

# Chapitre X

## Recherche d'un boson de Higgs de haute masse

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Citer The CMS Collaboration. « Search for additional neutral MSSM Higgs bosons in the di-tau final state in  $pp$  collisions at  $\sqrt{s} = 13$  TeV ». *Journal of High Energy Physics* **09.007** (sept. 2018). DOI : [10.1007/JHEP09\(2018\)007](https://doi.org/10.1007/JHEP09(2018)007)

et aussi nouvelle version full runII si possible

Citer la thèse de Gaël :

G. TOUQUET. « Search for an additional neutral MSSM Higgs boson decaying to tau leptons with the CMS experiment ». Thèse de doct. Université Claude Bernard Lyon 1, oct. 2019. URL : <https://hal.archives-ouvertes.fr/tel-02526393>

Citer également la thèse d'Artur ?

A. GOTTMANN. « Global Interpretation of  $\tau\tau$  Events in the Context of the Standard Model and Beyond ». Thèse de doct. Fakultät für Physik des Karlsruher Instituts für Technologie (KIT), juin 2020. URL : <https://publish.etp.kit.edu/record/22014>

Études déjà menées au LEP [4] et au Tevatron [5, 6]

LHC : aussi avec  $b\bar{b}$  [7, 8]

ATLAS  $\mu\mu$  et  $\tau\tau$  [9, 10]

CMS  $\mu\mu$  [11]  $\tau\tau$  [1, 12, 13]

object reco :

reconstruction  $\tau_h$  [14, 15]

tauID [16, 17]

For muons selected in the emu and mutau channels additional *Medium muon* requirements as recommended by the Muon POG, are applied.[18]

In addition, electrons are required to pass an identification variable based on a Boosted Decision Tree (BDT) discriminator which uses track quality, shower shapes and kinematic quantities as input. The following variables are used as input to the BDT... [19]

lumi unc. [20]

gen_match	Type de particule	Propriétés de l'objet au niveau générateur
1	électron natif	$ \text{pdgID}  = 11, p_T > 8 \text{ GeV}, \text{IsPrompt} == \text{True}$
2	muon natif	$ \text{pdgID}  = 13, p_T > 8 \text{ GeV}, \text{IsPrompt} == \text{True}$
3	$\tau \rightarrow e$	$ \text{pdgID}  = 11, p_T > 8 \text{ GeV},$ $\text{IsDirectPromptTauDecayProduct} == \text{True}$
4	$\tau \rightarrow \mu$	$ \text{pdgID}  = 13, p_T > 8 \text{ GeV},$ $\text{IsDirectPromptTauDecayProduct} == \text{True}$
5	$\tau \rightarrow \tau_h$	Tau hadronique généré
6	Faux $\tau_h, \tau_h$ de l'empilement	Tout objet ne rentrant pas dans les catégories 1 à 5

**Tableau X.1** – Valeurs prises par *gen\_match*, variable de correspondance des taus hadroniques à l'objet généré dans les événements simulés.

systematics EGamma recommendation [21].

PuppiMET [22] and PFJetsCHs

For the fit we use the implementation of the  $CL_s$  method [23] provided by COMBINE, the CMS Higgs combination tool based on RooStats [24].

In the absence of a signal, upper limits on the  $\sigma \times \mathcal{B}^{\tau\tau}$  are set using the modified frequentist approach [25, 26].

systematic unc. shifts [27, 28]

## 1 Introduction

## 2 Sélection d'événements et catégorisation

### 2.1 Données

### 2.2 Simulation

### 2.3 Catégorisation

## 3 Chaîne d'analyse

$\tau_h$  ID and reco?

