

# Fabien TARRADE

## Research experience:

During my PhD and my positions as a research associate in the ATLAS experiment, I have realized how **promising** are the physics which is produced in proton-proton collisions at **high energy**: Searching for one or more Higgs Boson(s) and new particles is a **fantastic activity**. The competition for the discovery of a Standard Model Higgs boson with the Tevatron and the CMS experiment was very exciting. My **leading work** in the Higgs group ( $H \rightarrow ZZ^{(*)} \rightarrow 4l$  analysis) is **very fascinating**, very instructive and **very productive**, resulting in the publication of important conference notes and papers. I **have played a key role** in the **discovery** of a new particle of mass around  $125 \text{ GeV}/c^2$  consistent with the Standard Model Higgs Boson which was announced by physicists from the ATLAS and CMS collaboration at the LHC on 4<sup>th</sup> of July 2012 during a special seminar at CERN. The **experience** I have **acquired** within the ATLAS experiment during the last seven years, especially by analysing the 2011 and 2012 collision data, will be **very crucial** for any **position** in **high-energy** physics.

During my short career as Research Associate at Brookhaven National Laboratory (BNL, USA) and as Research Associate at Carleton University (Canada) I **played a leading role** in the **Higgs searches** and **discovery**, in the preparation and production of **the list of good runs/events** and in the **calibration** of the ATLAS detectors. I am now the **co-convener** of the Higgs group responsible for the  $H \rightarrow ZZ$ ,  $H \rightarrow Z'Z$ ,  $H \rightarrow Z'Z'$  and  $ZH$ ,  $H \rightarrow \text{invisible}$  analyses; this is an international team, consisting of more than 150 physicists (students to senior scientific), that plays a major role in the Higgs discovery. As co-convener of this group I coordinated the **publications** of the 4 majors HSG2 LHC run I legacy papers and organize the **preparation** of analyses for LHC run II. In 2011, 2012 and 2013 I was **editor** of 7 of the 10  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  analysis papers and conference notes. I **published 5 conference notes and 2 papers**. I was **editor** of the  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  analysis for the 2012 HCP and the 2013 Moriond EW **conference notes**. These conference notes had more than **115 contributors** and I **organized** and **managed** this group in daily interaction with  $H \rightarrow ZZ$  conveners, Higgs conveners, Physics conveners and the ATLAS spokesperson. This task of being an editor of this important channel for Higgs searches, mass, signal strength, spin-parity and couplings measurement is much greater than being an editor of a standard note with 5-6 persons. Since I **played a key role** during the **Higgs-like particle discovery**, I could gain some experience that very few people have in our field. I learned to work under **extreme pressure** with care to provide the **best scientific results** knowing that this will be scrutinized by our community given the important topic. I also demonstrated my **team spirit** and my **excellent management skills** in such conditions.

### Research Associate at Carleton University, Canada:

I am now the **co-convener** of the Higgs group responsible for the  $H \rightarrow ZZ$ ,  $H \rightarrow Z'Z$ ,  $H \rightarrow Z'Z'$  and  $ZH$ ,  $H \rightarrow \text{invisible}$  analyses (HSG2 group). As co-convener of this group I coordinated the publications of the 4 majors HSG2 LHC run I legacy papers well before the restart of the LHC for run II:  $H \rightarrow ZZ$  mass, couplings, fiducial and differential cross sections papers,  $ZH$ ,  $H \rightarrow \text{invisible}$  paper as well as the publication of a conference note concerning the determination of the off-shell Higgs boson signal strength in the high-mass  $ZZ$  final state. This is a major achievement for the Higgs group. Some other publications are still on going. The main focus now is the preparation of ATLAS and of the analyses (software, Monte Carlo, theory inputs and models, ...) for LHC run II. We organized discussions and meetings with our theory colleagues and will have a HSG2 workshop to coordinate the effort in order to have all the analyses ready for the beginning of run II.

