Dr. Nicole d'Hose
IRFU-SPhN , CEA-Saclay
F-91191 Gif-sur-Yvette

Report on the Doctoral thesis of Mateusz Dyndal

Tittle :
Two-Photon Interactions in Proton-Proton Collisions with the ATLAS Experiment at LHC

The thesis presented by Mateusz Dyndal concerns an impressive work realized on the study of the two-photon interactions in proton-proton collisions with the ATLAS experiment at LHC. The thesis consists of three part dedicated to theory, detectors and data analysis respectively. The first and third parts are the bases of two publications where Mateusz was one of the main actors. This is so rare in the short time of a PhD student in a broad high energy physics experiment that it needs to be underlined. The second part is focused on the ATLAS forward detectors and a future hardware development which has led to a Technical Design Report.

The work presented in this thesis reports on contribution to the development of the current understanding of two-photon processes at high energies which can be studied with good experimental precision at the Large Hadron Collider (LHC). It is clear that a significant fraction of proton-proton collisions at high energies involved reactions mediated by quasi-real photons. These reactions are dominated by elastic scattering with a single photon exchange and the proton-proton collision can be considered as a photon-photon collision.

Part I gives theoretical motivations of the two-photon physics. This part recalls the bases of the Standard Model particles, Quantum Electrodynamics, Quantum Chromodynamics and classification of reactions (inclusive or non-diffractive interaction, elastic scattering, single diffraction and double diffraction interactions). Then it is reported that in proton-proton collision, each of the two incoming protons can emit a quasi-real photon which fuse to give a centrally produced final state X which can be a lepton pair or a vector boson pair or even a Higgs scalar boson. This exclusive reaction is noted $pp(\gamma\gamma) \rightarrow ppX$ and competitive reactions with single or double dissociation of the protons are also considered. The Equivalent Photon Approximation (EPA) allows to describe the total cross section of the reaction $pp(\gamma\gamma) \rightarrow ppX$ as a photon-photon fusion cross section $\gamma\gamma \rightarrow X$ folded with the equivalent photon distribution for the two protons. The author of the thesis proposed to generalize this description to the physics case where the impact parameter dependence cannot be neglected. The finite size of the colliding protons is taken into account in this calculation. Thus it results an absorptive correction defined by a survival factor. This work has been published recently by Mateusz Dyndal and Laurent Schoeffel, his research advisor, in Phys. Lett. B741 (2015) 66-70. Finally a comparison of different Monte Carlo (MC) generators for two photon reactions in proton-proton collisions is presented.

Part II of the thesis introduces the Large Hadron Collider and gives a detailed description of the ATLAS experimental setup including the sub-detectors, triggers, data processing and simulation chain. In the exclusive reaction, $pp(\gamma\gamma) \rightarrow ppX$ the protons are deflected at very small angles. The present forward detectors which provide a large pseudo-rapidity are reviewed. Their acceptances are studied as a function of the β^* LHC beam parameter which measures how the beam is squeezed towards the interaction point (IP). The ATLAS Forward Proton (AFP) project promises a significant extension of the ATLAS forward physics program by tagging and measuring the momentum and emission angle of diffractively scattered protons. A detailed description of the two detector beam interfaces which can be installed at 204m and 212m from the IP on both sides is given. Two solutions are envisaged (the Hamburg Beam Pipe solution and the Roman Pot stations already adopted at CERN). Tracking detectors with high resolution pixelated Silicon detectors and timing detectors based on Quartz Timing Cherenkov (QUARTIC) detectors to give a timing resolution of the order of 10ps are studied. Then MC simulations are presented. Mateusz significantly contributed to the development of models for simulated event digitization and reconstruction both for the Silicon detectors and the timing detector. A so-called Fast Cherenkov model for optical photon transportation has been elaborated by Mateusz to avoid time consuming simulation using the standard light Cherenkov option in GEANT4. The simulated performances, as geometrical acceptance, detector resolutions and proton reconstruction efficiency according different pile-up scenarios are presented. These studies are part of the Technical Design Report for the ATLAS detector.

Part III describes the different steps of the data analysis of a measurement of exclusive two-photon production of lepton pairs (electrons or muons) in proton-proton collisions at center-of-mass energy $\sqrt{s} = 7$ TeV with the ATLAS experiment at LHC. Exclusivity selection criteria are accurately chosen as a veto on additional particle track activity. To suppress the proton dissociation background, the lepton pair is required to have small transverse momentum. Moreover a fit to the dilepton acoplanarity distribution is used. Background to the exclusive signal includes contributions from single and double proton dissociative lepton pair production as well as $Z/\gamma\mu$, diboson, ttbar, multijet production. They are estimated using MC simulations. A detailed review on the systematic uncertainties and cross checks is given.
Using an integrated luminosity of 4.6 fb^{-1} of data, the fiducial cross sections for two photon production of lepton pairs have been measured and compared to the theory predictions. When proton absorptive effects due to the finite size of the proton are taken into account in the theory calculation, the measured cross sections are found to be consistent with the theory prediction made by Mateusz and Laurent Schoeffel. This underlines the quality and the comprehensiveness of the achievement of the work during this thesis.
The experimental result has been obtained by Mateusz and the analysis has passed all the criteria of quality and cross checks required by the ATLAS Collaboration in order to be approved and already published in Physics Letters B 749 (2015) 242-261. This provides the level of performance of the young author of the thesis.

The manuscript is rather long as it contains actually three topics. However it is very well written and it was a pleasure to read the 240 pages. Given the quality of the work presented in this thesis, the achievement with two publications and a Technical Design Report, there is no doubt that this work deserves to be presented and defended. I would like to add that Mateusz Dyndal deserves also the greatest distinction with the compliment for his excellent work.

Saclay, September 2, 2015

Nicole d'Hose