The Top Pair Forward-Backward Asymmetry with the Full CDF Dataset

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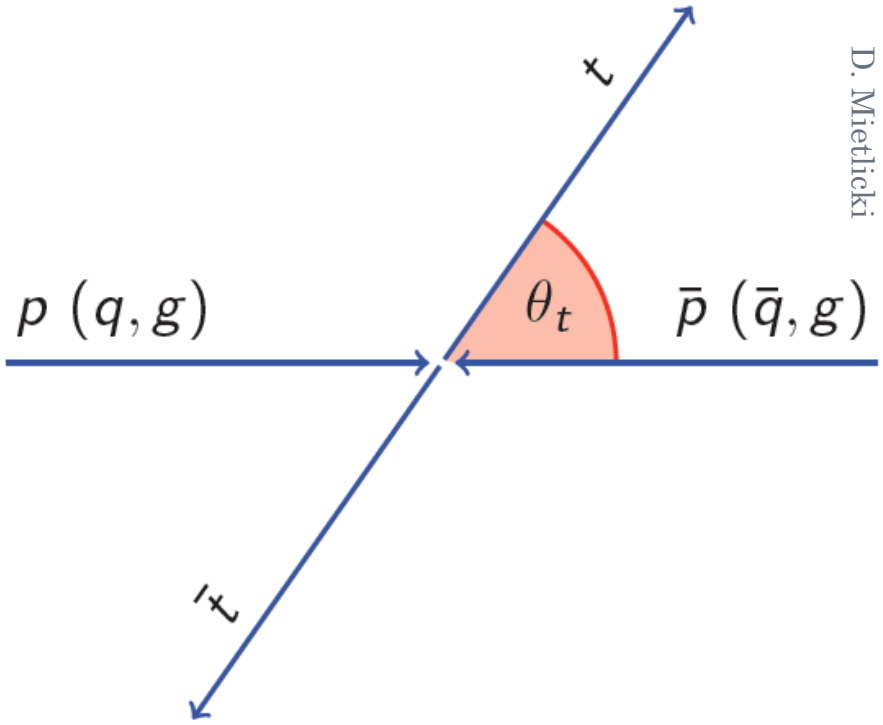
The Top Quark

- Top was the last quark to be discovered
- Top quarks are very heavy
  - Special role in electroweak symmetry breaking?
  - Enhanced coupling to new physics?
- Top pair production specified by:
  - α_s: strong coupling
  - q^2: energy scale
  - s: spin/polarization
  - θ: production angle (A_{FB}!)
- Recent measurements of A_{FB} give moderate excesses above SM prediction



Measuring the Top Asymmetry

- In proton-antiproton collisions, a charge asymmetry is equivalent to a forward-backward asymmetry in the production angle
- Use Δy as a proxy for production angle
  - Same variable as previous analyses
  - Invariant to boosts along the beamline
    - A_{FB} measured in top pair rest frame
  - Inclusive A_{FB} is the same in Δy and $\cos\theta$
- A_{FB} measurement is unique to the Tevatron
  - LHC experiments can see a top pair charge asymmetry
  - But it requires different techniques and the expected magnitude is much smaller

$$y = \frac{1}{2}\ln\left(\frac{E + p_z}{E - p_z}\right)$$

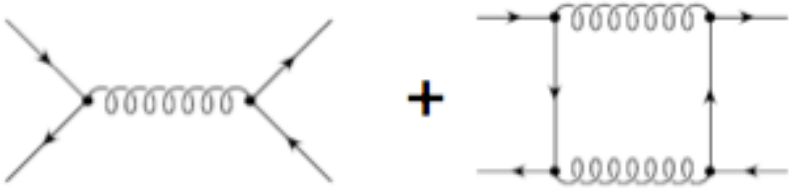
$$\Delta y = y_t - y_{\bar{t}}$$

$$A_{FB} = \frac{N_{\Delta y>0} - N_{\Delta y<0}}{N_{\Delta y>0} + N_{\Delta y<0}}$$

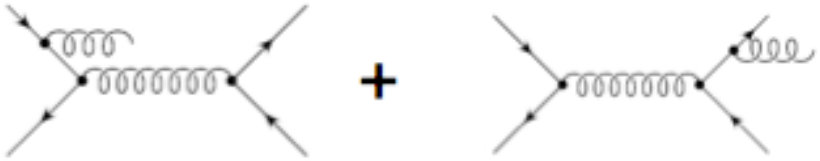
The Standard Model Prediction

- Leading order: no asymmetry
- Next-to-leading order: interference terms generate small asymmetry
- Some uncertainty regarding theory predictions
  - E.g., use LO or NLO cross-section for A_{FB} denominator?
- Predictions shown today are from NLO Monte Carlo generator POWHEG
  - No theory uncertainty quoted
    - Compare to one particular well-defined calculation
  - POWHEG (NLO) denominator
  - Flat correction of 26% for Δy asymmetries for electroweak contributions

Born + Box Interference
Positive Contribution to A_{FB}



ISR/FSR Interference
Negative Contribution to A_{FB}



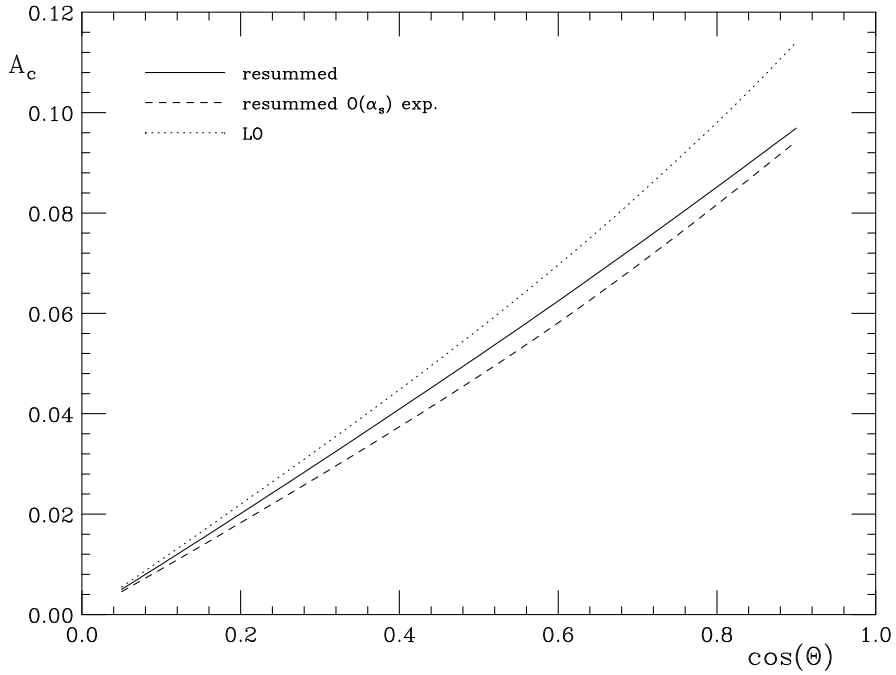
$$A_{FB}^{NLO} = 6.6\%$$

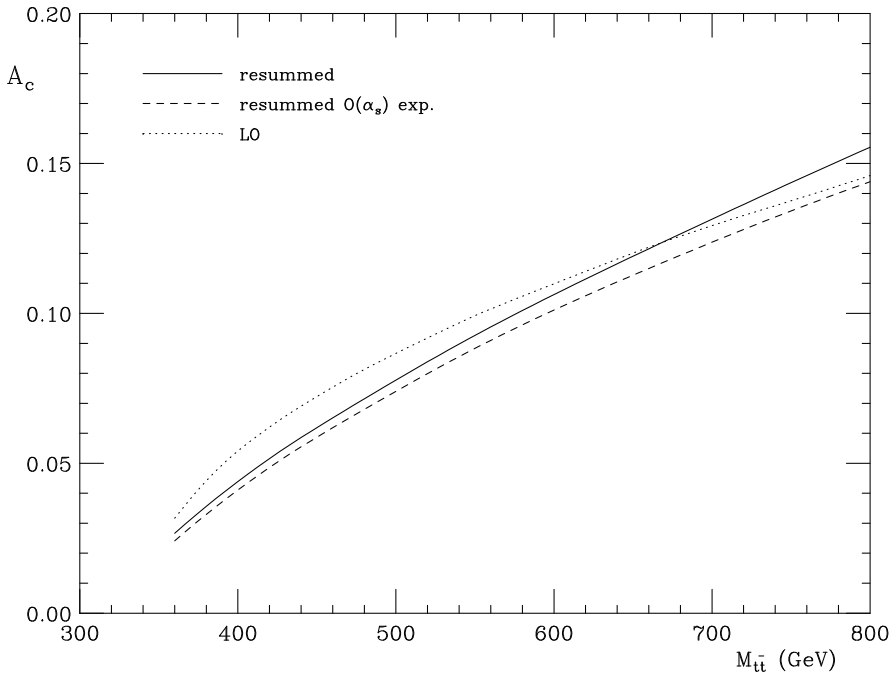
POWHEG: JHEP **0709**, 126 (2007)

EW Corrections: Phys. Rev. D **84**, 093003 (2011); JHEP **1201**, 063 (2012); arXiv:1201.3926[hep-ph]

Differential Asymmetries

- Expected standard model dependence of A_{FB} on $\cos\theta$ (top) and M_{tt} (bottom)
  - Plots from L. Almeida, G. Sterman, and W. Vogelsang, Phys. Rev. D **78**, 014008 (2008).

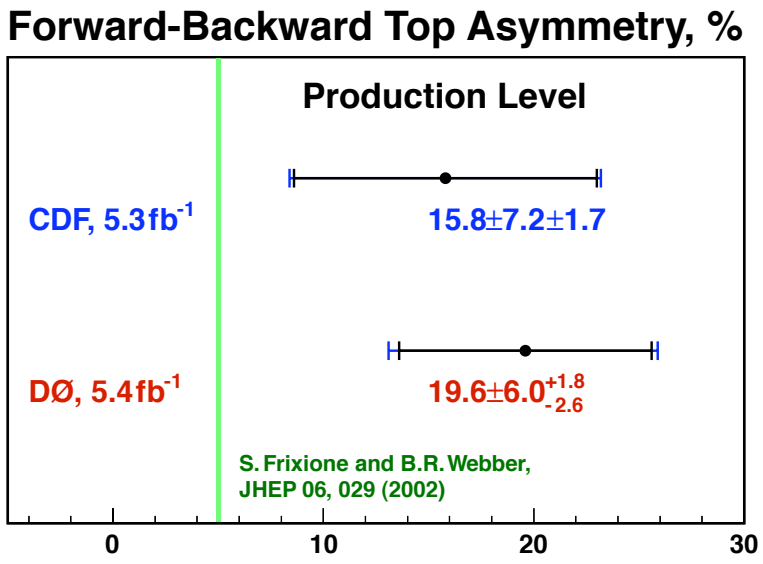




The Asymmetry in ~5 fb^{-1}

- Both CDF and D0 measure large inclusive A_{FB}
  - ~3 σ from no asymmetry
  - ~1.5-2 σ above SM prediction
  - Good consistency between measurements

Measurement	Parton Level A_{FB} (%)
[1]CDF Lep+Jets, 5.3 fb^{-1}	15.8 ± 7.4
[2]CDF Dilepton, 5.1 fb^{-1}	42 ± 16
[3]CDF Combined	20.1 ± 6.7
[4]D0 Lep+Jets, 5.4 fb^{-1}	19.6 ± 6.5
Informal Combination*	19.8 ± 4.7
NLO (QCD+EW)	6.6



*NOT an official result – just a simple weighted average of the D0 lepton+jets and the combined CDF results (correlations of systematics NOT included)

[1]Phys. Rev. D **83**, 112003 (2011). [2]CDF Conference Note 104367.
[3]CDF Conference Note 10584. [4]Phys. Rev. D **84**, 112005 (2011).

Mass and Rapidity Dependence

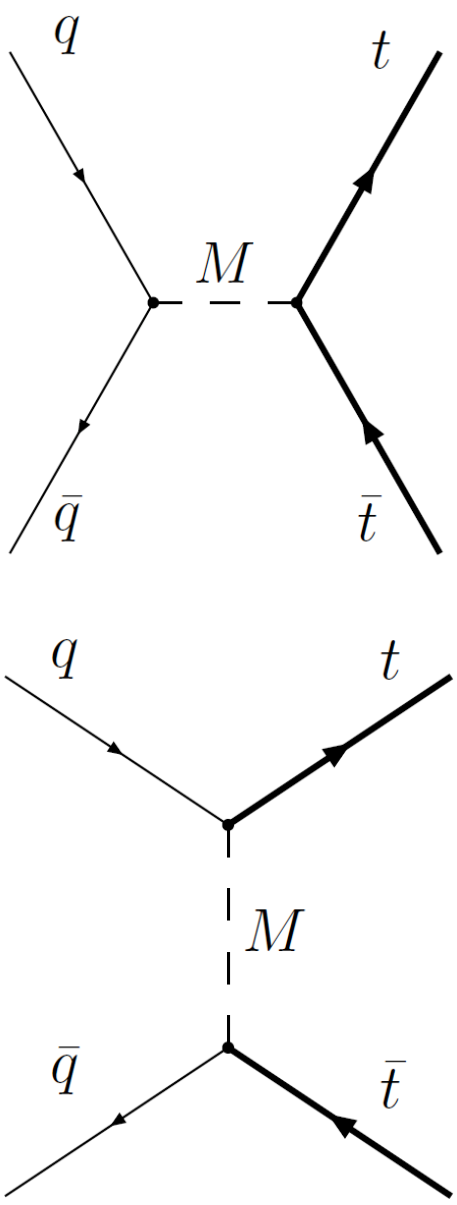
- Mass and rapidity dependence studied in only 2 bins of M_{tt} and Δy – results are somewhat ambiguous
  - Large mass dependence at CDF, no significant effect at D0
    - Consistent at ~1.7 σ level
  - CDF observes large rapidity dependence, smaller at D0
    - Consistent within 1 σ

Background-Subtracted A_{FB} (%)	D0 Lep+Jet, 5.4 fb^{-1}	CDF Lep+Jet, 5.3 fb^{-1}	Informal Combination*
$M_{tt} < 450$ GeV/c^2	7.6 ± 4.8	-2.2 ± 4.3	$2.1 \pm 3.2^*$
$M_{tt} \geq 450$ GeV/c^2	11.5 ± 6.0	26.6 ± 6.2	$18.6 \pm 4.3^*$
$\lvert\Delta y\rvert < 1.0$	6.1 ± 4.1	2.9 ± 4.0	$4.5 \pm 2.9^*$
$\lvert\Delta y\rvert \geq 1.0$	21.3 ± 9.7	29.1 ± 9.6	$25.2 \pm 6.8^*$

*NOT an official result – just a simple weighted average of the D0 and CDF lepton+jets results

Theoretical Considerations Regarding A_{FB}

- 5 fb^{-1} A_{FB} measurements moderately exceeded SM prediction
  - Largest deviation (CDF, high mass) > 3 σ
  - Much theoretical work followed
    - SPIRES: 190 citations of 5.3 fb^{-1} CDF PRD
- Do we need better understanding of SM?
  - Refined calculations
    - EW corrections
    - NNLO calculations in progress
  - SM prediction increased, but not yet enough to match observed data
- Could it be new physics?
  - Two main classes of models:
    - s-channel mediator (e.g., axigluon)
    - t-channel flavor changing mediator (e.g., W', Z')
  - Mass/rapidity dependence can untangle new physics from QCD
  - For a review, see, e.g., M. Gresham, I.-W. Kim, and K. Zurek, Phys. Rev. D **83**, 114027 (2011).



