SEARCH FOR FOURTH GENERATION T' QUARK AT THE TEVATRON

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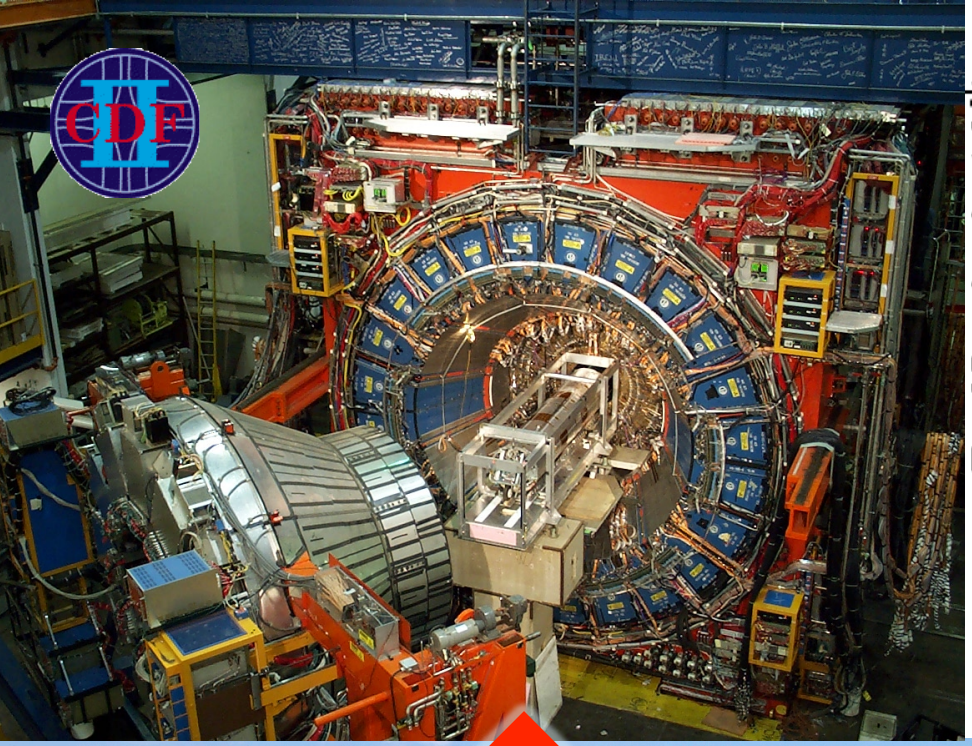
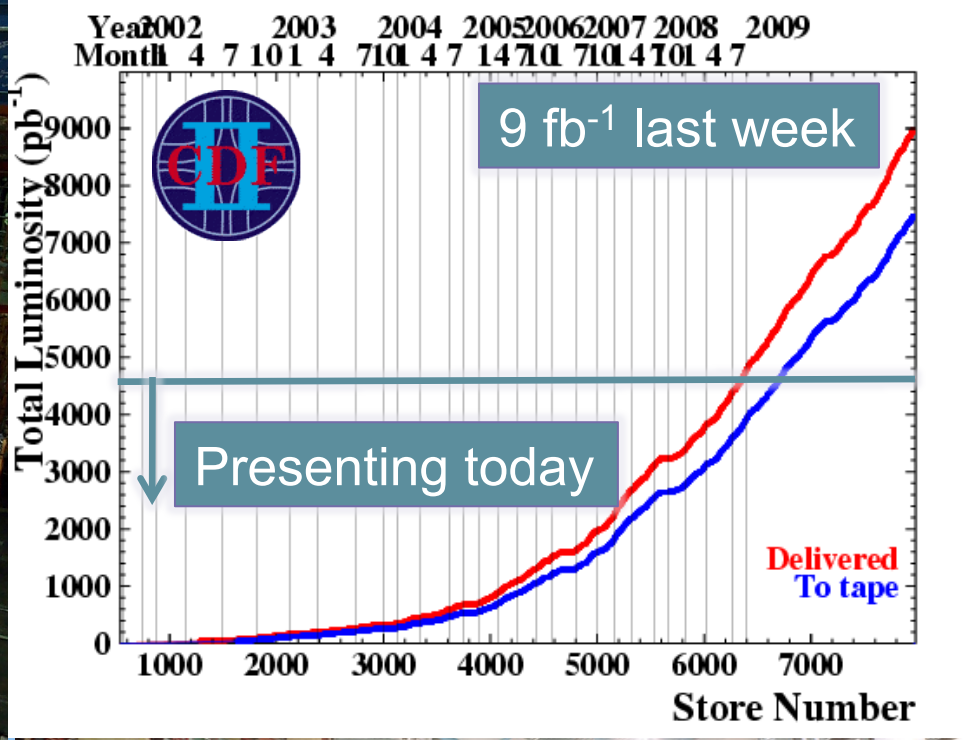
On behalf of the CDF and D0 Collaborations


