BB

GSI-Preprint-95-65
OCTOBER 1995

**DISCOVERY OF THE SUPERHEAVY ELEMENTS 110 AND
111 - SHELL STABILIZATION IN THE DEFORMED SHELL
Z=108 / N=162**

P. ARMBRUSTER

(Invited Paper at the 'Int. Nuclear Physics Conference', Beijing, P.R. of China,
Aug.21-26, 1995)

yw9547

Gesellschaft für Schwerionenforschung mbH
Postfach 110552 · D-64220 Darmstadt · Germany

DEFORMED SHELL Z=108/N=162

Postfach 110552, D-64200 Darmstadt, Germany

Experiments and Predictions 1995.

Proton number

Figure 1: The heaviest isotopes published March 1995

for Seaborgium, (Sg, $Z=106$), Nielsbohrium, (Ns, $Z=107$), Hassium, (Hs, $Z=108$), Meitnerium, (Mt, $Z=109$), $Z=110$, and $Z=111$ decay predominantly by α -emission, not by spontaneous fission. Fission branches are established only for $^{258,260}\text{Sg}$, and for ^{264}Hs . Chains of α -decays along lines of constant isospin connect the region of shell-stabilized nuclei of $Z \geq 106$ to the region of α -decaying isotopes for the well-known elements $Z \leq 102$.

The concept of SHE's was applied first to the next doubly closed nucleus $^{298}114$.

Figure 2: The recent microscopic shell corrections as calculated by Möller/Nix, [4], and the A. Sobiczewski group, [6, 7]. The contour lines have distances of 1 MeV. The energies in the saddle points and the minima are indicated. Crosses mark the heaviest isotopes investigated.

Theoretical work on the stability of SHE has progressed during the years. Ground-state properties and decay-modes for all isotopes up to $Z=130$ are tabulated by P. Möller and R. Nix [4, 5]. Fig. 2 compares the predictions of [4] to another set of data

by Z. Patyk, R. Smolanczuk, A. Sobiczewski and collaborators [6, 7]. Calculations reproducing the decay-modes of known nuclei beyond Fermium and predicting the unknown up to $Z=114$ presented by the same authors, are shown in Fig. 3. Half-lives

Figure 3: α - and fission half-lives for even-even isotopes of elements $Z=104-114$. This figure is based on results of Patyk, Smolanczuk and Sobiczewski et al. [6, 7]. The investigated heaviest isotopes are indicated.

for α -decay and spontaneous fission for the even-even isotopes of elements 104 - 114 are presented. The observed onset of α -decay beyond Seaborgium ($Z=106$) continues to stay the dominant decay mode up to $Z=114$. For all elements up to $Z=114$ there are even-even isotopes protected against spontaneous fission. The dynamical fission barriers underlying the half-life calculation are higher than the corresponding static barriers. In tunneling calculations the action integral is minimized, and the highest point above the projected tunneling path, the dynamical barrier, can be appreciably higher than the static barrier of the underlying energy surface. High barriers are found for $N=162$ with a maximum for ^{268}Sg of $B_F^{\text{dyn}} = 8.8$ MeV and $B_F^{\text{stat}} = 6.8$ MeV, respectively. The nuclei with $N \leq 170$ are deformed with large negative β_4 -values, as was shown already in 1986 [8]. The nuclei show a cylindrical-like shape and their fission barriers are narrow. The longest half-life is predicted for the deformed isotope ^{268}Sg lying on the $N=162$ sub-shell closure with a half-life of 2 h. The transition to spherical shapes is predicted for $Z=114$ at $N=164$ [4] and $N=170$ [6], respectively. As the barrier exit point is found for deformed and spherical nu-

clei in the same region of deformation near $\beta_2=0.7$, for equal fission barriers longer half-lives are expected for spherical isotopes of element 114 with $N=178-184$ due to their thicker barrier. However, how the γ -deformation affects the spontaneous fission half-lives of spherical nuclei is still an open question.

