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Status Report and Request for Beam Time

Experiment **IS 302**

High-Accuracy Mass Determination of Unstable Nuclei with a Penning Trap Mass Spectrometer

CERN - Burjassot - Darmstadt - Leuven - Mainz - Montreal - Orsay - Warsaw

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1. Introduction

The ISOLTRAP experiment has very successfully continued its mass measurement program during the last two and a half years. More than 70 mass values of rare earth isotopes in the vicinity of ^{146}Gd and of neutron-deficient mercury isotopes have been determined with an accuracy typically better than 20 keV. In parallel with these measurements, the Penning trap mass spectrometer has undergone a number of important modifications and improvements. They have allowed very accurate mass measurements in regions of the nuclide chart which were not accessible to direct mass measurements in the past. One step was the commissioning of a newly designed Penning trap for ion cooling, beam purification and bunching. This system was the prerequisite for the mass measurements on rare earth isotopes. The second step was the installation of an additional RFQ ion trap beam buncher. With such a system the applicability of ISOLTRAP has become widely independent of chemical properties of the ions delivered by ISOLDE, which was required for the mass measurements on mercury isotopes. The third step was the further improvement of the resolving power of the spectrometer. This has proved to be decisive for unambiguous determination of ground state masses and will play an important role in future measurements.

In the coming two years mass measurements are planned both on medium heavy and heavy isotopes:

- It is foreseen to complete the mass measurements on neutron deficient rare earth isotopes in particular in the region $N<82$, $Z>64$. From ^{146}Gd towards the proton drip line many masses are still unknown or doubtful. Furthermore some open questions concerning the existence of isomers in the region $N>82$ should be addressed. In addition, selected isotopes will be investigated which are the endpoints of long alpha decay chains, thus enabling the indirect determination of masses very far from stability around $Z=80$.
- The possibility for mass measurements on neutron-rich rare earth isotopes will be investigated. Such measurements would allow to establish the trend of the nuclear binding on the neutron-rich side of the valley of β-stability in a region in which our present knowledge about masses is restricted to the immediate vicinity of the backbone of stable nuclei.
- The mass measurements on neutron-deficient mercury isotopes will be extended and complemented by the investigation of Tl, Pb, and Bi isotopes. The goal is to provide accurate mass values in this region of interesting nuclear structure effects and to map the $Z=82$ shell closure. The particular difficulty here is the existence of long-living isomers. Furthermore some of the isotopes in this region have turned out to be key-nuclei required for an improved evaluation of the mass measurements performed on projectile fragments with the ESR at GSI in Darmstadt.
- A new mass region will be explored on the neutron-rich side of ^{208}Pb. Despite the fact that this nucleus is the classical shell model nucleus hardly any information exists if one embarks towards more neutron-rich isotopes. Such isotopes (like the recently discovered ^{215}Pb and ^{217}Bi) are particularly important for the adjustment of the parameters of models used for the prediction of the stability of 'super heavy' isotopes.

2. Technique and Recent Results

2.1 Experimental technique

The basic principle of mass measurements with ISOLTRAP is the determination of the cyclotron frequency $\omega_c = q/m \cdot B$ of ions with a charge-over-mass ratio q/m stored in a Penning trap with known magnetic field B. Figure 1 shows the present layout of the ISOLTRAP spectrometer [bo97]. It consists of an ion preparation section and two Penning traps. The ion preparation section has the task to stop the 60 keV ISOLDE beam and to prepare it for an efficient transfer into the cooler trap. In the past a stopping/re-ionization technique was applied which limited the applicability of ISOLTRAP to surface ionizable elements. Last year the system was considerably improved by the installation of an RFQ trap ion beam buncher, which allows to capture the continuous ISOLDE beam in flight. The lower Penning trap has the task to accumulate, cool, and mass separate the ions delivered from the ion preparation section and to bunch them for an efficient delivery to a second Penning trap. This trap is the actual mass spectrometer where the cyclotron frequency of the captured ions is determined. In the following several aspects of the performance of the different sections of ISOLTRAP will be discussed.

