

CMS – Compact Muon Solenoid @ NCBJ in 2018

Znaczenie rozpoznawania tau
dla pierwszych bezpośrednich obserwacji sprzężeń
bozonu Higgsa do fermionów tau lub top

Piotr Zalewski



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Observation of the Higgs boson decay to a pair of τ leptons with the CMS detector



The CMS Collaboration ^{*}

CERN, Switzerland

ARTICLE INFO

Article history:

Received 1 August 2017

Received in revised form 1 February 2018

Accepted 2 February 2018

Available online 7 February 2018

Editor: M. Doser

Keywords:

CMS

Physics

Tau

Higgs

Observation

LHC

ABSTRACT

A measurement of the $H \rightarrow \tau\tau$ signal strength is performed using events recorded in proton–proton collisions by the CMS experiment at the LHC in 2016 at a center-of-mass energy of 13 TeV. The data set corresponds to an integrated luminosity of 35.9 fb^{-1} . The $H \rightarrow \tau\tau$ signal is established with a significance of 4.9 standard deviations, to be compared to an expected significance of 4.7 standard deviations. The best fit of the product of the observed $H \rightarrow \tau\tau$ signal production cross section and branching fraction is $1.09^{+0.27}_{-0.26}$ times the standard model expectation. The combination with the corresponding measurement performed with data collected by the CMS experiment at center-of-mass energies of 7 and 8 TeV leads to an observed significance of 5.9 standard deviations, equal to the expected significance. This is the first observation of Higgs boson decays to τ leptons by a single experiment.

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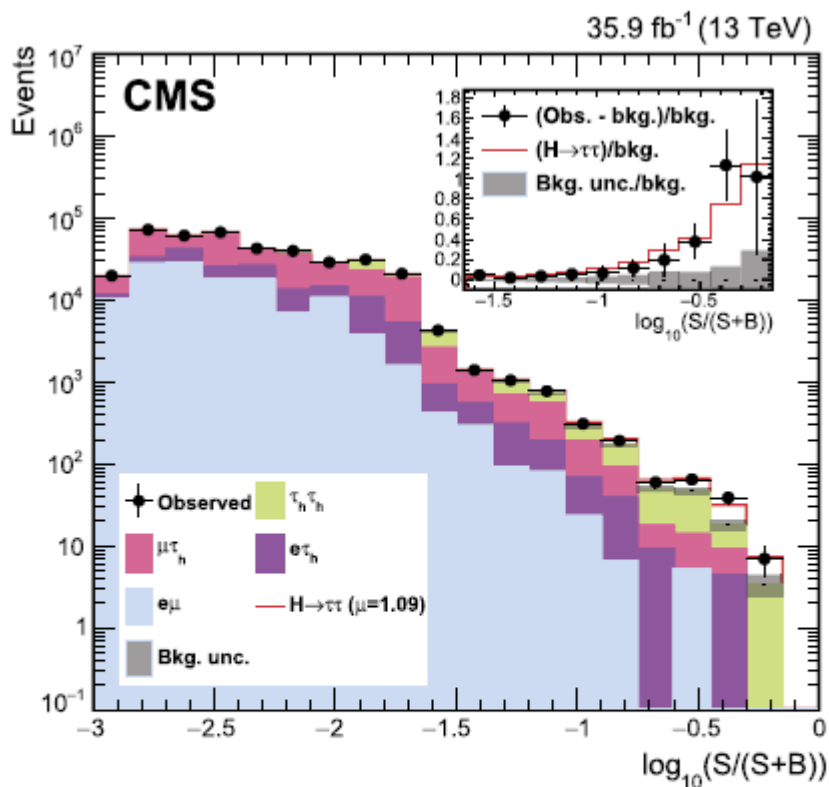


Fig. 18. Distribution of the decimal logarithm of the ratio between the expected signal and the sum of expected signal and expected background in each bin of the mass distributions used to extract the results, in all signal regions. The background contributions are separated by decay channel. The inset shows the corresponding difference between the observed data and expected background distributions divided by the background expectation, as well as the signal expectation divided by the background expectation.

A measurement of the $H \rightarrow \tau\tau$ signal strength, using events recorded in proton–proton collisions by the CMS experiment at the LHC in 2016 at a center-of-mass energy of 13 TeV, has been presented. Event categories are designed to target Higgs boson signal events produced by gluon or vector boson fusion. The results are extracted via maximum likelihood fits in two-dimensional planes, and give an observed significance for Higgs boson decays to τ

