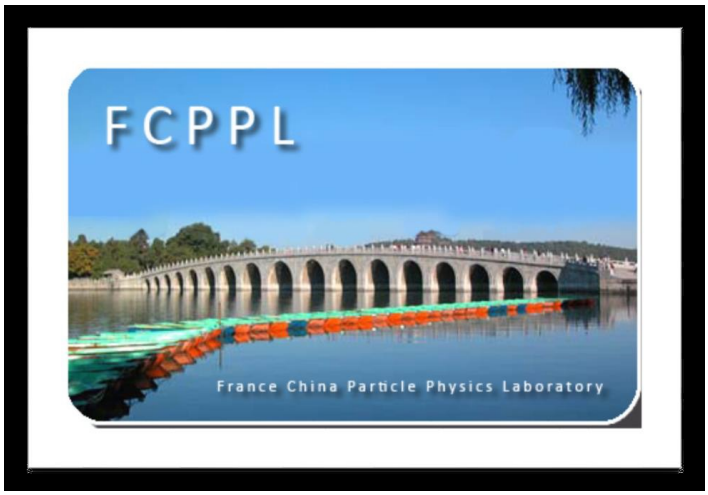
FCPPL PhD proposals 2016



List of PhD Proposals 2016

1. Measurement of the production cross section of the Higgs boson in association with vector boson and decaying to pairs of b quarks.

   Supervisor(s): Giovanni MARCHIORI giovanni.marchiori@lpnhe.in2p3.fr and Yanwen LIU yanwen@ustc.edu.cn

2. Open heavy-flavour measurements via muons in proton-proton and Lead-Lead collisions with the ALICE detector at the CERN-LHC

   Supervisor(s): Prof. Daicui Zhou (dczhou@mail.ccnu.edu.cn) , Prof. Nicole Bastid (bastid@clermont.in2p3.fr), Dr. Philippe Crochet (crochet@clermont.in2p3.fr)

3. Search for a second low-mass (m_h<125 GeV) Higgs boson and measurement of Higgs boson properties in the two-photon decay channel with the CMS experiment at the LHC (CERN)"

   Supervisor(s): Prof. GASCON-SHOTKIN Suzanne (smgascon@in2p3.fr), Prof. CHEN Guoming (chengm@ihep.ac.cn)

4. Optimization of a TPC detector for future e+/e- experiments : Study of distortions induced by space charge and ion backflow effects CEA/IRFU

   Supervisor(s): Roy Aleksan (roy.aleksan@cea.fr); Philippe Schwemling (Philippe.schwenling@cea.fr)

5. Fast luminosity monitoring and feedback using monocrystalline CVD diamond sensors at the SuperKEKB electron-positron collider in Japan

   Supervisor(s): Philip Bambade (bambade@lal.in2p3.fr), co-supervised by Cécile Rimbault (rimbault@lal.in2p3.fr)

PhD proposal n°1

Thesis title: Measurement of the production cross section of the Higgs boson in association with vector boson and decaying to pairs of b quarks.

Type of proposed PhD diploma: French & Chinese

French host laboratory: Laboratoire de physique nucléaire et des hautes énergies (LPNHE)

Chinese laboratory (if applicable): USTC – Department of Modern Physics

Thesis advisor(s) and email(s): Giovanni MARCHIORI giovanni.marchiori@lpnhe.in2p3.fr

Yanwen LIU yanwen@ustc.edu.cn

Planned date of start of stay in French lab: 01/10/2016

Planned duration of stay in French lab (months): 24

Expected date of thesis defense: Sep. 2018

Detailed description of the thesis subject:

The discovery in July 2012 by the ATLAS and CMS collaborations at the Large Hadron Collider (LHC) of a new particle consistent with the Higgs boson of the Standard Model (SM) is a major breakthrough for fundamental physics, since this is possibly the first observation of a fundamental scalar particle. One of the main priorities of the community is now to study the exact nature of this new boson (H) and in particular its couplings to SM particles, since those can give insights about the underlying mechanism of electroweak symmetry breaking (EWSB) and are sensitive to possible extensions of the SM. The Higgs boson mass of ~125 GeV allows access to a large variety of couplings of the Higgs boson to fermions, weak vector bosons (W and Z), photons and more indirectly to gluons. So far, only the bosonic couplings have been probed directly with some precision, through production via gluon-gluon or weak-boson fusion, and subsequent decays to a pair of photons or weak bosons. A combination of ATLAS and CMS data has also been able to observe Higgs decaying to a pair of tau leptons, a process which has a low branching ratio, but a characteristic final state. However, for the observed value of its mass, the fermionic decays are expected to dominate the width of the Higgs boson, since the largest branching fraction (57%) is expected to come from the decay to a pair of bottom quarks.

The first evidence for the H →bb decay was obtained in 2012 from the combination of the results of the CDF and D0 experiments at the Tevatron, at the 3 sigma-level, relying on the associated production of H with a W or Z boson (referred to collectively as V H production). The analysis of the full dataset accumulated during the Run 1 of the LHC has not led to a much clearer signal (~2.5 sigma sensitivity). The observation and measurement of the H →bb decay is therefore one of the main goals of the Run 2 of the LHC, which has started in 2015 at a center-of-mass energy of 13 TeV.

The candidate will work during his Ph.D. thesis project on the search of the H→bb decay in events in which a Higgs boson is produced in association with a vector boson (W,Z). Final states with leptonic decays of the vector boson will be searched for. The thesis will exploit all Run2 collected till summer 2018 (several tens of fb-1 at 13 TeV and 14 TeV). The increase in integrated luminosity compared to Run1 (25 fb-1), the twice larger signal cross section and a re-optimization of the selection criteria and of the background modeling systematic uncertainties profiting from the much larger statistics for both the signal and the background control samples, should lead to the sensitivity necessary for a 5-sigma discovery.

In addition to a measurement of the "signal strength" (the observed yield divided by the SM prediction) and of the significance of the observation (the p-value of the background only hypothesis), the candidate will

also exploit the large signal yield to measure simplified differential production cross-sections, as a function of a few kinematic variables, that can be exploited to constrain the Higgs boson couplings to the vector bosons and search for small deviations from the Standard model.

