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Search for Standard Model resonances decaying into a pair of b-jets at CDF II

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Abstract

CDF has collected 5.4 fb^{-1} of $p\bar{p}$ events using the dedicated SVT trigger path which required a displaced vertex compatible with a b-hadron decay. This unique dataset is used to search for Standard Model Z and Higgs resonances decaying into a pair of b-jets. The Z production cross section times the $b\bar{b}$ branching ratio is measured by extracting $Z \to b\bar{b}$ events from a fit to the dijet invariant mass distribution, where the dominant QCD b-jet background is estimated by a data-driven technique to minimize the dependence of the analysis on the Monte Carlo simulation. The measured cross section is

$$\sigma_Z \times B(Z \to b\bar{b}) = 1.11 \pm 0.08(stat) \pm 0.13(sys) \text{ nb}.$$

The analysis technique is used on the same dataset to search for $H \to b\bar{b}$. No signal is found and an upper limit on the $p\bar{p} \to H \to b\bar{b}$ cross section is set at 95% C.L. resulting on 33 times the expected Standard Model value. This result constitutes the first inclusive $p\bar{p} \to H \to b\bar{b}$ limit.

CONTENTS

I. INTRODUCTION

The Higgs boson has been discovered at LHC [1, 2], but its properties are measured with low precision at the moment. In particular the decay $H \to b\bar{b}$ was not established, despite its large branching ratio, 58% [3], due to the overwhelming $b\bar{b}$ QCD background. The search for $H \to b\bar{b}$ at CDF exploits proton anti-proton collisions and can count on lower background with respect to LHC, but it suffers of low production cross section. The analysis technique, based on data to evaluate the the $b\bar{b}$ QCD background, is validated on the reconstruction of $Z \to b\bar{b}$. The identification of this process benchmarks also the b-jet energy scale with respect to the Monte Carlo simulation. In addition, the measurement of $p\bar{p} \to Z \to b\bar{b}$ cross section at CDF helps in understanding the production of the electroweak boson at center of mass energy of 1.96 TeV and with different initial state with respect to the LHC experiments [4].

This note describes the $Z \to b\bar{b}$ cross section and the b-jet energy scale measurements by using events with at least two b-tag jets. The analysis technique is applied to the same dataset to search for $H \to b\bar{b}$. No signal events are found and a limit to the inclusive $p\bar{p} \to H \to b\bar{b}$ process is set.

Sec. II and Sec. III describe the experimental dataset, a sample of 5.4 fb^{-1} of data collected by requiring at least one displaced secondary vertex in the event compatible with a b-hadron decay using the CDF detector [5]. Here, the simulated samples used to determine the efficiencies of events selection and their scale factors with respect to data are also illustrated. The evaluation of the $b\bar{b}$ QCD background contribution is performed by using data itself, and the procedure is described in Sec. IV and Sec. V.

The fit to the double b-tagged data sample to extract the $Z \to b\bar{b}$ cross section and the Jet Energy Scale is discussed in Sec. VI, while the the errors evaluation is described in Sec. VII. The search for $H \to b\bar{b}$ with the the procedure to set an upper limit on the $p\bar{p} \to H \to b\bar{b}$ process is in Sec. VIII, together with the results.

II. DATA SAMPLE AND EVENT SELECTION

Data used in this measurement are collected with the DIJET_BTAG trigger [6]. The trigger algorithm, designed and optimized for $H \to b\bar{b}$ events collection, thereby it is aimed at high efficiency on any final state with b jets. The trigger algorithm exploits the long b-hadron lifetime searching for tracks coming from a secondary vertex displaced from the primary one and keeps the jet energies as low as possible to reconstruct events with low dijet invariant mass in order to better constrain the background distribution. These characteristics allow searches in invariant mass regions not covered by LHC experiments. The trigger algorithm was made possible by combining the CDF II eXtremelyFastTracker (XFT) improved on line tracking and the information of the Secondary Vertex from the Silicon Vertex Trigger (SVT) to perform an efficient track-jet matching. The trigger path is structured in three levels with the following requirements:

- Level-1: at least two central ($|\eta| < 1.5$) calorimetric towers with $E_{\rm T} \geq 5$ GeV and two XFT tracks having $p_T > 2$ GeV/c;

- Level-2: jets with $E_{\rm T} > 15$ GeV and $|\eta| < 1.0$ are reconstructed using the fixed-cone algorithm with a radius of 0.7. At least two XFT-SVT tracks with signed impact parameter $d_0 > 90$ µm matched to one of the jets and with the decay length in the transverse plane $R_{\rm b} > 0.1$ cm where $R_{\rm b}$ is obtained from the relation $d_0 = R_{\rm b} sin(\phi_{\rm b} - \phi)$ with ϕ and $\phi_{\rm b}$ the azimuthal angle of the jet and of the b-hadron respectively;

- Level-3 trigger algorithm confirms Level-2 requirements using Level-3 offline variables.

At the analysis level, the events are required to have:

- two jets with $E_{\rm T} > 22$ GeV;
- at least one jet with a secondary vertex found by using the tight SecVxt [7] b-tagging algorithm. This sample, referred as single tag, is used for the background determination;
- at least two jets with a secondary vertex identified by the tight SecVxt b-tagging algorithm. This sample, referred as double tag, is fitted to extract the signal yield.

In the rest of the paper, a jet is identified as

- ***b*-tag trigger** jet if it fires the DIJET_BTAG trigger and has a tight SecVtx tag;
- ***b*-tag** jet if has tight SecVtx tag;

III. TRIGGER AND *b*-TAG EFFICIENCY EVALUATION

The analysis uses Monte Carlo simulated events to evaluate the efficiencies and the acceptance of signals, $Z \to b\bar{b}$ and $H \to b\bar{b}$, and to determine the shape of the two b-jet invariant mass distribution for signals and background.