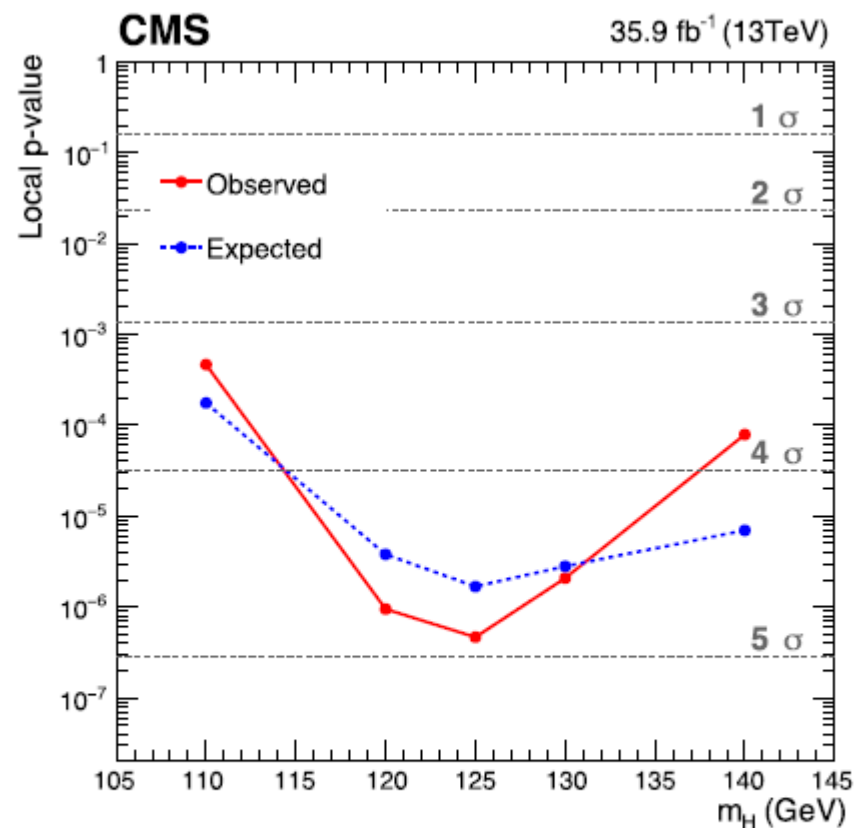
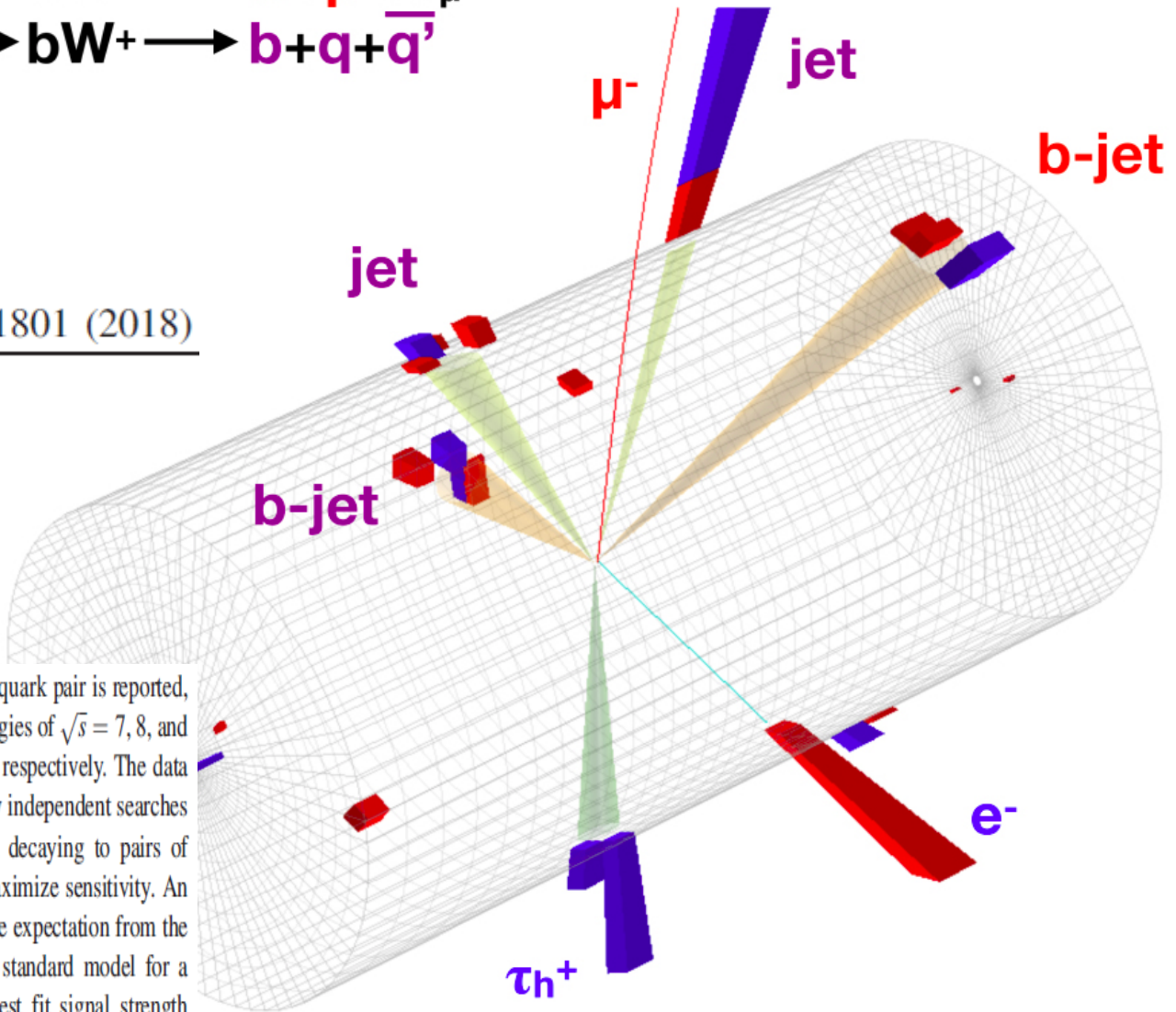


