Results from Fixed-Target Collisions at $\sqrt{s_{NN}}$ = 4.5, 3.5, and 3.0 GeV

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MOTIVATION

The RHIC Beam Energy Scan (BES) 7.7 < $\sqrt{s_{NN}}$ < 39 GeV was proposed to search for the possible critical point and to study the nature of the phase transition between hadronic and partonic matter. Collisions between beam halo nuclei and the aluminum beam pipe allow STAR to study fixed-target Au+Al collisions. The injection and sub-injection energy gold beams (kinetic energies of 8.8, 4.8 and 2.9 AGeV) produce Au+Al collisions at center-of-mass energies of 4.5, 3.5, and 3.0 GeV. Using these fixed-target collisions allows STAR to extend the beam energy scan to lower center of mass energies and higher baryon chemical potentials. Fixed target acceptances for tracking in the TPC are shown. Particle ratios are presented and compared to earlier published results from the AGS, SPS, and RHIC.

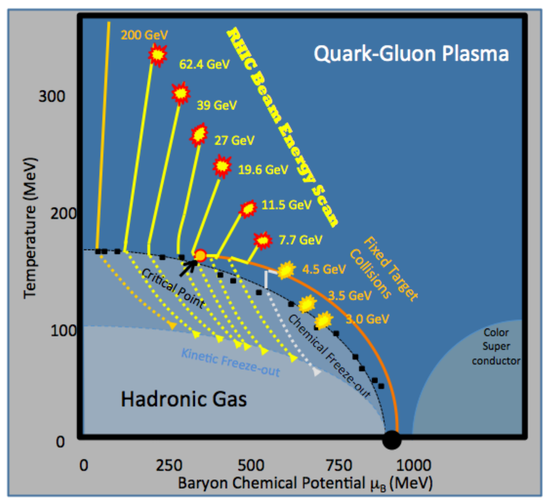


Figure 1. A cartoon of the phase diagram of nuclear matter showing the fixed target points with hypothetical critical point location.

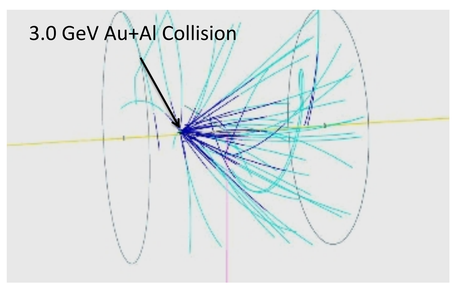


Figure 2. Reconstructed fixed-target collision.

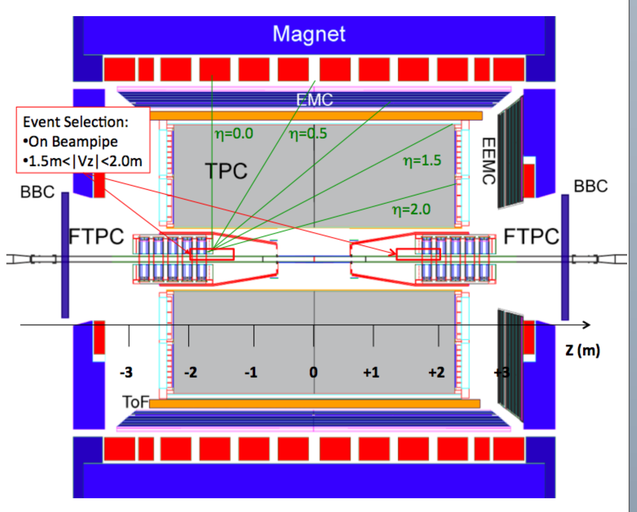


Figure 3. Schematic diagram of STAR showing location selected for fixed-target events.

EVENT SELECTION

Collider Mode Energies (GeV)	7.7	11.5	19.6
Fixed Target $\sqrt{s_{NN}}$ (GeV)	3.0	3.5	4.5
Fixed Target μ_B (MeV)[1]	720	670	585
Fixed Target y_{CM}	1.05	1.25	1.52
Events satisfying fixed target cuts	3.0 M	4.1 M	3.1 M
Au+Al top 10%	78k	114k	101k

[1] J. Cleymans, H. Oeschler, K. Redlich, S. Wheaton, Phys. Rev. C73, 034905 (2006).

Events were selected based on several cuts:

- reconstructed vertex z between 150 and 200 cm (Aluminum portion of beampipe)
- reconstructed vertex r ($v_x^2 + v_y^2$) between 2 and 5 cm
- events headed "into" the detector

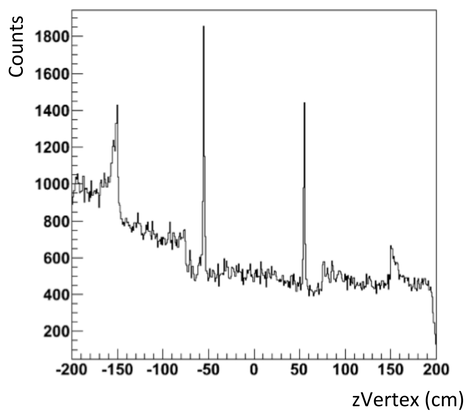


Figure 4. Inclusive z vertex distribution from the 7.7 GeV Au+Au run. Note there are detector support structures at +/- 50 cm and and +/- 150 cm. Beryllium beam pipe resides between +/-70 cm. Aluminum portion is located from 70 to 200 cm.

