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HIGH-PRECISION MASS MEASUREMENTS OF EXOTIC NUCLEI WITH THE TRIPLE-TRAP MASS SPECTROMETER ISOLTRAP

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In the running ISOLDE period of 2005 the experiment IS413 asked for six beam times (^{14}O, $^{17-19}$N, ^{26m}Al, $^{70-71}$Ni, $^{125-131}$Cd, and $^{131-134}$Sn) with a total number of 25 radioactive beam shifts (see Table 1). Since ISOLTRAP has been the only requester for an Al beam the run was not scheduled. The ^{14}O run was stopped already during the beam-line optimization with stable beam due to a broken target. Also the $^{70-71}$Ni run was stopped before taking radioactive beam because of a broken target (a failure at the HRS caused the shutdown of the target system including the GPS target which resulted in a broken transfer line). The first two runs on $^{17-19}$N produced no results for the desired radionuclides due to large amounts of molecular contaminants from the plasma ion source. In the first run the HRS separator magnet was not set to the required mass resolving power and thus the contaminants could not be removed with the slits. ISOLTRAP was allowed to take an additional (previously not scheduled) radioactive beam. However, in this run the gas inlet system of the plasma ion source was not clean enough and additional molecules were produced and observed as contaminants at ISOLTRAP - even with the HRS at a resolving power of about R=3500 it was not possible to remove the contaminants from the beam with the slits or at ISOLTRAP (due to the large yield of the molecules). Recently, and on very short notice, ISOLTRAP has been given the opportunity of another previously not schduled beam time. In total, 30 radioactive beam shifts have been taken in 2005.

Table 1: ISOLTRAP beam times scheduled in 2005.

Beam time	Dedicated for	No. of shifts	Remark	Separator	Target/ion source
April/May 2005	$^{17-19}$N	6	(heavily contaminated)	HRS	MgO / CP
May 2005	$^{17-19}$N	6	not requested (heavily contaminated)	HRS	MgO / CP
June 2004	^{14}O	3	stopped (broken target)	HRS	SiC / HP
June/July 2005	$^{131-134}$Sn	3		HRS	UCx / HP
July 2005	$^{70-71}$Ni	5	stopped (broken target)	GPS	UCx / graphite
October 2005	$^{74-79}$Zn	4	not requested	HRS	UCx / RILIS
October 2005	$^{125-131}$Cd	5		HRS	UCx / RILIS
	^{26m}Al	3	not scheduled		SiC / HP

A summary of the nuclides measured in 2005 is shown in Table 2. Since the importance of the physics output of these mass measurements was already explained in detail in our proposal P160, only a few further comments on the beam times and some specific highlights and problems will be addressed in the following:

$^{17-19}$N:

As mentioned above, due to a large amount of contaminants which could not be mass separated with the HRS (even by use of the slits) it was not possible to measure the nuclides of interest. However, the measurements showed that with a clean gas inlet of the plasma ion source it should be possible to get a beam of ^{14}N^{17}N, when the HRS is set to a resolving power of 3500 and the slits are used to cut away the ^{13}C^{18}O contaminant.

^{126,136}Xe:

As a first test of the feasibility of highly-charged ions at ISOLTRAP, stable highly-charged Xe ions (z= +4 and +3) from the ISOLDE plasma source were transferred to ISOLTRAP. Due to charge exchange with the helium buffer gas and residual gas, only the z = +2 states survived and could be further transported to the precision Penning trap for mass measurement. For the isotopes ^{126}Xe and ^{136}Xe the mass uncertainty could be improved. In addition, for ^{126}Xe a significant deviation from the literature value of the Atomic-Mass Evaluation AME2003 was found.

$^{127,128,131-134}$Sn:

In order to resolve the two isomeric states of ^{131}Sn, a duration of 9 seconds for the quadrupolar excitation was expected and experiments have been performed accordingly. However, no clear separation of the two isomeric states was observed. The data analysis is still in progress, but first results indicate an energy difference of less than 60keV. Other Sn nuclides that have been measured are summarized in Table 2.

