Abstract. RHIC has made groundbreaking contributions to the understanding of QCD under extreme conditions with the discovery of the quark gluon plasma (QGP) as a perfect fluid and first observations of energy loss. It continues to play a crucial role in understanding and quantifying the properties of the QGP as well as mapping out the QCD phase diagram. However, detailed questions concerning partonic energy loss in the QGP remain. There is a need to build a new detector at RHIC to measure important rare probes of the QGP. A new detector will benefit from advances in reconstructing jets in heavy ion collisions and the increased luminosity achievable with RHIC. Constraining models at RHIC and LHC energies are crucial for extracting the temperature dependence of transport properties of the QGP. To measure newly developed observables made at the LHC with high precision at RHIC, a detector with full azimuthal coverage and spanning a pseudorapidity range between -1.1 and 1.1, known as sPHENIX, has been proposed. The capabilities of the new detector will allow for a full understanding of jet energy loss and upsilon suppression. The goals for sPHENIX and route to achieving these goals along with the current status of the detector will be presented on behalf of the new collaboration.

1. The Motivation for sPHENIX

The 2015 Nuclear Science Long Range Plan explicitly states the need for “a state-of-the-art jet detector at RHIC, called sPHENIX” in its recommendations [1]. As the Relativistic Heavy Ion Collider (RHIC) completes its scientific mission, sPHENIX will play a crucial role in understanding the microscopic properties of the Quark Gluon Plasma (QGP). Fully reconstructed jets at RHIC probe the medium near the critical temperature, where the coupling is the strongest. A detector capable of detailed measurements of the modifications to the jet structure at these collision energies will greatly enhance our understanding of energy loss in the QGP. Capabilities for heavy flavor jet measurements will provide the ability to study the flavor dependence of energy loss, which will clarify the roles of radiative and collisional energy loss in the medium. In addition, the sPHENIX detector should be capable of separating the three states of the upsilon (ϒ), which can be used to study the density dependence of the color screening effect.

In two years of running, sPHENIX will collect a large statistics data set as a result of its high data acquisition rate (15 kHz) combined with the high luminosity RHIC can deliver after more than 15 years of accelerator developments. This will increase the kinematic reach of previous measurements and the accessibility of rare probes in 200 GeV Au+Au collisions.

The Long Range Plan also notes the importance of the complementarity between RHIC and the Large Hadron Collider (LHC). To fully utilize information gathered from experiments at both facilities, one should measure the same observables in the same kinematic range. The increased
kinematic range and statistics from sPHENIX will provide sufficient overlap in observables between RHIC and LHC to constrain models and improve our understanding of the properties of the QGP at different temperatures.

2. The sPHENIX Design
The sPHENIX detector \cite{4} will be housed where PHENIX is located on the RHIC ring and will utilize the existing infrastructure. The present PHENIX detector is currently collecting its last data set during RHIC Run 16. The schedule lists sPHENIX as fully installed and ready for beam in 2022 and includes two years of data taking. It would then be available for use at an electron ion collider.

The sPHENIX detector is comprised of a tracking system surrounded by calorimetry based around a 1.5 Telsa solenoid magnet. The calorimetry includes an electromagnetic calorimeter (EMCal) and two hadronic calorimeters (HCal). The inner and outer HCals are located inside and outside the solenoid magnet respectively. The hadronic calorimeter serves as the flux return for the magnet. The solenoid magnet has already been obtained by Brookhaven National Lab (BNL) from the Babar experiment for use in sPHENIX. Recently the magnet underwent a successful round of low power cold tests. The magnet has a diameter of 2.8 m and is 3.8 m long. The sPHENIX detector will have full azimuthal coverage and span $-1.1 < \eta < 1.1$ in pseudorapidity. A schematic of the detector is shown in Figure 1.

2.1. Tracking
To complete the $\Upsilon$, jet structure, and heavy flavor tagged jet programs, a high resolution tracking system is essential. The final configuration has yet to be determined however there are specific
5.2.4 Light Guides

Light guides will be used to optically couple the optical sensors to the readout surface of the calorimeter blocks. Each light guide will define a readout tower. The surface area of a single tower is 19.8 mm x 19.8 mm = 392 mm², while the combined active area of the 4 SiPMs is 4 x (3 mm x 3 mm) = 36 mm². The initial design for the light guide is a modified version of the SPACAL light guide, shown in Figure 5.15, which is a simple trapezoidal shape, with a height of 25 mm, to couple the 2 areas. These light guides are machined acrylic which has good optical transmission above 400 nm. The light guides will be epoxied to the absorber blocks as shown in Fig 5.16. Silicone cookies will be used to optically couple the SiPMs to the light guides. Initial measurements of these light guides, coupling a prototype W/fiber calorimeter block to photomultiplier tube, show an efficiency of 71 percent.