Fig. 20. Local p -value and significance as a function of the SM Higgs boson mass hypothesis. The observation (red, solid) is compared to the expectation (blue, dashed) for a Higgs boson with a mass $m_H = 125.09$ GeV. The background includes Higgs boson decays to pairs of W bosons, with $m_H = 125.09$ GeV.

lepton pairs of 4.9 standard deviations, to be compared with an expected significance of 4.7 standard deviations. The combination with the corresponding measurement performed at center-of-mass energies of 7 and 8 TeV with the CMS detector leads to the first observation by a single experiment of decays of the Higgs boson to pairs of τ leptons, with a significance of 5.9 standard deviations.

$pp \rightarrow t\bar{t}H$

$\tau^-\tau^+ \rightarrow e^- + \bar{\nu}_e + \nu_\tau + \tau h^+ + \bar{\nu}_\tau$
 $\bar{b}W^- \rightarrow \bar{b} + \mu^- + \bar{\nu}_\mu$
 $bW^+ \rightarrow b + q + \bar{q}'$



PHYSICAL REVIEW LETTERS **120**, 231801 (2018)

Editors' Suggestion

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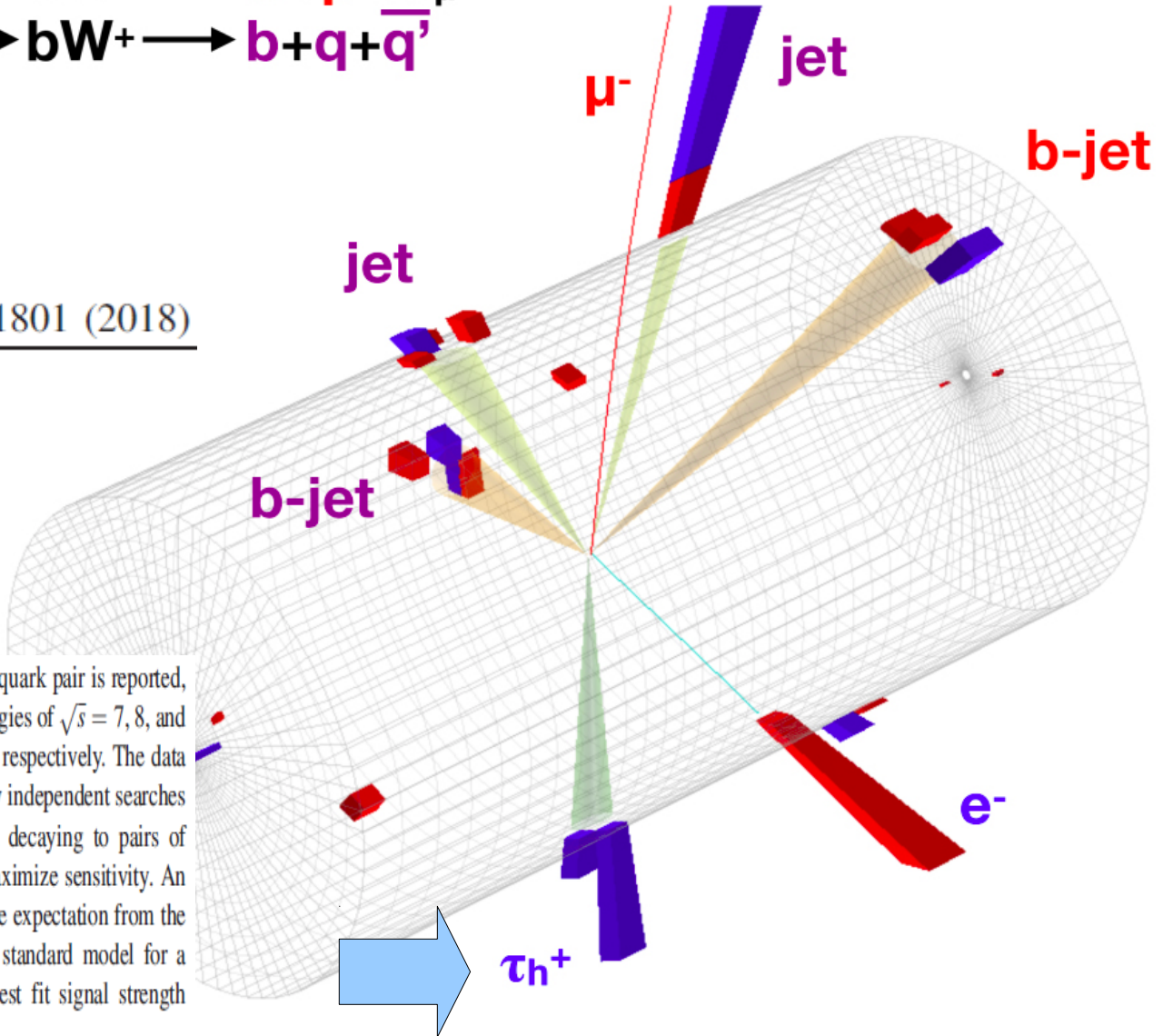
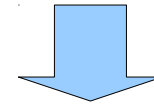
Observation of $t\bar{t}H$ Production

