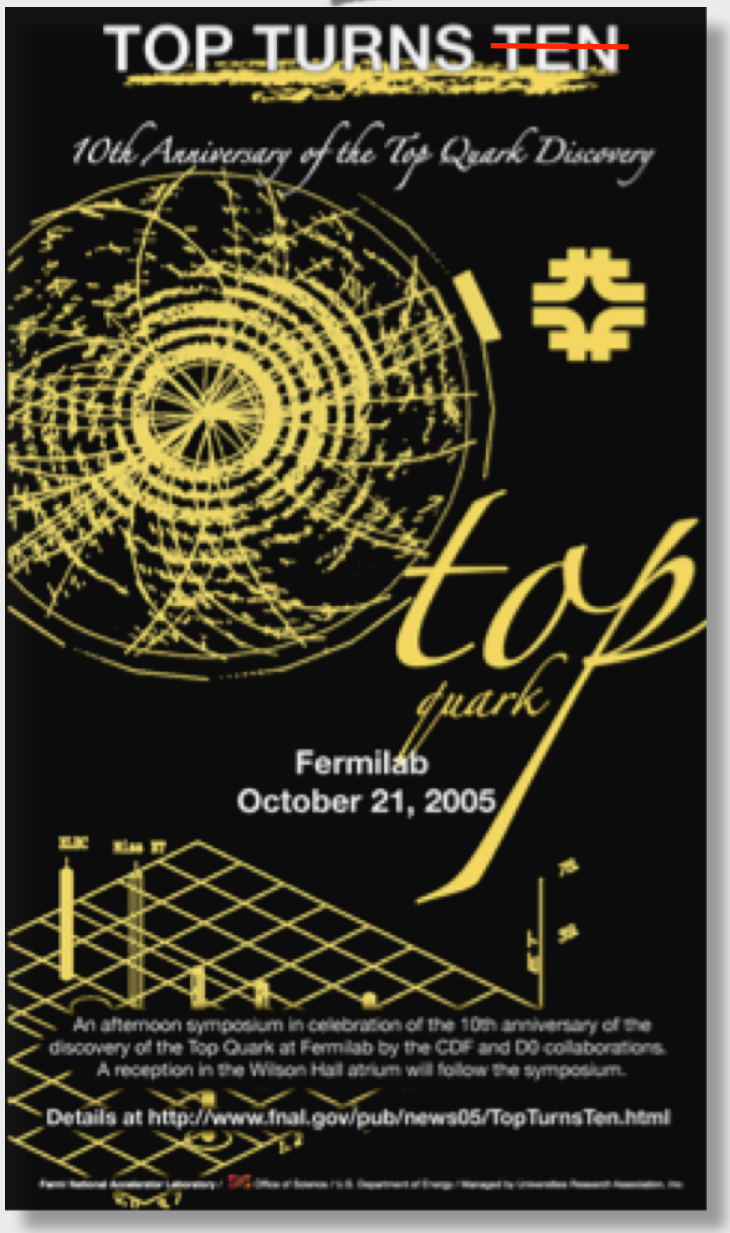
Searches for New Physics in Top Events at the Tevatron

Yuri Oksuzian on behalf of CDF and D0

Moriond QCD, March 2013

Tevatron's legacy

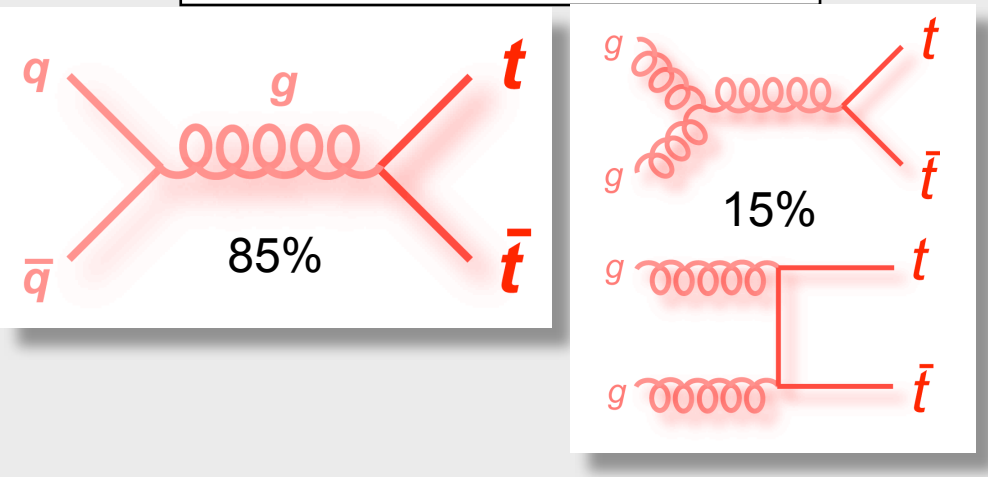
ALMOST TWENTY



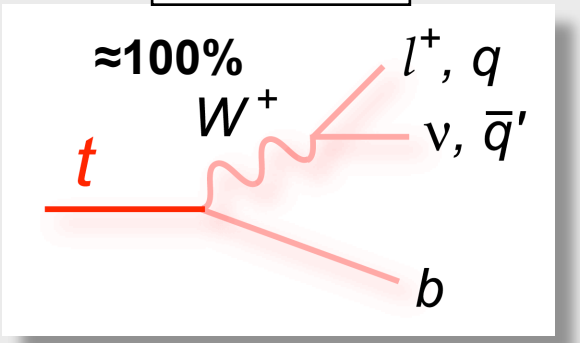
Top quark at Tevatron

- Observed and studied at Tevatron
- Strikingly large mass
  - $m_t = 173.18 \pm 0.94\ \mathrm{GeV/c^2}$
  - Strongest coupling to Higgs field
- $\sigma_{t\bar{t}} = 7.65 \pm 0.42\ \mathrm{pb}$ (Tevatron 2012)
- Search for new physics in top quark properties.
  - Look for deviation from SM
  - Observed large A_{fb}?
- Direct searches for new physics:
  - Many BSM models predict particles couple preferably to $t\bar{t}$
  - Z', W', b', t', t→Zq, anomalous coupling, dark matter...

Main production mechanism



Top decay



Tevatron vs LHC

- Why study top at Tevatron?
  - Tevatron is the $p\bar{p}$ collider
  - Still competitive sensitivity to $q\bar{q}$ initiated new physics models, like $q\bar{q} \to Z' \to t\bar{t}$

