

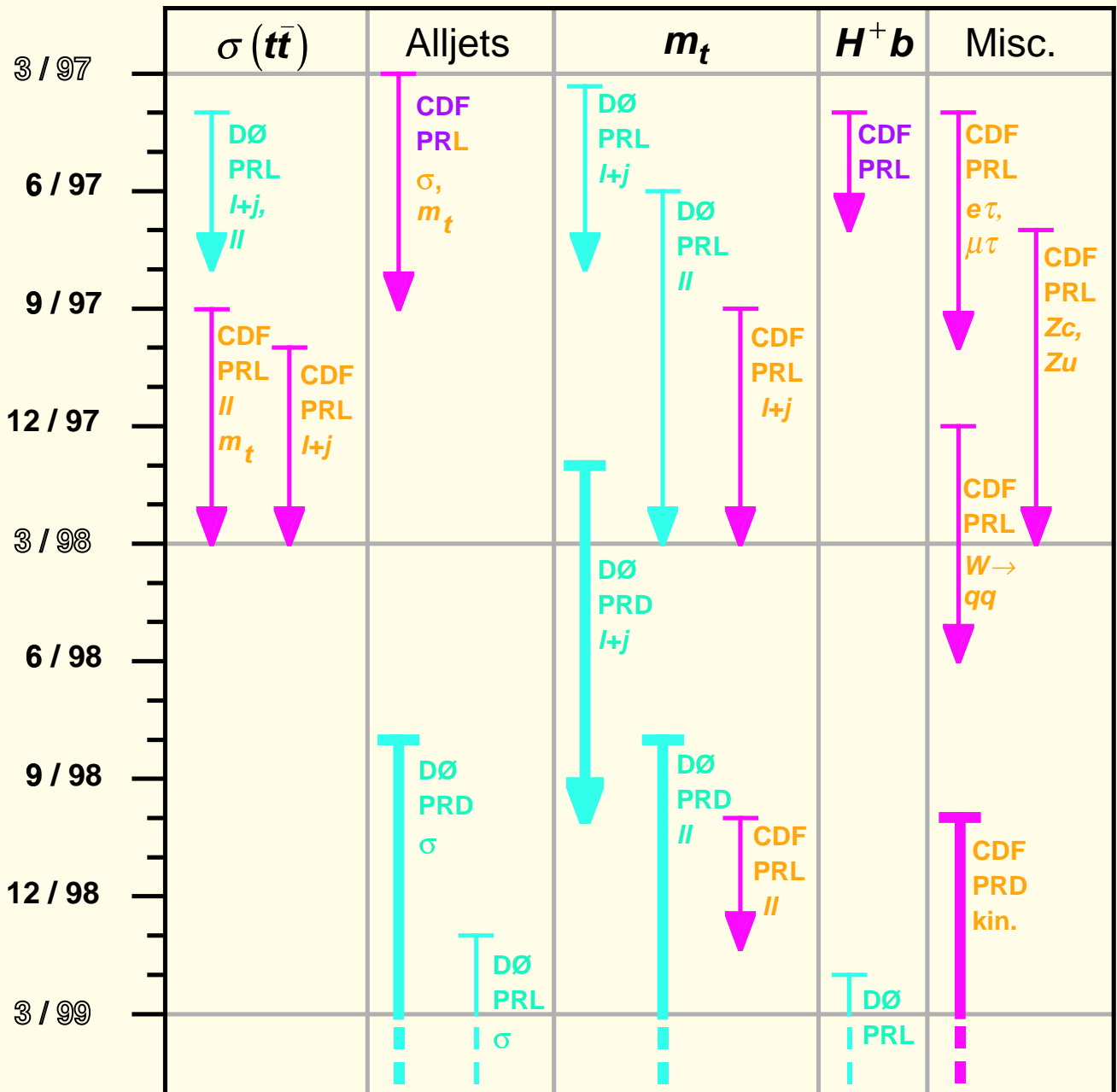
**Recent Results**  
on the  
***Top Quark***  
from the  
**Tevatron Collider**  
**Experiments**

**Ann Heinson**  
**University of California, Riverside, USA**

**Electroweak Interactions and Unified Theories**  
**XXXIVth Rencontres de Moriond**

**Les Arcs, Savoie, France**  
**13th – 20th March 1999**

# Recent Top Publications



## Talk Outline

- All-hadronic decay of  $t\bar{t}$  pairs
- Top quark mass measurements
- $W$  boson helicity in top quark decay
- Correlation of spins in the  $t\bar{t}$  system
- Invariant mass of the  $t\bar{t}$  system
- Decay to a charged Higgs boson
- Electroweak single top quark production

# All-Hadronic Decay of $t\bar{t}$ Pairs

Reminder of the CDF *Phys. Rev. Lett.* 1997 result:

Choose events with at least 5 jets,  $H_T > 300$  GeV, plus

$b$ -tag and  $H_T > 75\% \sqrt{\hat{s}}$  and  $A > 0.25\% H_T^{j^{3+}} + 0.54$

or two  $b$ -tags

Measure bkgds using tag rate functions applied to QCD data

$$\sigma(p\bar{p} \rightarrow t\bar{t}) = 10.1 \pm 1.9 \begin{matrix} +4.1 \\ -3.1 \end{matrix} \text{ pb (for } m_t = 175 \text{ GeV)}$$

Good  $b$ -tagging efficiency, so using cuts gets  $>3\sigma$  significance

New DØ measurement:

No silicon vertex detector, so use neural network analysis  
1.5 years more work, yields result of similar sensitivity  
(45% error on cross section) and smaller systematic error

## Neural Network Analysis

10 inputs for first network :

3 for energy      3 for radiation      4 for topology

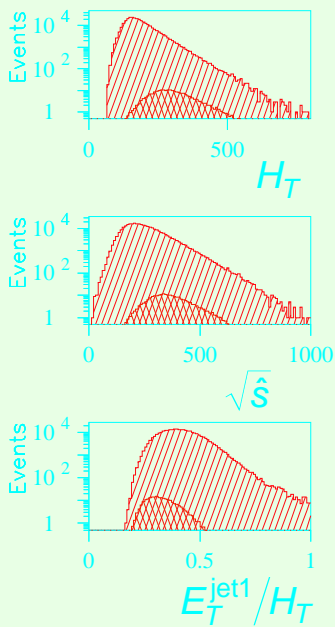
4 inputs for second network :

output of first network      3 for event structure

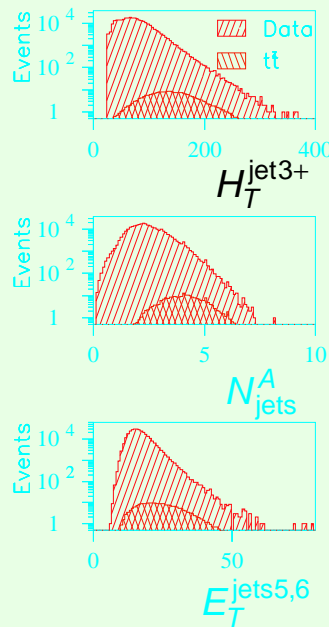
$$\sigma(p\bar{p} \rightarrow t\bar{t}) = 7.1 \pm 2.8 \pm 1.5 \text{ pb (for } m_t = 172.1 \text{ GeV)}$$