The procedure used to study the background contribution will be described later. QCD $b\bar{b}$, $c\bar{c}$ and generic di-jets events are produced using Pythia v. 6.216 [8] with the underlying event modeled by tune "A". The CTEQ5L Parton Distribution functions (PDF) are used. The signals, $Z \to b\bar{b}$ and $H \to b\bar{b}$ with mass at 125 GeV/c^2, are also generated with the same version of Pythia with tune "A". The Monte Carlo samples are prepared following the standard CDF procedure: event generation and simulation through the detector with CDFSim with the profile luminosity of the periods corresponding to the data taking.

The efficiency of the trigger on the $Z \to b\bar{b}$ is of about 5%, while on the $H \to b\bar{b}$ process is of about 10%.

The capability of the Monte Carlo simulation to reproduce data is verified by using events with at least one non-isolated muon with transverse momentum greater than 8 GeV/c. A corresponding Monte Carlo sample of events is simulated with Pythia v. 6.216. One of the jet must contain a good non-isolated muon and has to have a positive tight SecVtx tag in order to have a b purity greater than 95%. The second jet must contain at least two good loose SecVtx tracks. The different response of the online and of the SecVtx b-tagging algorithm to b-jets in data and in simulation has been studied using this sample and data/MC scale factors have been determined.

Figure 1, reports the data/MC scale factor for b-tag trigger jet, i.e. the ratio of the efficiency of data to that of MC. In this way the combined trigger and tagging scale factor is applied to all MC jets that fire the trigger. Figure 2 shows the data/MC scale factor for tight SecVtx b-tag jets as function of jet $E_{\rm T}$. This scale factor is applied to the MC jets that do not fire the DIJET_BTAG trigger.

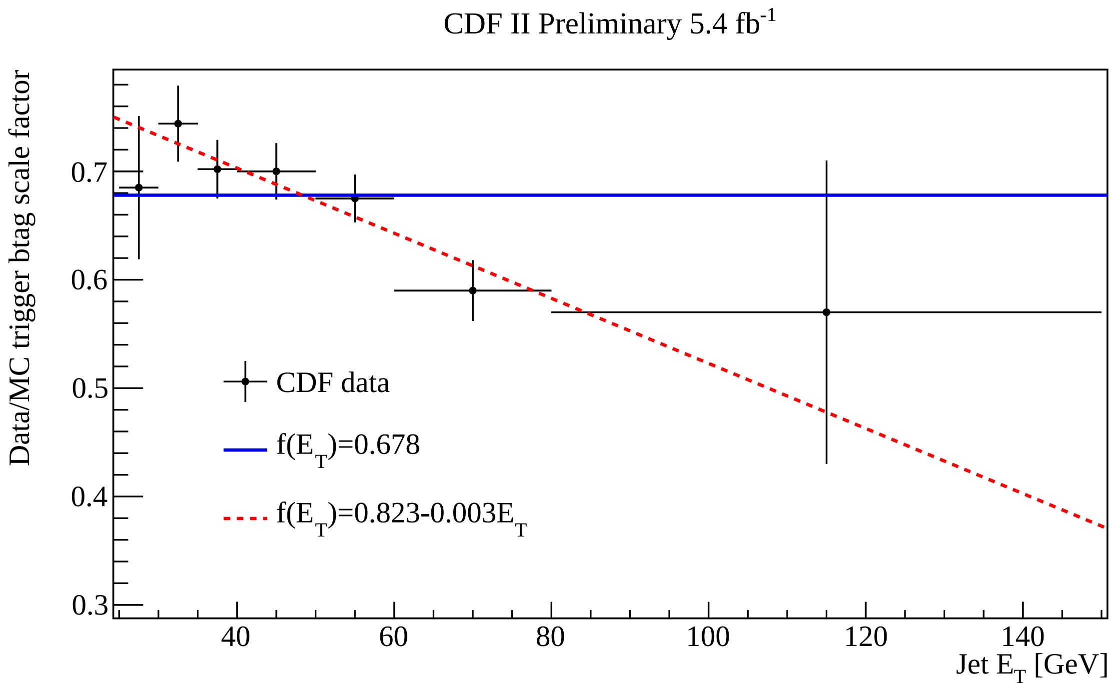

FIG. 1. Trigger b-tag data/MC scale factor distribution as a function of the jet transverse energy with result of the fit superimposed: in blue the constant line and in red a straight line.

IV. HEAVY FLAVOR CONTENT OF DATA

The composition of the data selected depends on the number of the b-tag jets though it is expected to be dominated by b-hadrons also in the single tag sample. The TagMass, defined as the invariant mass of all tracks originating from the secondary vertex assumed to be charged pions ($M_\pi = 139\text{MeV}/c^2$) is used to determine the heavy flavor content of the sample. The TagMass is sensitive to the flavor of the parton initiating the jet. Light quarks and gluons, which can generate a secondary vertex tag only due to track mis-measurement, have low invariant mass distribution. Hadrons originating in b quarks have larger invariant mass with respect to those originating in light- and also c-quarks, so the latter are distinguishable from the former ones.

Figure 3 shows the TagMass distribution of the b-tag trigger jets, which is fitted with a binned maximum likelihood as sum of three contributions: b quark, c quark and light quarks. The templates of the components are obtained from the TagMass distribution of the b-tag trigger jets in the b, c and light quarks jets Monte Carlo samples described in Sec. II. The result shows that in the b-tag trigger jets the fraction of b-quark jets is of $(75 \pm 2)\%$, c-quark jets are $(7 \pm 1)\%$ and light quarks jets are $(18 \pm 2)\%$ where the uncertainty is the quadratical sum of the statistical and the systematic uncertainties in the MC templates. Figure 3 shows that at high values of the TagMass the sample is made of almost pure b-quark jets. In fact, by requiring TagMass$>$ 1.8 GeV$/c^2$, the b-quark component is 96% and the rest 4% is light quarks. This requirement will be used in Sec. V to select a pure sample of b-tag trigger jets originating from b quarks.

