Exploring the limits of existence of heavy neutron-deficient nuclei in the Z=70-82 region

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Introduction

The one- and two-proton driplines determine the limit of existence for proton rich nuclei. In the quest of determining heavy, one- and two-proton unbound nuclei, knowledge of the mass surface can be of great help.
The present work draws on mass values determined at the TITAN facility and the algorithm for the Atomic Mass Evaluation to determine the mass surface in the region of neutron-deficient Z = 70-82 nuclides in order to locate the one- and two- proton driplines.

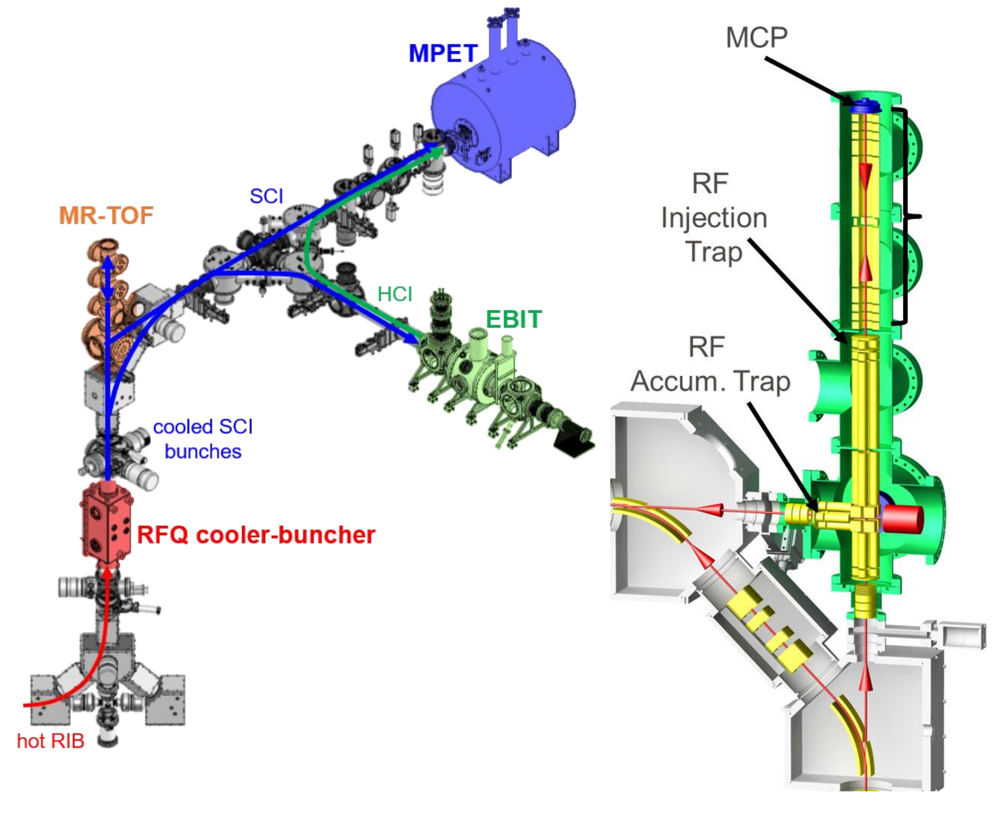

Figure 1: Left: The TITAN experiment. Right: Cross section of the TITAN MR-ToF MS.

Mass measurements at TITAN

TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN) is coupled to ISAC-TRIUMF and performs high precision mass measurements for nuclear structure, nuclear astrophysics and fundamental symmetries. It consists of 4 traps as can be seen in Fig. 1.
Radioactive beam from ISAC is being cooled and bunched at the TITAN RFQ. The bunched beam can then be sent a) to the MR-ToF for mass measurement or for isobaric cleaning, b) to EBIT for charge breeding or spectroscopy or c) to MPET for high-precision mass measurements.

Mass measurement of $^{150-157}$Yb mapping of the mass surface

The masses of $^{150-157}$Yb were determined using the TITAN MR-ToF [Beck PRL 2021].
Using known α,β and p-decay energies, the masses of all isotopes connected to $^{150-157}$Yb can be calculated. Due to the long alpha chains, we are able to reconstruct masses over the range of 18 elements. To do so, we used the Atomic Mass Evaluation (AME) algorithm.