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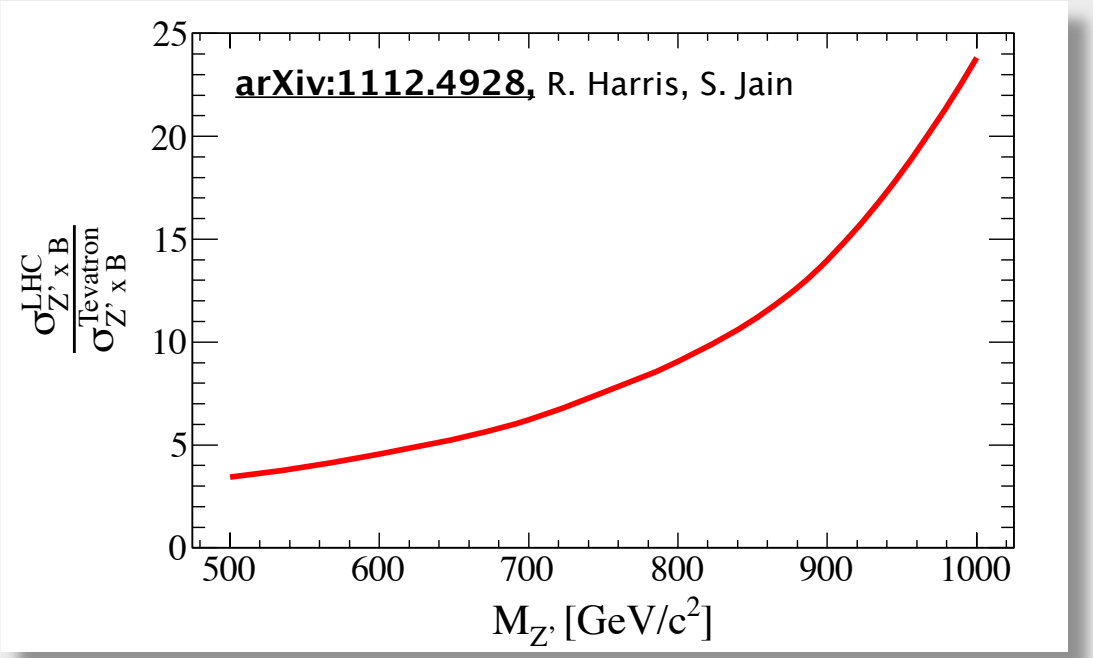
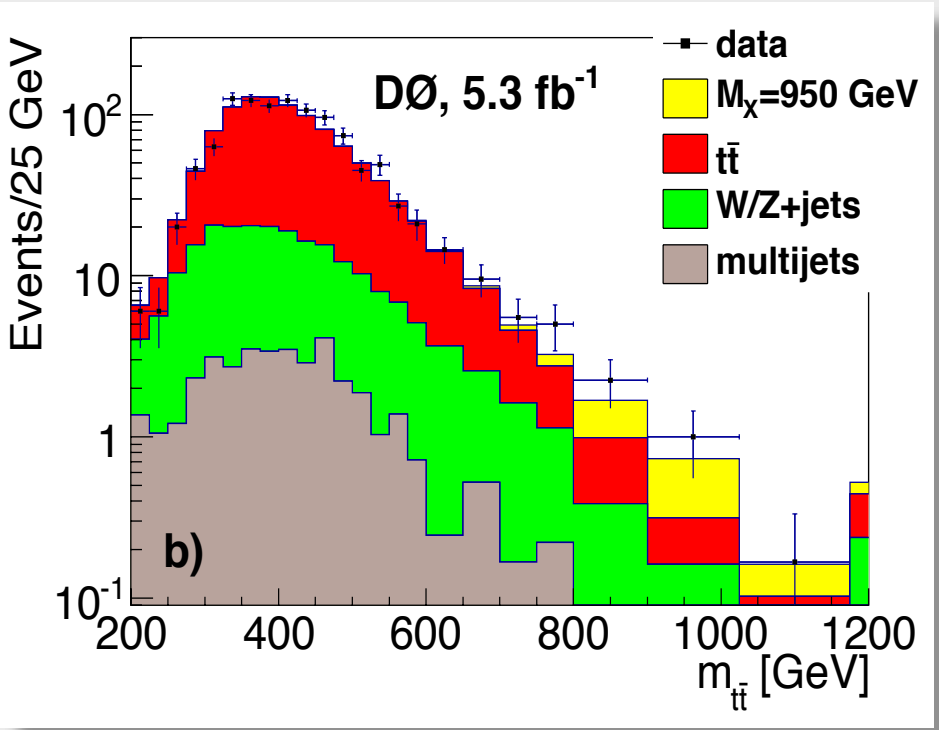
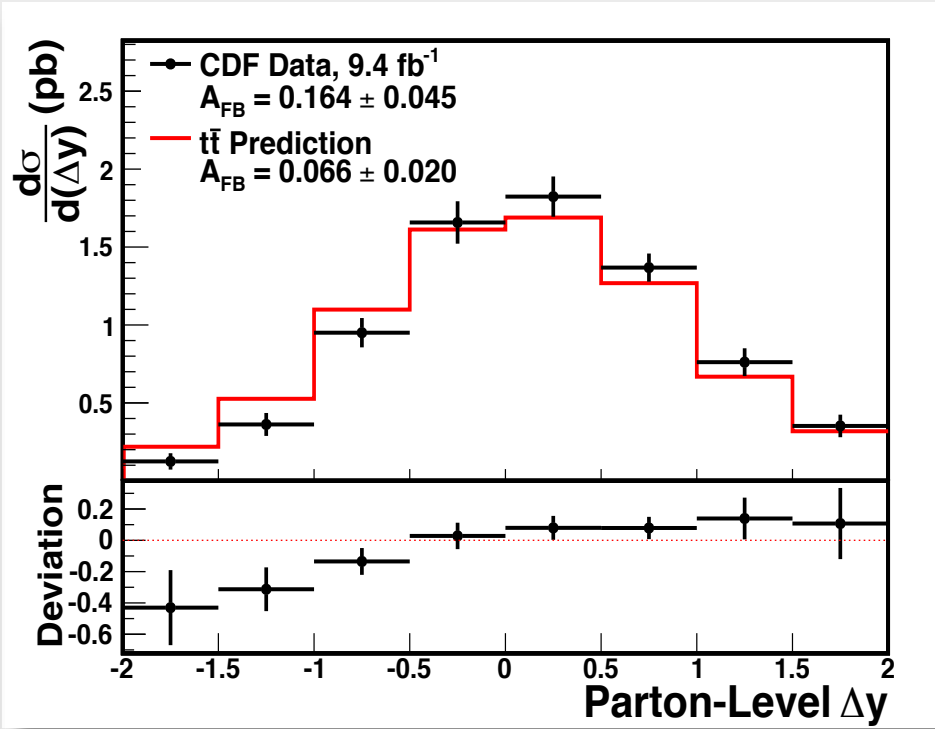
- SM: $\dfrac{\sigma_{t\bar{t}}^{\text{LHC}}}{\sigma_{t\bar{t}}^{\text{Tevatron}}} \simeq 25$
- Z': $\dfrac{\sigma_{Z' \to t\bar{t}}^{\text{LHC}}}{\sigma_{Z' \to t\bar{t}}^{\text{Tevatron}}} \simeq 5\text{-}10 \quad , M_{Z'} < 800\ \text{GeV}$



Motivation for Z' search

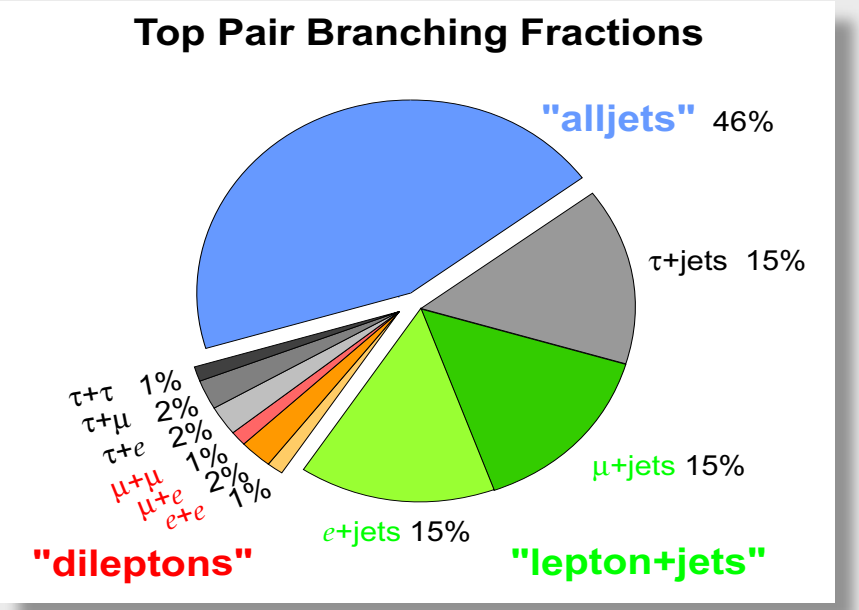
- Top is very heavy, maybe indication of coupling to new physics
- Various theoretical models predict $t\bar{t}$ resonant states: Z' in extended gauge theories, axigluons, KK states of gluon/Z, Topcolor
- Tevatron $t\bar{t}$ forward-backward asymmetry
- 2σ excess of events at masses around 950 GeV at D0

