PROCEEDINGS OF SCIENCE

Measurement of the top quark pole mass using $\mathrm{t\bar{t}}$+jet events in the dilepton final state at $\sqrt{s}$ = 13 TeV

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In these proceedings, a measurement of the differential cross section of top quark-antiquark pair ($\mathrm{t\bar{t}}$) production in association with one additional jet ($\mathrm{t\bar{t}}$+jet) as a function of the inverse of the invariant mass of the $\mathrm{t\bar{t}}$+jet system, $\rho = 340\,\mathrm{GeV}/m_{\mathrm{t\bar{t}+jet}}$, is presented. The normalized $\mathrm{t\bar{t}}$+jet cross section is used to extract values for the top quark pole mass $\mathrm{m_t^{pole}}$ by comparison to theoretical predictions at next-to-leading order accuracy. The used data set corresponds to an integrated luminosity of $36.3\,\mathrm{fb^{-1}}$ of proton–proton collisions as collected by the CMS experiment at $\sqrt{s}$ =13 TeV. Events with two opposite-sign leptons are analyzed. Machine learning techniques are employed to improve the kinematic reconstruction of the main observable and the event classification. The unfolding to the parton level is performed using a profiled likelihood fit. Given the ABMP16 parton distribution functions as a reference set, a value of $\mathrm{m_t^{pole}} = 172.94 \pm 1.37\,\mathrm{GeV}$ is extracted using the normalized $\mathrm{t\bar{t}}$+jet cross section.

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1. Introduction

The top quark is the heaviest particle of the standard model (SM) of particle physics, and its mass m_t is an important input to global electroweak fits and calculations of the Higgs boson self-coupling. Its value has to be determined experimentally. Direct measurements of m_t, which rely on the usage of multipurpose Monte-Carlo (MC) event generators, reach a precision on the order of 0.5 GeV. As they depend on the modeling of nonperturbative effects via the usage of heuristic models tuned to data, their interpretation is unclear. Usually, values for m_t^{MC} are associated to the top quark pole mass, m_t^{pole}, with an interpretation uncertainty on the order of 0.5–1 GeV [1].

In this contribution, a measurement of m_t^{pole} by the CMS Collaboration [2] is presented, which was updated in Ref. [3]. The production cross section of a top quark-antiquark pair ($t\bar{t}$) in association with at least one additional jet ($t\bar{t}$+jet) as a function of the inverse of the invariant mass of the $t\bar{t}$+jet system, $\rho = 340\,\mathrm{GeV}/m_{t\bar{t}+\mathrm{jet}}$, is sensitive to m_t^{pole}. It is measured at the parton level, and m_t^{pole} is extracted from a comparison to theoretical predictions at next-to-leading-order (NLO) accuracy [4]. Large mass sensitivity is expected for values of $\rho > 0.65$. The additional jet at parton level needs to have a transverse momentum of $p_T > 30\,\mathrm{GeV}$ and an absolute pseudorapidity of $|\eta| < 2.4$.

2. The experimental analysis

Proton-proton collision events recorded by the CMS experiment, corresponding to an integrated luminosity of 36.3 fb^{-1}, are analyzed. A combination of single and dilepton triggers is used to collect the events. They are selected if they contain one opposite-sign lepton pair with $p_T > 25$ (20) GeV for the leading (subleading) lepton. Combinations of e^+e^-, $\mu^+\mu^-$, $e^\pm\mu^\mp$ are considered. Jets are selected with $p_T > 30\,\mathrm{GeV}$, and leptons and jets need to satisfy $|\eta| < 2.4$. A tagging algorithm is used to identify jets originating from hadronized b quarks (b jets).