# All-Hadronic Decay of $t\bar{t}$ Pairs

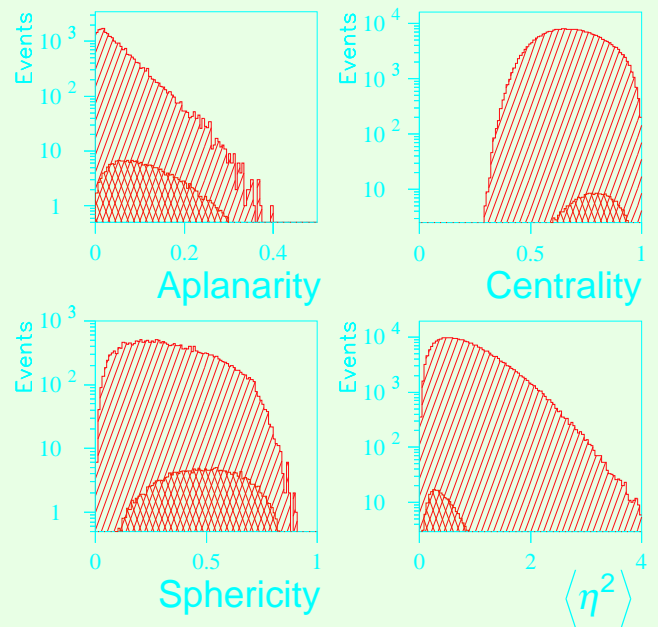
## Energy



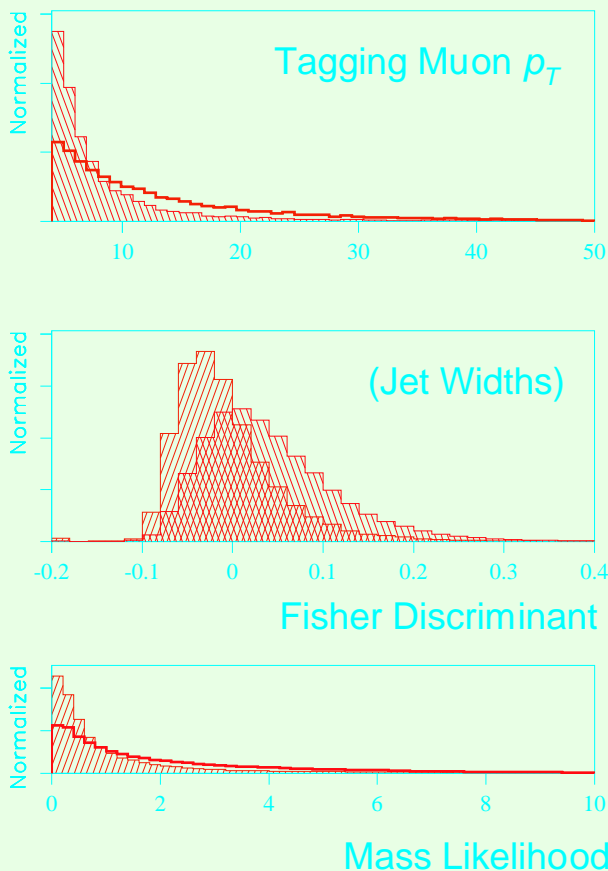
## Radiation



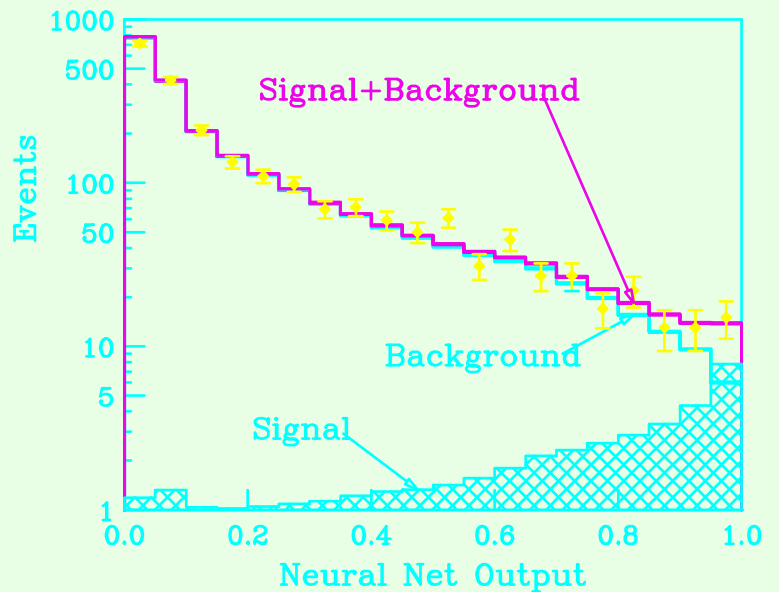
## Topology



## Event Structure



## DØ Neural Network Result



18 data events  
 Background =  $6.9 \pm 0.9$  events  
 3.2  $\sigma$  excess of  $t\bar{t}$  observed

# Top Quark Mass

Within the last year:

New  $m_t$  result from CDF for dilepton decays

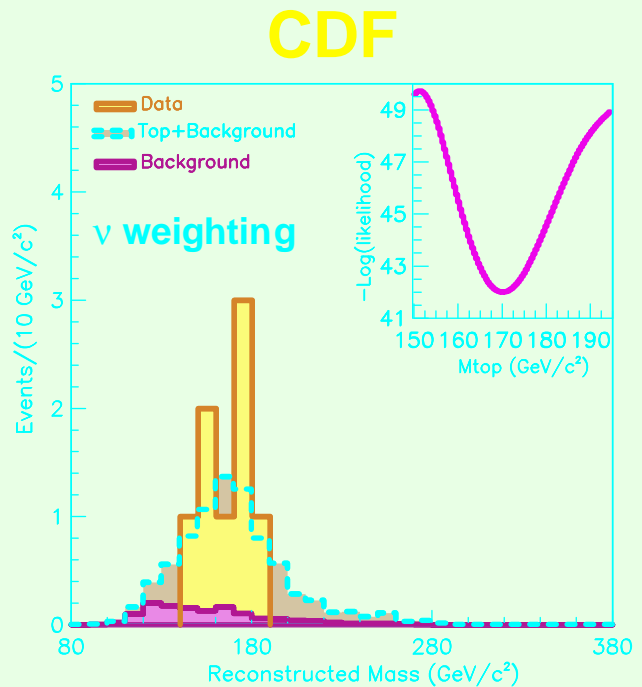
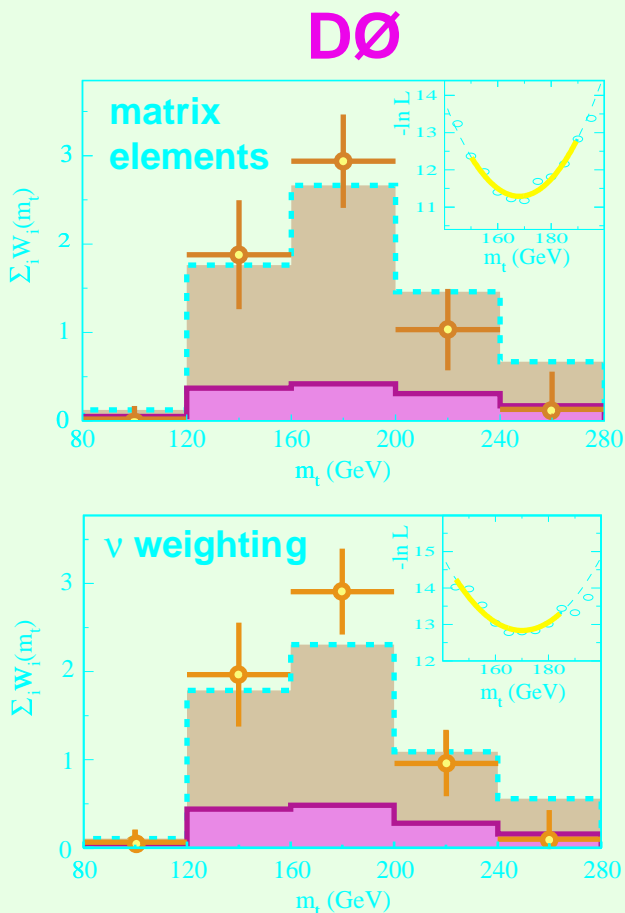
Re-evaluation of all-hadronic  $m_t$  errors by CDF

Official combination of DØ and CDF  $m_t$  results

Leading to:

