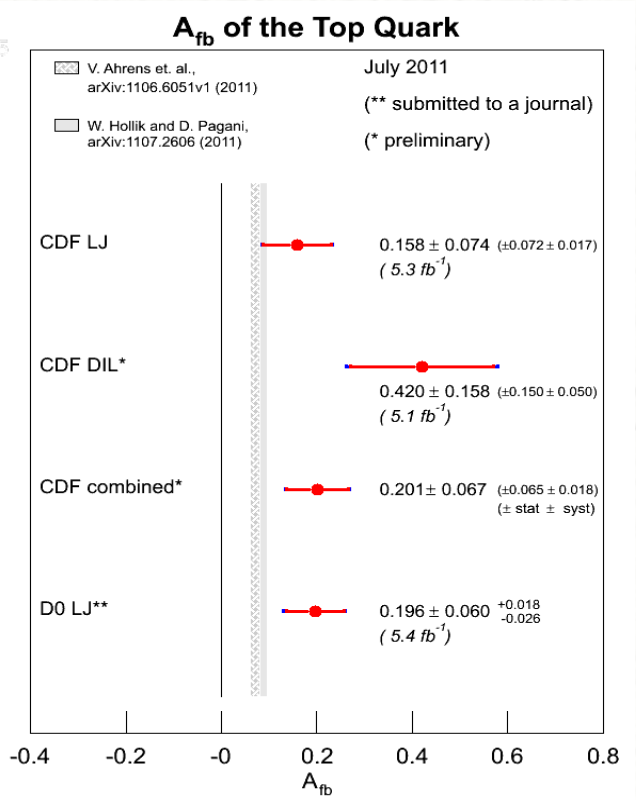
Measurements of the $t\bar{t}$ forward-backward asymmetry at CDF



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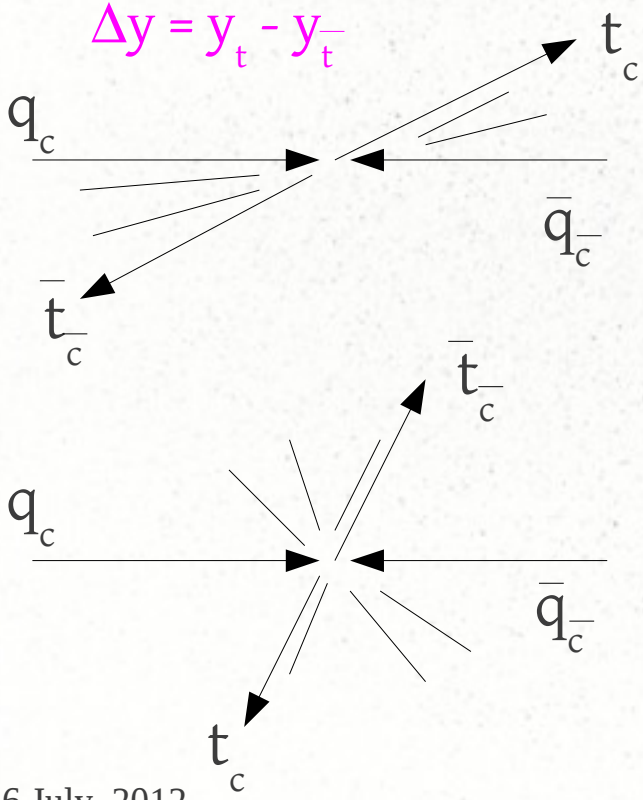
ICHEP2012 Melbourne

$t\bar{t}$ asymmetry in $\sqrt{s}$=1.96 TeV $p\bar{p}$ collisions

Top-quark pairs predominantly produced by valence-quark annihilation

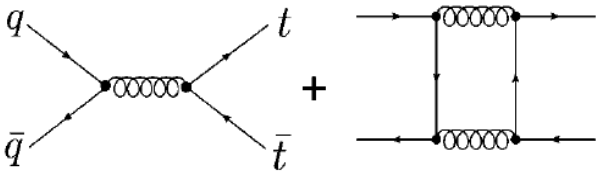
Forward-backward asymmetry $A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$ in terms of color flow:



Top quark produced in direction of proton

(positive asymmetry)

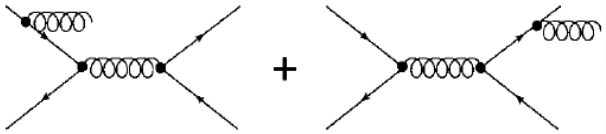
High mass & Δy



Top quark opposite to direction of proton

(negative asymmetry)

