



# Recent Results and Future Plans from the Fermilab Tevatron



Todd Adams  
Florida State University

Miami 2011  
December 17, 2011

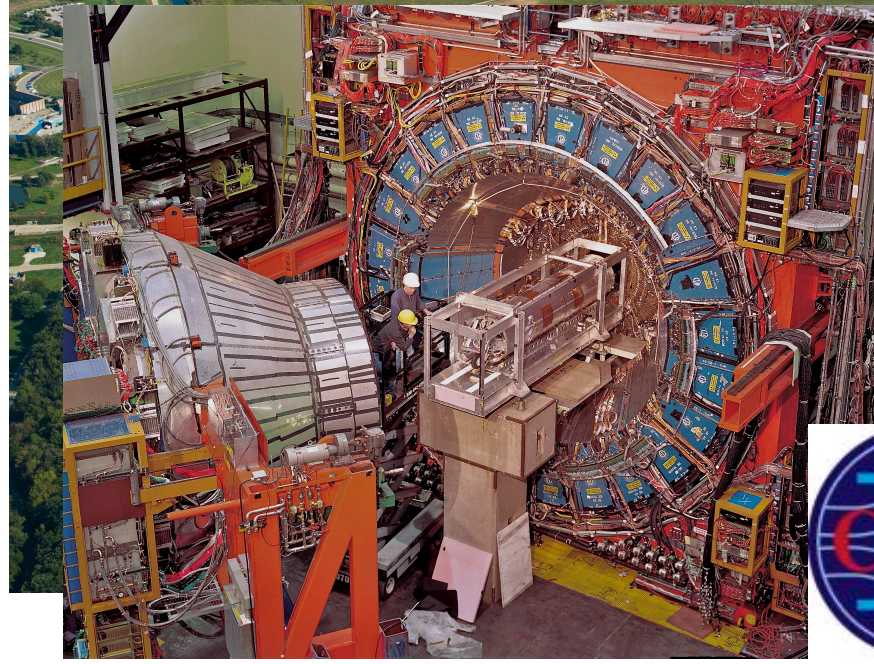
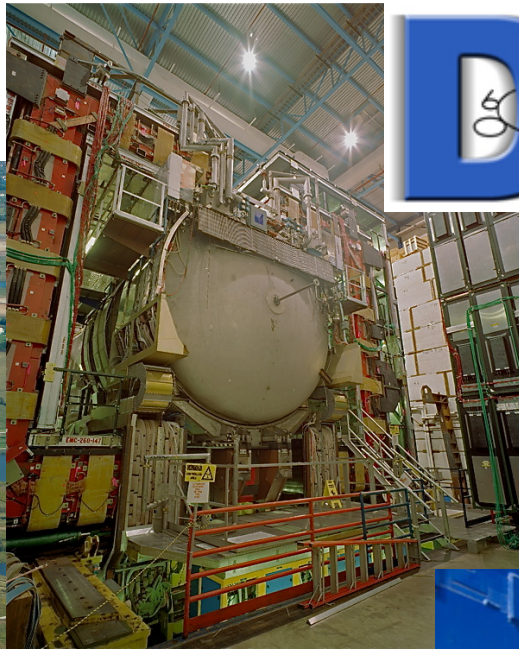


# Outline

- **Introduction**
- **Physics Results – electroweak, top, b-physics, QCD, new phenomena**
- **The Future**

