Recent progress of polarized Drell–Yan experiment at Fermilab, SpinQuest (E1039)

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The SpinQuest (E1039) experiment aims to investigate the structure of the proton through the polarized fixed-target Drell–Yan process at Fermilab. In the Drell–Yan process, an antiquark ($\bar{q}$) in a hadron and a quark (q) in another hadron annihilate and decay into a lepton pair ($\ell + \bar{\ell}$) via a virtual photon (γ^*): $q + \bar{q} \to \gamma^* \to \ell + \bar{\ell}$. The Drell–Yan process is a suitable probe to study antiquarks in the proton because the antiquark is always involved in this process.

One of the most important unresolved puzzles of the proton is the "proton spin puzzle." The proton spin has been considered to be carried by the quark spins. However, the EMC experiment at CERN showed that the contributions of spins of quarks and antiquarks to the proton spin are much less than 100%.[1,2] Further experiments later confirmed that these contributions constitute only approximately 30% of the proton spin. Many possible contributions have been considered to solve this puzzle. One of them is the contribution of the orbital angular momenta (OAM) of quarks and antiquarks.

The Sivers function, which is a function of the Bjorken x and the transverse momentum of the quarks, can give some hints about the OAM contributions. The Sivers function is a kind of so-called transverse-momentum-dependent parton distribution function (TMD). It represents the correlation beween the transverse momentum of a quark and the spin of the parent hadron. If the Sivers functions of antiquarks are non-zero, then the contributions of the OAM of antiquarks to the proton spin are not zero. The Sivers function (f_{Sivers}) is proportional to the single-spin asymmtry (A_N): $f_{\mathrm{Sivers}} \propto A_N \propto (N_L - N_R)/(N_L + N_R)$, where N is the number of Drell–Yan dimuons and the subscripts L and R denote the direction of the virtual photon (left and right, respectively). Therefore, the Sivers functions can be experimentally accessed by measuring the single-spin asymmetry.

The semi-inclusive deep inelastic scattering (SIDIS) experiments have found the non-zero value of single-spin asymmetries of quarks. The contributions of quarks and antiquarks are not separated by SIDIS. The SpinQuest experiment will measure the single-spin asymmetry of $\bar{d}$ and $\bar{u}$ in the Drell–Yan process using a 120 GeV proton beam and polarized hydrogen and deuterium targets.

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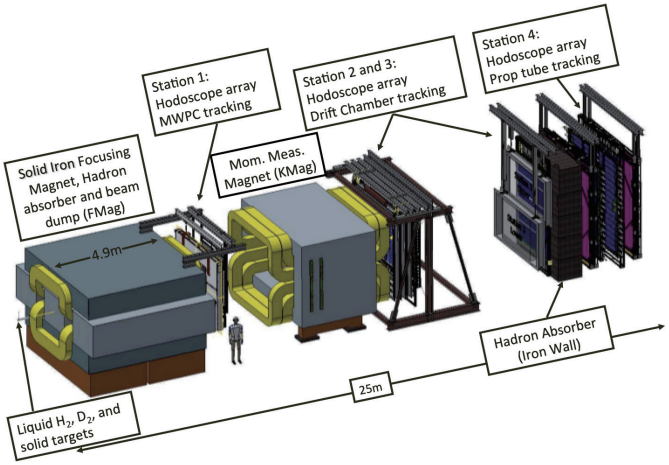

Fig. 1. The E906 spectrometer.[3] The target system has been renewed, and dark-photon hodoscopes are installed for SpinQuest.

The SpinQuest spectrometer is basically the same as the SeaQuest (E906) spectrometer[3] (Fig. 1). We are now updating it for the SpinQuest experiment. The major update is the installation of the polarized targets, as the E906 experiment used only unpolarized targets. The details have already been reported in the previous progress report.[4] We installed another set of hodoscope planes to detect potential dark photon events. Its optimization is underway.

The detectors are being repaired and updated. All the drift chambers for SpinQuest were used in the E906 experiment, but one of the drift chambers was damaged after the E906 experiment was completed. We have determined the cause of damage and have repaired the drift chamber. Some of the less efficient proportional tubes and hodoscopes have also been repaired. The optimization of their operation is now in progress.

The beam time is expected to begin in the middle of 2021. After two years of data aquisition, we expect to find an important piece in the proton spin puzzle.

References

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