Low mass & Δy



SM predictions of $t\bar{t}$ asymmetry

Study at parton-level with NLO generators MC@NLO, MCFM, & PowHeg

	MC@NLO	POWHEG	MCFM
Inclusive	0.067	0.066	0.073
$\|\Delta y\| < 1$	0.047	0.043	0.049
$\|\Delta y\| > 1$	0.130	0.139	0.150
$M_{t\bar{t}} < 450\ \mathrm{GeV}/c^2$	0.054	0.047	0.050
$M_{t\bar{t}} > 450\ \mathrm{GeV}/c^2$	0.089	0.100	0.110

Predictions include +26% correction due to electroweak diagrams

CDF measurements of $t\bar{t}$ asymmetry

Measure in semileptonic (lνbqqb) and leptonic (lνblνb) final states

Charged lepton(s) used to tag top and/or antitop quark(s)

Kinematic fitter determines y_t and $y_{\bar{t}}$

Semileptonic sample, 8.7 fb^{-1}

	≥ 4 jets
W+HF	241 ± 78
Non-W	98 ± 51
W+LF	96 ± 29
Single Top	33 ± 2
Diboson	19 ± 3
Z+Jets	18 ± 2
Total Background	505 ± 123
$t\bar{t}$ 7.4pb	2037 ± 277
Total Prediction	2542 ± 303
Data	2498

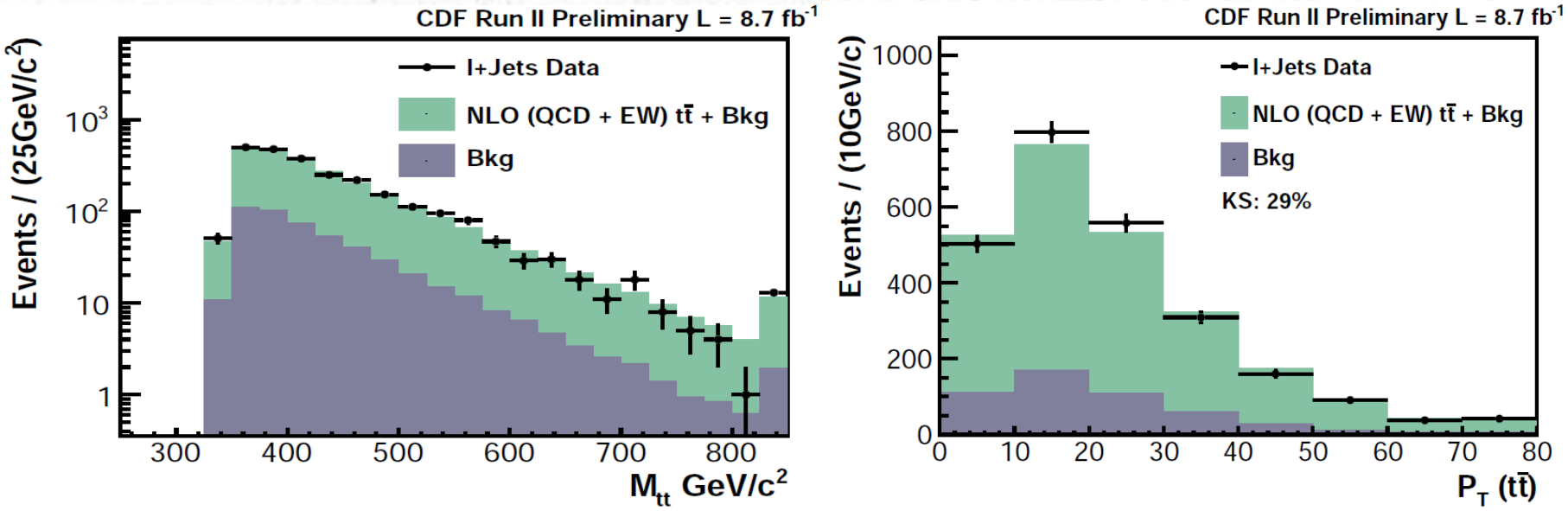
Includes extended muon coverage

Leptonic sample, 5.1 fb^{-1}

Process	Events
WW	11.7 ± 2.4
WZ	3.5 ± 0.6
ZZ	2.3 ± 1.8
Wγ	0.4 ± 0.4
DY$\rightarrow \tau\tau$	12.3 ± 2.2
DY$\rightarrow ee + \mu\mu$	22.4 ± 3.2
Fakes	34.3 ± 14.7
$t\bar{t}$	237.1 ± 11.3
Total	324.0 ± 28.3
Data	334

