INVESTIGATION OF ISOTOPES WITH Z ≥ 100

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Abstract

Evaporation residues from fusion reactions of ^{40}Ar, ^{50}Ti, and ^{54}Cr with isotopes of Pb and Bi respectively were investigated with a newly developed method of in-flight velocity separation and implantation into position sensitive surface barrier detectors. Our experimental method permits the investigation of α decaying or spontaneously fissioning nuclei with lifetimes down to 10^{-6} s and formation cross sections below 1nb.

Experimental results on the production of isotopes of Fm, Md, Lr, 104, 105, and the first observation of element 107 by α decay are presented. The possibility to form cold compound nuclei close to the fusion barrier is discussed in the view of recent experimental results.

1. Introduction

The well established techniques used so far for the identification of short lived nuclei with Z ≥ 100 from heavy ion fusion reactions, as the He-jet, rotating drums or moving tapes have been developed to a high state of perfection and hence approached the limits of their possibilities. Their main restrictions are due to the fact that the nuclei to identify have to be stopped in the gasflow or solid material before they are moved to the detector positions. Short halflives which become of increasing importance for the most heavy and instable nuclei can only be detected to a limit of some tenths of seconds with the He-jet or some parts of milliseconds with the rotating drum, the latter one being only applicable to reaction products undergoing spontaneous fission.

Moreover in the stopping process useful information from the reaction kinematics as angular and velocity distributions cannot be used to their full extent. Hence an in-flight separation seems to be the most suitable experimental method to separate the evaporation residues from the projectile beam. The in-flight separated nuclei are implanted into position sensitive surface barrier detectors, where they are identified by their α decay or spontaneous fission.

We have developed this experimental technique during the past five years at the velocity filter SHIP and applied it to the investigation of the heaviest nuclei.

2. Velocity Separation of Evaporation Residues

For complete fusion the velocity of the resulting compound nucleus follows from momentum conservation:

$$V_c = V_p M_p / M_c$$

M_c is the mass of the coumpound nucleus M_p, V_p are mass and velocity of the projectile. The compound nucleus moves in beam direction. As it is heated in the fusion process, neutrons, protons and/or α particles are evaporated. In our case only neutron emission is important due to the low exitation energy of the compound systems and the high Coulombwall of the nuclei with Z ≥ 100.

For isotropic particle evaporation the average velocity of the evaporation residues equals that of the compound nuclei. In the evaporation process and by scattering in the target velocity and angular distributions are spread.

Reaction products from other binary reactions, as fusion-fission or transfer cannot move with the velocity of the evaporation residues. In beam direction transfer products move with a velocity close to that of the elastic scattered target nuclei, which is $2V_c$. They can only reach V_c by multiple scattering.

3. Separation and Identification Techniques

SHIP[1]) principally operates like the Wien velocity filter, however it has spatially separated electric and magnetic fields (fig.1). For efficient suppression of background from scattered projectiles or products from nuclear reactions other than fusion, SHIP has two filter stages. Two quadrupole triplets focus the evaporation residues onto the velocity slit and the detector position respectively. The selected velocity range is determined by the variable velocity slit after the first stage. It is normally ± 5 %. The reaction products have highly excited electron shells and consequently cover a wide ionic charge distribution, SHIP accepts a maximum of ± 10 %. A thin carbon foil 8 cm downstream the target equilibrates the charge distribution 20 ns after formation of the evaporation residue to avoid losses due to exotic charge states from converted transitions. The solid angle of acceptance is 2.7 msr, separation time 2 μs.

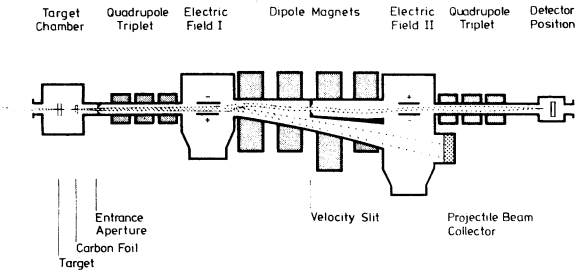

Fig.1: The velocity filter SHIP.

A schematic graph of our setup is shown in fig.2. Target thickness is monitored by Rutherford scattering. The separated evaporation residues pass a large area time-of-flight detector before they are implanted into a position sensitive surface barrier detector. From flight time and energy of the incoming ions a rough mass estimation is possible. By an anticoincidence between time of flight and the surface barrier detectors, decays in the detector can be discriminated from incoming particles. The system is completed by a γ-X-ray detector. The time of flight detector was only disposable in the ^{50}Ti and ^{54}Cr irradiations.