**NOTE – Higgs Results and Plans will be presented next by Florencia Canelli**





12/17/11

Tevatron Results and Plans - T. Adams, FSU

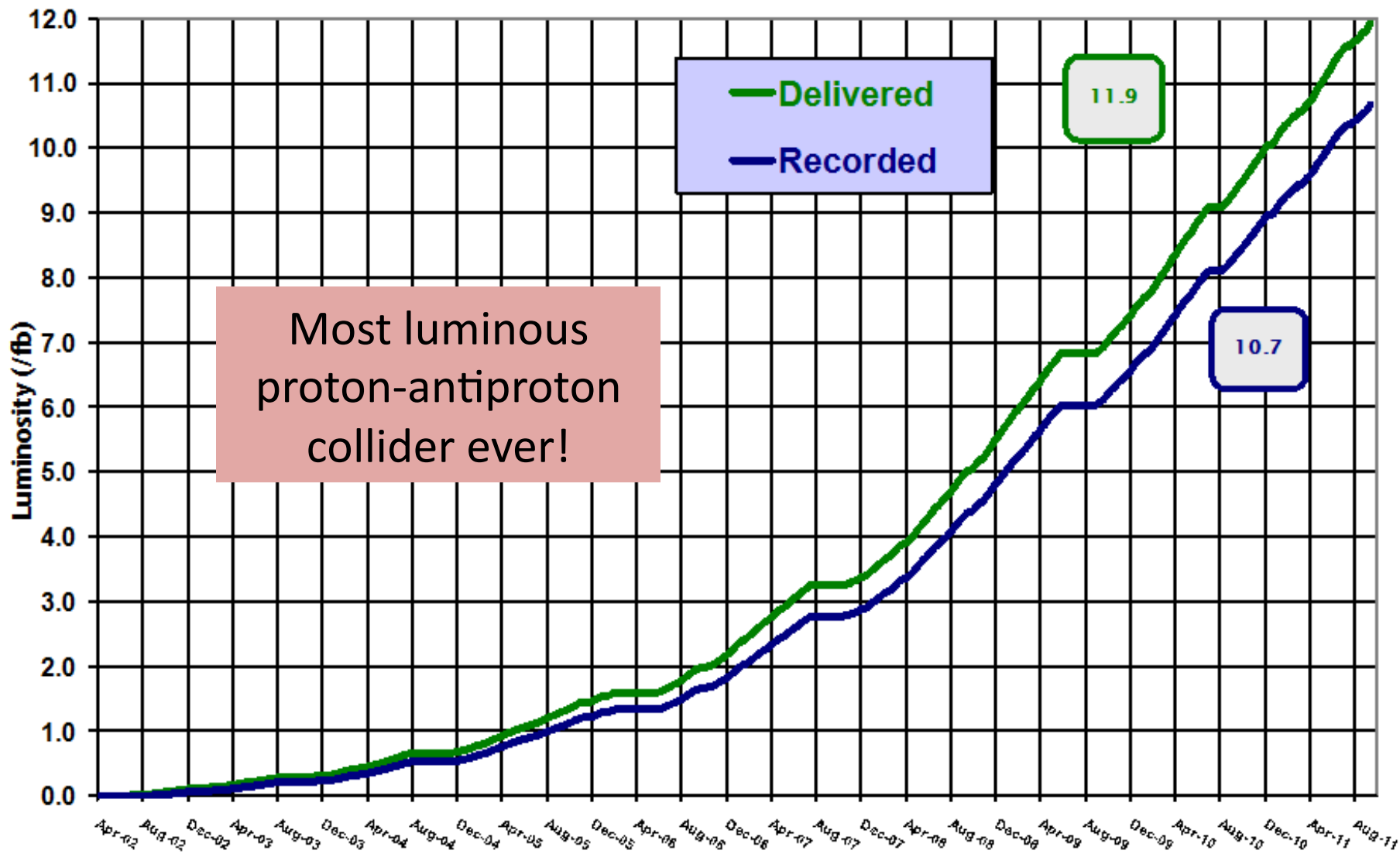
# Final Operations September 30, 2011





# Run II Integrated Luminosity

19 April 2002 - 30 September 2011



# Impressive Physics Results

- **Run II Publications**

  - CDF: 285

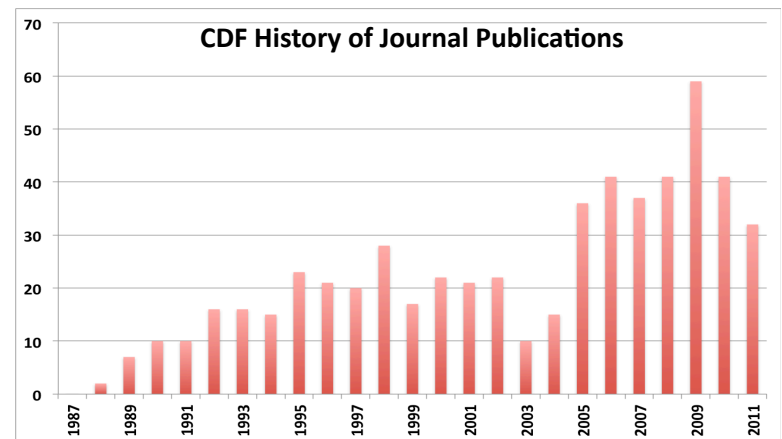
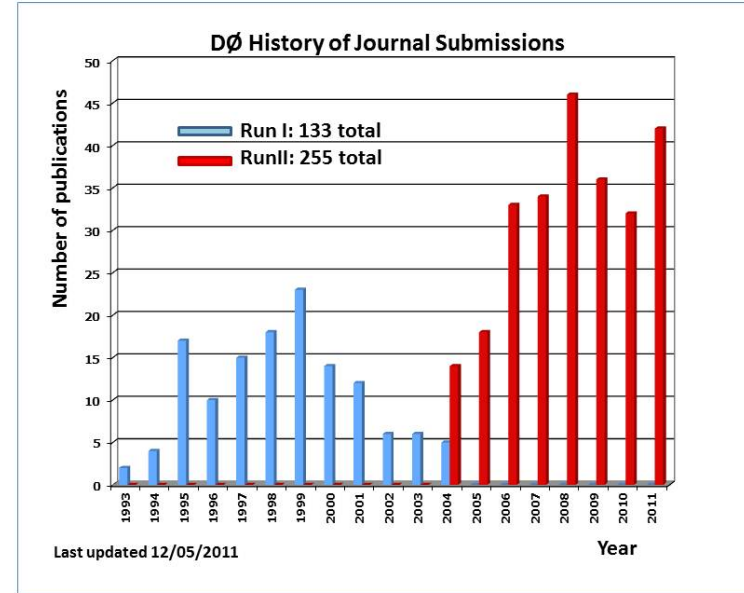
  - D0: 244

- **2011 Publications**

  - CDF: 32

  - D0: 40

- **Dozens of talks at EPS and DPF**



# **Electroweak Physics**



# Electroweak Physics Results

- **EW Boson Production**

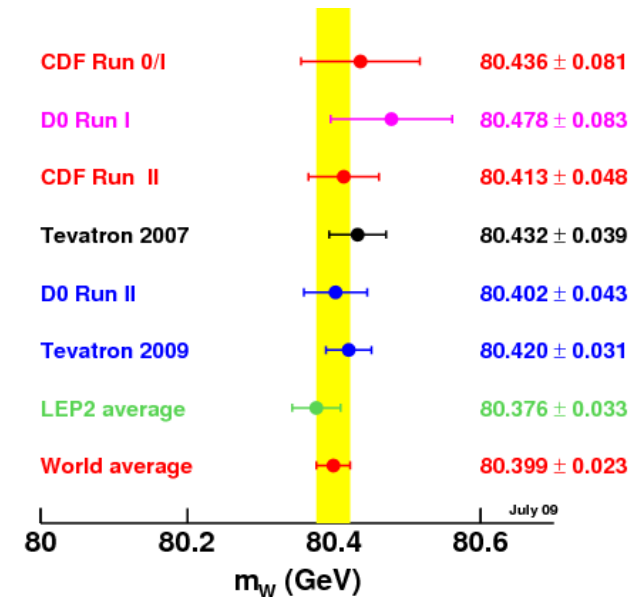
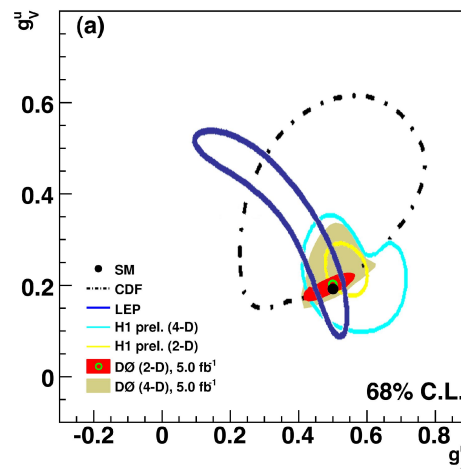
- W, Z production
- W, Z differential cross section
- anomalous couplings
- charge asymmetry

- **EW Boson Properties**

- W mass
- W width
- rare decays

- **Di-boson Production**

- WW
- WZ
- ZZ
- triple gauge couplings



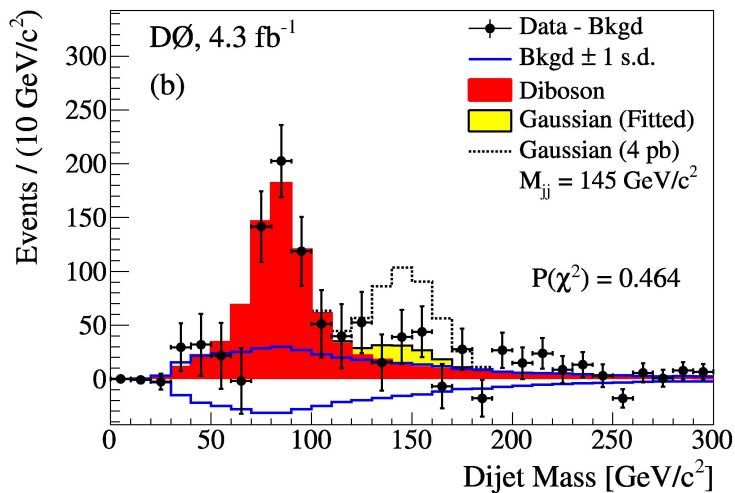
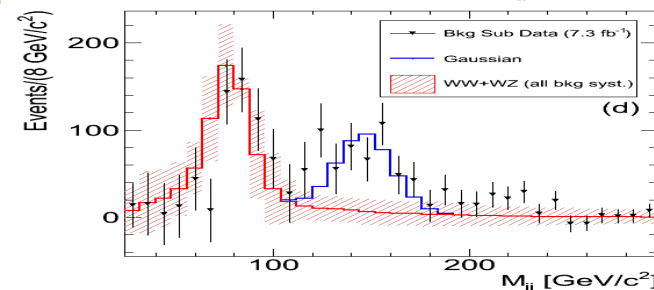
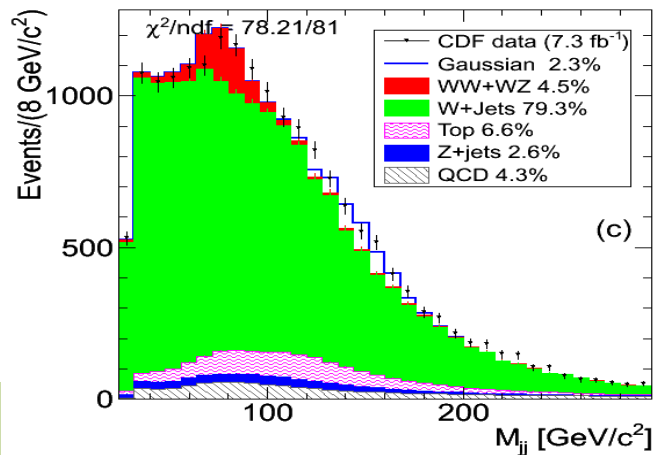


# WW/WZ → lvjj

## • CDF Analysis

7.3 fb<sup>-1</sup>

- Bkgs: W+jets, Z+jets, ttbar/single top, QCD multijets (data-driven)
- 4.1σ excess PRL 106, 171801 (2011)
- several theoretical models suggested



PRL 107, 011804 (2011)

## • DØ Analysis

4.3 fb<sup>-1</sup>

- no evidence observed
- Ongoing joint effort to evaluate differences between CDF and DØ