2 Approaching the pb-Limit at SHIP/GSI.

The technique the GSI-group used to discover elements $Z=107-109$ has become a standard method to detect isotopes of heavy elements in the subnanobarn cross section range in 1995. As a first step evaporation residues are separated by a recoil separator [9]. In a second step the separated recoils are implanted into position-sensitive silicon detectors establishing decay chains of the implanted nuclei [10, 11].

Efforts have been made to increase the separation efficiency and the background suppression of SHIP and to improve the sensitivity of the detection system [12]:

Using ECR-sources average currents of about $0.5 \text{ p}\mu\text{A}$ with very small beam intensity variations and reduced enriched isotope consumption are now available (gain factor 2.5).

The size of the targets was increased to $24 \text{ mm high} \times 122 \text{ mm length}$; 8 targets are mounted on a wheel rotating with 1125 rev./min . With the new wheel the duty factor of the UNILAC beam can be increased from 22.5% to 30.0% permitting higher beam currents (gain factor 1.3).

The availability of the accelerator and detection system was improved (gain factor 1.2).

The acceptance angle of SHIP has been increased from 1.8 msr to 3.8 msr by moving the target area closer to SHIP (gain factor 1.5).

A new detector system was built. It is an assembly of 7 identical 16-strip silicon wafers plus a composite germanium detector. The active area of one wafer is $(35 \times 80) \text{ mm}^2$. Each strip is position sensitive in the vertical direction with a resolution of $150 \mu\text{m}$. The stop detector is equivalent to 3700 single detectors of size $(0.15 \times 5) \text{ mm}^2$, but of 100% active area. The energy resolution is $\simeq 14 \text{ keV}$ for 5 MeV

α -particles. Fig. 4 shows the stop detector, the six detectors to measure escaping α 's

Figure 4: The improved new detector system of SHIP, [12].

or fission fragments (solid angle $\simeq 80\%$), the movable energy degrader mounted on a pneumatic drive, and the composite germanium detector. In case of the backward detectors neighbouring strips are connected so that 48 energy sensitive segments are formed (gain factor 1.4).

In front of the system two secondary electron detectors are mounted for a time-of-flight measurement. Their signals are also used to distinguish between implantations and radioactive decays of implanted nuclei (gain factor 1.1).

The evaporation residues are deflected by an additional dipole magnet placed directly behind SHIP. An angle of 7.5° is sufficient to protect the detectors from background of neutral or high-energy particles; the charge dispersion is small enough to avoid losses of evaporation residues.

The total sensitivity of the GSI-system was improved by a factor of at least 10. During the long measuring time with Ni-beams of our 1994-experiments (6 weeks) we reached an average beam current of $0.35 \mu\text{A}$. The effective luminosity assuming this beam current, 0.4 mg/cm^2 effective target thickness and a total efficiency of 0.45 amounts to $0.1 \text{ pb}^{-1} \cdot \text{d}^{-1}$, that is for a cross section of 1 pb an average measuring time of 10 days is needed to find 1 event.

3 Production Cross Sections of SHE.

Until now there are 2 successful ways to synthesize the heaviest elements.

Using actinides as targets and neutron-rich projectiles as beams the heaviest elements are produced via 4n- and 5n-channels, with 5n the main reaction channel. The n-rich targets are ^{238}U , ^{244}Pu , ^{248}Cm , ^{249}Cf and ^{254}Es , the most neutron-rich projectiles are the ($T_Z=1$)-isotopes ^{18}O , ^{22}Ne , ^{26}Mg , ^{30}Si and ^{34}S , the ($T_Z=2$) isotopes ^{36}S and ^{40}Ar , and ^{48}Ca ($T_Z=4$). Using ^{208}Pb and ^{209}Bi as targets and the neutron-rich ($T_Z=3$ and 4)-isotopes of elements Ti to Ni as projectiles the heaviest elements are produced via 2n- and 1n-channels. Above $Z=107$ the evaporation of 1n is the main deexcitation channel.

