



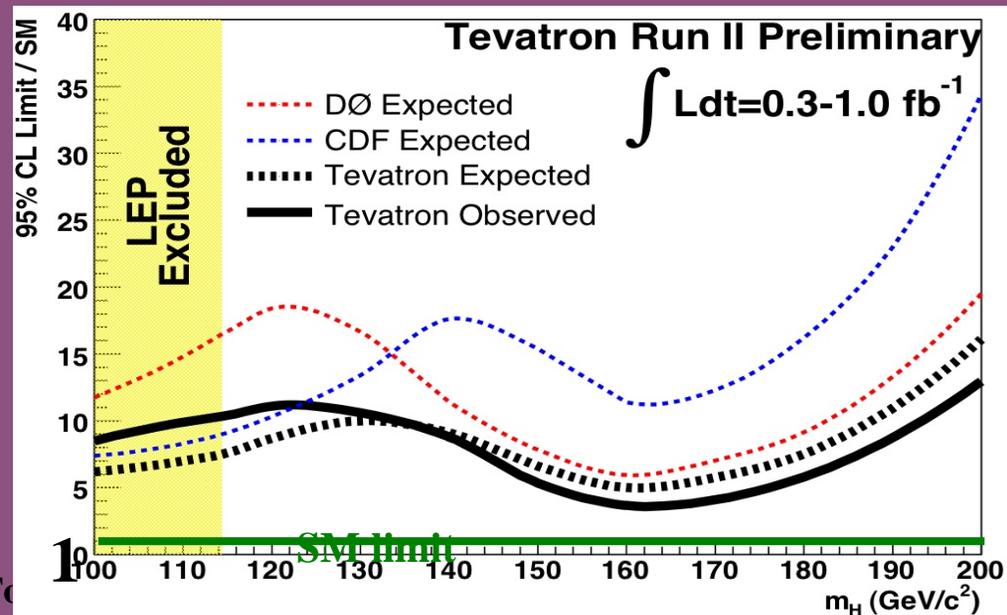
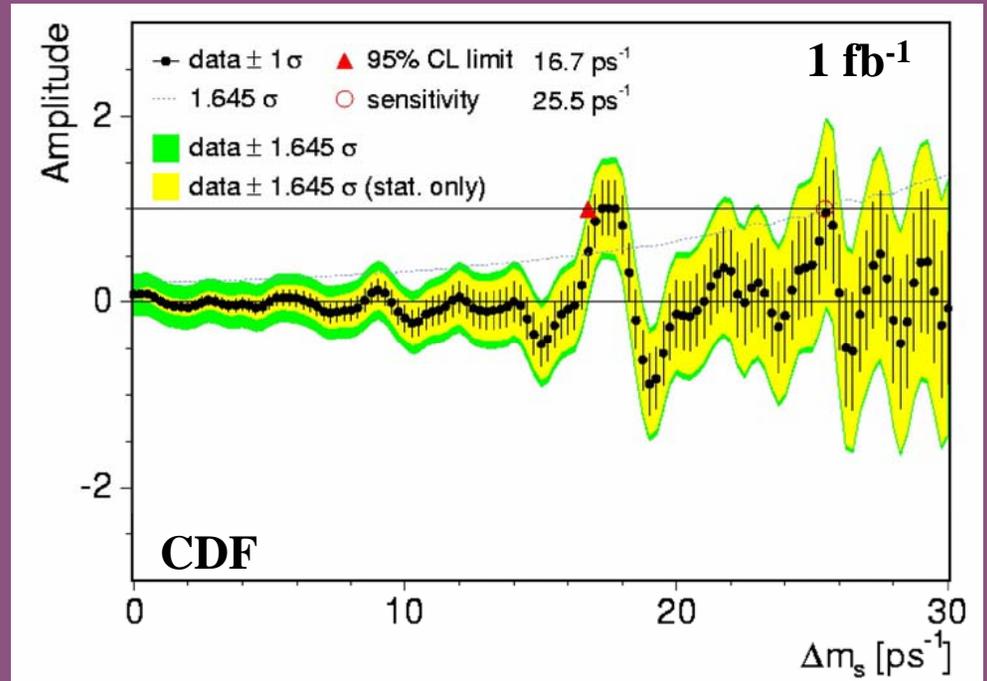
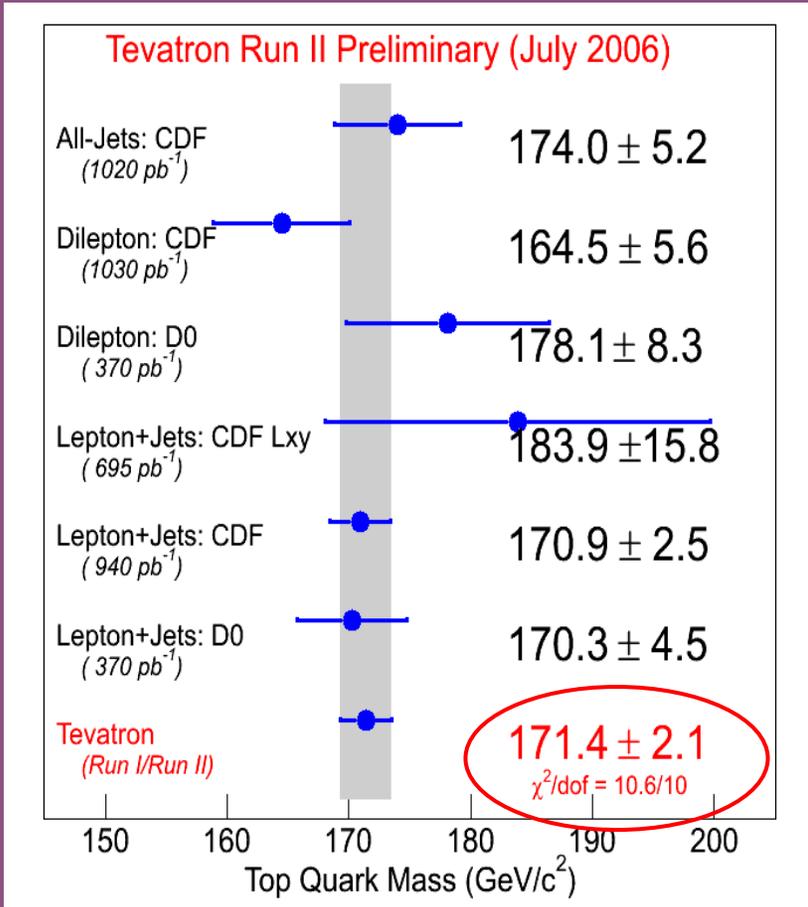
# Striking Results from the Tevatron

Kirsten Tollefson

Michigan State University

LP07

# A year ago...



“Hot Topics”, ICHEP ‘06  
D. Glenzinski

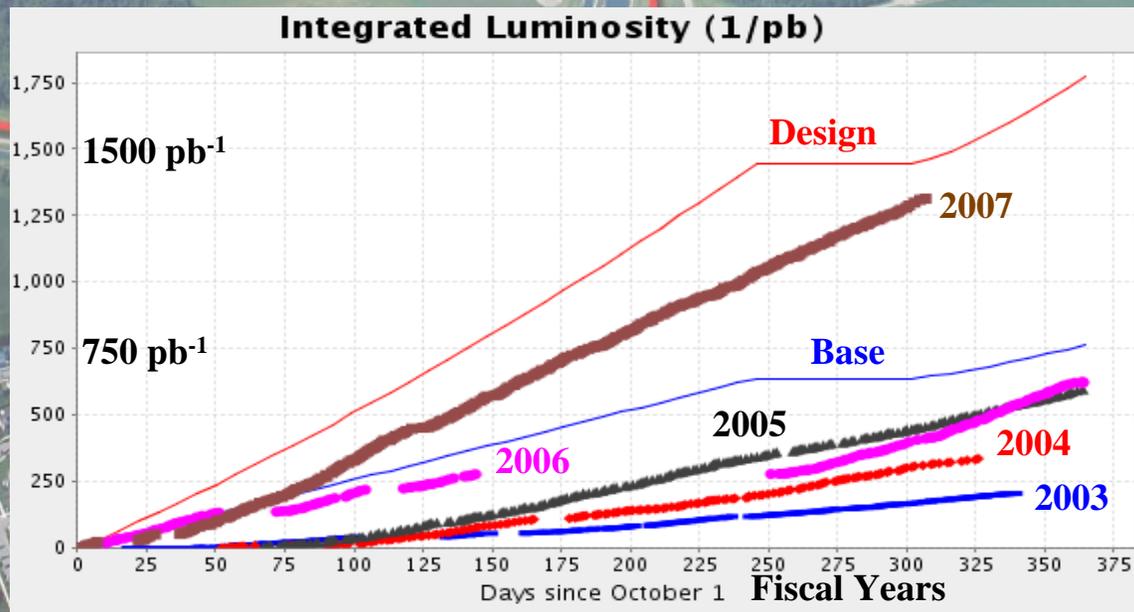
August 13, 2007

K. T.

# Tevatron Performance

- Many improvements over last year
  - More pbars, more reliable
    - Monthly int. lum. increased  $25 \rightarrow 45 \text{ pb}^{-1}$
    - Peak lum. increased  $180\text{e}30 \rightarrow 286\text{e}30 \text{ cm}^{-2} \text{ s}^{-1}$
- Expect  $\sim 6\text{-}7 \text{ fb}^{-1}$  by Oct. '09

Thanks to the Accelerator Division!



# In the last year...

- Added  $>1 \text{ fb}^{-1}$  of data to many analyses
- World's best  $W$  mass,  $W$  width and Top mass
- Precision cross section measurements
- Evidence for Single Top production
- Better understanding of Top Properties
- Discovery of  $B_s$  mixing
- First observation of  $\Sigma_b$  and  $\Xi_b$
- Prolific number of papers  $\sim 1.5$  pubs/week

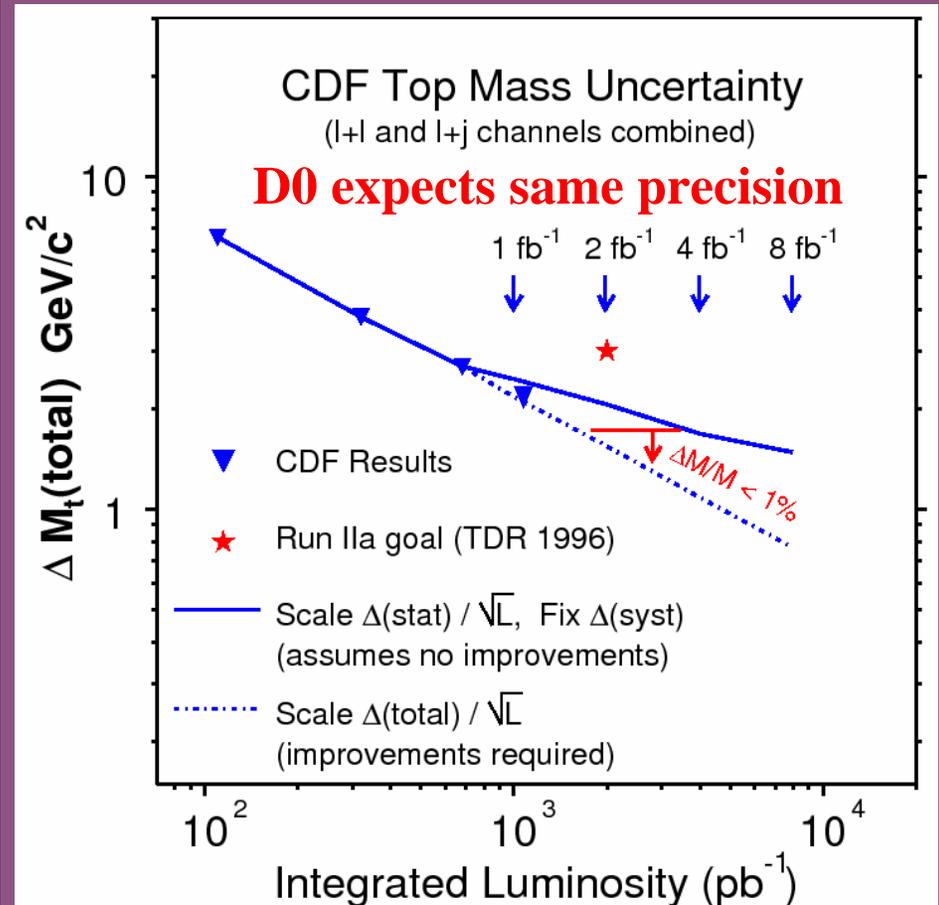
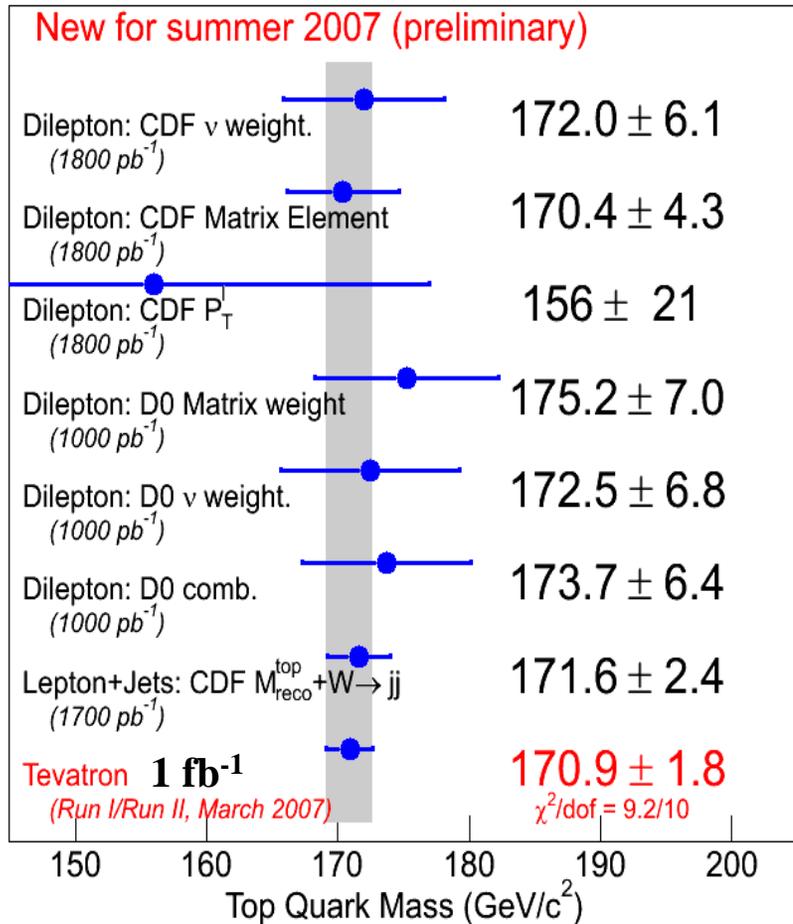
# Tevatron Goals for Run II

- **Precision measurements of**
  - Top mass
  - W boson mass and width
  - $B_s$  oscillation frequency  $\Delta m_s$
- **Exploration of**
  - B baryons
  - Dibosons (WW, WZ, ZZ)
  - Top quarks
- **Find Higgs and BSM physics**

