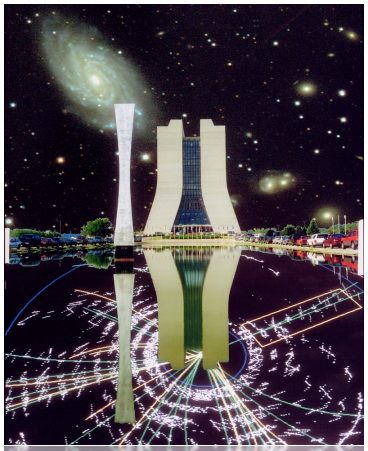
Electroweak and Top Physics at the Tevatron

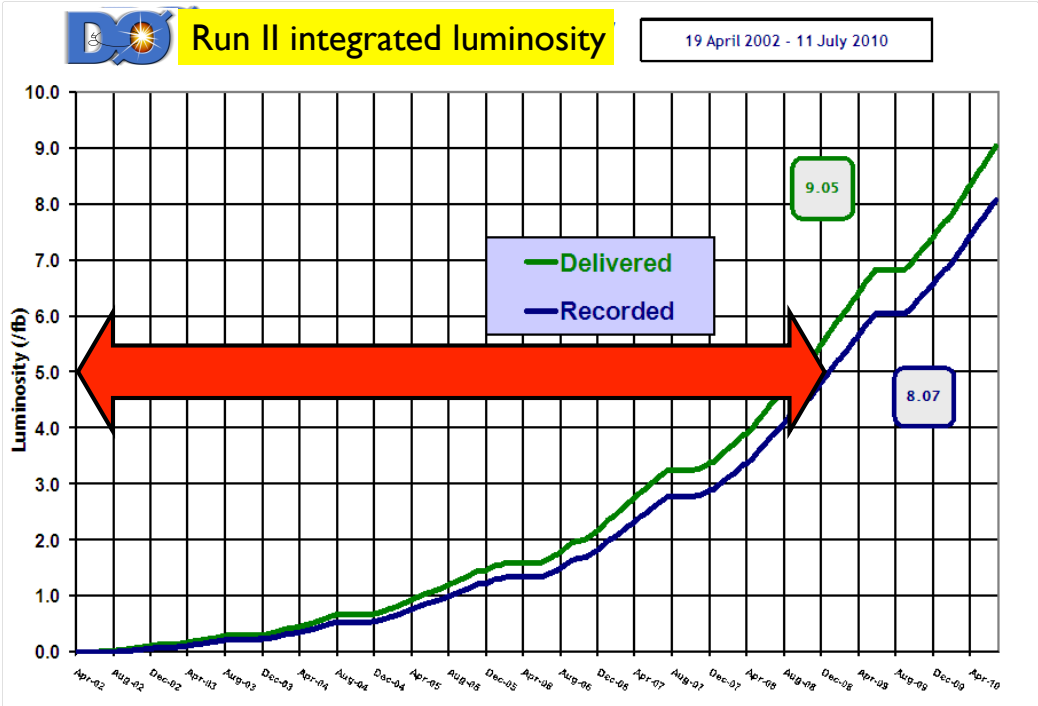


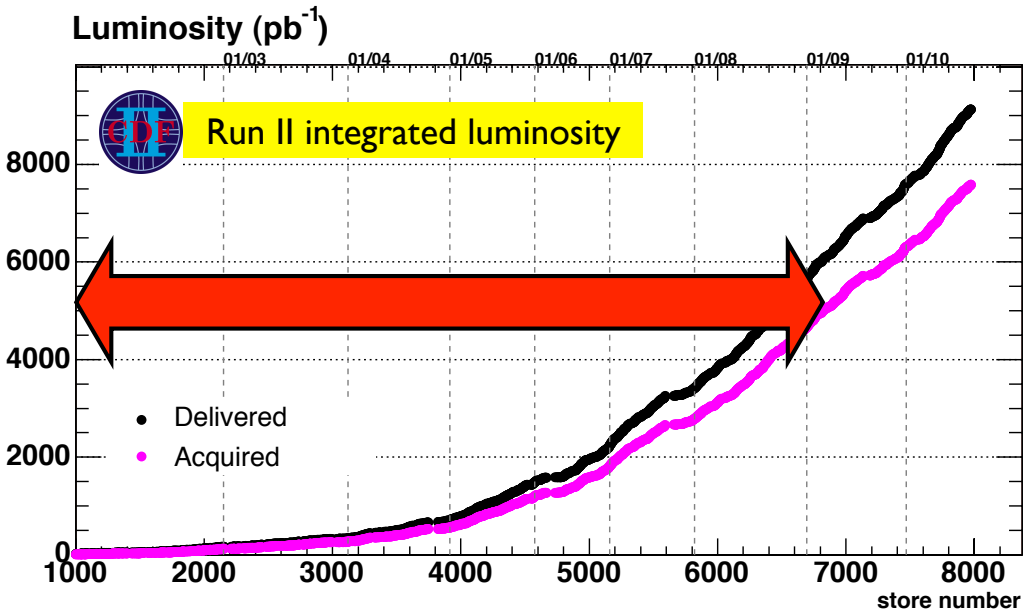
Dr. Lucio Cerrito
Queen Mary, University of London

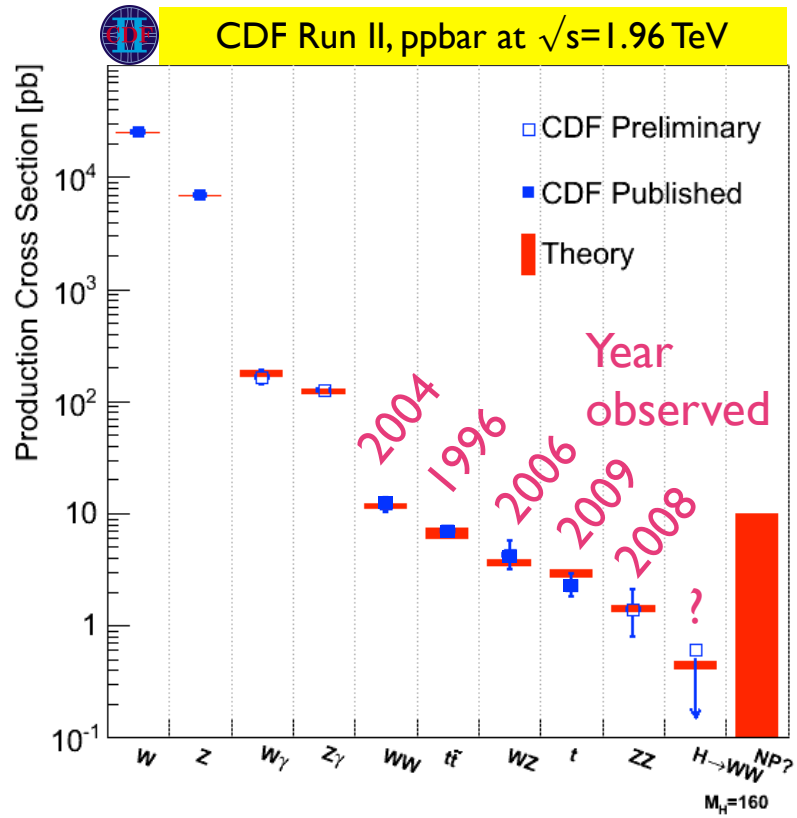
(on behalf of the CDF and DØ Collaborations)

PASCOS 2010
Valencia, July 2010

Tevatron EWK and Top sample





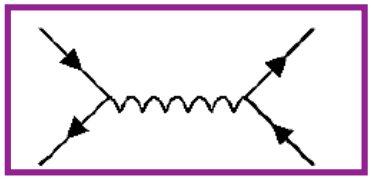


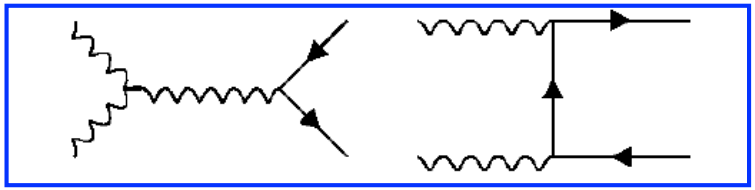
- several 100k Z→ee, ~M W→eν, ~k top pair
- Results shown today: data up to 3-5 fb^{-1}
- Measurements well within the ~pb production range.

Tevatron production and decay of top

Pair:

- *qq* annihilation via strong interaction (~85% at the Tevatron)
- *gg* fusion (dominant at LHC)





NOTE: Production through virtual Z and γ are much smaller

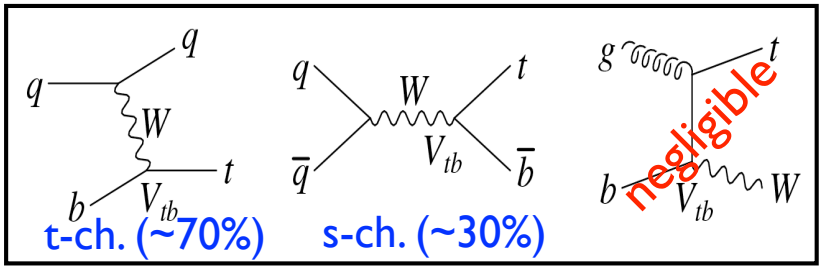
Theory Calculations

t-tbar NLO QCD (m_t=172.5 GeV/c^2)

➢ ~7.5±0.8 pb

Cacciari et al, arXiv:0804.2800 (2008)
Kidonakis & Vogt, arXiv:0805.3844 (2008)
Langenfeld, Moch & Uwer, arXiv:0906.5273 (2009)

Single:

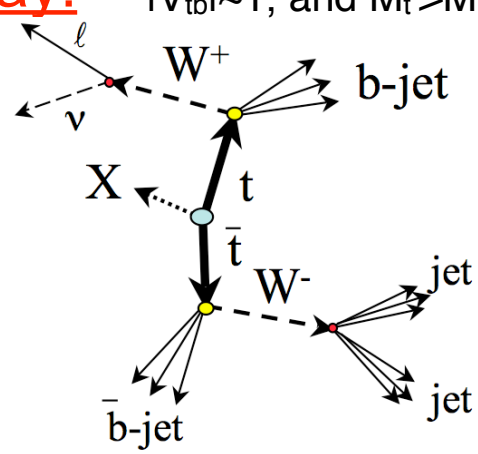


Single top NLO QCD (m_t=170 GeV/c^2)