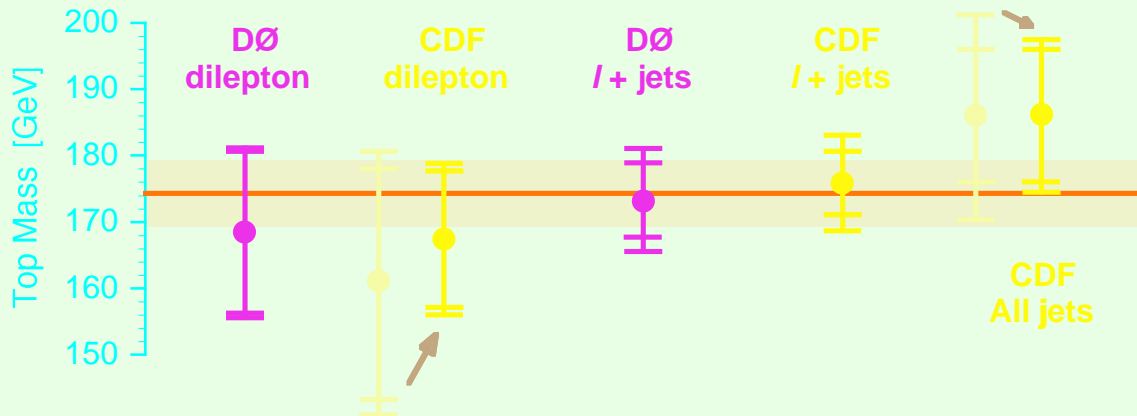
Top quark has the best measured mass of any quark

## Dilepton Mass Measurements



CDF  $167.4 \pm 10.3 \pm 4.8$  GeV  
DØ  $168.4 \pm 12.3 \pm 3.6$  GeV

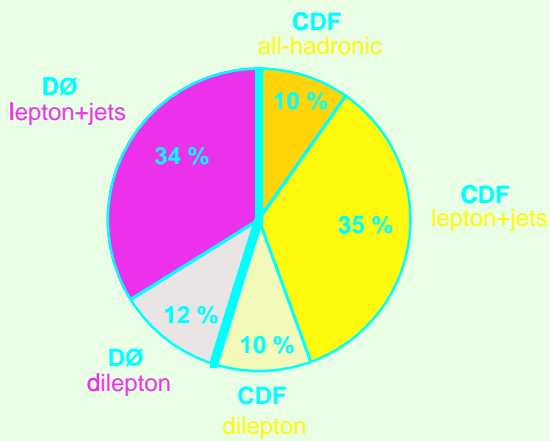
# Tevatron Combined Top Mass



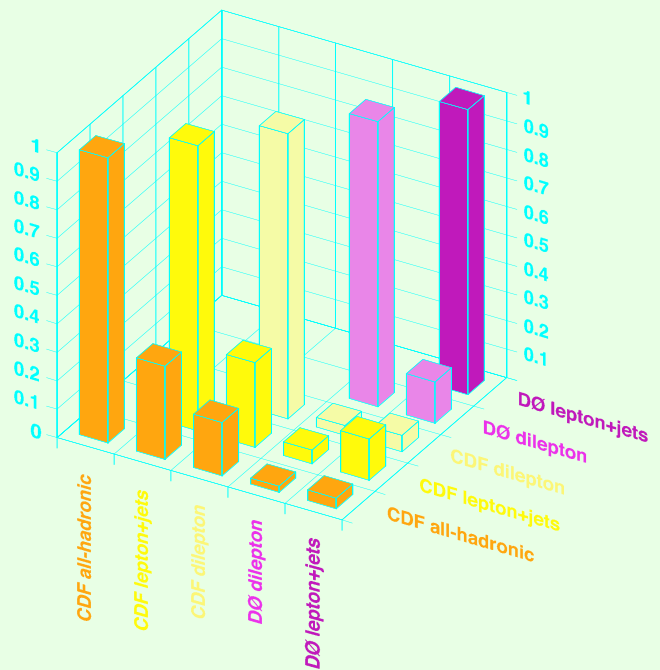
Divide systematic errors into six components, with 22 subparts  
 Determine all correlations between errors

$$m_{top} = 174.3 \pm 5.1 \text{ GeV}$$

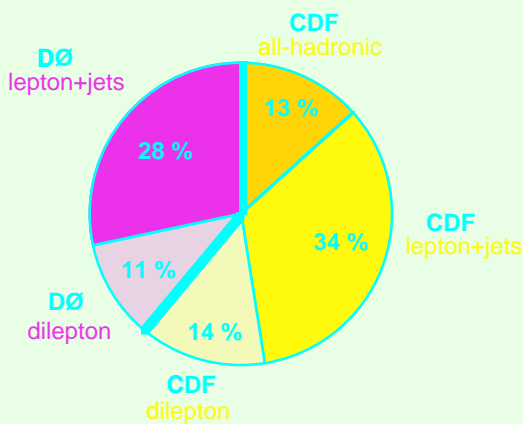
## Contribution to Central Value



## Correlations Between Measurements



## 1/σ² Contribution to Error



# W Boson Helicity in Top Decay

In SM, top decays only to a longitudinally polarized (helicity = 0) or left-handed ( $h_W = -1$ ) W boson, not to a right-handed one

