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The transverse momentum distribution of the Higgs boson at the LHC*

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We present QCD predictions for the transverse momentum (q_T) distribution of the Higgs boson at the LHC. At small q_T the logarithmically-enhanced terms are resummed to all orders up to next-to-next-to-leading logarithmic accuracy. The resummed component is consistently matched to the next-to-leading order calculation valid at large q_T. The results, which implement the most advanced perturbative predictions available at present for this observable, show a good stability with respect to theoretical uncertainties. The numerical program *HqT*, used to perform the calculation, is briefly discussed.

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The search for the Higgs boson is one of the highest priorities of the LHC physics program [1]. In the last years a significant effort has been devoted to refining the theoretical predictions for the various Higgs production channels and the corresponding backgrounds, which are now known to next-to-leading order accuracy (NLO) in most of the cases [2]. In the case of gluon–gluon fusion, which is the main Standard Model Higgs production channel, even next-to-next-to leading order (NNLO) QCD corrections have been computed, although in the large-M_t approximation (M_t being the mass of the top quark). The result has been obtained first for the total rate [3], and more recently for fully exclusive distributions [4]. Among the possible observables, an important role is played by the transverse-momentum spectrum of the Higgs boson, whose knowledge may help to enhance the statistical significance of the signal over the background.

When the transverse momentum q_T of the Higgs boson is of the order of its mass M_H, the perturbative series is controlled by a small expansion parameter, $\alpha_S(M_H^2)$, and the fixed-order prediction is reliable. The leading order (LO) calculation [5] shows that the large-M_t approximation works well as long as both M_H and q_T are smaller than M_t. In this framework, the NLO QCD corrections have been known for some time [6, 7, 8, 4].

The small-q_T region ($q_T \ll M_H$) is the most important, because it is here that the bulk of events is expected. In this region the coefficients of the perturbative series in $\alpha_S(M_H^2)$ are enhanced by powers of large logarithmic terms, $\ln^m(M_H^2/q_T^2)$. To obtain reliable perturbative predictions, these terms have to be systematically resummed to all orders in α_S [9]. In the case of the Higgs boson, the resummation has been explicitly worked out at leading logarithmic (LL), next-to-leading logarithmic (NLL) [10], [11] and next-to-next-to-leading logarithmic (NNLL) [12] level. The fixed-order and resummed approaches then have to be consistently matched at intermediate values of q_T, so as to avoid double counting.

In the following we present predictions for the Higgs boson q_T distribution at the LHC within the formalism of Refs. [13]–[15]. In particular, we include the best perturbative information that is available at present: NNLL resummation at small q_T and NLO calculation at large q_T.

An important feature of our formalism is that a unitarity constraint on the total cross section is automatically enforced, such that the integral of the spectrum reproduces the known fixed-order results. More details are given in Ref. [15]. Other phenomenological results can be found in Ref. [16].

We now present quantitative results from Ref. [15] at NLL+LO and NNLL+NLO accuracy. At NLL+LO (NNLL+NLO) accuracy the NLL (NNLL) resummed result is matched to the LO (NLO) perturbative calculation valid at large q_T. Our calculation is implemented in the numerical program `HqT`, which can be downloaded from [17]. The code is an improved version of the original program used in Ref. [14], the main difference being in the matching procedure, which is now performed using the results of Ref. [8].

The numerical results in Figs. 1 and 2 are obtained by choosing $M_H = 125$ GeV and using the MRST2004 set of parton distributions [18]. At NLL+LO, NLO parton densities and 2-loop α_S are used, whereas at NNLL+NLO we use NNLO parton densities and 3-loop α_S. The NLL+LO results at the LHC are shown in Fig. 1. In the left panel, the full NLL+LO result (solid line) is compared with the LO one (dashed line) at the default scales $\mu_F = \mu_R = M_H$. We see that the LO calculation diverges to $+\infty$ as $q_T \to 0$. The finite component, obtained through the matching procedure, is also shown (dotted line). The effect of the resummation, relevant below $q_T \sim 100$ GeV, leads to a