What's New in the Latest CDF Analsysis?

- Increase luminosity to 8.7 fb^{-1} and include new data stream ("loose muons")
  - Full CDF dataset with entire detector including silicon
  - Sample size (2498 events) is doubled
    - 1260 events in 5.3 fb^{-1}
- NLO generator POWHEG now used for signal modeling
  - 5.3 fb^{-1} analysis used PYTHIA (LO)
  - NLO model includes the small SM asymmetry
  - Better modeling of acceptances in events with extra jets
- New regularized unfolding method used for corrections to parton level
  - Properly treat multi-bin distributions for differential A_{FB}
- Improvements allow verification of the inclusive asymmetry and more robust study of the mass and rapidity dependence

Selecting Top Pair Events

- Top pairs produced by two main processes at Tevatron:
  - Quark-antiquark annihilation (~85%)
  - Gluon fusion (~15%)
    - Symmetric initial state, no contribution to A_{FB}
- Lepton+ jets decay channel:

$$t\bar{t} \rightarrow (W^+b)(W^-\bar{b}) \rightarrow (l\nu)(q\bar{q}')b\bar{b}$$

  - CDF also has a measurement where both W's decay leptonically
- Trigger on a central high P_T lepton or events with large missing E_T and at least 2 jets
  - Latter events (loose muons) new compared to 5.3 fb^{-1}
- Selection requirements:
  - Exactly one central electron (muon) with E_T (P_T) > 20 GeV (GeV/c)
  - At least four jets with E_T > 20 GeV
    - At least one tagged as a *b* jet
  - Missing E_T > 20 GeV
  - Total transverse energy H_T > 220 GeV
- 2498 total candidate events

Sample Composition

- Top signal modeled with NLO POWHEG
- Electroweak backgrounds from Monte Carlo
  - Diboson: PYTHIA
  - Single Top: MadEvent
  - Z+jets: ALPGEN
- W+jets shape modeled by ALPGEN
- QCD shape from data
- W+jets and QCD normalizations determined from fit to the missing E_T spectrum
- 505 predicted background events

Source	Predicted Event Count, 8.7 fb^{-1}
W + Heavy Flavor	241 ± 78
Non-W (QCD)	98 ± 51
W + Light Flavor	96 ± 29
Single Top	33 ± 2
Diboson	19 ± 3
Z + Jets	18 ± 2
Total Background	505 ± 123
Top Pairs (7.4 pb)	2037 ± 277
Total Prediction	2542 ± 303
Data	2498

Reconstructing Top Pair Events

- Match observed jets to top decay products: χ^2-based kinematic fit to top-antitop hypothesis
  - $M_t = 172.5$ GeV/c^2
  - $M_W = 80.4$ GeV/c^2

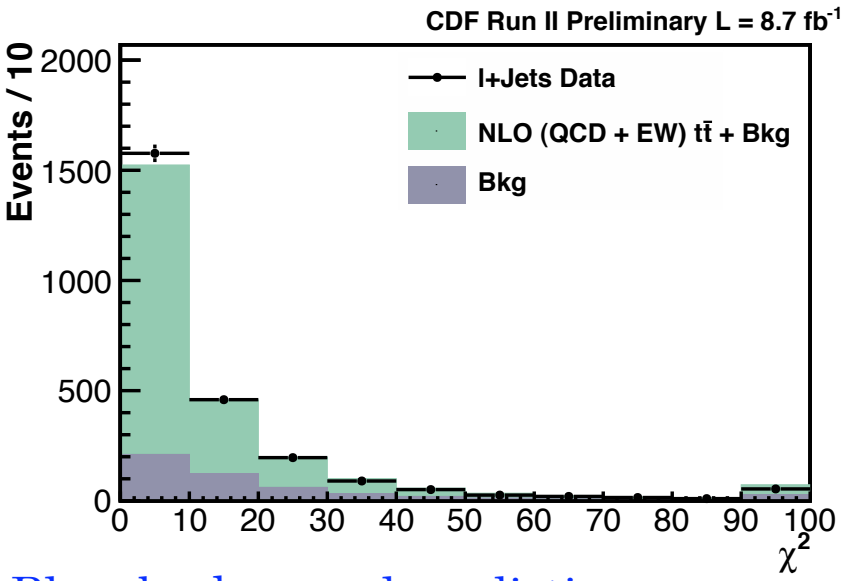
$$\chi^2 = \sum_{i=l,jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i} + \sum_{j=x,y} \frac{(p_j^{Unc.Energy,fit} - p_j^{Unc.Energy,meas})^2}{\sigma_j}$$

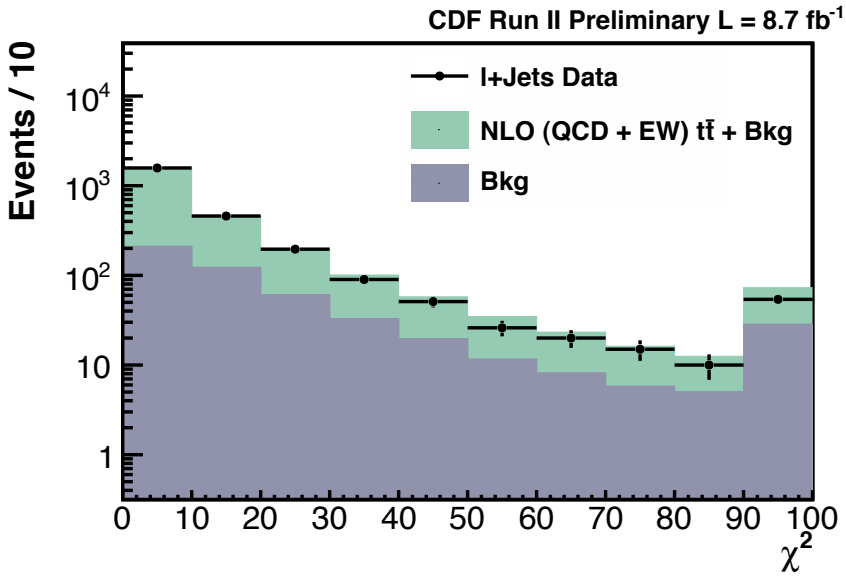
$$+ \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{l\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - M_t)^2}{\Gamma_t^2} + \frac{(M_{bl\nu} - M_t)^2}{\Gamma_t^2}$$

- Four leading jets enter the fit
- Measured energies float within uncertainties
- Choose solution with the smallest χ^2
- Determine top and antitop four-vectors from decay product momenta
- Lepton charge used to assign the charge of all final state objects

The χ^2 Distribution

- Plots: χ^2 for the best solution from the kinematic reconstruction
- Well-modeled by signal + background prediction,
  - Even for events with large χ^2





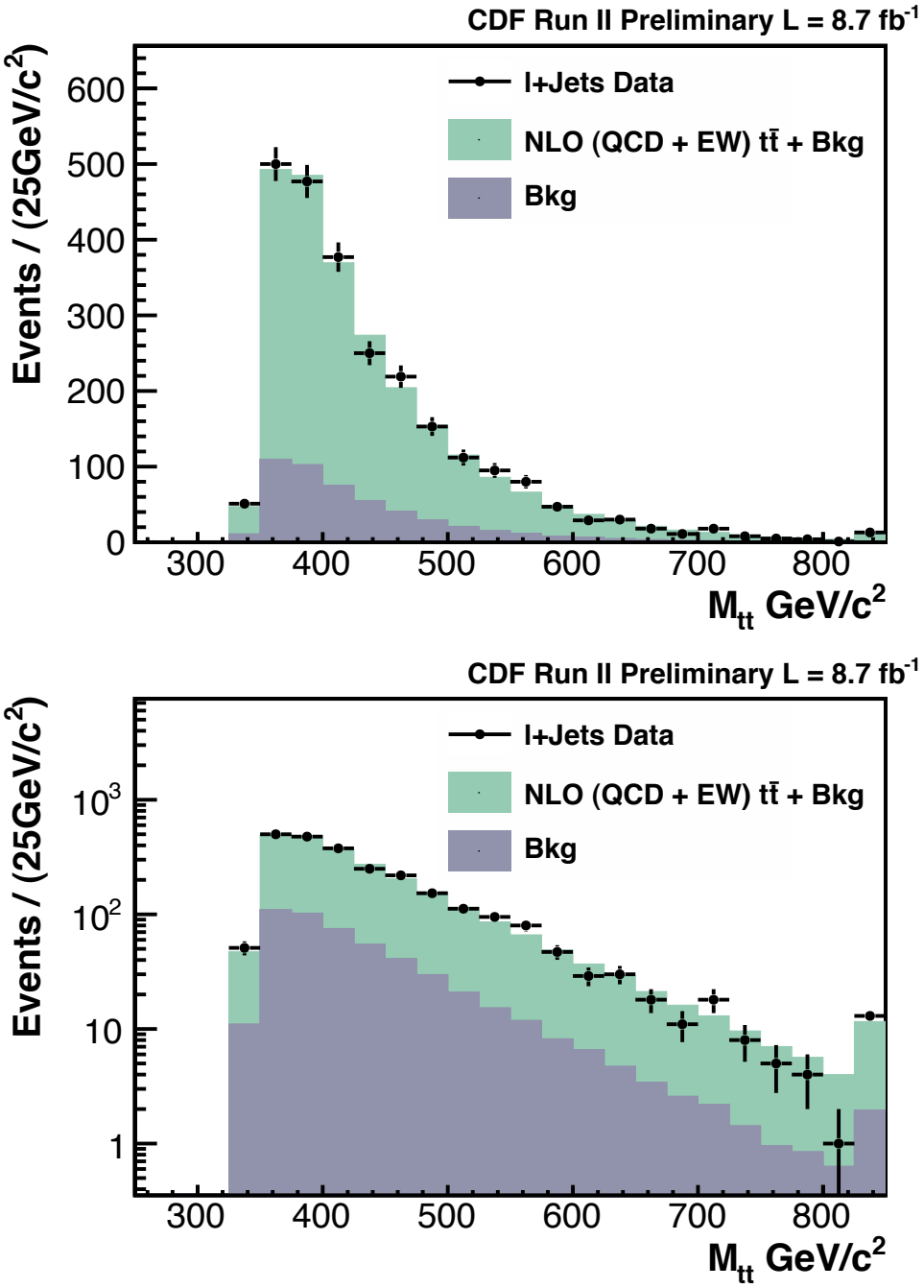
Blue: background prediction

Green: NLO POWHEG signal

– Stacked with backgrounds

Black: observed data

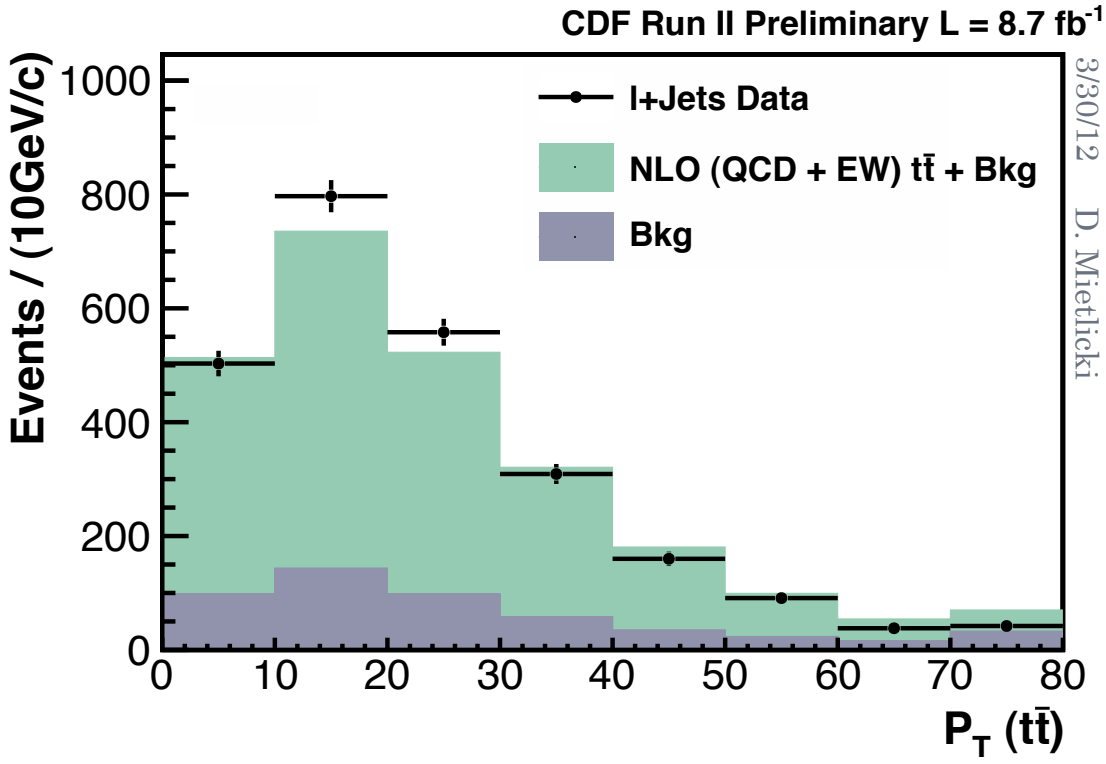
The Top-Pair Mass Distribution



- Reconstructed invariant mass of top-antitop system also well-modeled

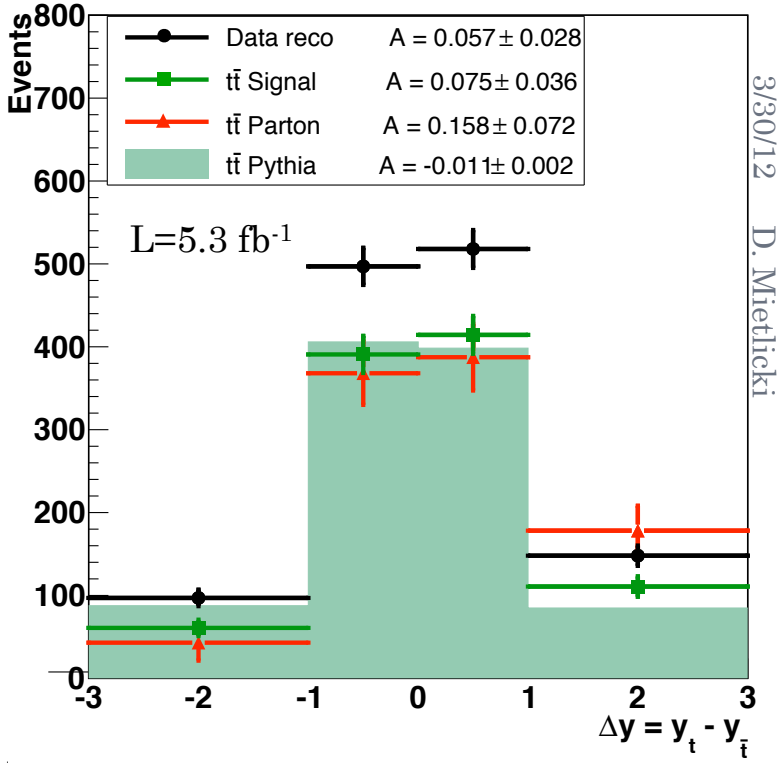
The Top Pair P_T

- Transverse momentum of top pair is a good check of background model, event reconstruction
  - Sensitive to soft jets
  - Correlated with A_{FB}
    - ISR/FSR give negative contribution to asymmetry
- Good agreement between data and NLO MC + background prediction