I played a **major role** in the **discovery** of the **Higgs-like particle** and in the **measurement** of its properties (mass, signal strength, spin-parity and couplings measurement). I have a **leading role** and **key contribution** in the search for the Standard Model (SM) Higgs boson in the decay channel  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  with proton-proton collisions at  $\sqrt{s}=7 \text{ TeV}$  ( $4.6 \text{ fb}^{-1}$ ) and at  $\sqrt{s}=8 \text{ TeV}$  ( $21.0 \text{ fb}^{-1}$ ) and in the ATLAS Higgs boson search **combination**, and both has been very fruitful. Using 7 TeV and 8 TeV data, ATLAS recently **observed clear evidence** for the production of a neutral Boson with a measured mass of  $125.5 \pm 0.2 \text{ (stat)} \pm 0.6 \text{ (sys)} \text{ GeV}/c^2$  (Phys. Lett. B 716 (2012) 1-

29, ATLAS-CONF-2013-012, ATLAS-CONF-2013-013 and ATLAS-CONF-2013-014). This is driven mainly by two channels:  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  and  $H \rightarrow \gamma\gamma$  (high mass resolution) and confirmed in  $H \rightarrow WW$  (no mass resolution). Using the channel  $H \rightarrow ZZ^{(*)} \rightarrow 4l$ , an **excess** of events over background is seen, with a minimum  $p_0$  value of  $2.7 \times 10^{-11}$  (**6.6** standard deviations) at  $m_H = 124.3$  **GeV** in the combined analysis of the two datasets. For the combined data sets, the SM Higgs boson is excluded at 95% CL in the mass ranges **128 – 168 GeV** and **174 – 580 GeV**. The expected exclusion range is **120.7 – 560 GeV**. An excess is observed around  $m_H = 125$  GeV preventing the exclusion of the full expected range. The fitted Higgs mass is measured to be  $m_H = 124.3 \pm 0.6$  (*stat*)  $\pm 0.4$  (*syst*) **GeV**, and the signal strength (the ratio of the observed cross-section to the expected SM cross-section) at this mass is found to be  $\mu = 1.7 +0.5 -0.4$ . A spin-parity analysis is performed on the events with  $115 \text{ GeV} < m_H < 130 \text{ GeV}$ . The Higgs-like boson is found to be compatible with the SM expectation of  $0^+$  when compared pair-wise with  $0^-, 1^+, 1^-, 2^+, \text{ and } 2^-$ . The  $0^-$  and  $1^+$  states are excluded at the 97.8% confidence level or higher using CLs in favour of  $0^+$ . A study of Higgs boson production mechanisms allows a first measurement of couplings with this channel.

I was editor of a conference **note** for the HCP 2012 conference of the Moriond 2013 conference **note**, all concerning the updated search for the Standard Model (SM) Higgs boson in the decay channel  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  at  $\sqrt{s} = 7$  TeV and at  $\sqrt{s} = 8$  TeV and the **new measurements** of the **Higgs-like particle properties**. I **played a leading role** in the **mass measurement** of the new particle with  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  and in all the checks that were done following the **mass discrepancy** with the other channel :  $H \rightarrow \gamma\gamma$ . For the HCP we reported some first measurements of the properties of the new particle and I **organized** this **new work** on **Spin/CP** with two methods: a multivariate techniques and a matrix element technic that were shown for the **first time** with **new results**. Several times I **reported** the results of **all the checks** we did to the **collaboration**. I was the **chairman** of the Higgs-like **mass measurement** session during the ATLAS  $H \rightarrow ZZ$  **workshop**. I was the **Higgs group contact person** for the reconstruction and identification of **electrons**. I was **responsible** for the selection of the **analysis cuts** and I **updated** and **maintained** the **documentation** with all the recommendations from various groups (data quality, data preparation, tracking, electron, muon, jet and missing  $E_T$ ) and from our own analysis cuts. I **put in place** some complete **documentation**, a public **analysis code** and a **webpage** to compare all the **analysis codes** of our group with each other at the per mil level for some given Monte Carlo files. This was copied by many other physics analyses. I **coordinated** the **Monte Carlo production** to be ready on time, especially for the discovery conference note and paper. I **coordinated** the **preparation** and **submission**, and I **monitored** the production of the analysis format for our **analysis**. These files represent more than **300 TB** of data (MC and 2011 and 2012 data). I **worked** on the **estimation** of the reducible **ZZ background** (the main background for all channels of our analysis). I **extracted**, **collected** and **supervised** the production of **all the systematics uncertainties** (both experimental and theoretical) for the analysis as well as their integration in our models. I first **introduced** for our analysis a common file called "**workspaces**" to share our **data**, **MC**, **model** and associated **systematics uncertainties** for the statistical treatment based on histograms. I **produced** the **limit** and  **$p_0$**  for our first publications. I **organised** the **migration** and the **validation** of a more **flexible system** able to use **unbinned data**, **MC histograms** and **various signal models**. This was used for the first time for the HCP conference note and we got improved results.

