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AGS Vacuum Losses For Au79+

G. R. Young

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Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

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RHIC-PG-17

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1. Normal Cycle
2. Storage at β injection for fast cycling booster operation

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RHIC-PG-17

AGS Vacuum Losses for Au^{79+}

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GR Young

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AGS Vacuum For Gold^{79+} Ions

We give a quick look at the AGS vacuum for two reasons
1) estimate beam loss during an AGS cycle due to electron capture
2) estimate beam loss for a fully stripped beam coasting in the AGS for up to 1 second, as would be required if the booster is fast cycling (eg 3 or 10 Hz)

We need the electron capture cross section for bare Au^{79+} at 340 MeV/A, the ejection energy from the booster. We estimate this two ways

① Following Fowler et al (see RHIC-PG-11), via detailed balance from the photoionization cross section ($\beta = .681$, $\gamma = 1.365$, $B_K = 80.72$ keV)

$$\sigma_c = 1.2 \times 10^{-32} \ (79)^{4.4} \ \frac{(1.365+1+80.72/511)^2}{(1.365^2-1)(1.365-1+80.72/511)} \ cm^2$$

$= 37.8$ barns, on hydrogen, per atom

$= 37.8 \times 7 = 264.9$ barns on nitrogen per atom

$= 264.9 \times 2 = 529.8$ barns on nitrogen / molecule N_2

For an AGS pressure of 10^{-7} torr, mostly N_2 or CO_2 or H_2O, this yields a decay time $\tau_B = \left(3.27 \times 10^{16} \frac{\text{molecules}}{cm^3 \ torr} \cdot 2.9979 \times 10^{10} cm/s \cdot \beta \cdot 10^{-7} torr \cdot \sigma_c\right)^{-1}$

$= 28.30$ seconds

where current $I = I_0 e^{-t/\tau_B}$

So in worst case for the value of σ_c ie. it does not change during acceleration (which is not true and quite pessimistic), for a 0.6 second ramp up,

$$\eta = \frac{I}{I_0} = e^{-0.6/28.30} = ~~0.955~~ \ .979$$

ie ~ ~~4.5%~~ 2.0% loss max.

② If we estimate from the Alonso & Gould data for Pb passing thru N_2 at $\beta = .134$ (8.5 MeV/A, SuperHILAC energies). The scaling given by those authors is

$$\sigma_c \propto Z^0 q^3 \beta^{-6} \qquad Z = \text{atomic number}, \quad q = \text{charge state}$$

Many other workers agree with the q^3 dependence and the Z^0 dependence. However, H Knudsen et al (Phys Rev A23, 597 (1981)) systematize a large set of data from ~~two~~ dozen groups and find a β^{-7} dependence. They show this dependence is expected on basic grounds from the Bohr & Lindhard model. One note of caution: their data set is done mostly for E/A < 5 MeV/A ($\beta = .1$)

Alonso & Gould measure $\sigma_c = 3 \times 10^{-17}\ cm^2$/molecule, for N_2, for Pb^{64+}

$$\text{Thus} \quad \sigma(Au^{79+}) = 3 \times 10^{-17} \left(\frac{79}{64}\right)^3 \left(\frac{.134}{.681}\right)^6 \ cm^2/\text{molecule}$$

= 3275 barns/molecule β^{-6} scaling

= 644 barns/molecule β^{-7} scaling

This gives τ_B = 4.57 seconds β^{-6} scaling → η = .877

23.3 seconds β^{-6} scaling → = .975

The smaller values of σ_c are in much better accord with Gould et al's value of $\sigma_c = 280$ barns for U^{92+} at 437 MeV/A in N_2 ($\beta = .733$) The experimental errors on this are $\sigma_c = 280^{+250}_{-140}$ barns.

Conclude: at 10^{-7} torr, 1 booster pulse, AGS losses are < 3%.

If we fast cycle the booster, then we must store bunches in the AGS for up to 1 second, coasting at $\beta = .681$ (340 MeV/A). We estimate losses for 2 modes of fast cycling.

① 10 cycles/second, 100 ms cycle, 50 ms ramp up for each cycle. We use $\tau_B = 23.3$ seconds for Au^{79+}. The first bunch stores in the AGS for 8 x 100 ms + 50 ms + 50 ms = 900 ms, corresponding to 50 ms to ramp down after it is accelerated, 8 x 100 ms for the next 8 pulses, and 50 ms to ramp up for the last pulse. Thus we need to evaluate

$$\eta' = \frac{1}{9} \sum_{i=1}^{9} e^{-(10-i)\,100\,\text{ms}/23.3\,\text{s}} = .979$$

which is the fraction of the beam surviving the storage.

② 3 cycles/second, 333 ms cycle, 167 ms ramp up. Then

$$\eta' = \frac{1}{2} \sum_{i=1}^{2} e^{-(3-i)\,333\,\text{ms}/23.3\,\text{s}} = .979$$

Then we apply η from the last page for loses during the AGS cycle.

Thus, fast cycling booster operation will not cause any large loss of beam during AGS storage. If the AGS vacuum can be improved to 10^{-8} torr, then $\eta' = .998$