CDF II

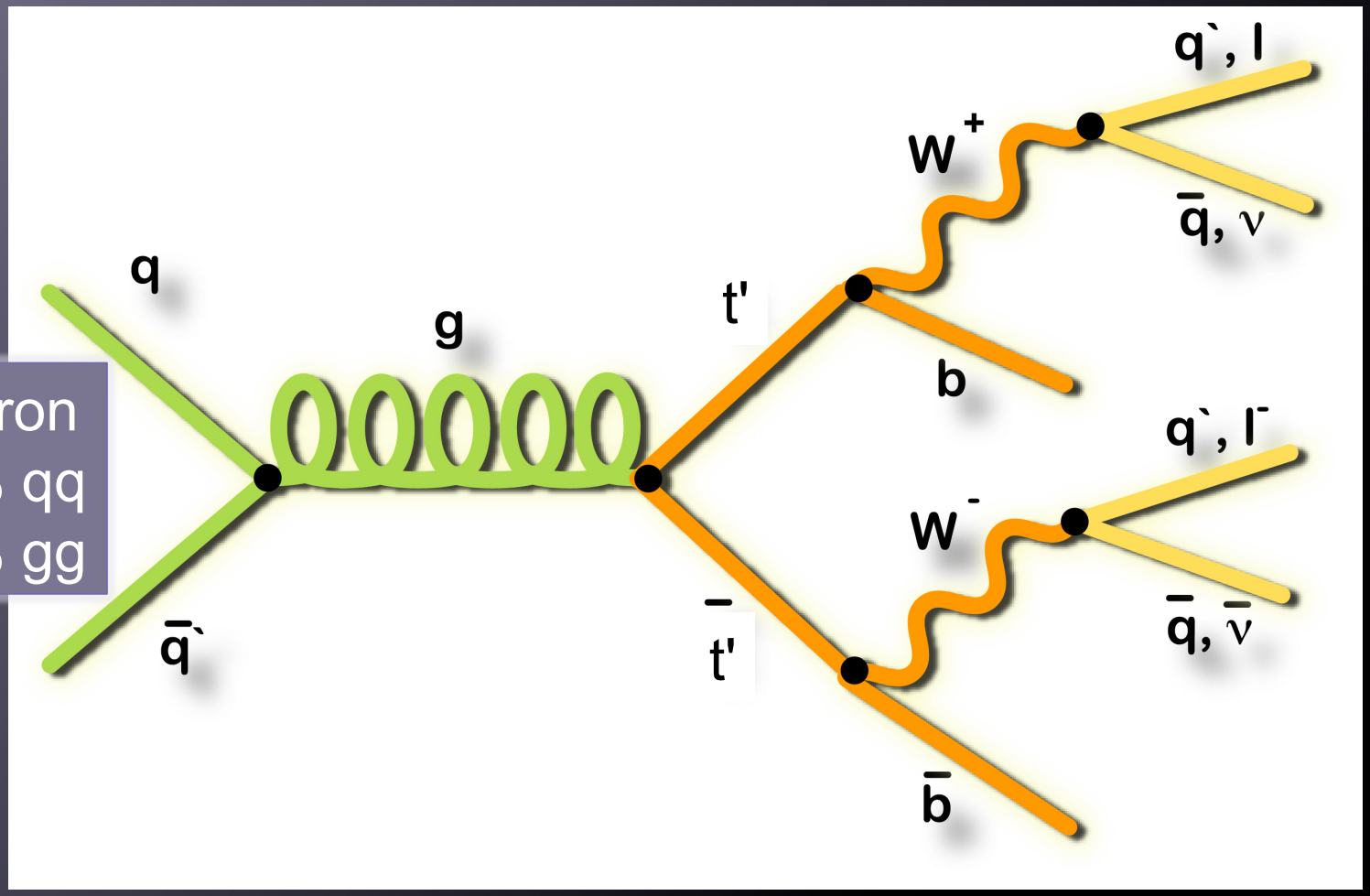

Year 2002 2003 2004 2005 2006 2007 2008 2009
Month 1 4 7 10 1 4 7 10 1 4 7 10 1 4 7 10 1 4 7 10 1 4 7
Total Luminosity (pb^{-1})
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1000 2000 3000 4000 5000 6000 7000
Store Number
CDF II
9 fb^{-1} last week
Presenting today
Delivered
To tape

DØ

Another Quark Generation?

- Not forbidden by EWK precision data
  - Mass order few hundred GeV
  - Small mass splitting preferred: M(t')-M(b') < M(W)
- Would have big effect on Higgs sector
  - Oblique corrections could drive mass up to ~500 GeV
- Could be lepton too if $m(\nu_4)$ > ~50 GeV

