Dependence of A_{FB} in $t\bar{t}$ Production on M_{tt}

Monica Tecchio
University of Michigan

on behalf of the CDF Collaboration

DPF 2009
Top Quark Physics Parallel Session
Detroit, July 27, 2009

Outline

- Motivation
- Experimental and Theoretical Input
- Measurement Technique
- Results
- Interpretation

Documentation:

✓ WEB page:
http://www-cdf.fnal.gov/physics/new/top/2009/AfbMtt/

✓ Public Note:
http://www-cdf.fnal.gov/physics/new/top/confNotes/cdf9853_Afb_Mtt.pdf

Motivation

In a top-antitop data sample of L=3.2 fb^{-1}, CDF II measures an integral forward-backward asymmetry at parton level in pp frame of:

$$A_{fb}^{pp} = (19.3 \pm 6.5_{stat} \pm 2.3_{syst})\%$$

More than 2 sigma excess from NLO prediction A_{FB}^{pp} = 5 ± 1.5%

Previous measurements:

- ✓ CDF II (L=1.9 fb^{-1}): at parton level, both in pp and tt frame

$$A_{fb}^{pp} = (17 \pm 8)\% \qquad A_{fb}^{tt} = (24 \pm 13)\%$$

- ✓ D0 (L=0.9 fb^{-1}): at reconstruction level

$$A_{fb}^{rec} = (12 \pm 8)\%$$

We present a study of the dependence of A_{FB} "excess" on M_{tt} invariant mass

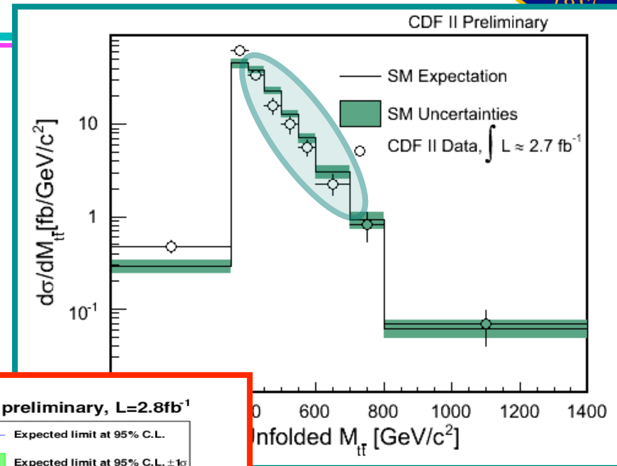
- Excess can be due presence of unknown particle with large A_{FB}
- Depending on the mass and nature of extra particle, excess can show itself as:
  - ✓ a bump in $A_{FB}(M_{tt})$
  - ✓ an edge or "kink" with sign change
  - ✓ slow raise at high M_{tt} values.

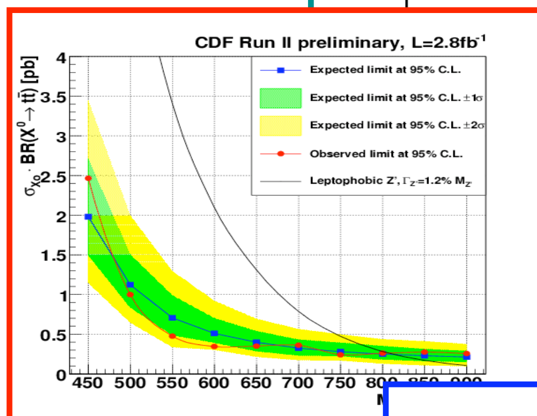
Pursue model independent measurement of $A_{FB}(M_{tt})$ assuming no change in M_{tt} spectrum as suggested by data.

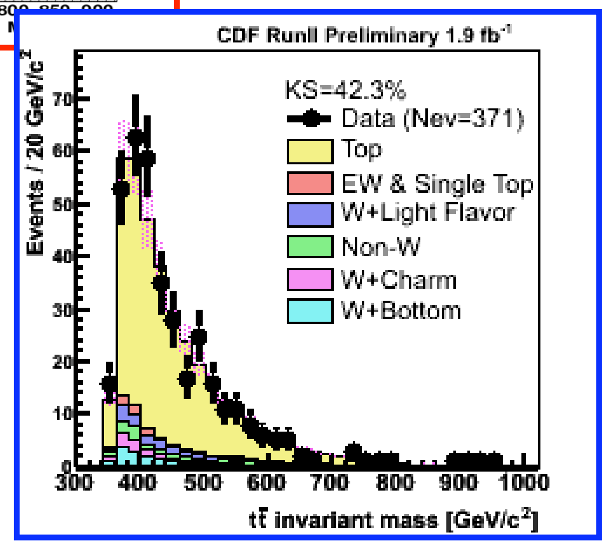
Experimental Inputs

Any new particle has to be consistent with observed M_{tt} spectrum!