The candidate will spend most of his/her research time in France. This will allow him/her to integrate himself/herself in the LPNHE Hbb group, which has had a leading role within ATLAS on the SM VH(bb) and on the searches of resonances decaying to a weak boson and a Higgs boson decaying to bb in the past two years. This will also allow him/her to travel frequently to CERN, for the meetings of the analysis and b-jet performance groups, to show the results of his/her studies and discuss with the ATLAS colleagues.

The thesis will be performed under joint supervision of Prof. Liu and Dr. Marchiori, who collaborate on the VH(bb) study since late 2014 and who have developed in the past 5 years a strong collaboration within the FCPPL framework. They have already had a very positive experience in the supervision of a co-tutorship Ph.D. thesis: their former student, Kun Liu, was awarded the ATLAS thesis award for one of the best Ph.D. theses defended in ATLAS in 2014.

Candidates' requested qualifications:
Good knowledge of the basis of particle physics
Knowledge of the LHC physics, of the ATLAS detector, and of the ATLAS data analysis infrastructure
Skilled with the C++ and python computer languages.

Tentative timeline of the PhD preparation
During the first 1.5 years (up to spring 2018) the candidate will carry on in parallel two projects.
The first one will consist in measuring, with the Run2 data, the efficiency of the algorithms used in ATLAS to identify b-jets. The candidate will exploit data-driven techniques to reduce the uncertainties on the measurement compared to the large uncertainties affecting estimates based on the simulation; this improvement will lead to a reduced systematic uncertainty on the measurement of the signal strength and differential cross sections.
The second project will consist in
1) a simulation-based optimization of the selection criteria, of the event classification in categories and of the final fit strategy to discriminate signal from background, in order to maximize the significance of the observation;
2) data-driven estimation of background by designing dedicated control regions;
3) estimations of systematic uncertainties affecting the signal uncertainty and background estimates;
4) implementation of the final statistical analysis, including combination between the three leptonic channels (Z->nunu, W->lnu, Z->ll) and combination with Run1 results. The results will be shown at the Moriond electroweak 2018 conference and a publication will be prepared.
During the last 6 months of the thesis the candidate will focus on writing the thesis document (part of which – notably the theoretical introduction and the description of the detector and of the main analysis technique will be already started before) and will collaborate to the update of the analysis with the latest ATLAS data collected between spring and summer 2018, giving a leading contribution to the ATLAS results on VH(bb) for the ICHEP 2018 conference. These results will be documented in the final chapters of the thesis.
Publications related to the PhD subject:
Search for the $b\bar{b}$ decay of the Standard Model Higgs boson in associated (W/Z)H production with the ATLAS detector

- ATLAS conference note:
  https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2013-079/
- Journal of High Energy Physics:
  http://link.springer.com/article/10.1007%2FJHEP01%282015%29069

Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC

- http://www.sciencedirect.com/science/article/pii/S037026931200857X

PhD proposal n°2

Thesis title: Open heavy-flavour measurements via muons in proton-proton and Lead-Lead collisions with the ALICE detector at the CERN-LHC

Type of proposed PhD diploma: French☐ Chinese ☐ French & Chinese X (tick correct answer)

French host laboratory: Laboratoire de Physique Corpusculaire de Clermont-Ferrand, Campus Universitaire des Cézeaux, 4 avenue Blaise Pascal, TSA 60026, CS 60026, F-63178 AUBIERE Cedex, France

Chinese laboratory (if applicable): Institute of Particle Physics (IOPP), Central China Normal University (CCNU), Key Laboratory of Quark & Lepton Physics, MoE, Luoyu Road 152, Wuhan 430079, China

Thesis advisor(s) and email(s): Prof. Daicui Zhou (dczhou@mail.ccnu.edu.cn), Prof. Nicole Bastid (bastid@clermont.in2p3.fr), Dr. Philippe Crochet (crochet@clermont.in2p3.fr)

Planned date of start of stay in French lab: 01/10/2016

Planned duration of stay in French lab (months): 24 months

Expected date of thesis defense: November 2018

Detailed description of the thesis subject:

The aim of ultra-relativistic heavy-ion collisions is to pin down the nuclear equation of state by studying the properties of nuclear matter under extreme conditions of temperature and pressure. The ultimate goal is to study the deconfinement of the hadron constituents in the so-called Quark-Gluon Plasma (QGP). This phase of matter is a prediction of Quantum ChromoDynamics (QCD), the theory of the strong interaction. It is believed that the Universe was made of a QGP a few microseconds after the Big Bang and that a QGP could be present in the core of neutron stars. The heavy-ion collision experimental program has started in the eighties at the Super Proton Synchrotron (SPS) at CERN and has then been pursued since 2000 at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven. With a nucleus-nucleus center-of-mass energy nearly 14 times larger than that reached at RHIC, the Large Hadron Collider (LHC) at CERN has been offering, since 2009, a totally new environment for systematic studies of the QGP. A Large Ion Collider Experiment (ALICE) is the unique LHC experiment dedicated to the study of heavy-ion collisions. The ALICE collaboration consists of 1600 physicists from 170 institutes in 42 countries. The detector is made of a central barrel, a forward angle muon spectrometer and a set of detectors for event characterization and triggering.