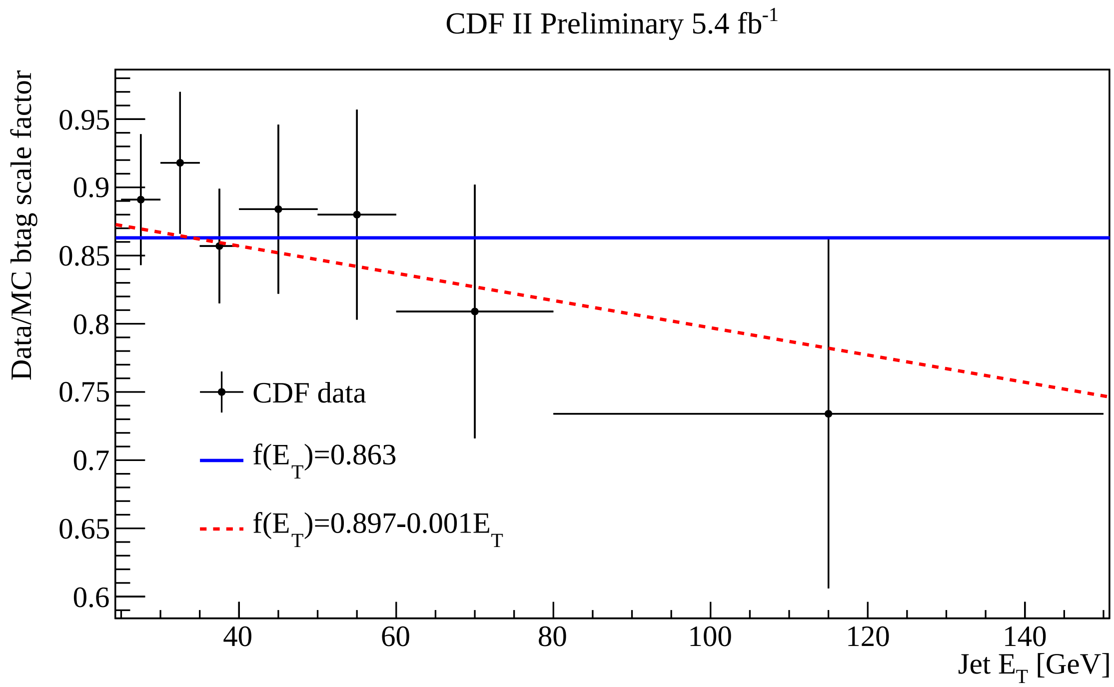

FIG. 2. Data/MC scale factor distribution as a function of the jet transverse energy for tight SecVtx tags with result of the fit superimposed: in blue the constant line and in red the straight line.

V. BACKGROUND MODELING

A. Method

The sample used to search for the signal has at least two SecVtx tags, and it is predominantly constituted by heavy quarks jets. These events arise from production mechanisms not precisely predicted by the theory therefore we can not rely on Monte Carlo to determine the sample composition. A data-driven method is applied to evaluate the background contribution as done in previous CDF measurements [9]. The method proceeds as follow:

- the probabilities, as function of jet E_T and η, to tag a b, c, light-quark initiated jet as a b jet are determined by using the Monte Carlo simulated data. These per jet probabilities represent the efficiency to tag (b, c or light quark initiated jet) as a b jet and are referred as tagging matrices;

- starting from the single b-tag jet data sample, the flavor of non-tagged jet is determined by weighting it with the tagging matrices for b, c, light quark jets;

- the invariant mass of the b-tag trigger and the second “flavour determined” jets is calculated to have the predicted shape of the background invariant mass under the three jet flavor hypothesis.

With this method only the shapes of the background distributions are determined while the normalizations are part of the data fit.

