2013/2014 P2IO activity report

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September, 5th 2014.

Project goals: Deeply Virtual Compton Scattering at COMPASS for the study of the nucleon structure

The introduction of the generalized parton distributions (GPDs) has brought a new insight on the study of the nucleon structure. GPDs correlate both momentum and transverse spatial information of the quarks inside the nucleon, providing a three dimensional imaging of the nucleon. Experimentally, those can be accessed by exclusive processes such as deeply virtual Compton scattering (DVCS), or hard exclusive meson production (HEMP).

COMPASS (Common Muon Proton Apparatus for Structure and Spectroscopy), at CERN, will be able to measure the DVCS cross section with both polarized μ^+ and μ^- beams, which will grant important additional insight for the extraction of the GPDs. It is also granted with a high luminosity ($10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$) and a wide kinematic range ($0.005 < x_{Bj} < 0.03$, Q^2 up to 10 GeV^2), which remains unexplored to date. To measure the DVCS process, the COMPASS setup will be completed with a Time-Of-Flight recoil detector (to identify the recoiling proton) and a new electromagnetic calorimeter (to enlarge the photon angular acceptance).

During 2012, a four weeks long test run has been recorded, to prove the capability to measure the DVCS cross section at COMPASS. I am in charge of the analysis of this test run for the DVCS and exclusive neutral pion channels, and ultimately plan to take participation into the phenomenological extraction of the GPDs with those results.

Main achievements

For the analysis of the COMPASS DVCS 2012 run, I have been performing many tasks, among which the following are complete or mostly complete: luminosity calculation; estimations of efficiencies for the electromagnetic calorimeters; and complete implementation of the Time-Of-Flight detector in the Monte Carlo simulation. In the context of the CEA-Saclay instrumental and technical commitment to COMPASS, I have also been involved, for part time (about 15 %) on the tests of the COMPASS drift chamber DC4, one of the large elements of the COMPASS tracking.

Luminosity calculation

The luminosity calculation is necessary for the absolute normalization of the cross section. This luminosity can be expressed as the product of the numbers of protons in the target multiplied by the the number of muons crossing the target. The number of protons is accessible by knowing the length and density of the target. The muons, on their side, have to be reconstructed individually in a “beam telescope”, composed of planes of scintillator fibers and silicon pixel detectors. To obtain a minimal bias on the flux measurement, the muon tracks have to be recorded independently of physics events. This is why the recording of the beam telescope is triggered by a random trigger, composed of an alpha source and two scintillators in coincidence. For each random trigger, the tracks are recorded and counted during the trigger time gate. At each cycle of the accelerator, we know the number of muons recorded during the random triggers, and, knowing how many random triggers were counted, and their time gate, we can deduce the total number of muons passing through the target during the cycle.

The flux obtained with this method has been evaluated to be 3.5×10^8 (1.5×10^8) muons per cycle for μ^+ (μ^-) runs, which is compatible (modulo the dead time) to an independent muon flux measurement made by a ionisation chamber. I have developed and implemented the muon flux calculation method, and I calculated the muon flux for all the runs of the DVCS 2012 data taking period.

Photons and neutral pion reconstruction efficiency thanks to Monte Carlo simulation

The photon efficiency is an important correction in the evaluation of the DVCS cross section. The π^0 efficiency is also vital to understand, since the π^0 with only one photon reconstructed is the main background of DVCS. Hence it is important to know, among produced π^0, the respective proportions of π^0 for which one photon and two photons are reconstructed.

The official Monte Carlo simulation of the experiment is composed of a complete description of the detector in GEANT3, for the simulation of the particles response into the detector, to which is adjoined an event generator, which can be choosed between many (LEPTO for semi-inclusive events, HepGEN for $\mu p \to \mu p \gamma$ and $\mu p \to \mu p \pi^0$ exclusive reactions). This allows to simulate the detector response to the reaction we want to study.

In the case of single photons, the efficiency globally increases with the angle, since the quantity of matter diminishes. It is around 70-80% for the large angle calorimeter (closest to the target), and goes down to 40-50% in the most forward calorimeter (furthest to the target, with more material to go through).

In the case of the neutral pions, the reconstruction efficiency is around 50% at intermediate angle and energies, to drop where we get close to the acceptance edges, because of geometrical effects at larger angles, and because of photon absorption at lower angles. Our study also demonstrate that a lower calorimeter threshold helps increasing the pion reconstruction efficiency, hence decreasing the π^0 contamination.

I have fully ensured the development and the implementation of this method of estimation of reconstruction efficiency.

Reconstruction of the information of the CAMERA Time-Of-Flight detector in the Monte Carlo simulation

The CAMERA proton recoil detector allows to reconstruct and identify the protons thanks to the measurement of the time-of-flight of the particles. For that it is equipped of two scintillator barrels, each composed of 24 elements, each of those being read by two PMTs.