I was the **editor** of the **supporting note**, in charge of the statistical treatment (**limit and  $p_0$  extraction**) and of the reanalysis of the 2011 data for the ICHEP **conference note** and **discovery paper**. I was the **ATLAS  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  representative** during the Higgs-like particle discovery seminar at CERN (July 4, 2012). For these publications (before the discovery), I worked on most of the items described above and on some **improvements** of the **analysis** and **detector performances** to achieve a **better sensitivity**, especially for the very interesting 120-135 GeV low mass region after the first hints of the presence of a Higgs Boson at low mass. As the **editor** of the 2011/2012 **papers** and conference **notes** (with more than **100 contributors**) for the December CERN Higgs seminar and the Lepton Photon and EPS conferences I published the **latest results** concerning the search for the Standard Model (SM) Higgs boson in the decay channel  $H \rightarrow ZZ^{(*)} \rightarrow 4l$ . I had also the big opportunity to give the **CERN seminar** (Collider Cross Talk, December 15<sup>th</sup> 2011): "Discussion of the status of the ATLAS and CMS searches for the Standard Model Higgs boson" and the **plenary talk** at HCP (Hadron Collider Physics Symposium 2011, November 16<sup>th</sup> 2011): "Standard Model Higgs Boson Combination at ATLAS". My last publication

in 2011 as **editor** concerned  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  corresponding to an average integrated luminosity of  $4.8 \text{ fb}^{-1}$  and the SM Higgs boson is excluded at 95% CL in the ranges 135–156, 181–224 GeV and 255–415 GeV which was the **best result ever** for this channel. The largest deviations from the background expectation were observed for  $m_H = 125 \text{ GeV}$  with a p0-value of 1.8%,  $m_H = 244 \text{ GeV}$  with a p0-value of 1.1% and  $m_H = 500 \text{ GeV}$  with a p0-value of 1.4%. This was quite exiting but - nevertheless - once the look-elsewhere effect was considered, none of these excesses was significant by itself and more data were needed to get the final answer.

I **studied** the **impact** of some lead-liquid argon **calorimeters' problems** (noise bursts, HV ramping up) in the  $H \rightarrow ZZ^{(*)} \rightarrow 4e$  and  $Z \rightarrow ee$  analysis and my studies concerning the **performances of electrons** with the new **brem-refitted tracks** showed that in the case of the channel  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  we gained between **12-24%** more **candidates**.

In 2011 I participated in the **procedure** for the LHC Higgs Boson search **combination between the ATLAS and CMS** collaboration and I **contributed strongly** to the first ATLAS-CMS Higgs Boson search combination.

I was a **member** of the task force and **Higgs contact person** for the **monitoring of interesting signature events** "Fast Physics Monitoring" put in place to avoid missing important discoveries.

I was the **coordinator** for the **preparation** and **production** of the list of **good runs/events**: ("Good Run List") for all combined performance and physics groups and I am **strongly involved** in the data preparation and data quality group.

