



Search for new fermion-pair decays
 $Q\bar{Q} \rightarrow (tW^\mp)(\bar{t}W^\pm)$
in same-charge dilepton events

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On behalf of the CDF Collaboration



Search for b' and

$B+T_{5/3}$

Why nothing here?

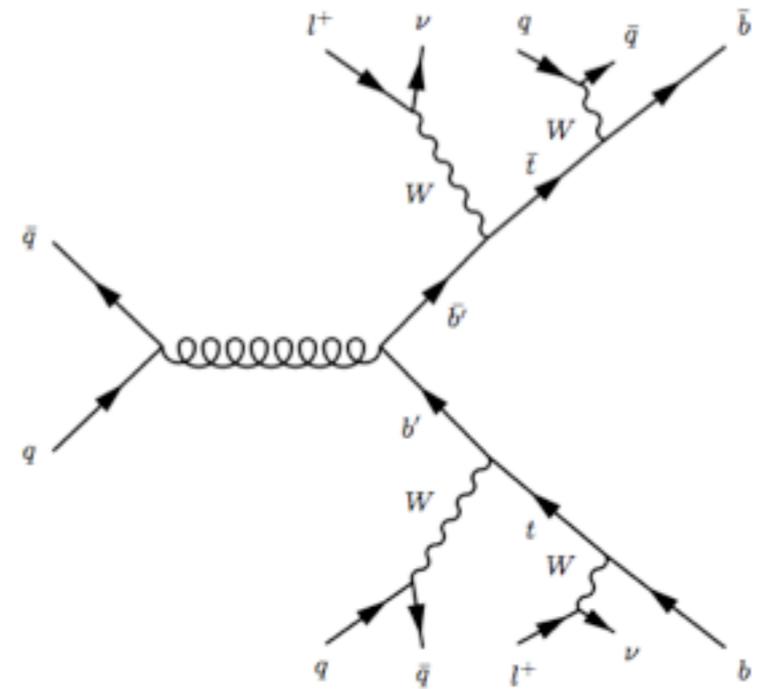
- Why only 3 generations of quarks?
- No current compelling reason to believe only 3 generations.
- Search for b', 4th generation down type quark.
- Past Limits:
 - > 128 GeV Neutral Current
 - *C.Amsler et al. (Particle Data Group), Phys. Lett. B667, 1 (2008)
 - > 268 GeV Charged Current (1/fb)
 - CDF Collaboration: T.Aaltonen, et al arXiv:0706.3264
- Also search for heavy B and $T_{5/3}$

Three Generations of Matter (Fermions)

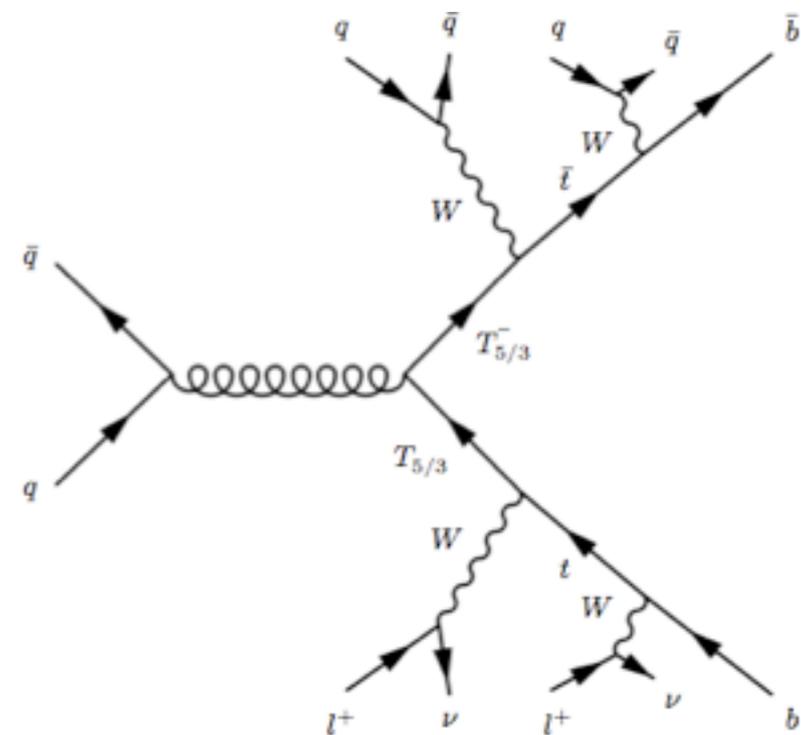
	I	II	III	
mass →	2.4 MeV	1.27 GeV	171.2 GeV	0
charge →	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0
spin →	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
name →	u up	c charm	t top	γ photon
Quarks	4.8 MeV $-\frac{1}{3}$ $\frac{1}{2}$ d down	104 MeV $-\frac{1}{3}$ $\frac{1}{2}$ s strange	4.2 GeV $-\frac{1}{3}$ $\frac{1}{2}$ b bottom	0 0 1 g gluon
Leptons	< 2.2 eV 0 $\frac{1}{2}$ ν_e electron neutrino	< 0.17 MeV 0 $\frac{1}{2}$ ν_μ muon neutrino	< 15.5 MeV 0 $\frac{1}{2}$ ν_τ tau neutrino	91.2 GeV 0 1 Z weak force
	0.511 MeV -1 $\frac{1}{2}$ e electron	105.7 MeV -1 $\frac{1}{2}$ μ muon	1.777 GeV -1 $\frac{1}{2}$ τ tau	80.4 GeV ± 1 1 W [±] weak force
				Bosons (Forces)

Signal and Background

- Pair production decays to same-sign dilepton signature.
- Rare in Standard Model, very sensitive at CDF
- Backgrounds
 - 2nd lepton faked
 - Mainly from W +Jets
 - 2nd lepton real
 - From $Z \rightarrow e^+e^-$ with asymmetric conversion.
 - $t\bar{t} \rightarrow e e b \bar{b}$, asymmetric conversion same as Z .
- Analysis implicitly assumes mass < 255 GeV because of $b' \rightarrow Wt$ decay
- For $B+T_{5/3}$ can assume masses about = equal due to constraints on electroweak observables.



