Top @ Tevatron 4 LHC at U C Davis

theory side

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Jan, 2010

This talk reports on the workshop

Top @ Tevatron 4 LHC

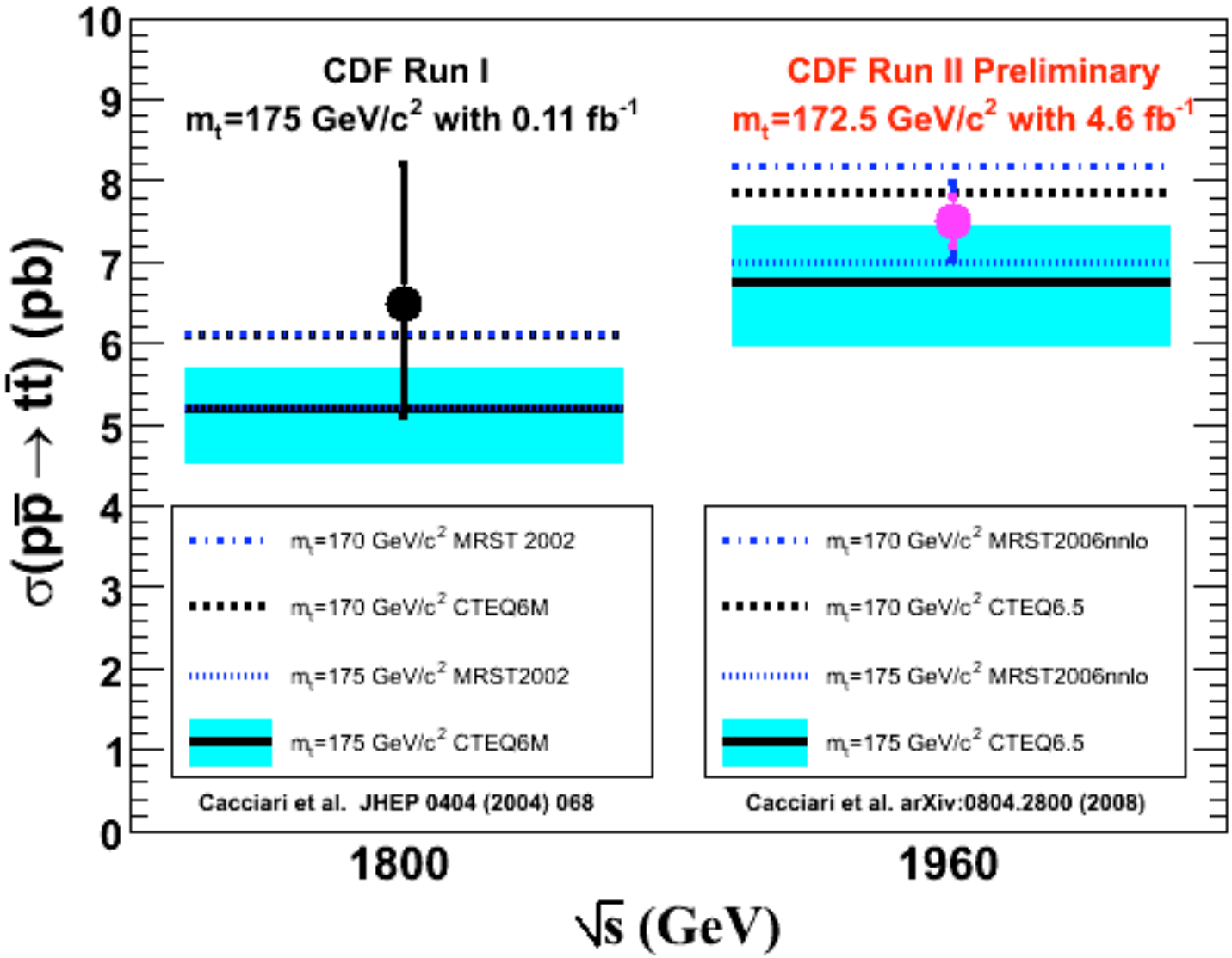
held at UC Davis on Nov. 20-21, 2009.

