Subject CHOICE OF RADIUS FOR NAL STORAGE RING

The choice of $R_{SR} = \frac{1}{3} R_{MAIN}$ is based on the assumption that one full turn of the main ring is injected into three turns of the SR on each pulse of the main ring. The stored current is then accelerated in the SR, and successive main ring pulses are stacked in energy-longitudinal phase space in the SR; the goal is to stack 20 pulses of the main ring to obtain a total stacked beam of 10^{15} protons.

It is estimated that this beam will have a vertical emittance of 0.36 μ-rad, a horizontal emittance of 5.0 μ-rad, and a momentum spread of $\pm 1 \times 10^{-3}$.

Keil [1] has pointed out that if more stacking takes place in transverse (horizontal) phase space and less in longitudinal phase space, one can achieve smaller energy spreads in the stacked beam, a feature which should be useful in experiments requiring good energy resolution. However, to accomplish this fairly simply, it is necessary that the ratio of radii R_{SR}/R_{MAIN} be of the form

$$\frac{R_S}{R_M} = \frac{a}{b}$$

where a and b are integers that are relatively prime, and b is large: then on each main ring pulse, a fraction 1/a of the SR is filled by b-fold multi-turn injection to b times the bucket population of the main ring. Keil proposed changing the radius ratio of the CERN ISR from 3/2 to 29/20; however the proposal was made too late to be implemented at CERN. Even so, Courant, Keil and Sessler [2] showed that substantial improvements in performance of the CERN ISR can be obtained by using this multi-turn injection with b = 2 both for the booster-synchrotron and the synchrotron-storage ring transfer.

One may propose, for NAL, to make the radius ratio b/a = 3/8 rather than 1/3, and inject in the following manner:

On the first pulse of the main ring, inject 1/8 of the circumference of the main ring into 1/3 of the storage ring. Then turn the main ring injection kicker off for 2/3 of a storage ring revolution (5.2 μsec), then turn it on again for 1/3 turn (2.6 μsec), transferring the fourth octant of the main ring into the same third of the SR. Repeat this process, ending up with octants no. 1, 4, 7, 2, 5, 8, 3, 6 all occupying the same third of the storage ring. On the next two MR pulses, fill the other two thirds of the SR in the same way, ending up with each bucket of the SR containing the equivalent of 8 buckets of the MR in a longitudinal phase space equal to that of a MR bucket, but with horizontal emittance 8 times that of the MR (plus dilution factor).

To accomplish this, multi-turn injection must be used into the SR, with as little dilution as possible. Computer studies at BNL [3] indicate that a dilution factor of 1/2 should be attainable; this is the same as assumed in previous NAL studies.

The choice R_S/R_M = 3/8 does not preclude the simpler three-turn filling scheme previously envisaged. The only complication is that 1/8 of the MR must be thrown away (to another experiment maybe) on each pulse, or better still one third of the SR is filled 33% more than the rest using four-turn injection. Injection on successive pulses could probably be timed so as to even this out if necessary.

Assuming the same dilution factor in all cases, we have the following comparison of parameters and performance:

	3/8 Ring	Parameters of 9/30/68
Radius	375 m	333 m
No. of protons	10^{15}	10^{15}
Emittance of stack:		
Horizontal	13.3×10^{-6} m-rad	5.0×10^{-6}
Vertical	0.36	0.36
$\frac{\Delta p}{p}$	$\pm 3.75 \times 10^{-4}$	1×10^{-3}
Δp	$\pm$ 37 MeV/c	$\pm$ 100 MeV/c
Beam size in interaction region:		
Vertical	0.73 mm	0.73 mm
Horizontal	23.0 mm	14.1 mm
Length of interaction	91 cm	56 cm
Beam size at maximum horizontal excursion (end of drift space)	34.6 mm	21.2 mm
Luminosity	1.5×10^{32} cm^{-2} sec^{-1}	1.9×10^{32}

(The lower luminosity is due to the slight increase in radius, which is hardly significant)

Similar results can be obtained by choosing other ratios near 1/3, such as 3/10, 4/11, 5/14, 8/21 etc.

References

[1] E. Keil, CERN ISR-TH/67-10

[2] E. Courant, E. Keil, A. M. Sessler, CERN ISR-TH/67-12; Proc. of VI International Accelerator Conference, Cambridge, 1967, A-163

[3] AGS Improvement Proposal (BNL 7956), Section IV. 2c