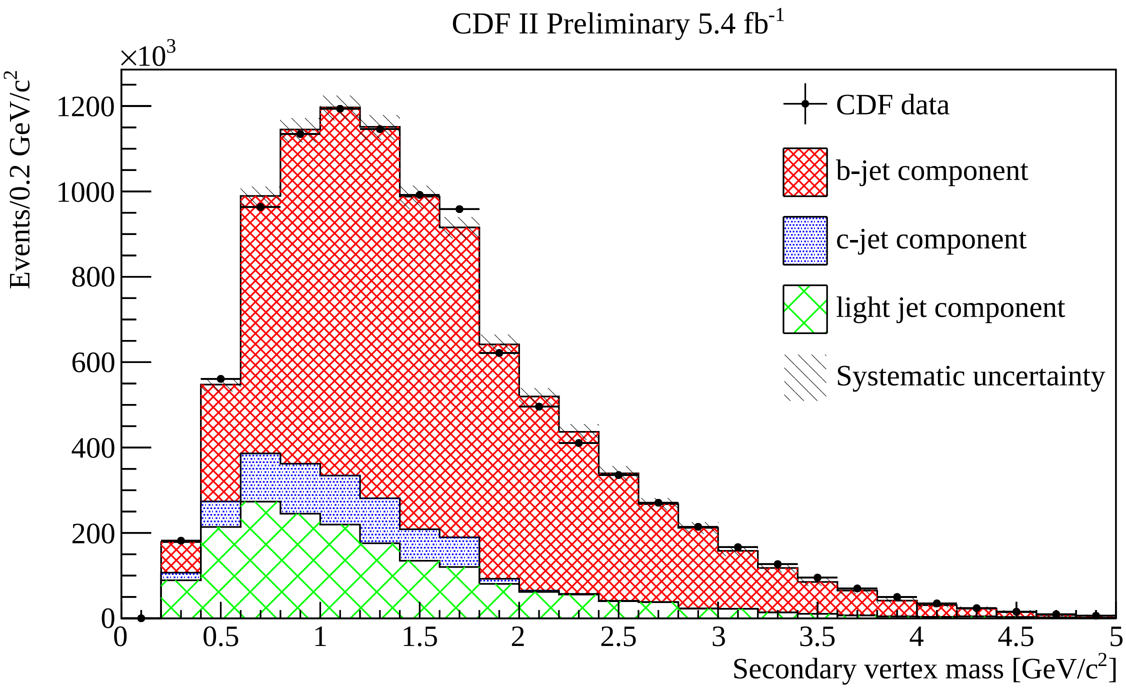

FIG. 3. Invariant mass distribution of the charged tracks of the secondary vertex for a sample of events with at least one b-tag trigger jet.

B. Background invariant mass distribution templates

The invariant mass distribution for $b\bar{b}$ and bc and bq from multijet production are necessary to describe the components of the double tagged sample together with the signal ones. The contribution of multiple non-b tags is expected to be negligible and it is not considered. Starting from the data sample with only the b-tag trigger jet, the tagging matrices are applied to the other jet of the event and the probability that it is a b, c or light-quark jet is determined. In this way the expected background is predicted using data itself where the signal is present but its contribution is less than 1% and in a specific invariant mass region therefore it does not bias the background description which spans over a large region. The configurations considered are: Bb, bB, Bc, cB, Bq and qB. The uppercase B indicates the b-tag trigger jet, lowercase letters give the flavor hypothesis obtained from the tagging matrices where q indicates the light quarks. The order of the letters follows the E_{T} ordering of the jets, for example bB means that the b-tag trigger jets is the second-leading one. It has to be noted that this construction holds only if the b-tag trigger jet (B) is a jet originating from a b quark. For this reason, a requirement on the TagMass of the b-tag trigger jet to be greater than 1.8 GeV/c^2 is applied. This cut is highly efficient to reject c and light quarks initiated jets, as shown in Ref. IV

VI. $Z \to b\bar{b}$ RESULTS

The search for the $Z \to b\bar{b}$ examines the invariant mass distribution of the two leading tagged jets, m_{12}, for an enhancement riding atop the continuum background. The double tagged sample is made of 925338 dijet events. Data is fitted using a signal template and the background invariant mass distribution templates obtained as described in Sec. V. The dijet invariant mass signal template is obtained from fully simulated Monte Carlo $Z \to b\bar{b}$ events. Since the invariant mass distribution templates built with the b-tagging and the c-tagging matrices are very similar and the fit is not able to distinguish them, they are merged assuming a fixed contribution. A systematics will be assigned for this assumption. Thus, to model the QCD background 4 different templates: Bb, bB, Bq, qB are used.

The fit is performed using a binned maximum-likelihood function, defined as:

$$\mathcal{L} = \prod_{i=1}^{N} \frac{n_{\mathrm{s}}^i P_{\mathrm{s}}(m_{\mathrm{jj}}^i) + \sum_{\mathrm{b}} n_{\mathrm{b}}^i P_{\mathrm{b}}(m_{\mathrm{jj}}^i)}{n_{\mathrm{s}}^i + \sum_{\mathrm{b}} n_{\mathrm{b}}^i} \tag{1}$$

where $\mathcal{L}$ is the product, over all bins, of the probability that the events in the ith bin with invariant mass m_{jj} are described by the 4 background p.d.f $P_{\mathrm{b}}(m_{\mathrm{jj}})$ plus the signal p.d.f. $P_{\mathrm{s}}(m_{\mathrm{jj}})$. The free parameters are the number of signal (n_{s}) and background (n_{b}) events that are constrained to be greater or equal to zero.

A. Fit Results

A fit to the 925338 double tagged events observed in the data is performed. Figure 4 shows data with the result of the fit superimposed. The results for signal and background yields are listed in Table I where the uncertainties are statistical only. The fit returns a sizable signal component and the light quark component compatible with zero, indicating that the sample is constituted by $b\bar{b}$ jets. The goodness of the fit is estimated by calculating the χ^2/NDF, which is found to be 0.7.

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Component	Fitted yield in events
$Z \to bb$	$(16.5 \pm 1.2) \times 10^3$
Bb+Cb	$(68.1 \pm 1.1) \times 10^4$
bB+bC	$(19.4 \pm 1.3) \times 10^4$
Bq	< 175 (1σ)
qB	< 61 (1σ)

TABLE I. Signal and background yields as returned by the fit to the double tagged sample. See Sec. VI A for more details.

The significance of the signal as obtained from the fit, is measured by computing the p-value, i.e. the probability that the background fluctuates to create the observed signal. We generated 50 millions pseudo-experiments in the background only hypothesis, H_0, and additional 50 millions in the background plus signal hypothesis, H_1. Systematics uncertainties, described in Sec. VII, are introduced as nuisance parameters. The statistic test employed is the difference in χ^2 between fits using only the background templates and fits using both background and signal templates, defined as:

$$T_s = -2ln\frac{\mathcal{L}_1}{\mathcal{L}_0} = \chi^2(data|H_1) - \chi^2(data|H_0); \tag{2}$$