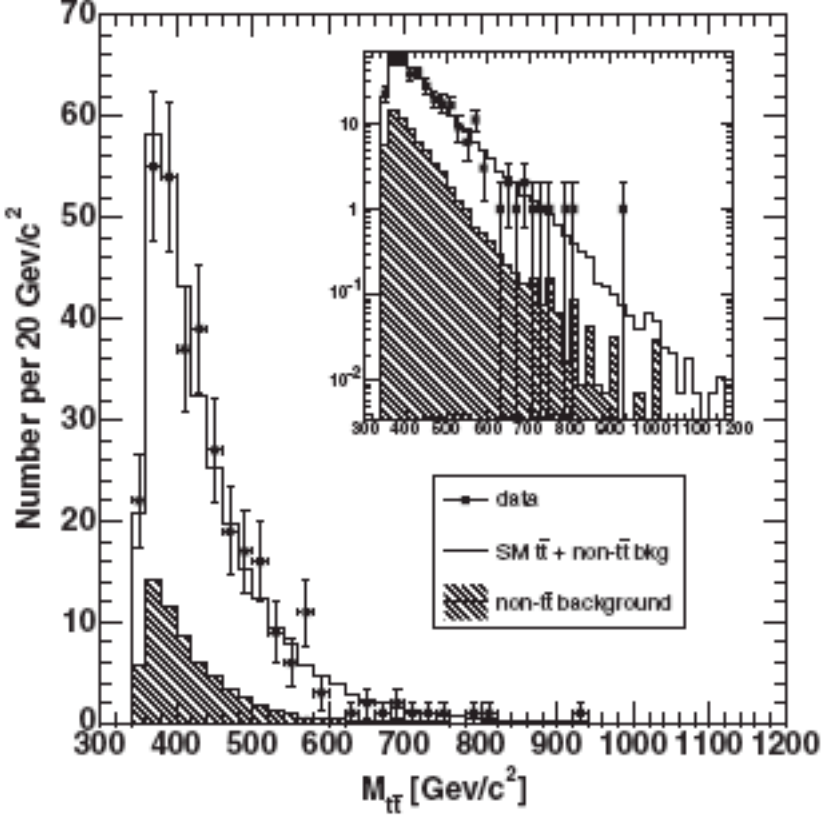
First of all, I would like to thank Robin Erbacher, Markus Luty, and the UC Davis group for organizing this valuable workshop and encouraging our group at SLAC to attend.

The Davis people also always arrange for excellent weather during their meetings. This time was no exception.

