Measurements of Top Production at CDF

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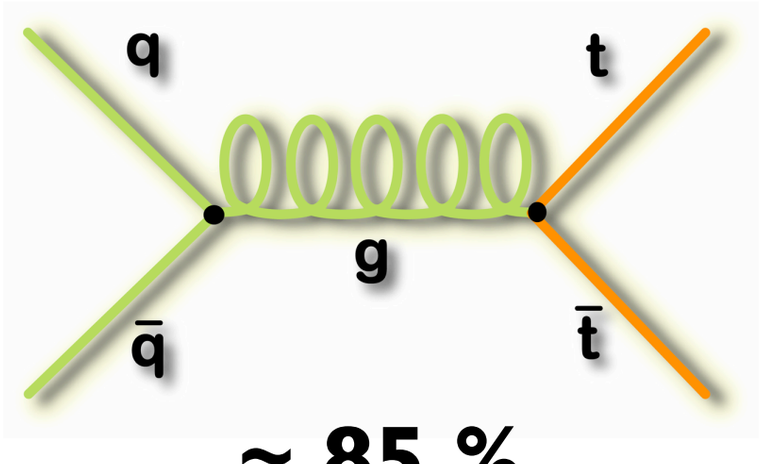
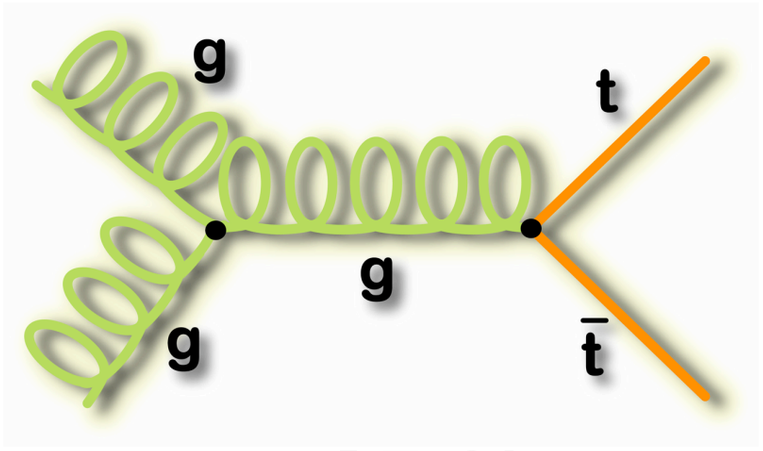
Strong

$\sigma \approx 6.7$ pb



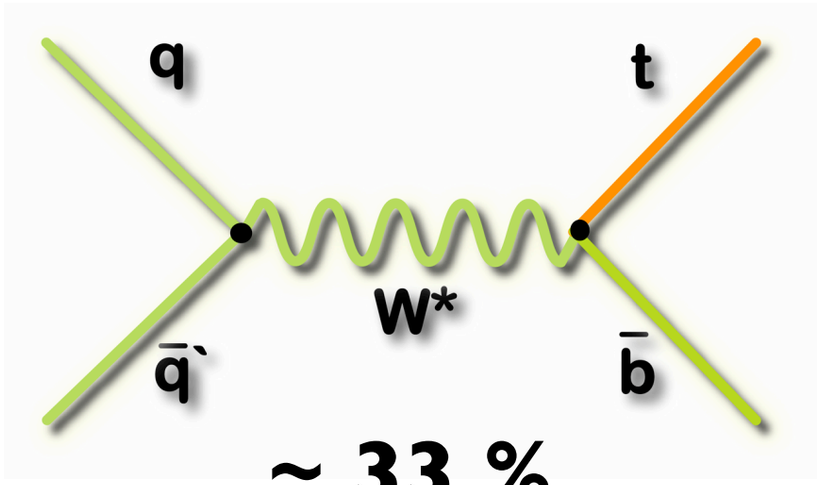
~ 85 %



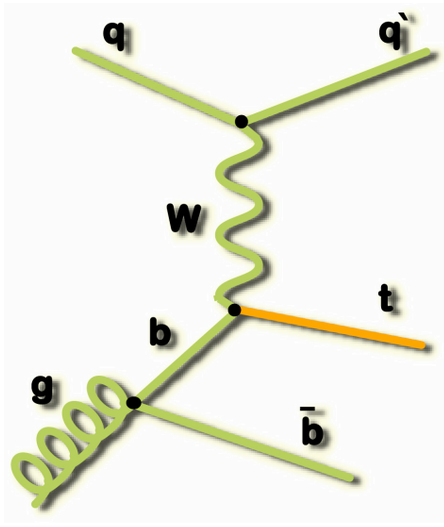
~ 15 %

Electroweak

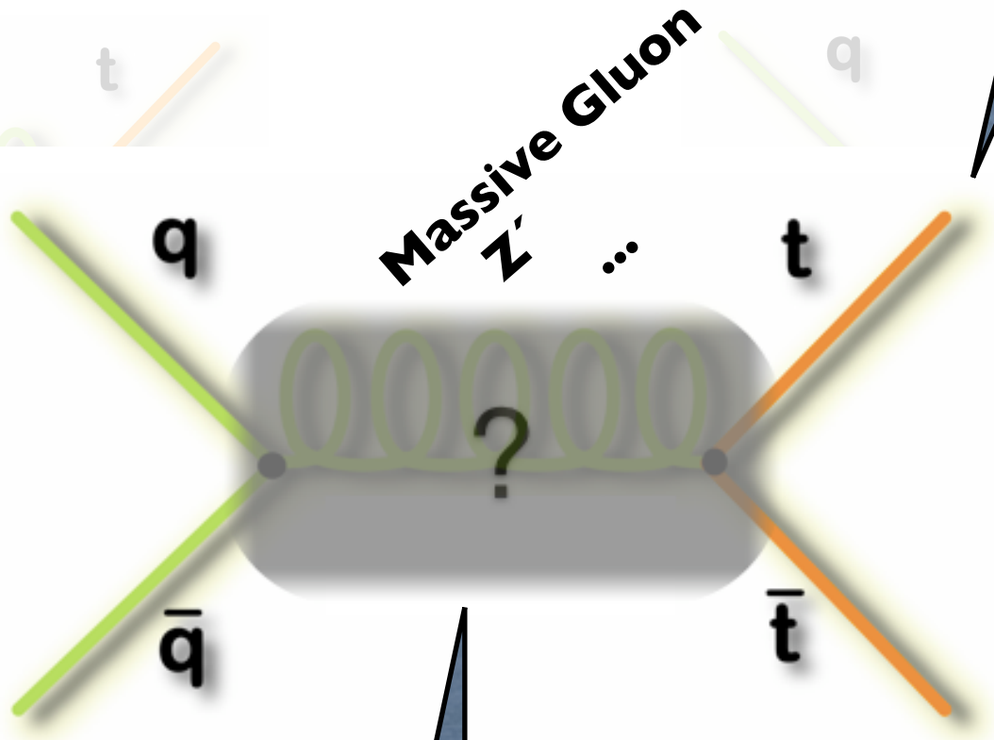
$\sigma_{s+t} \approx 3$ pb



~ 33 %

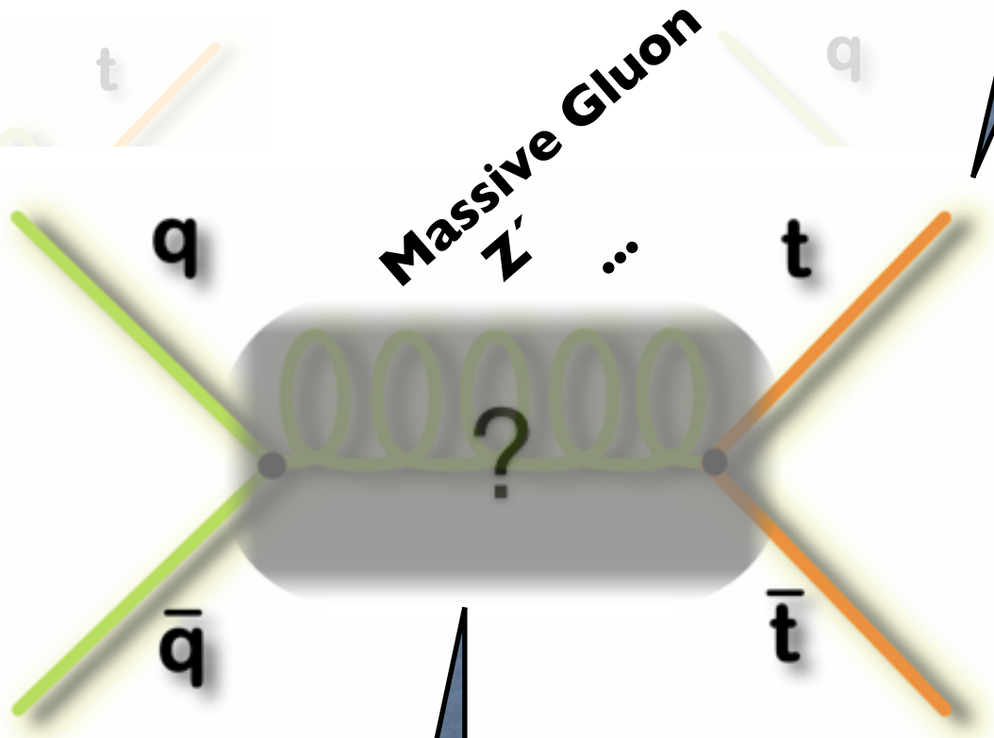


~ 67 %



- Rates different across decay channels

- Cross Section
- Afb
- qq/gg Production Rates
- Resonance Searches
- Spin Correlations



- Rates different across decay channels

- Cross Section
- Afb
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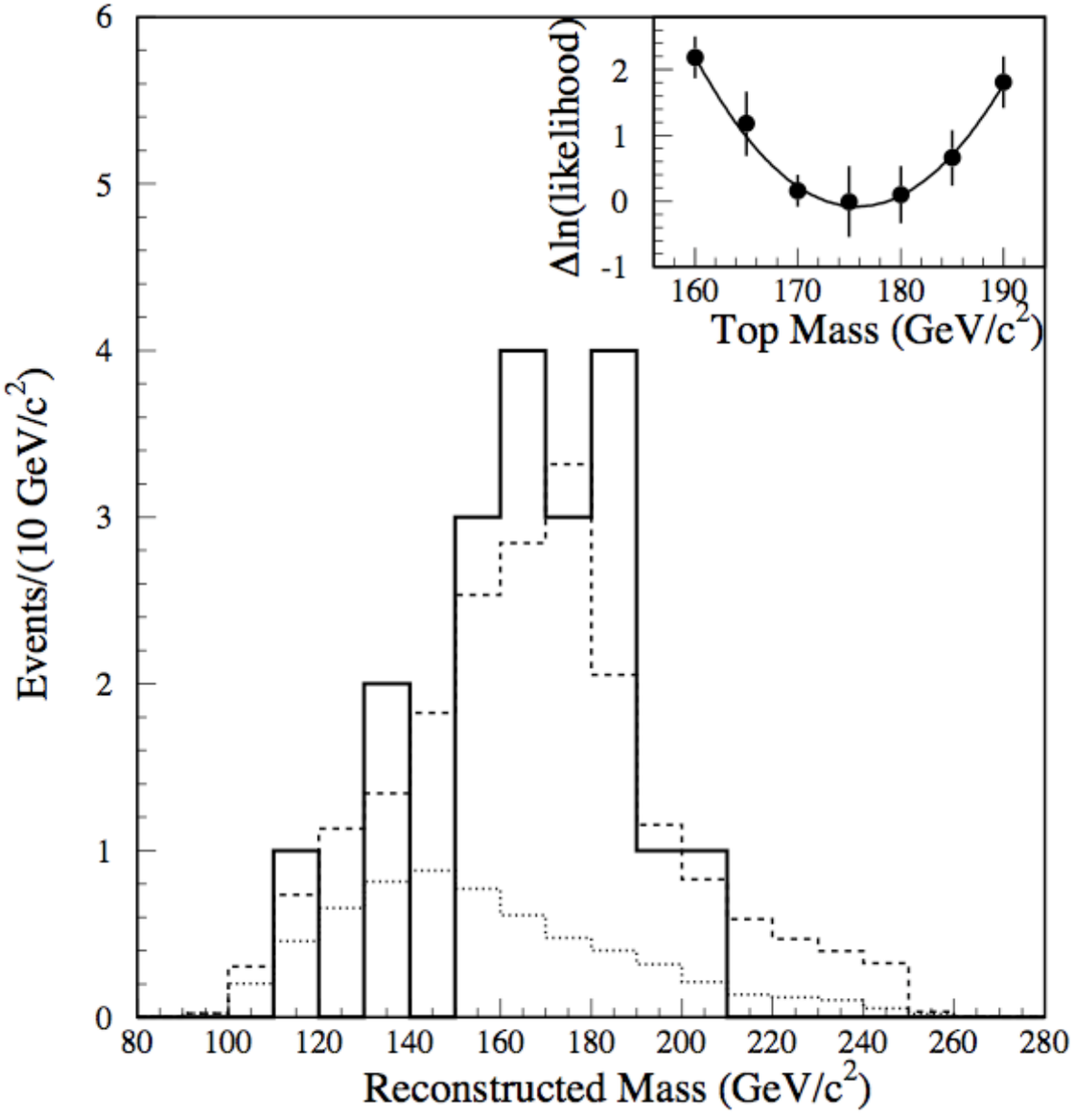
- Resonance Searches
- Spin Correlations

