Deeply Virtual Compton Scattering using COMPASS at CERN

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In this paper, we present the recent studies our group has conducted in order to show the feasibility of a Deeply Virtual Compton Scattering experiment using COMPASS and its high energy muon beam at CERN. The measurement of the cross section and the beam charge asymmetry in the kinematical domain : $0.03 < x_{bj} < 0.25$ and $1.5 < Q^2 < 7.5$ GeV^2 will provide a check of the factorization and will put strong constraints on the models. Experimental studies show that detection of the DVCS exclusive reaction is feasible with some upgrade of the COMPASS apparatus.

1. Physics motivations

1.1. Generalized parton distributions

The new formalism of the Generalized Parton Distributions has emerged in the past five years and is now receiving much attention both on the theoretical developments and experimental realizations[1]. GPDs provide a unique link between the form factors measured in elastic scattering and the polarized and unpolarized structure function measured in deep inelastic scattering. They also provide new information on the $q\bar{q}$ component of the nucleon wave function and are linked to the angular momentum carried by the partons.

The simplest process from which one can extract the GPDs is the Deeply Virtual Compton Scattering (DVCS). It is the extension of the virtual Compton scattering :

$$\mu + P \rightarrow \mu + P + \gamma \qquad (1)$$

in the Bjorken regime. In this regime, the amplitude can be factorized in a hard part calculable in perturbative QCD and a soft part containing the nucleon structure parameterized by the GPDs.

1.2. Impact of a measurement using COMPASS

The main advantage of an experiment using the COMPASS[2] setup and the high energy muon beam resides in the kinematical domain which can be accessed and especially a large lever arm in Q^2 (from 1.5 to 7.5 GeV^2) for x_{bj} values between 0.03 and 0.25, where the factorization can be checked. At 190 GeV, the DVCS process is dominant over the Bethe-Heitler. A measurement of the absolute cross section can be performed with an accuracy of a few % and will give access to the square of the amplitude of DVCS :

$$\sigma_{DVCS} \propto |T_{DVCS}|^2 \propto \left| \int_{-1}^{1} \frac{H(x,\xi,t)}{x-\xi+i\epsilon} dx ... \right|^2 \qquad (2)$$

where $H(x, \xi, t)$ is a generic name for the GPDs (for the definition of x, ξ and t see [1]). COMPASS appears to be the only place where one can measure this cross section at moderate x.

Furthermore, at 100 GeV, the DVCS process and the Bethe-Heitler have comparable sizes and their interference gives access to the amplitude itself. For instance, when the sign of the charge and the polarization of the incoming lepton is reversed one observes an asymmetry : $A_{\mu^+\mu^-} \propto T_{DVCS} T^*_{BH}$. The precision expected for 6 months of beam time and 25 % global efficiency is presented on figure 1. It demonstrates that this measurement is well suited to discriminate between the various models of GPD.

