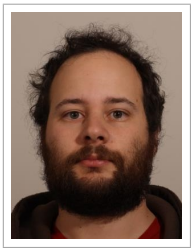

# Dr. Giacomo Ortona

Post-doc researcher at the LLR-Ecole Polytechnique.
Member of the CMS collaboration.

## Personal information


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Date of birth 14.07.1984

## Education

2009–2012 **PhD in Physics**, *Università Degli Studi di Torino*, PhD thesis topic: .
$D^+$ meson analysis at the LHC with ALICE. Discussed on March, 2nd, 2012

2006–2008 **Master degree**, *Università Degli Studi di Torino*, *110/110 cum laude*.
Master degree in Physics of Foundamental Interactions.
Dissertation: D mesons elliptic flow in Pb-Pb simulation for ALICE.
Supervisors: W. Alberico and M. Masera

2003–2006 **Bachelor's degree**, *Università Degli Studi di Torino*, *110/110*.
Bachelor's degree in Physics.
Dissertation: Distributed Measurement of Temperatures for the HADES MDC detector prepared at GSI (Darmstadt, Germany).

## PhD thesis

title *$D^+$ meson analysis at the LHC with ALICE.*

supervisors Prof. Dr. Massimo Masera

discussant Prof. Dr. Yves Schutz

description The thesis presents the analysis of the $D^+$ meson through its purely hadronic $D^+ \to K^-\pi^+\pi^+$ decay channel as it is done by the ALICE collaboration. The details of this analysis are described for proton–proton collisions at $\sqrt{s} = 7$TeV and $\sqrt{s} = 2.76$TeV and in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$TeV. The main results obtained in this decay channel are presented and compared to the results obtained for other open charm mesons. Special emphasis is given to fully discuss measurements such as the charm production cross–section in proton–proton collisions; the charm energy loss in the QGP and the charm elliptic flow from Pb–Pb collisions.



## Research Experience

Since October, 2014 I am a post-doc researcher at the Laboratoire Leprince-Ringuet with a grant founded by P2IO programme of the CNRS to study the Higgs boson physics.
Full list of 300+ publications available at: inspirehep.net
A detailed description of my research activities is listed in the "Research Activities" section.

### Fellowships and Fundings

2016–2018 **Marie Curie Individual Fellowship**, *European Union*.
Marie Skłodowska Curie Individual Fellowship awarded by the European Union Horizon2020 program to study a forward trigger for the CMS phase-2.

2014–2016 **Research Associate**, *Laboratoire Leprince-Ringuet* , Paris.
"CDD chercheur" position founded by P2IO and CNRS to study the Higgs trilinear coupling in the $bb\tau\tau$ final state.

2012–2014 **Research grant**, *Università degli Studi di Torino*.
Research grant awarded by University of Turin and Compagnia di San Paolo for research on the IMPACT project (Innovative Methods for Particle Colliders at the Terascale) studying the Higgs boson decay to 4 leptons.

2010–2011 **Associate Fellowship**, *CERN*, Geneva.
Fellowship for associate position at CERN.

2009–2011 **PhD grant**, *Università degli Studi di Torino*.
Full PhD grant.

12/2008 – 03/2009 **HELEN-ALFA fellowship**, *Universidade Federal do Rio de Janeiro*, Rio de Janeiro.
Grant for studying at UFRJ (Rio de Janeiro, Brazil) on elliptic flow in p-p collisions, in an European-Latin America exchange program ($\approx 5000$ €).

### Main Achievements

2014–now **HH$\rightarrow bb\tau\tau$.**

- Coordinator of the teams (≈80 people, ≈10 subgroups) studyng double Higgs production in CMS.
- Coordinator of the group (≈ 10 people from 2 different institutions) performing the Run2 HH$\rightarrow bb\tau\tau$ non-resonant analysis for CMS. In particularly focusing on Higgs self coupling to reconstruct Higgs potential and EWSB mechanism.
- Editor of the CMS Analysis Notes describing the analysis in 2015 (Analysis Note [4]) and 2016 (Analysis Note [3]).
- Leading role on the search for heavy particle decaying into Higgs pairs in the $bb\tau\tau$ final state. This search covers the low $\tan\beta$ MSSM scenario and offers insights into possible SM extensions. This analysis relies heavily on the tools I prepared for the Higgs self coupling measurement
- Main developer of the data processing tools used by several institutes (≈ 7 institutes) involved in the H$\rightarrow \tau\tau$ analyses in CMS.

2013–now **H$\rightarrow$ ZZ$\rightarrow 4l$ at CMS (off-shell)**.

- Main author and leading role in the analysis providing the measurement of the Higgs width from off-shell to on-shell cross-section ratio. This was the first time such an analysis has ever been proposed and performed [4].
- Use of the Off-shell technique to measure the Higgs lifetime and test the existence of anomalous couplings (Technical Note 6).
- Currently preparing the Run2 analysis.

2012–now **H→ ZZ→ $4l$ at CMS (on-shell)**.

Search discovery and measurement of the Higgs boson in the ZZ to 4l decay channel.

