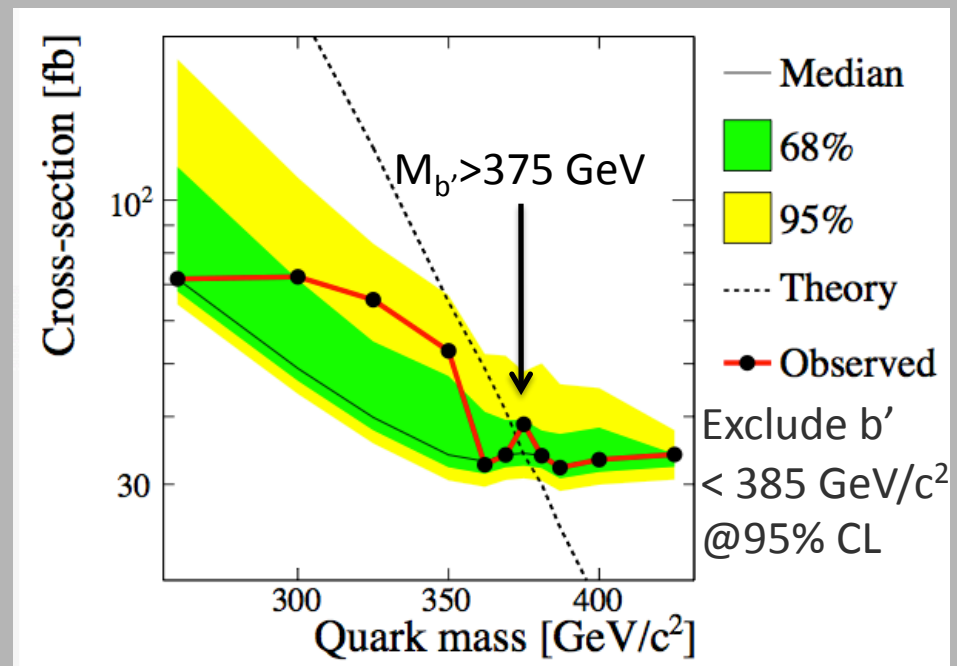
→Current limits push 4th generation down-type quark to be above m(top)+m(W)

→Final state comprising top and extra W's

→Lepton+jets signature - high acceptance due to hadronic decaying W's

Fit to $H_T = \Sigma$(Jet E_T + lepton E_T + MET)
Across different jet multiplicity bins





Exclude b' < 385 GeV/c² @95% CL

arXiv:1101.5728

Exotic Searches Summary

The search for new physics at the Tevatron continues…

- **The Tevatron has been performing very well**
  - Very Large Dataset!
  - Some limits are still the best!
- **The CDF and D0 collaborations are pushing:**
  - for better and improved limits on particles production
    - Small cross-section phenomena now accessible due to large luminosity
  - to exercise most techniques applicable
- **LHC is surpassing the Tevatron quickly as expected, but surprises might still come from CDF and D0….**

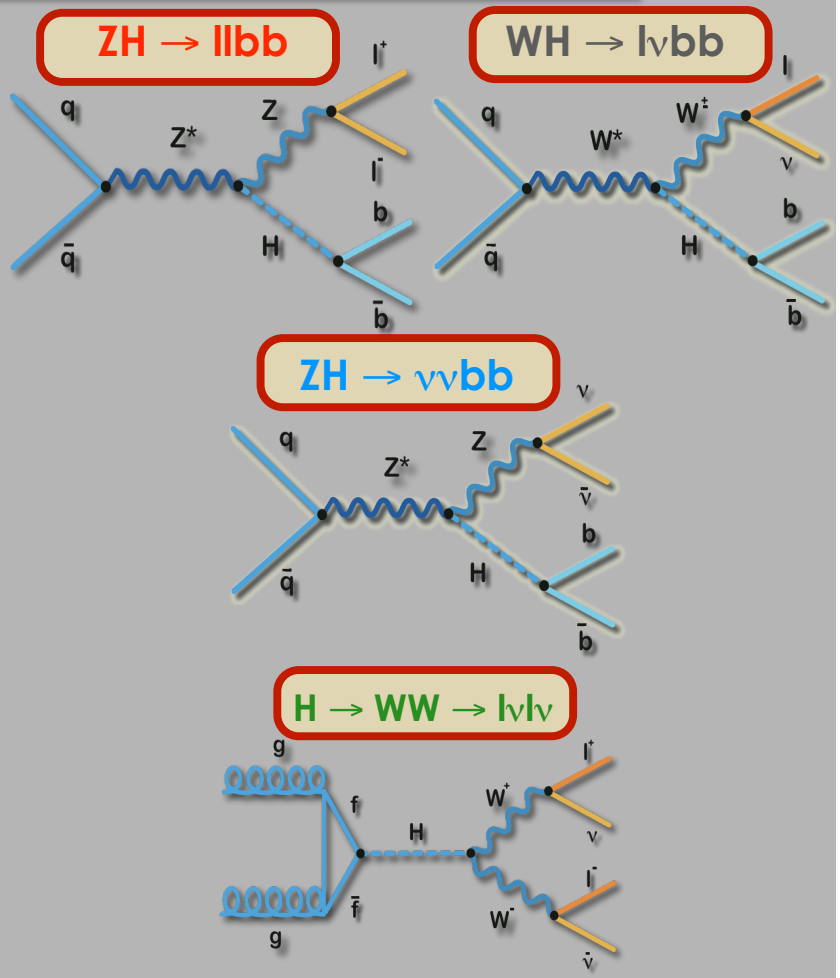
More search results and details:

- http://www-cdf.fnal.gov/physics/exotic/exotic.html
- http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

Higgs Searches at the Tevatron

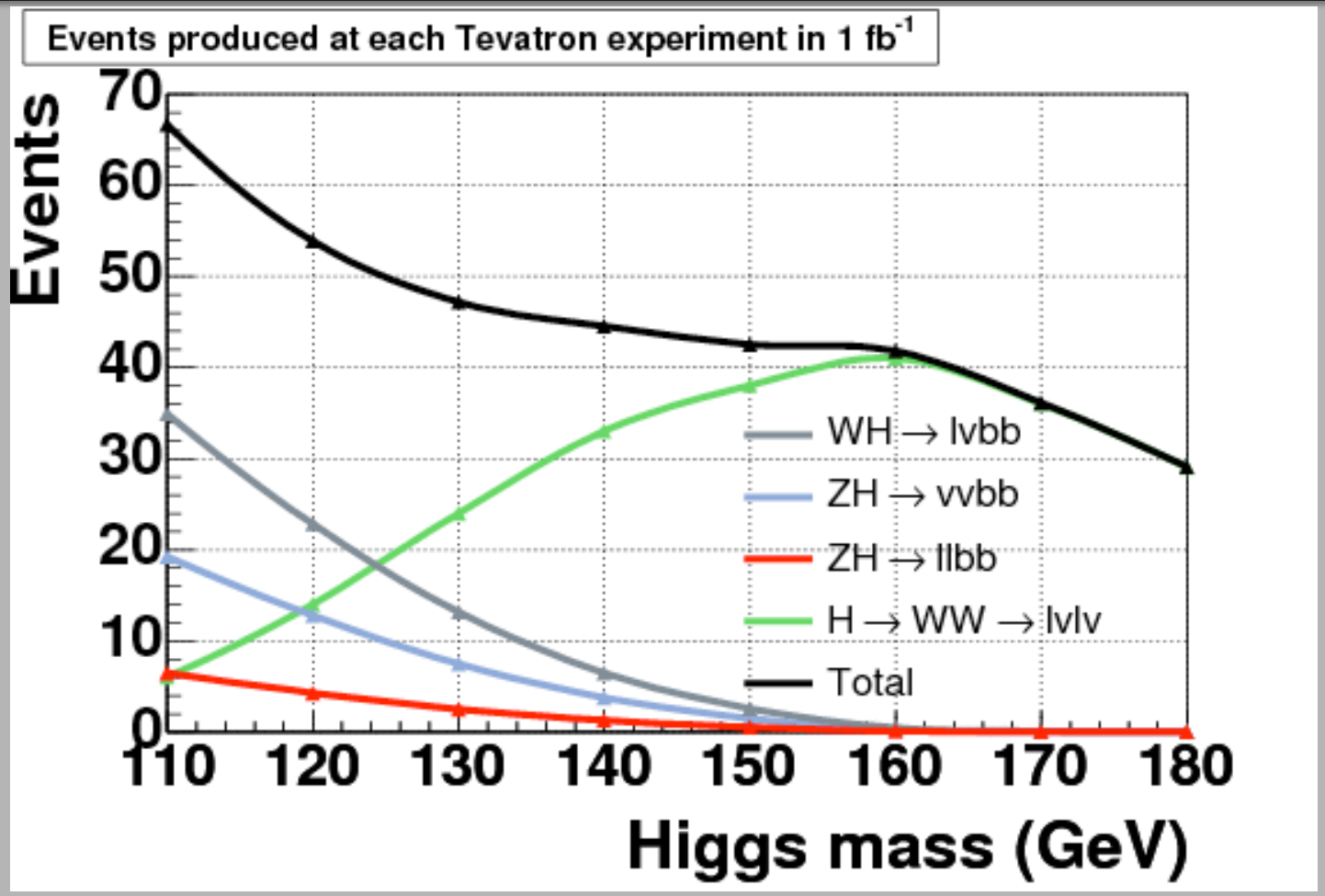
Higgs Searches: The basics

	Low Mass	High Mass
Primary Production:	WH, ZH	gg->H
Decay:	H -> bb	H -> WW
Main modes:	bb+lν bb+νν bb+ll	ll+νν
Important features:	• B-tagging • Dijet resolution	• Lepton acceptance • Angular correlations



Note: These are the most sensitive channels but all non-negligible production and decay modes are considered.

