Measurement of Forward-Backward Asymmetry in Top Quark Pair Production in ppbar Collisions at 1.96 TeV

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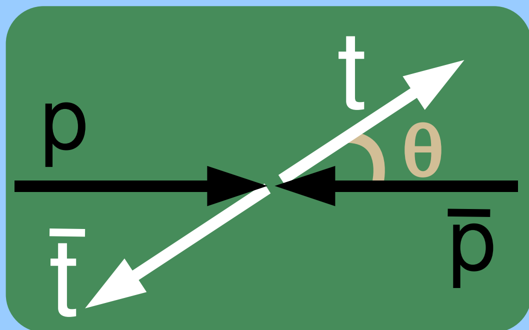
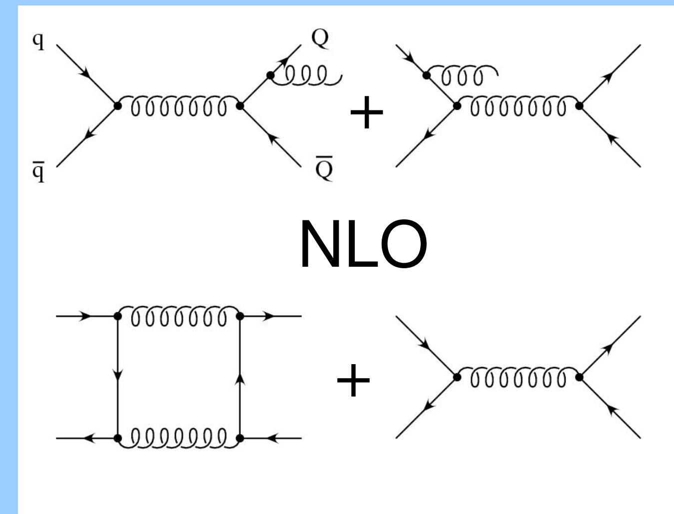
On behalf of the CDF Collaboration

Asymmetries in Top Production



$$A_{fb} = \frac{N_t(y>0) - N_t(y<0)}{N_t(y>0) + N_t(y<0)}$$



$t\bar{t} \rightarrow W^- \bar{b} \rightarrow l \nu \bar{b}$

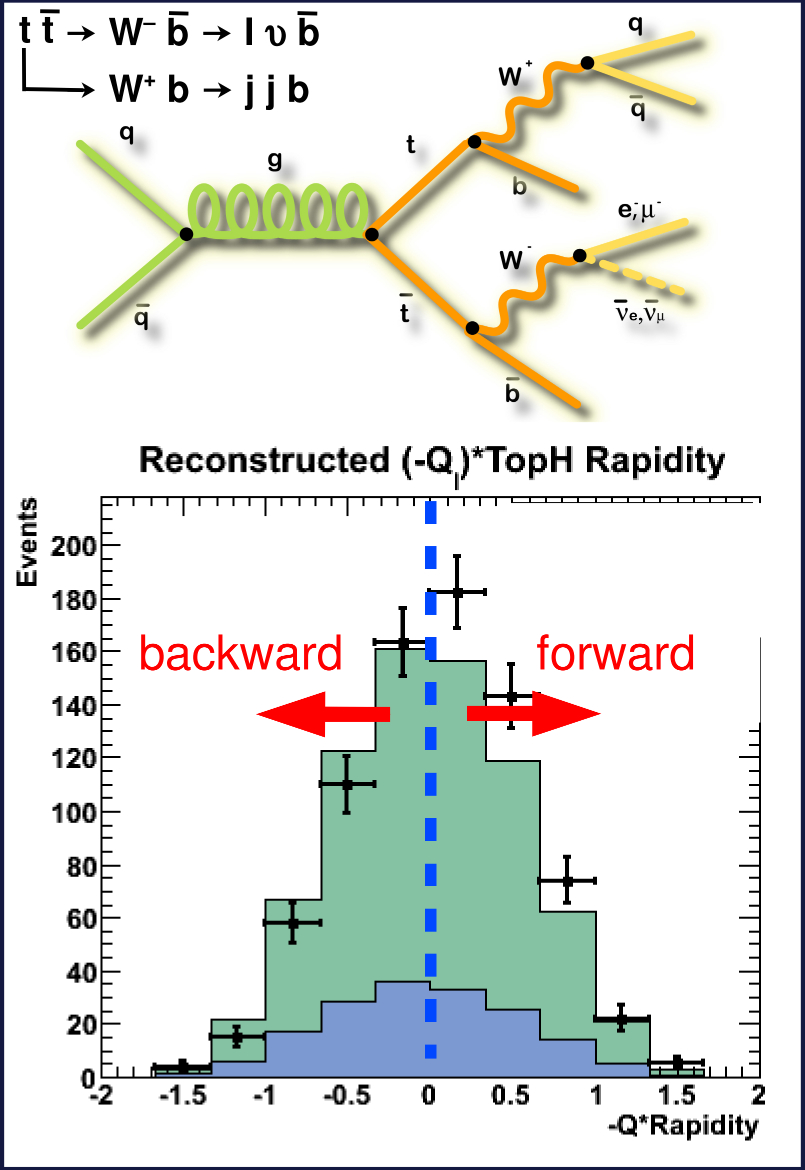
$\quad \hookrightarrow W^+ b \rightarrow j j b$