# Tevatron Goals for Run II

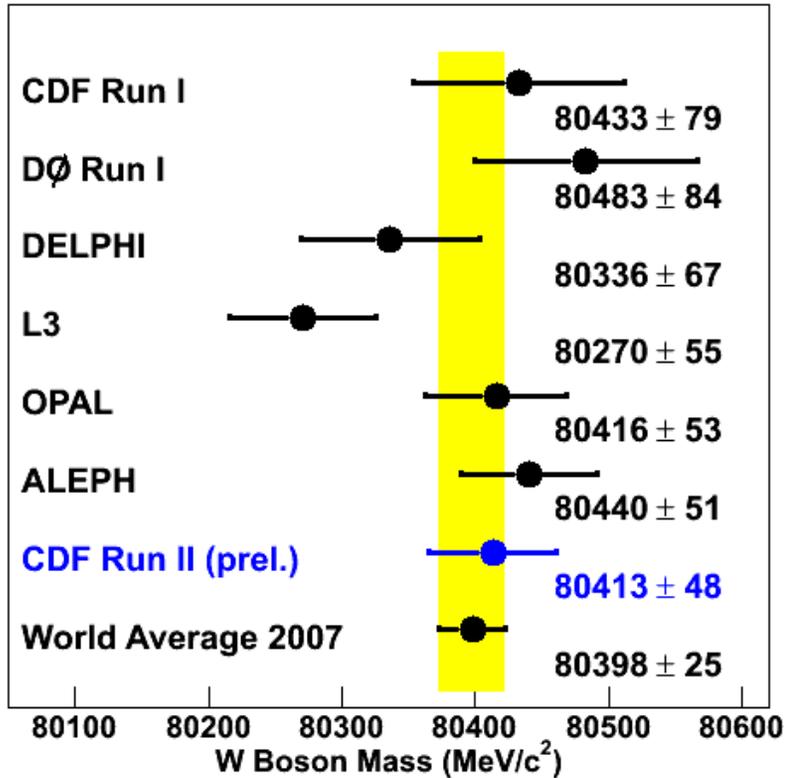
- Precision measurements of
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# Top Mass

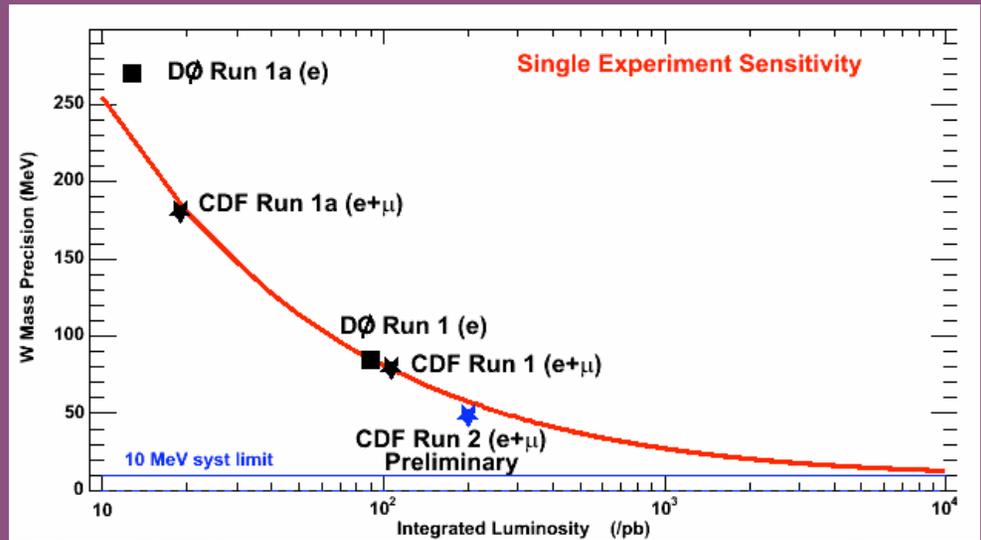
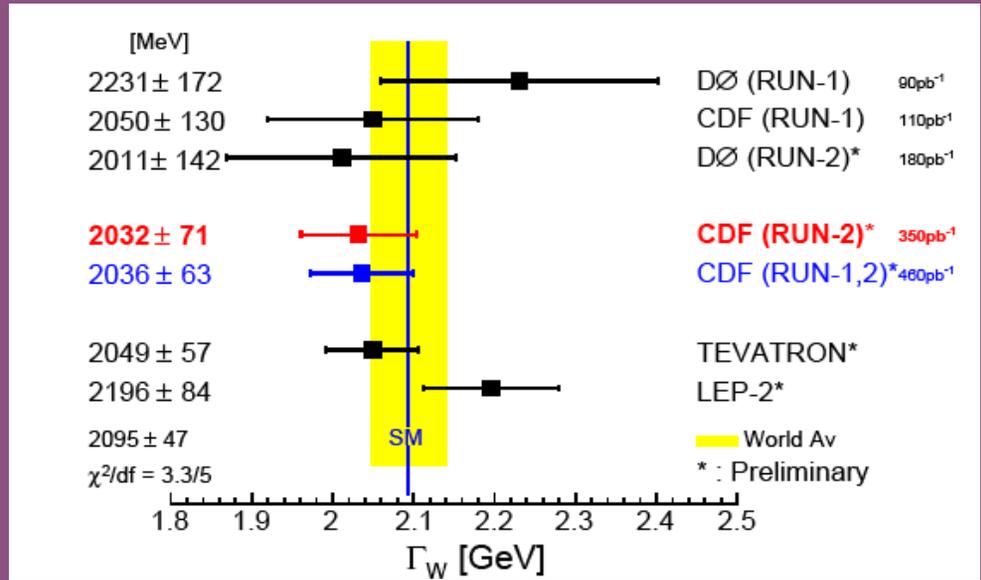


See S01-1 talk for details

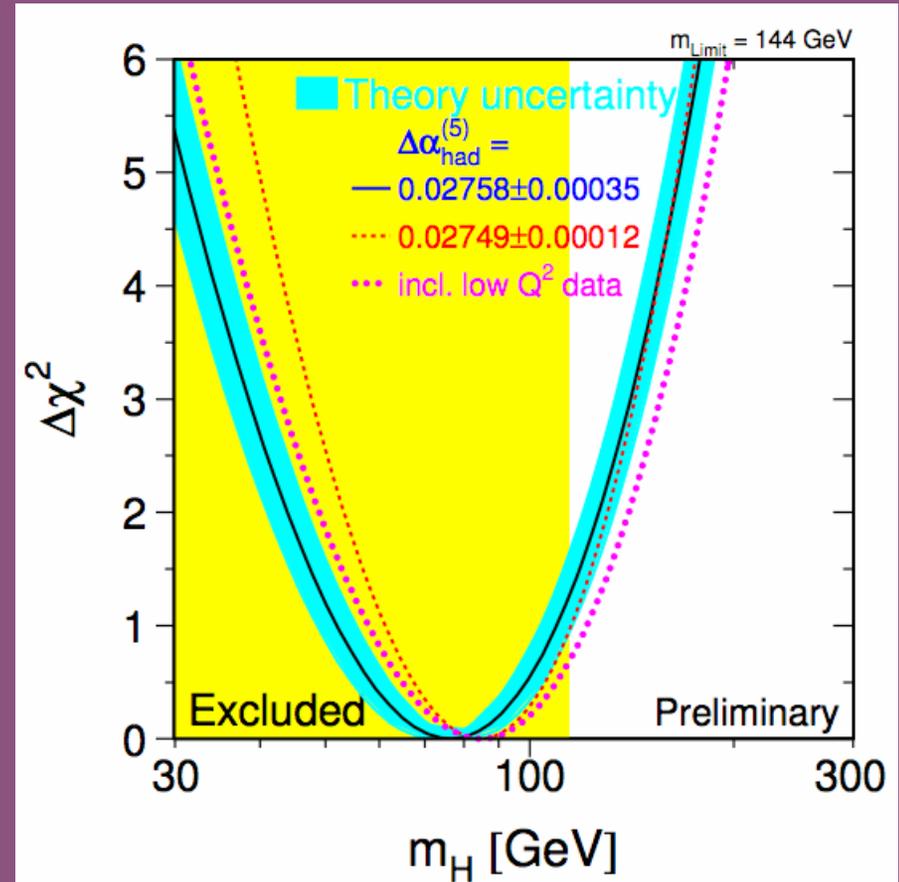
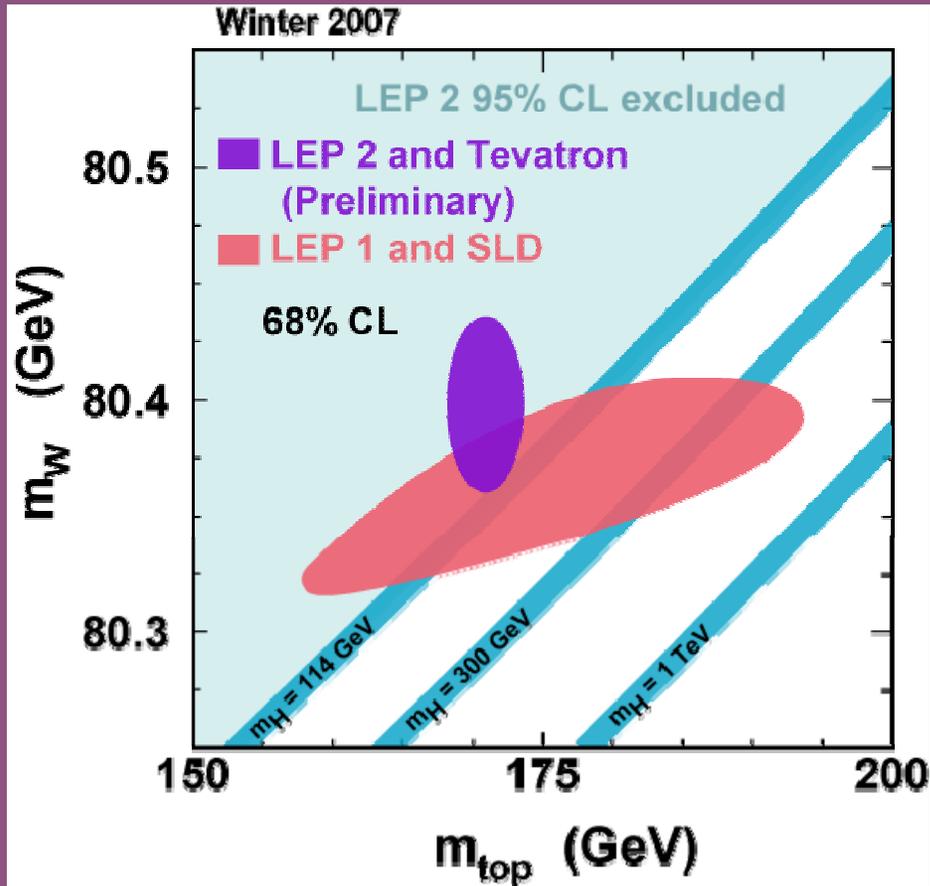
# W Mass and Width



See S01-2 talk  
for details



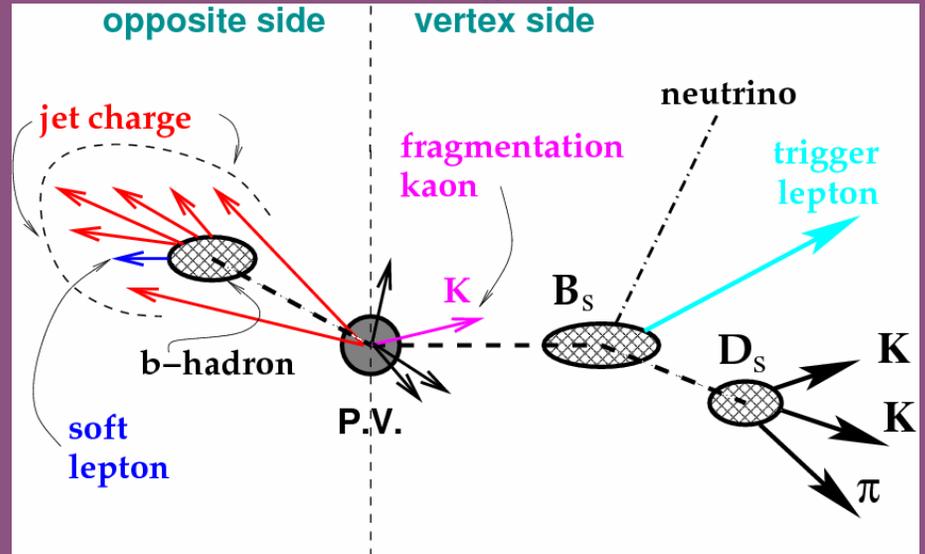
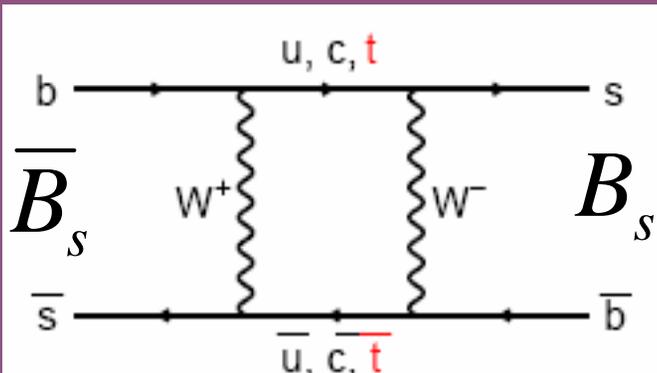
# Mw vs Mtop



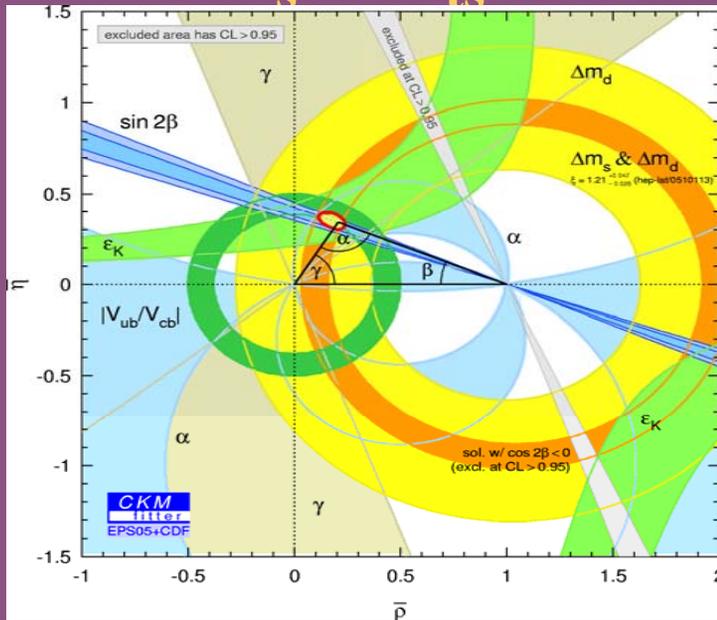
See S01-2 and S01-3  
talks for details

$M_H < 182 \text{ GeV}$   
(including LEP2  $M_H > 114 \text{ GeV}$ )

