ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-MOPC07

RHIC Au-Au OPERATION AT 100 GeV IN RUN 23*

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Abstract

The Relativistic Heavy Ion Collider (RHIC) Run 23 program consisted of collisions of 100 GeV gold beams at two collision points for the first time since 2016; the sPHENIX collaboration used the beam to commission their new detector systems while the STAR detector took physics data. Completion of sPHENIX construction pushed the start of the run to May, forcing the collider complex to operate over the summer months and incurring lower than normal availability due to heat and power dip related problems. Issues with dynamic pressure rise during acceleration through transition resulted in a slower ramp up of intensity compared to prior years. Finally, a failure of a warm-to-cold current lead interface in the valve box for the Main Magnet power supply forced the run to end. This paper will discuss the progress made by each experiment and the failure mode, repair and mitigation efforts in preparation for Run 24.

INTRODUCTION

The RHIC program in Run 23 called for 20 weeks of colliding beam operations with 100 GeV Au beams at two interaction points (IP), IP 6 and 8. IP 6 contains the STAR detector; the run plans called for an unspecified number of weeks taking physics data at lower rates. IP 8 contains the new sPHENIX experiment with plans to commission all of the detector sub-systems.

RUN ACHIEVEMENTS

Despite lower than average availability due to running during the summer (74% vs 10 year average of 86%) and the shortened run due to a valve box failure, the sPHENIX project was able to complete the majority of their detector systems checkout, with 4 items in their commissioning plan fully completed and the remaining 2 partially completed.

The STAR experiment collected 72% of their planned luminosity for the minimum-bias run.

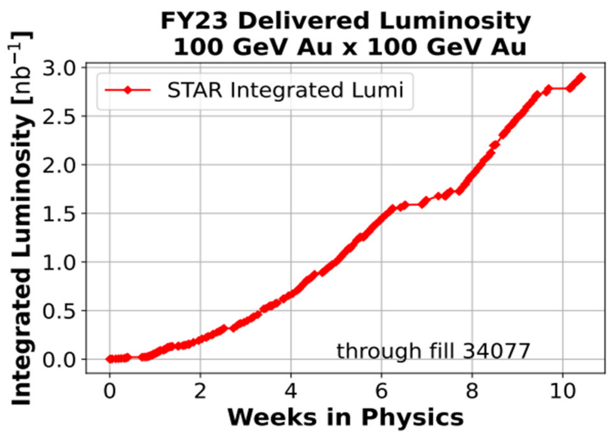

Figure 1: STAR luminosity plot

STAR BACKGROUNDS

Shortly after collisions were established STAR reported an unusual asymmetry in their experimental backgrounds. Several beam experiments were carried out in an attempt to understand this. Ultimately a tracking simulation indicated that Au^{78} generated by bound-free pair production in collisions in IP8 was responsible [1]. In the direction of the blue beam these particles would circulate for 3 turns before being lost in the high-beta triplet, creating particle showers in the detector.

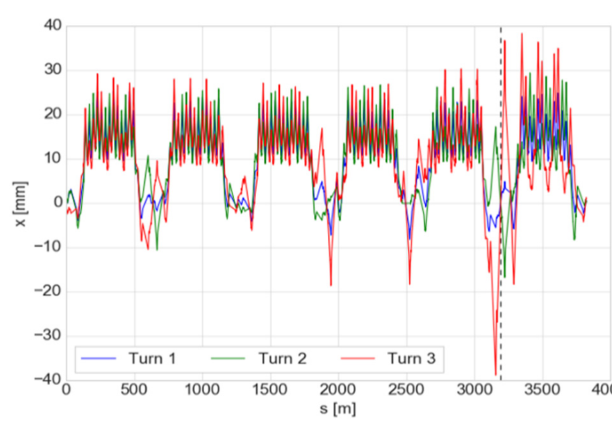

Figure 2: Au^{78} orbit tracking. After 3 turns the beam ends up in the triplet beampipe outside of IR6.

This suspicion was confirmed when a series of increasing amplitude orbit bumps were introduced further upstream, crashing the particles away from the detector.

* Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy.
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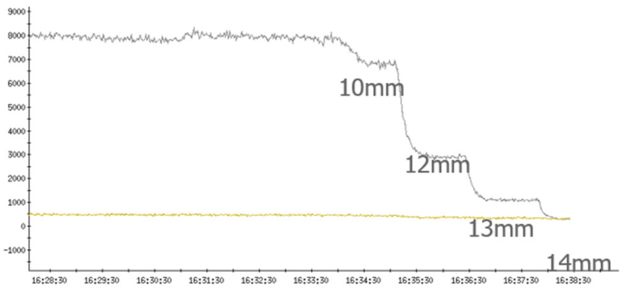

Figure 3: STAR blue (grey trace) backgrounds reduced to those of yellow (yellow trace) as an arc bump was added to crash the Au^{78} beam.

Unfortunately, there was no way to deposit this beam into one of the collimators or masks in RHIC, so work began to modify the optics to provide a distributed loss of this beam. The run ended before this work was completed; it will need to be implemented in Run 24.