- Prepared the event selection algorithms for the Higgs searches and discovery.
- In charge of the statistical treatment of the data for the discovery of the Higgs boson (July 2012 [6]) and for the first measurement of its properties [5].
- Since I was the responsable for the H→ ZZ→ $4l$ statistical treatment, I was in charge of preparing the analysis statistical inputs (datacards) for the Higgs combination and legacy paper [2] and to assure their compatibility with the other analysis.
- Measurement of the Higgs boson Spin-Parity properties, with the confirmation of the scalar nature of the new particle [3]
- Currently responsible for the statistical framework preparation for the Run2 analysis and contact person for the combination with the other Higgs boson decay channels.

2012-2014 **Drift Tubes upgrades**.

Participation in the CMS DT upgrade operations (Technical Note 5) . Board testing, electronic controllers and installation at P5.

2012-2013 **Tag and Probe**.

Estimate of the efficiency of muon reconstruction and identification for different classes of muon and for different momenta and rapidities. Performed both on real data and simulations in order to provide correction factor for CMS simulations.

2010-2012 **Silicon Drift Detector**.

Maintenance and operation of the ALICE Silicon Drift Detector. I was the main responsible for detector working conditions and maintenance [11].

2009–2012 **Open charm at ALICE**.

- Measurement of the D meson (open-charm) production cross-section in pp collisions at 7 [2]] and 2.76 [10] TeV and in pPb collisions at the LHC with ALICE.
- Measurement of the open charm suppression in PbPb collisions at the LHC [9], one of the key proof for the creation of a thermalized medium.
- Measurement of the D meson elliptic flow in PbPb collisions at ALICE [7].

2008 **Elliptic flow MC studies**.

Studied the introduction of elliptic flow parameters in MC generators [12] and applied the resulting techniques to the simulation of QGP conditions in pp collision [13]

### Service and Professional activities

2014 **CSA14**.

Responsible for the definition of CMS Run2 data format and computing tools preparation (CSA14) for the Higgs to ZZ analyses.

2014 **Contact**.

Contact person for the Drift Tubes detector of CMS.

2012-2014 **Magnetic field mapping**.

Provided and updated the CMS magnetic field parametrization to be used in MC simulations of the detectors responses.

## Professional responsibilities and commitments

2015 **Conference organization**, *Organization of the Journées CMS-France Physique et Upgrade*, Paris, 30th September-2nd October 2015.

Main organizer of a national workshop of the CMS collaboration. 3 days conference, ≈50 participants.

2010–2011 **Detector expert**.
For one year I was on-call expert and main responsible for the activities and maintenance of the ALICE Silicon Drift Detector.

2007–2008 **University Board Member**, *Università degli Studi di Torino*.
Elected member of the University of Turin Board (Senato Accademico) as students' representative.

## Student supervision, Teaching and outreach

### Teaching activities and Student supervision

**Advisor**.
Continously supervised the activities of students PhD students:
S. Casasso for 2 year while developing his PhD project at the University of Turin.
L. Finco for 1 year while defining her thesis project at the University of Turin.
I am currently an advisor for L. Cadamuro at the Ecole Polytechnique-LLR.

2016 **Stage advisor**, *Ecole Polytechnique*, Paris.
I was the advisor for the Master1 intern project of Vladimir Ohanesjan, studying the off-shell Higgs production in the ZZ→4l channels in 13 TeV collisions at CMS.

2015 **Teacher**, *Università degli Studi di Bari*, Bari, CMS Data Analysis School.
I was a facilitator at the CMS Data Analysis School teaching statisics and the H→ZZ→ $4l$ analysis to a class of 10-15 PhD students.
Teaching load: 15 hours.

2013 **Teacher**, *DESY*, Hamburg, CMS Data Analysis School.
I was a facilitator at the CMS Data Analysis School teaching statisics and the H→ZZ→ $4l$ analysis to a class of 10-15 PhD students.
Teaching load: 15 hours.

2013 **Teaching Assistant**, *Università degli Studi di Torino*.
TA for the experimental nuclear physics class.
Teaching load: 12 weeks x 4 hours ($\approx 40$ students).

2005 **Tutor**, *State Technical and Industrial School "A. Avogadro"*, Torino.
Tutorship in physics for first year high school students. I gave auxiliary classes in physics to pupils of migrant origin in a pilot project.
Teaching load: 20 weeks x 2 hours ($\approx 10$ students).

### Outreach activities

2012 **Public outreach**, *INFN*, Torino.
Participation at "Notte dei ricercatori" a yearly outreach activity for the general public

2010 **MasterClass2010**.
*The ALICE experiment*, 2010, Torino, Italy.

2010 **School guide**, *INFN*, Torino.
School guide for the exhibitions "Esploratori dell'Universo" (*Invisibile Meraviglia*, organized by INFN and *Accelerating Science* organized by CERN) in the framework of ESOF2010

## Selected Publications

Most important publications in which I had a leading or key role:


[1] CMS Collaboration. Search for non-resonant Higgs boson pair production in the $b\bar{b}\tau^+\tau^-$ final state. (CMS-PAS-HIG-16-012), 2016

[2] Vardan Khachatryan et al. Precise determination of the mass of the Higgs boson and tests of compatibility of its couplings with the standard model predictions using proton collisions at 7 and 8 TeV. *Eur. Phys. J.*, C75(5):212, 2015, 1412.8662