- Measurement of $d\sigma_{tt}/dM_{tt}$ after unfolding to parton level finds "no deviations from SM predictions"
  - ✓ KK excitations of gluons can explain "CDF data [..] systematically below the SM expectation" and predict $A_{FB}^{SM+KK} \approx 11\%$ *(A.Djouadi et al.,* arXiv:0906.06041, 2009)
- Search for narrow Z' resonance sets limits $M_{Z'} \geq 800$ GeV
  - ✓ Leptophobic Z' with preferential couplings to uubar-like fermions has $A_{FB}^{Z'} \approx 30\%$ *(J.Rosner,* Phys.Lett.B387, 1996)
- Search for new color-octet particle ($qq \rightarrow G \rightarrow tt$) which interferes with $qq \rightarrow tt$, finds "data is in agreement with SM"
  - ✓ Positive A_{FB} has already excluded axial-vector colorons up to 1.4 TeV @90% (*P.Ferrario et al.*, arXiv:0906.5541, 2009)



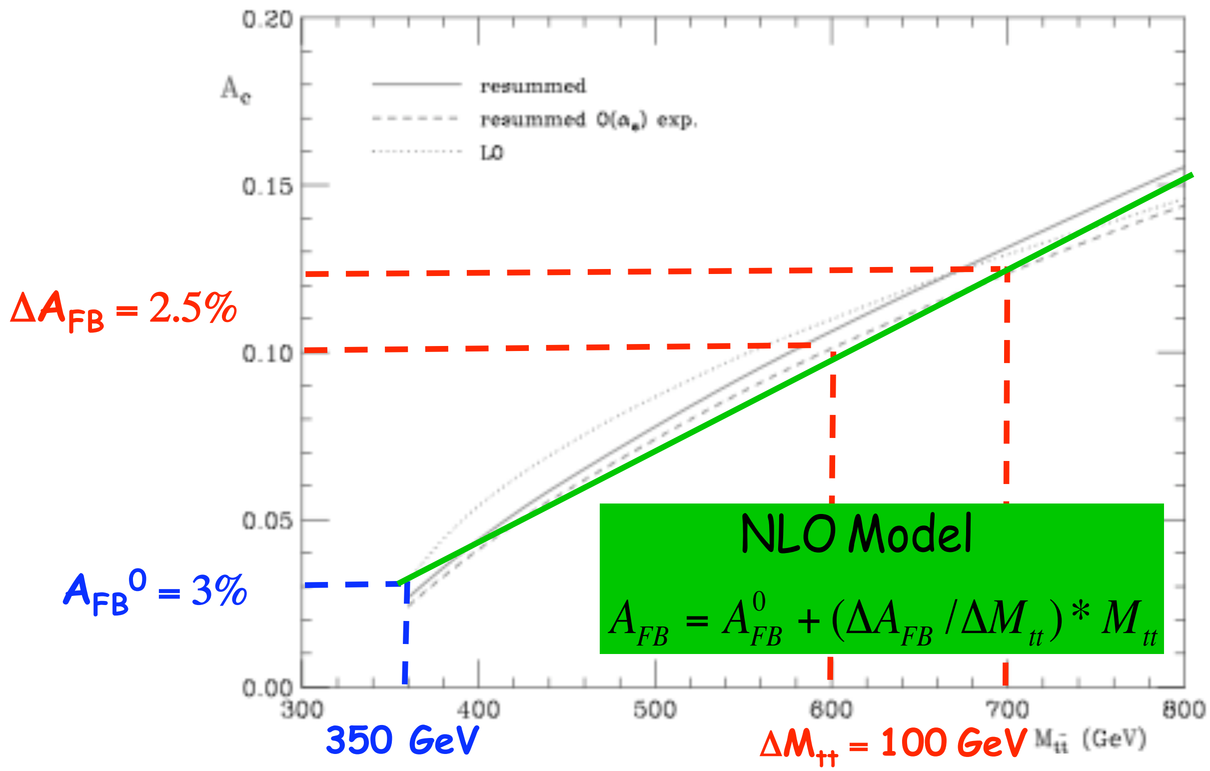




Theoretical Inputs

- NLO calculations predicts an overall slightly positive A_{FB}.
- It also predicts a "strong" mass dependence vs qq mass
  (*Almeida at al.* , arXiv:0805.1885v1, 2008)

