IEEE Transactions on Nuclear Science, Vol. NS-28, No. 3, June 1981

DEPENDENCE OF THE EMITTANCES OF THE FERMILAB INJECTORS ON INTENSITY

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Summary

This paper reports the dependence of the emittance of the Main Ring injected beam on Booster intensity. The intensity was changed in two different ways: by changing the number of turns injected into the Booster using the normal H^- charge-exchange injection and by changing the intensity of the Linac itself by varying the phase of the buncher. The measured emittance of the Linac beam was also compared, assuming adiabatic shrinkage, to the emittance of the Main Ring beam measured while injecting one turn into the Booster.

Introduction

A new program developed by the Main Ring group facilitates the measurement of multiwire beam profiles in the Main Ring[1]. The program automatically inserts the wires, fits a Gaussian to the first-turn profile of each Booster batch, and calculates the 90% width of each batch. The two injected and circulating beam-ellipse parameters and the beam emittance at the point of injection into the Main Ring are determined by a least squares fit to the measured beam sizes. The Main Ring lattice parameters used in the fit are a combination of measured parameters and parameters derived from a SYNCH run. In the horizontal plane, fits have been made with and without a dispersion correction.

Transverse Results

This report summarizes two measurements made a year apart (1/17/80 and 2/19/81). The Main Ring measurements are quite consistent. The scaled Linac emittances are larger than the first-turn emittances in the Main Ring, and the latest measurements (2/19/80) are the largest.

The quoted Linac emittance is the 90% emittance, and the Main Ring emittance is calculated from the 90% widths. For comparison purposes the measured Linac emittances have been scaled by the ratio of .644 GeV/c/8.88 GeV/c = .0725 to give the adiabatically shrunk emittance at the Main Ring injection energy. That the emittance in the Main Ring is smaller than the scaled Linac emittance is presumably due to scraping of beam in the Booster and/or the transport lines.

Figures 1 and 2 show the results of the transverse measurements. To give an indication of the stability of the results with respect to variations of the parameters, the emittances have been calculated under various assumptions. For the horizontal data the difference between assuming $\Delta p/p = 0$ and $\Delta p/p = .1\%$ ranges from 20% at low intensity to 10% at high intensity. Similarly, for the vertical data, the difference between using all the SYNCH data as input and using a combination of SYNCH data and measured[2] β data is approximately 10%. The horizontal emittances are plotted for a $\Delta p/p$ of .1% and the vertical emittances shown correspond to the SYNCH parameters. The various transmission efficiencies are given in Table I.

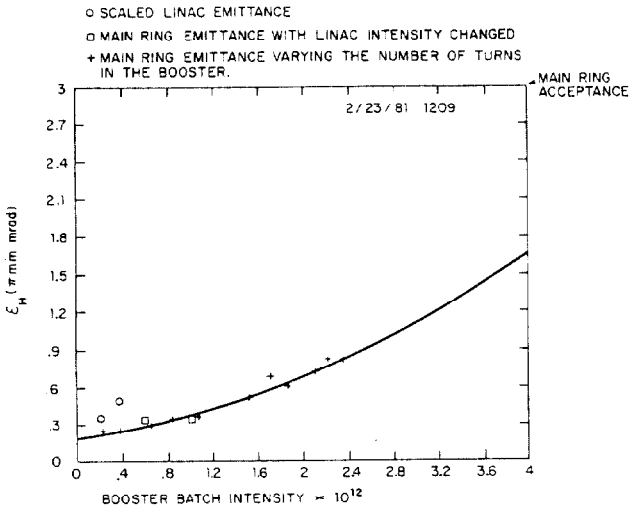

Figure 1. Intensity dependence of the horizontal emittance of the 8-GeV beam injected into the Main Ring.