- Forward-backward A_{fb} – does the top preferentially go one way or the other?
- Count events from rapidity distribution in lab frame and calculate:

  A_{fb} = (forward-backward)/total
- QCD at lowest order predicts 0 asymmetry
- NLO processes predicted an asymmetry Afb = 5±1.5% lab
- Unexpected new top production processes with chiral or axial couplings may cause an additional asymmetry

Measurement Techniques

- Hadronic top decay is more accurately reconstructed, so we will measure y_{had}
- Get hadronic top charge from lepton
- Invoke CP invariance and multiply hadronic-only distribution by -1 * lepton charge to find equivalent top rapidity in each event
- Measure A_{fb} using $-Q_{lep} \cdot y_{had}$ in the lab frame, count forward and backward events
- Correct A_{fb} back to parton level



- Previously, using $-Q_{lep} \cdot \cos(\theta_{had})$, we measured $A_{fb}^{lab} = 0.17 \pm 0.08$ using 1.9 fb^{-1} of data
- D-zero measured a detector-level $A_{fb} = 0.12 \pm 0.08 \pm 0.01$ using 0.9 fb^{-1} of data

Data Sample

Selection

- Measurement is performed using semi-leptonic top pair decays
- 3.2 fb^{-1} of CDF data
- ≥ 4 jets (Et > 20 GeV and $|\eta| < 2$)
- ≥ 1 b-tagged jet
- 1 electron (Et > 20 GeV and $|\eta| < 1$) –or– 1 muon (Pt > 20 GeV/c and $|\eta| < 1$)
- Missing Transverse Energy > 20 GeV

Backgrounds

- Use the techniques for estimating tagged backgrounds in the W+jets sample to determine semi-leptonic ttbar background

Process	
W+HF Jets	86.56 ± 27.40
Mistags (W+LF)	27.43 ± 7.70
Non-W (QCD)	33.44 ± 28.06
Single Top	7.82 ± 0.50
WW/WZ/ZZ	7.57 ± 0.74
Z+Jets	4.78 ± 0.59
Top	569.08 ± 78.81
Total Prediction	736.64 ± 89.22

