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Status-Report and Beam Time Request

IS302

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

CERN - Chalk River - GSI - Jülich - Leuven - Mainz - Montreal - Orsay - Stockholm - Warsaw

The ISOLTRAP mass spectrometer has been modified by replacing the previous hyperbolical cooler trap and its electromagnet with a cylindrical trap in the high field of a superconducting magnet. With the improved set-up we plan to perform accurate mass measurements on isotopes of neutron-rich alkali and alkali earth elements and on neutron-deficient rare earth isotopes in the vicinity of ^{146}Gd. After the installation of an additional Paul trap ion beam buncher in the shut-down period 1995/1996 we intend to investigate neutron-deficient mercury isotopes. In total we request 50 shifts of radioactive beam and 26 shifts of stable beam over a period of about two years.

1. Introduction

The Penning trap mass spectrometer ISOLTRAP, installed both at ISOLDE-2 and now at the PS-Booster ISOLDE, has been used very successfully to determine the mass of unstable isotopes. More than 70 radioactive isotopes, most of them far from stability with half-lives down to the 1 second region, could be determined so far [1-5]. The high accuracy of typically $1 \cdot 10^{-7}$ for all of the investigated isotopes of the elements Rb, Sr, Cs, Ba, Fr and Ra considerably helped to improve the knowledge of the nuclear binding energy. These accurate data had a large impact on the mass surface of the chart of nuclei. They helped to reveal a number of wrong mass values (even close to stability), to clarify a large number of inconsistencies and to set a solid and reliable anchorage for many Q-values links to different isotopes of other elements. ISOLTRAP data served as test ground for nuclear models and have been used for the local adjustment of the parameters of a macroscopic-microscopic mass formula [4].

The success of the ISOLTRAP experiment has started discussions about the installation of similar spectrometers at other places. At Chalk River, a Penning trap mass spectrometer is presently being built for measurements on unstable isotopes and will come into operation within one or two years. At the Manne Siegbahn Laboratory in Stockholm, a spectrometer has been set up for the very accurate determination of the mass of highly charged, stable isotopes. Both spectrometers are very similar to ISOLTRAP in their design.

Until now ISOLTRAP has only been used for mass measurements on isotopes of alkali and alkali earth elements. Within the next two years we plan to extend the investigations to isotopes of rare earth elements and mercury. In the case of the rare earth isotopes the aim is to investigate them in the region around ^{146}Gd. Mass values in the vicinity of this semi-doubly magic nucleus are

important for the investigation of the Z=64 proton sub-shell closure, as input data for shell model calculations and as a stringent test of the quality of predictions for not yet experimentally known masses close to ^{146}Gd. In the case of the mercury isotopes we will start investigations in a region where interesting nuclear structure effects have been observed but where the most fundamental property, the mass of the involved isotopes, is hardly known.