Higgs Production Rates



About 1000 Higgs events expected to be produced at the Tevatron in the full dataset! (10 fb^{-1})

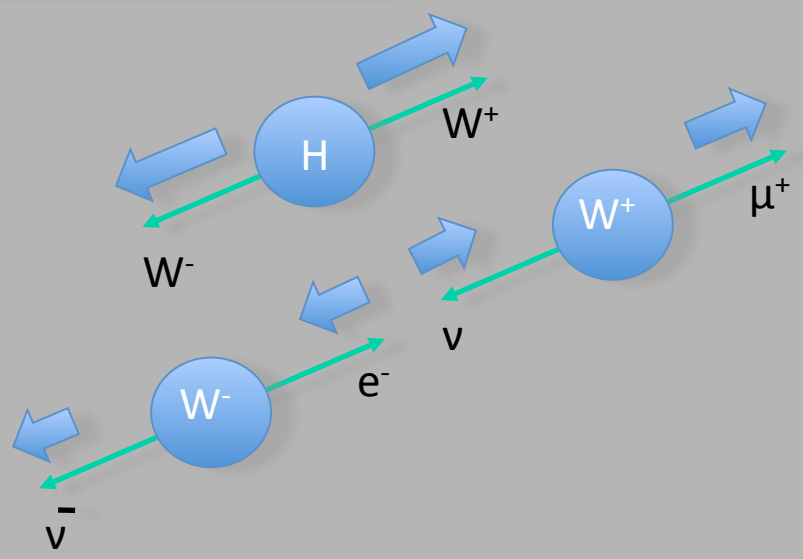
Results: Low Mass ($M_H = 115\ GeV/c^2$)

Channel	CDF Limit x SM (expected)	D0 Limit x SM (expected)
$WH \rightarrow l\nu bb$	3.5	4.8
$ZH \rightarrow \nu\nu bb$	4.0	4.0 (New!)
$ZH \rightarrow llbb$	5.5	5.7
$H \rightarrow WW \rightarrow l\nu l\nu$	10.8 (New!)	8.6 (New!)
$ZH+WH \rightarrow jjbb$	18	19.9
$H \rightarrow \tau\tau$	15 (New!)	12.8 (New!)
$H \rightarrow \Upsilon\Upsilon$	20.8	11 (New!)

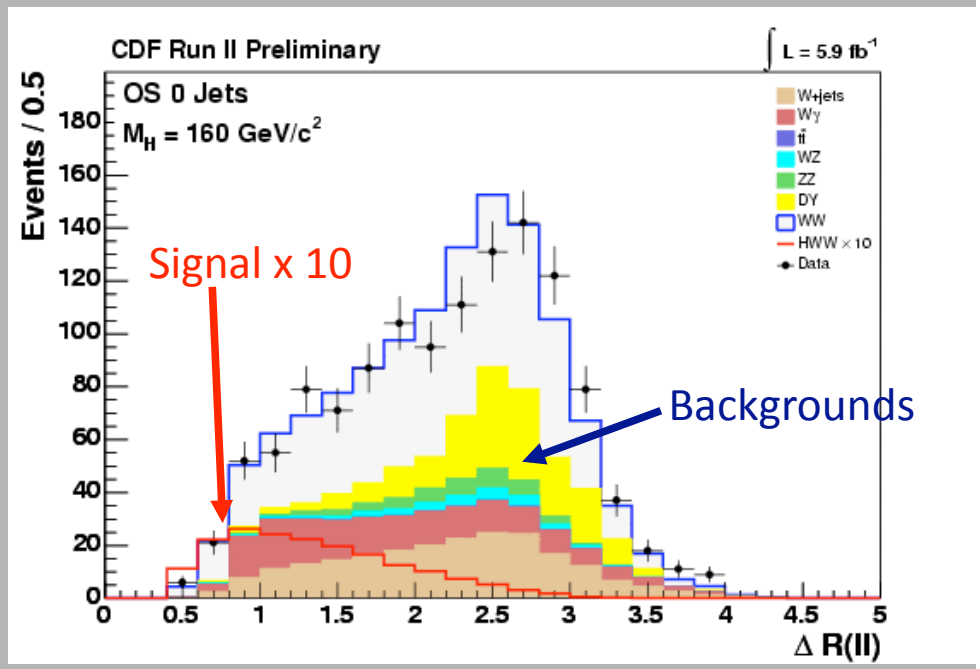
High Mass (H→WW)

- Most important channel for M_H> 125 GeV
- Contributes down to 115 GeV

Spin correlation: Leptons go in the same direction



Main challenge: to distinguish signal from EWK WW pair production.

