Towards the studies of proton ground-state radioactivities below ^{100}Sn

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Abstract. The discovery potential for new proton-emitting isotopes of elements with atomic numbers 35 < Z < 47 in a classical implantation-decay experiment is analyzed. In particular, proton separation energies and half-lives as well as the production and detection methods are discussed for nuclei below ^{100}Sn. Fusion-evaporation reactions studied by means of the Recoil Mass Separator at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory are compared to heavy-ion fragmentation based studies at the National Superconducting Cyclotron Laboratory using the A1900 separator. The *l=4* proton emitters ^{93}Ag and ^{89}Rh are identified as primary candidates to be discovered.

Keywords: proton radioactivity, fusion-evaporation reactions, heavy-ion fragmentation
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INTRODUCTION

Observation of proton-radioactive states in nuclei provides important information about the evolution of nuclear structure for extreme isospin values. The experimental data on proton activity are allowing us to identify the main proton orbital dominating the wave function. Therefore, the evolution of proton single-particle orbitals can be traced beyond the drip line. Particularly interesting is the observation of two (or more) proton-emitting states in the same nucleus, see, e.g., [1, 2]. The energy difference between the observed proton orbitals (ground-state and isomer) is related to the magnitude of spin-orbit splitting which depends strongly on the isospin value [3]. Studies of proton radioactivity offer unique data for the exploration of the origin of the spin-orbit interaction in nuclei.

Ground-state one-proton radioactivities were so far discovered for 15 elements in the region between Z=53 and Z=83, for all odd-Z nuclei except Z=61 Promethium, see [4] and this conference proceedings. There are up to four proton-emitting isotopes known for each odd-Z element in the rare earth region, where the $\pi h_{11/2}$ orbital is close to the Fermi surface. The emission of *l=5* $h_{11/2}$ protons is slowed down by the large centrifugal barrier adding to the Coulomb barrier. Proton emission competes with beta decay reaching an observable branching ratio of few percent near $S_p \approx 1$ MeV. For more exotic isotopes, proton emission begins to dominate, but a decay width around 10^{-16} MeV results in microsecond half-lives. Examples are 1.7 MeV proton emission from 2 μs ^{144}Tm [5] and from 3 μs ^{145}Tm [6, 7]. Such short-lived activities are near the observation limit for classical decay studies, since the time-of-flight through the fragment separator or recoil mass separator is a few hundred nanoseconds to a few microseconds. Hence, the S_p window for observation of proton emission is about 0.7

MeV around Z=70.

However, there are no ground-state proton radioactivities reported so far for elements below Z=50. Only highly excited multi-quasiparticle isomers ^{53m}Co [8], ^{54m}Ni [9] and ^{94m}Ag [10] were identified as proton-emitting states. The extension of proton radioactivity studies to the region below doubly-magic ^{100}Sn would allow us to understand better the evolution of masses, single-particle energies as well as the nuclear potential and decay properties of nuclei with $Z < 50$. In addition to the nuclear structure relevancy, experimental data on proton drip line nuclei are needed for better determination of the rapid proton capture process and formation of elements up to Z=52 Tellurium [11]. The properties of low-energy states in odd-Z nuclei just below ^{100}Sn are dominated by $g_{9/2}$ protons which are next to the Fermi surface. The proton emission will be slowed down by the moderately large $l=4$ centrifugal barrier. Extrapolations of known masses, see ref. [12], suggest that ^{93}Ag, ^{89}Rh, ^{85}Tc, ^{81}Nb, ^{76}Y and ^{73}Rb are among the candidates for proton radioactivity. Stable beam and target reactions to reach these nuclei require the *p4n* and *p3n* fusion-evaporation reaction channels. The decay properties of these potential proton emitters were not measured so far. Only evidence for ^{89}Rh surviving the 1.5 μs time of flight through the LISE spectrometer at GANIL has been reported [13]. The nuclei were identified via energy loss - time of flight measurement among the fragmentation products of 63 MeV/u ^{112}Sn. Tentative evidence of ^{93}Ag was obtained, too, but with statistics below the ten events required to report the identification of a new isotope (e.g., for ^{100}Sn 24 events were observed [13]). The masses of ^{93}Ag, ^{89}Rh, ^{85}Tc, ^{81}Nb, ^{76}Y and ^{73}Rb and their proton daughter nuclei are not known experimentally either. One has to rely on calculations to estimate proton separation energies and resulting half-lives. The half-life calculations for the $g_{9/2}$ proton emitters within a spherical approach [14] indicate that the Q_p energy window for detectable proton emission is about 300 keV wide. The upper limit for Q_p is defined by a half-life that is too short to be detectable in a classical radioactivity experiment. This limiting half-life value was arbitrarily selected as 0.5 μs for our analysis. The lower limit for Q_p comes from proton branching ratios that are too small to be detected. The beta transitions having Q_β values over 12 MeV and resulting half-life below 100 ms begin to dominate the decay. For example, for ^{93}Ag and ^{89}Rh both having calculated $Q_\beta \approx 12$ MeV and $T_{1/2}$ below 100 ms [17], the calculated Q_p limits are 1.02 - 0.65 MeV, and 0.94 - 0.60 MeV, respectively.

