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The PHENIX Experiment at RHIC

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The physics emphases of the PHENIX collaboration and the design and current status of the PHENIX detector are discussed. The plan of the collaboration for making the most effective use of the available luminosity in the first years of RHIC operation is also presented.[1]

1. Physics and Design Aims

The primary goals of the heavy-ion program of the PHENIX collaboration are the detection of the quark-gluon plasma and the subsequent characterization of its physical properties. To address these aims, PHENIX will pursue a wide range of high energy heavy-ion physics topics. The breadth of the physics program represents the expectation that it will require the synthesis of a number of measurements to investigate the physics of the quark-gluon plasma. The broad physics agenda of the collaboration is also reflected in the design of the PHENIX detector itself, which is capable of measuring hadrons, leptons and photons with excellent momentum and energy resolution. PHENIX has chosen to instrument a selective acceptance with multiple detector technologies to provide very discriminating particle identification abilities. Additionally, PHENIX will take advantage of RHIC's capability to collide beams of polarized protons

[1] Visit *http://www.rhic.bnl.gov/phenix* for the most current PHENIX information.

with a vigorous spin physics program, a subject covered in a separate contribution to these proceedings[1].

The first measurements PHENIX will make will be of global event properties such as charged particle multiplicity, E_T production, the $\langle p_\perp \rangle$ of charged particles, and fluctuations in these quantities. Charged particle multiplicity and E_T, alone or in correlation with zero-degree calorimetry, will provide information about the geometry of each collision. From these data one can also deduce the energy density achieved in each event. The geometry of the collision, charge particle multiplicity, E_T and energy density may all be used to classify events for other analyses.

PHENIX will study many proposed signatures of the deconfinement transition and the restoration of chiral symmetry. The first of these, the deconfinement transition, should produce a number of signals observable in the PHENIX detector. For instance, the suppression of J/ψ and ψ' production relative to that of the Υ will yield information about the strength of Debye screening in the deconfined plasma. Measuring J/ψ suppression relative to the Drell-Yan continuum will allow comparisons with current results such as those from NA50[2]. Comparison of charmonium production relative to that of open charm—primarily identified through the semi-leptonic decay of charm mesons—will allow PHENIX to disentangle initial state effects such as gluon shadowing from the later dissolving of any created charmonium. The many D$\bar{\text{D}}$ pairs that are expected in central Au+Au collisions will also give PHENIX a solid base from which to investigate open charm enhancement in the quark-gluon plasma.

An examination of chiral symmetry restoration will complement the study of deconfinement. The in-medium modification of meson properties due to the restoration of chiral symmetry is predicted to cause changes in the mass and width of the ϕ meson. Since the mass of the ϕ meson is only 33 MeV greater than twice the charged kaon mass, changes in its properties will also affect the relative branching ratio of ϕ mesons decaying via K^+K^- or e^+e^- channels.

The thermal history and available degrees of freedom will be studied through direct γ production and $\gamma^* \rightarrow e^+e^-, \mu^+\mu^-$ channels. Photons, like leptons, are unperturbed by the strong interactions that plague hadronic signals and thus retain information about the early history of the collision. Whether the colliding system forms a plasma with many degrees of freedom, remains a hot hadronic gas, or evolves through a long-lived mixed state, all have effects on the spectrum of emitted photons. Very high $p_\perp$ photons may also serve as a reliable flag for an oppositely directed jet, the properties of which may be measured via the leading particle spectrum.

The measurement of bosonic or fermionic Hanbury-Brown Twiss correlations and the coalescence likelihood of various nuclei and anti-nuclei will give insights into the space-time extent and evolution of heavy-ion collisions at RHIC.

Enhanced strangeness, already a staple feature of relativistic heavy-ion physics, will be studied in PHENIX by determining the production cross section of $K^\pm$ and ϕ mesons. This will be complemented by an investigation of enhanced charm production.

2. Construction and Current Status of the Experiment

Fundamentally, the PHENIX detector consists of a large acceptance charged particle detector and of four spectrometer arms—a pair of spectrometers measuring electrons, photons and hadrons which straddles mid-rapidity, and a pair of muon spectrometers at forward rapidities—

all working together in an integrated manner[3]. Each of the four arms has a geometric acceptance of approximately one steradian. The magnetic field in the volume of the collision region is axial, while the magnets of the muon arms produce radial fields. The PHENIX detector is comprised of eleven different subsystems, so that the task of integrating and commissioning the detector is one of the biggest hurdles facing the collaboration.

