Exploring with Simplified Models

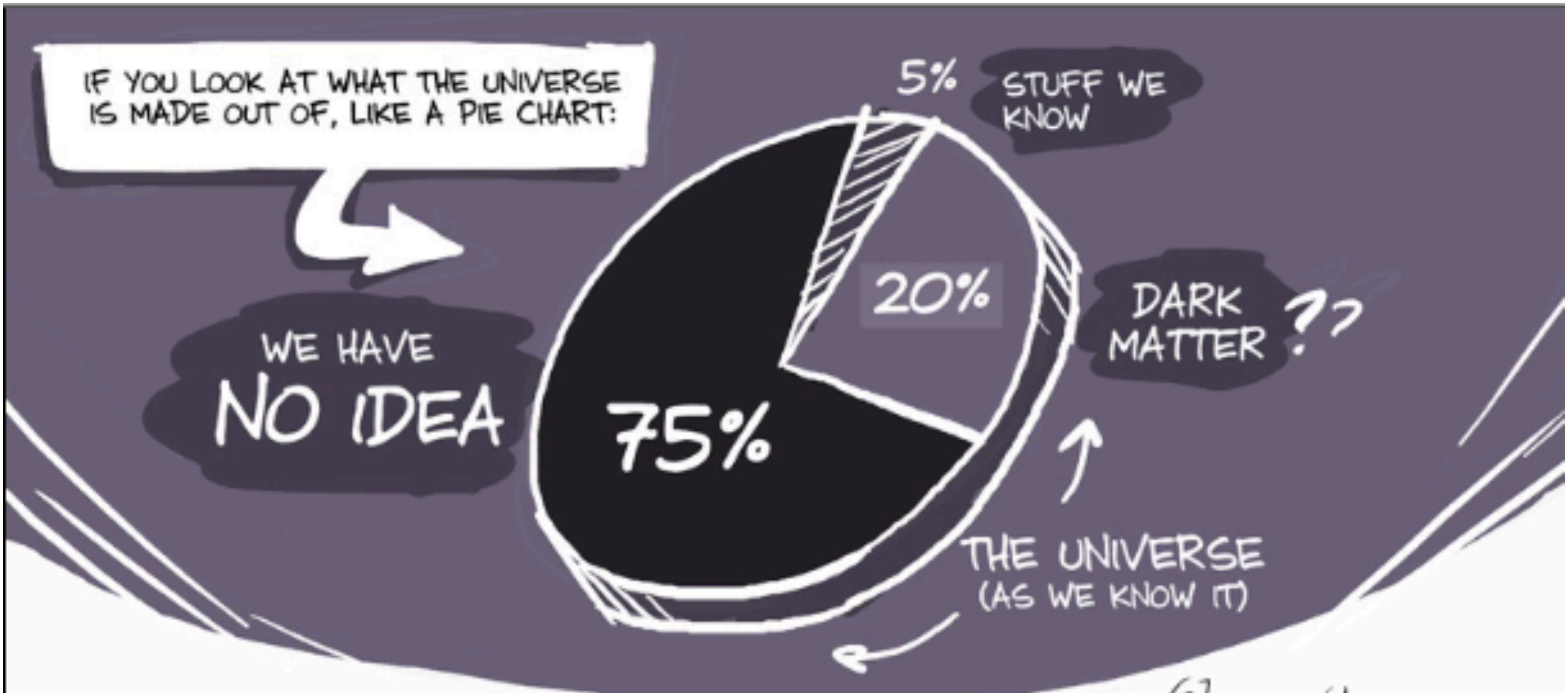
Daniel Whiteson, UC Irvine

I. Motivation

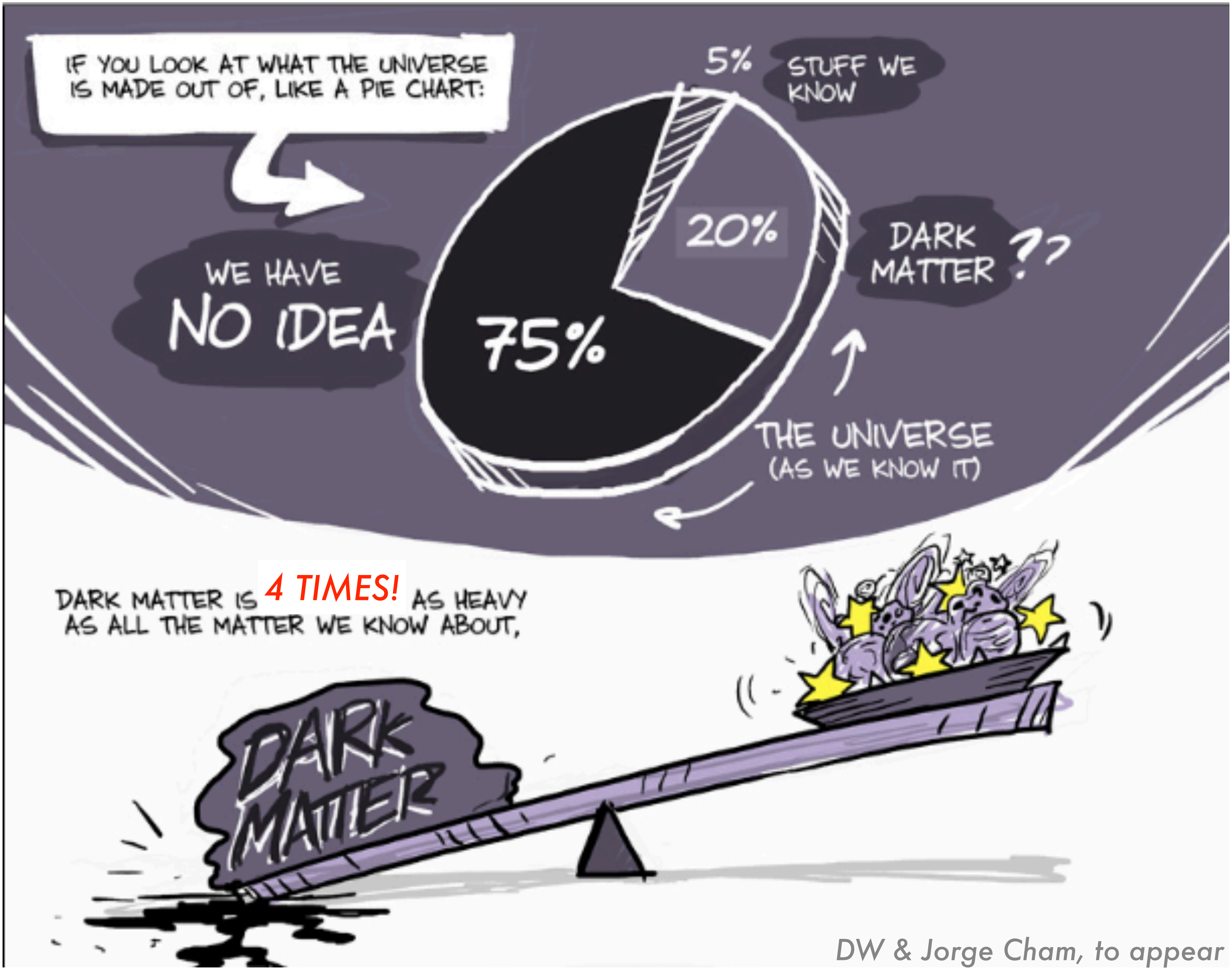
II. Strategy

III. Results

- CDF ss dilepton result ⟵ Brand new!
- Heavy quark searches



DW & Jorge Cham, to appear



DW & Jorge Cham, to appear


IS ONLY ON A TINY FRACTION OF WHAT THE UNIVERSE IS MADE OUT OF!
IT'S LIKE YOU'VE BEEN STUDYING AN ELEPHANT'S TAIL FOR TWO HUNDRED YEARS AND YOU DISCOVER...
IT'S ONLY THE TAIL!
DW & Jorge Cham, to appear

Outline

I. Motivation

II. Strategy

III. Results

Searching for new physics

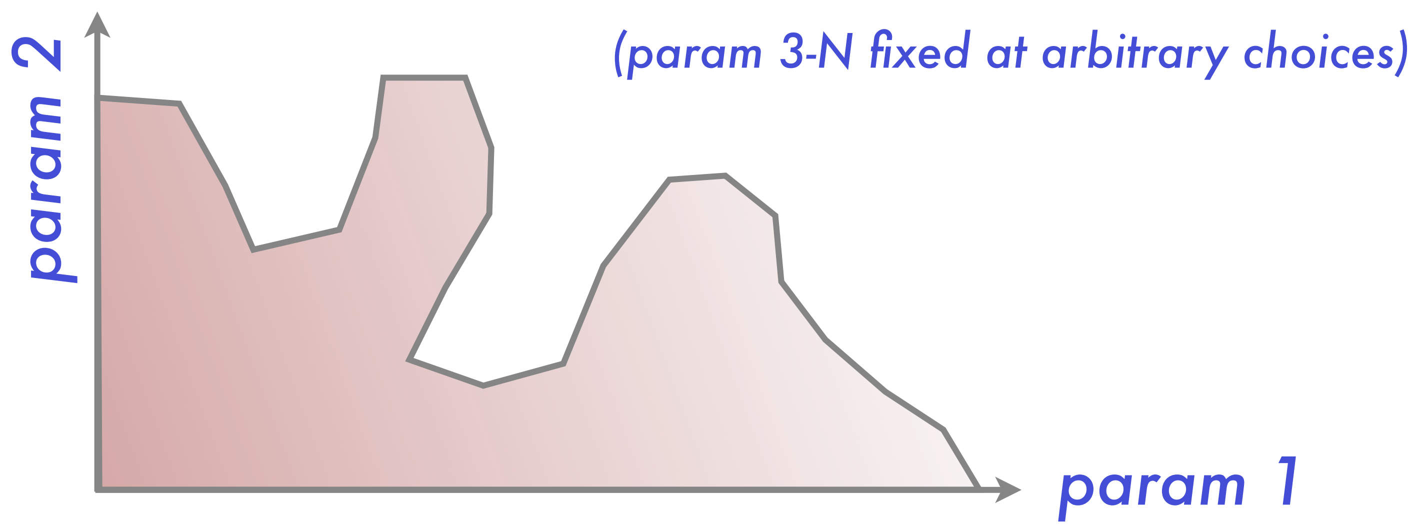
Our goals:

- Maximize possibility for discovery
- Learn something no matter what we see

Traditional approach

Bet on a specific full theory

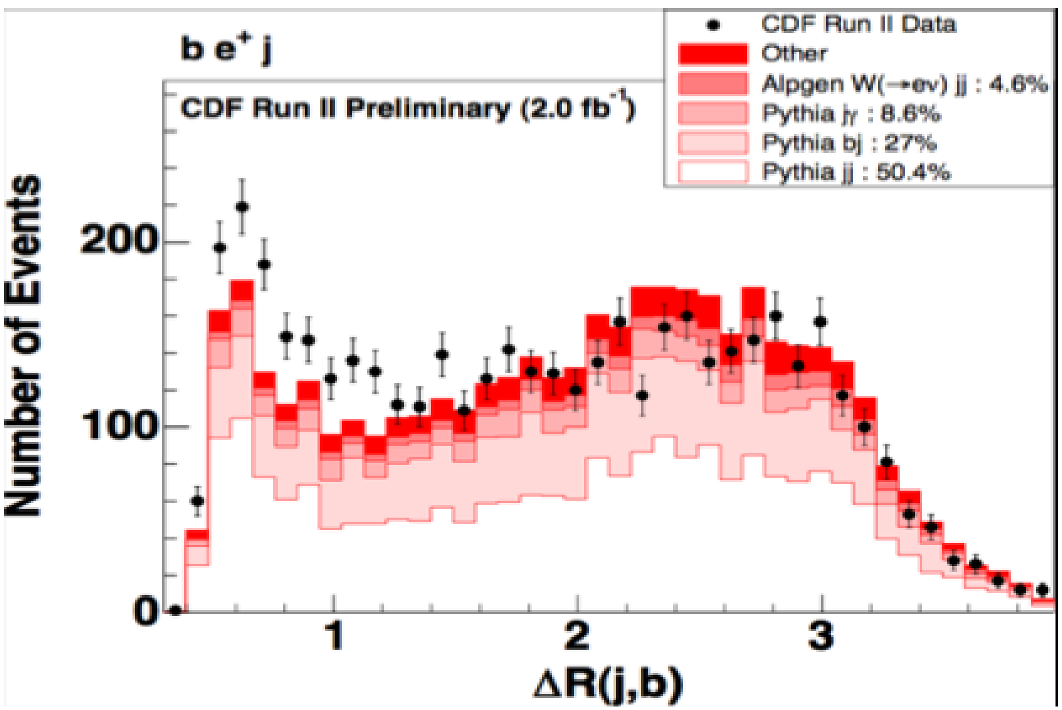
Optimize analysis to squeeze out maximal sensitivity to new physics.



Model independent search

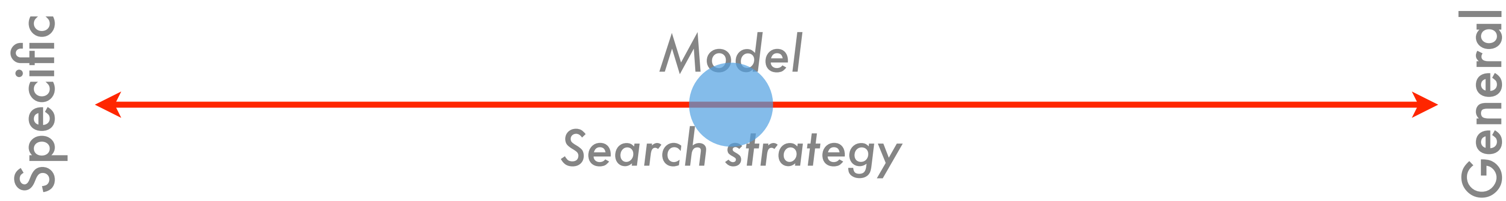
Discard the model

compare data to standard model



"Never listen to theorists."
–Aaron Pierce, Theorist

Compromise



<u>Admit the need for a model</u>

New signal requires a coherent physical explanation,
even trivial or effective

<u>Generalize your model</u>

Focus on the general experimental sensitivity

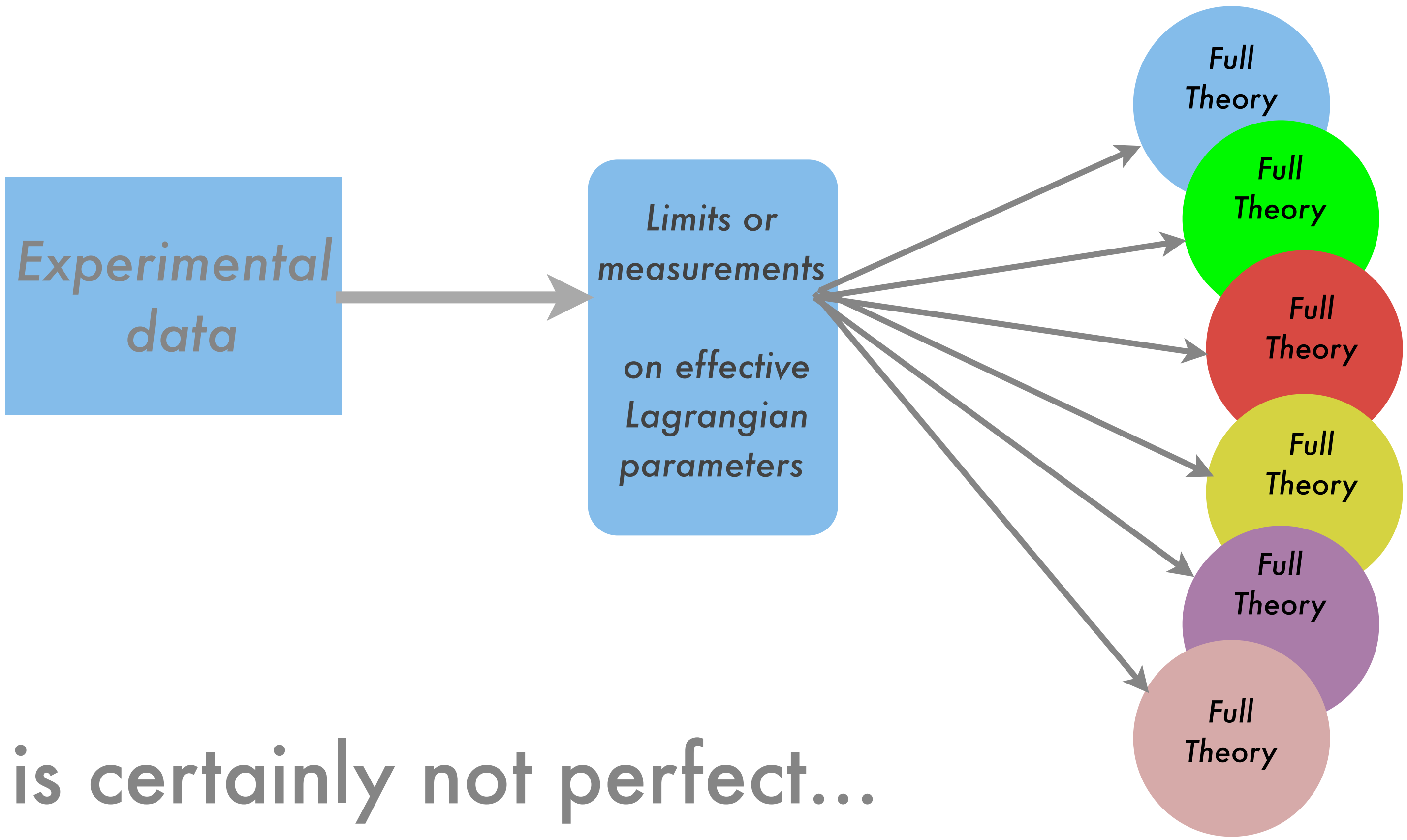
Construct simple models that describe classes of new physics

