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

Study of the Di-nuclear System ^{A}Rb + ^{209}Bi ($Z_1 + Z_2 = 120$)

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Abstract

We present an addendum to our experiment proposal IS550 concerning the reaction ^{A}Rb + ^{209}Bi, aiming at searching for possible new shell closures in the region of superheavy elements at Z=120, N=184. For this experiment, a total of 12 shifts was granted, based on the letter of intent from October 1, 2012 **(CERN-INTC-2012-043, INTC-P-344),** re-evaluated and confirmed in 2018. No shifts were consumed to date. For the experiment to come, we propose to change the reaction system to ^{A}Ni + ^{238}U. The reasons are given below.

Total of granted shifts: 12
Remaining shifts: 12

I. Summary of the experimental program

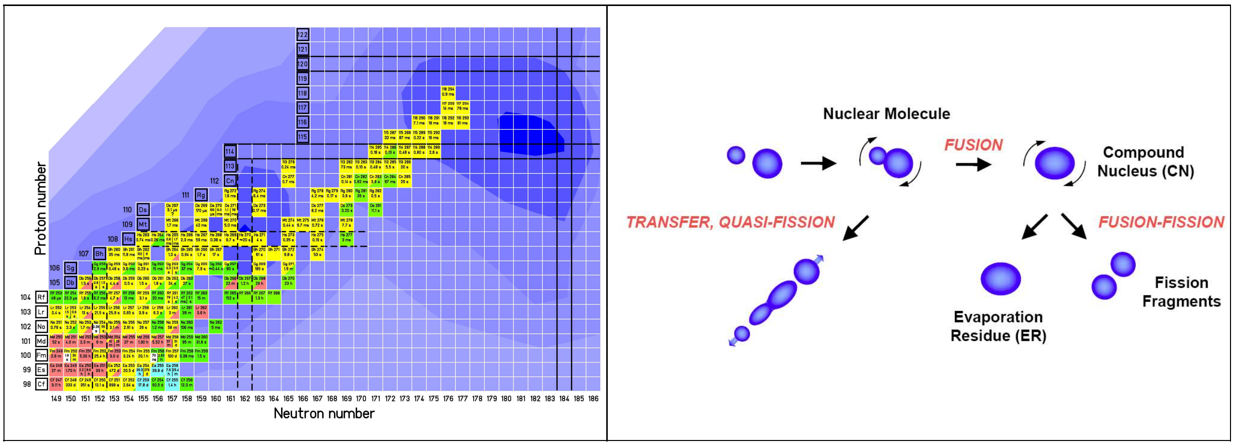

Figure 1. left: Presently known isotopes of superheavy elements. The blue background represents the expected stability of the nuclei and the location of the "island of stability" according to one of the theoretical models, which assumes the magic number at Z=114. If the next magic number is 120, the island would be shifted upwards, accordingly. right: Illustration of nuclear reaction paths in collisions of heavy ions at Coulomb-barrier energies.

The main goal of the proposal is to probe possible shell closures in the region of superheavy nuclei, at Z=120, N=184, by studying quasi-fission (QF) and fusion-fission (FF) reactions (Fig.1) with neutron-rich radioactive ion beams (RIBs). The application of RIBs is the only option to reach compound systems with N=184.

The capture cross-section is experimentally defined as the sum of QF, FF and fusion-evaporation residue (ER) cross-sections: $\sigma_{capture} = \sigma_{QF} + \sigma_{FF} + \sigma_{ER}$. In very heavy systems, such as Z=120, σ_{ER} is negligibly small, and $\sigma_{capture} \approx \sigma_{QF} + \sigma_{FF}$. In the mass range of the reactions which could lead to superheavy elements, the capture cross-section can attain values of (10 − 100) mb. This makes experiments with relatively low-intensity RIBs feasible.

We expect that shell effects are not only revealed by the properties of ER but act already in the QF and FF channels. If shell effects occur, we expect them to be revealed by the mass and total kinetic energy (TKE) distributions of QF and FF binary fragments. Our experimental program comprises the study of mass and TKE distributions of QF and FF fragments as a function of projectile neutron-number and beam energies around the Coulomb barrier at HIE-ISOLDE.

II. Intention to change the collision system from Rb + Bi to Ni + U

The availability of rare isotope beams which allows to reach nuclear systems with Z=120 and N=184 is very limited. In our previous proposal we suggested reactions of neutron-rich Rb beams on ^{209}Bi targets because only the needed neutron-rich Rb isotopes were available with sufficient intensity to reach the goal of the experiment. However, after the submission of the proposal, neutron-rich Ni beams were made available at ISOLDE. This allows, in combination with ^{238}U targets, to reach a Z=120, N=184 compound system. The study of Ni + U reactions offers the following advantages over Rb+Bi which encouraged us to request a change of collision system:

- The Ni+U reaction system is more asymmetric in the entrance channel and the Coulomb barrier lower than in Rb+Bi, therefore an enhancement of compound nucleus formation (complete fusion) is expected. Experimentally this is revealed by an enhancement of FF events with respect to QF. This was also revealed by our experiments on Z=120 systems with stable projectile beams [1]. Compound nucleus (i.e. FF) events are related with the longest possible lifetimes of the nuclear system and full statistical equilibrium. These are the optimum conditions to observe possible shell effects. Moreover, the lower Coulomb barrier would result in lower excitation energy, another feature that would help in the manifestation of shell effects.

- the isotopes $^{65,66,67}Ni$, which lead to Z=120, N= (184 ± 1) compound systems, have much longer half-lives and also higher intensities than the respective rubidium isotopes $^{94,95}Rb$ leading to Z=120, N=183, 184. Resulting from this, we can expect significantly larger yields of FF and QF products.

- the lighter Ni beams will keep the radiation level in the ISOLDE experimental hall on a more moderate level than Rb beams.

References:

1. K.V. Novikov et al., PRC **102**, 044605 (2020).