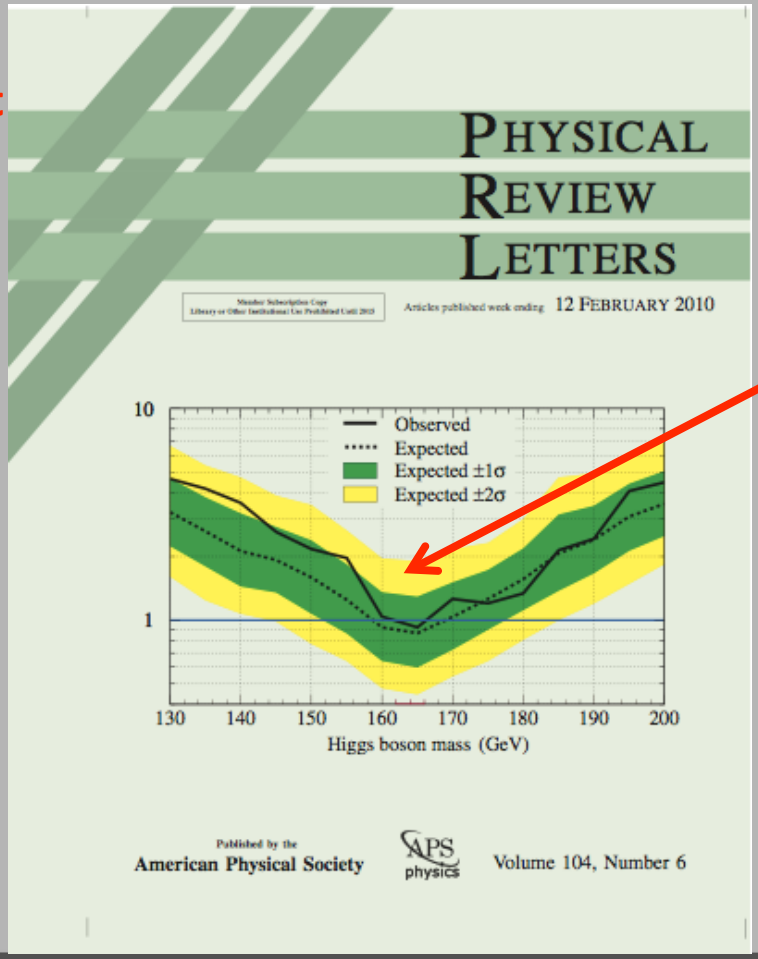


Dilepton opening angle is the strongest background discriminant

Tevatron Combination

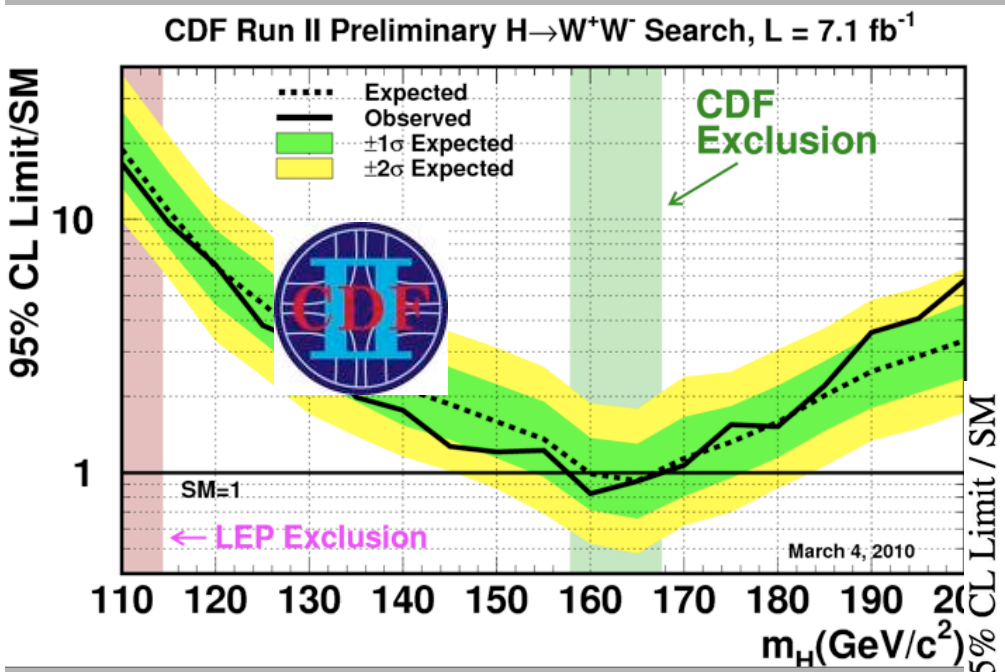
One experiment is not enough - need to combine CDF and D0 results!