Amongst the various probes of the QGP, heavy quarks (charm and beauty) are of particular interest since, due to their large masses, they are mainly produced in hard scattering processes at the early stages of the heavy-ion collision and subsequently interact with the strongly-interacting medium formed in the collision. Open heavy-flavour particles are sensitive to the density of this medium through heavy quark in-medium energy loss mechanism. This effect is usually studied by means of the so-called nuclear modification factor: $R_{AA}(p_T) = (dN_{AA}/dp_T) / (\langle T_{AA}\rangle \cdot d\sigma_{pp}/dp_T)$ where $\langle T_{AA}\rangle$ is the average nuclear overlap function corresponding to the considered collision centrality class; dN_{AA}/dp_T and $d\sigma_{pp}/dp_T$ are the transverse momentum (p_T) production yield and cross-section (σ) in nucleus-nucleus (AA) and proton-proton (pp) collisions. According to QCD, quarks should lose less energy than gluons when passing through the medium. This is due to the color-charge of gluons which is higher than that of quarks. In addition, heavy quarks are expected to lose less energy than light quarks due to the ``dead-cone'' effect. This color-charge and mass-dependence of parton energy loss should therefore result in the following R_{AA} hierarchy: $R^{\pi}_{AA} < R^{D}_{AA} < R^{B}_{AA}$. First measurements have been performed and published (see below) with the data taken with the ALICE detector during the LHC Run 1. In the LHC Run 2, the higher beam energy and luminosity will allow better precision measurements over a broader p_T range in a new kinematic region (higher beam energies). It will allow us to investigate in detail the features of in-medium parton energy loss and to provide new constraints on

theoretical models. On the other hand, the study of the heavy-flavour particle azimuthal elliptic flow can provide insight on the degree of thermalization of charm and beauty quarks in the medium and on the heavy-flavour hadronization mechanism at low p_T and intermediate p_T, respectively. In the high p_T region, the elliptic flow can constrain the path-length dependence of the in-medium parton energy loss. This is complementary to the study of parton energy loss. Here again, the larger statistics which will become available with the LHC Run 2 data will allow to extend the measurements done with the LHC Run 1 data at higher p_T. Besides providing the mandatory reference for the study of Pb-Pb collisions, the measurement of the open heavy-flavour production cross section in pp collisions represents an important test of perturbative QCD.

Heavy flavours are measured in ALICE in the charm hadronic decay channels and in the semi-electronic decay channel at mid-rapidity and, in the semi-muonic decay channel at forward rapidity.

The topic of the PhD thesis is the study of the heavy-flavour production in proton-proton (pp), and lead-lead (Pb-Pb) collisions via single muons measured at forward rapidity with the ALICE muon spectrometer. The study will be carried out with the LHC run2 data e.g. pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. A particular emphasis will be placed on the measurements in the high p_T region.

The manuscript will be organized in 6 chapters: 1) Introduction, 2) Heavy-flavour production as a probe of the QGP, 3) The ALICE experiment at the LHC, 4) Measuring heavy-flavours with the ALICE muon spectrometer, 5) Results and comparison to model predictions, 6) Conclusion. The first chapter will consist of a general overview of heavy-ion collisions and QCD phase transitions. The second chapter will present the motivations for measuring heavy flavours and their relevance for studying the QGP. In these two first chapters a comprehensive summary of the theoretical background and of the main experimental results obtained so far will be presented. Chapter three will give an overview of the ALICE experiment with a detailed description of the muon spectrometer. The ALICE data recording and analysis strategy will be presented in chapter four. It will include the heavy-flavour production and the strategy followed at different steps of the analysis chain i.e. data reduction, muon background subtraction, acceptance x efficiency correction, normalization, estimation of systematic uncertainties etc. Finally, results will be presented in chapter five. They will be discussed and compared to other experimental measurements and to model predictions. A summary and the conclusions will be given in the last chapter.

The results obtained will be regularly presented in various meetings of the ALICE collaboration, as well as in international conferences and workshops, and then published.

Candidates' requested qualifications: The candidate is already identified: Zuman Zhang from CCNU Wuhan. Zuman Zhang already works in collaboration with the ALICE group at Laboratoire de Physique Corpusculaire (LPC) Clermont-Ferrand. Zuman Zhang has already spent few months at LPC Clermont-Ferrand for his Master-I and Master-II trainings. Since his Master defense in May 2015, Zuman Zhang continues to work in close collaboration with the ALICE group at LPC Clermont-Ferrand and is presently at LPC Clermont-Ferrand for few months, in the framework of his PhD training. He has all requested qualifications for the proposed PhD and he already got familiar, during his various trainings, with the physics case and the ALICE data analysis tools. It is worth mentioning that the results obtained during his Master work concerning the measurement of the nuclear modification factor of muons from heavy-flavour hadron decays in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV collected during the LHC run 1 were approved by the ALICE Collaboration and presented as a poster in the prestigious international conference "Quark Matter 2015" (September 27 – October, 2015, Kobe, Japan).

Tentative timeline of the PhD preparation

[Detail content and duration of the various phases of the PhD work]

The candidate will have to analyze the pp and Pb-Pb data collected during the LHC run 2 with the ALICE detector, subtract the muon background, apply acceptance and efficiency corrections and normalization factors, and estimate the systematic uncertainties. The final results concerning muons from heavy-flavour

hadron decays (production cross sections in pp and Pb-Pb collisions and, nuclear modification factor and elliptic flow in various centrality classes in Pb-Pb collisions) will be interpreted and compared to other experimental results and predictions from different models. In parallel, the candidate will participate to data taking with the ALICE detector at CERN.

Below is a rough estimate of the timeline.

October 2016 – November 2018: regular participation to the various data taking campaigns with the ALICE detector at CERN;

October 2016 – summer 2017: the analysis of the pp data at $\sqrt{s}$ = 5.02 TeV and 13 TeV and of the Pb-Pb data at $\sqrt{s_{NN}}$ = 5.02 TeV started end of 2015. During the mentioned period, the pp data analyses ($\sqrt{s}$ = 5.02 TeV and 13 TeV) will be finalized and the analysis of the Pb-Pb data at $\sqrt{s_{NN}}$ = 5.02 TeV (nuclear modification factor and elliptic flow) will be pursued. The analyses will be presented in various meetings of the ALICE collaboration for approval and presented in international conferences;

September 2017 – December 2017: writing of the publications on pp data; finalization of the analysis of Pb-Pb data; presentation of the results in various meetings of the ALICE collaboration for approval of the paper proposal, and in international conferences;

January 2018 – October2018: publication of the Pb-Pb results; writing of the PhD manuscript;

November 2018: PhD defense.

Publications related to the PhD subject: The publications below are the result of the PhD of our former student from (Xiaoming Zhang) who has defended his PhD on May 2012, except the last one that Xiaoming Zhang prepared during his post-doctoral position at Lawrence Berkeley National Laboratory (U.S.A.). Two other publications on similar topics are being prepared and are the result of the work of our student (Shuang Li) who defended his PhD in October 2015. Both PhD theses are co-tutorships Wuhan - Clermont-Ferrand.