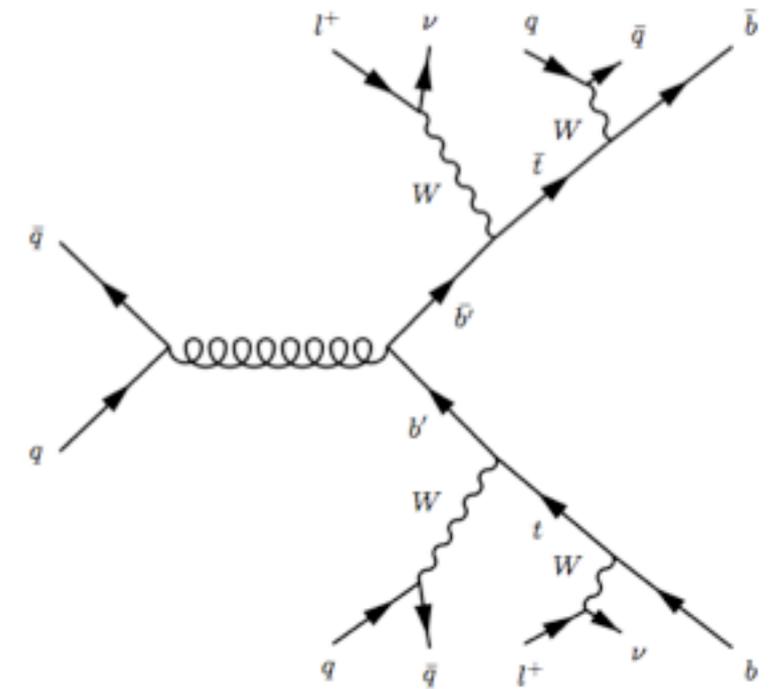
b' and B Production



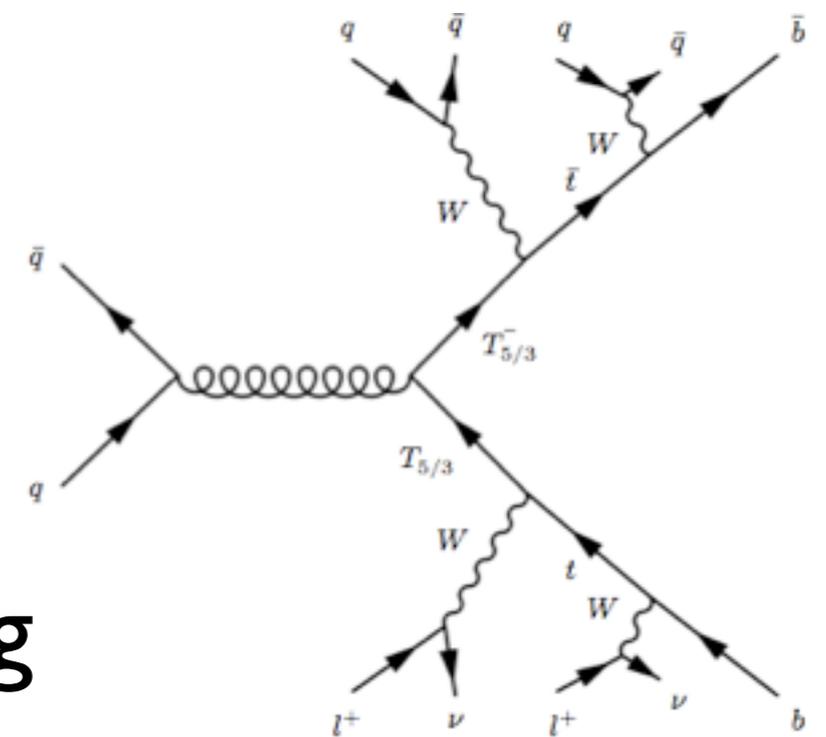
$T_{5/3}$ Production

Selection

- Two same-charge leptons
 - electrons or muons
 - $p_T > 20$ GeV.
 - $|\eta| < 1.1$
 - Avoid high misidentification of charge at large eta
- Jets
 - $p_T > 15$ GeV/c,
 - $|\eta| < 2.4$
 - At least 2 jets
- Missing Energy
 - > 20 GeV
- At least one positive SECVTX b-tag



b' and B Production

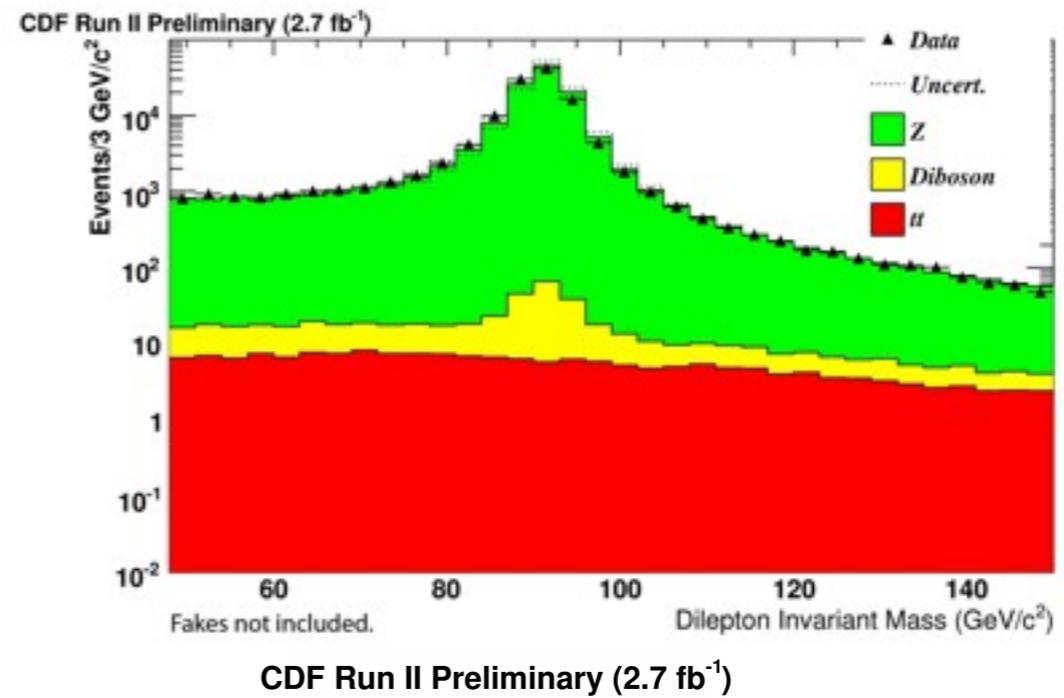


$T_{5/3}$ Production

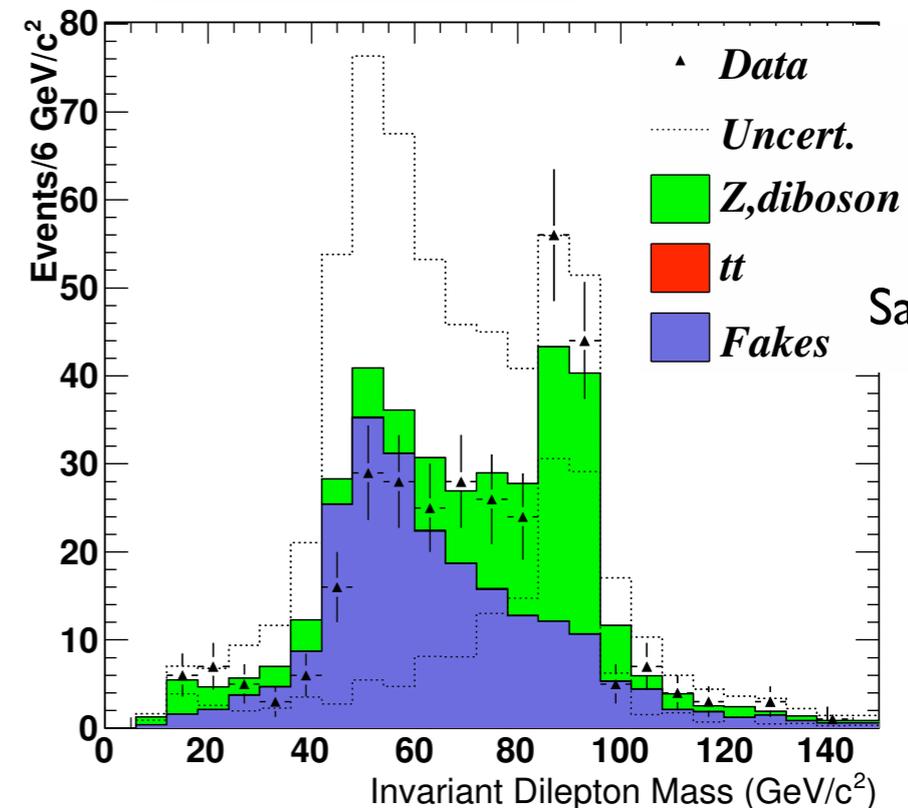


Z Verification

- Z Normalization verified in opposite-charge leptons.
- Same sign leptons shows $Z \rightarrow e^+e^+$ well understood.
- Fakes also well understood.



