



Chung-Yao Chao Fellowship 2018

Aniello Spiezia

IHEP, Beijing

27 March 2018



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



Resume



- 2015-Present** Postdoc at IHEP
- 2014-2015** **CERN/INFN associate** - INFN grant to spend one year at CERN.
- 2011-2014** **PhD student** in Physics at *Università degli Studi di Perugia*, Italy.
- 2008-2011** **Master's Degree** in Elementary Particle Physics at *Università degli Studi di Perugia*, Italy, **Mark:** 110/110
- 2005-2008** **Bachelor's Degree** in Physics at *Università degli studi di Perugia*, Italy, **Mark:** 110/110.

- In the **CMS collaboration** since 2011, I have joined **IHEP in June 2015** working on:
 - **search for new particles, called vector-like quarks**
 - **reconstruction of tau leptons pair in high pt regime**
- Other than this, my **roles in CMS experiment**:
 - I am **responsible for the simulated MC generation** for B2G group (100 people)
 - I am **responsible for online data acquisition (DAQ)** during daily and night shifts
 - I have worked in the **ttH (H → bb)** analysis
- I am **expert of data analysis** (all steps of a physics analysis: trigger, objects identification, efficiency studies, background estimations and systematics), through the use of several statistical methods, computer software and programming languages
- I am **author of >500 CMS articles** (see later for articles with major contribution)

Today I will focus my talk on my results obtained during my postdoc with IHEP

- The **Standard Model** is successfully theory describing the Particle Physics
- It has problems that have to be addressed: hierarchy problem, unification, etc.
- Several **extensions** of the Standard Model proposed with the introduction of new symmetries/properties → **new particles**
- I am working in an analysis that **looks for single production of vector-like quarks: $pp \rightarrow Tb/Tt$** in mass range **[0.7, 1.7] TeV**
- **I am the contact person of the analysis**
- **Two publications with 2015 and 2016 data: <https://arxiv.org/abs/1708.01062> and <https://arxiv.org/abs/1701.07409>**

Available on the CMS information server CMS AN-16-452

CMS Draft Analysis Note

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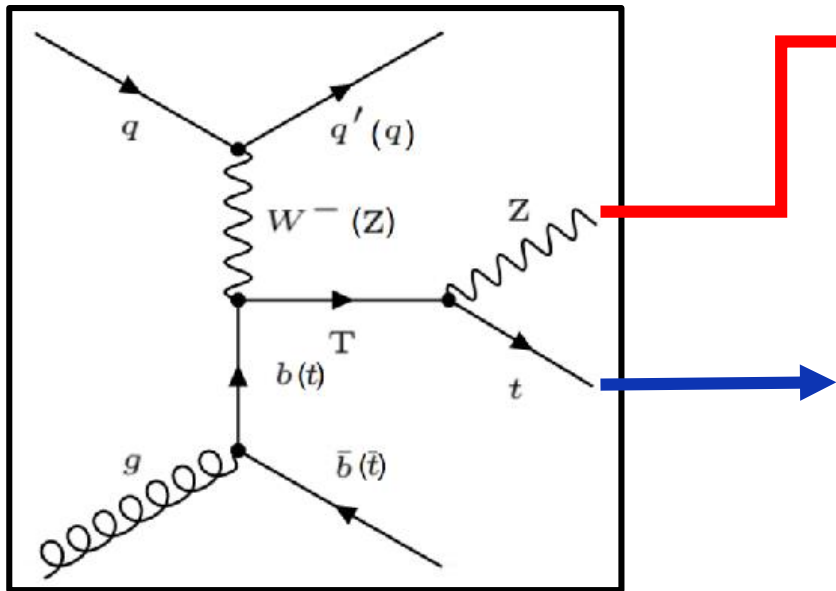
2017/03/01
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Archive Date: 2016/12/07
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Search for single production of vector-like quarks decaying into final states with a Z boson decaying leptonically and a top quark with 2016 data