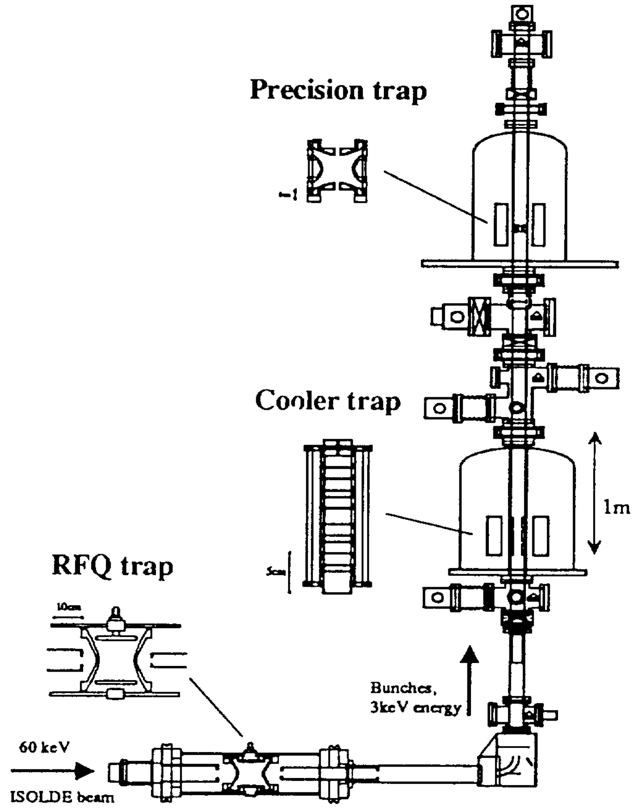

Fig. 1: Experimental set-up of the ISOLTRAP mass spectrometer

2.1.1 The RFQ-trap ion buncher

The only way to extend the applicability of ISOLTRAP to non-surface-ionizable elements is the implementation of a bunching technique where no implanting, diffusion and re-ionization processes are involved. For this purpose an RFQ trap ion beam buncher was developed at McGill University, Montreal [mo92] and integrated into the ISOLTRAP system last year. The buncher consists of a RFQ trap connected directly to the ISOLDE beam line but installed on a high voltage platform close to the potential of the beam. Ions from ISOLDE are thereby decelerated from their initial energy to a few electron volts before entering the RFQ trap. The ions are then captured in the trap by energy loss from buffer gas collisions. The collected ion cloud is ejected as a single bunch with an average kinetic energy of about 3 keV. In order to deliver the ions to the cooler Penning trap (Fig. 1), which is just above ground potential, the ion bunch enters a cavity immediately after extraction which is brought from the trap potential to ground potential while the ions are still inside.

At the end of last year the RFQ trap ion beam buncher was for the first time successfully used for the mass measurements on neutron-deficient mercury isotopes.

2.1.2 Isobar separation with the cooler trap

The cooler trap is a large cylindrical Penning trap [ha97] placed in the homogeneous field of a 4.7 T super conducting magnet. Ions from the RFQ trap are captured in the trap, cooled by the dissipating force provided by a buffer gas, and centered by the simultaneous application of an azimuthal rf-field at the cyclotron frequency of the ions. Since the ions cyclotron frequency is involved in the cooling process a purification of the stored ion cloud is achieved (for details see [sa91, kö95]). The new cooler trap system has been optimized for high mass selectivity in order to resolve isobars and to deliver a clean ion beam to the precision trap, an essential ingredient for highly accurate mass measurements. As an example, figure 2 shows a 'mass scan' performed with the cooler trap for an A=138 ion beam delivered by ISOLDE from a Ta-foil target. Shown is the number of ions extracted from the trap as a function of the applied radio frequency. The mass resolving power achieved here is about $R=10^5$, which is sufficient to resolve and separate isobars even close to stability.

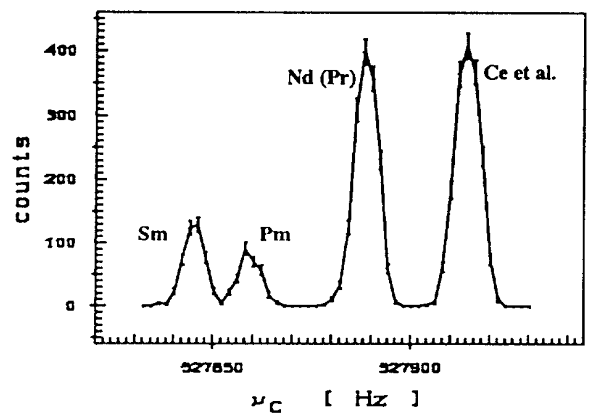

Fig. 2: 'Mass scan' with the cooler trap for A=138 ions delivered from a Ta-foil target with surface ionizer. Shown is the number of ions extracted from the trap as a function of the applied rf-frequency.