5.2.5 Sensors

The photosensor selected for the EMCal is the Hamamatsu S12572-015P SiPM, or Multi Pixel Photon Counter (MPPC), described in detail in the Electronics - 7.1 Optical Sensors section of this document. This device will be used for both the HCal and EMCal. The EMCal will use a 2x2 arrangement of 4 SiPMs per tower, passively summed into one preamp/electronics readout channel. The 4 SiPMs will be gain-matched (selected) and will share a common bias voltage.

technologies proposed that are being fully explored before a final decision is made. The options for an inner tracking system include reusing components of the current PHENIX silicon detector, the SVX [2], or monolithic active pixel sensors (MAPS). The MAPS detector would be designed similar to the ALICE ITS upgrade [3]. Options for the outer tracking system include a new silicon tracker similar to the current PHENIX SVX or a compact Time Projection Chamber. The reference design in the sPHENIX proposal includes seven layers of silicon. However all options are being fully evaluated to determine what best satisfies the sPHENIX tracking criteria, timeline and budget. A tracking review will occur in the Fall of 2016.

2.2. Electromagnetic Calorimeter

The EMCal is designed to measure electrons and photons. The electron identification is important for measuring the different upsilon states. Direct photon measurements at high \( p_T \) will be used to identify photon-jet events, which will provide insight into partonic energy loss. The segmentation of the current EMCal design is 0.025 x 0.025 for \( \Delta \eta \times \Delta \phi \), which results in a total of 24,576 (96 x 256) readout channels. Each tower is assembled by threading scintillator fibers through screens that are then positioned into a mold. Tungsten powder and epoxy are poured into the mold. After the tower has hardened the mold is removed, a light guide is attached as shown in the top right picture of Figure 2. The signal is then readout by silicon photo-multipliers (SiPMs). The Moliere radius for the EMCal design is approximately 2.3 cm. 1D projective modules have been assembled and studied in prototype testing. However, 2D projective towers, which would improve the electron-pion separation are also under investigation.
2.3. Hadronic Calorimeters

The purpose of the HCals is to measure the energy from hadrons produced in the events. The energy in the HCAL and EMCal is used to reconstruct the energy of jets produced in the collisions. To provide a jet energy resolution of approximately 20% the required single particle energy resolution for the HCAL is $\frac{\sigma_E}{E} < \frac{100}{\sqrt{E}}\%$.

The HCals are comprised of alternating layers of steel plates and scintillator tiles. The scintillator tiles are 7mm thick polystyrene. A 1mm wave length shifting fiber is embedded into the tiles. An unwrapped outer HCAL tile is shown in the left-most photograph in Figure 2. This shows the routing pattern of the fiber used in the prototype. The ends of the fiber come together at the edge of tile and each tile illuminates an SiPM. The SiPMs of five tiles are readout by a single pre-amplifier board as a single tower. This results in 3072 (2 x 24 x 64) total readout channels. The plates are tilted such that a straight line from the center of the detector will hit four tiles in each HCAL as illustrated in the middle of Figure 2. Due to the difference in size, this results in a stronger tilt angle for the inner HCAL. The plates in the inner HCAL are tilted in the opposite direction from the outer HCAL.

2.4. Calorimeter Prototype

Prototypes of the EMCal, inner and outer HCAL were constructed at BNL and tested at the test beam facility at Fermilab in April 2016. A photo of the prototype is included in Figure 3. The energy resolution of these detectors is being studied at beam energies ranging from 2 to 64 GeV. Analysis of the data collected during the beam test is ongoing.

3. Summary

The scientific case has been established for the need to build the proposed sPHENIX detector as demonstrated in the Nuclear Science Long Range Plan recommendations [1]. At present a total of 58 institutions have joined the sPHENIX collaboration, which held its first official collaboration meeting in December 2015 at Rutgers University. Open meetings for the collaboration, topical groups and detector subsystems are held regularly and participation by new members and those
interested in joining the sPHENIX collaboration is welcomed. Early results of the April 2016 test beam study for the calorimeter prototypes are promising and should be completed soon. Another prototype test for the calorimeters is planned in early 2017. The project is on track to have sPHENIX installed by 2022 and ready to take data. The new detectors and high data rate will allow sPHENIX to make high statistics measurements over a larger kinematic range than previous RHIC experiments. This is essential for measuring important observables such as jet structure, γ-jet and heavy flavor jets as well as separating the three Υ states. sPHENIX will play a crucial role as RHIC completes its scientific mission to understand the properties of the sQGP that it first created over a decade ago.

References
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