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Determination of positron emission probability in the decay of ^{86}Y

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JÜLICH Forschungszentrum

বাংলাদেশ পরমাণু শক্তি কমিশন

Outline:

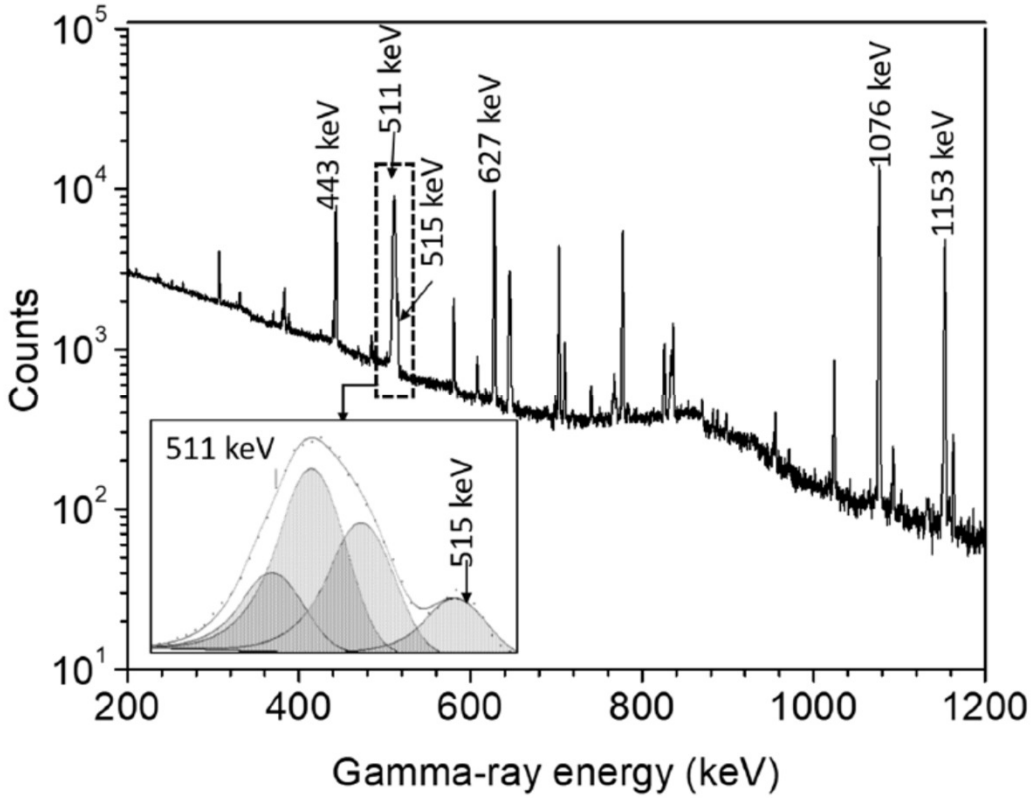
- Motivation
- Experiment and Measurements
- Corrections
- Results
- Conclusions and Outlook

Motivation:

- Emerging application of medical radionuclides: theranostic pair
- Combination of PET/targeted therapy: ^{86}Y (14.7 h)/^{90}Y (2.7 d)
- A precise knowledge of $\%P_{\beta+}$ branching of the PET nuclide ^{86}Y is needed
- Annihilation radiation 511-keV and K x-rays measurements can be used conveniently

