Measurement of $R = \frac{B(t \rightarrow Wb)}{B(t \rightarrow Wq)}$

using b-tagging in the $1+\text{jets}$ channel

on behalf of the DØ collaboration

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Introduction

- In the SM, the ratio $R = B(t \to Wb)/B(t \to Wq)$, can be expressed in terms of the CKM matrix elements:

$$R = \frac{|V_{tb}|^2}{|V_{tb}|^2 + |V_{ts}|^2 + |V_{td}|^2} = |V_{tb}|^2$$

- Under two assumptions:
  - Exactly three generations of coupling quarks.
  - The CKM matrix is unitary.

  The value of $|V_{tb}|$ is restricted to $0.9990 < |V_{tb}| < 0.9992$.

- Since $|V_{tb}| \sim 1$ in the SM, it is usually assumed that the branching fraction $B(t \to Wb)$ is 100%.

- The measurement of the single top production cross-section will provide a powerful constraint on $|V_{tb}|$. 
• This analysis is an extension of the cross-section analysis with $b$-tagging in the $l+$jets channel.

• The exact same dataset was used, corresponding to an integrated luminosity of:
  - $160 \text{ pb}^{-1}$ in the $\mu+$jets channel.
  - $170 \text{ pb}^{-1}$ in the $e+$jets channel.

• The number of $t\bar{t}$ events with one and two $b$-tags is determined by the probability to $b$-tag a jet from a top decay and the fraction of events with 0, 1 and 2 $b$-quarks.

• The most likely value of $R$ is deduced from the number of double tagged and single tagged events.

• The capability to distinguish between light jets and $b$-jets is crucial for this measurement.
b-tagging algorithms

- This analysis was done using two separate algorithms:
  - SVT (explicit reconstruction of secondary vertices).
  - CSIP (impact parameter significance based).

- Algorithms perform well:
  - Probability for tagging a $b$-jet $\sim 35\%$.
  - Probability for tagging a $\ell$-jet $< 0.5\%$.

- Performance measured in data and parametrized vs $E_T$ and $\eta$ of the jets.
Tagging efficiency for $t\bar{t}$

- When not requiring $B(t \rightarrow Wb)$ to be 100%, the probability to single tag a top event becomes:

  \[
P(tt) = R^2 P(tt \rightarrow bb) + 2R(1-R)P(tt \rightarrow bql) + (1-R)^2 P(tt \rightarrow qql)
  \]

  where $P$ denotes the tagging probability and $q_l = (s, d)$.

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<tr>
<th>Single Tags</th>
<th>$\mu$+jets</th>
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Preselection

All events are required to have:

- passed the signal trigger.
- a tight isolated 20 GeV electron or muon.
- large $E_T$, at least 20 (17) GeV in the $e$ ($\mu$) channel.
- no second high $p_T$ isolated lepton.
- a reconstructed PV with at least 3 tracks, within $|z| < 60$ cm.
Background calculation

- The expected number of tagged background events is calculated exactly like in the cross-section analysis.

- The preselected sample is first split into:
  - Physics backgrounds: Events with a real lepton.
  - Multijet QCD events with a fake lepton.

- The dominant background is $W+\text{jets}$.

- The event tagging probability, $P_{QCD}^{\text{tag}}$, for multijet QCD events is obtained in an independent data sample.

$$N_{QCD}^{\text{tag}} = P_{QCD}^{\text{tag}} \times N_{QCD}^{\text{presel}}$$
Other physics backgrounds include single top production and diboson ($WW$, $WZ$ and $ZZ$) production.
Observed events (SVT)

- The boxes represent the predicted number of tagged events including all statistical and systematic errors.

In these plots a 7 pb cross-section is assumed for $tt$. 
Observed events (CSIP)

- The boxes represent the predicted number of tagged events including all statistical and systematic errors.

- In these plots a 7 pb cross-section is assumed for $t \bar{t}$. 

Single tagged events

Double tagged events
Result

- The cross-section, $\sigma_{t\bar{t}}$, and the ratio $R$ are fitted together using a maximum likelihood function.

\[
\begin{align*}
SVT : & \quad R = 0.70^{+0.27}_{-0.24} (stat) ^{+0.11}_{-0.10} (syst) \\
CSIP : & \quad R = 0.65^{+0.34}_{-0.30} (stat) ^{+0.17}_{-0.12} (syst)
\end{align*}
\]

\[
\sigma_{t\bar{t}} = 11.6^{+5.6}_{-3.2} (stat) pb \\
\sigma_{t\bar{t}} = 10.7^{+8.2}_{-3.7} (stat) pb
\]
The fitted $\sigma_{t\bar{t}}$ for a given value of $R$, when $R$ is known with infinite precision. Also shown is $\sigma_{t\bar{t}}$ for the value $R = 1$. 
Conclusion

- New physics, like a fourth quark generation, could lead to a deviation from the predicted value for $R$.

- The most likely value of $R$ is found to be:

  \[
  SVT : \quad R = 0.70^{+0.27}_{-0.24}(\text{stat})^{+0.11}_{-0.10}(\text{syst})
  \]

  \[
  CSIP : \quad R = 0.65^{+0.34}_{-0.30}(\text{stat})^{+0.17}_{-0.12}(\text{syst})
  \]

- The dominant systematic errors are $b$-tagging efficiency measurements in data, and the uncertainty on the JES.

- The result presented above is in good agreement with the Standard Model expectation of $R \sim 1$. 