CERN - INTC - 2000 - 012

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-INTC/2000-012
INTC-P121
28th of February 2000
SW200009

Proposal to the Isolde and Neutron Time-of-Flight Committee

PRECISION STUDY OF THE BETA DECAY OF ^{74}Rb.

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Abstract

We are proposing a high-resolution study of the beta decay of ^{74}Rb in order to extrapolate our precision knowledge of the superallowed beta decays from the sd and fp shells towards the medium-heavy Z=N nuclei. The primary goal is to provide new data for testing the CVC hypothesis and the unitarity condition of the CKM matrix of the Standard Model. The presented programme would involve the careful measurements of the decay properties of ^{74}Rb including the branching ratios to the excited states as well as the precise determination of the decay energy of ^{74}Rb. The experimental methods readily available at ISOLDE include high-transmission conversion electron spectroscopy, gamma-ray spectroscopy as well as the measurements of the masses of ^{74}Rb and ^{74}Kr using two complementary techniques, ISOLTRAP and MISTRAL. The experiment would rely on a high-quality ^{74}Rb beam available at ISOLDE with adequate intensity.

1. Introduction

New physical phenomena associated with nuclear structure and decays along the Z = N line are expected to arise due to the equal filling of the proton and neutron states, as well as due to the increasing Coulomb repulsion with heavier nuclei. The latter is manifested by the proximity of the proton-drip line to Z = N nuclei at and beyond A = 69. In addition, the improving knowledge of neutron-proton pairing and charge dependent effects, nuclei near and at the Z = N line provide an ideal laboratory to study fundamental symmetries in nuclei, an example being the CVC hypothesis of the weak interaction.

According to the conserved vector current (CVC) hypothesis, the matrix elements of the super-allowed Fermi β transitions between the $(J^{\pi},T) = (0^{+},1)$ states should all be equal, independent of nuclear structure apart from small terms for nucleus-dependent radiative correction δ_R and for Coulomb correction δ_C. Provided this is true, the experimental *ft* values that include isospin mixing and radiative corrections (*Ft*), allow an accurate determination of the weak vector coupling constant G_V. Up to now, super-allowed (T=1) $0^{+} \rightarrow 0^{+}$ transitions have been measured to a precision of 0.1 % or better in the decays of nine nuclei between ^{10}C and ^{54}Co [1]. This low-energy nuclear physics result, together with the muon-decay data, gives presently the most precise value for the up-down quark mixing matrix element V_{ud} in the Cabibbo-Kobayashi-Maskawa (CKM) matrix [2]. The present nuclear beta-decay result differs at the 98 % confidence level from the unitarity condition of the CKM matrix. The uncertainty quoted for V_{ud} is largely due to theoretical corrections for δ_R and δ_C. Recent free neutron decay data for V_{ud} imply also a disagreement with unitarity in accordance with the nuclear beta-decay data. For more detailed discussion, see refs. [1,3,4].

Experimentally, the true *Ft* –value is obtained using the equation:

$$Ft = \mathrm{ft}\,(1+\delta_R)\,(1-\delta_C) = \mathrm{K} / G_V'^{\,2},$$

where f is the statistical rate function, t is the partial half-life, δ_R is the nucleus-dependent radiative correction, δ_C is the correction for Coulomb effects or isospin mixing, and K is a constant. The quantity $G_V'^{\,2}$ is an effective vector coupling constant accounting for the nucleus-independent radiative correction. The leading terms in the radiative corrections are well founded [4]. Therefore, attention has to focus on the less-understood nuclear-structure dependent Coulomb correction term δ_C.

Required precision for the measurement of the half-life, the decay energy and the branching ratios are of the order of 5×10^{-4}. The decays of nine suitable nuclei have been measured with a precision high enough: ^{10}C, ^{14}O, ^{26m}Al, ^{34}Cl, ^{38m}K, ^{42}Sc, ^{46}V, ^{50}Mn and ^{54}Co [5]. Including new super-allowed emitters to this series as well as extension of the systematic study towards nuclei with higher Z along the Z=N line would be very important. Theoretical calculations in this region, where δ_C is expected to be large and subject to collective nuclear structure effects not encountered among the shell-model nuclei in the sd- and fp-shells, have not been checked experimentally so far.

With the above arguments we are proposing to study the beta-decay properties of the odd-odd Z = N nucleus ^{74}Rb. This isotope is produced at ISOLDE with a rate of about 2000 ions/s, which is adequate enough for the high-precision measurements planned in this proposal. The presented experimental programme is based on several novel techniques developed and available at ISOLDE. On top of the primary motivation, the experiment is also expected to bring new information on Coulomb displacement energies far from the region of well-known nuclei, precise information on nuclear masses and binding energies near the proton drip-line, as well as information on the coexisting deformed structures in ^{74}Kr. This has been the subject of intense theoretical and experimental in-beam studies in recent years [6,7,8].

Crucial experimental quantities to be studied are the beta-decay half-life, the decay Q-value as well as branching ratios to excited states in ^{74}Kr. The half-life of ^{74}Rb has been measured recently both at ISOLDE [9] in connection with a target development experiment (preliminary value 64.90(9) ms) and at the new ISAC facility at TRIUMF [10]. The Q_{EC} value of ^{74}Rb has been determined within a poor accuracy by mass measurements of ^{74}Rb [11] at SC-ISOLDE and ^{74}Kr [12]. However, the decays to the excited states in ^{74}Kr have not been observed. As a guiding number for the Q_{EC} value we have adopted 10.44(72) MeV as given in the 1995 Mass Evaluation [13].

