Measurements of Top Quark Production and Properties at the Tevatron

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(Comenius University)
On behalf of CDF and D0 collaborations

Moriond QCD, March 22-29, 2014
Outline

→ **Top quark production**
  → differential and inclusive cross-section of $t \bar{t}$ production

→ **Top quark properties**
  → decay width
  → branching fraction
  → charge asymmetry

According to SM:
$$B(t \rightarrow Wb) \sim 100\%$$

→ **Not included**
  → top quark mass (Sung Woo Youn)
  → single top production (Matteo Cremonesi)
$t\bar{t}$ cross sections
Inclusive $t\bar{t}$ cross section

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Method</th>
<th>$\sigma_{t\bar{t}}$ (pb)</th>
<th>$\sigma_{t\bar{t}}$ (scales)</th>
<th>$\sigma_{t\bar{t}}$ (PDF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDF dilepton</td>
<td>2D0</td>
<td>$7.09 \pm 0.83$</td>
<td>$7.35^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
<tr>
<td>CDF ANN lepton+jets</td>
<td>4CDF</td>
<td>$7.82 \pm 0.56$</td>
<td>$6.14^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
<tr>
<td>CDF SVX lepton+jets</td>
<td>4CDF</td>
<td>$7.32 \pm 0.71$</td>
<td>$6.14^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
<tr>
<td>CDF all-jets</td>
<td>4CDF</td>
<td>$7.21 \pm 1.28$</td>
<td>$6.14^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
<tr>
<td>CDF combined</td>
<td>4CDF</td>
<td>$7.63 \pm 0.50$</td>
<td>$6.14^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
<tr>
<td>DØ dilepton</td>
<td>4CDF</td>
<td>$7.36 \pm 0.85$</td>
<td>$6.14^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
<tr>
<td>DØ lepton+jets</td>
<td>4CDF</td>
<td>$7.90 \pm 0.74$</td>
<td>$6.14^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
<tr>
<td>DØ combined</td>
<td>4CDF</td>
<td>$7.56 \pm 0.59$</td>
<td>$6.14^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
<tr>
<td>Tevatron combined</td>
<td>4CDF</td>
<td>$7.60 \pm 0.41$</td>
<td>$6.14^{+0.11}_{-0.21}$</td>
<td>$7.60 \pm 0.41$</td>
</tr>
</tbody>
</table>

$\chi^2 = 0.01/1$; Prob 92%

$\sigma_{t\bar{t}} = (7.60 \pm 0.41) \text{ pb}$

SM prediction (NNLO+NNLL):

$\sigma_{t\bar{t}} = 7.35^{+0.11}_{-0.21} \text{ (scales)}^{+0.17}_{-0.12} \text{ (PDF)}$

(using $M_t = 172.5 \text{ GeV}$)
**Differential $t\bar{t}$ cross sections (I)**

→ provides direct test of QCD, constraints on axigluon models
→ important for QCD modeling (searches for new physics)

→ **l+jet channel with 1 b-tag**
→ final state is obtained by kinematic reconstruction ($\chi^2$–based method)
→ result is corrected to parton-level top quark
→ cross section as a function of $m_{tt}$, $p_T(t)$, $|y(t)|$

arXiv:1401.5785, submitted to PRD

→ measured with typical precision ~9%
→ main systematic source: signal modeling
→ **general agreement with predictions**
   by QCD generators & approximate NNLO
Differential $t\bar{t}$ cross sections (II)

- Different axigluon models with different couplings (used in asymmetry studies)
  differential cross section predictions provided by A. Falkowski (et al)
  arXiv 1401.2443

- in these models, forward-backward asymmetry will be increased, but also the differential cross section distributions will be changed

- high-mass axigluons highly constrained by LHC measurements, while low masses not so much (but the effects are small)

Some models are in tension with the presented data!
Differential $t\bar{t}$ cross sections

→ employ Legendre polynomials to characterize the shape of differential cross section:

\[ \frac{d\sigma}{d(\cos \theta_t)} = \sum_{\ell=0}^{\infty} a_\ell P_\ell(\cos \theta_t), \]

$\theta_t$ is angle between top-quark momentum and the incoming proton momentum in $t\bar{t}$ center-of-mass frame

→ full shape has potential to discriminate among various calculations of SM and non-SM physics models

→ moment $a_0$ contains only total cross section, we scale all moments, $(a_\ell)$, so that $a_0 = 1$.