Hongbo Liao and Aniello Spiezia
IHEP/CAS, Beijing

Abstract

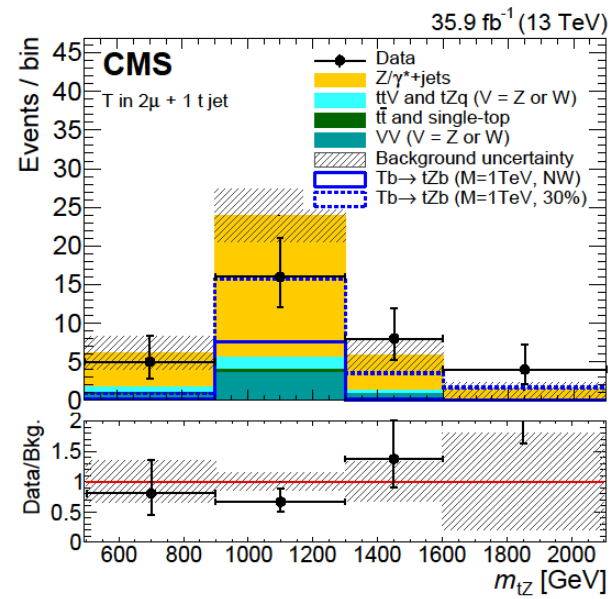
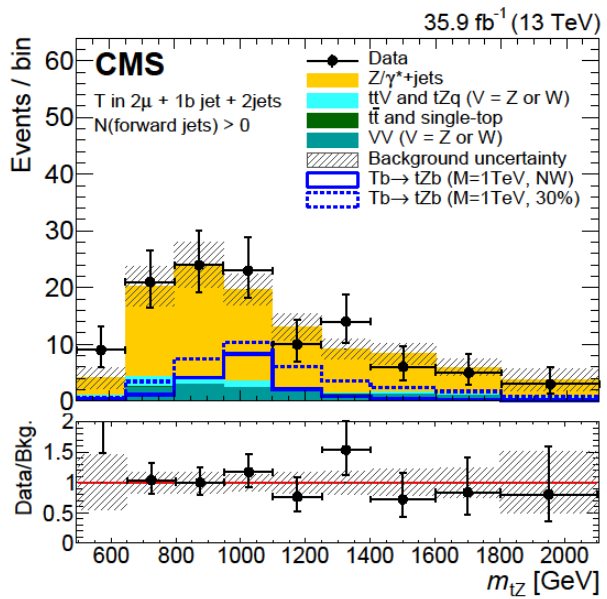
A search for the single production of vector-like T quark decaying into a Z boson and a top quark, is presented using data collected in 2016 by the CMS experiment in proton-proton collisions at $\sqrt{s} = 13$ TeV. The search has been performed in events with a Z boson decaying leptonically, accompanied by a top quark decaying hadronically.

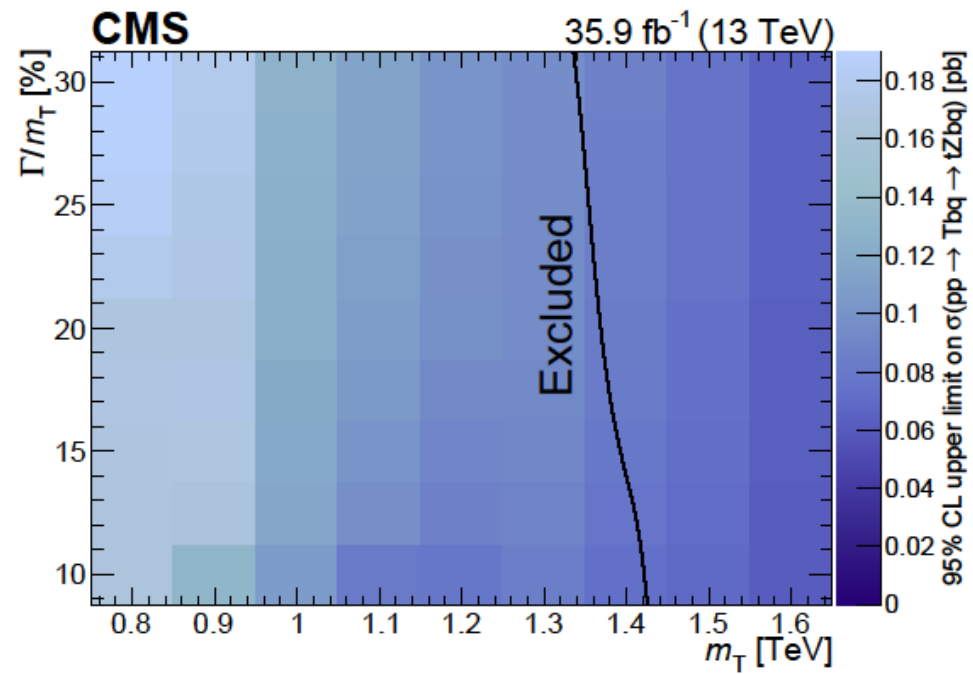
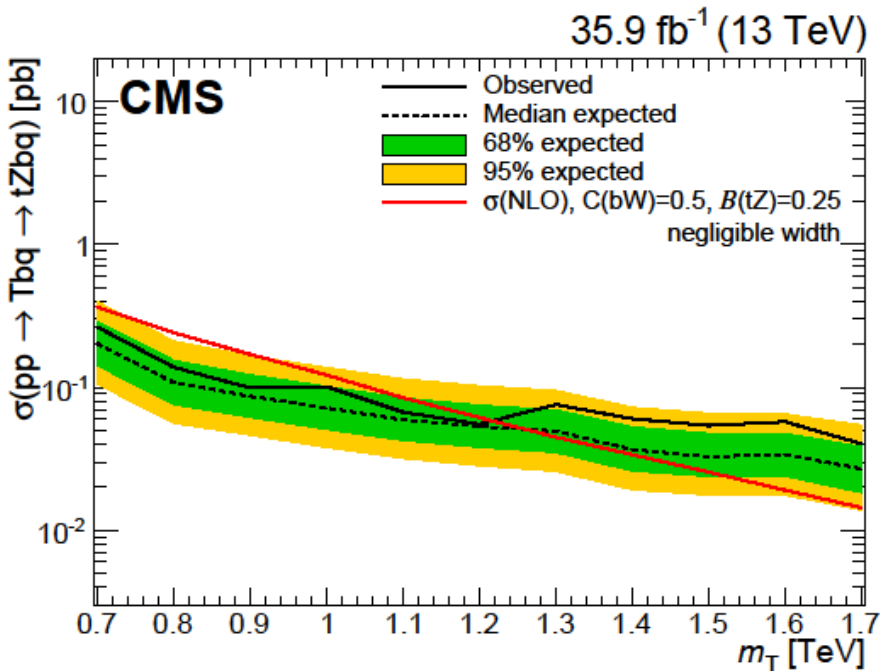