# WW/WZ Production

- Critical background to many Higgs searches

4.3 fb<sup>-1</sup>

- DØ W+jets analysis

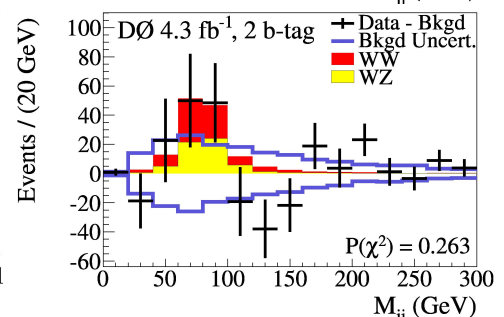
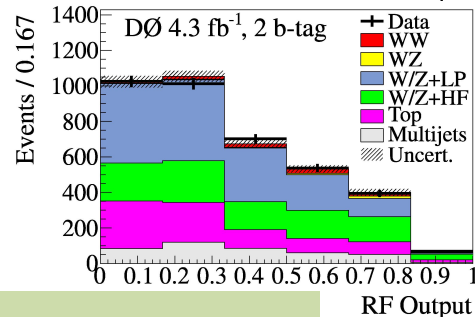
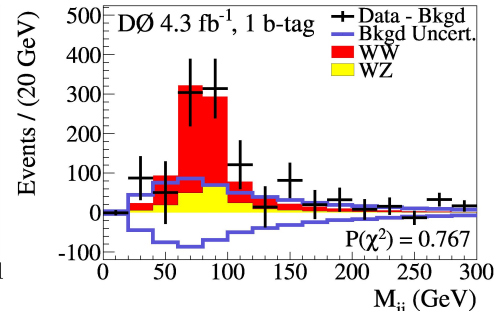
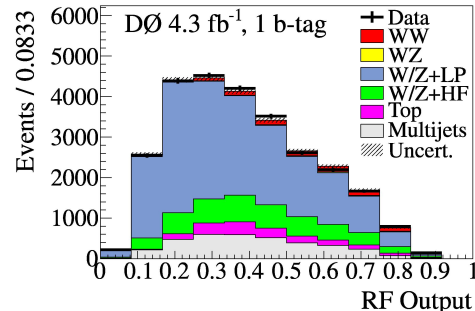
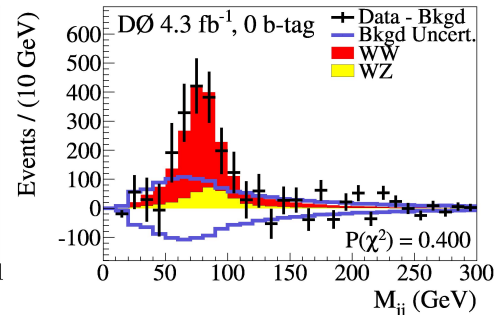
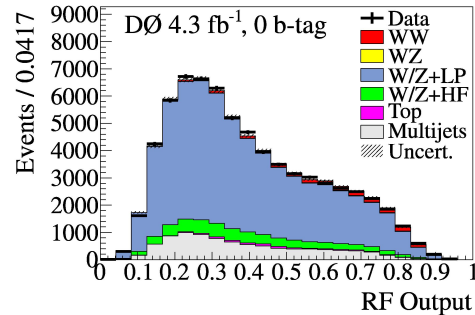
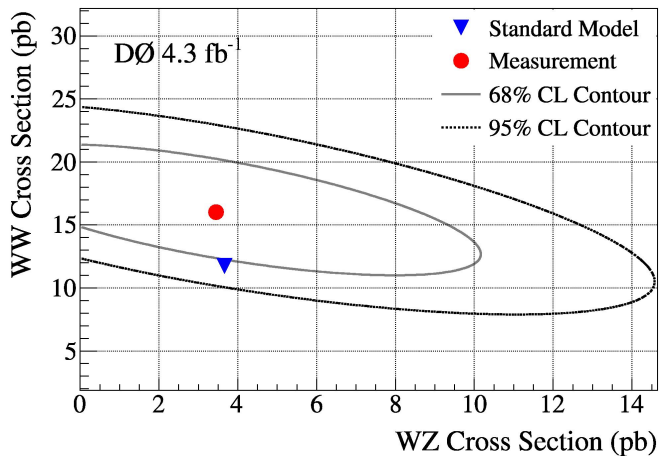
- $\sigma(WV) = 19.6^{+3.2}_{-3.0}$  pb

- 7.9 $\sigma$  significance

- use b-tagging to separate

- $\sigma(WW) = 15.9^{+3.7}_{-3.2}$  pb

- $\sigma(WZ) = 3.3^{+4.1}_{-3.3}$  pb



arXiv:1112.0536

# Top Quark Physics

# Top Quark Measurements

- **Production**

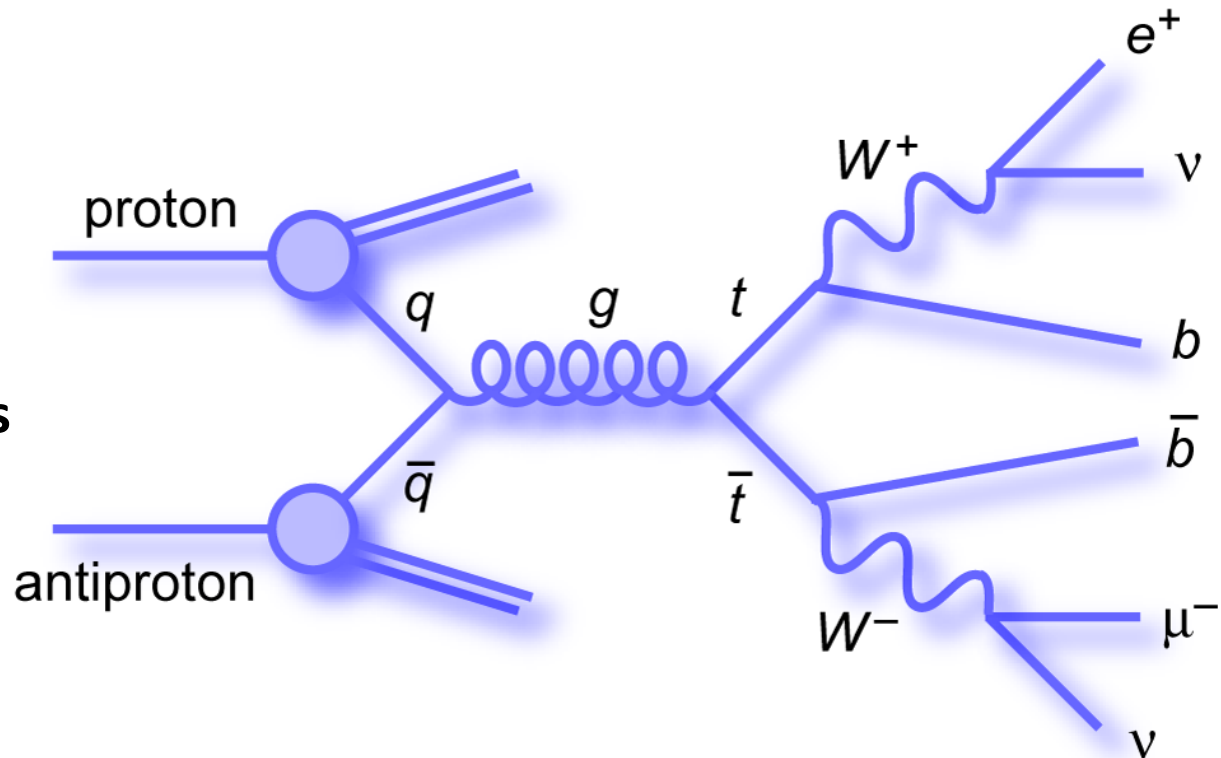
- cross sections
- asymmetry
- resonance production
- spin correlations

- **Decays**

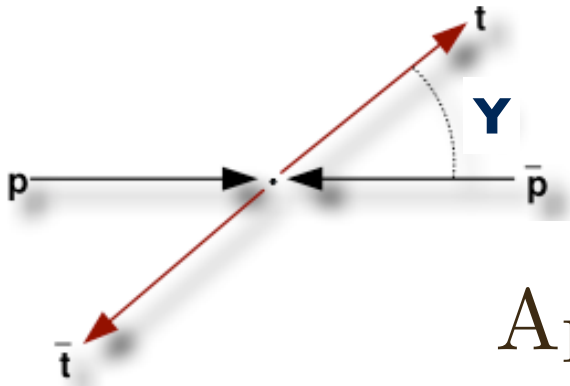
- $|V_{tb}|$
- anomalous couplings
- new particles