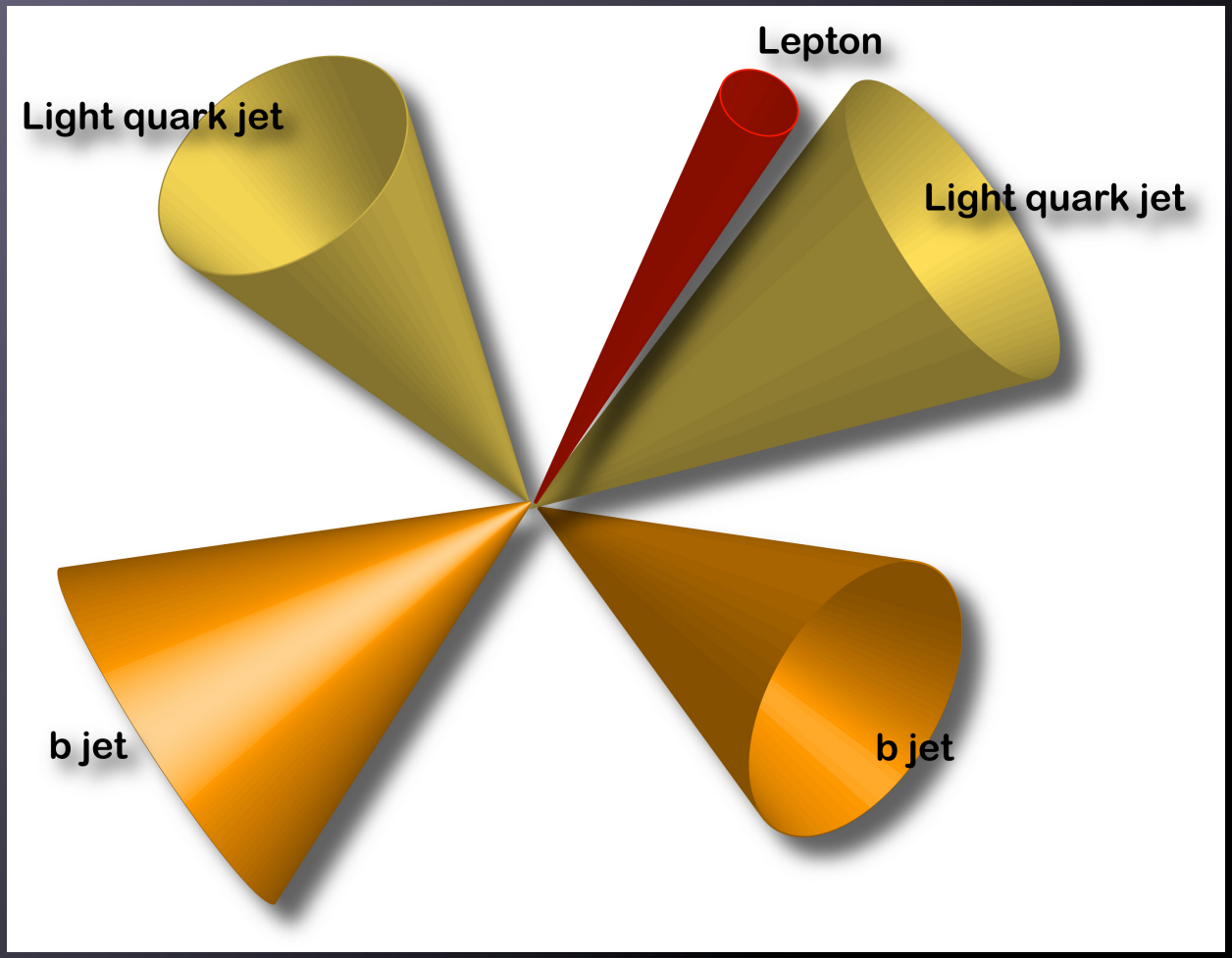
Looks like a Top… but not quite…



Tevatron
~85% qq
~15% gg

Also: Generic search for events in this final state in the tails of some distributions….

Our Search: Lepton + Jets + MET



Good compromise between BR and background rates

Event Selection (CDF)

- 1 isolated high p_T electron or muon (p_T > 25 GeV)
  - New: add muons from Missing E_T + jets trigger (non-trigger muons)
- Missing E_T > 20 GeV
- ≥4 jets (E_T > 20 GeV, $|\eta|<2.0$)
  - ≥2 jets with E_T >25 MeV for non-trigger muons
- QCD removal cuts (similar to single top)
  - Transverse momentum of W: $M_{T,W}$ > 20 GeV
  - Missing E_T significance > 3.5 -0.05•$M_{T,W}$
- For muons with E_T > 150 GeV
  - $\Delta\phi$(Missing E_T - muon) < 3.05
- 3724 events
  - 1677 electrons
  - 1240 trigger muons
  - 807 non-trigger muons

Monte Carlo Modelling (CDF)

	Generator	Model
t't'bar	PYTHIA6	NLO cross section
ttbar	PYTHIA6	NLO cross section M(t) = 172.5 GeV/c^2
W+jets	ALPGEN+PYTHIA	Exclusive W+0..3 Inclusive W+4p MLM matching
Other	MC	SM cross sections

- Other: single top, diboson, Drell-Yan, Z+jets
- QCD shapes from jet-triggered data
  - Require limit on fraction of energy in EM calorimeter
  - Normalisation from fit with Missing E_T cut relaxed

All MC samples are run through CDF detector simulation

Discriminating Variables

- Total transverse reconstructed energy (H_T)

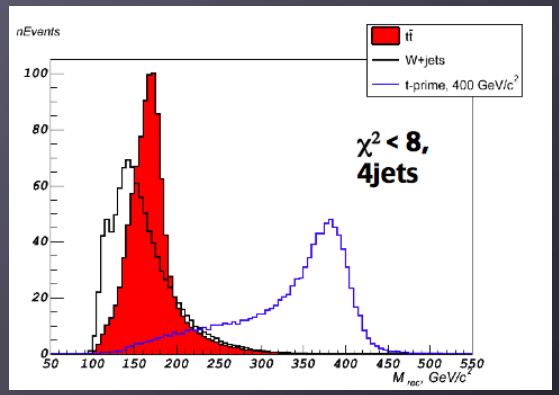
$$H_T = \sum_{jets} E_{T,jets} + E_{T,lepton} + \not{E}_T$$