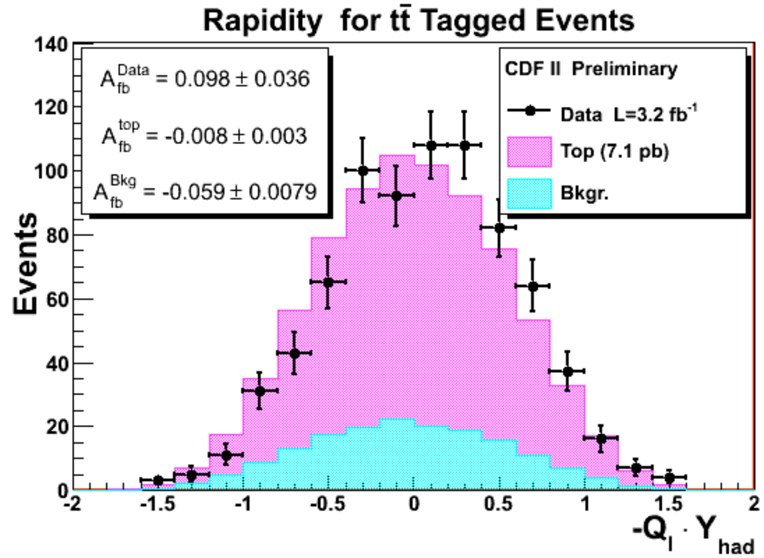
- We use NLO calculation as a model for $A_{FB}(M_{tt})$ with two approximations:
  - qq mass prediction can be used for tt mass frame dependence
  - $A_{FB}(M_{tt})$ is linearly dependent on M_{tt} in tt frame

