Introduction

My research experience and interests are varied. It led me to two paths of research that I have been involved with so far : (a) understanding the structure of the fundamental particles and their interactions (b) understanding the sources of the largest matter component in the Universe's energy budget, namely the Dark Matter.

I have been part of the PHENIX experiment at Relativistic Heavy Ion Collider (RHIC) facility in Brookhaven National Laboratory (BNL) during my doctoral thesis work and beyond. My work there included probing hadron structure for helicity as well as transverse-momentum dependent (TMD) spin distributions (Sivers function and Collins fragmentation function) via measurements of spin asymmetries and cross-sections.

For the later part of my career, I have been part of NA61/SHINE experiment at CERN Super Proton Synchroton (SPS) and the AMS-02 experiment on board International Space Station (ISS). My work with cosmic ray data from AMS-02 is focused on measuring the flux of light nuclei and especially antinuclei that could be signatures of Dark Matter annihilations. My work with data from NA61 experiment aims to improve our understanding of the formation of light (anti)nuclei in Nature, especieally in the interactions of cosmic rays and interstellar matter.

Dark Matter Signatures in Cosmic Rays

Physics Questions

We know that about $\sim 25\%$ of the total energy budget of the Universe comes from the elusive Dark Matter. Annihilations of Dark Matter may generate standard model particles that could be detected. In our matter dominated Universe, antiparticles are better probes for such searches because of their low expected background. A range of Dark Matter models propose that the flux of low-energy antideuterons ($\bar{d}$) should exceed the expected astrophysical background by $\mathcal{O}(100)$ or more, making it an ideal probe for the indirect detection of Dark Matter.

Cosmic-ray propagation through interstellar medium and formation of antideuterons are sources of significant uncertainties in the interpretation of possible measurements. High precision measurements of secondary-to-primary ratios (boron/carbon, deuteron/proton, He3/He4 etc.) can help to reduce propagation uncertainties to per cent level.

Work Experience

As a member of the AMS-02 experiment, I have taken part in data recording and monitoring duties at CERN control center and have been working on developing techniques for the separation and identification of low-energy (anti)deuterons and (anti)protons in the cosmic rays using Monte Carlo and GEANT4 based simulations and seven years of recorded AMS-02 data.

The analysis is part of a concerted and focused effort by the collaboration. *Considerable progress have been made towards measurements of* $\frac{d}{p}$ *ratio and deuteron and antiproton fluxes in recent years.*

Light Nuclei Formation

Physics Questions

Meaurements of light nuclei in cosmic rays are of intrinsic interest for the composition of the cosmic rays. But they are also of special interest as products from decay or secondary interactions of primary nuclei. Estimations of flux of cosmic rays reaching us include various uncertainties. Some of the most prominent among them are cross-section uncertainties and galactic propapagtion uncertainties. Both these uncertainties can be reduced by using measuements from collider data.

However, the formation of even the simplest of the light nuclei like deuteron is not well understood. There are competing mechanisms with limited success in different energy ranges. One of the most studied ones is coalescence formation. Measurements of light nuclei cross-sections in hard scattering of particles in colliders can be used to improve our understanding of the underlying mechanism. This in turn can improve estimations of astrophysical background of cosmic rays and reduce uncertainties.

Work Experience

I have worked with NA61/SHINE experiemnt as limited member of the collaboration. I have participated in data recording and worked with years of recorded data with the goal to measure cross-sections deuterons, antiprotons and antideuterons. I have also mentored a graduate student on this ongoing analysis.

I have collaborated with colleagues from National Autonomous University of Mexico (UNAM) in the studies on the dependence of the coalescence parameter on collision energies and developing an afterburner software to be used in tandem with Monte Carlo event generators like GEANT4 and EPOS-LHC. The work was published recently (Phys. Rev. D **98** 023012, 2018).

Recently AMS-02 have reported possible candidates of antihelium. I have been working on extending the work based on coalescence formation of secondary antihelium3 and antihelium4 to estimate the expected flux at top of the atmosphere. The work was recently reported at the 2nd Antideuteron Workshop at UCLA.

Nucleon Structure

Physics Questions

Proton spin structure has been a puzzle for decades. Valence quarks inside protons contribute to only $\sim 30\%$ of the spin of the proton. The rest must come from either gluon spin or orbital angular momenta of quarks and gluons. PHENIX (and STAR) at RHIC have been instrumental in the last decade in probing gluon spin. Although results so far have been consistent with zero gluon spin in the probed range of gluon momentum fraction ($0.02 \leq x_g \leq 0.3$), it is to be noted that in the low x_g, where the gluons are most abundant, the uncertainties are still very large. Extending measurements to as low x_g as possible is essential to understanding proton spin.

Sea-quark (antiquarks produced in pair-creation processes) polarizations are also poorly constrained. Measuring helicity dependent single spin asymmetries can extend the range of available data and reduce the uncertainties considerably.

In the burgeoning field of study of the transverse momentum dependent (TMD) distributions of partons (quarks and gluons) and their effects in partonic interactions, it is necessary to measure transverse single spin asymmetries and angular correlations of final state particles. These measurements can be used to extract TMD Sivers distribution functions and Collins fragmentation functions, providing a more complete picture of the nucleon structure. Single spin asymmetries (A_N) due to Sivers effect in Drell-Yan processes are predicted to be opposite and equal to that in the Deeply Inelastic Scattering (DIS) in comparable kinematic ranges. Measurements of Drell-Yan A_N can be a direct test of the theoretical prediction and of our understanding of the underlying physics.

Work Experience

During my doctoral thesis I worked on the measurements of cross-sections and double helicity asymmetries of charged hadrons from polarized proton-proton collisions at $\sqrt{s} = 62.4$ GeV and comparisons to the next-to-leading order perturbative (pQCD) calculations (Phys. Rev. D **86** 092006, 2012).

I was also a part of the work to measure parity violating single spin asymmetries of W boson from polarized proton-proton collision data at $\sqrt{s} = 500$ GeV (Phys. Rev. Lett. **106** 062001, 2011).

During my post-doctoral research at the University of New Mexico I participated in the work on the measurements of cross-sections and double helicity asymmetries of J/Ψ meson via di-muon decay channel (Phys. Rev. D **94** 112008, 2016).

I put considerable efforts towards a low-mass Drell-Yan single-spin asymmetry measurement with PHENIX data that would have been directly comparable to Sivers function measured in Deeply Inelastic Scattering (DIS) experiments (COMPASS, HERMES). The measurement was statistically challenging and we concluded at the time that possible forward upgrades at PHENIX or a new experiment in future would be a better source of data for low mass Drell-Yan A_N.

Future Plans

I feel highly motivated to pick up from my previous works on understanding spin structure of hadrons. A dedicated experiment like the proposed Spin Physics Detector (SPD) at Nuclotron-based Ion Collider fAcility (NICA) would be an excellent opportunity to study the details of spin structure of fundamental particles.

PHENIX suffered from limitations like the lack of 4π acceptance, dated electronics (DAQ) limiting event recording rate, lack of full acceptance particle ID detector (limited TOF) and lack of a high quality vertex detector to determine secondary decays.

A planned SPD will have none of these problem, creating an excellent opportunity for significant contributions in future in the field of spin physics and our understanding of Nature.

I look forward to joining the collaboration and take part in the early planning and development stage and give meaningful contributions to the effort of building the facility and the experiment.