Single Top Studies with MCFM *

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We report about next to leading order calculations for single top production at hadron colliders. These calculations have been implemented into the general purpose next to leading order Montecarlo program MCFM. They describe the production of single top to all the three possible channels foreseen in the Standard Model and the leptonic decay of the top quark with full spin correlation.

1 Introduction

In the Standard Model (SM) single top events may occurr only through weak interaction so that the evidence for single top production at the Tevatron [2] makes new tests of the SM possible. In particular we can test the Wtb weak vertex and in principle we could get information on its prefactor, the CKM matrix element V_{tb}.

Another strong motivation to calculate accurate predictions for single top event rates and distributions is the fact that such events give a significant contribution as background to Higgs boson discovery both at the Tevatron and the LHC. For a complete review on the subject see ref. [3]. The three ways to produce single top at the hadron colliders are the s-channel, the t-channel and the t-W associated production, the last two being sensitive to the b-pdf, nowadays still based on calculation rather then on measurements. In Figure 1 the leading order (LO) Feynman graphs for the three machanisms are painted. Calculations at LO are affected by large theoretical errors. The first serious approximation in QCD is obtained by including $O(\alpha_S)$ radiative corrections. Only at next to leading order (NLO) we obtain accurate predictions of event rates sensitive to the structure of jets in the final state. Furthermore, only at NLO we get important informations about the choice of factorization and renormalization scales. In Figure 2, we show the renormalization and factorization scale dependence of LO and NLO total rates for Wt production normalized to the LO rate for a fixed scales choice [4]. Previous NLO calculations [5] did not include the decays of the top quark (and the

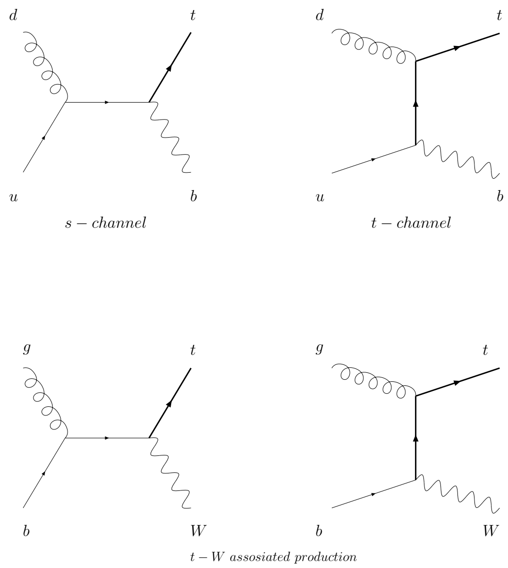

Figure 1: Leading order graphs representing the three possible mechanisms to produce single top (bold).

*The slides of this contribution can be found at the URL in ref. [1]

process	$p\bar{p}$ $\sqrt{s} = 1.96TeV$	$p\bar{p}$ $\sqrt{s} = 14TeV$
s-channel	0.872 pb	10.4 pb
t-channel	1.92 pb	245 pb
t-W	0.143 pb	68.7 pb

Table 1: Next to leading order cross sections for each channel of single top quark production at the Tevatron and LHC.

W boson in the case of the associated production). We added the leptonic decay of the top quark with full spin correlation, and included the effects of gluon radiation in the decay. The calculations were implemented in the next to leading order Montecarlo program MCFM [6]

2 Calculation

The NLO predictions for the total cross sections of the three single top channels are reported in Table 1 both for the Tevatron and the LHC. In refs. [7] and [4] the interested reader can find all the details of the calculations as well as a discussion of all the approximations. We work in the on shell approximation for the top quark. This is motivated by the fact that diagrams without an on shell top quark are suppressed by Γ_t/m_t. Furthermore, we neglect the interference of radiation emitted in the production and the decay stages. This simplifing approximation is possible due to the large difference in the time scale for the production ($1/m_t$) and the decay ($1/\Gamma_t$) of the top quark. The error introduced by this approximation is expected to be $O(\alpha_S \Gamma_t/m_t)$ [8]. We also assume $m_b = 0$ through all the calculations and inlcude no showering and hadronization. The cancellation of the singularities between the real and virtual contributions is performed with the subtraction method with massive quarks [9]. We extend this method by introducing a tunable parameter that controls the size of the subtractions. In this way we perform quicker calculations because the subtractions are evaluated only in the phase space region surrounding the singularities. Furthermore, the independence on this parameter is a valuable check of the implementation. The inclusion of the radiation in the decay of the top quark has been done through the implementation of a specific subraction counterterm mapping the singularities of the real matrix element [7]. This procedure can be useful to study the $t\bar{t}$ associated production with the decay of the top quarks. The comparison of this calculation with the forthcoming measurements for $t\bar{t}$ asso-

