



BNL-108532-2015-TECH

C-A/AP/549;BNL-108532-2015-IR

Polarized proton parameters for the 2015 PP-on-Au setup in RHIC

C. J. Gardner

August 2015

Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC), Nuclear Physics (NP) (SC-26)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

C-A/AP/549
August 2015

**Polarized proton parameters for the
2015 PP-on-Au setup in RHIC**

C. J. Gardner



**Collider-Accelerator Department
Brookhaven National Laboratory
Upton, NY 11973**

**U.S. Department of Energy
Office of Science, Office of Nuclear Physics**

Notice: This document has been authorized by employees of Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy. The United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this document, or allow others to do so, for United States Government purposes.

Polarized Proton Parameters for the 2015 PP-on-Au Setup in RHIC

C.J. Gardner

August 25, 2015

Proton mass-energy equivalent $m_p c^2 = 938.272046(21)$ MeV [1]

Proton g factor $g_p = 5.585694713(46)$ [1]

Proton $G = (g_p - 2)/2 = 1.79284735650$

Booster Injection Kinetic Energy = 200 MeV

Booster Extraction $G\gamma = 4.5$

Nominal Booster radius-of-curvature $\rho = 13.8656$ m

Nominal AGS radius-of-curvature $\rho = 85.378351$ m

Ags Injection $G\gamma = 4.5$

Ags Extraction $G\gamma = 45.5$

Nominal RHIC Circumference: $C_r = 3833.845181$ m

RHIC Store $G\gamma = 198.5$

Circumference Shifts

The RHIC circumference shift due to snakes [2, 3] is

$$\delta L = 26.1928376473988/(B\rho)^2 \quad (1)$$

where the units of δL and $B\rho$ are m and Tm respectively.

Shift at $G\gamma = 45.5$ due to snakes: $\delta L = 4.1582$ mm

Shift at $E = 100$ GeV due to snakes: $\delta L = 0.2354$ mm

Shift at $G\gamma = 191.5$ due to snakes: $\delta L = 0.2344$ mm

Shift at $G\gamma = 198.5$ due to snakes: $\delta L = 0.218156$ mm

Shift at $E = 250$ GeV due to snakes: $\delta L = 0.0377$ mm

There are also circumference shifts δD due to unequal ion rigidities in the DX magnets.

The total RHIC circumference shift is $\delta C = \delta L + \delta D$.

Ags Circumference at Extraction = $4(C_r + \delta C)/19$.

The DX magnets give shift $\delta D = 12.807866$ mm at blue injection [4].

The DX magnets give shift $\delta D = 11.225979$ mm at blue store [4].

References

- [1] P.J. Mohr and B.N. Taylor, "Values of Fundamental Physical Constants", Physical Constants, Physical Reference Data, www.nist.gov.
- [2] W. MacKay, "Path Length through Helical Snakes and Rotators", C-A/AP/Note 140, March 2004.
- [3] Formula (1) follows from those derived in [2]. It is used by Al Marusic to obtain path lengths in the RHIC snakes.
- [4] As calculated by Al Maursic.

Table 1: Polarized Protons in Booster

| Parameter | Injection | Extraction | Unit |
|-----------|------------------|----------------|------|
| $G\gamma$ | 2.17500674495 | 4.5 | |
| W | 200.000 | 1416.76626314 | MeV |
| cp | 644.444581326 | 2160.05810228 | MeV |
| E | 1.13827204600 | 2.35503830914 | GeV |
| $B\rho$ | 2.14963573675 | 7.20517826462 | Tm |
| β | 0.566160421483 | 0.917207203761 | |
| γ | 1.21315779454 | 2.50997386012 | |
| η | -0.6362 | -0.1159 | |
| h | 1 | 1 | |
| hf | 841.166737926 | 1362.77884657 | kHz |
| R | $201.780/(2\pi)$ | $128.4526/4$ | m |

Table 2: Polarized Protons in Booster

| Parameter | $G\gamma = 3$ | $G\gamma = 4$ | Unit |
|----------------|------------------|------------------|------|
| $G\gamma$ | 3.0 | 4.0 | |
| W | 631.753493427 | 1155.09533990 | MeV |
| cp | 1.25881919359 | 1.87131840691 | GeV |
| E | 1.57002553943 | 2.09336738590 | GeV |
| $B\rho$ | 4.19896885328 | 6.24204631230 | Tm |
| $(B\rho)/\rho$ | 0.302833548731 | 0.450182199999 | T |
| β | 0.801782621988 | 0.893927372480 | |
| γ | 1.67331590675 | 2.23108787566 | |
| η | -0.3143 | -0.1581 | |
| h | 1 | 1 | |
| hf | 1.19123988020 | 1.32814294910 | MHz |
| R | $201.780/(2\pi)$ | $201.780/(2\pi)$ | m |