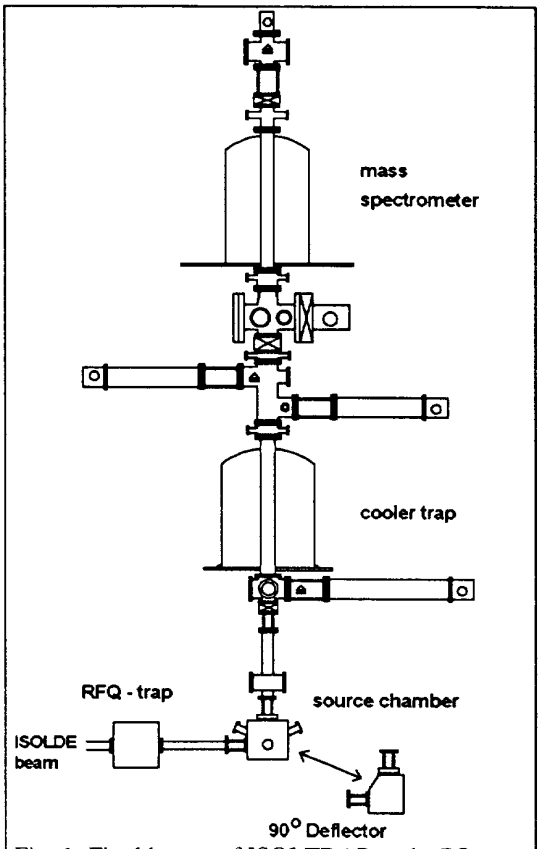

Fig. 1: Final layout of ISOLTRAP at the PS-Booster ISOLDE

2. Status of the ISOLTRAP-Experiment

During 1994 several major modifications have been applied to the ISOLTRAP spectrometer. Developments are still going on that aim to extend the applicability of the Penning trap technique to other elements, as well as to increase the efficiency of the spectrometer [6]. Figure 1 shows the present layout of ISOLTRAP at the PS-Booster ISOLDE. The most important modification was the replacement of the first (hyperbolic) trap in an electromagnet by a cylindrical trap in a superconducting solenoid. Either ion bunches or a continuous ion beam can be delivered to the new Penning trap ion cooler. Here the ions are collected and cooled by a mass selective buffer gas cooling technique. Subsequently, ion bunches are ejected and sent to the high-precision trap where a mass measurement is carried out via the determination of the cyclotron frequency $\omega_c = q/m \cdot B$ of the captured ions. The source and the new ion cooler trap were tested off-line in Mainz before their incorporation into the set-up at CERN. The first tests of the full system with stable and unstable beams were performed at ISOLDE at the end of 1994. As one of the next stages a Paul trap ion beam buncher will be placed in the horizontal ISOLDE beam line. When this buncher is used, the ion source will be replaced by a 90°-deflector.

2.1. The Ion Source

The source chamber shown in Fig. 1 can be equipped with different devices for the collection of the 60 keV ISOLDE beam and the re-ionization of the implanted atoms. Figure 2 shows two of these sources. One system (left) is intended for the release and surface ionization of the implanted ions by pulsed thermal heating of an appropriate foil by an intense laser pulse. In a later stage, additional lasers might by used for highly selective resonance-ionization of laser desorbed atoms. For surface-ionization ultra-pure rhenium or platinum foils are used.

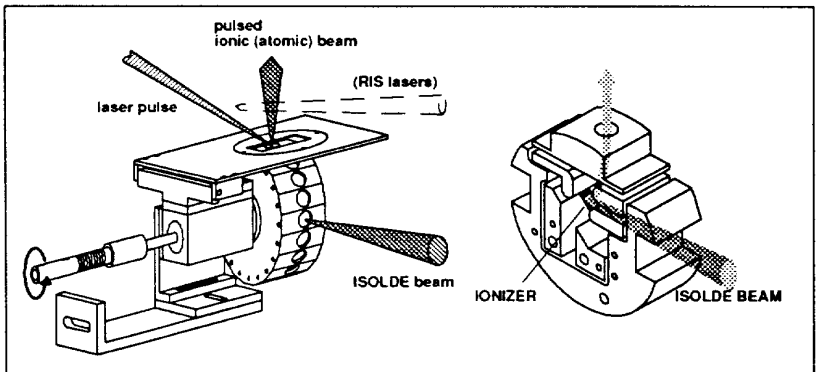

Fig.2: The two types of ion sources for laser desorption and surface ionization

Carbon foils are used for the creation of carbon cluster ions which can be used for the calibration of the magnetic field, avoiding any uncertainty in the mass of the reference isotope.

The source was tested off-line with a low-energy ion beam from an alkali ion source. Efficiencies exceeding 10 % for the release and ionization were found. However, it was not possible to desorb ions that were implanted with an energy of 60 keV. Therefore a deceleration system for the ISOLDE ions from 60 keV to near ground potential is under construction which will solve this problem.