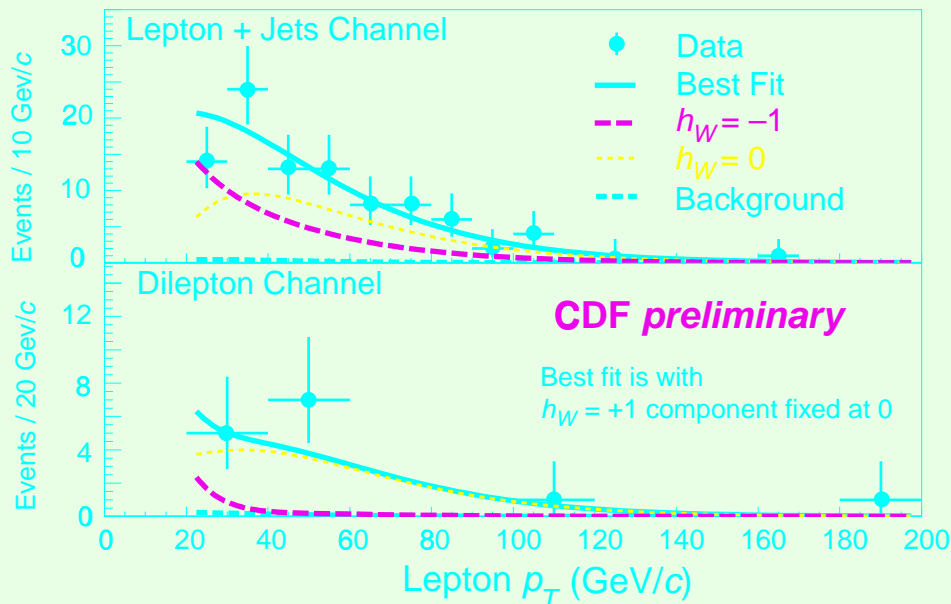
$$\frac{B(t \rightarrow bW_{\text{long}})}{B(t \rightarrow bW_{\text{left}})} = \frac{1}{2} \left( \frac{m_t}{m_W} \right)^2 = \frac{0.70}{0.30}$$

Direction of charged lepton from W decay is:

- perpendicular to W when  $h_W = 0$
- opposite to W when  $h_W = -1$

Use  $p_T$  of charged lepton to discriminate:

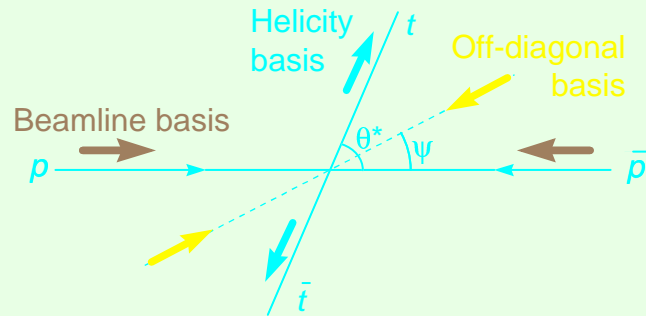
- better measured than angular correlations
- unaffected by combinatorics or  $\nu$  reconstruction



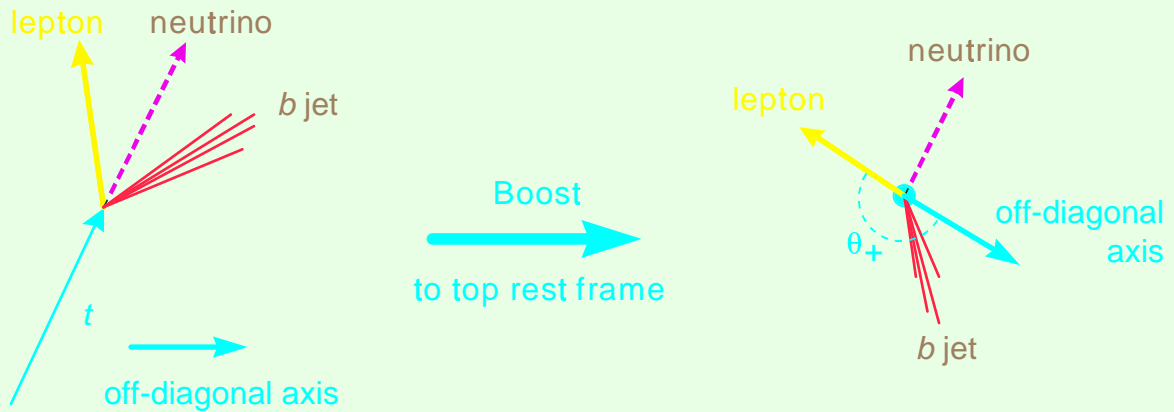
$$B(t \rightarrow bW_{\text{long}}) = 0.97 \pm 0.37 \pm 0.12 \quad [B(t \rightarrow bW_{\text{right}}) = 0]$$

$$B(t \rightarrow bW_{\text{right}}) = 0.11 \pm 0.15 \pm 0.06 \quad [B(t \rightarrow bW_{\text{long}}) = 0.75]$$