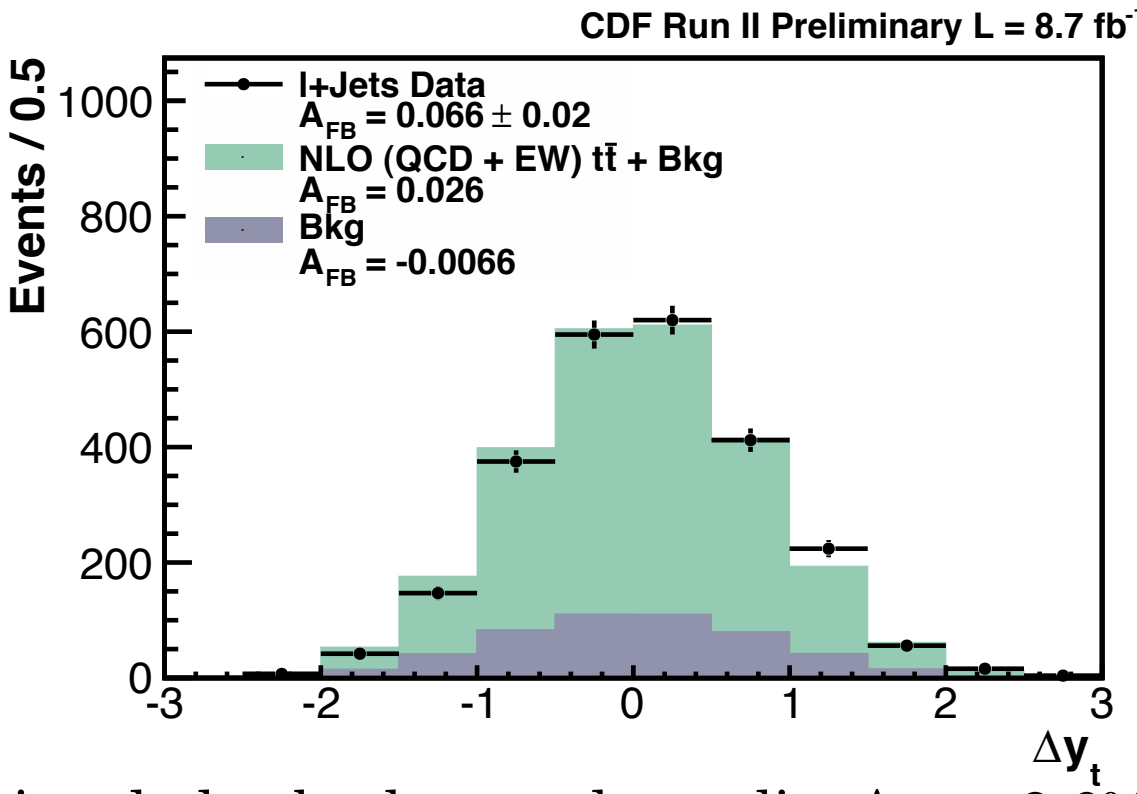
Three Measurement Levels

- Measure A_{FB} at three levels of correction:
  - Reconstruction (Raw Data) Level:
    - Observed data, no additional correction
    - Includes background contributions
    - *NLO A_{FB} (with backgrounds): 2.6%
  - Background Subtracted (Signal) Level:
    - Remove predicted backgrounds
    - Pure top sample, but includes effects of event selection and reconstruction
    - *NLO A_{FB}: 3.3%
  - Parton Level:
    - Correct for acceptances and reconstruction effects
    - Direct comparison to theoretical models
    - *NLO A_{FB}: 6.6%



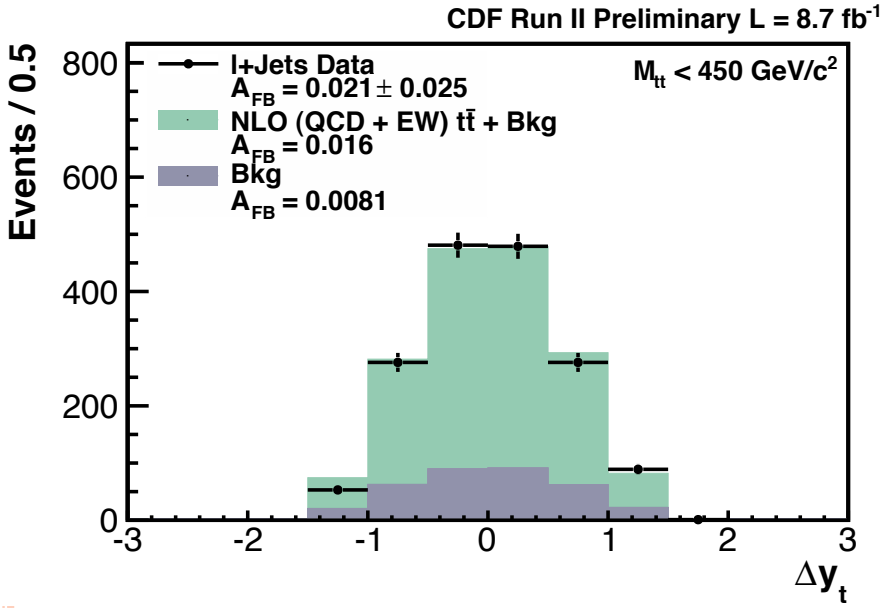
*NLO predictions in this talk always include flat 26% correction to POWHEG for electroweak contributions

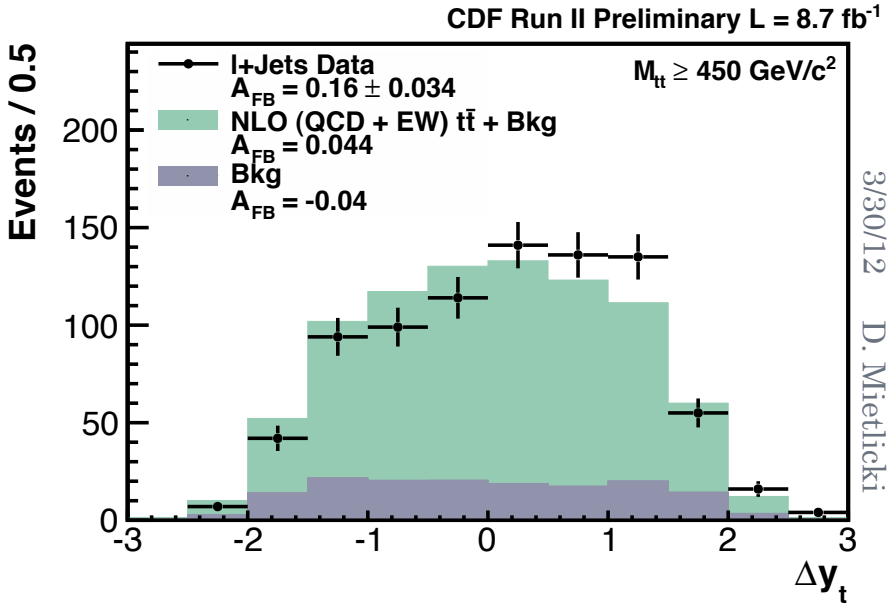
Reconstruction Level Δy in 8.7 fb^{-1}



- NLO signal plus backgrounds predict $A_{FB} = 2.6\%$
  - Signal prediction includes reweighting for electroweak contributions
- Observed inclusive asymmetry is $(6.6 \pm 2.0)\%$
  - $> 3\sigma$ from no asymmetry
- For large and small Δy:
  - $A_{FB}(|\Delta y| < 1.0) = (3.1 \pm 2.2)\%$
  - $A_{FB}(|\Delta y| \geq 1.0) = (21.0 \pm 4.4)\%$

Δy at High and Low Mass

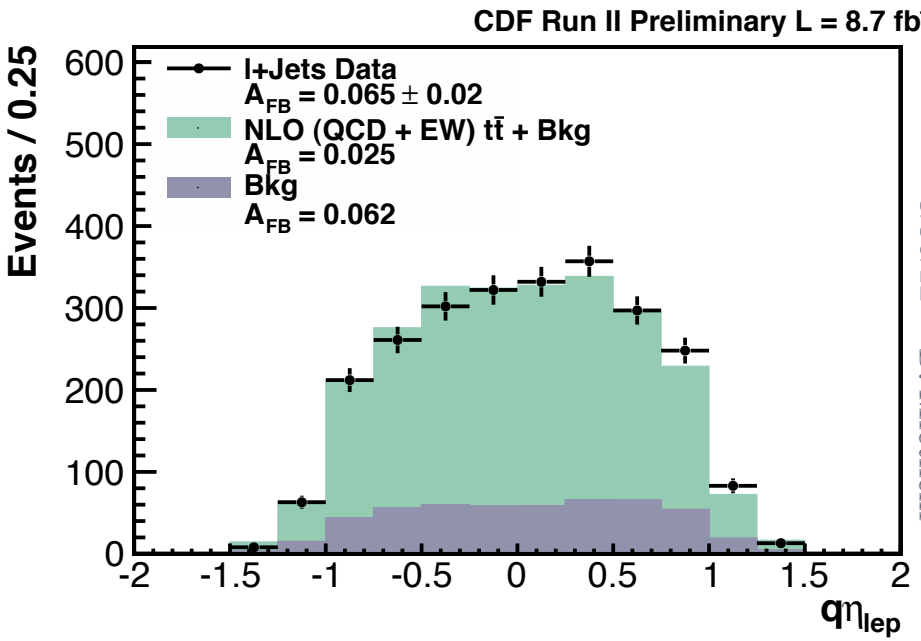




- Δy distribution for M_{tt} above and below 450 GeV/c^2
  - Cut-off defined in 5.3 fb^{-1} analysis
- Low mass consistent with expectation
- Large asymmetry at high mass: (15.5 ± 3.4)%
  - 4.5 σ from no asymmetry, 3.3 σ from prediction
  - Consistent in events with positive (15.5 ± 4.8)% and negative (15.6 ± 4.8)% leptons

The Leptonic Asymmetry

- Could A_{FB} be an artifact of the reconstruction?
- Lepton allows independent measurement of the asymmetry
  - Direction of motion correlated with parent top quark
  - Measurement of lepton direction does not require event reconstruction
- Find asymmetry in $q \times \eta_{lep}$
- A_{FB} exceeds signal + background prediction
  - Significance similar to that of Δy A_{FB}

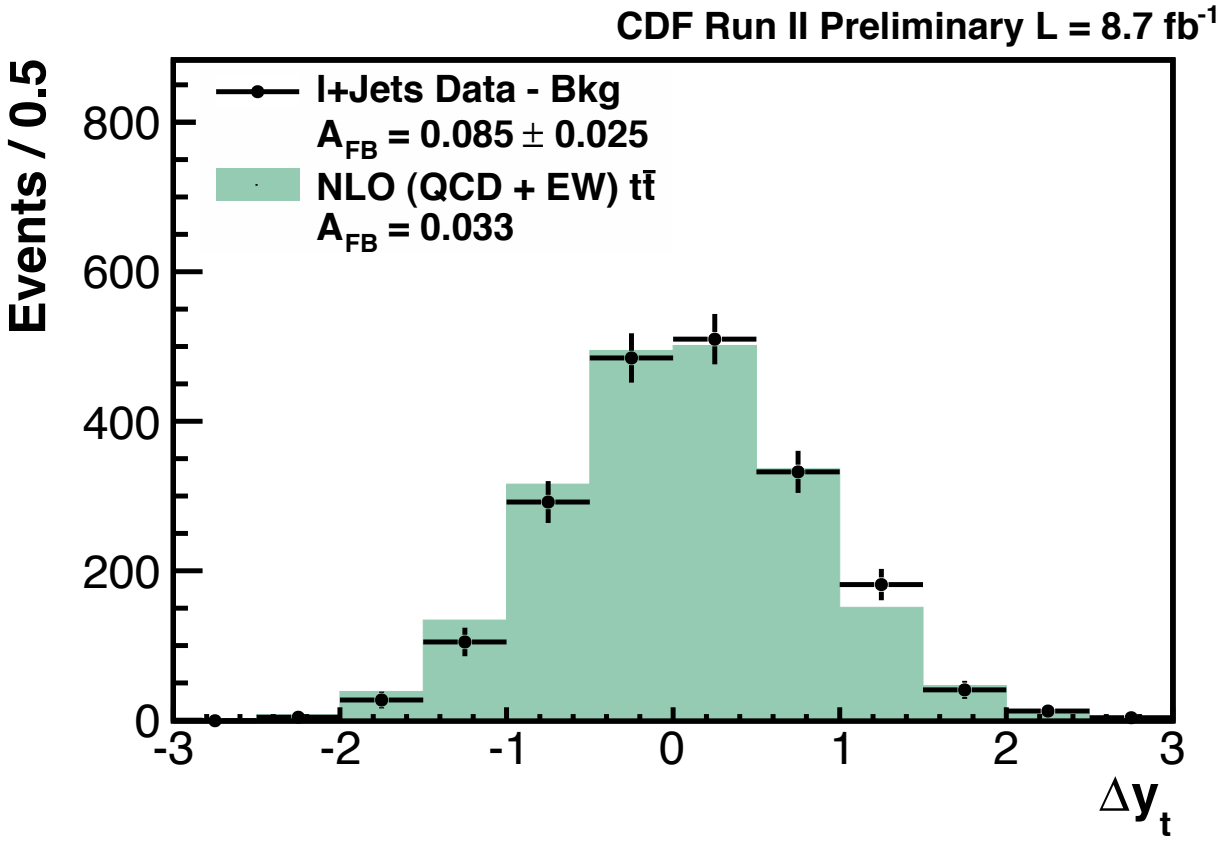


Sample	Predicted A_{FB} (%)	Observed A_{FB} (%)
Inclusive	2.5	6.5 ± 2.0
$M_{tt} < 450$ GeV/c^2	2.3	4.7 ± 2.5
$M_{tt} \geq 450$ GeV/c^2	3.3	10.1 ± 3.4