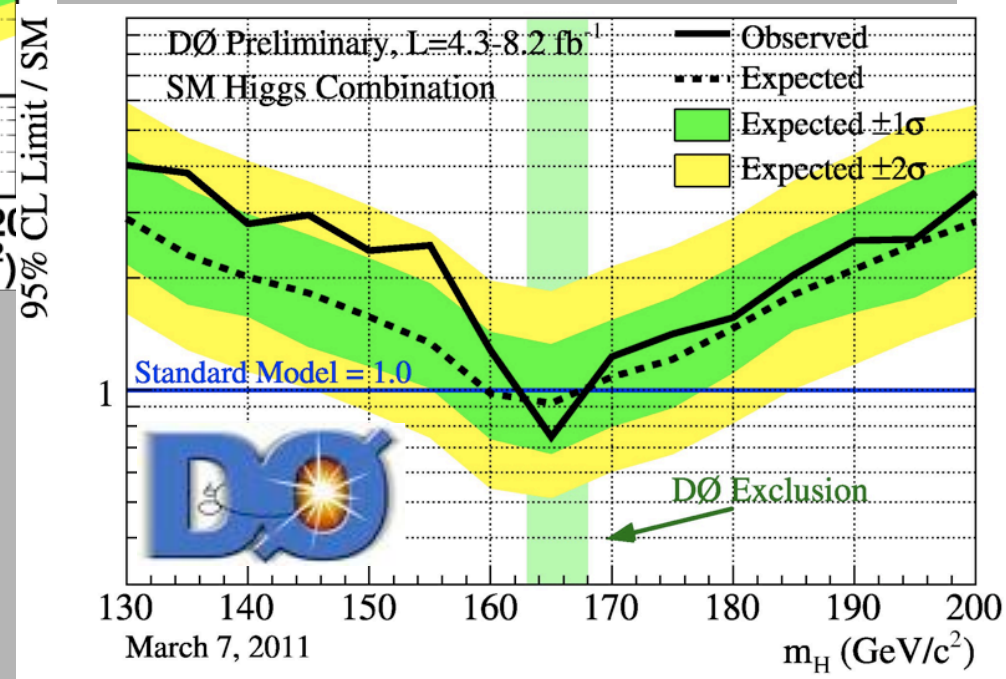
High mass result featured on PRL cover page



First published Standard Model Higgs exclusion since LEP!

But, one experiment is enough!

