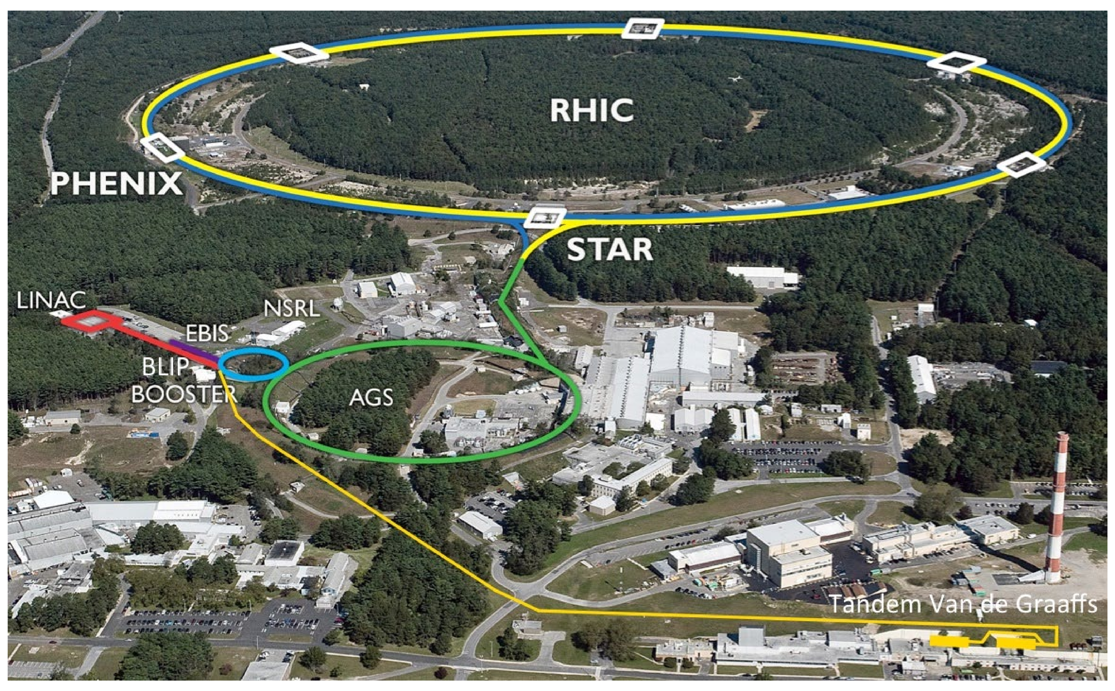

Introduction

With over 2 decades of operations at the RHIC, the generally improving trends in availability and reliability do include a number of running periods with anomalies; it is difficult to analyze coarse statistics in fine detail. Early trends can be attributed to improvements in general areas such as system upgrades or operational efficiency; later years involve ever greater concern for aging systems. Recent years are additionally complicated. This presentation looks at overall trends with focus on recent issues as we continue RHIC runs while planning reliability for the EIC.