Fig. 5 shows measured cross sections for the two production schemes. For the

Figure 5: Cross Sections for heavy element synthesis reactions for $Z \geq 102$. Actinides-based 5n-reactions, [13, 14, 15], and Pb/Bi-based 1n-reactions are compared.

Pb/Bi-based reactions cross sections of the 1n-channel are compared to cross sections of the 5n-channel observed in actinides-based reactions. Most of the latter data using ^{238}U -, ^{244}Pu -, and ^{248}Cm -targets were measured very recently at Dubna [13, 14, 15]. The cross sections decrease by 5 orders of magnitude going from Nobelium to $Z=111$. Each element more asks to manage at least a factor of 3 smaller

Figure 6: The excitation functions for Pb/Bi-based reactions. The Bass-fusion barriers are indicated by arrows, [16]. The lines are Gaussian fits to the data points.

cross sections. The 5n-channel reactions approach within an order of magnitude the values of the Pb/Bi-based 1n-channels. It was a surprise to find such a small difference between the 5n- and 1n-reaction mechanism. For isotopes of even elements and for $^{272}\text{111}$ excitation functions were measured in our recent experiments down to a level of 2 pb, Fig. 6. All isotopes show for the 1n-channel narrow distributions with a FWHM of about 4 MeV centered at energies below the fusion barrier which is evaluated following the Bass-description [16]. The most probable excitation energies are between 10 MeV and 15 MeV, with a tendency towards smaller values for the heavier elements. The FWHM observed is about half of the width of a fully opened 1n-deexcitation window. The maxima of the excitation functions approach more and more the lower end of this window near 8 MeV. The difference to the fusion barrier,

7 MeV for ^{257}Rf , shrinks to 3 MeV for $^{271}110$ and $^{272}111$.

4 The Discovery of Elements 110 to 111.

The search for element 110 started immediately after the successful synthesis of elements Nielsbohrium ($Z=107$), Hassium ($Z=108$) and Meitnerium ($Z=109$) [1, 2]. At GSI in 1985 the reaction $^{208}\text{Pb}(^{64}\text{Ni},n)^{271}110$ was investigated at a dose of 10^{18} ions in the excitation energy window of (15-21) MeV [17]. In 1985/86 the reactions ^{232}Th , $^{235,236}\text{U}(^{40}\text{Ar},xn)^{272,275,276-277}110$ were investigated in the dose range of a few 10^{18} at Dubna. A 10 ms spontaneous fission emitter was reported [18, 19]. In 1986 the $^{235}\text{U}(^{40}\text{Ar},xn)$ reaction was investigated as well at GSI, but no spontaneous fission was found [20]. A further report from Dubna on spontaneous fission in $^{236}\text{U}(^{40}\text{Ar},xn)$ using a gas-filled separator was published in 1992 [21]. Finally the reaction $^{209}\text{Bi}(^{59}\text{Co}, 1n)^{267}110$ was investigated at LBL, Berkeley in 1992. A single decay chain was reported in a publication in 1994 to give a possible evidence for element 110 [22]. All the experiments cited above show the continuous efforts to synthesize the next element following Meitnerium. None of them following the standards set by the Transfermium working group [23] can claim discovery of element 110. However, the many experiments showed that production cross sections lie in the pb-range corroborating our extrapolations from $Z<109$.

Production and Decay of $^{269}110$ [24].

When no beams of rare projectiles were available at the UNILAC during the final construction and commissioning period of the new synchrotron SIS in the years 1989-1993, the time was well used to prepare a research program continuing the synthesis of SHE. Parallel to the Wideroe-structure a new injector using an ECR-source, and a combination of a RFQ- and IH-structure was built in order to allow for a continuation of the low energy heavy ion experiments. This injector delivered first beams in 1993. At the experimental side the improvements described in section 2 allowed to attack the 1 pb-limit. Lower limits of 0.3 pb at doses of $2\cdot 10^{19}$ ions are within reach.