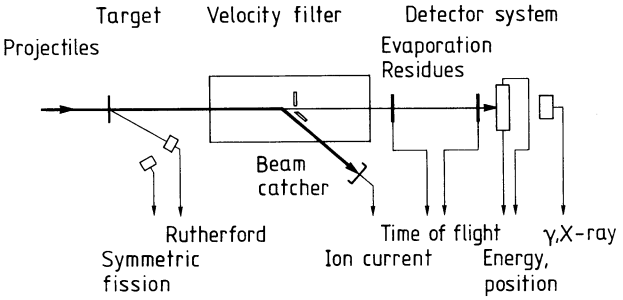

Fig.2: Experimental setup.

Symmetric fission of the compound nuclei can be detected with a simple time-of-flight energy measurement[2]) in our target chamber. We used the micro-bunches of the UNILAC beam of less than 1 ns width for timing and a surface barrier detector for energy measurement.

The position sensitive detector system consists of an array of seven position sensitive surface barrier detectors[3]) with a total area of 2 000 mm^2. Fig.3 shows a two dimensional plot of the spatial distributions of α decays from a certain de-excitation channel. The detectors are position sensitive in vertical direction. The horizontal position is given by the detector number. (The horizontal distribution across the single detectors is smeared out artificially for better presentation.) The active detector area is reduced by the frames of the single detectors to 80 %. SHIP is operated with velocity dispersion in the detector plane, so the horizontal position of implantation is determined by particle velocity. Ions with average velocity will be implanted in the central detector. The projections of horizontal and vertical distributions of the evaporation residues are also plotted.

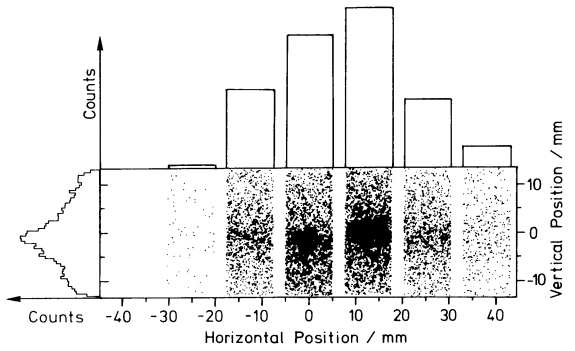

Fig.3: Intensity distribution of ^{162}W from the reaction ^{58}Ni on ^{110}Cd on the detector array (horizontal distribution across each detector artificial).

The efficiency is calculated with a Monte Carlo program including the recoil from evaporated neutrons on the evaporation residue, energy loss and scattering in the target, the ionic charge distribution of the evaporation residues and the ion optical properties of SHIP[4]). With the detector array we calculate (22-26)% for evaporation residues in the discussed reactions. As the evaporation residues are implanted close to the detector surface, about 50 % of the emitted α particles escape, the sensitivity is then (11-13)%. Suppression of the projectile beam is typically 10^{10} to 10^{12} integrated over the whole energy spectrum.

Unknown α emitters can be identified via α-α mother-daughter correlations, using the position sensitivity of the detector. All decays originating from a certain implanted evaporation residue have to occur at its position of implantation within the detector resolution. For all ions impinging the detector and all decays energy, position, and time are listed on tape. Off-line all events within a certain position and time window are evaluated. The time intervals between implantation and first decay or subsequent decays are taken for halflife determination[5]), which is peformed with the maximum likelihood method. Correlation time is limited by random correlations.

4. Experimental conditions

Monoisotopic targets of ^{206,207,208}Pb and ^{209}Bi were irradiated with ^{40}Ar, ^{50}Ti, or ^{54}Cr. Average beam intensities were 10^{12} sec^{-1}, target thickness around 0.7 mg/cm^2. The specific projectile energies were close to fusion barrier and about 4.85 MeV/u.

To withstand high beam intensities the targets were covered with carbon films of 0.03 mg/cm^2 and mounted on a wheel, which rotates synchronously to the accelerator pulsing. During subsequent beam bursts of 5 ms followed by 15 ms intervals eight consecutive targets are moved across the beam axis, with a velocity of 1 cm/ms.

5. ^{40}Ar on ^{206,208}Pb irradiations

The investigation of Fm isotopes from fusion of Ar and Pb is a good starting point to enter the region of the heaviest elements. Targets near the double magic ^{208}Pb allow the production of cold compound systems, formation cross sections are in the nanobarn region, the dominating decay modes are α decay or spontaneous fission, and halflives range from ms to s. These experimental conditions are also expected for the heavier nuclei.

Moreover special deexcitation channels have been investigated carefully by various authors: ^{208}Pb(^{40}Ar,3n)^{245}Fm[6]), and ^{206}Pb(^{40}Ar,2n)^{244}Fm[7]). With our experimental setup, observation of all deexcitation channels is possible for the first time.