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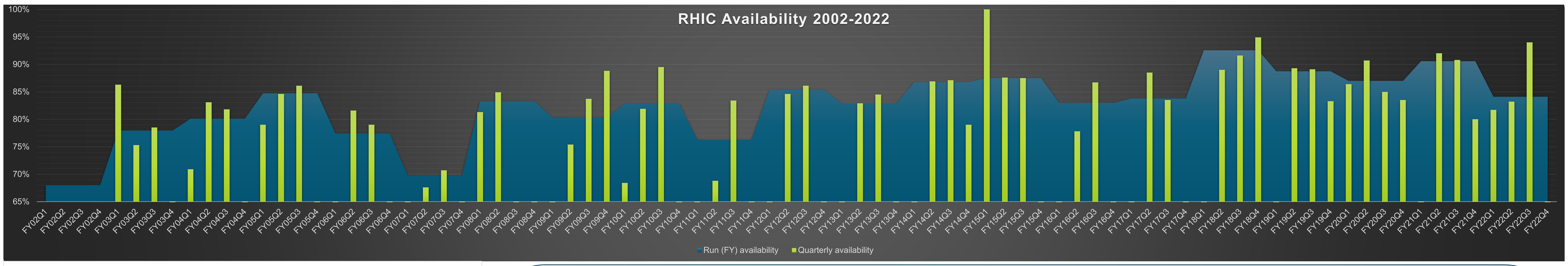
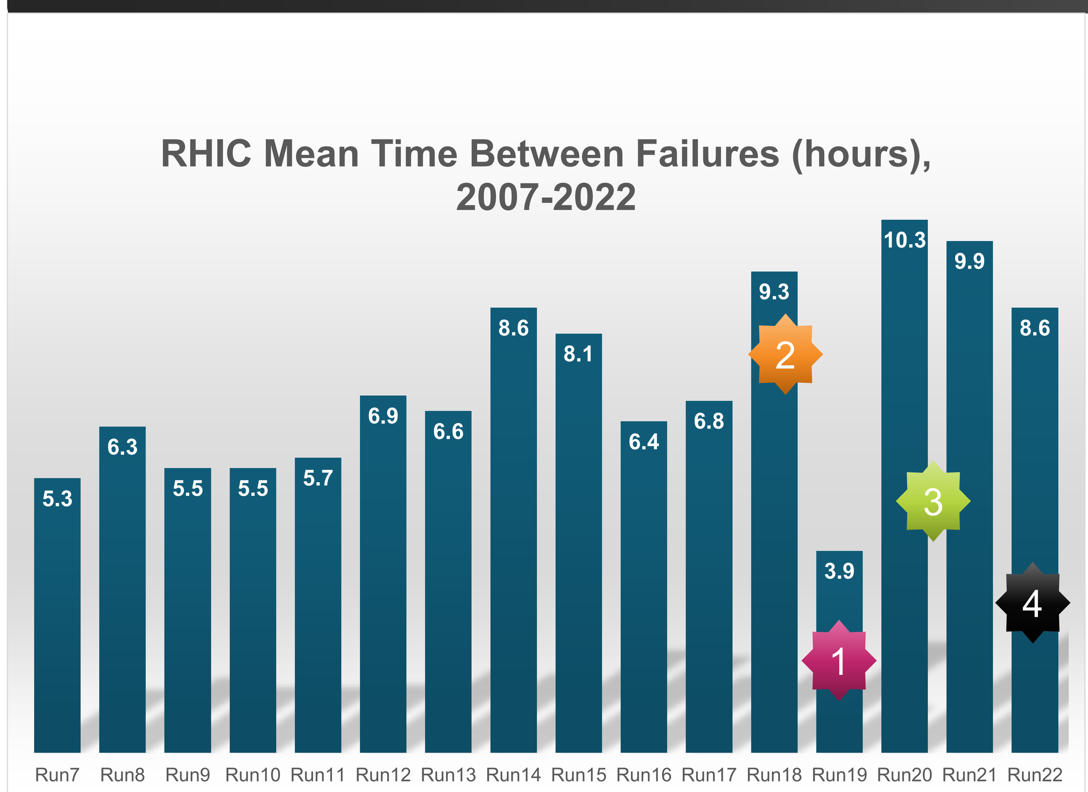