<u>Examples</u>

Simple SM extensions: fourth generation, Z′, resonances (X->tt) etc

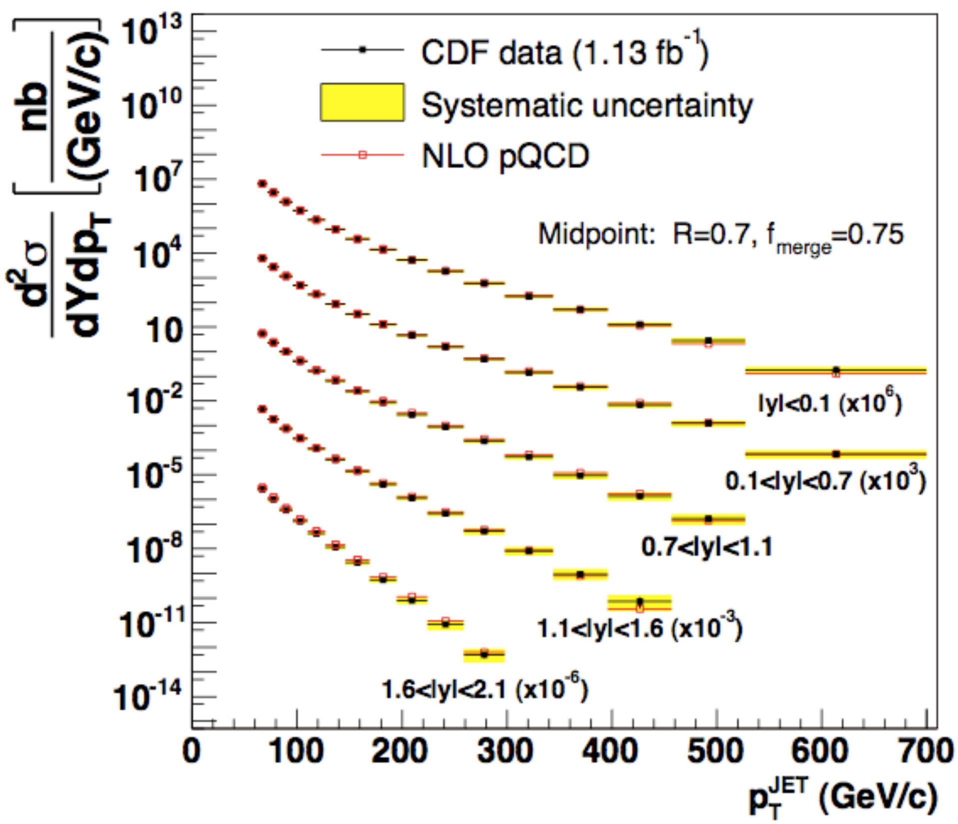
Effective Lagrangian

A natural, compact language for communication between theory and experiment.



This is certainly not perfect...

A Theorist's dream?



<u>Unfolded cross-sections</u>

Deconvolution to remove detector effects

Publish measured differential cross-sections

Theorists don't need to know/have detector description

This is hard!

Limits

Backgrounds → **Yield Limits**

Limits

Backgrounds → Yield Limits

+

Signal efficiency → Cross-section Limits

Limits

Backgrounds → Yield Limits

\+

Signal efficiency → Cross-section Limits

\+

Theory prediction → Parameter (mass) limits

RECAST

Backgrounds → Yield Limits

+

Signal efficiency → Cross-section Limits

Signal' efficiency → Cross-section Limits

RECAST

Backgrounds

+

Signal efficiency

Signal' efficiency

<u>Done by experiment</u>

Problem: people move on

- code rots away
- jobs/interests change
- tend to reoptimize cuts

<u>Done by theorist</u>

Problem: approximate

- No access to bg, fitting codes, etc

Dataset archive

Backgrounds

+

Signal efficiency

Signal′ efficiency

Dataset archive

Experiments require published analysis to archive

(1) bg description (weighted events)

(2) code to produce weighted signal events from full MC

(3) fitting code

Allows anyone in expt to recast

Dataset archive

Backgrounds

+

Signal efficiency

Signal' efficiency

Dataset archive

At CDF: 2l os

2l ss

1l + >=1 jets

0l jjbb

Outline

I. Motivation

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- a. CDF same-sign leptons
  - ss tops
  - Simplified SUSY
- b. Heavy quarks (CDF/ATLAS)

Outline

I. Motivation

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a. CDF same-sign leptons

- sstops

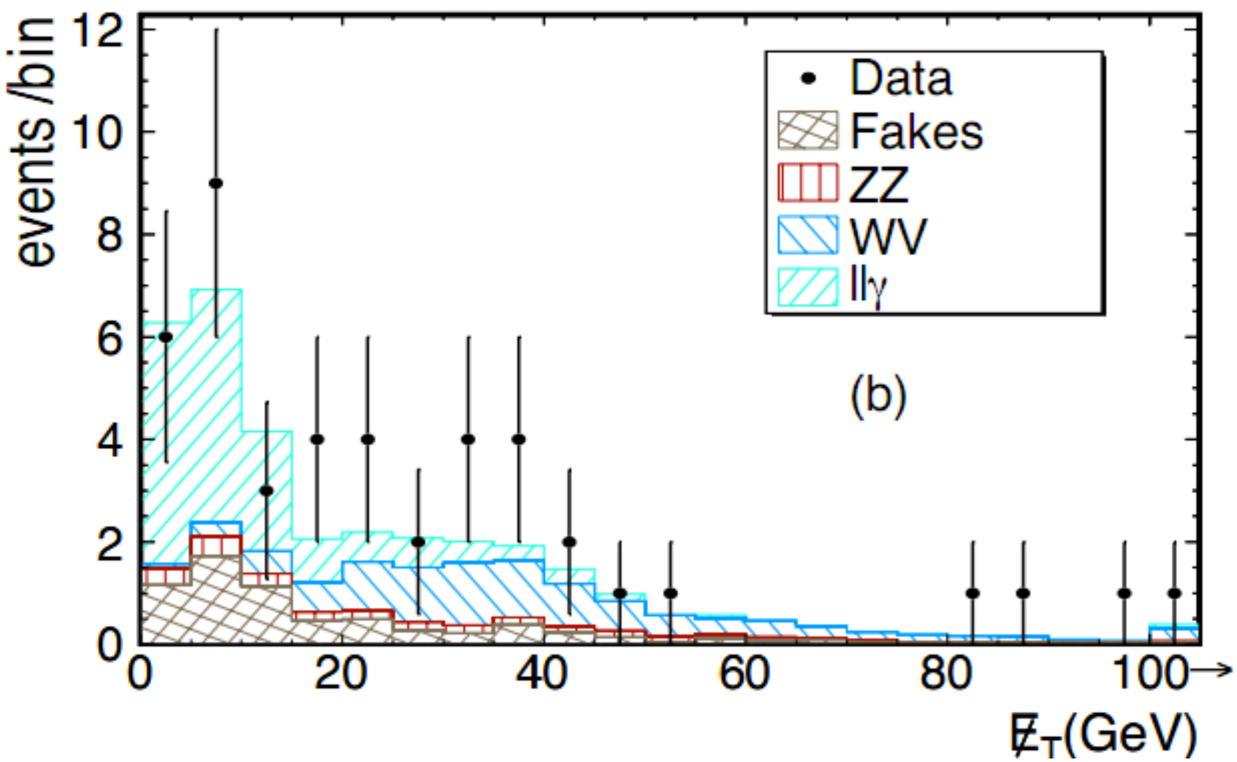
- Simplified SUSY

b. Heavy quarks (CDF/ATLAS)

Just released Thursday!

CDF like-sign dileptons

	$n_{\rm obs}$	$n_{\rm pred}$
$e_{si}e_{si}$	11	6.3±1.0
ee	3	1.3±0.3
$e_{si}e$	9	9.1±1.8
$e_{si}\mu$	11	6.8±0.8
$e\mu$	5	6.4±1.2
$\mu\mu$	5	3.2±0.3
Total	44	33.2±4.7

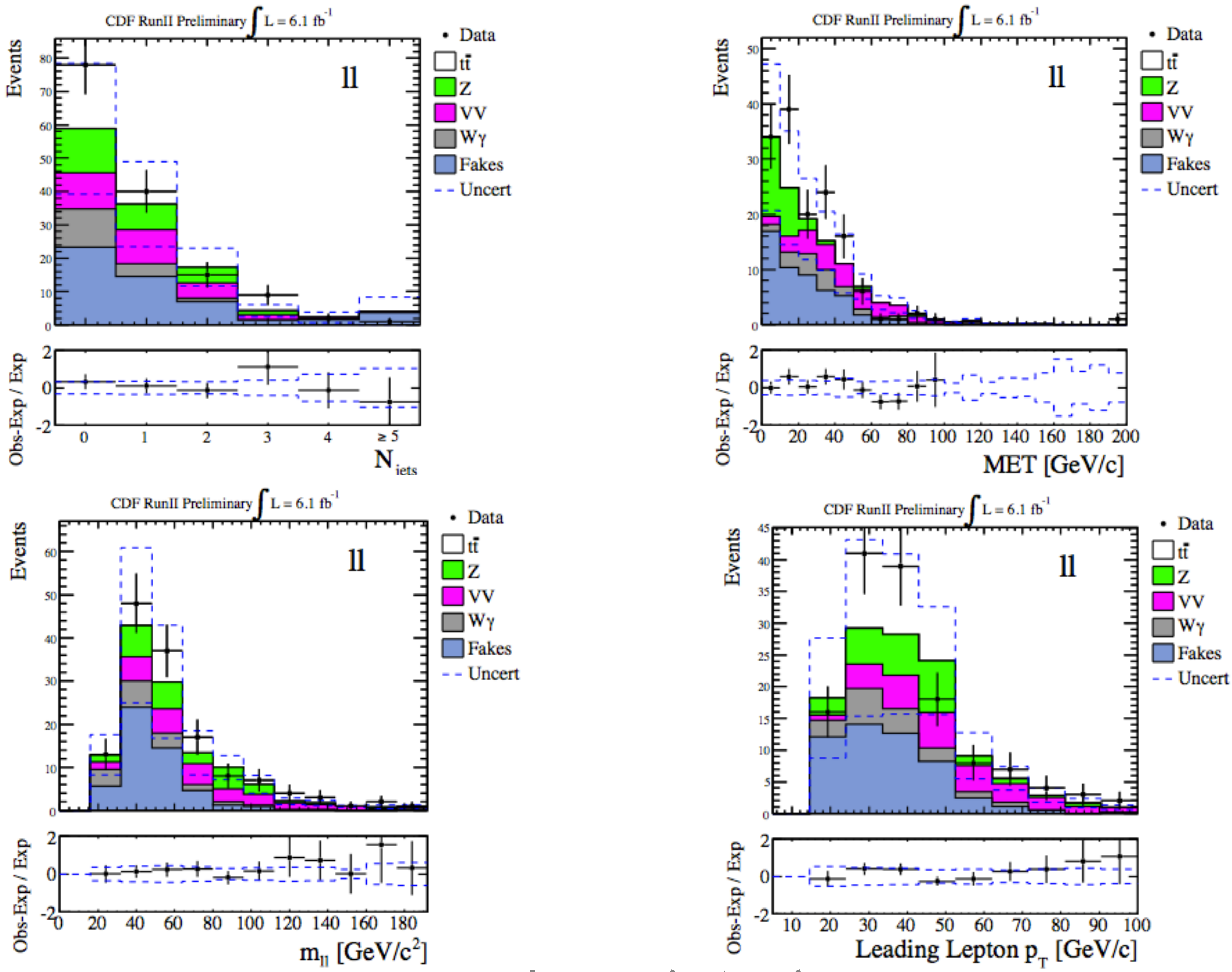


1/fb PRL 2007

ls dileptons 6.1/fb

UCI grad student Robert Porter

CDF RunII Preliminary	6.1/fb
top quark pairs	0.1 ± 0.1
Z	26.6 ± 3.4
WW,WZ,ZZ	28.4 ± 2.0
W+gamma	16.2 ± 2.4
Fakes	51.6 ± 24.2
Total	123.0 ± 24.6
Data	145

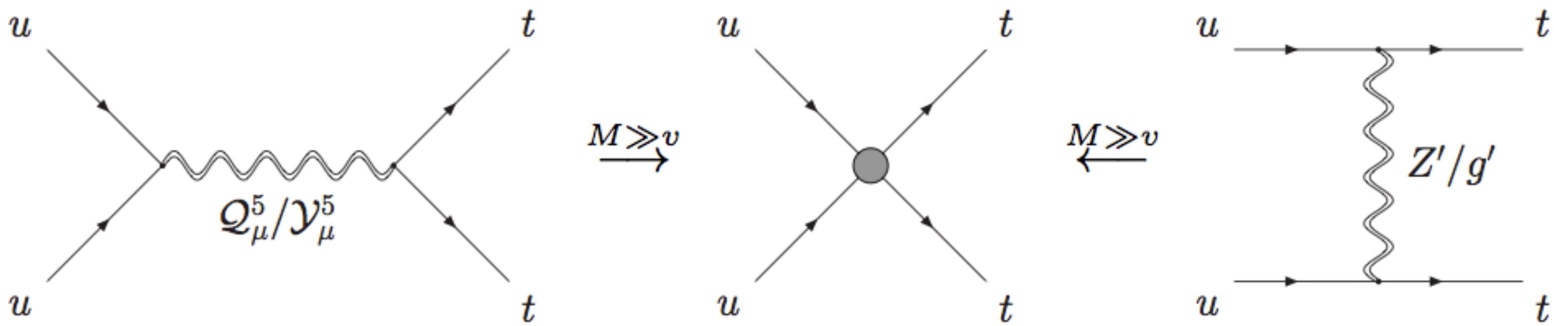


p-values in (34-79)%

same-sign tops

Many models predict ss tops

(esp. to explain CDF top A_{fb})