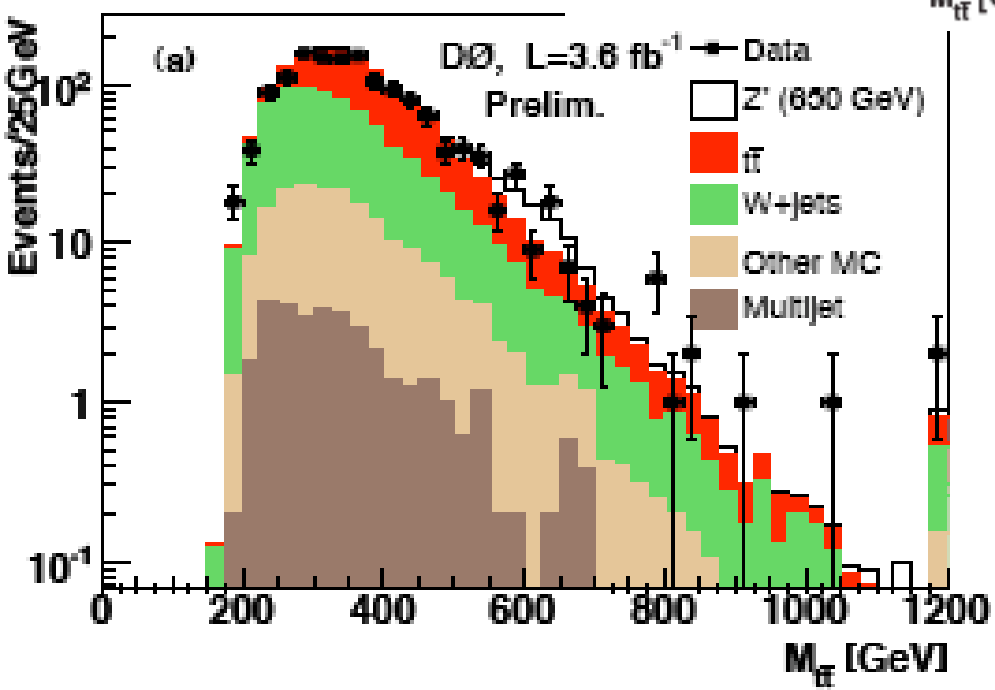
With a few important exceptions, top quark observables at the Tevatron are now in good agreement with the Standard Model.

The production cross section agrees with vanilla QCD within errors, and the evidence for ttbar resonances at high energy is negative within the available statistics. The polarization of top quarks, as reflected in the W helicity in top decay, is just what is expected. This limits the fun that theorists can have.

