Recent CDF Results

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On behalf of the CDF collaboration

Motivation

The Standard Model

$$
\begin{aligned}
&-\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4}g_s^2 f^{abc} f^{ade} g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \\
&\tfrac{1}{2}ig^2_s(\bar{q}^\sigma_i \gamma^\mu q^\sigma_j) g^a_\mu + \bar{G}^a \partial^2 G^a + g_s f^{abc}\partial_\mu \bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - \\
&M^2 W^+_\mu W^-_\mu - \tfrac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \tfrac{1}{2c_w^2} M^2 Z^0_\mu Z^0_\mu - \tfrac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - \tfrac{1}{2}\partial_\mu H \partial_\mu H - \\
&\tfrac{1}{2}m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - M^2 \phi^+ \phi^- - \tfrac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \tfrac{1}{2c_w^2} M \phi^0 \phi^0 - \beta_h [\tfrac{2M^2}{g^2} + \\
&\tfrac{2M}{g} H + \tfrac{1}{2}(H^2 + \phi^0 \phi^0 + 2\phi^+ \phi^-)] + \tfrac{2M^4}{g^2}\alpha_h - igc_w [\partial_\nu Z^0_\mu (W^+_\mu W^-_\nu - \\
&W^+_\nu W^-_\mu) - Z^0_\nu (W^+_\mu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu) + Z^0_\mu (W^+_\nu \partial_\nu W^-_\mu - \\
&W^-_\nu \partial_\nu W^+_\mu)] - igs_w [\partial_\nu A_\mu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu (W^+_\mu \partial_\nu W^-_\mu - \\
&W^-_\mu \partial_\nu W^+_\mu) + A_\mu (W^+_\nu \partial_\nu W^-_\mu - W^-_\nu \partial_\nu W^+_\mu)] - \tfrac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \\
&\tfrac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\nu W^-_\nu + g^2 c_w^2 (Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + \\
&g^2 s_w^2 (A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w [A_\mu Z^0_\nu (W^+_\mu W^-_\nu - \\
&W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha [H^3 + H\phi^0 \phi^0 + 2H\phi^+ \phi^-] - \\
&\tfrac{1}{8}g^2 \alpha_h [H^4 + (\phi^0)^4 + 4(\phi^+ \phi^-)^2 + 4(\phi^0)^2 \phi^+ \phi^- + 4H^2 \phi^+ \phi^- + 2(\phi^0)^2 H^2] - \\
&gMW^+_\mu W^-_\mu H - \tfrac{1}{2}g\tfrac{M}{c_w^2} Z^0_\mu Z^0_\mu H - \tfrac{1}{2}ig[W^+_\mu (\phi^0 \partial_\mu \phi^- - \phi^- \partial_\mu \phi^0) - \\
&W^-_\mu (\phi^0 \partial_\mu \phi^+ - \phi^+ \partial_\mu \phi^0)] + \tfrac{1}{2}g[W^+_\mu (H\partial_\mu \phi^- - \phi^- \partial_\mu H) - W^-_\mu (H\partial_\mu \phi^+ - \\
&\phi^+ \partial_\mu H)] + \tfrac{1}{2}g\tfrac{1}{c_w}(Z^0_\mu (H\partial_\mu \phi^0 - \phi^0 \partial_\mu H) - ig\tfrac{s_w^2}{c_w} M Z^0_\mu (W^+_\mu \phi^- - W^-_\mu \phi^+) + \\
&igs_w M A_\mu (W^+_\mu \phi^- - W^-_\mu \phi^+) - ig\tfrac{1-2c_w^2}{2c_w} Z^0_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) + \\
&igs_w A_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) - \tfrac{1}{4}g^2 W^+_\mu W^-_\mu [H^2 + (\phi^0)^2 + 2\phi^+ \phi^-] - \\
&\tfrac{1}{4}g^2 \tfrac{1}{c_w^2} Z^0_\mu Z^0_\mu [H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)^2 \phi^+ \phi^-] - \tfrac{1}{2}g^2 \tfrac{s_w^2}{c_w} Z^0_\mu \phi^0 (W^+_\mu \phi^- + \\
&W^-_\mu \phi^+) - \tfrac{1}{2}ig^2 \tfrac{s_w^2}{c_w} Z^0_\mu H (W^+_\mu \phi^- - W^-_\mu \phi^+) + \tfrac{1}{2}g^2 s_w A_\mu \phi^0 (W^+_\mu \phi^- + \\
&W^-_\mu \phi^+) + \tfrac{1}{2}ig^2 s_w A_\mu H (W^+_\mu \phi^- - W^-_\mu \phi^+) - g^2 \tfrac{s_w}{c_w} (2c_w^2 - 1) Z^0_\mu A_\mu \phi^+ \phi^- - \\
&g^1 s_w^2 A_\mu A_\mu \phi^+ \phi^- - \bar{e}^\lambda (\gamma \partial + m^\lambda_e) e^\lambda - \bar{\nu}^\lambda \gamma \partial \nu^\lambda - \bar{u}^\lambda_j (\gamma \partial + m^\lambda_u) u^\lambda_j - \\
&\bar{d}^\lambda_j (\gamma \partial + m^\lambda_d) d^\lambda_j + igs_w A_\mu [-(\bar{e}^\lambda \gamma^\mu e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j \gamma^\mu u^\lambda_j) - \tfrac{1}{3}(\bar{d}^\lambda_j \gamma^\mu d^\lambda_j)] + \\
&\tfrac{ig}{4c_w} Z^0_\mu [(\bar{\nu}^\lambda \gamma^\mu (1+\gamma^5) \nu^\lambda) + (\bar{e}^\lambda \gamma^\mu (4s_w^2 - 1 - \gamma^5) e^\lambda) + (\bar{u}^\lambda_j \gamma^\mu (\tfrac{4}{3}s_w^2 - \\
&1 - \gamma^5) u^\lambda_j) + (\bar{d}^\lambda_j \gamma^\mu (1 - \tfrac{8}{3}s_w^2 - \gamma^5) d^\lambda_j)] + \tfrac{ig}{2\sqrt{2}} W^+_\mu [(\bar{\nu}^\lambda \gamma^\mu (1+\gamma^5) e^\lambda) + \\
&(\bar{u}^\lambda_j \gamma^\mu (1+\gamma^5) C_{\lambda\kappa} d^\kappa_j)] + \tfrac{ig}{2\sqrt{2}} W^-_\mu [(\bar{e}^\lambda \gamma^\mu (1+\gamma^5) \nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa} \gamma^\mu (1 + \\
&\gamma^5) u^\lambda_j)] + \tfrac{ig}{2\sqrt{2}} \tfrac{m^\lambda_e}{M} [-\phi^+ (\bar{\nu}^\lambda (1-\gamma^5) e^\lambda) + \phi^- (\bar{e}^\lambda (1+\gamma^5) \nu^\lambda)] - \\
&\tfrac{g}{2}\tfrac{m^\lambda_e}{M} [H(\bar{e}^\lambda e^\lambda) + i\phi^0 (\bar{e}^\lambda \gamma^5 e^\lambda)] + \tfrac{ig}{2M\sqrt{2}} \phi^+ [-m^\kappa_d (\bar{u}^\lambda_j C_{\lambda\kappa} (1-\gamma^5) d^\kappa_j) + \\
&m^\lambda_u (\bar{u}^\lambda_j C_{\lambda\kappa} (1+\gamma^5) d^\kappa_j] + \tfrac{ig}{2M\sqrt{2}} \phi^- [m^\lambda_d (\bar{d}^\lambda_j C^\dagger_{\lambda\kappa} (1+\gamma^5) u^\kappa_j) - m^\kappa_u (\bar{d}^\lambda_j C^\dagger_{\lambda\kappa} (1 - \\
&\gamma^5) u^\kappa_j] - \tfrac{g}{2}\tfrac{m^\lambda_e}{M} H(\bar{u}^\lambda_j u^\lambda_j) - \tfrac{g}{2}\tfrac{m^\lambda_d}{M} H(\bar{d}^\lambda_j d^\lambda_j) + \tfrac{ig}{2}\tfrac{m^\lambda_u}{M} \phi^0 (\bar{u}^\lambda_j \gamma^5 u^\lambda_j) - \\
&\tfrac{ig}{2}\tfrac{m^\lambda_e}{M} \phi^0 (\bar{d}^\lambda_j \gamma^5 d^\lambda_j) + \bar{X}^+ (\partial^2 - M^2) X^+ + \bar{X}^- (\partial^2 - M^2) X^- + \bar{X}^0 (\partial^2 - \\
&\tfrac{M^2}{c_w^2}) X^0 + \bar{Y} \partial^2 Y + igc_w W^+_\mu (\partial_\mu \bar{X}^0 X^- - \partial_\mu \bar{X}^+ X^0) + igs_w W^+_\mu (\partial_\mu \bar{Y} X^- - \\
&\partial_\mu \bar{X}^+ Y) + igc_w W^-_\mu (\partial_\mu \bar{X}^- X^0 - \partial_\mu \bar{X}^0 X^+) + igs_w W^-_\mu (\partial_\mu \bar{X}^- Y - \\
&\partial_\mu \bar{Y} X^+) + igc_w Z^0_\mu (\partial_\mu \bar{X}^+ X^+ - \partial_\mu \bar{X}^- X^-) + igs_w A_\mu (\partial_\mu \bar{X}^+ X^+ - \\
&\partial_\mu \bar{X}^- X^-) - \tfrac{1}{2}gM[\bar{X}^+ X^+ H + \bar{X}^- X^- H + \tfrac{1}{c_w^2} \bar{X}^0 X^0 H] + \\
&\tfrac{1-2c_w^2}{2c_w} igM[\bar{X}^+ X^0 \phi^+ - \bar{X}^- X^0 \phi^-] + \tfrac{1}{2c_w} igM[\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + \\
&igMs_w [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + \tfrac{1}{2}igM[\bar{X}^+ X^+ \phi^0 - \bar{X}^- X^- \phi^0]
\end{aligned}
$$

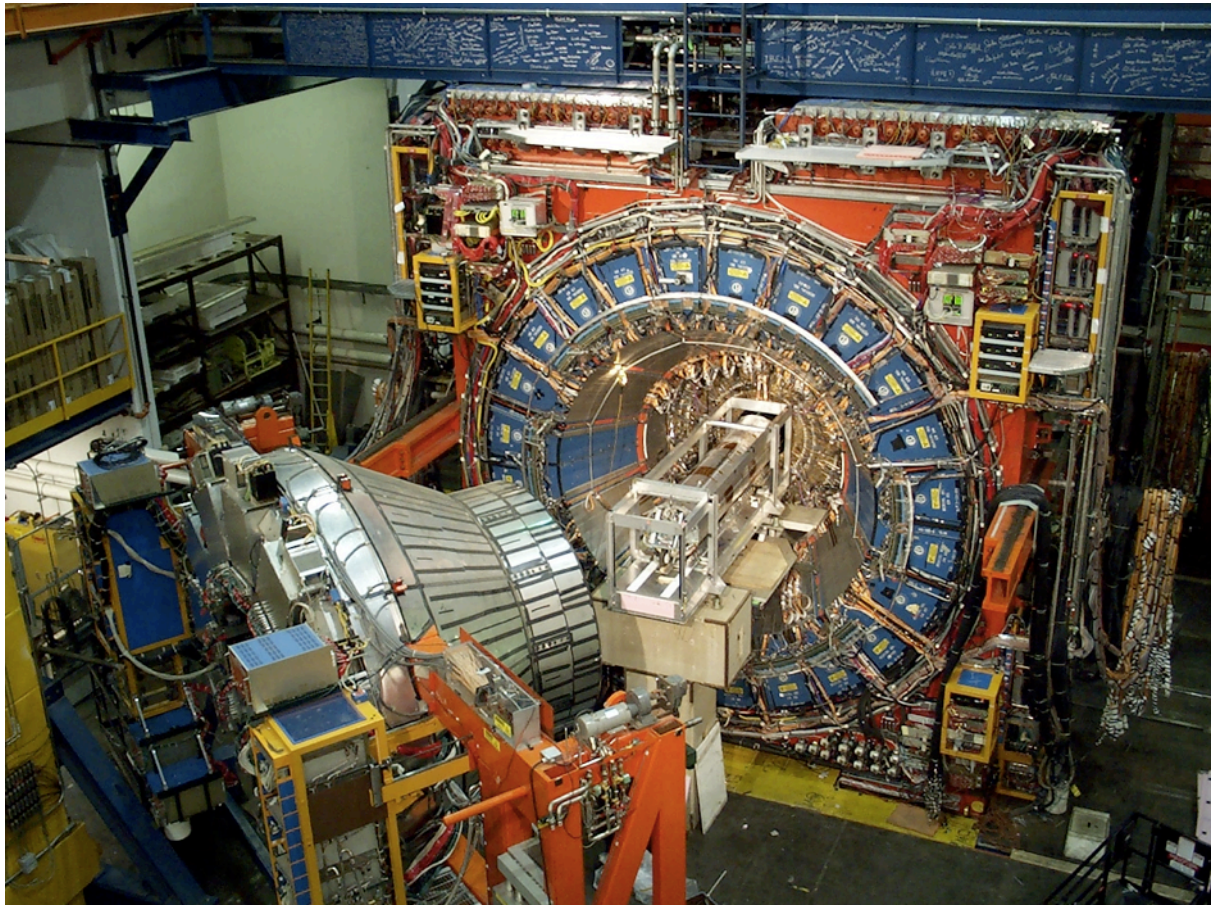
Can this be right?

Language

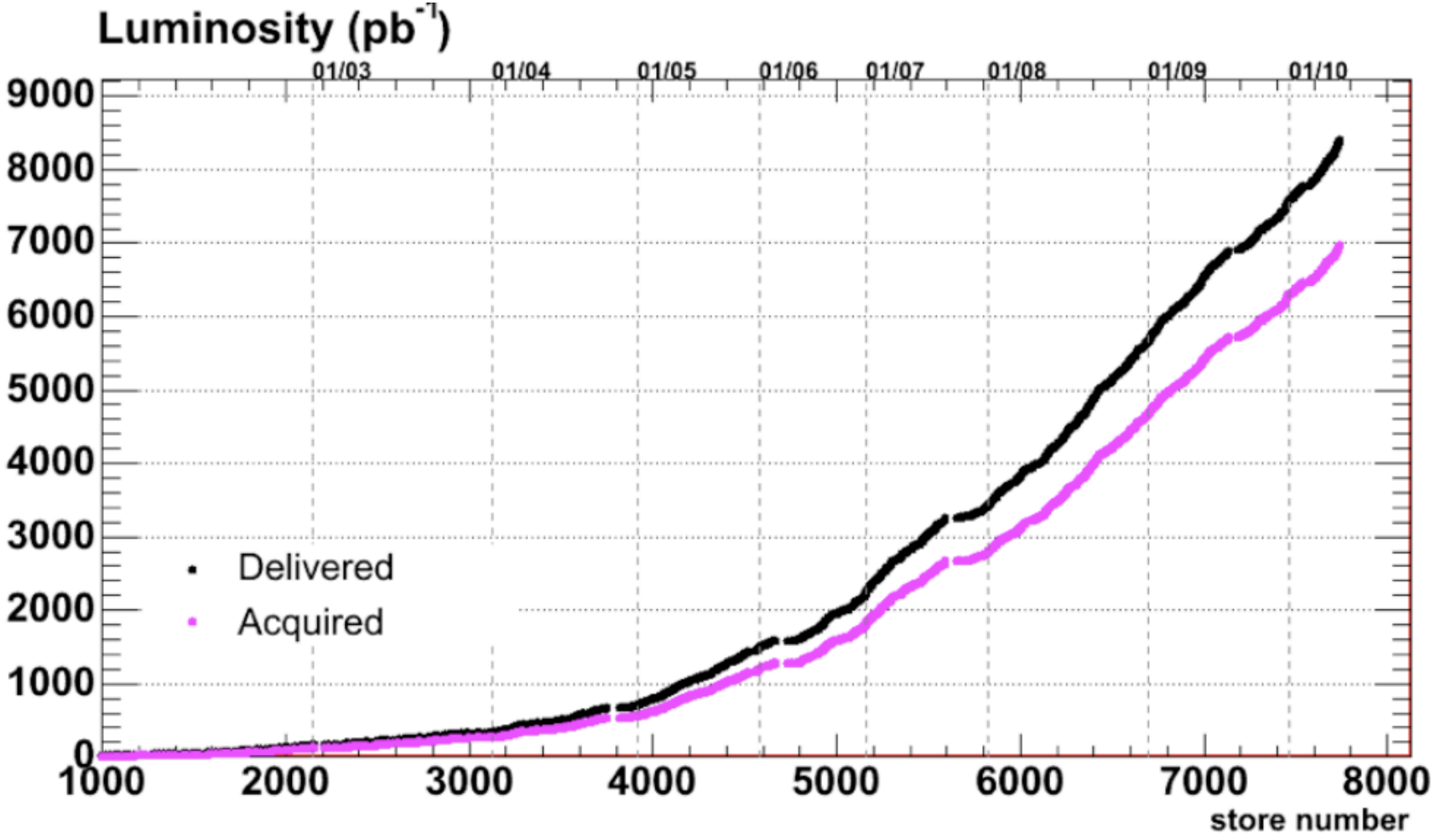
Are we speaking the wrong language?

"Matthews ... we're getting another one of those strange 'aw blah es span yol' sounds."

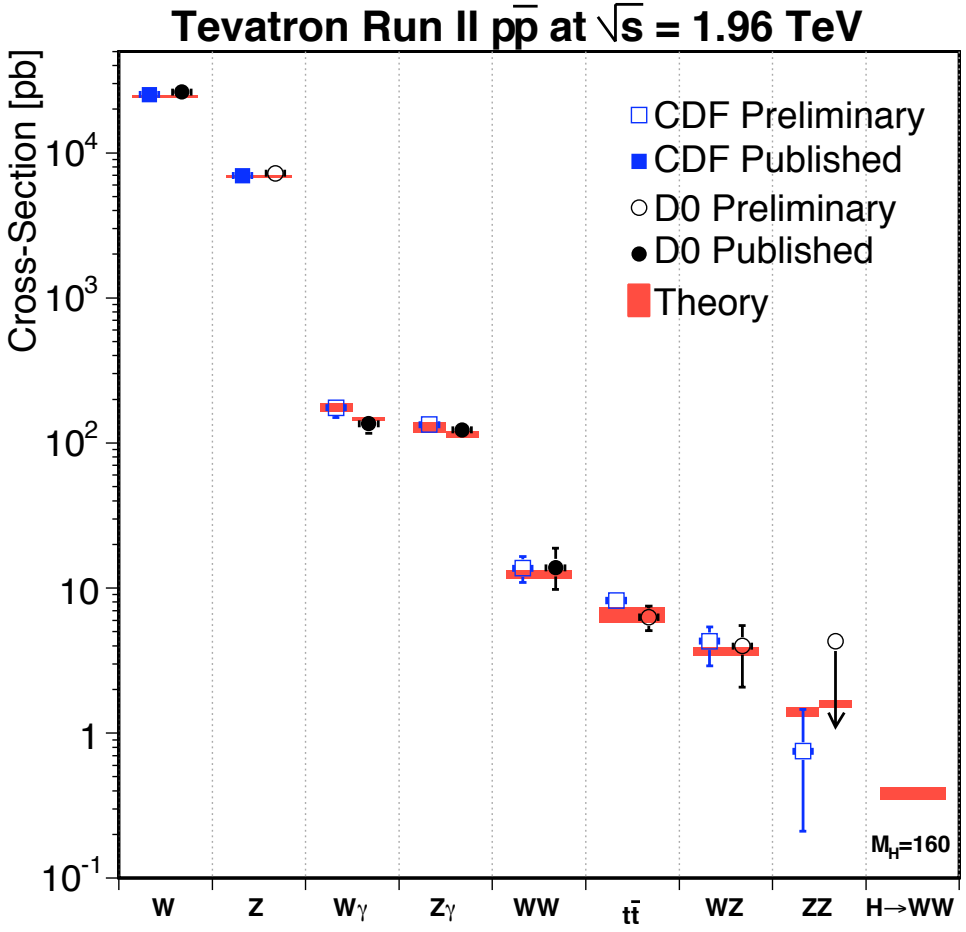
CDF



Dataset


Luminosity (pb^{-1})
01/03
01/04
01/05
01/06
01/07
01/08
01/09
01/10
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Delivered
Acquired
1000
2000
3000
4000
5000
6000
7000
8000
store number