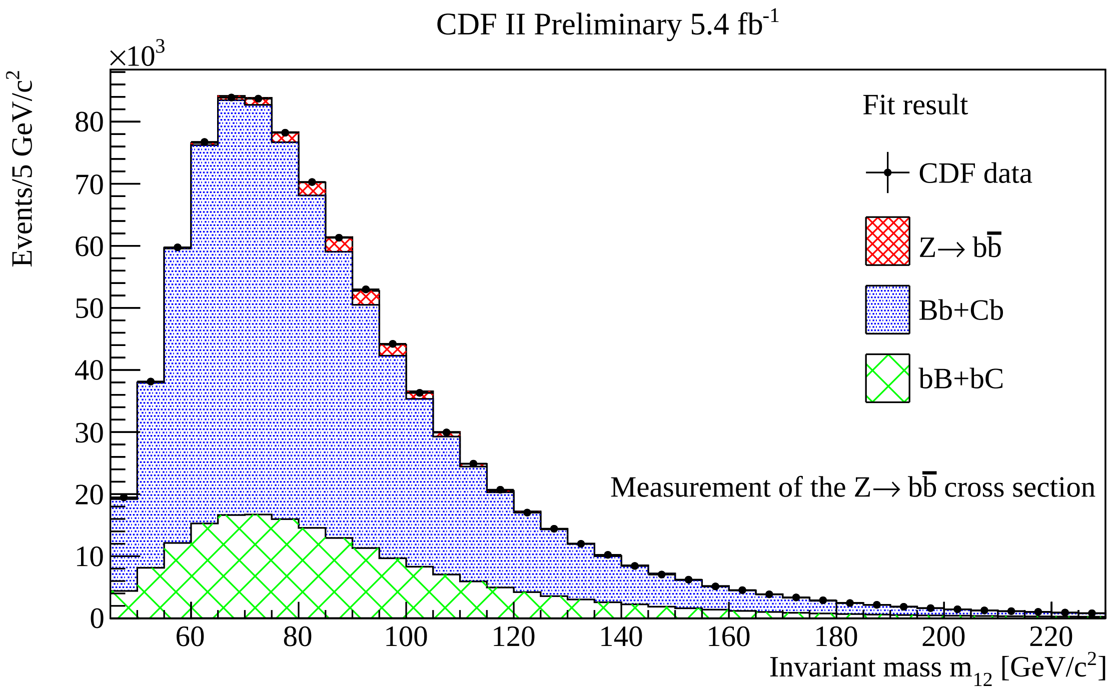

FIG. 4. Double tagged events invariant mass distribution with the result of the fit. In red the fitted $Z \to \bar{b}b$, in blue the Bb+Cb and in green the bB+bC background. Capital letter indicates the b-tag trigger jet.

where T_s is the test statistic, $\mathcal{L}_1$ is the likelihood under the H_1 hypothesis and $\mathcal{L}_0$ is the likelihood under the H_0 hypothesis.

The test statistic is evaluated for each of these 50 millions pseudo-experiments, and the expected significance is defined as the probability for a background only pseudo-experiment to have a T_s less than the T_s observed in data. We observed no pseudo-experiment with T_s less than the one evaluated in the data (and less than the median of the signal-like pseudo-experiments). We conclude that the observed $Z \to b\bar{b}$ signal has an observed significance greater than 5σ.

B. Jet energy scale determination

Since a sizable signal of $Z \to b\bar{b}$ decays is established, a measurement of the residual energy scale for b-jets between data and Monte Carlo is possible. The procedure is based on the fit to the data with the Z invariant mass template constructed varying the jet energy. Each jet of the $Z \to b\bar{b}$ Monte Carlo is multiplied by a factor k, which varies between 0.90 and 1.10 in steps of 0.01. This range largely covers the possible variation of this parameter since jets at CDF are well reconstructed and previous analysis [10] have shown that for b jets a minor correction is needed.

By varying k, 21 different dijet mass signal templates are built. The fit, described in Sec. VI, is performed to data sample for each signal template and the χ^2 calculated. The value of k which correspond to the minimum of the χ^2 distribution represents the value of the jet energy scale between data and Monte Carlo b jets. The statistical error is calculated taking the width of k interval corresponding to $\chi^2 = \chi^2(k_{\min} + 1)$. The measured JES is then