2.1.3 The precision trap as isomer separator

The precision trap in which the cyclotron frequency determination of the ions is performed is in operation without major modification since several years and performs excellently [be97c]. Nevertheless, improvements were achieved for the residual gas pressure inside the trap, which limits the minimum achievable line width of the resonances and hence the resolving power. This trap is normally operated with an resolving power R close to one million (corresponding to rf excitation times of T_{rf} = 1 s for A=100 ions). However, by increasing T_{rf} the resolving power R can be increased by about an order of magnitude: the maximum resolving power that has been realized in off-line tests with ^{133}Cs ions is R = 8 million for which an rf-excitation time of 12 s is required. This corresponds to a mass resolution of Δm_{fwhm} =15 keV.

Of course, a high resolving power is the prerequisite for a high accuracy. For the investigation of trends in nuclear binding energies an accuracy of $\delta m/m \approx 10^{-7}$ is sufficient and is already achieved with modest resolving powers ($R < 10^6$). Higher resolving powers become important in the case of long-lived isomers produced simultaneously with isotopes in their ground state. Over the nuclide chart nearly one third of the isotopes have long-lived isomeric states with (in many cases unknown) excitation energies down to <100 keV. Only in a few cases information about the production ratio exists which may vary drastically depending on the half-lives and release times from the targets. Therefore, the resolution of isotopes in their ground or isomeric state is essential for an unambiguous determination of the mass of the isotope in one or the other state. That this can be achieved with ISOLTRAP has now been demonstrated several times. Two recent examples are shown in Fig. 3 for ^{141}Sm (ΔE_{lit} = 175 keV) and ^{185}Hg (ΔE_{lit} = 103 keV).

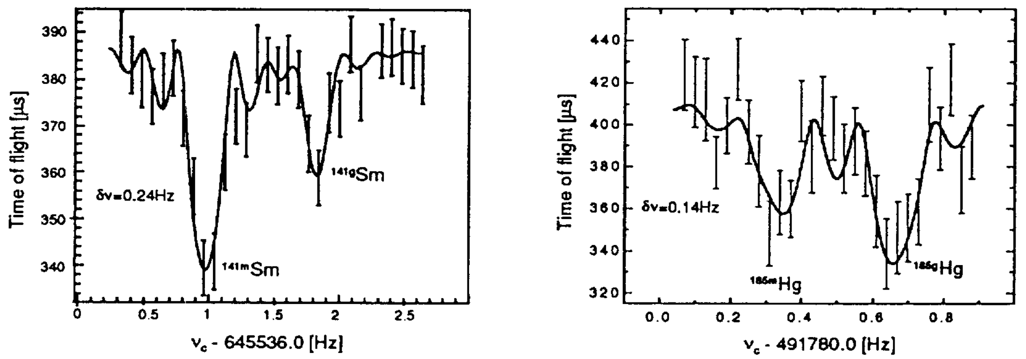

Fig. 3: Resolved isomeric and ground states for ^{141}Sm (ΔE = 175 keV) and ^{185}Hg (ΔE = 103 keV).

2.2 Mass measurements

The 30 shifts approved following the last beam request to the ISCC have been used very efficiently. In total 76 isotopes and states were investigated, which are listed in table 1. For practically all of these isotopes an accuracy in the mass determination of $\delta m/m=1\cdot 10^{-7}$ was achieved. Compared to the original plans some adjustments had to be made. Due to technical problems of ISOLDE, a run aiming for a continuation on the mass measurements on very neutron-rich alkali and earth alkali isotopes had to be postponed. Later on no heavy targets where available for an extended period of time. Therefore, we concentrated on the two other goals: measurements on rare earth isotopes and first measurements on mercury isotopes, both only possible due to the improvements discussed above.

Table 1: List of isotopes investigated since the last beam time allocation

Ba	123, 125, 127, 131
Cs	133 (Reference mass)
Ce	133, 134
Pr	133-137
Nd	130, 132, 134-138
Pm	136-141, 143
Sm	136-140, 141m, 141g, 142, 143
Eu	139, 141-149, 151, 153
Dy	148, 149, 154
Ho	150
Tm	165
Yb	158-164
Pb	208 (Reference mass)
Hg	184, 185g, 185m, 186, 187, 188, 189, 190, 191m, 192, 193g, 193m, 194, 195, 196, 197g

2.2.2 Rare earth isotopes

Due to a neutron shell closure at N = 82 and a proton sub-shell closure at Z = 64 the isotope ^{146}Gd exhibits some of the features of a doubly magic nucleus. The surrounding nuclei show interesting nuclear structure effects like the sudden onset of deformation around N=90 [ot89]. The investigation of the strength of the proton subshell closure (mutual support of magicity), the request for reliable and highly accurate ground state masses (δm < 20 keV) which are, as an example, needed as input data for shell calculations [bl83,ke95] are the motivation for measurements in this region. Most of the masses of isotopes with Z ≤ 64 and N ≥ 82 are known with high precision. However, this situation changes only a few neutrons and protons away. Prior to the ISOLTRAP measurements the experimentally determined mass values around ^{146}Gd were linked mainly by Q-values [au93]. The uncertainties of the mass values increase drastically as one recedes far from stability and a number of previous mass determinations in this region are questionable.