Use 4f effective operators

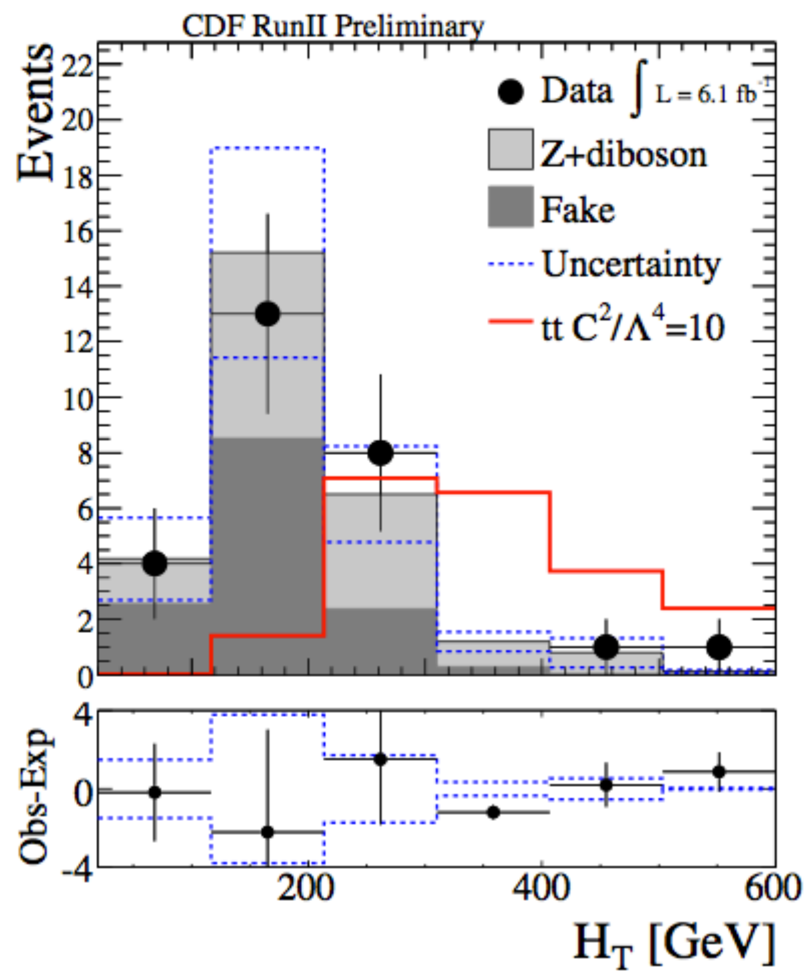
(LL,LR,RR) modes

same-sign leptons+2jets

Process	Total $\ell\ell$
$t\bar{t}$	0.1 ± 0.0
$Z \to \ell\ell$	5.9 ± 1.7
WW, WZ, ZZ	7.2 ± 0.5
$W(\to \ell\nu)\gamma$	0.9 ± 0.7
Fakes	13.8 ± 7.2
Total	28.0 ± 7.5
Data	27

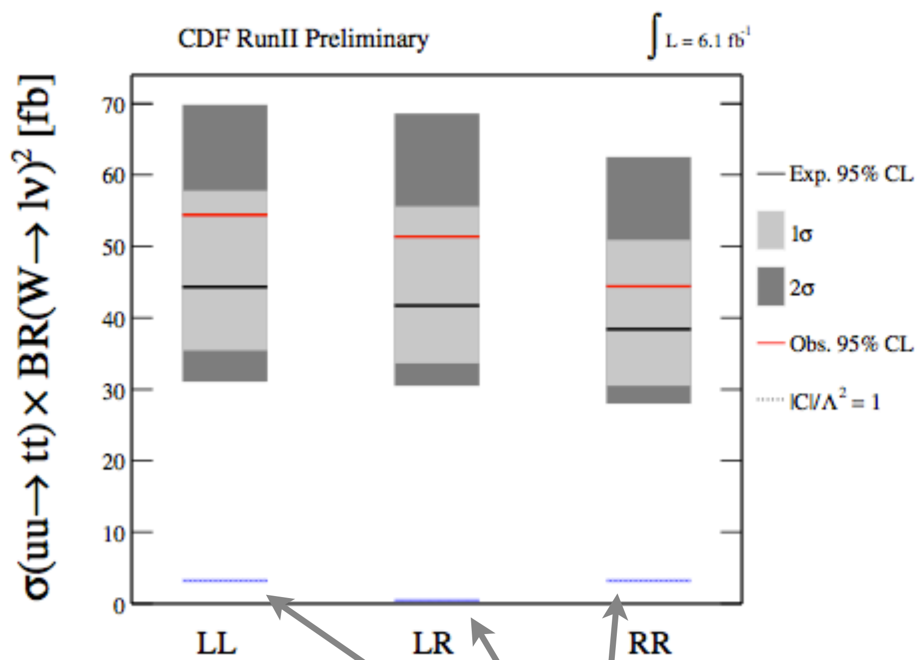
coupling $|C|/\Lambda^2$

cross-section $\propto C^2/\Lambda^4$

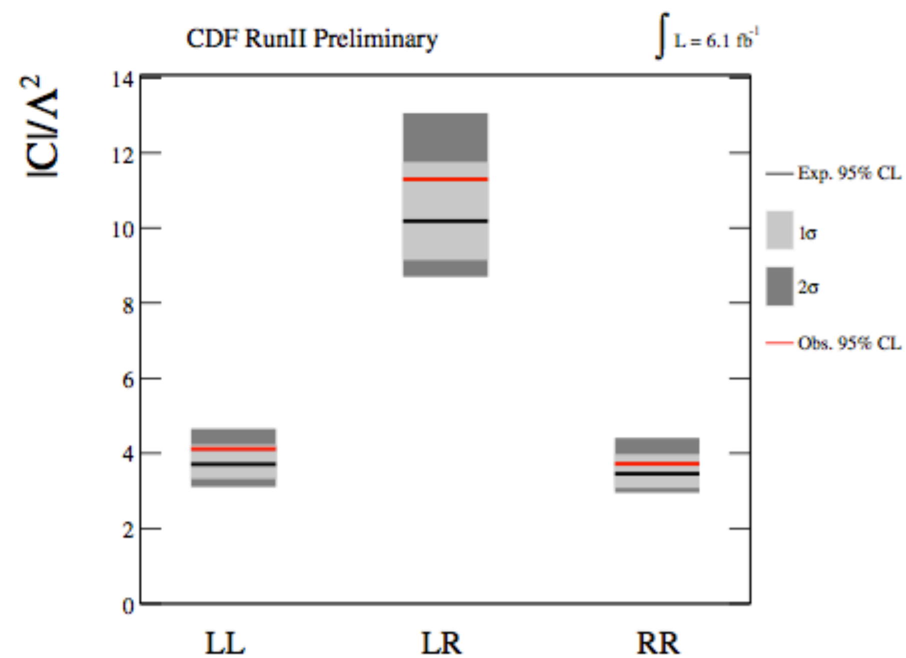


Limits

Cross-section limits

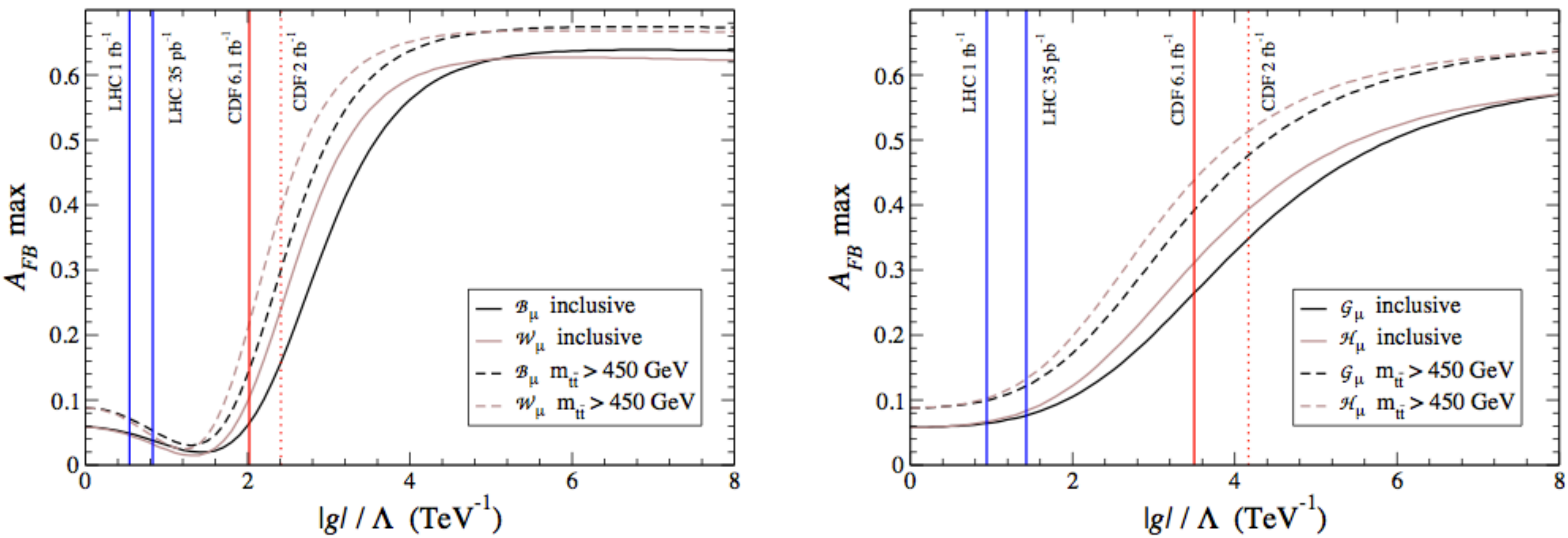


Coupling limits



coupling $|C|/\Lambda^2 = 1$

RE CAST



No like-sign tops at Tevatron:
Constraints on extended models
and implications for the $t\bar{t}$ asymmetry.

http://arxiv.org/abs/1104.1385

SUSY

Goal

Set limits on SUSY-like processes

in as general a fashion as possible

Approach

Use effective lagrangian, explicitly set particle masses (EW scale):

simple to handle, easy to interpret

Set limits as functions of these masses, not parameters of specific models:

can be easily translated into arbitrary models

How?

How many particles & parameters needed?

Want leptons

needs Ws and Zs, so chargino/neutralinos and sleptons

Want strong production

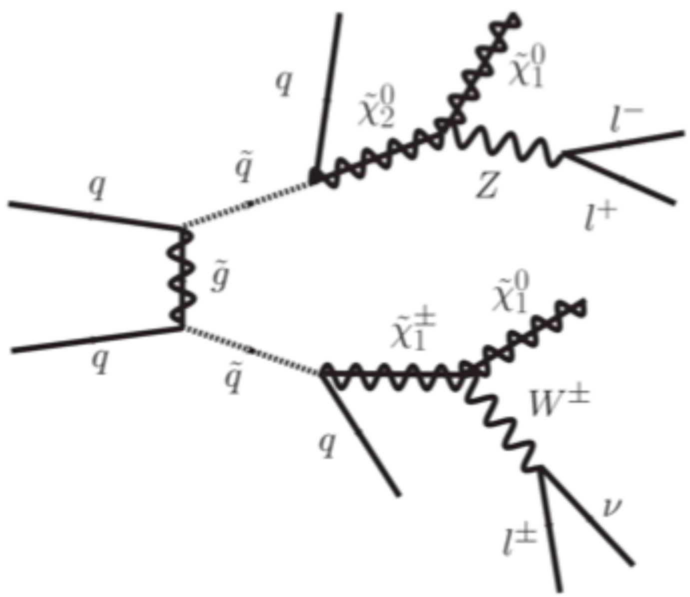
so squarks and gluinos

R-Parity conserving

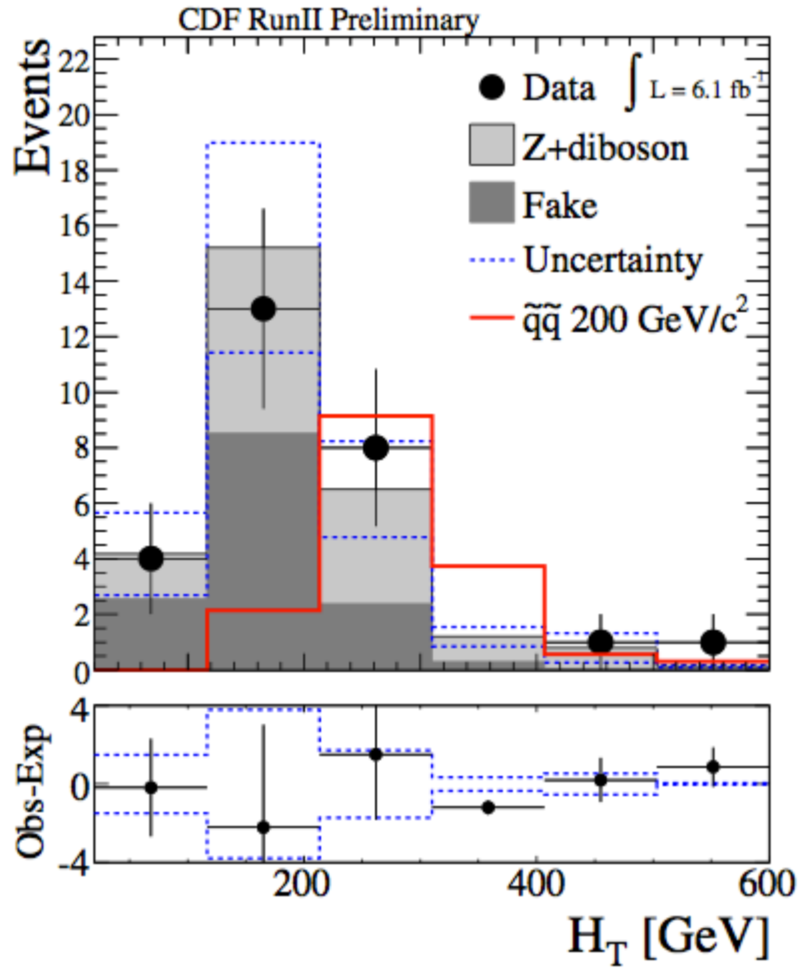
need LSP

Large sections of this space are 3 or 4-dimensional

Squark pairs



+WW,ZZ modes



Limits

<u>Upper limits on number of SUSY events: N^{95}(sparticle masses)</u>

Need: data, background shapes, signal shapes

Independent of signal efficiency, theoretical signal xs

<u>Upper limits on SUSY xs: σ^{95}(sparticle masses)</u>

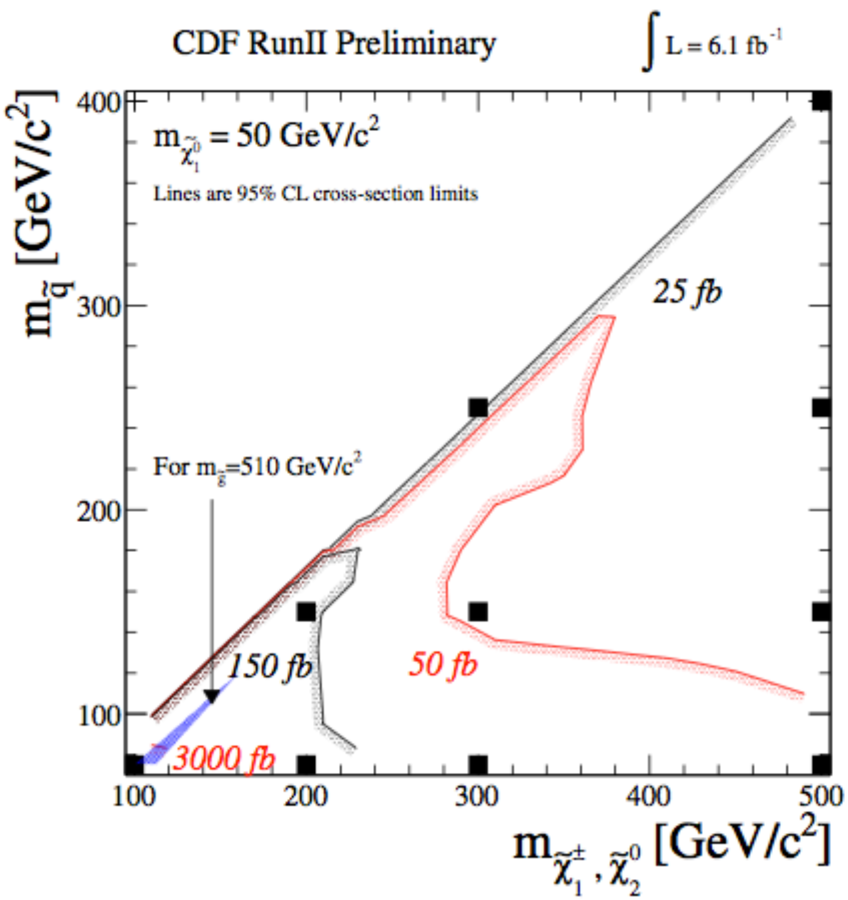
Need: N^{95}*(sparticle masses)*, signal efficiency: ε*(sparticle masses)*