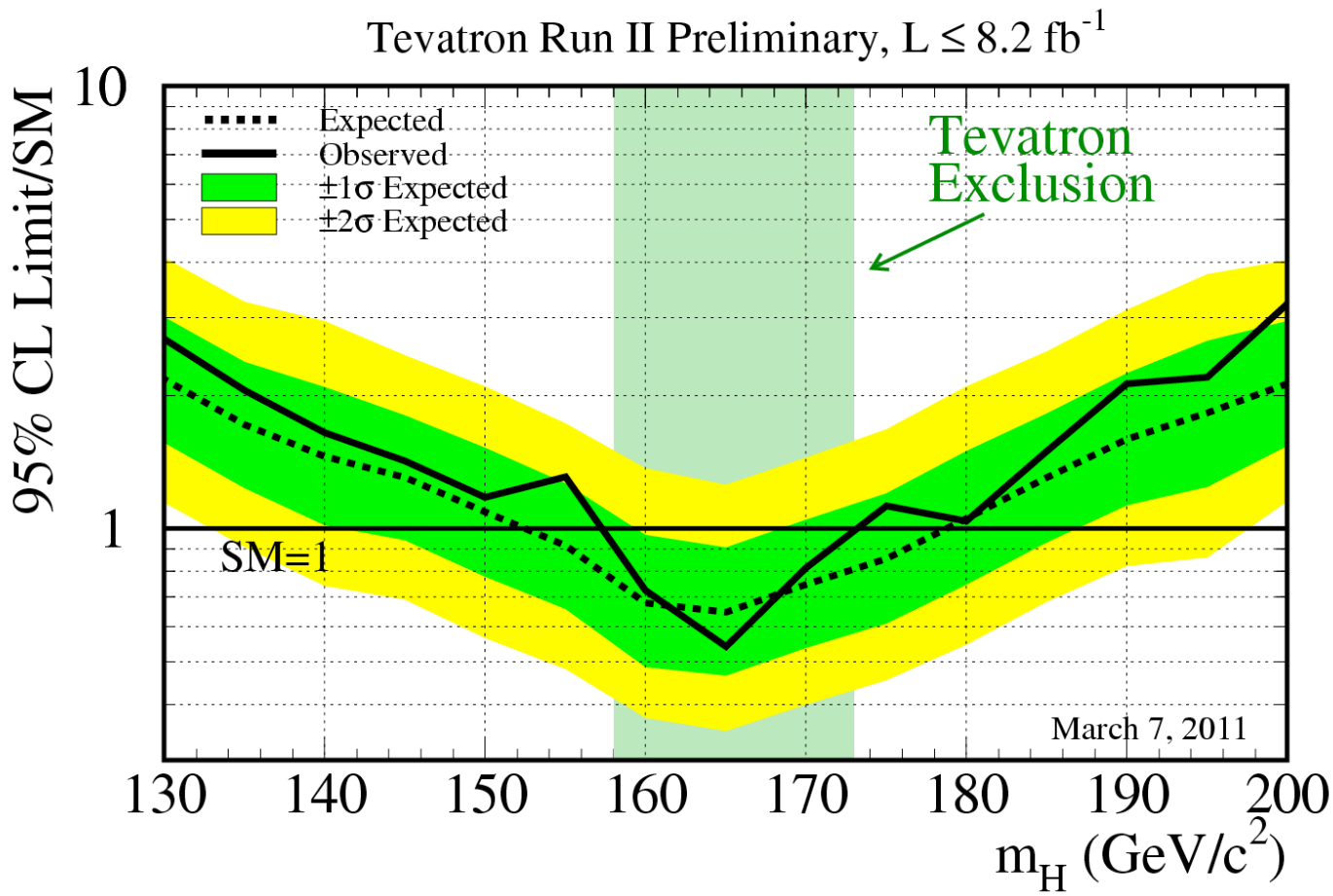




CDF and D0 have obtained single experiment exclusion at high mass!

New High-Mass Combination

SM Higgs is now excluded between 158 and 173 GeV!



arXiv:1103.3233

Results: Low Mass (M_H = 115 GeV/c^2)

Channel	CDF Limit x SM (expected)	D0 Limit x SM (expected)
WH → lνbb	3.5	4.8
ZH → ννbb	4.0	4.0 (New!)
ZH → llbb	5.5	5.7
H → WW → lνlν	10.8 (New!)	8.6 (New!)
ZH+WH → jjbb	18	19.9
H → ττ	15 (New!)	12.8 (New!)
H → ΥΥ	20.8	11 (New!)

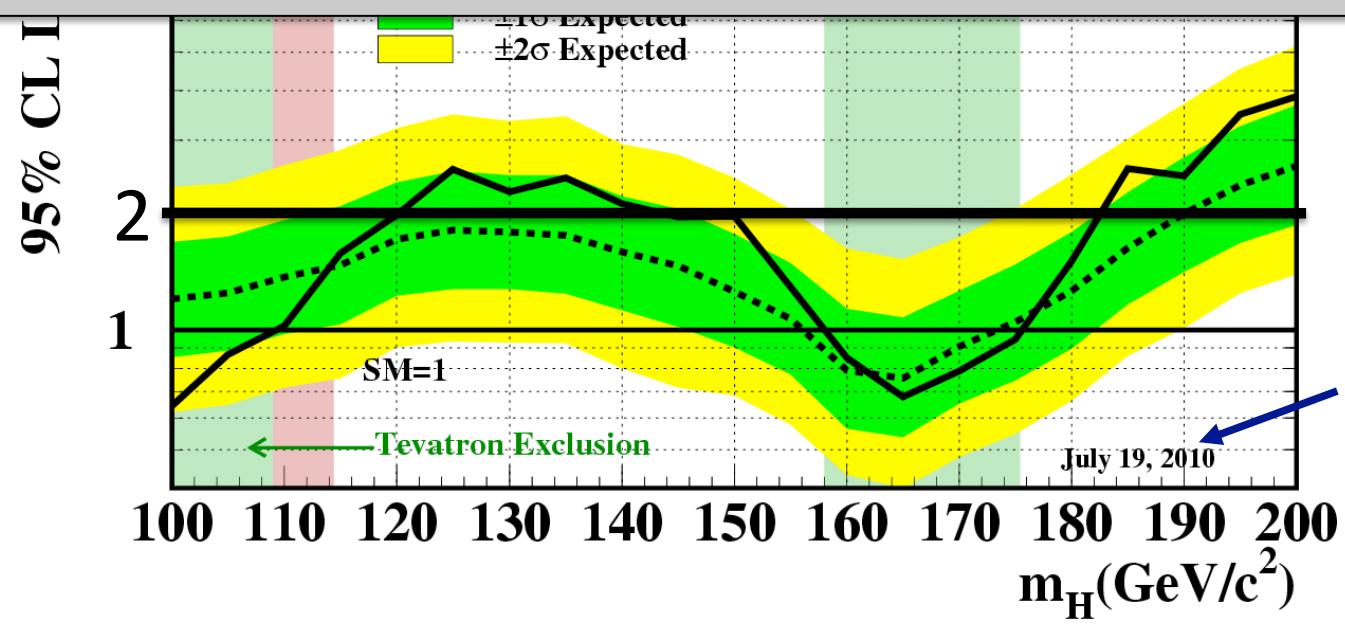
Combination (2010) 1.45xSM

See details and most recent D0 Higgs results from Maiko Takahashi
(Tues. session of EWK/BSM Working group talks)

Low-mass Combination

All channels combined from the CDF and D0 experiments

Within a factor of 2 of exclusion sensitivity to SM over the full interesting mass range!