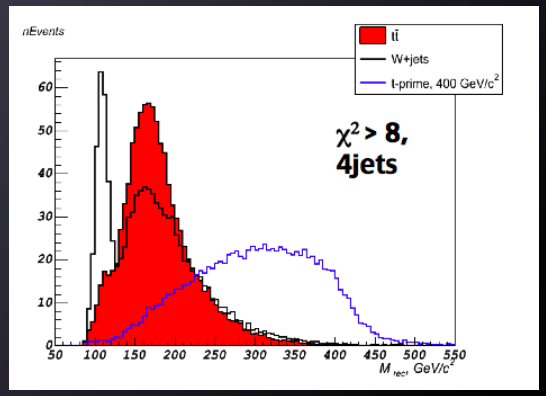
- Reconstructed top mass (M_{reco} CDF, M_{fit} D0)
  - From the combination with the lowest χ^2
    - e.g CDF

$$\chi^2 = \sum_{i=l,4jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i} + \sum_{j=x,y} \frac{(p_j^{UE,fit} - p_j^{UE,meas})^2}{\sigma_j} + \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{l\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - Mt)^2}{\Gamma_t^2} + \frac{(M_{bl\nu} - M_t)^2}{\Gamma_t^2}$$

The Fit (CDF)

- '3D' fit: H_T vs M_{reco} vs N_{jet} / good-bad χ^2
  - New: separate into 4 and ≥5 jets and into χ^2 <8 and χ^2>8





- Binned Poisson Likelihood approach
  - Sysetmatics represented as nuisance parameters
    - Remove by profiling
  - Obtain posterior in signal cross section
    - Using Bayes Theorem
  - Integrate to find 95% CL upper limit on signal assuming uniform prior

The Fit: D0

- 2D fit: H_T vs M_{fit}
- For each t' mass
  - Fit for background only
    - 3 parameter fit: ttbar, QCD and "rest" (mostly W+jets)
  - Fit for background + signal
    - 4 parameter fit: also t't'bar (free)
  - Likelihood ratio as test statistic
  - Set limits using CL_S method
    - $1 - CL_{S+B} / CL_B = 0.95$ -> 95% CL exclusion

$$L = -2\log\left(\frac{P_{S+B}}{P_B}\right)$$

Systematics: CDF

- Three types
  - All Gaussian-constrained
  - Normalization uncertainties
    - Integrated luminosity, ID scale factors, background cross sections
  - Shape (+normalization) uncertainties
    - jet energy scale, Q^2 scale, ISR/FSR
  - MC statistics
    - Handled using “Barlow-Beeston lite” method
    - Bins combined automatically to ensure accuracy

Dominant Systematics (D0)

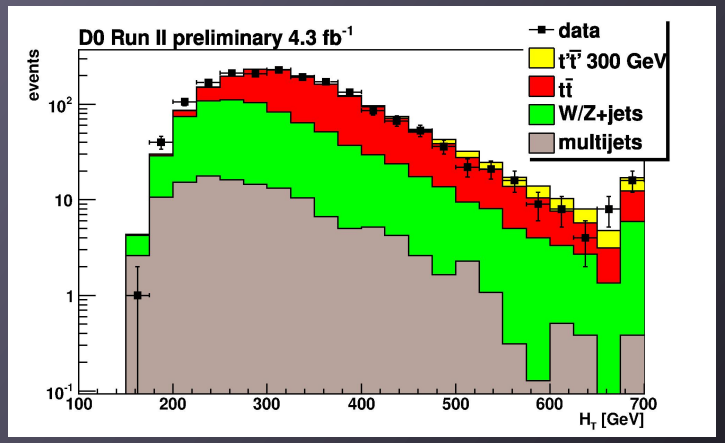
Source	Affects	Value
ttbar cross section	ttbar	+8% - 10%
MC model	ttbar	±4.3%
Integrated Luminosity	ttbar,t'bar	±6.1%
Lepton ID	ttbar,t'bar	±3.8% / ±2.9% (e / μ)
Multijet normalisation	QCD	±4.7% / ±52% (e / μ)

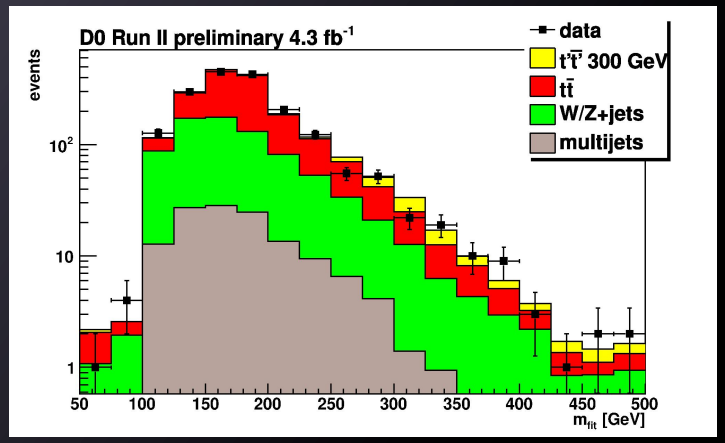
Can't find the W+jets systematics!!!!!!!!!
Don't really understand what you mean by "shape": there's still a residual effect even if fitted no?