In this contribution we analyze the most likely candidates for observation of proton ground-state radioactivity for elements between Z=35 Rb and Z=47 Ag.

DECAY PROPERTIES OF PROTON EMITTERS BELOW ^{100}SN

To analyze the decay properties of ^{93}Ag and ^{89}Rh we have selected the S_p calculations within a locally adjusted shell model [15] using a small model space ($1g_{9/2}$,$2p_{1/2}$) for protons and neutrons. These calculations seem to be justified for nuclei with mass number A from about 85 up to 100. A similar approach was successful in reproducing the observed Gamow-Teller decay properties and beta strength distributions in the region of $Z \leq 50$, $N \geq 50$ nuclei near ^{100}Sn [16]. The half-lives for spherical emitters are calculated following the approach of Aberg *et al.* [14]. The results obtained using the extrapolations of S_p values by Audi *et al.* [12], Möller *et al.* [17] and Brown *et al.* [18]

are also considered below. The spherical calculations were performed also for deformed ^{85}Tc, ^{81}Nb, ^{76}Y and ^{73}Rb just for comparison purposes.

^{93}Ag, ^{89}Rh, ^{85}Tc, ^{81}Nb, ^{76}Y and ^{73}Rb

A proton decay energy of Q_p=0.95 MeV is predicted in [15] for ^{93}Ag. This value is in the middle of the very different results obtained by Audi *et al.*, S_p = -1430(780) keV [12] and Möller *et al.* quoting S_p= -0.49 MeV [17]. The Z=47 isotope ^{93}Ag is close enough to doubly magic ^{100}Sn to be approximated by a spherical shape with $\pi g_{9/2}$ ground-state. The spherical calculations [14] using Q_p=0.95 MeV for *l=4* proton emission give a half-life of about 3 μs. For $Q_p > 0.9$ MeV the proton decay width will dominate over the β-decay channel which is expected to have a partial half-life about 100 ms [17]. However, the other S_p predictions result in non-observable proton radioactivity. Beta decay will dominate if S_p= -0.49 MeV. The ^{93}Ag activity will be much too short-lived to be detected for 1.4 MeV proton emission. The topology of the mass surface near ^{93}Ag will be perhaps better understood after mass measurements aimed at clarifying of the reported proton and two-proton emission from neighboring ^{94m}Ag [10, 19] discussed at this conference.