Measurement in semileptonic channel

Use PowHeg to model kinematics and acceptance of semileptonic data



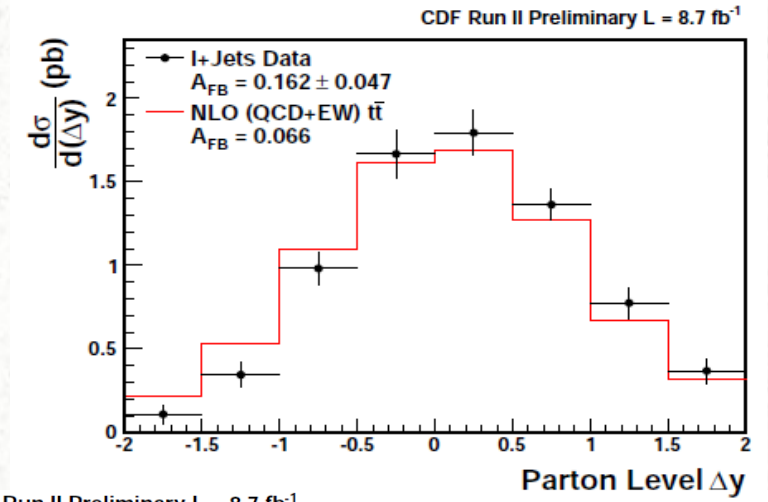
Measure parton-level asymmetry inclusively and as a function of M_{tt} & Δy

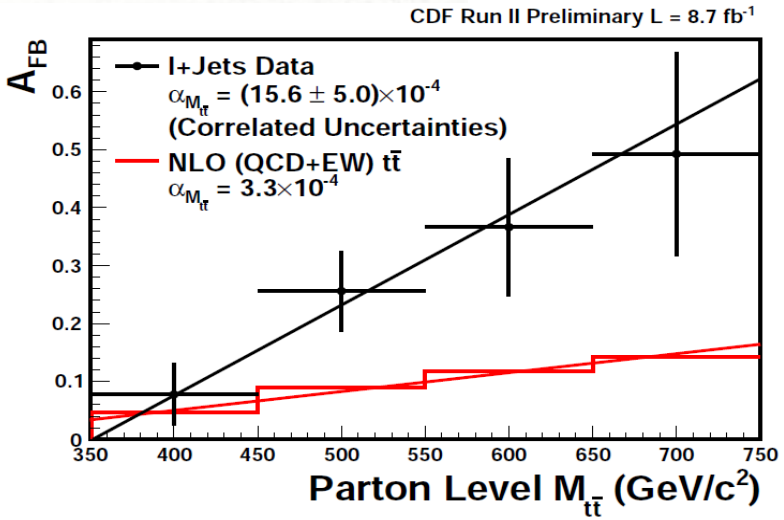
Also measure asymmetry as a function of $p_T(\bar{tt})$ at detector level

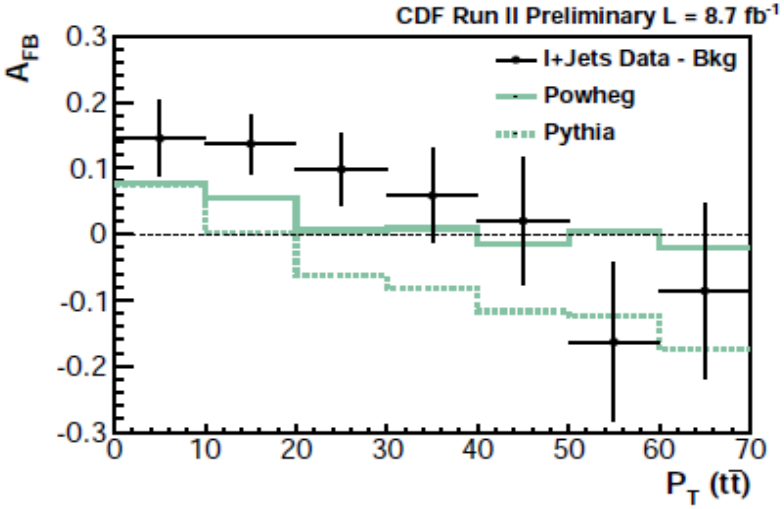
Measurement in semileptonic channel

>2σ deviation from SM predominantly at high $M_{t\bar{t}}$ and low $p_T(t\bar{t})$