Opposite-
Charge
Leptons

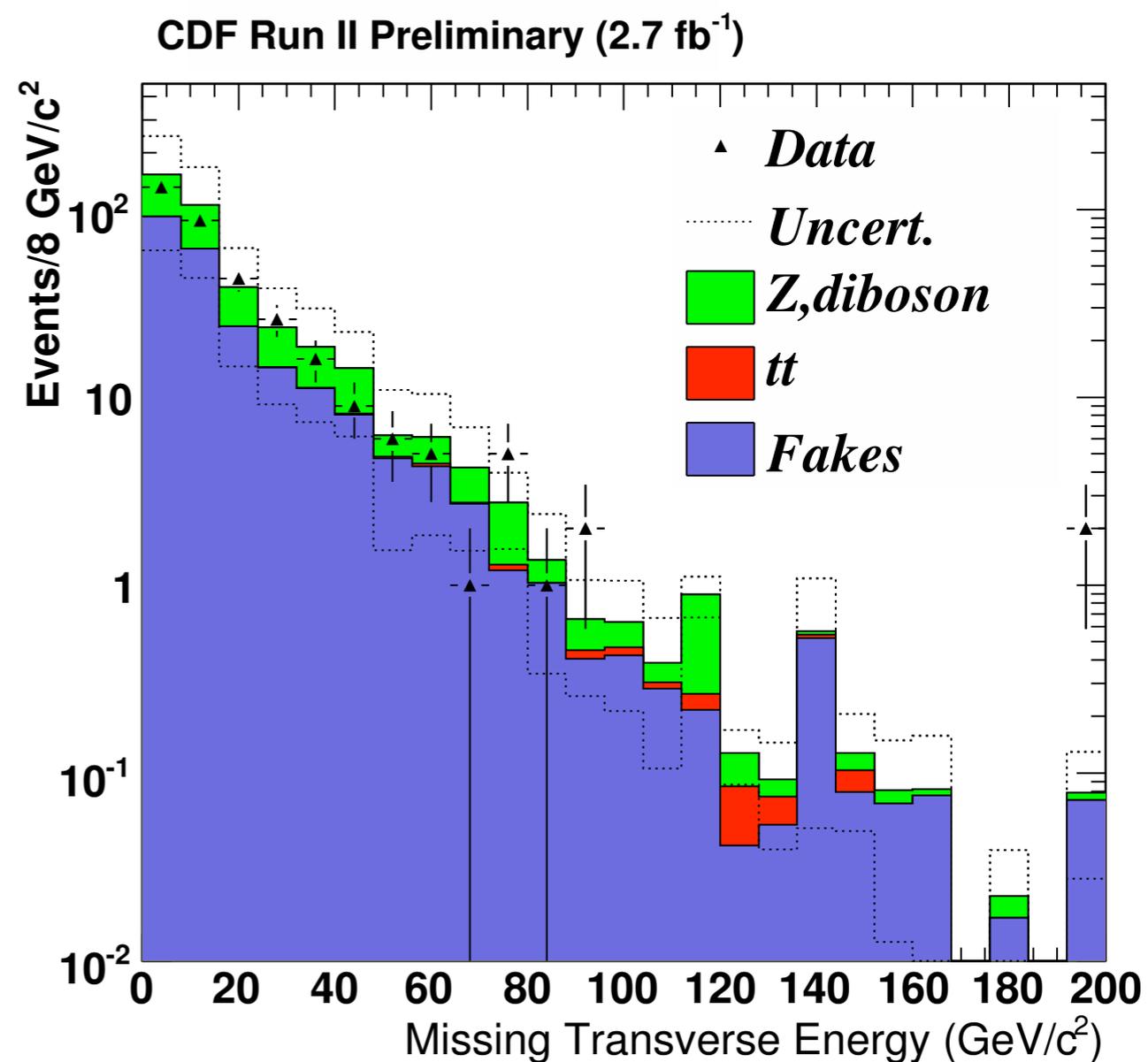


Same-Charge
Leptons



Missing Transverse Energy

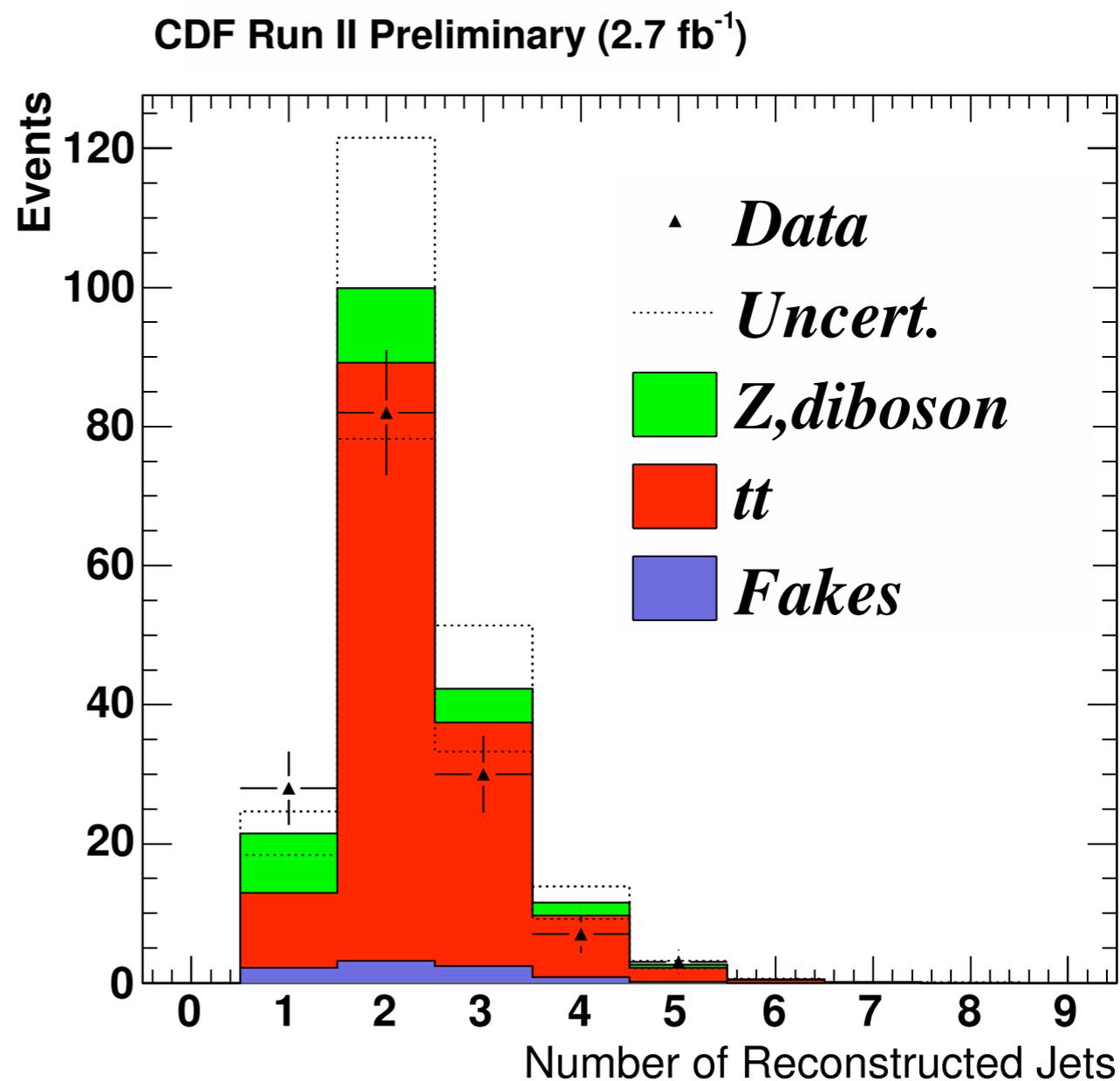
- 20 GeV MET cut done at analysis level.
- MET in same-sign leptons needs to be well understood.
- Plot shows MET in same-sign leptons.
- Falls off at high MET as expected.
- Data points within uncertainties.
- Fake rate is also verified here.