[3] Vardan Khachatryan et al. Constraints on the spin-parity and anomalous HVV couplings of the Higgs boson in proton collisions at 7 and 8 TeV. *Phys. Rev.*, D92(1):012004, 2015, 1411.3441

[4] Vardan Khachatryan et al. Constraints on the Higgs boson width from off-shell production and decay to Z-boson pairs. *Phys. Lett.*, B736:64–85, 2014, 1405.3455

[5] Serguei Chatrchyan et al. Measurement of the properties of a Higgs boson in the four-lepton final state. *Phys. Rev.*, D89(9):092007, 2014, 1312.5353

[6] Serguei Chatrchyan et al. Observation of a new boson with mass near 125 GeV in pp collisions at $\sqrt{s} = 7$ and 8 TeV. *JHEP*, 06:081, 2013, 1303.4571

[7] B. Abelev et al. D meson elliptic flow in non-central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76TeV. *Phys. Rev. Lett.*, 111:102301, 2013, 1305.2707

[8] Betty Abelev et al. Measurement of charm production at central rapidity in proton-proton collisions at $\sqrt{s} = 2.76$ TeV. *JHEP*, 07:191, 2012, 1205.4007

[9] Betty Abelev et al. Suppression of high transverse momentum D mesons in central Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. *JHEP*, 09:112, 2012, 1203.2160

[10] B. Abelev et al. Measurement of charm production at central rapidity in proton-proton collisions at $\sqrt{s} = 7$ TeV. *JHEP*, 01:128, 2012, 1111.1553

[11] B. Alessandro et al. Charge collection in the Silicon Drift Detectors of the ALICE experiment. *JINST*, 5:P02008, 2010, 1001.2276

[12] M. Masera, G. Ortona, M. G. Poghosyan, and F. Prino. Anisotropic transverse flow introduction in Monte Carlo generators for heavy ion collisions. *Phys. Rev.*, C79:064909, 2009

[13] G. Ortona, G. S. Denicol, Ph. Mota, and T. Kodama. Elliptic flow in high multiplicity proton-proton collisions at s88(1/2) = 14-TeV as a signature of deconfinement and quantum energy density fluctuations. 2009, 0911.5158


### PhD Thesis


[14] Giacomo Ortona. *D+ meson analysis at the LHC with ALICE*. PhD thesis, INFN, Turin, 2012

## Notes and other publications

1. CMS PAS HIG-16-012 – Search for non-resonant Higgs boson pair production in the $bb\tau\tau$ final state **editor**.
2. CMS PAS HIG-16-013 – Search for resonant Higgs boson pair production in the $bb\tau\tau$ final state.
3. CMS AN-16/232 – Search for non-resonant Higgs boson pair production in the $bb\tau\tau$ final state with 2016 data. **editor**.
4. CMS AN-15/315 – Search for non-resonant Higgs boson pair production in the $bb\tau\tau$ final state **editor**.
5. CMS DN-2015/011 – CMS Drift Tubes Sector Collector Relocation Phase 1 Upgrade
6. CMS AN-2014/247 – Lifetime of the Higgs boson and constraints on its width considering anomalous couplings
7. CMS AN-2014/018 – A model-independent measurement of the Higgs boson width using off-shell production and decay to 4 leptons
8. CMS CR-2013/443 – Search for the SM Higgs boson in the ZZ channel at CMS **author**
9. CMS AN-2013/108 – Measurement of the production and decay of a Higgs boson in the four-lepton final state. **main author** (events selection and statistical analysis sections).
10. CMS AN-2012/367 – Updated results on the new boson discovered in the search for the standard model Higgs boson in the H $\rightarrow$ ZZ $\rightarrow$ 4l channel in pp collisions at $\sqrt{s} = 7$ and 8 TeV
11. CERN-PH-EP-DRAFT-ALICE-2012-006 Suppression of high transverse momentum D mesons in central Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

## Invited talks, colloquia and seminars

### Major international conferences

1. **ICHEP 2016**: *"Searches for double Higgs production or decay using the CMS detector*, Chicago, USA, scheduled for August 2016.
2. GDR Terascale 2015: *Combination of couplings and mass in ATLAS and CMS.* (on behalf of the CMS and ATLAS collaborations),Saclay, France, March 2015.
3. Physics at LHC and beyond: *Higgs width measurements at LHC* (on behalf of the CMS and ATLAS collaborations), 10-17 Aug 2014, Quy-Nhon (Viet Nam).
4. **ASPEN 2014**, Frontiers in Particle Physics: From Dark Matter to the LHC and Beyond: *Measurement of spin and parity of Higgs boson* (on behalf of CMS and ATLAS collaborations), January 2014, Aspen, USA.
5. ICNFP 2013: *Study of the SM Higgs boson in the ZZ channel at CMS*, September 2013, Kolymbari, Crete.
6. **Hard Probes 2012**: *Open-charm meson elliptic flow measurement in Pb-Pb collisions at* $\sqrt{s_{NN}} = 2.76$ *TeV with ALICE at the LHC*, June 2012, Cagliari, Italy.
7. EPIC@LHC 2011: *D meson analysis in Pb-Pb collisions at* $\sqrt{s_{NN}} = 2.76$ *TeV at the LHC with ALICE*, July 2011, Bari, Italy
8. **QuarkMatter 2011**: (poster) $D^+$ *analysis in Pb-Pb collisions at* $\sqrt{s_{NN}} = 2.76$ *TeV at the LHC with ALICE*, May 2011, Annecy, France.
9. CHARM2010: *Heavy flavours analysis in proton-proton collisions at the LHC with ALICE*, October 2010, Beijing, China.
10. XLVIII International Winter Meeting on Nuclear Physics: *Heavy flavours analysis in proton-proton collisions at the LHC with ALICE*, January 2010, Bormio, Italy
11. $26_{th}$ Winter Workshop on Nuclear Dynamics: *Open charm meson analysis in proton-proton collisions at the LHC with ALICE*, January 2010, Ocho Rios, Jamaica

