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TOP MASS MEASUREMENT ON 1 fb^{-1} USING THE THREE BEST COMBINATIONS METHOD

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INTRODUCTION

We measured the top quark mass using the Template Method and events without b-tag information corresponding to 1 fb^{-1} of data. In doing this, we applied a statistical method to improve the resolution due to the statistical error. The reconstruction of each event, when using no b-tag information for the jets, can be done *a priori* in 24 different ways. Each of 24 reconstructions can be associated with χ^2 value which is smaller for better agreements of data and MC kinematics. Once 24 combinations are ordered by increasing χ^2 values, the first is commonly chosen when applying the standard Template Method. Figure 1 shows how many times each χ^2 rank is the correct assignment. The plot deals with events where the four leading jets are associated with the four $t\bar{t}$ decay quarks. We notice that the χ^2 rank = 1 point corresponds to the correct association in less than 50% of times. The $(2n)$th bins are less populated than the $(2n-1)$th ones because their entries are often rejected to avoid double counting. This happens when the 2nd degree equation for the neutrino longitudinal momentum determines appoximatively the same top mass value. We reject the second solution, whenever it differs less than 100 MeV from the first one.

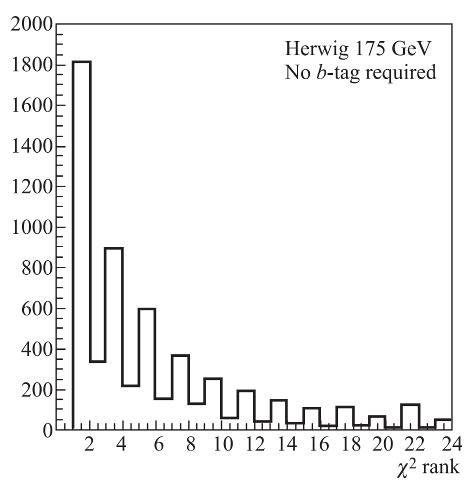


Fig. 1. The plot shows for the Herwig MC simulation with $M_{\text{top}} = 175\,\text{GeV}$ how many times the χ^2 rank corresponds to the correct jet-to-parton association. More details are in the text

We used the three best reconstructions and combined them together. In order to take into account the correlation between the three best combinations, we used the Best Linear Unbiased Estimate (BLUE) method to combine them and compute the BLUE-combined mass and error. This method is not expected to improve the systematic error.

1. PROCEDURE

Out of 1 fb^{-1} of data we selected 645 events passing the CDF standard kinematic cuts for high P_t physics and having $\chi^2 < 9$ as a quality factor for the best reconstructed combination. A number of relevant kinematic quantities are represented in Fig. 2 to compare the selection operated on the data and the closer MC sample to the most recent measurements.

The templates we used are the probability density functions obtained from 21 Herwig MC samples having as input 21 top masses from 150 to 200 GeV. Those signal templates have been parametrized using 30 parameters. The BG samples have been obtained using the four leading BG contributions: W + light jets (63.3%), W + heavy jets (13.9%), QCD (14.6%), diboson (8.2%). The BG shapes have been combined using the estimated relative ratios as weights. All signal templates and BG samples have been obtained for each of the the three best reconstructions so to run three mass measurements independently using the first, the second and the third best reconstructions.

We built a large number of experiments using the MC samples, each experiment modeling the data sample in composition and amount of events. In the Template Method, each experiment is treated as it was the actual data sample and fitted with a likelihood fit procedure providing a mass measure. In our BLUE method, this happens once for each of the three best reconstructions, so that we obtain three measures for each experiment.

Each of the three measures has been tested to check for biases: Fig. 3 shows the pull distribution means and widths as a function of M_{top} for the three reconstructed best combinations (*a*). We can see that, inside the errors, no appreciable bias is present. Figure 4 shows a number of reconstructed masses compared to the input masses (*a*) and the BLUE pull distribution means and widths as a function of the input masses compared with the three best combinations pulls (*b*).