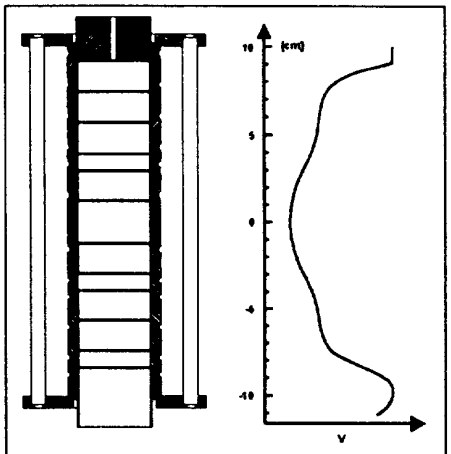

Fig. 3: The cylindrical trap in the new ion cooler

The second source contains a current heated filament which stops the ISOLDE ions, lets them diffuse out of the material and re-ionizes them. This source is presently installed in the chamber and has been used in the first radioactive beam experiment with the new set-up. It was found to work as expected from experience with the old cooler trap, where the same re-ionization scheme was applied. It is intended to use this scheme until the deceleration electrode system for the laser desorption source is available in summer 1995.

2.2. The New Cooler Trap

A new cooler trap has been designed and built. The aim was to achieve a high capture efficiency and an improved mass selectivity in the cooling process. Figure 3 shows the layout of the new Penning trap. It is a long cylindrical electrode assembly with a length of 20 cm (compared to 2 cm of the trap used in the previous set-up). This configuration allows the creation of a potential for a "nested" trap as shown on the right side of Fig. 3. The large potential well is needed for the efficient trapping of either ion bunches with a large phase space volume or dc-beams with a low energy spread. For a high mass selectivity in the cooling process a harmonic potential well is required in the center of the trap, which itself is placed in the high and homogeneous field of a superconducting magnet (B = 4.7 T).

2.2.1. Capture schemes and efficiencies

The large axial extent of the trap, the possibility of using high buffer gas pressures and the nested trapping potential enables the application of two different collection schemes: the collection of continuous ion beams and the dynamic capture of ion bunches. The collection of ions from continuous ion beams with near thermal energy spread is the simplest technique and has already been applied successfully in the old ion buncher and cooler trap. In a test experiment with the new system low-energy Cs-ions were injected into the cooler trap where they are captured by energy loss due to collisions with the buffer gas atoms in the trap. After a certain collection time the collected ions were ejected from the trap and detected. From the measured ion flux and the number of ions de-

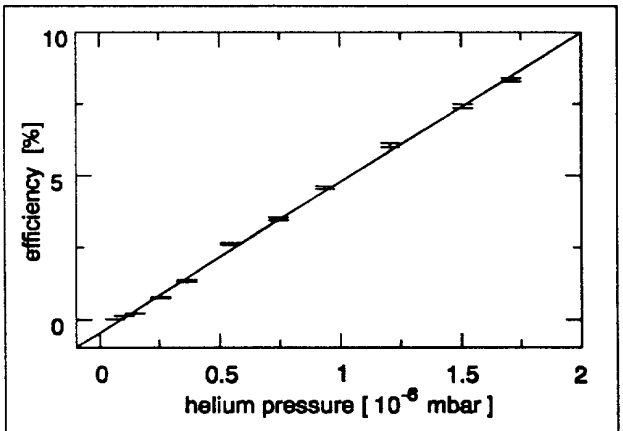

Fig. 4: Capture efficiency of a dc-ion beam as a function of the buffer gas pressure measured in some distance from the trap

tected in the ejected ion bunches the capture efficiency could be determined. As an example Fig. 4 shows the efficiency as a function of the helium gas pressure. A nearly linear increase is observed for the pressure range shown. Efficiencies of up to ten percent are reached, about two orders of magnitude larger than observed in the old set-up.

The most efficient way of collecting ions in a trap is the dynamic capture of ion bunches by appropriate switching of the trapping potential as already applied in the precision trap. In the case of the cooler trap, ion bunches with rather large longitudinal phase space volumes (several eV·μs) have to be captured, coming either from the laser desorption source or, as planned for 1996, from the Paul trap ion buncher. Due to the large size of the trap, capture efficiencies of up to 50 % were observed for laser desorbed ions, a figure that can still be improved by optimizing the parameters for the He gas pressure and the switching of the trapping potential.

