Luminosity determination for the quasi-free $pn \to pn\eta'$ reaction

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In this report we give an account on the determination of the luminosity for the measurement of the $pn \to pn\eta'$ reaction conducted using the proton beam and a deuteron target. The determination of the luminosity is based on the registration of the quasi-free $pp \to pp$ reaction [1].

The quasi-free proton-proton scattering was measured simultaneously with the η' meson production in proton-neutron collisions. In this kind of scattering, a proton from the beam interacts with a proton bound inside the deuteron target. The recoil proton is measured by the scintillator and by the position sensitive silicon detector. The forward proton is bent in the magnetic field of the dipole towards the drift chambers and scintillator detectors. Details concerning the detection setup can be found in [2]. The momentum of the fast proton is determined by tracking back the trajectory reconstructed from signals in the drift chambers. Figure 1 shows parallel versus transversal component of the reconstucted momentum of the forward scattered proton. Events corresponding to the elastic scattered protons are seen near the kinematical ellipse, which is marked as a solid line.

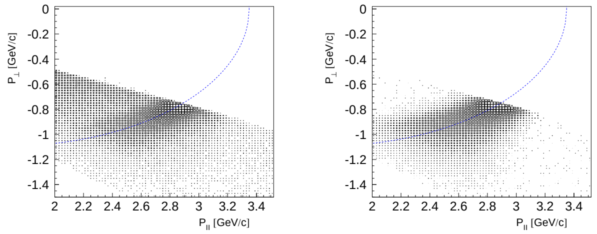

Fig. 1: Parallel versus transversal momentum component of the reconstructed forward proton momentum as obtained in the experiment **(left)** and in the simulation **(right)**.

To determine the luminosity, the known differential cross section for elastically scattered protons is compared to the number of scattered protons from the experimental data. However, in case of quasi–free ellasctic scattering we have to deal with Fermi motion of nucleons inside the deuteron. This motion implies that the value of the total energy in the center-of-mass system as well as the direction of the center-of-mass velocity varies from event to event. This means that in a single subrange of the scattering angle in the laboratory system there are events originating from scattering at different values of the total energy $\sqrt{s}$, as well as different scattering angles in the proton-proton center-of-mass system. Therefore, in order to calculate the integral luminosity, we have to perform simulations taking into account these effects. Each simulated event we have associated with a weight corresponding to the differential cross section which is a function of the scattering angle and the total energy in the center-of-mass system $\sqrt{s}$. For this purpose we have used cross section values for the $pp \to pp$ reaction computed by means of the SAID programme [4] because an accessible data base of the EDDA collaboration was insufficient. In our case, the effective beam momentum which is seen from the nucleon inside the deuteron changes from 2.2 GeV/c up to 4.5 GeV/c whereas EDDA measurements were performed in the range of beam momentum from 0.712 GeV/c to 3.387 GeV/c. Figure 2 shows a comparison of the existing differential cross sections from EDDA measurement and SAID calculations. In the same figure the distribution of the effective beam momentum is also shown.

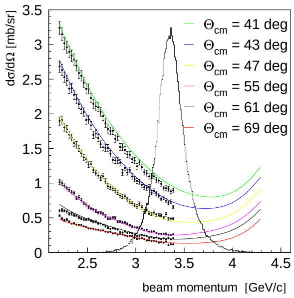

Fig. 2: Differential cross sections as a function of beam momentum for few values of a scattering angle in the center-of-mass system θ_{cm}. Black points stand for EDDA collaboration data [3], lines denote SAID calculations [4]. The solid histogram denotes the distribution of the effective beam momentum for quasi-free $pp \to pp$ reaction calculated at the beam momentum of 3.35 GeV/c.

In order to calculate the integrated luminosity, we have divided the avaiable range of the S1 detector into four subranges. For each subrange, the projection of the distance of the points from the kinematical ellipse was extracted, the background was subtracted and the real number of scattered events $\Delta N_{exp}(\theta_{lab})$ was obtained. The result for one subrange is shown in Fig. 3 (left).

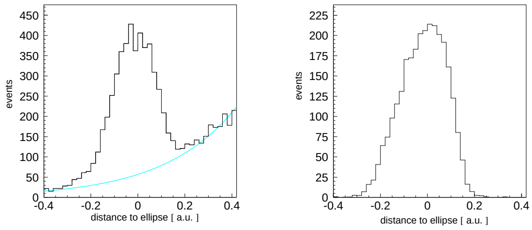

Fig. 3: Projection of the experimental event distribution from Fig. 1 (left) onto the expected kinematical ellipse **(left)**. Projection of the simulated event distribution from Fig. 1 (right) onto the expected kinematical ellipse **(right)**.

In order to determine the $\Delta N_{MC}(\theta_{lab})$ number, we have simulated $N_0 = 10^8$ quasi-free $pp \to pp$ events, which have been analysed using the same procedure as in the case of experimental data. The result for an analogous subrange as for the experimental distribution is shown in fig 3 (right). Assuming, that N_0 is the total number of simulated events, the equation for calculation of the integrated luminosity is as follows [1]:

$$L = \frac{N_0}{2\pi} \frac{\Delta N_{exp}(\theta_{lab})}{\Delta N_{MC}(\theta_{lab})}.$$

We have determined the integral luminosity for all subranges of the S1 detector individually and subsequently the average value. The average integrated luminosity is equal to $L = (4.77 \pm 0.06) x 10^{36} cm^{-2}$. The value of the systematical error is still under evaluation.

References:

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