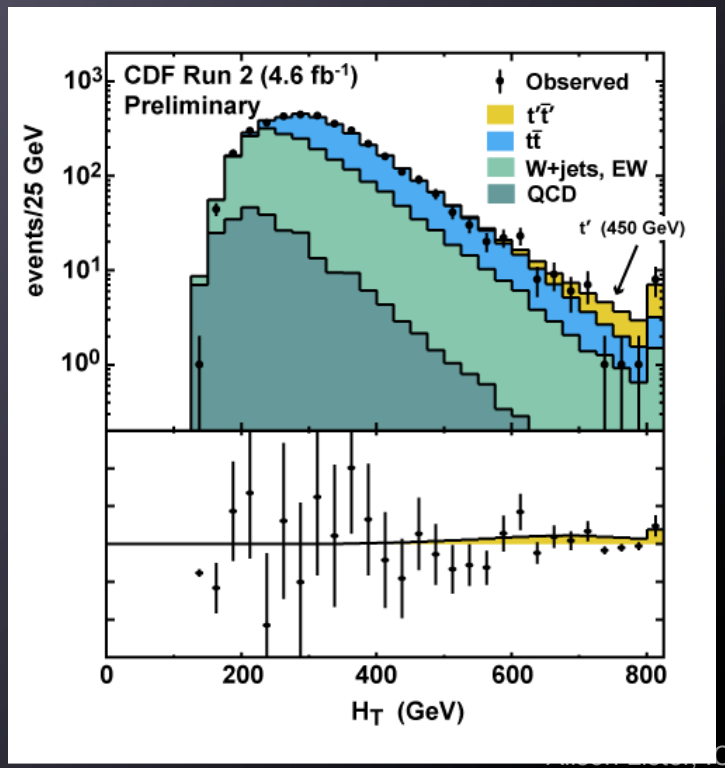
Model Independent Limits: CDF

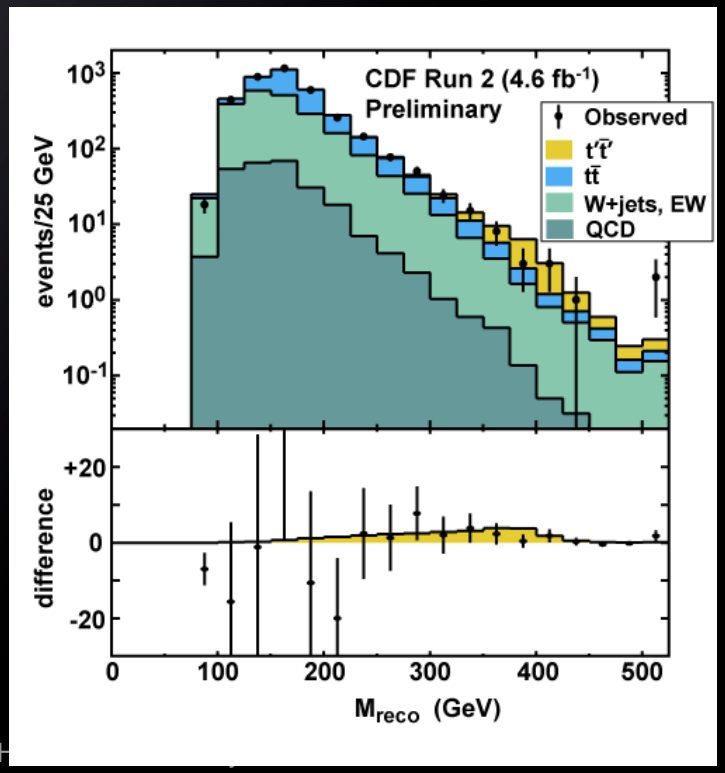
- Starting from highest H_T and M_{reco} bin
- p-value of that bin
  - Probability that the number of observed events in that range is compatible with the background only hypothesis
  - No signal model other than "something that is in the high M_{reco}, high H_T region
- Extend by 1 bin in each dimension and repeat fit
- Global p-value takes into account trials factor
- Largest excess in 2.8 fb^{-1}
  - $M_{reco} > 250$ MeV/c^2, $H_T > 550$ MeV
  - 29 events, 18.03 expected
    - p-value 0.01
- Excess order 2 sigma