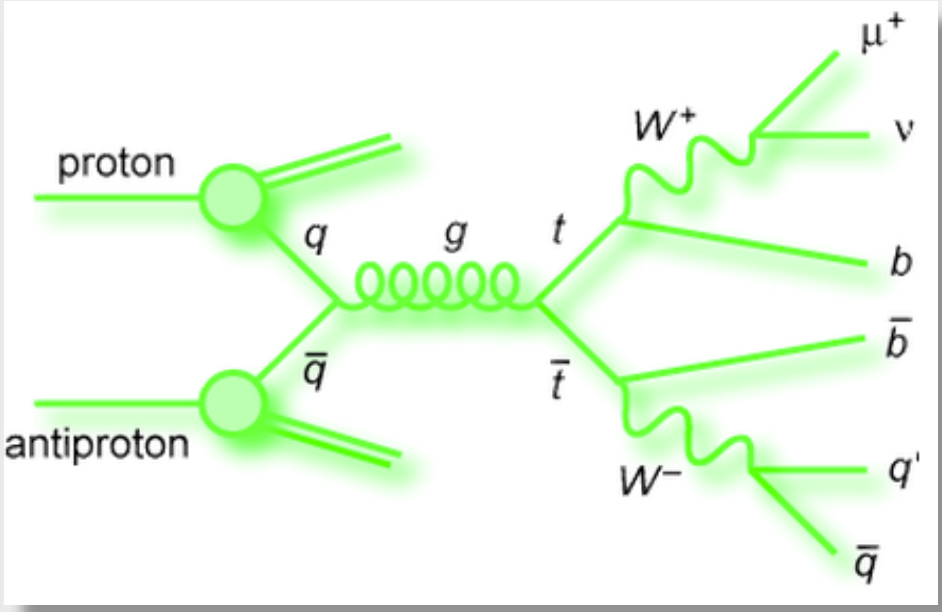




Search technique

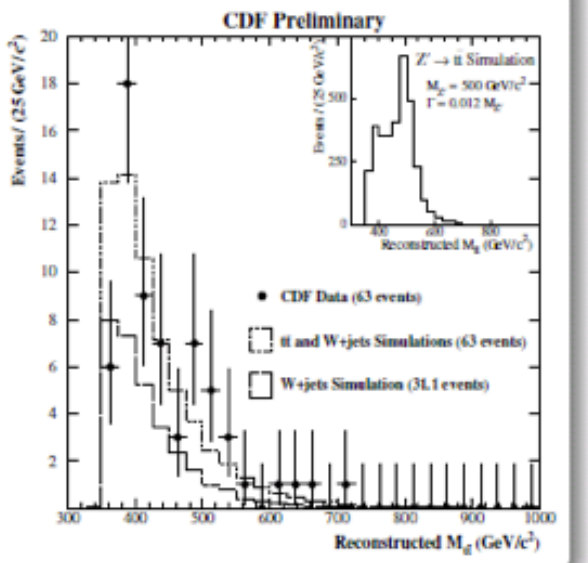
- Most of the searches in $t\bar{t}$ final state are done in leptop+jets final state
  - Clean signature, large statistics, only one neutrino is missing
- Search technique:
  - $M_{t\bar{t}}$ spectrum is reconstructed by taking invariant mass of all objects (lepton, jets, missing E_T)
  - ME, kinematic fitter, no kinematic constraint.
- Search for a peak in $M_{t\bar{t}}$ spectrum
  - Understand SM fluctuation probabilities
  - Calculate Upper Limits
  - Compare data with our expectations(SM or with new physics)