So far direct mass measurements in this region were hampered by the fact that many isobars are delivered simultaneously by ISOLDE. As discussed above the new cooler trap can be operated as an isobar separator which allows clean ion samples to be prepared and sent to the precision trap. In five short beam times it was possible to investigate more than 50 isotopes in the vicinity of ^{146}Gd, most of them with $N \leq 82$ and $Z < 64$. For more than 10 isotopes mass values were obtained for the first time, for others the mass values have been considerably improved. For most of the isotopes the detailed analysis of the data is finished [be97b] and an atomic mass evaluation similar to the work by G. Audi et al. [au93] has been performed [be97a]. The evaluation shows that the ISOLTRAP measurements have a large impact on this mass region. This is illustrated in Fig. 4 which shows the trend of the two neutron separation energies. The upper and lower part of the figure show the situation before and after the ISOLTRAP data have been included.

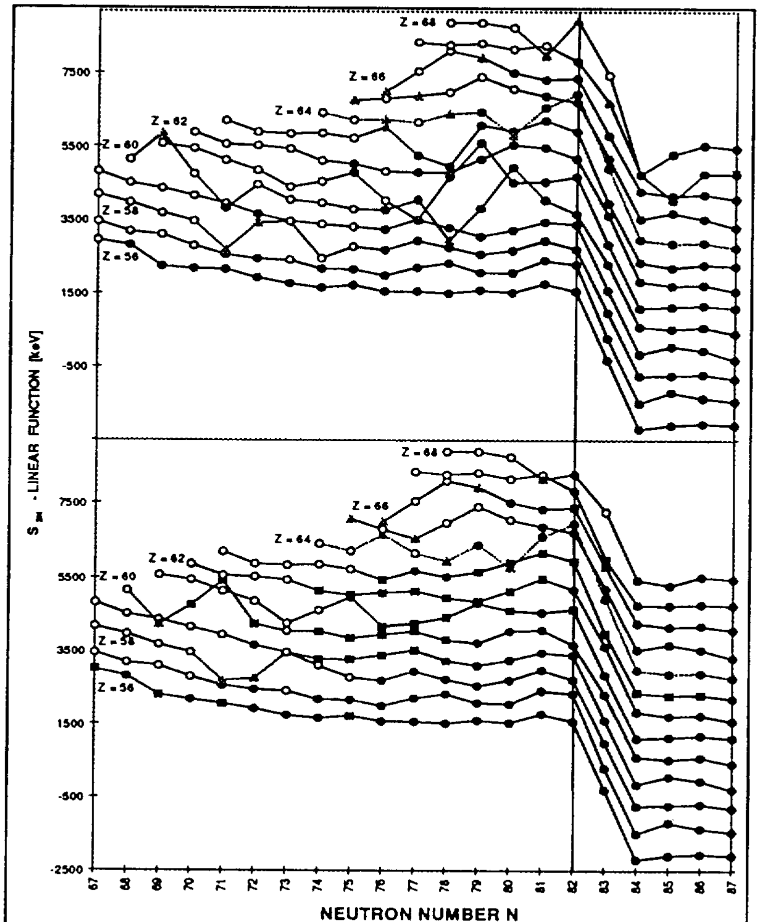

Fig 4: Two-neutron separation energies as a function of neutron number for the different elements. Shown are S_{2n}-values excluding (top) and including (bottom) ISOLTRAP data in the atomic mass evaluation. The isotopes are marked by squares (experimental value and measured by ISOLTRAP), filled circles (experimental value), open circles (estimated from systematic trends), and triangles (exp. value doubtful).

Prior to the ISOLTRAP measurements strong and certainly non-physical discontinuities were observed in the S_{2n} trends derived from estimated but also from experimental mass values as can be seen in the upper figure. Above the N=82 shell closure, for Z=67 and Z=78, these discontinuities are now removed and the separation energies follow the regular trend observed in the neighboring isotopic chains. Most of the isotopes investigated by ISOLTRAP are in the region with $N < 82$ and $Z < 64$. Also here trends are now more clearly established. Systematic deviations from a linear trend for $Z > 56$ around N=76,77 are now visible up to Z=60. They might be related to the eradication of the proton sub-shell gap at $Z \approx 64$ as one departs from N=82 and be accompanied by a change in nuclear deformation. For the investigation of the extent of this discontinuity towards higher Z (including Z=64), data are still missing.

