

# Francesco Santanastasio

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Born: 9 February 1980 — Roma, Italy  
Nationality: Italian

## Current Position

*CERN Research Fellow in Experimental Particle Physics*  
PH Department, CERN, Geneve, Switzerland

## Areas of specialization

Particle Physics, Data Analysis in High Energy Physics, Physics beyond the Standard Model of Fundamental Interactions, Electromagnetic and Hadronic Calorimetry

## Career

- Sept 2011 - **CERN Research Fellow in Experimental Particle Physics**  
today SUPERVISOR: Dott. Maurizio Pierini (CERN)  
CERN, Geneve, Switzerland
- Dec 2007 - **Post-Doctoral Research Assistant (Post-Doc) in Particle Physics**  
Aug 2011 SUPERVISOR: Prof. Sarah Eno (UMD)  
University of Maryland, College Park, MD, US  
Based at CERN, Geneve, Switzerland
- Nov 2004 - **PhD in Physics**  
Jan 2008 “Search for Supersymmetry with Gauge-Mediated Breaking using high energy photons at CMS experiment” [46]  
ADVISORS: Prof. Egidio Longo, Prof. Shahram Rahatlou, Dott. Daniele del Re (Sapienza)  
Sapienza Università di Roma, Roma, Italy
- Sept 1998 - **Laurea in Physics** (highest honors)  
May 2004 “Calibration of an electromagnetic calorimeter using the energy flow method” [47]  
ADVISORS: Prof. Egidio Longo (Sapienza), Dott. Riccardo Paramatti (INFN)  
Mark: 110/110 “magna cum laude”  
Sapienza Università di Roma, Roma, Italy

## Highlights of Research Activities

- Dec 2007 - to-day - Actively involved in the research activities of the exotic physics group (Exotica) of the CMS experiment, looking for evidence of new physics beyond the Standard Model of fundamental interactions [see “Talks at Conferences”].
- Dec 2007 - Aug 2011 - Search for pair production of first generation scalar Leptoquarks ( $LQ$ ) in the decay channels  $LQ\overline{LQ} \rightarrow eeqq$  [2, 23, 24, 39, 40] and  $LQ\overline{LQ} \rightarrow evqq$  [1, 38] with the CMS detector using the first  $36 \text{ pb}^{-1}$  of LHC collisions collected in 2010 at  $\sqrt{s} = 7 \text{ TeV}$ .
- Sep 2011 - to-day - Supervising a PhD student from Princeton University for the update of the  $LQ$  analyses with  $4.7 \text{ fb}^{-1}$  of data collected in 2011 at  $\sqrt{s} = 7 \text{ TeV}$  [3, 37], extending the exclusion on the  $LQ$  mass from about 400 GeV to 800 GeV, as well as with the  $19.6 \text{ fb}^{-1}$  of data collected in 2012 at  $\sqrt{s} = 8 \text{ TeV}$ , where the expected  $LQ$  mass exclusion is above 1 TeV [analysis in progress].
- Sept 2011 - Jul 2012 - Search for narrow resonances decaying into a pair of jets using the dijet mass spectrum with  $4.7 \text{ fb}^{-1}$  of data collected in 2011 at  $\sqrt{s} = 7 \text{ TeV}$  [4, 34] by the CMS detector. The lower mass limits on these resonances reach up to 4.3 TeV, depending on the model. The preliminary result preceding this publication included a novel trigger, data acquisition, and analysis strategy to recover sensitivity to new physics at dijet masses below 1 TeV [22].
- Mar 2012 - today - Supervising a PhD student from FNAL / Cukurova University (Turkey) for the update of the dijet analysis with the first  $4 \text{ fb}^{-1}$  of data collected in 2012 at  $\sqrt{s} = 8 \text{ TeV}$  [5, 33], as well as with the full 2012 data sample of  $19.6 \text{ fb}^{-1}$  [21, 32]. The 8 TeV results extend the previous 7 TeV exclusions on the resonance masses up to 5.1 TeV, depending on the model.
- Dec 2011 - to-day - Search for heavy  $WW / ZZ / WZ / qW / qZ$  resonances in semi-leptonic  $\ell\nu jj / \ell\ell jj$  [18, 30, 19, 31] and fully hadronic [6, 20, 35] final states at CMS using jet substructure techniques to identify the hadronic decays of boosted vector bosons.
- Jan 2013 - to-day - Coordination of the “*Exotica Lepton+Jets Working Group*” of the CMS experiment: analysis group working on searches for new physics beyond the Standard Model in final states containing leptons and jets (dedicated searches for Supersymmetry in these final states are performed in a different CMS working group).
- Mar 2012 - Mar 2013 - Coordination of the “*Dataset Definition Team*” of the CMS experiment: task force created to bring together experts from different areas (physics coordination, trigger study group, physics validation team, etc...) and acting as a main forum for the discussion of all the aspects related to the definition, maintaining and monitoring of the data streams to be used for physics analysis and detector calibration in 2012. Contribution to the design and the implementation of the *data parking* and the *data scouting* in the CMS experiment [25].
- Jun 2011 - Jun 2012 - Member of the “*Analysis Review Committee*” for the scrutiny of two public CMS results within the collaboration: top cross section measurements in all hadronic decay channel [28, 54] and search for Randall-Sundrum gravitons decaying into a jet plus missing transverse energy final state [7, 29] with 2011 collision data at  $\sqrt{s} = 7 \text{ TeV}$ .

- Sept 2008 - Coordination of the “*Prompt Feedback Group*” of the hadronic calorimeter (HCAL) of the CMS experiment: monitoring and data analysis concerning problems in the HCAL detector during data-taking of cosmic rays [see “Talks in Plenary Meetings of the CMS Collaboration” → presentations on behalf of the HCAL group].  
Sept 2010
- Nov 2009 - Commissioning of missing transverse energy (MET) reconstructed with the first proton-proton ( $pp$ ) collisions at  $\sqrt{s} = 0.9, 2.36$  and 7 TeV collected by the CMS experiment [26, 27, 41, 42].  
Sept 2010
- Nov 2009 - Development and implementation of algorithms for the identification of anomalous, beam-induced signals (“noise”) in the Hadronic Forward Calorimeter (HF) of the CMS experiment, observed in the first  $pp$  collisions at  $\sqrt{s} = 0.9, 2.36$  and 7 TeV [43].  
Sept 2010
- Jun 2009 - Jul 2009 Contribution to the test beam of the hadronic calorimeter of the CMS experiment (HCAL Test Beam 2009 [8]): commissioning and calibration of the “*delay wire chambers*” installed along the H2 beam line (CERN, Prevezsin site) for beam position measurements.
- Jan 2008 - Jul 2008 Commissioning of the hadronic calorimeter (HCAL) of the CMS experiment: “on-call” support for data acquisition (DAQ) and trigger configurations of HCAL during early periods of cosmic-ray data-taking.
- Dec 2006 - Feasibility study of the search for Gauge Mediated Supersymmetry Breaking (GMSB) models in the prompt photon decay channel  $pp \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 + X \rightarrow \tilde{G} \tilde{G} \gamma \gamma + X$  [46], with full simulation of the CMS detector.  
Dec 2007
- Jul 2006 - Monitoring of the high voltage system of the CMS electromagnetic calorimeter (ECAL) and data-taking shifts in the combined ECAL+HCAL test beam at CERN, Prevezsin site (H2 Test Beam 2006 [10]).  
Sept 2006
- Mar 2006 - Analysis and test of stability of ECAL high voltage system including development of software tools for data analysis [12].  
Nov 2006
- Oct 2005 - Study of the calibration of the CMS electromagnetic calorimeter using  $\pi^0 \rightarrow \gamma \gamma$  decays with full detector simulation [11, 44, 45].  
Oct 2006
- Jan 2003 - Study and implementation of the energy flow technique applied to the calibration of the electromagnetic calorimeter of the L3 experiment at LEP (CERN) [47].  
May 2004

