

## Determination of beam impurities by means of x-ray spectroscopy

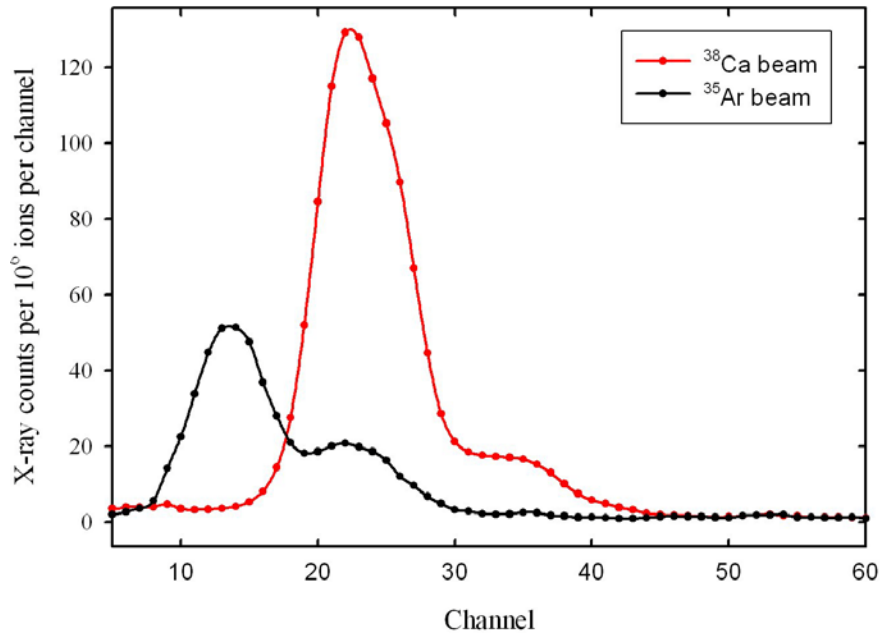
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Accurate high-precision measurements of nuclear half-lives require high-purity samples. Consequently, if the samples are prepared by implantation of a radioactive beam of the nuclide of interest, it is important (a) to ensure that the beam is as pure as possible and (b) to have an independent means of assessing quantitatively the actual contributions from contaminants.

For our half-life measurements of superallowed  $\beta$  emitters, we produce radioactive beams by directing a suitable primary heavy-ion beam at a hydrogen target and selecting the desired nuclide from the projectile-like reaction products using the Momentum Achromat Recoil Separator (MARS). However, if another reaction product has a charge-to-mass ratio similar to that of the desired nuclide, it may end up contributing to the secondary beam as an impurity. Currently we assess the contribution from impurities using a position-sensitive detector inserted at the focal plane of MARS. However, this process obviously interrupts the secondary beam, so it is only used on a periodic basis, at the beginning and end of the run, and at most once a day during the run.

Additional purification of the secondary beam is achieved because of the different ranges of the various ions in matter. The secondary beam passes through the MARS exit window, a plastic scintillator, and a series of suitably chosen degraders before reaching the 76- $\mu\text{m}$ -thick tape in which the nuclides of interest are implanted. Because of their different ranges, some impurities are stopped before reaching the tape, while some others pass entirely through the tape.

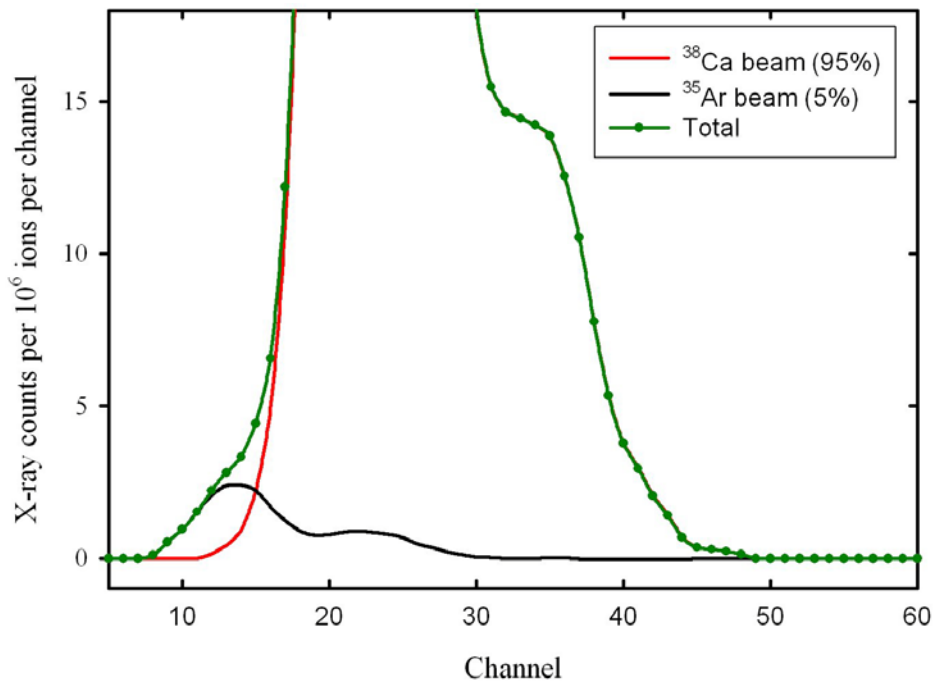
In order to investigate the feasibility of using x-ray spectroscopy to continuously monitor and



**FIG. 1.** X-ray spectra collected in the measurements with secondary beams of <sup>38</sup>Ca (red circles connected by red line) and <sup>35</sup>Ar (black circles connected by black line).

record the amount of impurities in the secondary beam based on their different atomic numbers, a PIN-diode detector was mounted behind the tape and positioned so that, for the most part, it accepts only those x rays that originate from the region near the intersection of the secondary beam and the tape. An example of the x-ray spectrum collected during measurements with a secondary beams of  $^{38}\text{Ca}$  (the beam of interest) and  $^{35}\text{Ar}$  (a potential impurity) is given in Fig. 1. The primary beam was 30 MeV/u  $^{39}\text{K}$  in both cases. The most prominent features in each spectrum are two peaks due mostly to the  $K_{\alpha}$  and  $K_{\beta}$  x-ray transitions. Note, though, that these transitions originate from atoms with a large variety of electronic configurations and velocities, so that the peak shapes, their centroids and their relative intensities may differ significantly from those observed from single-vacancy ions.

Based on the measured number of secondary-beam particles corresponding to each spectrum in Fig. 1, it was possible to construct a hypothetical background-subtracted spectrum of x rays simulating a secondary beam containing 95% of  $^{38}\text{Ca}$  ions and 5% of  $^{35}\text{Ar}$  ions. (Actual impurity levels are typically <1%.) The result is shown in Figure 2 (green circles connected with green line). Also shown in Fig. 2 are the separate contributions from each nuclide (red and black line, respectively). While the effect of the impurity on the total x-ray spectrum is relatively small, its contribution can, in principle, be assessed. The precision of the result will depend mostly on the amount of data collected.



**FIG. 2.** A hypothetical background-subtracted spectrum of x rays due to a secondary beam containing 95%  $^{38}\text{Ca}$  ions and 5%  $^{35}\text{Ar}$  ions (green circles connected with green line). Also shown are the separate contributions from each nuclide (red and black line, respectively).