D+AU COLLISIONS AT STAR

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STAR has measured forward π^0 production in p+p and d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The p+p yield generally agrees with NLO pQCD calculations. The d+Au yield is strongly suppressed at $\langle \eta \rangle = 4.0$, well below shadowing expectations. Exploratory measurements of azimuthal correlations between forward π^0 and mid-rapidity charged hadrons show a recoil peak in p+p that is suppressed in d+Au at low pion energy. These observations are qualitatively consistent with a saturation picture of the low-x gluon structure of heavy nuclei. Future measurements to elucidate the dynamics underlying these observations are also described.

1. Current Status

The BRAHMS Collaboration has reported that negative hadron production in the forward direction is strongly suppressed in d+Au collisions relative to p+p collisions.[1] The data are well described by calculations that treat the Au nucleus as a color glass condensate.[2] This may provide evidence at RHIC for the onset of gluon saturation at low-x in the Au nucleus. However, several other mechanisms have also been proposed to describe the BRAHMS results. For example, an NLO pQCD calculation[3] concludes that the $\langle x_g \rangle$ sampled by the BRAHMS measurement is ~ 0.02, which casts doubt on the saturation explanation.

To investigate the particle production mechanisms at forward rapidity at RHIC, STAR has measured inclusive π^0 production in p+p and d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV and explored azimuthal correlations between identified π^0 at $\eta = 4$ and leading charged hadrons at mid-rapidity.

Figure 1 shows STAR measurements of the inclusive π^0 production cross sections in p+p collisions at $\sqrt{s} = 200$ GeV for $\langle \eta \rangle = 3.3$, 3.8, and 4.0.[4] The curves are NLO pQCD calculations using CTEQ6M PDFs and KKP

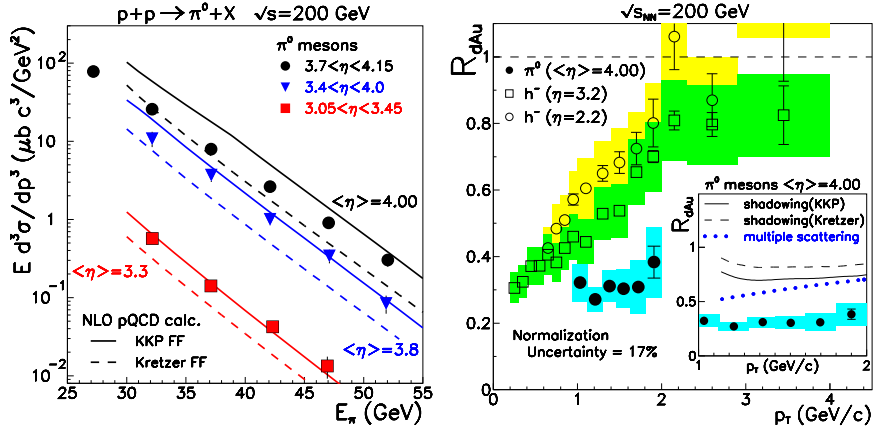[*]http://www.star.bnl.gov

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Figure 1.   The left panel shows the inclusive π^0 cross section vs. E_π, compared to NLO pQCD calculations that assume two different fragmentation functions. Note that $p_T = E_\pi/\cosh\eta$. The right panel shows R_{dAu} for minimum bias collisions vs. p_T for π^0 at $\langle\eta\rangle = 4.0$ from STAR, and for h^- at $\eta = 2.2$ and 3.2 from BRAHMS.[1] The inset compares the measured π^0 R_{dAu} to various predictions.

or Kretzer fragmentation functions. At $\langle\eta\rangle = 3.3$ and 3.8, the data are consistent with KKP. At $\langle\eta\rangle = 4.0$, the data drop below KKP and approach Kretzer as p_T decreases, similar to the behavior observed for mid-rapidity π^0 production at comparable p_T.[5] The NLO pQCD calculations provide a much better description of these data than is found for forward particle production at lower $\sqrt{s}$.[6]

Figure 1 also shows the nuclear modification factor for inclusive π^0 production in d+Au collisions at $\langle\eta\rangle = 4.00$, compared to the previous BRAHMS negative hadron measurements at smaller η.[1] The STAR R_{dAu} results at $\eta = 4$ are consistent with a linear extrapolation of the BRAHMS data, if the latter are scaled by 2/3 to account for isospin effects.[3] The inset demonstrates that the STAR data lie well below shadowing expectations.

To explore the dynamics that underlie forward particle production at RHIC, STAR has also studied the azimuthal correlation between forward π^0 and coincident leading charged hadrons detected at mid-rapidity. In models that attribute the suppression seen in d+Au collisions to nuclear shadowing or initial-state energy loss, but retain the conventional $2 \rightarrow 2$ partonic scattering process, a back-to-back correlation peak should be present for d+Au collisions similar to that found for p+p collisions. In contrast, in the saturation picture, forward particles arise from energetic quarks in the deuteron that undergo multiple interactions in the dense gluon field of the
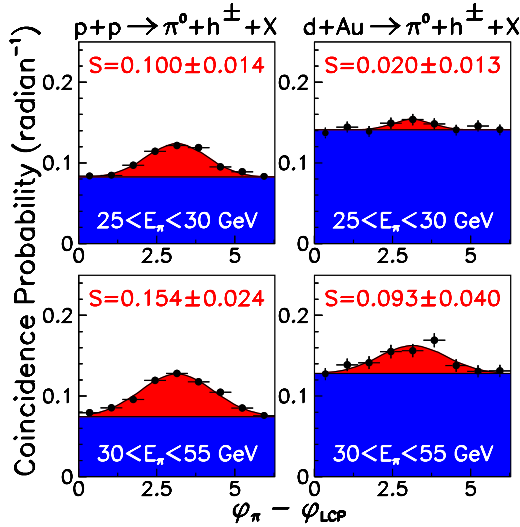
Figure 2. Coincidence probability vs. $\Delta\phi$ between a forward π^0 with $\langle\eta\rangle = 4.0$ and a leading charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 0.75$. The left (right) column shows p+p (d+Au). The curves show fits to a Gaussian centered at $\Delta\phi = \pi$ plus a constant background. S indicates the area of the back-to-back peak.