- B. Abelev et al. (The ALICE collaboration), Production of muons from heavy flavor decays at forward rapidity in pp and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, Phys. Rev. Lett. 109 (2012) 112301
- B. Abelev et al. (The ALICE collaboration), Heavy flavour decay muon production at forward rapidity in proton-proton collisions at $\sqrt{s}$ = 7 TeV, Phys. Lett. B 708 (2012) 265
- R. Averbeck, N. Bastid, Z. Conesa del Valle, P. Crochet, A. Dainese, X. Zhang, Reference heavy flavour cross sections in pp collisions at $\sqrt{s}$ = 2.76 TeV, using a pQCD-driven $\sqrt{s}$-scaling of ALICE measurements at $\sqrt{s}$ = 7 TeV, arXiv:1107.3243 [hep-ph]
- J. Adam et al. (The ALICE collaboration), Elliptic flow of muons from heavy-flavour hadron decays at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, Phys. Lett. B 753 (2016) 41

Conference proceedings related to the PhD subject:

- N. Bastid for the ALICE collaboration, Heavy-flavour and quarkonium measurements with ALICE XI International Conference on hyperons, charm and beauty hadrons, Birmingham, UK, July 2014, Journal of Physics: Conference Series 556 (2014) 012020
- S. Li for the ALICE collaboration, Heavy-flavour nuclear modification factor at forward and backward rapidity in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE at the LHC

XXIV international conference on ultra-relativistic nucleus-nucleus collisions (Quark Matter), Darmstadt, Germany, May 2014

Nucl.Phys. A931 (2014) 546-551

- S. Li for the ALICE collaboration, Nuclear modification factor and elliptic flow of muons from heavy-flavour decays in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with ALICE

6th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions (Hard Probes), Cape Town, South Africa, Nov. 2013

Nucl. Phys. A932 (2014) 32-37

- X. Zhang for the ALICE collaboration, Nuclear modification factor and elliptic flow of muons from heavy-flavour decays and muon elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

Strangeness in Quark Matter 2013 (SQM), Birmingham, UK, July 2013

Journal of Physics: Conference Series 509 (2014) 012045

- X. Zhang for the ALICE collaboration, Nuclear modification factor of muons from open heavy-flavour decays and single muon elliptic flow at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with ALICE

23th International conference on ultra-relativistic nucleus-nucleus collisions (Quark Matter), Washington, USA, August 2012

Nucl. Phys. A 904 (2013) 977c

- N. Bastid for the ALICE collaboration, Heavy-flavour and quarkonium measurements in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with ALICE

  Heavy Ion Collisions in the LHC Era, Quy Nhon, Vietnam, July 2012

  Journal of Physics: Conference Series 422 (2013) 012014

- P. Crochet for the ALICE collaboration, Heavy flavour production measurements with ALICE at the CERN-LHC

  16th International Conference In Quantum Chromodynamics (QCD), Montpellier, France, July 2012

  Nucl. Phys. B 234 (2013) 325

- P. Crochet, Heavy flavour production measurements at the CERN-LHC

  XLI International Symposium on Multiparticle Dynamics (ISMD), Miyajima Island, Hiroshima, Japan, Sept. 2011

  Progress of Theoretical Physics Supplement 193 (2012) 89

- N. Bastid for the ALICE collaboration, Quarkonium and heavy flavour physics in pp and Pb-Pb collisions with the ALICE muon spectrometer at the LHC

  International Workshop on Early Physics with Heavy-Ion Collisions at LHC, Bari, Italy, July 2011

  AIP Conf. Proc. 1422 (2012) 153

- X. Lopez for the ALICE collaboration, Heavy flavour production in the semi-muonic channel in pp and Pb-Pb collisions measured with the ALICE experiment

  Strangeness in Quark Matter (SQM), Cracow, Poland, Sept. 2011

  Acta Phys. Polon. Supp. 5 (2012) 297

- X. Zhang for the ALICE collaboration, Heavy flavour production cross section in the semi-muonic channel at forward rapidity in pp collisions at 7 TeV and measurement of its nuclear modification factor in Pb-Pb collisions at 2.76 TeV with ALICE

  22th International conference on ultra-relativistic nucleus-nucleus collisions (Quark Matter), Annecy, France, May 2011

  Journal of Physics G: Nuclear and Particle Physics 38 (2011) 124067

- X. Zhang for the ALICE collaboration, Heavy-flavour physics with the ALICE muon spectrometer at the LHC

  XLIX International Winter Meeting on Nuclear Physics, Bormio, Italy, Jan. 2011

  Pos (Bormio 2011) 030
- N. Bastid for the ALICE collaboration, Quarkonium and heavy-flavour physics with the ALICE muon spectrometer at the LHC

  International Conference on Hyperons, Charm and Beauty Hadron, Perugia, Italy, June 2010

  Nucl. Phys. B (Proc. Suppl.) 210-211 (2011) 53
- X. Zhang, L. Manceau, N. Bastid, P. Crochet, S. Grigoryan, D.C. Zhou for the ALICE collaboration, Measurement of (di)muons from heavy flavour decay in pp collisions at 14 TeV with ALICE at the LHC

  5th International conference on quarks and nuclear physics, Beijing, China, August 2009

  Chinese Physics C 34-9 (2010) 1538

ALICE Internal notes related to the PhD subject:

- Z. Zhang, X. Zhang, S. Li, N. Bastid, P. Crochet, D. Zhou
  Production of muons from heavy-flavour decays at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
  ALICE-ANA-2015-2573 (2015)
- S. Li, X. Zhang, Z. Zhang, N. Bastid, P. Crochet, D. Zhou
  Event activity dependence of muons from heavy-flavour decays in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
  ALICE-ANA-2015-2572 (2015)
- X. Zhang, N. Bastid, P. Crochet

  Measurement of the elliptic flow of muons from heavy-flavour decays at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

  ALICE-ANA-2013-921 (2013)
- S. Li, X. Zhang, Z. Zhang, N. Bastid, P. Crochet

  Production of muons from heavy-flavour decays at forward rapidity in p-Pb and Pb-p collisions at = 5.02 TeV