We decided to continue the Pb/Bi-based research on “cold fusion” reactions in order

to produce element 110 via the $1n$ -reaction channel. Knowing the energy window to be narrow (5 MeV), but the maxima of the excitation functions uncertain somewhere in the range of (10–25) MeV, the experiments started by a careful study of the excitation functions for xn -reactions between ^{208}Pb -target atoms and ^{50}Ti and ^{58}Fe projectiles, Fig. 7. Six weeks of beam-time were invested. The more than 10-fold higher sensitivity is demonstrated best by the fact, that instead of 3 atoms of ^{265}Hs detected in the 1984-discovery experiment [25], now 79 atoms were registered at 7 different excitation energies in the range of 10 MeV to 20 MeV. The cross section maximum was found at (13.4 ± 0.3) MeV. The FWHM of the excitation function is (4.8 ± 0.7) MeV. The energy of the maximum is 6 MeV lower than the bombarding energy chosen in the 1984-experiment. This 2% down-shift in bombarding energy remains unexplained.

The isotope $^{269}110$ was synthesized in the reaction $^{208}\text{Pb}(^{62}\text{Ni},1n)$ extrapolating the bombarding energy to $Z=110$. At $E^*=12.3$ MeV and a dose of $2.2 \cdot 10^{18}$ ions 4 decay chains connecting $^{269}110$ to previously investigated isotopes were observed. A complete chain is shown in Fig. 7. The cross section of $(3.5^{+2.7}_{-1.8})\text{pb}$ lies in the trend of falling cross sections from ^{257}Rf to ^{265}Hs . The α -energy of (11.11 ± 0.02) MeV and the α -half-life of $(0.17^{+0.16}_{-0.06})\text{ms}$ are close to the predicted values [6].

Production and Decay of $^{271}110$ [26].

The next ($T_Z=4$)-projectile following ^{48}Ca is ^{64}Ni . With $^{208}\text{Pb}(^{64}\text{Ni},1n)^{271}110$ the isospin of the compound system can be increased by one unit compared to the ($T_Z=3$)-projectiles. All isotopes in this chain are known. ^{267}Hs , the daughter nucleus of $^{271}110$ was synthesized recently in $^{238}\text{U}(^{34}\text{S},5n)$ by Lazarev et al. [14]; ^{263}Sg is the isotope having led to the discovery of element Seaborgium [27], ^{259}Rf was discovered by Ghiorso et al. in 1969 as α -emitter [28] and the last word on the share of the Dubna chemists on the discovery of $Z=104$ depends on the existence of a large fission branch in this isotope, [29]. ^{255}No finally is the only isotope seen before at SHIP in the reaction $^{208}\text{Pb}(^{48}\text{Ca},1n)$ [30].

The excitation energy chosen for the ^{64}Ni -induced reaction was 8.8 MeV. The same distance from the fusion barrier was kept as for the ^{62}Ni -induced synthesis of $^{269}110$.

Bombarding at 3 energies defined a maximum cross section of (15^{+9}_{-6}) pb at 9.8 MeV. The small FWHM is hardly compatible with the larger values of 4 MeV measured for the reactions leading to ^{257}Rf and ^{265}Hs . Altogether 9 events were registered. One of the chains is shown in Fig. 7.

The α -energy of 10.74 MeV is compared to $^{269}110$ smaller by 370 keV, the α -half-

Figure 7: Selected complete decay chains of the new isotopes $^{269}110$, $^{271}110$ and $^{272}111$ as observed in our 1994-experiments. The unique completeness of the chains was reached by the new detector-system, [12].

life of $(1.1^{+0.6}_{-0.3})$ ms is increased by a factor of 6. One chain was observed at 10.71 MeV with a long half-life of (56^{+270}_{-26}) ms, which might point to an isomer in $^{271}110$. The decay data of the daughter nuclei are compatible with the published values, especially the data on ^{267}Hs obtained recently in Dubna were confirmed [14]. None of the decay chains ends by a spontaneous fission event. A spontaneous fission branch of ^{259}Rf was seen neither in our experiment with 9 chains nor in the Dubna ^{267}Hs -experiment with 3 chains [14].