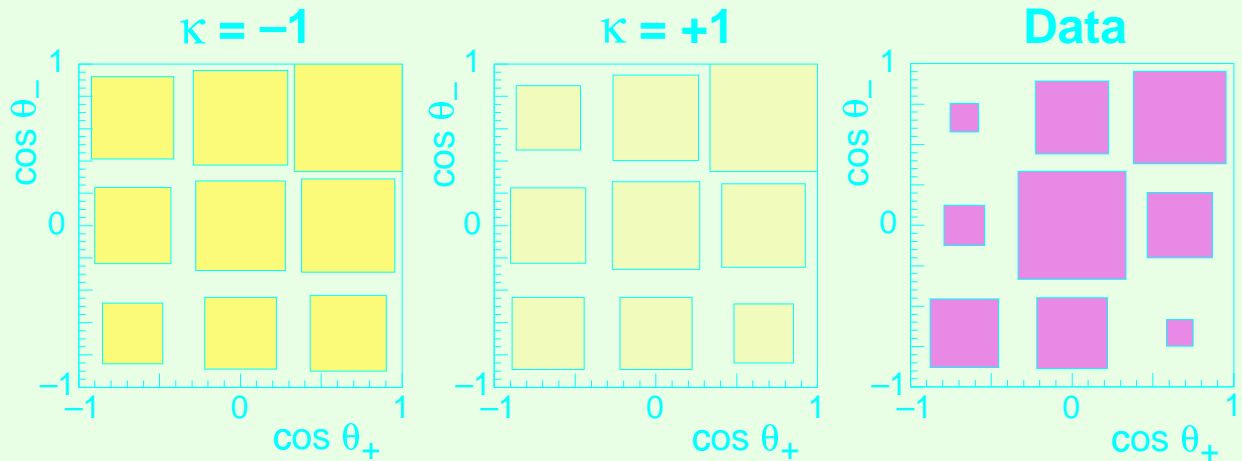
# Top-Antitop Spin Correlations



$$\frac{4}{\sigma} \frac{d^2\sigma}{d(\cos\theta_+)d(\cos\theta_-)} = 1 + \kappa(\cos\theta_+)(\cos\theta_-)$$



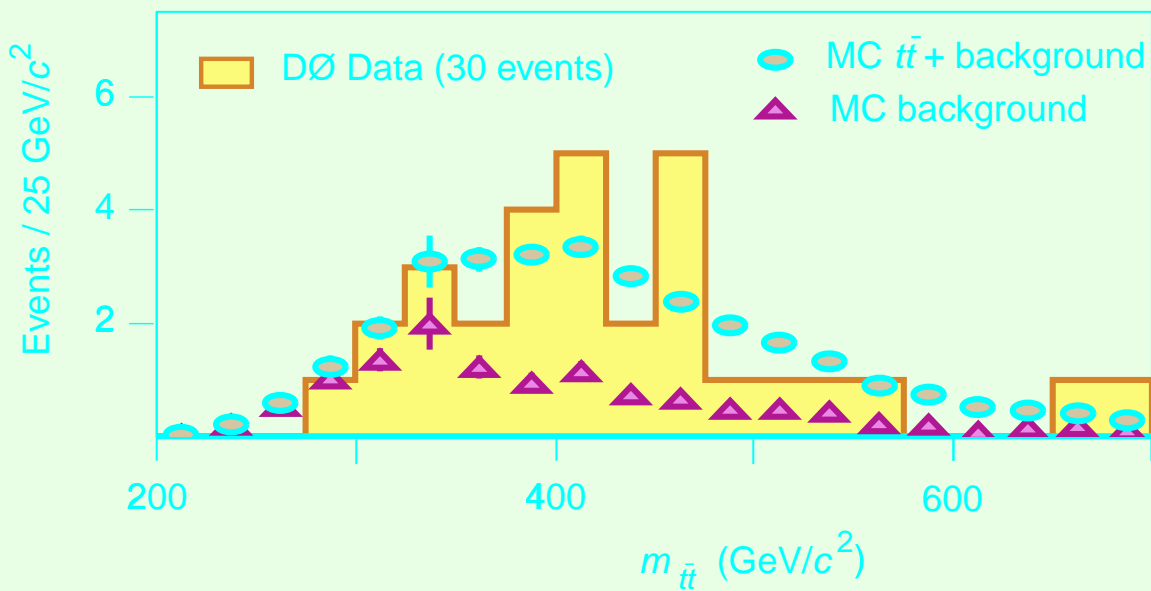
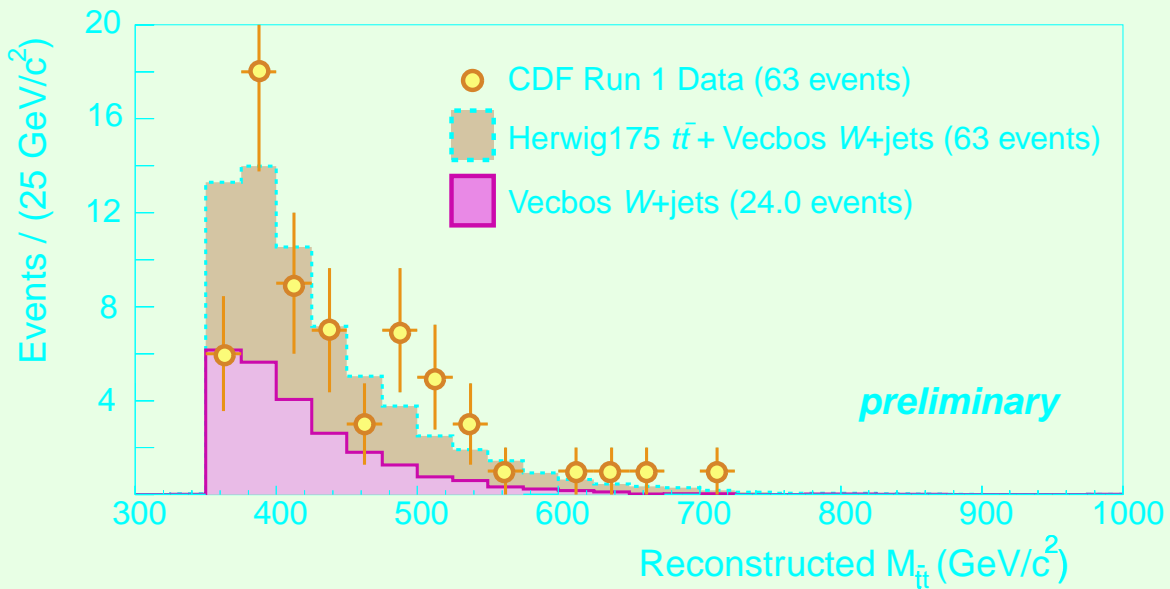
(DØ preliminary  
6 dilepton events)



