Low Mass Vector Mesons as Probes of (Partial) Chiral Symmetry Restoration

Mass states of light vector mesons are considered to be sensitive probes of partial chiral symmetry restoration theoretically expected in high energy and/or baryon dense matter. Some of the experimental results at CERN SPS (H. Obers谈话 Collaboration, PRL 91, 042301, 2003) and KEK PS (E325 Collaboration, PRL 96, 092301, 2006) are explained as onsets of the phenomenon. In high energy heavy ion collisions, their modifications have been looked for also as a signature of deconfinement of matter. Systematic comparison among results from different regions in the QCD phase diagram and via different channels will provide critical information for the study of partial chiral symmetry restoration.

A Recent Experimental Highlight

ω meson production in Au+Au collisions at the nucleon-nucleon collision energy (\(\sqrt{s_{NN}}\)) of 200 GeV has been measured in PHENIX both in \(e^+e^-\) and \(\pi^0\gamma\) decay channels, as well as in \(e^+e^-\) and \(\pi^0\) channels in \(p+p\) and \(d+Au\) collisions. More channels including \(\omega\) decaying into \(e^+e^-\) in the light collision systems are under study. See also posters by Y.Nakamura et al., M.Ouchi et al. and K.M.Nijima et al.

PHENIX Preliminary

PHENIX Low Mass Vector Mesons

PHENIX Invariant Yield of \(\omega\) per Nucleon-Nucleon Collision in Au+Au and \(p+p\) Collisions at \(\sqrt{s_{NN}} = 200\) GeV

PHENIX Multiplicity Dependence of Detection Efficiency of PHENIX for \(\omega\) Decaying into \(\pi^0\gamma\)

PHENIX Challenges and Progresses with Golden Data

While RHIC has demonstrated its versatility by providing various collision systems from \(p+p\) to Au+Au, with \(\sqrt{s_{NN}}\) from 22 to 200 GeV, the largest system of Au+Au at the top energy of 200 GeV naturally has a unique importance. In parallel to a long Au+Au run presently underway, the J/\(\psi\) measurement at \(\sqrt{s_{NN}} = 200\) GeV is blooming. In addition to a number of exciting results already published, even more challenging analyses are in steady progress. Measurement of low mass vector mesons is one of those challenging topics in heavy ion collision experiments. The largest challenge is their small signal to background (S/B) ratios due to huge combinatorial backgrounds in multi body decays. A number of key techniques are developed in evaluation and subtraction of background to extract the signal. Various kinematical selections have also been optimized based on simulation studies to maximize the statistical significance of the signal (S/B). The expectation of signals of vector mesons, huge combinatorial backgrounds need to be subtracted. Evaluation of the background is a key issue in measurement of cross section, as the subtraction is a major source of systematic error.

Invariant Mass Distribution of \(e^+e^-\) in \(\omega\) Mass Region in Au+Au Collisions at \(\sqrt{s_{NN}} = 200\) GeV

What are “Mesons in Non-Hadronic Phase”?

A frequently asked question on measurement of possible mass modification of light vector mesons in “deconfined partonic matter” is: what do we really see by looking at hadrons in non-hadronic phase ? Even above the phase boundary between confinement and deconfinement, quarks may form bound states which are referred to as “Mesons in Non-Hadronic Phase”. In parallel to a long Au+Au run presently underway on proper QCD phenomena, quarks may form bound states which are referred to as “Mesons in Non-Hadronic Phase”.

High Energy Densities Achieved at RHIC

A new state of nuclear matter is created at RHIC. It has been proven to be hot, dense, strongly coupled, and with partonic degrees of freedom. The apparent thermal component of direct photons suggests the temperature and the energy density of the created matter as high as 300-600 MeV and 15 GeV/fm³, respectively, which are well above the predicted critical values for the QCD phase transition.

PHENIX at RHIC: The Right Tool

The high capabilities of the PHENIX experiment to measure leptons and photons as well as hadrons, along with the high integrated luminosities achieved by the RHIC accelerator, make the experiment uniquely suitable for systematic studies on properties of mesons at high energy densities, hopefully including above the QCD phase transition. Another important feature of RHIC is its versatility. Comparison among collision systems from \(p+p\) to Au+Au provides a vital systematics, with baseline measurements in \(p+p\) and \(d+Au\) collisions with the same apparatus as in Au+Au. PHENIX is capable of measurements of multiple species of light vector mesons, in multiple decay channels into leptons, photons and hadrons. \(\omega\) mesons in Au+Au collisions, for instance, have been measured in hadronic and photonic decay channels in the high transverse momentum region as well as in the historically popular di-electron channel in the low region. Despite the possible difference between the probes in degree of penetration in the final hadronic states, the consequence wide kinematical coverage provides an additional axis in systematical decay probability in the mass dependence.

What are “Mesons in Non-Hadronic Phase”?