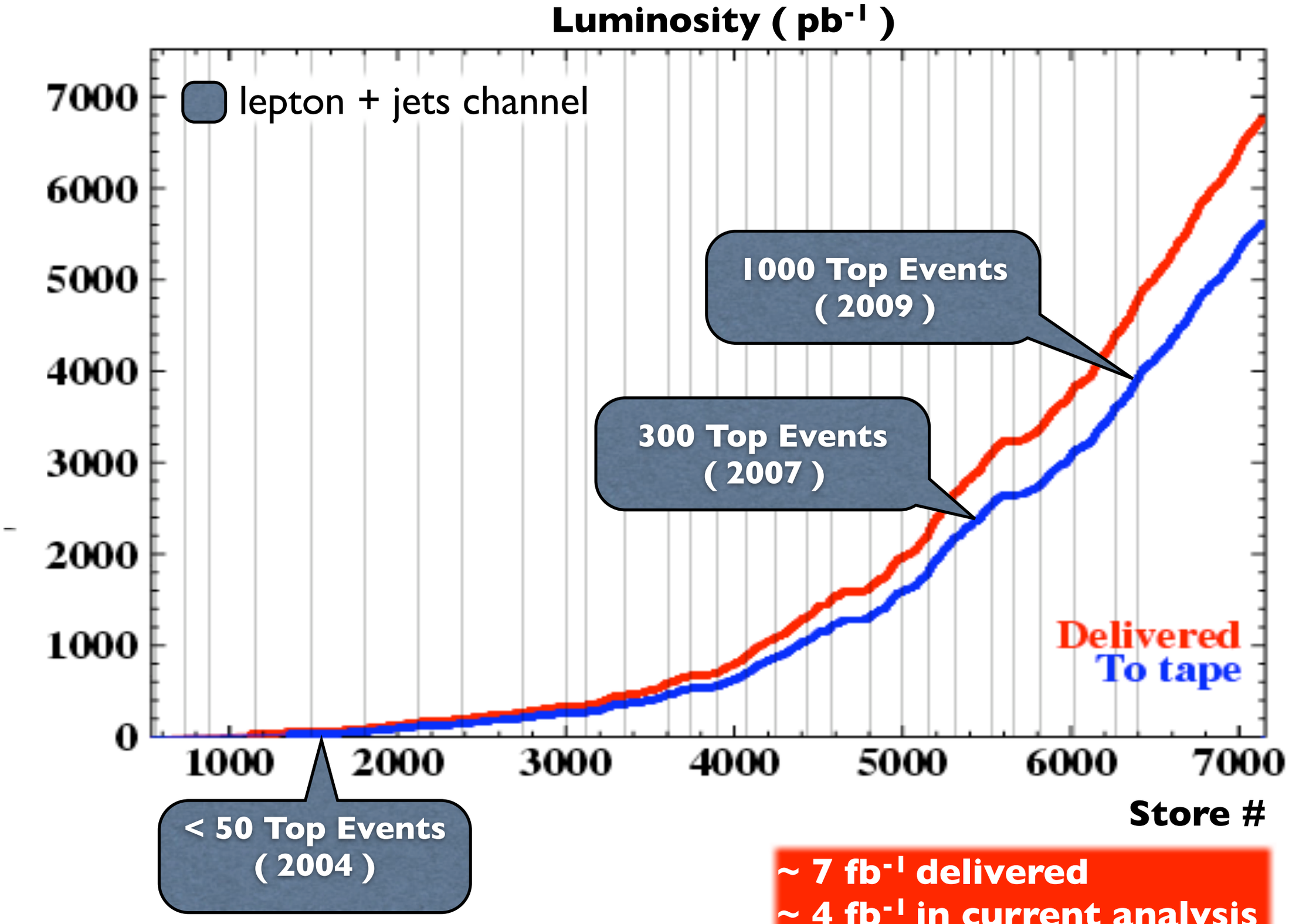
Run I Observation

Observed with 67 pb^{-1}

$$\mathbf{M_t = 176 \pm 12.8\ GeV/c^2}$$

$$\sigma_{\mathbf{t\bar{t}}} = \mathbf{6.8^{+3.6}_{-2.4}}\ \text{pb}$$



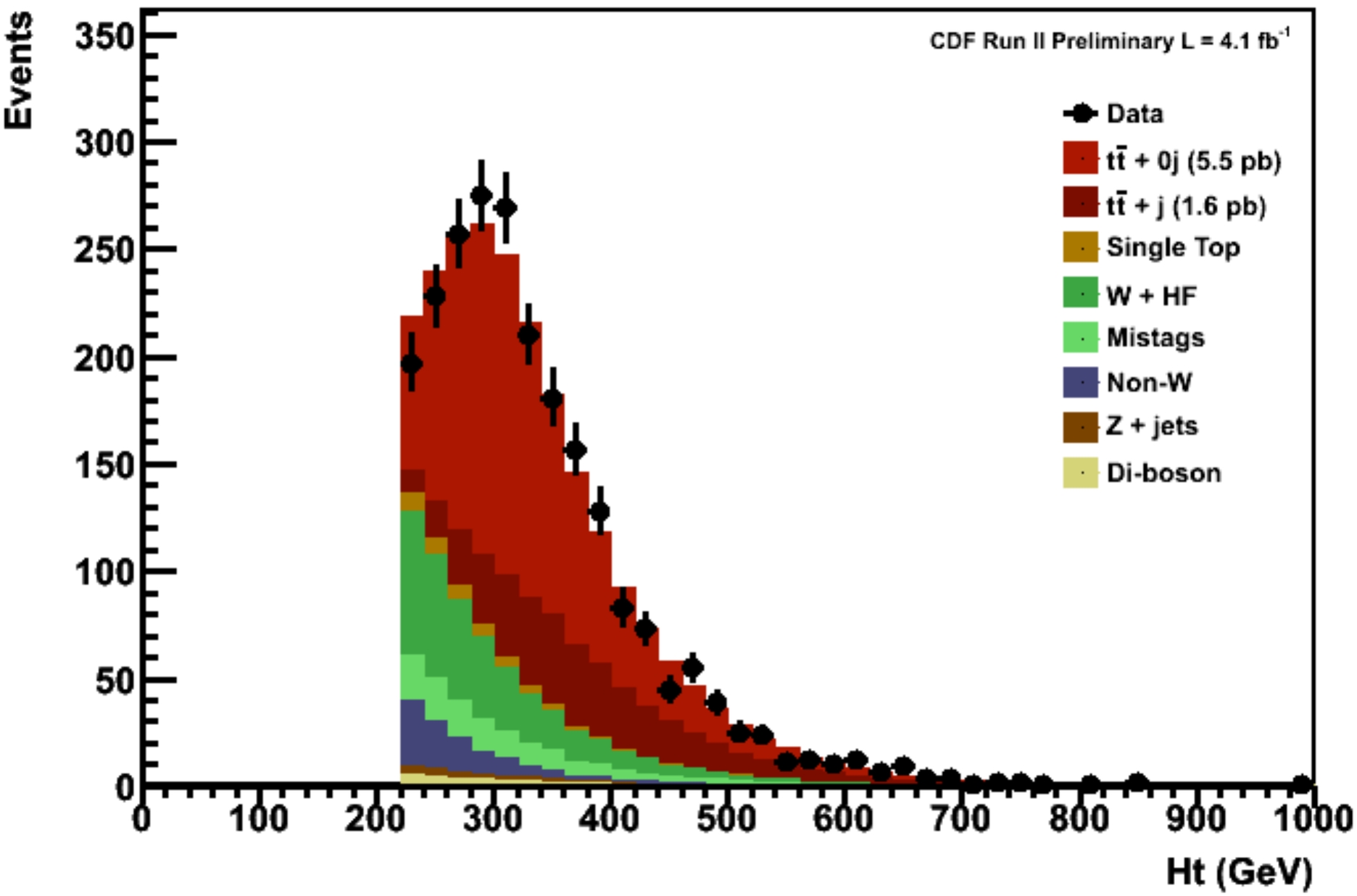

Luminosity (pb-1)
lepton + jets channel
7000
6000
5000
4000
3000
2000
1000
0
1000
2000
3000
4000
5000
6000
7000
Store #
1000 Top Events
(2009)
300 Top Events
(2007)
< 50 Top Events
(2004)
Delivered
To tape
~ 7 fb-1 delivered
~ 4 fb-1 in current analysis

Luminosity (pb^{-1})

lepton + jets channel

7000
6000
5000
4000
3000
2000
1000
0

< 5(



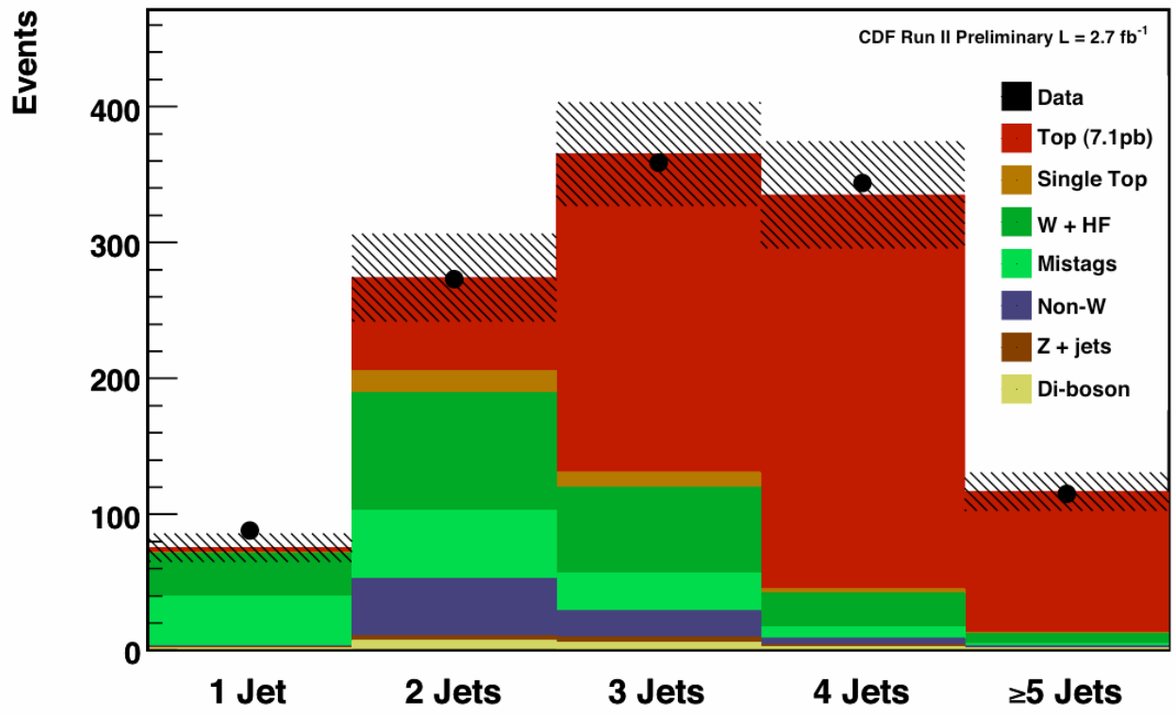
Do we know how much?