$\kappa > -0.2$  at 68% CL (In SM,  $\kappa \sim 0.9$ )

# Invariant Mass of $t\bar{t}$ System

Cross section excess could be from heavy resonance decay  
∴ Search for excess in  $m_{t\bar{t}}$  spectrum at high mass



**CDF:** No evidence for  $Z'$  (say) decaying to  $t\bar{t}$ , up to  $\sim 650 \text{ GeV}$

# Top Decay to Charged Higgs

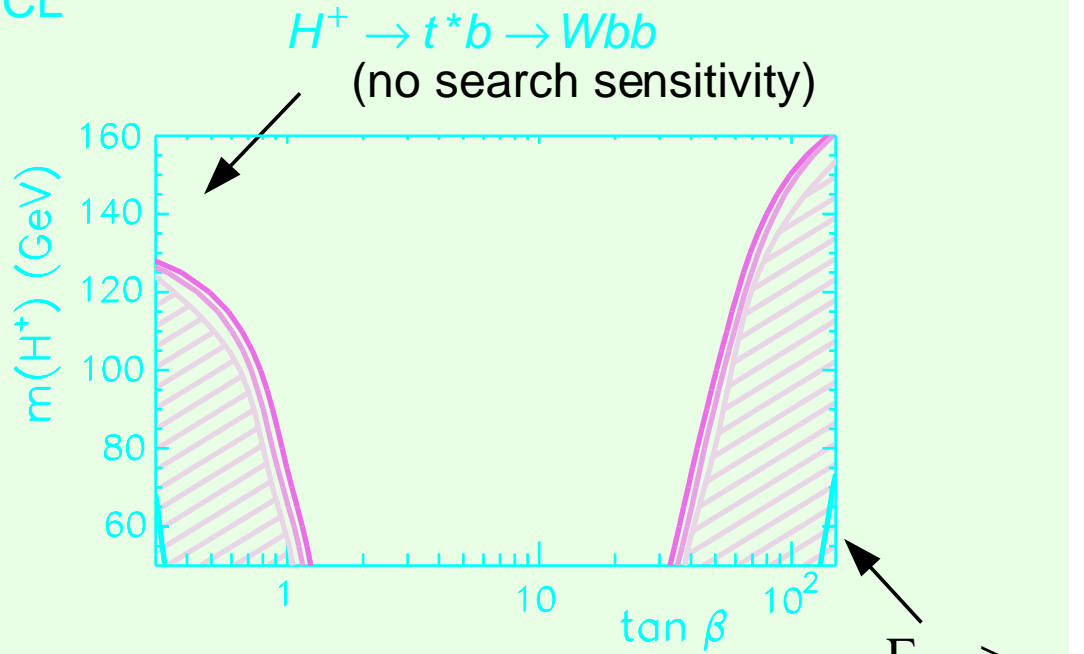
Search for  $t \rightarrow H^+ b$  via  $H^+ \rightarrow \bar{s} c$  (low  $\tan\beta$ ) or  $H^+ \rightarrow \tau \nu$  (high  $\tan\beta$ )

Disappearance experiments – shaded areas

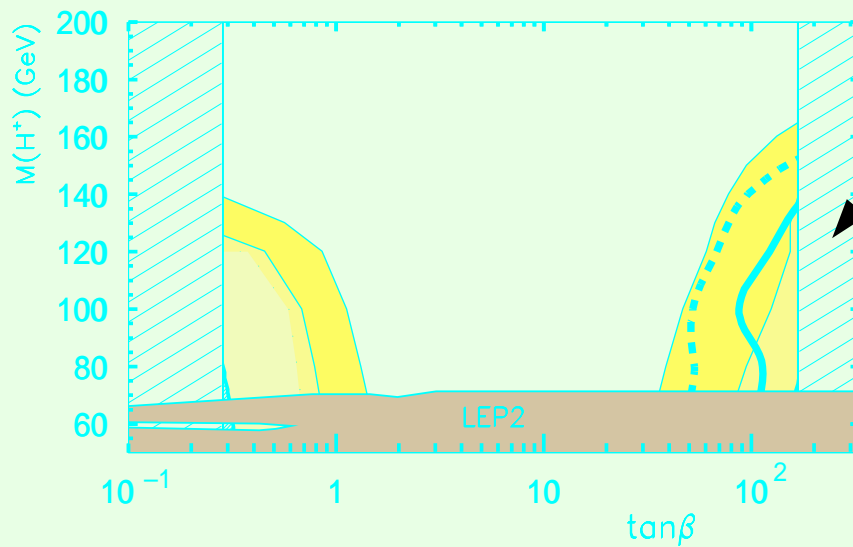
Appearance experiment – bold lines (CDF)