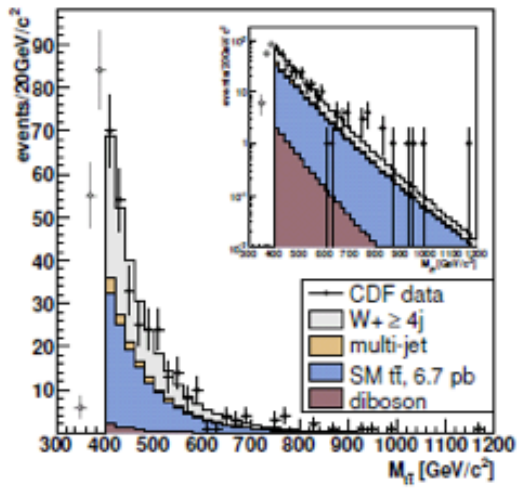


History of Z' searches

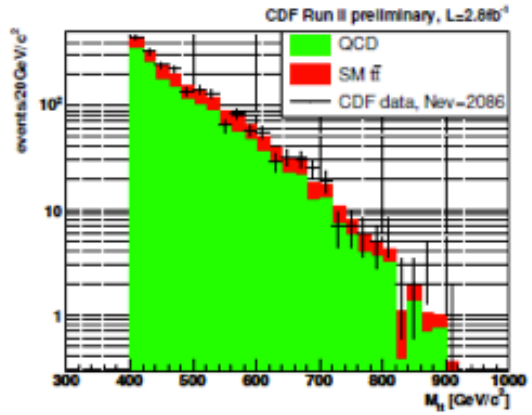
CDF RunI L+J $106pb^{-1}$



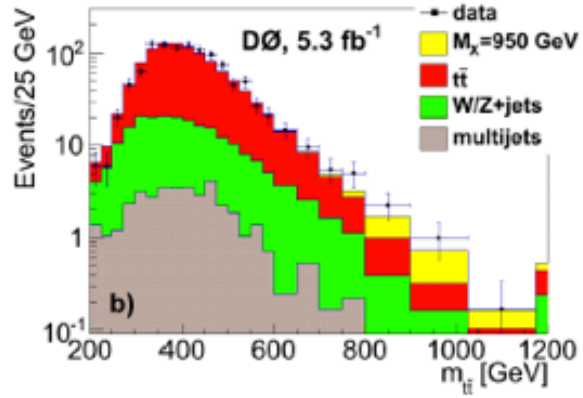
CDF RunII LJ $680pb^{-1}$



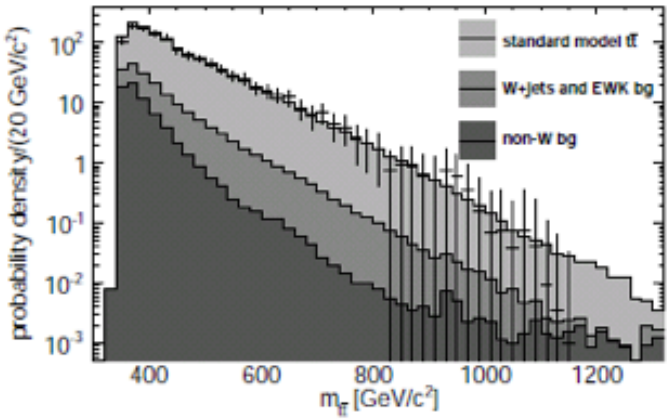
CDF RunII AllHad $2.8fb^{-1}$



D0 RunII LJ $5.8fb^{-1}$

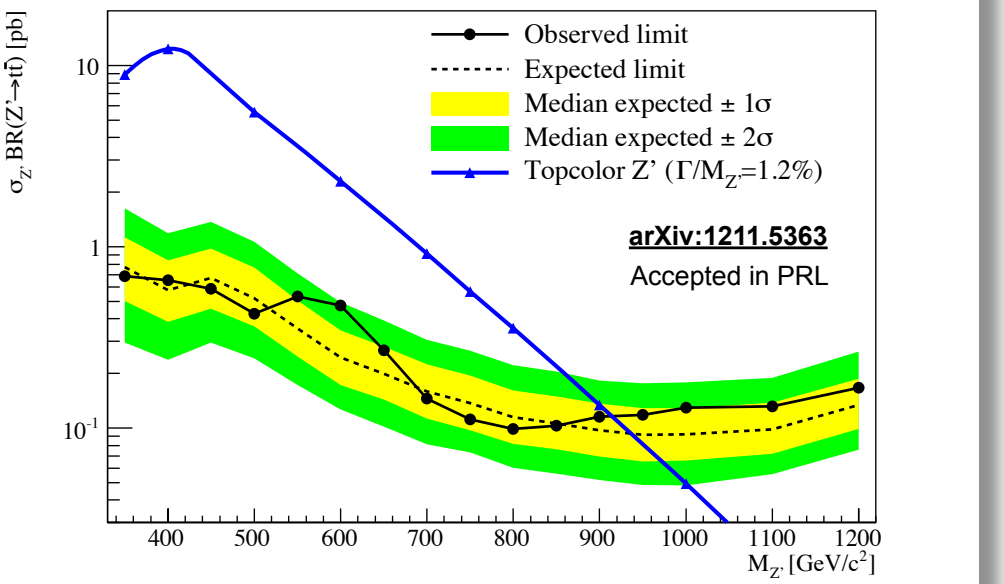


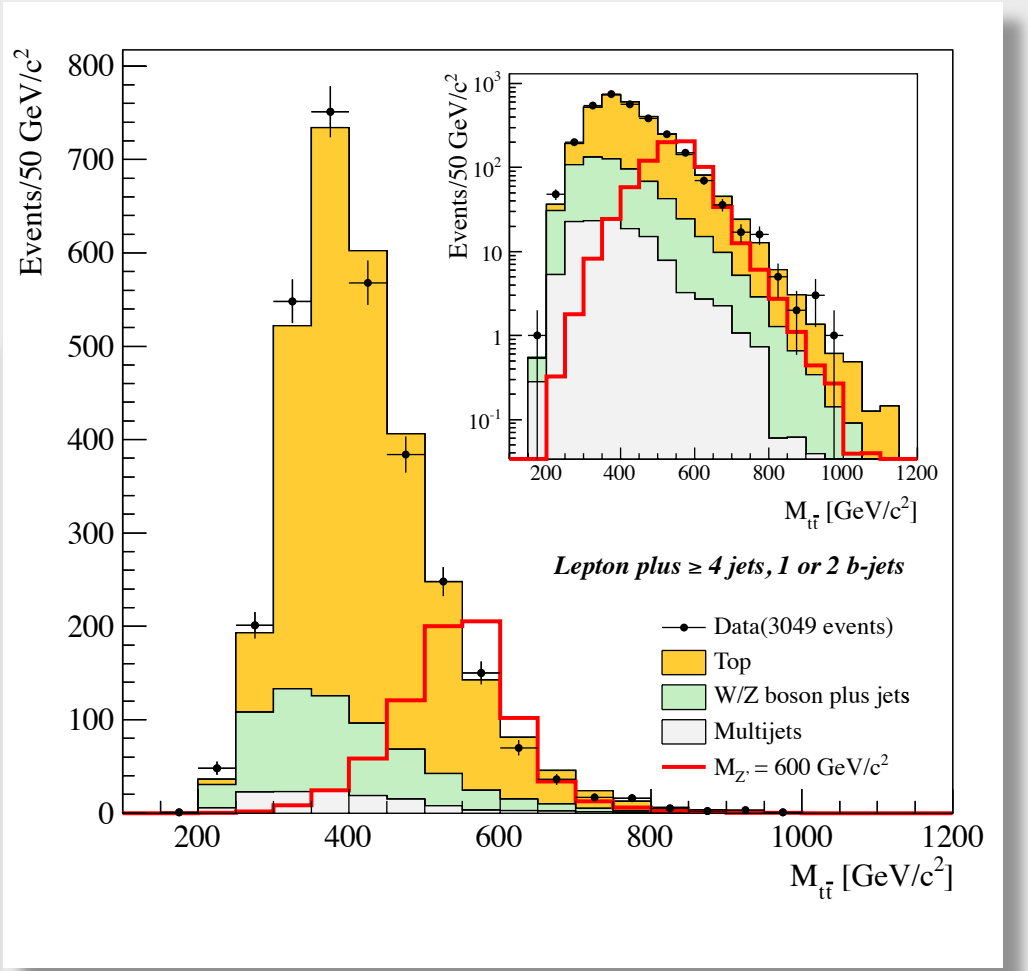
CDF RunII LJ $4.8fb^{-1}$



Latest result

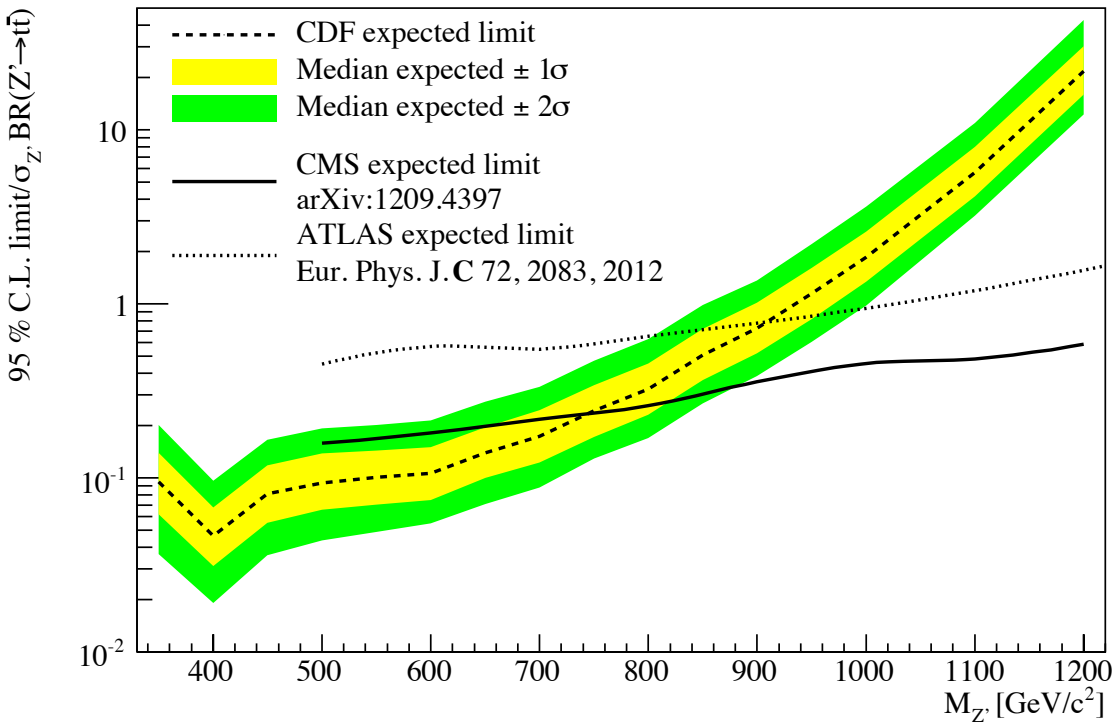
- CDF analyzed full Tevatron dataset of 9.4 fb^{-1} for resonance search in lepton plus jets final state
- Require at least 3 jets, 1 lepton, missing E_T and 1 or 2 b-jets
- Reconstruct $t\bar{t}$ invariant mass:
  - All objects in final
  - No constraint on top quark presence
- Leptophobic $M_{Z'} > 915$ GeV