  ALICE-ANA-2013-920 (2013)
- L. Manceau, X. Zhang, N. Bastid, P. Crochet, S. Grigoryan and D. Zhou

  Performance of the ALICE muon spectrometer for the measurement of the B-hadron and D-hadron production cross sections in pp collisions at √s = 14 TeV via single muons

  ALICE-INT-2011-xxx (2011)
- L. Manceau, X. Zhang, N. Bastid, P. Crochet, S. Grigoryan and D. Zhou

  Performance of the ALICE muon spectrometer for the measurement of the B-hadron and D-hadron production cross sections in pp collisions at √s = 14 TeV

  ALICE-INT-2010-004 (2010)

PhD proposal n°3

Thesis title: "Search for a second low-mass (m_h<125 GeV) Higgs boson and measurement of Higgs boson properties in the two-photon decay channel with the CMS experiment at the LHC (CERN)"

Type of proposed PhD diploma: French☐ Chinese ☐ French & Chinese X (tick correct answer)

French host laboratory: Institut de physique nucléaire de Lyon (IPNL)

Chinese laboratory (if applicable): IHEP/CAS

Thesis advisor(s) and email(s): Prof. GASCON-SHOTKIN Suzanne (smgascon@in2p3.fr), Prof. CHEN Guoming (chengm@ihep.ac.cn)

Planned date of start of stay in French lab: October 2016

Planned duration of stay in French lab (months): 22 months

Expected date of thesis defense: 30/06/2018

Detailed description of the thesis subject:

CMS ("Compact Muon Solenoid") is one of two general-purpose experiments at the CERN ((« Laboratoire Européen de Physique des Particules ») LHC (« Large Hadron Collider ») ; it is the fruit of an international collaboration bringing together more than 2000 scientists coming from ~200 laboratories in ~40 countries. Its objectives are the search for new phenomena beyond the Standard Model as well as precision measurements of interactions within it. Between 2009 and 2012, during "Run 1", the LHC collided two proton beams at center-of-mass energies as high as 8 TeV. On July 4 2012, the two experiments CMS and ATLAS announced the discovery of a boson having a mass of approximately 125 GeV compatible with that predicted by Higgs, Englert and Brout (referred to simply as the 'Higgs boson' in what follows), resulting in the award of the 2013 Nobel Prize in Physics to Higgs and Englert. In the context of the Standard Model, this boson, henceforth observed both in its fermionic (b-quark or lepton tau) and bosonic (W, Z or photons via a quark top or W boson loop) decay channels, constitutes evidence for the mechanism by which elementary particles aquire their mass, electroweak symmetry-breaking.

Within CMS, the Sino-French team supervising the proposed thesis topic had a major role in the discovery of this new boson via one of the two most important decay channels: the two-photon channel (the other being the ZZ* channel resulting in four leptons). The team was one of the principal developers of the photon identification methods used, making possible the distinction between photons coming from the decay of a Higgs boson and those from the copious decays of ordinary neutral mesons such as p^0 s, the principal source of background. The team is also responsible for the determination of the photon energy scale via radiative decays of the Z boson Z→mmg, as well as for the commissioning and the validation of photon energy corrections.

Today, many important questions dealing with the nature and the origin of the Higgs boson discovered in 2012 remain unanswered. The diphoton decay cannel continues to contribute to their elucidation: It is the channel par excellence for an increasingly precise measurement of its mass, and it could furnish a determination, independent from other channels, of its scalar or pseudoscalar nature, as well as of its spin. But although the event rates measured to-date are compatible with those predicted by the Standard Model, the uncertainties leave the door open for other models (called 'BSM' for 'Beyond the Standard Model') such as those inspired by Supersymmetry, which require the existence of several Higgs bosons and which address the deficiencies of the Standard Model. A good number of these models allow for the possibility that one of these additional Higgs bosons has a lower mass than that of the boson which has already been discovered. The interest in such a search is reinforced by the observation, by 3 of the 4 experiences at LEP (the CERN e+e- collider which preceded the LHC), of a slight excess at the level of 2s at a mass of 98 GeV during the initial Higgs boson searches.

The team responsible for the supervision of the proposed thesis is responsible within CMS for the search for a second Higgs boson lighter than that observed at the mass of 125 GeV, in the diphoton decay channel. We first performed a phenomenological study [1] in the context of a particular BSM model, the NMSSM ("Next-to-Minimal Supersymmetric Standard Model") which showed that a second Higgs boson with a mass below 110 GeV could exist and have a cross section convoluted with a branching ratio into two photons up to 3 times that of the Standard Model. The team then led the experimental search within CMS in the Run 1 data for an additional Higgs boson with mass in the interval [80, 110] GeV. The results, recently made public [2], show a slight excess of events (with respect to Standard Model predictions) in the neighborhood of m~97.5 GeV at the level of approximately 2s, corresponding to a probability of ~4% that the excess is due to a statistical fluctuation of background Standard Model processes. The team's priority is therefore to pursue this analysis with the Run 2 data (2015-2018) at an unprecedented center-of-mass energy of 13 TeV, in order to reinforce or refute the hypothesis of this excess as a new resonance.

The doctoral student will therefore have the opportunity to analyse these new Run 2 data which should amount to approximately 100fb^{-1}, in other words four times the quantity of data recorded between 2009 and 2012 during Run 1 at center-of-mass energies of 7 and 8 TeV. S/he will carry out the search for one or several additional Higgs bosons which could become detectable at the new center-of-mass energy in the diphoton decay channel. S/he will also have the possibility to carry out a measurement of one of the properties of the existing Higgs boson resonance at 125 GeV (width or spin).

The program of work for the proposed thesis is organized around four aspects:

-Work within one of the areas where the team has already made contributions contributing to the discovery of the first Higgs boson: The selection of a pure sample of validation photons and the determination of the photon energy scale, from radiative decays of the Z boson (Z→mmg).

