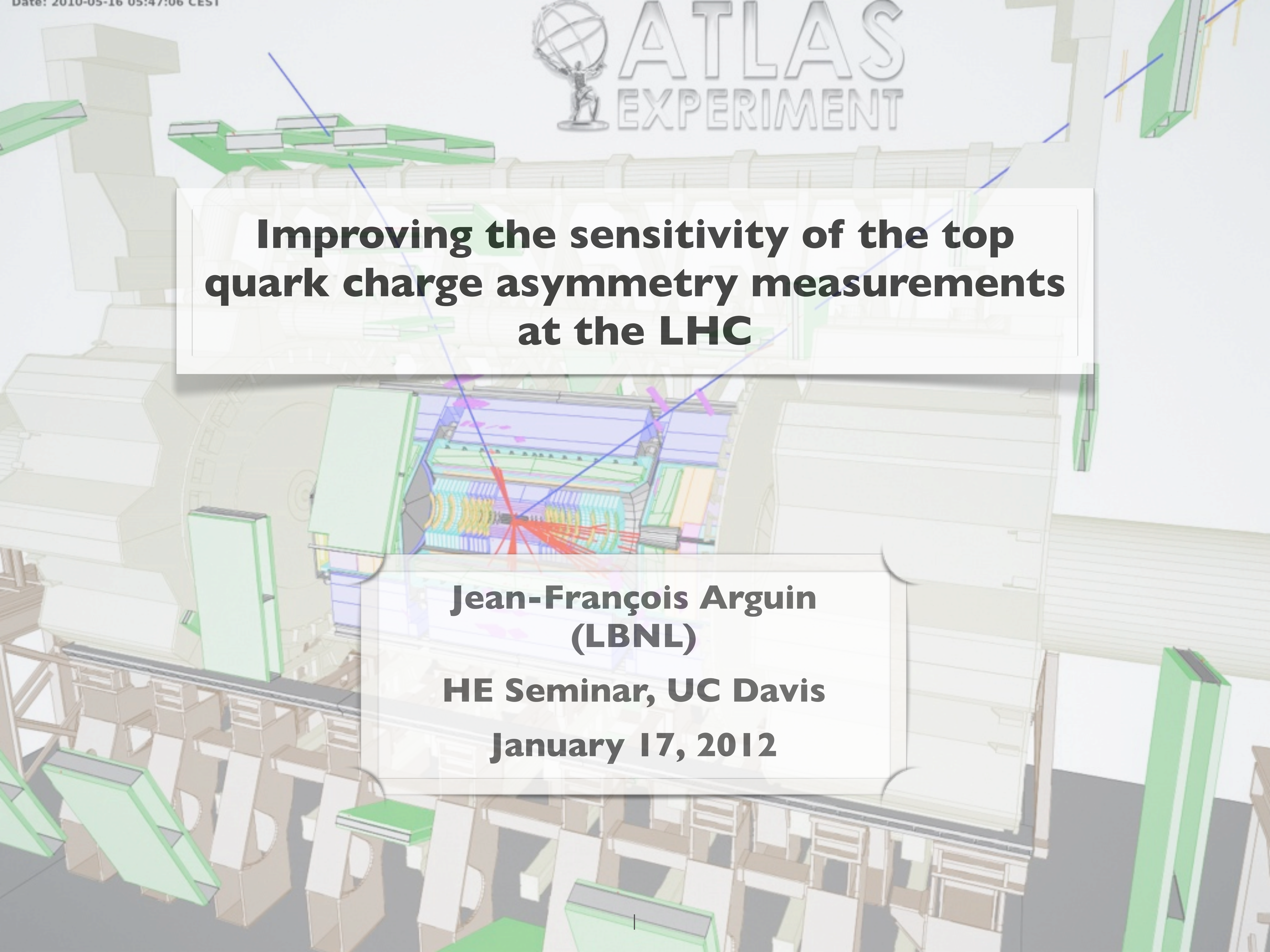



# Improving the sensitivity of the top quark charge asymmetry measurements at the LHC

Jean-François Arguin
(LBNL)

HE Seminar, UC Davis

January 17, 2012

# OUTLINE

★ Introduction to top quark and top asymmetry measurements

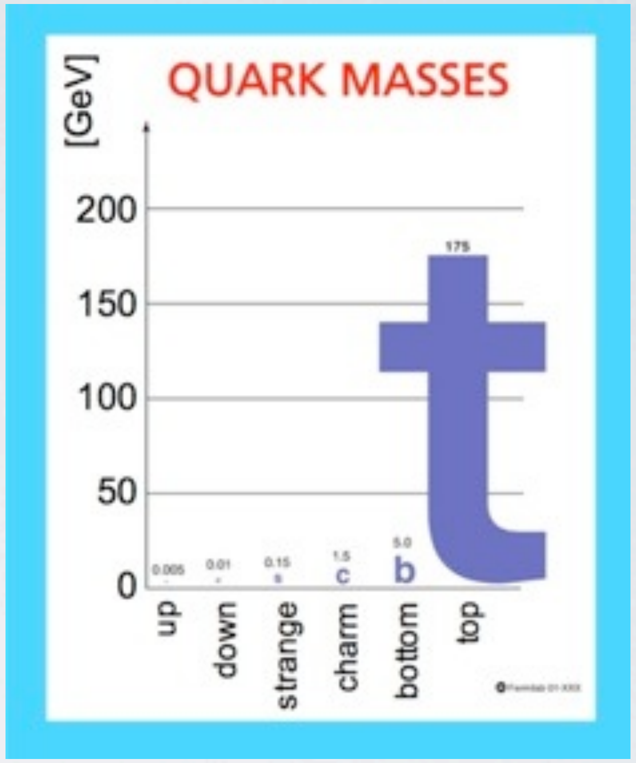
★ Three parts talk:

✳$A_{fb}$ measurements at the Tevatron

✳Current top asymmetry measurement at ATLAS

✳How to improve the $A_c$ measurements at the LHC

# TOP QUARK: A UNIQUE SM PARTICLE

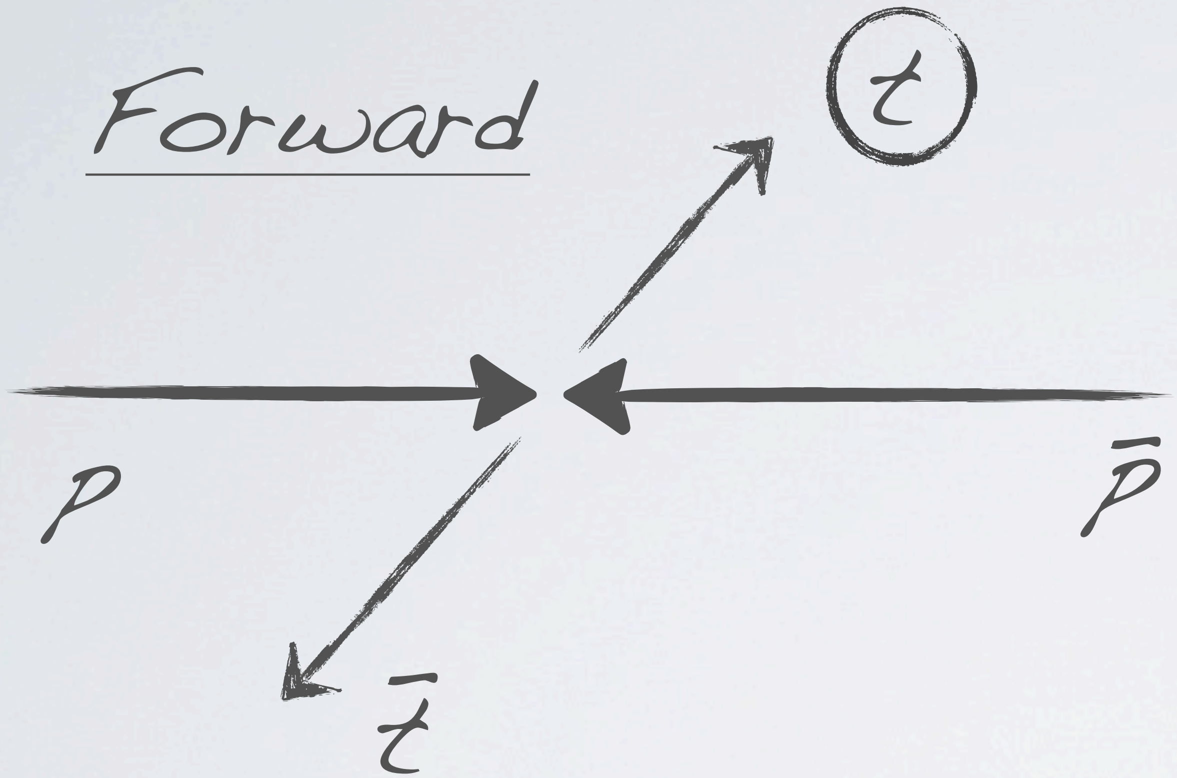



- ★ **Most striking characteristics: $M_{top}$=173.2±0.9 GeV**
- ★ **The study of top quark is highly motivated** (only observed particle with its own ATLAS and CMS physics groups):
  - ✳ Connection to new physics? Yukawa coupling =0.995±0.005
  - ✳ Couples to strong force ⇒ large $\sigma_{ttbar}$ ⇒ huge samples at LHC
  - ✳ Rich signature (jets, $E_T^{miss}$, b-jets, leptons)
  - ✳ Dominant background to new physics (e.g. SUSY with leptons and/or b-jets)
  - ✳ Tiny lifetime ⇒ can access top properties directly

# WHAT DO WE KNOW ABOUT THE TOP?

- ★ **We learned a lot since its discovery in 1995...**
  - ✳ Mass measured to 0.5% at the Tevatron. Consistent within the various channels
  - ✳ Single-top quark production observed
  - ✳ Plus many others (charge, W helicity, spin correlation, Br, etc, etc)
- ★ **... but there still lots of unknown.** Today's talk will focus on the **production mechanism of top-antitop pairs**
  - ✳ Cross-section measured to ≈6% experimentally (both Tevatron and LHC), theory uncertainty ≈10% ⇒ **room for new physics in top sample**
  - ✳ $d\sigma/dM_{ttbar}$: narrow width resonance excluded to 1.0-1.5 TeV (≲pb), but constraints on wide resonance weaker
  - ✳ Forward-backward asymmetry probed for the first time only recently (2008)

# $A_{FB}$ AT PROTON-ANTIPROTON COLLIDER



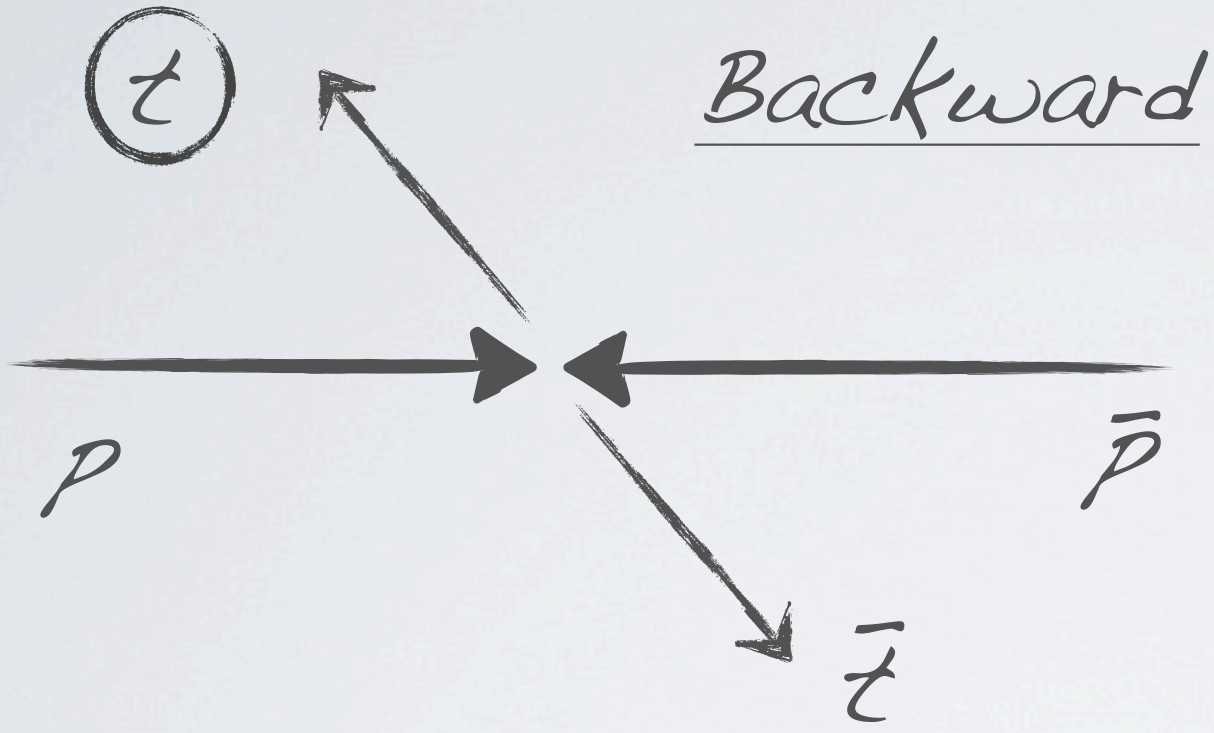

- **SM prediction (NLO)**: $A_{ttbar} = 0.06 \pm 0.01$
  - <u>Only non-zero at NLO</u>
- However recently pointed out that EW corrections not negligible: $A^{ttbar} \approx 0.089$ (Hollik, Pagani 2011)
- NNLO not fully known but partial results suggest < 10%