2.7 fb^{-1}

Cross Section using b-tagging

- Lepton + jets channel
- Essentially a counting measurement in lepton + jets channel

$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}}{A \cdot \int \mathcal{L}\, dt}$$



- use b-tagging to reduce backgrounds

$$\sigma_{t\bar{t}} = 7.1 \pm 0.4_{stat} \pm 0.6_{sys} \pm 0.4_{lum} \text{ pb}$$

@ M_t = 175 GeV/c^2

$$\frac{\Delta\sigma}{\sigma} = 11.6\%$$

2.7 fb^{-1}

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- Lepton + jets channel
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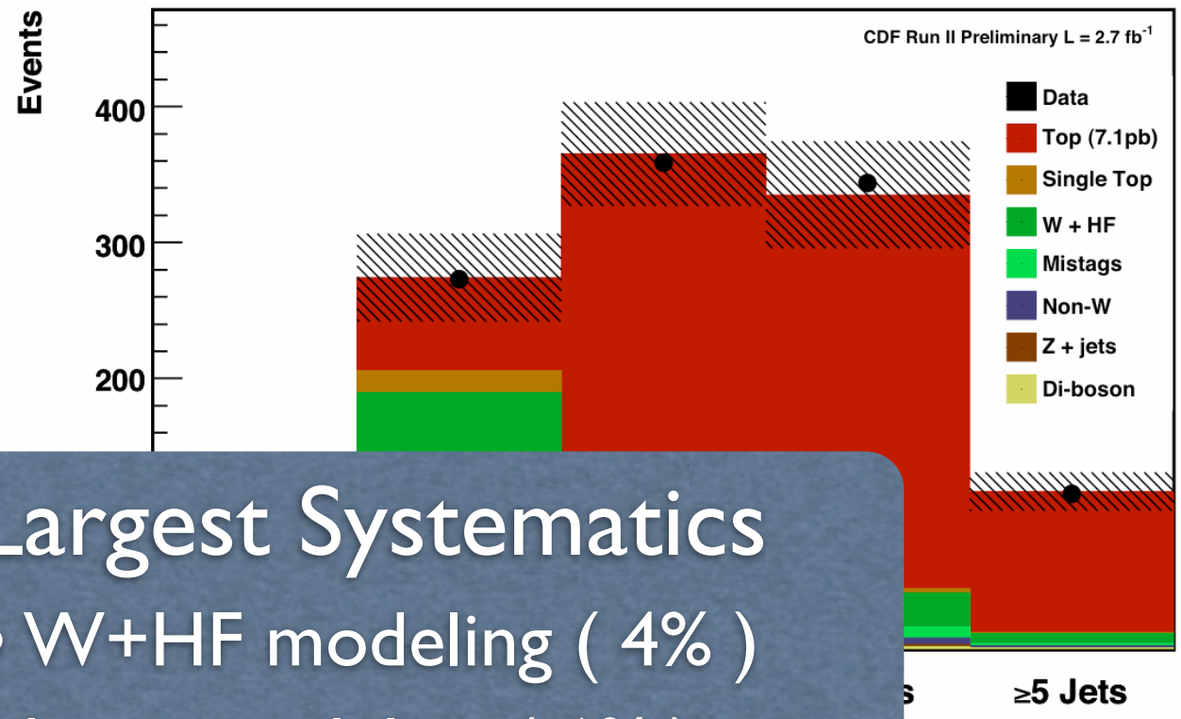


Largest Systematics

- W+HF modeling (4%)
- b-tag modeling (6%)
- Luminosity (6%)

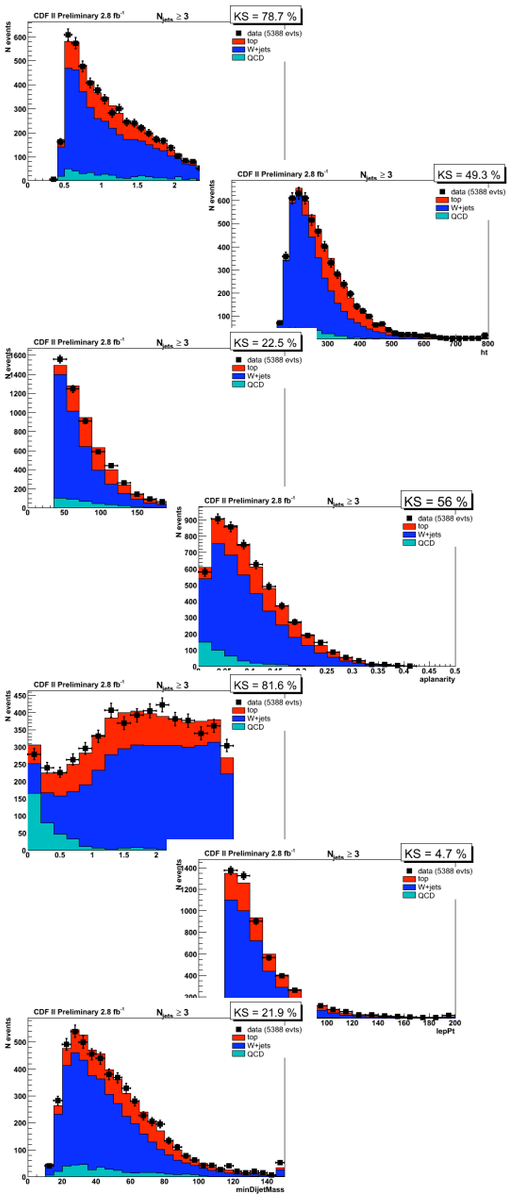
$$\sigma_{t\bar{t}} = 7.1 \pm 0.4_{\mathrm{stat}} \pm 0.6_{\mathrm{sys}} \pm 0.4_{\mathrm{lum}}\ \mathrm{pb}$$

$$\frac{\Delta\sigma}{\sigma} = 11.6\%$$

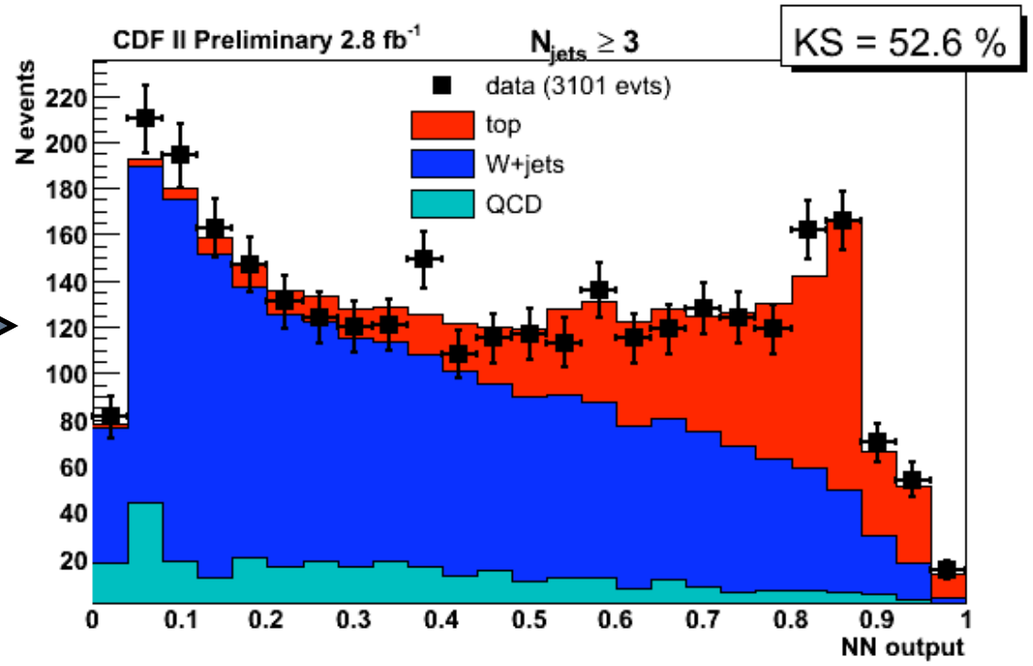
@ M_t = 175 GeV/c^2

2.8 fb^{-1}

Cross Section using Event Kinematics



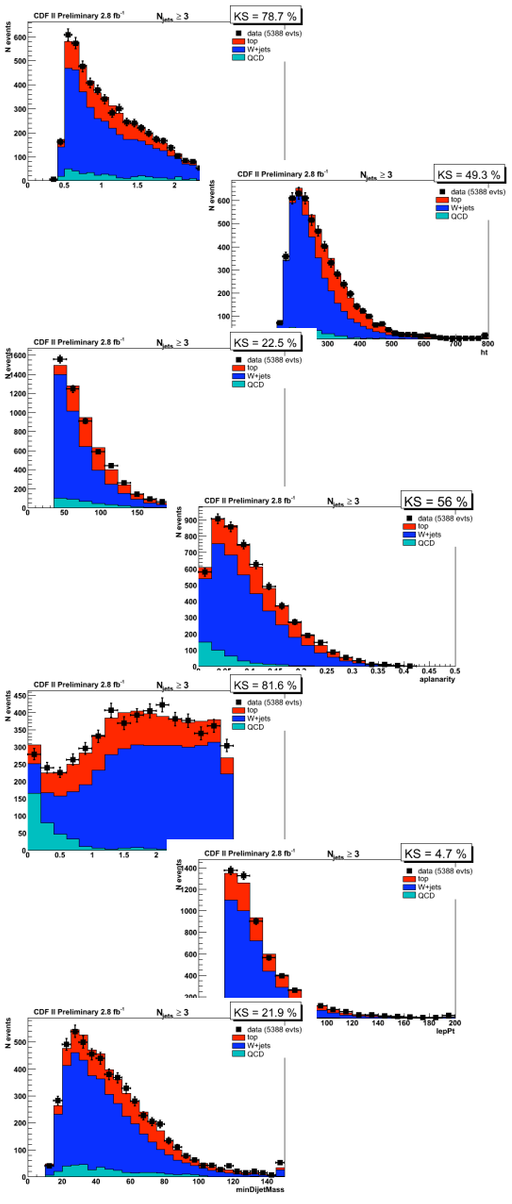
Neural Network



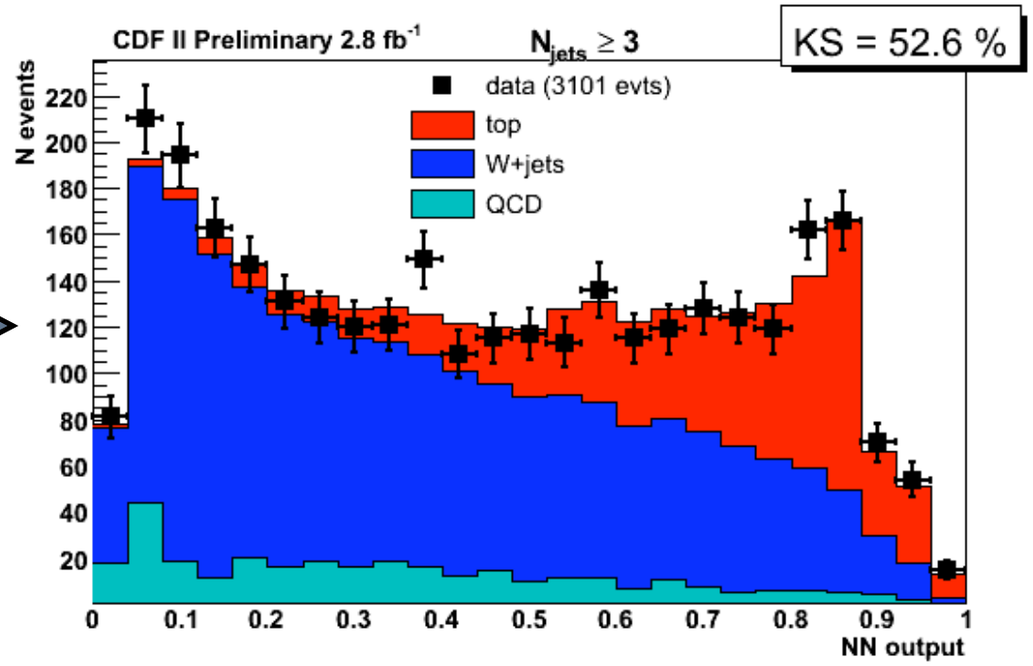
- Identify lepton + jets top events through kinematics as opposed to b-jet identification (no W+HF or b-tag systematics)
- Feed distributions into Neural Net, trained to distinguish signal from background, and fit templates to data