2. Characterisation of the ^{74}Rb beta decay

2.1 Decay scheme

Based on our present knowledge of the levels of ^{74}Rb and ^{74}Kr a decay scheme of Fig. 1 could be constructed. It is based on the decay from the 0^+ (T = 1) ground state of ^{74}Rb. No other beta decaying states in ^{74}Rb have been reported in any of the previous studies. Its beta decay was measured recently at ISOLDE, where only the fast super-allowed beta decay could be observed [9]. No indication of the population of the first excited 2^+ state in ^{74}Kr was observed and an upper limit for the population of any higher-spin beta-decaying state was set to be 10^{-3}. Both the excited T = 0 and the ground state T = 1 rotational bands were recently identified in ^{74}Rb, the former built on the I = 3 band head and the latter on the 0^+ ground state [14]. No evidence for other β-decaying states could be observed in this study.

The level structure of the daughter nucleus ^{74}Kr has been studied in several in-beam experiments for its high spin rotational states [6] as well as specifically for its low-lying 0^+ states predicted by several theoretical calculations in association with shape coexistence phenomena [7,8]. Since, the role of low-spin states with $J^\pi = 0^+$ and 1^+ are of particular importance for our proposed experiment, we would like to discuss them here specifically. Theoretically, both spherical as well as oblate deformed 0^+ states have been predicted to occur at about 600 – 700 keV excitation energy [15]. First experimental evidence for an isomeric 0^+ state was observed at GANIL [7] and later confirmed in an experiment at the Vivitron accelerator [8], where the energy of this state was determined as 508 keV. Neither one of these two experiments could measure the branching ratio for the E2 and E0 transitions via the 2_1^+ state and to the 0^+ ground state. However, the observation of the E0 transition together with calculations allowed to deduce information on mixing between coexisting prolate and oblate shapes. Still, a comprehensive measurement is needed to determine the monopole strength to confirm the proposed scenario of prolate-oblate shape coexistence. According to ref. [7] the direct E0 decay should dominate the de-excitation of the 508 keV 0^+ state.

In order to be able to extract the branching to the known 0^+ state in ^{74}Kr it is important to measure its decay via the 52 keV E2 transition to the 2_1^+ state simultaneously with the 508 keV E0 transition. This is an important part of the present proposal and is based on the use of the broad transmission electron spectrometer ELLI developed at Jyväskylä for studying short-lived exotic conversion electron activities [16].

It is also possible that allowed beta decay to 1^+ states in ^{74}Kr could amount to a detectable fraction of the total decay and hence would influence the total branching to the ground-state transition. No experimental nor theoretical information on these states exists. However, the location of these states can be estimated, for example, by applying the well-known relationship [17] for the position of the giant GT resonance with respect to the IAS: E(GT) – E(IAS) = 6.7 - 60 T_z/A [MeV]. This estimate suggests the average energy of the 1^+ states to be around 6 MeV above the ground state of ^{74}Kr. Thus, it is expected that some of the individual states could be lower, even at 2 - 3 MeV.

2.2 Determination of the isospin mixing correction δ_{C1}^1

An estimate for the feeding of the 0^+ state can be obtained by employing a two-level mixing model based on the two observed 0^+ states in ^{74}Kr. In this case, the feeding ratio between the excited 0^+ and the ground state is expressed as $R = t_0/t_1 \equiv f_1/f_0\ \delta_{C1}^1$ [3], where f_0 and f_1 are space phase integrals. The correction δ_{C1}^1 is due to isospin mixing involved in the non-analog Fermi transition to the first excited 0^+ state. In other words, the determination of the beta feeding to the excited 0^+ state yield direct information on the amount of isospin mixing. The total Coulomb correction in the analog Fermi transition, $\delta_C = \delta_{C1}^0 + \delta_{C2}$, consists of a isospin mixing correction δ_{C1}^0, for which the correction δ_{C1}^1 provides an experimental test, and a correction δ_{C2} for the radial overlap differences between the initial and final state wave functions. The Coulomb correction has been studied widely in connection with the precise measurements on the superallowed decays from A = 10 to A = 54. However, nearly no experimental information on this effect is available for the heavier nuclei along the Z = N line. There are many theoretical investigations based on different models such as those based on the shell model and reported by Ormand and Brown [18] and those based on HF and RPA calculations of Sagawa et al. [19]. In the shell model calculation the value of the total Coulomb correction δ_C for ^{74}Rb ranges within 1 - 2 % depending on the interaction used in the calculation. If the known experimental energy of the 0^+ state is used instead of the theoretical values the isospin mixing correction δ_{C1}^1 would be as high as 3.1 %. This would lead to a branching of the order of 2.4 % for the excited 0^+ state. In the HF and RPA calculations, a significantly lower level of total Coulomb correction is obtained with δ_C = 0.75 % only [19]. Therefore, the proposed experiment could provide important information for reliable model predictions of Coulomb effects in the "heavier part" of the Z = N line for the first time.