Region of soft emissions and virtual corrections







Uncertainties in semileptonic channel

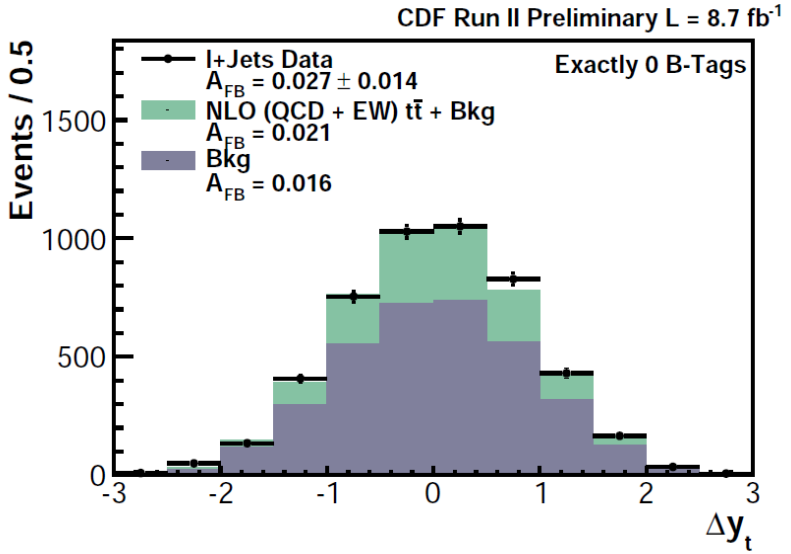
Statistical uncertainty dominates

Largest systematic uncertainties due to background modelling

Asymmetry well modelled in background-dominated pre-tag sample

CDF Run II Preliminary L = 8.7 fb^{-1}

Source	Systematic Uncertainty
Background Shape	0.014
Background Normalization	0.011
Parton Showering	0.010
Jet Energy Scale	0.005
Initial and Final State Radiation	0.005
Color Reconnection	0.001
Parton Distribution Functions	0.001
Correction Procedure	0.003
Total Systematic Uncertainty	0.022
Statistical Uncertainty	0.041
Total Uncertainty	0.047