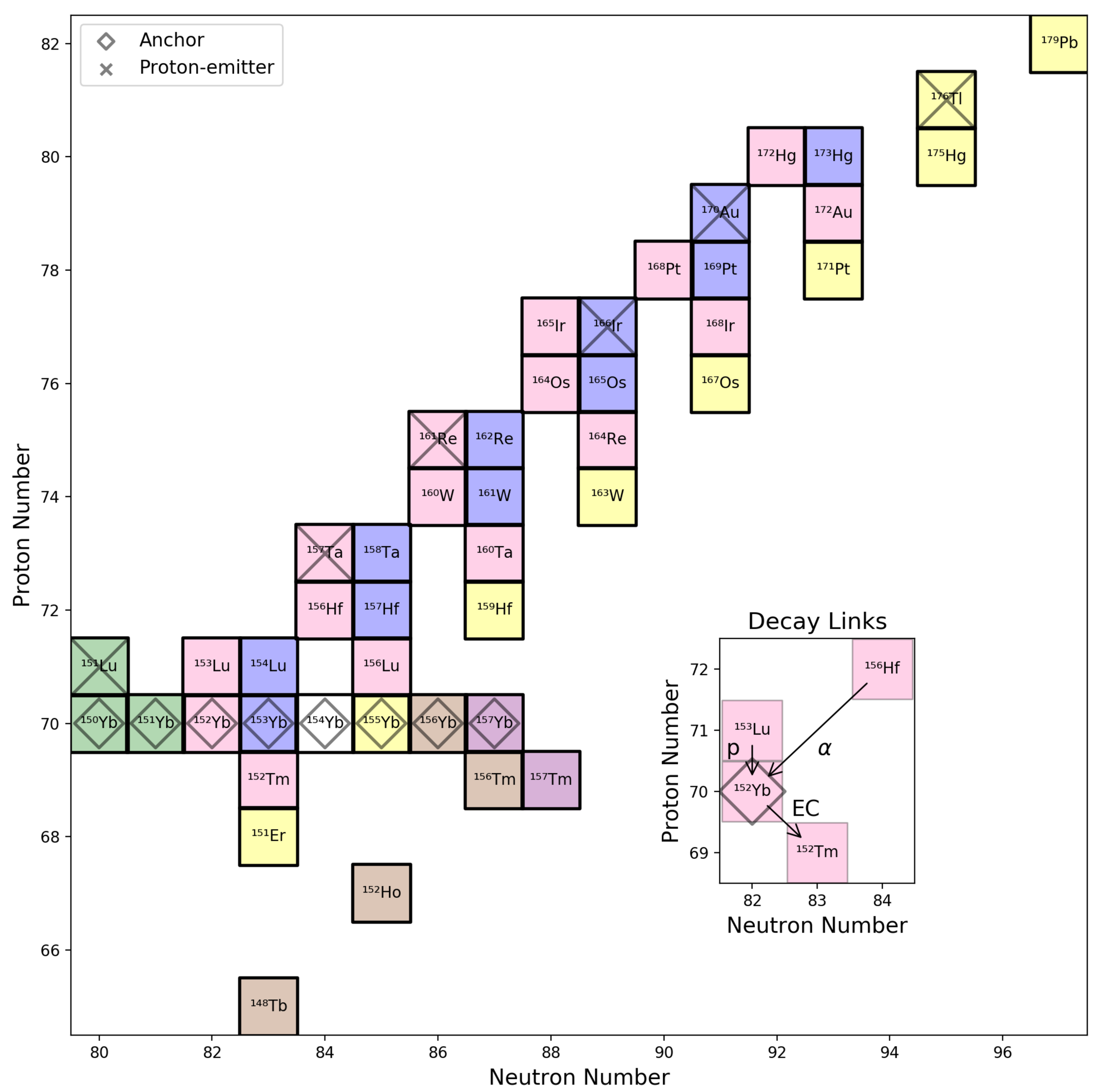

Figure 2: Connectivity plot of the region between Z=70-82.

Results

- **11 new ground-state masses were determined.**
- **The precision of 9 existent masses was improved by at least a factor of 2.**
- The one- and two-proton separation energies were calculated as follows:

$$S_p = (-m(Z,A) + m(Z-1,A-1) + m_p)c^2$$
$$S_{2p} = (-m(Z,A) + m(Z-2,A-2) + 2m_p)c^2$$

The results can be seen in Figures 3,4 as a function of the neutron number
Fig. 5 depicts the two-proton separation energies plotted on the nuclear chart, giving a perspective of the morphology of the mass surface from the two-proton bound area (red) to the two-proton unbound one (blue). In comparison, the theoretical two proton dripline prediction based on UNEDF1 is plotted in pink.