The Q_p value of 0.64 MeV predicted in [15] for Z=45 ^{89}Rh allows the proton branch to compete with β^+ and electron capture decay. The calculated half-life of 8 ms indicates that spherical *l=4* proton emission can be ten times faster than β-decay [17]. The S_p predictions of Möller *et al.* and Audi *et al.* are -0.5 MeV and -0.7(2) MeV, respectively. These values are relatively close to the Herndl-Brown value. However, the S_p of -0.5 MeV corresponds to partial proton half-life of about 5 seconds. In such case ^{89}Rh decay will be dominated by beta transitions and the proton branching ratio will be only about 2%. An S_p around -0.7 MeV gives almost 100% proton emission probability, with a half-life about 300 μs. These proton half-life predictions indicate that ^{89}Rh is a reasonably good candidate for observing ground-state proton radioactivity.

The proton decay energy of ^{85}Tc calculated in [15] is 0.85 MeV. The same value, however with a large error of 570 keV, results from the Audi *et al.* extrapolation [12]. The nucleus ^{85}Tc is 200 keV more bound according to Möller *et al.* calculating the S_p value as -0.66 MeV [17]. The Z=43 isotope ^{85}Tc is below the $\pi g_{9/2}$ mid-shell. Its nearly spherical shape, as for ^{93}Ag and ^{89}Rh, minimizes the ground-state's total energy according to [20]. The calculated half-life for spherical $g_{9/2}$ proton emission is around 1 μs for S_p= -0.85 MeV. However, the assumption of the spherical shape and half-life estimates for ^{85}Tc are not justified here, since neighboring ^{86}Mo [21] and ^{86}Nb [22] are known to be well deformed. The 5/2+[422] Nilsson orbital originating from the $\pi g_{9/2}$ was proposed as a ground-state configuration for ^{85}Tc by Janas *et al.* [23]. In such a case, the presence of a small *l=2* component in the ground-state wave function might result in a half-life even below 100 ns for Q_p=0.85 MeV. The energy difference between the $\pi g_{9/2}$ and *l=2* d-orbitals in the vicinity of proton drip line near $Z \approx 40$ is critical for

the estimation of the structure of the ^{85}Tc wave function.

A large deformation is expected for the Z=41 isotope ^{81}Nb. A quadrupole deformation parameter as large as β_2 = 0.46 was calculated by Möller *et al.* for the ^{81}Nb ground-state [20]. It is hard to make a reliable prediction of the wave function for the ground-state of this proton unbound isotope. The Nilsson orbital $3/2^-$[301] arising from negative parity $\pi f_{5/2}$ or one of the positive parity Nilsson states (5/2+[422],3/2+[431]) from the $\pi g_{9/2}$ state can minimize the ground-state energy and contribute to proton emission. Janas *et al.* considered even the 1/2+[431] orbital originating from $\pi g_{7/2}$ state above Z=50. The spherical calculations by Herndl and Brown do not apply here. The Audi *et al* extrapolation yields an S_p of -0.75 MeV, while Möller *et al.* obtain S_p= -1.00 MeV. A Q_p of 0.85 MeV might result in detectable proton activity for *l=4* emission ($T_{1/2} \approx 2$ μs). Proton emission with lower angular momentum shifts the half-life into the 100 ns range, which makes it hard to detect in a classical decay spectroscopy study.

The ground-state wave function of the deformed odd-odd nucleus ^{76}Y is complex. A large deformation (β_2 near 0.4 according to [20]) and coupling between the odd proton and odd neutron makes the predictions of its decay properties uncertain. Möller *et al.* calculations suggest the Nilsson orbitals originating from the $g_{9/2}$ state for both protons and neutrons which minimizes the energy of positive parity ground-state configuration. However, one can deduce the probable ground-state configuration of ^{76}Y from the structure of the mirror nucleus, the Z=37 and N=39 ^{76}Rb [24]. For ^{76}Y, a (1^-) ground-state can result from the coupling of π5/2+[422] and $\nu 3/2^-$[312] Nilsson orbitals. Such a ground-state configuration will have a component decaying via the *l=2* proton transition to the $\nu 3/2^-$[312] state in ^{75}Sr. However, this $3/2^-$ state is not necessarily the ground-state of ^{75}Sr. For example, Möller *et al.* predict the 3/2+[431] orbital minimizes the energy of ^{75}Sr. The corresponding $3/2^-$ and 3/2+ neutron levels are within 38 keV in the mirror nucleus ^{75}Rb [25]. Predicted S_p values are near -0.6 MeV (-0.63 MeV [12] and -0.57 MeV [17]). The *l=2* emission might result in microsecond half-lives. However, larger orbital momentum and/or a more complex wave function structure with only a small fraction of proton-radioactive component can increase the half-life and make the detection possible.