2.8 fb^{-1}

Cross Section using Event Kinematics



Neural Network



$$\sigma_{t\bar{t}} = 7.0 \pm 0.4_{stat} \pm 0.4_{sys} \pm 0.4_{lum} \text{ pb}$$

$$\frac{\Delta\sigma}{\sigma} = 10\%$$

@ M_t = 175 GeV/c^2

2.7 fb^{-1}

Reducing the Luminosity Systematic

- Measure the top cross section relative to the Z cross-section to reduce the large 6% luminosity systematic

$$\sigma_{\gamma^*/\mathbf{Z}} = \mathbf{253.5 \pm 1.1_{stat} \pm 4.5_{syst} \pm 14.9_{lumi}} \ \ \mathbf{pb}$$

$$\sigma^{\mathbf{theory}}_{\gamma^*/\mathbf{Z}} = \mathbf{251.3 \pm 5.0_{scales/pdf}} \ \ \mathbf{pb}$$ J. Phys. G: Nucl. Part. Phys. **34** (2007) 2457–2544

b-jet

$$\sigma_{t\bar{t}} = 7.0 \pm 0.4_{stat} \pm 0.6_{sys} \pm 0.1_{theory} \ \ pb \qquad \frac{\Delta\sigma}{\sigma} = 10\%$$

Kinematic

$$\sigma_{t\bar{t}} = 6.9 \pm 0.4_{stat} \pm 0.4_{sys} \pm 0.1_{theory} \ \ pb \qquad \frac{\Delta\sigma}{\sigma} = 8\%$$

2.8 fb^{-1}

Di-lepton Cross Section

Counting Measurement: $\sigma_{t\bar{t}} = \dfrac{N_{data} - N_{bkg}}{A \cdot \int \mathcal{L}\, dt}$

Process	Events
$t\bar{t}$ (6.7 pb)	110.6
Z/γ^*	26.6
WW	10.2
WZ	2.9
ZZ	1.5
Fakes	10.8
Sum	162.5 ± 4.5
Data	162

Monte Carlo Model:

$$N = \sigma \cdot \int \mathcal{L}\, dt \cdot A$$

Data Model: l^+l^+ and l^-l^- events

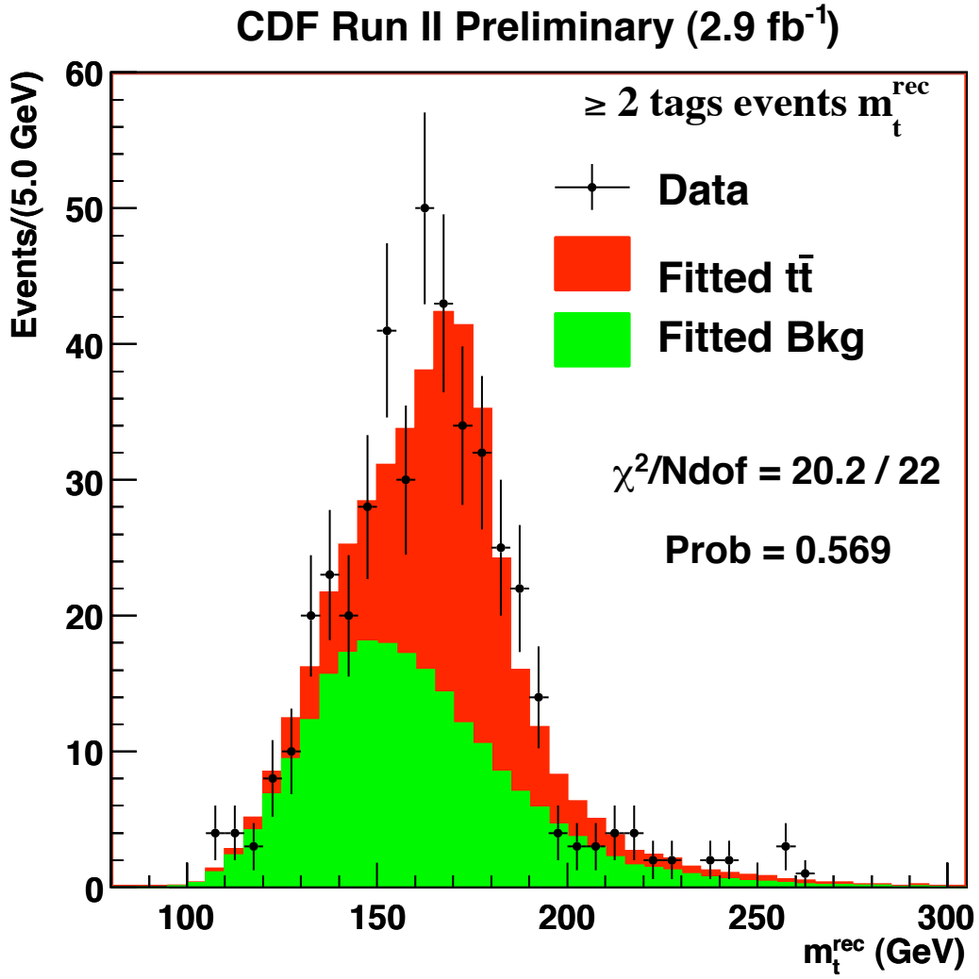
$$\sigma_{t\bar{t}} = 6.7 \pm 0.8_{stat} \pm 0.4_{sys} \pm 0.4_{lum}\ \text{pb}$$

@ M_t = 175 GeV/c^2

2.9 fb^{-1}

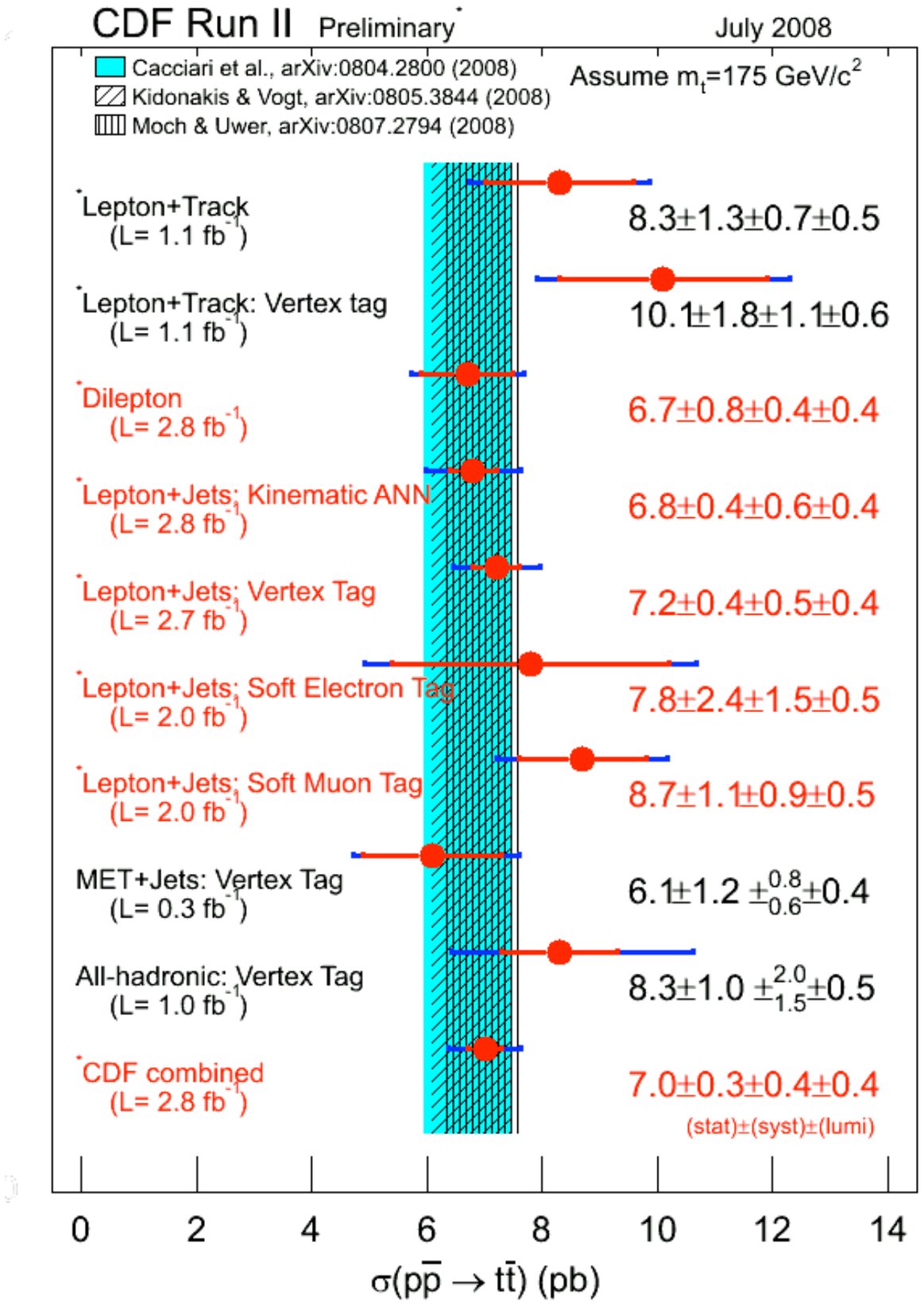
All-hadronic Cross Section

- b-tagging used to reduce background
- Background model is entirely data driven - tag rate parameterization applied to pre-tag data
- Likelihood fit of prediction to data used to extract cross-section



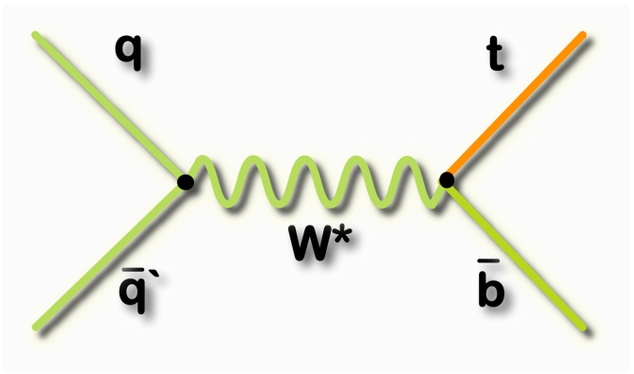
$$\sigma_{t\bar{t}} = 7.2 \pm 0.5_{stat} \pm 1.3_{syst} \pm 0.4_{lumi} \text{ pb}$$