<table>
<thead>
<tr>
<th>$\ell$</th>
<th>$a_\ell$ (obs)</th>
<th>$a_\ell$ (pred)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$0.40 \pm 0.12$</td>
<td>$0.15^{+0.07}_{-0.03}$</td>
</tr>
<tr>
<td>2</td>
<td>$0.44 \pm 0.25$</td>
<td>$0.28^{+0.05}_{-0.03}$</td>
</tr>
<tr>
<td>3</td>
<td>$0.11 \pm 0.21$</td>
<td>$0.03^{+0.014}_{-0.007}$</td>
</tr>
<tr>
<td>4</td>
<td>$0.22 \pm 0.28$</td>
<td>$0.035^{+0.016}_{-0.008}$</td>
</tr>
<tr>
<td>5</td>
<td>$0.11 \pm 0.33$</td>
<td>$0.005^{+0.002}_{-0.001}$</td>
</tr>
<tr>
<td>6</td>
<td>$0.24 \pm 0.40$</td>
<td>$0.006^{+0.002}_{-0.003}$</td>
</tr>
<tr>
<td>7</td>
<td>$-0.15 \pm 0.48$</td>
<td>$-0.003^{+0.001}_{-0.001}$</td>
</tr>
<tr>
<td>8</td>
<td>$0.16 \pm 0.65$</td>
<td>$-0.0019^{+0.0003}_{-0.0003}$</td>
</tr>
</tbody>
</table>

\[ a_1 = 0.40 \pm 0.12 \]

PRL 111 182002 (2013)

\sim 2\sigma \text{ difference w.r.t. predictions}
Decay width
&
branching fractions
Top quark width

→ largest decay width of the known fermions
→ deviation from SM could indicate decays via e.g., charged Higgs boson, stop squark, or flavor changing neutral current.

CDF direct measurement

→ data fitted by the MC templates
→ $\Gamma_t$ extracted from width of $m_t^{\text{reco}}$

CDF, l+jets, 8.7 fb$^{-1}$

$\Gamma_t = 2.21^{+1.84}_{-1.11}$ GeV

PRD 111, 202001 (2013)

D0 indirect measurement (l+jets, 5.4 fb$^{-1}$)

→ using $\sigma$(t-channel) to extract partial top width and $B(t \rightarrow Wb)$ to get total width

CDF, l+jets, 8.7 fb$^{-1}$

$\Gamma_t = 2.00^{+0.47}_{-0.43}$ GeV

PRD 85, 091104 (2012)
Branching fractions

→ using the measurement $V_{tb}$ can be extracted
→ deviation from expected value could imply existence of extra generation of quarks

→ **CDF measurement**
→ divide sample into bins by lepton flavour and number of b-tagged jets
→ using likelihood fit with R as free parameter

\[ R = 0.87 \pm 0.07 \text{ (stat+syst)} \]
\[ |V_{tb}| = 0.93 \pm 0.04 \text{ (stat+syst)} \]

CDF note 11048

→ **D0 – l+jets & dilepton combination**
→ fit R and the $t\bar{t}$ cross section together

\[ R = 0.90 \pm 0.04 \text{ (stat+syst)} \]

PRL 107, 121802 (2011)
Production asymmetries
**tt forward-backward asymmetry**

→ at NLO, the SM predicts asymmetry in \( \bar{t}t \) production
→ asymmetry comes from events with \( q\bar{q} \) initial states, \( gg \) is symmetric

\[ \begin{align*}
\text{positive asymmetry} & \quad + \\
\text{negative asymmetry} & 
\end{align*} \]

→ Definition:

\[ A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)} \], \text{where } \Delta y = y_t - y_{\bar{t}}\]

→ Methodology:

→ using \( l+\text{jet} \) events (full statistics)

→ full kinematic reconstruction of \( \bar{t}t \) final state
  → CDF: \( \chi^2 \)-based fit
  → D0: new kinematic fit algorithm for events with \( \geq 4 \) jets
    \( m_{\bar{t}t} \) obtained from multivariate regression combining 3 algorithms