The nucleus ^{73}Rb is a candidate for a short-lived proton emitter. Its proton separation energy was calculated by Brown *et al.* as -0.55 MeV [18], similar to the value of -600(150) keV estimated by Audi *et al.* [12]. Möller *et al.* predicted ^{73}Rb to be more unbound and with S_p of -0.8 MeV. For the S_p= -0.55 MeV, the assumption of the emission of *l=3* $f_{5/2}$ proton gives a half-life of about 20 μs. This value quoted here for demonstration purposes is obtained assuming the ^{73}Rb wave function as a spherical 100% $\pi f_{5/2} x 0^+$ configuration. This is not a realistic picture since a strong quadrupole deformation can be expected for ^{73}Rb (β_2=0.37 [20]). According to [17, 20] the ground-state configuration of ^{73}Rb can be related to the $3/2^+$[431] Nilsson state originating from $\pi g_{9/2}$ orbital. Therefore, its complex wave function can have small components triggering *l=2* proton emission to the 0^+ ground-state of deformed ^{72}Kr. However, the resulting half-life can be still in the detectable microsecond range. Janas *et al.*

obtained the $3/2^-[312]$ orbital, with only 9% contribution of the original $\pi p_{3/2}$ state as a configuration minimizing the ground-state energy of ^{73}Rb. In such case, the *l=1*, 0.55 MeV proton emission with a half-life below 50 ns would not be detectable in a classical decay experiment.

PRODUCTION OF PROTON EMITTERS BELOW ^{100}SN

Two alternative approaches are considered. The classical method proven to be very successful in the studies of proton radioactivity is based on fusion-evaporation reactions studied by means of a recoil mass separator. Almost all proton emitters were discovered using this technique. However, the limits of known nuclei below ^{100}Sn were mostly delineated using fragmentation of energetic heavy-ions. Fragmentation has specific advantages such as tracking of identified products and short time-of-flight required for separation of fragments. However, the energy deposition and range straggling of an implanted fragment is much larger when compared to fusion-evaporation reactions and makes the decay studies of short-lived activities difficult. The cross section for exotic nuclei is much larger in fusion-evaporation reactions. The yields for potential proton emitters below ^{100}Sn expected from both techniques are discussed below.

Fusion-evaporation reactions

The reactions between projectiles and targets of ^{32}S, ^{40}Ca, ^{46}Ti, ^{54}Fe and ^{58}Ni investigated at the Recoil Mass Separator (RMS) [26] at HRIBF are considered here for the identification of proton emitters below ^{100}Sn. The RMS has excellent primary beam rejection capability allowing us to run with high intensity primary beams accelerated by the 25 MV Tandem. The scattered beam contribution, even for symmetric reactions such as ^{54}Fe beam on a ^{58}Ni target, is around 1% of the total intensity of fusion-evaporation products reaching the implantation detectors at the RMS final focus. A dedicated rotating target device was designed and assembled to withstand high beam currents, see Fig 1. The target foil mounted on the frame has about 14 mm diameter; a ring of 7 mm diameter and about 1 to 2 mm wide is irradiated, see Fig.1. Beam intensities as high as 50 particle-nA of 207 MeV ^{54}Fe was used to irradiate the 300 μg/cm^2 thick ^{58}Ni target. The linear velocity of the target spot exposed to beam heating can reach 0.36 m/s although in the presented case it was 1/3 of this value.