The cross sections increased going from $^{269}110$ to $^{271}110$ by a factor of 4. That is a gain by a factor of 2 per neutron. It remains an open question whether the increase in cross section is due to the higher neutron number in $^{271}110$ compared to $^{269}110$, or to the increase of 0.7 MeV in the fission barrier height when approaching the

N=162 deformed shell. The extrapolations of Fig. 5 assume that the cross section depends on the projectile-isospin only, and that each neutron more is equivalent to an increase in the fusion probability by a factor of 2.

Production and Decay of $^{272}111$ [31].

The extrapolation from $^{271}110$ to $^{272}111$ gives a cross section of several picobarns. Having chosen the same excitation energy as for $^{271}110$ we did not observe any event at a dose of 10^{18} ions ($\sigma < 3$ pb). Increasing the energy to 11.0 MeV and 12.5 MeV we observed at ion doses of $1.1 \cdot 10^{18}$ one and two decay chains, respectively. A cross section of $(3.5_{-2.3}^{+4.6})$ pb follows at $E^* = 12.5$ MeV. A shift to higher excitation energy of about 3 MeV for the odd element compared to its even neighbour 110 is observed, a difference as found for the fusion barriers. All 3 isotopes we synthesized show a cross section maximum at 3 MeV below the corresponding fusion barrier.

A complete decay chain of $^{272}111$ is shown in Fig.7. The daughters ^{268}Mt and ^{264}Ns are new isotopes as well as their element 111-mother. The following members of the chain ^{260}Ha and ^{256}Lr are known isotopes, the decay data of which are confirmed. The completeness of the presented chain ending with known isotopes, definitely proves the existence of element 111. Moreover, the 2 other chains observed corroborate this conclusion. In one chain a (155 ± 0.8) keV γ -quantum was observed in coincidence with the mother-decay. Within the given detector resolution of 1.9 keV (FWHM) this energy agrees with the predicted $K_{\alpha 1}$ -energy for element 109 of 152 keV [32]. One event does not make an X-ray spectrum, but remarkably not a single further X-ray event was observed in any of the decay-chains registered at a ratio of chance to true coincidences of 3%.

The α -energies and half-lives for the 3 new isotopes are presented in Fig.1. The α -energy of $^{272}111$ (10.82 MeV) is very close to that of its isotone $^{271}110$. The increase of only 80 keV compares to about 400 keV, which is found for the majority of comparable odd-neutron isotones close to N=126 and N=152. The half-lives of the new isotopes ^{268}Mt and ^{264}Ns are increased by more than an order of magnitude compared to the known less n-rich isotopes ^{266}Mt and ^{262}Ns . The trends in α -half-lives are in agreement with the predictions of Smolanczuk et al. [7]. Especially the ap-

proach to the $N=162$ - deformed shell is indicated taking $^{269}110$ as a reference point. The lighter isotone ^{267}Hs has a factor 350 longer half-life and the heavier isotope $^{271}110$ shows an increase in half-life by a factor of 6. A similar increase in half-lives was observed going from ^{263}Sg to ^{265}Sg . However, a definite answer whether the shell-closure is really found at $N=162$ needs measurements on isotopes beyond the shell closure. The recent measurement on $^{244}\text{Pu}(^{34}\text{S},5n)^{263}110_{163}$ giving in the one chain observed an α -energy of 11.35 MeV would indicate a much stronger shell-gap than calculations predict [15, 7].