→ correction for parton level – using regularized unfolding in 2D
→ inclusive asymmetry expressed also as function of: \( m_{\bar{t}t} \) – CDF, DO

\[ |\Delta y|, p_T(t \bar{t}) - \text{CDF} \]
**tt forward-backward asymmetry**

→ **CDF Results:**

\[ A_{FB} = 0.164 \pm 0.039 \text{ (stat.)} \pm 0.026 \text{ (syst.)} \]

PRD 87, 092002 (2013)

Slopes different w.r.t. SM predictions:

- \( 2.4\sigma \) (\( M_{t\bar{t}} \)),
- \( 2.8\sigma \) (\(|\Delta y|\))

From differential cross section result (PRL 111 182002 (2013) and slide 7):

favors the asymmetry models with strong s-channel components

→ **D0 results**

\[ A_{FB} = 0.106 \pm 0.027 \text{ (stat.)} \pm 0.013 \text{ (syst.)} \]

D0 Conf note 6425

Compatible with SM predictions and with CDF result

March 22-29, 2014
**Lepton based asymmetry**

→ **Advantage:** no need to reconstruct the $t\bar{t}$ final state.
  sensitive to top quark polarization
  → lepton direction is measured with high precision + good charge determination

→ **Definition:**

Dilepton events: $\Delta \eta = \eta_+ - \eta_-$

$$A_{FB}^\ell = \frac{N(qy_\ell > 0) - N(qy_\ell < 0)}{N(qy_\ell > 0) + N(qy_\ell < 0)}.$$  

→ **CDF methodology:** (same for $l$+jets and dilepton events)

→ asymmetry is decomposed into symmetric and asymmetric parts:

$$S(qy_\ell) = \frac{N(qy_\ell) + N(-qy_\ell)}{2}, \quad A(qy_\ell) = \frac{N(qy_\ell) - N(-qy_\ell)}{N(qy_\ell) + N(-qy_\ell)},$$

→ symmetric part (obtained from MC) – largely insensitive to physics model
→ asymmetric part is parametrized:

$$\mathcal{A}(qy_\ell) = a \tanh \left( \frac{qy_\ell}{2} \right)$$

→ fit of asymmetric part allows to extrapolate to unmeasured region
Lepton based asymmetry

→ **D0 methodology: (l+jets events)**
  
  → using l + 3 jets in addition to l + ≥4 jets – increase statistics twice
  → l+3 jets has lower S/B ratio, helps to reduce acceptance corrections

→ improve modeling of $A_{FB}^l$ in W+jets using control region (3 jets+0 btag)
→ asymmetry and sample composition is extracted by likelihood fit
→ unfold for acceptance effects, study dependence on lepton $p_T$ and $y_l$

I+jets channel:

→ **D0 methodology: (dilepton events)**
  
  → background subtraction,
  → correction for selection effects
  → extrapolation to the full range of $\eta$
Single-lepton asymmetry results

**l+jets channel**

CDF:

PRD 88, 072003 (2013)

\[
A_{FB}^{l} = 0.094 \pm 0.024 \text{(stat.)}^{+0.022}_{-0.017} \text{(syst.)}
\]

D0:

|y|<1.5:

arXiv 1403.1294 submitted to PRD

\[
A_{FB}^{l} = 0.042 \pm 0.023 \text{(stat.)}^{+0.017}_{-0.020} \text{(syst.)}
\]

SM predicts:

\[
A_{FB}^{l} = 0.038 \pm 0.003
\]

MC@NLO |y|<1.5:

\[
A_{FB}^{l} = 0.020
\]
Single lepton asymmetry

Dilepton channel

SM predicts:

\[ A_{FB}^{l} = 0.038 \pm 0.003 \]

CDF:

CDF note 11035

\[ A_{FB}^{l} = 0.072 \pm 0.052 \text{ (stat.)} \pm 0.030 \text{ (syst.)} \]

CDF note 11035

\[ A_{FB}^{l} = 0.090 \pm 0.028 \]

2σ larger than the SM prediction

CDF: PRD 88, 112002 (2013)

D0:

\[ A_{FB}^{l} = 0.044 \pm 0.037 \text{ (stat.)} \pm 0.011 \text{ (syst.)} \]

Combination \((l+\text{jet, dilepton})\)

→ using BLUE method

SM predicts:

\[ A_{FB}^{l} = 0.038 \pm 0.003 \]