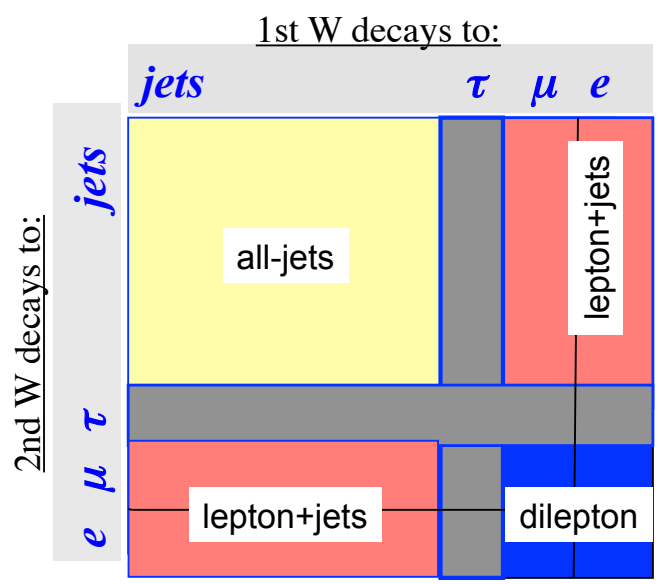
➢~3.4±0.2 pb

Harris, Laenen, Phaf, Sullivan, Weinzierl, PRD 66 (02) 054024.
Kidonakis, PRD 74, 114012 (06)
Campbell, Ellis, Tramontano, PRD 70 (04) 094012.

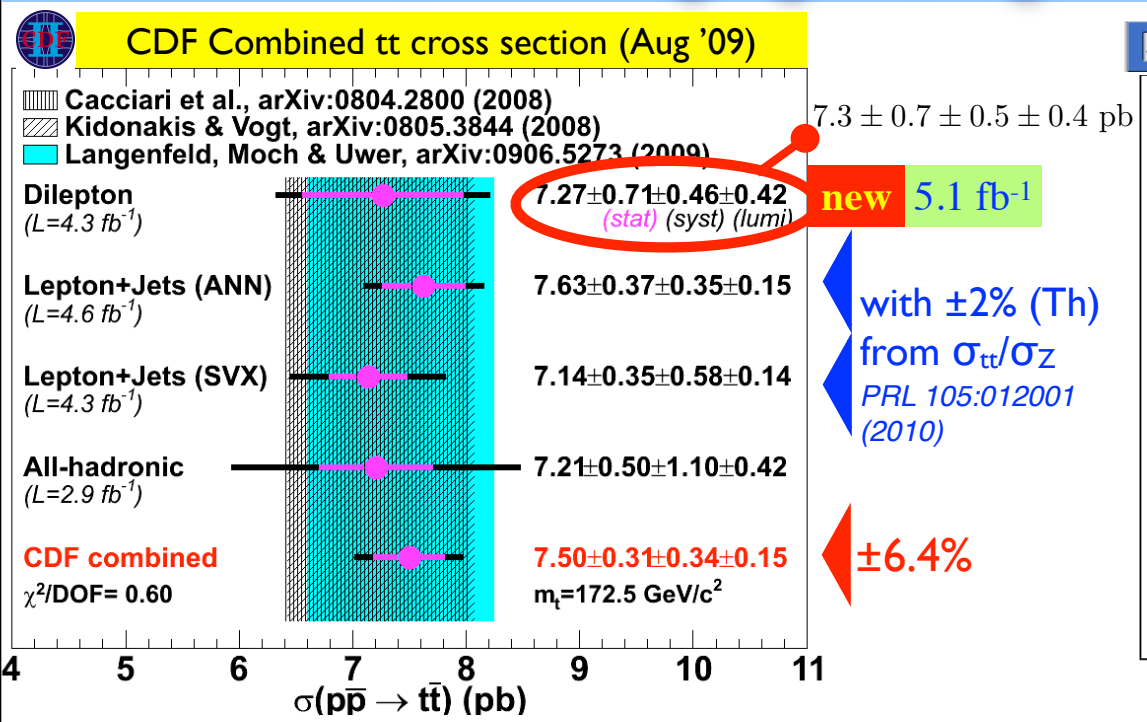
Decay: $|V_{tb}|$~1, and $M_t > M_W + M_b$ ⇒ t→*Wb (~100%)*



tt event classification:



Top pair production

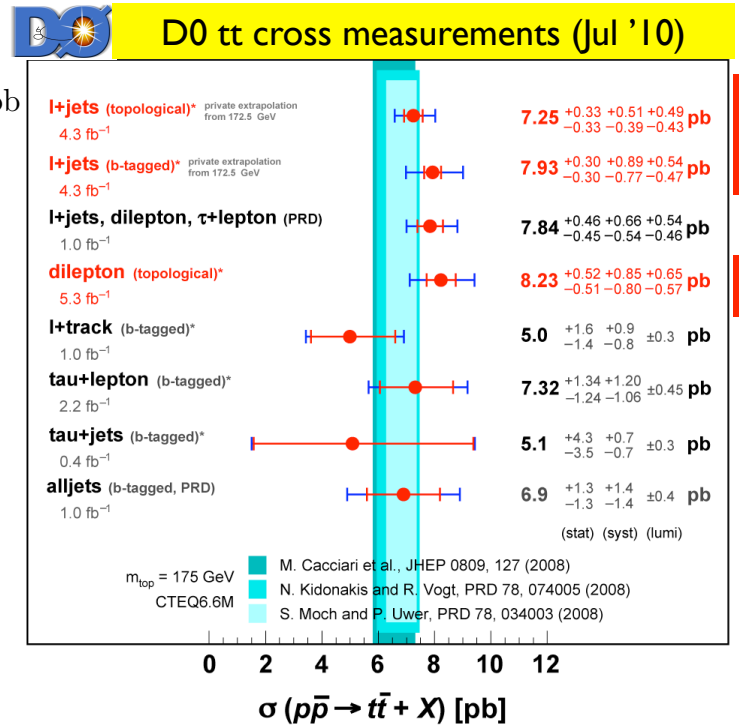


$7.3 \pm 0.7 \pm 0.5 \pm 0.4$ pb

new 5.1 fb^{-1}

with ±2% (Th) from σ_{tt}/σ_Z *PRL 105:012001 (2010)*

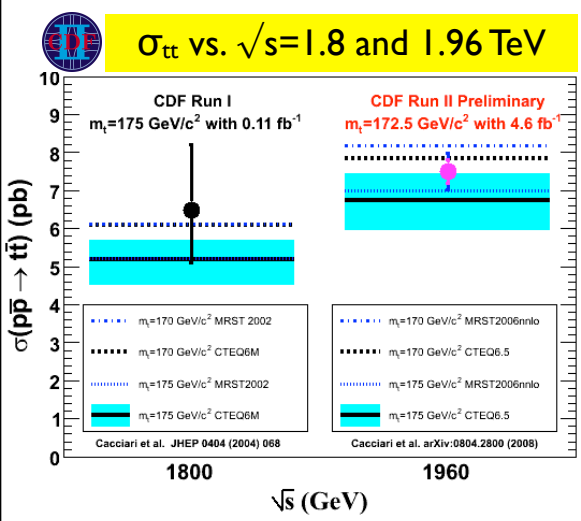
±6.4%

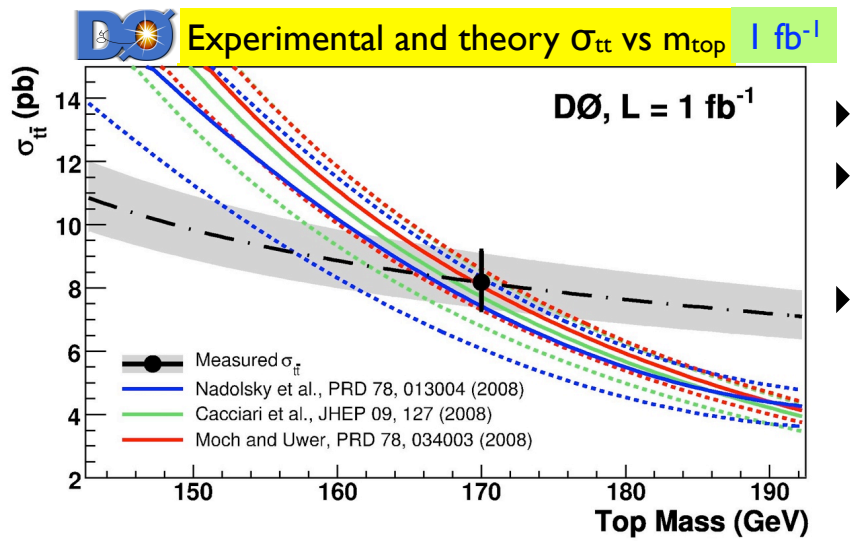


new 4.3 fb^{-1}

new 4.3 fb^{-1}

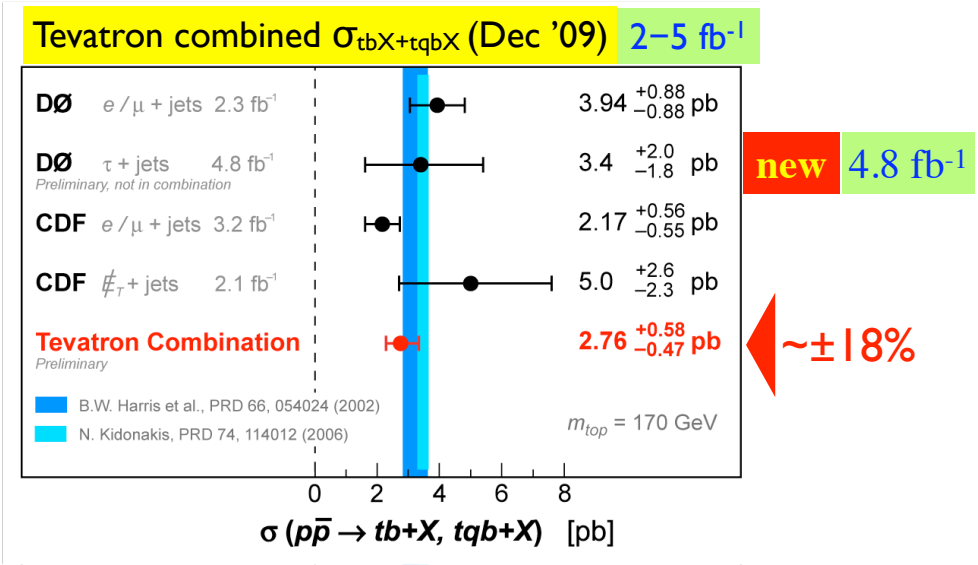
new 5.3 fb^{-1}





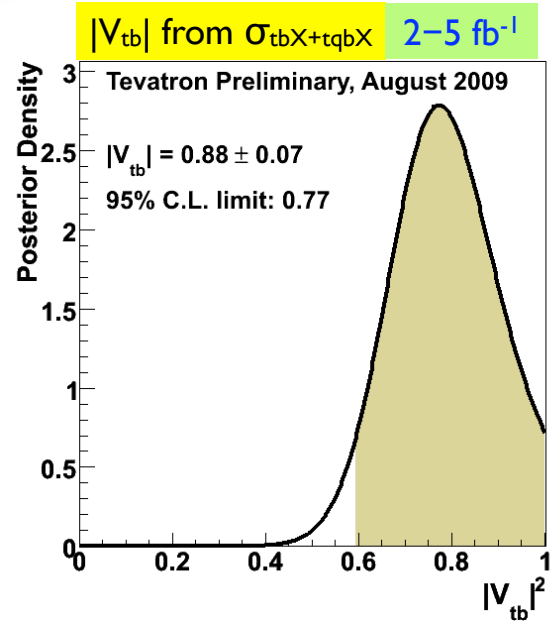
- All channels in agreement
- CDF combination well within the uncertainty on the theory (~±11%)
- Dominant uncertainties from statistics, E calibration, event modeling.

Single top production

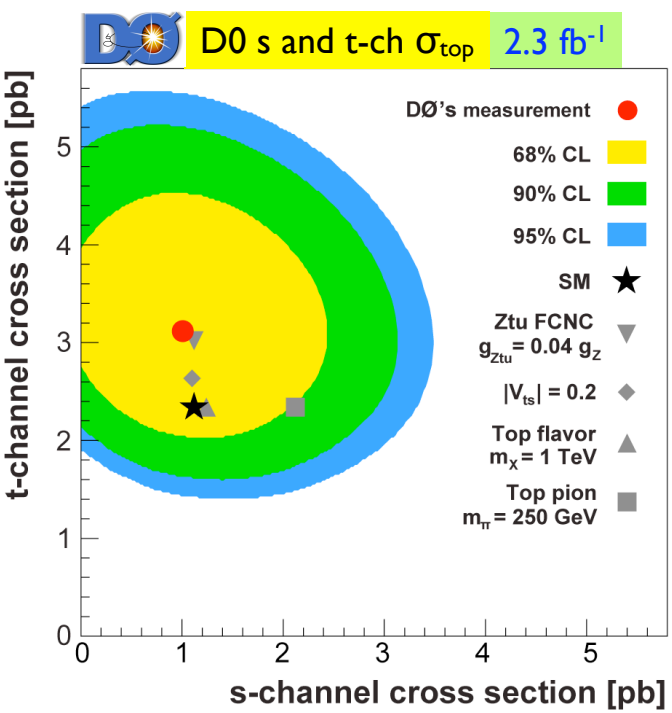


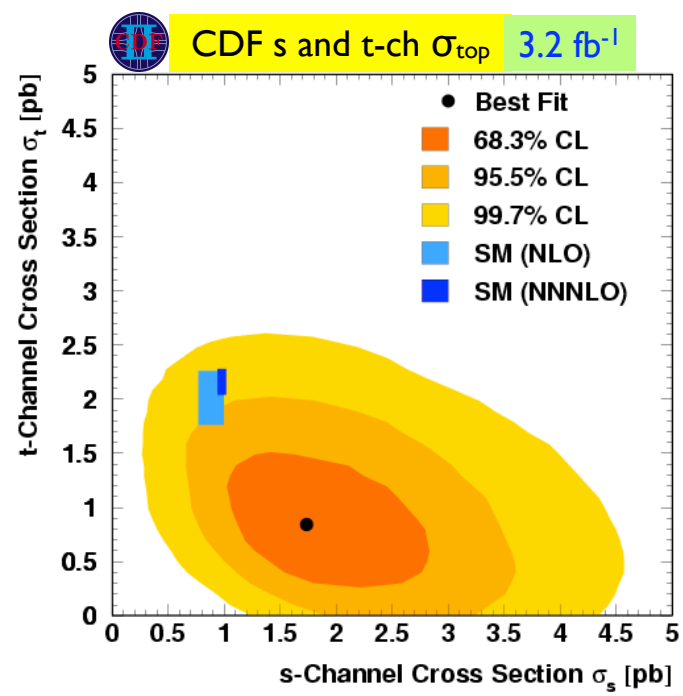
new 4.8 fb^{-1}

~±18%



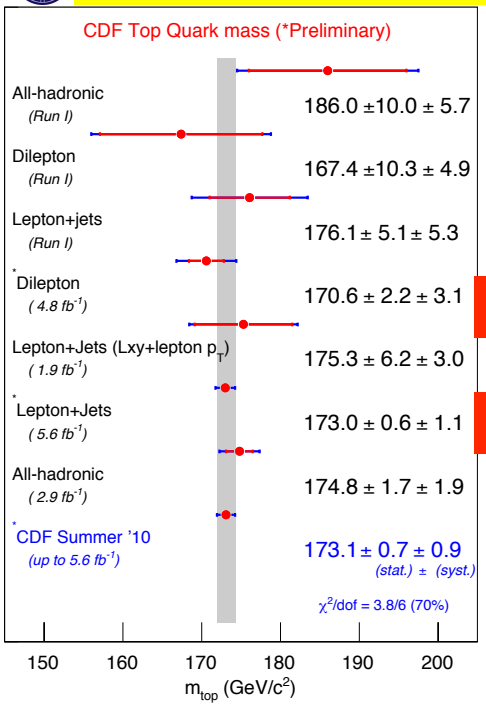
$|V_{tb}|=0.88\pm0.07$





Top Mass

CDF m_t measurements (Jul 2010) **new**

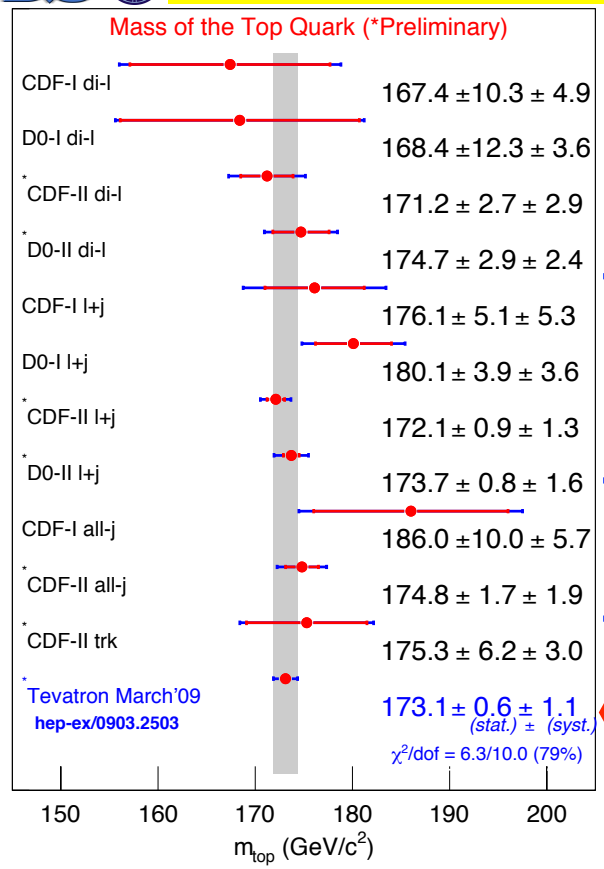


new 4.8 fb^{-1}

new 5.6 fb^{-1}

±0.67% (1.14 GeV)

Tevatron combination (Mar 2009)



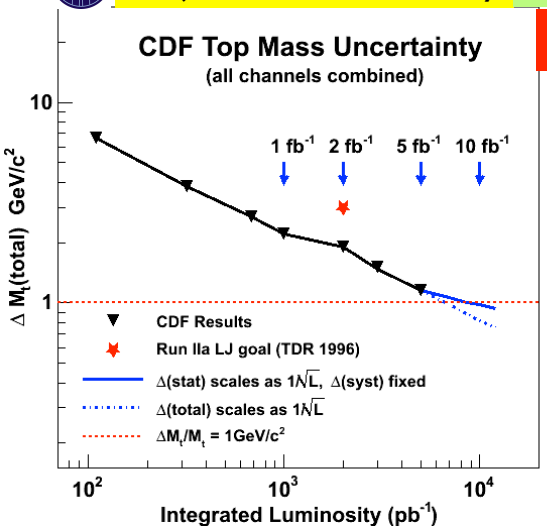
dilepton channel

lepton + jets

all hadronic

±0.72% (1.2 GeV)
New CDF measurements not included yet in this average

Projected m_t uncertainty 5.6 fb^{-1} **new**



- Mass in all decay modes consistent
- dilepton and hadronic channels becoming competitive
- New (2010) CDF average more precise than 2009 Tevatron average.
- Projection indicates ≈±0.8−1 GeV per-experiment with 10 fb^{-1}

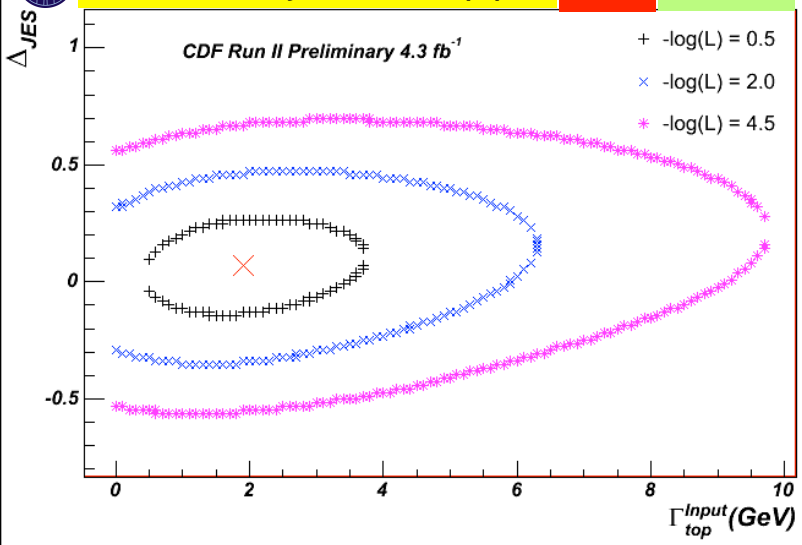
Top-antitop mass difference:

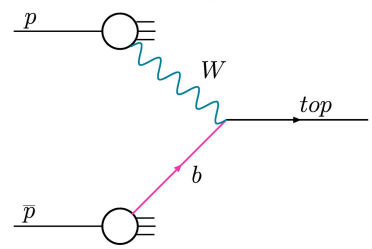
new ΔM_{top} = -3.3 ± 1.4 (stat.) ± 1.0 (syst.) GeV/c^2 5.6 fb^{-1}

ΔM_{top} = 3.8 ± 3.7 GeV/c^2 1.0 fb^{-1}

Width and charge of top quarks

Direct Γ_{top} vs JES, from top pair **new** 4.3 fb^{-1}

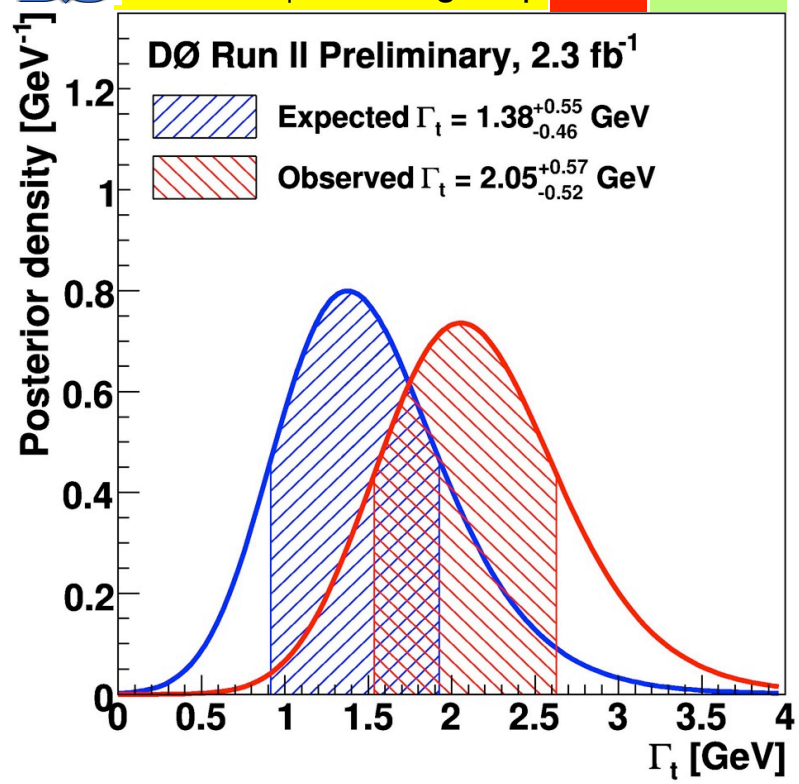




$\Gamma_{top} < 7.5$ GeV @ 95% C.L

$0.4 < \Gamma_{top} < 4.4$ GeV @ 68% C.L

Indirect Γ_{top}, from single top **new** 2.3 fb^{-1}

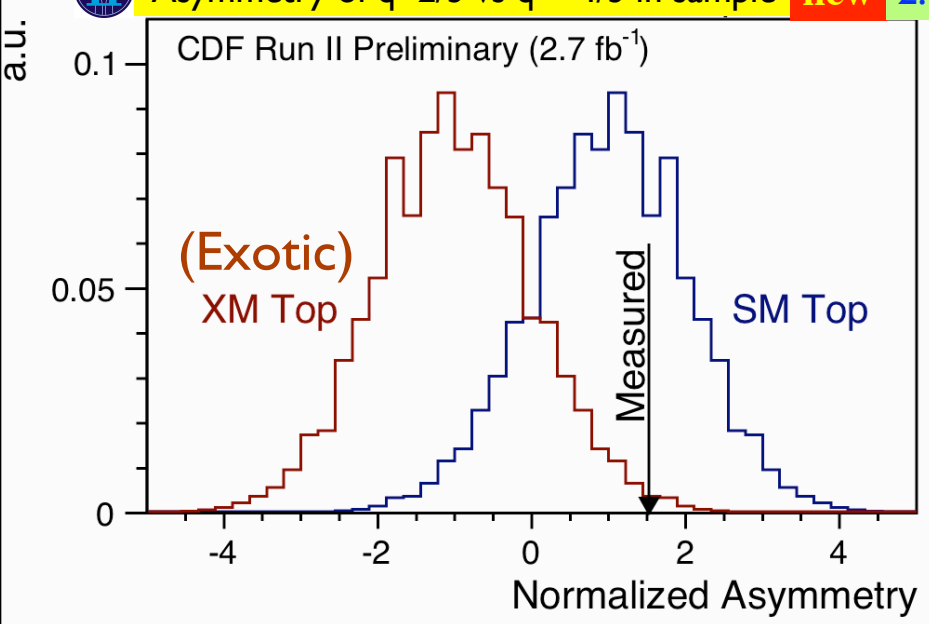


$$\Gamma_t = \frac{\sigma(t\text{−channel})\ \frac{\Gamma(t \to Wb)_{SM}}{\sigma(t\text{−channel})_{SM}}}{\mathcal{B}(t \to Wb)}\ .$$

$\Gamma_{top} = 2.1 \pm 0.6$ GeV

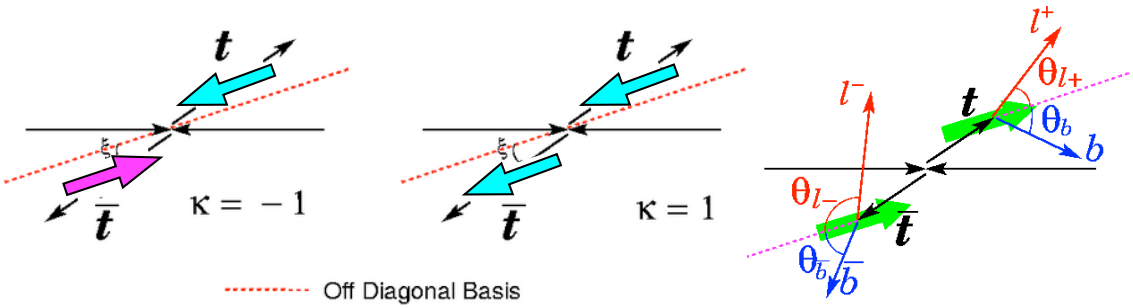
$\tau_{top} = (3 \pm 1) \cdot 10^{-25}$ s

Asymmetry of q=2/3 vs q=−4/3 in sample **new** 2.7 fb^{-1}

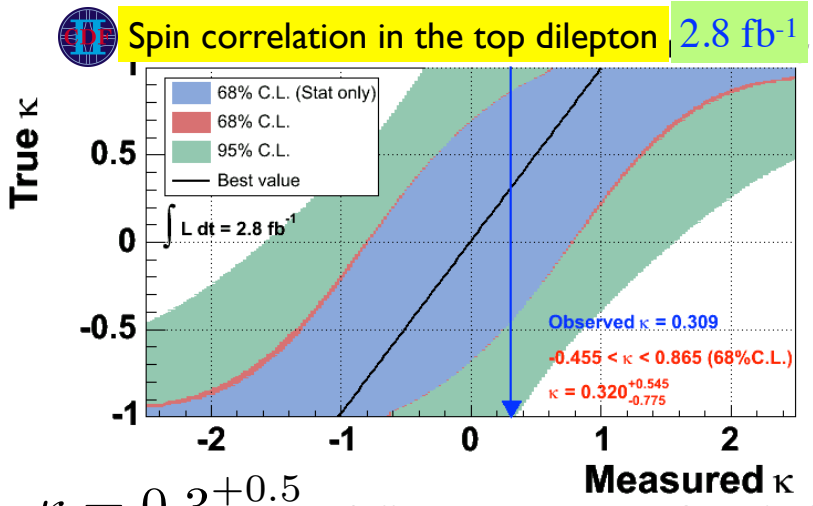


Excludes -4e/3 @ 95% C.L.