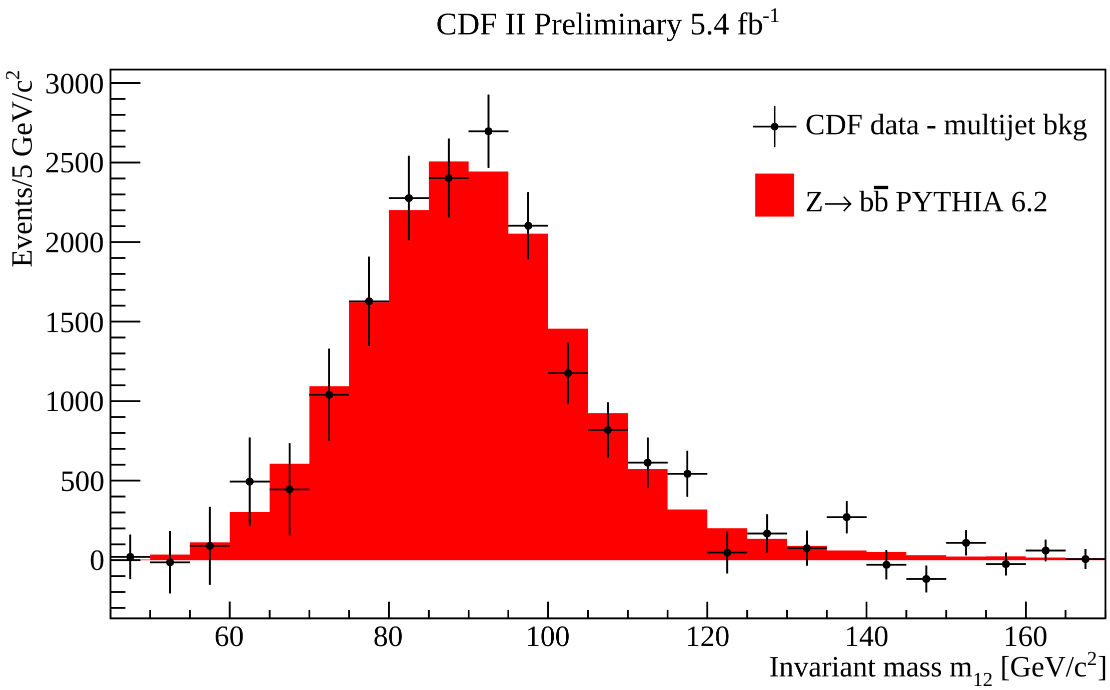

FIG. 5. Double tagged events invariant mass distribution after the background subtraction. The Z peak is clearly visible and it is in good agreement with the MC signal template, in red.

$k = 0.993 \pm 0.022$.

C. Cross section measurement

The selected Z sample is used to measure the cross section for Z boson production multiplied by the branching ratio of the decay to b-quark pairs.

Figure 5 shows the double tagged events invariant mass distribution after the background subtraction compared to the Monte Carlo $Z \to b\bar{b}$ signal template. From the fitted number of signal events we extract the cross-section using the formula:

$$\sigma_Z \times B(Z \to b\bar{b}) = \frac{N_{\text{sig}}}{\epsilon_{\text{kin}} \cdot \epsilon_{\text{trig}} \cdot \epsilon_{\text{tag}} \cdot SF_{\text{trig}} \cdot SF_{\text{tag}} \cdot \mathcal{L}} \tag{3}$$

where ϵ_{trig}, ϵ_{kin} and ϵ_{tag} are the trigger, kinematic cuts and tagging efficiencies; SF_{trig} and SF_{tag} the trigger and offline tagging data/MC scale factors and $\mathcal{L}$ is the luminosity. Trigger and b-tag efficiencies are evaluated using the MC, therefore they have to be corrected before they are applied to data, here we use the value determined in the single muon dataset as discussed in Sec III.

The calculated cross section value is then $\sigma_Z \times B(Z \to b\bar{b}) = 1.11 \pm 0.08$ nb, where the uncertainty is statistical only.

VII. SYSTEMATICS UNCERTAINTIES

Both the $Z \to b\bar{b}$ cross section and Jet Energy Scale measurements are affected by the systematic uncertainties. Some of them are related to data/MC differences, while other are related to the signal extraction procedure. They are summarized in Table II and discussed in more detail in the following.

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Source	Systematic uncertainty b-Jet Energy Scale	 $Z \to b\bar{b}$ cross section
Luminosity		5.9%
Background template statistics	0.004	2.3%
c-quark component in $b\bar{b}$ templates	0.005	2%
Signal Monte Carlo statistics	0.002	3%
b-tag energy dependence	0.004	5%
b-tag scale factor		5%
Trigger and b-tag combined scale factor		4%
Jet Energy Correction		1.4%
Final State Radiation		2.6%
Parton Distribution Functions		1.1%
Total	0.008	11.4%

TABLE II. Summary of the systematic uncertainties.

Three sources of systematic uncertainties are associated to the background modeling. The first one is due to the finite statistics of the background templates. To estimate the size of this effect we perform pseudo-experiments smearing the number of events in each bin of the background templates and measure the resulting bias on the fitted b-JES and signal yield. The value is found to be ± 0.013 for the JES and 9% for the signal yield. As described in Sec. VI, a fixed component of 2% of c quark jet is added to the Bb, bB and (bb)B templates. This value is obtained from studies on the TagMass and the systematic uncertainty is set varying the percentage from 0 to 10%, which is greater than the c component in the simple tag sample. Under these assumption the systematic uncertainty on JES is ± 0.005 and on the signal yield of 2%.

The systematic uncertainty related to the finite statistics of the MC signal template is evaluated through pseudo-experiments and it results to be ± 0.002 for JES and 3% for the signal yield.

Figures 2 and 1 show that the data/MC b-tagging scale factors may have a dependence on transverse energy, while they have been considered flat through the analysis. In order to evaluate the impact of this possible dependence, the distribution of the scale factors are fit with a straight line and the two jets of the signal MC events are weighted according to the new functions. The absolute difference in JES and signal yield is taken as systematic uncertainty and results ± 0.004 and 5% respectively. The data/MC scale factors are also applied to MC events in the evaluation of the signal selection efficiency. They are affected by systematic uncertainties which propagate to the cross section measurement.

The systematic uncertainty on the signal efficiency due to the CDF jet energy correction is estimated shifting the energy of the MC jets by CDF jets resolution, $\pm 1\sigma_c$ of the standard jet energy correction and it is found to be 1.4% on cross-section.

The effect of decreased or increased Final State Radiation (FSR) on signal efficiencies has been evaluated by generating $Z \rightarrow bb$ with different FSR tunings. The changes on the cross section corresponds to a systematic uncertainty of 2%. The effect on the measurement of a particular choice of PDF is measured by generating a $Z \rightarrow bb$ sample using a different PDF set, the CTEQ6L. Not all the PDF sets are considered since the impact on the measurement is found negligible. The difference in acceptance is taken as systematic uncertainty: 1.1% on the cross-section.

The systematic uncertainties on jet energy correction, FSR and PDF are not considered in the b-JES. In fact, the use of the measurement of a b-JES implies a choice of certain parameters and models in the simulation of MC events: if the same choices are made as those we used in the generation of the Z MC sample (choice of generator, PDF set, and specific settings for initial and FSR modeling), there is no need to consider any systematic uncertainties affecting the b-JES due to those sources.