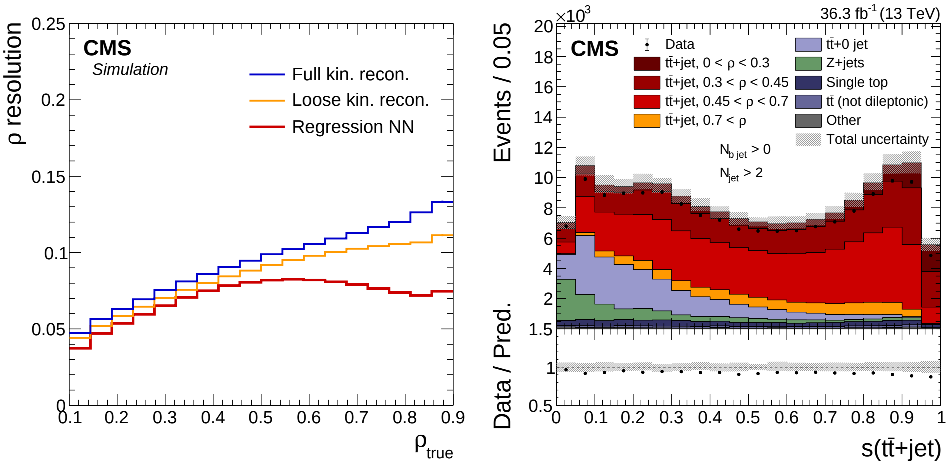

Figure 1: The ρ resolution as a function of the truth value for the regression NN and two analytical methods (left) [3]. Data and MC predicted distributions as a function of the signal output node of the classifier NN [3].

In dileptonic $t\bar{t}$+jet events, the amount of missing transverse momentum complicates the reconstruction of ρ. Thus, a multivariate technique is employed, and a regression neural network (NN) is trained. The resolution is shown in Fig. 1 left, and it is compared to approaches used in previous CMS publications. Using the NN approach, the ρ resolution is improved by up to a factor of two depending on its value.

The dominant background contribution arises from tt̄ production without an additional jet, tt̄+0jet, where the reconstructed jet originates from pileup effects or phase space migrations. As this is particularly relevant for large values of ρ, a multiclass classification NN is designed to discriminate between signal and background processes. The signal response of the NN is shown in Fig. 1 right, where the data is compared to the MC expectations.

Using a profiled likelihood fit, the tt̄+jet cross section is directly measured at the parton level. For the unfolding of the ρ distribution, a binning of 0–0.3, 0.3–0.45, 0.45–0.7, and 0.7–1 is considered. The fitted variables are the relative response of the classifier NN with respect to tt̄+0jet, the jet p_{T}, the minimal invariant mass of the lepton and b jets, and the total event yield. Events are categorized based on the ρ value, the jet and b jet multiplicities, and the dilepton type. Systematic uncertainties are profiled as nuisance parameters, and the dependence on $\mathrm{m_t}$ in the MC, $m_{\mathrm{t}}^{\mathrm{MC}}$, is mitigated by adding it as a free parameter. The data and MC predicted signal and background distributions after the fit are shown in Fig. 2, where a good agreement is observed.