By studying the experiments, we computed the correlations between the first and the second, the first and the third, the second and the third combinations. Making use of the correlation factors we computed then [1] the weights $\alpha_1, \alpha_2, \alpha_3$ we assign to each measured mass to obtain the combined mass.

$$\sigma^2_{\text{combined}} = (\alpha_1\ \alpha_2\ \alpha_3) \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_2^2 & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_3^2 \end{pmatrix} \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{pmatrix}. \tag{1}$$

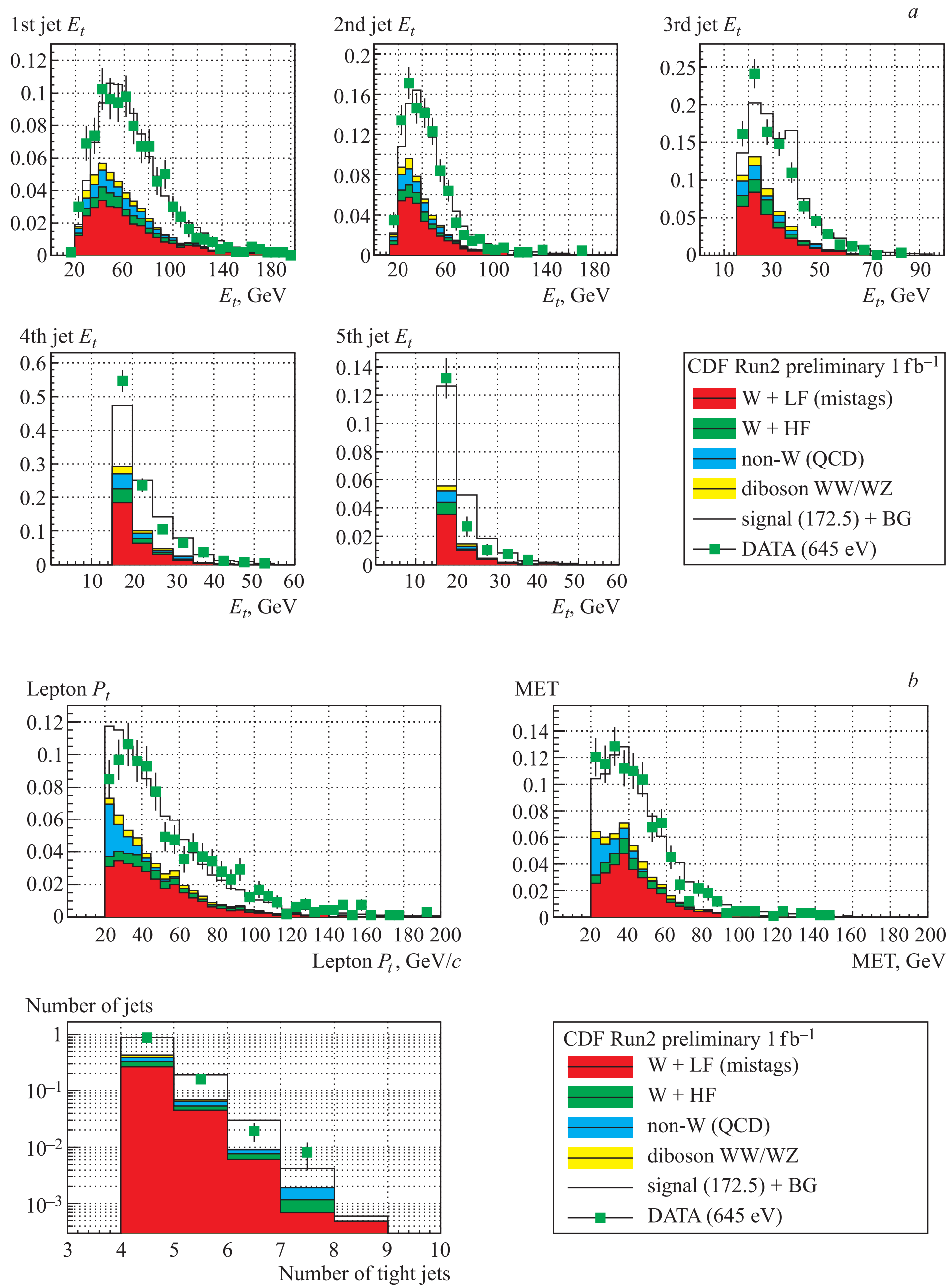
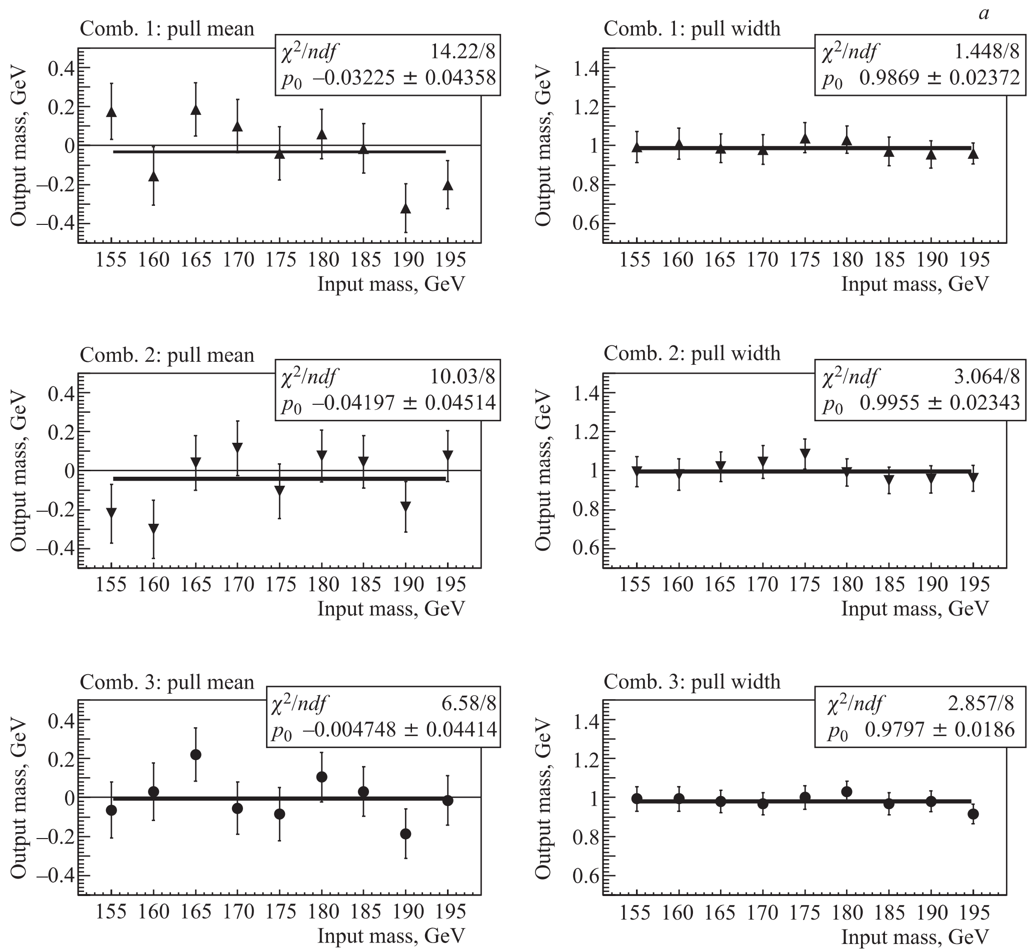