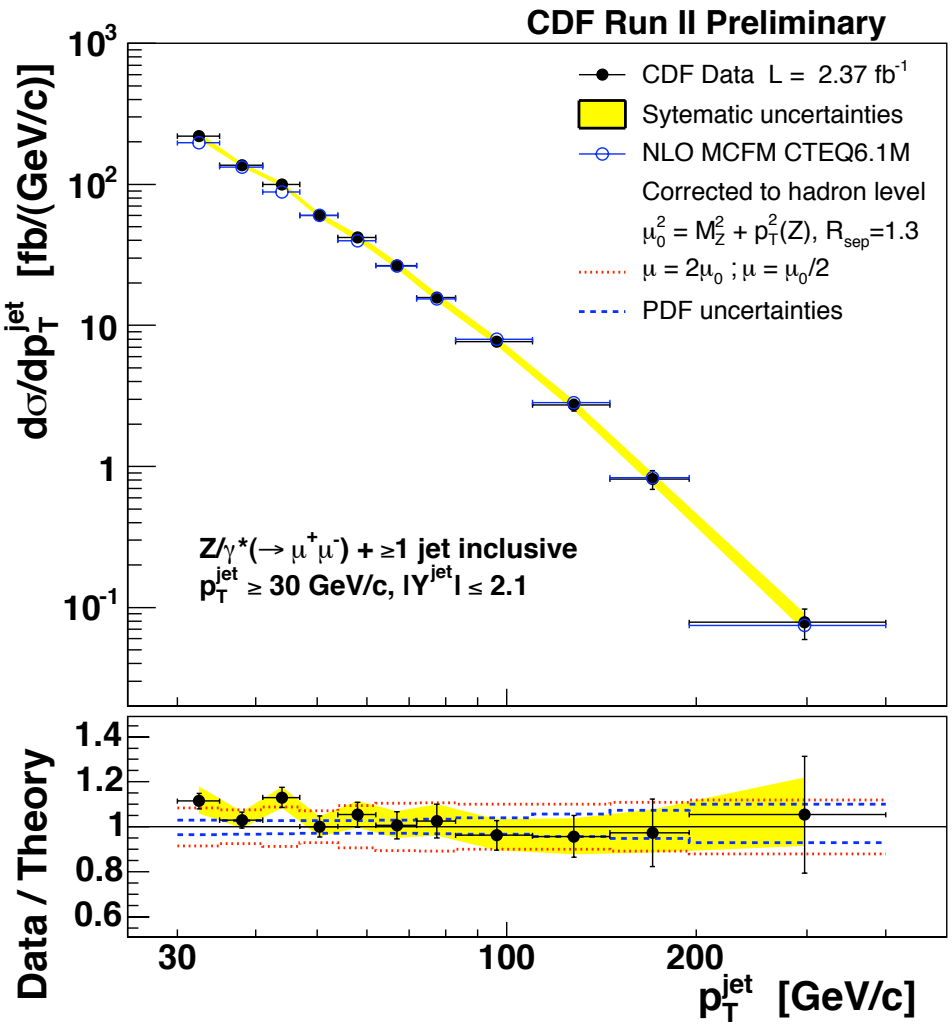
Physics Program



Electroweak studies

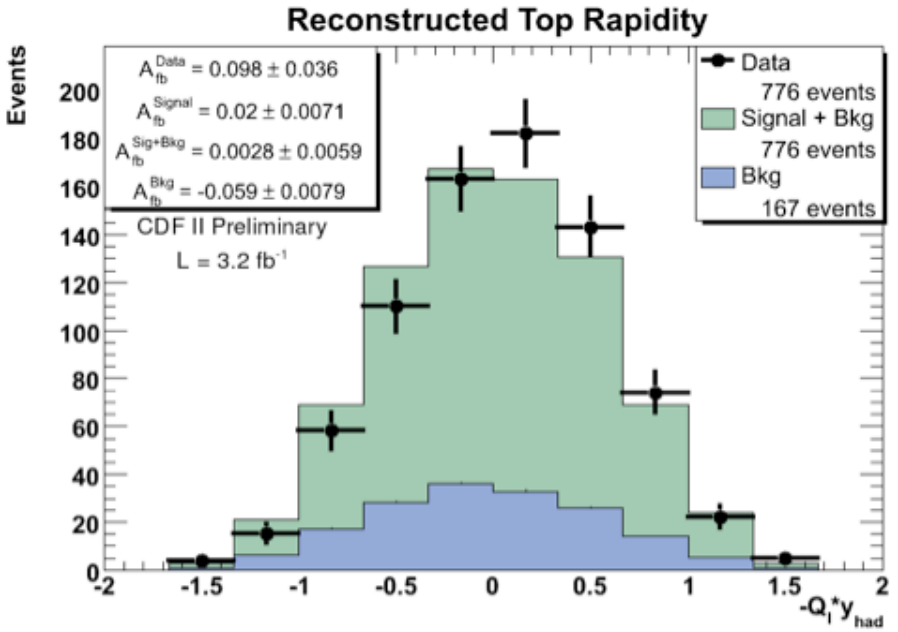
Z+jets

Looking in depth at all of our standard candles

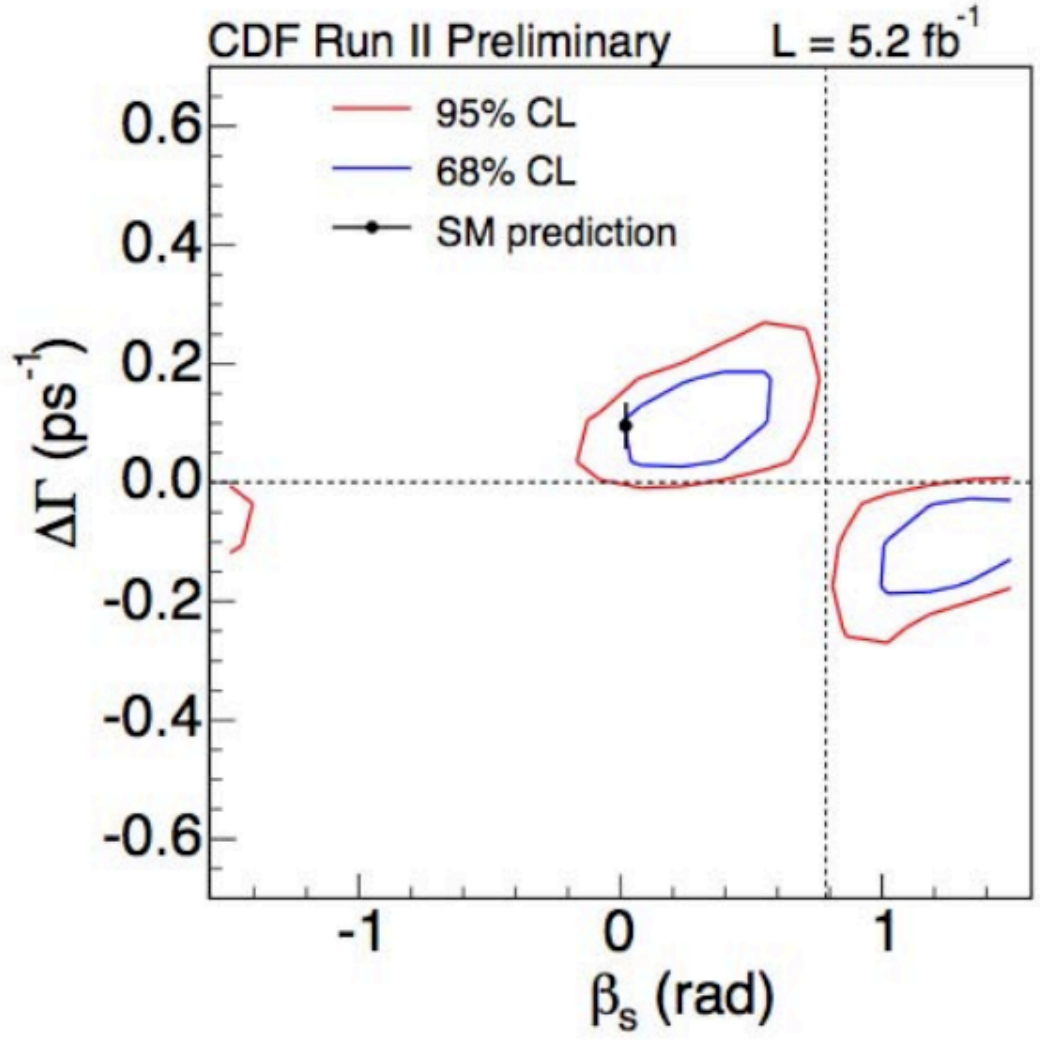


top rapidity

Some intriguing things have been revealed

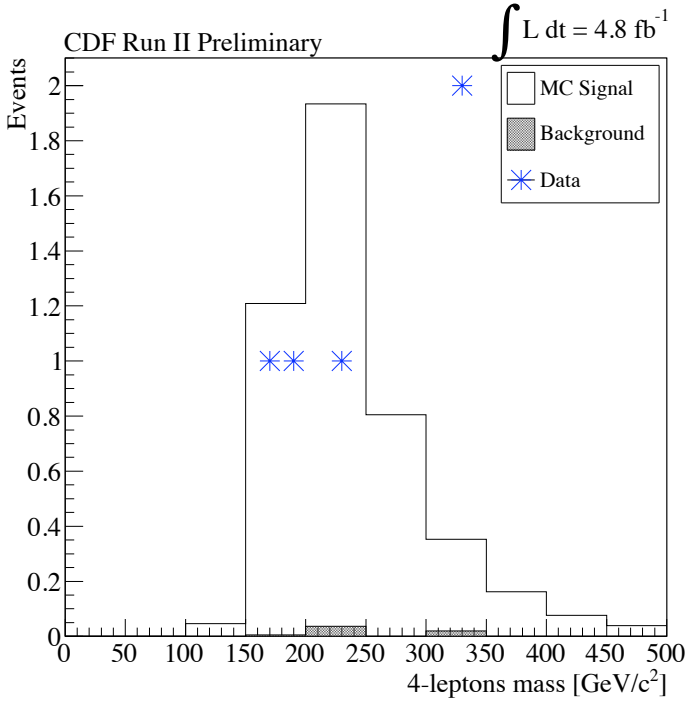


B physics

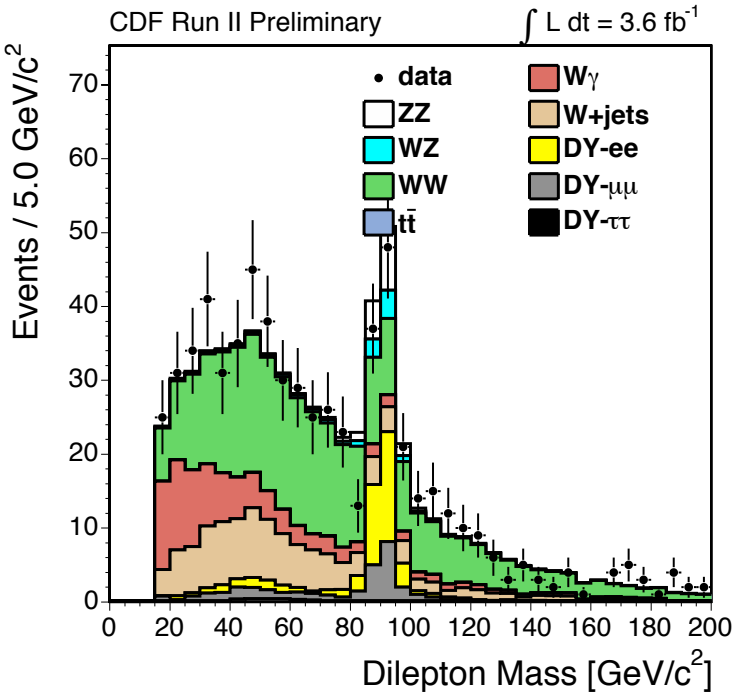

CDF Run II Preliminary
L = 5.2 fb-1
95% CL
68% CL
SM prediction
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
ΔΓ (ps-1)
-1
0
1
βs (rad)

Dibosons

ZZ->llll

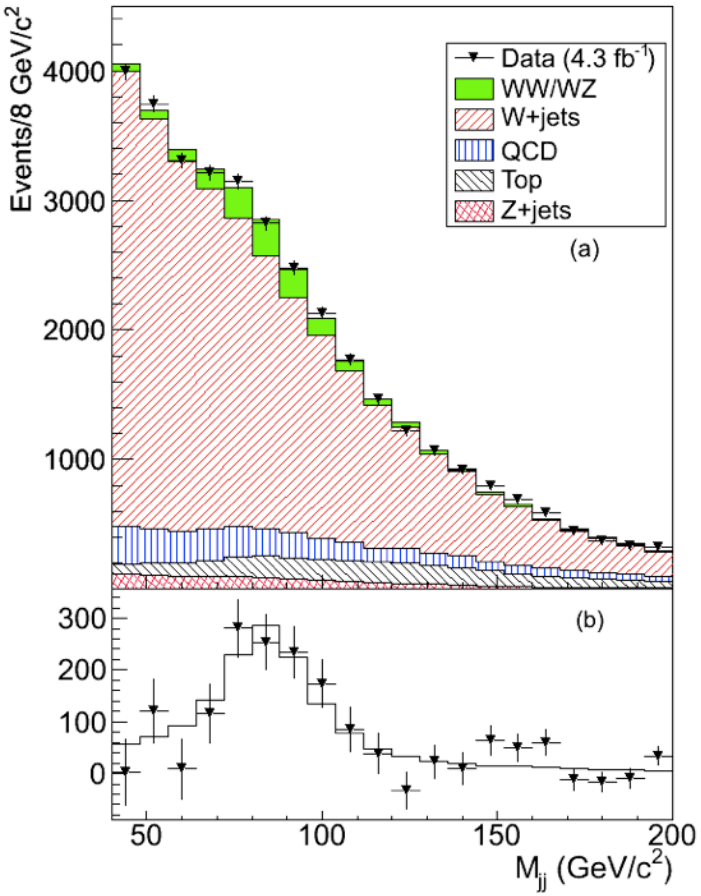


WW->llνν



Dibosons

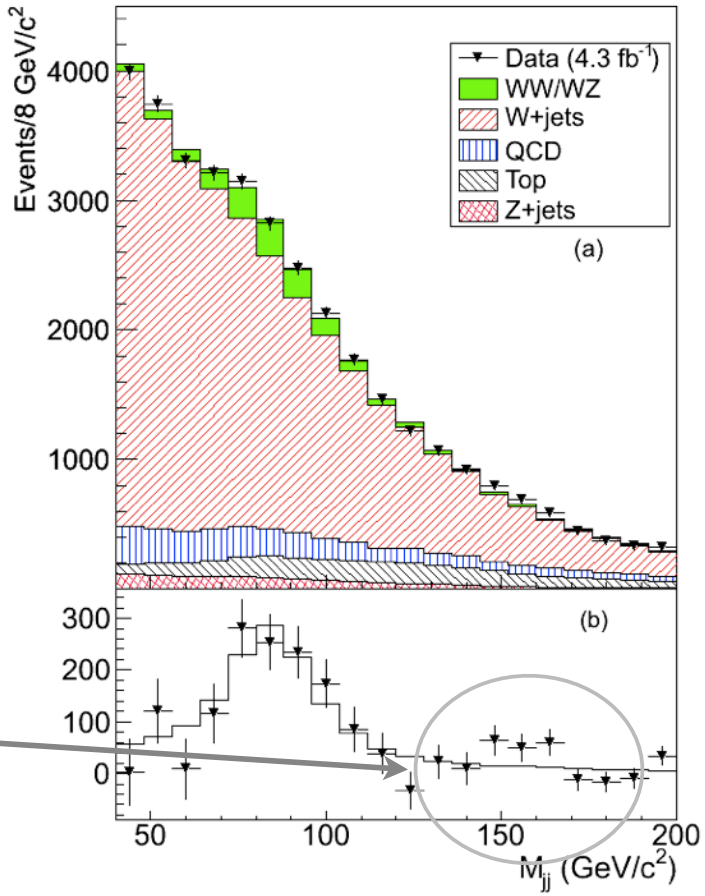
WW/WZ->lν jj



Dibosons

WW/WZ->lν jj

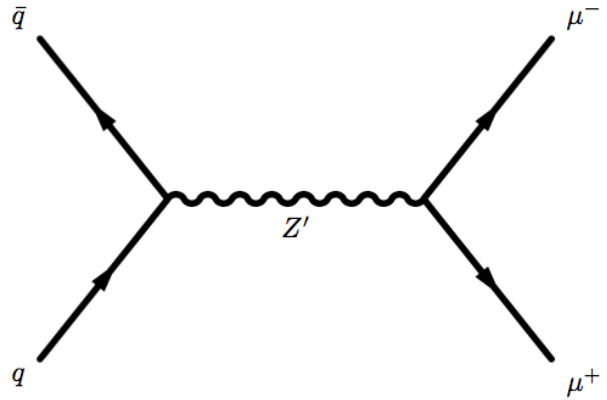
What's that?



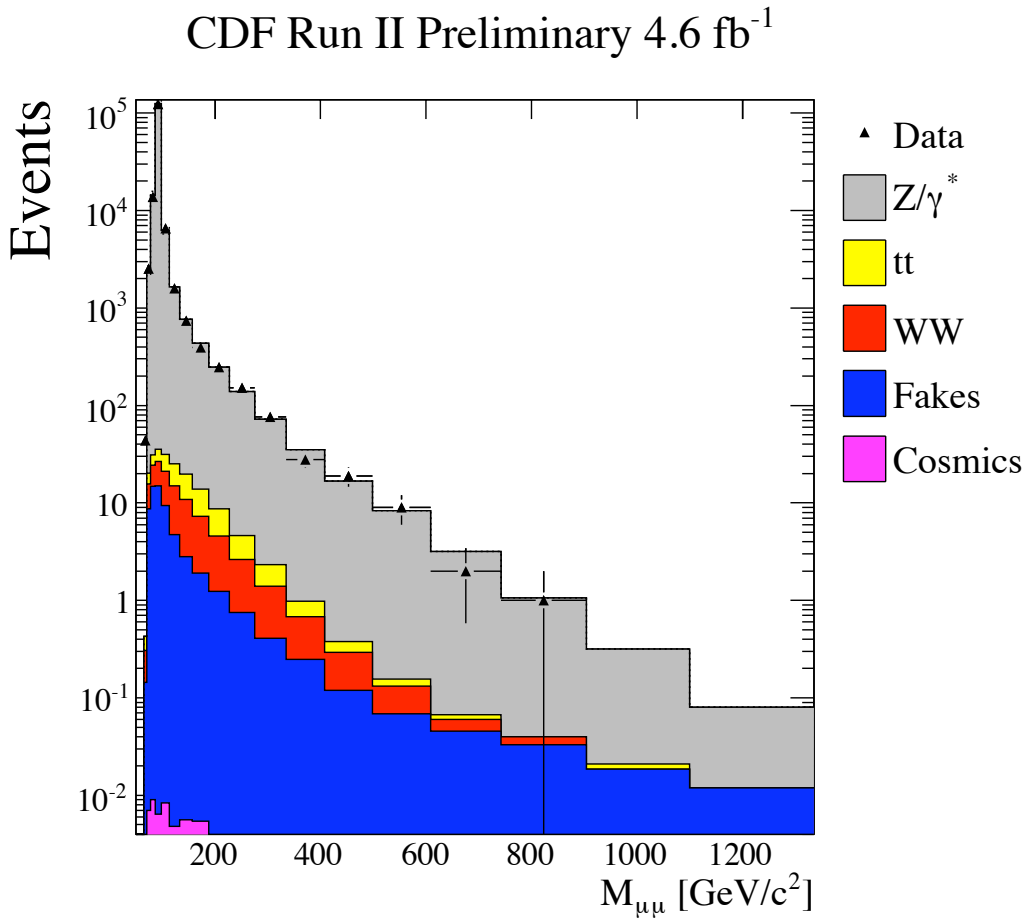
Searches

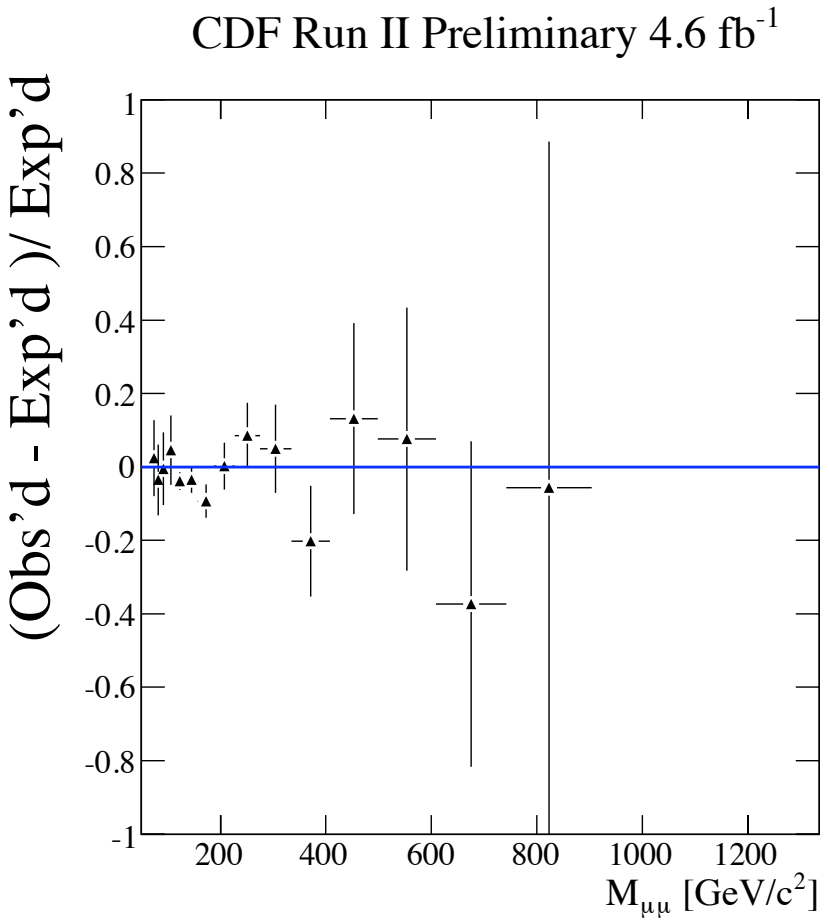
High mass resonances

Z′ to di-muons



High mass dimuon res.