CDF: arXiv 1403.1294, submitted to PRD

D0:

\[ A_{FB}^{l} = 0.047 \pm 0.023 \text{ (stat.)} \pm 0.015 \text{ (syst.)} \]
Dilepton asymmetry

Dilepton channel

CDF:

\[ A_{FB}^{\Delta \eta} = 0.072 \pm 0.081 \]

CDF note 11035

CDF:

\[ A_{FB}^{\Delta \eta} = 0.048 \pm 0.004 \]

D0:

\[ A_{FB}^{\Delta \eta} = 0.123 \pm 0.054 \text{(stat.)} \pm 0.015 \text{(syst.)} \]

PRD 88, 112002 (2013)

SM predicts:

\[ A_{FB}^{\Delta \eta} = 0.048 \pm 0.004 \]

PRD 88, 112002 (2013)

D0:

\[ A_{FB}^{l}/A_{FB}^{\Delta \eta} = 0.36 \pm 0.20 \]

SM (NLO):

\[ 0.79 \pm 0.10 \]

2\sigma difference

P. Bartoš

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Conclusions

→ the measurements are mostly in agreement with SM prediction

→ CDF see higher production asymmetry in both $t\bar{t}$ inclusive and lepton-based measurements

→ D0 data compatible with SM prediction and also with CDF results

→ For more Tevatron top quark results, please see Matteo Cremonesi’s talk on single top (after coffee break)

Plans

→ Tevatron combination of production asymmetry results is on the table

→ finalize other analysis using full data-set (spin correlation, mass,...)
Thank you!
Back up slides
### Inclusive $t\bar{t}$ cross section

arXiv:1309.7570, accepted by PRD

<table>
<thead>
<tr>
<th>Sources of systematic uncertainty</th>
<th>DIL</th>
<th>LJ-ANN</th>
<th>LJ-SVX</th>
<th>HAD</th>
<th>CDF combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central value of $\sigma_{t\bar{t}}$</td>
<td>7.09</td>
<td>7.82</td>
<td>7.32</td>
<td>7.21</td>
<td>7.63</td>
</tr>
<tr>
<td>Modeling of the detector</td>
<td>0.39</td>
<td>0.11</td>
<td>0.34</td>
<td>0.41</td>
<td>0.17</td>
</tr>
<tr>
<td>Modeling of signal</td>
<td>0.23</td>
<td>0.23</td>
<td>0.23</td>
<td>0.44</td>
<td>0.21</td>
</tr>
<tr>
<td>Modeling of jets</td>
<td>0.23</td>
<td>0.23</td>
<td>0.29</td>
<td>0.71</td>
<td>0.21</td>
</tr>
<tr>
<td>Method of extracting $\sigma_{t\bar{t}}$</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.08</td>
<td>0.01</td>
</tr>
<tr>
<td>Background modeled from theory</td>
<td>0.01</td>
<td>0.13</td>
<td>0.29</td>
<td>–</td>
<td>0.10</td>
</tr>
<tr>
<td>Background based on data</td>
<td>0.15</td>
<td>0.07</td>
<td>0.11</td>
<td>0.59</td>
<td>0.08</td>
</tr>
<tr>
<td>Normalization of $Z/\gamma^*$ prediction</td>
<td>–</td>
<td>0.16</td>
<td>0.15</td>
<td>–</td>
<td>0.13</td>
</tr>
<tr>
<td>Luminosity: inelastic $p\bar{p}$ cross section</td>
<td>0.28</td>
<td>–</td>
<td>–</td>
<td>0.29</td>
<td>0.05</td>
</tr>
<tr>
<td>Luminosity: detector</td>
<td>0.30</td>
<td>0.02</td>
<td>0.02</td>
<td>0.30</td>
<td>0.06</td>
</tr>
<tr>
<td>Total systematic uncertainty</td>
<td>0.67</td>
<td>0.41</td>
<td>0.61</td>
<td>1.18</td>
<td>0.39</td>
</tr>
<tr>
<td>Statistical uncertainty</td>
<td>0.49</td>
<td>0.38</td>
<td>0.36</td>
<td>0.50</td>
<td>0.31</td>
</tr>
<tr>
<td>Total uncertainty</td>
<td>0.83</td>
<td>0.56</td>
<td>0.71</td>
<td>1.28</td>
<td>0.50</td>
</tr>
</tbody>
</table>

