

# Relazione triennale (2014-16) of Francesco Santanastasio

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## Current Position

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*Assistant Professor (Ricercatore Tempo Determinato di Tipo B)*

Department of Physics, Sapienza Università di Roma, Rome, Italy

Start of the contract: 01/03/2014

End of the contract: 28/02/2017

## Research field

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My research field is the experimental high energy physics. Since 2006 I am part of the CMS collaboration, one of the 4 experiments running at the CERN Large Hadron Collider (LHC) in Geneva.

## Publications

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2016 **84 publications:** see [link to inspire](#)

[http://inspirehep.net/search?ln=en&ln=en&p=find+a+santanastasio+and+tc+p+and+date+2016&of=hb&action\\_\\_search=Search&sf=&so=d&rm=&rg=25&sc=0](http://inspirehep.net/search?ln=en&ln=en&p=find+a+santanastasio+and+tc+p+and+date+2016&of=hb&action__search=Search&sf=&so=d&rm=&rg=25&sc=0)

2015 **131 publications:** see [link to inspire](#)

[http://inspirehep.net/search?ln=en&ln=en&p=find+a+santanastasio+and+tc+p+and+date+2015&of=hb&action\\_\\_search=Search&sf=&so=d&rm=&rg=25&sc=0](http://inspirehep.net/search?ln=en&ln=en&p=find+a+santanastasio+and+tc+p+and+date+2015&of=hb&action__search=Search&sf=&so=d&rm=&rg=25&sc=0)

2014 **109 publications:** see [link to inspire](#)

[http://inspirehep.net/search?ln=en&ln=en&p=find+a+santanastasio+and+tc+p+and+date+2014&of=hb&action\\_\\_search=Search&sf=&so=d&rm=&rg=25&sc=0](http://inspirehep.net/search?ln=en&ln=en&p=find+a+santanastasio+and+tc+p+and+date+2014&of=hb&action__search=Search&sf=&so=d&rm=&rg=25&sc=0)

Total number of publications: 506 (ISI), 530 (inspire)

h-index: 56 (ISI)

## Teaching

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AA 14-15 **Corso di Fisica I, Sapienza, Dipartimento di Chimica Industriale (9 CFU)**

*Mechanics and Thermodynamics*

## Academic Responsibilities

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10/2014 - **“Referente di Con.Sienze per la Facoltà di SMFN” at Sapienza**

today *Organization of verification tests required for student registration at first year of University*

09/2015 - **Member of “Commissione Didattica del CdL in Chimica Industriale”**

today

## Research Grants

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- 08/2013 **Vincitore del Programma Per Giovani Ricercatori “Rita Levi Montalcini”**  
[Risultati Bando 2010](#)  
Research project: *Search for new physics beyond the Standard Model with the CMS detector at the CERN LHC*

## Scientific Coordination in the Period 2014-2016

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- 09/2016 - **Coordination of the *CMS Exotica Jets+X Working Group***  
today I started my 2-year mandate on September 1st, 2016. This analysis group works on searches for new physics beyond the Standard Model in final states containing jets. The group, constituted by more than 50 physicists working in universities and research institutions from all the world, performs about 10 physics analyses in this final state. The results of these searches are expected to be published in 2017.
- 09/2014 - **Coordination of the *Dijet Resonance Team of the CMS experiment***  
09/2016 This analysis team works on searches for new massive resonances at the TeV scale decaying into a pair of jets using the dijet mass spectrum. It is constituted by about 20 physicists from several institutions from all the world. This group produced the first paper at LHC on a search for new physics using proton-proton collisions at  $\sqrt{s} = 13$  TeV [1].
- 01/2013 - **Coordination of the *CMS Exotica Leptons+Jets Working Group***  
01/2015 This analysis group works on searches for new physics beyond the Standard Model in final states containing leptons and jets. The group, constituted by more than 50 physicists working in universities and research institutions from all the world, performed about 15 physics analyses in this final state. During my convenership, the group produced 3 publications [7, 8, 9] and 7 preliminary results that were then published or submitted for publication in 2015 (including [3, 4, 5]).

## Details of Research Activity in the Period 2014-2016

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My research field is the experimental high energy physics. Since 2006 I am part of the CMS collaboration, one of the 4 experiments running at the CERN Large Hadron Collider (LHC). During these years, I have been involved in several detector activities including calibration of the CMS electromagnetic calorimeter, commissioning of the CMS hadronic calorimeter, performance studies of the missing transverse energy reconstructed in the event, and I participated to several physics analyses. In the 2014-2016 period I focused on physics analyses, searching for physics beyond the Standard Model (SM).

