

SLOW EXTRACTION FROM THE FERMILAB MAIN INJECTOR*

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Abstract

Slow resonant extraction from the Fermilab Main Injector through the extraction channel was achieved in February 2000, with a spill length of 0.3 sec. Beam losses were small. Excellent wire chamber profiles were obtained and analyzed. The duty factor was not very good and needs to be improved.

1 INTRODUCTION

Resonant extraction from the Main Injector is based upon the half-integer extraction scheme utilizing electrostatic septa and magnetic Lambertsons [1]. Quadrupoles distributed on the 53rd harmonic provide the half-integer driving term, while octupoles distributed around the ring excite the 0th harmonic. The octupole field produces an amplitude dependent tune shift, with larger amplitude particles having tunes closer to the half-integer. Consequently, the phase space splits into stable and unstable regions. Ramping the harmonic quadrupoles increases the width of the half-integer stopband. As the area of the stable region shrinks to the point that it no longer encompasses the beam emittance, large amplitude particles become unstable and stream out along the separatrices. The main goal of the exercise was to set up the extraction process and consequently to obtain wire profiles in the extraction channel (the P1 and P2 beamlines) so that we could estimate the size of the beam in the SY120 Project beamlines using measured data. At location F17 in the P2 line the beam was sent into the AP1 beamline where it was dumped on the Pbar dump.

2 OPERATIONAL METHOD

2.1 Preparation

The Main Injector is a heavily used machine, but when E835 was running (using stored pbars in the accumulator) there were periods of time that could be used for some setup work. Three electrostatic septa have been installed in the MI for the purpose of resonant extraction for the Switchyard 120 (SY120) program. Two of the three septa are located at MI-52 approximate 90 degrees in phase upstream of the extraction Lambertsons. A third septa was installed in the MI30 straight section to generate a small separation at the entrance of the septa pair at MI-52 in hopes to reduce losses in the MI-52 region. For simplicity and the small amount of time available only the septa at MI-52 were used. Since we were only using two out the three possible septa we had to run the two at a higher than

normal voltage; they were conditioned by running them up to 105 kV so that they could run reliably at 100 kV. The special ramps for the power supplies in the P1, P2, and AP1 beamlines were developed and installed and the power supplies were checked out. The AP1 line normally handles single turn extraction and usually does not stay at 120 GeV currents for long. The length of spill was determined by heating consideration in this line. The septa were moved into their nominal position, and closed orbit bumps were developed to move the circulating beam around the septa.

2.2 Setup

For the extraction studies a 120 GeV ramp was installed that had a half-second flat top. It was determined that we needed approximately 200 milliseconds to bring the horizontal tune to a value of 26.486. In order to start from the proper initial conditions the intrinsic half-integer stopband of the machine was corrected. The half integer stop band was corrected by utilizing a sine (Q206 family) and cosine (Q308 family) pair of orthogonal trim quadrupole families. The current in the families was varied until beam was observed to fall out of the machine. Then the centroid of the values for the two quadrupole circuits was determined to cancel the stop band. There was sufficient 0th harmonic octupole from the octupole component of the 84th quadrupoles in the ring that the correction octupoles were set to zero. Thus the intrinsic quadrupole and octupole components of the machine were set for extraction 200 milliseconds into flattop.

2.3 Data Taking

Extraction proceeded by ramping the Q206 family. Figure 1 shows the beam being taken from the machine. After some orbit adjustments and septa position changes beam was cleanly extracted down the extraction channel and multiwire (MW) images were recorded.

2.4 Analysis

Flying wire data were taken, and the 95% emittance and machine parameters at location 522 in the Main Injector are shown in Table 1 under the columns labeled Data. The multiwire data was fit using TRANSPORT [2] and the fit was expressed in terms of emittance and machine parameters also at location 522 and are shown in the columns labeled Fit. It is not surprising that the vertical parameters are in good agreement since we have horizontal extraction, and the

close agreement in the horizontal case shows that the extraction process is proceeding as designed [[3]]

Table 1. Comparison of flying wire data to MW fit.

	Data -Hor	Fit- Hor	Data - Ver	Fit - Ver
β (m)	35.96	33.68	17.59	21.19
α	-1.78	-1.59	1.18	1.48
ϵ (mm mr)	14.95 Π	13.8 Π	14.44 Π	17.48 Π

The fitted values at location 522 from TRANSPORT were then used to propagate the beam down the extraction channel and figure 2 shows the multiwire data along with the projected distributions from the fit. The agreement is quite good considering that only a few wires were hit in some locations and estimating the size was difficult.

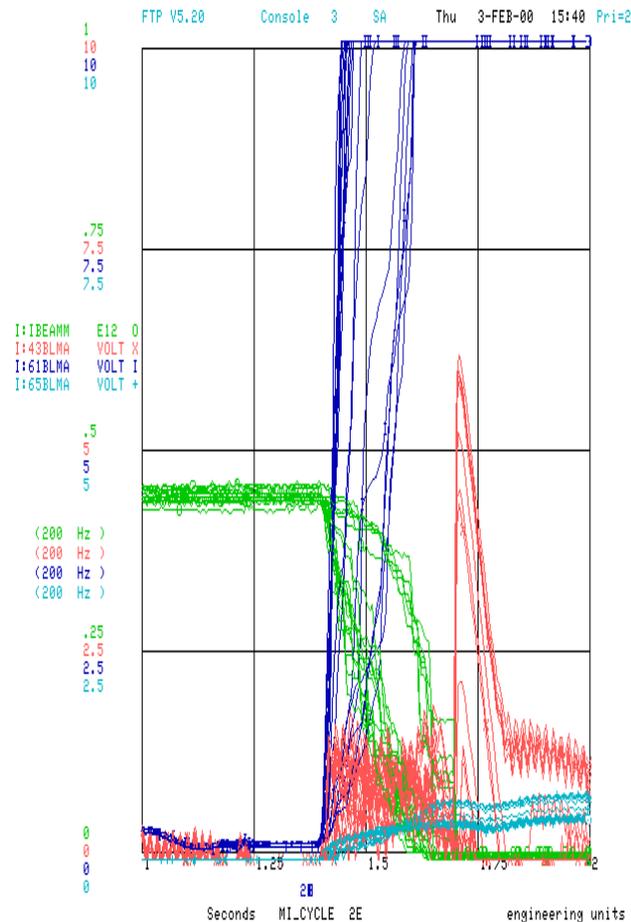


Figure 1. Beam trace showing resonant extraction.