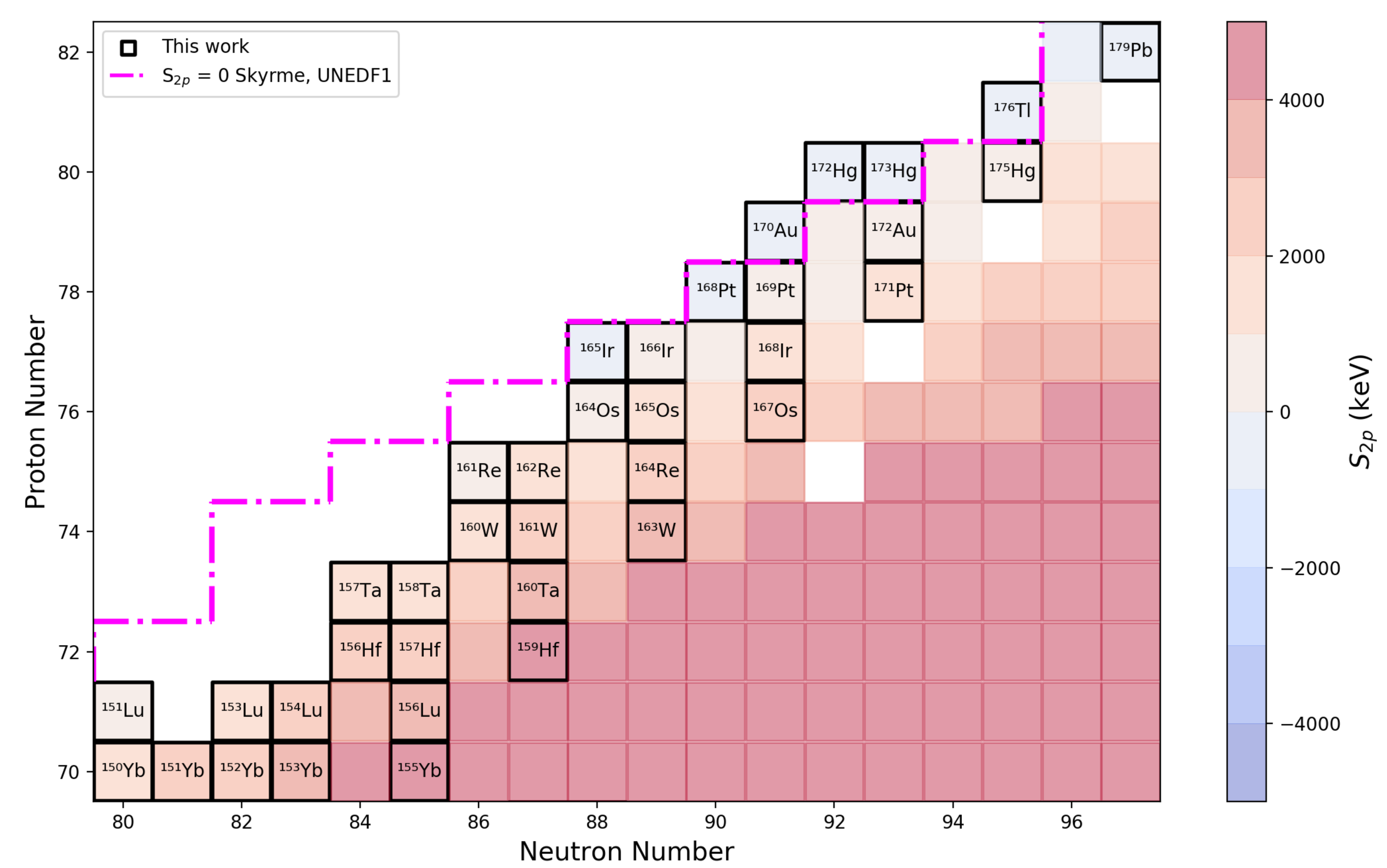

Figure 5: Plot of the two-proton separation energies. The two-proton separation energies determined in this work are marked with black squares. The light blue isotopes are two-proton unstable and therefore past the two-proton dripline. The pink line indicates the theoretical prediction for the two-proton dripline using Skyrme-UNEDF1 interactions and shows good agreement with our results.

Conclusions

Using mass measurements and the AME algorithm we determined 11 new ground state masses and improved the precision of 9 other ones, thus improving the knowledge of the mass surface in the region of neutron deficient isotopes between Z = 70-82. In addition, we determined the two-proton dripline between Z = 77-79 for the first time. Results have been submitted to PRC for publication.