The Variables in Data



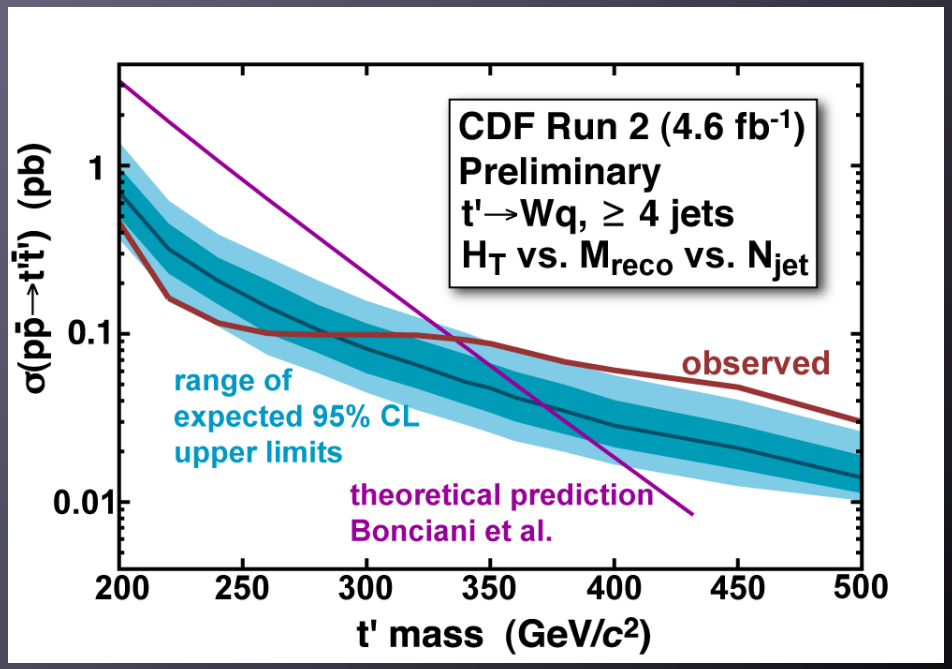


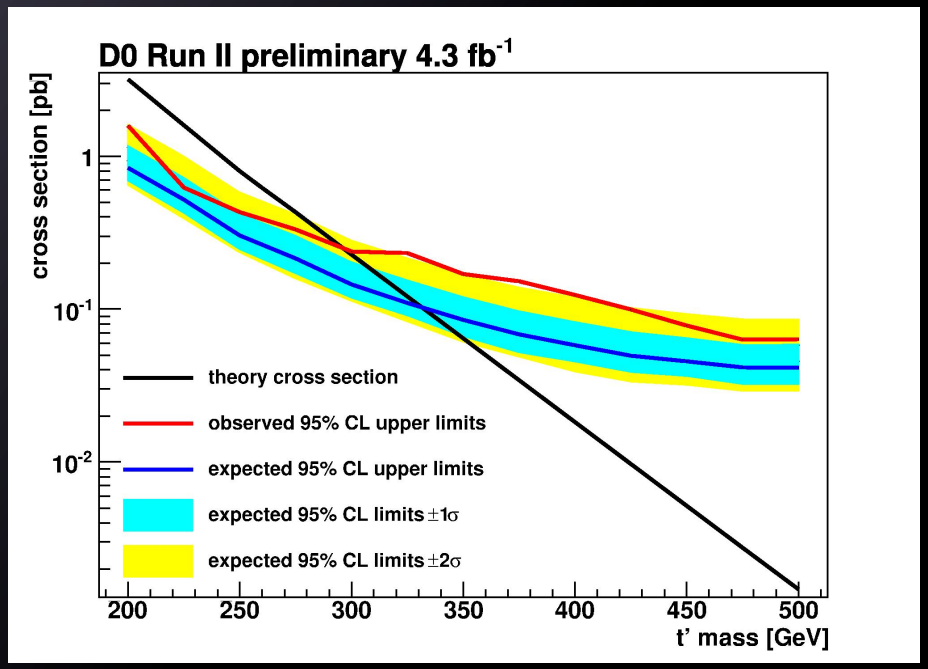




Limits

- Assume BR(t'->Wb) ≈100%
- Assume strong SM production (g->t't')