![Graph showing the cross-section measurement for Tevatron Run II, ≤ 8.8 fb⁻¹](image-url)
**Differential $t\bar{t}$ cross sections (I)**

| Source of uncertainty                  | $\delta_{\text{incl}}$ | $|\delta_{\text{diff}}|$ |
|----------------------------------------|-------------------------|---------------------------|
| Signal modeling                        | $+5.2$                   | $4.0 - 14.2$              |
| PDF                                    | $+3.0$                   | $0.9 - 4.4$               |
| Detector Modeling                      | $+4.0$                   | $3.1 - 13.7$              |
| Sample composition                     | $\pm 1.8$                | $2.8 - 9.2$               |
| Regularization strength                | $\pm 0.2$                | $0.8 - 2.1$               |
| Integrated luminosity                  | $\pm 6.1$                | $6.1 - 6.1$               |
| Total systematic uncertainty           | $^{+0.6}_{-0.3}$         | $8.5 - 23.1$              |

arXiv:1401.5785 submitted to PRD
**Differential $t\bar{t}$ cross sections (II)**

ArXiv:1401.5785, submitted to PRD

|         | $\sigma_{\text{tot}}(p\bar{p} \to t\bar{t})$ [pb] | $M(t\bar{t}) \ [\chi^2/ndf]$ | $|y^{\text{top}}| \ [\chi^2/ndf]$ | $p_T^{\text{top}} \ [\chi^2/ndf]$ |
|---------|--------------------------------------------------|--------------------------------|---------------------------------|----------------------------------|
| Data    | $8.27^{+0.92}_{-0.91}$ (stat. + syst.)           | n.a.                          | n.a.                            | n.a.                             |
| pQCD NNLO | $7.24^{+0.23}_{-0.27}$ (scales + pdf)            | 0.98                          | 3.71                            | 4.05                             |
| non-SM model | $\Delta\sigma_{\text{tot}}(p\bar{p} \to t\bar{t})$ [pb] | $M(t\bar{t}) \ [\chi^2/ndf]$ | $|y^{\text{top}}| \ [\chi^2/ndf]$ | $p_T^{\text{top}} \ [\chi^2/ndf]$ |
| $G'(l)$, $m = 0.2$ TeV | $+0.97 \pm 0.06$ (scales)           | 0.96                          | 1.07                            | 1.20                             |
| $G'(r)$, $m = 0.2$ TeV | $+0.97 \pm 0.06$ (scales)           | 0.96                          | 1.07                            | 1.20                             |
| $G'(a)$, $m = 0.2$ TeV | $+0.06 \pm 0.04$ (scales)           | 0.85                          | 3.55                            | 3.88                             |
| $G'(a)$, $m = 0.4$ TeV | $+0.26 \pm 0.04$ (scales)           | 0.44                          | 2.65                            | 3.26                             |
| $G'(a)$, $m = 0.8$ TeV | $+0.22 \pm 0.04$ (scales)           | 0.97                          | 2.86                            | 3.23                             |
| $G'(l)$, $m = 2.0$ TeV | $+0.87 \pm 0.15$ (scales)           | 0.58                          | 1.27                            | 3.78                             |
| $G'(r)$, $m = 2.0$ TeV | $+0.55 \pm 0.06$ (scales)           | 0.43                          | 1.94                            | 2.75                             |
| $G'(a)$, $m = 2.0$ TeV | $+0.05 \pm 0.06$ (scales)           | 0.88                          | 3.56                            | 4.11                             |
| $Z'$, $m = 0.22$ TeV | $-1.00 \pm 0.06$ (scales)           | 4.95                          | 8.27                            | 7.48                             |

Table of $\chi^2/ndf$ values for data versus approximate pQCD at NNLO and the various axi gluon models and one $Z'$ model. The masses of the new mediators are indicated together with the nature of the couplings ($l$ left, $r$ right and $a$ axial couplings) in the first column (more details are given in Ref. [arXiv:hep-ph/1401.2443]).
**Slopes** different w.r.t. SM predictions: 2.8σ for |Δy| distribution

**PRD 87. 092002 (2013)**

\[ \alpha_{\Delta y} = (25.3 \pm 6.2) \times 10^{-2} \]

\[ \alpha_{\Delta y} = (9.7 \pm 1.5) \times 10^{-2} \]