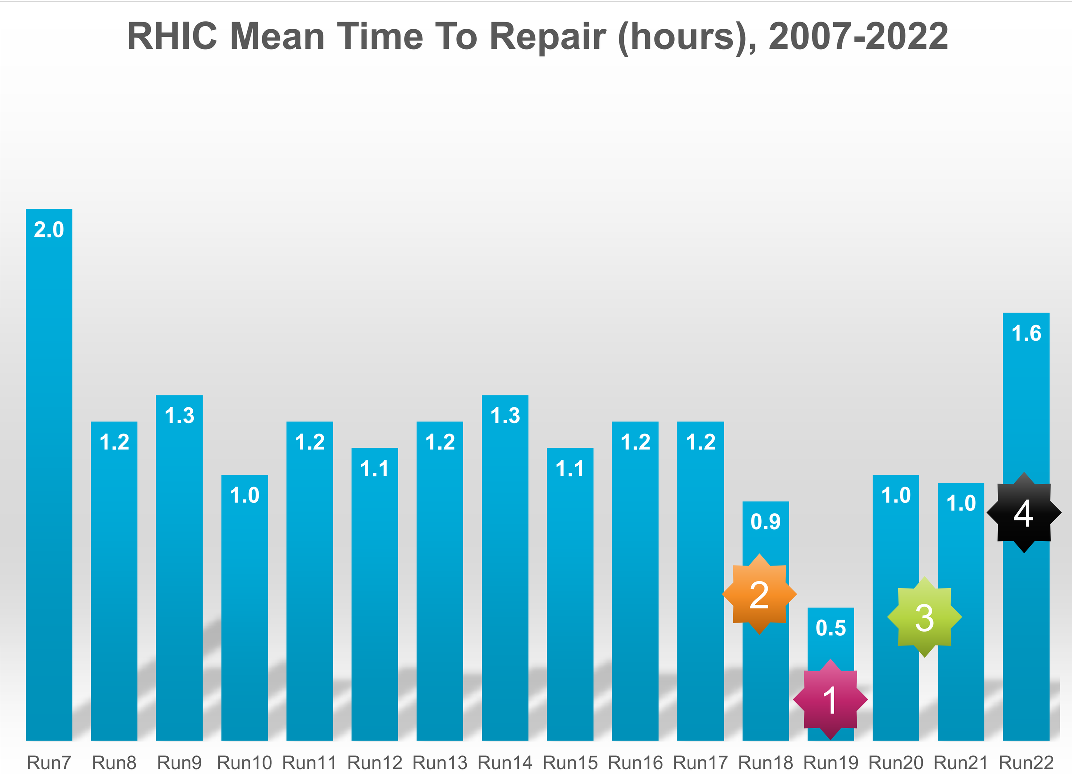
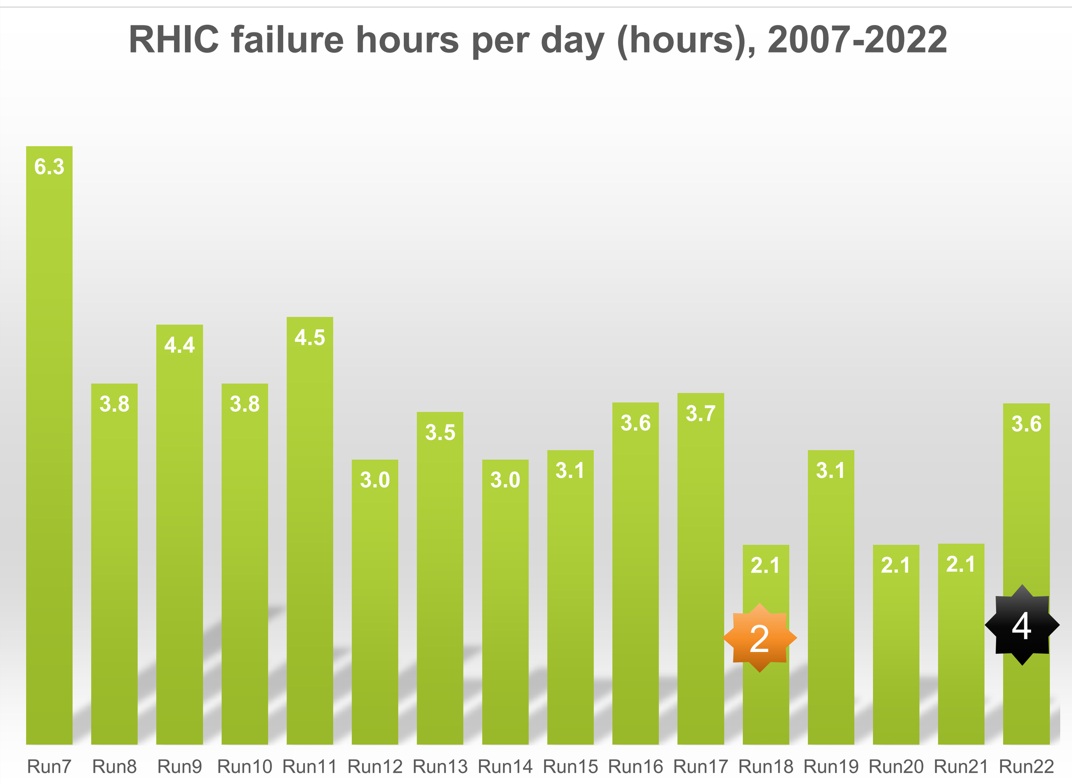
ACCELERATOR RELIABILITY WORKSHOP ARW 2022