A. M. Sirunyan *et al.**
(CMS Collaboration)

The observation of Higgs boson production in association with a top quark-antiquark pair is reported, based on a combined analysis of proton-proton collision data at center-of-mass energies of $\sqrt{s} = 7, 8,$ and 13 TeV, corresponding to integrated luminosities of up to $5.1, 19.7,$ and 35.9 fb^{-1} , respectively. The data were collected with the CMS detector at the CERN LHC. The results of statistically independent searches for Higgs bosons produced in conjunction with a top quark-antiquark pair and decaying to pairs of W bosons, Z bosons, photons, τ leptons, or bottom quark jets are combined to maximize sensitivity. An excess of events is observed, with a significance of 5.2 standard deviations, over the expectation from the background-only hypothesis. The corresponding expected significance from the standard model for a Higgs boson mass of 125.09 GeV is 4.2 standard deviations. The combined best fit signal strength normalized to the standard model prediction is $1.26^{+0.31}_{-0.26}$.

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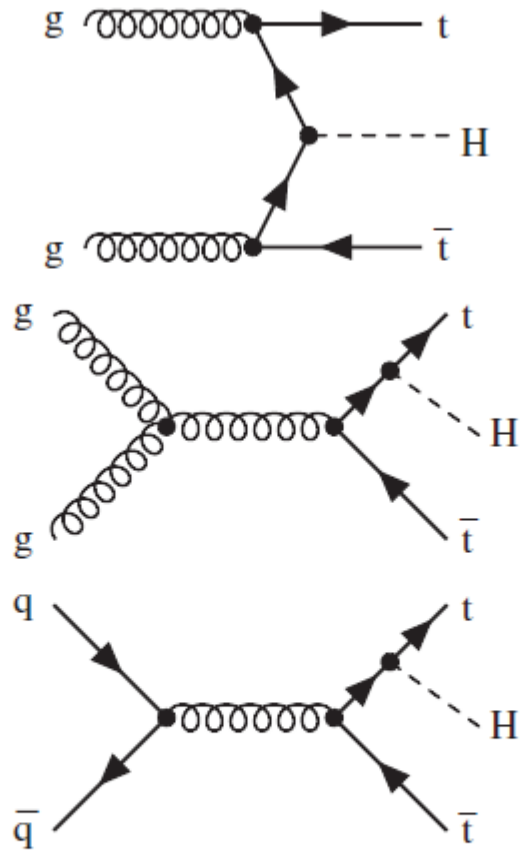


FIG. 1. Example tree-level Feynman diagrams for the $pp \rightarrow t\bar{t}H$ production process, with g a gluon, q a quark, t a top quark, and H a Higgs boson. For the present study, we consider Higgs boson decays to a pair of W bosons, Z bosons, photons, τ leptons, or bottom quark jets.