Au nucleus, leading to an apparent "mono-jet" mechanism.[7] Figure 2 shows the results.[4] The correlations seen in p+p collisions are very similar to those found in PYTHIA simulations. HIJING predicts that the back-to-back peak in d+Au collisions should be slightly smaller than that in p+p, with a larger combinatorial background. In contrast, the back-to-back peak observed in the d+Au data is strongly suppressed at low E_π. The behavior of the back-to-back peak as a function of E_π is qualitatively consistent with expectations of the gluon saturation model,[7] but other calculations based on the black-disk limit attribute the results to nearly complete suppression of forward π^0 production in central d+Au collisions.[8]

2. Future Plans

These results are qualitatively consistent with a gluon saturation picture of the Au nucleus, but they cannot rule out other interpretations. A systematic program of forward measurements is needed to obtain a definitive answer.

STAR is now constructing a Foward Meson Spectrometer (FMS) to enable this program. The FMS will provide STAR with electromagnetic calorimetry over the range $2.5 < \eta < 4$, and nearly complete coverage over the full range $-1 < \eta < 4$ when combined with the existing STAR barrel and endcap electromagnetic calorimeters. This will permit detailed $\pi^0 - \pi^0$ correlations to be observed over a broad kinematic range. Figure 3 shows
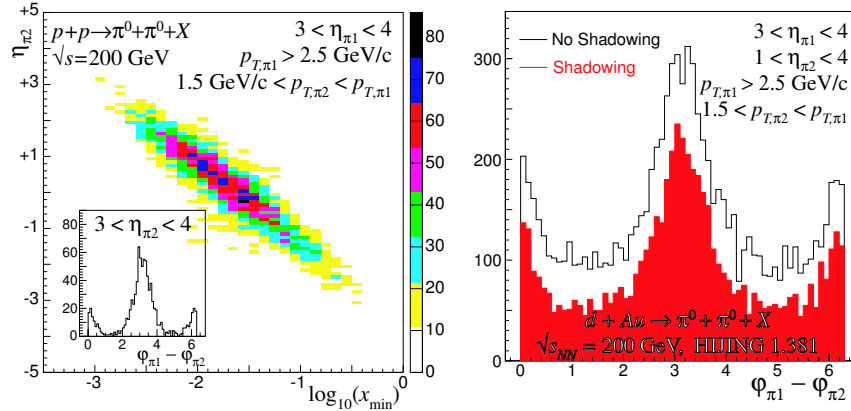
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Figure 3.   The left panel shows PYTHIA predictions for the correlation between η_2 and x_{min} for p+p $\rightarrow \pi^0 + \pi^0 + X$, where the first π^0 has $3 < \eta_1 < 4$ and $p_{T,1} > 2.5$ GeV/c, and the second π^0 obeys 1.5 GeV/c $< p_{T,2} < p_{T,1}$. The inset shows the corresponding $\Delta\phi$ distribution. The right panel shows similar HIJING predictions for the $\Delta\phi$ distribution in d+Au collisions, with and without shadowing.

how back-to-back $\pi^0 - \pi^0$ correlations in p+p and d+Au collisions will provide sensitivity to the gluon density in the Au nucleus down to $x_g \sim 10^{-3}$.[9] If the inclusive particle yield in d+Au is suppressed through shadowing, initial-state energy loss, or other mechanisms that retain the conventional $2 \rightarrow 2$ partonic scattering process, the back-to-back correlation will be unchanged, as illustrated by HIJING with shadowing. In contrast, if gluon saturation is the correct explanation, the back-to-back peak will be strongly modified,[7] in addition to the inclusive yield.

References

1. I. Arsene et al. (BRAHMS Collaboration), Phys. Rev. Lett. **93**, 242303 (2004).
2. D. Kharzeev, Yu.V. Kovchegov, and K. Tuchin, Phys. Lett. B **599**, 23 (2004); A. Dumitru, A. Hayashigaki, and J. Jalilian-Marian, Nucl. Phys. A **765**, 464 (2006).
3. V. Guzey, M. Strikman, and W. Vogelsang, Phys. Lett. B **603**, 173 (2004).
4. J. Adams et al. (STAR Collaboration), nucl-ex/0602011.
5. S.S. Adler et al. (PHENIX Collaboration), Phys. Rev. Lett. **91**, 241803 (2003).
6. C. Bourrely and J. Soffer, Eur. Phys. J. C **36**, 371 (2004).
7. D. Kharzeev, Nucl. Phys. A **715**, 35c (2003); D. Kharzeev, E. Levin, and L. McLerran, Nucl. Phys. A **748**, 627 (2005).
8. L. Frankfurt and M. Strikman, nucl-th/0603049.
9. L.C. Bland et al., Eur. Phys. J. C **43**, 427 (2005).