Fig. 2. *a*) Transverse energy distributions of the five leading jets in the selected data and MC events; *b*) distributions of lepton transverse momentum, $\not{E}_t$ and number of jets in the selected data and MC samples



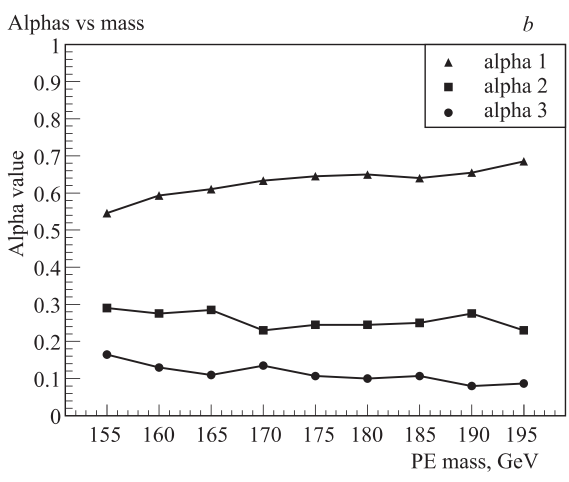


Fig. 3. *a*) Pull distribution means and widths. The rows correspond to the three combinations, in order up to down. The relatively large error bars are due to the limited statistics. The red horizontal lines show the fits to a constant; *b*) values of the weights used to combine the three measurements as in the text, to obtain the BLUE mass