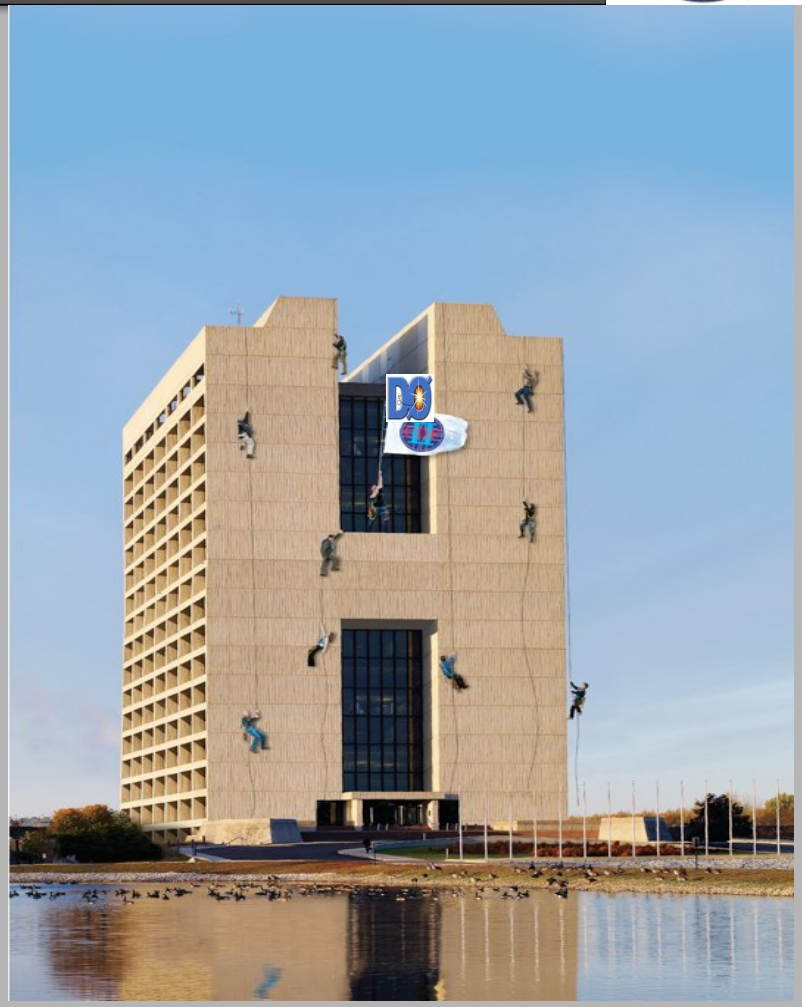
Expect new combination Summer 2011

arXiv:1007.4587

Tevatron SM Higgs Summary

- Dataset should reach 10 fb-1
- Tevatron has sensitivity to a SM Higgs boson!

  -> Should be able to exclude at 95% confidence level over the entire mass range with 10 fb^{-1}



Or, we might just see something!

For more details on Higgs searches:

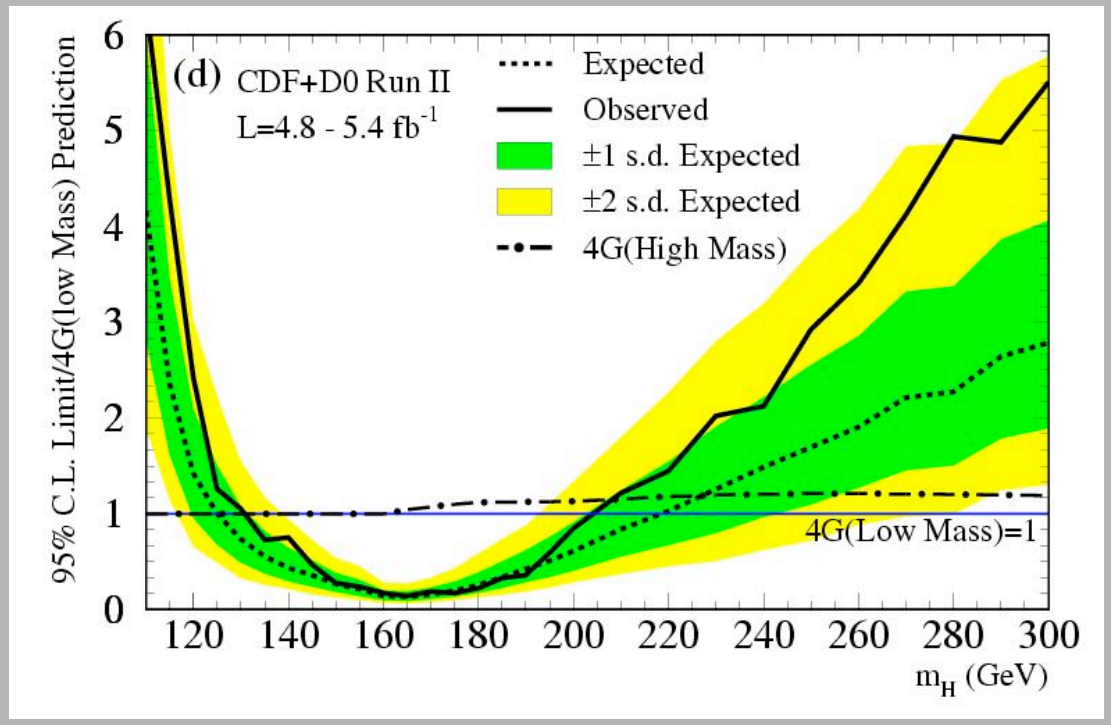
- http://www-cdf.fnal.gov/physics/new/hdg/hdg
- http://www-d0.fnal.gov/Run2Physics/higgs/