- **Properties**

- mass
- width
- charge
- spin
- polarization
- lifetime



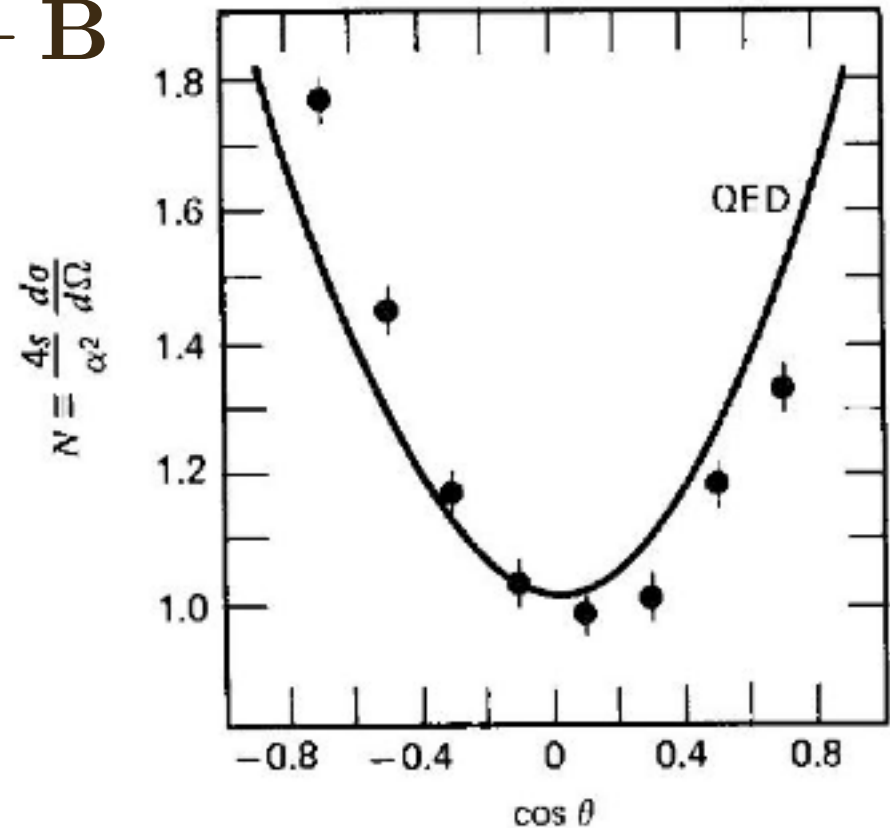
# Top Quark Asymmetry



$$A_{\text{FB}} = \frac{F - B}{F + B}$$

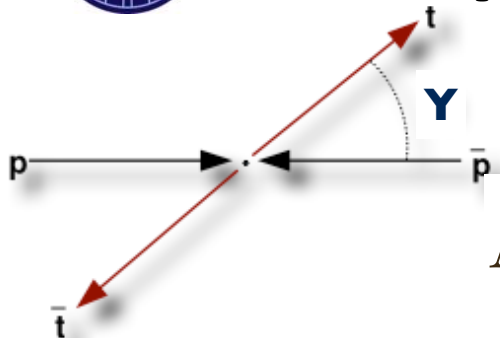
- **Why measure?**
  - evidence of new particles beyond our energy reach can appear in asymmetry
  - example: PETRA saw evidence of Z even at  $\sqrt{s} = 34 \text{ GeV}$

All PETRA experiments ( $\sqrt{s} = 34 \text{ GeV}$ )