- Measured quantity:

$$A^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

  - Where $\Delta y = y_t - y_{tbar}$

# $A_{FB}$ AT PROTON-ANTIPROTON COLLIDER

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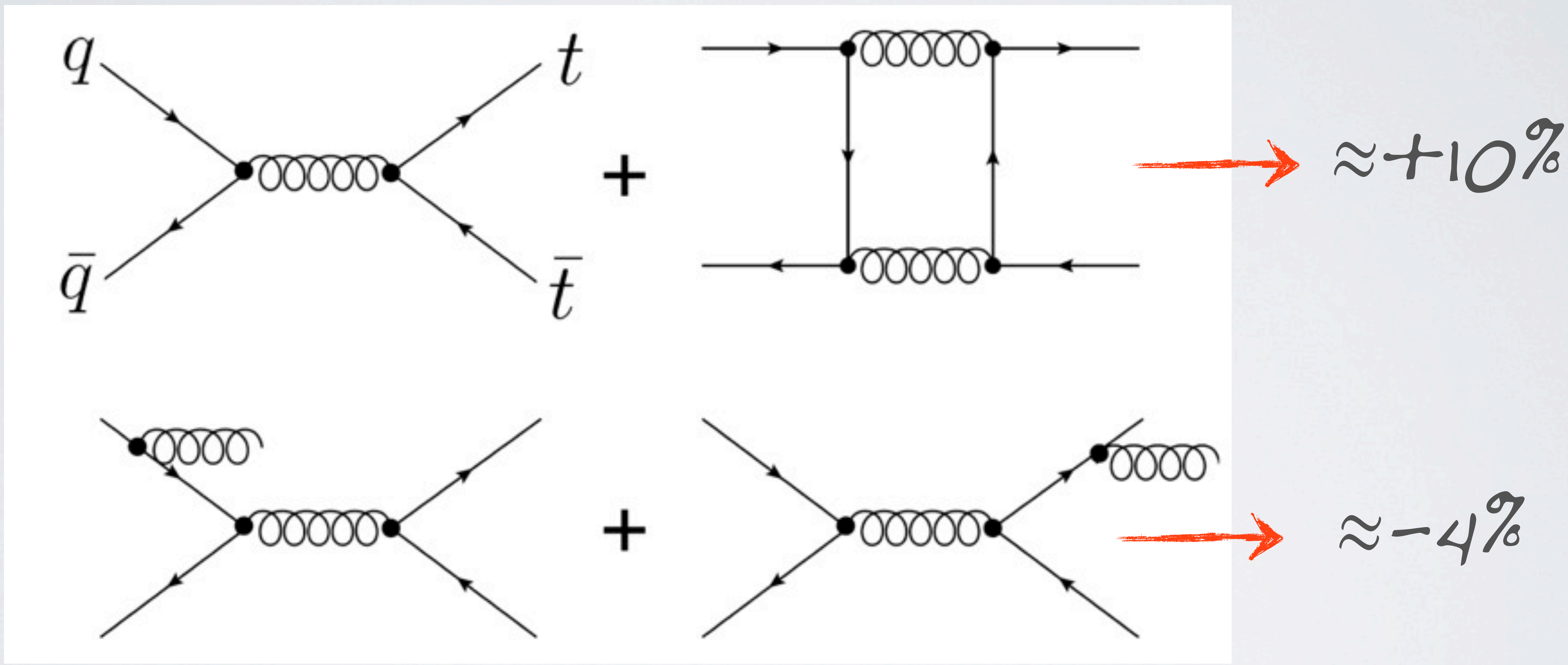
- ✳ Where $\Delta y = y_t - y_{tbar}$

# MORE ON SM PREDICTIONS

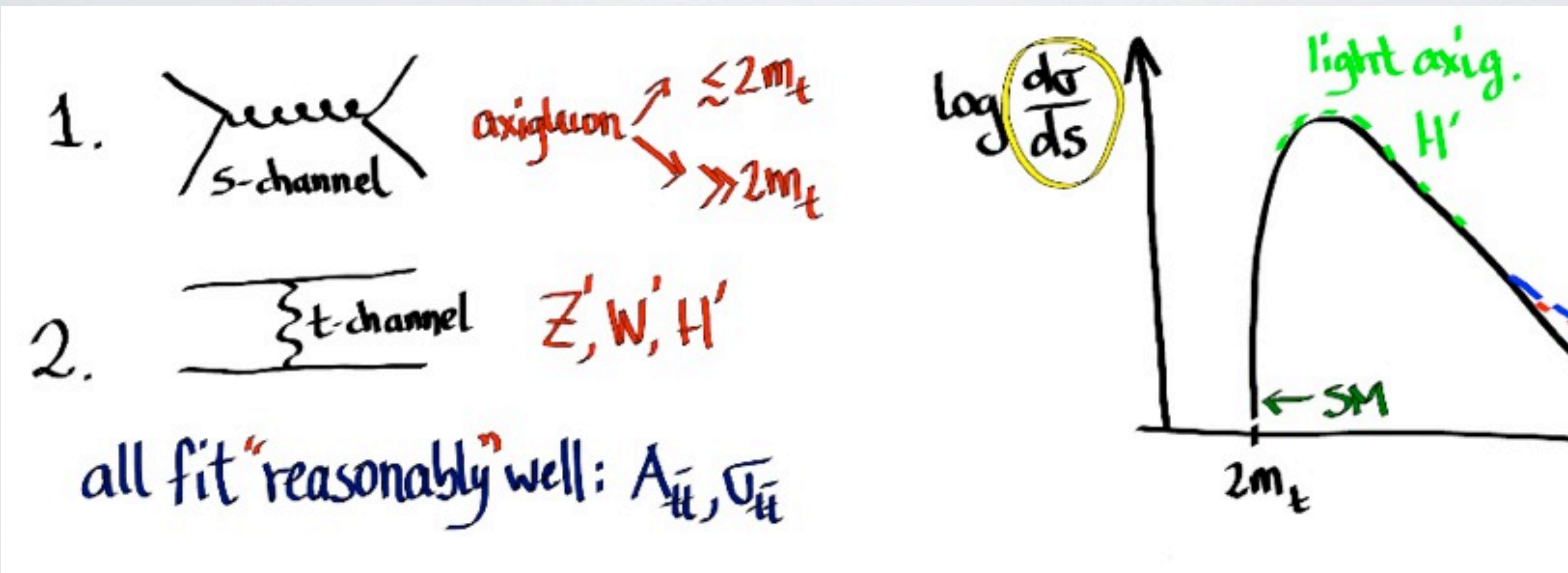
★SM $A_{fb}$ only occurs at $O(\alpha_s^3)$



# $A_{FB}$ BEYOND THE SM

★ Several models could be responsible for anomalous $A_{fb}$

★Model building constraints: $A_{ttbar}$, $\sigma_{ttbar}$, $d\sigma/dm_{ttbar}$, flavor, dijet resonance, same-sign top, etc

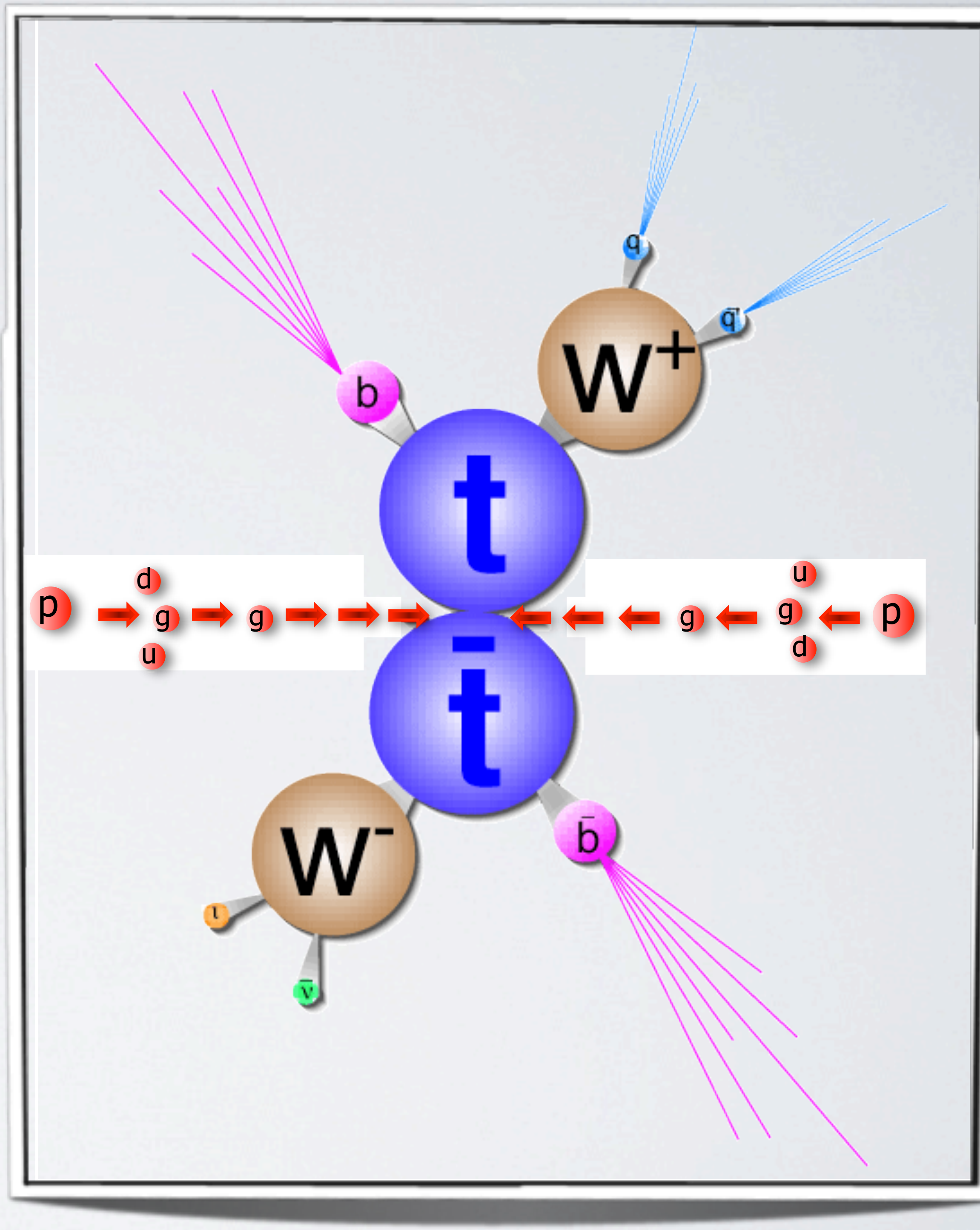



Drawings from Z. Ligeti

★Not the topic of this talk, take home message: several BSM can accommodate anomalous $A_{fb}$

# TOP COLLIDER PHENO 101

- Pair production dominates
  - Tevatron: qqbar dominated: $\sigma_{ttbar}$=7.2±0.8pb
  - LHC: gg dominated, $\sigma_{ttbar}=165^{+8}_{-11}$pb
- Top decays immediately and 100% of the time to a W boson and a b-quark: t→Wb
- The W boson decays define the experimental channel
  - W→lν or W→qqbar'
- This talk focuses on the lepton+jets channel:
  - One isolated e or μ from W
    - tau not yet considered
  - Missing $E_T$ from neutrino from W
  - 2 b-jets
  - 2 jets from W



# Tevatron Measurements

I'll concentrate on the results that came out
in 2011 from each experiment
(and created the most interest)

L+jets CDF: Phys. Rev. D **83**, 112003 (2011)
L+jets DØ: arXiv:1107.4995 [hep-ex]
Dilepton CDF: CDF Note 10436

# L+JETS EVENT SELECTIONS

**CDF**

- ★ 5.3 $fb^{-1}$
- ★ e(μ) $E_T(p_T)$ > 20 GeV
- ★ e(μ) $|\eta|<1.0$
- ★ $E_T^{miss}>20$ GeV
- ★ ≥4 jets with $E_T>20$ GeV, $|\eta|<2.0$
- ★ ≥1 b-tag (SECVTX)

**DØ**

- ★ 5.4 $fb^{-1}$
- ★ e(μ) $E_T(p_T)$ > 20(25) GeV
- ★ e(μ) $|\eta|<1.1(2.0)$
- ★ $E_T^{miss}>20(25)$GeV e(μ)
  - ✳ Plus some $\Delta\phi$ cuts
- ★ ≥4 jets with $E_T>20$ GeV, $|\eta|<2.5$
  - ✳ Leading jet $p_T>40$ GeV
- ★ ≥1 b-tag (neural network)

