RHIC Au-Au Operation at 100 GeV in Run16

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Thanks to the Committee for the invitation!
Outline

- High Intensity Beam
- Machine Lattice and Protection
- Parameters and Achievements
- Sub-systems
- Summary
Achieved peak luminosities:

- Au–Au (100 GeV/n): $155 \times 10^{26}$ cm$^{-2}$ s$^{-1}$
- $p\uparrow$–$p\uparrow$ (250 GeV): $245 \times 10^{30}$ cm$^{-2}$ s$^{-1}$

**Performance defined by**

1. Luminosity $L$
2. Proton polarization $P$
3. Versatility (species, $E$)
Operated modes (beam energies):
- U – U 100 GeV/n
- Au – Au 3.8/4.6/5.8/10/14/32/65/100 GeV/n
- d – Au 9.8/19.5/31.2/100 GeV/n
- Cu – Cu 11/31/100 GeV/n
- p↑ – p↑ 11/31/100/205/250 GeV
- H3 – Au 100 GeV/n
- p↑ – Al 100 GeV/n
- p↑ – Au 100 GeV/n

Achieved peak luminosities:
- Au–Au (100 GeV/n) \(1.55 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1}\)
- p↑–p↑ (250 GeV) \(2.45 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}\)

Performance defined by:
1. Luminosity L
2. Proton polarization P
3. Versatility (species, E)
Run-16 (last run for PHENIX, sPHENIX in ≥ 2022)

- Au+Au at 100 GeV, 10 weeks physics + 19.5 days diode repair

- d+Au at 9.8/19.5/31.2/100 GeV, 6 weeks
  PHENIX / STAR protection, minimization of setup time

- CeC PoP, 1 week (re-used for 100 GeV Au-Au run)
  Coherent electron Cooling (Proof of Principle) is a novel cooling technique for potential application in eRHIC.
Au Intensity Limits in RHIC

2016 Au Intensity = 1.845E9

28% more intensity than in Run-14

2014 Au Intensity = 1.41E9

20% or more Maximum Intensity Available in AGS

\[ L(t) = \frac{1}{4\pi} f_0 N \frac{N^2_b(t)}{\epsilon(t) \beta'(t)} h(\beta^*, \sigma_s, \theta) \]
More Au Intensity from Injectors in 2016

**Merge Method:**
- Run14: 8->4->2 merge in AGS
- Run16: 12->6->2 merge in AGS

**Max. Intensity in AGS:**
- Run14: 2.1E9 available in AGS
- Run16: 3.15E9 available in AGS

**Operation:**
- Injection: 2.5E9 from AGS used
- ~20% more intensity available
- Limited by Landau Cavity
Au Bunch Intensity Evolution

\[
L(t) = \frac{1}{4\pi} f_0 N \frac{N_b^2(t)}{\varepsilon(t) \beta^*(t)} h(\beta^*, \sigma_s, \theta)
\]

- injectors output
- transition instability in RHIC (e-clouds)
- presently Landau cavity RF amplifiers

**AGS: 20% more**

**Extended EBIS: 40% more**

H. Huang, K. Gardner, K. Zeno, RF, et al.
**Protection Bump and Beam Loss**

1. To protect detectors from pre-fire, the protection bumps were installed from Run14;
2. Pre-fire beam (orbit) can cause acute beam loss there as well as the de-bunched/off momentum (dispersion) beam during experiment;
3. The lattice with protection bump also caused chronic radiation (orbit and dispersion); The chronic beam losses come from luminosity/collision and dominated by blue beam;
4. They cause electronics upset $\rightarrow$ therefore store abort $\rightarrow$ associated losses are one reason of diode fail and 2.8 weeks repair.

![Graph showing beam loss and protection bumps](image-url)
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Solution

1. Change blue bumps location
2. Move beam more closer to mask;
3. Flip the max. BPM position pointing to outside of the rings (diode inside)

1. Less losses in ARC10~11;
2. More losses mask;
3. No losses at IP2;
4. Fewer communication error;

Many thanks to Mike Blaskiewicz, Guillaume, Vincent, Al, Christoph and others.
1. Starts levelling from the beginning of store with 70 kHz (60kHz for several stores);
2. Vertical separation was used for levelling;
3. Reduced initial SC cooling to reduce beam loss and L in PHENIX, preserves intensity, and allows for longer levelled stores for STAR (bottom plot)

1. $L_{\text{peak}} +85\%$
2. $L_{\text{avg}} +75\%$
3. 10 best store.
Run16 Delivered Luminosity

$L = 3.0 \text{ nb}^{-1}/\text{week} \ ( +33\% \ vs. \ 2014)$

1st plateau: 2.8 weeks
(not good – diode failure)
19.5 days diode repair

2nd plateau: 5.6 weeks
(good – switched in and out of d+Au quickly)

more collisions in 10 min than in the entire 5-week commissioning run in 2001

This plot can’t represent the best RHIC performance because of levelling.
56 MHz Cavity: Commissioning and Operation

Has achieved 1 MV cavity voltage during 100 GeV Au-Au run without HOM damper.
1. Coherent electron Cooling is a novel cooling technique for potential application in eRHIC.

2. Installation was completed, the commissioning stage started during 100 GeV run.

3. 8 MeV electron beam was propagated to high power beam dump.

4. 60~100nC charge has achieved with one cathode; beam profile and emittance were measured.

1. Run16 Integrated STAR luminosity is 2.1 times of Run11 and 1.7 times for initial luminosity.

2. Energy = 9.8 GeV (Run11 and Run16), beta* 1.4 time larger, emittance also larger;

3. Store15710 (Best store of Run11) and 19659 (Run16)
1. The gold (Au) intensity in the RHIC during the 2016 run exceeded the previously achieved intensity by **28%**. $L_{peak} + 85\%$ $L_{avg} + 75\%$

2. There is **20%** (compared with the max. intensity in 2016) more Au intensity available from AGS.

3. With more intensity in the future, the **machine protection** needs to be careful re-evaluated.

4. Low energy (10 GeV/nucleon) test has **2.1 times** integrated luminosity compared with the best store in Run11.

5. 8 MeV CeC beam delivered from the gun to the high energy dump

6. A replacement of a RHIC dipole cold quench protection diode in just 19 days.

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