In ^{208}Pb irradiations[8]) we observed the isotopes $^{244\text{-}246}$Fm. The α decaying isotopes ^{246,245}Fm were identified by their decay energies, their halflifes, and by correlations to daughter decays, the spontaneous fissioning ^{244}Fm by its halflife. In this experiment the finding of the 2n deexcitation channel by Oganessian et al.[9]), who only observed the spontaneous fission of ^{246}Fm was confirmed. From our data we can plot an integral excitation function for isotopes formed via neutron evaporation (fig.4). From theoretical considerations[10]) we expect, that the maximum of this excitation function coincides roughly with the fusion barrier obtained from the

measurement of compound fission. The position of the barrier can be described by an effective Coulomb radius. Schulte[11]) obtained r_{eff} = 1.44 fm in agreement to Oganessians value of r_{eff} = (1.44±0.01)fm[12]). Both values were taken from compound fission. The maximum of the excitation function (fig.4) corresponds to r_{eff} = (1.42±0.02)fm.

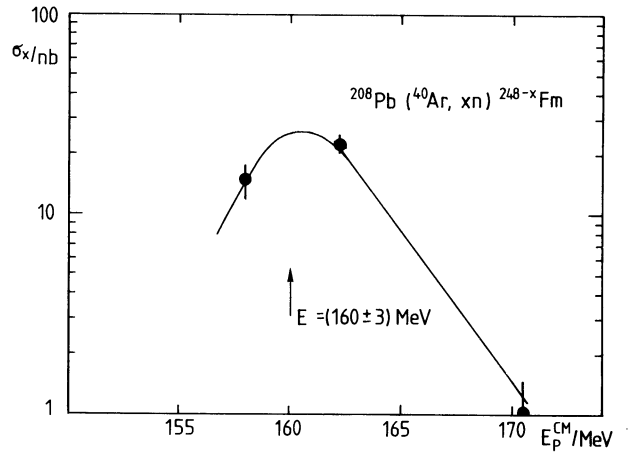

Fig.4: Integral excitation function for ^{40}Ar on ^{208}Pb, error bars indicate statistical error. The absolute error for the cross section is a factor of two, for energy ± 2 MeV.

Our results confirm the sugggestion of Oganessian to obtain cold heavy compound nuclei from fusion reactions making use of the favourable Q-value of the double magic ^{208}Pb.

Irradiating ^{206}Pb with ^{40}Ar we found the new isotopes ^{243}Fm and its daughter decay ^{239}Cf. Fig.5 shows an α spectrum without correlation conditions but taken between the UNILAC beam bursts, the irradiation time was 20 h, the projectile dose 8×10^{16}. The spectrum shows the decay assigned to ^{243}Fm and the daughter decays ^{239}Cf which could also be correlated (Table 1).The measured cross section is $(1.3^{+1.3}_{-0.7})$nb.

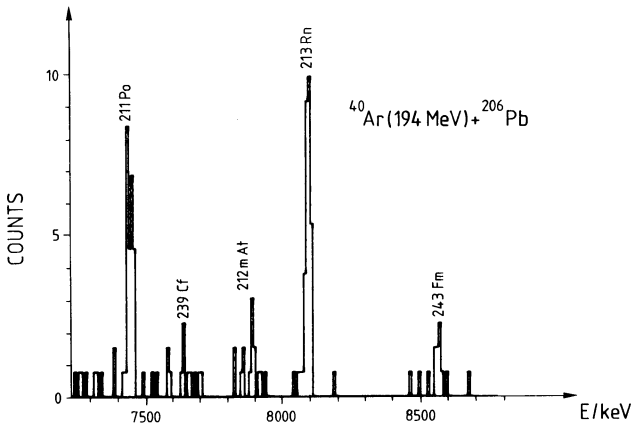

Fig.5: Alphaspectrum for ^{40}Ar on ^{206}Pb, taken between UNILAC beam bursts.

Isotope	Energy/kev	$T_{1/2}$/s
^{256}104	sf	$(8.1^{+1.3}_{-0.8}) \times 10^{-3}$
^{255}104	8 726,sf	$1.4^{+0.6}_{-0.3}$
^{247}Md	8 428	$2.9^{+1.7}_{-1.2}$
^{243}Fm	8 546	$0.18^{+0.08}_{-0.04}$
^{239}Cf	7 630	39^{+37}_{-12}

Table 1.

Isotopes from ^{40}Ar and ^{50}Ti irradiations. Error for decay energies ±25 keV, halflife for 68% probability.

The spectrum also shows α decays from transfer products. From comparison of our data to those of Nitschke we calculated that transfer products are suppressed by SHIP to more than three orders of magnitude. Our experiments show that they have the same velocity as the evaporation residues. As discussed in sec.1 this can only be explained by scattering processes.