# BACKGROUND AND SIMULATION

CDF

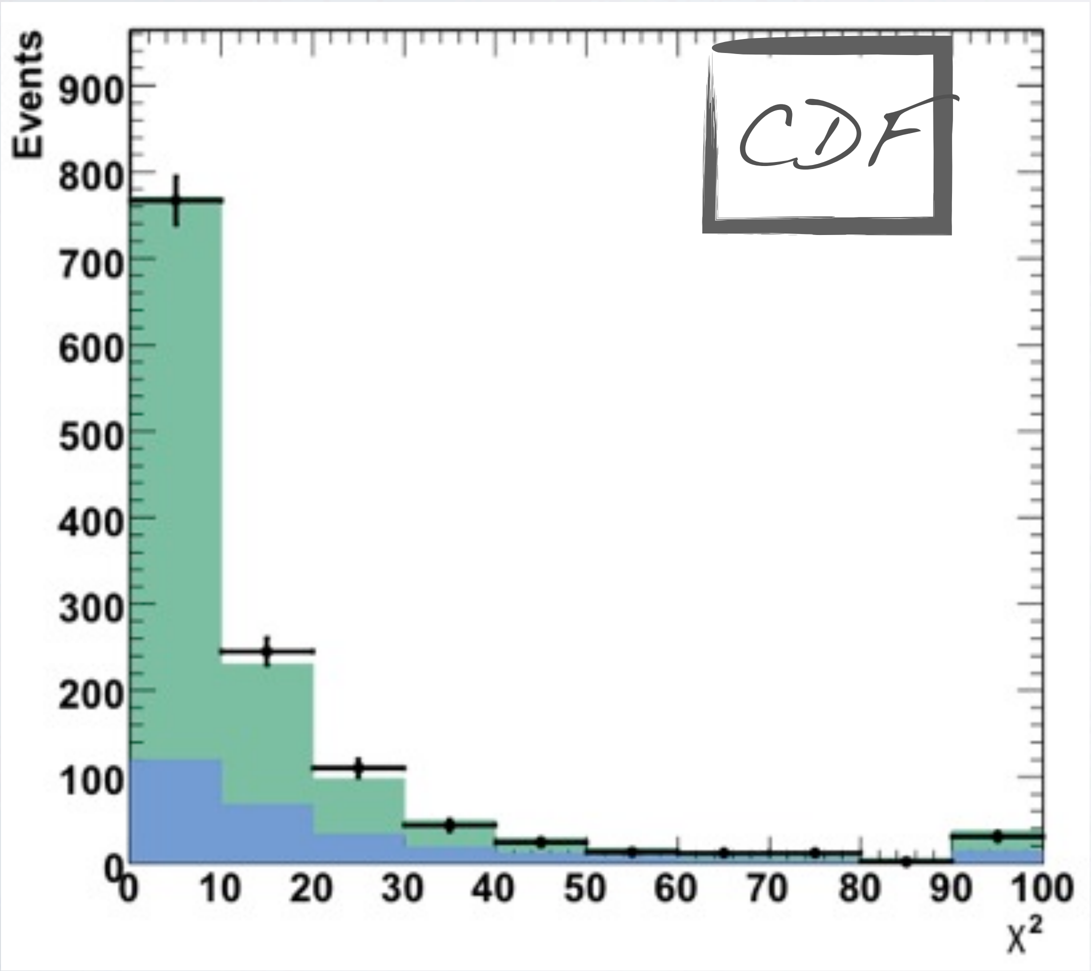
- **Number of events** (5.3 $fb^{-1}$)
  - Total: 1260
  - Background: 283±91
- **Simulation**:
  - Signal: Pythia
    - MC@NLO as cross-check
  - W+jets: ALPGEN

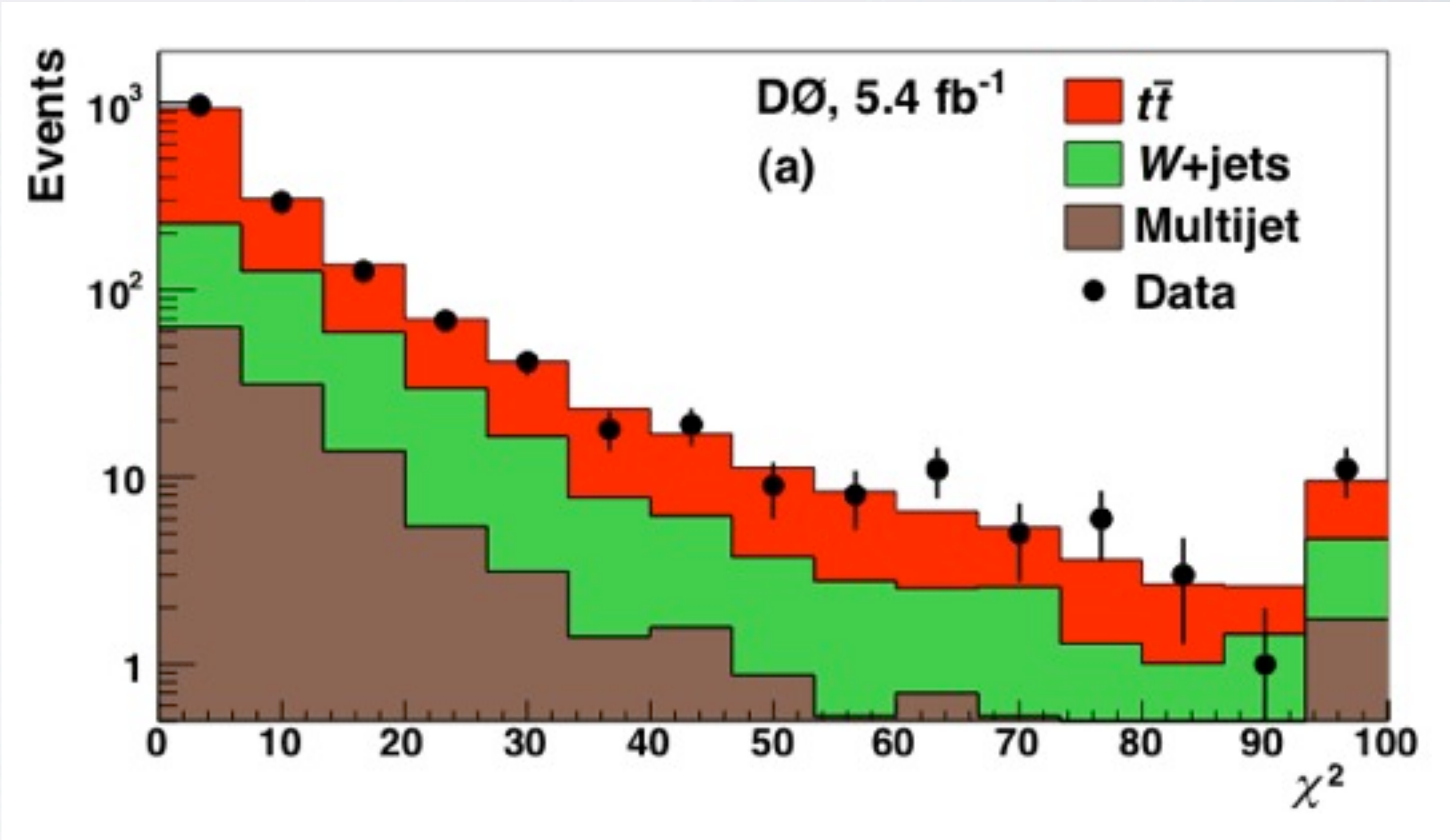
DØ

- **Number of events** (5.4 $fb^{-1}$)
  - Total: 1581
  - Background: 455±47
- **Simulation**:
  - Signal: MC@NLO
  - W+jets: ALPGEN

# TTBAR EVENT RECONSTRUCTION

- **Common to both**: $X^2$ fit based on the ttbar hypothesis
  - Mass constraints of W and top mass
  - Object momentum can float within experimental resolutions
- **Performance**: δΔy ~ 0.10 (CDF), 70% correct parton-jet assignment (DØ)



# SM PREDICTIONS

★ **Parton-level**: "truth"-level before any detector effects

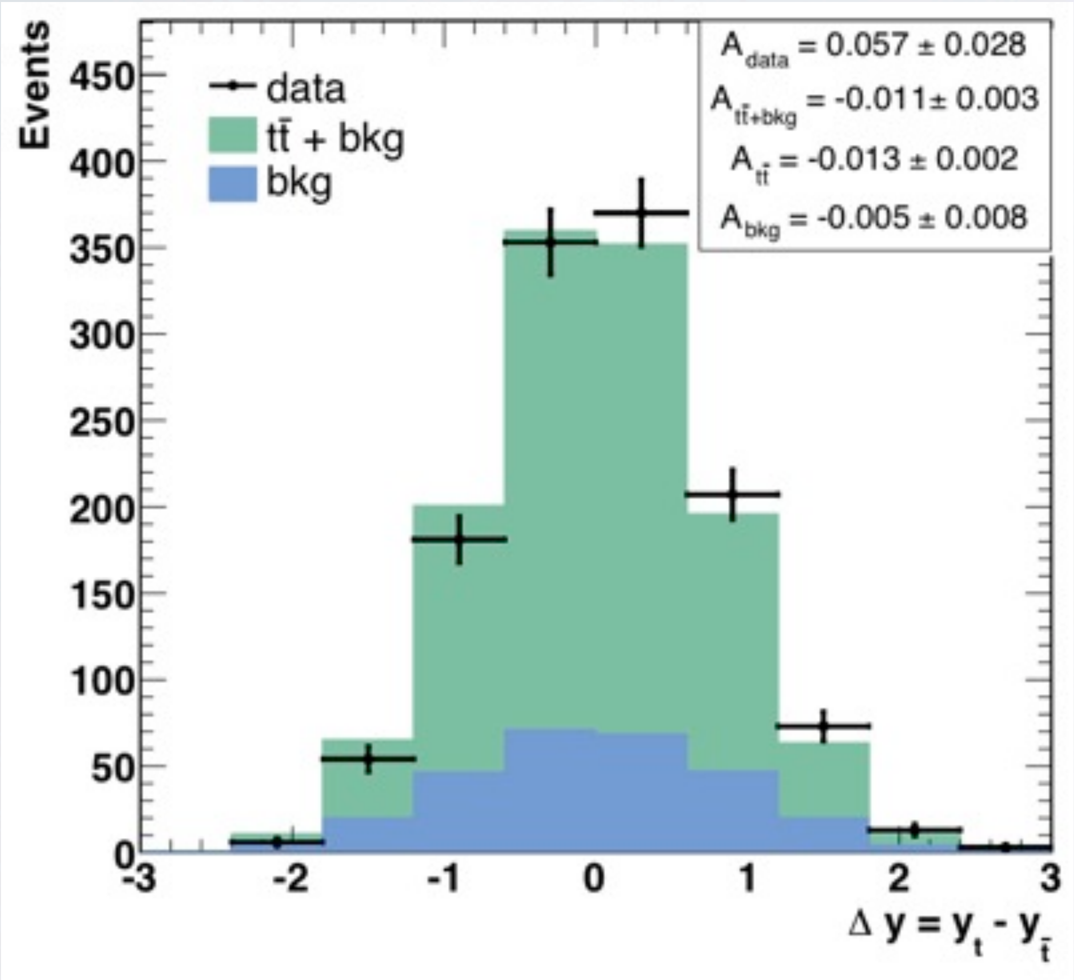
➡ **Desirable to compare to theory and other experiments**

★ **Reco-level**: Pure ttbar (no bkgd) but with detector acceptance and resolution effects

| SM (%) | CDF MCFM | CDF MC@NLO | DØ MC@NLO |
|---|---|---|---|
| Parton-level | 5.8±0.1 | 5.2±0.8 | 5.0±0.1 |
| Reco-level (no bkgd) | N/A | 2.4±0.5 | 2.4±0.7 |

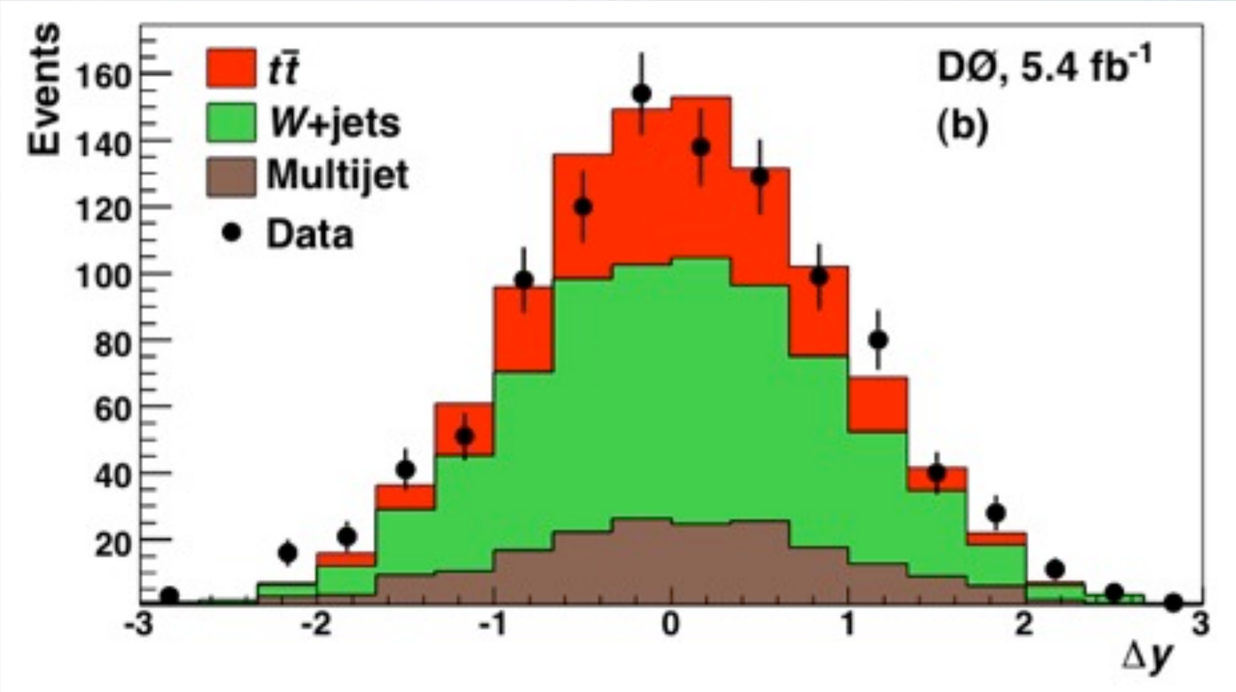
# RECO-LEVEL ASYMMETRY (BKGD SUBTRACTED)