## Talks at Conferences

- 08-10.05.2013 **Workshop LHCpp 2013** - VI Workshop Italiano sulla Fisica p-p a LHC  
INFN - Sezione di Genova  
Genova, Italy  
*"Hadronic Resonances"*  
Invited talk to present a review on this topic, including results from ATLAS and CMS Collaborations  
Conference proceedings [[13](#)]
- 12-15.09.2012 **PIC2012** - XXXII Physics in Collision 2012  
Strbske Pleso, Slovakia  
*"Exotic Phenomena Searches at Hadron Colliders"*  
Presentation in plenary session on behalf of the ATLAS and CMS Collaborations  
Conference proceedings [[14](#)]
- 13-20.03.2011 **Moriond/EW 2011** - Rencontres de Moriond on "EW Interactions and Unified Theories"  
La Thuile, Valle D'Aosta, Italy  
*"Exotica Searches at CMS"*  
Presentation in plenary session on behalf of the CMS Collaboration  
Conference proceedings [[15](#)]
- 19-23.04.2010 **DIS2010** - XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects  
Firenze, Italy  
*"Searches With Early Data At CMS"*  
Presentation in parallel session on behalf of the CMS Collaboration  
Conference proceedings [[16](#)]
- 15-17.04.2009 **IFAE2009** - Incontri di Fisica delle Alte Energie, VIII Edizione  
Bari, Italy  
*"Prospects for Exotica Searches at ATLAS and CMS Experiments"*  
Presentation in parallel session on behalf of the ATLAS and CMS Collaborations  
Conference proceedings [[17](#)]

## Talks in Plenary Meetings of the CMS Collaboration

- Mar 2010 **CMS General Weekly Meeting GWM11** - Preliminary results, plots, lessons from the first 7 TeV collisions - CERN, Geneva, Switzerland  
*"Report from HCAL/JetMET"*  
Presentation in plenary session on behalf of the HCAL and Jet/MET groups of the CMS experiment
- Jan 2010 **Riunione CMS Italia** - Pisa, Italy  
*"Example of prompt analysis at CERN: Jet/MET commissioning with first collision data"*
- Sept 2009 **CMS Commissioning and Run Coordination meeting** - CRAFT (Cosmic Run At Four Tesla) 2009 Data Analysis Jamboree - CERN, Geneva, Switzerland  
*"HCAL (Hadronic Calorimeter of CMS experiment) performance during CRAFT09"*  
Presentation in plenary session on behalf of the HCAL group of the CMS experiment
- Nov 2008 **CMS Commissioning and Run Coordination meeting** - CRAFT (Cosmic Run At Four Tesla) 2008 Data Analysis Jamboree - CERN, Geneva, Switzerland  
*"HCAL (Hadronic Calorimeter of CMS experiment) achievements during CRAFT08"*  
Presentation in plenary session on behalf of the HCAL group of the CMS experiment

## Teaching

- Jun 2012 - CERN - Geneve, Switzerland  
Aug 2012 *Supervisor of an undergraduate student from L’Institut de Physique Nucleaire de Lyon (INPL) in the contest of the “2012 CERN summer student” program*  
The student’s project in the summer of 2012 was well integrated in the contest of the CMS search for new, massive resonances decaying to a pair of jets. The student developed a statistical tool that was successfully used to estimate the significance of an excess of events seen in the data [36].
- Oct 2005 - Sapienza Università di Roma - Roma, Italy  
Feb 2006 *Teaching assistant for the course of “Fisica Generale I - meccanica classica”*  
Exercises of classic mechanics for mathematics majors

## Physics Schools

- 12-22.08.2008 **2008 Joint CERN-Fermilab Hadron Collider Physics Summer School**  
Fermilab, Batavia, Illinois, US
- 09-14.06.2005 **Italo-Hellenic School of Physics 2005**  
Martignano, Lecce, Italy  
*“The Physics of LHC: theoretical tools and experimental challenges”*

## Languages

*Italian* (native speaker)

*English* (fluent)

## Summary of Research Activities

In fall 2007, towards the end of my PhD studies in Rome, I decided to start a learning experience abroad in order to continue the research activity in particle physics at an high energy physics laboratory and to broaden my knowledge in this field.

In December 2007, I started an appointment as post-doctoral research assistant (*post-doc*) in particle physics at the University of Maryland. Since then I have been based at the CERN (Conseil Européen pour la Recherche Nucleaire) laboratory, working in the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) and focusing primarily on:

- analysis of proton-proton ( $pp$ ) collision data within the exotic physics group (Exotica), looking for evidence of new physics beyond the Standard Model of Fundamental Interactions (SM);
- commissioning, “*prompt analysis*” and detector performance studies of the hadronic calorimeter (HCAL);
- performance studies of missing transverse energy (MET) reconstruction with first  $pp$  collision data at LHC.

In September 2011, I started an appointment as Research Fellow in experimental particle physics at CERN, and I decided to continue my research activities in the CMS experiment. Since then, I have been extending my involvement in the Exotica group (by starting new physics analysis efforts). In March 2012, I began to coordinate a working team of the CMS experiment devoted to the definition, maintaining, and monitoring of the data streams to be used for physics analysis and detector calibration during the 2012 data taking. Since January 2013, I’m also one of the two coordinators of the “*Exotica Lepton+Jets Working Group*” of the CMS experiment, an analysis group working on searches for new physics beyond the SM in final states containing leptons and jets.

### RESEARCH ACTIVITIES RELATED TO PHYSICS ANALYSIS OF PP COLLISION DATA

Since the beginning of my post-doctoral appointment, I have been actively involved in the research activities of the CMS Exotica group, which is devoted to search for new physics phenomena beyond the SM. I presented the results of these analyses in international conferences on behalf of the CMS collaboration [see “Talks at Conferences”].