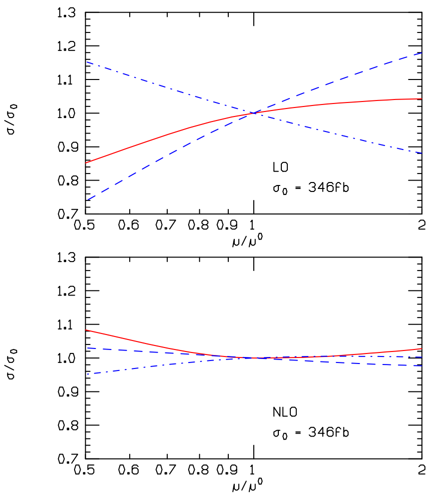

Figure 2: Factorization and renormalization scale dependence for W-t associate production cross section at leading order (top) and next to leading order (bottom). Solid curves represent the variation of both scales.

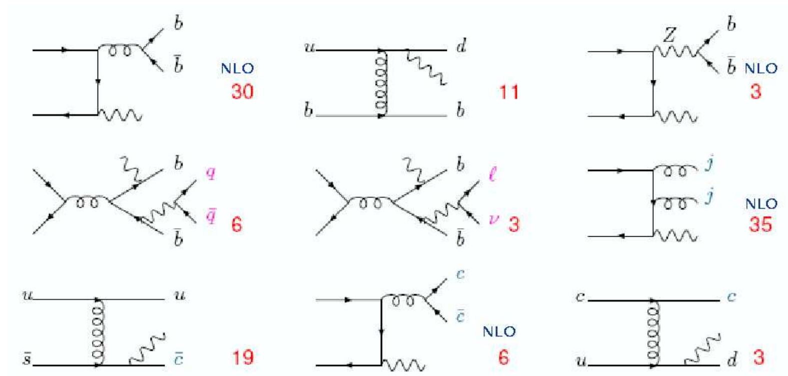

Figure 3: Main background processes for single top search at the Tevatron and their rate with the cuts contained in Table 2.

ciated production at Tevatron could improve the estimation of the top mass in the standard model.

3 Results

In ref. [7] we performed a signal and background analysis of the single top events at Tevatron, where only s and t channels can lead to an evidence for single top. Many background processes can be calculated at NLO within MCFM. With the cuts given in Table 2 we consider the contribution of the background events represented in Figure 3. Their estimated rates are also reported in the figure, together with the specification if they are evaluated at NLO. Furthermore, in Figure 4 we plot the distribution of the Ht variable, the sum of the lepton p_T, missing transverse energy and jet transverse momenta for the signal and the sum of the backgrounds. At the LHC the rate for the Wt channel is larger than the s-channel. It represents a large sourse of background for the Higgs boson searches through the discovery channel $H \to WW^*$. In Figure 5 we plot the distribution of the opening angle in the transverse plane beetwen the two charged leptons from the two W's both for signal and top backgrounds [4]. For the Wt channel the NLO corrections introduce important modifications to the simple LO prediction.

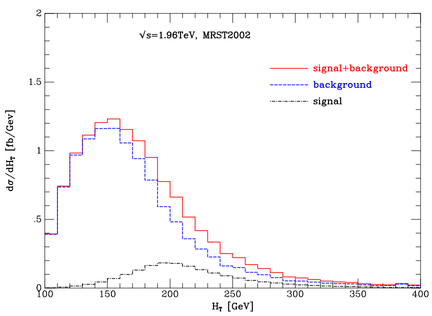

Figure 4: The Ht distributions of signal, background and signal plus background for s- and t-channel single top production at the Tevatron.