### National conferences, colloquia and seminars

- CMS France 2015: $hh \to bb\tau\tau$ *non-resonant production for Run2*, September 2015, Palaiseau, France.
- CMS Higgs Workshop: *Higgs width results and perspective for run 2*, June 2015, Split, Croatia.
- LLR seminars: *Highlights from Moriond 2015*, march 2015, Palaiseau, France.
- CMS Italia 2012: *HZZ Analysis at CMS*, November 2012, Bologna, Italy.

## Schools and other studies

- 2013: *INFN School of statistics* (Vietri, Italy).
- 2012: *Summer school and workshop on the Standard Model and Beyond* (Corfu, Greece).
- 2010: *XX giornate di studio sui rivelatori* (Torino, Italy).
- 2009: *Nuclear Physics School R. Anni* (Otranto, Lecce, Italy).
- 2009: UFRJ: Studies at Federal University of Rio de Janeiro (UFRJ), Brazil as part of the HELEN program, working on elliptic flow in p-p collisions.
- 2008: Villa Gualino: *International school on QGP and Heavy Ion Collisions (Torino, Italy)*

- 2008: ECT*: Doctoral Training Programme *Nuclear Matter under Extreme Conditions* (Trento, Italy)
- 2006: GSI: International Summer Student Program (Darmstadt, Germany)

## Languages

| | |
|---|---|
| Italian | **Mother Tongue** |
| English | **Fluent (C2)** |
| French | **Intermediate (B1)** |
| Spanish | **Basic (A2)** |

## Computing skills

| | |
|---|---|
| OS | Microsoft, Mac and Linux distributions |
| Office suites | LaTeX, Open Office and Microsoft Office |
| Programming languages | C/C++, Python, Fortran, Java, Bash |
| Mathematical packages: | Mathematica |
| Other environments | ROOT, AliRoot, GEANT3, RooStat, TMVA |
| Grid computing | Capability to work on distributed calculus environments (GRID, farms) |

## References

| | |
|---|---|
| SDD | Massimo Masera, masera@to.infn.it |
| ALICE | Paolo Giubellino, pgiubell@cern.ch (ALICE spokeperson) |
| CMS | Chiara Mariotti, chiara.mariotti@cern.ch (LHCHXSWG convenor) |
| Higgs | Nicola Amapane, nicola.amapane@to.infn.it (CMS HZZ convenor) |
| Higgs off-shell | Andrei Gritsan, andrei.gritsan@cern.ch |
| Double Higgs | Roberto Salerno, salerno@llr.in2p3.fr |

## Detailed description of the research activities

In the following, I will present a detailed description of my current and past research activities, starting from the most recent ones. A summary of my main activities and achievements has been already presented in the previous sections of this curriculum vitae.

### Summary

I obtained my master degree in theoretical physics under the supervision of Prof. Wanda Alberico. **The subject of my thesis was the thermalization of open charm in the Quark Gluon Plasma (QGP)**. After obtaining my master degree, I won a research grant from the HELEN-ALPHA project (founded by the European Union) for a 3 months internship period at the Universitade Federal of Rio de Janerio (UFRJ). In this period I worked with prof. Takeshi Kodama of UFRJ on possible **signatures of QGP formations in proton-proton collisions**. I showed that under the Color-Glass-Condensate hypothesis it was possible to create a thermalized medium in pp collisions at the LHC and that an elliptic flow could be visible in such occurences. This was the first time such a measurement was proposed in pp collision.

At the end of my period in Brazil, I won a grant from the University of Torino to do a PhD in experimental heavy ion physics under the supervision of prof. Massimo Masera. **The subject of my PhD studies was the study of $D^+$ meson production** in pp collision and the use of $D^+$ related observables (such as their suppression and elliptic flow) **as a probe of QGP creation** in Pb-Pb collisions at the LHC. During my PhD studies I participated actively at the very first LHC data taking activities and I was involved in the maintenance and operation of the ALICE Silicon Drift Detector (SDD).

In 2010 I was appointed an **Associate Fellowship at CERN in order to supervise the SDD activities**Associate Fellowship at CERN in order to supervise the SDD activities and for that period I was the main responsible of the detector. After the successful heavy ion data taking period in November 2010 I finalized the analyses of $D$ meson suppression in Pb-Pb events and performed the **first measurement of the $D^+$ elliptic flow**.