### Search for new massive resonances in the dijet final state

I have been working on a search for new resonances with mass at the TeV scale that decay to a pair of jets (dijet). This search is one of the most sensitive probes for new physics at LHC because any hypothetical new particle that might be produced is originated from the colliding protons and therefore it must couple to quarks and/or gluons, thus producing jets. The analysis strategy consists in reconstructing the invariant mass of the dijet system and searching for a resonant peak in its data spectrum. I have been the leading author of this search in CMS since 2012 publishing a paper on this topic with the full dataset collected at

$\sqrt{s} = 8$  TeV [6]. After a 2-year shutdown, the LHC has restarted proton-proton collisions in April 2015 with an increased center-of-mass energy of 13 TeV. This energy jump has largely enhanced the sensitivity of the dijet search to new physics. Since September 2014, I am coordinating the group, made of about 20 physicists, devoted to the analysis of the early 13 TeV data. The analysis performed on the data collected in 2015 has shown no sign of new particle production, setting the most stringent limits in this final state for several new physics models. The results of this search, thanks to their relevance for this scientific field, have been accepted for publication by PRL [1] in January 2016. This is also the first search for new physics in proton-proton collisions at  $\sqrt{s} = 13$  TeV from LHC.

### Search for sub-TeV dijet resonances using the novel *CMS data scouting* technique

It is important to extend the dijet search in the mass region below 1 TeV in order to probe hypothetical hadronic resonances with small couplings to quarks and gluons that similar searches performed at previous colliders could not find yet. The main experimental difficulties at LHC originate from the large cross section of multijet events at low dijet mass and the finite computing resources for processing and storing these data. To solve this issue, I first proposed in 2011 a new technique known as *data scouting*. This technique, by significantly reducing the event size compared to the standard CMS data stream, enabled CMS to relax the trigger thresholds and record 1 KHz of fully hadronic events to extend the search in the sub-TeV mass region. With this approach, the analysis is performed using jets reconstructed online in the CMS trigger computing farm. This novel research strategy was fully integrated in the CMS physics program in 2012, when I was convener of the “*CMS Dataset Definition Team*”, allowing to collect data corresponding to almost  $19 \text{ fb}^{-1}$  of integrated luminosity at  $\sqrt{s} = 8$  TeV in the sub-TeV dijet mass region. I worked at the search for dijet resonances using these data. No evidence for new particle production is found and the most stringent limits to date were set on the production cross section of dijet resonances in the mass range from 500 to 800 GeV. These results were published in 2016 by PRL [2].

### Search for new massive resonance in diboson final states

Many theories beyond the SM predict the existence of massive particles at the TeV scale that decays into pairs of SM bosons. The bosons coming from the massive particle can be W, Z, H or  $\gamma$ . As convener of the *CMS Exotica Leptons+Jets Working Group* in the 2013-2014 period I contributed to various diboson analyses in final states involving leptons and jets, documented in 3 papers [3, 4, 9]. In particular, I was deeply involved in the search for massive resonances in the WW and ZZ final states using proton-proton collisions at  $\sqrt{s} = 8$  TeV, focusing on the analysis of the semi-leptonic ( $\ell\ell qq$  and  $\ell\nu qq$ ) and fully-hadronic ( $qqqq$ ) decay modes [9]. These decay channels have the largest branching fraction, providing a higher sensitivity to new physics for resonance masses above 1 TeV compared to the fully leptonic channels. These are quite complex analyses. For resonances with mass above 1 TeV, the momentum of the W and Z bosons greatly exceeds their rest mass, and the quarks from their decay are emitted with a small angular separation in the laboratory reference frame, thus resulting into a single massive jet. By exploiting the substructure of a wide jet, it is possible to discriminate between the dipolar structure of an hadronic boson decay (signal events) and a jet created by the hadronization of a single quark/gluon (background events). The WW and ZZ searches were among the first in CMS to include the jet-substructure reconstruction algorithms in a physics analysis and my work contributed to define the experimental methodology for this kind of research in CMS.