Comparison of our cross sections, which are strongly dependent on our efficiency calculations, to experimental data from Gäggeler[7]), Nitschke[6]) and Oganessian[9]) show good agreement, and indicate the reliability of our calculations, even for the region of the heaviest nuclei, where most of the parameters necessary for the ion optical calculation are extrapolated.

6. ^{50}Ti on ^{207,208}Pb irradiations

One interesting aspect to investigate element 104 is the systematics of spontaneous fission halflives for even-even nuclei, which changes abruptly between No and 104 (fig.6).According to experiments from Oganessian[13]) the enhancement of halflifes on the N=152 subshell disappears. For the isotope ^{256}104 on this subshell one could expect an effect of about four orders of magnitude.

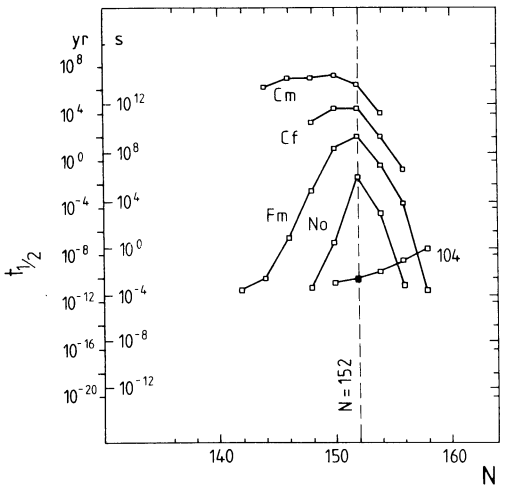

Fig.6: Systematics of experimental spontaneous fission halflives for even-even nuclei (filled square: investigated at SHIP).

We irradiated ^{208}Pb targets with (4.75-5.15) MeV/u. At the lowest energies the 1n channel was identified by observation of the well known α decay of $^{257}104$, which could also be correlated to α decays of ^{253}No. With increasing projectile energy the expected ms spontaneous fission activity, assigned to $^{256}104$, appeared. The width of the excitation function is about 10 MeV (fig.7), so we can exclude that the spontaneous fission activity originates from a transfer. Another proof is the agreement of our measured cross section to that given by Oganessian, which is about 6nb in both cases.

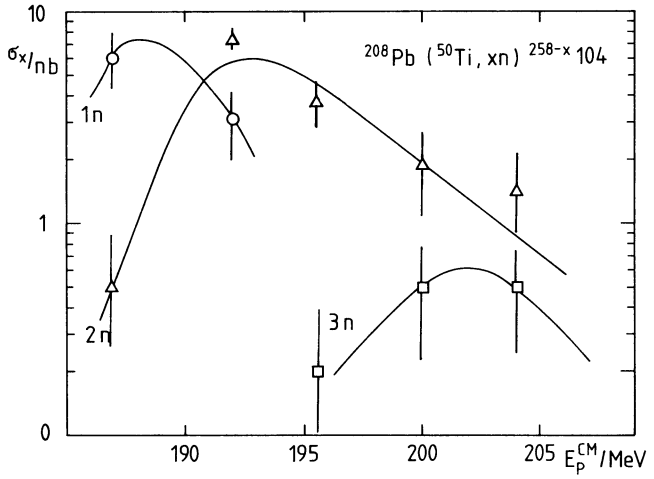

Fig.7: Excitation function for ^{50}Ti on ^{208}Pb (see also fig.4).

Another assignment of the decay than that given by Oganessian would mean the absence of the 2n channel, as we do not observe other decays, which could be assigned to the isotope $^{256}104$. Our halflife of $(8.1\ ^{+1.3}_{-0.8})$ms (fig.8) is in good agreement to that measured by Oganessian. At the highest energies we observed spontaneous fission events with seconds halflife, which might belong to the isotope $^{255}104$ and indicate the 3n channel.

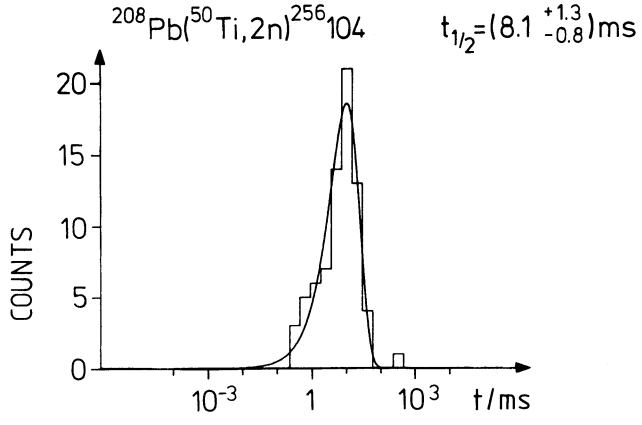

Fig.8: Logarithmic distribution of time distances between implantation and decay of $^{256}104$.

