Department of Energy

Office of Nuclear Physics Report

Addendum II
Response to Recommendations
for the
Nose Cone Calorimeter Detector (NCC)
Upgrade for the RHIC PHENIX Experiment

July 29, 2008

Introduction

In the Department of Energy (DOE) Science Review report (July 9, 2007) on the Nose Cone Calorimeter (NCC) detector upgrade proposal, substantial concerns were expressed about the scientific merit and feasibility of the NCC project. The concern was that the PHENIX Collaboration had not provided sufficient simulation data to address the original charge as to what science could be achieved with the addition of this detector to PHENIX. A broad set of NCC measurements were proposed by the Collaboration that included gamma-hadron correlations in conjunction with the silicon vertex (VTX) barrel tracker, "jet tomography", χ_c charm meson production, gluon distribution G(x) in cold nuclei down to $x \sim 10^{-3}$ with π^0s and gammas, transversity distributions through single spin asymmetries, and $\Delta G(x)$ measurements via A_{LL}^{γ} at low x.

The review found that while several measurement "concepts" were presented, the NCC proponents fell short of demonstrating the feasibility and impact of these measurements. In addition, the NCC technical performance parameters seemed largely optimized for the available space in the PHENIX experiment, rather than any particular measurement. Full simulations had yet to be completed to verify the achievable electromagnetic and hadronic discriminating power, energy resolution and the driving factors for the proposed granularity. The review panel believed the NCC's non-projective geometry required further studies to demonstrate that the proposed physics research could be realized. Sufficiently detailed simulation studies, which would include shower reconstitution, were not presented to the satisfaction of the panel. The panel indicated that the simulations needed to be finished with high priority so that the detector performance could be established and specifications for the detector identified.

As a result of these concerns, the DOE Science Review made two recommendations:

I. *"Each detector group should demonstrate and document scientific feasibility for two or more topics of high importance and submit to DOE for evaluation. PHENIX should submit to DOE a report documenting these studies for evaluation, prior to a technical review."*

II. *"The NCC group should demonstrate by simulations that the non-projective geometry and shower digitization does not preclude the ability to eliminate background at the level necessary to accomplish the proposed physics goals. PHENIX should submit to DOE a report documenting these studies for evaluation, prior to a technical review."*

This addendum to the Science Review report documents the overall evaluation of the Science Review panel concerning the proposed NCC project in light of the above DOE recommendations.

A written response to these recommendations was provided to the DOE Office of Nuclear Physics (NP) through Brookhaven National Laboratory management on March 11, 2008. This document (Attachment A) was distributed to the original science review panel, and a phone conference was held by the review panel and NP Program Managers to discuss the reviewer's initial evaluation. Further information was required and a set of questions was sent to the NCC proponents. A response to these questions (Attachment B) was circulated to the review panel. After lengthy deliberations, including a second phone conference on July 2, 2008 with the science panel, each reviewer concluded that further iterations with the NCC proponents were not necessary and they provided their individual final assessments. The panel's excerpted comments on the Collaboration's response are included in a separate document (Attachment C).

Evaluation

The reviewers commended the PHENIX Collaboration for the great deal of diligent work they have done in their response to the DOE Recommendations and the Science Review panel's questions.

In their response of March 11, 2008, the PHENIX Collaboration identified three scientific topics (two in Heavy Ion Physics and one in Spin Physics) that they believed required the NCC:

- π^0 yield suppression (R_{AA}) in heavy ion collisions with implications for direct photon measurements and gluon Parton Density Function (PDF) measurements through detection of γ-jet final states;
- Nuclear modification factor R_{AA} for the χ_c charm meson and
- "Prompt" photon asymmetries (A_{LL}) to determine the gluon spin contribution to the proton.

All of these measurements require efficient reconstruction of the photon with good resolution over a wide energy range and extended range in rapidity. Chapter 2 of the response document discussed principles of design of the NCC in an effort to address the second DOE recommendation. This section provided important performance information on the NCC device, particularly regarding the limitation of acceptance related to detector occupancy and various types of reconstruction efficiencies.

NCC Performance

The NCC proponents have done full GEANT simulations of electromagnetic and hadronic showers using realistic detector geometries. To show that the geometry will work, the responses for single γ, *e* and π^0 particles were generated in Monte Carlo. These signals were embedded into Monte Carlo background events generated with HIJING and PYTHIA for p+p, d+Au and Au+Au events, after which performance quantifications of the recovery of the embedded γ, *e* or π^0 were made. Significant new and important information on detector occupancies and various types of efficiencies has been documented in the NCC response that was not available to the reviewers at the time of the original Science Review. Several reviewers believed the NCC proponents had done a reasonable job in showing that the non-projective geometry could work

within specific kinematic regions. However, the simulation studies also highlighted significant problematic areas. These issues raised the question of whether the detector performance was adequate in the context of the proposed physics topics identified in the PHENIX Collaboration's response to the second DOE recommendation.

