Report on research activity during my P2IO postdoctoral position at IPN-Orsay

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1 Project Goals

One of the main directions of the Jefferson Lab (JLab) group of the Institut de Physique Nucléaire (IPN) is the investigation of the nucleon structure through Compton scattering on nucleon/nucleus in a deeply virtual (when initial and/or final photon is highly virtual) regime $\gamma^\star N \to \gamma^{\star\prime} N$. According to the formalism of Generalized Parton Distributions (GPDs) [1, 2, 3] Compton Scattering in a deeply virtual regime can provide important information on the 3 dimensional quark gluon structure of the nucleon, which cannot be accessed through elastic scattering or Deep Inelastic Scattering experiments. Two different cases of the general Compton process are called Deeply Virtual Compton Scattering (DVCS) and Timelike Compton Scattering (TCS), where the incoming/outgoing photon is highly spacelike/timelike virtual, whereas the outgoing/incoming is on shell. The main goal of this postdoctoral project was to analyze current experimental data (obtained using 6 GeV electron beam of CEBAF accelerator), and to study possibilities for new experiments with the upgraded CEBAF machine (11 GeV electron beam).

2 TCS

This process can be accessed experimentally through the photoproduction of lepton pairs $\gamma p \to l^- l^+ p$. For analyzing the TCS process, experimental data obtained by the CLAS detector located in experimental Hall-B at JLab was used. Particularly, data of two run periods called "e1-6" and "e1f" were used. Both are high energy (respectively 5.76 GeV and 5.479 GeV) electroproduction experiments on a liquid Hydrogen target. My work on TCS included skimming from experimental data events corresponding to quasi-real photoproduction, developing particle identification cuts for e^-, e^+ and proton, developing momentum corrections for electrons and protons, and extraction of preliminary results from the experimental data. In 2012, together with TCS group, I also have participated to the preparation of an experiment proposal for measuring TCS with the upgraded 11 GeV electron beam and the CLAS12 detector. The proposal is entitled "Timelike Compton Scattering and J/Ψ photoproduction in e^-e^+ pair production with CLAS12 at 11 GeV". I am co-spokesperson of this experiment that was approved by JLab Program Advisory Committee (PAC) [5] with an A- scientific rating for 120 days beam time. My work in the proposal includes projections of expected observables for different models and generation of Monte Carlo events which were used for acceptance studies and rate estimates.

In Sep. 2012 I participated to the "20th INTERNATIONAL SYMPOSIUM on Spin Physics (SPIN2012)", (JINR, Dubna, Russia), where I presented the above mentioned work. The proceedings of the conference has been published in the "Journal Physics of Elementary Particles and Atomic Nuclei" [6]. This work was also presented at the "Photon 2013" (Paris, France) conference on May 2013, and in a topical workshop "Deeply Virtual Compton Scattering: From Observables to GPDs" (Bochum Germany), on Feb 2014.

3 DVCS

This process is experimentally accessible through the electroproduction of real photons $ep \to ep\gamma$. The IPN group, together with CEA-Saclay group, is also collaborating with JLab experimental Hall A, and plays a central role in the preparation and implementation of completed/planned DVCS experiments in Hall A. The total analysis of experimental data is mainly conducted through the collaboration between IPN and SPhN/CEA-Saclay groups. One PhD student from SPhN/CEA-Saclay is involved in the analysis, Maxime Defurne, supervised by Frank Sabatié, and 2 PhD students from IPN, Camille Desnault and Alejandro Martí, and myself supervised by Carlos Muñoz Camacho. We hold regular meetings between our groups (SPhN and IPN) frequently to discuss the status of the analysis and future plans.

One of my main contributions to the data analysis has been the development of a full Monte Carlo simulation of the experimental setup based on Geant4. In order to extract observables from the experimental data precisely, it is very important to know the acceptance of the detector very well. The data from the first experiment in Hall A was analyzed by a Geant3 package which was implemented by a FORTRAN programming language, but now Geant3 is not supported anymore and instead the newer Geant version is Geant4 which is written in C++. Therefore the DVCS group decided to build a new Geant4 based simulation package for the Hall A DVCS experiment. I am responsible for the the construction/modeling of the HALL A experimental setup via the Geant4 package. Now the simulation package is ready and the experimental data taken in the 2010 DVCS experiment can be analyzed using this package. It is worth mentioning that the validity of this package was tested by analyzing the experimental data taken in 2004 and comparing to the results obtained using the Geant3 package. At this moment we have first preliminary results for the data with proton target, and results are now passing through final checks, before submission to Journal. First results with Deuteron target are expected within 3 months.