Historical Evolution of RHIC Availability









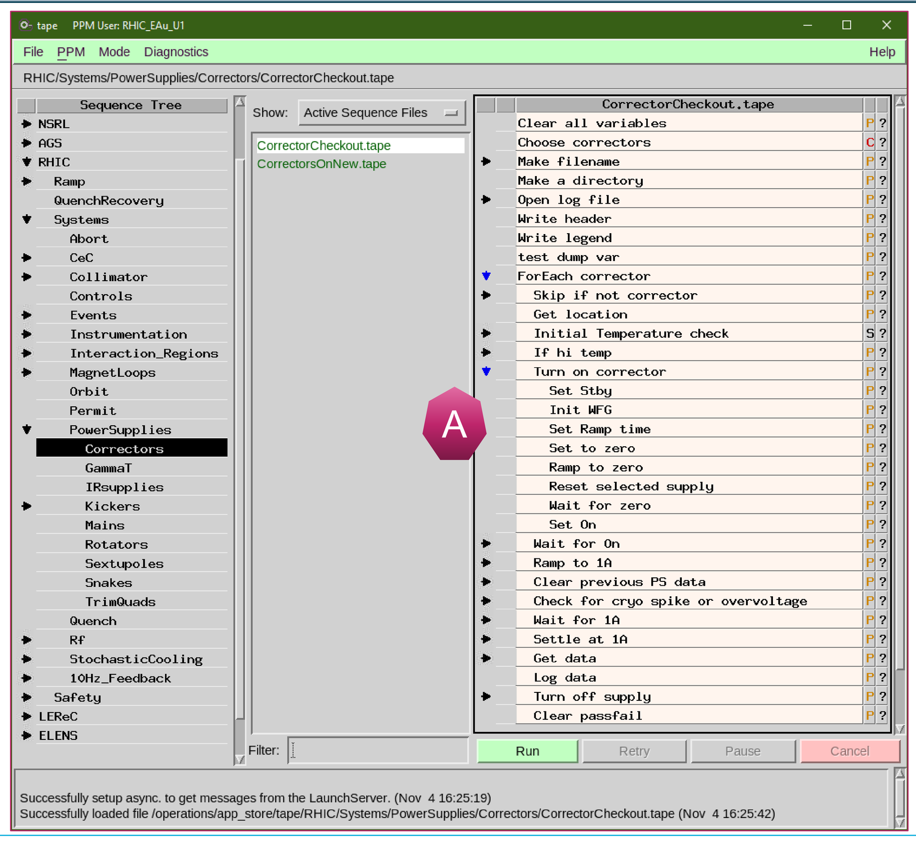
Overall Trends, Recent Impressions

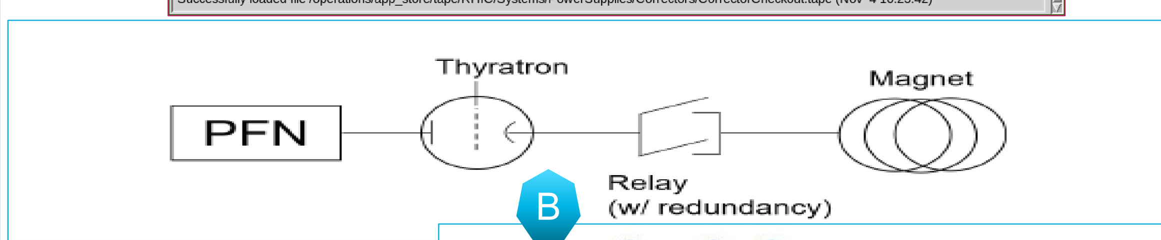
- In terms of availability, there is a general trend of improvement over decades (above). Anomalous years such as 2007 & 2011 tend to have a host of unrelated minor and major failure; some of those are examined in depth to avoid future incidents. For the most part, availability tends to improve over the course of a given RHIC Run.
- The FY2019, '20 and '21 Runs for RHIC mainly operated at low energy. The first year with Low Energy RHIC electron Cooling (LEReC) in full operation contributed anomalously low MTBF, yet also short MTTR (1).
- Our best availability year, in FY2018, came in part with some low energy running, but mostly due to infrequent cycling of RHIC – stored beam was useful up to 3x longer than typical ~6-8 hours. MTBF, MTTR, and average failure hours were lowest for any high energy run (2).
- Subsequent low energy running showed best MTBF and high availability; however, the advent of teleworking for the entire workforce resulted in higher MTTR than expected (3). Failure response from system experts took longer, even during daytime work hours.
- Compared to previous 2 years, FY2022 Run returned to first high energy, polarized proton operation since 2017. Despite acceptable MTBF rates, low availability reflected the historical difficulties with high energy, compounded with increased daily telework and some significant failures that resulted in high MTTR (4).