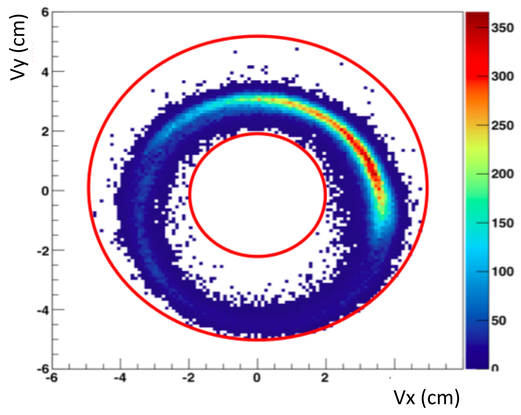


Figure 5. Sample XY vertex distribution for Au+Al 3.5 GeV beam pipe events selected from 11.5 GeV Au+Au run. Events falling between two red circles were selected for fixed-target analysis. Note that the beam pipe is well imaged with these event vertices.

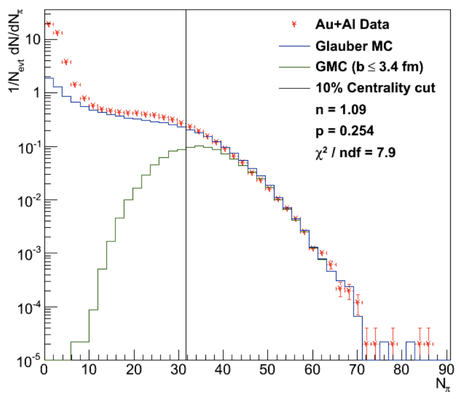
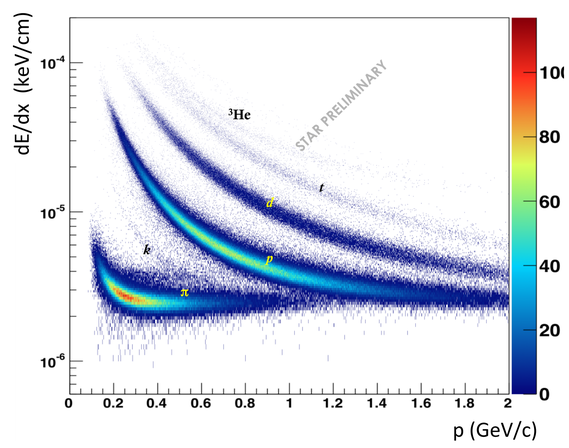


Figure 6. Centrality selection via pion multiplicity ($\pi^+ + \pi^-$). Au+Al 4.5 GeV fixed target pion multiplicity is in red. Glauber model histogram in blue is used to determine the top 10% centrality class. For comparison, the green histogram displays impact parameters ≤ 3.4 fm.

PARTICLE IDENTIFICATION



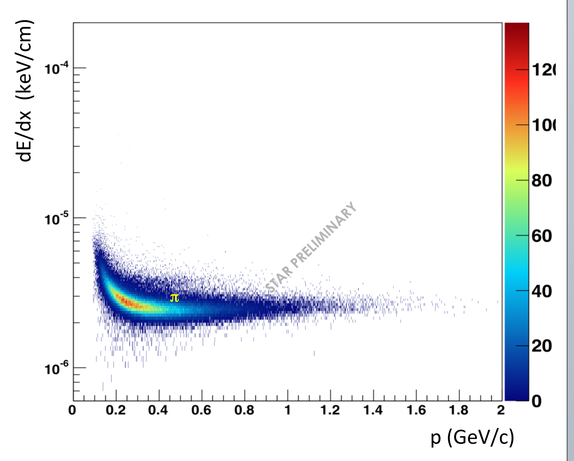


Figure 7 + 8. Particle identification for negative particles (right) and positive particles (left) via ionization in the TPC. 3.0 GeV Au+Al events with 1.5 m < $|V_z|$ < 2.0 m were selected for these figures.

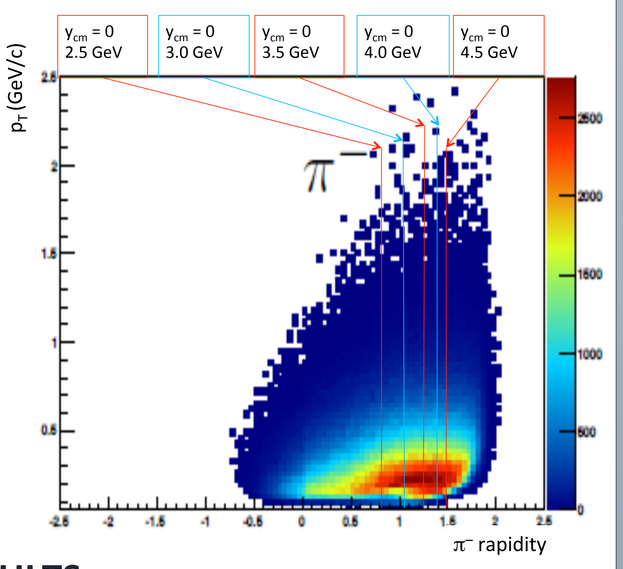


Figure 9. TPC acceptance of negative pions in p_T versus rapidity for fixed-target events. STAR has good acceptance up to y_{lab} = 1.6. This provides acceptance from target rapidity through midrapidity for all gold beams at injection energy or below.