2.3 Mass difference of ^{74}Rb and ^{74}Kr

The determination of the Q_{EC} –value for the beta decay of ^{74}Rb is the most important quantity to be measured in this work. Although this value can, in some cases, be determined from careful beta-gamma spectroscopy, it requires knowledge of the entire level scheme and it is therefore extremely difficult to ensure that nothing has been missed (e.g. a very weak branch). In fact, there are numerous cases in the atomic mass evaluation [13] where mass values determined by Q_β measurements are clearly in error due to this fact. The mass of ^{74}Rb is known to only 720 keV [13] and that of ^{74}Kr is known only to a precision of 60 keV [12]. For another estimation of the Q_{EC} value we have plotted in Figure 2 the Coulomb displacement energies for the 0^+ (T=1) states, as known experimentally and from the tabulation of ref. [13]. Using the broad systematics of Pape and Antony [20] drawn as a solid line in this figure we can get an estimate for the decay energy of ^{74}Rb to be 10.5 MeV in good agreement with the experimental value. The Coulomb displacement energies are often used in the analysis of the Wigner energy term in Z ~ N nuclei. Reliable value for the mass of ^{74}Rb would allow the studies of the trend of the Wigner energy with increasing A and investigations of the Wigner spin-isospin symmetry in general [21].

For the reasons of minimising possible systematic errors and providing the reliability of the final value we propose to measure the mass of ^{74}Rb using both MISTRAL and ISOLTRAP, two instruments unique world wide and available at ISOLDE only. The high-precision mass spectrometer MISTRAL has been designed for the measurements of masses of very short-lived nuclei, such as ^{74}Rb. The success of MISTRAL has recently been demonstrated by mass measurements of short-lived neutron-rich Na isotopes up to ^{30}Na [22-25]. Moreover, recent success in mass-measuring capability of ISOLTRAP for short-lived isotopes was demonstrated by the successful measurement of the mass of ^{33}Ar [26-29].

3. Experimental methods

3.1 Production of ^{74}Rb and ^{74}Kr

The production rate of 900 at/µC for ^{74}Rb has been measured at ISOLDE using Nb foil target (foil thickness 20 µm, target thickness 50 g/cm^2) equipped with tungsten surface ionizer (WSI) [9]. Due to a short half-life, about 98 % of the activity is still lost via decay. Thus there is some room for improvement. At the moment two possibilities can be considered: 1) use of Nb thin-foil target and 2) use of ZrO_2 fiber target. Fast release for Li out of Ta thin-foil target (foil thickness 2 µm), optimized for diffusion and effusion properties, compared to the typical Ta rolled-foil target (foil thickness 20 µm) was observed recently at ISOLDE [30]. In the case of Rb, the release out of Nb powder target is governed strongly by diffusion characteristics [31]. Assuming the diffusion to be dominant, a simple estimate based on diffusion and target thickness considerations gives a factor of 3 lower yield for ^{74}Rb for such a Nb thin-foil target compared to a typical Nb rolled-foil target. On the other hand, if assuming 19 g/cm^2 effective thickness of Zr, a calculated cross section [32] and the measured release properties for Rb out of ZrO_2 [33], about factor of 2 improvement is expected for the yield of ^{74}Rb when using a ZrO_2 fiber target. Thus, we propose the production of a ZrO_2 fiber target (similar to ZrO2-150) for the production of ^{74}Rb for these experiments. The Kr-ions could be produced with a conventional Nb-foil target equipped with a water-cooled transfer line and a plasma ion source. Note that the beamtime estimates for ^{74}Rb are based on the measured yield with the Nb foil target [9]. Especially for the decay spectroscopy this target provides already satisfactory yields.

The experiment would take an advantage of the ongoing development of the HRS separator. Strong production of $^{74,74m}Ga$ out of the Nb foil target + WSI impedes the measurements on ^{74}Rb. Fortunately, the amount of contamination can be reduced with HRS since the mass difference of ^{74}Rb and $^{74,74m}Ga$ is as high as 16 MeV. In the case of ^{74}Kr, the water-cooled transfer line prevents effectively other elements reaching the spectrometers and thus the use of HRS is not necessary.

3.2 Decay measurements

Beta-decay properties of ^{74}Rb will be studied by using the combination of electron and gamma-spectroscopy. Conversion electron measurement forms an important part of the decay study. For this purpose we will employ the broad-range electron transporter spectrometer ELLI, which was developed for studies of very short-lived radioactive decays at the IGISOL facility [16]. In this spectrometer, electrons from implanted nuclei are transported by the magnetic field over a distance of 20 cm to the cooled Si(Li) detector. The background due to gamma-rays and 511 annihilation quanta is thus strongly suppressed. Electrons can be measured in coincidence with a planar Ge-detector or with a beta-transmission detector shown in Figure 3. Both beta-decay and characteristic K-ray emission can be used for gating the electron detector. The proposed spectrometer provides ideal conditions for the conversion electron measurement in the very broad energy range. The efficiency of ELLI is more than 25 % for the 35 keV K52 transition and 10 % for the 495 keV K508 transition, and energy resolution better than 2 keV is possible.