Removing the Backgrounds

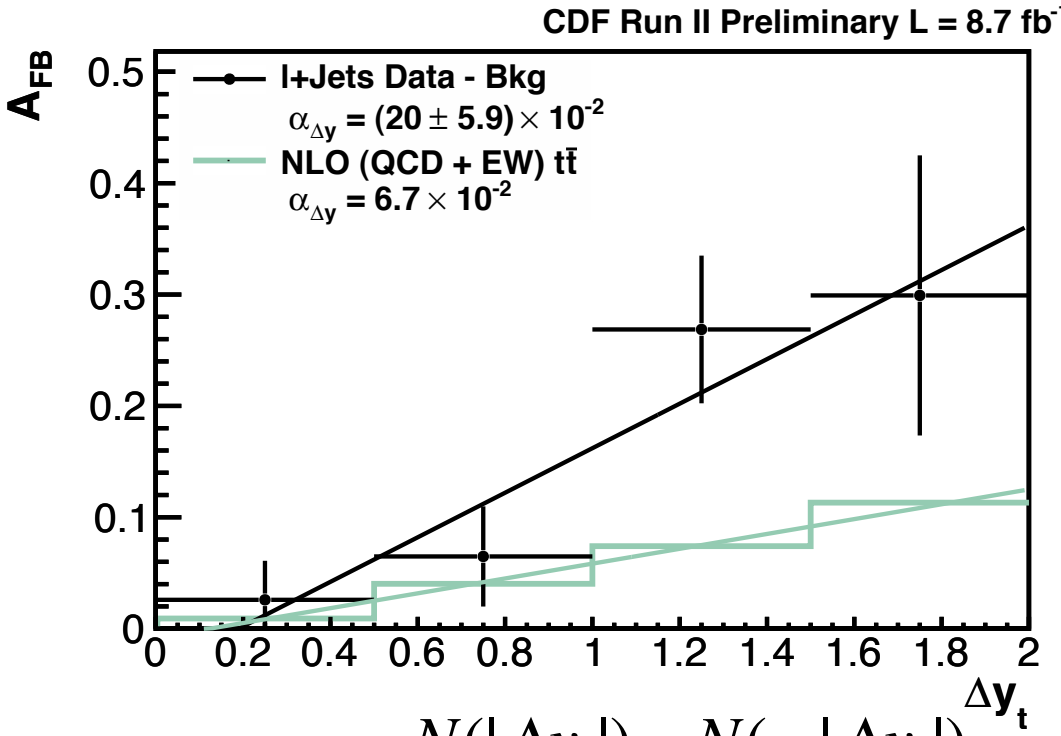
- ~20% of selected sample is composed of events from background sources
  - Dominant sources: W+jets, QCD multi-jet events
  - For Δy, the backgrounds have small inherent asymmetry, but dilute any A_{FB} in the top signal
- Remove background contribution by subtracting the predicted background distribution from the observed data
- Results include systematic uncertainties on the predicted background shape and normalization
  - $\sigma_{syst} <$ ~20% of σ_{stat} in general
    - Uncertainties still dominated by statistics

Δy After Background Subtraction



- Observed asymmetry after background subtraction is (8.5 ± 2.5)%
- NLO POWHEG predicts 3.3%
  - Observation is 3.4 σ from no A_{FB}, 2.1 σ from prediction

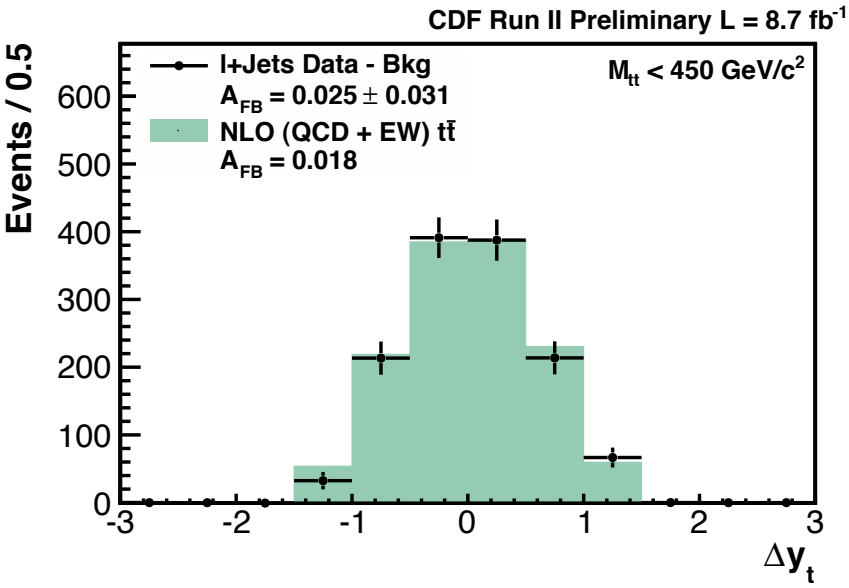
Rapidity-Dependent Differential A_{FB}

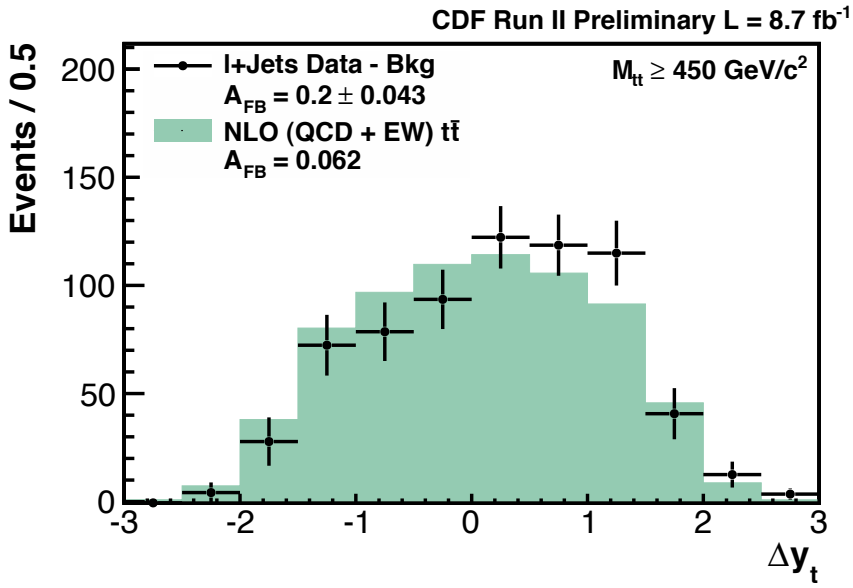


$$A_{FB}(|\Delta y|) = \frac{N(|\Delta y|) - N(-|\Delta y|)}{N(|\Delta y|) + N(-|\Delta y|)}$$

- Observed A_{FB} as a function of $|\Delta y|$ well-described by linear ansatz
  - Determine best-fit slope – easily compare data to prediction
  - χ^2/d.o.f. = 1.0, significant non-zero slope
  - Slope is not a specific theoretical parameter
    - Linear fit motivated by approximate linearity of SM prediction

Background-Subtracted Δy at High and Low Mass





- Low mass distribution consistent with NLO prediction
- The large asymmetry predominantly arises at high mass – $(19.8 \pm 4.3)\%$
  - $4.6\,\sigma$ from no asymmetry
  - NLO POWHEG predicts 6.2% at high mass

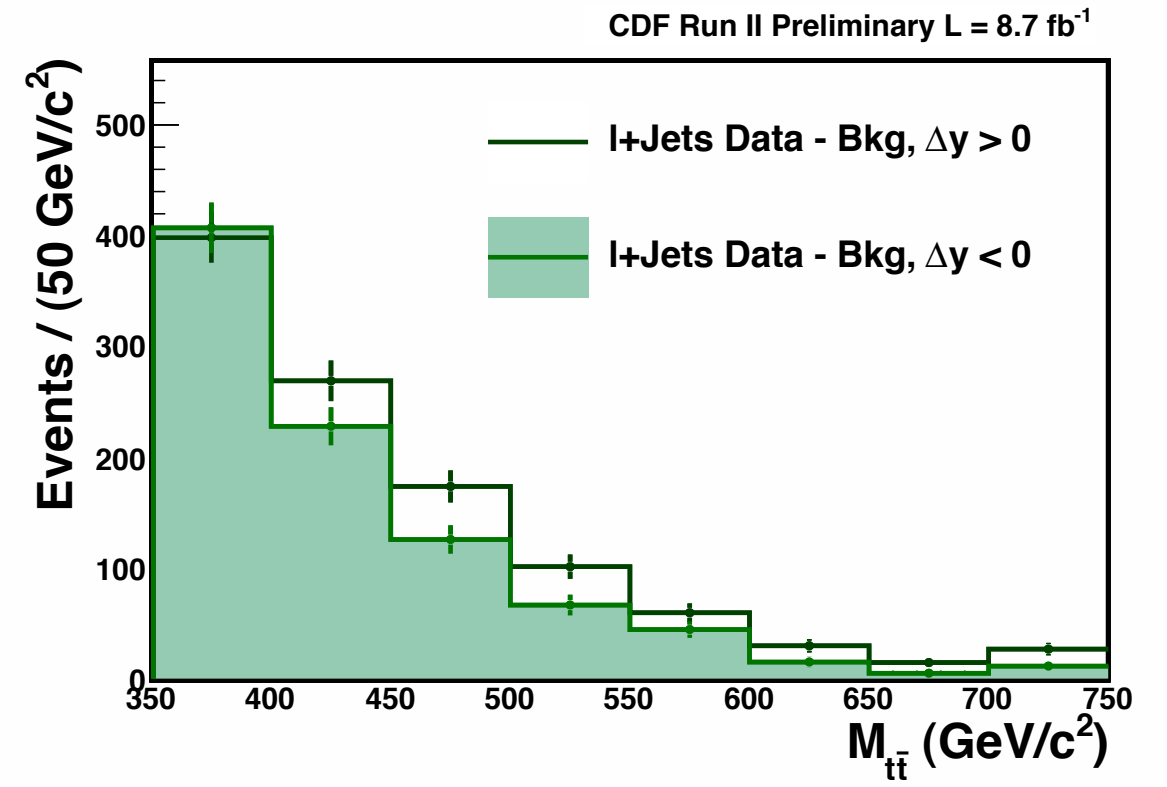
Comparison to Previous Background-Subtracted Mass-Dependent Results

Background -Subtracted A_{FB} (%)	D0 Lep+Jet, 5.4 fb^{-1}	CDF Lep +Jet, 5.3 fb^{-1}	Informal 5 fb^{-1} Combination*	CDF Lep +Jet, 8.7 fb^{-1}
$M_{tt} < 450$ GeV/c^2	7.6 ± 4.8	-2.2 ± 4.3	$2.1 \pm 3.2^*$	2.5 ± 3.1
$M_{tt} \geq 450$ GeV/c^2	11.5 ± 6.0	26.6 ± 6.2	$18.6 \pm 4.3^*$	19.8 ± 4.3

- Two-bin mass dependence statistically consistent among the D0 measurement and both CDF results
  - Very good agreement of new CDF data with simple weighted average of previous CDF and D0 results

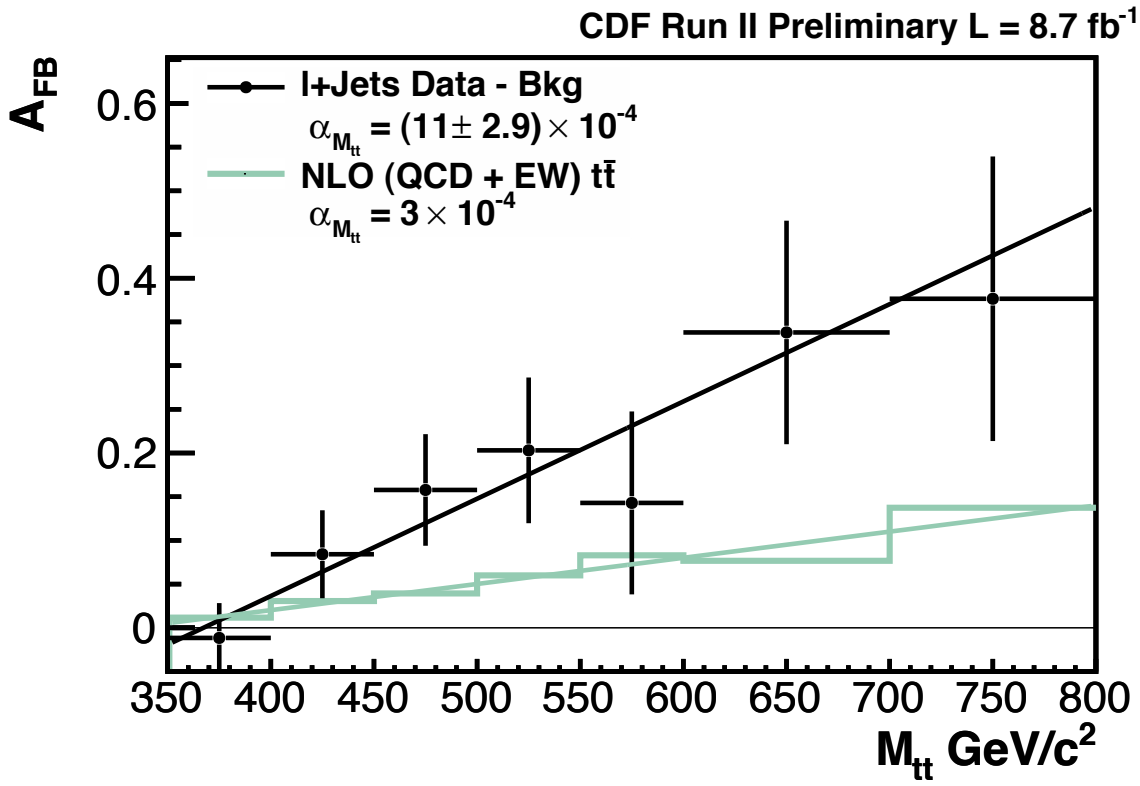
*NOT an official result – just a simple weighted average of the D0 and CDF lepton+jets results

The Invariant Mass Distribution for Forward and Backward Events



- Compare the M_{tt} distributions for events with positive and negative Δy
  - Approximately equal at lowest masses, but excess of forward events at higher mass