5 Towards a Fast, Direct Reaction Mechanism – Heavy Clusters, Compactness and Precompound n-Emission.

Given an element to be synthesized the most asymmetric collision system shows the smallest value of Coulomb to nuclear forces. Thus the effective fissility of an asymmetric fusing system is always smaller than the X -value of the compound system, with the latter finally reached by the corresponding symmetric collision system [33]. The fissility of an asymmetric collision system X_{eff} is a weighted arithmetic mean of the X -values of the final compound system and the system of two touching spheres in the entrance channel. Theory predicts a weighting factor of $2/3$ for the compound system and $1/3$ for the 2 touching spheres [34]. Experiments have verified the prediction [35] that a limitation of fusion in the entrance channel sets in at an effective fissility of $X=0.72$, [36]. Shell-stabilized collision partners increase the weighting factor of the entrance channel configuration [37]. For these systems the phenomenon of entrance channel limitation sets in relative to the theoretical $1/3$ weighting factor scheme delayed at higher X_{eff} -values, at $X_{eff}=0.78$ for the ^{208}Pb - and ^{209}Bi -based systems.

This delayed onset of entrance channel limitation of fusion for closed-shell collision partners results from the special stability of the cluster-structures and the hypothesis that they are dissolved in a deeper penetration stage. They disappear at $R=1.2$

R_0 , at about 2/3 of the distance to be passed in order to reach the compound system. As was proposed by S. Hofmann, [38], in this compact configuration the Pb-cluster surrounded by a cloud of paired nucleons, which were transferred from the projectile to the cluster in the first stage of the interaction process, may be a more adequate description of the configuration than an excited compound system. This holds especially for the $^{208}\text{Pb}/^{64}\text{Ni}$ -system which fuses at 10 MeV excitation energy. The stages of the fusion-fission process ($5 \cdot 10^{-20}$ s) are presented in Fig. 8.

The excited system can feel the ground-state stabilization of the shell-stabilized

Figure 8: The different stages of fusion in a one-step direct reaction mechanism. The excitation energies on the fusion path as a function of the center of mass distances R between the collision partners in units of R_0 . For heavy compound systems R_0 is about 7fm. For a spherical compound system R/R_0 is 0.75.

SHE only at this last stage of the rearrangement process, when the fission barrier protecting the SHE has been passed. As shell-stabilization disappears exponentially with a damping energy of 18 MeV, at excitation energies of about 20 MeV shell-stabilization already starts to get lost. In the formation process of the compound system the ground-state stabilization could be fully acting, if precompound neutron

emission had cooled down the system to energies below the fission barrier of the fused system. During the long formation time neutrons have a chance to be emitted, and the compound system may be much less excited than the total excitation available in the collision system suggests.

The precompound emission of a neutron ($E_n \geq 6$ MeV) at deformations smaller than the deformation of the fission barrier ($\beta_2 \sim 0.4$, $R/R_0 \sim 1$) cools a system with $E < S_n + B_f \sim 12$ MeV to excitation energies which are below the fission barrier. The system then is protected against reseparation. The precompound cooling has to occur not only at deformations inside the fission barrier but also in times shorter than the fission time ($3 \cdot 10^{-20}$ s). Neutrons and eventually also fast giant resonance γ -quanta have a chance to act as a fast heat exchanger. The cooling by γ -quanta alone, as in the case of a pure γ -deexcitation channel (0n-channel) may be too slow in order to protect the system against reseparation.

The energy window of $E^* = (10 \pm 2)$ MeV which leads to the observation of $^{271}110$, coincides with the GDR of $^{272}110$ at 11.2 MeV. Not only the position, but also the width of the GDR matches the measured excitation function, as shown in Fig. 6. The compound system is formed after a long time of about $1.5 \cdot 10^{-20}$ s [34]. This time is long compared to the GDR-eigentime, and there is enough time for a GDR to develop. The fusion entrance channel and the GDR of the compound nucleus to be correlated is still an interesting speculation which certainly needs to be corroborated by further experimental facts.

