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Design Studies of the Electromagnetic and Hadronic Calorimeters for sPHENIX

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The PHENIX Experiment at RHIC is planning a series of major upgrades that will transform the current PHENIX detector into a new detector, sPHENIX, which will be used to carry out a systematic measurement of jets in heavy ion collisions in order to study the phase transition of normal nuclear matter to the Quark Gluon Plasma near its critical temperature. The baseline design of sPHENIX will utilize the former BaBar solenoid magnet and incorporate two new calorimeters, one electromagnetic (EMCAL) and another hadronic (HCAL), that will be used to measure jets in the central region. The calorimeters will cover a region of ±1.1 in pseudorapidity and 2pi in phi, and will result in a factor of 6 increase in acceptance over the present PHENIX detector. The HCAL will be first hadronic calorimeter ever used in an experiment at RHIC and will enable this first comprehensive study of jets in heavy ion collisions. It will be based on scintillator plates interspersed between steel absorber plates that are read out using wavelength shifting fibers. It will have a total depth of $\sim$ 5 Labs that will be divided into two longitudinal sections, and will have an energy resolution $\sim 50\%/\sqrt{E}$ for single particles and $<100\%/\sqrt{E}$ for jets. The EMCAL will be a tungsten-scintillating fiber design, and will have a depth of $\sim$ 17 X0 and an energy resolution of $\sim 15\%/\sqrt{E}$. Both calorimeters will be read out using silicon photomultipliers and waveform digitizing electronics. In addition, it is planned to add a preshower detector in front of the EMCAL that will consist of $\sim$ 2 X0 of tungsten absorbers and silicon strip detectors in order to improve electron and single photon identification. This talk will discuss the detailed design of both calorimeters and the preshower, and the construction of the first prototypes of each of these devices. These prototypes were recently tested in a test beam at Fermilab and the first preliminary results of those tests will be presented. A discussion of additional upgrade plans that will transform sPHENIX into ePHENIX, which will be a detector for a future Electron Ion Collider at Brookhaven, will be discussed in a separate contribution to this conference.

Summary

The PHENIX Collaboration is planning a series of major new upgrades that will transform the current PHENIX detector at RHIC into a new, multipurpose detector that will be used to carry out a systematic study of jets in heavy ion collisions in order to study the Quark Gluon Plasma near its critical temperature, and to study polarized electron-hadron and electron-ion collisions at a future Electron Ion Collider at Brookhaven. The first in this series of upgrades is sPHENIX, which will utilize the BaBar solenoid magnet and instrument it with two new calorimeters, one electromagnetic and one hadronic, that will have full azimuthal coverage and cover 2.2 units of rapidity, thereby increasing the current PHENIX acceptance by a factor of six. The sPHENIX hadron calorimeter will be the first hadronic calorimeter ever used in an experiment at RHIC, and will enable the first study of jets at RHIC that utilizes a complete jet energy measurement. The evolution of sPHENIX to ePHENIX, which will be a new detector for eRHIC, will be described in a separate contribution to this conference.

The hadronic calorimeter will be a steel plate and scintillating tile design that is read out with wavelength shifting fibers and silicon photomultipliers (SiPMs). It will incorporate a novel design feature where the steel plates are oriented parallel to the beam direction so that they also function as the flux return for the magnet.

This results in the steel plates being wedged shaped and that the sampling fraction changes with depth. However, the calorimeter will be divided into two longitudinal compartments, which allows the measurement of the longitudinal center of gravity of the shower, and thereby an event by event correction for the longitudinal shower fluctuations. It will be divided roughly into 1/3 for the front section and 2/3 for the back section, and each section will oriented at a small angle with respect to the incoming particles. Scintillating tiles are interspersed between the steel plates and read out using wavelength shifting fibers. The fibers are bundled and read out using 3x3 mm3 silicon photomultiplers (SiPMs) which operate in the fringe field of the solenoid magnet.
The EMCAL will be a tungsten plate and scintillating fiber design with the plates and fibers oriented approximately along the incoming particle direction, as in the HCAL. In order to prevent channeling of particles through the calorimeter (i.e., particles that could only interact in the scintillator), the plates and fibers will either be tilted at a small angle with respect to the incoming particle, as in the HCAL, or the plates and fibers will have an accordion structure that will prevent any direct particle path through the scintillator. The fibers are brought to the back of the calorimeter where the light is collected by an array of light collecting cavities that form the readout towers and direct the light onto SiPMs. The EMCAL will have a Moliere radius ˜ 2 cm and a radiation length ˜ 7 mm.
Both calorimeters will use the same SiPMs and readout electronics, thereby simplifying the combined calorimeter design and resulting in an overall cost savings. The SiPM signals are amplified by custom designed preamplifiers that provide feedback for correcting the bias voltage to compensate for gain variations with temperature. An LED monitoring system is also incorporated for gain monitoring and calibration. The signals are digitized using flash ADC electronics that was used for a previous PHENIX detector.
There have been detailed design and simulation studies for both the EMCAL and HCAL and prototypes of both calorimeters have been constructed. These prototypes will be tested in a test beam at Fermilab in February 2014 where their actual performance properties will be measured. In addition, we plan to test a prototype of a silicon-tungsten preshower that would go in front of the EMCAL in the sPHENIX detector. This talk will describe the detailed design of both calorimeters and the preshower, including Monte Carlo simulations, and will discuss the first results from the prototype beam tests.

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