Mass-Dependent Differential A_{FB}



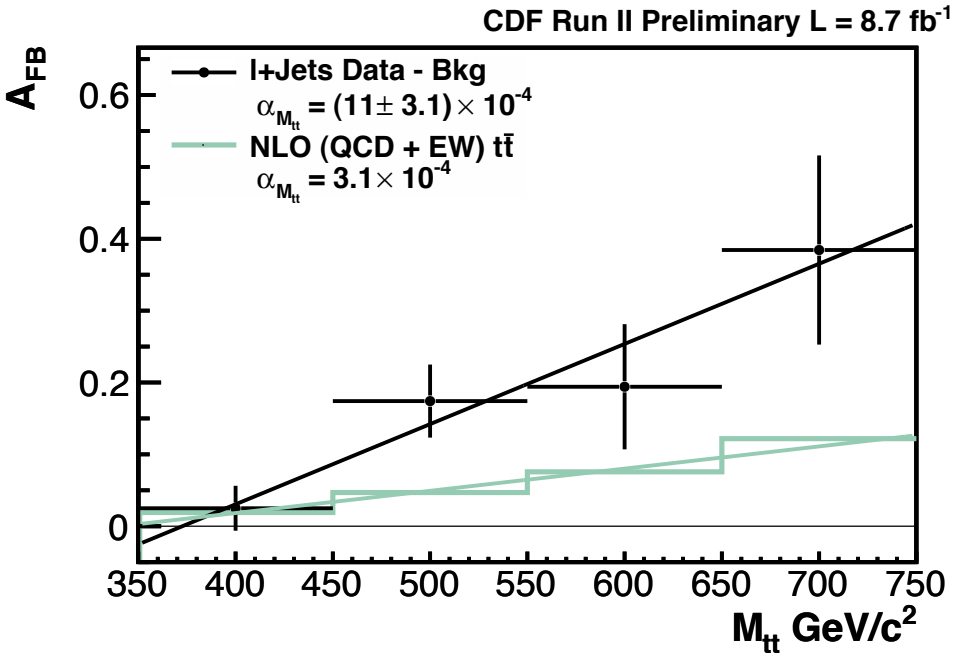
$$A_{FB}(M_{tt}) = \frac{N_F(M_{tt}) - N_B(M_{tt})}{N_F(M_{tt}) + N_B(M_{tt})}$$

- Determine A_{FB} as a function of M_{tt} with finer binning
- Again well-described by linear ansatz
  - Determine best-fit slope for data and prediction
  - χ^2/d.o.f. = 0.3

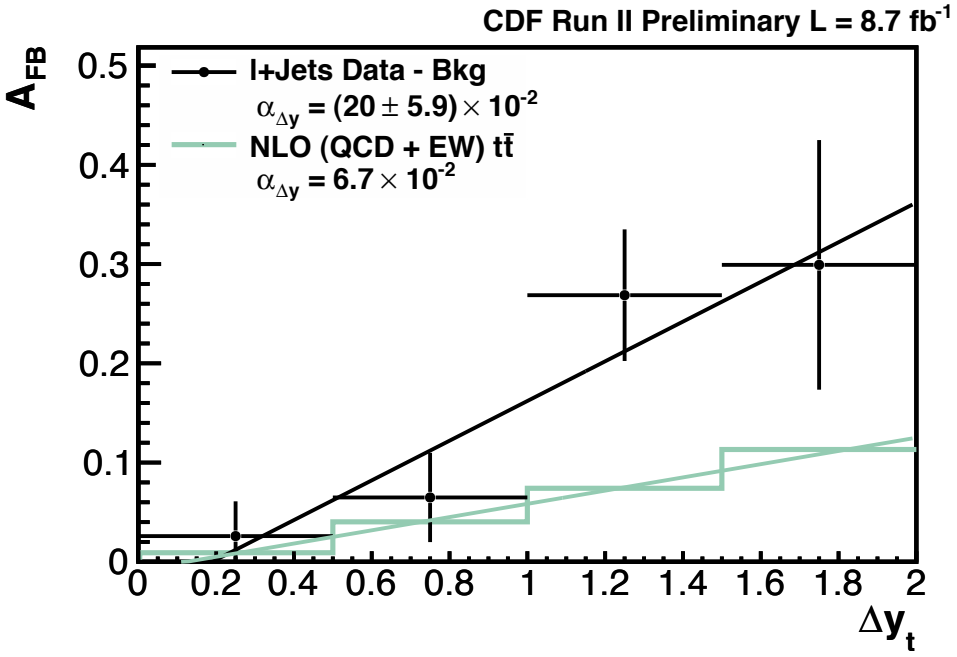
Determining the Significance

- How significant is the discrepancy between the POWHEG SM prediction and observed differential A_{FB}?
  - Evaluate at background-subtracted level – avoid any complications from the parton-level correction procedure
    - Correction assumes standard model acceptances and resolution
- Quantify by comparing best-fit slopes to find p-value
- Start with the nominal POWHEG prediction, perform simulated experiments with Poisson fluctuations on this prediction
  - No theory uncertainty included – compare specifically to the NLO POWHEG calculation (with EW corrections)
- p-value: fraction of experiments where $\alpha_{NLO} \geq \alpha_{data}$

P-VALUES FOR DATA SLOPES VS. PREDICTION



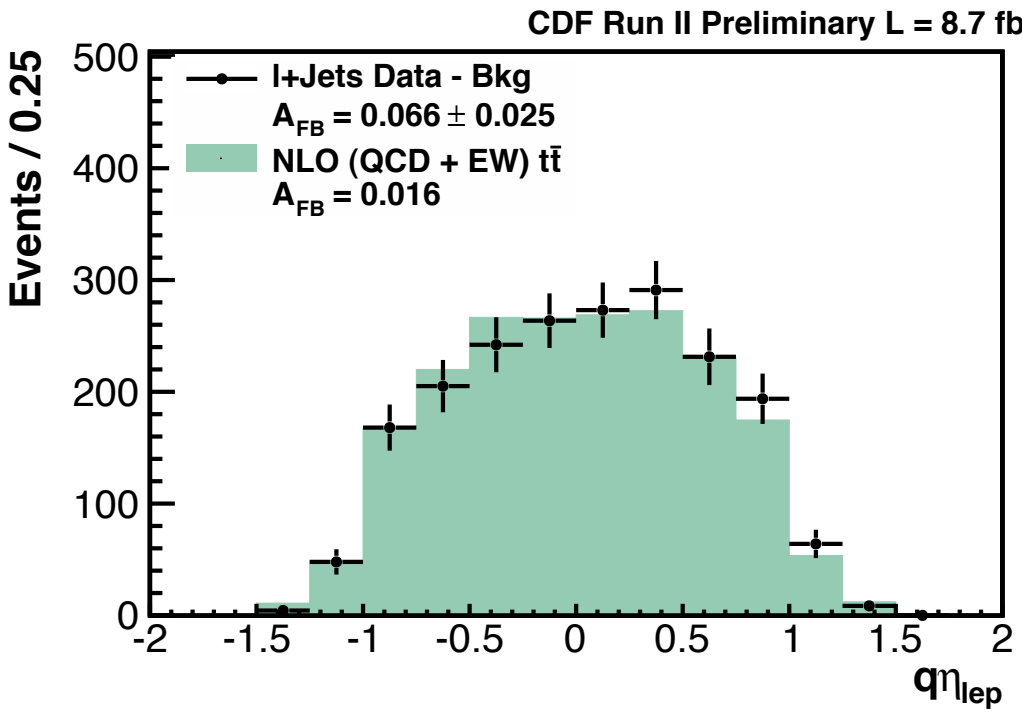
$\alpha(M_{tt})$ p-value: 6.46×10^{-3}



$\alpha(\Delta y)$ p-value: 8.92×10^{-3}

Background-Subtracted Leptonic A_{FB}

- Lepton-only A_{FB} also measured after background subtraction
  - Significant positive leptonic A_{FB} (from W+jets) is removed by background subtraction



Sample	Predicted A_{FB} (%)	Observed A_{FB} (%)
Inclusive	1.6	6.6 ± 2.5
$M_{tt} < 450$ GeV/c^2	0.7	3.7 ± 3.1
$M_{tt} \geq 450$ GeV/c^2	3.2	11.6 ± 4.2

Correcting to the Parton Level

- Background-subtracted results study A_{FB} in a background-free top sample
- Data cannot yet be directly compared to most theoretical predictions
  - Limited detector acceptance removes some signal events
  - Finite detector resolution results in bin migration between the true and observed distributions
  - Theory predictions must go through a full detector simulation before being compared to background-subtracted results
- Develop correction procedure to account for these effects and measure the differential cross-section and parton level A_{FB}

The Correction Procedure

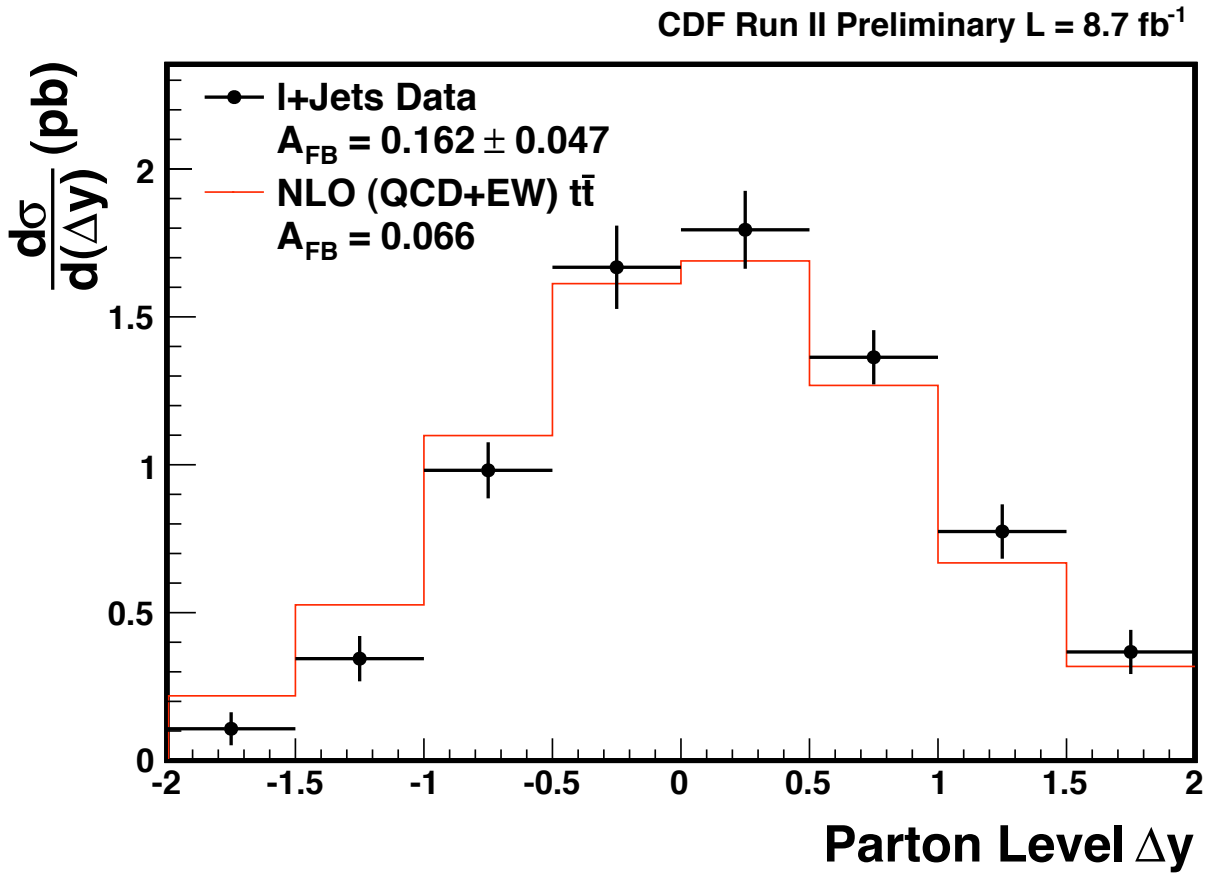
- $x_i^{Parton} = A_{ij}^{-1} S_{jk}^{-1} x_k^{Bkg.Sub.}$
- Unsmearing Correction:
  - Account for bin-to-bin migration via regularized unfolding
    - Inversion of the detector response matrix ***S***
  - Singular value decomposition algorithm
    - Höcker and Kartvelishvili, NIM A **372**, 496 (1996)
    - Implemented in RooUnfold software package
  - Matrix inversion with regularization term
    - Control statistical fluctuations with "smoothness" condition
- Acceptance Correction:
  - Multiplicative correction to each bin
    - Inversion of acceptance matrix ***A***
- Procedure is tested by correcting distributions created from SM and various BSM Monte Carlo samples

Systematic Uncertainties

- Correction procedure introduces systematic uncertainties related to the signal model, in addition to the background uncertainties discussed previously
  - Total is small compared to the statistical uncertainty

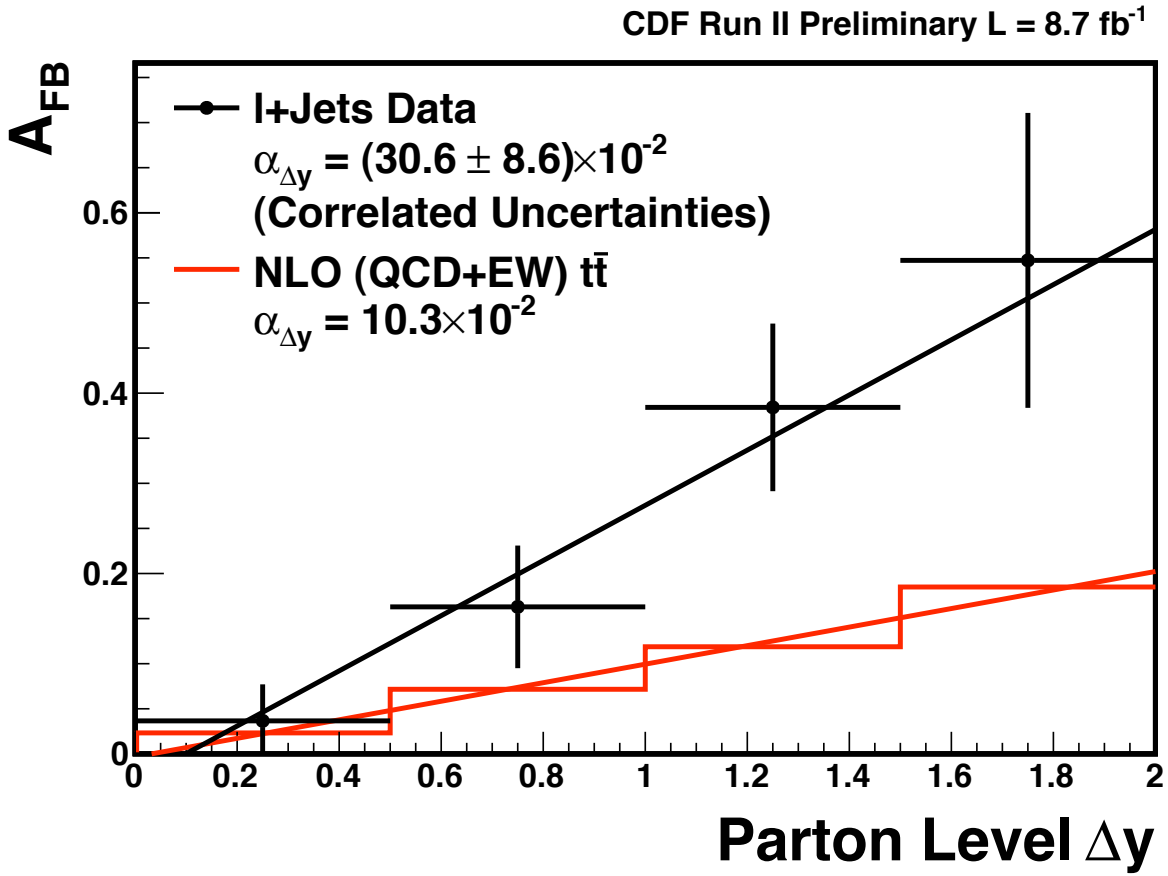
Source	Uncertainty (%)
Background Shape	1.4
Background Normalization	1.1
Parton Showering	1.0
Jet Energy Scale	0.5
Initial/Final State Radiation	0.5
Color Reconnection	0.1
Parton Distribution Functions	0.1
Correction Procedure	0.3
Total Systematic Uncertainty	2.2
Statistical Uncertainty	4.1
Total Uncertainty	4.7

