Production of positron emitting isotopes using a collective accelerator

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Experimental studies of the production of C^{11}, N^{13}, O^{15}, and F^{18} by collectively accelerated deuterons impinging on solid targets are presented.

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Collective accelerators, in which ions are accelerated by collective effects associated with the space charge of an intense relativistic electron beam, may prove attractive as alternatives to cyclotrons for the production of positron emitting isotopes, in particular because of their potentially lower cost and lower level of system complexity. We have measured the actual yield of such isotopes from collectively accelerated deuterons impinging on solid targets.

The basic experimental configuration is shown schematically in Fig. 1. A 1-MeV, 30-kA, 30-ns FWHM electron beam emitted from a 4-mm-diam tungsten cathode passes through a 20-mm-diam hole in the anode plate on axis into a 15-cm-diam drift tube. A fast gas puff valve is fired about 500 μs in advance of the electron beam pulse and produces a well confined cloud of neutral gas at the downstream side of the anode. Ionization gauge measurements of the gas cloud spatial distribution indicate that virtually all of the gas is located within 2 cm of the anode plane. Details of this configuration have been published elsewhere.[1]

For these experiments, deuterium gas was used in an attempt to produce C^{11}, N^{13}, O^{15}, and F^{18} using the reactions in Table I. These reactions were chosen because of the relatively high cross section and low threshold energies associated with them in comparison with proton induced reactions. A 1-cm-diam target was inserted into the experimental vacuum chamber and a vacuum gate valve was used to allow rapid removal of the target for activation analysis. All experiments were performed in a vacuum of 10^{-5} Torr.

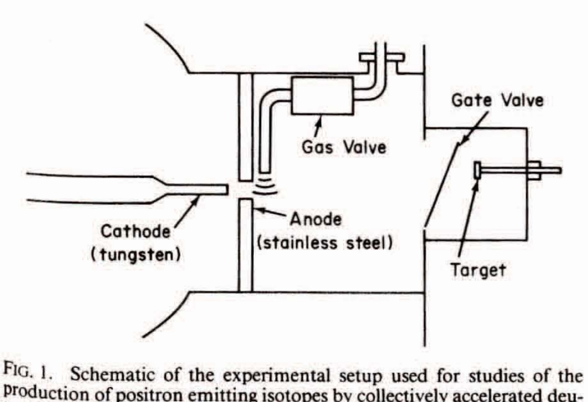

FIG. 1. Schematic of the experimental setup used for studies of the production of positron emitting isotopes by collectively accelerated deuterons.

Four different target materials were used: B, C, TiN (as a nitrogen target), and KF (as a flourine target), and the gamma spectra and half-lives of the radioisotopes produced were measured with a NaI crystal scintillation detector connected to a multichannel analyzer. Total activity was measured using a coincidence counting system of two NaI crystal detectors calibrated using a Na^{22} source of known activity. The measured half-lives of 10, 20, and 2 min are those expected for N^{13}, C^{11}, and O^{15}, respectively, and the gamma spectra for all three isotopes showed only the 0.511-MeV gamma characteristic of these isotopes. Production of F^{18} from the KF target was also demonstrated, but the level of activity was too low to measure the half-life accurately, although it was considerably longer than that of N^{13}, C^{11}, and O^{15}.

In contrast to conventional cyclotrons, collective accelerators of this type accelerate ions within a cone extending out from the anode in the axial direction. To estimate the total activity achievable by a collective ac-

TABLE I. Summary of experimental results.

Isotope	$\tau_{1/2}$ (min)	Target	Reaction	Inferred activity (μCi) (Single shot)
C^{11}	20	B	B^{10} (d,n) C^{11}	110
N^{13}	10	C	C^{12} (d,n) N^{13}	276
O^{15}	2	TiN	N^{14} (d,n) O^{15}	402
F^{18}	109	KF	F^{19} (n,2n) F^{18} F^{19} (d,t) F^{18}	7

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celerator, therefore, the activity of the 1-cm targets (whose diameter was chosen to allow accurate comparison with the calibrated Na^{22} source) must be multiplied by a correction factor obtained from measurements of the effective area over which ions are accelerated at the target position. This factor is about 10^2 for these experiments at $z = 40$ cm downstream of the anode. Obviously, the actual small target activity can be increased by moving the target closer to the anode plane. However, the intense electron currents accompanying the ions can damage the targets if they are moved too close to the anode. As a result, it is not likely that targets can be moved closer than about 20 cm from the anode plane. A summary of the results of these experiments can be seen in Table I. The activities inferred for O^{15} and F^{18} have also been corrected for the percentage by weight of nitrogen and flourine in the targets. It is apparent that total inferred activities of a few tenths of a millicurie have been achieved for a single shot for C^{11}, N^{13}, and O^{15}, but that considerably lower activities have been achieved for F^{18}. Since typical applications require activities of 1 mCi and up, it would be necessary, using this configuration, to fire several shots at a target within the half-life of the isotopes desired in order to build up the necessary total activity.

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[1] W. W. Destler, L. E. Floyd, and M. Reiser, IEEE Trans. Nucl. Sci. **NS-26**, 3 (1979).