6 Outlook to Future Experiments to Synthesize SHE Beyond Element 111.

The obvious next experiment using Pb/Bi-targets is to try to synthesize elements 112 and 113 using Zn-projectiles. The cross sections extrapolated from our previous experiments could be as high as 3 pb for $^{277}112_{163}$ and 1 pb for $^{278}113$, see Fig. 5, as once more ^{70}Zn allows to increase the isospin of the projectile by one unit to $T_z=5$. The isotopes envisaged have neutron numbers 163 and 165 using ^{68}Zn -

and ^{70}Zn -beams. Their fission barriers are predicted to be smaller than those of isotopes produced for elements 110 and 111 with 159 and 161 neutrons. The optimal excitation energy extrapolating from known reactions is for $^{277}112$ very close to the onset-energy of the 1n-channel at 7 MeV (Fig.6). For $^{275}112$ and $^{278}113$ the best energies are close to 10 MeV as is the case of $^{272}110$. We will try to synthesize these deformed superheavy isotopes in our next experiment. We hope to learn more how isospin, ground-state microscopic corrections, and the approach to the lower energy limit of 1n-channel play on the production cross section.

The projectiles ^{76}Ge and ^{82}Se aiming at elements 114 to 117 again allow to increase the isospin by one unit each. The neutron numbers of the isotopes produced are 169 and 173, respectively. Following the predictions of Möller/Nix, [4], all isotopes are spherical and have increased microscopic correction energies in their ground-state, whereas Smolanczuk et al., [7], predict transitional nuclei ($\beta_2 \sim 0.10$) with small static fission barriers between 3 MeV and 4 MeV. The extrapolated excitation energies are below the onset of the 1n-channel in the regime of the radiative capture reactions (0n-channel). To learn about radiative capture in fusion using Pb/Bi-targets is of utmost importance, as until now this channel has not been definitely established. The reaction $^{209}\text{Bi}(^{76}\text{Ge}, 1n)^{284}115_{169}$ with an excitation energy of $E^*=8$ MeV at the on-set of the 1n-channel may be the only one leading to spherical superheavy nuclei with a sufficiently high ground-state stabilization by microscopic corrections, circumventing the problem of radiative capture, and having a cross section of 0.3 pb which is accessible by our present equipment in beam times of 10 weeks.

Radioactive beams may be a future option. For the Pb/Bi-based reactions beams of light fission fragments are a most attractive choice. With $N=52$ -projectiles a neutron number of 178 in the center of the spherical island becomes accessible. The lightest fission product with reasonable yield is ^{84}Ge . Combined with ^{209}Bi the isotope $^{292}115_{177}$ is reached. Scaling the isospin dependence the gain in cross section compared to ^{76}Ge may become as high as 2^8 , Fig. 5. Using a facility like SHIP beams of about 1 pA of ^{84}Ge would be needed to produce $^{292}115$ with similar rates as for the now projected synthesis of $Z=112$ and 113. The PIAFE-project Grenoble

[39], which combines the ILL-HFR and the heavy ion accelerator at ISN, seems to be the world-wide most promising radioactive beam proposal allowing to reach via $^{209}\text{Bi}(^{84}\text{Ge},1n)^{292}115$ the center of the spherical SHE. Accelerators never will produce fission product currents which are competitive to a High Flux Reactor. 1pnA-beams of ^{84}Ge and ^{86}Se could be within reach at PIAFE in the not too far future.

Acknowledgement:

The work presented is the result of many years of work of the SHIP-group. The work on the two new elements would not have been possible without the permanent efforts of S. Hofmann, P. Hessberger and V. Ninov. Special thanks to them and all the other members of the SHIP-group. To the ECR ion source group, the accelerator development group, the UNILAC-operators and the Data Acquisition group goes a highly merited acknowledgement for their help during preparation and running of the experiment. I want to acknowledge that D. Guerreau, GANIL proposed in his GSI-colloquium May 1995 the use of ^{85}Ge to synthesize $^{292}114$ at SPIRAL-GANIL.