In addition to employing a 20 mm thick planar Ge-detector in the ELLI spectrometer we also plan to use a high-efficiency Ge-detector setup based on the 70 % Eurogam detectors deployed in a separate detection geometry. This would be important inclusion in the decay study, not only to confirm the decay branch via the 2_1^+ state but also to search for higher energy transitions from possible 1^+ states populated via allowed decay.

On-line calibrations for the conversion electron spectrometer can be performed using ^{77}Rb and ^{79}Rb β decays. Multipoles of the β-delayed γ transitions ranging from 15 to 700 keV are well known in these decays allowing calculations of conversion coefficients. On-line calibrations for γ spectroscopy setup will be performed using β decays of ^{26}Na and ^{58}Mn. For both setups, off-line calibrations with standard sources will also be done.

3.3 MISTRAL for accurate mass measurements of very short-lived nuclides

The experiment MISTRAL (Mass measurements at ISOLDE with a Transmission and Radiofrequency spectrometer on-Line; IS373) is an example of a modern technique of mass spectrometry. Using a radiofrequency excitation of the kinetic energy of ions injected into a homogeneous magnetic field, this spectrometer makes not only a precise measurement of the ion cyclotron frequency, but a very rapid one since the time-of-flight through the apparatus is less than 100 microseconds. MISTRAL is a transmission spectrometer with a sensitivity of approximately 1000 ions/s and a resolving power exceeding 100,000. In its recent commissioning phase, MISTRAL measured the masses of the neutron rich Na isotopes out to A = 30, and Mg isotopes out to A = 32, including half-lives as short as 31 ms. MISTRAL was able to improve the measurement precision of the most exotic isotopes by almost an order of magnitude with a relative error of about 5×10^{-7}. Thus, MISTRAL occupies an important position amongst the myriad of mass measurement programs due to its unique combination of high precision and rapid measurement time. A detailed description of MISTRAL can be found in a recent ISC proposal [22], and in the literature [23,24]. The results are the subject of a recent PhD thesis and will soon be published [25].

^{74}Rb mass determination with MISTRAL

The ^{74}Rb half-life of about 65 ms places this isotope squarely within the realm of MISTRAL. The uncertainty of its mass value is 720 keV [13]. With the current performance of MISTRAL, this value could be reduced by almost a factor of 20 (to about 40 keV). It is important to note that not only a reduction of error bar is necessary but also confirmation, by different measurement techniques, that the measured value is not just precise, but accurate.

The sensitivity of MISTRAL has been evaluated to be between 1000 and 2000 ions/s. Comparing this to the reported yield of 2000 ions/s [9] would make the measurement feasible. Since MISTRAL is very sensitive to beam emittance and also very far from the ion source, the planned alignment of the separator beam line will help improve this figure.

3.4 Mass determinations with ISOLTRAP

The ISOLTRAP spectrometer is in operation at ISOLDE since many years and has undergone continuous improvement. Today it consists of a linear RFQ ion trap and two Penning traps [23]. The RFQ ion trap is gas filled and acts as an accumulator and buncher for the ISOLDE ion beam. The first Penning trap has the task to capture and cool the ions delivered from the RFQ-trap and to bunch them again for an efficient delivery to the second Penning trap. This trap is the actual mass spectrometer, in which the mass measurement is carried out via a determination of the cyclotron frequency $\omega_c = q/m \cdot B$ of the ions with a charge-over-mass ratio q/m stored in a magnetic field B = 6 T.

To date the ISOLTRAP experiment has very successfully measured masses of more than 100 unstable isotopes [27,28]. An accuracy of $\delta m/m = 1 \cdot 10^{-7}$ (corresponding to $\delta m < 10$ keV for $A < 100$) is typically achieved. Most of the investigated isotopes have half-lives larger than 1 s. Recently, however, it was possible to demonstrate in the case of ^{33}Ar that the technique can very well be applied to isotopes with half-lives in the 100 ms range [29]. There are two main reasons why such measurements have now become feasible: the efficiency of ISOLTRAP has been greatly improved by the installation and successful operation of the ion beam accumulator and buncher and by the development of scenarios for a very fast handling of the ions in the spectrometer.

^{74}Rb and ^{74}Kr mass determination with ISOLTRAP

The Penning trap technique offers the unique advantage, that the ions are stored in a very small volume and that the electromagnetic fields determining the cyclotron frequency of the ions can be very well controlled. Hence, systematic errors are very small. The largest contribution is the stability of the magnetic field. If a magnetic field calibration is performed every 5-8 hours then the systematic error can be constraint to be not larger than $1 \cdot 10^{-7}$. A more frequent magnetic field calibration can reduce this uncertainty considerably.

The statistical uncertainty $\delta\nu/\nu$ of the cyclotron frequency determination is given mainly by the number N of detected ions and by the resolving power $R=\nu_c/\Delta\nu_c$(fwhm) with which the measurement is performed. A rule of thumb for the statistical (1σ) accuracy achievable with ISOLTRAP is $\delta\nu/\nu = 1 \cdot R^{-1} \cdot N^{-1/2}$.

The resolving power R is depending on the line width $\Delta\nu_c(\text{fwhm}) = 0.9/T_{obs}$ of the observed cyclotron resonances which is determined by the "observation" time T_{obs} of the ion motion in the trap. From this, it becomes clear that for very short-lived isotopes the resolving power is limited. However, it is not determined by the half-life but by the fact that at least one stored ion must have survived the total observation time without decay. In practice, values of up to $T_{obs} = 3 \cdot T_{1/2}$ seem to be reasonable.