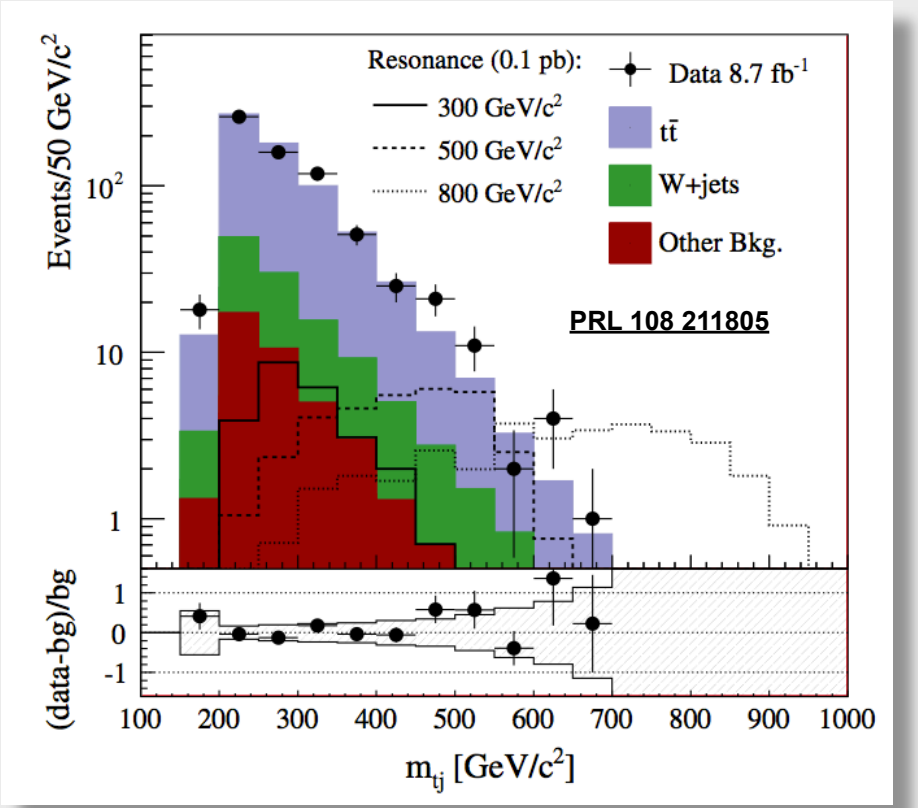
Comparison to LHC

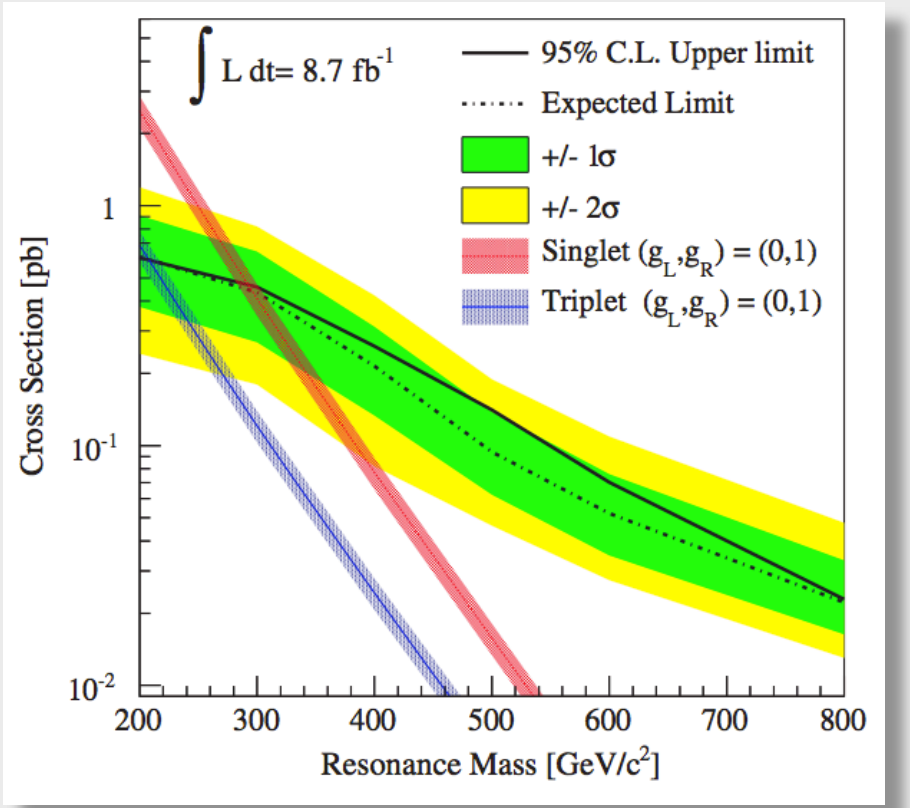
- LHC searches for the same benchmark narrow leptophobic Z' model
- LHC is more sensitive for the mass region above TeV
  - LHC excludes $M_{Z'} > 1.5$ TeV
- However, Tevatron is still more sensitive in the region below 750 GeV
- Increased colliding energies and instantaneous luminosity at LHC makes this mass region even harder to probe



Search for top+jet resonances

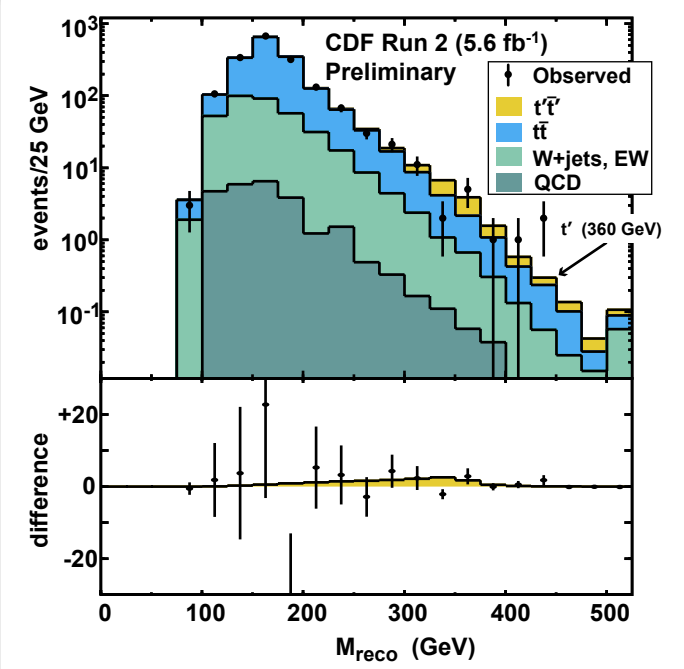
- One of the many models to explain A_{fb} predicts $p\bar{p} \rightarrow Xt \rightarrow \bar{t}jt$
- Default L+J event selection, but at least 5 jets in final state
- Identify the jets from $t\bar{t}$ decay using kinematic fitter
- Select the jet with the largest m_{tj}
- Data consistent with SM
- 0.61 pb to 0.02 pb for X masses ranging 200-800 GeV