#### **Research Associate at Brookhaven National Laboratory (BNL), USA:**

During my employment as a Research Associate at BNL I **participated strongly** in the search for the Standard Model (SM) **Higgs Boson** in the decay channel  $H \rightarrow ZZ^{(*)} \rightarrow 4l$ , in the Higgs **combination** (summarized above) as well as in the ATLAS **sensitivity prospects** for a Higgs Boson production at the LHC running at  $\sqrt{s}=7, 8$  or  $9 \text{ TeV}$  (working on SM Higgs boson via Vector Boson Fusion (VBF)). **Strongly involved** in the search for the SM Higgs boson via **VBF production** process in the channel  $qqH \rightarrow qq\tau\tau$  with simulated data, I also worked on the **optimization** of the cut based analysis and on the **background estimation**. I was the **main author** of the **analysis code**.

I was **responsible** for the selection of the **list of good runs/events** for the WZ analysis and  $e/\gamma$  group and contributed to the SM Z boson **cross-section measurement**.

I strongly contributed to the **performance** of the ATLAS electromagnetic calorimeter using  $\pi^0 \rightarrow \gamma\gamma$  events with the first LHC collision data at  $\sqrt{s}=900 \text{ GeV}$ .

I also participated in the **calibration of the liquid argon** (LAr) electromagnetic/hadronic calorimeter (~200000 cells) in the ATLAS experiment and I was the **main author** for the development and the realization of a missing and **crucial system automatizing** the chain of computation to extract the conditions (**electronic calibration**) for cells of the LAr calorimeters. I worked on the **production** and **validation** of the electronic calibration, which enables the online reconstruction of the deposited energy in the calorimeter and which is performed between each LHC fill. I also contributed to the **commissioning effort** of the **calorimeters** using cosmic rays (muons). I participated in **software development** and **maintenance** (i.e: monitoring, calibration) and was strongly involved in the ATLAS control room (as expert, shifter) during ATLAS commissioning with cosmic rays and LHC collisions at  $\sqrt{s}=0.9 \text{ TeV}$  and  $\sqrt{s}=7 \text{ TeV}$ .

#### **Phd at Laboratoire d'Annecy-le-vieux de physique des particules (LAPP), France :**

During my PhD on the ATLAS experiment at the LHC I worked on the **search** for a Standard Model **Higgs boson** produced by vector boson fusion in the  $H \rightarrow \tau\tau$  channel for a low mass Higgs ( $115 < m_{\text{Higgs}} < 145 \text{ GeV}$ ) with a fast and a full simulation of the ATLAS detector. The second dominant process to produce the Higgs at the LHC is vector boson fusion (VBF). I played an **important role** in this analysis and studied in particular the **irreducible background** of this channel using

generators with an improved description of Z+n jets events (i.e correct multiplicity of jets) and worked on some "pseudo data" driven background methods.

I also worked on the **development** and the **validation** of a new algorithm for **hadronic tau decay reconstruction and identification** as well as on its comparison with the previous algorithm. A track-based seeded approach was proposed to reconstruct objects, and an energy flow algorithm was used to define energy scale.

I participated in the 2004 **test beam** where for the first time a **complete and final slice of the ATLAS** detector was tested altogether. I had a **strong participation** in campaigns of **tests** as a shifter, by working on the **calibration** of the lead-liquid argon (LAr) electromagnetic (EM) calorimeter and by analyzing these data. I was **responsible** for the **production** of **optimal filtering coefficients** needed to extract the energy of the LAr calorimeter cells from the raw data while minimizing the electronic and pile-up noises. A model was developed to predict the physics signal waveform from the calibration waveform.

I was also involved in the **construction** and the **final electrical tests** of the LAr **calorimeters**. A final mapping of all cells, and in particular the problematic one, was done.

### **Leadership and Service:**

2013–2014 **Co-convener** of the ATLAS Higgs group (HSG2) responsible for the channels:  
 $H \rightarrow ZZ$  and  $ZH(H \rightarrow \text{invisible})$ .

2010–2012 **Coordination** of the preparation and production of the Data-Quality approved data.

2007–2009 **Coordination** of the production of the calibration constants for the calorimeters.

2012–2013 **Higgs** group **contact** person for the electron reconstruction and identification.

2011–2012 **Higgs** group **contact** person in the Task Force for the monitoring of interesting events.