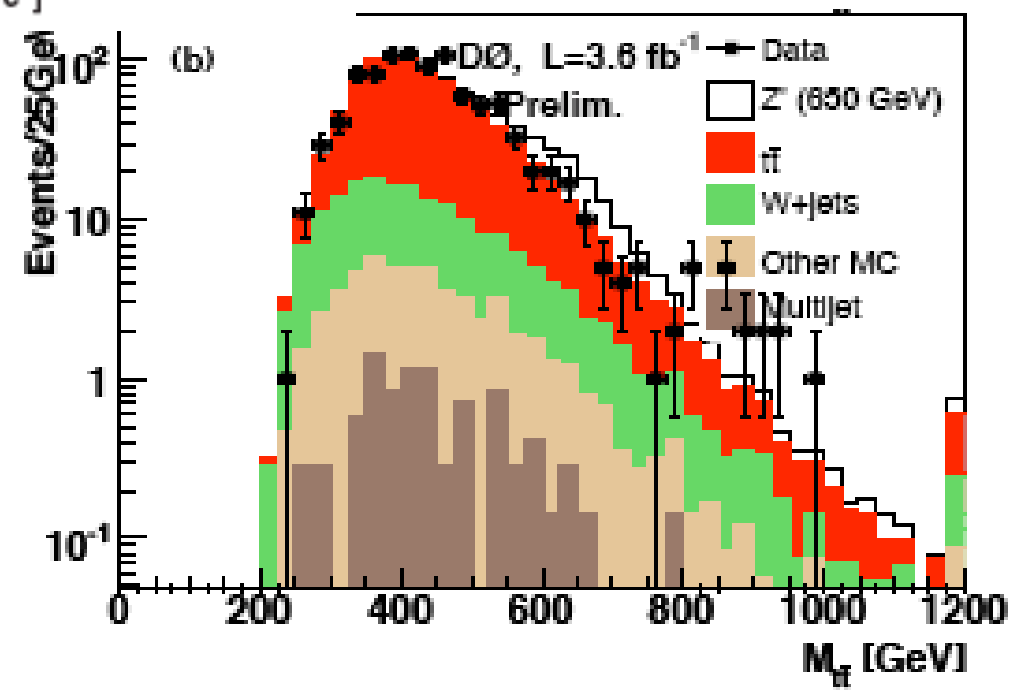

CDF Run I
m_t=175 GeV/c^2 with 0.11 fb^{-1}
CDF Run II Preliminary
m_t=172.5 GeV/c^2 with 4.6 fb^{-1}
$\sigma(p\bar{p} \rightarrow t\bar{t})$ (pb)
m_t=170 GeV/c^2 MRST 2002
m_t=170 GeV/c^2 CTEQ6M
m_t=175 GeV/c^2 MRST2002
m_t=175 GeV/c^2 CTEQ6M
m_t=170 GeV/c^2 MRST2006nnlo
m_t=170 GeV/c^2 CTEQ6.5
m_t=175 GeV/c^2 MRST2006nnlo
m_t=175 GeV/c^2 CTEQ6.5
Cacciari et al. JHEP 0404 (2004) 068
Cacciari et al. arXiv:0804.2800 (2008)
1800
1960
$\sqrt{s}$ (GeV)