# $B_s$ Mixing and $\Delta m_s$



$$\Delta m_s \sim V_{ts}$$



## Improvements:

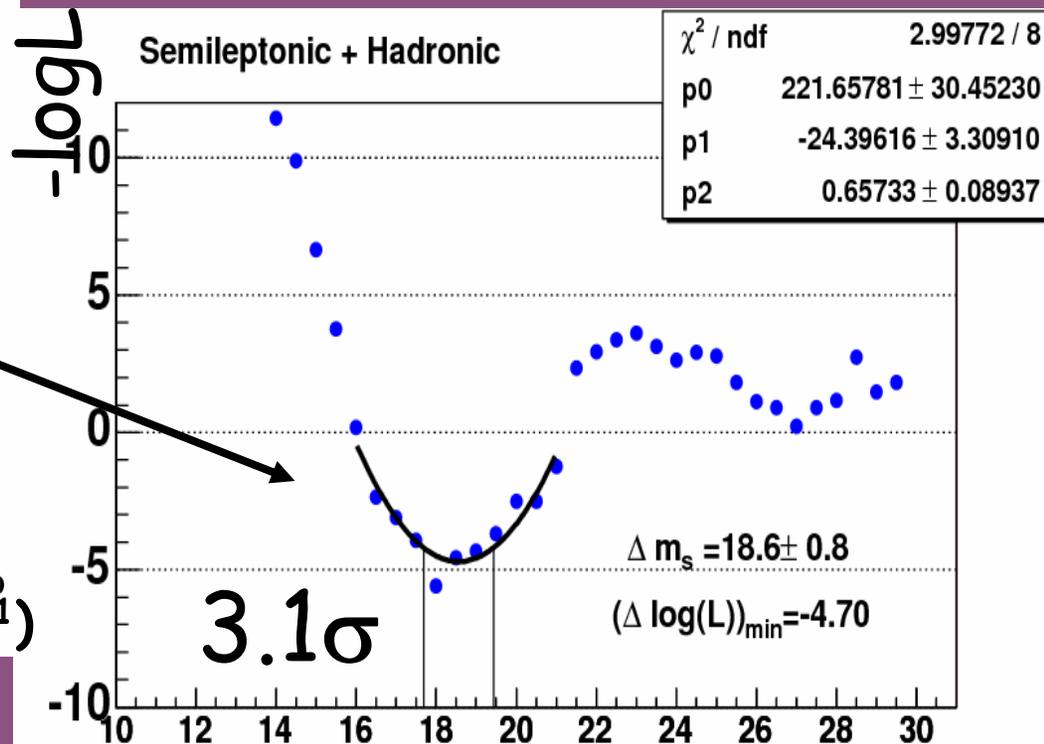
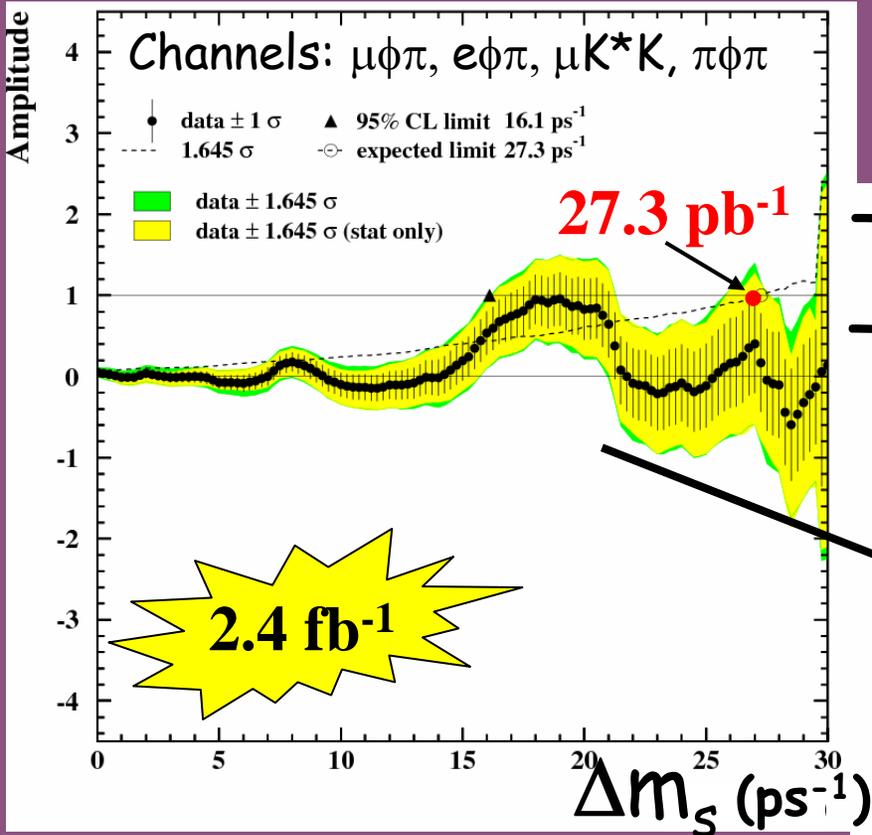
- Better detector: Layer 0 silicon
- Track-by-track IP resolution uncertainty
- Same side flavor tagging (SST)
- Additional channel: hadronic decays
- Better boost description



# $B_s$ Mixing and $\Delta m_s$

Many analysis improvements!

See S06-18 talk for details



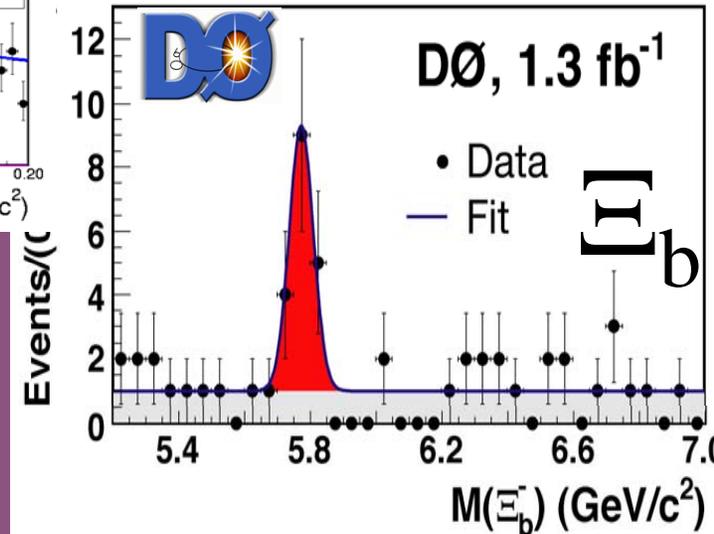
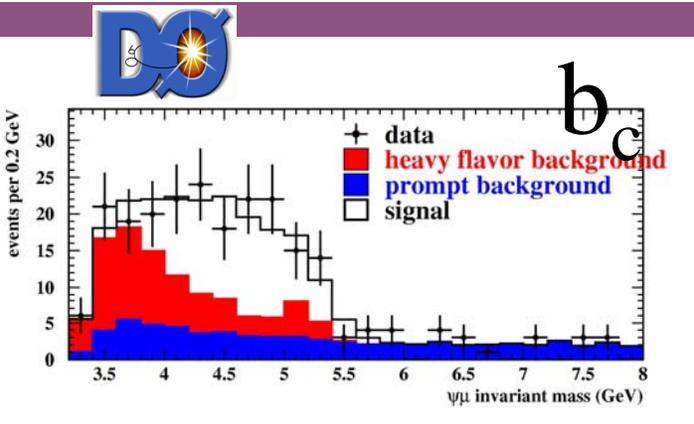
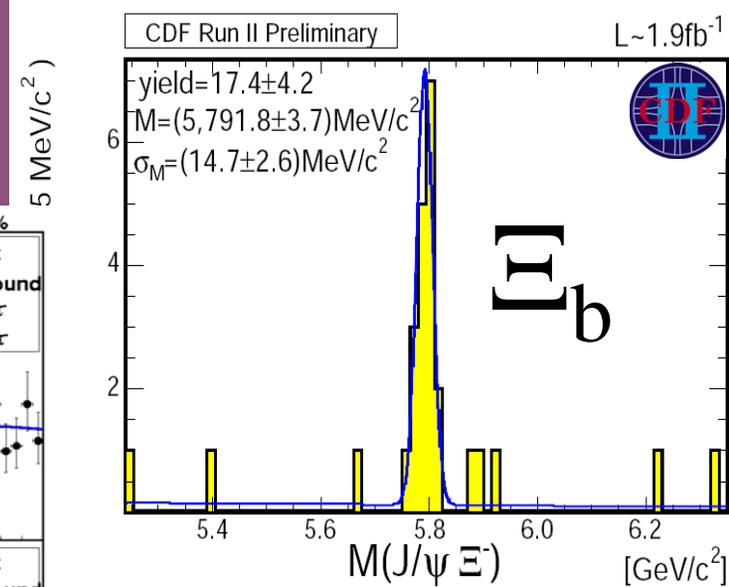
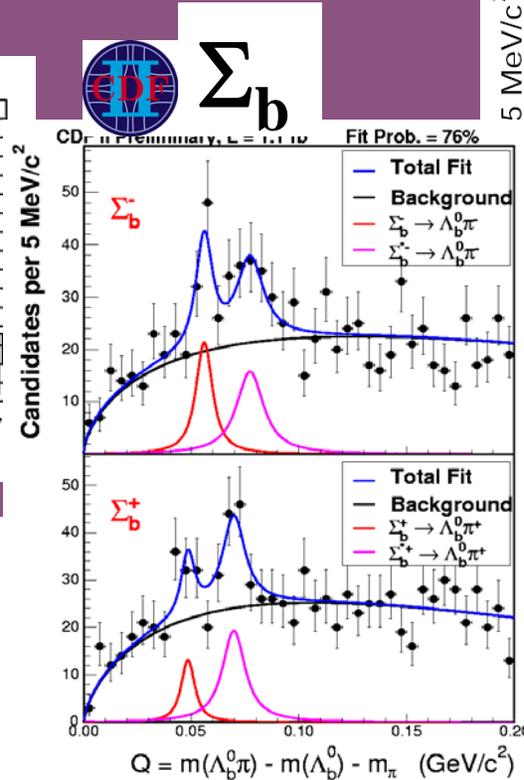
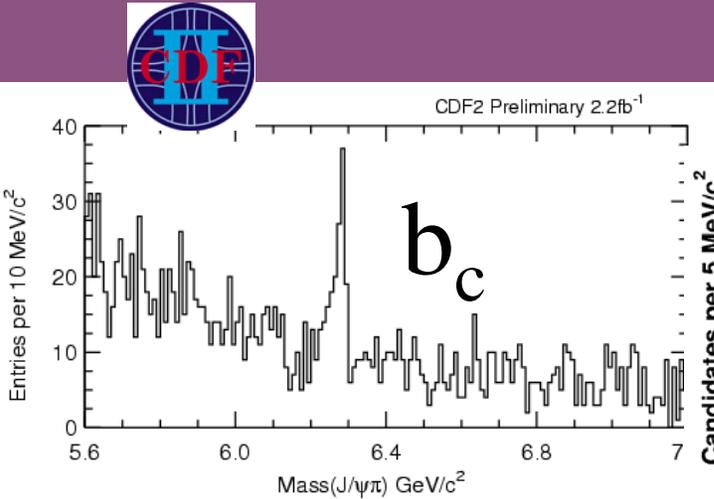
$\Delta m_s = 17.77 \pm 0.12\text{ ps}^{-1}$   
 PRL 97, 242003 2006

**$\Delta m_s = 18.6 \pm 0.8\text{ ps}^{-1}$**

# Tevatron Goals for Run II

- Precision measurements of
  - Top mass
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  - $B_s$  oscillation frequency  $\Delta m_s$
- Exploration of
  - **B baryons**
  - **Dibosons (WW, WZ, ZZ)**
  - **Top quarks**
- Find Higgs and BSM physics

# B baryon Discoveries

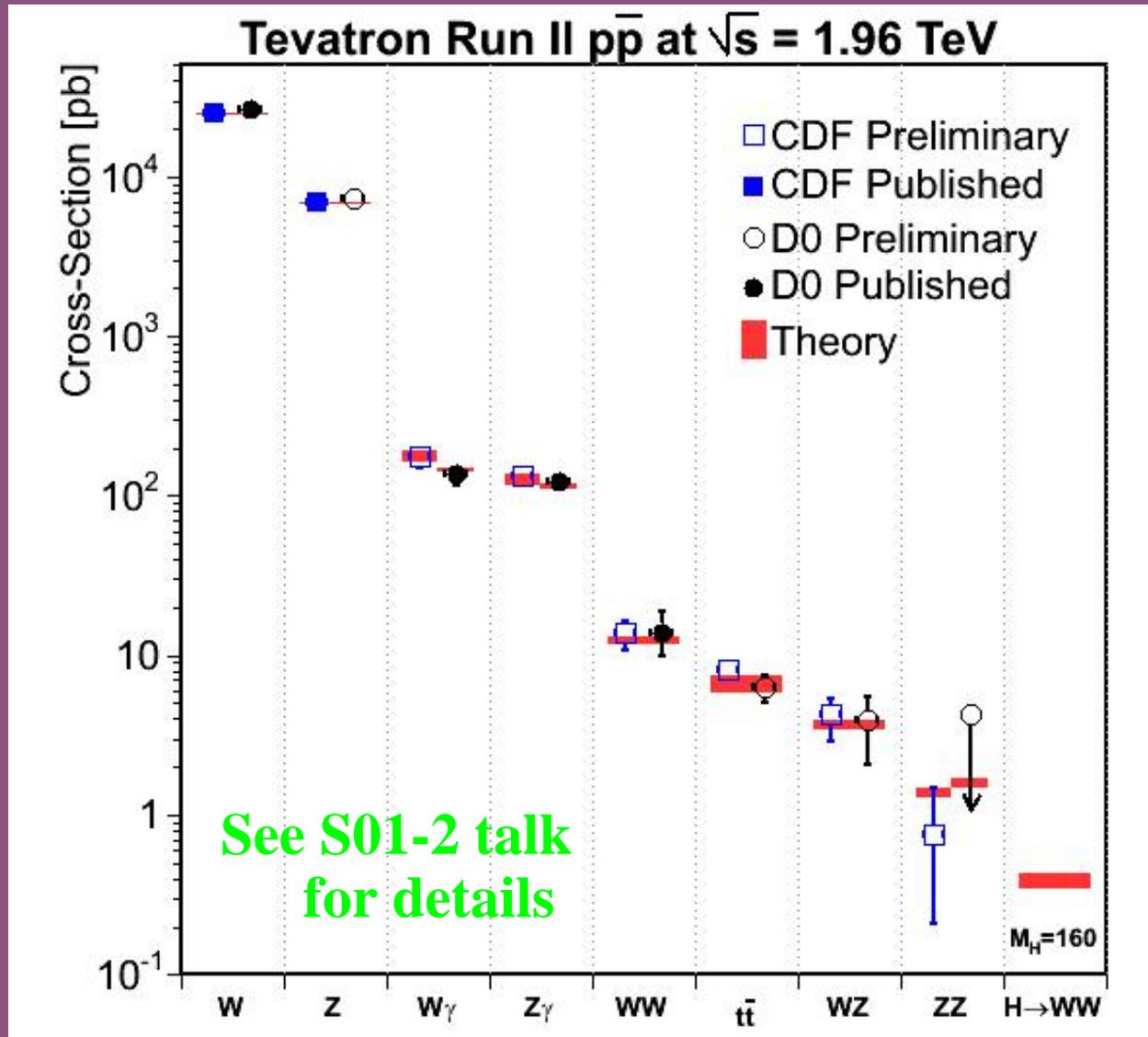


See Tuesday's sessions S06-S08

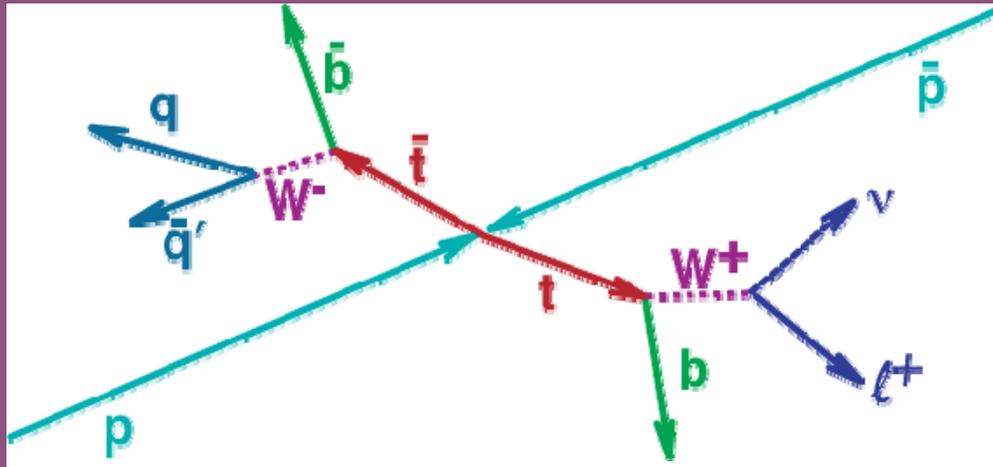
August 13, 2007

K. Tollefson, LP07

# Diboson Results



# Top Quarks



## Properties:

- Mass
- Width
- Charge
- Lifetime

## Production:

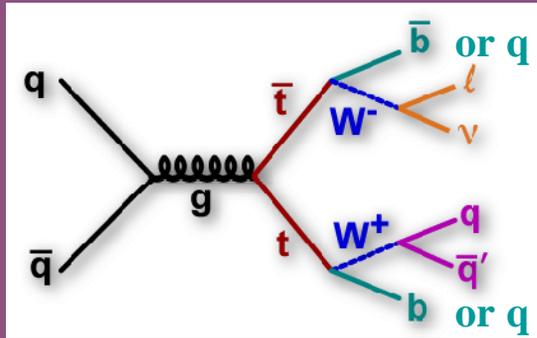
- Mechanism (qq vs. gg)
- EWK (single top)
- Resonances
- Cross Section
- Branching Ratios