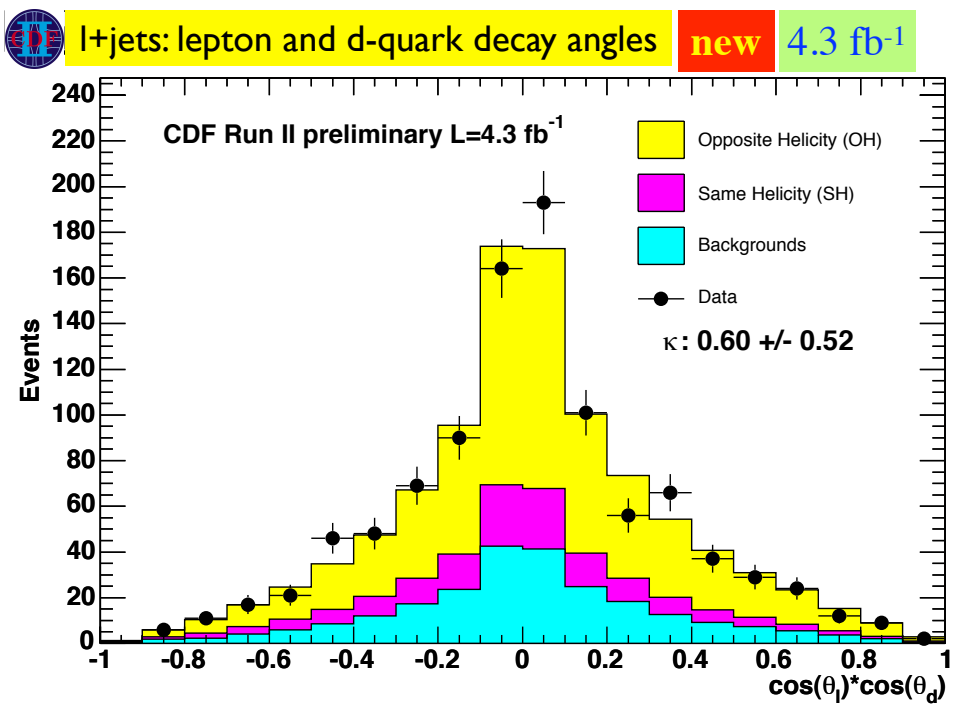
Top pair spin correlation



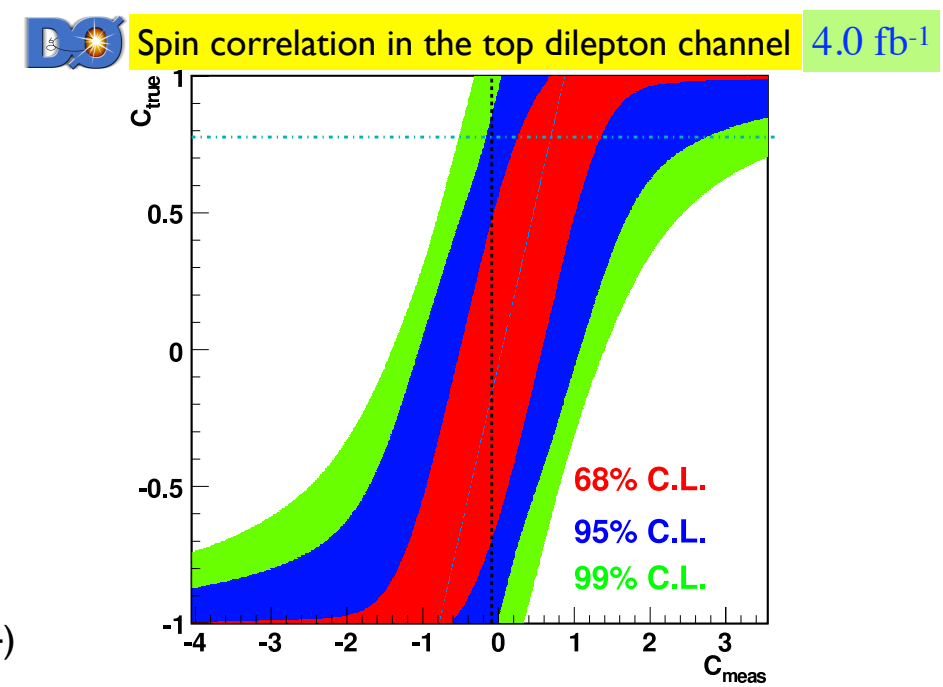
κ is the spin correlation parameter



$\kappa = 0.3^{+0.5}_{-0.8}$ (off-diagonal basis, NLO κ≅0.78)

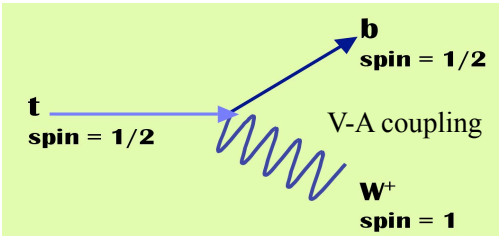


$\kappa = 0.60 \pm 0.50\ (\mathrm{stat}) \pm 0.16\ (\mathrm{syst})$ (helicity basis, NLO κ≅0.4)



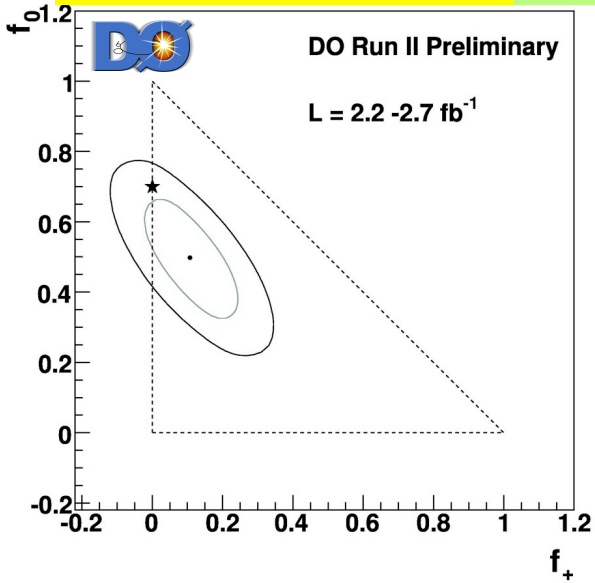
$\kappa = -0.17^{+0.65}_{-0.53}$ (beam basis, NLO κ≅0.78)

W polarisation in top pairs and A_{fb}



SM: $f_0 \cong 0.7$, $f_+ \cong 0.0$

f_0 and f_+ in ttbar (DIL and LJ) ≤ 2.7 fb^{-1}



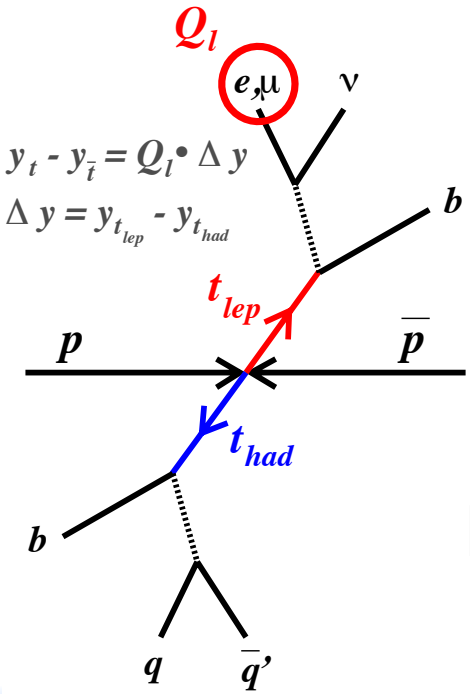
$f_0 = 0.490 \pm 0.106$ (stat) ± 0.085 (syst)

$f_+ = 0.110 \pm 0.059$ (stat) ± 0.052 (syst)

2.7 fb^{-1}

$f_0 = 0.88 \pm 0.11$ (stat) ± 0.06 (syst)

$f_+ = -0.15 \pm 0.07$ (stat) ± 0.06 (syst)



Arises at higher than tree-level order [PRD 77, 014003]:

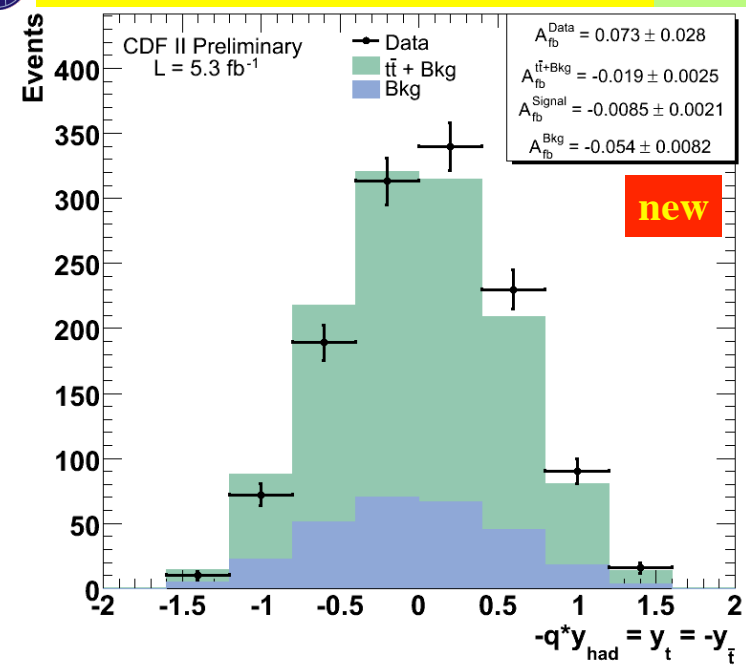
A_{fb} (SM, NLO, pp-frame)= 0.050±0.015

Parton-level:

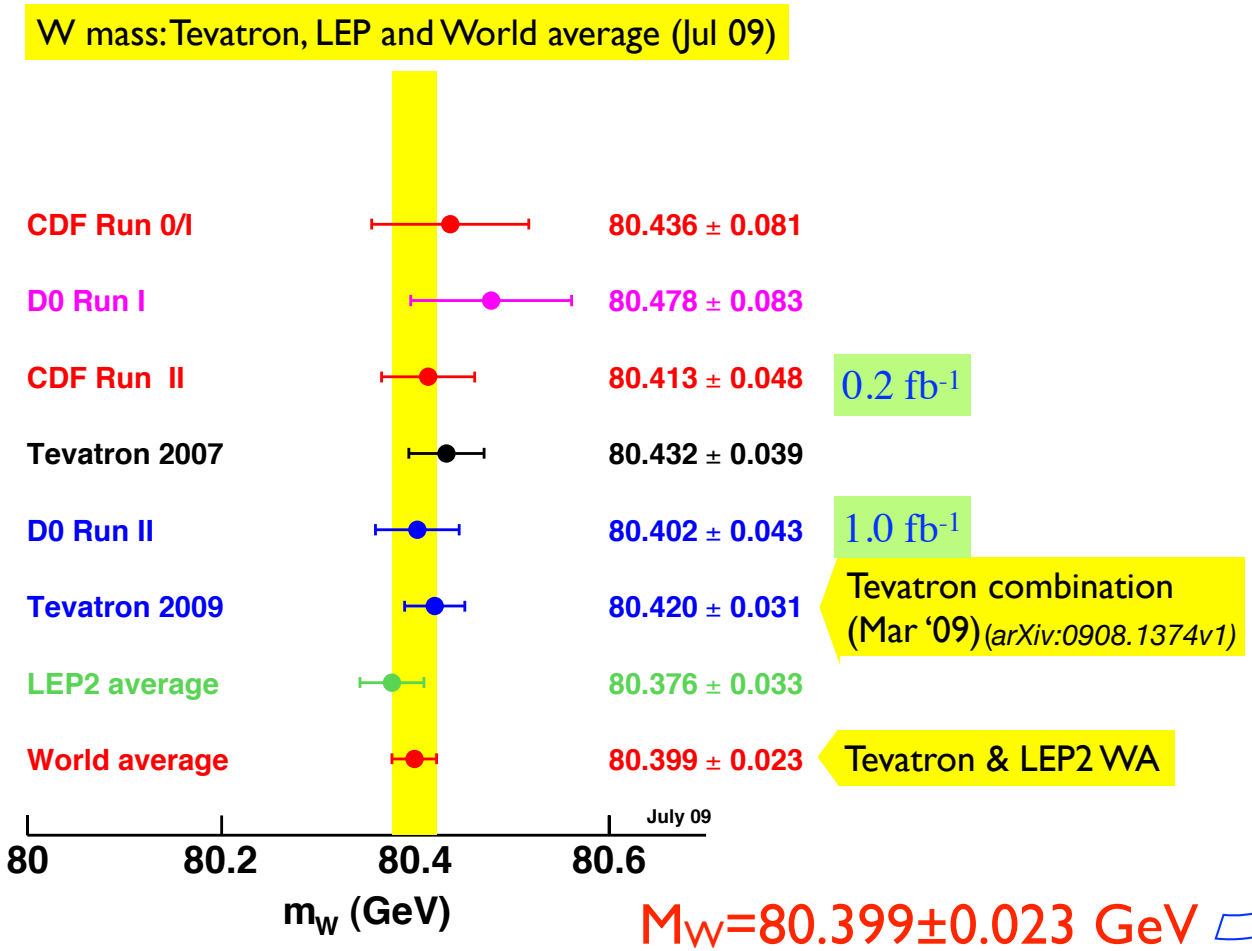
A_{fb} (pp)= 0.15±0.05(stat)±0.02(syst)