I started my activities in the Exotica group in 2008 with the search for pair production of first generation scalar “*leptoquarks*” (LQ) in the  $LQ\bar{L}Q \rightarrow eeqq$  decay channel ( $eejj$ ).

Leptoquarks are conjectured particles foreseen by some well-motivated theories beyond of the SM: they are coloured, have fractional electric charge, and couple to a lepton and a quark via an unknown coupling. The process under study has a very characteristic signature, with two high transverse momentum ( $p_T$ ) electrons and two high  $p_T$  jets, and a peak in the electron-jet invariant mass spectrum corresponding to the LQ mass.

The feasibility study, done in 2009 with full simulation of the CMS detector [24, 40], aimed to the optimization of selection criteria to reject the SM backgrounds, and to study techniques to estimate them directly from data.

The analysis has been performed with  $33 \text{ pb}^{-1}$  of  $pp$  collisions at  $\sqrt{s} = 7 \text{ TeV}$  collected by the CMS experiment in 2010 [2, 23, 39]. The data was in good agreement with the SM predictions. Therefore a 95% “*confidence level*” lower limit was set on the mass of first generation scalar LQ at  $384 \text{ GeV}/c^2$ , assuming a branching ratio of 100% for the decay  $LQ \rightarrow eq$ . This result exceeded the existing Tevatron limit on the LQ mass of  $300 \text{ GeV}/c^2$ , obtained with  $1 \text{ fb}^{-1}$  of proton-antiproton collisions

at  $\sqrt{s} = 1.96$  TeV, hence extended the search for leptoquarks in an unexplored mass region. The paper has been published in the Phys. Rev. Lett. journal.

In addition to the  $eejj$  analysis, I was the contact person of the search for pair production of first generation scalar leptoquarks in the  $LQ\bar{L}Q \rightarrow e\nu qq$  decay channel ( $e\nu jj$ ) [1, 38]. The combination of the results from these two channels has been used to improve the sensitivity to the new physics in the space of the unknown parameters of the theory model:  $M_{LQ}$  vs  $\beta$ , where  $M_{LQ}$  is the LQ mass, and  $\beta$  ( $1 - \beta$ ) is the branching ratio of the decay  $LQ \rightarrow eq$  ( $LQ \rightarrow \nu q$ ). The  $e\nu jj$  analysis has been published in the Phys. Lett. B journal using  $36 \text{ pb}^{-1}$  of data collected in 2010.

I have been involved in this search also during 2011 and 2012, by supervising a PhD student from the Princeton University to update both the  $eejj$  and  $e\nu jj$   $LQ$  analyses using the  $4.7 \text{ fb}^{-1}$  of data collected in 2011 by the CMS experiment [3, 37] as well as the  $19.6 \text{ fb}^{-1}$  of data collected in 2012 at  $\sqrt{s} = 8$  TeV [analysis in progress]. The 2011 analysis has been published in the Phys. Rev. D journal in combination with a complementary second-generation  $LQ$  search, extending the exclusion on the  $LQ$  mass from about 400 GeV to 800 GeV, thanks to the improvements in the analysis and the larger statistics available. The 2012 analysis should extend its sensitivity to leptoquarks masses above 1 TeV, thanks to the higher energy in the center of mass and the larger data sample compared to 2011.

Although low mass scale LQs, accessible at current colliders, are generally not considered to be one of the preferred extensions of the SM, searches for LQ pair production can be regarded as a prime example for new signatures with leptons, jets and MET with a SM background dominated by weak boson and top-pair production, and therefore represent important benchmark analyses. Furthermore, results from leptoquark searches can be interpreted in the context of Supersymmetry models with R-Parity Violating (RPV) decays to set lower limits on the mass of squarks decaying to leptons and quarks.

In September 2011, I started an appointment as Research Fellow in experimental particle physics at CERN and I joined the CMS analysis group working on a search for new resonances decaying to a pair of jets in the dijet mass spectrum.

Proton-proton collisions can produce two or more energetic jets when the constituent partons are scattered with large transverse momenta,  $p_T$ . The invariant mass spectrum of the two jets with largest  $p_T$  (dijets) is predicted to fall steeply and smoothly by quantum chromodynamics (QCD). Many extensions of the SM predict the existence of new massive objects that couple to quarks (q) and/or gluons (g), thus resulting in resonances in the dijet mass spectrum. The analysis is sensitive to a wide range of new physics models, including string resonances, excited quarks, axigluons, new vector bosons ( $W'$ ,  $Z'$ ), and Randall-Sundrum (RS) gravitons (G).

The first analysis was an update of the previous CMS published result [199], but performed with the entire  $4.7 \text{ fb}^{-1}$  data sample collected in 2011 at  $\sqrt{s} = 7$  TeV [4, 34]. The search was then repeated using the first  $4 \text{ fb}^{-1}$  of data collected in 2012 at  $\sqrt{s} = 8$  TeV [5, 33], as well as with the full 2012 data sample of  $19.6 \text{ fb}^{-1}$  [21, 32]. I'm currently the contact person of the 2012 dijet analysis, supervising the main analyst (a PhD student from FNAL / Cukurova University, Turkey). The  $4 \text{ fb}^{-1}$  result has been submitted for publication in the Phys. Rev. Lett. journal, while the  $19.6 \text{ fb}^{-1}$  analysis (at the moment a public preliminary result) is also aiming to a combined publication in 2013 with a search for heavy resonances decaying to pairs of b-jets. The current lower mass limits on heavy dijet resonances reach up to 5.1 TeV, depending on the model, extending by more than 1 TeV the previous limits based on 2011 data.

When I joined the dijet analysis group in 2011, I focused primarily on the improvements compared to the previous result. I am the main developer of the novel trigger, data acquisition, and analysis strategy employed in the 2011 search to recover sensitivity to new physics at dijet masses below 1 TeV [34]. In the standard analysis, the region below 1 TeV (dominated by a very large rate of events from QCD processes) is dropped due to limitations in the available jet trigger bandwidth. This is a natural consequence of the steady increase of the LHC instantaneous luminosity during 2011 and



2012. It is important to be able to explore this mass range since new resonances weakly-coupled to SM particles could still be hiding at low mass within large QCD background.

My proposal consists in performing the dijet search using a special sample of data collected with low jet  $p_T$  triggers (high rate of events), but storing only a reduced event content (small size per event). This allows to keep the bandwidth (rate of events  $\times$  size per event) to values acceptable by the data acquisition system. The reduced event content consists primarily of physics objects reconstructed at High Level Trigger (HLT), such as HLT jets which are the main ingredient for the dijet search, while the raw data from the detector electronics (full event content) are not saved. A similar conceptual design has already been used in CMS for detector calibration purpose, but it is the first time that this is employed for physics analysis. The dijet analysis, based on this special data sample of  $130 \text{ pb}^{-1}$  collected in 2011, has been delivered as a public preliminary result [22] by the CMS collaboration. In 2012, we have collected 100 times more data with a similar trigger setup. This data will be analyzed in 2013 extending significantly the sensitivity to heavy dijet resonances in the 300 GeV–1 TeV mass range.