References

- [1] P. Armbruster, Annu. Rev. Nucl. Part. Sci. **35**,135 (1985).
- [2] G. Münzenberg, Rep. Prog. Phys. **51**, 57 (1988).
- [3] P. Armbruster, Proc. Int. Nucl. Phys. Conf. São Paulo, 1989, World Scientific ISBN 981-02-0035-8, page 313.
- [4] P. Möller and R. J. Nix, At. Data Nucl. Data Tables **39**, 214 (1988).
- [5] P. Möller and R.J. Nix, J. Phys. G: Nucl Part. Phys. **20**, 1681 (1994).
- [6] Z. Patyk and A. Sobiczewski, Nucl. Phys **A533**, 132 (1991).
- [7] R. Smolanczuk et al., Phys. Rev. C, in press, GSI preprint - 94 - 77.
- [8] P. Möller et al., Z. Phys. **A323**, 41 (1986).
- [9] G. Münzenberg et al., NIM **61**, 65 (1979).
- [10] K. H. Schmidt et al., Nucl. Phys. **A318**, 253 (1979).
- [11] S. Hofmann et al., Z. Phys **A291**, 53 (1979).
- [12] S. Hofmann, Actinides 1993, Santa Fe, USA, Journal of Alloys and Compounds, **213/214**, 74 (1994).
- [13] Yu. A. Lazarev et al., Phys. Rev. Lett. **73**, 624, (1994).
- [14] Yu.A. Lazarev et al., Phys. Rev. Lett. to be published.
- [15] Yu. Ts. Oganessian, ENAM 95, Arles, France, to be published.
- [16] R. Bass, Phys. Rev. Lett. **39**, 265 (1977).
- [17] G. Münzenberg et al., GSI-Report 86-1 (1986), 30.

- [18] Y. Oganessian, Proceedings of the Symposium "10 Years of Uranium Beam at the Unilac", GSI Darmstadt (1986) page 201.
- [19] Y. Oganessian, Proc. of the Intern. School of Physics "Enrico Fermi Course CIII "Trends in Nuclear Physics" 1987. North-Holland, Amsterdam 1989, page 258.
- [20] G. Münzenberg et al., GSI Report 87-1 14, (1987).
- [21] Y. Oganessian et al., Proc. of the 6th Conf. on Nuclei far off stability, Bernkastel-Kues 1992. Inst. of Physics Conf. Series 13, (1993), page 429.
- [22] A. Ghiorso et al., Phys. Rev. C51, R 2293, (1995).
- [23] R.C. Barber et al., Prog. Part. Nucl. Phys., 29, 453, (1992).
- [24] S. Hofmann et al., Z. Phys. A350, 277, (1995).
- [25] G. Münzenberg et al., Z. Phys. A317, 235, (1984).
- [26] S. Hofmann et al., GSI-Nachrichten 02-95.
- [27] A. Ghiorso et al., Phys. Rev. Lett. 33, 1490, (1974).
- [28] A. Ghiorso et al., Phys. Rev. Lett. 22, 1317, (1969).
- [29] I. Zvara et al, Radio khimiya 11, 163, (1969).
- [30] H. Gäggeler et al., Nucl. Phys. A502, 561, (1989).
- [31] S. Hofmann, Z. Phys. A350, 281, (1995).
- [32] B. Fricke, private communication (1994).
- [33] R. Bass, Nucl. Phys. A231, 45 (1974).
- [34] J. P. Blocki, H. Feldmaier and W. J. Swiatecki, Nucl. Phys. A459, 145 (1986).
- [35] K. H. Schmidt and W. Morawek, Rep. Progr. Phys. 54, 949 (1991).
- [36] W. J. Swiatecki, Phys. Scr. 24, 113 (1981).
- [37] P. Armbruster, XXIV Winter Meeting on Nucl. Phys., Bormio, Italy, 1986, page 269, GSI Preprint 86-10.
- [38] S. Hofmann, XV Nuclear Physics Divisional Conf. on 'Low Energy Nuclear Dynamics', St. Petersburg 1995, to be published.
- [39] H. Nifenecker, Proc. of the 6th Franco-Japanese Coll., St. Malo, France; Edited by N. Alamanos, S. Fortier and F. Dykstra, page 384 (1992).