In May 2013, the DVCS group submitted a new proposal for measuring DVCS in experimental Hall C. Together with DVCS group I played a leading role in the preparation of a proposal entitled "Exclusive Deeply Virtual Compton and Neutral Pion Cross-Section Measurements in Hall C". I am co-spokesperson for the proposal, submitted to the JLab PAC on May 6th [7]. In particular, I used the Geant4 simulation package to estimate the expected rates for this future experiment. This proposal was presented in the Hall C collaboration meeting (Aug. 2013).

Starting Aug. 2013 with Supervisor Carlos Muñoz Camacho, and student C. Desnault, we have moved to JLab for participation to the construction of experimental setup for the upcoming DVCS experiment at experimental Hall A. Other than working on construction of experimental setup, with M. Defurne I was working on the estimation of exclusive π^0 contamination to the DVCS channel using the Geant4 package. These studies were presented in the DVCS collaboration meeting on Dec. 2013 at Old Dominion University (Norfolk, Virginia, USA).

4 Publications

- Timelike Compton Scattering at JLab, R.G. Paremuzyan Physics of Particles and Nuclei, 45, 1, pp 155-157. 2014., arXiv:1302.3088
- Timelike Compton Scattering and J/psi photoproduction on the proton in e^-e^+ pair production with CLAS12 at 11 GeV, Proposal PR12-12-001 [5]
- Exclusive Deeply Virtual Compton and Neutral Pion Cross Section Measurements in Hall C, Proposal: PR12-13-010 [7]

5 Relevance of the project within P2IO

This project belongs to the P2IO scientific theme dedicated to the study of strongly coupled nuclear matter. DVCS and TCS experiments aim at understanding the dynamics of QCD in the energy range where the theory is non-perturbative. The French groups of the P2IO network play a leading role in the design, construction and analysis of experiments carried out at Jefferson Lab (Virginia, USA).

This postdoctoral appointment have contributed to both the analysis of previous data, and the design of two new experiments, successfully approved, which will run soon after the Upgrade of Jefferson Lab to 12 GeV (2014). It has also strengthen the collaboration between the groups of SPhN/IRFU and IPNO, both of them with similar scientific interests and projects. Furthermore, these topics are the subject of theoretical research by our colleagues of CPhT at the École Polytechnique, and the subject of several interactions between theory and experimental teams within P2IO.

6 Position after P2IO

There is no new position at this moment.

7 Summary of work at IPN

I have presented works on TCS and DVCS simulations in several conferences and workshops. I was involved in the preparation of two experiment proposals submitted to the JLab PAC. Both of them are already approved with scientific "A" rating. In collaboration with the CEA-Saclay group, I was involved in the Geant4 modeling/construction of the DVCS experimental setup in experimental Hall A at JLab. One conference proceeding is published.

References

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[3] A. V. Radyushkin, Phys. Rev. D56, 5524 (1997), hep-ph/9704207.

[4] R.G. Paremuzyan Physics of Particles and Nuclei, 45, 1, pp 155-157. 2014., arXiv:1302.3088

[5] REPORT OF THE 39^{TH} PROGRAM ADVISORY COMMITTEE (PAC 39) MEETING `http://www.jlab.org/exp_prog/PACpage/PAC39/PAC39%20Final_Report.pdf`

[6] R.G. Paremuzyan Physics of Particles and Nuclei, 45, 1, pp 155-157. 2014., arXiv:1302.3088 [nucl-ex]

[7] REPORT OF THE 40^{TH} PROGRAM ADVISORY COMMITTEE (PAC 40) MEETING `http://www.jlab.org/exp_prog/PACpage/PAC40/PAC40_Final_Report.pdf`