Table 2: Radionuclides and stable masses measured with ISOLTRAP after the last report in 2004 and in 2005. For nuclides marked with an asterisk the evaluation is in progress. Literature values are taken from the Atomic-Mass Evaluation AME2003 [1]

Nuclide	Half-life $T_{1/2}$	δm_{lit} / keV	δm_{exp} / keV	$\delta m_{exp}/m$
end of 2004				
17Ne	109.2 ms	27	0.53	3.4E-8
19Ne	17.3 s	0.29	0.18	1.0E-8
2005				
114Cd*	stable	2.7		
118Cd*	50.3 min	20		
120Cd*	50.8 s	19		
122Cd*	5.24 s	40		
123Cd*	2.1 s	40		
124Cd*	1.25 s	60		
127Sn*	2.1 h	25		
128Sn*	59.1 min	27		
128mSn*	6.5 s	27		
131Sn*	56.0 s	21		
132Sn*	39.7 s	14		
133Sn*	1.45 s	40		
134Sn*	1.12 s	100		
71Zn*	2.45 min	10		
71mZn*	3.96 h	10		
72Zn*	46.5 h	6		
73Zn*	23.5 s	40		
74Zn*	95.6 s	50		
75Zn*	10.2 s	70		
76Zn*	5.7 s	80		
77Zn*	2.08 s	120		
77mZn*	1.05 s	120		
78Zn*	1.47 s	90		
79Zn*	995 ms	260		
80Zn*	545 ms	170		
81Zn*	290 ms	300		
126Xe	stable	6	3.6	3.1E-8
136Xe	stable	7	3.9	3.1E-8

$^{71-81}$Zn:

Due to a failure of the REX LINAC, ISOLTRAP was granted on short notice an additional (previously not scheduled) beam time on neutron rich Zn nuclides (which are included in the running four-year proposal). The quartz transfer line of the UC target in combination with the selective RILIS ionization produced a clean beam with enough yield to access ^{81}Zn for mass measurements. No radioactive and no stable contaminants were observed (except in the case of ^{71}Zn, where tiny quantities of ^{71}Ga were observed; ^{71}Ga was the mass marker and no problem for the ISOLTRAP cleaning procedure).

$^{114,118,120,122-124}$Cd:

It was planned to use the UC target with the quartz transfer line from the Zn run also for the scheduled Cd beam time. Unfortunately the transfer line broke and a standard UC target had to be used. Due to large amounts of contaminants and poor target performance the requested radionuclides could not be measured. However, some data was recorded for nuclides in the mass range *A*=114-124.

Table 3: Radionuclides requested in the P160 proposal. The nuclides measured with ISOLTRAP within the 2003-2005 period are marked with a green box.

Element	***Ref.***	***Mass number***											
He		6	8										
Li		9	11										
Be		11	12										
N		17	18	19									
O		14											
Ne	[2,3]	17	18	19				23	24	25	26		
Mg	[4]	22											
Al		26m											
K	[5]	35											
Mn		58	59	60	61	62	63	64	65	66			
Ni	[6]	67	68	69	70	71							
Cu	[6-8]	67	68	69	70	71	72	73	74	75	76	77	78
Zn		62					74	75	76	77	78	79	
Ga	[6]	62		74	75	76	77	78	79	80	81	82	83
Rb	[9]	74											
Ag		115	116	117	118	119	120	121	122	123	124		
Cd		125	126	127	128	129	130	131					
Sn	[10]	131	132	133	134								
Tl		211	212	213	214	215	216						
Pb		213	214	215	216	217							
Bi	[11]	215	216	217	218								
		nuclide measured											
		no successful measurement (contaminants or broken target)											
		requested but not scheduled											

Summary and shutdown plans 2005/2006:

At present, the precise determination of nuclear binding energies far from stability includes nuclides that are produced at rates of 100 ions/s and with half-lives well below 100 ms. The mass resolving power reaches 10^7 and the uncertainty of the resulting mass values has been pushed down below 10^{-8} [12].

