STUDIES OF TOP PAIR PRODUCTION IN THE FULLY HADRONIC CHANNEL WITH CMS

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The selection of top pair events in the fully hadronic final state with the CMS detector at LHC and the expected performance, the resulting cross section measurement and the top mass reconstruction accuracy are discussed.

1. Introduction

The LHC will be a top factory and will allow the top quark properties to be determined with significant precision by measuring observables in production and decay and exploiting all possible channels. The estimated $t\bar{t}$ production cross section is 488 pb at LO and 830 pb at NLO and the dominant production mechanisms are gg fusion (90%) and $q\bar{q}$ annihilation (10%). Within the SM the top quark decays almost exclusively via $t \to Wb$. The signature of the $t\bar{t}$ system is then classified according to the W^+W^- decay as dileptonic, semi-leptonic or fully hadronic.

The fully hadronic final state has the largest branching fraction (46%) and kinematics that can be fully reconstructed, but competes against a large QCD multi-jet background, which makes the isolation of the signal rather challenging, and internal jet-parton permutation uncertainties. A specific multi-jet trigger which uses b-tagging information has been devised for this analysis and an optimised selection has been applied [1,2].

2. Event selection and cross section measurement

The trigger preselection uses the inclusive jet trigger [3] and a special inclusive b-jet trigger [4] which combines an inclusive jet trigger with tuned E_T thresholds of 350, 150 and 55 GeV respectively for single, 3- and 4-jet topologies with a b-tagging performed on the two most energetic jets. After the trigger request of either multiple jets in the event or a b-tagged jet among the two highest-E_T jets, the QCD rate is reduced to 23 Hz.

The selection is seeked to optimise the statistical significance $S/\sqrt{S+B}$ for an integrated luminosity of $\mathcal{L} = 1\ \text{fb}^{-1}$. The first step requires a topology of $6 \leq N_{jet} \leq 8$, where for a jet to be counted, the jet pseudorapidity must satisfy $|\eta| < 2.4$ and its transverse energy must be greater than 30 GeV, Figure 1. Event shape variables able to discriminate the signal from the background are then investigated. The useful ones are centrality and aplanarity, whose distributions are shown in Figure 1, and non-leading jet total transverse energy obtained removing the two most energetic jets ($\sum_3 E_T$). Finally a b-tagging is applied where selection criteria of at least one and two

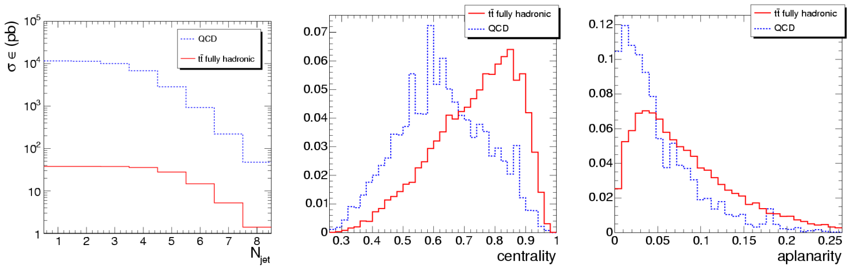

Figure 1. Effective cross sections as a function of N_{jet} for $E_T > 30$ GeV and distributions of centrality and aplanarity for $t\bar{t}$ and QCD events normalised to the same area.

b-jet are considered. Table 1 summarises the selection applied in cascade. The S/B ratio amounts to 1/9 resulting in a signal efficiency of 2.7%.

Table 1. $t\bar{t}$ and QCD effective cross sections, S/B ratio, statistical significance for 1 fb^{-1} and signal efficiency at each step of the selection.