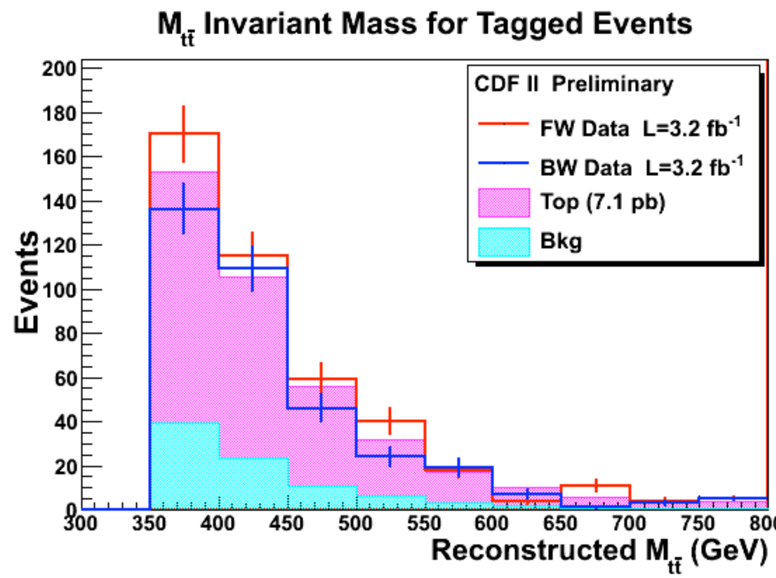


Measurement Technique

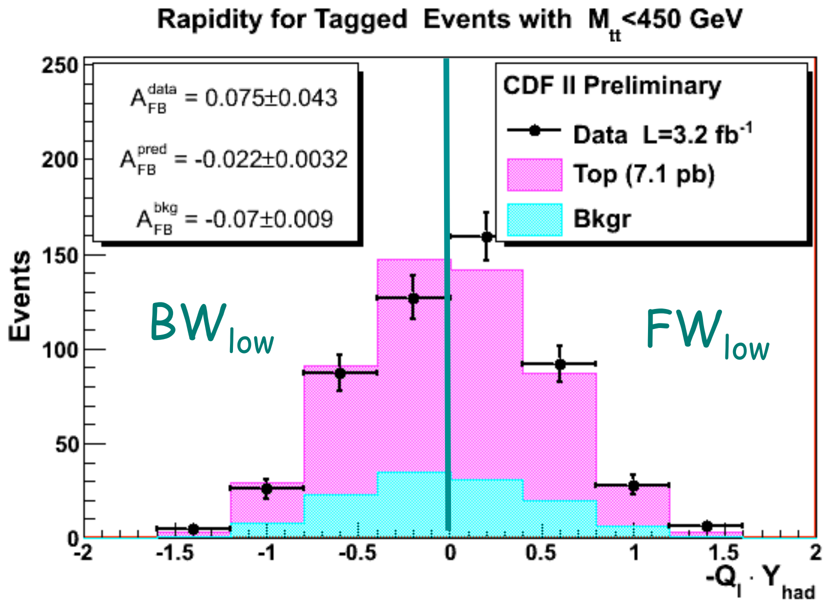
In 3.2 fb^{-1} data sample (same used for integral A_{FB} analysis), use $-Q_l * Y_{had}$ to measure top(antitop) angle in LAB frame for tagged ℓ+jets events, reconstructed with χ^2-based fit to M_{top}=175 GeV

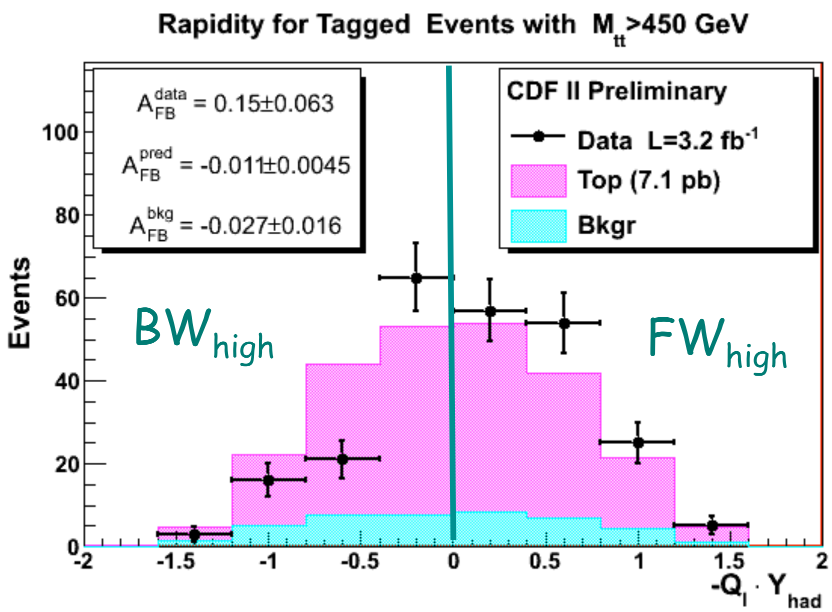
- divide events in FW vs BW events, below and above <u>reconstructed M_{tt}</u> threshold
- employ unfolding technique to go back to parton level both in rapidity and M_{tt}
- measure semi-integral asymmetries A_{FB}^{low} and A_{FB}^{high} w.r.t <u>parton-level M_{tt}</u>
- scan different M_{tt} threshold across allowed mass spectrum to look for bump or other structures