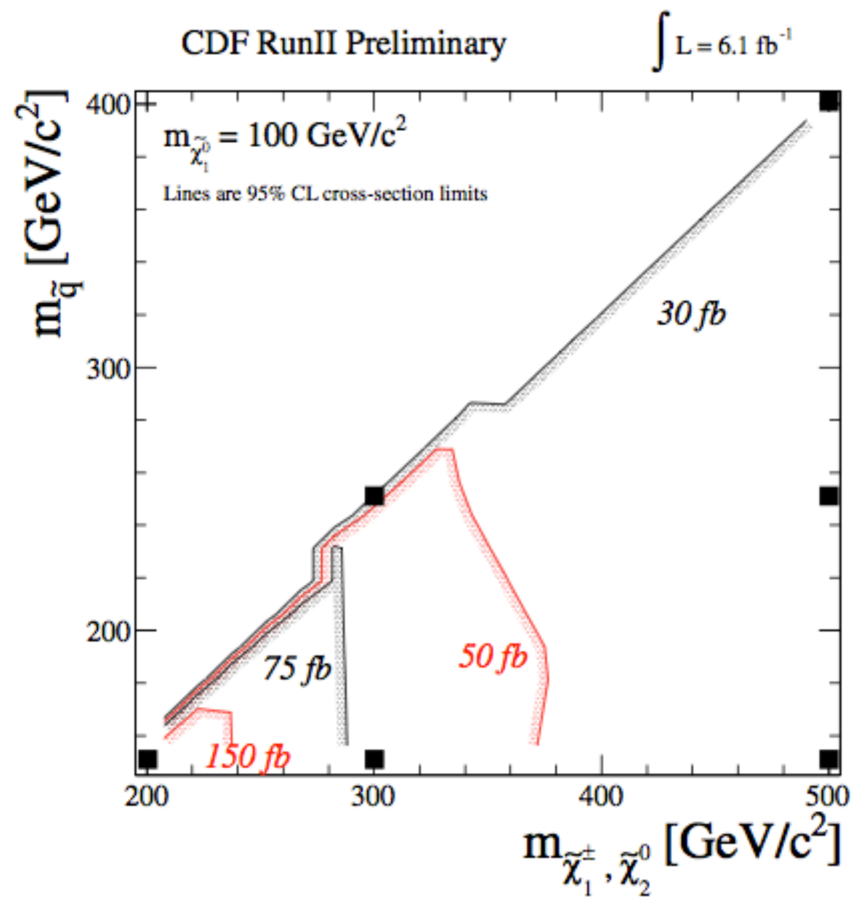
Independent of theory cross-sections

<u>Sparticle mass limits</u>

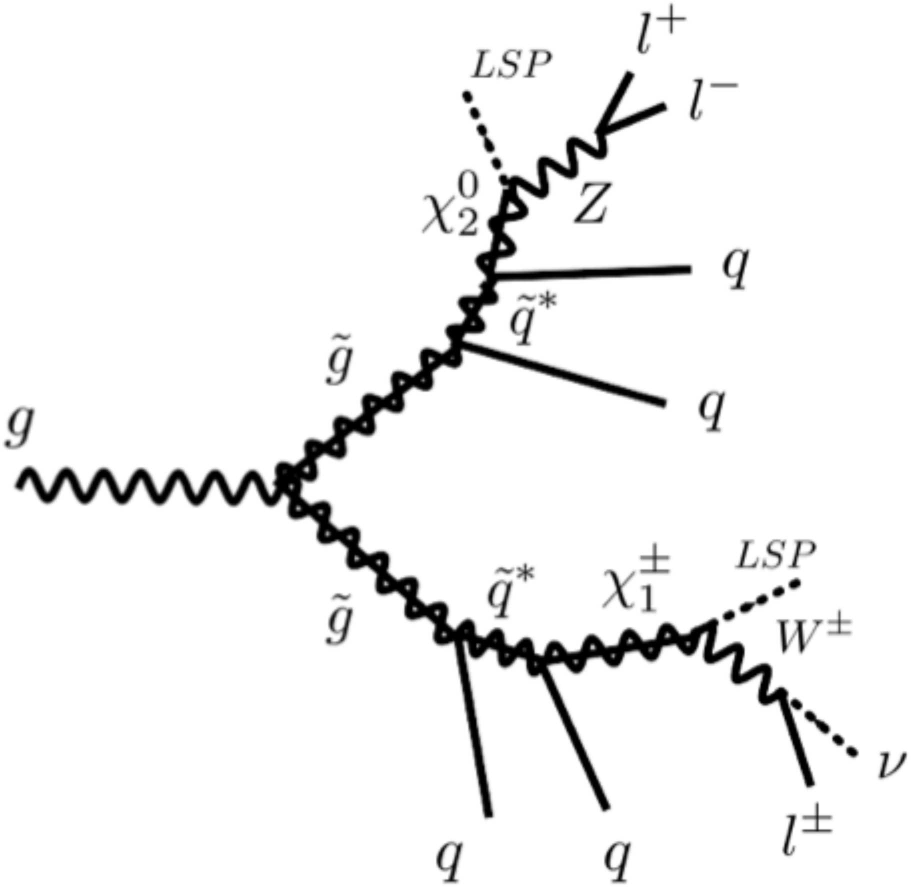
Compare upper limits on SUSY xs: σ^{95}*(sparticle masses)* to theory cross-sections.

Squark limits



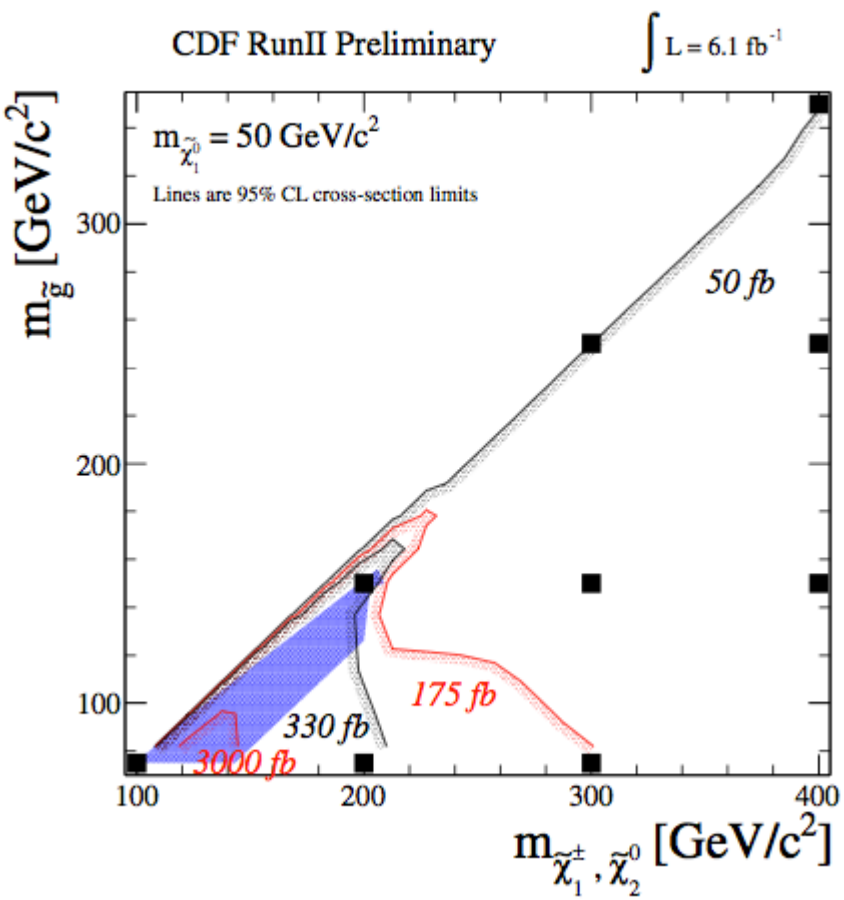


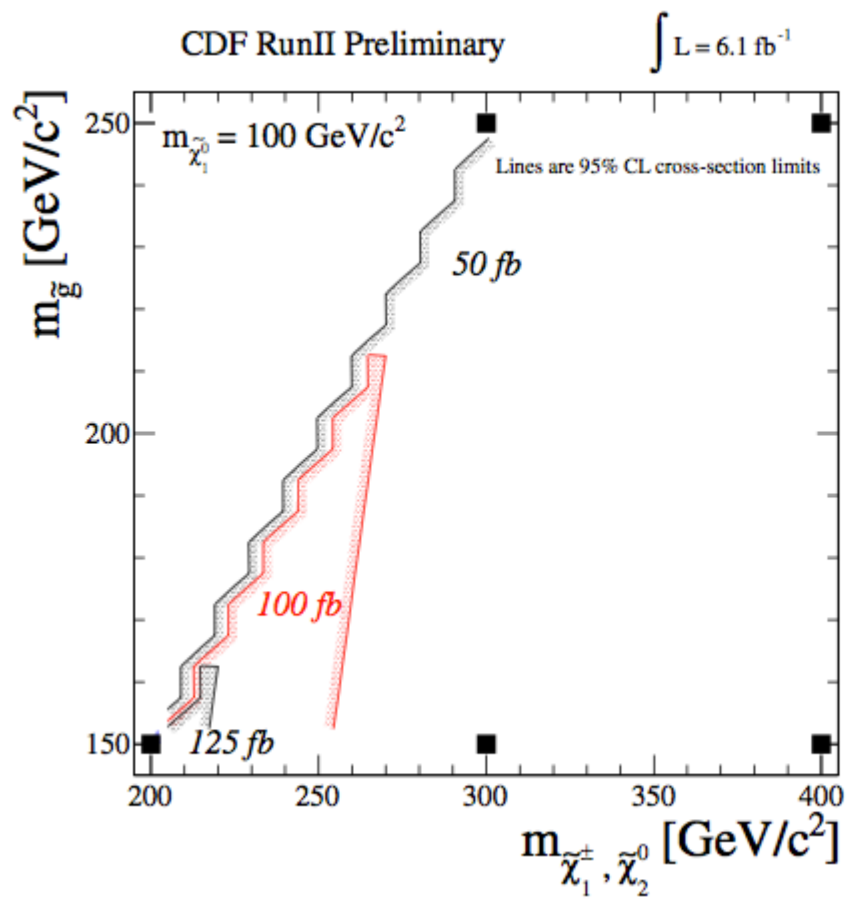
Gluinos



+WW,ZZ modes

Gluino limits





Outline

I. Motivation

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a. Heavy resonances (Z′)

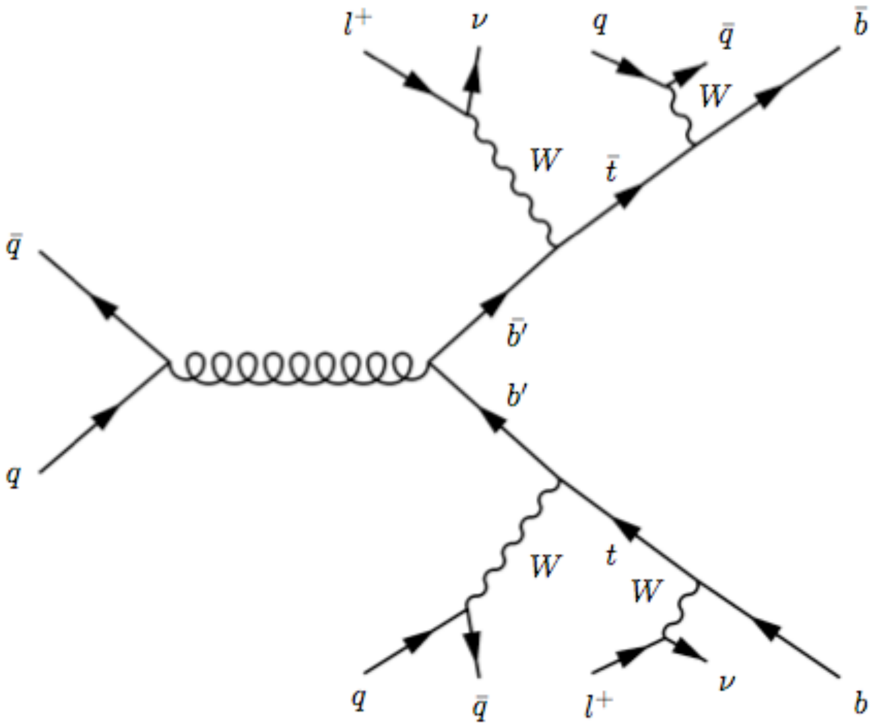
b. Heavy quarks (b′, t′)