2.2.2. Mass selective cooling

The large improvement in the quality of the magnetic and electric field compared to the old ion cooler and buncher trap is the key for a higher mass selectivity in the cooling process. First tests of this cooler trap with injected potassium ions indeed gave very promising results. Figure 5 shows a cooling resonance of ^{39}K where a selectivity of $m/\Delta m \approx 1 \cdot 10^5$ was realized. This is more than two orders of magnitude larger than achieved in the old cooler trap and in principle sufficient to remove isobaric contamination in a large number of cases. This is particularly important for the planned measurements on isotopes in the vicinity of ^{146}Gd where many isobars are delivered simultaneously by ISOLDE. In the test measurement shown here, ^{39}K ions were produced by laser desorption in the ion source and captured in the trap. After the axial motion of the ions was cooled by buffer gas collisions ($p_{He} \approx 1 \cdot 10^{-4}$ mbar), all ions were driven to an orbit larger than the size of the ejection hole of the trap by excitation of their magnetron motion, the frequency of which is practically mass independent. Subsequently, only ^{39}K ions were re-centered by excitation of their motion by an azimuthal quadrupole rf-field of frequency ω_d. Finally, the centered ions were ejected from the trap and detected. As described in detail in [7-9], only in the case of an excitation of the ion motion at the cyclotron frequency $\omega_{RF} = \omega_c(^{39}K)$, the combined action of the buffer gas and the driving field re-centers the potassium ions. Therefore, a resonance curve is observed if ω_d is scanned around $\omega_c(^{39}K)$. Further improvement of the mass selectivity can be expected if an experimental fine tuning of the trap potential is performed and, as discussed in [9], if a lower buffer gas pressure is used.

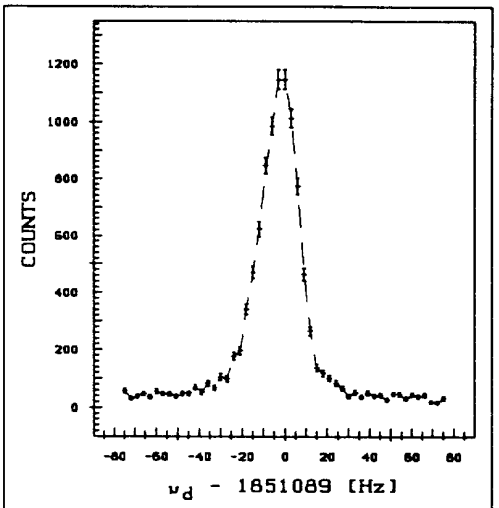

Fig. 5: Cooling resonance of ^{39}K ions

2.3. The Paul Trap Ion Beam Buncher

The applicability of ISOLTRAP can be extended most directly by an efficient bunching technique where no implanting, diffusion and re-ionization processes are involved. A Paul trap ion beam buncher has been developed for this purpose [10]. The buncher consists of a Paul trap connected directly to the ISOLDE beam line but installed on a high voltage platform close to the potential of the beam, i.e. typically 60 kV. Ions from ISOLDE are thereby decelerated from their initial 60 keV to a few electron volts before entering the Paul 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 1 keV. In order to deliver them to the buncher trap (Fig.

1), which is at near ground potential, the ion bunch enters a cavity immediately after extraction which is brought from 59 kV to near ground potential while the ions are still in it.

From experience with a prototype system, that was successfully tested at the ISOLDE-3 separator [10] a few years ago, construction of a completely new system dedicated to the ISOLTRAP experiment was undertaken in Montreal. The assembling of the new system was completed in summer 1994. In the first off-line tests at Montreal with a 60keV test ion source capture efficiencies of about 1 % were achieved before any optimization of the system.

This Paul trap system will be installed in the next winter shut down and is intended for the measurements on neutron-deficient mercury isotopes.

3. Overview on the Experimental Results

More than 70 radioactive isotopes have been investigated to date with the ISOLTRAP spectrometer both at ISOLDE-2 and the PS-Booster ISOLDE [1-5]. The high performance of the Penning trap mass spectrometer allowed the determination of the mass values of all isotopes with an accuracy of $\delta m/m \approx 10^{-7}$. New mass values could be determined in the cases of ^{78,79}Sr, ^{122m}Cs, ^{124,126}Ba, and ^{230}Ra. Far from stability the uncertainty of the mass values could in general be reduced by more than one order of magnitude. ISOLTRAP data helped to find a large number of inconsistencies in the mass tables due to wrong input data close to, as well as far from, stability.