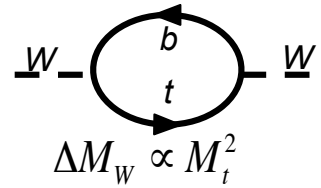
[PRL 100:142002,2008]

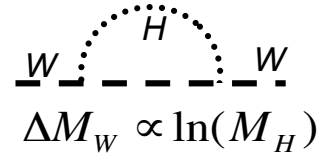
ppbar: Had top rapidity distribution · Q_l 5.3 fb^{-1}

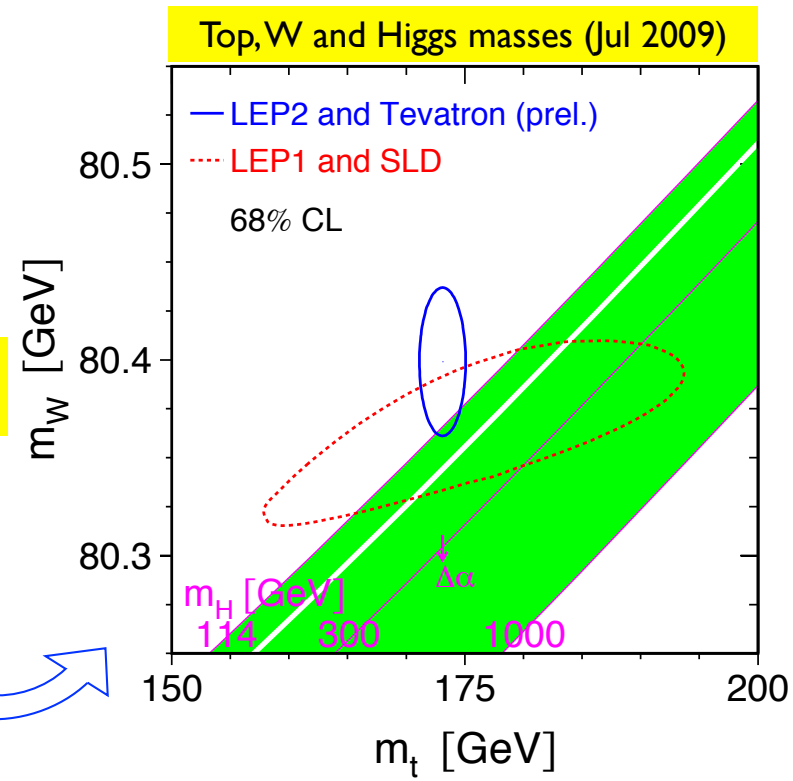


W boson mass









M_W=80.399±0.023 GeV

M_{top}=173.1±1.3 GeV

- World's most precise result is from D0 *(Phys. Rev. Lett. 103, 141801 (2009)*
- Tevatron average more precise (±0.038%) than LEP2
- Requires precision lepton momentum and recoil calibrations (stat.) and event modeling (PDF, QED: syst.)
- CDF (with 2 fb^{-1}) expects $\Delta M_W \approx \pm 25-35$ MeV

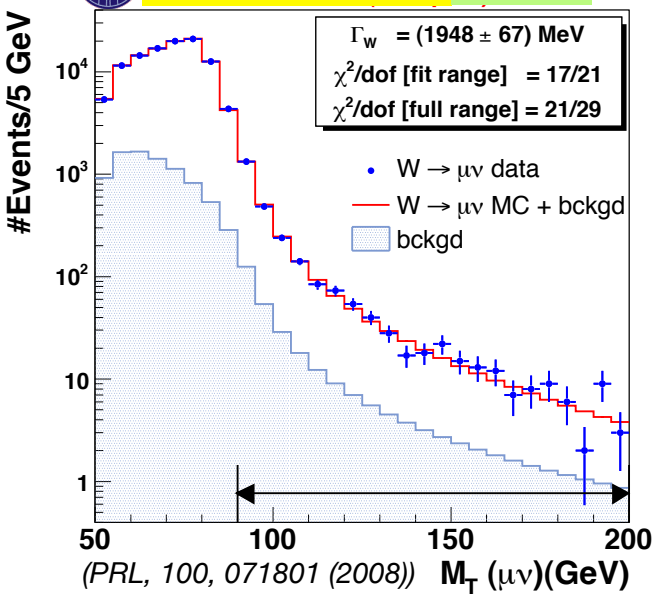
$$M_{Higgs} = 87^{+35}_{-26} \text{ GeV } (68\% \text{ C.L.})$$
$$M_{Higgs} < 157 \text{ GeV } (95\% \text{ C.L.})$$

including LEP direct limit:

$$M_{Higgs} < 186 \text{ GeV } (95\% \text{ C.L.})$$

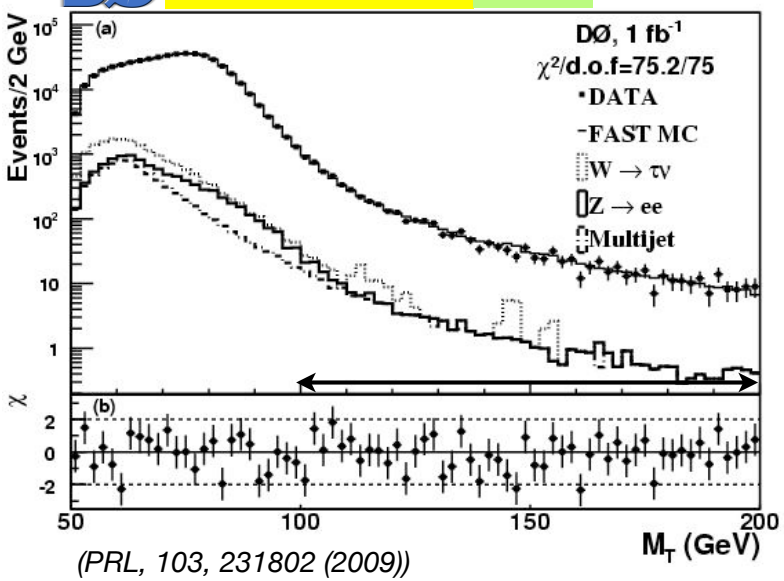
W boson width

W transverse mass 0.35 fb^{-1}



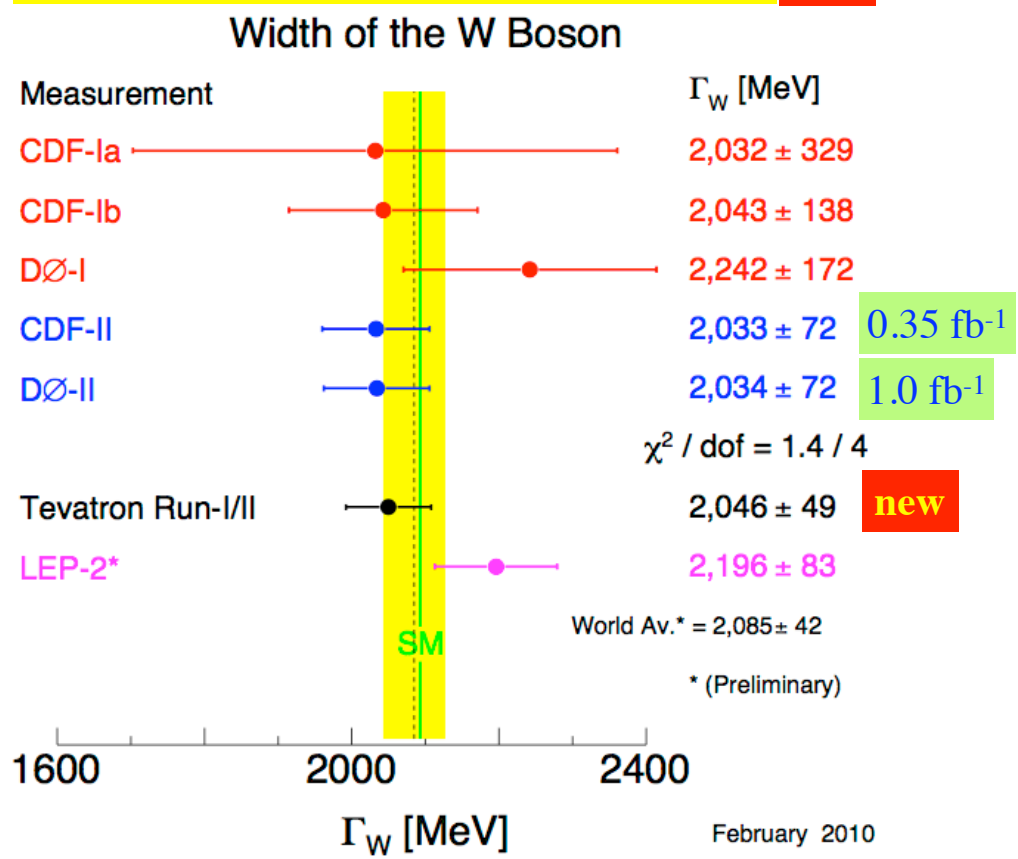
(PRL, 100, 071801 (2008))

W transverse mass 1.0 fb^{-1}



(PRL, 103, 231802 (2009))