## 4 Estimation du bruit de fond

### 4.1 Estimations de bruits de fond à partir de simulations

### 4.2 Estimations de bruits de fond à partir de données

#### 4.2.1 Méthode de l'encapsulation ou *embedding*

#### 4.2.2 Méthode du facteur de faux ou *fake factor*

## 5 Incertitudes systématiques

### 5.1 Incertitudes de normalisation

### 5.2 Incertitudes de forme

## 6 Résultats et interprétations

## 7 Conclusion

### Références

- [1] The CMS Collaboration. « Search for additional neutral MSSM Higgs bosons in the di-tau final state in  $pp$  collisions at  $\sqrt{s} = 13$  TeV ». *Journal of High Energy Physics* **09**.007 (sept. 2018). DOI : [10.1007/JHEP09\(2018\)007](https://doi.org/10.1007/JHEP09(2018)007).
- [2] G. TOUQUET. « Search for an additional neutral MSSM Higgs boson decaying to tau leptons with the CMS experiment ». Thèse de doct. Université Claude Bernard Lyon 1, oct. 2019. URL : <https://hal.archives-ouvertes.fr/tel-02526393>.
- [3] A. GOTTMANN. « Global Interpretation of  $\tau\tau$  Events in the Context of the Standard Model and Beyond ». Thèse de doct. Fakultät für Physik des Karlsruher Instituts für Technologie (KIT), juin 2020. URL : <https://publish.etp.kit.edu/record/22014>.
- [4] DELPHI, OPAL, ALEPH, LEP Working Group for Higgs Boson Searches, L3. « Search for neutral MSSM Higgs bosons at LEP ». *European Physical Journal* **C47** (2006), p. 547-587. DOI : [10.1140/epjc/s2006-02569-7](https://doi.org/10.1140/epjc/s2006-02569-7). arXiv : [hep-ex/0602042](https://arxiv.org/abs/hep-ex/0602042) [hep-ex].
- [5] The CDF Collaboration. « Search for Higgs bosons predicted in two-Higgs-doublet models via decays to tau lepton pairs in 1,96 TeV  $p\bar{p}$  collisions ». *Physical Review Letters* **103** (2009). DOI : [10.1103/PhysRevLett.103.201801](https://doi.org/10.1103/PhysRevLett.103.201801). arXiv : [0906.1014](https://arxiv.org/abs/0906.1014) [hep-ex].
- [6] The DØ Collaboration. « Search for Higgs bosons decaying to  $\tau\tau$  pairs in  $p\bar{p}$  collisions at  $\sqrt{s} = 1,96$  TeV ». *Physics Letters* **B707** (2012), p. 323-329. DOI : [10.1016/j.physletb.2011.12.050](https://doi.org/10.1016/j.physletb.2011.12.050). arXiv : [1106.4555](https://arxiv.org/abs/1106.4555) [hep-ex].
- [7] The CMS Collaboration. « Search for a Higgs boson decaying into a  $b$ -quark pair and produced in association with  $b$  quarks in proton-proton collisions at 7 TeV ». *Physics Letters* **B722** (2013), p. 207-232. DOI : [10.1016/j.physletb.2013.04.017](https://doi.org/10.1016/j.physletb.2013.04.017). arXiv : [1302.2892](https://arxiv.org/abs/1302.2892) [hep-ex].
- [8] The CMS Collaboration. « Search for neutral MSSM Higgs bosons decaying into a pair of bottom quarks ». *Journal of High Energy Physics* **11** (2015). DOI : [10.1007/JHEP11\(2015\)071](https://doi.org/10.1007/JHEP11(2015)071). arXiv : [1506.08329](https://arxiv.org/abs/1506.08329) [hep-ex].
- [9] The ATLAS Collaboration. « Search for the neutral Higgs bosons of the Minimal Supersymmetric Standard Model in  $pp$  collisions at  $\sqrt{s} = 7$  TeV with the ATLAS detector ». *Journal of High Energy Physics* **02** (2013). DOI : [10.1007/JHEP02\(2013\)095](https://doi.org/10.1007/JHEP02(2013)095). arXiv : [1211.6956](https://arxiv.org/abs/1211.6956) [hep-ex].
- [10] The ATLAS Collaboration. « Search for additional heavy neutral Higgs and gauge bosons in the ditau final state produced in  $36\text{ fb}^{-1}$  of  $pp$  collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector ». *Journal of High Energy Physics* **1** (jan. 2018). DOI : [10.1007/jhep01\(2018\)055](https://doi.org/10.1007/jhep01(2018)055).
- [11] The CMS Collaboration. « Search for neutral MSSM Higgs bosons decaying to  $\mu^+\mu^-$  in  $pp$  collisions at  $\sqrt{s} = 7$  and 8 TeV ». *Physics Letters* **B752** (2016), p. 221-246. DOI : [10.1016/j.physletb.2015.11.042](https://doi.org/10.1016/j.physletb.2015.11.042). arXiv : [1508.01437](https://arxiv.org/abs/1508.01437) [hep-ex].
- [12] The CMS Collaboration. « Search for neutral Higgs bosons decaying to tau pairs in  $pp$  collisions at  $\sqrt{s} = 7$  TeV ». *Physics Letters* **B713** (2012), p. 68-90. DOI : [10.1016/j.physletb.2012.05.028](https://doi.org/10.1016/j.physletb.2012.05.028). arXiv : [1202.4083](https://arxiv.org/abs/1202.4083) [hep-ex].
- [13] The CMS Collaboration. « Search for neutral MSSM Higgs bosons decaying to a pair of tau leptons in  $pp$  collisions ». *Journal of High Energy Physics* **10** (oct. 2014). DOI : [10.1007/jhep10\(2014\)160](https://doi.org/10.1007/jhep10(2014)160).
- [14] The CMS Collaboration. « Reconstruction and identification of tau lepton decays to hadrons and tau neutrino at CMS ». *Journal of Instrumentation* **11**.1 (2016). DOI : [10.1088/1748-0221/11/01/P01019](https://doi.org/10.1088/1748-0221/11/01/P01019). arXiv : [1510.07488](https://arxiv.org/abs/1510.07488) [physics.ins-det].
- [15] The CMS Collaboration. « Performance of reconstruction and identification of  $\tau$  leptons decaying to hadrons and  $\nu_\tau$  in  $pp$  collisions at  $\sqrt{s} = 13$  TeV ». *Journal of Instrumentation* **13**.10 (2018). DOI : [10.1088/1748-0221/13/10/P10005](https://doi.org/10.1088/1748-0221/13/10/P10005). arXiv : [1809.02816](https://arxiv.org/abs/1809.02816) [hep-ex].