Leptonic Z: two muons or two electrons

Hadronic top:

- fully-resolved topology → three jets
- partially-merged topology → a W-jet and a b-jet are identified
- fully-merged topology → decay products are within one top-jet

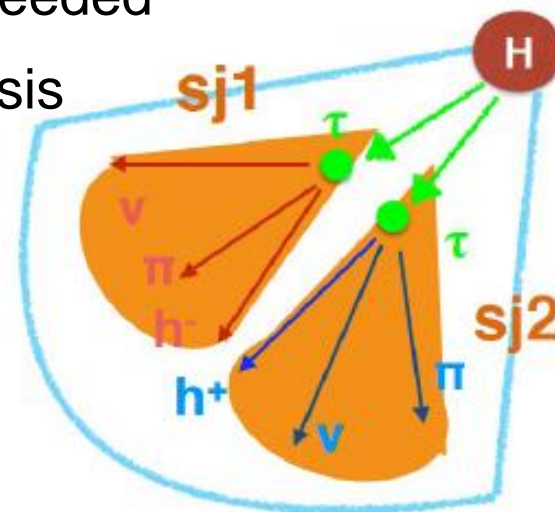




From the **summary** of the paper:

“The results presented in this paper are the most-stringent limits to date on the single production of heavy vector-like T quarks, the first to set limits for a variety of resonance widths, and the most-stringent limits for the production of a Z' boson decaying to Tt .”

- Many new physics models predict the existence of **heavy resonances** with masses ≥ 1 TeV that can decay into a **Higgs boson with high pt**
- If the Higgs decays to **taus**, those taus are produced **close to each other**
- If the $\Delta R(\tau, \tau)$ becomes lower than 0.4, i.e. the jet cone size used in the standard tau reconstruction, a new approach is needed
- **I have presented the approval talk** of the analysis



At small $\Delta R(\tau, \tau)$, the tau reconstruction is challenging with the standard reconstruction developed by CMS

Available on CMS information server CMS AN -2017/010

The Compact Muon Solenoid Experiment

Analysis Note

The content of this note is intended for CMS internal use and distribution only

11 January 2017 (v3, 09 November 2017)

Tau reconstruction for boosted ditau topologies

Camilla Galloni, Aniello Spiezia, Ben Kilminster, Hongbo Liao

Abstract

For bosons decaying to tau leptons with transverse momentum of few hundreds of GeV the final decay products are separated by a small angle and can overlap, causing problems in the reconstruction and identification of the tau pair. In this note a dedicated reconstruction for boosted tau pairs is described and validated in data.

