TWO TOPICS on TOP QUARKS

A. CHARGE ASYMMETRY in HADROPRODUCTION and AXIGLUONS

B. WEAK CORRECTIONS and SUDAKOV LOGARITHMS

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A. CHARGE ASYMMETRY in HADROPRODUCTION and AXIGLUONS

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I. Motivation and Main Idea
II. Results at Partonic Level
III. Asymmetries at Tevatron and LHC
IV. Limits on Axigluons
I MOTIVATION and MAIN IDEA

dominant process for $t\bar{t}$ production . . .

. . . is symmetric:

$$\frac{d\sigma}{d\cos\hat{\Theta}} \propto \left(1 + \frac{4m^2}{Q^2}\right) + \left(1 - \frac{4m^2}{Q^2}\right)\cos^2\hat{\Theta}$$

$O(\alpha_s)$ corrections:

virtual gluons

real emission
Interference between $C = +1$ and $C = -1$ amplitudes

$\Rightarrow$ charge asymmetry similar to QED!

Nonabelian terms:

similarly ("flavour excitation") 
numerically unimportant
real and virtual corrections must be combined to obtain sensible (=IR–finite) result

⇒ forward–backward asymmetry of top quarks in $p\bar{p}$ collisions (TEVATRON)

⇒ difference in rapidity distributions between $t$ and $\bar{t}$ in $pp$ collisions (LHC)

⇒ test of production mechanism

⇒ potential confusion with asymmetry from weak production avoided
Intuitive picture

inclusive cross section

top and light quark in same direction
preferred coherence with gluon field!

⇒ positive asymmetry for
inclusive cross section

$\bar{t}\bar{t}g$

probability for gluon emission enhanced
if $t$ and $q$ in opposite direction

⇒ negative asymmetry for $t\bar{t}g$
(tagged events)
II PARTONIC LEVEL

differential asymmetry
($q\bar{q}$ induced)

\[
\hat{A}(\cos \hat{\Theta}) = \frac{N_t(\cos \hat{\Theta}) - N\bar{t}(\cos \hat{\Theta})}{N_t(\cos \hat{\Theta}) + N\bar{t}(\cos \hat{\Theta})} - \frac{N_t(\cos \hat{\Theta}) - N\bar{t}(-\cos \hat{\Theta})}{N_t(\cos \hat{\Theta}) + N\bar{t}(-\cos \hat{\Theta})}
\]
integrated asymmetry
(parton level)

\[ \hat{A}(\cos \hat{\Theta}) = \frac{N_t(\cos \hat{\Theta} \geq 0) - N_{\bar{t}}(\cos \hat{\Theta} \geq 0)}{N_t(\cos \hat{\Theta} \geq 0) + N_{\bar{t}}(\cos \hat{\Theta} \geq 0)} \]

as function of \( \sqrt{s} \):

![Graph showing \( \hat{A}(\%) \) vs. \( \sqrt{s} \) (GeV)]
**III HADRONIC COLLISIONS**

$p\bar{p} - 1.96 \text{ TeV}$

dominantly central production:

$q\bar{q} \rightarrow t\bar{t}$

partonic asymmetry

$\downarrow$

hadronic asymmetry

$\Rightarrow$ Integrated asymmetry

$\bar{A}_{fb} = 4.5 - 5.7 \% \quad (1.96 \text{ TeV})$
Differential asymmetry: $\mathcal{A}(Y)$

top rapidity $y_+$ and anti-top rapidity $y_-$ are known (in one event)

Average: $Y \equiv \frac{1}{2}(y_+ + y_-)$

\[
\mathcal{A}(Y) = \frac{N_{ev}(y_+ > y_-) - N_{ev}(y_+ < y_-)}{N_{ev}(y_+ > y_-) + N_{ev}(y_+ < y_-)}
\]

nearly equivalent to partonic asymmetry

$Y \approx$ partonic rest frame!
\[ A_{total} \equiv \frac{N_{ev}(y_+ > y_-) - N_{ev}(y_+ < y_-)}{N_{ev}} \]

preliminary Tevatron results:

\[ A_{FB} = 0.20 \pm 0.11 \pm 0.05 \]
\[ A_{total} = 0.23 \pm 0.12 \pm 0.06 \]
Comments

• inclusive asymmetry hardly affected by radiative corrections (Almeida, Sterman, Vogelsang)

• $t\bar{t}g$ asymmetry strongly affected by radiative corrections, sensitive to cuts (Dittmaier, Uwer, Weinzierl)
no forward backward asymmetry

slight difference between rapidity distributions of $Q$ and $\bar{Q}$ from (small) admixture of $q\bar{q}$ processes

$\Rightarrow$ more $t$ at large rapidity
$\Rightarrow$ more $\bar{t}$ at small rapidity

main effect in regions of small cross section
$t\bar{t}$ production in proton-proton collisions (LHC) is forward-backward symmetric in the laboratory frame.