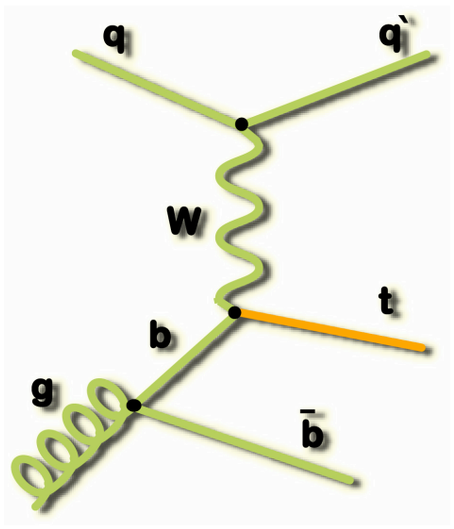
@ M_t = 175 GeV/c^2



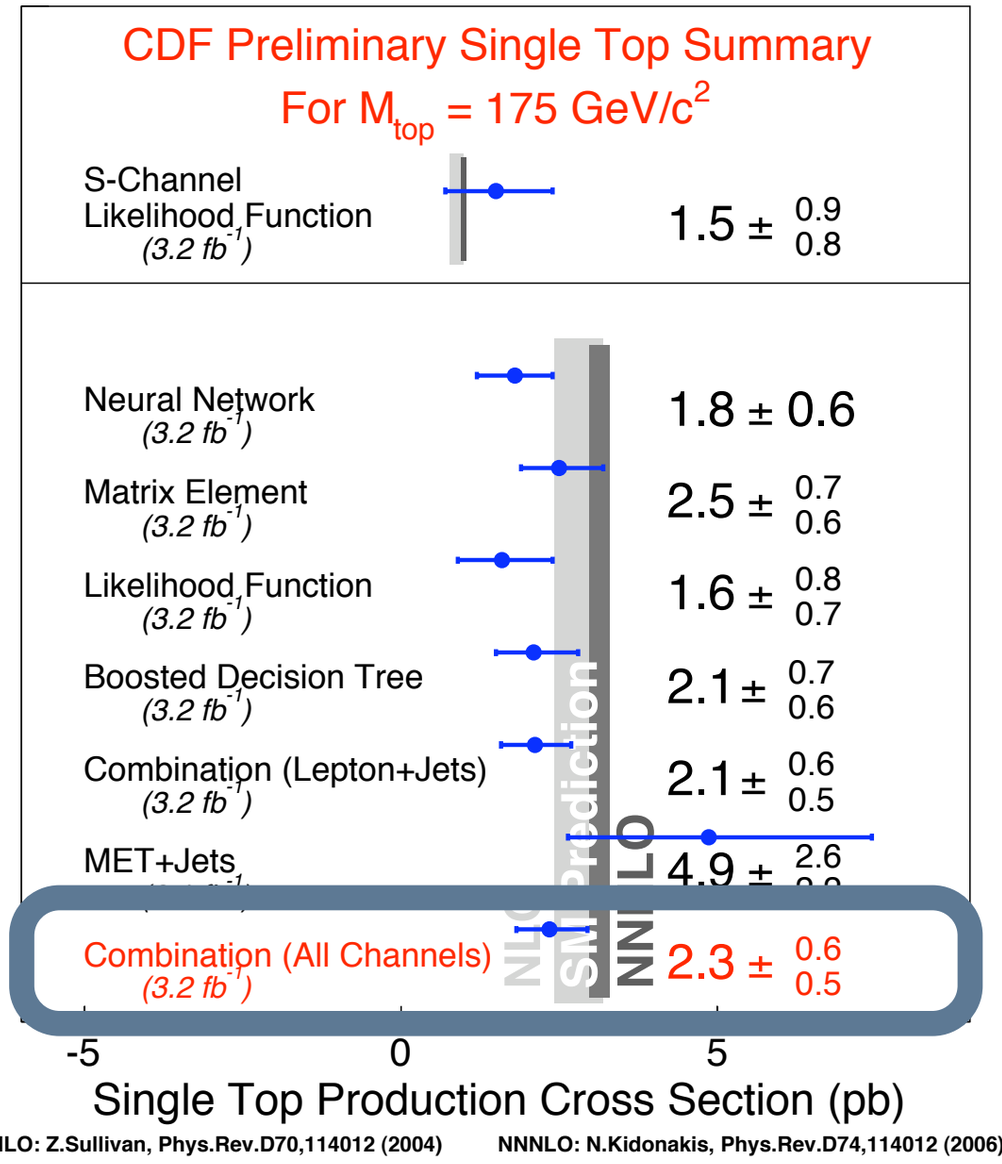
Great Consistency!!!

Electroweak Top Production





predicted $\sigma_{s+t} \approx 2.9$ pb



NLO: Z.Sullivan, Phys.Rev.D70,114012 (2004) NNNLO: N.Kidonakis, Phys.Rev.D74,114012 (2006)

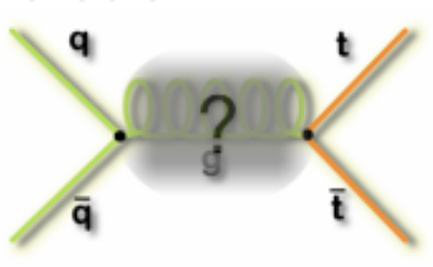
We seem to understand the rate of top production

But are we missing something...?

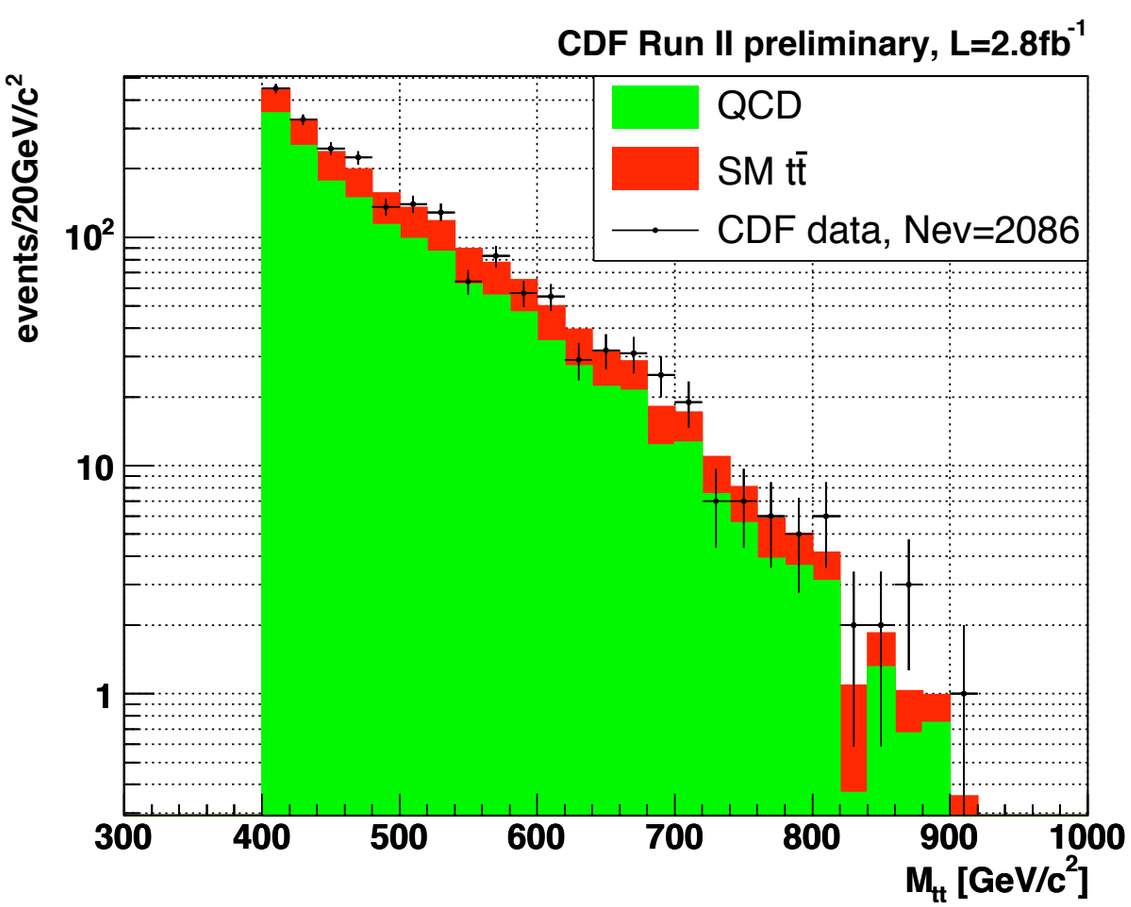
2.8 fb^{-1}

Resonant Top Production

- Looking for Z´, Massive Gluon in all-hadronic channel
- More direct search then cross section



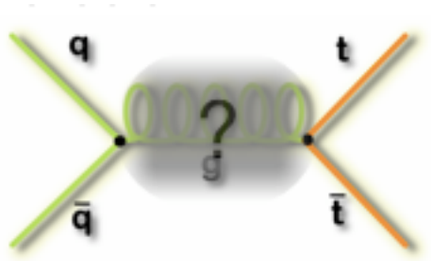
- Search in $M_{t\bar{t}}$
- Mass of the system fully reconstructed for each event
- Narrow resonance templates formed from Monte Carlo and fit to data



2.8 fb^{-1}

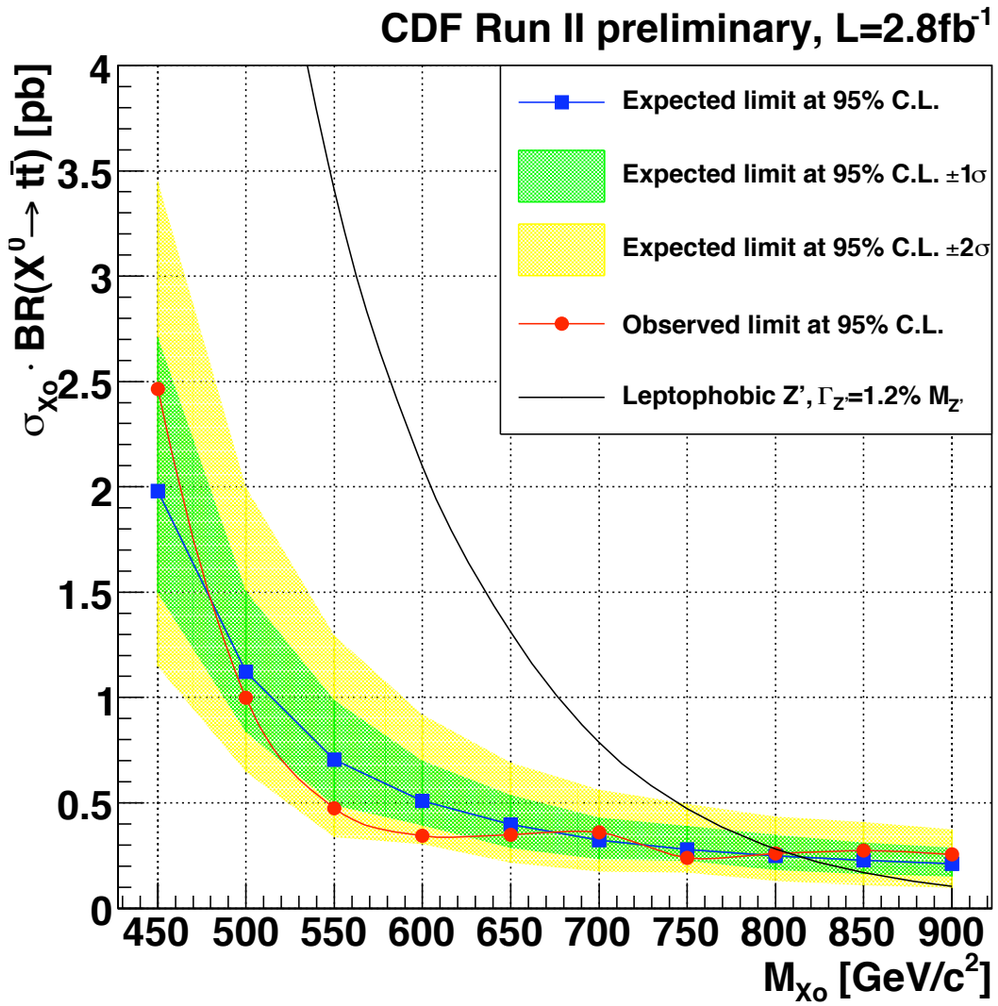
Resonant Top Production

- Looking for Z´, Massive Gluon in all-hadronic channel



- More direct search then cross section
- Search in $M_{t\bar{t}}$
- Mass of the system fully reconstructed for each event
- Narrow resonance templates formed from Monte Carlo and fit to data