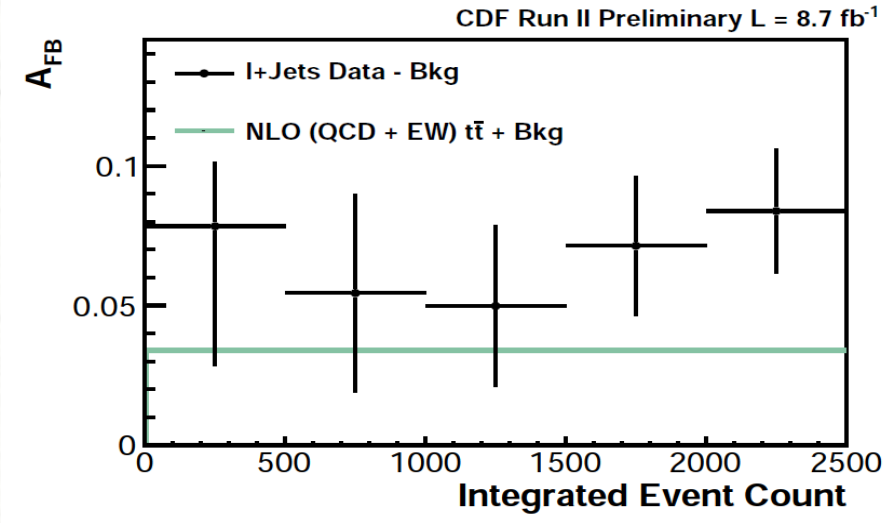


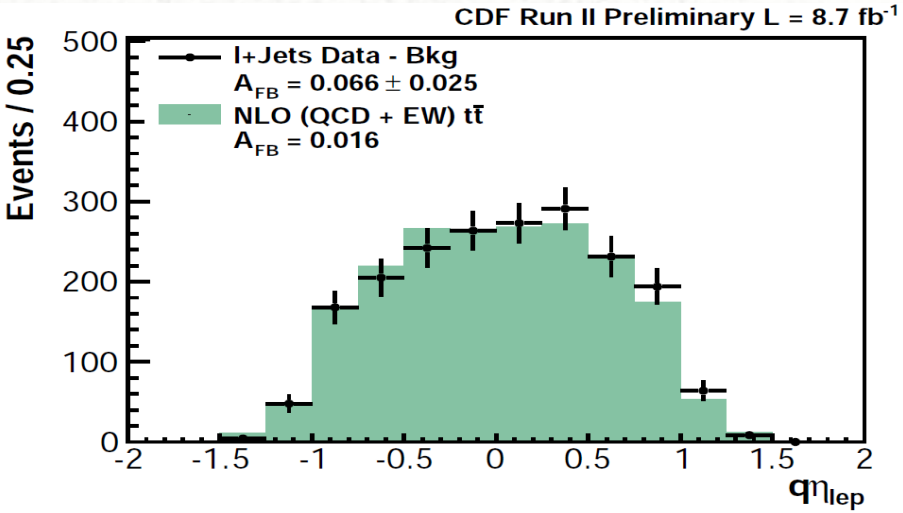
Cross-checks in semileptonic channel

Asymmetry stable over time

Asymmetry consistent between electrons & muons, positive & negative leptons, 1 & 2 b-tags

Asymmetry also observed in lepton rapidity distribution

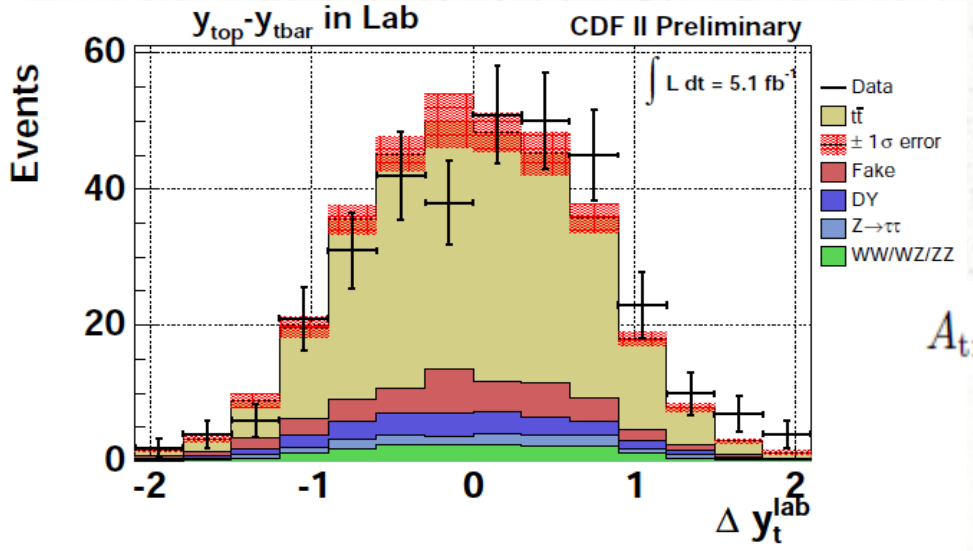




Measurement in leptonic channel

Solve for unobserved neutrino kinematics by minimizing likelihood:

$$\mathcal{L}\left(\vec{p}_\nu, \vec{p}_{\bar{\nu}}, E_b, E_{\bar{b}}\right) = P\left(p_z^{t\bar{t}}\right) P\left(p_T^{t\bar{t}}\right) P\left(M_{t\bar{t}}\right) \times$$
$$\frac{1}{\sigma_{\text{jet1}}} \exp\left[-\frac{1}{2}\left\{\frac{E_{\text{jet1}}^{\text{meas}} - E_{\text{jet1}}^{\text{guess}}}{\sigma_{\text{jet1}}}\right\}^2\right] \times \frac{1}{\sigma_{\text{jet2}}} \exp\left[-\frac{1}{2}\left\{\frac{E_{\text{jet2}}^{\text{meas}} - E_{\text{jet2}}^{\text{guess}}}{\sigma_{\text{jet2}}}\right\}^2\right]$$
$$\frac{1}{\sigma_x^{\text{MET}}} \exp\left[-\frac{1}{2}\left\{\frac{\not{E}_x^{\text{meas}} - \not{E}_x^{\text{guess}}}{\sigma_x^{\text{MET}}}\right\}^2\right] \times \frac{1}{\sigma_y^{\text{MET}}} \exp\left[-\frac{1}{2}\left\{\frac{\not{E}_y^{\text{meas}} - \not{E}_y^{\text{guess}}}{\sigma_y^{\text{MET}}}\right\}^2\right]$$