-Contribution to the development of the analysis for the search for a second light Higgs boson in Run 2 : The extension of the search zone down to masses ~60 GeV of the analysis used for the same search during Run 1, adapting it to the new operating conditions due to the greatly increased center-of-mass energy and foreseen improvements in its sensitivity imply:

o The validation of the new trigger path which the team specially developed for Run 2 to trigger events containing photons of lower transverse energy which could come from a lighter Higgs boson;

o A new method to treat background due to the Z boson resonance (~91.2 GeV) decaying to two electrons mistakenly identified as photons;

o The complete reoptimisation of the photon identification algorithm and the kinematic discriminants used in the analysis, for the case of a lighter Higgs boson.

-This thesis subject also includes a significant phenomenological aspect. What is involved is the interpretation of the experimental analysis results within the framework of classes of BSM models or of individual such models, notably 2HDM (« Two Higgs-double Models ») and the NMSSM. For this aspect, we collaborate with members of the French theory community who are specialists in this field, including several from the theory group of IPNL [3,4].

-Determination of the properties of the existing Higgs boson with m~125 GeV : As a result of the analysis of the Run 1 data, the mass of the 125 GeV Higgs boson and its indirect coupling to photons have been relatively well-measured. The doctoral student will have the possibility to contribute to the determination of some currently less well-measured properties, namely the parity and especially the spin (0 or 2) which will allow to distinguish between the hypothesis of the Higgs boson of the Standard Model and a more exotic particle such as the graviton (spin 2). The diphoton channel also has the capability to impose a strong constraint on the total width of the new boson. Interference effects in the production process produce a shift in the diphoton invariant mass spectrum which is a function of the total width of the boson [5].

Candidates' requested qualifications: Some experience in object-oriented C++ programming

Tentative timeline of the PhD preparation

- 2015-2016: The doctoral student will contribute to the validation of the first data recorded at 13 TeV, in particular as regards the following subject : The selection of validation photons as well as the extraction of the photon energy scale via Z→mmg. In addition, s/he will contribute to the reoptimisation of the entire analysis chain in view of the new data-taking conditions, under the hypothesis of a lower-mass Higgs boson. The objective is to obtain preliminary results which could be made public for presentation at conferences in 2016.
- 2016-2017: Continuation of Run 2 data taking. The doctoral student will carry out the analysis of these data in the search for a second low-mass Higgs boson. S/he will also have the possibility to participate in the study of the properties of the 125 GeV Higgs boson, notably to constrain the measurement of its natural width.
- 2017-2018: Continuation and end of Run 2 data taking. The doctoral student will finish her/his analyses and write the thesis manuscript.

Publications related to the PhD subject:

[1] “Observation of the diphoton decay of the Higgs boson and measurement of its properties”, CMS Collaboration (Vardan Khachatryan (Yerevan Phys. Inst.) et al.), Eur.Phys.J. C74 (2014) 10, 3076

[2] “Study of diphoton decays of the lightest scalar Higgs boson in the Next-to-Minimal Supersymmetric Standard Model ”, Jia-Wei Fan, Jun-Quan Tao, Yu-Qiao Shen, Guo-Ming Chen, He-Sheng Chen, S. Gascon-Shotkin, M. Lethuillier, L. Sgandurra, P. Soulet, Chin.Phys. C38 (2014) 073101

[3] “Search for new resonances in the diphoton final state in the mass range between 80 and 110 GeV in pp collisions at sqrt(s) = 8 TeV”, CMS Collaboration, https://cds.cern.ch/record/2063739

PhD proposal n°4

Optimization of a TPC detector for future e+/e- experiments : Study of distortions induced by space charge and ion backflow effects CEA/IRFU

Thesis title: "Optimization of a TPC detector for future e+/e- experiments: Study of distortions dues to space charge and ions feedbacks"

Type of proposed PhD diploma: French☐ Chinese ☐ French & Chinese X (tick correct answer)

French host laboratory: CEA-Saclay

Chinese laboratory (if applicable): Tsinghua University or IHEP

Thesis advisor(s) and email(s): Roy Aleksan (roy.aleksan@cea.fr); Philippe Schwemling (Philippe.schwenling@cea.fr)

Planned date of start of stay in French lab: 2016, October 1 or earlier

Planned duration of stay in French lab (months): 36

Expected date of thesis defense: 2019

Detailed description of the thesis subject:

Candidates' requested qualifications: Master-2 or equivalent in instrumentation or particle physics.
Tentative timeline of the PhD preparation
· _First year: Simulation of charge effect in a large TPC detector and estimation of track's resolution of the tracking system for circular ee collider experiments
· _Second year : Simulation of experimental test setup and experimental evaluation of ions' effect using cosmic TPC data and test-beam
· _Third year: Optimization of the tracking system for circular collider detectors, based on benchmark channels.

Publications related to the PhD subject:
· _"Ion backflow in the Micromegas TPC for the future linear collider", P. Colas et al., NIM A535, (2004), 226-230.
· _"Investigation of ion backflow in bulk micromegas detectors", P. Bhattacharya et al., JINST 10 (2015) P09017.
· _"Ion back-flow gating in a micromegas device", F. Jeanneau et al., NIM A623, 1 (2010), 94–96.
COMMISSARIAT A L'ENERGIE ATOMIQUE (CEA) DE SACLAY – FRANCE
Optimization of a TPC detector for future e+/e- experiments : Study of distortions induced by space charge and ion backflow effects CEA/IRFU

THESIS PROPOSAL

« Optimization of a TPC detector for future e+/e- experiments : Study of distortions induced by space charge and ion backflow effects»

DESCRIPTION AND CONTEXT

Direct searches for signatures of physics beyond the Standard Model and the complementary approach of looking for deviations from Standard Model predictions in measurements of observables that can be computed with high precision will both be possible by 2030 at an e+e- collider, either a linear collider (ILC) or a circular (FCC-ee/CEPC). In all cases, the detectors have to be of unequalled stability and precision, to allow measurement with a precision at the 10-5 level.

An attractive detection technique for charge particles is the Time Projection Chamber (TPC). The principle is to bend the tracks corresponding to the charged particle trajectory in a magnetic field. The measurement of the curvature radius of the tracks gives a measurement of the particle momentum. When they cross the gaseous volume of the TPC, the particles leave an ionization trail of electron-ion pairs called primary ionization. The electrons from the primary ionization drift under the combined effect of the magnetic field and an electric field towards the end flanges of the detector. They are then amplified by avalanche effect by gaseous structures, like Charpak Multiwire Proportional Chambers in past detectors, and presently micro-etched detectors like Micromegas, whose spatial resolution is much better.