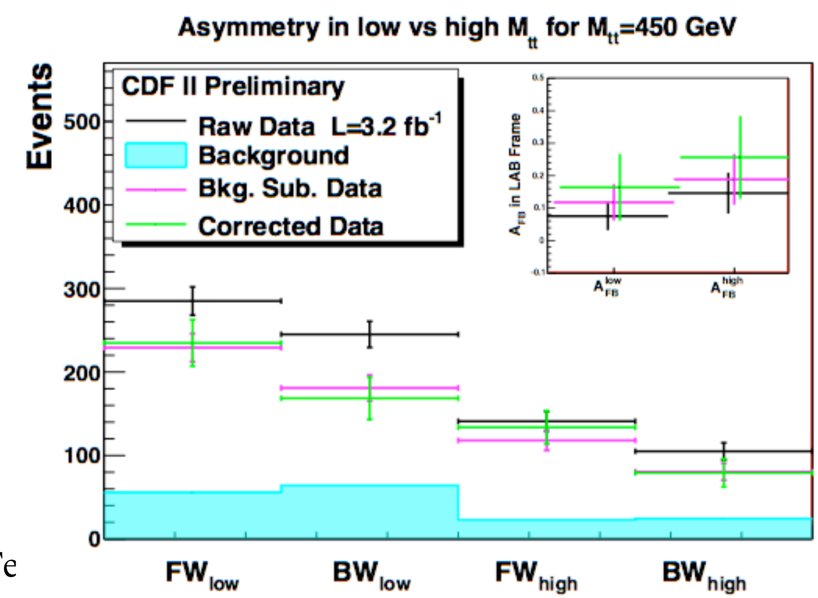


Measurement Technique





- ✓ Data are divided in 4 exclusive bins at reconstruction level
- ✓ Unfold signal events after background subtraction.
- ✓ Unfolding matrices correct for event selection and reconstruction resolution and return corrected number of events at parton level.

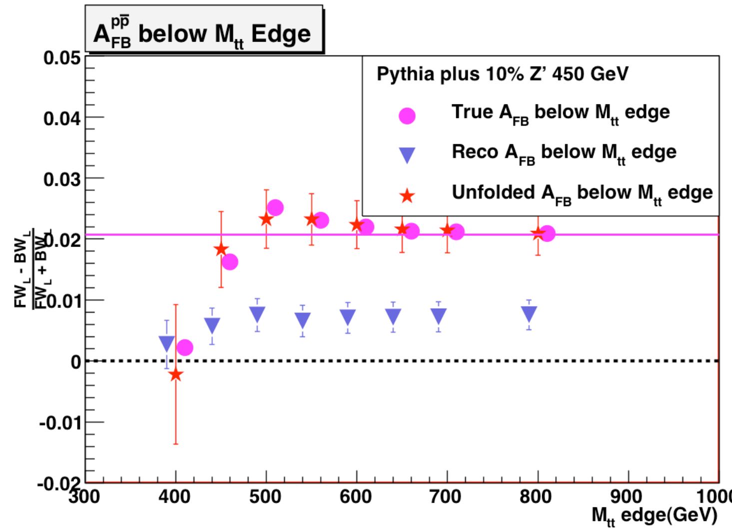


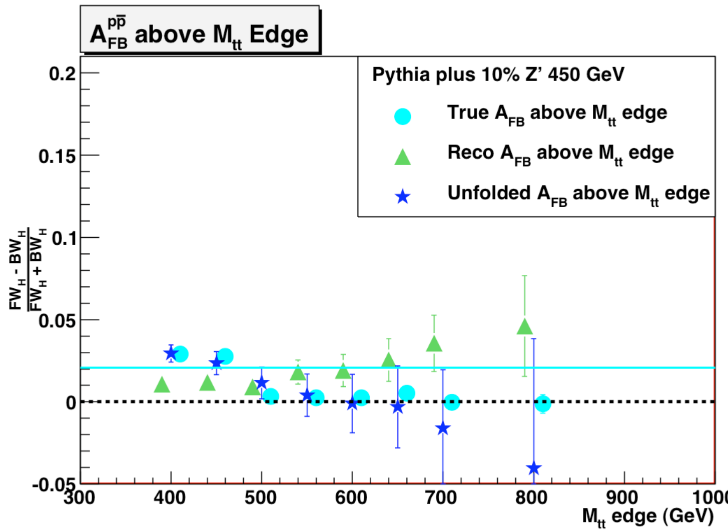
a Te

Examples of Unfolding M_{tt} Scan (I)

Adding to Pythia a 10% contribution from Z′ resonance of $M_{Z'}$=450 GeV

- Expected $A_{FB}^{tt+Z'} \approx 2\%$
- In A_{FB}^{low} scan:
  - sharp increase up to $A_{FB}^{tt+Z'}$
  - shoot a bit up as we cross M_{tt}=450 GeV
  - settles back toward $A_{FB}^{tt+Z'}$.
- In A_{FB}^{high} scan:
  - start above $A_{FB}^{tt+Z'}$
  - approach asymptotically the null value of A_{FB}^{tt} (LO Pythia!) as the Z′ contribution fades out