CDF




$A_{fb}$=7.5±3.7%

DØ




$A_{fb}$=9.2±3.7%

# UNFOLDING AND SYSTEMATICS

Unfolding: Invert acceptance and resolution matrix to go back to parton-level. Systematics affect the unfolding

**CDF**

| effect | $\delta A^{t\bar{t}}$ |
|---|---|
| background magnitude | 0.011 |
| background shape | 0.007 |
| ISR/FSR | 0.001 |
| JES | 0.007 |
| PDF | 0.005 |
| color reconnection | 0.004 |
| LO MC generator | 0.005 |
| total | 0.017 |

**DØ**

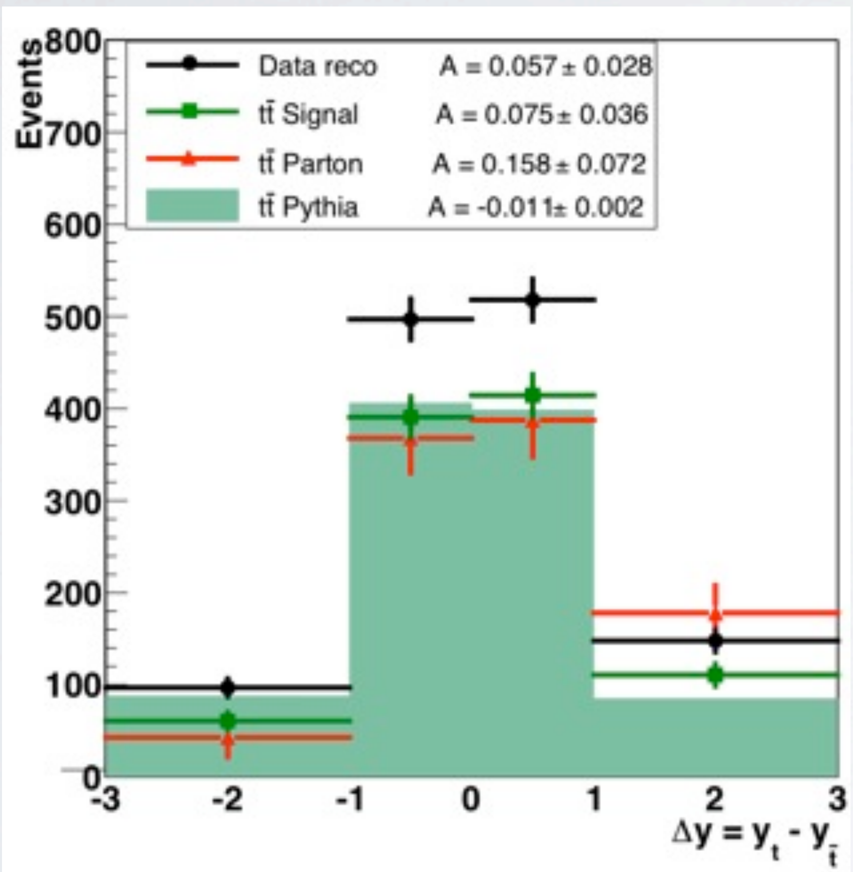
| Source | [a] (%) Prod. level Measurement |
|---|---|
| Jet reco | ±1.0 |
| JES/JER | −1.3 |
| Signal modeling | +0.3/−1.6 |
| *b* tagging | ±0.1 |
| Charge ID | +0.2/−0.1 |
| Bg subtraction | +0.8/−0.7 |
| Unfolding Bias | +1.1/−1.0 |
| Total | +1.8/−2.6 |

**Note:** statistical uncertainties (7% CDF, 6% DØ) dominate

# PARTON-LEVEL ASYMMETRY

**Reminder**: SM predicts $A_{fb}$~6±1%

CDF




$A_{fb}$=15.8±7.4%
1.3**σ** from SM

DØ

$A_{fb}$=19.6±6.5%
2.4**σ** from SM

DØ also performs a lepton-based asymmetry (MC@NLO: 2.1±0.1%)

$A_{fb}^{l}$=15.2±4.0%
3.3**σ** from SM

# CROSS-CHECKS

## CDF

★ Antitag (bkgd) control sample $A_{fb}$ consistent with zero: 3.3±1.8%

★ Δy consistent with lepton charge

| selection | $A^{t\bar{t}}$ |
|---|---|
| inclusive | $0.057 \pm 0.028$ |
| electrons | $0.026 \pm 0.037$ |
| muons | $0.105 \pm 0.043$ |
| single $b$-tags | $0.058 \pm 0.031$ |
| double $b$-tags | $0.053 \pm 0.059$ |

## DØ

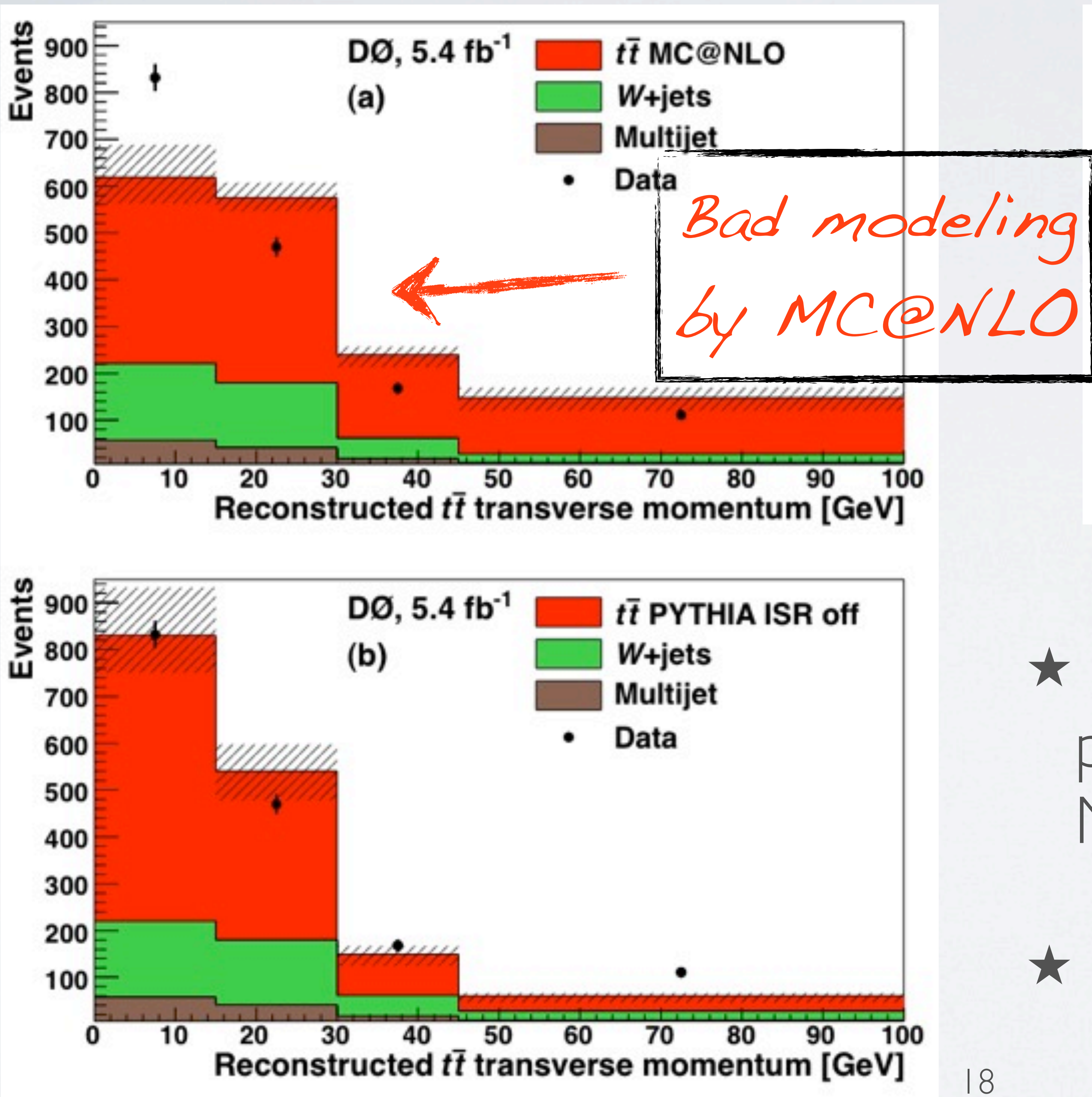
★ Antitag (bkgd) control sample $A_{fb}$ consistent with zero: 4.1±4.1%

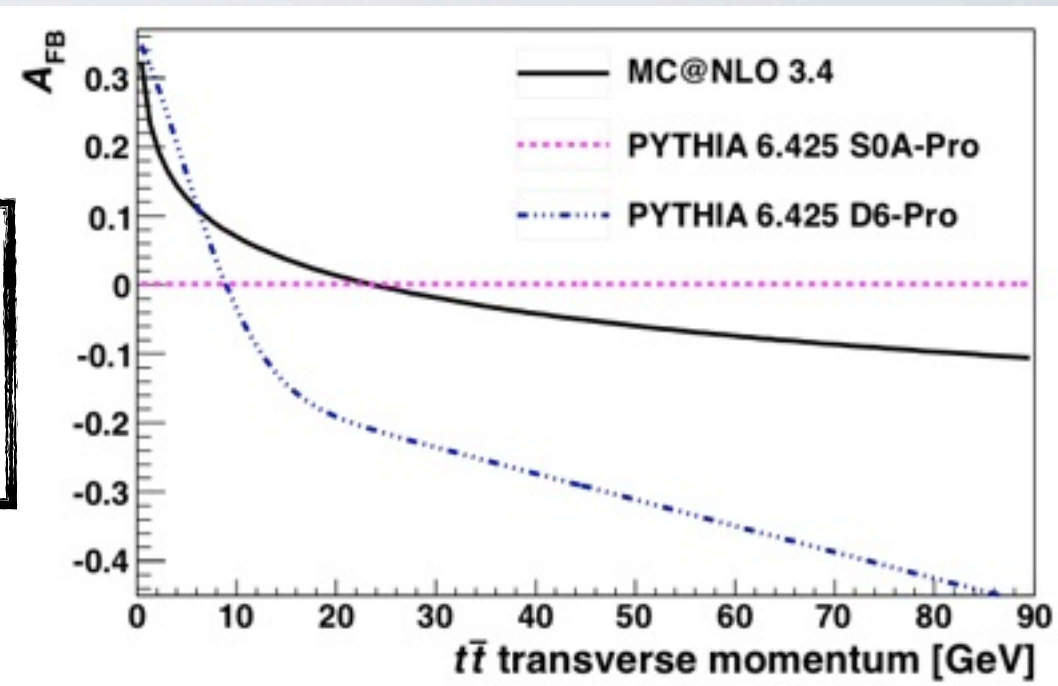
★ No dependence on magnet polarities (inverted regularly at DØ)

★ Consistent with lepton charge (reco-level)

# DØ $P_T$(TTBAR) ANALYSIS

★ SM $A_{fb}$ depends on $p_T$(ttbar): high value selects ttbar+jets (negative $A_{fb}$)




★ **However** CDF claims a good $p_T$(ttbar) modeling with their MC, but no public plots yet

★ Situation currently unclear

# CDF $M_{TTBAR}$ DEPENDENCE

- ★ New physics could produce larger $A_{fb}$ at high $M_{ttbar}$
- ★ Separate in two bins (chosen a priori): $M_{ttbar}$ < and > 450 GeV

| selection | all $M_{t\bar{t}}$ | $M_{t\bar{t}} < 450$ GeV/$c^2$ | $M_{t\bar{t}} \geq 450$ GeV/$c^2$ |
|---|---|---|---|
| reco data | 0.057±0.028 | -0.016±0.034 | 0.210±0.049 |
| MC@NLO | 0.017±0.004 | 0.012±0.006 | 0.030±0.007 |
| $A_{lh}^{+}$ | 0.067±0.040 | -0.013±0.050 | 0.210±0.066 |
| $A_{lh}^{-}$ | -0.048±0.039 | 0.020±0.047 | -0.210±0.071 |