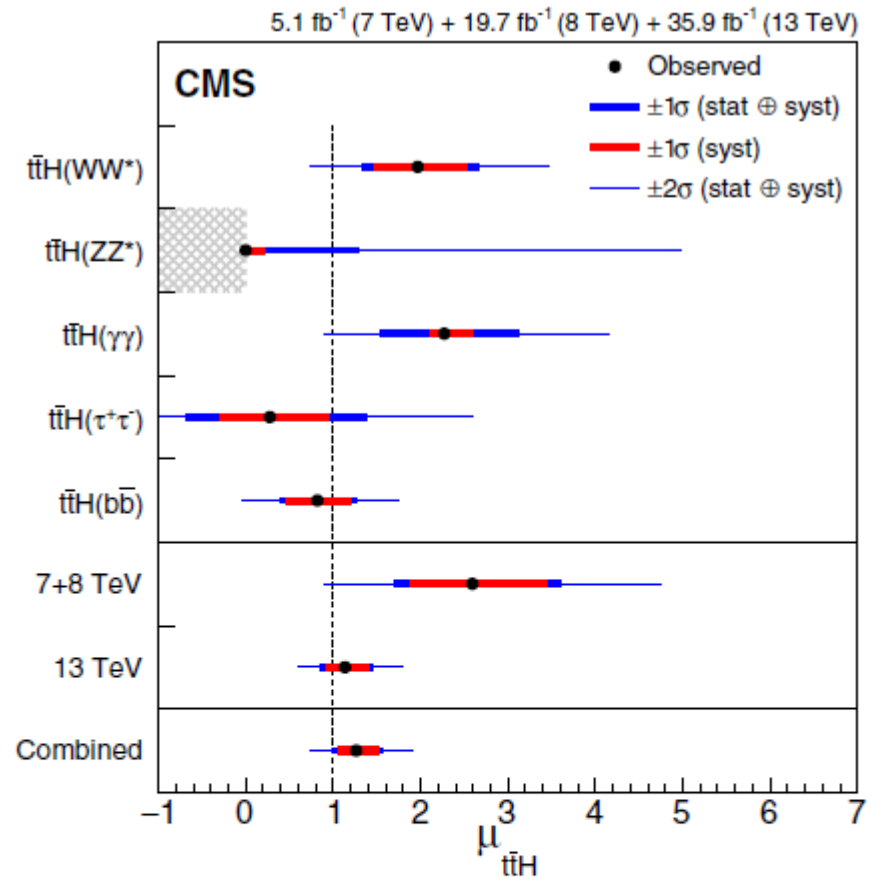


FIG. 2. Best fit value of the $t\bar{t}H$ signal strength modifier $\mu_{t\bar{t}H}$, with its 1 and 2 standard deviation confidence intervals (σ), for (upper section) the five individual decay channels considered, (middle section) the combined result for 7 + 8 TeV alone and for 13 TeV alone, and (lower section) the overall combined result. The Higgs boson mass is taken to be 125.09 GeV. For the $H \rightarrow ZZ^*$ decay mode, $\mu_{t\bar{t}H}$ is constrained to be positive to prevent the corresponding event yield from becoming negative. The SM expectation is shown as a dashed vertical line.

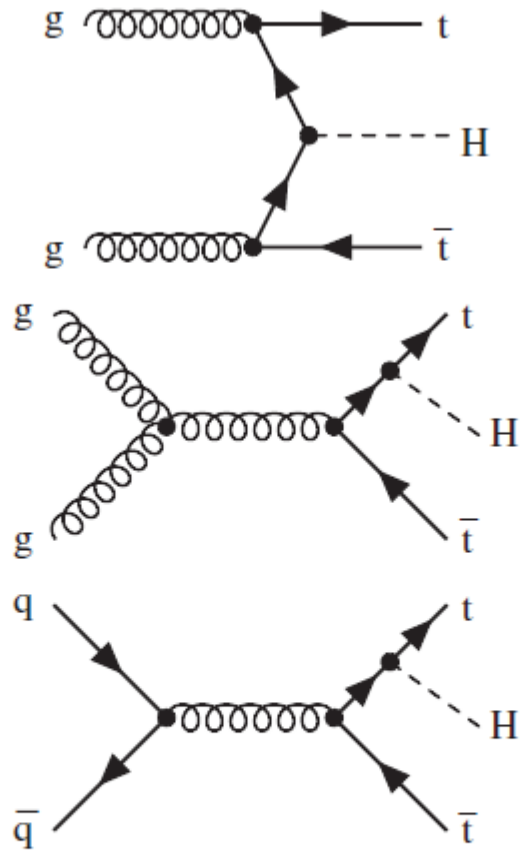


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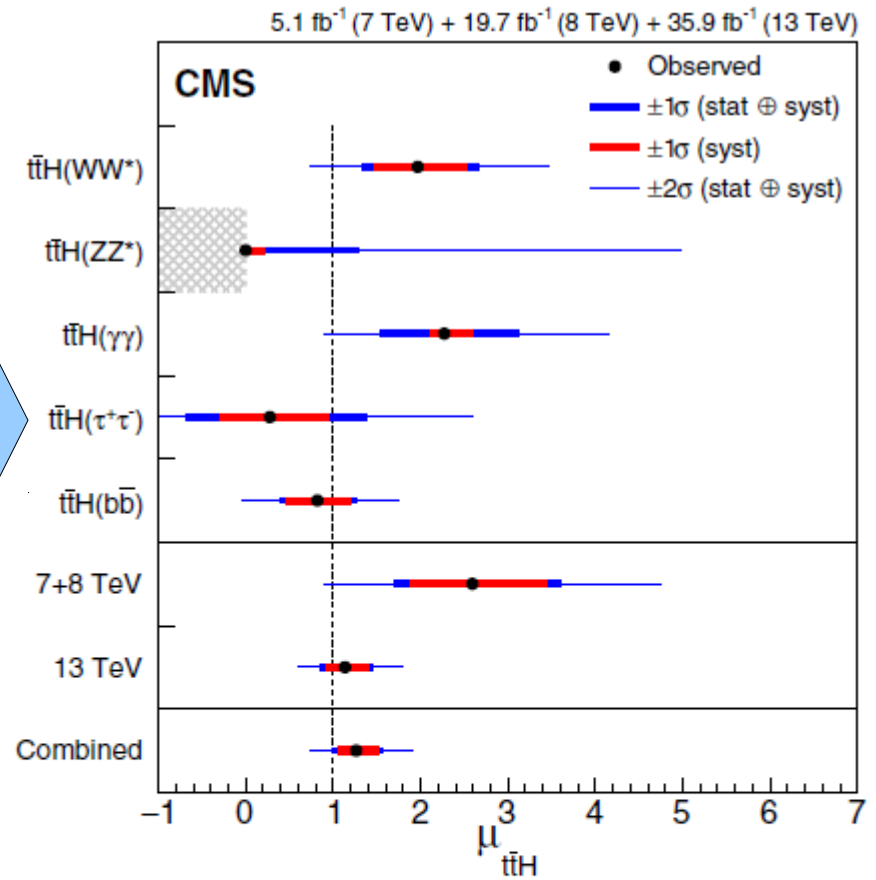
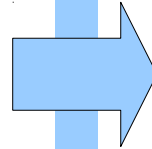


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Evidence for associated production of a Higgs boson with a top quark pair in final states with electrons, muons, and hadronically decaying τ leptons at

$\sqrt{s} = 13 \text{ TeV}$

JHEP08(2018)066

Jedna z trzech publikacji wspierających.