$M_{Z'} > 805$ GeV @ 95 % CL

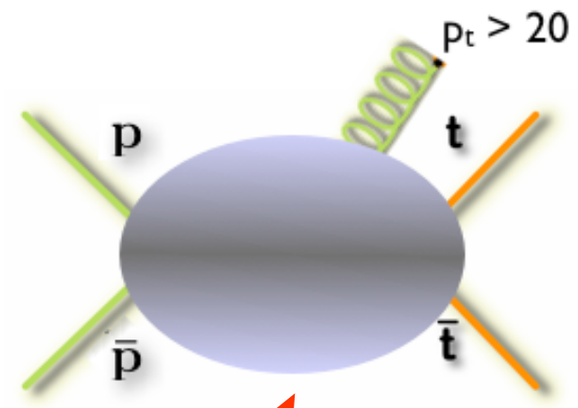


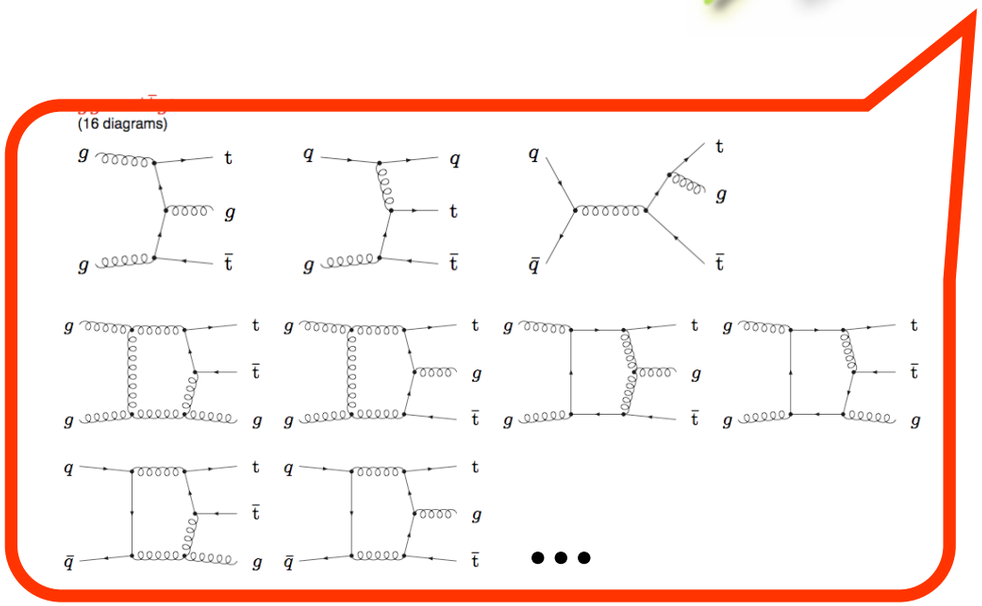
Looking to the Future

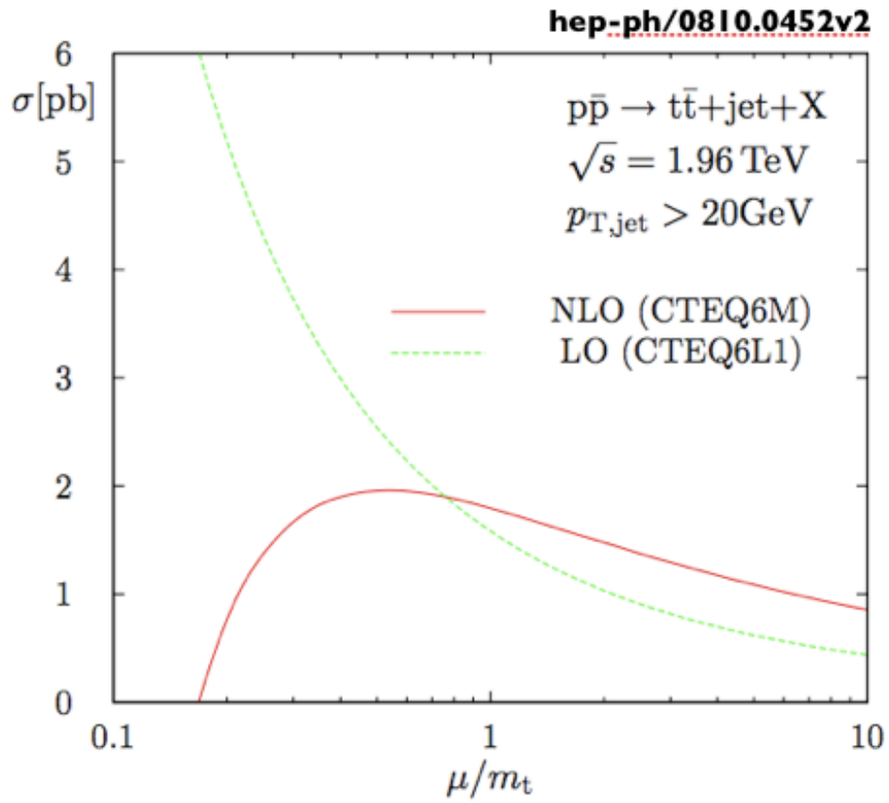
4.1 fb^{-1}

Measurement of the $t\bar{t}+j$ Cross Section

- Idea is to quantify the production of top anti-to pairs in association with a hard jet







$$\sigma_{t\bar{t}+j} = 1.79^{+0.16}_{-0.31}$$

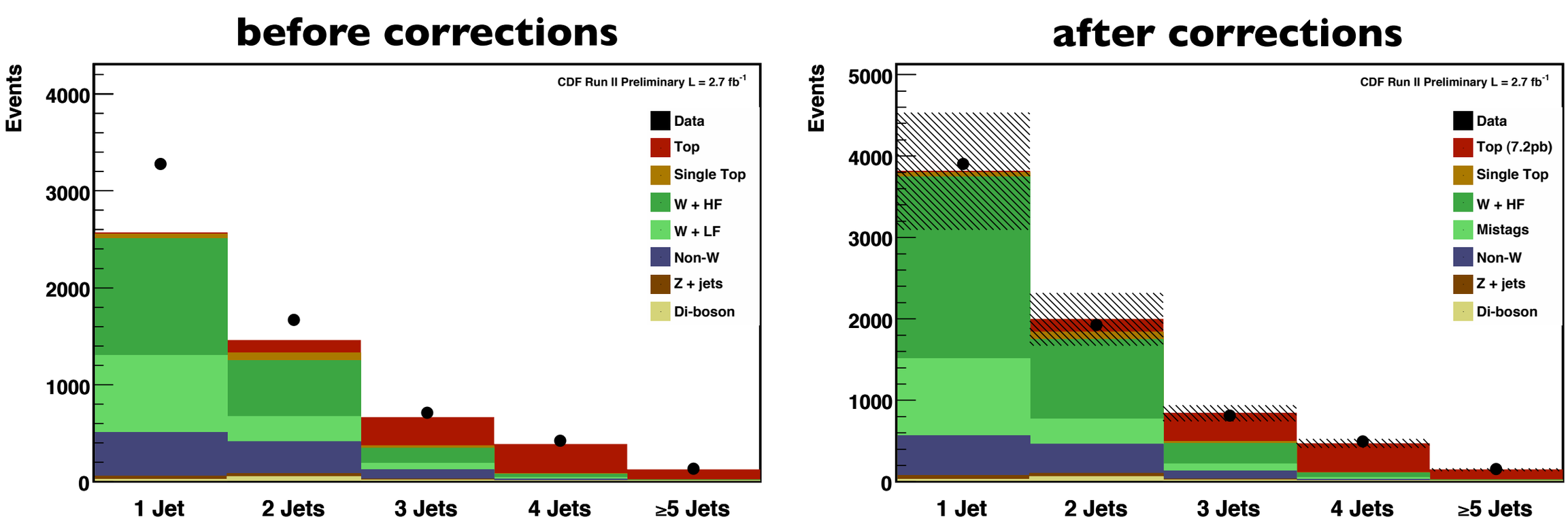
Dittmaier, Uwer, and Weinzierl hep-ph/0810.0452v2

4.1 fb^{-1}

Why should we care?

- Today's signal is tomorrow's background $H + 2\ jets$ $t\bar{t}H$
- tt+j is to the LHC what W + heavy flavor is to the Tevatron

The W+HF problem



4.1 fb^{-1}

Why should we care?

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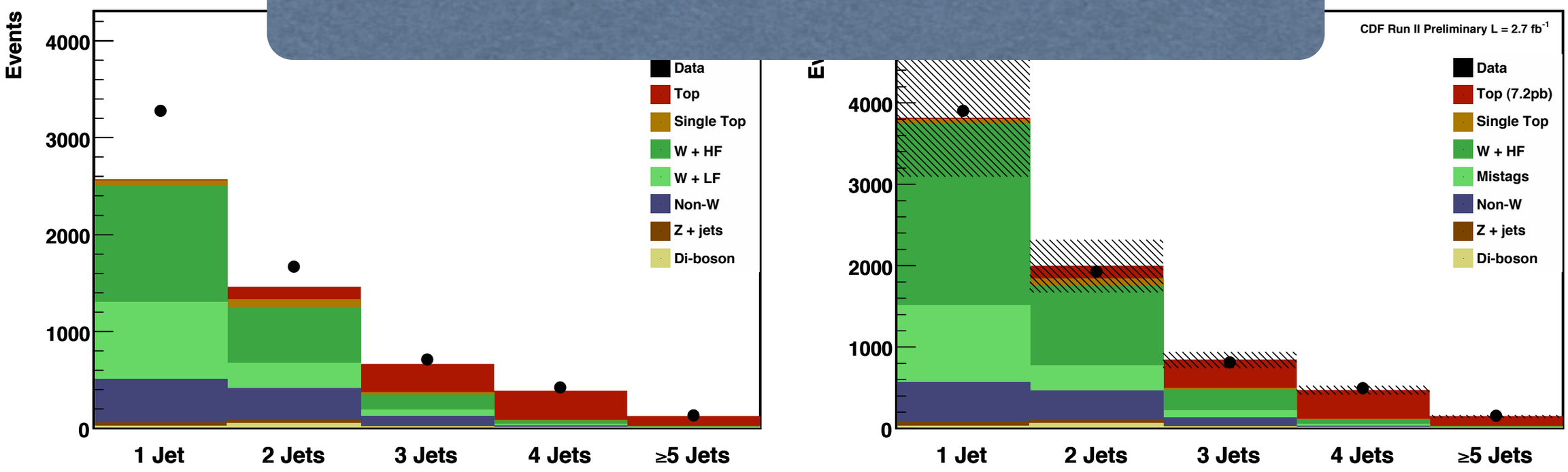
- tt+j is to the LHC what W + heavy flavor is to the Tevatron

What will this look like at the LHC?



4.1 fb^{-1}

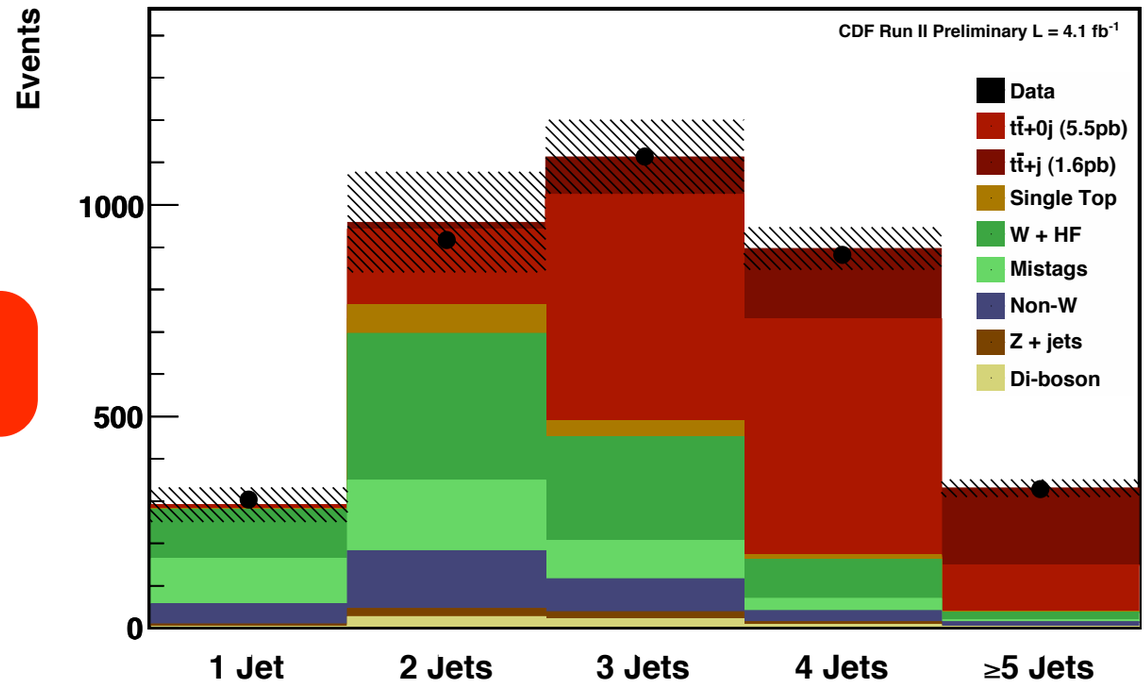
$t\bar{t} + j$ Cross Section

- Measurement performed in b-tagged lepton plus jets events
- Break top sample up into two samples no jet and "+j" by clustering at matrix element level
- 2D likelihood fit to extract tt+j and without jet cross sections

$$\sigma_{\mathbf{t\bar{t}+j}} = \mathbf{1.6 \pm 0.2_{stat} \pm 0.5_{syst}} \ \mathrm{pb}$$

$$\sigma^{theory}_{t\bar{t}+j} = 1.79^{+0.16}_{-0.31}$$

Dittmaier, Uwer, and Weinzierl hep-ph/0810.0452v2



4.1 fb^{-1}

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- Measurement performed in b-tagged lepton plus jets events
- Break top sample up into two samples no jet and "+j" by clustering at matrix element level
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$$\sigma_{t\bar{t}+j} = 1.6 \pm 0.2_{stat} \pm 0.5_{syst} \text{ pb}$$