## Decay:

- W Helicity
- FCNC

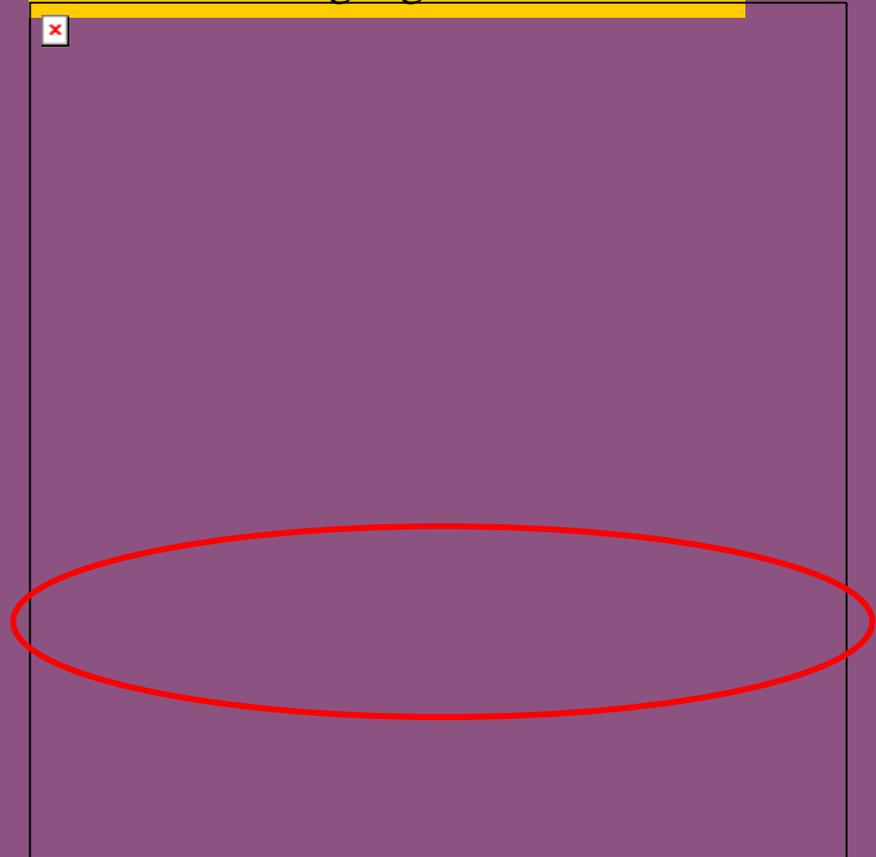
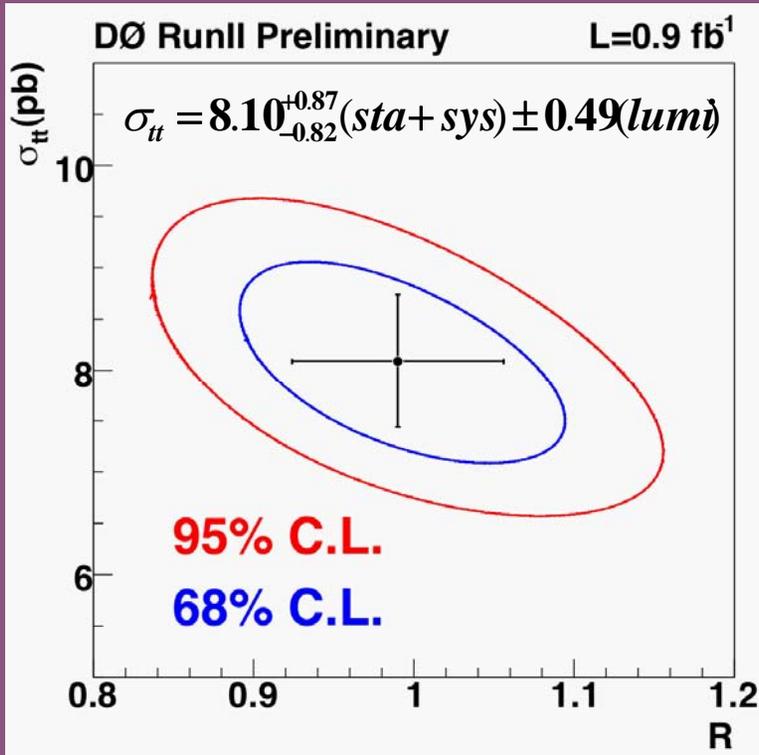


# Top Cross Section and R



$$R = \frac{BR(t \rightarrow Wb)}{BR(t \rightarrow Wq)} = |V_{tb}|^2$$

Assuming 3 generations



# Tevatron Goals for Run II

- Precision measurements of
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- **Find Higgs and BSM physics**

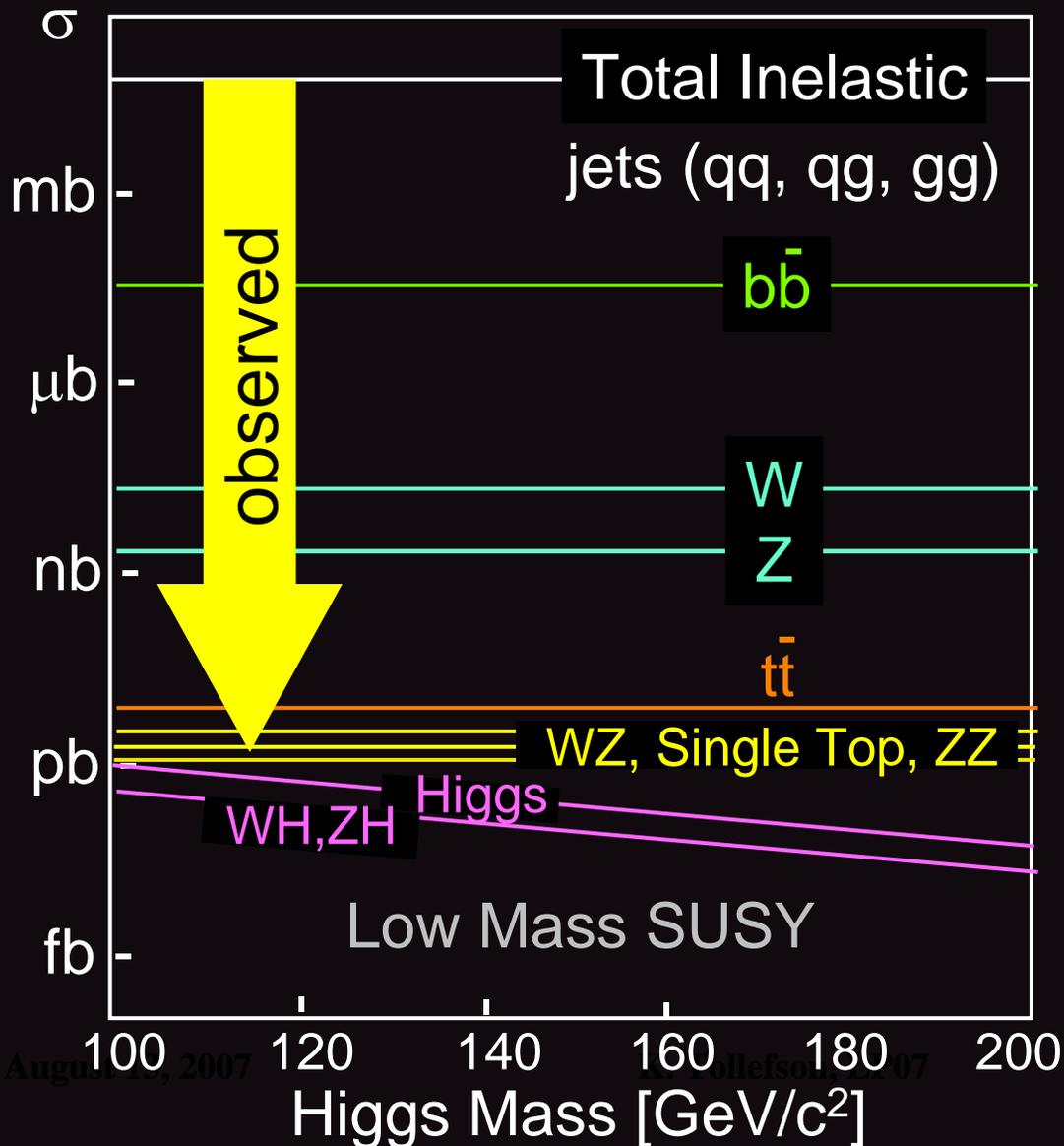
# Searches

- SM Higgs limit
- Indirect
  - Charm mixing
  - $B_s \rightarrow \mu\mu$  (FCNC)
- Direct
  - $t \rightarrow Zc$  (FCNC)
  - $M_{tt}$
  - SUSY Chargino and Neutralino
  - Global Search - Vista/Sleuth

**More Tevatron  
search results in S03**

# Tevatron: A Precision Machine

## Plus a Road to Higgs and Beyond



$B_s - \bar{B}_s$  Oscillation,  
 $\Xi_b$  Discovery +  
 Precision Meas.

$M_W \sim 0.05\%$

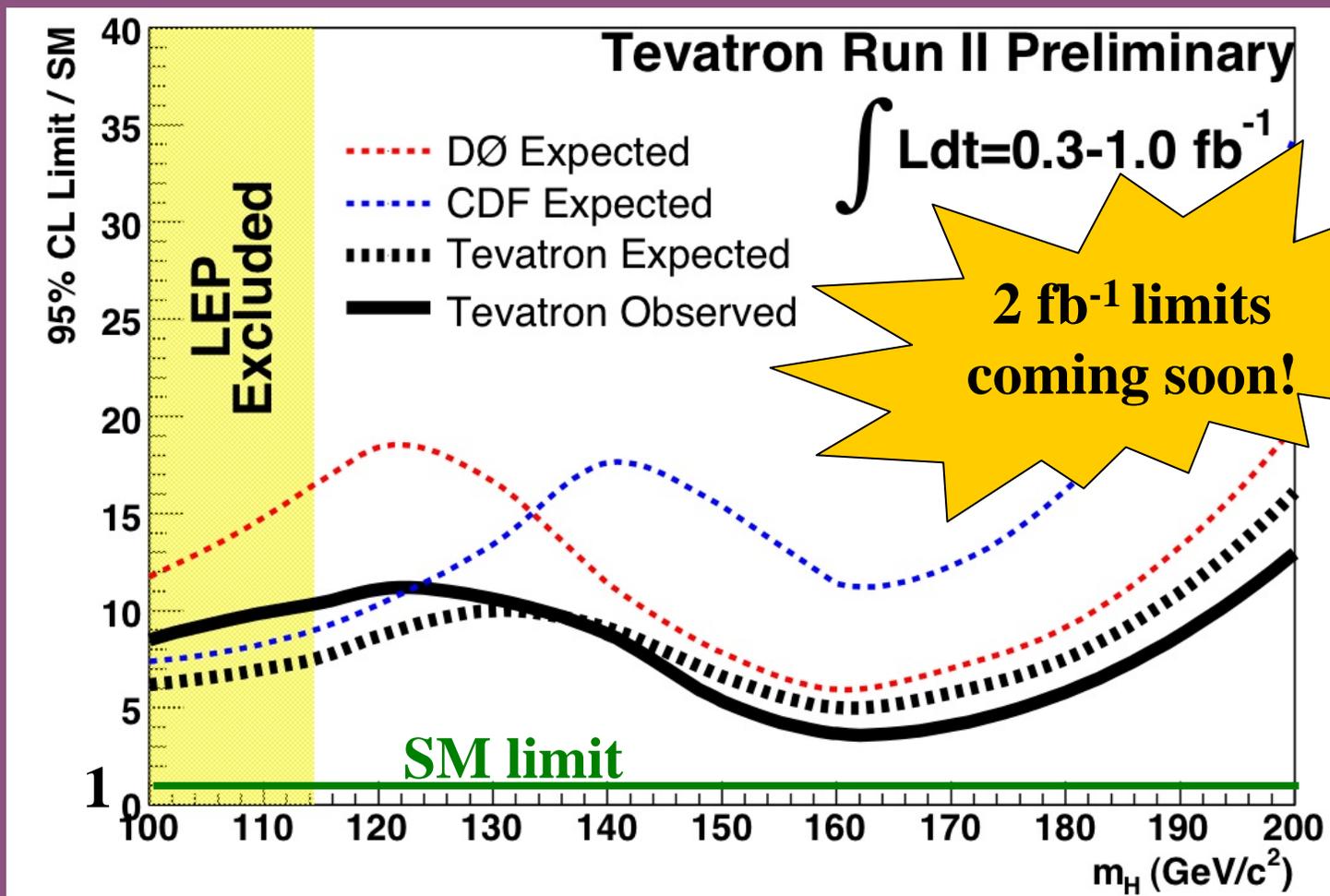
$M_{\text{top}} \sim 1.2\%$

Observed WZ,  
 Evidence for ZZ  
 and Single Top

$M_{\text{Higgs}} < ? \text{ GeV}$   
 at 95% CL



# SM Higgs Limits



See S03-8 talk for details

# Searches

- SM Higgs limit
- Indirect
  - Charm mixing
  - $B_s \rightarrow \mu\mu$  (FCNC)
- Direct
  - $t \rightarrow Zc$  (FCNC)
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# Charm Mixing