References

[1] Slides:
`http://indico.cern.ch/contributionDisplay.py?contribId=110&sessionId=9&confId=9499`

$p_T^e > 20\ GeV,$	$\|\eta^e\| < 1.1,$	$\not{E}_T > 20\ GeV,$
$p_T^{jet} > 15\ GeV,$	$\|\eta^{jet}\| < 2.8,$	$\Delta_R > 1,$

Table 2: Set of cuts used to study single top events at the Tevatron [7].

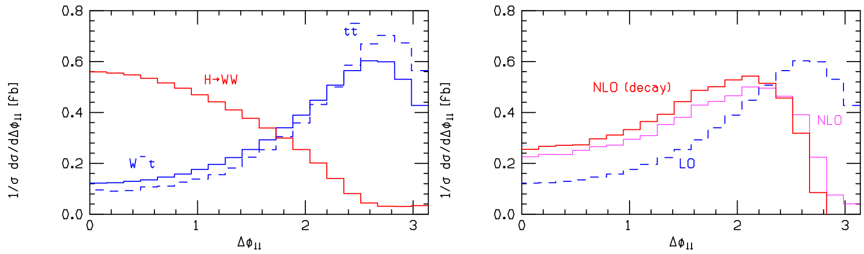

Figure 5: The opening angle between the leptons in the $H \rightarrow WW$ and $t\bar{t}$ associated production (left panel) and for the W-t associated production (right panel). Cross sections are normalized to unity, after suitable search cuts have been applied for an Higgs boson with mass 155 GeV.

[2] B. Stelzer [for the CDF Collaboration], arXiv:0706.0282 [hep-ex];
A. Garcia-Bellido [for the D0 collaboration], arXiv:0706.0037 [hep-ex].

[3] C. E. Gerber *et al.* [THe TeV4LHC-Top and Electroweak Working Group], arXiv:0705.3251.

[4] J. Campbell and F. Tramontano, Nucl. Phys. B **726**, 109 (2005) [arXiv:hep-ph/0408158].

[5] M. C. Smith and S. Willenbrock, Phys. Rev. D **54**, 6696 (1996) [arXiv:hep-ph/9604223];
G. Bordes and B. van Eijk, Nucl. Phys. B **435**, 23 (1995).
T. Stelzer, Z. Sullivan and S. Willenbrock, Phys. Rev. D **56**, 5919 (1997) [arXiv:hep-ph/9705398].
B. W. Harris, E. Laenen, L. Phaf, Z. Sullivan and S. Weinzierl, Phys. Rev. D **66**, 054024 (2002) [arXiv:hep-ph/0207055].
Z. Sullivan, arXiv:hep-ph/0408049;
S. Zhu, Phys. Lett. B **524**, 283 (2002) [Erratum-ibid. B **537**, 351 (2002)].

[6] J. M. Campbell and R. K. Ellis, Phys. Rev. D **60**, 113006 (1999) [arXiv:hep-ph/9905386];
J. M. Campbell and R. K. Ellis, Phys. Rev. D **62**, 114012 (2000) [arXiv:hep-ph/0006304];
J. Campbell and R. K. Ellis, Phys. Rev. D **65**, 113007 (2002) [arXiv:hep-ph/0202176].

[7] J. Campbell, R. K. Ellis and F. Tramontano, Phys. Rev. D **70**, 094012 (2004) [arXiv:hep-ph/0408158].

[8] V. S. Fadin, V. A. Khoze and A. D. Martin, Phys. Lett. B **320**, 141 (1994) [arXiv:hep-ph/9309234];
V. S. Fadin, V. A. Khoze and A. D. Martin, Phys. Rev. D **49**, 2247 (1994); K. Melnikov and O. I. Yakovlev, Phys. Lett. B **324**, 217 (1994) [arXiv:hep-ph/9302311];
R. Pittau, Phys. Lett. B **386**, 397 (1996) [arXiv:hep-ph/9603265];
C. Macesanu, Phys. Rev. D **65**, 074036 (2002) [arXiv:hep-ph/0112142].

[9] S. Catani and M. H. Seymour, Phys. Lett. B **378** (1996) 287 [hep-ph/9602277];
S. Catani and M. H. Seymour, Nucl. Phys. B **485** (1997) 291 [Erratum-ibid. B **510** (1997) 291] [hep-ph/9605323];
S. Catani, S. Dittmaier, M. H. Seymour and Z. Trocsanyi, Nucl. Phys. B **627**, 189 (2002) [arXiv:hep-ph/0201036].