Selection	Requirement	$\sigma\epsilon_{t\bar{t}}$ [pb]	$\sigma\epsilon_{\text{QCD}}$ [pb]	S/B	$S/\sqrt{S+B}$	ϵ (%)
Generation	(PYTHIA LO)	225	25M	$1/10^5$	0.04	100
Trigger	HLT multi-jet+b-jet	38	11600	1/300	11.1	16.8
Event	$6 \leq N_{jet} \leq 8$	35	7900	1/225	12.4	15.5
	$E_T \geq 30$ GeV	15	930	1/60	15.4	6.6
	centrality ≥ 0.68	9.9	324	1/33	17.1	4.4
	aplanarity ≥ 0.024	9.0	251	1/28	17.7	4.0
	$\sum_3 E_T \geq 148$ GeV	9.0	229	1/25	18.4	4.0
b-tagging	1 b-tag	8.6	148	1/17	21.7	3.8
	2 b-tag	6.0	54	1/9	24.1	2.7

The signal efficiency of the inclusive $t\bar{t}$ sample, to be used in the calculation of the production cross section, becomes 1.6%. The estimated statistical uncertainty on the cross section measurement for an integrated luminosity of 1 fb^{-1} amounts to $\Delta\sigma = 15$ pb with an expected number of $t\bar{t}$ inclusive and QCD events of 8000 and 54000 respectively. Sources of systematic uncertainty [5,6] are reported in Table 3. As from the experience of CDF and DØ experiments [7], one of the dominating contribution arises from jet energy scale. The total uncertainty on the cross section becomes $\Delta\sigma/\sigma = 3\%$ (stat.) + 20% (syst.) + 5% (luminosity).

3. Top mass measurement

For a kinematic top mass reconstruction, an additional cut of 100 GeV/c $< p_t <$ 300 GeV/c on the two most energetic jets, is effective against misreconstructed events and combinatorial background. Matching the six partons to six reconstructed jets, three disjunctive classes of signal events are defined: good when all six partons are well matched by jets, half good when only the three partons from one top are well matched and bad. To perform the correct jet pairing, a likelihood variable is constructed from the following event observables [1]: average and difference of the two W masses, sum of the inter-jet angles of the W and of the top candidates, difference of the two top masses, angle between the direction of the two top candidates. Only one top per event is chosen based on a likelihood variable constructed from p_t of the softest of the three jets of each top candidate, mass of the W as reconstructed in top decay, sum of the inter-jet angles of jets from top decay. The signal events selection is summarised in Table 2, where labels indicate whether the events are considered signal or background like.

Table 2. Distribution of the signal event classes after jet pairing and top choice.

reconstruction	pairing	[pb]	top choice	[pb]	label
good	correct	0.62 (35%)	always correct	0.62 (35%)	sig.
	wrong	0.26 (14%)	always wrong	0.26 (14%)	bkg.
half good	correct	0.46 (25%)	correct	0.33 (18%)	sig.
			wrong	0.13 (7%)	bkg.
	wrong	0.26 (15%)	always wrong	0.26 (15%)	bkg.
bad	always wrong	0.20 (11%)	always wrong	0.20 (11%)	bkg.

The resulting invariant mass distribution is shown in Figure 2. The extracted top mass is $m_t = 175.0 \pm 0.6$ (stat.) $\pm\ 4.2$ (syst.) GeV/c^2 for an input top mass of 175 GeV/c^2 and an integrated luminosity of $\mathcal{L} = 1$ fb^{-1}. The systematic uncertainties are summarised in Table 3. By far the biggest one is the QCD background. Experience from Tevatron [8] indicates that this uncertainty can be understood at the ~ 2 GeV/c^2 level, when using data for background estimation.

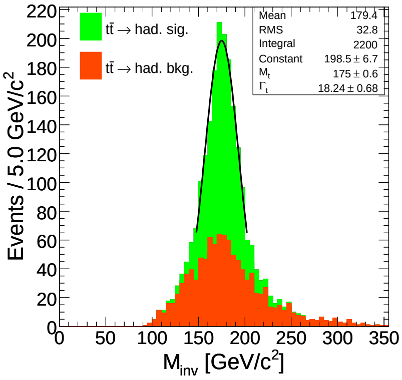

Figure 2. Invariant mass distribution of the reconstructed and rescaled, chosen top for both signal classes with a Gaussian fit to the peak.

Table 3. Contributions to the systematic uncertainty on the $t\bar{t}$ cross section and top-mass measurement.

	$\Delta\sigma/\sigma$ (%)	Δm_t [GeV/c^2]
High Level Trigger	5.9	
Pile Up	10.0	0.4
Underlying Event	4.1	0.6
PDF	4.2	1.4
IS/FS Radiation	7.9	2.3
Fragmentation	1.9	0.9
Jet Energy Scale	11.2	2.3
b-tagging	2.0	0.3
Background	5.0	2.0

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