An example of the impact of the ISOLTRAP results on the mass values far from stability and of the importance of a remeasurement of mass values believed to be known is shown in Fig. 6 for rubidium isotopes ranging from neutron-deficient to the neutron-rich nuclei. The measurements on the neutron-deficient side were carried out at ISOLDE-2 and the measurements on the neutron-rich side at the PS-Booster ISOLDE. In the top figure the difference is plotted between the Penning trap data and a mass adjustment of all known masses excluding the Penning trap data. Large deviations can be observed. A detailed investigation of all input data for the adjustment revealed wrong Q-values in the β-decay chains, a systematic deviation in direct mass measurements performed with a prism mass spectrometer [11] and correlated systematic deviations in the triplet mass measurements [12], as also observed earlier for neutron-deficient Cs-isotopes. Following the procedure of the authors of the mass tables, careful corrections were applied to these data after a thorough analysis of the original work. A completely new mass adjustment was performed, now also including the Penning trap data. The result is shown in the bottom figure. As can be seen, the discrepancies

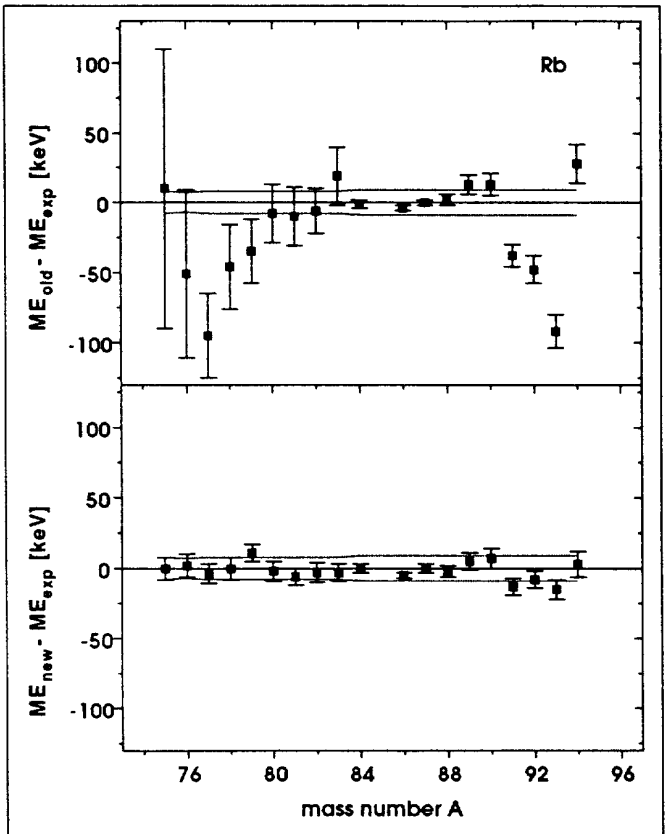

Fig. 6: Difference between the Penning trap data and a mass adjustment of all known masses excluding (top) and including (bottom) the Penning trap data

have disappeared completely and the uncertainties of the mass values are considerably reduced. Not only the mass values of the directly investigated isotopes have been improved but the ISOLTRAP results also significantly influenced the mass values of nuclides of the neighbouring elements due to the links between different nuclides by radioactive decays with known decay energies.

