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HEAVY-ION COLLISIONS IN A COLLIDER AT BNL*

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Summary

Heavy ions accelerated in the AGS can be injected into CBA providing colliding beams up to 400 Q/A GeV/amu. Luminosities approaching $10^{28}/cm^2 sec$. should be achievable even though the ions must be accelerated through phase transition. More current might be stacked by using a special γ_T jump method to avoid the excessive radial aperture usage at transition.

The availability of heavy ions in the AGS as described in the previous paper and the completion of the CBA[1] at Brookhaven opens up the unique and interesting possibility of colliding heavy ions at very high energies. With no significant modifications of the CBA hardware, it should be possible to accelerate and collide ion beams at energies up to 400 Q/A Gev/amu. This possiblity was first developed in the proposal for the cyclotron[2] (also mentioned in the previous paper) and further studies have confirmed the general features of that report.

The amount of current that can be stacked in the CBA is limited by the fact that ions, unlike protons, must be accelerated through the phase transition energy. It can be shown that the maximum phase space area that can be accelerated through transition for a scenario in which the rf amplitude and the rate of rise of magnetic field are held constant is given by

$$A = \frac{1}{\omega_o}\left(\frac{4\pi\ E_o^{\ 4}\ \gamma_T^{\ 2}\sin\phi_s}{h^2\ eV\ \cos^2\phi_s}\right)^{1/3}\ \frac{3^{10/3}\ \Gamma^2(5/3)}{2^4}\left(\frac{\Delta r}{X_p}\right)^2$$

where $\omega_o/2\pi$ is the rotation frequency, E_o the ion rest mass, e the ion charge, Δr the radial half aperture, and X_p the momentum dispersion function. The minimum $|\Delta r/X_p|$ of the lattice must be used. With the parameters of the CBA lattice, we find that ∼80 ev sec/amu can be accelerated in each of the three CBA bunches to be compared with ∼500 ev sec/amu that can be injected and captured.

In spite of this limitation, a quite acceptable luminosity can be achieved. The energy spread of the tandem-cyclotron-AGS system should be so low that more than 600 AGS cycles can be stacked in each ring. The vertical emittance is smaller than for protons even after allowing a generous amount of dilution. The beams can be retained in a bunched mode because the intensities are far below beam-beam limits and the interaction rates should be low enough that physicists can tolerate the unfavorable duty factor. Finally, the low beta and low crossing angle options which are visualized for highest luminosity cases for CBA can be invoked. Luminosity values approaching $L=10^{28}/cm^2 sec$. should then be achievable. Higher design values may be vacuous because the loss rate from electro-nuclear disintegrations at the crossing points becomes excessive.

It is possible to construct a CBA for heavy ions less expensively than for protons. This result is possible because the energy required for the physics is not so high. If one constructed CBA with a lattice similar to the usual proton design but with only one third of the dipole magnets in place (a missing magnet lattice), the resulting energy of 133 Q/A Gev/amu is quite adequate for the physics problems to be addressed. Presumably the full complement of dipole magnets would be added later for the usual program with protons.

At first, one might suspect that the loss of aperture due to sagitta in the dipole magnets would invalidate this concept. For a magnet of 4.36 m length in a lattice for which the bending radius is 253 meters, the sagitta is ∼0.9 cm. If the radius of curvature is reduced by a factor of three, the sagitta is 2.8 cm which would appear to be an unacceptable fraction of the 8.5 cm aperture. However one has a choice of which of the magnets are to be removed. The momentum aperture is limited near the focusing quadrupoles where the momentum dispersion function is large. If the missing magnet option is implemented by retaining only the magnets adjacent to defocusing quadrupoles, there is no net loss of momentum aperture. In fact, a missing magnet lattice so designed has a lower peak dispersion function everywhere and a higher transition energy, both of which are desirable and the relative momentum aperture $\Delta p/p$ is actually larger than for the usual full magnet lattice. Thus, it is possible to build a missing magnet lattice for heavy ions. Unfortunately, the geometry of the lattice is sufficiently different from that of the full magnet complex that, in adding the remaining magnets, one must be prepared to move all the magnets at considerable effort and expense.

Both the regular lattice and the missing magnet lattice have the problem that the ion injection energy is lower than the phase transition energy. Passage through transition limits the stackable current. This limiting current has been used in our luminosity estimates. There is a possible method of improving this situation. One can visualize programming the rf amplitude and the rate of rise of the magnetic field so that one asymptotically approaches the transition energy rather than passes through it. If one approaches γ_T sufficiently slowly, the tight bunching and concomitant radial aperture consuming growth can be avoided. One then passes through transition by rapidly reducing γ_T of the lattice while $\dot{B}$ and the rf amplitude are near zero. Acceleration can then proceed by adiabatically increasing the rate of rise of the magnetic field and the rf amplitude to normal values. The CBA lattice is well adapted to the quick γ_T change required for this process. Tuning the arc quadrupoles changes the γ_T and the betatron oscillation tunes. The quadrupoles in the insertions, being in regions of near zero momentum dispersion, can change the tunes without changing γ_T. One can thus imagine tuning the arc quadrupoles and the insertion quadrupoles in combination so that our desired γ_T shift can be implemented. Using the program SYNCH,[3] the following parameters were obtained for a missing magnet CBA lattice:

γ_T	ν_x	ν_y
25.35	22.62	22.62
25.21	22.62	22.62
25.07	22.62	22.62
24.91	22.61	22.62
24.75	22.61	22.62

*Work performed under the auspices of the U.S. Department of Energy.

Properties of this lattice, other than the lower dispersion function and higher γ_T are virtually identical to the usual CBA lattice. Thus it should be possible, if desirable, to work out a scheme involving this γ_T jump to remove the current limit caused by transition and increase the intensity of ion beams that can be stacked in the CBA to improve the luminosity or the safety margin, or both.

Acknowledgements

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