### **Editor:**

I was the editor of 7 of 10 papers and conference notes concerning the search for the Standard Model (SM) Higgs Boson in the decay channel  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  (with more than 115 contributors) :

2011–2013 **Co-editor:**

2012 **Paper:**  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  search (CERN Higgs boson seminar 2011).

2011 **Paper:**  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  search (Lepton Photon 2011 conference).

2013 **Conference note:**  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  : Higgs boson properties (Moriond 2013 conference).

2012 **Conference note:**  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  : Higgs boson properties (HCP 2012 conference).

2011 **Conference note:**  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  search (CERN seminar 2011).

2011 **Conference note:**  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  search (EPS 2011 conference).

### **Editorial member and reviewer:**

2013-2014 **Editorial board member:**

2013-2014 **Paper:** Search for extra dimensions in diphoton (**Co-chair**).

2013-2014 **Paper:** Measurement of  $W\gamma\gamma$  production.

2013-2014 **Paper:** Limits on fiducial cross sections of additional Higgs states in  $\gamma\gamma$ .

2007–2013 **Reviewer** of several ATLAS notes and conference talks (more than 15 talks).

### **Representative or chairman:**

2011–2013 Chairman:

2013:  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  **analysis session**, ATLAS  $H \rightarrow ZZ$  workshop, Rome, Italy.

2013: **ATLAS  $H \rightarrow ZZ$  representative**, Higgs-like discovery seminar, CERN, Switzerland, 2012.

2012: Higgs-like **mass measurement session**, ATLAS  $H \rightarrow ZZ$  workshop, Paris, France. 2011 **Young Scientific Forum**, Moriond EW 2011, La Thuile, Italy.

### **Talks in working meeting, workshop, seminar and conference:**

I gave **6 talks** during **major HEP conferences**, 1 CERN seminar, 12 talks in workshops, 3 tutorials and more than **300 other talks** (including 8 plenary talks) given in the context of the various working groups in which I am involved (Higgs searches, Higgs combination, W/Z Boson cross section measurement, WZ boson observation, electron and photon identification,  $\tau$ -jet identification, data preparation, data quality, test of a combined slice of the ATLAS detector, calibration of the liquid argon calorimeters). I was **invited** and went to **Moriond EW** 2011 and 2013.

### **Supervision of students and postdocs:**

Supervision of students and postdocs:

2011-2014: supervision of Ph.D students and researchers based at CERN (as editors of papers).

2011-2014: **unofficial supervision** of Ph.D students.

2014: **supervision** of a student (Syed Haider Abidi, University of Toronto).

2013: **supervision** of a CERN summer student (Syed Haider Abidi, University of Toronto).

2009: **supervision** of a CERN summer student (Andrea Thamm, University of Edinburgh).

2008: **supervision** of summer students (University of Johannesburg).

### **Outreach:**

I worked with the **media** and **participated** in the “Colliding Particles, Hunting the Higgs” - project (UK), in a project on the Higgs search discovery by the **Merminfilm** Company (UK) and in a **documentary film** on CERN by the Japanese television. I wrote some **articles** to explain the Higgs-like particle discovery to the **general public** with the article “La búsqueda experimental del bosón de Higgs en el LHC” (**Investigación y Ciencia** magazine, Dec 2012, Spain), the article “La découverte du boson de Higgs” (**Pour la science** magazine, Sept 2012, France) and the article “Why you should care about the Higgs boson” (**Astronomy** magazine, Nov 2012, USA). I participated in **media events** like the **press conference** that followed the announcement of the Higgs-like particle discovery at CERN on July 4<sup>th</sup> 2012. I am a **contact person for media** (CERN/ATLAS). I participated in a **Master-Class event** for high schools students from the New York area (2011), which was done via videoconference in the ATLAS control room, in a **visit to CERN** for 12 year old "collegiens" (France) and gave an interview with a **Master's student** in **scientific journalism** (Spain). During the CERN Open Day (2008) I participated as a **guide** for the ATLAS **pit visit** and did presentations of the ATLAS experiment in the ATLAS control room. I also helped during the **Open Days** at Laboratoire d'Annecy-le-vieux de Physique des Particules (LAPP) by presenting the ATLAS experiment to the **general public and students**.