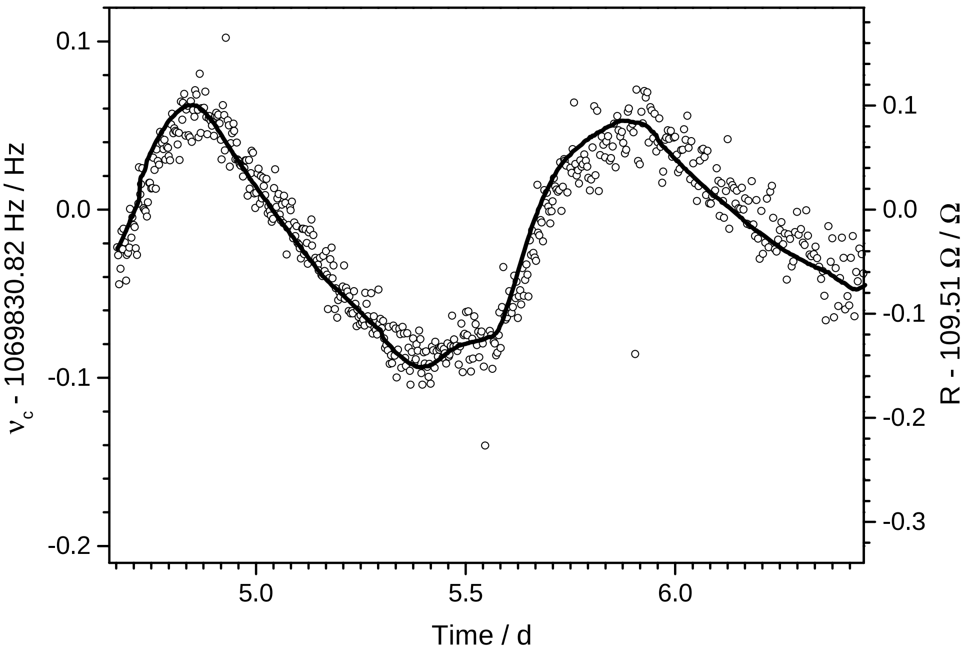

Figure 1: Cyclotron frequency of $^{85}Rb^+$ (open circles) and resistance of a Pt100 temperature sensor (solid line) as a function of time before the installation of the temperature regulation. The frequency values have been corrected for a linear temporal drift and the scaling of the two y-axes has been adjusted to obtain a match of the two data sets.

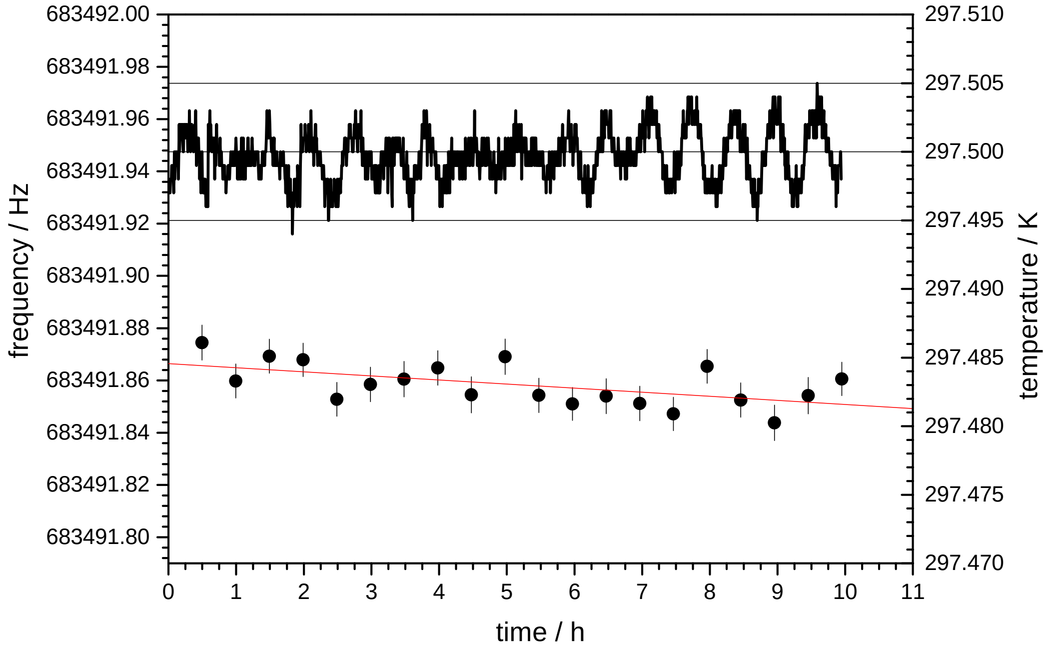

Figure 2: Cyclotron frequency of $^{133}Cs^+$ (data points, left y-scale) and temperature at the precision Penning trap (black line, right y-scale) as a function of time after the installation of the temperature regulation. The red solid line is a linear fit to the frequency values. The black horizontal lines show the set temperature (297.5 K) and the range of +/- 5 mK.