c. Simplified SUSY

b′ decays

UCI undergrad
Reza AmirArjomand

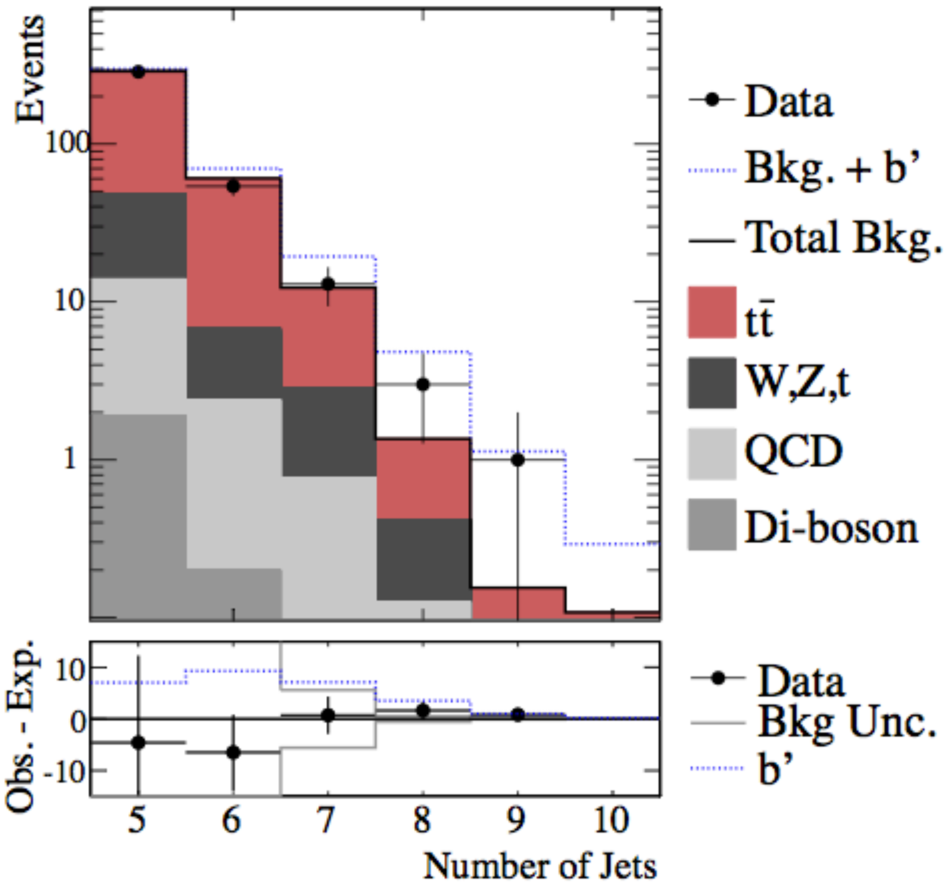
If b′ -> Wt



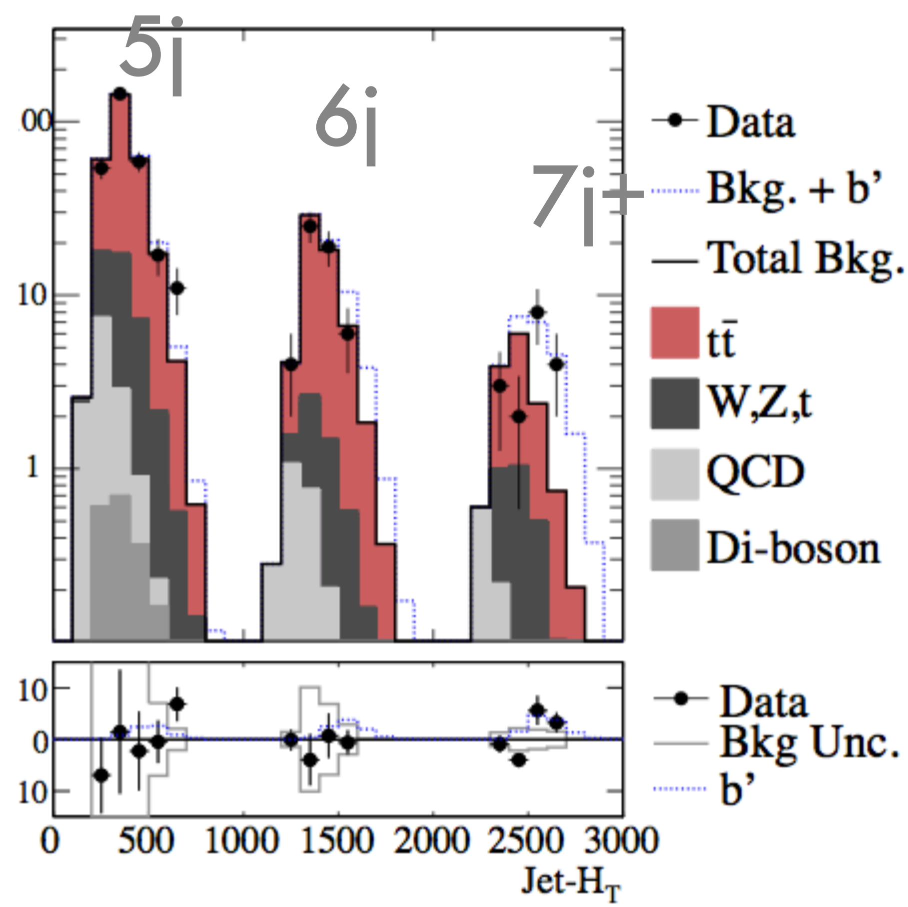
same-sign lepton selection: ~2%

consider single-lepton mode

Data, >=1 b-tag

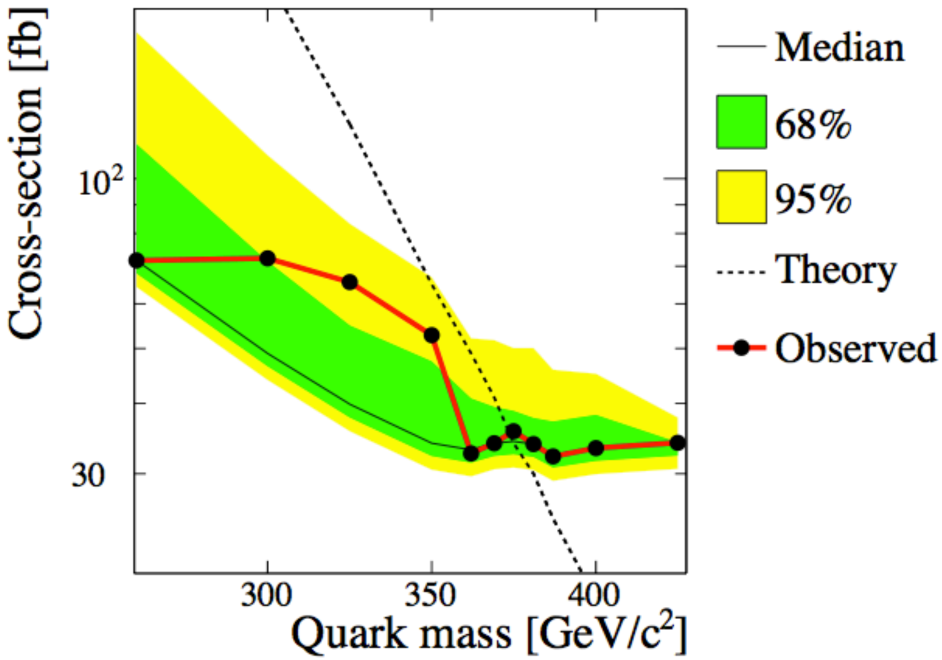


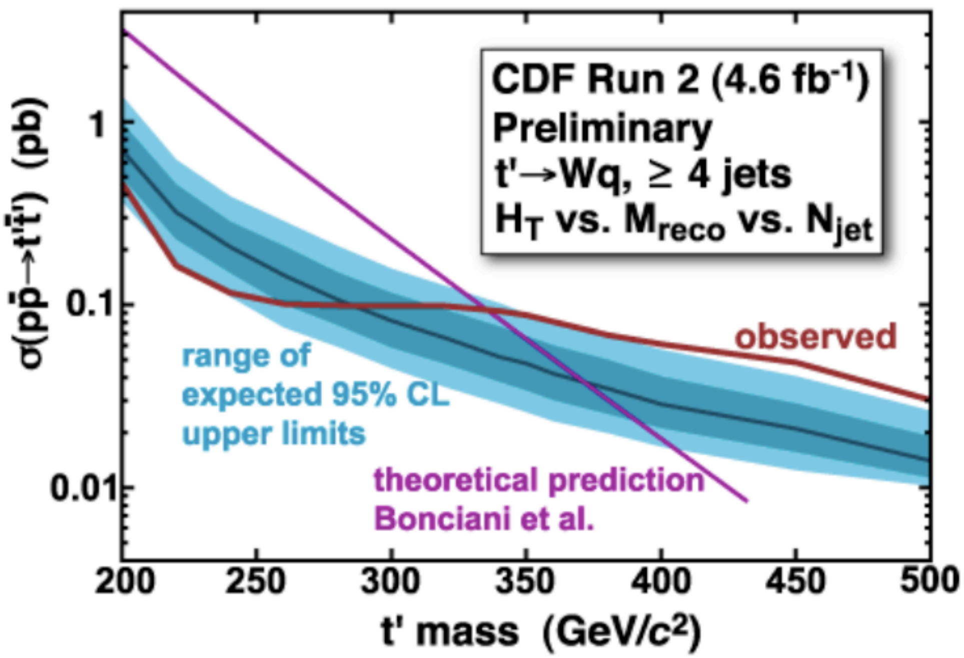
Events
100
10
1
Data
Bkg. + b'
Total Bkg.
$t\bar{t}$
W,Z,t
QCD
Di-boson
Obs. - Exp.
10
0
-10
Data
Bkg Unc.
b'
5
6
7
8
9
10
Number of Jets



5j
6j
7j+
00
10
1
Data
Bkg. + b'
Total Bkg.
$t\bar{t}$
W,Z,t
QCD
Di-boson
10
0
10
Data
Bkg Unc.
b'
0
500
1000
1500
2000
2500
3000
Jet-H_T