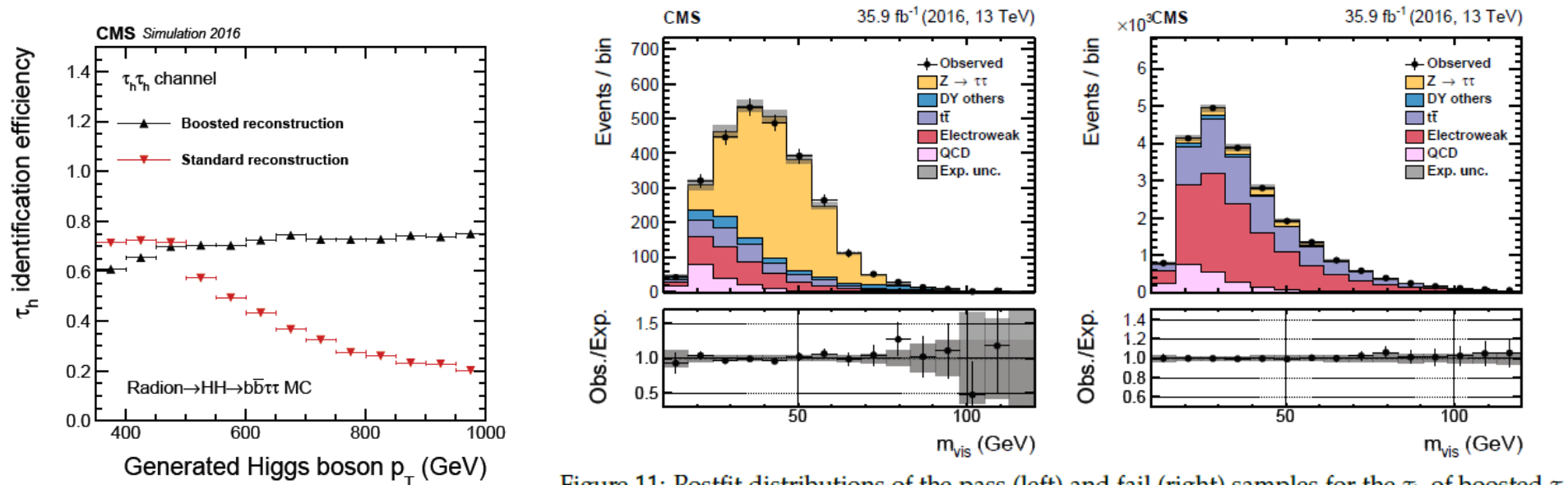


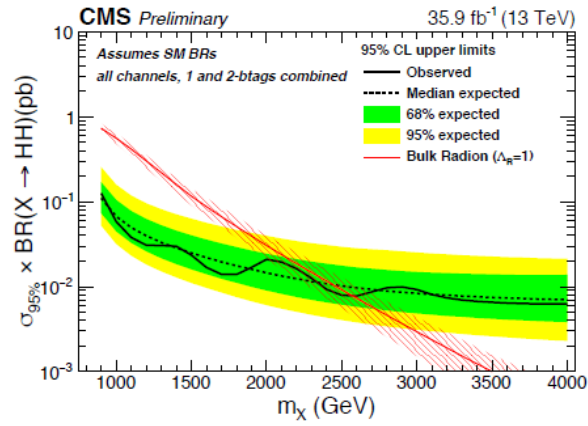
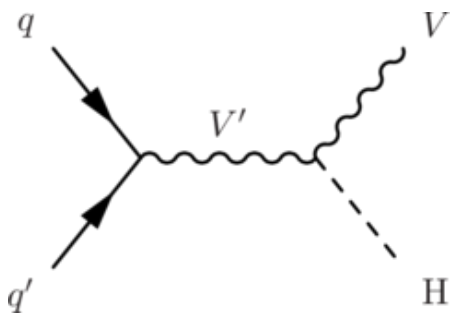
Figure 11: Postfit distributions of the pass (left) and fail (right) samples for the τ_h of boosted τ lepton pairs passing the medium working point of the MVA-based isolation discriminator.

- Performances of the boosted taus reconstruction compared with standard one
- Large improvement is observed
- **A paper is in preparation: TAU-16-006 (submission to journal before summer)**

- Boosted tau reconstruction used in the B2G-17-006 analysis (I am author):

Search for heavy resonances decaying into two Higgs bosons or into a Higgs and a vector boson in proton-proton collisions at 13 TeV

- Search for heavy resonances that decay to VV , VH , or HH
- **Publication before summer**



Available on the CMS information server CMS AN-16-375

CMS Draft Analysis Note

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2017/11/03
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Archive Id: 431053M
Archive Date: 2017/05/26
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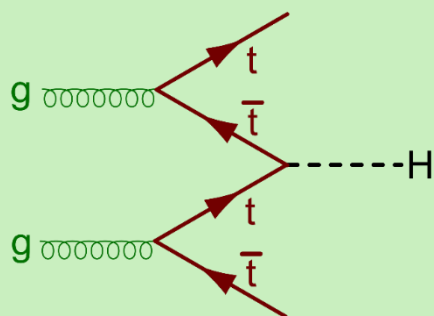
Search for heavy resonances decaying into a boson and a Higgs boson (WH, ZH, HH) in the $(q\bar{q}, b\bar{b}) \tau^+ \tau^-$ final state

Camilla Galloni¹, Andreas Hinzmann¹, Clemens Lange², Ben Kilminster¹, Alberto Zucchetta¹, Aniello Spiezia³, Pietro Govoni⁴, and Matteo Defranchis⁴

¹ University of Zurich
² CERN
³ IHEP/CAS Beijing
⁴ INFN and Università degli Studi di Milano Bicocca

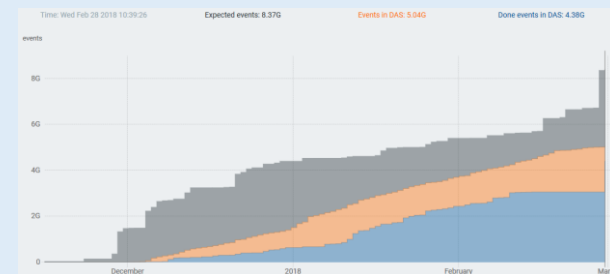
Abstract

This analysis note describes the search for heavy resonances decaying into a boson and a Higgs boson, where the first can be a W, a Z, or a H boson decaying hadronically while the Higgs boson decays into a pair of tau leptons, in the semileptonic and fully hadronic final state. Final states with at least a lepton and a hadronically decaying tau or two hadronically decaying taus and a large cone jet, compatible with either a W or a Z or a Higgs boson are investigated in the data collected in 2016 by the CMS experiment.