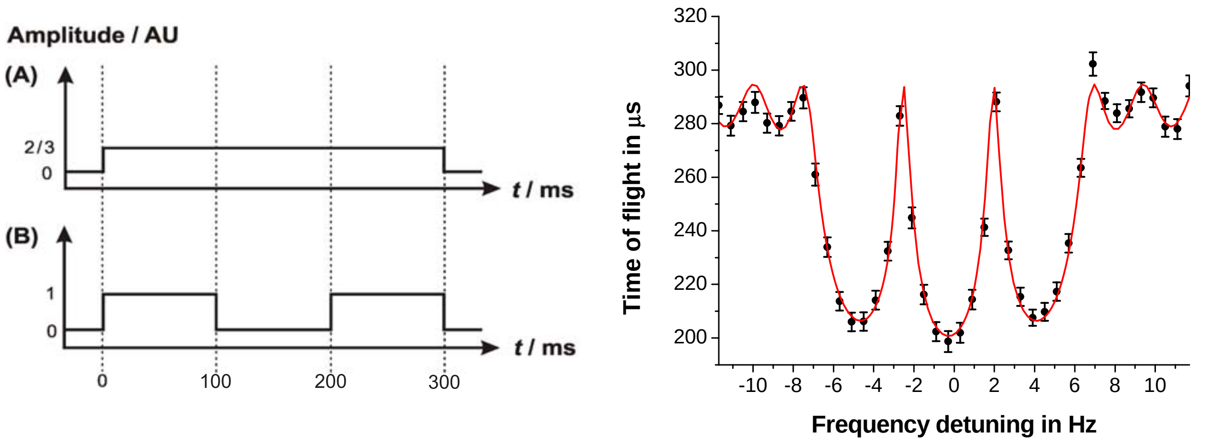

Figure 3: Left: Time structure of the regular quadrupolar excitation scheme (A) as compared to the Ramsey quadrupolar excitation scheme with two fringes (B). Right: Cyclotron resonance of $^{85}Rb^{+}$ after application of the Ramsey excitation with two fringes. The solid line is a fit of theoretical line shape to the data [13].

To further improve the relative mass uncertainty and to strengthen the ISOLDE/ISOLTRAP forefront position in the field of on-line mass spectrometry several technical and experimental improvements have been completed in 2005. A new channeltron detector with a conversion electrode has been installed which has a much increased detection efficiency and thus reduces the ion-ion-interaction in the trap since now a smaller number of ions are stored in each experimental cycle in the precision Penning trap. Furthermore a pressure and temperature regulation system has been installed and tested which allows the stabilization of the magnetic field in the precision trap for a reduction of any significant fluctuation in the frequency determination (see Fig. 1 and Fig. 2 for frequency measurements before and after the installation of the regulation system, respectively). Finally a new detection scheme has been tested that employs a Ramsey scheme for the quadrupolar excitation (see Fig. 3). This leads to a decrease of the width of the central peak by 50% and an increase in the precision by a factor of 2-3 [13].

References:

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Beam time request 2006:

We would like to ask for the last period of our originally submitted proposal P160 and ask especially for a total number of 36 radioactive beam shifts for next year to regain some of the lost runs in 2005. The beam time request is given in Table 4.

Table 4: Beam time request for 2006.

Nuclides	Field of interest	No. of shifts	Ion Source	Target
^{6,8}He	halo	6	CP	ThC / UC
6 radioactive beam shifts for test and mass measurement				
$^{17-19}$N	halo, IMME	6	CP	MgO
^{26m}Al	CVC,CKM	3	HP/WSI	SiC
$^{58-66}$Mn	mass surface	5	RILIS	UC
$^{115-124}$Ag	mid masses	7	RILIS	UC
$^{125-131}$Cd	mid masses	6	RILIS	UC / quartz transfer line
$^{213-217}$Pb	heavy masses	3	RILIS	ThC / UC
+30 radioactive beam shifts				