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FAST-SLOW EXTRACTION AT F10 INDUCED BY THE FAST KICKER

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The purpose of this note is to report the successful accomplishment of fast-kicker-induced resonance extraction[1] in the F10 external beam channel at momentum p $\approx$ 30 BeV/c and spill duration $\approx$ 200 μsec. This mode of extraction is of considerable interest for future bubble chamber operations in the H10 external beam, giving the possibility of positioning incident particles in the chamber with a sweeping magnet and thus obtaining optimum track density over a larger fraction of the chamber volume than is presently possible with $\approx$ 10 nsec single bunch extraction[2]. The total number of useful events per picture can thereby be increased. Other advantages of "fast-slow" resonance extraction include (1) smaller horizontal emittance of the extracted beam and thus smaller size of the source for secondaries than can be attained with present FEB extraction; hence, improved mass resolution in separated beams, and (2) ability to control the quantity of extracted protons by varying the magnitude or duration of the fast kicker pulse, making possible a small spill ($\sim 10^{10}$ protons) presently accomplished with poor efficiency by diffraction scattering from an internal target.

The method for stimulating resonance extraction with the fast kicker was as follows: The beam drifted radially outward during "flat-top" toward the $\nu_h = 8\text{-}2/3$ resonance radius with the slow beam (SEB) sextupoles, backleg windings and ejector magnets energized as in normal SEB extraction[3]. At an appropriate time prior to the point when the beam equilibrium orbit crossed the resonance radius, the fast kicker was energized and imparted an angle increment to protons in a small fraction of the machine azimuth. The particles thus affected continue to execute large amplitude coherent betatron oscillations (there is no mechanism for damping transverse oscillations in the AGS) about the unperturbed equilibrium orbit. As the equilibrium orbit approached the resonance radius, the triangular region of stability in the transverse phase plane (the separatrix) contracts and eventually the "kicked" particles are no longer contained within the separatrix. The particles in the unstable region then execute betatron oscillations of increasing amplitude with the same growth rate (and thus extraction efficiency) as in the normal SEB spill, and are extracted with the F5 and F10 ejector magnets.

For the experiment reported here, flat-top start time was 873 msec, SEB sextupoles, quadrupoles, backleg windings and ejector magnets were fully energized at 900 msec and magnet cycle "invert" time was 1332 msec. The fast kicker was energized at t = 1000 msec in the single bunch mode (170 nsec rise time, 20 nsec flat-top, 300 nsec fall time[4]); thus only a small fraction of the circulating beam (2.69 μsec per revolution) was affected by the maximum fast kicker deflection. The fast kicker delay line voltage was 43 kV which corresponds to a peak dipole strength of ~ 1 kG-meter[4] and results in an angle increment of ~ 1 mrad at p = 30 BeV/c. This angle displacement is comparable to the ≈ 1.34 mrad angle width of the circulating beam which can be calculated from the relation $\Delta X' = 2\sqrt{\gamma\epsilon}$ with horizontal beam emittance taken as $E = \pi\epsilon = .102\pi$ inch-mrad and $\gamma = 4.371\ 10^{-3}$ inch^{-1} at straight section L10 obtained from calculated AGS parameters[5]. Finally, the flat-top slope was empirically adjusted so that the beam equilibrium orbit approached but did not cross the resonance radius; thus, the normal slow spill was suppressed and the part of the beam unaffected by the fast kicker remained in the machine until "invert". We were thus able to readily distinguish the fast-slow spill component at t= 1000 msec.

The spill was observed with a lucite Čerenkov counter positioned near a collimator in the "R" channel approximately 45 ft. downstream of the F10 ejector magnet and with insulated plates at the end of the "S" channel approximately 270 ft. from F10. The counter was terminated with 470Ω and had adequate frequency response ($\tau_{rc} \approx 1$ μsec); the counter signal was displayed on a Tektronix 422 oscilloscope with horizontal sweep speed of 100 μsec/div and is shown in Fig. 1. The spill exhibits peaks with ≈ 8 μsec spacing as expected since the kicked particles are in the correct radial position for extraction at F5 only once in three revolutions about the AGS. We were unable to make a reliable measurement of the amount of beam extracted with existing instrumentation; the external beam was less than 1% of the normal SEB spill ($\sim 10^{12}$ protons/pulse) as estimated from the digital readout of an integrated secondary emission counter signal. The spill was observed to be quite reproducible in amplitude, duration and start time for many consecutive AGS pulses.