In 2012, the CMS experiment has employed the trigger strategy discussed above to design (and test) a more general *data scouting* tool for the online monitoring of those searches that are usually limited by the available trigger bandwidth. This fast preview of the data would allow to change the definition of the regular data stream, in case a potential new physics signal shows up in a region not covered by the triggers defining the stream with full event content. The definition of the *data scouting* monitoring system is part of the duties of the “Dataset Definition Team” (DDT) that I have been asked to coordinate in March 2012. The DDT is a task force created to bring together experts from different areas (physics coordination, trigger study group, physics validation team, etc...) and acting as a main forum for the discussion of all the aspects related to the definition, maintaining and monitoring of the data streams to be used for physics analysis and detector calibration in 2012. The DDT group has also contributed to the design of the *data parking* in CMS [25]. The core physics program of CMS at  $\sqrt{s} = 8 \text{ TeV}$  is realized using collision data collected at an average event rate of 300–350 Hz. The core data are promptly reconstructed at CERN and are generally available within 48 hours for physics analysis. Extra 300–350 Hz (which became 600 Hz toward the end of the 2012 data taking) are collected to extend the physics program (both SM measurement and searches for new physics). The triggers defining the parked datasets are either a looser version of the core physics triggers (for instance with reduced  $p_T$  thresholds on the reconstructed objects) or brand-new triggers with small overlap with the rest. These data were temporarily “parked”, waiting to be reconstructed at the end of 2012 data taking (when computing resources would be available). This provides a complementary set of collision events to perform new physics analyses or improve the existing ones (thanks to the increased trigger acceptance) during the 2013–14 LHC shutdown.

My current physics program in CMS is focused on searches for new heavy resonances decaying into pairs of vector bosons (WW / ZZ / WZ) or vector boson and quark (qW / qZ) which are foreseen by many models of physics beyond the SM such as technicolor, composite Higgs, Sequential Standard Model, and others. The WW / ZZ final state is also one of the possible decays of the Randall-Sundrum graviton. The analysis is performed in semi-leptonic  $\ell\nu jj$  /  $\ell\ell jj$  [18, 30, 19, 31] and fully hadronic [6, 20, 35] final states, and it focuses on resonances which are sufficiently heavy to result in vector bosons with large energy/ $p_T$ . In this scenario, the hadronic decay products of each vector boson are merged into a single massive jet. Jet substructure techniques are used to identify such decays in this boosted regime.

The analysis group is constituted by about 10 main analysts (for a total of more than 20 people involved) from CERN, Peking University, John Hopkins University, Sao Paulo Research and Analysis Center (SPRACE), FNAL, University of Wisconsin, and *L’Institut de Physique Nucleaire de Lyon* (INPL). I am the contact person and one of the analysts of the  $\ell\nu jj$  search based on  $19.6 \text{ fb}^{-1}$  of data collected in 2012 at  $\sqrt{s} = 8 \text{ TeV}$ . I’m also supervising a PhD student from Peking University resident



at CERN working on this channel. All the analyses are aiming to a publication in 2013, possibly combining the results from the different channels for a few benchmark models of new resonances.

Since January 2013, I am one of the two coordinators of the “*Exotica Lepton+Jets Working Group*” in the CMS experiment, an analysis group working on searches for new physics beyond the SM in final states containing leptons and jets (dedicated searches for Supersymmetry in these final states are performed in a different CMS working group). The wide physics program of this group consists in about 15 different searches for new physics in pp collisions at  $\sqrt{s}=8$  TeV (including searches for heavy Randall-Sundrum gravitons decaying to WW/ZZ final states, first / second / third generation leptoquarks, heavy Dirac or Majorana neutrinos, Technicolor, etc..) performed by physicists from more than 30 institutions in the CMS collaboration. The conveners have the responsibility to make sure that all important topics are prioritized, and high quality analyses delivered thanks to a careful scrutiny of the analysis. It’s important to ensure good contacts between the analysts and the detector experts, to guarantee that the most recent recommendations from the detector groups are propagated in the analyses, as well as with theorists, to be up to date on possible uncovered, exotic experimental signatures suggested by new theoretical models. The conveners should oversee the analyses, encourage people in the group to actively participate to the discussions, and make sure that young people get credits for their work.

Between June 2011 and June 2012, I have been member of the “*Analysis Review Committee*” (ARC) for the scrutiny of two public CMS results within the collaboration: the top cross section measurements in all hadronic decay channel [28, 54] and a search for Randall-Sundrum gravitons decaying into a massive jet plus missing transverse energy final state ( $G \rightarrow ZZ \rightarrow \nu\nu jj$ ) [7, 29]. The ARCs take an important role in the approval process of physics analyses within the CMS collaboration.

#### OTHER RESEARCH ACTIVITIES DURING MY POST-DOC AT UNIVERSITY OF MARYLAND

At CMS, the hadronic calorimeter HCAL is mainly employed, together with electromagnetic calorimeter ECAL, for the reconstruction of jets and the missing transverse energy in the event, hence playing an important role for many physics analyses. The very forward part of the HCAL is also used for luminosity measurement.

For the first six months of my appointment with the University of Maryland, I was involved in the HCAL commissioning, providing on-call support for data acquisition (DAQ) and trigger configurations during the early period of cosmic-ray data-taking by the CMS detector. In Summer 2009, I contributed to test beam studies of the hadronic calorimeter (HCAL Test Beam 2009 [8]) by commissioning and calibrating the “*delay wire chambers*” installed along the H2 beam line (CERN, Preessin site) for beam position measurements.

For two years, starting from September 2008, I coordinated the HCAL “*Prompt Feedback Group*” (PFG) of the CMS collaboration, composed of about 5-10 people. The PFG worked on data analysis related to anomalies found in the detector, including problems in the firmware of electronics boards, data-format and trigger issues, as well as the support to groups devoted to the online (“*Data Quality Monitoring*”, DQM) and offline (“*Run Certification*”) control of data quality.

On various occasions, I presented to the CMS collaboration the status of the detector on behalf of the HCAL group, including talks in plenary meetings that followed the two main cosmic-ray data-taking periods in 2008 and 2009 [see “*Talks in Plenary Meetings of the CMS Collaboration*” → talks on behalf on the HCAL group].

At the beginning of 2010, I coordinated the HCAL PFG in preparation to the first LHC  $pp$  collisions at  $\sqrt{s} = 7$  TeV, which occurred on 30 March 2010. For this event we provided results in real time giving evidence of the collisions. The following day, I presented to a CMS plenary meeting the

results of the very first detector performance analyses based on the  $pp$  collisions on behalf of the HCAL and Jet/MET groups [see “Talks in Plenary Meetings of the CMS Collaboration” → talks on behalf on the HCAL and Jet/MET group].