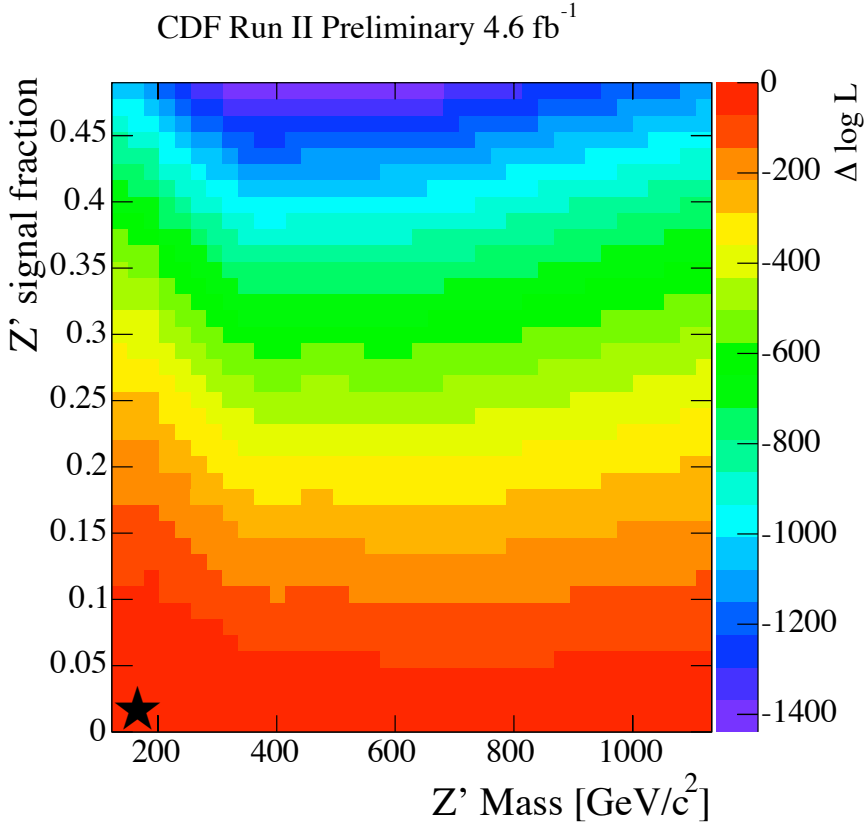


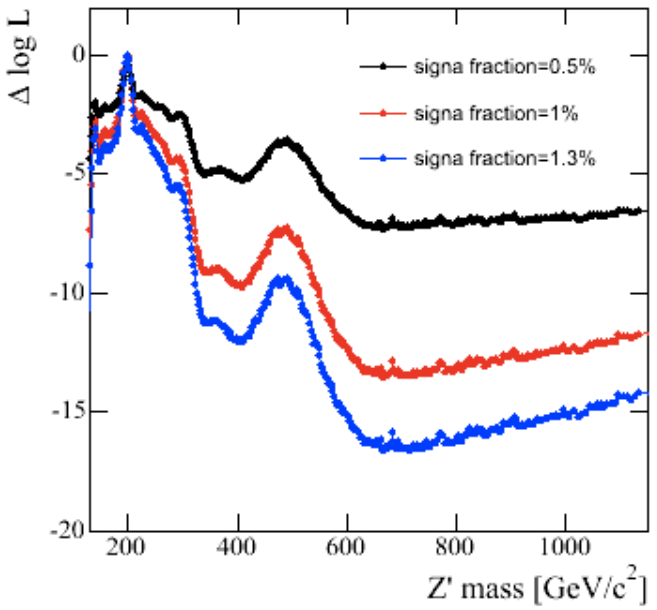


Z′ to muons

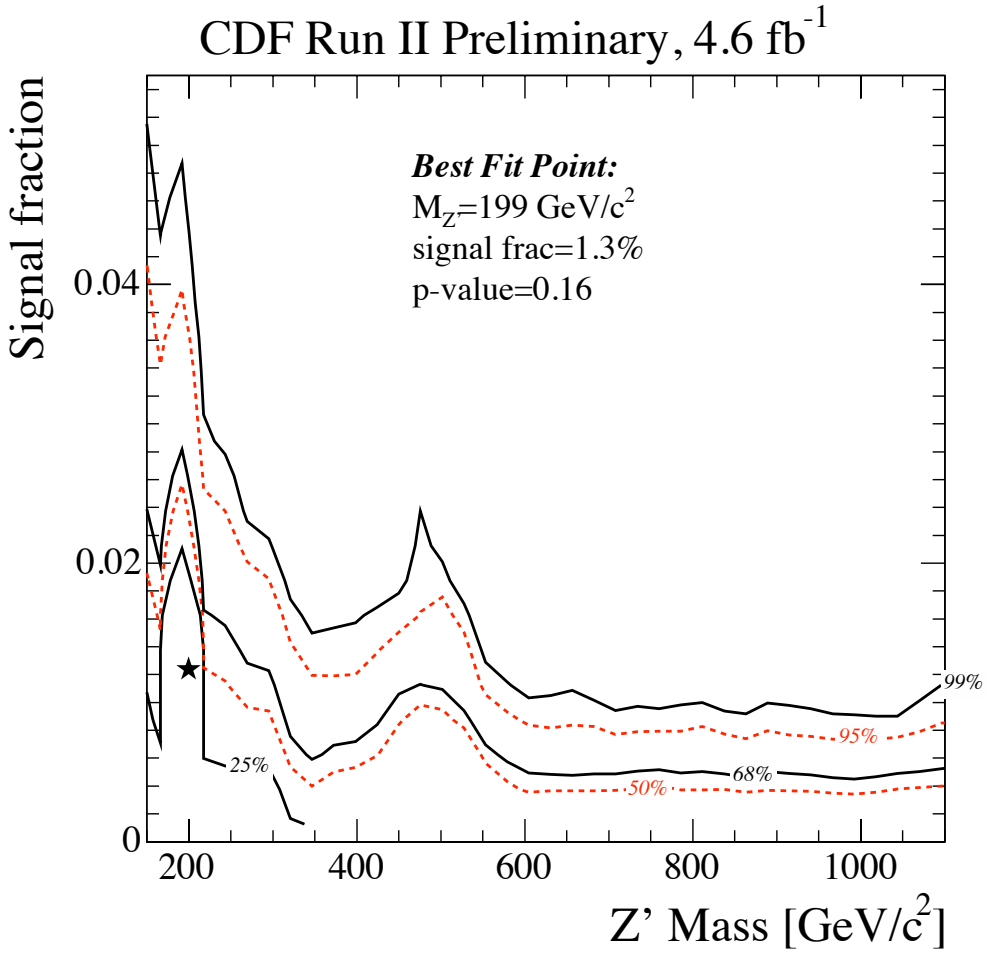
$$P_{Z'}(x_i|M_{Z'}) = \int dq_1 dq_2 |\mathcal{M}_{Z'}(M_{Z'})|^2$$

$$\times f_{PDF}(x_p) f_{PDF}(x_{\bar{p}}) T(p_1, q_1) T(p_2, q_2) P_{PT}(q_1 + q_2, N_{jets})$$

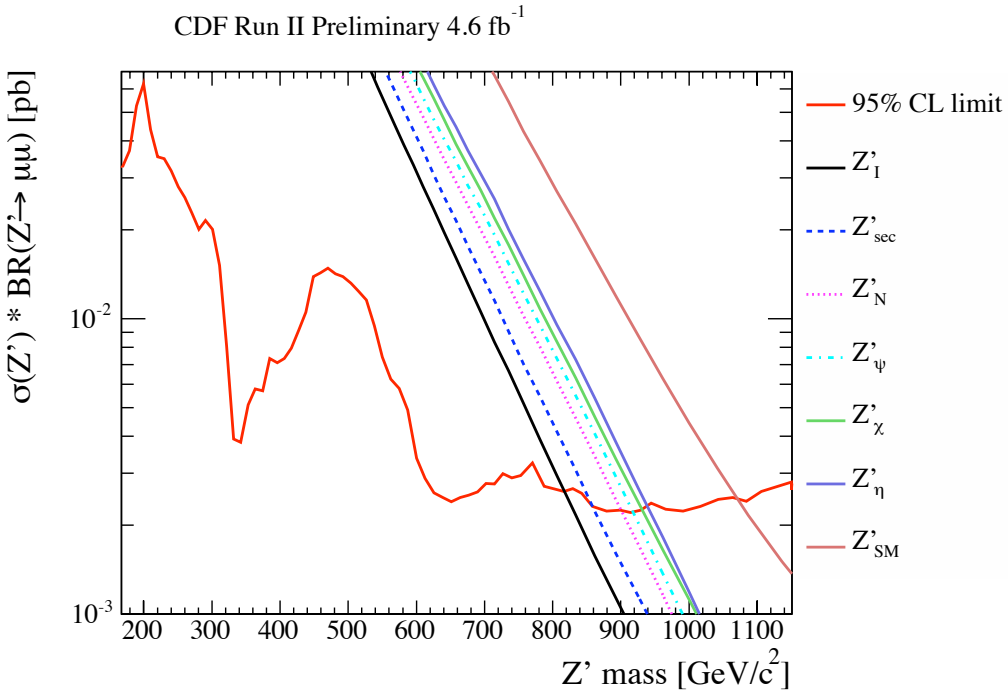




Z′ to muons


CDF Run II Preliminary, 4.6 fb-1
Signal fraction
Best Fit Point:
MZ'=199 GeV/c2
signal frac=1.3%
p-value=0.16
0.04
0.02
0
200
400
600
800
1000
Z' Mass [GeV/c2]
99%
95%
68%
50%
25%

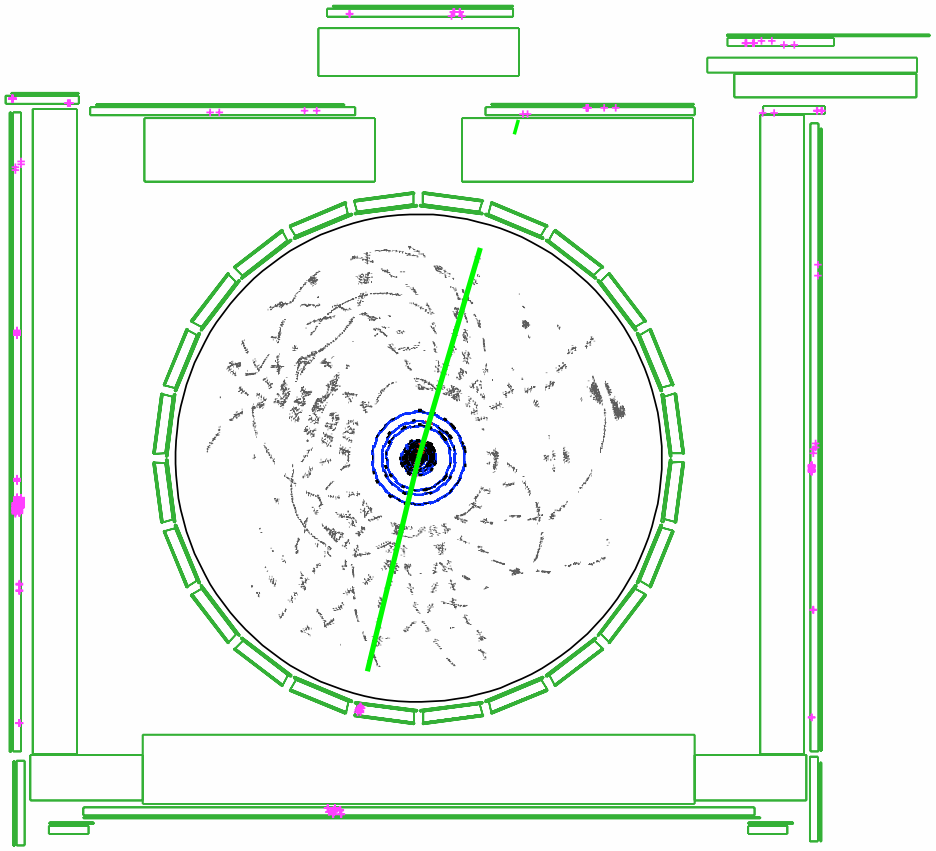
Z′ to muons

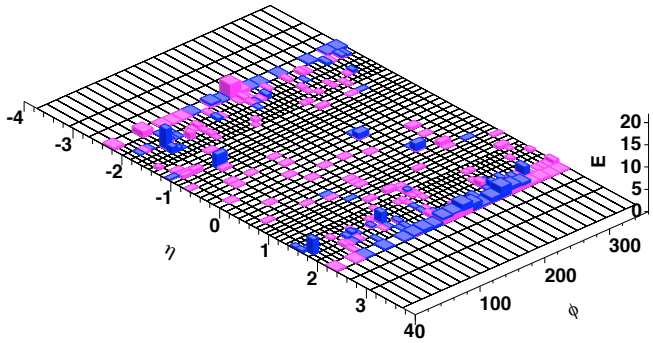


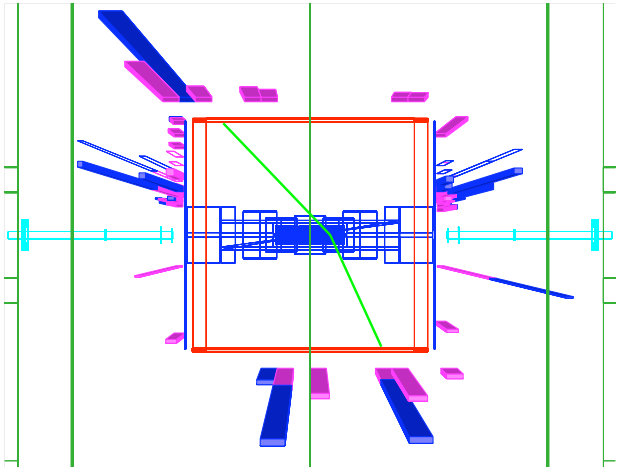
Model	Mass Limit (GeV/c^2)
Z'_l	817
Z'_{sec}	858
Z'_N	900
Z'_ψ	917
Z'_χ	930
Z'_η	938
Z'_{SM}	1071