4. Planned Mass Measurements

4.1. Neutron-Rich Alkali and Alkali-Earth Isotopes

Isotopes of these elements have been the subject of all the previous investigations with the ISOLTRAP spectrometer. Not very much is left to be done in order to complete this series of measurements. On the neutron-rich side we intend to perform measurements on neutron-rich Cs and Ba isotopes which was not possible during the last beam time due to initial technical problems with the ISOLTRAP set-up and a later break of the UC-Target after these problems were solved. Our interest in this region is to set a solid and reliable anchorage far from stability for β-decay chains and for mass estimates from systematic trends. The isotopic lines here are the longest known, due to favourable production yields. With the already improved efficiency of the apparatus we are confident to reach the isotopes ^{148}Ba ($T_{1/2}$ = 0.9 s) and hope to be able to measure the unknown mass of ^{149}Ba ($T_{1/2}$ = 350 ms). In this case, laser desorption has to be used for the production of ion pulses. In order to cope with the short half life the resolving power of the spectrometer has to be reduced to $\Delta m/m \approx 200000$.

4.2. Neutron-deficient Rare Earth Isotopes around ^{146}Gd

The semi-doubly magic nucleus ^{146}Gd and isotopes surrounding it have found considerable interest for many years. The investigation of the strength of the proton sub-shell closure at Z=64, the delivery of reliable and highly accurate ground state masses ($\delta m \approx 20$ keV) as input data for shell model calculations and the test of their mass predictions are the motivations for the planned measurements in this region.

Most of the masses with $Z \leq 64$ and $N \geq 82$ are known with high precision. This situation already changes a few neutrons and protons away from that region. The mass uncertainties rise quite drastically towards far from stability and many of those mass values determined experimentally are believed to be doubtful because they do not follow expected smooth trends. Not one of the experimentally determined mass values around ^{146}Gd has been measured by a direct technique. They are only known from links provided mainly by Q_β-values.

Keller et al. have performed a shell model analysis of the available data by using sets of shell-model equations which relate ground-state masses to known excitation energies [13]. In their analysis they found a number of doubtful Q-values that had to be excluded from the adjustment procedure in order to get a reasonably good agreement between the predictions and the experimentally deduced mass values. A systematic check of the accuracy of the derived mass values seems to be important. Since the set of shell model equations was over-determined, Keller et al. were able to give quite precise predictions for the still unknown mass values of ^{151}Er and ^{151}Tb. A measurement of these masses would be a stringent test on the range of the validity of these shell-model predictions.

Severe discrepancies still exist between different experimental data in this region. A case discussed in detail in [14] is ^{148}Tb where different experimental techniques give significantly different mass values for this isotope and consequently also for ^{148}Gd and its α-decay ancestors, the extremely proton-rich isotopes ^{176}Hg and ^{180}Pb. A re-measurement of just the isotope ^{148}Tb by ISOLTRAP would clarify this situation immediately.

From the experimental point of view the investigation of rare earth isobars is a challenging task: Many isotopes of different elements with the same mass number are delivered by ISOLDE simultaneously. This poses a difficulty in so far that in principle only one ion species must be stored in the precision trap during the determination of the cyclotron frequency. Therefore, the delivered isobaric mixture has to be purified first. One step is performed in the cooler trap which has a mass resolving power of 10^5 as discussed above. However, it will be not be possible to have this selectivity if the number of contamination ions is so high that Coulomb interaction between the different ion species starts to play an important role. Then the selectivity will be reduced. Fortunately there is a second purification step that can be applied in the precision trap by driving the unwanted ions to large orbits so that they are lost at the trap electrodes.

In order to estimate which isotopes would be accessible to ISOLTRAP we performed a calculation of the number of ISOLDE ions finally detectable with the spectrometer for each isotope in an isobaric chain, if the collection time and the time by which the start of the measurement is delayed are optimized. We took into account known and extrapolated yields for the different nuclides, their decays, and the surface ionization efficiency of the different elements for a reasonable temperature of the ionizer. We further took into account the efficiency of the ion capture in the cooler trap, if the continuous surface ionization source is used. Figure 7 shows the isotopes in the vicinity of ^{146}Gd. Marked in different grey tones are those isotopes that can be investigated for a certain isobaric ratio R_Y of the number of desired ions to the total number of undesired ones delivered to the cooler trap. From the present experience we will certainly be able to investigate isotopes with $R_Y>0.3$ and even isotopes with values of $R_Y \geq 0.1$ might be accessible.