Other methods have been suggested and utilized for a fast-slow spill. Reich[6] has discussed multiturn and resonance extraction techniques and shows that multiturn extraction would be inefficient for the beam size, septum thickness and spill duration of interest here. Robertson[7] has considered the interesting possibility of stimulating slow extraction by applying an rf perturbation to drive particles into the unstable region of the phase plane. The resulting spill duration and magnitude could be controlled by varying the rate of change of rf frequency and voltage. The spill will exhibit structure

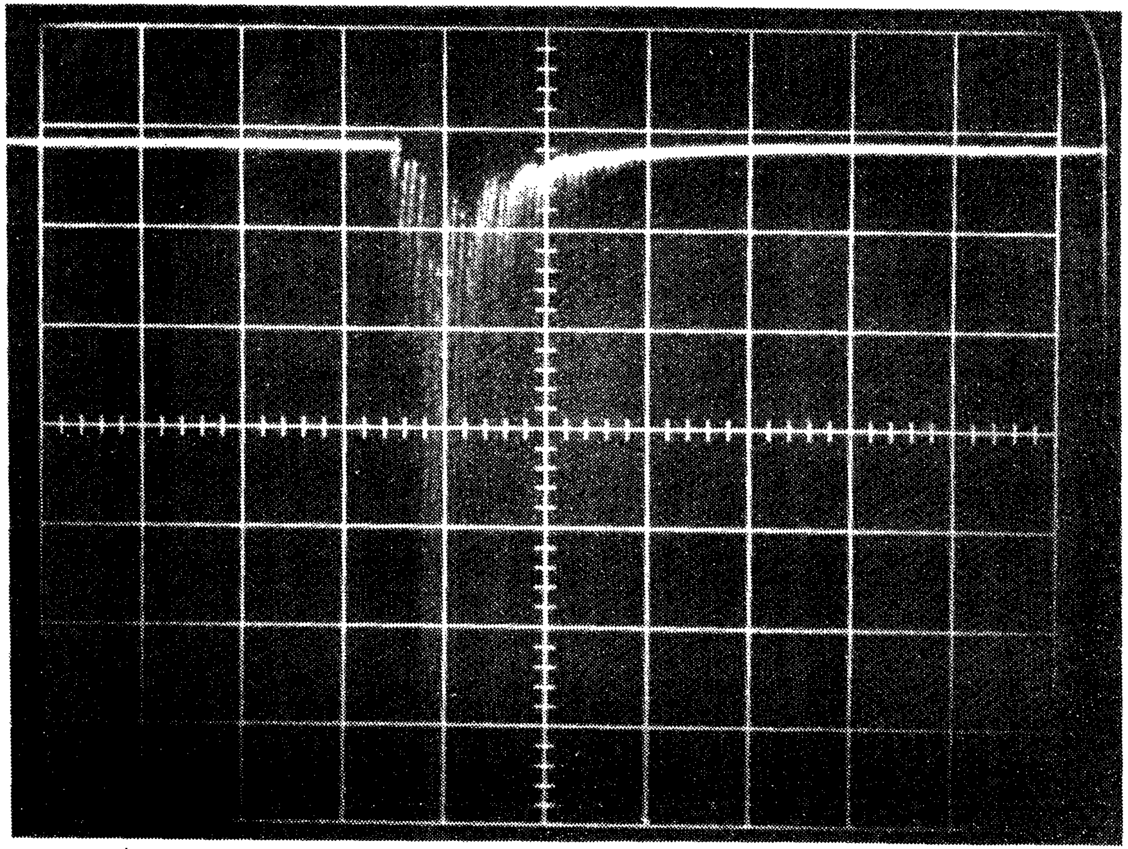

Fig. 1 Fast-slow spill induced by 20 nsec, 43 kV fast kicker pulse. Detector was lucite Čerenkov counter with 470 Ω termination viewing R20 collimator in slow external beam. Oscilloscope horizontal sweep rate is 100 μsec/div.

(4 μsec spacing) similar to the fast-kicker-induced spill. For cases where the fast-slow spill precedes a normal AGS slow spill, the rf technique could have an important advantage compared to the fast kicker method--in the latter method a "hole" remains in the circulating beam which could result in objectionable modulation of the SEB. In the rf method the circulating beam is de-populated more uniformly.

The CERN PS method for fast-slow spill has been resonance extraction at "invert" in which particles remaining in the machine after the flat-top SEB are ejected in approximately 1 msec[8]. A similar capability exists at the AGS. This method results in a spill without the structure inherent in the rf and fast kicker techniques and has the additional advantage of not perturbing the normal SEB spill. However, we are limited in this method to one spill per AGS cycle whereas the rf and fast kicker methods are capable of multiple spills per cycle with appropriate programming of the flat-top.