After my PhD I joined the CMS team of Torino University on the IMPACT (Innovative Methods for Particle Colliders at the Terascale). The goal of the project, founded by Compagnia di Sanpaolo, is to coordinate efforts between experimental physicists, theoretical physicists ,and computer scientists, to provide excellent research in the field of high-energy particle physics. I joined the team searching for the Higgs boson at a praticularly exciting moment, since after a few months I joined it, my team was able to claim **evidence for the existence of the Higgs boson in the $H \to ZZ \to 4l$ channel**. I continued to work on this channel, one of the most sensitive available in CMS, to perform measurements of the Higgs boson properties such as spin, parity, mass and width.

In parallel to my research program on the Higgs boson, I participated to the development of the CMS Drift Tubes (DT) upgrade, helping developing the firmware and testing the electronic boards before their installation.

At the end of my research grant in Turin, I decided to move to the LLR-Ecole Polytechnique equipe led by Prof. Yves Sirois and Dr. Roberto Salerno to study the **double Higgs boson production at the LHC**. Here I took the lead role on the team performing the double Higgs boson production measurement in the $bb\tau\tau$ final state and the search for MSSM particles decaying in 2 standard model Higgs bosons. Since 2016 I am the convener and responsible of the analysis teams performing double Higgs boson production searches in CMS, consisting of about 80 people.

### Double Higgs production

*CMS Collaboration 2014-2016*

Double Higgs decay

After the completion of my research program in Turin, I joined the research team of Prof. Yves Sirois and Dr. Roberto Salerno to work on double Higgs boson production in the $bb\tau\tau$ final state. The goal of this analysis is to study the non-resonant double Higgs boson production to set limits on the strength of the Higgs boson trilinear coupling $\lambda_{\mathsf{hhh}}$. **The Higgs trilinear coupling is a fundamental parameter of the Standard Model of particle physics**, and its measurement would strongly constrain any New Physics model. This is a particularly challenging analysis since the double Higgs production is a very rare process and a luminosity much larger than what is available at the moment at the LHC is needed to constrain the Higgs trilinear coupling value at the level of the standard model predictions. On the other hand the analysis I am developing will profit from the increase in the center of mass energy from 8 to 13 TeV which will results in a ≈3.5 times increase in the double Higgs production and from the fact that several New Physics phenomena can dramatically change its value. The measurement is particularly sensitive to modifications to $\lambda_{\mathsf{hhh}}$ and to the Higgs to top Yukawa coupling. The $bb\tau\tau$ final state is particularly suitable for this measurement since provides a clear experimental signature without losing to much statistics from the branching ratios of the Higgs decays.

Analysis Strategy

Since my arrive at the LLR in 2014 **I took the lead of a small analysis team** (≈ 10 people) and I started to develop the analysis strategy. given the search for a very rare final state, the analysis has been developed in order to have a powerful background rejection power and we decided to use only one inclusive category in order not to reduce too much the amount of signal available in the different data samples. $\tau$ leptons are divided in different channels according to their decay mode ( $\mu$, e or hadronic) with at least one of the two $\tau$ decaying hadronically. The b candidates are sorted accordingly to their likelihood of coming from a real b quark. **The tools we designed to reconstruct $\tau$ pairs have been adopted by several other institutes** working on the standard model $h \to \tau\tau$ decay. I took care of preparing ad-hoc MC samples, generated with MadGraph, to simulate signal samples with different values of $\lambda_{hhh}$. We rely on standard CMS MonteCarlo simulations to study the different background contributions, with the only exception of the QCD background processes which are measured from data. The dominant background contributions are from $t\bar{t}$ decays and from QCD processes. I also took care of the study of the systematic uncertainties and of the development of the statistical model. A first set of results has been made public in a collaboration Physics Analysis Summary [1] with an update scheduled to be presented at **ICHEP2016** (August 2016).

Given the similarities between the two analyses, the tools prepared for the non-resonant analysis have been adapted to the **searches of an heavy scalar decaying to two standard model Higgs bosons** ($X \to hh \to bb\tau\tau$). For this analysis, we search for a narrow resonance over a large mass range. This search covers the low $\tan\beta$ MSSM scenario, in a phase space currently not accessible in other searches, and offers insights into possible SM extensions. Resonant Analysis

Thanks to the expertise I gained from performing the $bb\tau\tau$ analysis, **I was selected by the CMS collaboration to coordinate the analysis teams performing searches for double Higgs production in CMS**. Currently, there are about 80 people from ≈10 different analysis teams performing these analyses in CMS, covering 6 different final states ($bb\tau\tau$, $bbbb$, $bbWW$ $bb\gamma\gamma$, $bbZZ$, $\gamma\gamma\gamma\gamma$) for the double Higgs decay. All the searches involve both resonant and non-resonant production. hh coordinator

