

## AGS Vacuum Losses For Au79+

G. R. Young

December 1983

Collider Accelerator Department  
**Brookhaven National Laboratory**

**U.S. Department of Energy**

USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-AC02-76CH00016 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.

AGS VACUUM LOSSES FOR Au<sup>79+</sup>

1. Normal Cycle
2. Storage at  $\beta$  injection for fast cycling booster operation

G. R. YOUNG

(BNL, December 8, 1983)

AGS VACUUM LOSSES FOR Au<sup>79+</sup>

1. Normal Cycle
2. Storage at  $\beta$ injection for fast cycling booster operation

G. R. YOUNG

(BNL, December 8, 1983)

AGS Vacuum Losses for Au<sup>79+</sup>

- 1) Normal cycle
- 2) Storage at  $\beta$  injection for fast cycling booster operation

GR Young

(BNL, December 9, 1983)

December 9, 1983

# AGS Vacuum For Gold<sup>79+</sup> 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<sup>79+</sup> 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 ( $\beta = 1.681$ ,  $\gamma = 1.365$ ),  $B_K = 80.72 \text{ keV}$ )

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

= 37.8 barns, on hydrogen, per atom

= 37.8 x 7 = 264.9 barns on nitrogen per atom

= 264.9 x 2 = 529.8 barns on nitrogen / molecule N<sub>2</sub>

For an AGS pressure of 10<sup>-7</sup> torr, mostly N<sub>2</sub> or CO<sub>2</sub> or H<sub>2</sub>O, this yields a decay time  $\tau_B = (3.27 \times 10^{16} \frac{\text{molecules}}{\text{cm}^3 \text{ torr}} \cdot 2.9979 \times 10^{10} \text{ cm/s} \cdot \beta \cdot 10^{-7} \text{ torr} \cdot \sigma_c)^{-1}$

= 28.30 seconds

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

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

$$\eta = \frac{I}{I_0} = e^{-0.6/28.30} = \frac{.979}{.975} \text{ ie } \sim \text{2.0\% loss max.}$$

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

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

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  $\beta^{-7}$  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  $E/A < 5 \text{ MeV/A}$  ( $\beta = .1$ )

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

$$\begin{aligned} \text{Thus } \sigma (Au^{79+}) &= 3 \times 10^{-17} \left( \frac{79}{64} \right)^3 \left( \frac{.134}{.1} \right)^6 \text{ cm}^2/\text{molecule} \\ &= 3275 \text{ barns/molecule} \quad \beta^{-6} \text{ scaling} \\ &= 644 \text{ barns/molecule} \quad \beta^{-7} \text{ scaling} \end{aligned}$$

$$\begin{array}{ll} \text{This gives } \tau_B = 4.57 \text{ seconds} & \beta^{-6} \text{ scaling} \rightarrow \eta = .877 \\ & 23.3 \text{ seconds} \quad \beta^{-6} \text{ scaling} \rightarrow = .975 \end{array}$$

The smaller values of  $\sigma_c$  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  $8 \times 100 \text{ ms} + 50 \text{ ms} + 50 \text{ ms} = 900 \text{ ms}$ , corresponding to 50 ms to ramp down after it is accelerated,  $8 \times 100 \text{ ms}$  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  $\eta$  from the last page for losses 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  $\eta' = .998$