As can be seen from Fig. 7 it will not be possible to access isotopes in the region with $Z\geq 64$ and $N<82$. For an investigation of these isotopes a more selective re-ionization technique has to be used such as resonance ionization of a laser-desorbed pulsed atomic beam for example. The use of such a technique will be considered in a later stage of the experiment. However the situation could be improved sooner by using ISOLDE ions from the HRS, since this will reduce the isobaric contamination considerably.

	77	78	79	80	81	82	83	84	85	86
67	^{144}Ho	^{145}Ho	^{146}Ho	^{147}Ho	^{148}Ho	^{149}Ho	^{150}Ho	^{151}Ho	^{152}Ho	^{153}Ho
66	^{143}Dy	^{144}Dy	^{145}Dy	^{146}Dy	^{147}Dy	^{148}Dy	^{149}Dy	^{150}Dy	^{151}Dy	^{152}Dy
65	^{142}Tb	^{143}Tb	^{144}Tb	^{145}Tb	^{146}Tb	^{147}Tb	^{148}Tb	^{149}Tb	^{150}Tb	^{151}Tb
64	^{141}Gd	^{142}Gd	^{143}Gd	^{144}Gd	^{145}Gd	^{146}Gd	^{147}Gd	^{148}Gd	^{149}Gd	^{150}Gd
63	^{140}Eu	^{141}Eu	^{142}Eu	^{143}Eu	^{144}Eu	^{145}Eu	^{146}Eu	^{147}Eu	^{148}Eu	^{149}Eu
62	^{139}Sm	^{140}Sm	^{141}Sm	^{142}Sm	^{143}Sm	^{144}Sm	^{145}Sm	^{146}Sm	^{147}Sm	^{148}Sm

$R_Y > 0.1$

$R_Y > 0.3$

$R_Y > 1$

Fig. 7: Isotopes in the vicinity of 146Gd which will be accessible for ISOLTRAP

4.3. Neutron-deficient Mercury Isotopes

The physics motivation for precise mass measurements of Hg, Au and Pt isotopes has already been given in a letter of intent (CERN/ISC 93-34 ISC/I9). Here we restrict ourselves to a brief overview and the discussion of the particular interest in the investigation of mercury isotopes which will be accessible after installation of the Paul trap system. The interest in the region arises from the appearance of shape coexistence at low excitation energy in the region around the proton shell closure at Z=82. The onset of rotational-like bands built on low-lying 0^+ states have been found [15] in the even-even Pt, Hg, Pb and Po nuclei with neutron number around N=104 - midshell between N=82 and 126. A large staggering in the $\delta\langle r^2\rangle$ values deduced from investigations by laser spectroscopy was observed in the light Hg isotopes [16], one jump from small to strong deformation in the neighbouring Au isotopes [17] and a smooth transition in the Pt isotopes [18]. A discontinuity of the surface of masses with a magnitude of 350 keV was observed [19] for Z = 72-76 (Hf, Ta, W, Re and Os). By a mass measurement on neutron-deficient mercury isotopes this discontinuity could be traced at higher Z and its magnitude measured there with good accuracy.

One may speculate on the existence of a connection between this irregularity and the experimental evidence for ground state prolate deformation of the (even) Pt isotopes existing for $A \leq 186$, in clear contrast to the heavier Pt isotopes where an oblate like deformation is observed. It has been suggested [20,21] that around ^{176,178}Pt the situation reverses again and that the prolate deformed states rise in energy with lower neutron numbers. The expected change of the ground state configuration of the light Pt isotopes should have an effect on the nuclear binding energy of these isotopes. It would be interesting to see if this can also be observed in the masses of mercury isotopes.

For most of the lighter Hg isotopes the masses are unknown [22]. All isotopes in the range of $175 \leq A \leq 192$ are part of long α-decay chains with well known Q-values or are linked to such chains via a known $Q\beta$ - value. The masses of the isotopes in this α-decay chains could be determined from the knowledge of the masses of the involved mercury isotopes. As a consequence a mass determination of the isotopes $^{180\text{-}192}$Hg (where only ^{182,186,189}Hg are known with uncertainties $\geq$ 200keV and ^{191}Hg with 90 keV) would result in new mass values for additional 35 even-Z nuclides and improved mass values for 10 nuclides. The expected accuracy of the mass values for those nuclides at the end of the decay chains is 20-40 keV since the α-decay energies are known with a precision of typically a few keV.