776 Candidate Events

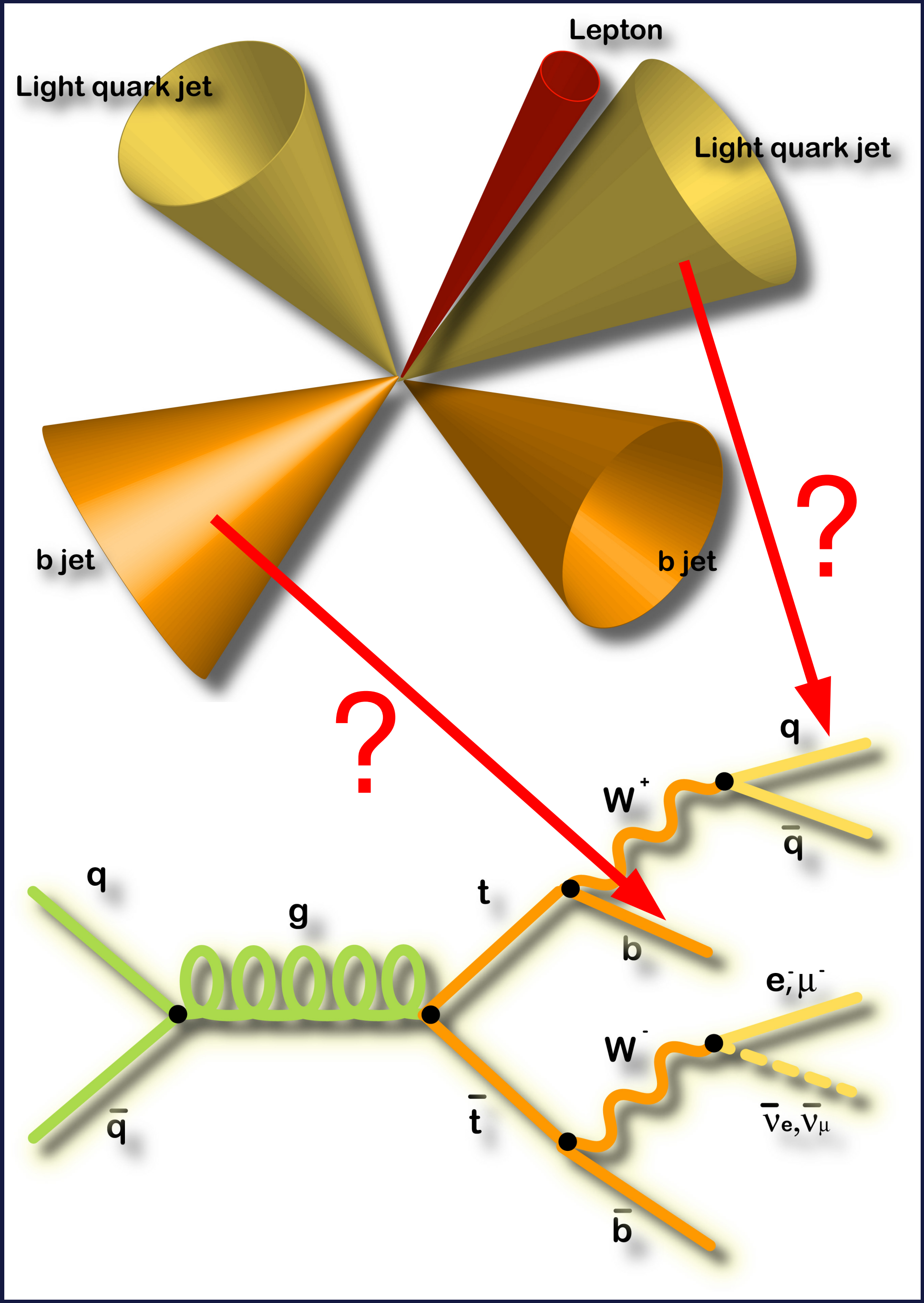
167 ± 34 Predicted Background

Event Reconstruction

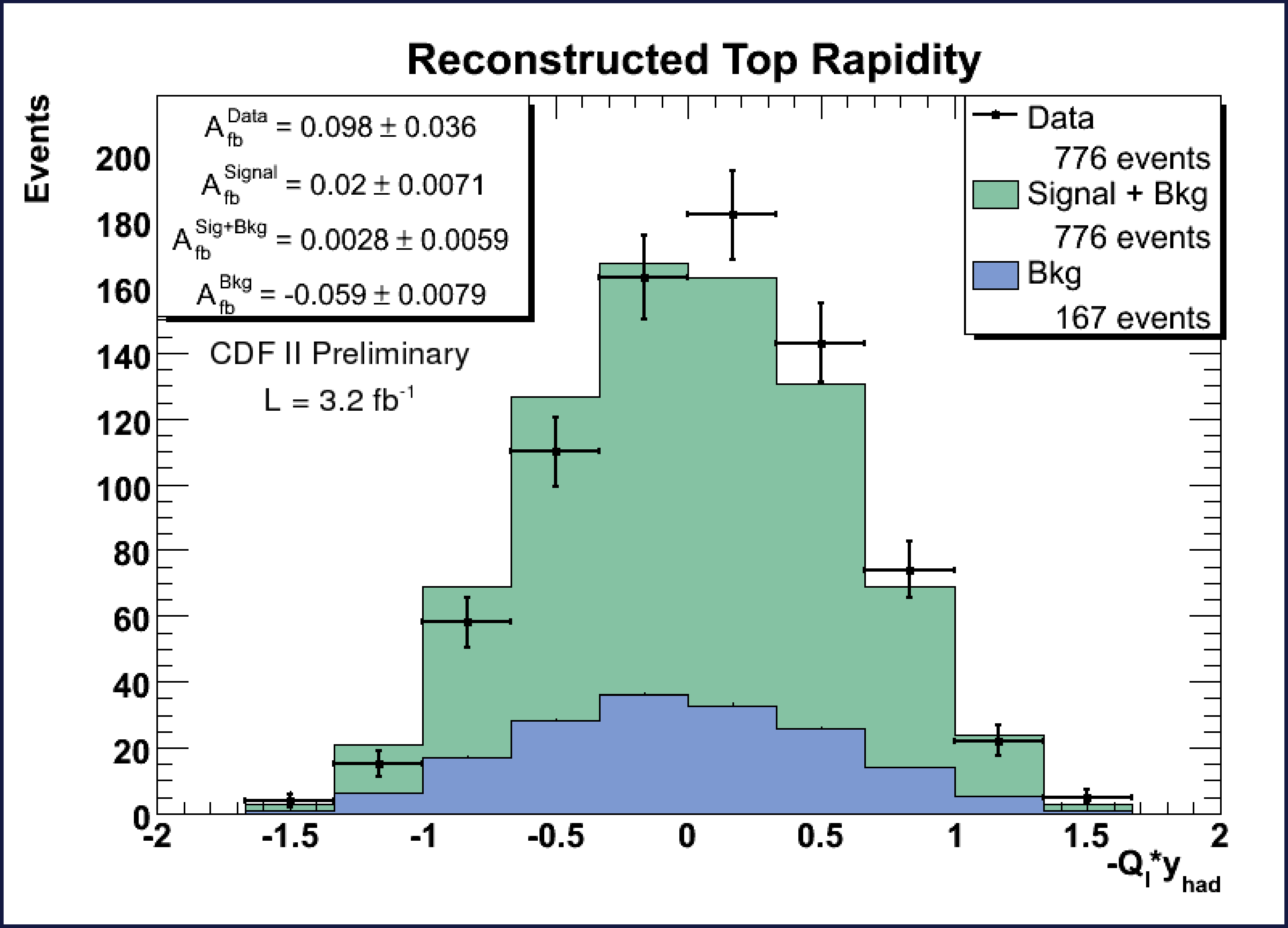
Reconstruction

- Match jets to b, bbar, up, down
- Constrain fit W mass to 80.4 GeV/c^2
- Constrain fit for a 175.0 GeV/c^2 Top
- Float momenta of jets within known resolution
- Use combination with lowest χ^2

$$\chi^2 = \sum_{lep,\,jets} \frac{(p_t^{i,\,meas} - p_t^{i,\,fit})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_j^{UE,\,meas} - p_j^{UE,\,fit})^2}{\sigma_j^2} + \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{l\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - M_{top})^2}{\Gamma_t^2} + \frac{(M_{bl\nu} - M_{top})^2}{\Gamma_t^2}$$