Top Verification

- Assuming mass of top = 172 GeV/c².
- 7.2 pb
- Cuts
 - opposite sign leptons, $|\eta| < 1.1$, Missing Transverse Energy > 20 GeV, b-tag
- Overall normalization in agreement with data.
- Remaining differences between data and background estimate used to generate uncertainties for fit.





Data and Expected Signal

CDF Run II Preliminary 2.7 fb^{-1}

Source	ee	$\mu\mu$	$e\mu$	ll
$Z, \text{ diboson}$	0.03 ± 0.02	0.02 ± 0.01	0.04 ± 0.02	0.1 ± 0.05
$t\bar{t}$	0.17 ± 0.02	0.06 ± 0.01	0.22 ± 0.02	0.5 ± 0.1
$W + \text{ jets}$	0.56 ± 0.56	0.34 ± 0.34	0.47 ± 0.47	1.4 ± 1.4
Total	0.8 ± 0.6	0.4 ± 0.3	0.7 ± 0.5	1.9 ± 1.4
Data	0	1	1	2

CDF Run II Preliminary 2.7 fb^{-1}

Source	ee	$\mu\mu$	$e\mu$	ll
$300 \text{ GeV}/c^2 \text{ } b'$	$1.97 \pm .20$	$2.14 \pm .21$	$4.88 \pm .49$	$9.0 \pm .90$
$300 \text{ GeV}/c^2 \text{ } T_{5/3} + B$	$4.17 \pm .42$	$4.22 \pm .42$	$9.56 \pm .96$	17.9 ± 1.8

- Observed 2 events at final cut level. In excellent agreement with background prediction.
- Well below 9.0 and 17.9 events for b' and $T_{5/3}+B$ signal.

Fitting Procedure

- Fitting

- For a specific experiment extract σ signal cross-section
- Use a binned likelihood fit in the number of jets
- Translate into scale factor:

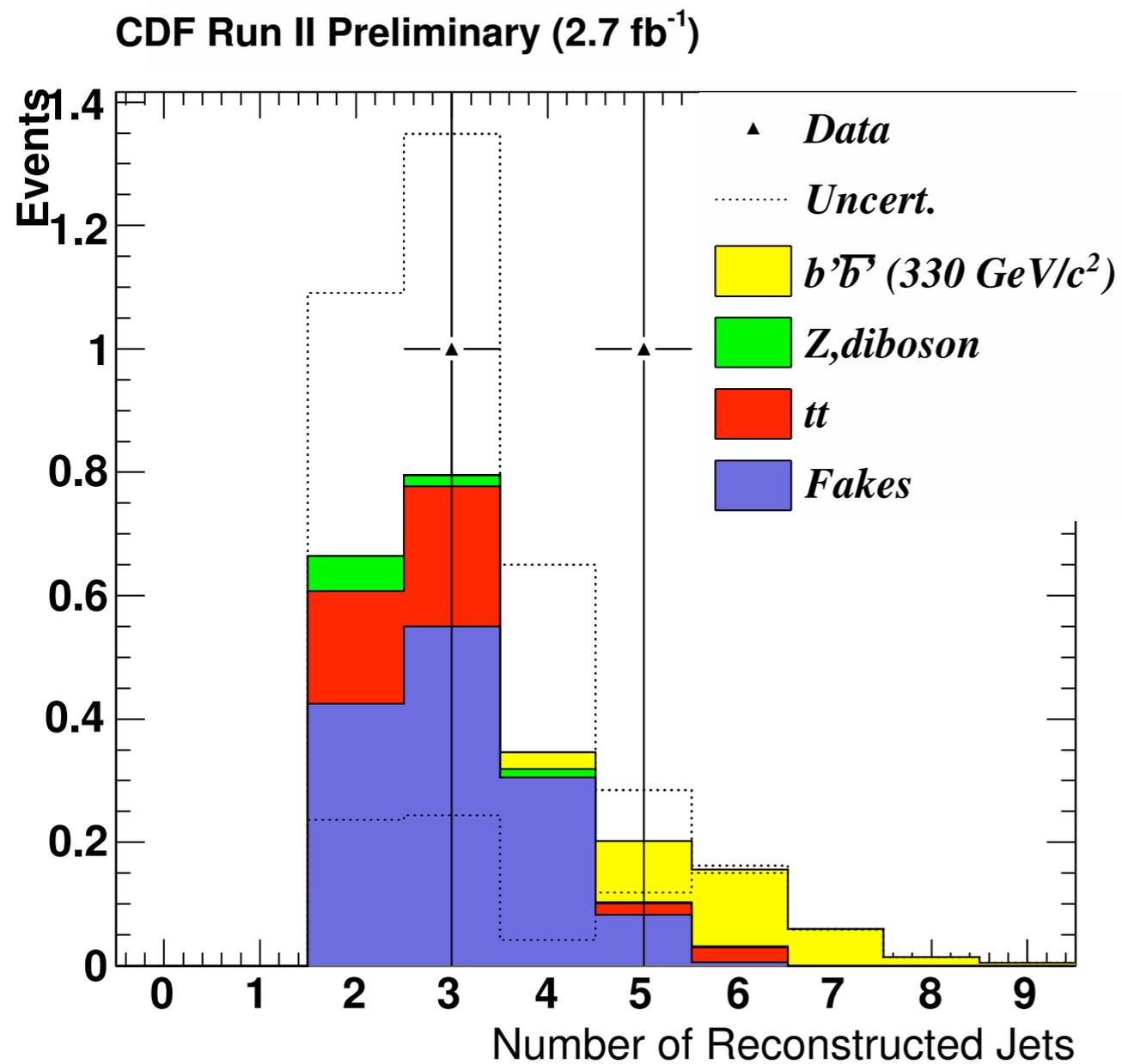
$$SF = \frac{\sigma}{\sigma_{Theory}}$$

- Pseudo-experiments

- Many pseudo-experiments at different true scale factors.
- Run Feldman-Cousins procedure to obtain 95% Confidence Bands