M_{ll} = 882 GeV

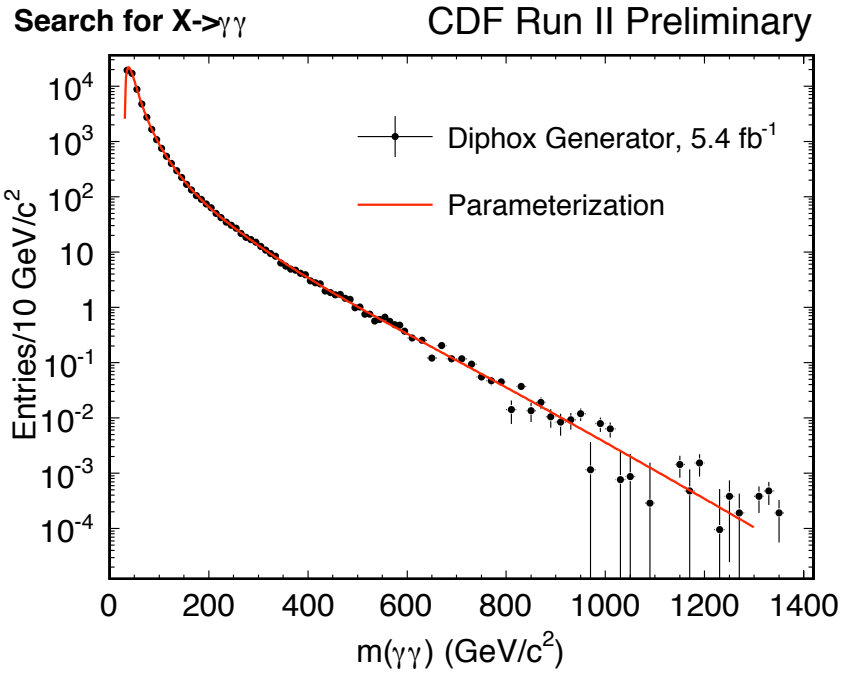
CDF Run II Preliminary

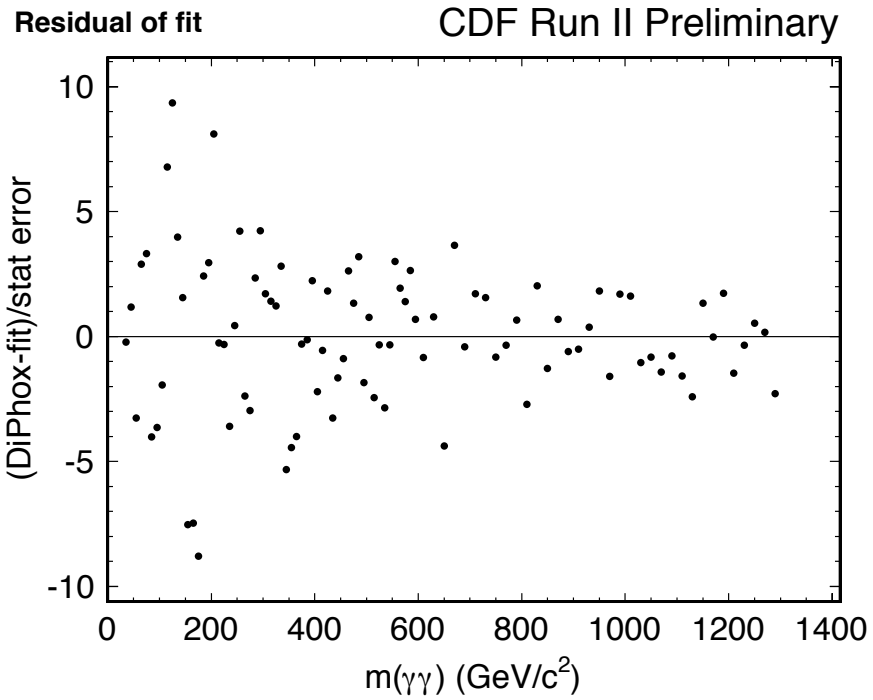




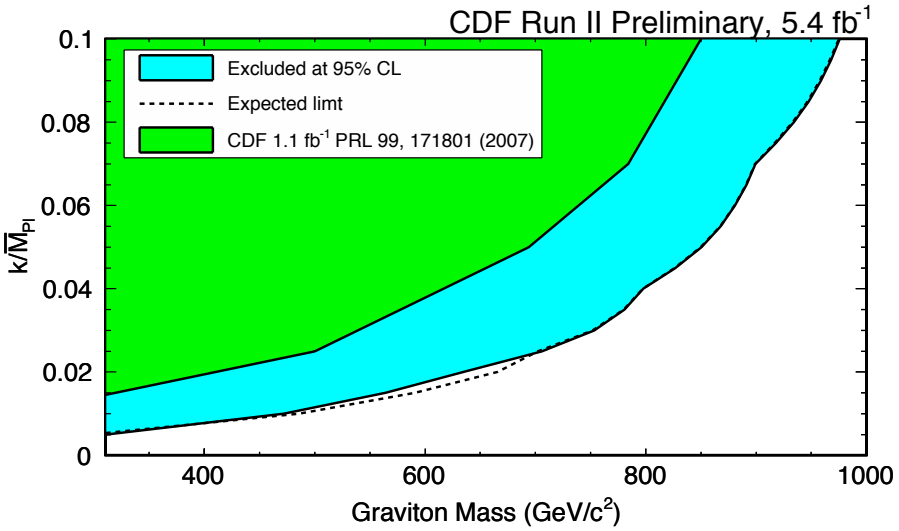


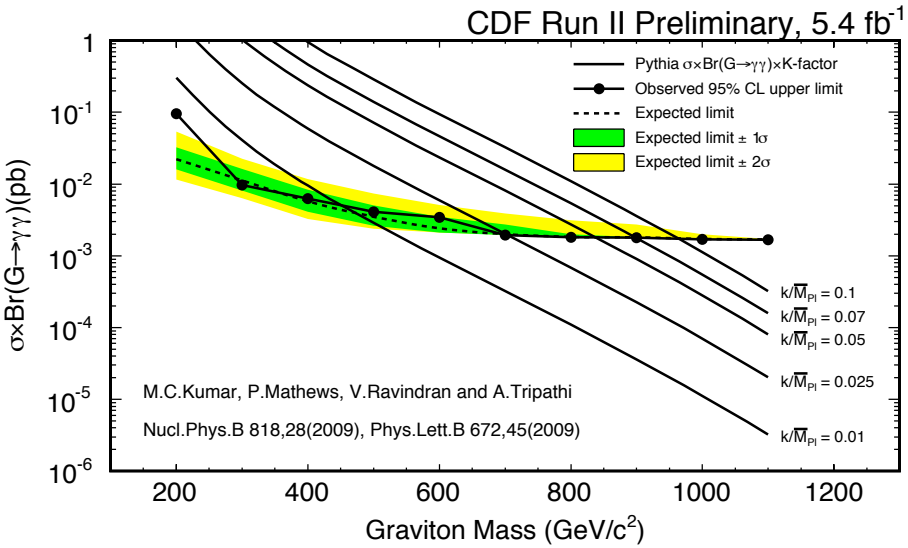
Diphoton resonances





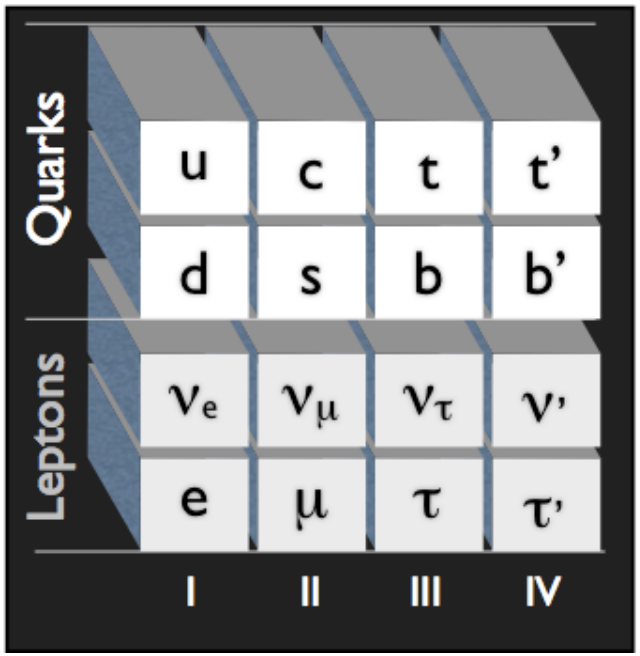
Diphoton resonances



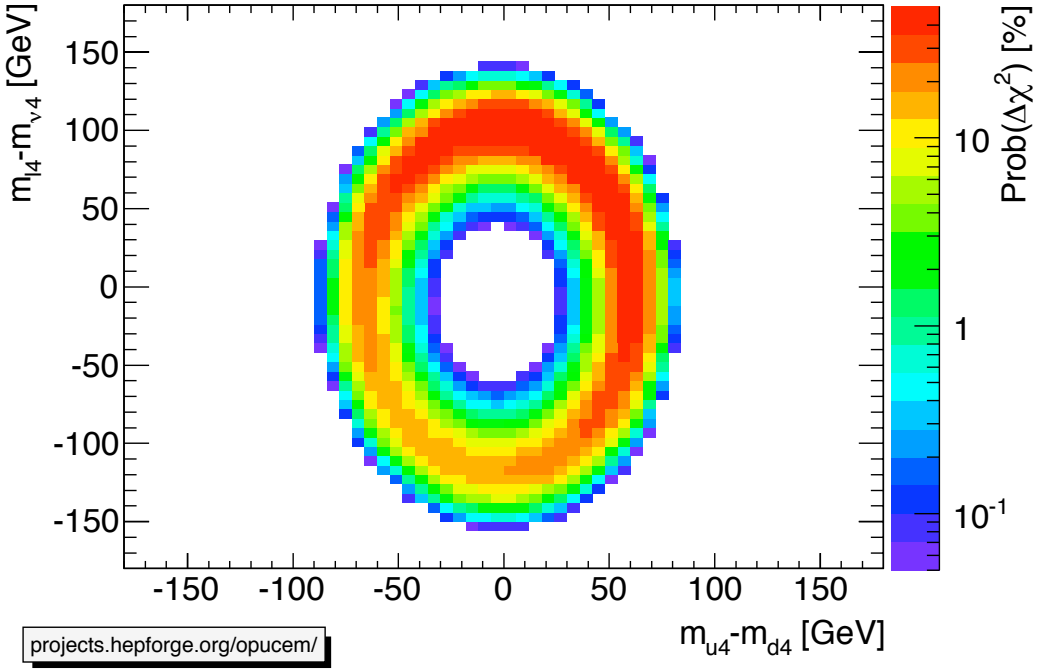


4th generation

PDG says it's ruled out to 6σ....



..that's true if the masses are degenerate



t'