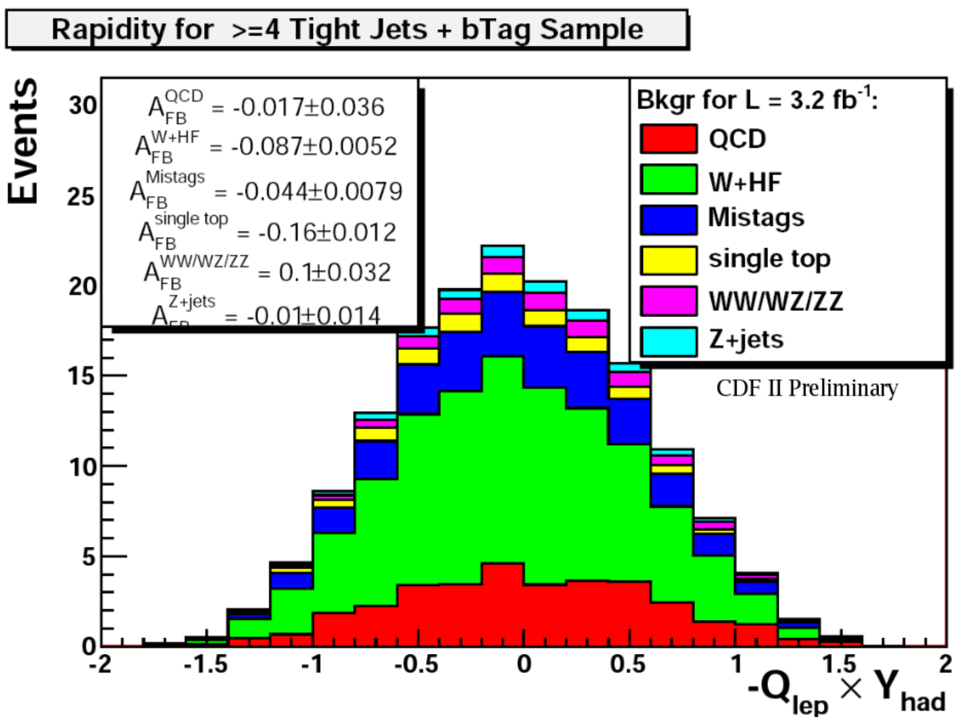
Raw Asymmetry

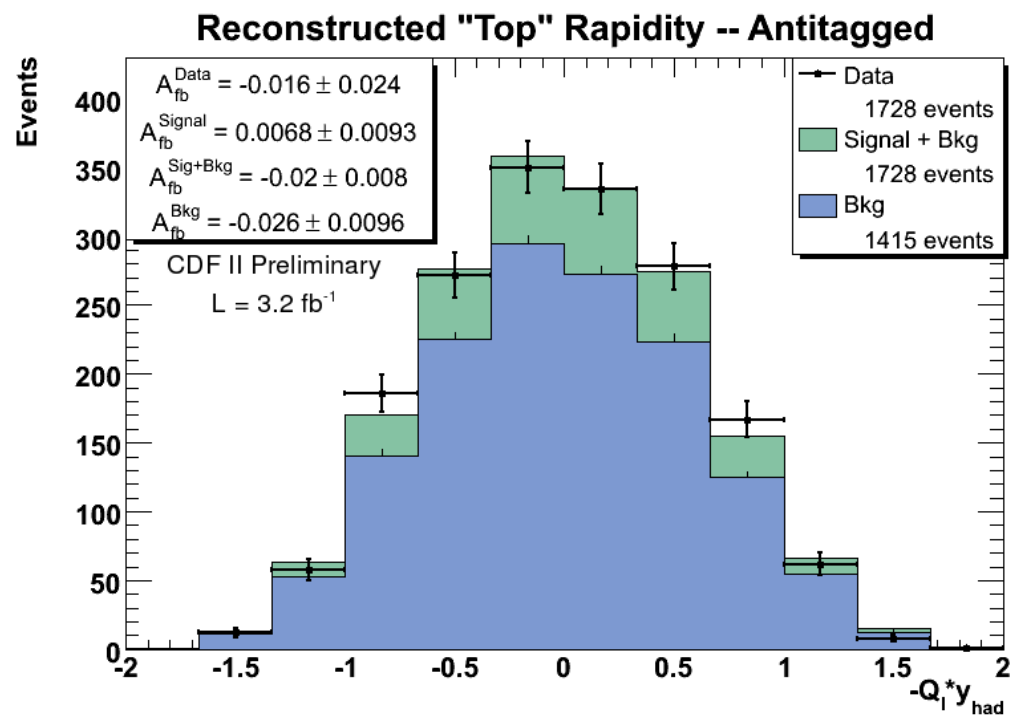


Signal MC is MC@NLO, normalized so signal+background = number of data events

Asymmetry Correction Technique

- Background has a known asymmetry that modifies the top A_{fb} measurement
- We subtract backgrounds from our data
- Check anti-tagged data and MC for consistency and cross-section

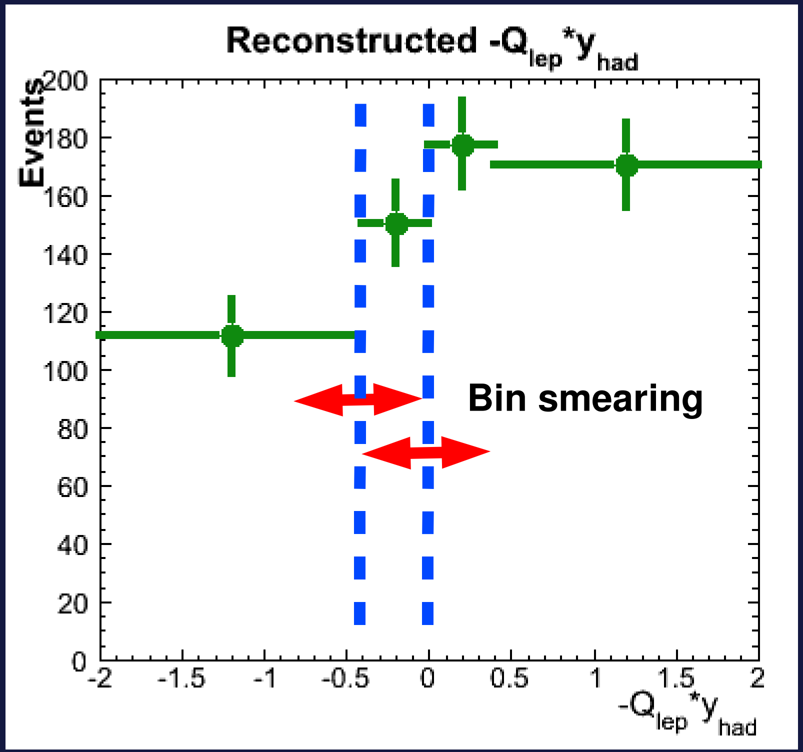




- We subtract off this total background from the data shape, 167 events out of 776 data events, which has A_{fb} = -0.059 ± 0.0079
- Negative values mostly due to electroweak processes (W+HF)