When I started working with the simulation, the CAMERA simulation was not complete. The geometry was added into GEANT3, and the energy deposited by the Monte Carlo particles were recorded. However, the geometry was not fully tested yet, and the digitization of the Monte Carlo hits was not implemented (by digitization we mean the conversion of the Monte Carlo energy deposits into digital hits as they are recorded by the detector).

Today, most of the bugs coming from the geometry have been fixed, and the digitization is mostly ready. The “pure” Monte Carlo signal recorded in the simulation is consistent with the signal recorded in the data, so as the digitized Monte Carlo signal. To date, only a few issues remain to be settled.

I have been responsible for the test of the CAMERA geometry. I have also been fully responsible of the implementation of the digitization.

Tests on large drift chamber DC4.

The large drift chamber DC4 is composed of four independent detection “views”, to measure the charged particle position in different directions: horizontal, vertical, and tilted -10 and +10 degrees wrt horizontal. Each of those “views” are composed of two planes of 128 sensitive wires each (the wires being perpendicular to the direction detections).

Various tests have followed the maintenance and reparation operations performed by the technical services at CEA Saclay. The goals of those tests were:

- to check the robustness of the sensitive wires to high voltages;
- to check the gain uniformity (plane by plane first, then as a function of the X,Y position in the plane);
- and to measure the level of background noise, and verify its uniformity.

Those tests have been performed at Saclay, and after the transportation of the detector to CERN (in order to check that the chamber properties have not been affected by transportation). I have been actively involved in performing these tests, both at Saclay and at CERN.

Relevance of the DVCS experiment at COMPASS within P2IO

The understanding of the nucleon structure remains a big challenge in nuclear physics.

As mentioned above, GPDs have been a major breakthrough in the study of the nucleon structure, as they parameterize the non-perturbative content of the nucleon.

The theory of GPDs, rooted in the middle 1990's, has known continuous improvement since then, and the effort goes on. There is, in this sense, an important ongoing theoretical effort from the phenomenology group at Saclay and the hadronic physics group at IPN Orsay for the extraction of GPDs observables with the available data.

On the experimental side, a significant set of DVCS data (mainly from DESY and Jefferson Lab) have been recorded and analysed (or are under analysis). Again, the contributions of both Jefferson Lab group at Saclay and the Orsay group are major.

The GPD experiment at COMPASS proposes to fill an important kinematic gap ($0.005 < x_{Bj} < 0.03$), between data sets from H1 and ZEUS (below this x_{Bj} range), and Hermes and Jefferson Lab (above this x_{Bj} range). For the extraction of the GPDs from those data we could really benefit from the expertise of the phenomenology group at Saclay, which is in total synergy between the experimental groups in Orsay and Saclay.

Publications and oral contributions

Co-authorsip in peer-reviewed articles

- I.Korover *et al.*: "Approaching the nucleon-nucleon short-range repulsive core via the 4He(e,e'pN) triple coincidence reaction", Physical Review Letter **113** (2014) 022501 (e-Print: arXiv:1401.6138).

COMPASS GPDs internal notes

- "Muon flux comparison: t10-t14 vs slot2" (July 4$^{\text{th}}$ 2014).

Conferences

- "The GPD physics program at COMPASS: present results and future perspectives" at Hamburg University, August 26$^{\text{th}}$ 2014.

Presentations at COMPASS GPDs and analyses meetings.

- "DVCS 2012 production control", COMPASS GPD meeting at Saclay, July 2$^{\text{nd}}$ 2014.

- "Flux for t10-t14: comparison with slot 2", COMPASS GPD meeting at Saclay, July 2$^{\text{nd}}$ 2014.

- “DVCS W44 t10 flux determination (brieve update)”, COMPASS GPD meeting at Freiburg, April 23rd 2014.
- “Single photon and pi0 efficiency with Monte Carlo”, COMPASS GPD meeting au CERN, April 9th 2014.
- “Camera simulation: work in progress”, COMPASS GPD meeting au CERN, April 9th 2014.
- “DVCS W44 t10 flux determination”, COMPASS GPD meeting at CERN, April 9th 2014.
- “Timing of COMPASS Ecals 1 and 2”, COMPASS GPD meeting at CERN, December 11th 2013.
- “LEPTO Monte Carlo for DVCS 2012”, COMPASS GPD meeting at CERN, December, 4th 2013.
- “Beam flux determination for DVCS2012 run” COMPASS GPD meeting and COMPASS Analysis meeting at CERN, November 18th and 19th 2013.
- “Beam flux determination for DVCS2012 run - in progress” COMPASS GPD meeting at CERN, October 15th 2013.