# Top Quark Asymmetry



$$A_{\text{FB}} = \frac{F - B}{F + B}$$

- **CDF**

- lepton+jets

**5.3 fb<sup>-1</sup>**

- ~2σ deviation from SM

- dileptons

**5.1 fb<sup>-1</sup>**

- ~2.7σ deviation from SM

- **DØ**

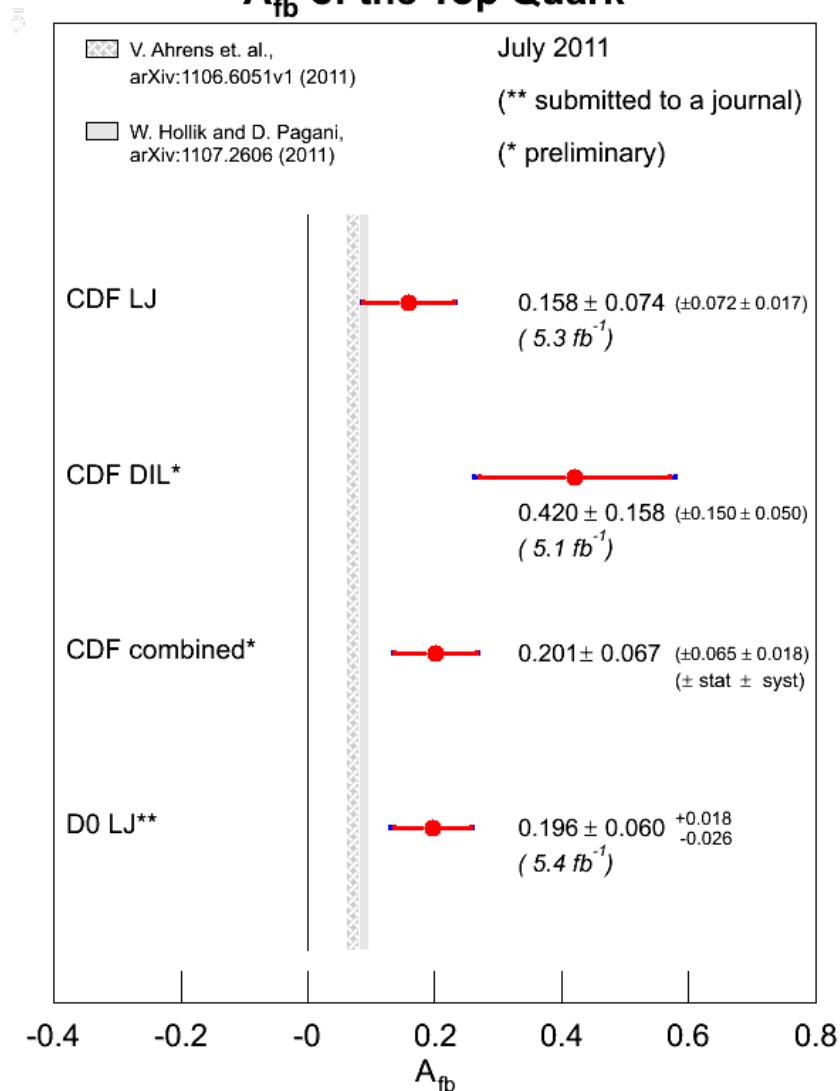
arXiv:1107.4995

- lepton+jets

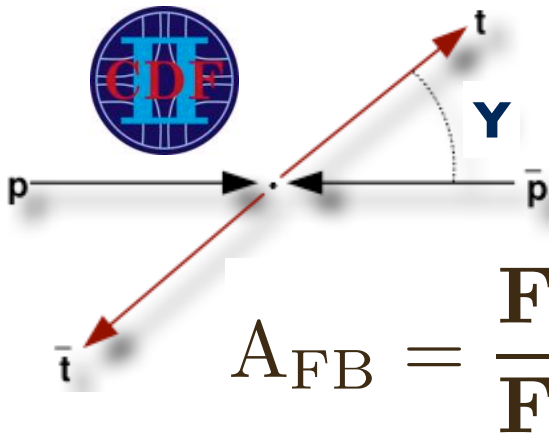
**5.4 fb<sup>-1</sup>**

- ~2.4σ deviation from SM

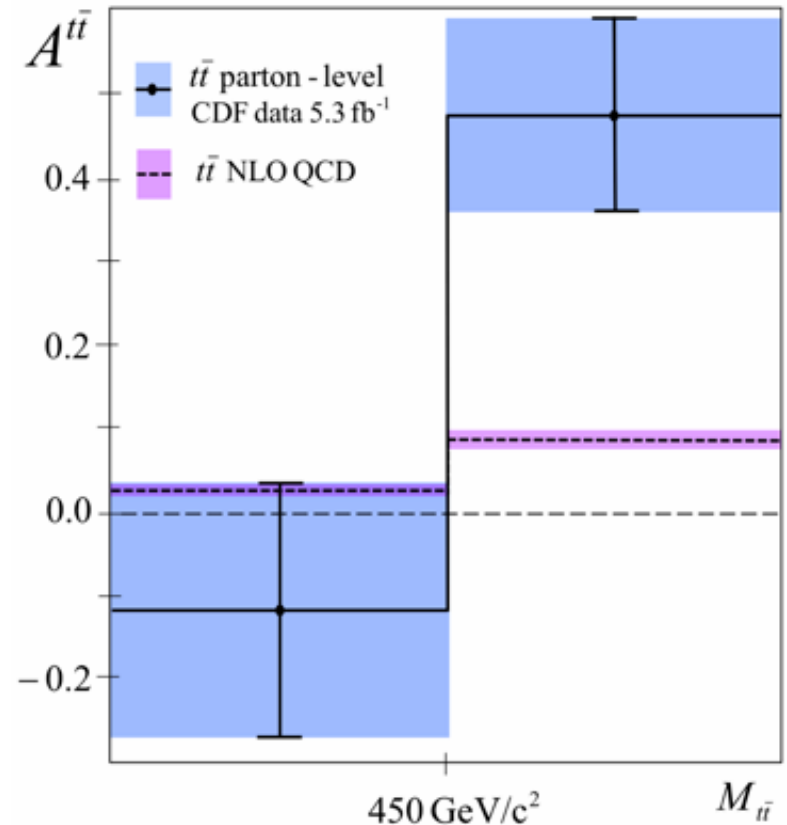
**A<sub>fb</sub> of the Top Quark**



# Top Quark Asymmetry



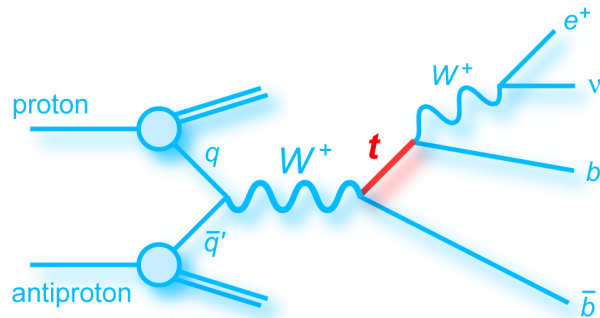
- CDF has also investigated a mass dependence
  - $D\bar{D}$  does not see a mass dependence
- Top quark asymmetry is a different measurement at the LHC, but this would manifest itself in other measurements







# Single Top Production

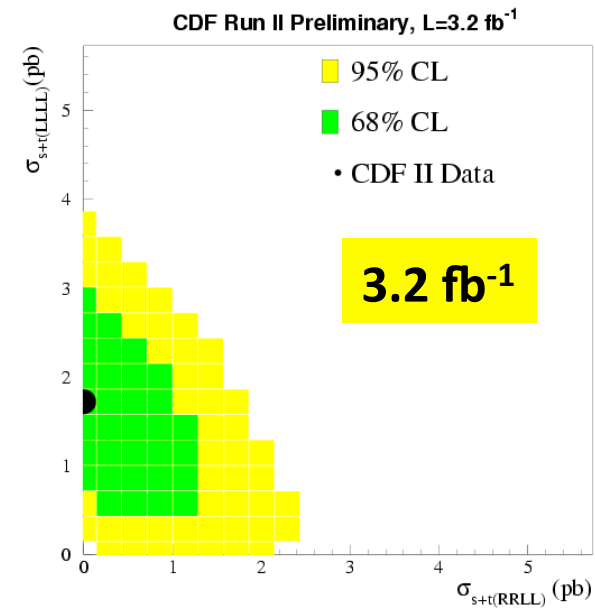
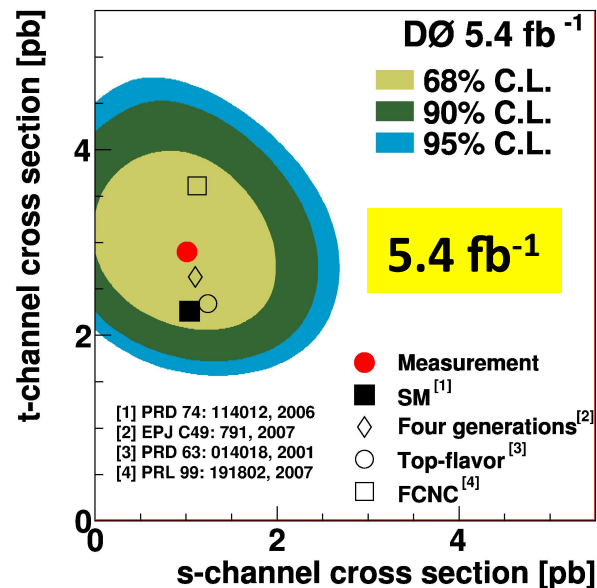
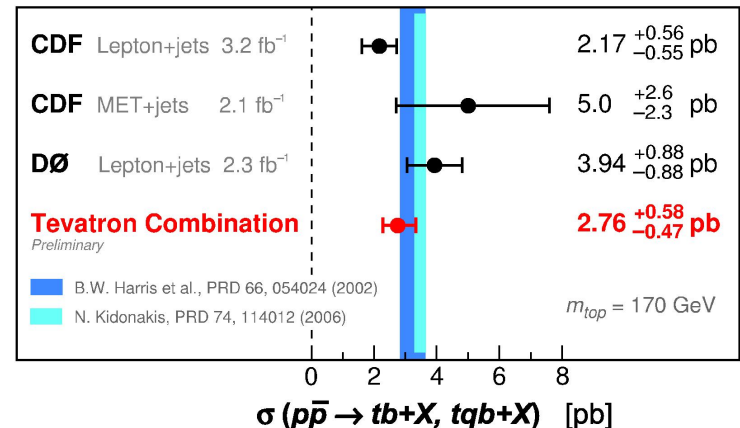


- We have now begun using single top production to study top quark properties and search for new physics

- $|V_{tb}|$
- Width
- Polarization
- $Wtb$  couplings
- $W' \rightarrow tb$
- FCNC production

Single Top Quark Cross Section

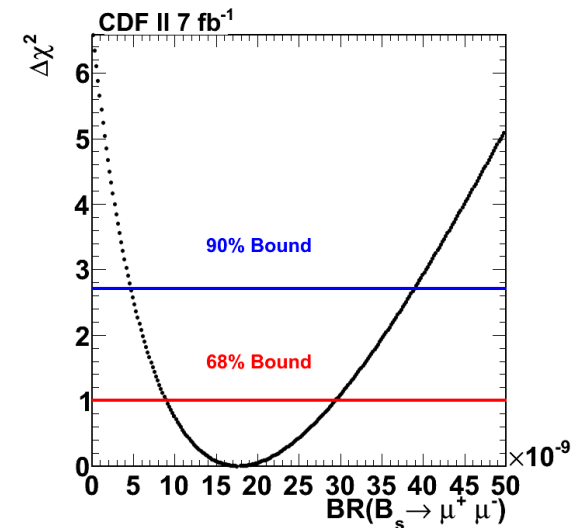
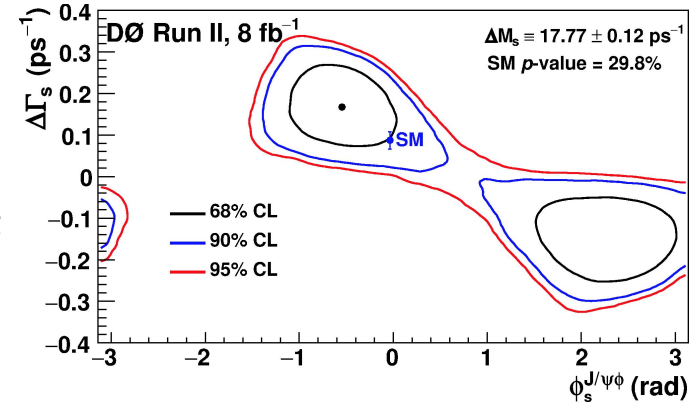
August 2009



# **B-Physics**

# B Physics

- **Hadron spectroscopy**
  - discovery, e.g.  $\Omega_b^-$ ,  $Y(4140)$ ,  $\Xi_b^-$ ,  $\Sigma_b^\pm$
- **CP-violation measurements**
  - e.g.  $D^0$ ,  $B^0$ ,  $B^s$ ,  $A_{CP}$ , dimuon charge asymmetry
- **Production cross sections**
  - generic charm and bottom, specific hadrons
- **Decays**
  - Including rare decays, e.g.  $B_s^0 \rightarrow \mu\mu$
- **Properties**
  - mass, lifetimes, etc.
- **Searches for new particles**