Since mass values of many isotopes are linked via known Q-values to other isotopes, accurate mass measurements of a few key isotopes can have a large impact on the knowledge of masses over a whole mass region. The case of ^{150}Ho will be discussed as an example. As shown in Fig. 5, the mass differences between 19 isotopes linked to ^{150}Ho, some of them beyond the proton dripline around $Z \approx 80$, are already known via experimental Q-values. No link existed between these nuclei and the backbone of stability, since an experimental Q-value for ^{150}Ho was rejected in the 1995 atomic mass evaluation [au95], as in other cases where ``...masses estimated from systematical trends are thought better than the experimental masses" [au95]. This unsatisfactory situation is now resolved by the ISOLTRAP measurement on ^{150}Ho, which justifies the early rejection of the old experimental datum, which is 810 keV away from the ISOLTRAP value. The ISOLTRAP measurement therefore not only gives an accurate experimental mass value for ^{150}Ho but also anchors the masses for all 19 isotopes linked to it.

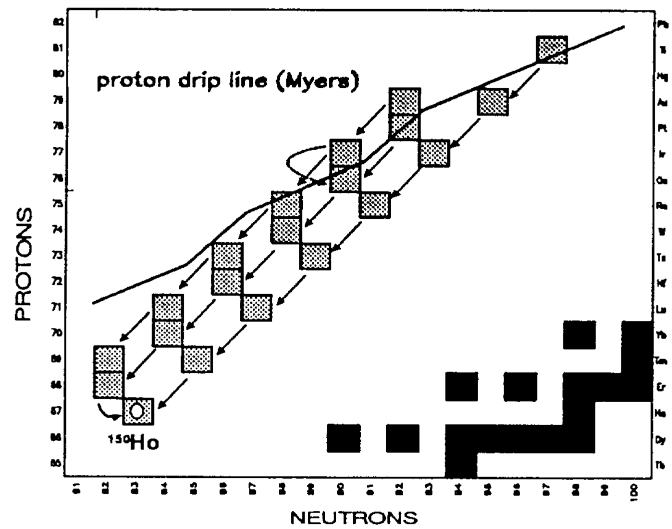

Fig. 5: Q-value links around ^{150}Ho, which is marked by a white circle. Shown are Q-alpha links (straight solid arrows), a Q_β link (curved solid arrow) and a Q-value of the proton decay of ^{167}Ir (curved dashed arrow).

2.2.3 Neutron-deficient mercury isotopes

The interest for nuclear structure investigations and mass measurements (see also letter of intent CERN ISC 93-34 ISC/I9) in this region arises from the appearance of shape coexistence at low excitation energies in the region around the shell closure at Z=82. The onset of rotational bands built on low-lying 0^+ states has been found [wo92] in even-even Pt, Hg, Pb and Po isotopes midshell between N = 82 and N = 126. A large staggering in the $\delta\langle r^2\rangle$ values determined from isotopic shift measurements was observed for $A \leq 185$ in the light Hg isotopes, a jump from small to strong deformation in the neighboring Au isotopes at $A \leq 186$ and a smooth transition in the Pt isotopes [ul86,pa94,hi92]. It is not expected that these effects will be reflected very strongly in the trend of the nuclear binding energies. However, until recently no mass values were known in this mass region and there where the strongest structural changes happen ($A \leq 185$) information is still lacking.

Furthermore, the neutron-deficient isotopes of elements around Z=82 are all members of long α-decay chains with well-known Q-values. Therefore, an accurate determination of such isotopes allows to fix these chains, making a large impact on a whole mass area starting at the upper part of the rare earth region and reaching to the border of known proton-rich isotopes.

With ISOLTRAP, mass measurements on neutron-deficient mercury isotopes were achieved for the first time in December 1996 after the installation of the RFQ trap ion beam buncher.

During only one day of beam time with a molten lead target, mass measurements of the isotopes $^{185-197}$Hg were carried out. In the case of the even isotopes where no isomeric states exist, the evaluation was straight forward and an accuracy of $\delta m \approx 20$ keV can be assigned to all mass values. However, in the case of the odd isotopes long lived isomers exist and are produced at ISOLDE. The excitation energies of typically 100-150 keV of these isotopes are very low. In the first measurements in December 1996 the spectrometer was operated with a resolving power of ≈500000, which corresponds to a mass resolution of 300 keV in this mass range. Therefore it was not possible to resolve isomeric and ground states. Some information from early laser spectroscopy experiments exists on the production ratio between isomer and ground state which, in the case that the isomeric state energy is known, can in principal be used for deriving a correction to the mass values. However, for A < 193 the energy of the isomer is only known for the isotope ^{185}Hg.