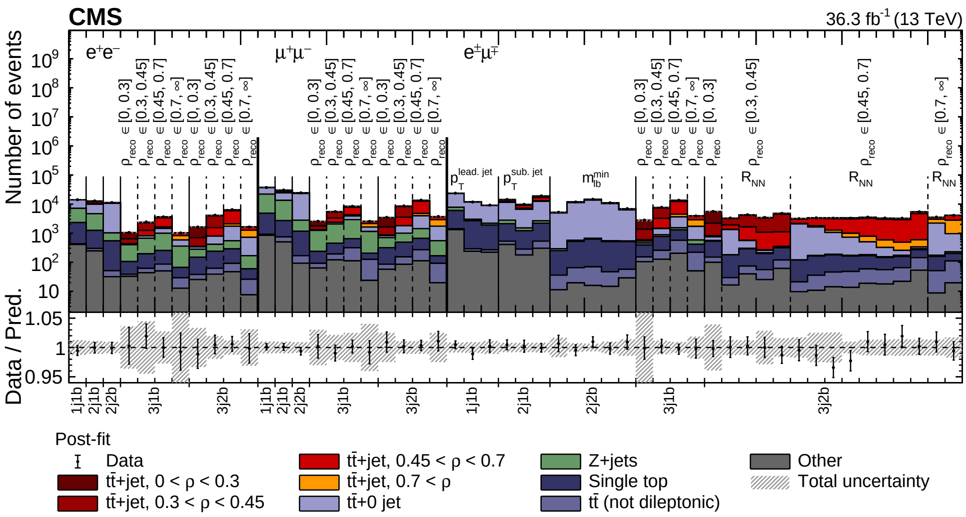

Figure 2: The data and MC predicted signal and background yields after the likelihood fit [3].

3. Results and top quark pole mass extraction

The tt̄+jet cross section as a function of ρ is directly obtained from the fit, and the normalized distribution is shown in Fig. 3 left. It is compared to theoretical predictions at NLO for different values of $\mathrm{m_t^{pole}}$. Here, the ABMP16NLO [5] parton distribution function (PDF) is used. By performing a χ^2 fit to the NLO predictions, and taking into account all bin-to-bin correlations in the covariance matrix of the fit, the value of $\mathrm{m_t^{pole}}$ is extracted. Additionally, PDF uncertainties and uncertainties arising from the extrapolation to the full phase space are included in the fit. The uncertainty due to the choice of the matrix-element scales is externalized. A value of $\mathrm{m_t^{pole}} = 172.94 \pm 1.27\,(\mathrm{fit})\,^{+0.51}_{-0.43}\,(\mathrm{scale})$ GeV is measured when using the ABMP16NLO PDF set. For the CT18NLO [6] PDF set, the value is $\mathrm{m_t^{pole}} = 172.16 \pm 1.35\,(\mathrm{fit})\,^{+0.50}_{-0.40}\,(\mathrm{scale})$ GeV. The measured cross section compared to predictions using the best-fit values for m_t^{pole} are shown in Fig. 3 right. The values of m_t^{pole} are in good agreement with previous measurements, also using the same method as done by the ATLAS Collaboration at $\sqrt{s} = 8$ TeV [7].

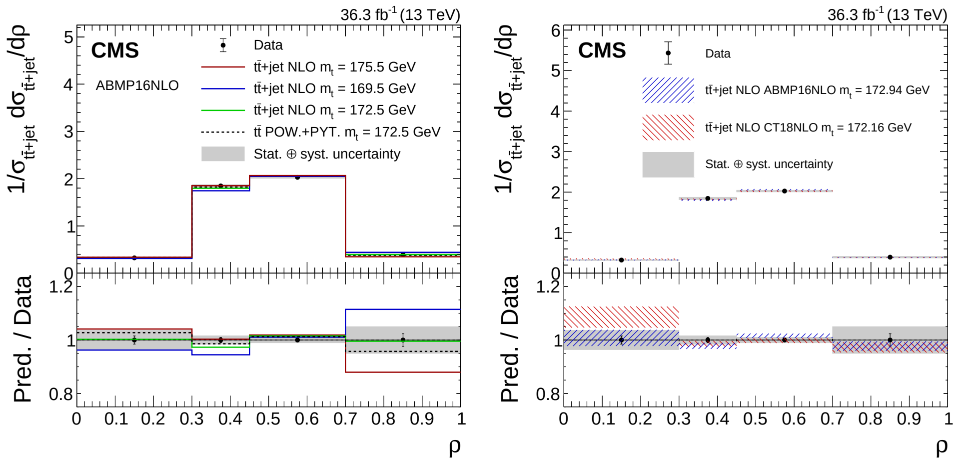

Figure 3: Left: The normalized $t\bar{t}$+jet differential cross section as a function of ρ compared to theoretical predictions for values of m_t^{pole} [3]. Right: The same measured cross section is shown, but compared to the predictions using the best-fit values of m_t^{pole} [3].

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