The amplification mechanism generates a lot of positive ions (secondary ionization), in addition to the primary ions coming from the primary ionization process. About 1% of the secondary ions end up in the detector drift volume, where they induce a space charge inducing distortions on the electron trajectories, and as a consequence, distortions on the track measurements. The target for FCC-ee, CEPC and ILC is to limit this ion back flow phenomenon to less than 0.1%. To reach this goal, there is a significant amount of work to be done, to get a detailed understanding of the phenomenon, and to design ion blocking systems, like gating grids.

Figure 1 : Principle of operation of a TPC detector.

TEAM DESCRIPTION

The IRFU-SPP and IRFU-SEDI teams have solid experience in design and construction of gaseous detectors for physics experiments. They contributed in the past to the construction of the TPCs for the ALEPH and DELPHI detectors, as well as T2K recently. They are presently involved in the existing linear and circular e+/e- collider projects. There is also at IRFU a strong expertise on the Micromegas detectors (invented and developed by IRFU teams) and their applications.

PROPOSED WORK

We propose in this thesis to study experimentally the distortions induced by positive ions on the charged tracks, and to study the amount of positive ions drifting back into the drift volume. This will be done using small to medium-scale detector prototypes. The measurements will be confronted to theoretical estimates from simulation. Building upon this study, the goal is to optimize the detector parameters, with the aim of minimizing the distortions. The student will have to master progressively the whole workflow, starting from the design of prototypes, their realization, up to the final COMMISSARIAT A L'ENERGIE ATOMIQUE (CEA) DE SACLAY – FRANCE

Optimization of a TPC detector for future e+/e- experiments : Study of distortions induced by space charge and ion backflow effects CEA/IRFU

experimental data acquisition and analysis. Data acquisition will be done using cosmic muons, radioactive sources and test-beams (at CERN-Geneva, or DESY-Hamburg). Finally, the measurements of the distortion will be used to predict the momentum resolution and invariant mass resolution of a complete detector system. The results on the resolutions will be used to check the expected detector performance, for various detector setup options, and for specific physics analyses, like the precision measurement of the Higgs boson mass in the HiggsStrahlung process.
This work is also taking place in the framework of the French Chinese Particle Physics Laboratory LIA-FCPPL, within which strong links have been established since several years with Chinese teams, in particular from the Tsinghua University and IHEP.
Figure 2 : medium-scale(left) and small-scale TPC prototypes.

REQUIRED ACADEMIC CURSUS AND COMPETENCES
Master-2 or equivalent academic level in instrumentation or elementary particle physics.
A basic knowledge of analog and digital electronics, of data acquisition systems and data processing techniques will be very useful.

ACQUIRED COMPETENCES
This thesis work will allow the successful candidate to acquire a global view of the design and detailed characterization of a detection system. It will allow him also to develop his understanding of particle physics, and it will give him many occasions for partnership with industrial companies. The international aspects of the collaboration will give the candidate many academic opportunities abroad.

COLLABORATIONS/PARTNERSHIPS
Within an international collaboration around ILC, FCC and CEPC projects, the student will have to participate to working meetings in France and abroad. He will also have technical discussion with detector manufacturers. The results obtained will be presented at international conferences and published in international peer-reviewed journals.

CONTACTS
Roy Aleksan
roy.aleksan@cea.fr

PhD proposal n°5

Thesis title: Fast luminosity monitoring and feedback using monocrystalline CVD diamond sensors at the SuperKEKB electron-positron collider in Japan

Type of proposed PhD diploma: French × Chinese ☐ French & Chinese × (if relevant)

French host laboratory: LAL Université Paris-Sud- Bâtiment 200, BP 34 – 91898 Orsay cedex, FRANCE

Chinese laboratory (if applicable):

Thesis advisor(s) and email(s):

Philip Bambade (bambade@lal.in2p3.fr), co-supervised by Cécile Rimbault (rimbault@lal.in2p3.fr)

Planned date of start of stay in French lab: October 2016

Planned duration of stay in French lab (months): 36 months

Expected date of thesis defense: September 2019

Detailed description of the thesis subject:

SUPERKEKB AND BELLE II

SuperKEKB [1] is a very high luminosity B meson factory constructed at KEK (Tsukuba, Japan). It is an electron-positron circular collider with asymmetric energies of 7 and 4 GeV respectively, designed to reach the highest ever achieved instantaneous luminosity of 8×1035 cm-2 s-1, 40 times larger than with the previous generation of B factories.

A newly invented nanobeam scheme will be used for the first time, in which two ultra-low emittance beams are collided with a large crossing angle, to significantly shorten the effective interaction region. This allows bunches to have tiny beam sizes of a few tens of nanometer in the vertical dimension without causing severe blow-up or instability from their space-charge. The total charge stored in the rings is maximized by filling RF buckets with bunches every 4 ns, leading to trains of 2500 bunches.

The accelerator infrastructure is almost complete and a first stage of commissioning will start in February 2016 without final focus optics (Phase 1). First focused beams are scheduled to be collided for tests and optimization of the nanobeam scheme in June 2017 (Phase 2), with the expectation of full luminosity delivery to the Belle II experiment from fall 2018 (Phase 3).

The aim of the scientific program of the Belle II experiment [2] is discovering quantum manifestations of physics beyond the standard model, through measurements of unprecedented precision in the flavor sector, complementing the studies done with LHC experiments (for instance for reactions involving significant loss of energy to neutrinos).

FAST LUMINOSITY MEASUREMENTS AND FEEDBACK

Because the beam sizes in SuperKEKB are tiny at the interaction point, the luminosity is very sensitive to the stability of the last focusing elements. Vibration of up to about 5-6 nm, corresponding to a tenth of the beam size, is expected in the vertical plane for frequencies up to 100 Hz. In the horizontal plane motion of hundreds of nm is expected at a few Hz.