Therefore, in a second 2-day run the attempt was made to verify the production of the isomers and to resolve them and the corresponding ground states. For this purpose the spectrometer was operated with resolving powers up to R = 5 million with which a mass resolution of $\delta m \approx 30$ keV was achieved. Using such a scenario it was possible to resolve isomeric and ground state in the cases of ^{185}Hg (see Fig. 3) and ^{193}Hg. Furthermore, it was verified that the ground state is dominantly produced in the case of ^{197}Hg, while for ^{193}Hg only the isomeric state has been seen, for which the excitation energy is known. Therefore for all these isotopes the ground state masses are now identified and determined with an accuracy of 20 keV. In addition, during this run it was possible to extend the measurements in the mercury chain out to ^{184}Hg.

3. Experimental Program

The experimental program proposed for ISOLTRAP for the next 2 years is to continue the exploration of binding energies in the medium mass region for Z > 64 and to perform mass measurements of isotopes on both the neutron-deficient and neutron-rich side around ^{208}Pb.

3.1 Rare earth isotopes

As discussed above the ISOLTRAP measurements have already considerably improved our knowledge of binding energies in this mass region. The main goals are to complete the mass measurements on the neutron-deficient side and to investigate the possibility of mass measurements on neutron-rich rare earth isotopes.

As can be seen in Fig. 4 most of the ISOLTRAP measurements have been performed in the region Z < 64. It is now planned to extend the studies to the region Z ≥ 64, N < 82 further away from stability, where many masses are still unknown or doubtful. The measurements will allow to investigate the strength of the Z = 64 subshell as a function of the departure from the N = 82 neutron shell closure. Furthermore, the discontinuity observed in the 2-neutron separation energies around N = 76, which may be correlated with a shape transition from weakly oblate to prolate as predicted by relativistic-mean-field RMF calculations [la96] for this region, can be traced towards higher Z. The RMF calculations predict (with large theoretical uncertainties) significant discontinuities in the trend of 2-neutron separation energies, for example for ^{144}Gd, which seem to be confirmed by Q_β-values (with large experimental uncertainty). These experimental data and the theoretical predictions do not agree with the general trends in this mass region. Important isotopes for the clarification of this situation are $^{140,142,144}Gd$ and $^{140,142,146}Dy$.

In addition to an establishment of the trends in this mass region there exist a number of isotopes which are of special interest. In some cases high resolution measurements are required to make yet unknown assignments of ground and isomeric states (examples $^{133-138}Pm$, ^{150}Ho) and there exist a number of isotopes of unknown mass which are end-points of long α-decay chains ($^{150,151}Er$, $^{151,152}Tm$ for example). Mass data for the latter will provide important input for the determination of the position of the proton drip-line and for the test of according model predictions.

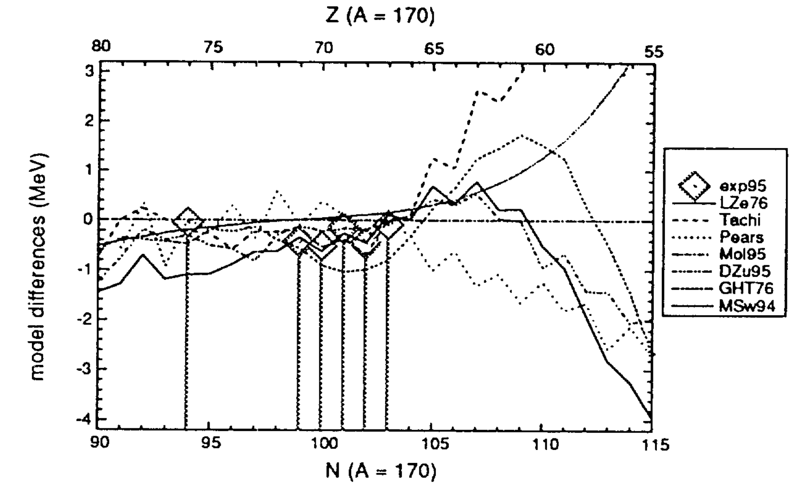

Fig. 6: Difference for A=170 between mass predictions of different models that have been used or are under consideration for r-process calculations. The squares denote experimental mass values [au95].

