EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Addendum to the ISOLDE and Neutron Time-of-Flight Committee

Investigating shape coexistence in ^{80,82}Sr with β^+/EC decay spectroscopy

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Abstract: Neutron deficient ^{80,82}Sr nuclides lie in a rich structural region of the nuclear chart, where sub-shell effects may give rise to rapid shape changes. Large $E0$ strengths, $\rho^2(E0)$, are related to fluctuations in the mean-square charge radius, $\langle r^2 \rangle$, and typically associated with coexisting shapes which become mixed. Although the structure of yrast states in this region is well known from heavy-ion fusion-evaporation reactions – where a shape evolution from spherical at $N = 50$ to strongly deformed in the $N \leqslant 40$ region has been observed as a function of spin – information of non-yrast states remains scarce. Currently, there are no data on excited 0^+ states for ^{80}Sr and little information on $E0$ strengths, in general. Excited 0^+ states can, however, be populated through β-decay and Coulomb-excitation studies. Here, we propose the investigation of shape effects in ^{80,82}Sr with the β^+/EC decay of ^{80,82}Y and with the measurement of internal conversion electrons using the SPEDE electron spectrometer at the ISOLDE Decay Station (IDS), equipped with a tape station, four germanium clover detectors, two $LaBr_3$(Ce) detectors, and a fast plastic detector. These measurements will complement the investigation of the shape effects in ^{80,82}Sr using safe multi-step Coulomb excitation measurements carried out at TRIUMF, where the excited 0^+_2 state has been populated in ^{82}Sr.

Summary of requested shifts: 14 shifts (tuning and data taking)

1 INTC-P-586 Minutes

This proposal aims to investigate shape effects in ^{80,82}Sr via beta decay from ^{80,82}Y, using the SPEDE electron spectrometer at the ISOLDE decay station. The measurements aim to complement Coulex experiments at TRIUMF, where the excited 0^+ state was recently populated in ^{82}Sr.
Shape coexistence is predicted to manifest in light Sr isotopes although for ^{76,78}Sr no such states have been identified; low-lying 0^+ states have been identified however in neutron-deficient Se and Kr isotopes. A tentative 0^+ excited state has been assigned from a reaction measurement in ^{80}Sr at ∼1 MeV. Although no $E0$ transitions have been observed, the identification of such states would allow the evolution of the nuclear shape to be studied at low excitation energies. Recent TRS calculations predict a narrow separation between oblate and prolate shape minima in ^{80}Sr, motivating the search for excited 0^+ states in this nucleus.
The committee finds that there are interesting results which could be learned from this experiment especially with regard to the $E0$ state of ^{82}Sr to which the previously performed Coulomb Excitation measurements is insensitive. This measurement would be important by itself but also to allow for a proper analysis of the Coulex work. However, there are a number of points that the committee would like the collaboration to address.

Regarding ^{80}Sr the committee feels that previous measurements did not indicate the presence of an $E0$ state and the study of this isotope is of less apparent interest. In addition, previous experiments were performed at facilities where the beam was produced using fusion evaporation reactions: could the advantage that ISOLDE presents over these facilities be clarified by the collaboration?

The production of Y beams has been observed at the booster but it is possible that the yields of ^{82,80}Y could be substantially lower than the levels previously seen at the SC. The collaboration are advised to contact the target group to obtain an estimation of these yields and to re-evaluate the shift request in this light. In short, the collaboration is requested to prepare a letter of clarification to address the points above.

The INTC recommends the submission of a letter of clarification.

2 Reply to the beam production and estimates

The proposed β-decay experiment is described in detail in our original proposal and letter of intent, where relevant questions from the INTC were answered in detail (e.g., about the advantage of running these experiments at IDS/ISOLDE). Relevant to this Addendum, we focus on the beam production and estimates. First, we would like to emphasize that yields measurements of ^{80,82}Y were carried out last November 2024 and we thank the target and accelerator groups for successful delivery of the isotopes of interest. A summary of the yields measurements is provided in Table 1:

Table 1: Summary of yields with Nb foil target with CF_4 leak and hot plasma ion source.

Isotope	Yield [ions/μC]	Expected Yield [ions/μC]
$^{78}YF_2$	—	—
$^{80}YF_2$	8.3×10^2	5×10^3
$^{82}YF_2$	2.2×10^4	5×10^4
$^{84}YF_2$	5.4×10^4	—
$^{89}YF_3$	7.7×10^1	—

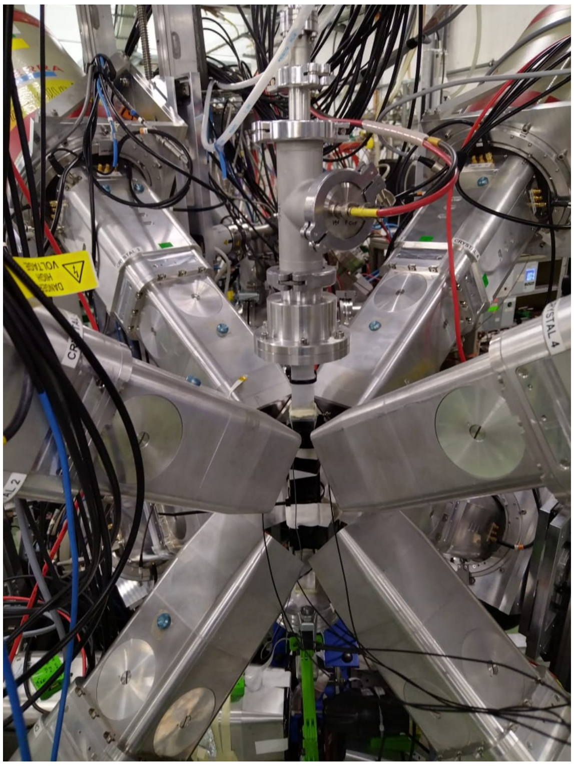

Figure 1: Experimental set up at IDS using 8 standard clover detectors.