Lessons Learned, Remediated

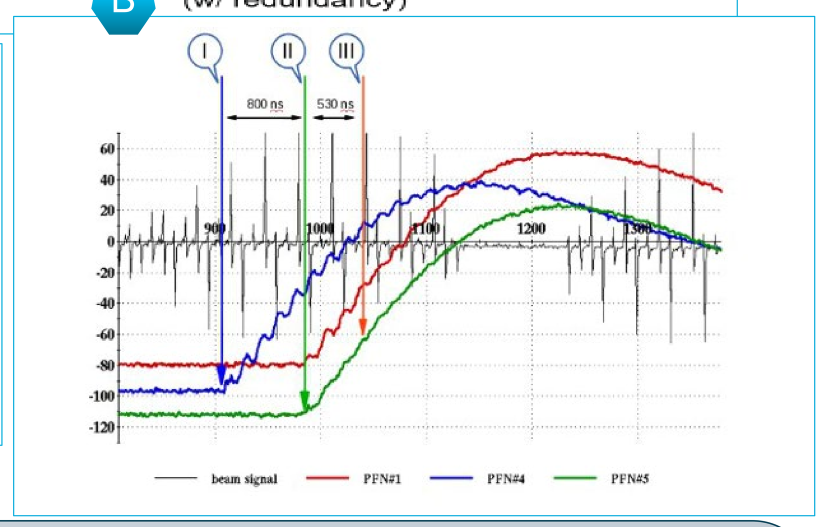
Continuous improvement initiatives contribute to efficient operations over the decades at RHIC. Examples include:

- Scripting common tasks in a readily editable interface reduced manual diagnostics and workload. The Tool for Automated Procedure Execution (TAPE) was an invaluable application upgrade beyond original command line shell scripts and sequencing GUIs, and is still used to organize a myriad of complicated tasks for Operators, such as:
  - Automating the process to turn on and evaluate over 1000 RHIC power supplies. This saves over 14 person-days of work each year, at the beginning of each run (A)
  - Coordinating complicated resets of superconducting magnet power supplies and quench protection systems
  - Orchestrating beam acceleration ramps from injection to high energy, including all tasks to initiate collisions for experiments with optimized luminosity and background rates.
- Beam interruptions and other events trigger scripts, to diagnose events and report results automatically in electronic logbooks.
- Beam losses from an abort kicker module's unsynchronized and spontaneous "prefire" events could induce magnet quenches, or damage to experiment detector systems. Mechanical relay switches were added to the abort system (B), along with improved diagnostics to pre-empt beam loss.
- Bench testing of failed power supplies often revealed trends that were methodically remediated in subsequent maintenance periods.





Schematic of the Abort Kicker triggering line with mechanical relays in series with the Pulse Forming Network and the Thyratron (above) prevents kicker modules from firing asynchronously (below).
M. Valette et al., https://doi.org/10.18429/JACoW-IPAC2022-THPOST048