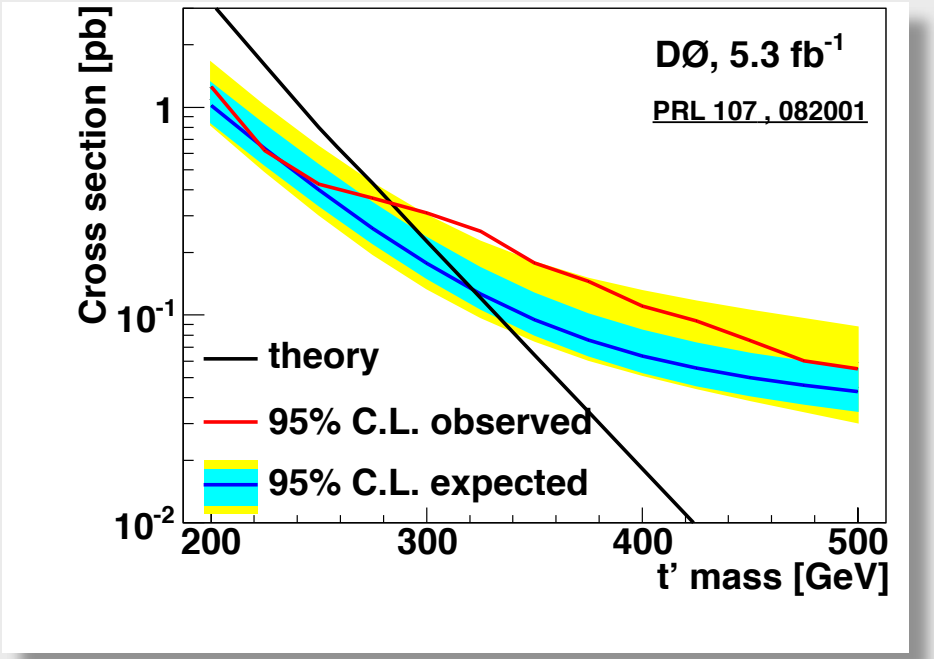


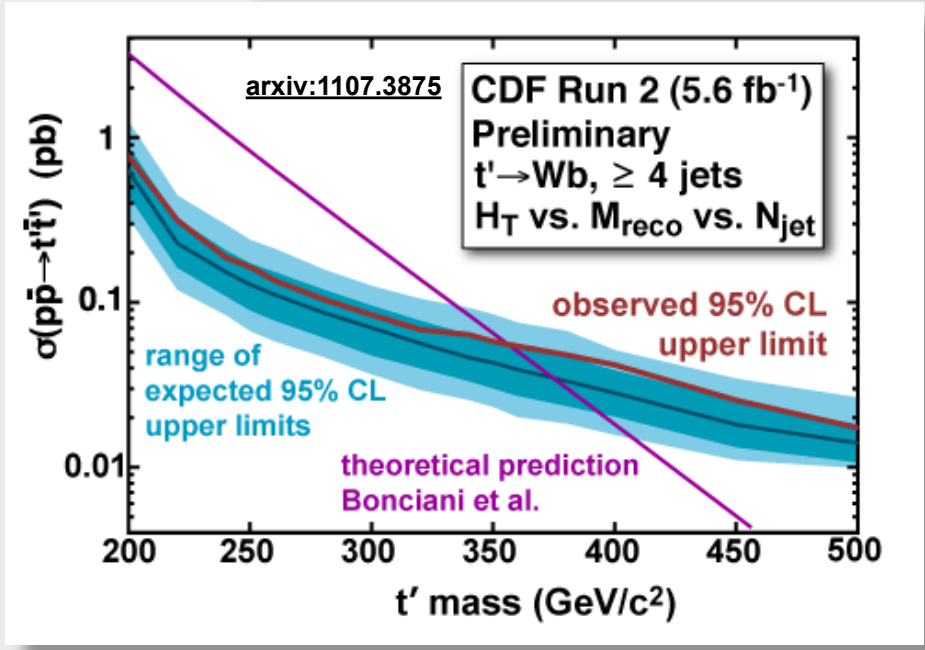


4th generation t'

- Heavier than SM top quark
  - Same production and decay mechanism as in SM
- Reconstruct t' mass using kinematic fitter
  - Simultaneous fit to reconstructed t' mass and H_t
- Data consistent with SM at 2σ
- Set the UL on $\sigma_{t't'}$
  - D0: $M_{t'} > 296$ GeV; CDF: $M_{t'} > 358$ GeV