The recoiling products are separated by the RMS according to their mass-to-charge ratio. The transmission efficiency, for the RMS ion optics allowing us to collect the recoils in two neighboring charge states, is about 4 to 5% [26]. For high primary beam currents at the level of 40-50 particle-nA, the ion rate at the RMS final focus is several thousand ions per second. The recoils pass through a position-sensitive micro-channel plate detector (MCP) [27] after about 2 microseconds time-of-flight between the target and RMS final focus. The MCP provides reference signals, for the implantation time and position (mass over charge ratio) of recoils at the dispersive RMS focal plane. Finally, the selected reaction products are implanted into a Double-sided Silicon Strip Detector (DSSD). The large kinetic energy of un-degraded recoils produced in symmetric reac-

FIGURE 1. Left panel : Rotating target device with 14 mm diameter 300 μg/cm^2 ^{58}Ni target is mounted in the RMS target chamber. Right panel : The back side of the ^{58}Ni target used during the tests with high-intensity 207 MeV ^{54}Fe Tandem beam is shown. There are four mounting spots visible at the edge of the foil. The dark ring shows the irradiated area of the target foil. Two round brighter spots indicate places irradiated with 20-25 particle-nA beams during short stops of target rotation.

tions results in deep implantation into the DSSD. Protons emitted with energies lower than 1 MeV are detected with nearly 100% efficiency in the 65 micron-thick DSSD. The ion and subsequent decay signals are recorded using digital data acquisition [28, 29] based on XIA Digital Gamma Finder (DGF) modules [30]. The "proton-catcher" signal acquisition mode [7] can be used to detect proton activities with microsecond half-lives. In "proton-catcher" mode only the digital images of pile-up signals are preselected on-board in the DGF. This very selective mode allows us to run the data acquisition practically without dead time despite the high recoil rate. The pile-up traces of the preamplifier signals are identified with full efficiency for the time difference between the recoil and decay signal from about 500 ns to 40 μs.

The rate calculations below assume :
- 100 hours of 50 particle-nA beam
- 300 μg/cm^2 rotating target
- 10 nb production cross section for the *p4n* fusion-evaporation reaction channel
- 5% recoil mass separator efficiency
- 100% low energy proton detection efficiency.

Beams of ^{58}Ni and ^{54}Fe on ^{40}Ca targets should be selected to produce ^{93}Ag ($T_{1/2}^{calc}$=3 μs) and ^{89}Rh ($T_{1/2}^{calc}$= 8 ms). The estimated proton yields of 140 counts and 250 counts, respectively, suggest that the identification of these new activities could be done even without optimal experimental conditions and/or within a time shorter than 100 hours. However, since the uncertainties in the predicted half-lives are large, at least 7 days seem to be necessary to attempt to identify these unknown activities.

Intense ^{32}S beam available at the HRIBF can be utilized to search for ^{85}Tc ($T_{1/2}^{calc}$=1 μs), ^{81}Nb ($T_{1/2}^{calc}$=3 μs) and ^{73}Rb ($T_{1/2}^{calc}$=20 μs). Total counting statistics of 30, 110 and 150 proton events can be expected for the reactions on ^{58}Ni, ^{54}Fe and ^{46}Ti targets, respectively. For these activities the counting rate estimations have very large uncertainties resulting from estimated half-lives.

The nucleus ^{76}Y can be produced at the HRIBF using a symmetric reaction between

^{40}Ca projectiles and target in a *p3n* evaporation channel. However, even cross sections at the 100 nb level might not be large enough to identify this potentially sub-microsecond activity after 2 μs time-of-flight between the target and RMS final focus. The assumption of 1 μs half-life leads to the estimate of about 90 proton counts during 100 hours experiment with 10 particle-nA of ^{40}Ca beam.