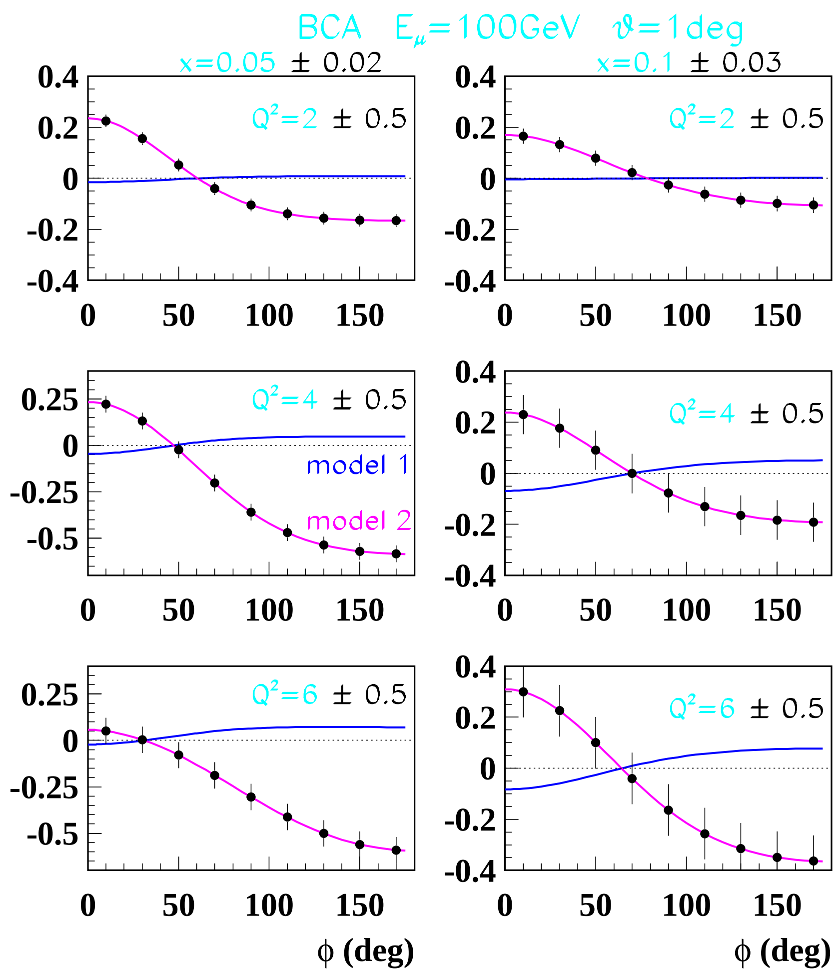

Figure 1. Experimental precision achievable for a 6 month running with 25 % global efficiency. The Beam Charge Asymmetry is plotted as a function of the angle between the leptonic and proton/photon plane. On each plot 2 models of GPD are represented. The first model just fulfills the sum rules while the second model[3] (corresponding to the expected data points) uses Regge theory to relate x and t dependences. This shows that an experiment using COMPASS has good sensitivity to discriminate between models.

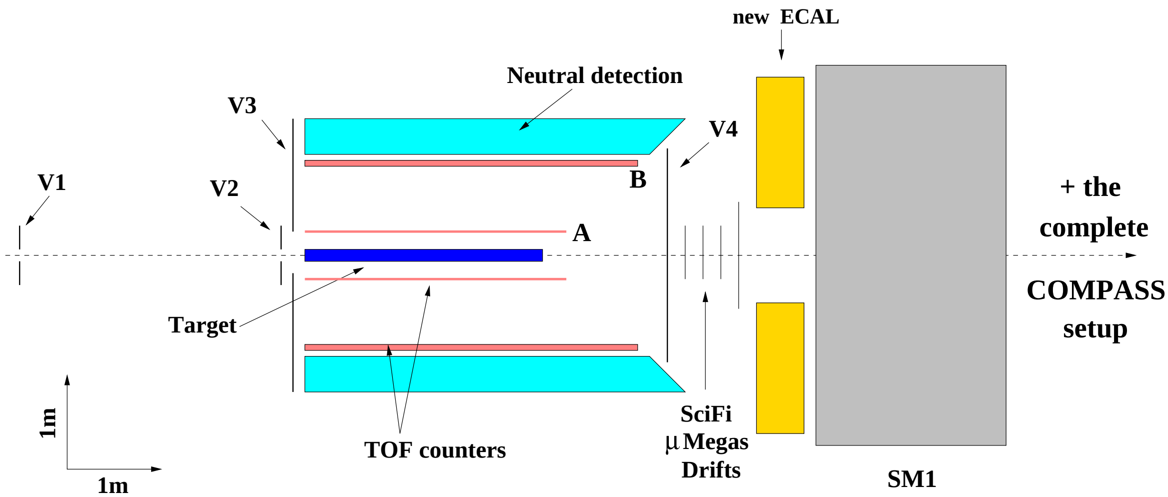

Figure 2. Scheme of a possible recoil detector system.

2. Experimental issues

2.1. Detector system

A possible experiment will use the 100-190 GeV muon beam at the CERN SPS. The muons will scatter off a 2.5 meter long liquid hydrogen target where the length is chosen in order to achieve a luminosity of 1.3 $10^{32} s^{-1} cm^{-2}$, comparable with HERMES[4].

