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Brief Summary of the Proposed Research

The Measurement of the Seaquark Sivers Function

Despite tremendous progress achieved in the last decades, the problem of the full description of the nucleon spin composition remains unresolved. As a continuing effort of this broad program, Fermilab E1039 experiment was proposed to access the sea quark Sivers function by measuring a transverse single spin asymmetry in Drell-Yan production where the muon pairs are created in proton transversely polarized target. If successful, this would be the first high-statistics measurement of the Sivers asymmetry in Drell-Yan production for the sea quarks. A nonzero asymmetry would provide clear evidence of the orbital angular momentum contribution of the sea quarks which will help to further disentangle the composition of the nucleon's spin. Additional physics that can be explored during the E1039 run include the dark photon search, an investigation of possible sensitivity of J/Psi production to the Sivers function, and sea quark transversity measurements.

A high luminosity transversely polarized target system represents a major innovation of the proposed experiment whose construction was a combined effort of LANL and the UVA polarized target group over the last four years. The experiment is quickly approaching an installation and commissioning phase of whose target system preparation and functionality plays one of the central roles. I propose to use the Intensity Frontier Fellowship to facilitate my continued presence at Fermilab where I will be responsible for assembling, verifying and commissioning all target subsystems during the preparation period. The Fellowship will also be of great benefit as the experiment enters the production period, during which time I will be responsible for the target expert level operational tasks and data analysis.

RESEARCH PLAN

The Measurement of the Seaquark Sivers Function

The Intensity Frontier Fellowship will be instrumental in achieving physics goals and performing the research tasks outlined below. I propose to use the Intensity Frontier Fellowship to support my extended presence at Fermilab for the period of October 1, 2018 - October 1, 2019 with my total residency at Fermilab consisting of about 6-7 months.

Motivation:

Despite tremendous progress achieved in the last decades, the problem of the full description of the nucleon spin composition remains unresolved. The question of how quark and gluon constituents assemble into spin-1/2 proton remains central challenge to the nuclear community since the discovery of the ”spin crisis” by the EMC collaboration. As a continuing effort of this broad program, Fermilab E1039 experiment was proposed to access the sea quark Sivers function by measuring a transverse single spin asymmetry in Drell-Yan production where the muon pairs are created in proton transversely polarized target. If successful, this would be the first high statistics measurement of the Sivers asymmetry in Drell-Yan production for the sea quarks. A nonzero asymmetry would provide clear evidence of the orbital angular momentum contribution of the sea quarks which will help to further disentangle the composition of the nucleon's spin.

Another appeal of E1039 is that, given a relatively modest budget, besides its primary goals it allows for many other interesting opportunities with a possibility of a large physics pay-off. The parasitic trigger related to the dimuon pair vertex shifted significantly downstream from the target provides investigational opportunity for the dark photon decay theorized in several models. In addition, an abundance of the J/Psi events makes it possible to check if J/Psi production is sensitive to quark's Sivers functions.

E1039 intends to utilize the 120 GeV unpolarized proton beam from the main injector at Fermilab and the existing detector package that was used by the E906 SeaQuest unpolarized Drell-Yan experiment. The very small cross section of the Drell-Yan reaction represents one of the major experimental challenges. That is why a thick, high-density, and highly polarized fixed target is critical to reach the physics goals of the proposed experiment. A solid dynamically polarized ammonia target was the optimum choice to satisfy these needs. To maintain the target polarization, the method of dynamic nuclear polarization (DNP) is used, which relies on a strong magnetic field acting on magnetic moments at a low temperature to generate a population difference that favors one spin state. The technology of DNP targets has matured over the last 50 years through many experiments performed at laboratories around the world and is now very well understood. However, high luminosity demands imposed by the experimental goals introduce a completely novel environment and previously unexplored challenges for a polarized target of this type.

Tasks:
The polarized target system construction was a combined effort of LANL and the UVA polarized target group over the last four years. The DNP target consists of a superconducting magnet capable of producing a magnetic field up to 5T, a ^{4}He cooled evaporation refrigerator with a high (up to 1.5W) capacity pumping system, a source of 140 GHz microwave radiation, and a NMR system to monitor polarization. The uniqueness of the current setup is its vertical, transverse to the beam, direction of the polarization which was achieved by complete reorientation of the magnet coils axis (90 degrees rotation) from the previous longitudinal configuration. The immediate tasks for implementation into E1039 will include:

1. Verification of the functionality of all subsystems after the shipment of the target system from UVA to Fermilab:
    - infrastructure preparation for the superconducting magnet arrival and initial cooldown test;
    - installation and verification of the evaporation refrigerator, target elevator and target inserts;
    - installation and verification of the microwave system;
    - installation and verification of the root pump and warm gas systems;
    - installation and verification of the 4He liquefier system;
    - installation and verification of the turbo pump system and corresponding beamline components;
    - preparation of the target material storage area and loading station.

2. Full target polarization test before commissioning procedures:
    - target system alignment with respect to the beamline;
    - preparation and tuning target data acquisition system for the specific experimental goals;
    - safe procedure development for the target material loading and extraction in new environment;
    - full system cooldown and polarization test.

3. Commissioning procedure:
   - verification of the superconducting magnet performance under high radiation environment;
   - verification of the amount of the radiation damage and the lifetime of the target material;
   - run plan optimization – number and species of the target cell on the target ladder;
   - run plan optimization – material change and annealing frequency;

Several projects focused on improving the figure of merit for polarized target scattering experiments were the subject of extensive studies both at UVA and LANL. They constitute extended research goals and include:

1. Performance optimization studies:
   - development of the automated microwave frequency control;
   - development of the system for the fast target helicity flips through Adiabatic Fast Passage;
   - development of the cold NMR for low-noise precise measurements of the target polarization.

2. Operation during production stage:
   - preparation of the target operator duties and appropriate training;
   - organization of the target-expert-on-call schedule for maintenance purposes;
   - online and offline polarization and target system performance data analysis.