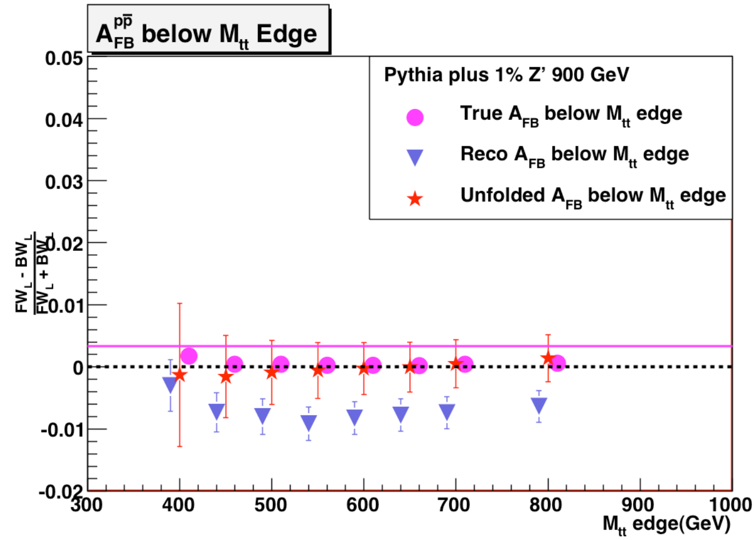


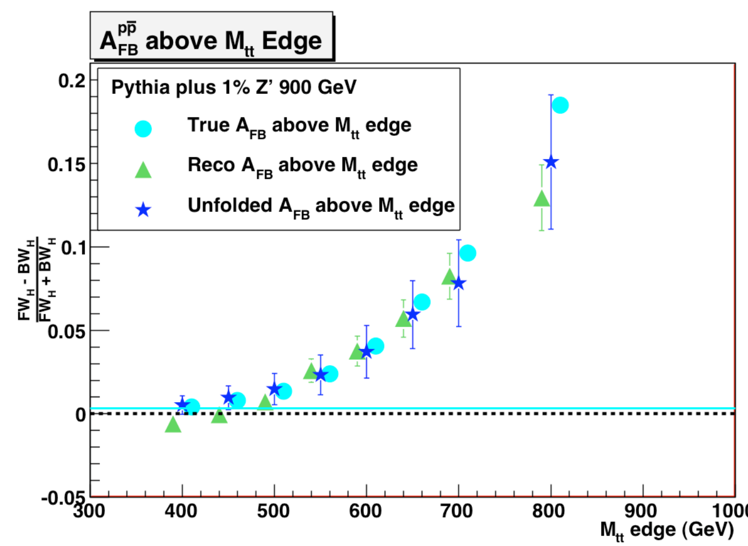


Examples of Unfolding M_{tt} Scan (II)

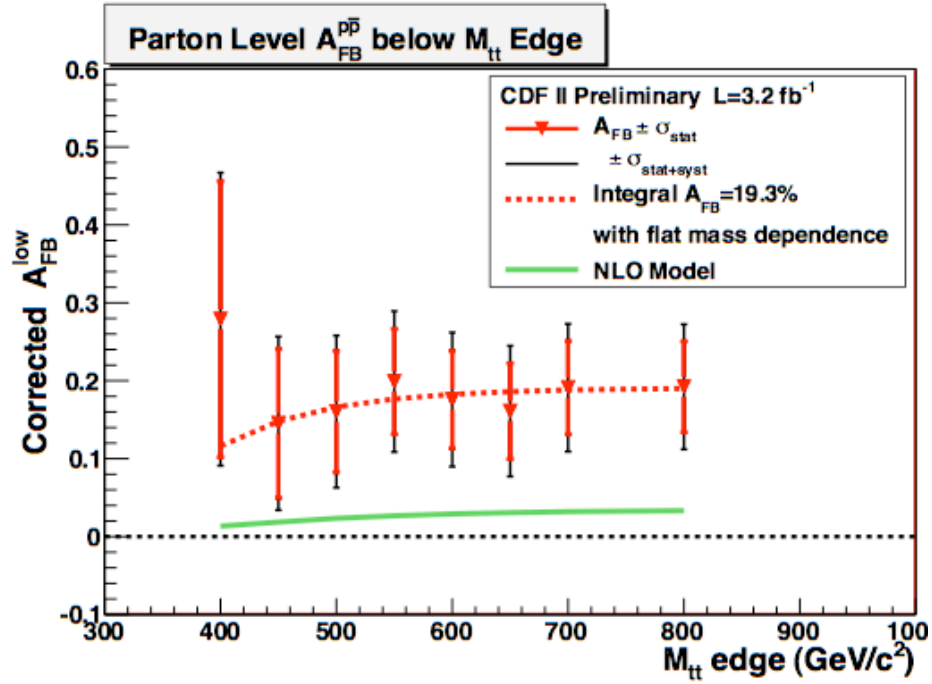
Adding to Pythia a 1% contribution from Z′ resonance of $M_{Z'}$=900 GeV