Physical background coming from hard processes was simulated using Pythia 6.1[5]. The angular coverage for neutral and charged particles as well as threshold in the calorimeter were tuned to minimize the background. The result of this study (figure 3) shows that DVCS is largely dominant over the whole Q^2 range with the setup described below.

The scattered muon is detected in the existing spectrometer. Detection of the scattered photon will be performed with the existing calorimeter at forward angle (below 10^o). From 10 to 24 degrees a dedicated calorimeter will need to be added in order to improve the separation between γ an π^0. Finally, a dedicated recoil detector should be designed to identify and measure the momentum of the recoiling proton and to guarantee the exclusivity of the reaction. A possible solution (see figure 2) is to use a fully hermetic detection system. The proton is detected in 2 segmented barrels of scintillation counters of 0.4 cm and 5 cm thickness which will provide the time of flight and energy loss measurements necessary to particle identification. An extensive veto system should be implemented to reject beam halo and to tag charged particles in the forward region. A third barrel, consisting of a few layers of scintillator and lead interleaved, will provide sensitivity to neutral particles in order to evaluate competing reactions such as DVCS off the nucleon resonances.

2.2. Feasibility studies

In 2000 and 2001 we have performed some tests on the actual COMPASS beamline in order to evaluate the detectability of recoiling protons. These tests were done using a 10 cm long polyethylene target and scintillator counters. The results of the tests which

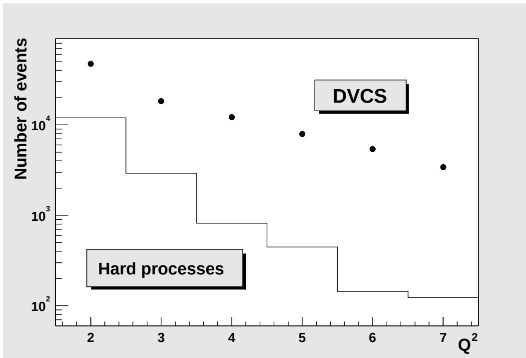

Figure 3. Number of events for DVCS and background originating from hard processes as simulated using Pythia 6.1. for a 6 month run.

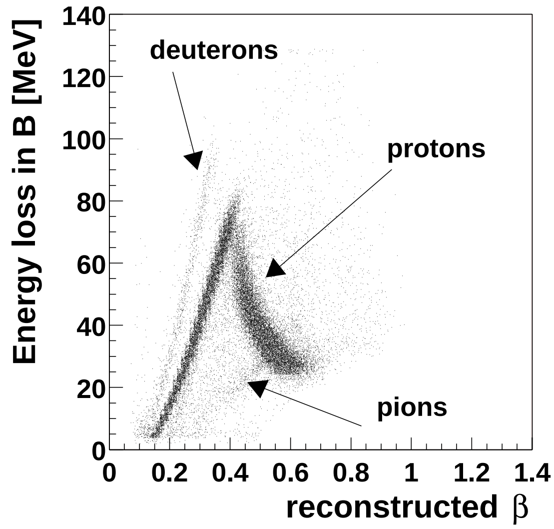

Figure 4. Energy loss as a function of the measured β for the test conducted on the COMPASS beam line. Protons, pions and deuterons. can be identified

were done using the nominal beam conditions are displayed on figure 4. They show that protons are easily discriminated against pions and deuterons in the useful momentum range of an interesting DVCS experiment. Resolutions obtained for time of flight are 300 ps in agreement with the literature.

3. Conclusions

DVCS seems very promising to get new insight on nucleon structure through the measurement of the Generalized Parton Distributions. The use of a high energy μ^+ and μ^- beams permits to put strong constraints on models of the GPDs. Tests and simulations are conducted to improve the COMPASS setup in order to detect the exclusive DVCS reaction. This physics case has been presented and warmly welcome by the COMPASS collaboration at the recent workshop on "Future Physics at COMPASS"[6].

REFERENCES

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