In conclusion the PFG, under my coordination, provided an active contribution to both the HCAL commissioning in 2008-2009, and to the regular operation of the detector during the physics data-taking in 2010.

In addition to the research activities related to electromagnetic and hadronic calorimeters, I joined in November 2009 the Jet/MET group of CMS, that is employed in development and performance studies of jets and MET reconstruction. In the first months of 2010, I played an active role in the MET commissioning, using the first  $pp$  collision data at  $\sqrt{s}=0.9, 2.36$  [27] and 7 TeV [26]. In particular, I am the main author of the following works: study of performance of the “*uncorrected calorimeter*” MET [42], classification of events in the non-gaussian tails of the MET distribution [41], and development and implementation of algorithms for the identification of anomalous, beam-induced noise in the Hadronic Forward Calorimeter (HF) [43]. The anomalous signals observed in HF can produce large apparent MET in the event; therefore it’s crucial to identify and reject them during the event reconstruction, since such uncharacteristic signals can worsen the precision of some physics measurements, or even simulate a fake signature of new physics beyond the SM. The understanding of the performance of jets and MET reconstruction is an important point for the physics analyses I’m currently working on.

#### RESEARCH ACTIVITIES DURING MY UNDERGRADUATE AND GRADUATE STUDIES

My interest in elementary particle physics drove me to choose this field when I was an undergraduate student in Rome and, since 2004, to do research as part of the CMS collaboration at the LHC of CERN.

In 2003, I started working on my undergraduate thesis at *Sapienza*, Università di Roma. The work concerned the study of the calibration of an electromagnetic calorimeter using the energy flow method [47], which allows to inter-calibrate calorimeter crystals by using the  $\phi$  symmetry of energy deposits at a collider.

In October 2004, I was admitted to the graduate school in physics to work with the CMS group. The Rome group was heavily involved in the construction of the electromagnetic calorimeter (ECAL), as well as in monitoring and calibration. In my three years as a graduate student I worked on the calibration of the calorimeter, the stability of the ECAL high voltage (HV) system and feasibility studies for physics analysis on the search for Supersymmetry.

In 2006, I worked on the feasibility study of using  $\pi^0 \rightarrow \gamma\gamma$  decays for the calibration of the ECAL crystals [44, 45]. This method has the advantage of high statistics, since  $\pi^0$  are produced in abundance at hadron colliders, and does not rely on information from the detectors measuring tracks from charged particles, and hence could be performed “*in situ*” in the early periods of data-taking of LHC if the alignment and calibration of the high precision tracking system are not yet understood. The real challenge of this analysis is finding a satisfactory signal to noise ratio while maintaining high selection efficiency for such events in order to achieve a calibration of the entire ECAL in a short period of data-taking.

In 2011, the CMS experiment collected enough data to calibrate at regular intervals of few months both the central (barrel) and the forward (endcaps) region of ECAL using  $\pi^0$ ’s. The plans for 2012 foresee the improvements of the methods to calibrate the endcaps, to contribute at the monitoring of the crystal transparency loss due to the high radiation environment at LHC, as well as the combination of different calibration techniques that are available, in order to achieve the design

precision on the ECAL calibration in the whole detector acceptance.

During summer of 2006, I participated in the combined test beam of the electromagnetic and hadronic calorimeters of the CMS experiment at the H2 area of CERN, Preveessin site (H2 Test Beam 2006 [10]), mainly performing data-taking shifts. An important feature of the H2 test facility was the possibility to produce a secondary beam of  $\pi^0$ 's by inserting a target along the primary charged pion beam line. This data [11] was used to verify and improve the  $\pi^0 \rightarrow \gamma\gamma$  reconstruction algorithm developed for the calibration studies with simulated events. During this period, I also worked on the monitoring of the ECAL high voltage system, which is under the direct responsibility of the Rome group.

My other activities included both development and implementation of the analysis software for the stability test of HV boards, and the relative analysis of data collected since 2003 [12]. The stability of the HV system is very important for the operation of ECAL because it affects directly the energy resolution of the electromagnetic calorimeter.

In 2007, I worked mainly on feasibility study of the search for Supersymmetry with Gauge-Mediated Breaking (GMSB) in the prompt photon decay channel  $pp \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 + X \rightarrow \tilde{G} \tilde{G} \gamma\gamma + X$  (see PhD thesis [46]). The presence of two high energy photons and large missing transverse energy in the final state due to gravitinos makes the experimental signature of such events very clear. This feasibility study, aimed at the optimization of selection criteria to reject SM backgrounds, showed that GMSB models, with parameters just above the limit fixed by Tevatron experiments, could be an early discovery at the CMS experiment with a few tens  $\text{pb}^{-1}$  of data and  $\sqrt{s} = 14$  TeV. This result was significantly better than the one shown by previous studies reported in the CMS collaboration.

## References

### PUBLICATIONS (RELATIVE TO RESEARCH ACTIVITIES)

- [1] **“Search for First Generation Scalar Leptoquarks in the  $e\nu jj$  channel in pp collisions at  $\sqrt{s} = 7$  TeV”**  
S. Chatrchyan *et al.* [CMS Collaboration],  
Phys. Lett. B **703**, 246 (2011), [arXiv:1105.5237 [hep-ex]].  
I am the contact person and one of the two analysts (from University of Maryland group) of this CMS paper based on collision data.
- [2] **“Search for Pair Production of First-Generation Scalar Leptoquarks in pp Collisions at  $\sqrt{s} = 7$  TeV”**  
V. Khachatryan *et al.* [CMS Collaboration]  
Phys. Rev. Lett. **106**, 201802 (2011), [arXiv:1012.4031 [hep-ex]]  
I am one of the four analysts (from University of Maryland group) of this CMS paper based on collision data.
- [3] **“Search for pair production of first- and second-generation scalar leptoquarks in pp collisions at  $\sqrt{s} = 7$  TeV”**  
S. Chatrchyan *et al.* [CMS Collaboration]  
Phys. Rev. D **86**, 052013 (2012) [arXiv:1207.5406 [hep-ex]].  
I supervised the main analyst (a PhD student from Princeton University) of the first-generation search included in this CMS paper based on collision data.
- [4] **“Search for narrow resonances and quantum black holes in inclusive and b-tagged dijet mass spectra from pp collisions at  $\sqrt{s} = 7$  TeV”**  
S. Chatrchyan *et al.* [CMS Collaboration]  
JHEP **1301**, 013 (2013) [arXiv:1210.2387 [hep-ex]].  
I am one of two analysts of the inclusive dijet search reported in this CMS paper based on collision data.
- [5] **“Search for narrow resonances using the dijet mass spectrum in pp collisions at  $\sqrt{s} = 8$  TeV”**  
S. Chatrchyan *et al.* [CMS Collaboration]  
arXiv:1302.4794 [hep-ex] (2013) , Paper submitted to Phys. Rev. Lett.  
I am the contact person of this CMS paper based on collision data. I supervised one of the two analysts working on this search (a PhD student from FNAL / Cukurova University, Turkey).
- [6] **“Search for heavy resonances in the W/Z-tagged dijet mass spectrum in pp collisions at 7 TeV”**  
S. Chatrchyan *et al.* [CMS Collaboration]  
arXiv:1212.1910 [hep-ex] (2012) , Paper submitted to Phys. Lett. B  
I’m part of the analysis group involved in this CMS search which is constituted by almost 10 people from CERN, John Hopkins University, and *L’Institut de Physique Nucleaire de Lyon* (INPL).
- [7] **“Search for exotic resonances decaying into WZ/ZZ in pp collisions at  $\sqrt{s} = 7$  TeV”**  
S. Chatrchyan *et al.* [CMS Collaboration],  
JHEP **1302**, 036 (2013) [arXiv:1211.5779 [hep-ex]]  
I was member of the “*Analysis Review Committee*” for the scrutiny of the ZZ search in jet plus missing transverse energy final state within the CMS collaboration.