### Off-shell Higgs production measurement

*CMS Collaboration, 2013-2015*

The determination of the Higgs decay width is an important research topic, as it can narrow (or broaden) the phase space available for the presence of new physics. Unfortunately the SM prediction (4.15 MeV) is orders of magnitude below the resolution available with direct measurements at the LHC which is of a few GeV. In 2013, G. Passarino noticed that the fact that the Higgs decay mode in two on-shell Z opens up ($m_ZZ > 180$ GeV) not far away from the on-shell Higgs mass ($m_H \approx 125$ GeV) has a very peculiar effect on the Higgs boson production PDF, with a relative increase of the off-shell part of the Higgs boson spectrum that can account for as much as 10% of the total cross-section. After this, few theoreticians (F. Caola, N. Melnikov and Passarino himself) realized that the fraction of off-shell production is directly related to the Higgs boson width, and that under some basic and quite general assumptions (such as the couplings to the Higgs boson remaining unchanged between off-shell and on-shell) **the width can be obtained by the simple ratio of the off-shell to the on-shell production cross-sections**. Not only this ratio can be more precise than direct measurements, but most of the systematics uncertainties will cancel out in the ratio, further boosting its precision. The analysis was mainly based on the selection and strategy already used for the Higgs searches and properties measurements in $4l$. This was a precise choice since it allowed us to base ourselves on the already published on-shell results without introducing any bias. One complication of the analysis is that negative interference effects with the $gg \to ZZ \to 4l$ process must be taken into account, so I had to develop some **novel techniques inside CMS to treat processes with negative PDFs**.

The off-shell cross-section measurement was performed by generating the expected distributions of our signal and background processes using MC generators (PowHeg and MadGraph). We then performed a two-dimensional maximum-likelihood fit in the $m_{4l}$ and KD variables and letting the Higgs boson width to float along with the production signal strength. The signal strength was then constrained by the results of the on-shell analysis, and at this point the Higgs boson could be determined by the off-shell information.

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I was one of the main contributors to the off-shell Higgs analysis helping building the statistical model; the modelization of the interference effect on the PDF; determining the signal and background lineshape; helping assessing the signal/background K-factors; studying the systematic uncertainties on the measurement and building the combination with the on-shell results. I also took care of combining the $ZZ \to 4l$ results with the $ZZ \to 2l2\nu$ results. The analysis was able to set a limit[4] on the Higgs decay width just a few times higher than the SM expectation ($\Gamma < 5.4 \times \Gamma_{\text{SM}}$), **a 100 times improvement with respect to previous measurements**.

Since I was one of the main authors of the analysis, I was invited by the CMS collaboration to present this technique and the results at the Rencontres du Vietnam 2014, Physics at LHC and beyond (Vietnam).

Rencontres du Vietnam 2014

### Higgs to 4 leptons

*CMS Collaboration, 2012-2015*

In July 2012 I joined the CMS collaboration to work on the search of the SM Higgs boson in the $H \to ZZ^{(*)} \to 4l$ channel in pp collisions at $\sqrt{s} = 8$ TeV. It was generally accepted that the channel would ultimately offer some of the very best sensitivity to a Higgs boson over a large mass range and for this reason it was termed the **golden channel** given the high mass resolution and good signal-to-background ratio.

The analysis was designed to rely solely on the on the measurement of leptons, and it achieves high lepton reconstruction, identification, and isolation efficiencies for the signal candidates. In this way, the analysis would remain "inclusive" and avoid the complication of the higher order effects (recoil against the $4l$ system) and of the different production modes. This made sense as a starting basis since we knew that essentially only the production by gluon-gluon fusion could contribute significantly by the time we would establish a discovery. At low mass, the background sources comprise an irreducible $4l$ contribution from $ZZ^{(*)}$ continuum production. Reducible background contributions arise mainly from Z + X events, where X consists of two reconstructed leptons, at least one of which is a non-prompt lepton, including misidentified leptons, leptons from heavy-quark decays, or photon conversions. At the time I joined the analysis, the remaining allowed region for the Higgs boson to exist was a **narrow range in the low mass region**. This region is particularly challenging for the $H \to ZZ^{(*)} \to 4l$ analysis because a majority of the 4l events contain final state leptons at very low transverse momentum (e.g. $p_T < 10$ GeV/c) and preserving a very high efficiency for low $p_T$ leptons while avoiding the background from misidentified jets is very difficult.

8 TeV searches

In order to improve the sensitivity of the analysis I started to use data-driven techniques (**Tag & Probe**) to provide a precise estimate of the muon reconstruction and identification efficiency for different classes of muon and for different momenta and rapidities. This was performed both on real data and simulations, and this study allowed to provide a correction factor for the simulations to the collaboration. Having an accurate computation of the number of expected observation is crucial to the analysis, as the observed results must be compared to the Standard Model predictions. Therefore I studied the Higgs reconstruction efficiency from MonteCarlo. I developed an accurate parametrization of the signal and background shapes in the interesting mass region.

Taking into account that with more luminosity we accumulated more events, the kinematic of the $H \to ZZ^{(*)} \to 4l$ channel, that can be fully reconstructed from the 4 leptons in the final state, became useful to have additional discriminating power between signal and background events. For 2012 analysis, few physicists having expertise with matrix element likelihood analysis had joined the team. Together with them I helped to integrate a **kinematic discriminant** (KD) inside the analysis flow. The KD is based on the probability ratio of the signal and background hypotheses, which combines, for each value of $m_{4l}$, the two di-lepton masses and the five angular variables in the 4l center-of-mass frame. I was in charge of preparing the final statistical framework for the statistical fits and for the combination with the other searches inside CMS (datacards). The final 2012 results were performed using a 2D maximum-likelihood fits for each value of mH, in the variables $m_{4l}$ and KD.