- [16] The CMS Collaboration. *Tau ID recommendations for Run-2*. URL : <https://twiki.cern.ch/twiki/bin/viewauth/CMS/TauIDRecommendationForRun2>.
- [17] The CMS Collaboration. « Performance of the DeepTau algorithm for the discrimination of taus against jets, electron, and muons » (oct. 2019). URL : <https://cds.cern.ch/record/2694158>.
- [18] The CMS Collaboration. *Baseline muon selections for Run-II*. URL : <https://twiki.cern.ch/twiki/bin/viewauth/CMS/SWGuideMuonIdRun2>.
- [19] The CMS Collaboration. *Multivariate Electron Identification for Run2*. URL : <https://twiki.cern.ch/twiki/bin/view/CMS/MultivariateElectronIdentificationRun2>.
- [20] The CMS Collaboration. *Luminosity Physics Object Group (Lumi POG)*. URL : <https://twiki.cern.ch/twiki/bin/viewauth/CMS/TWikiLUM>.
- [21] The CMS Collaboration. *Egamma Run II recommendations*. URL : <https://twiki.cern.ch/twiki/bin/view/CMS/EgammaRunIIRecommendations>.
- [22] D. BERTOLINI & coll. « Pileup per particle identification ». *Journal of High Energy Physics* **10** (oct. 2014). DOI : [10.1007/jhep10\(2014\)059](https://doi.org/10.1007/jhep10(2014)059).
- [23] A. L. READ. « Modified frequentist analysis of search results (the  $CL_s$  method) ». *Workshop on confidence limits, CERN, Geneva, Switzerland, 17-18 Jan 2000 : Proceedings*. CERN-OPEN-2000-205. Mai 2000. DOI : [10.5170/CERN-2000-005.81](https://doi.org/10.5170/CERN-2000-005.81). URL : <http://cds.cern.ch/record/451614>.
- [24] L. MONETA & coll. « The RooStats Project ». *13<sup>th</sup> International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT2010)*. 2010. URL : [http://pos.sissa.it/archive/conferences/093/057/ACAT2010\\_057.pdf](http://pos.sissa.it/archive/conferences/093/057/ACAT2010_057.pdf).
- [25] T. JUNK. « Confidence level computation for combining searches with small statistics ». *Nuclear Instruments and Methods in Physics Research A* **434.2-3** (sept. 1999), p. 435-443. DOI : [10.1016/S0168-9002\(99\)00498-2](https://doi.org/10.1016/S0168-9002(99)00498-2). arXiv : [hep-ex/9902006](https://arxiv.org/abs/hep-ex/9902006) [hep-ex].
- [26] A. L. READ. « Presentation of search results : The  $CL(s)$  technique ». *Journal of Physics* **G28.10** (sept. 2002), p. 2693-2704. DOI : [10.1088/0954-3899/28/10/313](https://doi.org/10.1088/0954-3899/28/10/313).
- [27] R. BARLOW & C. BEESTON. « Fitting using finite Monte Carlo samples ». *Computer Physics Communications* **77.2** (1993), p. 219-228. DOI : [10.1016/0010-4655\(93\)90005-W](https://doi.org/10.1016/0010-4655(93)90005-W).
- [28] J. S. CONWAY. « Incorporating Nuisance Parameters in Likelihoods for Multisource Spectra » (2011), p. 115-120. DOI : [10.5170/CERN-2011-006.115](https://doi.org/10.5170/CERN-2011-006.115).