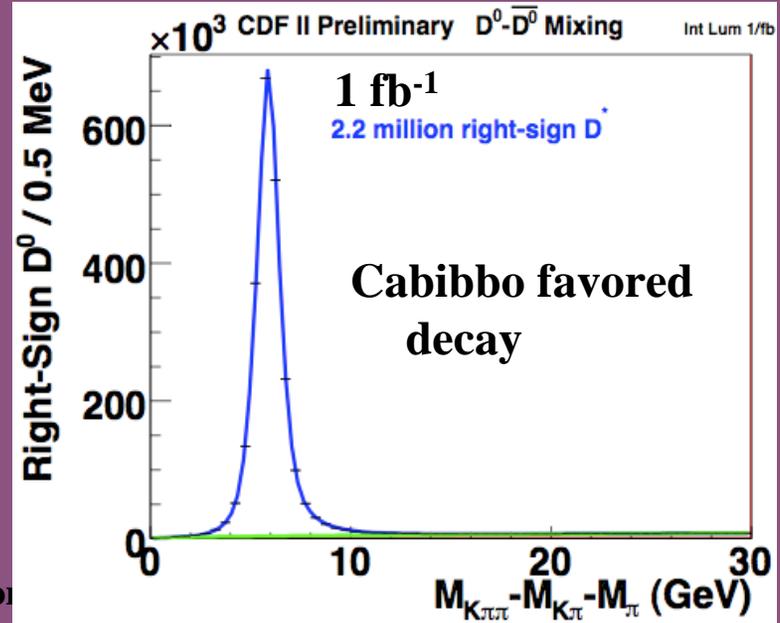
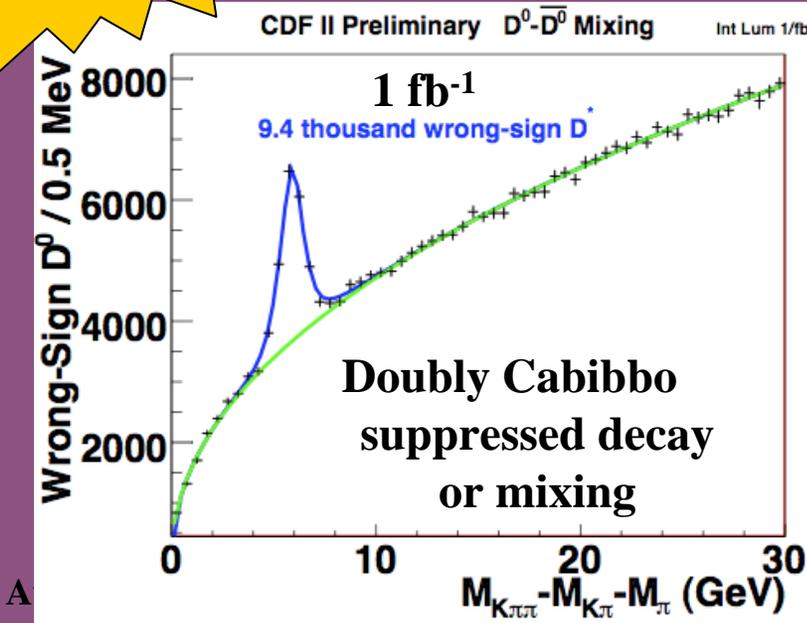
- Results from BaBar and Belle previous 2 talks
- CDF looked at  $D^* \rightarrow \pi D^0, D^0 \rightarrow K\pi$
- Measure time-dependent ratio

First time  
at Tevatron

$$R = \frac{BR(D^0 \rightarrow K^+ \pi^-)}{BR(D^0 \rightarrow K^- \pi^+)}$$

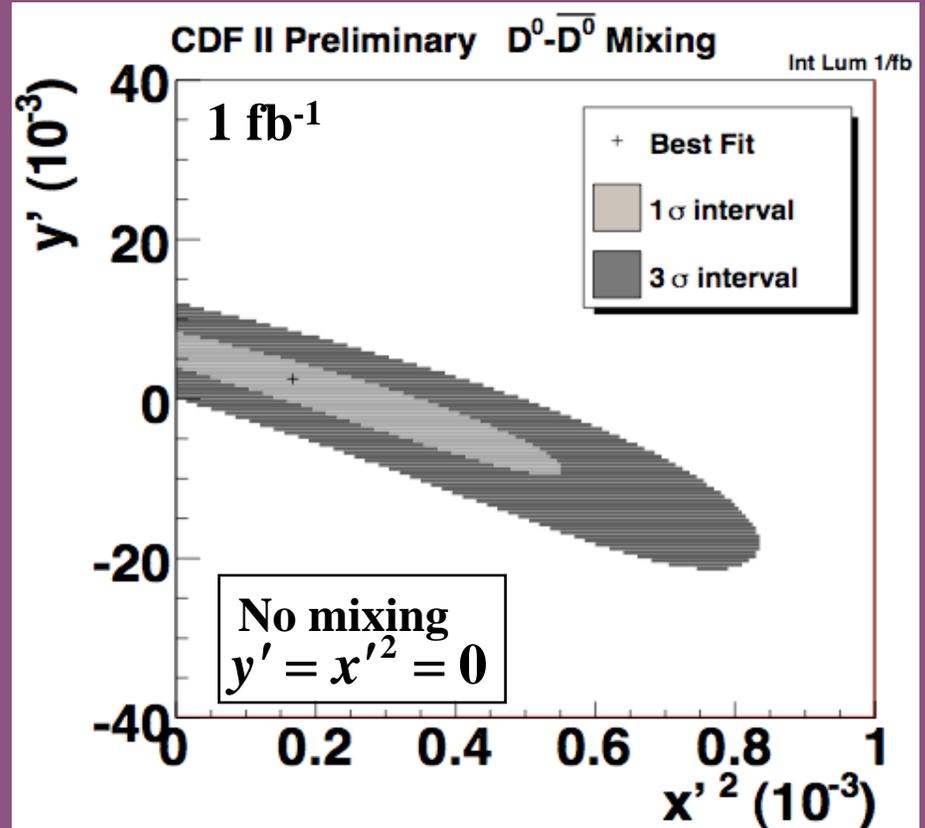
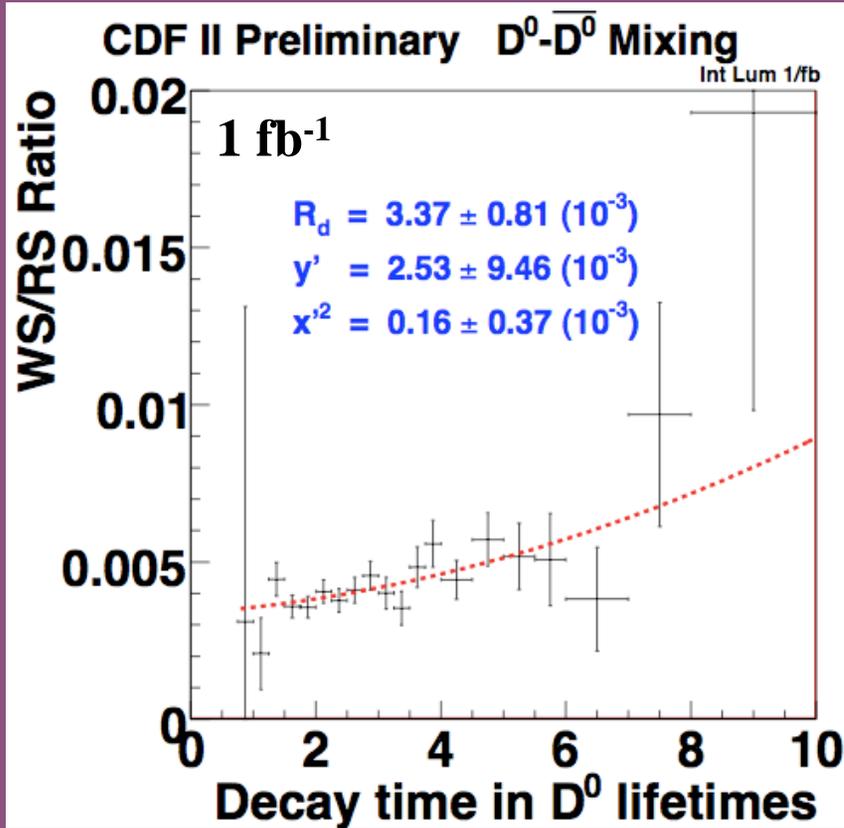
Wrong sign

Right sign





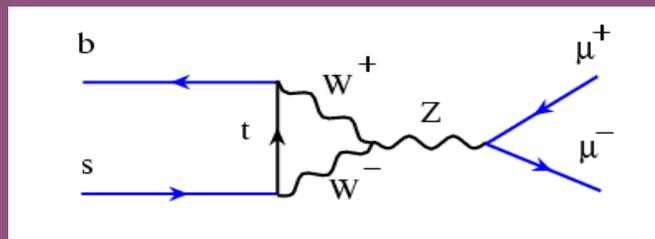
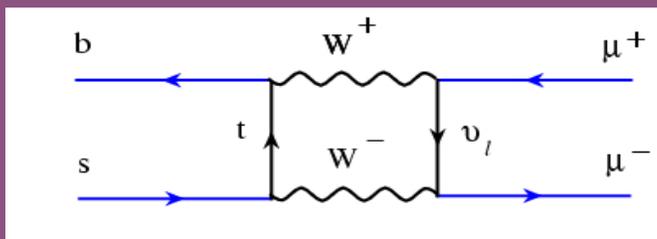
# Charm Mixing



$$R(t) = R_D + y' \sqrt{R_D} t + \frac{x'^2 + y'^2}{4} t^2$$

No mixing probability  
 is 0.13% (3.2  $\sigma$ )

# $B_s \rightarrow \mu\mu$

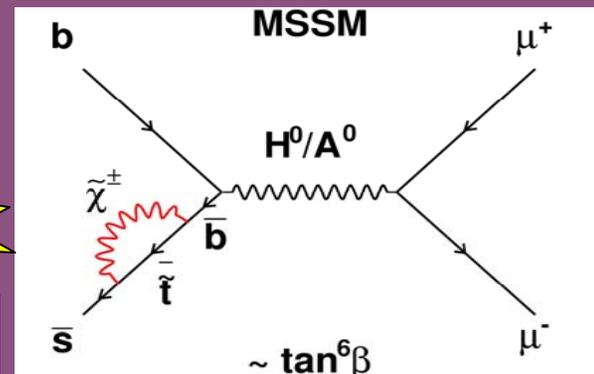


- In SM  $B_s \rightarrow \mu\mu$  is suppressed (need FCNC)
  - SM predicts  $BR(B_s \rightarrow \mu^+ \mu^-) \approx 3.5 \times 10^{-9}$
- SUSY can enhance BR  $\times 100$
- No excess seen in  $2 \text{ fb}^{-1}$

**New**



$BR(B_s \rightarrow \mu\mu) < 5.8 \times 10^{-8} @ 95\% C.L.$

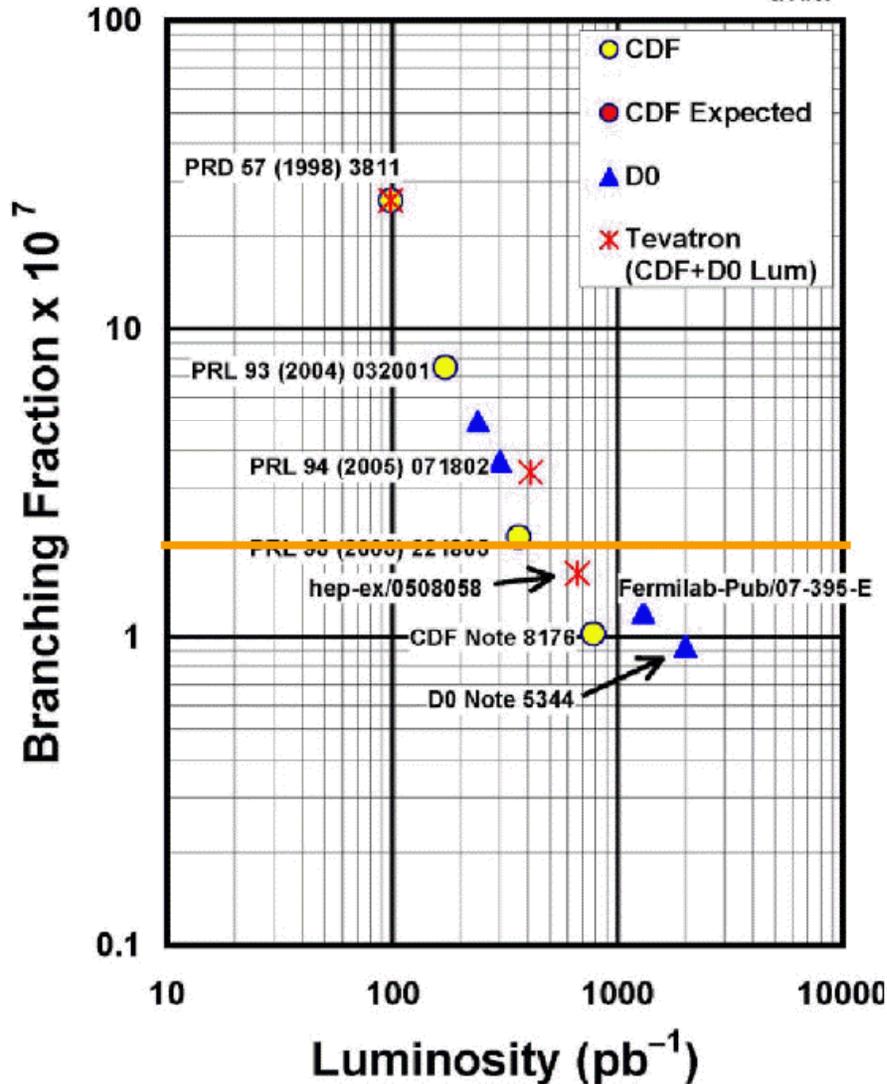


$BR(B_s \rightarrow \mu\mu) < 9.3 \times 10^{-8} @ 95\% C.L.$

# $\mathcal{B}(B_s \rightarrow \mu\mu)$ and Cosmological Connection

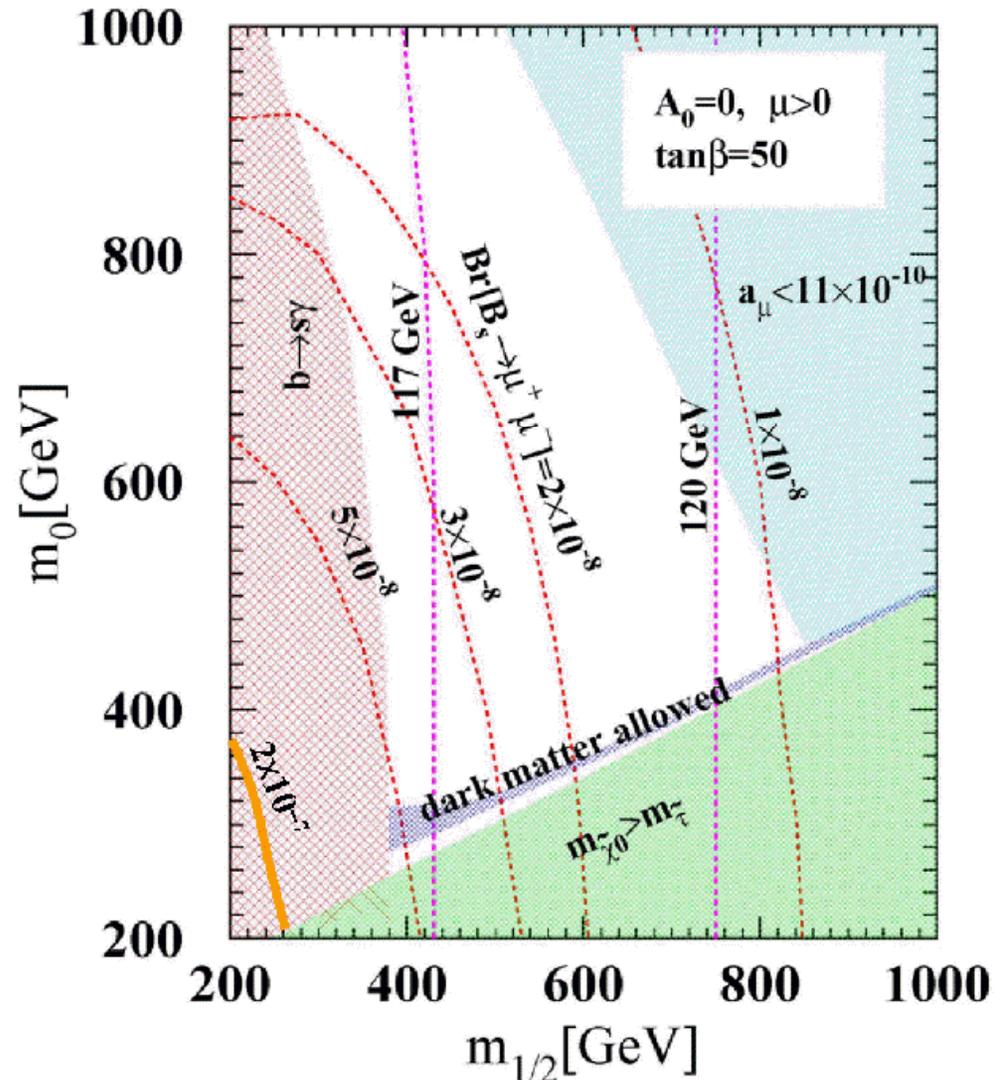
95% CL Limits on  $\mathcal{B}(B_s \rightarrow \mu\mu)$