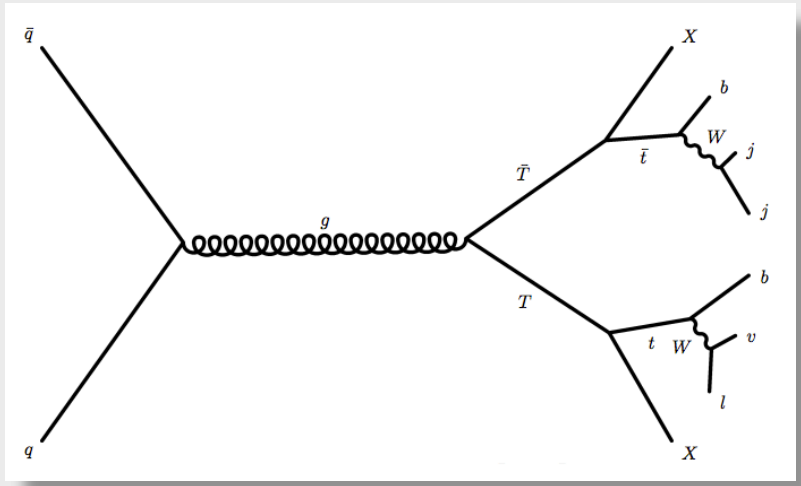


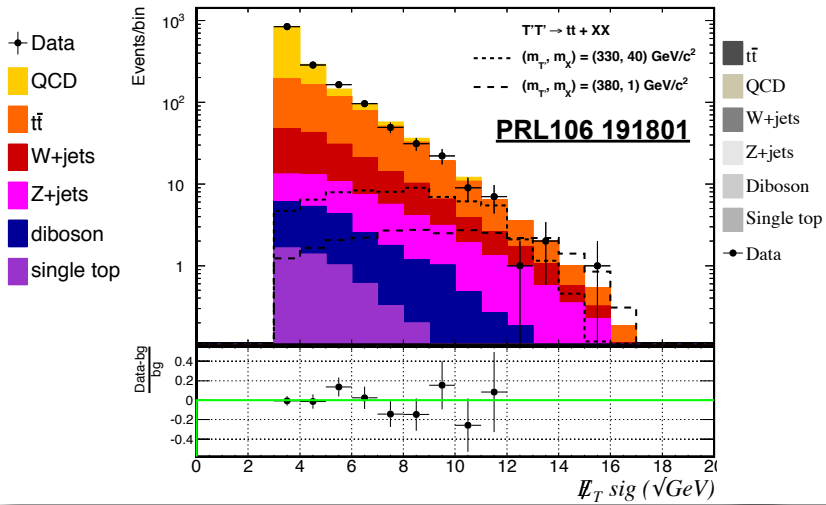


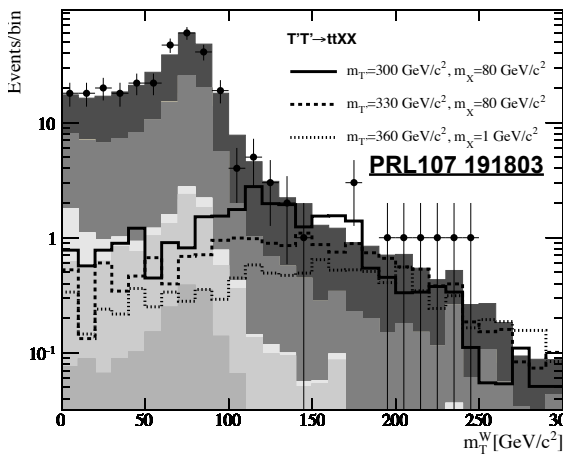


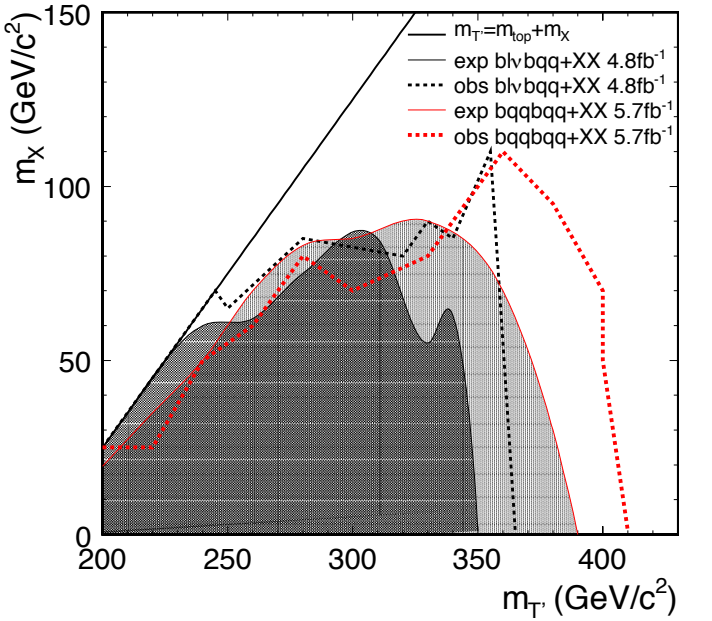
T'+dark matter

- Dark matter interacts with SM via T' carrying both dark matter and SM charges
- Decays: $T'T' \rightarrow tt + XX$, X is dark matter candidate
- Signature: $t\bar{t}$ plus large missing energy
- Search discriminant:
  - All hadronic: missing E_T significance
  - Lepton+jets: $m_T{}^W$ is W transverse mass
- Data consistent with SM
  - Limits set on $m_{T'}$ vs m_x



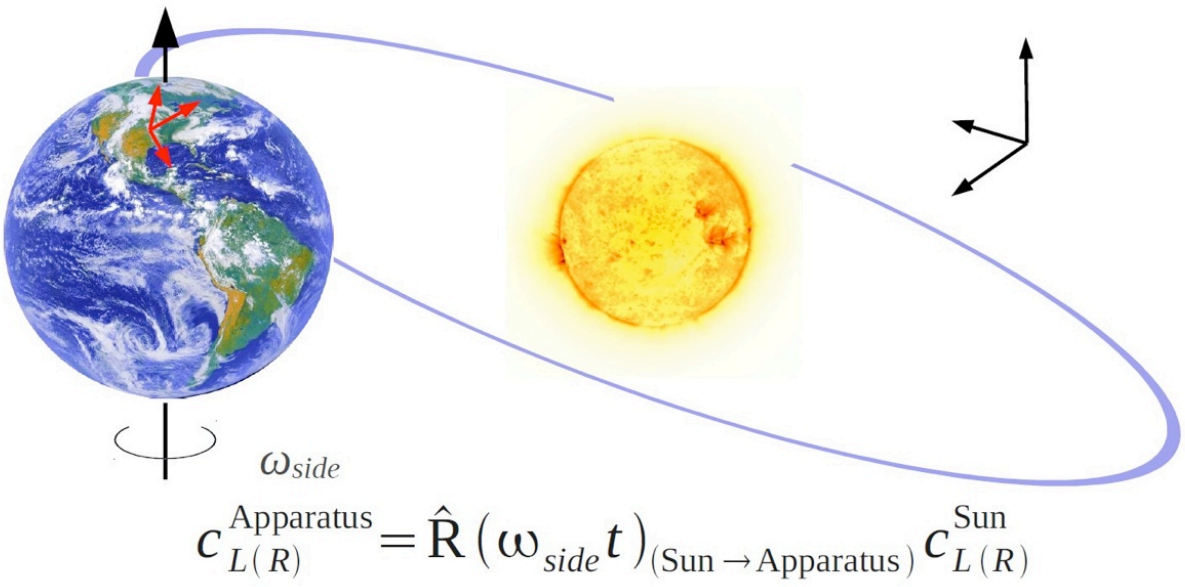


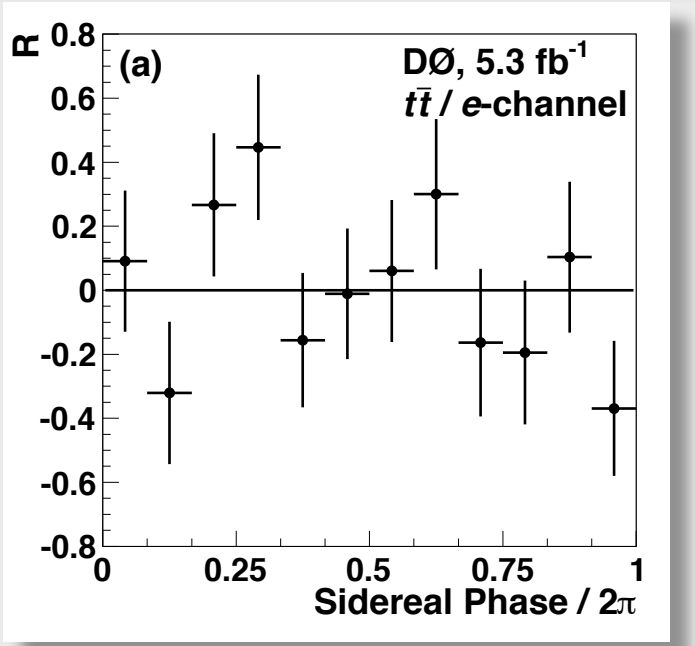


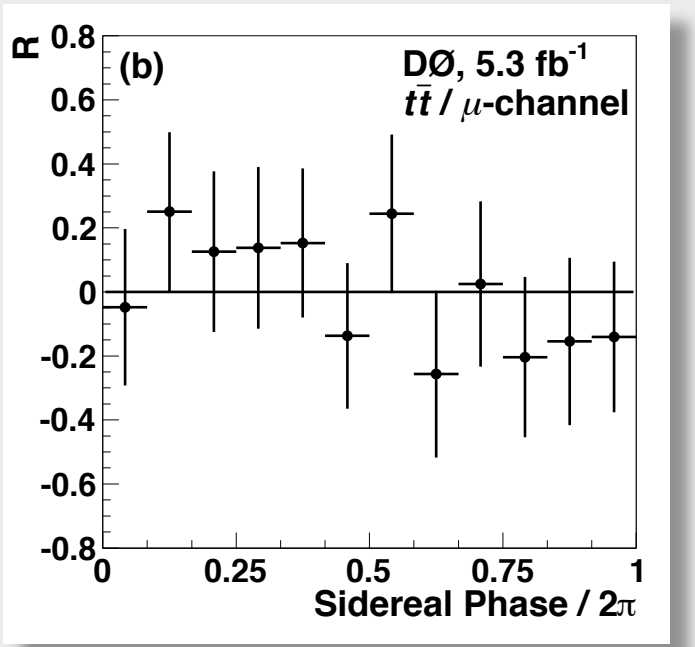


Search for violation of Lorentz invariance in top quark

- In one of SM extensions Lorentz-Violating term is introduced
- Lorentz violation predicts σ_{tt} dependence on time of a day
- For each block of data
  - Sidereal time is extracted
  - σ_{tt} is measured
- R+1 is the ratio of measured σ_{tt} divided on SM predcition
- Data is consistent with SM