This analysis with 7 TeV data is closely related with the searches for WW/ZZ resonances at 8 TeV which I'm currently involved in.

- [8] **“Study of various photomultiplier tubes with muon beams and Cherenkov light produced in electron showers”**  
S. Chatrchyan *et al.* [CMS HCAL Collaboration]  
JINST 5, P06002 (2010)  
The data were collected during the HCAL Test Beam 2009. I contributed to commissioning and calibration of the “*delay wire chambers*” installed along the H2 beam line (CERN, Preveessin site) for beam position measurements.
- [9] **“Identification and Filtering of Uncharacteristic Noise in the CMS Hadron Calorimeter”**  
S. Chatrchyan *et al.* [CMS Collaboration]  
JINST 5, T03014 (2010) [arXiv:0911.4881 [physics.ins-det]]
- [10] **“The CMS Barrel Calorimeter Response To Particle Beams From 2-Gev/C To 350-Gev/C”**  
S. Abdullin *et al.* [USCMS Collaboration and ECAL/HCAL Collaboration]  
Eur. Phys. J. C **60**, 359 (2009) [Erratum-ibid. C **61**, 353 (2009)]
- [11] **“Intercalibration of the barrel electromagnetic calorimeter of the CMS experiment at start-up”**  
P. Adzic *et al.* [CMS Electromagnetic Calorimeter Group]  
JINST 3, P10007 (2008)  
I performed a feasibility study of using  $\pi^0 \rightarrow \gamma\gamma$  decays for the calibration of the ECAL crystals, with full detector simulation.
- [12] **“High voltage system for the CMS electromagnetic calorimeter”**  
A. Bartoloni *et al.*  
Nucl. Instrum. Meth. A **582**, 462 (2007)  
I performed part of the stability tests on the high voltage boards at CERN laboratory and most of the data analysis

- [13] **“Searches for Heavy Hadronic Resonances with the ATLAS and CMS detectors at the LHC”**  
 F. Santanastasio, C. Doglioni  
 PoS LHCPP2013, 015 (2013)  
*Prepared for the Workshop LHCpp 2013 - VI Workshop Italiano sulla Fisica p-p a LHC, INFN - Sezione di Genova, Genova, Italy, 8-10 May 2013*
- [14] **“Exotic Phenomena Searches at Hadron Colliders”**  
 F. Santanastasio  
 arXiv:1301.2521 [hep-ex] (2013)  
*Prepared for the XXXII Physics in Collision 2012 conference (PIC2012), Strbske Pleso, Slovakia, 12-15 September 2012*
- [15] **“Exotica searches at the CMS experiment”**  
 F. Santanastasio  
 Proceedings of the XLVIth Rencontres de Moriond 2011 Electroweak Interactions and Unified Theories, 125-132 (2011), edited by Etienne Auge, Jacques Dumarchez, and Jean Tran Thanh Van © The Gioi Publishers  
*Prepared for XLVIth Rencontres de Moriond 2011 Electroweak Interactions and Unified Theories, La Thuile, Aosta Valley, Italy, 13-20 March 2011*
- [16] **“Searches With Early Data At CMS”**  
 F. Santanastasio  
 PoS DIS2010, 206 (2010)  
*Prepared for 18th International Workshop on Deep Inelastic Scattering and Related Subjects (DIS 2010), Florence, Italy, 19-23 Apr 2010*
- [17] **“Prospects for Exotica Searches at ATLAS and CMS Experiments”**  
 F. Santanastasio  
 Il Nuovo Cimento Vol.32 C, N.3-4 ncc9484 (2009)  
*Prepared for Incontri di Fisica delle Alte Energie (IFAE 2009), Bari, Italy, Apr 2009*

PRELIMINARY RESULTS OF THE CMS COLLABORATION (RELATIVE TO RESEARCH ACTIVITIES)

- [18] **“Search for new resonances decaying to  $WW$  to  $l\nu q\bar{q}$  in the final state with a lepton, missing transverse energy, and single reconstructed jet”**  
 [CMS Collaboration]  
 CMS PAS EXO-12-021 (2013), <http://cds.cern.ch/record/1590301/files/EXO-12-021-pas.pdf>  
 I am the contact person of this CMS analysis based on collision data, one of the four main analysts, and the main editor of this public CMS document. I supervised one of the two main analysts working on this search (a PhD student from Peking University, China). The analysis is aiming for publication in 2013 in combination with a complementary search for ZZ resonances (EXO-12-022).
- [19] **“Search for a narrow spin-2 resonance decaying to Z bosons in the semileptonic final state”**  
 [CMS Collaboration]  
 CMS PAS EXO-12-022 (2013), <https://cds.cern.ch/record/1596494/files/EXO-12-022-pas.pdf>  
 I’m part of the analysis group involved in this CMS search which is constituted by about 10 people from CERN, KIT, Peking University, SPRACE, and University of Perugia. The analysis is aiming for publication in 2013 in combination with a complementary search for WW resonances (EXO-12-021).