- ★ Large asymmetry for $M_{ttbar}$ > 450 GeV
- ★ Effect is CP conserving
- ★ After unfolding: $A_{fb}$=0.475±0.114 (SM: 0.088±0.013, 3.4$\sigma$ away)

# CROSS-CHECKS TO CDF $A_{FB}$ VS $M_{TTBAR}$

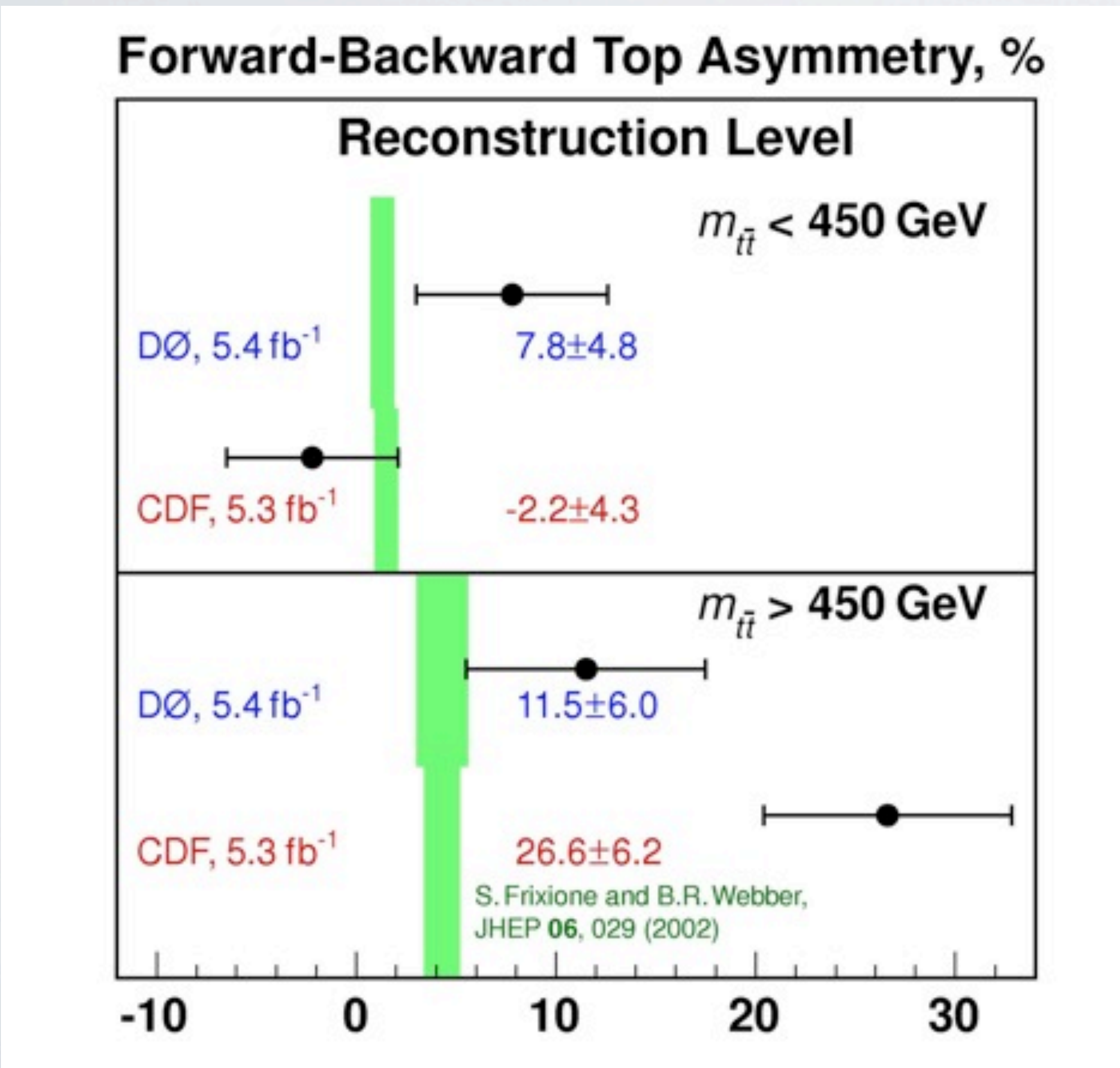
| selection | N events | all $M_{t\bar{t}}$ | $M_{t\bar{t}} < 450$ GeV/$c^2$ | $M_{t\bar{t}} \geq 450$ GeV/$c^2$ |
|---|---|---|---|---|
| standard | 1260 | 0.057±0.028 | -0.016±0.034 | 0.212±0.049 |
| electrons | 735 | 0.026±0.037 | -0.020±0.045 | 0.120±0.063 |
| muons | 525 | 0.105±0.043 | -0.012±0.054 | 0.348±0.080 |
| data $\chi^2 < 3.0$ | 338 | 0.030±0.054 | −0.033 ± 0.065 | 0.180 ± 0.099 |
| data no-b-fit | 1260 | 0.062±0.028 | 0.006 ± 0.034 | 0.190 ± 0.050 |
| data single b-tag | 979 | 0.058±0.031 | -0.015±0.038 | 0.224±0.056 |
| data double b-tag | 281 | 0.053±0.059 | -0.023±0.076 | 0.178±0.095 |
| data anti-tag | 3019 | 0.033±0.018 | 0.029±0.021 | 0.044±0.035 |
| pred anti-tag | - | 0.010±0.007 | 0.013±0.008 | 0.001±0.014 |
| pre-tag | 4279 | 0.040±0.015 | 0.017±0.018 | 0.100±0.029 |
| pre-tag no-b-fit | 4279 | 0.042±0.015 | 0.023±0.018 | 0.092±0.029 |

★ Plus:

- ✳ $M_{ttbar}$ spectrum: good data-MC agreement
- ✳ Study njets dependence (not enough stats to conclude)

# CDF VS DØ: $A_{FB}$ VS $M_{TTBAR}$ AND $\Delta$Y

| | sample | level | $\|\Delta y\| < 1.0$ | $\|\Delta y\| \geq 1.0$ |
|---|---|---|---|---|
| CDF | data | data | $0.021 \pm 0.031$ | $0.208 \pm 0.062$ |
| | DØ | Data | 0.061±0.041 | 0.213±0.097 |




- ★ Both DØ and CDF observe an increase of $A_{fb}$ vs $\Delta$y
- ★ DØ doesn't confirm nor rule out CDF mass dependence result
- ★ Situation needs clarification

# CDF DILEPTON $A_{FB}$ (5.1 $FB^{-1}$)

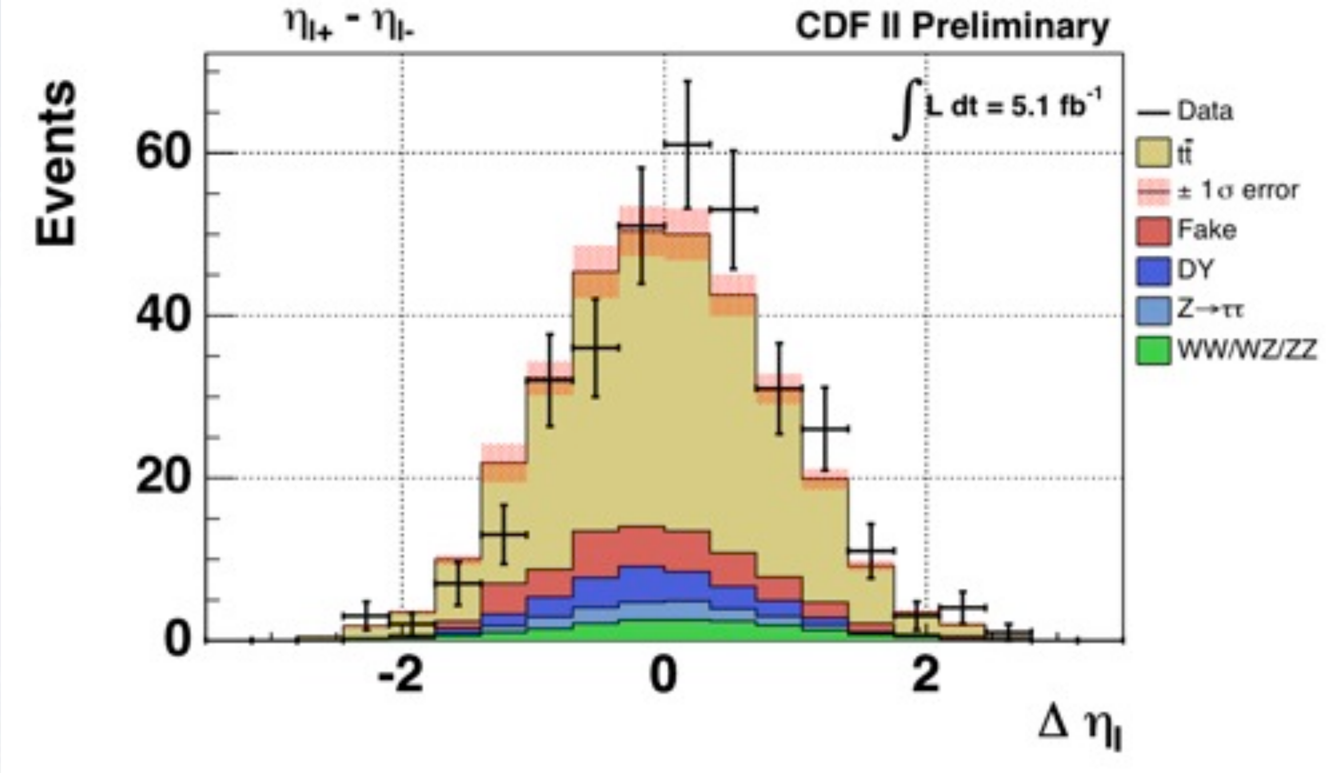
★ Sample of 334 events with 87±17 bkgd

★ Measure the $\Delta\eta_l$ asymmetry, unfold using simulation to $\Delta y_t$

★ Signal region (≥2-jets, $E_T^{miss}$>25 GeV) after unfolding:

$$A_{fb} = 0.42 \pm (0.15)^{stat} \pm (0.05)^{syst}$$

★ Cross-checks: $A_{fb}$ in the 0, 1, 2-jets bins (w/o $E_T^{miss}$) consistent with 0




★ Not enough stats to be sensitive at high $M_{ttbar}$

★ Combination with L+jets inclusive (2.9σ away from SM):

$$A_{fb} = 0.20 \pm 0.07_{stat} \pm 0.02_{sys}$$

# MY CONCLUSIONS ABOUT THE TEVATRON RESULTS

★ Discrepancy with the SM at the level of 2 up-to 3.3$\sigma$ observed by both CDF and DØ for the inclusive $A_{fb}$

★ CDF dependence over $M_{ttbar}$ neither confirmed nor ruled out by DØ

✳ But both see a larger $A_{fb}$ at large $\Delta y$

★ There are theory issues: SM predictions only effectively at LO, modeling problems observed by DØ

★ Results are statistically limited, increasing datasets by x2 but probably won't give unambiguous conclusions (i.e. neither clear 5$\sigma$ excess nor completely rule out the current deviation)

⇒ **Clarification will be needed from the LHC**

# LHC Measurements

L+jets ATLAS: https://cdsweb.cern.ch/record/1372916/files/ATLAS-CONF-2011-106.pdf
L+jets CMS: https://cdsweb.cern.ch/record/1369205/files/TOP-11-014-pas.pdf

# SM LHC PREDICTIONS

★ No forward-backward asymmetry at a pp collider

★ However a positive $A_{fb}$ at the Tevatron would result in the top be produced less centrally and the antitop be more central

- ✴ Because the quark (anti-quark) tends to be a valence (sea) quark


$$A_C = \frac{N(|y_t| > |y_{\bar{t}}|) - N(|y_{\bar{t}}| > |y_t|)}{N(|y_t| > |y_{\bar{t}}|) + N(|y_{\bar{t}}| > |y_t|)},$$

SM: $A_C \approx 1\%$

- ✴ Measurement is also complicated by the fact the gg production dominates (≈70% at $\sqrt{s}$=7 TeV) and dilutes any $A_c$

- ✴ However we have **huge datasets**! ~x35 more ttbar reco. on tape than Tevatron meas.

