Counting ^{82}Sr ions to determine the absolute β-decay yield of the 776.5 keV level in the granddaughter ^{82}Kr

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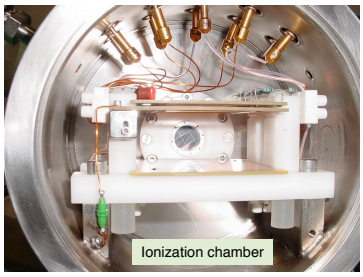
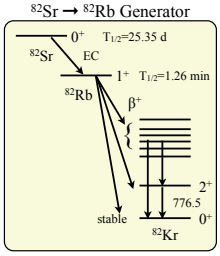


We have developed a method of counting ions prior to implantation into a foil to determine absolute decay probabilities. The technique was tested by measuring and confirming the decay probability of the 776.5 keV gamma-ray in the beta decay of ^{82}Sr→^{82}Rb→^{82}Kr. This isotope decay sequence is used by the medical community to produce ^{82}Rb (1.2575(2) min half-life) which is injected into the bloodstream to image the heart muscle using PET.

^{82}Sr → ^{82}Rb Generator



In the 70's, a value of 0.134(5) was adopted (H.-W. Muller, Nuclear Data Sheets **50**, 1 (1987)). It was reported to us by DOE that it may still be in use today. We note that in the prescribing information for CardioGen-82 (Bracco Diagnostics, 930206.SPE / K126815-011 Rev 3 (July 2010)) the decay probability of the 776.5 keV γ-ray is given as 0.13-0.15.

In 1987 two measurements were reported on samples of unknown activity:

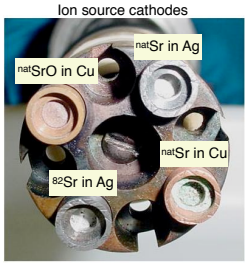
- chemical separation
- measured relative γ-emission rates using Ge detectors
- measured positron emission rates by 511 keV annihilation radiation
- calculated electron capture to positron emission rates
- must account for impurities such as ^{85}Sr

and reported in J.Applied Radiation and Isotopes, **38**, 1987

- 0.1512(18) Judge et al., p. 185
- 0.149(3) Hoppes et al., p. 195

In ENSDF today, we find 0.1508(16) - the weighted average of the 1987 measurements

Ion source cathodes



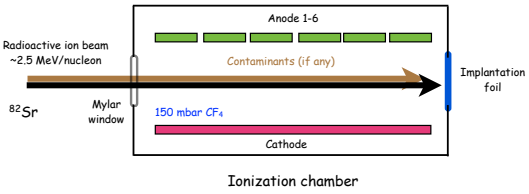
In 2010 our technique relies on:

- beam production of the desired isotope
- isotope separation by the tandem accelerator and magnets
- ion counting and identification by an ionization chamber
- commercially available γ-ray calibration sources
- measured absolute γ-emission rates using one Ge detector

Our technique has the following advantages:

- impurities are removed or identified and counted
- activity strength is measured (and tracked in time)
- standard γ-ray detection and analysis techniques
- only the very small correction for γ-ray summing is applied

Online implantation



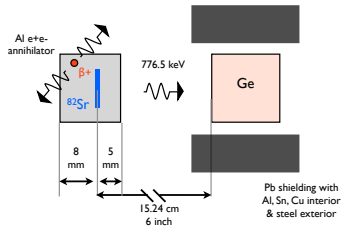
Beam techniques:

- Sr dissolved in HCl solution
- Solution dropped into Cu or Ag powder
- Mass of stable CuCl = Mass of ^{82}SrO = 98
- Ag powder cathodes sputter as well as Cu powder cathodes
- Total beam was 2300 ions/s and 66% was ^{82}Sr at 215 MeV
- Despite using Ag powder, Cu still contaminated the final beam

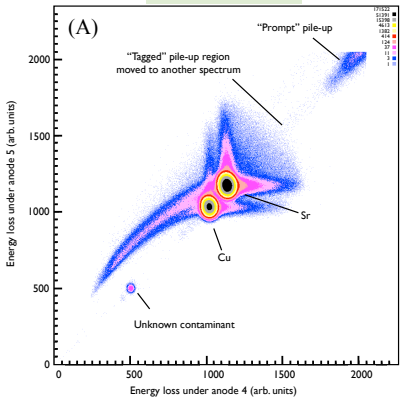
Data collection technique:

- Identify and tag ion-ion pileup events in ionization chamber
- Reduce contamination to avoid scale-down electronics
- Measure implantation efficiency (~99%) with Si detector
- Imbed 100 Hz clock in event-by-event data
- Count each ion including ions that are pile-up events
- Correct for DAQ dead-time, implantation efficiency, statistics, half-life
- Determine the number of ^{82}Sr atoms remaining in foil(s)
- Place foils in front of a well-calibrated, well-shielded, Ge detector

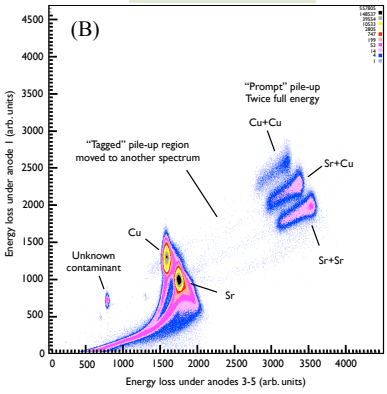
Offline γ spectroscopy



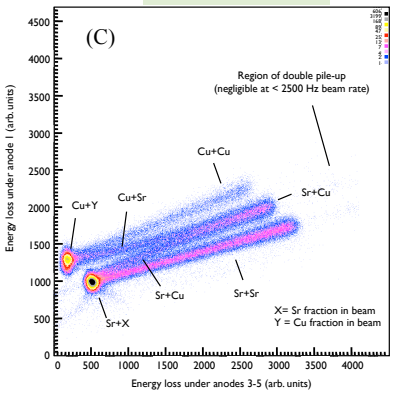
Non-pileup spectrum 99.45% of all events



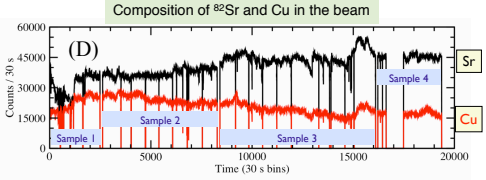
"Prompt"-pileup spectrum 0.14% of all events



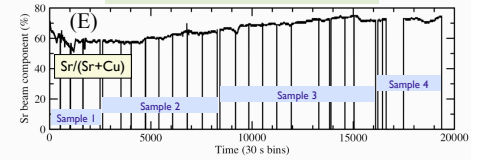
"Tagged"-pileup spectrum 0.41% of all events



Composition of ^{82}Sr and Cu in the beam



Fraction of ^{82}Sr in the beam



Implantation data:

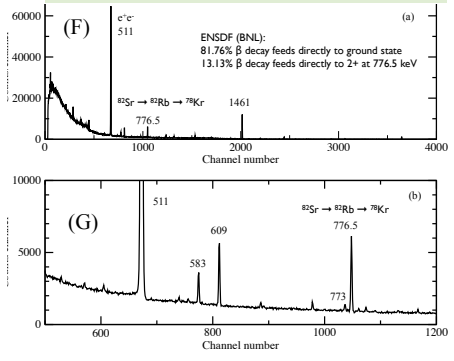
- Number of implanted atoms determined two ways and averaged:
  - Fraction of ^{82}Sr atoms in beam, see spec (E), as derived from spec (A) components times number of events identified in spec (A, B, & C)
  - Sum of ^{82}Sr atoms, shown in spec (D), derived from spec (A, B, & C)
- Apply corrections to determine the number of ^{82}Sr atoms
- At start of γ measurement: **7.264(27)x10^8 atoms of ^{82}Sr**
- DAQ dead-time contributes 34.8% of error
- Implantation efficiency contributes 65.2% of error

γ measurement for 776.5 keV transition in ^{82}Kr:

- Measurement lasted 20 days
- Total number of transitions recorded: 13660(160), see spec (F, G)
- Total number of ^{82}Sr that decayed: 1.895(34)x10^8 atoms
- Absolute detection efficiency: 0.0004872(58)
- Correction for 511 summing with 776.5 keV: 1.0088(2)
- Total number of transitions emitted: 0.2829(47)x10^8
- $T_{1/2}$(^{82}Sr) >> $T_{1/2}$(^{82}Rb), therefore we assume every ^{82}Sr decay represents a ^{82}Rb decay to ^{82}Kr
- γ efficiency contributes 24% of error
- Statistics contribute 24% of error
- Number of ^{82}Sr decays contribute 52% of error

Absolute yield per β decay: 0.1493(37)
Previously adopted value: 0.1508(16)

γ-ray decay spectrum (and region of same spectrum) of ^{82}Sr



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