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**PRL 111 182002 (2013)**

- **NLO SM (PRD 86, 034026)**
- **LO t-channel (Z′ 200 GeV/c²)**
- **LO s-channel (Octet A)**
- **Data (stat+syst uncertainty)**
- **Data (stat uncertainty only)**

**FIG. 3** (color online). Absolute contributions of the Legendre moments to the \(A_{\text{FB}}\), with theory predictions overlaid. The lines and symbols are the same as in Fig. 2. The inset shows the 1-, 2-, and 3-standard-deviation uncertainty ellipses.
**tt forward-backward asymmetry**

DØ preliminary

9.7 fb⁻¹

**D0 Conf note 6425**

![Graph showing the tt forward-backward asymmetry with data points for CDF and MC@NLO v3.4.](image)

- **CDF data**
- **MC@NLO v3.4**

**W. Bernreuther and Z.-G.Si**

PRD 86, 034026 (2012)
### CDF Results:

**PRD 87, 092002 (2013)**

TABLE V. Systematic uncertainties on the parton-level $A_{FB}$ measurement.

<table>
<thead>
<tr>
<th>Source</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background shape</td>
<td>0.018</td>
</tr>
<tr>
<td>Background normalization</td>
<td>0.013</td>
</tr>
<tr>
<td>Parton shower</td>
<td>0.010</td>
</tr>
<tr>
<td>Jet energy scale</td>
<td>0.007</td>
</tr>
<tr>
<td>Initial- and final-state radiation</td>
<td>0.005</td>
</tr>
<tr>
<td>Correction procedure</td>
<td>0.004</td>
</tr>
<tr>
<td>Color reconnection</td>
<td>0.001</td>
</tr>
<tr>
<td>Parton-distribution functions</td>
<td>0.001</td>
</tr>
<tr>
<td>Total systematic uncertainty</td>
<td>0.026</td>
</tr>
<tr>
<td>Statistical uncertainty</td>
<td>0.039</td>
</tr>
<tr>
<td>Total uncertainty</td>
<td>0.047</td>
</tr>
</tbody>
</table>

### D0 Results

**D0 Conf note 6425**

**Systematic uncertainties in absolute %**

<table>
<thead>
<tr>
<th>Source</th>
<th>Reco. level inclusive</th>
<th>Production level inclusive</th>
<th>2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background model</td>
<td>+0.7/−0.8</td>
<td>1.0</td>
<td>1.1–2.8</td>
</tr>
<tr>
<td>Signal model</td>
<td>&lt; 0.1</td>
<td>0.5</td>
<td>0.8–5.2</td>
</tr>
<tr>
<td>Unfolding</td>
<td>N/A</td>
<td>0.5</td>
<td>0.9–1.9</td>
</tr>
<tr>
<td>PDFs and pileup</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5–2.9</td>
</tr>
<tr>
<td>Detector model</td>
<td>+0.1/−0.3</td>
<td>0.3</td>
<td>0.4–3.3</td>
</tr>
<tr>
<td>Sample composition</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
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Lepton based asymmetry

PRD 88, 072003 (2013)

I+jets, single-lepton asymmetry

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<th>Source of uncertainty</th>
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<td>Initial- and final-state radiation</td>
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CDF note 11035

single-lepton asymmetry
I+jets + dilepton combination

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<th>DIL (9.1 fb^{-1})</th>
<th>Correlation</th>
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Lepton based asymmetry

DØ, $9.7 \text{fb}^{-1}$
Production Level, $|y|<1.5$

$A_{FB}^{l}$, %

$\begin{array}{c}
|y|<1.5 \\

DØ, 9.7 fb^{-1} \\
Production Level \\

MC@NLO 3.4 \\

l+jet channel \\
arXiv 1403.1294
\end{array}$

Forward-Backward Lepton Asymmetry, %

$\begin{array}{c}
3 \text{ jets, } 1 \ b \text{ tag} \\
3 \text{ jets, } \geq 2 \ b \text{ tags} \\
\geq 4 \text{ jets, } 1 \ b \text{ tag} \\
\geq 4 \text{ jets, } \geq 2 \ b \text{ tags} \\
MC@NLO 3.4 \\
\chi^{2}/\text{N.D.F.: } 8.1/3
\end{array}$

Dilepton channel (PRD 88, 112002 (2013))