Fermilab

TM-643
0311.000

INCREASED 200 MeV BEAM SIZE

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February 9, 1976

If the linac emittance is increased above the nominal design value of 10π mm-mrad, what devices in the 200-MeV line can be expected to limit the size transmitted to the Booster? To give an answer to that question transport runs were made for the nominal multiturn achromatic design and the nominal single turn design. Such considerations are in line with recent speculation about single turn booster injection using a linac beam of hundreds of milliamperes.

Calculations

The nominal 10π mm-mrad design transport was used to calculate beam radii at all quadrupoles and bending magnets. Since recent linac emittance measurements coupled with a pessimistic view of the effects of linac-preaccelerator variations needed to get the linac current up to several hundred multiamperes of beam current indicate that linac emittance of 20π mm-mrad may result from such operation, an acceptance of 20π is considered desirable. Taking the physical aperture of each device as given

in Table II, an "acceptance" for that device is calculated by multiplying the beam emittance (10π) by the square of the ratio of the device aperture radius to calculated beam radius at the device. Table I gives a list of the acceptances for the two design cases in decreasing order of importance to operating the line with such a large beam. This is a calculation based on only emittance size. No other complicating effects are included. Notice that each list includes all six of the bending elements and, in fact, in the single turn case the first four on the list are bending magnets.

To take a look at transient beam steering, the apertures were decreased by the square root of the sum of the squares of the beam movement caused by a 0.5 mm position shift and a 0.25 mr angle shift at the entrance to the 200-MeV line. Table III gives the resulting acceptance list. Some small change in the order is seen but of no significance. The more important effect is the decrease in acceptance. The above numbers are for zero momentum spread. Runs were made with a $\pm 0.2\%$ momentum spread; small increases did result but were also of minor significance compared to the overall confidence level in the numbers.

The above calculations did not include either the electrostatic chopper at the end of the linac or the electrostatic inflector at the booster injection point. The inflector is seen to be a problem for large beams from the following numbers. The downstream inflector width was believed to be about 0.6 inches in width (15.24 mm). At injection the booster XP is 1.84 mm

per 0.1 percent. An injection momentum spread of 0.2 percent for a matched beam reduces this width to approximately 11.56 mm. This allows only a 5.45π mm-mrad matched single turn beam. Foregoing the dispersive match by using an achromatic line for the single turn emittance match still gives only 9.48π mm-mrad for a horizontal beta of 6.122 m. Both numbers are smaller than the existing linac beam emittance. The inflector gap was widened on January 27, 1976 to 23 mm. Matched single turn beam acceptance is then 15.2π mm-mrad and 21.6π mm-mrad without the dispersive match. If the full width of the linac momentum spread is more like 0.3% ($\pm$0.15) the dispersive matched acceptance goes down to 12.5π mm-mrad.

Conclusion

From the present calculations it appears that to run a large linac beam in a matched single turn injection mode requires first a further increase in the inflector size, secondly larger aperture septa and bending magnets, and finally larger aperture quadrupoles in a couple locations if the beam is injected in an achromatic mode. However it is believed that a momentum match for single turn injection is more desirable if allowed by the inflector aperture size. Operationally the momentum matched mode seems basically more desirable because it is a less severe constraint requiring only 3 (not 7) magnets at greatly reduced strengths.

It should be noted that the values given for acceptances are based on two design configurations, neither one of which is used in operation. The single turn matched case has not been possible with the small inflector gap and the multiturn case

produces a narrow beam at injection for four turn injection which is not compatible with booster acceptance. The operational modes always involve retuning quadrupole strengths. The result is different beam widths in the line and consequently different acceptances.

Table I

EFFECT OF EMITTANCE ONLY ON

ACCEPTANCE

Multiturn Achromatic			Single Turn		
Device	Acceptance π mm-mrad	Plane	Device	Acceptance π mm-mrad	Plane
Q21	13.6	V	S2	15.1	V
MV1	15.3	H	MV1	15.3	H
S2	17.8	V			
			MH2	20.7	V
Q25	24.8	V	S1	25.3	V
S1	25.3	V	Q8	29.5	H
Q22	28.7	V	Q14	33.6	H
Q8	29.5	H	Q18	39.1	V
Q18	30.6	V	MH1	52.2	V
Q14	39.4	H	MV2	52.3	H
MH2	43.4	V			
MH1	52.2	V			
MV2	52.3	H			

Table II

APERTURES OF DEVICES (RADIUS)

	Hor (cm)	Vert (cm)
Quads	3.89	3.89
S1/S2	2.54	1.91
MH1	——	2.54
MV1/V2	3.175	——
MH2	——	1.67
Infector	Treated Separately	

Table III

ACCEPTANCE WITH INPUT BEAM SHIFT OF

0.5 mm AND 0.25 mr IN BOTH PLANES

Multiturn Achromatic			Single Turn		
Device	Acceptance π mm-rad	Plane	Device	Acceptance π mm-rad	Plane
Q21	8.5	V	S2	11.5	V
MV1	13.3	H	MV1	14.3	H
S2	14.1	V	MH2	16.7	V
Q25	19.1	V			
			S1	24.0	V
Q22	21.2	V	Q8	26.7	H
Q18	24.4	V	Q14	28.0	H
S1	24.0	V	Q18	30.7	V
Q8	26.7	H	MH1	38.1	V
MH2	32.7	V	MV2	44.7	H
Q14	33.0	H			
S1	35.1	H			
MH1	38.1	V			
Q26	43.2	V			
MV2	44.7	H			