# EVENT SELECTIONS AND DATASETS

- **Dataset**: 0.7 $fb^{-1}$
- **Event selections:**
  - e(μ): Isolated + $E_T$($p_T$) > 25(20) GeV + |η|<2.47(2.5)
  - $E_T^{miss}$>35(20) GeV e(μ) + $M_T$ cuts
  - ≥4 jets with $E_T$>25 GeV, |η|<2.5
  - ≥1b-tag (secondary vertex tagger)

- **MC simulations:**
  - Signal: MC@NLO+Herwig
  - W+jets: ALPGEN+Herwig

# BACKGROUNDS

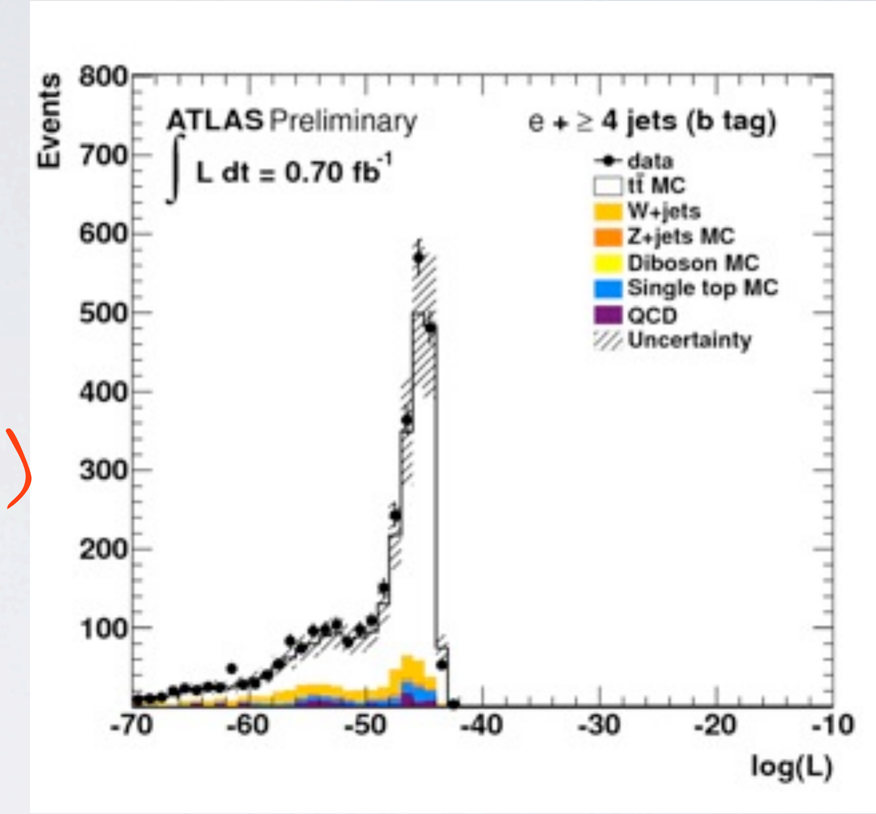
| Channel | μ + jets pretag | μ + jets tagged | e + jets pretag | e + jets tagged |
|---|---|---|---|---|
| $t\bar{t}$ | 4784 ± 5 | 3247 ± 4 | 3293 ± 4 | 2218 ± 4 |
| Single top | 306 ± 2 | 171 ± 2 | 219 ± 2 | 124 ± 2 |
| Z+jets | 632 ± 7 | 43 ± 2 | 535 ± 7 | 35 ± 1 |
| Diboson | 90 ± 2 | 8 ± 1 | 56 ± 1 | 5 ± 0 |
| W+jets | 5741 ± 915 | 494 ± 234 | 3436 ± 628 | 309 ± 144 |
| QCD | 1103 ± 552 | 227 ± 227 | 665 ± 332 | 84 ± 84 |
| Total background | 7871 ± 1068 | 943 ± 326 | 4910 ± 711 | 557 ± 167 |
| Signal + background | 12655 ± 1068 | 4189 ± 326 | 8203 ± 711 | 2775 ± 167 |
| Observed | 12705 | 4392 | 8193 | 2997 |

- **Background estimates**
  - W+jets: $W_{tagged} = W_{pretag} \times f_{tagged}$ (both terms estimated in a data-driven manner)
  - QCD (fake): matrix-method
  - Others: MC simulation

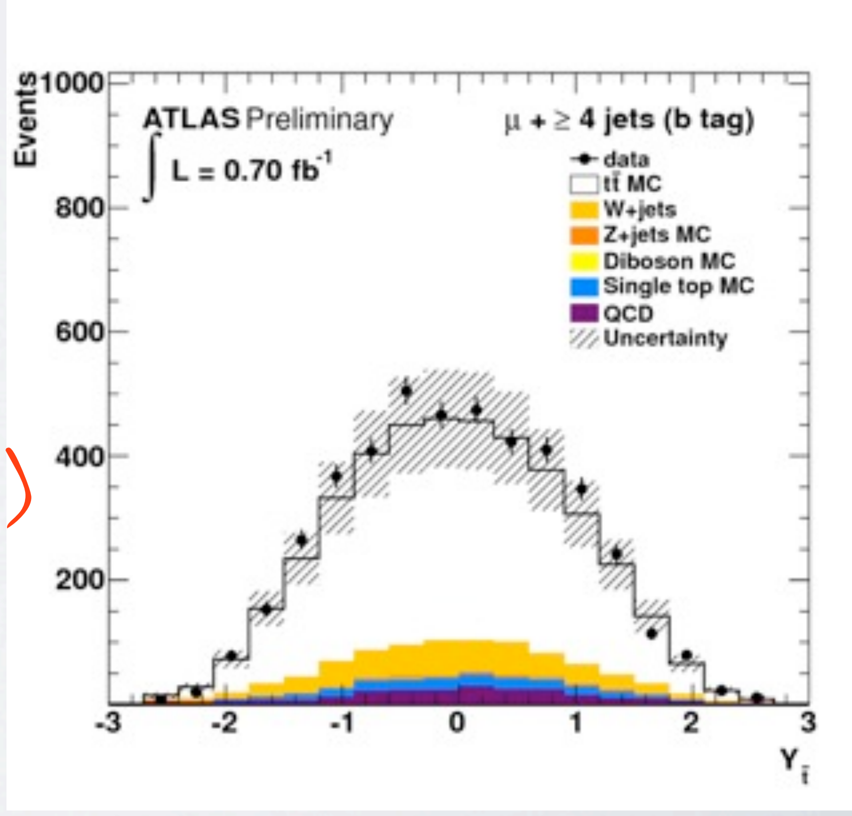
# TTBAR EVENT RECONSTRUCTION

- **Likelihood fitter based on ttbar event hypothesis**:
  - Top and W mass constraints
  - Lepton, $E_T^{miss}$ and jet energy (and angle) non-gaussian resolution transfer function
  - Includes up-to 5 jets
  - b-tagging probability
- Fraction of correct assign.: 74%

Log(L) (e+jets)

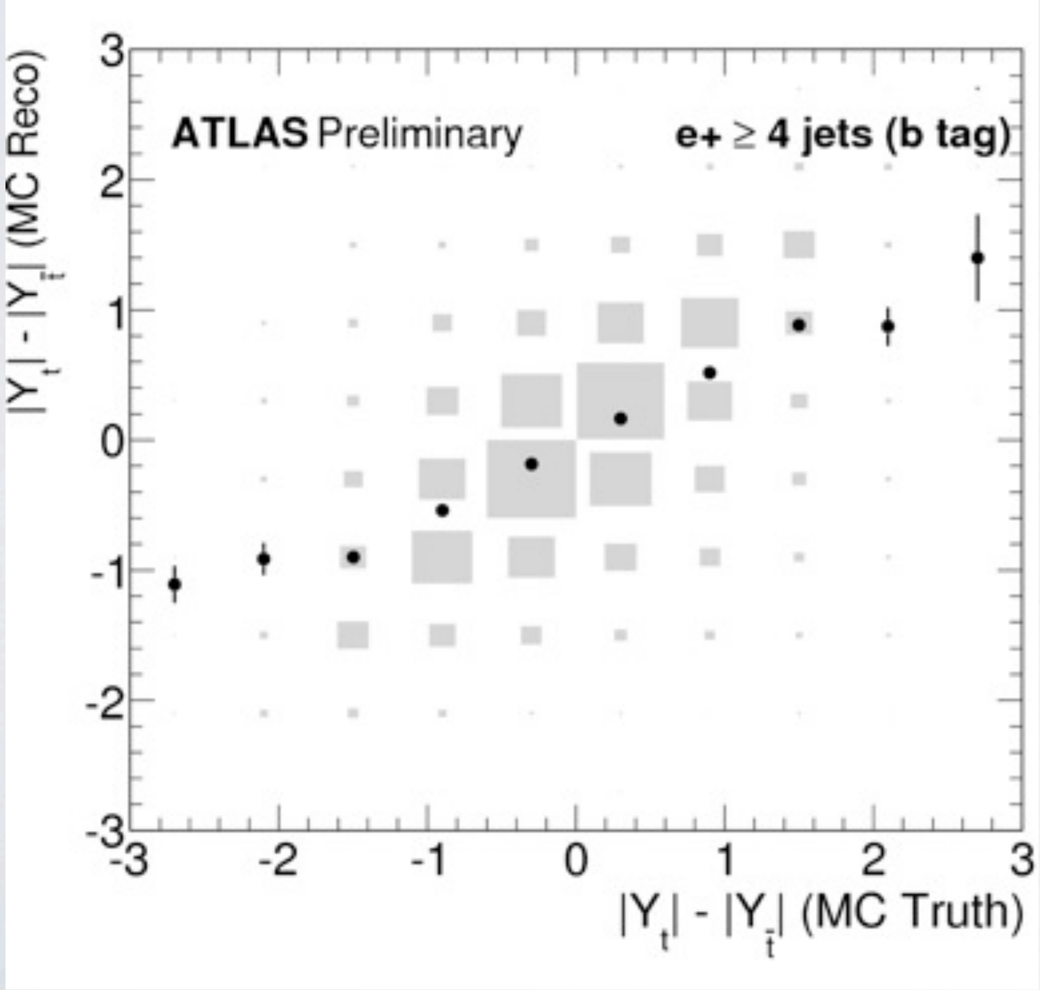



Ytbar (μ+jets)



# UNFOLDING AND SYSTEMATICS

Unfolding used to correct for detector and acceptance effects. Shown to be unbiased plus for large range of input $A_C$

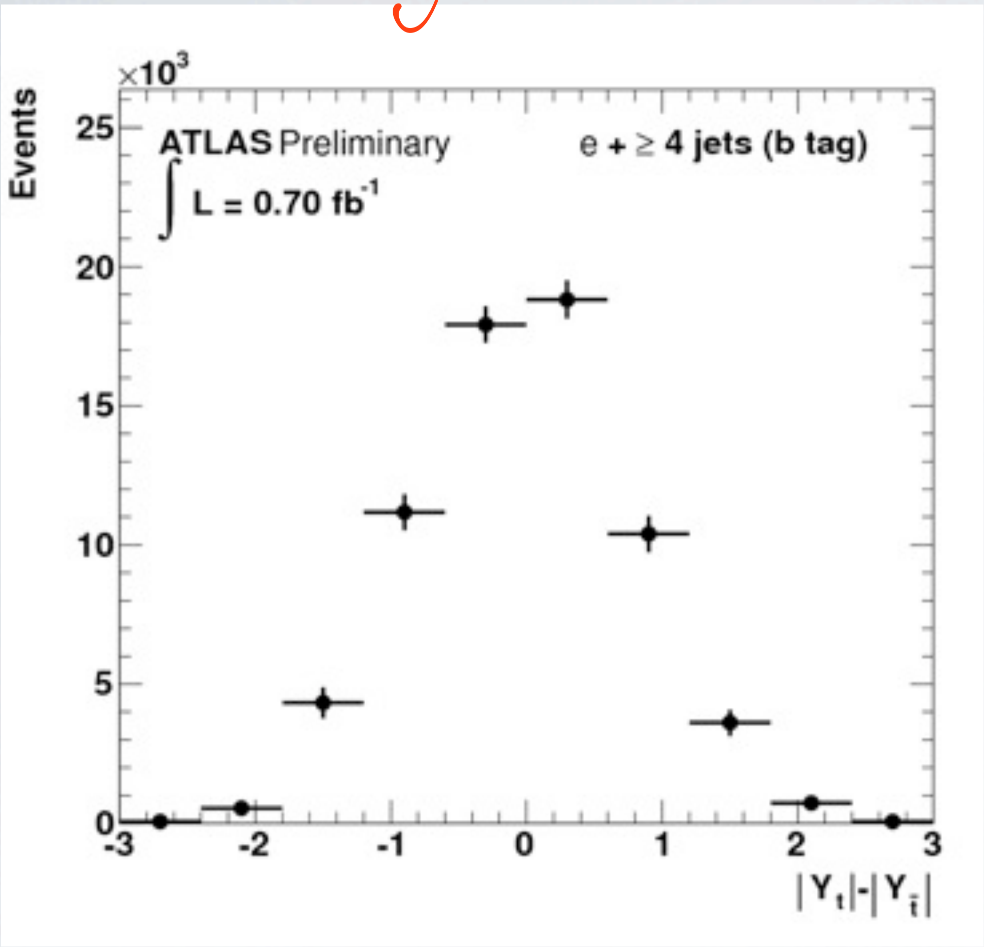



| | Electron channel | Muon channel |
|---|---|---|
| Source of systematic uncertainty | $\Delta A_C$ | |
| *Signal and background modelling* | | |
| $t\bar{t}$ generator | 0.0243 | 0.0100 |
| Parton shower/fragmentation | 0.0108 | 0.0079 |
| ISR/FSR | 0.0074 | 0.0074 |
| PDF uncertainty | 0.0008 | 0.0008 |
| Top mass | 0.0059 | 0.0059 |
| QCD normalisation | 0.0062 | 0.0059 |
| W+jets normalisation | 0.0054 | 0.0097 |
| W+jets shape | 0.0043 | 0.0043 |
| Z+jets normalisation | 0.0002 | 0.0002 |
| Z+jets shape | 0.0010 | 0.0010 |
| Single Top normalisation | 0.0002 | 0.0002 |
| Diboson normalisation | 0.00001 | 0.00001 |
| MC sample sizes | 0.0043 | 0.0029 |
| *Detector modelling* | | |
| Muon efficiencies | (n.a.) | 0.0002 |
| Muon momentum scale and resolution | 0.0004 | 0.0004 |
| Electron efficiencies | 0.0004 | (n.a.) |
| Electron energy scale and resolution | 0.0004 | 0.0004 |
| Lepton charge misidentification | 0.0002 | 0.0002 |
| Jet energy scale | 0.0041 | 0.0046 |
| Jet energy resolution | 0.0105 | 0.0040 |
| Jet reconstruction efficiency | 0.0003 | 0.0003 |
| *b*-tagging scale factors | 0.0038 | 0.0038 |
| Charge asymmetry in *b*-tagging efficiency | 0.0007 | 0.0007 |
| Calorimeter readout | 0.0015 | 0.0029 |
| Combined uncertainty | 0.032 | 0.022 |