- [20] **“Search for heavy resonances in the W/Z-tagged dijet mass spectrum in pp collisions at 8 TeV”**  
 [CMS Collaboration]  
 CMS PAS EXO-12-024 (2013), <http://cds.cern.ch/record/1563153/files/EXO-12-024-pas.pdf>  
 I’m part of the analysis group involved in this CMS search which is constituted by almost 10 people from CERN, John Hopkins University, and *L’Institut de Physique Nucleaire de Lyon* (INPL).
- [21] **“Search for Narrow Resonances using the Dijet Mass Spectrum with 19.6 fb<sup>-1</sup> of pp Collisions at sqrt(s)=8 TeV”**  
 [CMS Collaboration]  
 CMS PAS EXO-12-059 (2013), <http://cds.cern.ch/record/1519066/files/EXO-12-059-pas.pdf>  
 I’m the contact person and the main editor of this public CMS document. I supervised the main analyst working on this search (a PhD student from FNAL / Cukurova University, Turkey).
- [22] **“Search for Narrow Resonances using the Dijet Mass Spectrum in pp Collisions at sqrt(s)=7 TeV”**  
 [CMS Collaboration]  
 CMS PAS EXO-11-094 (2012), <http://cds.cern.ch/record/1461223/files/EXO-11-094-pas.pdf>  
 I am the main developer of the novel trigger, data acquisition, and analysis strategy employed in this search to recover sensitivity to new physics at dijet masses below 1 TeV.
- [23] **“Search for Pair Production of First Generation Leptoquarks Using Events Containing Two Electrons and Two Jets Produced in pp Collisions at sqrt(s) = 7 TeV”**  
 [CMS Collaboration]  
 CMS PAS EXO-10-005 (2010), <http://cdsweb.cern.ch/record/1289514/files/EXO-10-005-pas.pdf>  
 I am co-author and one of the four analysts (from University of Maryland group) of this public CMS Physics Analysis Summary based on collision data.
- [24] **“Search for Pair Production of First Generation Scalar Leptoquarks at the CMS Experiment”**  
 [CMS Collaboration]  
 CMS PAS EXO-08-010 (2009), <http://cdsweb.cern.ch/record/1196076/files/EXO-08-010-pas.pdf>  
 I am co-author and one of the four analysts (from University of Maryland group) of this public CMS Physics Analysis Summary based on MC simulation.
- [25] **“Data Parking and Data Scouting at the CMS Experiment”**  
 [CMS Collaboration]  
 CMS DP-2012/022 (2012), [http://cds.cern.ch/record/1480607/files/DP2012\\_022.pdf](http://cds.cern.ch/record/1480607/files/DP2012_022.pdf)  
 I’m the main editor of this public CMS document.
- [26] **“Missing Transverse Energy Performance in Minimum-Bias and Jet Events from Proton-Proton Collisions at sqrt(s)=7 TeV”**  
 [CMS Collaboration]  
 CMS PAS JME-10-004 (2010), <http://cdsweb.cern.ch/record/1279142/files/JME-10-004-pas.pdf>
- [27] **“Performance of Missing Transverse Energy Reconstruction in sqrt(s)=900 and 2360 GeV pp Collision Data”**  
 [CMS Collaboration]  
 CMS PAS JME-10-002 (2010), <http://cdsweb.cern.ch/record/1247385/files/JME-10-002-pas.pdf>  
 I worked mostly on the section related to calorimeter MET cleaning algorithms and performances.



- [28] **“Measurement of the  $t\bar{t}$  production cross section in the fully hadronic decay channel in pp collisions at 7 TeV”**  
 [CMS Collaboration]  
 CMS PAS TOP-11-007 (2011), <http://cdsweb.cern.ch/record/1371755/files/TOP-11-007-pas.pdf>  
 I was member of the “*Analysis Review Committee*” for the scrutiny of this public CMS result within the collaboration.
- [29] **“Search for Randall-Sundrum Gravitons Decaying into a Jet plus Missing ET at CMS”**  
 [CMS Collaboration]  
 CMS PAS EXO-11-061 (2012), <http://cdsweb.cern.ch/record/1426654/files/EXO-11-061-pas.pdf>  
 I was member of the “*Analysis Review Committee*” for the scrutiny of this public CMS result within the collaboration.

INTERNAL NOTES OF THE CMS COLLABORATION (RELATIVE TO RESEARCH ACTIVITIES)

- [30] **“Search for a BSM resonance decaying to W vector bosons in the semileptonic final state”**  
 F. Santanastasio *et al.*  
 CMS AN-2013/045 (2013)  
 I am the contact person of this CMS analysis based on collision data and one of the four main analysts. I supervised one of the two main analysts working on this search (a PhD student from Peking University, China). The analysis is aiming for publication in 2013 in combination with a complementary search for ZZ resonances (EXO-12-022).
- [31] **“Search for a BSM resonance decaying to Z vector bosons in the semileptonic final state”**  
 F. Santanastasio *et al.*  
 CMS AN-2013/040 (2013)  
 I’m part of the analysis group involved in this CMS search which is constituted by about 10 people from CERN, KIT, Peking University, SPRACE, and University of Perugia. The analysis is aiming for publication in 2013 in combination with a complementary search for WW resonances (EXO-12-021).
- [32] **“Search for Narrow Resonances using the Dijet Mass Spectrum in pp Collisions at  $\sqrt{s}=8$  TeV with full 2012 dataset”**  
 F. Santanastasio *et al.*  
 CMS AN-2012/455 (2012)  
 I am the contact person of this CMS analysis based on collision data. I supervised the main analyst working on this search (a PhD student from FNAL / Cukurova University, Turkey). A public preliminary result has been released by the CMS collaboration on February 2013 in view of the Moriond/EW conference. The analysis is aiming for publication in 2013 in combination with a search for high mass resonances decaying to pairs of b-quarks.
- [33] **“Search for Narrow Resonances using the Dijet Mass Spectrum in pp Collisions at  $\sqrt{s}=8$  TeV”**  
 F. Santanastasio *et al.*  
 CMS AN-2012/229 (2012)  
 I am the contact person of this CMS analysis based on collision data. I supervised one of the two analysts working on this search (a PhD student from FNAL / Cukurova University, Turkey). This analysis has been submitted for publication to the PRL journal in January 2013.
- [34] **“Search for Dijet Resonances in the Dijet Mass Spectrum in pp Collisions at  $\sqrt{s}=7$  TeV”**  
 F. Santanastasio *et al.*  
 CMS AN-2012/012 (2012)

I am one of the two analysts (from a group of about 10 people from various institutions including CERN) of this CMS analysis based on  $4.7 \text{ fb}^{-1}$  of pp collision data collected in 2011. I am the main developer of the novel trigger, data acquisition, and analysis strategy employed in this search to recover sensitivity to new physics at dijet masses below 1 TeV. This analysis has been published in 2012 in combination with a complementary search for heavy resonances decaying in pairs of b-quarks.