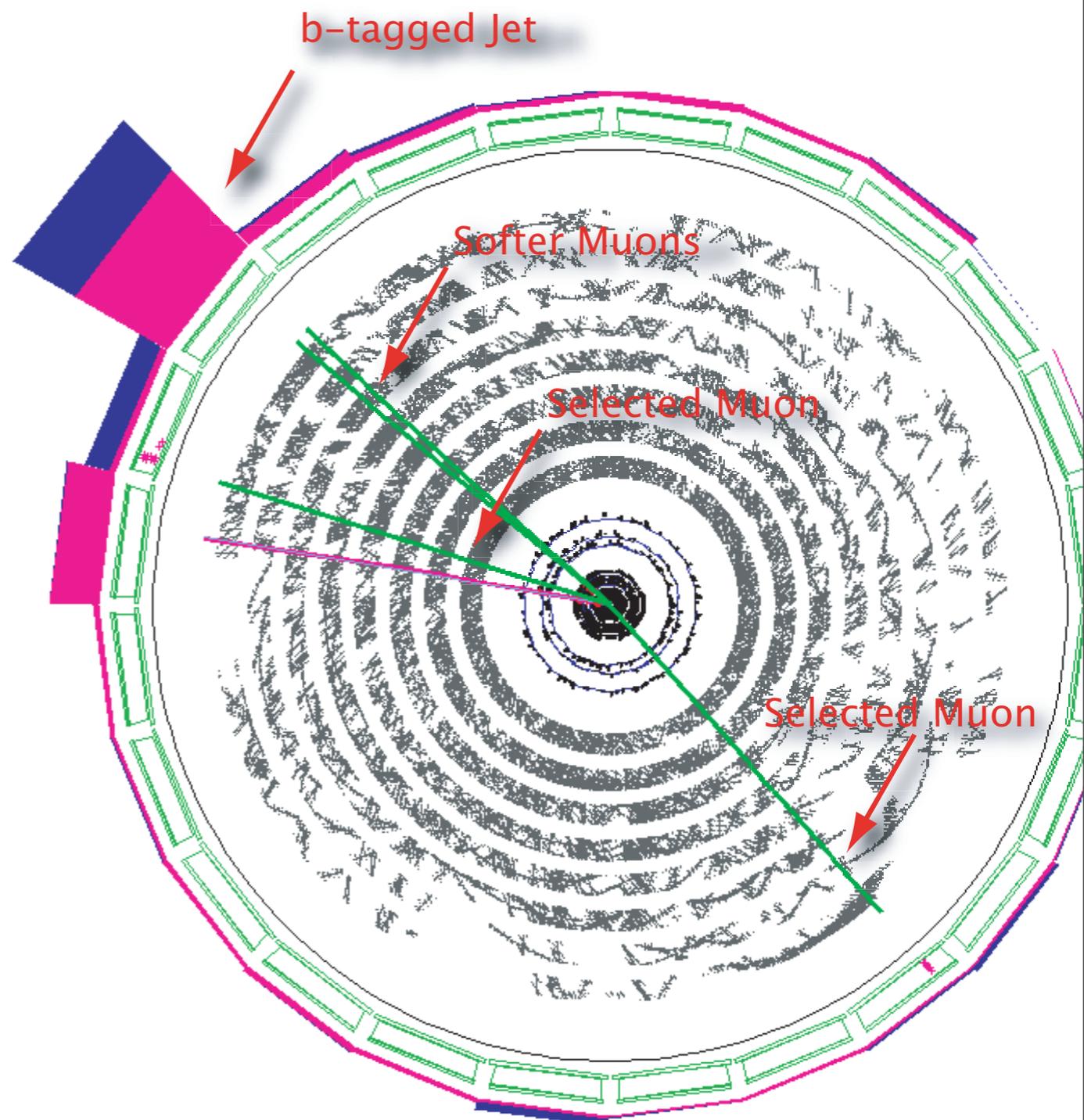
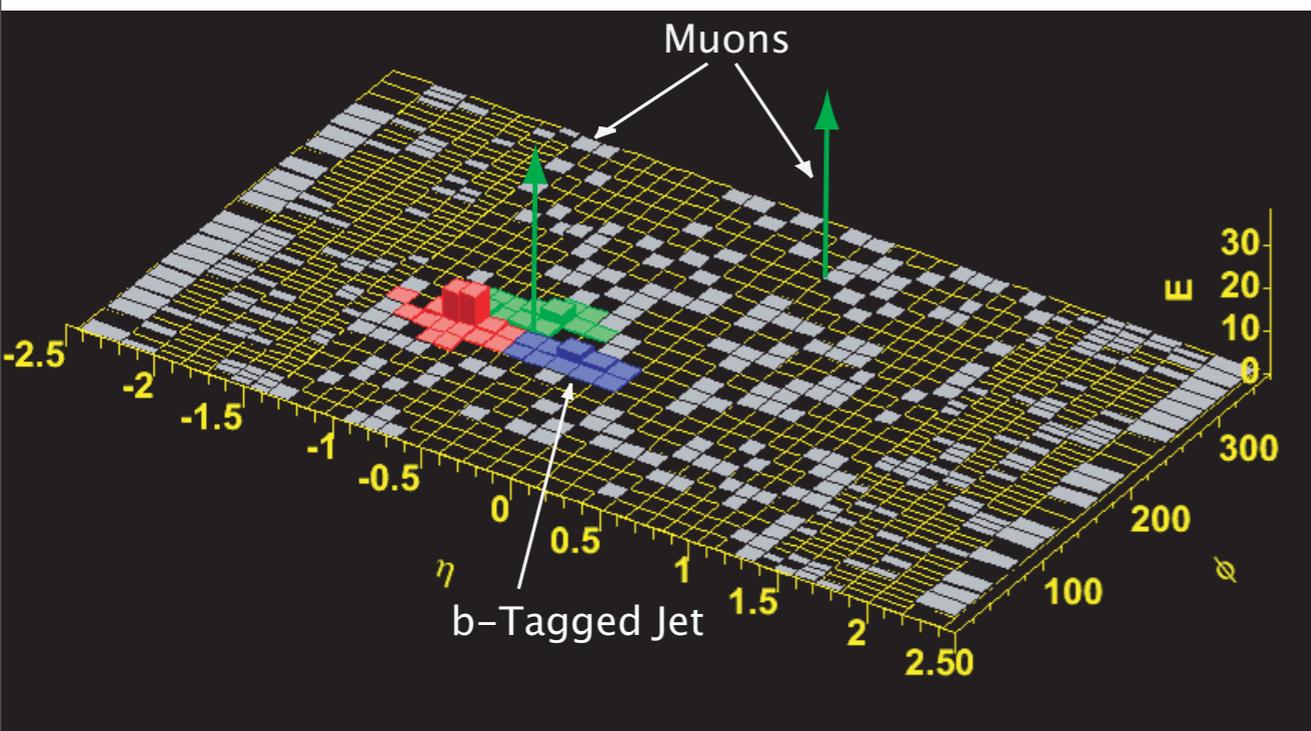
b' Best Fit



- Use binned likelihood to fit in number of jets.