A new experimental goal for ISOLTRAP is the investigation of masses of neutron-rich rare earth isotopes. The chart of nuclei exhibits a rather narrow band of known nuclei along the valley of stability between A=160 and A=210. In particular on the neutron-rich side our knowledge of isotopes and their properties is very restricted. On the other hand the expected r-process path is here furthest away from stability and one of the open questions concerning the r-process abundances is a mass peak around A=150 [kr97]. But exactly in the region where the mass predictions required for the r-process calculations must reach extremely far, existing mass models can be tested only in a very narrow range (see Fig. 6). Therefore, an extension of accurate mass measurements towards more neutron-rich isotopes is highly desirable. However, very little is presently known about ISOLDE production yields on the neutron-rich side. Yield information exists only for a few isotopes (for example ^{169}Ho: $2.5 \cdot 10^8$ atoms/s, ^{170}Ho: $1.3 \cdot 10^8$ atoms/s). Therefore, we propose both for Ta-foil targets from which still a quite large number of neutron rich isotopes (A<181) can be expected, and for UC or ThC targets, to map the production of isotopes on the neutron-rich side via mass scans with the ISOLTRAP cooler trap (see Fig. 2) and to select those isotopes for measurements for which mass values are not known.

3.2 Nuclei in the vicinity of ^{208}Pb

On the neutron-deficient side it is planned to extend the mass measurements along the mercury chain further away from stability and to cover the region where strong nuclear structure changes are observed (see above). Taking the existing yields into account it should be possible to reach as far out as ^{179}Hg ($T_{1/2}$ = 1s, Y $\approx 10^4$ /s). The extension of the mercury measurements so far out will also help minimize the gap between mass information originating from long α-chains in the rare earth region and reaching to isotopes as far as ^{176}Hg or ^{175}Hg.

As before it will be important to perform the measurements on the odd isotopes with high resolving power since isomeric states are known to exist or can be expected.

In addition to the measurements on the mercury isotopes it is planned to extend the mass determination to the neighboring thallium, lead and bismuth isotopic chains. These measurements combined with known Q_α-values will allow to map the strength of the Z=82 shell closure further out towards the drip line. Furthermore, via Q_α-values an indirect determination of the binding energy will be achieved for many isotopes of the neighboring elements Au, Pt, Ir, Os which are still difficult or impossible to produce at ISOLDE but where interesting nuclear structure effects are present (see above). A demand for very accurate masses in this region comes from the ESR mass measurement project at GSI/Darmstadt. Some of the isotopes in this region (for example ^{197}Bi) are important reference nuclei required for the evaluation of the data achieved with the experimental storage ring ESR.

As an interesting option for the investigation of isotopes which are not directly available at ISOLDE it is planned to test if their mass can be determined by accumulating their shorter-lived mothers in the cooler trap of the ISOLTRAP set-up, to let them decay and to separate the desired daughter by the mass selective cooling technique before the mass measurement. Good test candidates for mother nuclei are $^{178\text{-}181}$Hg for which the β-branching ratio is > 0.5.

An important mass region to be investigated is the neutron-rich side of ^{208}Pb. Despite the fact that this nucleus is the classical shell model nucleus hardly any information exists if one embarks towards more neutron-rich isotopes. Such isotopes are particularly important for the adjustment of the parameters of models used for the prediction of the stability of isotopes of 'superheavy' elements as will be explained in more detail in the following:

There is an intensive experimental activity in the synthesis and study of the properties of the heaviest nuclei (see for example [ho96]). The three new elements: 110,111,112 and new (heavy) isotopes of the elements 106 (Sg), 107 (Ns), 108 (Hs) and 109 (Mt) have been synthesized and studied. The most promising theoretical studies of superheavy element properties are performed within macroscopic-microscopic models [pa91, mo94, gh96], although a fully microscopic analysis of heaviest nuclei has been also done [cw96, la96b, ru96].

In the macroscopic-microscopic model as discussed by [pa91] the macroscopic part of the ground-state energy of a nucleus is described by the Yukawa-plus-exponential formula. The microscopic part is the Strutinski shell correction, based on the Woods-Saxon single-particle potential with a pairing contribution calculated in the BCS approach. The shell correction to the ground-state mass of a heavy nucleus gives a first orientation regarding the stability of this nucleus [pa89]. For Z > 82, the macroscopic-microscopic theory predicts two minima around Z=108, N=162 [pa91a] (recently confirmed experimentally) and Z=114, N=184, both with depths around 7 MeV.