The Differential Cross-Section dσ/d(Δy)



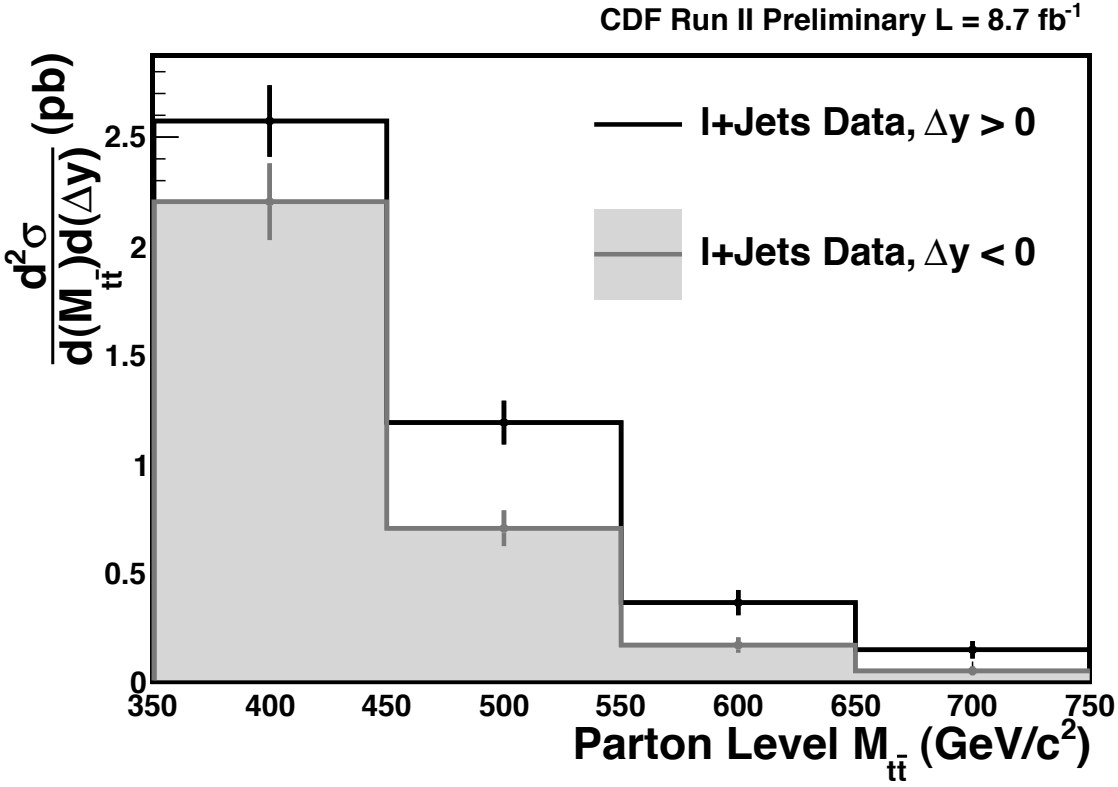
- Parton-level Δy distribution normalized to $\sigma_{tot} = 7.4$ pb
  - Result is $d\sigma/d(\Delta y)$
- Measured inclusive asymmetry is $(16.2 \pm 4.7)\%$
  - 3.4σ from null asymmetry
  - NLO prediction: 6.6%

Rapidity Dependence



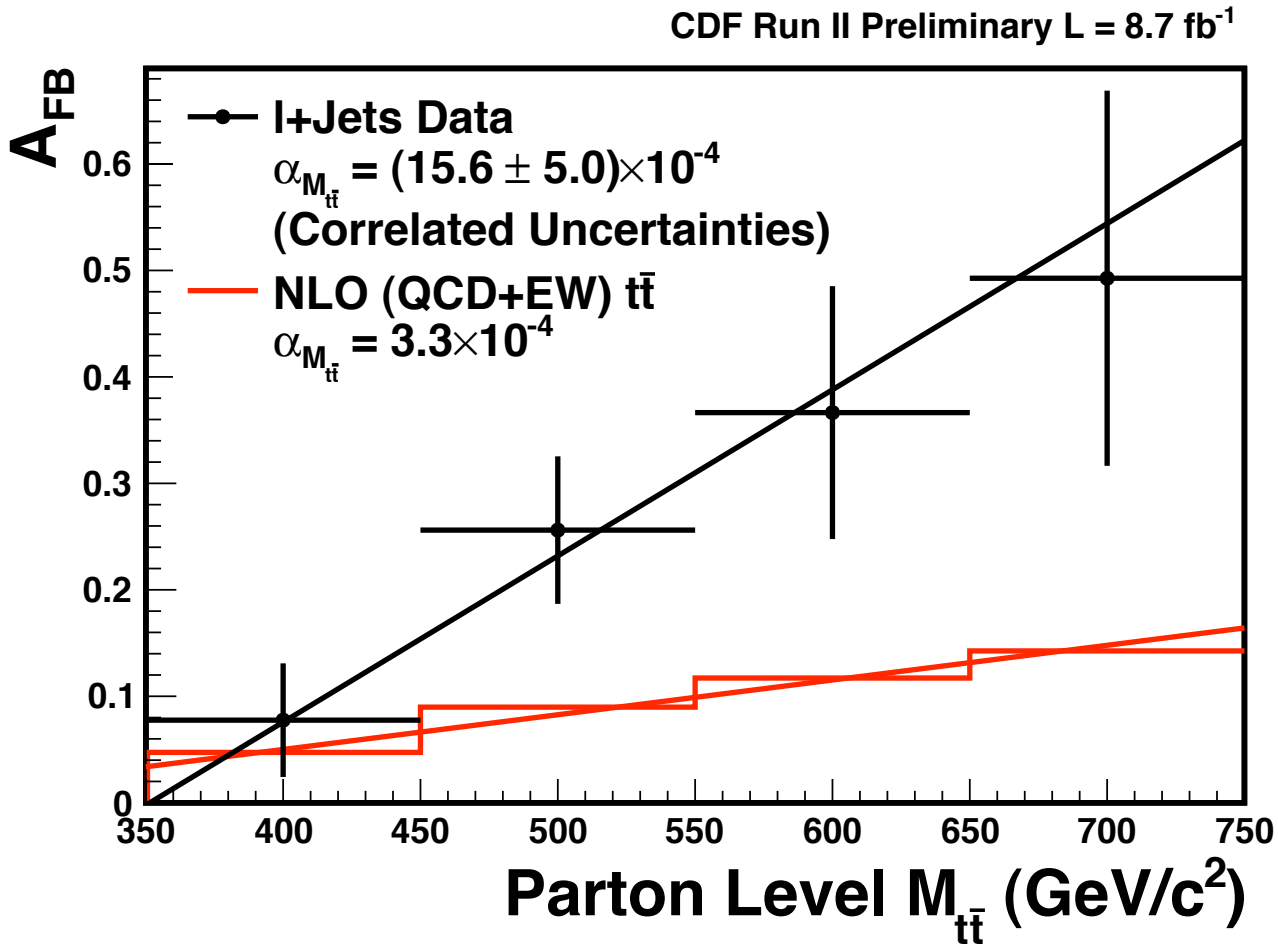
- Linear ansatz applies also to parton level A_{FB} as a function of $|\Delta y|$
  - $\chi^2/\text{d.o.f} = 0.3$
- After correction, bins are correlated – use full covariance matrix in performing the χ^2 fit

Mass Distributions for Forward and Backward Events



- Parton-level M_{tt} distributions for events with positive and negative Δy
- These distributions are then combined to find the differential asymmetry

Mass-Dependent Differential A_{FB}



- A_{FB} vs. Mtt well-described by a line with slope larger than NLO prediction
  - χ^2/d.o.f = 0.1

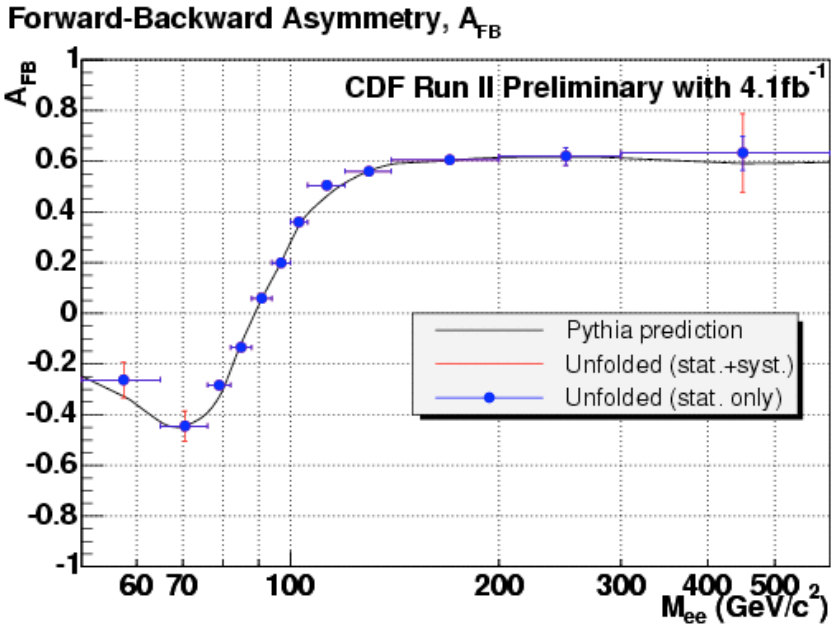
Conclusions

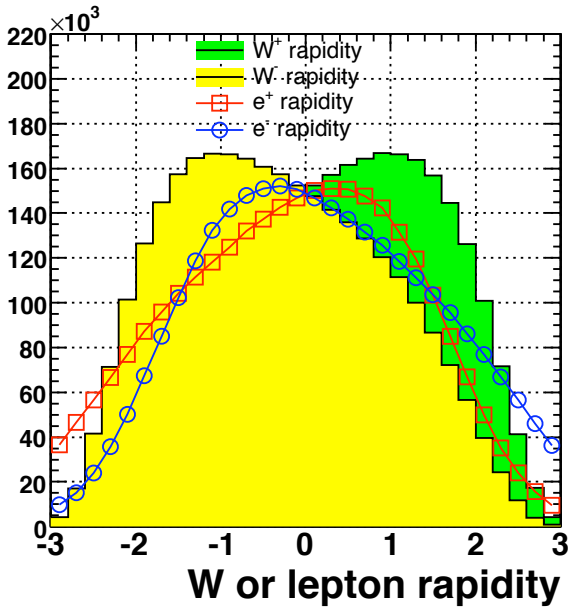
- CDF has measured the top pair A_{FB} using the full dataset
- Inclusive A_{FB} remains significant
  - Parton level $A_{FB} = (16.2 \pm 4.7)\%$
    - $3.4\,\sigma$ from no asymmetry, $2\,\sigma$ from NLO POWHEG prediction
- Mass and rapidity dependence from 5.3 fb^{-1} confirmed in full dataset
  - Behavior is well-described by a linear ansatz
    - Slopes are non-zero at $>3\,\sigma$ level
    - p-values (after background subtraction) relative to POWHEG of 6.46×10^{-3} for A_{FB} vs. M_{tt} and 8.92×10^{-3} for A_{FB} vs. $|\Delta y|$
  - Correct to parton-level for comparison to theory expectations
- CDF has several additional A_{FB} analyses coming soon
  - Exploring new kinematic variables in the lepton+jets analysis
  - Analyzing the full CDF dataset in the dilepton channel
  - Measuring A_{FB} in bottom-antibottom pairs

Backup Slides

Other Asymmetry Measurements at CDF

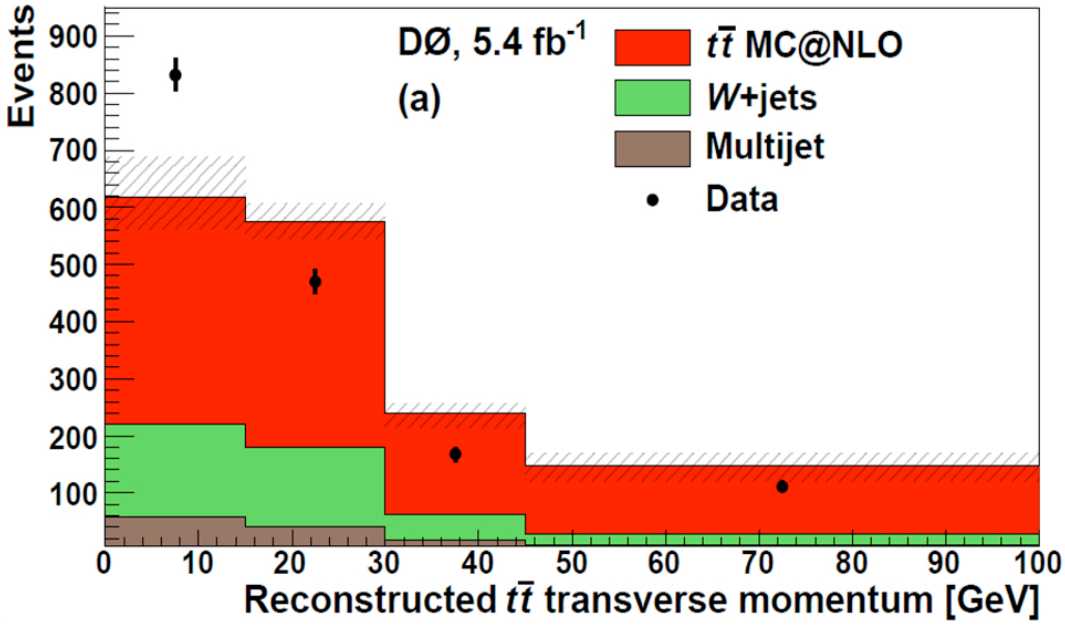
- The standard model is based on symmetries, but asymmetries arise naturally
  - Interference terms
  - Asymmetric initial states can produce asymmetric final states
- CDF has studied production asymmetries in various systems – not just top quarks!
  - Usually there is good agreement with the SM prediction
  - Left: A_{FB} in Z/γ decays to e^+e^-
    - Arises from Z couplings and Z/γ interference terms, changes sign at M_Z pole
  - Right: charge asymmetry in W production
    - Arises from asymmetries in the parton distribution functions