More indirect but also important improvements can be achieved for isotopes in α-decay chains of odd-Z isotopes that are linked to Hg-isotopes via $Q\beta$-values of Tl-isotopes. The following example should illustrate this: The isotope ^{192}Hg is linked via the $Q\beta(^{192}\text{Tl})$-value with an uncertainty of 200 keV to a chain that has its starting point at ^{204}Fr. This neutron-deficient isotope is the last one in the series of Fr-isotopes that has been determined by the Orsay group with a Mattauch-Herzog spectrometer. The error given is 690 keV. A mass determination of ^{192}Hg would test this result with a precision of about 200 keV (provided the $Q\beta(^{192}\text{Tl})$ -value is correct). One could find out if the triplet mass measurements suffer from correlated systematic deviations as already observed for Cs and Rb isotopes. With the resulting more accurate mass value for ^{204}Fr also the mass values of the less neutron-deficient Fr-isotopes would be improved. As a consequence all the mass values of isotopes in the α-decay chains with a neutron-deficient Fr-isotope as member would be more precisely known.

Most of the known α-chains start in very proton-rich regions. For a precise determination of proton separation and pairing energies, which are important for the prediction of the path of the proton drip line, also mass values for neighbouring odd-Z isotopes have to be known with high accuracy. Some of them can be determined indirectly via the Q_β-connections between α-decay chains to mercury isotopes as discussed above in the case of ^{192}Hg. In the four cases ($^{189-192}$Hg) presently existing, the uncertainty will be mainly determined by the uncertainty of the Q_β-values which unfortunately ranges from 200-400 keV. The uncertainties could be decreased and masses for the remaining odd-Z nuclides could be determined if mass measurement on isotopes of a neighbouring element could be performed. Neutron-deficient Au-isotopes will be accessible to ISOLTRAP if the technique of pulsed-laser desorption is combined with selective laser resonance ionization, which we plan for a later stage of the experiment. Then a determination of proton separation energies and also proton pairing energies very far from stability with an accuracy at a level of a few 10 keV will become possible.

The mass measurements on mercury isotopes can be performed when the Paul trap ion beam buncher has been installed. Taking the present ISOLDE yields, the currently achieved efficiency of 1% for the buncher and a total efficiency of 10% for the rest of the apparatus, we might be able to investigate nuclides as far from stability as ^{180}Hg.

5. Beam Time Request

5.1. Stable Beam

For the test of the Paul trap ion beam buncher we request in total **20 shifts** of stable beam from both a surface ionization source and a plasma ion source: Investigation and optimiziation of the capture efficiency for ISOLDE beams with different emittance and energy spread is required in order to find best operating parameters for the Paul trap. The bunched extraction of the collected ISOLDE ions from the Paul trap and their delivery to the cooler trap has to be studied in order to match the ion optical properties of both systems. For a continued usage of the stopping and re-ionization technique parameters for the transmission of the ISOLDE beam through the Paul trap to the source chamber (see Fig.1) have to be found.

In addition we ask for **6 shifts** of stable beam from a surface ionization source for testing the laser desorption and surface ionization after the deceleration electrode system has been installed in the source chamber (see above).

5.2. Radioactive Beam

In total **50 shifts** of radioactive beam are requested over a period of about two years:

- For completing the investigation of isotopes of neutron-rich alkali and alkali earth isotopes 10 shifts with an UC-target and W-ionizer are needed.
- The measurements planned in the vicinity of ^{146}Gd are, as discussed above, significantly more difficult than the previous investigations on isotopes of surface-ionizable elements. For a first series of mass measurements in this region we request 20 shifts with a Ta-foil target and W-ionizer. The use of the HRS would be desirable.
- For the mass determination of light Hg isotopes, which will be possible from 1996 on after the installation of the Paul trap ion buncher system, we ask for 20 shifts.

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