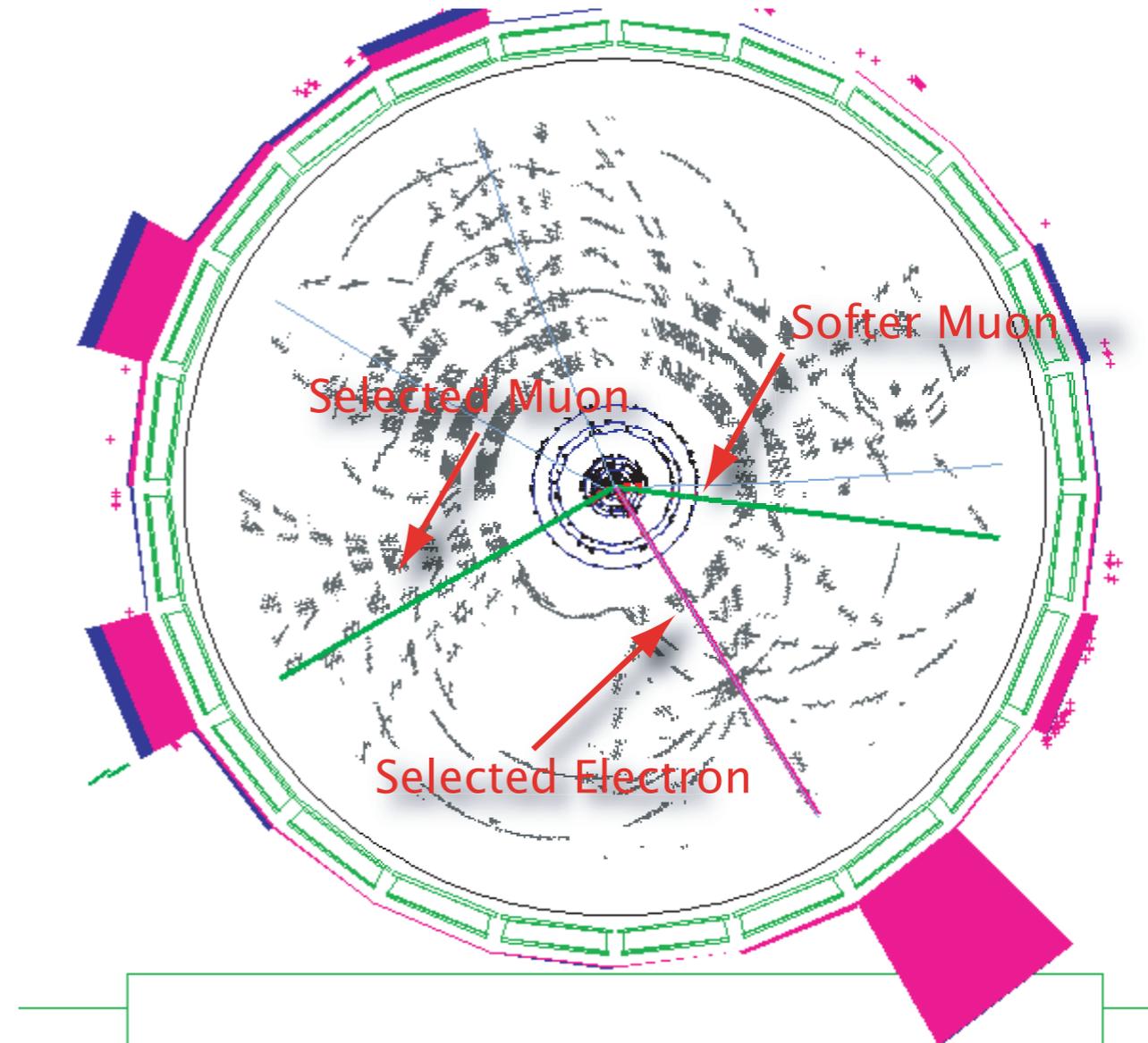
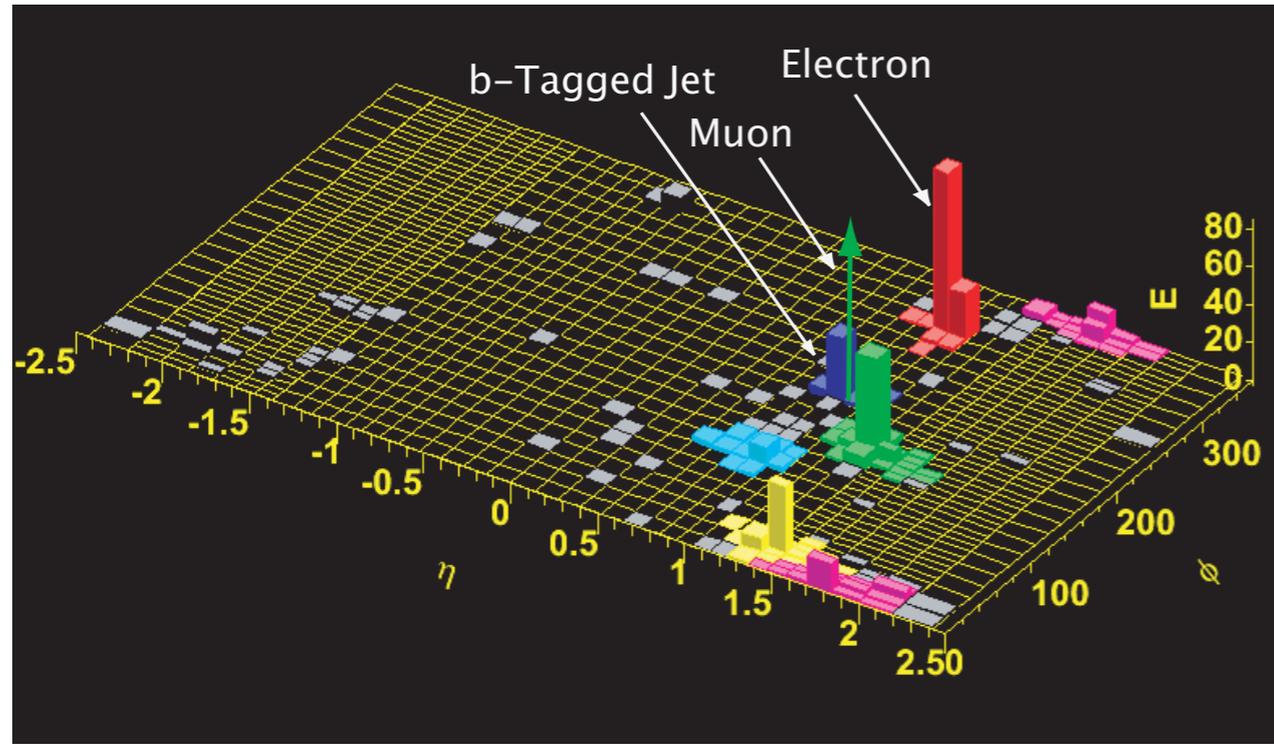
Observed dimuon Event (3 jets)