Asymmetry Correction Technique

- We optimize for number of bins and bin spacing
- Reconstruction of the event causes smearing between bins. We use a matrix unfolding technique to correct for this effect.
- Acceptance efficiencies also bias our sample, so an analogous correction is made using an acceptance matrix

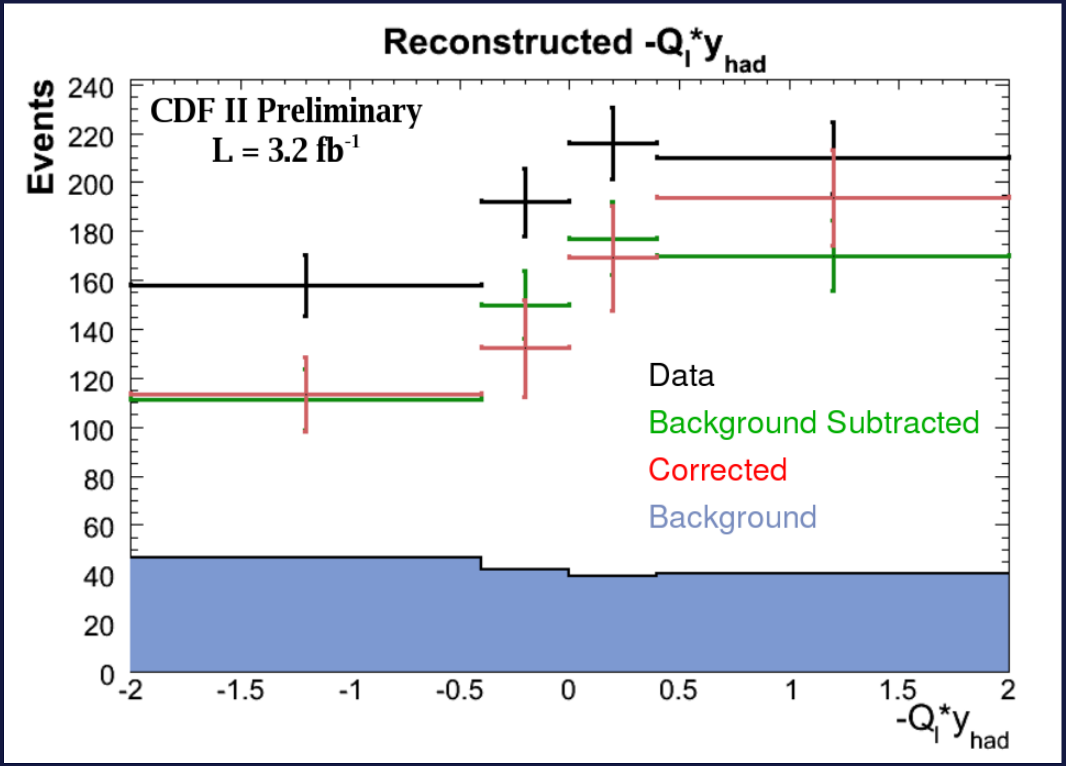


$$S_{ij} = N^{ij}_{recon}/N^{i}_{truth}$$

$$A_{ii} = N^{i}_{sel}/N^{i}_{gen}$$

$$N_{corrected} = A^{-1} \bullet S^{-1} \bullet N_{bkg\text{-}sub}$$

Corrected Asymmetry Measurement



Raw	$A_{fb} = 9.8 \pm 3.6\%$
Bkg-sub	$A_{fb} = 14.1 \pm 4.6\%$
Final Corrected	$A_{fb} = 19.3 \pm 6.5\%$

Systematic Errors and Result

Vary simulated data by ±σ and calculate A_{fb} difference with known sample

	Calc. Uncert.
Background Shape	0.011
Background Size	0.018
ISR/FSR	0.008
JES	0.002
PDF	0.001
MC Generator	0.003
Shape / Unfolding	0.006
Total Uncertainty	0.024

