Research Statement

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My research activities are focused on the study of relativistic heavy ion collisions. The goal of this field of nuclear physics is to study the formation and subsequent evolution of hot and very dense states of nuclear matter, and better understand non-perturbative quantum chromodynamics (QCD) through the study of hadronic matter under extreme conditions. At high densities and temperatures hadronic matter is expected to undergo a phase transition to a deconfined state, the Quark-Gluon Plasma (QGP), where quarks are no longer bound in colorless hadrons. Exact nature of quark confinement in hadrons is crucial and poorly understood aspect of the quark-gluon description of matter. QGP is believed to have existed during the first microseconds after the Big Bang, and understanding of its properties could provide valuable insights on the evolution of our Universe.

I am involved in the study of relativistic heavy ion collisions as a member of the PHENIX collaboration at Relativistic Heavy Ion Collider (RHIC), at Brookhaven National Laboratory. My physics interests are centered around heavy flavor production. Particles carrying heavy flavor, *i.e.* charm and beauty quarks, are sensitive probes of the hot and dense medium created in relativistic heavy ion collisions, and allow us to study it at both short and long timescales. On one hand, heavy quarks are produced at the very early stages of the collision, on the other hand, they decay weakly, so that their lifetime is greater than that of the created medium. In addition, quarkonium states, bound quark-antiquark pairs, have binding energies comparable to the QGP screening energy, which may result in significant suppression of quarkonium production if QGP is formed. Heavy flavor quark-antiquark pairs are produced mainly via gluon fusion, and are excellent probes of the gluon structure function and its modification in matter. Comparison of the spectra of particles carrying heavy flavor produced in proton-proton and nucleus-nucleus collisions should reveal crucial information about the observed large energy loss of hard scattered partons in heavy ion collisions at RHIC.

The study of quarkonium production in PHENIX is currently limited to the measurement of one charmed quark-antiquark state, the J/Ψ, via dielectron and dimuon decay channels. Suppression of J/Ψ production due to Debye screening was one of the first proposed signatures of QGP formation. Recent theoretical predictions of J/Ψ production at RHIC energies range from traditional suppression to even enhancement due to coalescence of copiously produced uncorrelated charm quarks. Currently available PHENIX data suffer from low statistics and don't permit to distinguish among many theoretical models, except for excluding strong enhancement of J/Ψ production.

Increase in RHIC luminosity and detector upgrades will allow, in the nearest future, to make important measurements in this field. Detailed measurements of production of charmonium, *i.e.* bound charm quark-antiquark pairs, will allow us to clarify the question of anomalous suppression of J/Ψ observed by the NA50 experiment at CERN. Especially important will be the measurement of not only J/Ψ, but also other quarkonium states, since different mechanisms of suppression predict different suppression magnitude for these states. Eventually, with the increase of RHIC luminosity, spectroscopy of bottonium states will become possible.

I am especially interested in the study of charmonium polarization. This is an important diagnostic tool for better understanding of the charmonium production mechanism and

subsequent hadronization process. Measurements of charmonium polarization in proton-antiproton collisions at Fermilab show increasing transverse polarization at high transverse momenta (>5GeV/c), in agreement with the commonly used non-relativistic QCD factorization (NRQCD) approach. At very high transverse momenta (>12GeV/c), however, polarization seems to decrease and even becomes longitudinal. In addition, Fermilab E866/NuSea experiment reported observation of longitudinal polarization of J/Ψ in proton-nucleus collisions, which can not be explained by NRQCD. Future charmonium polarization measurements at RHIC could clarify this puzzle and help to understand charmonium production mechanism. Up to now, polarization measurement in PHENIX had very large statistical errors, not allowing to make any conclusions. The situation will improve in the future, when RHIC achieves much higher luminosities.

Another area of interest I would like to pursue, is the study of open charm and beauty production. Unfortunately, the PHENIX experiment can currently study open charm production only indirectly, by measuring single leptons (electrons and muons). The STAR, another large RHIC experiment, measured open charm production direcly, via decays of D-mesons. The results from both experiments imply that the total open charm yield approximately scales with the number of binary collisions for all colliding systems (pp, dAu, AuAu) and centralities, as expected for point-like perturbative QCD process, and no in-medium modification of this process is observed. More detailed information will be obtained when direct open charm measurement in PHENIX will become feasible with the upcoming Silicon Vertex Detector upgrade. I'm actively involved in the Silicon Vertex Detector (SVD) upgrade for the PHENIX experiment as a software coordinator for the project. SVD upgrade will improve dielectron and dimuon mass resolution, opening up the possibility of upsilon spectroscopy. It will allow direct measurement of open charm by providing precise measurement of the displaced decay vertex of D-mesons. Currently, D-meson measurement in PHENIX is impossible due to huge combinatorial background. Eventually, displaced vertex measurement will enable open beauty measurement via B-meson decays. These measurements will require much higher RHIC luminosities, which will be available in the future.

Direct measurement of open charm and, later, beauty will provide information about the gluon structure function and its modification in the nuclei. For this purpose, measurement of open charm at different rapidities in asymmetric colliding systems is very important. Open charm measurement will also help to determine the energy loss of energetic heavy quarks in hot and dense nuclear matter, providing information about the state of this matter. Another diagnostic tool for studying heavy quark energy loss is charm flow measurement. Open charm yield can be used to form (J/Ψ)/(open charm) ratio and quantify exactly the suppression of J/Ψ. Important baseline measurements will be provided by studying proton-proton and proton-nucleus reactions.

A wealth of new important experimental results will be collected at RHIC in the coming years, but in 2007, when the Large Hadron Collider (LHC) will start to operate at CERN, the field of relativistic heavy ion physics will enter a new age. For two months each year LHC will be dedicated to accelerating heavy ions at energy almost 30 times larger than that at RHIC. This will allow the study of nuclear matter under conditions which were never created before. It is expected that at LHC at least three times larger energy density will be created in a significantly larger volume than at RHIC. The complete spectroscopy of quarkonium states will probe the deconfined medium and pin down its properties. Open heavy flavor measurements will provide information on primary production mechanisms and parton energy loss. All this will allow us to make important steps in understanding the nature of quark confinement in hadrons, QCD, and the propreties of matter under extreme conditions.