Fragmentation reactions

The NSCL facility presently offers the best rates for proton-rich fragmentation products in the mass region A=45 to 60, see, e.g., [31, 32]. Therefore, the potential of identification of new proton activities below ^{100}Sn in fragmentation reactions at NSCL is analyzed here. The production rates of ^{93}Ag, ^{89}Rh, ^{85}Tc, ^{81}Nb, ^{76}Y and ^{73}Rb at the A1900 fragment separator are calculated using LISE simulations [33]. Projectiles of ^{112}Sn, ^{107}Ag, ^{106}Cd, ^{92}Mo and ^{90}Zr at 140 MeV/u and 0.1 particle-nA intensity are used in the calculations as primary beams. The ^{9}Be target thickness, typically 350 to 550 mg/cm^2, is optimized for each beam and product combination. The cross section extrapolations are done with EPAX 2.15 [34]. The image and focal plane slits of A1900 were assumed to be fully open. A time-of-flight of 1 μs is included in our estimates. Implantation into a thick Si detector(s) covering the full fragment range distribution is assumed. The efficiency of low energy proton detection is also taken as 100%. The energy deposition of heavy fragments in the implantation Si detector will be very large, at the level of several GeV. Dedicated "linear-logarithmic" preamplifiers, which have recently become commercially available [35], might eventually help to detect a few GeV signal quickly followed by a 1 MeV proton pulse. Examples of response functions of such preamplifiers are given in Fig.2. Low energy signals should be linearly amplified up to the hardware-selected upper threshold such as 5 MeV or 10 MeV, see left panel of Fig.2. For the signals above this threshold, the response of the preamplifier should be logarithmic. However, the preamplifier should not saturate. In the measured trace of a few GeV heavy-ion signal, the flat saturation part occurs for about 2 μs. During this time the detection of a small signal following the ion implantation is not possible. This saturation effect should be investigated further. However, it might be difficult to detect the low energy proton signal occurring soon after the fragment implantation, even without the saturation effect. The total amplitude of the fragment implantation signal plus proton signal will be above the linear threshold, so the logarithmic preamplifier response might make the small proton signal hard to distinguish from the baseline noise.

For the present calculations a preamplifier saturation dead time of 2 μs was included in the rate estimates. A counting time of 100 hours, the same as for fusion-evaporation based studies, was assumed. The resulting total proton events rates are given in Table 1.

Tentative evidence for the production of ^{93}Ag and ^{89}Rh in the fragmentation of 63 MeV/u ^{112}Sn projectiles on 144 mg/cm^2 thick ^{58}Ni target [13] was not confirmed in an experiment fragmenting 1 GeV/u beam of ^{112}Sn with 4 g/cm^2 ^{9}Be target [36]. However, the different reaction mechanism and spectrometer settings in these two experiments might be responsible for the discrepancy. Production of ^{93}Ag and ^{89}Rh in fragmentation processes should be verified and better understood. The rates quoted in Table