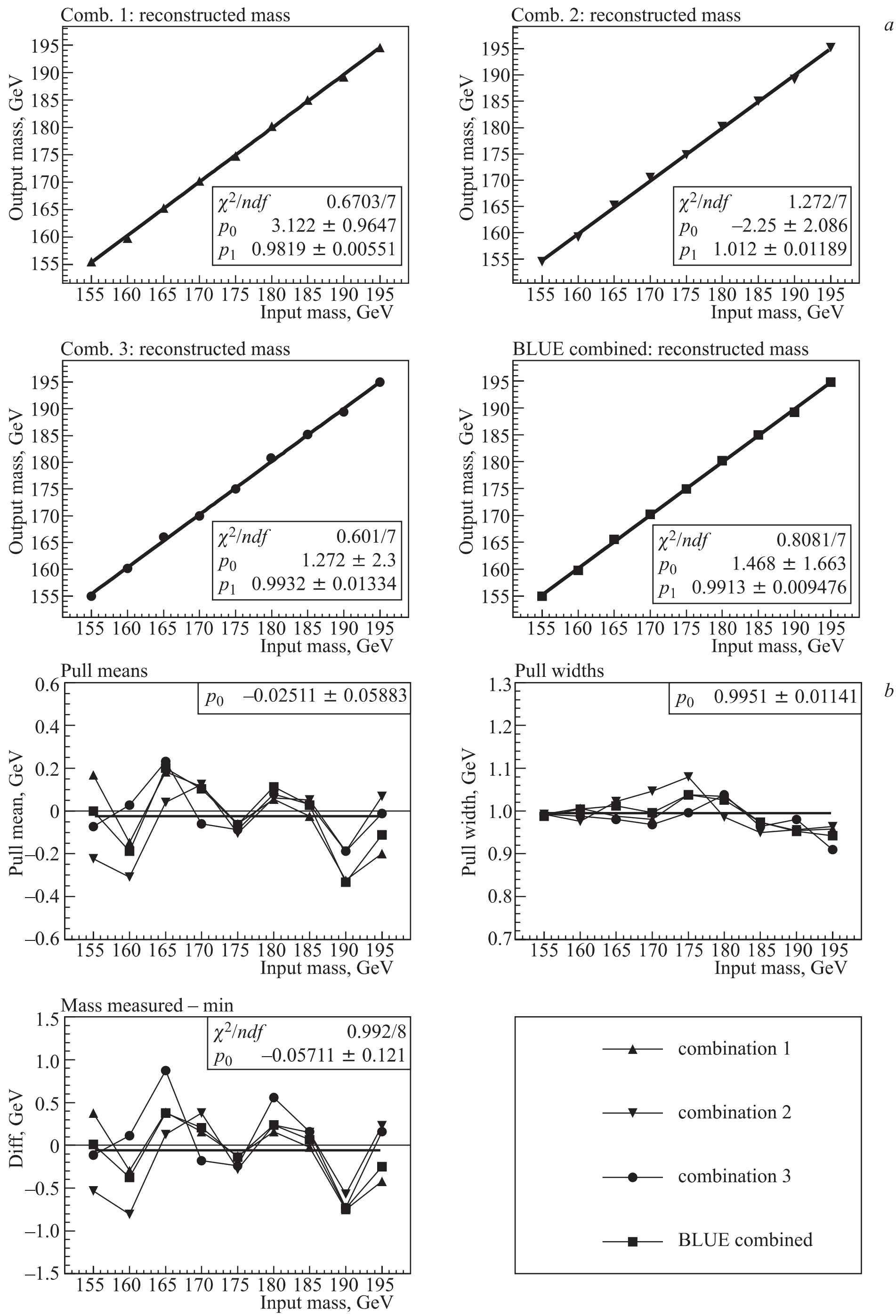


Fig. 4. *a*) Reconstructed masses vs input masses; *b*) pull means and widths of the three best combinations and the BLUE over the studied mass range

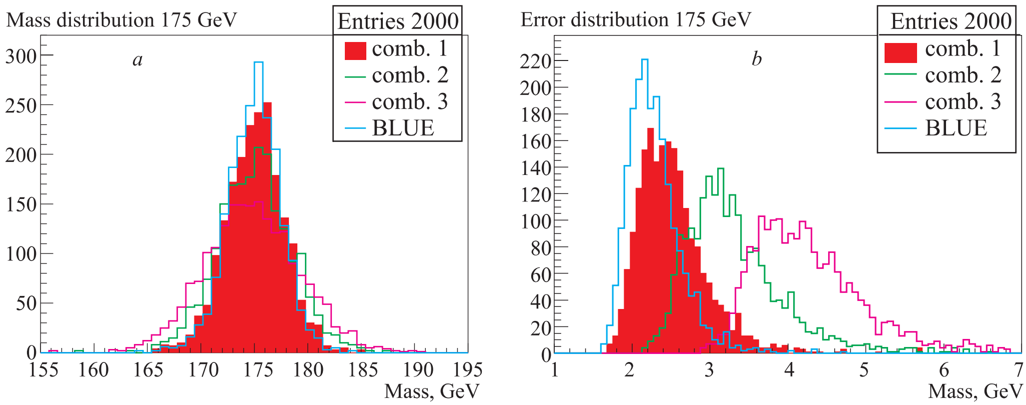


Fig. 5. *a*) The three combinations and the BLUE mass distributions for $M_{top} = 175$ GeV; *b*) error distributions for the three combinations and for the BLUE combined. Although the errors of the second and third combinations are larger, the information provided by these combinations reduce the BLUE errors below those of the first combination

Equation (1) shows the expression for the BLUE variance to be associated with the BLUE mass $M_{combined} = \alpha_1 M_1 + \alpha_2 M_2 + \alpha_3 M_3$. The $\alpha_1, \alpha_2, \alpha_3$ factors are computed for each experiment by minimizing the BLUE variance using the constrain $\alpha_1 + \alpha_2 + \alpha_3 = 1$.

Figure 3, *b* shows how the weight values depend on the M_{top} value.

In Fig. 5 we show the distribution of the reconstructed masses (*a*) and errors (*b*) relative to the experiments run for $M_{top} = 175$ GeV.

2. RESULTS

We report in Fig. 6, *a* the data fitted histograms relative to the three best combinations and the relative likelihood shapes. The data mass measure is reported in Table 1 where the statistical error only is reported. The unconstrained fit on the same data sample is reported in the right column as comparison. The BLUE-combined data measure is reported in the same table and allowed an improvement of the statistical error by 5.1% with respect to the standard choice of the best reconstructed mass.

In Fig. 6, *b* we report the distribution obtained in the MC study relative to $M_{top} = 175$ GeV of the BLUE improvements while running 2000 experiments. The mean of this distribution is about 10%. Basing on the MC study, the probability to obtain a BLUE improvement larger than 5.1% is 77%.

