RHIC Beam Energy Scan operation with electron cooling in 2020

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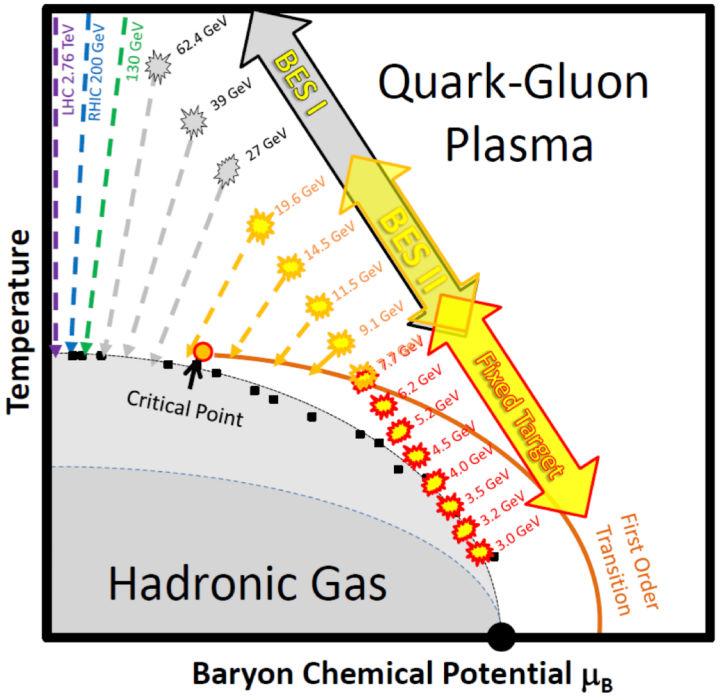
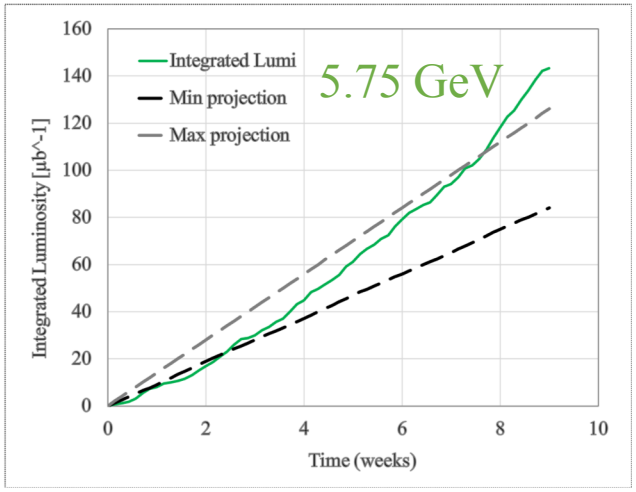
Beam Energy Scan at RHIC

- To explore the first-order phase transition and determine the location of a possible critical point.
- Method: scanning the phase diagram with variable beam energy from 3.85 to 9.8 GeV.
- BES-II requires a 4-fold improvement in luminosity compared to BES-I.

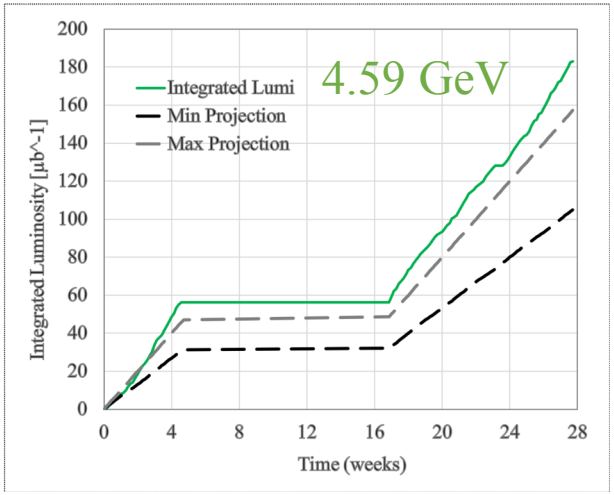


Can we discover QCD critical point at RHIC. RIKEN BNL Research Center Report No. BNL-75692-2006.

Goals achieved in 2020



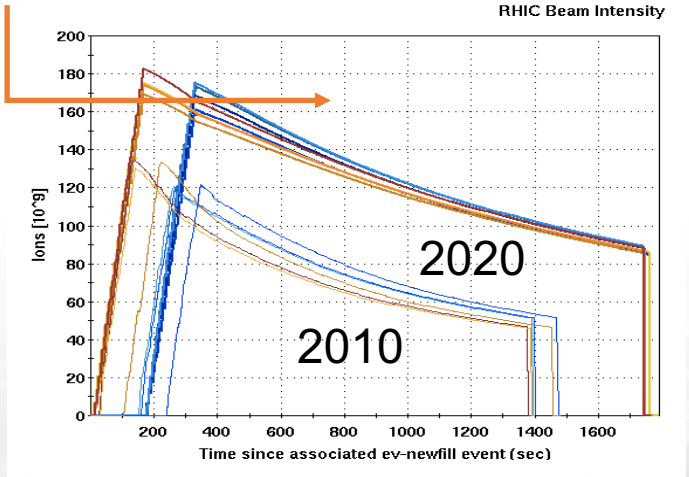
The integrated luminosity and the projections at 5.75 GeV in the 2020 RHIC operation.



