Forward hadron calorimeter R&D

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High energy polarized proton collision experiments at RHIC in Brookhaven National Laboratory have shown that the perturbative QCD describes experimental data accurately, and have largely developed an understanding of the internal structure of the proton. We will refine it much further and explore how the properties of the proton emerge from internal quark and gluon interactions by measuring the 3D structure of the proton with high precision measurements in the sPHENIX experiment at RHIC and the Electron-Ion Collider (EIC) in the future. The 3D understanding of the proton structure will enable us to understand the origin of the proton spin including the orbital motion of quarks and gluons (or collectively called partons).

We have proposed to construct a forward apparatus of the sPHENIX detector that will expand the kinematic coverage of the measurements of the 3D structure of the proton.[1)] In the forward rapidity region, a large single-spin asymmetry (SSA) or azimuthal modulation is known to exist, which will enable us to study the orbital motion of quarks and gluons. Theoretically, this phenomenon has been explained by the transverse-momentum dependent parton distribution function and correlations of partons in the proton. Based on these theoretical framework, we measure the SSAs of forward jets, hadrons, electrons, photons, etc. systematically in polarized proton collisions with high precision at sPHENIX.

The forward hadron calorimeter is essential for the forward jet reconstruction and hadron energy measurements, along with triggering. Designing and developing this calorimeter is a joint project with the EIC generic detector R&D group eRD1 and the STAR upgrade project.[2)] In addition to being a viable sPHENIX forward calorimeter, the system is designed to fulfill the requirements of a forward hadron calorimeter of an EIC detector.

The forward hadron calorimeter is located outside the flux return yoke of the superconducting solenoid magnet of the sPHENIX barrel detector system, with a front face 3.5 m away from the interaction point. The presence of the flux return yoke only has a minor effect on the calorimeter performance. The forward hadron calorimeter consists of 2,044 towers measuring 10 cm $\times$ 10 cm $\times$ 81 cm with an expected energy resolution of approximately $70\%/\sqrt{E(\mathrm{GeV})}$ for single hadrons. It covers a pseudorapidity range of $1.2 < \eta < 4.0$.

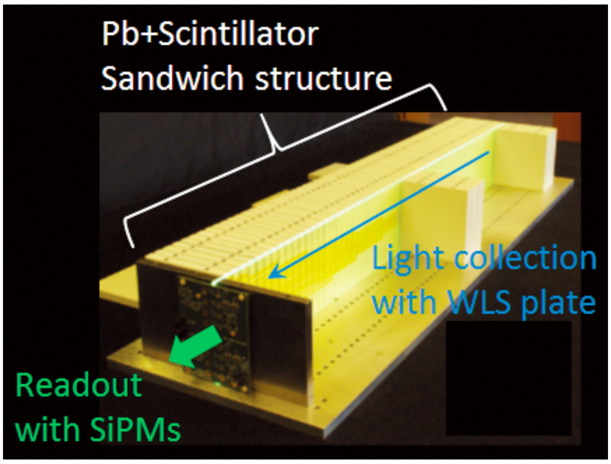

Fig. 1. An image of a tower of the hadron calorimeter.

The design of the calorimeter follows the design of the STAR upgrade project. A prototype calorimeter tower has been made by STAR and it has been tested at the FNAL test beam facility to validate the construction technique. It is scalable and re-configurable with a minimal number of mechanical components. Therefore, it minimizes the resources required for construction and operation. Figure 1 shows an image of the prototype calorimeter tower. It consists of 38 layers of 20 mm iron absorbers and 3 mm plastic scintillator plates, which correspond to a total depth of approximately 4.5 nuclear interaction lengths. A wavelength-shifting (WLS) plate provides uniform and efficient light collection from all scintillation tiles along the depth of the tower. The light from the WLS plate is measured with SiPMs similar to the sPHENIX barrel calorimeters. This allows for the use of common readout electronics for all sPHENIX calorimeter systems. Factors that limit the energy resolution are alignment and non-uniformity.

References

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