This isotope also can be formed in the reaction ^{207}Pb (^{50}Ti,2n)$^{255}104$.We irradiated ^{207}Pb with the optimum energy for the 2n channel, which is known from the preceding experiment and observed α decays and also spontaneous fission (Table 1).

So we have good arguments to prove the assignment of the observed spontaneous fission activity as proposed in ref.[13]). Fig.9 shows the integral excitation function for the ^{208}Pb irradiations, from which we take an effective Coulomb radius of (1.42 ± 0.02) fm for the maximum of the excitation function, in agreement to the result from ^{40}Ar on ^{208}Pb irradiations.

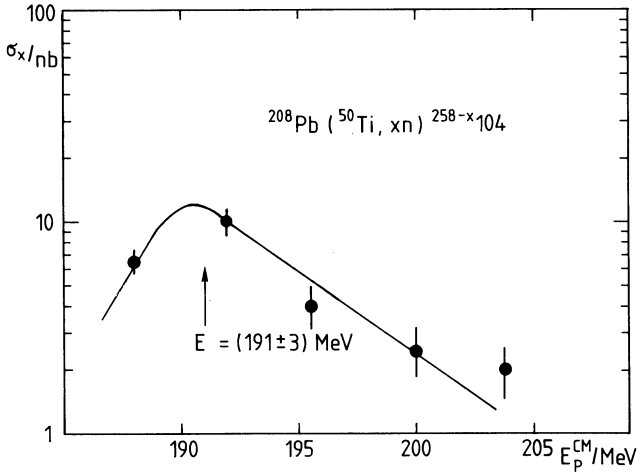

Fig.9: Integral xn excitation function for ^{50}Ti on ^{208}Pb (see also fig.4).

7. ^{50}Ti on ^{209}Bi irradiations

In irradiations of ^{209}Bi with ^{50}Ti we expect the formation of $^{258,257}105$. The isotope $^{257}105$ is of special interest: In irradiations of ^{54}Cr on ^{209}Bi to produce element 107 Oganessian et al.[14]) observed two spontaneous fission activities. One, with a halflife of (1-2)ms was assigned to $^{261}107$, the other one with 5s was explained by an unobserved α decay of $^{261}107$ leading to $^{257}105$, which was assumed to undergo spontaneous fission with the corresponding halflife. From the relative intensities of observed spontaneous fission events in both cases, for $^{261}107$ as well as for $^{257}105$ strong α decay branches were postulated.

We irradiated ^{209}Bi with ^{50}Ti beams between 4.65 MeV/u and 4.95 MeV/u with an integral ion dose of 10^{16} per energy. The 2 n channel was observed at 4.85 MeV/u und 4.95 MeV/u by decay chains from $^{257}105$ ending in the sequence ^{249}Md-^{245}Es. Due to the 50% detector efficiency, most of them are incomplete. At 4.92 MeV/u we found the decay chain of fig.10, in which decays of 8940 keV and 8750 keV are correlated to the known transition of ^{249}Md. The statistical error probability of this chain is less than 10^{-9}. So we can assign the decays to the isotopes $^{257}105$ and ^{253}Lr. The chain in fig.10 respresents the decay pattern of a single implanted nucleus of $^{257}105$, therefore we have to consider that the given decay energies and time distances scatter around the exact values of α decay energies and halflives.

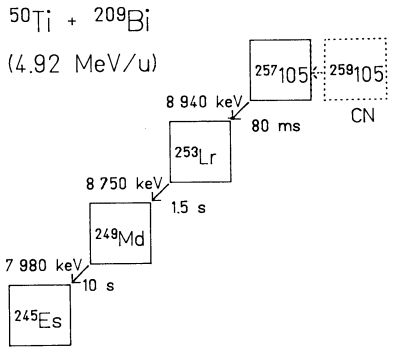

Fig.10: Decay chain observed in ^{50}Ti on ^{209}Bi irradiations, 2 n channel.

At 4.75 MeV/u we observed decay chains, two examples of which are shown in fig.11. For the odd-odd nuclei α decay as well as electron capture could be observed. The electron capture decay of $^{258}105$ would lead to the spontaneous fissioning $^{258}104$.

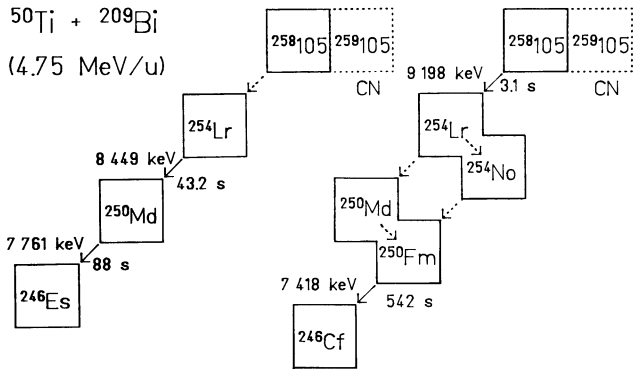

Fig.11: Decay chain observed in ^{50}Ti on ^{209}Bi irradiations, 1 n channel.