The integrated luminosity and the projections at 4.59 GeV in the 2020 RHIC operation. The flat portion was due to the pause of operation due to COVID-19.

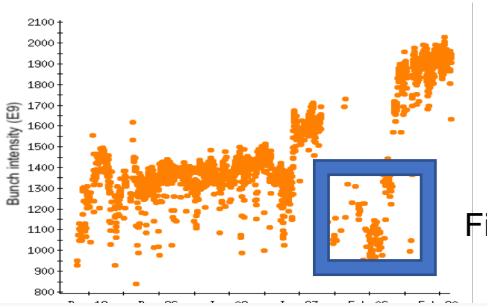
Lumi a factor of 4.7 compared to BES-I

Factor of 6.4 compared to BES-I



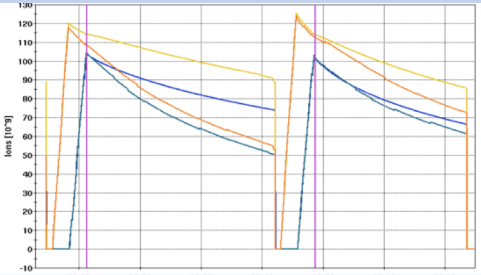
Contributions to luminosity improvement at 5.75 GeV

- Bunch intensity improvement
  - High intensity Tandem beam, short fill time.
  - Double RF systems for large long. Acceptance and better bunched beam lifetime.
  - Raise intensity limit in AGS from 8 to 9.8E9 per cycle.
- Exploration of working points for beam with large space charge tune shift
  - With high beam current, the space charge tune shift was close to 0.1.
  - Raise tunes from 0.09 to 0.12 and implement different tunes for injection and store (lower tunes) to avoid emittance dilution.



Fixed target mode

The average bunch intensity in RHIC at 5.75 GeV over the course of operation in 2020.



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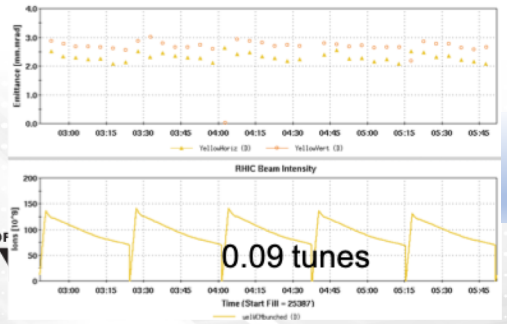
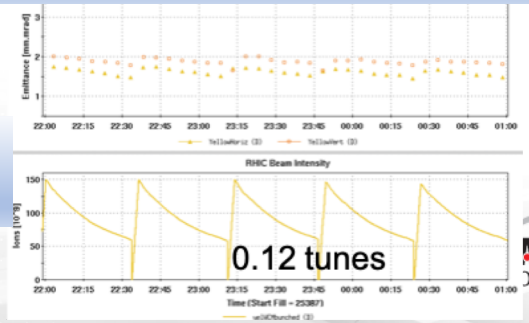
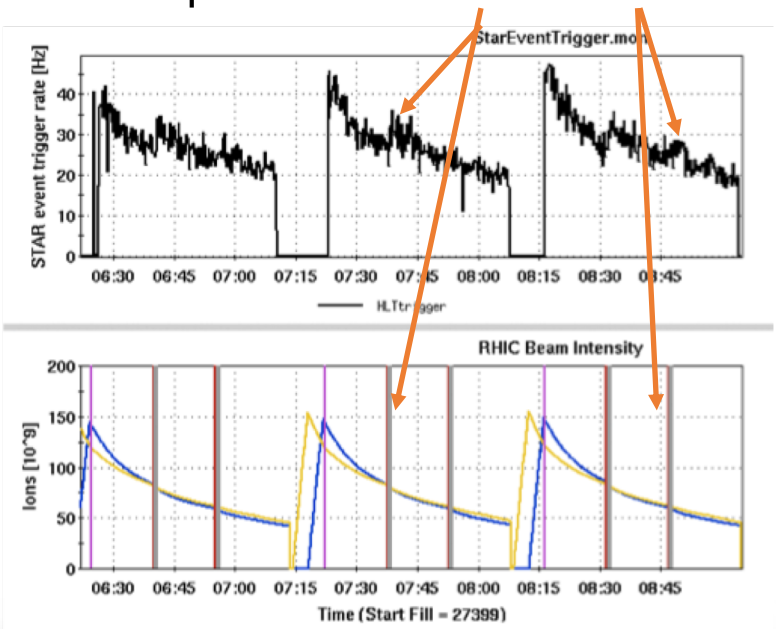