VIII. SEARCH FOR INCLUSIVE PRODUCTION OF STANDARD MODEL HIGGS INTO $b\bar{b}$

At Tevatron the predicted total SM Higgs production cross section is 1.23 ± 0.22 pb [3], while the branching ratio into a pair of b-quarks is $(58.4 \pm 3.3)\%$ [3]. Using the MC we evaluated the selection efficiencies, 1.5%, as described in Sec. III and the signal template shape which has a resolution σ of 19 GeV/c^2. Given the integrated luminosity of 5.4 fb^{-1}, we expect about 36 signal events. The background under the signal region, defined as the 2σ region around the nominal Higgs mass, is made of about 670 k events.

Figure 6 shows the result of the fit to the double tagged sample with the Higgs component magnified $\times$1k times with respect to the SM expectations. The selection of the events is the previously described for the Z reconstruction; the fit strategy is explained in Sec. VI with the $H \rightarrow b\bar{b}$ template added. The normalizations of all the components are the unconstrained parameters of the fit. The fit returns 0 ± 91 Higgs event.

A. Cross section times branching ratio limit

A 95% confidence level (C.L.) limit on the inclusive production of the SM Higgs is set using a modified frequentist CL_S method [11]. The limit calculator is based on the MCLIMIT package [12]. Pseudo-experiments from the background only hypotheses are generated. The CL_S for the expected limit are then evaluated by using as test statistic the difference in χ^2 of the fits to the pseudo-experiments using only the background templates and the fits using both background and signal templates. The same procedure is repeated for the observed limit by fitting the data instead of the pseudo-experiments.

The systematic uncertainties, listed in Table II for background and in Table III regarding the signal, can affect both the normalization and the shape. They have been calculated as described in Sec. VII and they are introduced in the limit calculator as nuisance parameters.

The expected and observed CL_s obtained as a function of the ratio between the cross section upper limit and the Standard Model cross section are presented in Figure 7. The observed(expected) upper limit at 95% C.L. on the $p\bar{p} \rightarrow H \rightarrow b\bar{b}$ is found to be 33(46) times the standard model cross section.

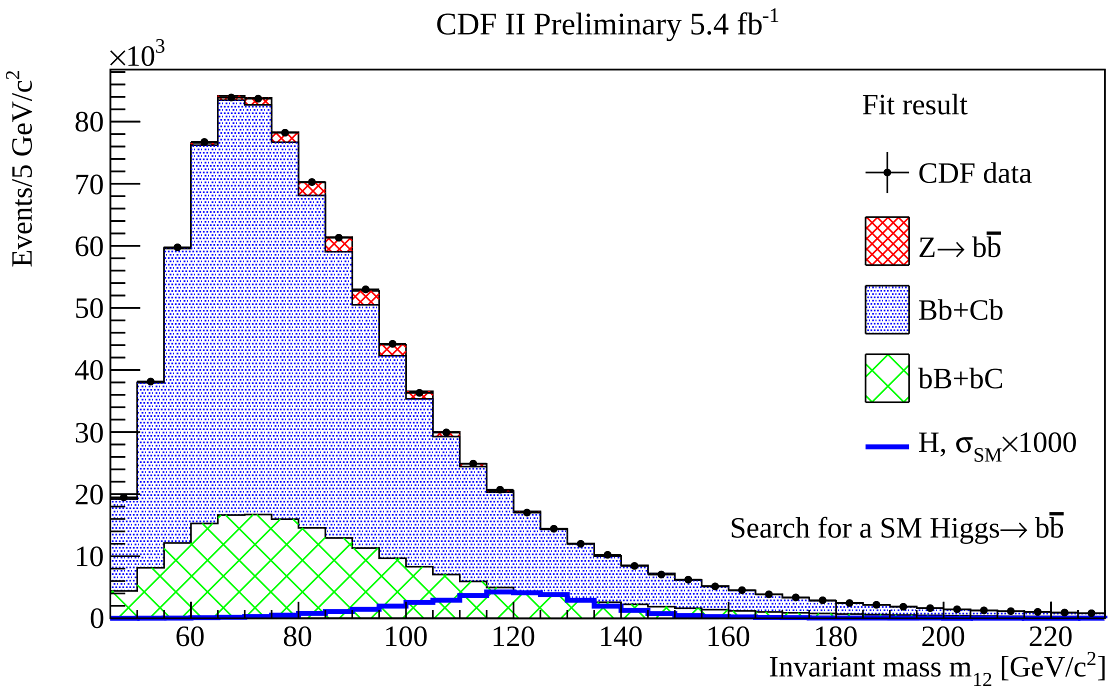

FIG. 6. Invariant mass distribution of the double tagged data sample with the result of the fit that includes the $H \to b\bar{b}$ decay. The normalization of the Higgs signal is set to $\times 10^3$ the expected SM cross section for illustrative purposes.