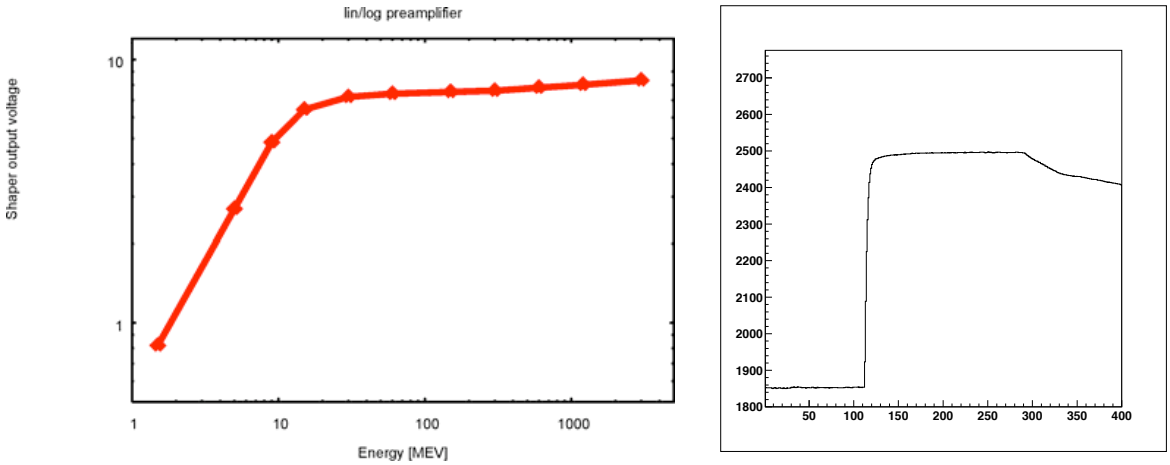

FIGURE 2. Left panel: the response function of the linear-logarithmic preamplifier to low and large amplitude signals [35]. Right panel: a trace of a few GeV ion implantation signal measured with 100 MHz Pixie-16 spectrometer [30] at the NSCL. The amplitude (relative units) is sampled every 10 ns.

1 clearly indicate that the intermediate energy fragmentation of several projectiles investigated at the A1900 spectrometer has a chance of success. However, the nuclei of ^{85}Tc, ^{81}Nb and ^{73}Rb were consistently not observed in several fragmentation studies [37, 38, 23, 39]. Half-life limits were evaluated after these studies accounting for the time-of-flight through the spectrometer and cross section predictions. These half-life limits are quoted as 110 ns, 44 ns and 30 ns for ^{85}Tc, ^{81}Nb and ^{73}Rb, respectively. In the most recent study using ^{107}Ag beam at 750 MeV/u at the GSI Fragment Separator (FRS) [22], the neighboring activities of ^{82m}Nb and ^{86m}Tc were detected and studied with γ-spectroscopy. The total number of implanted ions was about 4500 and about 7700 for ^{82}Nb and ^{86}Tc, respectively. Despite the fact that the FRS was optimized to transmit nuclei with N=Z, the non-observation of ^{81}Nb and ^{85}Tc now appears quite conclusive. Very likely, the half-lives of these proton-unbound nuclei are too short to survive the sub-microsecond time-of-flight through the FRS [22].

For ^{76}Y, two events identified in [39] might indicate that the half-life of this nucleus is longer than 170 ns, hence there is a chance to observe proton emission in a dedicated fragmentation or fusion-evaporation study.

CONCLUSIONS

The discovery of ground-state proton radioactivity below doubly magic ^{100}Sn is not a trivial task. In fact, the classical implantation-decay studies may fail completely, if the half-lives of all candidates are below the 100 ns level. In such cases, new techniques of the studies of radioactive ions are needed. The investigation of ^{19}Mg, discussed at this conference [40], relied on tracking of the daughter nucleus and the emitted protons and may suggest a viable option. For nuclei with half-life within 100 - 500 ns range, one can consider the fusion-evaporation reactions at the next generation radioactive beam facilities. The intense beams of ^{56}Ni or ^{30}S, and the use of high-transmission short time

TABLE 1. The total proton counting rates predicted for the experiments lasting 100 hours with A1900 fragment separator and 0.1 particle-nA beams at the NSCL. The rates, calculated assuming the half-life values listed in the table, were rounded to the first significant digit. See text for the input values to LISE simulations [33].

	assumed $T_{1/2}$ (μs)	**^{112}Sn**	**^{107}Ag**	**^{106}Cd**	**^{92}Mo**	**^{90}Zr**
^{93}Ag	3	40	10	100	-	-
^{89}Rh	8000	400	200	1000	-	-
^{85}Tc	1	200	100	500	-	-
^{81}Nb	3	2000	2000	6000	10000	-
^{76}Y	1	100	100	100	1000	200
^{73}Rb *	20	40000	50000	70000	400000	200000

* rates are about 10 times lower for 1 μs half-life

of flight recoil separators might be successful.

Among the potential candidates, ^{93}Ag and ^{89}Rh seem to be worth attempting to identify. Development of high beam intensity and a target system withstanding these beam currents in fusion-evaporation and fragmentation based experiments is of utmost importance. The HRIBF facility has basically all technical developments ready to perform a search for ground-state proton emitters below Z=50. Beam intensity development and further preamplifier improvement are needed to search for new proton emitters among the fragmentation products at the NSCL.

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