For the mass measurement of ^{74}Rb the following scenario can be envisaged. An observation time T_{obs}=150 ms of about 2 half-lives will yield a resolving power of R = 200000 ($\nu_c(^{74}\text{Rb})$=1.2 MHz). Then, a statistical accuracy of $\delta\nu/\nu = 1 \cdot 10^{-7}$ will already be achieved with about 3000 detected ions. Taking a conservative figure for the efficiency (transmission & detection) of the spectrometer of ε_{app} = 1 % and a decay loss factor of ε_{decay} = 4 % (total time of 280 ms for ion cooling and observation) results in a minimum number of about 10^7 ^{74}Rb ions to be delivered by ISOLDE. Hence, with the presently available yields (1000-2000/s) a complete measurement including frequent magnetic field calibration and systematic tests seems to be feasible in 6 shifts of beam time. The result will be a mass value for ^{74}Rb with a total uncertainty of $\delta m/m = 1 \cdot 10^{-7}$ (δm = 8 keV). In the case of a significant improvement of the yield, it is expected that an even more accurate measurement can be performed.

In the case of the long-lived ^{74}Kr a mass measurement can be performed with a resolving power exceeding R=10^6. Two shifts of beam time will be sufficient to achieve an accuracy of about $\delta m/m = 5 \cdot 10^{-8}$ (δm = 4 keV).

Both results combined will yield a decay Q-value of ^{74}Rb with an uncertainty of about 9 keV. Since such short half-lives as for ^{74}Rb represent new territory for ISOLTRAP, it is important to have a check with another technique of comparable precision. This is provided by the MISTRAL mass spectrometer.

4. Discussion on the overall precision

The proposed experiment on the beta decay of ^{74}Rb aims at reaching ultimate precision in decay energy and branching ratios to the excited states. This necessitates a careful investigation of the decay scheme also. In addition, the already well-known decay half-life could be improved for ^{74}Rb. In order to investigate the feasibility of the proposed experiment we have prepared graphical presentation to demonstrate the requirements for precision. Fig. 4 shows the error in the *Ft*-value as a function of the error in the Q_{EC} value for two different errors of partial half-life t, one from the recent ISOLDE experiment on the half-life of ^{74}Rb and the other from the global average of the well-studied 9 cases [3]. From this curve one may judge that a precision of the order of 10 keV in the mass measurements would provide a very meaningful first result for the *Ft*-value of ^{74}Rb provided that the partial half-life could be determined with a relative precision better than 10^{-3}.

5. Summary of beam request:

We propose to use HRS for Rb and GPS/HRS for Kr isotopes.

1) Decay measurement

	# of shifts	Separator	Target	Ion source
Stable beam preparation	1	HRS	Nb foil/ZrO_2 fiber	WSI
$T_{1/2}$ measurement	3	HRS	Nb foil/ZrO_2 fiber	WSI
Electron spectroscopy	4	HRS	Nb foil/ZrO_2 fiber	WSI
γ spectroscopy	3	HRS	Nb foil/ZrO_2 fiber	WSI
Calibrations	1	HRS	Nb foil/ZrO_2 fiber	WSI
Total	12			

2) MISTRAL

	# of shifts	Separator	Target	Ion source
Stable beam preparation	3	HRS	Nb foil/ZrO_2 fiber	WSI
Systematic error check(Rb's)	4	HRS	Nb foil/ZrO_2 fiber	WSI
^{74}Rb measurement	4	HRS	Nb foil/ZrO_2 fiber	WSI
Total	11			

Other constraints: MISTRAL needs the stable and radioactive beam time to be contiguous. Changing primary users greatly handicaps the experiment and takes too much time for re-tuning the beam though we can accommodate parasitic users.
date: November 2000

3) ISOLTRAP

	# of shifts	Separator	Target	Ion source
Stable beam preparation for ^{74}Kr	1	GPS/HRS	Nb foil	Plasma + cold line
^{74}Kr measurement	2	GPS/HRS	Nb foil	Plasma + cold line
Stable beam preparation for ^{74}Rb	1	HRS	Nb foil/ZrO_2 fiber	WSI
^{74}Rb measurement	6	HRS	Nb foil/ZrO_2 fiber	WSI
Total	10			

Other constraints: Running together with other users is normally possible.

4) Total

In total, we request 12 + 11 + 10 shifts = 33 shifts from which 27 are shifts with radioactive beams.