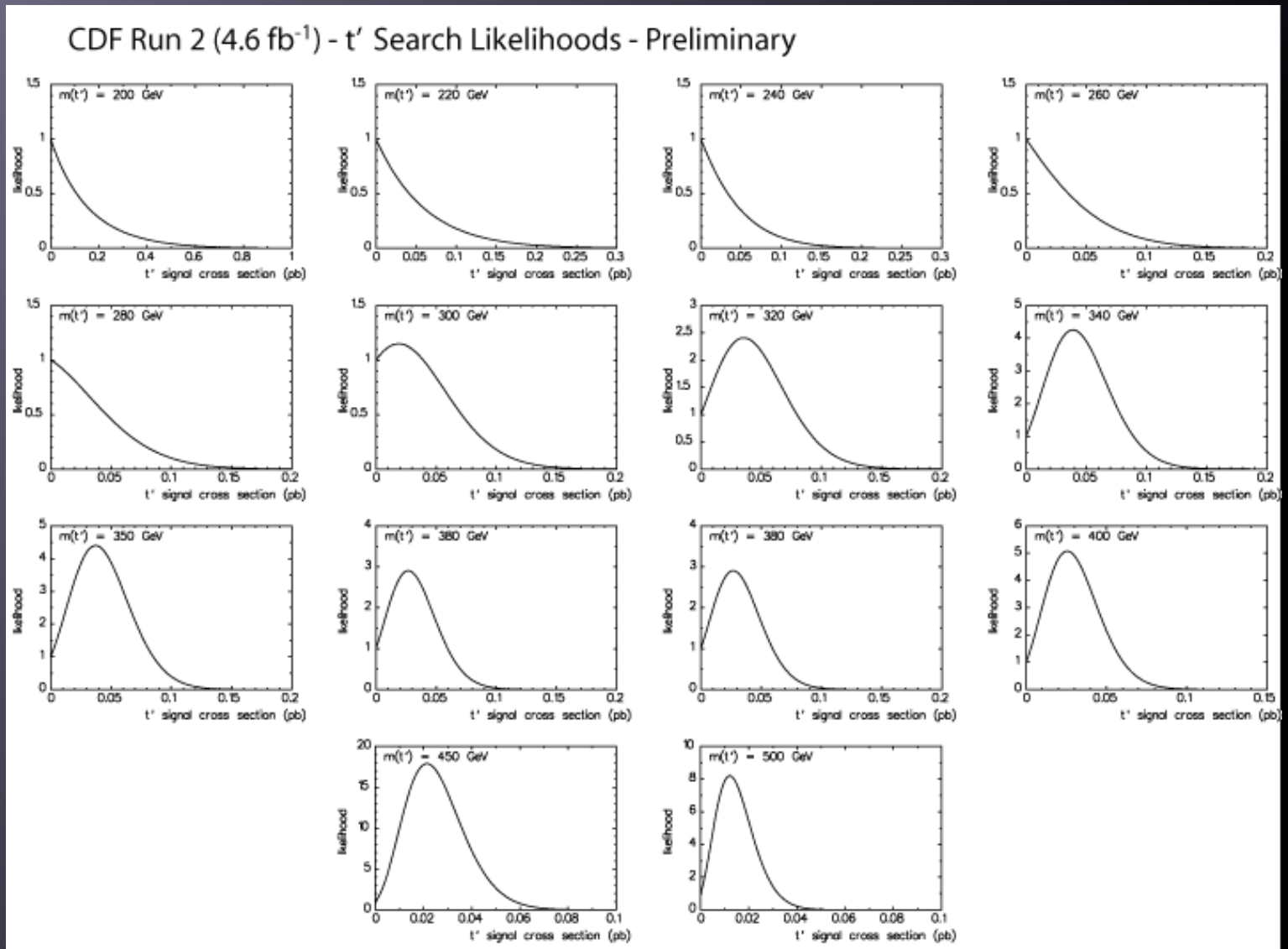




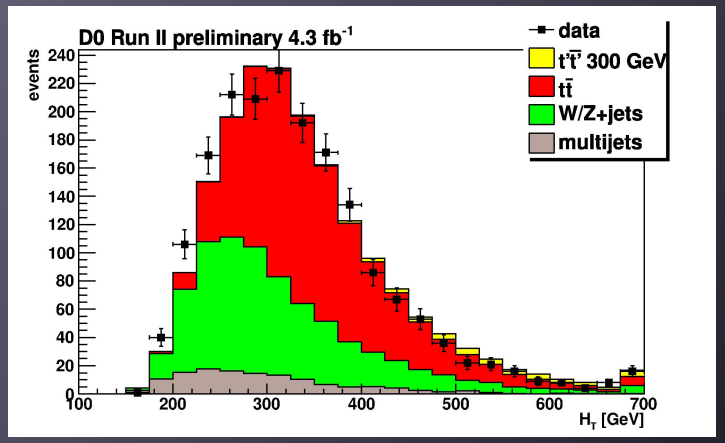
Exclude M(t') < 335 (296) GeV @ 95% CL at CDF (D0)

