

# 1.5 GeV/c FEB extraction

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Date 2/2/77 Time 0800 - 1800 Experimenters Bagley, Blumberg, Cahill, Eld, Feltman, Gabusi, Gill, Glenn, Keane, Lee, Raka, Soukas

Subject 1.5 GeV/c FEB Extraction

### OBSERVATIONS AND CONCLUSION

(1) Objective: Extract  $\sim 7 \times 10^{12}$  ppp in three turns.

(2) AGS and FEB conditions: rep. rate = 1 sec, CBM initially  $\approx 3 \times 10^{12}$  ppp, extraction time = 102 ms after To, Gauss-clock  $\approx 2900$ , tune  $\approx 8.7$ , E10 and H10 backleg bumps  $\approx 50$  A with 2 ms rise time, E10 septum  $\approx 700$  A, H10 ejector  $\approx 1000$  A, C15 and E15 kicker with half-sinusoid current waveforms of 20  $\mu$ sec duration and  $\approx 1200$  A amplitude, external magnets  $Q_1$ ,  $Q_2$ ,  $D1 \rightarrow 3$  and  $Q_3 \rightarrow 7 \approx 1/19$  of 28.5 GeV/c values, collimators U5 and U12 open, U186 beam stop closed.

#### (3) Procedure and Results

A. Initial optimization of parameters resulted in  $\sim 60\%$  extraction efficiency but with the E10 backleg bump and septum power supplies off and the E15 kicker off. The U165 current transformer indicated fractional extraction of 24 bunches during the 2nd and 3rd turn following the C15 kicker trigger. The explanation of these results was later unraveled as follows: The E10 septum current of 700 A was too large for the multi-turn extraction mode. Hence, protons entering the E10 aperture were lost before reaching H10 and we therefore improved efficiency by reducing the E10 bump and septum current to zero. The E15 kicker then simply restored the beam kicked by C15 back to the equilibrium orbit. With the E15 kicker off, the beam kicked at C15 executed  $3\frac{1}{2} \lambda$  of phase shift to H10 and hence little displacement at H10 occurred on the first turn. But on the second and subsequent turns the phase shift from C15 to H10 was  $\approx 12\frac{1}{4} \lambda$ . The horizontal external beam size at U15 was, however,  $> 3\frac{1}{2}$ " as expected from a direct "kick-out" technique. The width of the extracted bunches was also measured during this period to be  $\sim 100$  ns base-to-base.

B. The second attempt was to move in the E10 septum and vary the E10 septum current until the kicked beam spot was evident at H10. The E15 kicker was off. The beam spot at H10 was well-separated from the circulating beam with  $\sim 200$  A E10 current. The high field horizontal quadrupoles were also energized with current  $\lesssim 30$  A at 102 msec to increase  $v_H$  and thereby assure that the E10 to H10 phase shift was near the desired  $2\frac{1}{4} \lambda$ . The lack of significant improvement in H10 displacement vs quad current indicated that the uncorrected tune was essentially optimum. The maximum extraction efficiency in this mode was  $\sim 30\%$  and again the spot size at U15 was  $> 3\frac{1}{2}$ ".

C. A study was made with the C15 and E15 kickers to minimize the residual oscillation as observed at the I15 pick-up electrode. Amplitude and timing of the kickers were varied. It was not possible to eliminate residual oscillations for the second and

subsequent turns, but significant improvements were made. When the E10 and H10 bumps were energized we observed  $\sim 50\%$  efficiency and 3-turn extraction from the U165 transformer signal as well as the internal current transformer. Optimization was not possible due to a drift in the E10 septum current from  $\sim 0$  to 1000A. The beam spot at U15 was smaller ( $\sim 2''$ ) than in tests A and B.

#### (4) Conclusions and Recommendations

The 3-turn extraction method appears to be attainable with the C15-E15 kickers properly synchronized. The desired 70% extraction efficiency also appears possible with more tuning. Present results are comparable with those attained at 3 GeV/c on 1/19/77. We did not attempt to increase the internal beam to  $\sim 9 \times 10^{12}$  but no difficulty is anticipated if the  $\sim 20\%$  of beam with amplitude  $>$  the 1" vertical aperture of E10 is disposed of at the J19 target. Specific recommendations are:

- (1) Correct the drift in E10 current pulse.
- (2) Simplify the extraction procedure by using one instead of two power supplies for the E10 bump and one for the H10 backleg bump.
- (3) Move the "fast" current transformer from U165 to U15.
- (4) Proceed next studies with a careful optimization of C15 and E15 kicker amplitudes and horizontal tune. The time delay of E15 relative to C15 should be fixed at 529 nsec and should not be varied.
- (5) Calculations of expected external emittance and beam transport to the production target should be completed.
- (6) Explore possibility of programming the low field elliptical  $v$ -quads to vary  $v_H$  in (4) above.