Raise up tune to avoid emittance dilution

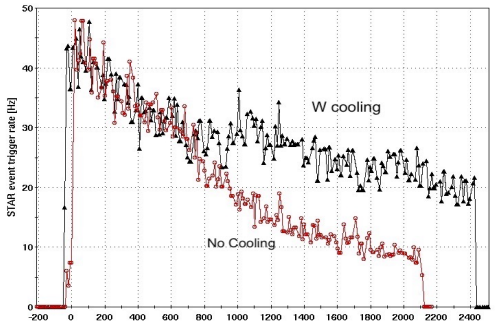


Operation at 4.59 GeV with cooling

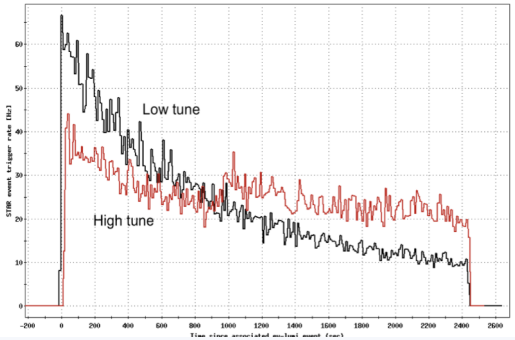
- World's first application of electron cooling at 4.59 GeV with colliding beams.
- With cooled transverse emittance, beta function at the IP were squeezed from 4 m to 3.5 m then to 3 m.



The experimental trigger rate in the upper plot, and the beam intensity in the lower plot for three stores at 4.59 GeV.



The experimental trigger rates for the case with cooling and without cooling, the store length was 40 and 30minutes respectively.

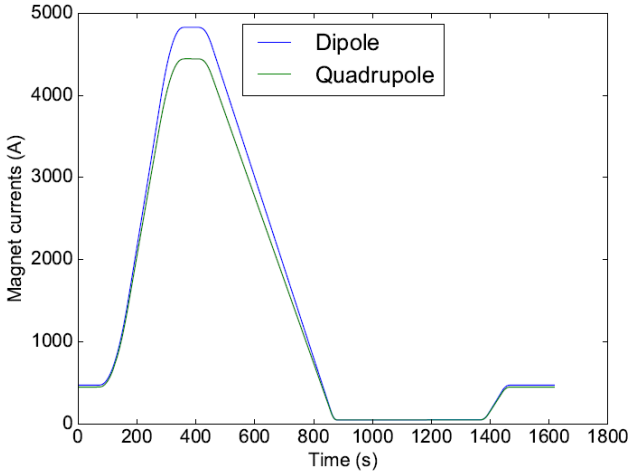


The experimental trigger rates for two stores onewith high tune (0.235) and one with low tune (0.12). At high tune, the cooling efficiency was optimal, however at low tune the cooling and heating all together did not help the experimental rates.

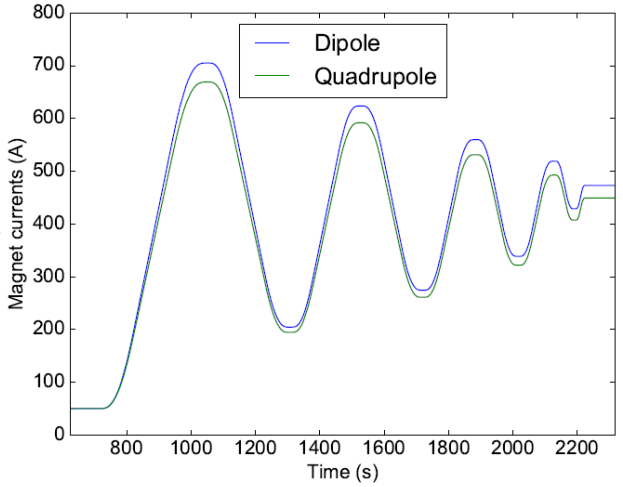
A.V. Fedotov et al., Operational electron cooling in the Relativistic Heavy Ion Collider. in these proceedings.

Design of demagnetization cycle for RHIC

C. Liu, D. Bruno, A. Marusic, M. Minty, P. Thieberger, X. Wang, Phys. Rev. Accel. Beams 22, 111003 (2019).



Regular cycle



Demagnetization cycle

These cycles reduce considerably the sextupole component contributed by the persistent current in the superconducting dipoles and suppress significantly the decay of persistent current thus the decay of beam parameters (orbit, tune and chromaticity). As a result, the beam lifetime in RHIC was improved and quick switching between different operating modes/energies were made possible.

Summary

- The operation for the BES-II program with 5.75 and 4.59 GeV/n Gold beams in 2020 both achieved the physics goals with more than 4-fold higher average luminosity of those in BES-I, the former without cooling and the latter with LEReC cooling operational.
- The major contributions to the luminosity improvement at 5.75 GeV/n were the improvement of lifetime in RHIC to accept and maintain higher bunch intensity from the injectors, and the intensity improvement in the injectors.
- At 4.59 GeV, LEReC electron cooling was operational for the first time and made major contribution to luminosity improvement. In addition, the intensity and lifetime improvement in the injectors and RHIC contributed to the luminosity improvement.