Heavy Ion Measurements

The performance of the NCC is highly dependent on the colliding beam species. The NCC acceptance, efficiency and purity of the photon restrict the kinematic reach of π^0 measurements. The inefficiency of the NCC is most severe for central Au+Au events where the rapidity reach is confined to $\eta<1.5$ and $p_T < 5$ GeV/c. The reviewers believed the single-track π^0's in Au+Au needed better simulations. Given the limited rapidity extension compared to the existing RHIC pion measurements, some reviewers considered that this aspect of the of the NCC physics program offered only incremental or marginal value, while others opined the physics-case was either missing or not argued well. The response lacked a comparison of the science reach achieved with the NCC and what might be learned from $R_{AA}(\pi^{\pm})$ that could be available without the NCC upgrade.

$R_{AA}(\chi_c)$ is also an important measurement to characterize the Quark Gluon Plasma (QGP), giving clues to the pattern of Charmonium suppression and color screening. This measurement is considered to be very challenging and its success will depend on factors (e.g., soft photon energy resolution, threshold cuts, efficiencies, etc.) that contribute to the χ_c invariant mass resolution and on a sufficient number of events above background to make a statistically significant measurements. The complete simulation and reconstruction analysis of the χ_c leading to the final "physics" plots were not included in the response. The simulated χ_c invariant mass peaks for Au+Au did not convince the reviewers that the signal-to-background ratio was understood. Credible estimates of the statistics achievable in one run-year assuming RHIC II integrated luminosity were not provided. The reviewers' estimate of the data sample is at variance with the NCC response and they were unable to reproduce the Collaboration's estimates which were significantly higher.

The measurement of gluon Parton Distribution Functions (PDFs) via γ-jet final states was introduced but an adequate analysis was not provided and thus the reviewers could not deduce from the response relevant comments pertaining to heavy ion measurements. This PDF topic may have been intended in the context of the proton spin measurements which is separately addressed below.

Spin Measurements

The Science Review panel in their original evaluation of the NCC proposal believed that making a precise $\Delta G(x)$ measurement via A_{LL}^{γ} at low x, as well as over a broader range in x, was necessary to probe the gluon polarization. But they considered the extraction of x from the measured p_T to be a difficult de-convolution problem. The away-side jet from the recoiling

parton may be measurable from other detectors to reconstruct the kinematics of the event. However, the resolution attainable in *x* was not demonstrated. In the NCC response document, the results of a sensitivity analysis for the inclusive "direct" or "prompt" A_{LL}^{γ} (p_T) measurement was presented assuming RHIC II luminosities for 250+250 GeV polarized proton collisions. Not withstanding the over-arching concern of several reviewers regarding the efficacy of photon identification and detection efficiency, the response contained limited information on this analysis. The reported A_{LL}^{γ} simulations indicated that the statistical significance would only marginally distinguish between two vastly different models of $\Delta G(x)$, but would not reveal any "fine" structure in the p_T distribution. In addition, these simulations did not include the dilution to A_{LL}^{γ} from background. This will definitely increase the uncertainties shown and since the statistics are marginal already, a background analysis is required before impact of the measurements can be determined. In addition, the reviewers noted that γ-jet correlations were needed; but as in the original proposal, these were not discussed. Finally, the spin discussion and figures needed to be updated in the context of the latest constraints imposed on $\Delta G(x)$ from the current data and other planned RHIC measurements. In conclusion, while $\Delta G(x)$ is considered to be an important measurement, the response failed to demonstrate that the NCC would be able to contribute to a significant measurement.

Summary

The PHENIX Collaboration has responded to the two DOE recommendations by providing more detail on the NCC performance and by presenting the case for the π^0, χ_c and "prompt" γ physics measurements. However, the response had left significant unanswered questions and concerns in place for the scientific topics chosen. The reviewers held that the proposed measurements, taken collectively, were either of marginal scientific value or that the proponents did not make a convincing case regarding feasibility of realizing the scientific goals. Thus, the PHENIX Collaboration's response to the DOE recommendations is found to be unsatisfactory by all the reviewers.

Based on these evaluations, the DOE Office of Nuclear Physics considers the Collaboration's response insufficient to take the next step towards the initiation of the NCC project.