Update on the OLYMPUS two-photon exchange experiment

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The OLYMPUS experiment performed on the DORIS accelerator at DESY was designed to measure the e$^-$p to e$^+$p elastic cross sections ratio with high accuracy (<1%) in order to determine the effect of the two-photon exchange. Presence of such effect can explain the existing difference in electric to magnetic elastic form factors ratio measured in unpolarized and polarized ep elastic scattering.

1 Introduction

The nucleon electric and magnetic elastic form factors $G_E^{(p,n)}$ and $G_M^{(p,n)}$ are fundamental observables reflecting the composite structure of the nucleon consisting of quarks and gluons. More than fifty years, since the famous measurements, performed by Hofstadter [1] the only experimental information on these form factors and their ratios was available with the unpolarized cross section measurements using the Rosenbluth separation method [2]. During the last fifteen years thanks to polarization techniques developed at JLab [3], independent experimental measures of the form factor ratio were obtained, and the ratio of $G_{E(p)}/G_{M(p)}$ as a function of squared four-momentum transfer Q^2 was found to be distinctly different from that measured before with the Rosenbluth method: $G_E^p/G_M^p \approx 1/\mu_p$, with μ_p being the proton anomalous magnetic moment. Such a difference (see Fig. 1) is puzzling and it suggests the two photon exchange contribution to the elastic ep cross section could explain this puzzle. The only direct way to estimate experimentally the two photon exchange contribution is the measurements of the ratio of e$^+$p/e$^-$p elastic cross sections. The OLYMPUS experiment performed on the DORIS accelerator at DESY has collected huge sample of data (more than 4.4 fb$^-$1 of integrated luminosity) with e$^+$p and e$^-$p elastic scattering, and will provide very precise results on the cross section ratio (less than 1% of total uncertainties).

2 The OLYMPUS experiment

The OLYMPUS experiment was designed to measure the ratio of the elastic cross sections e^+p/e^-p over a wide kinematic range with the high precision. The experiment used the intense e^-, e^+ beams stored in the DORIS ring at 2 GeV interacting with an internal windowless hydrogen gas target [4] with the scattered/recoiling e/p measured in the range of $(20^o < \theta < 80^o, -15^o < \phi < 15^o)$. The spectrometer [5] (see Fig. 2) consists of the following main components: the time-of-flight (ToF) scintillation detectors to provide the elastic trigger

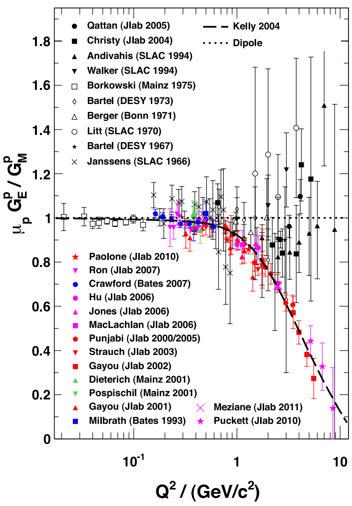

Figure 1: Proton electric to magnetic form factor ratio from unpolarized measurements (data points slightly deviated around unity) using the Rosenbluth method and from double polarization experiments (data points rapidly decreasing with Q^2). Also shown are two recent parametrization.

as well the particle identification, the drift chambers to provide the tracking and second level

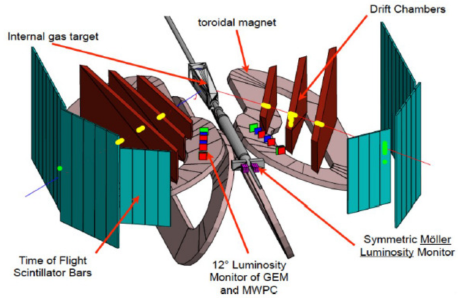

Figure 2: Schematic overview of the OLYMPUS spectrometer

trigger, and toroidal magnet to define the track momentum. To determine the relative e^+p/e^-p luminosity three sets of monitors were used, the first based on slow control information on target density and beam current, the second based on MWPC+GEMs tracking telescopes at 12^o, and the third based on symmetric Mǒller-Bhabha calorimeters installed at 1.3^o. The high efficiency of the spectrometer operating together with the excellent performance of the accelerator, both provided the successful data taking. The DORIS accelerator was operated in top-up injection mode, which allowed the target density to be increased beyond the design value. An integrated luminosity of 4.4 fb^{-1} was achieved, the collected data consists of about equal amount of e^+

(44.1%) and e^- (43.3%) beam luminosities for positive toroid polarity. Due to the high background smaller data sets: 5.4% with the e^- beam and 7.2% with the e^+ beam were taken with the negative polarity, which are mainly used for systematic studies.