The decay characteristics of the Lr and 105 isotopes from the 1n channel are, up to our present state of data evaluation for $^{258}105$ two decay energies, 9189 keV and 9073 keV and (3.3 ± 0.7)s halflife, for ^{254}Lr the decay energy 8459 keV, and the halflife (16 ± 4)s. The decay chains end in known transitions of ^{254}No, ^{250}Fm or ^{250}Md.

The errors of the decay energies are ± 35 keV. Halflifes may be corrected in the course of our further data evaluation, as up to now only the most significant events have been analysed, for instance those correlated to daughter decays or with short time distances to the evaporation residues.

We observed 12 spontaneous fission events with a halflife of $(3.9 \pm {}^{1.6}_{0.9})$s one at 4.65 MeV/u, 7 at 4.75 MeV/u, 3 at 4.85 MeV/u and one at 4.95 MeV/u. The maximum cross section is about 0.7 nb in good agreement to Oganessian et al., who measured 0.8 nb[14]).

8. ^{54}Cr on ^{209}Bi Irradiation, Element 107

As pointed out in the previous section Oganessian and coworkers observed a spontaneous fission activity of (1-2) ms in irradiations of ^{209}Bi with ^{54}Cr, which they assigned to the isotope $^{261}107$, they postulated a strong α decay branch of this isotope.

Isotope	Energy/kev	$T_{1/2}$/s	
$^{262}107$	10 376	$(4.7\ ^{+2.3}_{-1.6}) \times 10^{-3}$	
$^{258}105$	9 189 9 073	3.3± 0.7	Preliminary data
$^{257}105$	9 161 9 049 8 946	0.9± 0.3	
^{254}Lr	8 459	16 ± 4	
^{253}Lr	8 824 8 743	2.6± 4	
Spontaneous fission			
^{50}Ti+ ^{209}Bi	12 events	$3.9^{+\ 1.6}_{-\ 0.9}$	
^{54}Cr+ ^{209}Bi	1 event	$3\ ^{+\ 6}_{-\ 2}$	

Table 2. Decays observed in ^{50}Ti and ^{54}Cr on ^{209}Bi irradiations. The error for decay energies is ± 35 keV. The halflife is for 60% probability.

Intention of our experiment was to find the α decay of element 107 in correlation to decays of 105 and 103 observed in the ^{50}Ti on ^{209}Bi bombardements, and possibly down to transitions of ^{250}Fm or ^{250}Md.

From our previous experimental results we calculated the maximum of the excitation function for an effective radius of (1.42 ± 0.02) fm corresponding to 4.85 MeV/u and 4.95 MeV/u.

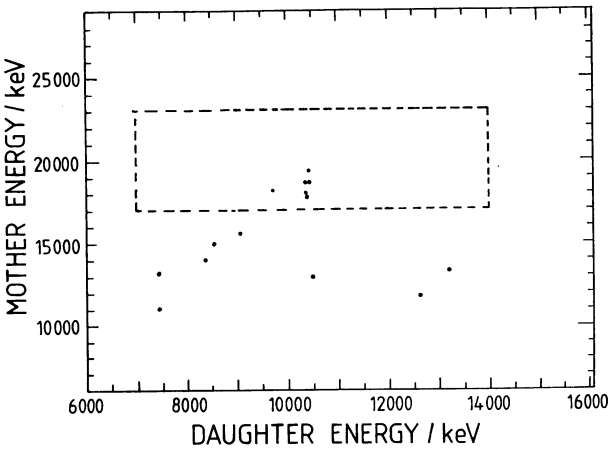

Fig.12: Correlation between evaporation residues and decays for ^{54}Cr on ^{209}Bi.

Fig.12 shows a plot of position and time correlations between evaporation residues, characterized by an energy exceeding 17 MeV and a time-of-flight signal, and daughter decays, characterized by an energy between 7 MeV and 14 MeV, and an anticonincidence to the time-of-flight detector. The time window is 200 ms, the position window ± 0.5 mm. The time distances between implantation and α decay for the 10.4 MeV events range from (1-13) ms, that of the 9.7 MeV event is 165 ms. The halflife of the short lived events is 4.7 ms (fig.13).