- In A_{FB}^{low} scan:
  - we never "see" Z′ as the last M_{tt} threshold is still below $M_{Z'}$.
- In A_{FB}^{high} scan:
  - continous increase in the measured half-integral asymmetry as tt contribution dies off
  - will see bump at $A_{FB}^{Z'}$ if last M_{tt} threshold above $M_{Z'}$
- Expected integral $A_{FB}^{tt+Z'}$ is only 0.3% !!





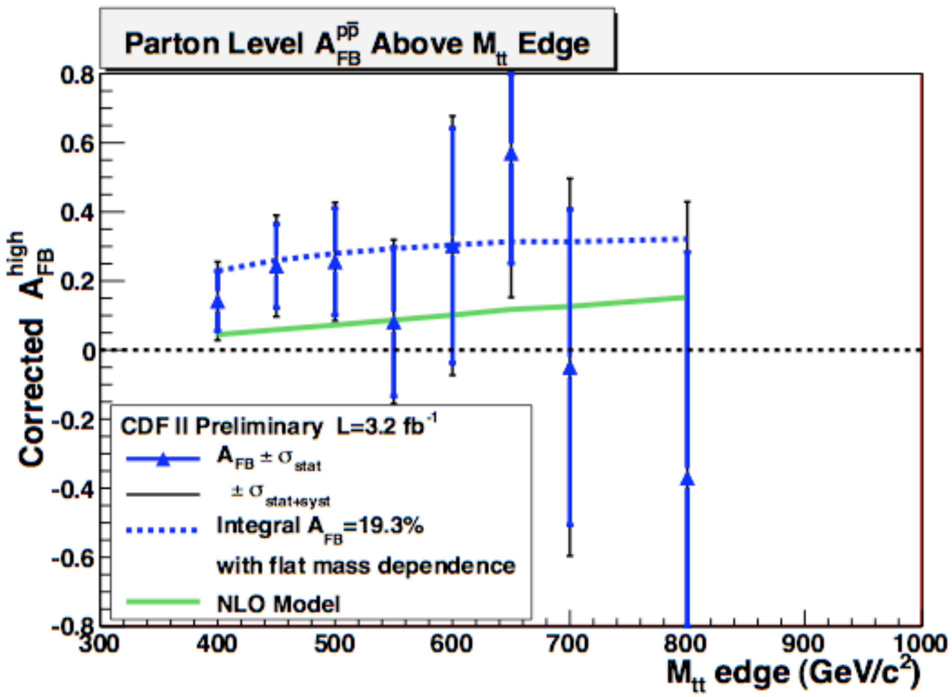
Data Results and Interpretation



Dashed line is prediction for a reweighted(*) Monte Carlo model with flat mass dependence and expected A_{FB} = 19.3% at parton level in pp frame.

(*) with asymmetric terms linear in $\cos\theta$

Solid green line is "NLO model", i.e. reweighted Monte Carlo model with A_{FB} linearly dependent on Mtt and constant term/slope and as per fit to NLL calculation.



Measurement is still statistical limited!

Conclusions

We presented a measurement of top forward-backward asymmetry vs $M_{t\bar{t}}$ in a 3.2 fb^{-1} data sample collected with CDF Run II detector at the Tevatron.

Analysis aims at model independent measurement of $A_{FB}(M_{tt})$ assuming no change in M_{tt} spectrum.

Unfolding technique is used to unsmear the effects of selection and reconstruction and get to the parton level simultaneously in rapidity and tt invariant mass.

Results are presented as half-integral parton level asymmetries in ppbar frame vs 8 different M_{tt} thresholds.

Data is compared to a model with constant A_{FB} independent of the mass and consistent with the measured integral A_{FB} and to a "NLO model" with A_{FB} linearly dependent on M_{tt}.

We will repeat with more data and more bins ("differential measurement"). Also using angular variable sensitive to ttbar frame (ex: $\Delta Y = -Q_l * (Y_{had} - Y_{lep})$).