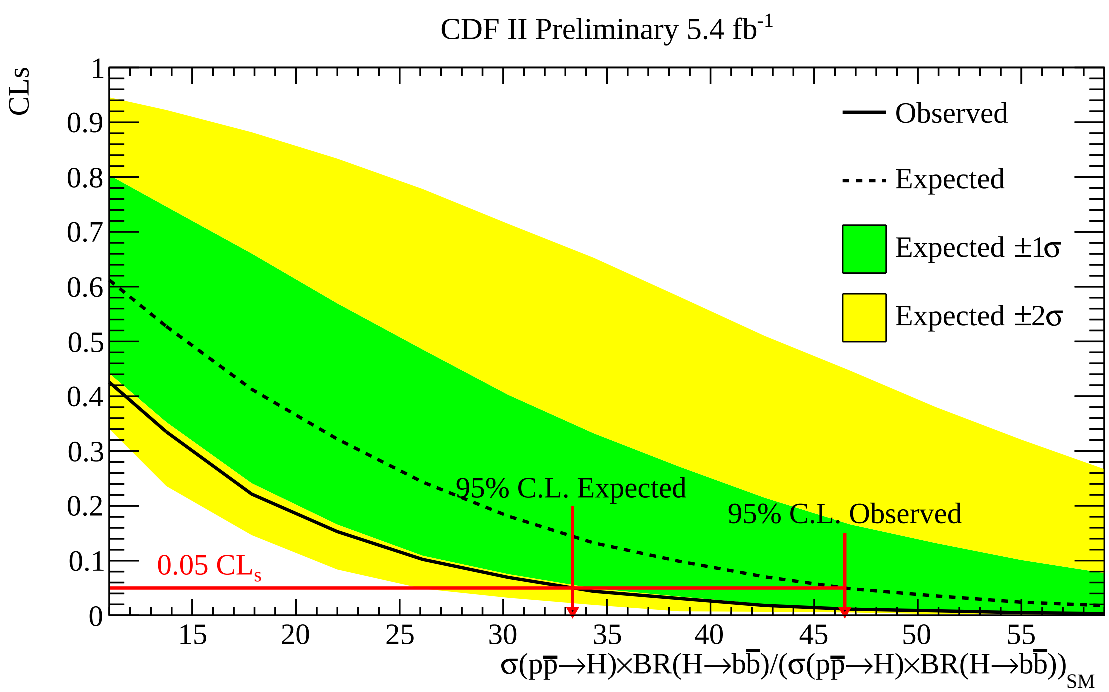

FIG. 7. Observed (black solid line) and expected (black dashed line) CL_s as function of the cross section times the branching ratio normalized to SM $H \to b\bar{b}$. Green and yellow regions are respectively the 1σ and 2σ bands on the expected CL_S. The 95% C.L. limits are indicated by the red vertical arrows under the red horizontal line.

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Systematic uncertainty source on $H \to b\bar{b}$	Variation	Type
Luminosity	5.9%	Rate
b-tag scale factor	5%	Rate
Trigger and b-tag combined scale factor	4%	Rate
Final State Radiation	2.9%	Rate
Jet Energy Correction	2.0%	Rate/Shape
Parton Density Functions	1.4%	Rate
Signal Monte Carlo statistics	-	Shape
Total	9.5%	

TABLE III. Summary of the systematic uncertainties on the $H \to b\bar{b}$ cross section limit.

IX. CONCLUSION

The $Z \to b\bar{b}$ decay has been observed and the production cross section times the branching ratio measured at CDF using the BTAG-trigger dataset. The final value is

$$\sigma_Z \times B(Z \to b\bar{b}) = 1.11 \pm 0.08(stat) \pm 0.13(sys) \text{ nb},$$

consistent with the NLO theoretical calculation [13] combined with the measured $Z \to b\bar{b}$ branching ratio, which predicts $\sigma_Z \times B(Z \to b\bar{b}) = 1.13 \pm 0.02$ nb. The Z sample is used to determine the Jet Energy Scale for b jets which can be used by CDF to improve any measurement involving b jets.

The $H \to b\bar{b}$ decay channel is searched exploiting the dataset and technique used for the $Z \to b\bar{b}$ process, with not positive result. The observed upper limit at 95% C.L. on the $p\bar{p} \to H \to b\bar{b}$ with an invariant mass of 125 GeV/c^2 is 40.6 pb which corresponds to 33 times the standard model expectations. This is the first inclusive limit on the $p\bar{p} \to H \to b\bar{b}$.

[1] A. Collaboration, Phys. Lett. B **716**, 01 (2012).
[2] C. Collaboration, Phys. Lett. B **716**, 30 (2012).
[3] C. Patrignani *et al.* (Particle Data Group), Chin. Phys. **C40**, 100001 (2016).
[4] G. Aad *et al.* (ATLAS), Phys. Lett. **B738**, 25 (2014), arXiv:1404.7042 [hep-ex].
[5] F. Abe *et al.* (CDF Collaboration), Nucl. Instrum. Methods A **271**, 387 (1988).
[6] S. Amerio, M. Casarsa, G. Cortiana, J. Donini, D. Lucchesi, and S. Pagan Griso, IEEE Trans. Nucl. Sci. **56**, 1690 (2009).
[7] D. Acosta *et al.* (CDF Collaboration), Phys. Rev. D **71**, 052003 (2005).
[8] T. Sjöstrand, S. Mrenna, and P. Skands, J. High Energy Phys. **05**, 026 (2006), we use PYTHIA version 6.216.
[9] T. Aaltonen *et al.* (CDF), Phys. Rev. **D85**, 032005 (2012), arXiv:1106.4782 [hep-ex].
[10] J. Donini, T. Dorigo, K. Hatakeyama, S. Kwang, C. Neu, M. Shochet, T. Tomura, M. Tosi, and D. Whiteson, Nucl. Instrum. Meth. **A596**, 354 (2008), arXiv:0801.3906 [hep-ex].
[11] A. L. Read, *Advanced Statistical Techniques in Particle Physics. Proceedings, Conference, Durham, UK, March 18-22, 2002*, J. Phys. **G28**, 2693 (2002), [,11(2002)].

[12] T. Junk, Nucl. Instrum. Meth. **A434**, 435 (1999), arXiv:hep-ex/9902006 [hep-ex].
[13] A. D. Martin, R. G. Roberts, W. J. Stirling, and R. S. Thorne, Eur. Phys. J. **C35**, 325 (2004), arXiv:hep-ph/0308087 [hep-ph].