Chapter 7

Conclusion

The important conclusion to be drawn from the results of our analysis is the estimate for the cross-section for the production of t quark at the Tevatron. We address this issue in the first section. The second section contains some closing comments on the state of affairs.

7.1 *top* quark production cross-section

The estimate for the number of signal events in our data (N) combined with the knowledge of efficiency (ε, in which the branching ratio is included) and the total integrated luminosity (L) can be readily translated into an estimate for the cross-section (σ):

$$\sigma = \frac{N}{\varepsilon \cdot L} \tag{7.1}$$

The total integrated luminosity corresponding to our data is

$$L \equiv \int \mathcal{L} dt = 13.5 \pm 1.6 \text{ pb}^{-1} \tag{7.2}$$

where $\mathcal{L}$ stands for the instantaneous luminosity. The efficiency is estimated using the Monte Carlo sample. For $M_t = 160$ GeV, we have $\varepsilon = 0.027 \pm 0.005$ for methods A and B and $\varepsilon' = 0.016 \pm 0.004$ for method C. In addition to these, we include the systematic uncertainties in the jet energy scale ($\sim 20\%$) and the acceptance of our signal ($\sim 20\%$) for either method. For Method A, an additional $\sim 16\%$ error comes from the quality of the exponential fit (this can be identified with the systematic uncertainty in the Berend's scaling rule). For Method B also, there's a systematic error associated with the fitting procedure. This is estimated to be $\sim 26\%$ based on the quality of the least-square fit (at the minimum, we have $\chi^2 = 5.1$ for 4 degrees of freedom). The systematic errors are added in quadrature.

We can thus estimate the cross section from each of the three methods described in the last chapter:

$$\sigma^A(t\bar{t}) = 8.0 \ \pm 7.7 \ \pm 2.7 \text{ pb} \tag{7.3}$$

$$\sigma^B(t\bar{t}) = 5.1 \ \pm 7.9 \ \pm 2.1 \text{ pb} \tag{7.4}$$

$$\sigma^C(t\bar{t}) = 3.7 \ \pm 12.6 \ \pm 2.0 \text{ pb} \tag{7.5}$$

where, the first set of errors is the statistical and the second, the systematic component of the total uncertainty. These cross-sections have been evaluated using $M_t = 160$ GeV in the Monte Carlo. The estimates are not terribly sensitive to M_t in our range of interest, changing by less than 20% for a 20 GeV shift in either direction. These cross-sections are to be compared with the theoretical prediction of

$$\sigma(t\bar{t}) = 7.41^{+1.37}_{-0.55} \text{ pb} \tag{7.6}$$

For the upper limit to the cross-section, we use only the cleanest (and smallest) sample, i.e. method C:

$$\sigma^C(t\bar{t}) < 28.2 \text{ pb} \quad (95\% \text{ C.L.}) \tag{7.7}$$

7.2 Remarks

Thanks to the large uncertainties, the results obtained in this thesis are consistent with the Standard Model prediction as well as the recent CDF results quoted in Chapter 1. For better or for worse, the results are also consistent with the scenario of there being no t quark with a mass below the upper limit in those predictions.

We have not attempted to calculate a lower limit for the mass of the t quark just from this channel. However, the final state we have studied is a key contributor to the analysis that combines several other channels. We have not discussed in this thesis, the details of our analysis of the $e + \not\!\!E_T + jets$ channel that, combined with the $\mu + \not\!\!E_T + jets$, $e + \mu$ and $e + e$ channels, led us to the deduction of the current lower limit on M_t, mainly because of the large overlap it has with what we have presented here. In that analysis, we used basically the same set of variables although the cuts were different owing to the dependence of the dynamics and cross-section on M_t. The analysis methods were less developed at that point and we did not have enough confidence in our estimates for backgrounds to subtract them from the observed data. The search was focused at the range of M_t immediately above the then-current lower limit of 91 GeV. Having established a new lower limit from that analysis, here we have focused on the region above it. Presently, DØ has results from all channels that involve at least one e or μ in the final state based on the same data set as the one used here. These results will soon be published [106]. The current estimate for the cross-section from the DØ data (all channels combined) stands at

$$\sigma_{t\bar{t}} = 7.2 \pm 5.4 \text{ pb} \tag{7.8}$$

The number of approaches presented here may seem too many for the available data. However, our aim has been to develop analysis techniques that will be useful in the long run. We note that the uncertainties are by far dominated by the statistical component. For a good while, the precision of the predictions made by these techniques will grow steadily with the size of our data sample even if no further reduction is achieved in the systematic uncertainties. Of course, our understanding of the detector performance in real life as well as in Monte Carlo simulation will grow with time. Much effort is being invested to attain this objective which will allow us to be more precise in our statements about the systematic effects as well in near future.

There are also other (more sophisticated) techniques to examine the data at hand. These include covariance matrix [107], Probability Density Estimators (PDE) [108] and Neural Networks [109]. Reference [110] contains a brief account of the working principle of these techniques which are better suited to approach the theoretical maximum for the discrimination between signal and background. However, our studies along these lines are not yet mature enough to be used for a prediction of cross-section. A better understanding of the systematics of these techniques is required before they can serve as "standard". Intensive studies are currently under way to achieve this end.

Finally, it is interesting to note that BR($b \rightarrow \mu + X$) $\approx$ 0.22 (inclusive). For high-p_T b jets, a muon from the b decay is expected to be embedded in the jet. Unlike the backgrounds, our signal always has two b quarks in the partonic final state. Hence, the probability of at least one of them containing a muon in its decay products is 0.44. Although the ability of the DØ detector to detect such muons is not particularly high, it is good enough to seduce people into studying only those events which have jets tagged with non-isolated muons. It is therefore only natural to ask if any of the 8 events in our 4-jet sample used in Methods A and B have a muon in it. The answer is "No".