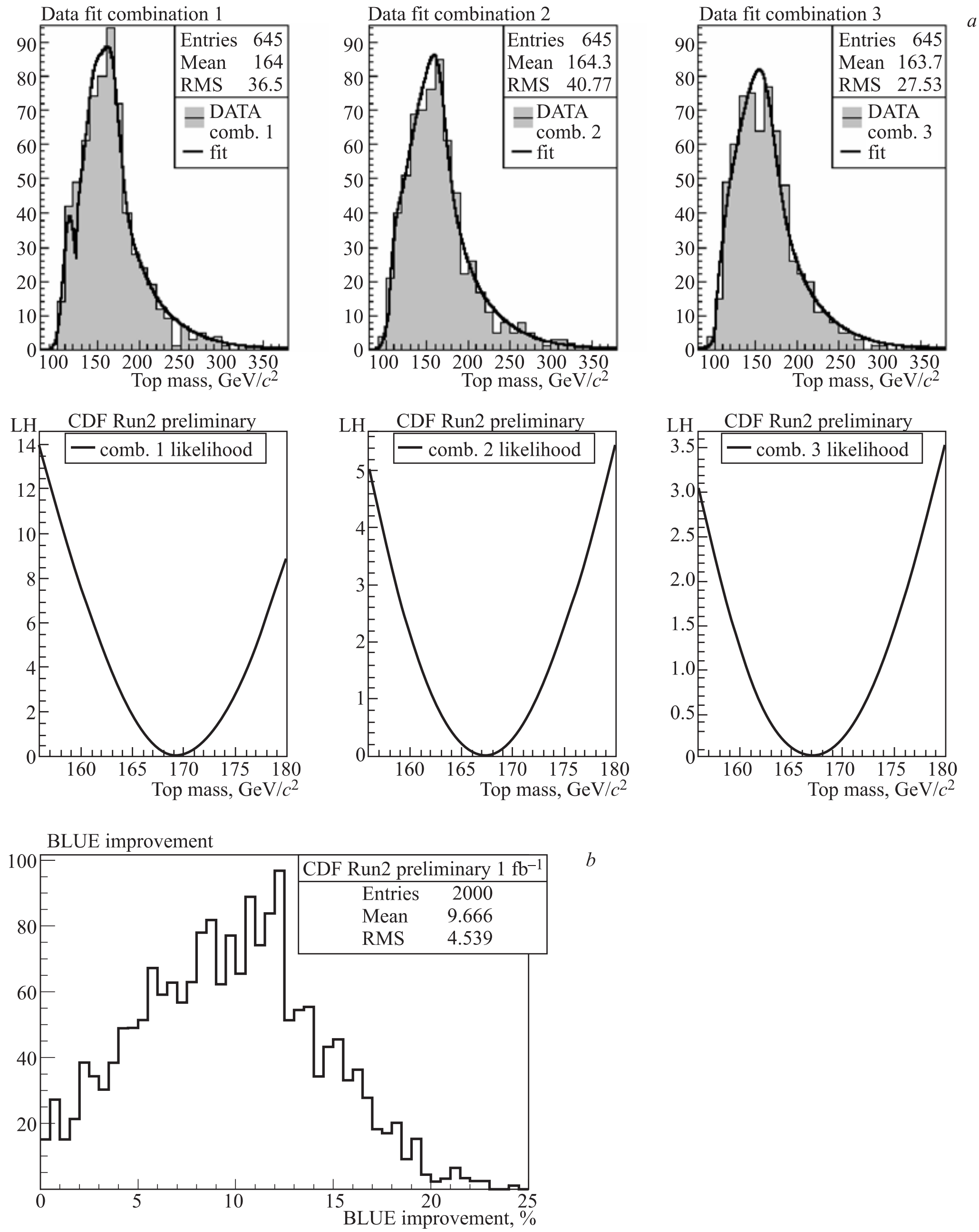


Fig. 6. *a*) Likelihood fit of the three best combinations and relative likelihood functions whose minimum determines the mass value; *b*) distribution of the BLUE improvements with respect to the best combination. This study is based on 2000 MC experiments