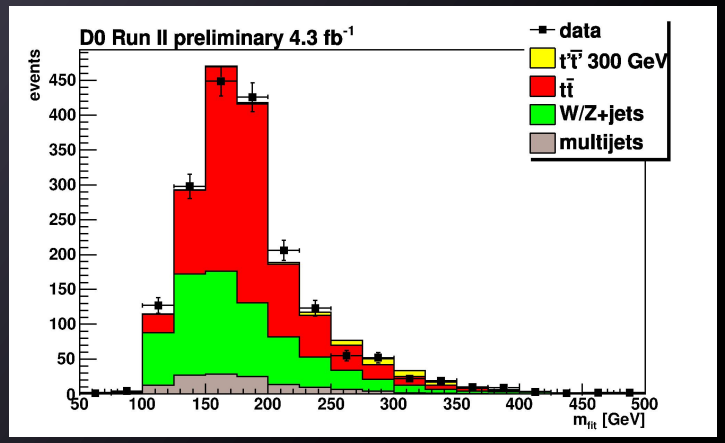
BACKUP

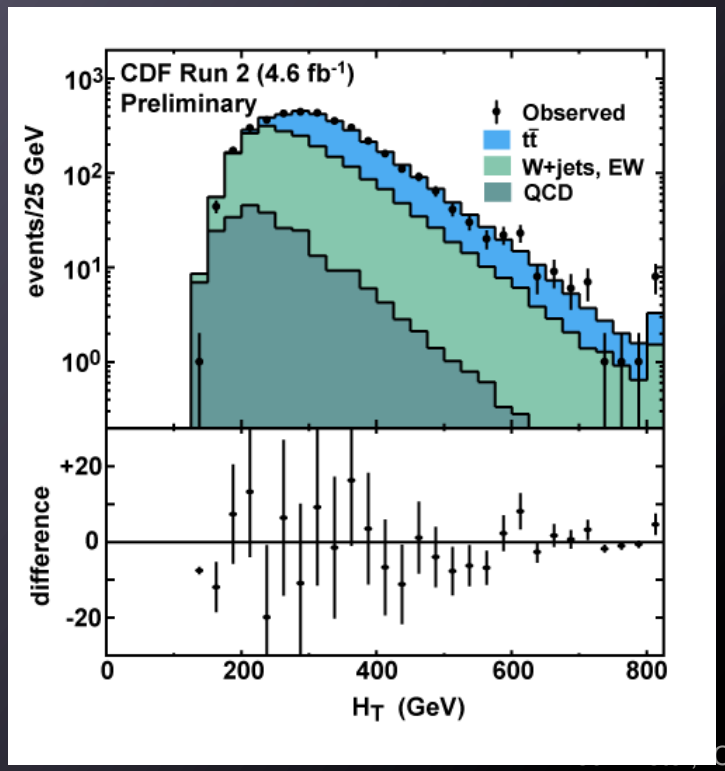
CDF Likelihood

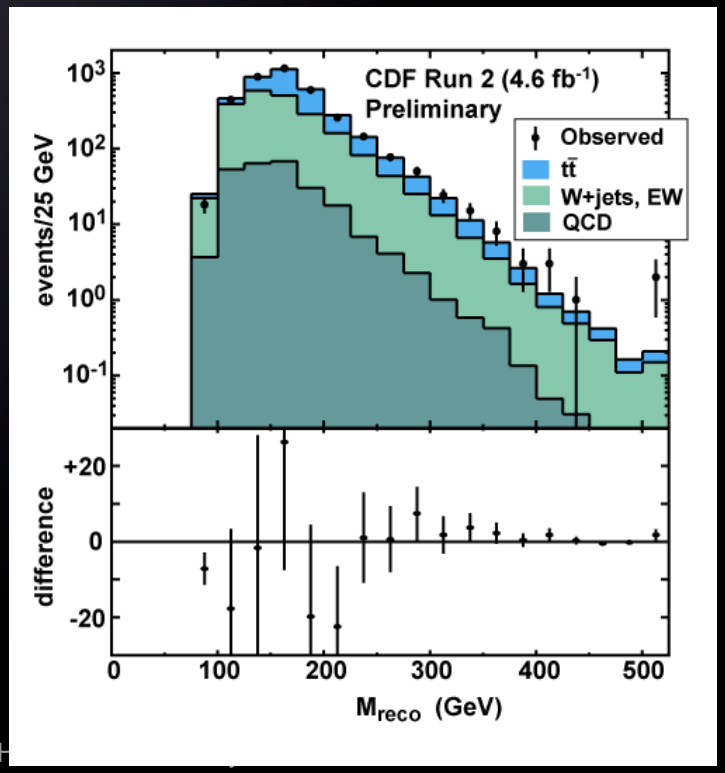


The Variables in Data

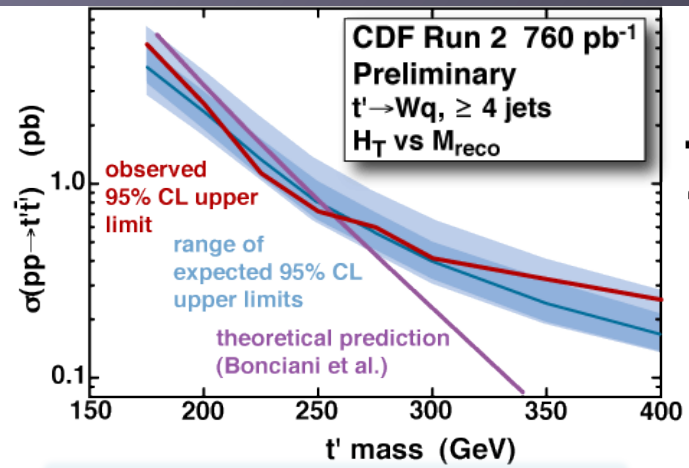




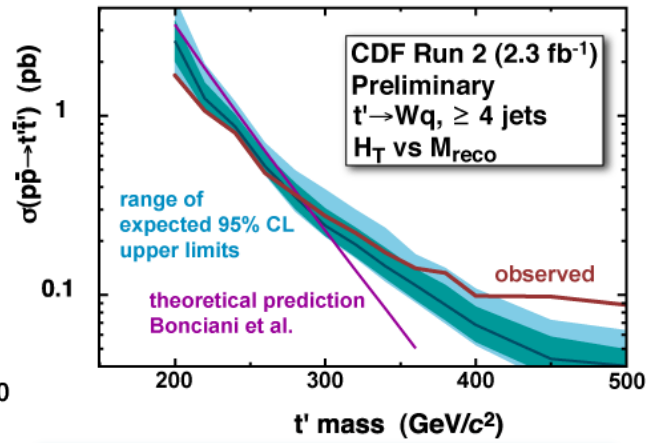




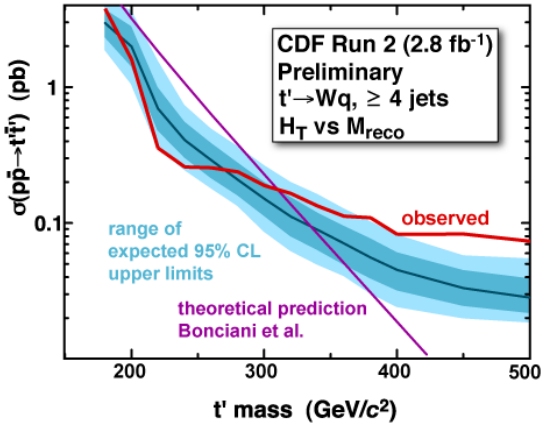
Previous Results (CDF)



Limit: M(t') > 256 GeV/c²



Limit: M(t') > 284 GeV/c²



Limit: M(t') > 311 GeV/c²

1118 events
Better QCD model
Better QCD removal cuts
New W+jets modelling

Top Event Reconstruction

- No b-tagging
  - 4! = 12 ways of associating jets to reconstruct a ttbar event
    - 4 highest p_T jets
    - Lepton + MET -> W(leptonic)
    - 2 jets -> W(hadronic)
    - W(leptonic) + jet -> top candidate
    - W(hadronic) + jet -> top candidate

- More theoretical motivation… different models roughly explained…