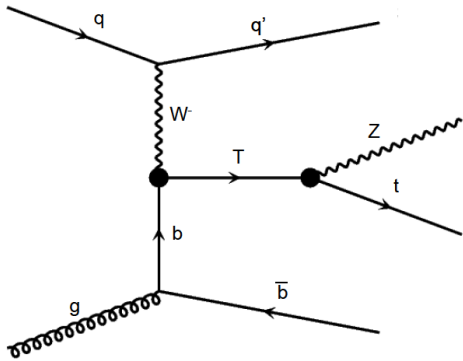
- I have been working on the Higgs search since 2012 (during my PhD) working in $H \rightarrow \gamma\gamma$ analysis
- With **IHEP** I worked in the search for the Higgs boson produced in association with two top quarks (**ttH**, **H** \rightarrow **bb**), in event identification, multivariate analysis (see backup)
- **Two public PAS** for which I am author

- I am **responsible** for production of **MC simulated samples** for B2G group (~100 people)
- I collect the requests from several analysis teams and I coordinate the production

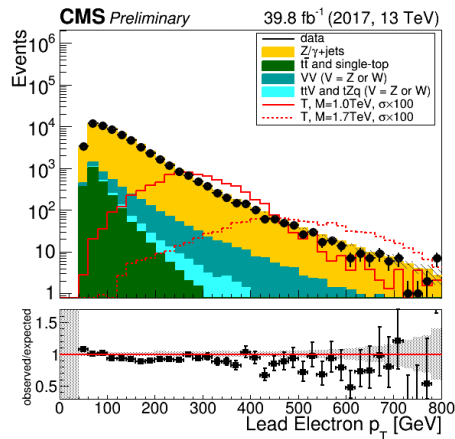


- I participate to the data taking operation, in the CMS Control Room at Point 5 of the LHC
- **I am a DAQ shifter**, i.e. I make sure the data acquisition is running smoothly and that CMS is collecting high quality data

VLQ analysis



- I plan to repeat the analysis with 2017 data
- To improve the sensitivity of the analysis, I plan to add the channels with $Z \rightarrow$ neutrinos
- Branching fraction of $Z \rightarrow$ neutrinos is 20% compared to 6% from leptonic decays
- A **publication is expected by the end of 2018**



2017 data result!

DAQ shifts

- I will participate in 2018 data taking as DAQ shifter

New search

- Several B-physics experiments (BaBar, LHCb, Belle) measured interesting and surprising anomaly in simple semi-leptonic decays of B-mesons
- $R_{D^{(*)}}$ found not in agreement with expectation of the SM at a level of $>3\sigma$

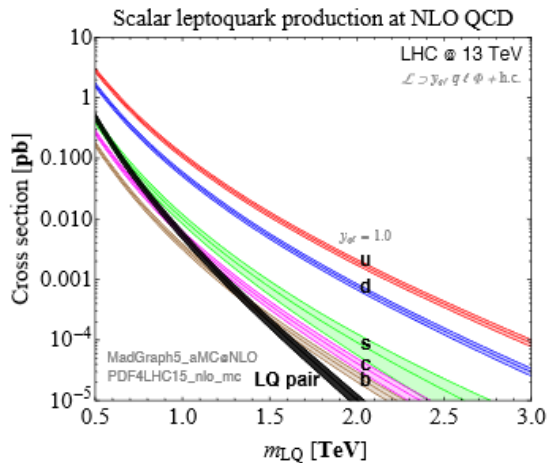
$$R_D = \frac{\mathcal{B}(B \rightarrow D\tau\nu)}{\mathcal{B}(B \rightarrow D\ell\nu)}, \quad R_{D^*} = \frac{\mathcal{B}(B \rightarrow D^*\tau\nu)}{\mathcal{B}(B \rightarrow D^*\ell\nu)}$$

$$R_D^{\text{exp}} = 0.403 \pm 0.040 \pm 0.024, \quad R_D^{\text{SM}} = 0.299 \pm 0.003,$$

$$R_{D^*}^{\text{exp}} = 0.310 \pm 0.015 \pm 0.008, \quad R_{D^*}^{\text{SM}} = 0.257 \pm 0.003$$

from <https://arxiv.org/pdf/1704.06659.pdf>

- While further investigations are ongoing at LHCb, a model independent search can be performed at CMS (and ATLAS)



- This anomaly is expected if leptoquarks exist
- I want to study pair production of leptoquarks
- Final state:
 $pp \rightarrow LQ_1 LQ_2, LQ_1 \rightarrow b\tau$ and $LQ_2 \rightarrow \text{top } \nu$
- **Publication** expected for the end of 2018



Publications (since I am in IHEP) with major contribution:

- 2017** Search for single production of a vector-like T quark decaying to a Z boson and a top quark in proton-proton collisions at $\sqrt{s} = 13$ TeV, CMS Collaboration, arXiv:1708.01062, submitted to PLB
- 2017** Search for heavy resonances decaying into two Higgs bosons or into a Higgs and a vector boson in proton-proton collisions at 13 TeV, CMS Collaboration, CMS-PAS-B2G-17-006, <http://cds.cern.ch/record/2296716>
- 2017** Performance of reconstruction and identification of leptons in their decays to hadrons and in the CMS detector in pp collision at $\sqrt{s} = 13$ TeV, CMS Collaboration, CMS-PAS-TAU-16-003, In preparation
- 2017** Search for ttH production in the H to bb decay channel with 2016 pp collision data at $\sqrt{s} = 13$ TeV, CMS Collaboration, CMS-PAS-HIG-16-038, <http://cds.cern.ch/record/2231510>
- 2016** Search for single production of vector-like quarks decaying to a Z boson and a top or a bottom quark in proton-proton collisions at $\sqrt{s} = 13$ TeV, CMS Collaboration, JHEP 1705, 029 (2017), arXiv:1701.07409
- 2016** Search for ttH production in the H to bb decay channel with $\sqrt{s} = 13$ TeV pp collisions at the CMS experiment, CMS Collaboration, CMS-PAS-HIG-16-004, <http://cds.cern.ch/record/2139578>
- 2016** Tau identification in boosted topologies, CMS Collaboration, CMS DP-2016/038
- 2015** Search for resonant pair production of Higgs bosons decaying to bb and tau tau in proton-proton collisions at $\sqrt{s} = 8$ TeV, CMS Collaboration, CMS-PAS-EXO-15-008, <http://cds.cern.ch/record/2125293>

Conference Proceedings (since I am in IHEP):

- 2016** A Pattern Recognition Mezzanine based on Associative Memory and FPGA technology for Level 1 Track Triggers for the HL-LHC upgrade, D. Magalotti et al., JINST 11, no. 02, C02063 (2016)
- 2017** Search for unconventional final states at ATLAS and CMS, Aniello Spiezia, on behalf of the ATLAS and CMS Collaborations, Conference Proceeding: 52nd Rencontres de Moriond, 2017 EW Interactions and Unified Theories
- 2017** Search for single production of a vector-like T quark decaying to tZ with CMS at $\sqrt{s} = 13$ TeV, Aniello Spiezia, on behalf of the CMS Collaboration, arXiv:1708.03124, Conference Proceeding: 5th Annual LHCP, Shanghai

CMS Internal Analysis Notes:

I have signed 23 internal notes, to which I have given my contribution



Conclusions



- I have joined the **CMS collaboration** in 2011
- Starting from June 2015, I am a postdoc in **IHEP**
- Since then I am mainly involved in the following projects:
 - **search for new particles, called vector-like quarks**
 - **boosted Higgs reconstruction in $\tau\tau$ final state**
 - **search for Higgs boson produced in association with two top quarks**
 - **DAQ shifter during CMS data taking**
 - **coordination of the MC production for the B2G group**
- I am **author of >500 CMS articles** (see previous slide for articles with major contribution)
- For the **next year the plan is:**
 - finalize the papers I am working on
 - improve the VLQ search by including 2018 data and a new channel: publication expected in the next months
 - work on a new search, related to the B-anomaly, in final states with $b\tau\text{top}\nu$: publication expected by the end of 2018
 - continue to contribute as DAQ shifter to the CMS data taking

BACKUP

2015-Present Postdoc at IHEP/CAS

2014 **CERN/INFN associate** - INFN grant to spend one year at CERN.

2011-2014 **PhD student** in Physics at *Università degli Studi di Perugia*, Italy.
Thesis title: "Associated production of a Higgs and a vector boson at the CMS experiment in the standard model and beyond"



2008-2011 **Master's Degree** in Elementary Particle Physics at *Università degli Studi di Perugia*, Italy, **Mark:** 110/110.
Thesis title: "Measurement of the charge misidentification rate for soft electrons and consequences on Supersym-metry searches"

2005-2008 **Bachelor's Degree** in Physics at *Università degli studi di Perugia*, Italy, **Mark:** 110/110.
Thesis title: "The new Read-out of the Electromagnetic Calorimeter of the NA62 Experiment"