Selection

1 lepton

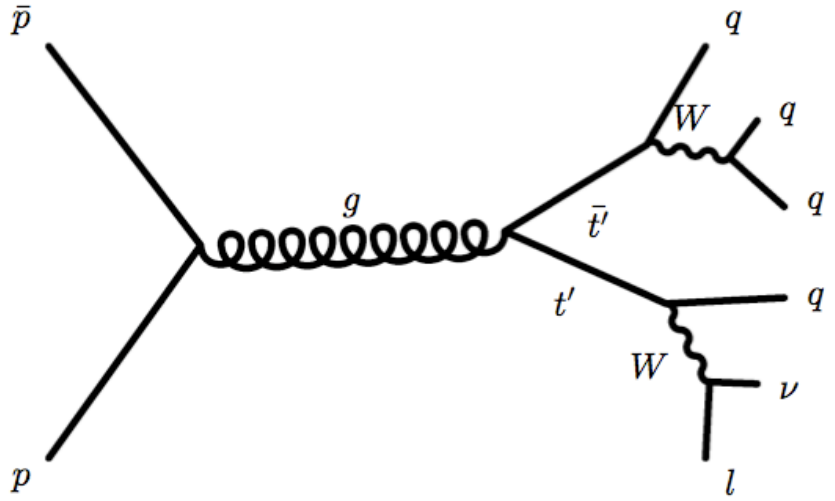
pt>20 GeV

4 jets

pt>20 GeV

Missing transverse energy

>20 GeV

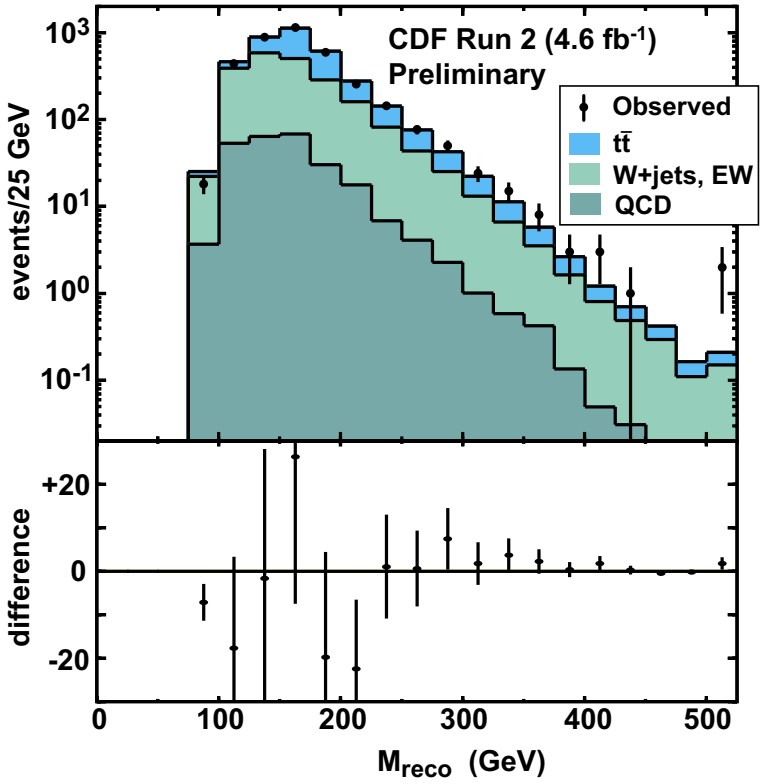


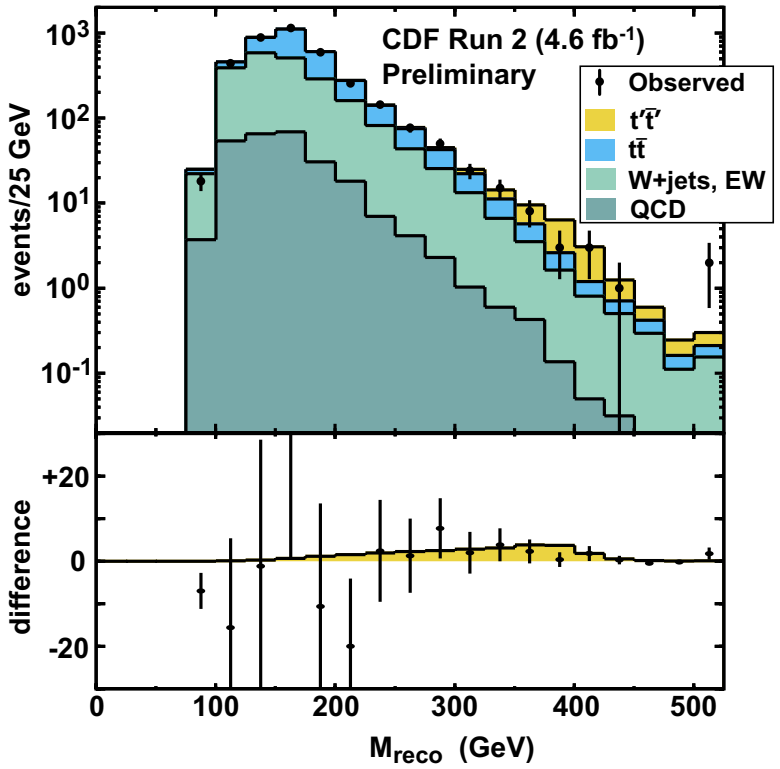
Sample

4.6/fb

t′

Fit mass of each event





Room on tail for signal events

t′

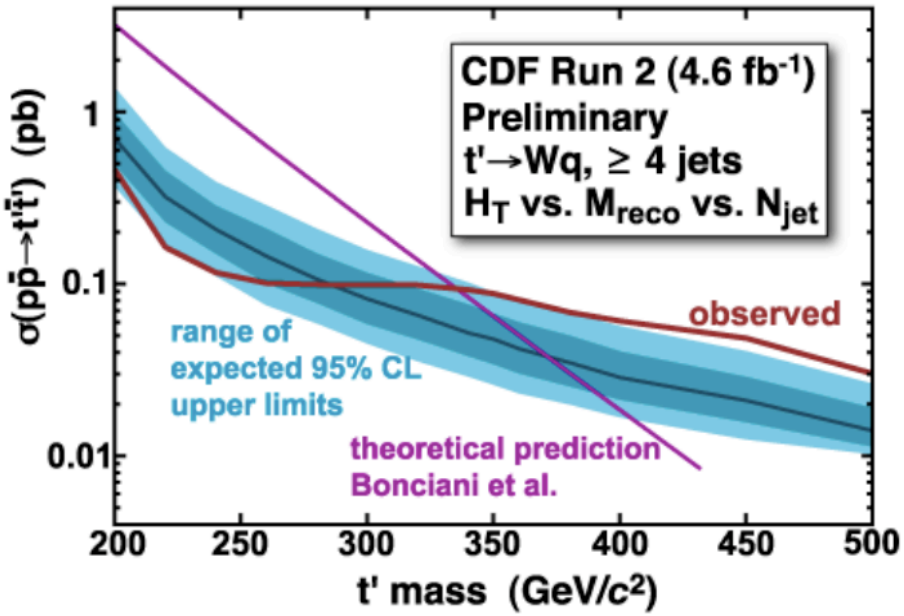
Limit

$m_{t'} > 335$ GeV

Plans

WbWb→lνb qqb mode

WqWq→lνq lνq mode



b′

Selection

2 like-signed leptons

pt>20 GeV

at least one isolated

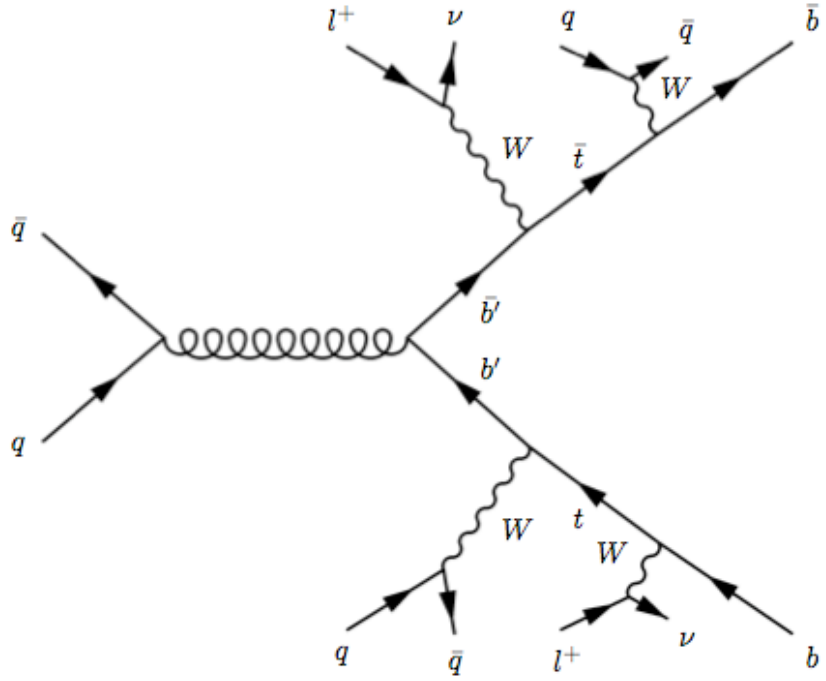
2 jets

pt>20 GeV

>=1 btags

Missing transverse energy

>20 GeV



Sample

2.7/fb

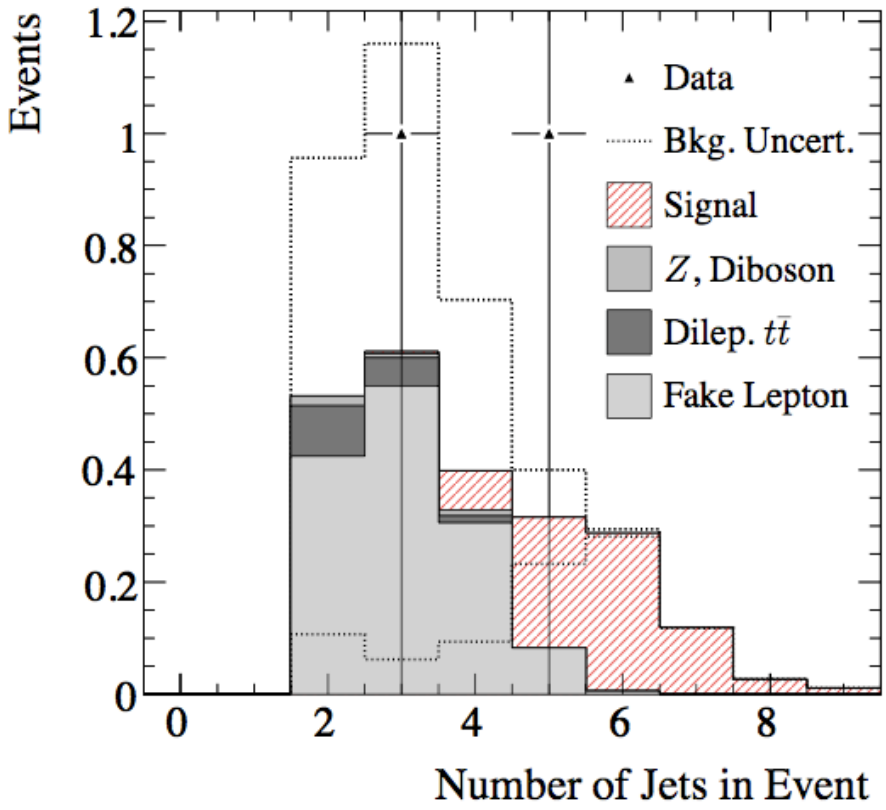
b′

Final selection

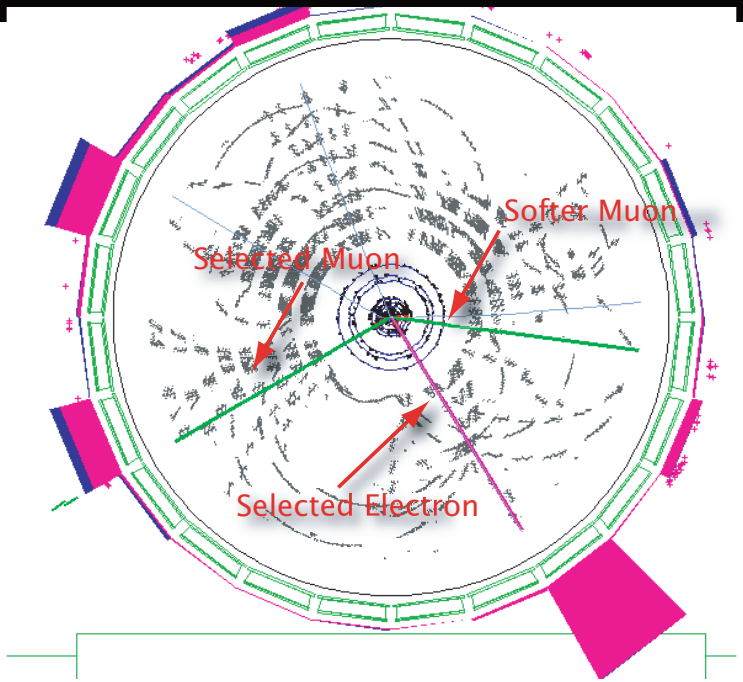
2 like-signed leptons

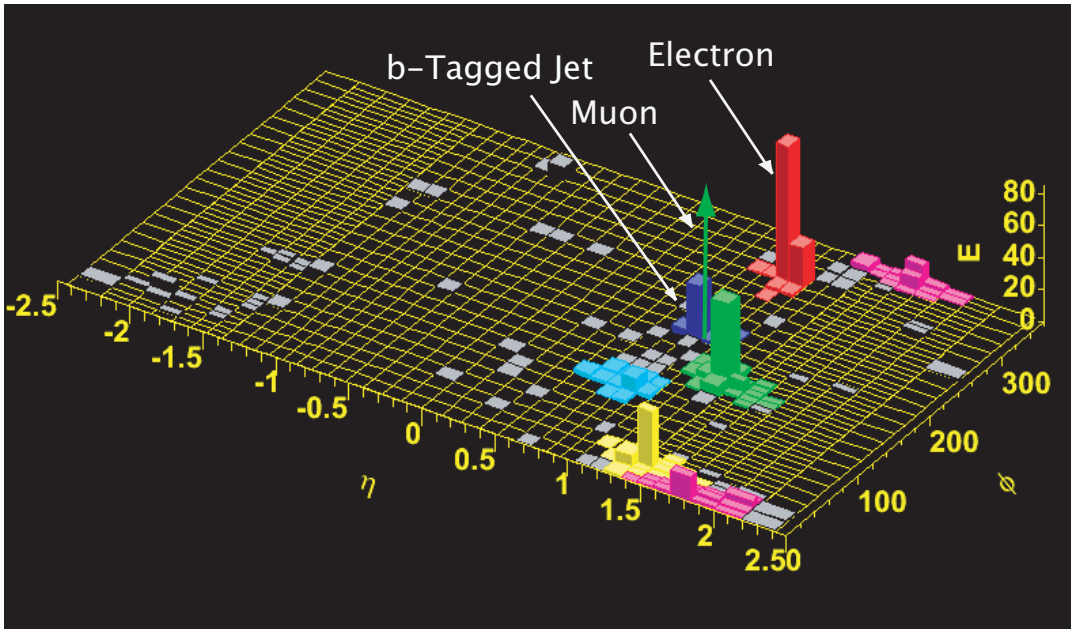
2 jets *>=1 btags*

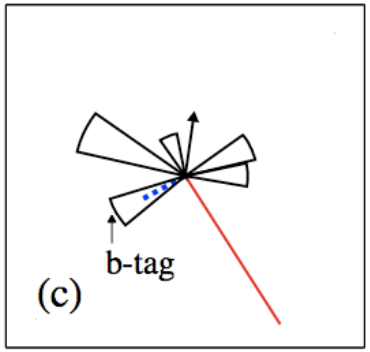
Missing transverse energy



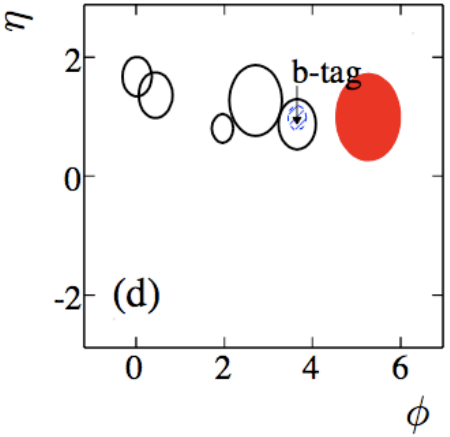
b′







r-ϕ Projection

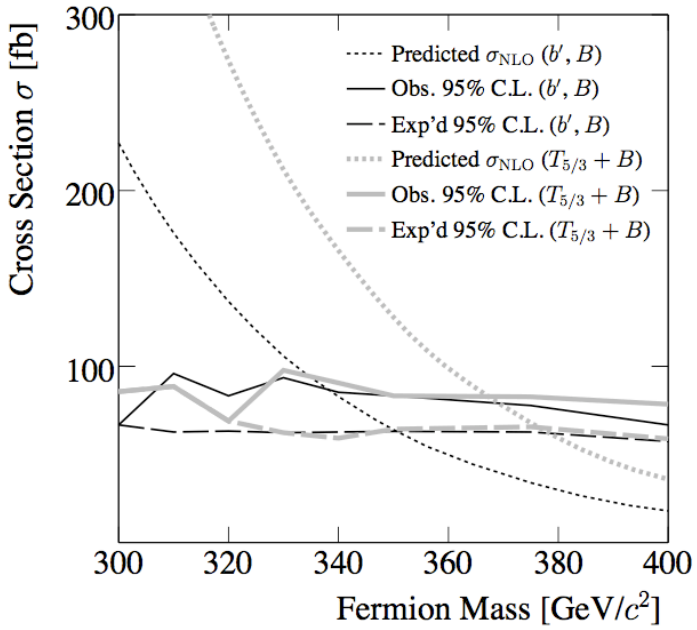


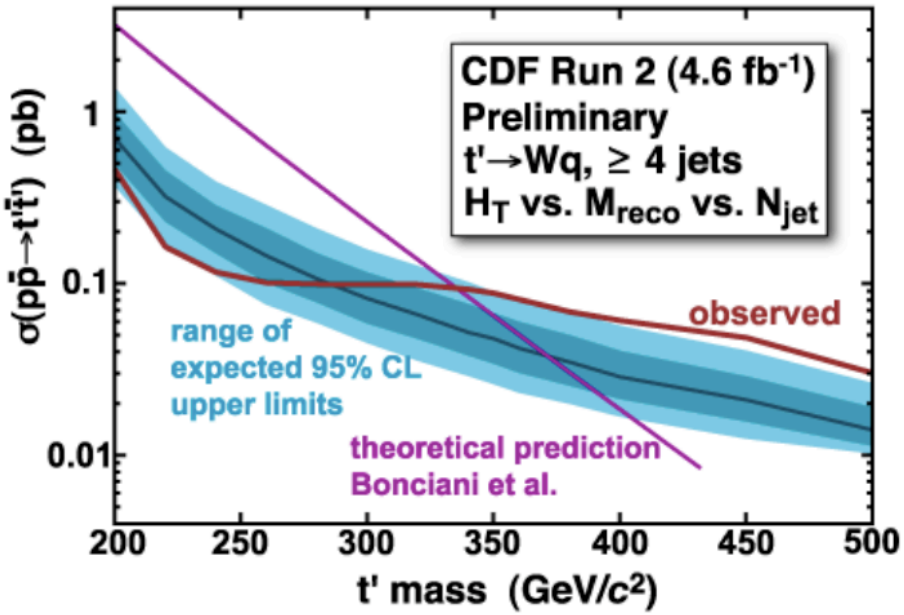
Jet

Electron

Muon

Direct searches

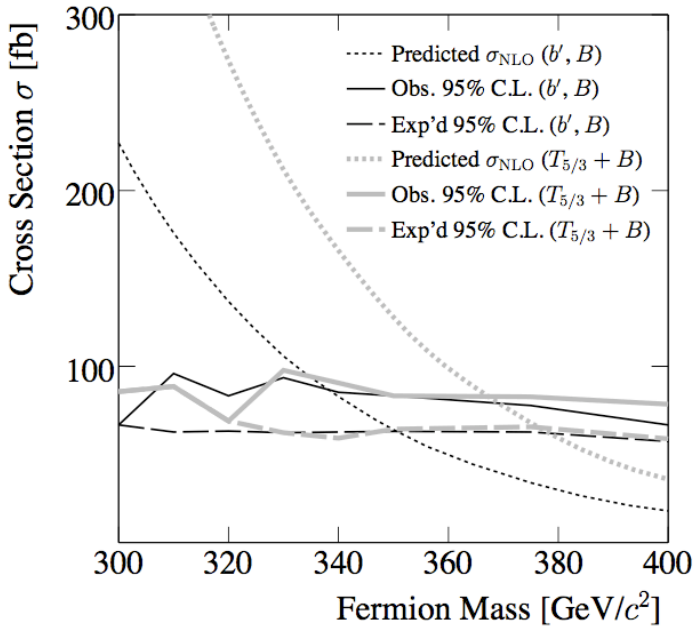


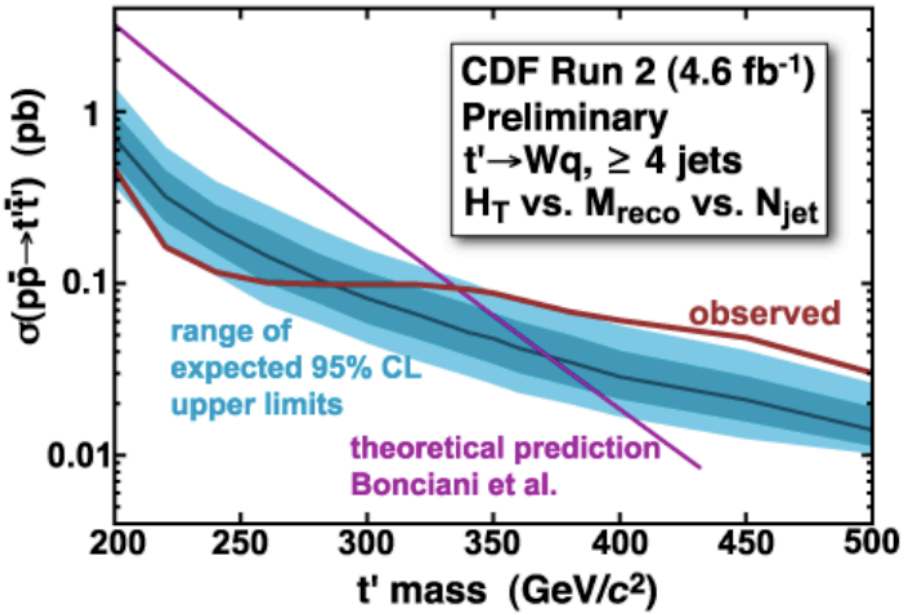


$m_{b'} > 338$ GeV

$m_{t'} > 335$ GeV

Direct searches





$m_{b'} > 338$ GeV

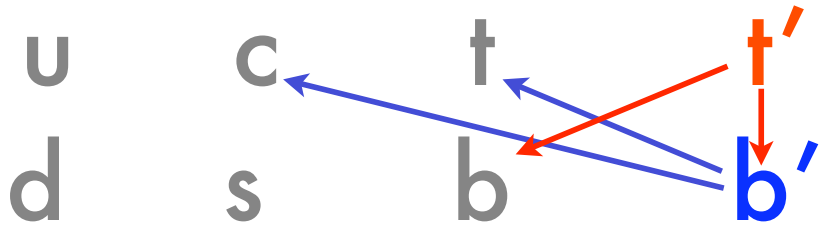
If BR(b′ →Wt)=100%

$m_{t'} > 335$ GeV

If BR(t′ →Wq)=100%

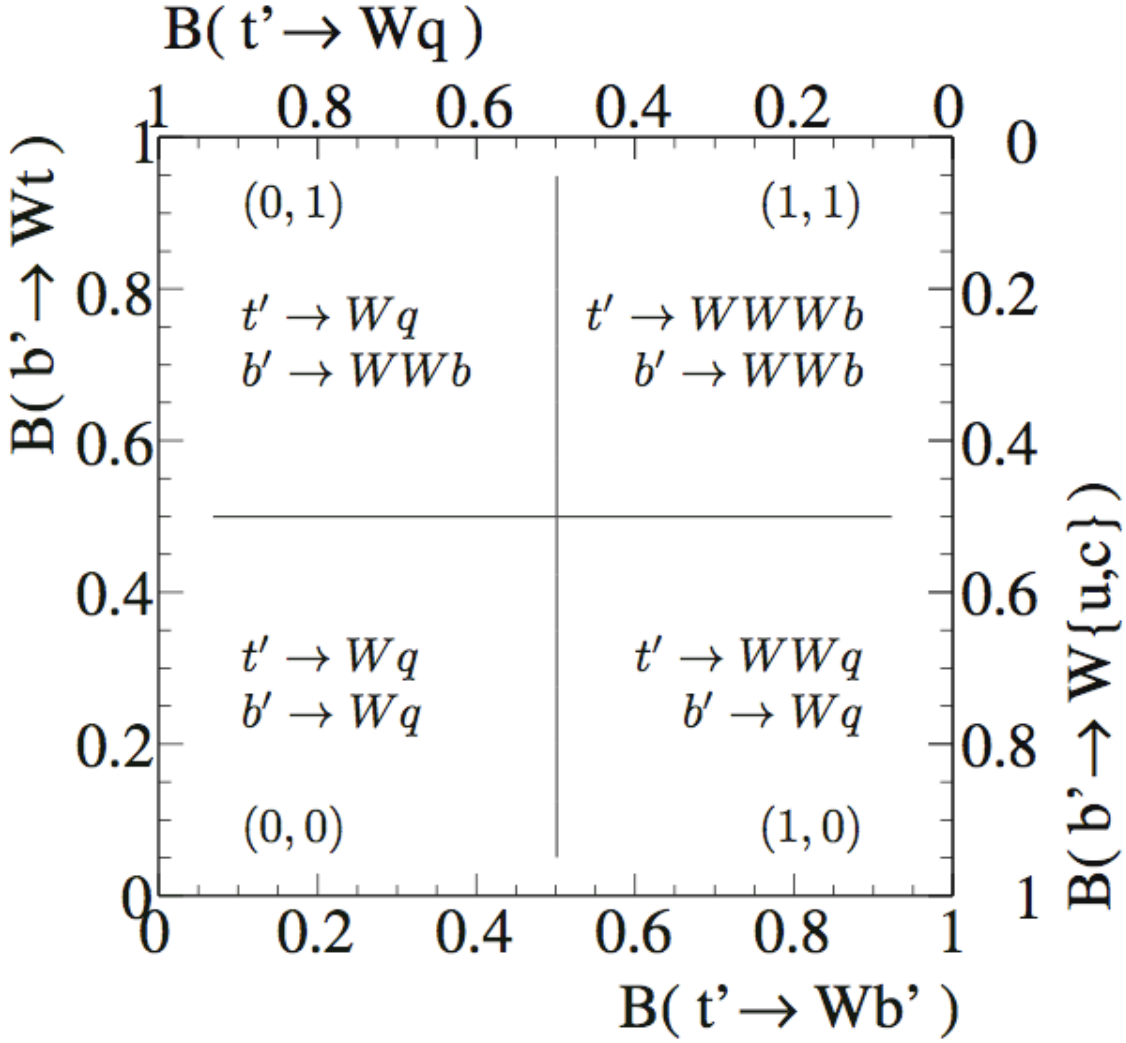
b′ and t′

If $m_{t'} > m_{b'}$

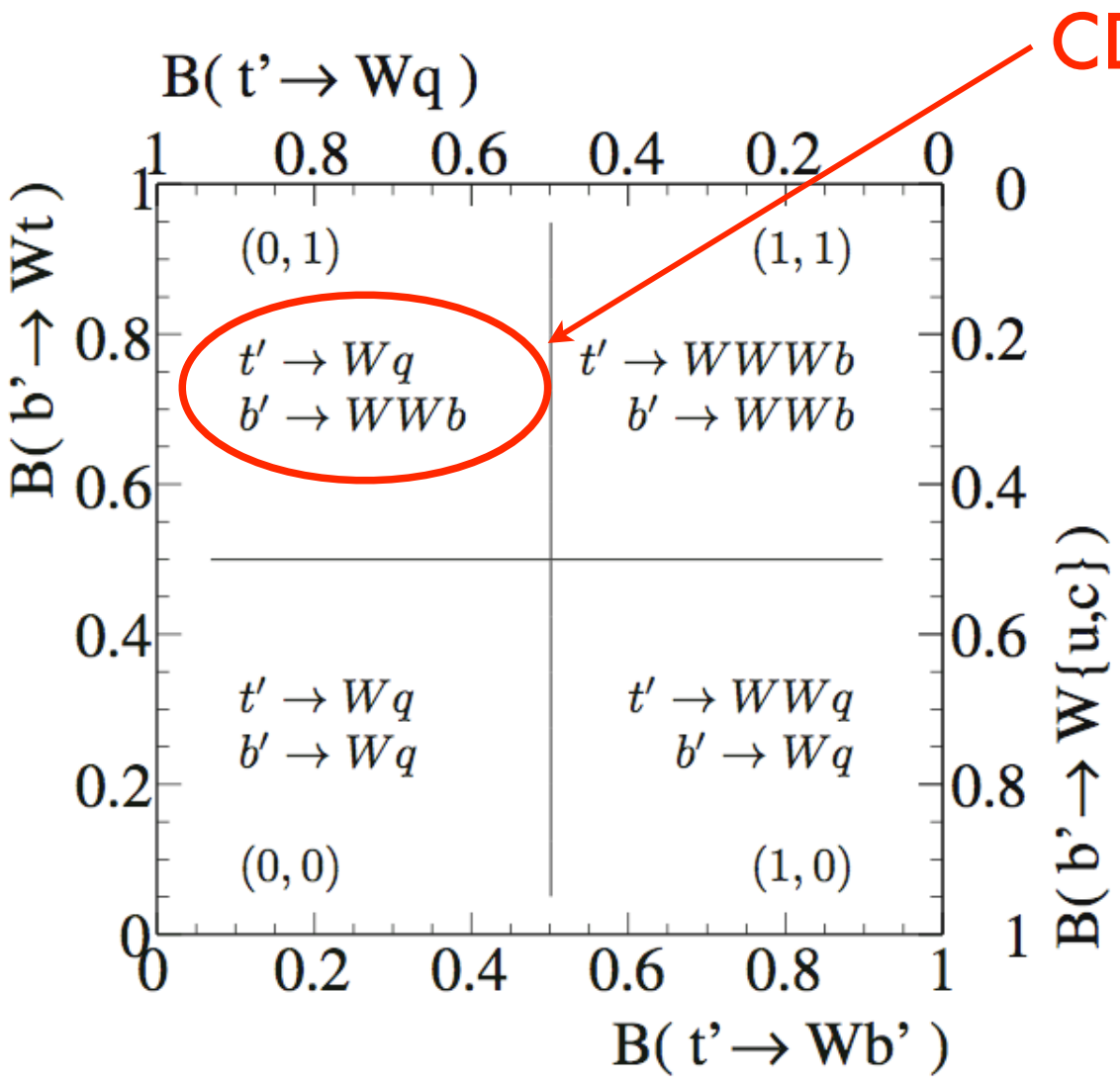


b′ and t′

Flacco, DW, Bar-Shalom & Tait
arvix: 1005.1077

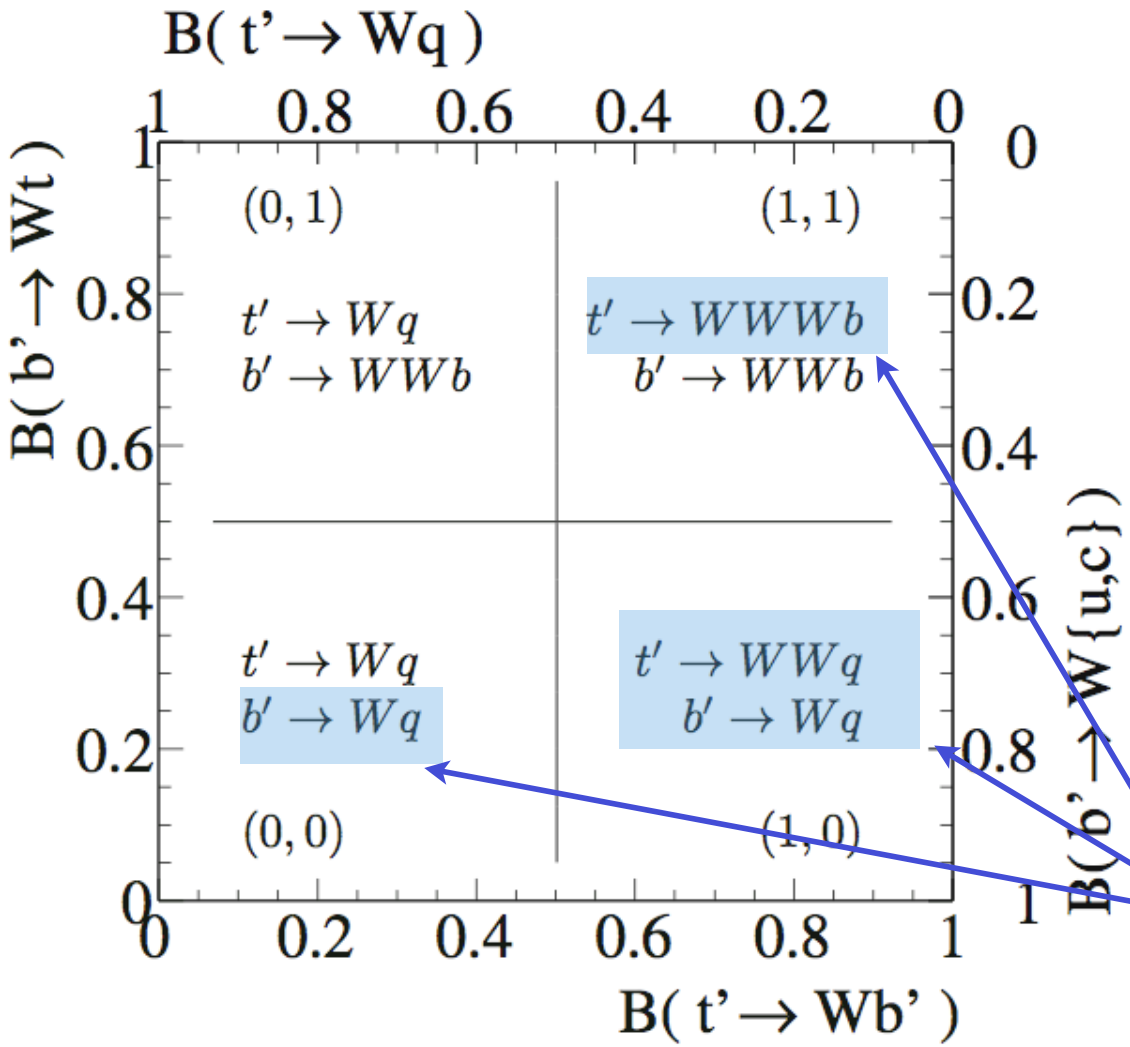


b′ and t′



Flacco, DW, Bar-Shalom & Tait
arvix: 1005.1077

b′ and t′



No direct limits!