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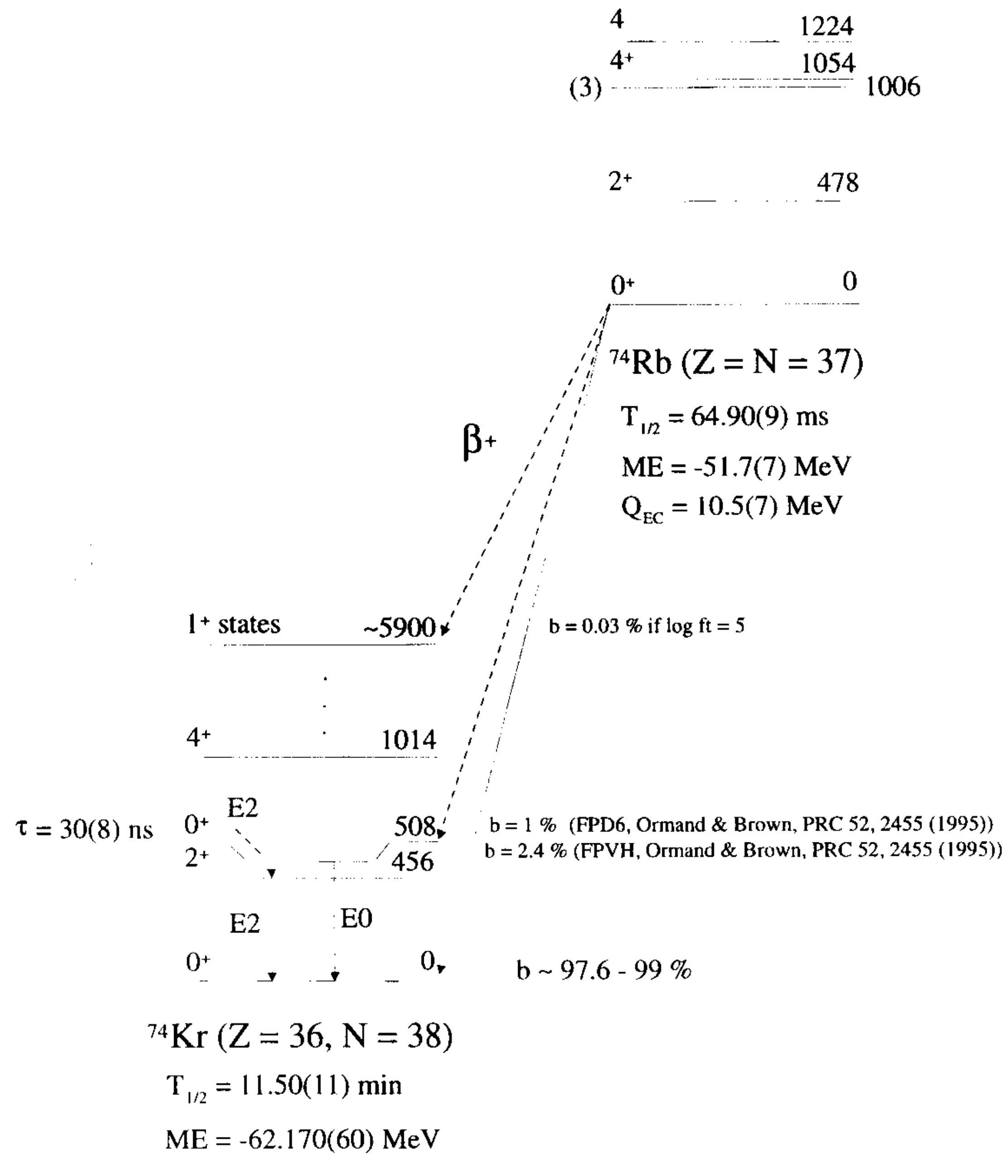

Figure 1) Expected decay scheme for ^{74}Rb. The energy for the 1^+ state is the position of the Gamow-Teller Giant resonance [17]. Branching ratio estimates for the feeding to the first excited 0^+ state is obtained from [18] by scaling the calculated result to correspond the experimental energy of 508 keV. The lifetime of 30(8) ns for the 508 keV state is weighted average from the results of [7] and [8].