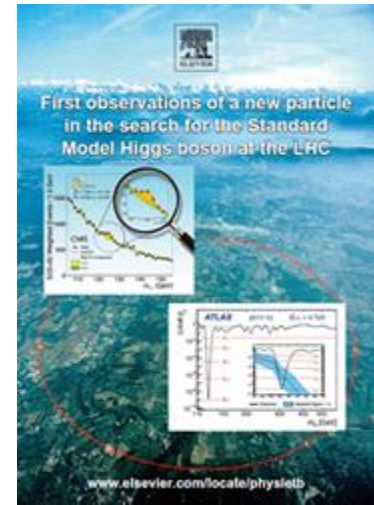
Conferences



- 2018** Alps 2018: Third Alpine LHC Physics Summit, Obergurgl, Austria
Talk: State and Prospects of BSM Searches at the LHC
- 2017** LHCP 2017: 5th Large Hadron Collider Physics Conference, Shanghai, China
Poster: Search for single production of a vector-like T quark
- 2017** Rencontres de Moriond: EW 2017, La Thuile, Italy
Talk: Searches for other unconventional final states with 13 TeV data
- 2016** Lake Louise Winter Institute 2016, Lake Louise, Canada
Talk: Search for vector-like quarks at CMS
- 2014** IFAE 2014: Incontri di Fisica delle Alte Energie, LNGS, Italy
Poster: Search for the Standard Model Higgs boson decaying into two photons
- 2013** QCD@LHC 2013, DESY, Hamburg, Germany
Talk: Boosted-objects and jet substructure at the CMS
- 2012** CKM2012: 7th International Workshop on the CKM Unitarity Triangle, USA
Talk: Measurements of Electroweak Top Production at the LHC
- 2012** 12th Hellenic School and Workshop on Elementary Particle Physics and Gravity, Corfu, Greece
Talk: Search for new physics with same-sign isolated dilepton events in CMS
- 2012** IFAE 2012: Incontri di Fisica delle Alte Energie, Ferrara, Italy
Poster: Search for new physics with same-sign isolated dilepton events in CMS₁₆



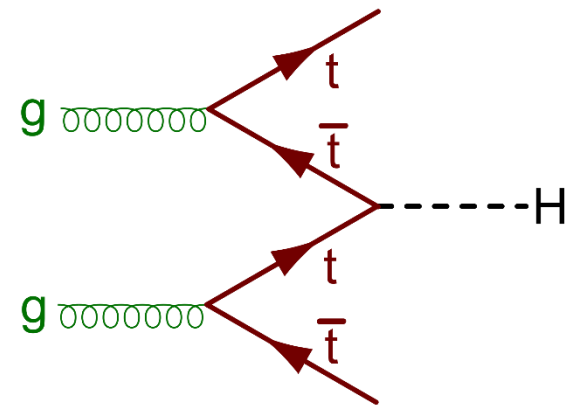
Higgs search



- The **Higgs boson has been discovered in 2012**, reaching a milestone in our understanding of nature
- **I am part of this search since 2012** when I have started to work on my PhD in the search for the Higgs boson in its decay to two photons (see backup)
- With **IHEP** I am working in the search for the Higgs boson produced in association with two top quarks (**ttH** in the next), where the Higgs decays to **two bottom quarks**

- **Direct measurement of the top-Higgs coupling** is essential: ttH production provides the best direct probe of this coupling at the LHC

- Stringent limits on ttH production provide indirect limits for the **new physics models** (Vector-like quarks, composite Higgs models, RS, little Higgs)



Available on the CMS information server CMS AN-15-216

CMS Draft Analysis Note

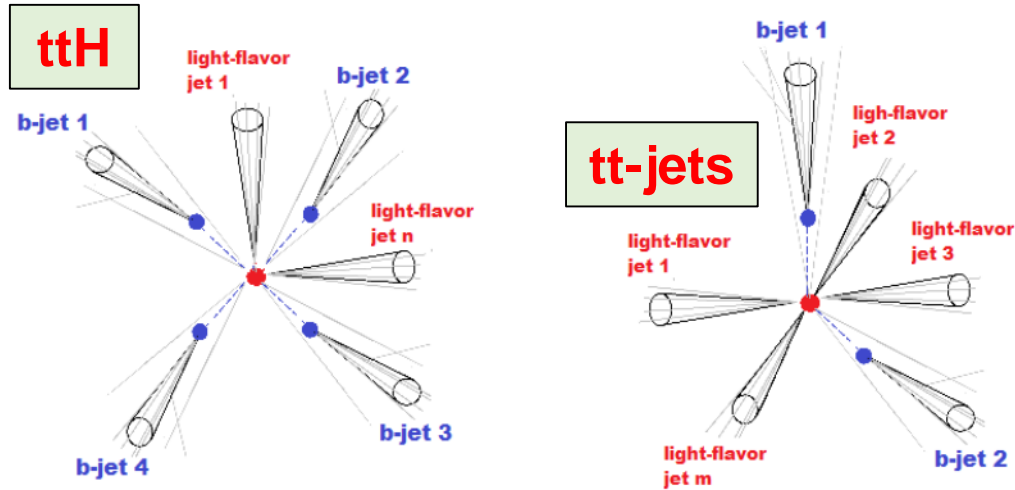
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2016/03/04
Head Id: 330169
Archive Id: 330533
Archive Date: 2016/03/03
Archive Tag: trunk

First results on ttH with $H \rightarrow b\bar{b}$ at 13 TeV

Maria Aldaya¹, Jim Alexander², Lorenzo Bianchini³, Lea Caminada⁴, Christian Contreras Campana¹, Florencia Canelli⁴, Abhisek Datta², Günther Dissertori³, Karim El Morabit⁵, Sean Flowers⁶, Jason Garcia¹, Marco Harrendorf⁷, Satoshi Hasegawa⁷, Johannes Hauk¹, Ulrich Husemann⁸, Gregor Kasieczka³, Thomas Klijsma³, Kevin Lannon⁹, Hongbo Liao⁹, Wuming Luo⁶, Hannes Mildner⁵, Chris Neu¹⁰, Eleni Ntomari¹, Carmen Diez Pardos¹, Joosep Pata³, Darren Puigh⁶, Thorben Quast¹¹, Felix Riese⁵, Aurelijus Rinkevicius², Francesco Romeo⁹, Andrej Savin¹¹, Daniel Salerno⁴, Matthias Schröder⁵, Korbinian Schweiger⁵, Tutanon Sinthuprasith¹⁰, Aniello Spiezia⁹, Shao Min Tan², Julia Thom², Gerrit Van Onsem¹, Rainer Wallny³, Michael Wasmer⁷, Sarah Williamson⁵, Brian Winer⁶, Evan Wolfe¹⁰, and Huaqiao Zhang⁹