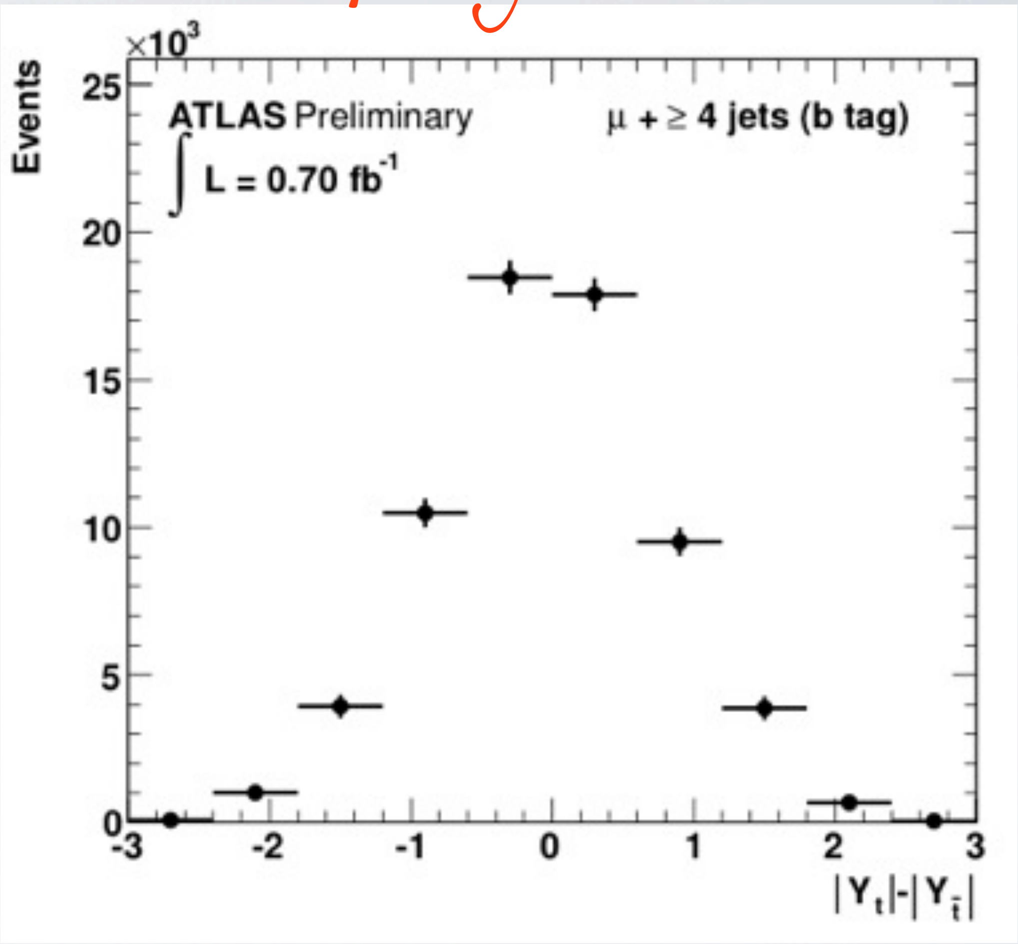
**Theory uncert. are important!**

# RESULTS (AFTER UNFOLDING)

e+jets




μ+jets

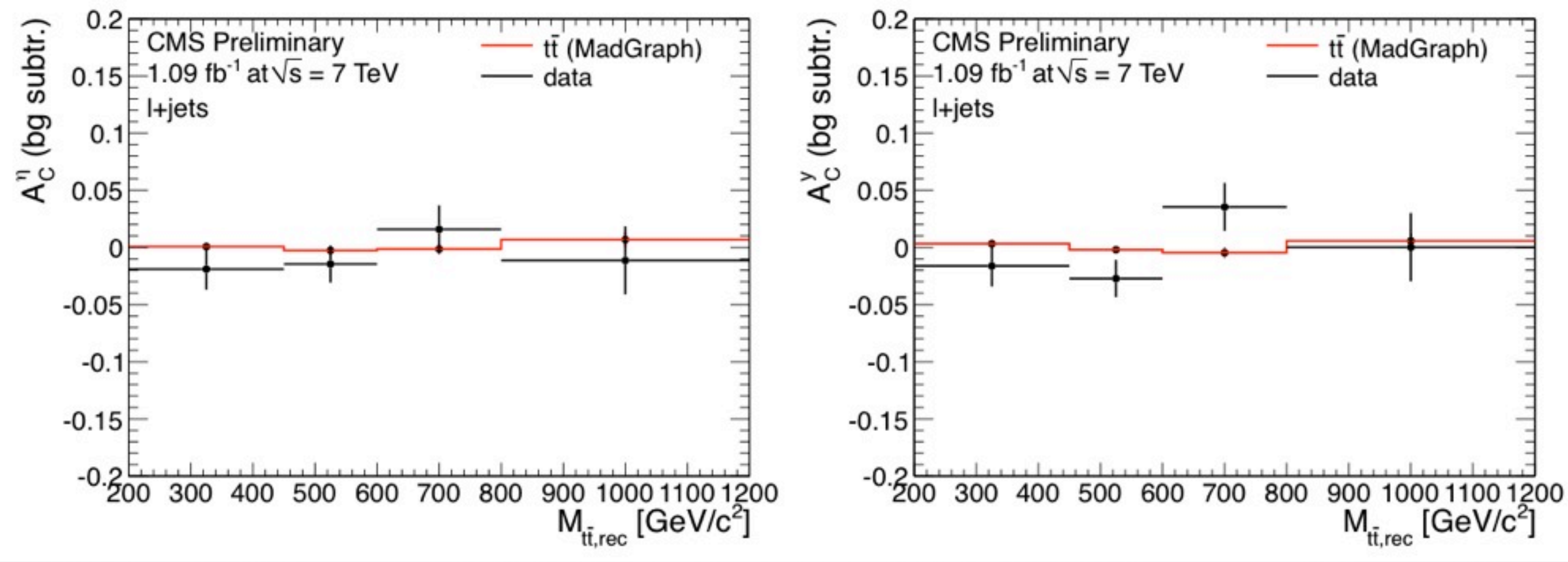



| Asymmetry | detector and acceptance unfolded |
|---|---|
| $A_C$ (muon pretag) | -0.016 ± 0.028 (stat.) ± 0.064 (syst.) |
| $A_C$ (muon *b*-tag) | -0.028 ± 0.019 (stat.) ± 0.022 (syst.) |
| $A_C$ (electron pretag) | -0.023 ± 0.034 (stat.) ± 0.065 (syst.) |
| $A_C$ (electron *b*-tag) | -0.009 ± 0.023 (stat.) ± 0.032 (syst.) |

Combination (B-tag): $A_C = -0.024 \pm 0.016\,(\text{stat.}) \pm 0.023\,(\text{syst.})$

# CMS MEASUREMENTS

*Inclusive asymmetry:* $A_C^y = -0.013 \pm 0.026\,(\text{stat.})^{+0.026}_{-0.021}(\text{syst.})$




★No dependence vs $M_{ttbar}$ observed, **but no unfolding applied**

# LHC CONCLUSIONS

★ No significant $A_C$ observed at LHC

★ **However this does not contradict the Tevatron results**

- ✳ Inclusive asymmetry not very sensitive to new physics at LHC
- ✳ Results vs $M_{ttbar}$ from CMS is only at reconstructed level

★ **Results already systematics-limited**

- ✳ Dominated by signal modeling uncertainties which will not improve quickly (require better understanding of ttbar production like differential cross-section measurements)

➡ **To have a chance to be sensitive to new physics effects, need to select corners of phase space to increase the asymmetry**

# Increasing $A_c$

**Presented today:**

M. Freytsis, Z. Ligeti, JFA, Phys. Rev. D 84, 071504 (2011)

Other similar work exist:

[Kagan, Kamenik, Perez, Stone, 1103.3747]

[Wang, Xiao, Zhu, 1008.2685; Aguilar-Saavedra, Juste, Rubbo, 1109.3710]

# FUTURE DIRECTIONS: GOING FORWARD

- ★ gg→ttbar dominates (~85%), but is really a **background** to $A_C$ measurement
- ★ The **signal qqbar** produced events tends to be produced **forwardly** since the q (qbar) tend to be valence (sea) quarks
- ★ The ttbar physics program of both ATLAS and CMS uses jet only up-to **$|\eta|$ ~2.5**
- ★ However the ATLAS and CMS calorimeters are capable to reconstruct jets up-to **$|\eta|$~4.5**
  - ✳ This is exemplified by important measurements such as single-top observation and inclusive jet cross-section which use forward jets

➡ **Can increase $A_C$ by using forward jets**

# METHODOLOGY

★ Choose a few representative models that:

✳ Yield roughly Tevatron $A_{fb}$

✳ Survive experimental bounds

✳ Scan range of possibilities (e.g. different channels s, t, u)

| Predictions | new physics models | | |
|---|---|---|---|
| | $Z'$ | Axigluon | Scalar **3** |
| $A_{t\bar{t}}^{\mathrm{TEV}}(m_{t\bar{t}} > 450\,\mathrm{GeV})$ | 0.30 | 0.26 | 0.29 |
| $A_{t\bar{t}}^{\mathrm{TEV}}$ | 0.15 | 0.14 | 0.17 |
| $\sigma_{t\bar{t}}^{\mathrm{TEV}}/\sigma_{t\bar{t}}^{\mathrm{TEV,SM}}$ | 0.85 | 1.08 | 1.19 |
| $\sigma_{t\bar{t}}^{\mathrm{LHC}}/\sigma_{t\bar{t}}^{\mathrm{LHC,SM}}$ | 1.01 | 1.16 | 1.11 |

$$\begin{aligned} Z' :&\quad m_{Z'} = 260\ \mathrm{GeV}, &\quad \alpha_{Z'} = 0.048\,, \\ \text{Axigluon} :&\quad m_A = 2\ \mathrm{TeV}, &\quad g_A = 2.4\,, \\ \text{Scalar } \mathbf{3} :&\quad m_S = 750\ \mathrm{GeV}, &\quad \lambda = 3.0\,. \end{aligned}$$

★ SM contributions using MCFM

★ New physics using Madgraph+Pythia

★ Study is performed at the **parton-level** (no bkgd)

# EVENT SELECTIONS

★R1: LHC-like cuts, including jets $|\eta|<2.5$

★R2: Same as above plus jets $|\eta|<4.5$. One of the b-jet has to be within $|\eta|<2.5$ to allow b-tagging.