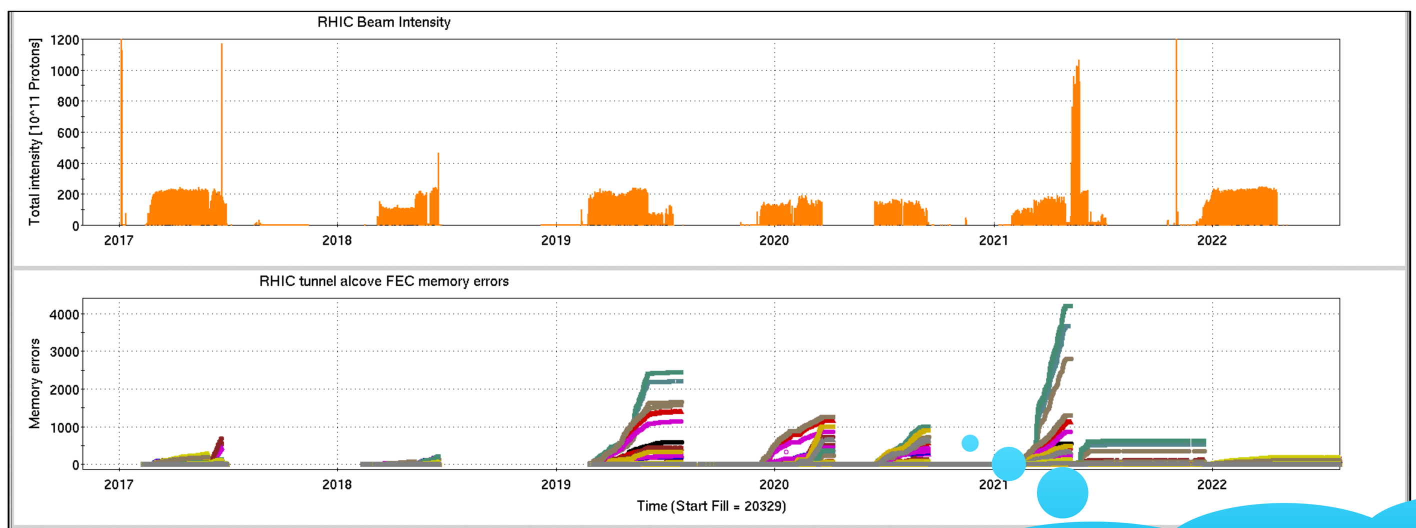


Future Considerations

Given accumulated experience, certain design considerations are given additional weight as we plan ahead for the EIC:

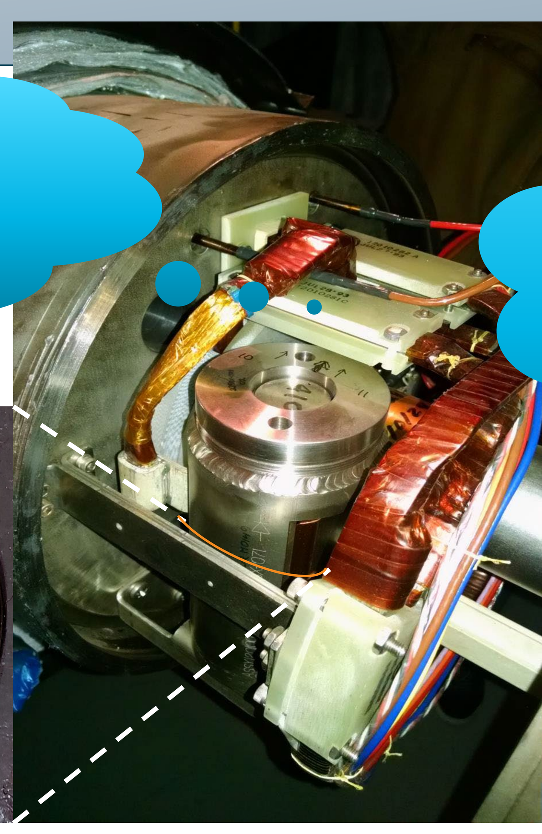
- Equipment in alcoves, especially network devices and CPU memory, are subject to radiation upset. Emphasis is placed on removing all possible assets from the tunnel and alcoves.
- Placing components on the horizontal plane of the beam is undesirable. While some existing infrastructure changes are not feasible, future tunnel component design includes this factor.
- Items that did not meet original RHIC design values, such as injection kicker strength, are prioritized for redesign. Stripline kickers are being specified to improve upon previous ferrite kicker design.

Best practices are communicated at the design stage, to be incorporated for future collider operations.



Beam losses from standard beam operations induce memory errors on computers and network switches in the tunnel, even when located away from beamlines in alcoves with increased shielding.

Beam induced quenches incurred damage to active quench protection diodes near the beam pipe.
K. A. Drees et al., https://doi.org/10.18429/JACoW-NAPAC2019-WEPLH11



Studies show injection kicker strength limitations can result in as much as 15% emittance growth at injection in RHIC.
V. Schoefer, "RHIC injection kicker measurement and emittance growth simulation", BNL-207810-2018-TECH, June 2018.