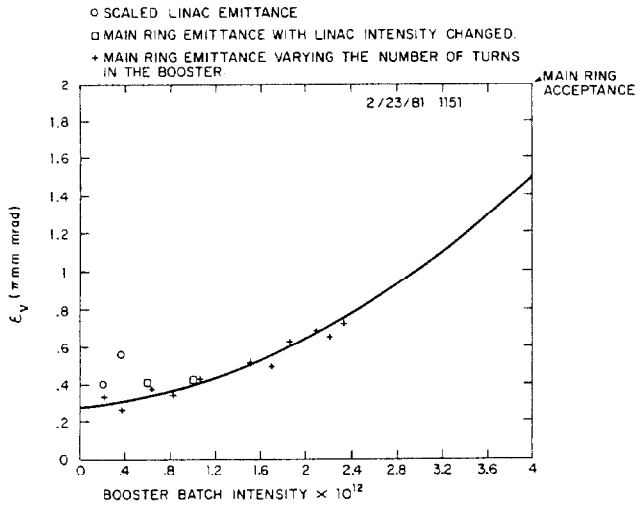

Figure 2. Intensity dependence of the vertical emittance of the 8-GeV beam injected into the Main Ring.

Table I

Booster transmission	73%
8 GeV transmission	100%
MR injection transmission	86%

The data sets of emittance vs. intensity were fit with a form $\varepsilon = A + B * I + C * I^2$, where I = Booster batch intensity. The smooth curves in Figures 1 and 2 show the fitted functions; the coefficients are presented in Table II.

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The results of the fits were extrapolated to higher Booster batch intensities as indicated on the figures. The Main Ring acceptances are also indicated on the figures.

Table II

	Horizontal ($\Delta p/p$ = .1%)	Vertical
A	1.919×10^{-1}	2.79×10^{-1}
B	1.149×10^{-1}	6.67×10^{-2}
C	6.148×10^{-2}	5.17×10^{-2}

The first conclusion that one can draw from the data presented here is that the measured emittance of the 8 GeV beam in the Main Ring (for one turn) is smaller than the adiabatically shrunken Linac emittance measured at 200 MeV. One should recognize that the 8 GeV emittance values are for less than 100% efficiency of transmission through the Booster and injection into the Main Ring.

A second conclusion drawn from a limited amount of data taken at a reduced Linac intensity is that the total charge in the Booster, rather than the number of turns necessary to acquire that charge, determines the 8 GeV emittance.

The final conclusion is that the growth in emittance with Booster intensity does not appear to be a limiting factor on intensity upon injection into the Main Ring, at the intensities reported here. However this conclusion is based upon the emittance of the beam with no regard to dilution because of mismatch at injection.

Longitudinal Results

The longitudinal emittance depends on two quantities: the momentum spread, $\Delta p/p$, and the phase spread, $\Delta\phi$. We shall not present any $\Delta p/p$ measurements in this paper; they will be measured and published later. We do have phase spread results in that the beam quality monitor[4] measures an equivalent quantity, the longitudinal length of the beam in nanoseconds. Figure 3 shows the variation in bunch length as a function of intensity. The slope of the straight line fitted to the data is 1.7 nsec/10^{12}.

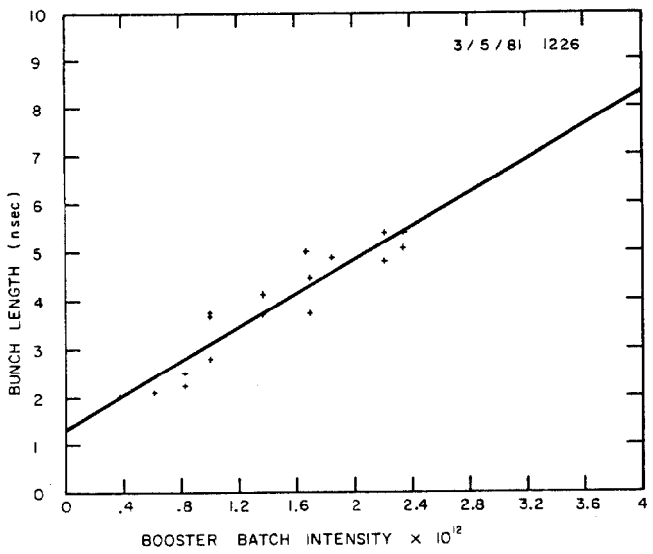

Figure 3. Intensity dependence of the bunch length of the 8-GeV beam injected into the Main Ring.

References

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