★R3: Same as above but require the hadronic top: $|\eta_t|>2.5$

✳$|\eta_t|$ can be >4.5 since the decay products in the opposite $\phi$ hemisphere

★M1: $M_{ttbar}>450$ GeV

★M2: $M_{ttbar}>550$ GeV

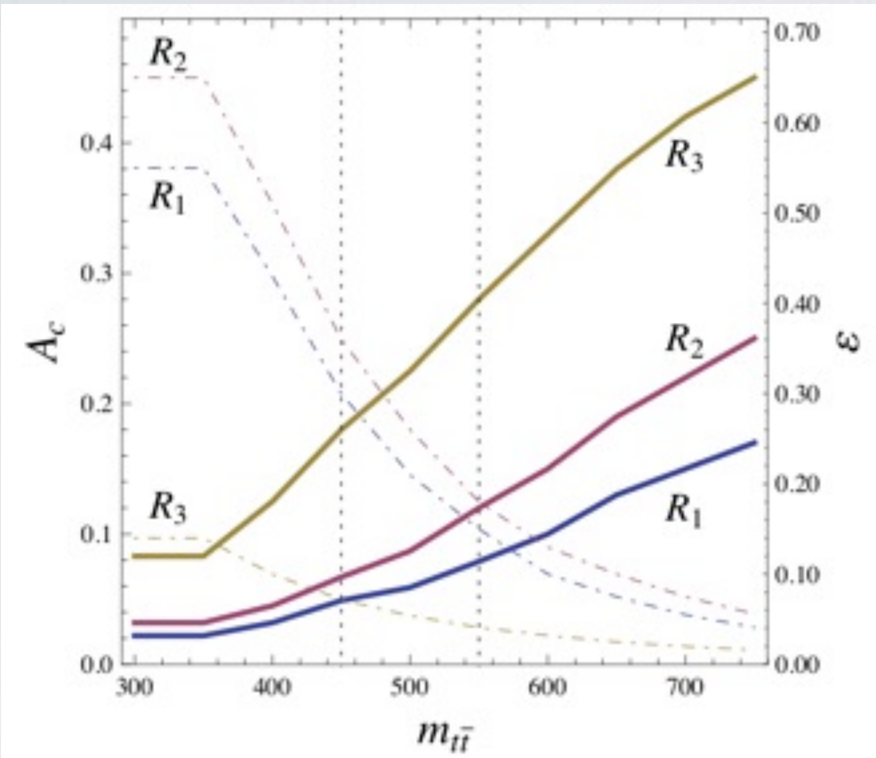
# RESULTS

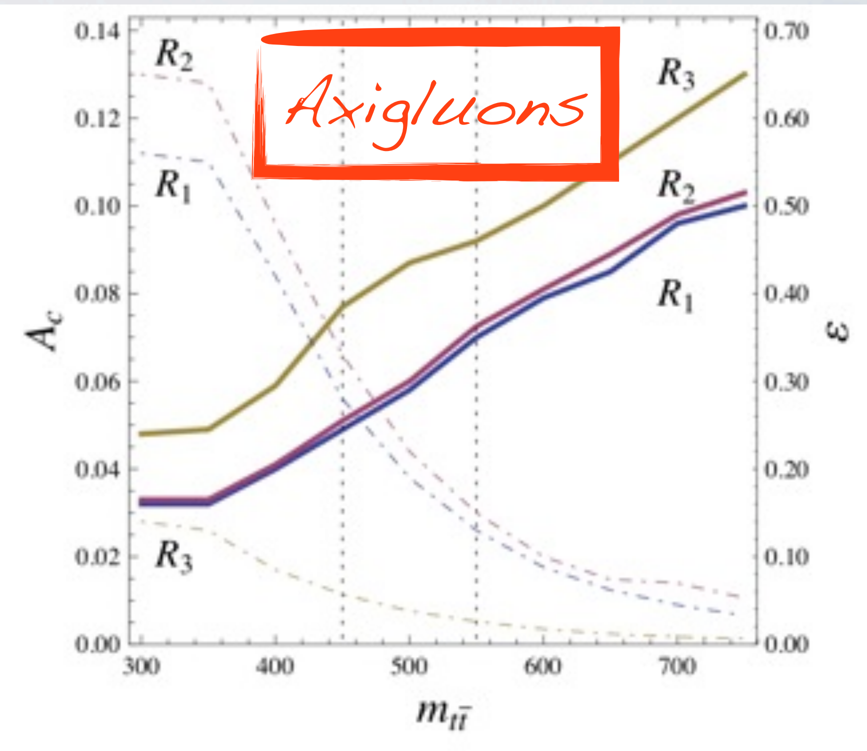
- R1-R3 alone hopeless to find new physics, need a mass cut in addition
- M1&M2 increase $A_C$ to ~5-9% but would like more given systematics are ~2-3%
- **Combinations of R&M** cut increase $A_C$ up-to 28% for Z'! Also 14% for scalar but only 9% for axigluon
  - Different behavior will help **distinguish between models**
- Large price to pay in efficiency → need large samples

| Cuts | SM MCFM | new physics models | | |
|---|---|---|---|---|
| | | $Z'$ | Axigluon | Scalar **3** |
| $R_1$ | $A_c = 0.014$ | $A_c = 0.022$ $\varepsilon = 0.55$ | $A_c = 0.032$ $\varepsilon = 0.56$ | $A_c = 0.041$ $\varepsilon = 0.56$ |
| $R_2$ | $A_c = 0.019$ | $A_c = 0.032$ $\varepsilon = 0.65$ | $A_c = 0.033$ $\varepsilon = 0.65$ | $A_c = 0.042$ $\varepsilon = 0.65$ |
| $R_3$ | $A_c = 0.020$ | $A_c = 0.083$ $\varepsilon = 0.14$ | $A_c = 0.048$ $\varepsilon = 0.14$ | $A_c = 0.054$ $\varepsilon = 0.13$ |
| $R_1$ & $M_1$ | $A_c = 0.022$ | $A_c = 0.049$ $\varepsilon = 0.30$ | $A_c = 0.050$ $\varepsilon = 0.28$ | $A_c = 0.062$ $\varepsilon = 0.33$ |
| $R_2$ & $M_1$ | $A_c = 0.023$ | $A_c = 0.067$ $\varepsilon = 0.36$ | $A_c = 0.051$ $\varepsilon = 0.33$ | $A_c = 0.068$ $\varepsilon = 0.38$ |
| $R_3$ & $M_1$ | $A_c = 0.042$ | $A_c = 0.18$ $\varepsilon = 0.072$ | $A_c = 0.077$ $\varepsilon = 0.057$ | $A_c = 0.099$ $\varepsilon = 0.060$ |
| $R_1$ & $M_2$ | $A_c = 0.025$ | $A_c = 0.079$ $\varepsilon = 0.15$ | $A_c = 0.070$ $\varepsilon = 0.13$ | $A_c = 0.092$ $\varepsilon = 0.17$ |
| $R_2$ & $M_2$ | $A_c = 0.023$ | $A_c = 0.12$ $\varepsilon = 0.18$ | $A_c = 0.072$ $\varepsilon = 0.15$ | $A_c = 0.10$ $\varepsilon = 0.20$ |
| $R_3$ & $M_2$ | $A_c = 0.044$ | $A_c = 0.28$ $\varepsilon = 0.041$ | $A_c = 0.092$ $\varepsilon = 0.026$ | $A_c = 0.14$ $\varepsilon = 0.029$ |

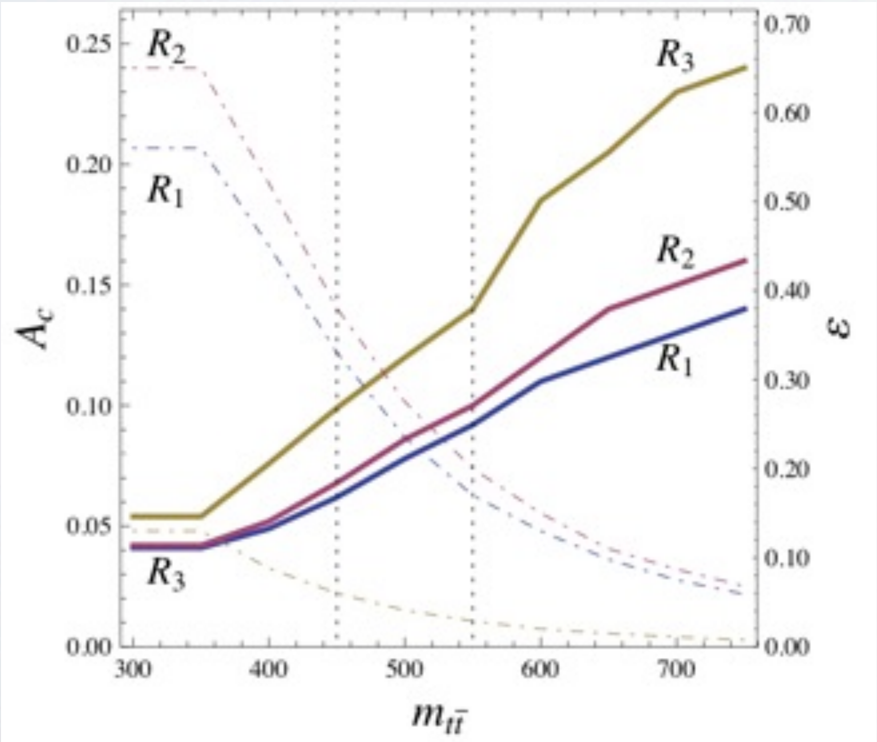
# AC AND EFF VS MTTBAR AND R CUTS

Z'



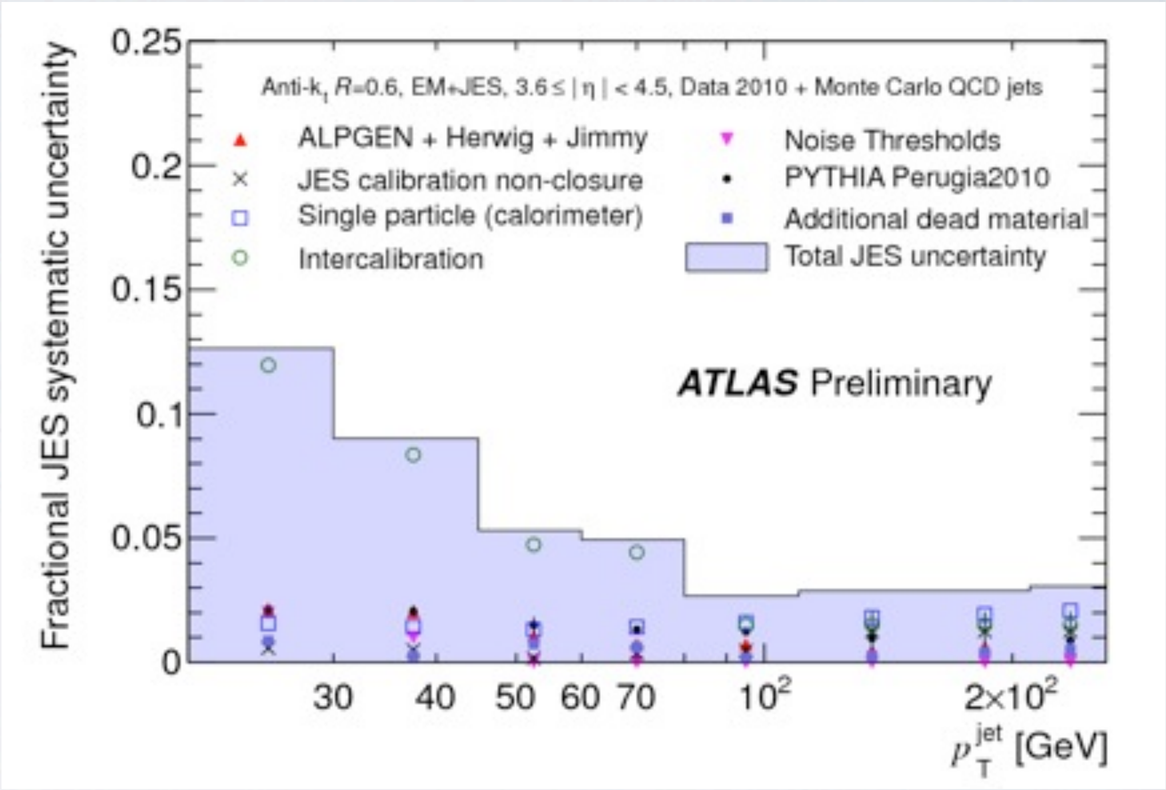

Scalar triplet




- ★ Assuming current stat. uncert. from ATLAS:
  - ✳ R2&M2: $\delta \sim 1\%$ (stat.) for 5 $fb^{-1}$
  - ✳ R3&M2: $\delta \sim 1.5\%$ (stat.) for 15 $fb^{-1}$
- ★ But need full simulation to confirm results!

# EXPERIMENTAL CHALLENGES OF USING FORWARD JETS

- **JES uncertainty** is significantly worse
  - This could be mitigated by performing in-situ W→jj measurement
- The effect of **pile-up** will be worse and tracking is not available to help
  - But pile-up jets will be reduced with the likelihood fit to the ttbar hypothesis




- More **boosted tops** (i.e. decay products merged in a single jet) in the forward region
  - True, but we found the fraction of boosted tops inside R=0.6 to be 10-25%, so manageable

# CONCLUSIONS: IMPROVING $A_C$ AT LHC

- **Inclusive asymmetry measurement not sensitive** to new physics at LHC

- We studied the effect of **$M_{ttbar}$ and $\eta_{jet}$ and $\eta_{top}$ cuts** using representative models yielding $A_{fb}$ similar to what is observed the Tevatron

- **Combinations of cuts can increase the asymmetry close or above ~0.1**, so observable with enough data

  - This assumes statistical uncertainty of 1-2% and systematics of ~2% can be achieved with the 2011-2012 dataset

- Work on **reducing the signal modeling systematics would help** the LHC $A_C$ measurement

- **Results need to be demonstrated in a realistic environment using full simulation**

# Back-up

# MODELS

$$
\begin{aligned}
Z' :&\quad m_{Z'} = 260\ \text{GeV}, &\quad \alpha_{Z'} &= 0.048\,,\\
\text{Axigluon} :&\quad m_A = 2\ \text{TeV}, &\quad g_A &= 2.4\,,\\
\text{Scalar } \mathbf{3} :&\quad m_S = 750\ \text{GeV}, &\quad \lambda &= 3.0\,.
\end{aligned}
$$