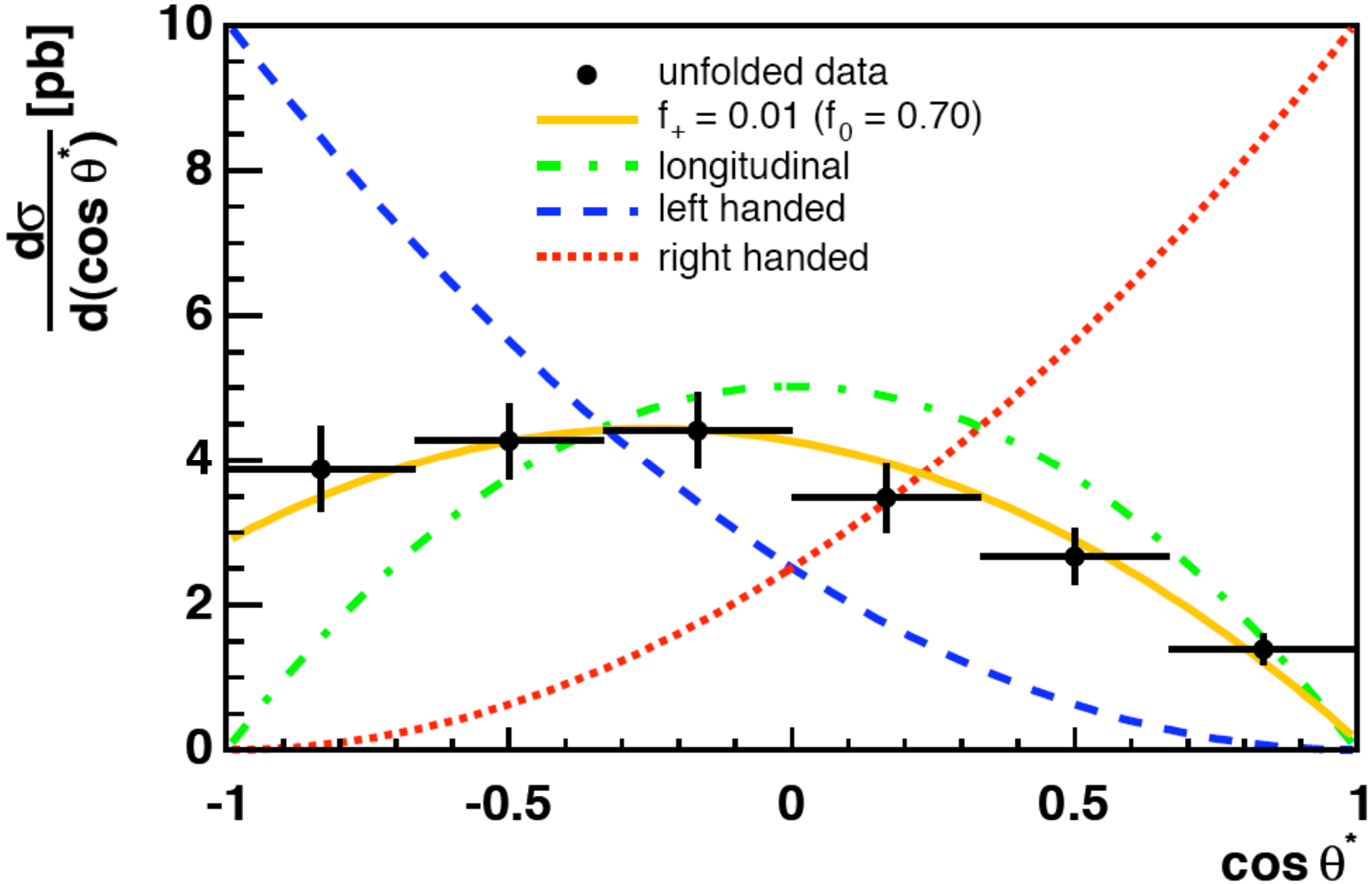
CDF 1 fb-1



DO W + 3 jet



W+ 4 or more jets


CDF
$\frac{d\sigma}{d(\cos\theta^*)}$ [pb]
10
8
6
4
2
0
-1
-0.5
0
0.5
1
$\cos\theta^*$
unfolded data
$f_+ = 0.01$ ($f_0 = 0.70$)
longitudinal
left handed
right handed

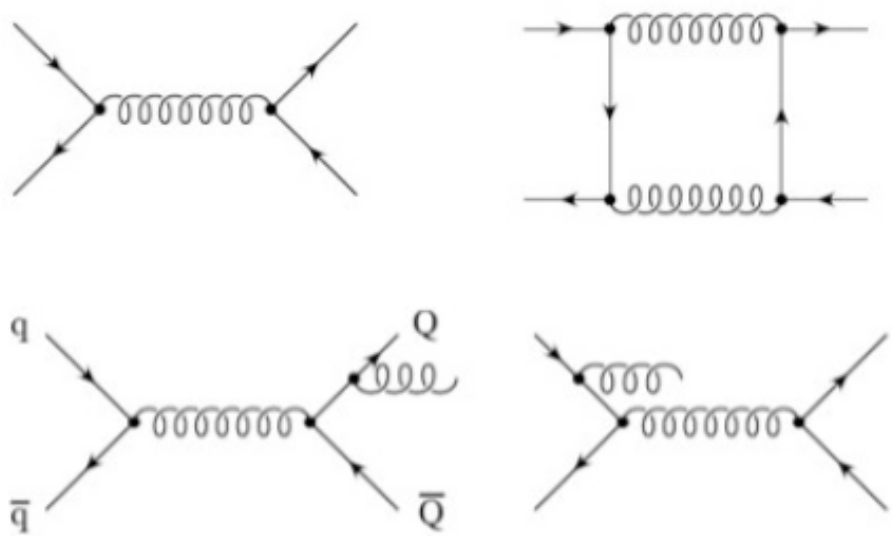
Nevertheless, the observation of a significant forward-backward asymmetry in ttbar is tantalizing:

CDF and D0 both report

$$A_{FB} \approx 20\% \pm \sim 9\%$$

while the expected Standard Model value is about 5%.

The Standard Model prediction is subtle to discuss. There are real and virtual contributions, respectively positive and negative, both IR divergent.



One might think that the observed asymmetry would depend strongly on the acceptance and experimental observables. But, top quark production at the Tevatron is so central that this is an ~ 1% effect.

Wai-Yee Keung reviewed BSM explanations of this effect.

A tree-level BSM contribution in

$$q\bar{q} \to t\bar{t}$$

must violate parity in both the $q\bar{q}$ and the $t\bar{t}$ states. An obvious suggestion is a new gauge boson that couples to $q\bar{q}$ and $t\bar{t}$ with purely chiral (L or R) couplings.