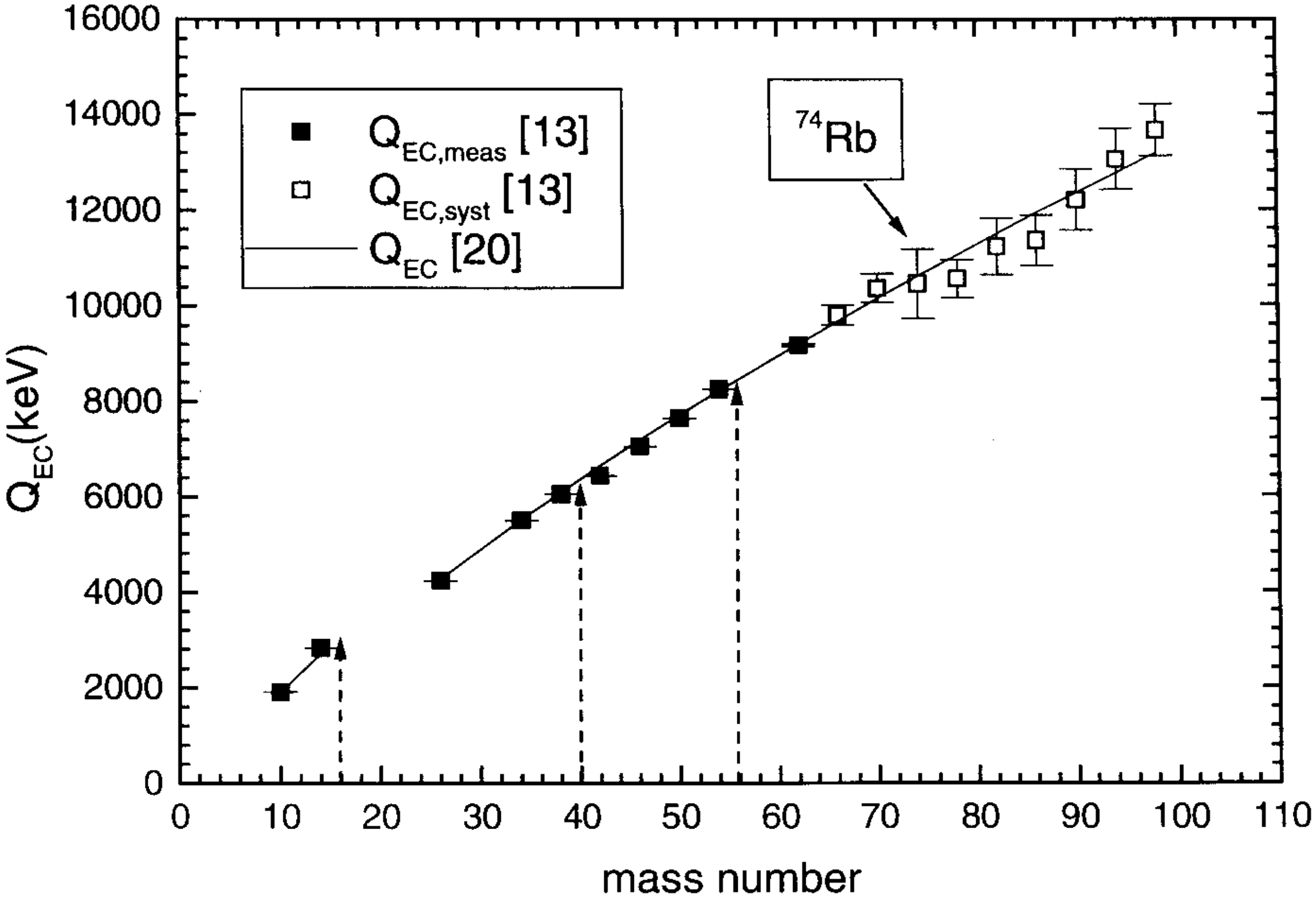

Figure 2) Decay-energy systematics of the Fermi β emitters from ^{10}O to ^{98}In based on refs. [13,20]. The vertical arrows show the positions of the doubly-magic shell closures at A = 16, 40 and 56. The figure illustrates effectively the lack of precision measurements above A = 60.