Table 3: Polarized Protons in AGS for PP-on-Au Stores

| Parameter | Injection | Transition | Extraction | Unit |
|-----------|----------------|----------------|----------------|------|
| $G\gamma$ | 4.5 | 15.2392025302 | 45.5 | |
| W | 1.41676626314 | 7.03703998500 | 22.8737819686 | GeV |
| cp | 2.16005810228 | 7.91992760710 | 23.7935613552 | GeV |
| E | 2.35503830914 | 7.97531239100 | 23.8120540146 | GeV |
| $B\rho$ | 7.20517826462 | 26.4180348630 | 79.3667776499 | Tm |
| β | 0.917207203761 | 0.993055471537 | 0.999223390833 | |
| γ | 2.50997386012 | 8.5000 | 25.3786245857 | |
| η | -0.1449 | 0.0 | 0.01229 | |
| h | 12 | 12 | 12 | |
| hf | 4.08833653972 | 4.42642071890 | 4.45370715516 | MHz |
| R | 128.4526 | 128.4526 | 128.458549862 | m |

Table 4: Polarized Protons in RHIC for PP-on-Au Stores

| Parameter | Injection | $G\gamma = 191.5$ | $G\gamma = 198.5$ | Unit |
|------------|------------------------|-------------------------|-------------------------|------|
| $G\gamma$ | 45.5 | 191.5 | 198.5 | |
| W | 22.8737819686 | 99.2816915541 | 102.945084479 | GeV |
| cp | 23.7935613552 | 100.215571393 | 103.879119213 | GeV |
| E | 23.8120540146 | 100.219963600 | 103.883356525 | GeV |
| $B\rho$ | 79.3667776499 | 334.283163964 | 346.503444104 | Tm |
| β | 0.999223390833 | 0.999956174327 | 0.999959210867 | |
| γ | 25.3786245857 | 106.813332047 | 110.717735830 | |
| η | 3.560×10^{-4} | 1.8209×10^{-3} | 1.8270×10^{-3} | |
| f | 78.1352132485 | | 78.1928640114 | kHz |
| h | 360 | | 360 | |
| hf | 28.1286767694 | | 28.1494310441 | MHz |
| δC | 16.9661 | | 11.4441 | mm |

Table 5: Polarized Protons in RHIC for 250 GeV PP Stores

| Parameter | Injection | $G\gamma = 477.5$ | $E = 250$ GeV | Unit |
|------------|------------------------|-------------------------|-------------------------|------|
| $G\gamma$ | 45.5 | 477.5 | 477.699235564 | |
| W | 22.8737819686 | 248.957459646 | 249.061727954 | GeV |
| cp | 23.7935613552 | 249.893970242 | 249.998239285 | GeV |
| E | 23.8120540146 | 249.895731692 | 250 | GeV |
| $B\rho$ | 79.3667776499 | 833.556560794 | 833.904364882 | Tm |
| β | 0.999223390833 | 0.999992951261 | 0.999992957140 | |
| γ | 25.3786245857 | 266.336115157 | 266.447243170 | |
| η | 3.560×10^{-4} | 1.8945×10^{-3} | 1.8945×10^{-3} | |
| h | 360 | 360 | 360 | |
| hf | 28.1287707269 | 28.1504646061 | 28.1504647716 | MHz |
| δC | 4.160 | 0.038 | 0.038 | mm |

Table 6: Polarized Protons in RHIC for 255 GeV PP Stores

| Parameter | Injection | $G\gamma = 487.0$ | $E = 255$ GeV | Unit |
|------------|------------------------|-------------------------|-------------------------|------|
| $G\gamma$ | 45.5 | 487.0 | 487.253220275 | |
| W | 22.8737819686 | 253.929207188 | 254.061727954 | GeV |
| cp | 23.7935613552 | 254.865752145 | 254.998273809 | GeV |
| E | 23.8120540146 | 254.867479234 | 255 | GeV |
| $B\rho$ | 79.3667776499 | 850.140640113 | 850.582684802 | Tm |
| β | 0.999223390833 | 0.999993223582 | 0.999993230624 | |
| γ | 25.3786245857 | 271.634948862 | 271.776188033 | |
| η | 3.560×10^{-4} | 1.8950×10^{-3} | 1.8950×10^{-3} | |
| h | 360 | 360 | 360 | |
| hf | 28.1287707269 | 28.1504722721 | 28.1504724704 | MHz |
| δC | 4.160 | 0.038 | 0.038 | mm |