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References

1. Preliminary tests with an internal target by A.W. Maschke established the feasibility of this method prior to the present work (private communication, 1968).

2. J.R. Sanford (private communication, 1968).

3. M.Q. Barton and J. Faure, BNL Accel. Dept. Int. Rep. AADD-131 (1967).

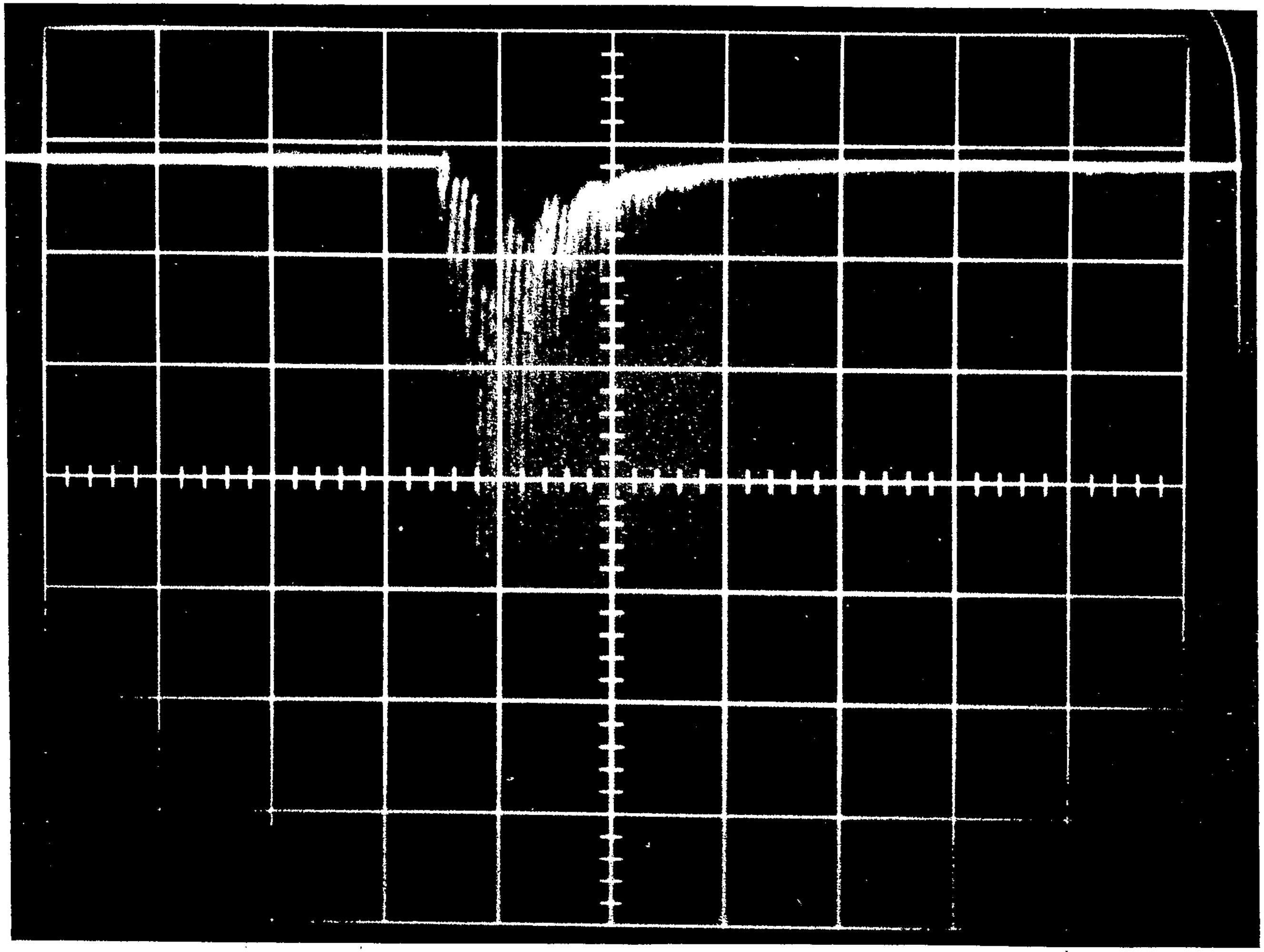
4. E.B. Forsyth, "Characteristics of the Fast Kicker," unpublished report, (November 1966).

5. M.Q. Barton, "αβγ Version of DATREP Subroutine of BEAM Code," private communication (1967).

6. K.H. Reich, BNL Accel. Dept. Int. Rep. AADD-100 (1966).

7. D.S. Robertson, BNL Accel. Dept. Int. Rep. AADD-97 (1966).

8. D. Dekkers, private communication (1968).



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