Γ_W: Tevatron, LEP and World average (Feb 2010) **new**



- Measurements use fits to the tail of the M_T distributions
- Averages using the BLUE method
- Earlier results corrected assuming the (Dec 09) M_W=80,399±23 MeV
- Both CDF and D0 Run II surpassed the direct LEP2 measurements

W charge asymmetry

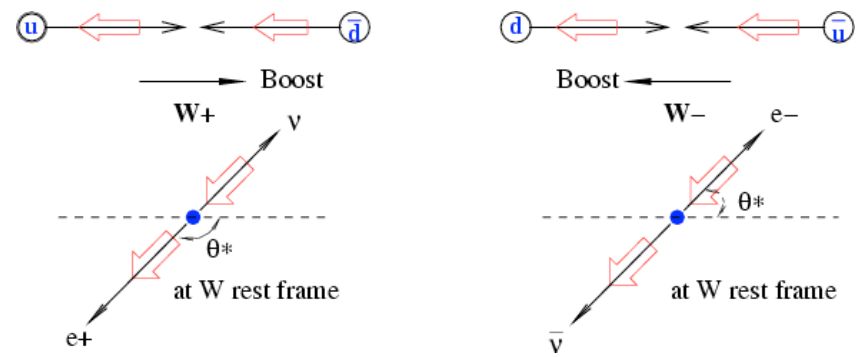
W charge forward-backward asymmetry arises from u(x) vs. d(x) in the proton:

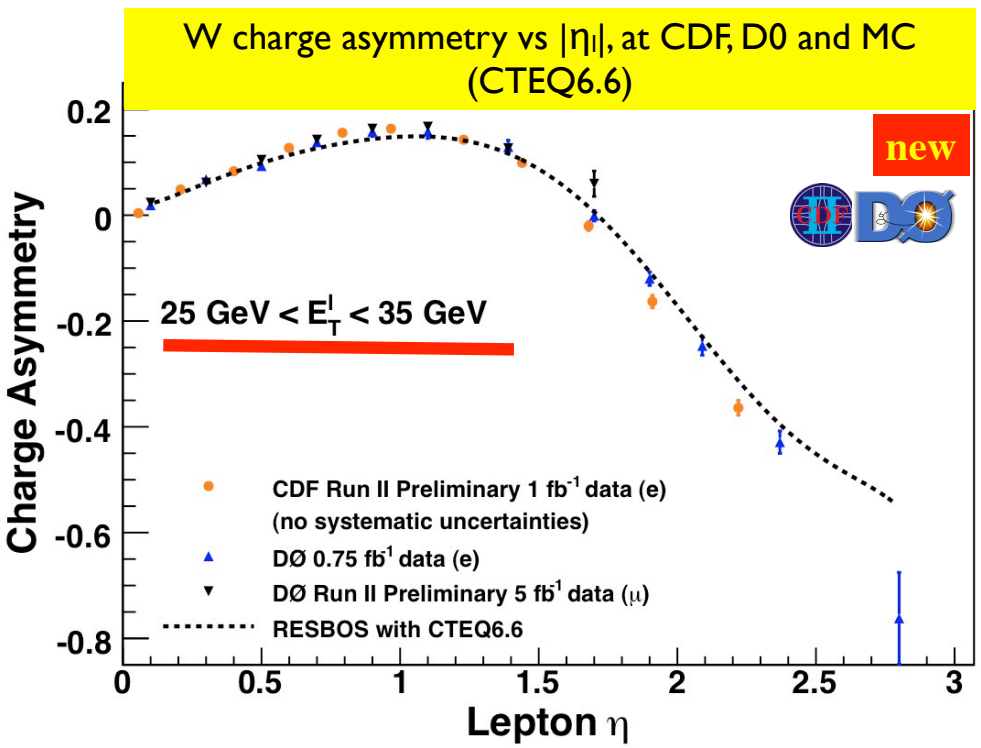
$$A(y_W) = \frac{d\sigma(W^+)/dy_W - d\sigma(W^-)/dy_W}{d\sigma(W^+)/dy_W + d\sigma(W^-)/dy_W} \approx \frac{u(x_1)d(x_2) - d(x_1)u(x_2)}{u(x_1)d(x_2) + d(x_1)u(x_2)}$$

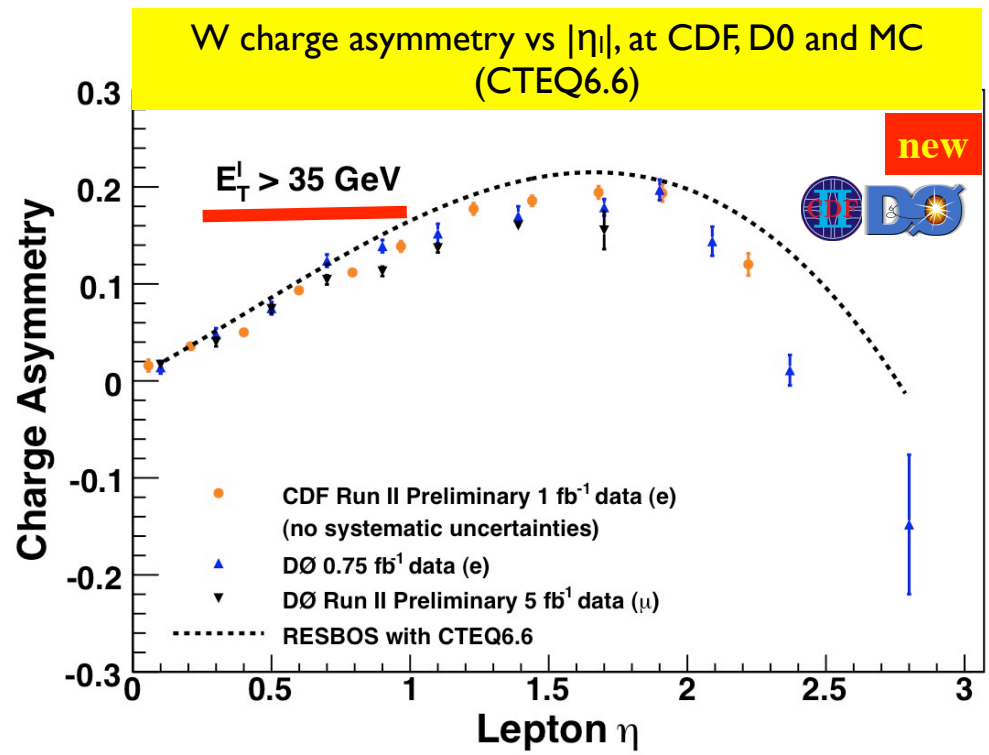
Precision of data allows to expose some inconsistencies with latest PDF fits:

- D0 (W→eν+X) 0.75 fb^{-1} *(PRL, 101, 211801 (2008))*
- D0 (W→μν+X) 4.9 fb^{-1} **new**
- CDF (W→eν+X) 1.0 fb^{-1} *(PRL, 102, 181801 (2009))*

Experiments agree with each other: effort ongoing to understand discrepancy at high lepton p_T

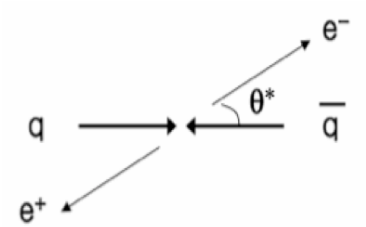






Z charge asymmetry and $d\sigma_Z/dy$

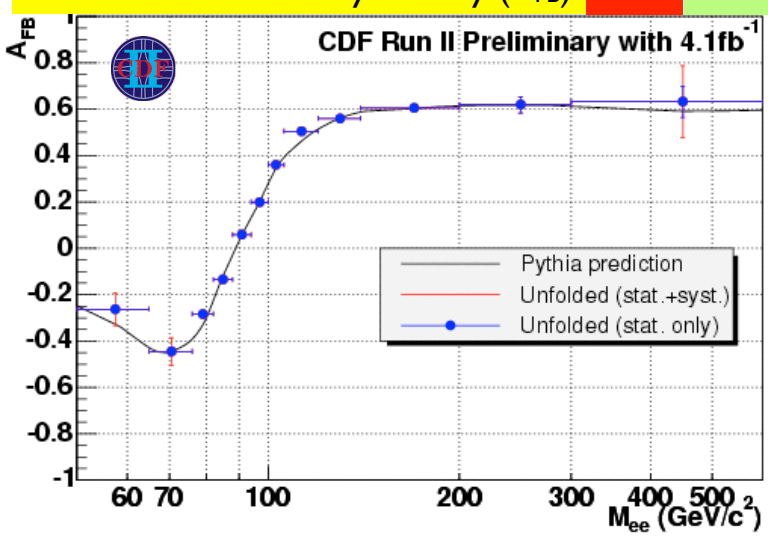
A_{FB} arises from vector and axial-vector couplings, and Z γ^* interference term:



$$A_{FB} = \frac{\int_0^{+1} \frac{d\sigma}{dcos\theta^*} dcos\theta^* - \int_{-1}^{0} \frac{d\sigma}{dcos\theta^*} dcos\theta^*}{\int_{-1}^{+1} \frac{d\sigma}{dcos\theta^*} dcos\theta^*} = \frac{N_F - N_B}{N_F + N_B}$$

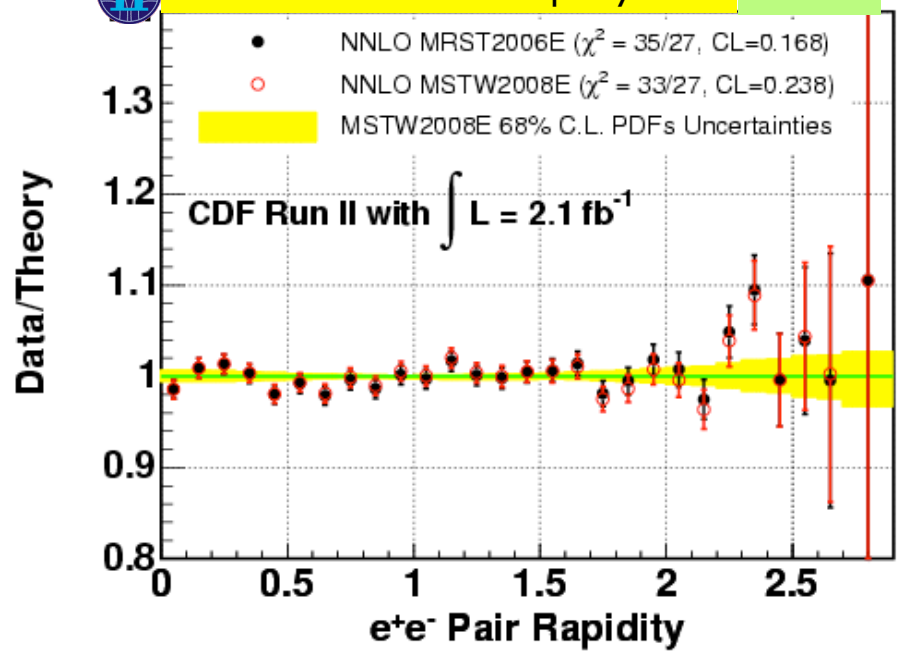
(θ^* in the CS frame)