## Invited Talks at Conferences

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- 07/2016 **ICNFP2016** - International Conference on New Frontiers in Physics, Kolymbari, Crete, “*Searches for BSM physics in final states with jets and leptons+jets at CMS*”, Proceedings [10]
- 07/2014 **ICHEP2014** - International Conference on High Energy Physics, Valencia, Spain, “*Search for heavy resonances decaying to bosons with the ATLAS and CMS detectors*”, Proceedings [11]

## PhD Student Supervision

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I have been the PhD thesis co-supervisor of the following students at Sapienza:

- 2015-2017 **Simone Gelli**, “*Search for new particles decaying into diboson final states in proton-proton collisions at  $\sqrt{s} = 13$  TeV*”, Thesis ongoing
- 2014-2015 **Giulia D’Imperio**, “*Search for narrow resonances in dijet final states at the LHC with  $\sqrt{s} = 13$  TeV*” [link to thesis](#) [1],

During my convenerships of analysis groups in the CMS experiment, I supervised the research activity of the following graduate students from foreign institutions:

- 2012-2015 **Emine Gurpinar**, Cukurova University, Turkey  
“*Searches for heavy resonances decaying to pair of jets at CMS*” [6]
- 2012-2014 **Shuai Liu**, Peking University, China  
“*Searches for beyond Standard Model  $WW \rightarrow \ell\nu qq$  resonances at CMS*” [9]
- 2012-2014 **Edmund Berry**, Princeton University, USA  
“*Searches for first-generation leptoquarks at CMS with  $\sqrt{s} = 7$  and 8 TeV data*” [5]

## References

### PUBLICATIONS QUOTED IN THIS DOCUMENT

- [1] [CMS Collaboration], “Search for narrow resonances decaying to dijets in proton proton collisions at  $\sqrt{s} = 13$  TeV,” Phys. Rev. Lett. 116, 071801 (2016), arXiv:1512.01224 [hep-ex].
- [2] [CMS Collaboration], “Search for narrow resonances in dijet final states at  $\sqrt{s} = 8$  TeV with the novel CMS technique of data scouting,” Phys. Rev. Lett. 117, 031802 (2016), arXiv:1604.08907 [hep-ex].
- [3] [CMS Collaboration], “Search for massive WH resonances decaying into the  $\ell\nu b\bar{b}$  final state at  $\sqrt{s} = 8$  TeV,” Eur. Phys. J. C 76, 237 (2016), arXiv:1601.06431 [hep-ex].
- [4] [CMS Collaboration], “Search for narrow high-mass resonances in proton-proton collisions at  $\sqrt{s} = 8$  TeV decaying to a Z and a Higgs boson,” Phys. Lett. B 748, 255 (2015), arXiv:1502.04994 [hep-ex].
- [5] [CMS Collaboration], “Search for pair production of first and second generation leptons in proton-proton collisions at  $\sqrt{s} = 8$  TeV,” Phys. Rev. D 93, 032004 (2016), arXiv:1509.03744 [hep-ex].
- [6] [CMS Collaboration], “Search for resonances and quantum black holes using dijet mass spectra in proton-proton collisions at  $\sqrt{s} = 8$  TeV,” Phys. Rev. D 91, no. 5, 052009 (2015), arXiv:1501.04198 [hep-ex].
- [7] [CMS Collaboration], “Search for pair production of third-generation scalar leptons and top squarks in proton-proton collisions at  $\sqrt{s} = 8$  TeV,” Phys. Lett. B 739, 229 (2014), arXiv:1408.0806 [hep-ex].
- [8] [CMS Collaboration], “Search for heavy neutrinos and W bosons with right-handed couplings in proton-proton collisions at  $\sqrt{s} = 8$  TeV,” Eur. Phys. J. C 74, no. 11, 3149 (2014), arXiv:1407.3683 [hep-ex].
- [9] [CMS Collaboration], “Search for massive resonances decaying into pairs of boosted bosons in semi-leptonic final states at  $\sqrt{s} = 8$  TeV,” JHEP 1408, 174 (2014), arXiv:1405.3447 [hep-ex].

### CONFERENCE PROCEEDINGS QUOTED IN THIS DOCUMENT

- [10] “Searches for BSM physics in final states with jets and leptons+jets at CMS”  
F. Santanastasio  
Proceedings will be published in European Physical Journal Web of Conferences  
*Prepared for the 5th International Conference on New Frontiers in Physics, Kolymbari, Crete, 6-14 July 2016*
- [11] “Search for heavy resonances decaying to bosons with the ATLAS and CMS detectors,”  
F. Santanastasio  
Nucl. Part. Phys. Proc. 273-275, 649 (2016)  
*Prepared for the XXXVII International Conference on High Energy Physics, Valencia, Spain, 2-9 July 2014*

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