Backup slides

Dependence of A_{FB} in $t\bar{t}$ Production on $M_{t\bar{t}}$

DPF 2009

Top Quark Physics Parallel Session

Detroit, July 27, 2009

Unfolding Formalism

- $\vec{N}$ is 4-dimensional vector

$$\vec{N}_{cor} = (A^{-1} \cdot S^{-1})\ \vec{N}_{raw}$$

- A and S matrices are calculated using LO Pythia Monte Carlo

$$\vec{N} = (FW_{low}, BW_{low}, FW_{high}, BW_{high})$$

For low vs high threshold at $M_{t\bar{t}} = 450\ GeV/c^2$:

- A matrix is diagonal and calculates the relative acceptance for each bin

$$A = \begin{bmatrix} 0.915 \pm 0.004 & 0 \pm 0 & 0 \pm 0 & 0 \pm 0 \\ 0 \pm 0 & 0.956 \pm 0.004 & 0 \pm 0 & 0 \pm 0 \\ 0 \pm 0 & 0 \pm 0 & 1.06 \pm 0.01 & 0 \pm 0 \\ 0 \pm 0 & 0 \pm 0 & 0 \pm 0 & 1.15 \pm 0.01 \end{bmatrix}$$

- S matrix corrects for reconstruction dilution of "true" events across FW vs BW events and across invariant mass regions.

$$S = \begin{bmatrix} 0.760 \pm 0.004 & 0.119 \pm 0.002 & 0.274 \pm 0.003 & 0.085 \pm 0.002 \\ 0.113 \pm 0.002 & 0.748 \pm 0.004 & 0.073 \pm 0.001 & 0.282 \pm 0.003 \\ 0.108 \pm 0.002 & 0.023 \pm 0.001 & 0.613 \pm 0.004 & 0.048 \pm 0.001 \\ 0.019 \pm 0.001 & 0.109 \pm 0.002 & 0.040 \pm 0.001 & 0.586 \pm 0.004 \end{bmatrix}$$

Mass Scan Results

Measured asymmetries at different steps in the unfolding procedure (L=3.2 fb^{-1})

Uncertainties are statistical only, except for the final corrected A_{FB}

	Forward-Backward Asymmetry Below $M_{t\bar{t}}$ Threshold			
$M_{t\bar{t}}$ (GeV/c^2)	Raw A_{FB}	Bkgr A_{FB}	A_{FB} after bkg. sub.	Corr A_{FB}^{low} $\pm\sigma_{stat}$ $\pm\sigma_{syst}$
400	0.111±0.057	-0.072±0.012	0.152±0.070	0.28±0.18±0.06
450	0.0755±0.043	-0.069±0.009	0.105±0.052	0.15±0.10±0.06
500	0.084±0.040	-0.060±0.009	0.112±0.048	0.16±0.08±0.06
550	0.099±0.038	-0.059±0.008	0.130±0.045	0.20±0.07±0.06
600	0.092±0.037	-0.059±0.008	0.122±0.044	0.18±0.06±0.06
650	0.087±0.036	-0.061±0.008	0.116±0.044	0.16±0.06±0.06
700	0.099±0.036	-0.059±0.008	0.130±0.043	0.19±0.06±0.06
800	0.100±0.036	-0.058±0.008	0.131±0.043	0.19±0.06±0.06

	Forward-Backward Asymmetry Above $M_{t\bar{t}}$ Threshold			
$M_{t\bar{t}}$ (GeV/c^2)	Raw A_{FB}	Bkgr A_{FB}	A_{FB} after bkg. sub.	Corr A_{FB}^{high} $\pm$ stat $\pm$ syst
400	0.089±0.046	-0.048±0.011	0.113±0.054	0.14±0.09±0.07
450	0.146±0.063	-0.031±0.015	0.176±0.074	0.24±0.12±0.08
500	0.16±0.08	-0.05±0.02	0.196±0.096	0.26±0.15±0.07
550	0.09±0.11	-0.050±0.027	0.11±0.13	0.08±0.22±0.10
600	0.20±0.16	-0.038±0.038	0.24±0.18	0.30±0.34±0.16
650	0.38±0.17	0.032±0.05	0.42±0.19	0.57±0.32±0.27
700	0.06±0.24	-0.008±0.072	0.066±0.267	-0.05±0.46±0.30
800	-0.14±0.38	-0.13±0.12	-0.14±0.40	-0.37±0.65±0.46