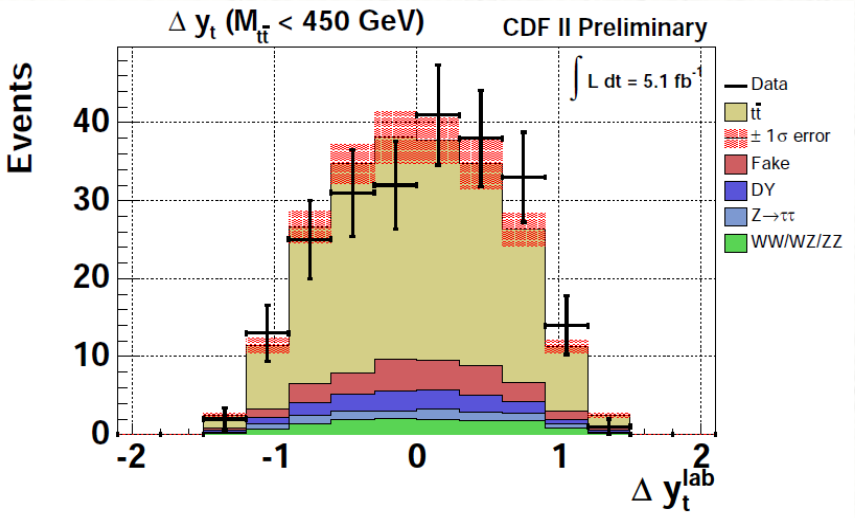


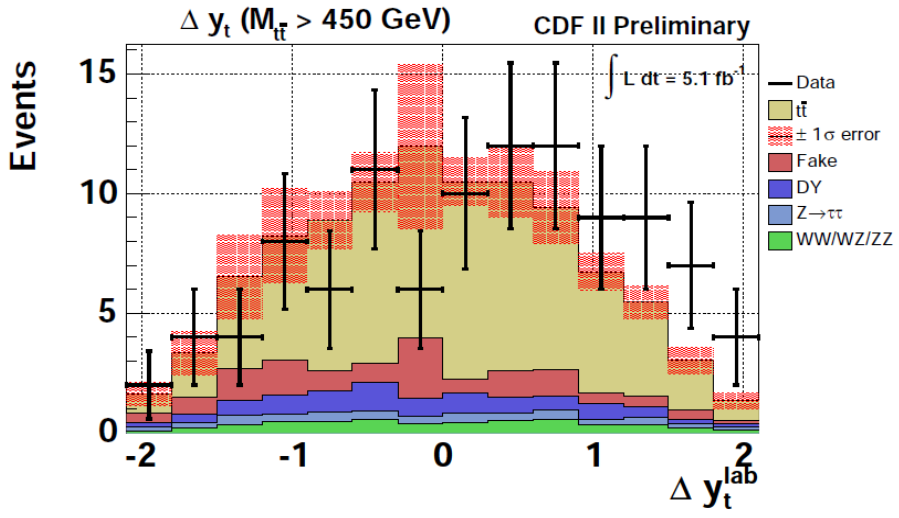
>2σ asymmetry observed

$$A_{\text{true}} = 0.42 \pm 0.15(\text{stat.}) \pm 0.04(\text{bkg} - \text{shape})$$

Measurement in leptonic channel

Study mass dependence





$$A_{\rm obs}^{<450\ {\rm GeV}} = 0.104 \pm 0.066({\rm stat.})$$

$$({\rm Pred.}: \ 0.003 \pm 0.031)$$

$$A_{\rm obs}^{>450\ {\rm GeV}} = 0.212 \pm 0.096({\rm stat.})$$

$$({\rm Pred.}: \ -0.040 \pm 0.055)$$

Larger asymmetry at higher mass, but statistically limited

Conclusions

CDF has updated semileptonic $t\bar{t}$ asymmetry measurement to the complete data set

Significant asymmetry measured predominantly at high mass and low p_T of the top-quark pair

Leptonic channel shows similar trend

Taken together, results suggest NLO QCD insufficient to describe asymmetry at high mass & low-p_T in $p\bar{p}$ collisions