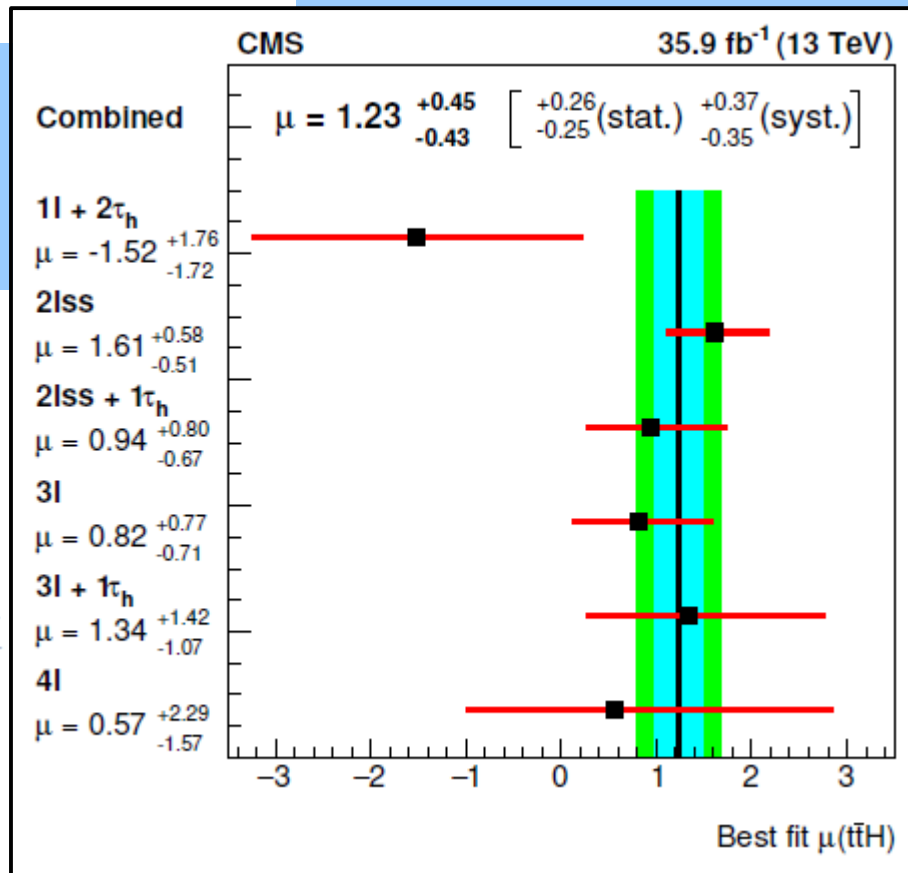
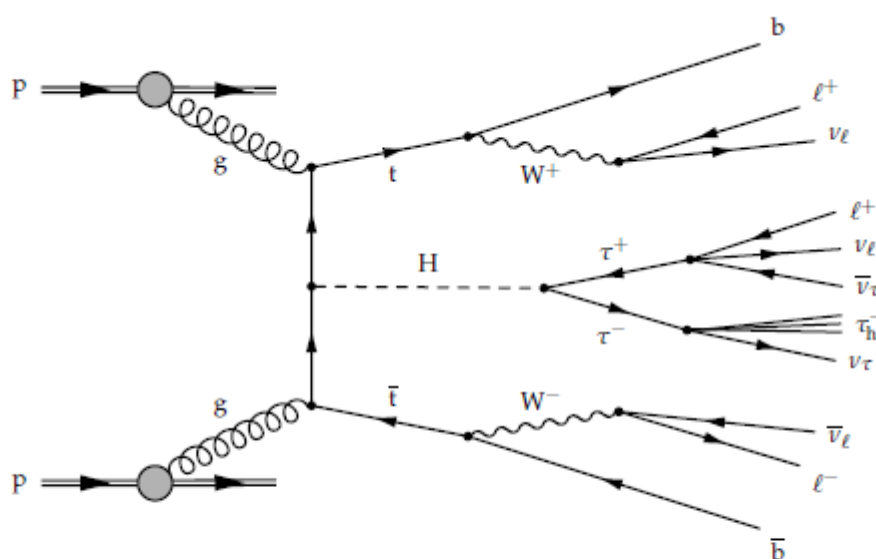


Figure 1. An example of a Feynman diagram for $t\bar{t}H$ production, with subsequent decay of the Higgs boson to a pair of τ leptons, producing a final state with two same-sign leptons and one reconstructed hadronic τ lepton decay (τ_h).