Object	Pt	Eta	Phi
Muon	79.7 GeV	0.33	-0.85
Muon	30.6 GeV	-0.57	2.85
Jet	77.5 GeV	-0.93	2.44
Jet	40.1 GeV	-0.66	2.92
bJet	25.2 GeV	-0.31	2.41
MET	86.6 GeV	---	-0.21



Observed electron-muon event (5 jets)



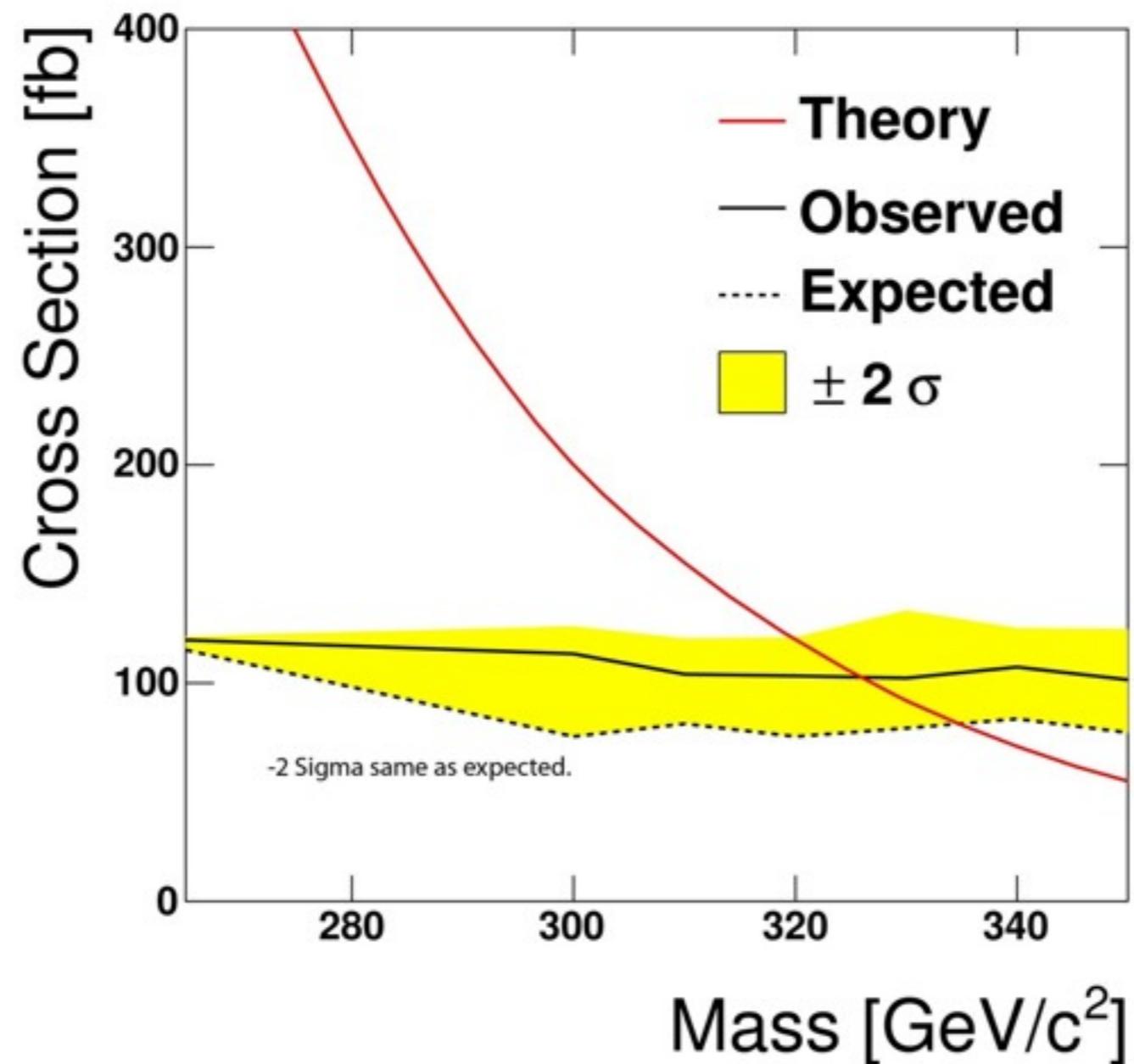
Object	Pt	Eta	Phi
Electron	73.1 GeV	0.99	-1.02
Muon	20.6 GeV	0.98	-2.63
Jet	59.5 GeV	1.27	2.71
bJet	42.3 GeV	0.87	-2.63
Jet	38.5 GeV	1.36	0.44
Jet	33.4 GeV	1.67	0.02
Jet	24.1 GeV	0.80	1.96
MET	26.5 GeV	---	1.44