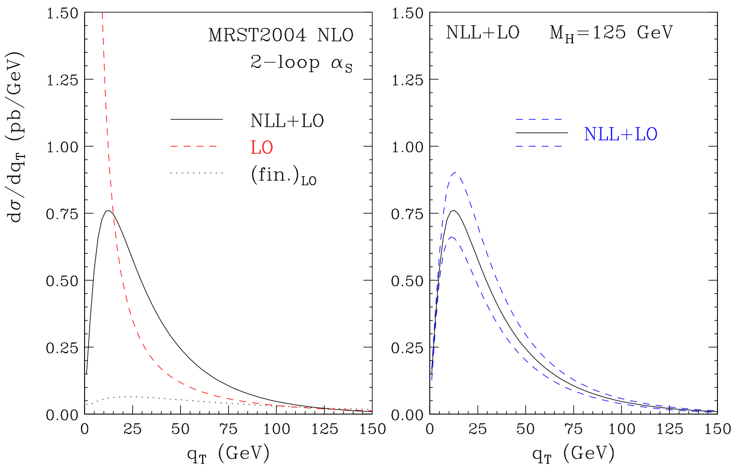

Figure 1: *LHC results at NLL+LO accuracy.*

physically well defined distribution at $q_T \to 0$. In the right panel we show the NLL+LO band obtained by varying μ_F and μ_R simultaneously and independently between $0.5M_H$ and $2M_H$, imposing $0.5 \leq \mu_F/\mu_R \leq 2$. The integral of the spectrum agrees with the total NLO cross section to better than 1%. The corresponding NNLL+NLO results are shown in Fig. 2. In the left panel, the full

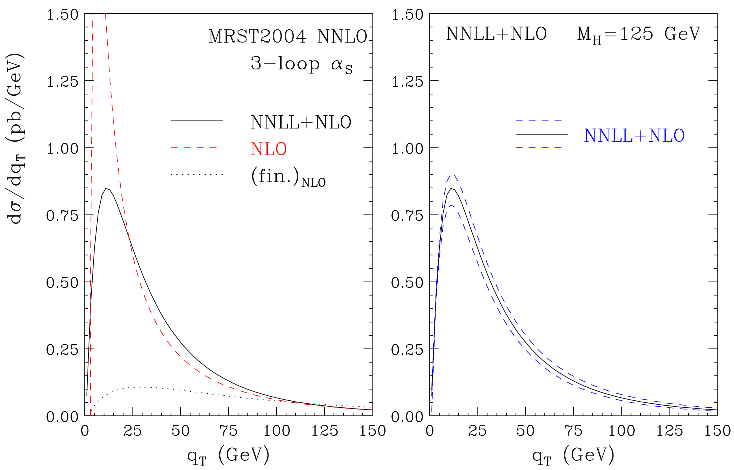

Figure 2: *LHC results at NNLL+NLO accuracy.*

result (solid line) is compared with the NLO one (dashed line) at the default scales $\mu_F = \mu_R = M_H$. The NLO result diverges to $-\infty$ as $q_T \to 0$ and, at small values of q_T, it has an unphysical peak that is produced by the numerical compensation of negative leading and positive subleading logarithmic contributions. The finite component (dotted line) vanishes smoothly as $q_T \to 0$, showing the quality of our matching procedure. The NNLL+NLO resummed result is slightly harder than the NLL+LO one, and its integral is in very good agreement with the NNLO total cross section. The right panel of Fig. 2 shows the scale dependence computed as in Fig. 1. Comparing Figs. 1 and 2, we see that the NNLL+NLO band is smaller than the NLL+LO one and overlaps with the latter at $q_T \lesssim 100$ GeV. This suggests a good convergence of the resummed perturbative expansion. Other sources of perturbative uncertainty give smaller effects [15].

In summary, considering the above results, the perturbative uncertainty of the NNLL+NLO spectrum is of about 10% at intermediate and small q_T, where the bulk of the events is concentrated. At very small q_T ($q_T \lesssim 10$ GeV) non-perturbative effects should be taken into account, whereas at large q_T the perturbative uncertainty increases. Our results for the q_T spectrum are thus fully consistent with those on the total NNLO cross section [3].

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