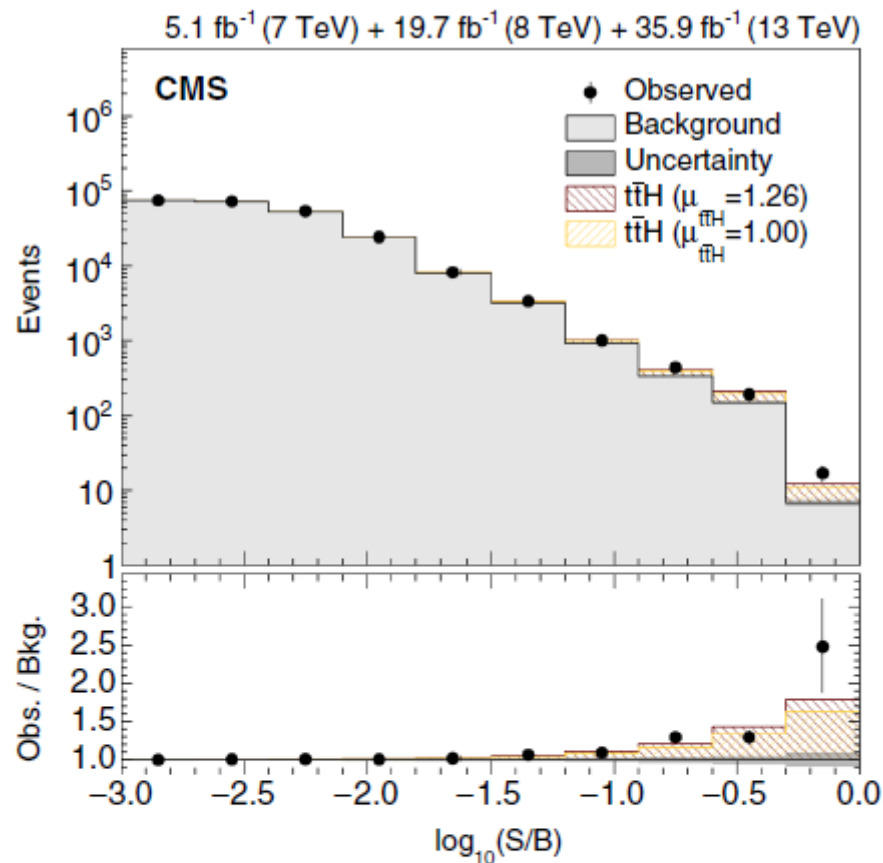


FIG. 3. Distribution of events as a function of the decimal logarithm of S/B , where S and B are the expected postfit signal (with $\mu_{\tilde{t}\tilde{t}H} = 1$) and background yields, respectively, in each bin of the distributions considered in this combination. The shaded histogram shows the expected background distribution. The two hatched histograms, each stacked on top of the background histogram, show the signal expectation for the SM ($\mu_{\tilde{t}\tilde{t}H} = 1$) and the observed ($\mu_{\tilde{t}\tilde{t}H} = 1.26$) signal strengths. The lower panel shows the ratios of the expected signal and observed results relative to the expected background.

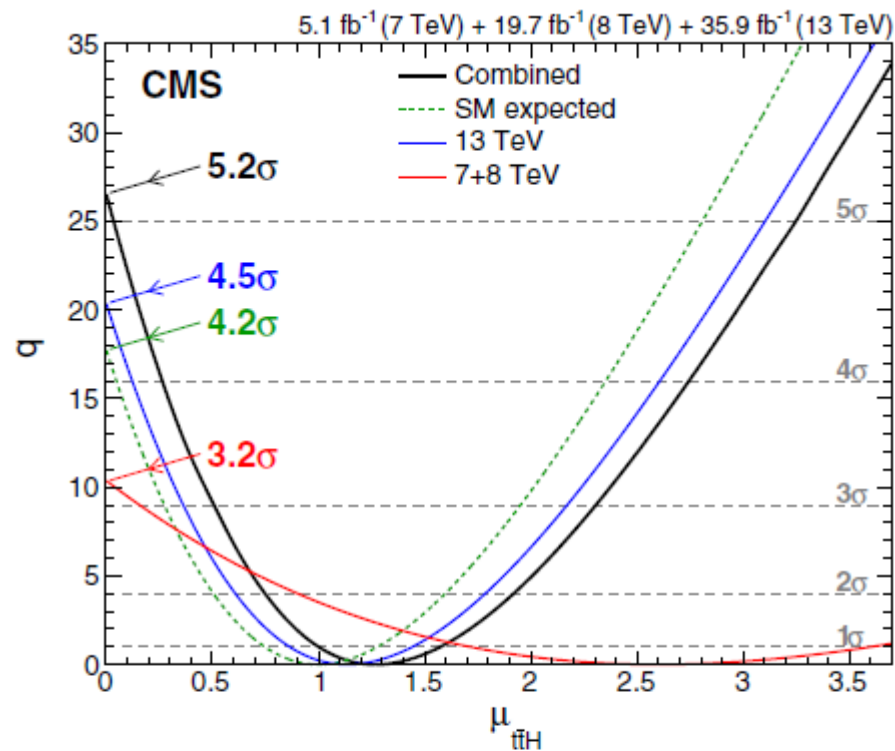


FIG. 4. Test statistic q , described in the text, as a function of $\mu_{\tilde{t}\tilde{t}H}$ for all decay modes at 7 + 8 TeV and at 13 TeV, separately, and for all decay modes at all c.m. energies. The expected SM result for the overall combination is also shown. The horizontal dashed lines indicate the p values for the background-only hypothesis obtained from the asymptotic distribution of q , expressed in units of the number of standard deviations.