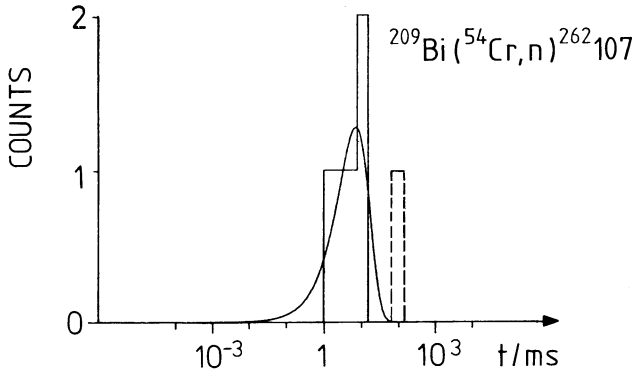

Fig.13: Logarithmic time distribution of events from fig.12.

The difference in mother energy signals between the average of the background from target like recoils with an average of 14 MeV and the 18 MeV events corresponds to the mass difference between Bi and the fused system, if the velocity is normal, as checked by the time of flight measurement.

One of the observed events is correlated to a decay chain ending in ^{254}Lr, two of them end in ^{250}Fm decay and one ends in ^{250}Md. The decay chains are partly incomplete, as in the average half of the α particles, emitted from the evaporation residues implanted close to the detector surface, escape the detector.

An example of a complete decay chain is shown in fig.14, the results of the irradiations are collected in table 2. The α decay energy of $^{262}107$ has been measured to (10376 ± 35)keV. One of the observed decays connected to a correlation chain has an energy of (9.704 ± 50)keV and its most probable halflife differs considerably from that of the other decays. In this case we have to consider that the evaporation residues are implanted into the detector close to its surface hence the possibility that not the full energy of an α decay is measured, cannot be excluded. For our case the probability for a decay with degraded energy between 9 and 10 MeV is less than 5 %.

At 4.85 MeV one spontaneous fission with a time distance of 4.3 s to the implantation of the evaporation residue was observed.

The cross section calculated from our counting rates is of the order of 0.2 nb, the integral dose of irradiation was 1.2×10^{17} particles.

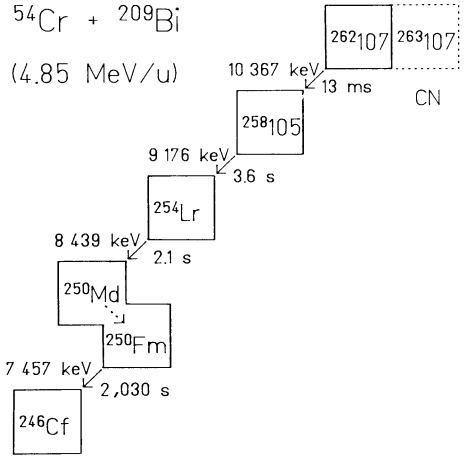

Fig.14: Alpha decay chain of element 107.

9. Discussion

Our experimental results show that the use of targets near the double magic ^{208}Pb makes it possible to form cold compound nuclei for the heaviest systems known up to now. The effective Coulomb radius of (1.42 ± 0.02) for which the integral excitation function for evaporation residues has a maximum did not decrease even for our heaviest projectile ^{54}Cr. So we can hope to produce even heavier evaporation residues with low excitation energies.

The indentification of the isotopes $^{255,256}104$ by their spontaneous fission and their assignment[13]) is supported by our results. The change in spontaneous fission halflife systematics when leaving the actinide region, as found by Oganessian et al. and calculated by Randrup et al.[15]) could be confirmed.

The assignment of the spontaneous fission activity observed in the ^{50}Ti on ^{209}Bi irradiations is not facilitated by our experimental results, as we have to take into account the 1n channel as possible source for this activity. The isotope $^{258}105$ is not likely to undergo spontaneous fission itself: The hindrance factors for spontaneous fission between even-even and odd mass nuclei are expected to be of about the same order as they are between odd mass and odd-odd nuclei [16]). From this point of view the odd-odd $^{258}105$ is not expected to undergo spontaneous fission decay. The predicted ß decay halflife of $^{258}105$ is 16s[17]), so this isotope could have a strong electron capture branch, which would lead to the spontaneous fissioning $^{258}104$, with a halflife of tens of milliseconds. Consequently the fission events would be observed with the longer halflife of $^{258}105$. $^{257}105$ however is expected to fission as interpreted by Oganessian et al. Our opinion is, that the spontaneous fission activity in ^{50}Ti on ^{209}Bi irradiations could originate as well from the 1n as from the 2n channel, as we observed it together with α decay from $^{258}105$ as well as from $^{257}105$.

Our experimental results show the first observation of α decays of element 107, assigned to the isotope $^{262}107$ by α-α correlations to known transitions of various isotopes. Spontaneous fission of this odd-odd isotope is not expected. The one spontaneous fission event we observed may belong to a daughter decay, as its lifetime agrees with those measured in the ^{50}Ti on ^{209}Bi iradiations. Electron capture of $^{262}107$ leading to the

spontaneous fissioning $^{262}106$ can be excluded from ß halflife predictions. The odd mass nucleus, $^{261}107$ which might be formed by 2 neutron evaporation could not be found, possibly due to the low excitation energy at the compound systems produced.