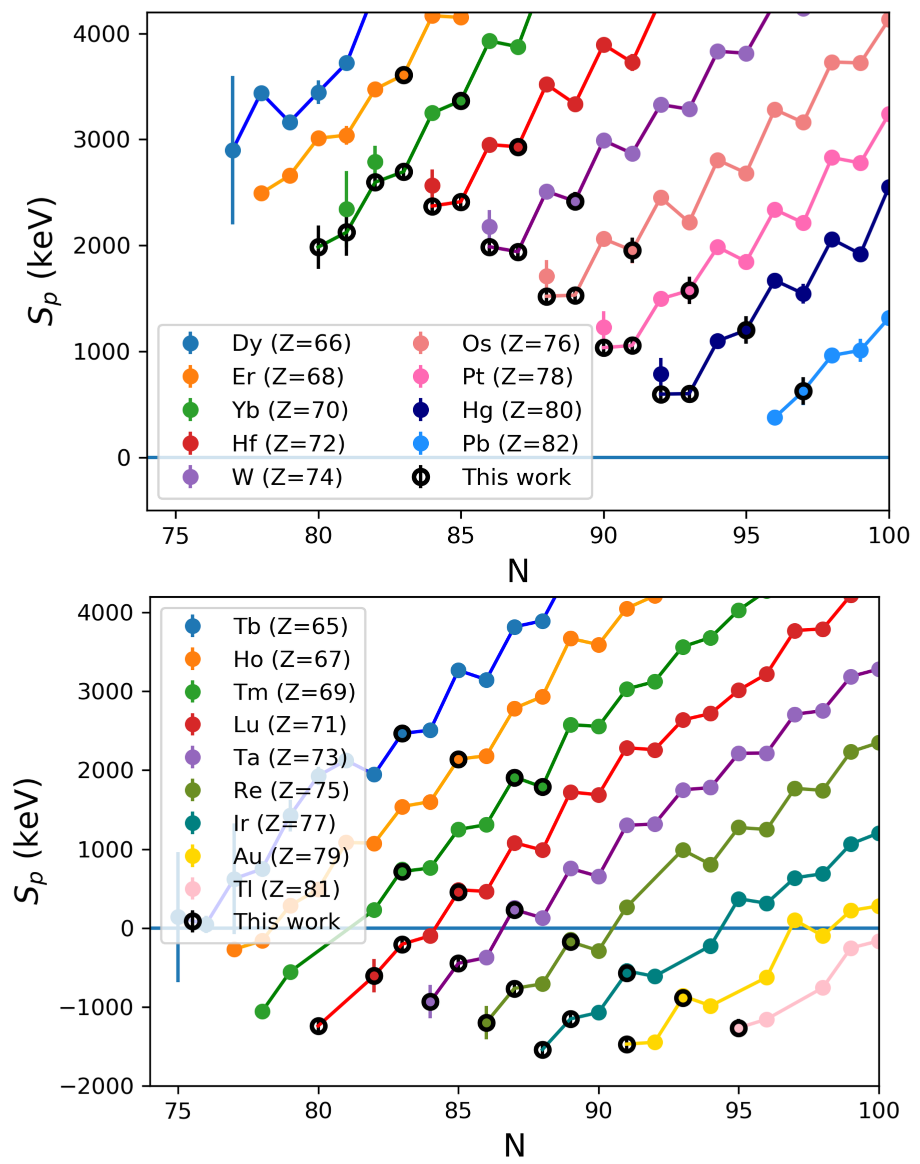

Figure 3: One-proton separation energies as a function of the neutron number. Results of this work are depicted with empty black circles.

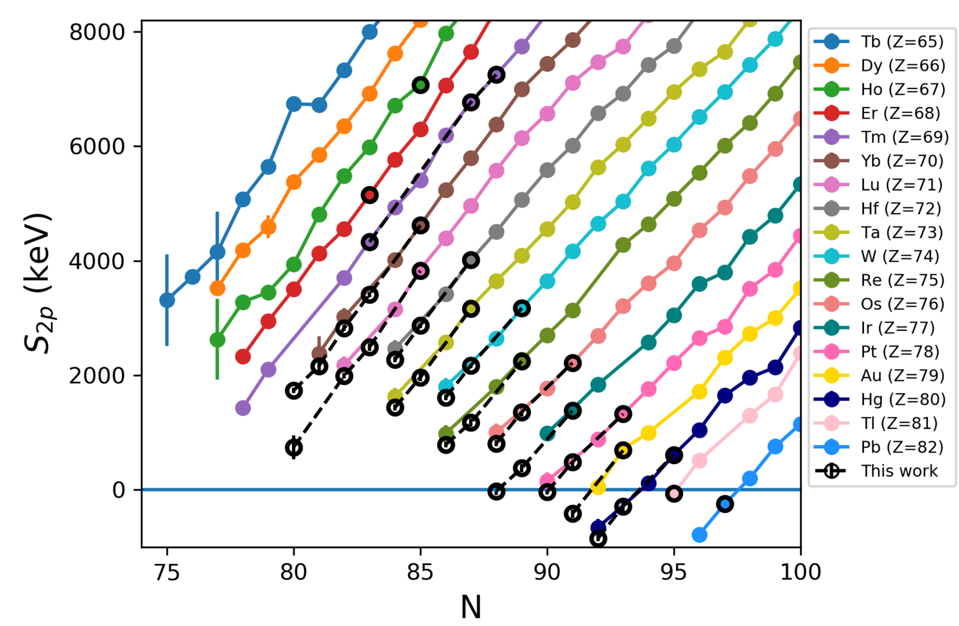

Figure 4: Two-proton separation energies as a function of the neutron number. Results of this work are depicted with empty black circles.

Discovery, accelerated