# Dimuon Asymmetry

9 fb<sup>-1</sup>

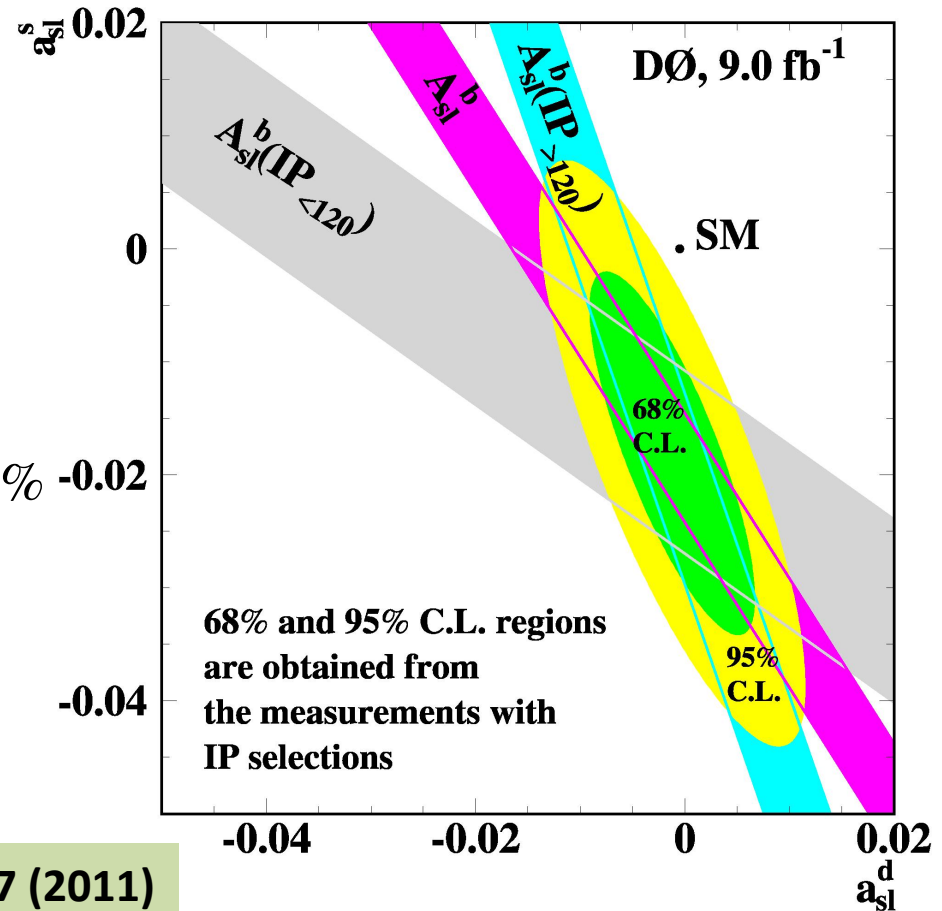
- Count dimuon events with same sign
  - subtract detector asymmetries
- Primarily from  $b\bar{b}$  events
  - one  $B^0$  or  $B_s^0$  oscillates
  - higher order effects sensitive to new particles

$$A_{sl}^b = \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$$

$$A_{sl}^b = (-0.787 \pm 0.172(stat) \pm 0.093(syst))\%$$

$$A_{sl}^b(SM) = (-0.028^{+0.005}_{-0.006})\%$$

- 3.9 $\sigma$  deviation
- Many cross checks have been performed



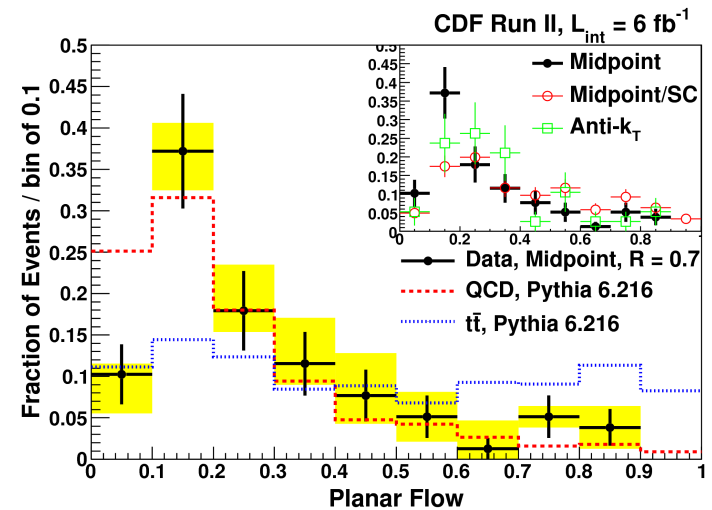
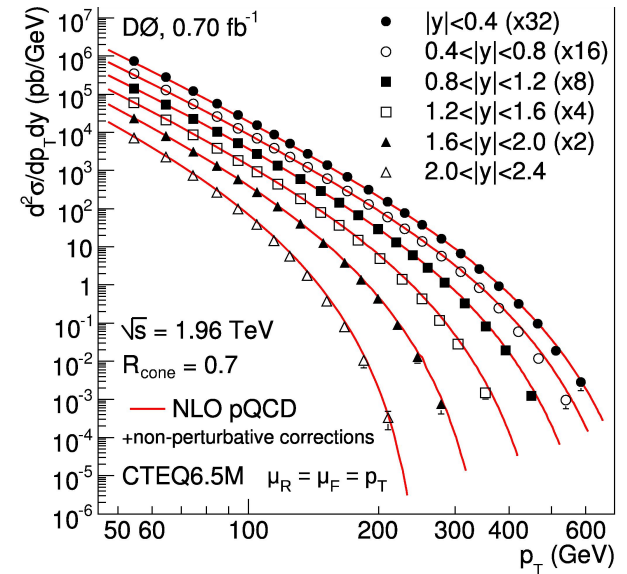
PRD 84, 052007 (2011)



**QCD**

# QCD

- **Jet production cross sections**
  - inclusive jets, exclusive jets, differential cross sections, minbias
- **Photon production**
  - inclusive photons, diphotons
- **W/Z+jets**
  - including heavy flavor jets
- **Angular correlations**
- **Jet substructure**
- **Multiple parton interactions**
- **Diffraction processes**

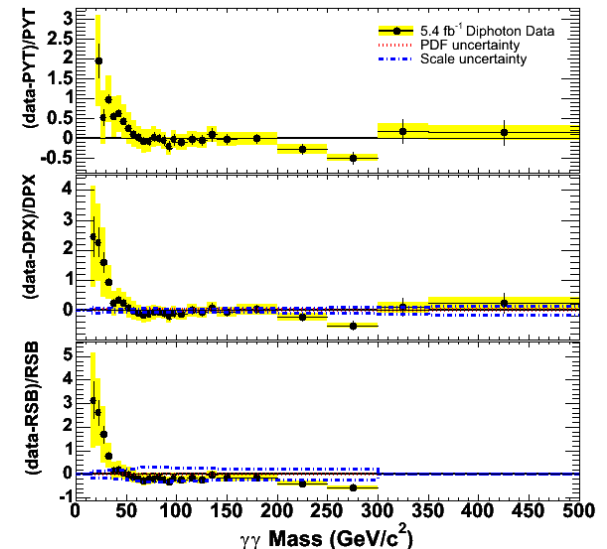
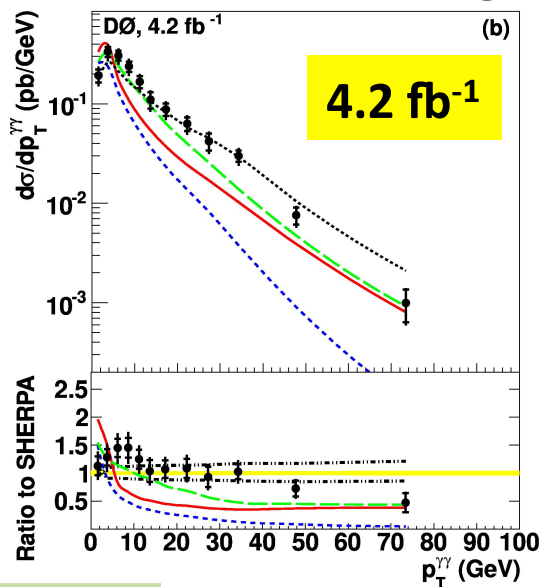
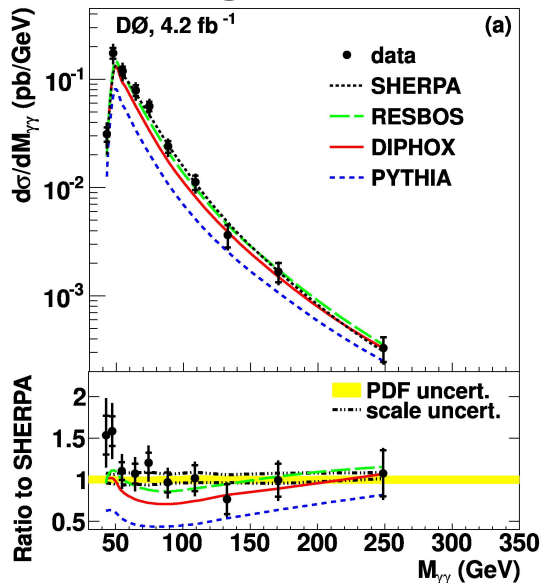
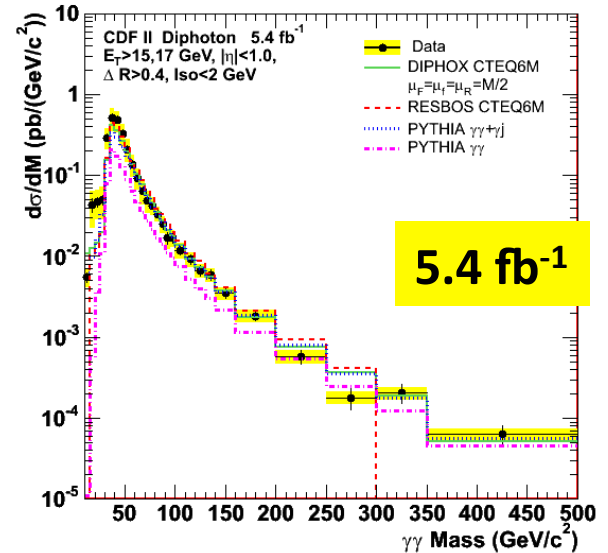