3 CONCLUSION

The main goal of this exercise was to measure reasonable initial conditions so that the SY120 project could design beamlines with appropriate apertures and/or sufficient focusing. This was accomplished.

4 ACKNOWLEDGMENTS

Many people helped with this study. Shekhar Mishra and Dave Capista helped with setting up. James Morgan set up the AP1 line for us. James Fitzgerald, James Crisp, and Gianni Tassoto helped with beamline instrumentation. Peter Prieto helped with other aspects of extraction that will be reported elsewhere.

5 REFERENCES

- [1] J. Johnstone, "A Simplified Analysis of Resonant Extraction at the Main Injector", MI-0091, (1993),
- [2] TRANSPORT D. Carey, K. Brown, and F. Rothacker SLAC Report 530, Oct. 1998
- [3] J. Johnstone, "A Numerical Simulation of Resonant Extraction", MI-0093, (1993)

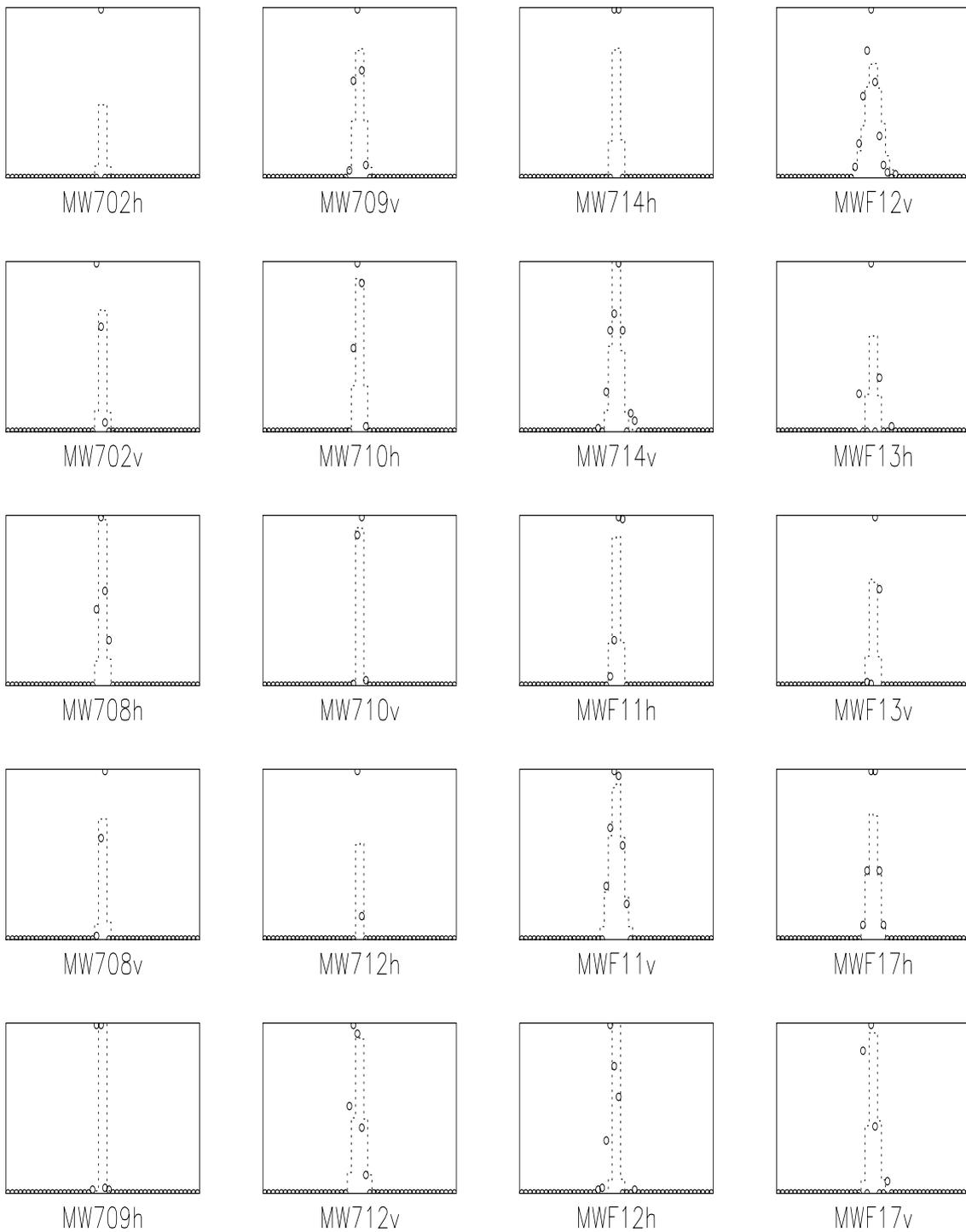


Figure 2: Multiwire profiles in the P1 and P2 beamlines. The dashed histogram is the measured data and the circles are results of a TRANSPORT fit. See the text for details.