Experiment and Measurements

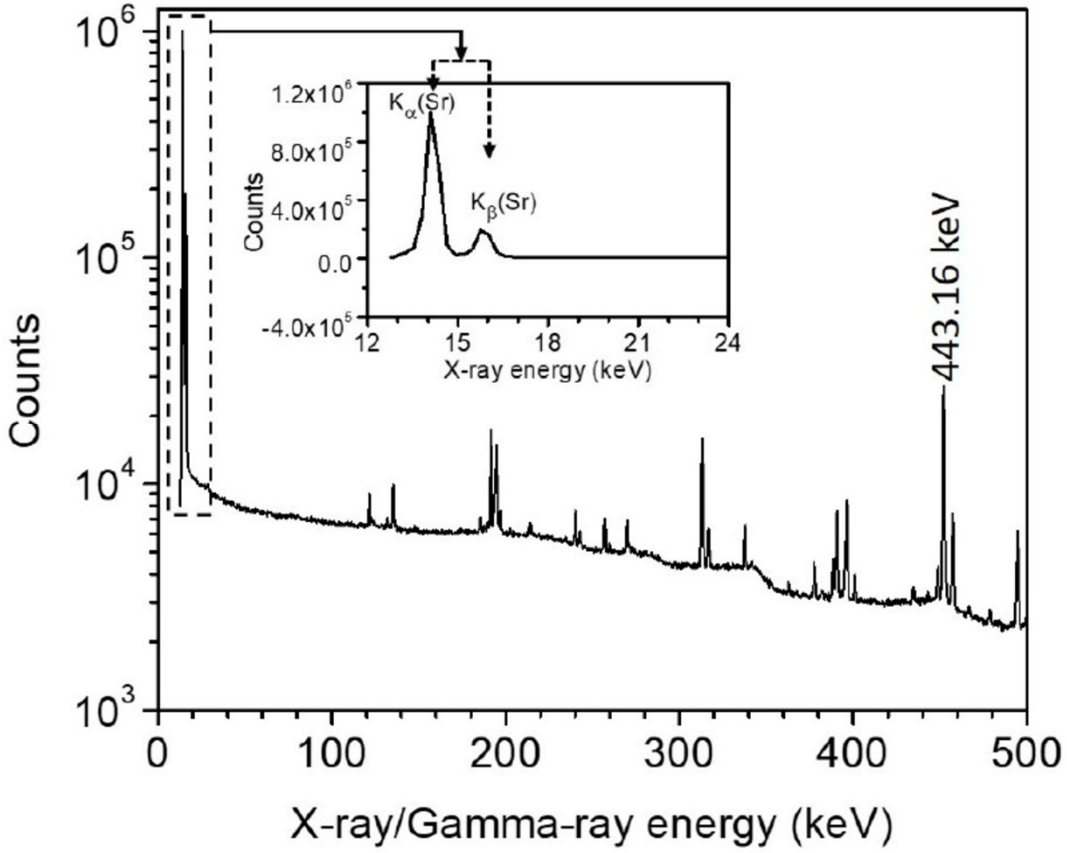
- Pure ^{86}Y was produced at Forschungszentrum Jülich:
  - Nuclear reaction: ^{86}Sr(p,n)^{86}Y
  - Target: $SrCO_3$ of enriched ^{86}Sr (96.4%): 1 cm diameter, areal density ~7.4 mg/cm^2 on Al foil
  - Beam: Ep = 8 and 7 MeV, degraded from 17 MeV
  - Irradiation: 1 h, beam current 250 nA



Experiment and Measurements

- Measurement: two HPGe detectors and another one with a Be-window (300 µm thickness; FWHM=330 eV at 5.9 keV and 540 eV at 122 keV)
- Counting geometry (511): Inside two Cu disks: diameter 3 cm, height 0.5 cm: groove – diameter 1.3 cm, depth 0.1 cm.
- Calibration: using ^{57}Co, ^{93m}Nb, ^{133}Ba, ^{210}Pb, ^{241}Am (for Be-window one)

$Q^{+}(^{86}Y)=5.24\pm0.01$ MeV

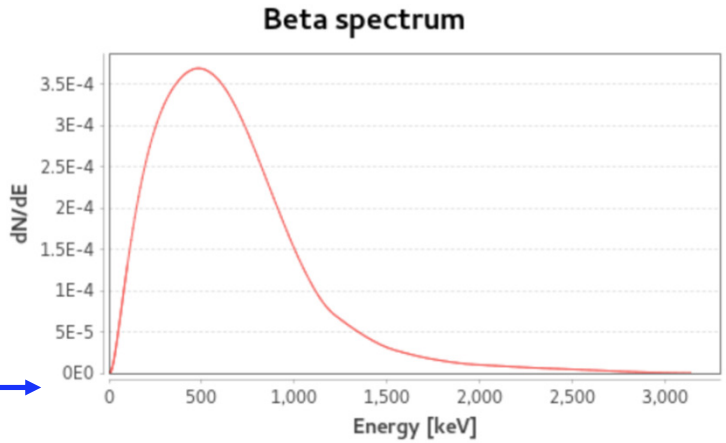


Corrections:

- For 511-keV data:
  - Counting geometry ensured localized annihilation of the positrons
  - Peak area of 511 separated from 515 keV of ^{86}Sr and efficiency corrected
  - Correction for the in-flight annihilation of the positron

$$P_\beta = 1 + \int_0^{E_{max}} S(E)P(0, E, Z)dE$$

  - Background check for a month around 511
  - 511 from pair production was negligible
  - Measurements of γ spectra with and without Cu enclosure



From the BetaShape code

Dolley, S.G. *et. al.,* Appl. Radiat. Isotopes, 129, 76, 2017

Corrections and Branching determination

- For K x-ray data:
  - Assessment of impurity
  - Conversion electron contribution was negligible
  - Pk – probability of k-shell electron capture (0.88 ± 0.02)
  - K x-ray fluorescence yield (0.69 ± 0.02)
- Branching determination: $\%P_{\beta+} + \%P\varepsilon\ (^{86}Y) = 100$

$$\beta^+ = \frac{CPS_{511\ keV\ \gamma-ray}/2\cdot\varepsilon}{CPS_{\gamma-ray}/I_\gamma\cdot\varepsilon}$$

$$EC = \frac{CPS_{X-ray}/\varepsilon\cdot FY\cdot P_K}{CPS_{\gamma-ray}/I_\gamma\cdot\varepsilon}$$

From known P_γ

$$EC = \frac{CPS_{X-ray}/\varepsilon\cdot FY\cdot P_K}{(CPS_{X-ray}/\varepsilon\cdot FY\cdot P_K) + (CPS_{511\ keV\ \gamma-ray}/2\cdot\varepsilon)}$$

From 100

Results:

- For two samples:

$\%P_{\beta+} = 27.1 \pm 1.9$

Using %Pγ (1076.6)	Using %Pγ (443.1)	For 100
72.4	73.5	72.0
71.7	73.3	72.9

- Average (of 4 values using %Pγ) = 72.7
- Average (of 2 values for 100) = 72.5

Consistency between %Pγ and total branching=100 approaches

$\%P\varepsilon = 72.6 \pm 5.2$

- Uncertainty: Propagated uncertainties of peak area, in-flight annihilation, detector efficiency, x-ray attenuation, fluorescence yield, electron capture from k-shell, etc.

Normalized Results and Literature data:

- This Work:

$\%P_{\beta+} = 27.2 \pm 2.0$ $\%P\varepsilon = 72.8 \pm 2.0$

- Literature values:

$\%P_{\beta+} = 27.9 \pm 1.2$ - Phys. Rev. C 102, 034316 - 2020Gu18

32.5 ± 2.0 - Nucl. Data Sheets 124, 1 - 2015Ne01

Good agreement of our value with that from the latest decay scheme (2020Gu18) and about 16% lower compared to that from the earlier decay scheme (2015Ne01)

Conclusions and outlook:

- We have determined $\%P_{\beta+}$ (^{86}Y(14.7 h)) = 27.2 ± 2.0 by measuring 511-keV annihilation radiation and x-rays
- The agreement is excellent (27.9 ± 1.2) with the value deduced using the latest decay scheme (2020Gu18) and about 16% lower compared to the value (32.5 ± 2.0) deduced using earlier decay scheme (2015Ne01)
- Our method provides a detailed procedure to measure positron emission probability by 511 and x-ray measurements.
- The method can also be used to check the accuracy of decay data normalization of special cases.

Collaborators:

- Forschungszentrum Jülich, Germany

  Syed M. Qaim (Leads the collaboration)
  Bernhard Scholten
  Ingo Spahn, and
  Bernd Neumaier

- Bangladesh Atomic Energy Commission

  M. Shuza Uddin

- LBNL

  Lee A. Bernstein

Thank you
Questions/Comments