FIXED TARGET OPERATION AT RHIC IN 2019

C. Liu*, I. Blacker, M. Blaskiewicz, D. Bruno, K.A. Brown, K.A. Drees, A.V. Fedotov, W. Fischer, C.J. Gardner, C. Giorgio, X. Gu, T. Hayes, H. Huang, R. Hulsart, D. Kayran, N. Kling, Y. Luo, D. Maffei, B. Martin, G. Marr, A. Marusic, C. Naylor, K. Mernick, R. Michnoff, M. Minty, C. Montag, J. Morris, S. Nemesure, I. Pinayev, S. Polizzo, V. Ranjbar, D. Raparia, G. Robert-Demolaize, T. Roser, J. Sandberg, V. Schoefer, F. Severino, T. Shrey, K. Smith, S. Tepikian, P. Thieberger, A. Zaltsman, K. Zeno, I. Zhang, W. Zhang, Brookhaven National Lab, Upton, NY, USA.

Abstract

RHIC operated in fixed target mode at beam energies 4.59, 7.3, and 31.2 GeV in 2019 as a part of the Beam Energy Scan II program. To scrape beam halo effectively at the fixed target which is 2.05 m away from the center of the STAR detectors, lattice design with relative large beta function at STAR was implemented at the two lower energies. The kickers of the baseband tune (BBQ) measurement system were engaged to dilute the beam transversely to maintain the event rate except for 31.2 GeV/nucleon. In addition, beam orbit control and/or tune chromticity adjustment were used to level the event rate. This paper will review the operational experience of RHIC in fixed target mode at various energies.

INTRODUCTION

Beam Energy Scan (BES) at RHIC [1] was aiming to investigate the first-order phase transition and location of the possible critical point [2–4]. The luminosity drops significantly with decreased center-of-mass (CoM) energy in colliding mode. It is extremely difficult to accumulate enough statistics with colliding beams at CoM energy as low as 3 GeV/nucleon. Therefore, fixed target experiments [5] were proposed as part of BES to extend the energy range. At the same time, fixed target experiments also compliment the physics data taken in colliding mode at the same CoM energy. The operation of fixed target experiments at some beam energies has already been tested or conducted in recent years at RHIC [6, 7].

Figure 1: Picture of the STAR gold fixed target. The target was inserted in the lower part of the 75 mm beam pipe.

The fixed target is located 2.05 m west of the center of STAR detectors. Fig. 1 shows the fixed target, which is 1 mm gold foil with the edge 2 cm away from the center of the beam pipe. The shortest distance from the center of the beam pipe to the edge of the fixed target is identical to the radius of the beryllium pipe.

Only 12 Yellow bunches were injected into equally distributed buckets for the fixed target experiments. The beam were lowered vertically using local orbit bump to scrape beam halo on the target. A variety of measures have been employed to keep a more or less constant rate around 1.6 kHz, which is the upper limit for the rate without increasing significantly the detector dead time. The operation of fixed target experiment at 4.59, 7.3 and 31.2 GeV/nucleon are presented in this report.

4.59 GEV/NUCLEON

The 9 MHz cavities were used at 4.59 GeV/nucleon for the fixed target experiment. This contributed to good lifetime therefore the long store length shown in the lower plot in Fig. 2. A typical store and the event rate at STAR for fixed target experiment at 4.59 GeV/nucleon is shown in Fig. 2.

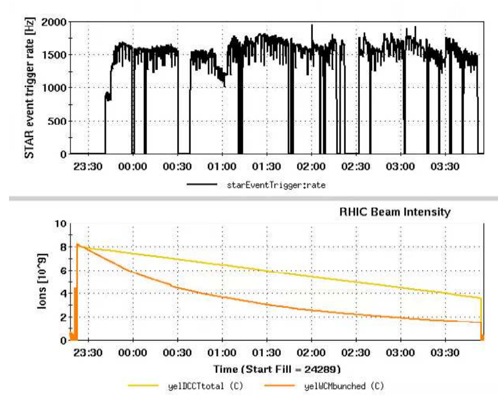

Figure 2: The upper plot shows the fixed target event rate over the time period of a physics store. The lower plot shows the beam intensity evolution during the store, DC beam intensity in light yellow and bunched beam intensity in dark yellow.

The beta function at STAR collision point is 10 m. The rms beam size at the fixed target location is 1.8 mm. At the same time, the beta function/beam size at the final focusing quadrupole is reduced by ~ 40 % with 10 m beta star compared to that with 2 m beta star in colliding mode. Therefore, the background was well under control during the store (the upper plot in Fig. 3). For this particular store shown in Fig. 2, only orbit control (lower plot in Fig. 3) was applied

* cliu1@bnl.gov

to level the event rate at about 1.6 kHz. For another store at 4.59 GeV/nucleon, both orbit control and BBQ kicker were employed to keep the event rate constant as shown in the lower plot in Fig. 4.