# Diphoton Production



- Important background to  $H \rightarrow \gamma\gamma$  and new phenomena searches
- Tests of perturbative QCD
- Differential cross sections
  - $M(\gamma\gamma)$ ,  $p_T(\gamma\gamma)$ ,  $\Delta\phi$ ,  $\cos\theta^*$
  - DØ also measured doubly differential cross sections
- Disagreement with models in some regions



PLB 690, 108 (2010)

PRL 107, 102003 (2011)

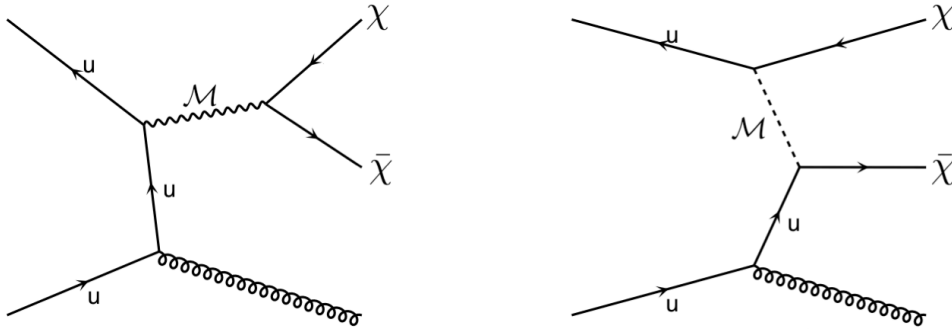


# **Searches for New Phenomena**

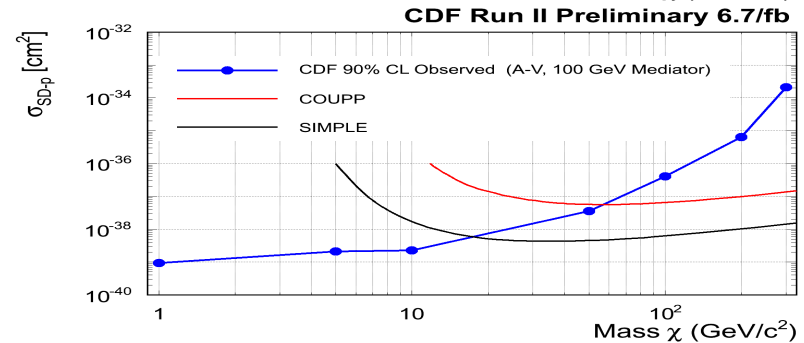
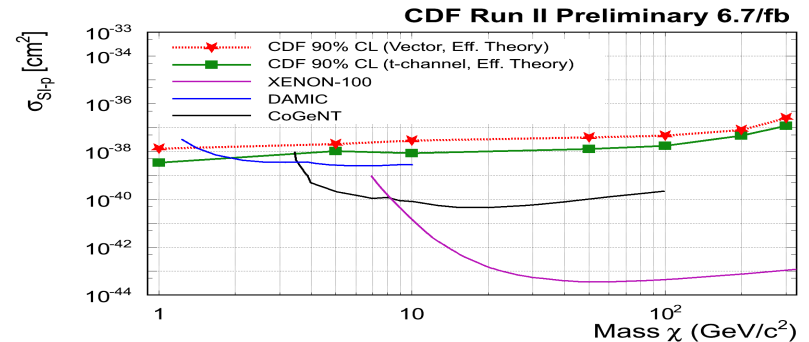
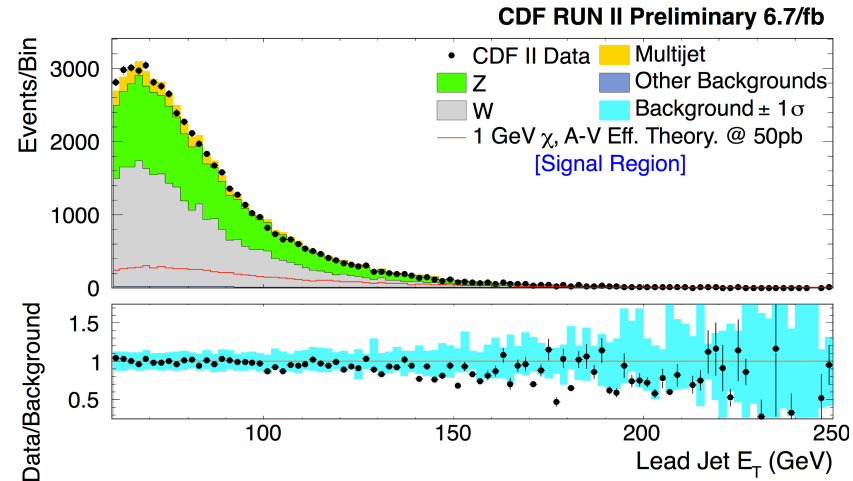


# Dark Matter - Monojets

6.7 fb<sup>-1</sup>



- Search for dark matter in monojets + MET
  - jet  $P_T > 60$  GeV and MET  $> 60$  GeV
  - no excess observed
  - several models investigated
  - improvements in reach beyond dedicated DM searches



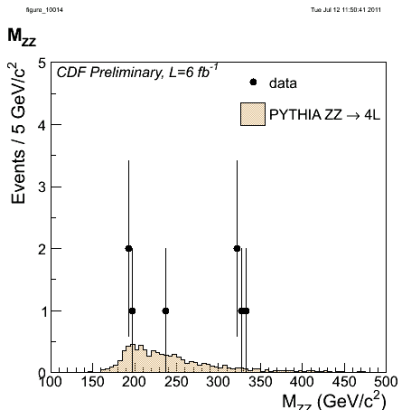


# Searches Based on Other Analyses



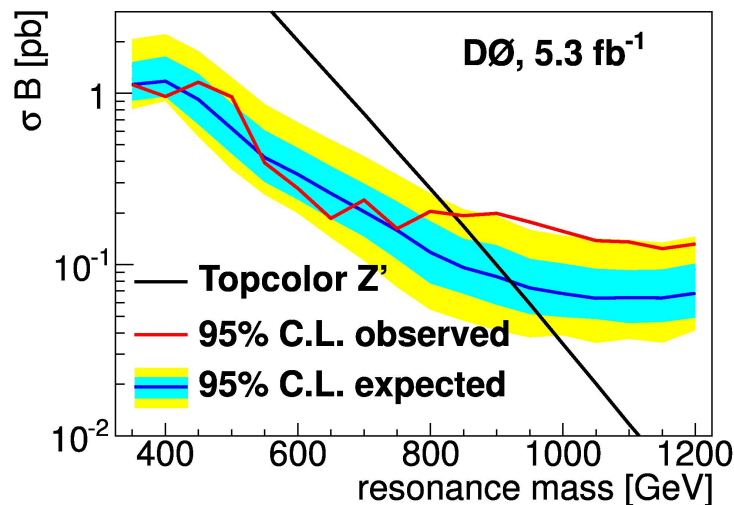
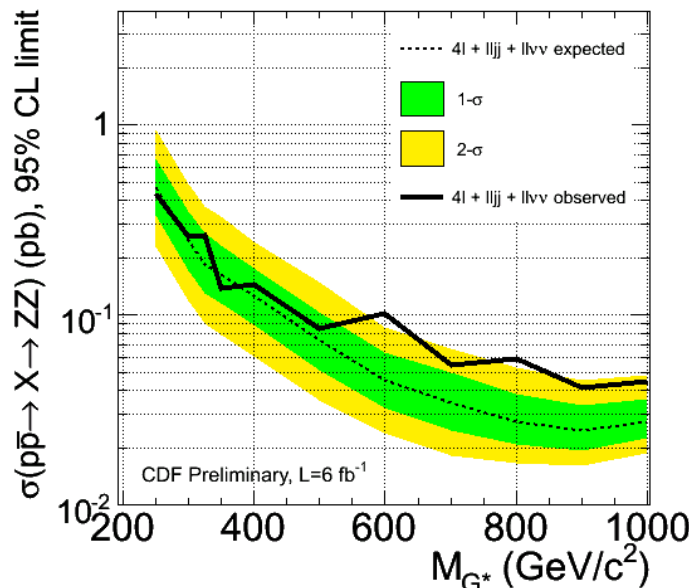
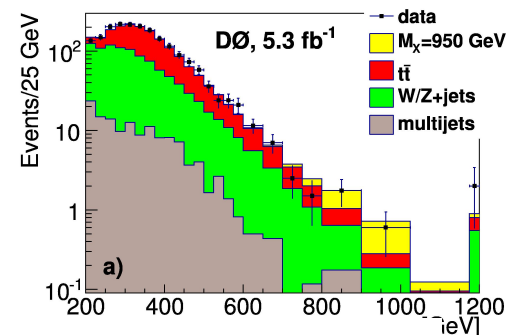
6 fb<sup>-1</sup>