Keung argued that a boson with g > 1 (strongly coupled) can be heavy, above 500 GeV in mass. The scaling is

$$\frac{g^2}{M^2} \sim \frac{1}{(250\ \mathrm{GeV})^2}$$

to give the right magnitude of the effect.

To keep the resonance from being visible, we can put it in a cross -channel. For clarity, think about a pure contact interaction:

$$\overline{q}_{iR}\gamma^{\mu}q_{jR}\ \overline{t}_{jR}\gamma_{\mu}t_{iR}$$

This is apparently mediated by an s-channel color 8 vector exchange. However, by a Fierz transformation, this is equivalent to

$$\overline{q}_{iR}\gamma^{\mu}t_{iR}\ \overline{t}_{jR}\gamma_{\mu}q_{jR}$$

with color 1 t-channel vector exchange (theory of Cheung, Keung, and Yuan)

and also to $\overline{q}_{jR}\cdot t_{iR}\ \overline{t}_{jR}\cdot\overline{q}_{iR}$

with a color 3 or 6 u-channel scalar exchange (theory of Shu, Tait, Wang).

It is very unlikely that a ttbar FB asymmetry can be observed at the LHC, since this is zero by rotational symmetry in the dominant ttbar production process

$$gg \to t\bar{t}$$

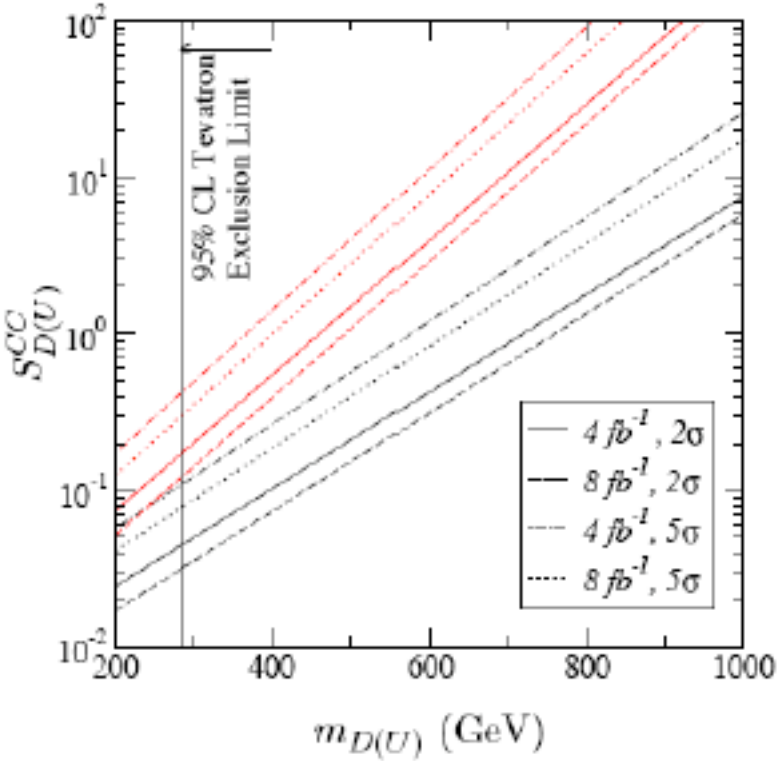
However, the resonances suggested by the models on the previous slide should be observable, each in its relevant channel.