Final Corrected A_{fb} = 19.3 ± 6.5 ± 2.4%

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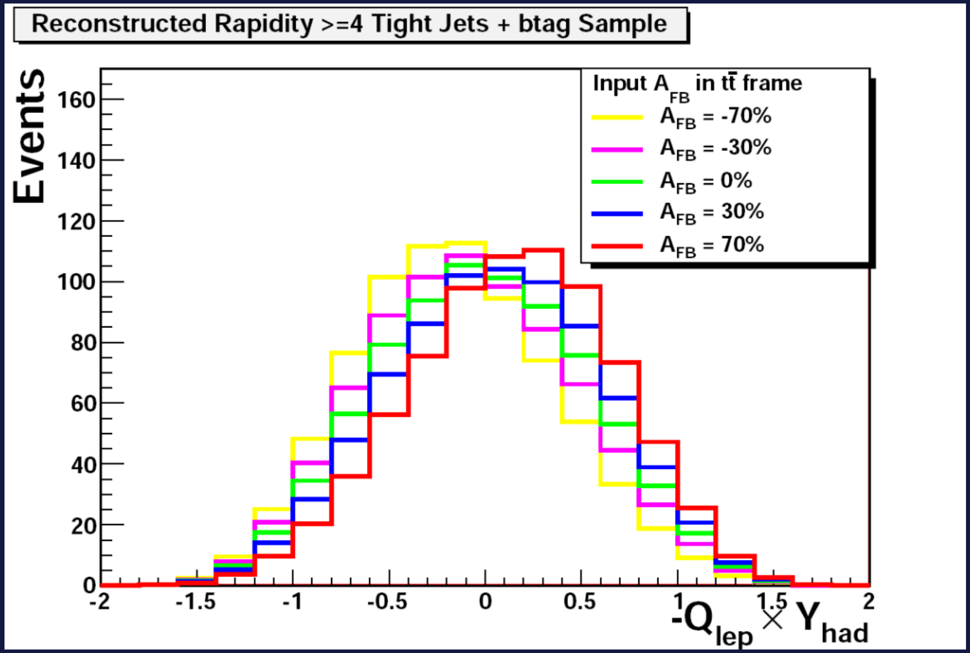
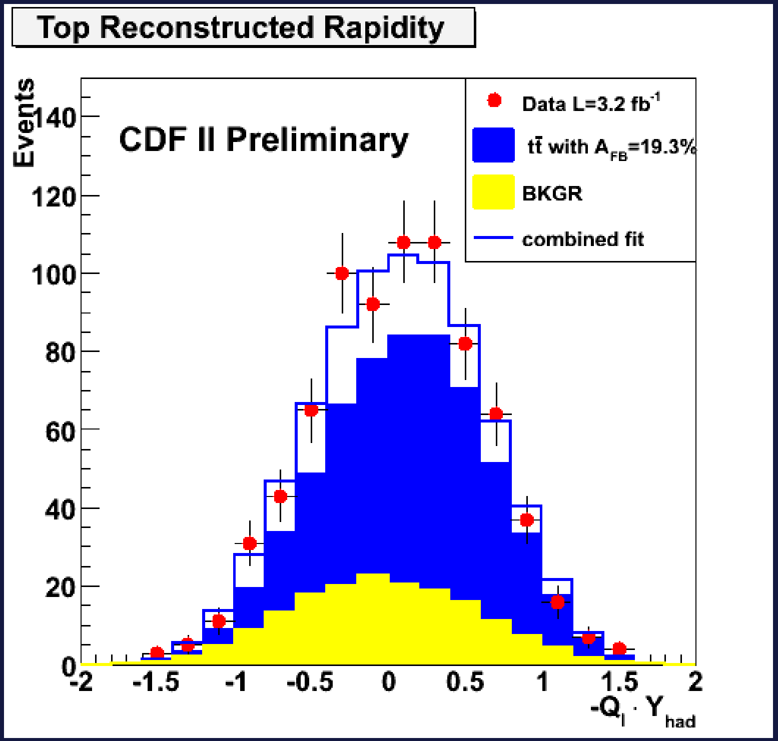
Statistical error dominates total error

Test of 1+A•Cos(θ) Hypothesis





The simplest form of an asymmetry is $1+A\cdot\cos(\theta_{tt})$

- Use Pythia MC (initial A_{fb}=0) and reweight by $1+A\cdot\cos(\theta_{tt})$ in the rest frame
- Propagate reweights to lab frame and rapidity variable to make a template
- Set up binned likelihood fit to data rapidity distribution using signal (templates) plus background contribution (Gaussian-constrained to background parameters)
- The good fit to the data supports the linear hypothesis

Conclusions

- Previous results (1.9 fb^{-1}):

  A_{fb} cos(θ) method: **$A_{fb}^{lab} = 17 \pm 8\%$**

- Current results (3.2 fb^{-1}):

  A_{fb} $-Q^{*}y_{hadtop}$ method: **$A_{fb}^{lab} = 19.3 \pm 6.5 \pm 2.4\%$**

- Are measured values are higher than the 5% SM prediction, but consistent within ~2 sigma

- Template technique shows data is consistent with linear hypothesis $1+A \cdot \cos(\theta_{tt})$