Flacco, DW, Bar-Shalom & Tait
arvix: 1005.1077

t′ and b′

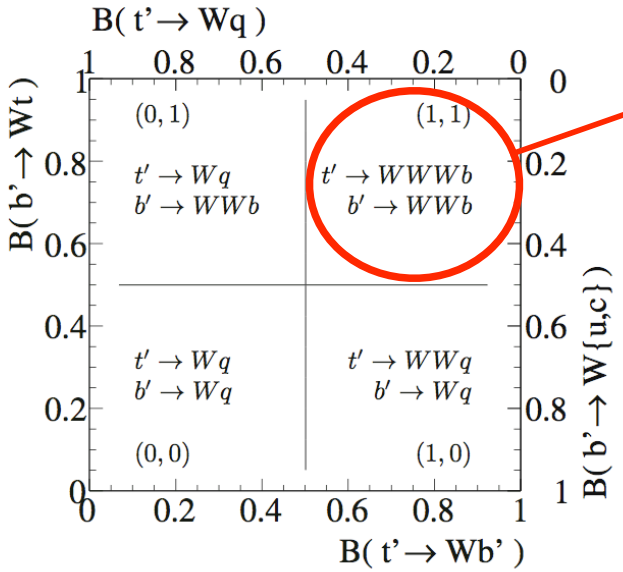
b′ only

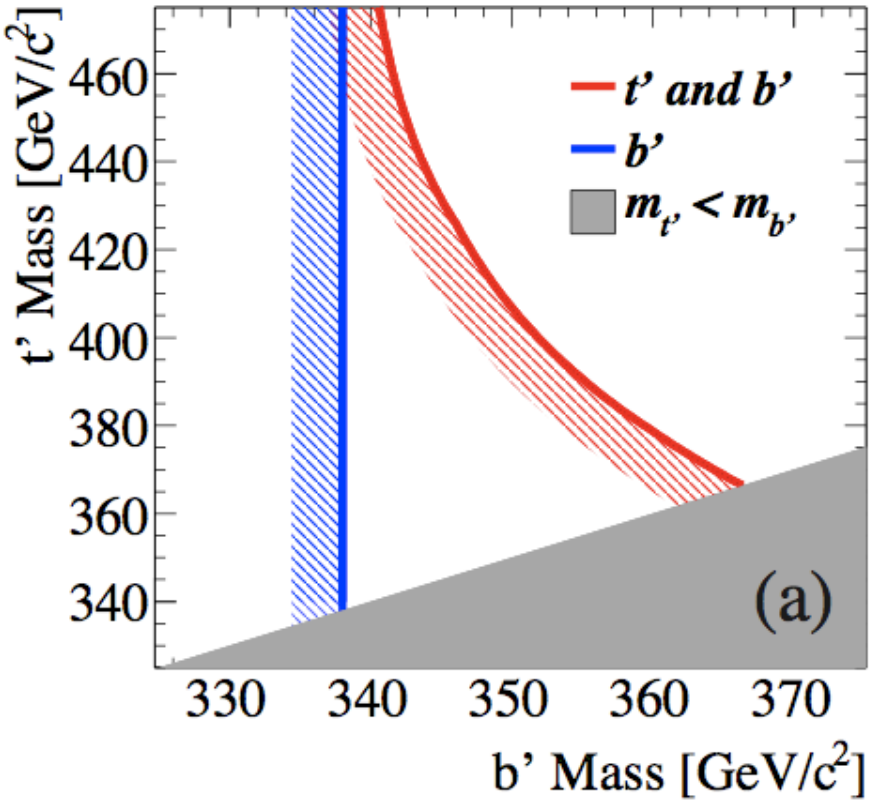
$m_{b'}$ > 335 GeV

b′+t′

$m_{b'}$ > 335-370 GeV

$m_{t'}$ > 360 GeV

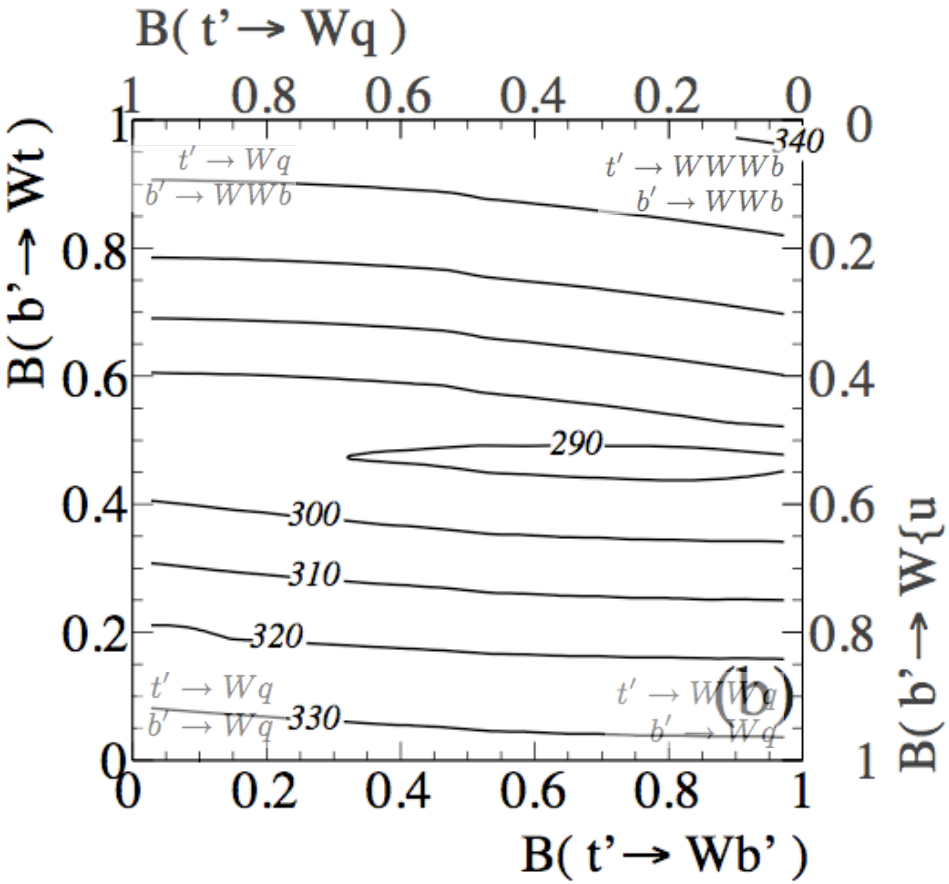


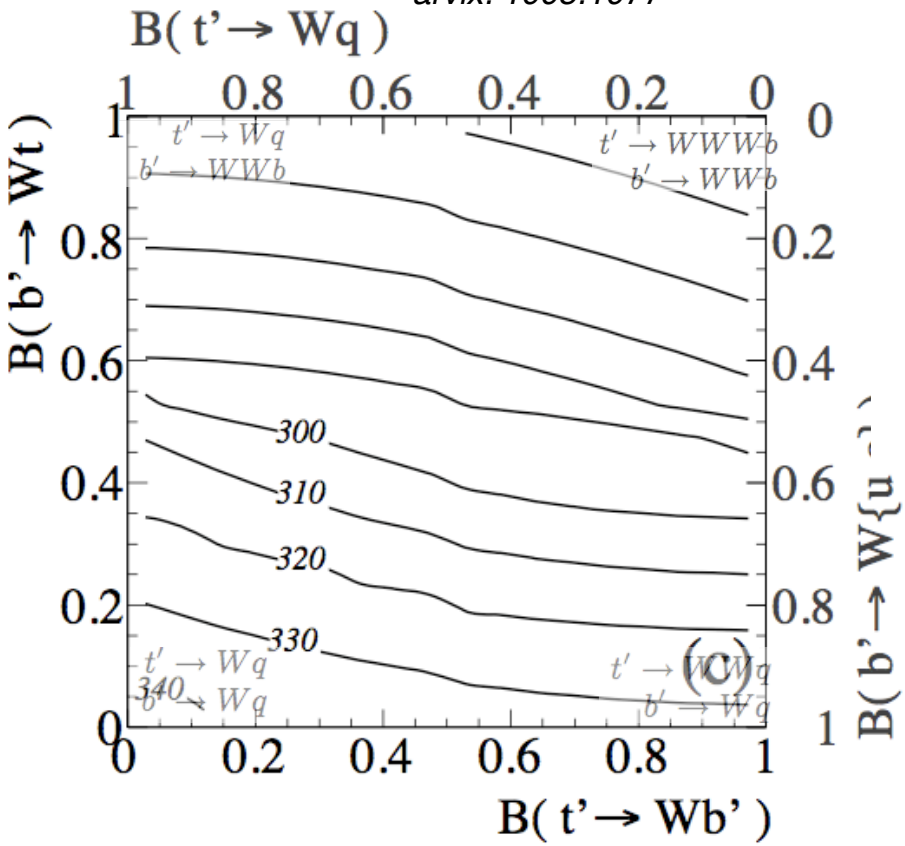


Flacco, DW, Bar-Shalom & Tait
arvix: 1005.1077

t′ and b′

Flacco, DW, Bar-Shalom & Tait
arvix: 1005.1077

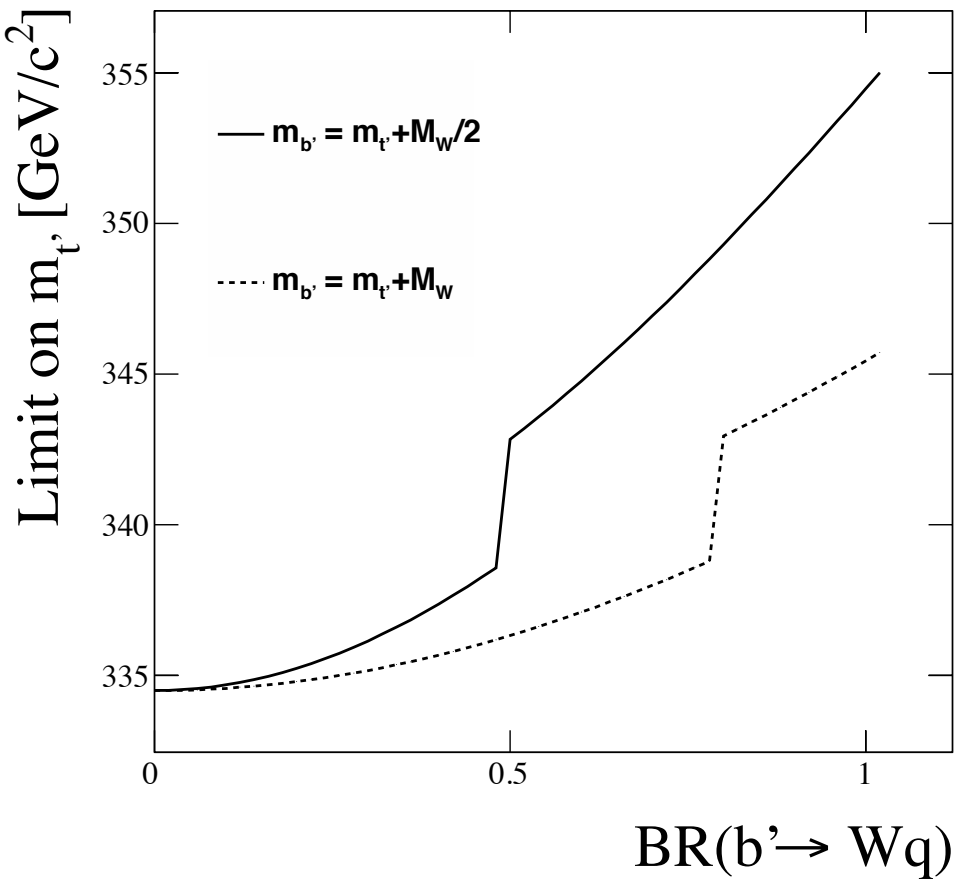




$m_{t'} = m_{b'} + 100$

$m_{t'} = m_{b'} + 50$

b′ heavier than t′?



l+4jets t′→4j search provides strong limits on t′ mass, imply strong limits on b′ if $m_{b'} > m_{t'}$, stronger than limits from WWb data.

Flacco, DW, Bar-Shalom & Tait
arvix: 1005.1077

heavy quarks

$m_{Q'} > 290$ GeV

Flacco, DW, Bar-Shalom & Tait
arvix: 1005.1077

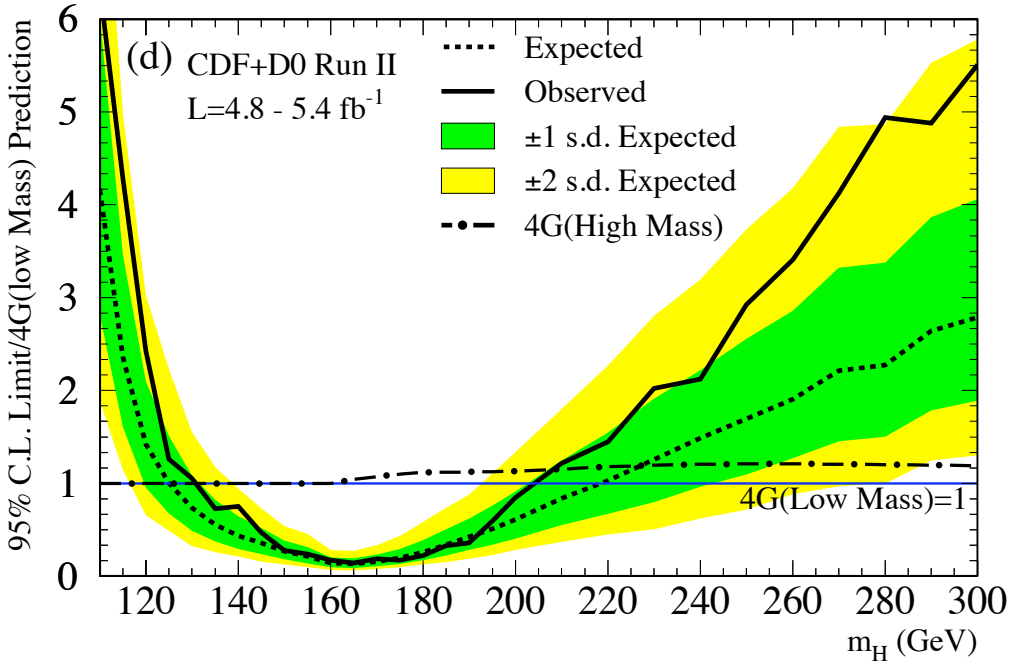
In progress: map to CKM space, apply constraints from other measurements

4th gen

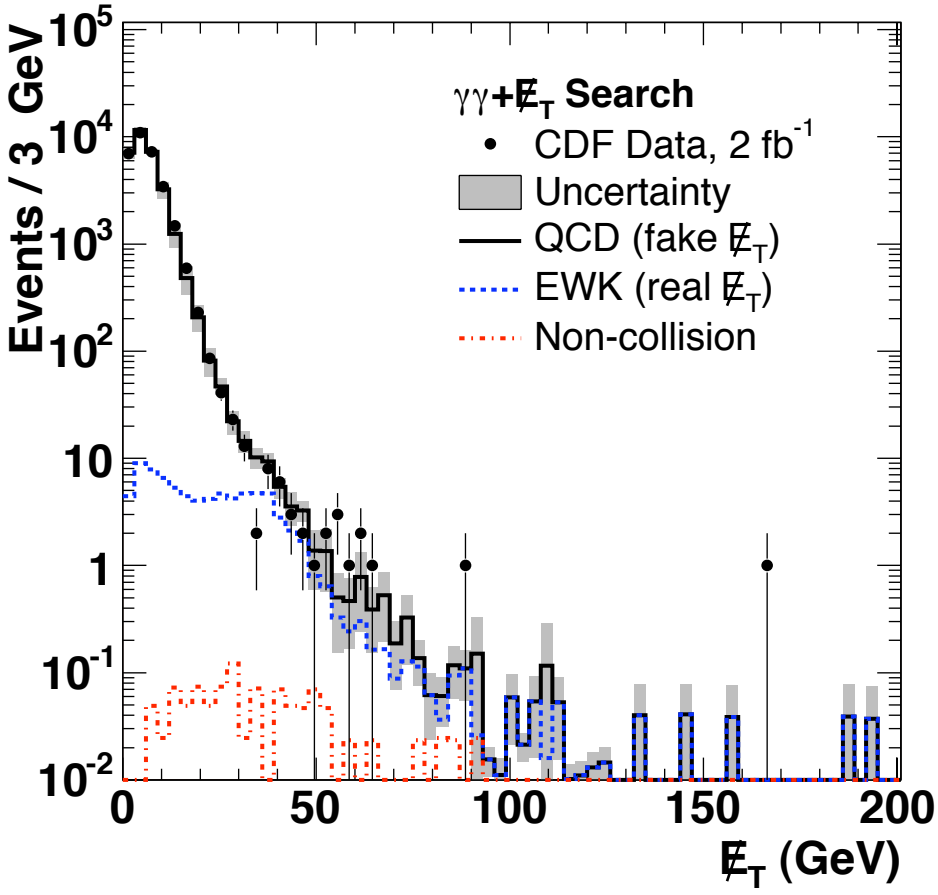
Heavy quarks would enhance gg→H.

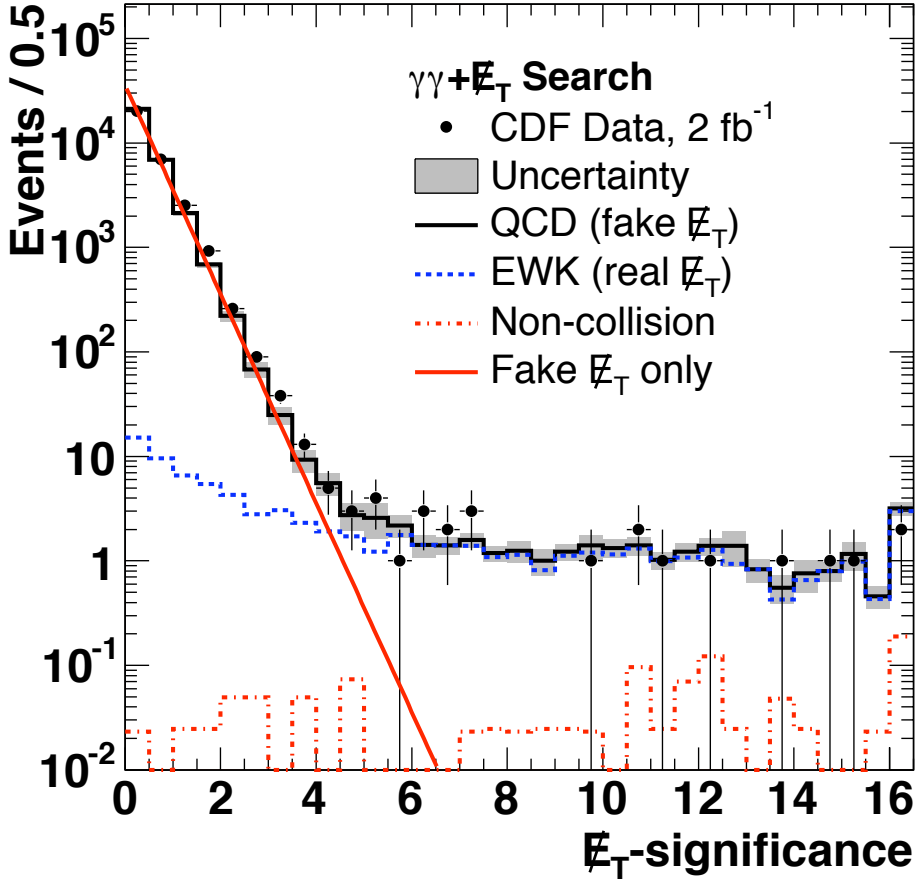
Tevatron Higgs searches are very sensitive.

New result rules out SM higgs in SM4 between
130 and 200 GeV.