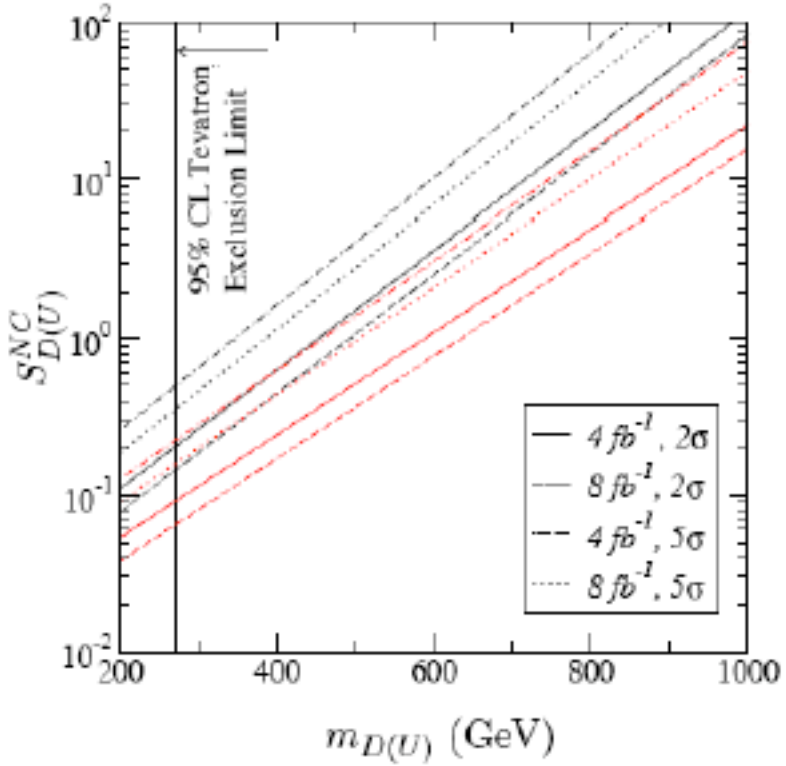
Anupama Atre, Gustavo Burdman, and K. C. Kong reviewed models with new quarks heavier than top.

Burdman argued that there is a phase space for a 4th generation consistent with precision electroweak. However, the production cross section for such a t' at the Tevatron is small and cannot explain the fluctuation seen by CDF.

Atre pointed out that there are many other possibilities in the literature for heavy colored particles. She also discussed the possibility that these particle could be discovered at the Tevatron in single production up to high mass.