- Select the invariant mass of the $t\bar{t}(+g)$ system and its longitudinal momentum.
  - For some extreme kinematic regions, large $x$ and/or large $\hat{s}$ (in practice $\hat{s} < 2\text{TeV}$), sizable asymmetry reconstruction of the $t\bar{t}(+g)$ rest frame required!!!
Leading order!
IV Limits on Axigluons

\[ q, \bar{q}, \gamma \mu \gamma^5, A, m_A, t, \bar{t} \]

\[ \Rightarrow \text{modified } t\bar{t} \text{ production} \]

(resonance for \( m(t\bar{t}) = m_A \))

\[ \Rightarrow \text{interference with gluon} \]

\[ \rightarrow \text{forward backward asymmetry} \]
\[ Y = \frac{y_{1} + y_{2}}{2} \]

<table>
<thead>
<tr>
<th>$m_A$ (TeV)</th>
<th>QCD</th>
<th>$m_A = 1$ TeV</th>
<th>$m_A = 2$ TeV</th>
<th>$m_A = 5$ TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{FB}$</td>
<td>0.051(6)</td>
<td>$-0.133(9)$</td>
<td>$-0.027(2)$</td>
<td>$-0.0041(3)$</td>
</tr>
<tr>
<td>$A$</td>
<td>0.078(9)</td>
<td>$-0.181(11)$</td>
<td>$-0.038(3)$</td>
<td>$-0.0058(4)$</td>
</tr>
</tbody>
</table>
Preliminary Tevatron results

$m_A > 1.2$ TeV at $2\sigma$
Summary

- Forward backward asymmetry for $t$ production at TEVATRON $\sim 7\%$
- Important test of production mechanism
- Unique possibility for $p\bar{p}$ collider
- Differences between $t$ and $\bar{t}$ distributions at LHC mainly in regions of small cross section (large rapidity!)
- Access to “new physics” signal for axigluons
B. **WEAK CORRECTIONS TO TOP PRODUCTION**


I. Results at Partonic Level
II. Tevatron and LHC
I. Results at Partonic Level

$q \bar{q} \rightarrow t \bar{t}$:

$\sim \mathcal{O}(\alpha_s)$

no interference with

$Z \sim \mathcal{O}(\alpha_{\text{weak}})$

$gg \rightarrow t \bar{t}$:

$\sim \mathcal{O}(\alpha_s)$
$\mathcal{O}(\alpha_s^2 \alpha_{\text{weak}})$ weak corrections ($q \bar{q} \rightarrow t \bar{t}$)

cuts of second group individually IR-divergent
$\mathcal{O}(\alpha_s^2\alpha_{\text{weak}})$ weak corrections ($gg \to t\bar{t}$)
• analytical & numerical results available
  (earlier partial results by Beenakker et al., some disagreements)
  independent evaluation by Bernreuther & Fücker

• \((\text{box contribution})_{\text{up–quark}} = -(\text{box contribution})_{\text{down–quark}}\)
  \(\Rightarrow\) suppression

• box contribution moderately \(\hat{s}\)-dependent

• strong increase with \(\hat{s}\)

• sizable \(M_h\)-dependence, large effect close to threshold
II. Tevatron and LHC

Small effects for total cross section
(dominated by $\sqrt{s} \sim 360-380$ GeV)
Sizeable effects for differential distribution

\[ \frac{d\sigma_{\text{NLO}}}{dp_T} / \frac{d\sigma_{\text{LO}}}{dp_T} \] [\%]

\[ \frac{d\sigma_{\text{NLO}}}{dM_{tt}} / \frac{d\sigma_{\text{LO}}}{dM_{tt}} \] [\%]

Tevatron

\( m_H = 1000 \text{ GeV} \)

\( m_H = 120 \text{ GeV} \)
large corrections for large $\sqrt{s}$

sizable $M_h$-dependence

(relative weak corrections [%])
Transverse momentum dependence (LHC)

relative composition

\[ \sigma_{\text{LO}}(p_T > p_{T\text{cut}}) / \sigma_T \]

- gg → tt
- qq → tt
- sum

relative weak corrections \( \sigma(p_T > p_{T\text{cut}}) \) [%]

- \( M_h = 120 \text{ GeV} \)
- \( M_h = 1000 \text{ GeV} \)
- stat. error
$M_{t\bar{t}}$ -dependence (LHC)

Relative weak corrections $\sigma(M_{t\bar{t}} > M_{t\bar{t}\text{cut}})[\%]$ as a function of $M_{tt\text{cut}}$ [GeV].

- $M_h = 120$ GeV
- $M_h = 1000$ GeV
- Stat. error

$M_{h} = 120$ GeV
$M_{h} = 1000$ GeV
Stat. error
IV. Conclusions on weak corrections

- LHC will explore the TeV-region: $\hat{s}/M_W^2 \gg 1$

- Electroweak corrections amount to $\mathcal{O}(10\% - 20\%)$ in the interesting kinematic region

- Top-quark distributions at large $\hat{s}$ are strongly modified

- Sizable $M_h$-dependence for small $p_T$