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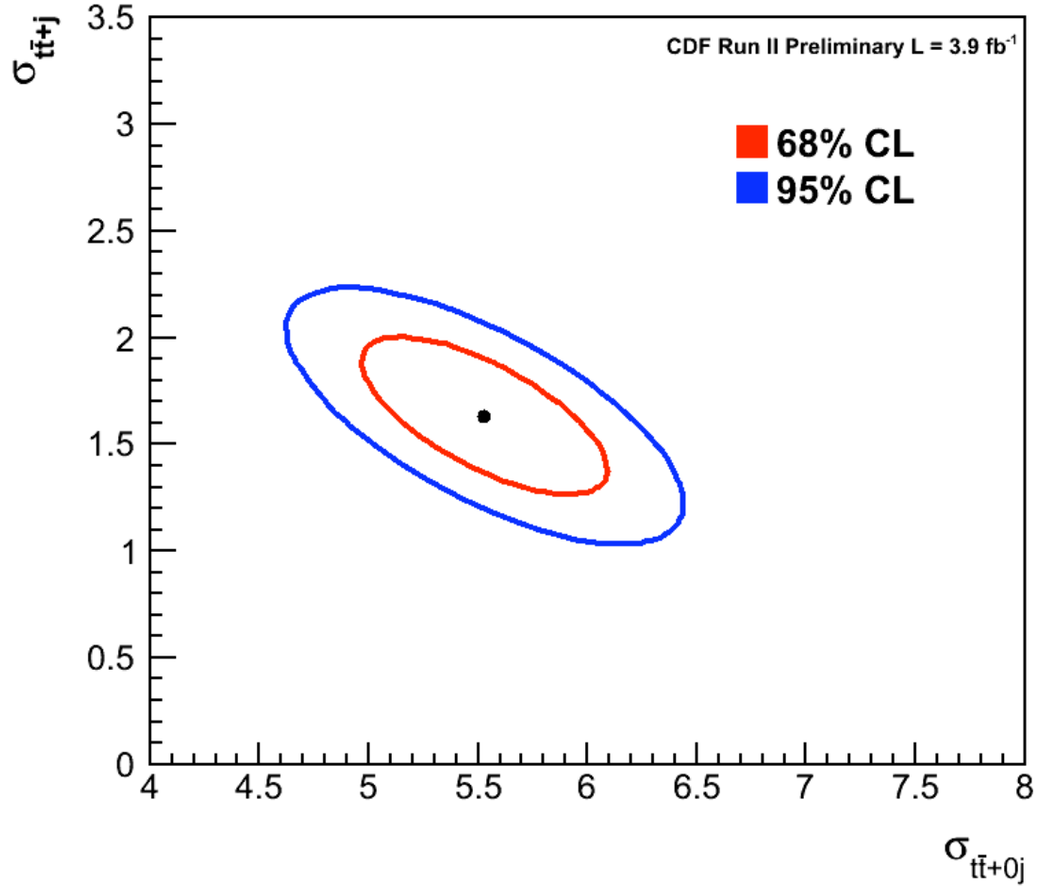


$t\bar{t} + j$ Cross Section

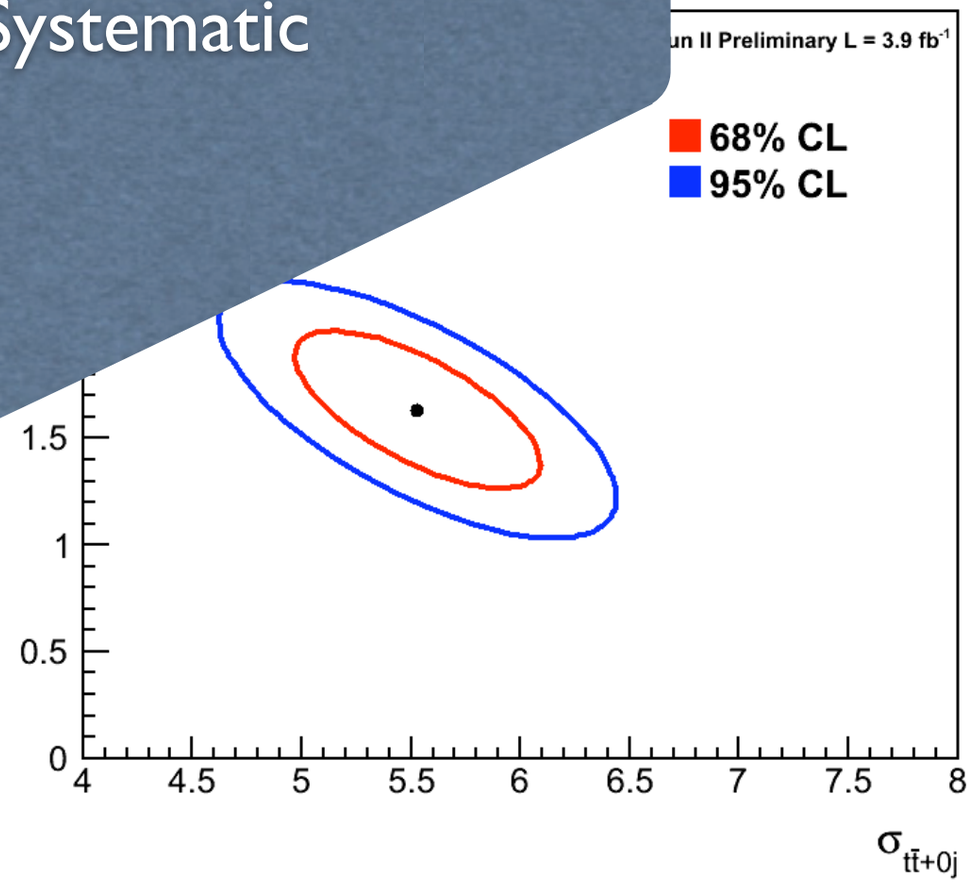
- Measurement performed in b-tagged lepton plus jets events
- Break top sample up into two samples no jet and "+j" by clustering at matrix eleme
- 2D likelihood fit to extra
and without jet cross se

• Almost all jet energy scale
~ 30% Systematic

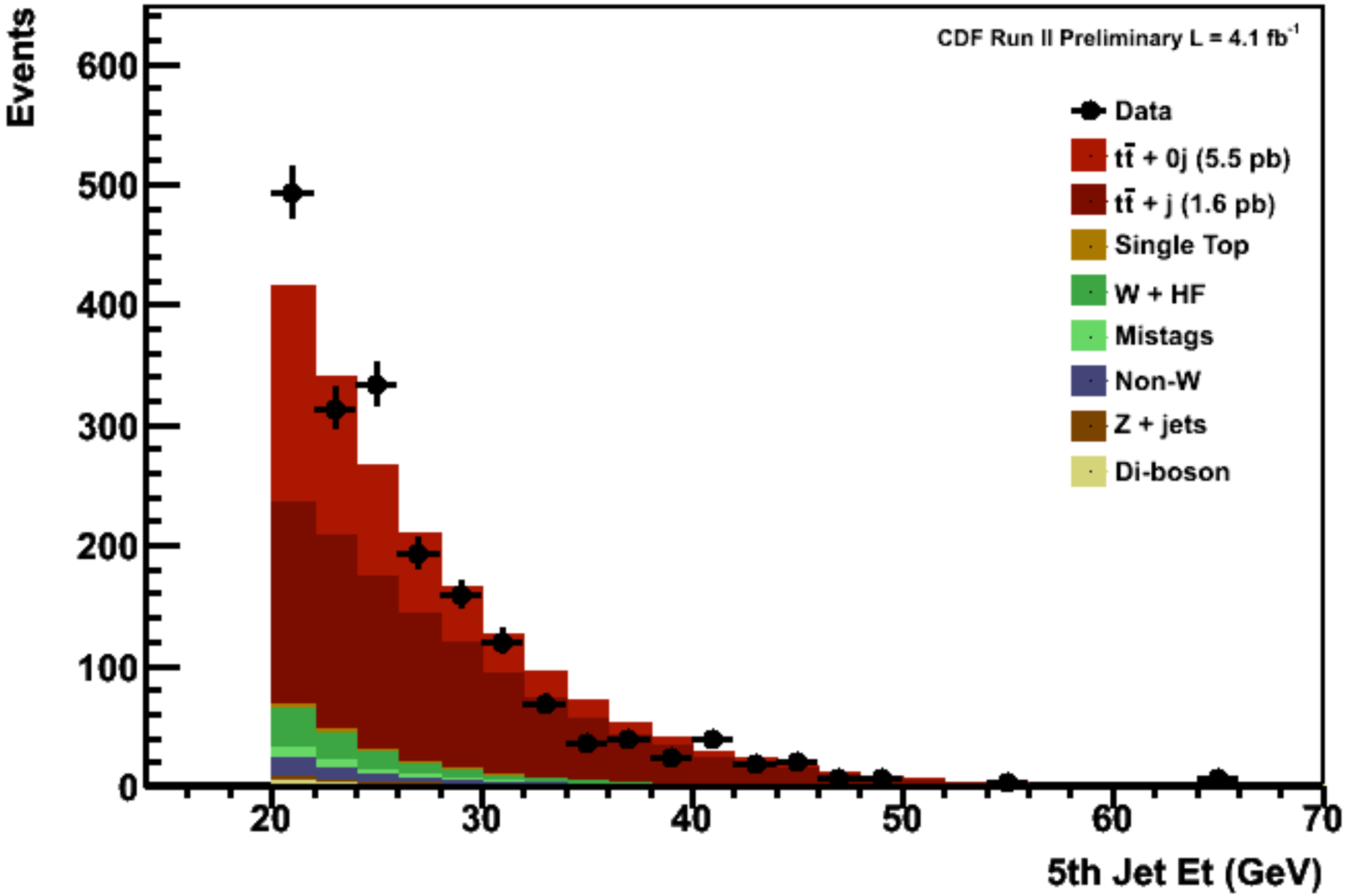
$\sigma_{t\bar{t}+j} = 1.6 \pm 0.2_{stat} \pm 0.5_{syst}$

$\sigma^{theory}_{t\bar{t}+j} = 1.79^{+0.16}_{-0.31}$

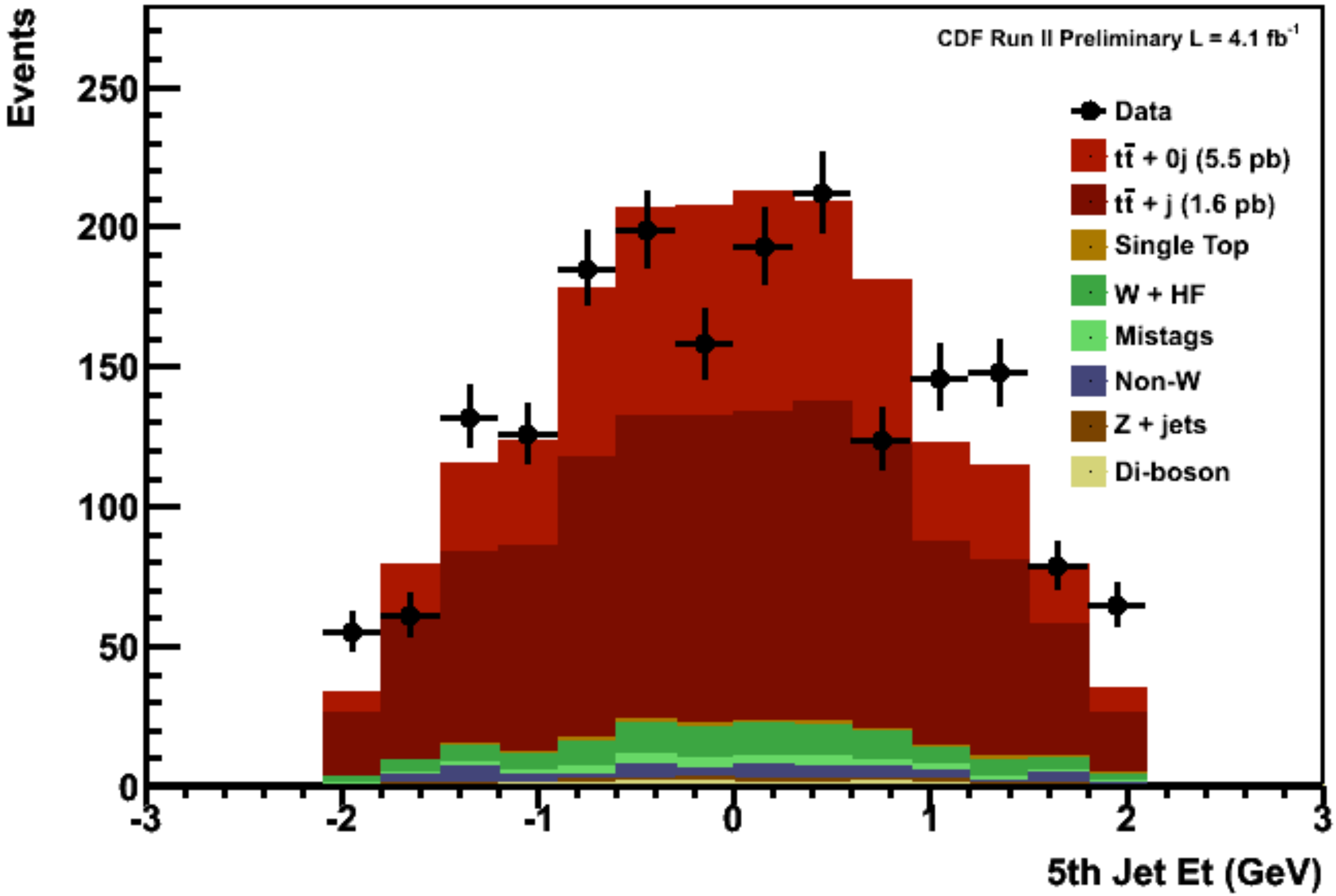
Dittmaier, Uwer, and Weinzierl hep-ph/0810.0452v2