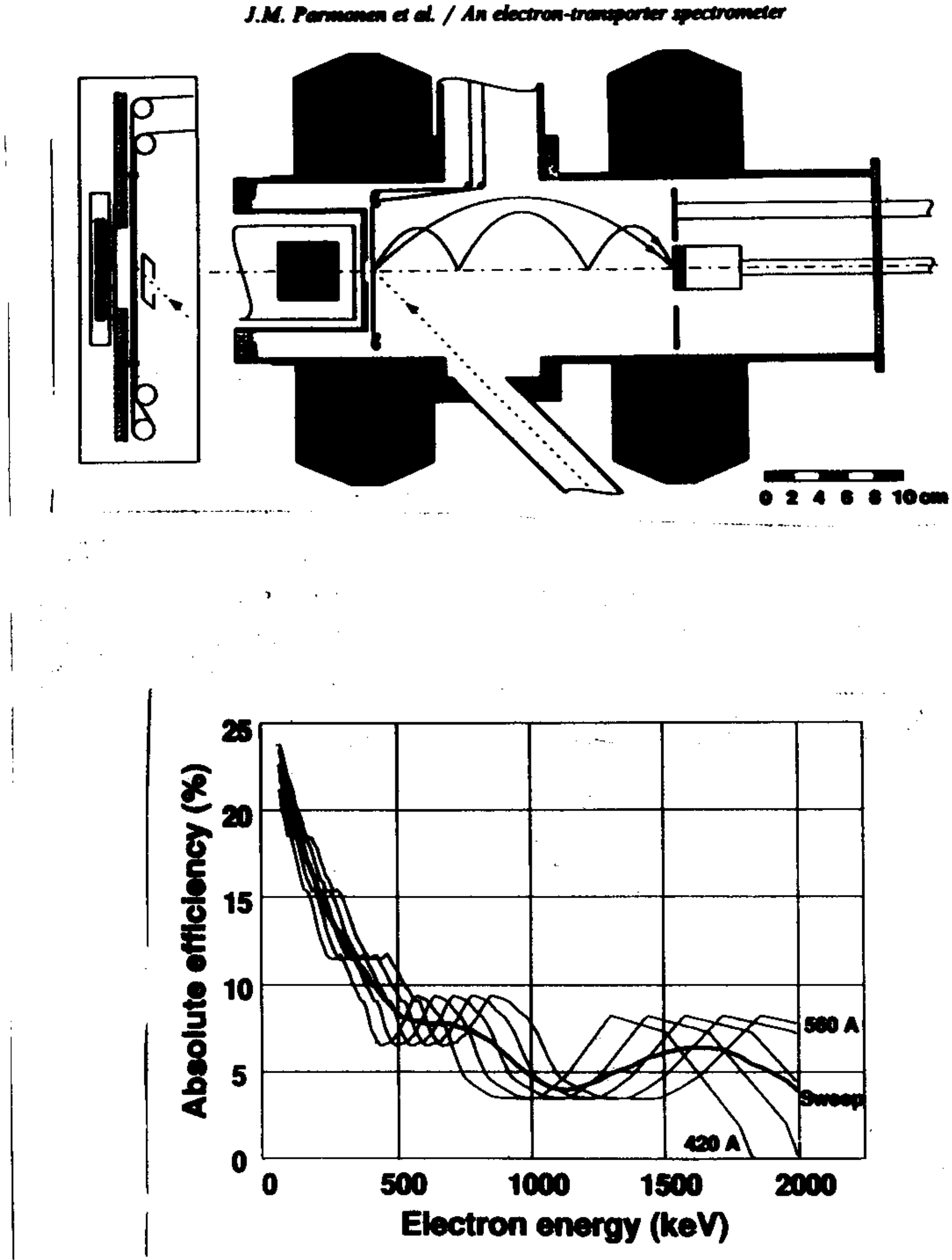

Figure 3) Lay-out of the electron transporter spectrometer ELLI (upper) and its calculated absolute efficiency curve (lower) [16]. The geometry allows an efficient reduction of γ-ray induced background in conversion electron measurements. Even 10 % effciency is possible for the electrons with 500 keV energy.

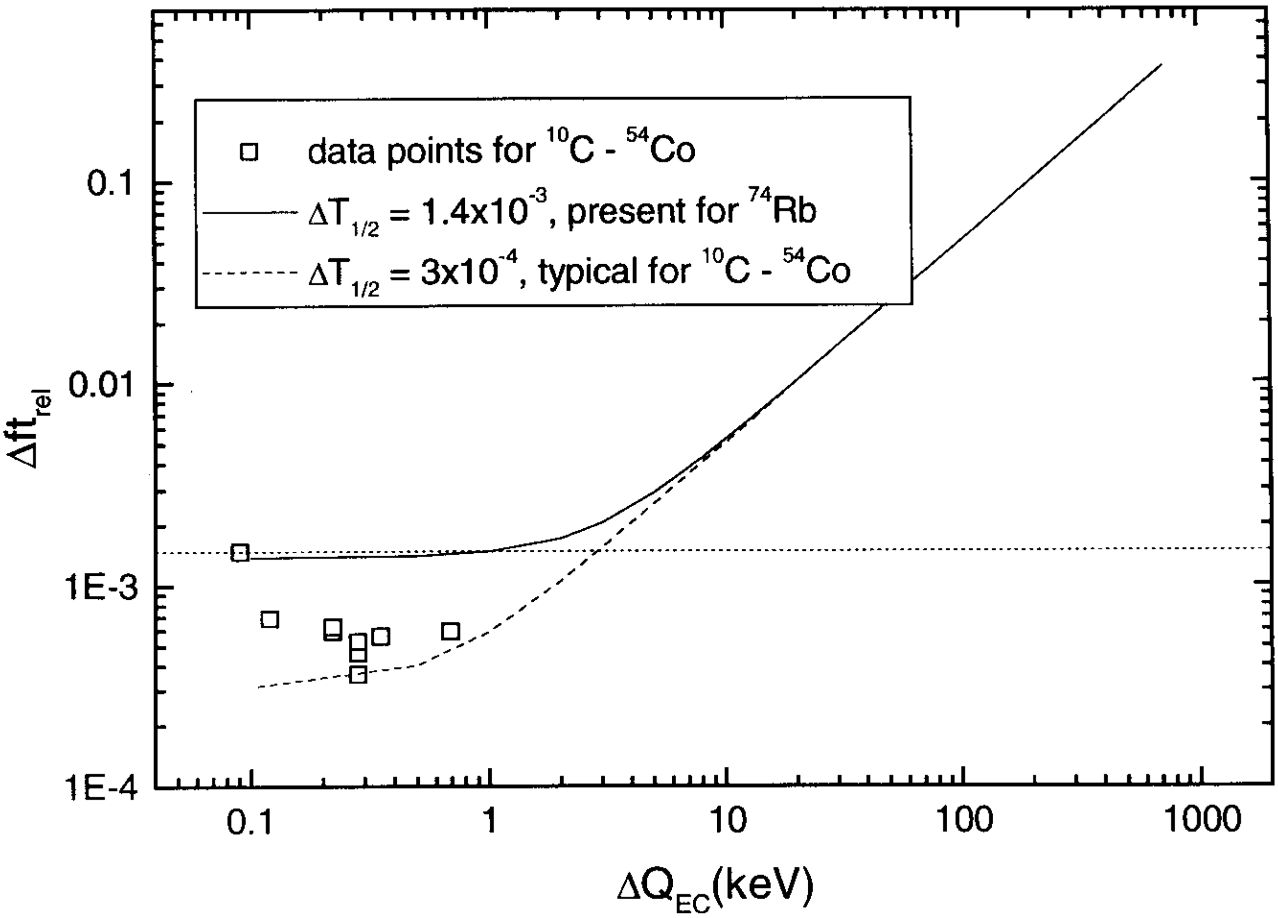

Figure 4) Requirements for the accuracies in the experimental results. The dotted line shows the upper limit of the relative accuracy in ft value for the 9 "official" members of the T = 1 Fermi decay systematics.