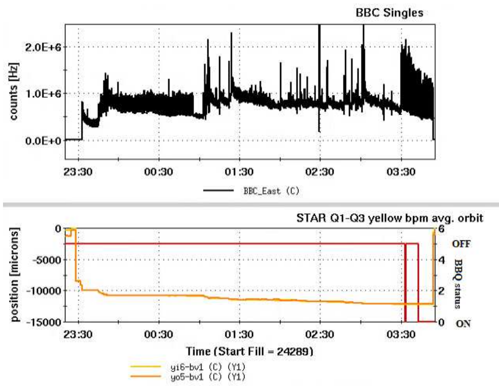

Figure 3: The upper plot shows the BBC singles rate (equivalent to background) over the period of a physics store. The lower plot shows the orbit variation for controlling the event rate. The BBQ tune meter kicker was only turned on briefly to maintain the rate in the end.

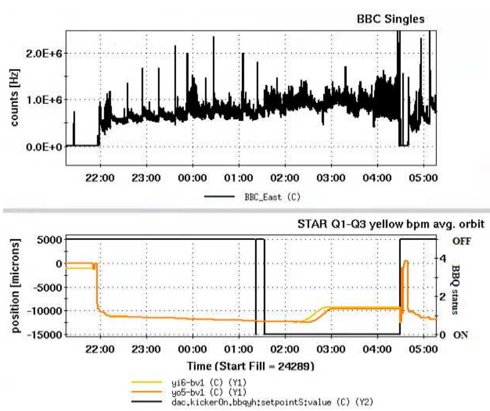

Figure 4: The upper plot shows the BBC singles rate (equivalent to background) over the period of a physics store. The lower plot shows the orbit variation and BBQ status for controlling the event rate. The BBQ tune meter kicker was turned on during the later half of the store to maintain the rate.

7.3 GEV/NUCLEON

The 28 MHz cavities were used at 7.3 GeV/nucleon for the fixed target experiment. The beta function at STAR collision point is 10 m. A typical store and the event rate at STAR for fixed target experiment at 7.3 GeV/nucleon is shown in Fig. 5. For most of the stores, the event rate was kept more or less constant by applying orbit control. The steps of the background seen in Fig. 6 were associated with the vertical orbit adjustments.

The working point also played a significant role during fixed target experiment at 7.3 GeV/nucleon. The beam lifetime was worse with working point (0.215, 0.240) compared to that with (0.235, 0.229) as shown in Fig. 7. With worse lifetime, collimator was engaged to control the beam halo so the event rate was at an acceptable level (Fig. 8).

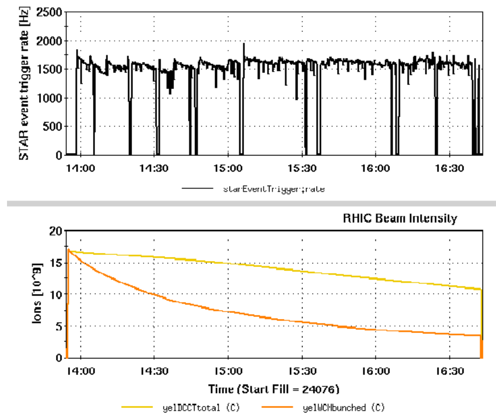

Figure 5: The upper plot shows the fixed target event rate over the time period of a physics store. The lower plot shows the beam intensity evolution during the store, DC beam intensity in light yellow and bunched beam intensity in dark yellow.

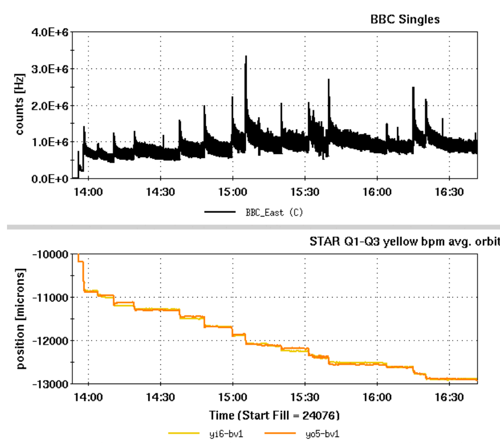

Figure 6: The upper plot shows the BBC singles rate (equivalent to background) over the period of a physics store. The lower plot shows the orbit variation for controlling the event rate. The BBQ tune meter kicker was not used to maintain the rate.

31.2 GEV/NUCLEON

The beam lifetime at 31.2 GeV/nucleon was significantly better than those at the other two energies. The goal of 50 M events was achieved within one physics store (Fig. 9).

The beta star was 5 m for fixed target experiment at 31.2 GeV/nucleon. The rms beam size at the target is only about 0.5 mm. Therefore the event rate was extremely sensitive to the beam position once beam is scraping on the target. It was found that the BBQ kickers were not strong enough to blow up beam emittance in a reasonable amount of time.