Direct searches

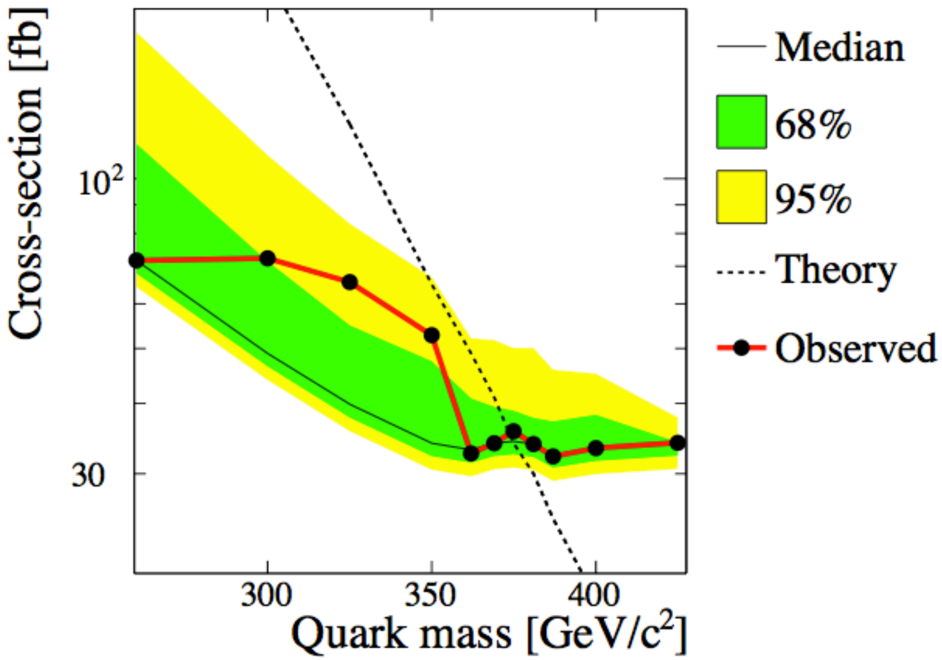


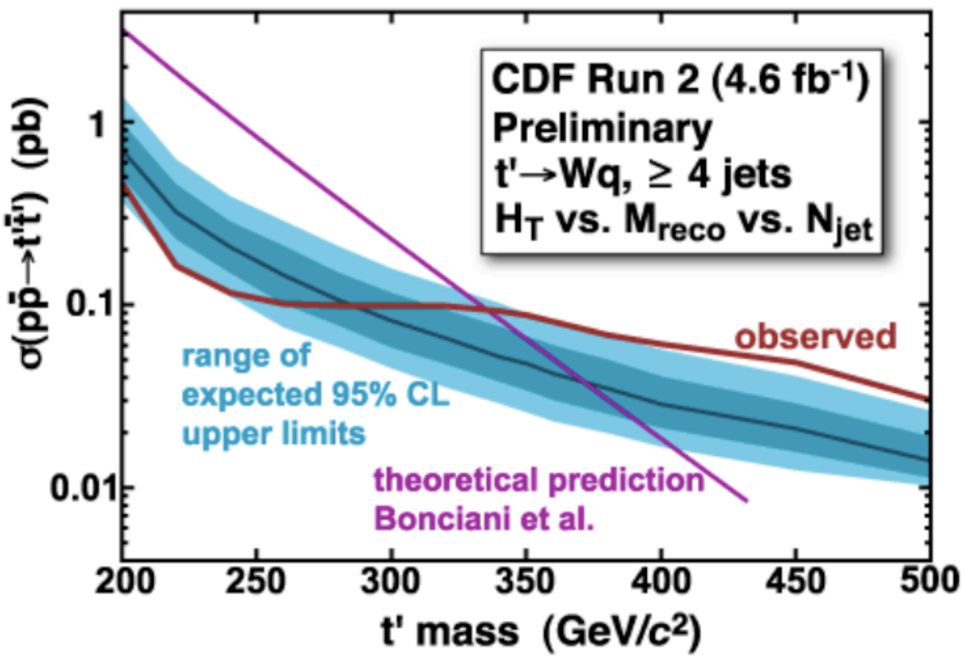


$m_{b'} > 372$ GeV

$m_{t'} > 335$ GeV

Direct searches





$m_{b'}$ > 372 GeV

If BR(b′ →Wt)=100%

$m_{t'}$ > 335 GeV

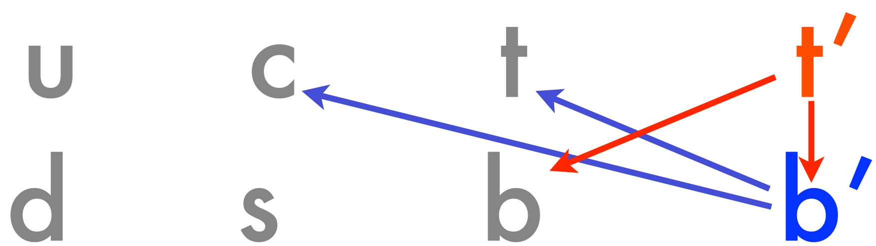
If BR(t′ →Wq)=100%

b′ and t′

UCI postdoc
Christian Flacco

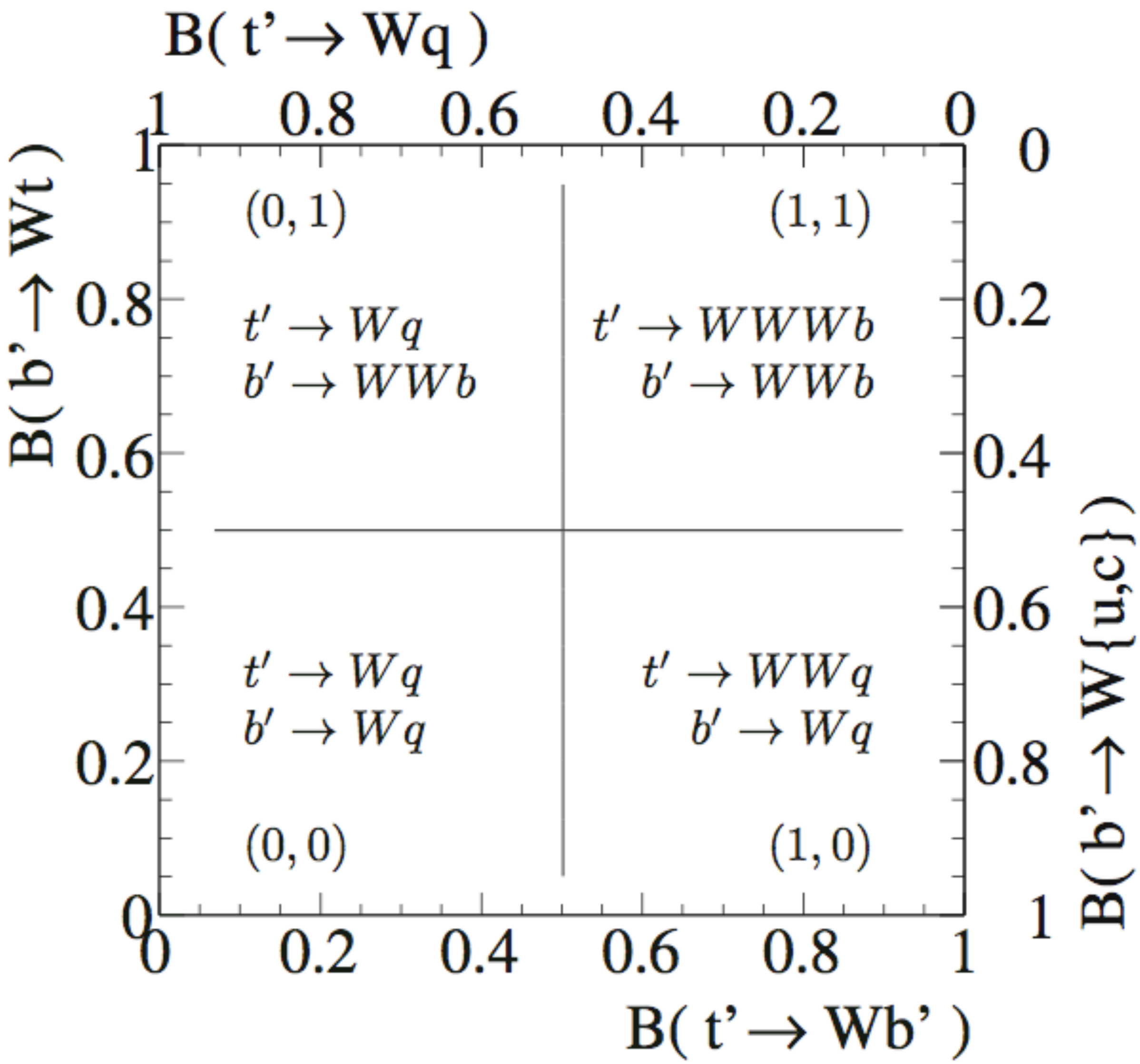
UCI undergrad
Matt Kelly

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



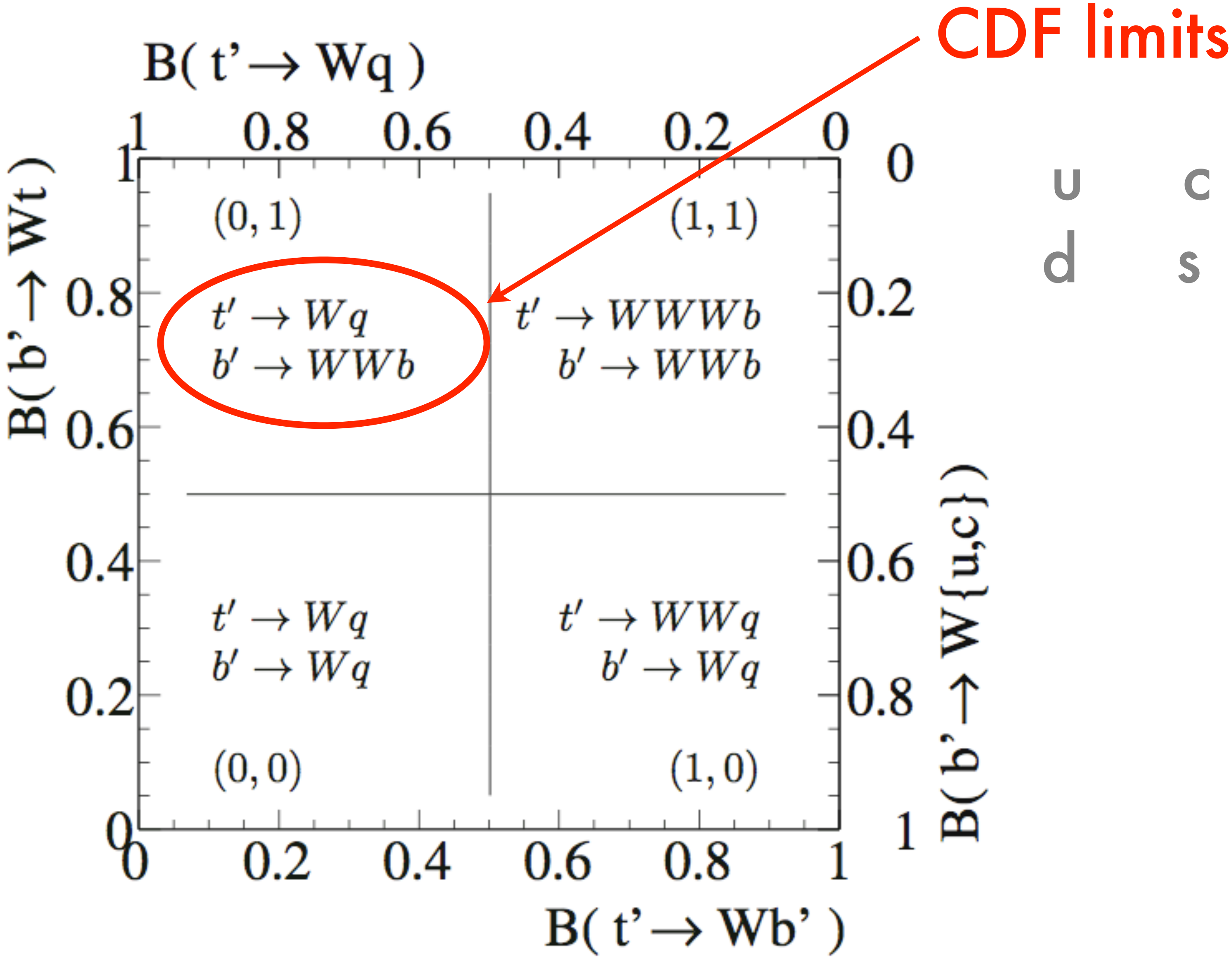
PRL 2010, PRD 2011

b′ and t′



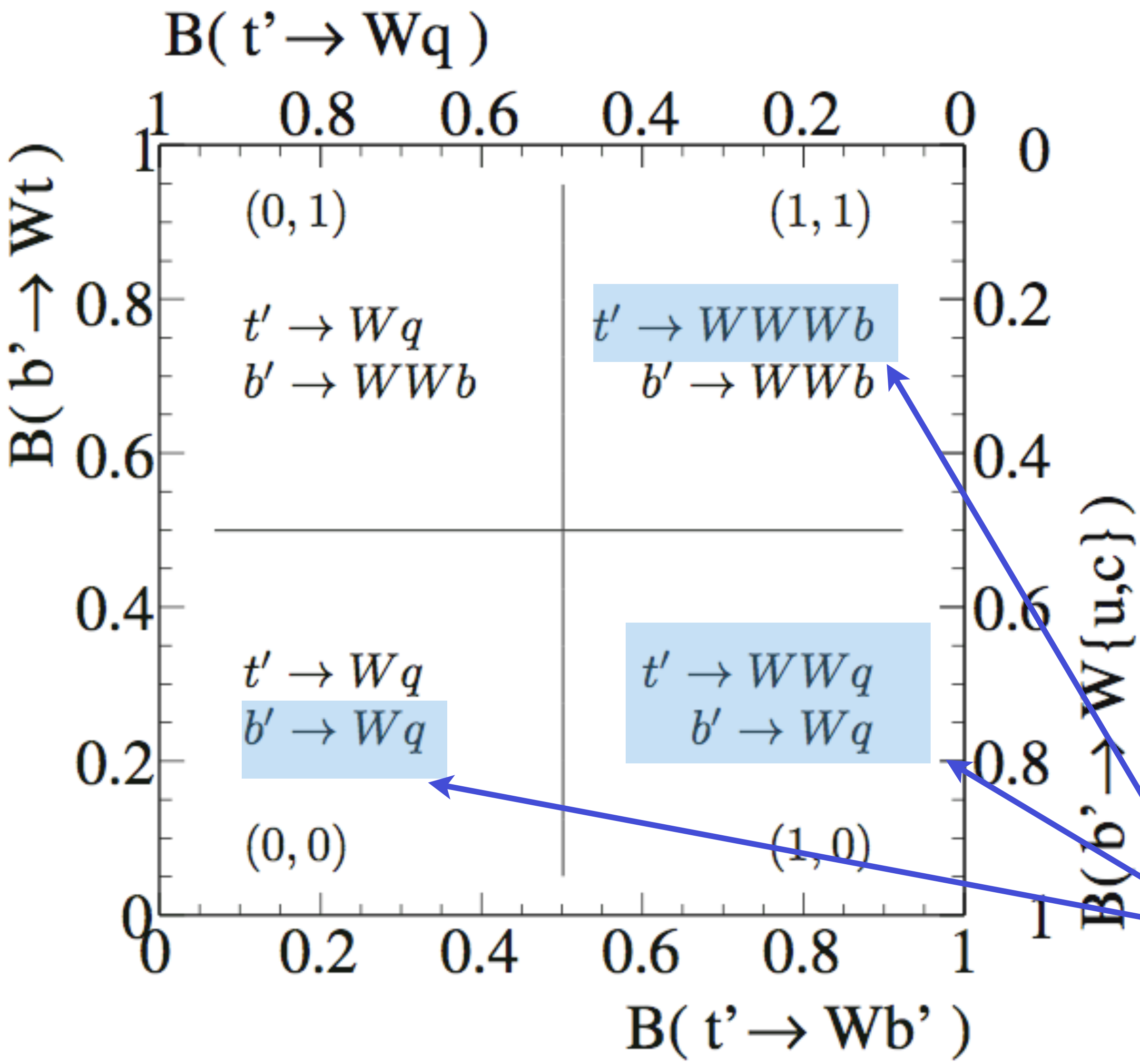
PRL 2010, PRD 2011

b′ and t′



PRL 2010, PRD 2011

b′ and t′



No direct limits!

PRL 2010, PRD 2011

Re-casting...

<u>RECAST</u>:

Have: t't' -> WqWq -> lv q qqq

Want: t't' -> Wb'Wb' ->WWqWWq-> lv q qqqqqq

<u>Top mass is fit per event</u>

how does new signal look?

<u>signal and background templates are fit</u>

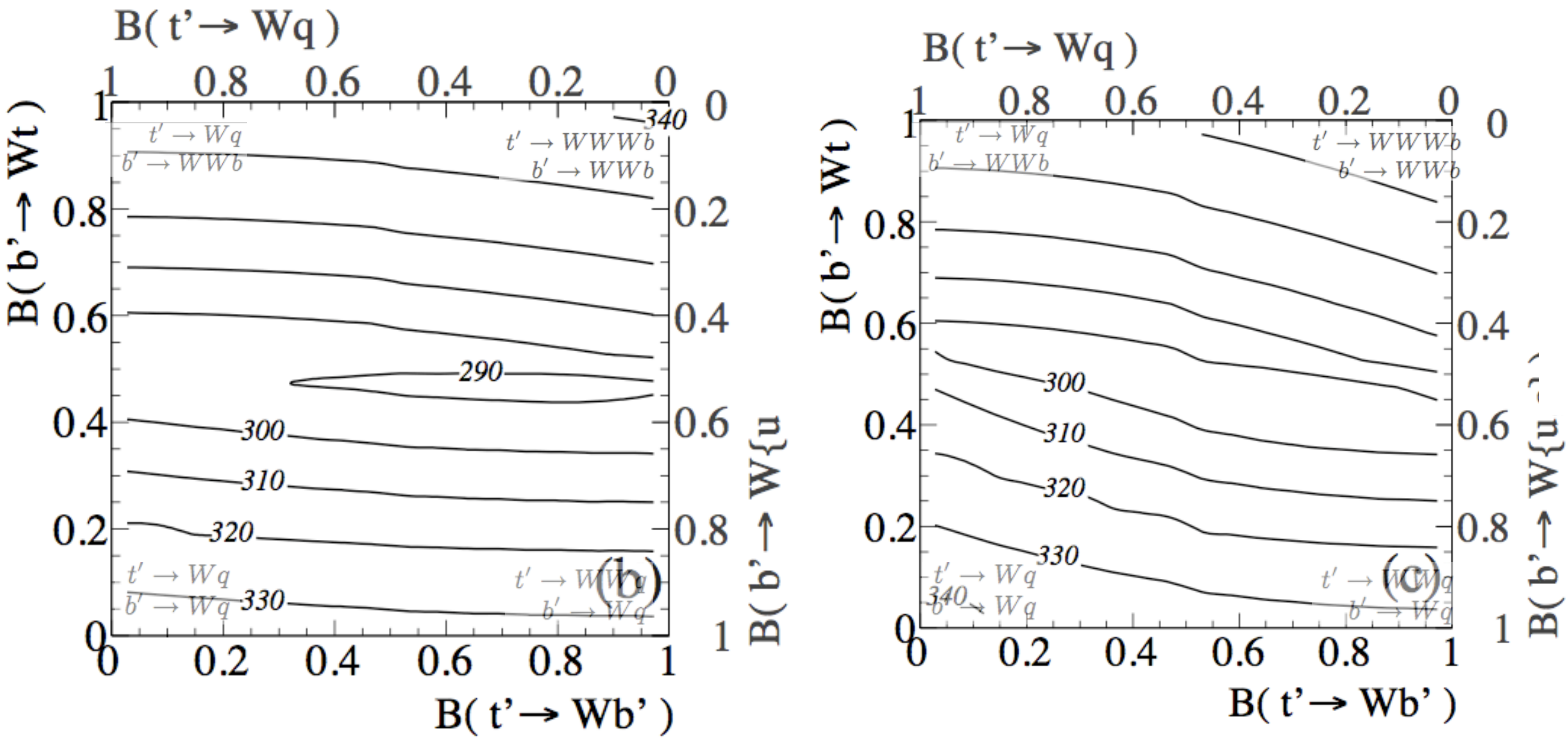
how does this perform?

