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# Possible Design Parameters for a 10-Bev High Repetition Rate Proton Alternating Gradient Synchrotron

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The following numbers were worked out to show the feasibility of an accelerator with 100 times the repetition rate of the machines currently planned by Brookhaven and CERN. Since space charge, injector capabilities, and magnet design put theoretical and practical limits on the beam current per pulse, such a high repetition rate machine would appear to make quantitative experiments possible which could not be done elsewhere. Kerst has found that the iron costs are very similar, whether thin laminations or one-inch plate are used. By powering the magnet in a resonant system with a condenser bank rather than with a flywheel higher Q can be obtained, hence the magnet power required is not proportionately greater than in the slow rate of rise machines. The greatest obstacle to high repetition rate is the R.F. voltage per turn required.

By powering the magnet with a sinusoidaly varying current and biasing to approximately half the maximum field, the condenser bank required is only one-fourth as expensive as in the unbiased case, the volts per turn is half as great, and the energy resolution is double for the same duty cycle. In addition, a low dB/dt at injection reduces eddy current problems, simplifies F.M. problems, and allows greater R.F. phase angle acceptance.

Following are some representative parameters.

| | |
|---|---|
| $E_{max}$ | 10 Bev |
| pulse rate f | 15 cps |
| $B_{max}$ | 10 kilogauss |
| aperture | 6 x 10 cm |
| $R_o$ | 30 meters |
| circumference | 250 meters |
| $f_o$ at relativistic energies | 1.2 mc/sec |

R.F. parameters

particle V/turn (max) $\frac{\pi f\ E_{max}}{f_o} = 4 \times 10^5$ volts/turn

V/cavity (peak) (currentBrookhaven design) = 8,000 volts for tuned, ferrite-loaded cavities)

R.F. V/turn (peak) for 64 cavities, $5.1 \times 10^5$ volts/turn

equilibrium phase angle at V/turn(max), $53^o$

approximate R.F. cost estimate of L. Haworth for 100-Bev A.G.S. of equivalent numbers of cavities and volts/turn, $\$4.4 \times 10^6$

With a low rate of rise of field near injection, the equilibrium phase angle at low energies is comfortably low. Only after considerable adiabatic damping of synchrotron oscillations has occurred would the high equilibrium phase angle be reached. A desirable feature of this high rate of rise is the speed with which the transition energy is crossed. In this machine, for instance, there is a factor of 50 in rate of rise over the Brookhaven design. From recent history of accelerators it is reasonable to expect the R.F. art to improve rapidly in the next few years, hence perhaps an

accelerator might be overdesigned as far as magnet, etc., are concerned and higher beam energies realized as better R.F. becomes available. The Haworth figures on R.F. cost probably are unduly pessimistic since much of the development of these systems is already being done at Brookhaven and elsewhere.

Magnet:

| | |
|---|---|
| B bias | 5,000 gauss |
| B(max) A.C. | 5,000 gauss |
| A.C. stored energy in gap | $\frac{B^2}{8\pi} V \times 10^{-7} = 1.5 \times 10^5$ joules |
| total A.C. stored energy allowing a factor of two for f magnet | $3.10^5$ joules leakage flux |
| $\omega$ | 15 cps |
| $\omega E$ stored | 100 radians sec |
| condenser bank cost at $10 per KVA | 30,000 KVA |
| Q of magnet-condenser bank | $300,000 |
| Power line load continuous | 50 |
| | 600 KW |

The above does not include the cost or power required by the biasing system. The power line load for biasing would probably equal that for the A.C. component. The choke required would be large and expensive, however it might be usefully incorporated into bending and analyzing magnets for the experimental areas. Any machine designed to give such higher currents would be more expensive to shield, and if a factor of 100 in beam over other machine designs is planned, this added cost would be very significant. With biased sine wave excitation, a duty cycle of 11% is possible for 3% beam energy resolution.