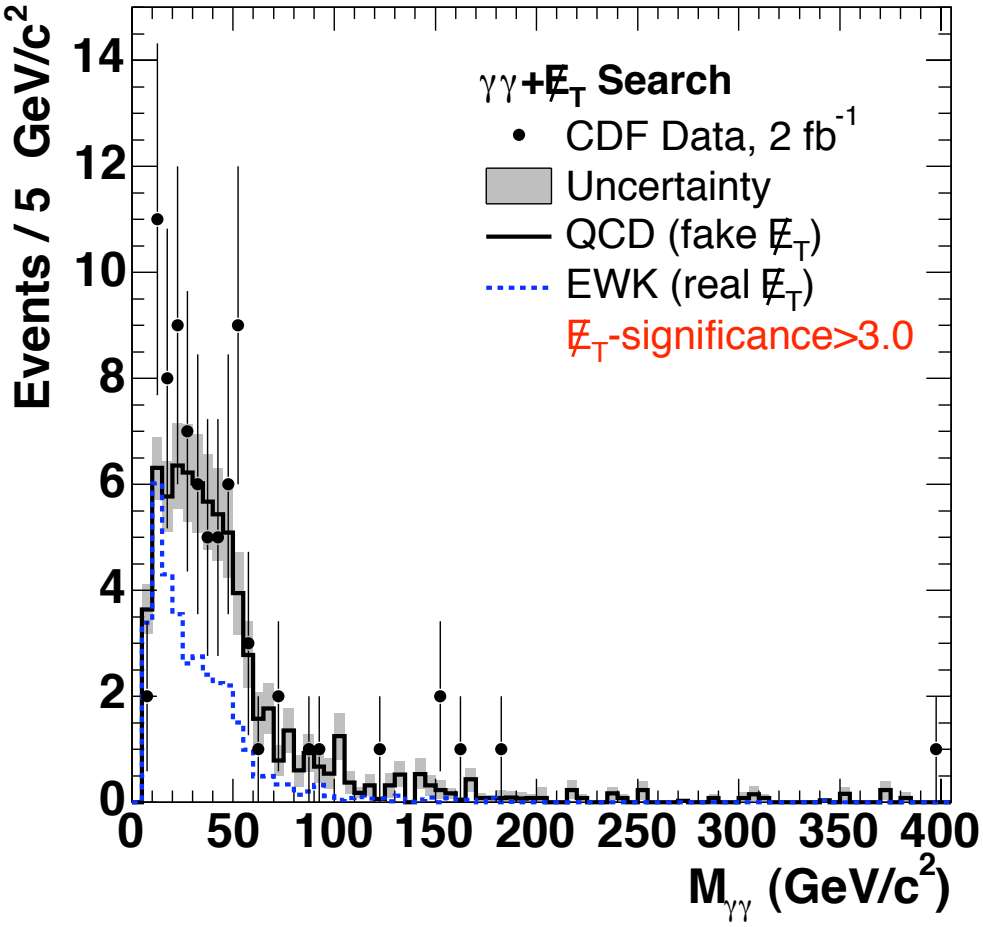


gg+MET


γγ+$\not\!\!E_T$ Search
CDF Data, 2 fb^{-1}
Uncertainty
QCD (fake $\not\!\!E_T$)
EWK (real $\not\!\!E_T$)
Non-collision
Events / 3 GeV
$\not\!\!E_T$ (GeV)


γγ+$\not\!\!E_T$ Search
CDF Data, 2 fb^{-1}
Uncertainty
QCD (fake $\not\!\!E_T$)
EWK (real $\not\!\!E_T$)
Non-collision
Fake $\not\!\!E_T$ only
Events / 0.5
$\not\!\!E_T$-significance

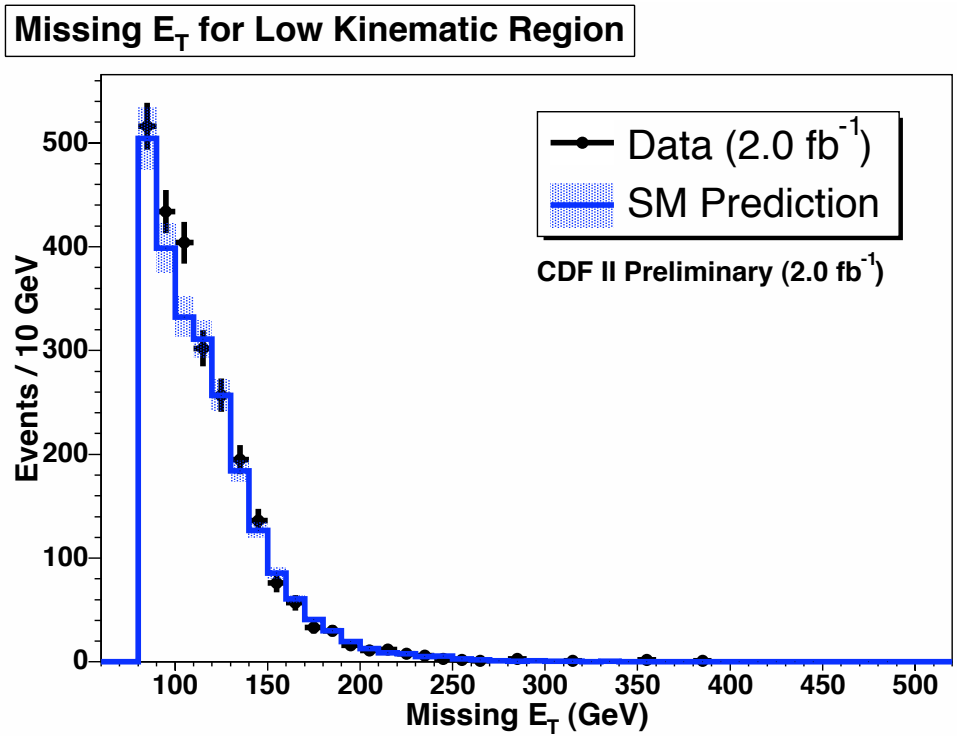
gg+MET

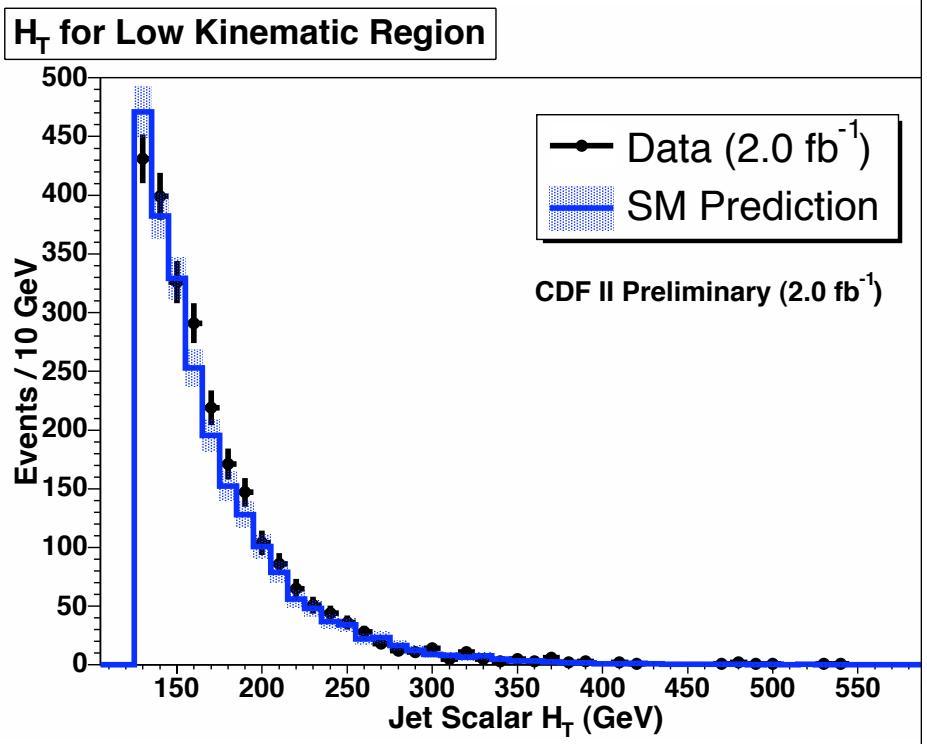

γγ+$\not\!\!E_T$ Search
CDF Data, 2 fb^{-1}
Uncertainty
QCD (fake $\not\!\!E_T$)
EWK (real $\not\!\!E_T$)
$\not\!\!E_T$-significance>3.0
Events / 5 GeV/c^2
0
2
4
6
8
10
12
14
0
50
100
150
200
250
300
350
400
$M_{\gamma\gamma}$ (GeV/c^2)