<u>Used rate of WqWq only</u>

b'b' -> WqWq

ignored any non-WqWq contribution

t′ and b′



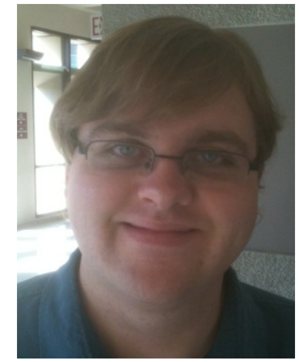
$m_{t'} = m_{b'} + 100$

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

PRL 2010, PRD 2011

ATLAS t′

UCI grad student
Michael Werth



Selection

2 OS leptons

pt>20 GeV

2 jets

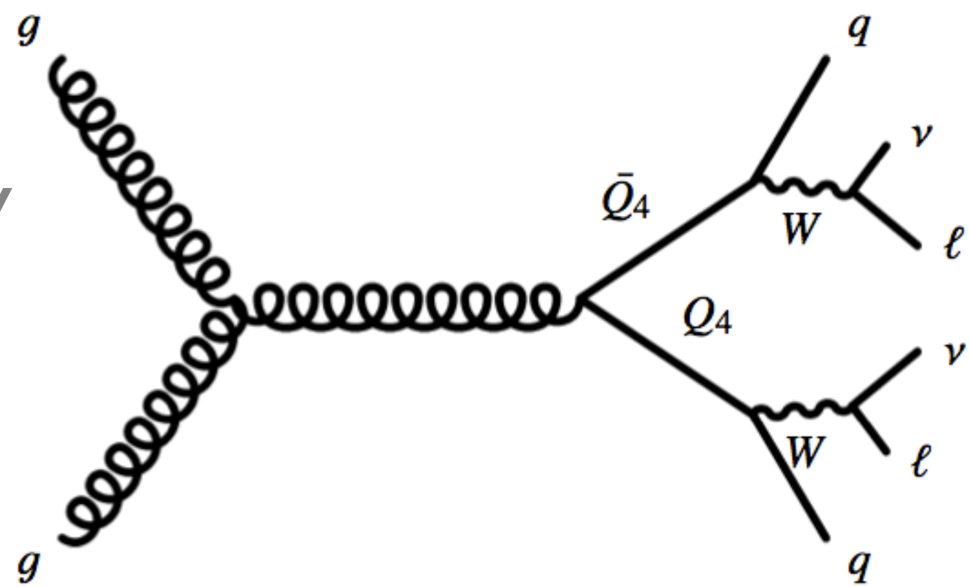
pt>20 GeV

Missing transverse energy

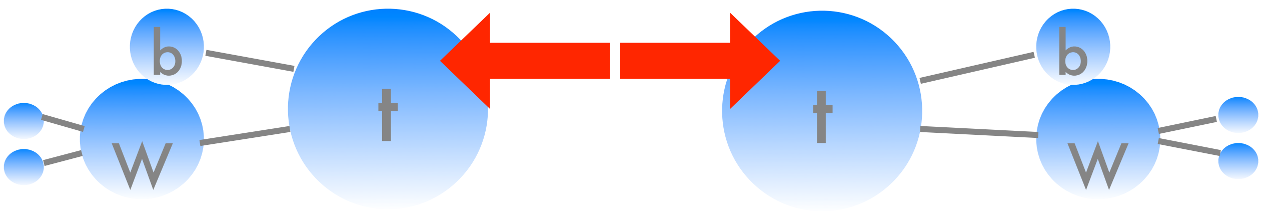
>20 GeV

Sample

35/pb

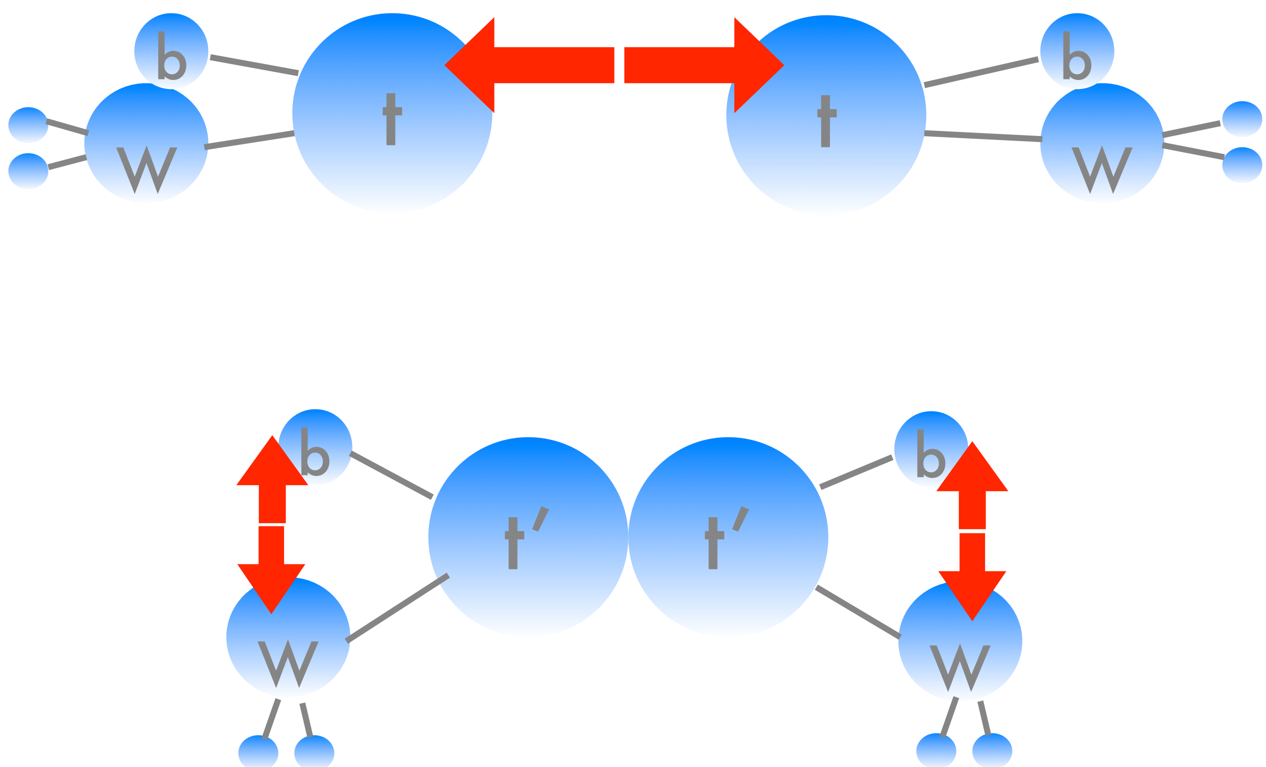


topology



Boosted tops

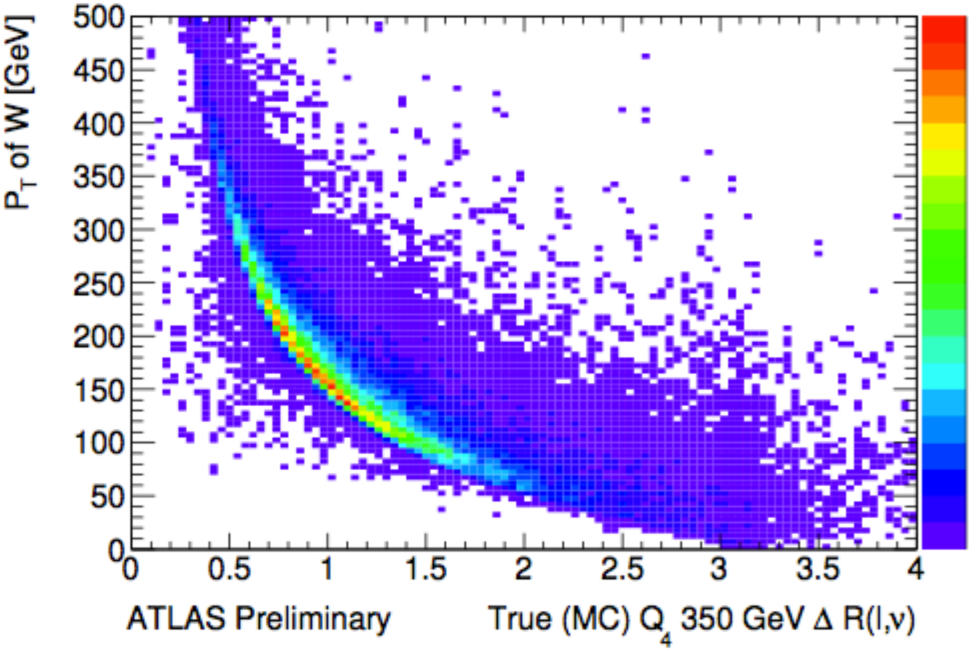
topology



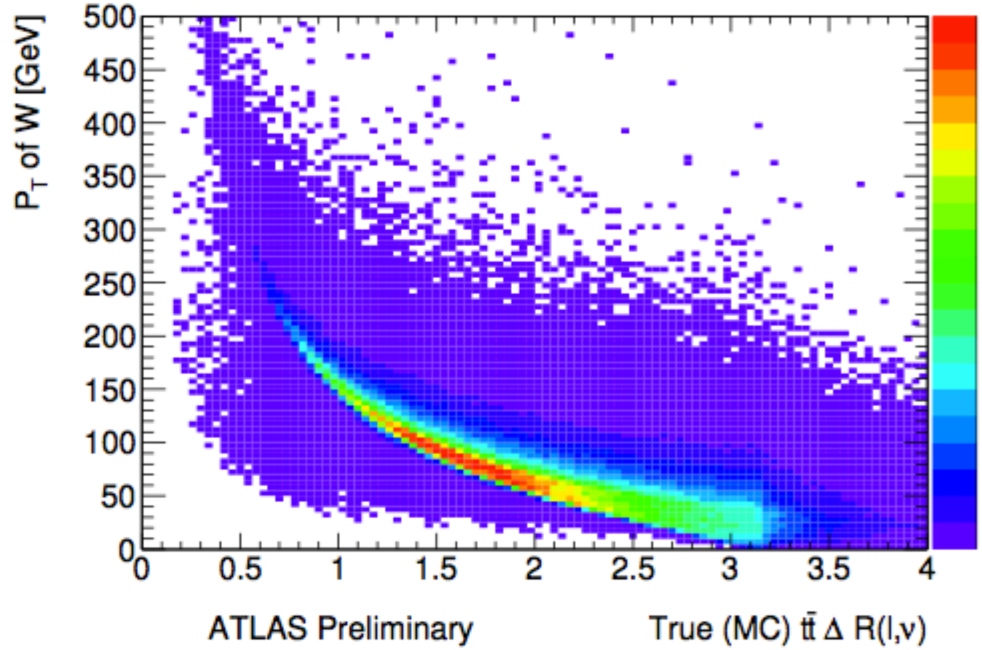
Boosted Ws!

Lepton-neutrino angles

Heavy t′



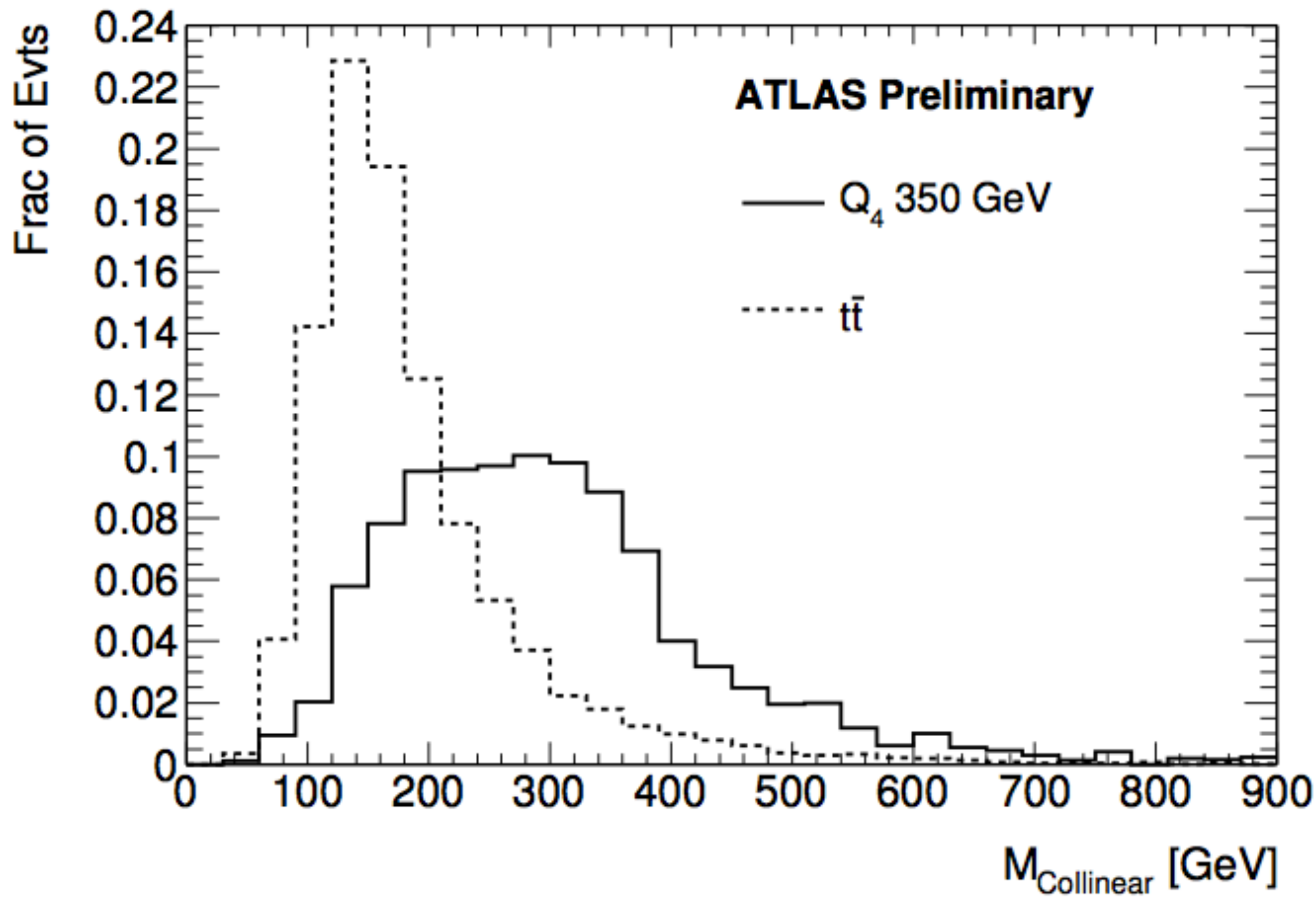
SM top



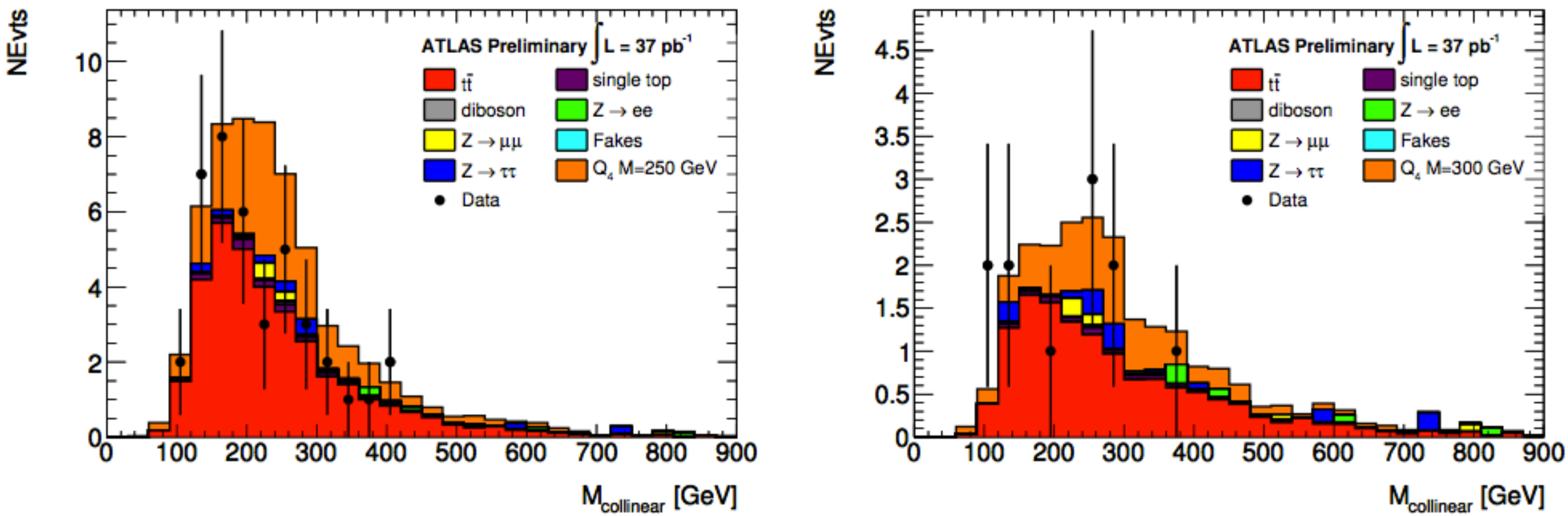
More W p_T means smaller opening angle

Mass reconstruction

Assume lepton and neutrino are ~collinear

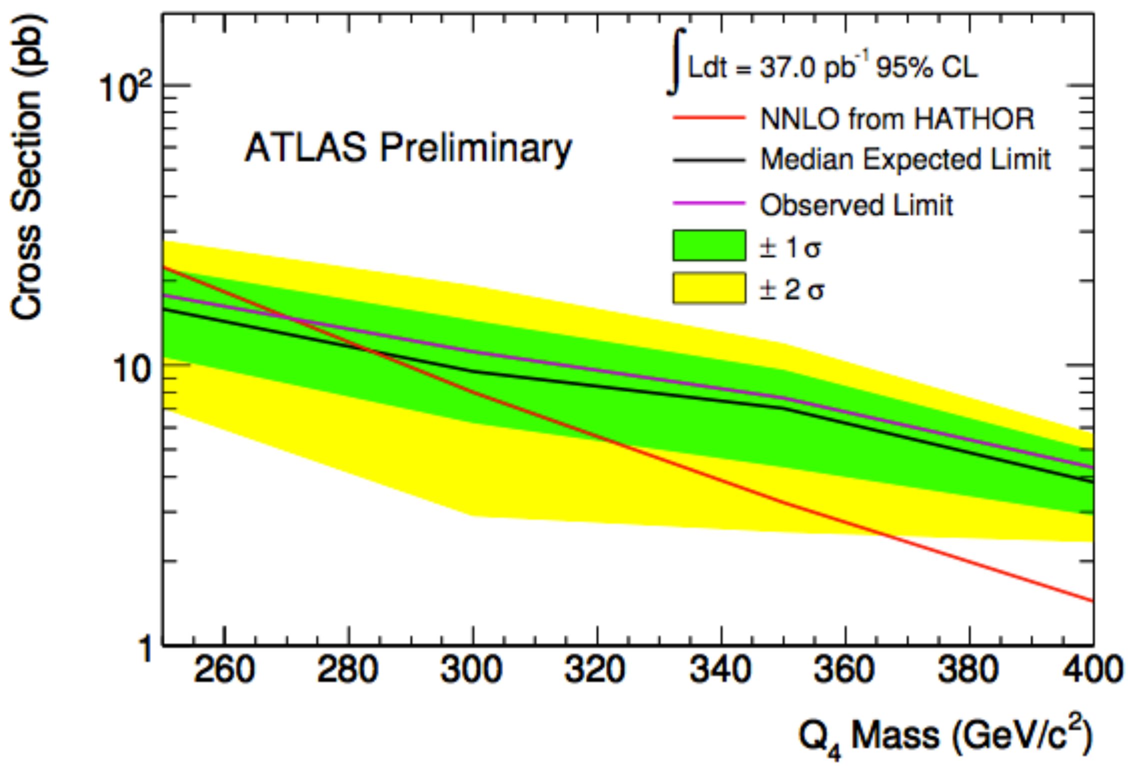


Data



No sign of heavy quarks...