BSM Higgs

4th Generation:

→ gg→H production mode enhanced by 4th generation fermions (by ~ factor of 9)

→ Re-interpret high-mass Higgs



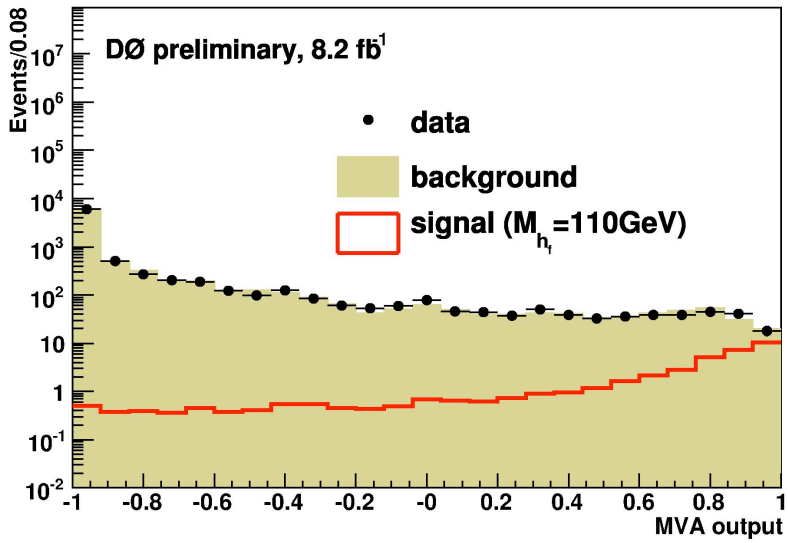
Higgs is now excluded between 131 and 204 GeV for 4th-generation models!

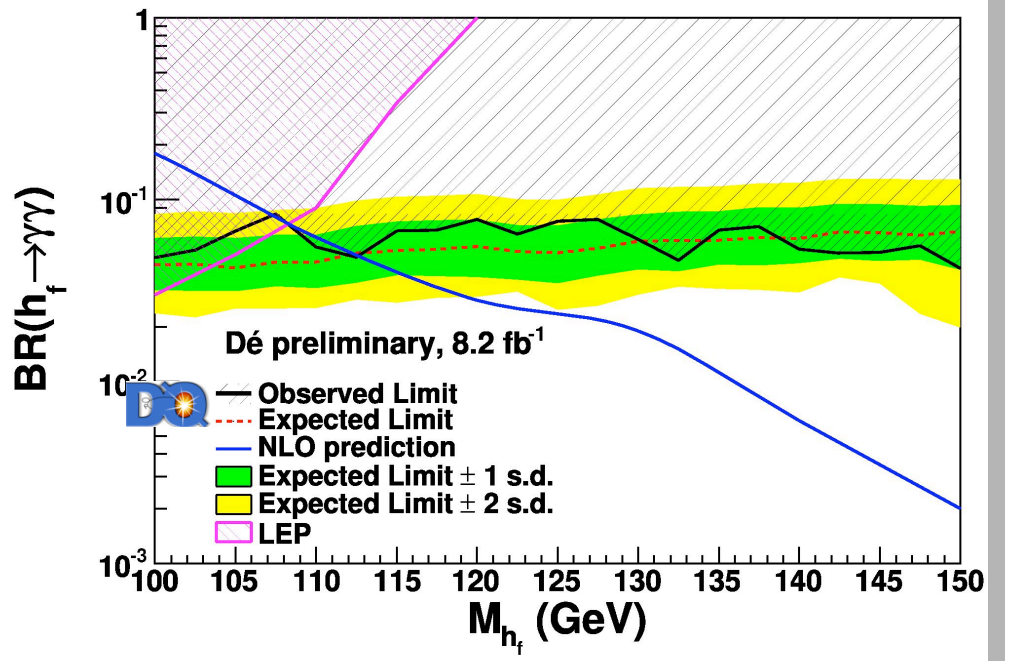
BSM Higgs

Fermiophobic Higgs:

→ No coupling to fermions

→ h->γγ enhanced





Sensitivity surpasses LEP!

8.2 fb^{-1}

See details and most recent D0 Higgs results from Per Jonsson (Tues. session of EWK/BSM Working group talks)

Searches at the Tevatron

- Summary:
  - Many interesting searches ongoing at the Tevatron
  - SM Higgs sensitivity
  - Some interesting excesses:
    - W+jj
    - Top forward/backward asymmetry
    - and others…
  - Still might see something new with the full dataset!
    - → Higgs/BSM physics still possible

We will be back next year!

"Just checking."