Forward-backward asymmetry (A_{FB}) **new** 4.1 fb^{-1}



arXiv:0908.3914v4 (2010)

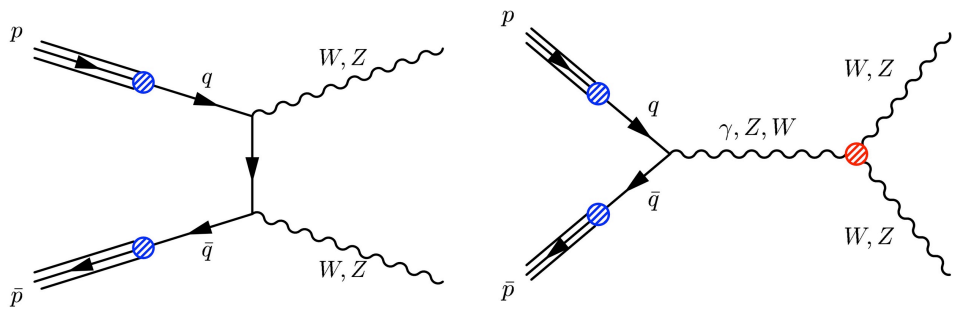
Production vs. Z rapidity 2.1 fb^{-1}



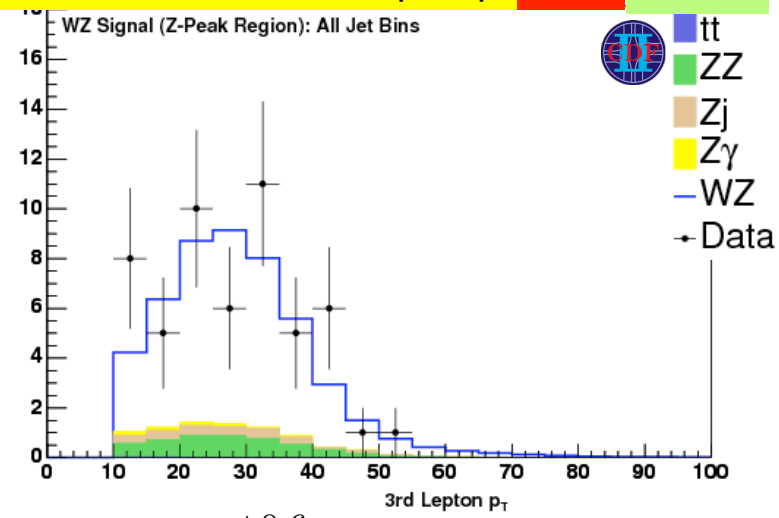
- CDF will extract $\sin^2\theta_W$ soon

  D0 $\sin^2\theta^{eff}_W$=0.2326±0.0018(stat)±0.0006(syst) 1.1 fb^{-1} *(PRL, 101, 191801 (2008))*
- With about 8 fb^{-1} per experiment expect to reach (Tevatron only) the WA precision.

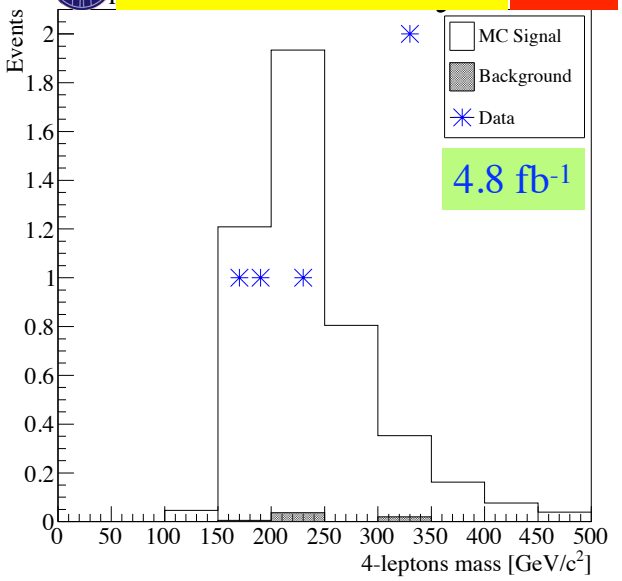
WW, WZ, ZZ production



WZ→3l+MET candidates: 3rd lepton p_T **new** 5.9 fb^{-1}



ZZ→4l: Invariant mass **new**

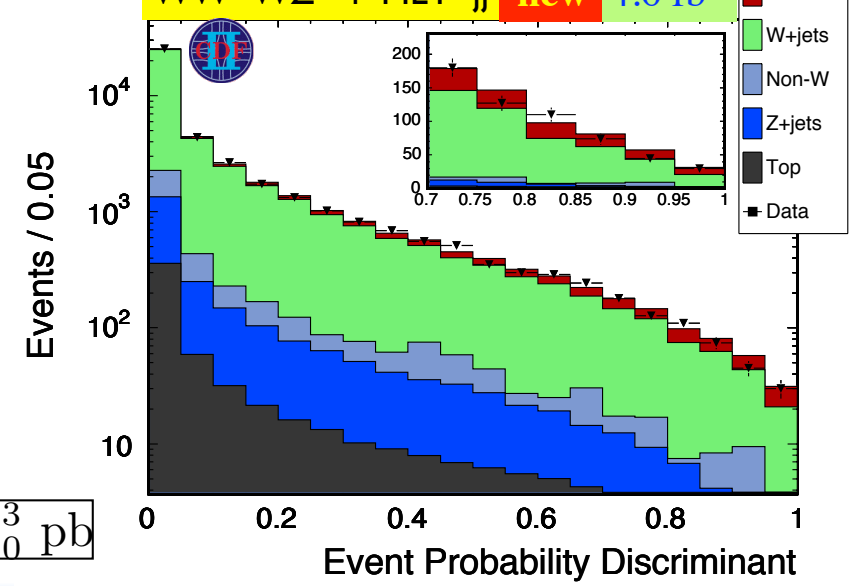


$$\sigma_{WZ} = 3.7 \pm 0.6(\text{stat})^{+0.6}_{-0.4}(\text{syst})\ \text{pb}$$

$$\sigma_{WZ} = 3.9^{+1.1}_{-0.9}\ \text{pb}$$ *[arXiv: 1006.0761v1 (2010)]*

$$\sigma_{WZ}^{Theory} = 3.46 \pm 0.21\ \text{pb}$$

WW+WZ→l+MET+jj **new** 4.6 fb^{-1}



- 5 events observed, 4.68±0.78 signal expected, 0.041±0.033 background

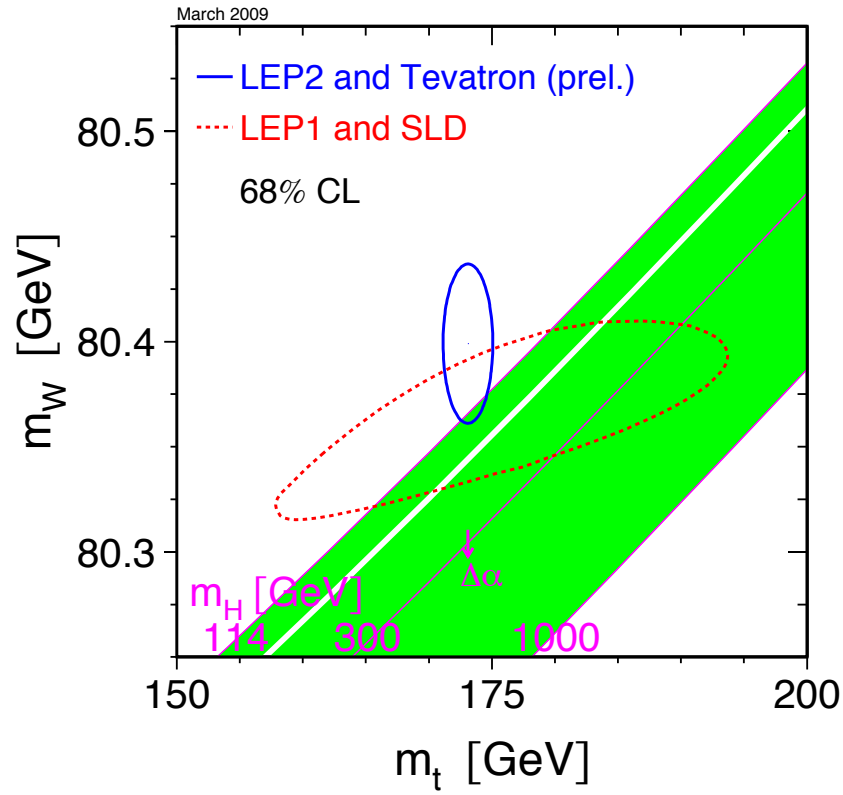
$$\sigma_{p\bar{p}\to ZZ} = 1.56^{+0.80}_{-0.63}(stat.) \pm 0.25(syst.)\ \text{pb}$$

$$\sigma_{p\bar{p}\to ZZ-Th} = 1.4 \pm 0.1(stat. + syst.)\ \text{pb}$$

$$\sigma_{WW+WZ} = 16.5^{+3.3}_{-3.0}\ \text{pb}$$

Summary

- CDF and D0 have very large samples of W, Z and top quarks
  - Detectors well understood
  - Backgrounds under control
- Top and W masses with lasting precision
- Diboson physics well established
- An extensive programme of top quark exploration



Experiments web pages:

http://www-cdf.fnal.gov/physics/new/top/top.htm
http://www-cdf.fnal.gov/physics/ewk/

http://www-d0.fnal.gov/Run2Physics/WWW/results/top.htm
http://www-d0.fnal.gov/Run2Physics/WWW/results/ew.htm