8/11/07



mSUGRA at  $\tan\beta = 50$

Arnowitz, Dutta, et al., PLB 538 (2002) 121



# Finding New Physics

- Indirect
  - Charm mixing
  - $B_s \rightarrow \mu\mu$  (FCNC)
- Direct
  - $t \rightarrow Zc$  (FCNC)
  - $M_{tt}$
  - SUSY Chargino and Neutralino
  - Global Search - Vista/Sleuth



# Top FCNC

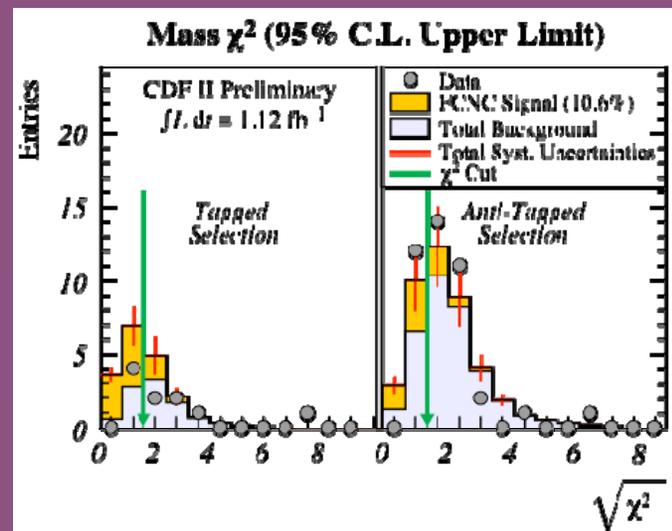
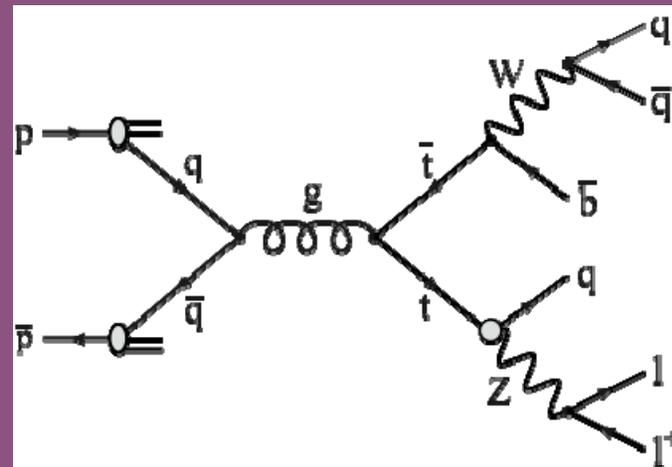
(Flavor Changing Neutral Currents)

- In SM  $BR(t \rightarrow Zq) = O(10^{-14})$
- BSM predict up to  $O(10^{-2})$
- LEP limit  $BR(t \rightarrow Zq) < 13.7\%$

Selection	Observed	Expected
Base Selection	141	$130 \pm 28$
Base Selection (Tagged)	17	$20 \pm 6$
Anti-Tagged Selection	12	$7.7 \pm 1.8$
Tagged Selection	4	$3.2 \pm 1.1$

- CDF sees no excess in  $1 \text{ fb}^{-1}$

**$BR(t \rightarrow Zq) < 10.6\% @ 95\% C.L.$**

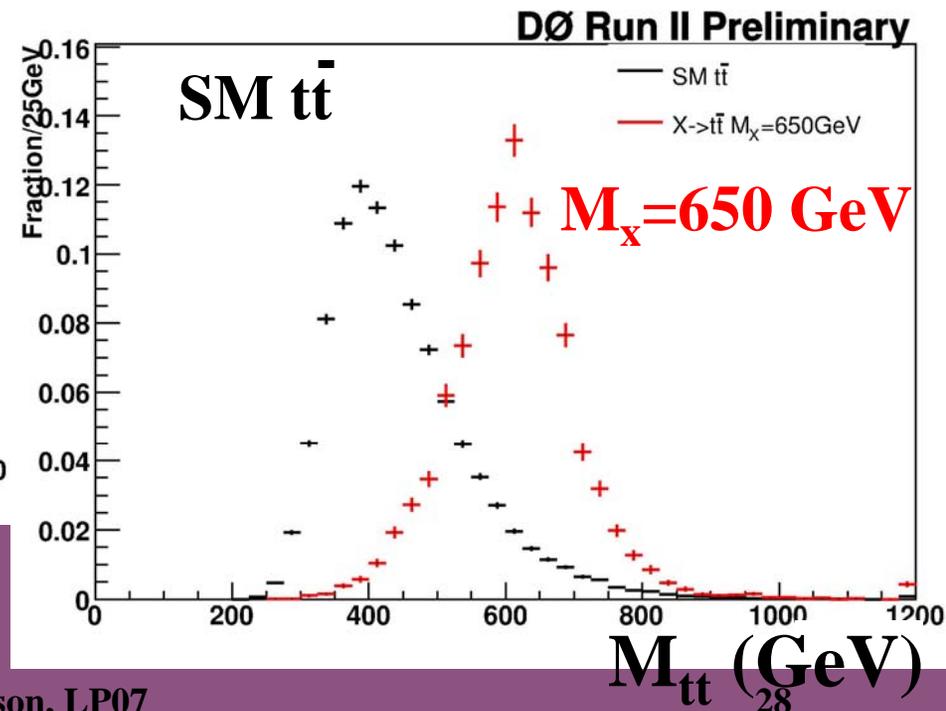
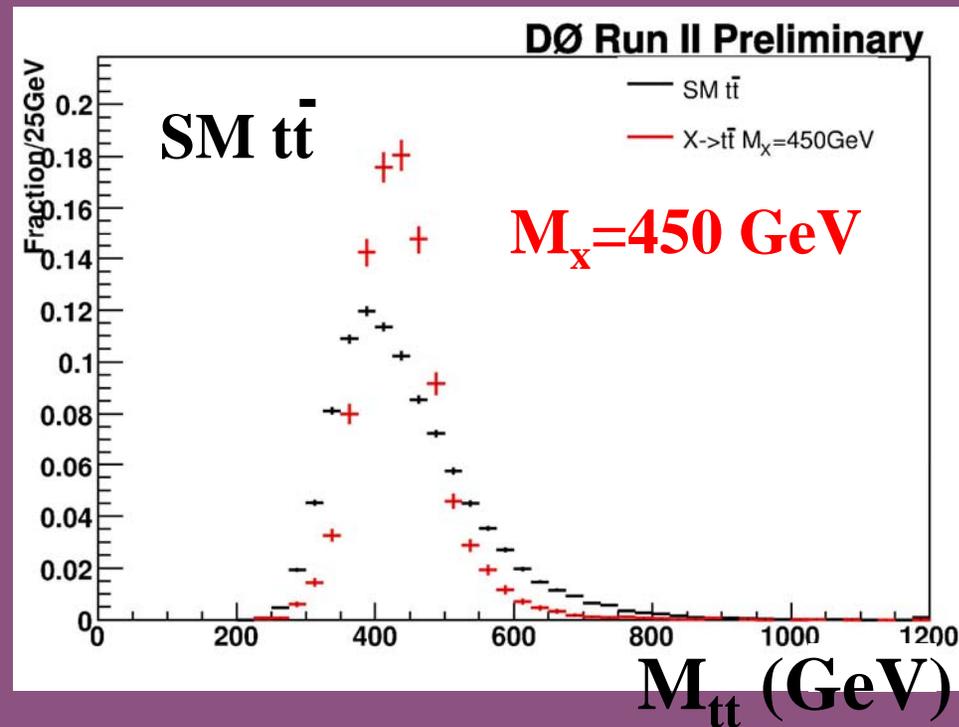


August 13, 2007

$$\chi^2 = \left( \frac{m_{W,rec} - m_{W,PDG}}{\sigma_{W,rec}} \right)^2 + \left( \frac{m_{t \rightarrow Wb,rec} - m_{t,PDG}}{\sigma_{t \rightarrow Wb}} \right)^2 + \left( \frac{m_{t \rightarrow Zq,rec} - m_{t,PDG}}{\sigma_{t \rightarrow Zq}} \right)^2$$

# $M_{t\bar{t}}$

- Search for  $X \rightarrow t\bar{t}$  (model independent)
  - Narrow resonance  $\Gamma_x = 0.012M_x$

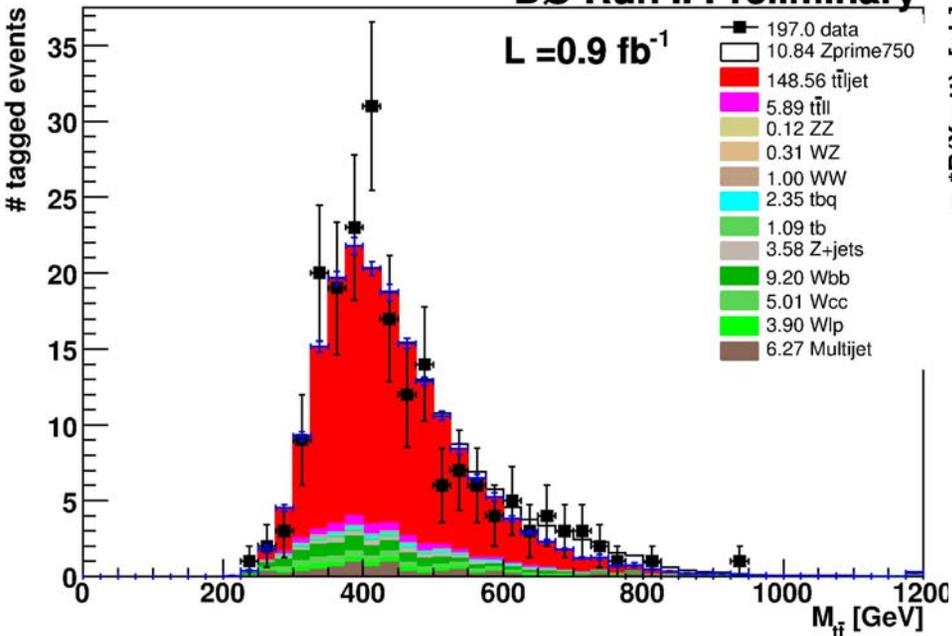




# $M_{t\bar{t}}$ and $Z'$

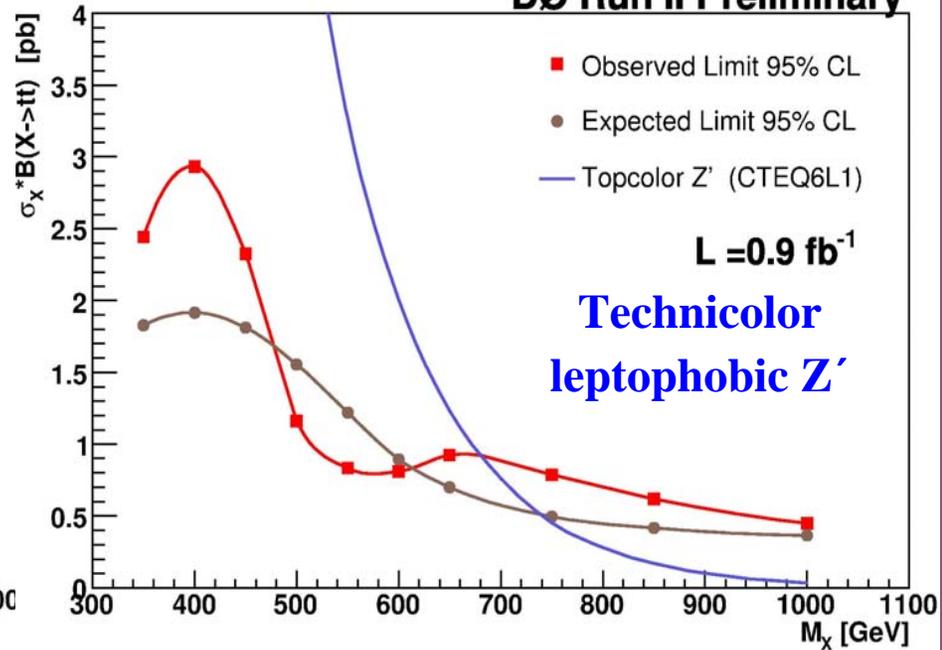
DØ Run II Preliminary

$L = 0.9 \text{ fb}^{-1}$



DØ Run II Preliminary

$L = 0.9 \text{ fb}^{-1}$



$M_{Z'} > 720 \text{ GeV}$   
 $L = 0.9 \text{ fb}^{-1}$

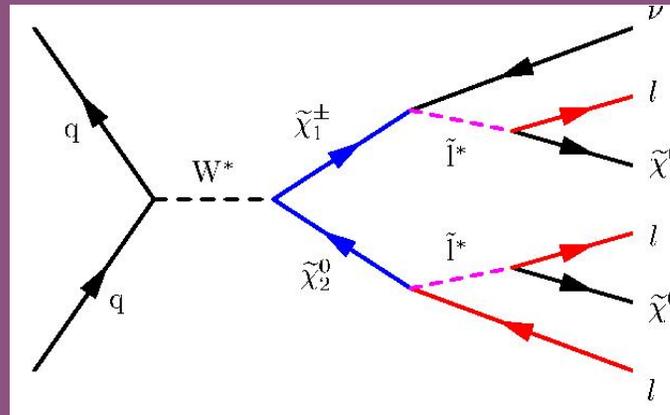
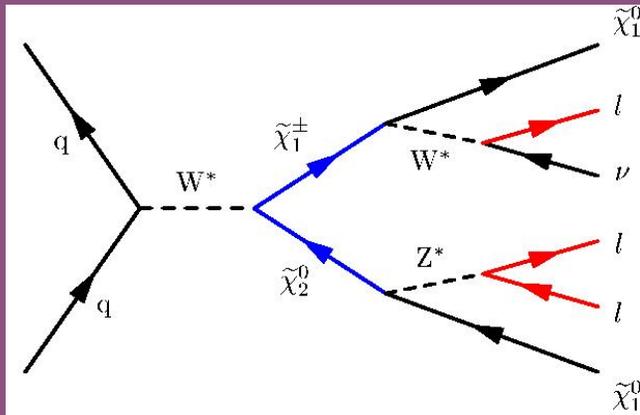
Expected  
 $M_{Z'} > 740 \text{ GeV}$

Observed  
 $M_{Z'} > 680 \text{ GeV}$



# Chargino and Neutralino

- Search for  $\tilde{\chi}_1^\pm$  and  $\tilde{\chi}_2^0$  in MSSM



Add data from Run IIb for ee+isolated track

Combine 4 different analyses:  
 - ee $\ell$ , e $\mu\ell$ ,  $\mu\mu\ell$  and  $\mu\mu$  like-sign  
 (here:  $\ell$  is an isolated track)