Limits are 95% CL

**DØ**  
*hep-ex/9902028*



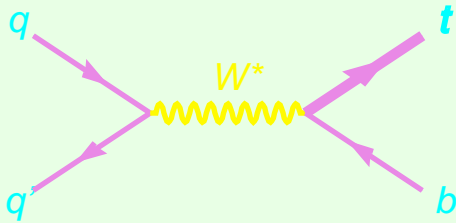
**CDF**  
*preliminary*



Difficult search – theory changes faster than measurement

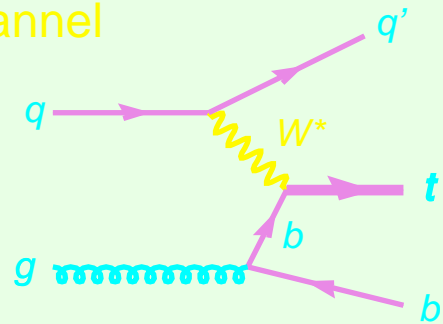
# Electroweak Single Top

s-channel



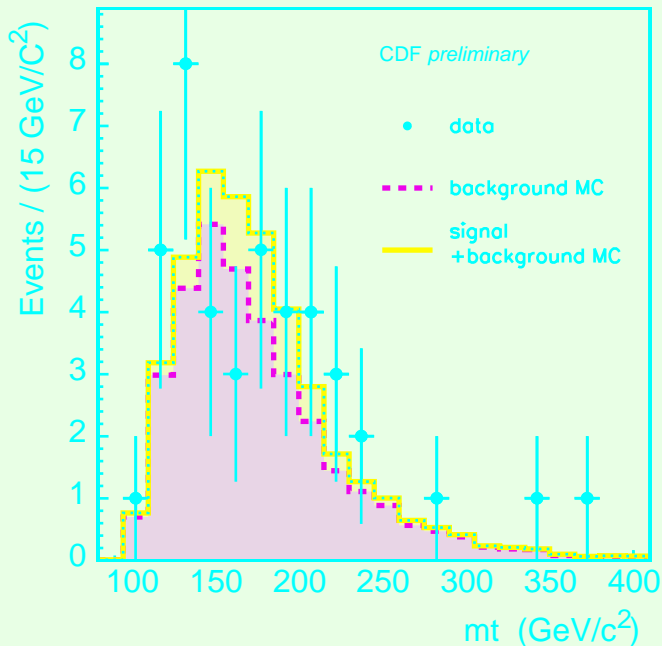
$$\sigma (p\bar{p} \rightarrow tb) = 0.7 \text{ pb}$$

t-channel

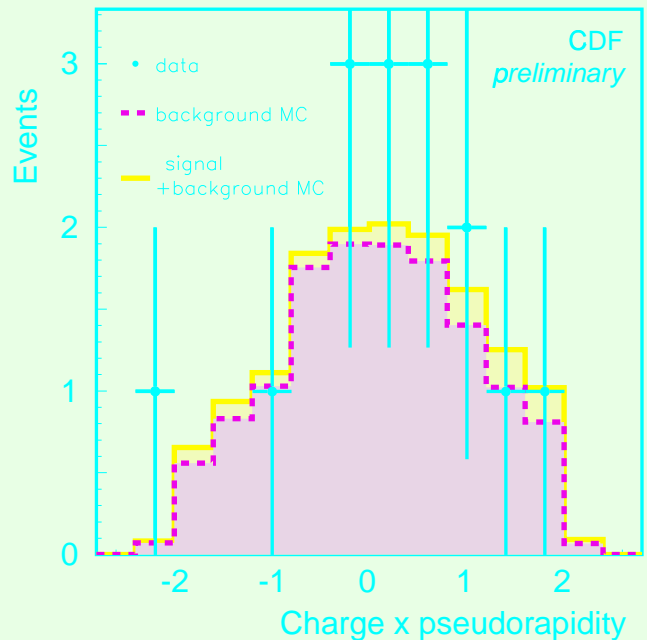


$$\sigma (p\bar{p} \rightarrow tqb) = 1.7 \text{ pb}$$

Search for  $(e \text{ or } \mu) + \cancel{E}_T + \text{exactly 2 jets} + \text{SVX } b\text{-tag}$   
 (One or more tags for s-channel, exactly one for t-channel)



$\sigma(tb) < 15.8 \text{ pb}$   
 at the 95% CL



$\sigma(tqb) < 15.4 \text{ pb}$   
 at the 95% CL

# Tevatron Top Quark Physics Summary

0. Since the discovery in March 1995, many new analyses:
1. Six new results submitted for publication in the last year with perhaps as many again to come this year and again the year after
2. Neural network analysis shown to be very powerful in the all-hadronic decay mode  
Cross section error almost as good as in all other channels combined (45% versus 33%)
3. New methods developed to measure top mass in dilepton decays  
Better systematic error than with  $l+jets$  (2% versus 3%)
4. New combined Tevatron top mass result:  
$$m_{top} = 174.3 \pm 5.1 \text{ GeV}$$
5. Detailed studies of top quark spin –  $W$  helicity, correlations
6. Kinematics of  $t\bar{t}$  pairs studied,  $m_{t\bar{t}}$  distribution searched for resonances
7. Decay to charged Higgs searched for with several methods
8. First limits on electroweak single top quark production set

Top physics is a rich field at the Tevatron  
Great prospects for Run 2 in 2000