RESULTS

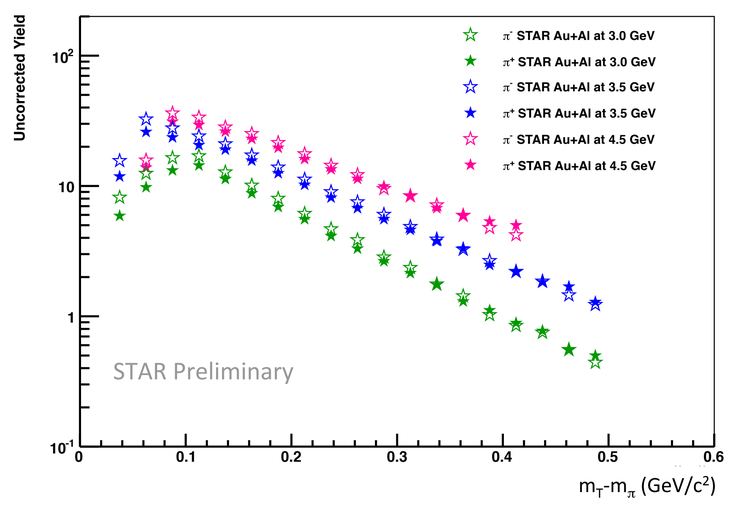


Figure 10. Raw invariant pion yields for Au+Al collisions, top 10% centrality, for $\sqrt{s_{NN}}$ = 3.0, 3.5, 4.5 GeV. Efficiency corrections are not yet available, however, the efficiencies for positive and negative pions should be nearly identical. Analysis to determine the tracking efficiency of STAR in fixed-target mode is underway.

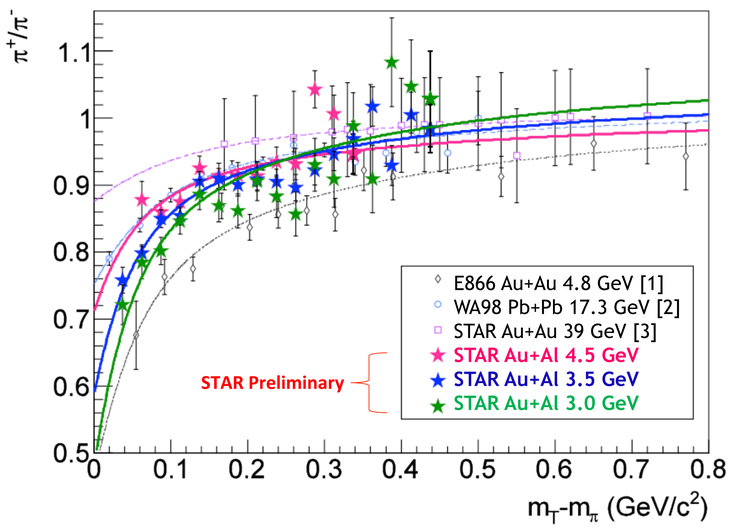


Figure 11. Pion ratios for Au+Al collisions, top 10% centrality, for $\sqrt{s_{NN}}$ = 3.0, 3.5, 4.5 GeV. Comparisons made to AGS, SPS, and RHIC. The curves on the figure correspond to fits assuming Coulomb acceleration from a charged source. However these results will not be final until we have completed studies which include the effects of tracking efficiency, feedback from weak decays, and contributions from secondaries. Fits applied to data come from [4].

[1] L. Ahle *et al.* (E866) Nucl.Phys. **A610,** 139c (1996), and PRC57, R446 (1998).
[2] L. Rosselet *et al.* (WA98) Nucl.Phys. **A698,** 647c (2002).
[3] L. Kumar *et al.* (STAR) J.Phys.G; Nucl.Part.Phys. **38** (2011) 124145.
[4] G. Baym and P. Braun-Munzinger, Nucl. Phys. A610, 286c (1996).

CONCLUSIONS

- We have successfully selected and analyzed Au + Al fixed target events using the STAR detector at RHIC.
- For gold beams at injection energy (collider $\sqrt{s_{NN}}$ = 19.6 GeV) and lower, STAR has good coverage and good particle identification from midrapidity back to target rapidity.
- Uncorrected pion ratios from Au + Al have been studied and compare reasonably to Au + Au data.

OUTLOOK

During the summer 2013 shutdown, an annular gold target will be installed inside the beam pipe at z = -2 m. With a fixed-target trigger configuration, special fixed-target runs at and below injection energy will be taken. Normal collider operations will not be disrupted.

ACKNOWLEDGEMENTS

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