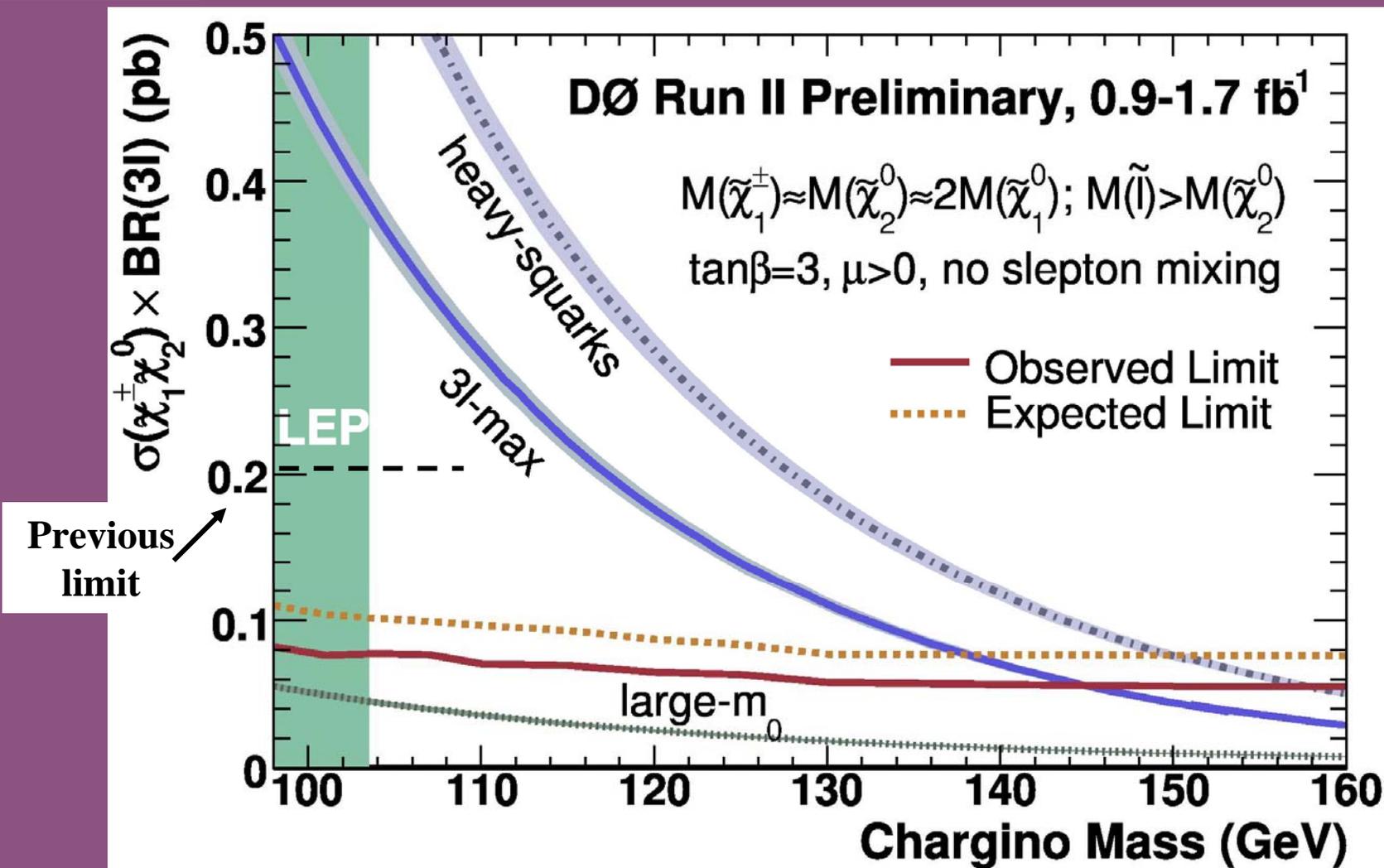
topologies	predicted	observed
ee $\ell$	0.76 $\pm$ 0.67	0
e $\mu\ell$	0.94 <sup>+0.40</sup> <sub>-0.13</sub>	0
$\mu\mu\ell$	0.32 <sup>+0.73</sup> <sub>-0.03</sub>	2
$\mu\mu$ (LS)	1.1 $\pm$ 0.4	1

**No excess seen**

**See S03-9 talk**



# SUSY Trileptons



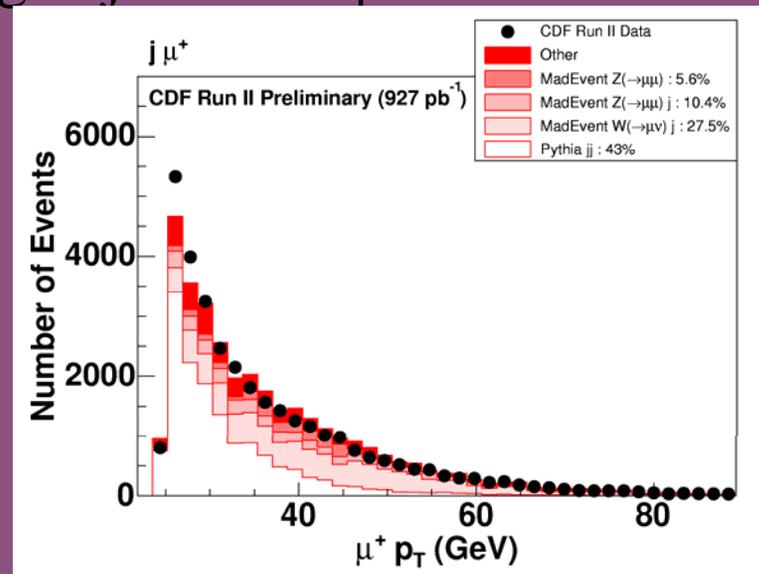


# Searching Broadly for New Physics using Vista

- Model independent search of high  $P_T$  data
    - Compare # of events and 16486 kinematic distributions to SM in 344 exclusive final states based on objects in event
- Objects = e,  $\mu$ ,  $\tau$ ,  $\gamma$ , jet, b-tagged jet with  $P_T > 17$  GeV

**CDF Run II Preliminary (927 pb<sup>-1</sup>)**

Final State	Data	Background
3j $\tau$ +	71	113.7 $\pm$ 3.6
5j	1661	1902.9 $\pm$ 50.3
2j $\tau$ +	233	296.5 $\pm$ 5.6
be+j	2207	2015.4 $\pm$ 28.7
3j $\Sigma p_T < 400$ GeV	35436	37294.6 $\pm$ 524.3
e+3j $\phi$	1954	1751.6 $\pm$ 42
be+2j	798	695.3 $\pm$ 13.3
3j $\phi$ $\Sigma p_T > 400$ GeV	811	967.5 $\pm$ 38.4
e+ $\mu$ +	26	11.6 $\pm$ 1.5
e+ $\gamma$	636	551.2 $\pm$ 11.2



**Probability of observing most discrepant excess = 8%**

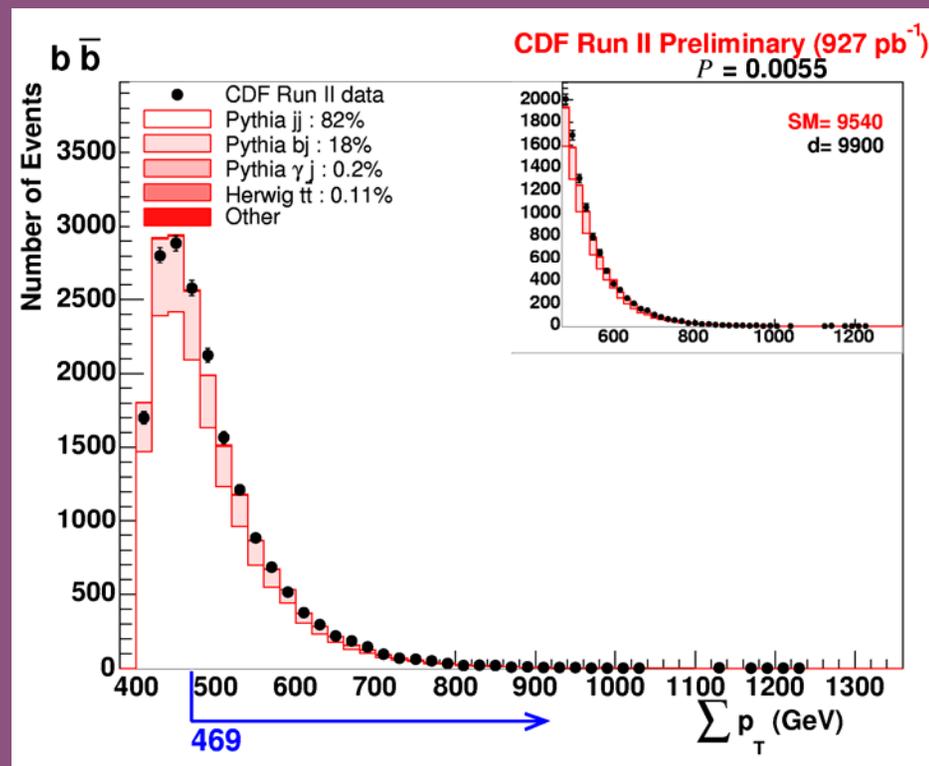


# Searching Broadly for New Physics using Sleuth

- Quasi-model independent search
- Look for excess in high  $\sum P_T$  tails
- Merge Vista final states
- Discovery case if  $P < 0.001$

Fraction of hypothetical similar experiments to observe something as interesting as CDF is 46%

Most interesting Sleuth final state is  $b\bar{b}$



# Conclusions

- **Tevatron delivering and CDF/D0 are collecting record data sets**
- **Achieving Run II precision goals**
  - $M_t, M_w, \Delta m_s$
- **Breaking new ground exploring Top, B baryon and Diboson sectors**
- **Searching everywhere for Higgs and signs of New Physics!**
- **Will double our datasets by ICHEP '08...**

# ICHEP '08

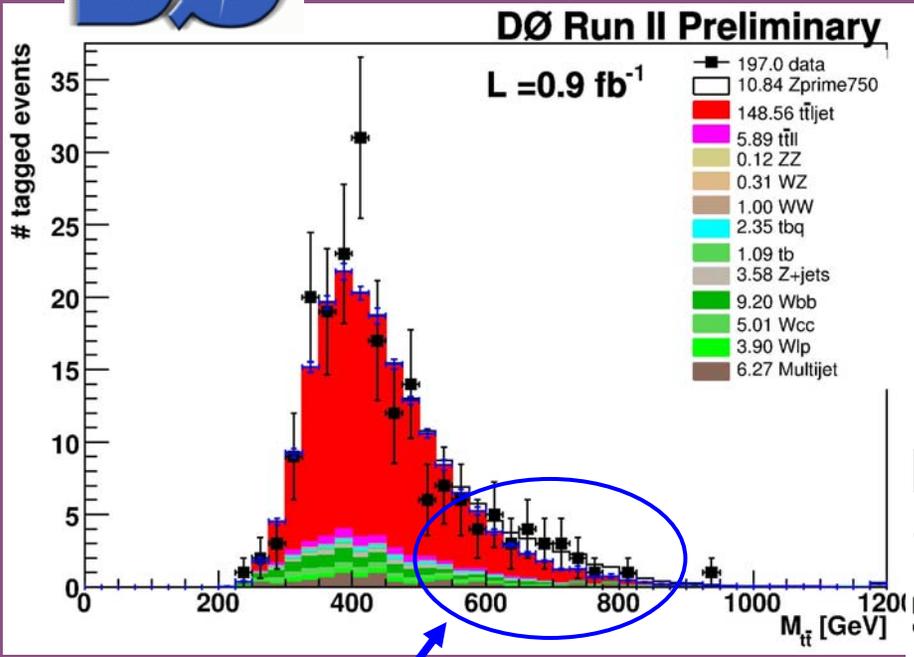
**Something new could  
emerge at any time!!!**