One other important result of our experiments is that the nuclei formed in the chosen target projectile combinations need no extra energy above the Coulomb barrier to undergo fusion. So we have a new hope, to reach the island of superheavy nuclei by cold fusion of ^{48}Ca and ^{248}Cm.

It is expected that fusion of very heavy systems is limited by Coulomb disruptive forces. This process can be characterized by the scaling factor $(Z^2/A)_{eff}$ [18]. From the presented results as well as from the data of Schmidt et al.[10] no enhancement of the barrier, e.g. no reduction of the effective Coulomb radius is measured even for $(Z^2/A)_{eff}$ values exceeding that for ^{48}Ca on ^{248}Cm (fig.15). With an effective Coulomb radius of 1.40 fm the excitation energy of the compound system at the fusion barrier has the unexpected low value of 28 MeV. As reasonable cross sections can be expected also below the barrier[10] (fig.7), there is some hope that the formation of a superheavy evaporation residue is possible by evaporation of one neutron with (4.7-4.9)MeV/u projectile energies.

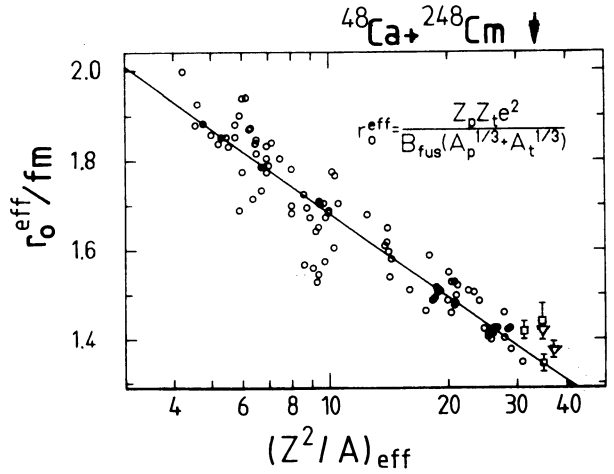

Fig.15: Effective radius parameter in dependence of $(Z^2/A)_{eff}$ circles: Vaz and Alexander[18], triangles: Schmidt et al.[10], squares: this work.

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DISCUSSION

J.B. Wilhelmy: Do you get any information on total kinetic energy release for this very heavy element fissions from summing in your crystal?

G. Münzenberg: This is a very big problem we thought about, because first of all our surface barrier detectors are more useful for detecting α-decay with good resolution. That means they have comparatively high resistance. On the other hand, you know always one of the fission fragments is leaving the detector so we have only a very small chance that both fragments are stopped in the same detector. That means if both are going just passing close to detectors surface. If you remember the figure of the detector system, you realize those long big detectors. They were really mounted for detecting the second fragment. I think up to our present state of art we are not able to have such a good energy resolution for the total kinetic energy.

W.-D. Schmidt-Ott: In your titanium experiment when you produce elements 105 and 104 you have to decide whether the 104 is spontaneous fissioning. Will there be a possibility to measure this spontaneous fission in anticoincidence with capture X-rays.

G. Münzenberg: This is one possibility we think about but you have several technical problems: one is comparatively long coincidence time of about 10 to 50 milliseconds and so you have to work at a very low level of background. We think about it and we hope that we will be able to do it once. The problem is not the efficiency, it is just the background.

R.K. Sheline: You have seen many new isotopes. I wonder if the additional isotopes and the additional systematics makes it possible for you to say whether or not one should really find a much longer lived region at Z = 100 and N = 184?

G. Münzenberg: We see no trends, everything is quite normal.

D.C. Hoffmann: You say you check the alpha systematics and for 107 it seems not inconsistent. Can you say anything more about agreement with the alpha decay of 105, for example, and what you observe in 107?

G. Münzenberg: The Q alpha systematics for the very heavy elements is somewhat difficult I would say, the reason being that some very important points are missing.

A. Sobiczewski: Concerning your data on the fission half-life T_{sf} for the nucleus $^{256}104$, which supports the change in the systematics of T_{sf} obtained by the Dubna group at Z = 104, I would like to add that theoretical results also give a support for such change. This was already discussed in Cargèse, but since then we made some improvements in the calculations. As a result, the calculated half-lives somewhat altered, but the change in the systematics remained.

G. Münzenberg: I think in respect to this comment it will be very interesting to have some spontaneous fission of some even-even nucleus of element 106 because then you get the trend of the new systematics and this could be done with our instruments because the half life is expected to be some tens of microseconds.