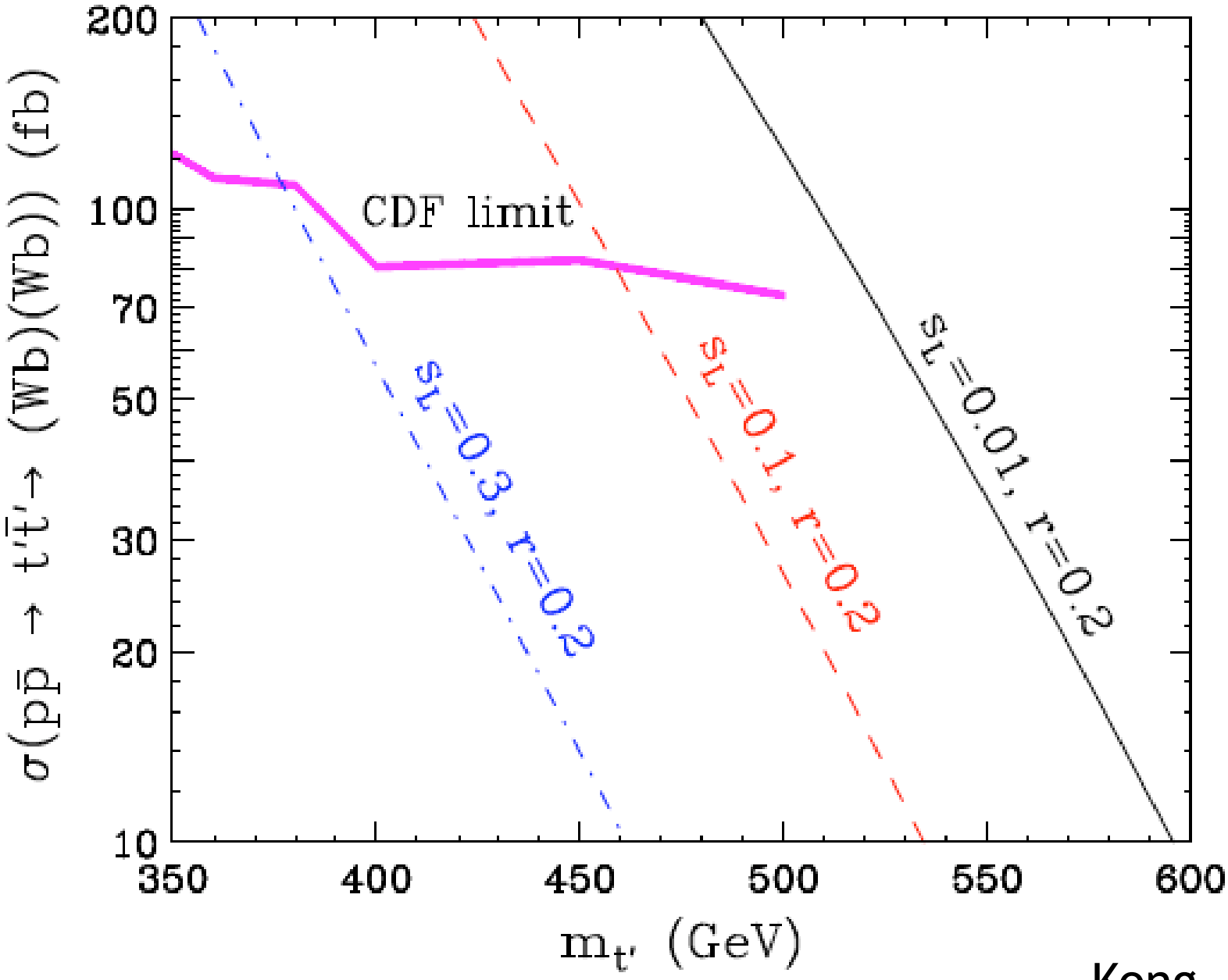
Sensitivity at Tevatron





$\int \mathcal{L}dt$	4 fb^{-1}		8 fb^{-1}	
Sensitivity	2σ	5σ	2σ	5σ
m_D for $S_D^{CC} = 1$ (2)	720 (820)	580 (670)	760 (860)	630 (710)
m_U for $S_U^{CC} = 1$ (2)	470 (530)	370 (440)	490 (560)	400 (470)
m_D for $S_D^{NC} = 1$ (2)	450 (530)	350 (420)	490 (570)	380 (470)
m_U for $S_U^{NC} = 1$ (2)	590 (680)	460 (540)	640 (730)	510 (590)

Atre


200
100
70
50
30
20
10
350
400
450
500
550
600
$\sigma(p\bar{p} \to t'\bar{t}' \to (Wb)(Wb))$ (fb)
$m_{t'}$ (GeV)
CDF limit
s_L=0.01, r=0.2
s_L=0.1, r=0.2
s_L=0.3, r=0.2

Kong

One of particular case of great interest to me is the Q = +4/3 quark needed to complete the multiplet

$$\begin{pmatrix} t & \mathbf{T} \\ b & T' \end{pmatrix}$$

A beautiful paper of Agashe, Contino, de Rold, and Pomarol argued that, if the horizontal SU(2) is an approximate global symmetry, this protects the electroweak prediction for

$$Z^0 \to b\bar{b}$$

even in a model with strongly coupled top quarks. The $\mathbf{T}$ has unique like-sign dilepton signatures.

Kong also discussed top quark reconstruction in

$$p\bar{p} \rightarrow t\bar{t} \rightarrow b\bar{b}\ell^{+}\ell^{-}\nu\bar{\nu}$$

as a proving ground for methods of supersymmetry particle reconstruction using m_{T2}.

K. C. will give a whole lecture on m_{T2} magic at today's SLAC theory seminar.

Thanks again to Robin, Markus, and their colleagues for helping us all get closer to the “truth”.