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THOUGHTS ON MULTIPLE PULSE INJECTION INTO THE AGS BOOSTER FROM AN EBIS SOURCE

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AGS/AD/Tech. Note No. 361 raised the possibility of injecting into the AGS Booster from an EBIS source and heavy ion linac combination. While leaving the output energy of the linac as a free parameter, the note concluded that the optimum charge state of the ions is 39 for gold and 54 for uranium. The conclusion is based on the number of ions in the EBIS source and the stripping efficiency between the Booster and the AGS. In this note, we are going to examine the possibility of injecting multiple pulses into the Booster and its implications for longitudinal phase space.

Stacking into the momentum space of the synchrotron has been accomplished at the CERN ISR and also in the booster synchrotron MIMAS of the SATURN at CEN Saclay.[1] In principle, the momentum space stacking is twice as efficient as betatron space. A momentum space stacking is done in the following way. After the first turn is injected, the injected beam is moved to a lower energy orbit of the synchrotron, leaving the original orbit for the next pulse to be injected. This can be accomplished in two ways; namely, by decelerating the injected beam or raising the magnetic field of the machine to raise the central energy of the synchrotron. For the last case, the injection energy has to be changed to an appropriate value for the next injection pulse. At MIMAS, the deceleration is accomplished by ramping the magnetic flux in the toroidal core around the beam, thus providing betatron deceleration.

Because the output energy of the heavy ion linac can be changed by varying the phase of the rf in the linac cavities, the second method could be more suitable for the AGS Booster. Let us examine multi-pulse injection into the horizontal admittance of the Booster. The Booster horizontal admittance can be defined as a 2-inch aperture at the horizontal beta maximum that is at the middle of the horizontal quadrupoles (13.66 m).

Instead of discussing general terms, we would like to analyze a specific case to see what can be accomplished. We have chosen the following ion to study injection and capture:

Ion Species	Gold
Charge State (Q)	39
Energy	2.36 MeV/u
Normalized Emittance	0.25 π mm-mr
Unnormalized Emittance	3.52 π mm-mr

The energy is such that the proton cavity of the Booster should be able to capture at the 24th harmonic. The normalized emittance is obtained from the EBIS source at MIMAS. At the downstream end of the injection septum of the AGS Booster, we have the following parameters:

Horizontal Beta	12.2 m
Horizontal Alpha	-1.848
Dispersion Function	2.66 m
Dispersion Prime	0.3962
Septum Thickness	1 mm

The distance between two successive injections should be 1.4 cm in order to avoid the overlap in the phase space. This distance includes the effect of the septum. We assume the pulse length of the EBIS source to be comparable to the 9.5 microsecond revolution time of the ion in the Booster.

The injection is illustrated in Figure 1. The injection bump is set up to inject the beam in an extreme outer location (Location 7 in the figure). In between the linac pulses, the field of the Booster is raised by 0.53 percent to move the injected beam from Location 7 to Location 6 along the dispersion line, leaving Location 7 open for the next pulse. The next linac pulse must have a momentum 0.53% higher (or kinetic energy 1.03% higher) than the previous pulse. One can continue the process until the first pulse starts to spill out of the inside edge of the acceptance. In principle, up to seven linac pulses can be stacked into the emittance of the Booster.

For adiabatic bunching of the coasting beam, the best energy spread is:

$$\left(\frac{\Delta E}{E}\right)_B = \left(\frac{\Delta E}{E}\right)_I \frac{\pi}{2} = \beta (QeV)^{1/2} \left(\frac{2}{h\ \eta\ \pi\ E}\right)^{1/2}$$

where $(\Delta E/E)_I$ and $(\Delta E/E)_B$ are the energy spread of the injected and bunched beam.

The variables are:

$\eta = 1/\gamma^2 - 1/\gamma_T^2 = 0.953$

E = total energy of the ion = 1.839×10^{11} eV

$\Delta P/P = 5.3\ (n-1) \times 10^{-3}$ n = number of injected pulses $n > 1$

$\beta = v/c = 0.07077$

h = harmonic number

Q = ion charge = 39

$$eV = \frac{\pi^3 \beta^2\ h\ \eta\ E}{8\ Q} \left(\frac{\Delta P}{P}\right)_I^2$$

$$= 0.6045\ h\ (n-1)^2$$

This would be the required rf voltage and the resulting bunch area would be:

$$S = (h\ Q\ eV)^{1/2}\ \frac{16\ \beta}{h} \left(\frac{E}{2\ \pi\ \eta}\right)^{1/2}\ eV\text{-}rad$$

$$= \frac{(h\ Q\ ev)^{1/2}}{2\pi\ f_o\ h}\ \frac{16\beta}{h} \left(\frac{E}{2\pi\eta}\right)^{1/2}\ eV\text{-sec}$$

where f_o is the rotation frequency of the ion in the Booster.

$$S = \frac{2\beta^2 E}{h\, f_O} \left(\frac{\Delta P}{P}\right)_I = \frac{2\beta\, E}{h\, f_{\bowtie}} \left(\frac{\Delta P}{P}\right)_I$$

$$= 46.08\ (n\text{-}1)/h\ \text{eV-sec}$$

$$S/u = 0.2339\ (n\text{-}1)\ \text{eV-sec/u}$$

Table I summarizes the results.

Table I

No. of Injected Pulses	RF Voltage (kV) h = 3	h = 24	Bucket Area (ev-sec/u) h = 3	h = 24
2	1.81	14.51	0.078	0.010
3	7.25	58.03	0.156	0.019
4	16.30	130.60	0.234	0.029
5	29.00	232.10	0.312	0.039

Although one can inject into the Booster up to 7 linac pulses, the lack of rf voltage limits the number of pulses stacked into the momentum space. The present rf system limits the number to 3-4 pulses per cycle.

I would like to thank Krsto Prelec for mentioning this possibility and for many valuable discussions.

Reference

1. J.C. Ciret, et al., Proc. EPAC 88, p. 812, 1988.

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MOMENTUM STACKED 2.36 MEV/U BEAM PULSES