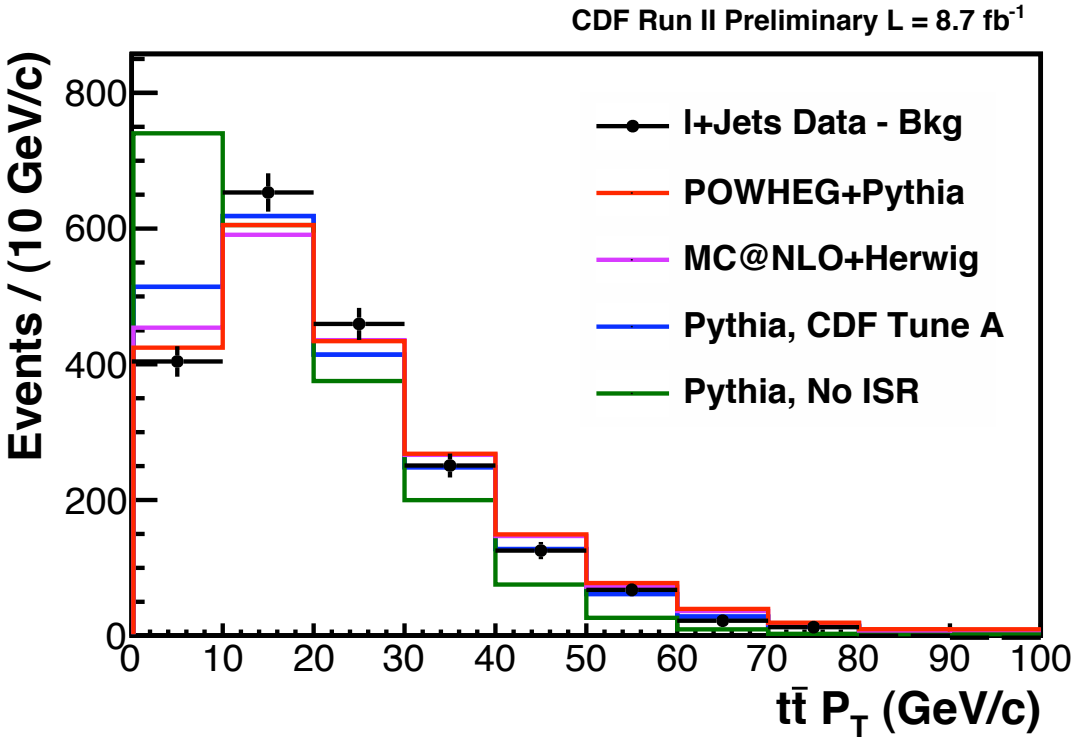




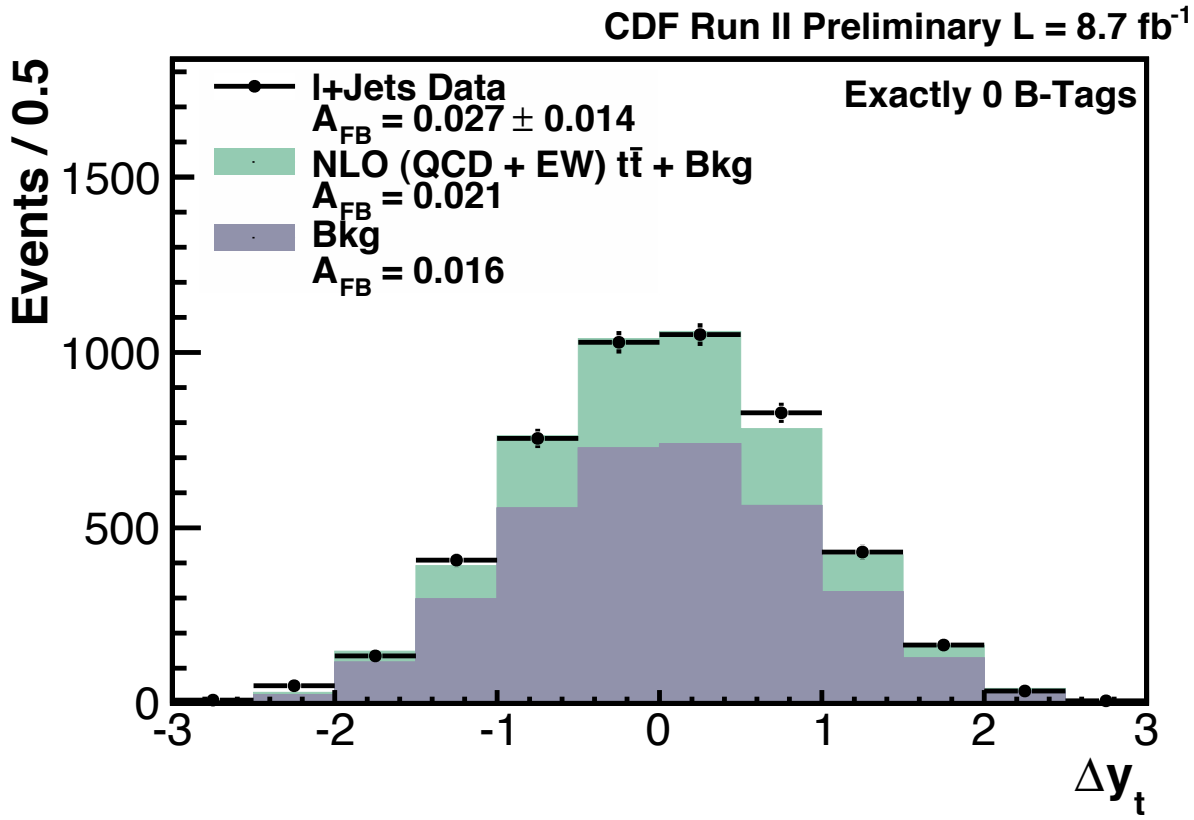
The Top Pair P_T

- D0 5.4 fb-1 analysis observed mis-modeling at low P_T (top)
- CDF finds agreement with NLO predictions of POWHEG and MC@NLO (bottom)



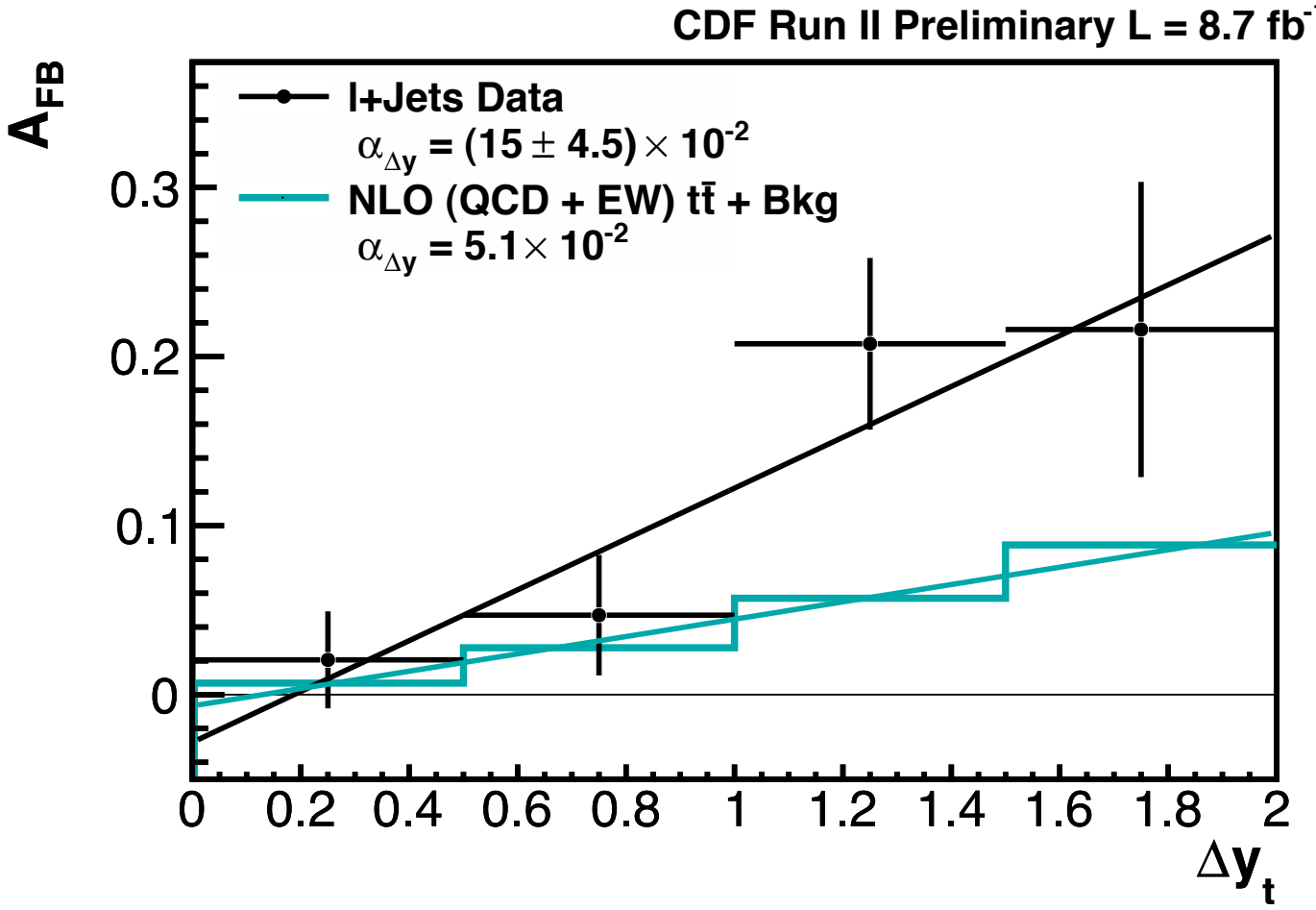


Δy IN EVENTS WITH NO b-TAGS



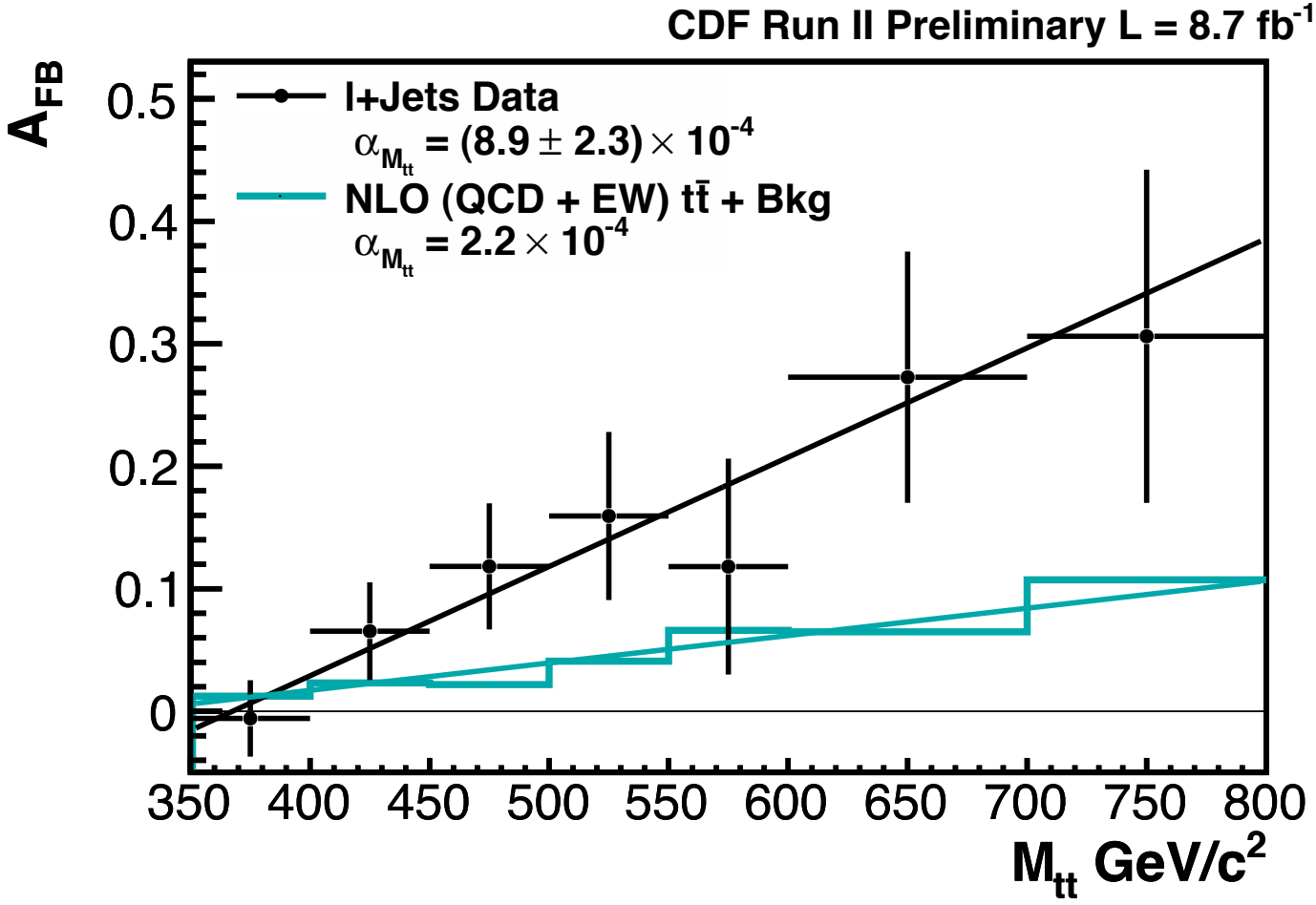
- Check background prediction in background-dominated region
- Events pass all selection requirements except they do not have any b-tagged jets
- Good agreement between data and expectation