The ^{80}Y yields came with the production of the $A = 118$ decay, which has a long half-life of 6 days, including 3 peaks in the region of interest where the excited 0_2^+ state is expected, as shown in Fig. 2. Although these contaminants could be avoided using a Molybdenum container rather than a Ta one (information provided by Ulli Koester), we shall focus on the investigation of the ^{82}Y decay following the 6 times lower than expected $^{80}YF_2$ yields and the advice of the INTC in the Letter of Intent (see Section 1). The yields measurement of $^{82}YF_2$ was about half of the expected and the beam time estimation has been changed accordingly. The updated number of shifts is provided in Table 2 with the individual estimates. The IDS setup for this yields measurements composed 8 clover and 2 $LaBr_3$ detectors and is shown in Fig. 1. Regarding ^{82}Sr, relevant γ-ray transitions connecting the excited 0_2^+ state could not be observed during the yields measurements and additional statistics are clearly needed.

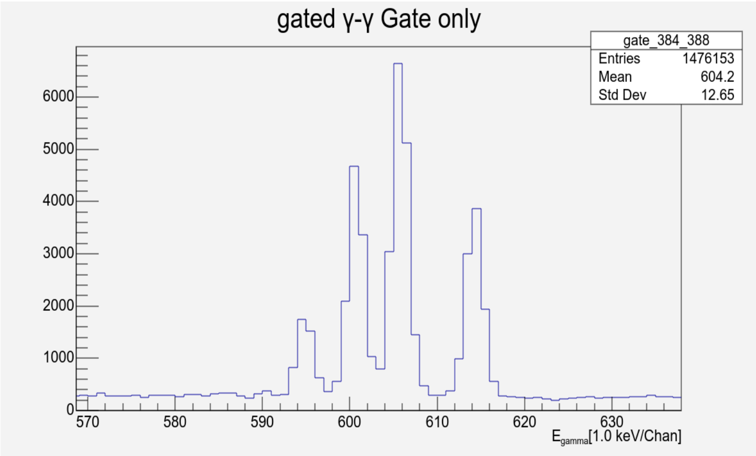

Figure 2: Gamma-gamma coincidence spectrum gated in the main 386-keV transition ($2_1^+ \rightarrow 0_1^+$) of ^{80}Sr illustrating peaks arising from the $A = 118$ decay in the region of interest for the decay of the tentative excited 0_2^+ state at approximately 1 MeV..

Table 2: New count estimates and number of shifts.

Isotope	Half-life	Yield [ions/s]	β-γ_{Ge}-γ_{Ge} [counts/shift]	β-γ_{Ge}-γ_{LaBr} [counts/shift]	$0_2^+ \rightarrow 0_1^+$ K $E0$ e$^-$ [counts/shift]	$2_\gamma^+ \rightarrow 2_1^+$ K $E0$ e$^-$ [counts/shift]	# of shifts
^{82}Y	8.3(2) s	4.4 x 10^4	4 x 10^4	1 x 10^4	140	9 x 10^4	12

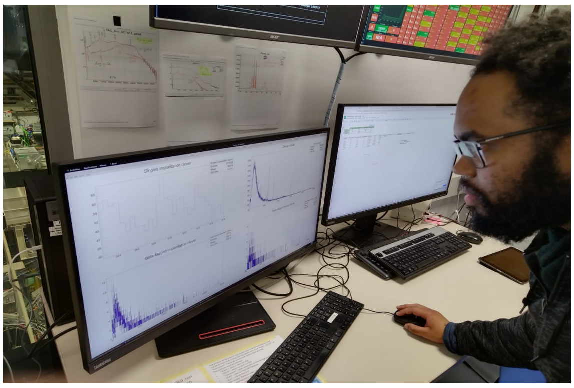

Figure 3: Manfred Jaftha looking at coincidence data at ISOLDE's control room.

This experiment is part of Manfred Jaftha's PhD work, who was also part of the yields measurements in November 2024. The estimation of 12 shifts considers the new yields measurements in November 2024 and is primarily based on the electron measurements with SPEDE. However, at the moment the SPEDE chamber has still to be manufactured and commissioned. Although we still hope to run this experiment with SPEDE before the LSD, we can still have enough coincidence data with 9 shifts aimed at gamma-gamma angular correlations. We are flexible to run at any time in 2025.

2.1 Shift breakdown

The beam request only includes the shifts requiring radioactive beam, but, for practical purposes, an overview of all the shifts is requested here.
Summary of requested shifts:

With protons	Requested shifts
Tuning of ^{82}Y	1
Optimization of experimental setup using ^{82}Y	1
Data taking, ^{82}Y	12
Calibration using isotope 2	—
Without protons	Requested shifts
Stable beam from REX-EBIS (after run)	—
Background measurement	