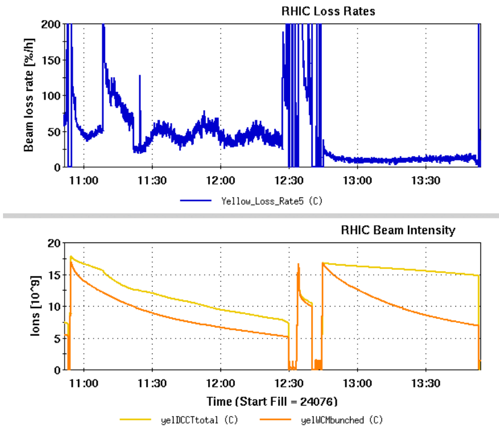

Figure 7: The upper plot shows the beam loss rate for two stores: high beam loss for the first one with working point at (0.215, 0.240), low beam loss rate for the second one with working points at (0.235, 0.229). The lower plot shows the beam intensity for the two stores.

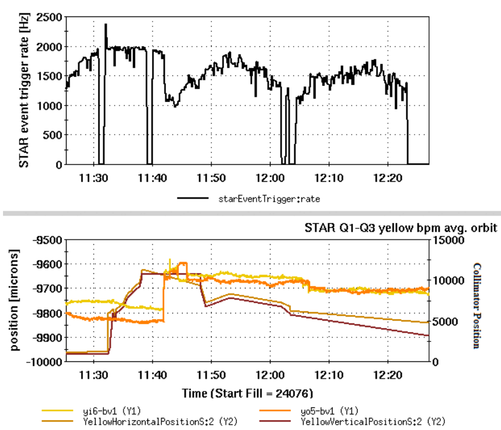

Figure 8: The upper plot shows the fixed target event rate over the time period of a physics store. The lower plot shows the orbit variation and collimator position for controlling the event rate.

A desirable event rate was only achieved when the horizontal emittance was diluted by instability with a close to zero chromaticity. The emittance evolution during the fixed target operation at 31.2 GeV/nucleon is shown in the upper plot in Fig. 10.

SUMMARY

This report summarized the operational experience for fixed target experiments at 4.59, 7.3 and 31.2 GeV/nucleon. Various measures have been taken to level the fixed target event rate and background. These measures include large beta function at the collision point, blowing up transverse emittance with BBQ kickers, orbit control for event rate leveling, tune and chromaticity adjustment for controlling the event rate. These measures will be applied for the future fixed target experiments at relative low and high energies.

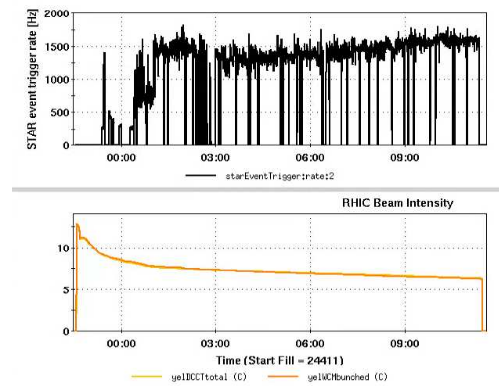

Figure 9: The upper plot shows the fixed target event rate over the time period of a physics store. The lower plot shows the beam intensity evolution during the store, DC beam intensity in light yellow and bunched beam intensity in dark yellow.

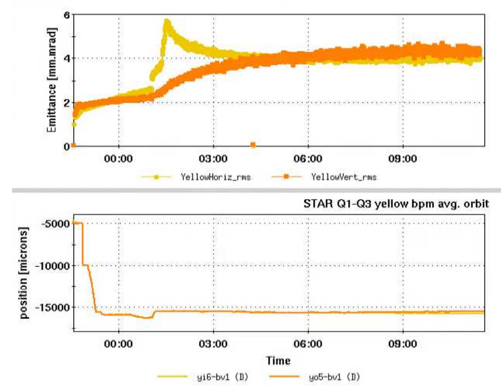

Figure 10: The upper plot shows the emittance evolution during the store for fixed target experiment at 31.2 GeV/nucleon. The lower plot shows the orbit variation for controlling the event rate during the store.

REFERENCES

[1] C. Liu et al. Accelerator performance during the Beam Energy Scan II at RHIC in 2019. In these proceedings

[2] Can we discover QCD critical point at RHIC. RIKEN BNL Research Center Report No. BNL-75692-2006.

[3] G. Stephans. critRHIC: the RHIC low energy program. *J. Phys. G: Nuclear and Particle Physics*, 32(12):S447, 2006.

[4] M. Stephanov, K. Rajagopal, and E. Shuryak. Signatures of the tricritical point in QCD. *Phys. Rev. Let.*, 81(22):4816, 1998.

[5] D. Cebra. Studying the Phase Diagram of QCD Matter at RHIC Extreme QCD MeetingStony Brook University, New York, 2014

[6] C. Montag. First operational experience with an internal halo target at RHIC in *Proc. of IPAC2016, Busan, Korea* 2016.

[7] P. Adams, N. Kling, G. Marr, C. Liu. Use of the Base-band tune meter kickers during the FY18 STAR fixed target run at 3.85 GeV/U. *In these proceedings*.