jj+MET

Exactly two jets

HT>125, MET>80



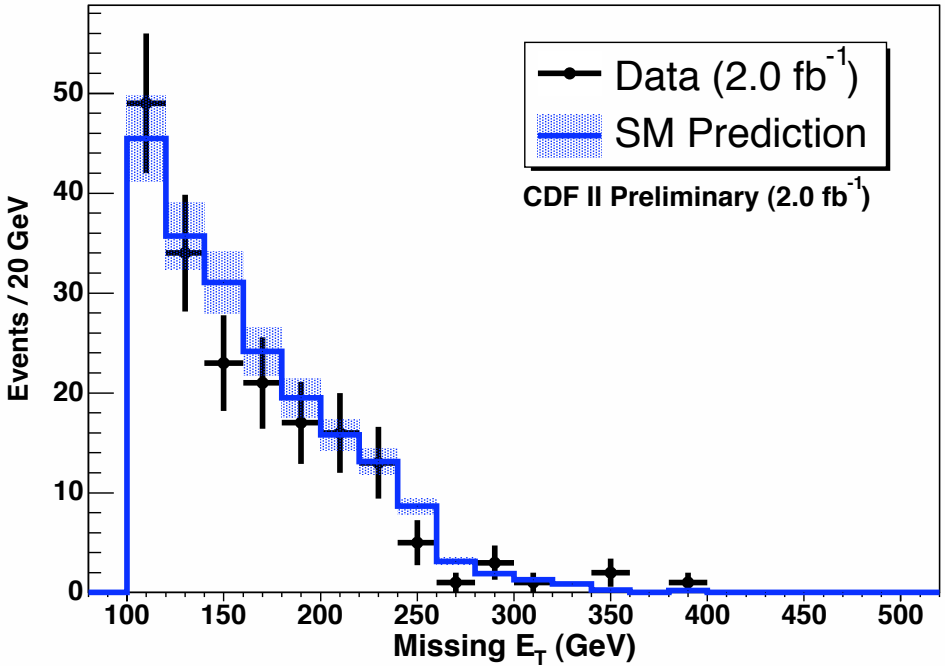


jj+MET

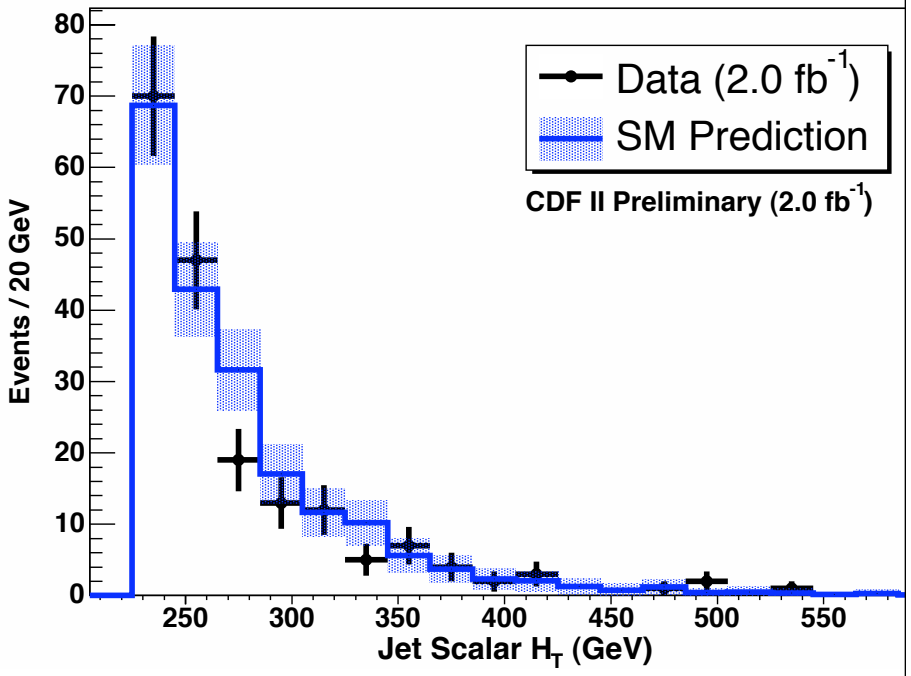
Exactly two jets

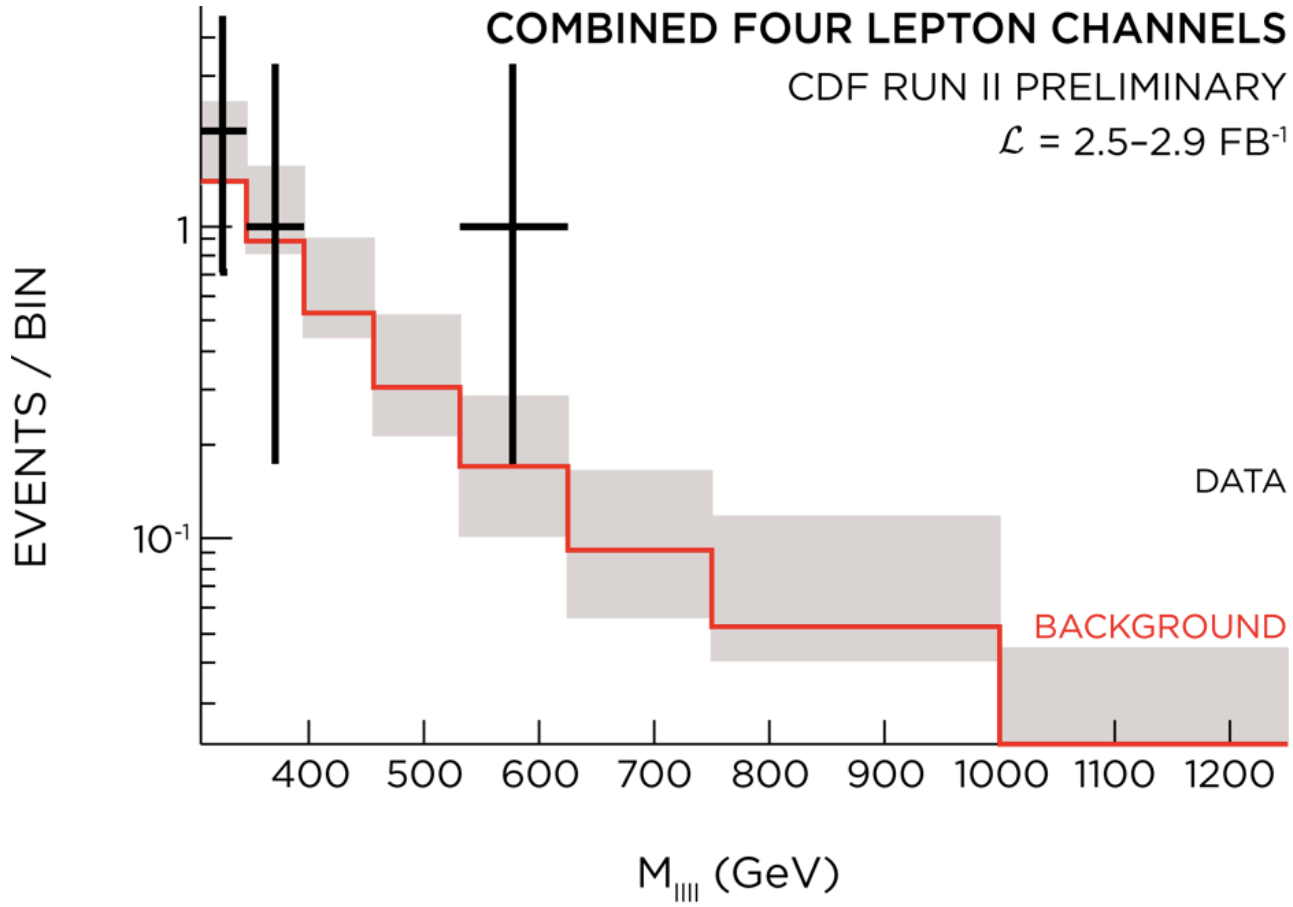
HT>225, MET>100

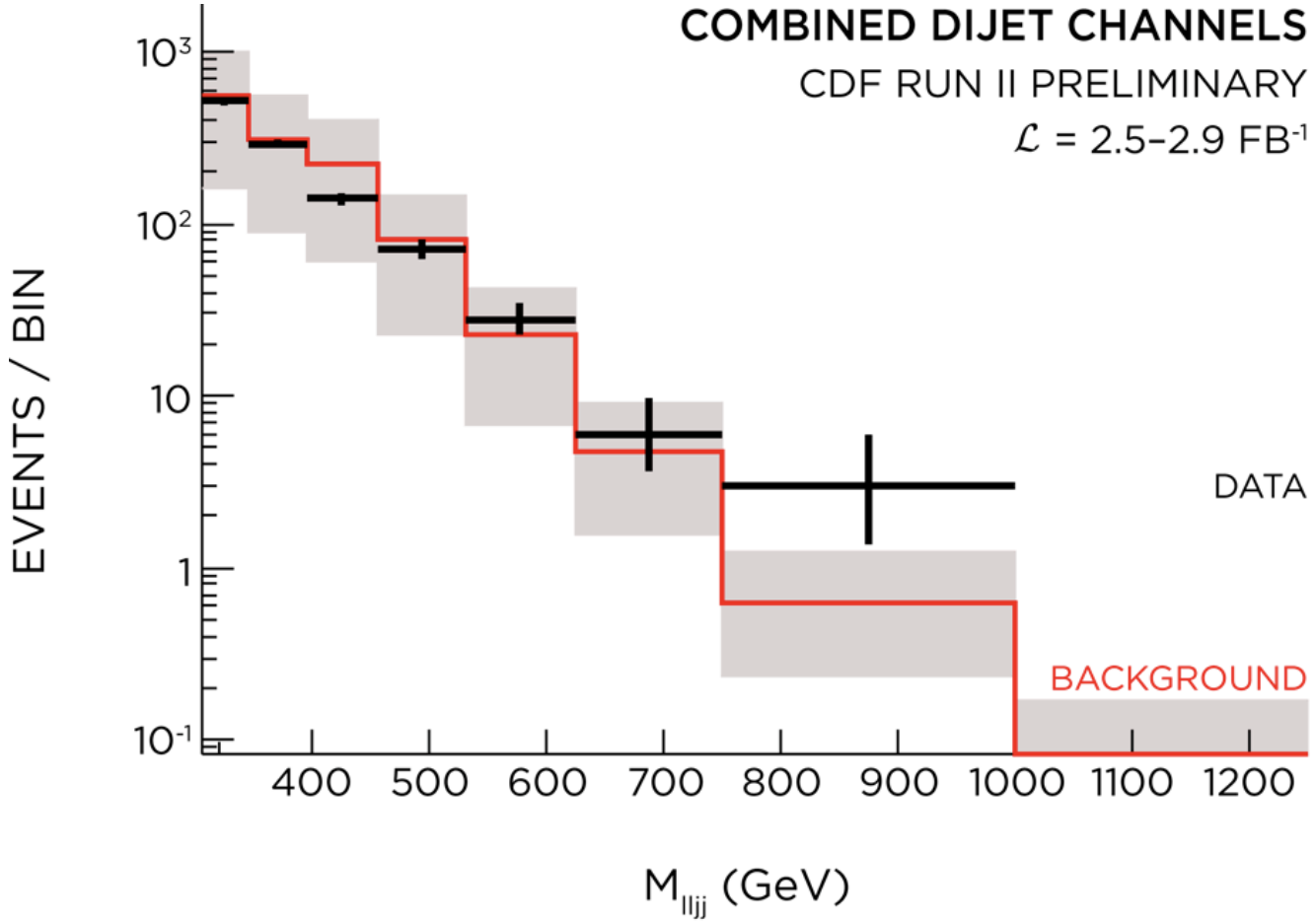
Missing E_T for High Kinematic Region



H_T for High Kinematic Region

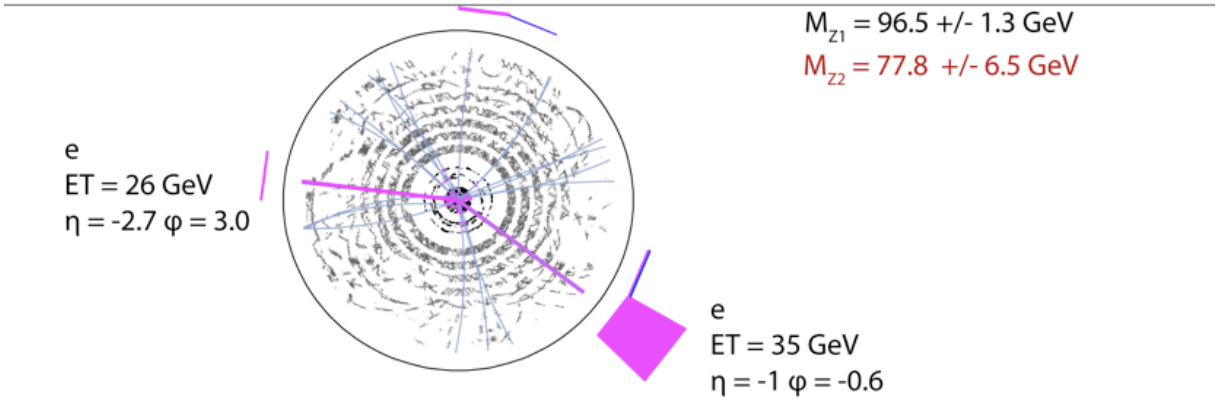


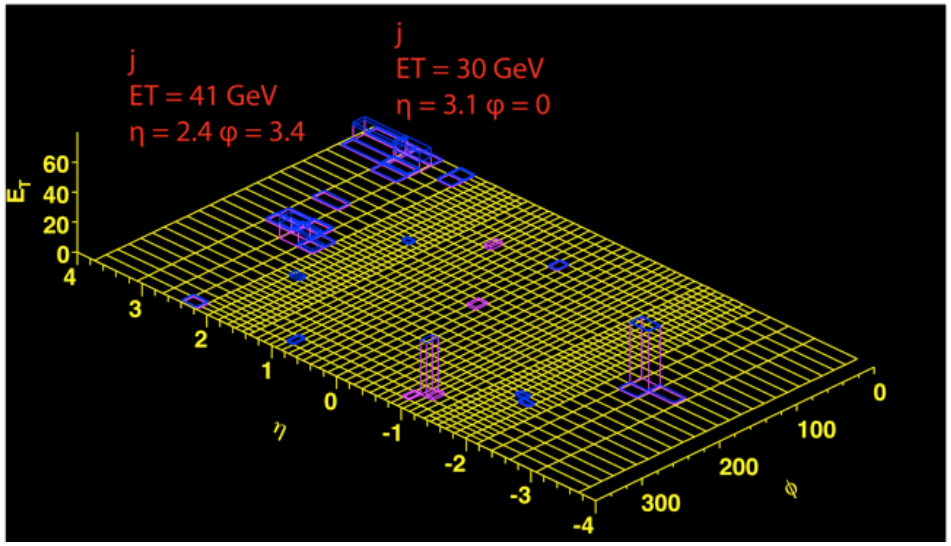

COMBINED FOUR LEPTON CHANNELS
CDF RUN II PRELIMINARY
$\mathcal{L}$ = 2.5–2.9 FB^{-1}
EVENTS / BIN
1
10^{-1}
DATA
BACKGROUND
400
500
600
700
800
900
1000
1100
1200
M_{llll} (GeV)


COMBINED DIJET CHANNELS
CDF RUN II PRELIMINARY
$\mathcal{L}$ = 2.5–2.9 FB^{-1}
DATA
BACKGROUND
EVENTS / BIN
10^3
10^2
10
1
10^{-1}
400
500
600
700
800
900
1000
1100
1200
M_{lljj} (GeV)

lljj event

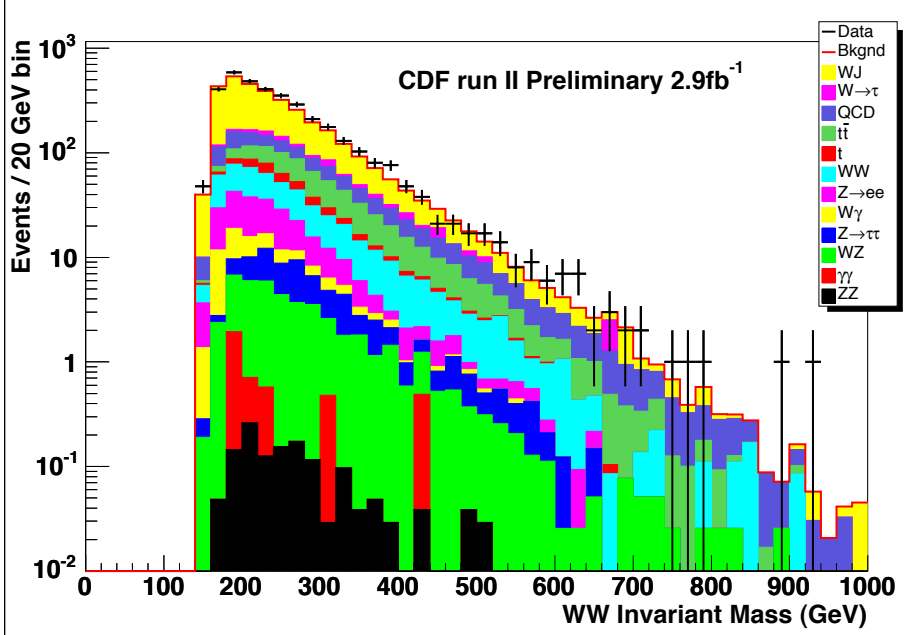
M_{lljj}=868 GeV



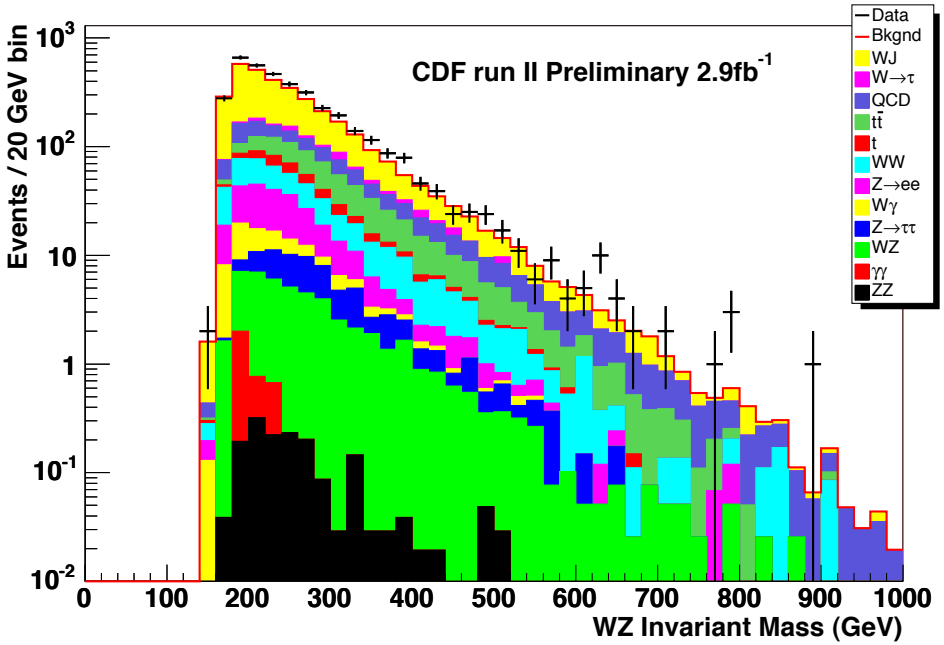


lnjj

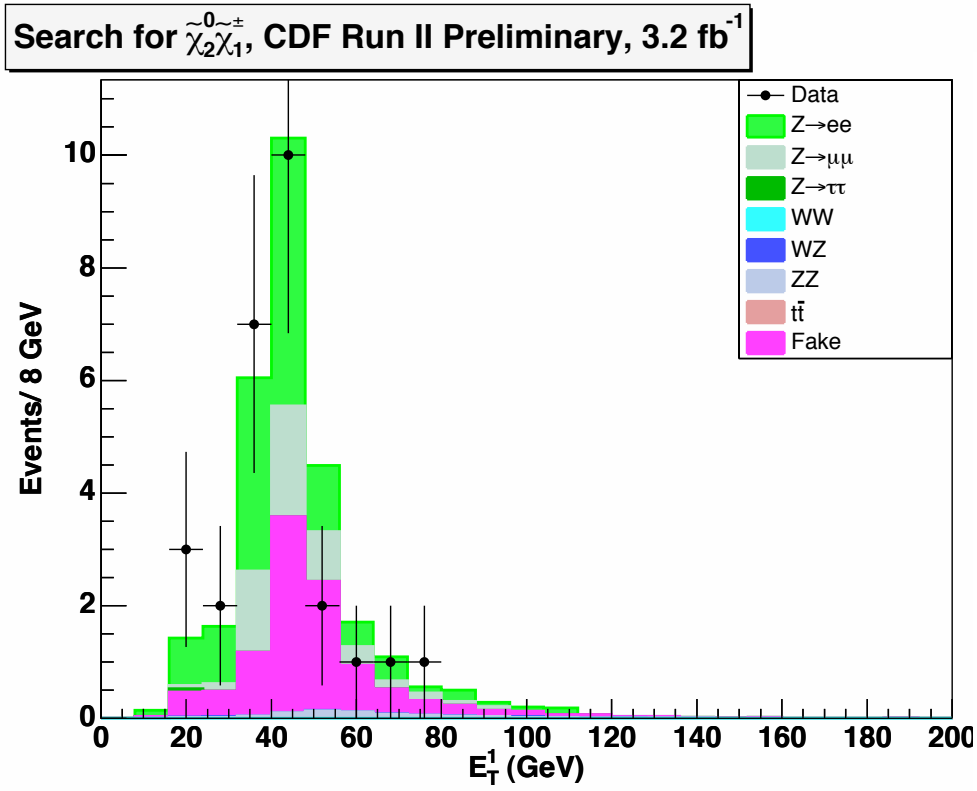
WW-like

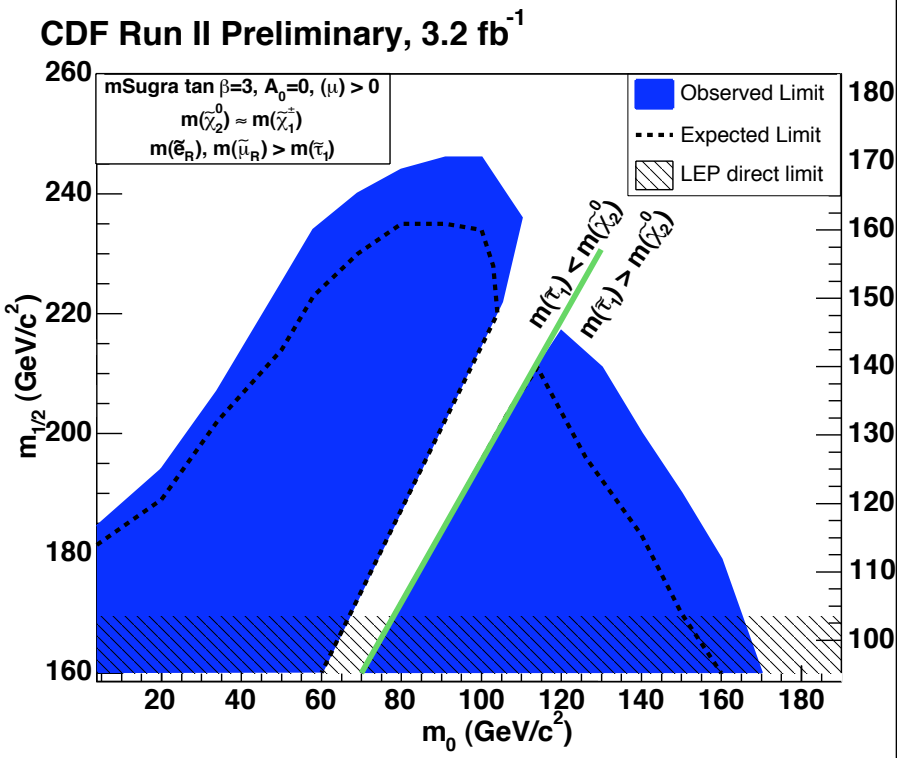


WZ-like

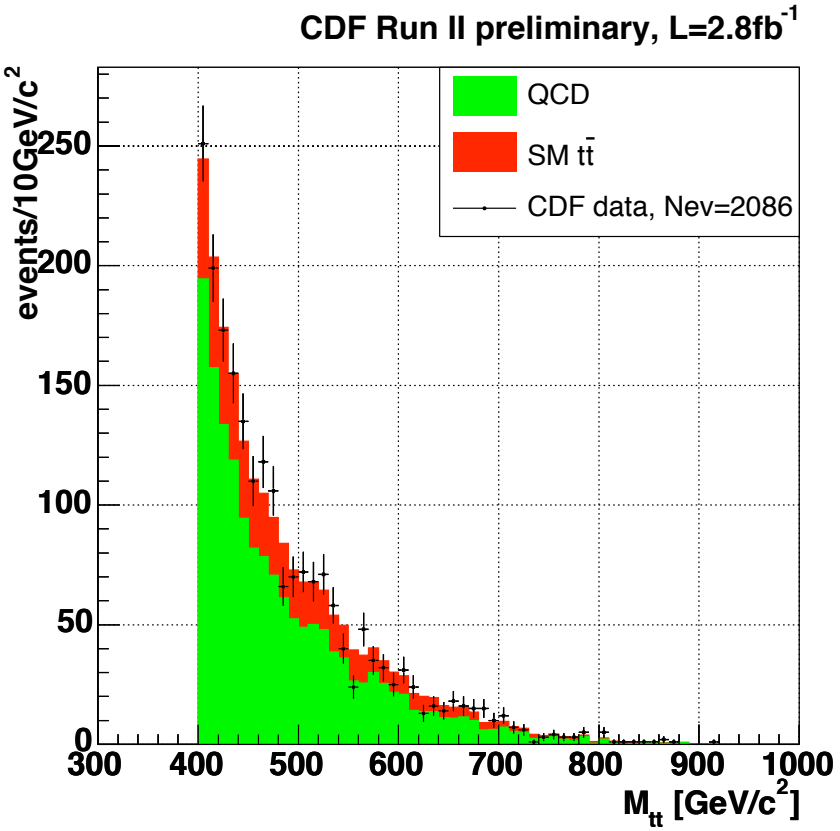


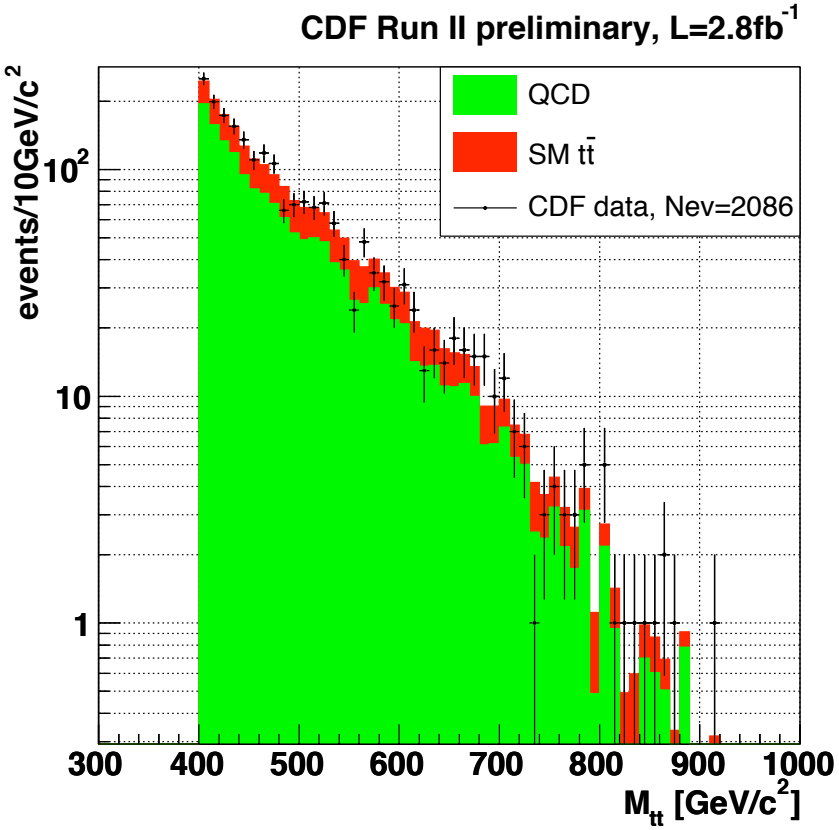
III

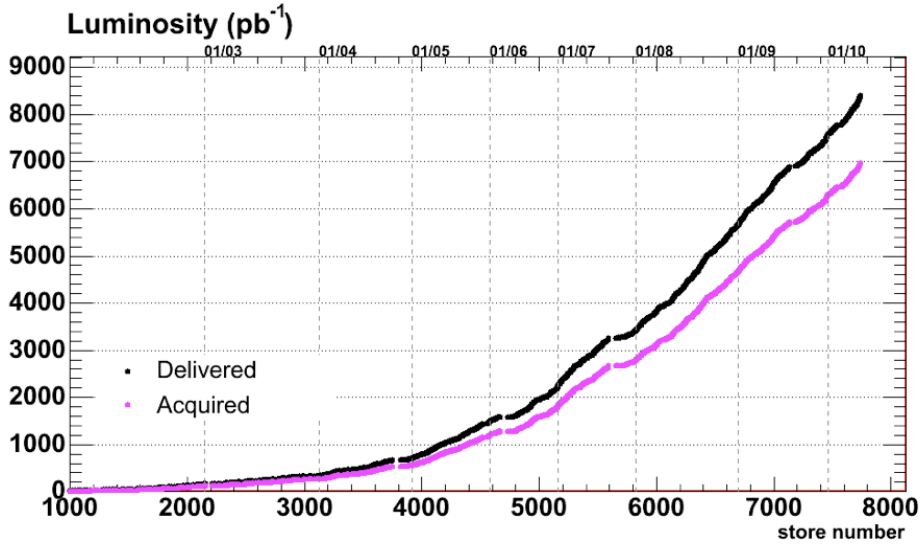
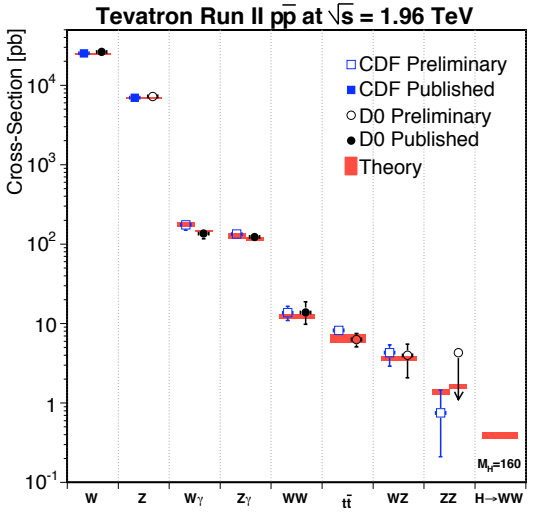

Search for $\tilde{\chi}_2^0\tilde{\chi}_1^\pm$, CDF Run II Preliminary, 3.2 fb^{-1}
Data
Z→ee
Z→μμ
Z→ττ
WW
WZ
ZZ
tt̄
Fake
Events/ 8 GeV
E_T^1 (GeV)


CDF Run II Preliminary, 3.2 fb^{-1}
mSugra tan β=3, A$_0$=0, (μ) > 0
$m(\tilde{\chi}_2^0) \approx m(\tilde{\chi}_1^\pm)$
$m(\tilde{e}_R), m(\tilde{\mu}_R) > m(\tilde{\tau}_1)$
Observed Limit
Expected Limit
LEP direct limit
$m(\tilde{\tau}_1) < m(\tilde{\chi}_2^0)$
$m(\tilde{\tau}_1) > m(\tilde{\chi}_2^0)$
$m_{1/2}$ (GeV/c^2)
m_0 (GeV/c^2)

X->tt


CDF Run II preliminary, L=2.8fb-1
events/10GeV/c2
QCD
SM tt̄
CDF data, Nev=2086
0
50
100
150
200
250
300
400
500
600
700
800
900
1000
Mtt [GeV/c2]


CDF Run II preliminary, L=2.8fb-1
events/10GeV/c2
QCD
SM tt̄
CDF data, Nev=2086
1
10
10²
300
400
500
600
700
800
900
1000
Mtt [GeV/c2]

Conclusions

Much more coming!