Discovery of a new boson

The results of the analysis performed with $5fb^{-1}$ collected at $\sqrt{s} = 7$ TeV and $5fb^{-1}$ collected at $\sqrt{s} = 8$ TeV were presented during the July 2012 CERN seminar. The observed upper limit indicates the presence of a **significant excess of events in the low m4l mass range**. These events cluster around a mass $m_{4l} = 126$ GeV, giving rise to a local excess with respect to the background expectation, with a significance of 3.2 $\sigma$. The result constitutes evidence for a new massive state. The combination of this analysis with the other SM Higgs searches, mainly $H \to \gamma\gamma$, resulted in the **discovery of a new massive neutral boson**[6], opening a new chapter in the history of particle physics.

Properties measurement

The analysis was further improved before the HCP conference (November 2012), when an additional 7 $fb^{-1}$ were collected at $\sqrt{s} = 8$ TeV. The **mass** of the newly discovered boson was measured with extremely high precision and for the first time the **spin-parity** is studied. The measurement of the mass is obtained using a maximum-likelihood fit to three-dimensional distributions combining for each event the m4l, the associated per-event uncertainties $\delta m_{4l}$, and KD. An estimate for the mass of 126.2 $\pm$ 0.6 (stat.) $\pm$ 0.2 (syst.) GeV is obtained. Combined with the compatible results from the $\gamma\gamma$ channel, we obtain a mass of 125.8 $\pm$ 0.4 (stat.) $\pm$ 0.4 (syst.) GeV. This value improves upon and supersedes any previous result.
Because the kinematics of the production and decay of the new boson in the $ZZ \to 4l$ channel are sensitive to its spin and parity, to distinguish any two spin-parity hypotheses we construct a new discriminant in the same way of the KD. Under the assumption of spin zero, the observed data are consistent with the pure scalar hypothesis, while disfavouring the pure pseudoscalar one, corresponding to a CLs value of 2.4%[5].

Legacy paper

For the end of the 2010-2012 LHC data taking campaign, the analysis was improved by the introduction of two different **jet categories** in order to discriminate between the gluon fusion and vector boson scattering production modes. The analysis was done on $5fb^{-1}$ collected at $\sqrt{s} = 7$ TeV and $19.7fb^{-1}$ collected at $\sqrt{s} = 8$ TeV, the full luminosity available at these energies. The final statistical treatment is performed in two different jet-based categories using a three-dimensional maximum-likelihood fits for each value of mH, in the variables $m_{4l}$, KD and a third category dependent variable. I was responsible for the collection of the results and for their statistical treatment, as well as for the introduction of the categorization in the code.

Several kinematic discriminants were introduce in order to test a whole range of spin-parity hypotheses for the Higgs boson. As a result, the pure scalar hypothesis is clearly favourite over all other tested spin and parities. The **Higgs boson couplings** are compatible with the standard model predictions and the final Higgs boson mass in the $4l$ channel alone is measured to be 125.59 $\pm$ 0.45 GeV. With the increased statistics the local excess significance at 125 GeV is now more the $5\sigma$ in the $4l$ channel alone. These results were collected in the so-called Legacy Paper[2] which summarize all the Higgs run 1 results.

ICNFP2013
Aspen2014
GDR2015
conferences

Thanks to my contributions and to my understanding of the subject, I was asked several times to present the CMS and ATLAS results on the Higgs searches and properties at international conferences. I presented for the first time the *Study of the SM Higgs boson in the ZZ channel at CMS* in 2013 at the International Conference on New Frontiers of Physics. Then in 2014 I presented the measurement of the Spin and Parity of the Higgs boson at CMS and ATLAS at the **Aspen 2014 conference** and finally I presented the *Combination of couplings and mass in ATLAS and CMS* at GDR 2015.

## DT Upgrade

*CMS Collaboration 2013-2014*

The Sector Collector (SC) relocation was the first step of the upgrade program of the Drift Tubes subdetector of the CMS experiment. Realization of the project took place in the Long Shutdown 2013-2014 in order to be ready for 2015 data taking period. It consisted in the **relocation of the second level of trigger (TSC) and read-out (ROS) electronics** from the experimental cavern to the USC service cavern, thus freeing it from the hazardous environment in the detector, minimizing the downtime in case of failure and allowing further upgrades not tighten to LHC long shutdowns. Since SC inputs are based on copper links whose length cannot be increased without compromising its reliability, a custom copper to optical link conversion (CuOF) capable of working as an extension of the not fully DC-balanced links has been developed and implemented. Since for the first stage of the Phase 1 upgrade program present ROS and TSC boards will be used, a backwards optical to copper conversion has also been produced for the 3500 links. I was deeply involved in the DT upgrade operations. During 2013 I helped in **testing the performance of all the 490 CuOF mezzanines** and I performed ageing tests on the boards in Torino to make sure the boards were capable of sustain the harsh environmental conditions of the CMS experimental area. Later in 2014 I moved to CERN to help develop the boards firmware with experts from other institutions and I worked on cabling all the boards in the CMS experimental cavern. The DT upgrade program for the 2013-2014 shutdown was completely successfully and according to schedule, and this will allow the DT to work reliably and stably for the LHC run 2 data taking.