¹ DESY
² Cornell University
³ ETH Zürich
⁴ University of Zürich
⁵ Karlsruhe Institute of Technology
⁶ The Ohio State University
⁷ FNAL
⁸ University of Notre Dame
⁹ IHEP, Beijing
¹⁰ University of Virginia
¹¹ RWTH Aachen



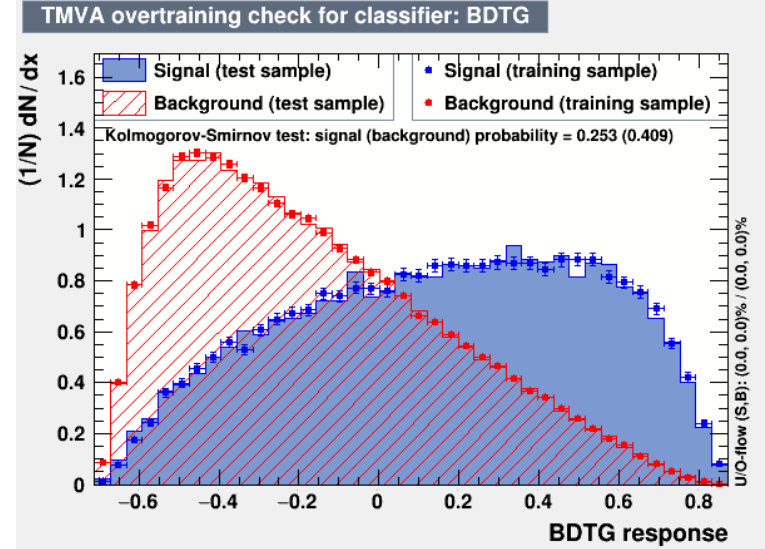
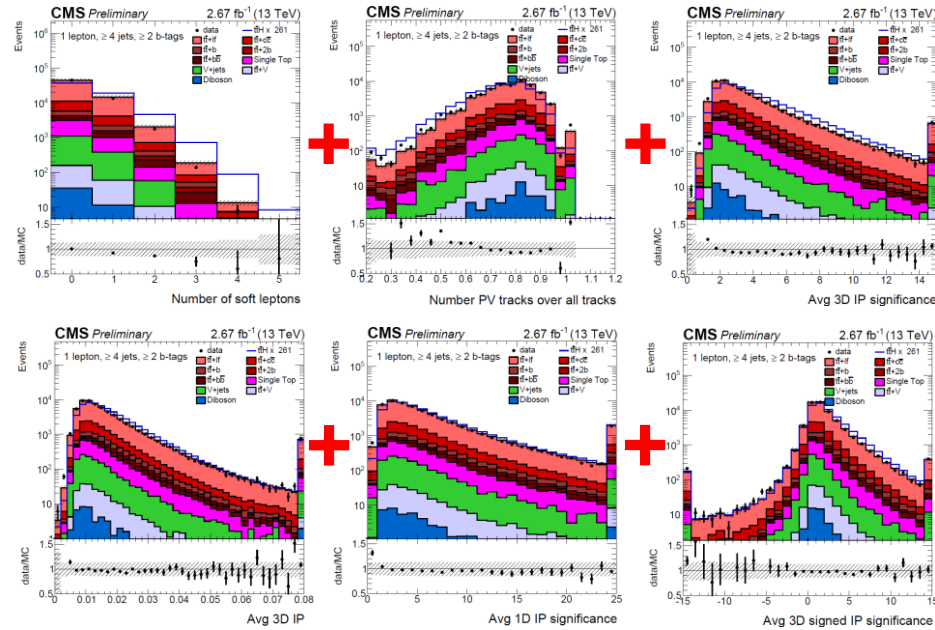
Main background of **ttH** signal is given by **ttjets** standard model production:

- **ttH, with $H \rightarrow bb$: 4 b jets + n light flavour jets**
- **ttjets: 2 b jets + m light flavour jets**

- Difference between the two processes is given by the number of jets coming from b-quark: higher in ttH signal
- b-jet properties allow discrimination with jets: long lifetime, large mass, high track multiplicity, large semileptonic BR
- **My contribution: bjetness definition**
- Property that allow to exploit the presence of **more than one b jet in the event**:
 - ✓ **average on the previous properties**
 - ✓ **consider displacement of b jets among each other (other than the primary vertex)**



My contribution to ttH



- I have defined a set of new variables with high discriminating power, exploiting the difference in topology between ttH and ttjets
- The new variables have been combined in a single BDT
- Adding this BDT to the analysis bring a 12% of improvement**