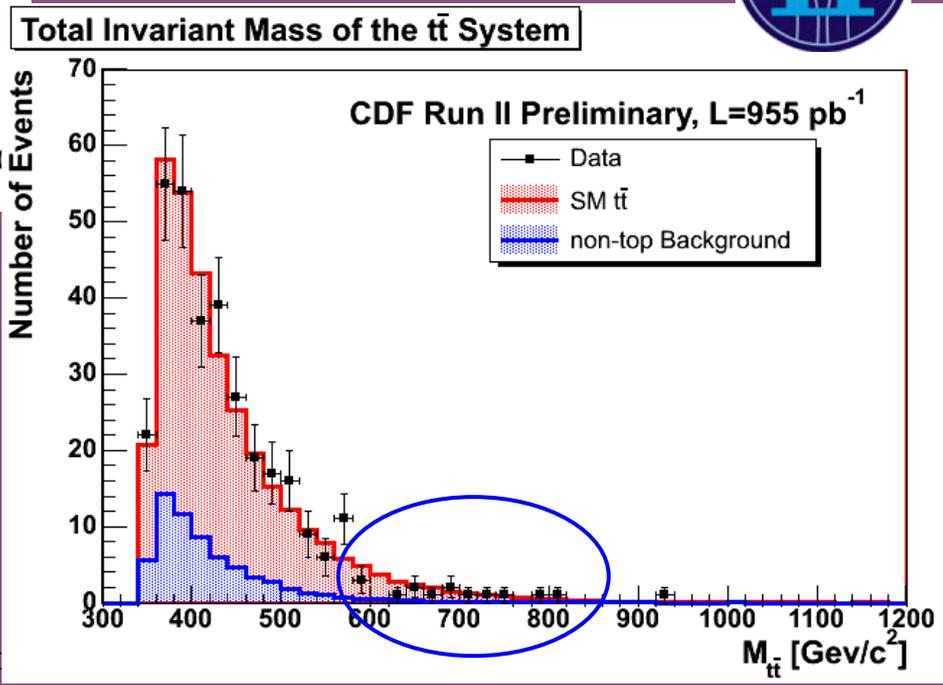
# Backups



# $M_{t\bar{t}}$ and $Z'$

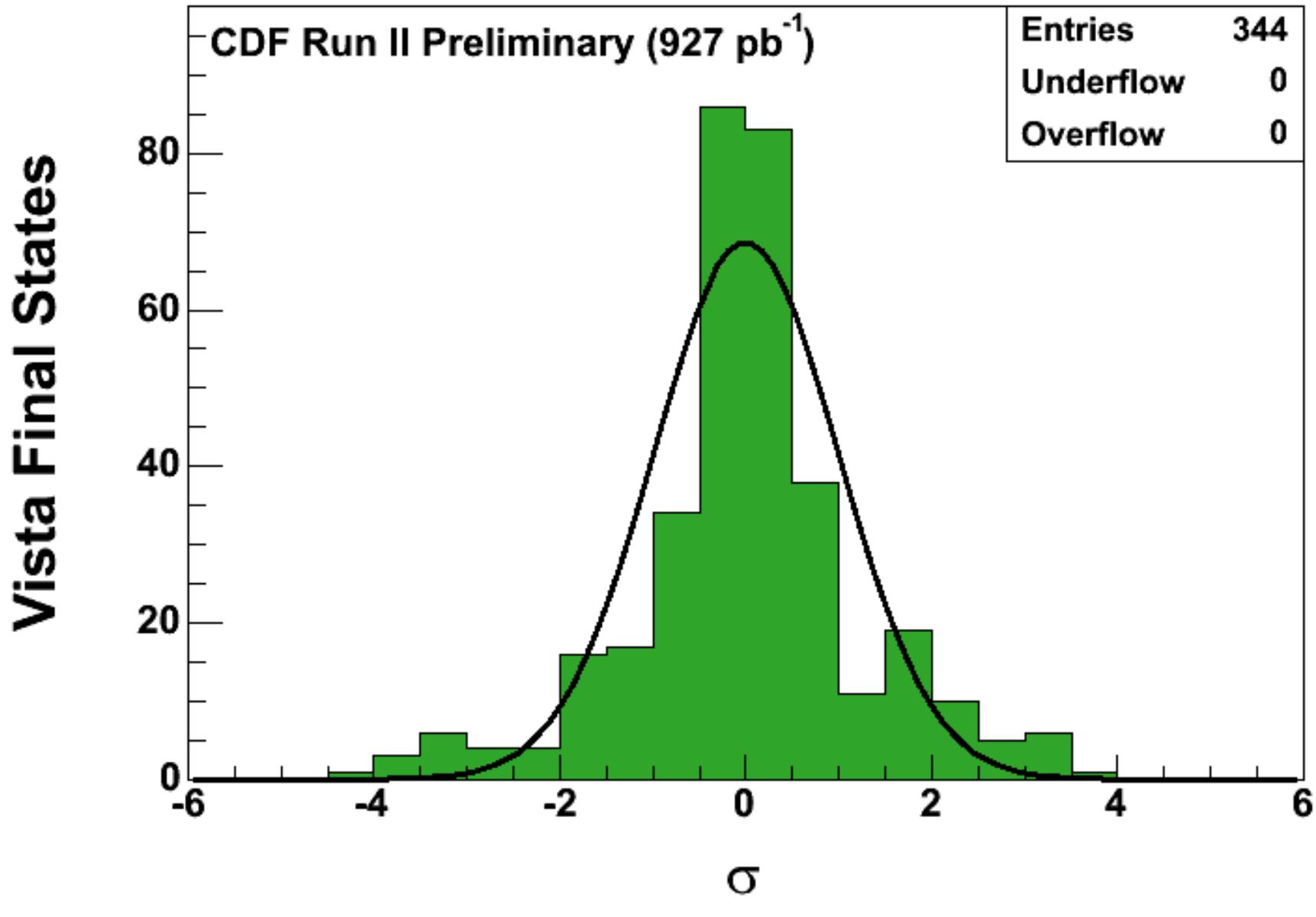


**Stay Tuned**

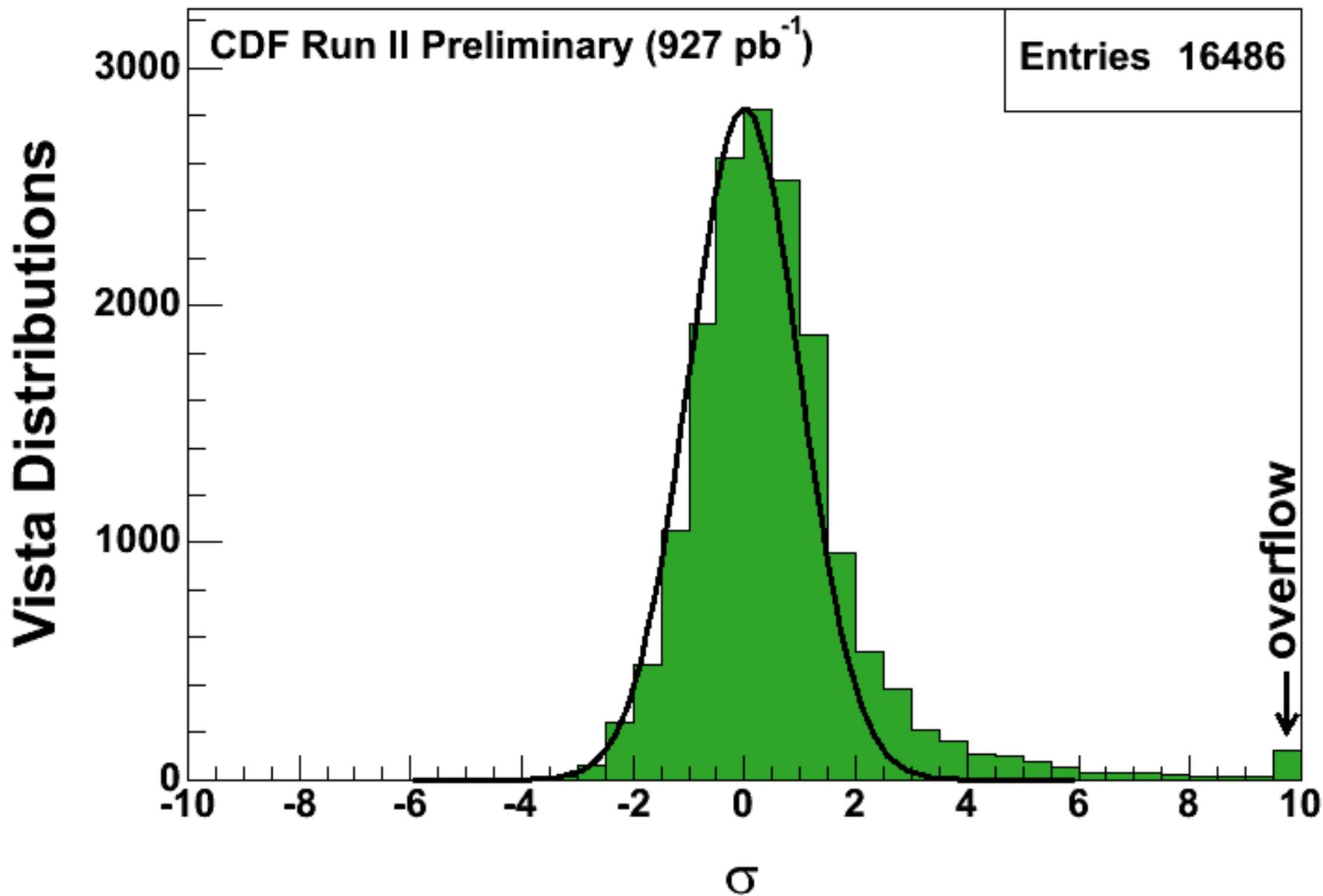


$M_{Z'} = 750 \text{ GeV}$

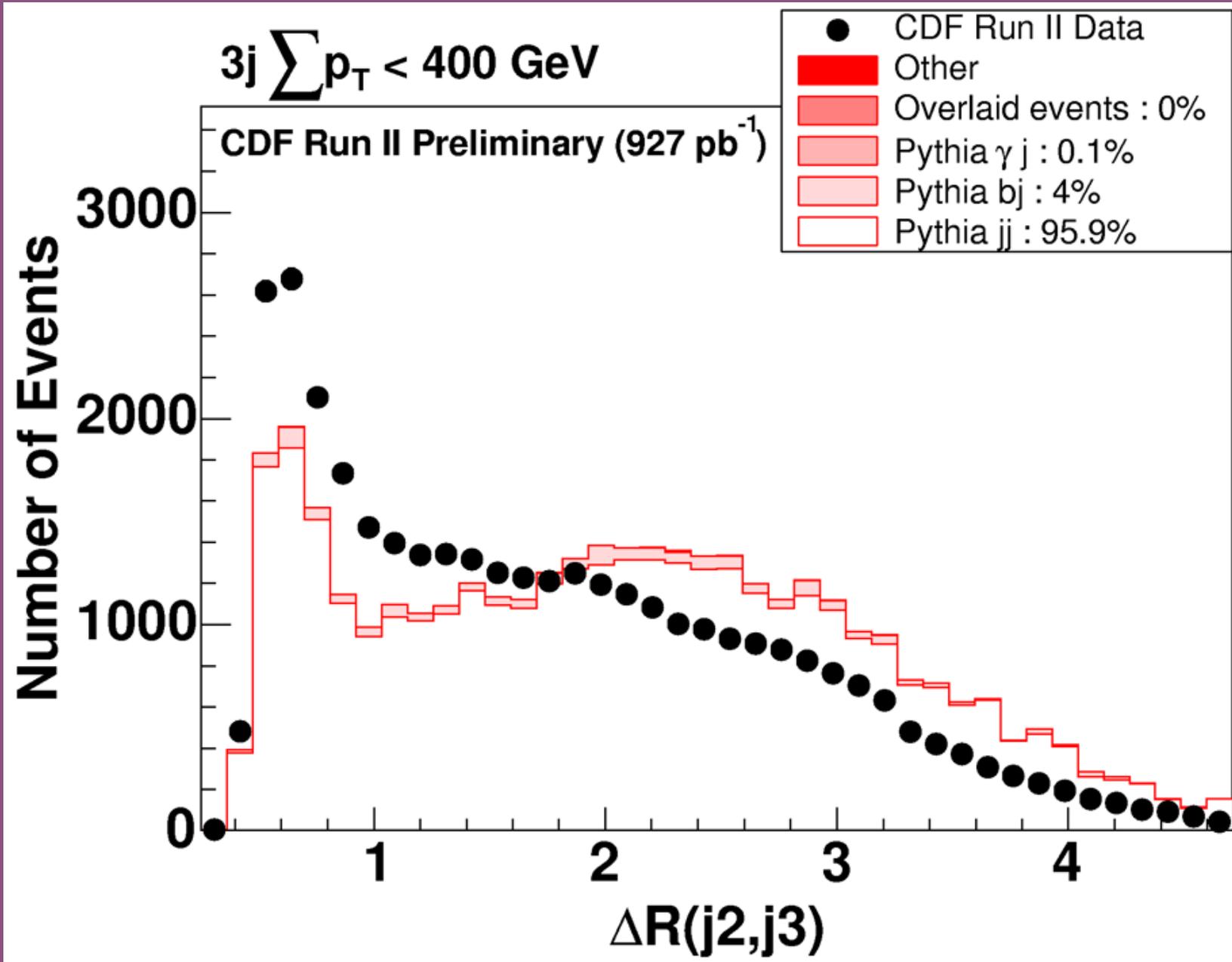
# Vista final state normalizations



# Vista kinematic shapes



# Sample discrepant distribution



# Sleuth Sensitivity

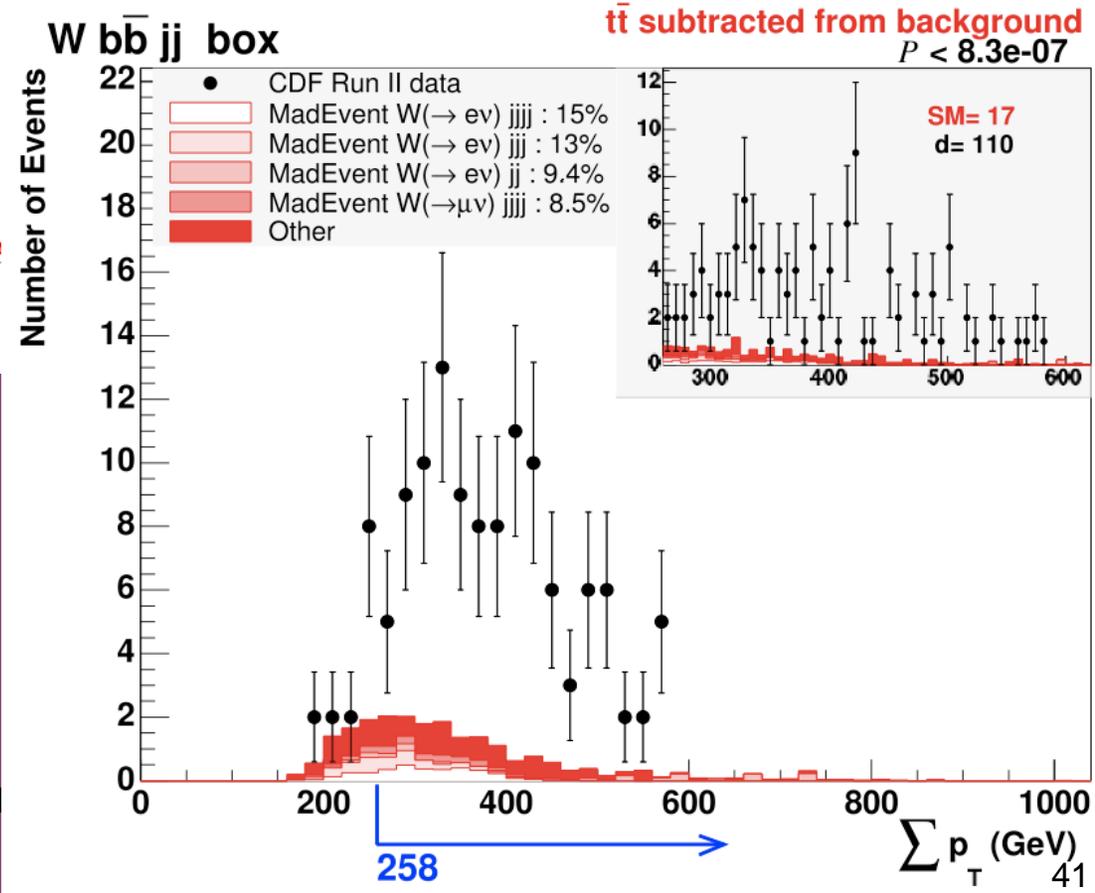
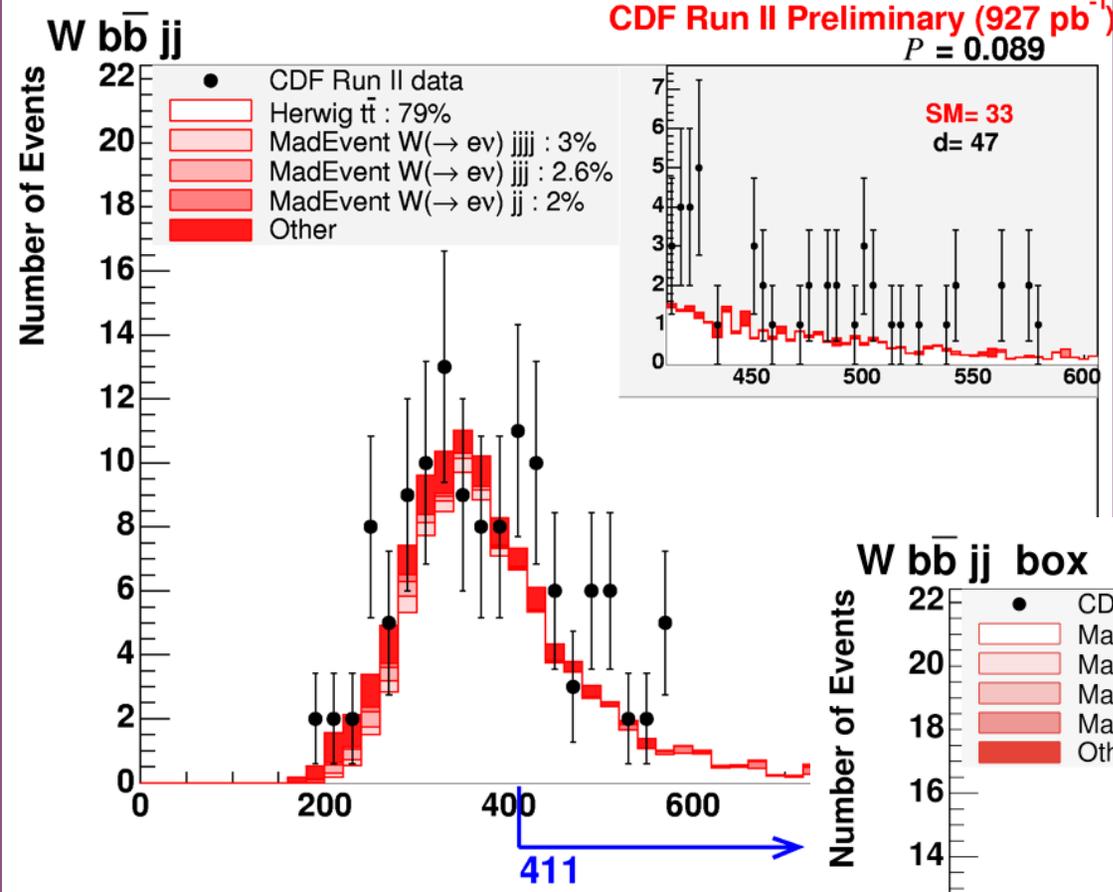
Q: Would Sleuth have found the top quark?

A: Yes.

Expected Run II discovery

luminosity  $\sim 80 \text{ pb}^{-1}$

(Drell-Yan  $\text{e}^+\text{e}^- \rightarrow \mu^+\mu^-$ )



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# Sleuth@CDFIIa

## result

(top 5)

SLEUTH Final State	$\mathcal{P}$
$b\bar{b}$	0.0055
$j\cancel{p}$	0.0092
$\ell^+\ell'^+\cancel{p}jj$	0.011
$\ell^+\ell'^+\cancel{p}$	0.016
$\tau\cancel{p}$	0.016

$$\tilde{\mathcal{P}} = 0.46$$

- Sleuth finds no significant excess in 1fb<sup>-1</sup> of CDF Run II high-p<sub>T</sub> data
- 46% of pseudo experiments are expected to be as interesting
- This does not prove there is no new physics present