Backup Slides

Background Afb

Process	=4 jets	>=5 Jets	>=4 jets
W+HF Jets	-0.095±0.0078	-0.078±0.007	-0.087±0.0052
Mistags (W+LF)	-0.038±0.012	-0.05±0.01	-0.044±0.0079
Non-W (QCD)	-0.044±0.06	-0.002±0.044	-0.017±0.036
Single Top	-0.18±0.016	-0.12±0.018	-0.16±0.012
WW/WZ/ZZ	0.078±0.046	0.13±0.045	0.1±0.032
Z+Jets	-0.016±0.021	-0.0041±0.018	-0.01±0.014
Total Prediction	-0.07±0.012	-0.045±0.012	-0.059±0.0079

Corrected Asymmetry Measurement

$$S = \begin{bmatrix} 0.76\pm0.0096 & 0.13\pm0.0041 & 0.035\pm0.0022 & 0.011\pm0.0012 \\ 0.17\pm0.0046 & 0.66\pm0.0093 & 0.16\pm0.0046 & 0.042\pm0.0023 \\ 0.053\pm0.0025 & 0.17\pm0.0047 & 0.67\pm0.0095 & 0.16\pm0.0045 \\ 0.017\pm0.0014 & 0.042\pm0.0023 & 0.13\pm0.0042 & 0.79\pm0.01 \end{bmatrix}$$

$$A = \begin{bmatrix} 0.981\pm0.00483 & 0 & 0 & 0 \\ 0 & 1.09\pm0.00555 & 0 & 0 \\ 0 & 0 & 1.05\pm0.00547 & 0 \\ 0 & 0 & 0 & 0.901\pm0.00464 \end{bmatrix}$$

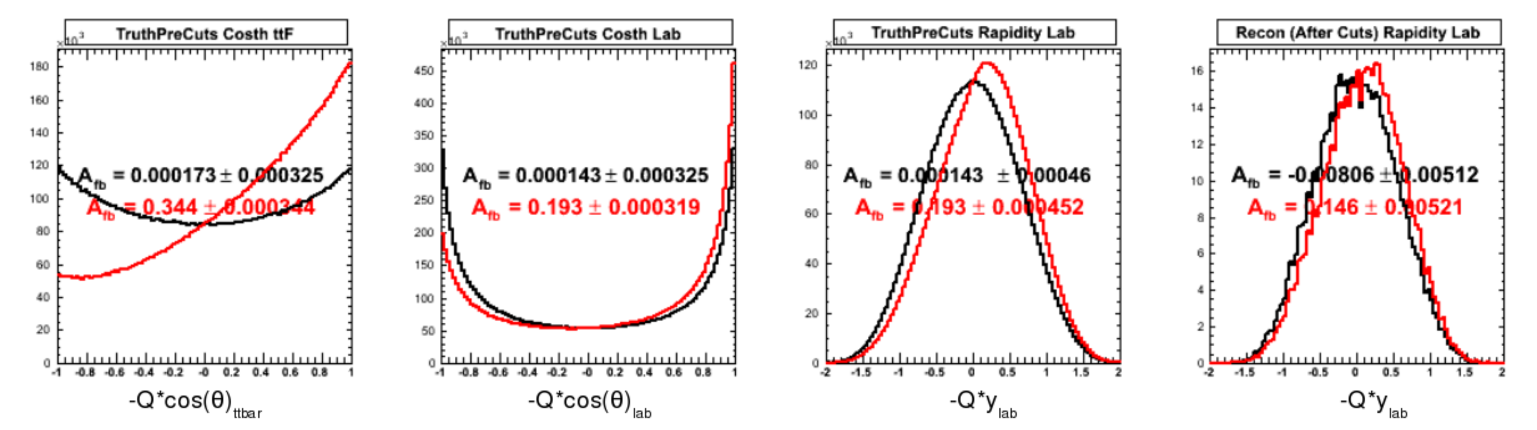
$$(A^{-1}\bullet S^{-1}) = \begin{bmatrix} 1.4 & -0.28 & -0.0061 & -0.0043 \\ -0.33 & 1.6 & -0.35 & -0.0084 \\ -0.016 & -0.38 & 1.6 & -0.29 \\ -0.0095 & -0.018 & -0.28 & 1.5 \end{bmatrix}$$

$S_{ij} = N^{ij}_{recon}/N^{i}_{truth}$

$A_{ii} = N^{i}_{sel}/N^{i}_{gen}$

$N_{corrected} = A^{-1}\bullet S^{-1}\bullet N_{bkg\text{-}sub}$

Propagation of Afb from ttbar frame to lab frame rapidity



- We make control samples with known asymmetry by reweighting Pythia Cos(θ) signal in the ttbar frame by

$$1+A\cdot\mathrm{Cos}(\theta_{tt})$$

- Propagate these changes to obtain appropriate factors for reweighting Y_{pp}
- Check corrected measurement vs known A_{fb} for $\mathrm{Cos}(\theta_{tt})$ signal