TRANSITION RESONANCE

During the intensity ramp up phase of the run an unexplained excitation peak was seen in the broadband tune (BBQ) system in the yellow vertical plane approximately .1 unit away from the beam tune. This very quickly became a limiting factor in the beam intensity for ramping, causing large emittance growth. This growth could initially be compensated for by the stochastic cooling system of RHIC at store, but eventually made the beam large enough that the stochastic tanks could not close due to losses when the beam reached flattop.

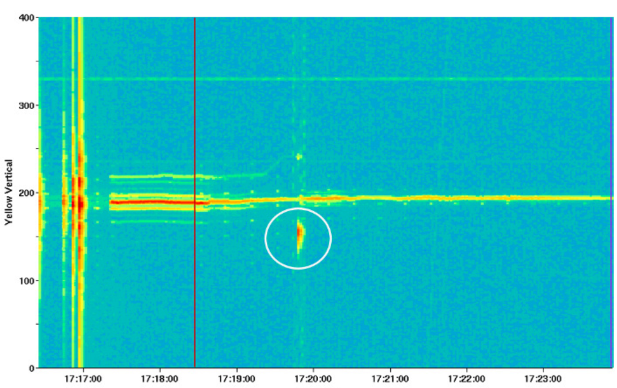

Figure 4: Unexplained BBQ excitation (circled) seen in the yellow vertical pickup away from the beam tune (yellow horizontal line) at transition crossing.

Up to this point it had been several years since the machine had run at full energy with high intensity; sources of secondary emission yield were investigated but nothing stood out. Ultimately this intensity limit was avoided by moving the yellow vertical tune away from the peak seen in the signal.

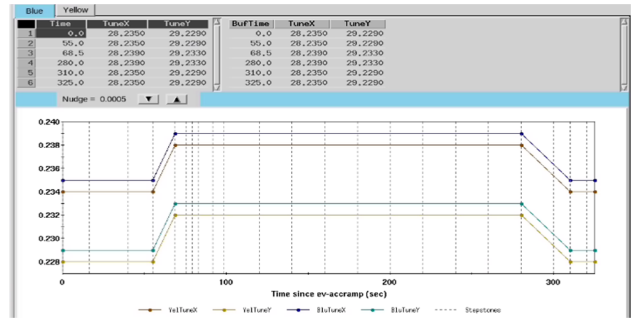

Figure 5: Target tunes for the ramp. To avoid the resonance a tune bridge was added to raise the vertical tune at transition crossing.

VALVE BOX FAILURE

Seven weeks before the scheduled end of the run a warm-to-cold wiring connection failed inside the blue ring valve box in the sector 4 service building. This was a run ending event, requiring slowly warming the area up before any mechanical inspection could begin.

After months of analysis several issues were discovered in the design and fabrication of the failed connection and associated structures [2].

A valve box is a 10m x 3m cylinder with most of the volume filled with insulation and vacuum. Within each valve box are 2 ‘lead pots’ where liquid helium and superconducting wiring from the ring enters the bottom of the pot and transitions into copper bars soldered into cups on a ceramic break at the top of the pot.

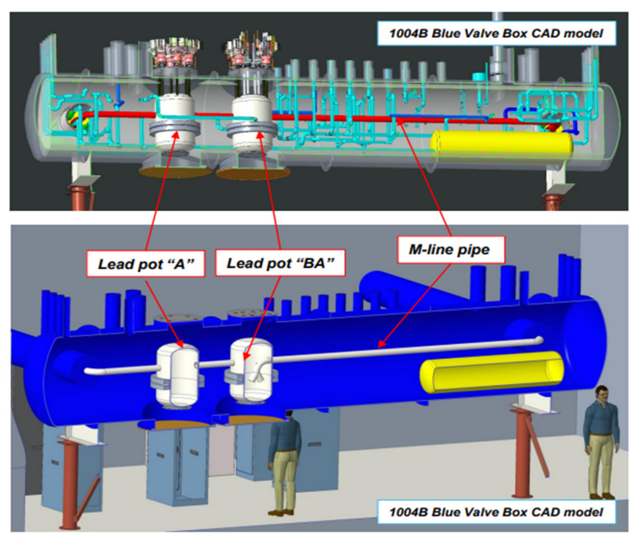

Figure 6: Valve box cutaway

Each lead pot contains several groups of connections referred to as ‘terminal boards. The failure occurred in terminal board D (TBD) that contained 12 connections each rated up to 150 amps. An arc developed across two of the gas-cooled leads which then expanded to engulf 10 of the 12 pins, destroying them and rupturing both the TBD feed-through wall and the bellows that separate the insulating vacuum from atmosphere.