Table 1. The results on the data fits. The BLUE-combined measurement is obtained, as mentioned in the text, using the correlation factors from M_{top} = 175 GeV. The quoted errors are statistical only

Data fit (stat. err. only), CDF Run2 preliminary, 1fb^{-1}		
	Constrained fit	Unconstrained fit
Comb. 1	169.5 ± 2.3 GeV	169.8 ± 2.4 GeV
Comb. 2	167.3 ± 3.6 GeV	168.7 ± 4.2 GeV
Comb. 3	167.0 ± 4.6 GeV	169.3 ± 5.7 GeV
α_1	0.758	0.841
α_2	0.165	0.120
α_3	0.077	0.038
BLUE	168.9 ± 2.2 GeV (stat.)	169.6 ± 2.4 GeV (stat.)
improvement	5.1%	4.0%

We estimated the systematic error relative to our mass measure using the same BLUE technique. The relevant contribution and their quadratic sum are reported in Table 2.

Table 2. The measured values of the systematic uncertainties

Source	GeV/c^2
Generator	0.8
BG shape	0.6
JES	3.9
Gluon radiations	0.7
PDF	0.5
BG estimation	0.7
Lepton P_t	0.2
b-jet systematics	0.6
Syst. tot. uncert.	4.2

Our final measure of the top quark mass in the semileptonic channel using no *b*-tag information and applying the BLUE technique is:

$$M_{top} = 168.9 \pm 2.2(\text{stat.}) \pm 4.2(\text{syst.})\,\text{GeV}/c^2. \quad (2)$$

REFERENCES

1. *Lyons L., Gibaut D.* // NIM A. 1998. V. 270. P. 110–117.

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Артиков А. и др. E1-2007-77
Измерение массы топ-кварка на статистике 1 фб$^{-1}$ с использованием метода трех лучших комбинаций

BLUE-метод (лучшая линейная несмещенная аппроксимация) применим для улучшения точности измерения массы топ-кварка всякий раз, когда масса может быть получена множеством различных способов для каждого события. Этот метод применялся для 1 фб$^{-1}$ накопленных данных в полулептонном канале, при этом не требовалось мечения b-струй для так называемой шаблонной техники. Ранее с помощью шаблонной техники выбиралось одно значение массы, возвращенное наиболее вероятной комбинацией струя–партон из 24 возможных. В этой статье используется информация о массе топ-кварка, возвращенная тремя лучшими (наиболее вероятными) комбинациями. Моделирование показывает, что в значительном числе случаев комбинации со вторым и третьим значениями χ^2 правильные. Моделирование по методу Монте-Карло показало, что BLUE-метод с тремя комбинациями уменьшает статистическую ошибку примерно на 10 %. В результате применения BLUE-метода с тремя лучшими комбинациями измерена $M_{\text{top}} = 168{,}9 \pm$ $\pm 2{,}2\,(\text{стат.}) \pm 4{,}2\,(\text{сист.})$ ГэВ/c^2.

Работа выполнена в Лаборатории ядерных проблем им. В. П. Джелепова ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 2007

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Top Mass Measurement on 1 fb^{-1} Using the Three Best Combinations Method

The BLUE method is applicable to improve the precision in the Top Mass Measurement, whenever the mass can be derived in a number of different ways for each candidate event. This method is applied to a 1 fb^{-1} data sample in the semileptonic channel requiring no b-tag information used in the Template Method. This method makes use of the mass value returned by the most likely jet-to-parton association (out of 24). In this note the mass information returned by the three best combinations is exploited. Simulations show that in a significant number of cases the associations giving the second and the third best χ^2 are actually the correct ones. It was found in MC that the statistical error is improved by about 10%. Combining the three best mass reconstructions by using a statistical technique called BLUE gives $M_{\text{top}} = 168.9 \pm 2.2\,(\text{stat.}) \pm 4.2\,(\text{syst.})$ GeV/c^2.

The investigation has been performed at the Dzhelepov Laboratory of Nuclear Problems, JINR.

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