Ageing tests

Installation at CERN

## D meson analysis

*ALICE Collaboration 2009-2012*

$D^+$ analysis preparation

Having prepared all the tools to properly simulate open-charm behaviour at the LHC, in the second half of 2009 I started to design the **charged D mesons analysis at ALICE** experiment in proton-proton collisions. I focused expecially on Like Sign subtraction and fitting analysis tools to subtract the large background contrbutions. This implied also participating in the work of ALICE physics working group 3 and to the D mesons paper preparation group. I reported these results several times at CERN during this period and I was selected to present the analysis strategy for the 2010 proton-proton data taking at two international conferences, the $26^{\text{th}}$ Winter Workshop on Nuclear Dynamics held in Ocho Rios, Jamaica and the XLVIII International Winter meeting on Nuclear Physics in Bormio, Italy, on behalf of the whole collaboration.

XXVI WWND

XLVIII Bormio conferences

In 2010 I moved to CERN to coordinate the first real data analyses with the other groups working on open charm and to help supervise the data taking operations of the ALICE SDD. The D meson analysis was divided in 3 subgroups and I was selected to **lead one of the subgroups** (focusing on the decays of the $D^+$, with the others working on $D^0$ and $D^*$).

D meson in pp

I started to analyze the data collected in p-p collisions at the LHC and to prepare the benchmark measurement for the Heavy Ion run foreseen for the end of 2010. I performed the **measurement of the $D^+$ meson production cross-sections**[10] at 7 TeV which is by itself an important test of perturbative QCD predictions and it is a necessary reference to measure heavy flavour suppresssion in the QCD. A second reference with p-p collisions at 2.76 TeV was taken at the end of 2011 run[8]. Just before the starting of the first LHC Pb-Pb run in November 2010 I was pleased to be selected by the collaboration to present all the collaboration heavy flavour results at the CHARM2010 conference in Beijing, China.

CHARM2010

Following the successful Heavy Ion run on November 2010, it was finally possible for the ALICE collaboration to start with its main physics program, i.e. the study and characterization of the QGP. In the first part of 2011 I focused on the **measurement of the energy loss suffered by charm quarks in the Quark Gluon Plasma** at the LHC. In addition to the measurement of the charm energy loss, also the **elliptic flow of $D^+$ meson** was studied since May 2011. Since I was in charge of the $D^+$ measurement in Pb-Pb, I was selected by the ALICE collaboration to report the details of the $D^+$ results in a poster at **Quark Matter 2011**, one of the top 3 conferences for the community working on the QGP, and the whole D meson analysis performed with ALICE at the EPIC2011 conference in Bari, Italy. I finalized the analysis of the open charm elliptic flow in Pb-Pb collision in the first part of 2012 and I was chosen to present it at Hard Probes 2012 (Cagliari, Italy), another important conference for QGP topics.. During this period I was also in charge of writing the paper drafts for the D meson suppression in Pb-Pb[9] and D meson elliptic flow[7] publications.

D meson in PbPb

QM2011

EPIC2011

HP2012

## SDD maintenance

*ALICE Collaboration 2010-2011*

My team in Torino was responsible for the design, construction and maintenance of the ALICE Silicon Drift Detector (SDD)[11]. The SDD formed the second layer of the ALICE Inner Tracking System and is characterized not only by having excellent tracking power but also by its capability to perform at the same time the identification of low momentum particles. These capabilities come at the price of having a detector very sensible to environmental factors and it was therefore crucial to have **constant monitoring of the detector performances** during its first years of activity. I was chosen to perform this tasks for the period 2010-2011. My main responsibility was to be **detector on-call expert**, meaning that I was always reachable in case of emergencies. I teached detector shifter how to monitor the status of the detector and I performed some mechanical interventions on the SDD cooling system. I also had the duty to report promptly to the ALICE coordination on the activities, needs and status of the detector operations.

## Elliptic flow in MC simulations

*2008-2009*

I started to work on **hydrodinamical simulations of the Quark-Gluon-Plasma** during my master thesis with Prof. Wanda Alberico and Massimo Masera, and I continued this activity during my first year of PhD. After the discussion of my master thesis I won an HELEN (High Energy Physics Latin American European Network) grant to pursue this topic at the Universidade Federal do Rio de Janeiro (UFRJ) for the first months of 2009. The HELEN project was a Europe-Latin America exchange program founded by the European Commission under the framework of the ALFA (America Latina Formacion Academica) project. My research activities in Rio de Janeiro were performed under the supervision of prof. Takeshi Kodama. In this period my focus was on the **simulation of proton-proton collisions evolution using hydrodinamical models** (mainly based on ideal hydrodinamic) to evaluate the chance of observing elliptic flow in proton-proton collisions at LHC. As a result of this work, I showed [13] that it even in p-p collisions it is possible to create high enough local energy densities to create a thermalized medium and that it should be possible to detect the effects of this medium creation at the LHC. After the end of my period at the UFRJ I started my PhD in Torino under the supervision of prof. Massimo Masera and Francesco Prino. Here, I started to study efficient and accurate ways to introduce elliptic flow and angular correlations between particles in hydrodynamic simulations. We developed a **novel recipe to introduce elliptic flow in MonteCarlo code after hadronization** and we showed that this new method was much more accurate than the algorithms available at the time [12].

HELEN grant at UFRJ

Elliptic flow in MC simulations

Paris, 28/07/2016

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