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The High Acceptance Recoil Polarimeter (HARP) and the Reaction $^{12}\text{C}(e,e'n)$

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The HARP detection system is a novel device which can be used for both neutron detection and for the determination of neutron and proton polarizations in nuclear physics experiments. It is currently under construction by the HARP collaboration, comprising Utrecht University, ISN-Grenoble and NIKHEF-Amsterdam. The instrument will be completed in 1995. A brief description of HARP is given. The physics which can be addressed with HARP is illustrated by presenting simulated data of a $^{12}\text{C}(e,e'\pi)$ experiment which will be carried out at the AmPS facility of NIKHEF.

In the past $(e,e'p)$ reactions have been performed to study the momentum distribution of protons in a nucleus. Until now there was no easily accessible way to determine its neutron counterpart. It is of fundamental interest to investigate by means of $(e,e'n)$ experiments, whether the neutron momentum distributions are similarly affected by many-body correlations as the proton ones. In doing so one wants to control charge-exchange effects in the final state and possible meson-exchange currents effects. Measurements of the outgoing neutron polarization (P_N) serve this purpose. Various authors [1,2,3] have demonstrated the sensitivity of P_N , which vanishes in PWIA, to such effects. The HARP detection system will be used to measure both cross sections and polarizations, and one of the first experiments to be performed is a $^{12}\text{C}(e,e'\pi)$ experiment.

The center of the HARP detector is formed by a nearly flat liquid hydrogen vessel of $20 \times 200 \times 600 \text{ mm}^3$ containing about three liters of liquid hydrogen. This vessel has stainless steel windows ($\pm 100 \mu\text{m}$ thick) on both large sides. In the middle, over its length, an H-profiled bar is located to support the foils. In this vessel the incident neutrons and protons scatter off the hydrogen nuclei. The tracks of the protons recoiling out of this vessel are reconstructed by two wire chambers, and their energies are determined by two ΔE scintillators (3 and 10 mm thick), and a E scintillator (200 mm thick). With this information the energies and momenta of the incident protons and neutrons can be obtained. For discrimination between protons and neutrons a charged particle tagger is placed in front of the liquid hydrogen vessel. This tagger consists of plastic scintillators (1.5 and 3 mm thick). The entire interior of the HARP detector is contained in a nitrogen atmosphere for safety purposes. The front side is shielded by lead to reduce the rates in the wire chambers and scintillators. Since identical sets of wire chambers and scintillators are placed on either flat side of the liquid hydrogen vessel, it is possible to determine the polarization of the incoming nucleons. As the detector can be rotated by 90 degrees, both left-right (normal polarization P_N) and up-down asymmetries (transverse polarization P_x) with respect to the horizontal reaction plane, can be determined.

In order to separate 1s and 1p knockout in a $^{12}\text{C}(e,e'N)$ experiment an energy resolution of 25 MeV is necessary. The most important parameter influencing the energy resolution of HARP is the uncertainty in the location of the scattering point of the incident neutron in the liquid hydrogen. In order to reach the desired resolution the vessel must not have a thickness exceeding some 40 mm, determined in extensive computer simulations. The total thickness of the liquid hydrogen layer is determined by both the frame itself and a sizable bulging of the foils. Calculations and extensive prototyping have indicated that we can limit the total thickness to less than 40 mm, which is sufficient to obtain the required energy

resolution. The liquid hydrogen vessel will be surrounded by a thin heat shield at a temperature of 80 K, located inside a vacuum vessel to minimize heat leakage into the vessel. Both the liquid hydrogen and vacuum vessel will have very thin entrance windows as well in order to minimize their effect on the energy resolution.

After completion the HARP detector will be commissioned at the AmPS facility of NIKHEF in Amsterdam. The neutron detection efficiency will be calibrated with a $^2\text{H}(\gamma, \text{pn})$ experiment. A $^2\text{H}(e, e'n)$ experiment will yield values of G_M^n which can be compared to values found in other experiments. Possible intrinsic asymmetries will be studied by measuring the transverse polarization P_x in a $^2\text{H}(e, e'n)$ reaction, which is known to vanish in the absence of electron polarization. Due to the precise knowledge of the n-p phase shifts no further calibration of the polarimeter is needed, provided that the efficiencies of the two parts of the detector are separately known.

Following the commissioning, a $^{12}\text{C}(e, e'n)$ experiment will be carried out, in which both the cross section and the normal polarization will be measured [4]. In figure 1 the anticipated data quality is shown. The indicated error bars correspond to a total running time of 200 hours at a luminosity of $1.6 \cdot 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$. The curves represent a calculation by Kelly [3], in which charge-exchange effects have been included. Other calculations of the cross section [1,2] yield the same shape, but show quite different normal polarizations.

In conclusion the HARP-detector will enable us to measure the neutron momentum distribution in nuclei, and it will provide us with a good control of possible charge-exchange effects through the measurement of the normal polarization.

Fig. 1 The expected data quality for the proposed $^{12}\text{C}(e, e'n)$ experiment. The top panel shows the reduced cross sections as a function of the missing momentum, while the bottom panel shows the normal polarization. The curves represent calculations by Kelly [3]. The error bars correspond to the proposed measuring times [4].

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