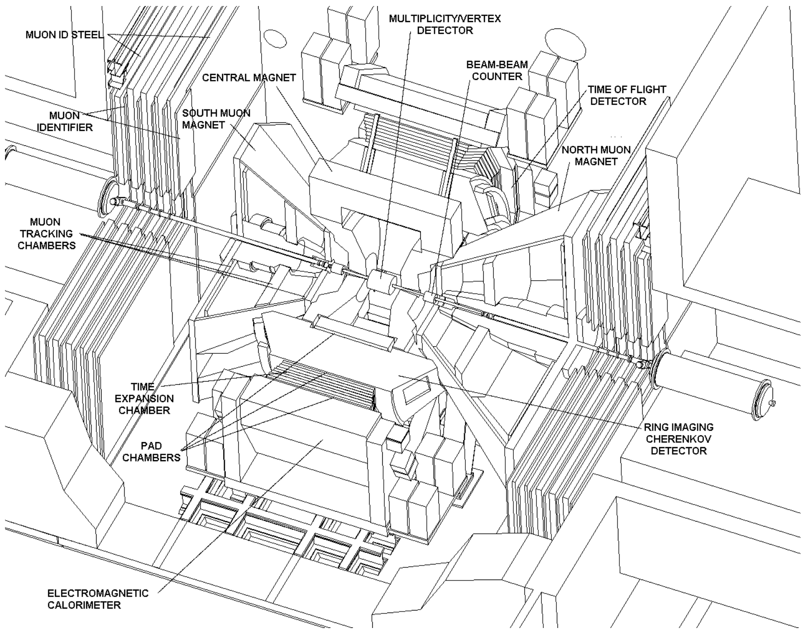

Figure 1. A cutaway drawing of the PHENIX experiment. Labeled arrows indicate the major subsystems of the detector.

The main sources of event characterization information are the beam-beam counter, which consists of two arrays of quartz Čerenkov telescopes surrounding the beam, and the multiplicity and vertex detector, composed of concentric barrels of silicon strip detectors and end-caps made of silicon pads.

Electromagnetic calorimeters are mounted outermost on each of the two central arms. PHENIX uses two technologies for calorimetry: lead-scintillator with good timing properties, and lead-glass with better energy resolution.

The central arm tracking system in PHENIX uses the information provided by several detectors. Pad chambers yield the three-dimensional space points that are essential for pattern recognition, drift chambers provide precise projective measurements of particle trajectories, and time-expansion chambers provide r-ϕ information as well as particle identification. Using this tracking information the mass resolution of $\phi \to e^+e^-$ is determined to better than 0.5% for $p_\perp < 2$ GeV/c.

Particle identification also hinges on several detectors. Panels of time of flight scintillators cover part of the central arm acceptance, and the 85 ps timing resolution of this time of flight system separates kaons from pions up to 2.5 GeV/c. The timing resolution of the lead-scintillator, 280 ps, can separate kaons from pions up to about 1.4 GeV/c, and its large acceptance greatly improves the rates for measurements such as $\phi \rightarrow K^+K^-$. For electron identification, information from the ring-imaging Čerenkov detector, the dE/dx measurement of the time-expansion chamber, and information from the electromagnetic calorimeter are combined to reject pion contamination of the identified electrons to one part in 10^4 over a wide range in momentum.

The first part of each muon arm (following a thick hadron absorber) contains three stations of cathode strip tracking chambers. The back part of each arm consists of panels of Iarocci streamer tubes alternating with plates of steel absorber. The pion contamination of identified muons is below one part in 10^4, matching the high degree of confidence in particle identification as is the case with the central arm electron identification. The excellent momentum resolution of identified tracks in the muon arms yields a mass resolution of 100 MeV/c^2 for J/$\psi \rightarrow \mu^+\mu^-$.

3. Physics Opportunities Grow with Luminosity

During its first two years of operation the luminosity of the RHIC accelerator will gradually ramp up to its full design value. In order to make the most effective use of the available luminosity, the collaboration has developed a plan which matches priorities for physics studies to the anticipated profile of integrated luminosity. Early in the first year of RHIC operation, when the luminosity will be about 1% of the design value, PHENIX will concentrate on measurements such as $dN_{ch}/d\eta$, $dE_T/d\eta$, hadronic spectra, HBT and inclusive γ and π^0. Each of these measurements can be made with just a few μb^{-1}. Toward the end of the first year of operation, as the luminosity rises to 10% of the design value, measurements of $\phi \rightarrow K^+K^-$, single high p_T leptons and $J/\psi \rightarrow \mu^+\mu^-$ become feasible. By the end of the first year of RHIC operation, PHENIX should have seen an integrated luminosity of roughly 100 μb^{-1}. It is in the second year of RHIC operation, as the luminosity reaches its design goal, that the full physics program becomes accessible. At that point, the machine will have sufficient luminosity for measurements of the Drell-Yan continuum, open charm production $\Upsilon \rightarrow \mu^+\mu^-$, and J/$\psi$ and other vector meson decays to e^+e^-. The PHENIX spin program also becomes possible in the second year of operation. However, even this luminosity does not exhaust the PHENIX appetite for physics. As the RHIC luminosity improves, the horizons of the PHENIX physics program broaden still further.

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