b' Limits

Limit set on b' for $> 325.5 \text{ GeV}/c^2$

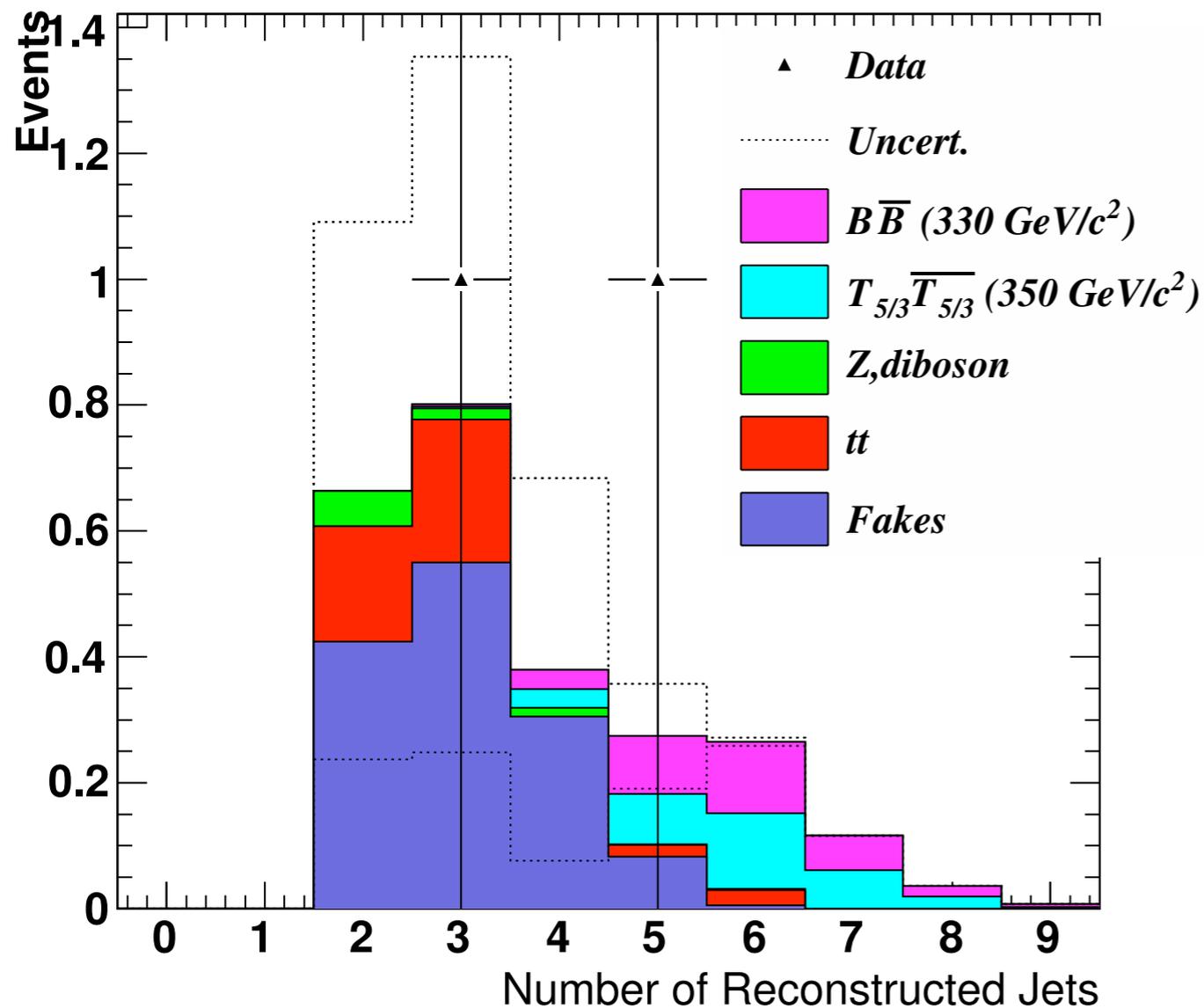
95% Limits for b' (CDF Run II Prelim 2.7/fb)





$B+T_{5/3}$ Best Fit

CDF Run II Preliminary (2.7 fb^{-1})



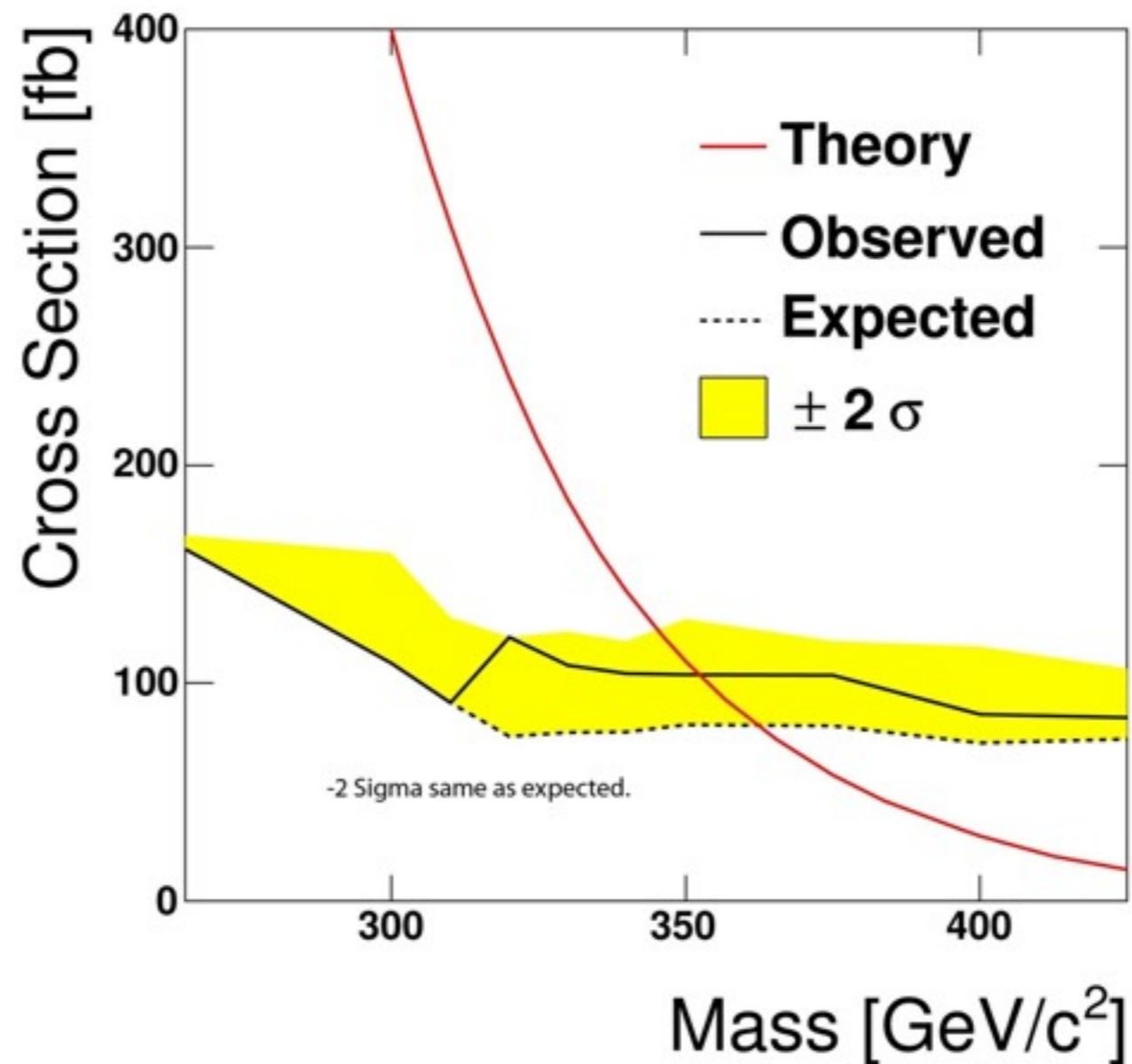
- Use binned likelihood to fit in number of jets.



B+T_{5/3} Limits

Limit set on B+T_{5/3} for $> \underline{351.6 \text{ GeV}/c^2}$

95% Limits for B + T_{5/3} (CDF Run II Prelim 2.7/fb)



Concluding Comments

- Best limits set in the world on b'
 - Mass $> 325.5 \text{ GeV}/c^2$
- Combined limits set on $T_{5/3}$ and B
 - Each mass $> 351.6 \text{ GeV}/c^2$
- Analysis done in 2.7/fb of data
- Plan to perform analysis at ATLAS

Thank You

Extra Slides

CDF Run II Preliminary 2.7 fb^{-1}

Mass b' (GeV/c^2)	95% CL upper limit $\sigma/\sigma_{\text{Theory}}$
260	.21
300	.57
310	.67
320	.86
330	1.11
340	1.51
350	1.85

CDF Run II Preliminary 2.7 fb^{-1}

Mass $B T_{5/3}$ (GeV/c^2)	95% CL upper limit $\sigma/\sigma_{\text{Theory}}$
260	.15
300	.27
310	.29
320	.50
330	.59
340	.74
350	.95
375	1.76
400	2.86
425	5.84