Forward Hadronic Calorimetry for STAR

The STAR detector is heavily instrumented in the pseudorapidity interval $|\eta|<2$. For larger $|\eta|$, the forward time projection chamber (FTPC) provides tracking for multiplicity and charge sign determinations, but the solenoidal magnetic field of STAR does not provide significant momentum analysis of large-$|\eta|$ charged hadrons. Due to the hole in the STAR poletips, there is on average less than one radiation length of material between the interaction region and positions outside of the magnet at large pseudorapidity. These positions can be instrumented to allow charged hadron detection over a broader range of $|\eta|$ then is presently available, expanding possibilities for the STAR physics program. To date, electromagnetic (EM) calorimeters have been successfully operated outside of the STAR magnet and close to the beam pipe. These calorimeters have been used to study forward production of neutral pions in both d+Au and polarized proton collisions. Supplementing the forward EM calorimeters with hadronic calorimeters would allow an extension of the physics accomplished to date, and would allow for greater exploitation of the FTPC by triggering on leading high-energy charged hadrons or forward jets.

Large spin effects were observed for forward pion production at STAR in the first polarized proton run at RHIC. Determining the origin of these effects should improve our understanding of the transverse spin structure of the proton. A key measurement to discriminate between models attributing the large spin effects to different sources is the complete detection of the hadrons that accompany a high-energy forward π^0 to allow the full reconstruction of the forward jet. Correlation of the spin effects with the angle between the plane defined by the π^0 momentum and the jet thrust axis and the plane perpendicular to the beam polarization would establish the dominance of the Collins mechanism, thereby providing a window to the unmeasured transversity structure function. Measurements of this sort in $p{\uparrow}p$ collisions at RHIC would be a timely complement to efforts underway in Europe and Japan to measure the Collins fragmentation function in e^+e^- collisions, and to probe the transversity structure function via transverse spin effects in semi-inclusive deep inelastic scattering. Reconstruction of the forward jet in $p{\uparrow}p$ collisions at RHIC would more directly establish the Bjorken x dependence of the transversity structure function by eliminating the momentum smearing associated with its fragmentation into a single hadron. Forward jet and single hadron production is dominated by highly asymmetric quark-gluon collisions at RHIC. In the forward direction, the momentum fraction of the initial-state quark that moves in the direction of the forward jet is nearly equal to the Feynman-x (x_F) variable of the final-state jet.

Addition of hadronic calorimetry in the forward direction of STAR is likely needed for successful reconstruction of forward jets. The FTPC were designed for multiplicity and charge sign determinations. Investigations of their applicability to forward jet reconstruction are underway. Even if the FTPC can provide sufficient p_T and η resolution for forward jets with leading π^0, extension of the forward spin physics measurements to jets with leading $\pi^\pm$ is expected to result in an overall better understanding of the underlying dynamics and possible quark flavor separation of the transversity structure functions. Forward hadronic calorimeters are essential to trigger on events with a $\pi^{\pm}$ meson having $x_F > 0.3$, where the analyzing power is expected to be large.

Another application of forward jet physics is to probe the gluon density in a heavy nucleus. Even if the Color Glass Condensate cannot explain the suppression of high- p_T particle production at mid-rapidity in Au+Au collisions, a detailed understanding of possible modification of the gluon structure functions for nucleons bound in heavy nuclei remains an important issue. A quantitative understanding of the gluon density in a heavy nucleus is essential to a detailed calculation of the dynamics of ultra-relativistic heavy-ion collisions. The first measurements providing sensitivity to possible gluon saturation phenomena were made at STAR at the end of d+Au collisions in RHIC run 3. The centrality dependence of the yield of forward ($|\eta| \sim 4$) π^0 mesons was measured in both the deuteron and Au beam directions. Analysis of that data is underway. Full reconstruction of the forward jet allows improved reconstruction of the initial-state parton kinematics, thereby enabling the determination of possible modification of the gluon field as a function of Bjorken x.

It would be natural to adapt the remains of the modular calorimeter, originally constructed for AGS experiment 864, to provide forward hadronic calorimetry for STAR. The cost associated with new detector construction would be eliminated. Mechanical support and readout electronics are significant issues that would require modest capital investment and design work. Good jet containment could be supplied by a hadronic calorimeter that subtended $\Delta\eta \times \Delta\phi = 1.5 \times 1.5$. Positioned at an average distance of 7.5 m from the interaction a 12×12 array of the E865 calorimeter modules would be required to provide this coverage. The measurement of the Collins angle with transverse polarization would greatly benefit from symmetry of a forward jet detector left and right of one of the beams. Concurrent detection of events at $\pm\phi$ with both spin up and spin down beams would provide important reduction in systematic error effects. For d+Au collisions, concurrent detection of forward jets at the same |h| in the direction of both the deuteron and Au ions are also desired. Detailed simulations of the optimal size and arrangement of forward hadronic calorimetry for the physics outlined above must still be completed.