3 Data Analysis

The analysis framework is based on ROOT C^{++}/Geant4 providing the opportunities to analyze the real data as well the Monte Carlo samples equivalently. The radiative corrections which are very important to define the final ratio of $\frac{\sigma(e^+p)}{\sigma(e^-p)}$ are implemented in Monte Carlo generator, also a pion generator to estimate the inelastic background has been developed and tested. The digitization for all detector components to perform a realistic Monte Carlo studies to estimate possible systematic uncertainties is done. The calibration constants for the ToF are well advanced which allows the lepton/proton separation (see Fig. 3) based on particle squared mass distribution defined with:

$$M^2 = p^2[(cT/L)^2 - 1],$$

where p is the track momentum, c is the speed of light, T is the time of ToF hit and L is the track path length from the interaction point to the ToF hit. The algorithm for the reconstruction

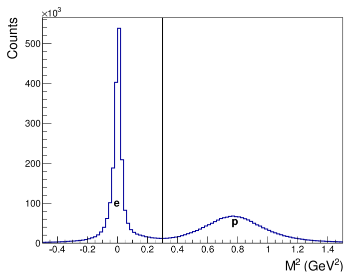

Figure 3: Particle squared mass distribution

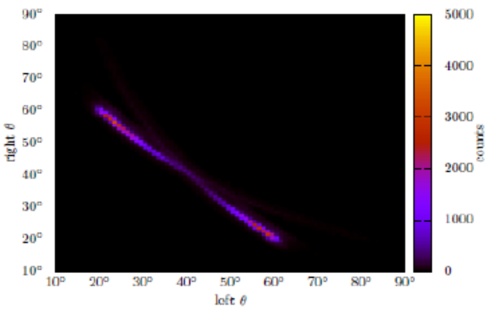

Figure 4: Polar left-right angles correlation with all elastic cuts applied

code is essentially improved, the massive production of the reconstructed runs is started. The set of kinematic and geometric constraints to select the elastic events such as the left and right tracks vertex difference, momentum balance, coplanarity is developed and optimized for certain bins over Q^2 and virtual photon polarization ϵ. The typical "elastic" picture with the left-right polar angles correlation after all cuts applied is shown on Fig. 4. The present level of the Monte Carlo data agreement can be seen in Fig. 5. One should note that still the data are

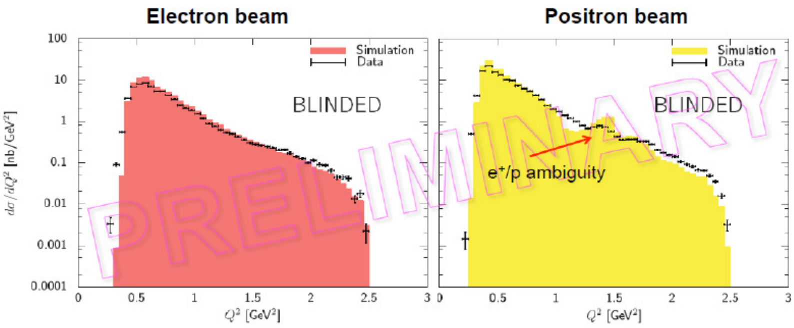

Figure 5: Q^2 distributions for selected elastic events for e^- sample (left panel) and e^+ sample (right panel). The dashed area on both panels is the Monte Carlo simulation.

blinded in order to prevent a bias in several independent analyzes. The data analysis is close to be completed. Two other experiments [6, 7] are close to publish the final results with the measured $\frac{\sigma(e^+p)}{\sigma(e^-p)}$ ratio. The preliminary results from the OLYMPUS collaboration are expected to be released at the end of 2014.

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