Determination of the Muon Transfer Function at DØ Run II

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At the Tevatron, a $p\bar{p}$-collider with a center-of-mass energy of $\sqrt{s} = 1.96$ TeV, the top quark can be accessed best by $t\bar{t}$ pair production. In the decay channel $t\bar{t} \to W^{\pm}W^{\mp}b\bar{b} \to q\bar{q}\,b\bar{b}\,l\nu$, called "lepton+jets" final state, the Matrix Element (ME) Method is used to derive the top mass [1]. In that analysis only the energy resolution of the jets was considered so far. The leptons, namely electrons and muons, were assumed to be "perfectly" measured. We studied the influence of the muon resolution on the top mass and determined the muon transfer function, meaning the probability density to reconstruct a certain muon momentum for a given generated muon momentum. This can be used to include a finite muon resolution in the ME method.

Monte-Carlo (MC) samples processed with two different reconstruction versions, Stradivarius and Ipanema, were taken into account if they have at least one isolated muon in the final state, like Z$\to \mu\mu$ or $t\bar{t} \to l{+}jets$. The first step was to calculate the top mass in the $t\bar{t}$-sample by adding the transverse energies of the b-jet, lepton and neutrino using the generated energies of two decay products and the reconstructed energy of the third one. From this we could deduce the influence of the different decay products on the resolution of the top mass. The result was that the resolution is a factor of 1.7 worse using reconstructed muons (μ_{rec}) than using reconstructed electrons. With the jet energy reconstructed (jet$_{rec}$) the resolution is again a factor of 2.7 worse than those for μ_{rec}. Further studies showed that for μ_{rec} with transverse energies above 100 GeV the resolution becomes comparable to the one obtaine d with jet$_{rec}$. From this we concluded that the finite muon resolution contributes a non-negligible fraction to the top mass resolution and that one should include a muon transfer function into the ME method.

To derive the muon transfer function we calculated the difference

$$\Delta\ (\eta, 1/p_t) = (q/p_t)_{rec} - \ (q/p_t)_{gen} \qquad (1)$$

of μ_{rec} and μ_{gen} (generated muon) as a function of inverse transverse momentum $1/p_t$ and pseudorapidity η. The muon charge is denoted by q. The difference (1) was plotted for 10x10 bins of η and $1/p_t$. Each distribution

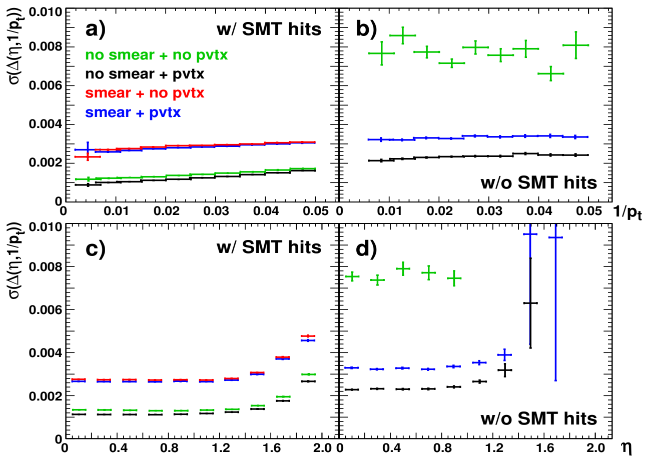

Fig. 1: Muon resolution vs. $1/p_t$ (a, b) and η (c, d) with and without SMT hits (smear = smearing, pvtx = primary vertex constraint).

par	Stradivarius	Ipanema
σ_0	$(2.746 \pm 0.006) \cdot 10^{-3}$	$(2.760 \pm 0.004) \cdot 10^{-3}$
c	$(5.45 \pm 0.31) \cdot 10^{-3}$	$(5.93 \pm 0.35) \cdot 10^{-3}$
η_0	1.224 ± 0.024	1.277 ± 0.024
$\sigma_0(0)$	$(2.670 \pm 0.023) \cdot 10^{-3}$	$(2.673 \pm 0.014) \cdot 10^{-3}$
$\sigma_0(1)$	$(3.27 \pm 0.83) \cdot 10^{-3}$	$(3.39 \pm 0.48) \cdot 10^{-3}$
c(0)	$(6.93 \pm 1.06) \cdot 10^{-3}$	$(7.45 \pm 1.22) \cdot 10^{-3}$
c(1)	$(-48 \pm 33) \cdot 10^{-3}$	$(-43 \pm 33) \cdot 10^{-3}$
$\eta_0(0)$	1.283 ± 0.073	1.453 ± 0.073
$\eta_0(1)$	-2.2 ± 2.5	-5.5 ± 2.1

Table 1: Parameters of the muon transfer function.

was fitted by a Gaussian, and the width σ, the muon resolution, was derived for every η- and $1/p_t$-bin. An example of both dependencies is given in Fig. 1 a), c). One observes the muon resolution being nearly flat in $1/p_t$ and the main dependence lying in a raise at large η. Therefore it was parametrized by a function having a constant value σ_0 beneath a threshold η_0 and above this is given by the quadratic sum of the constant σ_0 and a straight line with slope c:

$$\sigma = \begin{cases} \sigma_0 & for\ |\eta| \le \eta_0 \\ \sqrt{\sigma_0^2 + [\,c\cdot(|\eta| - \eta_0)\,]^2} & for\ |\eta| > \eta_0 \end{cases} . \qquad (2)$$

The parameters σ_0, η_0 and c of the muon transfer function (2) obtained for Stradivarius and Ipanema samples are given in the upper part of Table 1. To include a weak $1/p_t$-dependence into the muon transfer function the parameters were allowed to vary with $1/p_t$ and fitted by a straight line. Eq. (2) was extended as follows (with par $\epsilon\,\{\sigma_0,\ c,\ \eta_0\}$):

$$\text{par} = \text{par}(0) + \text{par}(1) \cdot 1/p_t\ .$$

For these parameters confer the lower part of Table 1.

The DØ tracking system consists of a silicon microstrip tracker (SMT) surrounded by a central fiber tracker (CFT) [2]. Since the simulation incorporates an idealized geometry of the tracking system and some of the dead material is not completely implemented, the MC is tuned to describe the data by smearing of the transverse muon momentum. For a muon only a CFT track is required and therefore about 10 % of the muons in the samples don't have SMT hits. As these muon tracks lack central hits the track curvature and thus the track p_t is less precise known and the resolution is worse than for muon tracks containing SMT hits. To correct for this effect in the MC, the SMTless muons are constraint to come from the primary vertex and the p_T is corrected accordingly.

We studied the influence of the smearing (smear) and primary vertex constraint (pvtx) for muons with and without SMT hits as shown in Fig. 1. It can be seen that the primary vertex constraint improves the resolution of SMT-less muons by a factor of three whereas it has much less influence ($\approx 5\%$) on muons with SMT hits. The smearing corrects the intrinsic MC resolution by about 40 %.

References

[1] P. Schieferdecker *et al.*, this report, p.40
[2] DØ Collaboration, The Upgraded DØ Detector, in preparation.