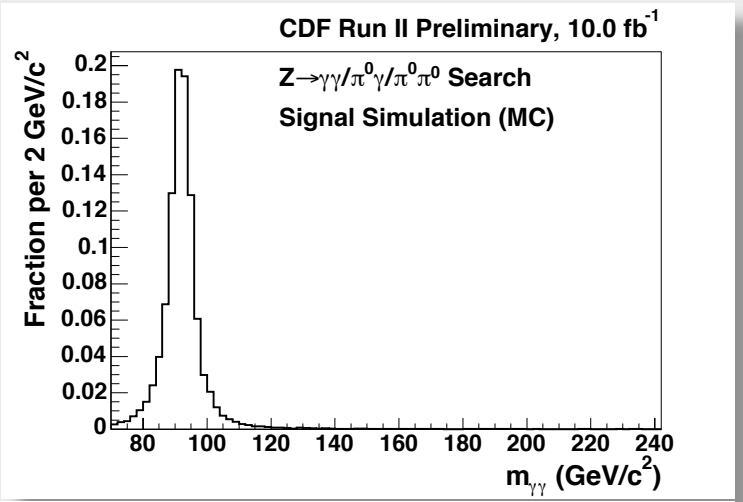






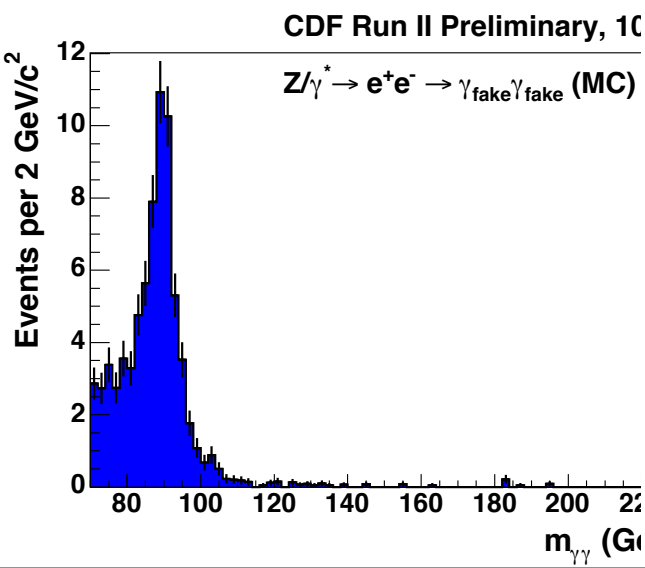
Rare Z Decays into Two Reconstructed Photons

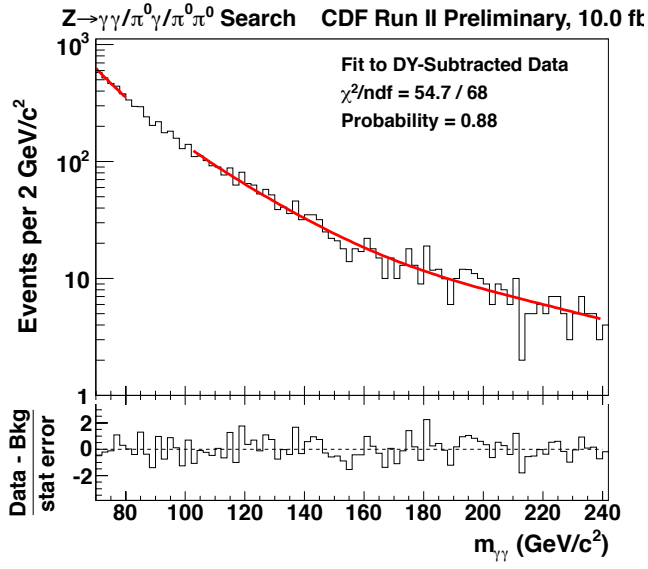
- LEP set UL on BR($Z\to\gamma\gamma$) and BR($Z\to\pi^0\gamma$) at 5×10^{-5}
- At Tevatron $\sigma_Z B(Z\to ee)$ = 250 pb. 2.5E6 $Z\to ee$ events
- Signal modeled by Pythia
- Main backgrounds:
  - Drell-Yan estimated from MC (54 ± 5)
  - $\gamma\gamma$, γj, and jj estimated from data sidebands fit (2251 ± 61)
- Results:
  - No excess observed
  - Best limits to date
  - http://www-cdf.fnal.gov/physics/exotic/run2/Zgamgam/

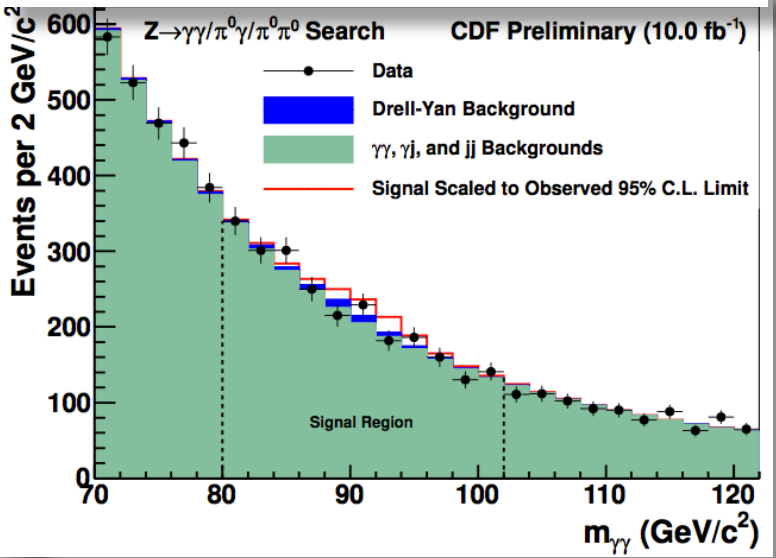


CDF Run II Preliminary — $\int \mathcal{L} = 10.0$ fb^{-1}

Signal Process	95% C.L. Limits: Expected ($\times10^{-5}$) -2σ	-1σ	Median	$+1\sigma$	$+2\sigma$	Observed ($\times10^{-5}$)
Br($Z\to\gamma\gamma$)	0.88	1.19	1.66	2.34	3.20	1.66
Br($Z\to\pi^0\gamma$)	1.21	1.63	2.28	3.21	4.37	2.28
Br($Z\to\pi^0\pi^0$)	0.93	1.23	1.72	2.41	3.29	1.73







Summary

- Tevatron has delivered unique data for top quark physics
- Wide range of property measurements and searches have been performed
  - Providing complementary results to LHC data
- CDF and D0 continue studies in top quark
- Many analyses have incorporated the full Tevatron dataset
- More information on the Tevatron results:
  - CDF: http://www-cdf.fnal.gov/physics/new/top/public_searches.html
  - D0: http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html
- Thank you!