- [35] **“Search for  $qW/qZ/WW/WZ/ZZ$  Resonances in the W/Z-tagged Dijet Mass Spectrum from 7 TeV pp Collisions at CMS”**  
F. Santanastasio *et al.*  
CMS AN-2011/524 (2011)  
I’m part of the analysis group involved in this CMS search which is constituted by almost 10 people from CERN, John Hopkins University, and *L’Institut de Physique Nucleaire de Lyon* (INPL). This analysis has been submitted for publication to the PLB journal in December 2012.
- [36] **“Significance estimation for the dijet resonance search using 8 TeV pp collision data”**  
F. Santanastasio, C. Guichardant *et al.*  
CMS AN-2012/325 (2012)  
I am the supervisor of this “2012 CERN summer student” project realized by an undergraduate student from *L’Institut de Physique Nucleaire de Lyon* (INPL).
- [37] **“Search for First-Generation Scalar Leptoquarks in pp Collisions at  $\sqrt{s}=7$  TeV using the CMS Detector”**  
F. Santanastasio *et al.*  
CMS AN-2011/492 (2011)  
I am one of the two analysts (supervising a PhD student from Princeton University) of this CMS analysis based on  $4.7 \text{ fb}^{-1}$  of pp collision data collected in 2011. This analysis has been published in 2012 in combination with a complementary second-generation leptoquark search.
- [38] **“Search for Pair Production of First-Generation Scalar Leptoquarks Using Events Produced in pp Collisions at  $\sqrt{s}=7$  TeV Containing One Electron, Two Jets and Large Missing Transverse Energy”**  
F. Santanastasio *et al.*  
CMS AN-2010/361 (2010)
- [39] **“Search for Pair Production of First Generation Leptoquarks Using Events Containing Two Electrons and Two Jets Produced in pp Collisions at  $\sqrt{s}=7$  TeV”**  
F. Santanastasio *et al.*  
CMS AN-2010/230 (2010)
- [40] **“Search for Pair Production of First Generation Scalar Leptoquarks at the CMS Experiment”**  
F. Santanastasio *et al.*  
CMS AN-2008/070 (2009)
- [41] **“Results of a visual scan of high MET events in 7 TeV pp collision data”**  
F. Santanastasio *et al.*  
CMS AN-2010/219 (2010)
- [42] **“Commissioning of Uncorrected Missing Transverse Energy in Zero Bias and Minimum Bias Events at  $\sqrt{s}=900$  GeV and 2360 GeV”**  
F. Santanastasio *et al.*  
CMS AN-2010/029 (2010)

- [43] “Optimization and Performance of HF PMT Hit Cleaning Algorithms Developed Using pp Collision Data at  $\sqrt{s}=0.9, 2.36$  and 7 TeV”  
F. Santanastasio *et al.*  
CMS DN-2010/008 (2010)
- [44] “InterCalibration of the CMS Barrel Electromagnetic Calorimeter Using Neutral Pion Decays”  
F. Santanastasio *et al.*  
CMS DN-2007/013 (2007)
- [45] “Study of ECAL calibration with  $\pi^0 \rightarrow \gamma\gamma$  decays”  
F. Santanastasio, D. del Re, S. Rahatlou  
CMS IN-2006/050 (2006)

#### THESES ( LAUREA AND PHD)

- [46] “Search for Supersymmetry with Gauge-Mediated Breaking using high energy photons at CMS experiment”  
F. Santanastasio  
PhD thesis at *Sapienza Università di Roma* (2007)  
<http://www.roma1.infn.it/cms/tesiPHD/santanastasio.pdf>
- [47] “Calibrazione di un calorimetro elettromagnetico tramite il flusso totale di energia”  
F. Santanastasio  
*Laurea* thesis at *Sapienza Università di Roma* (2004)  
<http://www.roma1.infn.it/cms/tesi/santanastasio.pdf>

#### OTHER PUBLICATIONS AND PRE-PRINTS OF THE CMS COLLABORATION

- [48] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1302.3968 [hep-ex].
- [49] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1302.2892 [hep-ex].
- [50] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1302.2812 [hep-ex].
- [51] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1302.2394 [hep-ex].
- [52] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1302.1764 [hep-ex].
- [53] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1302.0531 [hep-ex].
- [54] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1302.0508 [hep-ex].
- [55] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1301.5755 [hep-ex].
- [56] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1301.5023 [hep-ex].
- [57] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1301.4698 [hep-ex].
- [58] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1301.3792 [hep-ex].
- [59] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1301.2175 [hep-ex].
- [60] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1301.1646 [hep-ex].

- [61] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1301.0916 [hep-ex].
- [62] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1212.6428 [hep-ex].
- [63] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1212.6639 [hep-ex].
- [64] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1212.6660 [hep-ex].
- [65] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1212.6682 [hep-ex].
- [66] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1212.6961 [hep-ex].
- [67] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1212.6194 [hep-ex].
- [68] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Lett. B **2**, 3 (2013) [arXiv:1212.6175 [hep-ex]].
- [69] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1212.4563 [hep-ex].
- [70] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1212.1838 [hep-ex].
- [71] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1301**, 063 (2013) [arXiv:1211.4890 [hep-ex]].
- [72] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1211.4784 [hep-ex].
- [73] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1211.4462 [hep-ex].
- [74] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1211.3338 [hep-ex].
- [75] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1211.3143 [hep-ex].
- [76] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1302**, 085 (2013) [arXiv:1211.2472 [hep-ex]].
- [77] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1211.2220 [hep-ex].
- [78] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1301**, 077 (2013) [arXiv:1210.8115 [hep-ex]].
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- [81] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1210.7471 [hep-ex].
- [82] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1210.6718 [hep-ex].
- [83] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1210.5629 [hep-ex].
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- [88] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. Lett. **109**, 261802 (2012) [arXiv:1210.2402 [hep-ex]].
- [89] S. Chatrchyan *et al.* [CMS Collaboration], [arXiv:1210.2311 [hep-ex]].
- [90] S. Chatrchyan *et al.* [CMS Collaboration], [arXiv:1210.2052 [hep-ex]].

- [91] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Lett. B **718**, 348 (2012) [arXiv:1210.1797 [hep-ex]].
- [92] S. Chatrchyan *et al.* [CMS Collaboration], Eur. Phys. Jour. [Eur. Phys. J. C **72**, 2251 (2012)] [arXiv:1210.0875 [hep-ex]].
- [93] S. Chatrchyan *et al.* [CMS Collaboration], [arXiv:1210.0867 [hep-ex]].
- [94] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1211**, 147 (2012) [arXiv:1209.6620 [hep-ex]].
- [95] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1212**, 035 (2012) [arXiv:1209.4533 [hep-ex]].
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- [97] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1211**, 088 (2012) [arXiv:1209.3937 [hep-ex]].
- [98] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Lett. B **718**, 1208 (2013) [arXiv:1209.3807 [hep-ex]].
- [99] S. Chatrchyan *et al.* [CMS Collaboration], [arXiv:1209.3489 [hep-ex]].
- [100] S. Chatrchyan *et al.* [CMS Collaboration], [arXiv:1209.2922 [hep-ex]].
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- [102] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1212**, 105 (2012) [arXiv:1209.2319 [hep-ex]].
- [103] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. D **87**, 012006 (2013) [arXiv:1209.1805 [hep-ex]].
- [104] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1211**, 080 (2012) [arXiv:1209.1666 [hep-ex]].
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- [111] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1211**, 067 (2012) [arXiv:1208.2671 [hep-ex]].
- [112] S. Chatrchyan *et al.* [CMS Collaboration], [arXiv:1208.2470 [nucl-ex]].
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