In summary, we have reported the observation of $\tilde{t}\tilde{t}H$ production with a significance of 5.2 standard deviations

Te osiągnięcia eksperymentu CMS nie byłyby możliwe, bez (w szczególności) rozwinięcia metod rekonstrukcji, identyfikacji oraz wyzwalania.

Nasz kolega Michał Bluj został przez zespół badawczy eksperymentu CMS wybrany na koordynatora grupy odpowiadającej za leptony tau (kadencja 09.2015 - 09.2017).

Jednym z efektów jego pracy jest kilkudziesięciostronnicowa publikacja, której strona tytułowa jest pokazana obok. Jest ona wsparciem dla jednych z najistotniejszych tegorocznych publikacji CMS.

Proponujemy, żeby wkład dr Michała Bluja w tegoroczny zestaw publikacji CMS uznać za osiągnięcie NCBJ.



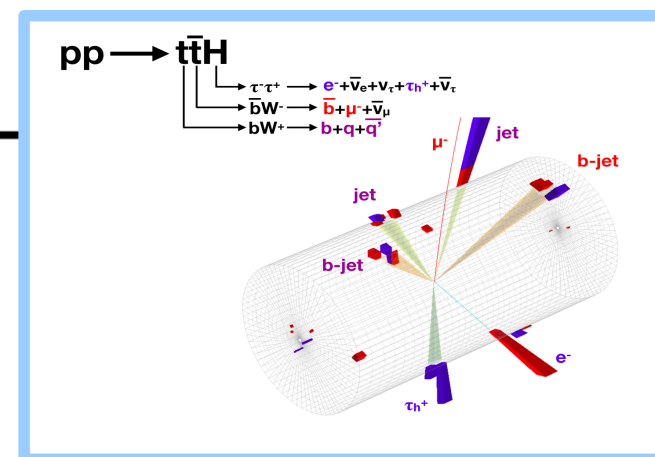
RECEIVED: September 8, 2018
ACCEPTED: September 19, 2018
PUBLISHED: October 2, 2018

Performance of reconstruction and identification of τ leptons decaying to hadrons and ν_τ in pp collisions at $\sqrt{s} = 13$ TeV



The CMS collaboration

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ABSTRACT: The algorithm developed by the CMS Collaboration to reconstruct and identify τ leptons produced in proton-proton collisions at $\sqrt{s} = 7$ and 8 TeV, via their decays to hadrons and a neutrino, has been significantly improved. The changes include a revised reconstruction of π^0 candidates, and improvements in multivariate discriminants to separate τ leptons from jets and electrons. The algorithm is extended to reconstruct τ leptons in highly Lorentz-boosted pair production, and in the high-level trigger. The performance of the algorithm is studied using proton-proton collisions recorded during 2016 at $\sqrt{s} = 13$ TeV, corresponding to an integrated luminosity of 35.9 fb^{-1} . The performance is evaluated in terms of the efficiency for a genuine τ lepton to pass the identification criteria and of the probabilities for jets, electrons, and muons to be misidentified as τ leptons. The results are found to be very close to those expected from Monte Carlo simulation.

Zestaw wybranych publikacji CMS z 2018 roku

- [1] Observation of the Higgs boson decay to a pair of τ leptons, PLB 779 (2018) 283**
- [2] Measurement of the $Z/\gamma^* \rightarrow \tau\tau$ cross section in pp collisions at $\sqrt{s} = 13$ TeV and validation of τ lepton analysis techniques, EPJC 78 (2018) 708 (wsparcie m.in. dla [1])
- [3] Performance of reconstruction and identification of τ leptons decaying to hadrons and $\nu\tau$ in pp collisions at $\sqrt{s} = 13$ TeV, JINST 13 (2018) P10005 (wsparcie m.in. dla [1,2,6,9])**
- [4] Observation of Higgs boson decay to bottom quarks, PRL 121 (2018) 121801
(Sprzężenie do kwarków b do kompletu głównych osiągnięć podgrupy „Higgsowej”)
- [5] Evidence for the Higgs boson decay to a bottom quark-antiquark pair, PLB 780 (2018) 501
(wsparcie dla [4])
- [6] Observation of $t\bar{t}H$ production, PRL 120 (2018) 231801**
(publikacja oparta na analizach [7-9] oraz publikacjach opartych na danych 7 oraz 8 TeV)
- [7] Search for $t\bar{t}H$ production in the $H \rightarrow b\bar{b}$ decay channel with leptonic $t\bar{t}$ decays in proton-proton collisions at $\sqrt{s} = 13$ TeV, Submitted to JHEP (jedna z analiz z [6])
- [8] Search for $t\bar{t}H$ production in the all-jet final state in proton-proton collisions at $\sqrt{s} = 13$ TeV, JHEP 06 (2018) 101 (jedna z analiz z [6])
- [9] Evidence for associated production of a Higgs boson with a top quark pair in final states with electrons, muons, and hadronically decaying τ leptons at $\sqrt{s} = 13$ TeV, JHEP 08 (2018) 066 (jedna z analiz z [6])