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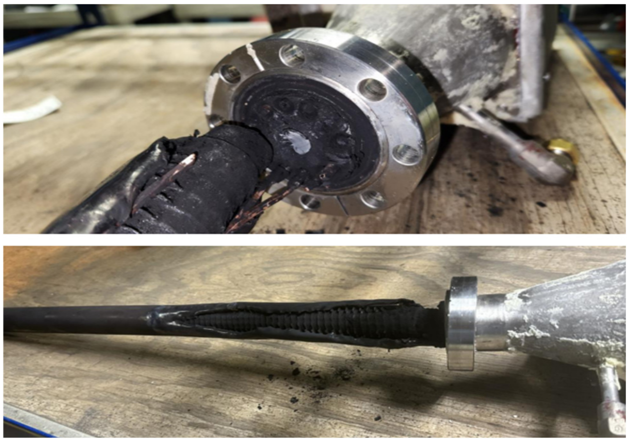

Figure 7: Site of arc on 10 of 12 pins in TBD

Most of the connections on the terminal board involved shunt supplies for the main quadrupole circuit, but one of them was an unused (but connected) circuit for the main dipole. When the arc occurred the dipole circuit became involved, firing the heaters for the 12 DX magnets around the ring. The combination of the arc in the valve box connection along with the warm gas flowing from the heaters firing led to a failure of the wiring connections on the upstream and downstream ends of the nearest DX magnet in the tunnel.

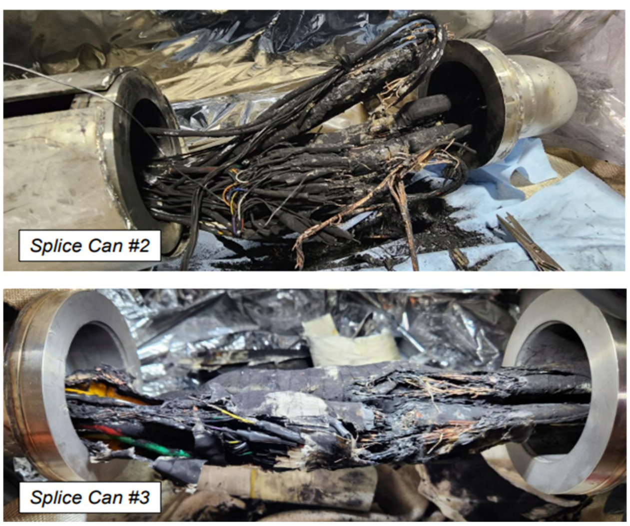

Figure 8: Wiring failure of 4 o'clock DX magnet

The postmortem investigation found several issues with the design and fabrication of the terminal board, mainly from dissecting the two pins that were not involved in the failure. The solder connections at the failure were done in blind cups with no weephole, causing very incomplete solder joints. There was no mechanical connection of the copper pins to the cups, the solder was used for that as well as electrical connection. The copper pins are cooled by liquid helium flashing to gas and flowing up around the pins via a helix of plastic; the plastic was an interference fit with the pins, not allowing for any level of expansion. Several pieces of the helix fell out of the assembly when the insulation was removed. The primary culprit leading to the failure is the control mechanism for the valve that determines the gas flow over the pins.

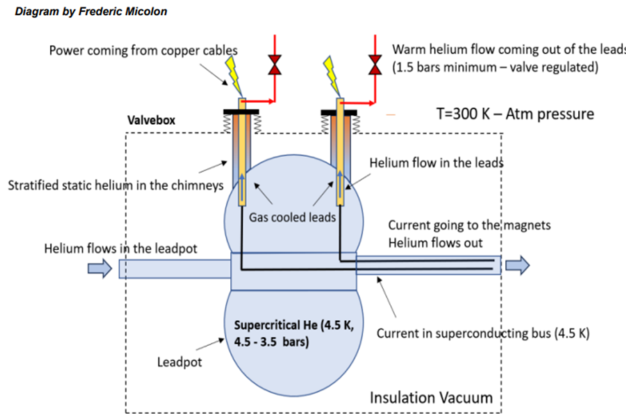

Figure 9: Helium gas flow for terminal board cooling controlled by red valves at the top of the diagram.

The flow control was set up in a very coarse way when RHIC was commissioned and wasn't specifically tuned for the currents involved in each terminal board when ramping. Analysis of logged voltages for each lead was used to calculate temperature in the leads and some temperature swings were seen to be over 200 degrees on every ramp.

ACTIONS FOR UPCOMING RUNS

The 4 o'clock DX magnet was replaced with a spare since the time needed to check for damage within the original magnet would exceed the shutdown time between runs. A spare terminal board was installed into the failed location and the ruptured bellows were replaced.

Control of the gas valves for each terminal board were upgraded and a new algorithm will be used to tune up each valve throughout the ring based on the currents within that specific terminal board during ramping [3]. Time will be added to the startup period in Run 24 to check out and commission both the new DX magnet and the new gas flow calculations.

Optics modifications to address the Au^{78} will be used in the lattice for gold operations scheduled for late in Run 24.

When the valve box failure occurred the cryogenic plant was shut down and the helium inventory was recovered. This has allowed the RHIC program to transfer 6 weeks of 100 GeV Au operation from Run23 to Run24.

REFERENCES

[1] V Schoefer *et al.*, private communication, May 2023

[2] BNL Tech Note Repository. `https://technotes.bnl.gov/PDF?publicationId=225547`

[3] F. Micolon *et al.*, "Solder joint cryogenic fatigue of the RHIC 12x150A current leads and mitigation for future operation", presented at the IPAC'24, Nashville, TN, USA, May 2024, paper TUPR56, this conference.