4.1 fb^{-1}


CDF Run II Preliminary L = 4.1 fb-1
Data
tt̄ + 0j (5.5 pb)
tt̄ + j (1.6 pb)
Single Top
W + HF
Mistags
Non-W
Z + jets
Di-boson
Events
600
500
400
300
200
100
0
20
30
40
50
60
70
5th Jet Et (GeV)

4.1 fb^{-1}


CDF Run II Preliminary L = 4.1 fb^{-1}
Events
250
200
150
100
50
0
-3
-2
-1
0
1
2
3
5th Jet Et (GeV)
Data
$t\bar{t}$ + 0j (5.5 pb)
$t\bar{t}$ + j (1.6 pb)
Single Top
W + HF
Mistags
Non-W
Z + jets
Di-boson

95% CL upper limit on BR: $90 < H^+ < 150$ GeV

BR($t \to Zq$) < 3.7% at 95% CL

$F_0 = 0.62 \pm 0.11$ & $F_+ = -0.04 \pm 0.05$

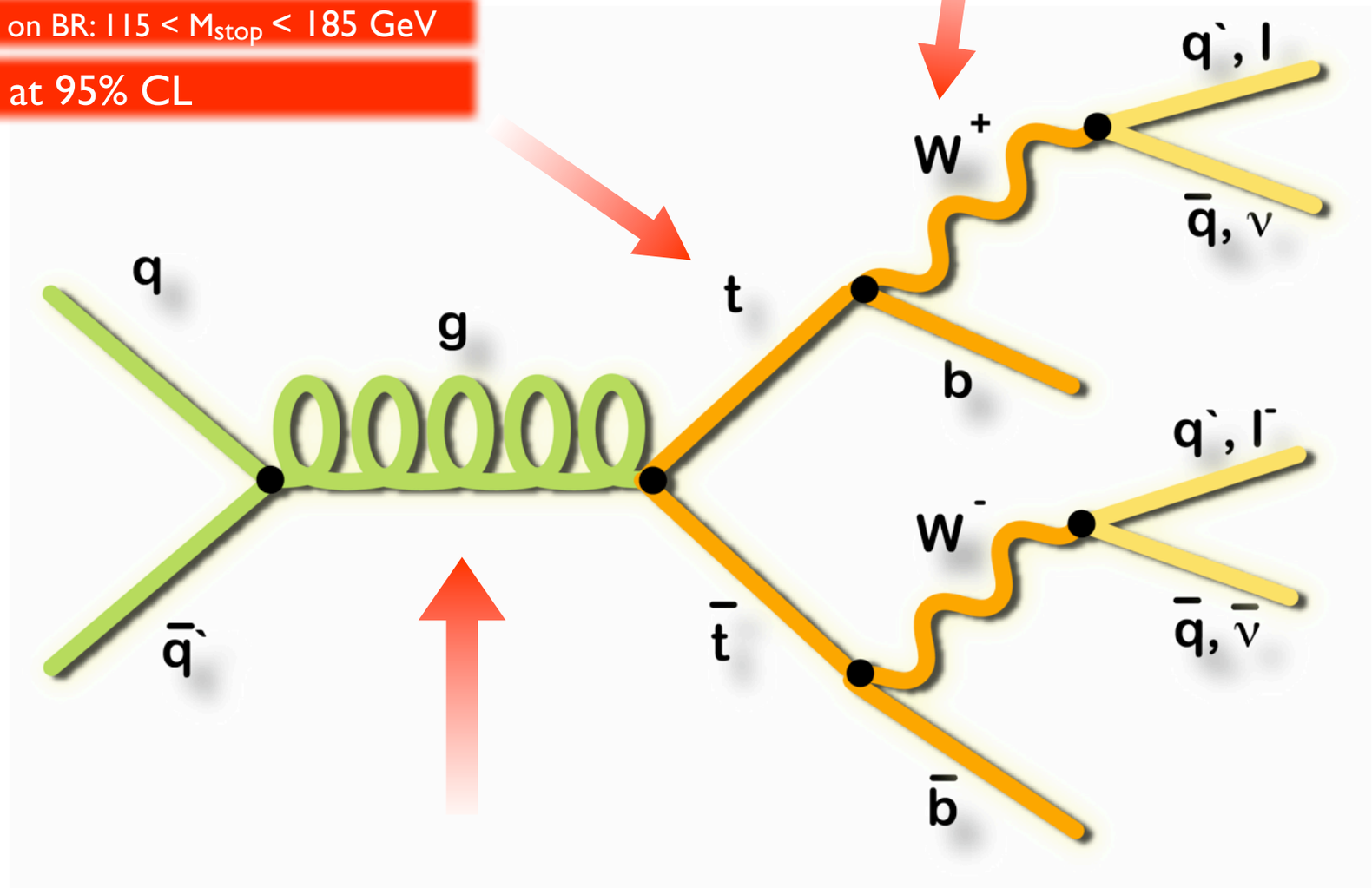
$M_t = 172.6 \pm 0.9_{stat} \pm 1.2_{sys}$ GeV/c^2

$\Gamma_t < 13.1$ GeV at 95% CL

Exclude q = -4/3 at 87%CL

95% CL upper limit on BR: $115 < M_{stop} < 185$ GeV

$M_{t'} > 311$ GeV at 95% CL



$\sigma_{l+jets} = 6.9 \pm 0.4_{stat} \pm 0.4_{sys} \pm 0.1_{z\text{-}theory}$ pb

$\sigma_{ll} = 6.7 \pm 0.8_{stat} \pm 0.4_{sys} \pm 0.4_{lumi}$ pb

$\sigma_{all\text{-}jets} = 7.2 \pm 0.5_{stat} \pm 1.3_{sys} \pm 0.4_{lumi}$ pb

$\sigma_{tt+j} = 1.6 \pm 0.2_{stat} \pm 0.5_{sys}$ pb

$F_{gg} = 0.07\ ^{+0.15}_{-0.07}$ (stat+sys)

$A_{fb}^{lab} = 0.19 \pm 0.07_{stat} \pm 0.02_{sys}$

$M_{Z'} > 805$ GeV at 95% CL

Spin Correlations $\kappa = 0.3^{+0.6}_{-0.8}$

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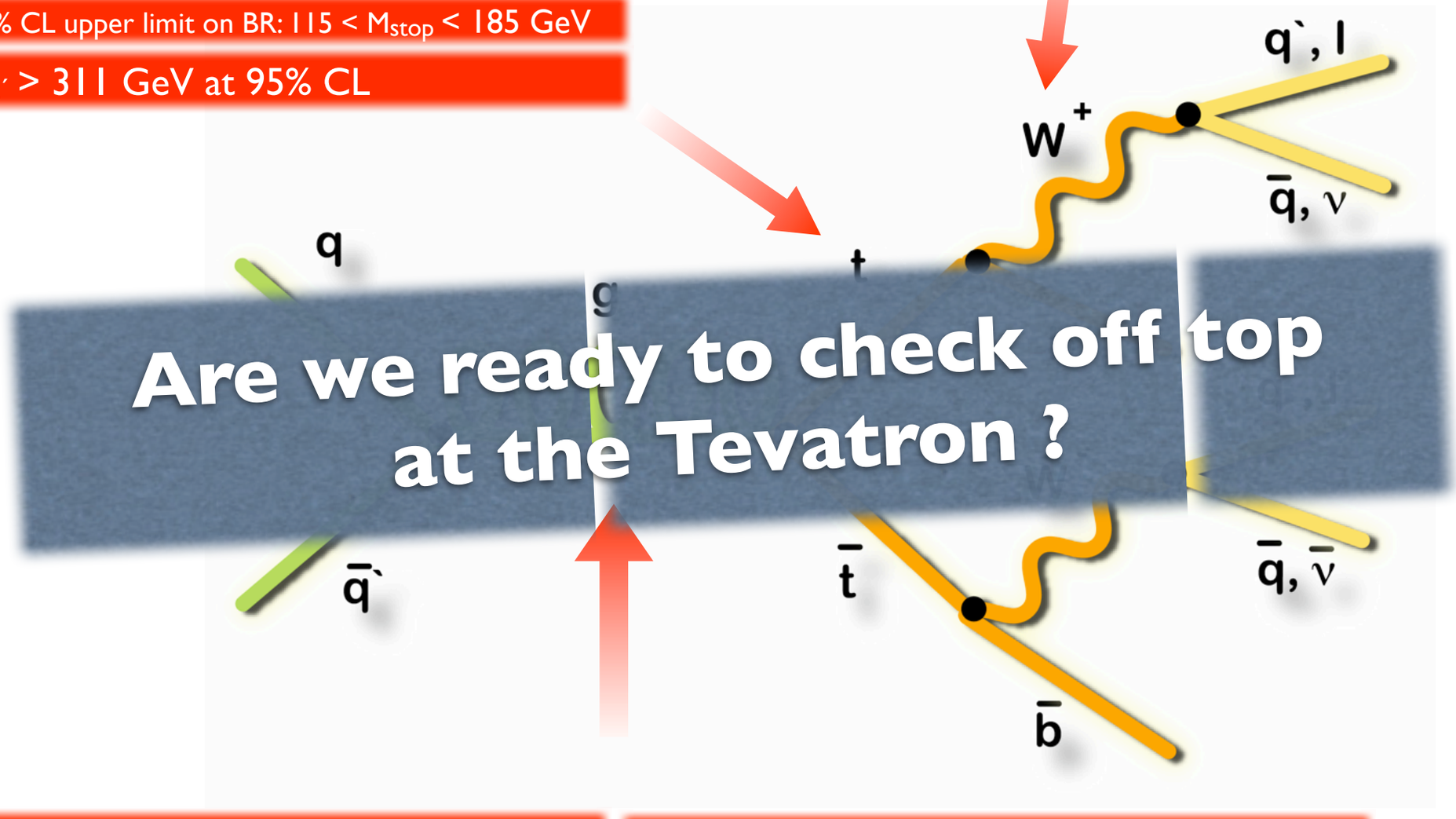
95% CL upper limit on BR: $115 < M_{stop} < 185$ GeV

$M_{t'} > 311$ GeV at 95% CL



Are we ready to check off top at the Tevatron ?

$\sigma_{l+jets} = 6.9 \pm 0.4_{stat} \pm 0.4_{sys} \pm 0.1_{z\text{-}theory}$ pb

$\sigma_{ll} = 6.7 \pm 0.8_{stat} \pm 0.4_{sys} \pm 0.4_{lumi}$ pb

$\sigma_{all\text{-}jets} = 7.2 \pm 0.5_{stat} \pm 1.3_{sys} \pm 0.4_{lumi}$ pb

$\sigma_{tt+j} = 1.6 \pm 0.2_{stat} \pm 0.5_{sys}$ pb

$F_{gg} = 0.07\ ^{+0.15}_{-0.07}$ (stat+sys)

$A_{fb}^{lab} = 0.19 \pm 0.07_{stat} \pm 0.02_{sys}$

$M_{Z'} > 805$ GeV at 95% CL

Spin Correlations $\kappa = 0.3^{+0.6}_{-0.8}$