Half-lives, both for the alpha-decay and the spontaneous fission of isotopes in these regions, are very sensitive to changes of the shell correction. A change of the shell correction by 1 MeV for the superheavy nuclei changes the calculated spontaneous-fission and α-decay half-lives by a few orders of magnitude. The calculated shell correction energy depends on the parametrization of the Wood-Saxon potential depth. A derivative of the shell correction as a function of this potential depth is presented in Fig. 7. The dark areas indicate those regions of nuclei with the largest instability against a change of the potential depth. Therefore, for a proper fit of the Wood-Saxon parameters and, as a result, better predictions of properties for heaviest elements, an investigation of unknown masses particularly in the region

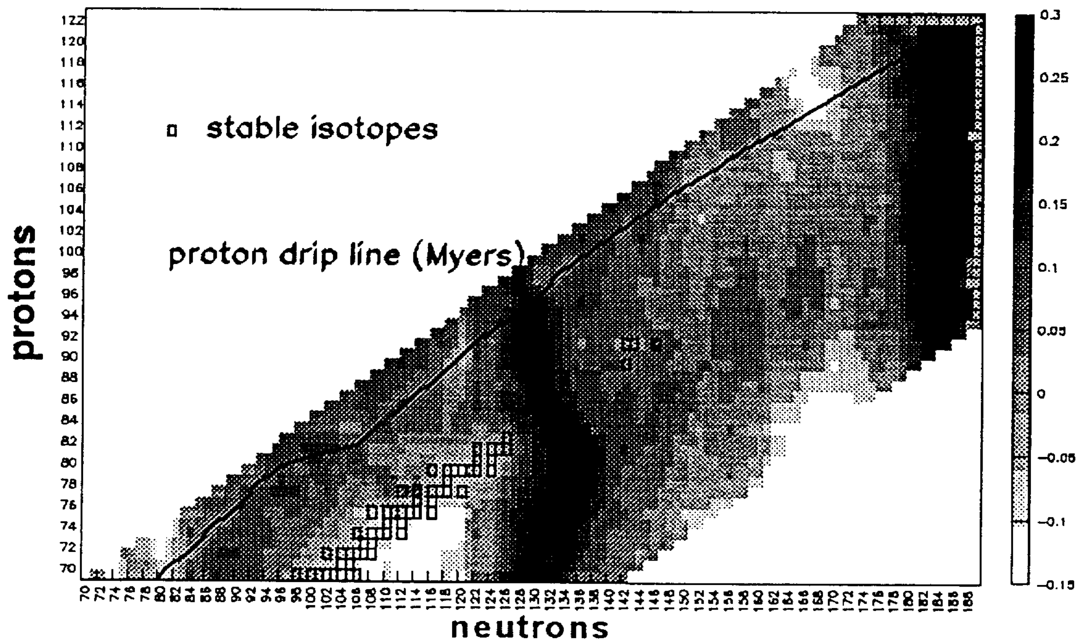

Fig. 7: The sensitivity of the shell correction energy (for even-even isotopes) against changes of the W-S potential depth.

($Z \approx 82$, $N > 126$) will help. The desirable accuracy of < 150 keV is very easy to achieve with ISOLTRAP.

Not very much is known about the production of isotopes far away from ^{208}Pb on the neutron-rich side. This has partly to do with the fact that the identification of these nuclei by nuclear spectroscopy was hampered by the huge background from isobaric very short-lived α-emitters. However, two years ago the isotopes ^{215}Pb and ^{217}Bi were discovered with yields exceeding 10^3 atoms/s. As half-lives change little in this region the same could therefore be expected for the yields of isotopes even further out and also for isotopes of neighboring elements. ISOLTRAP is not sensitive to any very short-lived activity and beside the mass determination of known isotopes it may even happen that new isotopes are discovered. Therefore we plan to map the region $Z \approx 82$, $N > 126$, including the new isotopes ^{215}Pb and ^{217}Bi which are just in the center of the important region indicated in Fig. 7.

4. Beam Time Request

The beam time request is based on the experience from runs with the ISOLTRAP spectrometer in the last years: if new regions are investigated for the first time there is normally a number of isotopes investigated within a few shifts. Going further out from stability and in the case of high resolution measurements one shift or more might be required per isotope.

For a period of about two years we ask for 45 shifts of radioactive beam. The beam time can be distributed over a number of shorter beam time periods (of typically 6-9 shifts):

- rare earth isotopes: 18 shifts Ta foil, ThC / UC with W-ionizer. We are interested in participating in laser ion source runs in this region if higher beam intensities are achieved.

- n-deficient Hg isotopes: 12 shifts molten Pb hot plasma

- Tl, Pb Bi region, n-deficient and n-rich side: 15 shifts ThC/UC, hot plasma

For beam tests with the RFQ trap and for further developments of the spectrometer we ask in addition for 15 shifts of stable beam.

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