Reconstruction Level Rapidity Dependence



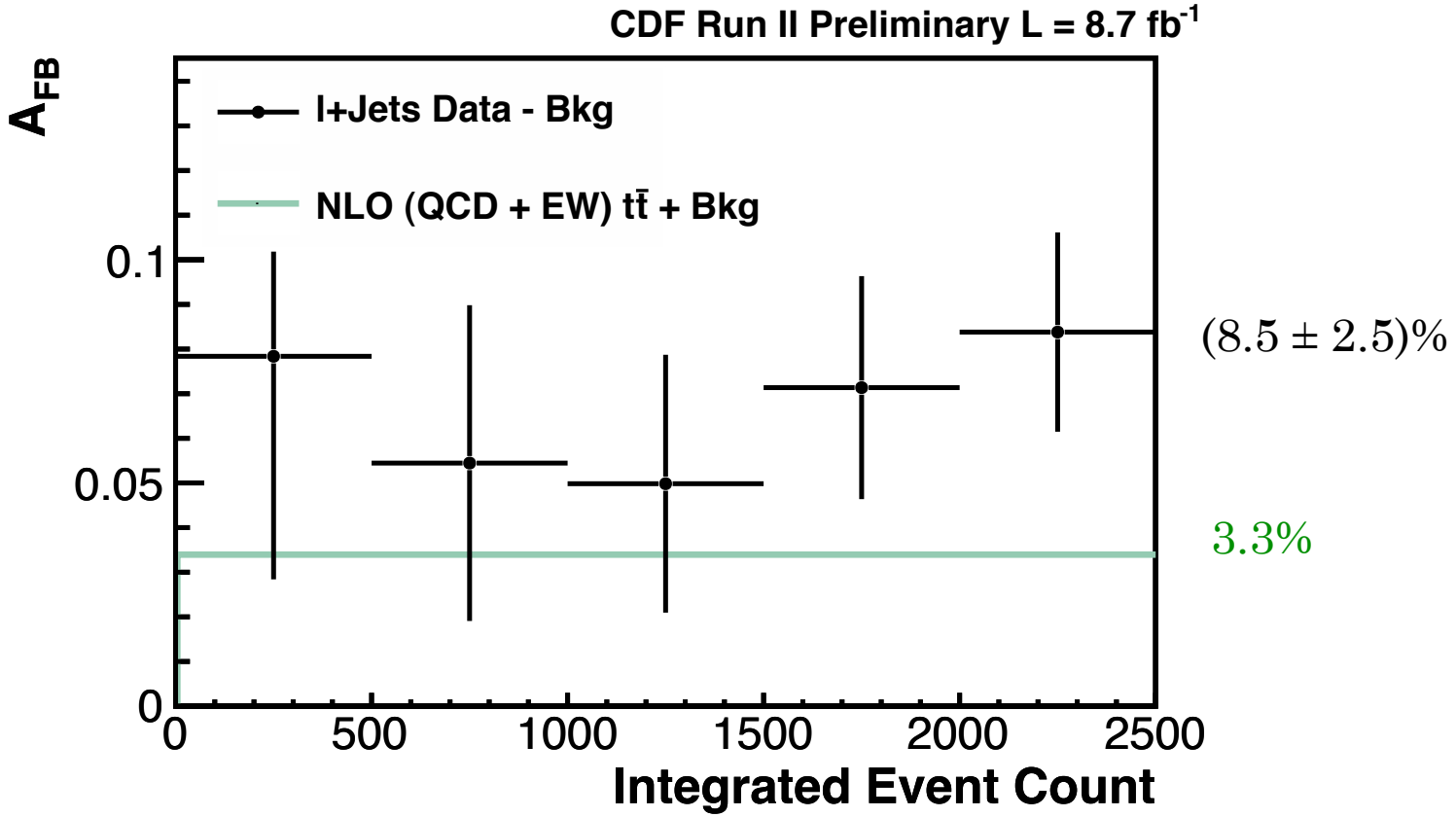
- Linear ansatz holds even at reconstruction level before any background subtraction
  - χ^2/d.o.f. = 1.1

Reconstruction Level Mass Dependence



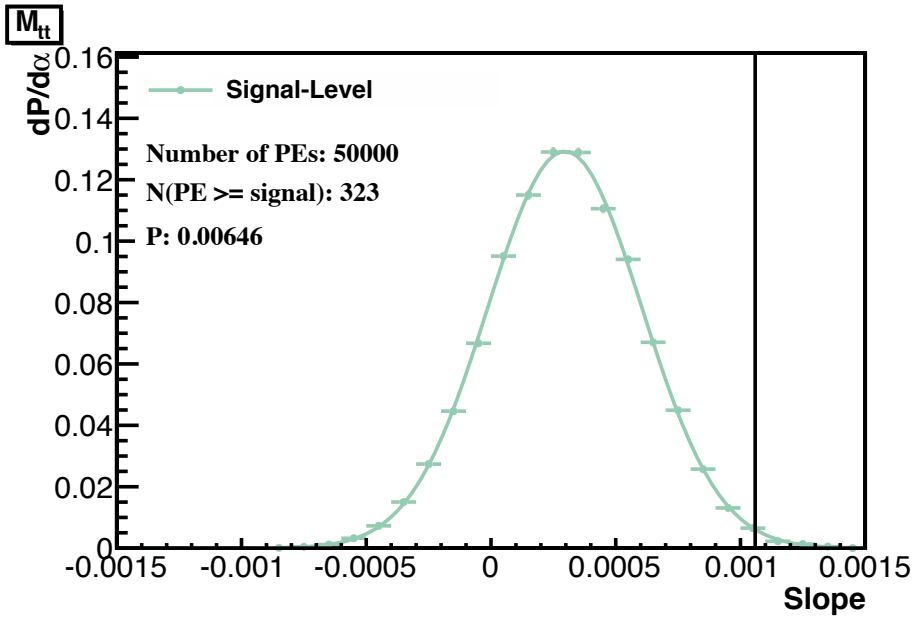
- A_{FB} as a function of M_{tt} at reconstruction level also well-described by linear ansatz
  - χ^2/d.o.f. = 0.2

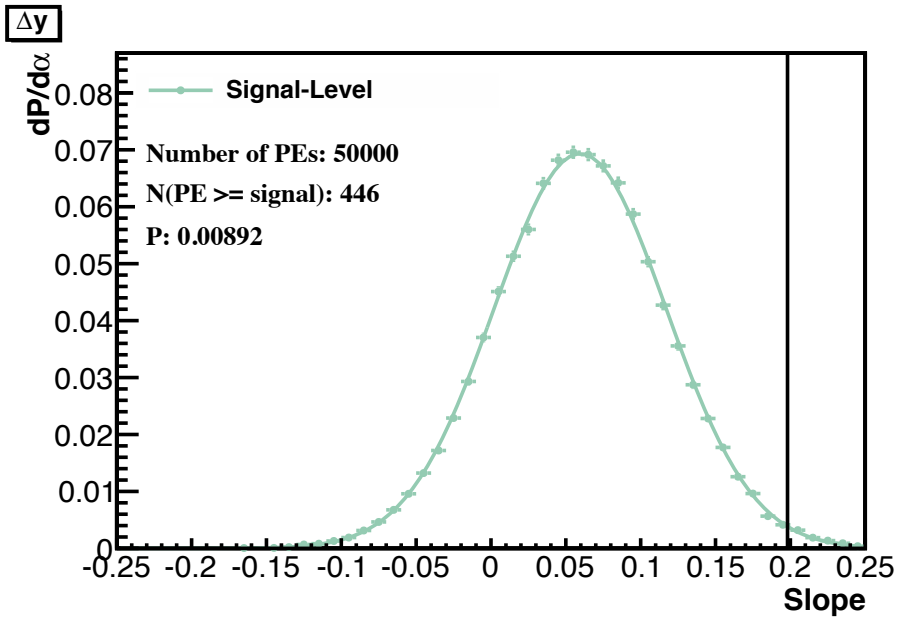
The Background-Subtracted A_{FB} Over Time



- Could the asymmetry result from a temporary detector effect, mis-calibration, etc.?
  - Measure A_{FB} as a function of the total number of observed events in the data sample
- A_{FB} constant within uncertainties through the entire course of Run II data taking

P-VALUE DETERMINATION





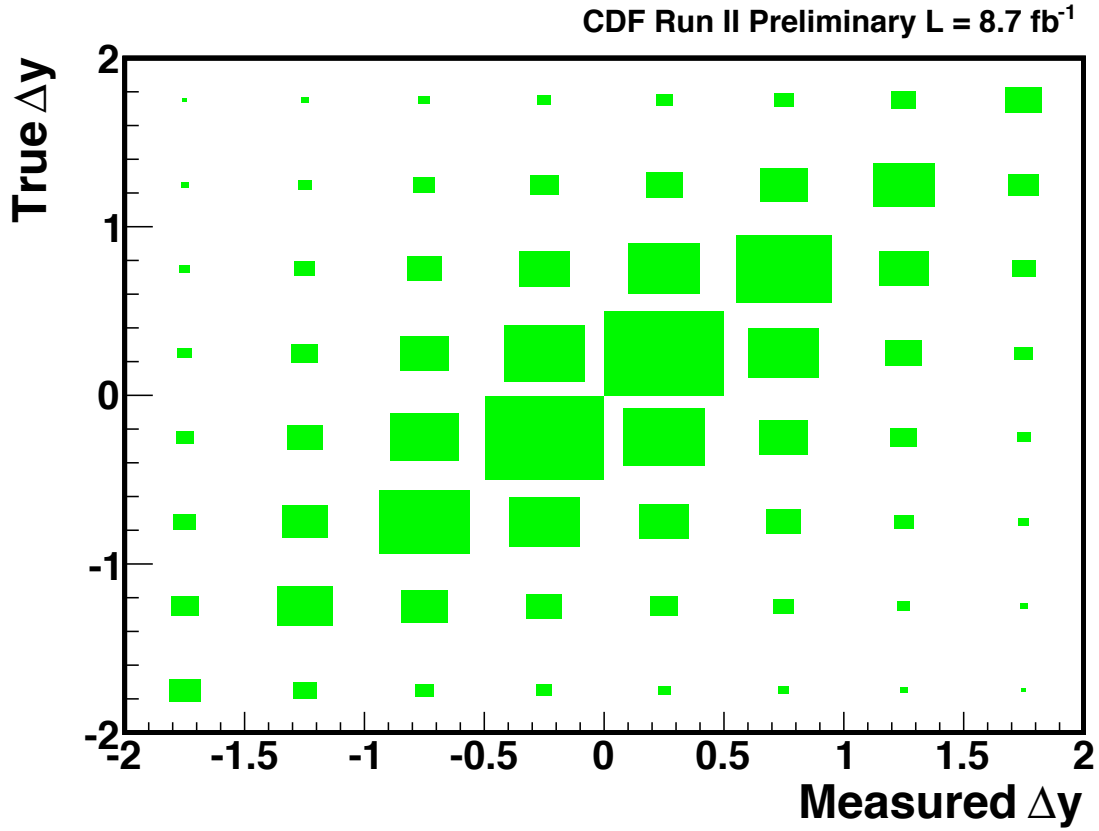
- Plots show slopes for A_{FB} vs. M_{tt} (top) and A_{FB} vs. Δy (bottom) measured from fluctuations on NLO prediction at the background-subtracted level
  - p-value: fraction of experiments in which $\alpha_{NLO} \geq \alpha_{Data}$

Comparison to the 5 fb^{-1} Results

Selection	Prediction	CDF, 5.3 fb^{-1}	D0, 5.4 fb^{-1}	CDF, 8.7 fb-1
Inclusive	6.6	15.8 ± 7.4	19.6 ± 6.5	16.2 ± 4.7
$M_{tt} < 450$ GeV/c^2	4.7	−11.6 ± 15.3	7.8 ± 4.8 (Bkg. Subtracted)	7.8 ± 5.4
$M_{tt} \geq 450$ GeV/c^2	10.0	47.5 ± 11.2	11.5 ± 6.0 (Bkg. Subtracted)	29.6 ± 6.7
$\lvert \Delta y \rvert < 1.0$	4.3	2.6 ± 11.8	6.1 ± 4.1 (Bkg. Subtracted)	8.8 ± 4.7
$\lvert \Delta y \rvert \geq 1.0$	13.9	61.1 ± 25.6	21.3 ± 9.7 (Bkg. Subtracted)	43.3 ± 10.9

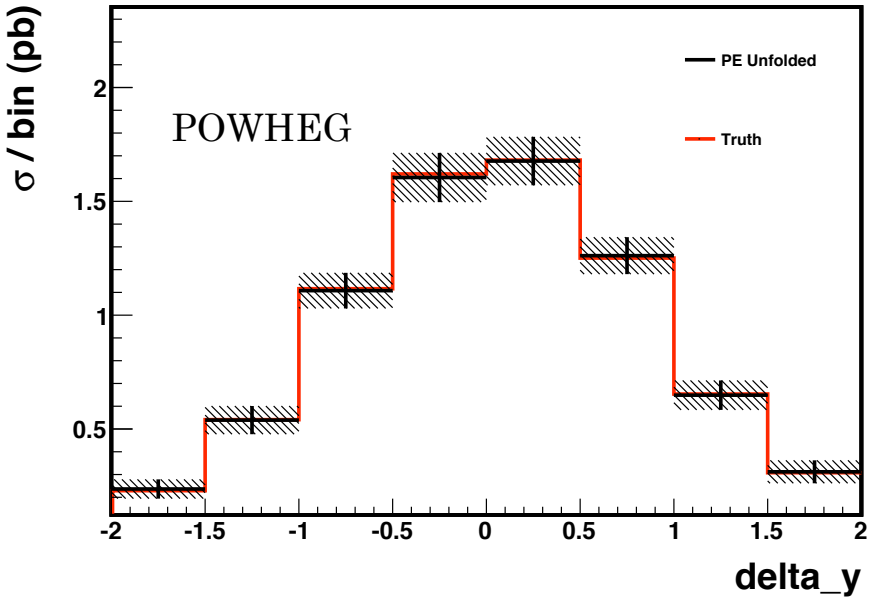
- Parton level asymmetries in two bins of M_{tt} and $\lvert \Delta y \rvert$ for direct comparison to previous results

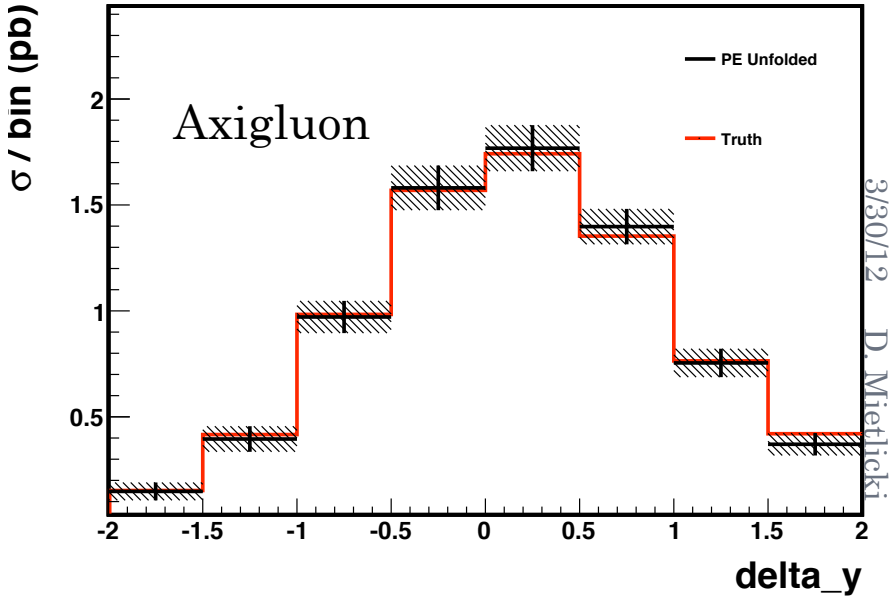
The Detector Response Matrix



- Plot shows detector response matrix used for regularized unfold of Δy
  - Box sizes proportional to bin contents
  - Does not include acceptances (acceptance matrix is diagonal, simply a multiplicative correction to each bin)
- Predominantly diagonal (good resolution) and symmetric (no bias for forward or backward events)

Bias Tests





Inclusive A_{FB}	*Value*
True A_{FB}	5.2
Average Meas. A_{FB}	5.5
Average Uncertainty	4.0

Inclusive A_{FB}	*Value*
True A_{FB}	15.6
Average Meas. A_{FB}	16.2
Average Uncertainty	3.9

- Check the correction procedure in simulated experiments based on Monte Carlo samples
- Plots show average corrected results compared to true MC distributions in POWHEG (left) and an example new physics (axigluon) sample (right)