A feedback system [3] based on fast luminosity measurements is essential to cope with such variations. A relative precision of 10-3 in 1 msec over all 2500 bunches, with less than 1% contamination from non-luminosity scaling effects, is specified. Average single bunch luminosities on second time scales are also important for beam dynamics studies, related for instance to the continuous top-up injection scheme used at SuperKEKB.

Such precise and fast measurements will only be possible exploiting the very large cross section of the radiative Bhabha process at zero photon scattering angle [4]. Both scattered photons and positrons will be measured, at two dedicated locations 11.5 and 30 meters downstream of the collision point, in the HER (High Energy Ring) and LER (Low Energy Ring), respectively. The LER location was chosen to maximize signal rates and minimize backgrounds, taking into account the beam pipe geometry.

To enable fast measurements, Chemical Vapor Deposition (CVD) diamond sensors are used immediately outside the beam pipe. Such sensors are well suited for particle accelerators and detectors at the intensity frontier, for cases where few channels are needed, because of their high tolerance to all types of radiation, the high carrier mobility in diamond, which enables fast signal collection, and their compactness and ease of use.

A 140 µm thick mono-crystalline CVD diamond sensor producing < 2 ns FWHM pulse widths is under study. A radiator will be placed after a specially tilted beam pipe currently being prepared by KEK to enhance our signal rates for Phase 2. For initial testing with unfocused beams during Phase 1 in 2016, thicker sensors (500 µm) will be used along with charge amplifiers with 10 ns shaping time to detect scattering events from bremsstrahlung of the beam on the residual gas. The same setup will also be adequate to detect Bhabha scattering rates during initial operation with colliding beams in 2017, when luminosities and pileup effects between subsequent bunch crossings are still moderate. Development of new faster charge amplifiers with a shaping time of about 2 ns is under way at LAL for the Phase 3 higher luminosity operation in 2018, as well as a dedicated ultra-compact sensor packaging and mechanical integration.

The data acquisition architecture is based on FPGA boards populated with a 4-channel ADC and DAC running at 1 GHz. The FPGA sums the signals from all bunches in a sliding 1 ms gate, as well as separately per bunch crossing. The ADC sampling is synchronous with the 4 ns bunch frequency. The development of the data acquisition system is almost complete and ready for tests at SuperKEKB in early 2016.

Our fast relative luminosity measurement will be calibrated against slower absolute measurements performed on much slower (several minutes) time scales by the Belle II experiment. This will allow original studies of a macroscopic QED suppression effect of the Bhabha cross section, predicted when the transverse beam sizes become smaller than the typical equivalent wave length of the transverse momentum exchanged in the radiative Bhabha process at zero photon scattering angle.

HOST TEAM AND COLLABORATORS

The host team is composed of two researchers (P. Bambade, C. Rimbault), with experience with several topics relevant to the Machine-Detector Interface of high energy electron positron colliders, including the related beam diagnostics and dynamics, one research associate (V. Kubytskyi), expert in diamond sensors and signal processing, one 3rd year PhD student (D. El Khechen), one electronics engineer (D. Jehanno), expert in digital electronics and feedback, and several technical staff (A. Blin, Y. Peinaud, P. Cornebise). We collaborate with the SERDI electronics group at LAL on the development of the ultra-compact diamond sensor and fast charge amplifier needed for Phase 3. Exchanges are moreover continuous with our partner team at KEK, in particular S. Uehara, coordinator of luminosity monitoring for Belle II, Y. Funakoshi, in charge of SuperKEKB commissioning/operation and main coordinator of the luminosity feedback systems, as well as the BEAST working group (coordinators: H. Nakayama and S. Vahsen), in charge of characterizing the SuperKEKB beam induced backgrounds for Belle II.

Candidates' requested qualifications:

Applicants need to have a master's degree or equivalent in physics, have strong experimental and analytical skills, and be able to communicate at a scientific level in English. Prior training and experience in subatomic experimental physics as well as computing skills would be an advantage. A cover letter outlining motivations

and goals, a CV and at least one reference letter should be sent to Philip Bambade (bambade@lal.in2p3.fr) and Cécile Rimbault (rimbault@lal.in2p3.fr).

Tentative timeline of the PhD preparation

The PhD student will be invited to join several of the following tasks and activities of our group, in the context of a personal career development plan taking into account his/her prior skills, training needs and interests:

1) Optimize the positioning and integration of the diamond sensor instrumentation near the HER beam pipe using GEANT4

2) Participate in Phase 2 commissioning of the nanobeam colliding beam scheme; Measure single beam backgrounds and luminosity during beam tuning with installed diamond sensors ; Compare and assess performance using simulation ; Compare with absolute measurements to probe predicted “beam size suppression” effects

3) Study dithering feedback technique to stabilize the beam orbit in the horizontal plane ; Investigate digital implementation at FPGA level

4) Design and test ultra-compact thin diamond sensor and fast charge amplifier for the Phase 3 highest luminosity operation

The expected approximate timeline is indicated below:

1) Autumn 2016 - Winter 2017: Finalize simulation study of new tilted beam pipe and radiator in LER; Optimize detector location in HER

2) Summer 2017 - Winter 2018: Participate in SuperKEKB Phase 2 nanobeam commissioning at KEK; Measurement and analysis of luminosity and single beam background rates ; Investigation of “beam size suppression” effects ; Feedback study

3) Summer 2018 - Summer 2019: Tests of ultra-compact thin diamond sensor and fast charge amplifier for Phase 3 highest luminosity operation; Digital FPGA based dithering feedback; Dissemination (publication, seminars) ; PhD writing and defense

Publications related to the PhD subject:

[1] Accelerator design at SuperKEKB, Y. Ohnishi,Prog. Theory. Exp. Phys. 2013, 03A0111, DOI 10.1093/ptep/pts083

[2] Belle II Technical Design Report, T. Abe et al., arXiv:1011.0352 [physics.ins-det], Oct. 2010

[3] Interaction Point Orbit Feedback System at SuperKEKB, Y. Funakoshi et al., IPAC 2015, MOPHA054

[4] Fast Luminosity Monitoring using Diamond Sensors for the Super Flavor Factory SuperKEKB, D. El Khechen et al., IPAC 2014, THPME090