- High mass ZZ resonance
  - ZZ → l+l+l+l, l+l+jj, l+l+vv
  - combine the three channels



5.3 fb<sup>-1</sup>

- Search for a narrow top-antitop resonance
  - use l+jets data
  - explore t-tbar mass spectrum





# Detector Plans



- Cosmic ray operations end this year
- Both detectors are being converted to public displays
- Part of the Tevatron tunnel will also be open



# Future Plans

- **Make legacy measurements**
- **Concentrate on:**
  - **unique measurements**
  - **complementary measurements**
  - **previously observed deviations**
- **We have the data**
- **We have the understanding**
- **We have the resources  
(people and computing)**



# Forthcoming Results



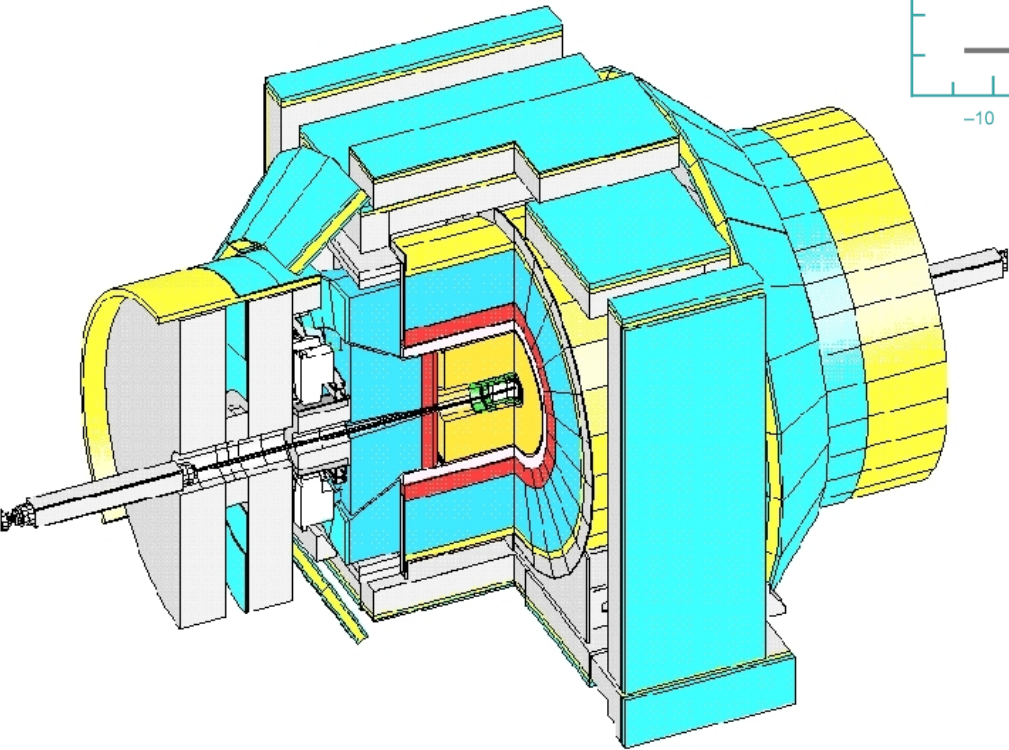
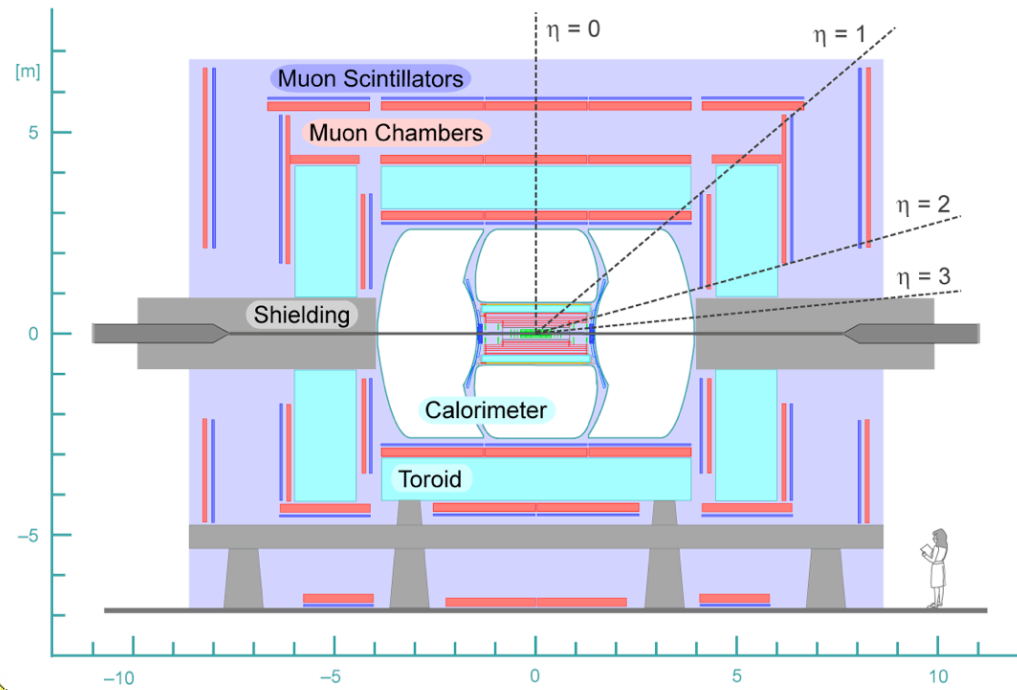
- Just a sampling:
- $W$  mass (world's best)
- $W$  charge asymmetry
- Weinberg angle
- top charge asymmetry
- top quark properties
- s-channel single top
- differential top cross section
- like-sign dimuon analysis
- CP-violating  $D^0$  measurement
- $B_s \rightarrow \mu\mu$
- differential  $V$ +jets and photon cross sections
- $\alpha_s$  dependence
- plus, of course, the Higgs boson...



We still expect 75-125 more publications from Run 2 data!

# Backup Slides

• X





# Production Asymmetry



# Top Quark Asymmetry



## • CDF

5.3 fb<sup>-1</sup>

### – lepton+jets

- Measured:  $0.158 \pm 0.072 \pm 0.01$
- SM:  $0.058 \pm 0.009$
- $\sim 2\sigma$  deviation from SM

### – dileptons

- Measured:  $0.42 \pm 0.15 \pm 0.05$
- SM:  $0.06 \pm 0.01$
- $\sim 2.7\sigma$  deviation from SM

### – Combined

- Measured:  $0.20 \pm 0.07 \pm 0.02$
- SM:  $0.06 \pm 0.01$

5.4 fb<sup>-1</sup>

## DØ

### – lepton+jets

- Measured:  $(19.6 \pm 6.5)\%$
- SM:  $(5.0 \pm 0.1)\%$
- $\sim 2.4\sigma$  deviation from SM

$$A_{FB} = \frac{F - B}{F + B}$$

## A<sub>fb</sub> of the Top Quark