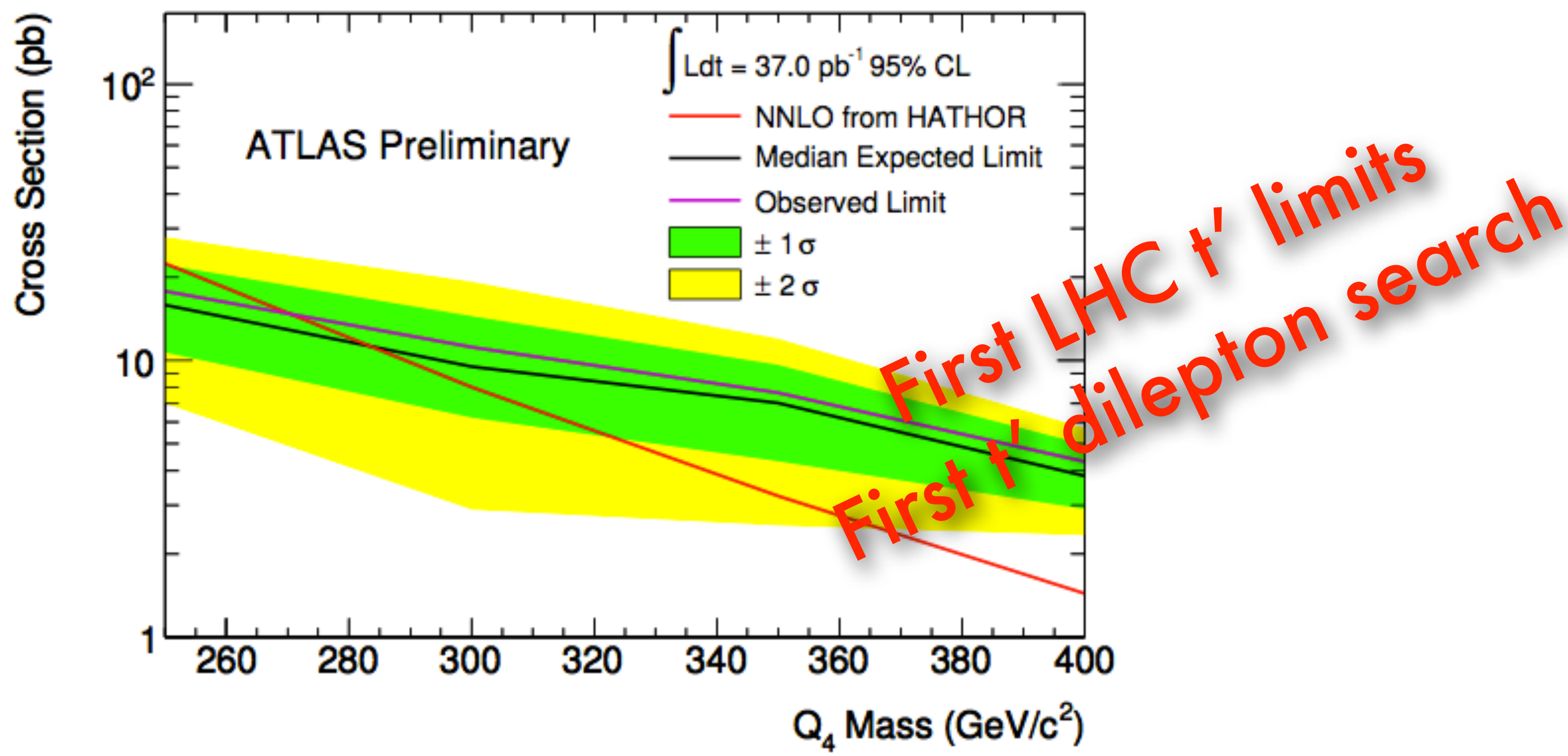
Limit



Limit

$m_{t'} > 275$ GeV

Limit

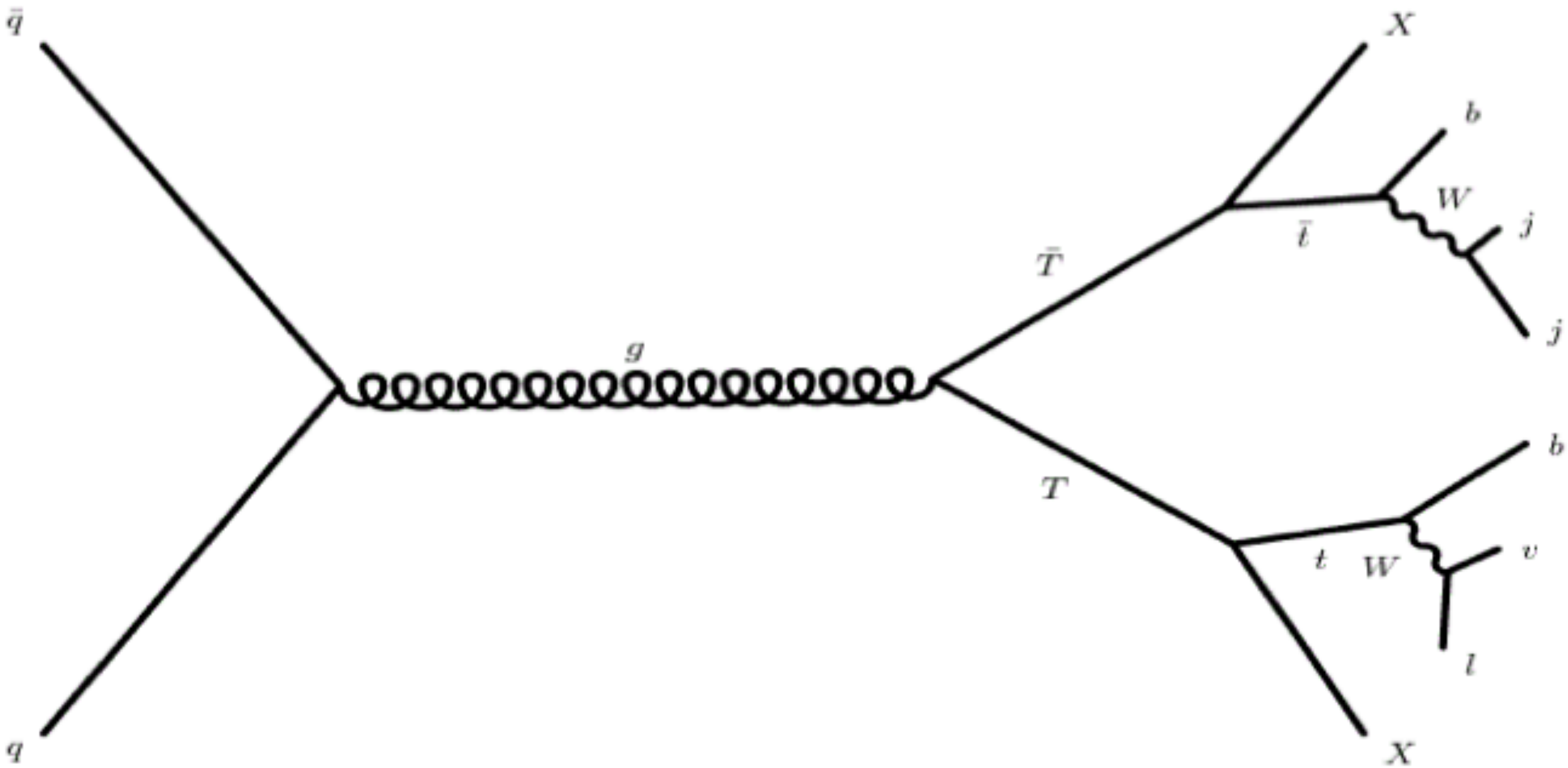


Limit

$m_{t'} > 275$ GeV

Dark Matter+4th gen

UCI grad student
Kanishka Rao

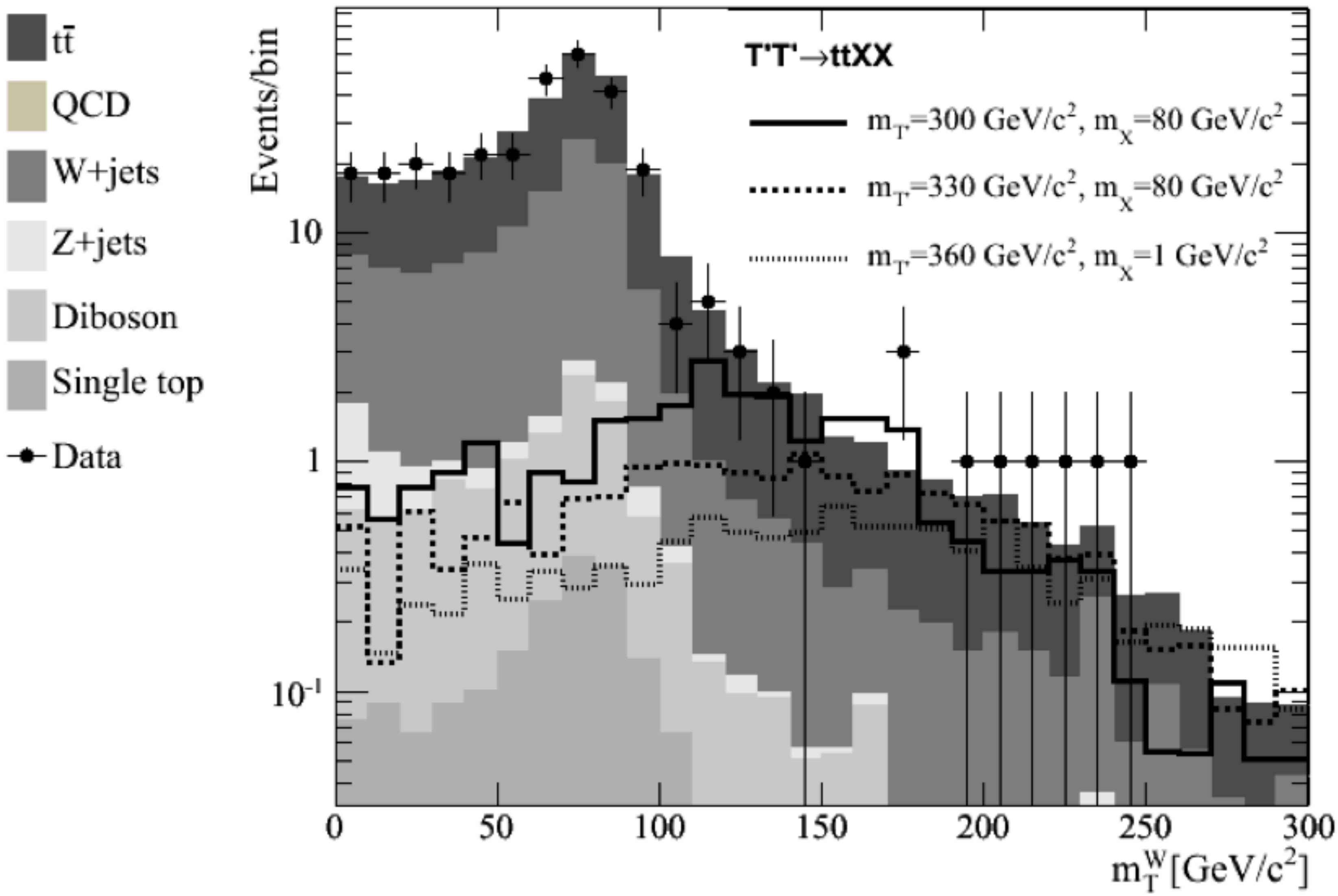


Look for ttbar + invisible X

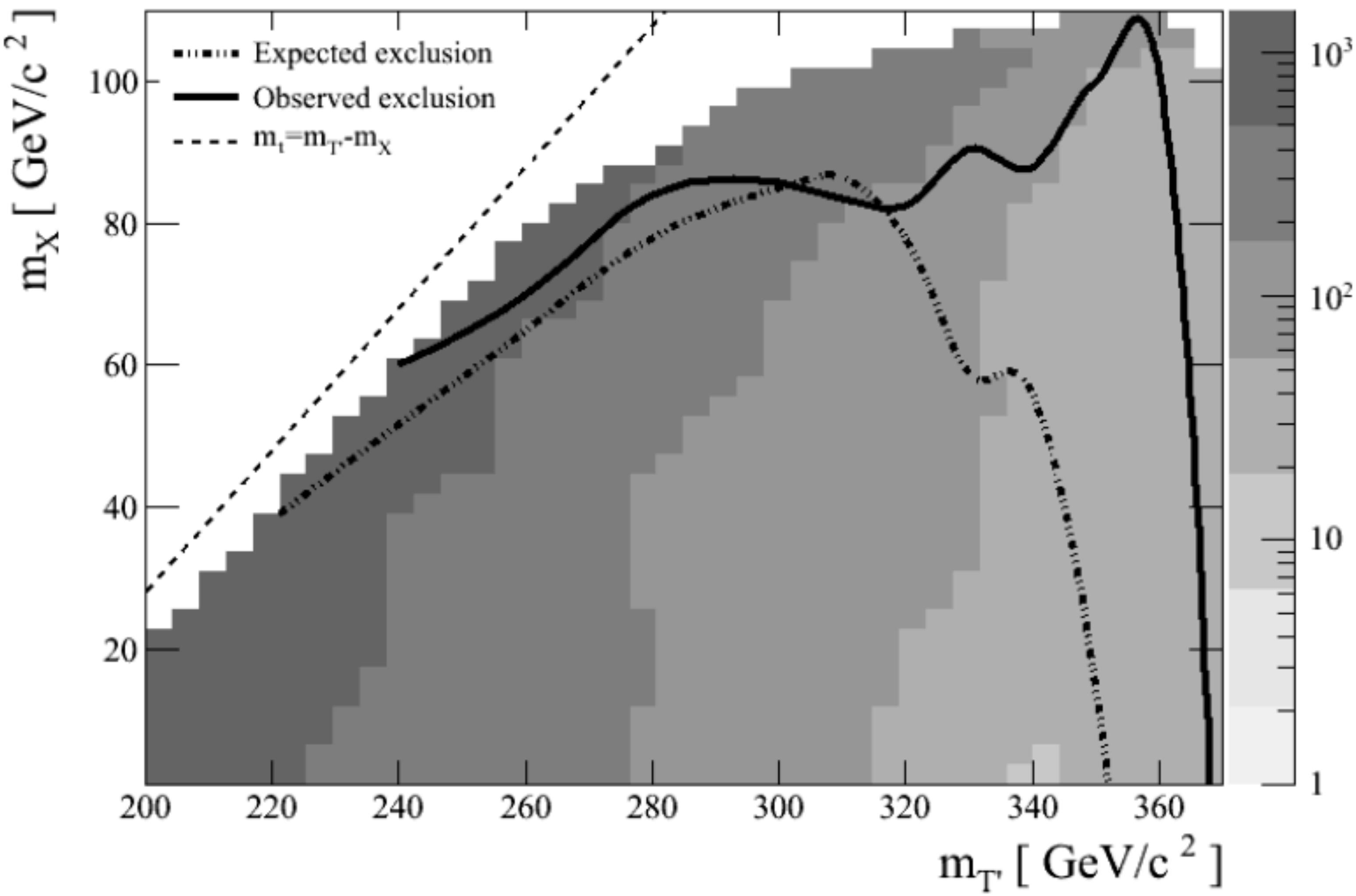
T' -> t+X

stop -> t + LSP

Transverse mass



Limits



Expected exclusion
Observed exclusion
$m_t = m_{T'} - m_X$
m_X [GeV/c ^{2}]
$m_{T'}$ [GeV/c ^{2}]
200
220
240
260
280
300
320
340
360
20
40
60
80
100
1
10
10^2
10^3

Summary

<u>Simplified models are powerful, but</u>

- limited ability to recast
- need to address issue of combining results

<u>New searches:</u>

- CDF same-sign dileptons
  same-sign tops
  supersymmetry
  http://www-cdf.fnal.gov/~danielw/lsdil/lsdil.html
- CDF/ATLAS heavy quark searches

backups

[redacted]

CDF RunII Preliminary $\int \mathcal{L}dt = 6.1$ fb^{-1}				
Process	Total $\ell\ell$	$\mu\mu$	ee	$e\mu$
$t\bar{t}$	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.0
$Z \to ee$	15.7 ± 2.7	0.0 ± 0.0	15.7 ± 2.7	0.0 ± 0.0
$Z \to \mu\mu$	8.7 ± 2.0	0.0 ± 0.0	0.0 ± 0.0	8.7 ± 2.0
$Z \to \tau\tau$	2.2 ± 0.9	0.0 ± 0.0	1.3 ± 0.6	1.0 ± 0.6
WZ	24.7 ± 1.3	7.0 ± 0.4	5.1 ± 0.3	12.7 ± 0.7
WW	0.2 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.0
ZZ	3.5 ± 0.2	0.9 ± 0.1	0.8 ± 0.1	1.7 ± 0.1
$W(\to e\nu)\gamma$	7.8 ± 1.7	0.0 ± 0.0	7.8 ± 1.7	0.0 ± 0.0
$W(\to \mu\nu)\gamma$	7.8 ± 1.7	0.0 ± 0.0	0.0 ± 0.0	7.8 ± 1.7
$W(\to \tau\nu)\gamma$	0.6 ± 0.4	0.0 ± 0.0	0.3 ± 0.3	0.3 ± 0.3
Fakes	51.6 ± 24.2	8.2 ± 5.3	22.1 ± 8.9	21.3 ± 10.6
Total	123.0 ± 24.6	16.1 ± 5.4	53.3 ± 9.5	53.6 ± 10.9
Data	145	14	66	65