PHENIX 広島大学 Quark Physics Laboratory Hiroshima University, Japan

Low Mass Vector Mesons at High Energy Densities at RHIC-PHENIX

Kenta Shigaki (Hiroshima University) for the PHENIX Collaboration

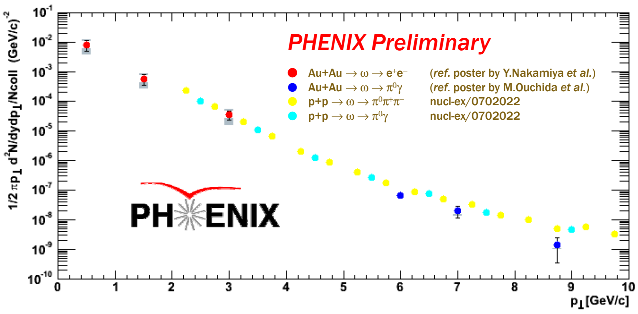
Low Mass Vector Mesons as Probes of (Partial) Chiral Symmetry Restoration

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 densities. Some of the experimental results at CERN SPS (*e.g.* CERES 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 deconfined partonic state 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.

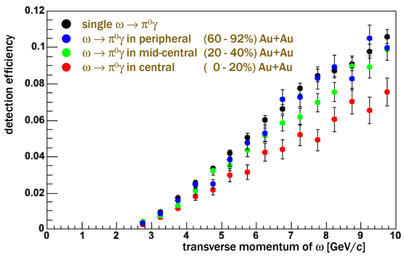
A Recent Experimental Highlight

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 $\pi^0\pi^+\pi^-$ and $\pi^0\gamma$ channels in p+p and d+Au collisions. More channels including ω decaying into e^+e^- in the light collision systems are under study. See also posters by Y.Nakamiya *et al.*, M.Ouchida *et al.* and K.M.Kijima *et al.*.

Invariant Yield of ω per Nucleon-Nucleon Collision in Au+Au and p+p Collisions at $\sqrt{s_{NN}}$ = 200 GeV

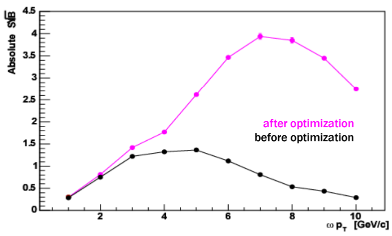


Multiplicity Dependence of Detection Efficiency of PHENIX for ω Decaying into $\pi^0\gamma$



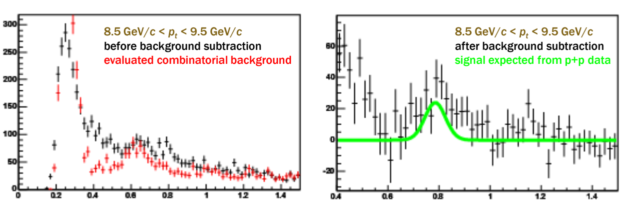
Multiplicity dependent factor of detection efficiency has been studied by embedding test particles into real events.

Signal to Background Ratio for ω Decaying into $\pi^0\gamma$ in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV Expected with the Existing Statistics of 0.24 nb^{-1}



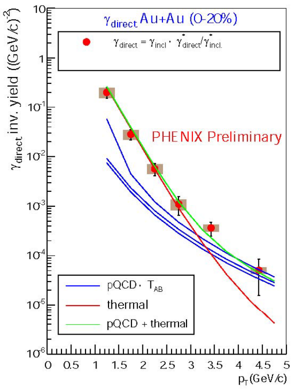
The expected significance of the signal of ω mesons decaying into $\pi^0\gamma$, with the existing statistics of 0.24 nb^{-1}, has been improved by a large factor by optimization of kinematical selections of the decay particles.

Invariant Mass Distribution of $\pi^0\gamma$ in ω Mass Region in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV



Signal to background ratios generally get worse in channels decaying into many bodies. Evaluation of combinatorial background also becomes more technically challenging due to (partially) correlated combinations. A mass peak of ω mesons is extracted in the high transverse momentum (p_t) region after optimized kinematical selections and improved evaluation of combinatorial background.

High Energy Densities Achieved at RHIC



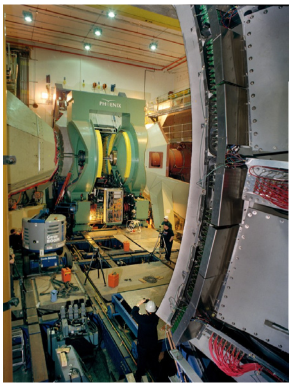
Spectra of direct photons in Au+Au collisions suggest existence of a thermal component with a temperature as high as 300-600 MeV.

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/fm^3, respectively, which are well above the predicted critical values for the QCD phase transition.

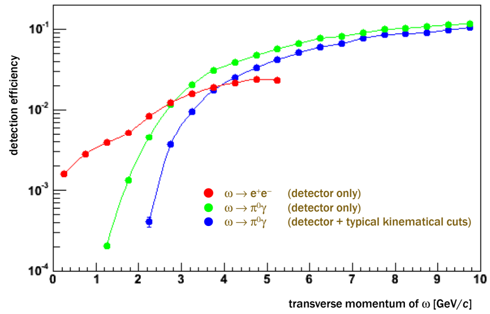
PHENIX at RHIC: The Right Tool

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. ω 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 consequent wide kinematical coverage provides an additional axis in systematics: decay probability in the matter.



Detection Efficiency of PHENIX for ω Decaying into e^+e^- and $\pi^0\gamma$

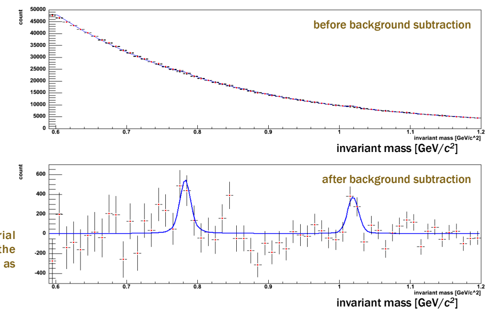


Challenges and Progresses with Golden Data

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 heaviest 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 from March 2007, shooting for an integrated luminosity of 1.1 nb^{-1}, physics analysis of existing Au+Au data of 0.24 nb^{-1} collected in 2003-2004 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/$\sqrt{(S+B)}$).

Invariant Mass Distribution of e^+e^- in ω and ϕ Mass Region in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV



To extract 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.

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 should be interpreted as precursors of hadrons. The recent discovery in lattice QCD that J/Ψ remains as a prominent peak up to about 1.6 times the critical temperature (M.Asakawa and T.Hatsuda, J.Phys.G30, S1337, 2004) is a numerical support of the picture. Their mass states may however be modified from those in vacuum and of special interest to understand the properties and origins of mass of hadrons.

presented by Kenta Shigaki (Hiroshima University) for the PHENIX Collaboration at the 23rd International Nuclear Physics Conference (INPC 2007) in Tokyo, Japan, on June 3 - 8, 2007